Overview of Atmos-B1

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1. Introduction

Up to now, we have many kinds of satellite, operational and experimental ones. The data from the space give us useful information about the atmosphere, land and ocean. A homogeneous and global data from the space are important for the earth environmental research, especially over ocean and at the polar regions not to be accessible easily. The global environmental research has been advanced by using these satellite data for recent several decades

On the other hand, the enlargement of the human activity and industrialization gives the crisis to the global environment through increase of CO2, biomass burning , ozone hole, abnormal weather phenomena such as drought, flood etc. It is essential to know what happens on the earth and what is the mechanism.

The incoming solar energy controls the earth environment totally, therefore the stabilization of the earth environment depends on the radiation budget of the earth. The mechanism of the interaction between cloud/aerosol and the solar/terrestrial radiation is not so clear. For example, each GCM model in the world produces each unique results for cloud sensitivity(1). There seems to be many reasons, one of which may be due to an unappropriate cloud treatment in the GCMs because of insufficient information of cloud.

The main purpose of the Atmos-B1 project is to understand the earth-atmosphere system in the viewpoint of the earth radiation budget including aerosol and cloud effects. In order to estimate the radiative effects of cloud and aerosol, the physical properties are important, such as optical thickness, size distribution, top/bottom height of cloud and so on.

In this presentation, the importance of aerosol and cloud to the radiation budget of the earth is mainly shown. Then we propose the new instrumental system for the Atmos-B1 to clear the radiative characteristics of aerosol and cloud.

2. Background of the Atmos-B1

For clear sky, the greenhouse gases consist of main part of radiative forcing, as shown in Fig.1(2), and it should be noted that aerosol also have a serious effect to the radiative forcing comparable to the greenhouse gases. One of the most basic parameters of aerosol is the optical thickness which determines the degree of warming or cooling. While the greenhouse gases has a positive warming generally, the aerosol has both effects, which depend on the optical characteristics of aerosol particles, i.e. the complex index of refraction of particles. Absorptive particles play a positive roll to the radiative forcing, while non-absorptive ones such as sulfate particles, including cloud particles suppress the global warming, i.e. negative effect.

Aerosol in the troposphere has an another function through cloud forming. This effect is not clear up to now.

The important thing is to know the aerosol behavior and source/origin which basically determines the optical characteristics, as well as the optical thickness.

The first target of aerosol in the Atmos-B1 project is to get a global data of the optical thickness.

The cloud plays the most important role to the earth radiation budget. Figure 2[3] shows the net cloud forcing. The global average of the net cloud forcing is 20W/m2, which may depend strongly on cloud amount of middle and higher latitude. The radiation budget of the low-latitude cloud, originated from the Hadley circulation, within 35 degrees in latitude, is relatively stable through the whole seasons, but on the contrary, the seasonal change of the shortwave radiation budget for the middle and higher latitude is great. This may be caused by the difference of cloud optical characteristics including the cloud top(bottom) height, ice/water phase and so on.

Figure 3 indicates the variation of cloud forcing of two types of cloud. Cirrus and other clouds has a contrary effect to the radiation budget, in which the cirrus contributes a part of global warming, resulting from a 10% increase in cloud amount.

We can understand the importance of cloud type, top/bottom height as well as optical thickness. In the Atmos-B1 project, these parameters will be observed using active and passive sensors.

3. Requirements of Sensors

The Atmos-B1 team has proposed two new sensors to implement the scientific objects, a space lidar and a cloud-profiling radar(CPR), in addition to usual three passive sensors, such as visible/infrared imager, microwave imager and broadband radiometer similar to the ERBE or CERES[4]. The active two sensors are very powerful for sounding cloud and aerosol.

For the tropospheric aerosol, the present method using satellite data can detect it only over the sea area because of unknown surface reflectance of land. Also at the polar regions, it is not available. When the lidar will be used, it can be got easily without dependence of the surface and solar conditions.

The ISCCP[5] data has been compiled as a WCRP project of WMO from 1983. This goal is to complete a cloud climatology to collect cloud and its related information using polar and geo-stationary satellite data, such as visible/near-infrared and thermal infrared data. Figure 4 shows an example of a zonal mean distribution of cloud amount from ISCCP data. The cloud height is classified into three groups using 11 μ m and TOVS data. It also discriminates type of cloud depending on the optical thickness, such as cirrus, cirro-cumulus and so on. This sample is a monthly mean of an every 3-hour average for January 1988. The total amount of cloud has three peaks except near the north pole, which means an ITCZ cloud and a mid-latitude to subarctic cloud zones. These are good agreement with our former knowledge. For the northern part over 60 degrees in latitude, however, the ISCCP algorithm cannot detect cirrus cloud in winter, as shown in the figure, and can discriminate a low cloud insufficiently, not shown here.

These limitation is for passive sensors. A combination of the space lidar and the CPR can cover this weakness, in particular to get a global distribution of cloud top/bottom height without any limitation. A lidar can detect cloud information with less than 2 to 3 in optical thickness, such as a most part of cirrus, altocumulus and lower cumulus while a CPR can observe a cloud with more than this optical thickness. The cloud can be covered over the whole globe with a simultaneous usage of these sensors.

Each specification of sensors is compiled in Table 1, and will be explained in other presentations by each expert.

4. Summary

The atmos-B1 team has proposed the new sensor system including a lidar and CPR to get a global data about aerosol and cloud, in order to estimate the earth radiation budget. This system can complement the present data only from the passive sensors, and has many characteristics;

1. the global distribution of aerosol optical thickness even over land can be estimated using a lidar for clear sky,
2. the cloud information, such as cloud base height and 3-dimensional structure which cannot be inferred using a passive sensor, will be obtained, and
3. the combined use of both active sensors with usual passive sensors lets us know the complicated cloud status totally at any locations including over-land and polar regions.

References

1. R.D. Cess et al.: Intercomparison and Interpretation of Climate Feedback Processes in 19 Atmospheric Global Circulation Models. J. Geophys. Res., 95(1990), 16601-16615.
2. Climate Change 1995, The Science of Climate Change: Part of the Working Group I contribution to the Second Assessment Report of the IPCC, 1996.
3. D.L. Hartmann: Radiataive Effects of Clouds on Earth's Climate, in Aerosol-Cloud-Climate Interactions Ed. Peter V. Hobbs, Academic Press, San Diego, 1993.
4. S.Q. Kidder and T.H. Vonder Haar: Satellite Meteorology, 466pp, Academic Press, San Diego, 1990.
5. R.A. Schiffer, and W.B. Rosssow: The International Satellite Cloud Climatology Project(ISCCP): The first project of the World Climate Research Programme. Bull. Am. Meteor. Soc., 64(1983), 779-784.

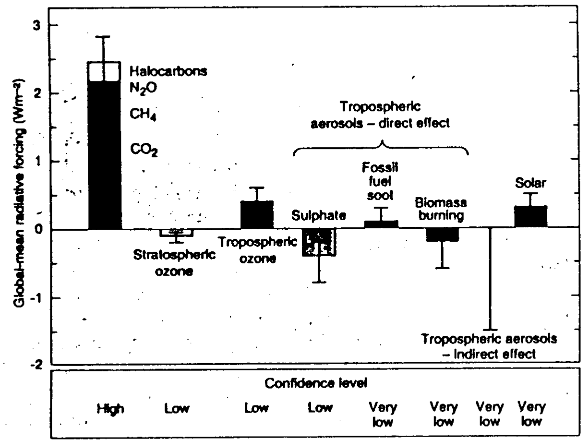

Fig. 1 Global-mean radiative forcing by greenhouse gases, ozone and aerosols. Uncertainty of aerosol in radiative forcing is relatively larger than that of greenhouse gases

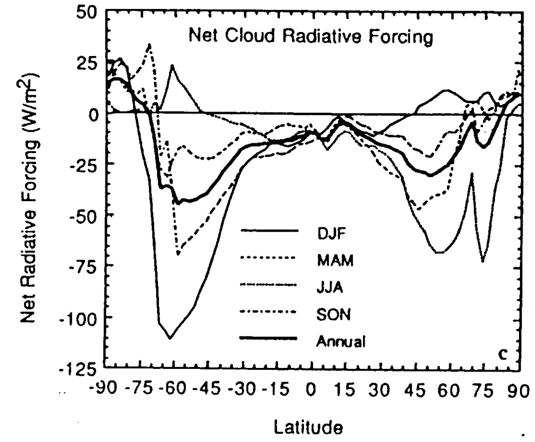

Fig.2 Zonal and seasonal averages of net cloud radiative forcing based on two years of ERBE data.

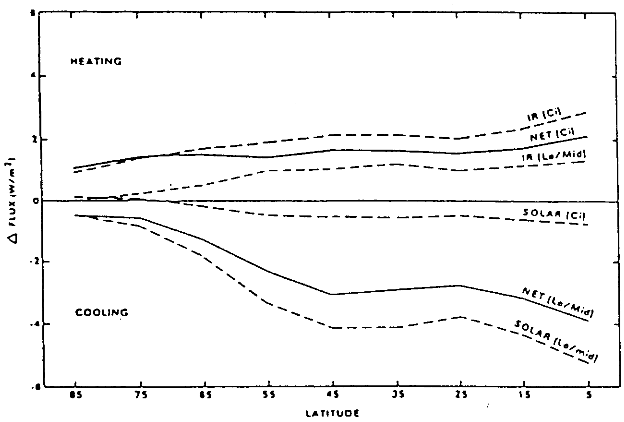

Fig.3 Change in the globally averaged annual mean flux into the earth-atmosphere system resulting from a 10%(relative) increase in cloud amount for cirrus clouds(Ci) and for all other clouds(Lo/Mid), shown for shortwave(SOLAR), longwave(IR) and net(NET) radiation components.

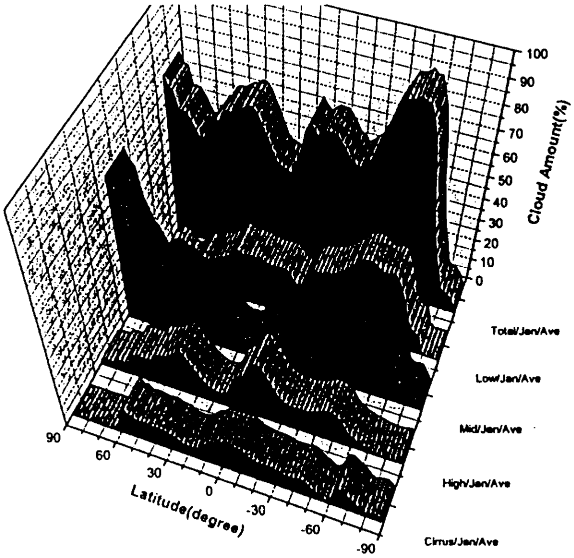

Fig.4 Zonal average of cloud amount for cirrus, high, middle, and low cloud based on ISCCP/C2 data. This statistics is a monthly mean for every 3-hour data of January, 1988. "Total" means the integrated cloud amount of "high", "middle" and "low" cloud.

Table 1 Summary of the sensors proposed in the Atmos-B1 project.

Instruments/Sensors(Not decided in detail)

(1) Cloud Profiling Radar(CPR) —> 1st priority

Frequency: 95GHz >> 78GHz (-3dB for 78GHz)
Polarization: Yes(?)
Resolution : Vertical < 500m
Horizontal <1000m
Scanning : Hopefully scanning
but maybe not due to S/N limitation

Present status:
Developing an airborn model at the CRL
End of 1996FY ... will be completed
1997FY ... Test flight

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(2) LIDAR —> 1st priority

Wavelength : 1064nm and/or 532nm (not decided)
Polarization : Yes
Resolution : Vertical 100m
Horizontal about 1500m
Scanning : Not(?)

present status:
Developing a lidar for the demonstration satellite

Instruments/Sensors(Not decided in detail)

(3) Visible/Infrared Imager —> 1st priority

Wavelength:		
	0.63μm	Optical thickness
	1.60	Effective radius
	3.75	Effective radius Cloud detect over snow/ice
	10.8	Cloud top temp/ Cirrus detect
	12.0	Cloud top temp/ Cirrus detect

Resolution: < 1000m
Swath : about 1000km

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(4) Microwave Imager —> 2nd priority

Frequency:		
19.4GHz	V & H	PWC, LWC, RR
22.2	H	PWC, LWC
37.0	V & H	PWC, LWC. RR
85.5	V & H	PWC, IWC

Resolution: < 4.5 - 5km
Swath : about 1000km

50 - 60GHz (3ch) —> Sounder for temperature profile

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(5) Broadband Radiometer/Imager —> 3rd priority

Wavelength: Visible(reflectance)
Infrared(emission)

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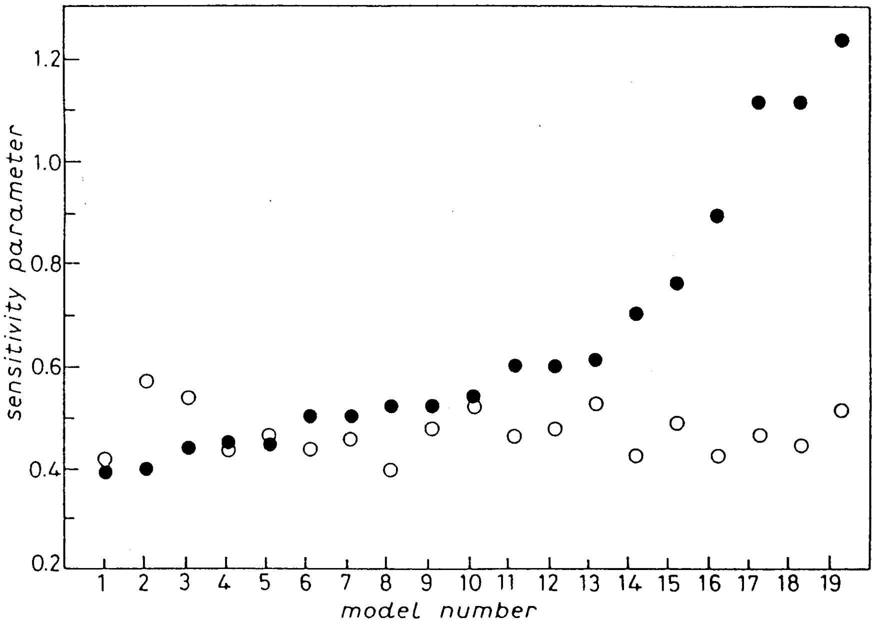
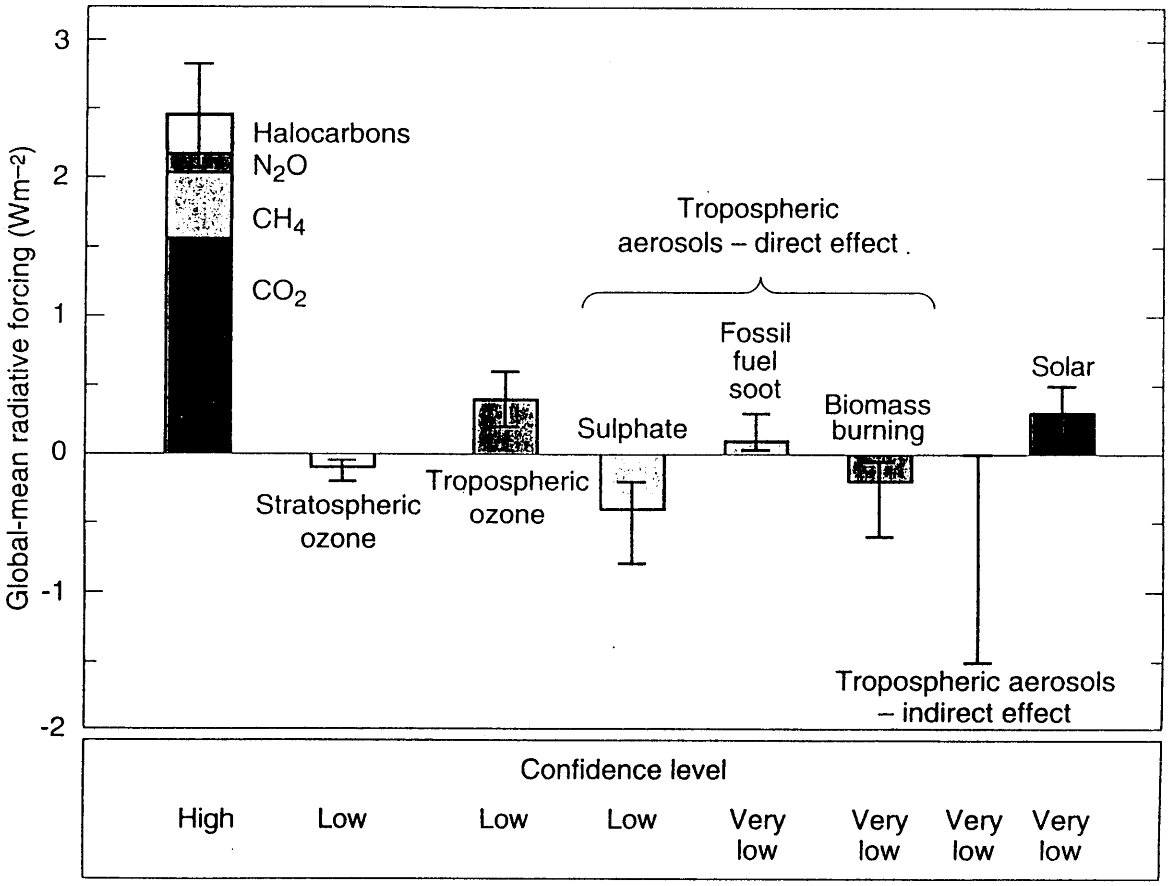


Fig. 2. – Clear-sky (○) and global (●) sensitivity parameters ($^{\circ}\mathrm{C\,m^{-2}\,W^{-1}}$) 19 GCMs.


Global-mean radiative forcing (Wm-2)
3
2
1
0
-1
-2
Halocarbons
N2O
CH4
CO2
Tropospheric aerosols – direct effect
Fossil fuel soot
Solar
Biomass burning
Sulphate
Stratospheric ozone
Tropospheric ozone
Tropospheric aerosols – indirect effect
Confidence level
High
Low
Low
Low
Very low
Very low
Very low
Very low

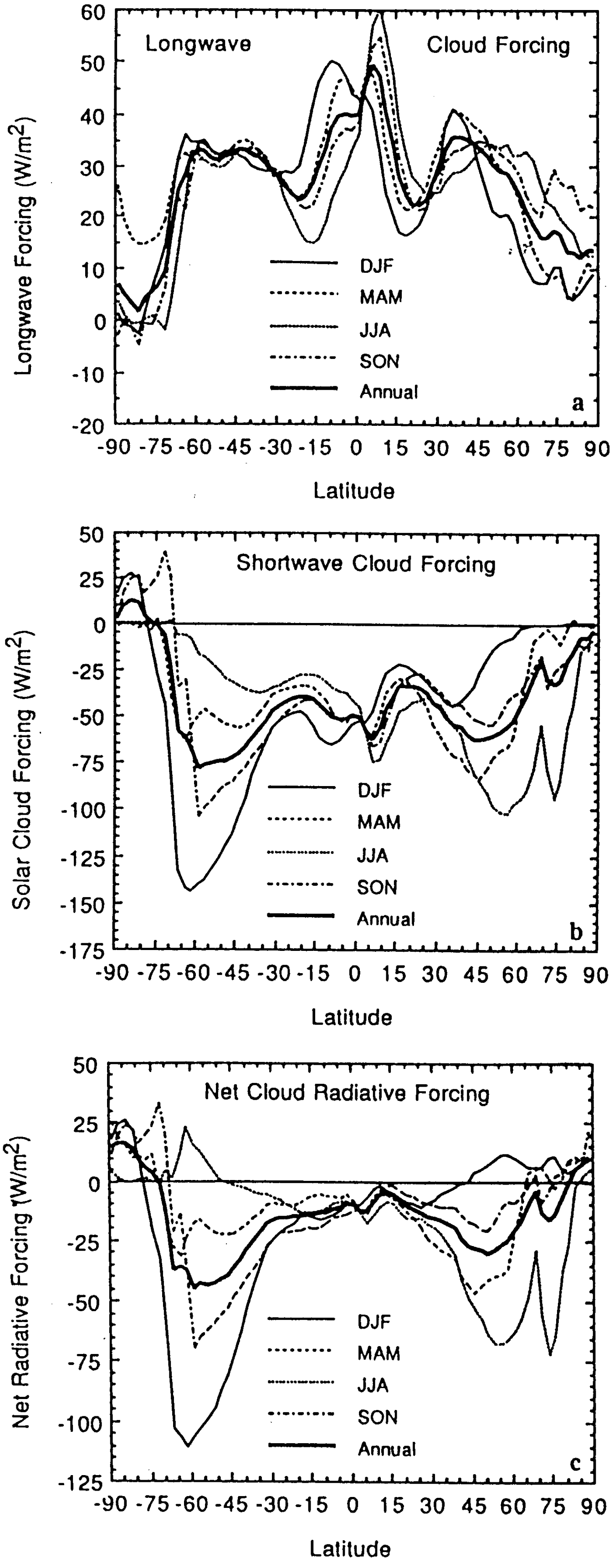
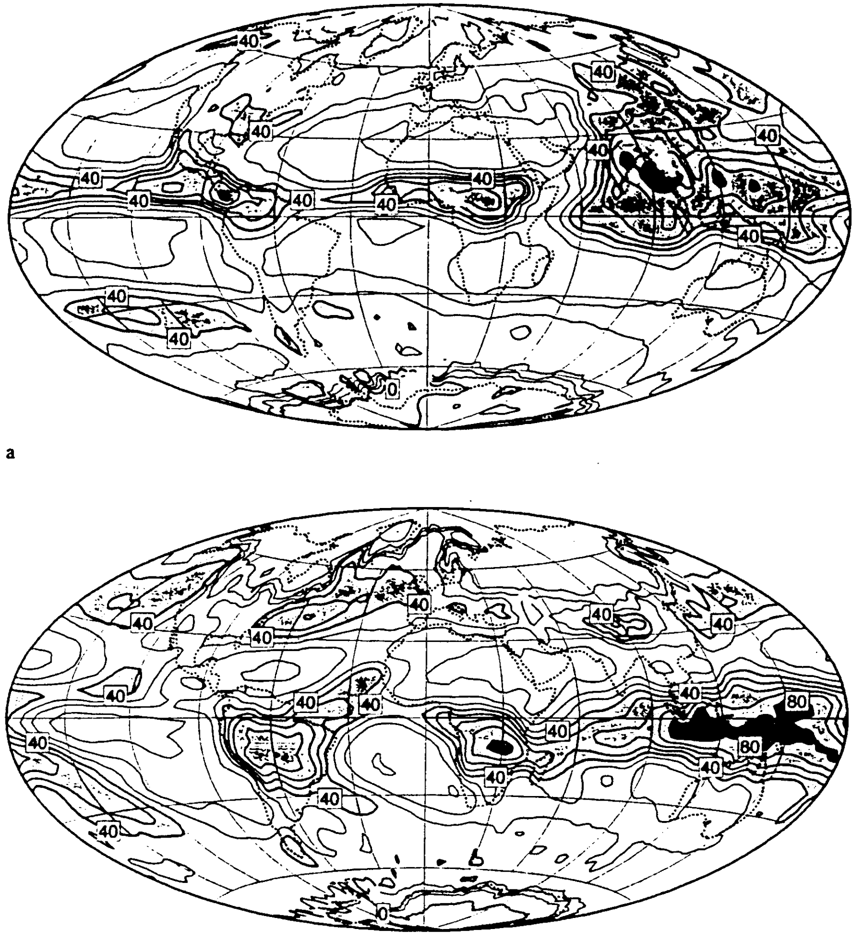


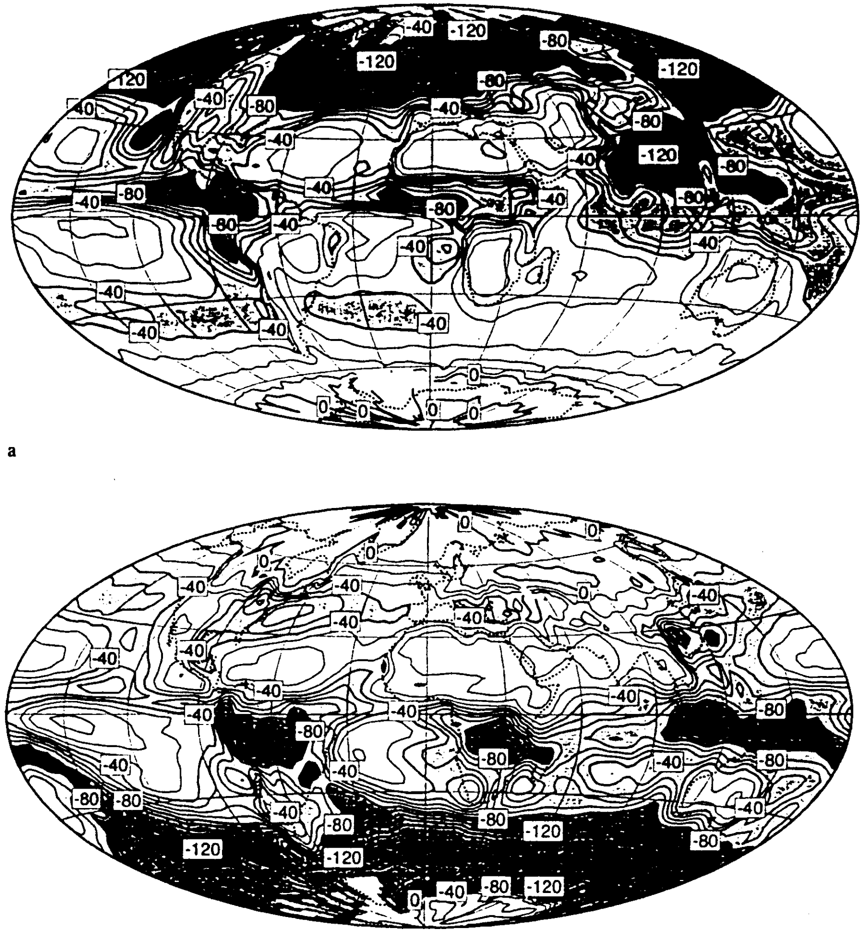
Figure 5 Zonal and seasonal averages of (a) longwave cloud forcing, (b) shortwave cloud forcing, and (c) net cloud radiative forcing based on two years of ERBE scanner data. Averages for each of four 3-month seasons and the annual mean are shown.



a

b

Figure 1 Longwave cloud radiative forcing of Earth's energy balance (a) for the June, July, August (JJA) and (b) for December, January, February (DJF) seasons determined from two years (Feb. 1985–Jan. 1987) of ERBE data from two scanning instruments on the ERBS and NOAA-9 satellites. The contour interval is 10 W m^{-2}. Values greater than +40 W m^{-2} are lightly shaded and values greater than +80 W m^{-2} are heavily shaded. Note that positive values indicate that clouds reduce the outgoing longwave radiation.



a

b

Figure 3 Cloud forcing of absorbed solar radiation (a) for JJA and (b) for DJF estimated from ERBE data. Contour interval is 20 W m^{-2}. Values more negative than −40 W m^{-2} are shaded and values more negative than −80 W m^{-2} are heavily shaded.

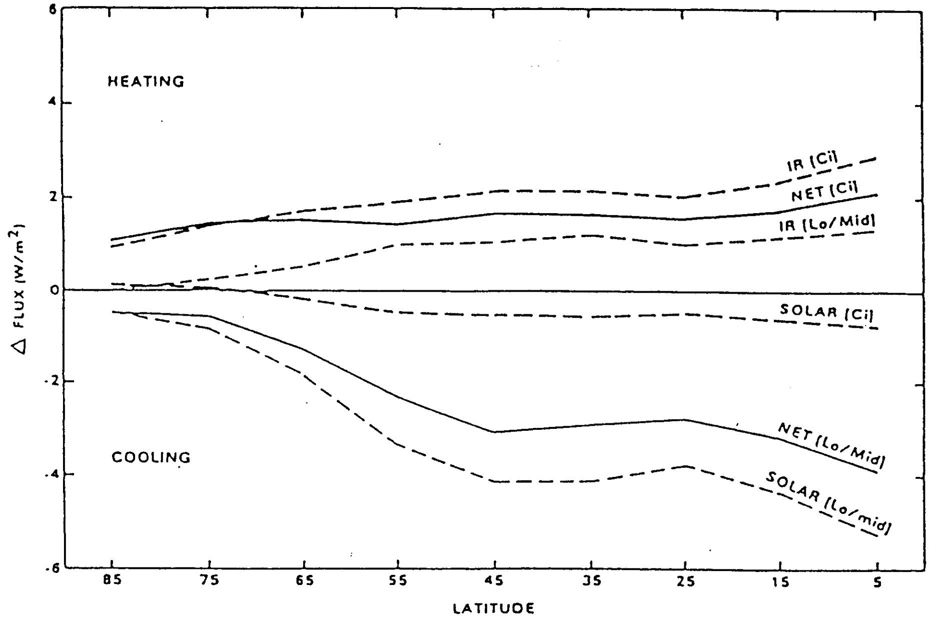


Figure 2. Change in the globally averaged annual mean flux into the earth-atmosphere system resulting from a 10% (relative) increase in cloud amount for cirrus clouds (Ci) and for all other clouds (Lo/Mid), shown for shortwave (SOLAR), longwave (IR), and net (NET) radiation components. Computations were done with the radiative transfer model and cloud parameterization of Peng *et al.* (1982) and the cloud cover data of London (1957).

図１：雲量を10％増加させた時の大気地表面系に入る放射量の変化、雲の種類、高度による違い（Arking, 1990）。

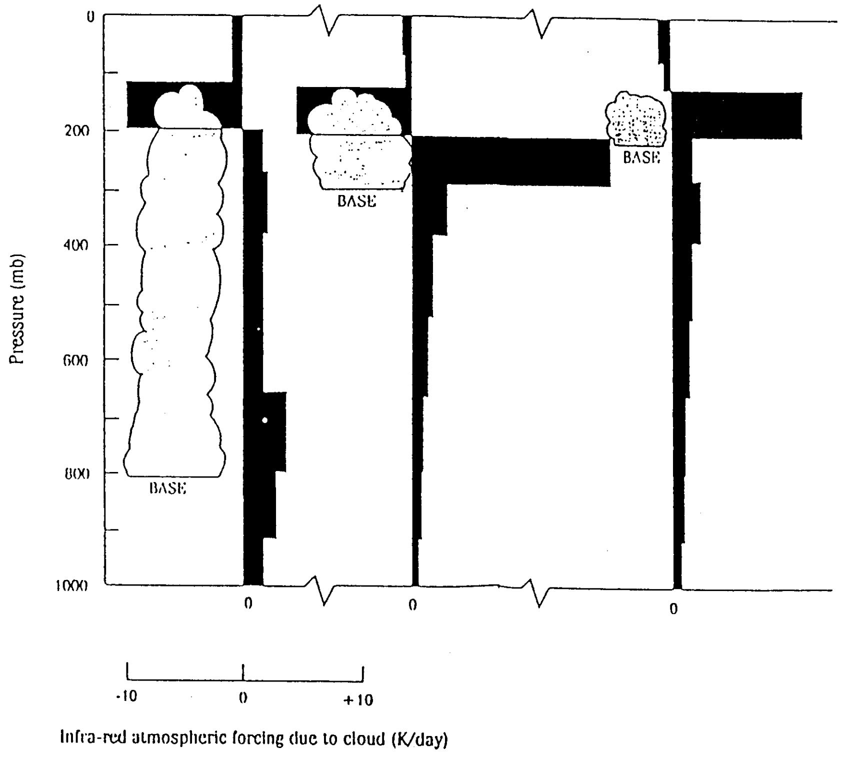


図２：長波長放射による加熱・冷却率の鉛直分布、雲底高度の違いによる変化（Slingo and Slingo, 1989）。

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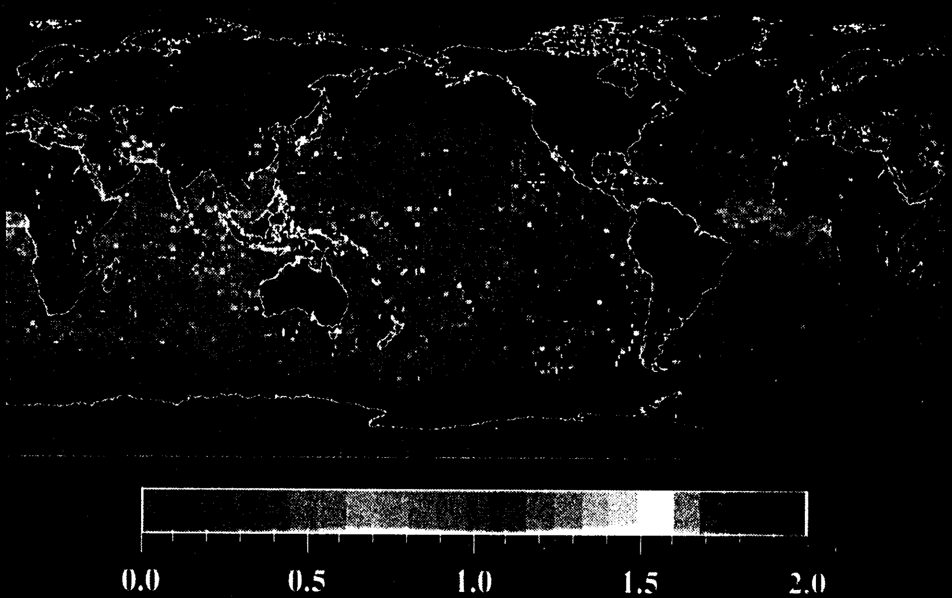
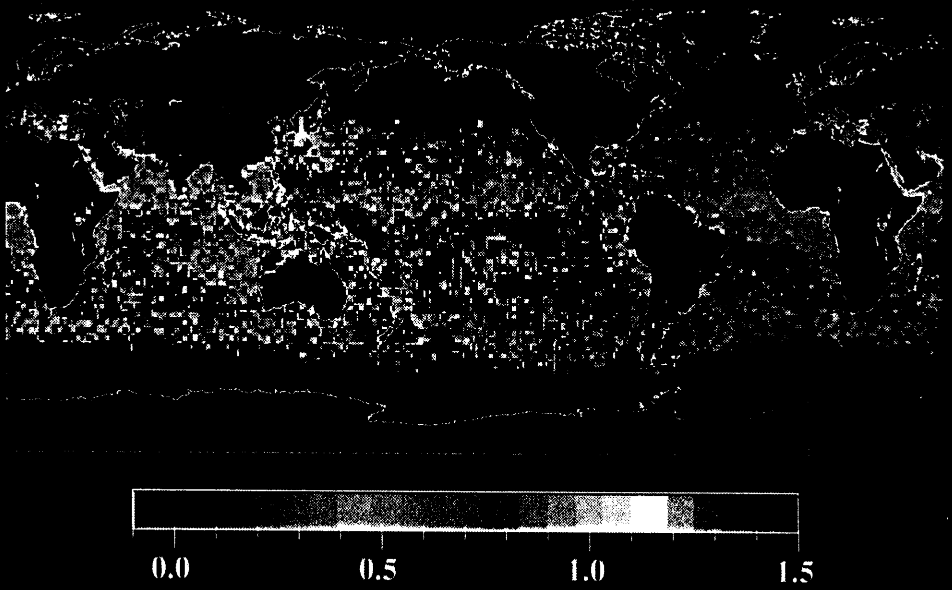
10 Day Composite of AVHRR-9 Retrievals
January, 1988

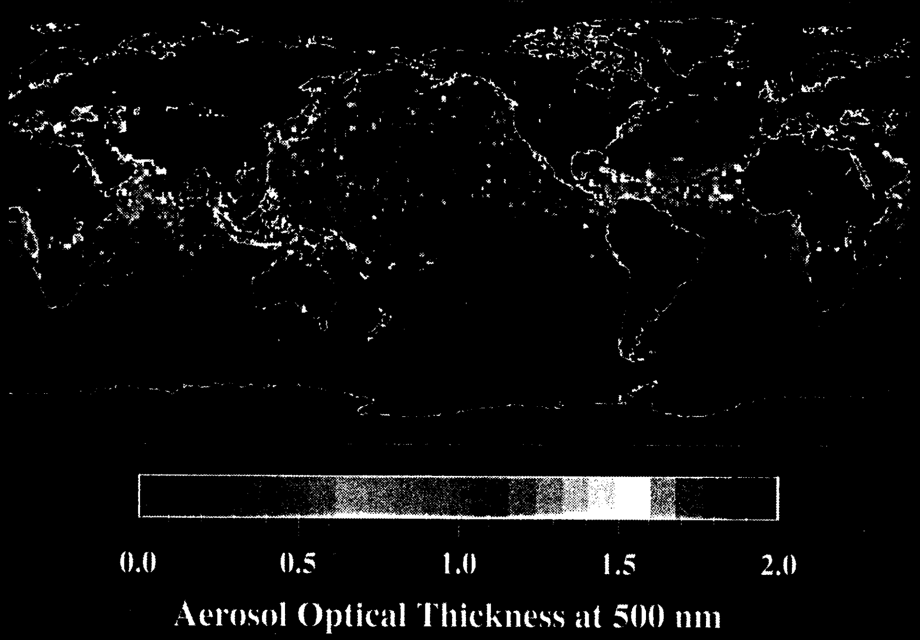


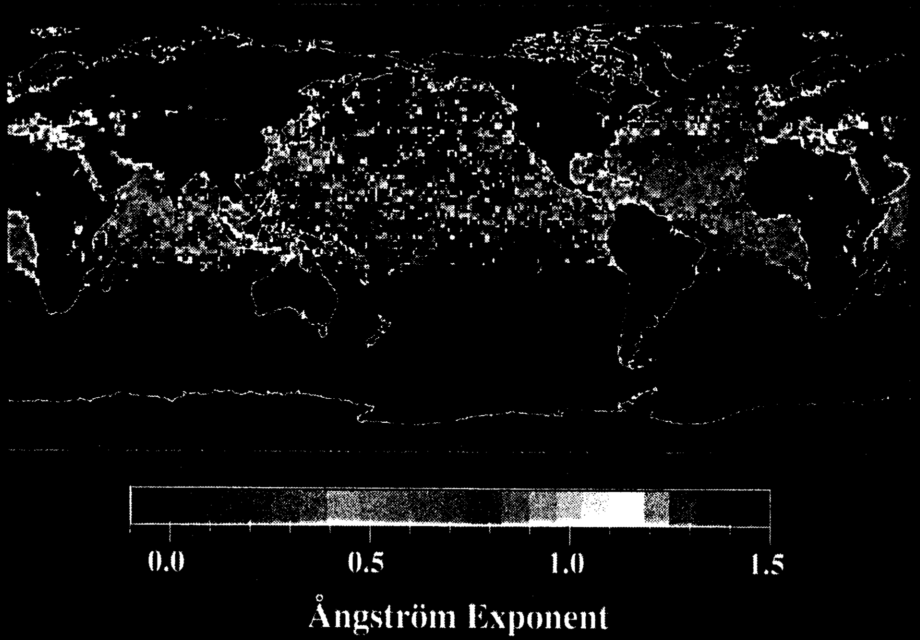
Aerosol Optical Thickness at 500 nm

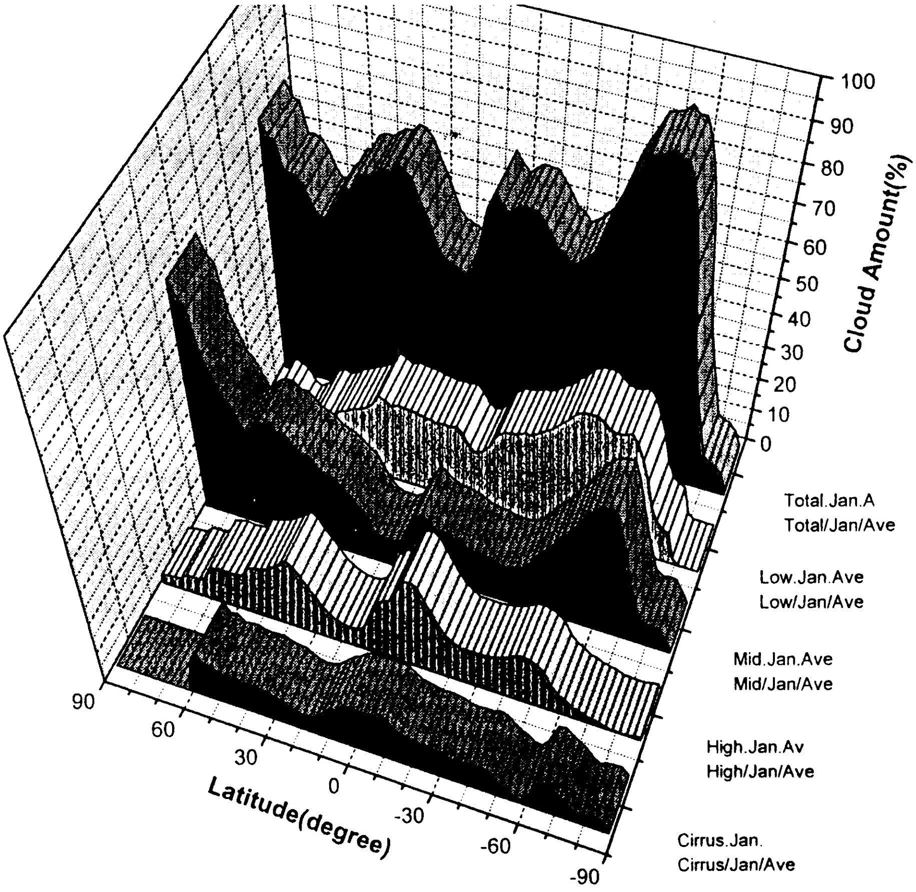


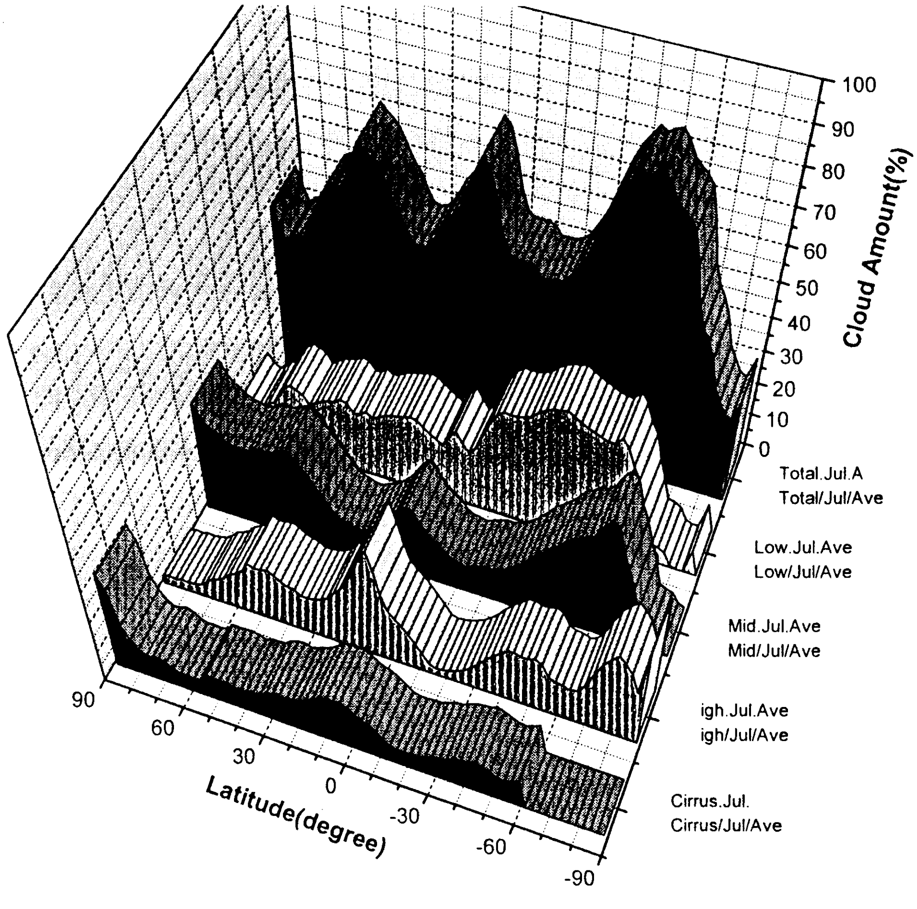
Ångström Exponent

10 Day Composite of AVHRR-9 Retrievals
July, 1988






100
90
80
70
60
50
40
30
20
10
0
Cloud Amount(%)
Total.Jan.A
Total/Jan/Ave
Low.Jan.Ave
Low/Jan/Ave
Mid.Jan.Ave
Mid/Jan/Ave
High.Jan.Av
High/Jan/Ave
Cirrus.Jan.
Cirrus/Jan/Ave
90
60
30
0
-30
-60
-90
Latitude(degree)


100
90
80
70
60
50
40
30
20
10
0
Cloud Amount(%)
Total.Jul.A
Total/Jul/Ave
Low.Jul.Ave
Low/Jul/Ave
Mid.Jul.Ave
Mid/Jul/Ave
igh.Jul.Ave
igh/Jul/Ave
Cirrus.Jul.
Cirrus/Jul/Ave
90
60
30
0
-30
-60
-90
Latitude(degree)

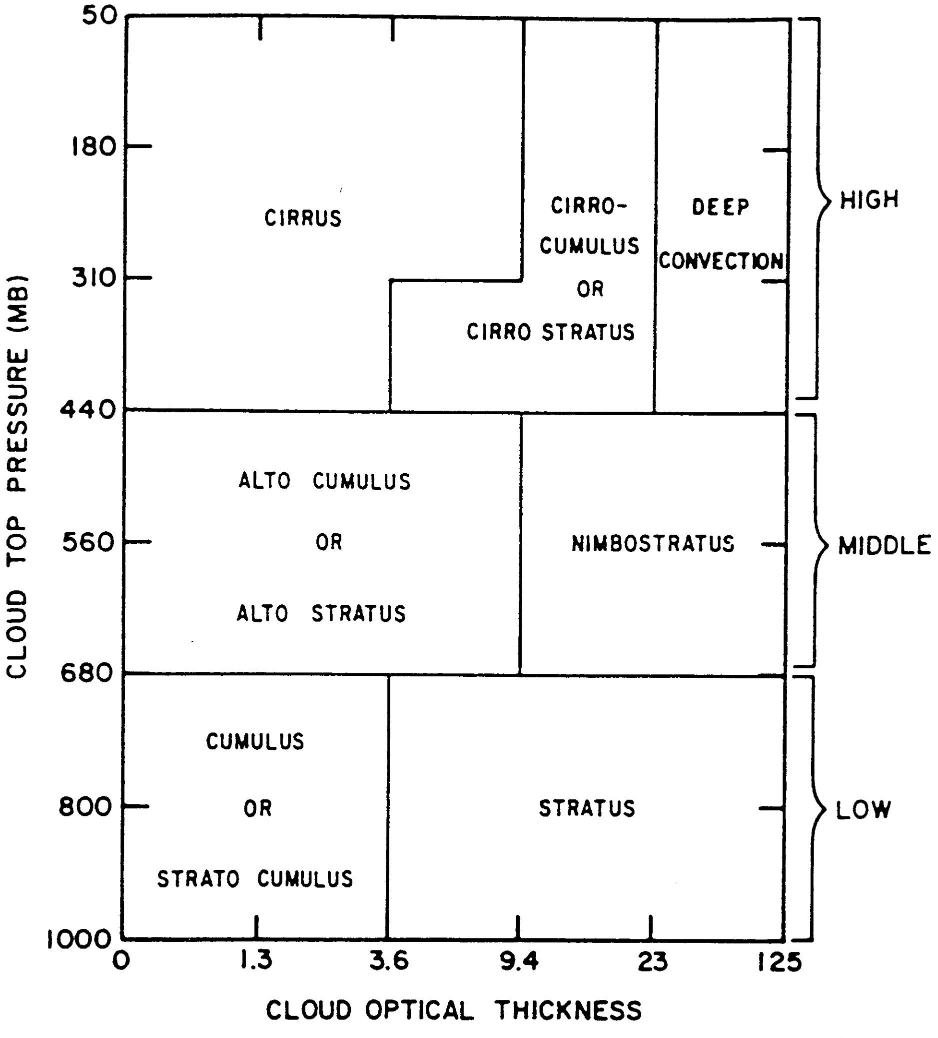
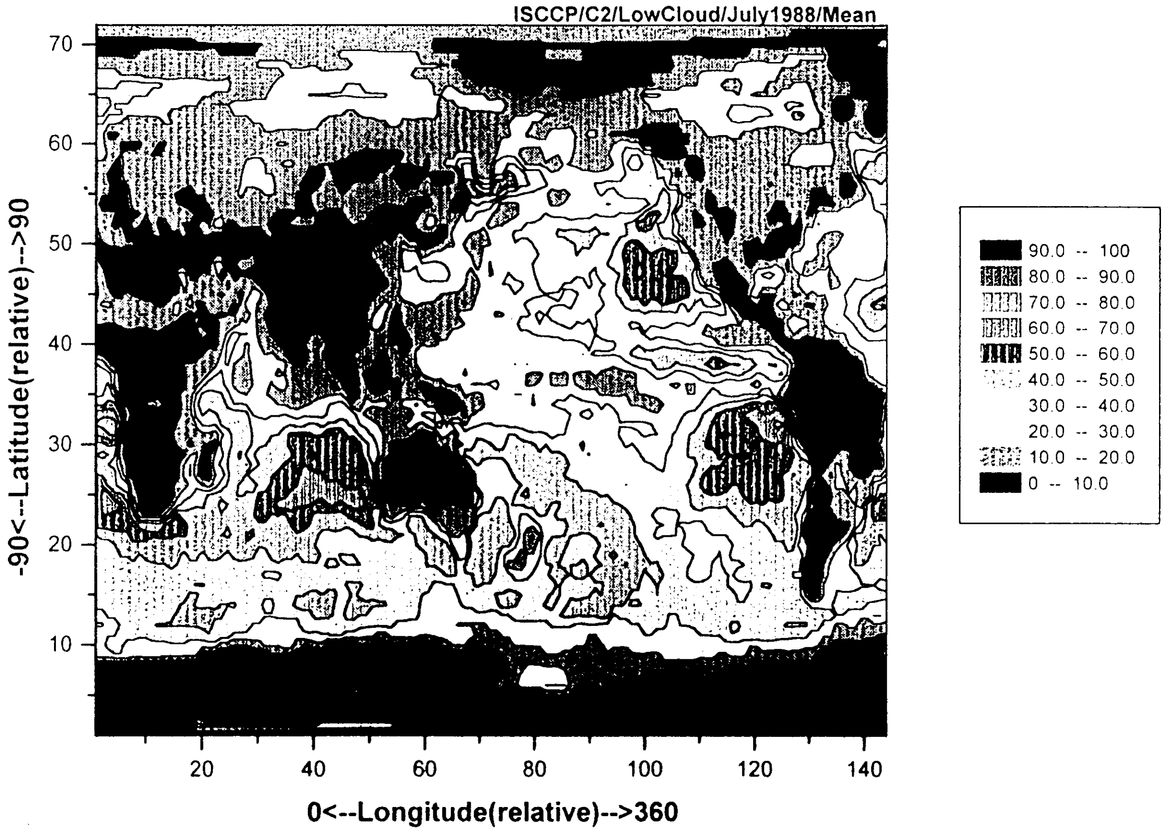
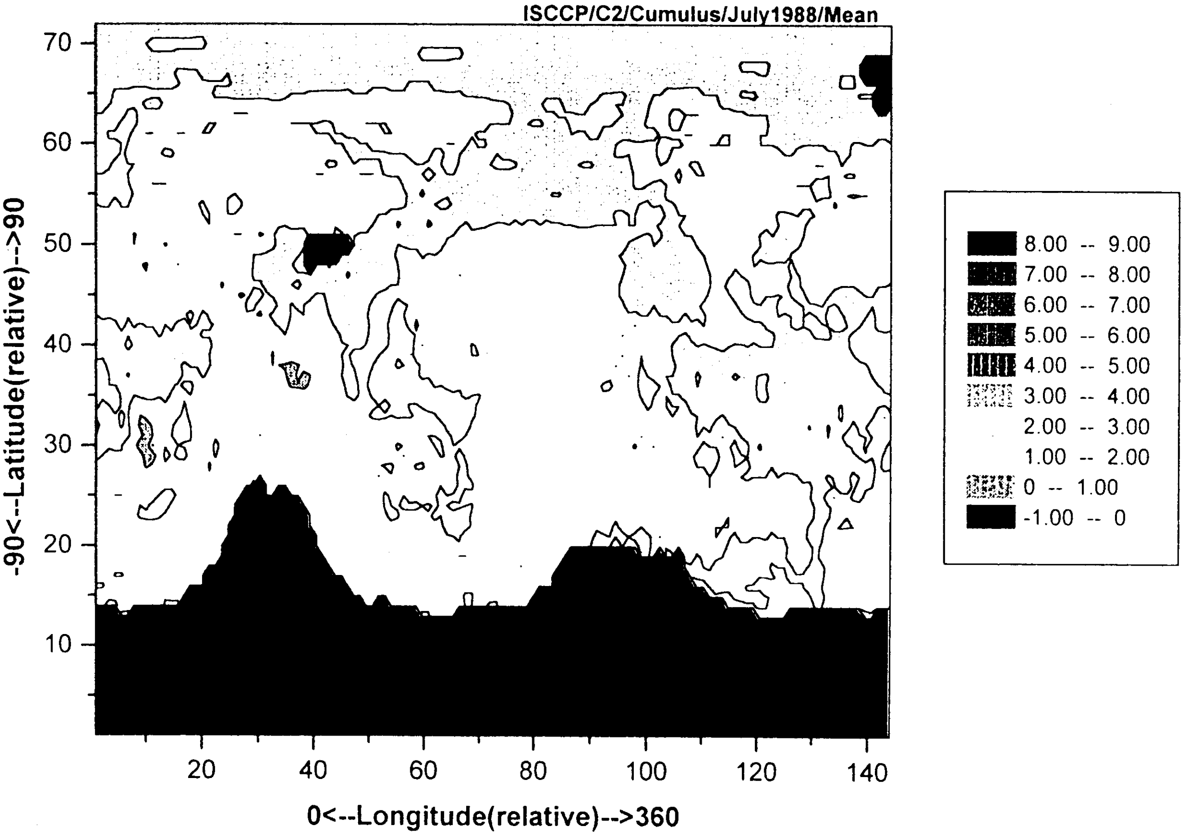
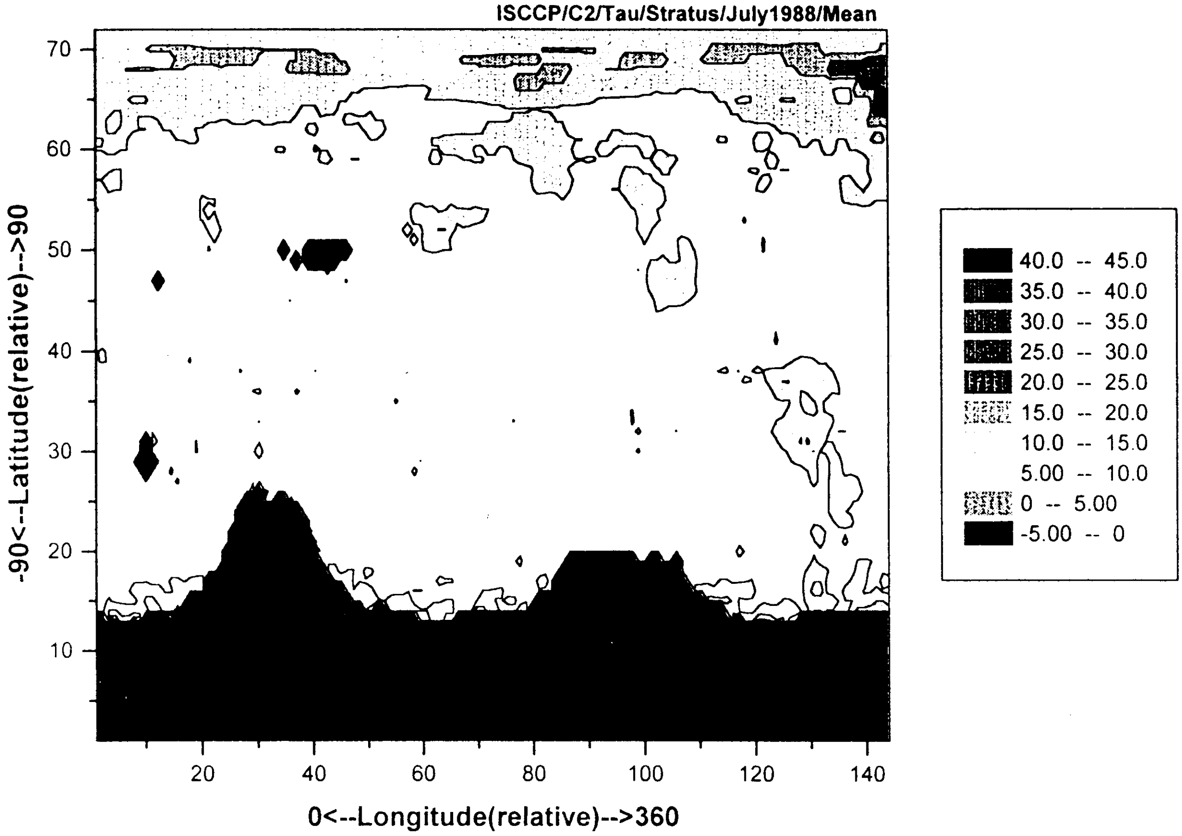
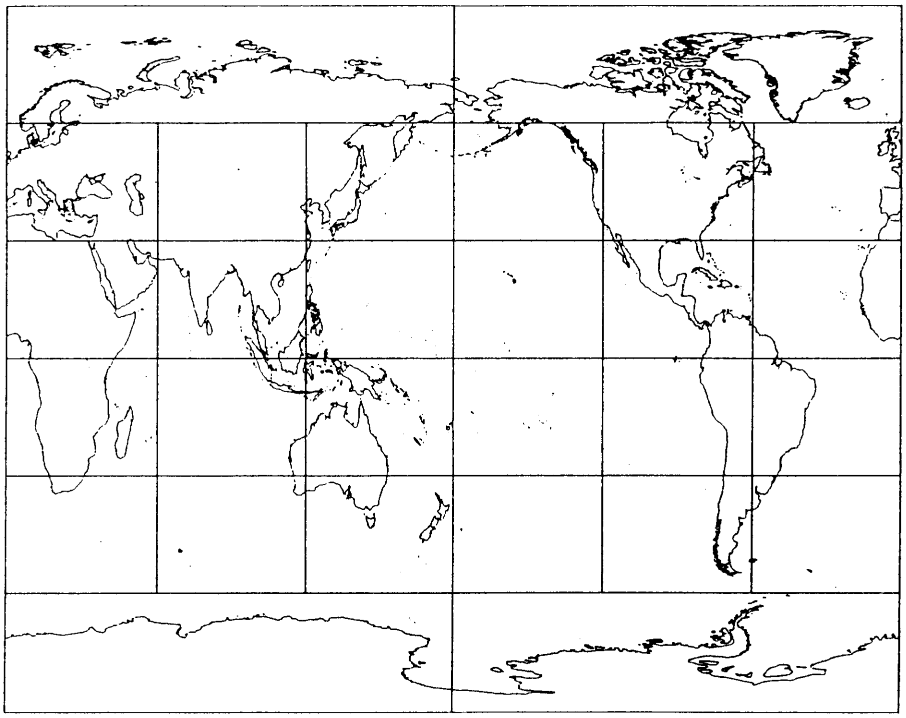


FIGURE 8.9. ISSCP radiometric classification of cloudy pixels by the measured values of optical thickness and cloud-top pressure. At night only cloud-top pressure is determined, so that only the low, middle, and high cloud types are counted. [After Rossow and Schiffer (1991).]


ISCCP/C2/LowCloud/July1988/Mean
-90<--Latitude(relative)-->90
70
60
50
40
30
20
10
20
40
60
80
100
120
140
0<--Longitude(relative)-->360
90.0 -- 100
80.0 -- 90.0
70.0 -- 80.0
60.0 -- 70.0
50.0 -- 60.0
40.0 -- 50.0
30.0 -- 40.0
20.0 -- 30.0
10.0 -- 20.0
0 -- 10.0


ISCCP/C2/Cumulus/July1988/Mean
-90<--Latitude(relative)-->90
70
60
50
40
30
20
10
20
40
60
80
100
120
140
0<--Longitude(relative)-->360
8.00 -- 9.00
7.00 -- 8.00
6.00 -- 7.00
5.00 -- 6.00
4.00 -- 5.00
3.00 -- 4.00
2.00 -- 3.00
1.00 -- 2.00
0 -- 1.00
-1.00 -- 0


ISCCP/C2/Tau/Stratus/July1988/Mean
70
60
50
40
30
20
10
-90<--Latitude(relative)-->90
20
40
60
80
100
120
140
0<--Longitude(relative)-->360
40.0 -- 45.0
35.0 -- 40.0
30.0 -- 35.0
25.0 -- 30.0
20.0 -- 25.0
15.0 -- 20.0
10.0 -- 15.0
5.00 -- 10.0
0 -- 5.00
-5.00 -- 0



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