5. RADIATION VARIABILITY AND CORRELATION STUDIES

5.1 INTRODUCTION

The deliberations of this Working Group centered around two very broad areas. The first was concerned with the variability of the emitted and reflected components of the outgoing radiation from the Earth-atmosphere system. Variability in this regard refers to the amount of variation that occurs on various time scales from diurnal changes to interannual differences as well as on various spatial scales from regions of the order of 250 km to the global scale. The second major area was concerned with the influence of the variability on climate and weather and with what meteorological and climate variables should the radiation budget measurements be correlated.

It became quite clear from the discussions that very little is known about the variability of the radiation budget except in qualitative terms. Professor Fred House of Drexel University presented some results of recent time-series analyses that he performed on ESSA-7 globally averaged data. He showed that application of different time filters to the time series resulted in generation of series that displayed some pseudo-regular behavior which possibly was indicative of actual relationships between the global budget components. Dr. Arnold Gruber of NOAA-National Environmental Satellite Service (NESS) displayed results of his analysis of the brightness variations in the ESSA data. Wave-number/frequency spectra of the brightness were generated for the period of February 1, 1967, through February 29, 1968, for the latitudes of 20° N, 10° N, the equator, and 10° S. These spectra showed the importance of quasi-stationary waves and when the propagating wave activity was best developed.

The group clearly saw the necessity for an expanded program on time series and spatial analysis of radiation budget data to study variability of the components. It was considered essential that we learn what periods are dominant in the range from two weeks to 5 to 10 years to better understand the mechanisms of climate change. Studies of shorter time periods down to studies of hourly variations and small spatial scales below 100 km are important for the development of the observation system such as ERBSS and for the data interpretation.

Following is a review of some of these problems along with recommendations of the Working Group for approaches to their solution. Data sets for performing required studies were identified, some of which already exist in some form or another and some which will be forthcoming from satellites soon to be launched.

5.2 PROBLEMS CONSIDERED

5.2.1 Determination of the Variability of the Radiation Budget Parameters

A prerequisite for the determination of the variability in the radiation budget is the assemblage of a data base of radiation budget data that is properly checked out, synthesized, and made easily accessible to the researchers. Powerful statistical tools can then be employed. Time series analyses (both unidimensional and multidimensional) can be used as well as principal component analyses and parameter estimation theory in determining the variability.

As mentioned earlier, a number of studies have already been conducted so that some knowledge of the variability of the radiation is available. Analyses of the spatial and temporal scales of the radiation budget parameters are possible utilizing NOAA scanning radiometer data sets as described by Gruber (1978). These data provide the inputs necessary for analyzing the dominant spatial and temporal variations in the outgoing longwave flux, absorbed solar energy, and net radiation. It should be anticipated that each of these parameters will have different spatial and temporal scales, especially in the tropics (30^{o} N to 30^{o} S) where large departures from zonally oriented patterns are to be found, at least on the mean monthly basis.

Reasons for the different spatial scales can be found in the latitude belts between 30^{o} N and 30^{o} S where the albedo is highly influenced by the deserts and the extensive areas of stratocumulus clouds found off the west coast of Africa and North and South America. These areas do not show minima in the outgoing longwave radiation corresponding to the albedo maxima as are typically found over cloudy regions composed of middle and high clouds. As a consequence, the spatial structure of the albedo is to a large extent determined by the distribution of cloud-free oceans and cloudy and desert areas found in this latitude belt whereas the emitted longwave radiation spatial structure is determined by cloud-free areas (including low cloud) and the highly convective cloud zones found in this zone.

The temporal scales are also different since enormous amounts of energy are absorbed in the oceans which have large storage capacity, whereas energy absorbed over land areas, with their limited storage capacity, can be delivered to the atmosphere quite readily.

5.2.2 Adequate Assessment of the Effects of Radiation Variability on the Climate

In assessing the influence of the radiation budget upon climate, one must smooth out the high frequency variations that occur naturally in space and time. The real noise of weather events has significant correlation out to one week so that the period over which one should average for climate analysis should exceed this period. Since there is a significant, but yet unknown and unpredictable, diurnal variation in the emitted and reflected components of the radiation budget, many local times must be sampled during the averaging period to avoid systematic errors. Studies of the diurnal oscillation might yield sufficiently accurate models for estimating the daily averages from measurements made at a single local time. Utilizing measurements at only a single time without models will bring in systematic biases.

Spatial averaging on the scale of 250 km or greater is appropriate since weather shows correlations to these levels. It is expected that each time scale (weekly, monthly, seasonally, and annually) will have associated with it a minimally useful spatial scale which will become evident as a consequence of analyzing the data on different time scales.

To study the influence of radiation on the climate, various radiation budget parameters must be correlated with climate variables that are suggested by physical theory. There are just too many combinations of variables that could be correlated so that it is necessary to limit the possibilities. After all, physical understanding of the influence of radiation on climate change should result from the analysis.

5.2.3 Determination of the Influence of Variability on the Design of Future Radiation Sensors

As mentioned earlier, time scales of the order of days and spatial scales of the order of tens of kilometers become important in designing radiation sensors. Proper sampling is essential if the systematic biases are to be removed. It is important, therefore, that data sets be made available for studying variations in the outgoing radiation for periods of much less than a day if one is to properly assess the diurnal variability. Only then can an observing system be designed that properly samples in time. Data from geostationary satellites will be extremely valuable toward this end.

The manner in which the outgoing radiation is sampled spatially is also important as it influences the choice of the size of the field-of-view and the manner in which narrow-angle radiometers should scan the Earth's surface. The design of the instrument must be guided by the accuracy required and the natural variability of the radiation.

High resolution radiometric observations should be utilized as a basis for testing various candidate radiometric systems. Simulations of radiometers flying over such high resolution fields could aid the design greatly. Analyses of spatial autocorrelation functions determined for various scales from the data could also play an important part in selecting the size of the field-of-view.

5.2.4 Accuracy of Radiation Budget Required for Use in Climate Studies

The response of simple atmospheric/hydrospheric models to radiation forcing on various space and time scales should be studied. Changes in the response due to changes in the radiation forcing will yield a measure of the accuracies required of the observations. On the basis of the results of the simpler models, the response of more complex models to radiation forcing should be studied. Sensitivity studies should permit inference of the amount of error that can be tolerated.

5.2.5 Meteorological and Climate Parameters That Might be Correlated with Radiation Budget Parameters

The basic driving mechanisms for the global atmospheric and oceanic circulation is the pole-to-equator gradient of incoming solar insolation and the Earth's rotation. The monthly and zonal mean pole-to-equator gradient of net radiation demonstrates an annual variation of the same characteristic shape as the mean pole-to-equator gradient of insolation. However, the net radiation gradient demonstrates an interannual variability, as determined from satellite measurements of the planetary radiation budget, which is not seen in the pole-to-equator gradient of insolation.

Correlative studies to date, such as those by J. Ellis (1972) indicate that interannual variations in the net radiation gradient are related in a statistical sense to interannual variations in atmospheric energetics parameters computed for the northern hemisphere.

Positive and negative peak correlations are observed at a two-month positive lag between the interannual variations of pole-to-equator net radiation gradient and the zonal and eddy available potential energies, respectively. A positive lag is defined such that features of the net radiation gradient precede in time features of the energetics parameters.

That a relationship should exist between the pole-to-equator gradient of net radiation and zonal and eddy available potential energy on the time scale of synoptic events at zero lag is plausible. The lag correlation results at a monthly time scale, and its implication for predictability, requires further investigation. Time series composed of radiation budget data from ERB and ERBSS and atmospheric parameters will permit in-depth investigation required to validate the results derived from pre-ERB satellite radiation budget data sets.

Other parameters that have been recommended for correlation with the radiation budget parameters besides the atmospheric energetics parameters are surface variability (ice, snow, sea surface temperature, vegetation, soil moisture, etc.), cloudiness, and appropriate atmospheric temperatures. Exceptional events such as volcanic eruptions should be studied to see whether any causal relationships can be shown to exist between the exceptional event and the radiation budget parameters.

5.2.6 Evaluation of Existing Data Sets

Many data sets exist today which are probably adequate for assessing the principal features of the variability of the radiation budget. NOAA scanning radiometer data have been archived without interruption for a period of nearly four years. Analysis of this data should permit one to gain some insight into the variability for at least the monthly mean values for regions with linear dimensions of the order of 200 - 250 km (Gruber, 1978). GOES data on geostationary satellites should yield information on the diurnal variability of the radiation as well as providing additional information on spatial variability.

NIMBUS-6 ERB low resolution data exist for nearly three years with short breaks occurring during the first (Jacobowitz, et al., 1978). The launch of NIMBUS-7 in 1978 should extend this data record a number of years as well as provide good narrow-angle scanning radiometer data. These data are already starting to give us insight into the zonal and global variations of the radiation budget.

To make these data more useful for studies, the existing radiation data sets should be assembled into an atlas which should include information such as the type of orbit, instrument, data quality, the type of corrections that have gone into the final product, and an estimate of its accuracy and precision. Data sets of this nature have been produced in the past, but they need to be updated and should include and standardize past work so as to provide as thorough and uniform a record as possible.

5.3 REFERENCES

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