SOME USES OF ISCCP DATA FOR CLOUD-RADIATIVE MODELING STUDIES

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1. INTRODUCTION

The International Satellite Cloud Climatology Project (ISCCP) is the first project of the World Climate Research Programme sponsored by the World Meteorological Organization and the International Council of Scientific Unions. A series of scientific conferences has identified the crucial uncertainty in climate research caused by poor understanding of cloud-radiative interactions (Stockholm, 1975; Oxford, 1978; New York, 1981). The investigation of the role of the clouds in climate involves the study of many complex dynamic and thermodynamic processes, but the focus of ISCCP is on the study of cloud effects on earth's radiation budget. However, the scientific objectives of the ISCCP recognize the importance of a uniform global cloud climatology to further progress in all areas of cloud studies (World Climate Program, 1982). These objectives are:

(1) To produce a global, reduced resolution, calibrated and normalized, infrared and visible radiance data set, along with a data set describing the radiative properties of the atmosphere, from which cloud parameters can be derived.

(2) To coordinate basic research on techniques for inferring the physical properties of clouds from satellite radiance data and to derive and validate a global cloud climatology.

(3) To promote research using ISCCP data to improve parameterizations of clouds in climate models and to improve understanding of the earth's radiation budget and hydrological cycle.

The strategy is to collect data from the available operational weather satellite network which provides global coverage with sufficient time resolution to observe the diurnal variations of clouds (Schiffer and Rossow, 1983). The network involves five geostationary satellites (METEOSAT, INSAT, GMS, GOES-WEST and GOES-EAST) and at least one NOAA polar orbiter, all of which carry imaging radiometers with similar characteristics. Operational data collection began on 1 July 1983 and is planned to continue for at least five years. At original full resolution, a complete global data set from six satellites would occupy more than 60,000 high density (6250 bpi) tapes per year; thus, the data processing strategy involves eight primary data centers to collect reduced-volume versions of the data and to produce the cloud climatology (Fig. 1).

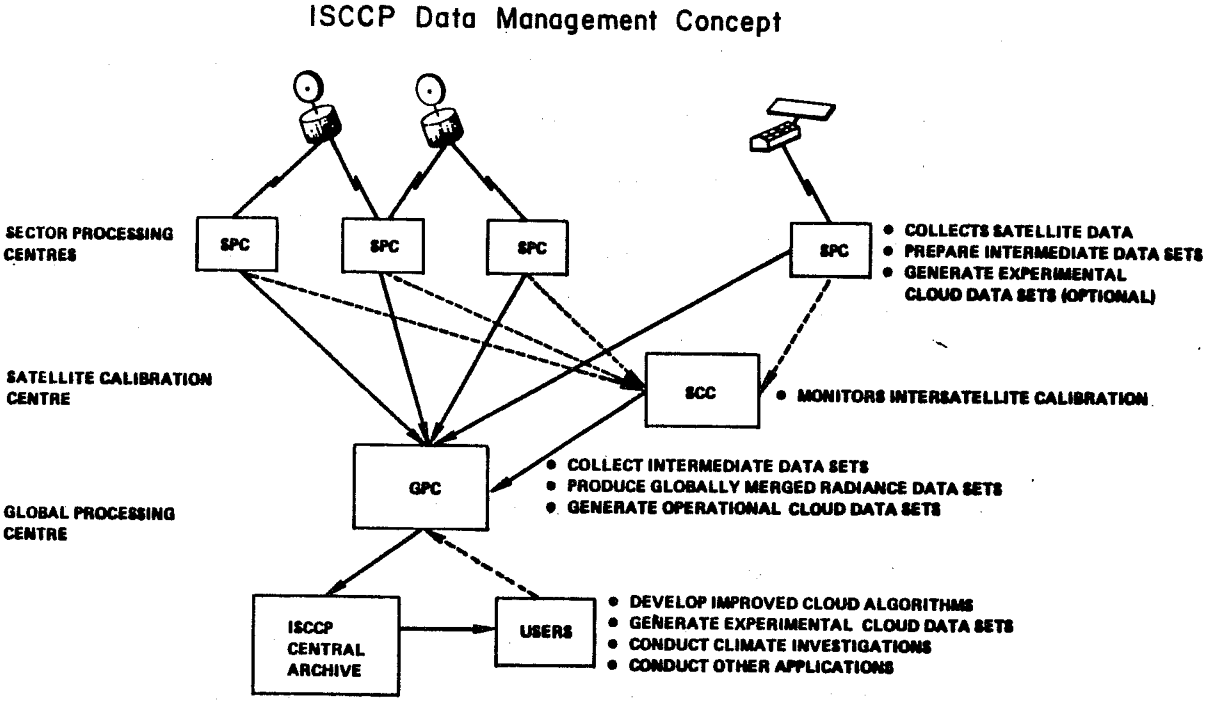

ISCCP Data Management Concept

Fig. 1. Schematic diagram of ISCCP data management concept. Functions of each data centre are indicated.

The Sector Processing Centres produce a radiance data set (B1) with nominal 10 km and 3 hr resolution that can be used for case studies. These centers, as well as Special Area Processing Centres, also produce limited full resolution data sets for special research purposes. The Satellite Calibration Centre is responsible for normalizing all geostationary satellite radiometers to the polar orbiter radiometer used as the reference standard. The Global Processing Centre produces another radiance data set (B3) with nominal 30 km and 3 hr resolution, for use in climatological studies, and derives, with the use of correlative data about the surface and atmosphere (CD), a global cloud climatology data set (C1) with nominal 250 km and 3 hr resolution. Monthly statistical summaries of the cloud properties (C2) are also prepared. The ISCCP Central Archive maintains copies of the B1, B3, CD, C1 and C2 data sets for use by the research community.

The analysis algorithm used to obtain the cloud climatology has four basic steps: (1) determination of clear sky radiances, (2) radiance threshold , (3) radiative property analysis, and (4) diagnostic analysis. Since the spatial and temporal statistics of clear sky (or surface) properties generally differ from those of cloud properties, the first step of the analysis employs a stastistical approach to identify clear scenes and to determine global maps of clear sky (or surface) properties. This analysis is facilitated by use of available conventional data describing the distributions of snow and sea ice cover and land/ocean surface temperatures. The second step compares observed radiances to the inferred clear sky radiances and labels as clouds all image pixels for which the difference between these radiance values exceeds some threshold value.

The threshold value represents the uncertainty in the inferred clear sky radiance values. In the third step, cloudy radiance values are compared to radiative model calculations which parameterize cloud effects in terms of the cloud optical thickness and cloud top temperature of a single, plane-parallel cloud layer. Surface and atmospheric effects are accounted for using the clear sky radiances together with correlative data specifying atmospheric temperature and composition. Finally, all specified and derived quantities are combined to assess the spatial and temporal statistics of cloud behavior. Classification of cloud types is part of this diagnostic analysis.

The purpose of this paper is to highlight briefly the questions which arise when ISCCP (or any other) data are compared with climate models. The discussion focuses attention on the need for precise definitions of quantities through a radiative model; but also leads to the conclusion that careful definition of diagnostic quantities obtained from the data is also necessary to cross-check comparisons. Two examples of comparing data and model are presented that illustrate the difficulties. By considering these issues, this workshop can help define the key parameters that should be produced by ISCCP.

2. ILLUSTRATIONS OF USES OF ISCCP DATA

2.1 Comparison of cloud properties

The most straightfoward approach to the use of cloud data in model improvement studies is a direct comparison of the distribution of some cloud property in the data and in the model. Figure 2 shows a global, "monthly mean cloud cover fraction" distribution derived from NOAA-5 polar orbiter imagery data (Rossow et al., 1985) and obtained from the GISS climate GCM (Model II) (Hansen et al., 1983). The comparison indicates a generally favorably conclusion about the realism of the model's climate simulation, but some interesting differences can also be noted. The most obvious shortcoming of the model is the lack of the marine boundary layer strato-cumulus regions off the west, subtropical coasts of continents. The model's low resolution also reduces the ITCZ cloud feature.

Useful conclusions about the model's validity from such a comparison are limited for two crucial reasons: (1) the effective meaning of "cloud" is different in the data and the model and (2) the effective meaning of "monthly mean cloud cover fraction" is different in the data and the model. For example, in the data shown a cloud is defined by the data resolution and uncertainties in the analysis procedure to be a single plane-parallel cloud layer with a minimum horizontal dimension of 4 km, a variable cloud top altitude >1.5 km and a variable optical thickness >1.5. In the model a cloud is a multi-layer, plane parallel cloud with a horizontal dimension of ~1000 km, seven discrete vertical positions and a specified optical thickness (as a function of altitude). In the data, the monthly mean cloud cover is the count of the number of 4 km regions containing "cloud" measured only at one local time of day. In the model, the mean cloud cover represents the frequency of occurrence of complete cloud cover of a grid box where clouds can occur only at 5 hr intervals. These differences mean that data and model "results" are not strictly comparable, hence agreement or disagreement can only be evaluated by determining the relationship between the cloud definitions more carefully.

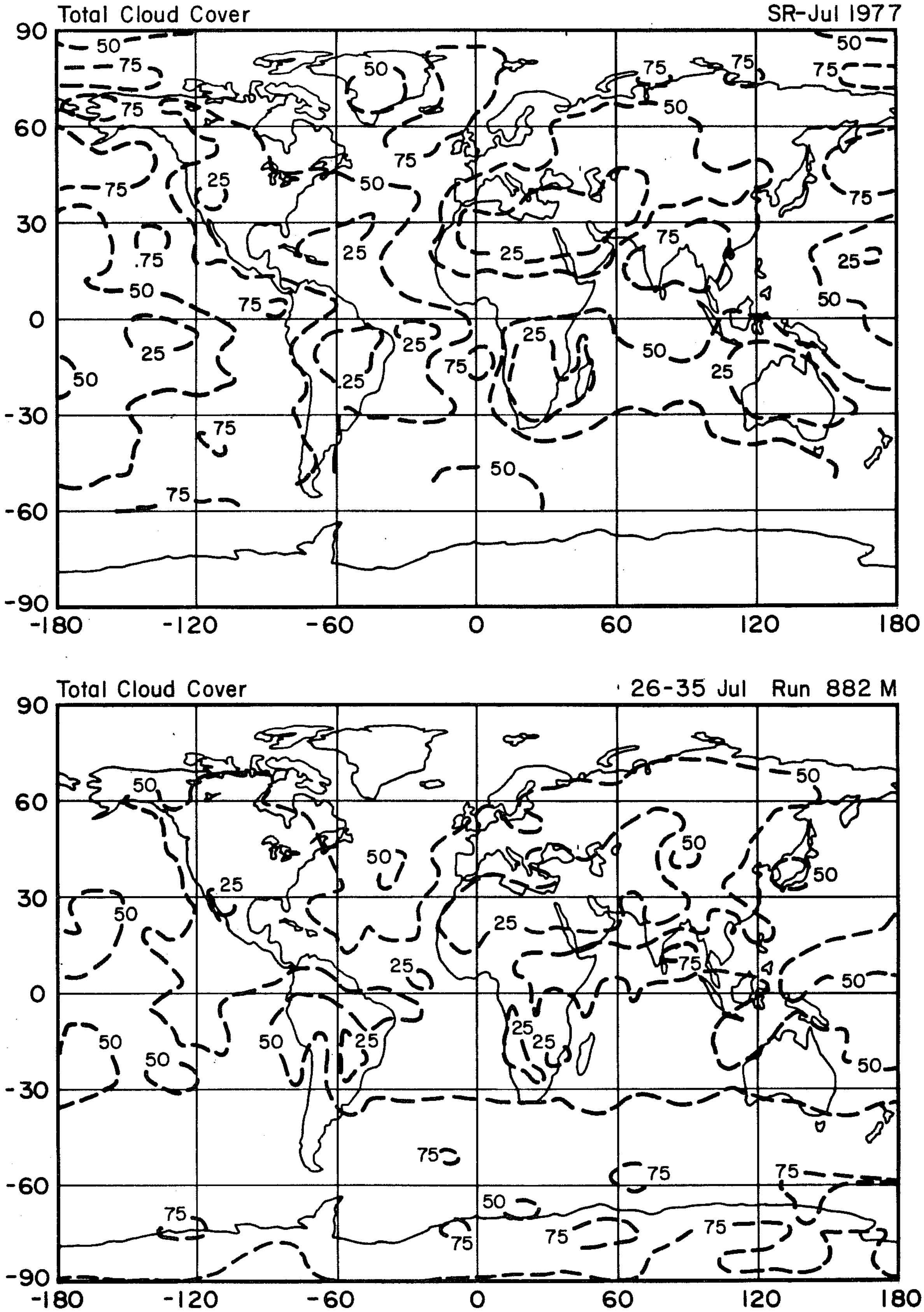


Fig. 2. Global distribution of cloud cover fraction for the month of July from (a) 1977 NOAA-5 scanning radiometer (SR) data and from (b) 10-yr average produced by the GISS climate GCM.

In the case of the climate model, one crucial effect of the parameterized clouds is the radiative effect. This suggests that a more meaningful comparison between the data and the model might be comparison of the radiative consequences of both sets of clouds, which requires that the radiative model of a cloud used in the data analysis be the same as that used in the model. The retrieval method used for the NOAA-5 data analysis was built around the radiative transfer model used in the GISS climate GCM for this very purpose.

2.2 Comparison of cloud radiative effects

Figure 3 shows the zonal mean net radiation balance at the top of the atmosphere and at the surface that is inferred from the satellite cloud data and calculated by the climate model. The general variation with latitude is similar in both the data and the model, but the small regional differences are large enough to be very important to regional climate. Comparison of the net fluxes, as well as the individual solar and infrared fluxes shown in Table 1, indicates that the models low resolution ITCZ and lack of marine strato-cumulus does not reproduce the associated local minimum in the data's radiation balance near the equator (Fig. 3). The model exhibits more variation in hemispheric solar flux at the surface than the data but less variation at the top of the atmosphere (Table 1). The latter example is consistent with the generally lower seasonal variation of southern hemisphere cloud cover in the model compared to the However, like the direct comparison of cloud properties, the comparison of radiative effects involves model behavior not incorporated in the data analysis. For example, the data retrieval requires information on surface temperature in order to distinguish clear from cloudy scenes. The same

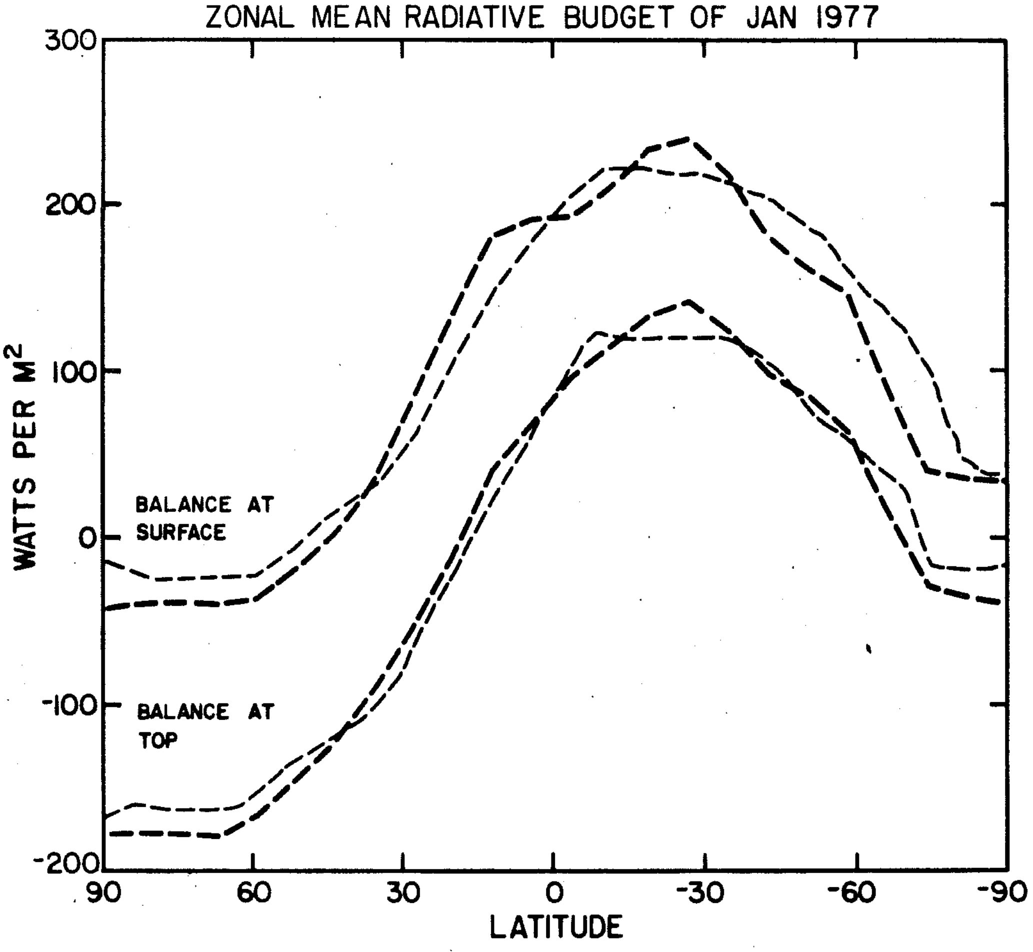


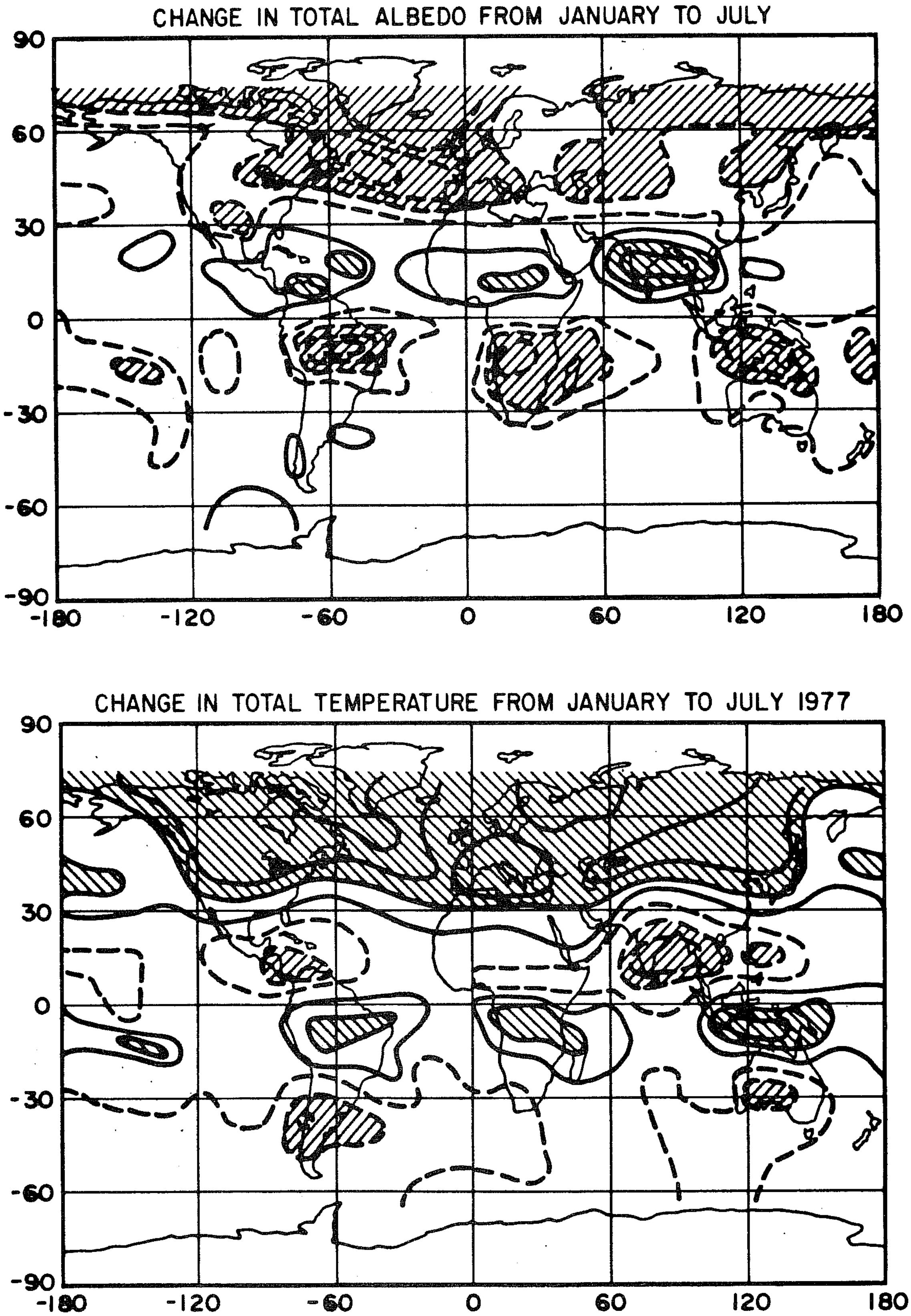
Fig. 3. Zonal mean net radiation budget at the top of the atmosphere and at the surface derived from the NOAA-5 cloud data (thick lines) and the GISS climate GCM (thin lines). Positive net fluxes indicate net heating.

surface temperature must be used in the calculation of the net thermal effects of the clouds; the model surface temperatures may differ from the data values even if the clouds do not. Futhermore, the data values, shown here, are calculated using monthly mean cloud and surface temperatures, obtained seperately, while the model values are monthly mean fluxes. Thus, to be useful in the study of cloud-radiative feedback, the data analysis must incorporate a complete description of the radiative state of atmosphere and surface as well, so that the cloud effects can be properly isolated. Compatible averaging of derived and model quantities is also necessary.

Table 1. Hemispheric and global mean radiative fluxes (watts m^{-2}) derived from satellite data and a climate model.

	Climate Model			Satellite Data		
Quantity	Global	NH	SH	Global	NH	SH
Net surface balance	129	66	192	128	72	184
Net top atm. balance	16	-63	96	19	-58	95
IR Flux ↓ at surface	341	324	357	332	324	339
IR Flux ↑ at surface	390	371	409	371	367	374
IR Flux ↑ at top atm.	231	222	239	215	218	213
Sol. Flux ↓ at surface	201	127	275	181	122	241
Sol. Flux ↑ at surface	23	14	32	15	8	21
Sol. Flux ↓ at top atm.	353	227	479	353	225	481
Sol. Flux ↑ at top atm.	107	68	145	119	65	173

Figure 4 demonstrates why this conclusion is so important by showing the implied seasonal cloud-radiative feedback as a difference of monthly mean solar and thermal radiances. The geographic complexity of the changes present even more of a challenge when it is realized that the largest changes generally cancel, leaving only a few key regions, plus a global residual, to determine the net global effect. Consequently, proper determination of cloud feedback effects will require careful treatment of both data analysis and model results for comparison.


CHANGE IN TOTAL ALBEDO FROM JANUARY TO JULY

CHANGE IN TOTAL TEMPERATURE FROM JANUARY TO JULY 1977

Fig. 4. Distribution of seasonal cloud feedback illustrated by a difference between (a) mean July and January albedo and (b) mean July and January brightness temperatures obtained from NOAA-5 SR data. Negative values are indicated by dashed contours. Shading indicates changes >15% of the total fluxes.

3. KEY ISSUES

Some general conclusions are suggested by the brief examples discussed. First, since remote sensing data can only be related to the physical properties of clouds through a radiative model, definition of cloud quantities by a radiative model is unavoidable. The model used in the data analysis must be related to the cloud model used in a climate model before data comparisons can be meaningfully interpreted. Second, since different cloud models will be related by several properties, multivariate comparisons are necessary to constrain the radiative models used in the analyses. Definition of the statistics of the cloud distribution and variation must be consistent between models and data. Third, since analysis of remote sensing data necessarily involves removing atmospheric and surface effects to isolate cloud contributions, radiatively complete comparisons between data and models are possible. With a complete specification of atmosphere, surface and clouds, the model can be used to calculate many other observable quantities that can be measured to verify the radiative model used. Such comparisons are necessary in the study of cloud-radiative feedbacks in order to determine the cloud effects on spectrally integrated fluxes. Finally, the complexity of the distribution and variation of cloud optical properties means that models must be compared to more than the average cloud properties obtained from remote sensing. Derivation of more complex statistics of cloud behavior will provide a more challenging test of climate model performance.

4. REFERENCES

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