Climatology of Aerosol Radiative Properties in the Free Troposphere

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Motivation

The combined observatory measurements of high elevation aerosol radiative properties have the potential to contribute to aerosol-climate research in a way that far exceeds the contribution from individual sites.

→High elevations may be more sensitive to climate change
→Mountain observatories sample multiple air mass types (local, free troposphere and long range transport air masses)

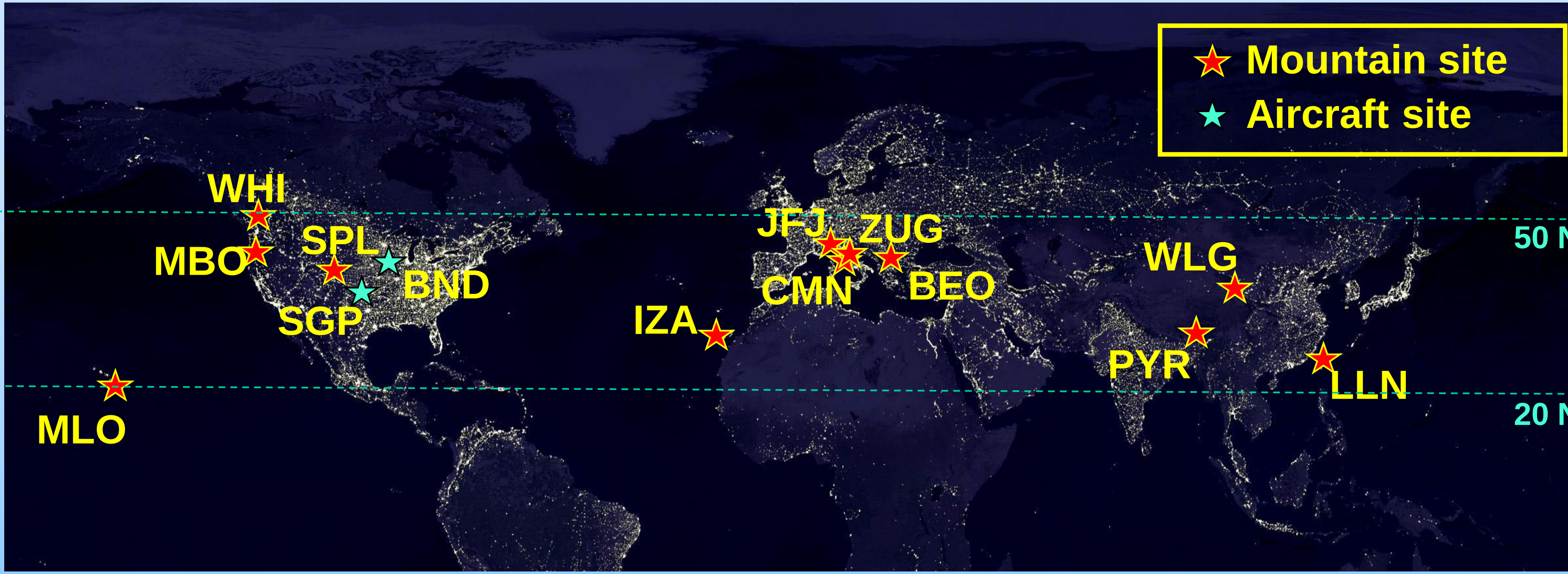
Aerosol climatologies based on long-term measurements can be used to put field campaign data in context:

- →regional variability
- →temporal variability

Additionally, climatological information on aerosol properties may help:

- →validate satellite measurements
- →constrain/evaluate chemical transport models
- →interpret climate models

Location of Free Troposphere Sites

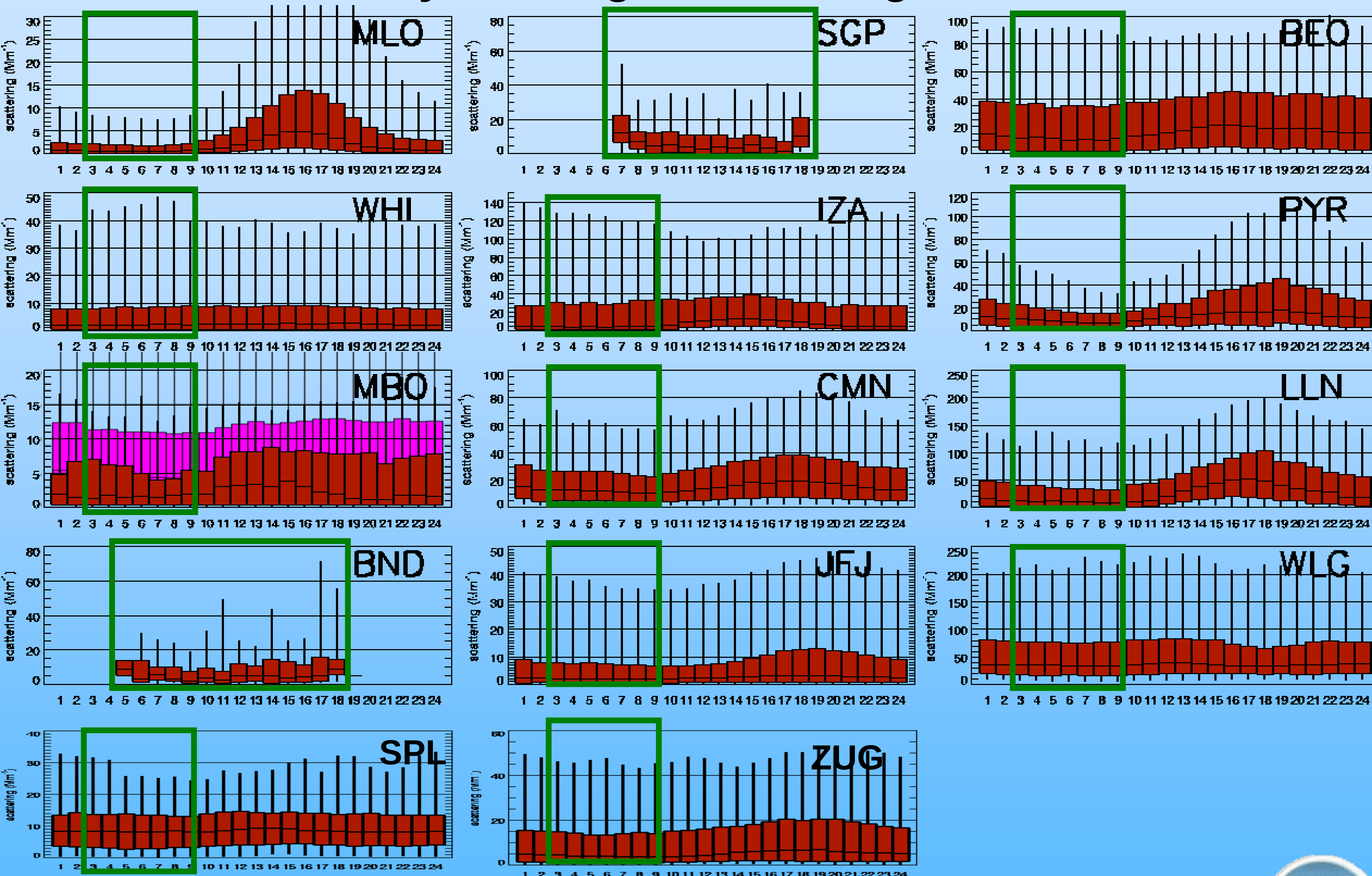


MLO – Mauna Loa, USA (3.4 km)
MBO – Mt Bachelor, USA (2.4 km)
WHI – Whistler, Canada (2.2 km)
SPL – Storm Peak, USA (3.2 km)
SGP – Oklahoma, USA (3-5 km)
BND – Illinois, USA (3-5 km)
IZA – Izana, Spain (2.4 km)

JFJ – Jungfraujoch, Switzerland (3.6 km)
CMN – Monte Cimone, Italy (2.2 km)
ZUG – Zugspitze, Germany (2.9 km)
BEO – Beo Moussala, Bulgaria (2.4 km)
PYR – Pyramid, Nepal (5.1 km)
WLG – Mt Waliguan, China (3.8 km)
LLN – Mt Lulin, Taiwan (2.9 km)

All sites have scattering and absorption data (except BEO and ZUG).
Results adjusted to and presented at STP and 550 nm (where possible)

Diurnal cycle of light scattering – all data

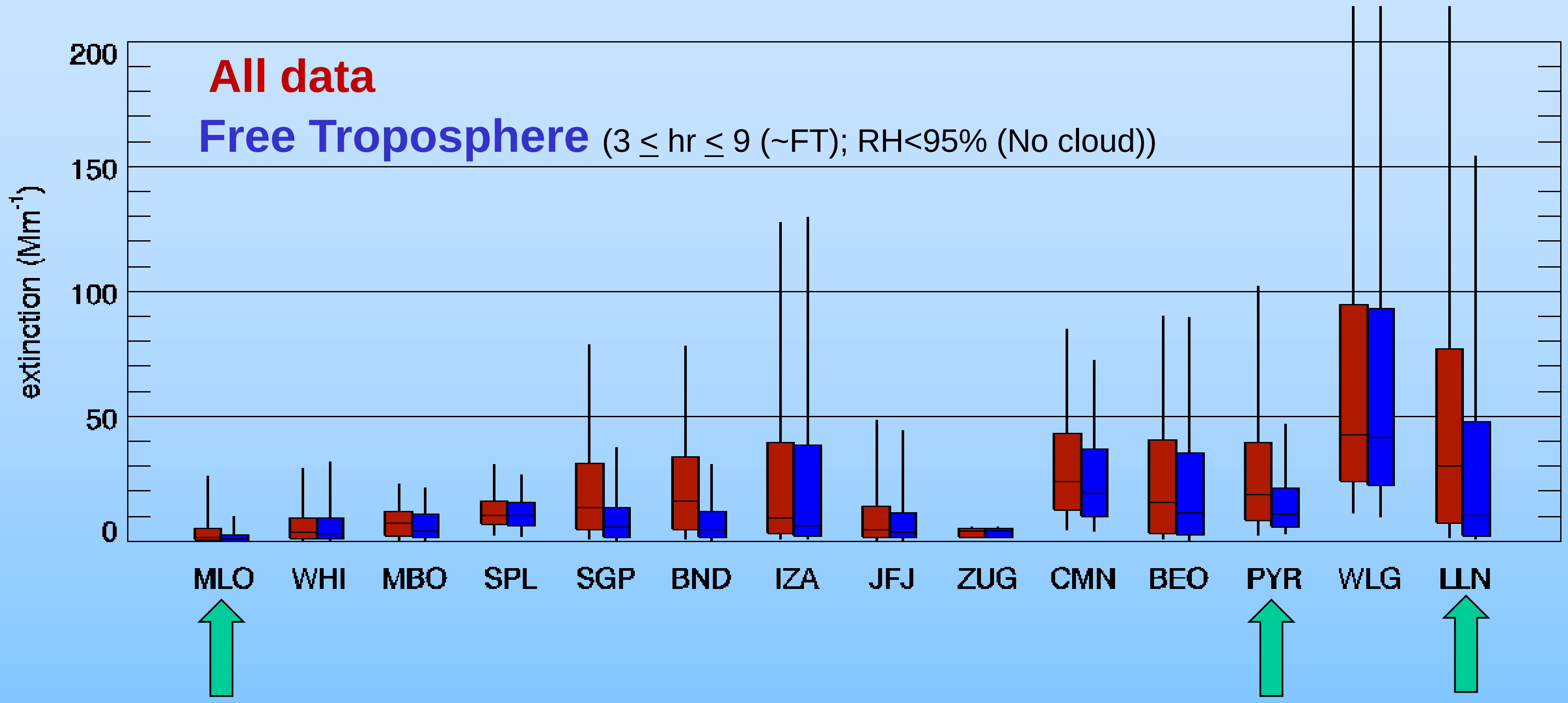


Data presented in local time

Green boxes indicate FT time period.

MBO April-June (1um, 550 nm) All year (1um, 530 nm)

Extinction (all data vs. ~ free troposphere)



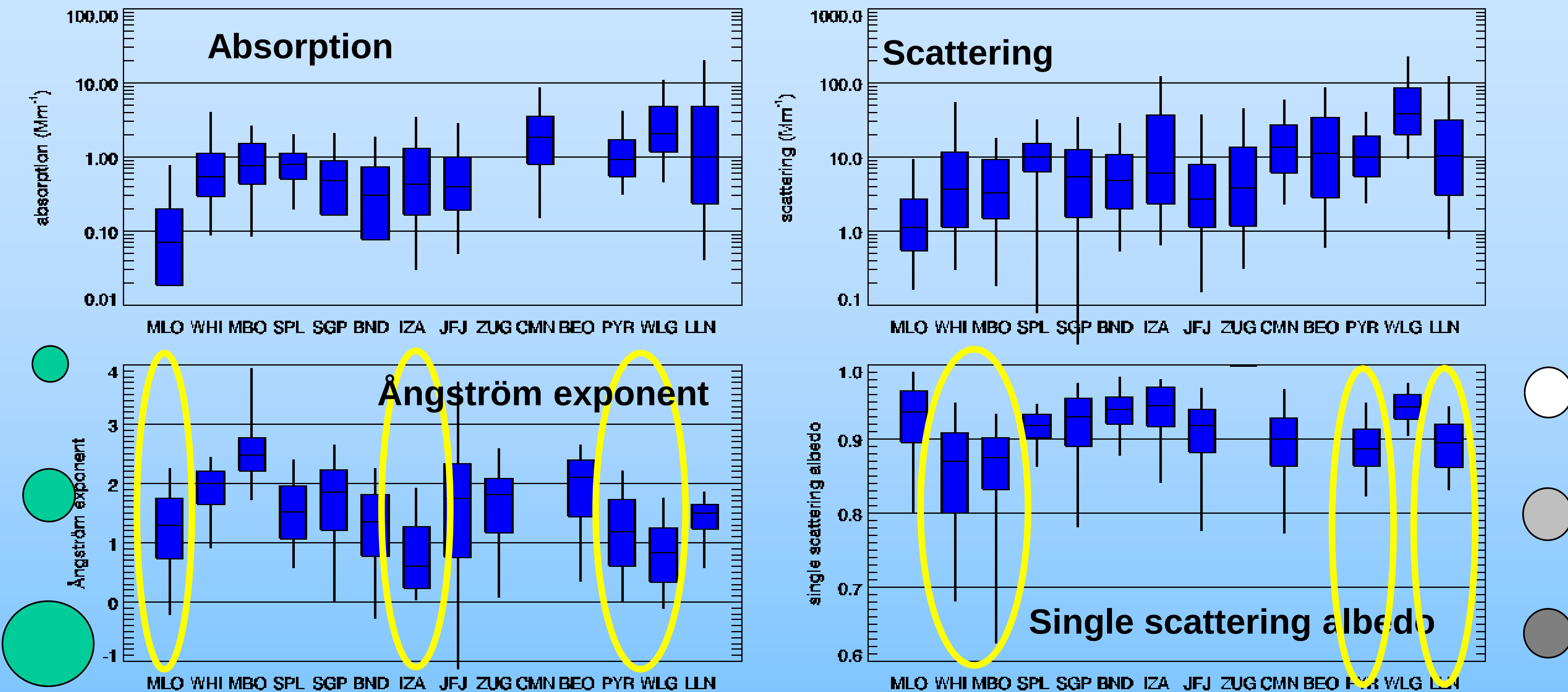
- Increase in aerosol loading from west to east.
- At many sites all data and FT data measurements are quite similar.
- Difference between ‘all data’ and ‘FT’ data largest for sites with strongest diurnal cycle (MLO, PYR, LLN).

SGP and BND are aircraft profile data sets, so ‘all data’ includes BL.

E. Andrews 3/5/2015

BEO, ZUG data = scattering

Comparison of FT aerosol optical properties



"Sites influenced by DUST"

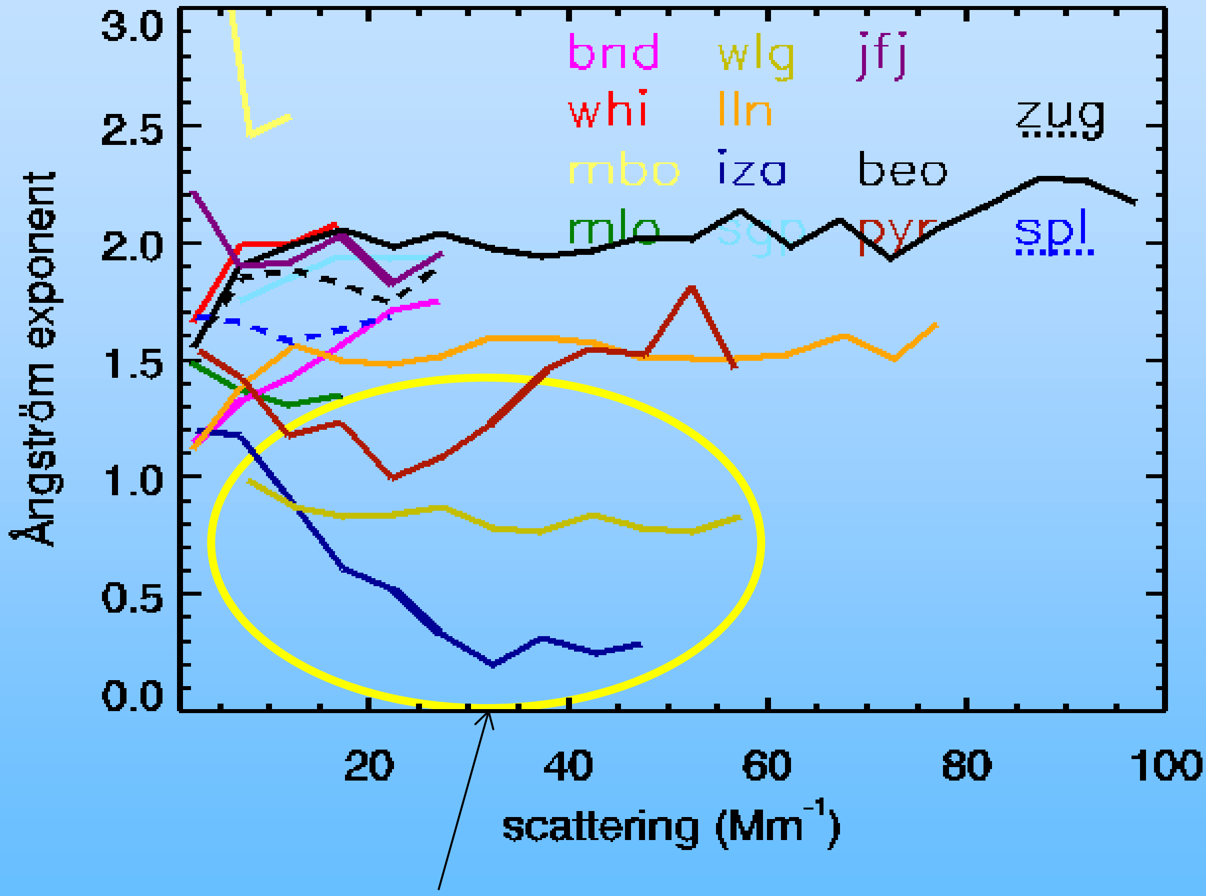
"Sites influenced by SMOKE"

- No obvious relationship between aerosol loading and Å and SSA
- source signatures can be seen in values of Å and SSA

MBO-size cut=1um (hence highest Ångström exponent!)

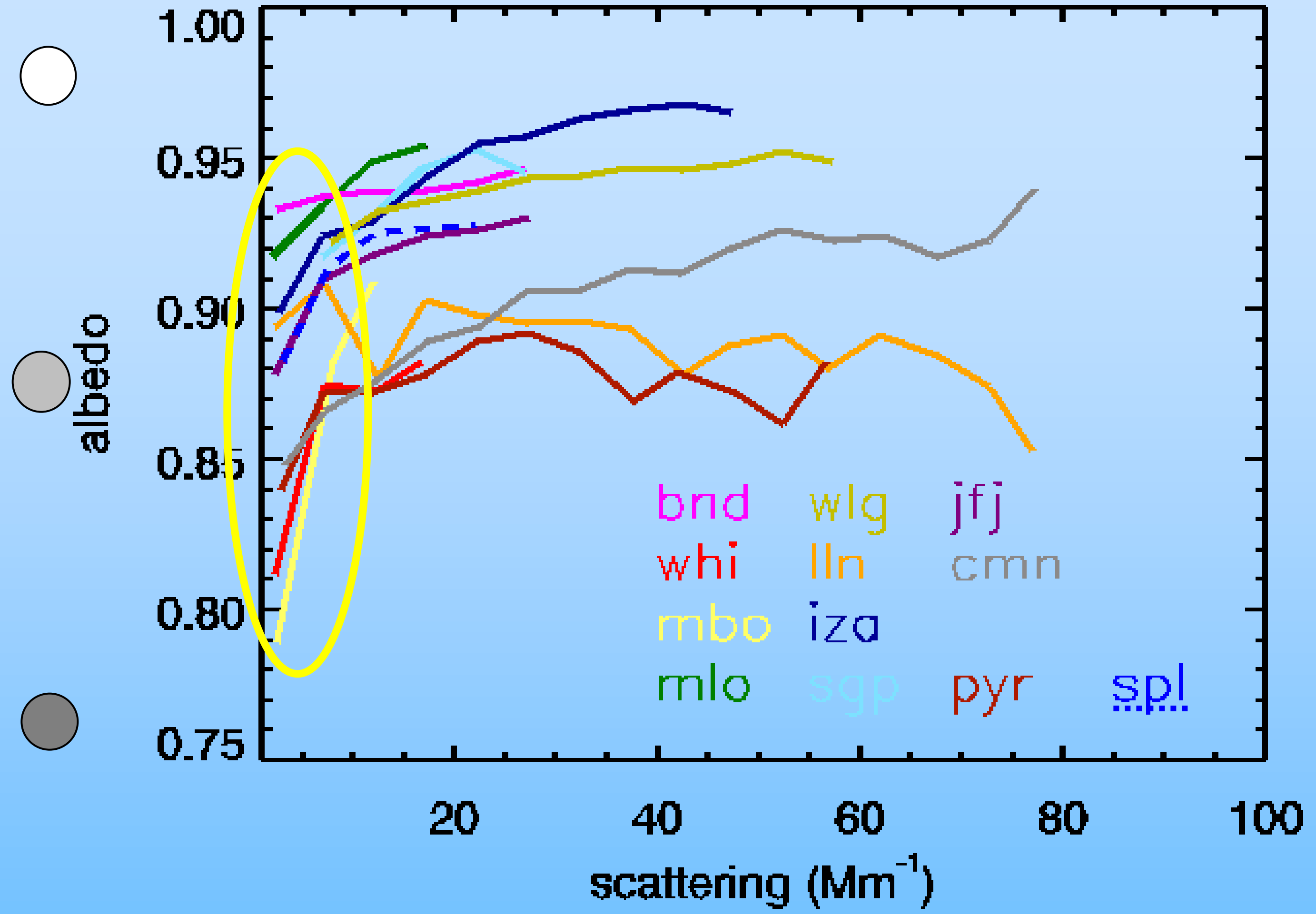
Systematic variation of aerosol properties with loading

→atmospheric processing/sources
→aerosol parameterizations (e.g., in models)



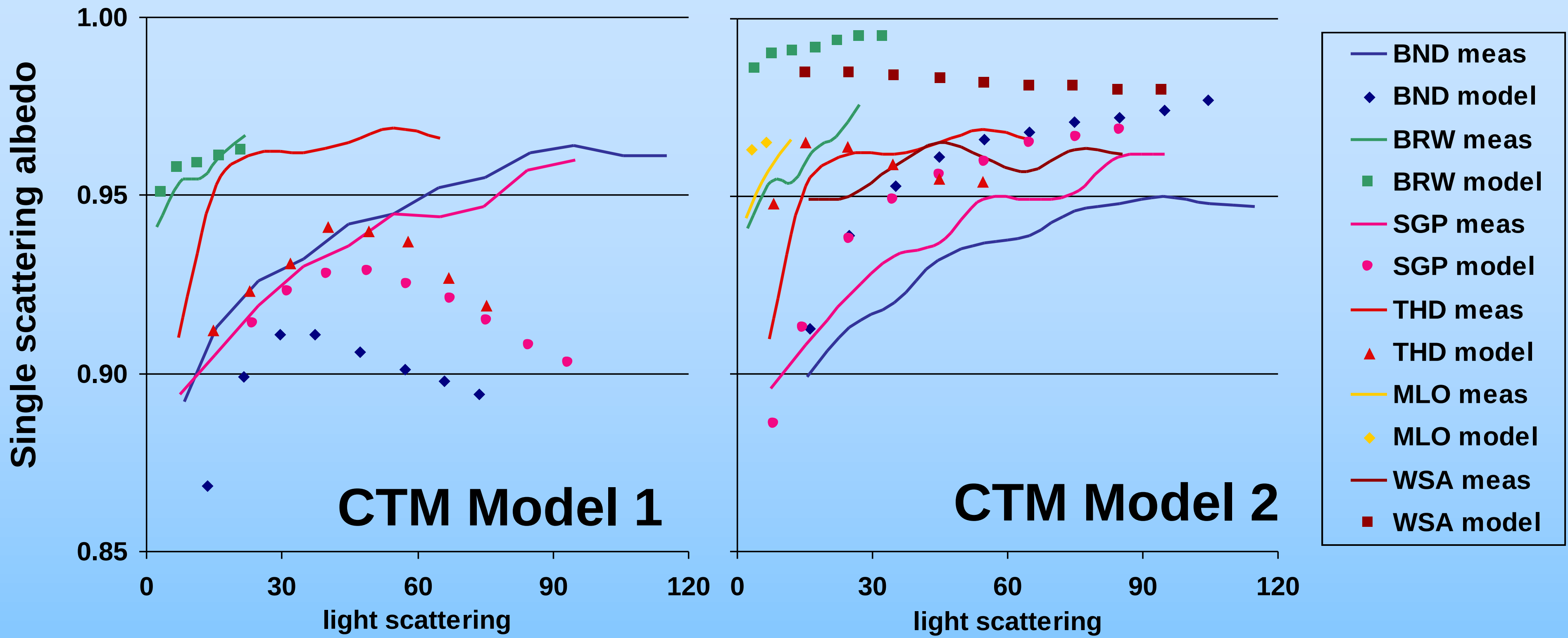
These three sites (**IZA**, **WLG**, **PYR**) impacted by regional dust.
Note: Some other sites also experience dust events, but tend to be more distant from dust source.

Systematic variation of aerosol properties with loading



Most sites show lower single scattering albedo values for clean air (low scattering).
→Cloud processing?
→Preferential removal of more hygroscopic scattering aerosol?
LLN does not show this behavior. →highest loading during biomass burning events

Modelled Systematic Variability of SSA at NOAA surface sites



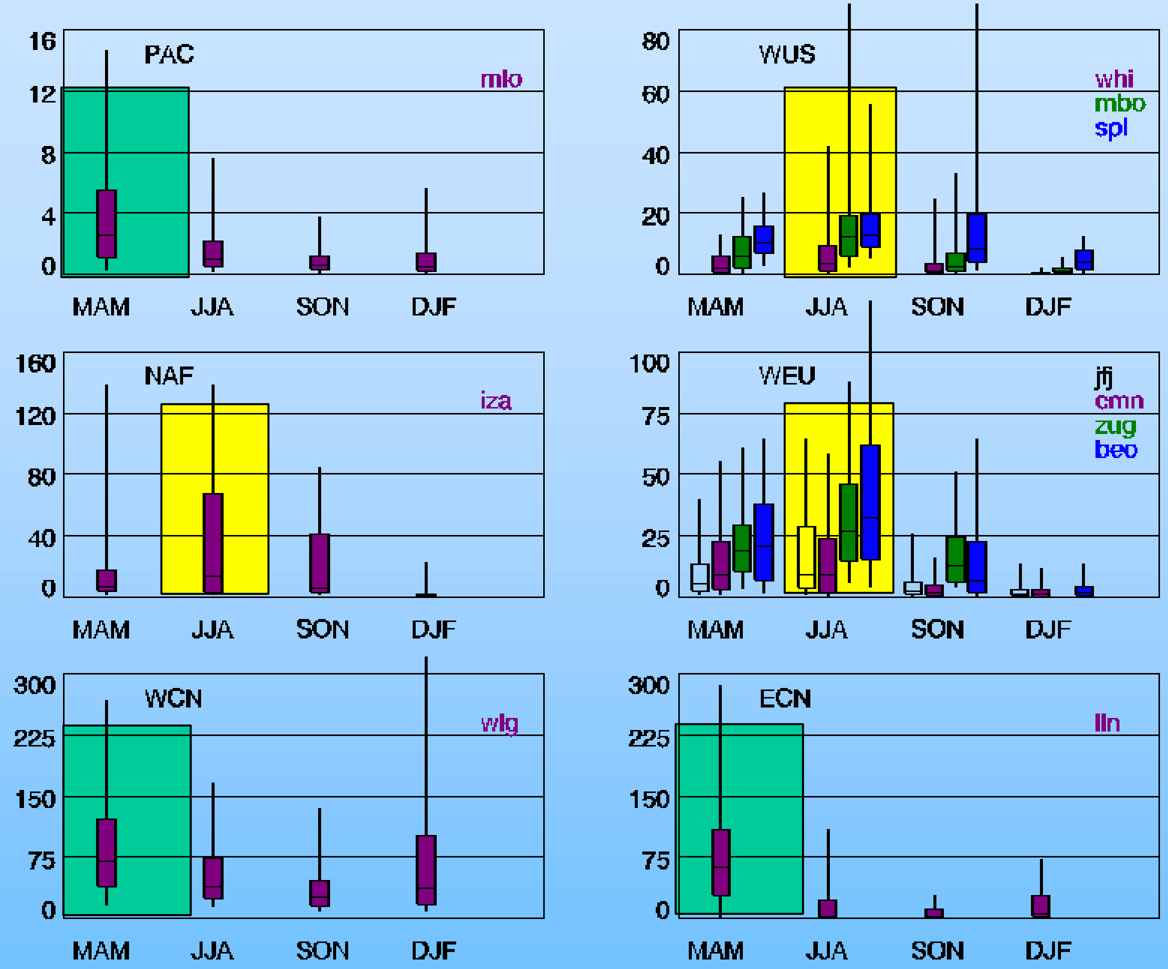
Models also suggest that the darkest aerosols are in the cleanest air, but…

→quantitative values are different

→modelled relationships do not show the monotonic behavior that is observed in the in situ data.

Unpublished work from Ogren, Ginoux, Chin, 2009

Monthly in-situ FT climatologies (Extinction)

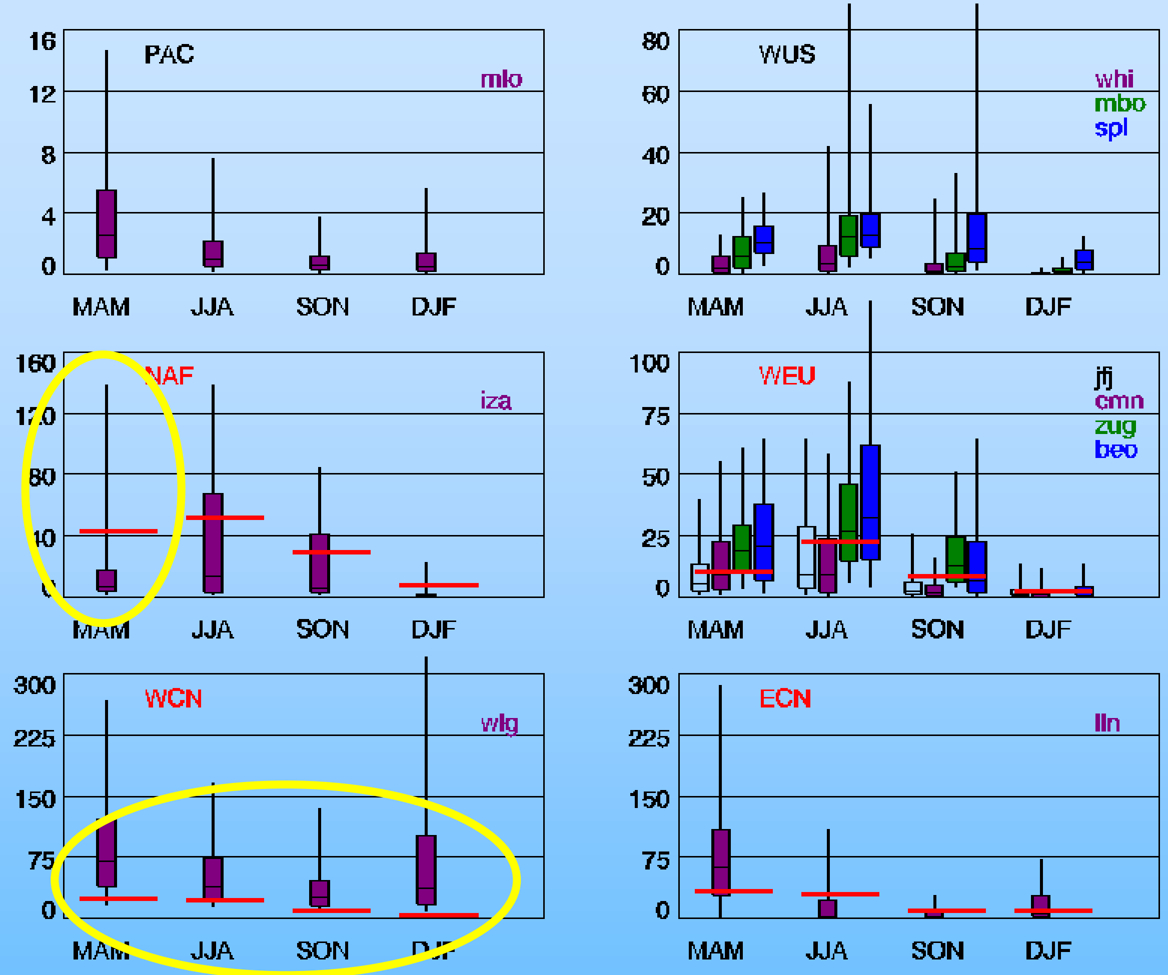


Spring max (MAM)
Summer max (JJA)

Aerosol loading tends to peak in spring or summer
Most sites with springtime maxima are Asian dust-impacted sites.
Summertime peaks primarily related to fires and increased BL/FT interaction.

PAC=Pacific; WUS=West US; EUS=East US; NAF= North Africa; WEU=West Europe; IND=Himalayas WCN=West China; ECN=East China

Comparison with CALIOP lidar



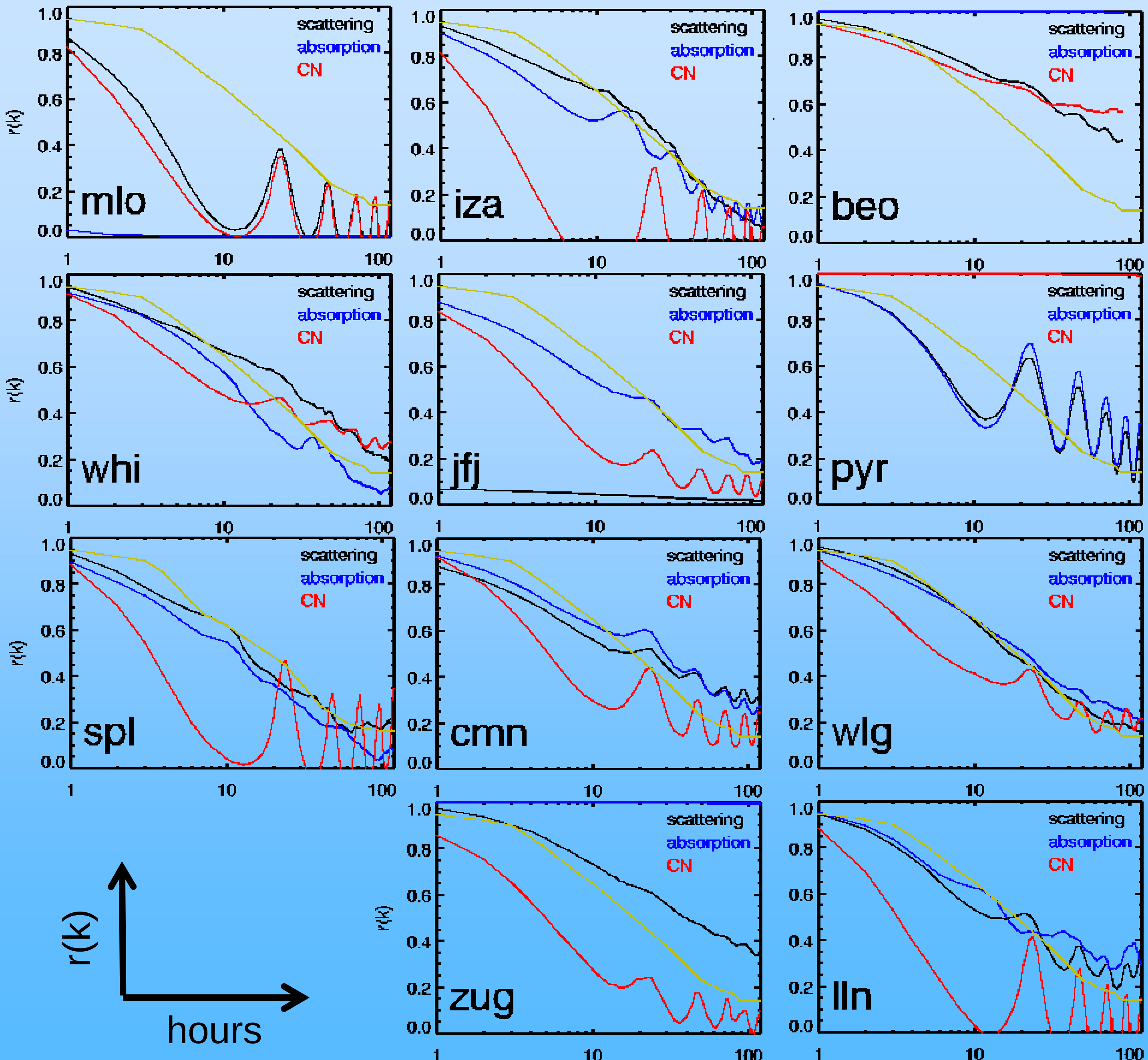
In situ data
CALIPSO data

→In-situ and satellite lidar extinction have similar seasonality and magnitudes

→Biggest differences are spring at IZA and most seasons at WLG
– likely due to regional dust variability

CALIPSO data from Yu et al., 2010

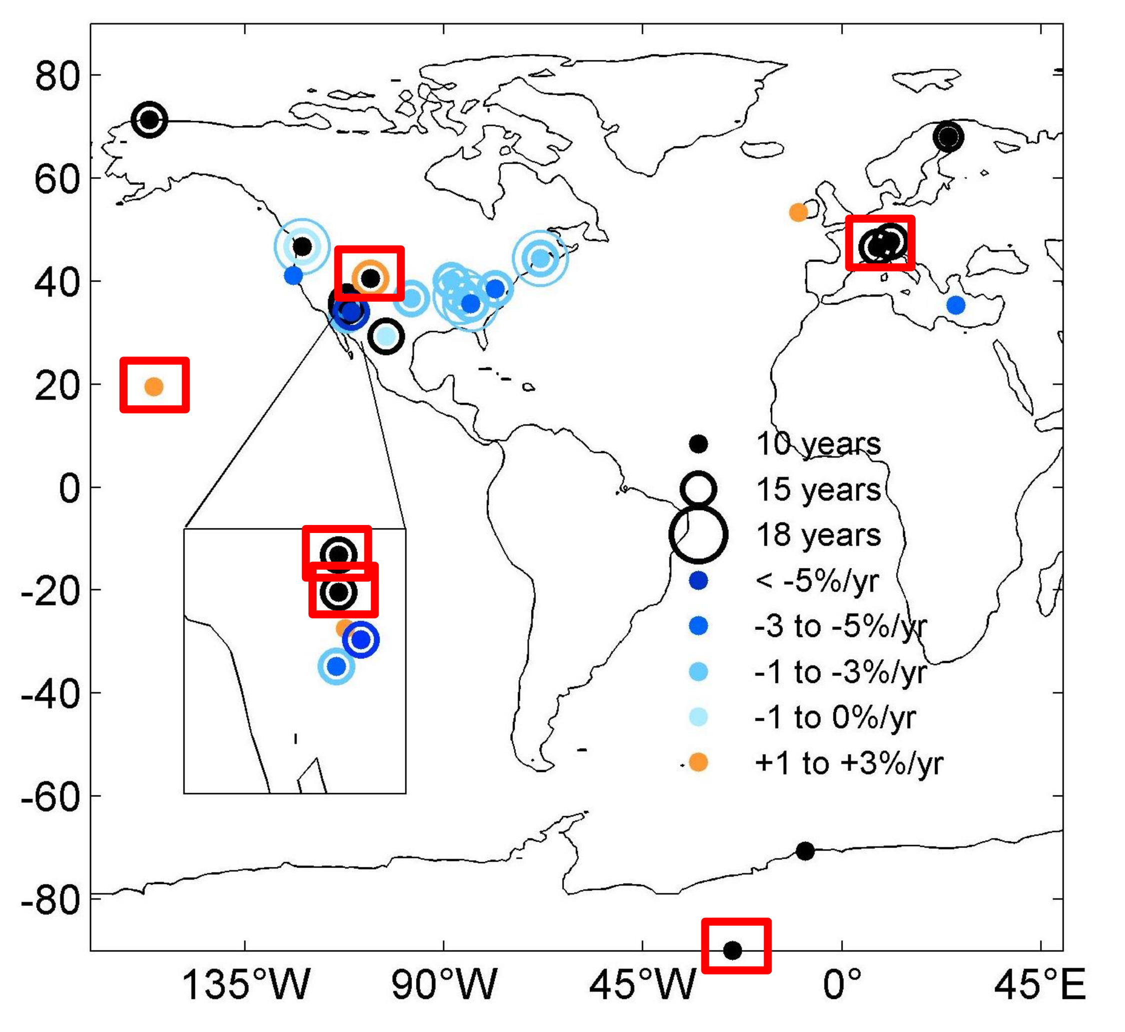
Autocorrelation Statistics for Mountain Aerosol Properties



Yellow line based on mid-continental low elevation US surface site (from Anderson et al., 2003)

Properties behave differently:
Most sites show CN oscillations→NPF?
Oscillations in scattering and/or absorption largest at MLO, LLN, PYR →upslope

Trends in Scattering Coefficient



Mountain sites

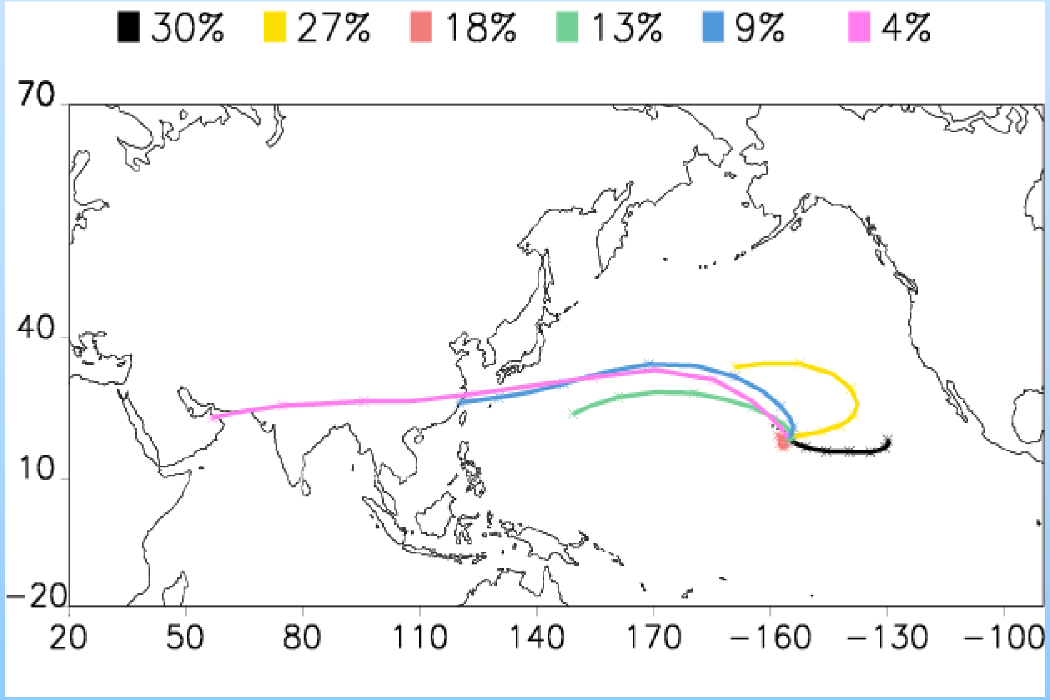
Black: trends not statistically significant.

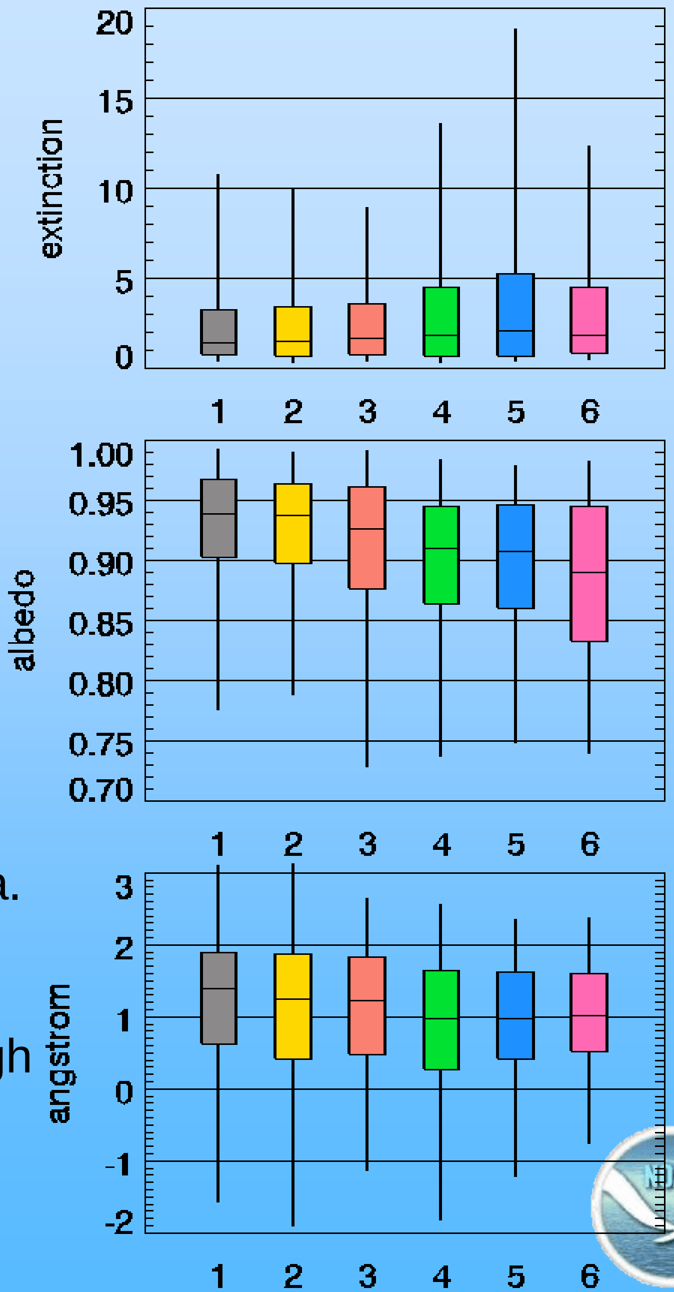
Colors: statistically significant trends

From Collaud Coen et al., 2012

→ None of the mountain sites showed decreasing trends in this study.

Mauna Loa





- Increasing aerosol amount and decreasing single scattering albedo as trajectories get closer to Asia.
- Slightly lower Ångström exponents for the most westerly trajectories as well (dust?) (these are high altitude trajectories so unlikely to be sea salt.)

Conclusions

- **What is climatology of FT aerosol at a range of sites?**
  →Order of magnitude difference in amount of aerosol among sites
  →See influence of sources (e.g., dust) on aerosol optical properties
  →Values increase from west to east – appear to be 2 groups of sites
  →Sites tend to see maximums in spring or summer

- **Do FT aerosol properties vary systematically?**
  →At dust-influenced sites Ångström exponent decreases with loading
  →Most sites have low SSA at low loading (cloud processing?)

- **How do in-situ climatologies of free tropospheric light extinction compare to the extinction values obtained from CALIPSO?**
  →They are quite similar in seasonality and amount of extinction
  →Further work with smaller CALIPSO averaging regions could help pinpoint reasons for differences.

- **Mountain sites do/will present a challenge**
  →High aerosol variability (sources and transport)
  →Important to understand in terms of changing climate

Thanks!! ☺

Systematic variability with single scattering albedo