EarthCARE MISSION WITH JAPANESE SPACE BORNE DOPPLER CLOUD RADAR; CPR

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ABSTRACT:
Cloud is still one of the most powerful uncertainties in climate system, together with aerosol. Japanese Aerospace Exploration Agency (JAXA), National Institute of Information and Communications Technology (NICT) and European Space Agency (ESA) are going to materialize a project named "Earth Cloud, Aerosol and Radiation Mission; EarthCARE". The objective of the mission is to reveal the process from cloud formation with aerosol, to washout as precipitation with radiative evaluation. The new space borne radar; Cloud Profiling Radar (CPR) is going to be developed in the cooperation between JAXA and NICT. CPR is the first W-band space borne Doppler Cloud Radar to observe vertical distribution and motion of cloud particle. This quite unique sensor is equipped with a large diameter antenna and high-power 94GHz transmitter to materialize the Doppler measurement. The instrument is now in Engineering Model phase. Flight Model will be completed in 2012. The EarthCARE satellite will be launch in 2013.

1. INTRODUCTION

1.1 Cloud and Climate Change

Since the last report of IPCC (Third Report), the level of scientific understandings regarding the effect of aerosols and clouds, show a good progress. However, the most recent report (Fourth Assessment Report; FAR) says that it still remains the dominant uncertainty in radiative forcing. It is reported that -0.5 W/m2 for aerosol direct effect and -0.7W/m2 for cloud albedo effect, -1.2 W/m2 as aerosol total, are counted for radiative forcing relating with aerosol/cloud. The figure is enough large comparing with the total anthropogenic radiative forcing ; +1.6 W/m2. Especially we have to make an attention to that the uncertainty of the cloud albedo effect, i.e. interactions between aerosol and cloud, is very large; 2W/m2. This leads, without the correct understanding of the interaction between aerosol and cloud, climate change is still uncertain to predict future status with sufficient accuracy.
Further more, FAR suggests the cloud life cycle process should be examined not just for cloud forming but also for the precipitation process or cloud termination process, which will effect global radiation budget through latent heat release and changing the ground surface radiative characteristics by such as snowing (IPCC, 2007).

1.2 EarthCARE mission and instruments

EarthCARE is a challenging mission toward to solve this issue. The observation scope of the EarthCARE is to observe globally such processes; the aerosol distribution, cloud forming with aerosol interaction and beginning of precipitation. To materialize such observation, LIDAR and Doppler Radar for the aerosol/cloud profile observation, multi spectral imager for aerosol/cloud lateral distribution observation and broadband radiometer for Earth radiative flux observation, are chosen. The relationship between target geophysical parameters and instruments is shown in figure 1. The final goal of the mission is to reconstruct aerosol cloud structure with their physical characteristics with the accuracy of 10 W/m2 as radiative flux at top of atmosphere(ESA,2004, Gelsthorpe et.al., 2008).

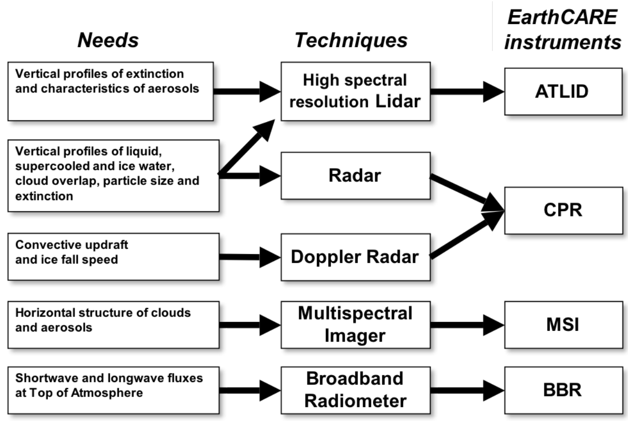

Figure 1 Relationship between target geophysical parameters and instruments

The outlook of EarthCARE satellite and CPR are shown in figure 2. An Sun synchronous orbit was chosen as the observational orbit to cover all region of the Earth. Local time at equator of the orbit is 13:45 to 14:00 with consideration of that cloud process is active in afternoon.
To get the accurate aerosol/cloud observation data, several unique points are implemented for instrumentation. The LIDAR is a Ultra Violet range single wavelength High Spectral Resolution LIDAR. The wavelength ; 355 nm has well sensitivity for the small aerosol particle and make high transmit power possible for its eye safe character. High spectral resolution makes to receive Mie and Rayleigh scattering signals independently. This leads real measurement of particle number and its microphysical characteristics, such as effective radius. Doppler W-band Radar penetrates thick cloud layers. Doppler measurement function distinguishes cumulus / convective cloud types and its particle status inside of cloud layer. Using Doppler value, we precisely know kinds of cloud particles. The channels employed for MSI will be used with split window method to get optical depth and effective radius of cloud and aerosols. BBR design is a heritage of past Earth Radiation Mission, such as ERBE or CERES. Three angle radiometer will be used for flux determination considering its angular distribution. General characteristics for all four instruments are shown in Table 1.

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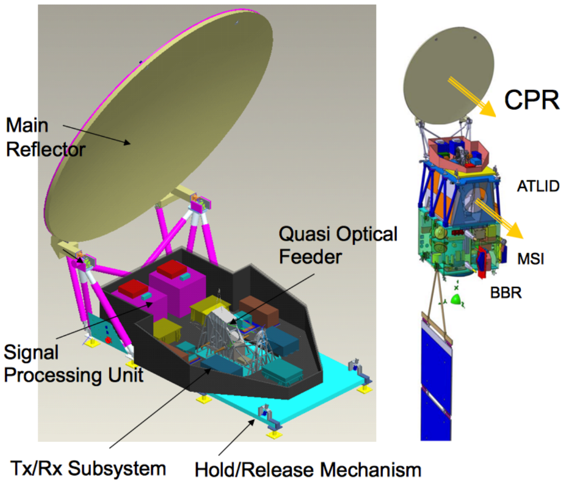

Figure 2. Outlook of CPR and EarthCARE satellite

Table 1 General characteristics of instruments

Instrument	Description
CPR	94 GHz Doppler Radar (see Table 2.)
ATLID	355 nm H yper Spectral Resolution Lidar with three channels (Mie co-polar, Rayleigh, Mie cross-polar)
MSI	Push broom imager Resolution 500m, swath 150 km seven channels (0.67, 0.865, 1.65, 2.21, 8.8, 10.8, 12.0 micron)
BBR	Three views radiometer Angle: Nadir, +- 55 deg Two channels; 0.2-4, 4-50 micron

2. DOPPLER CLOUD PROFILING RADAR

2.1 System Requirements and Design

From CPR observational requirements, we identified following design requirements. First point is the high sensitivity. This requirement is divided into large antenna size requirement, low noise figure of receiver requirement and high power of transmitter requirement. Second point is the Doppler capability. To materialize this function with satisfactory accuracy, large diameter of antenna with precise surface figure and high pulse repetition frequency (PRF) are required. To keep accuracy especially at boundary layer region, several other fine characteristics, such as side lobe characteristics of antenna, cross polarization characteristics and so on, are also required for CPR design.

As the result of design, we chose pulse pair scheme for Doppler measurement. And the diameter of antenna was set as 2.5 m considering the limited diameter of launcher fairing. For transmitter, we employed improved Extended Interaction Klystron (EIK), of which original model is already employed for CloudSAT mission by NASA(Stephens et.al., 2002). The transmit power is 1.5 kW at end of three year mission. For PRF design, CPR has variable control capability of PRF with satellite altitude information. This is for maximizing frequency to keep good coherency between radar pulses, also good sensitivity by having much integration. Outlook of CPR is shown in Figure 2 and major specification of CPR is shown in Table 2.

Table 2. General Specifications of CPR

Item	Specification
Radar type	94 GHz Doppler Radar
Center frequency	94.05 GHz
Pulse width	3.3 micro second (equivalent to 500m vertical resolution)
Beam width	0.095 deg
Polarization	Circular
Transmit power	> 1.5 kW (Klystron spec.)
Height range	-0.5 ~ 20 km
Resolution	500 m (100 m sample); Vertical, 500m integration; Horizontal
Sensitivity*	-35 ~ +21 dBZ
Radiometric accuracy*	< 2.7 dB
Doppler range*	-10 ~ +10 m/s
Doppler accuracy*	< 1 m/s
Pulse repetition frequency	Variable; 6100~7500 Hz
Pointing accuracy	< 0.015 degree

*; at 10 km integration and 387 km orbit height

However, the PRF is a factor of trade off between observational height. Considering the natural cloud height distribution, the planned operation of CPR is to change observational height with latitude. As natural cloud height distribution, For low latitude region, the cloud height is rather high, in contrast, the polar region cloud height is rather low. The image of CPR operation is shown in Figure 3.

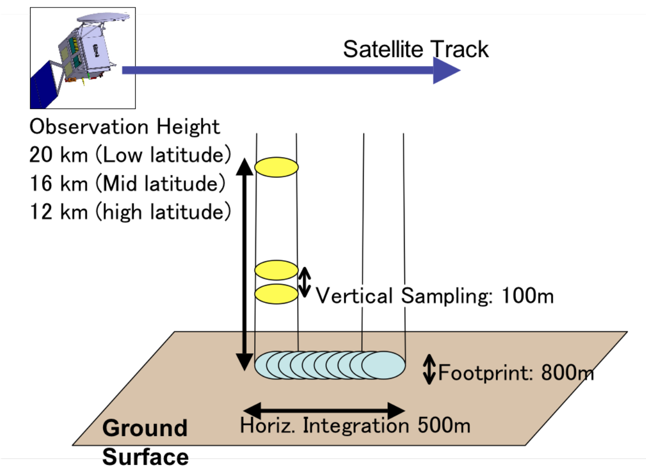

Figure 3. CPR Operation Image

2.2 Operation Plan

CPR will be under operation for two and a half year, after commissioning phase of a half year. Commissioning phase is for first check out and first calibration. During standard operation, design duty of CPR 100% except for calibration period. CPR has three modes for calibration. Internal cal mode is defined for electrical circuit calibration. This will be done at polar region. External cal is defined for the calibration with Active Radar Calibrators (ARC) on the ground. ARCs are specially developed for CPR and used in Japan. The last calibration mode; sea surface calibration mode is used for Doppler calibration with satellite roll manoeuvre. The image of the operation and calibration is shown in Figure. 4.

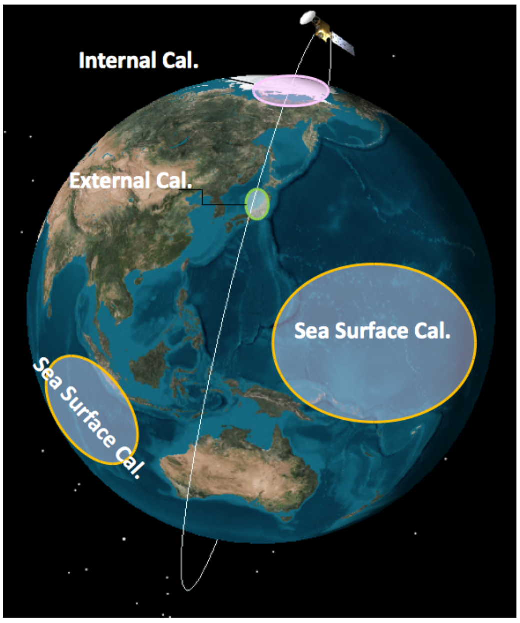

Figure 4. CPR Operation Image for calibration

3. CURRENT STATUS AND CONCLUSIONS

CPR is currently in Engineering Model Phase. Large main reflector and structure are already built and under environmental test. All electrical and RF components are independently under manufacturing and soon to be tested. CPR functional and performance test will be done by spring 2011. In parallel, EarthCARE satellite SM integration will be done by ESA throughout 2011. Launch of EarthCARE satellite will be in 2013.

During EarthCARE/CPR preparation for development, CloudSAT/CALIPSO satellites continue their missions and a lot of new facts being discovered. For the continuation and improvement of the CloudSAT/CALIPSO, EarthCARE is expected, and also believed that more new facts will be discovered with its improved capabilities.

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