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

T. Wehr, P. Ingmann, T. Fehr
Heraklion, Crete, Greece
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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

Dry launch mass about 2.2 ton
Heritage: A-Train Observations

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CloudSat Radar
CALIPSO Lidar
Target Classification
MODIS

North/mid-Atlantic
**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 horizontal 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**
Sampling

Pulse repetition of 51Hz leads to horizontal sampling distance of 140m. To improve SNR, two consecutive profiles are integrated on-board, leading to actual horizontal sampling of 280m.

Vertical sampling: ~100m
Cloud Profiling Radar (CPR)

- High power W-band (94GHz) nadir-pointing
- Doppler capability (Doppler velocity \(\pm 10\) m/s, accuracy 1 m/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 \(\rightarrow\) higher PRF \(\rightarrow\) better Doppler
- -3dB beamwidth = 0.09° \(\rightarrow\) 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 (–35 km 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>
</tr>
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<tr>
<td>VIS</td>
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<td>0.02</td>
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<tr>
<td>NIR</td>
<td>0.865</td>
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<tr>
<td>SWIR 1</td>
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<td>SWIR 2</td>
<td>2.21</td>
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<tr>
<td>TIR 1</td>
<td>8.8</td>
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</tr>
<tr>
<td>TIR 3</td>
<td>12.0</td>
<td>0.9</td>
</tr>
</tbody>
</table>

VNS = visible, near-infrared, short-wave infrared
TIR = thermal infrared

EarthCARE | T. Wehr, P. Ingmann, T. Fehr | Heraklion, Crete, Greece
ESA UNCLASSIFIED – For Official Use
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⁻²sr⁻¹

Spatial resolution 10 km x 10 km

Spatial sampling distance 1 km

Interface data: 48 W, 45 kg, 145 kbps

Products: TOA SW/LW radiances & flux

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
CPR
Ø<1km, nadir
500m sampling

BBR nadir
10km x 10km

BBR forward view (+50°)

BBR backward view (-50°)

ATLID
3° depoint, Ø<30m
280m sampling

10km x 10km

10km x 10km

-35km to +115km

3°

50°

54-55°

zenith

flight direction
**Payload & Level 1 (L1) Products:**

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

**95GHz 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
Advanced Retrieval Techniques

Synergistic retrieval using lidar, radar and imager together.

Example: North-Atlantic cloud system observed by CloudSat and CALIPSO.

Left column: forward-modelled radar reflectivity and lidar backscatter versus observed, showing successful algorithm convergence.

Right column: Retrieved atmospheric constituents.

Figures courtesy of Robin Hogan, VARSY Project.
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 microphysical 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

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

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

Linking clouds/aerosols and radiation

Assessment
- Comparison of Radiative Transfer Products (radiances, fluxes) to BBR radiances and fluxes
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, ground-/air-based radar/lidar, modelling, ...

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

Preparation GCM evaluation
Dedicated data processor (CFMIP-type) development

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

Preparation Validation
- JAXA: 2yrs prep progr completed
- ESA: announcement of opportunity call planned for 2016
- Joint validation workshop before launch

Scientific Workshops
- several workshops in about 2-year intervals, most recent: 2012, Paris, jointly with CloudSat and Calipso science teams
- 2014, Tokyo
ESA Tentative Schedule

1. Draft EarthCARE Validation Requirements Document
2. Validation Requirements Status Review
3. **Issue ESA International Validation AO** ≈ L – 2 yrs
4. Evaluate Val AO → draft Validation Implementation Plan
5. **First ESA Validation Workshop** ≈ L – 1½ yrs
6. Consolidate Val. Implementation Plan (incl. securing funding)
7. Start implementation
8. **Pre-launch Joint ESA-JAXA Validation Workshop** < L – ½ yrs
9. Validation Rehearsal, Val. Readiness Review
10. Flight Acceptance Review
11. Launch 2nd half 2018
Cloud profiles are the key to atmospheric heating

Community concern: **What after CloudSat, CALIPSO and EarthCARE?**
- Clouds-precip-water vapour → hydrological cycle
- Cloud profiles → key to atmospheric heating, not possible to quantify with passive imagers
- Aerosol → air quality, cloud interaction
- NWP → impact of assimilation in NWP to be studied with EarthCARE → if successful, what’s next?

Any Questions?

**No CloudSat-CALIPSO-EarthCARE type of mission on the horizon for the 2020’s**