Modelling El Niño - Southern Oscillation

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El Niño-Southern Oscillation (ENSO) is the strongest natural climate phenomenon on times-cales from months to a few years. Sucessfully modelling and subsequently forecasting ENSO is still a challenge although significant progess has been made during the past decades. IFM-GE-OMAR scientists developed a new model which is currently being tested for ENSO applications.

The El Niño/Southern Oscillation (ENSO) phenomenon is associated with extreme weather conditions around the globe, and hence of major socioeconomic importance. It originates from ocean - atmosphere interaction in the Tropical Pacific. Although its basic nature is understood, climate models still struggle to simulate it faithfully. A major reason for this is ocean - atmosphere interaction, as it amplifies errors intrinsically existing in component general circulation models. Here we describe results for the Tropical Pacific from the first version of the Kiel Climate Model (KCM, Park et al., 2009), a model that will serve as the dynamical core of the earth system model being developed at the Leibniz Institute of Marine Sciences. The model simulates Tropical Pacific climate relatively well: Sea surface temperature (SST) biases are generally less than 1˚C and the annual cycle of SST along the equator matches observations well. Simulated ENSO variability and associated atmospheric patterns are in agreement with observations. Experiments with KCM indicate that ENSO variability will become stronger in response to global warming.

ENSO is characterized by quasi-periodic variations of the Equatorial Pacific SST with a period of about 4 years. Its warm and cold phases are referred to as El Niño and La Niña, respectively. ENSO impacts are felt globally. The record El Niño event of 1997/1998, for instance, "helped" to make 1998 the warmest year to date globally. El Niño events have impacts on almost every aspect of human life: disease outbreaks, low and high agricultural yields, natural disasters, availability of water resources, energy demand, disruption to hydropower generation, price fluctuations, fishery catch fluctuations, animal movements, forest fires, the economic well-being of nations, and many others.

Coupled air-sea feedbacks in the Tropical Pacific influence its annual mean state, annual cycle, and interannual variability. For instance, the existence of an annual cycle in the eastern equatorial Pacific, which is unexpected since the sun crosses the equator twice, is due to such coupled interactions. Also ENSO is an inherently coupled air-sea mode, and its predictability is derived from its coupled nature (Latif et al. 1998). The simulation of Tropical Pacific climate and its variability, however, proves a challenge for global climate model and a wide range of behaviour is simulated. This applies also to the response of the Tropical Pacific to global warming (e. g., Latif and Keenlyside 2009).
In contrast to many models, KCM (Park et al. 2009) simulates Tropical Pacific climate reasonably well. KCM consists of the ECHAM5 atmospheric general circulation model coupled to the NEMO ocean-sea ice general circulation model. No form of flux correction is used. In the Tropics simulated biases are generally not greater than 1˚C, except for the warm biases – common to most models – along the west coasts of South America, North America, and Africa. The annual cycle in the eastern Pacific along the equator in KCM agrees well with observations in terms of strength and westward phase propagation indicating its proper representations of coupled air-sea feedback, which is not the case in many other models.

ENSO variability is also reasonably simulated. The spatial pattern of SST standard deviation generally agrees well with observations, but is stronger (not shown). The standard deviations of observed and simulated Niño3 (150-90˚W, 5˚S-5˚N) averaged SST anomalies is 0.79 and 0.93, respectively. As observed, KCM's ENSO variability has a dominant periodicity of four years. Associated sea level pressure patterns are well represented

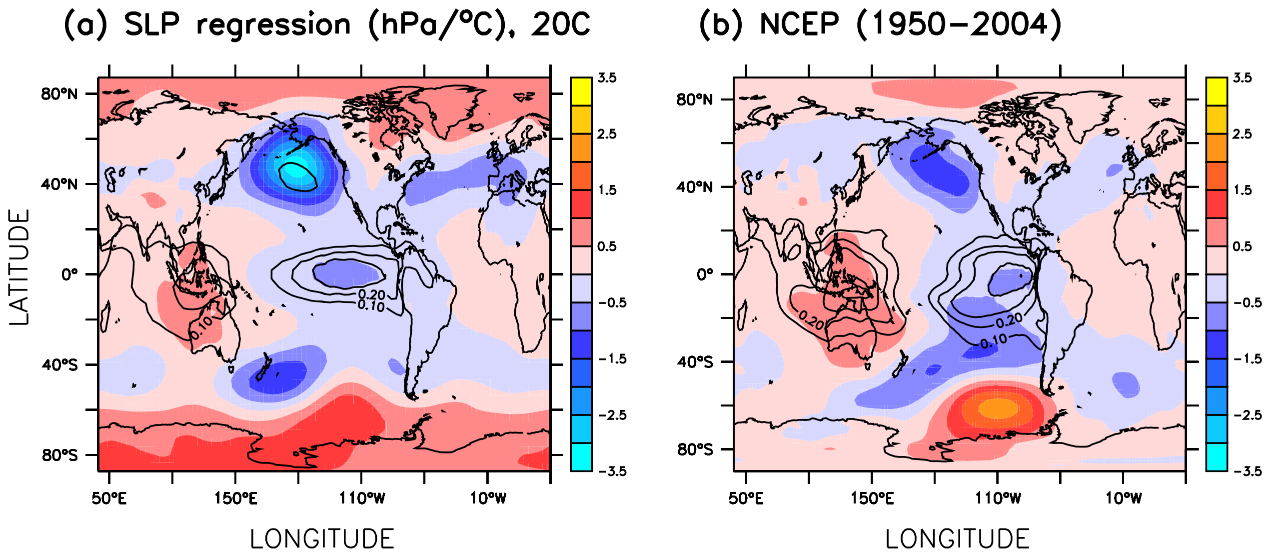

Figure 1: Regression (shading) and explained variance (contour) of monthly anomalies of Niño3 SST onto sea level pressure (hPa/°C): (a) simulated, and (b) observed. From: Park et al. 2009.

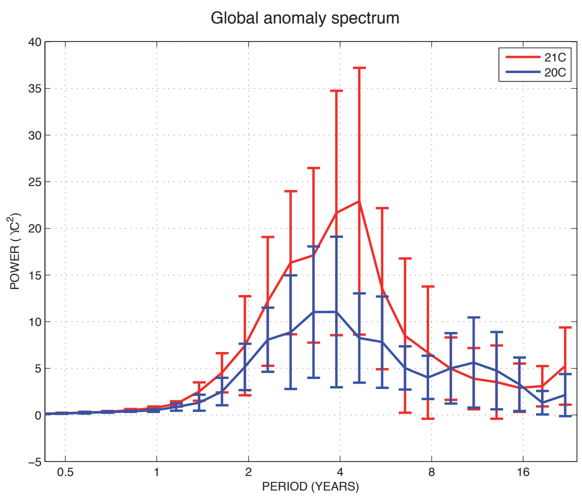

Figure 2: Ensemble-mean spectra [°C²] of Niño3 SST anomalies. Bars indicate the ensemble one standard deviation range. From: Park et al., 2009.

(Fig.1): during warm events the model simulates the typical Southern Oscillation pattern in the Tropics, the intensification (deepening) of the Aleutian low over the North Pacific, enhanced pressure over the eastern South Pacific, and the weak teleconnection over the North Atlantic.

The ENSO response to global warming was investigated in ensemble simulations with CO_2 concentration increasing at 1%/year (compound). The ensemble mean spectrum (21C) displays an increase in variability relative to that derived from the control run (20C) that is most pronounced at interannual timescales (Fig. 2). At the ENSO peak period of about 4 years the increase in power amounts to about 70%. The overall shape of the spectrum does not change much and the ENSO period remains almost constant at about 4 years, although a small shift to a longer period is simulated. The distribution of Niño3 SST anomalies (not shown) becomes wider in the global warming (21C) integrations indicating an overall enhanced variability. Of particular interest, both extreme warm and extreme cold events become more frequent, with stronger changes in the warm extremes.

Next steps will involve the extension of KCM by adding other components of the earth system. Special emphasis will be put on the coupling of ocean biogeochemistry and the investigation of the coupled physical/ocean biogeochemistry response to global warming.

References

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Scientific Highlights