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Semi-annual Report: NASA Grant NAG 5-849

Investigating the role of the Land Surface  
in Explaining the Interannual Variation of the  
Net Radiation Balance  
over the Western Sahara and Sub-Sahara

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(NASA-CR-181183) INVESTIGATING THE ROLE OF  
THE LAND SURFACE IN EXPLAINING THE  
INTERANNUAL VARIATION OF THE NET RADIATION  
BALANCE OVER THE WESTERN SAHARA AND  
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Table of Contents

	<u>Page</u>
1.0 Summary of Activity .....	2
2.0 Project Personnel .....	2
3.0 Status of Data Sets .....	2
4.0 Research Progress .....	3
5.0 Meetings, Conferences, Reports, and Publications.....	5
Appendix A: Report from the IRAP Rio Rico Meeting	

### 1.0 Summary of Activity

This report covers project activity from 10-1-86 to 5-31-87 during the first year of the grant. Personnel supported under the auspices of the project are identified in Section 2. Sections 3 and 4 discuss the data sets and research progress. Section 5 provides a list of meetings attended and publications sponsored under the grant.

### 2.0 Project Personnel

One Ph.D. dissertation and one Master's Thesis are being directed in conjunction with this project. Mr. B.J. Sohn and Mr. Andrew Lare are the advisees of Professors Smith and Nicholson respectively. Computer programming support is being provided by Mr. Matthew Smith and Mr. Kung W. Oh. Ms. Patricia Williams provides part-time clerical support.

### 3.0 Status of Data Sets

Six data sets were identified as being essential for this project:

1. Nimbus 7 ERB WFOV/NFOV EMST Data [1979-1983]
2. NOAA Heat Budget Tapes [1979-1983]
3. NMC Global Analyses of Atmospheric Profiles [1979-1983]
4. African Rainfall Station Data [1979-1983]
5. E. Matthews Surface Albedo Tape
6. ISCCP Cloud Data (1983 July-December)

Currently we have all data except for the 1983 August-December ISCCP cloud tapes. In addition we have recently placed an order for a new NASA cloud data set obtained from the Nimbus 7 THIR/TOMS for the 1979-1985 period (CMATRIX tapes). Since these data are contiguous with our complete study period, we will substitute them in place of the ISCCP data. We expect to receive the CMATRIX data in mid-August, 1987 directly from the NASA Space Science Data Center.

We have operational format cracking software for all of the data sets excepting CMATRIX and have conducted preliminary analysis with all data sets mentioned in the above table.

#### 4.0 Research Progress

We have made steady progress in both the data analysis and modeling areas. The science investigation proposed and supported by this grant is illustrated in the flow diagram shown in Figure 1. In essence, we are trying to decouple the atmospheric and land surface contributions to the net radiation budget over the Sahara-Sahel region, investigate the interannual variability of these two processes and relate this variability to seasonal rainfall fluctuations. We intend to use the principals of climatonic modeling to examine the physical feedbacks taking place between precipitation, land surface changes and the surface energy budget.

As a point of reference on Figure 1 we have completed the tasks associated with steps 1,2,5,10; are completing development of shortwave and longwave radiation transfer codes needed at steps 3,6,11, and 14; and have developed parts of the climatonic model needed at step 15.

In order to bring the precipitation data into a form consistent with the time-space grid used in the analyses, we have developed a modified Barnes objective analysis scheme which uses an elliptic scan pattern and a 3-pass iteration of the difference fields. Figure 2 provides an example of monthly station data over Northern Africa along with the objectively analyzed grid field. The 9999 values represent missing data regions which will be replaced with subjectively analyzed estimates.

We are nearing completion of the computational work on a paper focused on minimum planetary albedo variability during the 1979-1983 period. This study is based on synthesizing a 5-year time series of minimum planetary albedo from the NOAA heat budget data using the 18 month record of ERB-NFOV minimum albedo as the reference.

Figures 3 - 6 illustrate some of the results of this study. In Fig. 3 we examine the latitude-time behavior of minimum planetary albedo calculated from a multiple-regression scheme using Nimbus 7 ERB-NFOV measurements as the training data set. It is easily noted that most of the variability in this quantity takes place in the Northern Sahel. Figure 4 illustrates the composite seasonal analysis of minimum albedo (Winter, Spring, Summer, Autumn). These diagrams portray the dominant geographical features of North Africa. The Meteosat photo shown in Figure 5 can be used as a means of comparison. Figure 6 illustrates the interannual dispersion index. It presents our preliminary estimates of the source regions of variability in the minimum planetary albedo. The dominant regions are numbered with numerals 1-4.

## 5.0 Meetings, Conferences, Reports, and Publications

### A. Meetings:

1. Smith, E.A., and S.E. Nicholson, 1986: Attendance at the NASA-ISLSCP Retrospective Analysis Project (IRAP) Science Team Organizing Meeting, October 22-24, 1986, Rio Rico, AZ. [A report is given in Appendix A].
2. Smith, M.R., 1986: Attendance at PLDS Team Meeting, September 24-26, Ames Research Center, San Francisco, CA.

### B. Publications in Progress:

Smith, E.A., and B.J. Sohn, 1987: An extended time series of the minimum planetary albedo over Northern Africa from a combination of Nimbus 7 and NOAA satellite measurements. To be submitted to J. Clim. Appl. Meteor.

List of Figures

Figure 1: Flow diagram of diagnostic modeling process.

Figure 2: Monthly precipitation accumulation (cm) at individual stations over Northern Africa during August, 1979 (top). Objectively analyzed gridded representation using a modified Barnes scheme (bottom).

Figure 3: Time-latitude section of the minimum planetary albedo over North African latitudes for 60 months.

Figure 4: Five year (1979-1983) seasonal composites of minimum planetary albedo over Northern Africa derived from multiple-linear regression scheme.

Figure 5: METEOSAT visible satellite image from April 24, 1979.

Figure 6: Dispersion index of minimum planetary albedo. The 4 dominant interannual variational centers are indicated with large numbers.

SEPARATION OF SURFACE AND ATMOSPHERIC CONTRIBUTIONS

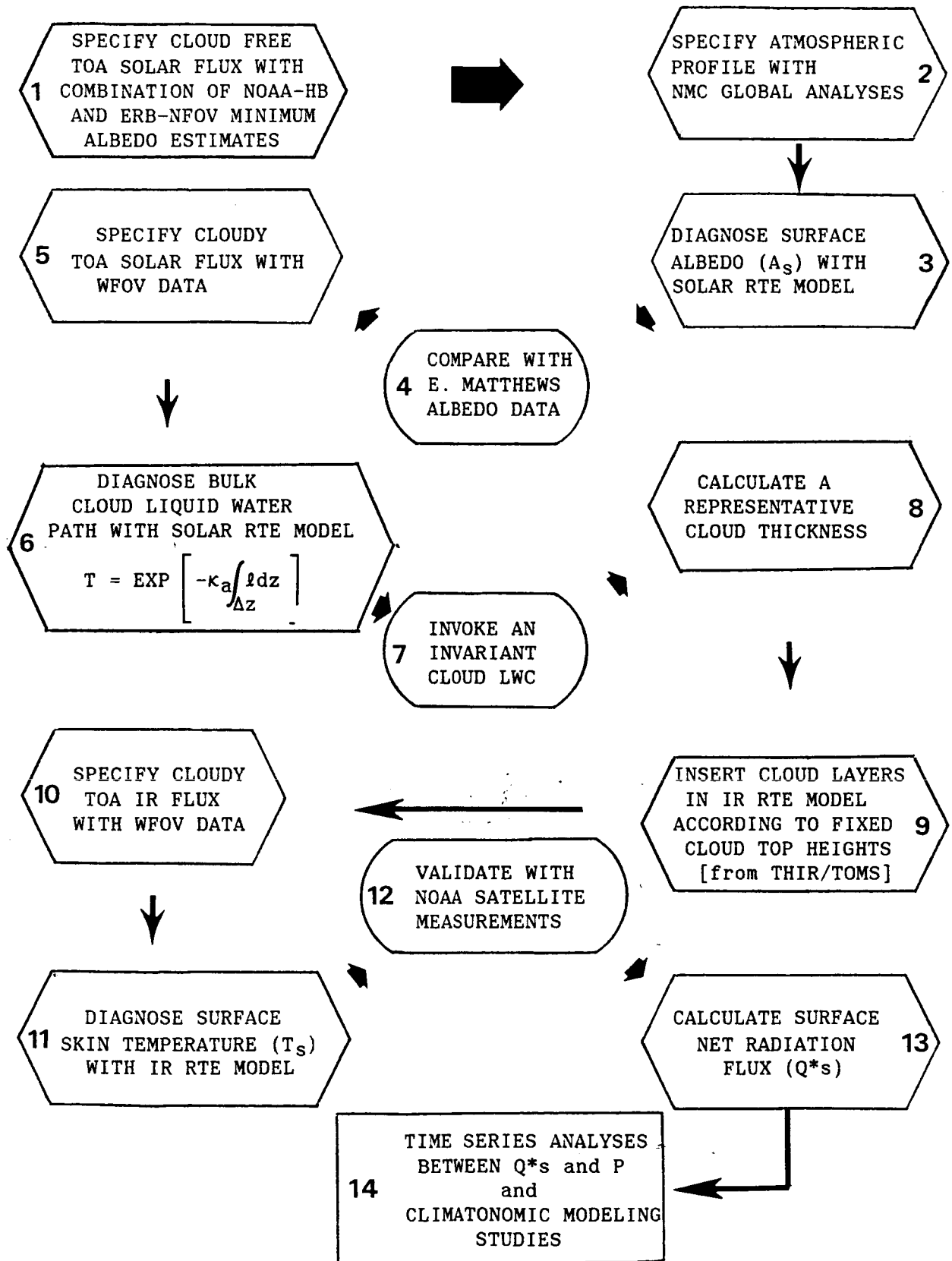


Figure 1: Flow diagram of diagnostic modeling process.





TIME SERIES OF ZON. AVE. A(REG)

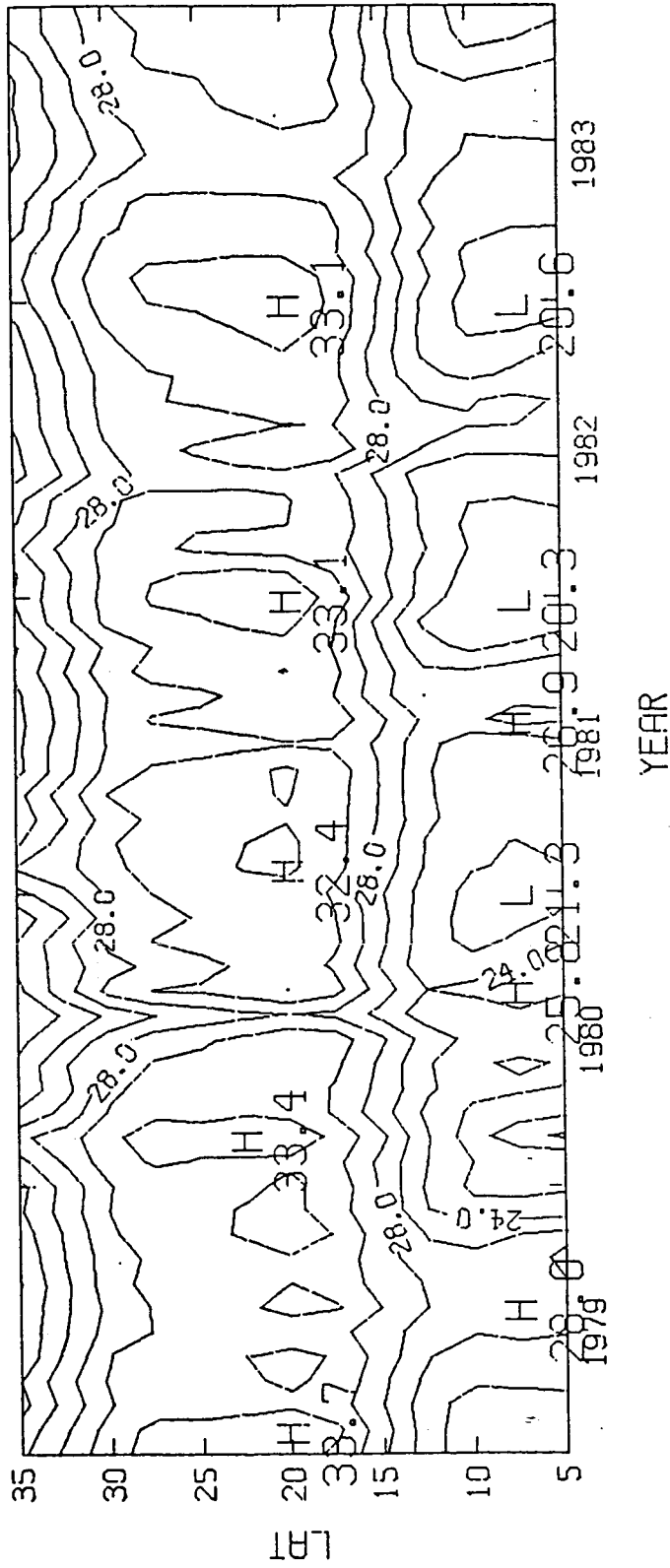
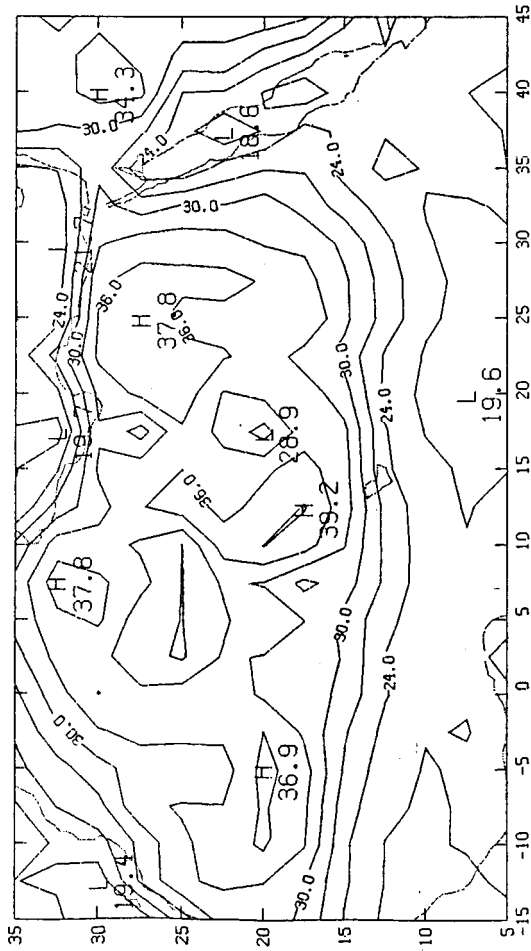
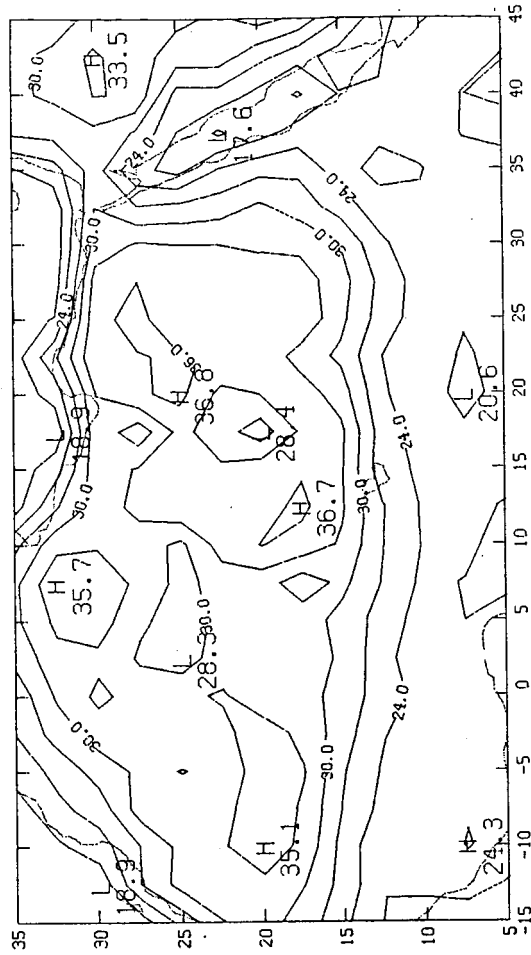


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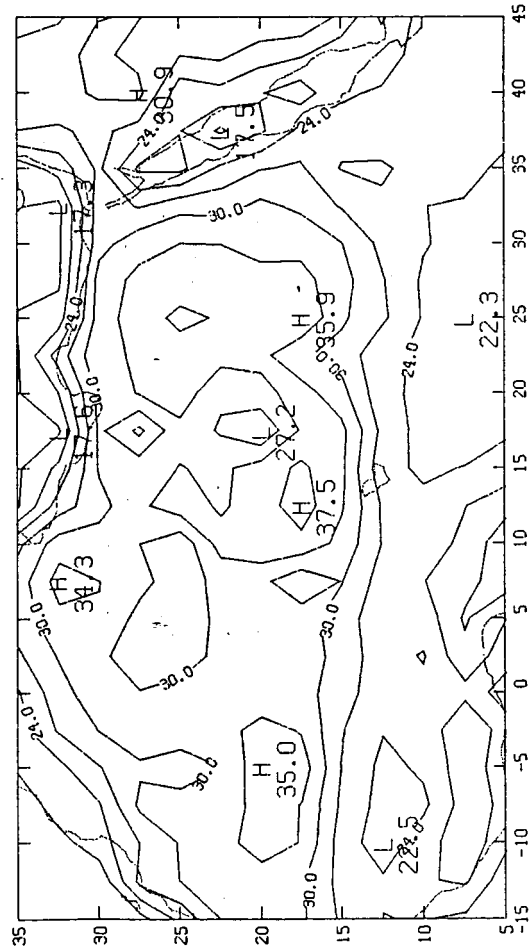
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JJA 5-YR MEAN OF A (REG)



SON 5-YR MEAN OF A (REG)

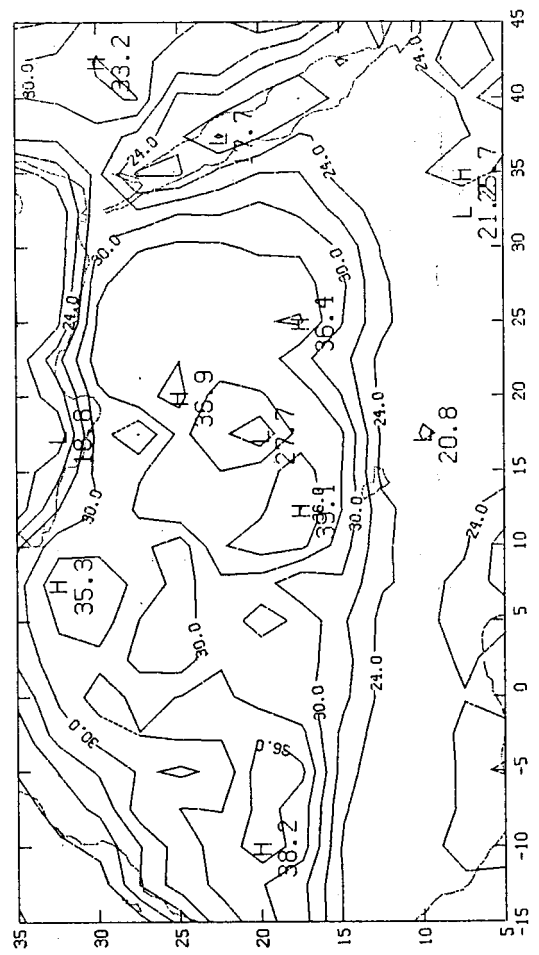


Figure 4: Five year (1979-1983) seasonal composites of minimum planetary albedo over Northern Africa derived from multiple-linear regression scheme.

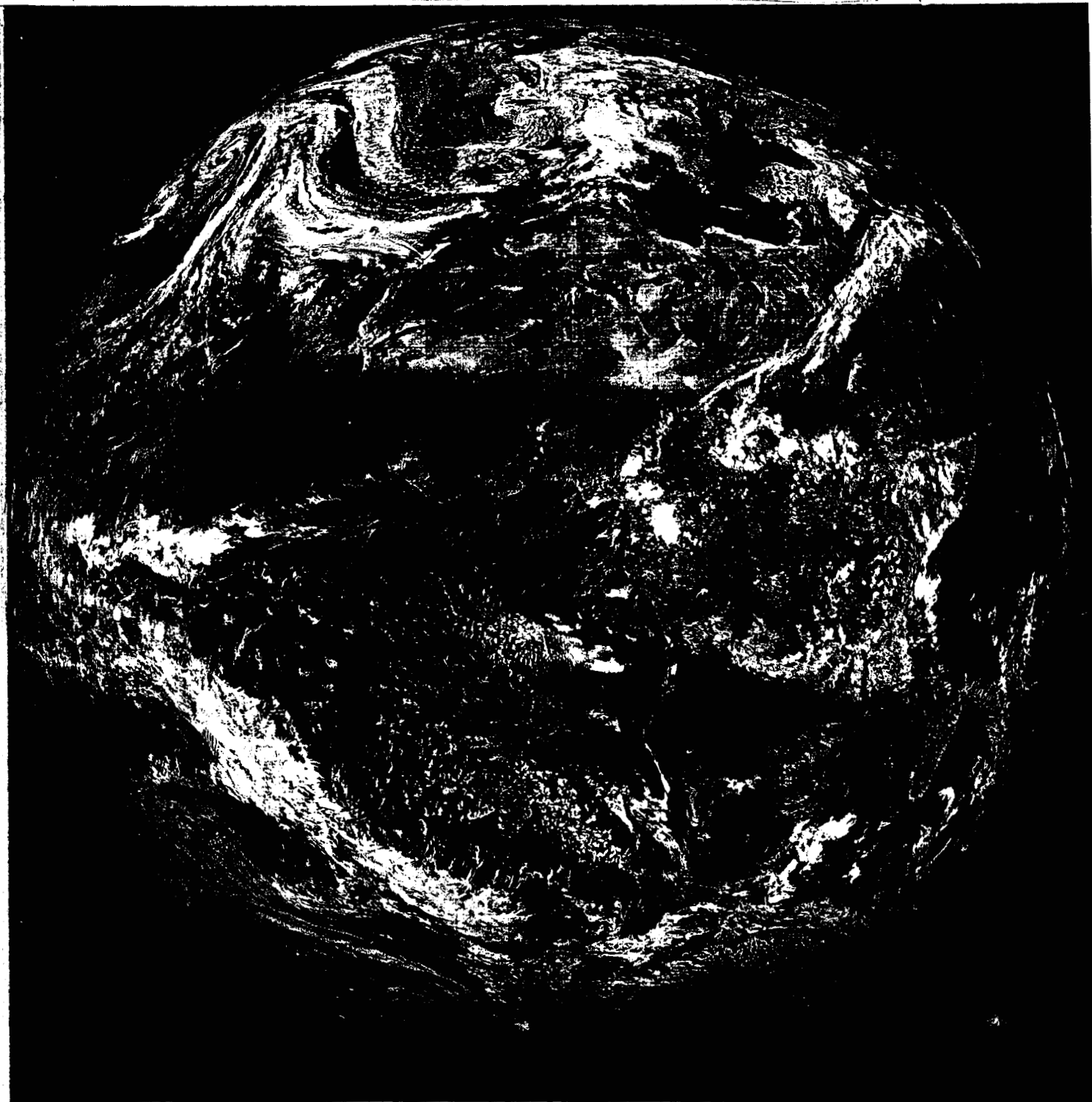


Figure 5: METEOSAT visible satellite image from April 24, 1979.

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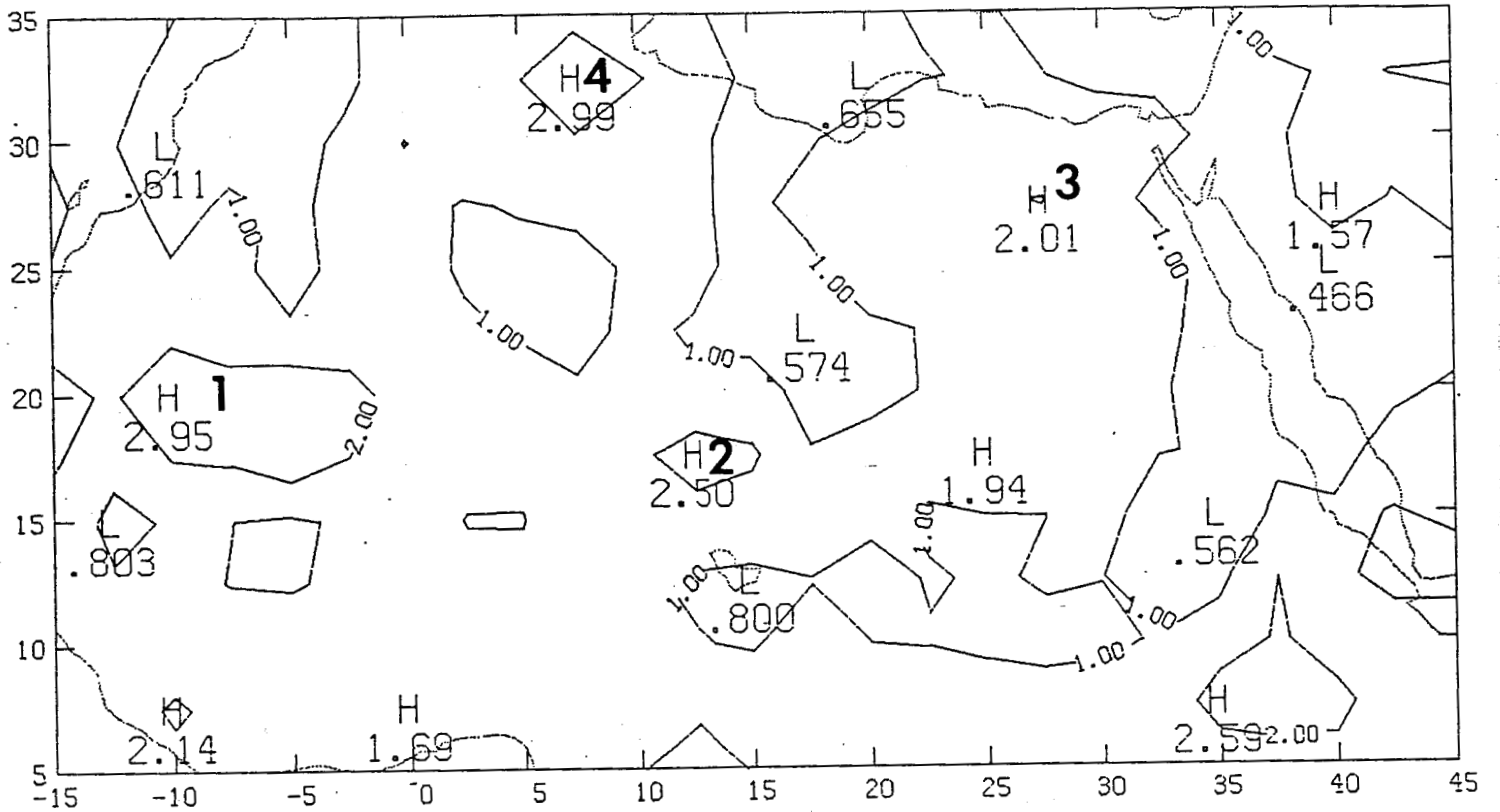


Figure 6: Dispersion index of minimum planetary albedo. The 4 dominant interannual variational centers are indicated with large numbers.

Appendix A: Report from the IRAP Rio Rico Meeting.

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Abstract

Investigating the Role of the Land Surface  
in Explaining the Interannual Variation of  
the Net Radiation Balance over the  
Northwest Sahara and Sub-Sahara

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This investigation examines how much of the interannual variation in the satellite derived radiation balance can be purely attributed to changes taking place at the land surface. The basic scientific objective is to decompose the variance terms associated with the radiation budget parameters over Northwest Africa into the part due to surface induced variations versus the part due to atmospheric induced variations. Determining the relative magnitude of these partitioned terms is one of the central issues of the International Satellite Land Surface Climatology Project (ISLSCP) since part of the climate system is forced by the interactions between the surface radiation budget and the planetary radiation budget in conjunction with feedbacks with the zonal energy transport process. Underlying this basic objective will be a concentrated effort to develop consistent time series of conditions at the surface of desert and Sahelian regions of Northwest Africa. The principle parameters under study are surface albedo [A], skin temperature [ $T_s$ ], net radiation [ $Q^*_s$ ], surface air temperature [ $T_a$ ], skin temperature jump [ $\Delta T$ ], precipitation [P], dryness index [ $Q^*(L \cdot P)^{-1}$ ], soil water storage [ $dw/dt$ ], and evaporation [E].

Upon developing a 5-year time series of these parameters we intend to examine the role of surface latent heating and its control of the precipitation pattern from one year to the next. Along this same line we will examine how the local moisture source acts as a memory mechanism in the Northwest African desert/semi-desert regimes. The latent heat exchange term will be arrived at diagnostically from a climatonic modeling approach in which satellite radiation budget measurements and surface precipitation data are used to specify the forcing to the surface energy balance equation.

The study region boundaries are  $10^{\circ}N - 30^{\circ}N$ ;  $15^{\circ}W - 30^{\circ}E$ . The period of study extends from 1979 to 1984 during which we have high quality coincident satellite radiation budget measurements, precipitation measurements and gridded vertical profiles of temperatures and mixing ratio. The space and time scales of the analysis are 2.5 degrees and 30 days respectively.

Figures 1 and 2 serve to emphasize the importance of understanding how surface processes operate over Northwest Africa. Figure 1 illustrates the portion of variance that can be attributed to interannual variation in the planetary albedo. There is a strong gradient from the Sahara, into the Sahelian zone where a closed high of  $\approx 90\%$  is located. The variance then decreases south of the Sahel into equatorial Africa. It is of interest to determine how much of this variance is explainable by interannual fluctuations in the cloud and precipitation systems which migrate through the Sahel and over the Southern Saharan



fringe, and how much is due to surface fluctuations of vegetation and soil moisture. Both processes lead to variations in the planetary albedo.

Figure 2 illustrates two key features of Northwest Africa vis-a-vis the radiation budget process. The top part of the figure depicts the difference in shortwave and near-infrared planetary albedo. This result is based on a 5-year average of Nimbus-7 ERB measurements. Note that Northern Africa is the only continental or oceanic region on the globe which exhibits negative differences. This emphasizes the fundamental contrast between the North African desert regime and other arid regions; it is drier, more cloud free and less vegetated than any of the other desert systems. These are the required conditions for high near-infrared planetary albedo. This map is somewhat analagous to a Normalized Difference Vegetation Index (NDVI) map, but derived from and on the time-space scale of radiation budget measurements.

The bottom panel illustrates the 5-year averaged difference field of day-night planetary emission temperature. Note that the three global maxima are centered over the African Sudd, the South African Kalahari desert, and the great Australian desert. All three of these regions are large scale desert systems. Note that the position of the maximum diurnal temperature swing in Northern Africa corresponds with the position of the albedo variance maximum seen in Figure 1. This type of correspondence is not observed with respect to the other two major diurnal anomalies. This is an indirect indication that the interannual planetary albedo variation over the African Sudd is largely forced by surface processes.

ALBEDO (A) - REMAINING VARIANCE

LOW = 9.58 HIGH = 96.50

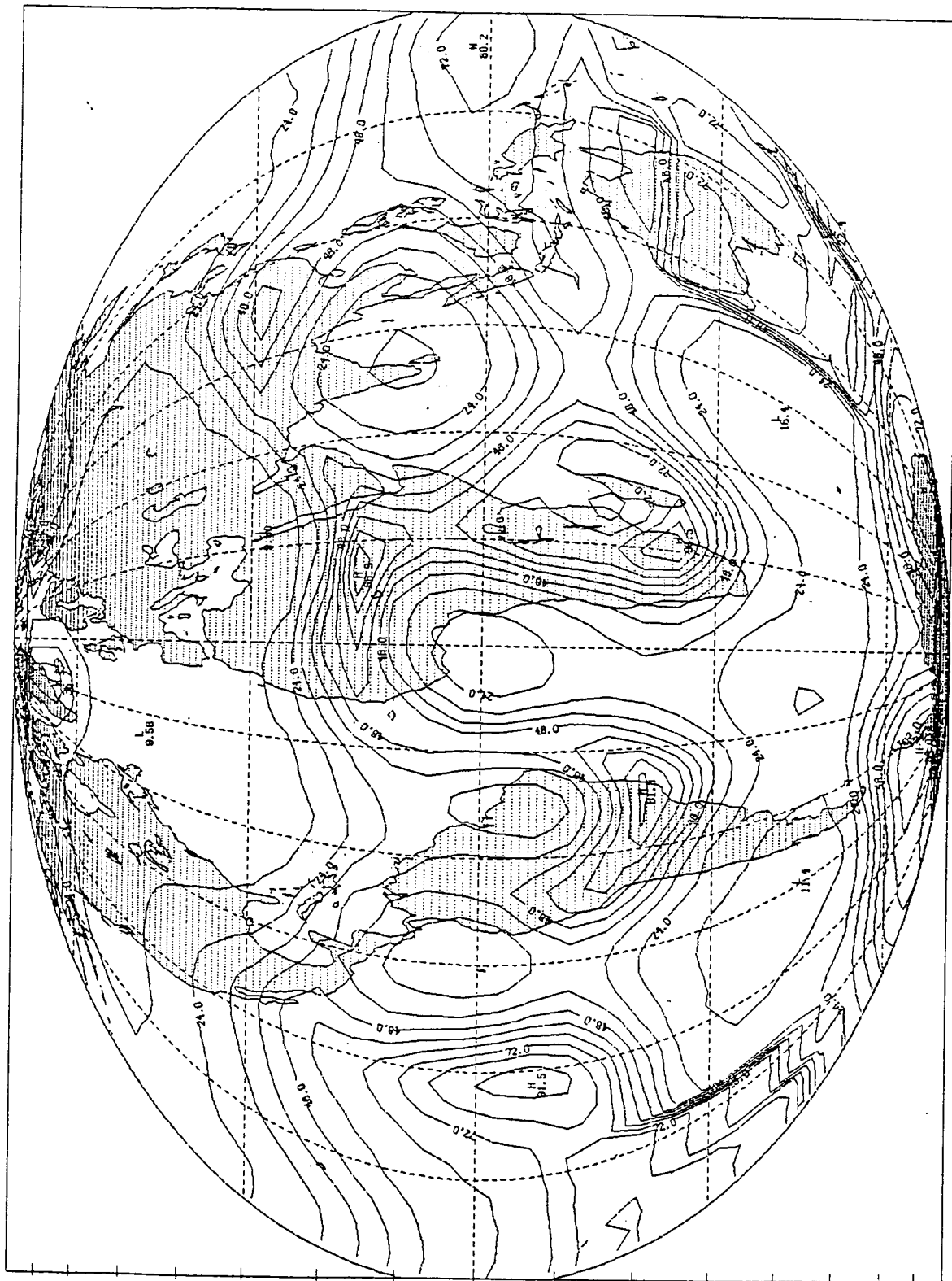
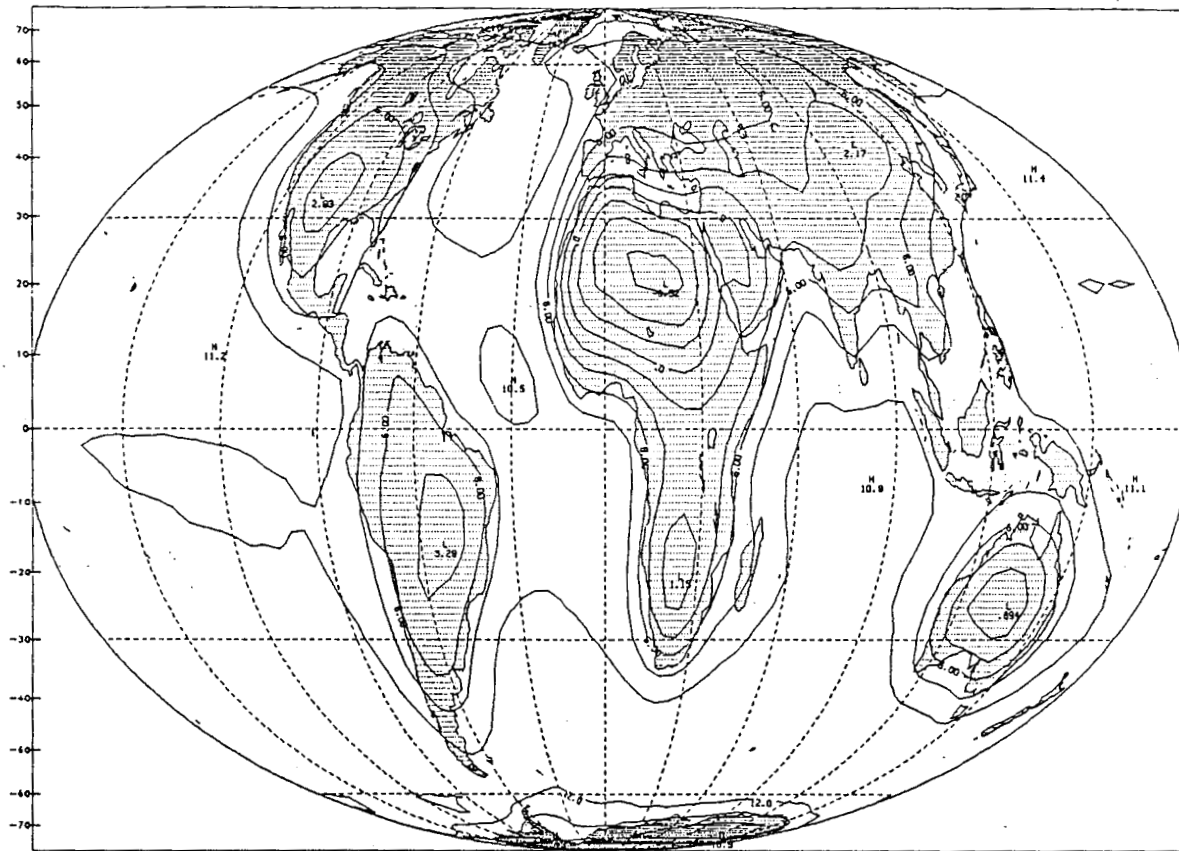


Figure 1: Variance associated with interannual variability in planetary albedo

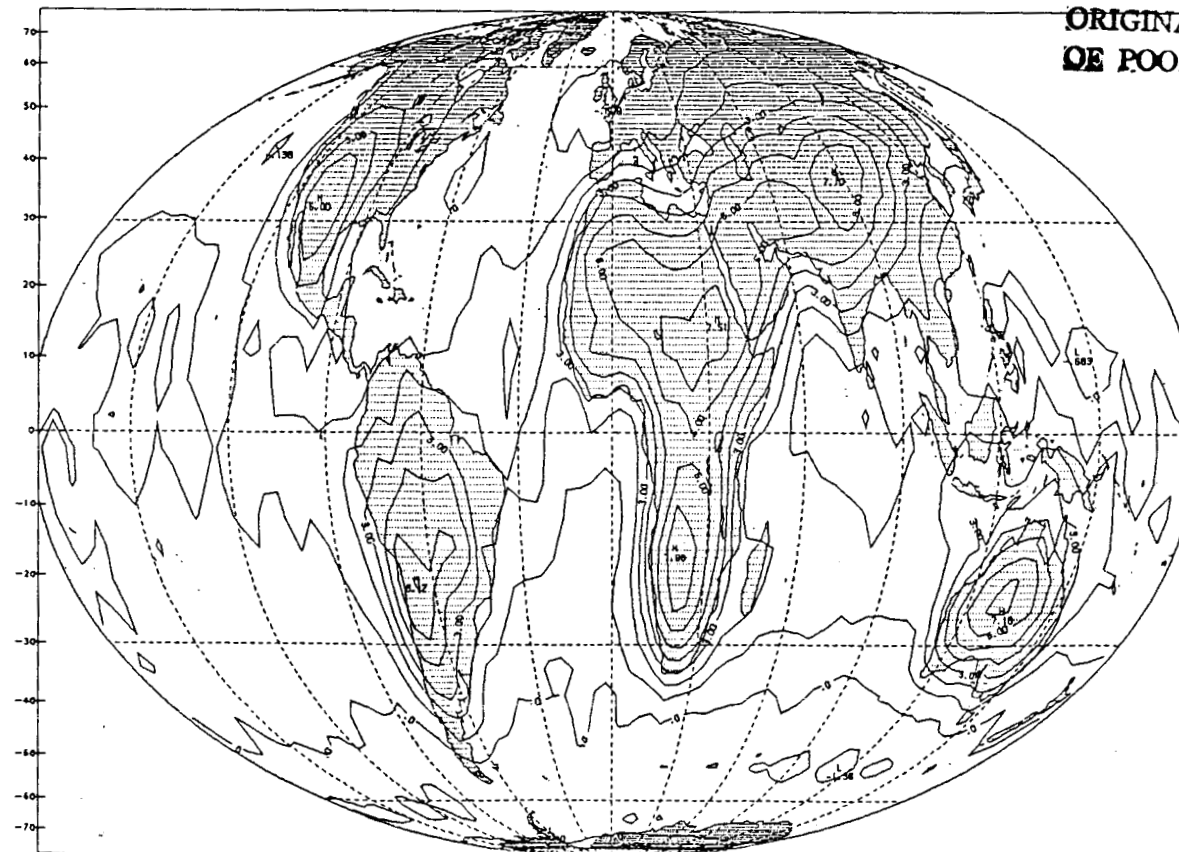
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DAY-NIGHT EBB TEMPERATURE DIFFERENCES ( $EBBT_D - EBBT_N$ )

WFOV - no spatial filtering



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Figure 2: Spectral albedo differences (top): diurnal temperature differences (bottom)