The EarthCARE mission: An active view on aerosols, clouds and radiation

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EarthCARE is ESA’s sixth Earth Explorer Mission and will be implemented in cooperation with JAXA

Mission Goal: Relationship of clouds, aerosols and radiation

ESA: satellite, three instruments, launch, operations

JAXA: one instrument
Mission Objective:
Understanding of cloud-aerosol-radiation interactions so as to include them correctly and reliably in climate and NWP models

Required Global Observations:
- Vertical profiles of natural and anthropogenic aerosols, their radiative properties and interaction with clouds.
- Vertical distributions of atmospheric liquid water and ice, their transport by clouds and their radiative impact.
- Cloud distribution (‘cloud overlap’), cloud-precipitation interactions and 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.
**Needs**

- **Aerosols:** Vertical profiles of extinction and characteristics of aerosols
- **Clouds:** Vertical profiles of liquid, supercooled and ice water, cloud overlap, particle size and extinction
- **Vertical motion:** Convective updraft and ice fall speed
- **2-D Context:** Clouds and aerosols horiz. structures
- **Radiation and Flux:** Broadband SW & LW @ TOA

**Techniques**

- **Lidar**
- **Radar**
- **Doppler Radar**
- **Multi-spectral Imager**
- **Broadband Radiometer**

**EarthCARE instruments**

- **ATLID UV & HSR**
- **CPR with Doppler**
- **MSI**
- **BBR**

**Temperature and humidity from operational analysis (e.g. ECMWF...)**
UV(355nm) linearly polarized HSRL with Mie, Rayleigh and depolarisation channel

Sampling:
Pulse repetition of 51Hz leads to horizontal sampling distance of 145m. To improve SNR, two consecutive profiles are integrated on-board, leading to actual horizontal sampling of 290m

Vertical sampling: 103m

L1: Attenuated back-scatter profiles
Cloud Profiling Radar
CPR

- High power W-band (94GHz) nadir-pointing
- Doppler capability (Doppler velocity ±10m/s, accuracy 1m/s)
- Antenna aperture 2.5m
- Variable pulse rep. freq.: 6100-7500 Hz
- Sensitivity at least -35dBZ at 20km height
- Sampling: 500m horizontal, 100m vertical
- Vertical range up to 12, 16 or 20km as function of latitude. Lower vertical range → higher PRF → better Doppler
- -3dB beamwidth = 0.09° → effective footprint on ground = 750m x 1000m
- Instrument: 321 W, 270 kg, 265 kbps
- Level 1 product: reflectivity & Doppler profiles
Objective:

To provide contextual imagery information to support the retrievals of geophysical parameters by the active instruments on-board EarthCARE

Characteristics:

150 km swath (−35km to +115 km)  
500 m ground sampling distance  
57 W, 58 kg, 652 kbps

Level 1 product: radiances (VNS) & brightness temperatures (TIR)

<table>
<thead>
<tr>
<th>Channel</th>
<th>Centre Wavelength [μm]</th>
<th>Bandwidth (50%) [μm]</th>
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<td>0.02</td>
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<tr>
<td>NIR</td>
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<td>TIR 1</td>
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<td>0.9</td>
</tr>
<tr>
<td>TIR 3</td>
<td>12.0</td>
<td>0.9</td>
</tr>
</tbody>
</table>
Three fixed telescopes:
forward (55°), nadir, backward (-55°)

Two channels:
Short-wave (SW) channel 0.25 µm to 4 µm
Total-wave (TW) channel 0.25 µm to >50 µm
→ “synthetic” LW derived

Abs. accuracy 2.5 (SW) / 1.5 (LW) Wm\(^{-2}\)sr\(^{-1}\)

Spatial resolution 10 km x 10 km
Spatial sampling distance 1 km
48 W, 45 kg, 145 kbps

**Products:** TOA SW/LW radiances & flux

Instrument prime: SEA (UK)

3 fixed, single mirror telescopes, each with a linear microbolometer detector array
Chopper drum rotates continuously, chopping the signal between SW, drum & TW views
Calibration drum periodically rotates into view:
- Hot or cold blackbody, every 88s, to calibrate LW
- View to sun diffuser, every 2 months for 30 orbits, to monitor aging in the SW chain
Payload & Level 1 Products:

**HSR Lidar:** $\lambda=355\text{nm}$ with depol. channel:
- L1: attenuated backscatter profiles

**94GHz Radar** with Doppler (JAXA/NICT):
- L1: Reflectivity and Doppler profiles

**Multi-spectral Imager**, 4 solar + 3 TIR channels
- L1: TOA radiances and brightness temperatures in 7 spectral bands

**Broad-band Radiometer**, 3 fixed FoV’s
- L1: Filtered top-of-atmosphere radiances short- and long-wave
Science Data Products

ATLID Level 1 (ESA)
Attenuated backscatter in
• Rayleigh channel
• Co-polar Mie channel
• Cross-polar Mie channel

CPR Level 1 (JAXA)
Radar reflectivity and Doppler profile

MSI Level 1 (ESA)
TOA radiances for four solar channels, TOA brightness temperatures for three thermal channels

BBR Level 1 (ESA)
TOA long-wave and total-wave radiances

ATLID Level 2
Feature mask and target classification, extinction, backscatter & depolarisation profiles, aerosol properties, ice cloud properties, ...

CPR Level 2
Radar echo product, feature mask, cloud type, liquid and ice cloud properties, vertical motion, rain and snow estimates, ...

MSI Level 2
Cloud mask, cloud micro-physical parameters, cloud top height, aerosol parameters, ...

BBR Level 2
Unfiltered top-of-atmosphere radiances, short-wave and long-wave fluxes

Synergistic Level 2
Target classification, cloud and aerosol 2-dim. profiles

Closure: linking clouds/aerosols and radiation

Closure
Comparison of Radiative Transfer Products (radiances, fluxes) to BBR radiances and fluxes

3-dim. Scenes Construction
Expand syn. retrievals across-track using MSI information

Radiative Transfer Products
1D & 3D rad. transfer: radiances, fluxes, heating rates
Preparatory Science Activities

Level 2 Developments
- clouds profiles from radar, lidar, imager
- aerosol profiles from lidar, imager
- calculated radiation from retrieved profiles and measured broad-band SW, LW → closure assessment

Science Preparation
Building on CloudSat, Calipso, CERES/GERB, MODIS heritage, also ground-/air-based radar/lidar, modelling, ...

Joint Mission Advisory Group
Members: Europe, Japan, Canada
Observers: USA

Preparation Validation
- JAXA: 2yrs prep progr completed
- ESA: announcement of opportunity call planned
- Joint validation workshop before launch

Preparation of NWP Assimilation
ECMWF: preparation of radar and lidar assimilation

Scientific Workshops
- several workshops in about 2-year intervals, most recent:
  2012, Paris, jointly with CloudSat and Calipso science teams
  2014, Tokyo
EarthCARE: continuation and improvement of ongoing cloud-aerosol profile and radiation data record

CloudSat / CALIPSO / MODIS / CERES: cloud-aerosol profile + radiation data record since 2007 (and counting)

Any Questions?