The Impact of Recent Model Improvements on GISS GCM
Predictions of Climate Change

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Abstract

Multiple year simulations of the GISS GCM at 4x5 degree horizontal resolution were made for the standard Model II and also for alternative versions of the GCM which incorporate new formulations of the planetary boundary layer (PBL), the moist convection, ground hydrology and C- grid numerics. Five-year January and July mean fields from each simulation, representing each version's basic climatology, each showed certain improvements when compared to analyses based on observed data and to each other. (Report #1)

Observed monthly mean SST were used in a continuous GISS model integration (8x10 resolution) covering 1980-1986 which indicated qualitatively realistic influences of SST forcing in the tropical Atlantic and Pacific Oceans on near-surface circulation, tropospheric temperatures and Northeast Brazil rainfall. (Report #2)

An investigation which applied 6-hourly averaged winds from the GISS GCM at 4x5 resolution demonstrated the feasibility of using the model to study African wave disturbances and their sensitivity to interannual variability of SST. (Report #3)

Model runs (4x5 resolution) based on observed SST for June-August 1987 and 1988 have been found suitable for evaluating how the various modeling schemes compare in their simulation of these sharply contrasting seasons.

Reports submitted for publication acknowledging DOE Grant

1. Marengo, J. and L. Druyan, 1993: Validation of model improvements for the GISS GCM, Climate Dynamics, in press.
2. Hastenrath, S. and L. Druyan, 1993: Circulation anomaly mechanisms in the tropical North Atlantic sector during the Northeast Brazil rainy season: results from the GISS GCM, submitted to JGR- Atmospheres.
3. Druyan, L. and T. Hall, 1993: Studies of African wave disturbances with the GISS GCM, submitted to J. Climate.

Since the beginning of the current term (9/15/92), the PI has devoted at least 50% of his time to the grant work. This level of participation is not expected to change during the remainder of the current term.

The climatology of the GISS GCM has been thoroughly documented by analyzing 5-year simulations at 4x5 degree grid resolution with climatological SST. Five-year mean fields were taken from model runs using the published format of the GCM (Model II) as well as alternative versions, each of which include a change in some basic model scheme. In this study by Marengo and Druyan (1993), improvements in the simulation of tropical surface winds are evident in the results which were based on a new and more physically accurate parameterization of the planetary boundary layer. Incorporation of the new moist convection scheme made tropical distributions of modeled rainfall and ambient moisture more realistic. The main impact of using a new ground hydrology formulation was increases in the modeled surface air temperatures. Better sea-level pressures and rainfall patterns obtained with C-grid numerics were somewhat offset by increases in speed excesses at the cores of the summer hemisphere westerly jets.

Observed monthly mean SST were used in a continuous GISS model integration (8×10 resolution) covering 1980-1986 to study the influence of SST forcing in the tropical Atlantic and Pacific Oceans on near-surface circulation, tropospheric temperatures and Northeast Brazil rainfall (Hastenrath and Druyan, 1993). These GCM simulations of March-April means reproduce the thermal and hydrostatic forcing of SST on the meridional gradients of lower tropospheric thicknesses and pressure in a sense which parallels observations, but with a smaller range of variability. The modeled meridional surface winds show a similar response, but they are altogether too weak compared with observations. Both modeled and observed March-April precipitation for Northeast Brazil are negatively related with SST anomalies in the equatorial Pacific in March-April, as well as with preceeding January SSTA. The weakness of modeled surface winds emphasizes the deficiencies in the Model II formulation of the PBL which has since been revised. The study also suggests that higher grid resolution would be better suited to studying the small interannual meridional displacements observed in the ITCZ over Northeast Brazil.

An investigation which applied 6-hourly averaged winds from the GISS GCM at 4×5 resolution demonstrated that the model can be used to study African wave disturbances and their sensitivity to interannual variability of SST. The study by Druyan and Hall (1993) found that Model II represents African waves as 5-10 day period oscillations in mid-tropospheric meridional wind with zonal wave lengths of 2200 km. Model II's vertical mixing of horizontal momentum causes a severe weakening of the African Easterly Jet in August-September and consequently too slow wave propagation speeds and rather weak amplitudes during the second half of the summer. The modeled waves modulate precipitation by altering the pattern of moisture advection but not by the zonally alternating regions of convergence and divergence which appear quite realistic in model composites. One can surmise that the proposed new convection scheme will improve the wave modulation of precipitation rates. The spatial distributions of wave amplitudes was significantly different for each of the two model ensembles, simulated with SST forcing from June-September 1987 and 1988, respectively. This

indicates that the GCM can be used to investigate the interannual variations of African wave climatology forced by observed interannual variations of SST. The best model versions should give the best representations of seasonal trends in the wave-related climate variables.

A preliminary evaluation of the different versions of the GCM relates to their simulation of the very contrasting climates of June-August 1987 and 1988. While 1987 was during the warm phase of an El Nino/Southern Oscillation (ENSO) event, the following year experienced the ENSO cold phase. Large differences in Pacific Ocean SST between these seasons provides very strong differential forcing which had distinct observed atmospheric responses, both local and remote. Concomitant with this part of the project, special diagnostic tools were developed. In particular, planetary circulation patterns are being studied by computer workstation drawn graphics which depict the velocity potential and streamfunction fields of the 200 mb modeled winds. These are compared with counterpart analyses based on observed winds from the two seasons. Interannual differences in modeled precipitation and cloud cover are also compared to the observational evidence. The report of this research is in preparation by Druyan and Hastenrath.

To date, two ensembles of three runs each have been made and analyzed using Model II at 4x5 degrees resolution. Individual runs for the same period have also been made for model versions based on the C-grid, the new convection scheme, the new ground hydrology and a combined new PBL and ground hydrology. These results are still undergoing evaluation and new runs are being planned which will use AMIP SST for the entire 1979-1988 period.