Arctic spring and summertime aerosol extreme events: statistics and implications for the impact of regional biomass burning processes

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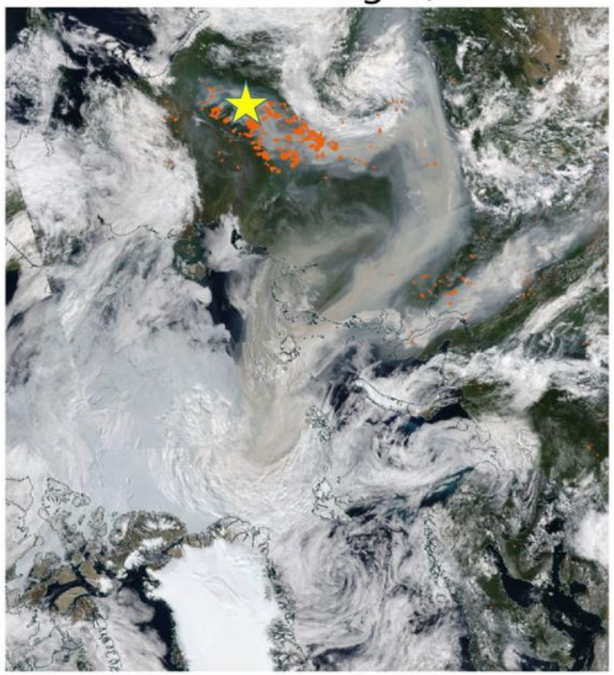
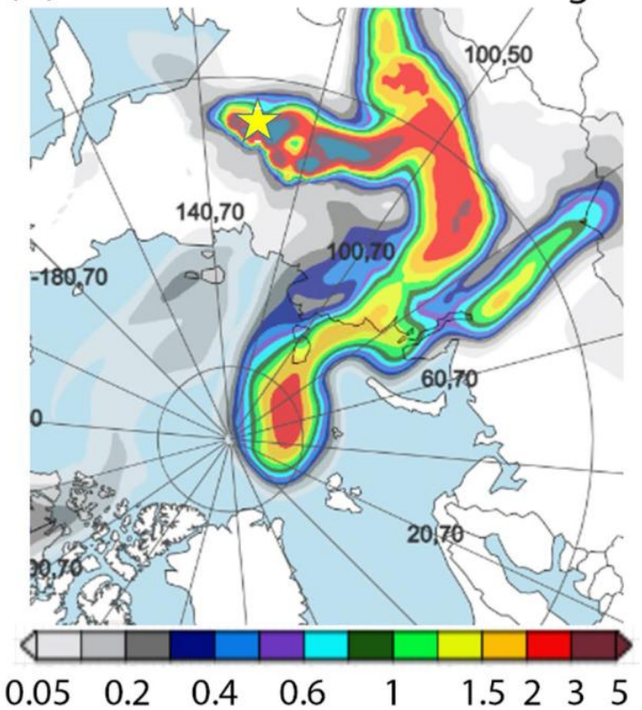
Example of biomass burning smoke transport to the Arctic

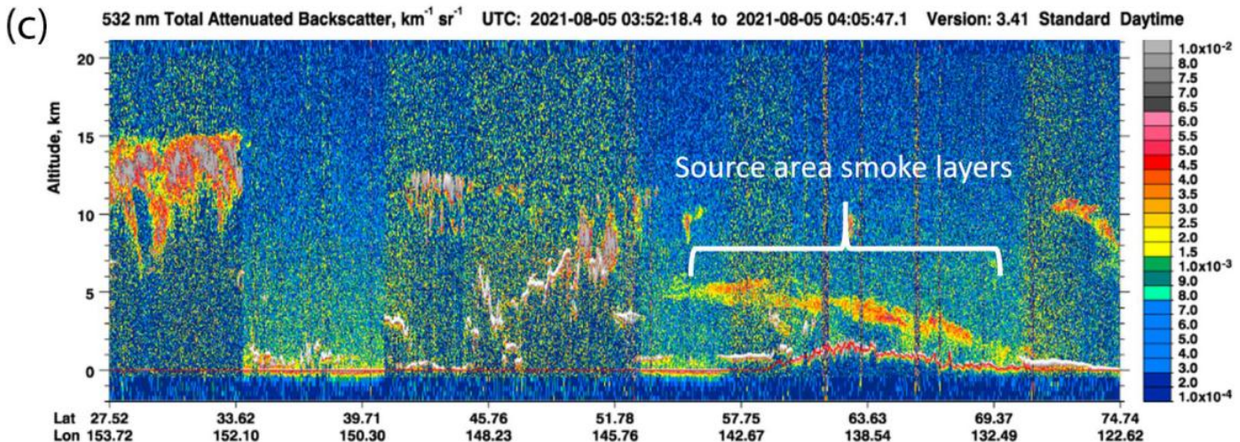
(a) Terra True-color Aug. 5, 2021



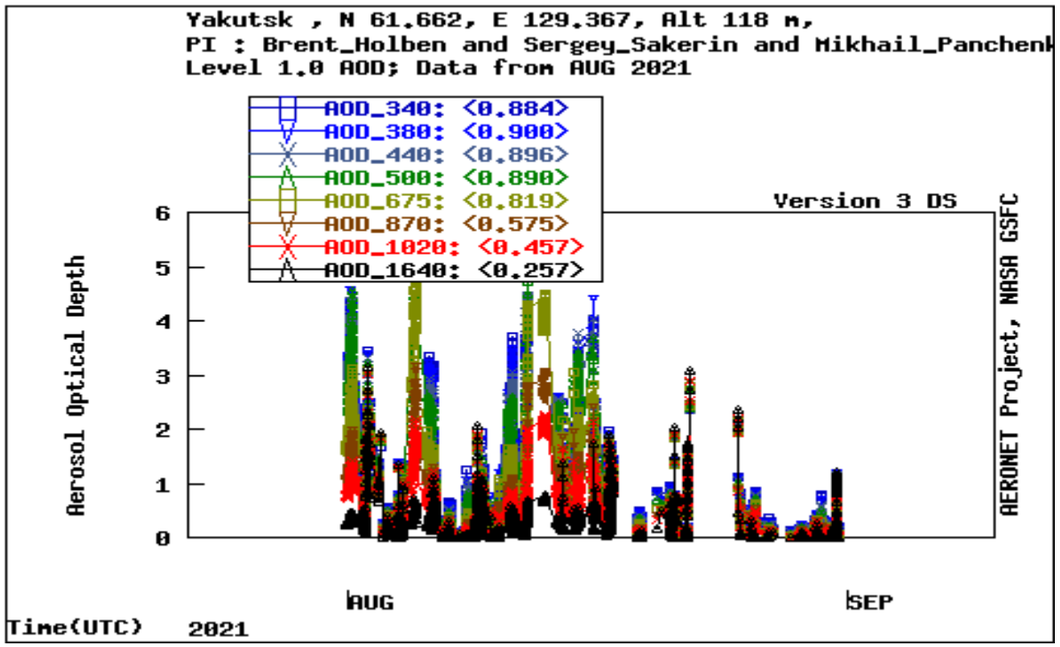
(b) NAAPS smoke AOD 12Z Aug. 5



(c)



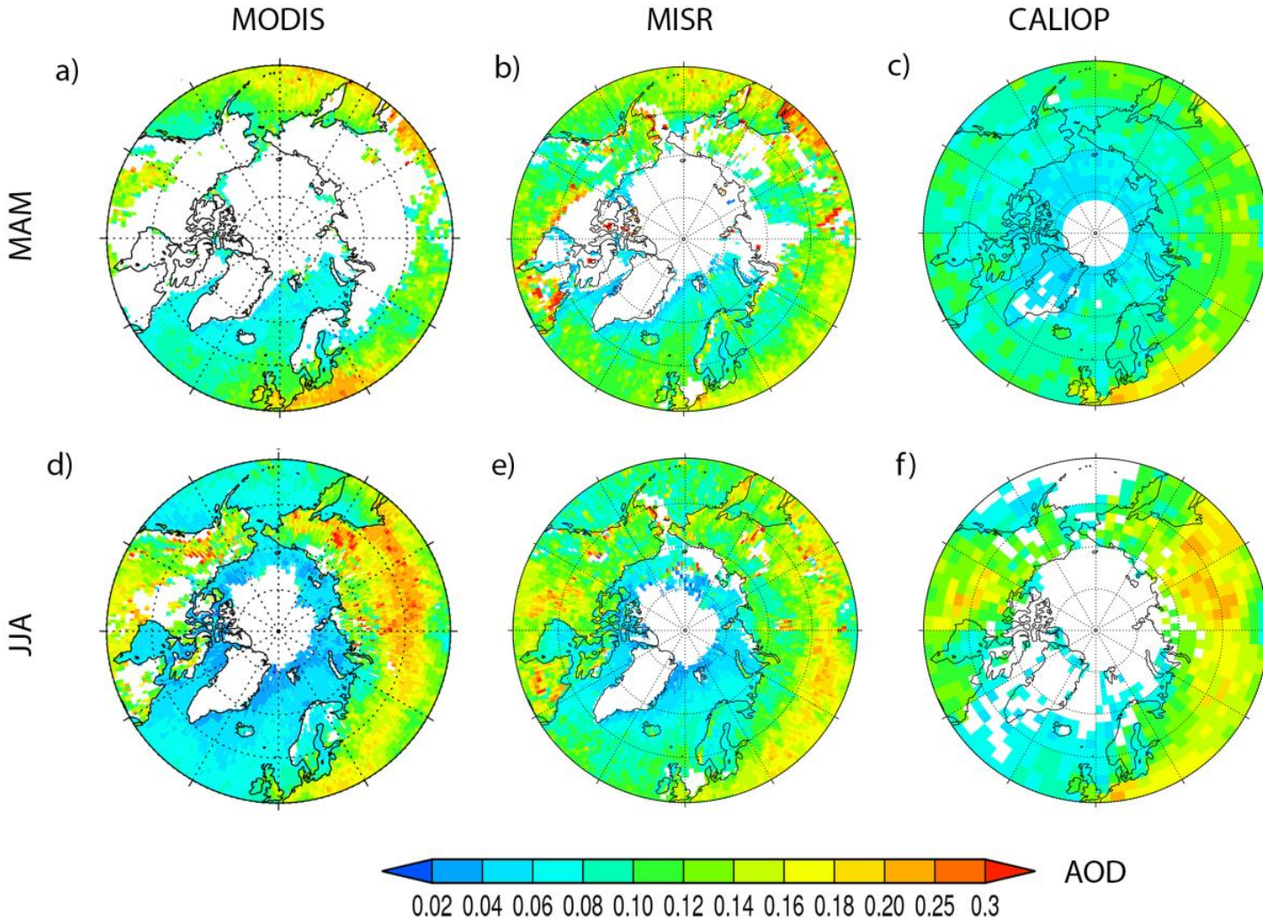
AERONET site
Yakutsk , Aug 5.
AOD@500nm = 4.4



AOD spring and summertime climatology over Arctic (>60° N)

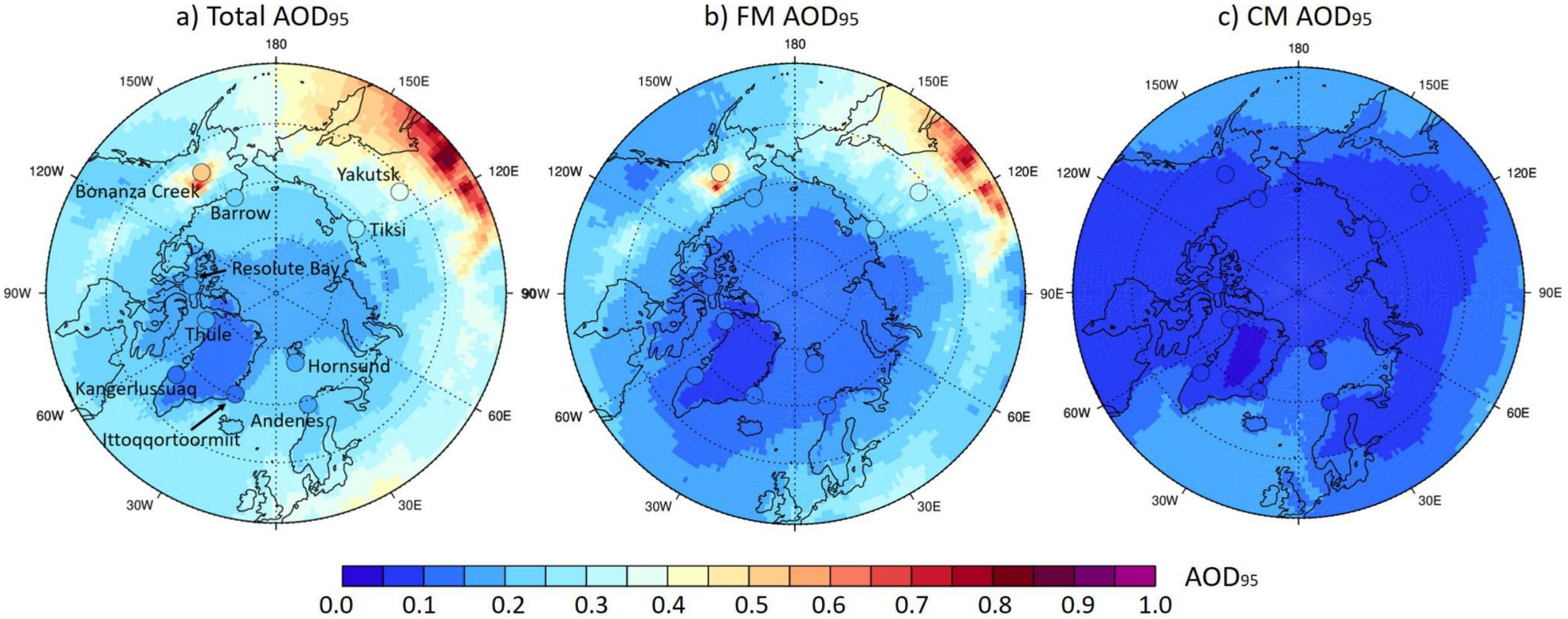
Data used in this study:
NRL NAAPS-RA speciated AOD at 550 nm (Lynch et al. 2016)
AERONET V3L2 (Giles et al, 2019) with SDA (O' Neil et al. 2001, 2003).
MAN AOD data with SDA (Smirnov et al., 2009, 2011).
OMI Level-2 OMAERUV V003 UV Aerosol Index (AI) data
NASA MERRA2 speciated AOD at 550 nm (Randles et al. 2017)
ECMWF CAMSRA speciated AOD at 550 nm (Inness et al. 2019
CALIOP V4.1 Level 2 532 nm (2006-2019, Toth et al. 2018)

High Arctic Challenge:
Passive-based sensors have very limited ability in retrieving aerosol properties over snow/ice.
Active-sensors, like CALIOP, only goes to 82°Latitude.



Xian et al., ACP, 2022a

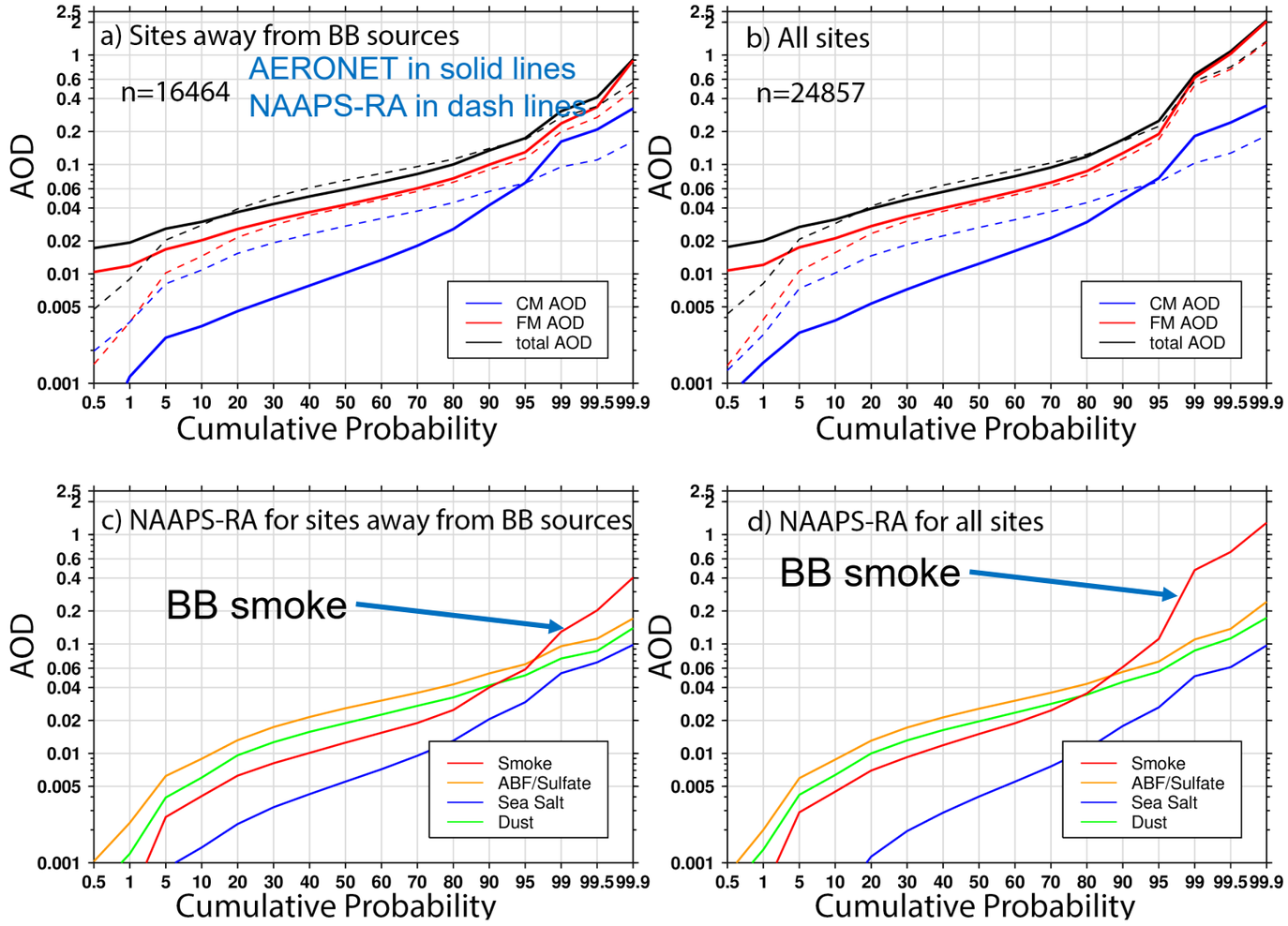
Total, Fine-mode, Coarse-mode AOD at 95th percentile



- 2003-2019 March-August time frame.
- Arctic spring and summer extreme AOD events are dominated with fine-mode events in general.
- NAAPS-RA is capable of capturing the 95th percentile events compared with AERONET measurements.

Xian et al., ACP, 2022b

Cumulative probability distributions FM, and CM AOD at 550 nm for AERONET and NAAPS-RA (2003-2019)



- The median of 6-hr total AODs at 550 nm for all 10 Arctic AERONET sites and MAN (>70°N) retrievals over the 2003–2019 period is 0.07, while AOD_{95} is 0.23.
- Both the median and AOD95 values show a dominant FM AOD contribution. The CM AOD median is 0.01, while AOD_{95} is 0.07.
- The maximum AOD over the 2003–2019 period varies between 0.5–3.0 for measurements made away from BB source regions and 1.5 to greater than 3.0 for measurements made closer to BB source regions.
- Arctic spring and summer extreme AOD events are largely attributable to BB smoke transport events in general.

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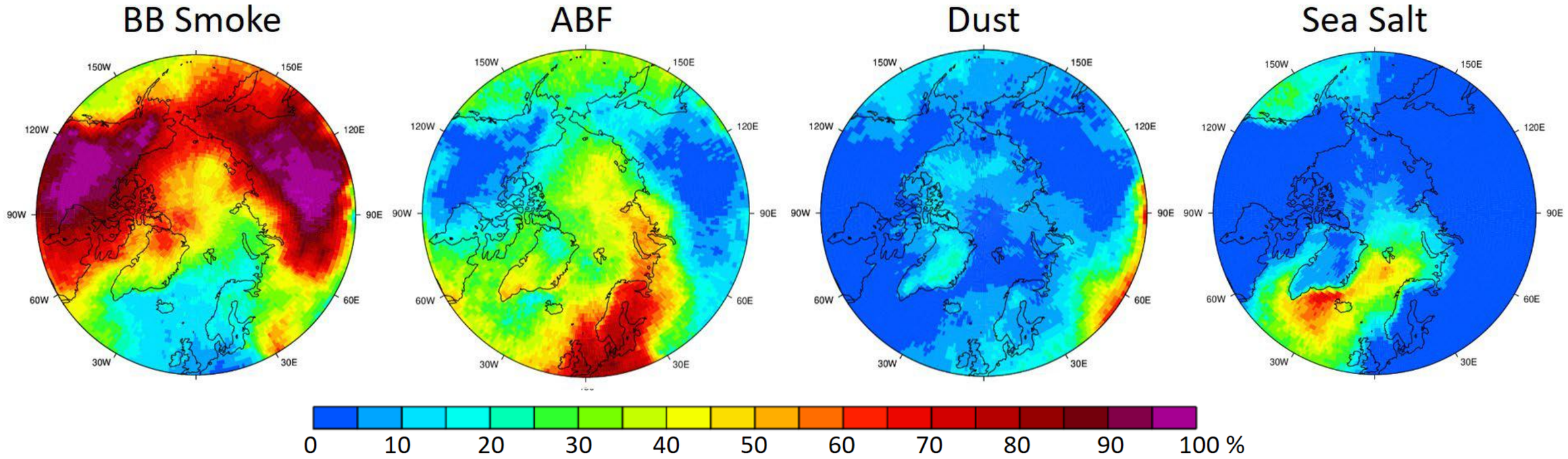
Contribution of aerosol species to local extreme AOD events

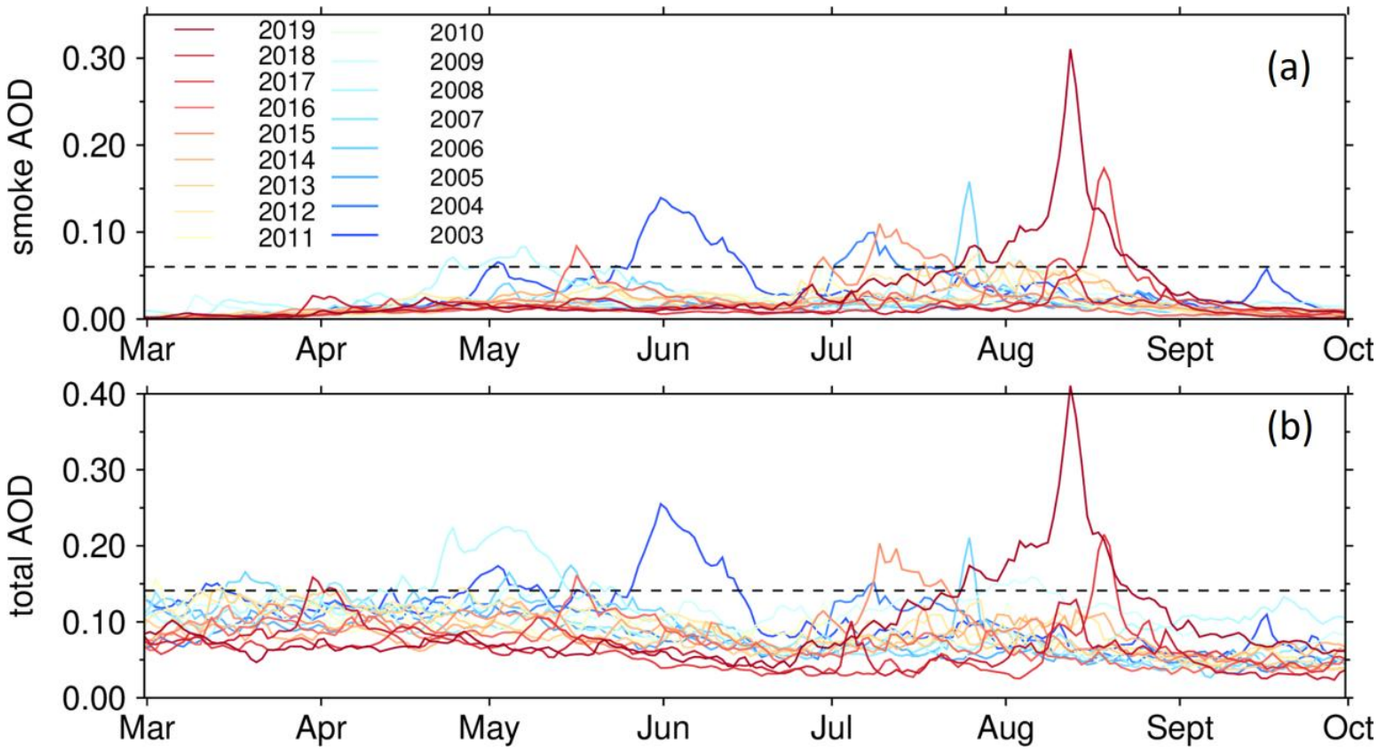
2003-2019



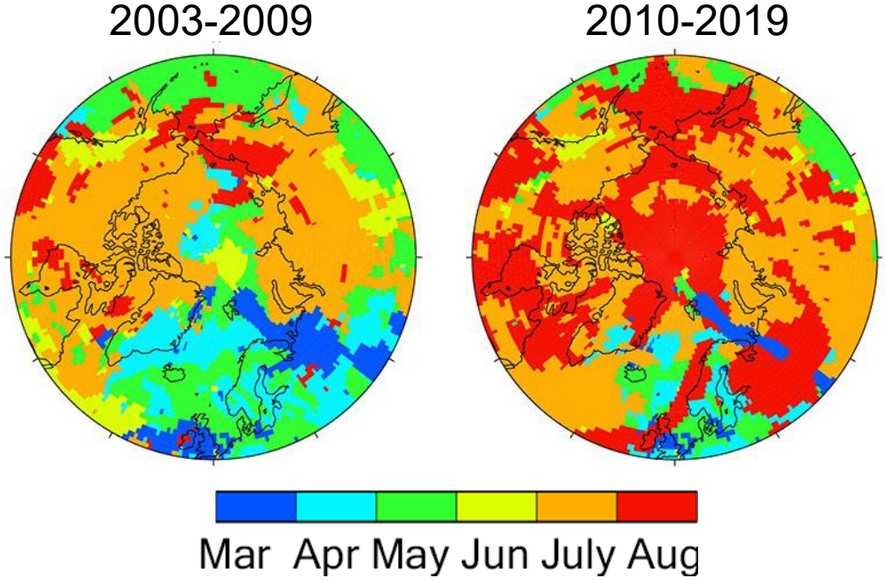
- Occurrence of different aerosol species (expressed as a percent) relative tot he occurrence of total AOD extreme events (daily tota AOD > AOD_{95} locally) for the March-August time frame.
- Extreme AOD occurrences in the North American Arctic, the Asian Arctic, and the high Arctic are dominated by BB smoke events.
- The occurrence of regionally extreme AOD events is attributed more to ABF in the lower European Arctic.
- The extreme-event occurrence dominance of sea salt aerosols is largely limited to the North Atlantic and Norwegian Seas.
- The extreme AOD amplitudes of ABF and sea-salt AOD are, however, significantly lower than those regions where extreme-AOD smoke AOD is dominant.

Shift of extreme AOD events from spring–summer to summer season during 2003-2019

Time series of daily-mean AODs averaged over the 70-90N domain

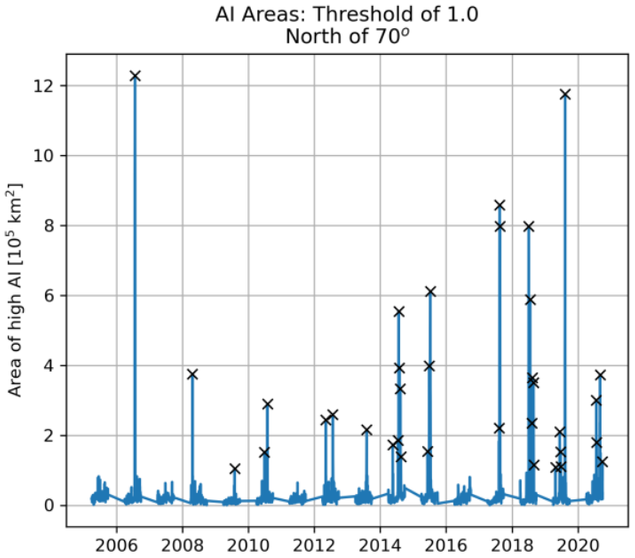


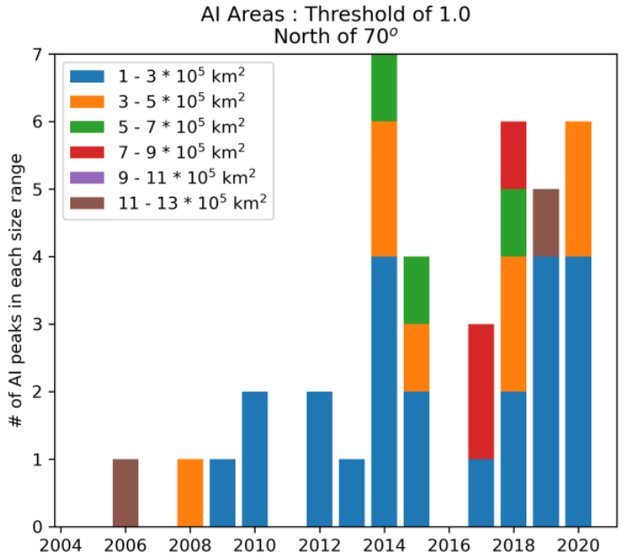
Occurring month of AOD_{max}

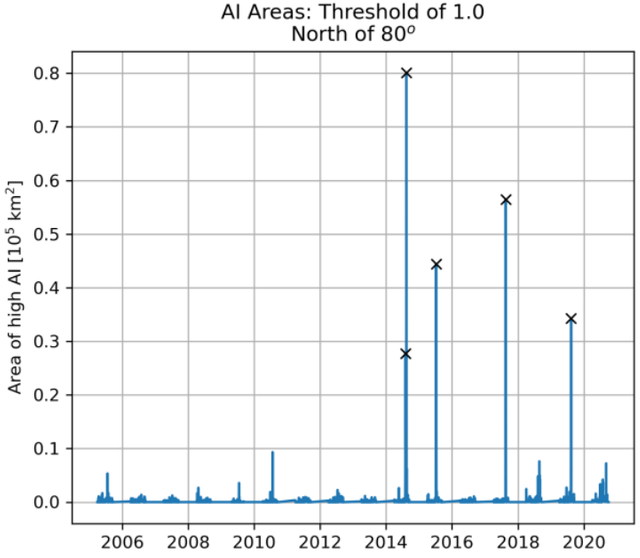


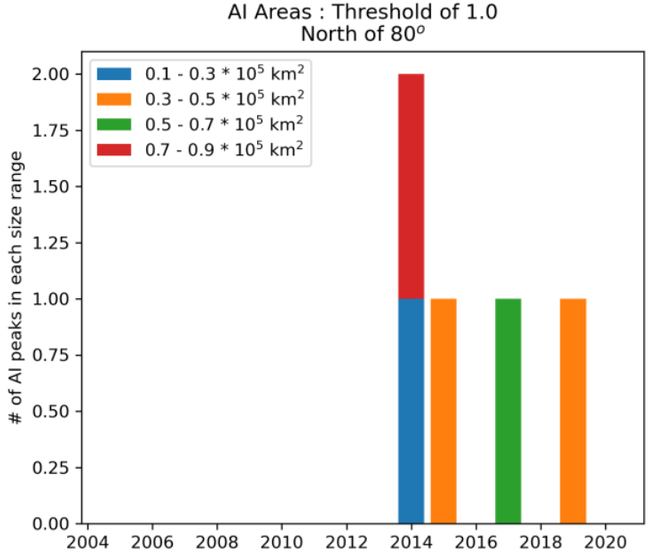
- Extreme AOD events are observed to occur in a more balanced fashion over the entire April–August season during 2003–2009 while being more concentrated in the latter part of the season (i.e., July and August) during 2010–2019.
- The seasonal shift in extreme smoke AOD events is consistent with the multi-year negative MAM trend and positive JJA trend in BB emissions.
- Decreasing trend in spring time anthropogenic pollutions.

Arctic OMI Aerosol Index: more AI events in 2014-2020





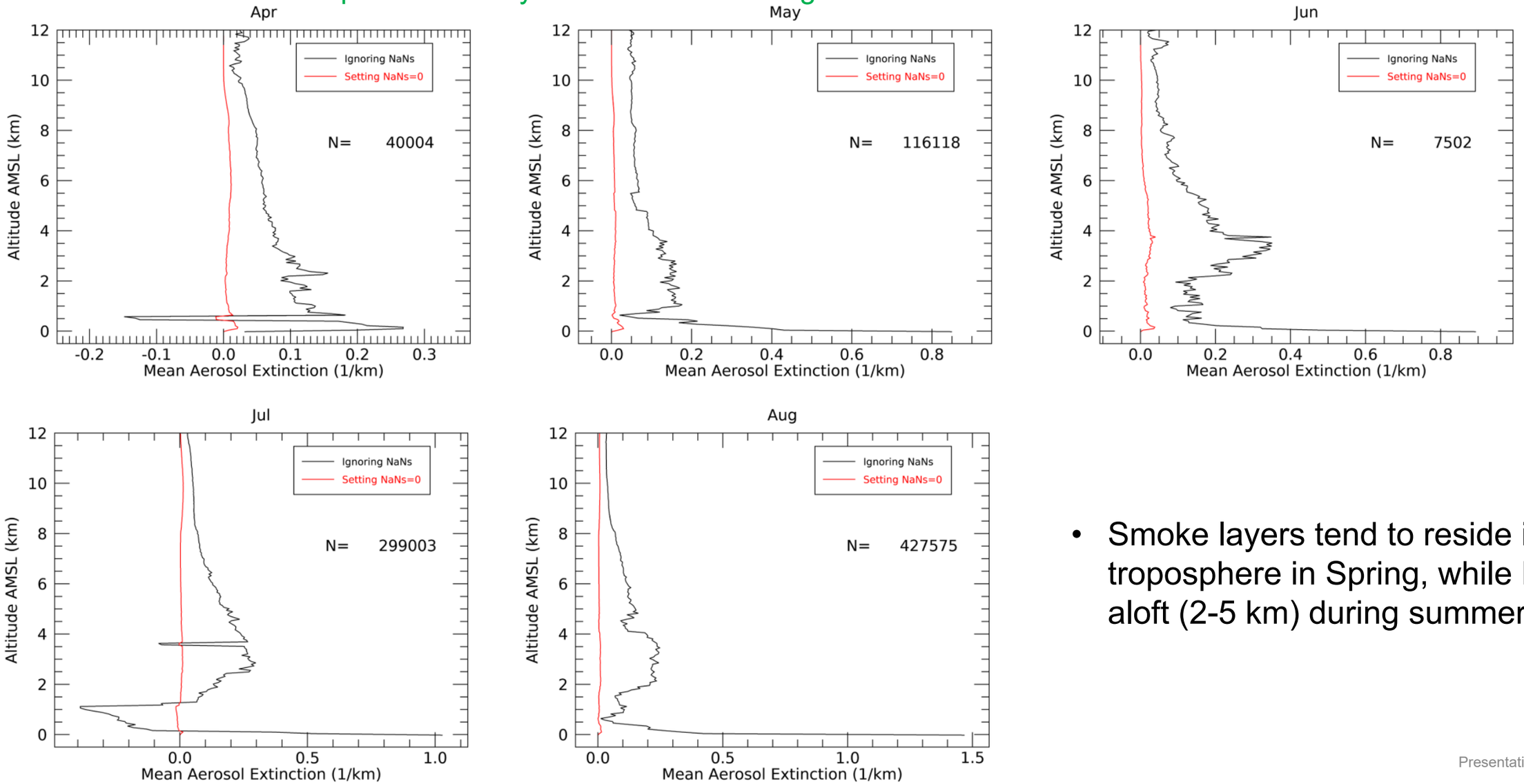




- The number of peaks in daily perturbed AI areas, as well as the size of each peak, are calculated per year
- More high-amplitude Arctic AI peaks north of 70 °N occurred in 2014-2020 than 2005-2013
  - Results are consistent with stats of extreme AOD events associated with biomass burning events
- All large (> 10^4 km^2) very high Arctic (>80 °N) AI peaks occurred between 2014 and 2019
- Sorenson et al., ACPD, in review

Vertical profiles from CALIOP for north of 70°N (2006-2019)

Extinction profiles for days with NAAPS-RA regional mean smoke AOD >0.06



- Smoke layers tend to reside in lower troposphere in Spring, while being aloft (2-5 km) during summertime.

Summary on Spring and Summertime Arctic Aerosol extreme events

- Biomass burning (BB) smoke is the largest contributor to extreme aerosol events in Spring and Summertime over the Arctic, despite some regional dependency.
- Locally, the occurrence of extreme AOD events (AOD above 95th percentile) is attributed more to anthropogenic pollutions in the lower European Arctic and marine aerosols in the north Atlantic.
- There is a shift of extreme events from spring-summer to summer season from the earlier decade to the later decade during 2003–2019. The seasonal shift in extreme smoke AOD events is consistent with the negative MAM trend and positive JJA trend in BB emissions.
- Smoke layers tend to reside in lower troposphere in Spring, while being aloft (2-5 km) during summertime.

References:
Xian, P., et al. : Arctic spring and summertime aerosol optical depth baseline from long-term observations and model reanalyses – Part 1: Climatology and trend, Atmos. Chem. Phys., 22, 9915–9947, https://doi.org/10.5194/acp-22-9915-2022, 2022.
Xian, P., et al. Part 2: Statistics of extreme AOD events, and implications for the impact of regional biomass burning processes, Atmos. Chem. Phys., 22, 9949–9967, https://doi.org/10.5194/acp-22-9949-2022, 2022.
Sorenson et al., An investigation into the use of OMI UV aerosol index for data assimilation and aerosol climate forcing applications over the Arctic region, ACPD, 2022
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