

ANSWERS TO REFEREE #2

First of all, we thank Referee #2 for these positive constructive remarks and comments. The comments have been addressed below and have been taken into account for revising the manuscript. The responses are below after the reviewer points that are in italics.

Major comments

*In this work, a new method for estimating AOD from SD measurements under cloud-free days is proposed. The adopted method relies on a broadband DNI model that takes into account the local conditions affecting SD measurements. The work is well suited to the readership of AMT. However, there are a number of issues with the procedure developed in the paper that prevent its publication in the current form. **The main issues with the work concern the decision to use daily mean of cloud cover data obtained only from four observations terms (every 6-hours).** There are also other meteorological databases which contain a variety of hourly meteorological data from weather stations located in Europe (e.g. <https://www.ncdc.noaa.gov/isd>). Therefore, the authors must quantify if there are significant differences between selecting the cloud-free days using hourly cloud data and ECAD dataset. Also, satellite cloud cover product data could be used in the analysis, as they provide hourly cloud cover data for more than twenty years (https://www.cmsaf.eu/EN/Products/AvailableProducts/Climate_Data_records/Climate_Data_Records_node.html)*

Thank you for this valuable remark and the suggested database i.e. Integrated Surface Database (ISD) for hourly meteorological data. It will be useful for the subsequent work which aims to apply the proposed method for the reconstruction of the historical evolution of aerosol load at the global scale with the best possible ground-based measurements, while here we presented, validated and applied the method for a couple of stations. Nevertheless, we have explored the ISD database with a focus on cloud information. For those ground-based stations where SD measurements are also available, cloud cover measurements are mostly provided with 6-hourly temporal resolution in the past i.e. before 1980 (and it is worth remembering that our major goal is to reconstruct past AOD before the satellite era). This 6-hourly cloud cover

measurements are still (up to now) given for some stations. In general, this temporal resolution is the most widely available resolution for numerous stations over the world within the reconstruction period.

In this study, a cloud-free day is assumed when the mean daily value of TCC is rounded to 0 okta. That average value is computed from three-daily observations, typically at 06:00, 12:00 and 18:00 UTC. Obviously, it is a very low temporal resolution for cloud-free days selection because within a 6-hour period, the sky can be absolutely obscured by clouds resulting in an erroneous selection. Therefore, and following the referee comment, it is relevant to quantify how accurate the selection algorithm is when using 6-hourly observations instead of a much higher temporal resolution such as 1-hourly observations as requested by the referee. In other words, which proportion of days with cloud influence in SD is included in the set of clear sky days based on our selection algorithm.

In order to achieve this goal, we selected the well-known KNMI database instead of the ISD database because of the availability of metadata. This latter allows avoiding as much as possible inhomogeneity problems caused by station movements and changes in instruments. The KNMI database consists of hourly observations of numerous meteorological parameters from about 30 ground-based stations. The automatized hourly cloud cover measurements can be downloaded through the website <http://projects.knmi.nl/klimatologie/uurgegevens/selectie.cgi>. We used the temporal coverage from 2010 onwards. For the sake of clarity, let TCC1 and TCC6 denote the daily averages computed from 1-hourly and 6-hourly data, respectively. According to the WMO guidelines, TCC of 0 okta corresponds to completely cloud-free sky, so it was considered that the limit of 1 okta could be extended to represent almost cloud-free sky conditions representing cases when clouds do not obstruct the SD measurements.

For each station, we retained days obeying to these following filters: (1) no missing hourly TCC between sunrise and sunset, (2) no missing TCC values at 06:00, 12:00 and 18:00 UTC and (3) rounded TCC6 is equal to 0. Therefore, we investigated the set of remaining days. Figure 1 shows the distribution of frequency of days over the Netherlands. The x-axis is the okta bin with a width of 0.5 based on TCC1 represented by the upper limit and the y-axis is the maximum value from the 1-hourly cloud observations between sunrise and sunset.

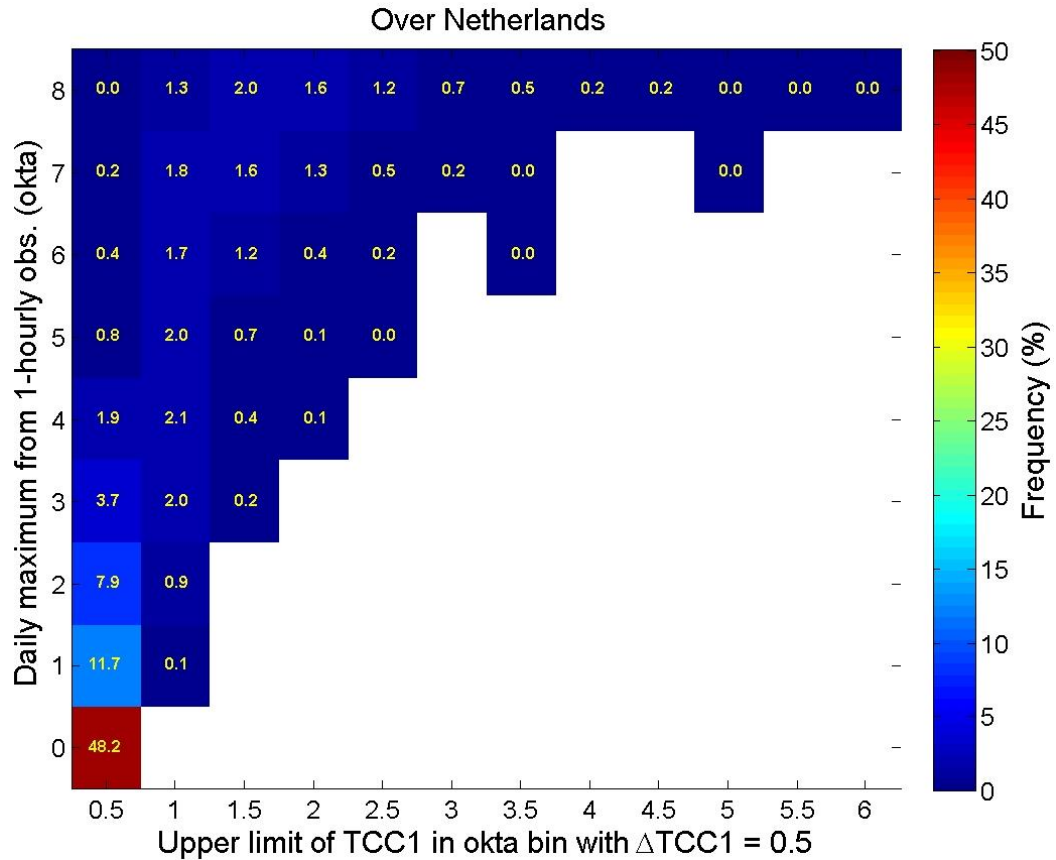


Figure 1. Relative frequency of days per okta bin with respect to the maximum cloud cover measurements between the sunrise and sunset.

Regarding the TCC1 threshold of 1 okta for almost cloud-free days, one can observe that the selection algorithm successfully captures cloud-free days in 87% of cases. Only 13% of the cases have a significant cloud influence. That demonstrates the good performance of the selection algorithm. For these 13% of cases, the retrieved AOD are overestimated by cloud contamination whose the impact is considered in the uncertainty estimates. For more detailed information on the uncertainty estimates, please refer to the answer to first comment of Referee #1.

Minor issues:

Comment 1. Page 5 Line 20. The authors must mention the studies in which was performed the comparison between ECMWF reanalysis product and AERONET data.

Thanks. The comparison was carried out by ourselves and we have re-written the relevant part accordingly as follows:

“A comparison between ECWMF and AERONET daily TWC is carried out over Europe with AERONET measurements serving as reference. On average, we found that the ECMWF values slightly underestimate TWC by 4%, or below 1 kg m^{-2} with a correlation coefficient of 0.8 and a small standard deviation”

Comment 2. Page 6 Line 5. Which are the studies that demonstrate the performances of TOC estimates?

Thanks. The answer is the same as for the previous comment. We have re-written the relevant part accordingly as follows:

“Our comparisons of TOC from ECMWF and OMI serving as reference show on average a high correlation of 0.9, a low bias of +3% and very limited spread of points denoting the accuracy of ECMWF TOC.”

Comment 3. Page 6 Line 15. The authors must motivate why they have used the MxD08_D3mModis product instead of the higher spatial and temporal resolution Modis aerosols data (MxD04_L2product).

Thank you very much for this remark. We have added the motivation in the relevant part of the paragraph as follows:

“Despite of the coarser spatial resolution than the corresponding one for the level-2 product, the level-3 product was used because it takes into account all overpasses of the instrument during the same day, thereby making it to be more representative of daily average aerosol properties than the level-2 instantaneous data products.”

Comment 4. Page 10 Line 20. For which station the 12000 the clear sky atmospheric states were built?

Thanks. No specific station was needed here. The set of 12 000 clear sky atmospheric states was built for comparisons between the robust model and the simplified model with necessary inputs describing the state of the atmosphere.

Comment 5. Page 15 Line 5. The authors must discuss why most of the stations selected after applying the homogenization test are located in the Mediterranean climate. It is hard to believe

that, excepting data from two stations, only the stations located in Spain provide homogenous SDF data.

Thanks. The reviewer is right as most of the selected stations in Table are from Spain It is worth mentioning that Spain is one of the countries with more long-term measurements of SD and TCC available on ECA&D, in contrast with other countries such as United Kingdom or, France where data is not provided. We have slightly modified the relevant part of the text to make it clear as follows:

“To ensure a reasonable set of ground-based stations as well as a good quality of measurements, four criteria have been applied on those ECA&D stations having both SD and TCC measurements within a calendar day. First, to include at least the brightening period, ECA&D stations having SD measurements starting before the year 1985 were chosen. Second, ECA&D stations should be collocated with AERONET stations with a maximum distance of 50 km. Third, the overlapping period where that both cloud-free SD and AERONET measurements are available should cover at least three years. Finally, as the fourth criteria, temporal homogeneity tests have been applied on SD measurements to select stations with homogeneous time series. For this last one, three main tests are used:”

Comment 6. Page 18 Line 10. The authors must provide the burning thresholds computed for all the stations as an ESM table. This will add value to the paper.

Thanks. We have added an ESM Table as requested and have written in the text as follows:

“See Table S1 in the supplement for computed monthly burning thresholds for all stations.”

Comment 7. Page 19 Line 5. In order to better emphasize the results of the three models tested, trend lines for each model should be added on the scatterplot.

Thanks. Done as requested.

Comment 8. Some references mentioned in the text are missing from the Bibliography section (e.g. Qui, 1998).

Thanks. We have carefully checked the Bibliography accordingly to citations in the text.