Inter-Annual Variability Simulated in a Coupled Tropical Ocean Global Atmosphere General Circulation Model

Francis W. Zwiers
Canadian Climate Centre
Downsview, Ontario, Canada

Hans von Storch
Max Planck Institute fuer Meteorologie
Hamburg, F.R. Germany

1. Introduction

The purpose of this note is to report some initial results of the atmospheric variability in a recently completed 10 year simulation with a coupled tropical Pacific Ocean general circulation model and a low order atmospheric general circulation model (see Latif and Biercamp in this issue).

2. Simulation of SST

As is shown by Latif and Biercamp (this issue), the most striking feature of the SST field simulated in this coupled run is a gradual cooling which is most prominent in the equatorial Pacific ocean. The rate of cooling is highest during the initial year of the simulation, and highest directly at the equator (as much as 0.1¡C/year in this region).

The linear component of the trend in DJF SST is illustrated in Fig. 1. It is significantly large in a statistical sense in the equatorial Pacific region, but the large trend appearing over Siberia cannot be distinguished from interannual variability with sufficient reliability.

Interannual standard deviations of seasonal mean SSTs do not exceed 0.5¡C. However, some of this variability is "potentially predictable" (Zwiers, 1987); i.e., larger than would be expected to arise only from short time scale fluctuations occurring within the simulated ocean, and the simulated ocean does show events in which considerable portions of the ocean are anomalously warm over extended periods of time. These anomalies are not anywhere near as large in amplitude or spatial extent as an "El-Niño".

3. Response of the Coupled Atmosphere

The response of the coupled atmosphere to the slowly cooling ocean may be clearly seen in 300mb velocity potential. Fig. 2 illustrates the difference of means in this quantity between the coupled run and an earlier simulation with the AGCM forced by prescribed SST for the DJF season. The illustrated difference is typical of that observed in all seasons. The signature of reduced heating from below all over the equatorial Pacific is reflected in the strong wave number one structure: Cooler Pacific SSTs evidently result in reduced evaporation, hence reduced precipitation and subsequently, anomalous convergence in the upper troposphere above the ITCZ.

Outside of the Pacific region, there is increased upper air divergence, which may be seen as balancing the anomalous vertical flow over the Pacific. The area of anomalous ascent is larger than in the area of anomalous subsidence, while the positive anomalies are stronger than the negative ones.

A clear time dependent signal can also be seen in 300mb velocity potential. A linear trend (not shown) is plainly evident in the seasonal means of this quantity. The geographical pattern of trend coefficients is similar to that of the difference in means, with positive trend coefficients over the Pacific and negative values elsewhere. Rates of increase are as large as $0.3 \times 10^6 m^2/s/year$ in the tropical Pacific and as low as $-0.45 \times 10^6 m^2/s/year$ over the Indian Ocean. Both the difference of means and the trend are statistically significant features of the coupled simulation. There is weak evidence for a trend of opposite sign in the uncoupled run. After taking trend into account, there is no evidence for potentially predictable variations in velocity potential in either simulation.

There are also considerable differences in the simulation of 300 mb stream function between the two simulations. The clearest response to the interactive ocean is evident in JJA over the western tropical Pacific where it is possible to see changes in the tropical circulation which are characteristic of negative equatorial SST anomalies (Gill, 1980). The differences in the means are again statistically significant. Unlike velocity potential, a significant trend is not evident in stream function. However, this variable does show considerable evidence for potential predictability which is enhanced in the coupled simulation even though the underlying ocean does not have a great deal of variability.

There is a large difference in sea level pressure simulated by the coupled and uncoupled models for reasons which we do not fully understand. Tropical surface pressures are generally 2mb lower in the coupled run in all seasons. However, Antarctic surface pressures are generally higher, particularly in the transition seasons when the increase is as much as 6mb. The Aleutian low is not as deep in NH winter as in the uncoupled run. These changes, taken together with the observation that the inter-annual variance of slp in the coupled climate tends to be lower than in the uncoupled climate, suggest that the coupled atmosphere is, for some reason, somewhat less energetic than the uncoupled atmosphere, at least on interannual time scales. This observation is more or less consistent with the presence of a continually cooling underlying ocean, in the sense that the ability of the ocean to act as an unlimited heat source decreases with time, and that there is subsequently a less active tropical circulation.

Also consistent with this picture is the change in 850 mb temperature which is observed. The changes may be characterized by an increase in tropical and midlatitude temperatures of between 0.5°C and 1°C in most seasons and a decrease in polar temperatures. This is perhaps an indication that a less vigorous tropical circulation is transporting less heat poleward.

References

Gill, A.E., 1980, Quart. J. Roy. Met. Soc., 106, 447-462

Latif, M., and J. Biercamp, this issue.

Zwiers, F.W., 1987, Mon. Weath. Rev., in press.

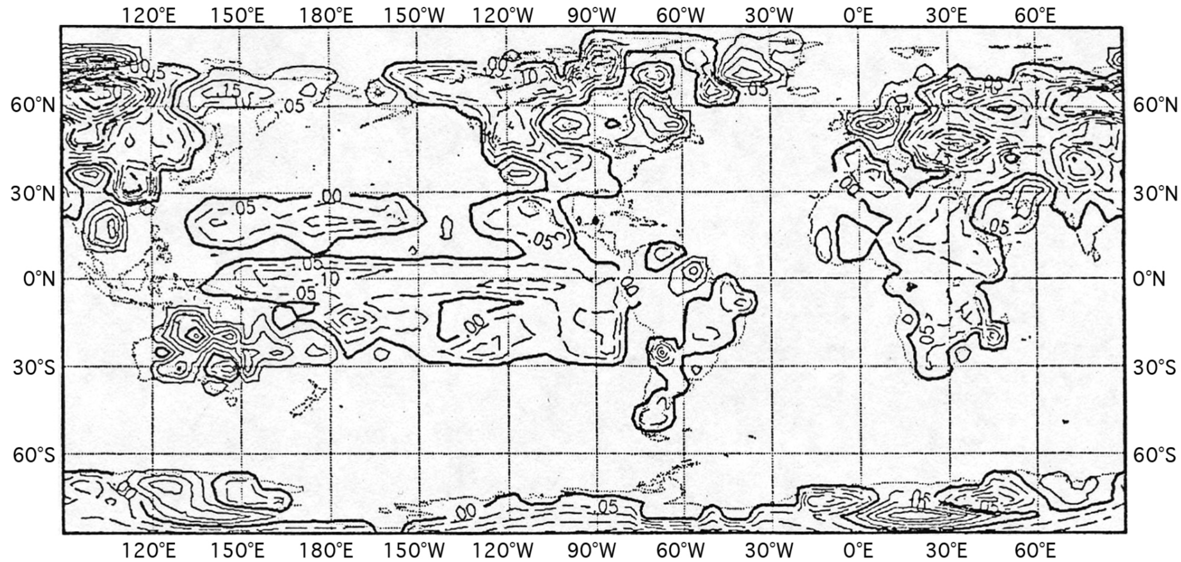

Figure 1: Linear trend coefficients of DJF mean surface temperatures. The contour interval is 0.05°C/year. Statistically significant rates of decrease of approximately 0.1°C/year are seen in the western equatorial Pacific. The negative trend coefficients in excess of 0.5°C/year over Siberia are not statistically significant.

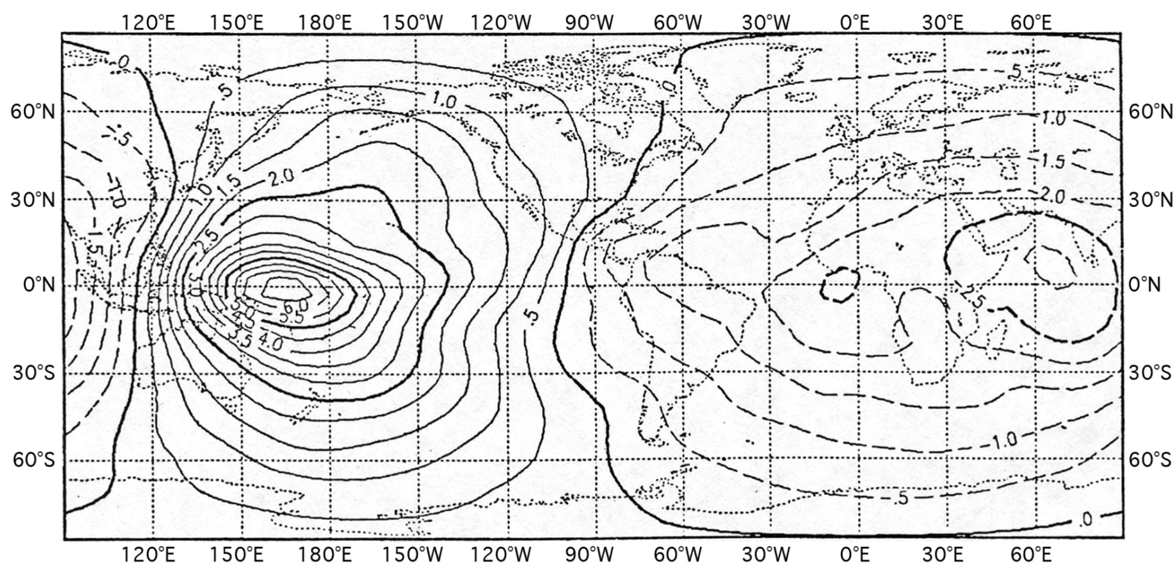

Figure 2: The difference between mean DJF 300 mb velocity potential in the coupled and uncoupled simulations. The contour interval is $0.5x10^{6}m^{2}/s$.