Ocean-Atmosphere Coupled Climate Model Development at SAWS: Description and Diagnosis

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1. INTRODUCTION

The most complex procedure of modelling the climate system is to model all components of the system believed to be relevant at the respective timescales. At the seasonal lead-time for instance the optimum way is when at least models for the atmosphere and ocean are run synchronously and exchanged information interactively. With this in mind, an Ocean-Atmosphere Coupled General Climate Model (OAGCM) is developed at the South African Weather Service (SAWS) and is running at the Centre for High Performance Computing (CHPC) computer clusters. The aim of this study is, therefore, to describe the model and evaluate the skill of retrospective forecasts.

2. METHODOLOGY

The ECHAM4.5 Atmospheric General Circulation Model (AGCM; Roeckner et al., 1996) is coupled with the Geophysical Fluid Dynamics Laboratory (GFDL) Modular Oceanic Model version 3 (MOM3; Pacanowski and Griffes, 1998) using the Multiple Program and Multiple Data (MPMD) coupling paradigm. Essentially, this means that the models are the same as standalone versions except for changes needed to handle passing of data in between. Each model is treated as an independent set of Message Passing Interface (MPI) parallel processes.

In this experiment, the ocean model is initialized independently using the GFDL ocean state produced by the ocean data assimilation (ODA) system which employs an optimum interpolation scheme (Derber and Rosati, 1989). The use of the product is done by a horizontal and vertical interpolation procedure described by DeWitt (2005). Similarly the atmospheric component is initialized in a manner discussed by Beraki and Olivier (2010) except that the lower layer atmospheric temperature is assimilated from the upper layer of the GFDL ODA in order to maintain consistency and balance, that is, to minimize the imbalance between the (near-equatorial) upper-ocean mass field and wind stress (DeWitt, 2005). This initialization strategy makes this system uniquely different from previous systems involving the ECHAM4.5 AGCM coupled with the MOM3 ocean model. As the coupling information is needed at the time of initialization, the coupling state is also initially reconstructed from the National Centers for Environmental Prediction (NCEP) Reanalysis (R2) dataset (Kanamitsu *et al.,* 2002). The Potential Evaporation (PE) is, however, computed using the Penman-Monteith procedure (Allen *et al.,* 1998). The two GCMs exchange information once per simulation day. The AGCM feeds the OGCM with heat, momentum, freshwater, and surface solar flux. The OGCM, in turn, feeds the AGCM sea-surface temperature (SST) information. The coupling strategy used in this study is anomaly coupling on the AGCM side and full-field coupling on the OGCM side meaning that the anomalous atmospheric fluxes are super-imposed on the observed climatology. In addition, since the ocean model lacks a sea-ice model, the OGCM SST is relaxed toward the observed climatology in high latitudes to suppress the generation of spurious ice.

3. RESULTS AND DISCUSSIONS

The skill of the OAGCM is assessed using the Standardized Verification System (SVS) for Long-Range Forecasts (LRF) as recommended by the Commission for Basic Systems (CBS) of the World Meteorological Organization (WMO). This norm is adopted here as SAWS is recognised as a Global Producing Centre for LRF, one of only three in the Southern Hemisphere. The analysis has been conducted using the austral summer season (DJF) hindcasts for a 1-month lead-time using 10 ensemble members for the period spanning from 1982 to 2000. The model

integration mimics a set of operational forecasts as if issued on the 4th of November starting from 1982 to December 2000.
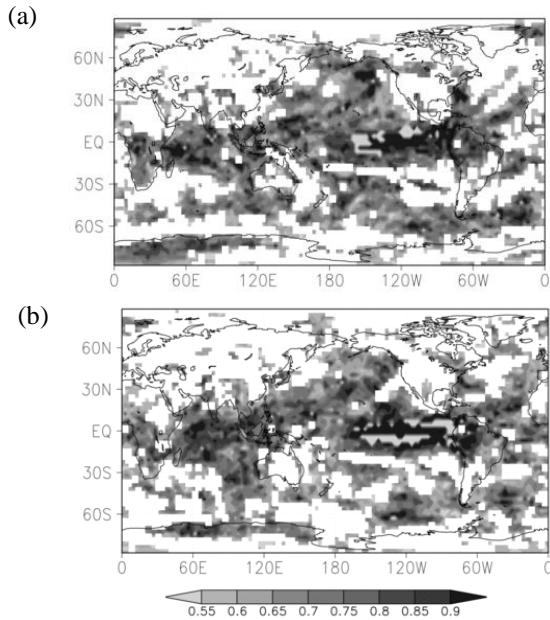
(a)

(b)

Fig.1: ROC area (a) below-normal and (b) above-normal computed for OAGCM surface air temperature hindcasts against ERA-40 (only statistically significant at 95% are indicated).

Fig. 1 shows the relative operating characteristic (ROC) area for the austral summer season (one-month lead) for below- (a) and above-normal (b) categories for surface air temperatures. The category thresholds are tercile values of the model climatology. The significance test (at 95% confidence level) is conducted using the classical Wilcoxon–Mann–Whitney nonparametric procedure variant suggested by Mason & Graham (2002). The level of skill demonstrated by the model is robust and may be attributed to coupled ocean–atmosphere teleconnection effects. The model performs best in the equatorial regions and is also skillful over southern Africa. The model also yields similar results on other diagnostics such as precipitation, rainfall, upper air flow and geopotential heights (maps not shown).

4. CONCLUSIONS

The paper has demonstrated the advances made in configuring an operational coupled ocean-atmosphere model in South Africa for seasonal forecast production. This coupled model development is also a first for Africa and has made a unique contribution to the notion of coupled model development both locally and internationally through the experience gained to couple the model and to develop a state-of-the-art data-assimilation interface that enables the adoption of an optimum initialization strategy.

6. REFERENCES

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