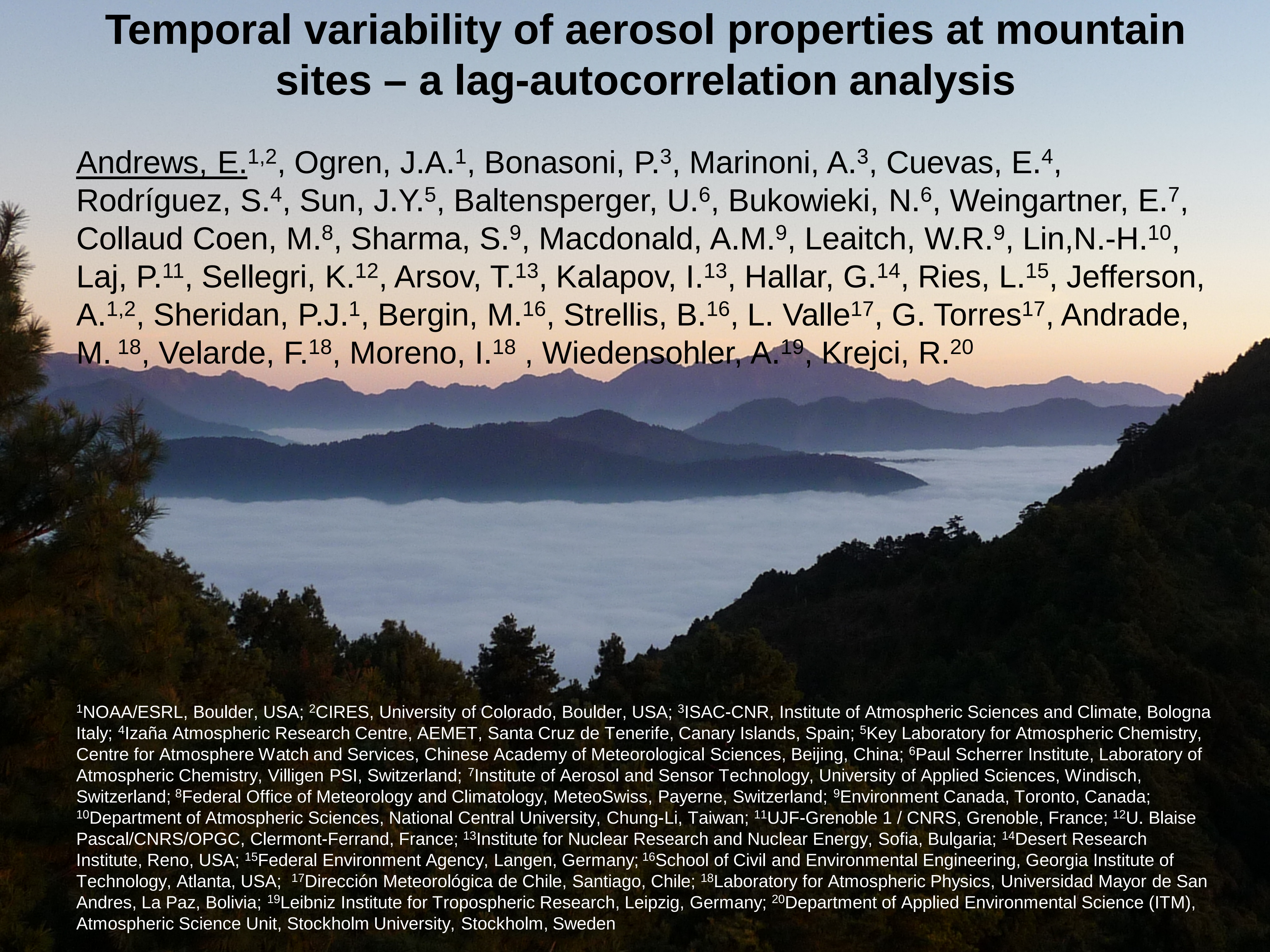
Temporal variability of aerosol properties at mountain sites – a lag-autocorrelation analysis



Andrews, E.[1,2], Ogren, J.A.[1], Bonasoni, P.[3], Marinoni, A.[3], Cuevas, E.[4], Rodríguez, S.[4], Sun, J.Y.[5], Baltensperger, U.[6], Bukowieki, N.[6], Weingartner, E.[7], Collaud Coen, M.[8], Sharma, S.[9], Macdonald, A.M.[9], Leaitch, W.R.[9], Lin,N.-H.[10], Laj, P.[11], Sellegri, K.[12], Arsov, T.[13], Kalapov, I.[13], Hallar, G.[14], Ries, L.[15], Jefferson, A.[1,2], Sheridan, P.J.[1], Bergin, M.[16], Strellis, B.[16], L. Valle[17], G. Torres[17], Andrade, M. [18], Velarde, F.[18], Moreno, I.[18] , Wiedensohler, A.[19], Krejci, R.[20]

[1]NOAA/ESRL, Boulder, USA; [2]CIRES, University of Colorado, Boulder, USA; [3]ISAC-CNR, Institute of Atmospheric Sciences and Climate, Bologna Italy; [4]Izaña Atmospheric Research Centre, AEMET, Santa Cruz de Tenerife, Canary Islands, Spain; [5]Key Laboratory for Atmospheric Chemistry, Centre for Atmosphere Watch and Services, Chinese Academy of Meteorological Sciences, Beijing, China; [6]Paul Scherrer Institute, Laboratory of Atmospheric Chemistry, Villigen PSI, Switzerland; [7]Institute of Aerosol and Sensor Technology, University of Applied Sciences, Windisch, Switzerland; [8]Federal Office of Meteorology and Climatology, MeteoSwiss, Payerne, Switzerland; [9]Environment Canada, Toronto, Canada; [10]Department of Atmospheric Sciences, National Central University, Chung-Li, Taiwan; [11]UJF-Grenoble 1 / CNRS, Grenoble, France; [12]U. Blaise Pascal/CNRS/OPGC, Clermont-Ferrand, France; [13]Institute for Nuclear Research and Nuclear Energy, Sofia, Bulgaria; [14]Desert Research Institute, Reno, USA; [15]Federal Environment Agency, Langen, Germany; [16]School of Civil and Environmental Engineering, Georgia Institute of Technology, Atlanta, USA; [17]Dirección Meteorológica de Chile, Santiago, Chile; [18]Laboratory for Atmospheric Physics, Universidad Mayor de San Andres, La Paz, Bolivia; [19]Leibniz Institute for Tropospheric Research, Leipzig, Germany; [20]Department of Applied Environmental Science (ITM), Atmospheric Science Unit, Stockholm University, Stockholm, Sweden

Motivation

- Mountains are an interface between the atmospheric boundary layer and free troposphere.

- Complex terrain →difficult to parameterize aerosol and atmosphere properties.

- Lag-autocorrelation analysis can tell us about the time scales of mountain aerosols.

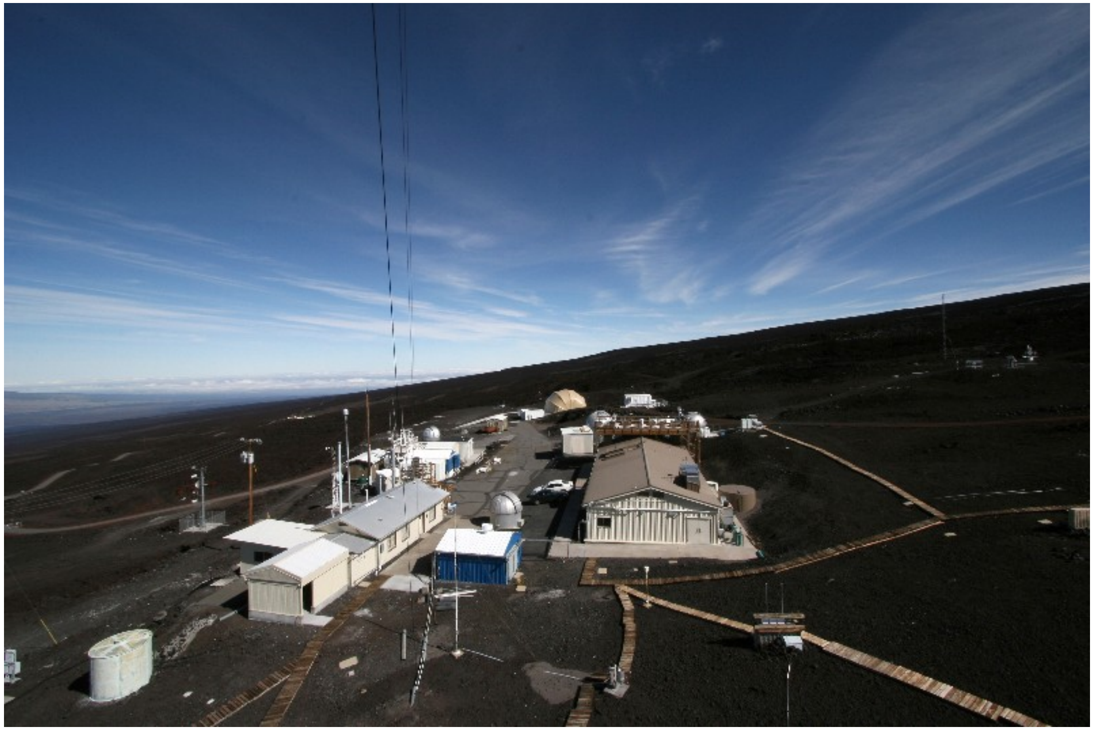
Photo: Luis Manuel Roca Gallardo

Scientific questions

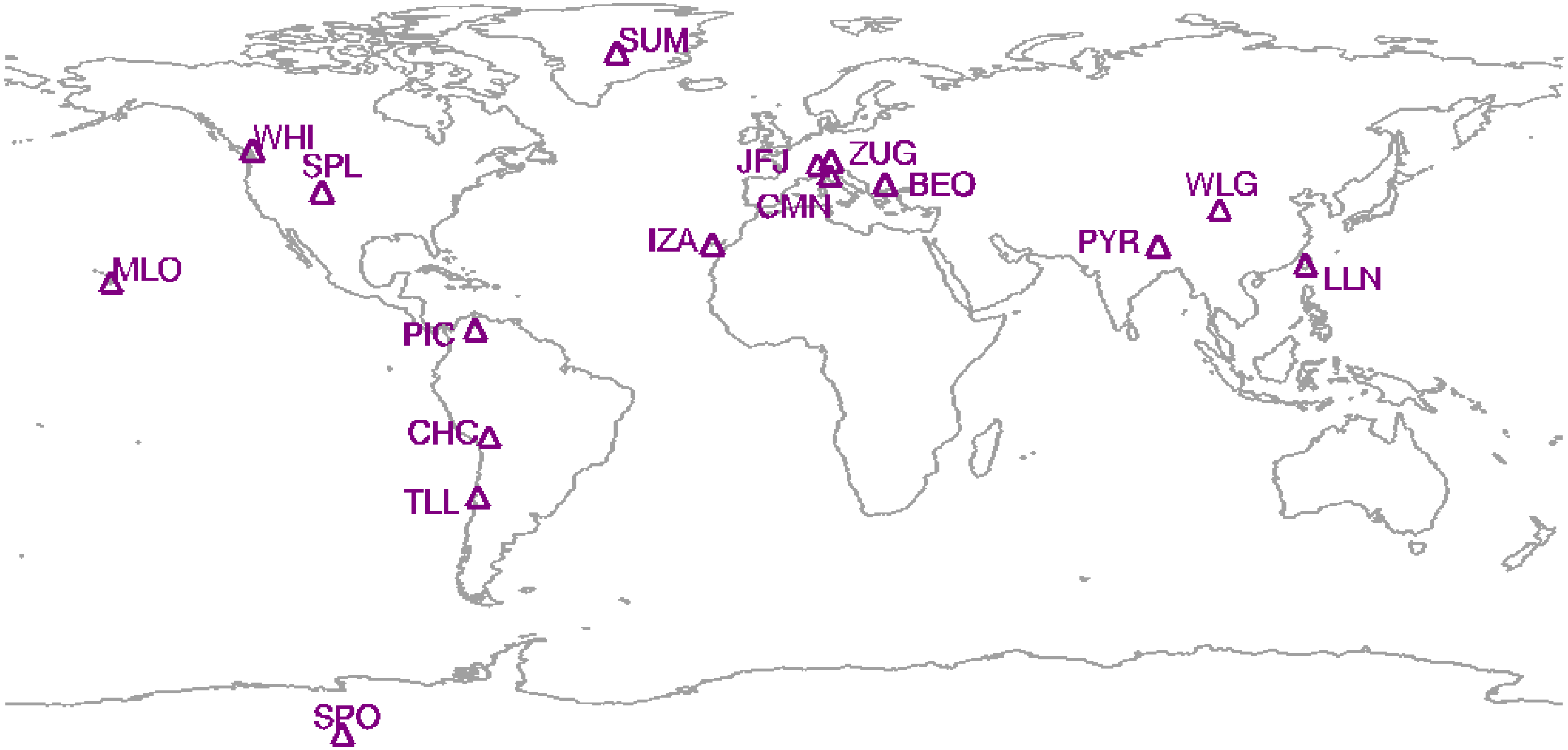
- What are the temporal variation scales of in-situ high elevation aerosol properties?

- What can autocorrelation analysis tell us about aerosol sources and/or atmospheric processes at high altitude sites?

- Does the aerosol persistence observed at mountain sites differ from that observed at other (low elevation) site types (e.g., coastal, continental, polar)?



Location of Mountain Sites



MLO – Mauna Loa, USA (3.4 km)
SPO – South Pole, Antarctica (2.8)
WHI – Whistler, Canada (2.2 km)
SPL – Storm Peak, USA (3.2 km)
PIC – Pico Espeje, Venezuela (4.7 km)
CHC – Chacaltaya, Bolivia (5.3 km)
TLL – El Tololo, Chile (2.2 km)
SUM – Summit, Denmark (3.2 km)

IZA – Izana, Spain (2.4 km)
JFJ – Jungfraujoch, Switzerland (3.6 km)
CMN – Monte Cimone, Italy (2.2 km)
ZUG – Zugspitz, Germany (3.0 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)

Sites have CN, scattering and/or absorption data.

Measurements and Data

Aerosol light scattering,

- 3λ nephelometer (TSI or Ecotech)
- total and hemispheric backscattering

Aerosol light absorption

- Multiple instruments (MAAP, PSAP, CLAP, aethalometer)
- Single and multi-wavelength
- BC →absorption using 7.5 m^2/g

Particle number concentration

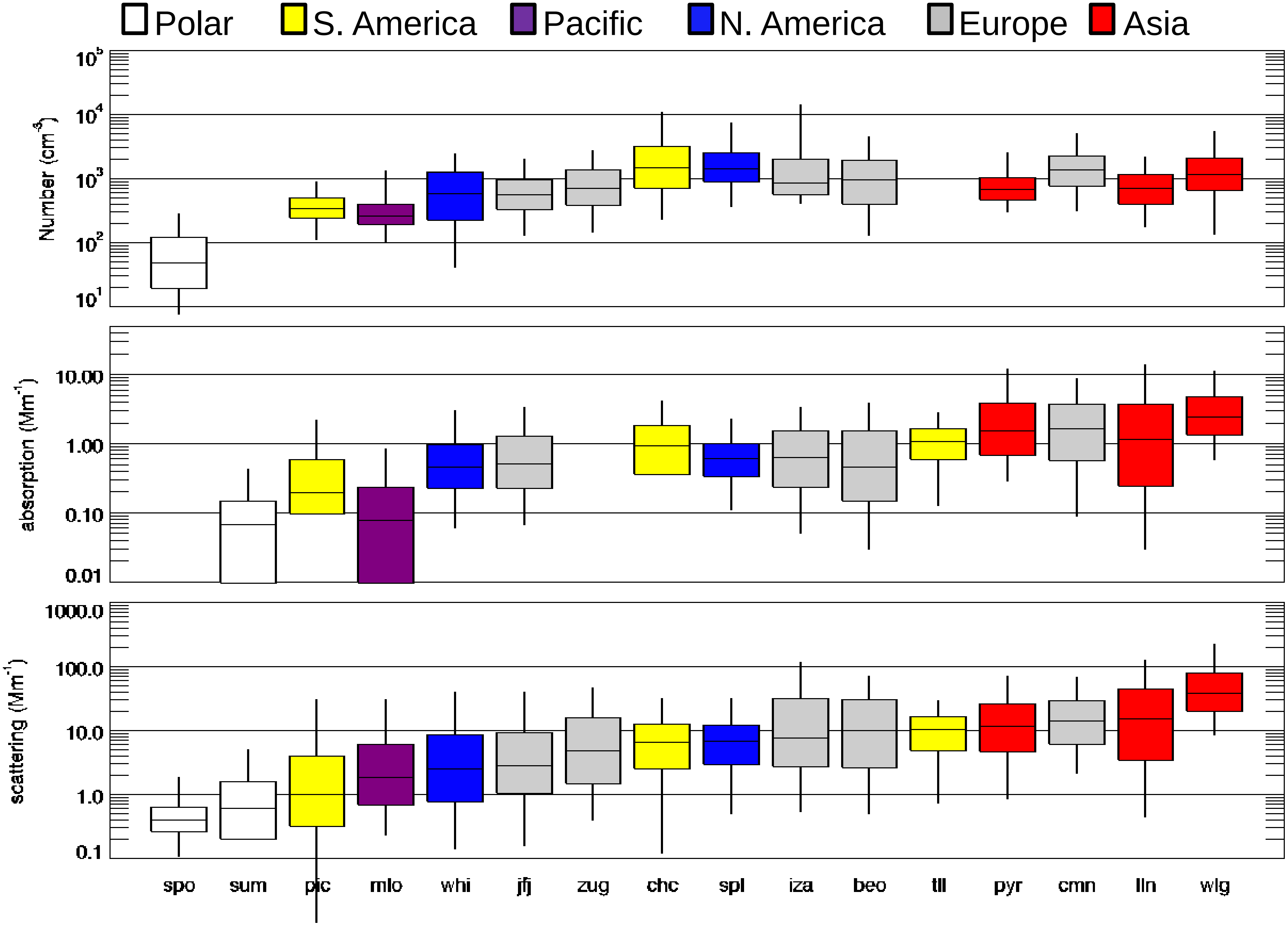
- Multiple instruments
- Different lower size cuts

Data Processing

- Hourly averaged, edited and corrected
- Absorption and scattering adjusted to and presented at STP and 550 nm (where possible)

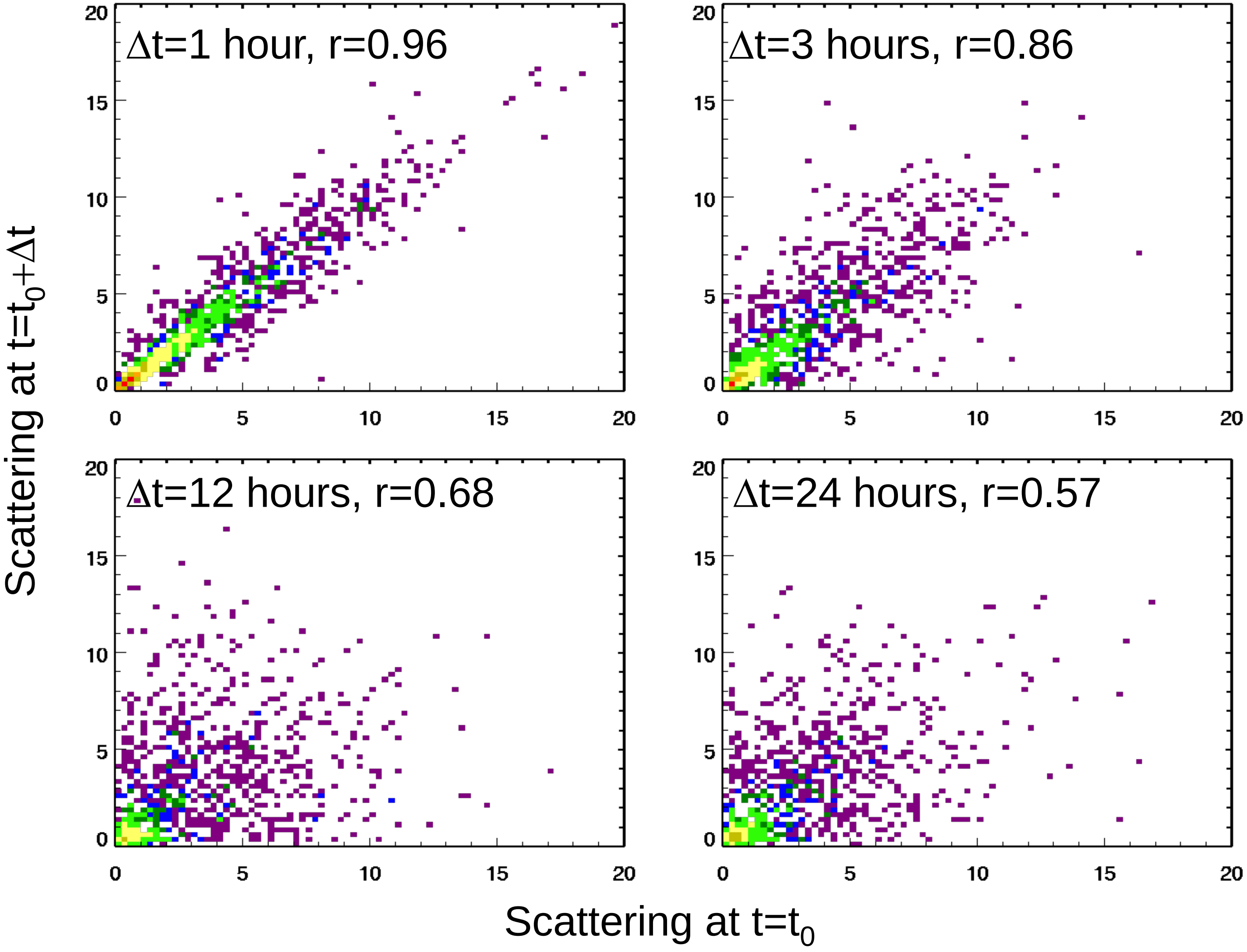
(Bond et al., 2005)

Scattering/absorption/CN statistics comparison



Aerosol Persistence

How well does a measurement at time ‘t’ represent a measurement at time t+Δt?

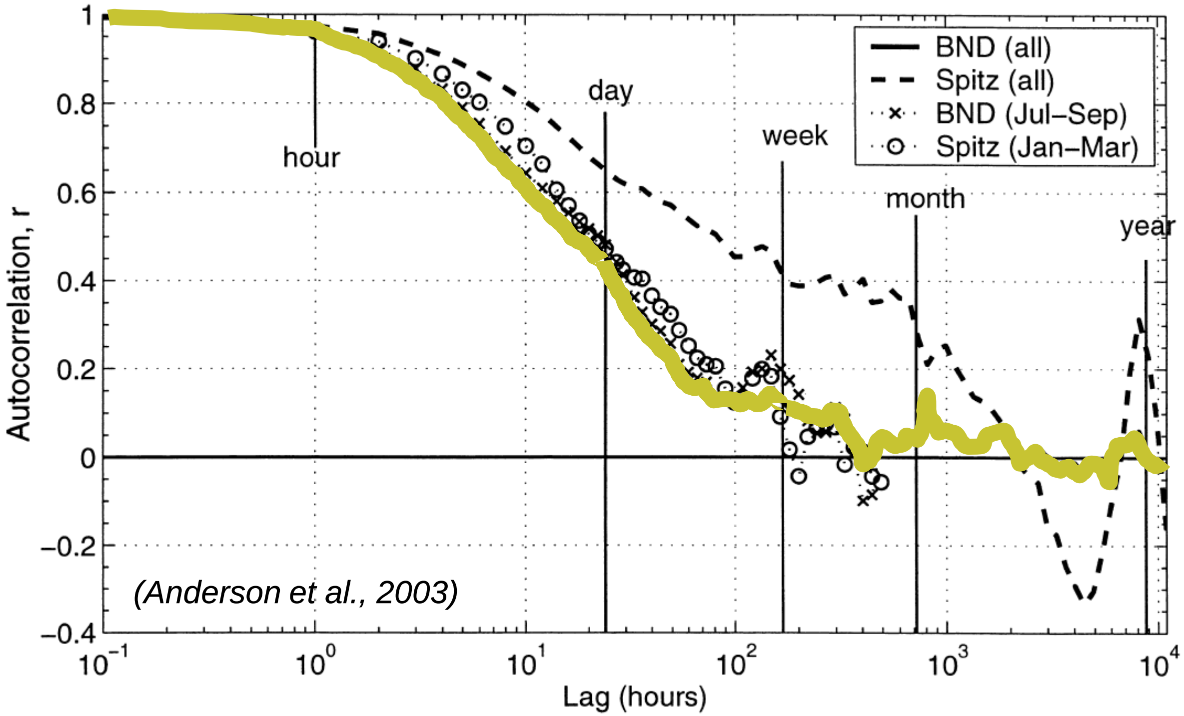


Colors represent density of points

IZA scattering

Autocorrelation Analysis

Lag autocorrelation relationships for aerosol light scattering at Bondville, IL (rural continental site) and Spitzbergen (Arctic site)



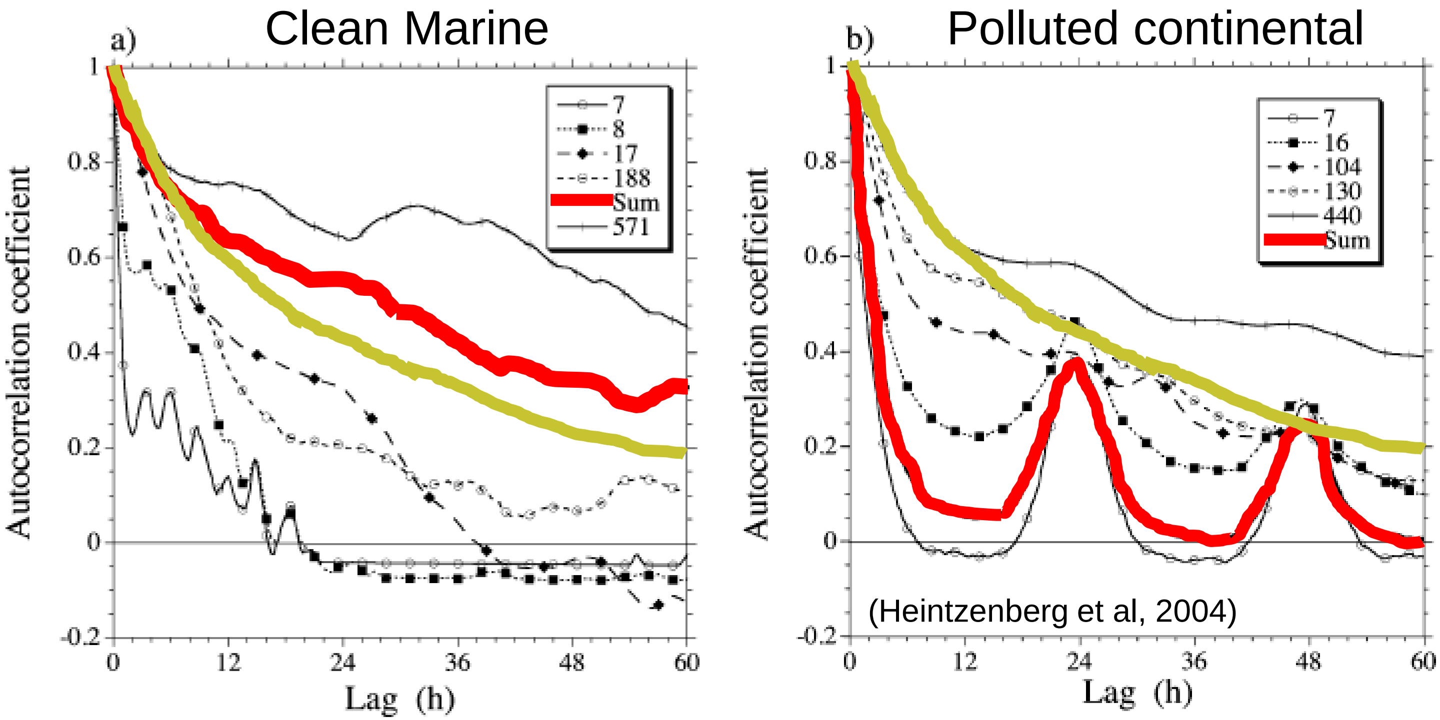
(Anderson et al., 2003)

Lag is the time between measurements being compared (Δt).
‘r’ is the lag autocorrelation statistic.

Autocorrelation analysis can be used to identify aerosol persistence.

Autocorrelation Analysis

Lag autocorrelation relationships for aerosol number concentration at Cape Grim (clean marine site) and Melpitz (polluted continental site)



Clean Marine

Polluted continental

(Heintzenberg et al, 2004)

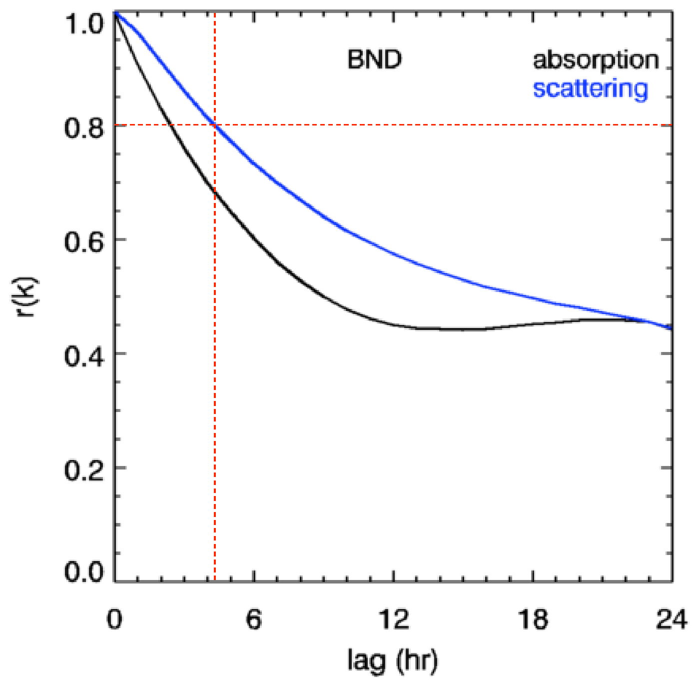
Autocorrelation can be strong function of site characteristics.
Autocorrelation may provide information about atmospheric processes.
Peaks at 24 and 48 h indicate diurnal variations.

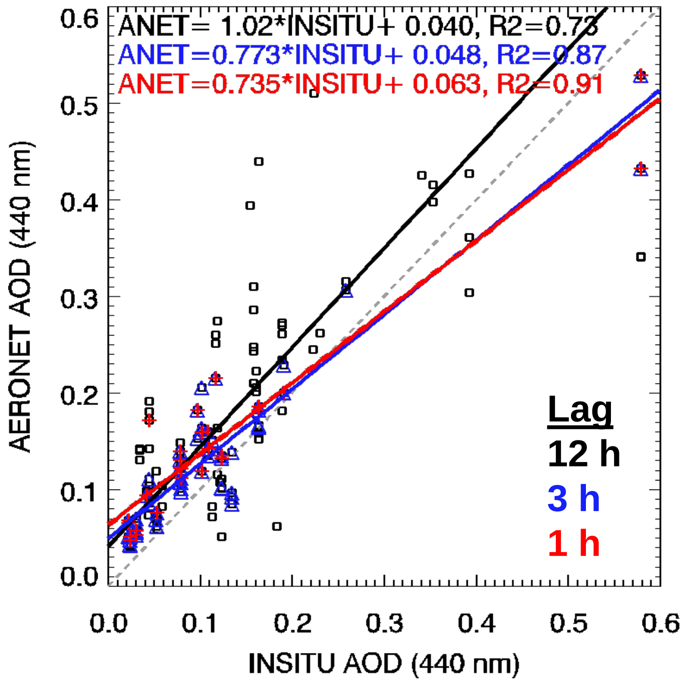
Applications of lag autocorrelation analysis

→coordinate measurement strategies (e.g., during a campaign)

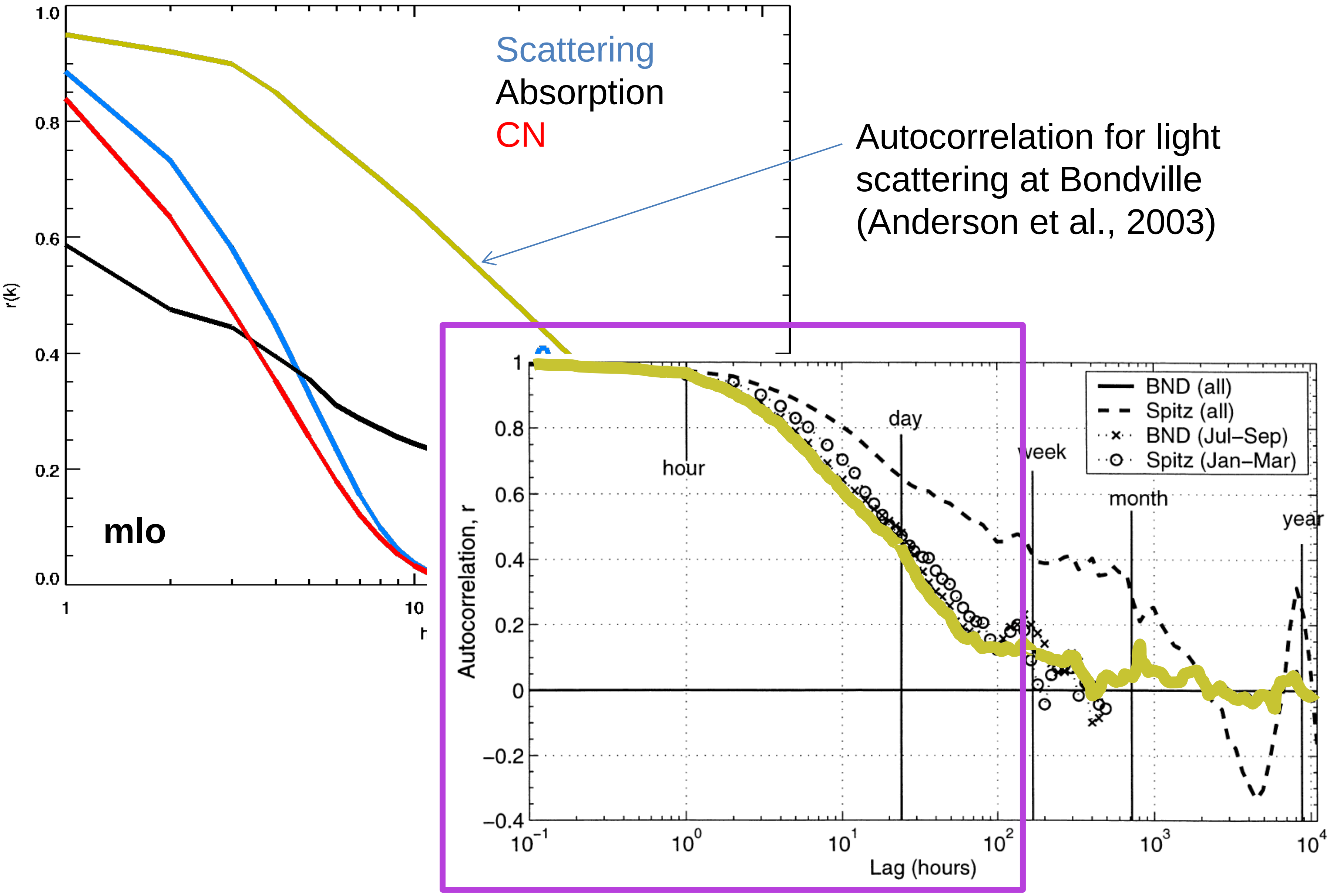
→constrain comparisons by identification of expected ‘best case’ agreement between different data sources

→determine whether data from different measurement platforms and models are internally consistent such that satellites/models can be used to fill the spatial gaps in in-situ measurements.



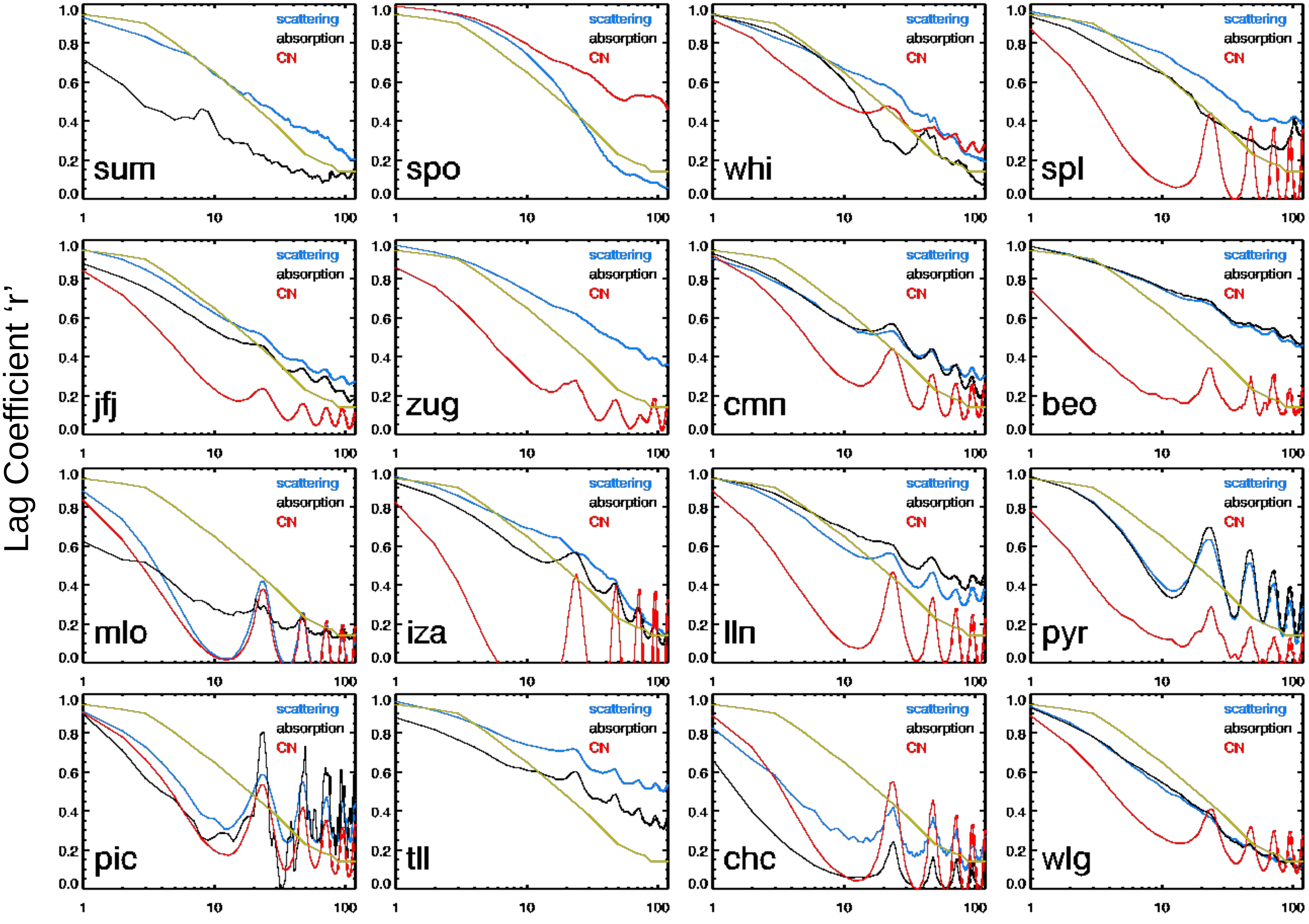


What do we see at these 16 mountain sites?



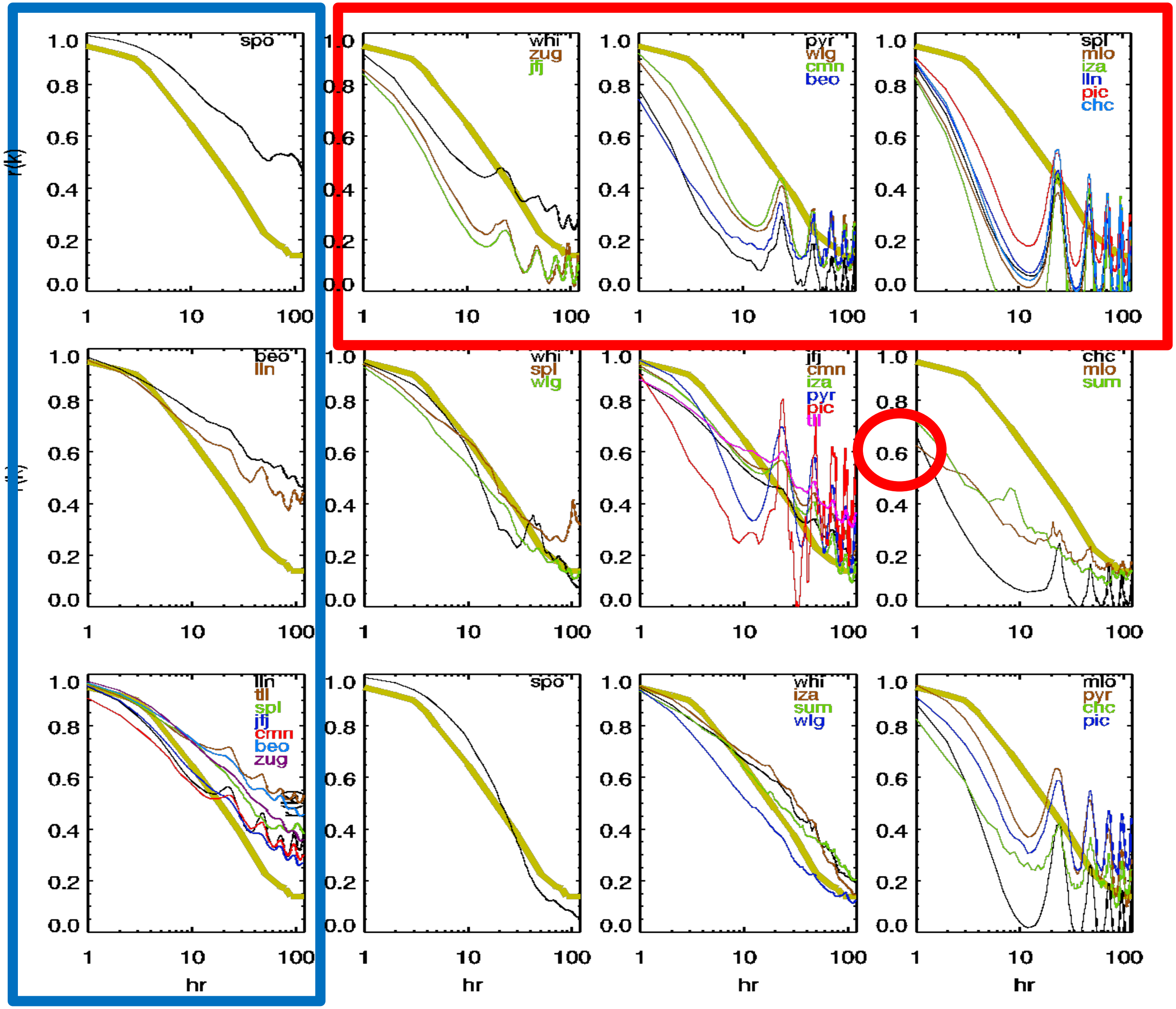
Autocorrelation for light scattering at Bondville (Anderson et al., 2003)

Lag Autocorrelation of mountain sites – Short term



Similarities among mountain sites

Increasing persistence



Number

Absorption

Scattering

Decreasing persistence

Summary of short term lag results

- All mountain sites experience diurnal oscillations in CN, except SPO

- Strength of diurnal cycle varies at each site and for each parameter
  - →atmospheric processing (NPF)
  - →transport (upslope/downslope)

- Lowest persistence (<0.75 at 1h lag) observed for absorption
  - →sum, mlo, chc

- Persistence tends to decrease with elevation and increase with latitude

- Anderson 2003 autocorrelation curve is good surrogate for some sites and some parameters

Future work
Seasonality of the lag autocorrelation – cold weather months when the site is more likely to be isolated in the free troposphere may look different than all year, while diurnal cycles may be enhanced in the summer.

Sources/processes

Lag-autocorrelation analysis can help identify whether aerosol properties co-vary.

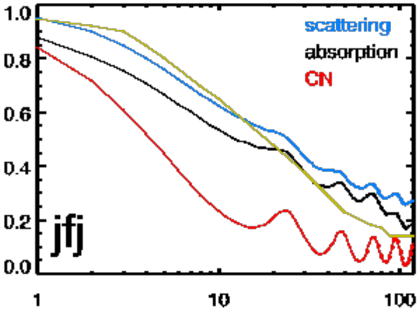
Co-variance could indicate similarities in:
→source and/or transport
→atmospheric processes

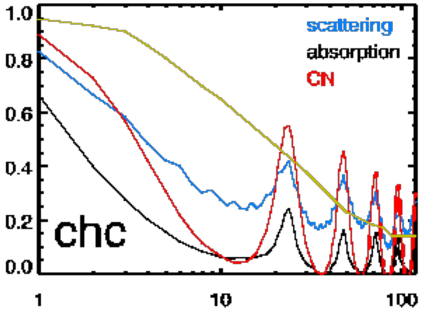
Conversely, lack of co-variance suggests differences in sources/transport or atmospheric processing

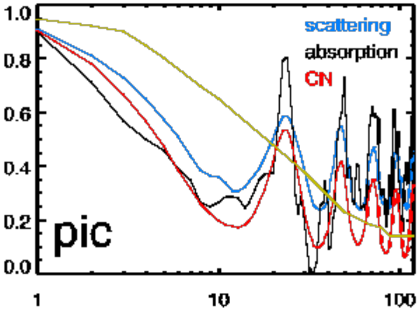


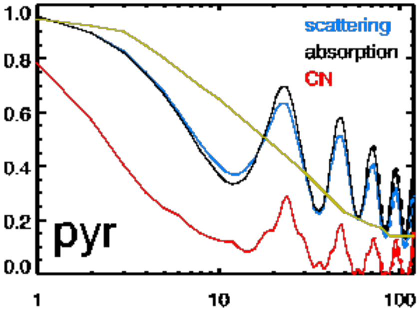
Some Examples

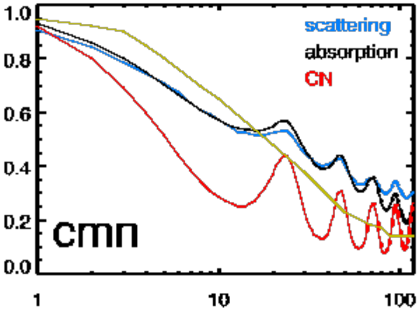
Similar cycles in all 3 properties



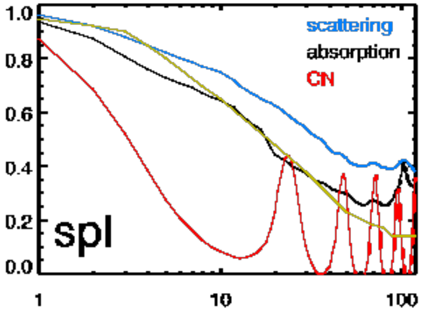


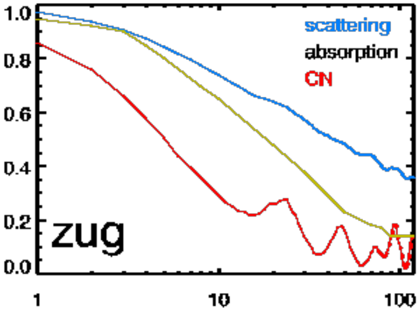


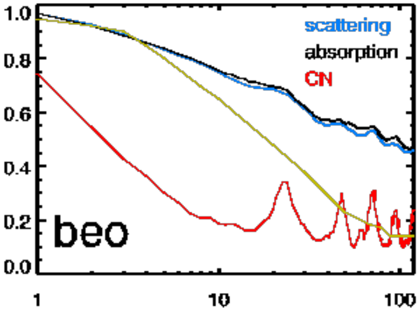


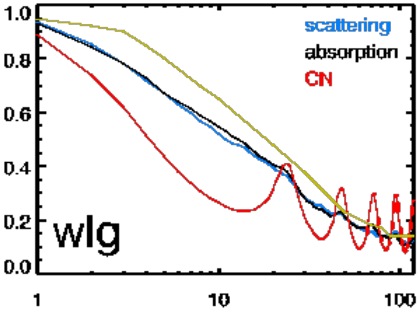


Different cycles for CN and scattering/absorption

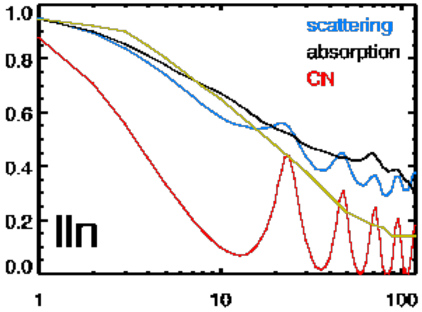




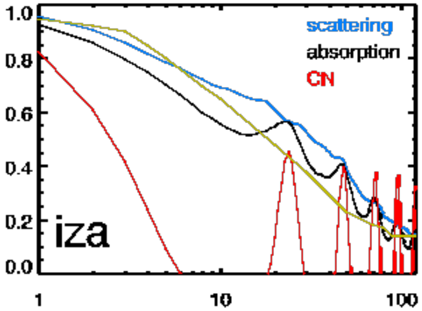




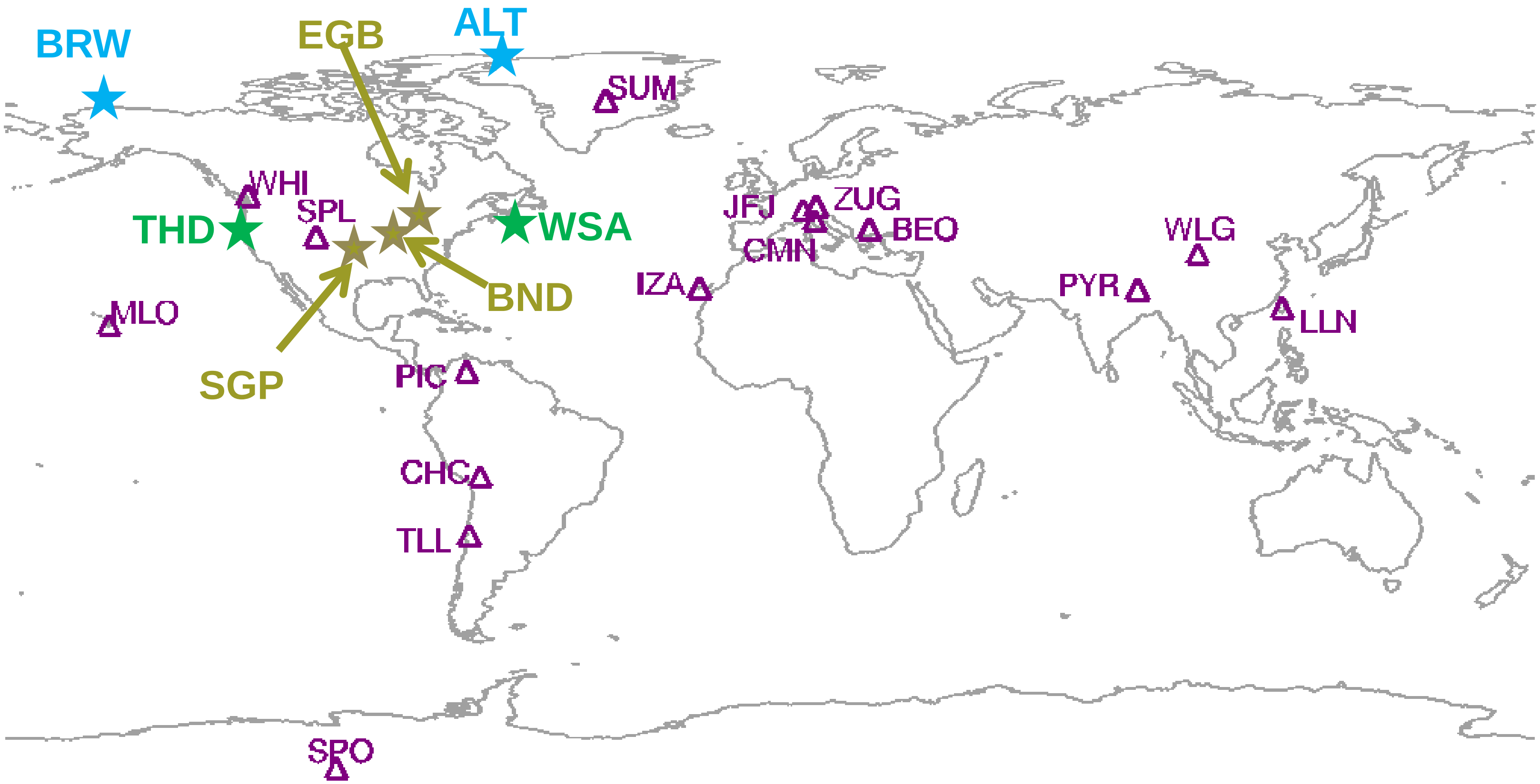
Absorption is different…



Scattering is different…



Comparison with other site types



Low elevation<315 m asl

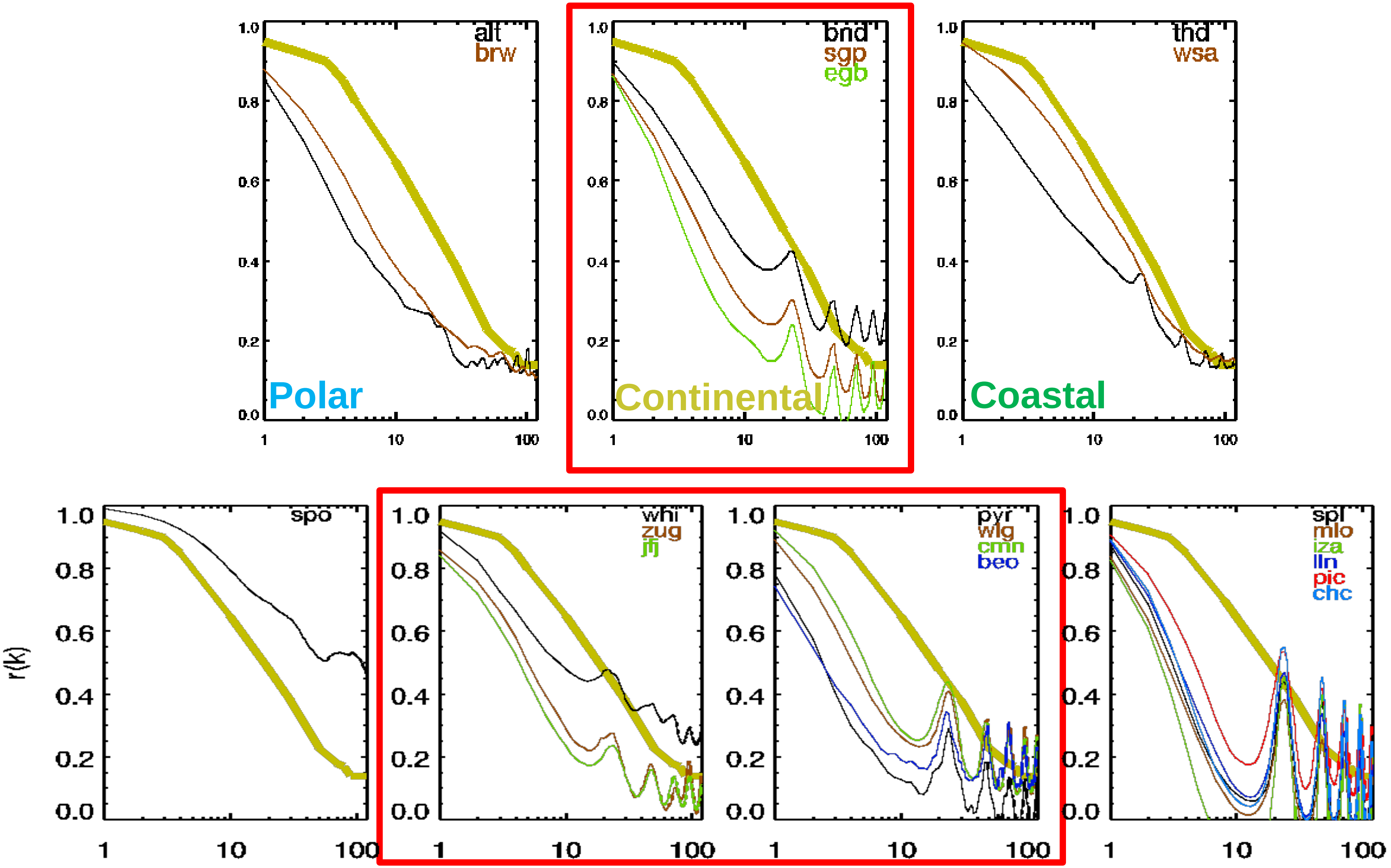
Continental: BND, EGB, SGP

Coastal: THD, WSA

Polar: ALT, BRW

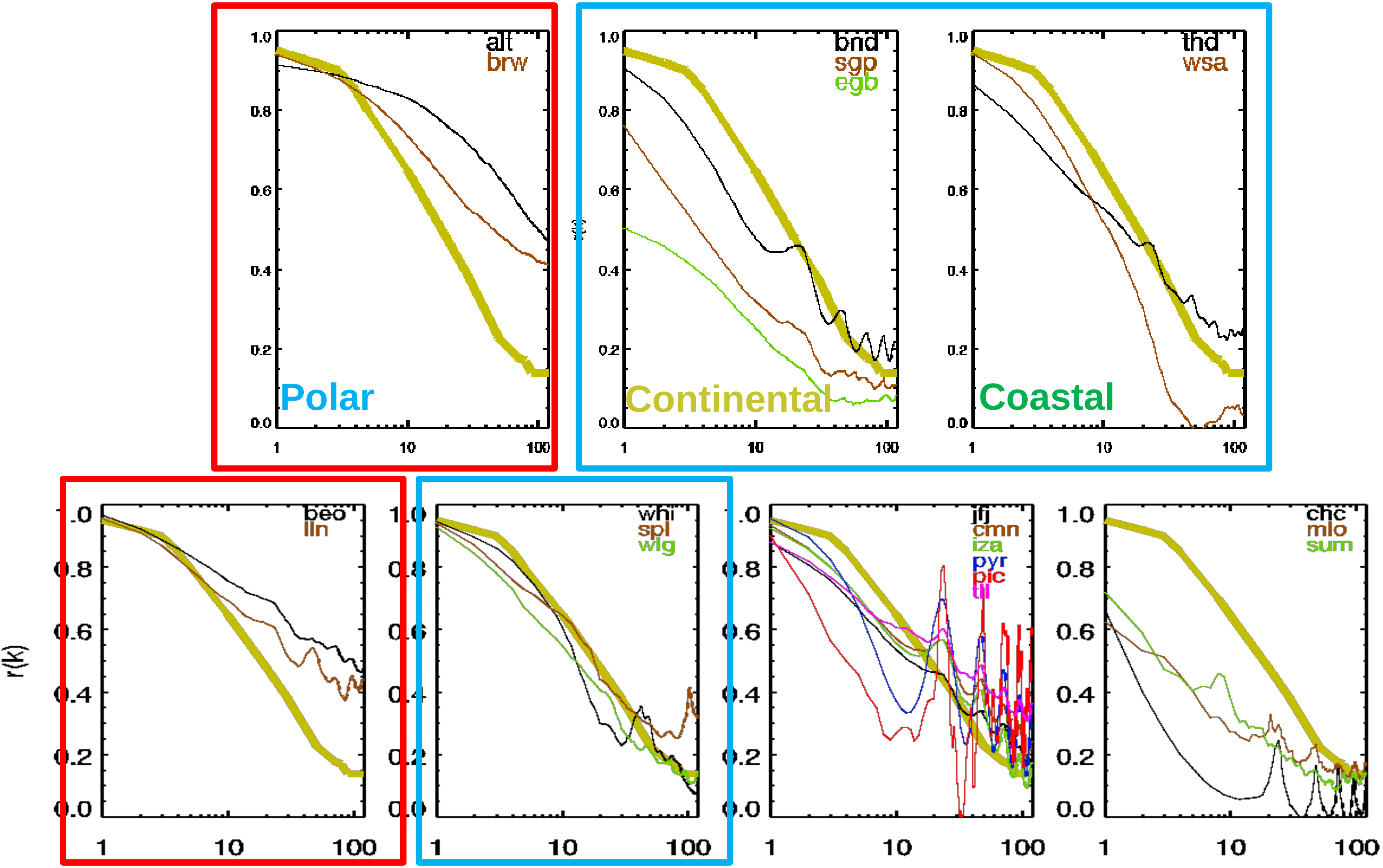
Are there characteristics of mountain sites that allow us to distinguish them from other site types?

CN – Compare with other site types



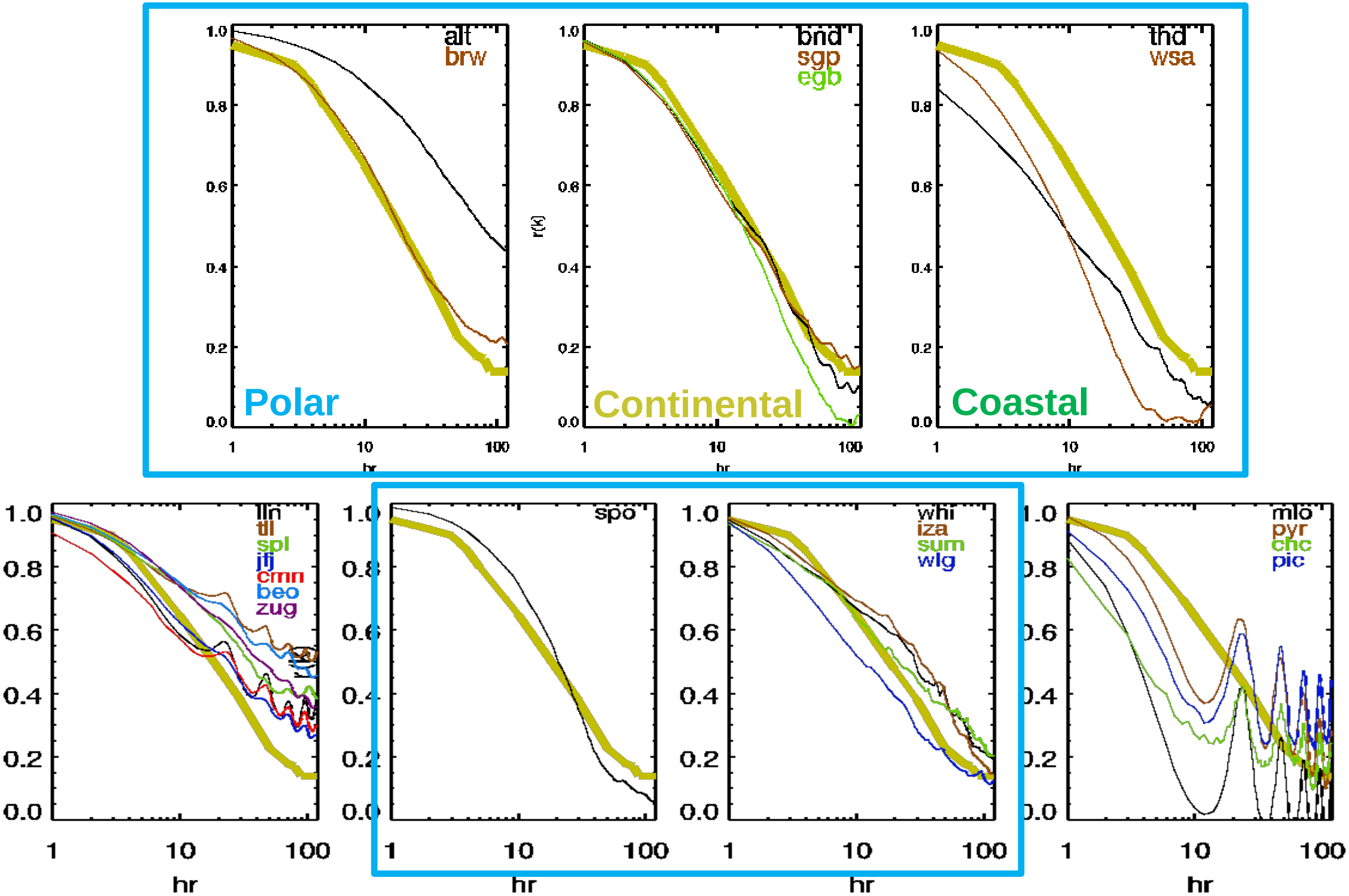
- Mountain CN are most similar to continental CN in terms of temporal variance
- Mountain sites can see both more and less CN persistence than other site types

Absorption – Compare with other site types



- Variability of mountain site absorption may be similar to that at other site types
- Only mountain sites see strong diurnal variation in absorption

Scattering – Compare with other site types



- Variability of mountain site scattering may be similar to that at other site types
- Only mountain sites see strong diurnal variation in scattering

Summary of site type comparison

There is a range in the lag-autocorrelation for other site types as well as mountain sites.

Primary difference: mountain sites are more likely to see stronger diurnal oscillations in all parameters (CN, absorption, scattering).
→this is likely upslope/downslope flow driven.

However, there is no obviously distinct characteristic of mountain sites.

Future work
Compare with additional polar, continental and coastal sites (e.g., sites in NOAA federated network)

Conclusions/implications/future work

- Mountain top measurements have widely varying time scales

- Aerosol parameters may have different time scales at the same site

- Mountain sites tend to have stronger diurnal patterns than other site types
  →Critical how FT air is filtered from BL and orographically lifted BL air
  →Care must be taken when comparing data sets on different time scales

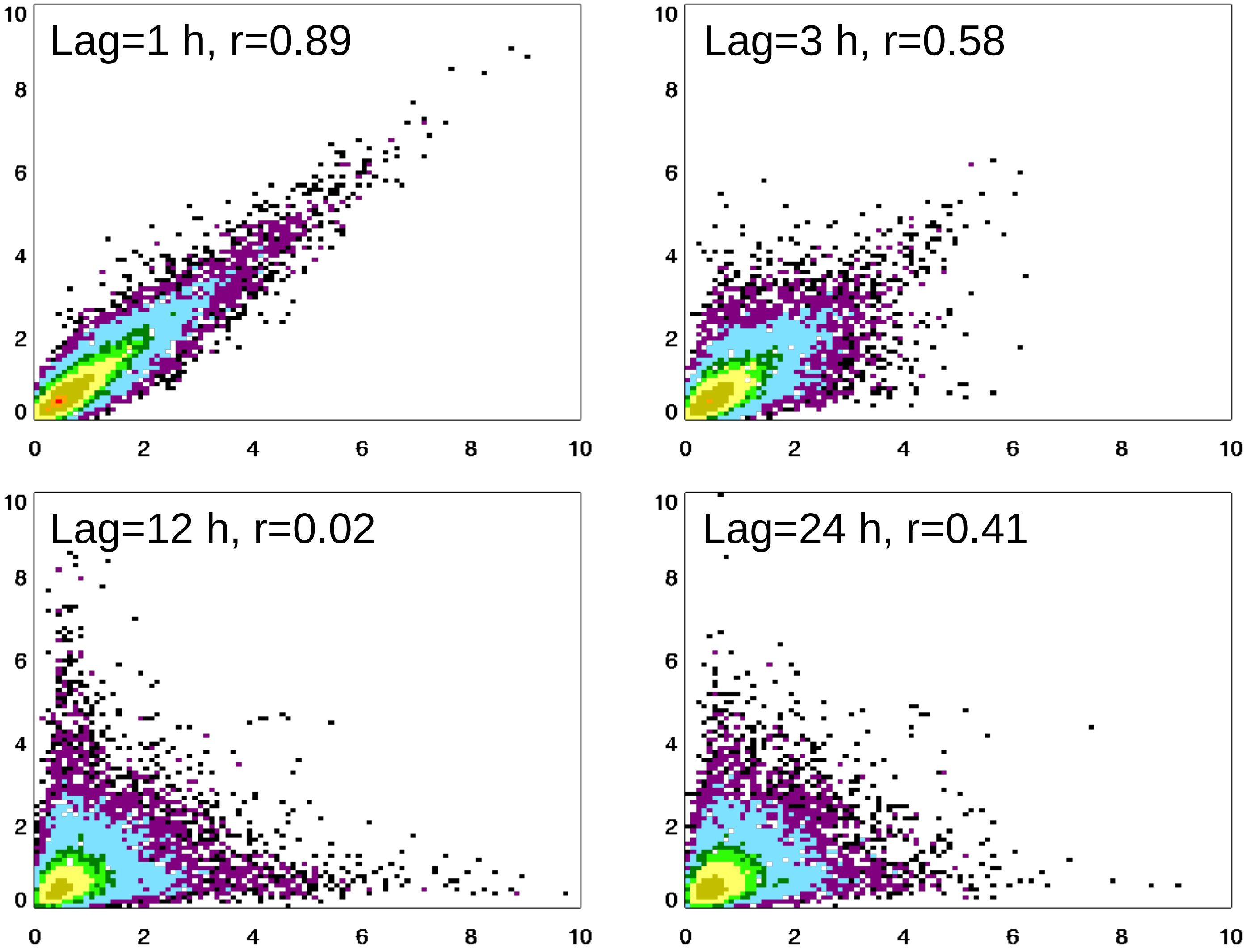
Future work

- Size distributions can help identify processes vs transport (e.g., Wehner et al. and Heintzenberg et al.)
- How do other aerosol parameters autocorrelate (e.g., single scattering albedo, Ångström exponent, etc.)?
- Seasonality of persistence
- Paper using NOAA network sites is in progress (includes mountain, coastal, polar, and continental sites)

Extra slides…

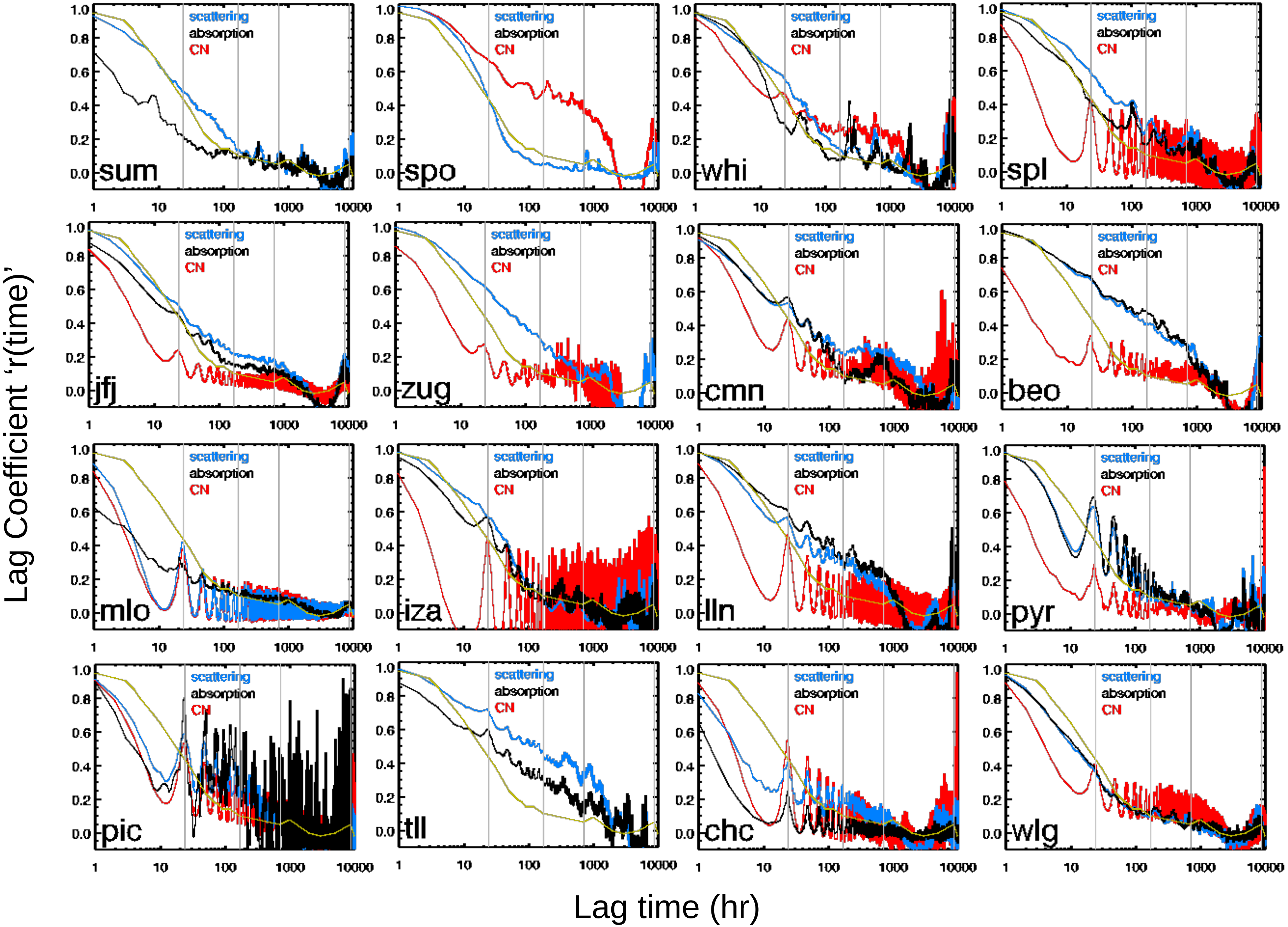
Instruments used for autocorrelation analysis

SITE	Number	Absorb.	Scatter	
BEO	DMPS	CLAP	TSI	
CHC	SMPS	MAAP	Ecotech	
CMN	3772	MAAP	Ecotech	
IZA	3025	MAAP	TSI	
JFJ	3010	Aeth	TSI	
LLN	3010	PSAP	TSI	
MLO	3760	PSAP	TSI	
PIC	3010	PSAP	DMPS	
PYR	SMPS	MAAP	TSI	
SPL	3010	PSAP	TSI	
SPO	3760	-	TSI	
SUM	-	PSAP	TSI	
TLL	-	Aeth	Ecotech	
WHI	3022	PSAP	TSI	
WLG	3010	PSAP	TSI	
ZUG	3772	-	TSI	

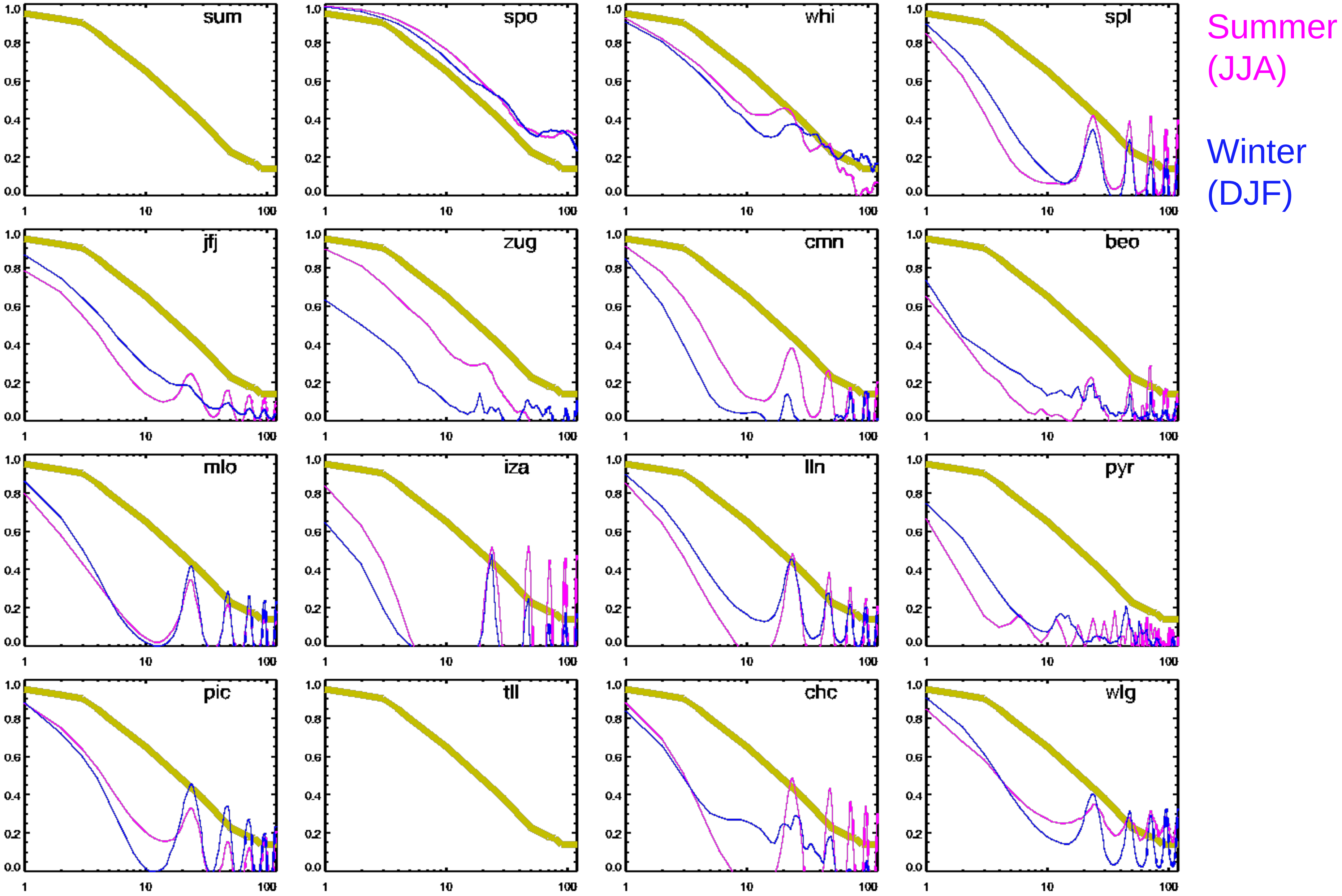


MLO scattering

Lag Autocorrelation of mountain sites – Long term

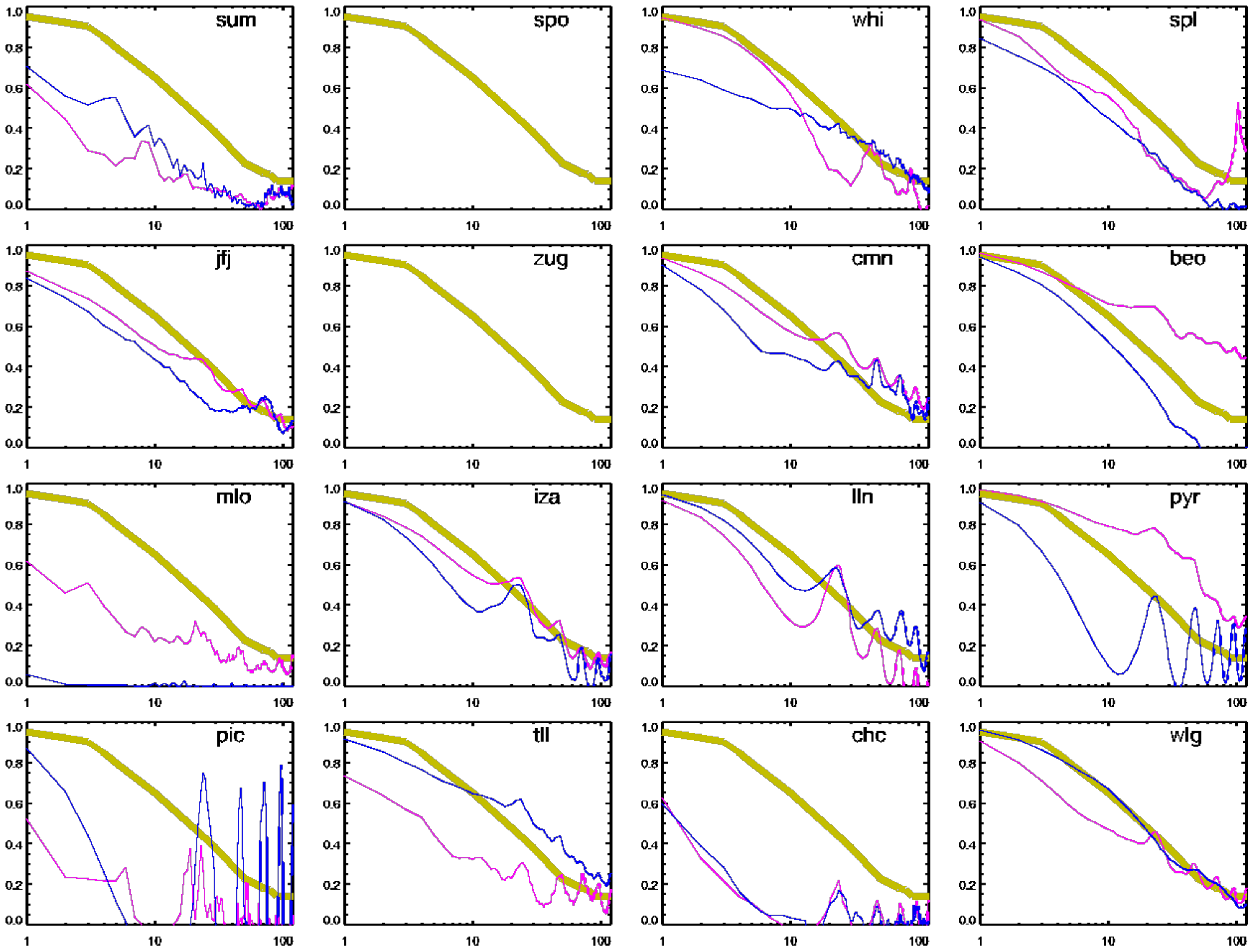


Seasonality of CN Persistence



Summer diurnal oscillations in CN tend to have larger magnitude than winter oscillations

Seasonality of Absorption Persistence

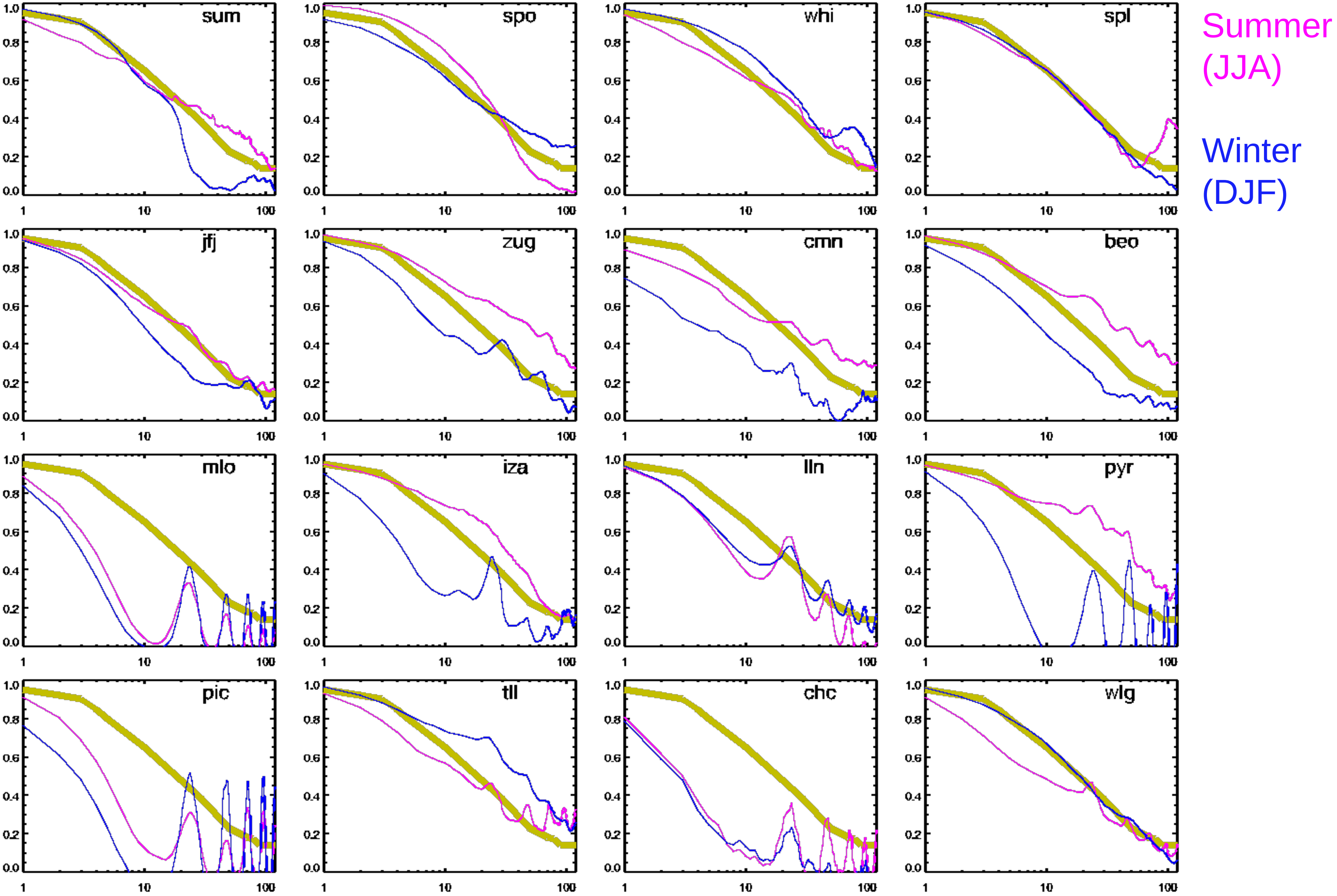


Summer (JJA)

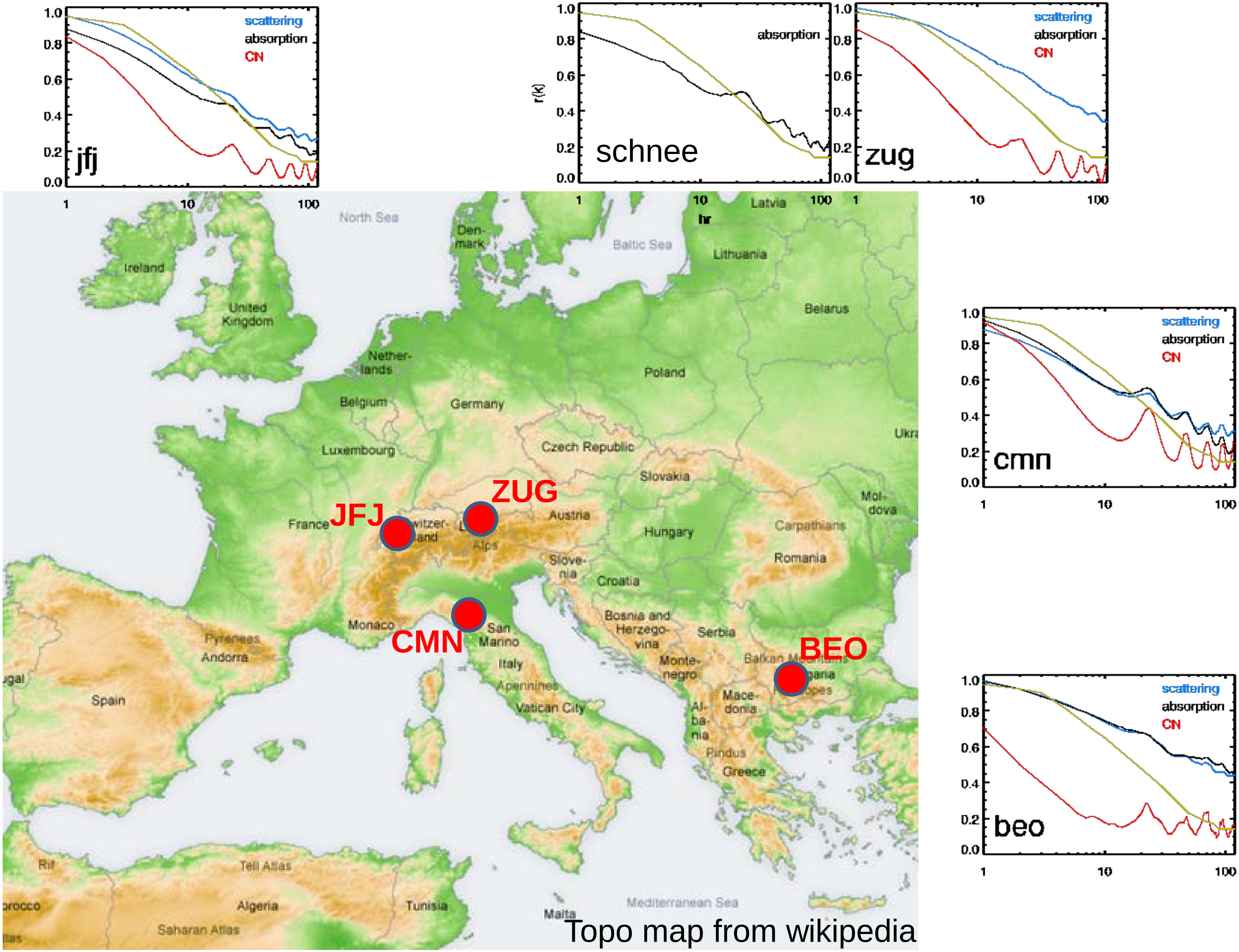
Winter (DJF)

Summer absorption is often more persistent than in winter; diurnal cycle = f(season)

Seasonality of Scattering Persistence



Summer scattering is often more persistent than in winter; diurnal cycle = f(season)



Topo map from wikipedia