esa

# aerosol_cci

## Climate relevant aerosol retrieval over ocean from the ESA aerosol_cci project


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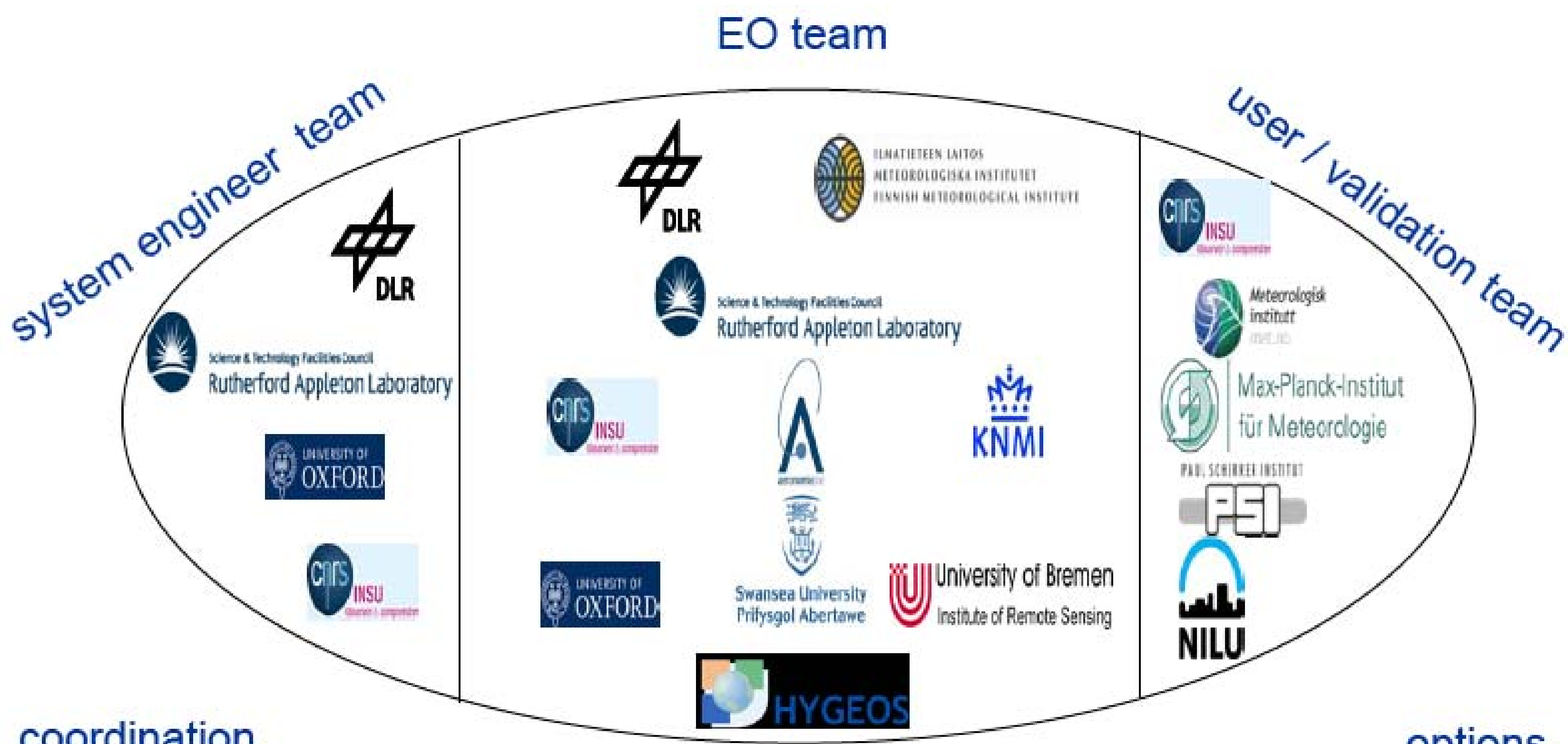
# aerosol_cci team




coordination

DLR, Ilmatieteen laitos / Meteorologiska institutet / Finnish Meteorological Institute

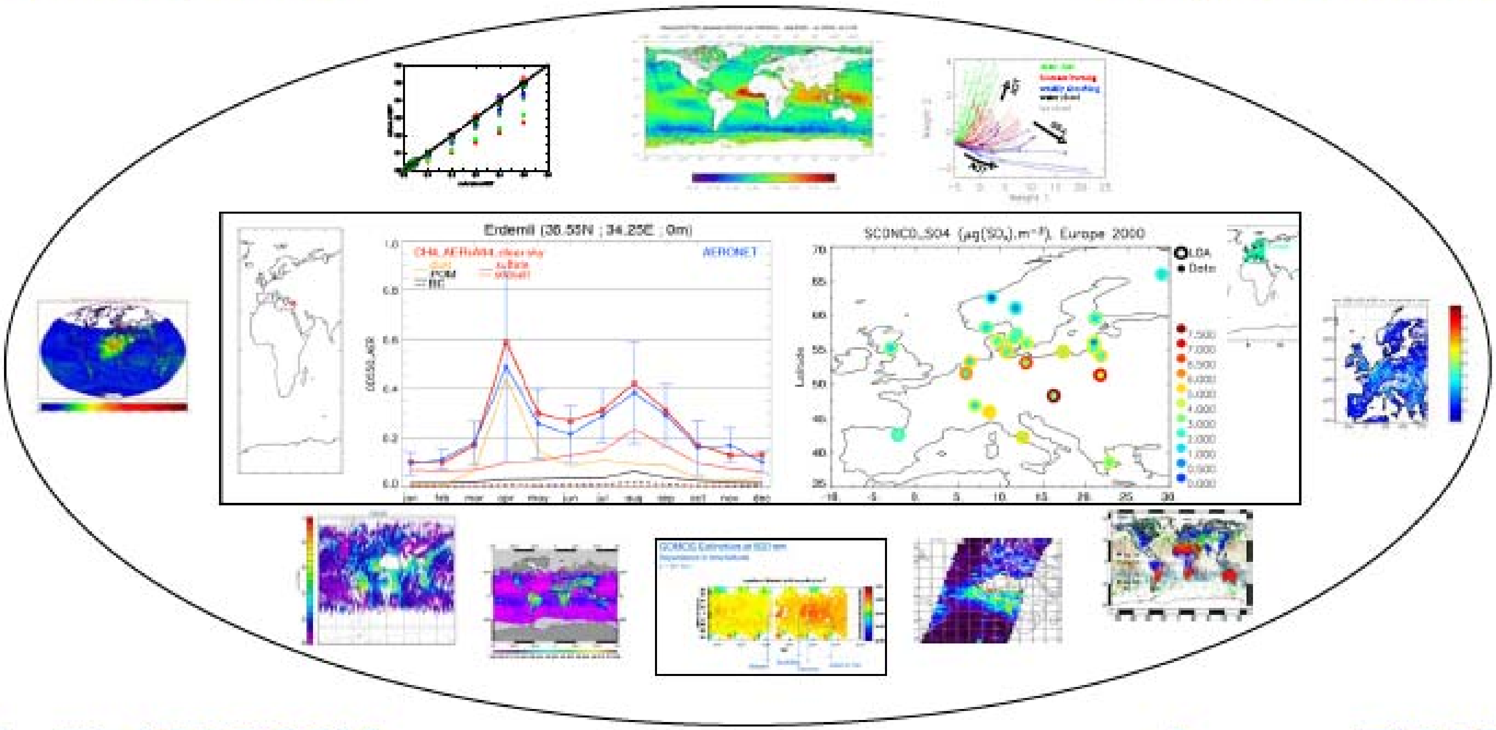
options

Freie Universität Berlin

# aerosol_cci concept

understand differences
of various products

integrate major
European EO teams




work with AEROCOM
user community

focus on ENVISAT
and European sensors

# aerosol scientific issues

- joint definition of **micro-physical / optical aerosol types**
  -> consistent inter-comparisons between different algorithms / use for all prototype ECVs

- **cloud masking** comparison and optimization between 4 ATSR and AVHRR/3 algorithms
  -> reference for sensors with lower resolution or smaller spectral coverage

- inter-comparison of different approaches for **treatment of surface reflectance and BRDF**
  -> optimal / combined solutions identified for ATSR, MERIS, POLDER instruments

- inter-comparison of **auxiliary data** used by the different retrievals
  -> harmonized datasets (elevation, land cover, ocean reflectance, BRDF, humidity, …)

- investigate **merging of datasets and pixel selection** / outlier screening
  -> proper error weighing for merging different AOD from complementary sensors

- **improve stratospheric limb products** (longitudinal dependence)
  -> correction of nadir products for volcanic cases

# approach

- **Three scientific workshops** early in the project with participation of external experts:
  - Aerosol **micro-physical and optical properties**
    - Set of common aerosol models for use in the round robin exercise
    - Climatology based on AERROCOM median
  - **Cloud detection** workshop
    - The presence of clouds leads to the retrieval of high AOD
  - **Treatment of surface reflectance and BRDF**
    - optimal / combined solutions identified for ATSR, MERIS, POLDER
- inter-comparison of **auxiliary data** used by the different retrievals
  - harmonized datasets (elevation, land cover, ocean reflectance, BRDF, humidity, …)
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  - correction of nadir products for volcanic cases

# GCOS requirements

- Aerosol optical depth

| | goal | threshold |
|---|---|---|
| • accuracy | 0.01 | 0.02 |
| • stability | 0.005 / decade | N/A |
| • resolution | 1 km / daily | 10 km / weekly |

- Other aerosol properties
    - to supplement AOD
    - e.g. single scattering albedo

| | |
|---|---|
| • accuracy | 0.02 |
| • stability | 0.015 / decade |

- Comprehensive ground-based independent validation

-> can not be met (**per pixel**) by any satellite product

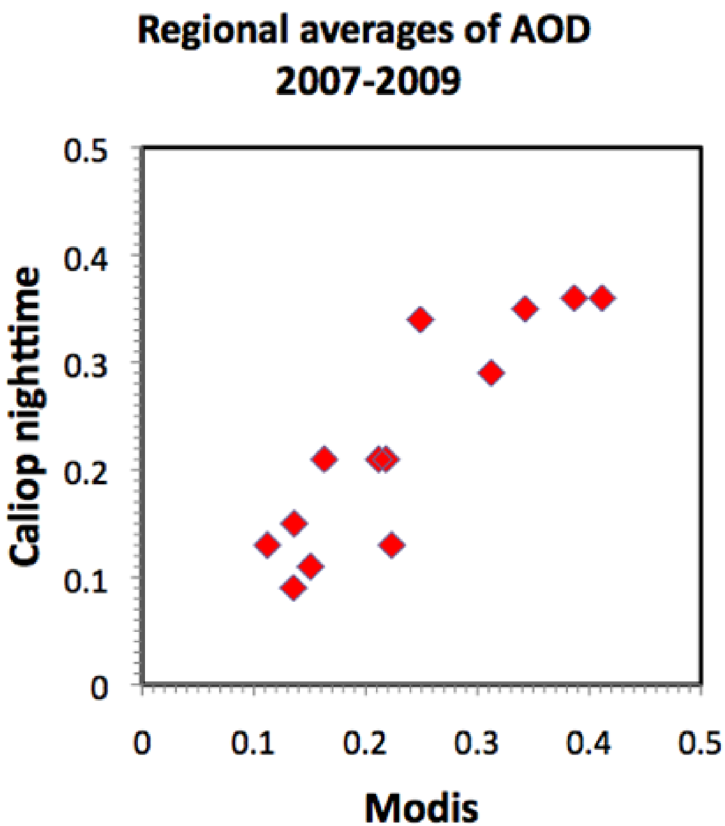
The GCOS requirements are under revision!

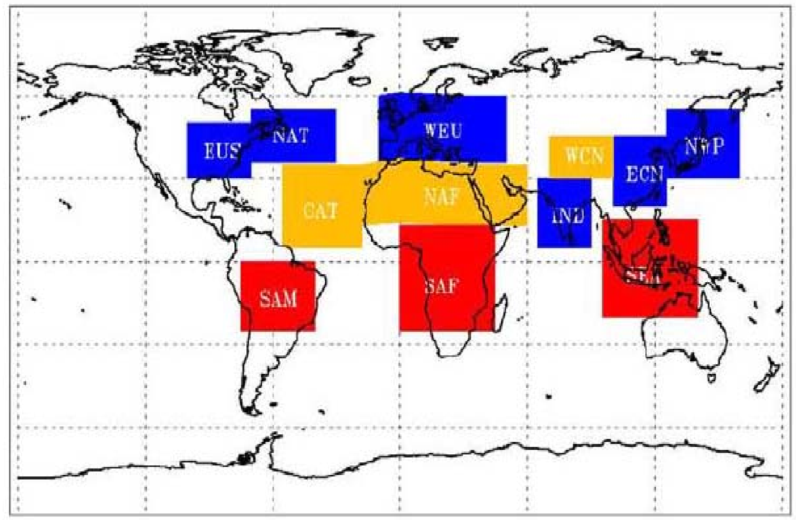
# User requirements

- GCOS as baseline, elaborated by AEROCOM (model development, trend monitoring) and MACC (assimilation for re-analysis)
- Overall user needs: eEasy availability (netCDF), proven and documented quality, aerosol species linked to source categories, observation of long-term trends (many years) for regions and globally, prepare for easy and complete re-processing with new versions
- Level2 products for data assimilation: AOD at 4 wavelengths (440, 550, 670, 870 nm) and several layers
  - 500 (1000) level 2 observations globally per hour
  - with pixel level uncertainty (random + systematic)
  - consistent with clouds and fire

- Level3 products for model comparison: Ångström coefficient (440-870), fine mode fraction (D<1μm), dust fraction
  - Absorption aerosol optical depth (or single scattering albedo)
  - Aerosol vertical extinction / AOD profile (any information is valuable)
  - Accuracy: combined absolute (low AOD) and relative (high AOD)
  - Error characteristics

# User requirements




derived stability need

regional AOD range (0.1 – 0.5) * 5% trend detection -> 0.005

# User requirements

| **Satellite variable (reference dataset)** | **required RMS at superpixel level of 10x10 km$^2$** | **required RMS at climate model grid level of 1°x1°** | **required RMS at regional level of 1000x1000 km$^2$** |
|---|---|---|---|
| Aerosol optical depth at 550nm and other wavelengths (Aeronet global dataset daily mean) | 20% or 0.05 | 10% or 0.02 | 0.02 |
| Fine mode fraction (Aeronet global dataset daily mean) | 20% or 0.1 | 20% or 0.1 | 0.1 |
| Dust fraction (Coarse fraction from Aeronet global dataset in known dusty conditions daily mean) | 30% or 0.2 | 30% or 0.2 | 30% or 0.2 |
| Absorption optical depth (Absorption optical depth computed from SSA and size of Aeronet daily mean) | 20% or 0.05 | 20% or 0.02 | 0.02 |

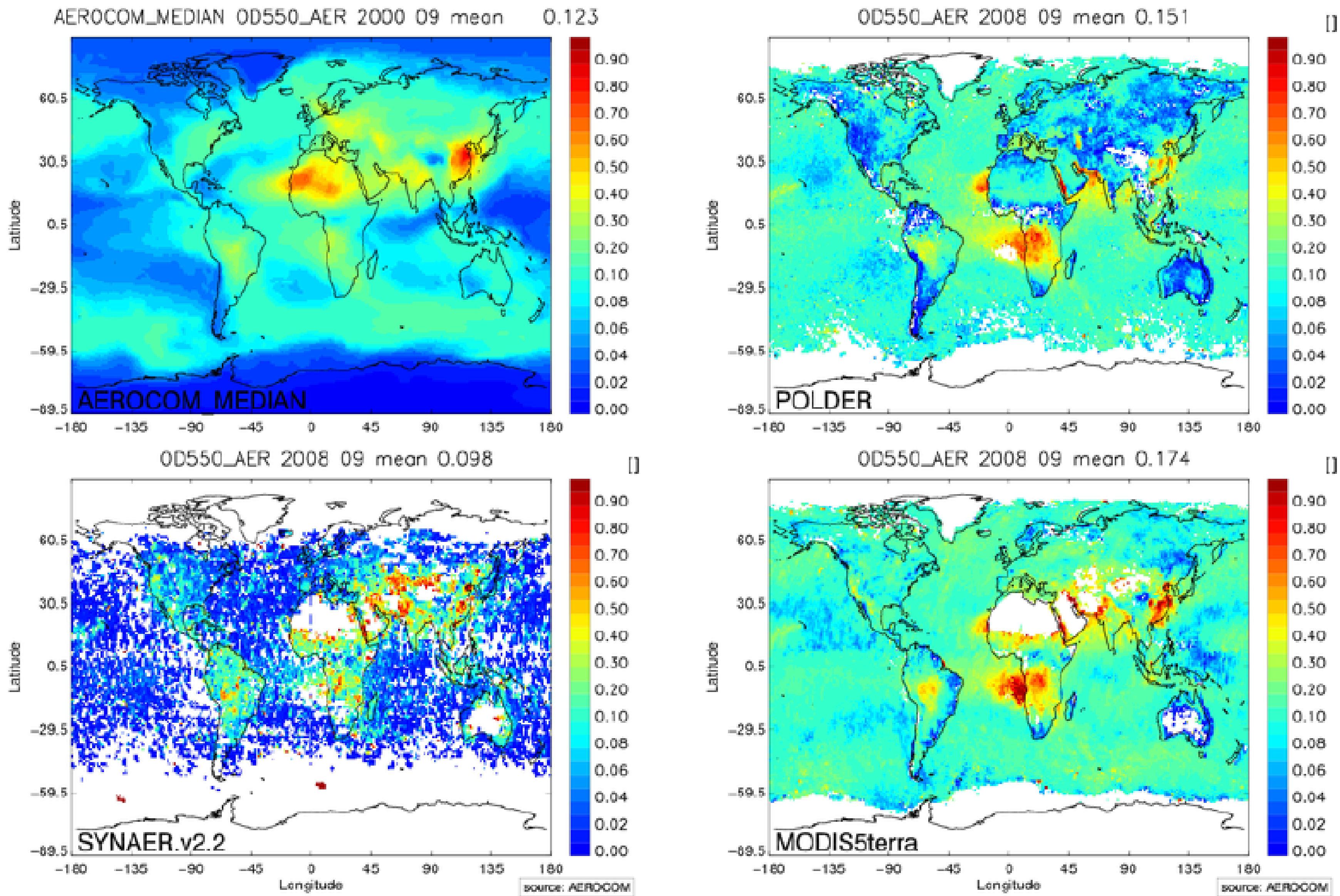
# Product Specification

<table>
<tr><th>Product name</th><th>Parameter(s)</th><th>sensors</th><th>level</th><th>comment</th></tr>
<tr><td colspan="5">Tropospheric / total column products</td></tr>
<tr><td>Single-sensor<br>AOD / type</td><td>Multi-spectral AOD<br>Aerosol type<br>probability</td><td>ATSR-2 / AATSR<br>MERIS<br>POLDER</td><td>Level2,3</td><td rowspan="4">Multi-spectral AOD depending on instrument caabilities<br><br>Ångström coefficient can be derived from multi-spectral AOD.<br>Aerosol type may include information on fine / coarse mode fraction and chemical components, which together best describe the observations</td></tr>
<tr><td>Synergetic<br>AOD / type</td><td>Multi-spectral AOD<br>Aerosol type<br>probability</td><td>AATSR/SCIAMACHY<br>ATSR-2/GOME<br>AVHRR/GOME-2</td><td>Level2,3</td></tr>
<tr><td>AAI</td><td>Absorbing aerosol index<br>averaging kernel</td><td>OMI<br>SCIAMACHY<br>GOME</td><td>Level2,3</td></tr>
<tr><td>Merged AOD / type</td><td>Multi-spectral AOD<br>Aerosol type<br>probability</td><td>Combining several level2 with appropriate weighing</td><td>Level3</td></tr>
<tr><td>Aerosol type<br>“climatology”</td><td>Aerosol type probability / dominant aerosol type</td><td>All AOD products</td><td>Level3</td><td>Based on one year of data</td></tr>
<tr><td colspan="5">Stratospheric products</td></tr>
<tr><td>Extinction</td><td>Gridded extinction profile</td><td>GOMOS<br>(SCIAMACHY)</td><td>Level3</td><td></td></tr>
</table>

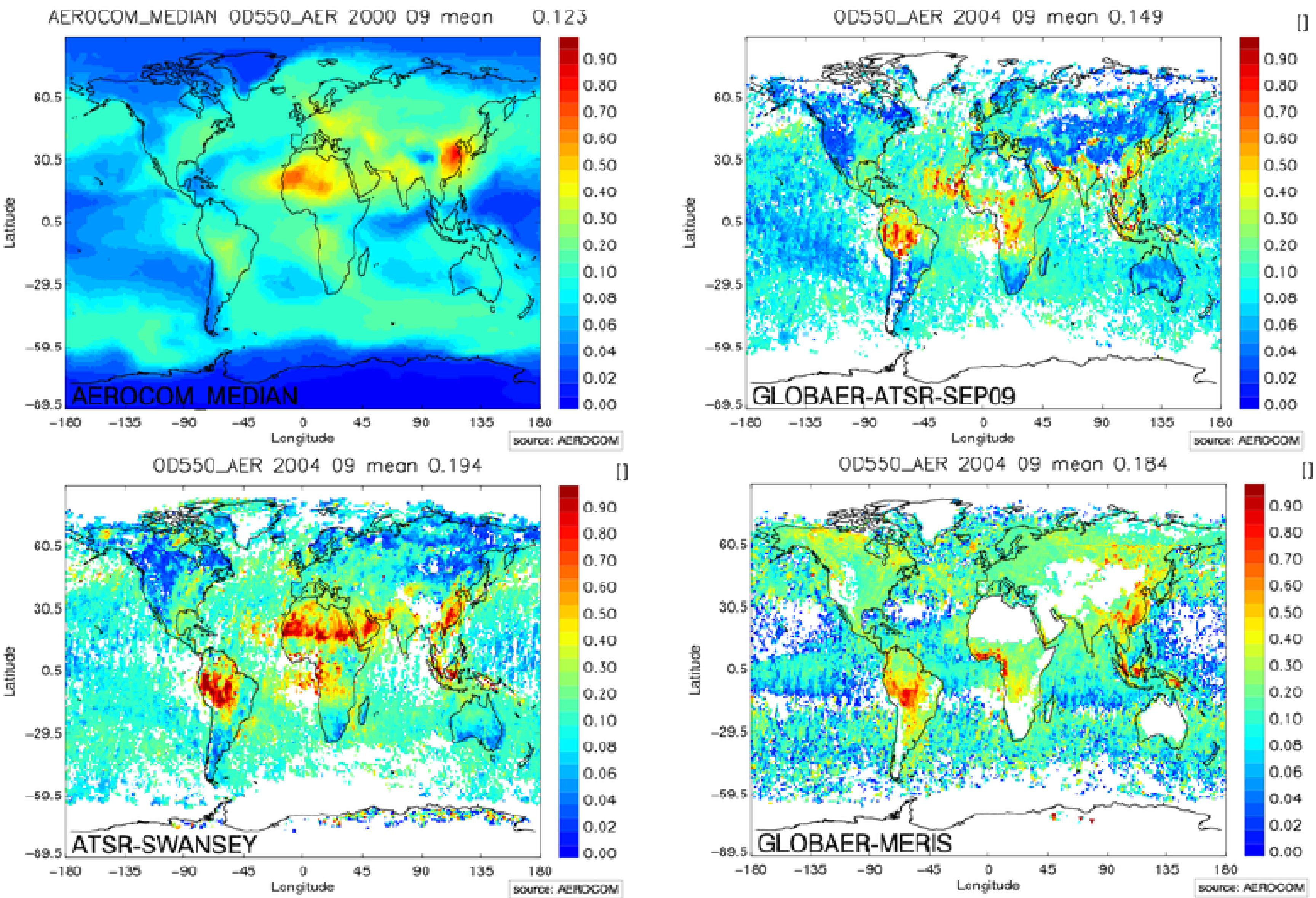
# Analysis Tools

- ICARE statistical inter-comparison (level2)
  - versus AERONET
  - versus other satellites (MODIS, MISR, POLDER)
- MPI scoring (level2)
  - spatial patterns, bias, noise
  - versus AERONET
- AEROCOM model inter-comparison (level3)

# Analysis Tools



# Analysis Tools



## Approach

- Define common small set of components for inter-comparisons
- Aerosol types are determined by mixing of the 4 basic components
- Provide aerosol climatology based on AEROCOM median

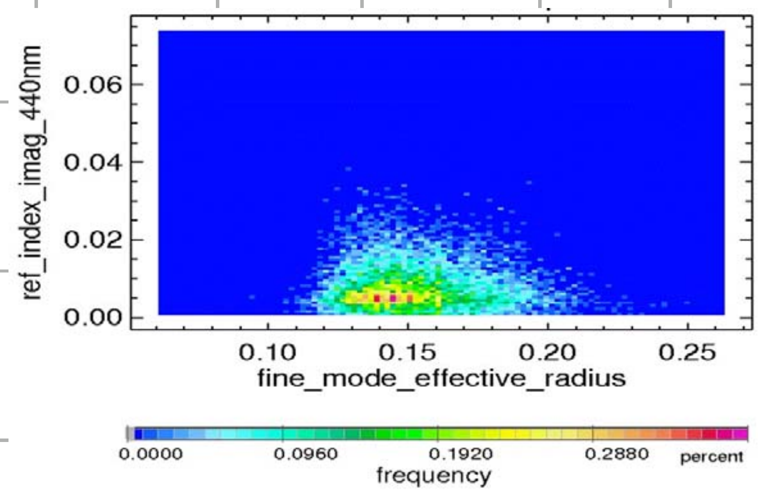
Possible algorithm test datasets:

- AOD retrieval with fixed aerosol component mixtures as determined by the AEROCOM median climatology;
- AOD retrieval where the occurrence of one mode (or mode mixture) is taken from the AEROCOM median, but the mixing ratio of the fine and coarse components is determined from the satellite data: both FMF and CMF can vary to match radiance and its wavelength dependence;
- Free retrieval of AOD and type selection.

# Aerosol Optical Properties

Table 1. Parameters describing the microphysical and optical properties of the aerosol components used in the Aerosol-cci round-robin excersizes.

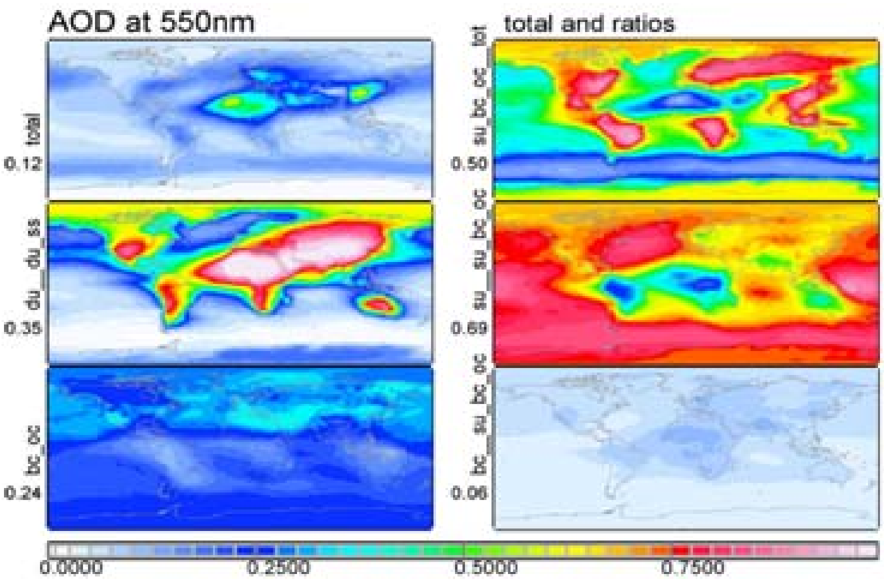
| Aerosol Component | Real part Refr Index (550 nm) | Im Part Refr Index (550 nm) | Reff* (μm) | Geom. st dev ($\sigma_i$) | Variance (ln $\sigma_i$) | Geom. mean radius ($\bar{r}_{gi}$, μm) | Comments | Aerosol layer height |
|---|---|---|---|---|---|---|---|---|
| Dust§ | 1.56 (varies with wavelength)§ | 0.0018 (varies with wavelength)§ | 1.94 | 1.822 | 0.6 | 0.788 | Non-spherical | Fixed hgt at 2-4km |
| Sea salt | 1.4 | 0 | 1.94 | 1.822 | 0.6 | 0.788 | AOD threshold | 0-1 km |
| Fine mode very weak-abs | 1.4 | 0.003 | 0.142 | 1.7 | | | | |
| Fine mode strong-abs | 1.5 | 0.040 | 0.142 | 1.7 | | | | |



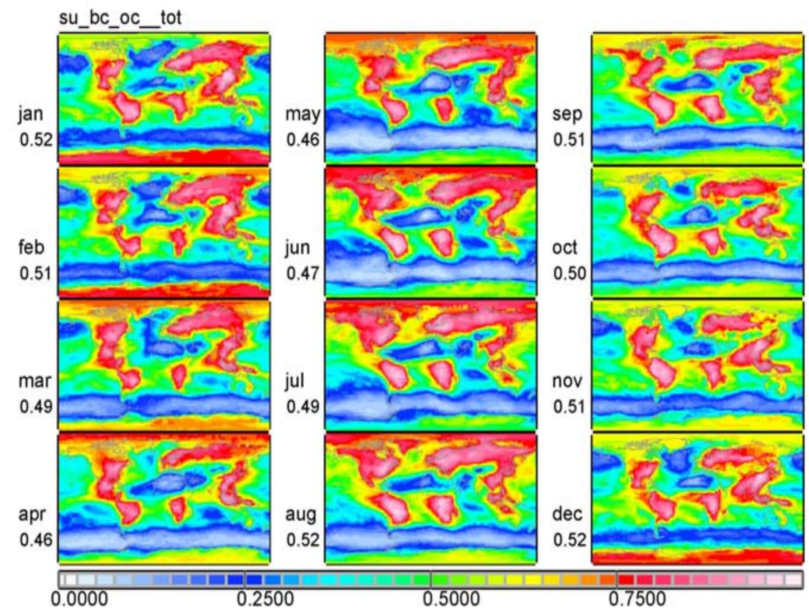

§Dubovik et al., 2002

# Aerosol Optical Properties

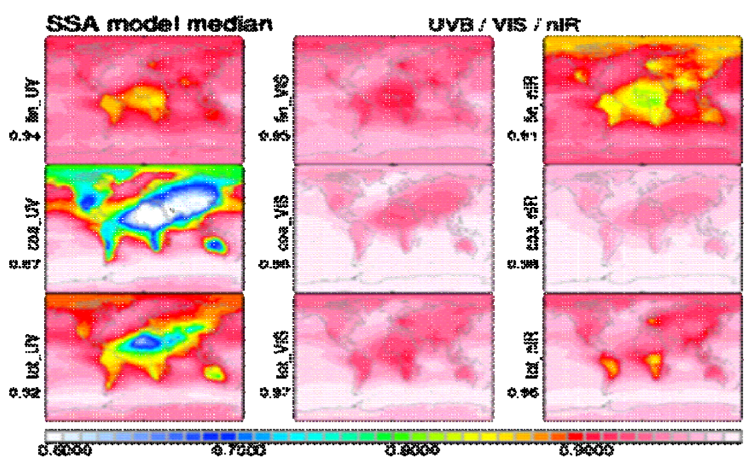
## AEROCOM median




AOD fractions;
example: annual




Fine mode fraction;
example: monthly



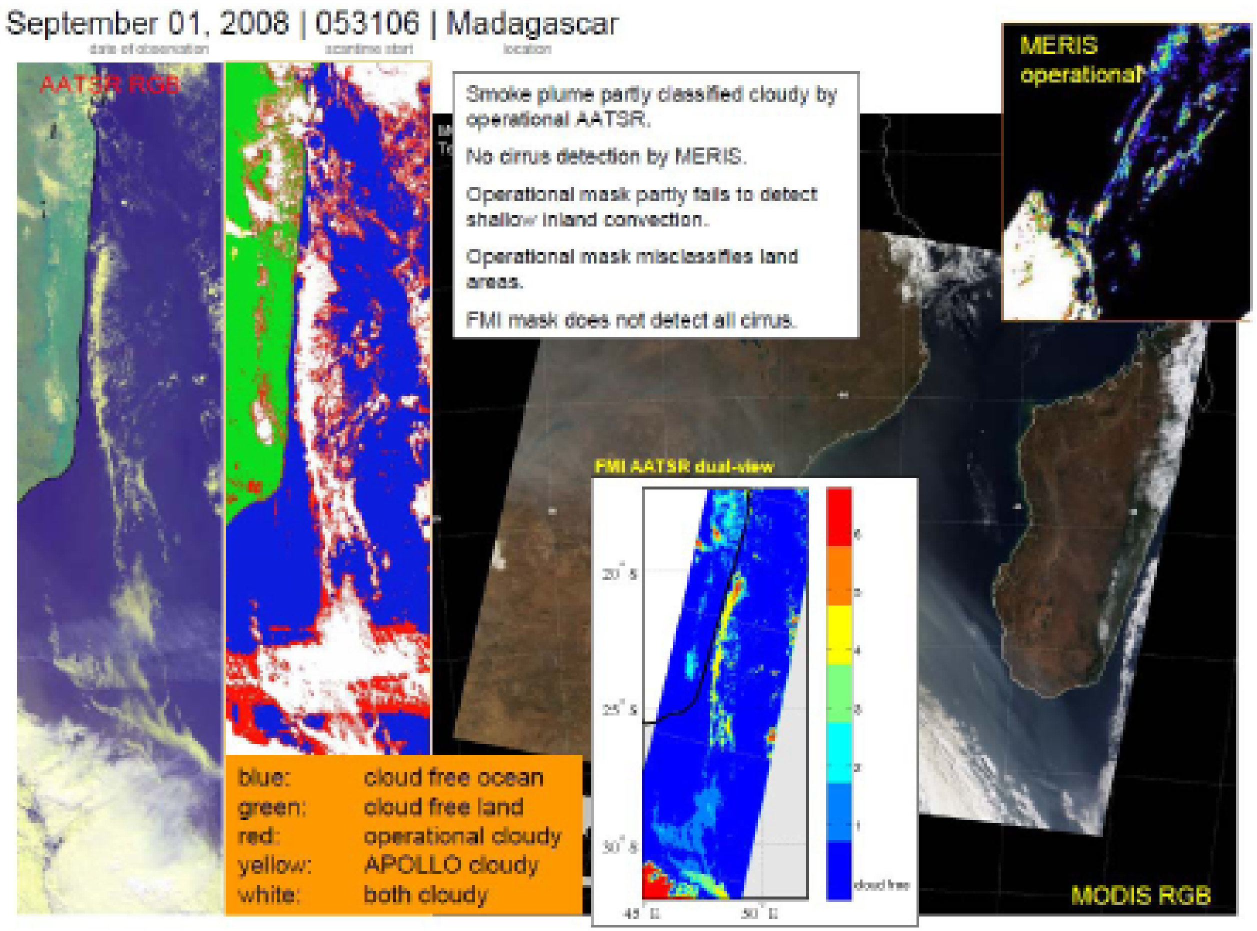

SSA: UVB VIS NIR

# Cloud detection

- Compare different cloud masks
  - various AATSR algorithms
  - AATSR versus MERIS
  - information content of PARASOL
- Transfer to larger spectrometer pixels
- Prepare common cloud mask for selected inter-comparison
- Compare to external reference datasets (SYNOP, MODIS/CALIPSO)

# Cloud detection

Single scene analysis



# Cloud detection

## Use of cloud information in the Aerosol_CCI Round Robin exercise

- 17 ENVISAT single scenes (AATSR, MERIS) have been analysed, using MODIS Terra true colour RGB images for comparison
- OMI and PARASOL are in afternoon orbit and have been compared with MODIS Aqua
- These comparison revealed the strengths and weaknesses of the various participating algorithms.

**Recommendations:**

- The working group recommends using APOLLO as common cloud mask for retrieval exploiting ENVISAT sensors for the Round Robin exercise
- APOLLO has much lower sensitivity to cloud edges than the operational AATSR cloud mask. Without substantial evaluation of the cloud masks through comparison with external data it is not clear if the APOLLO sensitivity is too low or the sensitivity of the operational mask is too high (see e.g. Koren et al., 2007; Koren et al., 2008). Thus for the Round Robin a rather conservative safety zone filtering is important which also will be used for evaluation.
- PARASOL cloud information can be used for cloud contamination analysis in the OMI AAI retrieval in the Round Robin exercise

# Surface treatment

- Analyse different approaches (multi-angle, multi-spectral, polarisation)
- Over ocean use common auxiliary datasets and modules
- Analyse critically independence from other retrieval results (e.g. Globcolour)
- Over land compare with external reference reflectance (e.g. MODIS)
- Test use of common BRDF dataset (MODIS, POLDER)

# Surface treatment

## Approach

(i) Direct comparison of the retrieved surface reflectance (interim output) between the various algorithms

(ii) Comparison of the retrieved surface reflectance (interim output) versus a selected subset of the AERONET-based Surface Reflectance Validation Network (ASRVN) (Wang et al., 2009), to make use of the MODIS BRDF estimates in sensor intercomparison and in prescribed reflectance experiments

(iii) to compare aerosol retrieval AOD where all surface reflectance is fixed to a common estimate

# Surface treatment

## Ocean Surface: preliminary WG recommendations

**Wind speed**

A single wind speed database will be made available to allow estimation of white caps and glint. The ECMWF ERA-INTERIM 6h data reanalysis data linearly interpolated to a sinusoidal grid with resolution of 1°x1° or higher, to include directional wind vector information – this interpolation will be made by UOxford.

**Common model to relate wind speed to white caps**

The Koepke (1964) model is commonly used, but recommendation of a single 'best' model is still to be defined. Monahan and O'Muircheartaigh (1980) for whitecap fraction?

**Glint**

Use of the Cox and Munk model is recommended

**Chlorophyll/Gelbstoff**

We propose use of GlobColour database in the 1 month test dataset processing – however, for later production we need to understand the "chicken and egg" problem and assure independence of our dataset from another dataset that relies on atmospheric correction using aerosol assumptions.

**Common model to calculate water leaving reflectance from chlorophyll/Gelbstoff**

This should be combined with above Chlorophyll/Gelbstoff – aerosol_cci teams should avoid each recalculating the ocean internal processes.

**Common model for spectral dependence of whitecaps**

The model of Kokhanovsky (2004) is recommended.

**Common flagging of coastal water**

Coastal water should be flagged for its higher uncertainties (liaise with new COASTCOLOUR project) – we will define a 'safe' distance from nearest coastline.

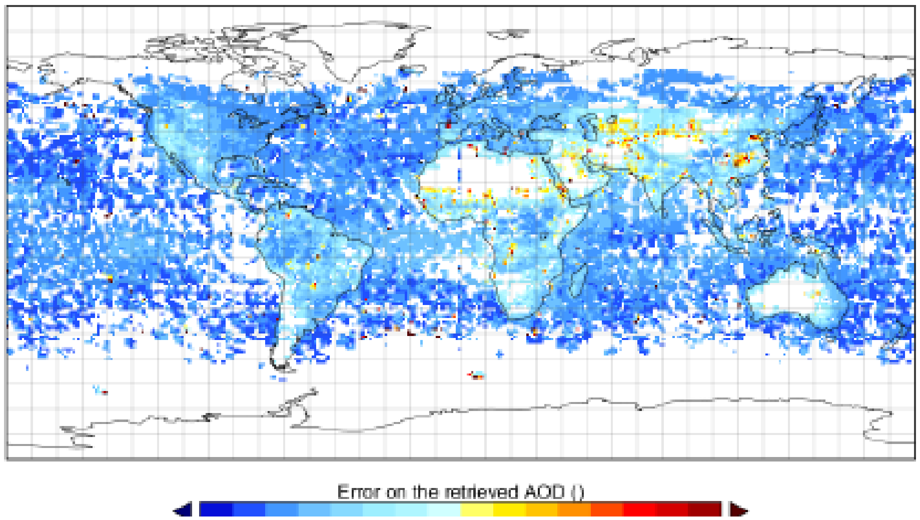
# Product uncertainties

## An example: synergetic retrieval algorithm (first estimation based on validation results)

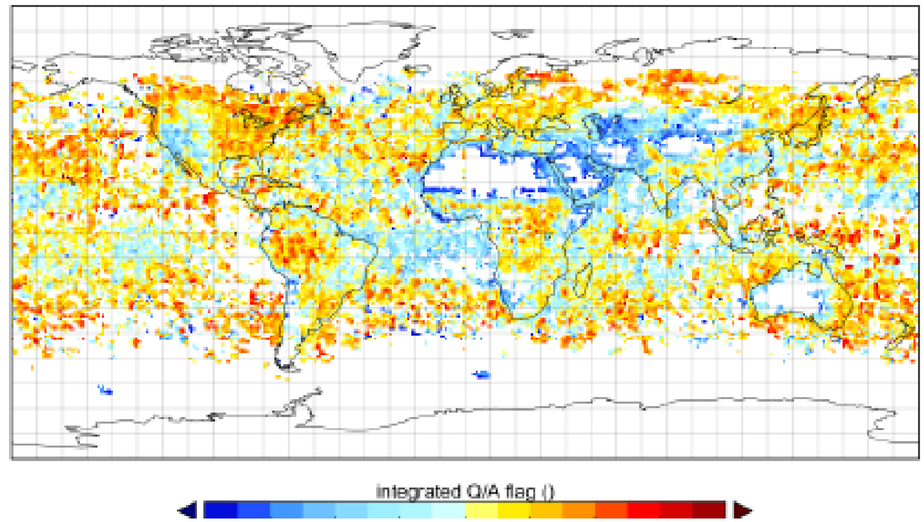
| **Error source** | **Absolute error contribution** | **comment** |
|---|---|---|
| calibration | TBD | Can be critical |
| Radiative transfer | negligible | Error due to Mie calculations for dust TBD |
| Noise due to pixel size | 0.05 | Varies for different continents |
| Cloud fraction | TBD | Validation showed that pixels up to cloud fraction of 35% can be exploited for the retrieval |
| Surface reflectance | Land: 0.05 – 0.15 (for visible surface reflectance from 0 – 0.25)<br><br>Ocean: 0.03 – 0.1 (for visible surface reflectance from 0 – 0.05) | |
| Choice of wrong aerosol type (spectral extinction, absorption, phase function) | 0 – 0.2 for AOD550 0. – 1. | Is estimated for each pixel by identifying ambiguous aerosol types through comparing quality of fit with difference between aerosol types with similar spectra) |

# Product uncertainties

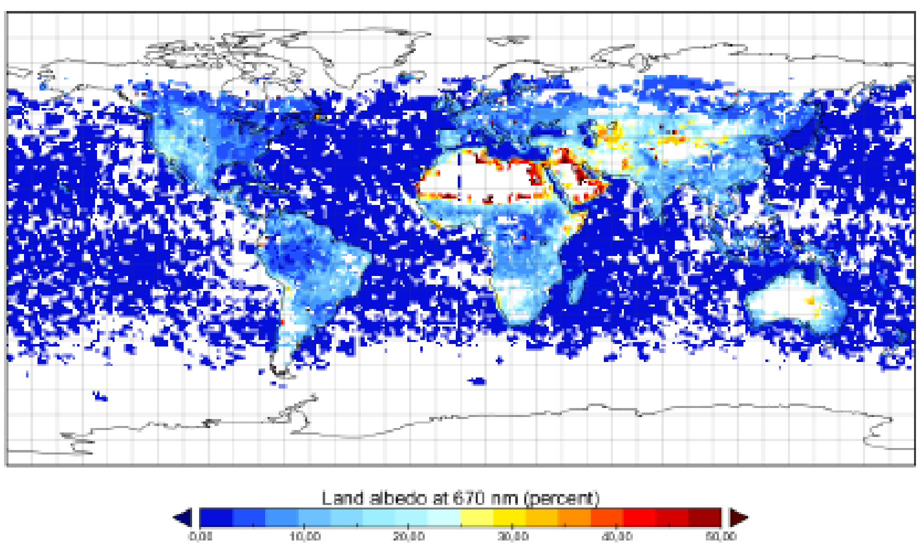
Error on the retrieved AOD



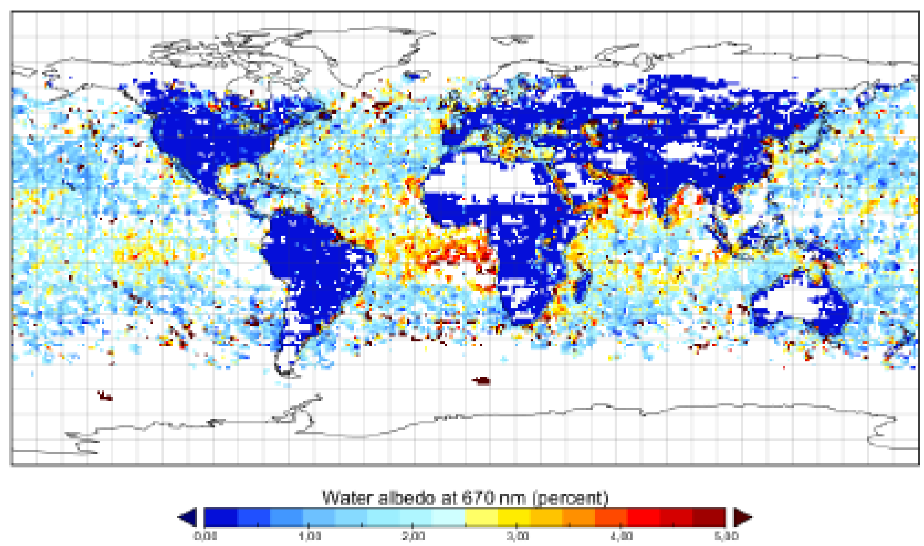

integrated Q/A flag




Land albedo at 670 nm




Water albedo at 670 nm



# Conclusion

- phase 1 (summer 2011) analysis of various retrieval versions
  - test dataset global September 2008
  - 8 tropospheric algorithms
- phase 2 (autumn 2011) round robin
  - dataset global March, June, September, December 2008
  - 8 tropospheric algorithms
- phase 3 (autumn 2012)
  - ECV production global all 2008 (baseline)
  - 5 tropospheric algorithms + merged dataset(s)
- validation with established tools in all stages
- evaluation by AEROCOM (MACC)

# title

Thank you for your attention