APPENDIX 3

OVERVIEW OF THE EARTH CLOUD, AEROSOL AND RADIATION EXPLORER (EarthCARE) MISSION

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. From the most recent report (Fourth Assessment Report; FAR), carbon dioxide is said to be the largest factor to the influence of the global warming. However, the effect of carbon dioxide to the global warming is considered to have been evaluated with a good accuracy. On the other hand, the radiative forcing of clouds and aerosols still remains as the dominant uncertainty in the prediction of the climate change in the future. It is reported that -0.5 W/m^2 for aerosol direct effect and -0.7 W/m^2 for cloud albedo effect, -1.2 W/m^2 as total aerosol, are counted for radiative forcing relating with aerosol/cloud. The figure is large enough comparing with the total anthropogenic radiative forcing; +1.6 W/m^2. We have to make a special attention to the fact that the uncertainty of the cloud albedo effect, i.e. interactions between aerosol and cloud, is very large; 2 W/m^2. This leads, without the correct understanding of the interaction between aerosol and cloud, climate change to remain uncertainties to predict future status with sufficient accuracy.

Furthermore, FAR suggests that 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 affect global radiation budget through latent heat release and changing the radiative characteristics of the ground surface by such as snowing (IPCC, 2007).

1.2 EarthCARE mission and instruments

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". EarthCARE is a challenging mission toward to solve the issues noted in the previous section. 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, four instruments were chosen, with their respective needs, to load on EarthCARE; LIDAR (light detection and ranging) and Doppler Radar for the aerosol/cloud profile observation, multi spectral imager (MSI) for aerosol/cloud lateral distribution observation and broadband radiometer (BBR) for Earth radiative flux observation. The observations by these instruments guarantee their synchronism and their uniformity in the observation region. In other word, more accurate synergy observations are preserved, by minimizing the differences in the condition of the observations between the instruments, resulted from such as the differences in the timing of the observation. 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).

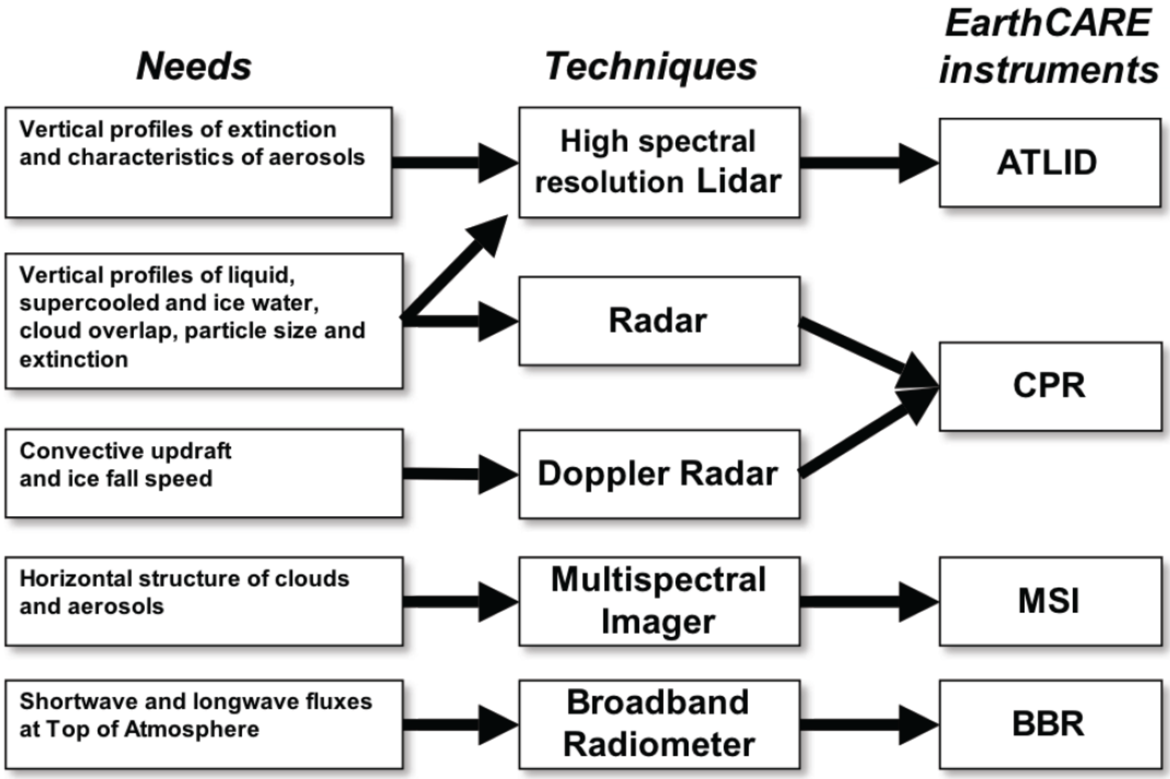

Figure 1 Relationship between target geophysical parameters and instruments

The outlook of EarthCARE satellite and CPR are shown in figure 2. A 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 cloud processes being active in the afternoon.

To get the accurate aerosol/cloud observation data, several unique points are implemented for instrumentation. The LIDAR is an Ultra Violet range single wavelength High Spectral Resolution LIDAR. The wavelength, 355 nm, has well sensitivity for the small aerosol particles that are missed by Radar, and make high transmit power possible for its eye safe character. It is possible for the LIDAR signals to be strongly attenuated when they meet dense regions composed by large particles such as clouds. High spectral resolution enables to receive Mie and Rayleigh scattering signals independently. In this way, the optical properties of aerosols can be retrieved directly, without an assumption of liar ratio. Through its polarization measurement, the depolarization ratio can be calculated to estimate the nonsphericity of the observed particle. 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 detailed description of the Doppler Radar is noted in Section 2.1. The MSI has 7 channels with their central wavelengths to be 0.67, 0.865, 1.65, 2.21, 8.8, 10.8 and 12.0 μm, respectively. These channels will be used with split window method to get optical depth and effective radius of cloud and aerosols. Thermal infrared channel can be used to retrieve the cloud top height. The ground resolution of MSI is 500 m^2 and the swath width is 150 km. BBR design is a heritage of past Earth Radiation Mission, such as ERBE or CERES. BBR has two channels; one for the observing shortwave (0.25 ~ 4μm) and the other for longwave (4 ~ 50μm). Three angle radiometer will be used for flux determination considering its angular distribution. The effect of cloud forcing by the reflection of sunlight as well as by its emittence of longwave radiation are expected to be evaluated from the BBR observation. General characteristics for all four instruments are shown in Table 1.

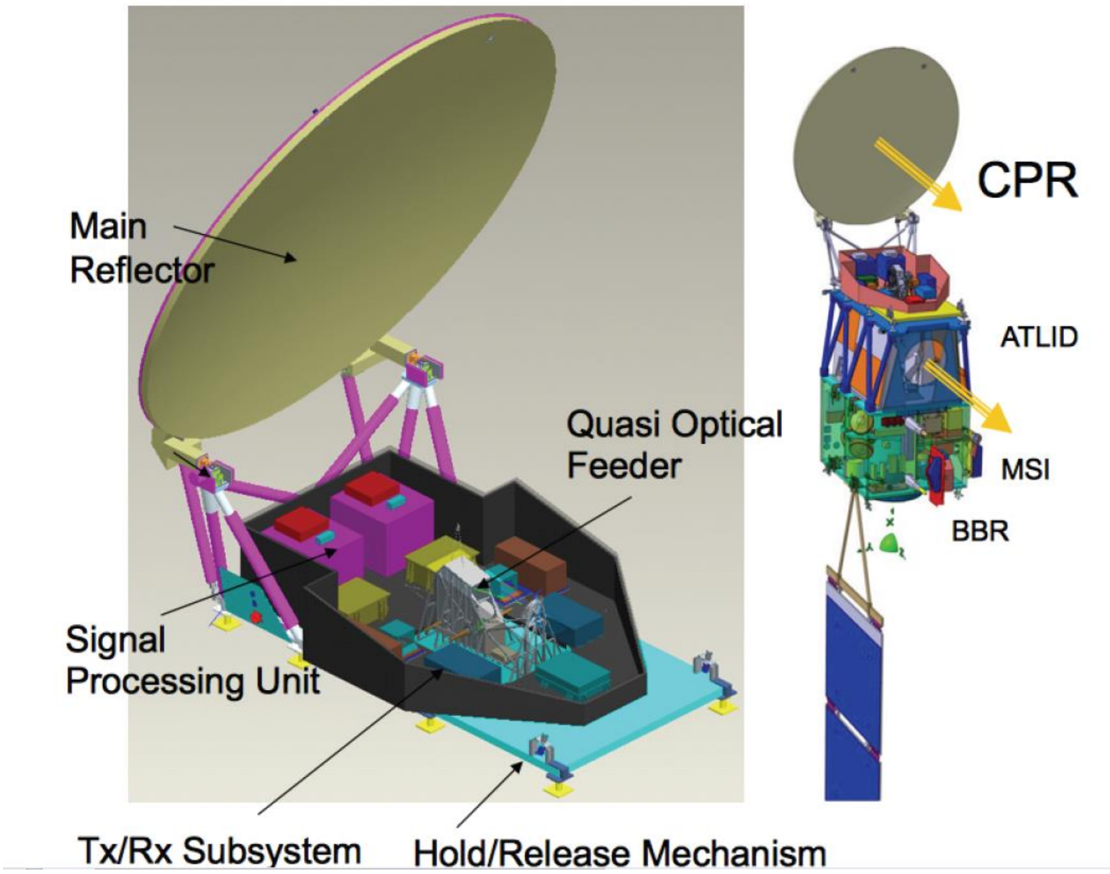

Figure 2. Outlook of CPR and EarthCARE satellite

Table 1 General characteristic of instruments

Instrument	Description
CPR	94 GHz Doppler Radar (see Table 2.)
ATLID	355 nm Hyper 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

The new space borne radar; Cloud Profiling Radar (CPR) is going to be developed in the cooperation between JAXA and NICT. 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. In addition, 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.

However, the PRF is a factor of trade off between observational heights. 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.

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 500 m 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

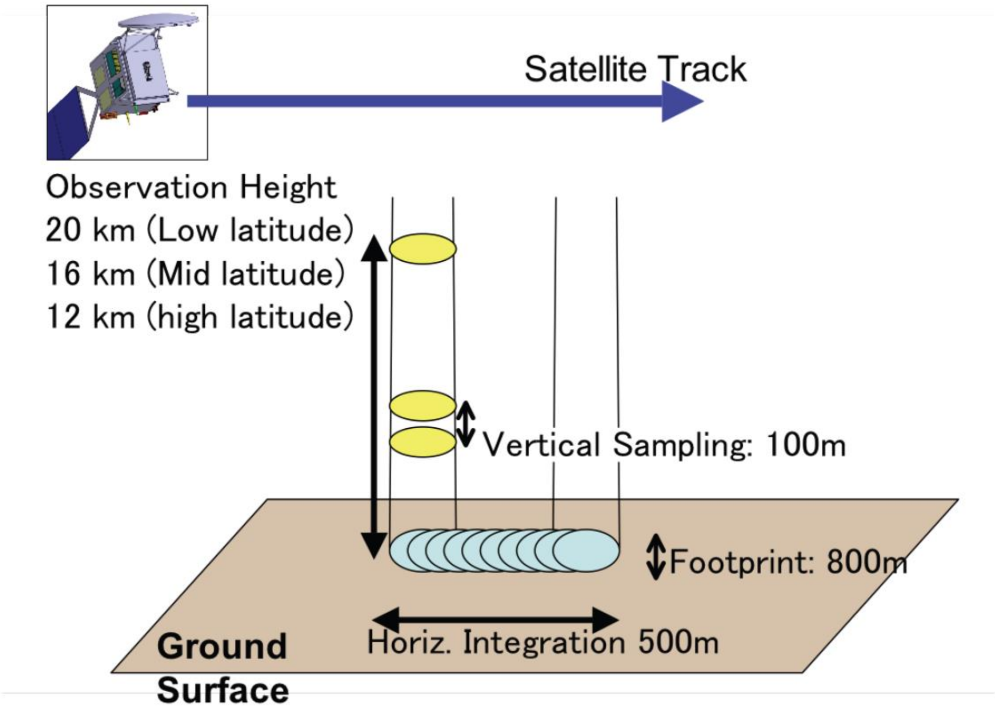

Figure 3. CPR Operation Image

3. Operation Planning

EarthCARE is planned to be launched in JFY2021. The calibrated engineering parameters (Level 1 data) and the retrieved physical parameters (Level 2 data) by all four sensors on EarthCARE will be stored and distributed from both JAXA and ESA. Data are planned to be used by research institutes and agencies in order to improve the accuracies of numerical weather/climate models. The data are also opened to researchers (after appropriate procedures), and are used in the analysis of radiation/aerosol/cloud/precipitation process.

REFERENCES

EarthCARE – Earth Clouds, Aerosols and Radiation Explore Mission Report, ESA SP-1279(1).2004, available from http://esamultimedia.esa.int/docs/SP_1279_1_EarthCARE.pdf

RV. Gelsthorpe, A. Heliere, A. Lefebvre, J. Lemanczyk, E. Mateu and K. Wallace, "EarthCARE and its payload", *Proc. SPIE,* Vol. 7152, 2008

T. Kimura and H. Kumagai, "Japanese Cloud Profiling RADAR for EarthCARE", *Proc. 26th ISTS*, Hamamatsu 2008

T. Kimura, H. Nakatsuka, K. Sato, Y. Sakaide , Y. Seki , K. Okada, N. Takahashi , Y. Ohno , H. Horie, "EARTHCARE MISSION WITH JAPANESE SPACE BORNE DOPPLER CLOUD RADAR; CPR", *Proc. ISPRS Technical Commission VIII symposium,* 2010.