Cloud Inhomogeneity and Shortwave Radiation Budget

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Radiation budgets at the top of atmosphere and surface are critical to the climate system of the Earth. Recent estimation of these radiation budgets using satellite and ground-based measurements suggested a possibility that the shortwave radiation absorbed by the atmosphere, especially by clouds, is more than that predicted by theory. This discrepancy seems to be related with cloud inhomogeneity because it is conspicuous in the tropical region where cloud system is more complicated than middle and higher latitudes.

Radiation budget at the top of atmosphere is estimated by converting the radiance measured from the satellite into flux. Both shortwave and longwave radiative properties are well investigated as far as the atmosphere is assumed to be plane-parallel. However, radiative properties of inhomogeneous cloud are quite different from those of plane-parallel cloud. This difference is much larger in the shortwave radiation than in longwave radiation. Monte Carlo method is available to investigate the radiative properties of inhomogeneous cloud. To perform such an investigation an appropriate cloud model as well as water vapor has to be prepared for the calculation of radiative transfer. Accordingly the study on the radiation depends on how to make the three dimensional model atmosphere including clouds.

Active sensors such as lidar and radar are quite effective to investigate and model the inhomogeneous cloud system. In a case of optically thick cloud, cloud morphology is important and the spaceborne lidar will contribute to elucidate it. Also the lidar is expected to measure the fine structure of stratification of water vapor. With these measurements a statistical technique will be necessary for obtaining the global distribution and variation of clouds.

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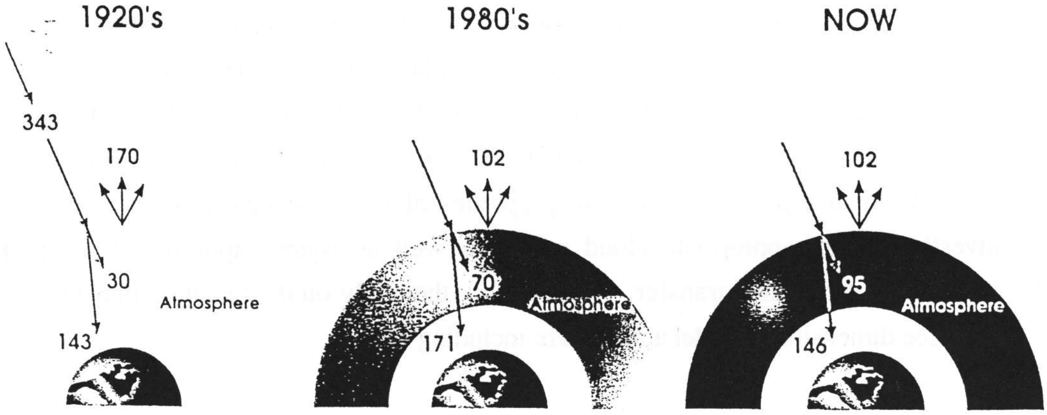

Figure 2. Evolution of the understanding of the atmospheric absorption in the global energy budget (in Wm^{-2}). (*Ohmura and Gilgen*, 1993; *Cess et al.*, 1995; *Pilewskie and Valero*, 1995; *Ramanathan et al.*, 1995)

14~15 W/m^2 : clouds → ?
55~56 ·· clear → ?

- Cloud Radiative Forcing (Shortwave)

$$C_S(TOA) = F_S^{net}(TOA, Cloudy) - F_S^{net}(TOA, Clear)$$

(from satellite measurements such as ERBE)

$$C_S(SFC) = F_S^{net}(SFC, Cloudy) - F_S^{net}(SFC, Clear)$$

(from ground based measurements)

- $C_S(SFC)/C_S(TOA) = 1.08$ from theoretical calculation

  $C_S(SFC)/C_S(TOA) = 1.4 \sim 1.5$ from observation

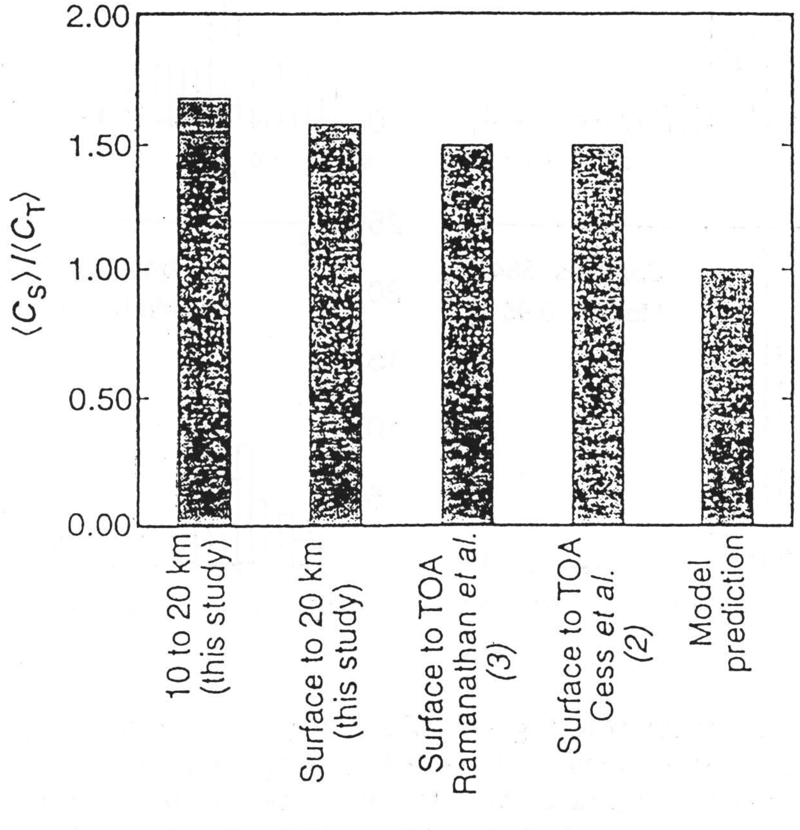

Fig. 5. Summary of estimates of $\langle C_S \rangle / \langle C_T \rangle$ determined by this study, (2, 3), and model calculations.

Pilewskie and Valero, (1995)

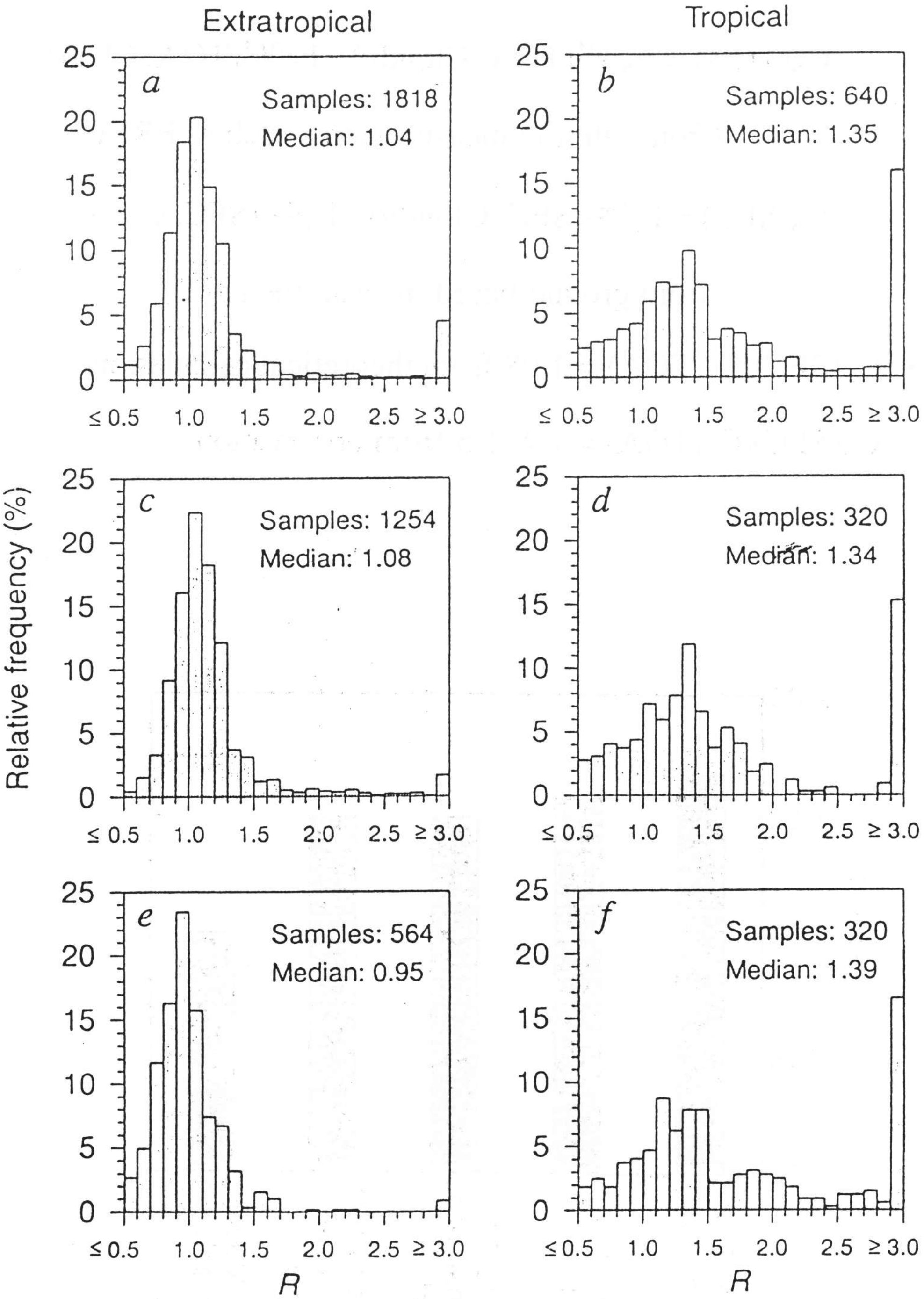

FIG. 2 Relative frequency histograms of monthly R for the tropics (latitude <30°) and extratropics (latitude >30°) using data from: *a* and *b*, all available months; *c* and *d*, April to September inclusive; *e* and *f*, October to March inclusive. Listed on the plots are number of samples and median values of R.

Li et al. (1995)

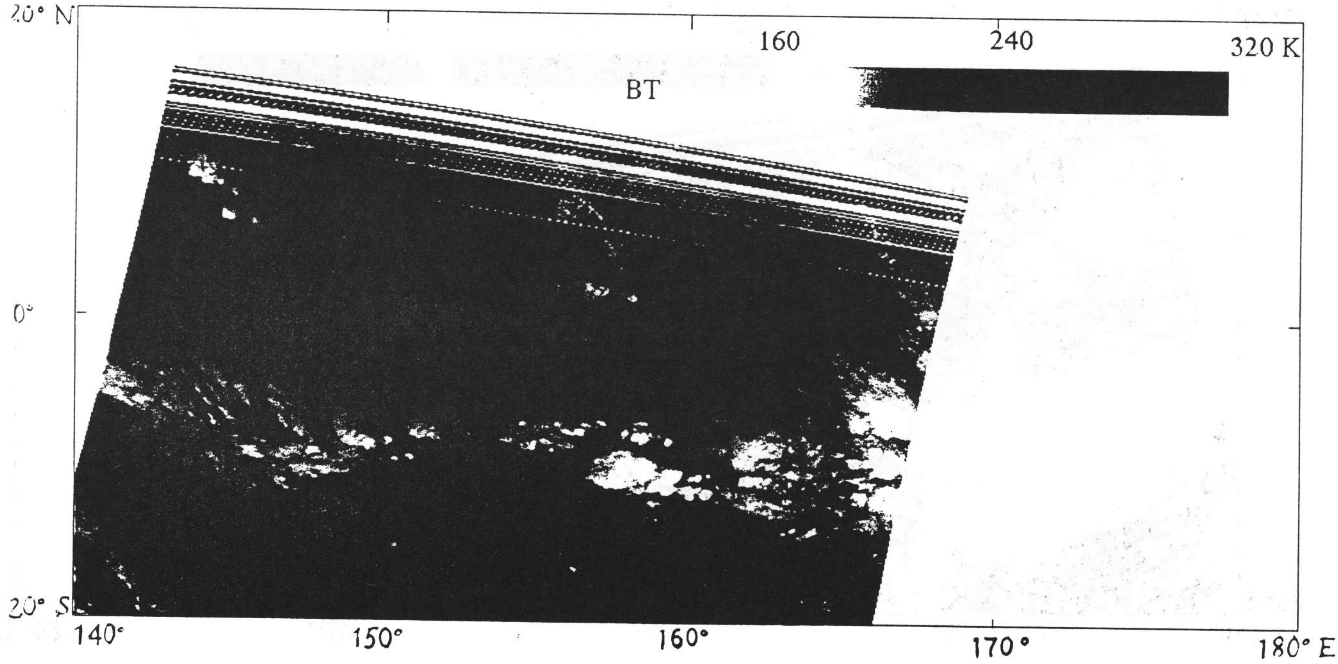

図3　NOAA/AVHRR 赤外画像 (中心波長 10.8 μm)

1992.12.23. 21:12:27GMT

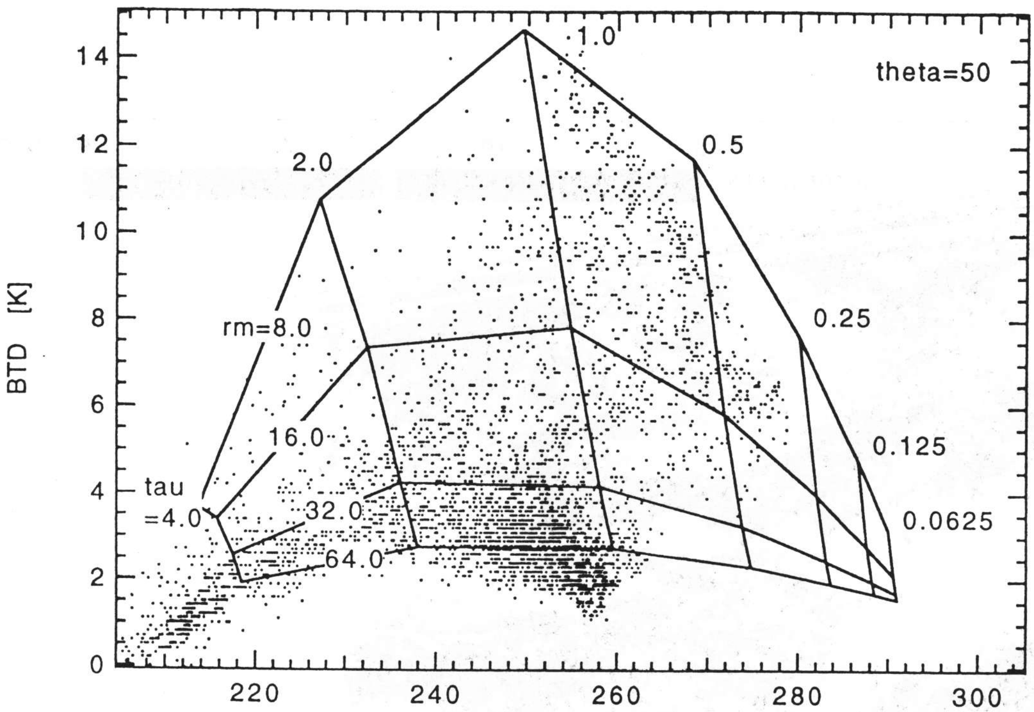

図２　BTD・BT10.8と光学的厚さ・モード半径の関係
実線は理論計算値・点は衛星観測データ値

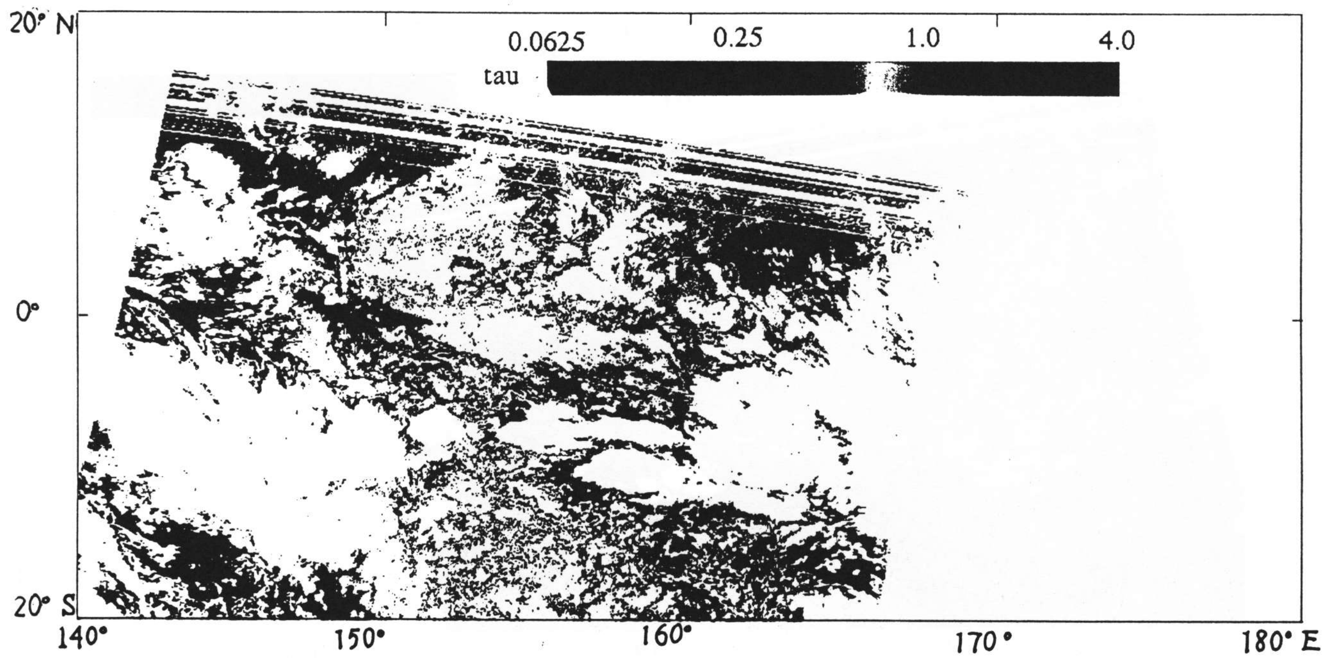

図５　光学的厚さの分布図

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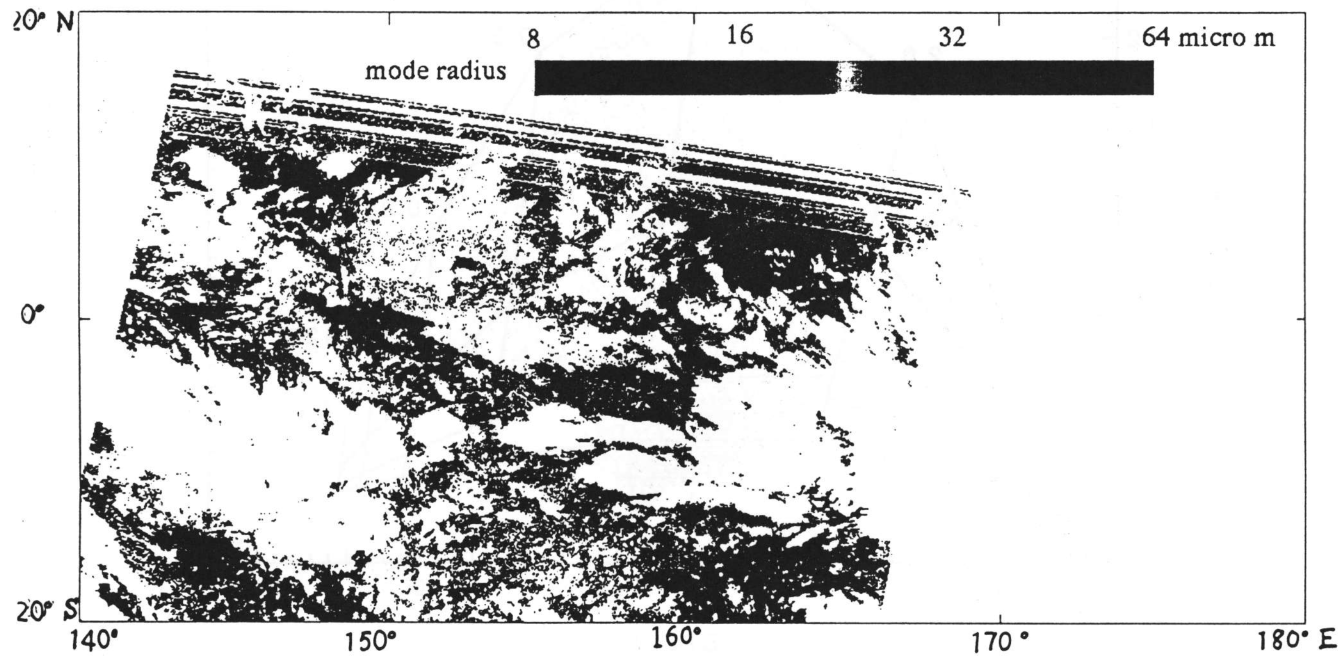

図４　モード半径の分布図

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$$W = a_0 + \Sigma a_i * T_{Bi}$$

○ **Regression Coefficient**

	constant	19V	19H	22V	37V	37H	85V	85H
Clear Water vapor	-50.45	0.1314	-0.3610	—	—	0.3444	0.0619	0.0269
nonprecipitating Water Vapor	-12.20	—	-0.0423	0.2165	-0.0586	—	-0.1832	0.1289
Liquid Water	-1.851	—	0.0199	-0.0186	—	-0.0043	0.0263	-0.0122
precipitating Water Vapor	-42.78	-0.0816	—	0.3112	-0.0519	0.0043	—	-0.0055
Liquid Water	0.9180	0.0204	—	-0.0204	-0.0021	0.0000	—	0.0010
Ice Water	0.3037	-0.0027	—	0.0029	0.0000	0.0006	—	-0.0021
Rainfall Rate	35.94	1.101	—	-1.045	-0.1546	-0.0133	—	0.0906

○ **Correlation Coefficient**

	Clear Water Vapor	nonprecipitating Water Vapor	Liquid Water	precipitating Water Vapor	Liquid Water	Ice Water	Rainfall Rate
R^*	0.99	0.86	0.99	0.86	0.99	0.98	0.98

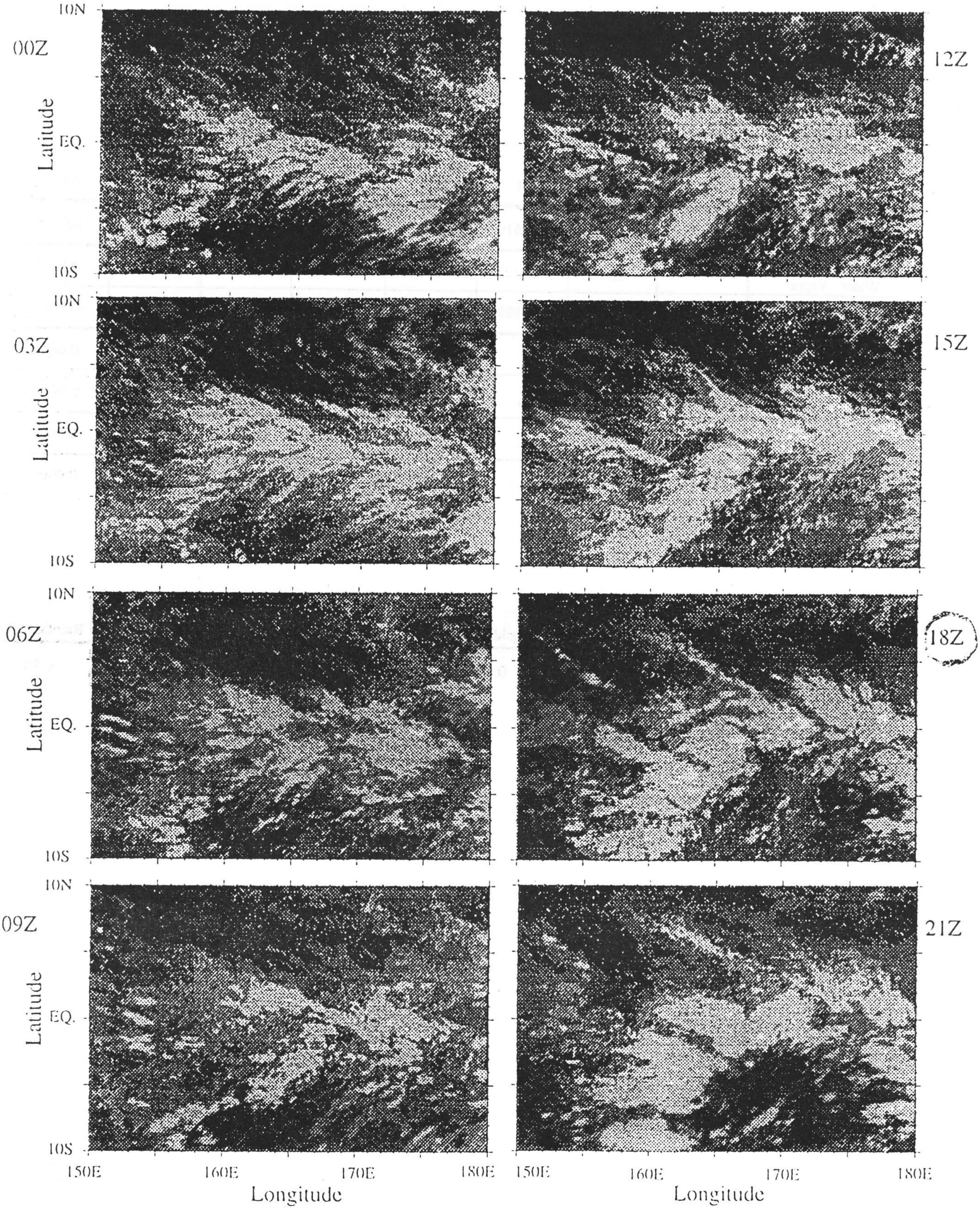


図.4-2-2 図.4-2-1 と同じ
ただし、1993.01.31.(GMT) の事例

GMSの赤外画像
1993.01.31

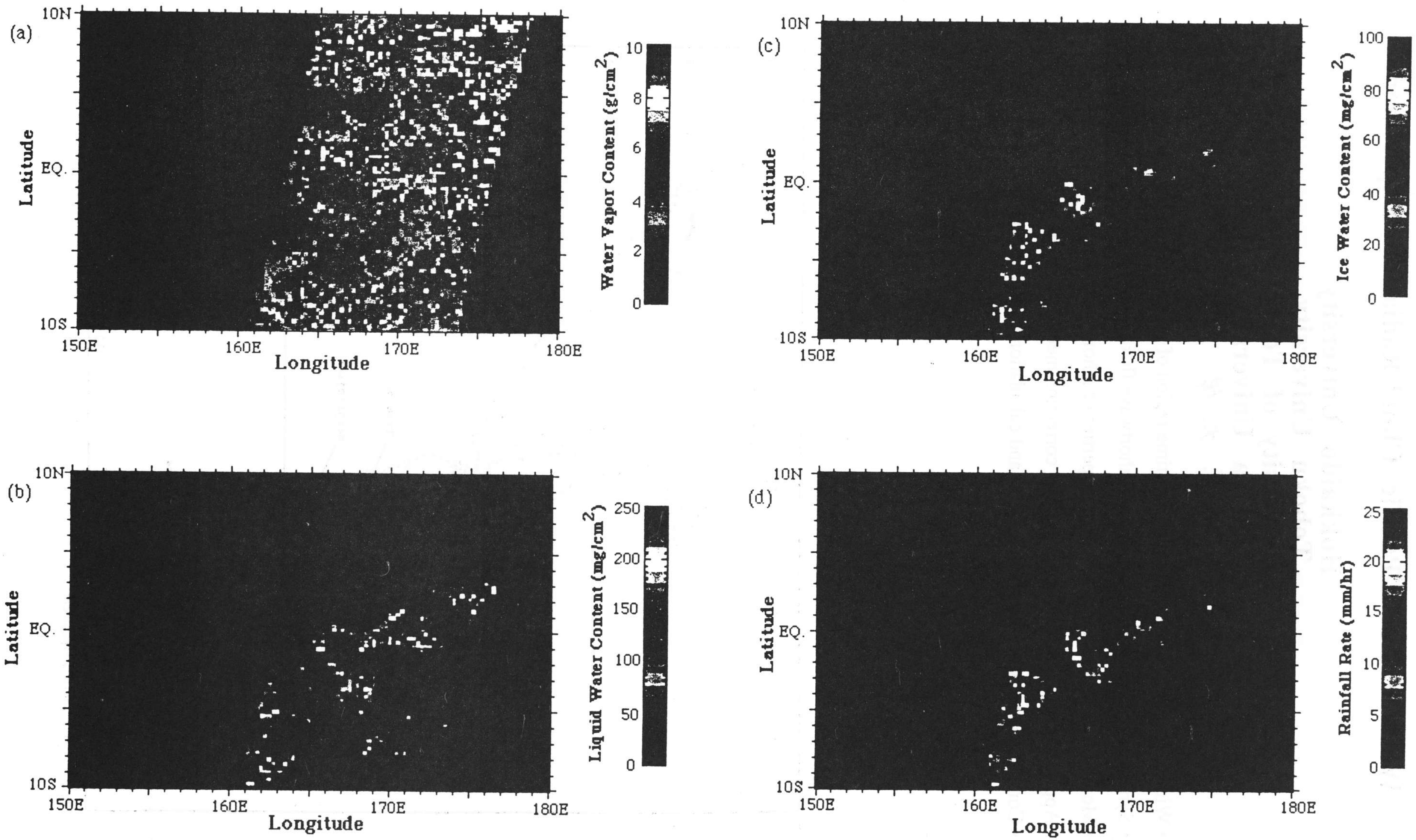


図.4-3-2　　図.4-3-1 と同じ
ただし、1993.01.31. 18:06(GMT) の事例

Western North-Pacific Cloud-Radiation Experiment

Hokkaido University
Tohoku University
University of Tokyo
Nagoya University
北京大学

- Winter stratocumulus clouds in the maritime region of southern Japan
- Synchronized aircraft measurements of shortwave fluxes above and below the cloud
- Monte Carlo simulation of radiative properties of inhomogeneous clouds
- Application of Ackerman & Cox (1981) correction method to the measurements
- Comparison between the measurements and calculation with plane-parallel clouds

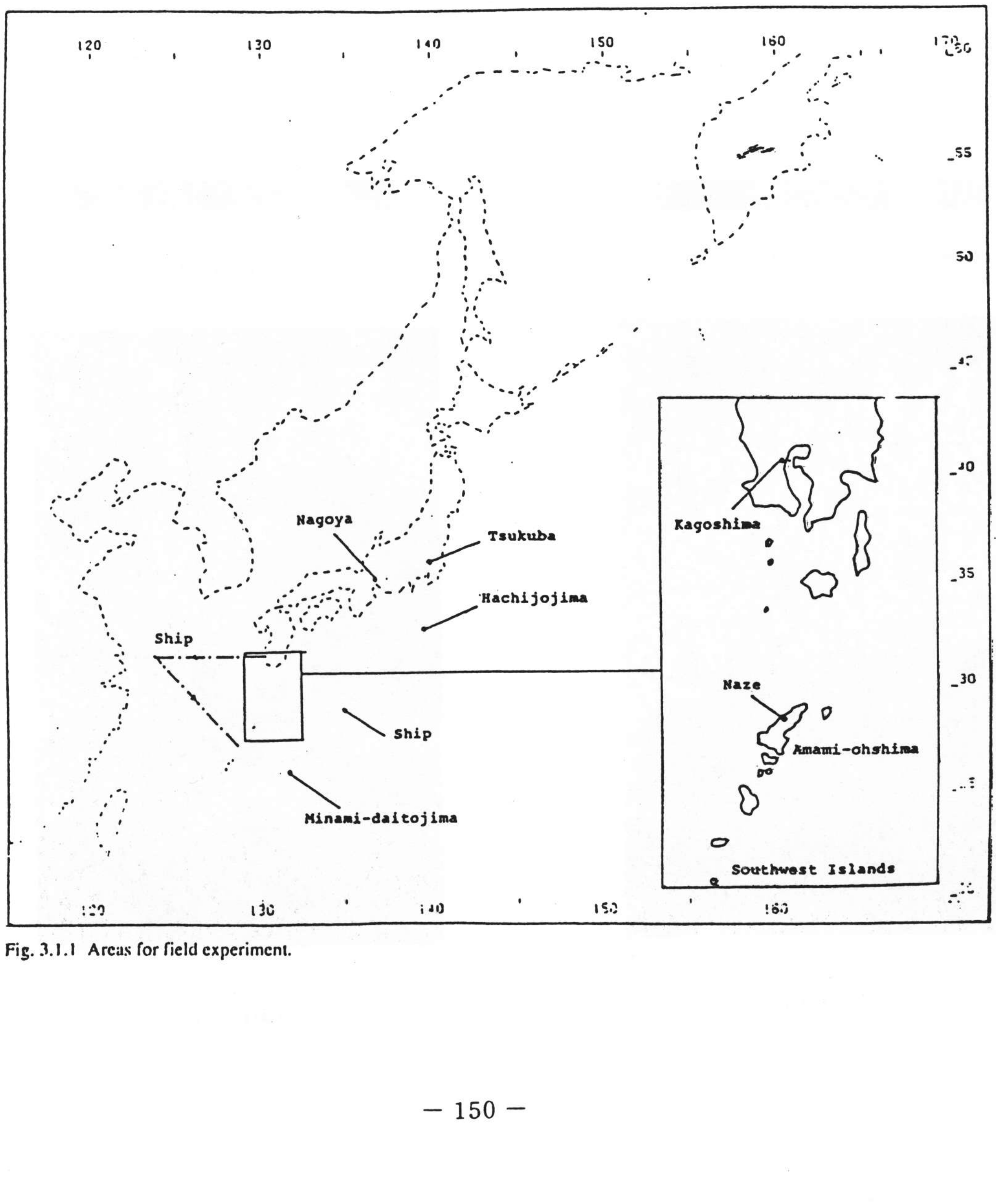
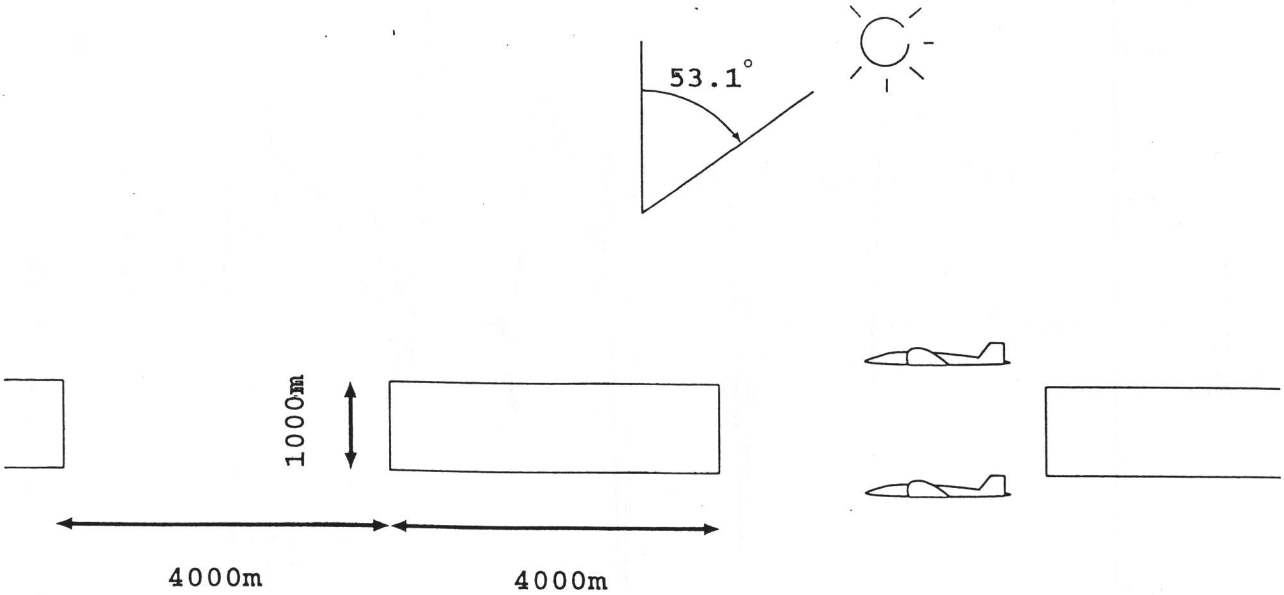
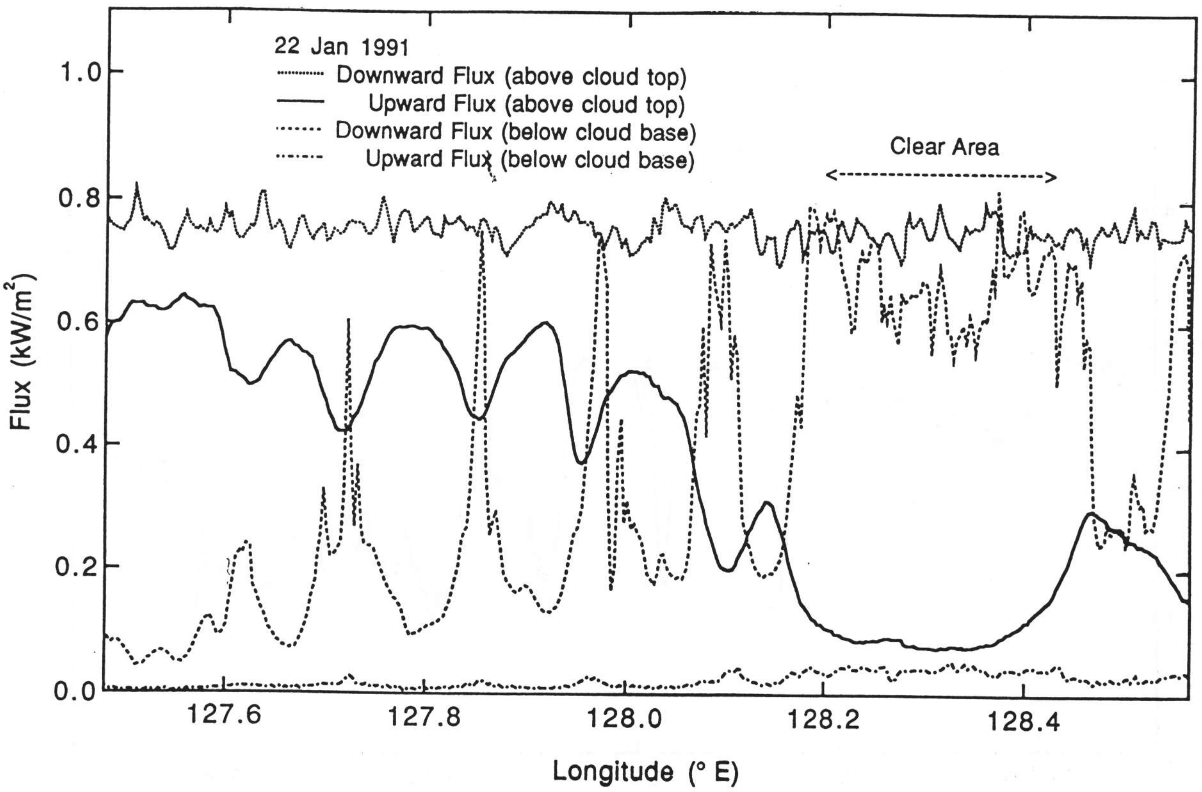


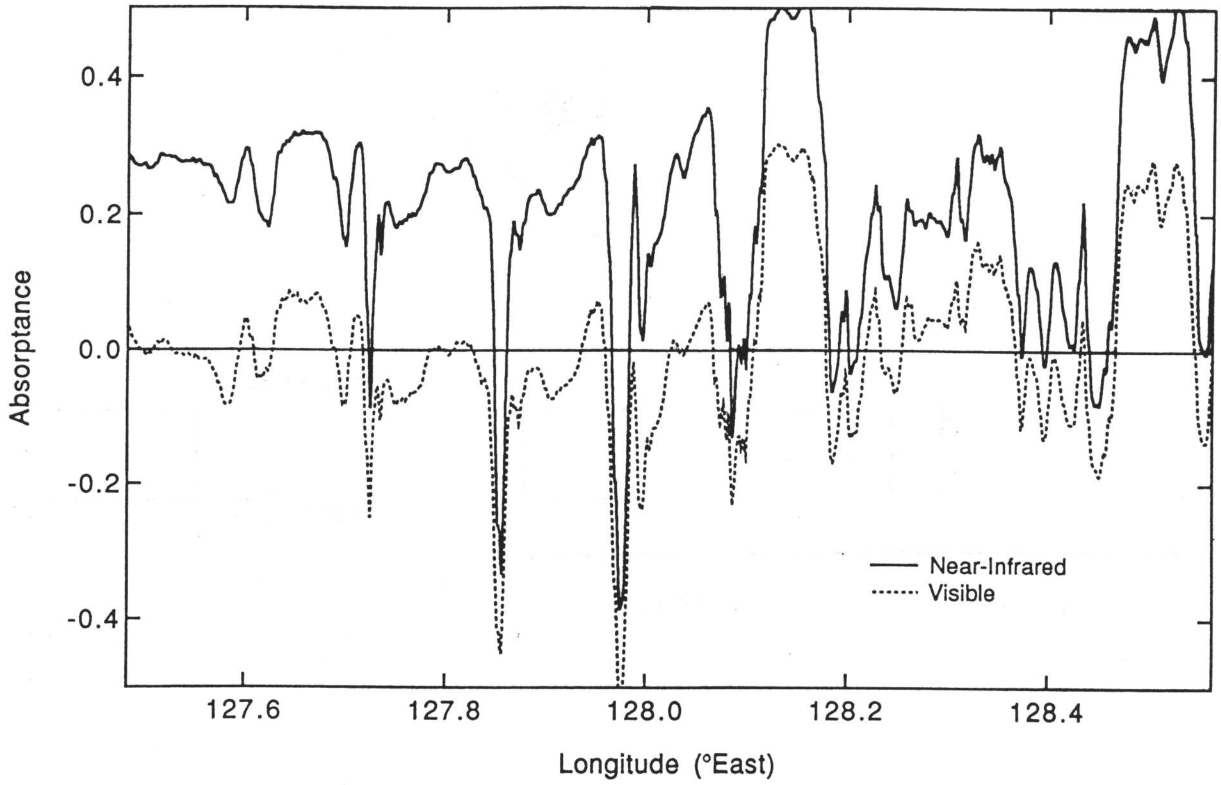
Fig. 3.1.1 Areas for field experiment.



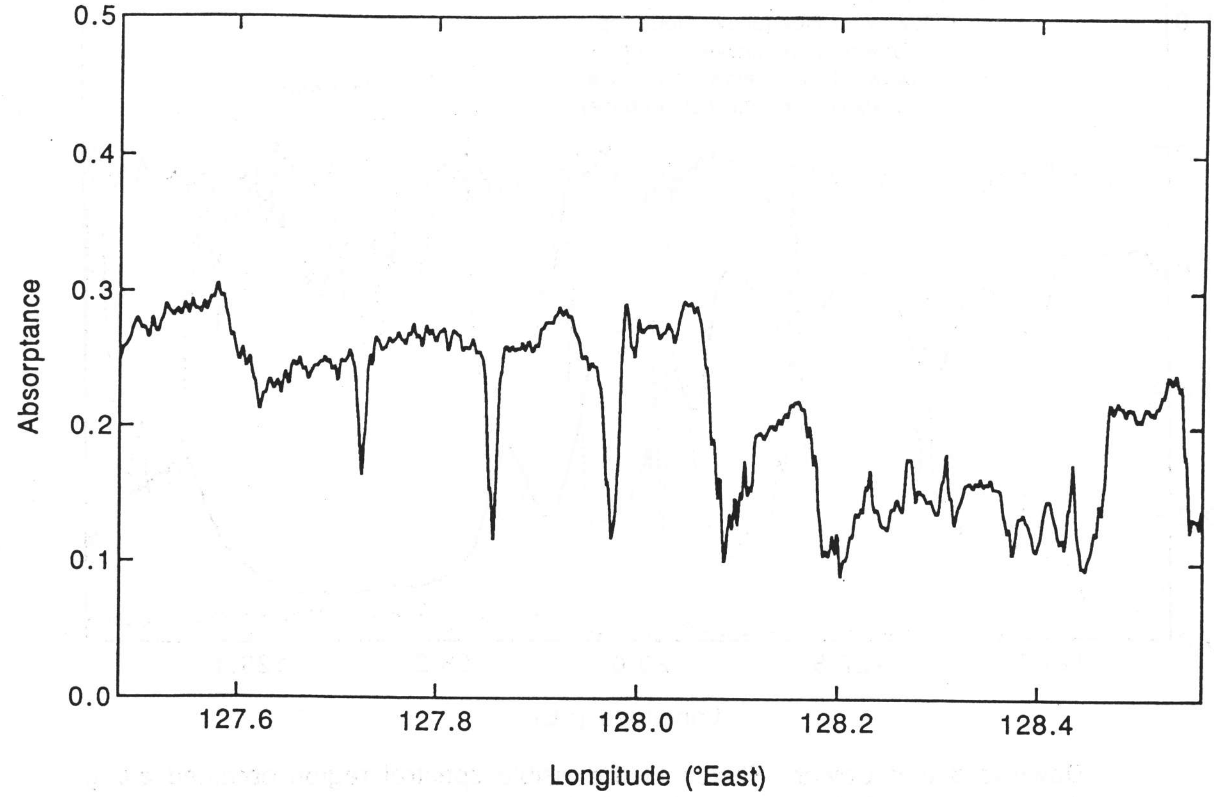
Hayasaka et al., Figure 4



Downward and Upward Fluxes in the visible spectral region obtained along the latitude of 28°15'N on 22 Jan 1991.



Absorptance in the visible and near-infrared spectral region on 22 Jan 1991.



Absorptance in the near-inrared spectral region obtained with a correction method of Ackerman and Cox (1981).

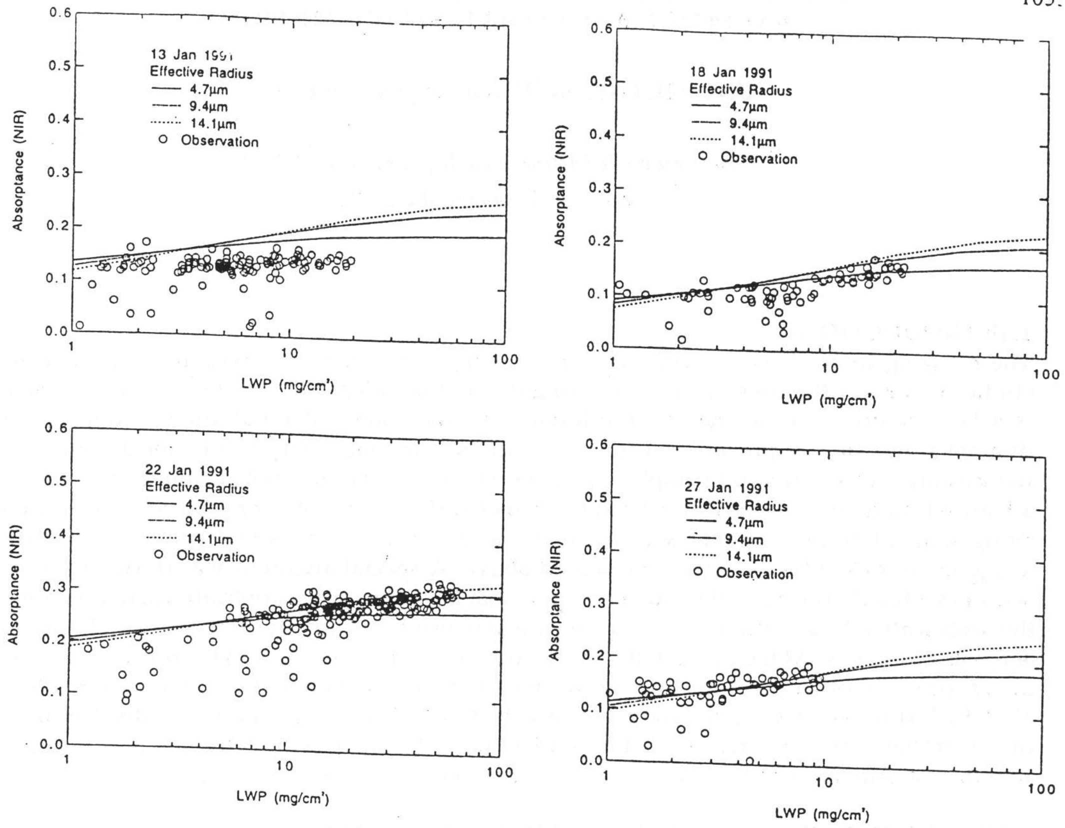


FIG. 7. The relationship between the cloud liquid water path and the near-infrared absorptance corrected by the method of Ackerman and Cox (1981). Circles shows the observed data. Three lines indicate the calculated values with size distributions of respective mode radii, under the assumption of plane-parallel atmosphere.

Summary

- Estimation of shortwave radiative flux of inhomogeneous cloud system is difficult.

  -> We must be careful about
  (1) Conversion from radiance to flux
  (2) Statistics of measurement data

- Spatial distribution of water vapor, liquid water content, ice water content should be investigated.