A regulatory effect of ENSO on the time-mean thermal stratification of the equatorial upper ocean

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[1] To investigate the role of ENSO in regulating the time-mean thermal stratification of the equatorial Pacific, perturbation experiments are conducted in pairs with a coupled model. In one experiment, ENSO is turned off while in the other experiment ENSO is kept on. Perturbations are introduced through either enhancing tropical heating or increasing subtropical cooling. In the absence of ENSO, the time-mean difference between the warm-pool SST (Tw) and the characteristic temperature of the equatorial thermocline (Tc) responds sensitively to either enhanced tropical heating or enhanced subtropical cooling. In the presence of ENSO, such a sensitivity to destabilizing forcing disappears. The lack of sensitivity in the response of Tw-Tc is linked to a stronger ENSO in response to the destabilizing forcing. ENSO in the model acts as a basin-scale heat "mixer" that enables surface heat to be transported to the depths of the equatorial thermocline. The study raises the question whether models with poor simulations of ENSO can give reliable predictions of the response of the time-mean climate to global warming. **Citation:** Sun, D.-Z., and T. Zhang (2006), A regulatory effect of ENSO on the time-mean thermal stratification of the equatorial upper ocean, *Geophys. Res. Lett.*, *33*, L07710, doi:10.1029/2005GL025296.

1. Introduction

[2] The dependence of ENSO on the stability of the time-mean state of the coupled tropical Pacific ocean-atmosphere has been extensively studied [*Neelin et al.*, 1998]. Whether ENSO in turn contributes to the maintenance of the stability of the time-mean climate is less well understood. In this connection, a question of particular interest is the effect of ENSO on the time-mean upper ocean thermal stratification of the equatorial Pacific, namely, the time-mean difference between the warm-pool SST (Tw) and the characteristic temperature of the equatorial undercurrent (Tc). The difference between Tw-Tc is a key parameter that measures the stability of the coupled tropical Pacific ocean-atmosphere [*Jin*, 1996; *Sun*, 1997]. Note that through upwelling, this difference controls the zonal SST contrast and therefore the strength of the zonal winds. It has been suggested that the time-mean climate state of the coupled tropical Pacific ocean-atmosphere hovers closely around its neutral point [*Penland and Sardeshmukh*, 1995; *Penland et al.*, 2000]. What prevents the time-mean coupled system from becoming substantially unstable? Could it be ENSO?

[3] A role of ENSO in regulating the stability of the time-mean state of the coupled system has been suggested by recent analyses of the role of ENSO in the heat balance of the tropical Pacific [*Sun*, 2000, 2003; *Sun et al.*, 2004]. What destabilizes the coupled tropical ocean-atmosphere system is the meridional differential heating. Tropical heating tends to increase the SST of the warm-pool (Tw). Subtropical cooling tends to reduce the temperature of the equatorial thermocline (Tc) as the cooling can be extended to the equatorial subsurface through subduction [*Shin and Liu*, 2000, *Sun et al.*, 2004]. If ENSO corresponds to a mechanism of downward and poleward heat transport, there is a good chance that ENSO may play a role in stabilizing the time-mean state of the coupled tropical Pacific ocean-atmosphere system. The reasoning here is similar to the reasoning that has led to the hypothesis that the neutrality of the time-mean thermal structure of the tropical troposphere to moist convection is due to moist convection [*Xu and Emanuel*, 1989]. (As radiative heating of the surface and cooling of the interior of the atmosphere destabilize the atmosphere, moist convection takes place to deliver heat from the surface to the free troposphere. Consequently, the mean lapse rate is strongly regulated).

[4] Whether the analogy with the relationship between moist convection and the lapse rate of the tropical troposphere is entirely pertinent to the relationship between ENSO and the value of Tw-Tc, it appears to be appealing enough to test the hypothesis that ENSO may play a fundamental role in regulating the stability of the time-mean state of the coupled tropical Pacific ocean-atmosphere, in general, and the long-term mean value of Tw-Tc in particular. The purpose of this paper is to report the results from a group of numerical experiments that were especially designed to test this hypothesis. A hallmark of ENSO is the zonal "sloshing" of water in the equatorial upper Pacific [*Philander*, 1990]. So from a pure phenomenological perspective, it is of interest to investigate the effect of the recurrent occurrence of ENSO on the time-mean upper ocean temperature structure.

[5] This paper is organized as follows. First, the methodology is briefly described in section 2. Section 3 presents the results. Summary and discussion are provided in section 4.

2. Methodology

[6] Our method to test this hypothesis is through conducting numerical experiments in pairs with a coupled model. In one experiment, ENSO is turned off. We turn off ENSO in the model by setting the coupling coefficients between the SST and surface winds in the equatorial region to zero. In the other experiment, ENSO is kept on. We then contrast the differences in the response in the time-mean

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higher level of ENSO activity generally warms the thermocline water and cools the surface western Pacific. Figure 4 also suggests a warming effect of the presence of ENSO on the surface ocean of the central Pacific and cooling effect on the surface ocean near the eastern boundary, consistent with our earlier inference from Figures 1 and 2. Corresponding calculations from the subtropical cooling experiments lead to the same results. The gross features shown in Figure 4 are similar to those in Figure 11 of *Schopf and Burgman* [2006].

4. Summary and Conclusion

[14] Numerical experiments have been carried out to investigate the role of ENSO in regulating the stability of the time-mean state of coupled tropical Pacific ocean-atmosphere system. The results suggest that ENSO acts as a basin-scale heat mixer that prevents any significant increase from occurring in the time-mean difference between the warm-pool SST (Tw) and the temperature of the thermocline water (Tc). A positive perturbation to the value of Tw-Tc results in a higher level of ENSO activity, which damps out this perturbation. The finding that a higher level of ENSO activity tends to cool the western Pacific warm-pool and warm the subsurface thermocline water is consistent with the results from *Schopf and Burgman* [2006].

[15] Given the regulating effect of ENSO on the time-mean state of the equatorial upper ocean, one naturally wonders about the reliability of predictions of global warming made by climate models that do not have good simulations of ENSO. Moreover, if ENSO regulates the stability of the time-mean climate, using changes in the time-mean climate to predict changes in the level of ENSO activity could be problematic. Therefore, the present results echo the concern raised by *Schopf and Burgman* [2006]. The results also lend support to the suggestion by *Rodgers et al.* [2004] and *Yeh and Kirtman* [2004] that the tropical Pacific decadal variability may be more a consequence of the decadal variations in the level of ENSO activity than a cause of them. In the same vein, some outstanding biases in the coupled GCM simulations of the time-mean tropical Pacific SST, such as the excessive cold-tongue [*Sun et al.*, 2006], may not just be a cause of errors in the simulated ENSO—it could well be a consequence of the poor simulation of ENSO as well.

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