climate change initiative

→ AEROSOL NEWSLETTER

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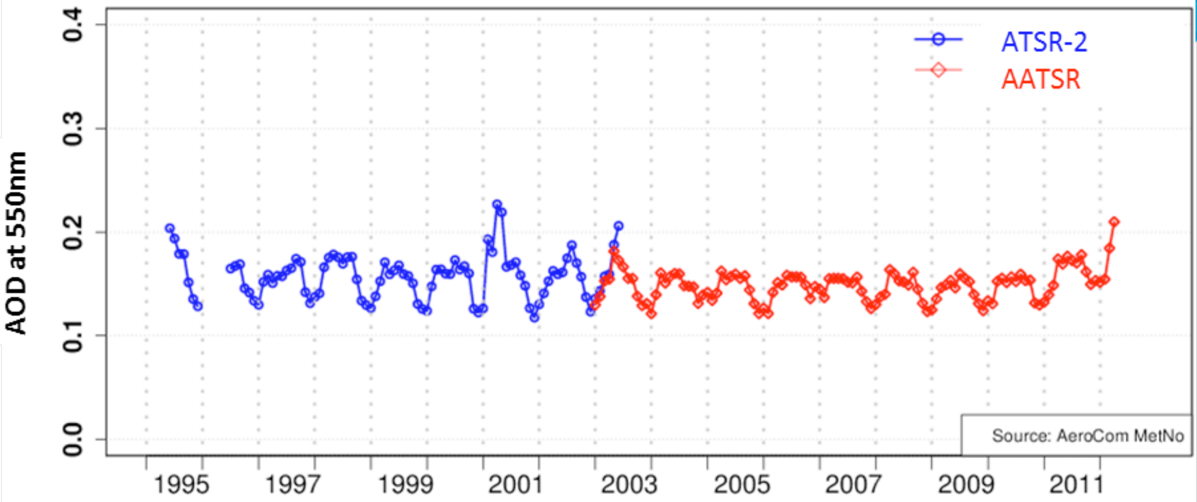

Figure 1: 17 year ATSR-2/AATSR AOD time series

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ATSR 17 year Aerosol Optical Depth (AOD) datasets

A first fully evaluated 17-year Essential Climate Variable (ECV) time series of Aerosol Optical Depth (AOD) from the two subsequent instruments ATSR-2 and AATSR is available. Reprocessed time series with three improved algorithms are currently validated.

The dual view instruments ATSR-2 (Along Track Scanning Radiometer No. 2, on board the ERS-2 platform from 1995 – 2002) and AATSR (Advanced ATSR, on board ENVISAT 2002 - 2012) have been used to retrieve a 17 year Essential Climate Variable (ECV) time series 1995 – 2012 of the Aerosol Optical Depth (AOD). The dataset contains pixel level AOD uncertainties.

The time series was thoroughly validated (AOD and uncertainties; global, regional, seasonal; separately over land and water) by independent experts through comparison to ground-based reference measurements (AERONET, MAN) and to other satellite AOD products (MODIS, MISR, SeaWIFs). AOD maps in the 8 month overlap period of the two sensors were assessed to ascertain the small deviations. The long-term stability of the retrieved AOD and AOD uncertainties were proven by annual statistics of the validation. The quality of the retrieved AOD values was shown to be similar to other satellite datasets, however for larger AOD values turned to be slightly weaker.

This dataset reaches back in time until 1995, which provides unique information. The pixel-level uncertainties need further absolute improvement, but contain valuable seasonal/regional characterization of retrievals with more or less accurate results.

Cycles of annual algorithm improvement and re-evaluation are ongoing by three teams to reduce remaining errors in cloud masking, surface treatment and assumed aerosol properties. Three new validated datasets, which also include more aerosol properties such as fine mode AOD, are expected in November 2015. The usefulness of the dataset for model comparisons, trend analysis and anomaly detection was demonstrated. Fig. 1 shows the global average AOD time series from the two ATSR instruments.

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Upcoming meetings

Aerosol_cci will hold two user workshops in October 2015 and April 2016 to discuss user needs and selected applications. As backbone to continued algorithm improvement, the International Satellite Aerosol Science Network AEROSAT is convened in October 2015.

Close collaboration with users of the ECV datasets is key to assure their usefulness. For this purpose, a Climate Research Group embedded into the Aerosol_cci project and the Climate Model User Group of the Climate Change Initiative (CCI) have been accompanying the algorithm development as advisors from the start of the project. Furthermore, they conduct independent validation of the products. To reach out to wider user communities, dedicated user workshops are organised, where possible in association with relevant user communities.

The first, on 14 and 15 October 2015 will be hosted by the Eidgenössisch-Technische Hochschule Zürich and bring together selected representatives of different user communities, such as model development (AEROCOM), stratospheric chemistry (CCMI), re-analysis / data assimilation (ECMWF/MACC), climate research (university Reading).

The second user workshop will be coordinated with a meeting of the IGBP/IGAC/WCRP initiative on "Aerosols, Clouds, Precipitation and Climate" (ACPC) and the Cloud_cci project at Oxford university on 13-15 April 2016 with a focus on aerosol-cloud interaction.

AEROSAT, the International Satellite Aerosol Science Network, which was initiated by Aerosol_cci will bring together satellite aerosol retrieval experts from ESA, NASA, EUMETSAT, NOAA, CMA, JAXA and users of the AEROCOM model community on 8 and 9 October 2015 in Frascati. Discussions will focus on the evolution of approaches for pixel level uncertainty calculation and aerosol type definition in satellite retrievals. Furthermore, interaction on the concrete needs for those two aspects from model users will be conducted.

GOMOS 10 year stratospheric aerosol dataset

A 10-year dataset of stratospheric extinction profiles and integrated stratospheric aerosol optical depth form the star occultation experiment GOMOS was processed and is currently evaluated. Additional information (higher temporal resolution, particle size) is under evaluation and will be contained in the next annual dataset release.

Star occultation observations of the "Global Ozone Monitoring by Occultation of Stars" (GOMOS) instrument on board ENVISAT from 2002 – 2012 have been exploited to retrieve monthly average vertical profiles of aerosol extinction above the tropopause. The deduced stratospheric AOD dataset is needed for a correction of total column AOD algorithms. Vertically resolved aerosol is needed to study the impact of volcanic eruptions on stratospheric chemistry and the interaction with the climate.

Validation of the GOMOS stratospheric dataset is currently conducted by comparison to ground-based reference datasets (NDAAC), other passive or active satellite instruments (OSIRIS, SAGE, CALIOP) and stratospheric chemistry models. The evaluation extends to additional information on particle size (Angström coefficient) and experimentally processed weekly resolved datasets (with then weaker spatial resolution). Figure 2 shows the 550 nm monthly extinction profiles as latitudinal averages at 25, 20 and 18 km altitude (from top to bottom).

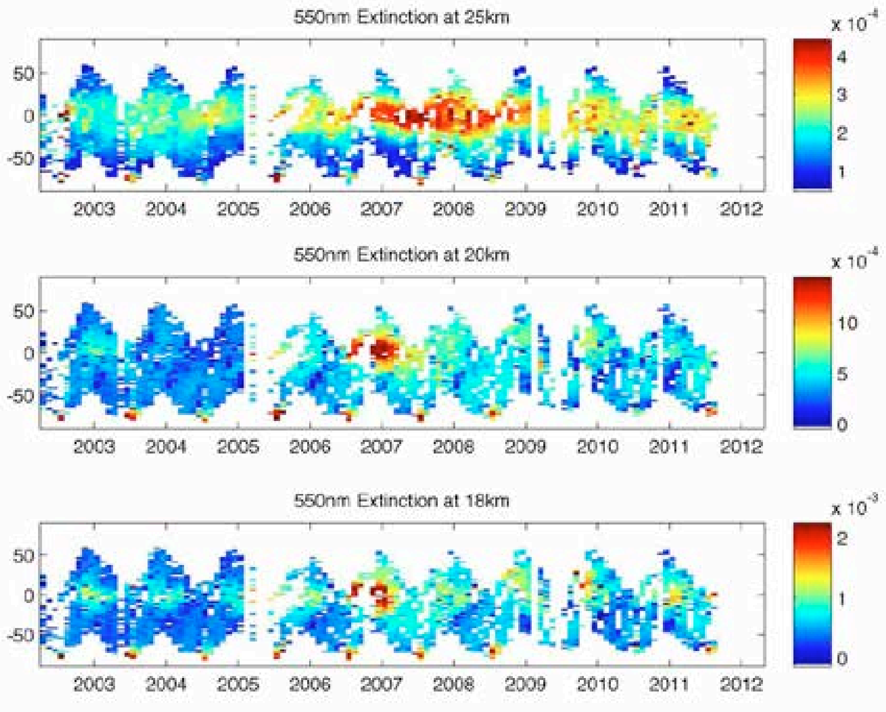

Figure 2: 10 year stratospheric extinction from GOMOS at 3 altitudes

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POLDER aerosol properties diagnostic sites

A multi-pixel algorithm exploits POLDER observations, which have the highest information content for aerosol and surface properties. This complex algorithm is used to process a reference dataset at four "diagnostic sites" of each 1200 x 1200 km^2 – this reference dataset can then serve for validation of other satellite aerosol datasets.

The "Polarization and Directionality of the Earth's Reflectances" (POLDER) instrument on board of PARASOL provides the largest number of independent observations for each pixel including multi-spectral, multi-directional and polarization information. This allows to acuurately retrieve several properties of atmospheric aerosols and the underlying surface at the same time.

The retrieval of aerosol and surface properties from POLDER is conducted with the multi-pixel algorithm GRASP (Generalized Retrieval for Aerosol and Surface Properties) which is based on the algorithm used to infer aerosol properties from ground-based sun-photometer (AERONET) observations. In addition to the POLDER measurements GRASP exploits constraints on the smoothness of aerosol properties (in space) and surface properties (in time).

Since GRASP has to process the spatial and temporal surrounding for each pixel, it can so far not be applied to a 10 year global dataset. However, it was applied to 1 year of data over Africa and to four selected regions of each 1200 x 1200 km^2. Those four regions are near Oklahoma, Banizoumbou, Mongu, and Bejing covering different regimes with the major aerosol types on the globe (industrial, desert, biomass burning).

In a first step, POLDER observations themselves were validated against AERONET ground-based reference data to establish the GRASP product quality. Thorough analysis was able to identify a correlation between an algorithm-intrinsic fit quality parameter and the accuracy of the retrieval output. Accordingly, highest quality GRASP-POLDER results can thus be used as quasi-reference for validating other satellite aerosol retrievals in regions, where only sparse AERONET ground-based observations are available. The full 10 year dataset from POLDER over the selected four "diagnostic sites" will be processed with GRASP for this purpose. Figure 3 shows an example seasonal average of GRASP retrieval output: AOD and SSA (single scattering albedo).

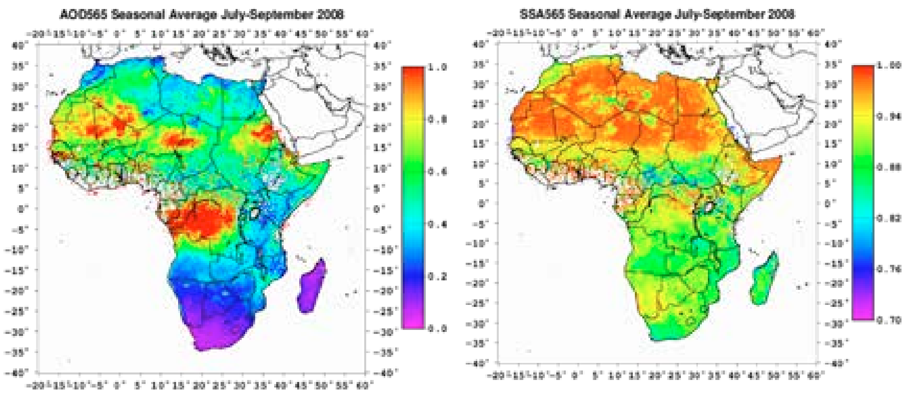

Figure 3: POLDER summer 2008 average AOD (left) and SSA (right)

User case studies

Four dedicated user case studies within Aerosol_cci have started. They will analyse the full mission datasets available from the project to study aerosol radiative forcing, long-term aerosol absorption trends, aerosol impact on stratospheric chemistry and aerosol cloud interaction.

To assess heating rates and climate forcing by stratospheric aerosols simulations of an aerosol-climate-chemistry model will be compared to the new GOMOS dataset focusing on volcanic aerosol and the separation between sulphate and meteoric aerosol.

In order to understand the local heating by absorbing aerosols (which affect atmospheric stability and thus potentially cloudiness and precipitation), a multi-sensor time series of the Aerosol Absorbing Index (AAI) from 1978 to 2013 will be analysed with regard to plumes of desert dust, biomass burning and volcanic ash. Preparatory studies of Aerosol_cci (sensitivity analysis, model simulator) will be exploited to interpret trends of the qualitative AAI for several interesting geographical regions.

Monitoring regional aerosol climate impacts will be demonstrated by using ATSR aerosol measurements to constrain model assumptions with current conditions, decadal records of regional trends. Anthropogenic change will be approximated by trends of sub-micrometer (or fine-mode) aerosol. Regional shifts determined by modeling e.g. from Europe and the US (reductions by mitigation) to southern and eastern Asia (industrial and population growth) shall be confronted with the satellite dataset.

To investigate the aerosol indirect effect, susceptibilities of cloud properties (from Cloud_cci) to aerosol properties from the Aerosol_cci ATSR 17 year dataset will be compared to susceptibilities from a general circulation model using joint histograms for different oceanic and continental regions including the Amazon rain forest. Uncertainties in cloud properties and aerosol properties will be compared to diurnal, seasonal and inter-annual variations on different scales.

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Future perspectives

Aerosol_cci has now reached full mission processing for two GCOS variables (AOD, extinction profiles). However, evolving GCOS and user community requirements ask for additional variables (absorption, layer height, dust, aerosol type) and further improved quality.

By the end of Phase 2 (2017) Aerosol_cci will provide two GCOS-required aerosol parameters, i.e. total Aerosol Optical Depth AOD (ATSR-2/AATSR, global, 17 years) and stratospheric extinction profile (GOMOS, global, 10 years). In addition, a parameter in response to requirements from the climate modeling community, i.e. mineral dust AOD (IASI, dust belt over the Atlantic/Northern Africa/Central Asia, 7 years) and a qualitative spectrometer UV absorbing aerosol index AAI (multi-sensor, 35 years) are provided. All products will contain uncertainties on all levels.

Capabilities for other aerosol products in response to requirements from GCOS and the climate modelling community will have been explored through round robin exercises: aerosol type (e.g. from POLDER, for certain areas), fine mode AOD, aerosol absorption and aerosol layer height.

Algorithms for ATSR/SLSTR, GOMOS, IASI and POLDER will be ready for transfer to COPERNICUS operational services (regular dataset extension, repeated reprocessing).

Further research is needed to advance algorithms to better meet GCOS requirements. This includes completing necessary adaptations to new operational instruments. New GCOS-required products currently explored in CCI round robin exercises will need further development, initial full mission processing and detailed evaluation in a research context, before sufficient maturity for their transfer to operations can be reached. Other promising algorithms need to be further developed, e.g. better coverage with MERIS/OLCI time series, aerosol type from Sentinel sensor synergies or future instruments such as 3MI, and the use of geostationary sensors for the diurnal cycle.

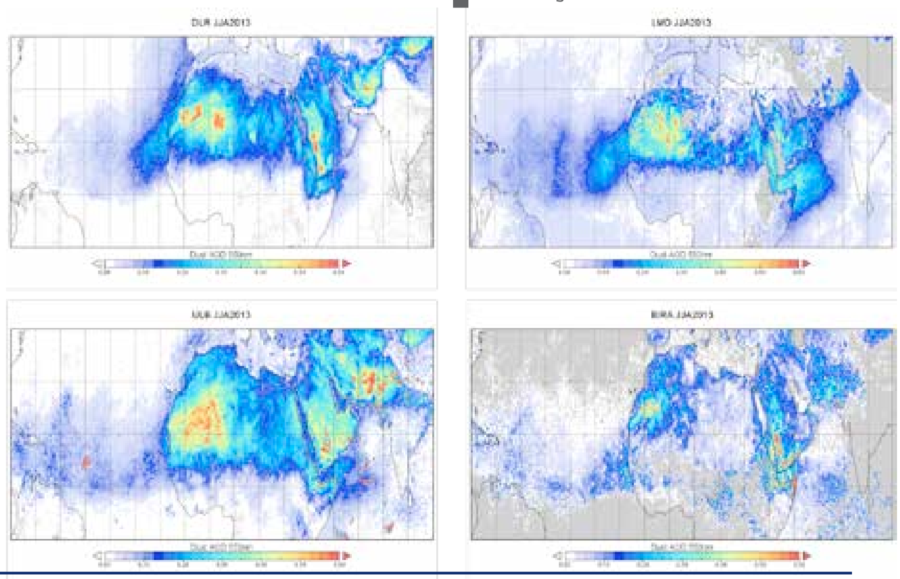
IASI 1-year mineral dust round robin datasets

Observations of the "Infrared Atmospheric Sounding Interferometer" (IASI) are sensitive to the presence of mineral dust aerosol and thus provide complementary information to the total AOD from UV-visible instruments. A round robin exercise is currently conducted to compare results obtained with four different algorithms.

Datasets of the entire year 2013 over the dust belt covering the Atlantic, Sahara, and Central Asia have been processed with four algorithms based on differing mathematical approaches and auxiliary information. The comparison between those four datasets and against external observations (coarse mode AERONET AOD, campaign measurements, other satellite retrievals, e.g. POLDER, MISR) is complemented with an intensive dialogue between the 4 IASI teams. Altogether, this will allow identifying opportunities for algorithm improvement and understanding best practices to retrieve mineral dust AOD.

The aerosol information obtainable from IASI is complementary to the one from UV-visible instruments, which do retrieve the total aerosol column amount of all different aerosol species. Therefore, the IASI products allow fulfilling specific user needs for separate monitoring of dust aerosols. However, the consistent integration and validation of both datasets is challenging because of the different parts of the spectra exploited (conversion from infrared to visible wavelengths). Fig. 4 shows seasonal summer mean AOD at 550 nm obtained from the 4 IASI algorithms as input to the round robin exercise.

Figure 4: Summer 2013 average dust AOD from 4 algorithms



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