P2.10

NUMERICAL EXPERIMENTS WITH A ZONALLY SYMMETRIC CLIMATE MODEL

Sergio H. Franchito

Center for Weather Forecasting and Climate Research
Institute for Space Research

Vadlamudi B. Rao

Laboratory for Atmospheric and Oceanic Research
Institute for Space Research
São José dos Campos - SP - Brazil

1. INTRODUCTION

A great deal of effort in climate modeling has been devoted to study the variations in the the climate caused by modifications in the surface boundary conditions, particularly, the climatic impact caused by sea surface temperature anomalies and by deforestation. An efficient way of obtaining some preliminary ideas of the climatic effects is using a simple climate model. Such a model is useful in experiments related to long-term climatic changes particularly when a large number of experiments are realized. However, very few tests concerning the climatic impact of surface boundary conditions modifications have been conducted with simple models. For example, Wiin-Nielsen (1986) simulated a simple situation of "El Niño" using a hemispheric statistical-dynamic (SD) quasi-geostrophic model; and Potter et al. (1975) studied the effects of the removal of tropical rain forest using a SD primitive equation model.

In the present study we propose to make a series of experiments with a SD zonally averaged model to investigate the influence on climate caused by sea surface temperature anomalies and by deforestation. In the former case the following effects are examined: a) a "El Niño" situation; b) "La Niña" situation; and c) the effects of dipole mechanism involving the centers of positive and negative anomalies studied by Moura and Shukla (1981). In the latter case is considered a situation of the removal of tropical forest, like in Potter et al. (1975). The model is global in extent and so permits the study of Southern Hemisphere conditions also.

2. THE MODEL

The model developed is a two-level SD primitive equations model in sigma- coordinate system, similar to that used by Taylor (1980). However some improvements were done to permit the inclusion of some important climatic processes. The model is extented to Southern Hemisphere and some processes not considered by Taylor (1980) were incorporated: the effects of latent heat of condensation, evaporative cooling and sub-surface conduction. These processes are important in the surface and atmospheric heat balance. The functional form of the physical processes was taken from Saltzman (1971). The latent heat of condensation considered was similar to that given in Gutman et al.(1984).

3. RESULTS

The experiments carried out considering the case of sea surface anomalies were: a) "El Niño" situation (Experiment 1); b) "La Niña" situation (Experiment 2); and c) dipole case (Experiment 3). The principal results (perturbed minus control) regarding the zonally averaged temperature at 500 mb, the zonally averaged zonal wind at 250 mb and the zonally averaged precipitation are shown in Figs 1-3, respectively. The most notable deviations occur in the perturbed areas. In the Experiment 1 there is an increase in the 500 mb temperature, with the largest variation occuring in the region where the source of anomalies is strongest. As a consequence of the thermal wind balance the zonal wind is intensified in both the hemispheres, with the largest variation occuring in the latitudes belt imediately situated northward (southward) from the perturbed area in the Northern (Southern) Hemisphere. These results agree with those of Wiin-Nielsen (1986). As a consequence of the intensification of the Hadley cell and the increase of the evaporation (not shown) there is an increase in the precipitation in the tropical region.

The opposite is observed in the Experiment 2: there is a decrease in the intensity of the zonal wind and in the 500 mb temperature. The Hadley cell is weak and the evaporation decreases (not shown) so the precipitation is reduced in the equatorial region. In the Experiment 3, the 500 mb temperature increased (decreased) northward (southward) from 10°S, with the largest variation occuring in the area where the souce is strongest. The 250 mb zonal wind increases northward from the maximum of the source in the Northern Hemisphere. In the Southern Hemisphere the largest increase also occurs northward of the region where the source is more intense. The rising motion in the Hadley cell increases in the Northern Hemisphere and decreases in the Southern Hemisphere, and the same occurs with the evaporation (not shown), so that there is an enhancement in the precipitation in the tropical region of the Northern Hemisphere and a reduction in the Southern Hemisphere. These results agree with those given in Moura and Shukla (1981).

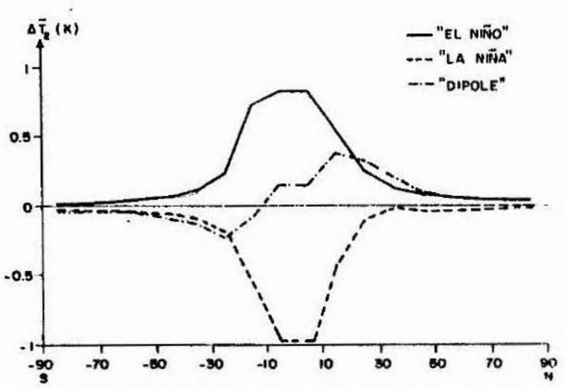

Fig. 1. The zonally averaged temperature at 500 mb in the Experiments 1-3 (perturbed minus control case).

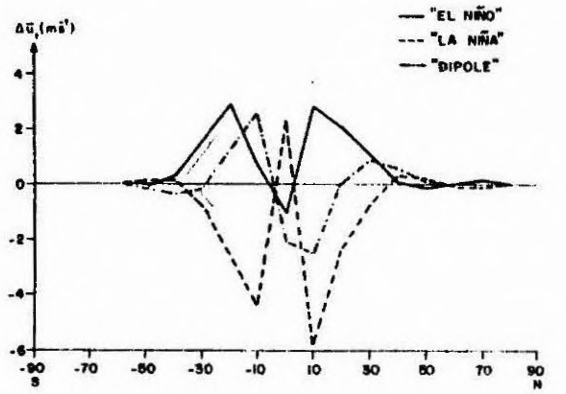

Fig. 2. The zonally averaged zonal wind at 250 mb in the Experiments 1-3 (perturbed minus control case).

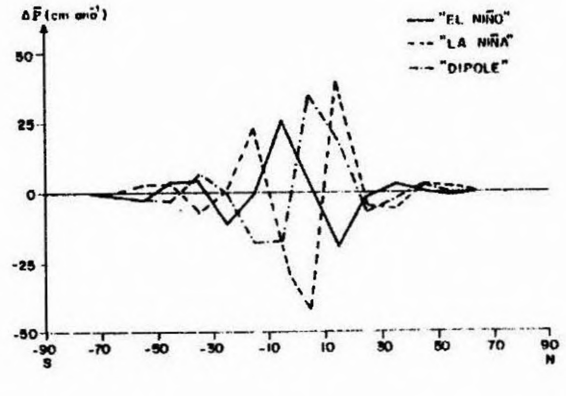

Fig. 3. The zonally averaged precipitation in the Experiments 1-3 (perturbed minus control case).

In the Experiment 4 a deforestation case was simulated where all the tropical forest was removed. A value of 0.25 for land surface albedo was assigned in the belt between 5°S and 5°N like in Potter et al. (1975). The principal results (perturbed minus control) refering to the alterations in the zonally averaged surface temperature, the 250 mb zonally averaged zonal wind and the zonally averaged precipitation are shown in the Figs 4-6, respectively. The surface temperature variations are small, however a decrease in the tropical region caused by the larger surface albedo value is noted. The 500 mb temperature variations are still smaller (not shown). It is also noted that a small decrease in the 250 mb zonal wind occurs when the forest is removed. The weakness of the Hadley cell and the reduction in the evaporation (not shown) contributes to the smaller precipitation values in the equatorial region. These results agree with those from Potter et al. (1975), however the variations obtained in that work were larger.

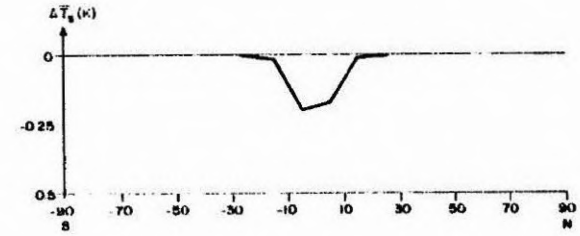

Fig. 4. The zonally averaged surface temperature in the Experiment 4 (perturbed minus control case).

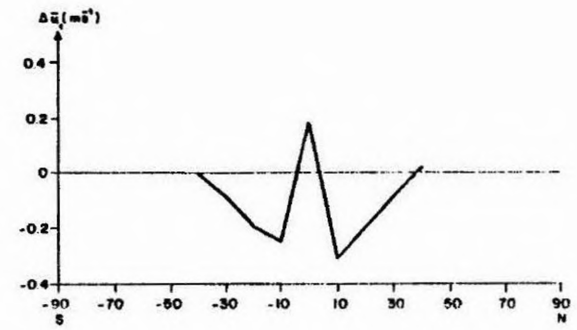

Fig. 5. The zonally averaged zonal wind at 250 mb in the Experiment 4 (perturbed minus control case.

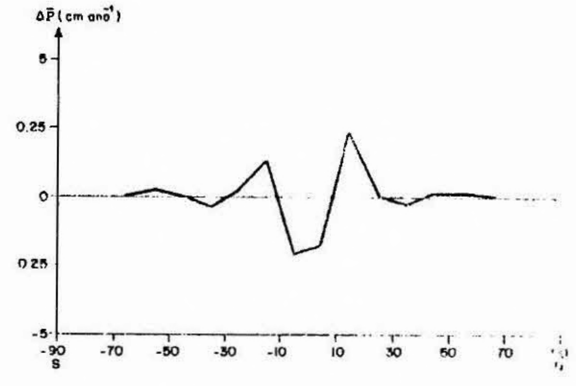

Fig. 6. The zonally averaged precipitation in the Experiment 4 (perturbed minus control case).

4. REFERENCES

Gutman, G., G. Ohring and J.H. Joseph, 1984: Interaction between the geobotanic state and climate: A suggested approach and a test with a zonal model. J. Atmos. Sci., 41, 2663-2678.

Moura, A.D., and J. Shukla, 1981: On the dynamics of droughts in northeast Brazil: Observations, theory and numerical experiments with a general circulation model. J. Atmos. Sci., 38, 2653-2675.

Potter, G.L., H.W. Ellsaesser, M.C. MacCracken and F.M. Luther, 1975: Possible climatic impact of tropical deforestation. Nature, 258, 697-698.

Taylor, K.E., 1980: The roles of mean meridional motions and large-scale eddies in zonally averaged circulations. J. Atmos. Sci., 37, 1-19.

Wiin-Nielsen, A., 1986: On simple estimates of the impact of heating anomalies on the zonal atmospheric circulation. Annales Geophysicae, 4, B: 365-376.