EARTHCARE SCIENCE MISSION OBJECTIVES

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ABSTRACT:

Clouds and aerosols are known to play crucial roles in the climate system; however, they are also main sources of uncertainty in our knowledge, and especially large efforts are needed to evaluate their interactions (IPCC 2007). The Japan Aerospace Exploration Agency (JAXA) is carrying out the EarthCARE (Earth Clouds, Aerosols, and Radiation Explorer) mission in cooperation with the European Space Agency (ESA) under ESA’s Earth Explorer Program. The primary objective of the EarthCARE mission is to improve our understanding of the roles of clouds and aerosols and their interaction in the context of the Earth's radiation budget and climate in order that they may be represented well in regional and global climate models and in numerical weather prediction models. Currently, JAXA expects the EarthCARE data to be used to improve cloud formation processes in cloud system resolving models and radiative characteristic models of aerosols and clouds. Then, the improved models can be used to analyze the EarthCARE data and reduce the inconsistency between satellite-observed data and calculated results through the assimilation process. We have several numerical models in Japan to simulate aerosol and cloud fields on various scales from meso to global. For example, the MIROC coupled atmosphere-ocean General Circulation Model (GCM) developed by the University of Tokyo and the NIES (National Institute for Environmental Studies) will be useful in evaluating climate sensitivity and the interaction of aerosols and clouds with climate systems. The NICAM cloud system resolving model developed by JAMSTEC (Japan Agency for Marine-Earth Science and Technology) and the University of Tokyo cloud system resolving model can simulate the global cloud system with a spatial scale of several kilometers without cumulus parameterization, which produces a large uncertainty in the GCM models. To achieve the purposes written above, JAXA and the National Institute of Information and Communications Technology (NICT) are in charge of the Cloud Profiling Radar (CPR) and ESA is in charge of the Atmospheric Lidar (ATLID), Multi-spectral Imager (MSI), and Broadband Radiometer (BBR). The three agencies will work collectively. This is one more advantageous point over the A-train mission. Furthermore, the CPR was designed with the capability of measuring vertical profiles of Doppler velocity. This measurement will be the first attempt to obtain Doppler Velocity from space. This paper describes the scientific strategy and plans for each activity in Japan.

1. INTRODUCTION

1.1 General Instructions

Earth observation by satellites is an important tool for us to investigate the Earth's climate system, which is disturbed by human activities, such as global warming and global air pollution. The original concept of the EarthCARE satellite was built in the 1990s when new cloud profiling radar (CPR) technology became available. The CPR can detect cloud particles with its high-frequency microwave radar pulse to measure cloud stratification. ESA's Earth Radiation Mission (ERM) was the first satellite-borne CPR proposed in the early 1990s. The Japanese ATMOS-B1 mission was also proposed as a project of JAXA's MDS (Mission Demonstration Satellite) program in the mid-1990s.

After these first generation mission proposals, the EarthCARE mission was finally approved in 2006 in Europe and in 2007 in Japan for Phase-B study of the third Earth Explorer core mission. This mission is a joint ESA-JAXA-NICT mission to carry a CPR and a Mie lidar (ATLID) on the same satellite platform accompanied by an imager (MSI) and a Broadband Radiometer (BBR). This package is the most advanced one to measure the vertical stratification of the atmosphere with clouds and aerosols. The CPR and lidar will measure the vertical stratification of the atmosphere. This capability is especially important to understanding the phenomenon of aerosol and cloud interaction. The MSI and BBR will add information on

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horizontal distribution of aerosols and clouds and of broadband radiative fluxes, respectively. An important task of EarthCARE is providing useful data to reduce the uncertainty in evaluation of radiative forcing of clouds and aerosols. This will bring about the enormous benefit of increasing the modeling ability of cloud- and aerosol-laden atmospheres. Doppler velocity sensing, a new technology of the NICT, is another innovation of the EarthCARE platform that will produce a new dataset of global cloud particle motion data.

In May 2008, the EarthCARE Mission Advisory Group of Japan drafted the Japanese Science Plan for the EarthCARE mission to present important science targets for the mission and activities to be performed as Japanese contributions. In March 2009, the Algorithms Theoretical Basis Document (ATBD) was drafted by the EarthCARE Mission Advisory Group of Japan to present algorithms to be used in mission product generation as a Japanese activity.

1.2 Introduction of the science in the EarthCARE mission

Clouds and aerosols are the key players in deciding the Earth's climate, affecting the atmosphere in two opposite ways, such as reflecting sunlight, i.e., the albedo effect, and absorbing terrestrial radiation, i.e., the greenhouse effect. However, these two opposite effects are main sources of uncertainty in our knowledge, and large efforts are needed to evaluate their interactions (IPCC, 2007). The primary objective of the EarthCARE mission is to improve our understanding of the roles of clouds and aerosols and their interaction in the context of the Earth's radiation budget and climate in order that they may be represented well in regional and global climate models and in numerical weather prediction models (EarthCARE Science Plan, 2007). This paper describes the scientific strategy and plans for each activity in Japan.

Figure 1 illustrates the structure of research activities in our science plan, the members in charge of the core research studies for the remote sensing algorithms, and the modules for the satellite signal simulation model, the EarthCARE simulator.

We basically follow the primary objectives of the EarthCARE mission, which can be broken down into several items listed bellow as derived from the MRD (Mission Required Document):

- To observe the vertical profiles of natural and anthropogenic aerosols on a global scale, and to infer their radiative properties and interaction with clouds,
- To observe the vertical distributions of atmospheric liquid, water, and ice on a global scale, as well as inferring their transport by clouds and their radiative impact,
- To observe cloud distribution (e.g., cloud phase, vertical overlap patterns, and horizontal fluctuations), cloud-precipitation interactions, and the characteristics of vertical motions within clouds, and
- To utilize retrieved aerosol and cloud properties to estimate profiles of atmospheric radiative heating and cooling.

To accomplish these objectives, we, JAXA and the NICT, are developing a CPR with the ability to obtain Doppler velocity of atmospheric particles and the algorithms to yield L1 datasets of it. The other instruments, ATLID, MSI, and BBR, and their algorithms for L1 datasets are being developed by ESA and their collaborators.

Therefore, EarthCARE will attain these objectives by inferring simultaneously the vertical structure and horizontal distribution of cloud and aerosol fields and radiative fluxes at the top of the atmosphere (TOA) over all climate zones as defined in the EarthCARE Science Plan (2007). EarthCARE will infer:

Properties of aerosol layers:
- The occurrence of aerosol layers, their profile of extinction coefficient, boundary layer height.
- The presence of various types of aerosols including those from anthropogenic and natural sources.

Properties of cloud fields:
- Cloud boundaries (top and base heights) including multi-layer clouds.
- Height-resolved fractional cloud amounts and overlap rates.
- The occurrence of ice, liquid, and super-cooled cloud layers.
- Vertical profiles of ice water content and effective ice particle size and shape.
- Vertical profiles of liquid water content and effective droplet size.
- Small-scale (1 km or less) fluctuations in these cloud properties.

Other Properties
- Vertical velocities to characterize cloud-scale convective motions and ice sedimentation.
- Drizzle rates and estimates of heavier rainfall rates.
- Narrowband and broadband reflected solar and emitted thermal fluxes at the top of the atmosphere from measured radiances.

The final scientific goal of the EarthCARE mission is to understand how much climate sensitivity the Earth-Atmosphere system has, and how the climate is driven by clouds, aerosols, and their interaction.

EarthCARE data will be used to improve cloud formation processes in cloud system resolving models as well as radiative characteristic models of aerosols and clouds. Then, the improved models can be used to analyze the EarthCARE data and reduce inconsistency between satellite-observed data and calculated results through the assimilation process. We have several numerical models to simulate aerosol and cloud fields on various scales from meso to global. The MIROC coupled atmosphere-ocean General Circulation Model (GCM) will be useful in evaluating the climate sensitivity and interaction of aerosols and clouds with the climate systems. The Nonhydrostatic Icosahedral Atmospheric Model (NICAM) (Satoh et al., 2008) can simulate the global cloud system with a spatial scale of several kilometers without cumulus parameterization, which produces a large uncertainty in the GCM models.

Another important plan is to utilize EarthCARE data in numerical weather prediction (NWP) simulations and assimilations. The JMA/MRI (Japan Meteorological Agency/ Meteorological Research Institute) is an important potential user of data for developing an assimilation method and for improving weather prediction.

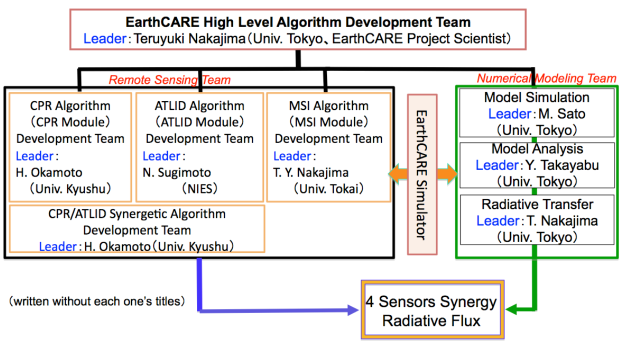

Figure 1. Structure of Research Activities in the Japanese Science Plan

2. EARTHCARE PLATFORM

The EarthCARE platform and payload, illustrated in Figure 2, are being developed by ESA, and JAXA and the NICT are collaborating with them in developing the CPR system. The specifications of the EarthCARE platform are shown in Table 3. The EarthCARE Space Segment is a satellite composed of a platform and a payload with the following instruments:

- Atmospheric Lidar (ATLID): to retrieve vertical profiles of aerosol physical parameters and, in synergy with the cloud profiling radar, vertical profiles of cloud physical parameters.
- Cloud Profiling Radar (CPR): to retrieve micro- and macroscopic parameters of clouds and the vertical velocity of cloud particles.
- Multi-Spectral Imager (MSI): to provide information on the horizontal structure of cloud fields in support of the vertical profiles measured by the active instruments.
- Broadband Radiometer (BBR): to measure shortwave (SW) and long-wave (LW) fluxes at the top of atmosphere (TOA) as a crosscheck of the radiative flux derived from the cloud-aerosol profiles measured by the active instruments.

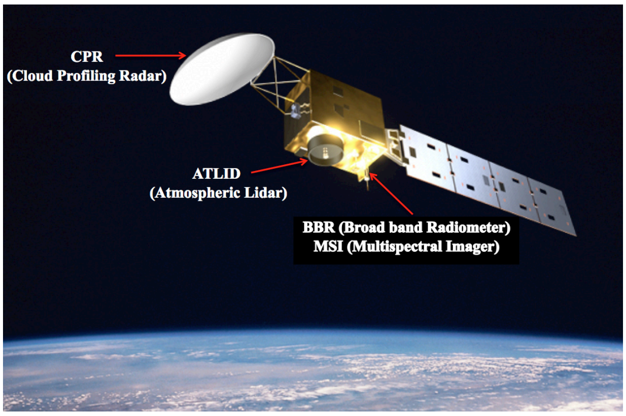

Figure 2. Image of EarthCARE Satellite (courtesy of ESA)

	Low Orbit Values (mean kepler)	High Orbit Values (mean kepler)
Semi-major axis	6750.040 km	6803.451 km
Eccentricity	0.001293	0.001274
Inclination (sun-synchronous)	96.951°	97.146°
Argument of perigee	90°	90°
Mean Local Solar Time, Ascending Node	13:30-14:00	13:30-14:00
Repeat cycle / cycle length	30 days, 469 orbits	20 days, 309 orbits
Orbital duration	5516.652 s	5592.233 s
Mean Spherical Altitude	371.903 km	425.314 km
Minimum Geodetic Altitude	377.113 km	430.478 km
Maximum Geodetic Altitude	404.760 km	458.055 km
Average Geodetic Altitude	387.130 km	440.483 km

Table 3. Specifications of EarthCARE

3. JAPANESE SCIENCE PLAN

Figure 4 illustrates the structure of the research flow and the relation among each study in the Japanese Science Plan. The leading part of our science is to estimate the value of climate sensitivity of the Earth. Therefore, we aim to retrieve radiative fluxes at the top of the atmosphere (TOA) and the bottom of the atmosphere (BOA) within accuracies of 10 W/m^2. In brief, we plan to make synergistic use of the method of remote sensing and numerical model simulations as a pair.

3.1 Remote Sensing Part

We plan to yield microphysical and optical properties of clouds and aerosols by single and synergistic use of the EarthCARE sensors. The left light-orange box indicates the remote sensing part in which L2 products will be retrieved vertically with the CPR and ATLID and horizontally with the MSI. The high-level products from one sensor will be named L2a products and the products from synergistic use of multi-sensors will be named L2b products. We also plan to reproduce the composite products as L2c. Furthermore, near real-time products will be produced as NRT products, though the details of the NRT products are currently under consideration.
The retrieved parameters, the vertical profiles with CPR and ATLID, and the horizontal distribution with the MSI, will be combined to generate three-dimensional scenes having regions coincident with BBR footprints and in which the radiative transfer calculations will be performed. These calculated results in three-dimensional domains will be compared with the BBR-derived radiative fluxes to check consistency between them.

3.2 Feedback process to adjust between Remote Sensing and Climate Model simulations

The upper right illustration shows one of the ways we use EarthCARE data, such as assimilation and validation with numerical models. We use the remote sensing data as input for the models, and we use output from the models as data for the validation of algorithms.

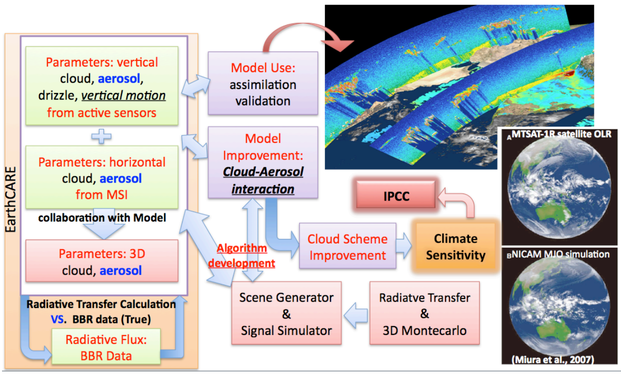

Figure 4. Structure of Research Flow in the Japanese Science Plan

The lower right panel, in which you can see two pictures of the Earth, shows the likeness between the outgoing longwave radiation (OLR) from the satellite MTSAT-1R and the OLR simulated Madden-Julian Oscillation (MJO) with NICAM (Miura et al., 2007). This result indicates that NICAM can reproduce the Earth system with good agreement. This insists that if the tendency of the interaction between clouds and aerosols, which could be retrieved from EarthCARE, are taken into account, then the cloud scheme used in NICAM and other numerical climate models will be more finely adjusted. On the contrary, the algorithms used with several assumptions could be adjusted by comparing the results from NICAM. In this procedure we will adopt the scene generator and the signal simulator (Masunaga, 2010) illustrated in the lower center part of Figure 4 to compare the consistency between the radiances observed by EarthCARE and the model yielded radiances to avoid uncertain assumptions in the retrieval algorithms.
We will usually use plane-parallel radiative transfer calculations (Nakajima and Tanaka, 1986; 1988) to proceed in CPU time; however, when the three-dimensional effect has to be

considered, we will use three-dimensional Efficient Monte Carlo methods improved by Iwabuchi (2006).

As written above, our plan is to reveal uncertainties in the interaction between clouds and aerosols. This will be very helpful in assessing the cloud scheme in climate models and will lead us to obtaining the climate sensitivity of the Earth.

4. PRODUCTS AND ALGORITHMS

The EarthCARE data analyses generate L2 data in two by two categories: aerosol and cloud; horizontal and vertical.

Aerosol optical thickness at 550 nm (AOT) from the MSI is difficult to retrieve with the limited swath and wavelengths of the MSI, especially over land, so, we tentatively selected AOT using the MSI as a research product. Cloud microphysical properties from the MSI are derived using two channel pairs of 0.67 µm vs. 1.65 µm and 0.67 µm vs. 2.21 µm; therefore, we can see the structure difference of clouds horizontally. The NIES lidar algorithm is unique in the sense that it produces multi-aerosol extinction cross section profiles. JAXA and the NICT are in charge of producing CPR L1b data, such as Received Echo Power, Radar Reflectivity, Surface Radar Cross Section, and, particularly, Doppler Velocity and Covariance of Pulse Pair, which are categorized as L1b standard products of JAXA.

Other CPR L2 products are divided between standard products and research products because some research products from CPR will use Doppler velocity, whose accuracy is very sensitive to the movements of the EarthCARE satellite. The research community asked to generate high-resolution data better than 10 km numerical model use. Although it was decided that CPR data would be integrated as 10 km in the original specification, we then decided to produce CPR products with 1-km resolution.

The JAXA standard L1b, L2a, and L2b products are summarized in Table 6a and 6b, where "Product Name" means simply categories for JAXA management, "Primary Parameters" means the actual products derived by each algorithm, and we define the accuracy of each product through the combination of the red horizontal and vertical value in "Product Resolution." Note that the upper vs. upper part and lower vs. lower part are the pairs of resolution.

Sensor(s)	Processing Level	Product Name	Primary Parameters	Product Resolution	
				Horizontal	Vertical
CPR	L1b	Received Echo Power Products	Received Echo Power	0.5km	100m
			Radar Reflectivity		
			Surface Radar Cross Section		-
CPR	L1b	Doppler Products	Doppler Velocity	0.5km	100m
			Covariance of Pulse Pair		
CPR	L2a	CPR Echo Product	Integrated Reflective factor	1km / 10km	100m / 500m
			Integrated Doppler Velocity		
			gas correction factor		
CPR	L2a	Cloud Mask without Doppler	Cloud Mask	1km / 10km	100m / 500m
		Cloud Type Products without Doppler	Cloud Particle Type	1km / 10km	100m / 500m
		Cloud Products without Doppler	Radar Reflectivity with attenuation correction	1km	100m
			Reff of Liquid & Ice and LWC & IWC		
			Optical Thickness		-
MSI	L2a	Cloud Flag	Cloud Flag including Cloud Phase	500m	-
		Cloud Products	Cloud Optical Thickness (Liquid)	500m	-
			Reff of Liquid (1.6um & 2.16um)		
			Cloud Top Temperature & Pressure & Height		

Table 6a. JAXA Standard Products List of EarthCARE Mission

Sensor(s)	Processing Level	Product Name	Primary Parameters	Product Resolution	
				Horizontal	Vertical
ATLID	L2a	Feature Mask Product	Feature Mask	200m	100m
		Target Products	Target Mask	1km / 10km	100m / 100m
		Aerosol Product	Ext. & Backscat. Coeff. and Lidar & Depolarization Ratio	10km	100m
		Cloud Products	Ext. & Backscat. Coeff. and Lidar & Depolarization Ratio	1km / 10km	100m / 100m
		Atmospheric Boundary Layer	Planetary Boundary Layer Height	1km / 10km	100m / 100m
CPR + ATLID	L2b	Cloud Mask without doppler	Cloud Mask	1km / 10km	100m / 500m
		Cloud Type Products without doppler	Cloud Particle Type	1km / 10km	100m / 500m
		Cloud Products without Doppler	Reff of Liquid & Ice	1km / 10km	100m / 500m
			LWC & IWC		
			Optical Thickness	1km	-
CPR + ATLID + MSI	L2b	Cloud Products	Cloud Particle Type	1km / 10km	100m / 500m
			Reff of Liquid & Ice		
			LWC & IWC		
			Optical Thickness		-
CPR + ATLID + MSI + BBR	L2b	Four Sensors Synergy by 1D RT computation with all the EarthCARE products	SW & LW Radiative Flux	10km	-
			SW & LW Radiative Heating Rate		500m

Table 6b. JAXA Standard Products List of EarthCARE Mission (continued)

Table 7 shows the summarized JAXA research L2a and L2b product list, where no red values in "Product Resolution" are defined, i.e., no accuracies, due to difficulties in validation and retrieval. Especially, algorithms using Doppler velocity data as input are very challenging, and as such, we do not define the accuracies; they are categorized as research products.

Sensor(s)	Processing Level	Product Name	Primary Parameters	Product Resolution	
				Horizontal	Vertical
ATLID	L2a	Aerosol Extinction Products	Aerosol Extinction Coefficient (Water Soluble)	1km / 10km	100m / 100m
			Aerosol Extinction Coefficient (Dust)		
			Aerosol Extinction Coefficient (Sea Salt)		
			Aerosol Extinction Coefficient (Black Carbon)		
ATLID + MSI	L2b	Aerosol Component Products	Aerosol Extinction Coefficient (Water Soluble)	10km	100m
			Aerosol Extinction Coefficient (Dust)		
			Aerosol Extinction Coefficient (Sea Salt)		
			Aerosol Extinction Coefficient (Black Carbon)		
			Aerosol Size information (Fine-mode) -> mode radius		
BBR	L2a	Radiative Flux Products	Radiative Flux at TOA & BOA	10 km	-
CPR	L2a	Doppler Products	Doppler Velocity (inhomogenious)	1km / 10km	100m / 500m
			multiple scattering effect		
		Cloud Product with Doppler	LWC & IWC	1km / 10km	100m / 500m
			Reff of Liquid & Ice		
			Optical Thickness with Doppler		-
		Rain & Snow Products	Rain & Snow Water Content without doppler	1km / 10km	100m / 500m
			Rain & Snow Water Content with Doppler		
			Rain & Snow rate		
		Vertical Velocity Products	Vertical air motion	1km / 10km	100m / 500m
			Sedimentation velocity		
MSI	L2a	Ice Cloud Products	Optical Thickness (Ice) with Reflection-method	500m	-
			Reff of Ice with Reflection-method (1.6 & 2.1µm channel)		
			Ice Cloud Top Temperature, Pressure & Height		
		Aerosol Products	Aerosol Optical Thickness (Ocean & Land)	500m	-
			Angstrom Parameter (Ocean)		
CPR + ATLID	L2b	Cloud Mask Products with Doppler	Cloud Mask	1km / 10km	100m / 500m
		Cloud Type Products with Doppler	Cloud Particle Type	1km / 10km	100m / 500m
		Cloud Products with Doppler	Reff of Liquid & Ice	1km / 10km	100m / 500m
			LWC & IWC		
			Mass Ratio (2D_Ice/IWC) with/without doppler		
			Optical Thickness		-
		Rain &Snow	Rain Water Content with/without Doppler	1km / 10km	100m / 500m
			Snow Water Content with/without Doppler		
			Rain & Snow Rate		
		Vertical Velocity Products	Vertical air motion	1km / 10km	100m / 500m
			Sedimentation Velocity		
CPR + ATLID + MSI	L2b	Cloud Products with Doppler	Cloud Particle Type	1km / 10km	100m / 500m
			Reff of Liquid & Ice		
			LWC & IWC		
			Optical Thickness		-
			LWP & IWP		-
		Rain & Snow Products	Rain & Snow Water Content	1km / 10km	100m / 500m
			Rain & Snow Rate		
		Vertical Velocity Products	Vertical air motion	1km / 10km	100m / 500m
			Sedimentation Velocity		
		Emission Method Products	Effective Radius (Ice)	500m	-
			Optical Thickness (Ice)	500m	-

Figure 7. JAXA Research Product List of EarthCARE Mission

4.1 Algorithms for CPR and CPR/ATLID products

Figure 8 shows the flow of algorithms to make CPR L2a products, where the red flow and the blue flow indicate retrieval from the CPR L1b data without Doppler velocity and with Doppler velocity, respectively. ECMWF data, such as the profile of water vapor, pressure, and temperature, are used in both algorithm flows, and the gas correction will be applied to obtain the radar reflective factor. In this procedure, the algorithms for hydrometeor masks will make cloud mask products, which are shown in the second layer of the flow chart.
Hydrometeor-type Algorithms are developed by Yoshida (Yoshida, to be submitted) and applied to the corrected radar reflective factor. Then, cloud particle types, such as water, two-dimensional ice, three-dimensional ice, water-precipitation, and ice-precipitation, are discriminated.
Finally, Hydrometeor Microphysics Algorithms calculate microphysical parameters, such as the optical thickness, effective radius, liquid water path (LWP), ice water path (IWP), rain water content, snow water content, rain rate, and snow rate.

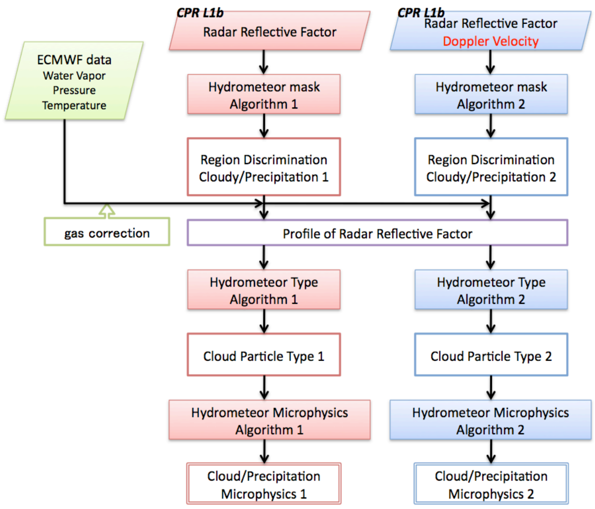

Figure 8. Flow Chart of CPR L2a Algorithm

Figure 9 shows the flow of L2b retrieval with CPR and ATLID. This flow chart contains the availability and unavailability of Doppler velocity like that of L2a retrieval.

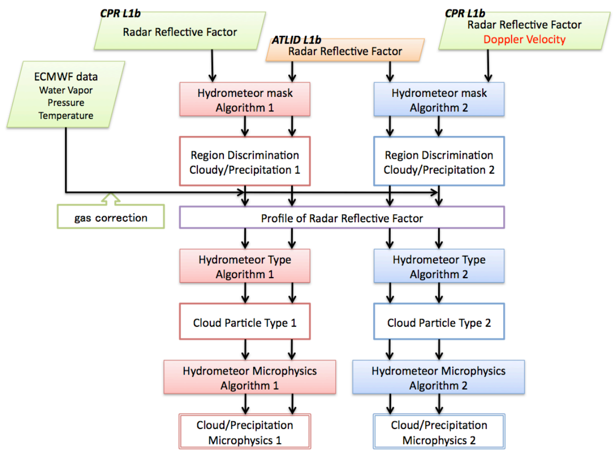

Figure 9. Flow Chart of Algorithm for Synergetic Use of CPR & ATLID L2b Retrieval

In this flow, hydrometeor mask algorithms with synergistic use of CPR and ATLID are developed by Hagihara (Hagihara et al., 2010) and will be applied. Hydrometeor-type algorithms will be applied as in the flow shown in Figure 8. They will then yield the L2b cloud hydrometeor products (Sato et al., 2009). Finally, hydrometeor microphysics algorithms (Okamoto et al., 2010; Sato et al., 2009; Yoshida et al., 2010) will be applied to retrieve the products, such as the effective radius of water and ice, LWP, IWP, optical thickness, liquid water content (LWC), ice water content (IWC), rain water content, snow water content, rain rate, and snow rate. These algorithms were applied to shipborne observation, and comparisons to the model calculations were also done (Sato et al., 2010).

4.2 Algorithms for ATLID products

The algorithms are designed to provide the following five products: (1) extinction coefficients (α), backscatter coefficients (β), and depolarization ratio (δ) of particles (i.e., aerosols and clouds); (2) flags representing the molecules, aerosols, or clouds existing in each slab layer (for example, the algorithm gives "1" as a flag number when mainly clouds exist in a slab layer or it gives a flag number of "2" when mainly aerosols exist in a slab layer); (3) flags representing cloud type (e.g., water cloud or ice cloud) and aerosol type (e.g., maritime aerosols); (4) planetary boundary layer (PBL) height; (5) extinction coefficients for aerosol components (e.g., dust, black carbon, sea-salt, and water-soluble particles) (Nishizawa et al., 2008; Nishizawa et al., 2010).
Figure 10 shows the analysis flow of the algorithm developed to provide the products. The abovementioned products are produced in each of the following procedures: "Particle Optical Properties (POP) retrieval" for product (1); "Aerosol/Cloud mask" for product (2); "Aerosol/Cloud type" for product (3); "PBL height detection" for product (4); and "Aerosol component retrieval" for product (5).

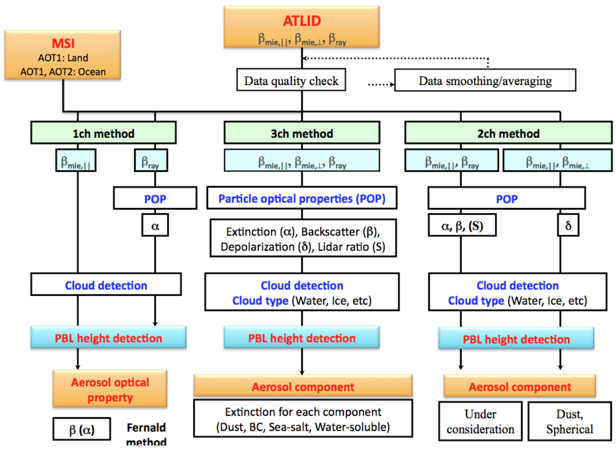

Figure 10. Flow Chart of ATLID L2a Algorithm

The algorithm produces the abovementioned L2A ATLID products, using only the L1B ATLID data of three-channel attenuated backscatter coefficients for particle Mie co-polar ($\beta_{mie,\parallel}$), particle Mie cross-polar ($\beta_{mie,\perp}$), and molecule Rayleigh co-polar (β_{ray}) components at 355 nm. The algorithm first checks the data quality and smoothes and/or averages the data if necessary. After that, the algorithm conducts each procedure sequentially, such as "POP retrieval" and "Aerosol/Cloud mask." The algorithm is developed to not only use all the three-channel data of the L1B ATLID data (3-ch method) but also use only two- (2-ch method) or one-channel (1-ch method) data of the L1B ATLID data, anticipating that some of the L1B ATLID data are without sufficient quality or blank. Therefore, the three methods (i.e., 3-ch, 2-ch, and 1-ch methods) are developed to produce similar products; however, it should be noted that the 3-ch method produces the most products with the best quality of the three methods (i.e., 3-ch > 2-ch > 1ch).

4.3 Algorithms for MSI L2a

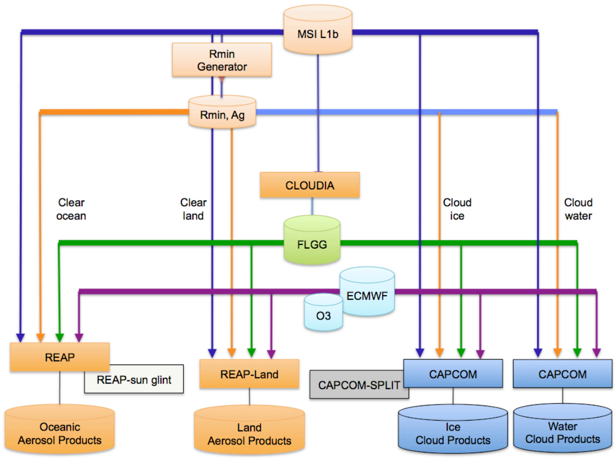

Figure 11. Flow of MSI L2a Algorithm

Figure 11 shows the flow of the MSI algorithm, which uses the visible channel (0.67 μm) and two from short wave infrared channels (1.65 and 2.21 μm), together with thermal infrared 11-μm bands, and will be used to retrieve cloud optical thickness and effective particle radius. In Figure 11, CLOUDIA is the cloud masking algorithm package (Ishida and Nakajima, 2009), CAPCOM is the cloud retrieval package (Nakajima and Nakajima, 1995), and REAP is the aerosol retrieval package (Higurashi and Nakajima, 1999). These packages for cloud and aerosol microphysics retrieval have been used over the long term and can be recognized as stable algorithms. REAP-sun glint is the new algorithm to reveal aerosol parameters over sun-glint regions, but it is under development and the MSI doesn't have appropriate channels. Consequently, it is listed as a research product.

5. CONCLUSION

In this paper, we mentioned the outline of the Japanese Science Plan and its mission objectives. We will actually carry out the EarthCARE mission in collaboration with ESA. In addition, we need many more scientists interested in the science derived from the EarthCARE mission. As described, in this mission we have to involve a variety of researchers who study not only remote sensing but also modeling for climate change, weather prediction, analytical meteorology, and analytical climatology.

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