

# AN EXPERIMENT ON THE BUILDING OF LONG-RANGE FORECASTING OF TROPICAL CYCLONE ACTIVITY IN NORTHWEST PACIFIC AND BIEN DONG (EASTERN) SEA

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## ABSTRACT

*Long-range forecasting of tropical cyclone activity on Northwest Pacific (NWP) is one of important requirements of the countries in the Northwest of Pacific. Up to now, there are some big forecast centers of Japan, Honkong, UK and US studied and issued the forecasting news on annual tropical cyclone (TC) activity in NWP. This forecasting news is also necessary for Vietnam in the productivity managing and leading as well as disaster preventing. Together with TC activity in NWP in general, information on outlook of TC activity in the South China Sea (SCS) has directly value.*

*Many studies have shown that, there is a close relation between TC originating and activity in this area with the variation of sea surface temperature (SST) in the Pacific and Indian Ocean. Therefore, the using of these ocean SSTs as predictors for building of TC forecast models have been attended by many researchers. In this report, the investigation and using of 12 principal components of Pacific and Indian Ocean SST field, supplied by Australian Meteorology as predictors for building of TC forecast models have been presented. The TC frequency and number day of TC activity in NWP and SCS as the main as predictants. The cross validation has been used for Model verifying. Studied results possibly used in climate outlook of Vietnam as references for production guidance and disaster prevention planning.*

## 1. INTRODUCTION

Tropical cyclone (TC), which main impacts are influences of strong wind, heavy rain and surge, have became one of top-ranking disasters in the world. Damage created by TC is up to billions USD per year. In many TCs, there was thousands of dead and missing; ten thousands of houses, schools, hospitals.. have been destroyed. Therefore, TC study and forecasting has become the first task of Meteorological Service of many countries longtime ago. Vietnam is one of the countries influenced strongly of this phenomenon. Yearly, TC threatened usually to the coastal and sea areas of Vietnam. Many typhoons brought to these areas terrible calamities with thousand dead and missing, loss up to thousands billions VND. By this reason, study on and forecasting of TC has also been the important duty of Vietnam Meteorological Agencies. Short-range forecast of TC has been attended and developed in Vietnam many decades ago, became the top-object of meteorological forecasting in the "flood-typhoon season" (FTS), but long-range forecast of this phenomenon is most yet studied.

Study on long range forecasting of TC has also been developed in many countries, especially in US, Australia, UK, Japan, China in general and Hong Kong in particular... The studied results on TC forecasting in Atlantic has been used in US meteorological forecast operation yearly. Nine indexes of annual TC activity on this area as predictands of forecast model have been produced in US [4]. This model based on 10 predictors, including QBO zonal wind near 10°N, rainfall in Guinea, West Sahel, Darwin pressure, Nino4 SST, SOI...

Forecast model of TC frequency (TCF) in South Pacific near Australia has been developed is very simple with only one predictor - SOI (Nicholls - 1984). In Southwest Indian Ocean near India, forecast model for annual TC days (TCD) has been studied by Mark R. Jury, B. Pathnack and B. Parker [6]. On the Northwest Pacific, up to now, there is also some studies results on annual and seasonal forecast models for TCF, TYF (typhoon frequency) and TCD [1,2,3,6,10]. In some studies [1,8], the TCF in South China Sea and landfall to South China Coast have also been developed. Most of these models to be built on statistical method with predictors based on ENSO characteristics and some others from regional monsoon circulation. In the first quarter of the year 2004, annual TC forecast for 2004 of NWP have been issued by University of Hong Kong and University College London.

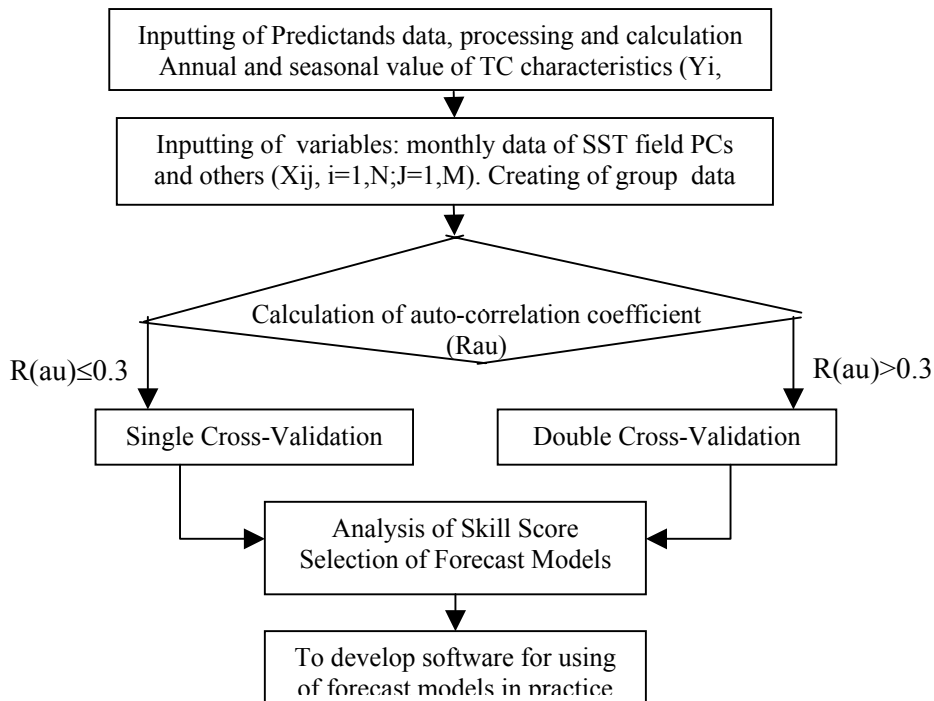
In Vietnam, by requirement of "Flood-typhoon Protection Committee", long time ago, Hydro-Meteorological Service (HMS) has to supplying yearly a report on the TC activity before the "Flood-typhoon Season (FTS)". This outlook is mostly based on subjective considering not yet on the forecast models. Up to near time, in the national theme "Impacts of ENSO phenomena to weather, climate and socio-economic of Vietnam", one statistical model on TC forecasting has been developed, with the predictors based on some characteristics of ENSO. This model has been complemented in the study of Project "An experimental study on climate forecast in Vietnam". This report based mainly on this study and to be added with some new studies of author.

## **2 DATA**

Data sources have been used in this study: 1) TC characteristics to be employed from CD-ROM "Global tropical/extra tropical cyclone climatic Atlas", produced in 1996 by National Climate Data Center (NCDC-NOAA) and complemented from data source of Joint Warning Typhoon Center (JWTC). TC data source from Meteorological Japan Agency website is also employed to consult. That is monthly values of the period 1950-2003. 2) First twelve Principal Components of SST fields on Pacific and Indian Ocean produced by Bureau of Meteorology (Australia). The beginning of these data is the year 1946 and to be updated monthly. 3) Characteristics on ENSO data source produced by Climate Prediction Center (CPC) to be issued monthly on CPC Website. These data to be started different from 1900 to 1979 and also updated monthly.

## **3 METHODOLOGY**

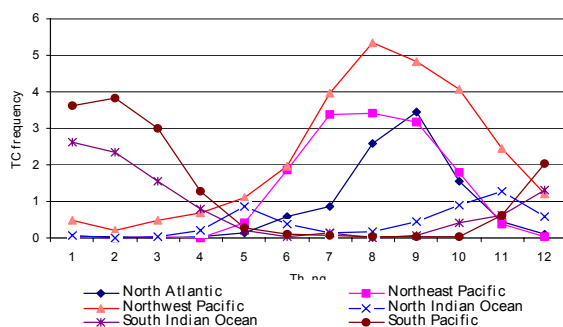
The building and verification of seasonal as well as annual TC forecast models based on statistical methods mainly by cross-validation technique with one-year hindcasts. There are two uses of the cross-validation mythology: single and double cross-validation [5]. Single cross-validation technique to be used when the series of data is independent or weakly auto-correlated (weak autocorrelation ( $R_a$ ) to be considered here when  $R_a < 0.1$ ). In order to choosing of predictors from a great number of variables, the stepwise multiple regression method has been used. Two statistical methods: multiple regression and discriminant analysis to be used in the developing and verifying forecast models. In the verification some following indexes have been used: Root Mean Square Error (RMSE) with the deterministic forecasts and Hit Rate (HR), Heike Skill Score (HSS) or Linear Error in Probability Space (LEPS) with the probabilistic forecasts. Figure 1 is framework for implementing the development and verification of seasonal and annual TC forecast models in this study.



**Figure 1: Framework for developing and verifying TC forecast models**

#### 4 SOME CHARACTERISTICS OF TC ACTIVITIES IN NWP AND SCS

As we known, Vietnam is impacted directly by Northwest Pacific TC center, a biggest TC center in the world ( figure 1). Yearly, there is about 30-31 TC (including tropical depression - TD) active in this area, occupied 34% of TC originated in all the world. More than half of them (54%) TC intensity is up to typhoon level with maximum wind speed overcomes 64 knot (>32,7 m/s). There are many characteristics expressed TC activity and its variation, but two of them: TC frequency (TCF) and number of TC-day (TCD) (*TCD is number day to have TC activity in the region*) are characteristics have been used mainly in the studies and forecasting of TC variation in the world.

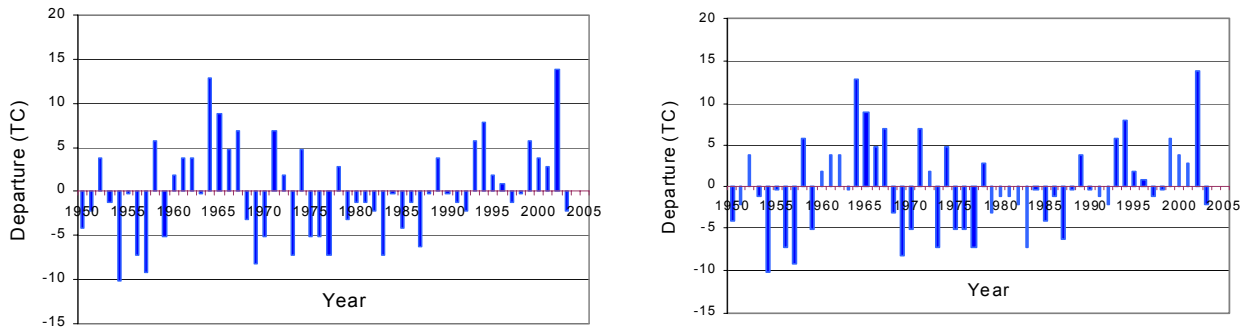


**Figure 2. Annual variation of TC centers in the World**

As many other climatic elements, TCF, TCD... are also vitiated rather strong from year to year. Monthly as well annual TC variation are not small. The vitiated coefficient of monthly TCF in "TC season" in Northwest Pacific region is about 0.3-0.4 and about 0.20-0.25 of monthly typhoon frequency (TYF) and annual TCF (Fig 3)

East Sea (South China Sea) is apart of Northwest Pacific (5-23°N; 105-120°E) but has an important role for Vietnam by its influence directly to most country. There is about 12-13 TCs active in this area with 6-7

typhoon per year. In which, about half (6-7 TCs) influenced directly to Vietnam coastal zone. As well as all of Northwest Pacific, TCF and TCD in South China Sea are also vitiated rather strong. (Figure 3,4) By this variation, TCF and TSD out looking has been an important information of long-range forecast to be



**Figure 3: Variation of annual TC frequency in NWP**

#### 4.1 Predictands

As above presented, the predictands to be chosen here: TCF, TYF and TCD in Northwest Pacific and South China Sea. These characteristics have been calculated from data source of NCDC and JTWC with the period 1950-2003 in use. That is the monthly values and can be updated from Website of JTWC. From this data source, TCF, TCD is included all tropical depression (TD), storm (ST), severe storm (sST) and typhoon (TY). Thus there are 6 predictands have been studied.

**Figure 4: Variation of annual TC frequency in SCS**

#### 4.2 Predictors

From these data sources, it is possibly created many kinds of predictors. Based on the analysis of relation between the above predictands and ocean-climatic elements have been collected, two groups of these variables to be selected to put into the assessment of this study.

- The first one from first twelve PCs of SST fields on Pacific and Indian Ocean. Significance as well as spatial pattern and time series of each PC have been presented in documents of BOM [5]. Each PC, 6 monthly values before 1 month of the started-time of forecast-season or forecast-year (lead time is one month) to be taken for predictor choosing. Thus, there are 72 variables can be put into the selection in this case.

- The second one including 5 indexes: a) 3 indexes of ENSO phenomenon, comprised SST anomaly (SSTA) of the NINO4 and NINO1+2 regions, Southern Oscillation Index (SOI). b) Sea surface Pressure anomaly (SSPA) of 12 grid-points of North Hemisphere strongly correlated with TCF in NWP. c) Month-to-month change in TCF itself. Monthly value of 12 months before the started-time of forecast-season or forecast-year have also been taken for choosing of predictor. In this case, there is 60 variables have been used in selection.

#### 4.3 Results

The result to be presented in this paper is only for yearly forecast models. Skill of model verification to be shown in the Table 1.

From the results of developing and verifying process , we have some remark as follows:

- R-CV is correlation coefficient between observations and forecasts after N hindcast in cross-validation technique (N is number years of observation has been used). R-CV is not same for all forecasting indexes but it is similar with the results of *Zin Ping Yu, Pao Shin Chou and Thomas Schroeder, 1997*. In both modes, R-CV rather high for TCF-NWP and TYF-ES forecast models and rather low for TYF-NWP and TCF-ES.
- RMSE is not high for TCF and TCD for NWP, about 10-15%; increases to 20-25% for TCF and TCD of SCS; up to more than 40% for TYF of SCS.
- Other skill scores, such as HR, HSS, LEPS, are rather good, similar with some studied results in other countries.

The verification of annual TC<sup>Fig 5</sup> and TCF-EC (1951-2003) by comparing of observation and forecast from N hindcasts in use of cross-validation technique to be presented in Figure 5 and 6 (follows the first mode with 12 PCs of SST field).

Table 1 Some CV-Skill scores of forecast model verification

TC Indexes	R-CV	HS(%)	HSS(%)	RMSE(TC)	LESP(%)
First Group of predictor selection (N=52: 1951-2002)					
TCF-NWP	0.650	59	39	4.54	17.4
TYF-NWP	0.480	45	15	3.19	8.3
TCD-NWP	0.489	49	26	3.88	12.6
TCF-ES	0.497	67	40	2.25	12.8
TYF-ES	0.741	61	41	19.99	15.5
TCD-ES	0.417	51	26	15.96	9.2
Second Group of predictor selection (N=41: 1962-2002)					
TCF-NWP	0.77	62	42	3.72	18.1
TYF-NWP	0.312	54	27	2.81	8.1
TCD-NWP	0.671	57	35	3.08	14.7
TCF-ES	0.398	51	30	2.32	9.8
TYF-ES	0.714	59	39	20.6	13.8
TCD-ES	0.548	41	10	11.67	13.4

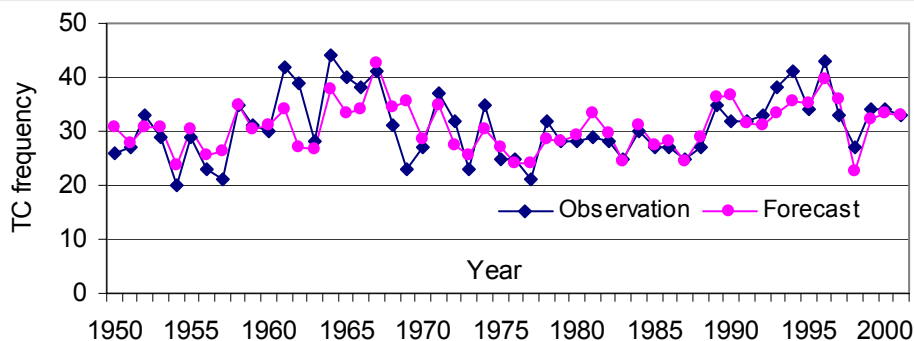
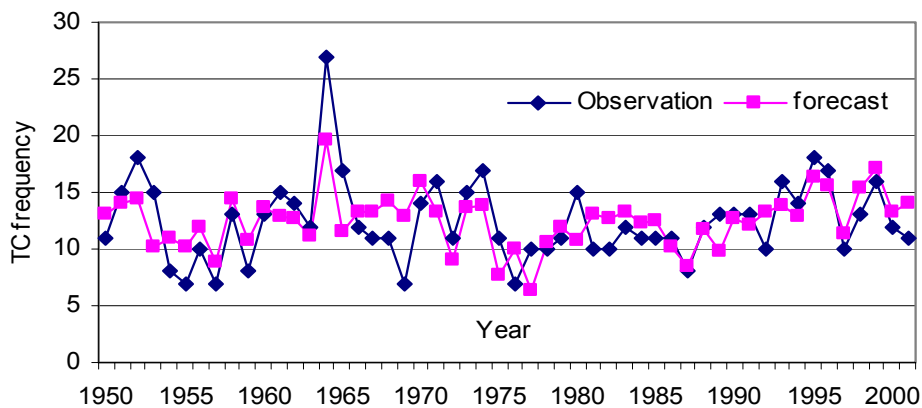


Figure 5: Variation of TCF in Northwest Pacific (1950-2001)



**Figure 6: Variation of TCF in South China Sea (1950-2001)**

Using of these forecast models to make an outlook on some characteristics of TC activity in NWP and SCS in the year 2004, we received the following results in February of 2004:

- Number of TC and TYF generated in the NWP as well as TCF active in the SCS in 2004 are above normal (normal to be calculated from the period 1970-2000) with probability 45-60%.
- TYF in SCS in the year is near normal normal with probability 36%
- TCD in NWP is near normal and TCD in SCS is near or above normal

## 5 CONCLUSION

Long-range forecasting of TC activity in NWP in general, in SCS in particular is necessary for study on influences of this phenomenon to Vietnam territory. Seasonal and annual Outlook on TC activity in this area as well as its impacts to the country is very useful for productivity planning and management, especially in the disaster prevention. The results has been presented is only apart of this problem and is only a primary study. In order to putting TC forecast models into practice of climate forecast operation it is necessary to complement the new groups of predictor based on the analysis of relation between TC activity with zonal atmospheric and oceanic environment, especially ENSO phenomenon and Asian Monsoon Circulation.

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