



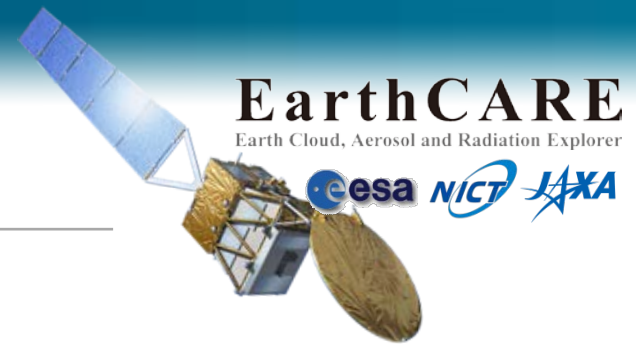
EarthCARE

Maki Hirakata, Riko Oki (JAXA/EORC)

Michael Eisinger (ESA/ESTEC) and
EarthCARE project members

6th Nov. 2013

EarthCARE Mission Objective



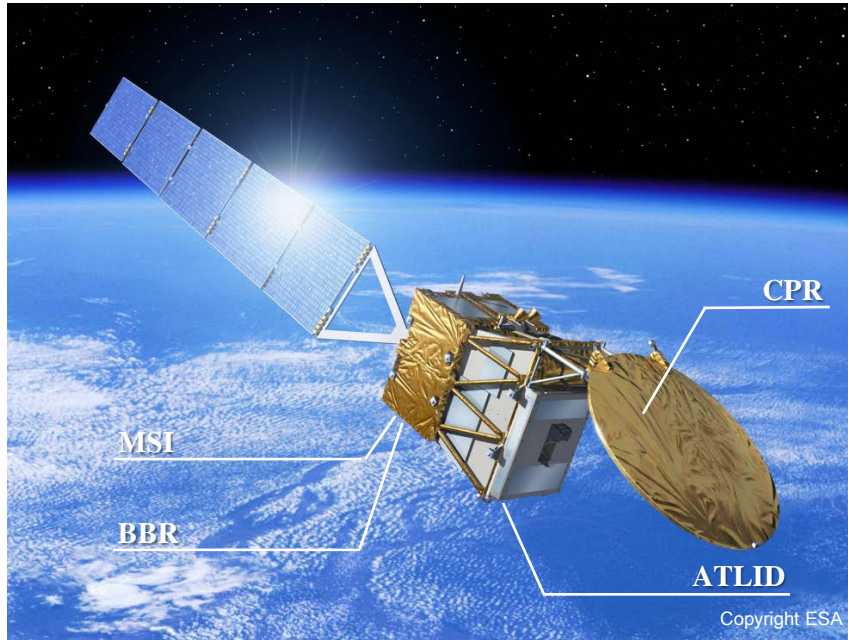
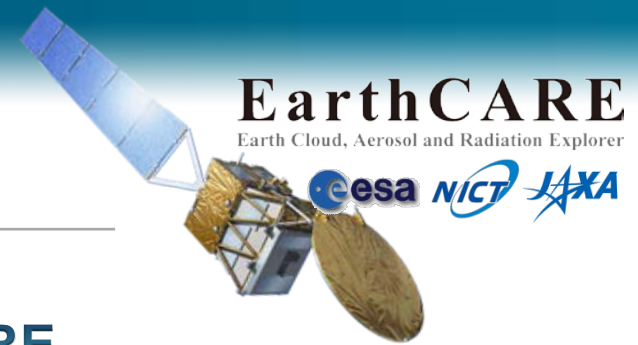
EarthCARE Mission Objective

To evaluate the radiative interaction and radiative forcing of cloud and aerosol, and to reduce the uncertainties in global warming prediction by measuring *the three dimensional global structure of clouds and aerosols*, the most uncertain parameter in the numerical climate

- The observation of the vertical profiles of **natural and anthropogenic aerosols** on a global scale, **their radiative properties and interaction with clouds**.
- The observation of the vertical distributions of **atmospheric liquid water and ice** on a global scale, **their transport by clouds** and **their radiative impact**.
- The observation of **cloud distribution ('cloud overlap')**, **cloud-precipitation interactions** and **the characteristics of vertical motions within clouds**
- retrieval of profiles of **atmospheric radiative heating and cooling** through the combination of the retrieved aerosol and cloud properties

Reflect to climate models,
meteorological models
and regional models

EarthCARE Satellite



EarthCARE

Earth Clouds, Aerosol and Radiation Explorer

Observation Instruments on EarthCARE

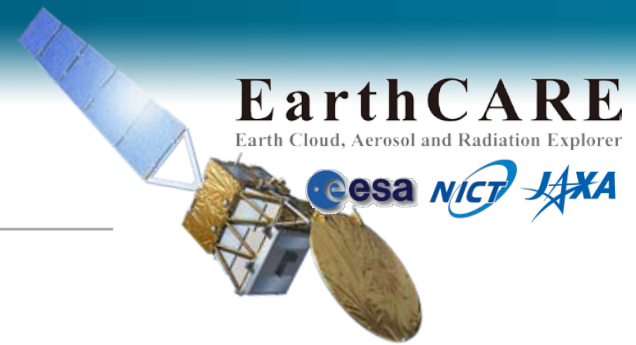
- CPR** Cloud Profiling Radar
- ATLID** Atmospheric Lidar
- MSI** Multi-Spectral Imager
- BBR** Broadband Radiometer



Synergetic Observation by 4 sensors

Institutions	European Space Agency (ESA) / National Institute of Information and Communications Technology (NICT) / Japan Aerospace Exploration Agency (JAXA)
Launch	2016 using Soyuz or Zenit (by ESA)
Mission Duration	3-years
Mass	Approx. 2200kg
Orbit	Sun-synchronous sub-recurrent orbit Altitude: approx. 400km Mean Local Solar Time (Descending): 14:00
Repeat Cycle	25 days
Orbit Period	5552.7 seconds
Semi Major Axis	6771.28 km
Eccentricity	0.001283
Inclination	97.050°

Science Needs vs EarthCARE



Radiative flux profile in cloudy condition within 10W/m² accuracy

Needs

Observation Needs/Target

Vertical profiles of extinction and characteristics of aerosols

Vertical profiles of liquid, supercooled and ice water, cloud overlap, particle size and extinction

Convective updraft and ice fall speed

Horizontal structure of clouds and aerosols

Shortwave and longwave fluxes at Top of Atmosphere

Active

High Spectral Resolution LIDAR (HSRL)

Active

Millimeter-wave RADAR

Active

Doppler RADAR

Passive

Multispectral Imager

Passive

Broadband Radiometer

Techniques

Remote Sensing Techniques

EarthCARE Instruments

ATLID

Atmospheric Lidar

CPR

Cloud Profiling Radar

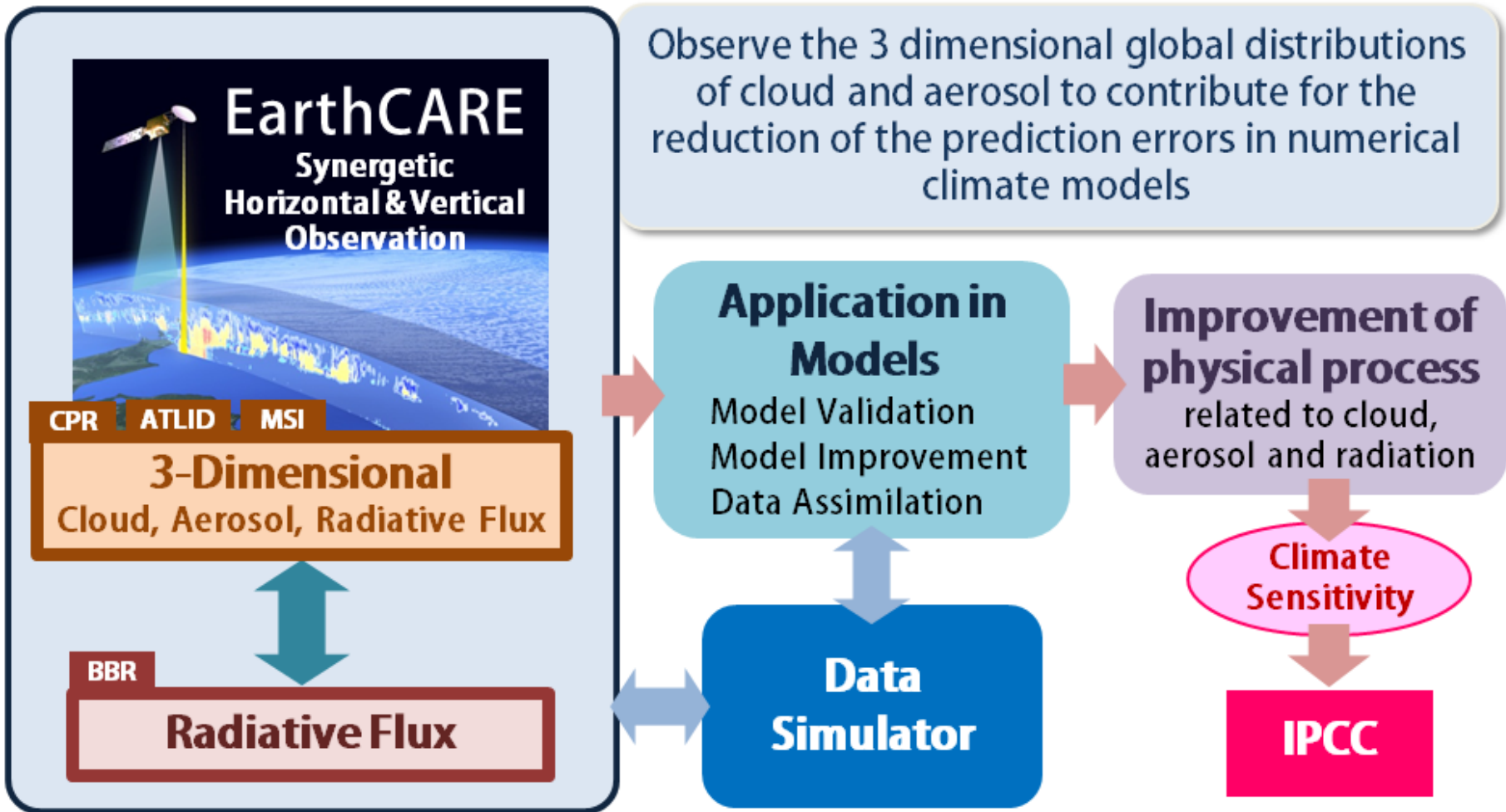
MSI

Multispectral Imager

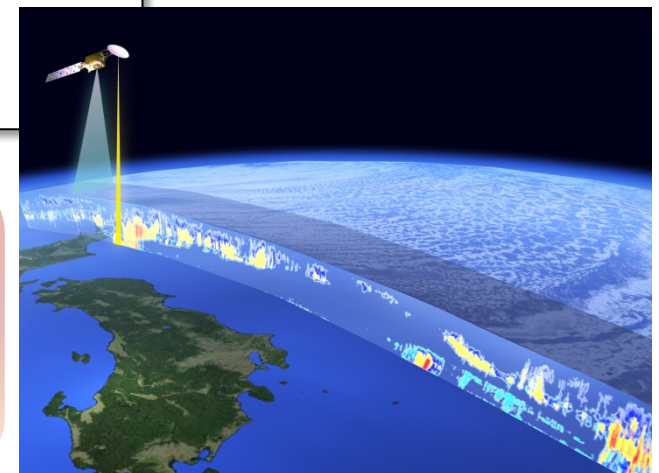
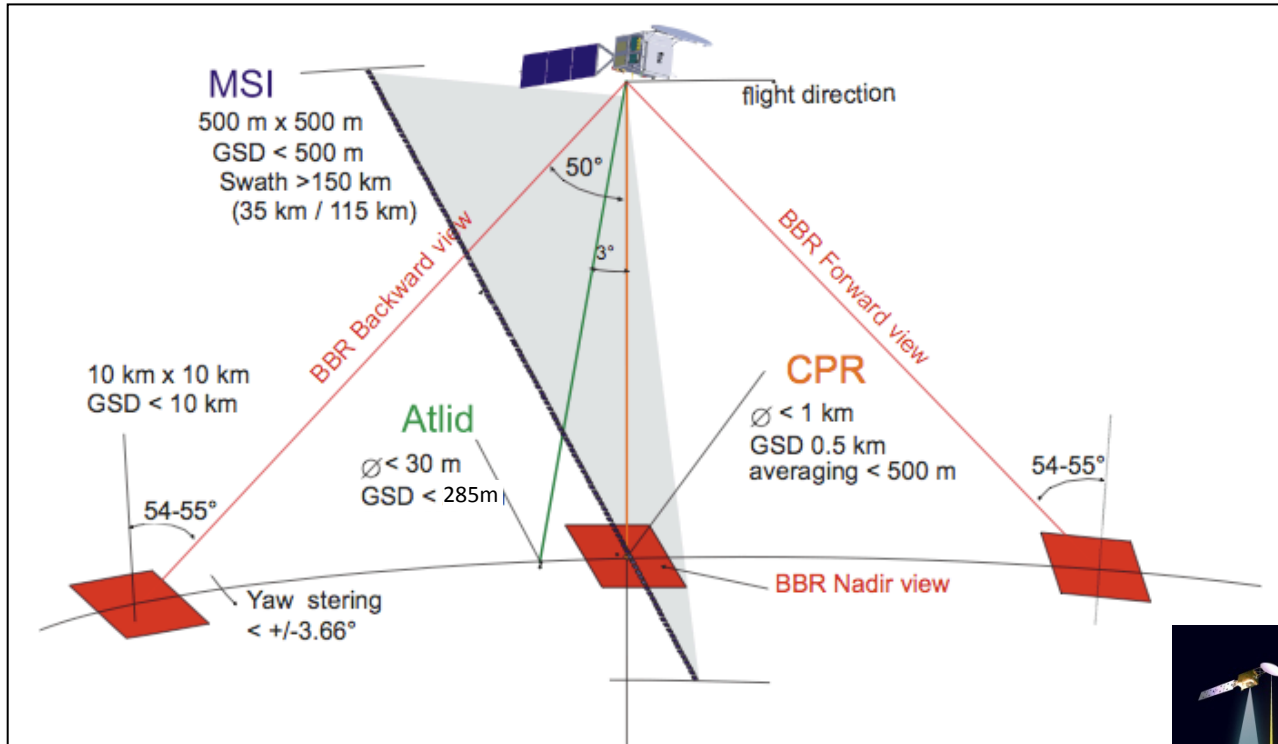
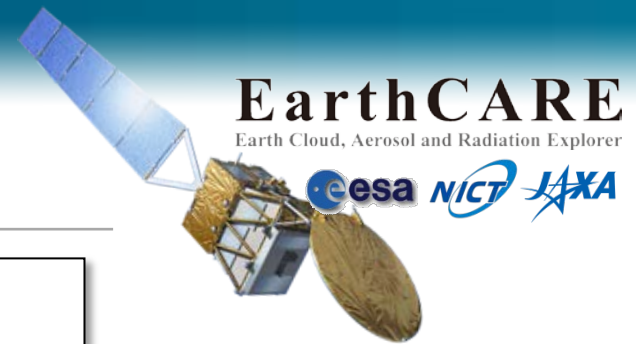
BBR

Broadband Radiometer

Goal of EarthCARE Science

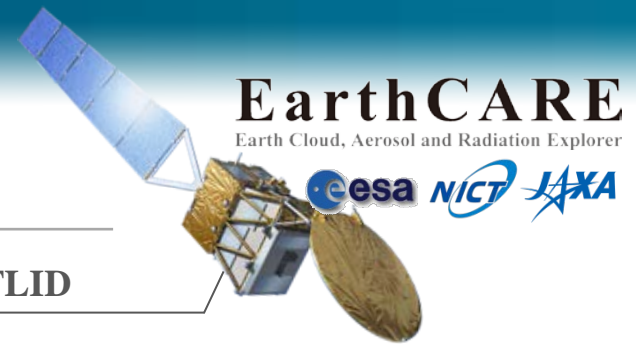


Strategy



Synergetic Observation by 4 Sensors on Global Scale

- 3-dimensional structure of aerosol and cloud including vertical motion
- Radiation flux at top of atmosphere
- Aerosol – cloud – radiation interactions



ATLID

ATLID Atmospheric Lidar

Instrument	355nm High Spectral Resolution Lidar (HSRL)
Channel	<ul style="list-style-type: none"> - Rayleigh Channel - Mie Channel (Cross-polarization) - Mie Channel (Co-polarization)
Sampling	Horizontal : 285m / Vertical : 100m
Observation Direction	3° Off Nadir (TBD)

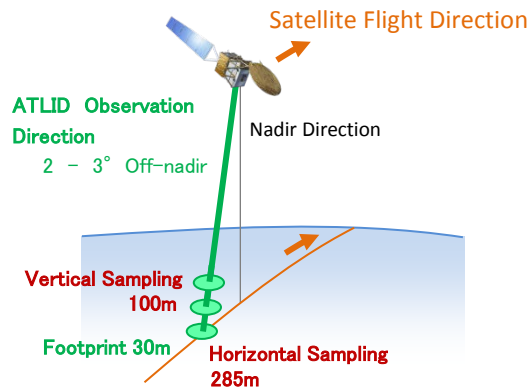
Global Observation of Cloud and Aerosol Vertical Profile and Optical Properties

ATLID is a High Spectral Resolution Lidar (HSRL) developed by European Space Agency.

Different from the traditional Mie lidar, it has the capability to separate Rayleigh scattering signal (originate from atmospheric molecules) and Mie scattering signal (originate from aerosol and cloud) by high spectral resolution filter. Thus, it has the potential to independently retrieve **backscattering coefficient** and **extinction coefficient** of atmospheric particles.

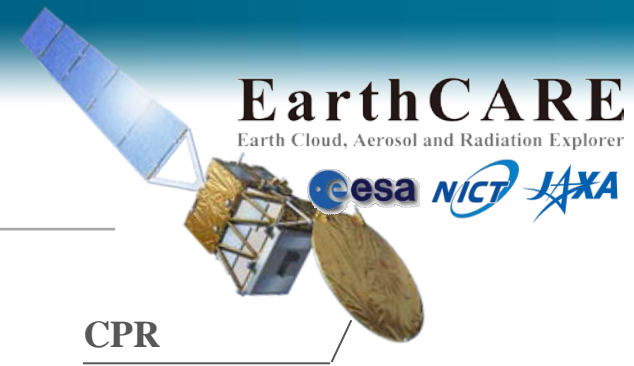
Derived Parameters

Backscattering Coefficient
Target Mask
Feature Mask
Extinction Coefficient
Depolarization Ratio
Lidar Ratio



Observation of Fine Particles within the Atmosphere

By 355nm (UV) wavelength, ATLID has the capability to **detect fine particles, such as thin cloud and aerosol, that were difficult to be observed by radars**. In addition, it also has the capability to achieve information of **particle shapes** by polarization observation.



CPR

Cloud Profiling Radar

Instrument	94 GHz (W-band) Doppler Radar
Center Frequency	94.05 GHz
Sampling	Horizontal : 500 m Vertical : 500m (Oversampling 100m)
Footprint	800m (Horizontal)
Pulse Repetition Frequency	6100 ~ 7500 Hz (Variable PRF)
Observation Height Range	Surface to 20km (low latitude), 16km, 12km (high latitude)

The World's First Satellite-borne Doppler Cloud Radar

CPR is a **94 GHz (W-band) Doppler Radar** jointly developed by Japan Aerospace Exploration Agency (JAXA) and National Institute of Information and Communications Technology (NICT).

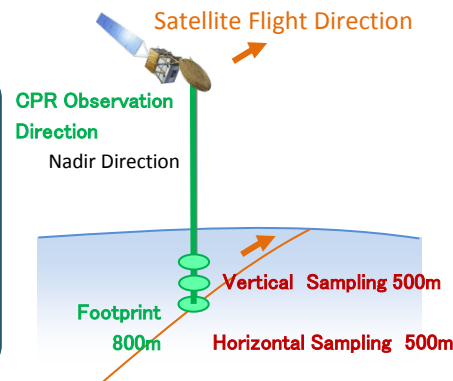
From its millimeter radar signal, it has the capability to observe **3-dimensional distribution** and **physical characteristics** of **cloud** and **drizzle**.

In addition, information on the **in-cloud vertical motion** by **Doppler measurement function** has the potential to contribute to the understanding of cloud and precipitation process.

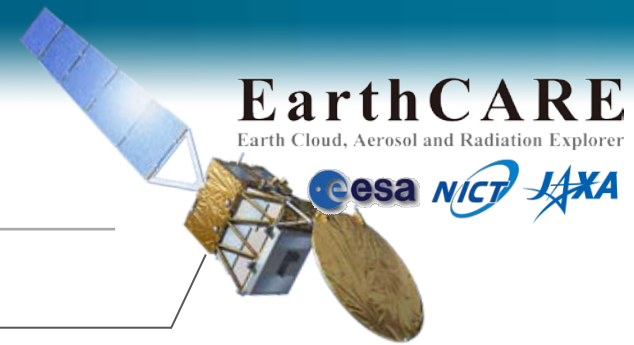
EarthCARE CPR has approximately **6 times higher sensitivity** compared to CloudSat CPR onboard in the A-Train Constellation.

Derived Parameters

- | | |
|---------------------|-------------------------|
| Radar Reflectivity | Liquid Water Content |
| Doppler Velocity | Ice Water Content |
| Cloud Mask | Liquid Effective Radius |
| Cloud Particle Type | Ice Effective Radius |
| | Optical Thickness |



Sensors

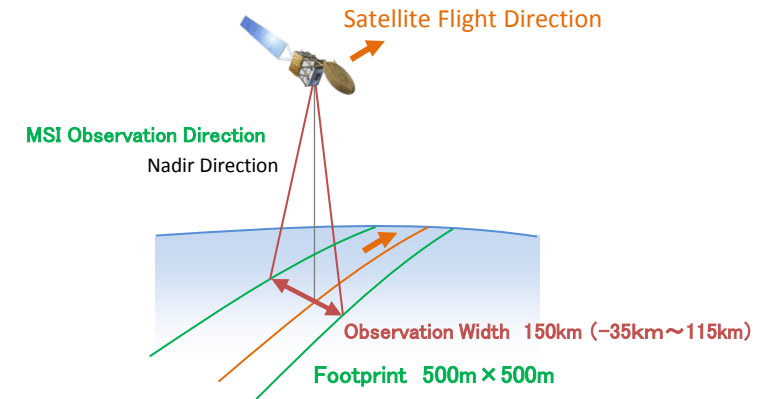


MSI

Multi-Spectral Imager

Instrument	Pushbroom Imager
Wavelength Band (Visible / Near-Infrared / Shortwave Infrared)	0.670 μm , 0.865 μm , 1.65 μm , and 2.21 μm
Wavelength Band (Thermal Infrared)	8.80 μm , 10.80 μm , and 12.00 μm
Observation Width	150 km (-35 km to +115 km)*
Footprint	500 m x 500 m

*This asymmetry is intended to reduce the influence of sunglint



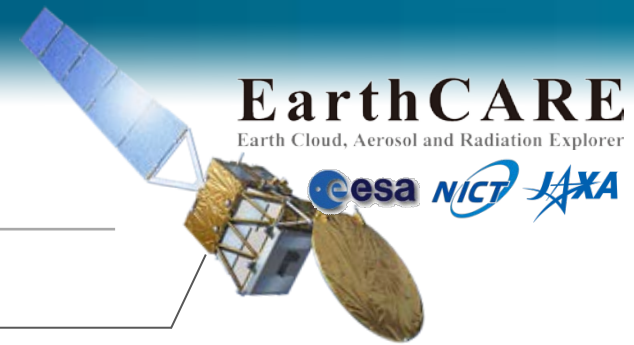
Measurement of Cloud by Multiband

MSI is an optical sensor with 7 channels from visible to thermal infrared, which measures the **cloud distribution** and cloud physical properties including **cloud effective radius** and **optical thickness**.

Derived Parameters

- Cloud Flag / Cloud Phase
- Liquid Optical Thickness
- Liquid Effective Radius (1.6 μm)
- Liquid Effective Radius (2.2 μm)
- Cloud Top Height
- Cloud Top Pressure
- Cloud Top Temperature

Sensors



BBR

Broadband Radiometer

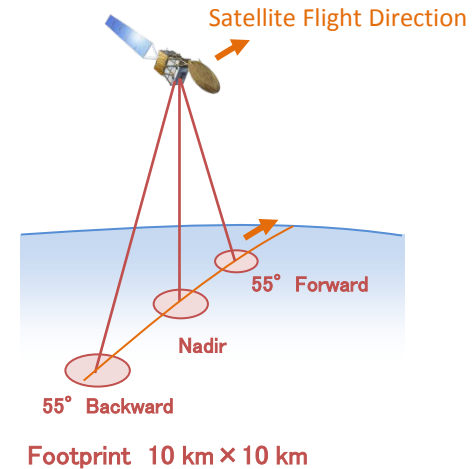
Wavelength Range	- Short wave : 0.2 – 4.0 μm - Long wave : 4.0 – 50 μm^*
Dynamic Range	- Short wave: 0 – 450 $\text{W}/\text{m}^2/\text{str}$ - Long wave: 0 – 130 $\text{W}/\text{m}^2/\text{str}$
Observation Direction	nadir, forward (55 deg), backward (-55 deg)
Footprint	10 km x 10 km

*The spectral radiance in Long-wave channel is calculated from Short-wave and Total-wave (0.2- 50 μm) observations. (based on MRD)

Measurement of Radiation Flux at Top of Atmosphere

BBR has the sensitivity to shortwave and totalwave broadband radiances from which **shortwave and longwave radiation flux** at the top of atmosphere can be retrieved.

BBR



Derived Parameters

Radiation (Longwave / Shortwave)
Radiation Flux(Longwave / Shortwave)

EarthCARE Products



ATLID Level 1

Attenuated backscatter in Rayleigh channel, co-polar Mie channel, cross-polar Mie channel

ATLID Level 2

Feature mask, target mask, extinction, backscatter and depolarization profiles, cloud properties, aerosol properties

CPR Level 1

Radar reflectivity profile, Doppler velocity profile

CPR Level 2

Radar reflectivity, Doppler velocity, feature mask, cloud type, liquid and ice cloud properties, vertical motion, rain and snow estimates

MSI Level 1

TOA radiances for 4 solar channels, TOA brightness temperatures for 3 thermal channels

MSI Level 2

Feature mask, liquid and ice cloud properties, cloud top height, aerosol properties

BBR Level 1

Filtered TOA long-wave and total-wave radiances

BBR Level 2

Unfiltered TOA short-wave and long-wave radiances, TOA short-wave and long-wave fluxes

2 or 3 Sensors Synergetic Level 2

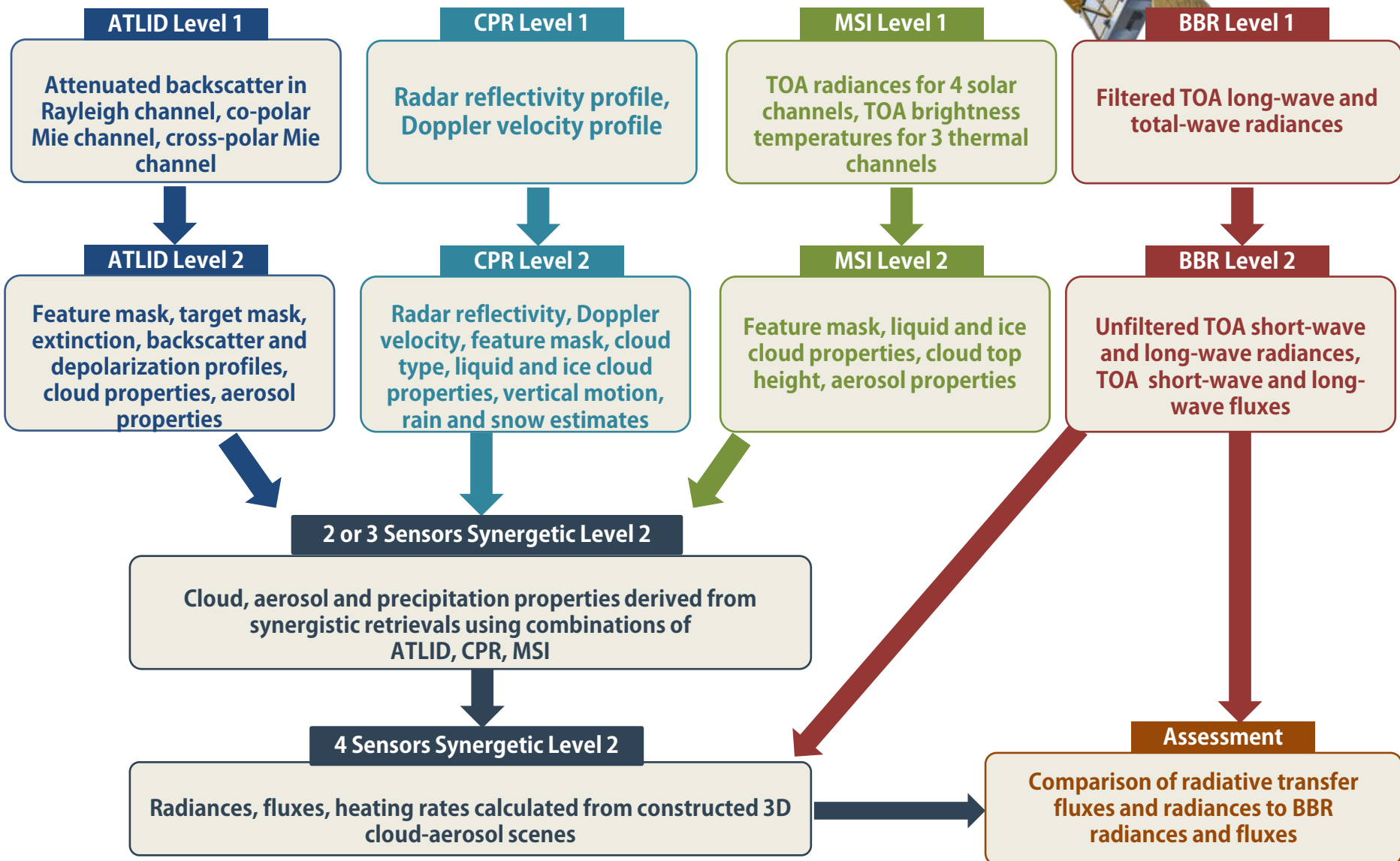
Cloud, aerosol and precipitation properties derived from synergistic retrievals using combinations of ATLID, CPR, MSI

4 Sensors Synergetic Level 2

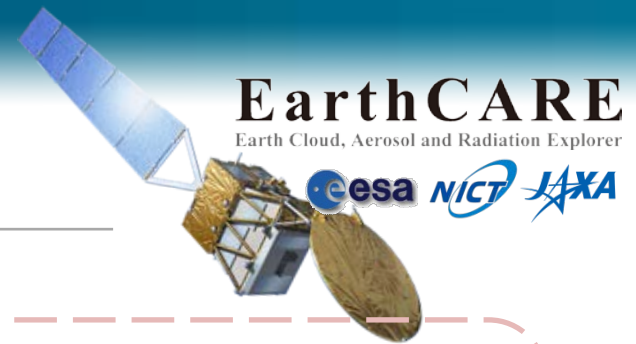
Radiances, fluxes, heating rates calculated from constructed 3D cloud-aerosol scenes

Assessment

Comparison of radiative transfer fluxes and radiances to BBR radiances and fluxes



JAXA EarthCARE Products



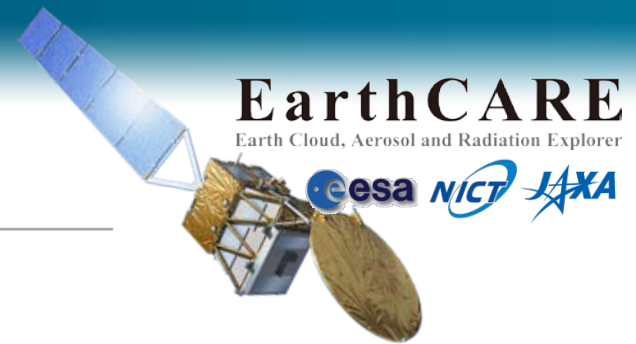
Standard Product

- strongly promoted to be developed and released
- processed and released from JAXA/MOS (Mission Operation System)
- all data will be able to be sent to ESA when produced

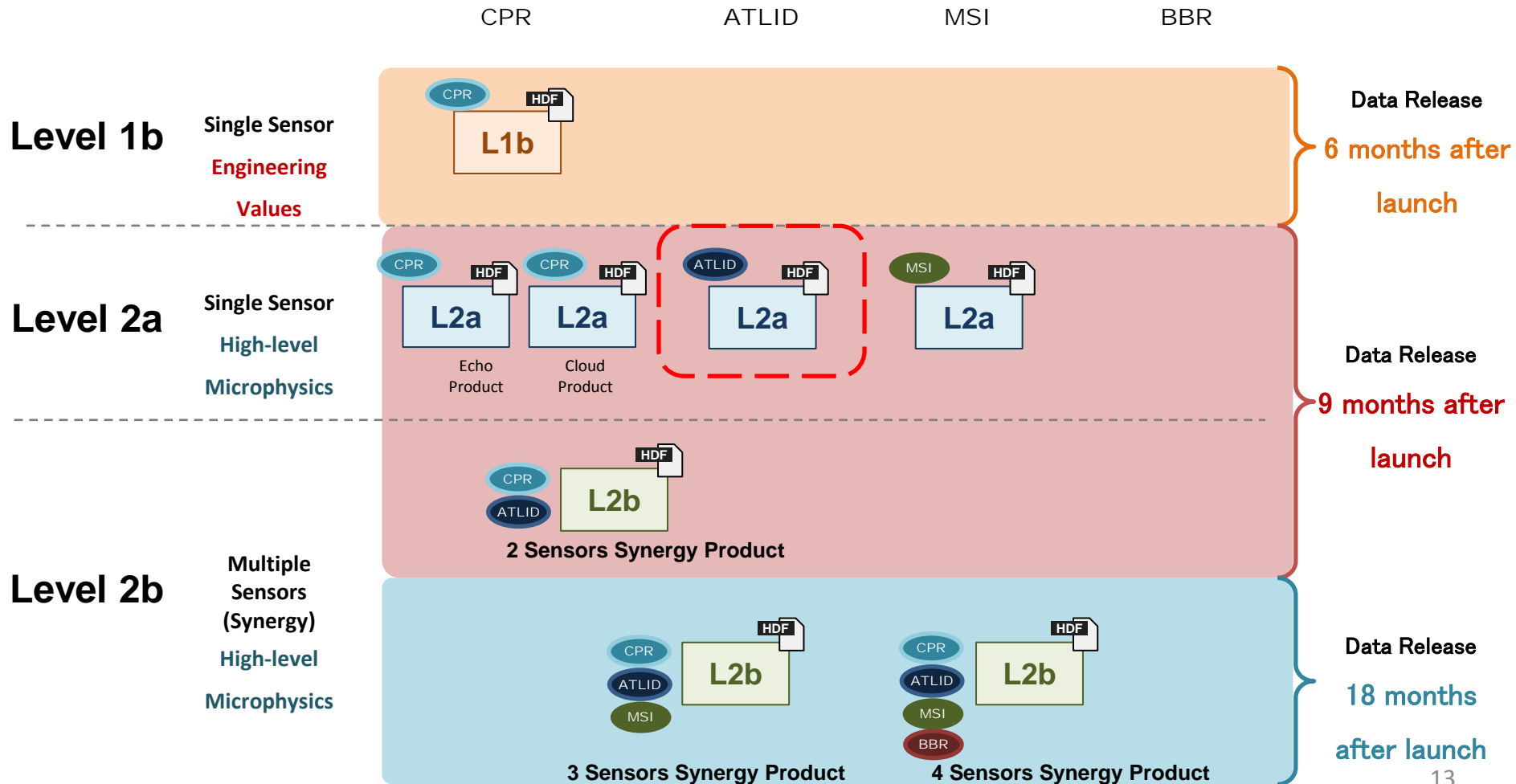
Research Product

- promoted to be developed and released
- some are planned to be upgraded to standard products
- further divided into two groups;
 - EORC Research Products (ER)
 - processed and released from JAXA/EORC
 - Laboratory Research Products (LR)
 - from cooperating Japanese Laboratories

Product Release Timing



JAXA Standard Product and its Release Timing



EarthCARE Products

JAXA & ESA Product (L1b/c:Stand-alone)



Sensor(s)	Processing Level	Product Name (Product ID for ESA)	Primary Parameter	Grid Spacing		File Unit File Format	Data Volume per day*
				Horizontal	Vertical		
CPR	L1b	CPR One-Sensor Received Power and Doppler Product	Received Echo Power / Radar Reflectivity Factor / Doppler Velocity / Pulse Pair Covariance / Spectrum Width	0.5 km	0.1 km	1/8 orbit HDF	51.3GB
			Surface Radar Cross Section	0.5 km	-		
ATLID	L1b	A-NOM	Rayleigh and Mie Backscattering coefficient * Mie component has horizontal and vertical depolarization component	0.285 km	0.103 km	1/8 orbit netCDF	91.6GB
MSI	L1b	M-NOM	Radiation Intensity * Visible(0.67μm), Near IR(0.865μm), SW IR(1.65μm, 2.21μm), LW IR(8.80μm, 10.80μm, 12.00μm)	0.5 km	-	1/8 orbit netCDF	83.9GB
BBR	L1b	B-NOM	SW and LW Radiation (Forward, Nadir, Backward)	10 km	-	1/8 orbit netCDF	2.3GB
Sensor(s)	Processing Level	Product Name (Product ID for ESA)	Primary Parameter	Grid Spacing		File Unit File Format	Data Volume per day*
				Horizontal	Vertical		
MSI	L1c	M-NOM	L1b Radiation Intensity (interpolated to the location of a reference band)	0.5 km	-	1/8 orbit netCDF	18.3GB

* 125 files per day is assumed without compression. ATLID, MSI, BBR is ESA product.

JAXA Standard Products (L2a:Stand-alone)



Sensor(s)	Processing Level	Product Name	Primary Parameter (Red: Spatial-integrated values will be also generated)	Grid Spacing		File Unit File Format	Data Volume per day*
				Horizontal	Vertical		
CPR	L2a	CPR One-sensor Echo Products	Integrated Radar Reflectivity Factor Integrated Doppler Velocity Gas Correction Factor	1 km	0.1 km	1/8 orbit HDF	116.0GB
CPR	L2a	CPR One-sensor Cloud Products	Cloud Mask / Cloud Particle Type / Liquid Water Content / Ice Water Content / Effective Radius of Liquid Water Cloud / Effective Radius of Ice Water Cloud	1 km	0.1 km	1/8 orbit HDF	131.8GB
			Optical Thickness	1 km	-		
ATLID	L2a	ATLID One-sensor Cloud and Aerosol Products	Feature Mask	0.2 km	0.1 km	1/8 orbit HDF	70.8GB
			Target Mask	1 km	0.1 km		
			Aerosol Extinction Coeff. / Aerosol Backscat. Coeff. / Aerosol Lidar Ratio / Aerosol Depolarization Ratio	10km	0.1 km		
			Cloud Extinction Coeff. / Cloud Backscat. Coeff. / Cloud Backscat. Coeff. / Cloud Depolarization Ratio	1 km	0.1 km		
			Cloud Depolarization Ratio	1 km	0.1 km		
MSI	L2a	MSI One-sensor Cloud Products	Cloud Flag including Cloud Phase / Optical Thickness of Liquid Water Cloud / Effective Radius of Liquid (1.6 μ m) / Effective Radius of Liquid (2.2 μ m) / Cloud Top Temperature / Cloud Top Pressure / Cloud Top Height	0.5 km	-	1/8 orbit HDF	163.6GB

* 125 files per day is assumed without compression.

JAXA Standard Products (L2a:Synergy)



Sensor(s)	Processing Level	Product Name	Primary Parameter (<i>Red</i> : Spatial-integrated values will be also generated)	Grid Spacing		File Unit File Format	Data Volume per day*
				Horizontal	Vertical		
CPR + ATLID	L2b	CPR-ATLID Synergy Cloud Products	Cloud Mask / Cloud Particle Type / Radar Reflective Factor with Attenuation / Liquid Water Content / Ice Water Content / Effective Radius of Liquid Water Cloud / Effective Radius of Ice Water Cloud	1 km	0.1 km	1/8 orbit HDF	136.7GB
			Optical Thickness	1 km	-		
CPR + ATLID + MSI	L2b	CPR-ATLID-MSI Synergy Cloud Products	Cloud Mask / Cloud Particle Type / Radar Reflective Factor with Attenuation / Liquid Water Content / Ice Water Content / Effective Radius of Liquid Water Cloud / Effective Radius of Ice Water Cloud	1 km	0.1 km	1/8 orbit HDF	136.7GB
			Optical Thickness / Liquid Water Path / Ice Water Path	1 km	-		
4 sensors	L2b	Four Sensors Synergy Radiation Budget Products	SW Radiative Flux / LW Radiative Flux	10 km	-	1/8 orbit HDF	7.3GB
			SW Radiative Heating Rate / LW Radiative Heating Rate	10 km	0.5 km		

* 125 files per day is assumed without compression.

JAXA Research Products (L2a:Stand-alone)

Sensor(s)	Processing Level	Status	Product Name	Primary Parameter (Red: Spatial-integrated values will be also generated)	Grid Spacing		File Unit File Format
					Horizontal	Vertical	
CPR	L2a	Red R	CPR One-sensor Doppler Products	Doppler velocity correction value (considering inhomogeneity) / Doppler velocity unfolding Value / Radar Reflective Factor with Attenuation	1 km	0.1 km	1/8 orbit HDF
		ER	CPR One-sensor Rain and Snow Products	Rain Water Content / Snow Water Content / Rain Rate / Snow Rate	1 km	0.1 km	1/8 orbit HDF
		ER	CPR One-sensor Vertical Velocity Products	Vertical Air Motion / Sedimentation Velocity	1 km	0.1 km	1/8 orbit HDF
ATLID	L2a	ER	ATLID One-sensor Aerosol Extinction Products	Aerosol Extinction Coefficient (Water Soluble) / Aerosol Extinction Coefficient (Dust) / Aerosol Extinction Coefficient (Sea Salt) / Aerosol Extinction Coefficient (Black Carbon)	1 km	0.1 km	1/8 orbit HDF
MSI	L2a	ER	MSI One-sensor Ice Cloud Products	Optical Thickness of Ice Cloud with Reflection method / Effective Radius of Ice Cloud (1.6 μ m) / Effective Radius of Ice Cloud (2.2 μ m) / Ice Cloud Top Temperature / Ice Cloud Top Pressure / Ice Cloud Top Height	0.5 km	-	1/8 orbit HDF
		ER	MSI One-sensor Aerosol Products	Aerosol Optical Thickness (Ocean) / Aerosol Optical Thickness(Land) / Angstrom Exponent (Ocean)	0.5 km	-	1/8 orbit HDF

JAXA Research Products (L2a:Synergy)

EarthCARE

Earth Cloud, Aerosol and Radiation Explorer



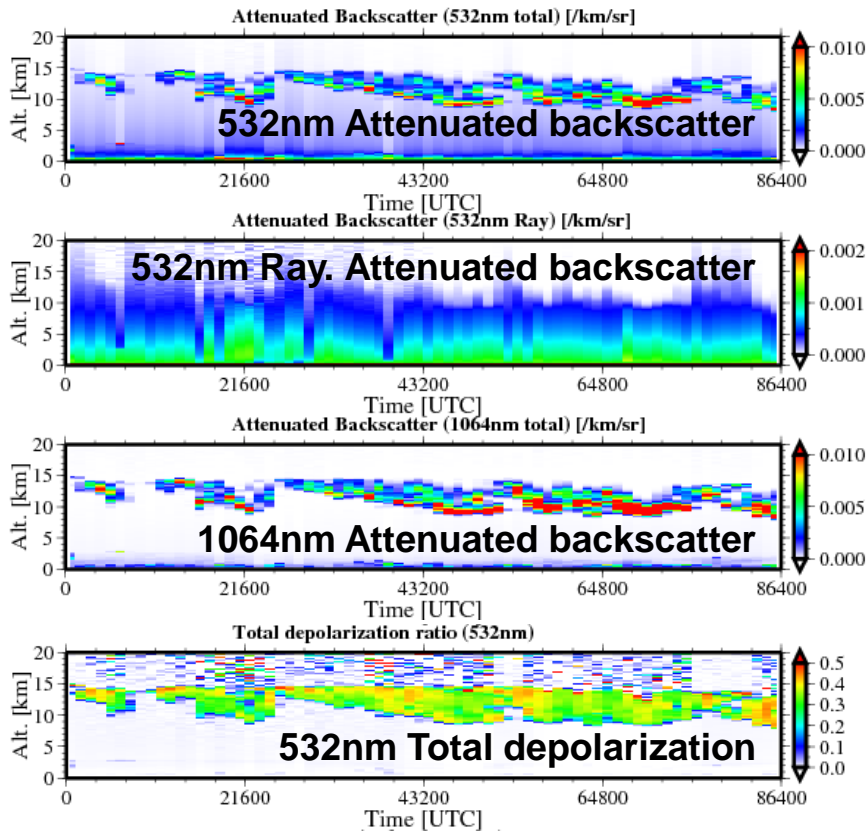
Sensor(s)	Processing Level	Status	Product Name	Primary Parameter (Red: Spatial-integrated values will be also generated)	Grid Spacing		File Unit File Format
					Horizontal	Vertical	
CPR + ATLID	L2a	Red R	CPR-ATLID Synergy Particle Mass Ratio Products	Mass Ratio (2D_Ice/IWC)	1 km	-	1/8 orbit HDF
		ER	CPR-ATLID Synergy Rain & Snow Products	Rain Water Content / Snow Water Content / Rain Rate / Snow Rate	1 km	0.1 km	1/8 orbit HDF
		ER	CPR-ATLID Synergy Vertical Velocity Products	Vertical Air Motion / Sedimentation Velocity	1 km	0.1 km	1/8 orbit HDF
ATLID + MSI	L2a	ER	ATLID-MSI synergy Aerosol Components Products	Aerosol Extinction Coefficient (Water Soluble) / Aerosol Extinction Coefficient (Dust) / Aerosol Extinction Coefficient (Sea Salt) / Aerosol Extinction Coefficient (Black Carbon) / Mode Radius	10 km	0.1 km	1/8 orbit HDF
CPR + ATLID + MSI	L2a	LR	CPR-ATLID-MSI Synergy Cloud Doppler Products	Cloud Mask / Cloud Particle Type / Liquid Water Content / Ice Water Content / Effective Radius of Liquid Water Cloud / Effective Radius of Ice Water Cloud (with Doppler)	1 km	0.1 km	1/8 orbit HDF
				Optical Thickness / Liquid Water Path / Ice Water Path (with Doppler)	1 km	-	1/8 orbit HDF
		LR	CPR-ATLID-MSI Synergy Rain and Snow Products	Rain Water Content / Snow Water Content / Rain Rate / Snow Rate	1 km	0.1 km	1/8 orbit HDF
		LR	CPR-ATLID-MSI Synergy Vertical Velocity Products	Vertical Air Motion / Sedimentation Velocity	1 km	0.1 km	1/8 orbit HDF
		LR	CPR-ATLID-MSI Synergy Emission Method Products	Effective Radius of Ice Cloud derived from Emission Method / Optical Thickness of Ice Cloud derived from Emission	0.5 km	-	1/8 orbit HDF

“Red R” = Research product, would be processed in Japanese Research and Application System, and to be upgraded to standard after one year or later when the release accuracy is approved.
 “ER” = Research product, would be processed in Japanese Research and Application System. LR = Research product, would be processed in Japanese Laboratories

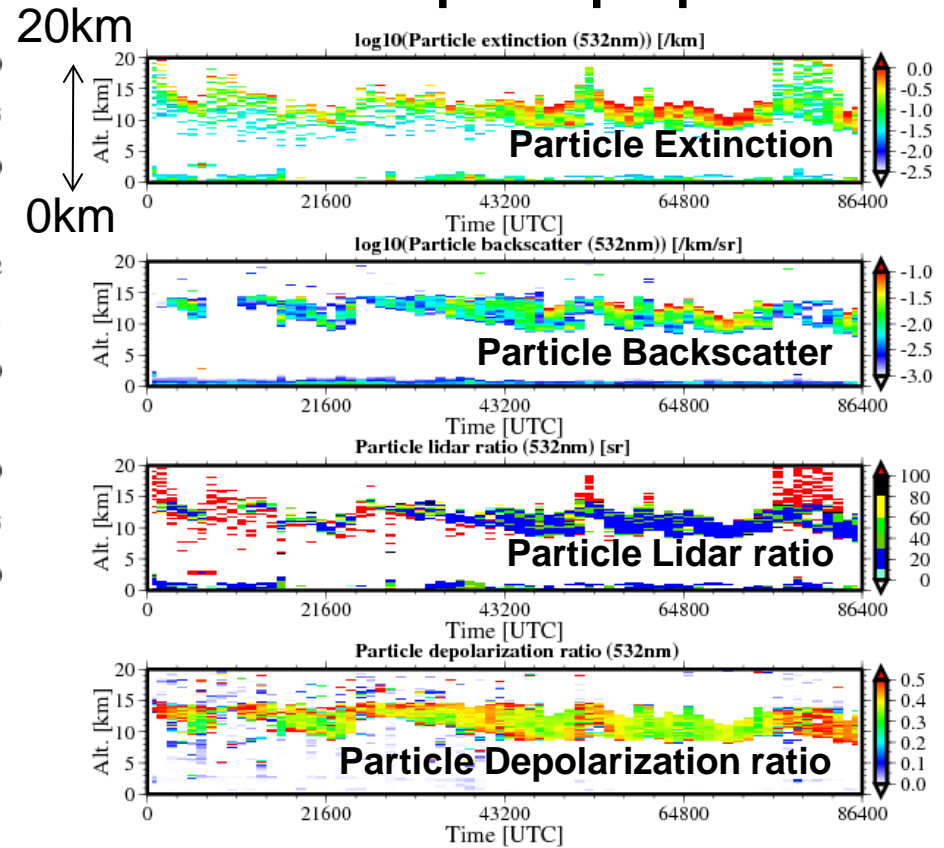
An example of expected Lidar Products

→ detailed information by Dr. Sugimoto (NIES) tomorrow

Measured signals



Derived optical properties



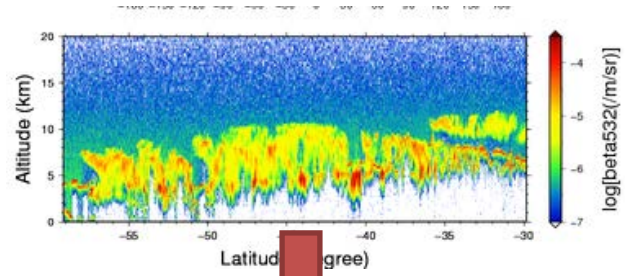
$\Delta Z = 90 \text{ m}$
 $\Delta T = 20 \text{ min}$

[Indian ocean (8S,80E), 1 Nov. 2011, Shipborn HSRL]

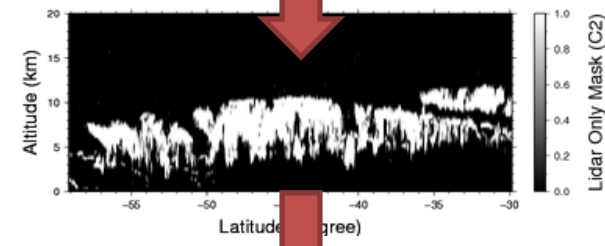


An example of expected Lidar and Radar Products

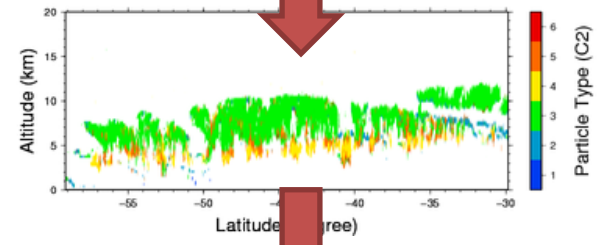
Observed data



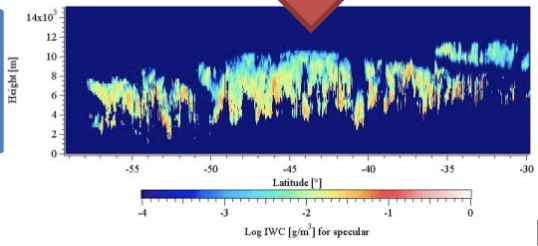
Cloud mask



Cloud Particle Type



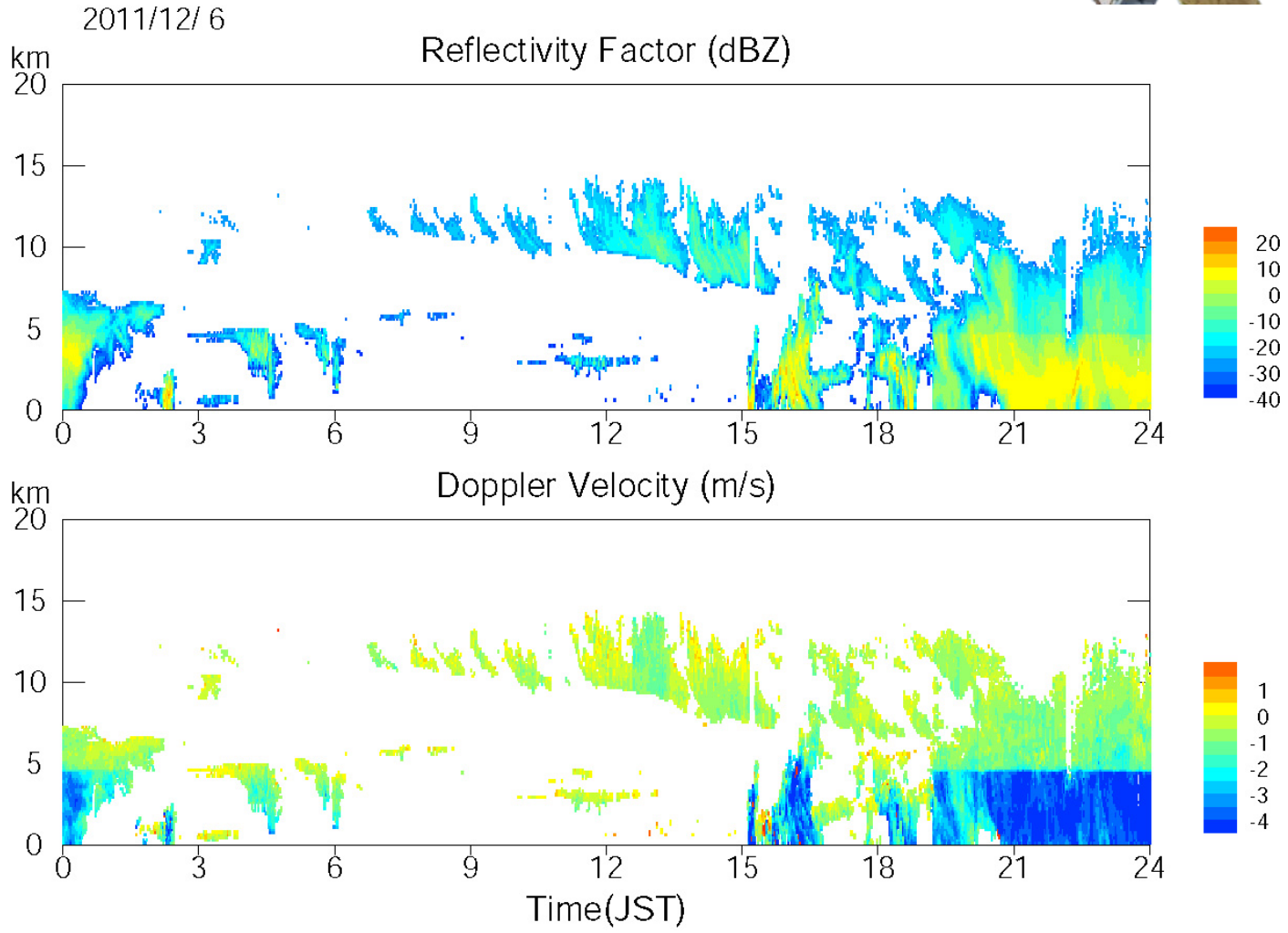
Cloud Microphysics (LWC, reff, etc)



EarthCARE JAXA Product List

Sensor(s)	Processing Level	Primary Parameters
CPR	L2a	Cloud Mask
		Cloud Particle Type
		Radar Reflective Factor with Attenuation Correction
		Liquid Water Content
		Ice Water Content
		Effective Radius of Liquid
		Effective Radius of Ice Optical Thickness

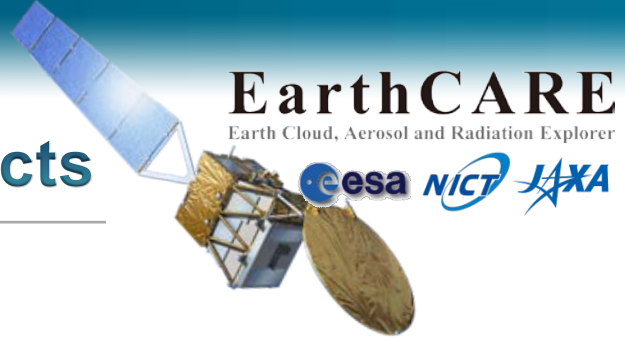
Doppler Observation



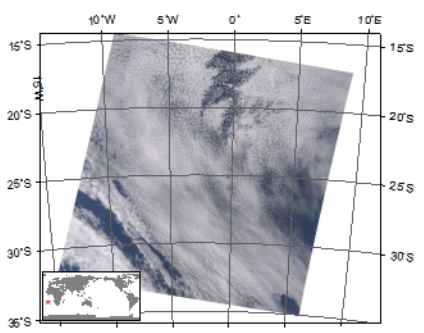
Cloud Vertical Profile Observed by ground-based Doppler Radar(NICT/SPIDER)

The figure provided by Mr. Ohno(NICT)

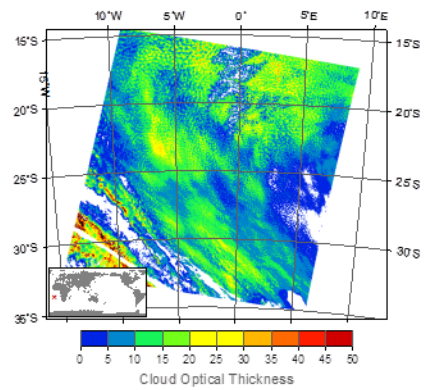
An example of expected Imager Products



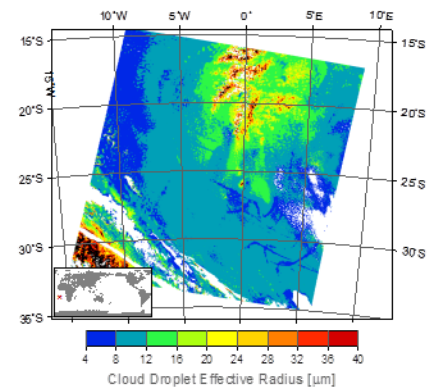
Visible Composite



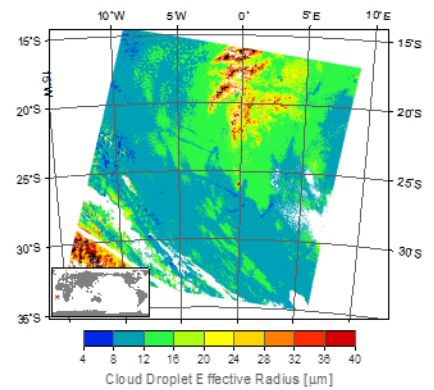
Cloud Optical Thickness



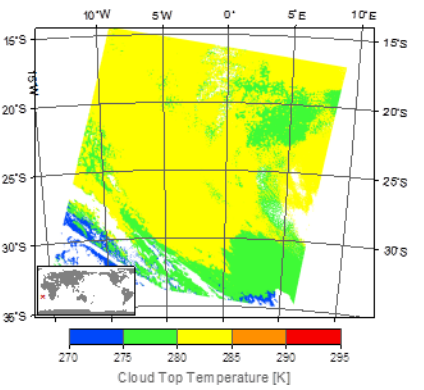
Cloud Droplet Effective Radius (R16)



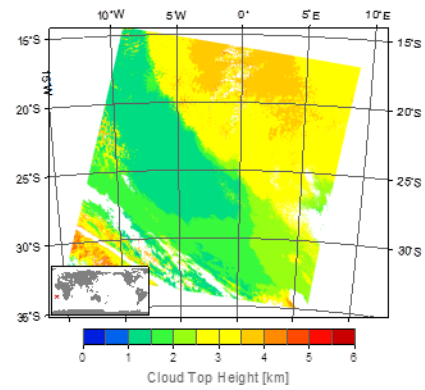
Cloud Droplet Effective Radius (R21)



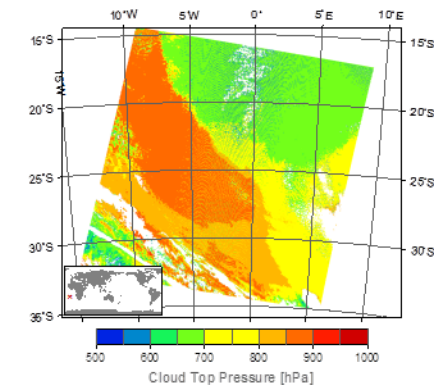
Cloud Top Temperature



Cloud Top Height



Cloud Top Pressure

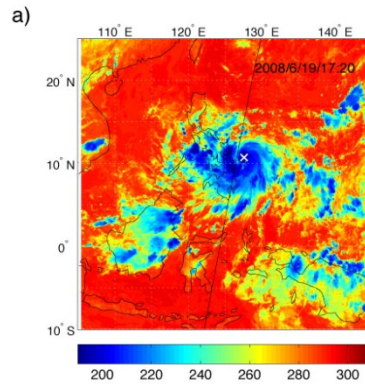


CPR & Lidar Examples by Joint-Simulator

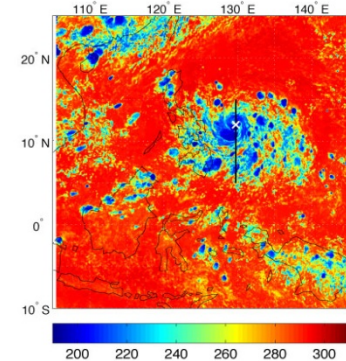


Infrared (10.8 mm) T_b

Observation

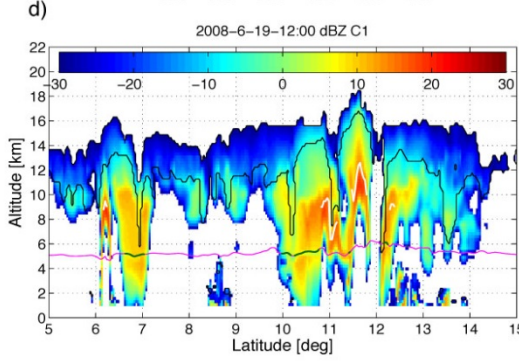
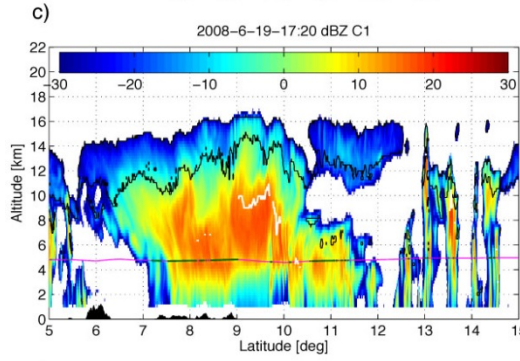


Simulation
(NICAM & Joint-Simulator)

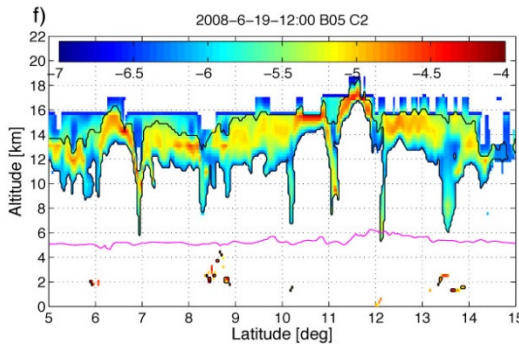
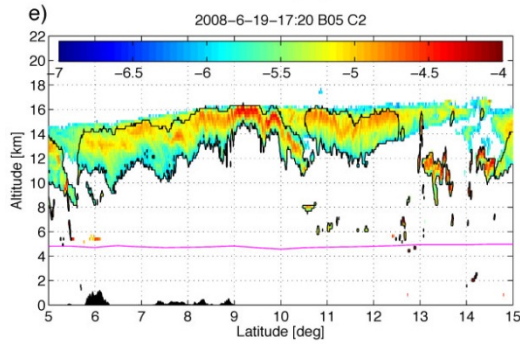


(This analysis uses NICAM data. It also can be used for WRF and JMA-NHM)

95 GHz radar reflectivity
(CloudSat/CPR)

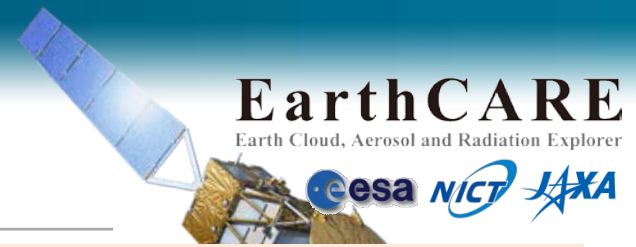


532 nm backscattering
coefficient
(CALIPSO)



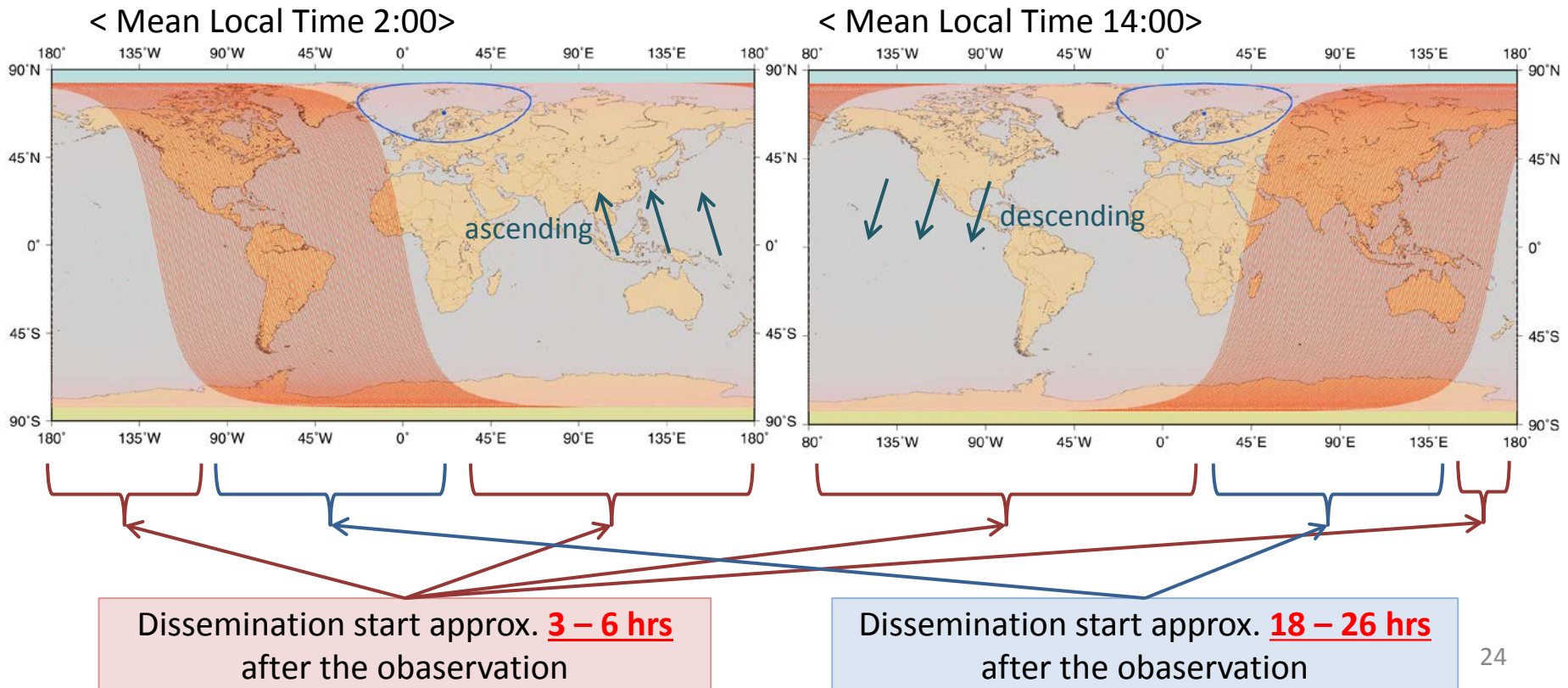
(Hashino et al. 2013)

Data Latency



60-65% of the data products are able to be disseminated a few hours after the observation where the EarthCARE satellite passes over relatively close to the ground station.

However, 35-40% of the data product dissemination will delay to some extent where the satellite is on the blind orbit and the station cannot downlink the data.



EarthCARE Data Dissemination Timing

JAXA(Standard) & ESA Products (L1b/c: Stand-alone)

EarthCARE

Earth Cloud, Aerosol and Radiation Explorer



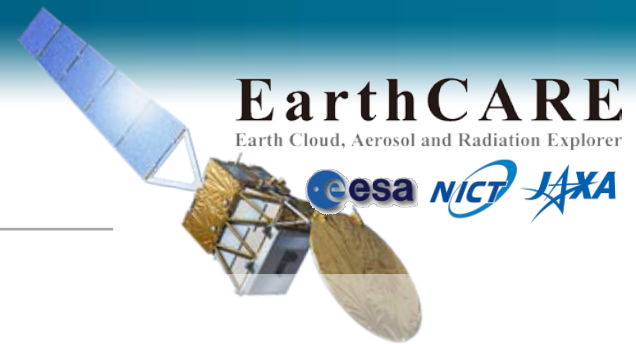
Sensor	Level	Product Name (Product Identifier for ESA)	Nominal (60–65%)	Worst (35–40%)
CPR	L1b	CPR One-Sensor Received Power and Doppler Product		
ATLID	L1b	A-NOM	3.1 hours	18 hours
MSI	L1b	M-NOM		
BBR	L1b	B-NOM		
MSI	L1c	M-NOM	3.6 hours	20 hours
CPR	L2a	CPR One-sensor Echo Product	5.4 hours	23 hours
CPR	L2a	CPR One-sensor Cloud Product		
ATLID	L2a	ATLID One-sensor Cloud Aerosol Product	4.4 hours	23 hours
MSI	L2a	MSI One-sensor Cloud Product		
CPR ATLID	L2b	CPR-ATLID Synergy Cloud Product	6.1 hours	26 hours
CPR ATLID MSI	L2b	CPR-ATLID-MSI Synergy Cloud Product		
4Sensors	L2b	4 Sensor Synergy Radiation Budget Product		

※ ATLID, BBR, MSI products are ESA product. Primary parameters are TBD.

※ Hours are time after observations

※ All information are TBD

Conclusion



Thank you for your attention

For further information, please visit http://www.eorc.jaxa.jp/EARTHCARE/ja/index_j.html
or send an e-mail to EC-EORC@jaxa.jp