Part I

Workshop Summary

SUMMARY OF THE FIRST INTERNATIONAL WORKSHOP ON SPACEBORNE CLOUD PROFILING RADAR

TSUKUBA , JAPAN

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Highlights of the Workshop

Need for accurate and reliable information on the vertical profiles of the liquid and solid states of clouds in the atmosphere is emphasized to improve climate models. Such information cannot be obtained from passive satellite measurements. Future climate observation systems must include vertical soundings with lidar and short-wave radar, where only their simultaneous and collocated use may guarantee the ability to derive the required parameters on clouds. On the other side, new assimilation techniques must be developed to make direct use of measured backscatter radiances. Further coordinated activities are expected that link modeling to measurements and retrieval techniques.

Considerable progress in radar/lidar synergy retrievals has been demonstrated. More progress in these methods should be achieved if they are applied to various types of clouds, such as those under polar and tropical airmass conditions. The next challenge will be application of synergy techniques to satellite measurements. In this context, the requirements for satellite measurement, such as the spatial overlap of two observations, need to be clarified.

The pioneering CloudSat-Picasso/Cena satellite program to study cloud radiation is going well toward launch in 2003. Two satellites will be in formation flying in an orbit with 705 km altitude with a radar and lidar footprint separation being 2 km in max. A planned Japanese-European satellite will be a major milestone after the CloudSat era to improve our understanding of processes in energy and water cycles in the climate system.

Key Note Speeches

Three overview speeches cover current status of CPR activity, and related Field and Space programs. Therein future directions were indicated:

(1) Necessity of CPR in space? (Raschke)

- We need many preparatory studies as:

- Data assimilations
- Synergy techniques with other satellite data
- Retrieval algorithms

(2) CloudSat program (Stephens)
- Objectives and Goals are to contribute better represents and cloud processes in global weather predictions and climate models!
- Launch 2003

(3) ARM programs (Ackerman):
- 4 sites in operation
- Climatology basis of cloud property
- Can be used for satellite validation both direct and statistical ways

SESSION 1: Model and Simulation

The session was covered by 6 contributions, where numerical simulations were presented on

(1) Clouds and aerosols in Asian Monsoon (Iwasaki)
- Data is needed to validate cloud and aerosol characteristics and also radiation budget (TOA, Sfc)
- Changes in some cloud parameters (eg. In LLCs) impact or turbulence.

(2) Analysis of TRMM data (Takayabu)
- Multiscale interactions need to be understood.
- Vertical profile of diabatic heating required.

(3) Cirrus simulations with a non-hydrostatic model (Maruyama)
- More sensitivity studies with ice microphysics
→ effects on radiation from sfc characteristics
- vertical wind shear tends to make cirrus more homogeneous

(4) Rain (TRMM) assimilation in the ECMWF model (Illingworth for ECMWF)
- Positive impact of TRMM-RR on analysis
- Positive impact of TRMM-RR on forecast

(5) Effects of low level clouds and water vapor on convection (Numaguchi)
- Simulations with regional model showed importance PBL
- LLCs need to be identified with acculately during night

(6) Studies of aerosol radiative forcing with a global 3-d model (Takemura)
- Model seems to agree with observations
- SO_2 and sea salt → negative forcing
- Soil dust + others → depending on optical properties
Spaceborne lidar is useful!

The results of all these 6 studies emphasize the need of accurate and reliable information on vertical profiles of liquid and solid phase of clouds in the atmosphere to improve the reality of them. Since such information cannot be derived from present and future passive multispectral satellite measurements, the need for active soundings are the (hopefully soon operational) use of such data in models has been demonstrated in these contributions. This, future climate observing systems must include also vertical soundings with lidar and short-wave radar, where only their simultaneous and collocated use as later presented papers showed, may guarantee the ability to derive the required parameters on clouds. On the other side, new assimilation techniques must be developed to make direct (hopefully online) use of the measured backscatter radiances. The scientific community should be given more opportunities to

⇒ perform more such sensitivity studies – also making use of relevant ground based and airborne measurements

⇒ participate in the use of data from TRMM and from the CloudSat and Picasso-Cena missions.

The planned Japanese-European ERM will be a major milestone to improve our capability to improve weather forecast and our understanding of various processes participating in energy and water cycles in our climate system.

Session 2: Passive Remote Sensing: Ground-based and Airborne

Two papers on results from the Japanese Cloud Climate (JACCS) Program and one from polar cloud research:

(1) Microphysical and radiative properties of stratiform clouds (Asano);
    Estimates of τ, r_e , LWC from MCP measurements:
    - r_e and LWC: good agreement with in situ data in pure liquid phase clouds; not that good in mixed phase clouds and clouds with absorbing aerosols
    - Phase function: γ = 0.5: liquid; γ = 0.8: mixed

(2) Airborne measurement of the cloud radiation budget for stratocumulus (Uchiyama)
    - radiation measurements above and below clouds; no evidence of anomalous absorption in water and mixed phase clouds

(3) Polar clouds and aerosols for radiation budget and climate study (Yamanouchi)
    - Cloud detection algorithms using AVHRR data
        T4 - T5 were tested in the Antarctic inland area
        T3 - T4 during Polar night conditions
    - plans for polar aerosol studies
    - SHEBA data set:

Session 3: Passive Remote Sensing –Satellite-

(1) Evaluation of remote sensing of clouds (Hayasaka)
    - Retrieval of τ, r_e, LWP from VIS-IR radiometers
    - 3-D cloud geometry associated to direction of sun + observation may bias the retrieval;
        Monte Carlo Simulations
        Data analysis
    - Large scanning angle are not appropriate

(2) Cirrus Remote Sensing using split window + 6.7 μm (Inoue)
    ⇒ Absorption ≠ for ice at 11 and 12 μm
    ⇒ split window effectively detect cirrus clouds
    ⇒ Combination of SW + 6.7 μm allows retrieving τ, r_e and cloud Temp;
    ⇒ Validation by active instruments like lidar and/or CPR is modeled;
        - ground based
        -aircraft
        -CoudSat/Picasso-CENA

(3) Spectral aerosol optical thickness retrieval using polarization from space (Masuda)
    - Compose performance of retrievals founded on polarization and on radiances.
    - Polder/ADEOS at 670 nm and 865 nm to retrieve optical depth at 550 nm;
        α: slope of the PSD
    - Measurement errors
    - Aerosol model assumption

PSD, refractive index, shape
Affect differently; Retrieval from radiance: Retrieval from polarization

(4) Radiative forcing of indirect effects of anthropogenic aerosols (Nakajima)
⇒ Radiative forcing of indirect effects of anthropogenic aerosols from AVHRR data and climate modeling: -0.85 to –2.1 W/m^2
⇒ Color coded superposition of Na and Nc highlighted region dominated by aerosols and clouds
(question about how aerosols could be transported more than 1000 km to the west to California coast)

Session 4: Active remote sensing –Radar

Part 1

Excellent summary of state of retrievals
(1) Radiative parameters from CPR (Testud)
(2) Retrievals of cloud content and particle characteristic sizes (Matrosov)
(3) Millimeter wave scattering from ice crystals (Aydin)
(4))Toward retrieval algorithms for CloudSat (Mace)
- Focus on micro-physics (location is solved problem)
⇒ Retrieval of crystal habit/orientation
- demonstrated but limited to $\Theta_{ELEV} < 45$ deg
⇒ Retrieval of microphysics from vertical beam
(radar, lidar, radiometer)
- Agreement with in situ observations
- Operational algorithms
⇒ Application to Spaceborne system
・Radar only retrievals
- Major problem is spread in dBZ-LWC/IWC relationships
- Spread due to limited data and different life stages (? not sure)
- Priority is to resolve this issue!

Part 2

(5) Potential to measure clouds and precipitation (Kobayashi)
⇒ 94 GHz cloud profiling radar for measuring rainfall (modeling study)
⇒ LWC estimated from Z
⇒ Use Doppler spectrum for estimating mean size to improve LWC estimate
(updraft/down draft can introduce significant error in estimating size information from Doppler spectra)

(6) Airborne radar system (SPIDER) (Horie)
⇒ Presented preliminary results (ground-based and airborne) from SPIDER: CRL's 95 GHz polarimetric Doppler cloud profiling radar (comments were made about Z being high in some cloud measurements)
⇒ Min. detectable signal: -35 dBZ at 4 km range
⇒ Sea surface reflectivity for calibration
⇒ Measurement plans:
- Ground based radar and lidar with airborne probe
- airborne radar

(7) Ka band Doppler radar for fog and clouds (Hamazu)

⇒ Presented preliminary results from a Ka-band Doppler radar (0.3 deg beam width):
- vertical profiles of stratiform clouds, drizzle, cumulonimbus cloud growth, and sea fog growth
⇒ Doppler velocity range ±30 m/s with unfolding correction
⇒ Structure of multi-layer clouds observation
⇒ Structure of sea fog observable

(8) NIED dual-frequency cloud radar (Iwanami)
⇒ Described the NIED dual-frequency cloud radar system, which is being developed.
⇒ Radar mounted on truck

35 GHz	95 GHz
0.40 deg	
H-pol	H, V pols (two recs)
100 kW	1.5 kW
Doppler	Doppler

⇒ Plan to study cloud and precipitation formation processes.

SESSION 5: Active Sensors - Lidar

(1) Remote sensing of aerosol by lidar at AIOFM (HU)
Lidar activities at AIOFM were presented regarding stratospheric aerosol measurements over 9 years and tropospheric aerosol measurements that has recently started. It was pointed out that the lidar ratio uncertainties affects very much quantitative analysis of tropospheric aerosols, which is a well-known fact.

(2) Co-located airborne lidar and ground based radar measurements of mid-level mixed phase clouds during Clare'98 (G. Ehret)
Observational results obtained during the LITE and CLARE98 were presented. Lidar and radar synergism data were shown to provide information on mixed phase clouds. High spectral resolution lidar was recommended in order to get more quantitative information from lidar measurements.

(3) Arctic cloud and aerosol observations using a Micro-pulse Lidar in Svalbard (Shiobara)
A micro-pulse lidar was set-up at Svalbard and remotely controlled via internet. Clouds, precipitation, snowfall, and aerosols were detected. It is operated basically maintenance-free, but a concern was pointed out regarding its reliability.

(4) Statistical analysis of cloud distribution observed with a ground based lidar (Shimizu)
NIES lidar data on cloud-base heights were statistically treated to give model distributions. A problem of data missing due to low-level cloud overlapping was discussed.

(5) Bi-directional radiative characteristics of finite clouds and Asian dust (Kosa) (Gotoh)
Raman lidar measurements were presented regarding backscatter, water vapor, relative humidity, and depolarization of Kosa (Asian dust) events. Numerical simulations using Monte Carlo method for fractal surfaces were discussed. It was suggested that bi-directional radiative properties could be used to discriminate Kosa aerosols from clouds in image data obtained from more than one satellite on different orbits.

(6) Model calculation of multiple scattering for an incident pencil beam and the effect of non-spherical particles (Ishimoto)
Backward Monte Carlo calculations were discussed to show multiple scattering effects on polarization in lidar signals for non-spherical particles such as hexagonals. It is suggested that multiple FOV observations could contribute much to estimating depolarization of single scattering,

thus enabling to distinguish crystal particles.

Session 6: Synergy Use

All presentations, and discussions based on the presentations were directed largely toward the synergy at radar and lidar observations of clouds. These papers demonstrated that there has been considerable progress in radar/ lidar cloud retrievals and that much more progress is to be expected in the coming years (Illingworth, Pelon, Lammeren, Testud, Okamoto).

The discussions of synergy between sensors highlighted the following points:

- ⇒ the relative detection characteristics of the two active systems when observing mid-latitude cloud systems, the analyses presented pointed to the need to contrast these detection properties for different cloud types at different locations (such as under polar, tropical and mid-latitude airmass conditions).
- ⇒ the requirements for spatial overlap of the two observations.
- ⇒ example retrievals of cloud properties using combinations of lidar and radar. Adoption of these approaches to space-borne measurements remains a challenge and requires more data for evaluation.
- ⇒ cloud property retrievals using synergy of active and passive measurements were also described as well as the synergy of multi-frequency radar.

The session also provided some discussion of the application of radar / lidar data in evaluating and testing global models. Examples included comparison of model forced cloud occurrence and a preliminary example of how radar data can be analyzed in the context of cloud overlap.

The development and evaluation of algorithms to be applied to space-borne radar and lidar data requires testing of these algorithms with observations preferably collected at diverse locations world-wide. The papers presented revealed how the surface observational capabilities have grown world wide. Some coordination of campaign and routine surface measurement data bases could be extremely desirable for assisting the development and testing of space-borne algorithms.

Session 7: Satellite Missions

(1) PICASSO-CENA (Winker)
- 3 channel Lidar
- O2 A-band (763-767 nm)
- 3 channel IR + high resoltion camera
- 705 km Orbit Launch March 2003
- LIDAR: uncertain backscatter/ extinct ratio ; use O_2 A-band to remove this [Exactly how?]

(2) CloudSat (Vane)
- 2 km max footprint separation from PICASSO
- radar minimum detection –28 dBZ (pulse compression gain 5 dB)
- Combine radar + O2 A-band optical depth [Exactly how? Cloud inhomogenuity
- Launch 2003

(3) ERM (Baptista, Lin)
- Post Granada now re-appraisal for joint Japanese Mission
- Radar / Lidar / MSI / BBR
- radar – quasi-optic vs wave-guide? Z = -36 dBZ; 380 km Orbit
- Greenland to calibrate

(4) Sub-mm radiometer (Walter)
- Ice colder To than upwelling w. vapor radiation
- 183, 325, 448, 640 GHz; fly on A/C. Aug/Sep 2000
- higher frequency →more
- sensitive T; 0.1 sec integration time
- If IWP .> 5 g/m2 ⇒ IWP to 1 dB (25 %) size to 1 dB (25%)
- looks promising

(5) ELISE (MDS2 launch 2002; CANCELED) (Asai)
- 527 / 1053 nm; 100 Hz

(6) CPR-MDS3 (Kuroiwa)
- proposal under review---94 GHz radar
- Full: multi beam + Doppler (5 beam; 40 km swath; -30 dBZ; antenna 3.2 * 2.3 m)
- Descope: nadir + Doppler – pulse pair H and V ; de-correlation time? V to 1m/s
- launch 2004

(7) TRMM (Iguchi)
- Successful model of international collaboration
- good model, good preparation for data processing
- Exchange data / people
- Feasibility study + algorithm development
- prepare simulated data