**Visibility-derived aerosol optical depth over global land from 1980 to 2021**

**Response to Anonymous Referee #1 and #3 (AR1 and AR3)**

We thank the referee for the constructive and helpful comments. We carefully thought about the comments and made corresponding revisions to the manuscript and the datasets, which have substantially improved the manuscript and the datasets.

1. Improved the underlying data products.

- Added other meteorological variables into the station product.
- Added 95% CI and quality flags into the gridded product.
- Discussed the uncertainty for gridded product in section 3.4.1.
- Added a description in section 4.

2. Discussed the uncertainty in regions with sparse stations, such as high-latitude and desert, in section 3.3.3 and 3.4.1.

3. Added new figures to compare VIS_AOD with AERONET AOD (Figure 6) and MERRA-2 AOD (Figure 7) before/after 2000.

**Response to Anonymous Referee #1 (AR1)**

***General Comments:***

*In general, the document has improved from the first version, but some questions remain regarding usefulness of this data set.*

***Data Access and Interpretation:***

***GC 1.*** *The data can be accessed via the National Tibetan Plateau Data Center. The data can be downloaded via FTP using the provided credentials on the web site or they can be downloaded without login but after a wait of up to several minutes. The files provided include netCDF data file with monthly gridded VIS_AOD AOD 550nm values as well as a metafile description. Further, a text file includes the weather station locations where visibility measurement was performed and provides only the "VIS_AOD" result and not the station visibility or any other meteorological information that could be useful in interpreting these data.*

**Response for GC 1:**

- We have added other meteorological variables (temperature, dew point temperature, relative humidity, wind speed, sea level pressure, dry visibility) and the corresponding units into the station VIS_AOD product.

***GC 2.*** *The netCDF file "VIS_AOD" variable needed to be transposed (rows and columns swapped) to enable plotting with Python's matplotlib module.*

**Response for GC 2:**

- We have transposed (rows and columns swapped) the "VIS_AOD" variable and supplemented the "W95CI" variable (the uncertainty with the 95% confidence interval) and the "QA_FLAG" variable (the quality flag of VIS_AOD).

***GC 3.*** During the northern hemisphere winter, landmasses at high latitude are in

darkness for significant periods. How are the visibility data utilized during these periods?

**Response for GC 3:**

- We have excluded visibility records under "blowing snow" weather at high latitude (Husar et al., 2000). In the darkness, visibility can be considered as nighttime visibility and did not perform any other special processing.

***GC 4. In data spare regions such as over Greenland and northern and central Asia, how well does this method perform. It seems that these regions should be excluded from the analysis due to low data availability.***

**Response for GC 4:**

- We have quantified the uncertainty and provided a 95% confidence interval based on kriging variance, as detailed in section 3.4.1. We also have supplemented the uncertainty and the quality flag of VIS_AOD into the gridded product.

***GC 5.*** *When viewing the gridded monthly data, it was obvious data anomalies are present. For example, in northwestern Europe in January 2009, the monthly average over this region showed values between 0.5 and 0.6. These monthly values are very high for a monthly average in this region and generally rare in this region even during periods of high aerosol. When examining visible satellite images for this period and region, it is evident that clouds dominated the view and when they parted it could be determined that snowfall had encompassed the landscape. What controls are in place to restrict visibility measurements in the presence of snow?*

**Response for GC 5:**

- We have excluded low visibility records caused by "blowing snow" at high latitude during data preprocessing (Husar et al., 2000).

***GC 6.*** *For the same month (January 2009), the area of the Indo-Gangetic plain in Northern India shows very low VIS_AOD (generally 0.1-0.2) however this area was highly polluted during this period and monthly average values from satellite and AERONET exceeded 0.5. Missing this magnitude of AOD over a large region gives concerns to the applicability of this approach of converting surface-based visibility to column AOD.*

**Response for GC 6:**

- We have supplemented and discussed the uncertainty of VIS_AOD in high latitude and regions in sections 3.3.3 and 3.4.1.

***GC 7.*** *Given the two cases above, the reviewer examined some other months and found similar issues. How should the user interpret these types of issues? Figure 6 clearly shows these anomalies exist. It should be specified that these anomalies will likely translate to the period 1980-2000 in which this data set is meant to be applied according to the Authors. In this regard, have the authors made an assessment on how their technique compares to data assimilation model such as ERA or MERRA-2? Perhaps the few measurements from AERONET before 2000 could be used to assess the performance of the VIS_AOD with respect to AOD provided by ERA and/or MERRA-2.*

**Response for GC 7:**

- We have added a comparison with AERONET AOD (Figure 6 d, f, i) and MERRA-2 AOD (Figure 7) before/after 2000 in section 3.3.1.

***Technical Manuscript Comments:***

***TC 1.*** *Line 121: What does "1126 ground stations" mean? The sentence is referencing Holben et al which is AERONET. In 2002, only about 150-200 sites existed, not 1126 sites.*

**Response for TC 1:**

- Thank you for your correction. We have counted the number of AERONET sites with 15-minute observations of level 3 in 2002, totaling 152. We have made modifications in the manuscript.

***TC 2.*** *Line 426: tau_target variable is defined as "Aqua MODIS" in Figure 2 and not AERONET/Terra MODIS as stated here.*

**Response for TC 2:**

- To avoid confusion, we have replaced "target" with "true".

***TC 3.*** *Line 429: Validation should be used from AERONET and not Terra MODIS. Terra MODIS is not a validation data set. For inputs, using MODIS from Terra or Aqua will pass the biases associated with them into the model. Why not use only AERONET? Also, training the model with the Aqua MODIS (afternoon overpass) and validating with the Terra MODIS (morning overpass) may have some implications in different meteorological environments (e.g., more clouds in the afternoon).*

**Response for TC 3:**

- We use ground-based AERONET AOD and spaceborne Terra MODIS AOD as independent validation datasets. AERONET provides "true" AOD. Despite changes in the meteorological environment, Terra AOD is also meaningful in long-term data (such as on the monthly and yearly scales) validation and provides a large number of comparable samples over global land.

***TC 4.*** *Line 515-516: Can a plot be added to show the comparison with AERONET prior to 2000?*

**Response for TC 4:**

- We have added the comparison with AERONET before 2000 in Figure 6.

***TC 5.*** *Line 518: VIS_AOD shows a large range of points for the daily average especially around 1 +/-1 AOD. This is a huge range in terms of variation of the AOD. More explanation and investigation into the variation is needed to better understand these variations. Even the monthly average plots have a wide range yet more narrow due to averaging of the errors.*

**Response for TC 5:**

- We have provided explanation and investigation in section 3.3.3.

***TC 6.*** *Line 556: change "word" to "world"*

**Response for TC 6:**

- We have made the modifications.

***TC 7.*** *Line 573: change "AERONT" to "AERONET"*

**Response for TC 7:**

- We have made the modifications.

***TC 8.*** *Line 571-572- Why do these regions have high RMSE?*

**Response for TC 8:**

- We have added explanations in section 3.3.3.

***TC 9.*** *Line 578: "Except for Asia" is disconnected from the previous sentence.*

**Response for TC 9:**

- We have made the modifications.

***TC 10.*** *Line 610-612: If emissions and terrain effects are persistent, then these would be systematic then though?*

**Response for TC 10:**

- We have made modifications to this sentence. Averaging over time scale can reduce representation errors effectively, and emission sources and orography can increase representation errors (Schutgens et al., 2017).

***TC 11.*** *Line 799: Please check header formatting.*

**Response for TC 11:**

- We have made the modifications.

**Response to Anonymous Referee #3 (AR3)**

***Comments:***

*1. Vis-derived AOD does not appear to be superior to satellite retrievals. Just as the authors claim that this method is essential for obtaining long-term AOD before the satellite era, I'm very curious if we can have Vis-derived AOD since the 1950s? if not, could you please say a few words why?*

- **Response:** We have achieved visibility-derived AOD since 1959 and updated it into the station VIS_AOD product.

*2. I am a bit worried about the interpolation of AOD, as there are very few stations in many regions, e.g. the Far East, so caution should be taken with the gridded AOD. In fact, I am not comfortable with the gridded product because in my opinion, large uncertainties are not free from the interpolation.*

- **Response:** We have quantified the uncertainty and provided a 95% confidence interval based on kriging variance, as detailed in section 3.4.1. We have supplemented the uncertainty and the quality flag of VIS_AOD in the gridded product.

*3. There is considerable interannual variability of AOD, if possible could you please consider other AOD products to support the analysis in this study, e.g. MERRA-2 product.*

- **Response:** Thank you for your suggestion. We have added a comparison with MERRA-2 AOD in section 3.3.1.