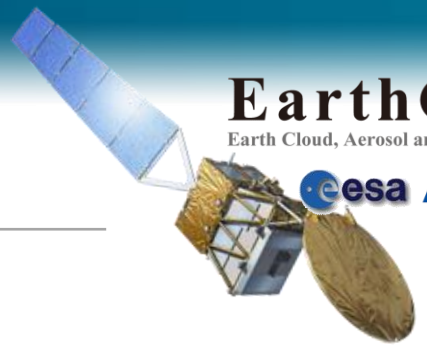


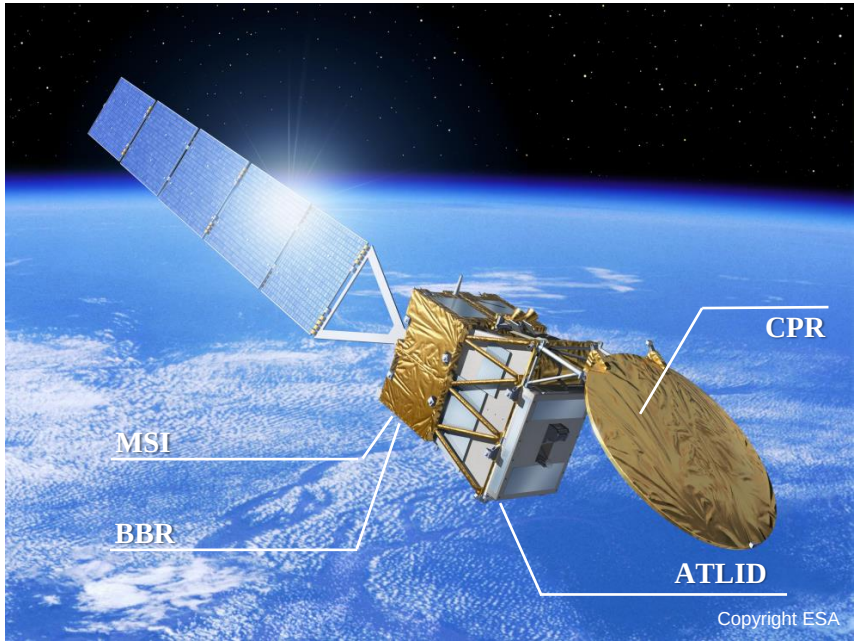
EarthCARE
Earth Cloud, Aerosol and Radiation Explorer

esa NICT JAXA

EarthCARE Overview

Takuji Kubota
Earth Observation Research Center (EORC)
Japan Aerospace Exploration Agency (JAXA)
February 2022

EarthCARE Satellite



Institutions	European Space Agency（ESA）／National Institute of Information and Communications Technology（NICT）／Japan Aerospace Exploration Agency（JAXA）
Launch	JFY2023
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°

EarthCARE
Earth Cloud, Aerosol and Radiation Explorer

EarthCARE

Earth Clouds, Aerosol and Radiation Explorer

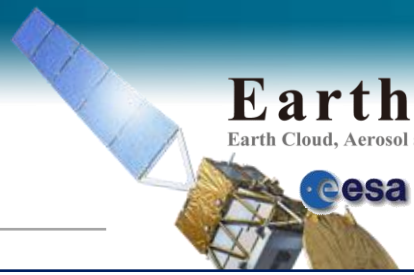
EarthCARE is an earth observation satellite that Japan and Europe have been jointly developing to observe clouds, aerosols and radiation (Illingworth et al. 2015, *BAMS*).

Observation Instruments on EarthCARE

- **CPR** — Cloud Profiling Radar (NICT, JAXA)
- **ATLID** — Atmospheric Lidar (esa)
- **MSI** — Multi-Spectral Imager (esa)
- **BBR** — Broadband Radiometer (esa)

Synergetic Observation by 4 sensors

Needs vs EarthCARE



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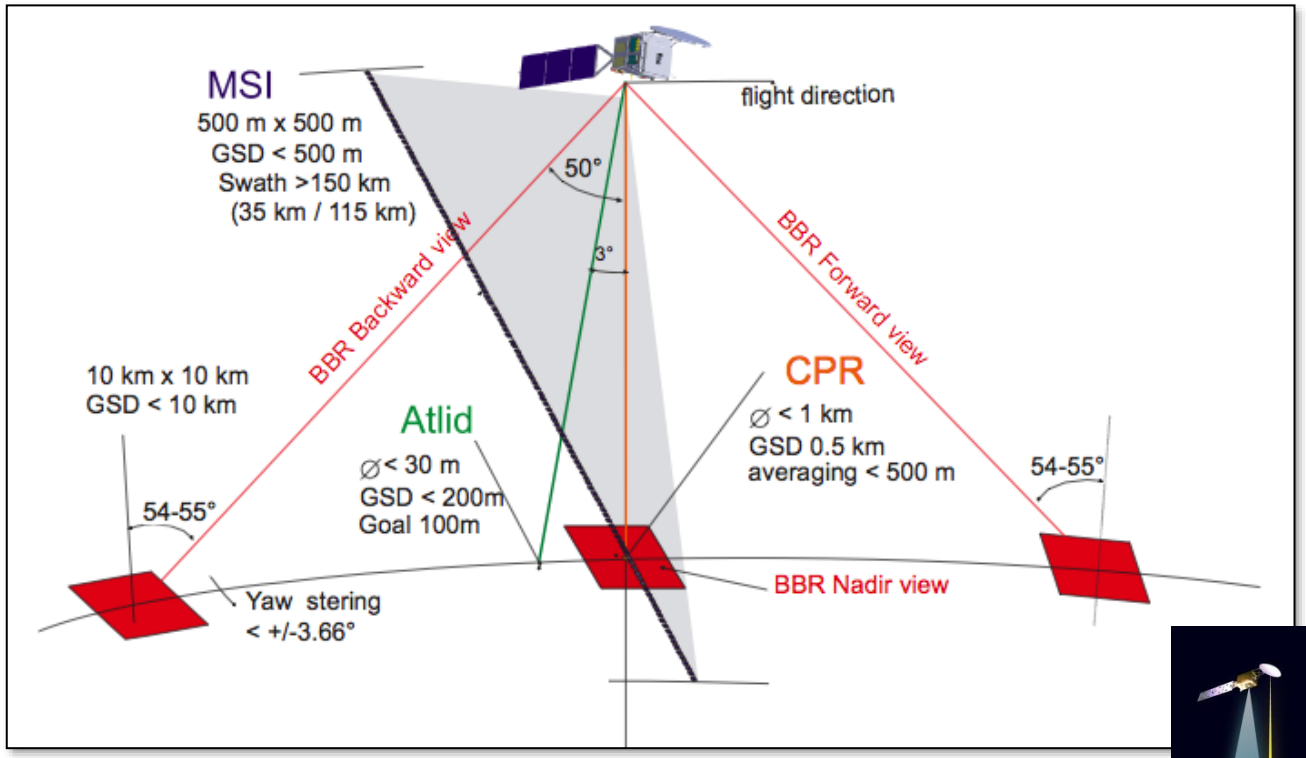
- Clouds and Aerosols continue to contribute the two largest sources of uncertainty in current climate predictions.
- The need for reliable information on the vertical structure of clouds and aerosol layers

Needs
Observation Needs/Target

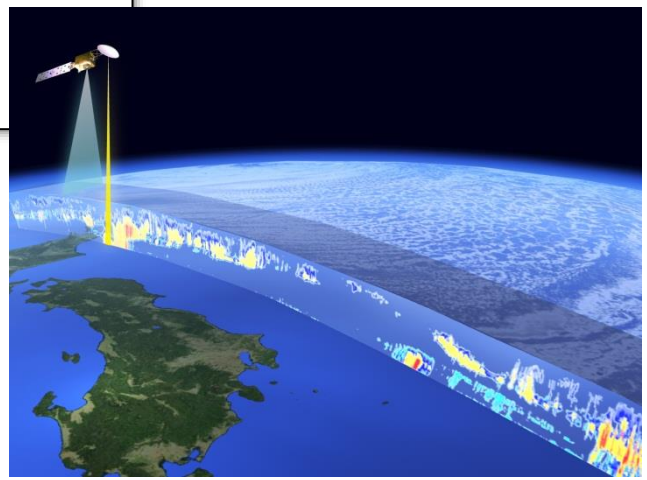
Mission objectives: Improving the understanding of cloud-aerosol-radiation interactions so as to include them correctly and reliably in climate and numerical weather prediction models.

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
Techniques Remote Sensing Techniques				
Active: High Spectral Resolution LIDAR (HSRL)	Active: Millimeter-wave RADAR	Active: Doppler RADAR	Passive: Muiltispectral Imager	Passive: Broadband Radiometer
EarthCARE Instruments				
ATLID — Atmospheric Lidar	CPR — Cloud Profiling Radar		MSI — Multispectral Imager	BBR — Broadband Radiometer

Strategy



Observation of 4 sensors (movie)
https://www.eorc.jaxa.jp/EARTHCARE/museum/movie_gallary.html



Synergetic Observation by 4 Sensors on Global Scale

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

EarthCARE Orbit & Data latency

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Earth Cloud, Aerosol and Radiation Explorer
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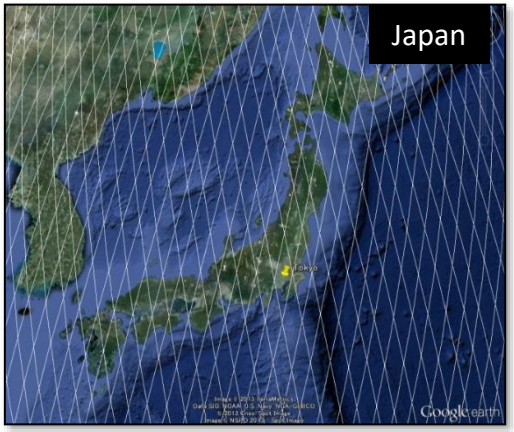
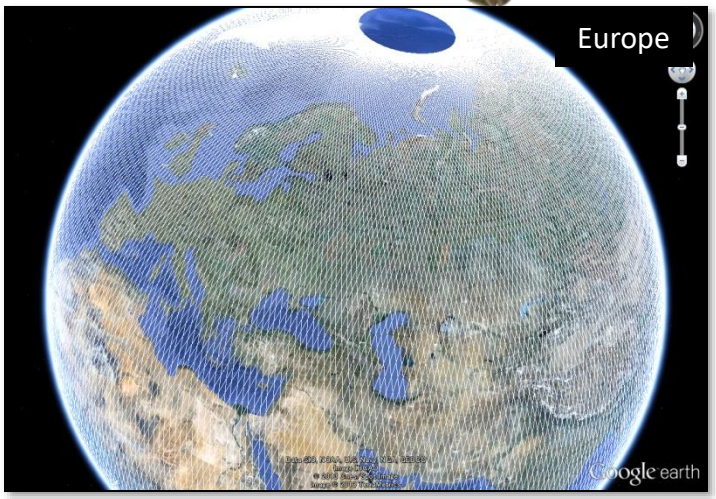
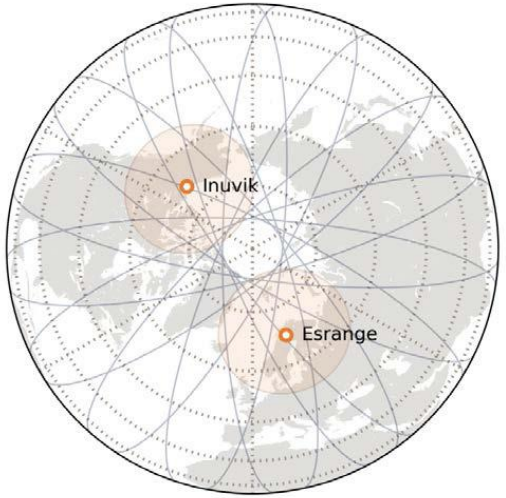
Mean Local Time : Approx. 14:00 (Descending)
2:00 (Ascending)



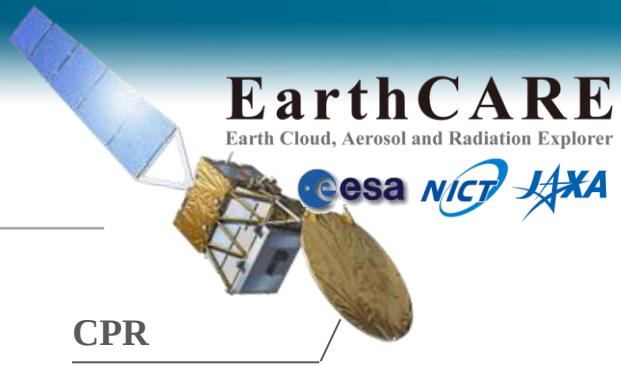


- **Stations:**
  - **Esrange/Kiruna & Inuvik (SSC)**
  - **Two 13-m antenna at each GS location**

- **Data latency**
- **a. Nominal (60% of data) : max. 93 minutes**
- **b. Worst case (blind orbits): 203 minutes max**



Sensors



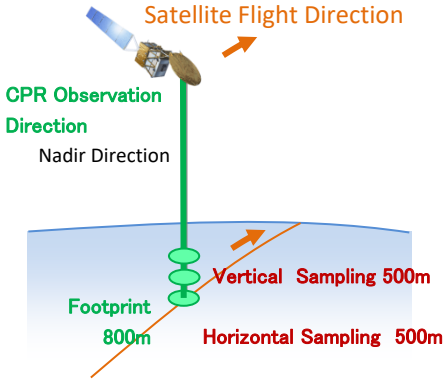
CPR

Cloud Profiling Radar

Instrument	94 GHz（W-band) Doppler Radar
Center Frequency	94.05 GHz
Sampling	Horizontal : 500 m Vertical : 500m （Oversampling 100m)
Footprint	Approx. 800m （Horizontal）
Pulse Repetition Frequency	6100 ～ 7500 Hz (Variable PRF)
Observation Height Range	Surface to 20km (low latitude), 18km, 16km, (high latitude)

Observable Parameters

Radar Reflectivity	Liquid Water Content
Doppler Velocity	Ice Water Content
Gas Attenuation Factor	Liquid Effective Radius
Cloud Mask	Ice Effective Radius
Cloud Particle Type	Optical Thickness



The World's First Satellite-borne Doppler Cloud Radar

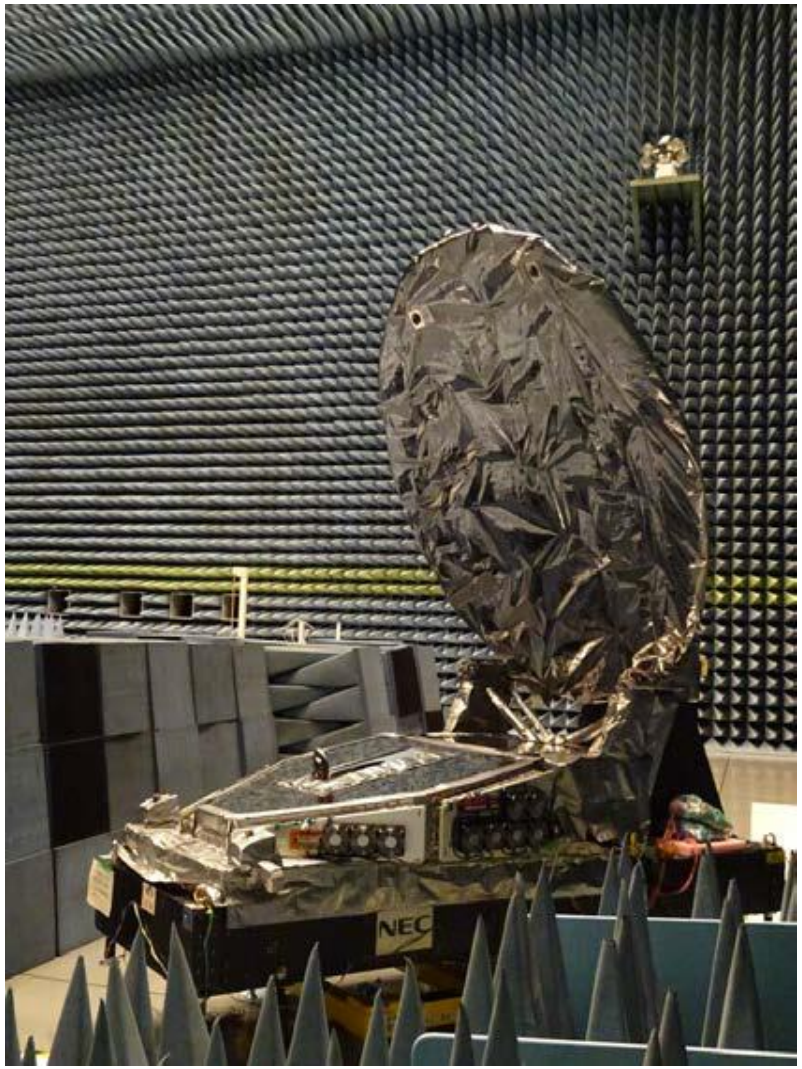
CPR is a **94 GHz (W-band) Doppler Radar** jointly developed by Japan Aerospace Exploration Agency (JAXA) and National Institute of Information and Communications Technology (NICT).

From its millimeter radar signal, it has the capability to observe **vertical 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 **10 times higher sensitivity** compared to CloudSat CPR onboard in the A-Train Constellation.

Photo of the EarthCARE/CPR



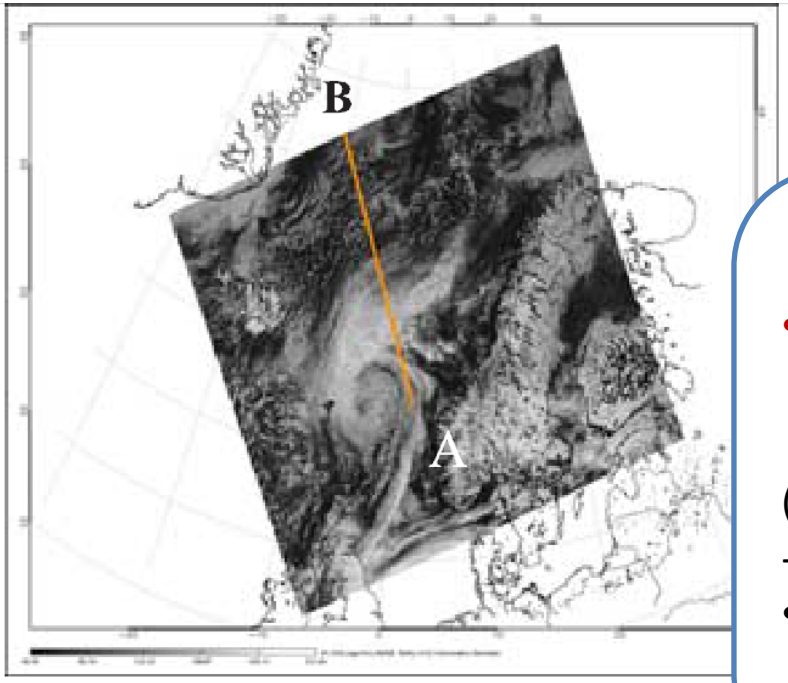
CPR instrument @ JAXA Tsukuba Space center (Sep. 2015)

EarthCARE@Airbus（April.2021）
©Airbus

CPR Observation (by NASA CloudSat)

A orbit on 20 May 2006 (Stephans et al. 2008)

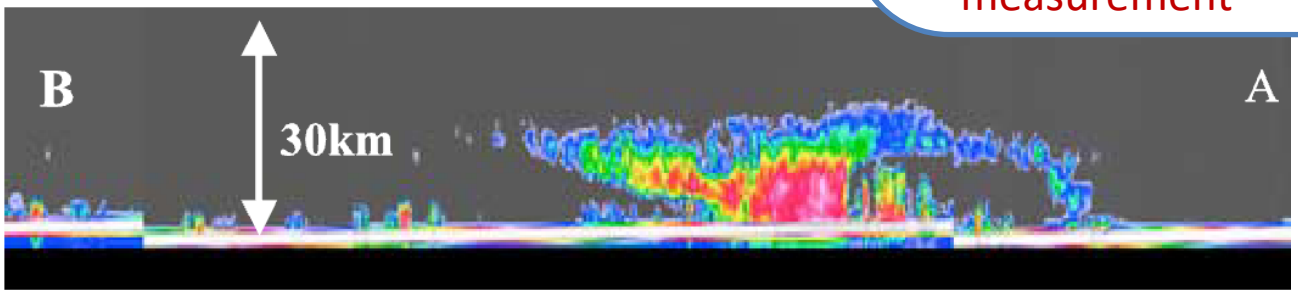
A MODIS image of a warm frontal system



Features of EarthCARE/CPR :

- More sensitivity than CloudSat/CPR by larger antenna size (**2.5 m** diameter) that is, -29dBZ→-35dBZ.
- Capability of the doppler velocity measurement

Cloud profiling radar (CPR) reflectivity by CloudSat satellite



EarthCARE JAXA Product

- Level 1 product will be developed by sensor provider agencies.
  - ✓ i.e. JAXA will provide CPR Level 1 product
- JAXA and ESA develop Level 2 geophysical products individually, under the framework of the Joint Mission Advisory Group (JMAG).
- JAXA and ESA products will be distributed by both agencies.

- For JAXA Level 2 Products, it is consisted by two categories;
  - **Standard Products**
    - strongly promoted to be developed and released
    - processed and released from JAXA G-Portal
    - all data will be able to be sent to ESA when produced
  - **Research Products**
    - promoted to be developed
    - released from JAXA Earth Observation Research Center(EORC)
    - some are planned to be upgraded to standard products

JAXA & ESA Level 1 Product & JAXA Standard Level 2 Product

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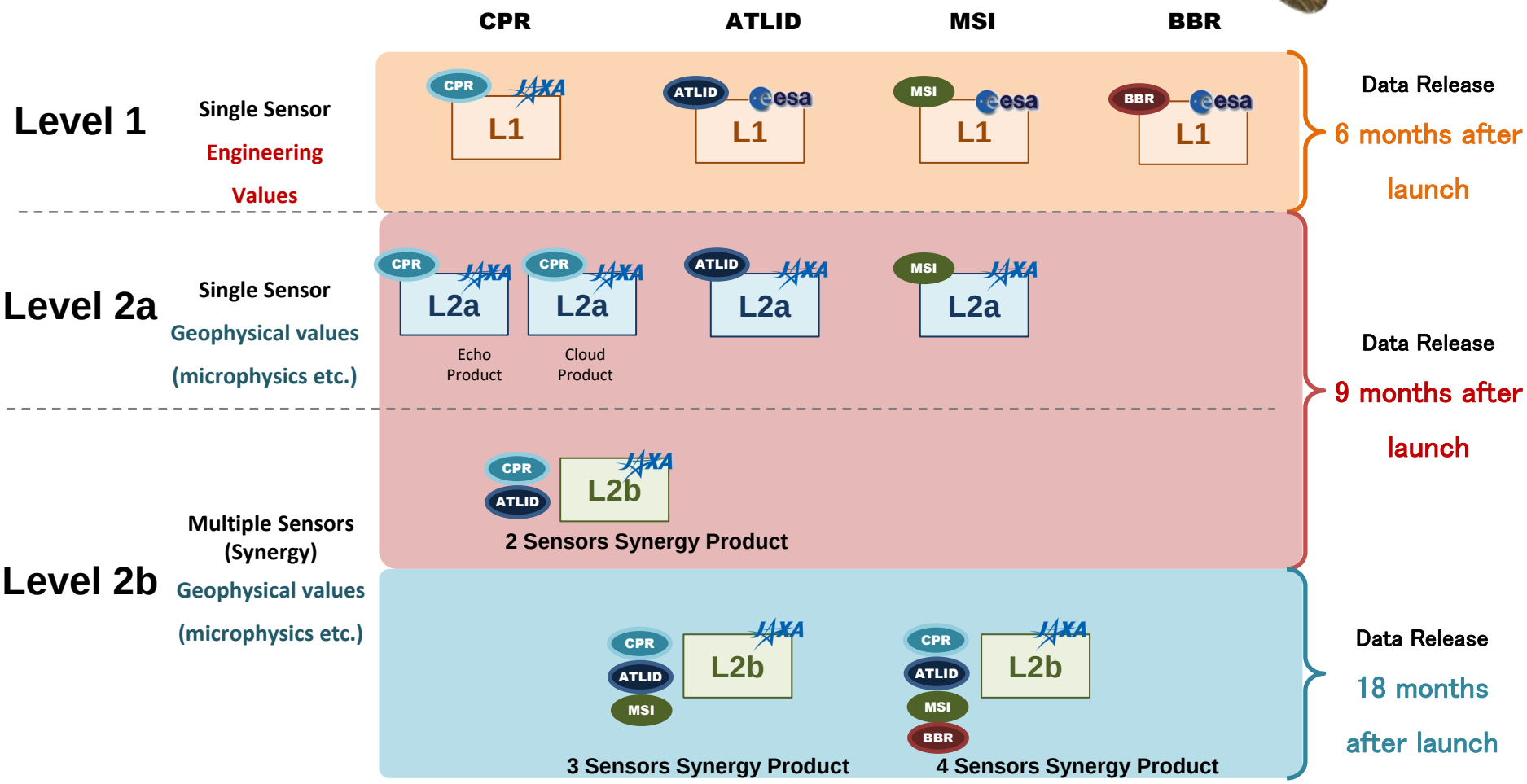
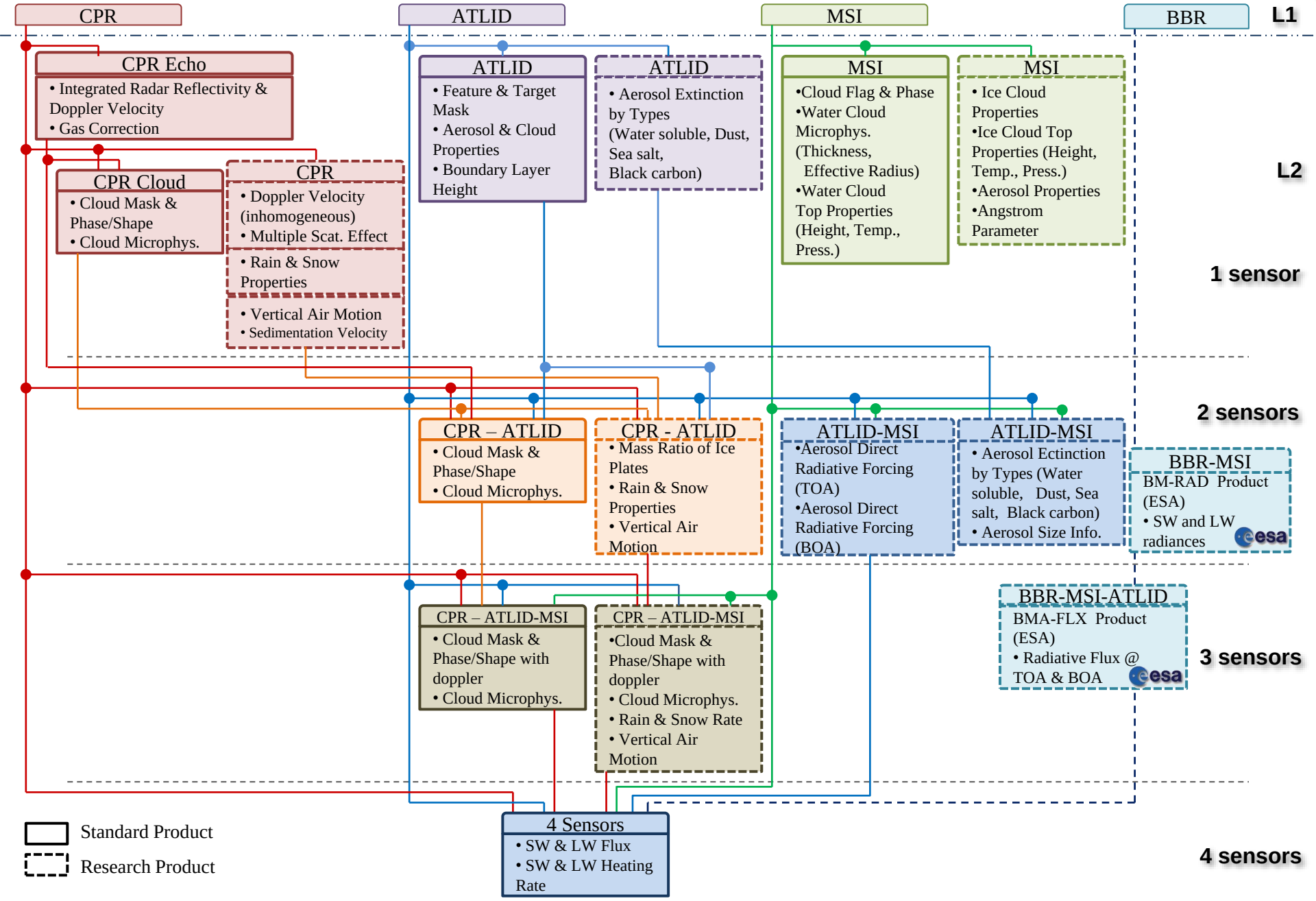
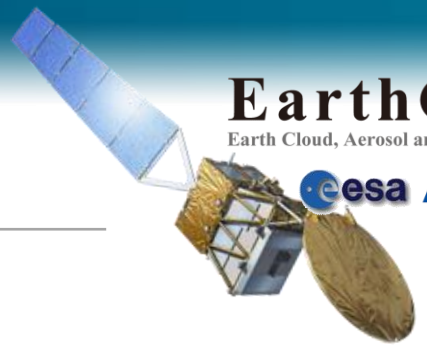


EarthCARE JAXA L2 Production Model

See appendix for the full list.



JAXA Algorithm development with the Joint-Simulator L1 synthetic data



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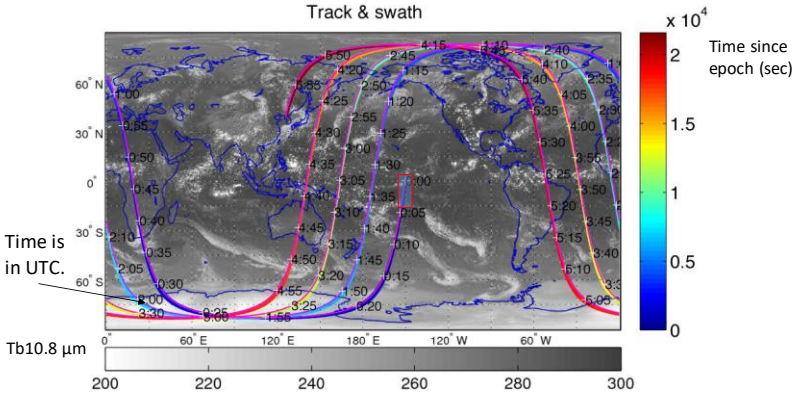
- Level 2 algorithm development ongoing
  - Developments by 6 Algorithm PIs are ongoing.
  - Now All JAXA EarthCARE L2 algorithms can input synthetic data with the JAXA/ESA L1 formats from the Joint-Simulator and output physical variables in the JAXA L2 format.
- JAXA L2 ATBD is provided in the JAXA/EORC Website: http://www.eorc.jaxa.jp/EARTHCARE/index.html

EarthCARE L1 data construction in Japan

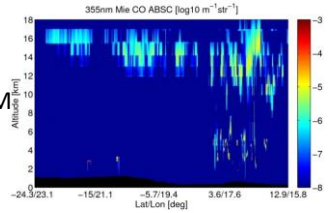
Algorithms have been developed using the synthetic data by the Joint-Simulator in the JAXA EarthCARE Science team.



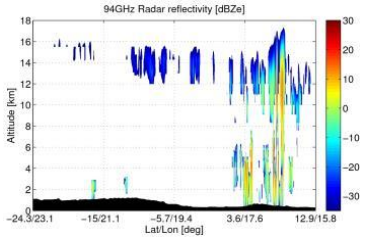
- NICAM 3.5 km simulation, 2008 June 19th 00Z
- The data was interpolated based on the sampling procedure of each sensor.
- The orbit was simulated such a way that EarthCARE passes equator at 14:00 local time in the descending node.

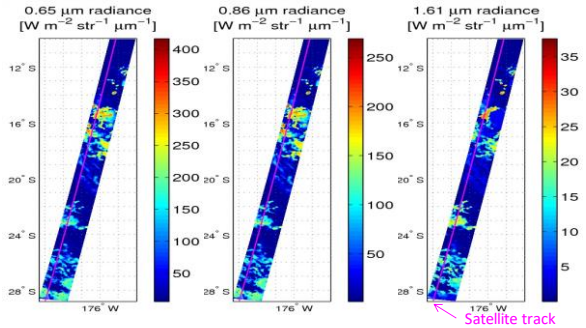
EarthCARE L1 Simulation by the Joint-Simulator using NICAM-SPRINTARS data

Lidar Simulation from NICAM (Last version: only cloud signals simulated)



CPR Radar reflectivity Simulation from NICAM





MSI simulation

JAXA A-Train Product for EarthCARE

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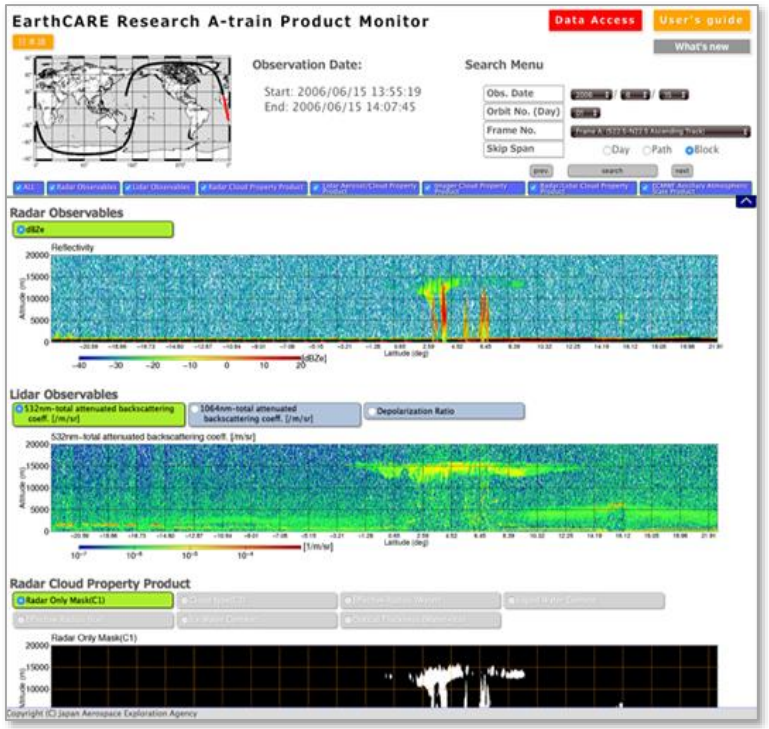
- JAXA has provided the "**EarthCARE Research A-Train Product**" since Oct. 2017.
  - ***http://www.eorc.jaxa.jp/EARTHCARE/research_product/ecare_monitor_e.html***



Latest algorithms for EarthCARE

↓

Algorithms for A-Train satellites

↓

JAXA A-Train Product

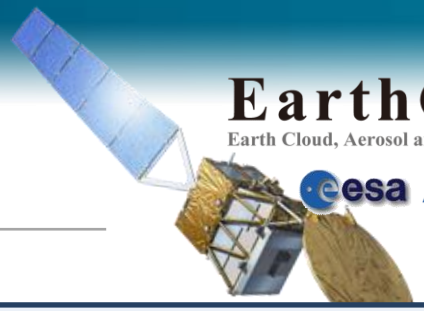
↙ ↘

Validation using heritages of the ground observations, *"Japanese validation rehearsal"*

Applications: Cloud/Aerosol/Radiation Process study, Model evaluations, …etc.

Toward long-term dataset with the A-Train and the EarthCARE…

Promotion for weather/climate model communities



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IPCC Domestic Committee

IPCC

Reflection to Policies

Japan Meteorological Agency [Operational Model]

ECMWF [Operational Model]

Improvement of forecasting accuracy

Operational Use

Improvement of climate prediction accuracy

Univ. of Tokyo/NIES/JAMSTEC [MIROC]

Univ. of Tokyo*3 /JAMSTEC/RIKEN [NICAM]

JMAMRI [MRI-ESM]

Improvement of severe weather prediction accuracy

Nagoya Univ. [CReSS]

Monitoring of air pollution (aerosol)

JMA/MRI & Kyusyu Univ. [MASINGAR]

Kyushu Univ. [SPRINTARS]

JMA/MRI [Volcanic ash monitoring]

NIES [VENUS/NICAM-Chem]

JMA/MRI [Asuca]

General Users

JAXA G-Portal/EORC Website

ESA Website

National Institute of Polar Research

Academic Research

Model Input [Name of Model]

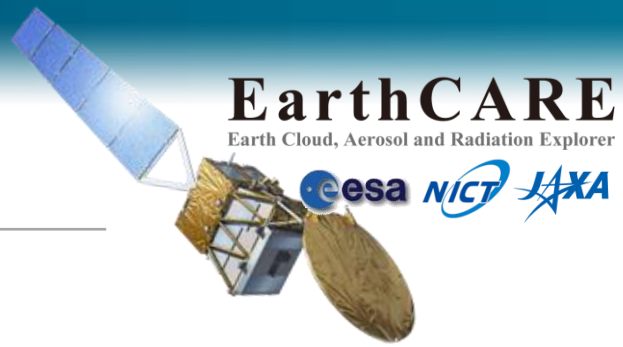
Exit Strategy

Via ESA

Academic Research

Summary

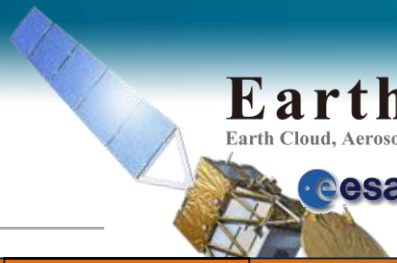
- EarthCARE Overview
  - EarthCARE is an earth observation satellite that Japan and Europe have been jointly developing to observe clouds, aerosols and radiation. (Overview paper: Illingworth et al. 2015, BAMS, https://doi.org/10.1175/BAMS-D-12-00227.1)
  - will be launched in JFY2023
  - Features of the EarthCARE/CPR developed by Japan
    - ✓ More sensitivity than CloudSat/CPR by larger antenna size (2.5 m diameter) that is, -29dBZ → -35dBZ.
    - ✓ Capability of the doppler velocity measurement
- Algorithm status
  - Developments by 6 Algorithm PIs are ongoing.
  - JAXA L2 ATBD is provided in the JAXA/EORC Website: http://www.eorc.jaxa.jp/EARTHCARE/index.html
- JAXA A-Train Product for EarthCARE
  - http://www.eorc.jaxa.jp/EARTHCARE/research_product/ecare_monitor_e.html
- Applications with weather/climate models
  - Data assimilation, evaluations of climate models, …



Appendix:
JAXA EarthCARE Product list

EarthCARE Products

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



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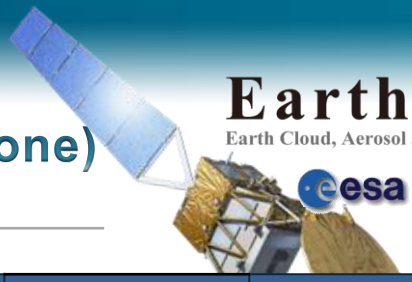
Sensor(s)	Processing Level	Product Name (Product ID for ESA)	Primary Parameter	Grid Spacing		File Unit File Format	Data Volume per day*
				Horizontal	Vertical		
CPR	L1b	CPR One-Sensor Received Power and Doppler Product	Received Echo Power / Radar Reflectivity Factor / Doppler Velocity / Pulse Pair Covariance / 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)



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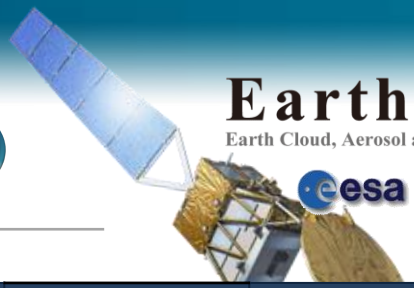
Sensor(s)	Processing Level	Product Name	Primary Parameter (Red: Spatial-integrated values will be also generated)	Grid Spacing		File Unit File Format	Data Volume per day*
				Horizontal	Vertical		
CPR	L2a	CPR One-sensor Echo Products	Integrated Radar Reflectivity Factor Integrated Doppler Velocity Gas 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 μm) / Effective Radius of Liquid (2.2 μm) / 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 (L2b:Synergy)



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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 + 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)

EarthCARE
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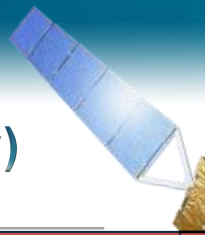
Sensor(s)	Processing Level	Status	Product Name	Primary Parameter (Red: Spatial-integrated values will be also generated)	Grid Spacing		File Unit File Format
					Horizontal	Vertical	
CPR	L2a	Red R	CPR One-sensor Doppler Products	Doppler velocity correction value (considering inhomogeneity) / Doppler 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 μm) / Effective Radius of Ice Cloud (2.2 μm) / 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

"Red R" = Research product, would be processed in JAXA EORC 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 JAXA EORC Research and Application System. "LR" = Research product, would be processed in Japanese Laboratories

JAXA Research Products (L2b:Synergy)



EarthCARE
Earth Cloud, Aerosol and Radiation Explorer
esa NICT JAXA

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 JAXA EORC 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 JAXA EORC Research and Application System. "LR" = Research product, would be processed in Japanese Laboratories