ST-1

Seasonal Climate Predictability Using the SINTEX-F1 Coupled GCM

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By using the SINTEX-F1 coupled GCM (ECHAM4 [T106L19]/OPA[ORCA2] /OASIS), we have implemented several seasonal hindcast experiments for the period 1982-2001 with different coupling physics for each run. The initial conditions were provided by using a simple coupled SST-nudging scheme after 11-year spinup of the CGCM. This scheme generates realistic subsurface signal and zonal wind stress along the equatorial Pacific and captures some intraseasonal wind bursts. The coupled model gives a skillful ENSO prediction over one year lead time with the highest skill appearing in the central tropical Pacific. Especially, the strongest 1997/98 El Nino event was predicted quite well and with a amplitude close to the observation. The spatial pattern of predicted ENSO SST anomaly is similar to the observation with a broad meridional structure in the Pacific. Concerning the global precipitation changes associated with the ENSO, the model also realistically predicted, up to 9-month lead time, the rainfall anomalies in the Indo-Pacific regions, the East Asian area, the American continents and the tropical Atlantic not only for the winter (DJF) season during the peak of ENSO but also for the summer (JJA) season after the ENSO peak. For the Indian Ocean and the Atlantic SST, the model produces skillful predictions only up to about three months.

ST-2

NSIPP-1 Skill and Predictability on Seasonal to Interannual Timescales

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The NSIPP-1 coupled GCM includes state-of-the-art atmosphere, ocean, and land models which can be run on tier-1 or tier-2 mode. In the tier-2 simulations used in this study the monthly mean observed sea-surface-temperatures (SSTs) are prescribed and there is no need to use the ocean model. Tier-1 simulations use the coupled ocean-land-atmosphere model to forecast the states of the atmosphere, land, and ocean.

Results from a 9-member ensemble of 70-year long tier-2 simulations with the NSIPP-1 coupled land-atmosphere model will be used to study the seasonal-to-interannual variability and potential for predictability of various atmospheric indices, including the Southern Oscillation Index, the Pacific-North-American Pattern, the Antartic Oscillation, the Artic Oscillation, as well as a number of precipitation indices for various regions of the world.

The skill of the NSIPP-1 coupled land-ocean-atmosphere model in representing the variability of those atmospheric indices will then be investigated using ensembles of tier-1 simulations.

ST-3

DEMETER: A Multi-Model Ensemble System for Reliable Seasonal to Interannual Prediction

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The potential end users of seasonal to inter-annual climate predictions span a wide range of different sectors from agriculture, food, energy, and health up to insurance and finance applications. Reliable predictions of seasonal climate would allow more efficient planning in all these sectors and, therefore, improve the quality of life, health, and safety.

Known limitations for producing reliable forecasts using dynamical models are uncertainties in both initial data and model formulation. To account for these inaccuracies a multi-model ensemble prediction system has been developed a joint European project known as DEMETER. The model system consists of seven different global coupled atmosphere-ocean models and runs from sets of initial conditions, each slightly different from one another, but consistent with availableo bservations. State-of-the-art atmosphere and ocean analyses are used to initialize the models. Nine-member ensemble integrations are run for each single model four times per year over six month periods.

To assess the potential skill of the multi-model system, an extensive set of hindcast ensemble integrations for the period 1958-2001 has been run, with a common period of 22 years (1980-2001) for all models. Hindcasts are verified as both deterministic (ensemble mean) and probabilistic predictions. Results illustrate that the skill improvement due to the multi-model approach is primarily the consequence of an increase in forecast reliability. Further diagnostics demonstrate that the skill improvement is not attainable by simply increasing the ensemble size of a single-model ensemble.

Innovative examples of seasonal forecast applications in crop yield and malaria incidence prediction have also been undertaken. They show the potential socio-economic value of well-calibrated multi-model seasonal predictions.

The recently EU-funded ENSEMBLES project will be partly built upon this knowledge and will extend the experimentation to longer time scales, from multiannual, through decadal to century-scale climate prediction. In addition, the advantages of the

multi-model and related approaches will be tested against less empirical methods such as stochastic physics.

ST-4

Seasonal and Regional Dependence of Climate Predictability

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The physical basis for atmospheric predictability on seasonal time scales resides primarily on the notion that slowly varying anomalous lower boundary forcing can have significant impact on atmospheric development. Such external forcing is generally thought to be associated with sea surface temperature (SST) anomalies, though the effect of long-lived anomalies in soil moisture and snow cover may also play a significant role. It is clearly important to be able to access where on the global atmospheric variations are sufficiently affected by oceanic forcing to enable practical seasonal prediction. This requires measurements of atmospheric potential predictability. It is commonly believed that lower boundary conditions dominate interannual variability in the tropics and major monsoon systems. Therefore, the atmospheric variability may be highly predictable in those regions. But is there any regional differences? For example, would one expect the circulation over the equatorial eastern Pacific to be more predictable than the North Pacific warm pool. Further, one might also question whether the short-term climate predictability is the same throughout the year. In particular, how does the annual cycle influence the relative impact of anomalous lower-boundary forcing?

An ensemble of ten 45-yr (1956-2000) ECHAM4 GCM integrations, forced throughout by the observed SST and sea-ice datasets, are used together to provide a global and regional assessment of potential seasonal predictability and its annual-cycle dependency. For the precipitation, the predictability in the tropical Indian Ocean and western Pacific is lower than the eastern Pacific. Spring rainfall is more predictable than the other season for both the Tropical Atlantic and NINO 3.4 regions. On the other hand, the summer precipitation predictability in the maritime continent is higher than the other season. For the mean sea-level pressure, NINO 3.4 region is more predictable in summer and autumn while the North Pacific warm pool is more predictable in winter and spring. For the 500 hPa geopotential height, all northern hemisphere mid-latitude sections (Asia, North Pacific, North America, North Atlantic and Europe) have lowest predictability in autumn. North Pacific and North America regions are with largest potential predictability in winter while it is more predictable in summer for the Asia region.

ST-5

The ECMWF "System 2" Seasonal Forecasting System

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ECMWF has run an operational seasonal forecasting system since the 1997 El Nino event. The present system was introduced at the beginning of 2002, and its performance in both 'hindcast' mode and real time forecasting is presented. The ENSO SST forecasts are good, particularly in the first few months of lead time. The improved quality of initialization is thought to be an important factor in the overall performance. Real-time forecasts since the system was introduced have been better than expected from past performance. There are some problems, though, stemming from model error.

The operational system produces a wide range of seasonal forecast products. The system uses a single tier strategy, with a 40 member ensemble which samples the uncertainty in both SST and atmospheric fields. A range of fields and products are available on the web to WMO National Met. Services, and forecast SST data will shortly be disseminated on the GTS. Examples of forecast products and verification scores are shown.

ST-6

ECMWF Seasonal Forecasting: Some Challenges for the Future

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Although ECMWF have set up a relatively successful operational seasonal forecasting system, it is clear that many challenges remain, and this poster aims to explore just a few of them.

Model errors are the biggest factor in degrading our seasonal forecasts, and their impact can often be subtle. An example is given from the West Pacific, where small changes in a coupled GCM have a significant impact on local SST prediction skill, in unexpected ways.

Our present forecast system has no interannual variation in the level or properties of aerosol. In the case of volcanic aerosol, we can clearly see the impact of this on our global SST forecasts, where the omission of the effects of Pinatubo resulted in a sustained period of forecast error. Prediction of eruptions is not envisaged (!), but the ability to capture the sustained after-effects is important.

A critical issue is the calibration of model forecasts over longer periods. Trends and low frequency variability are clearly important, but are often not well captured by models. This issue is explored in the context of the DEMETER integrations, and diagnosis of the ERA40 analysis. A critical question is how much we can expect to

model decadal trends with today's systems, and how much we may need to rely on statistical treatments. A related question concerns the quality of our global ocean analyses, both for the present time, where new data sources are greatly enhancing our capabilities, and for trends over the past few decades, where different issues arise.

A final challenge is the strategy for making use of multi-model forecast ensembles, and our ability to issue calibrated probabilistic forecasts. Given the always-limited number of past cases we can test our models with, it is pointed out that no definitive 'right' answer exists as to the Bayesian probability of some future climate event, but that we can nonetheless issue forecasts that give a rational basis for decision making and planning.

ST-7

Seasonal Prediction Efforts at NCEP: Toward a Seamless Suite of Forecast Products

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Efforts to improve the seasonal prediction using numerical models have been one of the main activities of the Global Climate and Weather Modeling Branch at the National Centers for Environmental Prediction. We are in the process to validate the latest effort using a current operational weather forecast model (GFS03) coupled to the Modular Ocean Model version 3 (MOM3) to produce seasonal predictions. A free run of 32 years has been conducted with this coupled model without flux corrections in an effort to examine the model's performance in reproducing observed climatology and interannual variability. We have found the model capable to simulate the earth climate with small bias in tropical Sea surface Temperature (SST) (generally less than 1 K). In addition, the coupled model is able to simulate realistic ENSO events with comparable amplitude compared to the observed and with comparable periods. We are in the process to generate a 22-year hindcast database for 1981-2002 to investigate the model's skill in ENSO prediction. Our initial forecast experiments for January, April, July, and October initial conditions indicate that this coupled model is superior to the previous version of NCEP's operational coupled model. We will present the results of the hindcasts as well as the free run.

ST-8

IAP Dynamical Seasonal Prediction System

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In this paper, the IAP dynamical seasonal-to-interannual prediction system (IAP DCP) will be briefly described, and its application to the real-time prediction of climate anomalies over China since year 1998 will also be summarized. Generally, IAP DCP is comprised of five components, i.e., IAP ENSO Prediction system, Prediction Integrations and Anomaly Coupling Technique, Ensemble Prediction Technique, Correction System, Prediction Products and Analyses.

The skill of IAP DCP for the seasonal prediction of drought/flood situations over China has been assessed by several sets of hindcast experiments during the period 1980-1995. Hindcast experiments show that IAP DCP can well predict the large positive and negative anomalies of summer rainfall over China, especially over Yangtze River and Huaihe River Valley.

Since 1998, the IAP DCP has been applied to the real-time prediction of summer rainfall anomalies over China every year. During the real-time extraseasonal prediction, the ensemble technique have been used, with sea surface temperature anomalies (SSTA) taken from the IAP ENSO prediction system, and different atmospheric conditions from NCEP reanalysis, and the final prediction product is obtained by averaging the total ensemble after correction. Verification with the observed summer rainfall anomalies shows that, IAP DCP can quite well predict the large-scale patterns of summer flood and drought conditions over China. For example, the severe flood over Yangtze River Valley and Northeast China for year 1998, the positive summer rainfall anomalies over Southern part of China for year 1999, and the rainfall maximum over lower reach of Yangtze River valley for year 2001, all these are quite well predicted by IAP DCP. Meanwhile, the persisted drought conditions over North China from 1999 to 2002 have also been pretty well predicted by IAP DCP-II. All these indicate the capability of IAP DCP in the seasonal prediction of summer rainfall anomalies over China.

Even the application of IAP DCP to seasonal prediction of summer precipitation in China is encouraging. However, in order to meet the national demand on more accurate climate prediction, considerable efforts are also needed, which include the improvement of climate system model, the improvement of oceanic and land data assimilation system, and exploitation of generalized ensemble technique, etc.

ST-9

POAMA: Dynamical Seasonal Prediction System of the BMRC

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POAMA (Predictive Ocean Atmosphere Model for Australia) is a state-of-the-art coupled ocean/atmosphere model seasonal forecast system developed jointly by the

Bureau of Meteorology Research Centre (BMRC), Melbourne and CSIRO arine Research (CMR), Hobart, in a project partly funded by the Climate Variability in Agriculture Program (CVAP).

It is based on the latest version of BMRC's unified climate/Numerical Weather Prediction atmosphere model (BAM) and the Australian Community Ocean Model (ACOM2). The POAMA system uses a sophisticated ocean data assimilation system that incorporates the latest oceanic observations into the initialisation procedure for the model forecasts. It is also one of the few models that uses real atmospheric data, taken from the Bureau's operational weather forecast system. One of its unique features is that it always uses the very latest oceanic and atmospheric data. The POAMA system has been run in real-time by the operational section of the Bureau of Meteorology since 1st October 2002. The initial focus of POAMA is the prediction of El Nino. POAMA was the first coupled model, back in November 2002, to forecast that the 2002 El Nino would rapidly decay at the beginning of 2003.The operational system and latest results will be described. Results show that the skill of POAMA forecasts is at least as good as the best international models. Also discussed is the model's unique ability to simulate and predict intra-seasonal variability, such as, the Madden-Julian Oscillation (MJO), which is normally not well simulated by coupled models. Such variability is believed to be very important for predicting the onset of El Nino. POAMA web site:

http://www.bom.gov.au/bmrc/ocean/JAFOOS/POAMA

ST-10

Results from the CERFACS Global Ocean Analysis and Coupled Ocean-Atmosphere Seasonal Climate Prediction System.

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Predictability of seasonal climate anomalies is investigated using the ORCA-OASIS-ARPEGE global coupled model. Initial conditions are obtained from ERA40 analyses, and a global ocean analysis system forced by ERA40 fluxes and winds. Ensemble ocean initial conditions are obtained by using perturbed winds, surface temperatures and in-situ temperature observations, in a way close to what is done operationnally at ECMWF. Several sets of 9-member ensemble 6-month-lead hindcast experiments have been produced for every season of the years 1987 to 2000. These experiments are part of the DEMETER project where similar hindcasts are been produced by other dynamical models in order to be intercompared and merged using the ``multi-model'' approach.

Results from a global ocean 3D-variational assimilation system are shown. These results are used to initialise coupled integrations, and their impact is evaluated through comparison to a former reference set of hindacsts. They show a significant improvement of both the mean ocean state and its variability. The impact of a thorough modelling of background errors clearly has an effect on dynamics, and on long-term evolution of water masses, and salinity.

Results from the coupled prediction system have been verified against several data sets. Surface temperature drift amplitudes are contained within one degree almost everywhere and everytime in the tropics and subtropics, but can reach more than 5 degrees in polar areas where sea ice is poorly modelled. In the ``nino3'' region where predictability is maximum, the anomaly correlation scores are of the order of 0.95 for the first season of the forecast and 0.85 for the second one. A close look at the 1997-98 event shows that this system gives good results, especially for the onset period, that the peak is forecasted within less than 0.5 degree, but the switch to ``la nina'' early 1998 is too fast. For the Indian ocean, February is the forecast season giving best results while May is the worse. The tropical Atlantic is best forecasted in February and November. In May, the surface temperature scores for the first season are quite equivallent in the three tropical basins, around 0.7, while in August, they are of the order of 0.9 in the Pacific, 0.7 in the Indian and 0.4 in the Atlantic. Predictions of other variables such as precipitation, atmosphere circulation in the northern extratropics or large scale variability patterns are also summarised.

ST-11

A Study of ENSO with New NCEP Global Coupled Atmosphere-Ocean Forecast Model

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The new NCEP global coupled atmosphere-ocean forecast model consists of a T62L64 version of the operational NCEP Atmospheric Global Forecast System model and the Geophysical Fluid Dynamics Laboratorys Modular Ocean Model version 3. The coupled model has been run freely for 30 year without flux correction. We describe the climatology and interannual variability of the key atmospheric and oceanic variables associated with ENSO, and make comparisons with those obtained with the reanalysis 2 and ocean analysis produced at NCEP. The physical mechanisms that are responsible for the onset and decay of El Nino and La Nina events in the model are also investigated.

Preliminary results suggest that the coupled model is capable of producing a realistic ENSO oscillation. However, in contrast to a spring start as in the observations, warm events in the model generally start during the winter before the ENSO year, develop quickly in spring, pause somewhat in summer, and reach mature phase in the winter of ENSO years. The early winter start of warm events is companied with strong westerly wind anomalies in the western equatorial Pacific, the mechanisms of which need further study. The decay phase of warm events appears consistent with the “Western Pacific oscillator” theory that associates the off-equator SST anomalies in the north Western Pacific with anticyclone and easterlies anomalies in the far western equatorial Pacific that gradually decreases warm anomalies in the eastern Pacific by exciting upwelling Kelvin waves.

To understand the physical mechanisms for the model ENSO events in detail, we plan to do a budget analysis of SST anomalies that include both advective and flux terms. We will evaluate the model current field with TAO and satellite-derived currents. The results will be compared with a parallel analysis of the SST budget with the new global ocean data assimilation system at NCEP.

ST-12

Analysis of Recent Atmospheric Climate Anomalies Using the NSIPP-1 AGCM

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Ensembles of 3 month hindcasts were carried out with the NSIPP-1 AGCM to assess the impact of SST anomalies and atmospheric intial conditions on monthly and seasonal predictions of 2002/2003 climate anomlies. The runs were initialized from NCEP/NCAR reanalyses and forced with observed SSTs. Nine member ensembles were produced by perturbing the initial atmospheric state. Additional runs were made to help diagnose the role of the SST forcing and the atmospheric initial conditions. The results obtained so far for the NH winter of 2002/2003 show intriguing evidence for skillful predictions of month-to-month 200mb height and precipitation variability over the United States. The skill appears to come about partly from the memory of the initial atmospheric conditions and partly from the monthly SST variations. These results, as well as the results from several other planned experiments focused on recent summer and spring climate anomalies, will be presented at the meeting.

ST-13

Effect of Altimeter Data on Seasonal Forecasts Using a Coupled Ocean-Atmosphere General Circulation Model

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During the planning for the TOPEX mission, one of the major drivers for the mission's design was to aid with the monitoring and prediction of ENSO variability. The TAO moored array provides temporally fine resolution measurements of the upper ocean thermal structure, but TAO lacks the spatial detail to resolve anything finer than planetary-scale waves. In this presentation, the comparisons between predictions from a coupled ocean-atmosphere model that assimilates available thermal ocean profiles and

predictions that assimilate altimeter data are used to highlight the impact of global satellite altimeter data on seasonal-to-interannual prediction in the Pacific. Whereas it is difficult to demonstrate a marked improvement in predictive skill in the immediate vicinity of the equator by using altimeter data alone, the altimeter data does have a demonstrable positive impact in areas away from the equator that eventually could have ramifications for longer scale variability, such as that associated with the Pacific Decadal Oscillation. The analyses in this study specifically target the effects of satellite data assimilation on the observed basin scale modes of variability resolved by the TOPEX altimeter for the period 1993-2002. Special emphasis is placed on the very strong 1997/1998 El Nino.

ST-14

Observational Impact on Seasonal Forecast Skill of a Coupled Model Using an Ocean Data Assimilation System

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The impact of different observation suites on the forecast skill of the NASA Seasonal-to-Interannual Prediction Project (NSIPP) coupled model is investigated by a series of forecast experiments initialized with the NSIPP ocean data assimilation system. An optimal interpolation scheme is used to assimilate in situ temperature data from 1993 to 2002, including TAO array data. The impact of TAO array data on forecast skill is investigated by data withholding, i.e., only part of the TAO data are used in certain experiments. The skill in forecasting Nino-3 and upper ocean heat content is assessed. Different assimilation strategies are employed to compare the effectiveness of the assimilation. We will consider issues such as salinity adjustments and geostrophic current correction so as to achieve balanced initialization.

ST-15

A Bayesian Method for Combining Multiple Atmospheric GCM Ensembles for Seasonal Prediction

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The skill of seasonal climate predictions can be enhanced by combining together the predictions made with different models, and it is desirable to be able to combine them in an optimal way. This poster develops an improved Bayesian optimal weighting scheme to combine six atmospheric general circulation model (GCM) seasonal hindcast ensembles. The approach is based on the prior belief that the forecast tercile-category

probabilities are equal to the climatological ones. The six GCMs are integrated over the 1950-97 period with observed monthly SST prescribed at the lower boundary, and the scheme is applied to seasonal-mean simulations of precipitation as well as near-surface temperature.

A key ingredient of the scheme is the climatological equal-odds forecast, which is included as one of the "models" in the multi-model combination. The weights of the individual models are determined by maximizing the log-likelihood of the combination by season over the integration period. Refinements are made to the original Bayesian scheme of Rajagopalan, Lall and Zebiak (2002), by reducing the dimensionality of the numerical optimization, averaging across data sub-samples, and including spatial smoothing of the likelihood function. These modifications are shown to yield increases in cross-validated Ranked Probability Skill Score (RPSS) skills.

The Bayesian optimal weighting scheme is shown to outperform a simple unweighted pooling together of the models, which in turn outperforms the individual models. In the extratropics, the main benefit is to bring much of the large area of negative precipitation RPSS up to near-zero values. The skill of the optimal combination is almost always found to increase when the number of models in the combination is increased from 3 to 6, regardless of which models are included in the 3-model combination.

ST-16

Initialization of Unstable Coupled Systems by Breeding Ensembles

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A major challenge in the design of a coupled ocean-atmosphere data assimilation system is the existence of a wide range of growing instabilities. An effective data assimilation for the longer time scales has to be able to incorporate the slow instabilities of the ENSO background flow into, for example, the background error covariance, since the forecast errors will have a strong projection on these instabilities. Without a special effort to isolate the slow modes in a coupled data assimilation system, the faster but less relevant instabilities that dominate linear tangent models will wipe out the slower but important coupled processes from the estimated forecast and analysis errors (but not from the real analysis and forecast errors!).

To study whether it is possible to isolate the slow, coupled instabilities in the background flow, we have done experiments with breeding, a simple process that mimics ensemble data assimilation. We will present results of breeding in the NSIPP coupled ocean-atmosphere data assimilation system and in a perfect model coupled simulation. The crucial condition is that the interval for rescaling the ocean-atmosphere perturbations is large (one month) allowing atmospheric noise to saturate. The results are very encouraging and suggest that coupled data assimilation designed for seasonal and interannual prediction is feasible and could be based on a coupled Ensemble

Kalman Filter using similarly long intervals between the coupled assimilation cycles. Simple experiments with a coupled Lorenz model confirm this "finite Lyapunov vector" approach should work.

ST-17

Internal Atmospheric Dynamics and Climate Variability

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A fundamental distinction in understanding the mechanisms that cause low frequency variability of SST in mid-latitude is between the role of unstable coupled feedbacks between the ocean and the atmosphere and the passive response of the ocean stochastic forcing from atmospheric internal dynamics. The stochastic forcing hypothesis can be generalized to stable coupled feedbacks that potential include tropical ocean variability, such as ENSO. This stochastic forcing theory is often thought of as the "null hypothesis" for ocean climate variability. Here we present a novel approach for testing the null hypothesis in the context of a coupled GCM. The procedure is to simultaneously couple multiple realizations of a single atmospheric model to a single realization of an ocean model. All the atmospheric models experience the same SST, whereas the ocean model is forced by the ensemble mean fluxes from the atmospheric models. The procedure, which is referred to as an interactive ensemble, severely reduces the stochastic forcing felt by the ocean model at the air-sea interface without altering the internal dynamics of the atmospheric models.

In this poster we describe how the interactive ensemble is implemented and how it impacts global climate variability on seasonal-to-interannual time scales. We compare multi-century simulations with and without the interactive ensemble. In terms of testing the null hypothesis, SST variance ratios indicate that there are significant regions in the tropical Indo-Pacific region where there are unstable coupled interactions. However, there are surprisingly large regions where we cannot eliminate noise due to internal ocean dynamics as a contributor to the SST variability.

ST-18

The Danish Climate Model: A New Model for Climate Studies

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At the Danish Meteorological Institute, a new climate model, DCM, is under development in cooperation with Météo-France, the Max-Planck-Institute for Meteorology in Hamburg and the Nansen Environmental and Remote Sensing Center in Bergen. This model consists of a new atmospheric GCM coupled to a global version of ocean model MICOM including a dynamic-thermodynamic sea ice model using the OASIS coupler package.

The DCM's atmospheric GCM is constructed by combining the efficiency advantage of the semi-implicit, semi-Lagrangian method in the Integrated Forecasting

System (IFS) and ECHAM physics parameterisation package that is designed for climate simulation. The current version of the model has a dynamical core of the ARPEGE climate version 3 (equivalent to IFS cycle18 at the ECMWF) that is coupled to the most updated physics package of ECHAM (version 5). The model's prognostic variables include vorticity, divergence, temperature, surface pressure and humidity on spectral space, and cloud liquid and ice water on grid-point space. The model uses a semi-Lagrangian advection scheme on the linear, reduced Gausian grid combined with a semi-implicit two-time level scheme. Thus the model is of the efficiency advantage of IFS and may perform extended simulations even at high resolution such as T159. The DCM's AGCM has been configurated to run at a variety of horizontal resolutions, i.e., T63, T106, T159, etc., with either 31 or 60 vertical levels in hybrid vertical coordinates that are identical to those for ERA15 (for 31 levels) or ERA40 (for 60 levels) of the re-analyses from the ECMWF.

In this presentation, we will focus on the quality of the DCM's AGCM. Three 30-year simulations have been carried out using the DCM's AGCM, the ARPEGE (climate version 3) and the ECHAM5 at resolution of T63 and 31 levels and forced by the climatological SSTs. The climatology of these simulations were compared and validated by using the 40-year re-analysis of the ERA40. The preliminary results show some improvement in the DCM's AGCM, while the systematic errors of the three models are generally comparable.

ST-19

Adjusting OCN Prediction Method by Invoking EOF Modes

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The optimal climate normal (OCN) method is one of the major tools of seasonal climate predictions at the climate prediction center (CPC). With this method, the climate prediction for a given season of the next year is essentially given by the average of the most recent K years. The K is determined according to the hindcast skill. Such an optimally determined number K is usually spatially and seasonally varying (Huang et al. 1996). In the current operational OCN seasonal temperature forecasts, a constant time period K=10 years is used for all locations and all seasons. The major purpose of using the constant time period is to make the forecast spatially consistent. However, as a cost of that purpose, the prediction skill becomes significantly lower than that using the spatially varying time period.

By analyzing the US climate variability, it is found that most variance (> 85%) of the seasonal mean US surface air temperature can be explained by a few empirical orthogonal function (EOF) modes. These EOF modes are different not only in their spatial pattern, but also in their dominant time scales. This finding has guided us to construct an EOF based OCN prediction scheme. With this scheme, the OCN prediction is conducted for each EOF component separately and independently, and the predicted EOF components are then synthesized to give a prediction for the total anomaly field. Since the dominant time scales of different EOF modes are different, so are the optimal Ks corresponding to these EOF modes. Therefore, this new OCN scheme can take account of multiple time scales of climate variability and meanwhile guarantee the

forecast to be spatially consistent. The hindcasts for the last 42 years have shown that the skill of this new OCN scheme is significantly higher than the current operational one.

ST-20

Dynamical Fingerprints of Climate Sensitivity

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The availability of high spatial and spectral resolution infrared radiances from instruments such as AIRS places renewed emphasis on the development of analytic tools for the comparison of model output and climate date. We analyze the behavior of a one-dimensional radiative-convective subject to various stochastic forcings (solar, vertical velocity, heat sources at various levels), and for various climate sensitivities, modulated by either albedo or water vapor feedbacks. The instrinsic dynamics of the model data for these different runs and model configurations are determined either directly from selected model variables and levels, from EOFs of temperatures and water vapor, or from EOFs of model-calculated spectrally resolved radiances. The latter can then be compared to the intrinsic dynamics calculated for spectrally resolved radiance data.

ST-21

International Stretched-Grid Model Intercomparison Project (SGMIP)

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The international Stretched-Grid Model Intercomparison Project (SGMIP) has been initiated for studying the new emerging global variable-resolution/stretched-grid approach to regional climate modeling.

The variable-resolution stretched-grid (SG) GCMs have been developed and successfully tested in the straightforward simulation mode (like that used for a typical atmospheric GCM) during the mid-late 90s. The SG-GCMs are the variable-resolution versions of the basic GCMs of the following four major meteorological centers/groups: the Meteo-France, ARPEGE model, the RPN/Canadian Meteorological Centre, GEM model, the Australian CSIRO C-CAM model, and the U.S. NASA/GSFC GEOS model. The regional climate simulation results obtained with the SG-GCMs have shown the maturity of the SG-approach. There is a consensus among the groups involved in the SG-GCM developments on the necessity of the model intercomparison at this stage of

experimentation with the models. The intercomparison is focused on addressing the following major scientific and computational issues: simulation of anomalous regional climate events; stretching strategies; approximations of model dynamics; treatment of model physics; multi-model ensemble calculations; optimal performance on parallel supercomputers.

The total number of global grid points for the SG-GCMs is (or close to) that of the 1º x 1º uniform grid. The area of interest is (or close to) the major part of North America: 20º – 60º N and 130º – 60º W. The regional resolution is about 0.5º. The surface boundary forcing (SST and sea ice) is used at 2º x 2.5º or 1º x 1º resolution. The 12-year period (1987-1998) chosen for model simulations includes the recent ENSO cycles.

The existing reanalysis data as well as independent data like high-resolution gauge precipitation and high-resolution satellite data, are used for the SG-GCMs validation. Analyzing multi-model ensemble integrations is one of the focal points of SGMIP.

The 12-year SG-GCM ensemble simulations are analyzed in terms of studying: the impact of resolution on efficient/realistic downscaling to mesoscales; ENSO related and other anomalous regional climate events (floods, droughts, etc.) and major monsoonal circulations at mesoscale resolution; water and energy cycles; the impact of surface boundary forcing. Also, studying up-scaling effects that can be assessed for SG-GCMs, will be included.

The experience obtained will allow us to make meaningful connections to CLIVAR, AMIP-2, and IPCC with a better understanding what could be contributed to regional climate studies and predictions.

Our joint SGMIP effort, focused on a better understanding of the SG-approach and its potential for regional climate studies and applications, is beneficial to all the participants as well as to a broader regional (and eventually global) climate modeling community. The SGMIP web site, that is periodically updated, is located at http://essic.umd.edu/~foxrab/sgmip.html

ST-22

3-D Structure of Atmospheric Temperature and Moisture Retrieved from AIRS and Its Applications in Climate Model Verifications

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The Atmospheric InfraRed Sounder (AIRS) is the first of a new generation of high spectral resolution infrared sounder with 2378 channels measuring outgoing radiance between 650 cm-1 and 2675 cm-1. The improved vertical resolving power of AIRS is

expected to greatly improve the accuracy of temperature and moisture soundings, as well as other important climate parameters, such as sea surface temperature, OLR, trace gases, etc..

In NOAA/NESDIS, these AIRS-based high quality atmospheric temperature and moisture products have been produced operationally on a near real-time basis since August 2002. In addition to the real time monitoring of the global weather and climate, these data can be also applied to verify the climate models. In this paper, the mean state and seasonal variations of the 3-dimensional structure of the atmospheric temperature and moisture will be described using the AIRS data for the 15 months period from September 2002 to December 2003. A comprehensive comparison will be conducted with the temperature and moisture fields generated by several climate models (NCEP, ECMWF and NASA/GMAO)to see how well the 3-D structure is represented. Research work is underway and the detailed results will be reported at the conference.

ST-23

HIRS Outgoing Longwave Radiation Climate Data Record

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The outgoing longwave radiation (OLR) at the top of the atmosphere is one of the components of the energy budget for the earth system. This parameter has long been used in the tuning and evaluation of numerical weather prediction models. One needs a long history and high quality OLR data record suitable for climate study when pursuing seasonal, inter-annual, or decadal predictions. The US National Oceanic and Atmospheric Administration (NOAA) has been producing OLR based on the Advance Very High Resolution Radiometer (AVHRR) observations operationally since 1979. This data set has served the community well for many research topics. With the multi-spectral HIRS OLR algorithm, we can provide more accurate OLR data record comparable to ERBE/CERES for the same time span, from 1979's TIROS-N to today's NOAA-17 polar orbiters, with consistencies in instrument calibrations, cloud detections, and removals/minimizations of inter-satellite biases, and orbital drift effects. This HIRS OLR data set shall provide a continuous, homogenous, and bias-free data set in the form of gridded monthly mean. We will demonstrate the use of HIRS OLR data with the comparison of the NCEP Reanalysis R-1 and the ECMWF Reanalysis ERA-40.

ST-24

Steady Linear Solutions of Thermal Waves in Atmosphere and the Relevant Energy Cycle

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This study focus on the atmospheric standing waves excited by diabatic heating and the associated energy cycle by means of theoretical research and data diagnosis. Based on existing theories, the wave solutions of large-scale latent heating and sensible heating under linear system are obtained by assuming normal mode solutions and employing the radiation boundary conditions. The general solution of latent heating represents a kind of wave that is able to carry wave energy downward and with phase-lines titled downstream with height. However, the particular solution of latent heating wave cannot convey energy in vertical direction. As for the mountain wave with the effects of sensible heating, there are two parts in complete solution: one is the traditional mountain wave which has been studied by many authors and the other is sensible heating wave with phase-lines titled windward and exponential decay with height. For the need of discussing the wave energy transfer, an improved Eliassen-Palm (EP) flux with considering diabatic effects is also introduced. Moreover, a linkage between the wave energy equation and the Lorenz energy cycle is established to further verify the importance of diabatic heating in the atmospheric energy cycle. All these results suggest an explanation for the features and patterns described in observational studies

Observational wave energy source, EP flux cross section, as well as stationary wave at various seasons and latitudes are presented for East Asia (EA). It turns out that stationary waves over EA vary remarkably with latitude and season. Latent heating wave is dominant in the tropics, whereas waves in subtropics are composed of mountain wave, latent heating wave as well as sensible heating wave. In the mid-latitude, however, latent heating wave can be identified only over the coastal regions in summer.

ST-25

VHF Radar Observations of Seasonal Variability of Gravity Wave Activity over a Tropical Station

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Studies on the variability of gravity waves on different time scales is important, since the inclusion of gravity wave drag parameterization in numerical weather prediction has led to significant improvements in their simulation of winds in the upper troposphere and lower stratosphere. MST radars provide wind velocities with fine time and height resolutions, which enable us to investigate detailed structures of small-scale gravity waves in a wide range of frequency and vertical wave number spectra. Seasonal variability of gravity wave activity in the upper troposphere and lower stratosphere has been studied by using diurnal wind data monitored by 53 MHz Indian MST radar at

Gadanki (13.50N, 79.20E). A statistical analysis is made of gravity waves with long periods to study the change in intensity of gravity wave energy and momentum flux during different seasons. Vertical variability of wave activity has also been studied by spectral analysis of the time series. The difference in the vertical flux of horizontal momentum during equinox seasons and solstices and the effect of Tropical Easterly Jet stream on the intensity of gravity waves during summer season is analysed statistically. The results will be presented in more detail in the conference.

ST-26

Spatial and Temporal Variability of Stratospheric Streamers with Respect to Different Climate Indices

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Meridionally elongated intrusions of stratospheric air into the troposphere (i.e. stratospheric streamers) are important in connection with a number of synoptic and larger scale phenomena.

Streamers have on one hand significance for the short-term synoptic forecasting. Case-studies show that they can act as an important precursor for heavy precipitation events in the Alpine region (Massacand,1998). They can also have marked influence on the transition of hurricanes from the tropics into the extra-tropics (Ritchie, 2003).

On the other hand, on the monthly to inter-annual time-scale their variability of distribution and form is closely linked to different climate indices. For example the different phases of ENSO have a significant influence on the life-cycle that breaking waves undergo (Orlanski, 2003).

Since streamers can be interpreted as breaking planetary Rossby-waves, a change in the ambient wave propagation and breaking properties of a distinct region, should have an influence on the form and the occurence of streamers. It is conceivable that breaking-waves themselves can influence the large-scale indices. Franzke et. al (2004) found in several different case-studies a a link from the life-cycles of breaking waves to the North Atlantic Oscillation.

It is therefore of interest to investigate the monthly to inter-annual variability of the spatial distribution of the stratospheric intrusions. In this study we present a climatology of stratospheric streamers on the northern hemisphere for the ERA-40 period (1958-2002). The inter-annual variability of the spatial distribution of the streamers and of some of their form attributes is evaluated with respect to different phases of climate indices.

ST- 27

Potential Vorticity Intrusion Indices and Climate Variability of Surface Temperature

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Daily pressure fields on a constant potential vorticity (PV) surface (PV = 2.5 unit) are analyzed using NCEP/NCAR reanalysis II (1979-2002) dataset. Potential vorticity intrusion (PVI) indices are developed to measure the mean latitudinal position, area, and intensity of the subtropical and polar front zones, as well as the equatorial convection zones.

It is found that the polar front indices are closely related to the interannual and decadal variability of the cold air temperature anomalies over the high latitudes. In general, more (fewer) of extreme cold surface air temperature episodes in high latitudes coincide with a high (low) extratropical PVI index. The interannual variability of the extratropical PVI index exhibits a strong QBO- like signal. The high (low) PVI index prevails when the equatorial zonal mean zonal wind at 50 hPa is easterly (westerly). The composite anomaly surface air temperature maps of high versus low extratropical PVI indices exhibit a pattern resembling to the familiar regression map against the AO index found in Thomson and Wallace (1998). However, the composite maps of surface pressure anomaly show a different pattern: the circulation anomalies over the north Atlantic basin are very like NAO but the anomaly pattern over the Pacific shows a dipole that is out of phase with the pattern over the Atlantic basin. The probability distribution map of PV intrusion activities shows a shift of the preferred regions of frontogenesis from the oceans to the continents when the extratropical PVI index is high. This explains directly why more extreme cold events are observed over the northern Eurasian and Northern America continents when the PVI index is high or the QBO is in the easterly phase.

The equatorial PVI indices exhibit a pure QBO signal as one may expect. It shows that in the easterly phase of QBO, the equatorial air expands while subtropical front moves equatorward and polar frontogenesis area increases and intensifies. This is particularly evident in the Northern Hemisphere. The reverse is observed in the westerly phase. It is found that the observed warming trend in the high-latitudes in the last two decades can be explained an upward trend of the PVI index of subtropical fronts.

ST-28

Methodology and Methods for Restoration of Missing Data and Long-Term Time Series of Meteorological Characteristics

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Time series of observed meteorological characteristics have different period of observations and lack of information (missing data) in some years. Such situation is not suitable for decision of such main problems of modern climatology as:

- restoration of the information in the points of regular grids for GSMs application, because the accuracy of interpolation can be differ for different time periods;
- classification, regionalization and extrapolation of long-term climate change tendencies over the space, because records of observations have different size and period that lead to different assessments of long-term climate changes.

For restoration of long-term time series and lacks in observations with an aim to extend them for long-term and the same period, for example the period of last one century at least, the general methodology based on the space-time synchronism can be developed and suggested. This methodology has three main steps of consecutive realization, beginning with the most effective one:

- extending of short-term time observations on the basis of relationships with the particular analogues, which have the longest records, on the basis of simple and multiply regression (principle of long-term time synchronous among the neighbouring space points);
- restoration on the basis of regional relationships for different time sections (principle of synchronous inside a homogeneous region and the existing of space gradient);
- restoration of different characteristics in the same point (station) on the basis of relationships between different meteorological characteristics, for example, data in one month with data in other month using a seasonal function, etc.

The particular methods and statistical models have been developed for realization of each approach.

The next step of methodology connects with an assessment of efficiency of restored values. This assessment includes the following stages:

- development of the criteria for creation of effective model for the data restoration;
- assessment of efficiency for results of restoration on the basis of the same data which have been used for the processing;
- assessment of efficiency of restored values on the basis of independent data.

The criteria and indexes of efficiency have been developed for each stage of development of the model and assessment of efficiency and the result was the complex of criteria for assessment of efficiency of data restoration in the particular point.

The last problem of data restoration connects with the generalization of the results obtained by different methods of restoration and on the basis of different models. Methods of restoration based on the averaging of the results with weight coefficients inverse to their random errors as well as methods based on the distribution function of errors have been developed and suggested. As a result, such developed system of restoration of meteorological data allows take into account all space-time climatic properties and give the most effective assessment of data restoration in each point.

Application of suggested approach is given for processing and restoration of time series of monthly air temperature for the European part of Russia. More than 100 stations have been chosen with average period of observation in 80 years. In the result of step by step restoration the sizes of records have been extended up to 110-130 years in dependence on the particular month. For months of cold period of year the size of restored data was more than for warm period. Random errors of restoration obtained by independent way, as a rule, do not exceeded 20% to standard deviation of long-term time series.

ST-29

The Study of Transitory Forcings in Geophysical Time-Series Using the Scale Dependent Correlation Analysis (SDC)

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In this presentation, we provide a practical step-by-step explanation of how to find transitory forcings in geophysical time-series by means of the scale-dependent correlation (SDC) analysis. The analysis of transitory processes is an important topic in climate studies. Some climatic drivers have long-distance and non-continuous effects that appear as transitory signals in local time-series. Because only a few statistical techniques are capable to detect temporary features in time-series, these forcings have been often neglected. We introduce here the scale-dependent correlation (SDC) analysis, a statistical and graphical method to study transitory processes at any temporal or spatial scale. Though SDC analysis relies on conventional procedures and simple well-known statistical techniques, it is an improved time-domain analogue of wavelet analysis. Here, we use several synthetic examples to describe the method and to compare it to wavelet analysis, and some selected geophysical time-series to illustrate the methodology and to highlight the importance of the detection of transitory features in geophysical studies.

ST-30

The Use of Scale Dependent Correlation Analysis (SDC) to Highlight the Predominant Role of Transitory Processes in Most Interactions between the Tropics and Mid-Latitudes

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The signal to noise ratio is larger in extratropical time-series than in the tropical ones. The noisy condition of mid-latitude time-series prevents an easy and straightforward identification of the dominant paths of tropical-extratropical interactions. Nevertheless, two strategies can be applied in order to improve the characterization of such teleconnections: to understand better the noise and to consider the transient nature of far-distant forcings. The size-dependent correlation analysis is a new time-domain statistical technique that allows to perform both tasks at the same time because it is capable to separate short-living signals from the background noise. SDC analysis is a very simple statistical procedure with a powerful graphical output that allows to describe the nature and intensity of the underlying noise, but also to identify the timing, duration and main characteristics of temporary forcings. Tropical-extratropical interactions are geophysical processes often characterized by the non-linear interplay between the

atmosphere and different oceanic basins. This sort of climatic drivers are not easy to detect and appear to be even more complicated to be fully reconstructed in either phase, amplitude and timing. In this context of, SDC becomes the most efficient tool to detect tropical forcings in extratropical time-series, as we show in the examples provided.

ST-31

The Climate Driver of Interannual CO2 Variability

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The observed atmospheric CO2 growth rate consists of a large interannual variability superimposed on a gradual increase due to human fossil fuel carbon release. This work studies the characteristics of such variabilities on interannual to interdecadal time scales and how corresponding carbon sources and sinks on land and in the oceans are related to known climate variabilities such as ENSO.

ST-32

Global Precipitation Variability in 1979-2001 as Derived from the GPCP and CMAP

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The GPCP and the CMAP are the two most widely used merged satellite-gauge precipitation products with full global coverage. The new versions of the two products provide information for more than 23-year period from 1979 to 2002 and they are being constantly updated. They have been created independently using different analysis procedures but use much of the same input data.

For the long-term mean, major precipitation patterns including the monsoon and the ITCZ, are clearly demonstrated by both products. The global mean precipitation is respectively 964 and 967 mm/year as calculated from the GPCP and the CMAP. Relative difference of the two products shows that compared to the CMAP the GPCP is lower in the tropical ocean but higher in the high latitude ocean. For the GPCP-CMAP correlation it is higher over land than over water because of the incorporation of gauge data in both products. However, the GPCP over-land precipitation is higher than the CMAP one due to the correction in gauge data used by the GPCP only. For the zonal mean, both products show a primary maximum just north of the Equator, two secondary maxima in mid-latitudes, two primary minma in the polar regions, and two secondary minma between the tropics and subtropics. The Equator-to-pole precipitation gradient is lower in the GPCP than in the CMAP.

EOF analysis reveals that the GPCP and the CMAP are nearly identical in the first two modes, highly correlated in the next two modes. Starting from the fifth modes, neither the spatial patterns nor the temporal variabilities of the two products show any significant similarity. The first three EOF modes are ENSO connected. The first one represents the mature stage of an ENSO event, with a strong variational center along the Equator over the west to the central Pacific Ocean. The second one, having two opposite variational areas in the west and the central-east equatorial Pacific Ocean, describes the final stages of strong El Nino events. The spatial pattern is similar to that of the first mode but has moved to the east by 30 degrees. The third mode features a strong variational region in the central-east equatorial Indian Ocean. Since the it reaches its peak 4-6 months before the ENSO mature stage time, the third mode can be used as an ENSO precursor.

ST-33

Seasonality in Precipitation Variability over Europe

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A gridded monthly and pentad precipitation for 1979-2001 from the Climate Prediction Center Merged Analysis of Precipitation (CMAP) dataset and terrestrial monthly gauge-based precipitation for 1958-1998 from the Climatic Research Unit, University of East Anglia (CRU) dataset are used to investigate seasonality in the long- and short-term precipitation variability over Europe. Prominent seasonal differences are detected both in precipitation climatologies and in characteristics of precipitation variability. It is shown that over western Europe the summer precipitation climatology and its year-to-year variability (expressed by standard deviations) are approximately equal to those of the winter precipitation. Major seasonal differences are found over central-eastern Europe. In this region, the summer precipitation climatology and magnitudes of its interannual variability exceed respective winter characteristics by a factor of 2-3.5. Similar relationships are found for the summer and winter magnitudes of intraseasonal fluctuations of precipitation.

The first EOF modes of both summer and winter seasonal mean precipitation over Europe are associated with the North Atlantic Oscillation (NAO). However, they explain very different (42% for winter, and 25% for summer) fractions of total precipitation variability, and form principally different spatial patterns. Temporal behavior of the respective principal components is also essentially different. The first EOF mode of the winter magnitudes of intraseasonal precipitation fluctuations is also associated with the NAO. The second EOF mode of the winter precipitation is linked to the East Atlantic teleconnection pattern. However, the respective mode in the magnitudes of intraseasonal fluctuations was not detected. The second EOF mode of the summer precipitation is not associated with the known teleconnection patterns, and its origin is unclear.

ST-34

ENSO Influence on Eurasian Autumn Rainfall

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It has long been a matter of debate whether and how ENSO warm and cold extremes influence Euro-Mediterranean rainfall. Since the early works on ENSO teleconnections, there has been increasing evidence supporting such a link and pointing to a strong seasonal dependence. In particular, rainfall in southern Europe seems to be affected by ENSO in autumn more than in other seasons with coherent correlation values found accross a large stretch of land regions reaching South and East. This work presents a detailed analysis of the influence tropical climate variability has on autumn rainfall in parts of the eurasian continent comprised in the region 30W-80E and 25N-70N on interannual time-scales. The investigation is based on 50 years of rainfall data from CRU, observed sea level pressure (GMSLP2) and sea surface temperatures (GISST) from the UKMO and NCEP/NCAR reanalyses. Results show that interannual autumn rainfall variability in southern Europe, Northern Africa and the Middle East is significantly and primarily affected by ENSO events, with enfanced rainfall being associated to warm events. The global patterns of anomalous circulation and sea surface temperature related to this rainfall anomalies are clearly evocative of ENSO. The anomalous patterns are presented as to evidence the potential paths for this teleconnection.

ST-35

Global 1km Land-Atmosphere Modeling with the Land Information System

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NASA's Goddard Space Flight Center has developed a global Land Information System (LIS; http://lis.gsfc.nasa.gov) capable of modeling land-atmosphere interactions at spatial resolutions down to 1km. LIS consists of several land surface models run offline using observationally-based precipitation, radiation and meteorological inputs, and surface parameters including MODIS-based Leaf Area Index (LAI). LIS's emphasis on observationally based forcing and parameters (following the Land Data Assimilation System LDAS; http://ldas.gsfc.nasa.gov) and high performance computing make it particularly well-suited for initializing seasonal-to-interannual prediction models in addition to numerical weather prediction models. The high spatial resolution of LIS makes it capable of resolving urban areas, and a key area of ongoing work is updating land surface models to represent the impacts of engineered surfaces (buildings, roads, parking lots, sidewalks, etc.) on mesoscale land-atmosphere interactions, including water, energy, and momentum fluxes. We will present results demonstrating LIS applied at multiple resolutions globally.

ST-36

GLACE: Quantifying Land-Atmosphere Coupling Strength across a Broad Range of Climate Models

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In analogy to ocean heat content, land surface soil moisture and snow cover have a longer memory than atmospheric quantities and can potentially contribute to atmospheric variability and seasonal predictability. The degree, however, to which the atmosphere responds to land surface anomalies (i.e., the land-atmosphere coupling strength) is still largely unknown. Coupling strength is a complex function of the numerous interacting model parameterizations controlling the land surface energy balance, the development of the boundary layer, precipitation generation (particularly convection), and other AGCM features. The quantification and documentation of coupling strength across a broad range of models would be valuable, if only to serve as a frame of reference when interpreting the experimental results of any particular model.

This quantification and documentation is indeed the goal of GLACE (Global Land Atmosphere Coupling Experiment), an experiment jointly sponsored by the CLIVAR Working Group on Seasonal-to-Interannual Prediction (WGSIP) and the GEWEX Global Land Atmosphere System Study (GLASS) panel. The AGCM experiments defined by GLACE allow the computation of objective indices of coupling strength that can be directly compared between models. At present, eleven AGCM groups have completed the GLACE experiments. Results show a broad disparity in the inherent coupling strengths of the different models – an indication of the uncertainty with which nature's unmeasurable "coupling strength" is known. Some agreement, however, is seen in the

geographical patterns of the coupling strength; several models agree on certain "hot spots" of coupling. For some – but certainly not all – models, coupling strength appears to be largest in the transition zones between dry and wet areas.

The poster will present the basic results from the GLACE experiments. Further details regarding GLACE may be found at http://glace.gsfc.nasa.gov/ . We acknowledge invaluable contributions from the following participants: Tony Gordon and Sergey Malyshev (GFDL); Yongkang Xue and Ratko Vasic (UCLA); David Lawrence, Peter Cox, and Chris Taylor (HadAM3): Bryant McAvaney (BMRC); Sarah Lu and Ken Mitchell (NCEP/GFS); Diana Verseghy and Edmond Chan (CCCma); Ping Liu (NSIPP); and Eva Kowalczyk and Harvey Davies (CSIRO).

ST-37

Impact of Amazon Deforestation in a Coupled General Circulation Model

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The atmospheric response to Amazon deforestation has been the subject to several investigations, using atmospheric GCMs forced by specified SST. These investigations found an increase in surface temperature, and a decrease in evapotranspiration, precipitation and runoff local to the deforested region. A recent coupled GCM experiment indicates that changes in the surface energy balance in the Amazon region could have a significant impact on ENSO variability. Motivated by these results, we are investigating the response of the climate of a coupled atmosphere-ocean-land GCM to large scale Amazon deforestation. Two long simulations are being made using the COLA land-ocean-atmosphere anomaly coupled GCM. The control case has prescribed land surface boundary conditions appropriate for the current climate. In the other simulation, the rain forest is replaced by degraded grassland over the Amazon regions. The local response over the Amazon is prominient and very similar to that found in the specified SST simulations. The effects of the deforestation on the coupled climate and its variability during the first century of the simulations will be described.

ST-38

The Contribution of Land-Atmosphere Interaction to Boreal Summer Season Predictability

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The potential role of the land surface state in improving predictions of seasonal climate is investigated with a coupled land-atmosphere climate model. Climate simulations for 18 boreal summer seasons (1982-1999) have been conducted with specified observed sea surface temperature (SST). The impact on prediction skill of initial land surface state (interannually varying versus climatological soil wetness) and the effect of errors in downward surface fluxes (precipitation, longwave and shortwave radiation) over land are investigated with a number of parallel experiments. Flux errors are addressed by replacing the downward fluxes with observed values in various combinations to ascertain the separate roles of water and energy flux errors on land surface state variables, upward water and energy fluxes from the land surface, and the important climate variables of precipitation and near-surface air temperature.

Strong systematic errors are found in the model, which are only mildly alleviated by the specification of realistic initial soil wetness. The model shows little skill in simulating seasonal anomalies of precipitation, but it does have some skill in simulating temperature variations. Replacement of the downward surface fluxes has a clear positive impact on systematic errors, suggesting that the land-atmosphere feedback is helping to exacerbate climate drift. Improvement in the simulation of year-to-year variations in climate is even more evident. This suggests that the land surface can communicate climate anomalies to the atmosphere, given proper meteorological forcing.

The evolution of signal-to-noise between ensembles with different soil wetness initialization reveals the properties of land surface memory in the model, and the changes in this evolution under flux replacement suggest pathways through which this memory may be reinforced. The changes in skill under flux replacement suggests the parameterizations within the atmospheric model that need critical attention, and raises the hope that a different coupling strategy (e.g., flux adjustment or anomaly coupling) between land and atmosphere may significantly improve climate prediction.

ST-39

A Global Land Daytime Canopy Resistance Data Set from 1949-1995

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A global monthly data set of daytime canopy resistance with 1 degree resolution from 1949-1995 has been derived. Similar to SST, but it prescribes the bottom boundary conditions over land for climate models. Canopy resistance is about 500-20000 s/m in desert areas, 50-800 s/m in Mediterranean areas and the Near East, 0-500 s/m in Polar regions and Siberia, 20-300 s/m in North European plain, Canadian Shield, North America plain and North China, and 30-130 s/m in tropical rainforests, South China and the Far East. The canopy resistance is derived according to the energy budget equations of planetary boundary layer and land surface. The first 5 EOFs of the ratio (EPR) between evaporation rate and potential evaporation rate explains 71% of the variance of the monthly EPR. The dominated EOF for 63% of land grids belongs to

EOF1, 22% of land grids belong to EOF2, and 8% belongs to EOF3. It shows that the highest solar radiation and leaf area index in summer does not always yield the lowest canopy resistance especially over croplands. In addition, the persistent increase of canopy resistance during the past 50 years has been found in several locations in evergreen broadleaf forests (rainforests).

ST-40

Impact of Spin-Up of Land-Surface Initial Conditions on Warm Season Predictability Simulated by the NCEP Global Forecast System Coupled with the Noah LSM

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As part of NCEP efforts to unify the land-model component in all NCEP global and regional models and their data assimilation systems, the NCEP Noah LSM (Ek et al., 2003) has been implemented in the test bed of the NCEP Global Forecast System (GFS) in late 2002 and subsequently been incorporated into the framework of the NCEP Global Data Assimilation System (GDAS) in early 2003. Two strings of low-resolution (T62L28) data assimilation runs starting from 1 Aug 2002 are in progress; one is based on the operational version of GFS employing the OSU LSM, and the other uses an experimental version of GFS coupled with the newer Noah LSM. A soil wetness nudging procedure (with relaxation time equals to 60 days) is used in the GDAS runs and such application is likely to reduce the differences between OSU cycled GDAS versus Noah cycled GDAS. Therefore, a third string of GDAS using the experimental version of GFS but with soil wetness nudging procedure turned off is conducted. The efforts for conducting retroactive GDAS runs aim to evaluate the impact of LSM upgrade on GFS forecasts as well as to provide continuously cycled Noah LSM land states in GDAS.

This poster presents summer-time seasonal hindcasts for 2003 using the NCEP GFS. The length of integration is 3 months, starting from late spring/early summer, and the ocean surface boundary fields are taken from observed 1-deg NCEP Reyolds/Stokes SST. Four sets of GFS ensemble runs are conducted, including the control run (the operational version of GFS initialized from OSU cycled GDAS) and three test runs (the experimental version of GFS initialized from the three strings of GDAS mentioned above). Results from summer time integrations are analyzed and compared against observed near-surface temperature from the NCEP Climate Prediction Center (CPC) 344 Climate Division data and precipitation fields from CPC gauge date. The impact of using Noah cycled GDAS (which provide initial land states that are strictly self consistent with the experimental version of GFS) on warm season predictions is examined.

ST-41

Land Surface Hydrological States and Their Global Teleconnections

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The interaction between the land surface and the atmosphere is well-known and of particular research interest. Land surface hydrology is influenced by and is itself a feedback to large-scale atmospheric circulation processes. Land surface states such as soil moisture and snow cover extent have a major role in this mechanism, providing reservoirs that govern interactions between the land and the atmosphere. The influence of these interactions may reach over great distances in the form of anomalies in sea surface temperatures (SSTs), changes in sea ice and weather patterns. In this study we attempt to identify teleconnections between anomalies in regional land surface hydrological states and climate anomalies around the globe and whether these are the result of long-term climate oscillations or random events. The analyses are based on a global, 50-year dataset of land surface hydrological states and fluxes generated by forcing the Variable Infiltration Capacity (VIC) land surface model with an observation based meteorological dataset. Standard indices (ENSO, NAO and PDO) and the AVHRR/in-situ based NCEP Reynolds Historical Reconstructed SST dataset are used to characterize climate oscillations and anomalies. We use various statistical techniques to explore possible teleconnections between not only the land surface and SST phenomena but also the influence of the land surface itself on distant land surface processes. The long-term nature of these datasets enables us to encompass a range of climatic oscillations and variability in hydrological state variables. Snow and soil water storage also play a central role in the occurrence of extreme hydrological events such as large scale floods and droughts. Timely prediction and warning of the possibility of major flooding and long-term drought may help to anticipate and reduce the costs of these hydrologic extremes. We discuss the potential use of relationships between land surface hydrological states and climate anomalies in the prediction of extreme events.

ST-42

A Long-Term Land Surface Hydrological Dataset for Global Climate Studies

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Model simulations of large scale water and energy balances are useful for the study of climate change and variability, and in some cases can act as surrogates for observations that are sparse or nonexistent. This paper describes a global, 50-yr, sub-daily, 1.0 degree terrestrial dataset of water and energy fluxes and states using observation based forcings and a state of the art land surface model. The dataset provides a long-term, globally-consistent product that is useful for the study of seasonal and inter-annual variability and for the evaluation of coupled models and other land surface prediction schemes. The forcing dataset is constructed from a combination of global monthly precipitation, temperature and radiation data disaggregated to subdaily time steps using the NCEP/NCAR Reanalysis. Known biases in the Reanalysis precipitation and near-surface meteorology are corrected using observations where available. Corrections are made to the wet-dry day statistics of the reanalysis precipitation which have been found to exhibit a spurious wave-like pattern in the high-latitude winter. Wind-induced undercatch of solid precipitation is corrected using the results from the World Meteorological Organization (WMO) Solid Precipitation Measurement Intercomparison. Underestimation of precipitation in mountainous regions is corrected using a hydrologic water balance approach based on watershed runoff ratios and historical discharge data. Biases in monthly downward short and longwave radiation are corrected using data from the Surface Radiation Budget (SRB) analysis. An initial version of the dataset is available at a daily and 2.0 degree resolution. A second version has been created at 3-hourly and 1.0 degree resolution to capture the finer temporal and spatial variability of land surface fluxes and states. This dataset is obtained by disaggregating the 2.0 degree precipitation by statistical downscaling using relationships developed with the 0.5 degree GPCP daily 1997-present dataset. Temporal disaggregation from daily to 3-hourly also uses statistical downscaling but with the TRMM 1/4 deg 3-hourly dataset (Feb 2002 - Jan 2003). The forcing dataset is used to drive the Variable Infiltration Capacity (VIC) land surface model to produce fields of land surface water and energy fluxes and states. Calibration of the model is achieved through the use of a multi-objective and multi-seasonal calibration strategy which uses representative sampling techniques and geostatistical interpolation to reduce the computational overhead.

ST-43

Potential Predictability of U.S. Summer Climate with "Perfect" Soil Moisture

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The potential predictability of surface-sir temperature and precipitation over the United States continent was assessed for a GCM forced by observed sea surface temperatures and an estimate of observed ground soil moisture contents. The latter was obtained by substituting the GCM simulated precipitation, which is used to drive the GCM's land-surface component, with observed pentad-mean precipitation at each time step of the model's integration. With this substitution, the simulated soil moisture correlates well with an independent estimate of observed soil moisture in all seasons over the entire US continent. Significant enhancements on the predictability of surface-air temperature and precipitation were found in boreal late spring and summer over the US continent. Anomalous pattern correlations of soil moisture, precipitation and surface-air temperature over the US continent in the June-July-August season averaged for the 1979-2000 period increased from 0.09, 0.01, and 0.06 for the GCM simulations without precipitation substitution to 0.52, 0.23, and 0.31, respectively, for the simulations with precipitation substitution. Results provide an estimate for the limits of potential predictability if soil moisture variability is to be perfectly predicted. However, this estimate may be model dependent, and needs to be substantiated by other modeling groups.

ST-44

Verification Techniques for Short-Term Ensemble Predictions

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Over the past decade, many ensemble prediction systems (EPS) have been implemented for operational forecasting of climate and hydrologic conditions. With a climate EPS, ensemble members are created using a set of perturbed initial conditions. In contrast, with a hydrologic EPS, ensemble members are created using alternate boundary forcings (e.g., weather inputs). Although there are fundamental differences in climatic and hydrologic approaches to ensemble prediction, the verification of EPS forecasts is a common challenge. In this presentation, a technical approach for verifying ensemble predictions is described. The ensemble predictions are interpreted as a probability distribution forecast, and a distributions-oriented approach is utilized to assess forecast quality over the continuous range of possible outcomes. This approach facilitates a diagnostic verification for the EPS, which can help identify aspects limiting forecast skill and provide a basis for correcting forecast biases. Still, a common challenge for verification of climate and hydrologic ensemble predictions is sampling uncertainty. Even though hindcasts are essential for constructing verification data sets, the resulting forecast sample size is small (compared to those for weather forecasts). Hence, uncertainties in the forecast quality measures are also examined.

ST-45

Western U.S. Long-Range Hydrologic Forecast System

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We describe a real-time seasonal streamflow forecasting system for the western U.S. that incorporates the following elements. First, climate forecast ensembles (for 6-7 months lead) are taken from the NOAA/NCEP and NASA/NSIPP global forecast models, for which forecast period climate model simulations (predictions) are constrained by predicted sea surface temperature. Forecast ensembles (1 year lead) are also constructed via extended streamflow prediction (ESP) resampling of observed forecast period precipitation and temperature (with additional compositing to reflect ENSO/PDO states). Second, the Variable Infiltration Capacity (VIC) macroscale hydrology model, implemented at 1/8 degree spatial resolution over the major river basins of the western U.S., is used to transform the forecast ensembles of land surface forcing variables (primarily precipitation and temperature) into corresponding ensemble forecasts of soil moisture, snow water equivalent (SWE), runoff, and, for about 60 river locations, streamflow. The initial land surface condition for the forecasts uses data assimilation to combine the final state of a 2 year spin-up simulation with current SNOTEL SWE observations (and, for an experimental Snake River basin domain, with MODIS-based snow cover imagery). Third, for the Columbia, Colorado and Sacramento - San Joaquin River systems, reservoir simulation models are used to produce corresponding ensembles of future reservoir storage, releases, and associated variables like hydropower production. We review previous experience with a pilot forecast domain consisting of the Pacific Northwest, with real-time testing beginning in January 2001. Forecast results for the entire domain for winter 2003-4 beginning in September 2003 are also presented.

ST-46

Impact of the Quikscat Surface Winds on the Summer Precipitation Simulation over the US Great Plains

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Quantitative precipitation forecasts of the fine scale precipitation events over the US Great Plains at the timescales of a few days to months during the warm season remains a great challenge. A special precipitation feature in this region is that summer precipitation occurs most frequently from middle night to early morning, and the nocturnal precipitation contributes significantly to the total precipitation amount. This is quite different from other inland regions such as the Large-Scale Area-East (LSA-E) and the southwestern US, where the summer precipitation and thunderstorms tend to be more frequent during the afternoon.

This study uses the coupled MM5 and the Simplified Simple Biosphere (SSiB) land surface model at a resolution of 15Km/45Km to simulate the US Great Plains summer precipitation in a monthly continuous integration for June 2000. This couple MM5-SSiB model has recently been successful used by Zhang et al. (2003) in simulating the summer precipitation in the LSA-E region. Results in this study suggest that many daily characteristics of the weather evolution and the precipitation dirunal cycle can be reasonably reproduced during the monthly integration over the Great Plains region, though the dirunal cycle characteristics of the precipitation in this region is different from the LSA-E region. This study further examines the impact of the QuikSCAT surface wind on the simulation. Here the QuikSCAT surface wind is assimilated into MM5-SSiB using a Four-Dimensional Data Assimilation (FDDA) scheme, in which the model surface wind is continuously nudged toward the QuikSCAT wind during thde integration. The assimilation of the QuikSCAT wind results in a good positive impact on the simulated rainbelt amount, position, and orientation in some of the weather events where the model surface winds are significantly different from the QuikSCAT winds. In addition, monthly mean precipitation patterns are also improved by the assimilation of the QuikSCAT winds. Detailed results will be discussed in the conference.

ST-47

Regional Seasonal Prediction over the United States and Mexico

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Seasonal precipitation hindcasts for North America including the United States and Mexico were performed using the NCEP Global Forecast System (GFS) high resolution T126 model with 28 levels in the vertical. There were 8 members in the ensemble. The cases chosen were the wet monsoon year July-September (JAS) 1999, a relatively dry year JAS 2000, the great floods of 1993 over the central United States (JAS 1993) and a drought year over the central United States of 1988 June-August. The predicted rainfall pattern over Mexico and the Southwest is realistic. The model is also able to capture the relative wetness of 1999 and the dryness of 2000. The model shows a maximum over the central Untied States in 1993, but the center is shifted to the north and the magnitude of precipitation is much less than the observed maximum. However, the model is able to capture the rainfall difference between 1993 and 1988.

Experiments were repeated with the same GFS model but with the horizontal resolution reduced to T62. The T62 model is able to capture the relative rainfall difference over the central United States, but the forecasts over the Southwest and northwestern Mexico are very dry. The T62 model is not able to resolve the narrow Gulf of California. There is no low level jet from the Gulf to the Southwest. Most moisture sources for precipitation over the Southwest come from the moisture transport from the North Pacific and the Gulf of Mexico. The increase of vertical resolution does not improve the precipitation hindcasts over the Southwest.

Work is started to perform downscaling from the T62 hindcasts using the NCEP regional spectral model (RSM) with 80km and 50km resolution respectively. The

preliminary results are encouraging. The results of downscaling will be reported during the conference.

ST-48

The Eta Regional Climate Model: Model Development and Its Sensitivity to Domain Size, Convection Scheme, and Lateral Boundary Conditions

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To examine climate predictability on seasonal time scales (3-6 month forecasts) using regional models, in this study we continue our ongoing advancement and testing of a high resolution (32-km), Eta model-based Regional Climate Model (Eta RCM). The model was based on the NCEP operational Eta NWP model as of 24 July, 2001 (which is the Eta model version used in the NCEP 25-year Regional Reanalysis), with changes made to make the configuration of the model execution consistent with the longer time scales of seasonal forecasts, including daily updates to the fields of sea surface temperature (SST), sea ice cover, green vegetation cover, and albedo.

To test the skill of the Eta RCM in predicting warm-season anomalies of precipitation and the sensitivity of this skill to domain size, convection scheme, and source of the lateral boundary conditions, we chose two summers from two contiguous years (2001, 2002). For each year, the model was run on three different domains sizes that vary by about 20 percent from largest to smallest -- wherein even the smallest domain was kept rather large to include the entire continental United States (CONUS). For each domain, two convection schemes (Betts-Miller-Janjic and Kain-Fritsch) were used with either analyzed lateral boundary conditions from the NCEP Global Reanalysis II or predicted lateral boundary conditions from the NCEP global Seasonal Forecast Model (SFM). The Eta RCM was run with a combination of these scenarios to examine individual impacts.

The RCM seasonal simulations in many previous studies were driven by analysis lateral boundary conditions and were initialized from one single date (i.e., one member realization). In contrast, we used both analyzed and predicted boundary condition fields, and for each testing scenario we executed 6 members whose starting dates vary by one and half days. The study examined the June - September period and included 4-5 month long model executions initialized from late May and ending in early October. The results obtained from the two years are compared and we focus on both the model sensitivities and the model ability to capture interannual variability in precipitation.

We examine the resulting ensemble mean and individual members to demonstrate whether a) the model is sensitive to size of the large domain, chosen convection scheme, and source of lateral boundary conditions, b) the Eta RCM successfully captures both wet and dry interannual anomalies in total precipitation over the U.S., c) there is significant member-to-member difference in both total monthly precipitation and surface energy and water budgets. The results show that the Eta RCM has a great sensitivity to the choice of both domain size and convection scheme. Also, there is substantial member-to-member variability (even with lateral boundary conditions

from reanalysis), indicating that previous RCM studies that employed only "one member" initialized from one single date may be misleading by side stepping inherent internal variability.

ST-49

Relationships between Severe Weather and Global Climate and Their Application to Seasonal Forecasting

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In the general public and in the media, severe weather events are often attributed to unusual conditions that are unique to that particular year. For example, the devastating January 1998 ice storm in the northeast United States was attributed in the press and media to the strong El Niño pattern present that winter. To test this public assumption, studies have been undertaken that verify a cause and effect relationship between the El Niño of 1997-98 and the ice storm that left nearly a million people in the northeast U.S. and southern Canada without power. Following on the positive association these studies established between the ice storm and El Niño, we have undertaken a project to quantify further such relationships between severe winter weather and other global climate patterns. Using empirical orthogonal functions (EOF) and regression analyses, we have examined the dependence of river ice jams, damaging ice storms, and accumulated freezing degree days (AFDD) in the continental U.S. on several global climate indices (Southern Oscillation Index, North Atlantic Oscillation, Pacific Decadal Oscillation, Pacific-North America pattern, and Northern Hemisphere temperature anomalies). Preliminary results for AFDD indicate that, during our period of analysis (1950-2000), the global climate indices can be linearly combined to account for over 30% of the interannual variation in AFDD. Ice storms do not initially appear to be significantly related to the climate indices, but work remains on this as well as on normalizing the ice jam data for evaluation. Our immediate goal is to use relationships established through this project to assist with improved forecasts of winter severity, both for the entire season, as with AFDD, and with individual events, as with ice storms and ice jams. Ultimately, we plan to extend the method that we establish to seasons other than winter (to include severe events such as floods, droughts, and heat waves) and locations outside the U.S. with much lower meteorological data density. Such quantification of historic relationships between severe regional weather and global climate would preferably displace static climatology as a method for making dynamic forecasts in many data-poor regions of the globe and would allow for forecasts of seasonal severity at least a few months in advance.

ST-50

Climatic Feedbacks during the 2003 European Heatwave

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During the summer of 2003, a record heat wave over Europe occurred, to which the deaths of over 12,000 people in 18 countries were attributed, 10,000 of those in France alone. There were widespread wildfires, and the wildlife in the region was also dramatically affected, with high tolls being taken in the bird and fish populations. The Danube river reached its lowest level in more than a century, and Mediterranean Sea surface temperatures off the coast of Spain reached the highest levels observed in 45 years (32°C). Temperatures across Europe were above normal for most of the summer, but reached their peak during the first 2 weeks of August, when most of the deaths occurred.

Ensemble simulations done with a recent version of the Center for Ocean-Land-Atmosphere Studies (COLA) atmospheric general circulation model (AGCM) have been analyzed over the European region. The simulations were forced by weekly mean observed sea-surface temperature (SST) obtained from the U.S. National Centers for Environmental Prediction (NCEP) and were initialized in late 1981. Relative to the 1982-2001 period, the COLA AGCM simulated anomalous warmth over the European region during June, July and August 2003, in response to the observed SST, however the simulated magnitude was smaller than observed. Additional simulations done with climatological SST verified that the simulated warmth was indeed related to SST.

Analysis of the near real-time calculated global soil wetness provided by NCEP reveals that by early June the soil over much of the European region was anomalously dry, which is consistent with the below normal precipitation observed over the region in the preceding months. The soil wetness anomalies obtained from NCEP were adapted for use in the COLA AGCM and the model was restarted in early June with the resultant anomalies imposed on the soil wetness from the control simulations. Although the model soil wetness was then allowed to evolve as usual, the simulations with the imposed initial soil wetness anomaly enhanced the simulated surface temperature anomaly during June, July and August by 1-2 °C. The experiments suggest that both the warm local SST and the dry local soil were important in intensifying the 2003 European heat wave.

ST-51

Subseasonal Variability and Extreme Winter Weather Events over the United States

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There is increasing evidence that certain winter weather events over the continental United States, including extreme events, are affected by the Madden-Julian

Oscillation (MJO) and other variability on subseasonal time scales. Quantifying the impact of the MJO is a particularly challenging task since most current atmospheric general circulation models do poorly in simulating the MJO. In this study, we force the NSIPP-1 AGCM with idealized MJO-like heating to examine the link between the MJO and extreme precipitation events over the western United States. We also quantify the impact of other subseasonal modes of variability including the PNA and AO) on extreme weather throughout the continent. Results from the simulations are compared with observations that are composited according to the different phases of the MJO, other atmospheric indices (e.g., PNA, AO), as well as ENSO.

ST-52

Interannual Variability in the Tropical South Atlantic: A Quasi-Biennial Component Simulated by an Atmospheric GCM Coupled to an Ocean Mixed Layer

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Seasonal climate forecasts over tropical Africa and South America are hampered by the lack of skillful predictions of sea surface temperatures (SST) in the Tropical Atlantic.

The mechanisms sustaining the internal modes of variability in the tropical Atlantic and the atmospheric bridge carrying the teleconnections from the eastern Pacific indicate potential benefits to seasonal prediction from including simple air-sea interactions over the Atlantic in prediction systems.

This question is investigated using the latest version of the UCLA atmospheric General Circulation Model, which includes a state of the art stratus parameterization, coupled to a simple, uniformly 50-m deep Mixed Layer in the Atlantic basin. Modes of variability arising from air-sea interactions internal to the Atlantic are identified from a 29-yr simulation using an interactive mixed-layer in the Atlantic and prescribed climatological SST poleward of 50N and 50S and outside of the basin. The control run consists of prescribed SST climatology everywhere. Land-surface parameters are held at their climatological values in all simulations.

The coupling in the Atlantic is found to give rise to a 'dipolar' leading mode of rainfall variability straddling the equator, not present in the control run. This structure exhibits a red spectrum and is associated with SST anomalies on either side of the equator. Further investigation reveals an NAO-type mode over the North Atlantic, while the tropical and South Atlantic are dominated by a SST anomalies resembling the equatorial zonal mode, despite the lack of ocean dynamics in the model. The associated SLP pattern is similar to the leading mode in the control run but with a highly reddened spectrum and an enhanced quasi-biennial component. The latter has also been found in the observations. Local air-sea interactions in the tropical and subtropical South Atlantic

are found to play an important role in the QB component, with a counter-clockwise propagation around the South Atlantic basin that modulates the timing of the seasonal cycle.

It is suggested that this type of behavior could precondition the impact of ENSO in the tropical Atlantic sector with implications for seasonal prediction in the region.

ST-53

Atmospheric Response for Two Different Parameterization Schemes in Sensitivity Experiments Using SST Anomalies over the South Atlantic Ocean

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The goal of this work is to investigate how different convective parameterizations can influence the results of sensitivity experiments with prescribed sea surface temperature (SST) over the South Atlantic Ocean. The CPTEC/COLA AGCM is used to perform sensitivity analysis with prescribed boundary conditions. Kuo and the Relaxed Arakawa Schubert (RAS) cumulus parameterizations schemes were used. Three experiments were performed for each parameterization scheme. One control with observed global SST from NCEP for November 2000 to February 2001 as surface ocean boundary condition. Two experiments with negative and positive values added to the South Atlantic Ocean (from 40ºS to Equator and 50ºW to 20ºE) and observed SST over the remaining oceans were done. In this period the equatorial Pacific and large portions of the tropical oceans presented near climatological SST, while positive SST anomalies around 1ºC were observed over the South Atlantic. The AGCM was integrated with 5 different initial conditions from NCEP operational analysis. The ensemble averages of December 2000 to February 2001 were analyzed for each experiment. The results were focused over South America in order to evaluate how the cumulus adjustment process affects the South Atlantic Convergence Zones (SACZ) in the context of sensitivity experiments to the SST anomalies over South Atlantic Ocean. The Kuo and RAS simulations were able of simulate the main features of the global climate, as ITCZ, SPCZ and subtropical highs. However, the Kuo simulation presented better performance to convection over South America and South Atlantic than RAS simulation when compared to the rainfall data from GPCP/NASA (Global Precipitation Climatology Project). The former presented rainfall patterns and intensity similar to the observational data. The intensity of the SACZ seems to be sensitive to the convective parameterization scheme and SST anomalies. The AGCM experiments with both parameterization showed that warm SST anomalies over the South Atlantic tend to intensify the SACZ, while cool SST anomalies have an opposite effect. However, the rainfall patterns for all experiments in the Kuo simulations are less intense over South America and South Atlantic than the RAS simulations. The SACZ characteristics and atmospheric circulation associated to the cold SST anomalies over the South Atlantic Ocean is more sensitive for the RAS simulation. The atmospheric response only differs in magnitude but not in the general distribution. The rainfall variability over the South America due to the warm SST

anomalies over the South Atlantic Ocean is similar in both parameterizations. In the RAS simulation the position of the SACZ is independent of the SST anomalies over the South Atlantic Ocean. However, in the Kuo simulation the warming of South Atlantic Ocean tends move the SACZ northward. It is interesting to notice that the Kuo experiments indicated an inverse relationship between the SACZ (strong) and ITCZ (weak) systems. There was not association between these systems for the RAS simulation. In the Kuo and RAS simulations when positive SST anomalies were added over South Atlantic Ocean the cooling of the underlying ocean was verified, causing the appearance of cold SST anomalies or the weakening of pre-existing warm SST anomalies. The Kuo simulations showed that the intensification of the SACZ contributed to cool the underlying ocean through the reduction of incident shortwave solar radiation. The RAS simulations also showed cooling in the underlying ocean, however, with less intensity than the Kuo simulation. In summary, the interactions between SST over the South Atlantic Ocean and the SACZ in the CPTEC/COLA AGCM seems to be dependent of the convection parameterization scheme used.

ST-54

Identification of Atlantic Signals using a New Filter

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The strength of the El Nino signal often masks other dynamical SST processes, particularly in the north tropical Atlantic (NTA) and Caribbean regions. We are able to identify much of the linearly predictable, evolving ENSO signal by identifying the nonorthogonal normal modes associated with it in the global tropical strip between 30N and 30S. This identification is effected by using POP analysis (Von Storch *et al.*, 1988) to diagnose those propagating modes associated with the growth of SST anomalies from an optimal initial structure into a mature El Niño pattern (Penland and Sardeshmukh 1995). Using this technique we find the following: 1) An abrupt climate change occurred in the ENSO signal in NTA SST anomalies during the mid-1970's. This climate change is confined to the ENSO signal. 2) When the ENSO signal is removed from the tropical SSTs, the first EOF of these background-pass filtered SSTs consists of a pattern very similar to the global trend pattern found by Livezey and Smith (1999), but with a very smooth time series. A parabolic fit to this time series explains 76% of its variance. The pattern itself has large loadings in the southern tropical Atlantic (STA). 3) When the ENSO and trend patterns are removed from the SST anomalies, the background/detrended STA and NTA time series are significantly anticorrelated (R = -0.5) in all seasons. This result indicates that the modeling results of Penland and Matrosova (1998) suggesting that ENSO disrupts the northern branch of a tropical Atlantic dipole were correct but incomplete; the trend also plays a strong role in disrupting the dipole signal.

ST-55

Interannual Climate Variability in the Atlantic Equatorial Region

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Interannual climate variability in the tropical Atlantic sector associated with the Atlantic Nino mode is investigated. Anomalous warm sea surface temperature (SST) in the eastern equatorial region primarily occurs during June-July together with evident precipitation, surface convergence and upper-tropospheric divergence anomalies. Strongest precipitation and surface westerly wind anomalies, however, are observed during April-May, about one month before the equatorial warming, suggesting a strong air-sea interaction and possibly a direct impact of convective forcing on the coupled system. Furthermore, intense upper-tropospheric divergence anomalies appear during both April-May and June-July, whereas equatorial surface convergence anomalies can evidently be seen only during June-July, the peak warm season. The lack of strong surface convergence anomalies during April-May may imply a nonlocal cause for the observed precipitation anomalies. Thus, the Atlantic Nino mode seems to be mostly a remote response to the variability in other basins, specifically in the Pacific, given the intermediate role of convection and precipitation. The lag-correlation analyses between various variables provide a consistent and clear pattern during 1982-2002.

ST-56

Observations of 30 -- 70 Day Oscillations in the Northern Tropical Atlantic

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The ocean-atmosphere system is characterized by a prominent mode of intraseasonal variability associated with the Madden-Julian Oscillation, which is particularly pronounced over the warm surface waters of the Indian and Pacific Oceans. Here we provide observational evidence of 30 - 70 day oscillations in surface oceanic and atmospheric properties in the northern tropical Atlantic (5N - 20N, 50W - 30W). Most prominent during October - March, these oscillations are characterized by anomalous wind speed of ~ 2 m/s, latent heat loss of ~ 20 W/m^2, and SST of ~ 0.3 C. It appears that these tropical anomalies are forced by oscillations of a north-south dipole of atmospheric pressure (similar in nature to that of the North Atlantic Oscillation). The origins of this oscillation and its potential role in the evolution of interannual tropical Atlantic SST anomalies will be discussed.

ST-57

The Generation of African Easterly Waves, and Implications for Tropical Atlantic Variability

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Observations during GATE revealed synoptic-scale wave disturbances propagating into the Atlantic off the west coast of Africa with periods of 3-5 days and wavelengths of 2000-4000 km, traveling with phase speeds of 6-8 m/s. Subsequent observational studies using radiosonde data and reanalysis output reveal a complex African easterly wave climatology, with at least two waves types and tracks. Here, an analysis of the NCEP reanalysis is used to characterize modes of interannual variability of the waves and to quantify their contributions to variability over the tropical Atlantic on intraseasonal to interannual.

Generation mechanisms for the waves are examined in a mesoscale atmospheric model to better understand the reasons for the waves' interannual variability and to improve prediction capabilities. Unlike some previous studies, which theorize that wind shears associated with the African easterly jet are necessary for African easterly waves to occur, our modeling study shows that African easterly wave growth is more closely associated with baroclinic energy conversions in association with intense diabatic heating.

ST-58

A Technique for Improving Seasonal Prediction of Tropical Atlantic Sea Surface Temperature Using an AGCM Coupled to a Slab Ocean

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A methodology to correct a slab ocean such that it incorporates the effect of linear ocean dynamics is presented.

The approach consists of introducing an anomalous Q-flux to the mixed layer equation. This Q-flux is derived by minimizing the prediction error of an atmospheric general circulation model coupled to a slab ocean using a technique related to Linear Inverse Modeling.

We applied this methodology to the NCAR Community Climate Model (CCM3) coupled to a slab ocean. It is shown that when coupled to the corrected slab ocean the CCM3 has large skill in predicting SST anomalies two seasons in advance not only in the largely heat flux-driven tropical north Atlantic, but also in the equatorial and cold tongue regions where ocean dynamics plays a fundamental role.

As a result, when initialized in December, the corrected coupled model shows high skill in predicting rainfall anomalies in the Intertropical Convergence Zone during the next boreal spring. The experiments suggest that ocean dynamics (correction) tends to weaken the thermodynamic coupling between SST and heat flux during boreal spring. This effect is strongest toward the end of the season, and may be important for the decay of the gradient mode of variability.

COAPEC (Coupled Ocean Atmosphere Processes and European Climate): A UK Research Programme

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COAPEC (http://coapec.nerc.ac.uk/) is a five-year Thematic Programme funded by the UK's Natural Environment Research Council. The goal of COAPEC is to determine the impact on climate, especially European climate, of the coupling between the atmosphere and the ocean on seasonal to decadal timescales. The programme has funded science projects and studentships addressing the 5 key areas outlined in the programme science plan:

- What are the observed characteristics of seasonal-to-decadal climate variability in the Atlantic Sector?
- How do the mean climate and climate variability in the Atlantic Sector simulated by a Coupled General Circulation Model differ from that observed? How do we correct model deficiencies?
- What are the physical mechanisms that determine the mean climate and seasonal-to- decadal climate variability in the Atlantic Sector?
- What processes determine the predictability of climate fluctuations in the Atlantic- European region?
- Bridging the gap between scientific output and societal needs.

Actively supporting the research carried out by project holders is the COAPEC core team of three researchers, who each also follow their own research themes.

This poster will present some of the key findings of the programme to date. COAPEC is providing advances in understanding the mechanisms by which the ocean and atmosphere interact, how these processes are represented in state-of-the-art numerical climate models and how they determine the predictability of the climate system over seasonal-decadal timescales. Processes studied include the generation and propagation of salinity and heat anomalies in the North Atlantic, the influence of the thermohaline circulation and the role of storm tracks on European Climate. The influence of remote processes, including ocean-atmosphere coupling in tropical Atlantic warm events and Southern Ocean circulation are also being investigated.

As part of the programme, new coupled models are being developed, including: a coupled hybrid isopycnal coordinate model; fast models for multi-ensemble runs to investigate model parameters space, using both high performance machines and spare home PC resources; a QG model to investigate high resolution ocean processes in coupled systems and validated ice models for coupled modelling. Underpinning research into improving the observational datasets, such as the SOC flux climatology, is also being carried out as part of the programme.

To place these advances into a socially relevant context, COAPEC is also investigating the methods for using, and economic benefits of, climate forecasts at seasonal timescales for the UK health sector and the UK energy industry.

ST-60

A Common Source for the Positive PNA and NAO

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Using the NCEP/NCAR global reanalysis data for 51 boreal winters, a mean-winter convective index (CI) for the tropical Pacific is constructed. The relationship between the convective index CI and the extra-tropical atmospheric anomalies is found to be markedly nonlinear. Composites of winters with a large positive CI are associated with a positive Pacific North American (PNA) pattern, whereas winters with a large negative CI show little evidence of a negative PNA. Instead, the large negative CI winters show a significant pattern in the North Atlantic region that is quite similar to a positive North Atlantic Oscillation (NAO) pattern.

A simple AGCM is used to investigate the response to positive and negative tropical Pacific forcing. The nonlinear model reproduces much of the observed extra-tropical asymmetry between winters with large positive and negative convective indices. Linear experiments are used to shed some light on the results.

ST-61

Relationships between the Features Variations of Highs and Lows in the North Atlantic Region and North Atlantic Oscillation from 1950 to 2000.

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Keys words: NAO, Highs, Lows, North Atlantic aerological dynamic.

Aim: To improve the description, the analysis of the North Atlantic aerological dynamic in relation with the North Atlantic Oscillation (NAO) by studying the features of Highs and Lows.

The NAO is pertinent for the description of the dynamic of the climate of the North Atlantic region. Many studies have been made and others are continuing to understand the different aspects of this oscillation: mechanisms, variability, impacts. But in spite of these, many questions remain:

The dynamics of the NAO are not fully understood (M.H.Visbeck personal web site, 2000) Even the question, What exactly is the North Atlantic Oscillation? is controversial. (H. Langenberg, Nature vol 408, 21-28 décembre 2000). After more than a century of scientific investigation, the fundamental mechanims determining evolution of

the NAO are still far from being elucidated (Stephenson D.B., V. Pavan, R. Bojura, International journal of climatology n°20 ,2000).

Working from NCEP-NCAR Reanalysis (sea level pressure and surface pressure) daily records from 01/01/1950 to 12/31/2000, I have retraced, using a method developed by A. Favre (University Jean Moulin Lyon III) and A. Gershunov (Scripps Institution of Oceanography), the trajectories of the Highs – whose leave southward the arctic area with more or less eastward component- and Lows. This method is made up of two successive automated stages: recognition of the maxima (minima) pressure on each map, - connections between the different maxima (minima) during their movement, at all the measures of time (synoptic, seasonal, annual, for the whole period) with those characteristics (latitude (min,max,mean), longitude (min,max,mean), pressure (min,max,mean), speed, distance, time span).

Using the different records of Highs and Lows thus collected, we established Dynamic Index: Highs Dynamic Index (HDI), Lows Dynamic Index (LDI). By merging the index, we obtained an Aerological Dynamic Index (ADI), which correlated with the NAO: Yearly at R=0.749, Winter (JFM) at R=0.762, Spring (AMJ) at R=0.629, Summer (JAS) at R=0.584 and Fall (OND) at R=0.643.

The precise analysis of the dynamic and features of Highs and Lows helps to complete the understanding of the aerological dynamic and thus to the internal dynamic of the NAO.

ST-62

Interannual Variability of Winter Anticyclonic Activity

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Anticyclones are structures that appear over a broad spectrum of scales ranging from the planetary scale subtropical anticyclones, to the blocking highs, with scales smaller than planetary but larger than synoptic, and down to the small subsynoptic scale anticyclones observed in regions of intense cooling in the Northern latitudes. In this pilot study we use the 14-year ECMWF Re-Analysis dataset to a) examine interannual variations of anticyclonic activity of different scales and b) relate them to interannual variations of the PNA and the NAO teleconnection patterns.

The global mean sea level pressure and other variable fields are spectrally decomposed in three bands of scales at consecutive timesteps. The three bands are referred to as the large, intermediate and small scale band and correspond to contributions to anticyclonic development from the planetary scales, from scales characteristic of blocking highs/baroclinic waves and from the lower synoptic/upper meso-scales, respectively. In each band anticyclone centers are identified as maxima in the band-passed field. A tracking model is used to monitor the anticyclones' positions in time and to generate maps of their genesis, lysis and track densities and of their characteristic properties. The distributions are evaluated as averages over the 14 years of the dateset and subsequently for the subsets of years characterised by a positive/negative NAO and a positive/negative PNA index.

The results indicate that the sensitivity of anticyclonic activity to opposing polarities of the two teleconnection patterns is significant in all three bands of scales. For the large scale band the effect of opposite phases is manifested by a shift in the position of the anticyclone centers and a change in the orientation of the growth/decay axis ; in some regions even a reversal in the relative position of the genesis and lysis locations is seen. For the intermediate scales an association is identified between a particular PNA/NAO phase with the Bering blocks in the Pacific and with certain preferred transitions between quasi-stationary regimes in the Atlantic. In the small scales we observe differences in the direction and the distance of propagation of the anticyclones for opposite PNA/NAO phases. Finally, the effect of opposite phases is more global in character for the large and the intermediate scales bands while for the small scales it is localised for the PNA/NAO pattern in the vicinity of the Pacific/Atlantic basin respectively.

ST-63

Low-Frequency Variability of the Atmospheric Circulation During the North Winter

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The simulation analysis of the spatial-temporal structure of the long-periods variations of the tropospheric and stratospheric parameters of the Global Atmospheric Circulation (GAC) model of the IBM RAS has shown, that the model correctly reflects the main peculiarities of the low-frequency atmospheric circulation variability. It was shown that the North-Atlantic Oscillation observed not only in the surface data, but also in the distribution of the absolute geopotential and the zonal wind up to the lower stratosphere. Above all, the analysis of the average zonal wind fields decomposition along the orthogonal components showed, that the western air mass transfer predominates in the 30 per cent cases at the low and high troposphere and distributes even to the low stratosphere (approximately up to the isobaric surface of the 20 hPa).

ST-64

Dynamical Aspects of Atmospheric Blocking and Its Relation to Short-Term Climate Variability

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A persistent large-scale anomaly of the west to east flow in the midlatitudes with a weakening and meridional splitting of the jet can be specified as atmospheric blocking.

Lifetimes last from several days up to weeks so that blocking can therefore significantly determine monthly circulation index values as well as in-situ and downstream weather and climate. The dynamical mechanisms contributing to the establishment, maintance and breakdown of blocking are still not completely understood and therefore their prediction remains a major task for medium-range and seasonal forecasting.

Here a systematic analysis of blocked flow is undertaken to identify such blockings. A recently developed dynamically-based blocking indicator is introduced that is based upon quasi-stationary, large-scale, tropopause-level PV (Potential Vorticity) anomalies. A vertically averaged measure (PV within the 500 - 150 hPa layer) is calculated, underlining the quasi-barotropic nature of blocked atmospheric state.

The investigation is conducted over the whole ERA40 ECMWF-reanalysis period (1958 - 2001) by applying both Lagrangian and Eulerian diagnostics. Statistical analysis are undertaken to shed more light in the frequency, geographical distribution, amplitude, scale, movement, seasonal variation, and multi-year trend of blocking events. Dynamical aspects in contrast emphasize the physics of Rossby-wave breaking and diabatic heating processes which both can modify the upper-level PV structure. They may therefore play a key role in the maintanance and decay of blocking. Furthermore comparisons of atmospheric blocking to climate modes such as the NAO, AO, PNA and El Nino are provided. This can establish information on the link of blocking phenomenon with the dominant planetary-scale patterns of atmospheric variability as well as with concomittent synoptic-scale processes.

ST-65

North Atlantic Oscillation (NAO) Impacts on the Climatic Variability in West Africa: Particular Case of Guinea.

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In West Africa, particularly in Guinea the most important income for rural population (>80%) is from Agriculture and farming, whish depend upon the climatic variability, especially from rainfall. In fact that meteorological parameter varies strongly on space and time.

The West African Climate is well known and quite well understood, because of many done studies on that matter by well-known scientists. And also, since 1998 at the African Center for Meteorological Applications and Development (ACMAD) a scientific team is working on the Seasonal rainfall forecast in West Africa through PRESAO 1,2,3,4,and 5. However the precipitation forecast is still experimental and is not sufficient for farmers.Their need is particularly related to the onset,length and end of rainfall and what would be the drought spell risks after the seeding.

Daily rainfall data during the 70 past years (1931-2000) for at least thirty stations in Guinea was used for calculating the Onset,the End and the duration of rainy season. Charts done from the results show parallel isolines between them and they have a zonal configuration more or less. The rain starts on the beginning of March and ends in December in the Sub-equatorial Zone (south of 8°N)of Guinea,while in the Northern part and Sub-Sahelian Zone (north of 12°N), it starts later in June and ends earlier in October.It is seen that the length of rainy season is from 10 months in the first zone and 4 months in the second one.

A strong correlation was found between the standard normalized anomalies of, in one hand the onset and the End of rain and the other hand, the Normalized North Atlantic Oscillation Index. It is indicated that a positive winter NAO is followed by a later Onset in the Sub-equatorial zone and an earlier End of rain in the Sub-Sahelian zone with a strong decrease of observed rain in Guinea, consequently. In the opposite a good correlation were found between rainfall and the SST anomalies in the Southern Atlantic Ocean; no link or a very weak link seems to be existing with Onset, End and the duration of the rainy season.

In the study period (1931-2000), some can observe a wet sub-period from 1941 to 1970 with a record in 1954 and very dry sub-period from 1971 to 2000 with a deficit record in 1984. These two periods are different if to look at the Onset, the End and the duration of the rainy season. The wet years are generally those whose Onset occurs earlier and the End appears later with bigger length.

If to compare anomalies of Onset and End of rain during the two periods and the normalized NAO Index it is easier to observe the following:

- The wet period corresponds to a period of negative anomalies of NAO Index with negative Onset anomalies and positive End anomalies of rainfall.

- The dry period corresponds to a period of positive anomalies of NAO Index, as consequence with a later Onset (positive anomalies) and an earlier End of rainfall (positive anomalies).

Some of these anomalies obtained during winter, would allow doing a valuable forecast of Onset, End and Length of rainy season in the area.

ST-66

Non-linear North Atlantic SLP Variability in Winter Period

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The North Atlantic Oscillation (NAO) is the most significant oscillatory system in North hemisphere extratropics. It can be simply described with the help of standardized anomalies of SLP differences between one station in Icelandic region and the other in the region of Azores or in SW Europe. More sophisticated approach to the NAO is based on Principal Component Analysis (PCA) of SLP or geopotential heights at low tropospheric levels in North Atlantic region. As PCA is linear method, the results of PCA are influenced by the application of linear method to the non-linear problem (interpretation of the results of non-rotated vs. rotated PCA, etc.).

Neural networks belong to Artificial Intelligence (AI) systems. One of the special kinds of neural networks, so called “autoassociative neural network” is able to perform the non-linear counterpart of PCA. This method has been used in our study for the non-linear description of winter North Atlantic SLP variability. Due to the fact that the original SLP values in near grid points are highly intercorrelated, linear PCA has been used for data pre-processing (for dimensionality reduction only, not for description of the individual oscillatory systems). Then the autoassociative neural netowork non-linearly combining several linear PCA scores to a single non-linear score has been built.

Results of our study indicate that the SLP variability in North Atlantic region is non-linear in its origin. It is indicated by:

• the shift between positions of NAO centers in the positive and negative NAO phases

• some non-linear links between NAO and other NH oscillatory systems (especially Scandinavian Oscillation) which can not be revealed with the help of linear methods

• signs of “rotational exchange” of the individual centers of SLP anomalies during the transition between positive and negative NAO phase.

Moreover, as the results may be affected by the pre-processing method (PCA) itself, different possible configurations of pre-processing were tested (non-rotated PCA vs. rotated PCA with different rotation methods).

ST-67

Dynamics of Low-Frequency Modes

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There are several persistent and recurring large scale patterns existing in the low-frequency atmospheric variability, such as the Antarctic Oscillation (AAO), Arctic Oscillation (AO) or North Atlantic Oscillation (NAO), and Pacific-North America (PNA) pattern.

A five-layer primitive equation model is used to investigate the dynamics of the organized low-frequency modes. In this model, based on the Complex Empirical Orthogonal Function (CEOF) analysis, the four dimensional storm track variability is characterized in terms of spatial structures, variances, decay time scales and propagation speeds, which represents the "normal" storm activity. We derived and validated the synoptic eddy and low-frequency flow (SELF) feedback operator. The three dimensional eddy fluxes associated with AO and AAO are well simulated in this model. Eddy momentum flux anomaly associated with the planetary modes helps to maintain these modes. However, the eddy heat flux mainly has a damping effect and it reduces the north-south temperature gradient in the middle and high latitudes, which probably help to maintain the barotropic structure of the planetary modes. Singular value decomposition (SVD) analysis of the system suggests both AO and AAO are internal modes of the atmospheric low-frequency dynamics, which can be generated through the SELF feedback. SELF feedback makes the annular modes be the least damped mode in the atmospheric general circulation through the "tilted trough" mechanism.

ST-68

Probabilistic Seasonal Prediction of the Winter North Atlantic Oscillation

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The North Atlantic Oscillation (NAO) provides a statistically well defined pattern to study the predictability of the European winter climate. In this presentation the predictability of the NAO is explored using a dynamical prediction approach. Two state-of-the-art fully coupled atmosphere-ocean ensemble forecast systems were used, namely the seasonal forecast system 2 from the European Centre for Medium Range Weather Forecast (ECMWF) and the multi-model system developed within the joint European project DEMETER (Development of a European Multi-Model Ensemble Prediction System for Seasonal to Inter-annual Prediction).

The predictability is defined in probabilistic space using the ranked probability skill score. A discretization adapted RPSSd is used to account for forecast systems with low size of ensemble members. It is shown that the standard RPSS has an equitability problem for such systems. The potential NAO predictability was also investigated in a perfect model approach where each ensemble member was used once as the "observation". This approach assumed that the climate system was fully represented by the model physics and provided a large enough sample size for a robust estimation. The observed and modelled NAO index was defined by an EOF analysis of the 500hPa geopotential height of the ERA40 reanalysis and the models, and by regression of the model EOF pattern to each ensemble member.

It is shown, that the mean winter NAO index is potentially predictable one season ahead (one lead month). The prediction benefit is rather small (7% relative to the hindcast climatology) but statistically significant. The potential NAO rapidly diminishes if longer lead times are considered. Furthermore the NAO hindcast predictability is decreased to non-significant values if a hindcast period of 1959 to 2001 is considered. An exception is the period 1987 to 2001 where a statistically significant NAO hindcast skill up to 27% is found for the ECMWF system 2. In this period the multi-model approach suggest an enhancement of predictive skill related to the mean of all individual models. Finally the relation between the strength of the NAO amplitude and the potential predictability of the NAO itself is discussed. Unlike for the El Niño Southern Oscillation only a weak relation is found. In general robust results are only achieved if the sensitivity to the sample size (both ensemble size and length of hindcast period) is correctly accounted for.

ST-69

A Synthetic Analysis of Recent Arctic Climate Variability

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A synthetic analysis of recent arctic climate variability is conducted using a high-resolution regional climate model and observations. The object of this study is to better understand recent climate trend and variability in the Arctic. The study focuses on the interacting land-atmosphere processes. Surface fluxes and near-surface fields are examined to assess the impacts of changes in land cover and vegetation properties on interannual climate variability.

ST-70

Synoptic Core of the Main Components Variability of Surface Level Pressure (SLP) and Surface Level Air Temperature (SLT) over Arctic for 1948-2001

Prof. Oleg Y. Korneev

The weather of the northern countries depends on the statement of the atmosphere over Arctic. We decide to find out the structure of variability of SLP and SLT over Arctic, the synoptic nature of her components and temporal tendency of nearest climatic changing.

The daily SLP and SLT fields above the Arctic for 1948-2001 (NCEP/NCAR) was researched with using method of the Empirical Orthogonal Function (EOF). The basis of the investigations was a annual EOF of SLP for 1948-2001 and the climatic variability of the factors of the EOF decomposition of the daily SLP fields.

The next results was received:

1. The amount of earliest 6 factors of decomposition of SLP fields by month's EOF describes the meaning of the total SLP variability above Arctic for 1948-2001 from 80% (August) to 88% (February).
2. Maximum contribution to the total SLP variability carry in not solar radiation influx variability but thermodynamic processes connected with snow melting on spring for coast with latitudes from 50o to 60o, when river's levels increase. Given processes are closely correlated with the month's variability of factor 1, which describes the total SLP variability about 32.3%.
3. Month's variability of factor 2 is closely correlated with month solar radiation deficit variability to latitude 70o regarding 25o. The contribution of factor 2 to annual SLP variability is 21%.
4. Month's variability of factor 3 is closely correlated with the variability of SLP anomaly over Bofort Sea – Climatic Arctic Anticyclone (AA). The contribution given factor to annual SLP variability is 12.6%.
5. The reproduction of the mean month's SLP fields using the proper factors (1-6) and their EOF allowed to determine a synoptic core of the given factor.
6. The variability of mean year's factors 1-6 for 1948-2001 had not a pronounced monotonous temporal tendency, that don't confirm the hypothesis about warming of climate.
7. The latest tendency of temporal variability of factors 1-6 witness about the relaxation of AA and deepening of Climatic Cyclone over Norway Sea with proper consequences for future weather of the northern countries.
8. The repeatability of the penetrations of the blocking anticyclone to North Pole from Europe and Eastern Siberia has a pronounced opposite periodical

character (3-4 year). At present, the intensity of the penetration – meridional air mass transfer - decreases and, hence, the zonal intensity of air mass transfer will be increase.

9. Using the spatial scale of SLP variability over Arctic allowed to develop quantity classification of the daily SLP fields, to computer the basic statistics and develop the New modification (NM) of the Objective Analysis Method (OAM). The given method was successfully testified on instance of SLP reproduction to the drift buoy position at Arctic Ocean. The advantage of NM regarding existing OAM is about 50%.

Analogous results was obtained for components of SLT variability, which will be represent in the poster presentation. Thus, the obtained results could be useful for understanding of the nature of Arctic SLP variability and for definition of the future temporal tendency of the climate changing.

ST-71

Investigation of Air-Sea Interaction and Cloud Processes in the EPIC Stratocumulus Region:

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ETL has cooperated with the Woods Hole Oceanographic Institution (WHOI) for two research cruises to the stratocumulus region of Peru/Chile as part of NOAA's CLIVAR EPIC program. Ship-based measurements have taken in the fall of 2001 and 2003 at the WHOI ocean reference buoy at 20 S 85 W during the annual cruise to service the buoy. The goal of this work is to improve understanding of coupled air-sea processes in subtropical stratocumulus regions and to gather statistics on flux, boundary layer, and cloud properties to promote the evaluation of models and satellite data products. Specific scientific objectives involve improved bulk cloud-radiative parameterizations, methods for retrieving cloud microphysical properties, and investigation of the relative roles of cloud-top entrainment and drizzle production on the dynamics of stratocumulus. The ETL measurements provide a more detailed context for measurements made on the WHOI buoy over the annual cycle. This will be achieved through:

* Comprehensive characterization of clouds, surface fluxes, and PBL profiles using a variety of in situ and remote sensing systems

* Evaluation of various bulk models of stratocumulus cloud radiative transfer properties using resulting cloud microphysics (integrated liquid water, drop size and number concentration) determined with ship-board remote sensors

In this paper we will present the results from the two cruises emphasizing then diurnal cycle of cloud properties and contrasting the 2001 and 2003 results.

ST-72

The Seasonal Heat Balance in the Eastern Tropical Pacific

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We have analyzed the seasonal heat balance in the eastern tropical Pacific (ETP), from 10°N through 20°S, and from 120°W to the South American coast. The analysis in the upper layer (30m) of the ETP shows that the relative importance of the terms in the heat balance equation has a meridional dependence. Three different regimes have been identified: the north equatorial countercurrent- Intertropical convergence zone (NECC-ITCZ) regime (4°-10°N), the cold tongue-south equatorial current (SEC) one (2°N-4°S), and the slow westward drift (10°-20°S). The processes responsible for the balance in each of the analyzed regimes are shown to be different. Within the NECC-ITCZ subregion the oceanic term that primarily offsets the warming by the surface heat flux is the vertical diffusive heat flux divergence. The annual average of the horizontal plus vertical diffusive flux is about – 40Wm-2, similar to that of the entire Northeastern Pacific warm pool, as estimated by others. In the cold tongue-SEC area the permanent maximum in surface warming by the surface heat flux is balanced primarily by advective cooling (71%) within the upper layer, and secondarily by vertical diffusive cooling (22%), the main contributor to the advective fluxes being the vertical component (upwelling). Lateral diffusion is not an important contributing term because it is very small (5-10Wm-2) due to the reduced horizontal temperature gradients within the 30-m slab (4-8 times smaller than SST gradients derived from a finer grid). South of 10°S the oceanic terms are small and the balance is primarily between the heat storage rate and the surface heat flux all-year round. The large seasonal cycle of SST off Chile and Peru is therefore a direct response to the very large annual variation of solar heating due to the highly seasonal stratocumulus cloud regime.

The annual average of the residuals in the heat balance equation is slightly negative, between –5 and –10Wm-2 whereas a nil result is expected by construction. The residual analysis shows that the offset can be easily accounted for by uncertainties in the bulk formulas used to derive the terms in surface heat fluxes, errors due to poor data coverage, and/or underestimation of the cooling by advection or diffusion.

ST-73

Mesoscale Oceanic Variability Observed during Epic 2001

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The Eastern North Pacific Ocean is a region of significant oceanic variability given the warm pool and the cold tongue and the gradual shoaling of the seasonal oceanic thermocline from west to east. During the Eastern Pacific Investigation of Climate (EPIC) 2001 field program, upper ocean oceanic current, temperature and salinity profiles were acquired from airborne expendable profilers deployed from the National Center of Atmospheric Research (NCAR) WC-130J and the National Oceanographic and Atmospheric Administration (NOAA) WP-3D research aircraft. Concurrent atmospheric data from Global Positioning System (GPS) sondes were acquired along flight tracks located on each side of the R/V Brown and R/V New Horizon centered on the TAO mooring.

Since cyclogenesis often occurs over the Eastern North Pacific Ocean Warm Pool, large sea surface temperature gradients and thermal gradients across the base of the ocean mixed layer (OML) have an important impact on mesoscale air-sea interactions. These large vertical gradients begin at 30 to 40 m beneath the ocean's surface and support buoyancy frequencies approaching 20 cph, which may inhibit significant upper-ocean cooling events by shear instability strong forcing events. For example, during the genesis and intensification of hurricane Juliette in Sept 2001 to category 4 status, SSTs were cooled by less than 1oC in the northern part of the warm pool. Wind-driven ocean current shear was insufficient to significantly cool the upper ocean through shear instability until the storm moved into an area with weaker stratification (buoyancy frequencies of ~10 cph) where observed SST cooling was 4 to 5oC. In this framework, entrainment mixing across the OML base due to slowly developing near-inertial ocean current shear did not lower the bulk Richardson number to below criticality in the warm pool. A larger fraction of the upper ocean's heat is then available for storms through enhanced air-sea fluxes even though the oceanic heat content estimate is lower than those observed in the warm pools of the Gulf of Mexico and Caribbean Sea. These preliminary results raise questions about using coarse-scale climatologies to represent strong gradient regimes in the eastern Pacific Ocean for coupled model studies.

ST-74

Observations of Multiple Scales of Lower Tropospheric Variability over the East Pacific Cold Tongue

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Since 1994, support from PACS has enabled the NOAA Aeronomy Lab to operate a wind profiler and surface met station at San Cristóbal, the easternmost of the Galápagos Islands (0.90°S, 89.61°W). Half-hourly averaged wind profiles, extending 3 km or more with vertical resolution of 100-250 m, have been disseminated in real time over the GTS and also post-processed for research purposes. The combination of the marine environment and the remote location have led to two long (over 1 year) gaps in the data. The dataset has revealed new details about the structure and variability of the lower troposphere over the Cold Tongue. The availability of near-surface oceanic and atmospheric data from TAO buoys at 95°W has enhanced our ability to interpret the Galápagos winds, while the detailed longterm measurements at San Cristóbal help provide a context for sonde-based dynamic and thermodynamic profiles collected over the eastern Pacific from ships tending the TAO buoys.

The daily cycle of winds shows no evidence of a land/sea breeze, increasing our confidence that these profiles resemble open-ocean conditions. The daily cycle is dominated by the zonal semidiurnal tide and a diurnal cycle of nighttime northwesterly and daytime southeasterly anomalies, the latter possibly driven by the effects of the daily cycle of convection over the Andes. Below about 500 m, the daily cycle decouples from the flow aloft during periods of cold (< 23°C) SSTs. While this decoupling is not evident in mean profiles constructed over many weeks or months of data, it does appear to inhibit the vertical propagation of the semidiurnal tide and synoptic-scale equatorial waves.

The profiler data are being used to examine the sub-seasonal variability of the region in conjunction with other observational assets available, e.g. the soundings collected by the TAO buoy tender and the intensive field observations from EPIC 2001. On even longer time scales, seasonal-mean profiles from the Galápagos profiler reveal a clear annual cycle in the lower troposphere. The low-level jet in the mixed layer is weakest and highest during austral summer, occasionally rising above 1 km MSL. It is strongest and lowest (below 400 m MSL) mid-year. This annual cycle was disrupted in the December-February season during the strong 1997-98 ENSO; the seasonal deepening of the lowest layer was enhanced and the low-level flow became northerly as the ITCZ moved briefly into the Southern Hemisphere.

ST-75

Cloud Forcing of the Surface Energy Budget of the ITCZ/Cold Tongue Complex in the Tropical Eastern Pacific

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ETL and PMEL have cooperated on a ship-based cloud and flux measurement program to obtain statistics on key surface, MBL, and low-cloud macrophysical, microphysical, and radiative properties. The measurements were made as part of the PACS/EPIC monitoring program for the 95 W and 110 W TAO buoy lines in the tropical eastern Pacific. Our goal was to acquire a good sample of most of the relevant bulk variables that are commonly used in GCM parameterizations of these processes and to provide a more detailed context for measurements made on the TAO buoys over the annual cycle. These data are useful for coupled ocean-atmosphere modeling efforts, MBL/cloud modelers (both statistically, and for specific simulations) and to improve satellite retrieval methods for deducing MBL and cloud properties on larger spatial and temporal scales. In this paper we will report on results from the first three years of the project. Data from 7 cruises have been analyzed to reveal the latitudinal structure of surface forcing of the ocean and the role that clouds play in that structure. We will also contrast northern hemisphere spring and fall seasons. Cloud forcing of surface fluxes will be related to mean cloud fraction; cloud base heights and liquid water path will also be examined.

ST-76

Pacific Cold Bias in CGCMs: Possibly a Projection of the Systematic Errors in Ajacent Monsoons

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The cold bias of equatorial Pacific sea surface temperature with a magnitude of 1C-3C exists in a lot of coupled general circulation models. The causes are attributed to two aspects: 1) the errors from the external forcings and 2) the errors in representing the positive atmosphere-ocean feedbacks in the equatorial Pacific. In this study, it is shown that the systematic errors of adjacent monsoons can project significant errors in the equatorial trades. Further, the monsoon-induced errors on the trades are able to account for the cold bias existing in current coupled models though invoking the Bjerknes' positive atmosphere-ocean feedback in the equatorial Pacific

Significant correlations between the bias of equatorial easterly winds and precipitation errors in adjacent monsoons are found from the outputs of 10 atmospheric general circulation models (AGCMs) participating in the CLIVAR/monsoon intercomparison project. The stronger monsoons in the west of Pacific basin and the weaker monsoons in the east are associated with a stronger equatorial easterly. Sensitivity experiments with atmospheric models indicate that the systematic errors in the above two monsoons could account for the equatorial easterly bias.

Finally, a conceptual equatorial Pacific air-sea coupled model, which reproduces both SST climatology and ENSO, has been used to assess the impacts of the adjacent monsoon errors on the SST climatology and interannual variability of the equatorial

Pacific. When the monsoon errors cause the trades to increase from 1.2 m/s to 4 m/s, the SST cold bias in the equatorial Pacific reaches 1C to 3C. Associated with the enhanced trades, the model ENSO becomes a decaying mode first, then disappears totally.

ST-77

Equatorial Pacific Cold Tongue Bias - A High Resolution Ocean Study

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The GFDL CM2 coupled climate model is subject to a 2-3 degree cold bias in the eastern equatorial Pacific and has an equatorial ocean resoultion of 100km x 33km in the zonal and meridional directions respectively. The role of intraseasonal variability, particularly tropical instability waves (TIWs) and associated meridional heat flux convergence is examined towards their influence in the maintanence of the cold tongue region. A high resolution ocean-only model with 25km x 10km resolution shows significant warming due to intraseasonal variability compared with a coarser version at 50km x 33km resolution. The maximum cold tongue bias is reduced from approximately 1.5C to 0.5C at higher resolution. Comparisions with observational estimates of eddy kinetic energy production in this region show reasonable agreement with the high resolution model.

ST-78

On the Formation of Cold Tongue and ENSO in the Equatorial Pacific Basin

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This paper proposes a mechanism that explains how the coupled dynamics alone can spontaneously give rise to a realistic west-east asymmetric mean state and an ENSO-like interannual variability without requiring the existence of an external pre-existing west-east asymmetry in circulation. The essence of the newly proposed mechanism is that the basin-wide ocean-atmosphere coupling acts to reduce the effective restoring force. As a result, the coupled oceanic waves travel more and more slowly within the equatorial ocean basin as the coupling strength increases. When the coupling strength reaches a critical value, the zonally leveled thermocline becomes unstable as a result of the weakening of the effective restoring force, at which the theoretical limit of the traveling time scale would be infinite without nonlinearity. Due to nonlinearity in the coupled system, this primary air-sea interaction instability leads to a west-east asymmetric mean state in which the atmosphere has a prevailing easterly and the ocean basin has a deep-in-west/shallow-in-east thermocline with a warm-west/cold-east sea surface temperature. The direction of the west-east asymmetry in the mean state is dictated by a planetary factor of the Earth, namely, that the Coriolis parameter

changes sign at the equator. As the coupling strength further increases, the asymmetry in the mean state amplifies and the phase speeds of the coupled equatorial oceanic waves begin to decrease gradually towards an asymptotic limit equal to the full speed in the uncoupled situation.

Using the coupling coefficient that is consistent with the observation, the fully coupled model can produce a realistic mean state in which the basin-wide SST (thermocline depth) difference is 4.2°C (116 meters) and the westward wind stress at the central Pacific basin is 0.54 dyne/cm2. The self-sustained oscillation has a primary period of 3.7 years. The SST in the west (east) oscillates between 27.5°C and 28.5°C (between 25.2°C and 22.5°C).

ST-79

Air-Sea Heat Fluxes in the Stratocumulus Deck / Cold Tongue / ITCZ Complex of the Eastern Tropical Pacific

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The Eastern Pacific Investigation of Climate Processes (EPIC) experiment was designed to improve understanding of the intertropical convergence zone (ITCZ), its interactions with the cold tongue of water that extends along the equator, and the physics of the stratocumulus cloud deck that forms over the cool waters off South America. In this presentation, we analyze the structure and evolution of the air-sea heat fluxes and their relation to underlying sea surface temperature and overlying clouds within the stratocumulus deck / cold tongue / ITCZ complex. The primary data used in the analysis are from the EPIC enhanced monitoring array that includes an IMET mooring at 20S, 85W in the stratocumulus region, 10 enhanced Tropical Atmosphere and Ocean (TAO) moorings along 95W from 8S to 12N, and surface flux and boundary layer data collected from the TAO tende ship which visited the 95W moorings at 6 monthly intervals. Comparisons with fluxes from numerical weather products identify biases which can impact general circulation models. Careful attention is paid to the role of near surface temperature stratification, ocean currents relative to wind, and variance from mesoscale gustiness, each of which has its own structure within the stratocumulus deck / cold tongue / ITCZ complex.

ST-80

The Variability in ABL Structure and Air-Sea Fluxes over the Eastern Equatorial Pacific Cold Tongue

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This study examines the causes and effects of atmospheric boundary layer (ABL) conditions over the cold tongue in the eastern equatorial Pacific during the boreal fall. It is based on shipboard measurements collected during TAO buoy tender cruises from 1999 through 2003 and research aircraft observations from the Eastern Pacific Investigation of Climate Processes (EPIC) field program in 2001. The ABL of the region is noteworthy because it mediates air-sea interactions. The coverage of ABL stratus clouds appears to be a primary factor related to the variability in ABL structure over the cold tongue. Clouds reduce the atmosphere's heating of the cold tongue in two ways. They have the obvious effect on the downward shortwave (solar) radiation at the surface, but also tend to have a cooling effect by increasing the loss of longwave radiation at the top of the ABL. This loss of heat cools the entire ABL, ultimately causing greater upward sensible heat fluxes at the surface. Clouds also have an indirect effect on surface stresses. The presence of clouds is generally accompanied by more vigorous ABL turbulence, less ABL stratification (but better defined capping inversions), and much less vertical wind shear. The implication is that clear skies tend to be associated with a prominent southerly low-level jet but relatively weak surface winds; cloudy skies are associated with less of a low-level jet but stronger surface winds, given similar meridional sea level pressure gradients. Differences in the stratus cloud coverage hence appear to be significant to both the momentum and the heat fluxes at the surface in the vicinity of the cold tongue. It is uncertain what determines the stratus cloud coverage in the region but previous results indicate that a primary factor relates to the history of the incident low-level flow from the Southern Hemisphere. Circumstantial evidence from the ship transects and aircraft surveys suggest that a secondary role may be played by the humidity above the ABL in terms of its impact on the downwelling longwave radiative fluxes at the top of the ABL. The overall result of our research is that proper account of stratus clouds is probably required to realistically model air-sea interactions in the eastern equatorial Pacific.

ST-81

Marine Atmospheric Boundary Layer Height over the Eastern Pacific: Data Analysis and Model Evaluation

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The atmospheric boundary layer (ABL) height (h) is a crucial parameter for the treatment of the ABL in weather and climate models. About 1000 soundings from eleven cruises between 1995 and 2001 over the eastern Pacific have been analyzed to document the large meridional, zonal, seasonal, and interannual variations of h. In particular, its latitudinal distribution in August has three minima: near the equator, in the intertropical convergence zone (ITCZ), and over the subtropical stratus/stratocumulus region near the west coast of California and Mexico. The peak of h in the ITCZ zone (between 5.6degN and 11.2degN) occurs in the spring (February or April), while it occurs in August between the equator and 5.6degN.

Comparison of these data with the 10-year monthly output of the Community Climate System Model (CCSM2) reveals that overall the model underestimates h, particularly from 8.4degS to 5.6degN in February and north of 20degN in August and September. Directly applying the radiosonde data to the CCSM2 formulation for computing h shows that, at the original vertical resolution (with the lowest 5 layers below 2100 m), the CCSM2 formulation would significantly underestimate h. In particular, the correlation coefficient is only 0.06 for cloudy cases.If the model resolution were doubled below 2100 m, however, model results would be significantly improved with a correlation coefficient of 0.78 for cloudy cases.

ST-82

Comparison of NWP Model/Reanalysis Air-sea Fluxes of Heat and Momentum to In Situ Observations at Several Sites in the Tropical Pacific

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An important challenge to accurate weather and climate prediction is the simulation of the exchange of heat and momentum between the ocean and atmosphere. While a great deal is understood about the physical processes by which these quantities are exchanged between the ocean and atmosphere, accurate simulation and parameterization of these fluxes in operational models remains a great challenge. The ECMWF, NCEP, and NCAR flux products are often used to force ocean models for seasonal to decadal oceanic simulations, and it is clear that realistic simulations require realistic forcing fields. The purpose of this study is to compare the air-sea fluxes of heat and momentum in state-of-the-art numerical weather prediction models and reanalysis products to in situ observations at several sites, with an aim of diagnosing strengths and weaknesses of the models and improving our understanding of the factors responsible for discrepancies.

In association with the CLIVAR program, several heavily instrumented air-sea interaction surface moorings have been deployed in the tropical Pacific to produce

accurate estimates of the air-sea fluxes of heat, momentum, and mass. Sites include the Western Pacific Warm Pool and a location under the stratus cloud deck off the coast of northern Chile, and two moorings were in place in the eastern tropical Pacific during the strong El Nino/La Nina event of 1997-98. Comparisons of the observed fluxes with the NCEP1, NCEP2, ECMWF, and NCAR flux products are presented, and possible reasons for discrepancies are discussed for some cases. Attention is focused primarily on timescales longer than monthly.

ST-83

Regional Modeling of Eastern Pacific Climate: Implication to ST-

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Eastern Pacific climate is characterized by strong gradients in SST, surface wind and cloud fields and is strongly influenced by the shape and orography of the American continents. Many of these features are inadequately represented in global climate models. The high-resolution regional climate model developed at the International Pacific Research Center is used to study the climate processes over the eastern Pacific. The model simulates reasonably well the low cloud deck over the Southeast Pacific and precipitation in the ITCZ. A positive feedback between the low cloud deck over the Southeast Pacific and precipitation in the ITCZ north of the equator is identified through sensitivity numerical experiemnts. It is found that this positive feedback contributes to both the seasonal and ENSO cycles, and thus plays an important role in the seasonal-to-interannual climate variability over the eastern tropical Pacific. The effect of the steep and narrow Andean mountain range, which rises from near the sea level to over 4 km high in less than 200 km, on this postivie feedback, and on the eastern Pacific climate and it variability are also evaluated. The implications of our results to ST- will be discussed at the conference.

ST-84

On the Influence of the Madden-Julian Oscillation (MJO) on ENSO

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Several numerical and observational experiments suggest that the MJO could be an important factor for ENSO variability and predictability. A systematic study on the

impact of the MJO as differentiated from other sources of stochastic is presented. MJO can affect ENSO via two dynamical regimes: (1) by non-linear interactions where some of the intraseasonal variability is rectified to low frequencies, and (2) by linear interactions where the low-frequency tail of the MJO is amplified. We analyze these two possibilities by forcing a hierarchy of ENSO models with different estimates of zonal wind stress associated with the MJO based on 23 years of the NCEP/NCAR reanalysis. The first estimate is based on the band-passed intraseasonal timeseries and is used to study the rectification problem. In the second estimate, we first remove the ENSO related anomalies with the aid of an empirical model, and then we isolate the MJO signals with the same spatial structures than those of the first estimate but including its low frequency variability. We show that the spatial structure that dominates the intraseasonal band also dominates the low frequency band of the anomalies independent of ENSO SST. This second estimate is used to study the linear amplification of the MJO perturbations by the coupled system. The aspects that make the MJO different from other sources of stochastic forcing and the implications for predictability of ENSO are discussed.

ST-85

Horizontal and Vertical Structures of the Madden-Julian Oscillation

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This study examines detailed horizontal and vertical structures of the Madden-Julian Oscillation (MJO) using composite analysisfor 19 years of the NCEP reanalysis and NOAA outgoing longwave radiation data. The horizontal structure shows that low-level moisture convergence (LLMC) by meridional winds along the equator precedes the LLMC by zonal winds. The imbedded double structure typifies the development of shallow convection east of deep convection. Vertical temperature structure shows a hint of the second baroclinic mode associated with stratiform precipitation. Results suggest that both the wave-CISK and stratiform instability theories predict important features ofobserved MJO as in moist Kelvin waves.

ST-86

MM5 Simulations of Boundary Influences on the Madden and Julian Oscillation

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The Madden-Julian Oscillation (MJO) substantially contributes to the tropical variability. The characteristic signature of the MJO is the large-scale equatorial propagation of many dynamical variables, including wind, pressure, moisture, and convection with a local periodicity of around 45 days. Understanding the MJO is critical to comprehending global atmospheric behavior and for improving medium to long-range weather forecasts. This study seeks an improved understanding of the MJO by using a regional scale model to investigate the processes leading to the onset and growth of MJO activity.

A series of two-year NCAR/Penn State Mesoscale Model 5 (MM5) v3 runs for the tropical Indian/Western Pacific Ocean (15ºE-165ºW) region have been carried out. The National Center for Environmental Prediction (NCEP) reanalysis fields provided both initial and boundary conditions for all runs plus part of the data used to evaluate the model; in addition satellite outgoing longwave radiation (OLR) is used for verification.

Two-year means of model winds, moist static energy, and OLR show very good agreement with observations. The MJO signals in the model and observations are identified by using a 201-day Lanczos filter for the 30-70 day periodicities. Overall, there is excellent agreement as to both magnitude and phase of the zonal wind variations. MM5 OLR variations are also in good qualitative agreement with the much coarser resolution satellite OLR. However, the model OLR changes appear to be noisier and to have less regular eastward propagation.

In order to make a first estimate of the relative importance of circumglobal Kelvin waves or internal recharge mechanisms for MJO initiation and periodicity, we have also run a "notch-filtered" version of the model. In this case the normal horizontal boundary forcing has been replaced by variables in which the 30-70 day periodicities have been removed. The two-year means of winds and OLR are very similar to those of the control calculations. In addition, the model still exhibits significant 30-70 periodicities in zonal winds and OLR. These results suggest that 30-70 days waves entering the model boundaries are only partially responsible for the observed periodicities in the model. The relative importance of boundary forcing and internal mechanisms for establishing the MJO perodicity are analyzed.

ST-87

Modeling and Predicting the Madden-Julian Oscillation: Building a Bridge between Weather and Climate

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This presentation will discuss modeling and forecast issues associated with the Madden-Julian Oscillation (MJO). Introductory material will include a basic description of this form of tropical variability as well as a brief enumeration of the extensive interactions it has with other components of our weather and climate systems. The latter includes a considerable influence over low-frequency weather variations over much of the Tropics, the onsets and breaks of the Asian-Australian monsoon systems, extra-tropical synoptic variability, tropical storm and hurricane development in the Pacific and Atlantic sectors, and possibly the timing and strength of El Nino / La Nina events. This material will be used to motivate the need for exploring and exploiting the potential predictability associated the MJO. Based on this need, relevant numerical forecast skill studies and empirical forecast methods of the MJO will be highlighted. Following the above material, results will be presented from recent studies designed to estimate the theoretical limits of dynamic predictability of the MJO as well as what these imply for extended-range weather and short-term climate forecasts. The remainder of the presentation will discuss outstanding questions, remaining challenges, and current plans associated with developing and improving forecasts of the MJO.

ST-88

Long-term Changes in the Madden-Julian Oscillation

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One of the major goals of the CLIVAR program is to understand and predict seasonal-to-decadal climate variability in the Pacific sector, specially improvement of simulations and predictions of El Niño/Southern Oscillation (ENSO) and ENSO-like decadal variability. It is also widely recognized that tropical intraseasonal oscillations have a significant role in global scale precipitation changes and a potential role in interacting with ENSO. On this range of time scales, the Madden-Julian Oscillation (MJO) stands out as the main mode of tropical intraseasonal variability. The influences of the MJO on the patterns of precipitation in the global tropics and in portions of the extratropics have been well documented. The MJO strongly influences the precipitation patterns associated with the monsoons in Asia, Australia, North America and South America. This influence has been shown to modulate rainfall variability and extreme events in the Americas. Some studies have additionally indicated that interaction of the MJO with extra-tropical regions can influence weather forecasts on medium and extended ranges. Some previous studies have suggested possible decadal changes in the MJO with an increase in its activity after about 1977. This presentation uses a comprehensive data set of radiosonde observations to examine long-term changes in the MJO behavior.

ST-89

A Model Study of Intraseasonal Oscillations over South America

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Recent observations have revealed that there are intraseasonal oscillations (ISO) of convection within the South America (SA) monsoon. A reconstruction of the flow pattern in association with the SA ISO suggests that their sources could be (1) the Madden-Julian Oscillation (MJO) from the Western Pacific and (2) a local forcing mechanism (Zhou and Lau, 1999). In the present study, the physical mechanism of the SA ISO has been investigated by using the National Center for Atmospheric Research (NCAR) regional climate model (RegCM2). The National Centers for Environmental Prediction (NCEP) reanalysis was used to provide initial conditions and time-dependent or time-averaged lateral boundary conditions for the model integration. Our results indicate that the SA ISO still exists with time-averaged lateral boundary conditions, which prevent the MJO and other outside disturbances from entering the model's domain, suggesting a local forcing mechanism for the SA ISO in addition to the MJO. Further experiments show that the SA ISO still exist even with temporally constant radiative cooling rates, a result distinct from the theory proposed by Hu and Randall (1994).

ST-90

A GCM Study of Tropical Eastern North Pacific Wind-Induced Ocean-Atmosphere Exchange during Intraseasonal Oscillation Events

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Intraseasonal precipitation variability over the northeast Pacific warm pool during June-October in the National Center for Atmospheric Research Community Atmosphere Model 2.0.1 with relaxed Arakawa-Schubert convection is found to be strongly sensitive to wind-induced variations in surface latent heat flux. These findings may help us to understand the processes that contribute to realistic tropical intraseasonal variability in climate and forecasting models, and thus may help us improve prediction on subseasonal timescales.

A control simulation with interactive surface fluxes produces northeast Pacific warm pool intraseasonal wind and precipitation variations that are of similar magnitude and structure to those associated with the observed intraseasonal oscillation (ISO). Periods of low-level westerly intraseasonal wind anomalies are associated with enhanced surface latent heat fluxes and enhanced precipitation, as in observations. Variations in surface wind speed primarily control the surface flux anomalies. A simulation in which eastern north Pacific oceanic latent heat fluxes are set to their climatological values produces intraseasonal precipitation variations that are significantly lower than those in the control simulation and in observations. These results support the

observational findings of Maloney and Esbensen, who suggested that wind-induced latent heat flux variability is a significant driver of ISO-related convective variability over the northeast Pacific warm pool during Northern Hemisphere summer. East Pacific ISO convection in this model thus appears to be forced by an analogous mechanism to that proposed by Maloney and Sobel to explain forcing of west Pacific ISO convection.

Summertime eastern north Pacific intraseasonal wind variability does not vary significantly between the control and fixed-evaporation simulations. A strong coupling between the east Pacific flow and convection over Central America may be responsible for the relatively small changes between the simulations. Such a strong relationship is not reflected in observations. The coarse resolution of Central American orography in the model may contribute to this anomalous coupling.

ST-91

ENSO-Related Variation in delta 13C and delta 18O In Benthic and Planktonic Foraminiferal from the Gulf of California

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The analysis of multicore samples collected during CALMEX-NH01 cruise (2001) in two locations of the Gulf of California provide information regarding changes in climate and oceanography of the region. Alfonso Basin on the western side and Pescadero Basin on the center slope of the east side of the gulf are marginal basins with sills or shoreward slopes in the Oxygen Minimum Zone. Each basin represents different oceanographic conditions in the Gulf, which can be recognized in the sedimentary history.

Accumulation rates of 0.5 to 1.1 mm/yr. were calculated by 210Pb dating. Multicores were sampled at 2.2mm intervals (~3-5 yr./sample) to produce a high-resolutioin record of delta^{18}O and delta ^{13}C base on benthic (Bolivina subadvena) and planktonic (Globigerina Bulloides) foraminifera. For the first 22 mm of each multicore, benthic and planktonic forams total abundance were measured in order to calculate benthic/plaktonic ratios to establish possible diagenetic alteration of the assemblage. delta18O for live and dead B. subadvena specimens were obtain to infer possible sedimentary transport from the basin slope.

In the Gulf of California at least four morphologies of B. subadvena have been reported. To establish if there is isotopic fractionation between morphologies, delta18O and delta13C were measure in the most abundant varieties of *B. subadvena* (macrospheric and microspheric). The results showed a difference of ~0.2% in both ^{13}C and ^{18}O between the two morphologies. Macrospheric specimens showed lighter delta^{13}C and heavier delta^{18}O, than microspheric specimens. These morphology related isotopic differences are preserved downcore, and suggest that there is relative macro and microspheric abundances to support this hypothesis. Because the difference in the isotopic signals, the records were generated by using exclusively macrospheric specimens.

Downcore delta^{18}O variations show that changes in surface temperature associated with ENSO events leave a measurable signal in the composition of planktonic foraminifera. For the last 50 yr, *G. bulloides* delta^{18}O records from Alfonso and Pescadero Basins show negative excursions that can be associated with the 1972-73, 1982-83, 1986-88, and 1997-98 ENSO events. In contrast, variations in *B. subadvena* delta ^{18}O records are more closely related to changes in circulation patterns than with changes in surface temperature.

Except for some excursions, delta 1^{3}C values in Alfonso Basin are ~0.5% lighter than in Pescadero Basin, in agreement with the lower productivity satellite-measure rate in Alfonso Basin.

ST-92

The Spring Predictability Barrier for ENSO Events

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Approach of conditional nonlinear optimal perturbation (CNOP) is used to study the spring predictability barrier of ENSO events with a theoretical coupled ocean-atmosphere model for ENSO. By computing the CNOPs of El Nino and La Nina events, it is found out that the largest growth of CNOP for El Nino occurs during the season of spring, which corresponds to the time of ENSO predictability barrier. For La Nina events, there is no this phenomena. To further investigate what causes the spring predictability barrier in the model, we perform a series of sensitivity experiments. The results show that the spring predictability barrier for ENSO is caused by the collective effect of the two following aspects: (i) the spring strong ocean-atmosphere coupling instability of annual cycle; (ii) the same growth mechanism that El Nino and its CNOP possess during spring.

ST-93

What is the Role of the Salinity Barrier Layer on El Nino Dynamics and Prediction?

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The western tropical Pacific Ocean is characterized by warm and low-salinity surface waters and by the presence of a specific vertical salinity stratification known as barrier layer. This layer isolates the warm surface water from entrainment cooling at the base of the mixed layer and potentially maintains the heat content of the warm pool.

These processes are able to alter the coupling between sea surface temperature and wind and hence the growing mode that leads to El Nino-Southern Oscillation (ENSO). Investigations using a coupled general circulation model have confirmed the importance of the salinity barrier layer during the onset and buildup phases of El Nino. Reliable forecasts of ENSO may thus depend, in part, on model ability to reproduce barrier layer and to take into account its impact in the western tropical Pacific. State of the art ENSO prediction models use oceanic initial conditions derived from assimilated observations. Because of the lack of in situ salinity observations, only temperature and sea surface height data are usually considered. This poster analyses several ocean data assimilation systems in order to evaluate their salinity variability along the equatorial Pacific. The model outputs are compared to indirect estimates of the salinity variability along the upper water column based on a combination of in situ temperature and salinity data from VOS, TAO/TRITON moorings and sea level data from TOPEX/Poseidon. The comparisons focus on the variability of sea surface salinity (SSS) and barrier layer thickness at the equator over the 1993-2001 period. The main features of the SSS are relatively well simulated with the presence of fresh waters in the western Pacific and saltier waters in the central Pacific. The SSS variability is too low when the model uses a too strong restoring term toward the climatology. There is some evidence of barrier layer in the different models but its variability noticeably differs from observations, in time and space. Several models are however able to simulate a reasonable barrier layer thickness within the warm pool prior to the onset of the major 1997-98 El Nino. Despite these encouraging results, further improvements are necessary to represent more accurately the variability of the barrier layer in ENSO predictions. This comparison pleads for the continued development of real time observations of in situ salinity.

ST-94

A Possible Limit for ENSO Predictability

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According to the TAO/TRITON mooring array, equatorial Pacific subsurface temperature anomalies in January 2003 were showing signs of an incipient La Niña event. In the western Pacific subsurface, cold anomalies exceeding -2ºC contrasted with the positive eastern near-surface and surface temperature anomalies associated with the 2002 – 2003 El Niño event. Following standard theory of ENSO, these western subsurface equatorial anomalies should affect the eastern Pacific SST two to three months later through Kelvin wave dynamics. Indeed, the canonical ENSO scenario was successful in describing what occurred in nature until May 2003. However, between May and June 2003 there was an abrupt change in the subsurface equatorial temperature anomaly field. Strong westerly wind bursts occurred at the end of May and beginning of June. In response, weak warm anomalies suddenly appeared in the western and central

Pacific equatorial surface and subsurface, signaling the cessation of the preconditioning for a la Nina. Indeed no such event occurred.

Comprehensive climate general circulation models are notorious for their inadequacy in representing high frequency events in the western Pacific; even weather prediction models are unable to forecast such variability after 5 – 6 days. Forecasts with a state-of-the-art seasonal forecasting system such as NSIPP-1 initialized from January to the end of May 2003 were predicting a strong La Niña event in December 2004. As soon as the ocean data assimilation captured and therefore initialized the ocean model with the abrupt change that occurred in the ocean subsurface the forecast system also modified the prediction to a slight warm event, more consistent with observations. A series of experiments presented here sheds light on the relative importance of the spring 2003 westerly wind burst event for the abrupt change in the ocean state and therefore on seasonal forecast for 2003.

ST-95

Seasonal Forcing and ENSO Suppression in the Cane-Zebiak Model

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The effect of a seasonal forcing on the intensity of ENSO is studied using the Cane-Zebiak model. The intensity of ENSO changes significantly with the seasonal forcing. With a basic seasonal climate close to the present, ENSO tends to be suppressed by the enhancement of the background seasonal cycle fields; ENSO can also be suppressed by a substantially enhanced seasonal external equatorial wind, which could be induced by the monsoon forcing. ENSO suppression is usually more effective for an unstable self-exciting ENSO than for a stable stochastic-exciting ENSO. In addition, ENSO also tends to be suppressed by sufficiently strong periodic forcings of longer periods. The suppression of ENSO seems to be related to the nonlinear mechanism of frequency entrainment. These conclusions are in qualitative agreement with previous studies in conceptual ENSO models, although the Cane-Zebiak model shows a much more complicated dependence of the amplitude of ENSO on seasonal forcing.

ST-96

Role of SST Anomalies in the SW Atlantic and SE Pacific Oceans in Prediction of ENSO Events

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This paper is devoted to study the relation between Sea Surface Temperatures (SST) anomalies in the Southwestern Atlantic and Southeastern Pacific Oceans in periods previous to ENSO events (El Niño, La Niña or Neutral year), for 1951-2000. SST anomalies were taken from Kaplan data set at 8 points in the Atlantic Ocean and 11 points in the Pacific Ocean, and ENSO events from the Climate Prediction Center. Gradients of sea level pressure (SLP) were measured in order to determine the causes of the SST anomalies variability. Data of SLP were taken from Climate Diagnostic Center. Daily displacements of the SLP centers of medium and high latitudes in the southern hemisphere were analyzed for the Atlantic and Pacific oceans. SLP patterns were compared with the variability of the SLP gradients and SST anomalies. Decrease of the negative SST anomalies in Malvinas current in April and the preservation of its trend until October is suggested as the precursor of El Niño. The principal cause of the strengthening of the Malvinas Current and the weakening of the Humboldt Current is the displacement of the southern-pacific anticyclone center towards the Strait of Drake. In order to analyze the role of SST anomalies in the Southwestern Atlantic and Southeastern Pacific to predict ENSO events, statistical instruments were used. A logistic regression model was employed as the prediction method, consistent in finding the coefficients of a hyperplane that discriminates, in the best possible way, two dot-clouds, given a group of variables. Coefficients were estimated by the maximum likelihood method from a matrix containing information of the corresponding observations of the explicative variables. The method to predict ENSO is based in two logistic regression models: first to discriminate “Neutral” from “Non Neutral” years, and in presence of a “Non Neutral” year, discriminate between El Niño or La Niña year. For the first model, the most informative variables as precursors are: 77.5W-52.5S in February, 47.5W-32.5S in July of the current year, and 57.5W-42.5S in September of the previous year. For the second model, this variables are: 32.5W-17.5S in January, 47.5W-32.5S in August and 52.5W-32.5S in October of the current year.

ST-97

Evaluation of Operational Predictions by the Heat Content/Indo-Pacific Wind ENSO Prediction Model

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Anomalous equatorial Pacific heat content, a space-time integration of Indo-Pacific equatorial winds and, in the second half of the calendar year, the El Nino index NINO3.4, are all excellent precursors of ENSO. A prediction scheme based on a linear

combination of these three precursors has been operational since August 2002. It claims (Clarke and Van Gorder, Geophys. Res. Lett., vol. 30, No. 7, 2003) to be able to predict across the nearest spring barrier, but not the one after that. The model successfully forecast the present (Fall 2003) weak El Nino conditions but only from the end of June; before then it predicted neutral conditions. On the other hand, at the end of June most other ENSO prediction models were still forecasting neutral or cooler than normal Fall conditions. Currently, the model forecasts the present mild El Nino to die over the spring and near-neutral conditions to prevail in fall 2004. The neutral fall prediction results from the cancellation of the wind predictor, which favors La Nina, and the heat content predictor, which favors El Nino.

ST-98

Low-Level Circulations over the Western North Pacific in Relation with the Duration Time of El Nino

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We investigates differences between the low-level circulations over the western north Pacific for the shorter (SHORT-E) and longer (LONG-E). El Nino events classified with their duration. The major difference between the circulations of the SHORT-E and of the LONG-E lies in their intensity. The El Nino signal shows prominent spectral peaks of 2-3 year quasi-biennial (QB) and 3-6 year interannual bands. The interannual signal is almost the same for the both event types, whereas the QB signal leads to their difference. During the SHORT-E, the amplitude of the QB signal is in phase to that of the interannual. So the circulation as well as the underlying ocean heat content intensifies and evolves rapidly. Such intensification of the circulation seems to be closely linked with the zonal SSTA gradient over the Indian Ocean. During the LONG-E, the aforementioned features diminishes because of the weak QB.

ST-99

The Equatorial Western Winds in the Pacific and the Culmination of the El-Nino Events.

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The analysis of the ECMWF daily data of the wind allows to determine the main role of the western winds in the El-Nino forming. The western winds appear in the low troposphere above the equatorial Pacific simultaneously with the development of the positive sea surface temperature anomaly. In particular, the equatorial western winds,

which replace the classical trade winds in the tropical Pacific, form the zonal circulation anomaly in the low troposphere. This leads to the appearance of warm water in the central and eastern regions of the Pacific, including the coastal regions of Central and Southern America. To classify the synoptical processes in the tropical Pacific the criterions were worked out, which were based on the equatorial western winds activity.

It is found that during the southern summer, when the 1982-83 El-Nino was in the culmination phase, the activity of the equatorial western wind zone changed 11 times, i.e. every day there was a change in the synoptic type of the atmospheric circulation. Analysis of the typical situations for each of the identified classes has shown that the localization, extent and intensity of the western wind anomaly were largely determined by conditions of the Pacific tropical cyclogenesis, whose everyday pattern display high variability. Thus, of the 90 considered cases there were days when 8-9 tropical cyclones of different intensity (active class) were observed simultaneously, and some days over the whole tropical zone of the Pacific the vortices with the cyclonic circulation were not presented at all and gave way to weak anticyclones (outbreak class). With the formation of the active western winds (western bursts), tropical cyclones reached the stage of tropical storms and were located just over the central regions of the tropical Pacific. This ensured the maximum extent of the equatorial western winds, which occupied 1/3 part of the whole tropical zone of the globe.

During the strong 1997-98 El-Nino the “active” class continued almost without breaks from January 5 until February 22, 1998, and in some days western winds were observed on the 850 hPa level in the unbroken zone from Northern Australia to the coast of Ecuador, Columbia and Peru.

ST-100

Does ENSO Affect WWB?

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Episodic westerly wind bursts (WWB) are a common feature in the western equatorial Pacific (WEP) between the months of November – April. The role of WWB in El Niño – Southern Oscillation (ENSO) has gained an increasing attention because WWB appear to be a key ingredient for the timing and magnitude of the El Niño warming. On interannual timescales, the activity of WWB varies greatly with ENSO as WWB become more frequent, more energetic, and extend farther eastward along the equator prior to and during El Niño and vice versa during La Niña. The variation of WWB with ENSO phase suggests that low-frequency ENSO might have a role in the occurrence of high-frequency WWB. In this study, possible ENSO influence on the generation of WWB was investigated by using observational data.

It hypnotized that WWB are regulated by the structure of the warm pool in the WEP through the coupling between low sea level pressure (SLP) and high sea surface temperatures (SST). As the warm pool undergoes east-west migrations on interannual time scales in phase with ENSO, low SLPs are subject to the same east-west migrations. The change in the location of low SLPs induces the change in the strength of the eastward SLP gradient in the WEP. At near equatorial latitudes, the SLP gradient drives westerly winds and preconditions the cyclone formation that leads to large

amplitude WWB. The eastward SLP gradient is enhanced (weakened) when the warm pool is displayed eastward (westward). That is to say, active WWB before and during El Niño are promoted by the eastward displayed warm pool.

That the variations of WWB are subject to the changes of the warm pool location, and hence ENSO, implies that WWB may not be an atmospheric noise but rather than a part of the ENSO dynamics. This suggests that WWB-ENSO relationship is likely an interactive relationship with each influencing the other's development, although they may not be the genesis for each other. WWB are induced by atmospheric transient forcing (e.g., Madden-Julian Oscillation, mid-latitude surges) outside of the tropical Pacific, whereas ENSO resides in coupled ocean-atmosphere interactions in the tropical Pacific.

Clearly, an improved understanding of the role of ENSO on WWB would be useful to ENSO predictability studies.

ST-101

Precipitation in the Eastern Indian Ocean as a Predictor for the Onset of El Niño: What Can TRMM and QuikSCAT Tell Us?

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This study explains an experimental prediction index for the onset of El Niño based on intraseasonal to seasonal variations in observed precipitation from September to March in the eastern Indian Ocean. An example of how these variations are linked to climate variations in the western Pacific is examined for the 2001-2002 season, which preceded the 2002-03 El Niño, with the Tropical Rainfall Measuring Mission (TRMM) and QuikSCAT satellites. Twice, maxima in precipitation and zonal winds propagated eastward, first to the north of the Equator and then to the south. For the southern case, warm waters preceded heavy precipitation in the eastern Indian Ocean, which led strong westerly winds. These climate anomalies followed each other through the ocean passage between Indonesia and Australia, suggesting a coupling of convection, wind, and sea surface temperatures on the time scale of days. Furthermore, this coupling may serve as the mechanism that intensifies and propagates atmospheric disturbances from the Indian to western Pacific Ocean.

ST-102

Equatorial Waves and the 2002-2003 El Nino

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A simple 4-vertical mode linear equatorial wave model, based on method of characteristics, is developed to simulate low frequency wave dynamics in the tropical Pacific for the recent 2002-2003 El Nino event. Wind forcing is via both ECMWF and

Quikscat scatterometer wind stresses. Model parameters were tuned and outputs validated with TOPEX/Poseidon and Jason altimeter measurements. The onset of the 2002-2003 event coincided with several intraseasonal eastward propagating downwelling equatorial Kelvin waves forced by episodic westerly winds in early-to-mid 2002. Most notable of these downwelling Kelvin waves were those in May and June 2002 with sea level elevations of 5-10 cm. The El Nino then matured in the latter half of 2002 in response to continued westerly wind anomalies in the western Pacific, during which sea level rose east of the date line by 15-25 cm. At the same time, the westerly wind anomalies forced westward upwelling Rossby waves which lowered sea level by about 5-15 cm west of date line. On arrival at the western boundary, these upwelling Rossby waves reflected into eastward propagating upwelling Kelvin waves which resulted in a tendency for sea level to fall (and the thermocline to rise) along the equator in accordance with delayed oscillator theory. In addition, an even stronger shoaling tendency resulted from direct wind forcing by easterly anomalies in the western Pacific during the late 2002 and early 2003. These results will be compared with results for the 1997-98 El Nino using the same model. Implications for theories of ENSO variability will also be discussed.

ST-103

The Termination of El Niño Events

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Understanding the processes that control the termination of El Niño is essential to representing them properly in dynamical prediction schemes and in , to understand how the duration of events may change in changing climate. We explore the processes that lead to the end of El Niño events using a combination of data analysis, and forced ocean general circulation model (OGCM) and coupled general circulation model (CGCM) experiments. We find that meridional changes the western Pacific zonal wind anomaly field are fundamental to the termination of El Nino events, and representing these processes is important in forecasts of the termination of El Niño.

We find that the termination of recent El Niño events has been characterized by (1) a late-year southward shift of near-Dateline westerly wind anomalies, and (2) subsequent cold tongue thermocline shallowing is driven by the wind shift. OGCM experiments establish the shift as the primary cause of cold tongue thermocline shallowing. Reflected equatorial waves and local wind anomaly changes are much less important in setting the timing. The structure and timing of the meridional changes suggests that interactions between the seasonal cycle of solar heating and anomalous El Niño conditions lead to the termination.

Analysis of the GFDL CGCM shows that the late-year southward shift of zonal wind anomalies is also a characteristic feature of the termination of El Niño in the coupled model. This southward shift is followed by thermocline shallowing and a cooling of eastern equatorial Pacific SSTs. We perform perturbation experiments with the CGCM

to determine the processes that drive the meridional changes in the zonal wind anomaly field.

Succesful theories and models of El Niño should either represent or parametrize the processes that cause the meridional changes in the west Pacific wind anomaly field, since these processes are fundamental to the termination of El Niño.

ST-104

A Relationship Between the Timing of El Nino Onset and Subsequent Evolution

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A relationship between the timing of El Nino onset and subsequent evolution is examined. Based on the Nino-3.4 index, we found that El Nino events are classified into two major types: one is the onset of which is from April to June (spring type) and the other is from July to October (summer-fall type). Here, the definition of El Nino is when the 5-month running mean of Nino3.4 index is exceeding 0.5 C more than six consecutive months. In general, spring type El Nino events take large SST anomalies around the end of the calendar year, and continue for one year or so. On the other hand, summer-fall type ones are weaker in magnitude, and are further classified into two types in duration: shorter one and longer one. The evolution of El Nino event is quite regular in spring type, while it is rather irregular in summer-fall type.

Evolution processes are also examined by the composite analysis of various fields such as ocean heat content (OHC), sea level pressure (SLP), and sea surface wind stress. It is also seen that the spatial and temporal variations of spring type El Nino events are quite similar each other, while those of summer-fall type are not the case. Especially, for the termination of El Nino, there is a clear difference between those of spring type and summer-fall type. We can suggest that western equatorial Pacific is one of the key-region that determines the regular or irregular behaviors of El Nino. In spring type El Nino events, around the mature stage, strong negative OHC anomalies and anticyclonic SLP anomalies appear in the western equatorial Pacific. By propagation of negative OHC anomalies along the equator from western equatorial Pacific to east, transition mechanism from El Nino to La Nina can act effectively. In summer-fall type, on the contrary, the negative OHC or anticyclonic SLP anomalies in the western equatorial Pacific are weak. Therefore, transition mechanism does not act effectively, and resultantly this type of El Nino often last more than one year.

ST-105

Meteorology Dynamic on ENSO Period (El Nino, La Nina) 1997-1999

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Meteorology dynamic i.e. moving of warm pool, convection, and wind circulation in Indian Ocean to Pacific Ocean were observed on ENSO period (El Nino and La NIna) in 1997-1999. The warm ENSO period or El Nino start in March 1997 with SOI -1.1, similar with this situation the warm pool and convection from Indonesia move to the East (Pacific Ocean) in 170W with SST anomaly (SSTa) 1.52 C and OLR anomaly (OLRa)-20 W/m2.

In July 1997 - January 1998 SSTa in The East Pacific was 3.5 C and the OLRa 30 W/m2, which indicate strong convection and cloudburst. On the contrary in Indonesia and the West Pacific SSTa (-30 C), so the OLRa (30 W/m2), which indicate weak convection and no rainy. The Easterly in low level (850 mb) become weaker, and the Westerly in highy level (250 mb) so strong.

The peak of El Nino 1997/1998 occur on August to October 1997 and January to March 1998, and become extinct on April 1998. In Indonesia has become crucial situation i.e. worst dryness and forest fire, but in the Central Pacific to the East Pacific and Peru experience has happened heavy rain and flooding.

In the normal period (after El Nino period) was very short, that is on May to June 1998. The continue priod is the cold phase of ENSO or La Nina begin in July 1998 with indication SOI positive 1.3. The La Nina become stronger on October to November 1998. Cold tongue was formed in the Central and East Pacific (SST anomaly is –10 C) and convection become decrease (OLRa is 20W/m2). Whereas condition in the West Pacific and Indonesia have become surplus of rain, and some place become flooding because there were positife SSTa (10 C) and increase convection (OLRa minus 30 W/m2).

ST-106

Sensitivities of ENSO: Lessons from the GFDL CM2 Global Coupled GCM

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The El Niño/Southern Oscillation simulated in the new GFDL coupled GCM (CM2) has proved quite sensitive to changes in model physics; in some cases, substantial and unexpected improvements in the ENSO simulation have come from development work aimed at improving other aspects of the model. For example, changes in parameters affecting mean low cloudiness in the eastern Pacific have helped not only to reduce the climatological cold bias along the equator, but also to attenuate ENSO to more realistic levels by increasing the radiative damping of SST anomalies. Adding a representation of the vertical transport of horizontal momentum by cumulus convection has lengthened the period of ENSO, by altering the position and structure of the zonal wind stress response to SST anomalies. Changes in ocean mixing parameters have likewise affected ENSO by altering the response of subsurface temperatures and currents to changes in surface wind stresses. Intermediate and

theoretical ENSO models lend insight into many of these changes. The results emphasize the importance of the oceanic background state in determining ENSO behavior, and may shed light on some widespread problems simulating ENSO in coupled GCMs.

ST-107

The Decadal Adjustment of ENSO Cycles and its Mechanism

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The wavelet analysis about ENSO index denoted by SSTA in Nino3 of OISST data shows that there is obvious difference between the dominant period of ENSO before 1976 and that after 1976. The former is relatively shorter than the later. The correlation analysis is used to capture the propagation of the related oceanic anomaly in the chosen El Nino events by the wavelet analysis, such as 1965/1966, 1972/1973, 1982/1983. The December of year-1 in the El Nino events is chosen as the fiducial time because El Nino is always phase-locked to the seasonal cycle. Analyzing the correlation coefficient figures with different lagging time, We can find much commonness in the El Nino events before 1976 and those after 1976:

1. In the El Nino events before 1976, the anomaly signal related to El Nino propagates northeast to southwest slightly and mainly in zonal direction from the east of North Pacific. After 1976, the anomaly signal propagates northeast to southwest to a relatively larger extent. Some of the anomaly signal comes from a region in relatively north latitude.

2. The anomaly signal in the tropical western Pacific before 1976 appeared 4-8 months earlier and propagated much faster than that after 1976.

3. There is always a similar correlation with Nino3 in the Equatorial southwest Pacific and the Equatorial western Pacific region. For example, there is always a region of similar correlation coefficients in southwest Pacific connected with the Equatorial region. Such an region is relatively smaller before 1976 and with smaller correlation coefficients. The region is relatively narrow in longitudinal direction and moving relatively swiftly eastward. After 1976, the area is relatively wide in longitudinal direction and larger. The correlation coefficients here increased too. The area moved relative slowly. The change of ENSO characteristics after 1976 with a longer period and higher intensity may be explained by that.

The distribution of the thermocline depth related to the El Nino events is analyzed. We can find that the thermocline related to the El Nino events after 1976 is relatively deeper in the extra-tropical region of North Pacific and South Pacific and the Equatorial eastern Pacific, and relatively shallower in the Equatorial western and central Pacific and its northern and southern neighboring region than the corresponding region before 1976. Such decadal adjustment of the thermocline and related change of air-sea interaction helps the change of the propagation of oceanic anomaly signal.

ST-108

Interdecadal Change in Properties of El Niño in an Intermediate Coupled Model

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SST variability in the eastern equatorial Pacific is highly dependent on temperature of subsurface water entrained into the mixed layer (Te). The sensitivity of El Nino properties to Te is examined using an intermediate coupled model (ICM). The ocean component is based on an intermediate complexity model developed by Keenlyside and Kleeman (2002) that is an extension of the McCreary (1981) baroclinic modal model to include varying stratification and partial nonlinearity effects. An empirical procedure is used to parameterize Te from sea level (SL) anomalies via a singular value decomposition (SVD) analysis. The ocean model is coupled to a statistical atmospheric model that estimates wind stress anomalies also from a SVD analysis. It is found that the subsurface entrainment of heat into the mixed layer and its parameterization for the thermodynamic effect on SST determine the El Nino properties in the ICM. Using the empirical Te models constructed from two periods 1963-79 (Te(63-79)) and 1980-96 (Te(80-96)), the coupled model exhibits strikingly different properties of interannual and temporal evolution). For the Te(63-79) model, the system features 2-year oscillation and westward propagation of SST anomalies on the equator, while for the Te(80-96) model, it is characterized by 5-year oscillation and eastward propagation. These changes in El Nino properties in the ICM are consistent with behavior shift of El Nino observed in the late 1970s. The implications for coupled modeling and prediction are discussed in terms of the sensitivity of model performance to the parameterization of subsurface entrainment in the equatorial Pacific Ocean.

ST-109

Decadal Changes in the Tropical Mean State and ENSO Variance in a Coupled GCM

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Connections between decadal changes in the mean state of the tropical Pacific and ENSO variance are examined using three runs of a fully coupled ocean-atmosphere general circulation model. The difference in the three simulations, i.e., a standard

coupled model (one AGCM is coupled to a single OGCM) and two interactive ensemble models (six or twelve AGCMs are coupled to a single OGCM), is only in the amplitude of internal atmospheric variability felt by the ocean component at the air-sea interface. All three simulations have the same Pacific basin scale SST mode that dominates the low frequency (time scales longer than 10 years) variability, which is identified by the first EOF mode. This low frequency mode is largely independent of the simulated ENSO and is neither a residual of the decadal ENSO variability nor does it produce any low frequency modulation of ENSO. The analysis presented here suggests that this low frequency mode is stochastically driven by atmosphere noise.

There are, however, low frequency changes of tropical mean state are connected with the simulated ENSO variance. The tropical mean state associated with ENSO variance has different structures of SSTAs and wind stress anomalies compared to the dominant tropical mean state identified by the first EOF. We found that this tropical mean state associated with ENSO variance, which looks surprisingly similar to the structure and variability of the second EOF SST mode in two interactive ensemble models, is not detected in a standard coupled model. We argue that the large amplitude of atmospheric noise makes it difficult to detect decadal mean state changes associated with ENSO variance. When the overall noise level is reduced, the tropical mean state associated with ENSO variance (identified by the second EOF mode) is detected in the interactive ensemble models. We do not know whether the variability of the second EOF mode associated with ENSO variance forces the ENSO changes or that is merely a residual mode. Based on simple Markov model experiments, however, we suggest that this mode of decadal variability associated ENSO variance is not forced by atmospheric noise, indicating that non-linear dynamics or external forcing is needed to explain this mode of decadal variability in the tropical Pacific.

ST-110

Tropical Pacific Climate and Variability in the GFDL CM2 Global Coupled GCM

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A new global coupled ocean/atmosphere/land/ice model (CM2), developed at the Geophysical Fluid Dynamics Laboratory, is evaluated in terms of its tropical Pacific climate and interannual variability. The atmosphere component includes a B-grid dynamical core with 18 vertical levels, 2.5° longitude by 2° latitude grid spacing, relaxed Arakawa-Schubert convection, a Mellor-Yamada 2.5 dry planetary boundary layer, and a representation of the vertical momentum transport due to cumulus convection. The ocean component is the Modular Ocean Model, version 4, with 50 vertical levels, 1°x1° horizontal grid spacing telescoping to 1/3° meridional spacing near the equator, an explicit free surface with true freshwater fluxes, neutral physics, KPP vertical mixing, and a shortwave penetration depth that depends on prescribed climatological ocean color. The coupled model exhibits a robust equatorial annual cycle and a strong ENSO with an irregular period of 2 to 4 years. Simulated interannual subsurface temperature anomalies propagate eastward, while sea surface temperature anomalies exhibit eastward, westward, and non-propagating signatures. Elements of delayed-oscillator/recharge

theory, SST modes, and advective-reflective modes are all evident in the ENSO simulation. Many of the remaining biases in the model are common among other coupled GCMs; implications of these biases, and progress towards addressing them, are described.

ST-111

Recent Trends in the Southern Oscillation

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The Southern Oscillation Index, the difference between standardized sea-level pressure between Tahiti (18°S, 150°W) and Darwin (12°S, 131°E), (hereafter denoted TN - DN) has tended to be lower during the past few decades than during the earlier part of the record.

This shift is mainly a reflection of a pressure rise at Darwin: pressure at Tahiti has not fallen noticeably. The pressure rise at Darwin and the drop in (TN - DN) that took place in the mid- 1970's are both statistically significant on an a priori basis, but the downward trend in (TN - DN) since the mid-twentieth century is not. Of greater significance is the upward trend in (TN + DN). Fluctuations in TN + DN are shown to be significantly correlated with fluctuations in tropical mean sea-level pressure and the Northern and Southern Hemisphere annular modes. The trend toward the high index polarity of the annular modes accounts for roughly half the observed rise in (TN + DN) since the mid-20th century.

The above findings are in accord with the statement in the Third Assessment Report of the Intergovernmental Panel Climate Change that "Warm episodes compared to the previous 100-years". However, the evidence examined here is inconclusive as to whether the shift that occurred in the mid-1970's is indicative of a secular trend toward the warm polarity of the ENSO cycle.

ST-112

Thermodynamic Coupling and Predictability of Tropical Sea Surface Temperature

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Air-sea coupling involves the exchange of both momentum and heat between the atmosphere and the ocean. Dynamic coupling, which relates to the momentum exchange, is believed to play the dominant role in the tropics, especially in phenomena such as the El Nino-Southern Oscillation in the tropical Pacific. However, thermodynamic heat exchange between the atmosphere and the ocean can also play a significant role in air-sea coupling. This is especially true in the tropical Atlantic, where dynamic coupling may be of secondary importance. In this study, the role of this thermodynamic circulation model coupled to a slab ocean model. Two thermodynamic feedback mechanisms are

considered: the reduced thermal damping mechanism and the thermodynamic coupling leads to amplification and increased persistence of surface wind variability in the deep tropical Atlantic region. This effect is anisotropic, being stronger in the meridional component than in the zonal component of the surface wind. These features cannot be explained by the isotropic reduced thermal damping mechanism, and indicates a possible role for the WES feedback. Predictability experiments using observed December sea surface temperature (SST) initial conditions were also carried out. These show that thermodynamic coupling can lead to forecasts of north tropical Atlantic SST that are significantly better than persistence forecasts during the boreal spring. These results mean that thermodynamic coupling certainly leads to a richer, more complex set of interactions than a local, Hasselmann-type of red-noise model would imply.

ST-113

Circulation Regimes and SST Forcing: Results from Large GCM Ensembles

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This paper studies the influence of tropical sea surface temperature on mid-latitude circulation regime behavior on low-frequency intraseasonal time scales in the Pacific North American region. A cluster analysis has been applied to 55-member ensembles of winter seasonal simulations of the COLA GCM for each of 18 winters. The ensemble members for each winter utilize the same, prescribed weekly SST from observations.

Applying a partitioning algorithm to each winter's ensemble separately, we find clusters in the 200 hPa height field which are significant (vis-à-vis a suitable Gaussian background), reproducible (in half-length data sets), and consistent (with clusters obtained from the u-wind) for all winters except the strong El-Nino events of 1982/83, 1986/87 and 1997/98.

One cluster found consistently in many winters, consisting of a strong ridge over the Alaskan region and a trough over central North America, is quite similar to the Alaska pattern identified from observations (Renwick and Wallace, 1996) as being particularly difficult to predict, and which occurs preferentially during La-Nina events. Two other clusters found in many winters have no obvious observational counterparts. A regime which is very similar to the seasonal mean response to cold Pacific SSTs is seen during several La-Nina winters.

A strong negative correlation between a measure of the strength of the clustering and the Nino3 SST index is found.That this correlation is as strong as the correlation between the seasonal mean response to the same SST index indicates that the ENSO related SSTs affect the regime structure of intra-seasonal flow as strongly as they do the seasonal mean state.

ST-114

What Are the Causes of the Skewness of El Niño?

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SST is positively skewed in the Eastern Pacific, so El Niño's are more pronounced than La Niña's. The effect is most pronounced during periods of high ENSO activity, and probably the cause of the link between ENSO activity and decadal variability. In addition, it contributes to the apparently sporadic character of El Niño. Understanding and representing skewness correctly in ENSO models is essential for improving forecast skill beyond that of linear models. Currently, GCMs tend to underestimate the asymmetry between the strength of El Niño and La Niña.

The data that have become available in recent decades show that while SST is positively skewed in the Eastern Pacific, thermocline depth displays a see-saw pattern: positive in the Eastern Pacific and negative in the West. In the region of strong zonal wind stress response to Niño-3 anomalies, zonal wind stress is positively skewed. In the western Pacific, westerly wind events give a positive contribution, but the skewness of yearly zonal wind stress anomalies is negative. Are these signals due to oceanic or atmospheric processes, or both?

We use forced and coupled runs with a simple intermediate model and atmospheric and oceanic GCMs for identifying processes that can give sizeable contributions to the skewness of El Niño. In the ocean, the dependence of the depth of the mixed layer on the ENSO phase appears to be a major factor, augmented in the coastal region by the thermocline coinciding with the bottom of the mixed layer during La Niña. In the atmosphere, random wind perturbations are found to be larger during El Niño than during neutral or La Niña conditions, also enhancing the strength of El Niño.

ST-115

The Effect of El Nino on Oceanic Mass Redistribution

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Using model generated proxy data of ocean bottom pressure (OBP), we have shown that GRACE is able to detect El Nino development; therefore, it would provide deep ocean information for early detection of El Nino. We have also proposed an OBP index useful for effectively determining El Nino events. It is shown that the OBP index has a significant value (up to 2 mbar), 10 times higher than the GRACE detectable range (~0.1 mbar) and has been correlated tightly with other ocean variables over the past 50 years. The proxy data is verified by both SSH measurements of T/P satellite and in-situ data, suggesting that El Nino has a profound effect on oceanic mass redistributions.

ST-116

The Role of Tropospheric Temperature in the ENSO-Driven Surface Temperature Variability over the Remote Tropics

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Previous observational and modeling studies have shown the importance of wind speed and the shortwave influence of cloud cover in mediating the El Niño warming over the remote tropical oceans via the 'atmospheric bridge'. We argue - based on simulations with a single column model and with an atmospheric GCM coupled to a thermodynamic slab ocean model - that atmospheric boundary layer humidity effects, and also the influence of net LW, can also be significant influences. The relative strengths of each surface flux influence differ from region to region, indicating the complicating influence of regional climate processes. However, we argue that tropospheric temperature plays a central role in the El Nino-related remote surface temperature warming by i) communicating the ENSO influence to the remote tropics; and ii) setting the equilibrium surface temperature response over moist convective regions, through the convective quasi-equilibrium constraint linking planetary boundary layer moist static energy to the free tropospheric temperature. This constraint offers a simple explanation why all remote moist convective regions (over ocean and land) warm during and after the El Niño peak, despite the region-dependent nature of the surface flux response.

ST-117

Studying Climate Variability over the Tropical Pacific Using Wind Profilers

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Wind profilers have operated in the tropical Pacific for over a decade and have provided extensive wind data sets (Gage et al. 1991). In this study we focus on seasonal winds observed by profilers at Darwin and Biak in the western Pacific, Christmas Island in the central Pacific, and Piura in the eastern Pacific. These profiler observations are

compared to the NCEP/NCAR reanalysis. Currently only Christmas Island profiler winds are assimilated into the reanalysis.

Monthly average winds in the western Pacific show a clear monsoon signal, with a transition from easterly to westerly winds in late-December and late-November for Darwin and Biak respectively (Schafer et al. 2003). Comparison with the reanalysis showed differences in both timing and vertical extent of the circulation. Walker and Hadley circulations dominate in the central Pacific (Christmas Island). The expansion and contraction of the Walker circulation leads to alternating easterly and westerly winds above 6 km. The reanalysis shows a similar zonal pattern with similar timing and depth. From May to November there are two levels of meridional overturning, with southerly winds below 3 km and two cores of northerly winds above. This meridional wind feature is much weaker in the reanalysis. At Piura, zonal winds are easterly with a decrease in wind speed toward the surface as a result of blocking by the Andes. This blocking is not well represented in the reanalysis due to errors of representativeness. The meridional winds show periods of low-level (below 4 km) northerly and southerly flow. Northerly winds occurring from mid-February to late-May might represent the formation of a double ITCZ. The reanalysis does not show these northerly winds.

Profilers are a valuable source of wind observations in particular over the tropical Pacific where observations are geographically sparse. Continuing efforts should focus on data quality assurance and the subsequent assimilation into atmospheric models.

Gage, K. S., B. B. Balsley, W. L. Ecklund, D. A. Carter, and J. R. McAfee, 1991: Wind profiler-related research in the tropical Pacific. J. Geophys. Res., 96, 3209-3220.Schafer, R., S. K. Avery, and K. S. Gage, 2003: A comparison of VHF wind profiler observations and the NCEP/NCAR re-analysis over the tropical Pacific. J. Appl. Met.,42, 873-889.

ST- 118

Developing Phase of the South Pacific Convergence Zone and the Cross-Equatorial Flow in the Western Tropical Pacific

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This paper is focused on the investigation of the subtleties in the process of the South Pacific Convergence Zone (SPCZ) development in the transitional period, boreal autumn, by taking advantage of a combination of satellite observations of the ocean and atmosphere such as TRMM satellite microwave imager estimated SSTs, rain-rates and surface wind speeds.

Based on analysis of these satellite data, an ocean-atmosphere interaction feedback mechanism is presented that traces the origin of the development of the SPCZ,critically, to the monthly wind vector increment (winds of the present month minus that of the immediately preceding month) that appear to be, at least in part, related to the thermal winds with magnitude about 1m/s to the east of New Guinea in August. Along with the northerly wind increment, a decrease in velocity of the prevailing southeasterly wind could lead to a drop in evaporation at the sea surface, which may cause an

increase in SST as well as in low-level convergence. The heat surplus, due to the reduced evaporation, produces the SST to rise at a rate of about 0.05-0.25C per week in the south- western Pacific compared with its counterpart in the central Pacific in the process of the SPCZ development.

The cross-equatorial flows adjacent 135-145E contribute much to the substantial intensification of the SPCZ in November.These northerly cross-equatorial flows, certainly related to the seasonal adjustment of the Asian-Australian monsoon, deflect to the east when approaching 5S or farther south forced by the Coriolis effect, and form a northwesterly jet impacted by the topographic land mass of New Guinea. The jet encounters the prevailing southeasterly wind originally existed there, thus, causing extremely intense convergence, most expansive convective cloud bands, and more rainfall, which shows the entrance of the fully developed episode of the SPCZ.

Therefore, the whole developing phase of the SPCZ can be divided into two stages.The mechanism of atmosphere-ocean interaction appears to contribute much to the earlier stage of the SPCZ development, while the second stage is marked by the interaction between the Northern Hemisphere and the Southern Hemisphere combined with the effect of the terrestrial mountains, which is the principal cause for the substantial intensification of the SPCZ.

ST-119

The Impact of ENSO on the North Pacific Ocean during Summer

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Most previous studies of ENSO teleconnections to the Northern extratropics have focused on the winter, since the atmospheric circulation anomalies are largest during December-February. While the ENSO-related circulation anomalies are much weaker in summer, changes in low-level surface winds, temperature, moisture and clouds associated with ENSO can still drive changes in the extratropical oceans. This "atmospheric bridge" between the tropical and extratropical Pacific Ocean can create substantial summertime SST anomalies, since anomalies in solar radiation at the surface can be large in summer and because the mixed layer is shallow, so anomalous surface forcing is spread over a much thinner layer than in winter. Indeed, composite analyses shows that the magnitude of the El Niño-La Niña SST difference exceeds 2ºC along 40ºN in the western North Pacific during July and September, which is more than twice the amplitude of the North Pacific SST anomalies in winter. Here we use NCEP reanalysis, solar radiation estimates from satellites and subsurface ocean temperature data to diagnose what causes these SST anomalies to form and the extent to which they may feedback on the atmosphere.

ST-120

Atmospheric Response to North Pacific SST: The Role of Ocean-Atmosphere Coupling

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Atmospheric response to a mid-latitude winter SST anomaly is studied in a coupled ocean-atmosphere general circulation model. The role of ocean-atmosphere coupling is examined with ensemble experiments of different coupling configurations. The atmospheric response is found to depend critically on ocean-atmosphere coupling. The full coupling experiment produces the strongest warm-ridge response and agrees the best with a statistic estimation of the atmospheric response. The fixed SST experiment and the thermodynamic coupling experiment also generate a warm-ridge response, but with a substantially weaker magnitude. This weaker warm-ridge response is caused by an excessive heat flux into the atmosphere, which tends to force an anomalous warm-low response and therefore weakens the warm-ridge response of the full coupling experiment.

Our study suggests that the atmospheric response is forced by both the SST and heat flux. The SST forcing favors a warm-ridge response, while the heat flux forcing favors a warm-low response. The correct atmospheric response is generated in the fully coupled experiment which produces the correct combination of SST and heat flux naturally.

ST-121

Relationship between Springtime Surface Temperature over Siberia and Subsequent Blocking Activity over the North-West Pacific Ocean

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Influences of surface temperature over Siberia in spring upon the subsequent blocking events that are observed over the north-west Pacific Ocean are examined from daily NCEP/NCAR reanalysis dataset. The analyses are conducted for the 54-year period from 1949 to 2002. Blocking anti-cyclones in this area has large interannual variability and influence climatic change of East Asia in summer. Index of surface temperature on Siberia is defined as average of surface temperature of the region of 80-140E, 50-70N. From this definition, we pick up the high surface temperature years in April: 1949, 53, 68, 75, 81, 82, 85, 97, 2000, which are referred to as the high years. Blocking events are defined using 10 day low-pass filtered 500 hPa geopotential field. It is found that when the surface temperature of Siberia is high in April, blocking events over the north-west Pacific Ocean in May and June more frequently occur than that of 54 years average. Causal process of this relationship is shown in this study; In spring, high temperature anomaly in Siberia generates a meridional temperature gradient between the north of Siberia and a westerly jet over just north of this area (around 70N). This jet stream in high latitude forms a double jet structure on East Asia with a subtropical jet that is developed in early summer. For this double jet structure, the meridional gradient of potential vorticity is gradual between these two westerly jets. Because of the gradual

meridional gradient of potential vorticity, it is considered that a percel with low potential vorticity that originated from lower latitude can easily mixes with a high potential vorticity parcel at higher latitude in this area. Blocking anticyclones are formed more frequently than usual years due to this mixing process. Moreover, each blocking anticyclones formed in the high years are compared with that formed in the low years. It is shown that amplitude of blocking anticyclones is larger and period of blocking events is longer in the high years than that in the low years. The influence of high surface temperature on Siberia in spring upon summertime Japanese climate is also examined by station data provided by the Japan Meteorological Agency. The mean precipitation/temperature increases/decreases in June, in the central of Japan in high years. This fact represents that the climate of Japan in the Baiu season, namely early summer is reinforced by high temperature of Siberia in springtime.

ST-122

Prediction Skill Dependence on the Forcing Direction between Ocean and Atmospheric Anomalies in the Northern Pacific

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Previous studies have suggested that the local phase relationship between low-level atmospheric circulation and SST anomalies gives guidance to determine the primary forcing direction of locally coupled anomalies of sub-seasonal timescales. Such a local phase relationship can be computed on a case-by-case basis either from observations or from reanalysis datasets. We here evaluate the skill of sub-seasonal simulation and the skill of medium-range forecast of atmospheric anomalies as a function of the diagnosed forcing direction over the Northern Pacific. For the simulation, we measure the skill of an NCEP-AMIP run to simulate the sign of the anomaly with respect to the reanalysis in the five-days average data. For the forecasts, the skill of the control run of the CDC-Reforecast data is measured using the Anomaly Correlation Forecast and expressed as a function of the fraction area of forcing direction, which is diagnosed prior to the initial time, over the region. In both cases we use the NCEP/NCAR reanalysis data to diagnose the forcing direction

Our results indicate larger errors in the skill of AMIP simulation in cases when the atmosphere forces the ocean. This result is not surprising since the AMIP is based on an ocean-driving scenario that, in principle, gives better results when, as assumed, the ocean forces the atmosphere. This result also reinforces the warning on the use ocean-driving scenarios to perform extended range predictions. Medium range forecasts are, on the average more skillful when the ocean drives the atmosphere in a large percentage of the ocean's basin. This is consistent with the fact that the forecasts are made with the initial SST anomalies persisted through the run, making it an ocean-driving scenario model as the AMIP run. Compositing analysis of 500-hPa Height anomaly when the ocean-driving conditions prevail over most of the North Pacific basin

and when the atmosphere-driving conditions prevail show respectively, a negative and positive PNA pattern, suggesting that this pattern is related to local and not just to remote mechanisms.

ST-123

Important Physical Process for the Mixed Layer Variability in the North Pacific

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When considering air-sea interaction, a mixed layer plays an important role as a boundary layer of the ocean, and has influence on both of the ocean and the atmosphere. Therefore, it is thought to be very important in order to solve the formation mechanism of a mixed layer, when we consider the role of the ocean climate variability. Many of previous studies have found that anomalous Ekman drift plays an important role in generating SST anomalies (Jacob, 1967, Namias, 1972).

However, on the time scale less than ~10years, most studies have found that surface heat flux plays a dominant role in forcing mid-latitude SST anomalies (e.g, Battisti et al., 1995; Halliwell and Mayer, 1996). Moreover, because of lack of spatially extensive and temporally continuous data, the mixed layer depth (MLD) variability in the North Pacific has never been fully examined. In this study we investigated about important physical process for the mixed layer variability in the North Pacific using a numerical model. Although the seasonal variability of mixed layer temperature (MLT) in our model well reproduced observational results, it is not the case south of 20ºN.

Same as previous studies, heat flux greatly contributes to MLT seasonal variability, and it is shown that contribution of horizontal advection is large to generate MLT anomalies. On the other hand, the Ekman advection contributes to MLD variability as large as an entrainment, and it is remarkable south of 20ºN,where model performance for MLD is not so good. Then, in order to confirm an impact of the wind forcing to a mixed layer, wind stress data were changed into J-OFURO from NRA. And latent heat flux greatly influenced by wind data was also changed from NRA to J-OFURO. Then, a remarkable difference is found only south of 20ºN, and MLD in the model well consistent with observation data south of 20ºN.

When satellite data for wind stress and latent heat flux are used, best results were obtained. This suggests that the accuracy of satellite data seems to be higher than reanalysis data.

ST-124

On the Variability of Pacific Subtropical Highs

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The subtropical highs in sea level pressure (SLP) are not fully understood. Three groups of mechanisms link remote variability to variability of these highs: tropical divergent circulations, tropical/subtropical Rossby wavetrains, and midlatitude frontal system interactions. Studying the highs provides a realm for understanding how the tropics and midlatitudes interact.

We focus on links between these mechanisms and the Pacific subtropical highs. Precipitation, OLR, velocity potential, and divergent winds are used as proxy indicators for the remote mechanisms. Tools used include: composites, one-point correlations, autocorrelations, cross-correlations, and cross spectra. Monthly and daily observations give some support to each mechanism. Associations seen in monthly data are better understood in daily data at various lags.

For the South Pacific: convection over Amazonia, coordinated with suppressed convection in the western tropical Pacific lead to enhanced SLP on the tropical side of the high. Midlatitude systems are the strongest influence upon the maximum SLP and SLP on the higher latitude side of the high. The western side is associated with both middle and lower latitude phenomena, such as the south Pacific convergence zone. Various properties of the high have a strong period around 45 days, and show a link to the Madden-Julian oscillation. The link to ENSO is confined to the west and tropical side of the high.

In the North Pacific similar links are found except the connection to convection over the Americas is weaker. Seasonal variability differs between North and South Pacific highs.

ST-125

Interseasonal and Interannual Variability of the Southern Hemisphere Energetics

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The subject of this work is to evaluate the interseasonal and interannual variability of the Southern Hemisphere energetics. For this purpose, a data set of 30 years from NCEP/NCAR (National Center for Environmental Prediction/National Center for Atmospheric Research) was used. In the period between 1969 and 1999, moderate to strong ENSO (El Niño/Southern Oscillation) events were selected. The 5 El Niño and 4 La Niña events selected from this data set were composed to study the ENSO-related interannual variability. Energy components are in good agreement with those from Oort and Peixoto (1983) for winter and summer seasons. These components have an annual cicle, which is maximum in summer and minimum in winter for latent heat and internal and potential energy. However, kinetic energy has the highest value in winter and lowest in summer. ENSO composites have shown that during winter the APE (Available Potential Energy) and consequently the Total Energy are weaker in warm and cold events. During the summer, the results are different: El Niño APE is stronger than

neutral years, indicating an increasing in summer and decreasing in winter. For the ENSO cold events, summer results are similar to neutral years. APE ENSO-related variability is smaller in the others seasons and APE annual mean is greater in neutral years. In terms of amplitude, interannual variability of kinetic energy and latent heat are small, though interesting features can be found. As expected, latent heat variability is more pronounced in the tropics. Latent heat zonal mean is small northward of 20o S during cold events. Kinetic energy analisys indicate that ENSO events produce important regional variability, which could change atmospheric circulation as a consequence.

ST-126

Extra-Polar Climate Impacts on Antarctic Sea Ice: Phenomenon and Mechanisms

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Many remote and local climate variabilities influence on Antarctic sea ice at different time scales. The strongest sea ice teleconnection at the interannual time scale was found between ENSO events and a high latitude climate mode named Antarctic Dipole. The Antarctic Dipole is characterized by an out-of-phase relationship between sea ice and surface temperature anomalies in the South Pacific and South Atlantic. The Antarctic Dipole manifests itself and persists seasons after being triggered by the ENSO forcing. This study investigates what mechanisms transport tropical signals to Polar Regions and why ADP anomalies persist at high latitudes. The study summarizes current knowledge regarding ENSO/polar region teleconnection and puts a few isolated teleconnection mechanisms into a coherent scheme. The hypothesised scheme suggests that the heat flux due to the mean meridional circulation of regional Ferrel Cell and regional anomalous circulation generated by stationary eddies are the two main mechanisms responsible for the formation/maintenance of the Antarctic Dipole. The changes in the Hadley Cell and jet stream in the subtropics associated with the ENSO link the tropical forcing to these high latitude processes. Moreover, these two mechanisms operate in phase and are comparable in magnitude. The positive feedback between the jet stream and stationary eddies in the atmosphere, positive feedback within the air-sea-ice system, and seasonality all reinforce the anomalies, resulting in long-lasting Antarctic Dipole anomalies.

ST-127

Seasonal Forecast of Antarctic Sea Ice with a Markov Model

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A linear Markov model has been developed to simulate and predict the short-term climate change in Antarctic, with particular emphasis on sea ice variability. Seven atmospheric variables along with sea ice were chosen to define the state of the Antarctic climate, and the multivariate empirical orthogonal functions of these variables were used

as the building blocks of the model. The predictive skill of the model was evaluated in a cross-validated fashion, and a series of sensitivity experiments were carried out. In both hindcast and forecast experiments, the model showed considerable skill in predicting the anomalous Antarctic sea ice concentration a few seasons in advance, especially in austral winter and in the Antarctic dipole regions. The success of the model is attributed to the domination of the Antarctic climate variability by a few distinctive modes in the coupled air-sea-ice system, and to the model's ability to pick up these modes. We are presently using this model for experimental seasonal forecasting of Antarctic sea ice. An example of our current prediction is presented here.

ST-128

A Study of Antarctic Circumpolar Wave in the NCAR Coupled Model

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The Antarctic Circumpolar Wave (ACW) was first presented by White and Peterson (1996). They used four types of data to characterize it: i) anomalies in sea ice edge (SIE), sea level pressure (SLP), sea surface temperature (SST) and wind stress. The ACW as revealed by their analysis exhibits a wavenumber two structure and takes 8-10 years to travel around the globe. This is also consistent with the ACW observed by Jacobs and Mitchell (1996) using sea level height data. Analytical ocean-atmosphere coupled models of the ACW were constructed by Qiu and Jin (1997), White et al. (1998) and Haarsma et al. (2000). Qiu and Jin (1997) proposed a mechanism for the ACW based on local ocean-atmosphere interaction. Following this idea, White et al. (1998) using a simplified model, found that in the absence of ocean-atmosphere coupling, the SST anomalies are advected slowly and soon dissipate, whereas with active coupling advection occurs at the observed speed. Haarsma et al. (2000) using the ECBilt model investigated the physical processes and feedback mechanism of the ACW. In their model, the ACW-like mode is generated by the advective ressonace mechanism of Saravanan and McWilliams (1998), which assumes that the ocean passively advects SST anomalies that are generated by the atmospheric circulation anomalies. On the same note, White et al. (2002) found the ACW in the eastern Pacific and western Atlantic sectors to be a result of damped resonance remotely forced by the slow eastward phase propagation of covaring SST and SLP anomalies associated to what they called Global ENSO Wave (GEW).

In this study, we investigate the existence of an ACW-like signal in the National Center for Atmospheric Research/ Community System Model – CSM 1.4 coupled model using 150 years simulation data. Hovmoeller diagrams show eastward propagating

patterns of sea surface temperature and of subsurface ocean temperature anomalies (at 250m depth). In this coupled model ocean dynamics play a predominant role in explaining the Antarctic Circumpolar Wave. Preliminary results from Empirical Orthogonal Function analysis reveals for example, that the first spatial mode for subsurface temperature exhibits a combination of both zonal wavenumbers two and three patterns, which is in agreement with other numerical studies that show predominance of the same wave numbers.

ST-129

Trends in the Southern Hemisphere Polar Vortex and Implications for Blocking Frequency

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Analysis of observations has shown that the polar vortex in the Southern Hemisphere stratosphere has increased in strength over recent decades, especially in spring and summer. Results from both the NCEP/NCAR and ECMWF 40-50 year reanalyses confirm the trend towards increasing zonal winds in the stratosphere, and show the same kind of behaviour down to the surface of the Earth. Despite sometimes large differences between NCEP/NCAR and ECMWF reanalyses on a daily basis, the two data sets show a large degree of agreement in the form and temporal behaviour of trends in the Southern Hemisphere polar vortex. This presentation will document differences and similarities in the two reanalyses depiction of trends in the tropospheric and stratospheric circulation in the Southern Hemisphere.

The existence of an increasing trend in the strength of the zonal circulation has implications for the formation and maintenance of blocking anticyclones over the southern oceans. Here, Southern Hemisphere blocking statistics derived from both reanalyses, with and without the inclusion of trends in the zonal winds, will be presented. Impacts of the strengthening polar vortex on Southern Hemisphere blocking activity will be discussed.

ST-130

Antarctic Climate Variability - Results from the SCAR READER Project

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The READER (REference Antarctic Data for Environmental Research) project of the Scientific Committee on Antarctic Research has created a new data set of monthly and annual mean near-surface and upper-air climate data (temperature, surface and mean sea level pressure (MSLP), wind speed and height of pressure surfaces) for the Antarctic using historical observations. Where possible, 6 or 12 hourly surface and upper-air synoptic and automatic weather station observations were used to compute

the means, allowing a rigorous quality control of the data to be carried out at the level of the individual observations. This has produced a much better data set than previously available. The monthly mean data are available on the web at http://www.antarctica.ac.uk/met/READER/. Trends of annual and seasonal near surface temperature, MSLP and wind speed, have been computed for 18 stations with long records extending back to the 1950s or 1960s. Eleven (seven) of these stations had warming (cooling) trends in their annual data, indicating the spatial complexity of change that has occurred across the Antarctic in recent decades. The western side of the Antarctic Peninsula has experienced a major warming over the last 50 years with Faraday/Vernadsky station having warmed at a rate of 0.56o C (10 yr)-1 over the year and 1.09o C (10 yr)-1 during the winter, both figures are statistically significant at <5% level. This is as large a warming as has been experienced anywhere on Earth over this period. Overlapping thirty year trends of annual mean temperatures indicate that at all but two of the 10 coastal stations for which trends could be computed back to 1961, the warming trend was greater (or the cooling trend less) during the 1961-90 period compared to 1971-2000. This points to possible recovery from more extensive sea ice conditions in the 1960s. All the continental stations for which MSLP data were available show negative trends in the annual mean pressures over the full length of their records, which we attribute to the trend in recent decades towards the Southern Hemisphere annular mode (SAM) being in its high index state. All but two of the coastal stations have recorded increasing mean wind speeds over recent decades, which is also consistent with the change in the nature of the SAM.

ST-131

ENSO, Interannual Rainfall Variability and Food Security for Zimbabwe

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The smallholder farmer in Zimbabwe grows grain crops, mainly maize/corn, for his subsistence, and sells the surplus in order to earn some cash. In this way he makes an invaluable contribution to the food security of not only his household and immediate community, but of the country as well, and also adds to the country's GDP (smallholder farmers contribute up to 70% of the country's maize/corn total production).

Climate change and the apparent increase in the frequency and severity of extreme climate and weather events has taken a toll on the smallholder farmer whose crops, that are mostly rain-fed, suffer tremendously in the face of drought. (Recurrent droughts are quite evident in Zimbabwe's climate history.) Adequate knowledge of the quality of the next rain and cropping season is paramount if the smallholder farmer is to plan so as to mitigate the ravages of a drought. The farmer invariably needs to know whether the whole season or part of it will experience a deficit in precipitation.

It is the effort of this work, and results are there, to reaffirm that indeed the Zimbabwe summer rainfall season, which runs from October to March, does respond to ENSO fluctuations. (Monthly rainfall and SOI values data spanning the period 1916 to

2001 is used.) Further it is quantitatively shown that the chance of drought occurring in Zimbabwe as a result of ENSO is highest when ENSO is in the warm phase and lowest when ENSO is in the cold phase. Yet still, it is shown that there are three types of drought seasons: one being when the October to December rainfall is below average, but normal rains falling from January to March; the other is when the October to December period has normal rains but January to March is anomalously dry; the third type is when the whole period from October to March has a rainfall deficit. ENSO is shown to be a reliable predictor of these three types of drought seasons for Zimbabwe. Although numerous other well performing seasonal forecast schemes are in place presently, an ENSO based seasonal forecast (one that is able to pick any one of the three types of drought) is found to have a strong bearing on decision making by the smallholder farmer who can adjust his cropping plans accordingly.

ST-132

A New Analysis on Variability and Predictability of Seasonal Rainfall of Central Southern Africa

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Using wavelet analysis and wavelet based empirical orthogonal function analysis (WEOF) on scale-averaged-wavelet power (SAWP), we classified non-stationary SST fields into spatially coherent regions of the south Atlantic and Indian Oceans that are associated with rainfall variability (in space, time and frequency) in Central Southern Africa (CSA). The Benguela, Brazil and Guinea ocean currents in the south Atlantic, the Agulhas, and south equatorial currents and northern Indian Ocean appears to exert important influence on the rainfall variability of CSA. Persistent warming (increasing wavelet power) of the Benguela current in south Atlantic ocean and Central Indian ocean coupled with persistent cooling (decreasing wavelet power) of the south equatorial current, the Agulhas system in the Indian ocean and the Guinea and Brazil ocean currents in the south Atlantic ocean have been observed to result in prolonged decline of rainfall in Zambia, Malawi and eastern half of Angola (eastern CSA) and above average rainfall in western Angola (western CSA). It has also been found that after 1970 ENSO events were enhanced by the warming of SST in the northern half of Indian Ocean but were suppressed prior to 1970 when SSTs in the northern Indian Ocean were cooler. By driving a non-linear model, the Genetic Algorithm Neural Network (ANN-GA) using SST data of the two oceans delineated by WEOF as predictor fields, we achieved better prediction skill than that of a linear prediction model, the Canonical Correlation Analysis (CCA). We demonstrated the advantage of combining a nonstationary data analysis (WEOF) and a non-linear teleconnection model to achieve high prediction skill of seasonal rainfall at 3-month lead-time.

ST-133

Southern African Climate: Non-ENSO Related Sources of Variability

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The impact of ENSO on the climate of southern Africa (SA) has been well documented. However, although there is potential for predictability of SA climate from ENSO the association is such that (a) ENSO only account for a small proportion of total variance and (b) the correlation exhibits marked decadal variability. This study attempts to quantify sources of SA climate variability independent of ENSO. Using both empirical analysis of observational data (including river discharge in data-sparse Angola) and idealised experiments with the HADAM3 model we quantify the impact of SSTs in key regions of the Southwest Indian Ocean and the tropical East Atlantic on the regional climate of SA.

ST-134

Variability in Recent ENSO Impacts over Southern Africa

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This study investigates the impacts of five recent ENSO events on southern Africa, the associated circulation anomalies and the ability of an atmospheric general circulation model (UKMO HadAM3) to represent these impacts when forced by observed sea surface temperature (SST). It is found that the model is most successful for the 1997/8 El Niño but does less well for the 1991/2 and 2002/3 El Niños and the 1995/6 and 1999/00 La Niña events. Diagnostics from the model, CMAP rainfall observations and NCEP re-analyses suggest that modulations to the Angola low, an important centre of tropical convection over southern Africa during austral summer, are often important for influencing the rainfall impacts of ENSO over subtropical southern Africa. Since the model has difficulty in adequately representing this regional circulation feature and its variability, it has problems in capturing ENSO rainfall impacts over southern Africa. During 1997/8, modulations to the Angola low were weak and Indian Ocean SST forcing strong and the model was relatively successful. The ability of the model to adequately represent modulations to intraseasonal variability over the southern African / tropical Indian Ocean region during ENSO are examined. These modulations impact on the preferred location of convection across this region. The implications for improving the

seasonal forecasting of southern African rainfall variability during ENSO events are discussed.

ST-135

Variability in Central Equatorial African Rainfall at Sub-Monthly Timescales

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The central equatorial African (CEA) region (10S-10N, 10-30E) represents the third largest centre of moist convection globally. However, our understanding of the CEA climate is relatively limited. In contrast to other parts of tropical Africa (notably west Africa) there have been very few studies of the nature of convective rainfall over CEA. This study utilises a recently released record of daily rainfall derived from satellite IR observations (the RGPI) over the period 1983-2001. Results indicate that high frequency rainfall variability (sub-seasonal) is dominated by strong spectral power in the 4-7day band. Using lagged regression with the RGPI and NCEP diagnostics we identify the propagation of tropical wave activity associated with these events.

ST-136

Climate Variability in Central Equatorial Africa: Interannual to Multi-Decadal Timescales

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The central equatorial African (CEA) region (10S-10N, 10-30E) represents the third largest centre of moist convection globally. However, our understanding of the CEA climate is relatively limited, in comparison to other regions. This study presents an analysis of the seasonal CEA climate, based on (a) empirical analysis of long-term observations of rainfall and Congo river discharge over the 20th century (b) idealised GCM experiments using the HADAM3 and HADCM3. Our results indicate that the CEA climate is modulated by (a) tropical ocean-atmosphere interaction involving the Atlantic and Pacific regions, (b) extra-tropical influences. During DJF there is a strong influence of the NAO on CEA at both interannual and multi-annual timescales. The positive phase of the NAO is associated with reduced rainfall over CEA, most likely due to strong mid-troposheric zonal wind anomalies over the region. Observational results indicate that the influence of tropical SSTs (including ENSO) is relatively weak. During the peak SON rainfall season SST anomalies in the tropical east Atlantic drive an east/west dipole in rainfall anomalies across CEA.

ST-137

Wavelet Analysis on Variability, Teleconnectivity and Predictability of East African Rainfall

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Applying wavelet analysis, wavelet based Principal Component Analysis (WLPCA) and wavelet based Independent Component Analysis (WLICA) to individual wavelet scale power and averaged wavelet scale power (SAWP), we objectively identified East Africa (EA) into zones of coherent variability and predictability. We also established links of teleconnectivity between the EA September-November (SON) and March-May (MAM) rainfall and the Indian and the south Atlantic Ocean sea surface temperatures (SST). For SON, except at its western boundary, EA was found to exhibit a single leading mode of spatial and temporal variability. For MAM, southern Uganda and eastern Tanzania was found to be out-of-phase with the rest of EA. Wavelet analysis revealed that (1) EA suffered a consistent decrease of the SON rainfall from 1960 to 1997, (2) EA suffered a consistent decrease of MAM rainfall from 1982-1997, (3) the failure of the MAM rainfall triggered the most severe droughts in EA, (4) the failure of SON rainfall resulted in droughts in Uganda and Kenya, and (5) the SON rainfall is strongly linked to the SW Indian ocean and less strongly to the south Atlantic ocean, while the MAM rainfall is strongly linked to the NW Indian Ocean SST and the Brazil and Guinea ocean currents SST in the south Atlantic ocean. Using predictors identified in the April-May-June season from the Indian and South Atlantic Ocean, the prediction skill achieved for the SON (2-months lead time) and MAM (8-months lead time) seasons by the non-linear, ANN-GA model was excellent but that by the linear, CCA model was modest.

ST-138

Prediction of East African Seasonal Rainfall Using Simplex-Canonical Correlation Analysis

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A linear statistical model, canonical correlation analysis (CCA) was driven by the Simplex optimization algorithm (called CCA-NMS) to predict the standardized seasonal rainfall totals of East Africa at 3-month lead-time using SLP and SST anomaly fields of the Indian and Atlantic Oceans combined together by 24 Simplex optimized weights, and then “reduced” by the principle component analysis. Applying the optimized weights to the predictor fields produced better March-May (MAM) and September-November (SON) seasonal rain forecasts than a direct application of the same, unweighted predictor fields to CCA at both calibration and validation stages. Northeastern Tanzania and south-central Kenya had the best SON prediction results with both validation correlation and Hanssen-Kuipers skill scores exceeding +0.3. The MAM season was better predicted in

the western parts of East Africa. The CCA correlation maps showed that low SON rainfall in East Africa is associated with cold SSTs off the Somali Coast and the Benguela coast, and low MAM rainfall is associated with a buildup of low SSTs in the Indian Ocean adjacent to East Africa and the Gulf of Guinea.

ST-139

Verification of Climate Variability and Change in Nigeria for the Past Five Decades

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In this work, the climate variability and change in Nigeria were investigated using the climate dements of rainfall, Temperature and Relative humidity with the aim of determining whether there has been a change and variation in Nigeria Climate over the half century.

The results showed as steady increase in temperature in which its climatic impact. Could include increased evaporation and reduced water resources. Consquently, warming of the environment steadily continued which led to the decrease in rainfall and Relative humidity respectively.

Meanwhile, rainfall amount declined from a climatic normal or 1439.1mm for the period 1951-1980, to 1357.8 as at 2002. Which revealed that rainfall has dropped by almost 5.6%. However, the atmospheric moisture gradually fell and indicates a drop in relative himidity. the fall in that moisture became pronounced from 1981 to the present time of consideration (2002) except 1991 when it was about average.

There is therefore a cause for concern of the social-economic implication of this climate variation and changes on agriculture and water resources, which are vital tools for sustainable development.

ST-140

The Impact of Soil Moisture Initialization on Seasonal Precipitation in the West African Sahel Using the Regional Spectral Model

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This study provides a preliminary assessment of the impact of soil moisture initialization on model forecasts of seasonal precipitation in the West African Sahel. A key reason for studying this region is that studies have shown that soil moisture impact may be most significant in transition zones such as the Sahel, and may be an important consideration in seasonal forecast of precipitation. Additionally this region has experienced persistent drought since the late 1960s, and changes in soil moisture due to land-use changes may be contributing to this observed change.

Regional Spectral Model implemented at Howard University (HU-RSMCVS) is used to assess the impact of soil moisture initialization on model estimates of seasonal precipitation in the West African Sahel. In the study, simulations are performed to (1) test and validate the model, (2) assess the atmosphere's sensitivity to the fluctuations in soil moisture in this region (land-atmospheric coupling strength) and (3) assess how the atmosphere responds to various soil moisture data used to initialize the model. It will be shown that analysis of these simulations aid in understanding how the soil moisture states in the model affect seasonal precipitation variability in the Sahel and examining possible methods to improving seasonal precipitation forecasts in this region.

ST-141

Sahelian and Brazilian Hydoclimate Variability

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The variability of tropical North Africa climate is dominated by Sahelian climate, which is characterised by ENSO and decadal rhythm. This spectral band is dictated by large-scale east-west Atlantic and Pacific circulations.

Skillful climate variability prediction models in linear modes 12-month ahead are developed that surpass the current operational practice in lead-time and hit rate.

Predicting the tropical climate at a year ahead is attained owing to the memory and stability of the equatorial ocean winds associated with Atlantic Overturning teleconnection to Pacific. It is also found that surface winds in the equatorial oceans have longer memory than tropical sea surface temperatures.

The study contributes to the understanding of climate variability and prediction of tropical Africa towards CLIVAR programme.

ST-142

Developing Regional Climate Model for West Africa

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As part of the contributions of the CLIVAR group to developing Regional Climate Model in Nigeria, this study forms an attempt by the Climate group of the Laboratory of Climatology, University of Lagos (Nigeria) to apply (i) the General Climate Model (GCM) developed by the United States National Centre for Environmental Prediction–National Centre for Atmospheric Research (NCEP – NCAR) and (ii) a Regional Climate Model (RCM) of the Pennsylvania State University fifth–generation mesoscale model (NN5) adapted for West Africa to simulate the climate of the region. The data used for the GCM were obtained from several sources including NCAR, University of Missouri and NOAA, Other data sources include the Geophysical Fluid Dynamics Laboratory (GFDL), the United Kingdom Meteorological Office, the Japanese Meteorological Agency (JMA), the European Centre of Medium Range Weather Forecasts (ECMWF), and the National Aeronautics and Space Administration/Goddard Laboratory for Atmospheres

(NASA/GLA). The sources of data for the Regional Climate Model included NCEP and the United States Geological Survey (USGS). Precipitation and temperature data were collected from the Nigerian Meteorological Agency as well as from higher institutions and research centers in West Africa and Europe for example, the Climate Research Unit, East Anglia University, United Kingdom.

The results of the model application showed that the Regional Climate Model (MM5) performed better than the GCM for simulating the climate of West Africa. In June for example, the GCM computed values generally vary between 80% and 120% of observed values for locations along the coast (latitudes 4oN-8oN) while the computed values of the RCM vary between about 94% and 103% of the observed values for the same locations. In the Middle Belt (latitudes 8oN to 13oN), the accuracy for the models was much less than for the coastal areas with the computed values using the GCM varying between about 22% and 104% while those for the RCM were between 95% and 102% of the observed values. The performance of the two models was worst for the northern locations (latitude 13oN to 18oN) where the GCM did not give any value for low rainfall observed. Results similar to those obtained for June were also obtained for July, August and September with the best results usually obtained along the coast, and the worst results to the north of West Africa. The paper finally discusses the potentials and challenges for the improvement and future applications of the RCM, emphasizing the need for further increasing resolutions and cooperation among scientists.

ST-143

Interseasonal Climate Variability in the Mediterranean Sea Simulated with an AORCM

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In this study a dynamical downscaling in the Mediterranean region has been carried out using a coupled atmosphere-ocean-wave model, named MIAO. The MIAO (Model of Interacting Atmosphere and Ocean) model is composed of three modules, BOLAM (Limited Area atmospheric circulation model) POM (ocean circulation model) and WAM (ocean waves model), that can be coupled to each other. In the Mediterranean region, that is characterized by complex land-sea distribution, steep orography near the coasts, and intense air-sea interactions, the air-sea fluxes show interesting mesoscale features, important for dense water formation processes and Mediterranean cyclogenesis. In order to study the importance of the coupling between atmosphere and ocean, simulations have been carried out in both coupled and uncoupled mode. Results have been analyzed and compared with satellite observations, climatologies and data from the ECMWF reanalysis The differences in the SST, precipitation and air-sea interface fields (air-sea fluxes, air temperature, SWH, etc) between the two simulations are discussed. The coupled simulation results in a much better reproduction of the SST annual cycle, removing a large cooling trend present in

the uncoupled simulation. Over sea, the coupled simulation results in lower precipitation, consistently with the decreased air-sea temperature contrast. Over land the precipitation climate is similar in the coupled and uncoupled simulations. The model seems to underestimate precipitation and evaporation over land, probably because of a too simplified parametriztion of the physical processes of the land-atmospere interface. The use of a more sophisticated soil scheme, describing vegetation evapotranspiration, produces an increase both in precipitation and evaporation, that is anyway not sufficient to compensate for thedifference between model results and observations.

ST-144

Evaluation of the GCM/RCM Seasonal Sensitivity by the Classified Synoptic Systems' Approach

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Evaluation of General/Regional Circulation Models' prediction skills for future requires to first evaluate the models for the past. Consideration of the regionally confined output allows to compare the modeled past climate with well-established real regional climate as reconstructed from the reanalysis.

The daily synoptic classification for the Eastern Mediterranean (EM) region has been used for evaluation of the ECHAM4/OPYC3 modeled EM past climate by comparison with NCEP reanalysis during 1950-2000. The EM synoptic groups are: the autumn/winter Red Sea Troughs (RST), Winter rainy Mediterranean Lows, spring hot and dusty Sharav Lows, summer Persian Troughs, and highs during a year.

It was found that on the average the ECHAM4/OPYC3 model predicts the annual frequencies of occurrence for each synoptic system quite similar to the reanalysis. But, there are some specific features in the seasonal distribution of the EM synoptic systems that are not correctly reflected by the model or missed. Analysis of the daily frequency functions throughout the year yields the following main findings:

The Persian Trough persists over EM in summer (along with the timing of the Asian Monsoon). Its frequency function has been quickly rising since April and fading by October, but locally reducing by nearly 10% during the high summer. The reason for this mid-summer local minimum is the Subtropical High moving to its most northward position and partly replacing the Persian Trough over EM. The model, however, does not depict this process.

The main peak of the RST frequency function is in the fall. This peak shows up in the model on the second half of October instead of first half of November. That means that the model generates the typical EM fall weather, which is characterized by the dry air masses with the significant differences between day and night temperatures, by 2 weeks earlier.

The RST reanalysis frequency function drops during January, while the model one increases. The modeled Winter Lows frequency function has the local minimum instead of increasing trend during January. Both facts mean that in the high winter the modeled EM climate tends to be too dry.

The modeled Sharav Lows have the peak on the first half of May that is about 3 weeks later than the reanalysis one on the middle of April. This means that the model

generates the typical EM spring weather with the dusty and hot desert air masses later by about 3 weeks as compared to observation.

ST-145

Drought Monitoring in I. R. of Iran Using Physical Determination of Drought Indices

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Drought hazard differs from other natural hazards with slow onset, where it is called creeping phenomena. The impacts of drought are non-structural and spread over large areas, where affect many people. There is not any precise universal definition. In order to compare the severity of drought in different regions, it is necessary to apply drought indices which uses physical parameters to monitor drought. Severe drought over the past five years (1999-2003), in combination with the effects of protracted socio-political disruption has led to widespread famine affecting over60 million people in central and southwest (CSW) Asia which includes I. R. of Iran. In order to drought risk management, in this research the monitoring of drought using different indices, such as Standardized Precipitation Index (SPI), Palmer Drought Severity Index (PDSI), Percentage of Normal (PN), and Normalized Difference Vegetation Index (NDVI) have been carried out over Iran. The SPI values have been computed for 115 meteorological synoptic stations of I. R. of Iran Meteorological Organization (IRIMO) network for 1-, 3-, 6-, 12-, 24-, 48-, and 72- months scales, covering 1960-2003. The result of SPI patterns shows that the 3-month scale drought frequency increases but it's duration decreases. On the other hand, as the time scale increases, the index responds more slowly. The drought monitoring using PDSI, as well as field measurement of the soil moisture in 10 agro-meteorological stations, in north-east of Iran are carried out. There is a good agreement between the soil moisture situation and derived PDSI over the selected area. Besides, the NDVI spatial distribution has been derived over I. R. of Iran from AVHRR sensor of NOAA satellite images in order of drought monitoring from 1998-2002. The results of this research are going to be used as operational drought monitoring system in this country.

ST-146

Fluctuation of Climatic Parameters in I. R. of Iran

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In recent years, sustainable development has become on of the main issues in strategic planning of the most countries. Natural climate variability, including that associated with ElNino events, gives rise to hydrological extremes, in particular floods and drought. Human induced climate change is expected to lead to an intensification of the hydrological cycle causing a higher frequency and severity of the climatic hazards. Evaluation of climatic factors trend, such as temperature, precipitation, humidity and pressure are one of the most important techniques to detect the climate change in any region. This paper examines climatic parameters (minimum, maximum, and mean surface temperature, precipitation, relative humidity and surface pressure) annual and seasonal variability and trend over I. R. of Iran during the last 50 years (1950-2000), based on the data from I. R. of Iran Meteorological Organization (IRIMO) networks. The results of the research show that most weather stations in north-west and central parts of the country have experienced a warming trend and decreasing a annual precipitation, where cooling trend were detected for north-east and south-east of the Iran. Besides, since the variation in seasonal pressure patterns can change amount of the precipitation of the region, the surface pressure patterns of the country has been also studied. The results show that different parts of Iran experience various synoptic systems such as Siberian high pressure, Monsoon low pressure, Mediterranean low pressure, and Sudan low Pressure during different seasons. Based on this research, the northeastern-southwestern pressure gradient increases the amount of precipitation, while the strong high pressure over Ghazaghestan area and Indian Ocean would decrease rainfall over I. R. of Iran.

ST-147

Seasonal Prediction over I. R. of Iran in Order to Drought Risk Management

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Drought is a silent and vulnerable event which in recent years, severe drought has been occurred in period of 1999-2002 in most regions of I. R. of Iran. The drought has caused significant impacts in agriculture and frosty and resulted in depleted lakes, increased ground water pumping and environmental impact was significant, particularly the tremendous increase in soil erosion and effects on indigenous plant and wildlife population. In order to approach drought risk management, drought monitoring and prediction are necessary as the components of early warning. In this regard, seasonal prediction in this country has been studied and this paper will discuses the results of the research. The distribution and magnitude of the precipitation and temperature would be predicted from one to 6 months using the European Center Mesoscale Weather Forecast (ECMWF) products, such as seasonal prediction of pressure pattern at the surface, prediction of temperature at the tropical regions and also prediction of North Atlantic Oscillation (NAO) and ENSO index issued at global meteorology center. The

temporal and spatial analysis of precipitation in different regions of Iran shows some good correlation between precipitation anomaly and NAO and ENSO indexes. Based on the results of this research the precipitation over the most regions of the country, except south parts, in spring 2004 is around normal.

ST-148

Influence of North Sea-Caspian Pattern (NCP), an Atmospheric Teleconnection, on the Surface Fluxes over the Mediterranean Sea

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This study is intended to examine the influence of North Sea Caspian Pattern (NCP), recently proposed upper layer atmospheric circulation defined by the averaged difference of 500 hPA geopotential height between the two poles centered over the North Sea and Northern Caspian Sea, on the air-sea surface fluxes of the Mediterranean Sea. It was shown that NCP have effect on air-sea flux components namely, momentum flux (wind stress), heat flux (net heat flux) and water flux (evaporation and precipitation) over the Mediterranean Sea based on ECMWF-ERA40 Re-Analysis (1958-2001) data sets.

In order to show any large scale controls in the studied marine regions, correlations of surface atmospheric variables and sea surface temperature (SST) were seeked with various climate indices. In the beginning, the analyses were based on monthly time series, which did not produce significant correlations. Repeating the analyses with seasonal averages of the variables yielded higher correlations especially in winter when the weather systems in the studied latitudes are more active. For further analysis Empirical Orthogonal Function (EOF) analyses are also applied to identify relationships between dominant spatial and temporal patterns in individual marine basins and climate indices.

Among the investigated climate indices, a remarkable correlation was identified between surface variables in the Eastern Mediterranean-Aegean-Black Sea regions and especially the North Sea - Caspian Pattern (NCP) introduced by Kutiel.

ST-149

Inter-Annual Variability of Rainfall and Vegetation Index and Their Effect on Crop Yield Prediction over Indian Sub-Continent

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Monsoon rainfall distribution over Indian sub-continent is inconsistent every year. The agriculture in India is very much dependent on Indian monsoon. Due to uncertainty of monsoon onset, prediction of crop yield is not reliable. India being a major producer of food grains (wheat and rice) a detailed statistical time series analysis of rainfall distribution, NDVI (Normalized Difference Vegetation Index) and other associated parameters have been carried out for the period 1984-1999. Spatial and temporal variations in rainfall over Indian sub-continent have been studied for last century. Decade wise analyses of change in rainfall distribution have been carried out for whole Indian region in GIS (Geographic Information System) environment. Rainfall distribution inconsistency due to Monsoon rainfall is also analyzed for the period 1984 - 1999. Results show a distinct dynamic variation. Statistical time series of NDVI pattern and population growth for the periods 1984 - 1999 show essentially non-linear trend. Population growth shows adverse effect on NDVI and rainfall distribution, which are more apparent in northwestern India. Increase in desertification and drought is a prominent effect. Change in wheat and crop yield conform to the variations in rainfall distribution for period 1984 - 1999.

Wheat is a major crop of Rabi cropping season (October to April) and that of Kharif season (May to October) is rice. Crop yield, NDVI, soil moisture, surface temperature and rainfall data of 16 years (1984 – 2000) have been used. Non-linear multivariate optimization approaches have been used to derive empirical crop yield prediction equation. Quasi-Newton methods have been used for multivariate optimization. It is a non-linear method used to minimize least square loss function through iterative convergence of pre-defined empirical equation. Empirical equation is based on Piecewise linear regression method with break point. A non-linear optimization approach achieves acceptable lower residual values with predicted values very close to observed values with R square value greater than 0.90.

Forecasting of rainfall distribution for coming decade have been carried out based on historical data on rainfall and NDVI trend. A crop yield prediction equation have been obtained for each state for both wheat and rice separately that takes into account more than 90% of variance in data set. It can be used to predict any shortfall in crop production due to climate effect based on data from pre harvesting months. Such empirical prediction equations are useful for local planners and governmental agencies for taking remedial measures.

ST-150

Rainfall Variability in Indian Himalaya

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Variability in climatic conditions and climate change are seen in the geological climate record with large fluctuations in global and regional climates over the past million years. The climatic data has been procured for mainly the rainfall and temperature conditions during the time period 1964 to 1992 for Bhuntar and Manali stations in the Himalayan region. The monthly rainfall conditions have been analysed by plotting the total rainfall in a month over the years and the heaviest rainfall in a day. The monthly analysis of rainfall do not show any constant increasing or decreasing trend for both the

stations except for a few months. During December there is a sharp increasing trend in the total rainfall in both stations. Some of the notable features of the rainfall data are that there is a decreasing trend in the total rainfall in the main monsoon months of July and August. On the other hand during winters there is an increasing trend in the total rainfall in December, February and March. Rainfall is variable over the years in different months with abnormally heavy rainfall taking place on a single day in some of the years. Bhuntar station has recorded the maximum total rainfall in 1974 when it was 35.6 mm. The monsoon rainfalls in both stations indicate a decline. The annual total rainfall curves of both stations show an overall-increasing trend. On the whole there is a decreasing trend in the monsoon rainfall, which is accompanied, by a slight increasing trend in temperatures. The winter rainfall on the other hand shows an increasing trend accompanied by slightly increasing trend in temperatures during December to March thus compensating for decreased monsoon rains. The overall similarity of rainfall variation trend at Manali and Bhuntar indicates that climate trends are determined more by global or regional factor rather than local factor.

Keywords: Rainfall variability, Indian Himalaya, mountain meteorology, climate change, monsoon.

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Variability of Monsoon Rainfall and Its Inter-Station Correlation in Bangladesh

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Inter-annual variability of the rainfall for the monsoon months of June through September as well as the seasonal country averaged rainfall along with the linear trends has been studied. The study reveals that the country-averaged rainfall in Bangladesh has a slight decreasing trend in June and increasing trends in the months of July, August and September. The trends for these months are –0.8308 mm/year, 1.3934 mm/year, 0.9574 mm/year and 2.7738 mm/year respectively. The seasonal rainfall over the country has also increasing trend at 4.2939 mm/year. These rates are not statistically insignificant. 3-year moving average curves have been used to see the cycle of variation of monthly rainfall. It has been found that the country-averaged monthly rainfall shows a cycle of variation of about 7-12 years and sometimes 3-5 years during the monsoon seasons. Similarly, polynomial curves of sixth degree have used to see the long-term cycle of variation of the seasonal rainfall in Bangladesh, which shows 12-16 years cycles of variation.

Linear correlations of the monthly and seasonal rainfall at six divisions such as Dhaka, Chittagong, Barisal, Khulna, Rajshahi and Sylhet with the rainfall of other stations have been studied and the corresponding correlation co-efficients have been computed. Most of the correlation co-efficients are statistically significant. The correlation co-efficients have been found to decrease exponentially with the distance in almost all the cases. The regression equations corresponding relatively higher significant

correlation co-efficients have been obtained. These equations will be useful for the computation of missing data.

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Variability Monsoon Onset over the Indonesian Maritime Continent

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The weather and climate of the maritime continent is dominated by the seasonal cycle and by the seasonal shift, from one side of the equator to the other, of tropical heating. This seasonal shift mechanism has been interpreted as a monsoonal (seasonal) mechanism that are invariably described in terms of the wet monsoon or the dry monsoon with their onsets have, traditionally, been defined using in situ rainfall criteria. As such there is a strong variation across the region with the wet monsoon onset in the western and equatorial part preceding the southeastern onset by several months.

This study examines time-longitude sections of Out Going Longwave Radiation (OLR) over various longitudes within the region. Inspection of the data reveals two preferential states for Inter Tropical Convergence Zone (ITCZ) convection, described respectively as the southern summer and northern summer states. Monsoon onset is defined as the sudden transition of the ITCZ from a Northern Hemisphere location to a Southern Hemisphere, and conversely at the opposite season. By using this definition, a clear onset occurs over the entire region for the northern monsoon onset in April-May. Meanwhile, a clear sudden southern onset occurs also, but only over a much more restricted range of longitudes, especially near eastern Indonesia and northern Australia.

A sine-wave seasonal structure OLR and zonal wind-component in the anti-symmetric component with respect to the equator to define monsoonal structure is utilised as well. Using this model, a well-defined monsoon is seen to exist over the entire region with the seasonal cycles of anti-symmetric low-level wind and of OLR being in phase.

Composites study for both monsoon definitions have been carried out for ENSO and normal years. Concerning timing of onset the southern onset is strongly influenced by ENSO with a much later onset in the warm-event phase. The timing of the northern onset seems to be little affected, however, by ENSO. In terms of the seasonal monsoon structure, due to suppression of the convection on the winter hemisphere side of the equator, the monsoon strength is actually enhanced in an El Nino.

Algorithms have been tried to be invented to objectively or quantitatively define the two transitions. Thus they can be related to other definitions of onset.

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Dynamics of 'Internal' Interannual Variability of the Indian Summer Monsoon in a GCM

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The interannual variability (IAV) of the tropical climate is partially driven by anomalous boundary conditions as well as by the internal low frequency feedbacks within the system. As the internal IAV is less predictable, predictability of the system depends on the relative contributions of these two components, that are difficult to separate. Predictability studies of the Indian summer monsoon indicate that at least 50% of IAV of the Indian monsoon is of internal origin. However, mechanisms responsible for the internal IAV of the monsoon have not been clearly identified. Here, using a general circulation model (GCM) driven by fixed annual cycle boundary forcing, the internal variability of the Indian summer monsoon is simulated and compared with the observed interannual variability of the seasonal (June-September) mean. It is shown that the internal interannual variability of the summer monsoon simulated by the model is comparable in amplitude and similar in spatial structure to those in observations. An attempt has been made to determine the causes of these internal interannual variability. The hypothesis that the monsoon intraseasonal oscillations (ISO) are responsible for the IAV, is tested in this study. The spatial and temporal characteristics of simulated intraseasonal variability are examined and are in good agreement to those observed. The spatial patterns of ISOs and IAV are found to be similar and it is shown that higher frequency of occurrance of active (break) phase of ISOs gives rise to strong(weak) monsoons. This hypothesis is confirmed by a thorough examination of the anomalies of seasonal mean and the seasonal mean of intraseasonal anomalies. It is concluded that the internal IAV of the Indian summer monsoon is governed primarily by projection of ISOs on the IAV mode. However, this contribution explains only about 50% of the simulated IAV, implying that the nonlinear processes, such as the soil moisture feedback, also play an equally important role in amplifying the internal interannual variations of the Indian summer monsoon driven by the monsoon ISOs.

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Variations of the U.S. and China Precipitation: Regional Manifestations of Large-Scale Patterns of Climate Variability

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Previous studies have shown that tropical North America and East Asia are both "classical monsoon" regions and that there exists a possible climate link between the regions in various seasons on intraseasonal-to-interannual time scales. We have analyzed the Climatic Research Unit precipitation, NCEP/NCAR reanalysis, and other data sets to reveal the difference, similarity, and connective relationship between the U.S. and China precipitation.

While the U.S. precipitation has larger annual total and long-term variability, the China precipitation has a much stronger seasonal cycle. In both U.S. and China, the largest seasonality occurs to the northern flank of monsoon regions. This study confirms the relationship between the U.S. and China precipitation and the large-scale patterns of natural variability especially those associated with El Niño-Southern Oscillation. It emphasizes the importance of Pacific Decadal Oscillation for the U.S. and China climate, especially in fall, and shows that the variability of China precipitation is more closely related to the Artic Oscillation than previously expected.

This study also emphasizes the mutual impact of multiple climate phenomena on the variability of U.S. and China precipitation. It demonstrates that appropriately-constructed indices combining multiple impact factors improve our dynamical understanding of precipitation variability and the skill of precipitation prediction.

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The Basic Characteristics of Surface Heating Field of Spring Sand-dust Storms in North-west China

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Using reanalysis grid data of NCEP/NCAR of global monthly average(1958-2000),the comparative analysis of discrepancy was done between the typical and non-typical sand-dust storms years in spring about sensible heat flux and latent heat flux in north-west China, and the relationship of sand-dust storms with sensible heat flux and latent heat flux was found. The results showed that before and at the period of sand-dust storms occurrence, the upstream area was a heat sink area, namely a area of energy convergence, whereas the sand-dust storms area (except the eastern area of it) was a heat source area, namely a area of energy release. The three regions, which were located the juncture of north Mongolia and south-west Baikal Lake, the area of north Xinjiang and near west Mongolia, and the area between Balkash Lake and north Taklimakan Desert, and the east of north-west China were the key regions to affected the sand-dust storms occurrence. In the key regions, before and at the period of sand-dust storms occurrence, in the three areas mentioned above, the distribution of the discrepancy field (typical sand-dust storms years subtracted non-typical years) of the average sensible heat flux, latent heat flux was alike. But in the eastern area of north-west China, the distribution of the discrepancy field was in opposition.

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Cross-Equatorial Progression of ENSO Signal in Southeast Asia Rainfall Anomalies

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We investigate the evolution of ENSO related variability in the Southeast Asia (SEA) anomalous rainfall. We use the high resolution (0.5°˙0.5°) monthly precipitation data that span a period of 49 years from Jan 1951 to December 1999, compiled by the University of Delaware. The sea surface temperature (SST) data is version 1.1 of Hadley Centre Global Ice and Sea Surface Temperature (HADiSST1) obtained from the United Kingdom Meteorological Office (UKMO). Other datasets including outgoing long radiation (OLR) and 850mb winds (UV850) are obtained from the National Center Environmental Prediction (NCEP). We employ several empirical analyses including correlation analysis, the composite analysis and the extended empirical orthogonal function analysis (EEOF). Based on the EEOF analysis, we find that the ENSO related variability in the SEA anoamlous rainfall tends to evolve northward across the equator from the developing to the decaying stage of an ENSO event. Rainfall in the region south of equator exhibits strong relationship with ENSO during the boreal summer and autumn when region north of the equator has no significant relationship with ENSO. During the boreal winter and subsequent spring, the ENSO influence is considerably strong in the region north of the equator while the region south of the equator exhibits weaker or no relationship. The ENSO seasonal composite of OLR also show consistent result. We perform the same analysis on the anomalous SST and found that the most dominant EEOF mode of SST evolution is correlated well (r=0.86) with that of the SEA anomalous rainfall. The spatial patterns of the SST EEOF indicate that the seasonal variability associated with the SEA anomalous rainfall is dominated by the variability associated with the strengthening and weakening of the “boomerang shaped” SST in the Pacific Ocean and the emergence and disappearence of anomalous SST in the Indian Ocean and reagional seas surrounding the region. By correlating SST changes with the anomalous wind, we find that the SST and SEA anoamlous rainfall evolutions are related to the existence of two anomalous anticyclonic/cyclonic circulations which dominate the eastern Indian and north western Pacific during the two opposite monsoon regimes in the region. We postulate that the two anomalous anticyclonic/cyclonic circulations in the eastern Indian Ocean and north western Pacific Ocean play an important role in the cross-equatorial evolution of the ENSO related variability in the SEA anomalous rainfall. Such understanding would presumably lead to better seasonal-to-interannual prediction of SEA anomalous rainfall.

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The Use of Large-Scale Climate Information to Predict Central Asia River Flows at One and Two Season Leads

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River flows in Central Asia are largely determined by snow melt, with peak flows occurring in spring and summer as the snow pack in the high mountains melts. Accurate knowledge of the snow pack present at the end of winter, therefore, would give a significant amount of advance information about the magnitude of river flows. These river flows are of considerable importance, as they are critical to both agriculture and water resources in the region. Unfortunately, accurate, high-resolution estimates of snow pack are difficult to obtain. Previous research, however, has suggested both that local winter precipitation can serve as a useful proxy for snow pack, and that the local precipitation is influenced by large-scale, potentially predictable climate variability. Here we use 35 years of river flow data for 25 stations in Central Asia to determine the potential to predict the average spring and summer river flow from large-scale climate information in the preceding autumn and winter.

Canonical Correlation Analysis (CCA) is used to extract the relationships between the predictor (e.g., Nov-Mar precipitation) and predictand (e.g, Apr-Aug river flow), with Empirical Orthogonal Function (EOF) filtering applied to the data prior to the CCA. A clear relationship between gridded regional winter precipitation and spring/summer river flows is obtained, with correlations exceeding 0.6 for several of the stations. This relationship can also be obtained using the NCEP/NCAR Climate Data Assimilation System (CDAS) precipitation, which is operationally available. The CCA results are regressed to large-scale winds and Sea Surface Temperature (SST) anomalies, to examine the relationship to large-scale climate variability. The regressed winds show changes in the intensity of the westerly flow that impinges on the mountains of the region, consistent with the anomalies in precipitation. These changes in regional winds and precipitation are associated with SST anomalies in the equatorial Pacific Ocean. The SST anomalies are similar to the El Nino pattern, but with greater strength in the central Pacific relative to the eastern Pacific--an SST pattern previously shown to affect the region. The potential to use this Pacific SST linkage to make river flow forecasts at a two season lead is examined.

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A Numerical Prediction Test of Monthly Precipitation on East-Asia with the Indian Ocean SST Data

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During the ENSO event period, the Indian Ocean SST will be anomalous almost simulataneously. Some research results indicate that the Indian Ocean SSTA would mainly influence the climates of Bengal, Indo-China, Indonesia, India and China, the Indian Ocean. SSTA is important to Asian climate especially to the anomalous

precipitation pattern of China. Based on the IAP-GCM2L model developed in the Institute of Atmospheric Physics, Chinese Academy of Sciences, and used the SST data of Indian Ocean and median Pacific Ocean during 1~6,1999 and 2000 in the model, the prediction monthly precipitation of east-Asia region were obtained in this paper. The results indicate that the SSTA of the Indian Ocean and the median Pacific Ocean would mainly influence the atmospheric circulation and the precipitation of east-Asia region, the prediction monthly precipitation of the numerical simulation are effective in mostly region of east-Asia, especially in southwest China and south China.

ST-159

Inter-Annual Climate Forecasting in China

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China is a country with frequent disasters caused by climate anomalies. The inter-seasonal and inter-annual forecasting are useful to mitigate the damages. Institute of Atmospheric Physics in Beijing has a history of almost two decades to study the climate forecasting on this time scale. Currently we are limited by our understanding on the atmospheric motion and also restricted by the resolution and physical processes of the numerical models, so currently the forecasting is done by combining numerical models and statistic method.

We analyze the key regions and key physical processes which affect the climatic anomalies and reveal the impact of different phases of ENSO on the summer and winter monsoons in China. We pin down the physical factors which cause the climate anomalies in China such as the dual static modes in Tibet plateau and so on. We analyze these precursor signals systematically, conduct short-term climate historical hindcasting and the forecasting experiments, and establish complete forecasting resources. From the precursor signals we select three to four factors which are relatively independent and stable, and build a short-term forecasting statistic model.

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A Fundamental Problem in Climate Simulation and Prediction of Summer Monsoon Precipitation

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We show that the eleven-atmospheric general circulation model (GCM) ensemble simulations forced by observed sea surface temperature (SST) yield unexpected negative skills in simulating seasonal mean rainfall over the Southeast Asia and western North Pacific summer monsoon convergence zones (MCZ). We found that this fundamental problem is related to the models' failure in simulating the local rainfall-SST relationship: The observed summer mean rainfall anomalies are negatively correlated with local SST anomalies, whereas in the models, they show significant positive correlations.

Over the summer MCZ, the observed negative SST-rainfall correlation considerably strengthens when rainfall leads SST by one month, whereas it decreases as rainfall lags SST. This suggests the atmosphere playing an active role in regulating local SSTs. Seven coupled GCMs that participating DEMETER project are able to realistically produce the negative rainfall-SST relationship over the summer MCZ as observed. However, the AGCMs, when forced by the daily SST generated by its coupled version, yields a positive rainfall-SST correlation over the MCZ, indicating that in the forced GCM simulation, the SST anomalies determine the atmospheric response. It is concluded that AGCM-alone simulations have neglected the important feedback from the atmosphere to ocean, hence encountering a fundamental problem in simulation of heavy monsoon rainfall.

Our results suggest that the atmosphere-warm ocean interaction may be critical for realistic modeling summer monsoon rainfall. Thus, assessment of performance of an atmospheric GCM based on its stand-alone simulation is inadequate, and making seasonal prediction based on atmospheric models driven by separately forecasted SST (the two-tier approach) might have fundamental difficulty in prediction of the major summer monsoon rainfall anomalies.

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Seasonal Prediction Experiments with RegCM_NCC in China National Climate Center

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The seasonal prediction experiments by using the improved regional climate model of China National Climate Center (noted as RegCM_NCC) have been presented in this paper. The RegCM_NCC has been developed by modifying/planting some improved schemes of various processes on the basis of the NCAR/RegCM2.

By nesting with the global coupled T63 model (noted as CGCM_NCC), the 10-year (1991-2000) hindcasts and 3-year (2001-2003) seasonal prediction experiments for the flooding season in China have been made with the RegCM_NCC. The primary results have shown that the model can capture the main rain-belt position for summer 2001, 2002 and 2003. In particular, the RegCM_NCC has successfully forecasted the abnormal precipitation over the regions between the Yellow River and Yangtze River

Valley during the summer of 2003. Additionally, the prediction for the winter season has also been made from last year.

By comparing with the global model results and the observations, the model hindcasts show a certain capability to reproduce the rain-belt pattern of China in summer. The analysis of the precipitation anomaly correlation between the hindcast and observation has indicated that the best regions include the north China and the Northeast China. Compared with the CGCM nested with the RegCM_NCC, the obvious improvement is the forecast over the Yangtze River Valley. And overall, the correlation coefficient of precipitation is higher than that of temperature in both summer and winter season prediction.

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Significant Progress of Researches and Practice in Seasonal Climate Prediction through 40 Recent Years

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Present paper summarizes the course and main progress of the author's researches and practice in seasonal climate predictions through 40 recent years. In 1960's, the author suggested and made seasonal prediction (SP) by using the seasonal teleconnections between preceding characteristics of atmospheric circulation in extratropical/tropical zones and the summer rainy trend of Yangtze/Huaihe Basins. In early 1980's, this method was improved by an analogues method to consider the combined influences of preceding physical causes, such as the influences of preceding ENSO, volcanic eruptions, solar activity and anthropogenic dusts. Good scores had been obtained in SPs on summer drought/flooding trend predictions of the mid- lower Yangtze Basins during the 20 years of 1968- 1987. In following years, although the author had obtained large success in correctly predicting the large summer floods of 1991, 1993 and 1995, some failures occurred with increasing difficulty due to the rising trend of global climate abnormalities. A physical- statistical method for variable factors of short- term climate system (Xu & Yang, 1997) has been formed in late 1995. The factors are selected from a series of high correlation regions of 4 monthly climate fields for January-March preceding the summer monsoon. The process for selecting the factors and predictands was described in June 1997 of Experimental Long-Lead Forecast Bulletin (NOAA). Except skillful hindcasts, very significant statistical result (at 0.001 level) has been achieved, skill scores have reached to 0.40- 0.47 for summer regional SP of central-east China during 8 recent years (1996-2003) through verifications between the forecasted and observed predictands with both categorized in terms of 3 terciles. The case ratio of serious failure has been significantly reduced from 4/20 (1968-1987 year) and 3/8 (1988- 1995 year) to present 1/8 (1996- 2003 year). Except year 2000, most summer climate abnormalities of central-east China of other 7 years have been correctly predicted with a series of documentary proofs, which manifest that this method of SP is worthy of the applications to more regions of our world. The author thinks that the best way for developing SP would be an effective combination among physical analysis, statistics and dynamical model.

Downscaling of Daily Rainfall Occurrence over Northeast Brazil Using a Hidden Markov Model: How Predictable is Weather-Within-Climate?

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As part of the endeavor to produce seasonal climate forecasts that are useful in societal decision-making, an important task is to understand, on a regional basis, just what aspects of the "weather-within-climate" are predictable a season or more in advance. To help address this question, we construct a hidden Markov model (HMM) to examine relationships between daily rainfall at ten gauge stations in northeast Brazil, and modes of sub-seasonal atmospheric and interannual climate variability, for the February-April wet season 1975-2002. Thus, we assume the daily rainfall occurrence is governed by a few discrete states, with Markovian daily transitions between them. Four rainfall states are identified. The estimated daily state-sequence is characterized by a systematic seasonal evolution, together with considerable variability on intraseasonal, interannual and longer time scales. One pair of the states represents wet vs. dry conditions at all stations, while a second pair of states represents north-south gradients in rainfall occurrence. The first pair is shown to be associated with large-scale displacements of the tropical convergence zones, and with teleconnections typical of the El Nino-Southern Oscillation and the North Atlantic Oscillation. A trend toward greater rainfall occurrence in the north of the region compared to the south since the 1980s is identified with the second pair of states.

A non-homogeneous HMM (NHMM) is then used to downscale daily precipitation occurrence general circulation model (GCM) simulations of seasonal-mean large-scale precipitation, obtained with historical sea surface temperatures prescribed globally. Interannual variability of the GCM's large-scale precipitation simulation is well correlated with seasonal- and spatial-averaged station rainfall-occurrence data. Simulations from the NHMM are found to be able to reproduce this relationship. The GCM-NHMM simulations are also able to capture quite well interannual changes in daily rainfall occurrence and 10-day dry spell frequencies at some individual stations. It is suggested that the NHMM provides a useful tool (a) to understand the statistics of daily rainfall occurrence at the station level in terms of large-scale atmospheric patterns, and (b) to produce station-scale daily rainfall sequence scenarios for input into crop models etc.

Interseasonal Variations of Low and Middle Troposphere Flows Associated with Precipitation East of the Andes

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A purpose of this work is to study interseasonal fluctuations of low- and middle-level circulations and their anomalies in relation to precipitation occurrence in central-northern Argentina. The seasonal cycle of anomalous flows occurring when light and/or heavy precipitaion takes place is analyzed through diagnostic studies of daily 1000-hPa and 500-hPa analyses from ECMWF in order to explore the climatological signal of the interseasonal variations surrounding the Andes mountain range.

Daily precipitation data at stations in the Argentine Chaco region: Las Lomitas (24º42'S, 60º35'W), Santiago del Estero (27º46'S, 64º18'W) and Resistencia (27º27'S, 59º03'W) are used as well as ECMWF daily 500 mb and 1000 mb analyses at 1200 z.
The synoptic-climatological approach used to study the governing dynamical controls of geopotential height and thickness fields on precipitation and monsoonal circulation associated is that suggested by Yarnal (1993): environment-to-circulation. The biserial correlation-based map technique is employed to provide classification schemes that show anomaly fields of a variable in relation to rainfall.

Anomaly patterns of low- and middle-level atmospheric flow in relation to precipitation are clearly defined. An anomalously low geopotential height center located over the continent but strongly depending on the station studied and two anomalously high centers over the adjacent Pacific and Atlantic Oceans are observed. The positive Pacific anomaly appears to be more significant, excepting for Resistencia for which the Atlantic anomaly becomes more important. A sort of high-low-high configuration may be seen in the lower troposphere. This evidences an anomalous geostrophic low-level flow component southwards to the east of the station, assuming the form of a low-level jet, and an important anomalous geostrophic low-level flow component northwards to the west in connection to rainfall. Anomalously high height centers increase markedly during the warm season.

At higher levels, the patterns of anomaly thickness fields associated with precipitation are clearly identified for central northern Argentina stations during all year round, possibly indicating a mode of variability of the climate system. Anomalous NW-SE thermal wind associated with precipitation in the surroundings of the sites studied reveals as a strongly well-marked characteristic of circulation.

This general behaviour is observed in both cold and warm seasons, though certain features characterize the interseasonal fluctuations such as magnitude and geographical location of the significant correlation coefficient centers, which favour the occurrence of precipitation. Notwithstanding, each single locality exhibits a particularly different anomaly pattern whose structure in some extent defines the precipitation zones, mainly the position and shift of the anomalous low center. Interseasonal variations show that low geopotential height anomalies the middle troposphere reinforce in summer while high anomalies are more significant in winter. These results bring about the influence of dynamical mechanisms involved in producing precipitation all year round.

It is emphasized the particular response features of each one of the stations connected to precipitation and the geographic variability of the anomaly patterns. On the other hand, anomaly thickness patterns associated with precipitation in central northern Argentina stations still remain all over the year . Through this point of view, there seems not to be a marked difference between summer and winter circulations in connexion with precipitation occurrence. Then, in this view a moonsonal effect over central northern Argentina tropospheric circulation in relation to rainfall is not evident enough.

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Interannual Variability of January Precipitation over Southern South America Simulated by a Regional Climate Model

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We assess the performance of a regional model to represent the interannual variability of January precipitation over southern South America. To this end, an ensemble of month-long simulations (January of the 6 years 1996-2001) driven by assimilated lateral boundary conditions and sea surface temperatures from the NCEP reanalysis were conducted. This period is large enough to represent a broad range of climatic conditions including normal, La Niña and El Niño years. We use the Fifth-generation Penn State/NCAR Mesoscale Model (MM5), version 3.5, coupled with the Oregon State University/NCEP Eta Land-Surface Model. Overall, the model shows a reasonably good performance in simulating various characteristics of the regional climatology during these period.

All the main mean precipitation patterns are captured by the model. Precipitation over Brazil, Paraguay and northern Argentina is particularly very well reproduced. In opposition, precipitation amounts are underestimated over Uruguay and central-eastern Argentina and overestimated over elevated terrain. The errors over central Argentina and Uruguay are probably related to an over enhanced South Atlantic Convergence Zone, but we also found large sensitivity to model settings of cumulus parameterization and land surface representation.

Results are encouraging since the model captures the large-scale circulation changes between the different years and in general successfully translates this variability into precipitation changes. The magnitude and geographical distribution of the interannual variability of monthly precipitation, in terms of percentage standard deviation, appear generally reasonable. In particular, the model nicely captures the maximum of the percentage interannual standard deviation over northeastern Argentina. However, the model skill to reproduce the year-to-year variability in January absolute precipitation amounts for different sub-regions varies a great deal between the sub-regions considered. The simulated diurnal cycle of precipitation is also analyzed. The diurnal cycle of the simulated convective precipitation presents a nocturnal maximum over northeastern Argentina.

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Variability of the Contamination Index in the Metropolitan Zone of Guadalajara (ZMG) during 2003

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The levels of polluting agents are a good indicator of the quality of the air and are used for the prevention of programs of environmental contingency in the great large cities like the city of Mexico, Guadalajara, and Monterrey. The located urban zones in valleys (as it is it the case of the ZMG), present/display a low dispersion of polluting agents which is translated in a exhibition to factors of risk of respiratory diseases, mainly at the winter time where the thermal investments have a space of time and prolonged thickness but.

The indices of quality of the air are evaluated based on the concentration of the polluting agents certain CO, NOx, NO2, SO2, PM10 and O3 during an area and times. The objective of this work is to evaluate the evolution of the contamination during triennium 2000-2003 in the ZMG. The concentrations of polluting agents were acquired through the automatic network of atmospheric monitoring (RAMA for the abbreviations in Spanish) operated by the Secretary of the Environment and Sustainable Development (SEMADES) of the Government of the State of Jalisco, which monitors the polluting agents every 10 min in 8 stations located strategically in the ZMG.

The annual results average during period 2000-2003 show that 125 (34%) of the 365 monitoring days exceed the Mexican standards for the emission of polluting agents. April, May and June present high concentrations of secondary polluting agents like the ozone that is been from the reaction of primary polluting agents (NOx and NO2) that react with the solar radiation, whereas the months of December, January, February and March it presents high concentrations of primary polluting agents, result of low temperatures that prolong the times of duration of the thermal investments, which does not allow the dispersion of these polluting agents

The results demonstrate that in the ZMG a great variability in the dispersion of polluting agents exists during triennium 2000-2003. This variability depends mainly on the own atmospheric dynamics of the zone.

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The Influence of Cold Air Intrusion on the Wet Season Onset over Tropical South

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The onset of monsoon rains is usually triggered by the intraseasonal variation of the atmospheric circulation. Using 15-year ERA data, the impact of the cold air from mid-latitude on the wet season onset over tropical South America is studied. Our results suggest that during the transition period of October-November, enhanced precipitation due to cold air penetration is found in the western Amazon and SACZ, where precipitation decreases are mainly confined to the subtropics. This spatial pattern of enhanced precipitation and the 5-12 days temporal scale of cold surges over South America suggest that cold air intrusions may trigger wet season onset and cause the rapid, southeastward expansion of the rainy area from the western Amazon to southeastern Brazil during the transition.

Comparisons among an early onset year 1979, a normal onset year 1983 and a relatively late onset year 1982 suggest that the triggering impact of cold air incursions is sometimes critical for determining when the onset happens. During the transition period of the early onset years, local land surface and atmospheric conditions are already destabilized for deep convection at early stages, but the triggering mechanism appears to be necessary for the release of potential energy, intense moisture convergence and enhanced deep convection that lead to wet season onset. On the contrary, without the triggering influence of frequent and sufficiently strong cold surges, the wet season onset of 1982 is about 30 days later than the climatology even though the land surface and large-scale conditions were favorable for early onset. The cold air intrusion immediately preceding wet season onset in 1983 appears to trigger a normal onset date (pentad 60th) even though the land surface and atmospheric conditions are more unfavorable to early onset than in 1982.

El Niño years tend to exhibit a northward shift and higher intensity in the subtropical jet stream over South America. The abnormal strength and position of the subtropical jet stream, such as in 1982, tends to block moisture convergence into tropical South America and confine cold air to the subtropical region, leading to less (more) precipitation over the Amazon basin (subtropics), a result that was also reported by Lenters and Cook (1997), Coelho and Ambrizzi (2000), and Coelho et al. (2002).

ST-168

Seasonal Precipitation Forecast in the Central Peruvian Andes

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The observed glacier retreat in the central Peruvian Andes from increased global temperatures has motivated to implement an initiative aimed at understanding climate variability and climate change in this region. The Mantaro river basin in the high central Andes, that receive water from melting of snow and glaciers, has been selected as a pilot study area, and an effort has begun to assemble adequate spatial and temporal meteorological and social data coverage to attempt a first analysis of major issues related to the impacts, vulnerability and adaptations to climate variability and climate change.

In this paper, the characteristics of the seasonal and interannual precipitation variability and seasonal precipitation forecast for the central Peruvian Andes are described. To search for potential mechanism related to the observed seasonal and interannual precipitation variability, one-point correlation maps of global data and precipitation data from the Mantaro river basin for the period 1950 to 2002 were prepared. The variable in the areas with high correlation index in the correlation maps are used to select the predictors. Sea surface temperature (SST) in the Pacific and Atlantic is particularly interesting and useful since global SST forecast is routinely available. Multiple linear regression analysis is used for precipitation forecast. The forecast will be useful for mitigating the disruptions of the existing socio-economic structure in the Mantaro basin due to changes in precipitation and for adaptation to climate variability and climate change.

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Comparative Study of ENSO Effects on Some of the Major Rivers of South America during Most of the Twentieth Century

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This is a preliminary study of the influence of ENSO on the monthly flows of some of the major rivers of the South American continent. The rivers included in the study are: the Amazon river (north Brazil, south Venezuela, east Colombia, east Peru, east Ecuador and north Bolivia), the Negro river (north Brazil, south Venezuela and east Colombia), the Paraná river (southwest Brazil and extreme northeast Argentina), the Orinoco river (Venezuela), the San Francisco river (east-central Brazil) and the Tocantins river (central-north Brazil). The original river flow data is converted into standardized monthly anomalies and the annual cycle is removed. Two subsets are generated, a first group includes the years of warm ENSO events or El Niño and the

second group includes the years of cold ENSO events or La Niña. The elements of the subsets are composites of 24 consecutive months starting in January of the year when the ENSO event begins, identified as year(0), and ending in December of the following year, identified as year(1). The length of the river flow records and the number of ENSO events considered are the following: Amazon river (45 years, 20 events), Negro river (92 years, 39 events), Paraná river (97 years, 42 events), Orinoco river (70 years, 29 events), San Francisco river (62 years, 25 events), and Tocantins river (68 years, 30 events). The following is a summary of the preliminary results obtained. The Amazon river shows above (below) normal flows during April(1)-September(1) of La Niña (El Niño). During May(0)-July(0) of both El Niña and La Niña the flows are above normal, although not so significantly. The Negro river (tributary to the Amazon river) shows above (below) normal flows from March(1) until December(1) of La Niña (El Niño). This signal is particularly strong between June(1)-September(1). The Paraná River shows below (above) normal flows during October(0)-April(1) of La Niña (El Niño), with a significant peak of this relationship during November0)-December(0). Curiously, in January(1) this signal completely disappears and normal year flows are equal to ENSO years flows. During May(1)-June(1) of both La Niña and El Niño events, the flows are above normal. The Orinoco river shows below normal flows during February(1)-March(1) of La Niña (El Niño). River flows during El Niño years do not differ from those of normal years, except during August(1) when they are above normal. The San Francisco river shows below normal flows during January(1)-April(1) of La Niña, particularly during February(1) and March(1). During El Niño years the flows are similar to those of normal years. The Tocantins river shows below normal flows during January(1)-April(1) of La Niña, while during El Niño the flows are similar to those of normal years.

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Modes and Circulation Features of the Dry and Early Wet Seasons for the Caribbean

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Canonical correlation analysis (CCA) is used to investigate the relationship between anomalies of Caribbean precipitation and sea surface temperature anomalies (SSTA) in the Pacific and Atlantic basins respectively. Correlations are used to determine the connection of the primary CCA modes for bi-monthly periods to global climatic fluctuations such as the El Niño Southern Oscillation (ENSO). ENSO is found to be the leading mode of Caribbean rainfall variability during the dry season (Nov-Apr), particularly during the boreal winter months (Jan-Feb) while variability in the early rainfall season (May-Jun) is modulated by the gradient in sea surface temperatures (SST) over the tropical North Atlantic (TNA) and tropical South Atlantic (TSA). The ENSO mode is characterized by oppositely signed precipitation anomalies over the northern and southern Caribbean, the latter being negatively signed in response to a warm event. A warm TNA-cold TSA is related to positive precipitation anomalies over the entire region.

Composites of divergent wind, vorticity, and vertical velocity are used to investigate the mean circulation and that evident when the Caribbean is anomalously wet or dry. For Jan-Feb climatology, Walker and Hadley cells are identified over the equatorial Atlantic and Pacific. The circulation involves ascent over northern South America coupled with descent over the eastern equatorial Atlantic and Pacific regions to complete the Walker (zonal) cells, and descent over the tropical Atlantic to complete the Hadley (meridional) cell. Anomalously wet years (over the southern Caribbean region) are characterized by an alteration of the Atlantic part of the climatological Walker and Hadley cells. Anomalous ascent is evident over northern South America and the eastern equatorial Atlantic with descent over the tropical Atlantic. The ascending motion over South America appears to penetrate the southern Caribbean region while the Hadley-related descent facilitates a drying in the northern region. This circulation pattern is reversed for the anomalously dry years. For May-Jun the climatological pattern reveals a superpositon of low-level convergence zones over northern South America, the Caribbean, western United States and the eastern coast of United States. This pattern breaks down for an anomalously wet or dry Caribbean basin.