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FINAL REPORT
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Simulations of weather and climate with general circulation models show that the circulation and rainfall are sensitive to the transfers of radiation, sensible heat, water vapor and momentum across the atmosphere land surface interface. Because, in nature, these transfers depend in large measure on the morphological and physiological characteristics of the surface vegetation, an interactive biosphere is needed for GCMs. The simple model of the biosphere (SiB) that we have constructed is based on the recognized difference between groundcover vegetation (grasses and other herbaceous plants) and canopy vegetation (trees and shrubs), where the latter act like elevated blocks of porous material which efficiently extract momentum from the air that flows through them, by a large number of multiple reflections enhance the absorption of the incident solar radiation and, when the canopy is wet, act like well ventilated psychrometers which extract sensible heat from the air and produce a negative Bowen ratio: and, in all of these ways, behave differently from groundcover vegetation. The complete set of governing equations of SiB, whereby the various allowable combinations of trees, groundcovers and bare ground, in interaction with the atmosphere, determine all of the vegetation dependent transfers at the land surface, have been presented and described succinctly as follows.

The vegetation in each grid area is represented by two distinct layers, either or both of which may be present or absent in any given location. The upper layer represents a perennial canopy of trees or shrubs, while the lower layer is a groundcover (carpet) of annual grasses or other herbaceous plants. The local coverage of each vegetation layer may be fractional or complete; but as the individual vegetation elements are considered to be evenly spaced the root systems are assumed to extend uniformly throughout the entire gridarea. Besides the vegetation morphology, the physical and physiological properties of each vegetation layer are also prescribed. With the given set of governing biophysical equations and the relevant atmospheric parameters, these properties determine: 1) the reflection, transmission, absorption and emission of direct and diffuse radiation in the visible, near–infrared and thermal wavelength intervals; 2) the interception of rainfall and its evaporation from the leaf surfaces; 3) the infiltration, drainage and storage of the residual rainfall in the soil; 4) the control by the photosynthetically active radiation and the soil moisture potential, among other things, over the stomatal functioning and, thereby, over the return transfer of soil moisture to the atmosphere through the root–stem–leaf system of the vegetation; and 5) the aerodynamic transfer of water vapor, sensible heat and momentum from the vegetation and soil surfaces to a reference level in the atmospheric boundary layer.

The biosphere model has only seven prognostic physical state variables: two temperatures (one for the vegetation canopy and one for the groundcover and soil); two interception water stores (one for the canopy and one for the groundcover); and three soil moisture stores (two of which can be reached by the vegetation root systems and one underlying recharge layer into and out of which moisture is transferred only by hydraulic diffusion.)

We have also determined and presented the rationale for distinguishing between groundcover vegetation (grasses and other herbaceous plants) and canopy vegetation (trees and shrubs) when determining the transfers of radiation, sensible heat, water and momentum between the atmosphere and the vegetated surface of the earth; and we presented a global map of the 10 natural biomes (10 allowable combinations of trees, shrubs, groundcover, bare ground and ice) that can be used with the simple numerical model of the biosphere (SiB). They are the following:

(NASA-CR-193423) MODELING OF INTERACTIONS BETWEEN BIOSPHERE AND ATMOSPHERE ON THE GLOBAL SCALE Final Report (Maryland Univ.) 4 p

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Unclas

1. broadleaf trees (evergreen or deciduous)
2. broadleaf and needleleaf trees
3. needleleaf trees (evergreen or deciduous)
4. broadleaf trees with groundcover
5. groundcover
6. broadleaf shrubs with groundcover
7. broadleaf shrubs with bare soil
8. dwarf trees and shrubs with groundcover (tundra)
9. bare soil
10. perpetual ice

This biosphere has been tested with the GLA atmospheric general circulation model. Results indicate that it produces very realistic fluxes of radiational energy, sensible heat, water mass and momentum across the atmosphere–land surface boundary.

We have also shown that the SiB calculated transfers of radiation, sensible heat and water vapor, for a forest of needleleaf trees and for three grain crops, are sufficiently close to the micrometeorological field measurements to warrant the use of SiB with present day GCMs.

The extensive computer program for SiB, and its off–line testing, were completed: and SiB was incorporated, by Sellers and Sud, into the GLA–4th Order (Kalnay) GCM; by Sellers and Randall into the GLA/UCLA GCM; and by Sellers and Shukla into the UM/NMC spectral GCM. Interactive testing was done with the three models. Sellers, Sud and Mintz added SiB to the modified GLA–4th Order GCM which was used for analytical studies of the global hydrologic cycle.

Details on the research reviewed above can be found in the following publications, which have given acknowledgement to this grant.

Y. Mintz and P. J. Sellers, 1986: Proposal for a Numerical Model of the Biosphere for Use with Numerical Models of the Atmosphere. A chapter (pp 244–264) in *Vistas in Applied Mathematics, Numerical Analysis, Atmospheric Sciences, Immunology.* (Eds. A. V. Balakrishnan, A. A. Dorodnitsyn and J. L. Lions.) Springer–Verlag. New York/Berlin/Tokyo.

P. J. Sellers, Y. Mintz, Y. C. Sud and A. Dalcher, 1986: A Simple Biosphere Model (SiB) for Use within General Circulation Models. *JAS*, **43**, 505–531.

P. J. Sellers and J. L. Dorman, 1987: Testing the Simple Biosphere Model (SiB) Using Point Micrometeorological and Biophysical Data. *JCAM*, **26**, 622–651.

D. Rosenfeld and Y. Mintz, 1988: Evaporation of Rain Falling from Convective Clouds as Derived from Radar Measurements. *J. Appl. Meteor.* **27**, pp. 209–215.

Y. C. Sud, J. Shukla and Y. Mintz, 1988: Influence of Land Surface Roughness on Atmospheric Circulation and Precipitation: A Sensitivity Study with a General Circulation Model. *J. Appl. Meteor.*, **27**, pp. 1036–1054.

Mintz, Y., 1986: GCM–Derived Hydrologic Time Series from Satellite and Surface Data. *Lecture Notes of the NATO Advanced Study Institute on Physically–Based Modeling and Simulation of Climate and Climate Change*, Erice, Sicily, 11–23 May 1986. 37 pp.

The following research projects were also initiated during the final year of the grant.

1. **Quasi–stationary Meteorological Patterns (Dr. Kintse Mo)**

The quasi–stationary periods were studied with and without the new parameterization of the interactions of the biosphere to evaluate how this parameterization contributes to persistent anomalies. The identification of quasi–stationary patterns in both the Northern and Southern Hemisphere and the physical and statistical descriptions of how they are maintained has been considered. Multivariate and time series analyses were used to describe persistent patterns. The statistical relationships between these persistent events and tropical convection, soil moisture, vegetation and other boundary conditions was studied. GCM studies were designed to study the importance of tropical heating with the new parameterization of the biosphere–atmosphere. After identifying most quasi–stationary periods, the existence and the influence of sea–surface temperatures anomalies that may be associated with such events was evaluated.

2. **The African Drought (Dr. F. Semazzi)**

Work on the African drought and the four dimensional data assimilation problem was initiated in association with the role of biophysical feedback of vegetation in maintaining the recent African droughts. A comprehensive study to understand the mechanisms responsible for recurring droughts in Sahelian Africa including Ethiopia was considered. The work focused on the role of biophysical feedback of vegetation in maintaining the recent droughts. Analyses of vegetation, rainfall and SST time series obtained from satellite data and supplemented by ground based observations were carried out to isolate spatial and temporal anomalous variations in these quantities. The interactive GLA GCM model of the biosphere was employed to investigate if the anomalies in vegetation, such as inferred from satellite observations, could perpetuate the Sahelian drought.

Regarding the four dimensional data assimilation problem, we initiated the development of an efficient method of accelerating the assimilation of patches of asynoptic wind data (with emphasis on NSCAT wind data) during the progress of a numerical forecast. The primary technique was based on the bounded derivative method which has the potential capability of reducing the rejection of the asynoptic patches of data and the excitation of high frequency motions. The available versions of the GLA global barotropic model and GCM were used to perform the experiments.

3. **Low Frequency Variability (Dr. S. Schubert)**

This work focused on analyses of low frequency fluctuations in the atmosphere and in long term simulations of the atmosphere produced by the GLA 4th order General Circulation Model. Since long term fluctuations of the atmosphere are forced by slowly varying boundary conditions and in tern result in changes in these boundary conditions (soil moisture and other biosphere parameters, sea–surface temperatures, etc.), the work enhanced the SiB initiative.

The methodology of the diagnostic study involved the project of the atmospheric model output data onto an empirically derived orthogonal basis. The intent was to isolate global scale modes of fluctuations and examine possible tropical–mid latitude interactions in the atmosphere of the model. The model data was studied to determine the level of correspondence with observations. The projection of the various model–generated forcing functions onto the modes helped to isolate the processes relevant to the quasi–stationary behavior in the model. The analysis of a 4–year total ozone data set was undertaken in an attempt to incorporate 2–dimensional tropopause height information into temperature retrieval algorithms. Also, GLA assimilations with frequent data output was generated to study the relaxation times and adjustments with the model physical processes and numerical integration scheme in order to determine optimum data insertion rates and sampling times.

These projects were subsequently continued on a new grant.