AeroCom INSITU Project: Comparing modeled and measured aerosol optical properties

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https://wiki.met.no/aerocom/phase3-experiments#in-situ_measurement_comparison

OBJECTIVE

Evaluate AeroCom model simulations of aerosol optical properties using long-term, in-situ surface aerosol measurements

DESCRIPTION

Three-tiered project:

I. Evaluation of dry, in-situ aerosol optical parameters (this talk)
II. Trend analysis of dry, in-situ aerosol optical properties
III. Evaluation of hygroscopicity of aerosol scattering

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Process

- Acquire and review surface in-situ aerosol optical data
- Obtain high frequency model output consistent with measured in-situ aerosol parameters from AeroCom community
  - → dry, spectral extinction and absorption
- Sample model output at station locations
- Compare model output and measurements:
  - → Scattering
  - → Absorption
  - → Scattering Ångström exponent (SAE)
  - → Single scattering albedo (SSA)

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In-situ Aerosol Optical Properties

Mauna Loa aerosol rack

Aerosol light scattering

- Nephelometer (TSI or Ecotech)

Aerosol light absorption

- Instruments: MAAP, PSAP, or CLAP

Data Collection

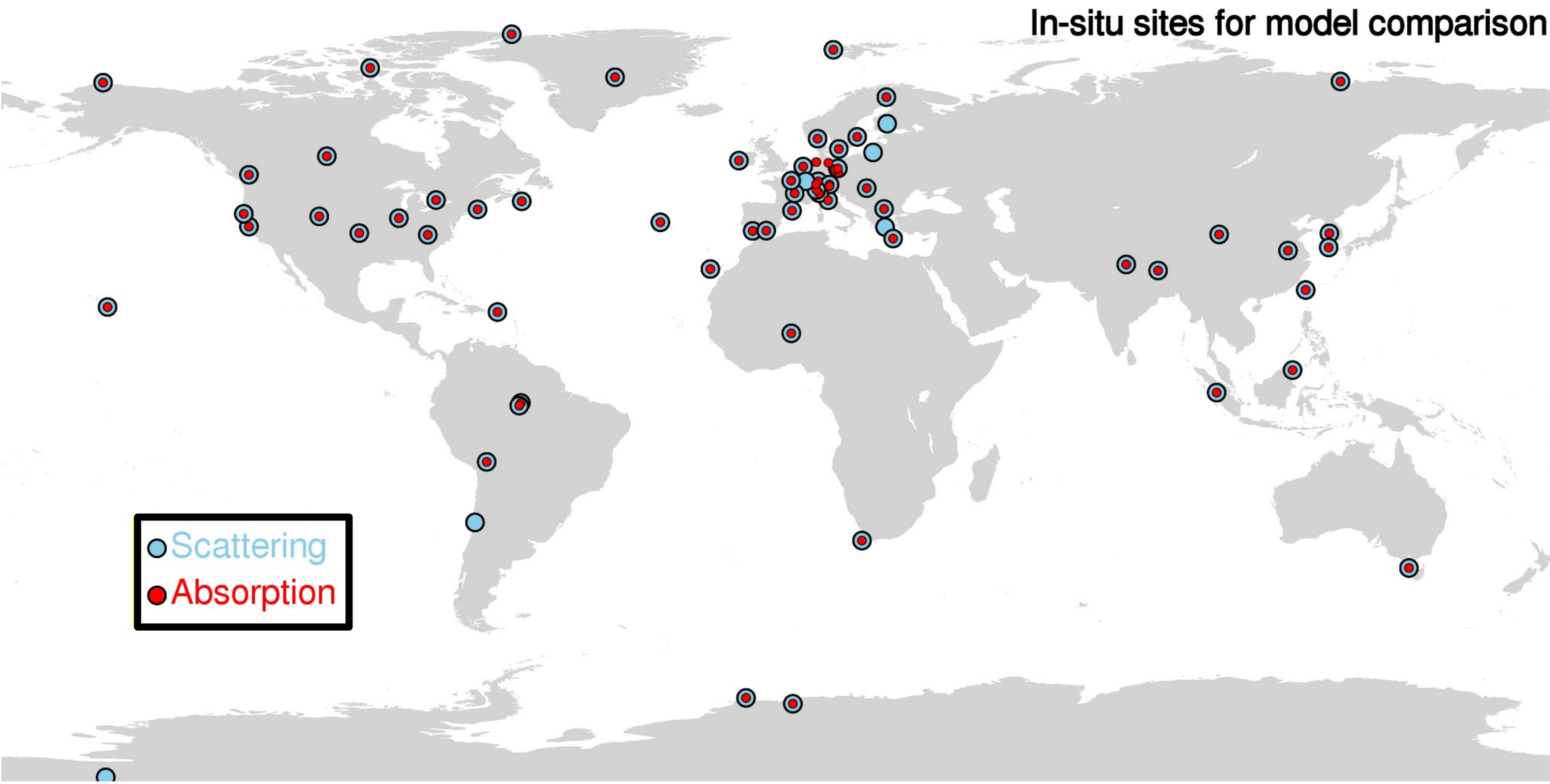
- Low RH (<40% RH)
- 1 min resolution (typically)
- 1 & 10 um size cuts (at some sites)

Data Processing

- QC'd and corrected
- Averaged (H, D, M, Y),
- Absorption and scattering reported at STP

Data are primarily from the EBAS data archive

In-situ Measurement Sites

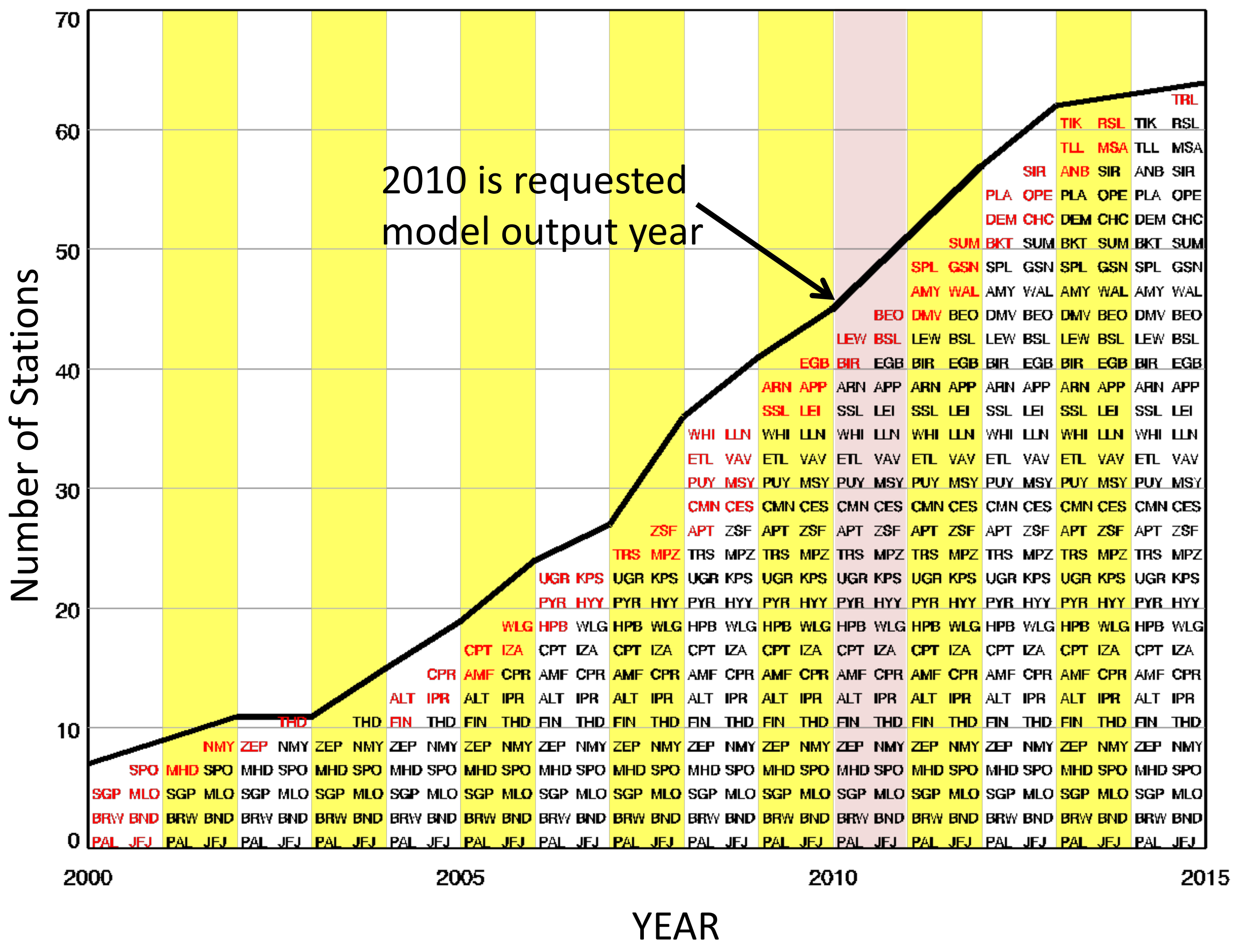


- Sites with aerosol light scattering and/or absorption (~65 sites)
- Fewer sites than AERONET
- Gaps in S. America, Africa, Middle East, Russia, Pacific Asia Nations

→Currently working on getting data into consistent format – ‘benchmark data files’

When are in-situ data available?

Stations with absorption and/or scattering data between 2000 and 2015



- Number of stations increasing by ~5/year
- Data for more than 60 sites by 2015
- ~45 sites in 2010 for time-matched model-measurement comparisons

AeroCom Models Used in this Analysis

	Gridbox size	Year(s)
TM5	3.0° x 2.0°	2010
GEOS-Chem	2.4° x 2.0°	2010
CAM5	2.4° x 1.9°	2010
ECHAM6-SALSA	1.8° x 1.9°	2010
GEOS5-Globase	1.25° x 1°	2010
GEOS5-MERRAero	0.6° x 0.5°	2010
OsloCTM2	2.8° x 2.8°	2008
GOCART	2.5° x 2.0°	2000-2007
MPIHAM	1.8° x 0.9°	2006-2008
SPRINTARS	1.1° x 1.1°	2000-2008

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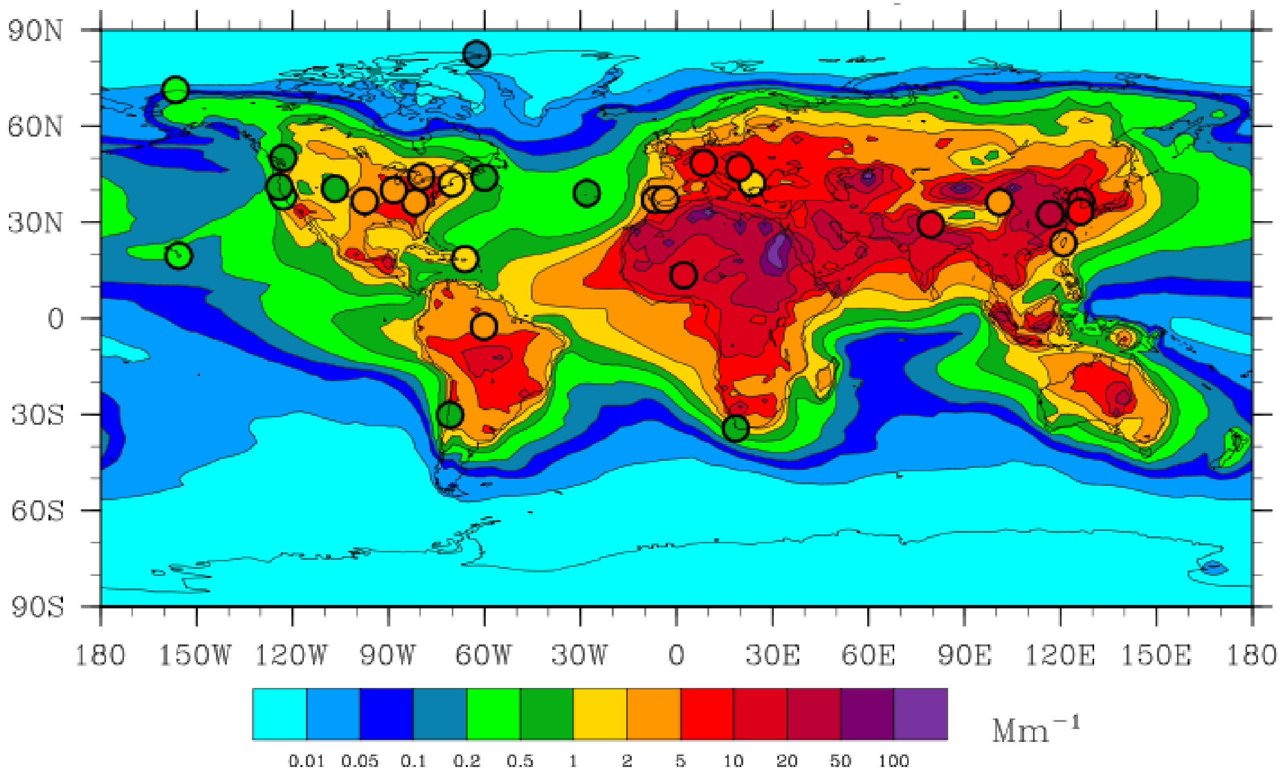
Comparisons

Compare models/measurements from several perspectives…

CLIMATOLOGY	Tells us how well the model is doing at given locations
CHARACTERISTICS & BEHAVIOR	Tells us how well the model is simulating aerosol processing, sources, transport, etc. • Co-variance of aerosol optical properties • Lag-autocorrelation

Aerosol Climatology: **Big Picture**

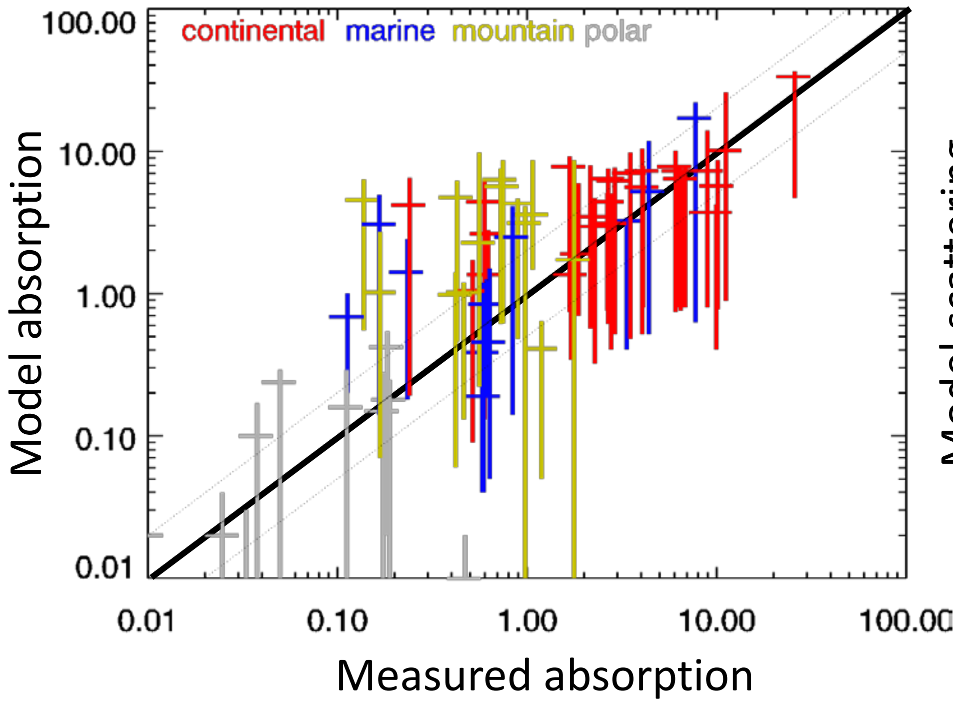
OsloCTM2 (2008 simulated aerosol absorption)

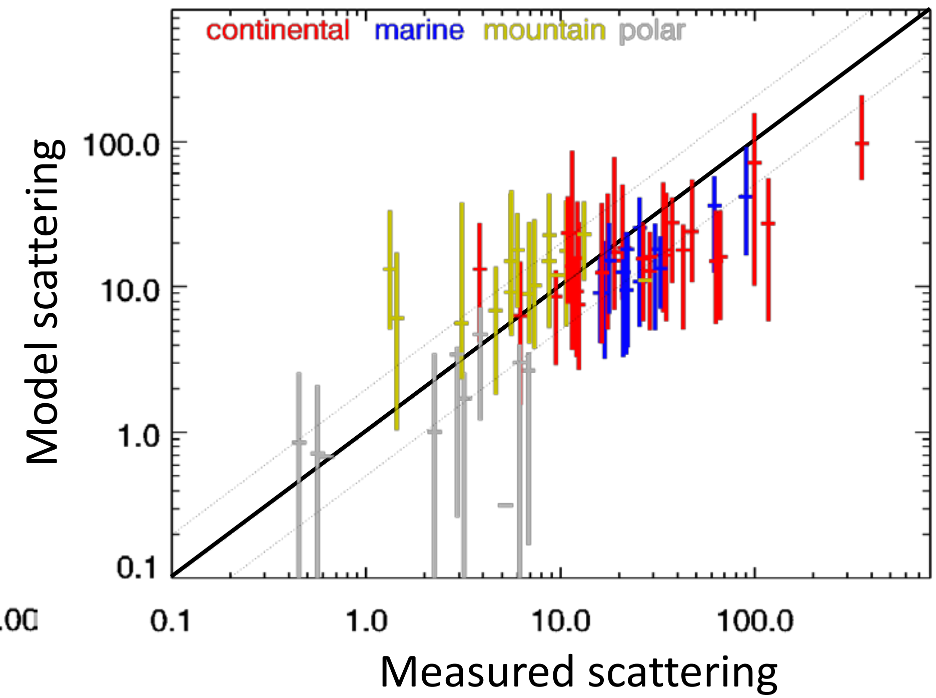


→NOAA collaborative network sites only (~25 sites)
→Model year = 2008
→In-situ = variable years
→<u>Log</u> color scale

- General pattern of absorption similar for models and in-situ measurements
- Biggest differences may be observed for some high altitude and coastal sites

Aerosol Annual Climatology: **Absorption and Scattering**

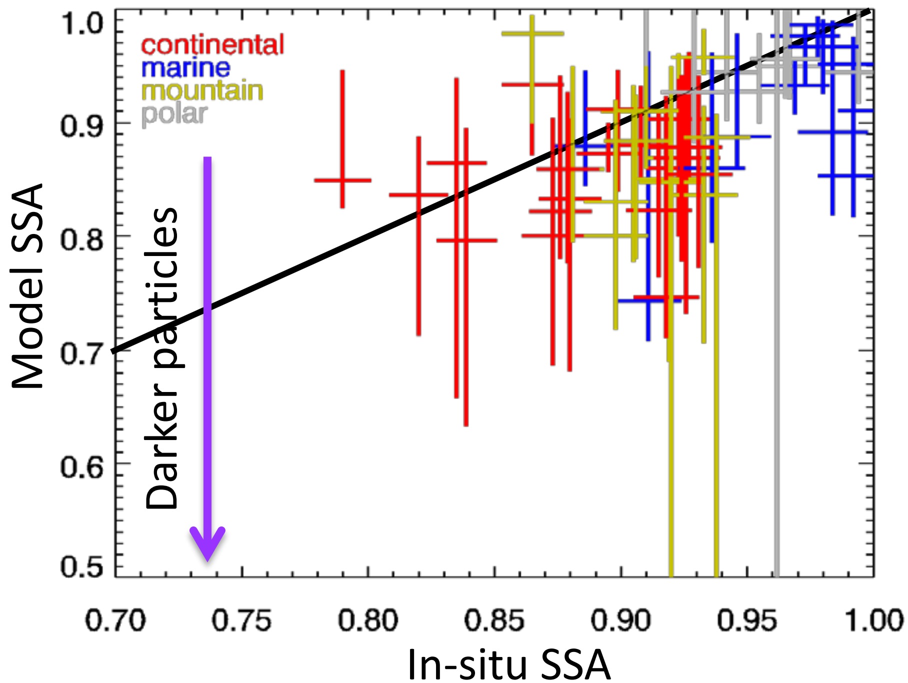


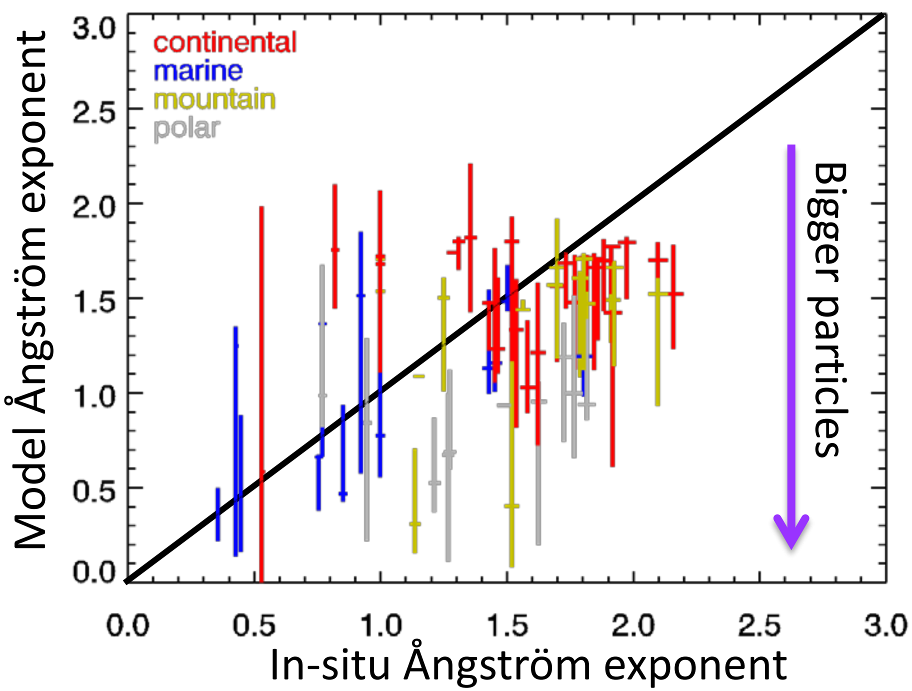


- Models tend to over-predict absorption and scattering at mountain sites
- Scattering tends to be under-predicted at other site types
- Less of an bias in modelled absorption than scattering
- More range (relatively) in model prediction of absorption than scattering

Vertical bar shows range of model medians, horizontal bar is measurement uncertainty based on Sherman et al. (2015), only 2010 model output.

Aerosol Annual Climatology: **SSA and Ångström exponent**



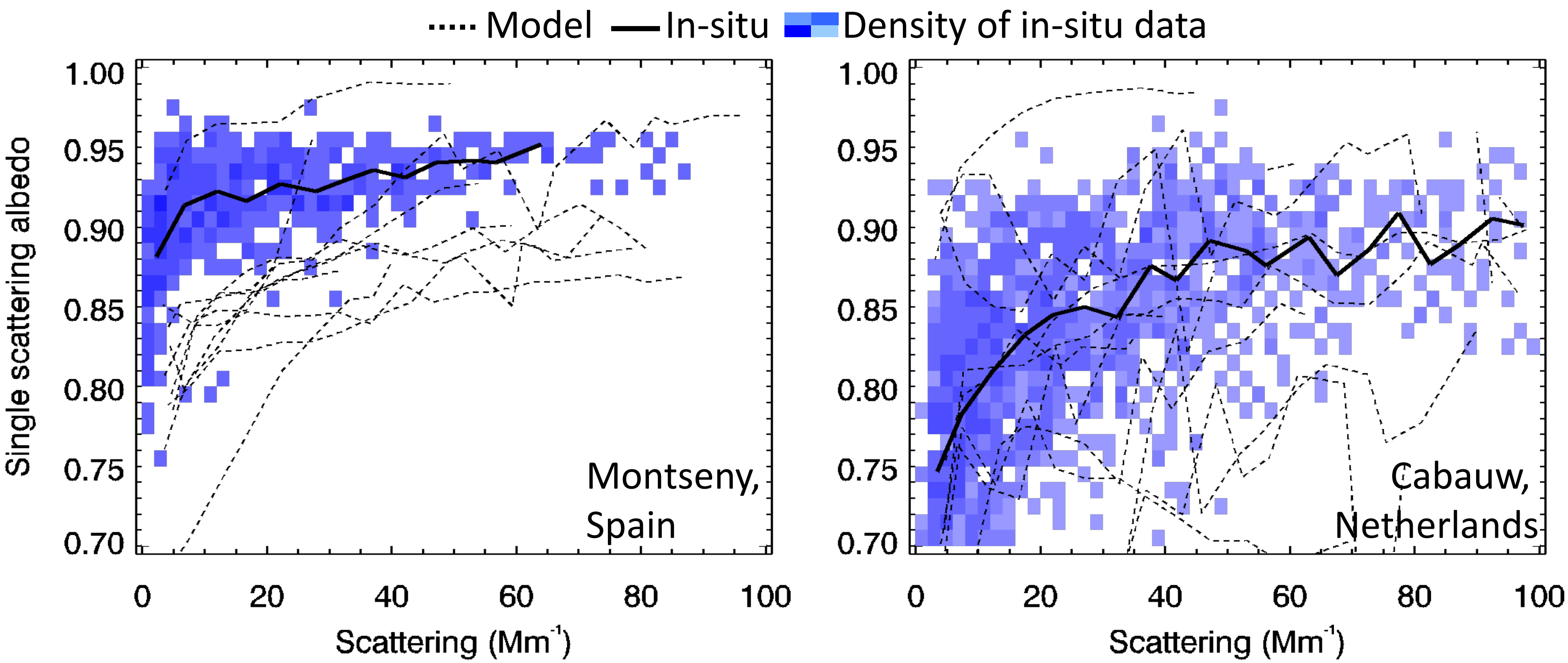


- Model SSA tends to be lower (more absorbing) than in-situ SSA
  → partly driven by model under-prediction of scattering

- Modelled Ångström exponents suggest larger particles than observed by in-situ measurements

Vertical bar shows range of model medians, horizontal bar is measurement uncertainty based on Sherman et al. (2015), only 2010 model output.

Aerosol Behavior: **Systematic Variability**

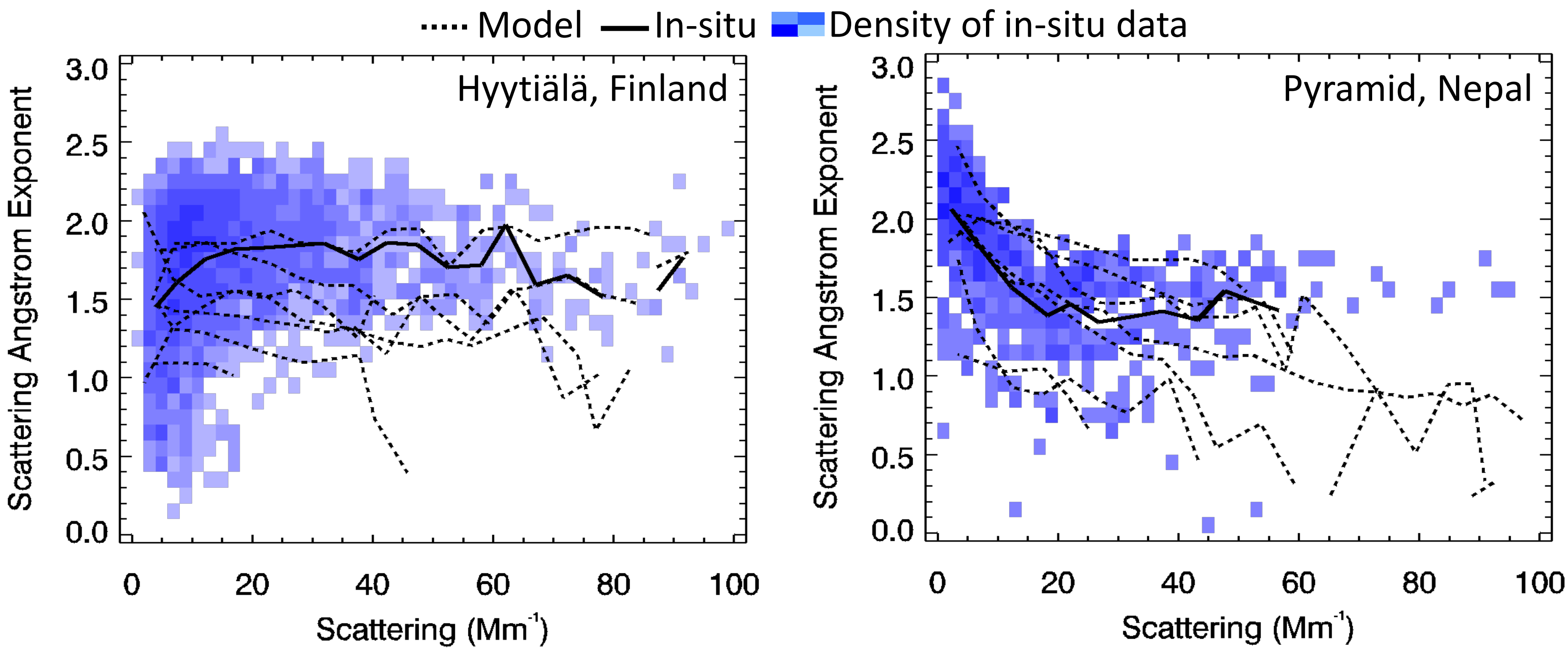


- Lower loading corresponds to darker (and smaller) particles

→ preferential scavenging of large, scattering aerosol by clouds/precipitation?

The co-variance observed between SSA and scattering for in-situ data is not necessarily reproduced by model output

Aerosol Behavior: **Systematic Variability**

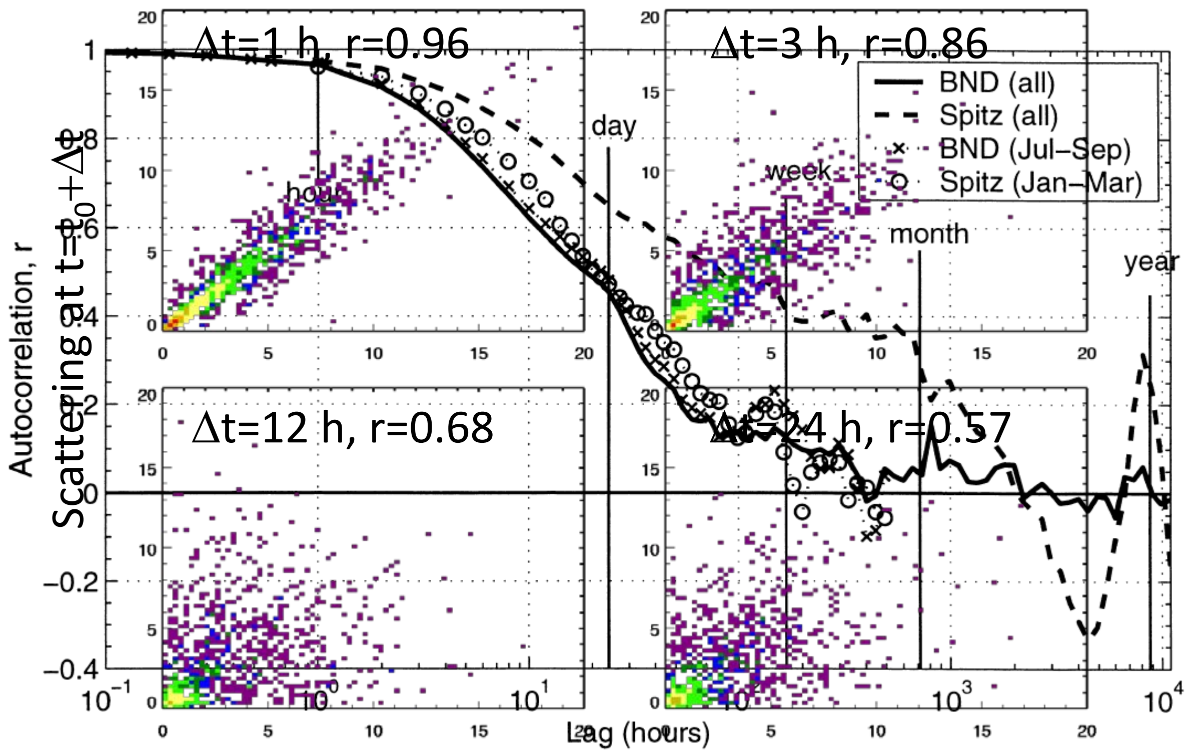


- Relationship between aerosol loading and aerosol size distribution changes with location (i.e., aerosol type)

- The co-variance observed between Ångström exponent and scattering for in-situ data is not necessarily reproduced by model output

Aerosol Behavior: **Lag-Autocorrelation**

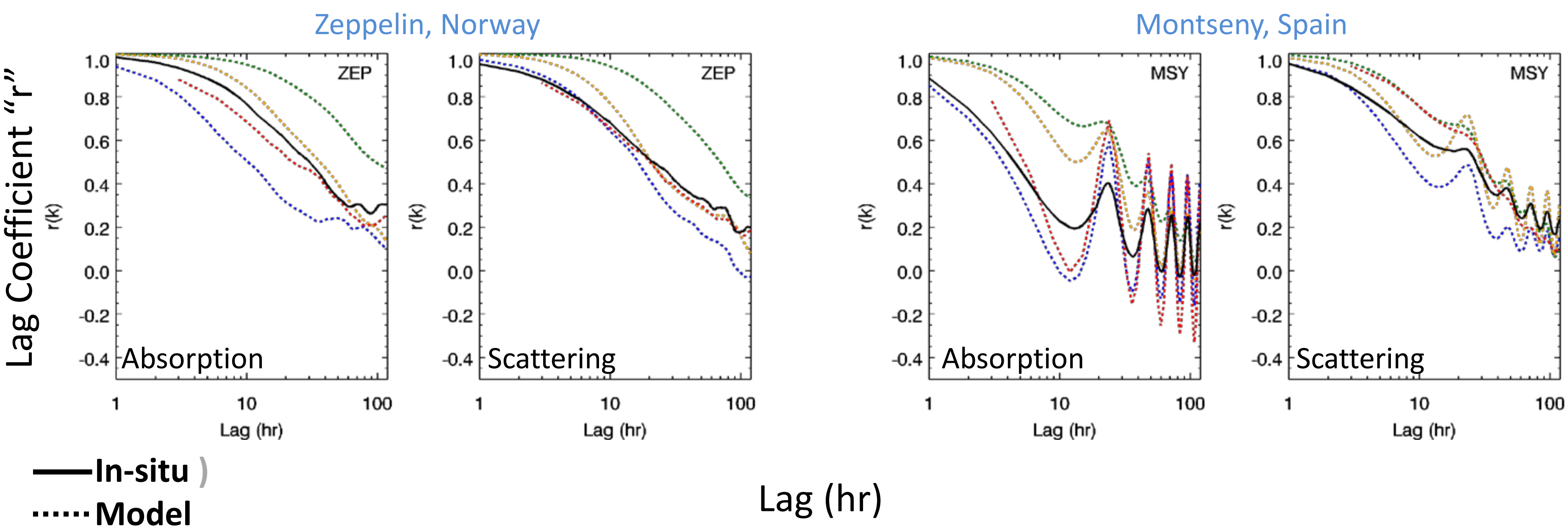
- Indicator of aerosol persistence
- Provides information about atmospheric processes, especially for higher frequency data (e.g., NPF, uplope/downslope…)
- Constrain comparisons by identification of expected 'best case' agreement between data sources with different temporal/spatial resolution



Scattering at $t=t_0+\Delta t$

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

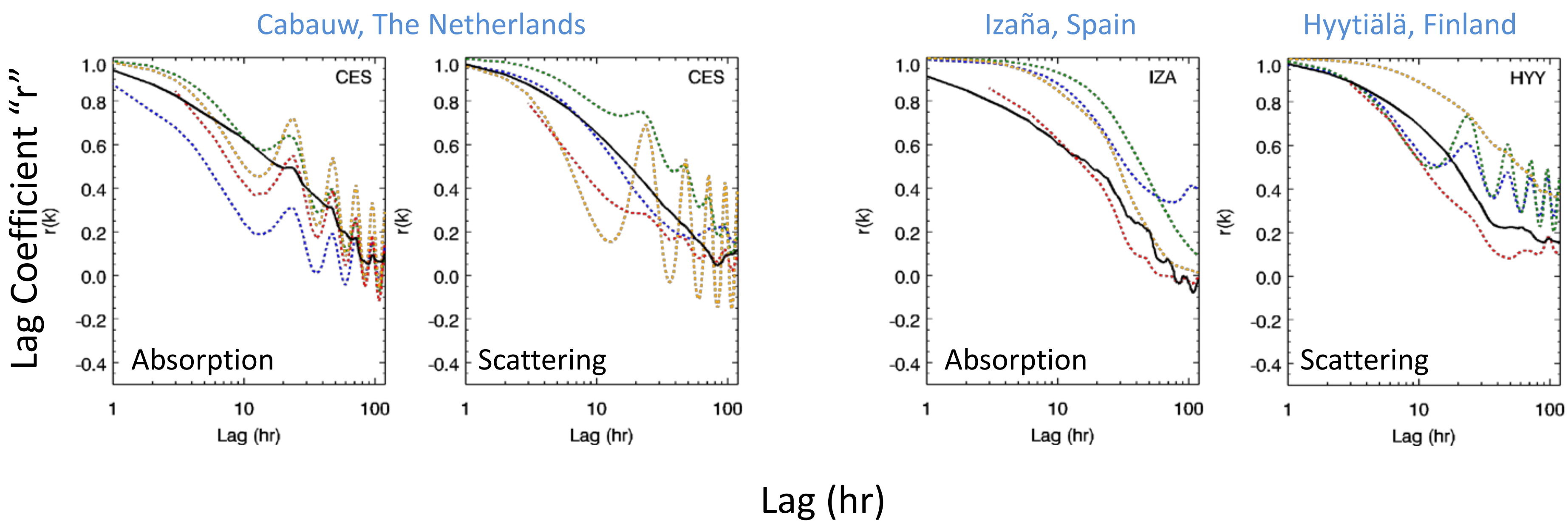
Aerosol Behavior: Autocorrelation



- Lag-autocorrelation provides information about atmospheric processes, especially for higher frequency data (e.g., NPF, upslope/downslope…)

- Differences in lag-autocorrelation amongst models may be due to grid size, grid boundaries, differences in atmospheric processes and/or some combination.

Aerosol Behavior: **Autocorrelation**



- Fairly common for models to predict strong diurnal oscillations when none are observed in in-situ data.

- No consistent pattern in terms of models over- or under- predicting aerosol persistence.

Takeaways

- Potential for many types of measurement/model comparisons

- Climatological comparisons tell us how models are doing now and may identify regions of difficulty for models
  →models tend to see lower scattering than in-situ
  →models tend to see darker aerosol (lower SSA) than in-situ
  →models tend to see larger aerosol (lower Ångström exponent) than in-situ

- Behavioral comparisons may indicate discrepancies in aerosol modules in terms of atmospheric sources/processes
  →models have varying success in reproducing observed co-variance amongst aerosol optical properties
  →lag-autocorrelation analysis allows model/measurement comparisons of aerosol persistence

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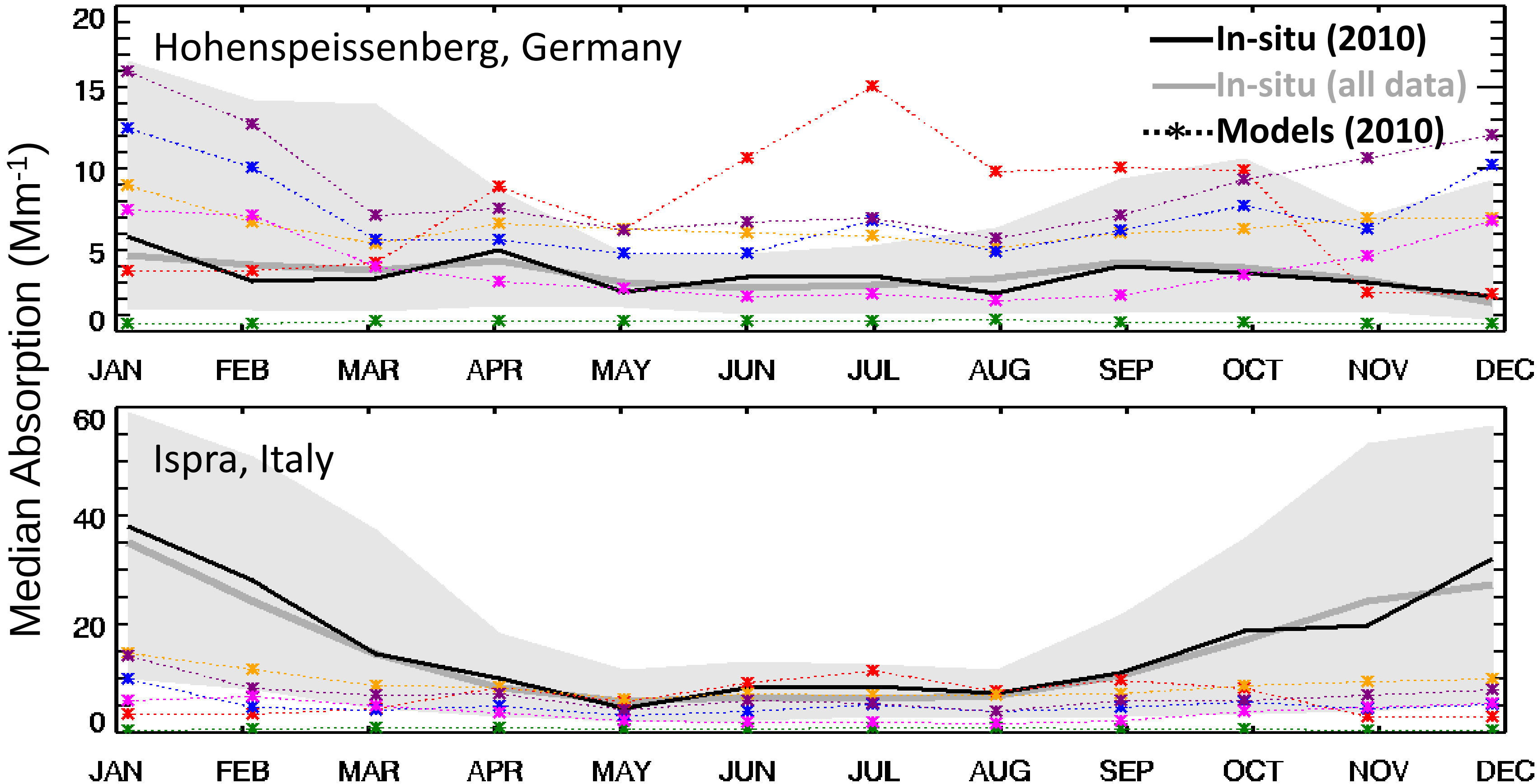
Extra slides

Aerosol Climatology: **Seasonality**

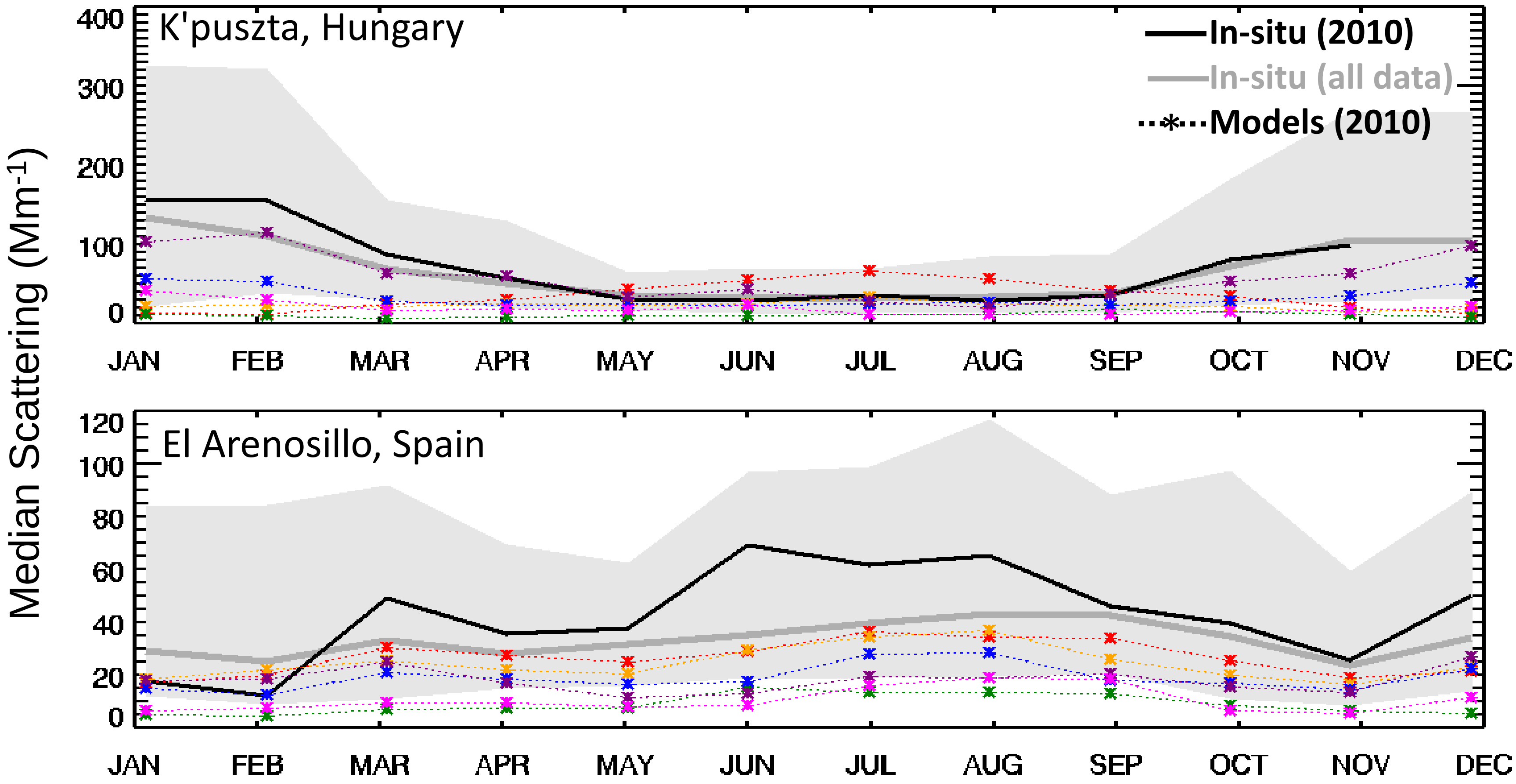
Discrepancies in seasonality may help identify issues with model emissions, transport and/or atmospheric processing



In-situ (all data) and in-situ (2010) tend to be closer to each other than to model 2010 data →reasonable to do monthly statistical comparisons (ignoring year)

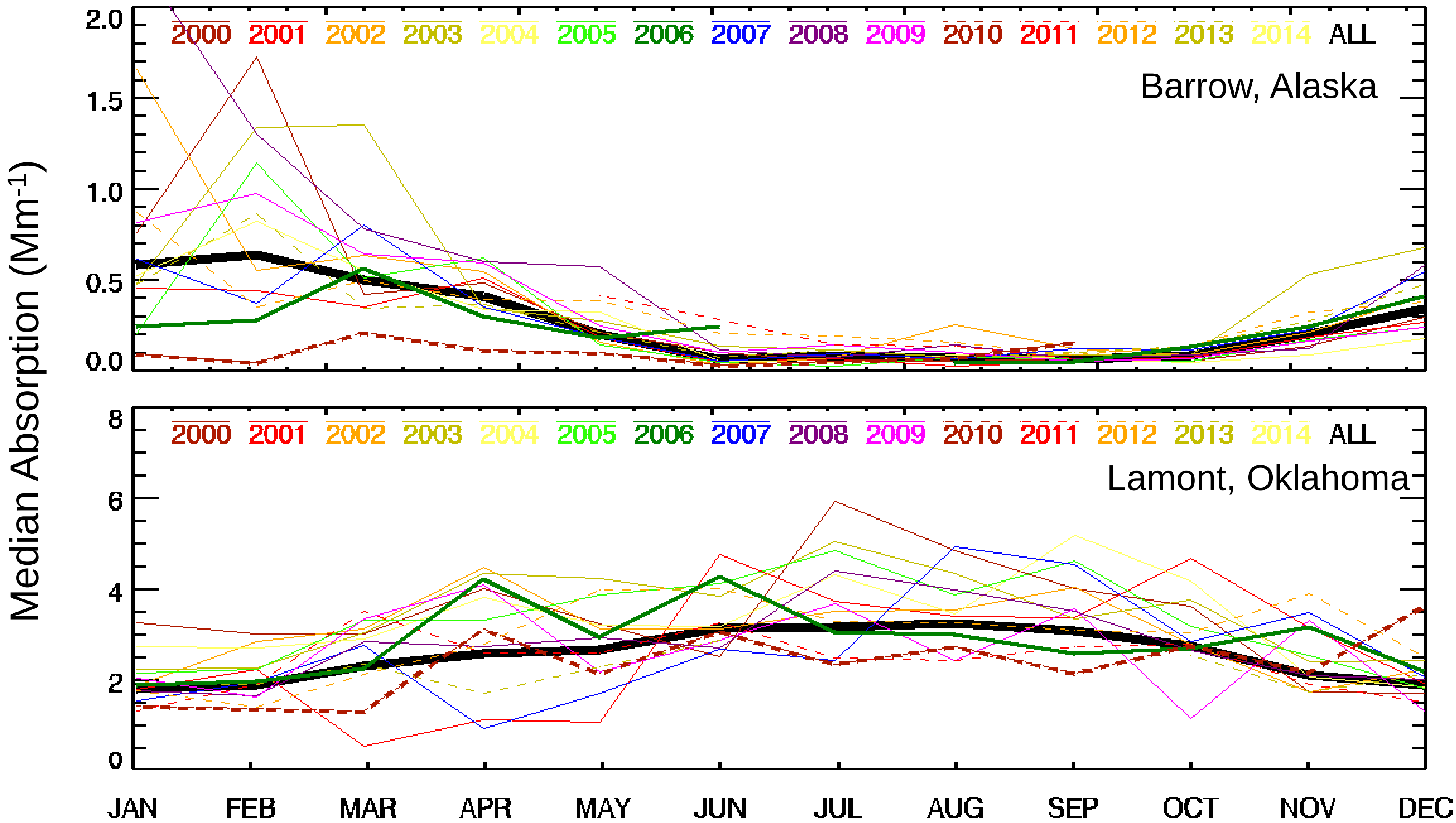
Aerosol Climatology: **Seasonality**

Discrepancies in seasonality may help identify issues with model emissions, transport and/or atmospheric processing



- Models can get observed seasonality right at one location and not at another,
- Models can capture seasonality well, but not magnitude
- Seasonality at one location can be totally different among models

Aerosol Climatology: Inter-annual Variability

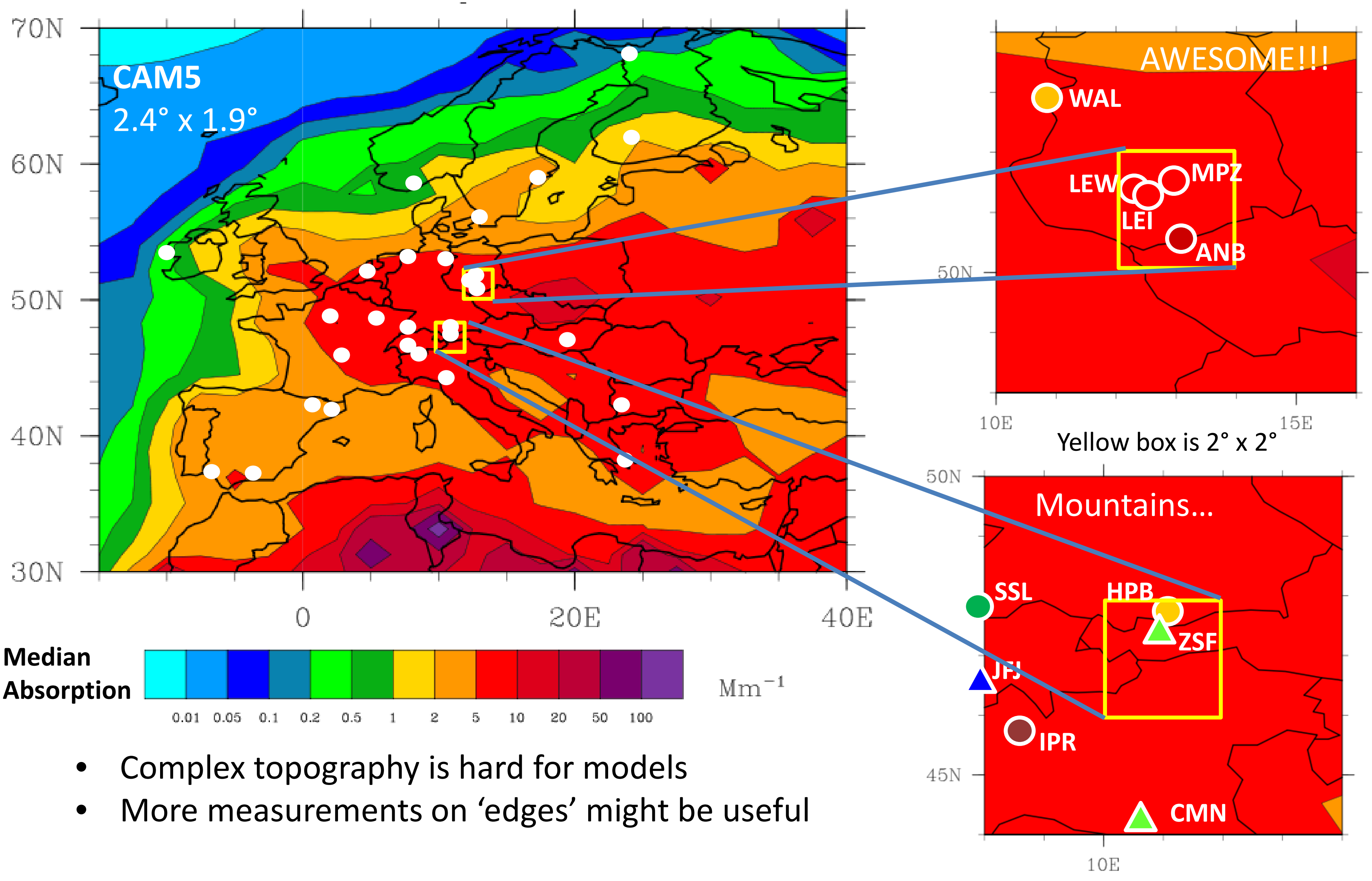


Plot shows only in-situ data for two sites with long term records

Thick black lines are ‘in-situ’ lines from previous slide.

→inter-annual variability is very site dependent

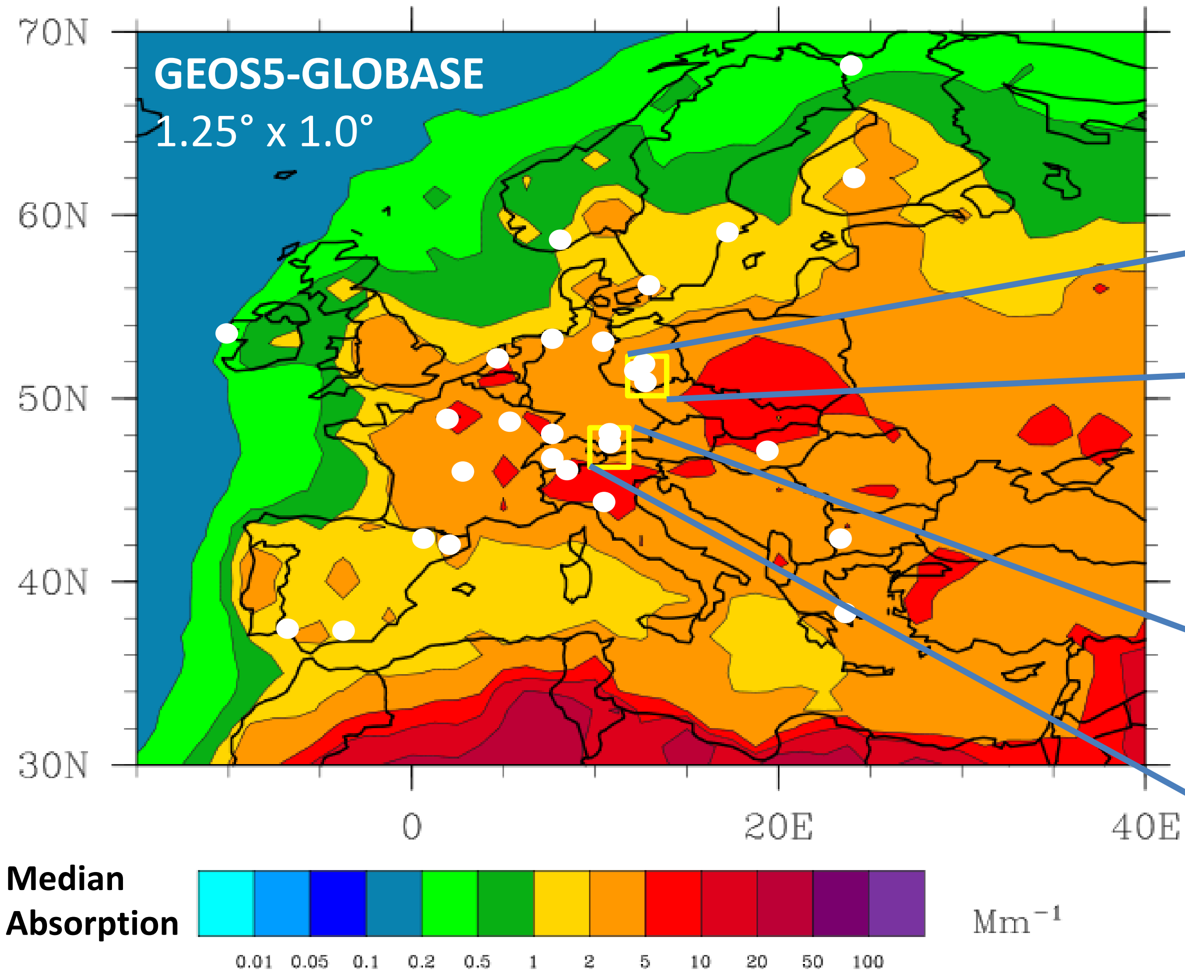
Aerosol Climatology: Sub-grid variability

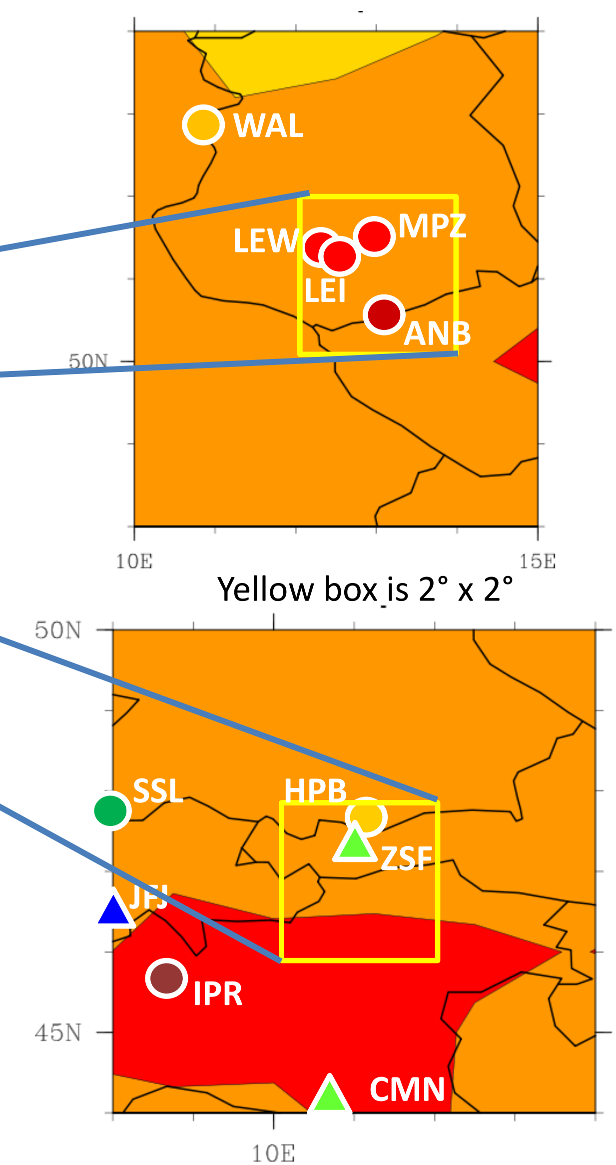


- Complex topography is hard for models
- More measurements on 'edges' might be useful

Note: Only Europe has high enough density of in-situ measurements to look at sub-grid variability.

Aerosol Climatology: **Sub-grid variability**





- Higher resolution model improves comparison in some cases but not others…
- Topography is still an issue.

Potential Issues for In-situ/Model Comparisons

- **Point measurement vs Area prediction**
  - *"…sites dominated by local pollution or sites near mountains are expected to introduce unwanted biases with respect to the regional average" (Kinne et al., 2006)*

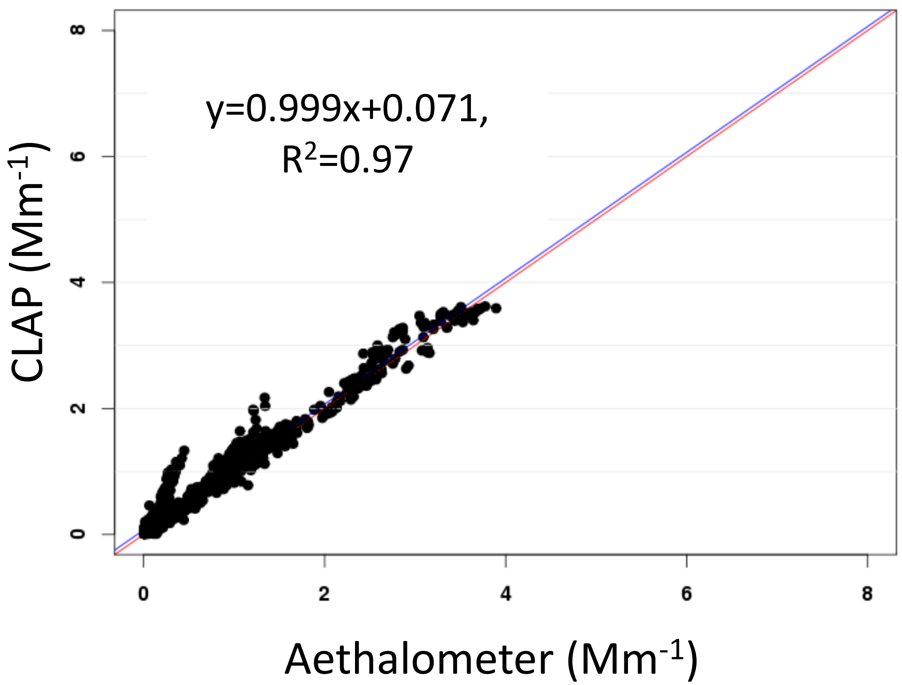
- **Meteorological adjustments**
  - *e.g., Measurement to ambient conditions (T, P) or model to STP*

- **Averaging**
  - *In-situ daily: 0 UTC-24 UTC, time=start of average*
  - *Model daily: ??*

Aethalometers

- Currently, have not included aethalometer data sets due to correction scheme issues
- Including aethalometer data increases number of sites with in-situ absorption data

Barrow, Alaska



Preliminary analyses suggest properly corrected aethalometer data are in good agreement with better characterized aerosol absorption instruments.

Why long-term, in-situ, surface aerosol optical data?

	NOAA & GAW Surface Networks	Aircraft Campaigns	AERONET	Satellite
Length of dataset	Long-term 🙂	Short-term ❌	Long-term 🙂	Long-term 🙂
Temporal continuity	Continuous 🙂	Variable ❌	Intermittent ❌	Intermittent ❌
Geographical Coverage	Sparse ❌	Sparse ❌	Medium Sparse 🙂	Global 🙂
Vertical Resolution	Surface only ❌	Vertically resolved 🙂	Column only ❌	Column (mostly) ❌ 🙂
Aerosol optical properties	Complete RFE suite; @ low RH 🙂	Various ❌ 🙂	Complete RFE suite (at high loading); @ ambient RH 🙂	Various ❌ 🙂

→There are advantages and disadvantages for each data set.