ENSO PREDICTABILITY AND PREDICTION STUDIES AT NCAR

Joseph J. Tribbia, Peter Gent and H-L Lee
National Center for Atmospheric Research
Boulder, Colorado, USA

1. INTRODUCTION

For several years the National Center for Atmospheric Research (NCAR) has developed and improved its capabilities in the general scientific area of the study of seasonal to interannual variability from the perspective of simulation and prediction using a coupled atmosphere ocean model. Over this time, the component models have been improved both in their ability to simulate and predict ENSO phenomena and in the number and complexity of the physical processes incorporated. We will review here two incarnations of the NCAR system, and the ability of these models to reproduce observed equatorial Pacific SST variability, estimate ENSO predictability and "predict" in historical prediction mode the warm event of 1982–83.

2. SIMULATION

The first version of the NCAR system was designed to be a minimal model for ENSO within the constraint of coupling an atmospheric GCM to a reasonably complete model of the equatorial Pacific. Balancing the competing aspects of these requirements led to a configuration which included a radiationally simplified version of NCAR CCM1 run at Trapezoidal 21 resolution to maximize atmospheric resolution in the tropics and a reduced gravity upper ocean (upper 400 m) primitive equation ocean component with active dynamics and between 20 degrees North and South. In addition to the above noted simplifications, the surface conditions for the atmosphere outside the latitude band of ±20 degrees and the longitudinal domain of 130°E to 80°W consisted of ocean surface at prescribed seasonally varying sea surface temperatures. More details of the radiative simplifications and the model configuration can be found in *Gent and Tribbia* (1993).

After some tuning of the empirical parameters within the AGCM, e.g., the surface roughness length over the ocean and the imposed radiative forcing, a reasonable facsimile of observed interannual variability of SST in the tropical Pacific was simulated (Figure 1). In comparing this to a Hovmoller of COADS SST for the decade of 1979–1989, one can notice that while interannual variability on the biennial time scale is rather well simulated by this configuration, variability in the quadrennial time range is under-represented by about a factor of two or more (*Gent and Tribbia*, 1993). This will have some bearing on the examination of ENSO predictability within this system, which is discussed below. Other aspects of SST variability examined the spatial structure of the interannual variations in SST. EOF analysis and a comparison of the spatial structure of the coupled model leading EOF with that computed from COADS showed a strong similarity with again the amplitude of the principal component associated with the leading EOF being about one half as large in the coupled model as compared to the COADS observations.

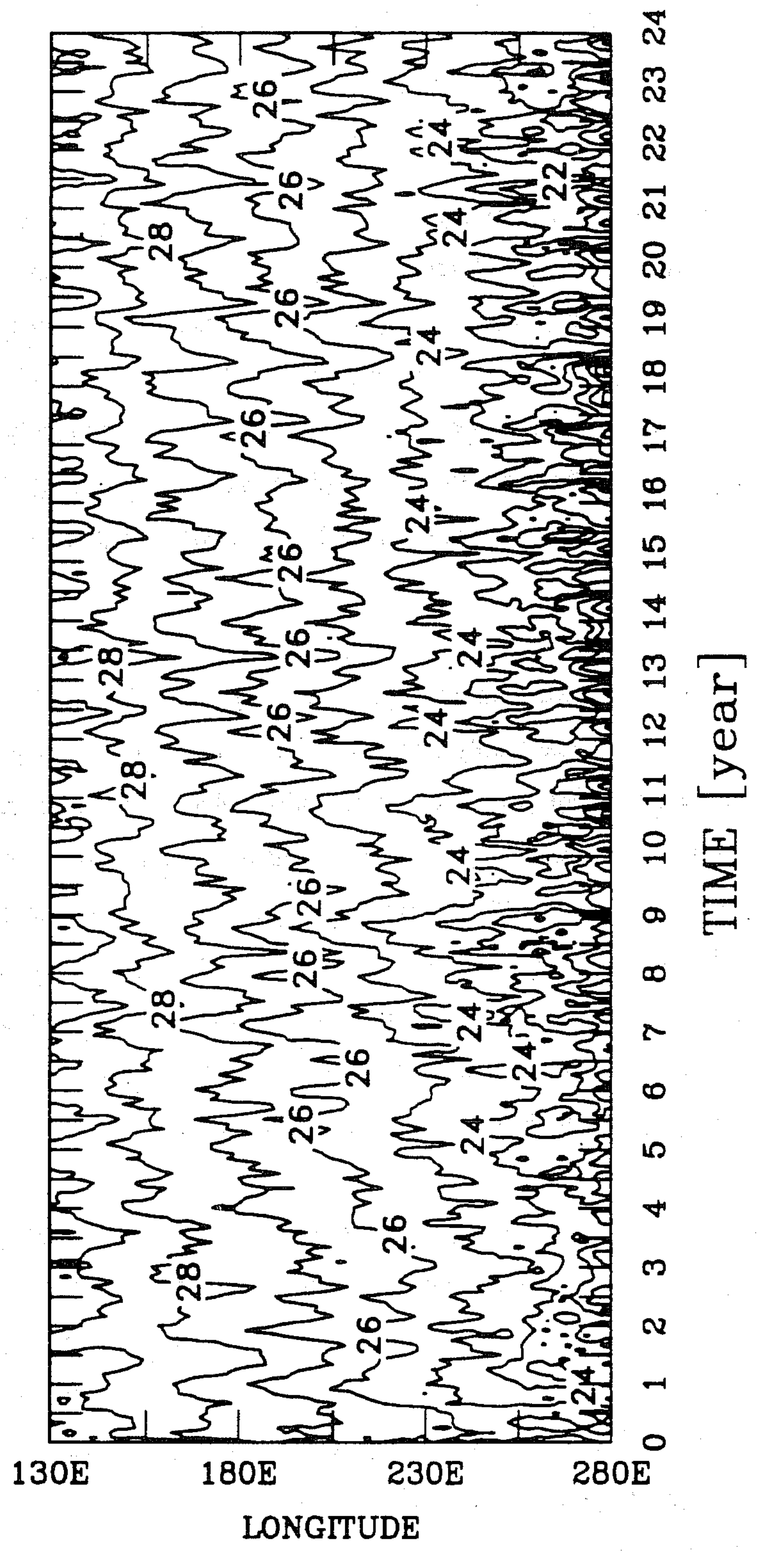

Figure 1 Hovmoller diagram of SST along the equator in "Pacific basin" as simulated in the first NCAR ENSO model configuration. Time in years increases vertically. SST in degrees Celsius averaged between ±5 degrees latitude.

3. INTERANNUAL PREDICTABILITY

Despite the somewhat weaker than observed ENSO time scale variability, it was deemed worthwhile to examine the predictability of such variations in the framework of coupled system that included (essentially) GCM components for both the atmosphere and ocean which were coupled without flux adjustments. Since any predictability study using models is only an imperfect estimate of the true predictability of the natural system, estimates with various models, modeling frameworks and methodologies are useful in determining a range of potential predictability. Possible modeling frameworks include no flux adjustments with (likely) incorrect variability, flux adjustments with artificial coupling to maintain climatology and anomaly coupling with artificial coupling constants to maintain variability; different methodologies include initializing from model climate or observed conditions and identical or fraternal model twin framework. Each choice of configuration and methodology biases the estimate in some fashion and all should be attempted to obtain the range of possible outcomes.

In *Gent and Tribbia* (1993) the control run discussed above was used in an identical model twin experiment in which twenty perturbed ENSO "forecasts" were produced at roughly six month intervals between year 8 and year 16 of the simulation. The perturbed forecasts were performed by adding a very small SST perturbation of less than one tenth of a degree Celsius in the spatial form of the leading EOF to coupled model and integrating the forecast forward. In the mean, it was found that the PC associated with the leading EOF of SST remained correlated above the .5 value in the control and forecast integrations for only six months, surprisingly short compared to the skill of persistence forecasts and the skill of statistical forecasting techniques for ENSO events occurring in nature. An even more surprising result from this study can be seen in figure 3 which depicts the decorrelation in time for the leading EOF's PC in the least skillful (Case 1) and most skillful (Case 5) experiments for two different levels of initial perturbation SST. As can be discerned from this figure, the decorrelation rate is nearly identical for perturbations in SST of order .1 and .0001. This result was examined in detail and found to be caused by a rapid amplification of air–sea flux perturbations associated with high frequency weather phenomena in the atmosphere. This rapid amplification has been recently verified by a number of groups and may be realistic in a coupled system with many spatial and temporal degrees of freedom, or may be an artifact of current model parameterizations. In any case, the fact that the rapid decorrelation equilibrates below the level of useful skill (.5), is likely due to the weak amplitude of quadrennial variability in the model.

4. HISTORICAL FORECASTS

With the advent of a new version of the NCAR CCM (CCM2) and additional computer power, we were encouraged to revamp our coupled system to take advantage of these developments. Our first attempts were not very successful, as can be seen from the coupled model comparison of seasonal cycle simulations

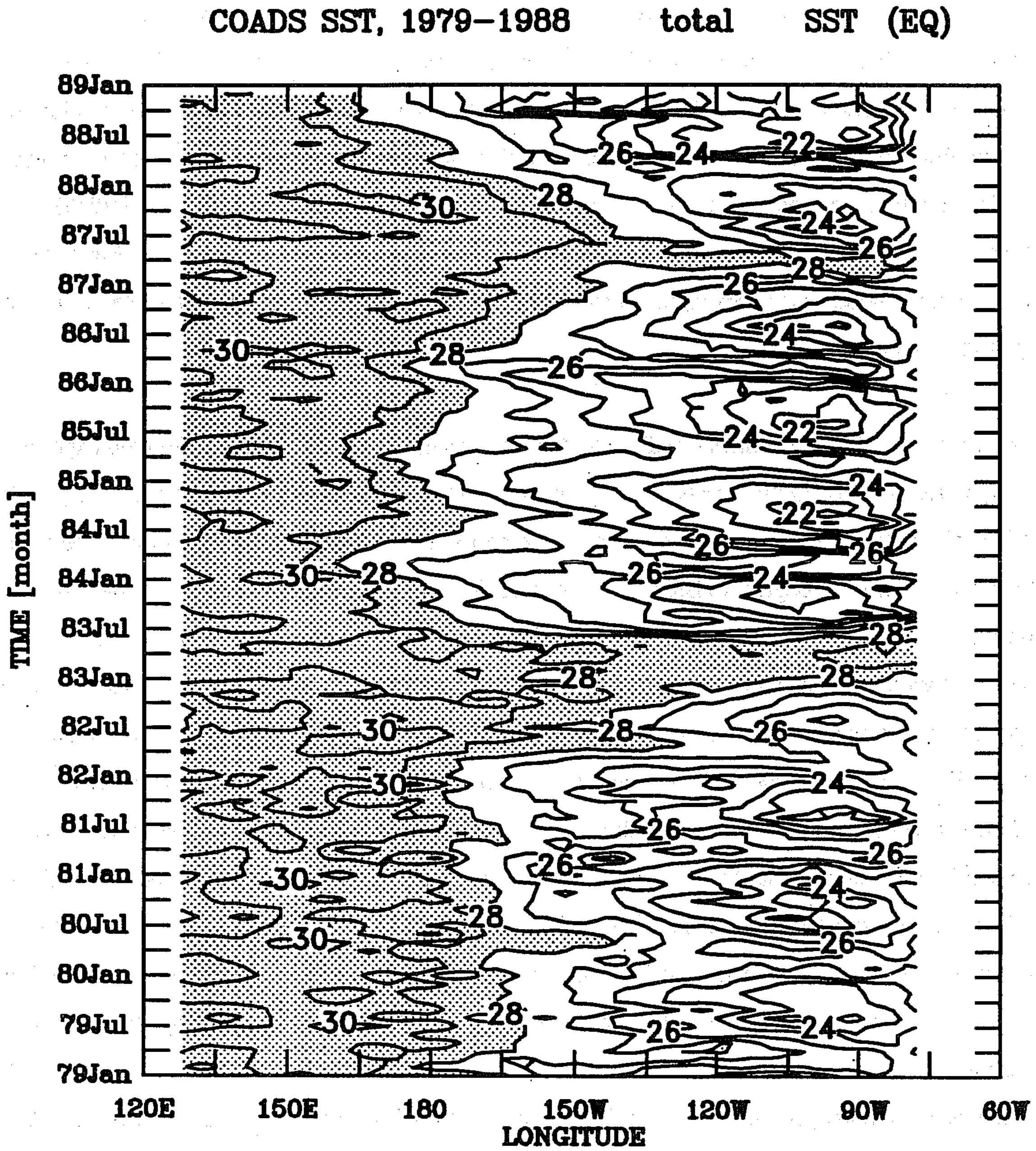

Figure 2 As in figure 1 but for COADS SST analysis. Years depicted are 1979 to 1989.

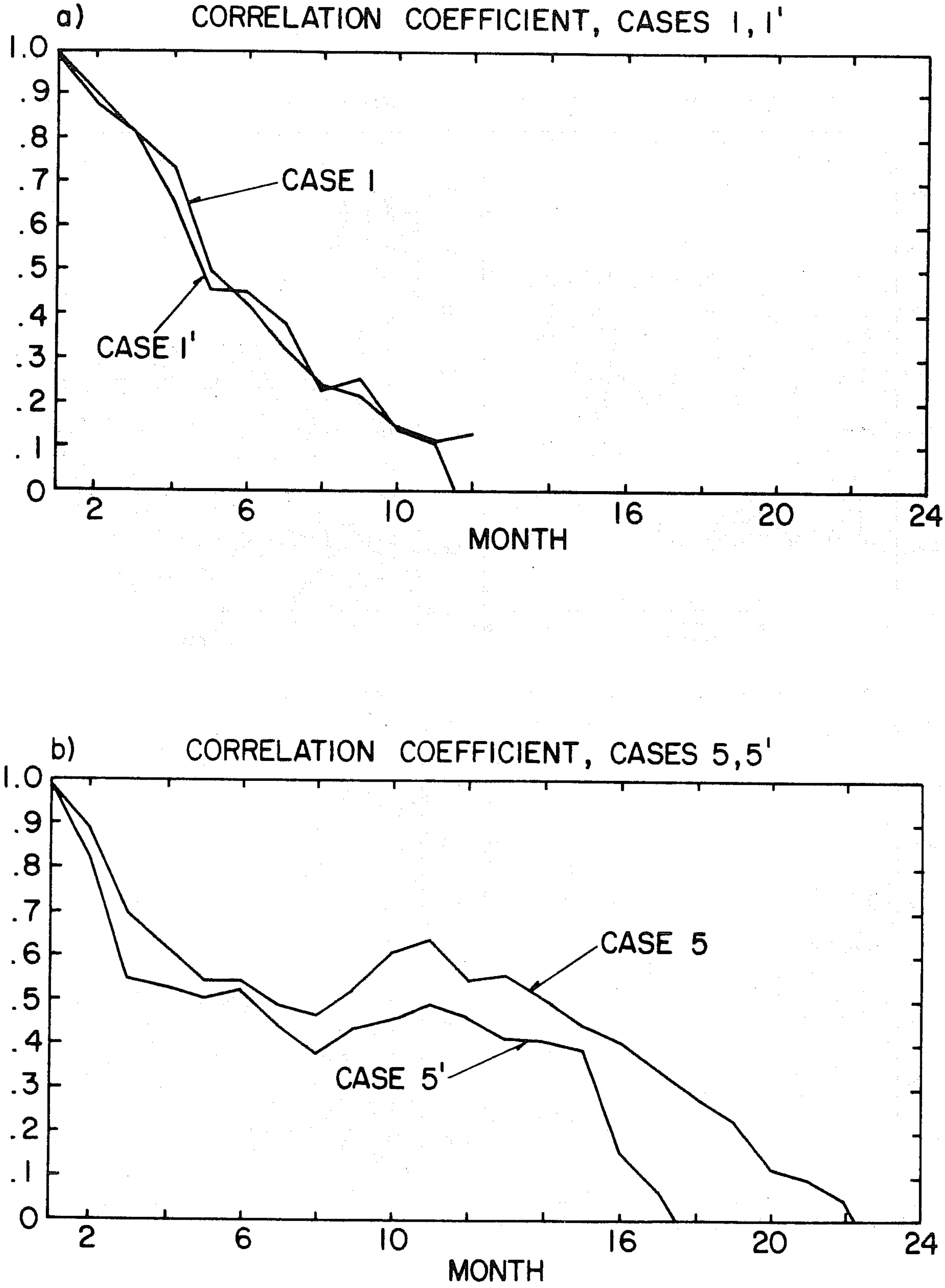

Figure 3 Anomaly correlation score for SST associated with the PC of the leading EOF for both the best and worst case of the twenty cases run. Primed curves correspond to initial perturbations of .1 degree Celsius, while unprimed curves correspond to initial perturbations of .0001 degrees.

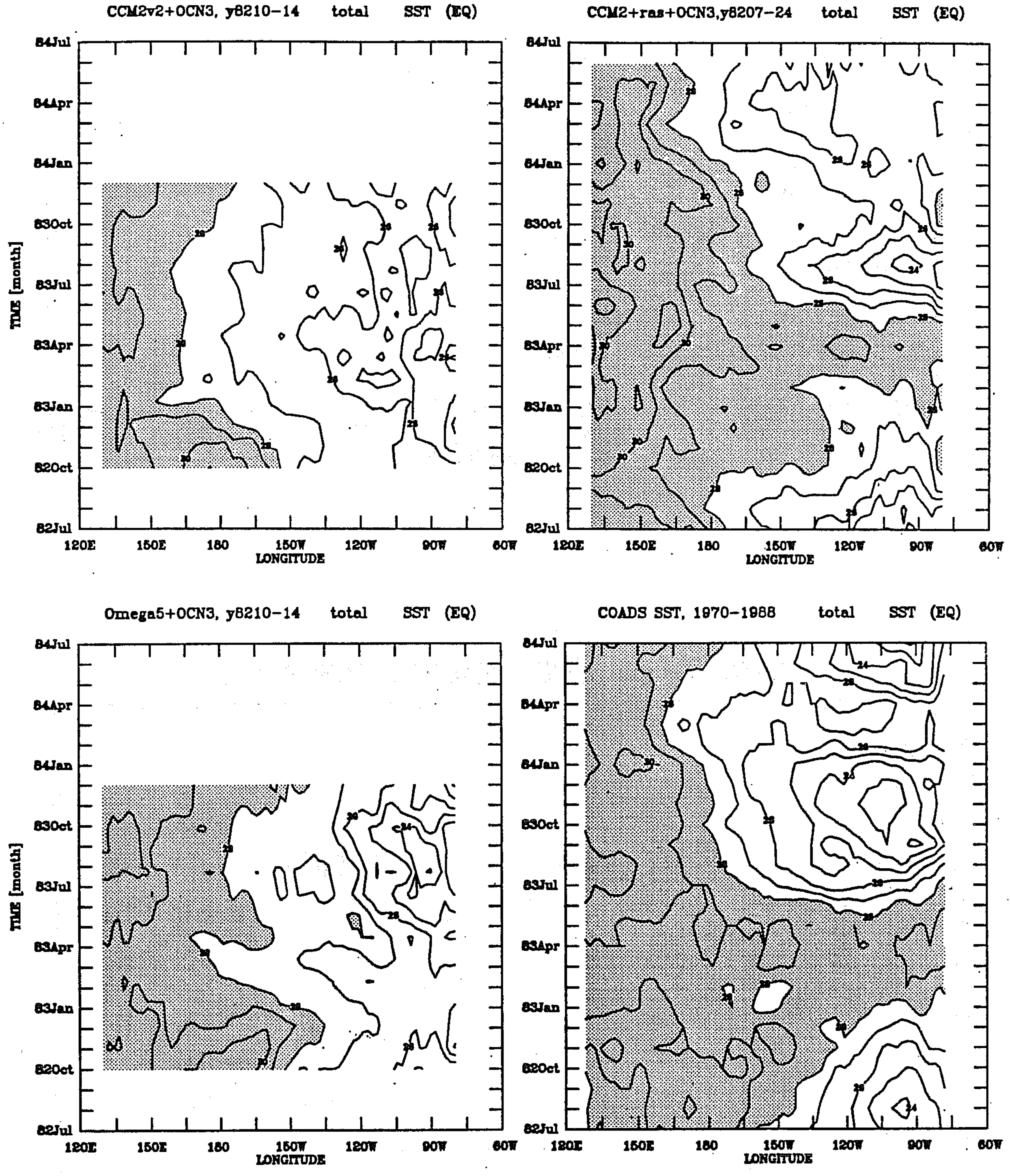

Figure 4 Left hand panels depict hindcasts made with standard CCM2 and CCM2 with some improvements (upper and lower respectively) with the simple mass flux convective parameterization. Upper right panel is hindcast of the 1982–83 ENSO event using the RAS convection scheme. Lower right panel is COADS analysis for this period. Shading is SST greater than 28 degrees Celsius.

described in *Mechoso et al.* (1995). In order to correct the major deficiencies of our coupled system both the atmosphere and ocean component models required developmental improvements. On the atmosphere side, a major improvement in our tropical simulation was obtained by replacing the simple mass flux cumulus convection parameterization of the standard CCM2 with the more elaborate Relaxed Arakawa–Schubert (RAS) scheme of *Moorthi and Suarez* (1991). On the ocean side, the addition of a parameterized PBL using a K–profile formulation as in *Large et al.* (1994) significantly improved the simulation of the seasonal cycle in the Pacific.

Buoyed by our improvements in the simulation of the tropical atmosphere using CCM2 with the RAS scheme, we attempted some historical prediction experiments (hindcasts) of the 1982–83 warm event. Figure 4 shows the Hovmoller of SST along the equatorial Pacific for various versions of CCM2 without RAS (left panels) and including RAS (upper right panel) along with the COADS SST for the period July 1982 to July 1984. All forecasts were initialized using FSU winds to drive the ocean model and all forecasts were fully coupled using CCM2 at T42 and begun on July 1, 1982. As can be seen in this figure, only the version of CCM with RAS is able to capture the basin wide warm event obvious in January of 1983.

5. CONCLUDING REMARKS

Despite the obvious successes of our recent developments, many improvements are still needed to reach our goal of an accurate simulation and prediction of the ENSO phenomenon using GCMs as components. As the example of the rapid predictability loss in our first configuration exemplifies, there is much yet to be learned regarding the behavior of both the coupled variations in models and in nature.

6. REFERENCES

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