The cleaning of air by convective clouds

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Introduction

Convective clouds are large clouds that span the troposphere and contain large amounts of water vapour. As they advect, aerosols in the air act as nucleation points, about which water vapour condenses and forms water droplets. These droplets may grow and, eventually, rain out as precipitation; 'cleaning' the air of aerosol.

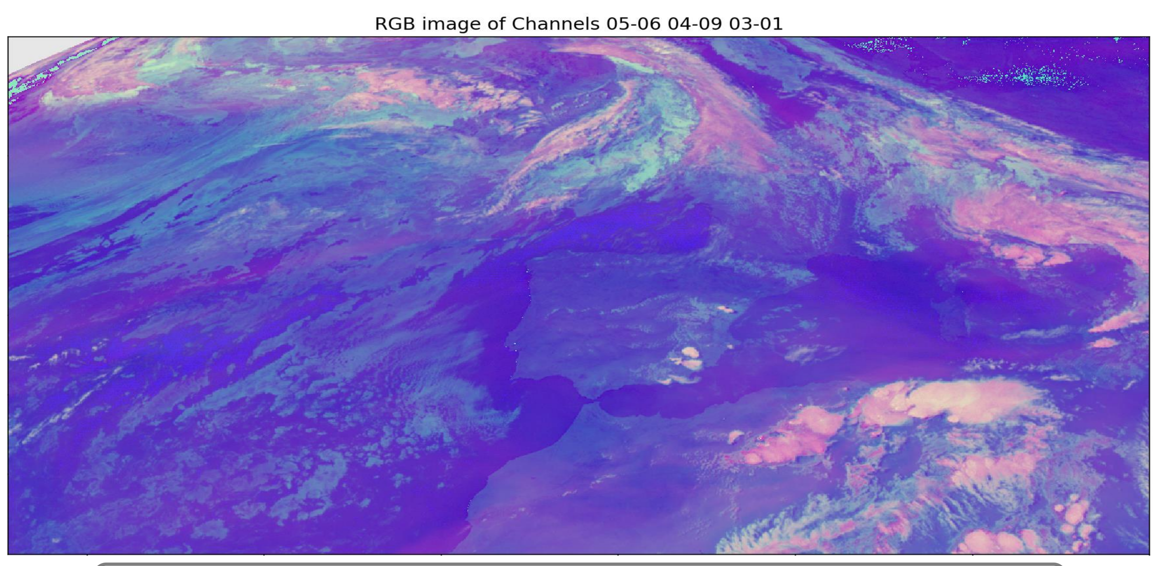
SEVIRI satellite retrievals over Europe using the Optimal Retrieval of Aerosol and Cloud (ORAC) [1,2] were used to quantify a change in aerosol optical thickness, at 550nm, in areas where a convective cloud was observed. The analysis was carried out for 24 hours worth of 15 minutely data from 19/08/2015.

A more detailed analysis of this phenomena could be used to constrain cloud-aerosol interactions in atmospheric models and also to determine its effect on the Earth's radiation budget.

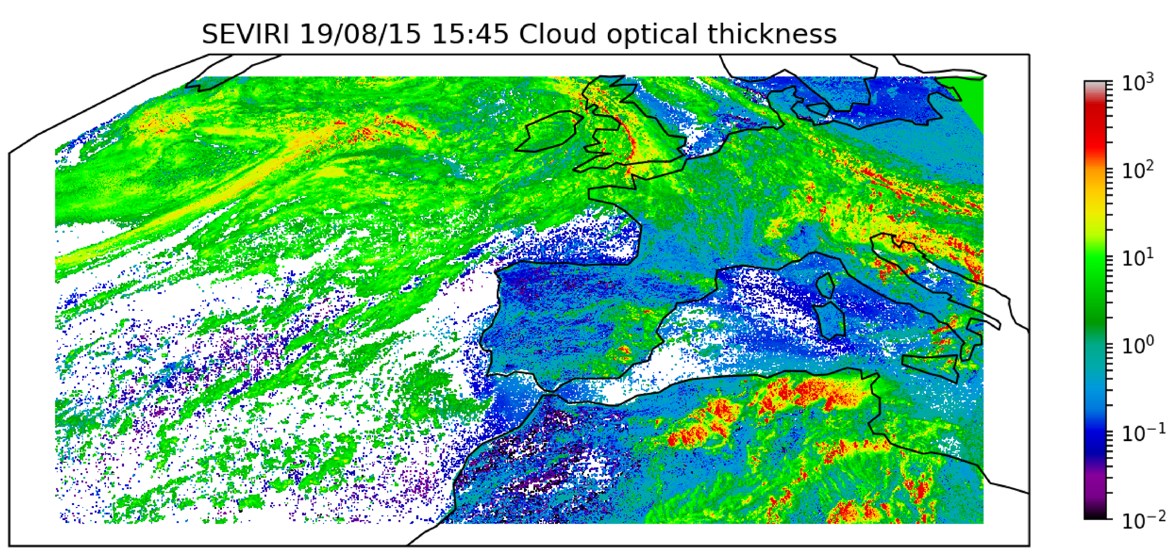
Identifying convective clouds

Convective clouds were identified based on their emissivity, cloud top temperature (CTT) and cloud top height (CTH). As convective clouds span the entire tropopause, clouds whose cloud top height was more than 2 km below the tropopause were filtered out. Next clouds were filtered by cloud emissivity, with emissivities below 0.8 being removed. This was done to filter out cirrus clouds as they also tend to have a CTH close to the tropopause.

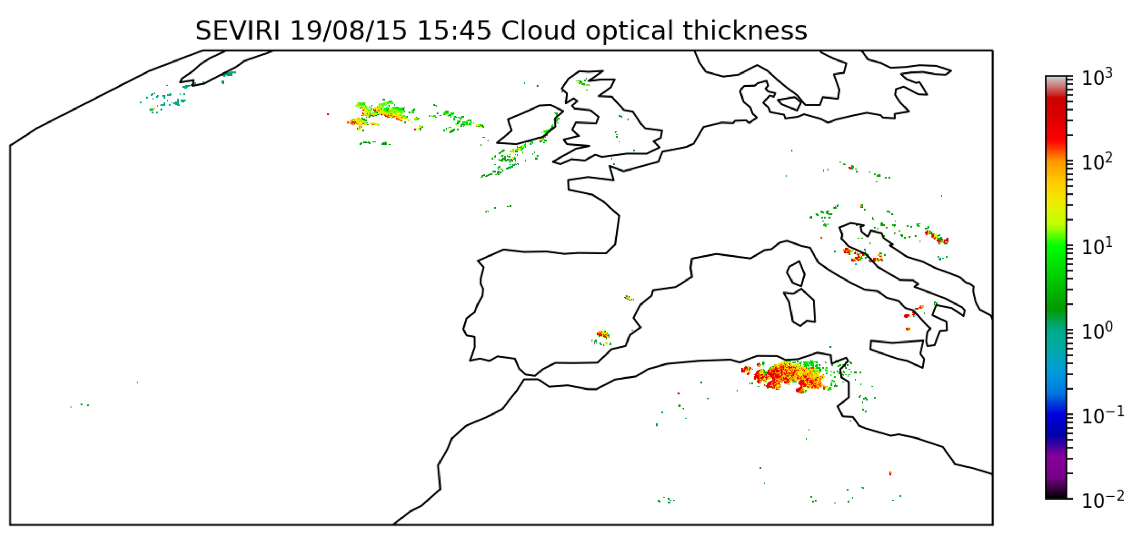
Finally clouds were filtered by CTT. If a cloud pixel was within 3K of the tropopause it was flagged as convective. In addition, pixels with a CTT that was within 5K of the tropopause were also flagged as convective if they had a pixel within 50km of them horizontally that was within 3K of the tropopause. This additional criterion was added to insure that when a convective clouds was identified, all pixels associated with that cloud were flagged as convective.



False colour image of channel outputs



Example cloud field



Convective clouds identified in cloud field

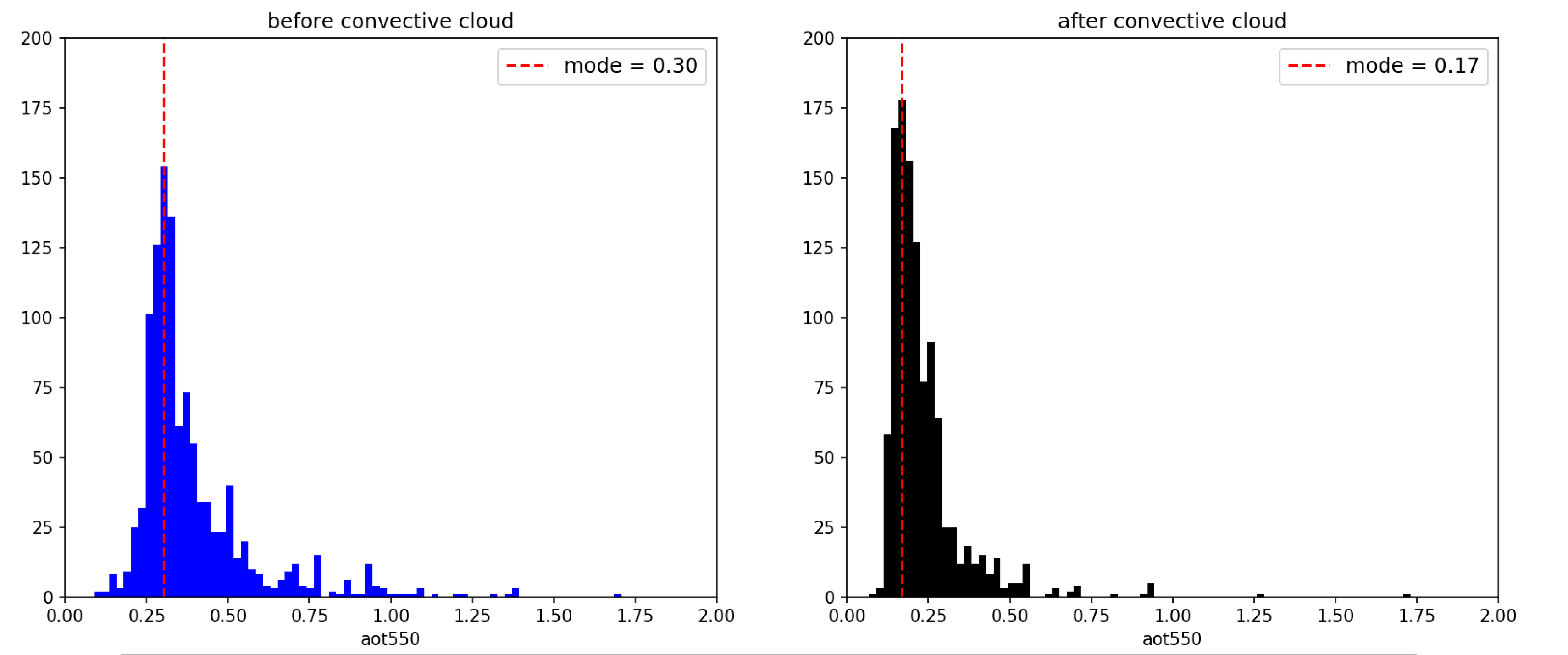
References

[1] G.E. Thomas et. al. (2009), doi:10.5194/amt-2- 679-2009.
[2] C.A. Poulsen et. al. (2012), doi:10.5194/amt-5- 1889-2012.

Change in aerosol optical thickness

Once convective pixels were identified the median aerosol optical thickness (AOT) in the 6 hours before and after the pixel was convective were compared. The AOT distributions (per pixel) across time were first filtered to remove pixels where the aerosol retrieval was unreliable and contained a lot of noise or cloud contamination. This was carried out for retrievals over sea due to the high unreliability of the ORAC aerosol retrieval over land.

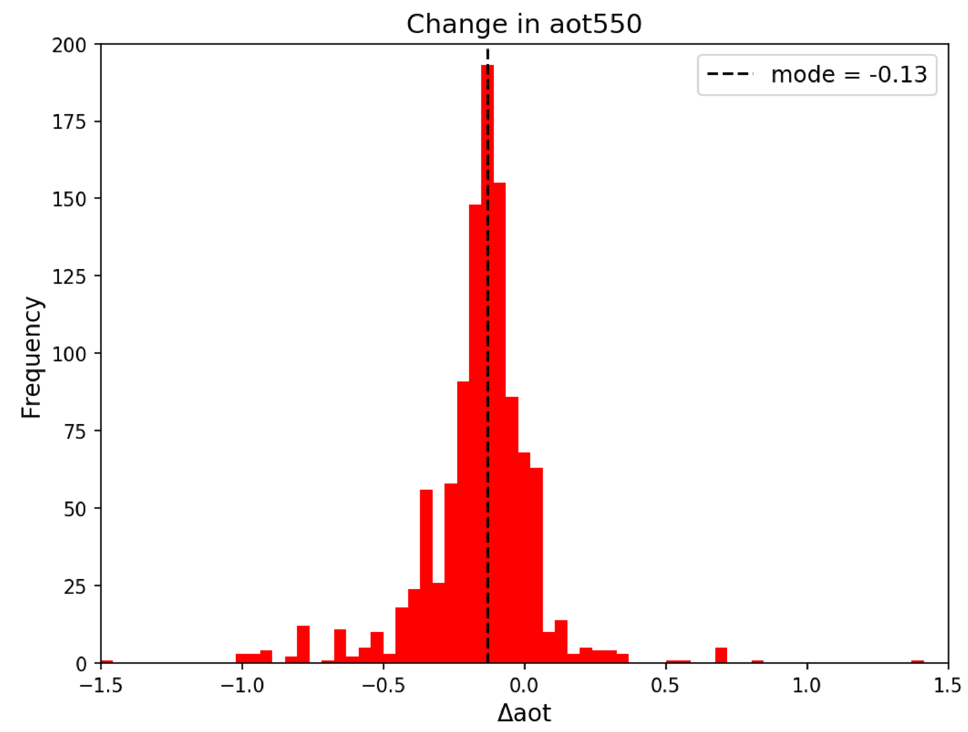
The histogram below shows a comparison of the distributions of median AOT before and after a convective cloud. Each data point represents a pixel that was flagged as convective. This analysis was carried for a days worth of data with a temporal resolution of 15 minutes.



Distributions of filtered median aerosol optical thickness values in the 6hrs before and after a convective cloud.

A drop in the mode of the distribution of 0.13 can be viewed after the convective cloud, along with an increased localisation of median AOT measurements about the peak.

A histogram of the distribution of the change in AOT can be viewed below. This once again used the filtered median AOT values before and after a convective cloud.



Distribution of change in aerosol optical thickness between before and after a convective cloud.

This distribution shows more clearly the aforementioned drop in the previous image. The distribution is roughly Gaussian, with a median of -0.14 and a mean of -0.16.

The observed change could be caused by a variety of phenomena; the displacement of aerosol with the cloud (without necessarily raining out), a change in aerosol size but not necessarily number, a reduction in aerosol altitude or diurnal variations in AOT. A further, more detailed analysis would be required in order to quantify how much of the observed effect can be attributed to the 'cleaning' by convective clouds.

Future work

The described analysis needs to be carried out for a larger data set with more rigorous filtering techniques before any robust, quantitative conclusions and can be derived from the results.

Further analyses could incorporate the vertical distribution of aerosol from lidar measurements to investigate possible changes in aerosol altitude and an analysis of the change in aerosol effective radius could be used to determine its contribution to the change AOT.