Aral Sea AOD trends

Our analysis identifies the strongest trend in the monthly level 3 MODIS AOD product (MODIS MOD08 M3) over the Aral Sea region. The dust activity in this region is increasing due to the drying Aral Sea which exposes new dust sources (Wiggs et al., 2003). However, due to rapidly changing shorelines and land cover, and the lack of ground based observations for validation, space-borne AOD retrievals over this region are very challenging (Sayer, 2016). This suggests that the extreme MODIS trend is not real in its full magnitude, but includes a spurious component due to retrieval artefacts, and motivates a more detailed analysis of the AOD data in question.

Figure Fig. S31 shows the time series of the one degree cell with the centre 44.5°N59.5°W in the Aral Sea region, which corresponds to the maximum in Fig. 1. The data exhibits a very constant growth over the 15 year period, i.e., the trend does not result from a few years of high AOD, and the small p value indicates a very high significance of the trend. What often characterises a reliable result for an AOD trend, in view of the shrinking Aral Sea rather appears to be a spurious drift related to the changing surface reflectance, in particular due to the changing shorelines. This is further supported by the extremely high AOD values towards the end of the period which suggest that the surface in reality is brighter than assumed for the retrieval algorithm.

Figure S32 shows that the high AOD values and the strong positive trend is restricted to only a few grid cells. The same cells suffer from a low number of AOD retrievals per month (Fig. S33), revealing difficult retrieval conditions. Moreover, in their AOD histograms, Fig. S34, the bin for large AOD values above 1.5 has a frequency comparable to that of bins for lower AOD values which under normal conditions does not occur. Based on this observation, a simple filter can be used to filter out the affected grid cells in the Aral Sea region with little impact on the retrievals globally: for considering a grid cell the frequency of the bin for large AODs (1.5 to 5) is required to be smaller than the mean frequency of all bins (0 to 0.1, 0.1 to 0.3, 0.3 to 0.6, 0.6 to 1.5, 1.5 to 5). As Fig. S35 shows, this condition is fulfilled almost globally. Applying the filter to Fig. 1 yields Fig. S36, where the AOD trend has an upper limit of about 0.025 per year.

References

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Wiggs, G. F. S., O'hara, S. L., Wegerdt, J., Van Der Meer, J., Small, I., and Hubbard, R.: The dynamics and characteristics of aeolian dust in dryland Central Asia: possible impacts on human exposure and respiratory health in the Aral Sea basin, Geographical Journal, 169, 142–157, doi:10.1111/1475-4959.04976, http://dx.doi.org/10.1111/1475-4959.04976, 2003.

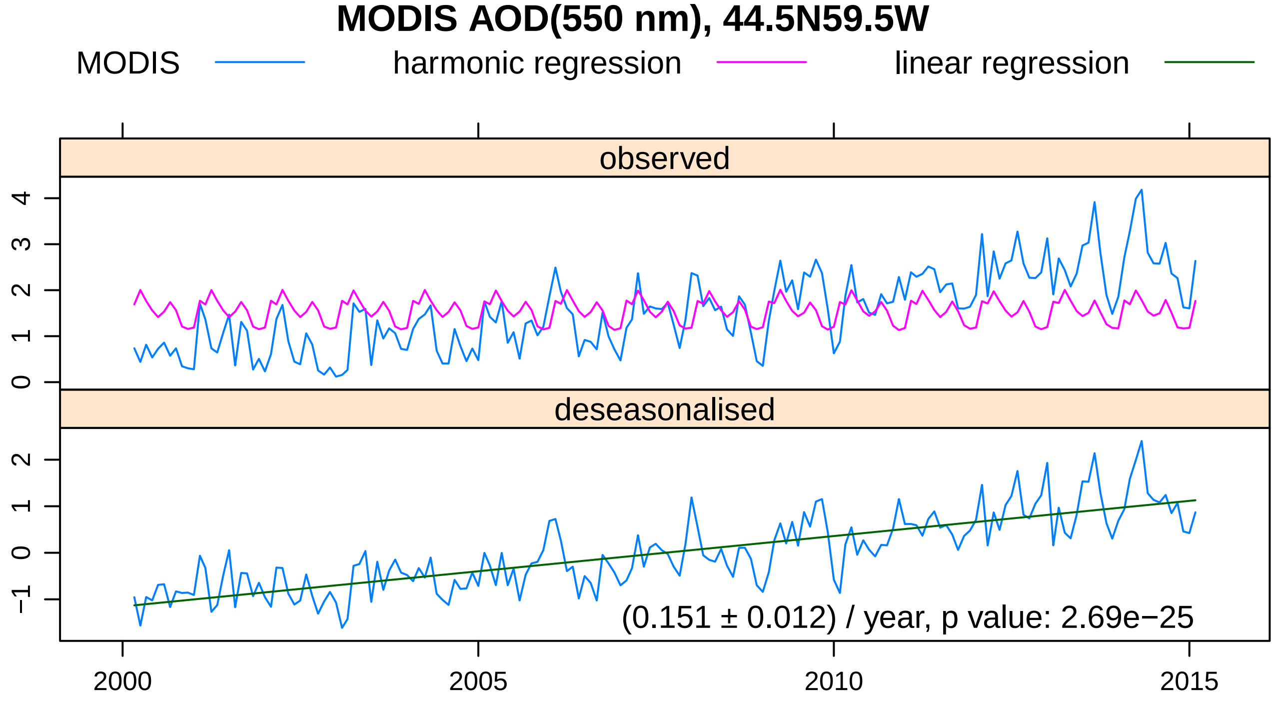

Figure S31. Same as Fig. 3, but for the one degree cell with the centre 44.5°N59.5°W in the Aral Sea region.

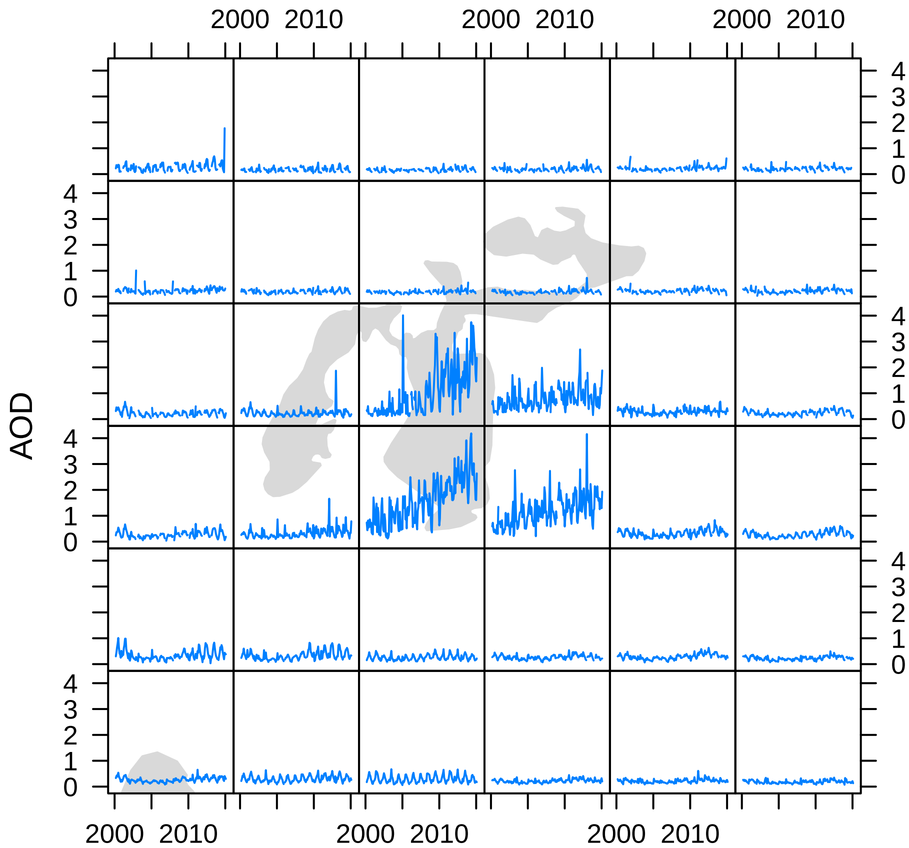

Figure S32. Each panel displays the 15 year AOD time series for a one degree grid cell the location of which is indicated by the grey silhouette showing the Aral Sea. Figure S31 corresponds to the third pixel in the fourth row. Some cells have incomplete monthly time series and therefore are not shown in Fig. 1.

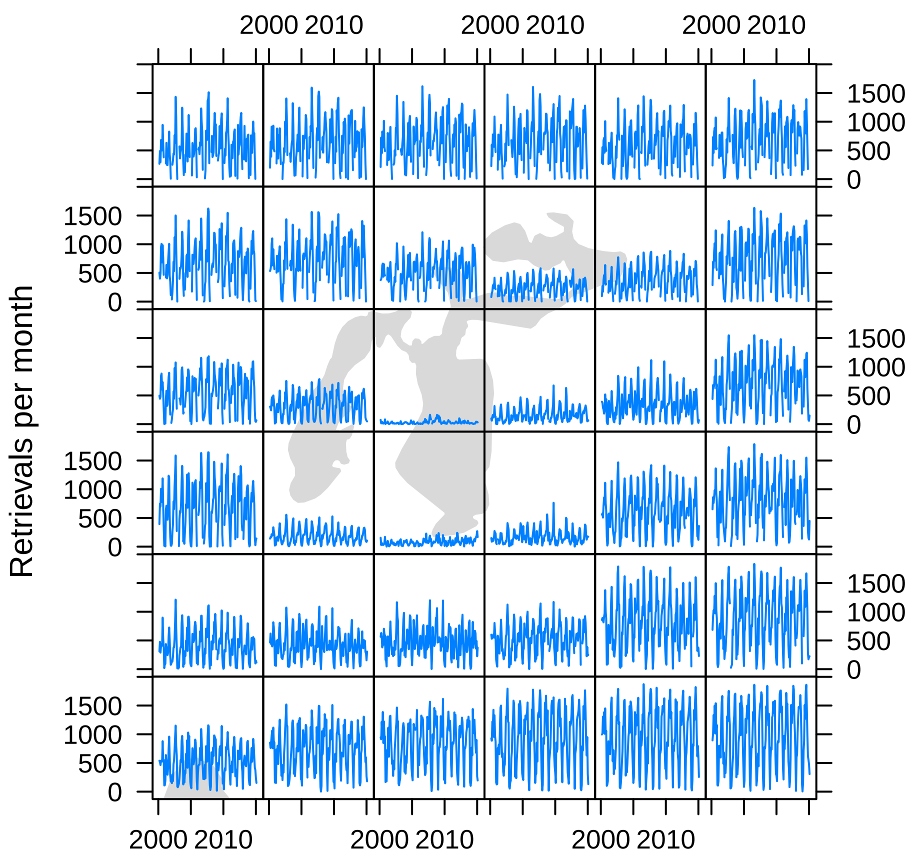

Figure S33. Same as Fig. S32 but showing the number of retrievals per month instead of the AOD.

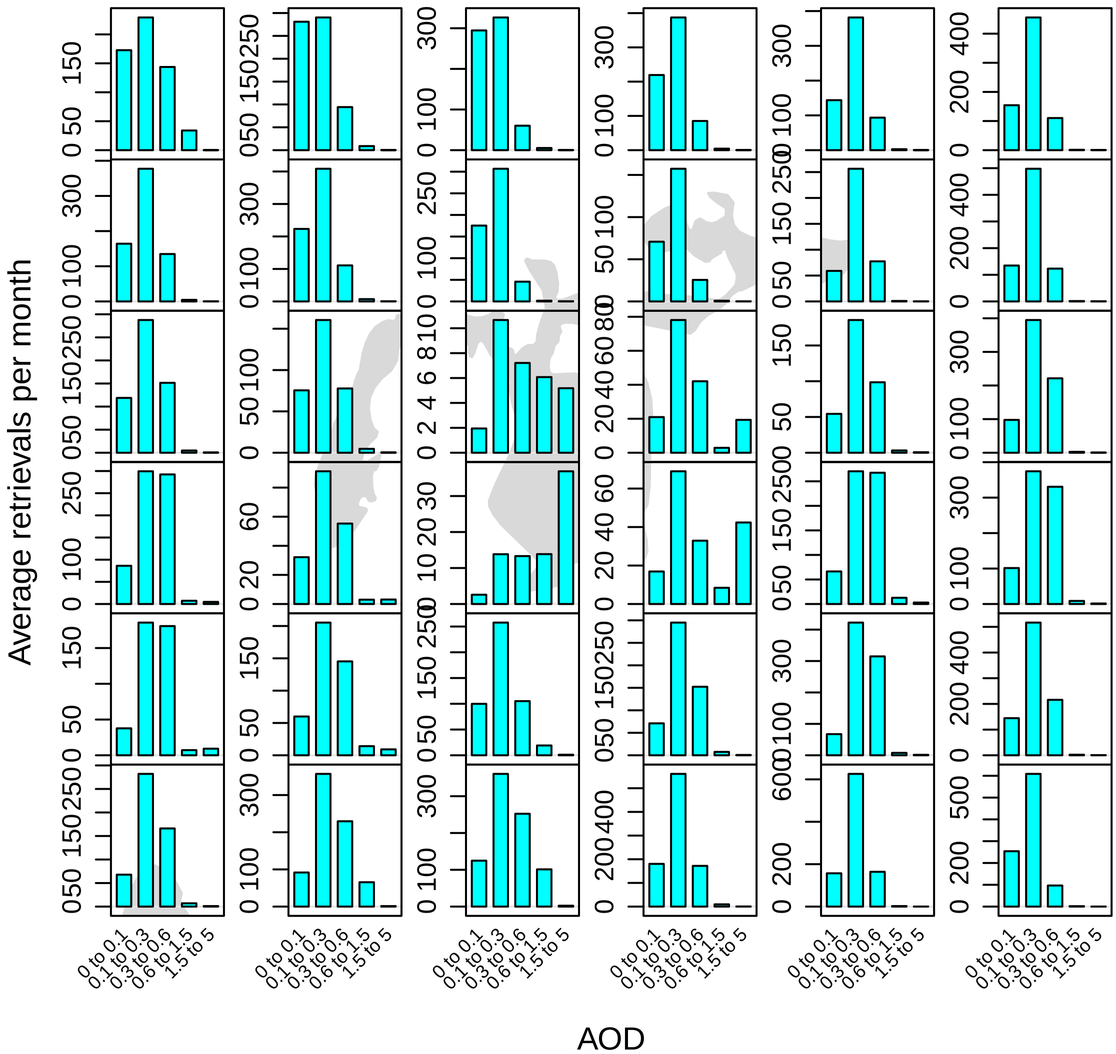

Figure S34. 15 year averages of the monthly AOD histograms. Each panel shows the histogram for the one degree grid cell the location of which is indicated by the grey silhouette showing the Aral Sea.

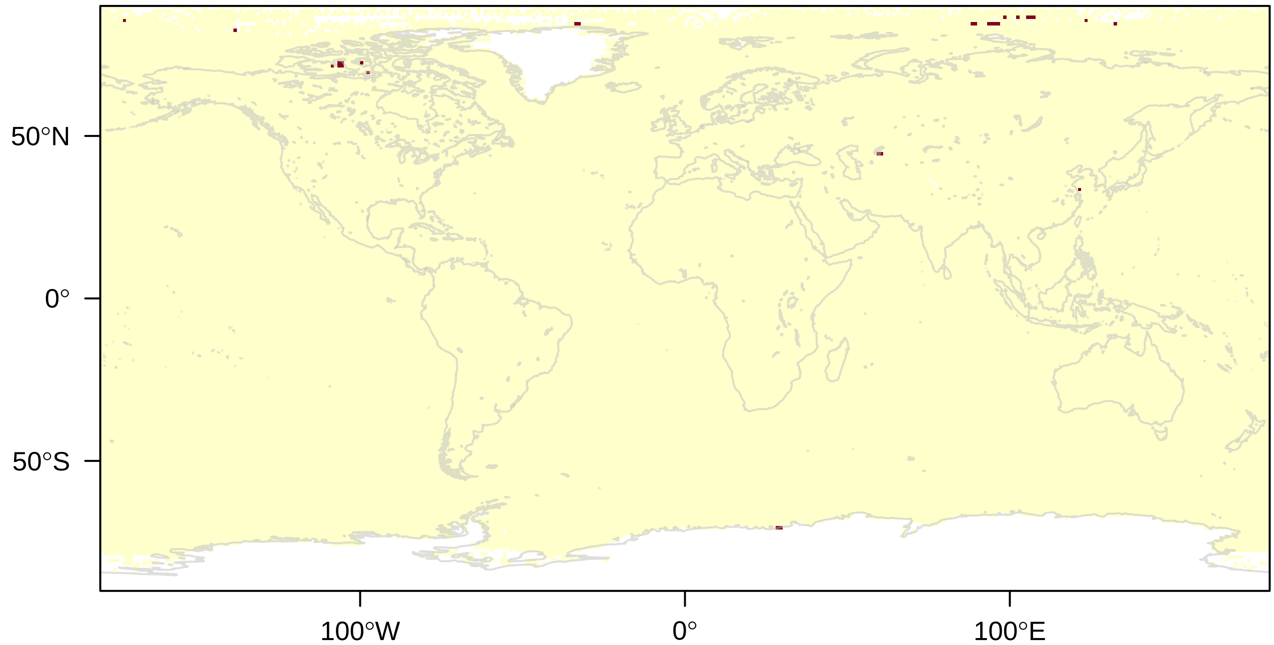

Figure S35. In light yellow grid cells the frequency of high AOD values above 1.5 is smaller than the average frequency of the AOD bins 0 to 0.1, 0.1 to 0.3, 0.3 to 0.6, 0.6 to 1.5 and 1.5 to 5. In dark red cells this condition is not fulfilled, which raises the suspicion that the retrievals over these regions are unreliable and gives reason to not consider them for further analysis.

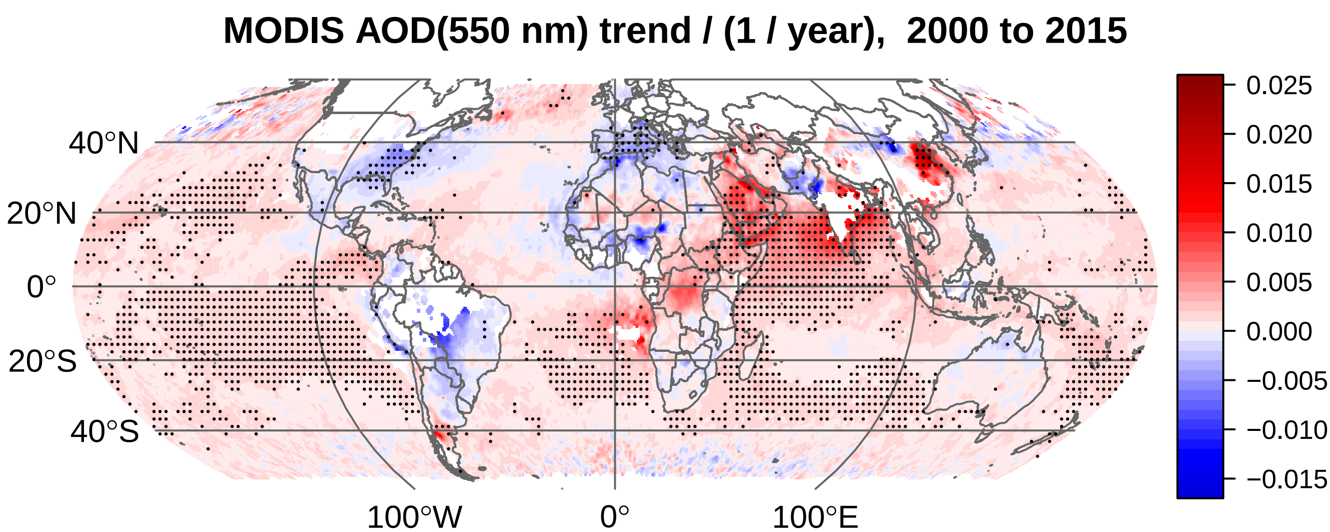

Figure S36. As Fig. 1, but after applying the filter shown in Fig. S35.