Comparison of ground-based meteorological observations and remote sensing datasets for understanding Arctic dust, using MODIS L3 Aerosol products (2001 – 2022).

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Rationale

- The wind-blown entrainment, transportation, and deposition of mineral dust originating in the Arctic exerts a significant control on regional atmospheric, cryospheric, marine and terrestrial environmental systems[1]. Remote sensing (RS) has been pivotal in understanding dust sources, transport pathways and spatial-temporal variability for dust hotspots across the globe[2] but lacks application in the Arctic. Consequently, there are clear opportunities (and challenges) for the systematic use of RS techniques and datasets alongside complimentary ground-based dust records to better understand and quantify sources of dust originating in the Arctic. Present weather coded (synoptic) observations recorded by routine surface meteorological observations represent an independent ground-based record of dust activity, from which there is potential to evaluate the satellite retrieval of dust information.

Aim: To produce the first systematic comparison of Aerosol Optical Depth (AOD) and dust code weather records for a High Latitude (HL) region, using Iceland as a case study.

Background: MODIS and AOD

- The **MOD**erate Resolution **I**maging **S**pectroradiometer (**MODIS**) is a sensor installed on the NASA EOS twin satellite platforms, Terra and Aqua. MODIS samples in 36 spectral bands (0.4 µm – 14.4 µm), operating on a sun-synchronous polar orbit that provides near global data coverage every 1-2 days (Figure 1a). The data acquisition lifetime of Terra MOD (2001 – present) and Aqua MYD (2003 - present) has generated a >20-year archive of data retrievals. One such data retrieval is AOD.
- **Aerosol Optical Depth (AOD)** is a measure of the extinction of light in a column of air due to the presence of aerosols in the atmosphere. AOD is dependent on wavelength and is dimensionless, where values <0.1 indicate clear skies and maximum ground-based visibility, and >0.1 indicate the presence of atmospheric aerosols (e.g. dust, smoke, pollution, sea salt). AOD values therefore represent the magnitude of suspended aerosols (Figure 1b).

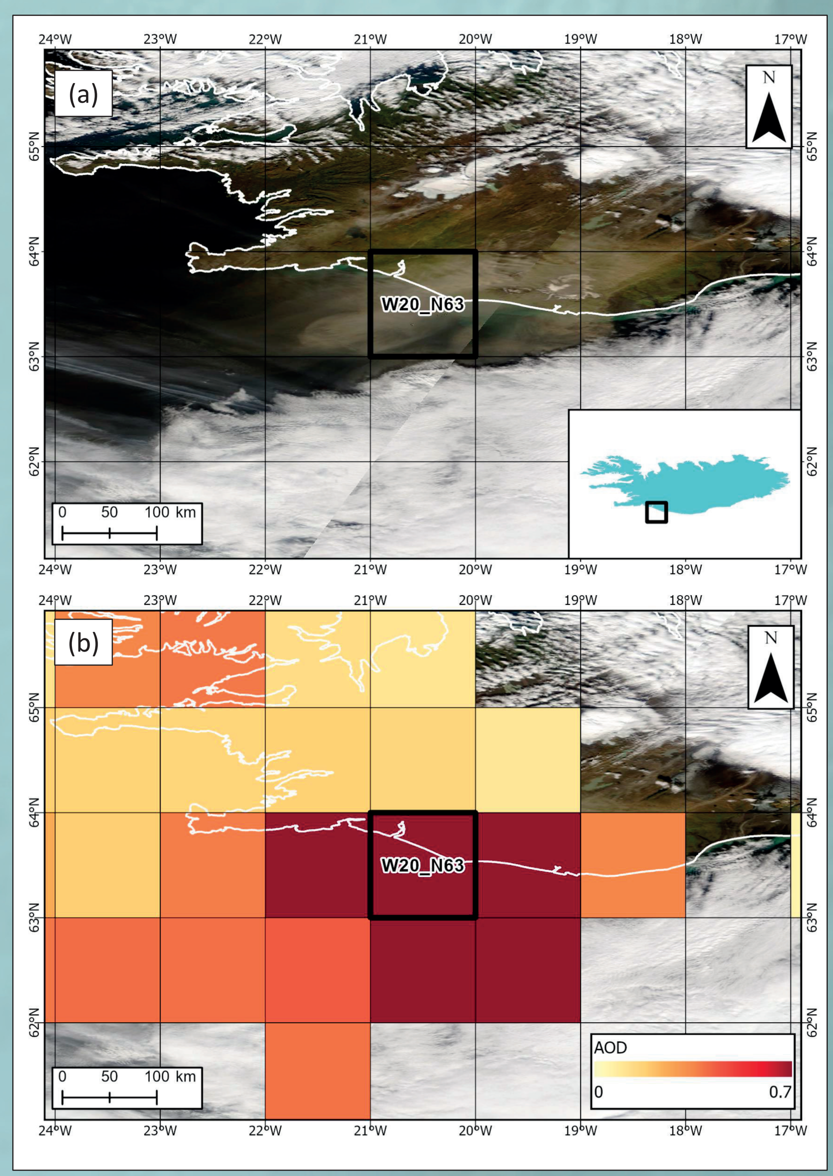


Figure 1: (a) MODIS True Colour Image of SE Iceland 12/09/2011 dust event. (b). MODIS MxD08_D3 AOD distribution for the same event.

Methods

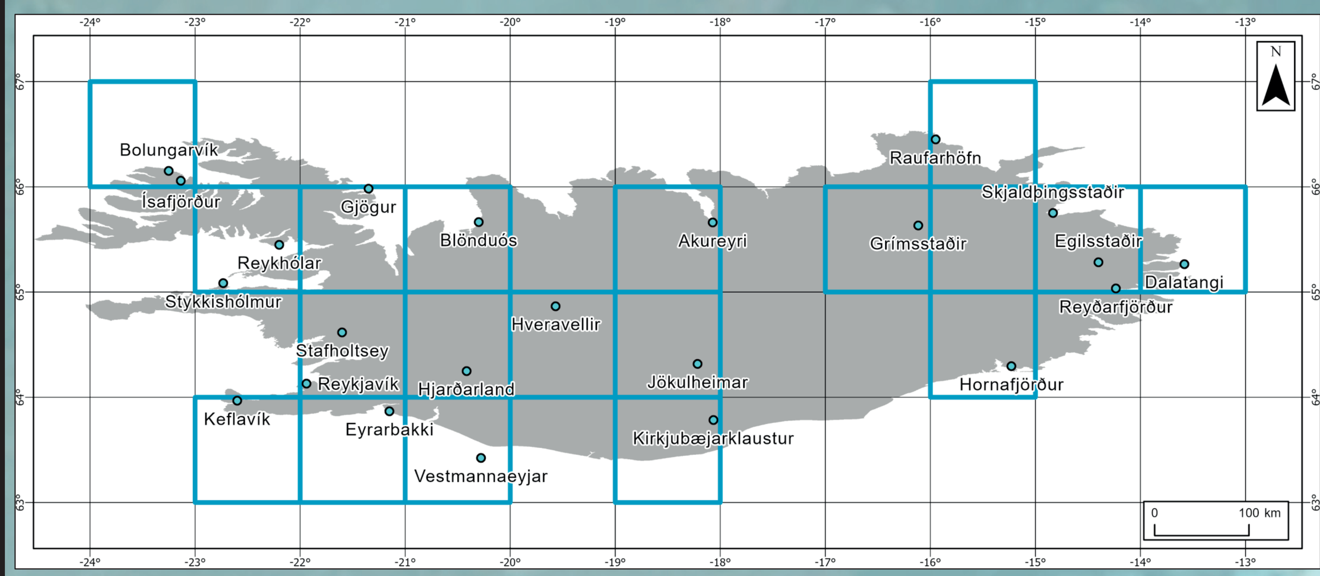


Figure 2. Spatial distribution of 23 meteorological stations that recorded dust codes (2001 – 2022) and the associated MxD08_D3 1° x 1 grid cells.

- Study Area: Iceland (63° - 67° N) (Figure 2).
- All present weather observations of dust (WMO SYNOP Codes. 06-09: blowing dust phenomena, 30-35, 98: specifically, dust storms) recorded between 2001 – 2022 were obtained from 23 meteorological stations across Iceland. Any day that records an observation of dust is defined as a **Dust Event Day (DED)**.
- MODIS Level-3 Daily Aerosol Global Gridded Data Product (MxD08_D3) provides daily mean AOD values at a 1° x 1° grid resolution (Figure 1b). Grid cells containing one or more meteorological stations that recorded dust codes (n = 18) were selected for analysis (Figure 2). Data was acquired for the entire Terra (a.m. overpass) and Aqua (p.m. overpass) record (exc. 2010).

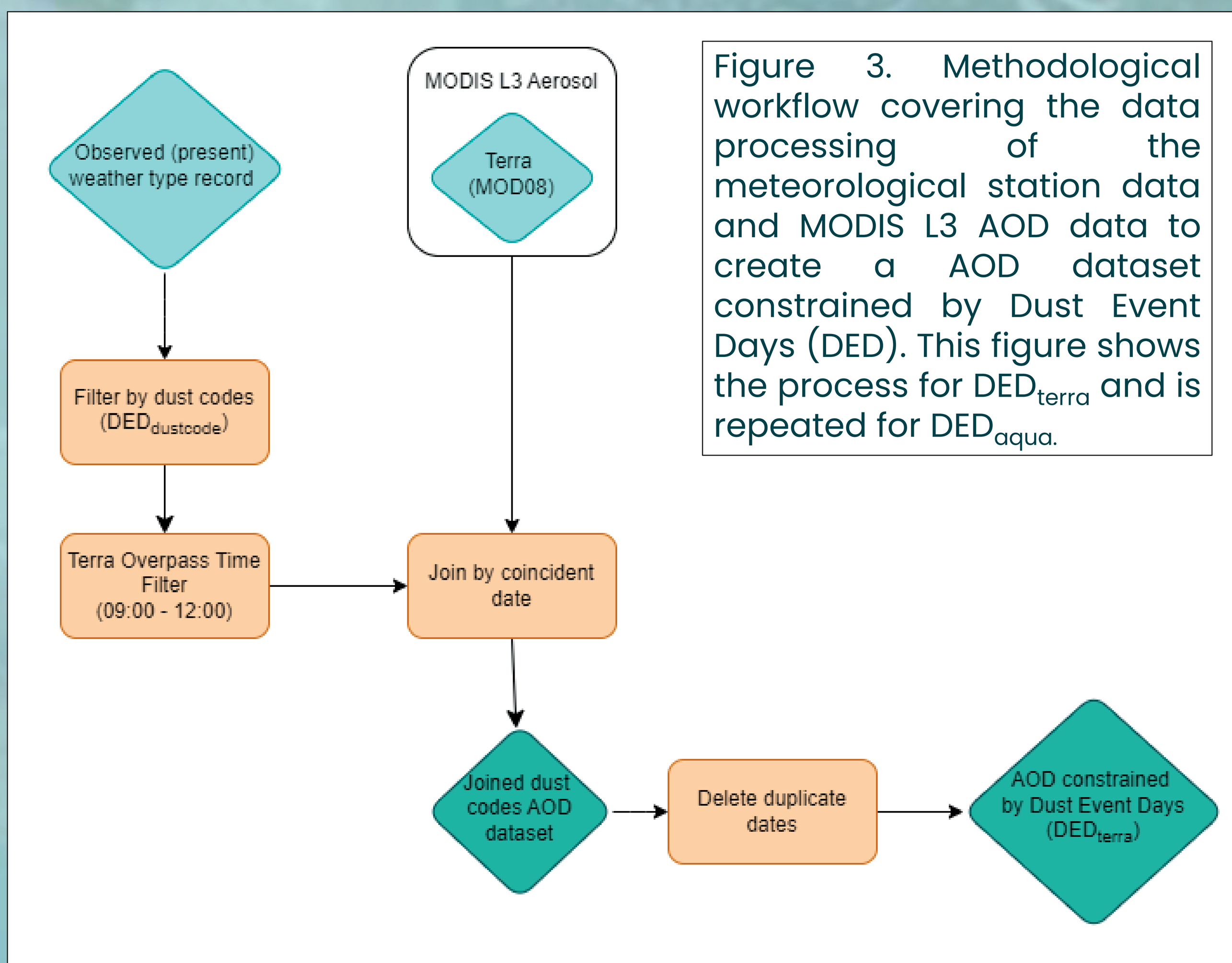
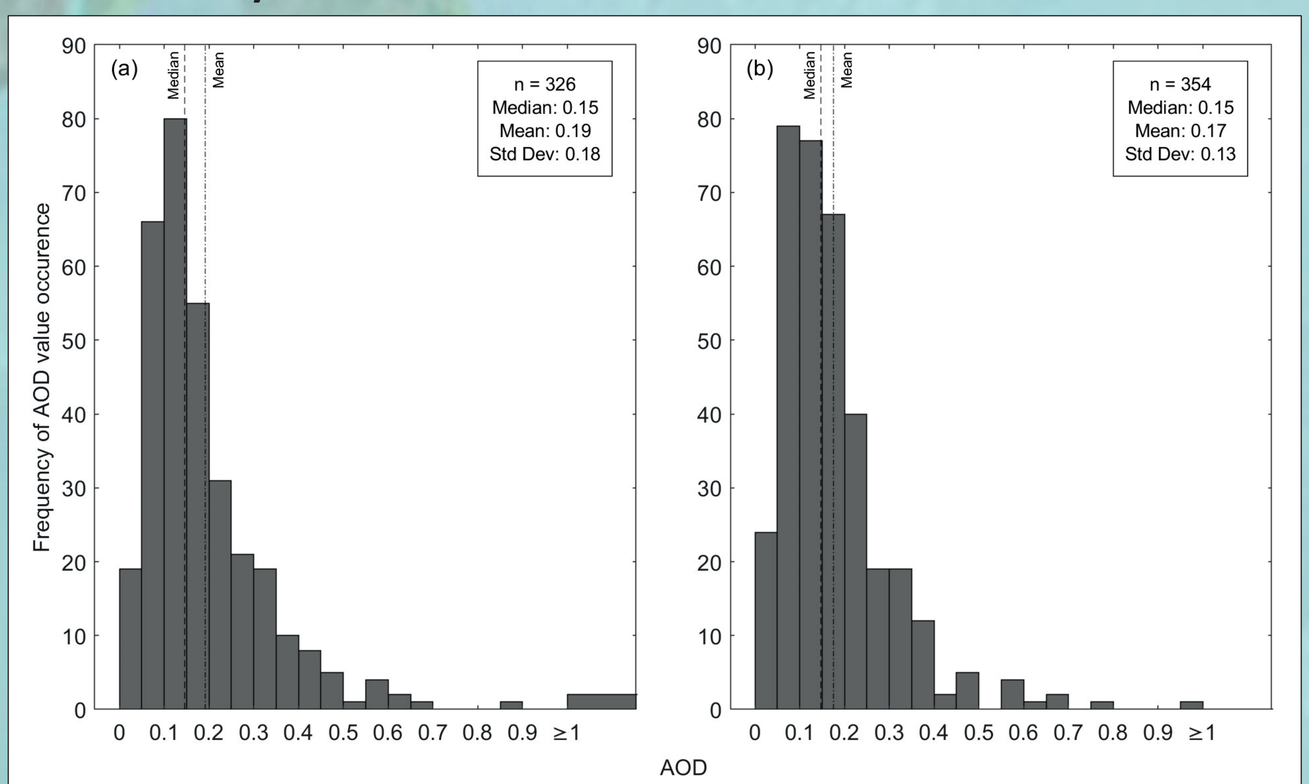


Figure 3. Methodological workflow covering the data processing of the meteorological station data and MODIS L3 AOD data to create a AOD dataset constrained by Dust Event Days (DED). This figure shows the process for DED_{terra} and is repeated for DED_{aqua}.

Preliminary Results



Distribution of AOD values on dust event days (DEDs), for Terra (DED_{terra}) and Aqua (DED_{aqua}), are relatively consistent, indicating no difference in morning and afternoon retrievals (Figure 4).

Data is positively-skewed, with 32% (Terra) and 31% (Aqua) of values exceeding 0.2.

Figure 4 (left): Distribution of AOD values for DED across all 18 cells. (a) DED_{terra} and (b) DED_{aqua}

Across all 18 AOD cells, DED_{terra} and DED_{aqua} show elevated values in comparison to the full (exc. DED) AOD_{terra} and AOD_{aqua} records (Figure 5) ($p<0.05$). This suggests that the variation of AOD, as evidenced by known dust days might be used to understand mineral dust activity in Iceland.

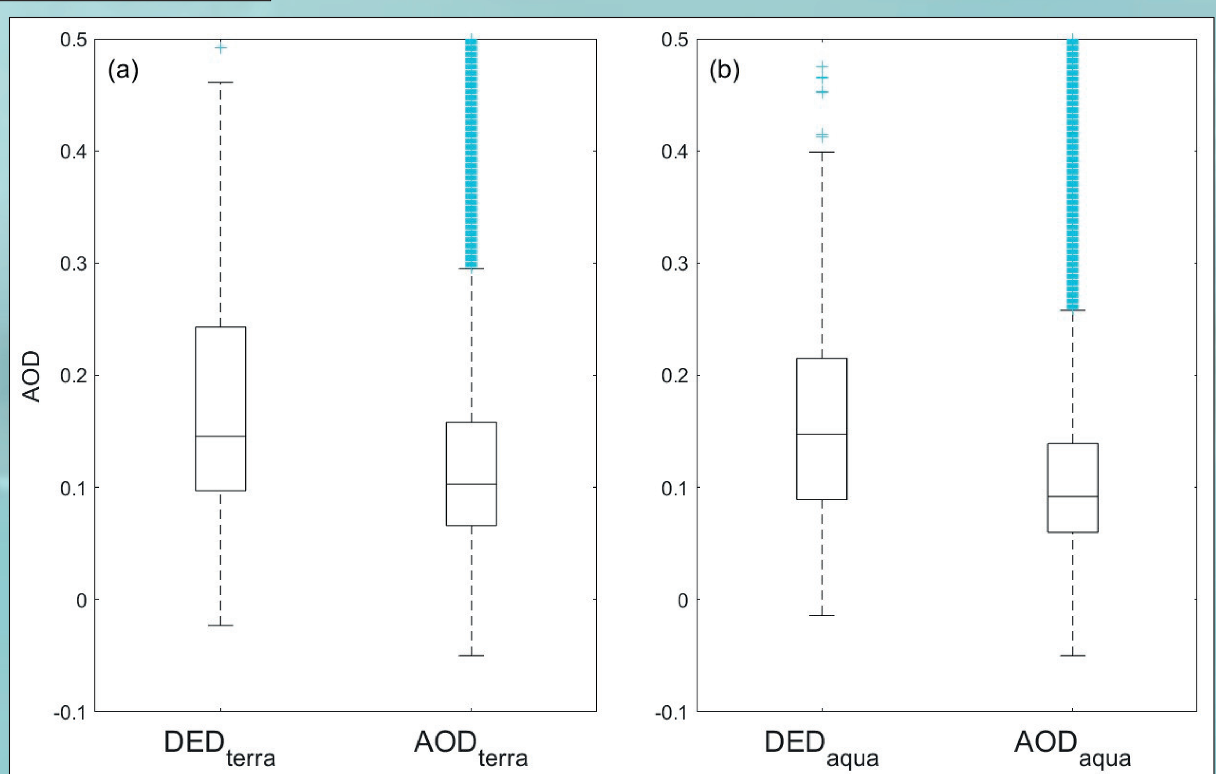
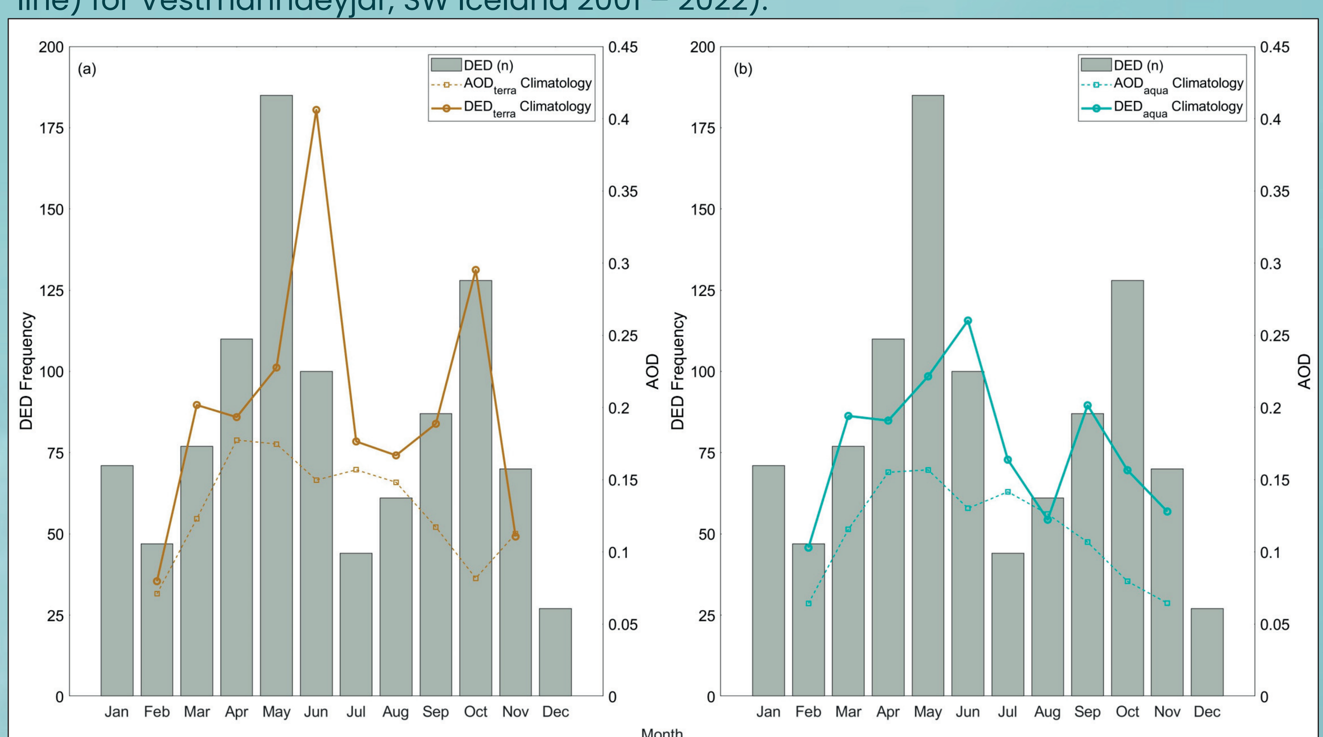


Figure 5 (right): Distribution of AOD data for DED and AOD record (exc. DED). Black line represents the median, blue crosses represent data outliers exceeding the upper quartile range (a) Terra (b) Aqua

Figure 6 (below): Frequency of dust event days per month (grey bars), DED climatology (solid line), AOD climatology (dashed line) for Vestmannaeyjar, SW Iceland 2001 – 2022).



Using Vestmannaeyjar as an example of seasonal AOD patterns, monthly DED_{aqua} and DED_{terra} are elevated vs. total AOD_{terra} and AOD_{aqua} (Figure 6). AOD exhibits bimodality with peaks during spring and autumn, following similar patterns to $DED_{dustcode}$ and periods of maximum dust emission potential (spring melt of snow cover, autumn meltwater recession) from dust source surfaces.

Next Steps

- Expand the analysis shown in Figure 6 to other stations and grid cells to examine how seasonal patterns of AOD change with location.
- Examine the differences in AOD monthly variation between north and south Iceland.
- Account for where AOD values might be missing and understand the reasons why.

References

[1]Bullard, J.E. et al. (2016) High-latitude dust in the Earth System, *Review of Geophysics*, 54, 447-485.

[2]Ginoux, P. et al. (2012) Global-scale attribution of anthropogenic and natural dust sources and their emission rates based on MODIS Deep Blue aerosol products, Reviews of Geophysics, 50, 1-36.