ORAC: The Optimal Retrieval of Aerosol and Cloud

Aerosol and cloud products from ATSR, MODIS, AVHRR, and SEVIRI

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Introduction

ORAC is a generalised optimal estimation scheme [1] to retrieve cloud, aerosol, and surface properties from satellite-based visible and/or infrared measurements. Various implementations exist to process observations from (A)ATSR, AVHRR, MODIS, and SEVIRI retrieving

- aerosol optical thickness (AOT) and effective radius with surface reflectance (at 550 nm);
- aerosol optical thickness, effective radius, and layer height with sea surface temperature; or
- cloud optical thickness (COT), effective radius, and top pressure with surface temperature.

Work is under way to integrate the various distinct modules into one computer code and homogenise the pre-processing of satellite data, the modelling of surface reflectance, and numerous efficiencies made over the past decade of development.

Available datasets

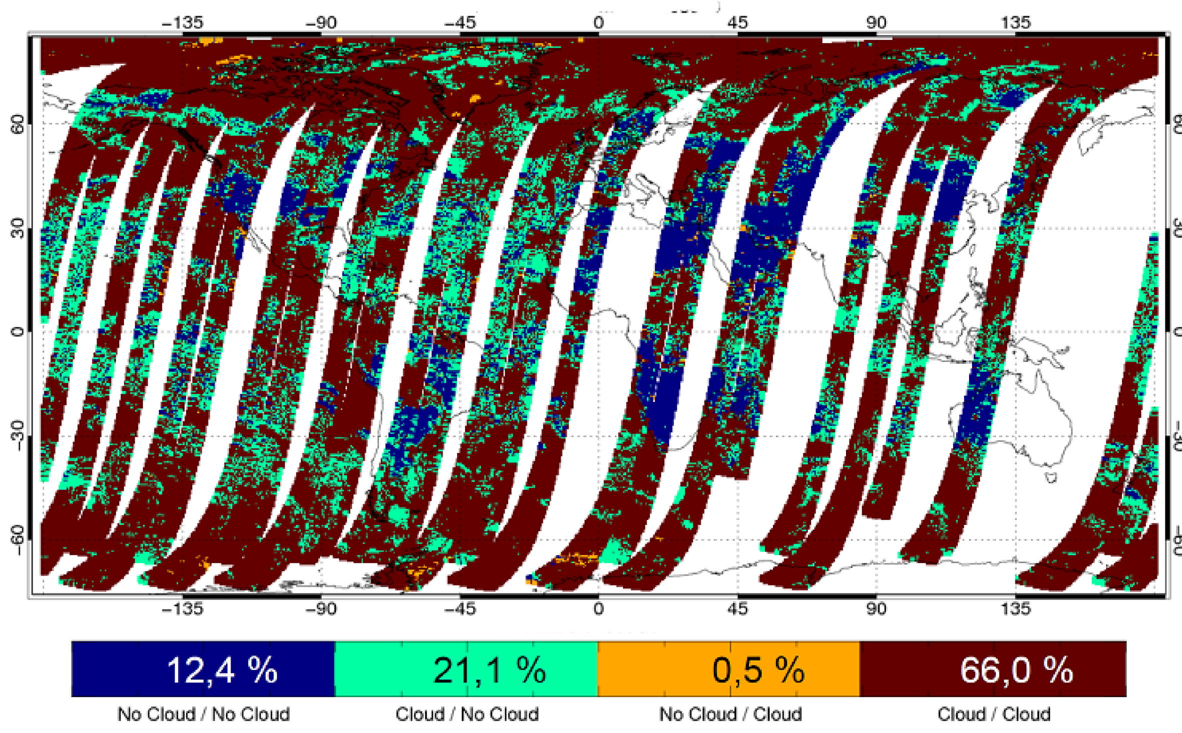
Several aerosol and cloud datasets have been produced with ORAC and are freely available:

- ESA's Climate Change Initiative (CCI) aims to produce climate data records that extend from the 1980s to the present for both aerosol and cloud properties.
  - The first phase of the aerosol project (`www.esa-aerosol-cci.org`) has produced AOT at 550 and 870 nm with 10 km resolution for 2003 and 2008 from ATSR-2 and AATSR. [2]
  - The cloud project (`www.esa-cloud-cci.org`) provides all cloud properties from ATSR-2 and AATSR at the sensor's native 1 km resolution, though AVHRR and MODIS also will be included in the eventual record. [3]
- GlobAEROSOL (`www.globaerosol.info`) retrieved AOT at 550 and 870 nm (and the Ångström coefficient over that range) with 10 km resolution. The data cover 1995 to 2008 from ATSR-2, AATSR, and SEVIRI and include pixel-level uncertainty estimates. [4, 5]
- GRAPE, the Global Retrieval of ATSR Cloud Parameters and Evaluation (`badc.nerc.ac.uk/data/grape`), retrieved cloud optical depth, phase, particle size, top pressure, fraction, and water path from ATSR-2 and AATSR on the same grid as the GlobAEROSOL data. [6]

Level 3 daily and monthly averages of all of these are also available.

Aerosol and cloud masking

From the top of the atmosphere, a thin cloud resembles a thick aerosol plume. This ambiguity means that it is not currently possible to retrieve aerosol and cloud properties simultaneously from the same observation. In fact, each is a significant source of error in the retrieval of the other such that stringent filtering is applied to current products and, though this confines analysis to only observations that should be well-modelled, it limits the spatial coverage of the data.

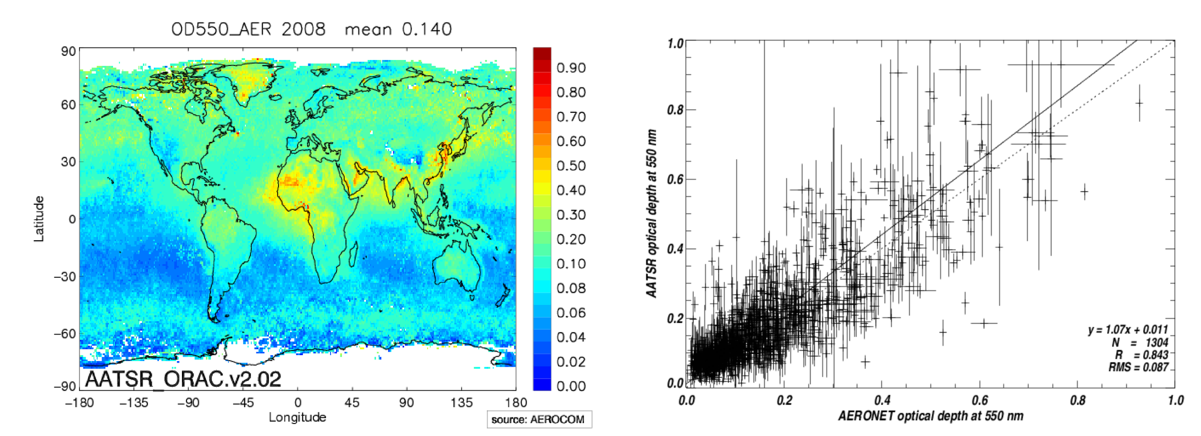


Aerosol CCI Cloud Flag/Cloud CCI Cloud Flag

Above is a comparison of the masks from the CCI Cloud and Aerosol projects over five days in September 2008 [7]. Dark blue and brown indicates the masks agree in the classification. Note that 20 % of the globe is rejected by both masks (light blue), representing a significant limitation of the spatial coverage for a supposedly global climate product.

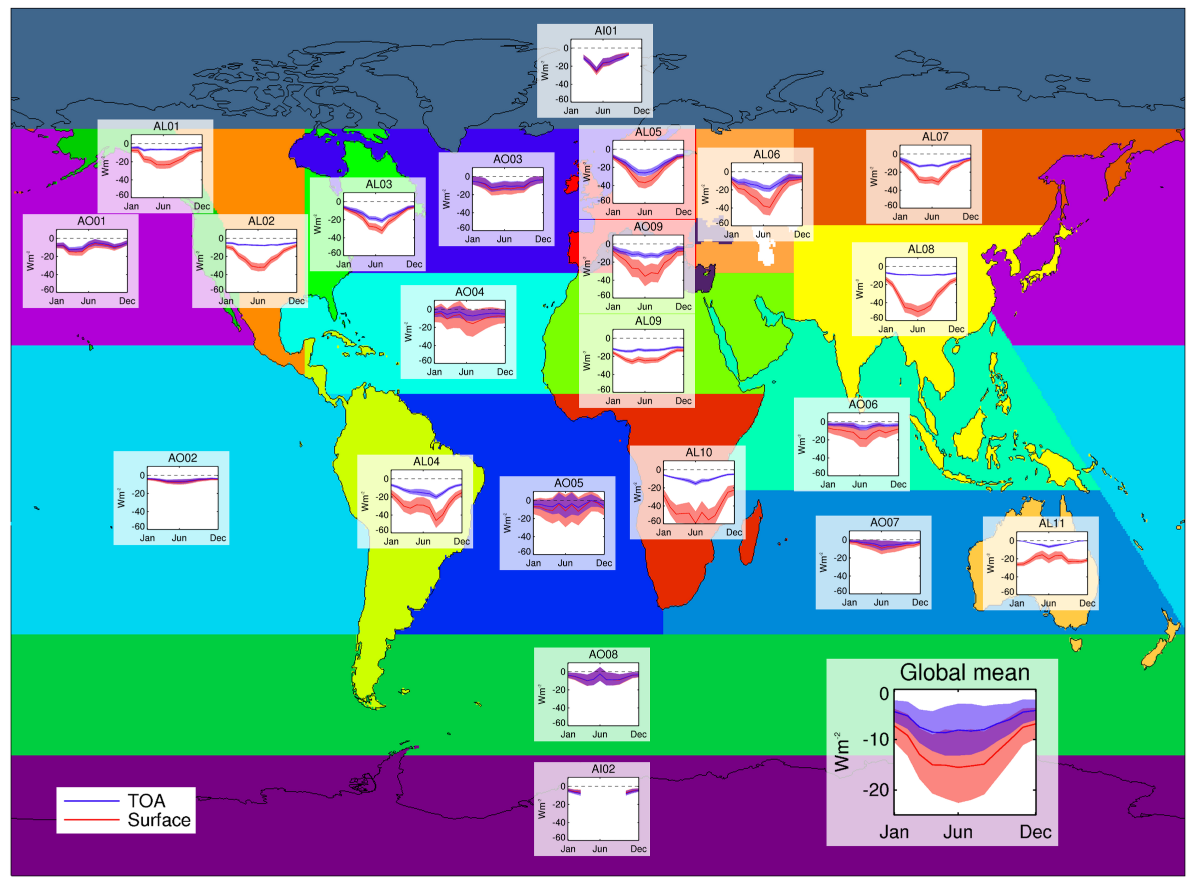
ORAC does not require masking as it can retrieve both aerosol and cloud over land and sea. Instead, observations are processed using each model and the probability that it conforms to a given type is determined from the fit of the model to the observations.

Validation — aerosol



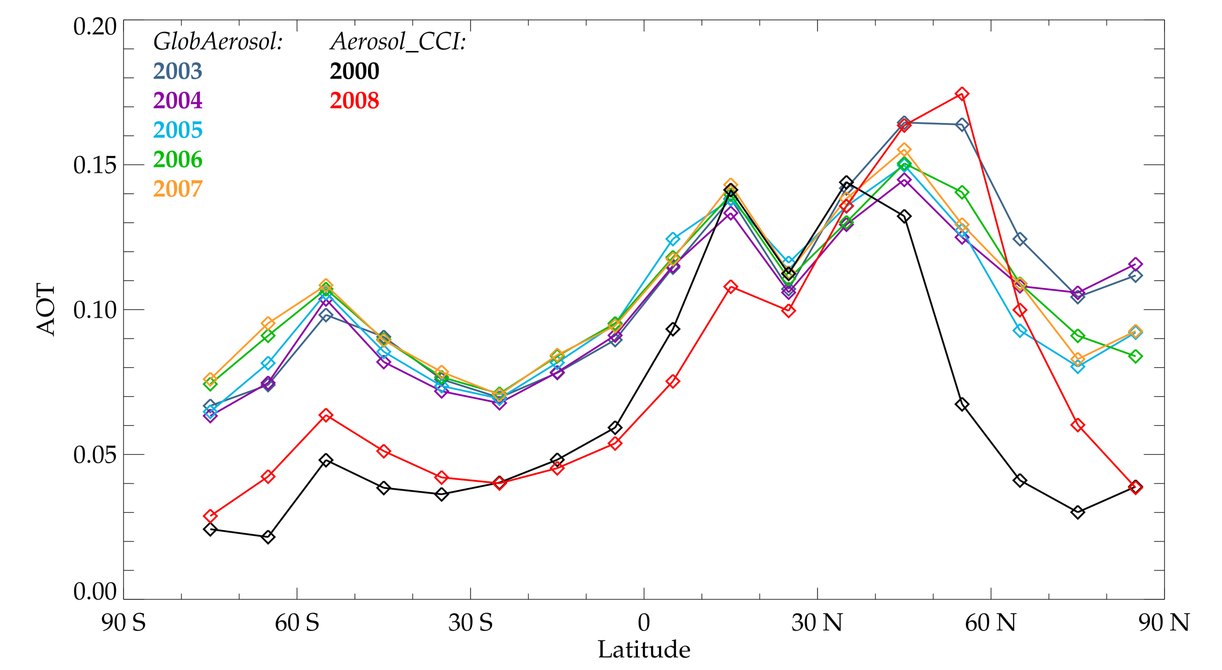
The global distribution of AOT (left) compares favourably to that from MODIS while also retrieving more realistic values over the Southern Ocean. Correlations against AERONET (right) are 0.8-0.9 with RMS less than 0.1.

Aerosol direct effect



In one application, GlobAEROSOL data has been used to estimate the instantaneous, clear-sky, direct aerosol radiative effect for the year 2006 [8]. The globe was divided into 22 regions with similar mean aerosol properties and, within each, AERONET was used to correct for regional biases in the retrieval. The mean clear-sky aerosol radiative effect was calculated for each region and month, shown above, giving a global-average TOA forcing of $-1.6 \pm 2.5\,\mathrm{W\,m^{2}}$. The shading represents the uncertainty and the plot in the lower right corner shows the global mean. This estimate required the removal of anomalously strong forcing over the Southern Ocean.

Zonal mean of AOT



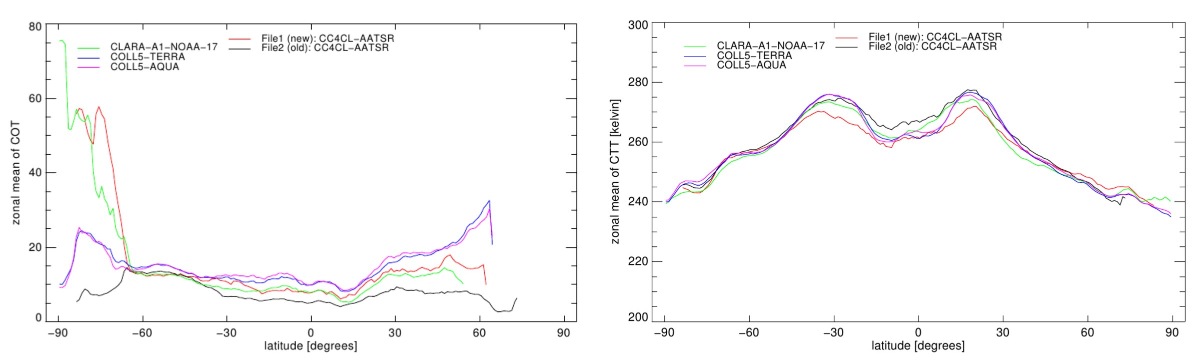
The yearly-averaged, zonal mean of AOT from AATSR in the currently available GlobAEROSOL and Aerosol CCI datasets.

Community code

ORAC is open-source software developed by a worldwide community of researchers within a version control system managed by the British Atmospheric Data Group (BADC). The Fortran 90 source code can be obtained from `http://proj.badc.rl.ac.uk/orac`. Currently only the cloud retrieval for ATSR, AVHRR, and MODIS is available, though the aerosol retrieval should appear this year. Introducing additional radiometers, if desired, is generally straightforward.

Validation — cloud

Ongoing research in Phase 2 of Cloud CCI is structured around successive loops of comparison of the retrieval against CLARA-A1 (CLoud, Albedo and RAdiation dataset, AVHRR-based, version 1) during 2008 followed by directed algorithm development. The plots below show January from the first feedback loop.



The zonal mean cloud optical thickness (left) given by CLARA (green) and ORAC (red) are similar but both differ from the Collection 5 MODIS TERRA and AQUA products (blue and pink). This is likely due to the MODIS observations using channels without an AVHRR heritage. The CCI project desires a self-consistent record and so limits itself to those channels.

Agreement is closer for the cloud top temperature (right), though ORAC finds higher cloud around 30° latitude. This appears to be an excess of thin, high clouds in ORAC relative to CLARA.

The next comparison is under way following the introduction of a more detailed BRDF surface model and corrections for clouds near the tropopause.

References

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[6] C.A. Poulsen et. al. (2012), doi:10.5194/amt-5-1889-2012.

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[8] G.E. Thomas et. al. (2013), doi:10.5194/acp-13-393-2013.