J10.6 NORTH AMERICAN REGIONAL CLIMATE CHANGE ASSESSMENT PROGRAM

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1. SCIENTIFIC MOTIVATION

From a global climate point of view, two main uncertainties have been identified regarding determining future climate in the 21st century: the trajectories of future emissions of greenhouse gases and aerosols; and the response of the various global climate models to any given set of future emissions (Cubasch et al., 2001). However, as greater interest and concern is focused on the regional scale of climate change, and the desire for greater regional detail continues to grow, the uncertainty due to the application of regional climate models to the climate change problem introduces an additional uncertainty (Giorgi et al., 2001). This uncertainty in the regional climate response (contrasting the climate response of a regional model to that of the global model that provides it with boundary conditions) has now been documented (Giorgi et al. 2001) and has furthermore been found to extend to uncertainties in climate impacts (Mearns et al., 2001, Mearns, 2003; Stone et al., 2002, Wilby et al., 1999; Wood et al., 2004). While European research has moved forward to systematically examine the combined uncertainty in future climate predictions from global and regional models (Christensen et al., 2002), North American climate programs have lagged behind. We have developed the North American Regional Climate Change Assessment Program (NARCCAP) in the spirit of filling this research gap.

The fundamental scientific motivation of this project is to explore the combined uncertainty in climate change scenarios resulting from use of different Atmosphere-Ocean General Circulation Models (AOGCMs) providing boundary conditions for different regional climate models (RCMs).

An additional and equally important (and related) motivation for this project is to provide the climate impacts community with regionally resolved climate change projections that can be used as the basis of studies of the societal impacts of climate change. Because we will use multiple models and climate-change scenarios, impacts researchers will have the ingredients needed to produce impacts assessments that characterize uncertainties.

The project will also contribute to some of the most important goals of the U.S. Climate Change Science Program (CCSP, 2003), particularly Objective 1.6 "Accelerate the development of scientifically based predictive models to provide regional and fine-scale climate and climate impacts information relevant for scientific research and decision support applications." Moreover this effort

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will catalyze the establishment of a process for coordination of regional model activities, a near term priority goal of the CCSP modeling strategy.

This plan is modeled on the very successful PRUDENCE project in Europe wherein 11 different RCMs have been used to produce climate change scenarios over Europe and their uncertainty for the A2 and B2 SRES scenarios using boundary conditions from several different AOGCMs or time slices from the AOGCMs (http://prudence.dmi.dk).

However, in PRUDENCE most of the regional models used only one or at most two AOGCMs for boundary conditions, and few used more than one emission scenario (A2). In the North American plan we wish to create a smaller and more balanced project focusing mainly on the uncertainty of the different AOGCMs and RCMs. Performing the suite of runs for more than one emissions scenario is discussed as a possible addition to the project (see below).

The goals of this plan are multifold:

1. Exploration of multiple uncertainties in regional model and global climate model regional projections;
2. development of multiple high resolution regional climate scenarios for use in impacts models;
3. further evaluation of regional model performance over North America through nesting the RCMs in reanalyses;
4. exploration of some remaining uncertainties in regional climate modeling (e.g., importance of compatibility of physics in nesting and nested models);
5. creation of greater collaboration between US and Canadian climate modeling groups, as well as with the European modeling community that leverages the diverse modeling capability across the countries;
6. coordination of and adding value to diverse regional and global modeling projects and programs currently underway in the US, Canada, and Europe.

2. GENERAL PLAN

The basic plan for this project is to use four driving AOGCMs to provide boundary conditions for five RCMs for 30 years of control run (current climate) and 30 years of a future climate (2035-2064 and/or 2071-2100) for the A2 SRES emissions scenario. (While it may be desirable to also explore the uncertainty resulting from varying emissions scenarios, the initial focus of NARCCAP will be on the global model/regional model uncertainty). Given stakeholder interest in nearer term climate change, some runs (for example using two AOGCMs) may be started in 2040 and extended through 2100.. The domain will include all of the lower 48 US States as well as as far north as possible, minimally to 60 deg. N, and adjacent Atlantic and Pacific Oceans (see Figure 1 for a sample domain of RegCM3).

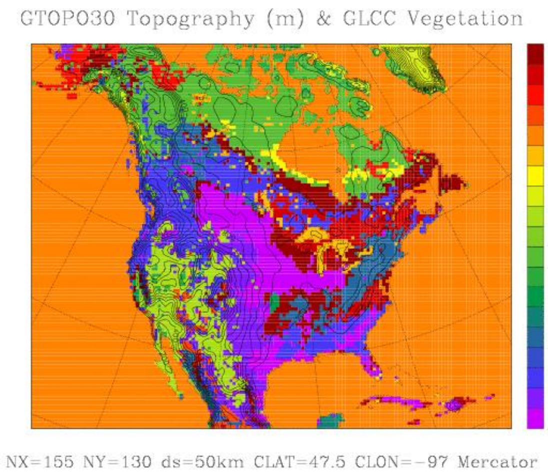

Figure 1. Sample domain for NARCCAP. Domain of the RegCM3 at 50 km grid point spacing over North America. Colors refer to land cover types.

2.1 Added Value to and Interactions with Related Programs

2.1.1 PRUDENCE

This project will provide further value to the original PRUDENCE project (Christensen et al., 2002), since two of the RCMs (HadRM3 and RegCM3) and one of the AOGCMs (HadCM3) are being used in that project as well. Hence, some comparative analysis of performance over Europe and North America will be possible, which will benefit both programs. It will also be possible to have coordinated European-North American impact assessment programs based on consistent, high resolution climate change scenarios.

2.1.2 PIRCS

Evaluations of RCM simulations when driven by reanalysis ("observed") boundary conditions form a vital baseline for assessing confidence in RCM projections of scenario climates (e.g., Pan et al. 2001). PIRCS has coordinated short-term climate simulations involving up to 16 RCMs. The current PIRCS 1(c) experiment spans at least 7 years and has commitments from 6 modeling groups (3 US). The extensive array of simulations produced on a largely voluntary basis has resulted from careful, diplomatic community building. NARCCAP will benefit from the additional simulations PIRCS will make available. Differences between PIRCS and NARCCAP simulations run with identical models will form a basis for evaluating sensitivity to domain choice.

3. DETAILED PROJECT PLANS

Regional Climate Models to be used include: the Canadian RCM (CRCM), MM5, HadRM3, RegCM3 and RSM. Versions of four of these models have already been run over domains over North America using boundary conditions from both reanalyses and GCMs (e.g., MM5, western US, Leung et al. 2003a,b, 2004; earlier versions of RegCM, RegCM2 over western US (Giorgi et al., 1998; Bell et al., 2004, Snyder et al., 2002) the southeastern US (Mearns et al., 2003), the entire continental US (Pan et al., 2001), the RSM over the continental US (Roads, 2003; Han and Roads, 2004) and the Canadian RCM (Laprise et al.,1998; Laprise et al., 2003; Caya and LaPrise, 1999) over western and eastern Canada). They have also participated in PIRCS (Project to Intercompare Regional Climate Simulations (http://www.pircs.iastate.edu)) or plan to in the near future. These particular models have been chosen to provide a variety of model physics, and/or to use models that have already performed multi-year climate change experiments, preferably in a transient mode, and/or to overlap with the European PRUDENCE program.

3.1 *Phase I. Production and Evaluation of Runs using Reanalysis Boundary Conditions*

Phase I will include production of RCM model runs using reanalyses for boundary conditions for a 30-year period. Such evaluation is a crucial prerequisite to generating climate scenarios and characterizing their uncertainties (Pan et al, 2001). Such runs were performed in the MERCURE program in Europe ((http://www.pa.op.dlr.de/climate/mercure.html) prior to PRUDENCE and have been performed and continue to be performed in the PIRCS program (Takle et al., 1999; Pan et al., 2001; Anderson et al., 2003; http://www.pircs.iastate.edu/). Currently PIRCS has moved into Phase 1c of their model intercomparisons (see above). In addition Ruby Leung, PNNL, using MM5 has recently run 10 years over the continental US using NCEP reanalyses, at a 36 km resolution. Daniel Caya at Ouranos has run the CRCM driven by NCEP for 25 years over most of North America. Either ECMWF or NCEP boundary conditions will be used, or possibly both.

The Iowa State group will plan and direct the reanalysis phase of the project (i.e., Bill Gutowski, Ray Arritt, Gene Takle) and will further organize the project in terms of provision of boundary conditions, etc. Hence this project phase may be seen as a further extension of PIRCS. The reanalysis phase will occur first.

3.1.1 Progress so far:

NARCCAP Experiment 0

Overview

The objective of NARCCAP Experiment 0 is to examine the possible influence of regional climate model domain size and boundary location on simulated meteorological fields in the domain interior. Previous experiments have suggested that regional climate model domains that are too large may allow the climate simulated by the regional model to decouple unrealistically from that of the driving boundary conditions. In contrast, if the domain is too small, the regional model may not have sufficient physical space to fully develop the dominant mesoscale flow features indigenous to the region. Also, if the domain is not optimally located it may not allow for sufficient horizontal space for coupling to remote large-scale forcing features. The experiments described below are ongoing.

Experimental Design

The Regional Climate Modeling Laboratory at Iowa State University is managing Experiment 0. The modeling team will perform a series of 1-year simulations with alternative domains and with boundary conditions supplied by the NCEP/DOE Reanalysis - II (R2) data Land/ocean distribution and preferred flow directions for meteorological systems suggest that the direction of domain enlargement might make a difference. To allow for this possibility, a series of up to four simulations will be performed, as described below. Each group should perform at least the first two. Each run consists of a 12-month simulation beginning January 1979.

Description of Individual Runs

Run 0.0

This will be considered the control run and will use the base domain shown in Figure 1.

Run 0.1

Run 0.1 will be identical to Run 0.0, except that the number of gridpoints in the east-west direction will be multiplied 1.5 (keeping the same center point).

Run 0.2

Run 0.2 will be the same as Run 0.0, except that the number of gridpoints in the north-south direction will be multiplied by 1.5 (keeping the same center point).

Run 0.3

Run 0.3 will be the same as Run 0.0, except that the number of gridpoints in both the north-south and east-west dimensions will be multiplied by 1.5 (total of 2.25 times the original number of points).

3.2 *Phase II. Current and Future Climate Simulations – Nesting within AOGCMs*

Preliminary plans are to use the following AOGCMs or time-slices from the following AOGCMS: (NCAR-CCSM, Canadian Climate Centre CGCM3, the Hadley Center HADCM3 and HadAM3 (time slice), and the GFDL AOGCM). All of these models have already performed simulations using the A2 SRES emissions scenario and most (all, except the GFDL model) have saved output at intervals appropriate for driving regional climate models. Future runs with the GFDL model will store the appropriate data. However, use of these specific global models will also depend on how well they simulate various aspects of climate over North America. Finally, a high resolution version of the NCAR CAM3 may be used (e.g. Govindasamy et al., 2003) as well as a high resolution version of the atmospheric model from the GFDL AOGCM (Stouffer, pers.comm.). These high resolution time slice experiments would provide the opportunity to directly compare a 50 km global time slice experiment with the 50 km regional climate model runs nested within a coarser resolution time slice with the same atmospheric model. Phil Duffy and colleagues at LLNL will run the high resolution version of the global model CAM. Isaac Held and colleagues at GFDL will perform the time slice experiments with the GFDL atmospheric model

3.3 *Model Evaluation, Diagnostics, and Characterization of Uncertainty*

Participants will jointly apply existing model evaluation and diagnostics techniques to intercompare and diagnose model differences. New analysis and diagnostic methods focusing on aspects of regional climate that are important for assessing climate change impacts will be developed and applied to provide further insights into model biases and uncertainties in projecting climate change and impacts. This will include analysis of extremes (e.g., Kunkel et al., 2002; Bell et al., 2004) and various timescales of climatic variability (interannual to daily). We have also involved geophysical statisticians to produce formal statistical models that characterize the uncertainty based on the entire suite of model runs (Doug Nychka, and Steve Sain, NCAR).

3.4 *Additional Project Elements to Follow*

Impacts-related projects naturally could be developed in which the output from the climate model runs can serve as input for hydrologic, agricultural and other impacts models. This will provide the opportunity to have programs well in place for the next US Assessment. One clear opportunity is to develop a multiple-nesting project over certain key regions of the domain, which will also expand the involvement of the RCM community in the US. Examples of such areas include California, and the Northeastern US (very high resolution over urban areas). Also, a statistical downscaling project in parallel with the regional modeling could be developed. Further climate modeling activities could also be developed, for example, specific experiments testing sensitivities to model physics parameterizations (e.g. other versions of MM5 physics). Finally some simulations with an additional emissions scenario (e.g., B2 or A1B) may be produced.

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