GLOBAL CLOUD PROPERTIES INFERRED FROM ISCCP ANALYSIS

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1. STATUS OF ISCCP

The International Satellite Cloud Climatology Project (ISCCP) of the World Climate Research Program (WCRP) began data collection in July 1983 and plans to continue through 1995 at least. Radiance measurements are collected from all available spectral channels of the imaging radiometers on the operational weather satellites; global coverage with three hour time resolution is provided by combining observations from the NOAA polar orbiting satellites with the geostationary satellites. Data are currently provided from NOAA-10, NOAA-11, METEOSAT-4, GOES-7 and GMS-4. Figure 1 shows the coverage statistics over the past seven years.

The ISCCP radiance dataset (Stage B3) is produced by sampling the original imaging data at 30 km and 3 hour intervals. All visible (0.6 μm) and infrared (11 μm) radiances are normalized to a single calibration standard, navigated, and placed into a uniform computer tape format. Approximate B3 data volume is about 150 tapes (6250 bpi density) per year. Stage B3 data are now available from July 1983 through 1987; data for 1988 and 1989 will be available within the next few months.

Visible (VS) and infrared (IR) radiances are analyzed, together with correlative datasets that describe the atmospheric temperature, humidity and ozone abundances as well as surface type, topography and snow/ice cover, to produce the cloud climatology. The cloud analysis has three steps: cloud detection, radiative analysis, and statistical analysis. Two data products are produced from the analysis results. Stage C1 data are merged analysis results gridded to a spatial resolution of about 280 km with a three hour time resolution. These data are very detailed and are suitable for cloud process and radiation studies (Table 1). Stage C2 data are monthly summaries of Stage C1 data which are suitable for climate diagnostic studies (Table 2). Stage C1 data occupy 24 tapes per year; Stage C2 data occupy one tape per year. C1/C2 datasets are available though 1986; the pace of data production is about two years per year.

2. VALIDATION STUDIES

Evaluation of ISCCP datasets involves several different kinds of studies: (1) verification of radiance calibrations, (2) determination of cloud amount uncertainties, and (3) interpretation of retrieved cloud optical properties. These studies are carried out by the ISCCP data processing centers, by intensive regional experiments, and by researchers studying the behavior of clouds.

Table 1: C1 Data contents

Global information provided every three hours
for each 250 km grid cell

Cloud amount and distribution information
- Total number of image pixels
- Total number of cloudy pixels
- Total number of IR-cloudy pixels
- Total number of marginal cloudy pixels
- Total number of IR-only cloudy pixels
- Number of cloudy pixels in 7 PC classes
- Number of cloudy pixels in 35 PC/TAU classes

Average total cloud properties
- PC, cloud top pressure without visible channel information
- PC, cloud top pressure with visible channel information
- PC, cloud top pressure of marginal clouds
- Spatial variation of PC
- TC, cloud top pressure without visible channel information
- TC, cloud top pressure with visible channel information
- TC, cloud top pressure of marginal clouds
- Spatial variation of TC
- TAU, cloud optical thickness
- TAU, cloud optical thickness of marginal clouds
- Spatial variation of TAU

Average surface properties
- PS, surface pressure
- TS, surface temperature
- RS, surface visible reflectance
- Snow/ice cover fraction
- Topography and land/water flag

Average radiances
- IR-cloudy
- IR-clear
- Spatial variation of IR
- VIS-cloudy
- VIS-clear
- Spatial variation of VIS
- Viewing geometry and day/night flag
- Satellite identification

Average atmospheric properties
- T, atmospheric temperatures for seven levels
- TS, surface temperature
- TT, tropopause temperature
- PT, tropopause pressure
- PW, precipitable water amount for five levels
- O3, column ozone abundance
- Source of atmospheric data

Table 2: C2 Data contents

Global, monthly average information provided
at eight times of day and over all times of day

Cloud amount information
- Monthly average cloud amount
- Monthly frequency of cloud occurrence
- Monthly average IR-cloud amount
- Monthly average marginal cloud amount

Average total cloud properties
- PC, cloud top pressure
- Average spatial and temporal variations of PC
- TC, cloud top temperature
- Average spatial and temporal variations of TC
- TAU, cloud optical thickness
- Average spatial and temporal variations of TAU
- ALB, cloud spherical albedo
- Average spatial and temporal variations of ALB

Average properties (amount, PC, TC, TAU) for cloud types
- Low cloud (IR-only)
- Middle cloud (IR-only)
- High cloud (IR-only)
- Cumulus, stratocumulus cloud
- Stratus cloud
- Alto-cumulus, alto-stratus cloud
- Nimbostratus cloud
- Cirrus cloud
- Cirro-cumulus, cirro-stratus cloud
- Deep convective cloud

Average surface properties
- TS, surface temperature
- Average temporal variations of TS
- RS, surface visible reflectance
- Snow/ice cover fraction

Average atmospheric properties
- PS, surface pressure
- TS, surface temperature
- T5, temperature at 500 mb
- PT, tropopause pressure
- TT, tropopause temperature
- ST, stratospheric temperature
- PW, column water amount
- O3, column ozone amount

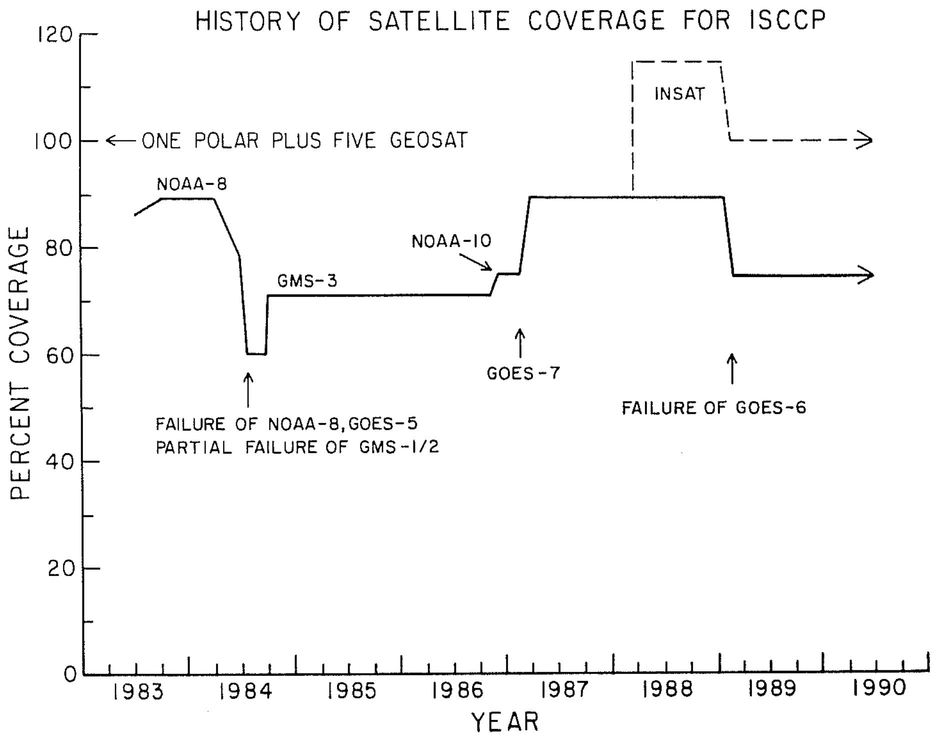

Fig 1. History of weather satellite coverage for ISCCP. The coverage provided by one polar orbiting and five geostationary satellites is defined to be 100%.

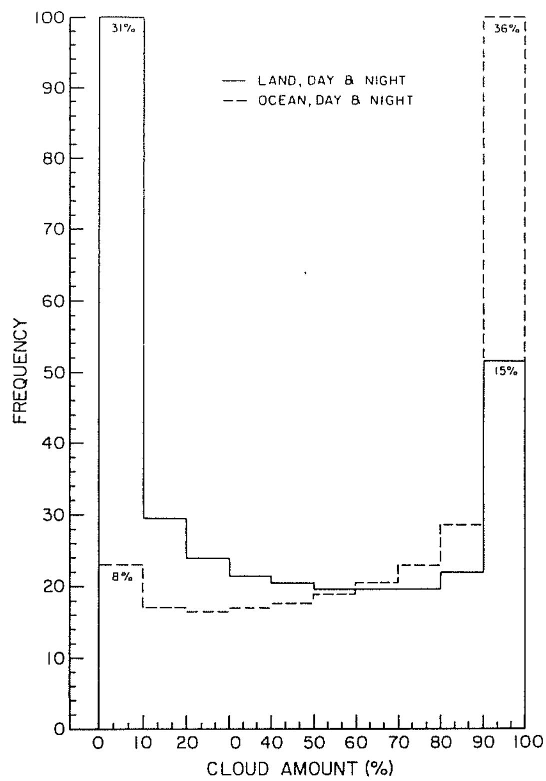

Fig 2. Relative frequency distribution of cloud amounts occurring in 2.5° map grid cells every three hours for land (solid) and ocean (dashed) collected for the period July 1983 - June 1984. Actual frequencies are indicated.

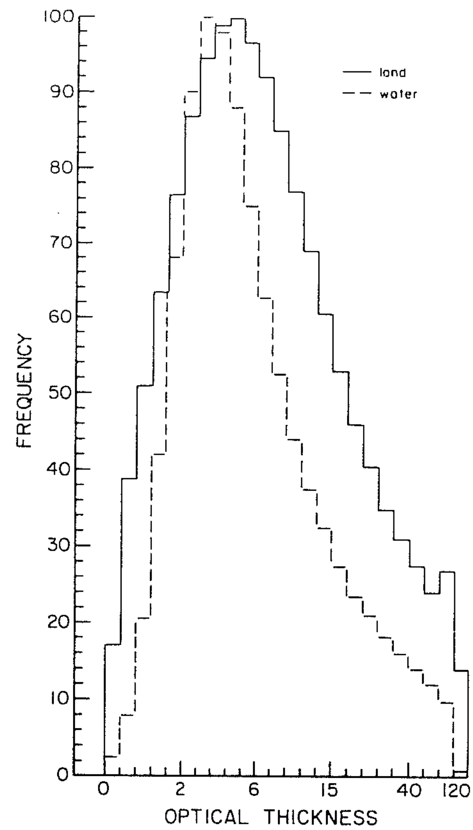

Fig 3. Frequency distribution of average cloud optical thickness values (see caption for Figure 2).

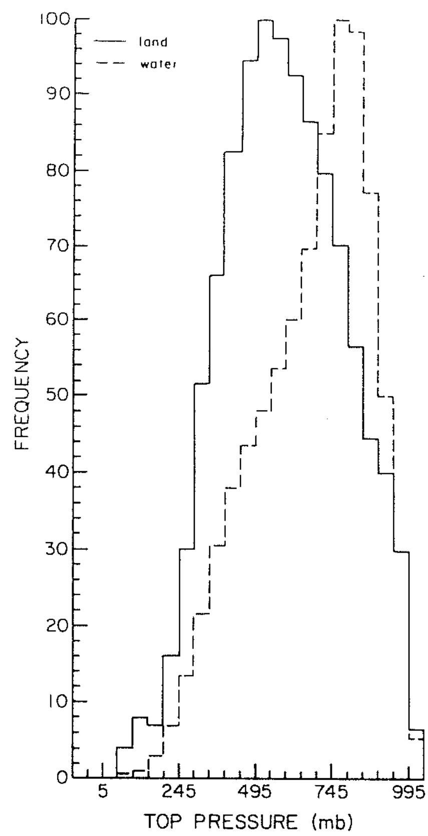

Fig 4. Frequency distribution of average cloud top pressure values (see caption for Figure 2).

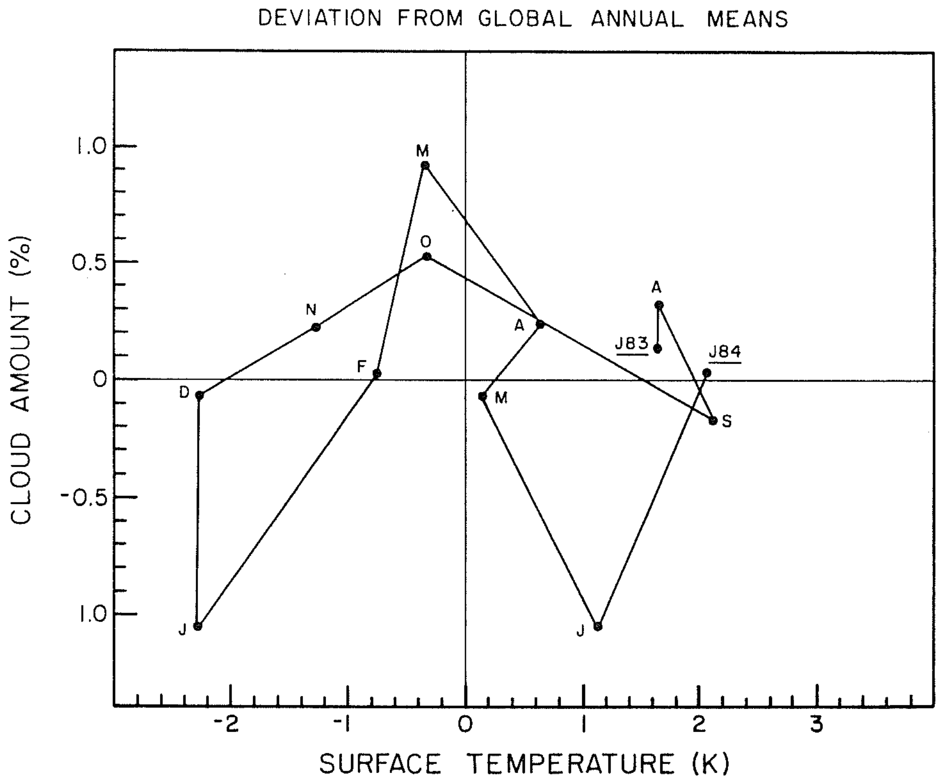

Fig 5. Deviations of global, monthly mean cloud amount and surface temperature from their annual mean values. Individual months are indicated.

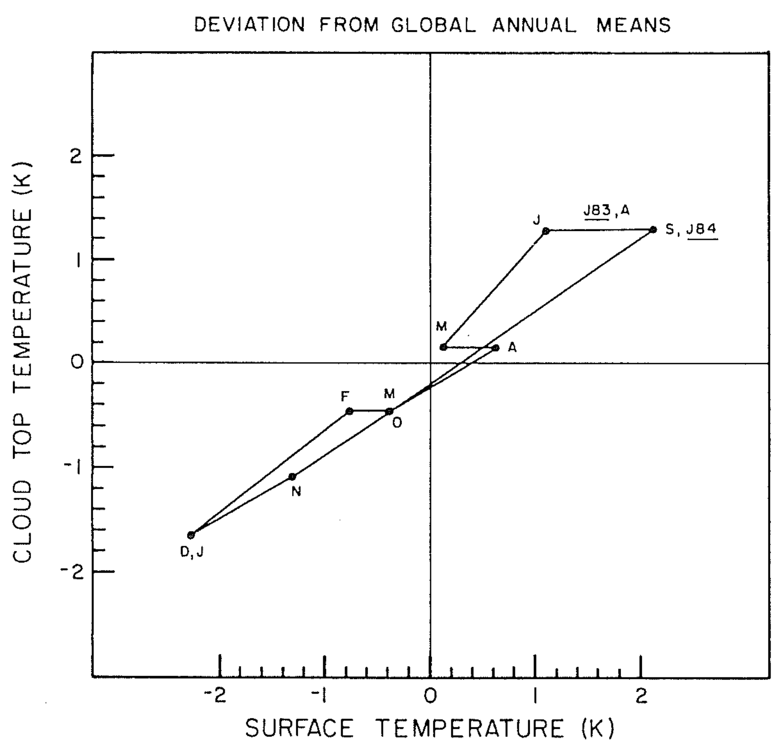

Fig 6. Deviations of global, monthly mean cloud top and surface temperature from their annual mean values.

Verification of the radiance calibration includes both direct comparisons to aircraft monitoring results and other inferences of the calibration of the same radiometers and indirect comparisons to calibrated flux measurements, such as from ERBE and surface radiation stations. These results suggest uncertainties in the ISCCP radiance calibrations of no more than 5%.

Uncertainties in derived cloud amounts are associated with three accuracy issues: cloud detections, determining areal coverage, and defining "cloud amount". The accuracy of cloud detections can be determined by verifying the accuracy of the clear radiance values and uncertainties assumed in the threshold analysis and by determining how much cloudiness exists with radiometric properties nearly identical to the surface. Comparison of surface properties retrieved from the clear radiances with other available information confirms their average values and uncertainty estimates. On-going studies suggest that "undetectable" clouds are not prevalent, globally, but are significant in polar regions. One check of the actual cloud cover obtained from the ISCCP analysis is to compare it with completely different analyses, such as ground observations. However, such comparisons raise the issue of just how to define the cloud amount parameter; this is still a key research question. These studies currently suggest an uncertainty of single cloud amount determinations of about 10-20% and an uncertainty of monthly mean values of less than 10% (though these estimates vary somewhat with region).

3. MEAN CLOUD PROPERTIES

Some results from ISCCP are illustrated in the following figures. Figures 2, 3 and 4 show the distribution of cloud amounts, optical thicknesses and top pressures for global land and ocean areas, collected over one year of data. Cloud amounts are larger over oceans than land, primarily associated with fewer completely clear areas. Cloud optical thicknesses are typically larger over land than ocean, while cloud top pressures are lower over land. The geographic distributions of these quantities reveal the well-known climate zones; however, longitudinal contrasts of cloud properties within these zones are as large as the latitudinal contrasts. The largest cloud amounts occur in the tropics and middle latitudes. The largest cloud optical thicknesses occur in middle latitudes, while the lowest cloud top pressures occur in the tropics.

4. SEASONAL VARIATIONS

Seasonal variations in cloudiness are usually considered as simple variations of cloud amount with surface temperature; however, figures 5, 6, and 7 show that this is not the case. The semi-annual variation of cloud amount (Figure 5) is caused by the amplitude and phase differences of the annual variations of the two hemispheres; summer cloud amounts are generally lower than winter cloud amounts. However, the hemispheric mean variations of cloud amount are dominated by low latitudes, while those of surface temperature are dominated by high latitudes. The annual cycle of cloud top temperature (Figure 6) is caused by the predominance of the seasonal variations over northern hemisphere land areas; however, the phases of tropical and middle latitude seasonal

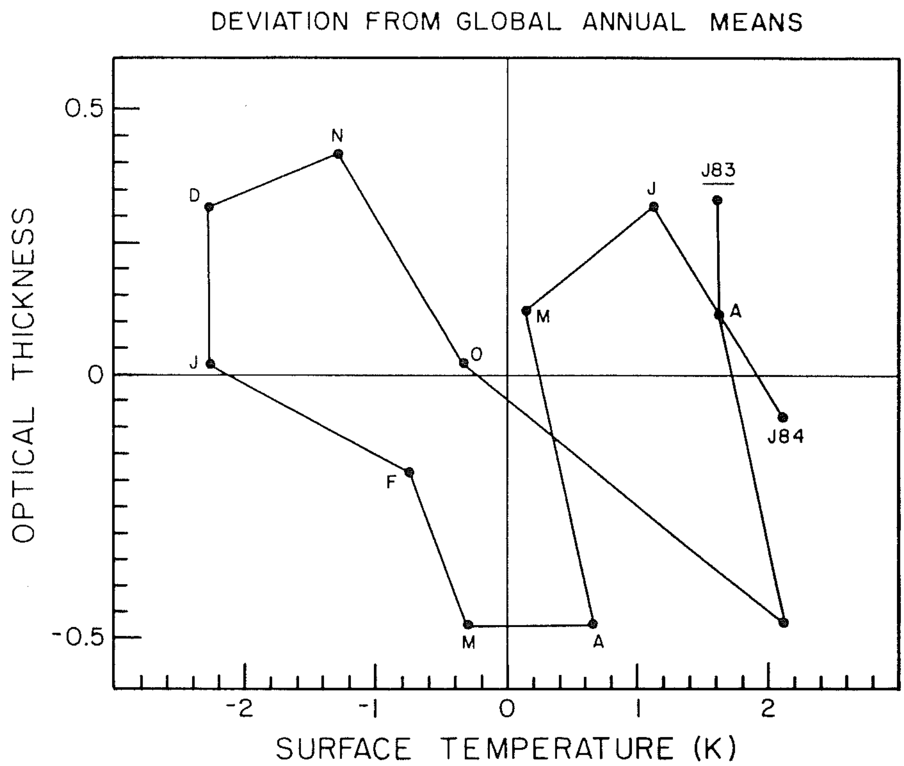

Fig 7. Deviations of global, monthly mean cloud optical thickness and surface temperature from their annual mean values.

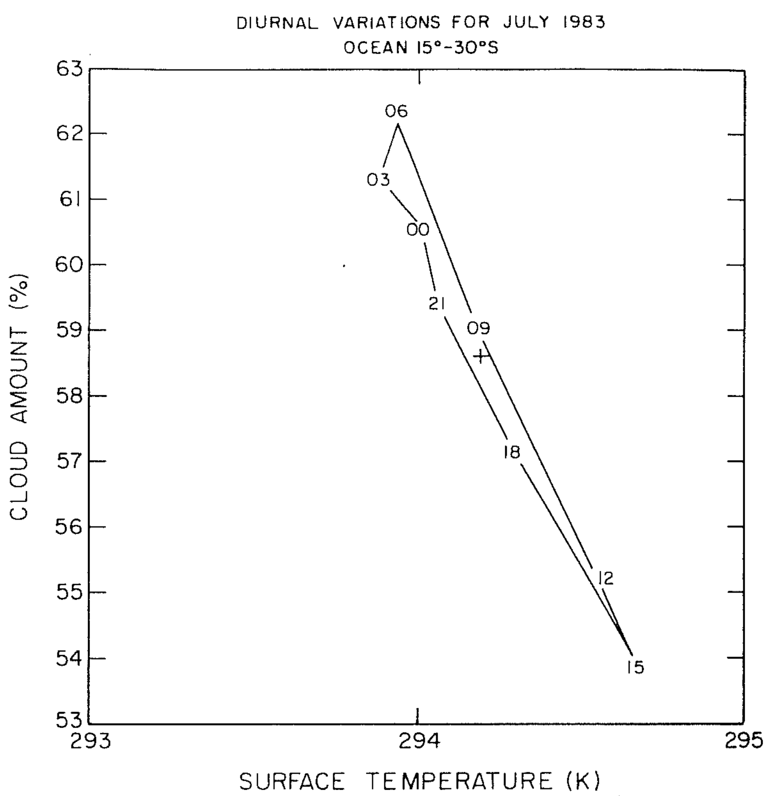

Fig 8. Monthly mean diurnal variations of cloud amount and surface temperature for July 1983 over low latitude oceans.

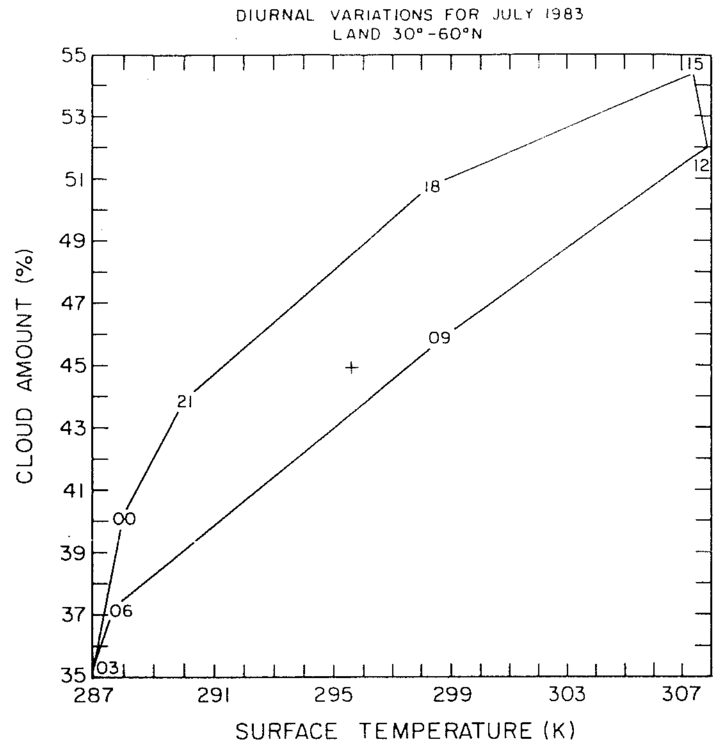

Fig 9. Monthly mean diurnal variations of cloud amount and surface temperature for July 1983 over midlatitude land areas (summer).

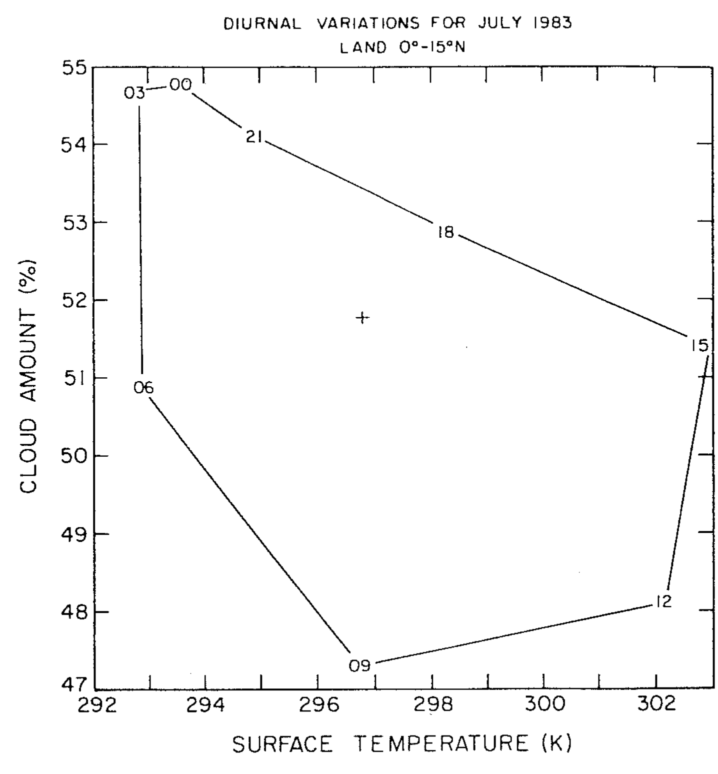

Fig 10. Monthly mean diurnal variations of cloud amount and surface temperature for July 1983 over tropical land areas.

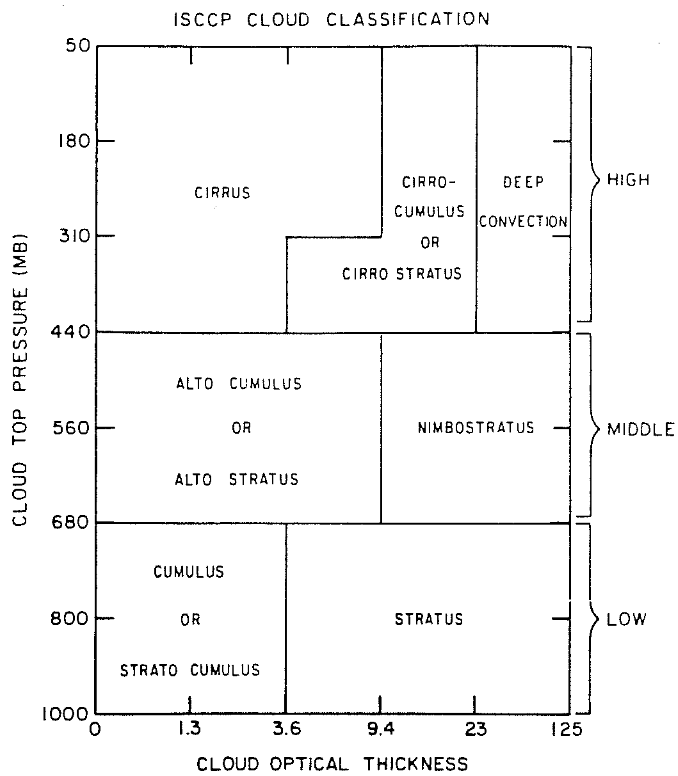

Fig 11. Radiometric definition of cloud types for ISCCP according to cloud top pressures and optical thicknesses.

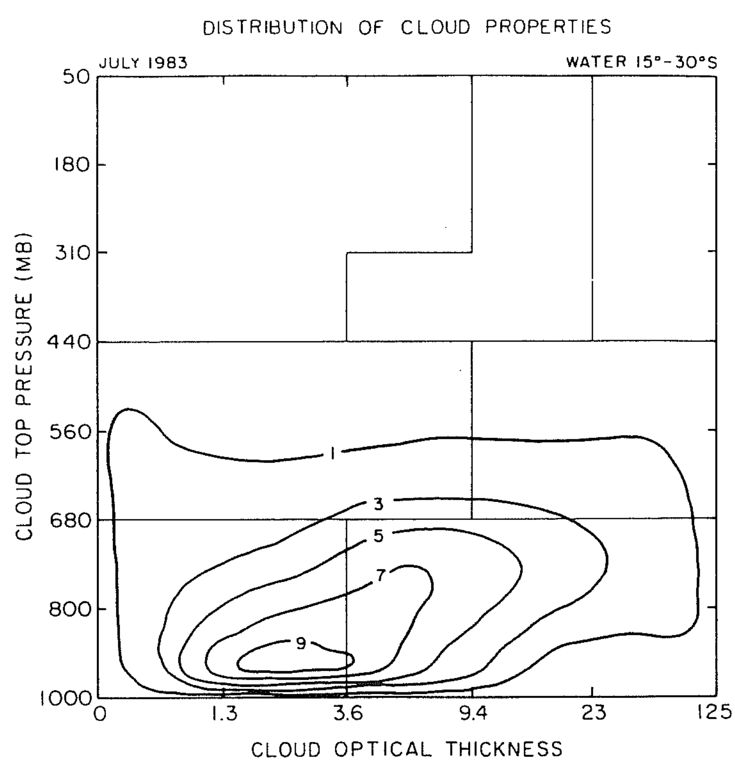

Fig 12. Frequency distribution of cloud top pressures and optical thicknesses for July 1983 over subtropical ocean areas.

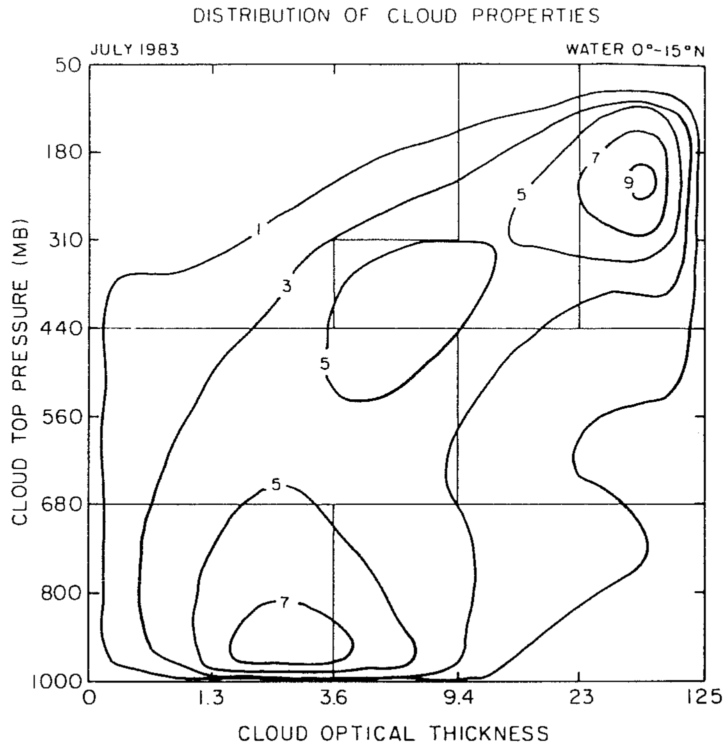

Fig 13. Frequency distribution of cloud top pressures and optical thicknesses for July 1983 over tropical ocean areas.

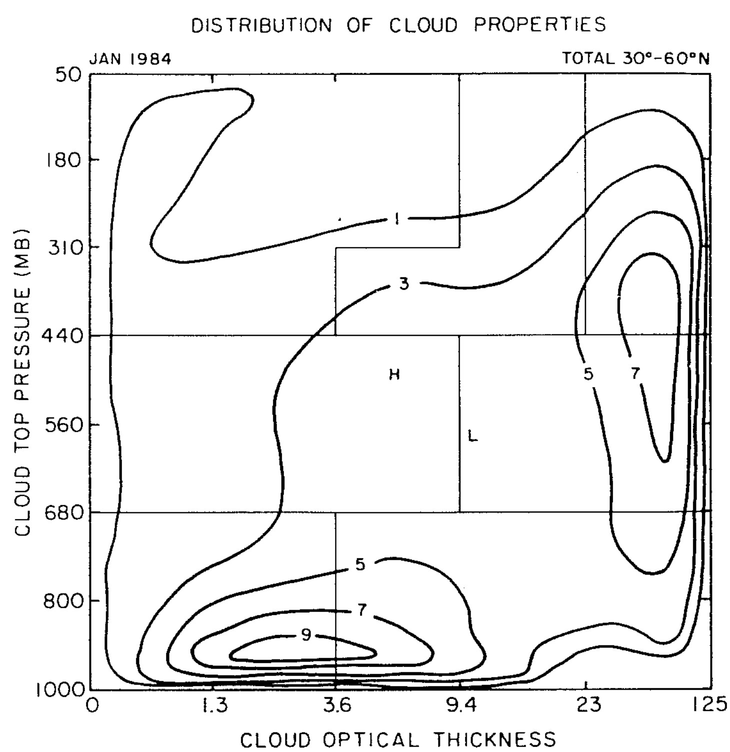

Fig 14. Frequency distribution of cloud top pressures and optical thicknesses for July 1984 over winter middle latitudes.

cycles are opposite. The semi-annual cycle of cloud optical thicknesses (Figure 7) is also caused by phase and amplitude differences between annual cycles in the two hemispheres. Summer clouds in middle latitudes are generally optical thinner than winter clouds, but the opposite is true in the tropics: the midlatitude variations dominate the hemispheric averages.

5. DIURNAL VARIATIONS

Figures 8, 9 and 10 show the diurnal variations of cloud amount over low latitude ocean areas, middle latitude (summer) land areas and low latitude land areas (these are the areas with the largest amplitude diurnal variations). Despite a diurnal variation of surface temperature over oceans that is an order of magnitude smaller than over midlatitude land areas, the ocean cloud amount varies by almost half the amplitude of that over the land. Peak cloudiness occurs near dawn over oceans, but in the afternoon over midlatitude land areas. Tropical land areas exhibit both a diurnal and semi-diurnal variation of cloud amounts.

6. CLOUD TYPES

The cloud properties deduced from satellite radiances can also be used to identify cloud types that have different effects on the radiation budget; however, the geographical variations of the frequencies of occurrence of these radiometric cloud types also seems to correspond to the classical morphological cloud types defined by surface observers (Figure 11). Some examples of the distributions of radiometric cloud types are given in Figures 12, 13 and 14. This suggests a linkage of cloud radiative properties with meteorology that is the key relationship needed to improve the simulation of clouds in weather and climate GCMs. These relationships can be studied more carefully by combining the ISCCP and surface observation cloud climatologies.

7. REFERENCES

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