CLIVAR Climate Variability & Predictability World Climate Research Programme

Exchanges

- Scientific Contributions -

SPEEDO: A flexible coupled model for climate studies*

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Introduction

In recent years considerable progress in understanding the climate system has been achieved by using models of intermediate complexity. Those models range from idealized one or two-dimensional representations of the ocean and atmosphere dynamics, to more complex 3-dimensional coupled models (see Stocker and Knutti 2003). The advantage of intermediate complexity models lies in their computational efficiency. Large ensembles, long runs, twin-experiments and parameter sensitivity studies are easier done than with state-of-the-art GCMs. Intermediate complexity models proved to be valuable in detecting mechanisms of climate variability, they can help to interpret results from more complex coupled integrations, and are a precious tool in the assessment of the statistical significance of predictability studies (Molteni et al., 2003). Here, we report on the development of a coupled model of intermediate complexity that is closer to the state-of-the-art GCMs than previously developed simplified models. The atmospheric component is faster than state-of-the-art GCMs by an order of magnitude. A modular setup easily allows configuring integrations with different model components. This makes the model very attractive to study, for instance, the role of oceanic or land processes in climate. In the following, technical aspects of the model are first discussed. The advantage of the modular setup and the hierarchy of ocean models implemented are illustrated with results from a study after South Atlantic coupled variability.

Technical Aspects

The atmospheric module, nicknamed SPEEDY (Simplified Parameterizations primitivE Equation DYnamics, see Molteni 2003 for a description), uses a set of parameterization schemes based on the same principles adopted in state-of-the-art AGCMs. It is configured with 7 vertical layers and with spectral truncation at wavenumber 30 and is computationally very efficient. Despite its relative coarse resolution, SPEEDY has been shown to reproduce reasonably well the observed variability of the atmospheric circulation in the 20th century (Bracco et al., 2003). The land component consists of a land bucket model with interactive temperature, soil moisture, soil ice, snow depth and run off. The ocean component consists of a hierarchy of models that facilitates studying the mechanisms of climate variability and the role of the oceans therein. Such a hierarchy includes a slab ocean model, a linear ocean model for tropical oceans (Burgers et al. 2001) and a primitive equation isopycnic ocean model (MICOM, Bleck et al. 1992). The slab ocean model can be used in different ways. It can be run in a "qflux" configuration, in which heat fluxes are diagnosed from a run with prescibed SST and then specified, so that only heat transport by the ocean is represented, or including also other processes, such as anomalous Ekman transports, anomalous wind-driven turbulent mixing and anomalous barotropic transport. Regional configurations of these ocean models can be overlayed on the global ocean and land models easily (e.g. it is possible to use MICOM in the Atlantic and a slab ocean in other basins). The coupled model is called SPEEDO (SPEEDy-Ocean).

Except for the atmospheric model, all components have been set up in a Generic Model Framework (GMF). In GMF each module has an initialization phase and a time stepping loop. The latter includes time stepping of the model physics, collection and storing of the output data in a history file, writing of a restart file and preparation for the next time step. Generic functions and subroutines have been developed to implement such a structure in all model components. Each module has a parameter file in which critical parameters such as type of run, calendar, and physical parameters are set. Output and input data are in NetCDF format. SPEEDO uses a distributed coupler implemented as a library that is linked to each component of the coupled system. The modular set up facilitates identifying the role of the different components of the coupled system in determining climate variability and the physical mechanisms involved. More details can be found in a technical report on the model (Hazeleger et al. 2003) together with a validation of the atmospheric component, which is also available in Molteni et al. (2003) and Bracco et al. (2003).

* Contribution to Exchanges No. 28, December 2003

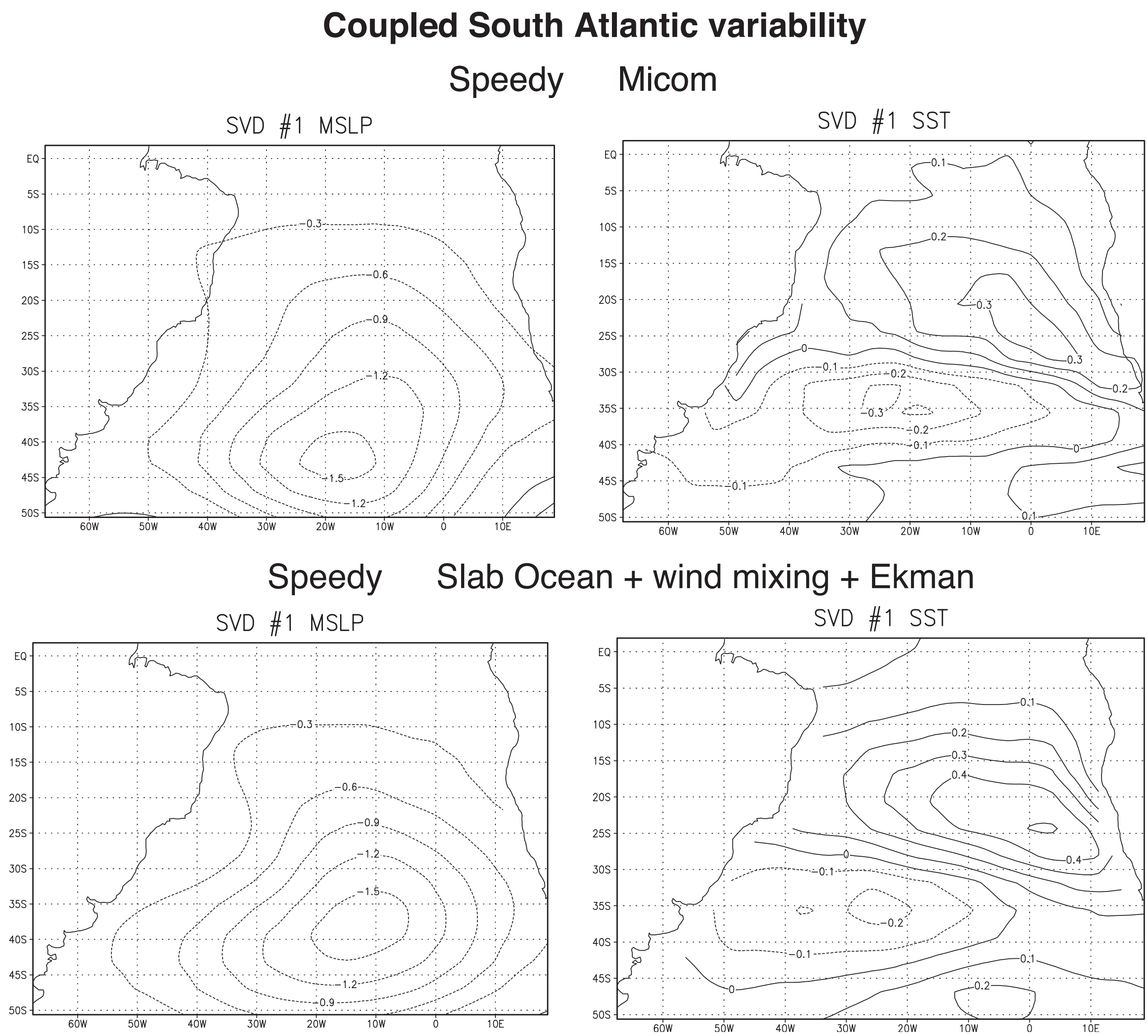

Fig. 1: First SVD pattern of sea surface temperature (right) and sea level pressure (left). Top: the coupled Speedy-Micom model. Bottom: Speedy-Slab Ocean with anomalous wind mixing and anomalous Ekman transport (Haarsma et al., 2003).

South Atlantic climate variability: use of a hierarchy of ocean models.

Here we present an example of a study in which SPEEDO was used to identify the ocean's role in generating coupled variability in the South Atlantic (Haarsma et al., 2003). Observations show that the dominant mode of coupled variability in the South Atlantic Ocean consists of a dipole in SST and a monopole in SLP variability. The data suggest a dominant role of the atmosphere in generating this mode of variability (Venegas et al. 1997), but the ocean does not seem to be entirely passive. Reanalysis data suggest an important role for wind-driven turbulent mixing (Sterl and Hazeleger, 2003).

The SPEEDO model, with MICOM (1 degree resolution in the horizontal, 16 layers) as ocean model in the South and Tropical Atlantic and slab ocean elsewhere, captures the observed dominant mode of coupled variability (Fig 1a and b). To investigate which oceanic processes are involved in generating this mode of variability we used the hierarchy of ocean models. The hierarchy consists of the following: (I) MICOM, (II) slab ocean model (i.e. interactive surface heat fluxes), (III) slab ocean model including anomalous Ekman currents induced by anomalous wind stress, (IV) slab ocean model including anomalous Ekman currents and anomalous turbulent wind-induced mixing, and (V) slab ocean with anomalous Ekman currents, wind-induced mixing and anomalous barotropic flow. When MICOM is replaced by the slab ocean model with anomalous wind-induced mixing and anomalous Ekman transport, the pattern of coupled variability is similar to the observed one (see Fig. 1c). This confirms the results from Sterl and Hazeleger (2003) who found that surface latent heat fluxes and wind-induced oceanic mixing are the most important mechanisms in generating South Atlantic SST variability. However, the model shows that role of Ekman currents is more important than expected from Renalysis data. Although their contribution to generating SST variability is relatively small, Ekman currents have a profound impact on the coupled variability. The role of anomalous barotropic flow is relatively small.

This example shows the attractiveness of using SPEEDO for studies after climate variability. By using different ocean model components, mechanisms that are important for generating coupled variability could be identified. As such, the model is very well suited for CLIVAR-related projects. Further work with SPEEDO is under way in the PATCH (Patterns of climate change) project initiated at KNMI. The project focuses on changes in teleconnections from the tropics to the midlatitudes and, especially, over Europe. The effect of CO_2 rise on the changes in teleconnections gets specific attention. Climate variability in the tropical Pacific and Indian Ocean is also under investigation at ICTP.

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