Ground-Based Cirrus Observation in the Japanese Cloud and Climate Study: A Sonde System for Radiation and Cloud Microphysics Measurement

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Introduction

Clouds play a crucial role in radiative energy budget and water cycle in the earth-atmosphere system. In order to understand processes such as global warming and to improve assessment of climate change, it is necessary to develop climate models which properly take into account radiation and cloud processes. In addition, it is also important to improve satellite monitoring systems for measuring the global distribution of cloudiness and to derive cloud microphysical properties. The Japanese Cloud and Climate Study (JACCS) is a Japanese research effort focusing on the difficult problems associated with issues related to cloud-radiation interactions (Asano et al. 1994). It is one of many decade-long (FY1991-2000) climate research programs sponsored by the Japanese Science and Technology Agency.

Major scientific objectives of the JACCS program are to 1) advance our understanding of the relationship between microphysical properties, the macro-physical structures, and the radiative properties of various mid-latitude clouds; 2) develop advanced uses of satellite data in the cloud-climate study; and 3) develop better parametarization of cloud and radiation processes used in general circulation models (GCMs).

Research activity involves field observations of cloud and radiation, satellite data analyses, and numerical modeling of cloud and radiation processes. JACCS conducts two types of field observations for various midlatitude clouds around Japan; one involves ground-based observations for high-level ice clouds (direct aircraft measurements not available) associated with fronts in spring seasons. The other is aircraft observations of stratiform water and mixed-phase clouds in winter seasons.

Ground-Based Cirrus Observation

The main purpose of taking ground-based cirrus measurements is to obtain simultaneous observational data on cloud microphysical and radiative properties of high-level ice clouds from the ground, and to study the relationship between them for cirrus and cirrostratus associated with mid-latitude fronts. We have organized a ground-based cirrus observing system by combing various instruments shown in Table 1 at the Meteorological Research Institute (MRI), Tsukuba (36.0 ºN, 140.1 ºE). The system is expected to provide various information such as cloud height, thickness, and backscattering profiles measured by an MRI cloud lidar, spectral solar and infra-red (IR) zenith radiance measured by the spectroradiometers, and the solar and IR fluxes at the surface. In addition, cloud optical thickness in the solar spectral region can be obtained from sunphotometery (Shiobara and Asano 1994; Spinhirne et al. 1996). FT-IR spectral data can be used to infer IR optical thickness and effective ice particle size (Uchiyama et al. 1994). The cloud microphysical properties are obtained by using Cloud-Particle Video Sonde (CPVS), which is an improved model of the MRI Hydrometer Video Sonde (HYVIS; Murakami and Matsuo 1990) in order to get a higher resolution and a larger sampling volume in tenuous ice clouds. We have newly developed a radiation sonde to measure vertical profiles of the solar and IR radiative fluxes as well as temperature and humidity. These data, along with concurrent NOAA polar-orbit satellite data, will be analyzed to study ice cloud-radiation interactions.

Through 1991 to 1994, several instruments such as the cloud lidar, cloud-particle video sonde, and radiation-sonde have been developed and performance tested. In 1995, a

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Table 1. Instrumentation for the ground-based cirrus observation.

Instruments	Wavelength	Measured Quantity	Extracted Physical Parameters
[Sonde]			
Radiation Sonde* + (Rawin Sonde)	0.3-3 µm 4-50 µm	up/down solar fluxes up/down longwave fluxes *P*,*T*,*H*	Vertical profile of the upward/downward fluxes of the solar and terrestrial radiation Vertical profile of temperature and humidity
Cloud Video Sonde* (Improved HYVIS)		Images of ice crystals	Cloud microphysical parameters (cloud particle size, shape, phase, number density, and ice water content)
[Lidar]			
MRI Cloud lidar*	532 nm (YAG)	backscattering ratio depolarization	Cloud base/top heights, optical thickness, cloud particle phase, and vertical structure
CRL CO_2 lidar	10.6 µm	backscattering coefficients	Cloud IR reflectivity
[Radiometer]			
Sunphotometer	368, 421, 502, 676, 864, 938, 938, 1050 nm	spectral attenuation of the direct solar radiation	Spectral cloud optical thickness, Column water vapor amount
Multichannel sky-scanning photometer*	367, 500, 676, 943, 1021, 1650, 2220 nm	sky radiance/polarization	Effective particle size, scattering phase function
Multichannel-Cloud-Pyranometer*	420, 500, 675, 760, 862, 938, 1080, 1225, 1650 nm	spectral solar flux	Spectral solar flux at the surface
Spectrordiometer	0.4-2.0 µm	spectral solar radiance	Spectral transmissivity and optical thickness
FT-IR spectrometer	800-1200 cm^{-1}	spectral zenith IR radiance	Spectral effective emissivity, IR optical thickness
IR Radiation-thermometer	9.5-11.5 µm	brightness temperature	Cloud effective temperature, effective emissivity
Pyranometers	0.3-3 µm 0.7-3 µm	broad-band solar flux broad-band solar flux	Broad-band total solar flux Broad-band near-IR solar flux
Pyrgeometer	4-50 µm	longwave flux	Broad-band atmospheric radiative flux
Microwave-radiometer	22GHz, 37GHz	brightness temperature	Column water vapor amount, and column liquid water content
[Other Remote Sensor]			
Wind-profiler	404 MHZ	wind speed and direction	Vertical profile of wind field
Radar	X-band	profile of Z	Cloud structure
CCD TV camera		whole sky image	Monitoring of cloud distribution
[Satellite]			
NOAA	AVHRR, HIRS	visible reflectance brightness temperature	Cloud distribution, cloud type, optical thickness, emissivity
GMS	Yis, IR	cloud image	Cloud distribution and movement

*Developed by the MRI

preliminary experiment was conducted to test the performance of the ground-based observing system. Intensive ground-based observations for midlatitude ice clouds are scheduled at the MRI in the three seasons of April through June from 1996 to 1998.

Sonde System for Radiation and Cloud Microphysics Measurement

The radiation-sonde is under development to measure vertical profiles of the upward and downward fluxes of the shortwave and longwave broad-band radiation, respectively. Small and light pyranometer and pyrgeometer were newly developed for the sonde. A rawinsonde (JMA model RS2-91; Meisei Co.) is built in the radiation-sonde to simultaneously measure temperature and humidity profile. A special sonde system combining a radiation-sonde and a CPVS, hung to the same balloon, can provide simultaneous vertical profiles of cloud microphysical properties and radiative fluxes as well as temperature and humidity. Figure 1 shows the temperature and humidity profiles measured by a rawinsonde built in a radiation-sonde for the cirrostratus observed on 8 June 1995. The cirrostratus was associated with a summer-monsoon (Baiu) front, and extended from 7 km up to 13.5 km (tropopause) at that time. Figure 2 shows vertical profiles of the ice water content and ice crystal concentration measured by the accompanied CPVS. The corresponding profiles of the downward and upward fluxes of the shortwave and longwave radiation are shown in Figure 3. The solar reflectance and transmittance were estimated to be 0.27 and 0.58, respectively, for the cirrostratus layer, and the IR effective emittance was estimated to be 0.95 ±0.05. Further, the figures indicate the net radiative heating of the cloud layer due to the shortwave and longwave radiation.

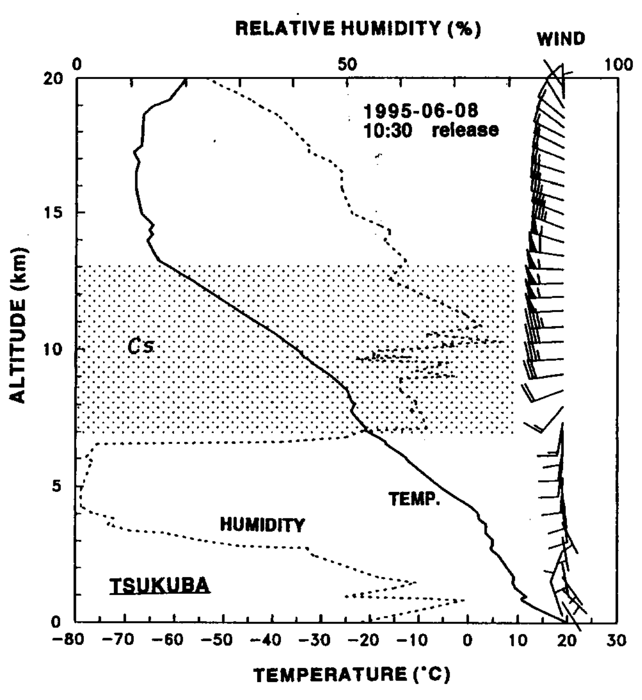

Figure 1. Vertical profiles of the temperature, relative humidity and wind measured by a rawinsonde built in the radiation-sonde launched at 10:30 on 8 June 1995.

Concluding Remarks

An outline of the JACCS/MRI program and the state of the art of the radiation-sonde development are reported. The newly developed sonde system has proved to be effective for simultaneous measurements of detailed vertical profiles of the cloud microphysical properties and radiation fluxes for high-level ice clouds. The research efforts within JACCS lead to interesting individual results through direct field observations, laboratory experiment, satellite data analyses, and modeling.

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References

Asano, S., and JACCS/MRI Research Group, 1994: Japanese Cloud Climate Study (JACCS): Research plan and preliminary results, Preprint of the 8th Conf. Atmos. Radiation (23-28 Jan. 1994, Nashville, TN), Am. Meteor. Soc., 282-284.

Murakami M., and T. Matsuo, 1990: Development of hydrometeor video sonde (HYVIS), *J Atmos. Oceanic Tech.*, **7**, 613-620.

Shiobara M., and S. Asano, 1994: Estimation of cirrus optical thickness from sunphotometer measurements, *J. Appl. Meteor.*, **33**, 672-681.

Spinhirne, J.D., A. Uchiyama, and S. Asano, 1996: Optical depth measurement of aerosol, cloud, and water vapor using sun photometers during FIRE cirrus IFO II, *J. Appl. Meteor.*, **35**, 36-46.

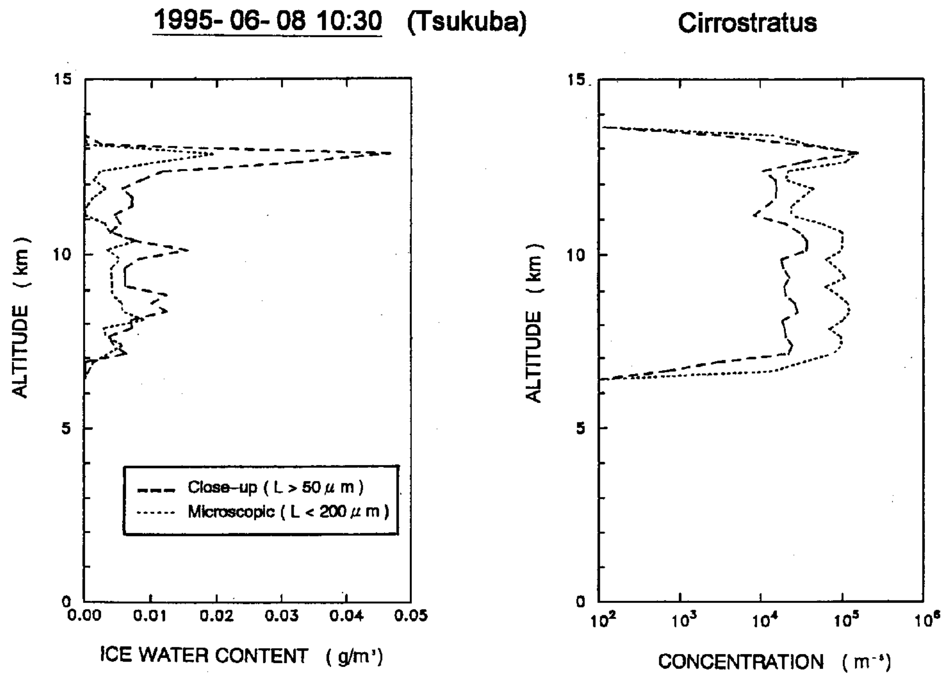

Figure 2. Vertical profiles of the ice water content and ice crystal concentration measured by a Cloud-particle Video Sonde for the cirrostratus observed at 10:30 on 8 June 1995.

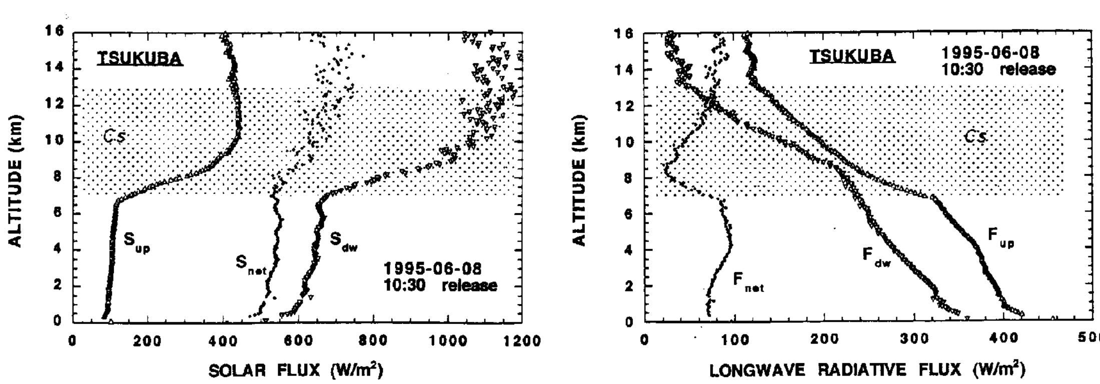

Figure 3. Vertical profiles of the downward and upward fluxes of the shortwave radiation (LEFT) and the longwave radiation (RIGHT), respectively, measured by the accompanied radiation-sonde for the same case as Fig. 2.

Uchiyama A., M. Fukabori, S. Asano, and M. Shiobara, 1994: Estimation of ice cloud parameter from the ground-based infrared 10-12 µm radiance measurement, Preprint of the 8th Conf. Atmos. Radiation (23-28 Jan. 1994, Nashville, TN), Am. Meteor. Soc., 488-490.