A climate change demonstrator for the ecoinformatics platform – Technical Implementation

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[DPI/PIRVic = Department of Primary Industries, Primary Industries Research Victoria; RCG/MU = Regional climate group/Monash University]

1. Aims and background

The Ecoinformatics Platform will be an online collaborative and shared resource for managing climate, ecosystem and environmental data and information products. The Ecoinformatics eScience contribution will be to develop this platform and data and models for research, development and policy/community applications. In recognition of the magnitude of the task of creating a fully integrated Ecoinformatics Platform, the proposal aims to develop a demonstrator applying the principles of an Ecoinformatics Platform to undertake research into *climate change impacts and adaptation within primary industries*. This document provides the detail of the technical implementation of the climate change demonstrator for the Ecoinformatics Platform.

The ability to simulate climate and its variability at regional and local levels is an essential policy making tool [1]. The method of dynamical downscaling is the most physically consistent approach to refine coarse resolution meteorological data to finer spatial scales. Models currently applied in climate predictions have been developed from numerical weather prediction models. These atmospheric global circulation models (GCMs) are usually coupled with ocean and terrestrial models and hence are known as coupled GCMs or more recently, climate system models (CSMs). Because of limited computational resources, GCMs generally have a spatial resolution of around 200 km, which is too coarse to provide detailed information on climate at regional and local levels. In dynamical downscaling, output of a GCM provides initial values and boundary conditions for a regional climate model (RCM). The high resolution RCM output is downscaled from the GCM output using detailed topography and other surface characteristics, physical parameterisations and high resolution (non-hydrostatic) flow dynamics. The requirement to accurately refine climate data using an RCM is especially important over the regions of varying topography, like mountain regions and coastal zones, of which Victoria is a good example.

[**Add a paragraph on crop modelling and importance of utilising high resolution climate data for planning purposes and decision making.**]

The implementation of the climate change demonstrator for the Ecoinformatics Platform will provide high resolution climate data for crop modelling and land suitability analysis at a regional scale and will serve to demonstrate the applicability of the concept of the Ecoinformatics Platform to other users. The major goals are of a fully functioning system are:

1. Understand the extent of Climate change with respect to Victorian plant industries.

2. Understand the impact of Climate Change on management options for Victorian plant industries, aquaculture and similar.

3. Engage and communicate with the communities of interest on the likely impacts, extent and management options for Victorian plant industries.

2. Approach and training

2.1. Climate model configuration

We propose that the RCM should be implemented as a modular part of the demonstrator being easily exchangeable when required. This is important because the forthcoming Australian earth system model under the Australian Community Climate and Earth System Simulator (ACCESS) initiative, will provide high quality modelling capability for the Australian region. The ACCESS modelling system includes a RCM suitable for downscaling efforts, originating from the Hadley Centre, UK. ACCESS is a joint development initiative involving the Bureau of Meteorology, CSIRO and key universities and is expected to be fully functional in 2008. In 2009-2010 the ACCESS model will be available to perform the climate data simulation component of the Ecoinformatics Platform. RCG/MU includes ACCESS Team Leader Amanda Lynch and is hence permitted to use the ACCESS modelling system under the academic license.

Meanwhile, we suggest the climate change demonstrator will be launched using the state-of-the-art North American Regional Climate Change Assessment Program (NARCCAP) protocol (see http://www.narccap.ucar.edu/). NARCCAP is an international program that will serve the high resolution climate scenario needs of the United States, Canada, and northern Mexico. Prof. Lynch is collaborating with researchers from NARCCAP. The selected RCM is the Weather Research and Forecasting (WRF) model, which has been developed as a joint effort among the leading atmospheric research institutions in the U.S. (National Center for Atmospheric Research, the National Centers for Environmental Prediction, the Forecast Systems Laboratory, the Air Force Weather Agency, the Naval Research Laboratory, Oklahoma University, and the Federal Aviation Administration). WRF is a next-generation mesoscale (i.e. high resolution) numerical weather prediction system designed to serve both operational forecasting and atmospheric research needs and is suitable for a broad spectrum of applications across scales ranging from meters to thousands of kilometres.

The GCM data, which will be used as initial and boundary values for the RCM, needs to have sub-daily resolution, generally 6 hourly, to avoid aliasing of the diurnal cycle. The GCM data available for the study (and used by NARCCAP) are CCSM version 3.0 simulations from National Center for Atmospheric Research, USA. The CCSM model provides output data in the similar standard format NetCDF and are assessed to simulate realistically the southern hemisphere circulation [2,3].

Refined climate data should be first quality controlled by comparing the RCM output with the observations from the present climate. The comparison material can be derived from weather observations available from the Australian Bureau of Meteorology and the historical climate data from the SILO repository maintained by DPI and from the publicly available global re-analysis data. A sufficient time period to be used for comparisons will be the last decade of the

20th century (1990-1999), for which most of the GCM output data is available as well. Refined climate data from 1990-1999 will then also be used to derive statistics of recent climate conditions.

Having defined the time period of the present climate conditions one has to define time period(s) in the future to be compared with the present climate. As agreed in discussions with DPI/PIRVic the time period of 2046-2055 is suitable for the demonstrator. This time period also represents climate conditions which already differ significantly from the present climate.

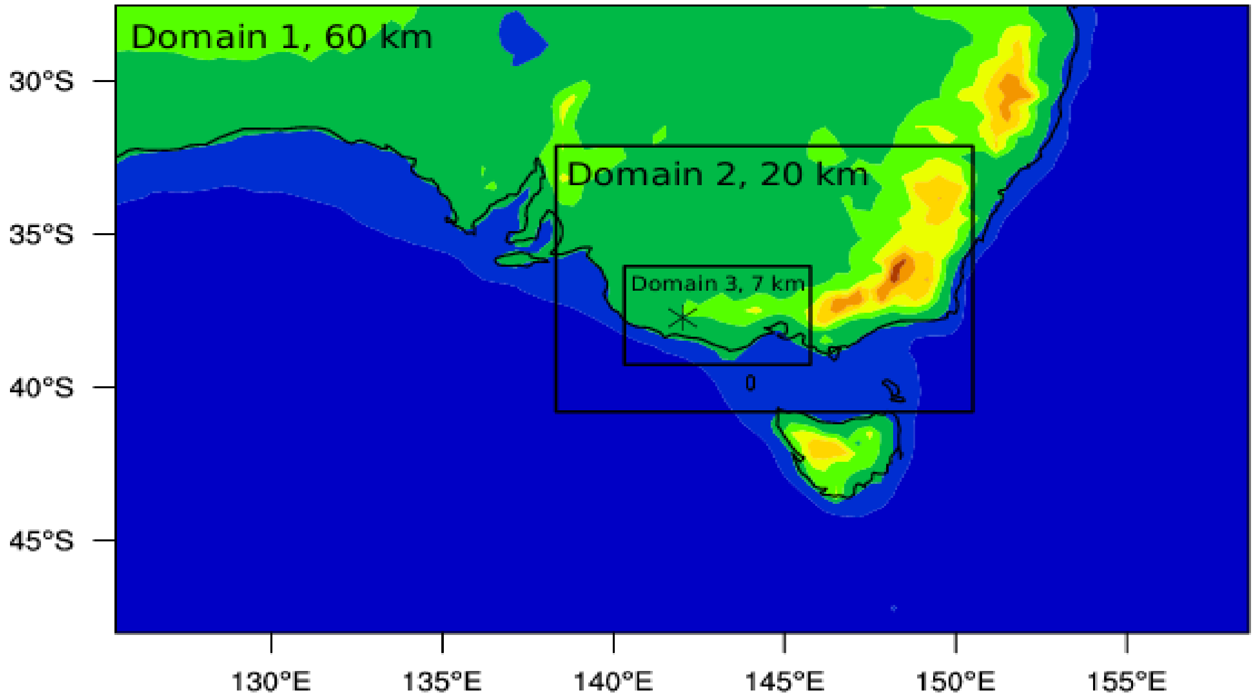

Fig. 1: Illustration of three nested RCM model domains: Domain 1 (60 km resolution), Domain 2 (20 km), and Domain 3 (6.667 km). The location of the city of Hamilton is marked with the asterisk inside Domain 3.

GCM climate projections are based on greenhouse gas emission scenarios, which start to deviate significantly after the middle of the 21st century. Hence the results derived from the 2046-2055 time period of a GCM simulation do not significantly depend on the choice of emission scenario. Currently available CCSM output is based on SRES A2 emission scenario. This scenario represents high level of GHG emissions. Later time periods in the 21st century will be simulated based on a range of emission scenarios.

An example of three nested RCM domains is shown in Fig. 1. Domain 1 is initialised and obtains its boundary values from CCSM output data of about 160 km resolution (1.4 degrees of latitude). The required resolution ratio between the GCM output and domain 1 and each successive nested domains is about three, leading to 60 km resolution for domain 1, 20 km for domain 2 and 6.667 km for domain 3. Domain 2 covers roughly Victoria and Domain 3 a region around the city of Hamilton in Western Victoria plus the metropolitan region of Melbourne. The region in Western Victoria was identified as a key study areas by DPI/PIRVIC. Coarser GCM output data leads to lower resolutions of nested domains.

Running the RCM is computationally demanding mainly because the higher spatial resolution requires shorter time steps (advance of computation in time) and to resolve climate time scales long, multidecadal simulation periods are required. Typically WRF can be run with 60 km resolution using a 360 s timestep, while 6.667 km requires a 40 s timestep. When an experiment using similar configuration as in Fig. 1. is run on a modern multiprocessor computer system, one day in model time takes approximately 21 minutes real time using 24 processors (Monash Sun Grid at Information Technology Services cluster (MSG@ITS)). Using this system to run an experiment of two ten-year periods would take 107 days in real time. To complete simulations faster one may consider running different time periods simultaneously on different computing platforms.

The following possible computational UNIX platforms for the demonstrator experiment has been discussed:

1. MSG@ITS cluster (easiest access for RCG/MU)
2. APAC National Facility, AC cluster (most powerful)
3. DPI Bendigo computing centre cluster (32 CPUs)

The Monash cluster runs WRF approximately two times slower than the APAC cluster, but the usage of memory and storage is less restricted. Finally, the fully functional climate change demonstrator should be able to serve the RCM output seamlessly as input to crop modelling and land suitability applications. To complete the RCM experiments a user account with secure shell login is required and a Fortran 90 compiler (preferably Intel, Portland Group or perhaps G95) plus installation of some additional libraries (like NetCDF and MPI).

2.2. Experimental Protocol

The basic experiment described above is that required for the short time frames required of the Demonstrator. The immediate goal of the Demonstrator is to develop the infrastructural requirements of the platform. However, it is also important to maintain a vision of the future pathway to obtain the ideal model output resources that can then be used in the Ecoinformatics Platform to attain project goals. Hence, it is not intended that the scenarios provided in the Demonstrator should be used for policy making. The table below indicates the recommended development pathway for the experimental protocol and the expected timing that these milestones could be achieved, with an appropriate level of funding.

	Scenario choice	Model	Timeslice	Length of experiment	Number of global ensembles scenarios	ETA
Demonstrator	20C3M A2	CCSM-WRF	1990-1999 2046-2055	10 yrs 10 yrs	1 1	30 Nov 2007 30 Nov 2007
1	20C3M A1B A2 B1	CCSM-WRF	1990-1999 2046-2055 2046-2055 2046-2055	10 yrs 10 yrs 10 yrs 10 yrs	Up to 10 Up to 14 Up to 6 Up to 9	mid 2008
2	20C3M	ACCESS	1990-1999	10 yrs	1	late 2008
3	Available scenarios	ACCESS	2046-2055	10 yrs	Available ensemble	early 2009

	from CSIRO				members from CSIRO	
Ideal	Current climate A2 or A1B A2 or A1B A1F1 B1	ACCESS	1990-1999 2046-2055 2090-2099 2090-2099 2090-2099	10 yrs 10 yrs 10 yrs 10 yrs 10 yrs	>4	late 2009

2.3. Crop Modelling

Input is daily weather data: max and min temperature, rainfall and solar radiation.

2.4. Land suitability analysis models

Input is monthly seasonal data (mean of 30-40 years) as described in the document prepared by Yingxin Wu (DPI/PIRVic). Variables are:

- Mean monthly maximum and minimum temperature in ^{o}C.
- Mean monthly frost days (minimum temperature less than 2 ^{o}C).
- Mean monthly rainfall in mm.
- Wind speed in m/s.
- Branas index (optional).
- Heat degree days (optional).
- Extreme heat days as a number of days per month when maximum temperature is above 35 ^{o}C.
- Monthly solar radiation in MJ m^{-2} day^{-1}.

The data format has to be in raster (grid) spatially covered the whole study area. Data 250m grid or higher resolution is desired. Data projected in AGD1984 AMG Zone 55 or Zone 54 is highly preferred.

3. Partner organisation commitment and collaboration

1. In this project a GCM projection will be downscaled to Victoria, by the regional climate group, Monash University (RCG/MU) using a RCM. RCG/MU will
    - program a routine converting GCM output to RCM input,
    - program routines converting RCM output to interchangeable formats (with assistance from the DART/ARCHER group),
    - run RCM experiment for the present climate,
    - quality assess the present climate experiment results (comparing RCM output with observations),
    - run RCM experiment for the future climate
    - convert climate data to crop model format (with assistance from the DART/ARCHER group)
    - convert climate data to land suitability analysis model format (with

assistance from the DART/ARCHER group)

2. Refined climate data produced by RCM will be converted to interchangeable formats suitable for crop models and land suitability analyses of DPI/PIRVic. The data format will be defined in collaboration between RCG/MU and DPI/PIRVic. Also the accessibility to the historical climate data needs to be coordinated by DPI/PIRVic in collaboration with RCG/MU.
3. DPI/PIRVic will carry out crop modelling and land suitability analyses creating end products [**which are ?**].
4. The DART/ARCHER group from the Faculty of IT/Monash University will assist in programming and automation of the data exchange between the RCM and DPI's models. It will contribute its expertise in shared data management, data rights management, data mining and analysis and access control and authorisation as embodied in the DEST-funded DART and ARCHER project. The users of the automated approach will be trained.

References

[1] Burroughs, W.S. (Ed.), *Climate Into the 21st Century*, World Meteorological Organization, Cambridge University Press, Cambridge, U.K., p. 195, 2003.

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[3] Uotila, P, A.H. Lynch, J.J. Cassano, R.I. Cullather, Changes in Antarctic Net Precipitation in the 21st Century Based on IPCC ModelScenarios, *J. Geophys. Res. -- Atmospheres*, 112, D10107, DOI:10.1029/2006JD007482, 2007.