Long-term records of aerosol and cloud properties with pixel-level uncertainties

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Optimal retrieval of aerosol and cloud

ORAC [1, 2] is a generalised optimal estimation scheme [3] to retrieve cloud, aerosol, and surface properties from satellite-based visible and/or infrared measurements. It is a single code for processing observations from (A)ATSR, AVHRR, MODIS, SEVIRI, and other sensors to retrieve:

- 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;
- cloud optical thickness (COT), effective radius, and top pressure with surface temperature; or
- volcanic ash optical thickness, effective radius, and plume top pressure.

By integrating these modules, ORAC products can bypass the need for cloud or aerosol masking. 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.

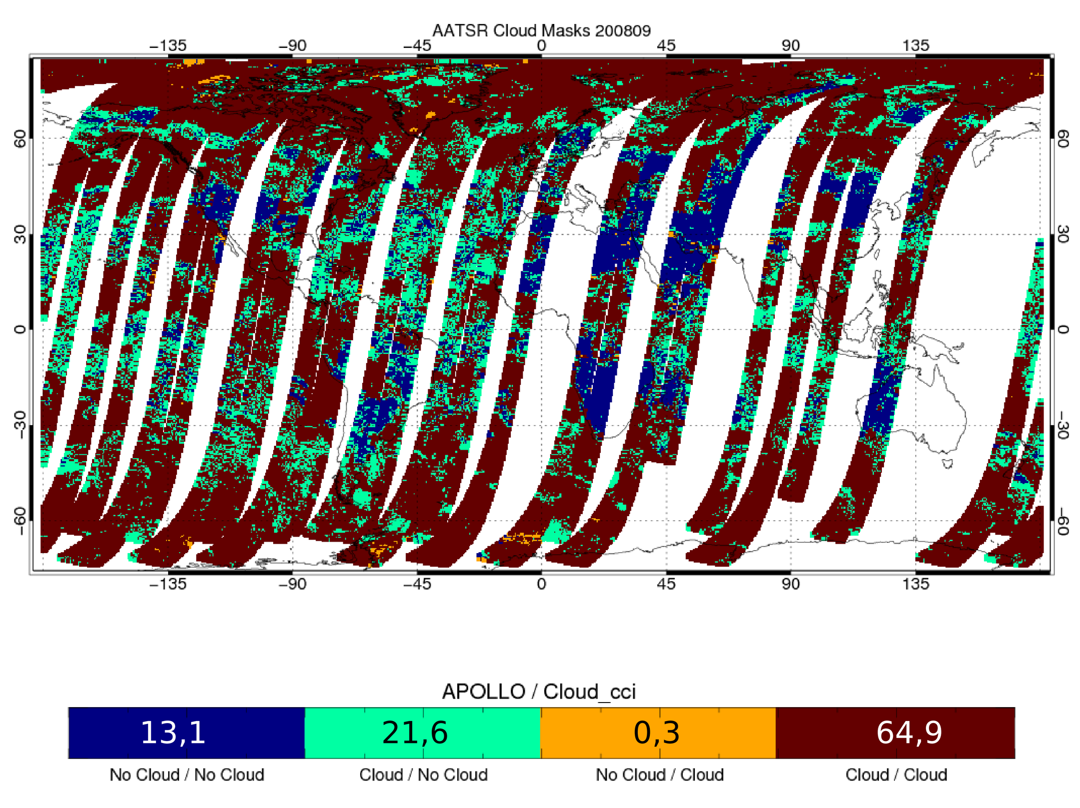
This poster outlines the recently completed cloud and aerosol CCI datasets (Climate Change Initiative) and presents initial results from an application of that data to the study of cloud-aerosol interactions. Further details on the datasets can be found in [4, 5]. The data can be downloaded from `http://cci.esa.int/`.

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`. Introducing additional radiometers, if desired, is generally straightforward.

Coverage

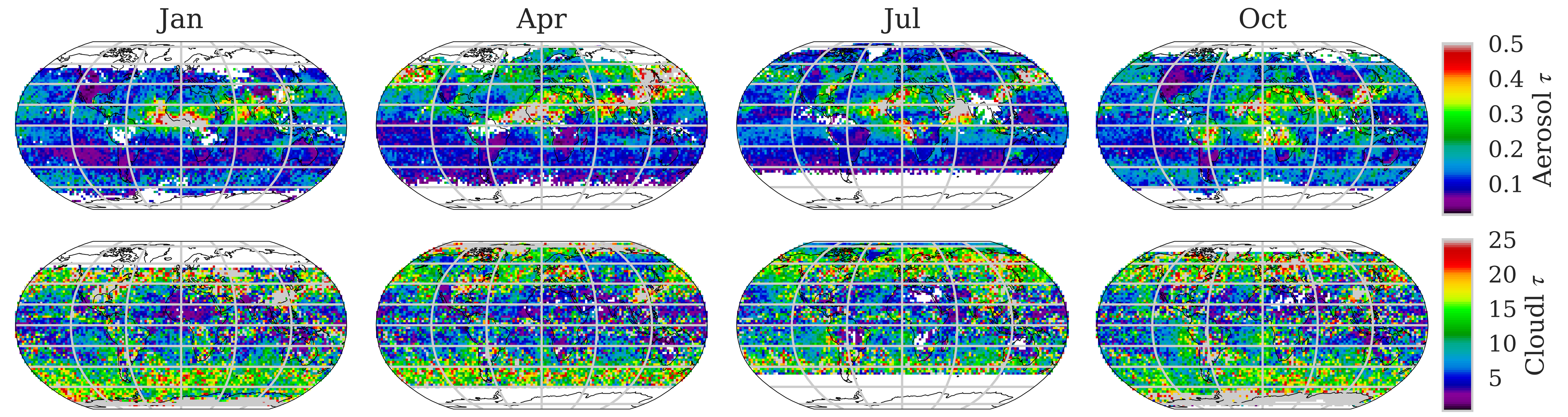
From the top of the atmosphere, a thin cloud resembles a thick aerosol plume, such that it is not usually possible to retrieve aerosol and cloud properties simultaneously from passive, nadir observations. In fact, cloud and aerosols are a significant source of error in the retrieval of the other. Common practice is to apply stringent filtering to confine analysis to observations that should be well-modelled, but this limits the spatial coverage of the data.



Above is a comparison of the cloud masks from the ESA CCI Cloud and Aerosol projects over five days in September 2008 [6]. Dark blue and brown indicate 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 global product. ORAC products can minimise this.

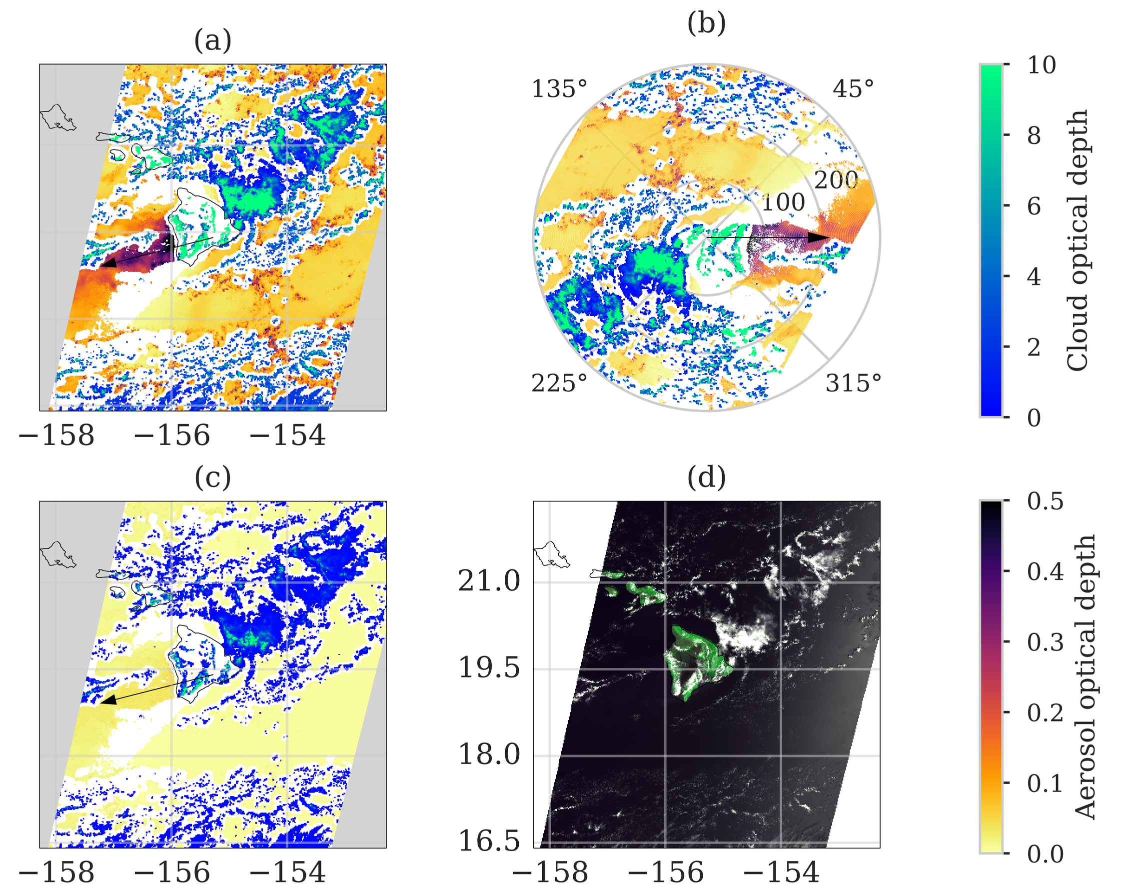
A climate data record of aerosol and cloud

The primary outputs of the CCI projects are datasets of Essential Climate Variables of sufficient duration and stability for the study of climate. ORAC has been used to produce records of aerosol optical depth and cloud optical depth, effective radius, and top height. The aerosol data is drawn from the ATSR mission, covering 1995 to 2012. The cloud data uses AVHRR, MODIS, and ATSR providing data from 1982 to the present day. Below are monthly averages from 2008 for aerosol and cloud optical depth (top and bottom rows) from the AATSR sensor.



Localised aerosol sources

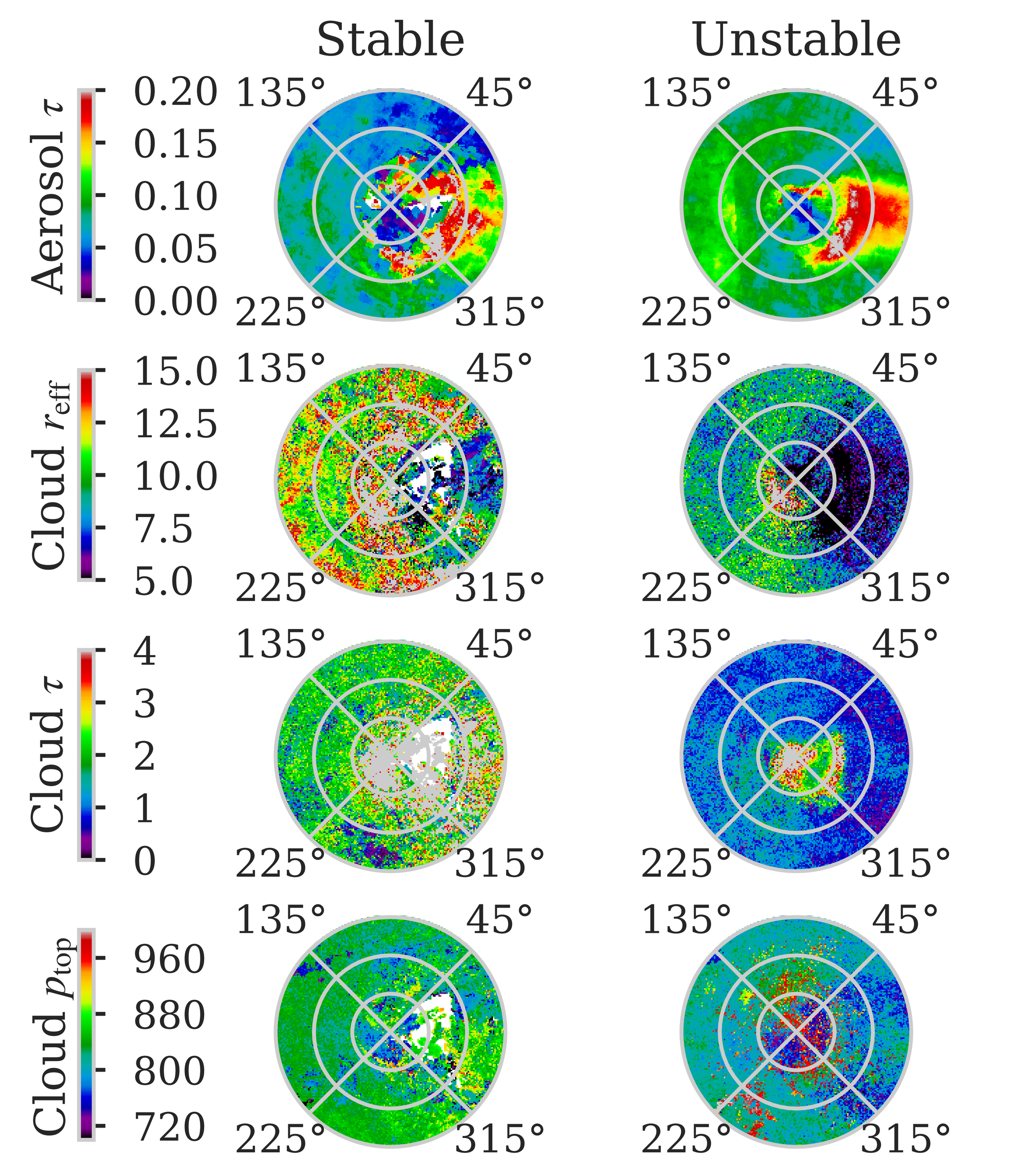
These datasets are being used to evaluate aerosol-cloud interactions in the vicinity of localised aerosol sources. The images below are centred on Mt. Kilauea in Hawaii, which regularly degasses SO_2, which nucleates into aerosol. Tile (d) is a false-colour image from AATSR on 9 Sep 2008 at 19:44 GMT. Tile (a) shows the aerosol and cloud products retrieved from that image with the corresponding uncertainties presented in tile (c). White denotes retrievals excluded from further analysis by quality control, where any clear sky within 7 km of a cloud has been excluded to avoid contamination [7].



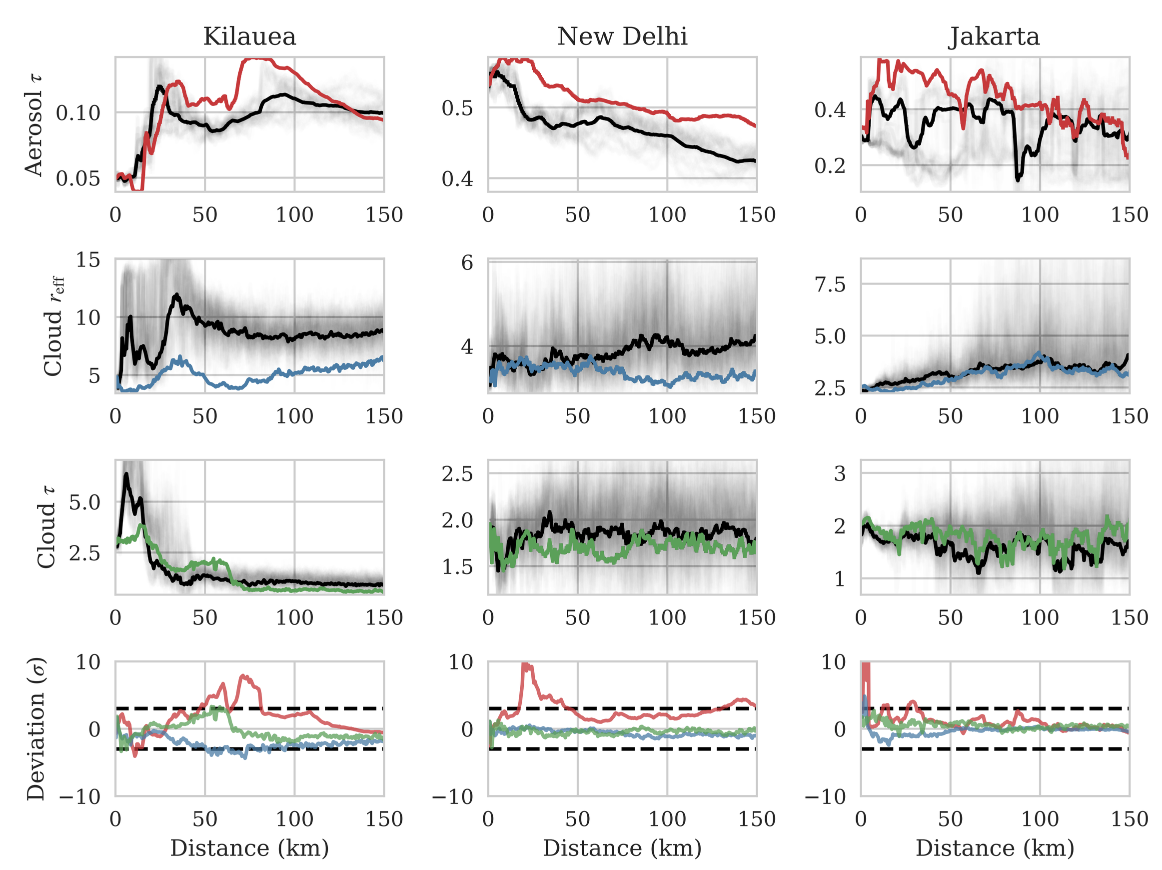
To study the impact of the volcano, ECMWF ERA-Interim analyses have been used to estimate the wind speed at the summit of the volcano, shown by the arrow in tile (a). The data has then been rotated into the direction of the wind using image processing software, shown in tile (b) with the wind blowing towards the right.

Long-term averages

To compare properties before and after exposure to the localised source, long-term averages have been made from these rotated products. Separate averages have been made based on the lower troposphere stability (stable > 17 K) and free troposphere humidity (dry < 40 %) to mitigate the influence of meteorology. Shown below are averages for the entire AATSR mission around Kilauea in wet stable or unstable conditions (left and right) for the aerosol optical depth, cloud effective radius, cloud optical depth, and cloud top pressure (top to bottom). Note the enhanced decrease of r_{eff} downwind in unstable conditions relative to stable conditions for similar τ perturbations.



Cloud-aerosol interactions



These plots show the angular average of the rotated plots above as a function of distance from the site. The downwind direction is shown in colour and the upwind direction in black, with the variation in the upwind direction highlighted in grey. Ninety natural and anthropogenic sites around the world have been evaluated; Kilauea, New Delhi, and Jakarta are shown here. The bottom row presents the difference between the downwind and upwind means, divided by the standard deviation in the upwind data.

At these sites, the aerosol is enhanced downwind. At Kilauea and New Delhi, there is a reduction in cloud effective radius (as expected from the Twomey effect) with no change in cloud optical depth. No change is seen around Jakarta. It is being investigated if the type of aerosol emitted at a location can explain such differences.

References

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