Aerosols from Sentinel 3 and EarthCARE missions

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Outline

Aerosols from Imagers / Sentinel-3

EarthCARE: Mission and products

Practicalities (data format / latency / policy)

Questions

Satellite instruments which can be used for aerosol observations

Satellite	Coop. Partner	Launch date	Single-view imager	Dual-view imager	Spectrometer	LIDAR
ERS-2		1995		ATSR-2	GOME-1	
Envisat		2002	**MERIS**	**AATSR**	SCIAMACHY	
MetOp A-C	EUM	2006-2016	AVHRR/3		GOME-2	
EarthCARE	JAXA	TBD	**MSI**			**ATLID**
Sentinel 3	EUM, EC	2013	**OLCI**	**SLSTR**		
MTG-S	EUM, EC	2018/ 2025			Sentinel 4	
Sentinel 5 Precursor		2014			TROPOMI	
post-EPS	EUM, EC	2020+	VII		Sentinel 5	

Imager characteristics

Instrument Satellite	# views	# bands	Spectral range [µm]	Swath [km]	Spatial resolution [m]
MERIS Envisat	1	15	0.4 – 0.9	1150	1200 (RR)
OLCI Sentinel 3	1	**21**	0.4 – 1.0	1270 tilted	300
MSI EarthCARE	1	4 VNS +3 TIR	0.67 – 2.2 8.8 – 12.0	150 tilted	500
AATSR Envisat	2	5 VNS +2 TIR	0.55 - 3.74 10.85 – 12.0	500	1000/1300
SLSTR Sentinel 3	2	**7** VNS +2 TIR	0.55 – 3.74 10.85 – 12.0	1675/750	500

Sentinel-3 requires improved "atmospheric corrections" for ocean/land products, therefore will have improved aerosol capability wrt Envisat.

Sentinel 3

The GMES medium resolution ocean and land mission

Sentinel-3 mission objectives

Provide accurate and reliable long-term measurements primarily for the GMES **marine** services, with capability to support other application areas:

Ocean (and land) colour, in continuation of MERIS

Sea (and land) surface temperature , in continuation of AATSR

Sea surface (and land/ice) topography, in continuation of ENVISAT altimetry

Sentinel-3 mission profile

GMES mission (Operational mission)

Cooperation with EC/EUMETSAT/CNES

Currently in phase C/D

Operational: 2013-2024 (2x2 satellites for global coverage in 2 days)

Orbit: polar sun-synchronous, 815 km,

mean local solar time 1000h at descending node

Primary instruments:

OLCI – Ocean and Land Colour

SLST – Sea and Land Surface Temperature

SRAL – Sentinel-3 Ku/C Radar Altimeter

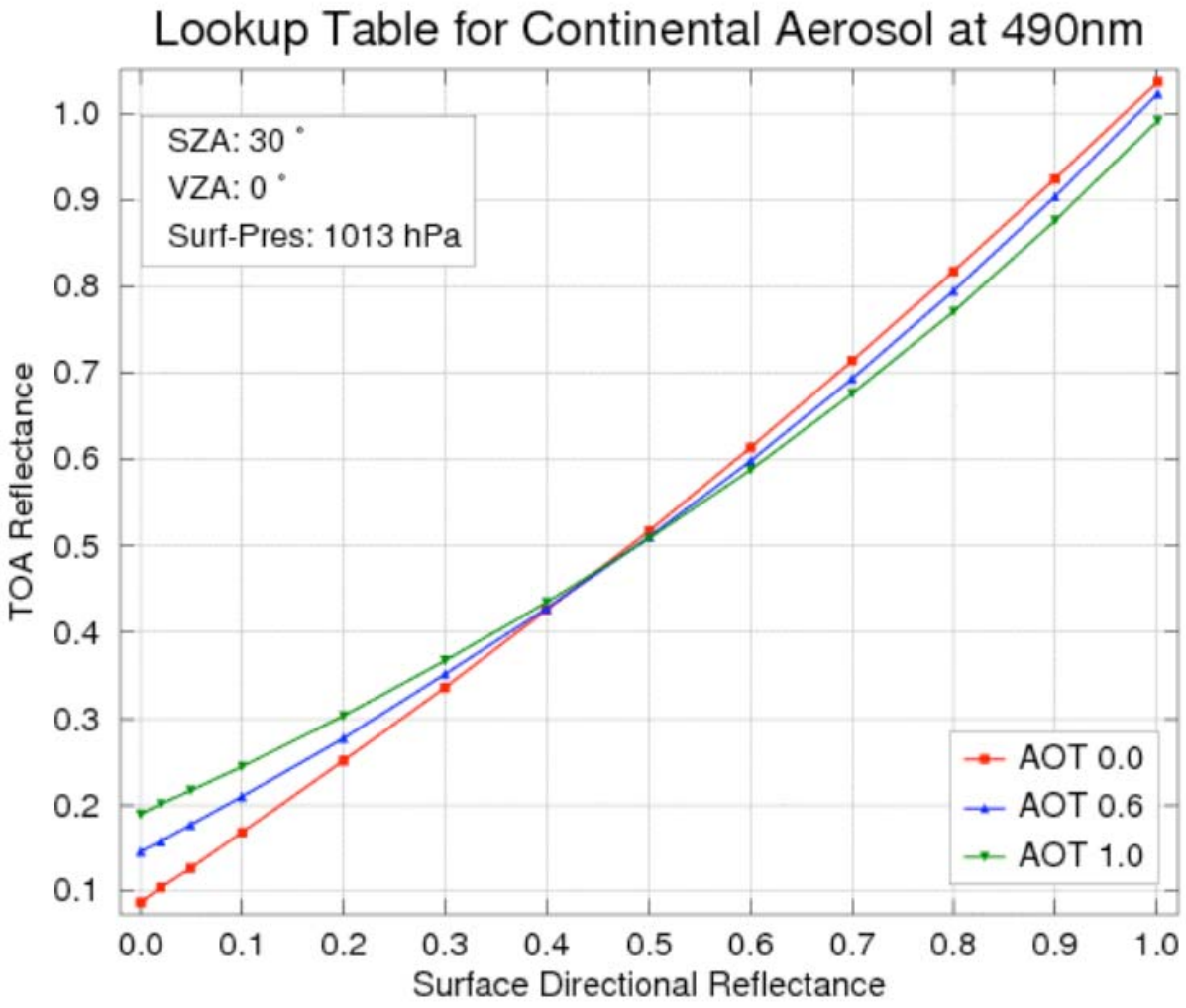
Aerosol algorithms (imagers)

Typical elements:

1. Model TOA radiances – generate LUTs
2. Define parameterised surface reflectance models
3. Find and select cloud-free pixels
4. Retrieve atmospheric profiles and surface reflectance (inversion step)

Separating surface and atmosphere parameters much more demanding over land than over ocean

LUT example



Peter North et al., MERIS/AATSR synergy algorithms ATBD, v4.2 (2010)

Synergistic use of single / dual view imagers

Algorithm has been developed for synergistic retrievals of surface reflectance and AOD from Envisat MERIS/AATSR.

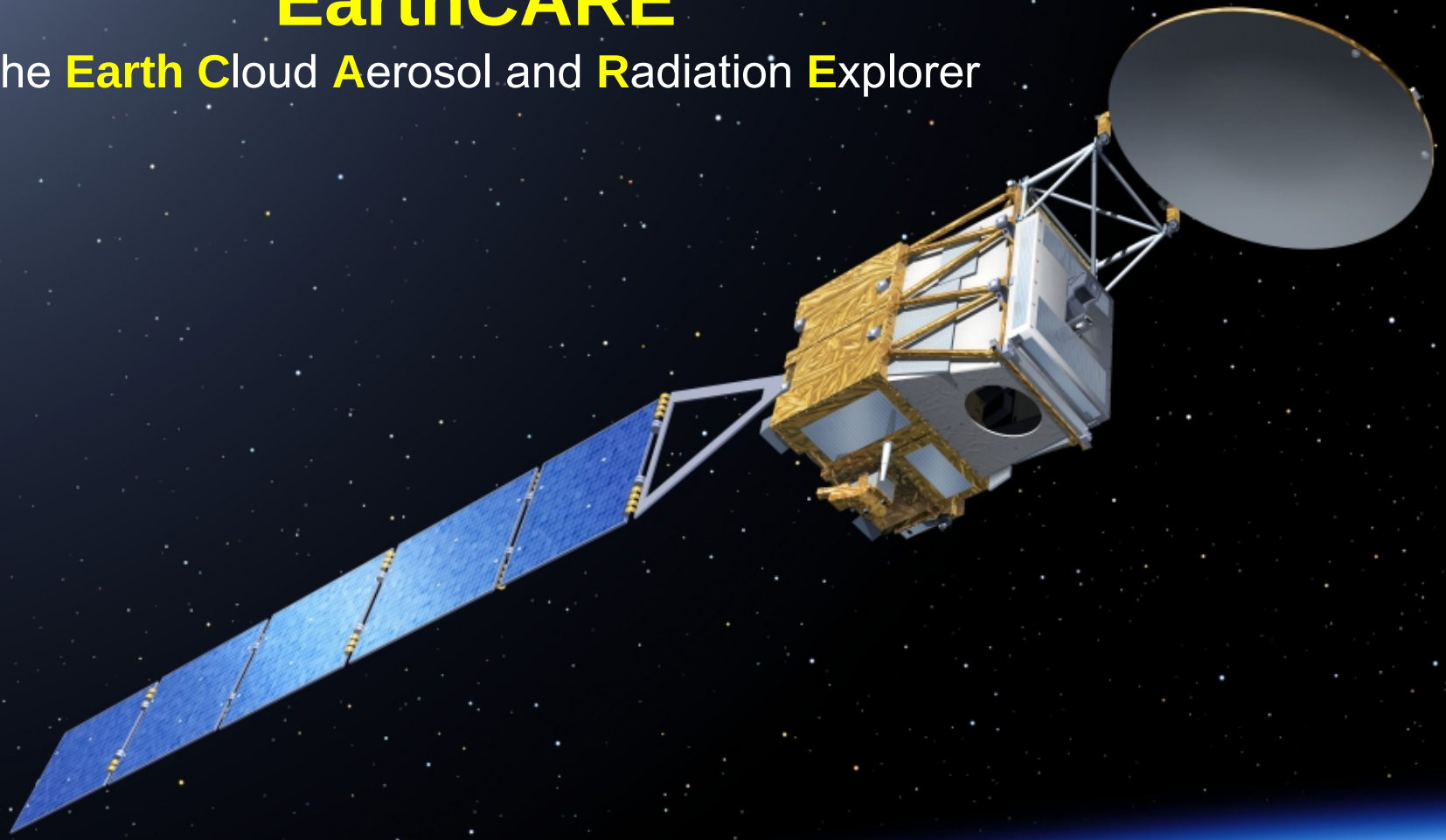
Validation with Aeronet shows significant improvements wrt single-instrument retrievals.

Future work:

- Adaptation to Sentinel 3 OLCI/SLSTR
- Retrieval of additional aerosol parameters, e.g. aerosol height, aerosol class

EarthCARE

The **E**arth **C**loud **A**erosol and **R**adiation **E**xplorer



EarthCARE science objectives

Quantify **cloud-aerosol-radiation interactions** so they may be included correctly in climate and numerical weather prediction models to provide:

- Vertical distribution of atmospheric **liquid water and ice** on a global scale, their transport by clouds and radiative impact.
- **Cloud overlap** in the vertical, **cloud-precipitation** interactions and the characteristics of **vertical motion** within clouds.
- Vertical profiles of natural and anthropogenic **aerosols** on a global scale, their radiative properties and interaction with clouds.
- The profiles of atmospheric **radiative heating and cooling** through a combination of retrieved aerosol and cloud properties.

EarthCARE mission profile

ESA Earth Explorer Core Mission (Science mission)

Cooperation with JAXA/NICT

Currently at the end of phase B (preliminary design phase)

Orbit: polar sun-synchronous, 410 km, 389 orbits/25 days

mean local solar time 1400h at descending node

Single satellite with 4 instruments employed in synergy:

2 active: ATLID lidar + CPR radar

2 passive: MSI imager + BBR radiometer

Overview

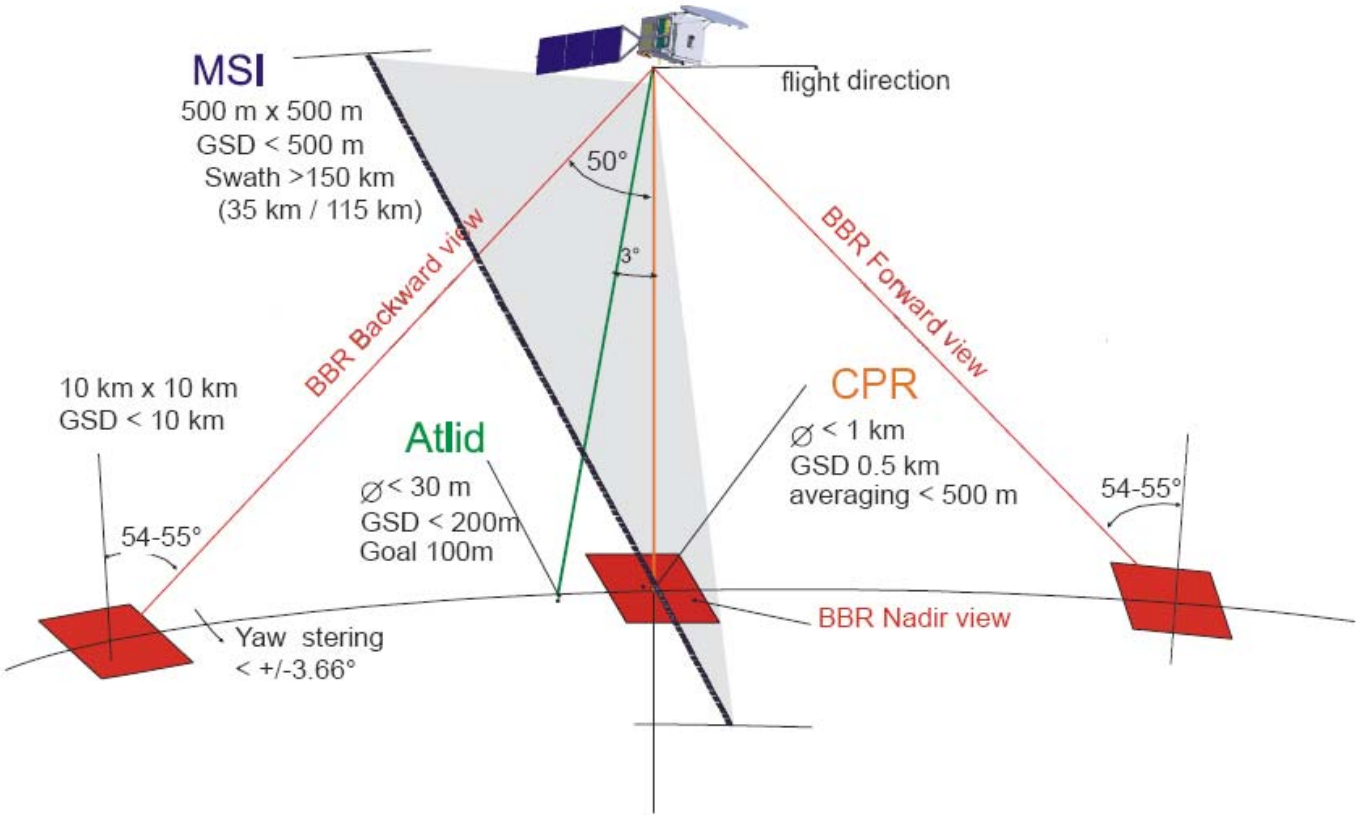
Scope:

Global simultaneous observations of

- Cloud & **aerosol** profiles, 3D structures
- Cloud-precipitation-convection
- Radiation and flux

Mission Concept:

- Cloud-**aerosol** HSR-lidar ATLID
- Cloud radar with Doppler CPR (JAXA/NICT)
- Cloud-**(aerosol)** imager MSI
- Broad-band radiometer BBR



EarthCARE instruments

Atmospheric Lidar (ATLID)

- Backscatter UV (355nm, circular pol.) with high spectral resolution receiver (HSRL)
- 3 channels receiver: Rayleigh scatter, co-polar Mie, cross-polar Mie
- Sampling: horizontal: 200m (=2x100m integrated), vertical: 100m
- 3 deg off-nadir (backwards) pointing to reduce specular reflection on ice clouds
- Required accuracy for AOD: 0.05 or 20 % (whichever is largest) for 100 km horizontal, 1km vertical integration

Cloud Profiling Radar (CPR), contribution of JAXA (see following talk by Igarashi-san)

- 94GHz with Doppler capability
- Sensitivity at least -35dBZ@20km height, Doppler accuracy: 1 m/s (both at 10km horiz.)
- Sampling: horizontal: 500m, vertical 100m (vertical resolution 500m)

Multi-Spectral Imager (MSI)

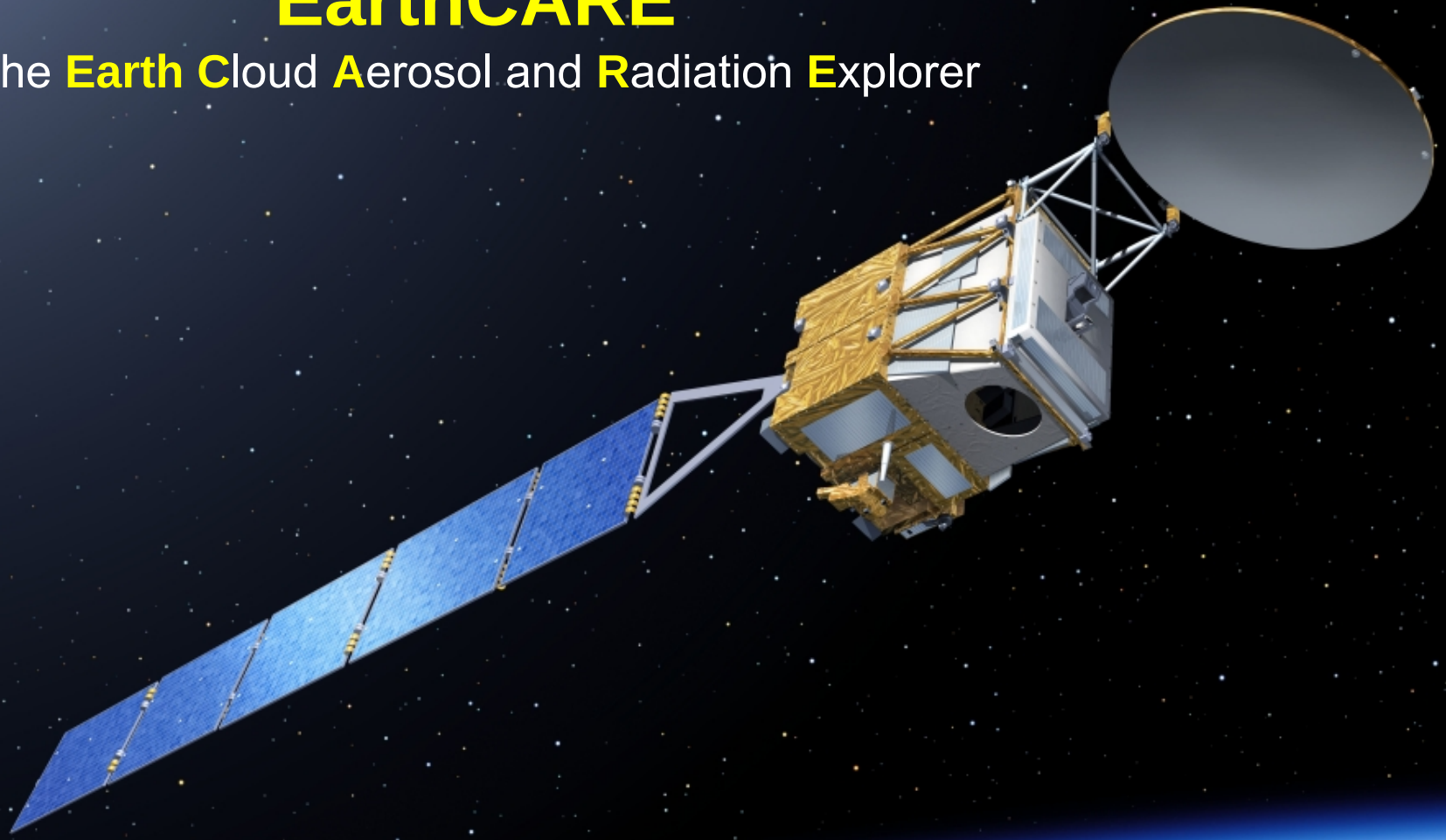
- 4 solar channels: Vis (670nm), NIR (865nm), SWIR1&2 (1.65µm & 2.21µm)
  3 TIR channels: 8.80µm, 10.80µm, 12.00µm
- Nadir viewing push-broom, swath: -35km to +115km (to minimize sunglint), $(500m)^2$ res.
- Products: scene identification, 'imager cloud products' (ice clouds, water clouds), **aerosols**, ...

Broad-Band Radiometer (BBR)

- Short-wave (0.25µm-4µm) and total wave channel (0.25µm-50µm)
- 3 views: nadir, forward (55deg), backward (-55deg), 10km x 10km pixels
- Products: TOA radiance and flux (goal: 10 W/m^2 accuracy)

EarthCARE

The **E**arth **C**loud **A**erosol and **R**adiation **E**xplorer



EarthCARE level 1 products

ATLID

Range corrected attenuated backscatter profiles (3 channels), corrected for cross-talk

CPR (produced by JAXA)

Radar reflectivity profiles
Doppler velocity profiles

MSI

Top-of-atmosphere radiances (4 solar channels) and brightness temperatures (3 thermal infrared channels)

BBR

Top-of-atmosphere *filtered* radiances (2 spectral channels, 3 views)

+ geolocation, error descriptors, quality flags

Single-instrument products (L2a)

ATLID
Feature mask
Target classification
Extinction, backscatter, depolarisation
Aerosol extinction, backscatter, type
Ice water content (empirical)

CPR
Feature mask
Target classification
Ice water content / eff. Radius
Liquid water content / eff. Radius
Vertical motion
Precipitation / snow

MSI
Cloud flag / cloud type
Cloud phase
Cloud top temperature / height
Effective cloud particle radius
Aerosol optical thickness

BBR
Unfiltered radiances (TBC)

Synergistic products (L2b)

ATLID+CPR
Ice water content / eff. Radius
Liquid water content / eff. Radius

ATLID+MSI
Cloud top height
Aerosol optical thickness
Aerosol type

ATLID+CPR+MSI
Target classification
Ice/liquid water content / eff. Radius
Aerosol extinction / type
Rain water content / rain rates
Cloud fraction and overlap
Reconstructed 3D scene
Reconstructed TOA radiances
Flux and heating rate profiles

BBR+MSI
Unfiltered radiances
TOA flux estimates

Synergistic products are provided on a common spatial grid

Level 2 products overview

CPR

feature mask
target classification
ice water content/
effective radius
liquid water content/
effective radius
vertical motion
precipitation/snow

ATLID

feature mask
target classification
α, β, δ
aerosol α, β
ice water content

MSI

cloud flag/type
cloud phase
cloud top T
effective radius
aerosol opt thickness
scene classification

BBR

unfiltered radiances

ATLID+CPR

Ice water content / eff. Radius
Liquid water content / eff. Radius

ATLID+MSI

cloud top height
aerosol optical thickness
aerosol type

BBR+MSI

unfiltered radiances
TOA flux estimates

ATLID+CPR+MSI

target classification
ice/liquid water content / eff. radius
aerosol extinction / type
rain water content / rain rates
cloud fraction and overlap
reconstructed 3D scene

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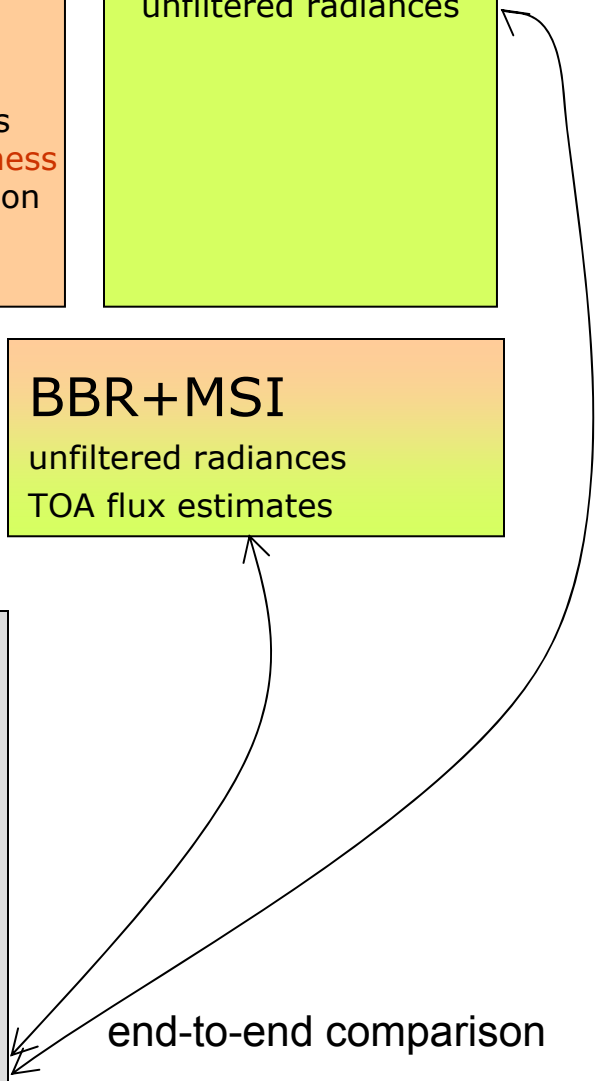
reconstructed TOA radiances
flux and heating rate profiles



EarthCARE aerosol products (Level 2a)

MSI (along-/across track)

Aerosol optical depth (AOD)
for ocean: at 659 and 865 nm
for land:at 659 nm

Ångstrøm exponent (ocean only)

ATLID (along track/vertical)

Target classification

Aerosol backscatter, extinction, depolarisation and Lidar ratio profiles

Aerosol type

Aerosol layer properties

Aerosol typing

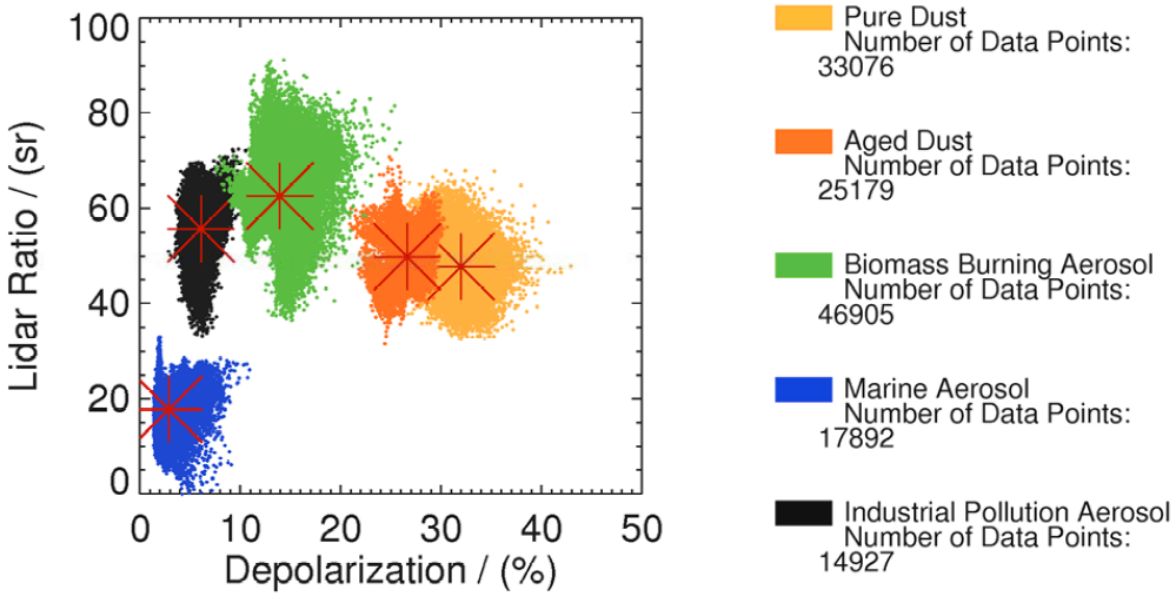


Figure 4. Depolarization- and lidar-ratios of various aerosol types measured by airborne HSRL.

EarthCARE aerosol products (Level 2b)

MSI + ATLID in synergy:

Target classification

Aerosol optical depth (AOD) at 355 and **550** nm

Ångstrøm exponent

Aerosol type

Aerosol products will be at 1 km (where possible) and 10 km horizontal and 100 m vertical resolution.

Currently under development in phase 1 (ATBD generation).

ATLID and synergistic target mask: KNMI (NL)
MSI: U Bremen (D), ATLID+MSI: IfT Leipzig (D)

Product accuracy

	MSI		MSI + ATLID		accuracy	
	ocean	land	ocean	land	ocean	land
AOD 355 nm			x	x	0.05	0.05
AOD 659 nm	x	x	x	x	0.10	0.15
AOD 865 nm	x		x		0.10	
Ångstrøm α	x		x	x		
aerosol type	x		x	x		

Product format

After user consultation and considering inter-agency format harmonisation

NetCDF-4/HDF 5

has been selected as EarthCARE product format.

Metadata convention (under development):

NetCDF CF (Climate and Forecast) merged with

CEOS GEOMS (Generic Earth Observation Metadata Standard)

Timeliness

Current EarthCARE requirements (no NRT!):

L0 within 1 orbit (92 min) *after downlink/reception*

L1 within 3 orbits (4 h 38 min) after L0 availability

L2 within 3 orbits (4 h 38 min) after L1 availability

Baseline: Single ground station Kiruna

Blind orbits: 6.5 out of 15.5 per day (42%)

NRT without blind orbits would require at least 2 ground stations, e.g., Svalbard (NH) and Troll (SH).

(New) ESA data policy (1)

Goals

Politically: Continue international trend for full and open access to EO data, promoting their widest possible use and sharing, in line with GEO data sharing principles, setting context for future data policies

Technically: Improve availability and ease access to EO data, using simple data dissemination system and interfaces to users

(New) ESA data policy (2)

Sentinels (operational)

Part of overall GMES data policy. Includes S1-S5 and S5 precursor.

- Anybody can (has the right to) access acquired Sentinel data (and information produced by GMES services)
- Licenses for the Sentinel data are free of charge
- Online access with user registration including acceptance of generic Terms & Conditions

Approved by ESA member states at PB-EO in Nov 2009
To be approved by EC and ESA council end 2010

(New) ESA data policy (3)

Earth Explorers (Science)

Will be aligned (retrofitted) to Sentinel data policy. Approval foreseen by mid-2010.

- Comprises majority of data available (except SAR/ASAR), for on-line data collections
- Full and open access to data, free of charge.
- User registration done electronically including user acceptance of ESA Terms & Conditions. T&C allow all uses (i.e. Research, Development of applications and Operations).
- Immediate on-line access to the dataset.

Data access (1)

Target

All products shall be available on an on-line storage (accessible via HTTP and FTP URLs)

Internet band-width available for downloading products from the on-line storage is correctly sized to fulfill user needs

Online Access

Download of systematically processed products

Use of Rolling Archives (TBD retention period)

Suitable for Near Real-Time production

The Enhanced Online Access Service virtually gives access to the complete mission archive (a few minutes of delays before a product can be downloaded)

Several generic and instrument specific tools: EOLi, MERCI, EWFS, E-OA FTP (Virtual File System)

Data access (2)

http://earth.esa.int/EOLi/EOLi.html

EOLi-SA client provides multi-mission interface for catalogue and ordering functions

Issues for discussion

Need for NRT delivery:
why? max # hours *from sensing*?
how useful would the current (non-NRT) latency be?

Aerosol classification:

Basic aerosol classes vs Aerosols as external mixtures of aerosol components