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Construction of JAXA EarthCARE A-train Research Procuct

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Introduction

Clouds and aerosols play a crucial role in the climate system. Moreover, they are among the most significant uncertainties in global climate models. To improve our understanding of the roles of clouds, aerosols, and their interaction, the Japan Aerospace Exploration Agency (JAXA)/European Space Agency (ESA) are developing the EarthCARE (Earth Clouds, Aerosols, and Radiation Explorer) mission. The EarthCARE satellite will carry the Cloud Profiling Radar (CPR) developed by JAXA and the National Institute of Information and Communications Technology (NICT), the Atmospheric Lidar (ATLID), Multi-spectral Imager (MSI), and Broadband Radiometer (BBR) developed by ESA. Especially, the CPR will have the first 94-GHz radar in space with Doppler capability, which gives information on particle fall speeds, leading to improve the accuracy of classification and microphysical retrieval of hydrometeor particles, and their representations of global climate models.

Before the launch, JAXA Earth Observation Research Center (EORC) is constructing a JAXA EarthCARE "A-train research product" derived from A-train (CloudSat/CALIOP/MODIS) data using algorithms developing for the JAXA EarthCARE mission. The retrieved products include radar and lidar cloud masks [Hagihara et al., 2010], vertically resolved lidar cloud particle type [Yoshida et al., 2010; Hirakata et al., 2014], radar and lidar cloud microphysics [Okamoto et al., 2010], lidar aerosol mask and properties [Nishizawa et al., 2007; 2008], and imager cloud mask and microphysics [Ishida and Nakajima 2009; Kawamoto et al., 2001]. The product is expected to be used in the evaluation of climate models [e.g., Hashino et al., 2013], and they are available online through the JAXA/EORC website with various visualized figures.

Misson Overview

EarthCARE Misson Objective

To evaluate the radiative interaction and radiative forcing of cloud and aerosol, and to reduce the uncertainties in global climate chanage prediction by measuring *the three dimensional structure of clouds and aerosols*, which are most significant uncertainties in global climate models [Illingworh et al., 2015].

Satellite overview

- Joint development by JAXA/NICT and ESA
- Sun-synchronous orbit (Local time: 14:00)
- Orbit height approx. 393km
- Orbit inclination 97deg.
- Reccurent period 25days
- Launch in 2019
- 3 years life time

4 Sensor Synergestic Observation

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

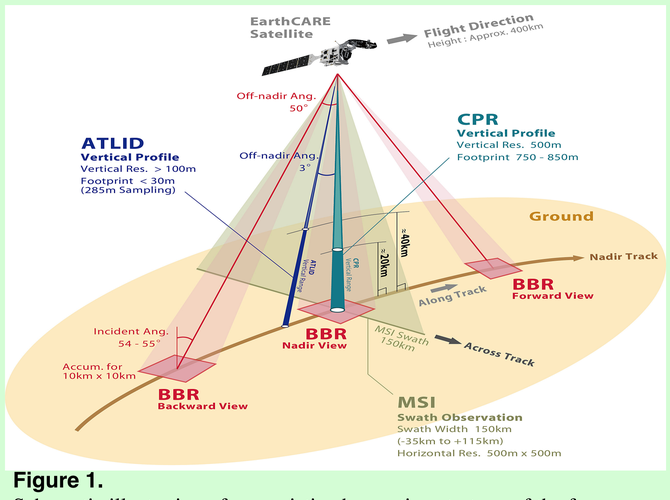


Figure 1.
Schematic illustration of synergistic observation strategy of the four instruments on the EarthCARE.

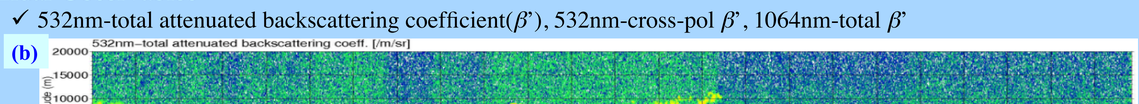
Sensor Characteristics

- Cloud Profiling Radar (**CPR**), 94.05 GHz
  - ✓ High power W-band nadir-pointing
  - ✓ Doppler capability (accuracy 1.3m/s)
  - ✓ Antenna aperture 2.5m
  - ✓ Variable pulse rep. freq.: 6100-7500Hz
  - ✓ Sensitivity at least -35dBZ at 20km
- ATmospheric LIDar (**ATLID**), 355 nm
  - ✓ Backscatter UV lidar with high spectral resolution receiver
  - ✓ 3 receiver ch.: molecular, co-polar and cross-polar particle backscatter (backscatter and extinction measured independently)
  - ✓ Pulse repetition 51Hz, pulse energy -> 34mJ
  - ✓ 3deg off-nadir (backwards) pointing
- MultiSpectral Imager (**MSI**)
  - ✓ Nadir-viewing push-broom imager
  - ✓ 7 ch.: 670nm, 865nm, 1.65μm, 2.21μm, 8.80μm, 10.80μm, 12.00μm
  - ✓ 150km swath tilted away from sunglint
- BroadBand Radiometer (**BBR**)
  - ✓ 2 ch.: 0.25-50μm, 0.25-4.0μm -> 0.25-4.0μm (SW), 4.0-50μm (LW)
  - ✓ 3 fixed telescopes: nadir, forward (+50deg), backward (-50deg)
  - ✓ Integrated pixel size of 10km x 10km
  - ✓ Radiometric accuracy: SW 2.5Wm^{-2}sr^{-1}, LW 1.5Wm^{-2}sr^{-1}

A-train Research Product

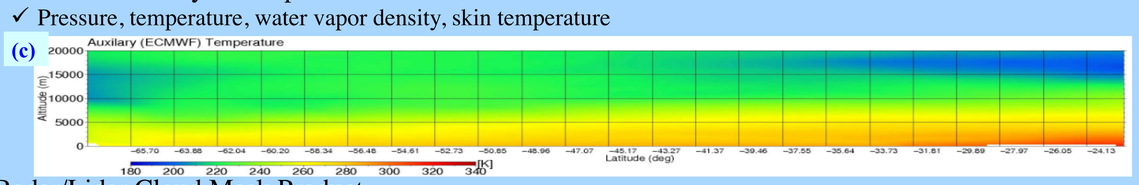
Data List & Sample Figures

- Constructintng "A-train Research Product" derived from A-train data by using the algorithms developing for the EarthCARE.
- All the observables and retrieved parameters are generated from CloudSat R04 and CALIPSO Lidar L1b V3 data with re-sampling to "same" 240m in vertical and 1.1km in horizontal grid, respectively [Hagihara et al., 2010].
- Radar Observables
  - ✓ Radar reflectivity factor, gaseous attenuation (cumulative)

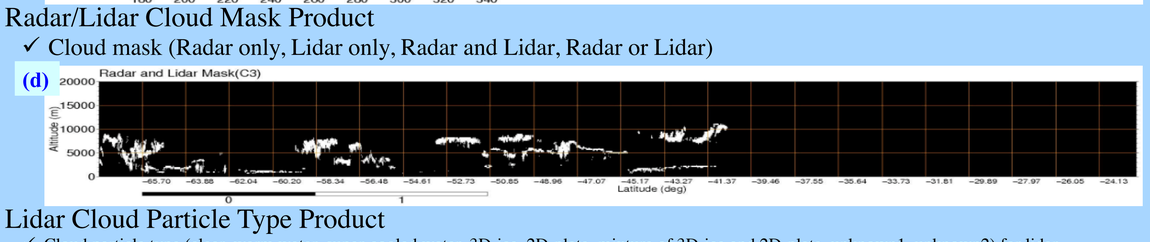


- Lidar Observables
  - ✓ 532nm-total attenuated backscattering coefficient(β'), 532nm-cross-pol β', 1064nm-total β'

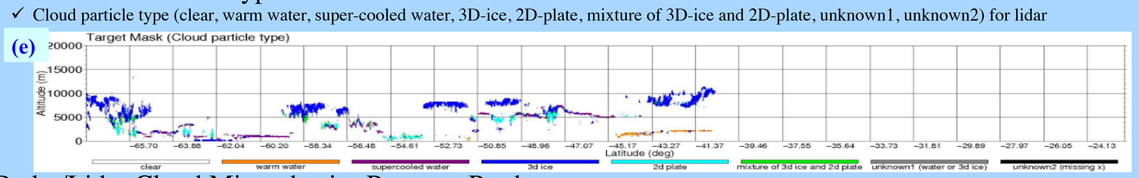
- ECMWF Ancillary Atmospheric State Product
  - ✓ Pressure, temperature, water vapor density, skin temperature



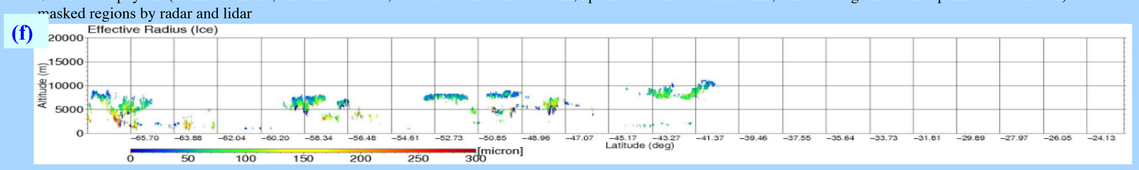
- Radar/Lidar Cloud Mask Product
  - ✓ Cloud mask (Radar only, Lidar only, Radar and Lidar, Radar or Lidar)



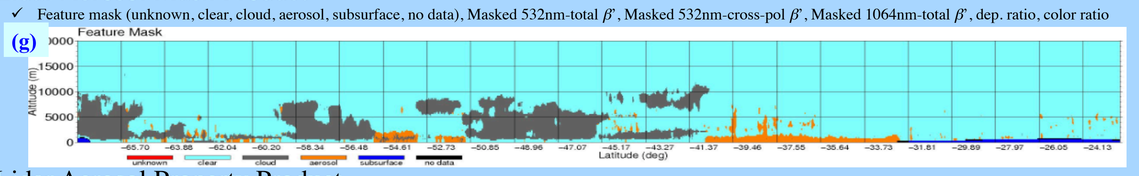
- Lidar Cloud Particle Type Product
  - ✓ Cloud particle type (clear, warm water, super-cooled water, 3D-ice, 2D-plate, mixture of 3D-ice and 2D-plate, unknown1, unknown2) for lidar



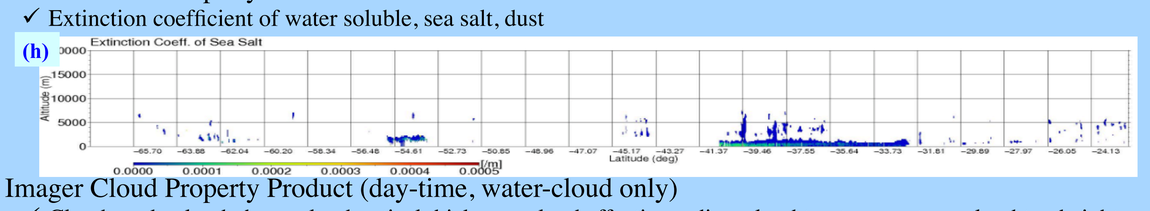
- Radar/Lidar Cloud Microphysics Property Product
  - ✓ Cloud microphysics (effective radius, ice water content, number concentration of ice, optical thickness of ice clouds, mass mixing ratio of 2D-plate to the total ice) of masked regions by radar and lidar



- Lidar Aerosol Mask Product
  - ✓ Feature mask (unknown, clear, cloud, aerosol, subsurface, no data), Masked 532nm-total β', Masked 532nm-cross-pol β', Masked 1064nm-total β', dep. ratio, color ratio



- Lidar Aerosol Property Product
  - ✓ Extinction coefficient of water soluble, sea salt, dust



- Imager Cloud Property Product (day-time, water-cloud only)
  - ✓ Cloud mask, cloud phase, cloud optical thickness, cloud effective radius, cloud top temperature, cloud top height

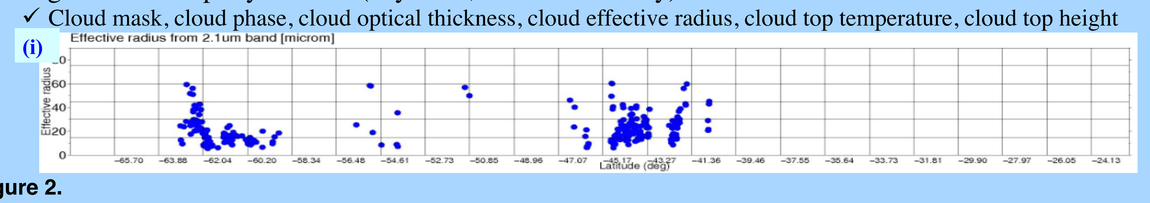


Figure 2.
Height-latitude cross section of (a) dBZe on 5 Oct. 2006 in the area of 0-30 degrees S, (b) β'532, (c) temperature, (d) cloud mask results for radar and lidar (C3), (e) cloud type results for lidar (C2), (f) retrieved R_{eff} for C3, (g) lidar feature mask results, (h) retrieved ext. coeff. for sea salt, and (i) retrieved R_{eff} for 2.1micron for water cloud corresponding the center of CloudSat footprint.

Demonstration analysis using Radar/Lidar Cloud Mask Product

- Seasonal cloud coverage (CC) maps for radar or lidar mask results (4 year average)
- Coverage = num. of cloud profiles (mask values>0.5) / total num. of obs., Topmost layer only
- Low(ECMWF CTP >680hPa), Middle(440-680hPa), High(0-440hPa)

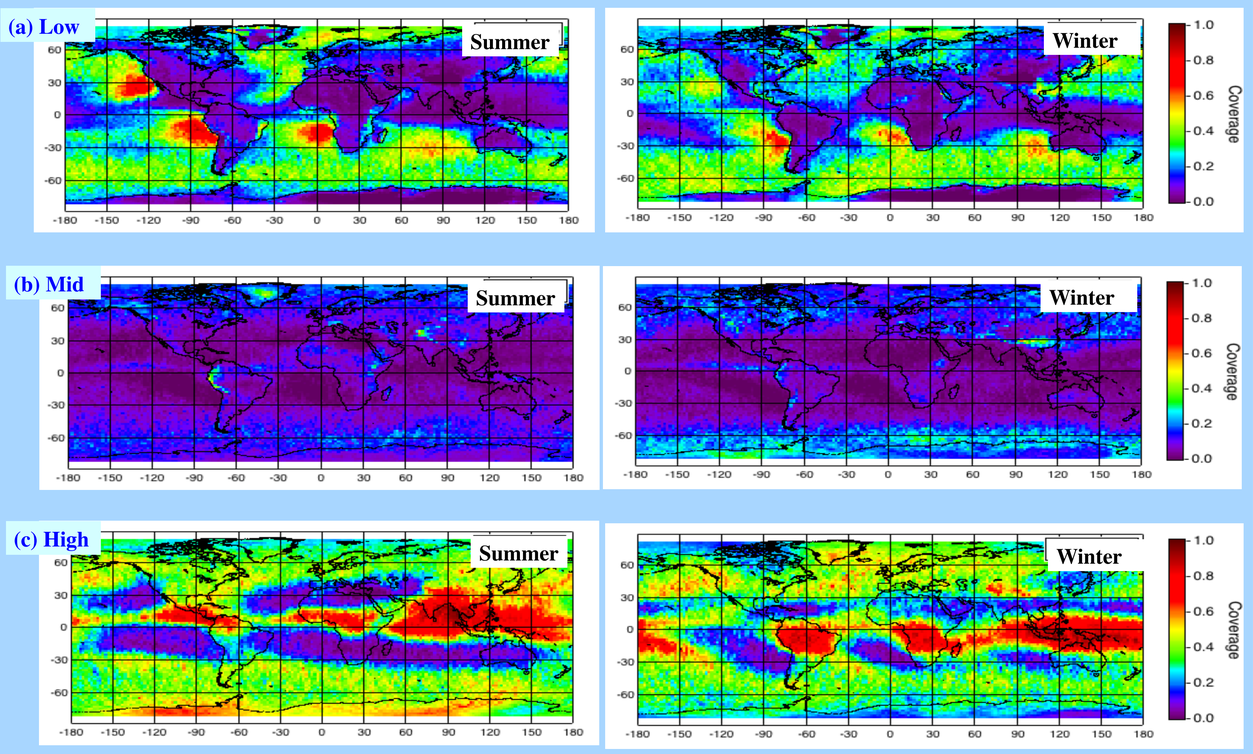
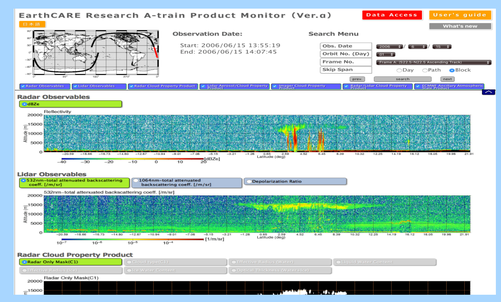


Figure 3.
The 4 year average (July 2006 - May 2010) seasonal cloud coverage for the topmost layer maps for radar or lidar mask in the (a) low-level, (b) middle-level, and (c) high-level for summer (JJA) and winter (DJF) seasons.

- In the low-level (Fig.3a), CC is relatively smallter over land and in the ITCZ depend on season due to a high frequency of cloud overlap. Very large CC (~92%) is shown over the western coasts of continents, especially during the suumer.
- Fig. 3c clearly illustrates the seasonal variation of the ITCZ and the subtropical high in the high-level. These findings are consistent with previous studies [e.g., Jin et al., 1996; Wylie et al., 2005].

Data Distribution

- The "A-train Research Product" is distributed from JAXA/EORC in NetCDF4 format.
- Users can acquire the product and quicklook images from JAXA EarthCARE Research A-train Product Monitor website including user registration form and user's guide (data description and references).



http://www.eorc.jaxa.jp/EARTHCARE/research_product/ecare_monitor_e.html

Summary

- JAXA/ESA are developing the EarthCARE satellite, which will carry the world's first 94GHz Doppler cloud radar CPR, the high spectral resolution lidar ATLID, the 7ch imager MSI, and the broadband radiometer BBR.
- Before the launch, JAXA/EORC is constructing a JAXA EarthCARE "A-train research product" derived from A-train data using algorithms developing for the JAXA EarthCARE mission.
- The product data have "same" 240m in vertical and 1.1km in horizontal grid, respectively, and available online via JAXA/EORC website.