A SHORT SURVEY ON THE ATMOSPHERIC MODELING STUDIES CONDUCTED AT INPE'S

J. P. BONATTI, S. H. FRANCHITO, M. A. M. LEMES AND YOSHIHIRO YAMAZAKI

Department of Meteorology
Instituto de Pesquisas Espaciais - INPE

ABSTRACT

The main purpose is to present a brief but comprehensive account of the activities being conducted at the Atmospheric Modeling Center (CEMA/INPE), in the area of numerical modeling of the atmosphere and oceans. Basically, these activities cover a broad spectrum of problems that have been successfully tackled by numerical techniques, ranging from the simulation of the general circulation features to boundary layer studies, including some aspects of the oceaninc modeling. Numerical Weather Prediction is also considered from the practical viewpoint, together with the observational requirements to be fulfilled and the objective analyses and initialization schemes, necessary to make it operationally feasible. The importance of the studies is emphasized in terms of their applications to handle adequately the meteorological problems that affect the South America continent, notably Brazil.

I. INTRODUCTION

The Atmospheric Modeling Center (CEMA) plays an essential role in the INPE's Meteorology Department promoting research in the area of atmospheric modeling. Since its establishment in June 1982, CEMA has expanded to include modeling of oceanic basins.

Its computational facilities consist of a remote terminal RJE connected to the CYBER-175/750 operational system, of the Institute for Advanced Studies of the Ministry of Aeronautics, and a second one to INPE's Burrough 6800. In addition, it is planned to have installed a graphic terminal Tektroniks 4041 to provide quick visual displays of the results of numerical experiments.

Although the research activities cover a broad spectrum of relevant geophysical problems, emphasis is given to: a) the study of climate and its variability using the so-called general circulation models, and b) the design of Numerical Weather Prediction models and accompaning objective analysis schemes.

The main purpose of this work is to present a brief account of the on going activities at CEMA, related to numerical modeling of the atmosphere and oceans.

II. SIMULATION OF THE GENERAL CIRCULATION

CEMA's general circulation model is an adopted version of the two layer, σ coordinate model designed by Mintz and Arakawa at UCLA's Meteorology Department. A complete description of the original model may be found in Gates et al. (1971). Is suffices for the present purpose to mention that the model is based on the primitive equations, written in their flux forms which are solved numerically using conservative finite-difference schemes and a rather efficient time integration procedure, designed so as to control the unwanted computational modes. The initial state of the model corresponds to an isothermal ($T = 289^{o}k$) atmosphere at rest, with sea surface temperatures being prescribed and not allowed to change during the course of the integration.

Although its relative simplicity, this model was exhaustively used by a number of investigators, such as Jastrow and Halem (1970), Schlesinger and Gates (1980), to cite a few. At CEMA this model has been used in studies of sensitivity involving climatic aspects of relevance for Brazil. The simulation of the climate for January and July was completed, integrating the model for 50 days in each experiment; these are the control runs with which the subsequent experiments with changed lower boundary conditions are to be compared. Figs. 1 and 2 show the monthly averaged surface pressure fields for January and July, respectively.

Among the climate simulation studies under way, it is worthwhile mentioning the following ones. The response of the tropical atmosphere to anomalous sea surface temperature (SST) distribution in the Atlantic Ocean is being considered as a plausible mechanism for the droughts in the Northeast region of Brazil. This experiment has already been done by Moura and Shukla (1980), but the idea here is to reproduce, at least partially, the essence of the important result using a much less simplified model than the one used by these authors. The same line of research has been pursued when the role of very intense positive SST anomalies in the tropical Pacific in producing thermally-forced circulation was studied. Another experiment to be conducted is to introduce a major modification in the original version, replacing the constant surface albedo, by a climatolo-

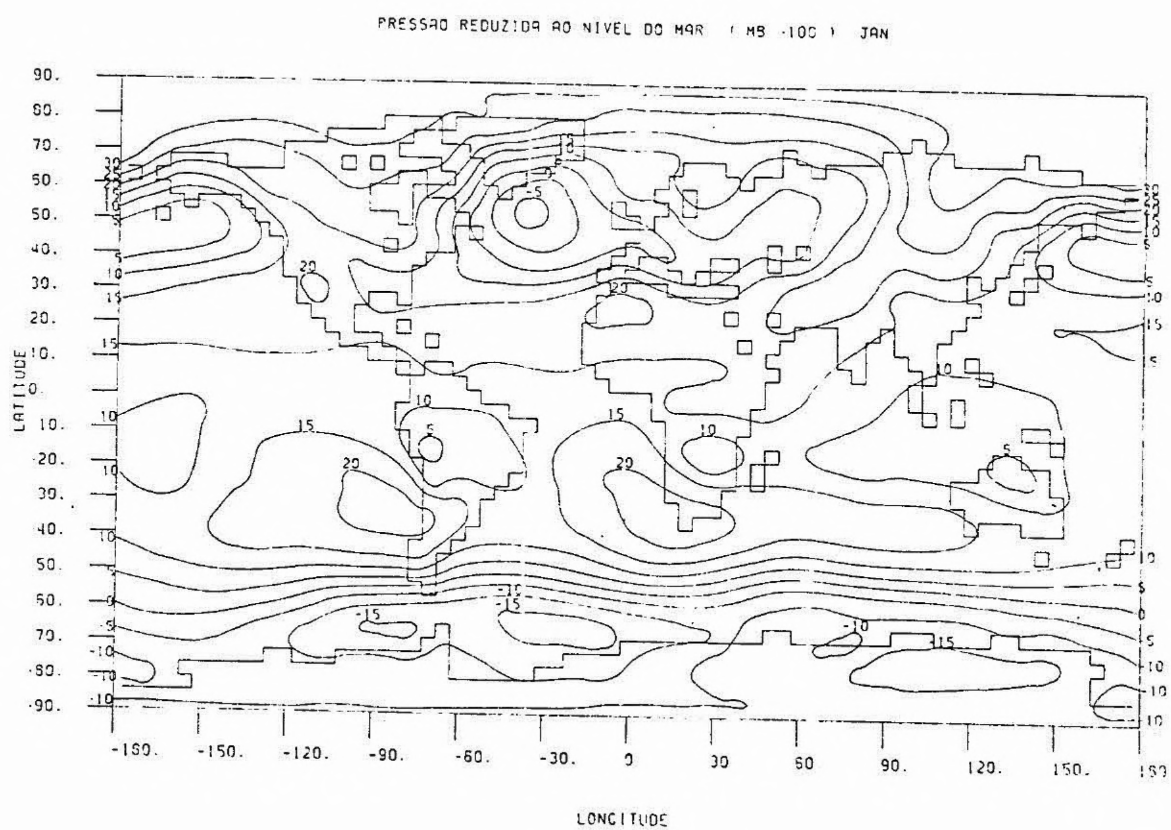

Fig. 1 - Monthly averaged sea-level reduced pressure field as given by the January simulation experiment.

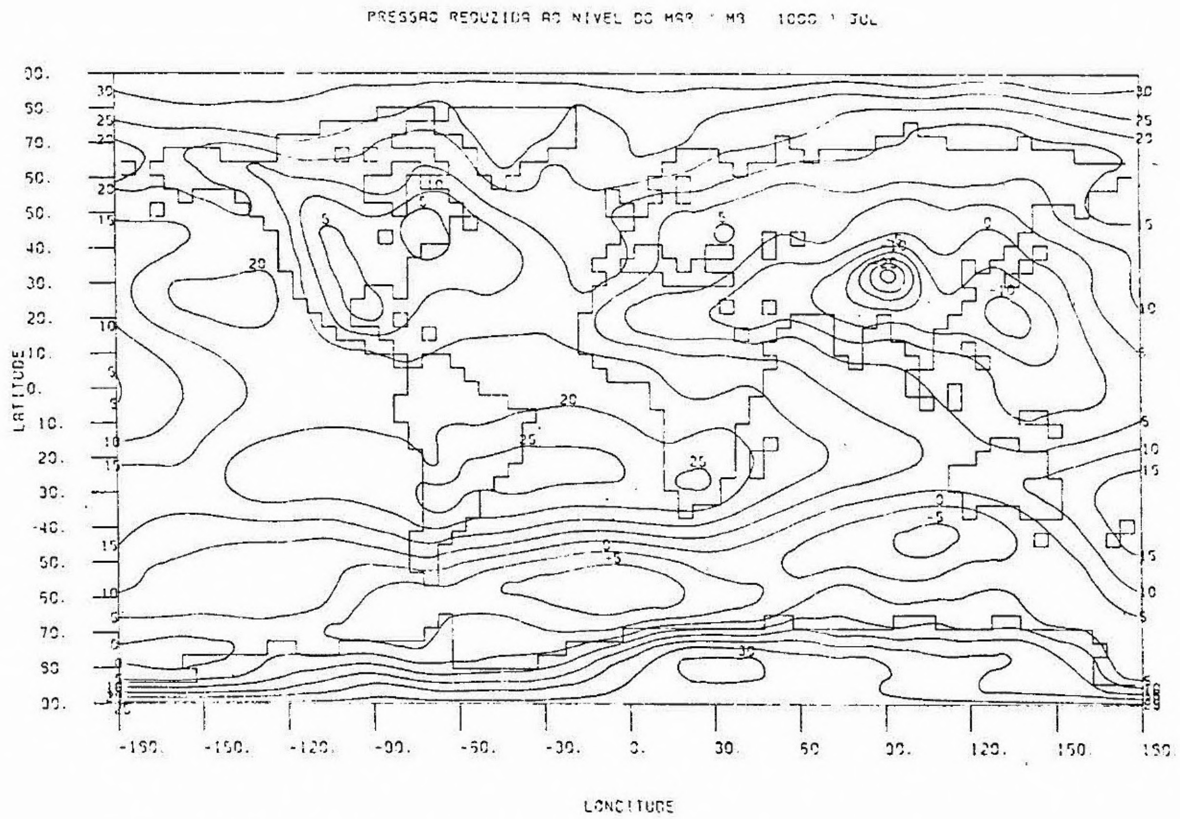

Fig. 2 - As in Fig. 1 except for July.

gical distribution. Climate experiments involving changes in the surface albedo could be used to simulate the effects of a large-scale deforestation on the local and global circulation.

Some other features of the general circulation, not necessarily global in nature, have been considered using limited area numerical models. To illustrate this point, the permanent trough to the side of the Andes near the east coast of South America was simulated by numerically integrating a primitive equation barotropic model, forced by topography, with the observed mean flow at 500 mb as the initial condition. The position and tilt of the simulated trough explained satisfactorily the mean climatological position of the polar front and the associated maximum rainfall area in the region.

III. NUMERICAL WEATHER PREDICTION

Numerical Weather Prediction (NWP) is a highly effective way of producing short-range forecasting with an increased reliability, provided some basic requirements are fulfilled. Researchers at CEMA have been considering the problem of NWP as a whole, and so a great deal of attention has been given to the processing of meteorological data, in order to construct dynamically consistent input fields for the models.

Two objective analysis schemes were adapted to suit the computational facilities of CEMA. They are used to interpolate information, measured at irregularly distributed points, to the grid points of the domain of integration. One of them, a modified version of the original "Wind Stanford Research Institute (WSRI)" is coupled to a barotropic primitive equation model and together they form the basis of an operational package of NWP.

The interpolated fields thus obtained are not quite ready to be used in the numerical models because they may have dynamical inconsistencies, resulting in unwanted effects on the process of generating the forecasts. The normal technique has been used to minimize these damaging effects. The determination of the normal mode of the model's equation allows us to distinguish between the high and low frequency components present in the data sets. It is often desirable to separate out the high frequency components, for they contain litlle meteorological large-scale information and they may obscure the low frequency modes or meteorological modes.

There are two variations of the normal mode technique. The first, known as linear initialization, eliminates all the rapid oscillations and extra care must be taken if a nonlinear model is used because the nonlinear terms work as generators of unreal high frequency oscillations. In the second kind of initialization (nonlinear), the initial tendency of the faster modes is set null, but again these modes could reappear during the integration. One way to eliminate this problem would be the application of the nonlinear initialization at every time step.

In the case of the NWP models available at CEMA, the nonlinear initialization procedure has been adopted because the total filtering of the high frequency component may mask conspicuously phenomena like the moist convection that plays an important role in the Amazone Region.

One of the first NWP model designed at CEMA was a limited area, primitive equation barotropic model, that can be used to produce forecast of the 500 mb flow and mass distribution. Since then, other models were either designed or adapted from already existing versions, including the multilevel ones that have not been tested for operational purposes but nevertheless can be used for research work.

The success of NWP depends on the availability of representative data sets that characterize the initial state of the atmosphere in the model. Considering the peculiatities of the Southern Hemisphere in terms of data, the observational aspect of the NWP problem will be tackled with the use of nonconventional data, notably those provided by the meteorological satellites. The future objective analysis schemes to be designed at CEMA will permit the full use of the asynoptic data in a "four dimensional assimilation".

IV. MESOSCALE FEATURES

Mesoscale numerical models are being developed in several places of the world, both for simulation studies as well as for regional weather prediction. The activities involving mesoscale models at CEMA are still in an embryonic stage and restricted to simulation studies only.

A predictive, two-dimensional, nonlinear primitive equation model has been developed to study the land-sea breeze circulation in North-Northeast Brazil. The model considers dry air and involves a boundary layer formulation. In this study the aspect of interaction between the mesoscale breeze and the synoptic scale circulation in which it was imbedded was focussed and the topography was taken into account. In addition, the seasonal variations of the land-sea breeze, based on the continent and ocean surface temperature distribution, were considered, attempting to correlate the breeze intensity and the monthly precipitation of the region. Further improvements of this model include the addition of a third coordinate and the process of moist convection.

REFERENCES

GATES, W. L.; BATTEN, E.S.; KAHLE, A. B.; NELSON, A. B. A documentation of the Mintz-Arakawa two level atmospheric general circulation model. R-877-ARPA, The Rand Corporation, California, 408 pp. Dec 1971.

JASTROW, R.; HALEM, M. Simulation studies related to GARP Bulletin of the American Meteorological Society, 51 (6), 409-513, Jun 1970.

MOURA, A. D.; SHUKLA, J. Um estudo sobre a dinâmica da seca do Nordeste do Brasil. Observaççoes, teoria e experimentos numé ricos com um modelo global de circulação atmosférica. São Jo sé dos Campos, INPE, out 1980 (INPE-1930-RPE/255).

SCMLESSINGER, M. E.; GATES. W. L. The January and July performance of the OSU two-level atmospheric general circulation model. Journal of the Atmospheric Sciences, 37 (9), Sep 1980.