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Short-term variability of aerosol optical properties at NOAA's federated aerosol network

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Aerosol measurements are made on many different time and space scales (e.g., satellite retrieval vs continuous in-situ data from a surface site).
Aerosol properties can be quite variable in space and time due to variations in sources, atmospheric processing and transport.
These variations in temporal and spatial measurement resolution combined with the inherent variations in aerosol properties make it difficult to create a global (or even regional) picture of atmospheric aerosol properties on scales relevant to climate and air quality investigations

Why is it useful to understand the short-term variability in aerosol optical properties?

- Improve understanding of how well measurements with different resolution can be expected to agree – e.g., satellite (or model) compared to in situ data
- Identify the degree to which independent measurements of an aerosol property are internally consistent (e.g., remote sensing vs in situ data)
- Determine spatial/temporal representativeness of data as well as the influence of atmospheric dynamics/processing on those measurements

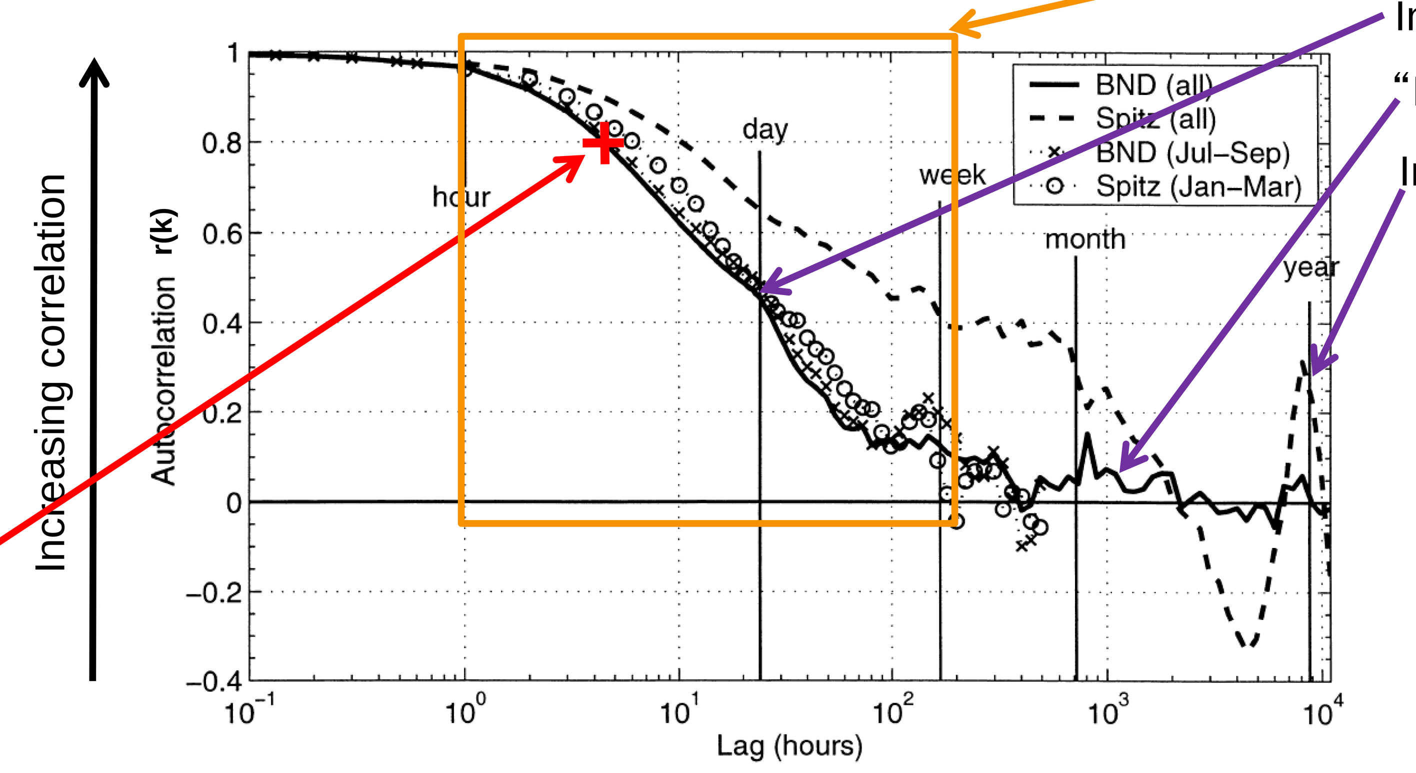
→ Autocorrelation analysis is a tool that can help assess aerosol variability

Autocorrelation analysis

The calculated autocorrelation statistic, r(k), represents the correlation coefficient between all pairs of points in a data set that are separated by 'k' (where k in this study has units of time).

Anderson et al. (2003) use plots of the autocorrelation statistic to suggest:

- Aerosol light scattering is controlled by mesoscale variability (not synoptic).
- Coherent time scales for aerosol light scattering are less than 10h (i.e., where r(k)>0.8).
- This identification of coherent time scales places strong constraints on comparisons of measurements with different temporal resolution.



Autocorrelation statistic 'r(k)' for aerosol light scattering at Bondville, IL (BND) and Spitzbergen, Sweden (Spitz). (From Anderson et al., 2003)

Plots in analysis discussed below cover this range of lag (i.e., time)

Inflection point at 24 h indicates slight diurnal cycle

"BND (all)" line used as point of comparison on plots below

Increase in r(k) at lag=1 yr indicates strong annual cycle

Autocorrelation analysis in the literature:

Heintzenberg et al. (2004) evaluated the atmospheric processes affecting the variability of aerosol number concentration.

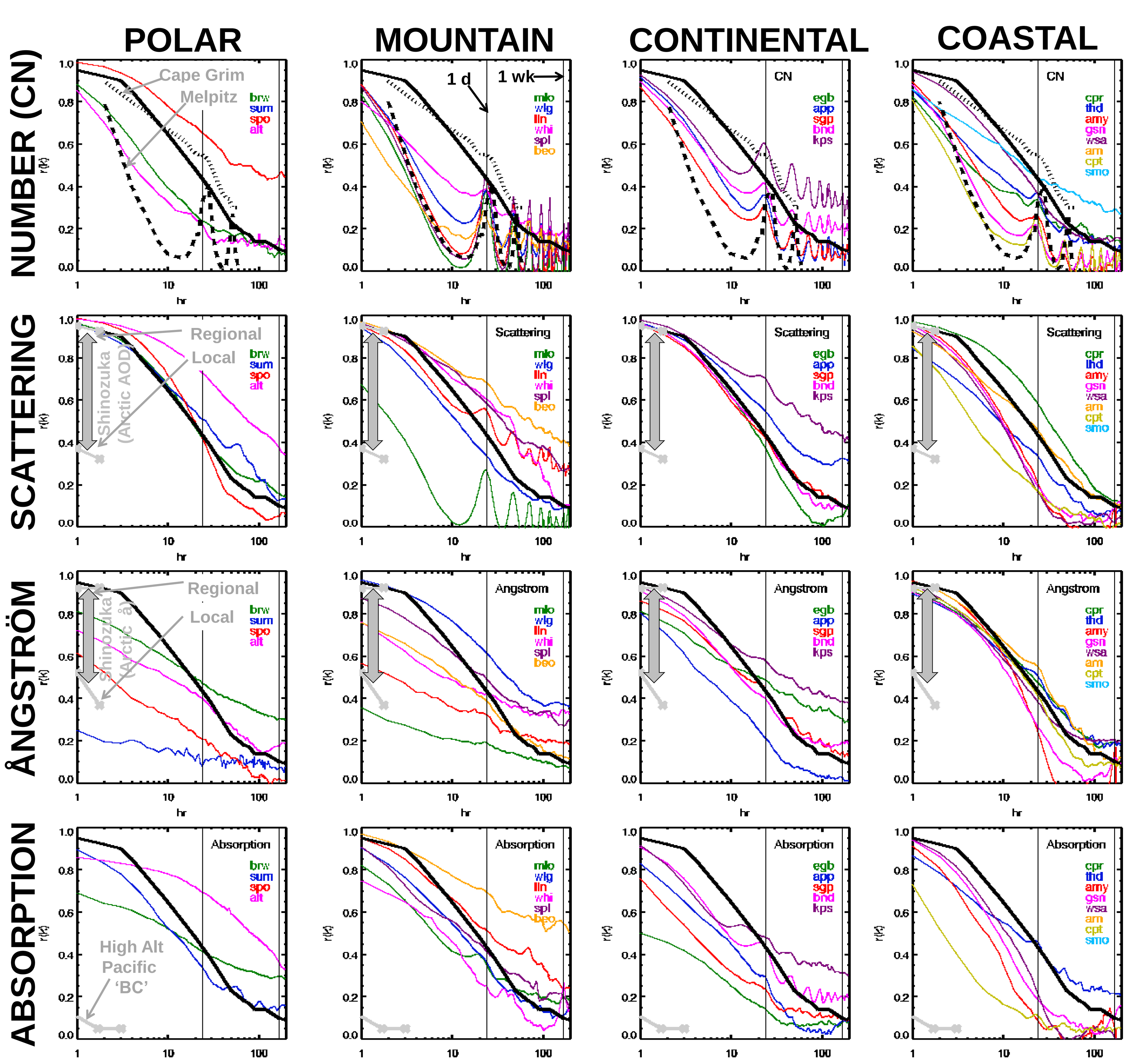
Shinozuka and Redemann (2011) explored the range of variability in aerosol optical depth and Ångström exponent as a function of air mass source (local forest fires vs. long range transport).

Weigum et al. (2012) investigated variability of high altitude absorbing aerosol (black carbon (BC)) plumes over Pacific Ocean.

Goals of this study:
(a) Investigate aerosol property variability as a function of site type
(b) Relate our findings to previous research
(c) Assess implications for inter-platform comparisons

Results of autocorrelation analysis for NOAA federated aerosol network sites

Plots show the correlation coefficient 'r(k)' as a function of time (e.g., lag) based on hourly averaged, quality-controlled data.



Number Concentration (CN)

- Cape Grim (coastal) and Melpitz (continental) CN data from Heintzenberg et al. (2004)
- No diurnal oscillations at polar sites, similar to observations for Cape Grim
- Strong diurnal oscillations at mountain and continental sites, similar to data from Melpitz

→Raises question: are diurnal cycle drivers different for different site types (e.g., new particle formation; changes in boundary layer height; or upslope/downslope (or onshore/offshore) flow)?

Light Scattering (σ_{sp})

- MLO is only site with strong diurnal scattering cycle – due to upslope/downslope flow
- Most sites similar to "BND (all)" curve from Anderson et al. (2003)

→No site has r(k) values for scattering as low as that observed by Shinozuka and Redemann (2011) for locally-influenced, Arctic AOD measurements; suggests NOAA network sites are relatively free of local influences (whew!)

→Perhaps some of S&R2011's variability is related to changes in RH?

Ångström Exponent (*å*)

- Calculation of å limited to data where σ_{sp} >1 Mm^{-1} - minimizes noise
- Wide variability in r(k) values at polar and mountain sites
- Very low variabilty in r(k) values at coastal sites
- Range of Ångström exponent r(k) values similar to S&R2011

→Despite σ_{sp} constraint, range in r(k) observed for NOAA network sites is partly due to very clean conditions at some locations, causing noise in calculation of *å*.

Light Absorption (σ_{ap})

- Absorption r(k) values tend to be lower than scattering r(k) values
- Unlike CN and σ_{sp}, no large diurnal oscillations in σ_{ap} are observed at any site
- Weigum et al.'s (2012) r(k) values over the Pacific are significantly lower than those observed at any surface site, even MLO which is in the region and at similar altitude

→Weigum's findings may not be representative of region's long term climatology.
→Noise and/or source differences may be reason for lower absorption r(k).
→Different sources/processing affect CN and σ_{ap}, based on different r(k) curves.

CONCLUSIONS

- **NOAA network data for CN and å tend to fall within r(k) bounds reported in literature; σ_{sp} tends toward r(k) range identified as 'regional' by Shinozuka and Redemann (2011); σ_{ap} tends to be less persistent than σ_{sp}, possibly reflecting different sources or measurement noise.**
- **Diurnal oscillations in CN r(k) hint at differences in sources and/or atmospheric processing for CN versus aerosol optical properties.**
- **Aerosol properties (scattering, å) at continental and coastal sites tend to vary on scales of 1-5 h (i.e., r(k) decreases below 0.8 after ~1-5 h).**
- **The range of r(k) values observed among polar and mountain sites makes it difficult to identify a single scale of variability for those site types.**

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