Understanding the response of ENSO to global warming

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ENSO affects climate world-wide including the climate over the continental US (Glantz 2001, Ropelewski, and Halpert 1996, Smith et al. 1999). Potential strengthening of the ENSO cycle in response to global warming is estimated to have severe economical consequences—the annual cost to US alone could be a billion dollars (Chen et al. 2001). Therefore, how ENSO responds to global warming is an issue of both scientific and economical concern, and should figure prominently in the study of global climate change.

Our current understanding of how ENSO responds to global warming is still primitive. The scattered results from the coupled GCM predictions of the response of ENSO reflect this primitive understanding. Some early models suggest that the level of ENSO activity may decrease in response to global warming (Meehl et al. 1993, Tetts 1995, Knutson et al. 1997). The more recent experiments by Timmerman et al (1999) suggest the opposite effect: the level of ENSO activity will increase in response to global warming. Collins (2001) even found different responses of ENSO to global warming in two different versions of the same model. Obviously, the lack of consistency in the model predictions of the response of ENSO to global warming undermines our confidence in using these predictions to address societal concerns.

On the other hand, the existence of significant differences in the model predictions of the response of ENSO to global warming may provide an opportunity to better understand factors controlling the amplitude of ENSO. By comparing simulations of ENSO by various models with different spatial resolutions, Meehl et al. (2001) are able to identify the background diffusion as an important factor in determining the amplitude of ENSO. The logic employed in the study by

Meehl et al. (2001) may be extended to global warming experiments by different coupled models to identify factors influencing the response of ENSO to global warming. CMIP has collected and archived global warming simulations by many coupled GCMs under the same forcing scenarios (specifically, the 1% per year CO2 increase integrations). Such data archives provide convenience for undertaking a diagnostic effort to understand the inter-model differences and thereby improve our understanding of ENSO.

We hypothesize that the scattered results from the prediction of GCMs may be in part due to differences in their predictions of the net surface heating over the Pacific Ocean to CO2 increases. Specifically, we conjecture that the differences in the response of ENSO amplitude to global warming in different models are due to differences in the response in the net surface heating over the Pacific Ocean, the response in the meridional differential surface heating in particular. This conjecture is based on recent theoretical advances in understanding the effect of surface heating on the amplitude of ENSO, specifically, the heat-pump hypothesis (Sun 2003, Sun et al. 2004, and Sun 2004). The heat-pump hypothesis states that the level of ENSO activity is controlled by the meridional differential heating over the Pacific. Either an increase in the tropical heating or an increase in the subtropical/extratropical heating may generate stronger ENSO activity (Sun 2003, Sun et al. 2004, Sun 2004). It has been noted before that different models have different cloud feedbacks (Cess et al 1989, Sun et al. 2003, Sun et al. 2004). Models also differ significantly in their simulations of the feedback from the latent heat flux (Sun et al. 2004). These differences in the feedbacks then result in different responses in the net surface heating to the increase of CO2, causing different responses of ENSO to global warming.

Data required for such an analysis are SST and the net surface heat flux data from 1% CO2 per year compound increase integrations.

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