A way too quick overview of long-term, surface, in-situ aerosol optical property network measurements

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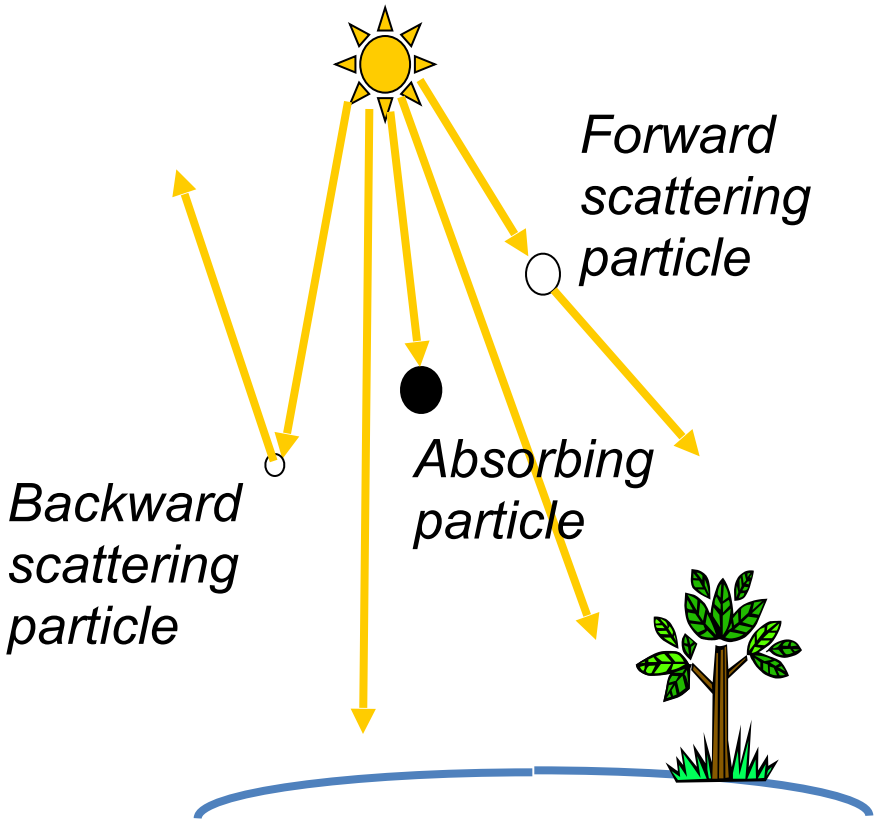
All photos in this presentation by E. Andrews and the NOAA team.

Focus – In-Situ Aerosol optical properties

- *Surface cooling:* sunlight is prevented from reaching the Earth's surface
- *Atmospheric warming:* energy is transferred as heat by absorbing particles.

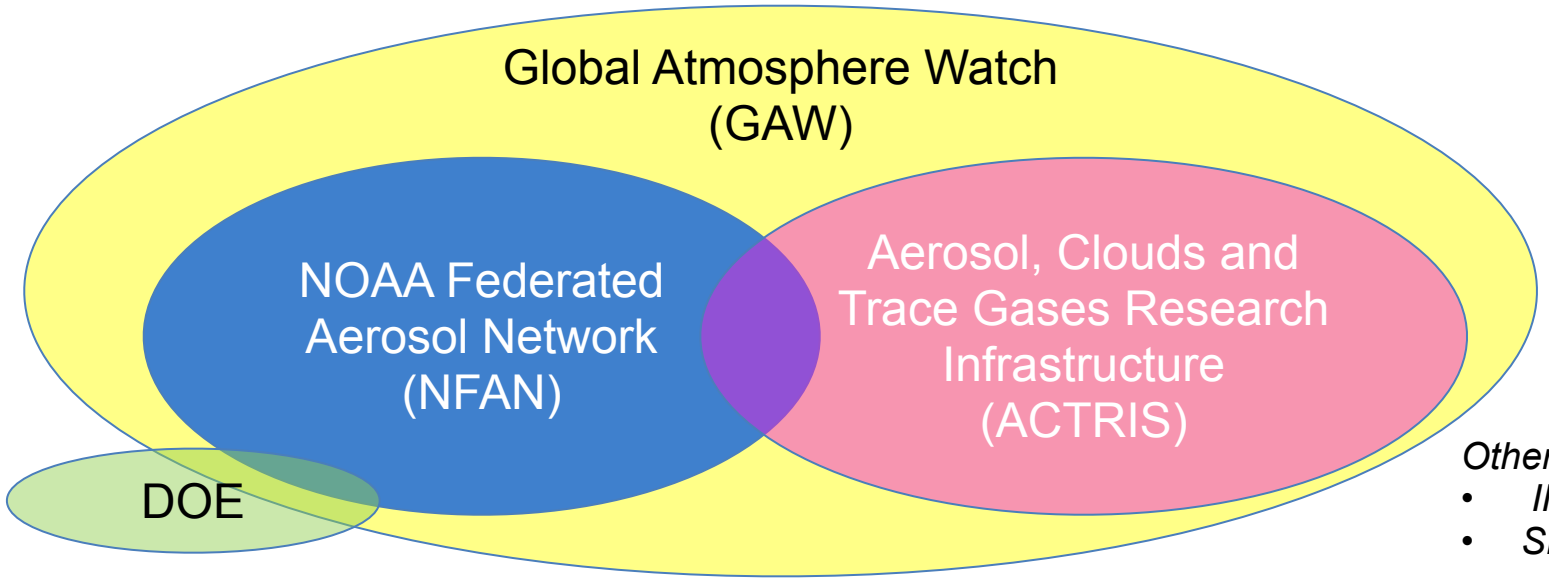


What I'm **NOT** talking about here:

- Aerosol remote sensing
- Aerosol chemistry
- Aerosol physical properties
- Aerosol cloud stuff

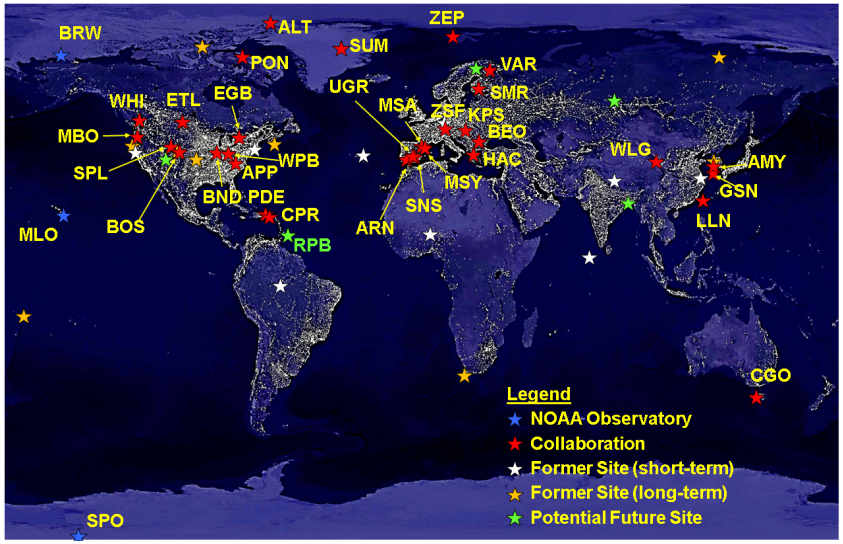
→ Many GAW network sites have more than just aerosol optical measurements!

Intro – In-situ aerosol optical property networks

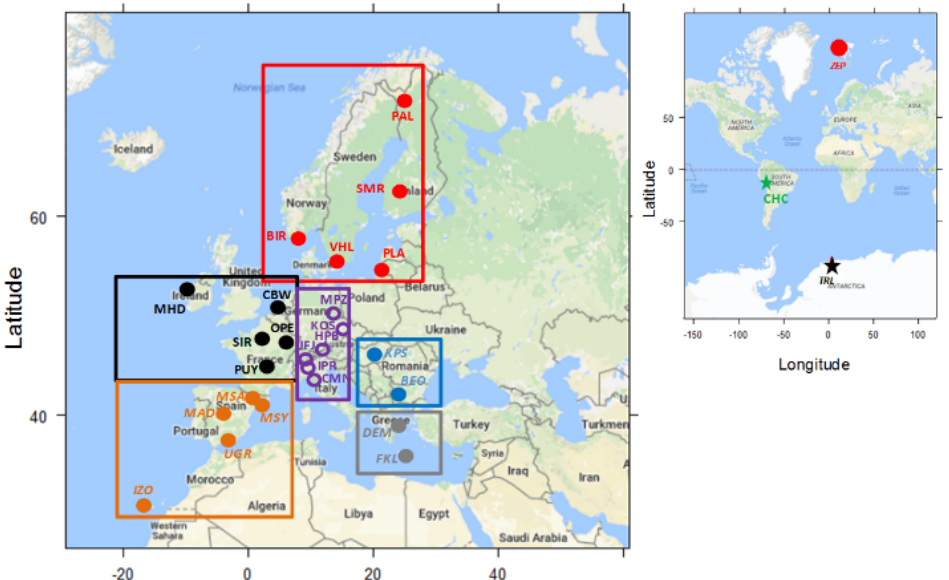


Other networks
- *IMPROVE*
- *SPARTAN*

NFAN



ACTRIS



https://gml.noaa.gov/aero/net/stations.html

Pandolfi et al., ACP, 2018

Intro – In-situ aerosol optical property networks

Objective:

- Characterize the means, variabilities, and trends of aerosol properties
- Identify the factors that control these properties.
- Improve understanding of climate and air quality

Approach:

→Long-term permanent sites

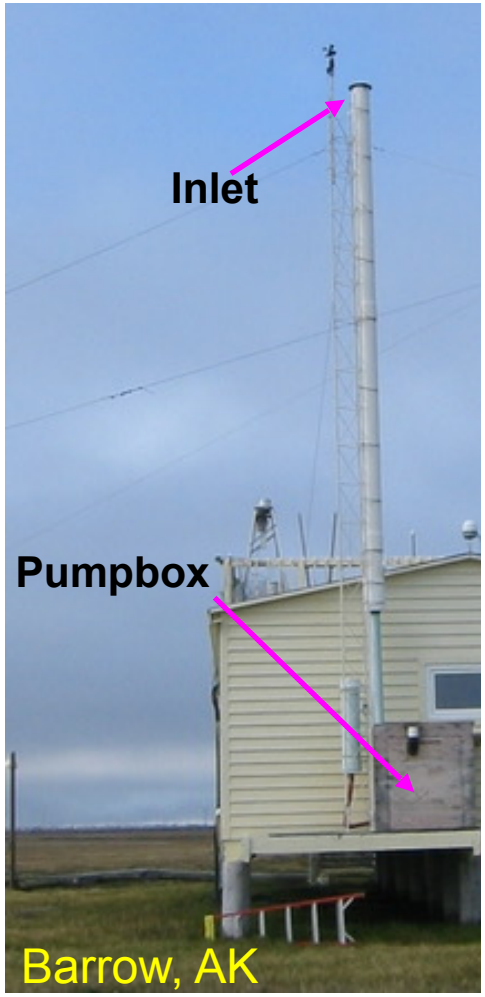
→Standardized suite of measurements and protocols

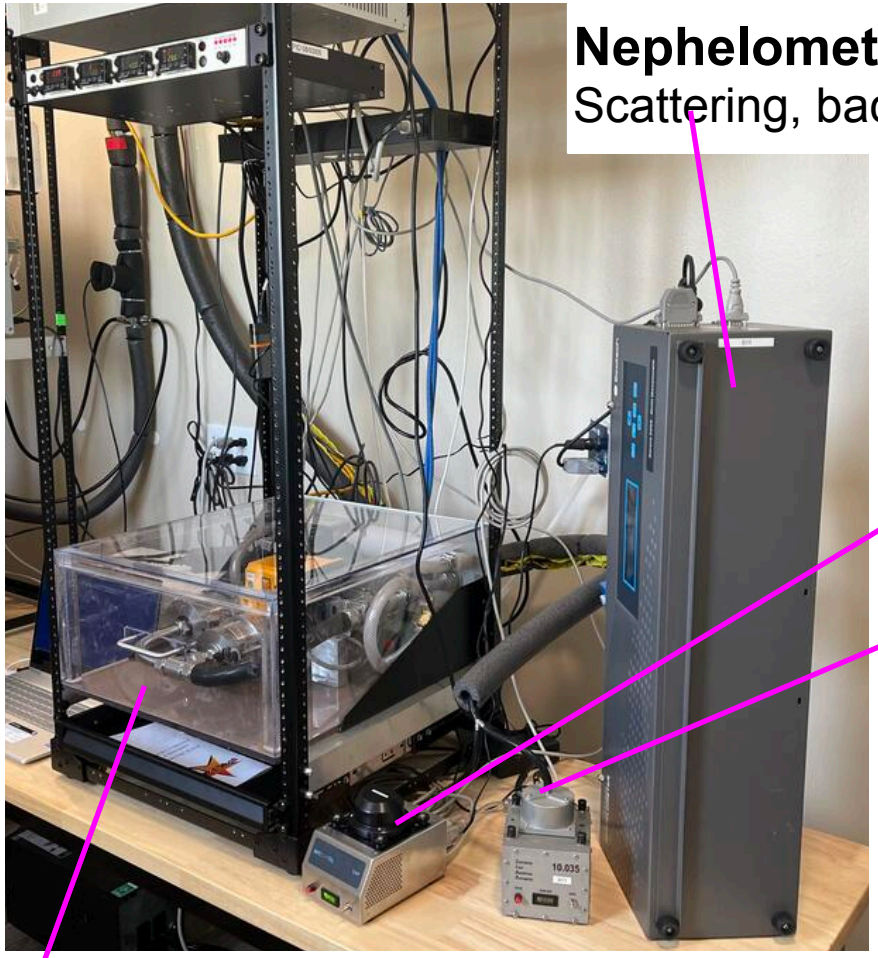
→Globally distributed sites (pristine and polluted)

Applications:

- Context for field campaigns and aerosol ‘events’
- Document long-term changes
- Evaluate/constrain global models
- Process studies
- …

Methods - Surface in-situ aerosol measurements





Nephelometer
Scattering, backscattering

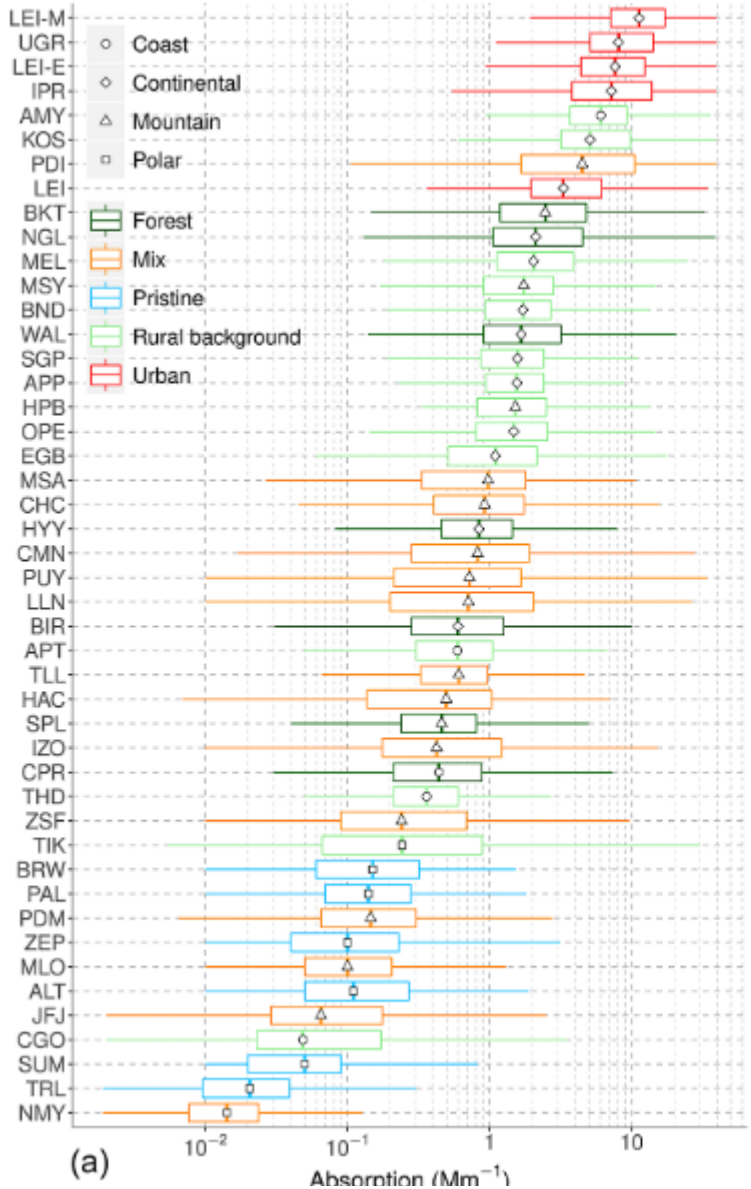
TAP
Absorption

CLAP
Absorption

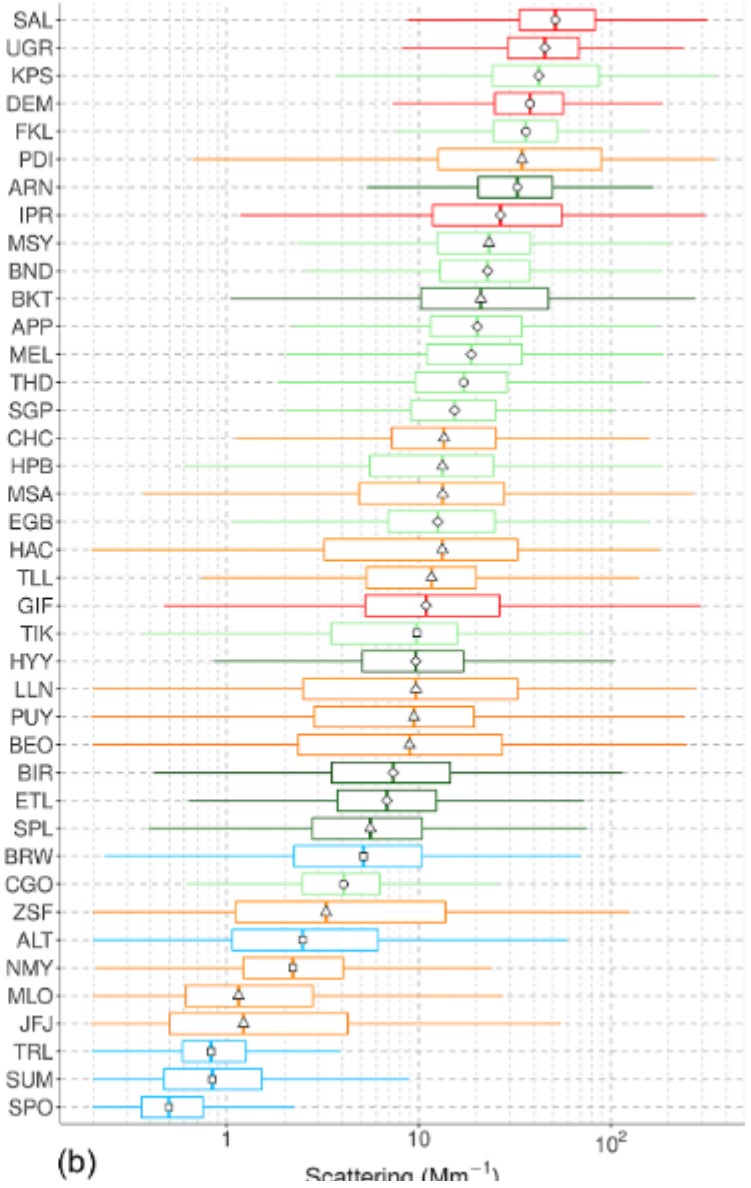
Switched Impactors
Size cut (1 and 10 μm)

Measurements made continuously (1 min frequency) and at low RH (<40%)

Climatology – GAW annual statistics



Absorption (Mm^{-1})



Scattering (Mm^{-1})

Laj et al., AMT 2020

Wide range in aerosol amount across NFAN and ACTRIS sites

Derived aerosol optical properties

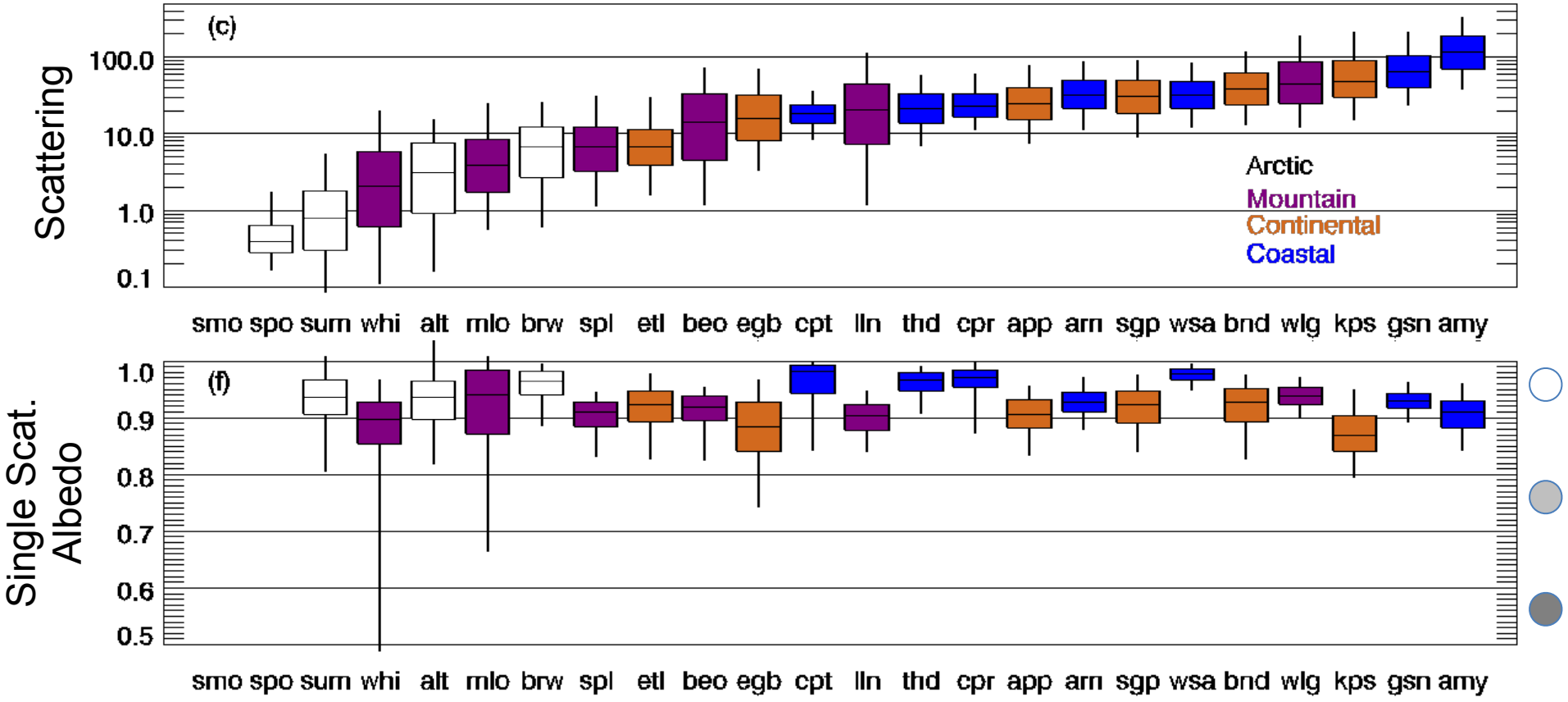
- DON'T depend on amount of particles – dimensionless
- Additional hints about particle 'nature' (chemistry/microphysics)
- Useful for comparing different sites, events
- Used in climate forcing calculations

Size
- Backscatter fraction/asymmetry parameter
- Scattering Ångström exponent

Composition
- Absorption Ångström exponent
- Single scattering albedo

Together the measured and derived parameters enable calculation of aerosol radiative forcing efficiency

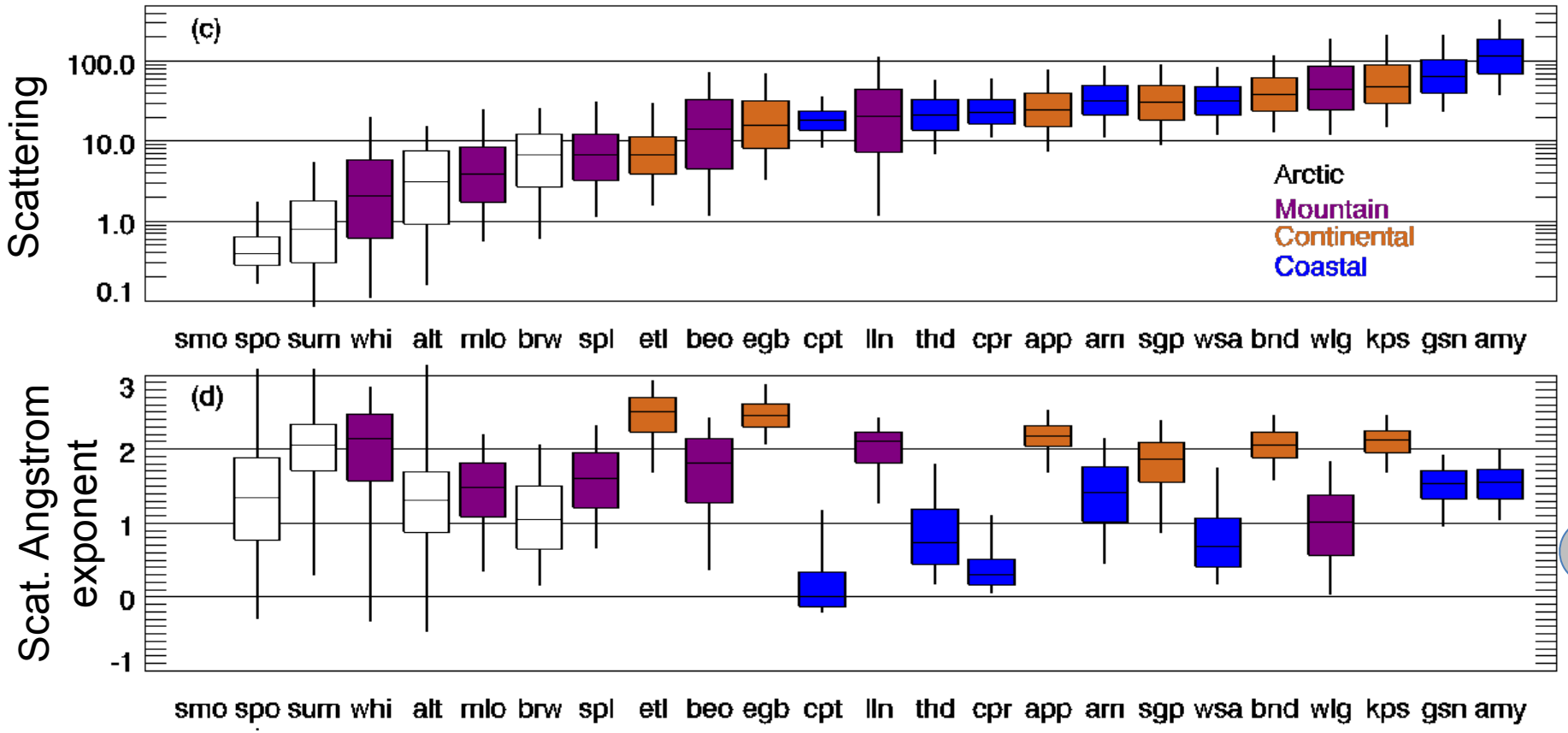
Climatology – NFAN annual statistics



No relationship between amount and “nature” of aerosol.

More info in Andrews et al., BAMS, 2019

Climatology – NFAN annual statistics



- No relationship between amount and “nature” of aerosol

→Important to measure regionally representative air masses.

More info in Andrews et al., BAMS, 2019

Comparing platforms – in-situ and remote

	Surface IS Networks	Aircraft Campaigns	AERONET	Satellite
Length of dataset	Long-term	Short-term	Long-term	Long-term
Temporal resolution	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 load); @ amb RH	Various

→There are advantages and disadvantages for each platform.
→Combined networks can provide holistic view of the atmosphere

Mixing and matching – trials and tribulations

Combined networks can provide a holistic vies of the atmosphere

Things to think about when comparing measurements from different platforms?

- Wavelength
- Size cut
- Sampling conditions
- Temporal/spatial matching
- Uncertainties, sensitivities and measurement/retrieval constraints
- …

Cute fruit graphic with unknown copyright protections.

https://shirt.woot.com/offers/comparing-apples-to-oranges

Wavelength and size cut

Wavelength:

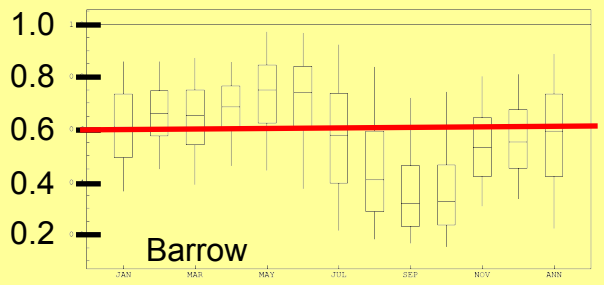
- Most in-situ measurements are spectral (depending on instrument)
- If have spectral info → use Ångström exponent to adjust wavelength
- If not – need to make reasonable assumptions about Ångström exponent

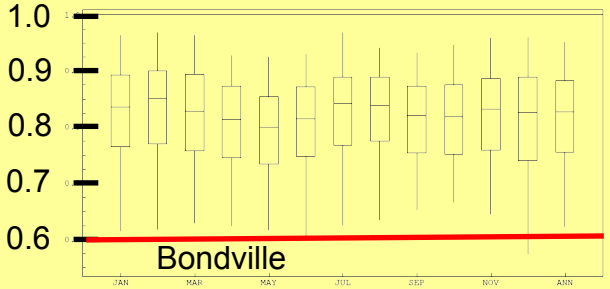
Size cut:

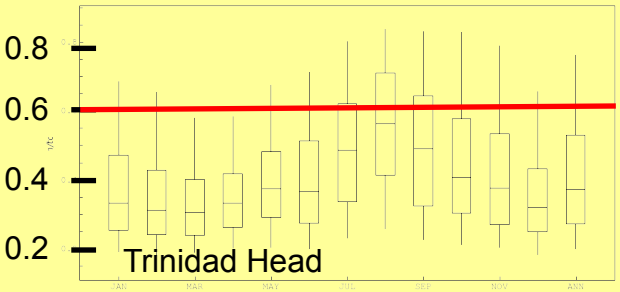
- Many sites measure one size cut (e.g., whole air or 2.5 um)
- Some sites measure two size cuts (e.g., <10 um and <1 um)
- Typical assumption is whole air ~ 10 um and 2.5 um ~ 1 um

→ Lacking spectral and/or size information →reasonable *a priori* assumptions about aerosol type

Seasonal cycle of sub-micron scattering fraction – PM1/PM10



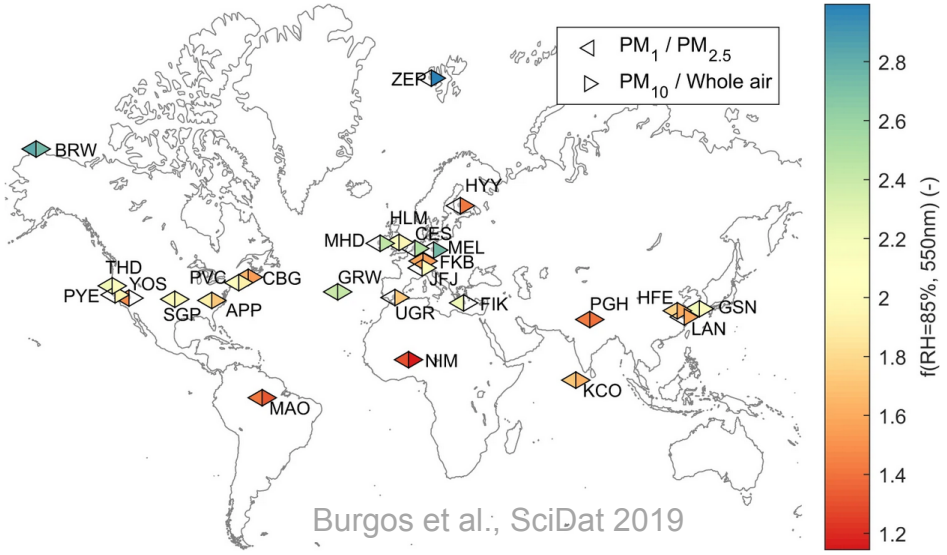


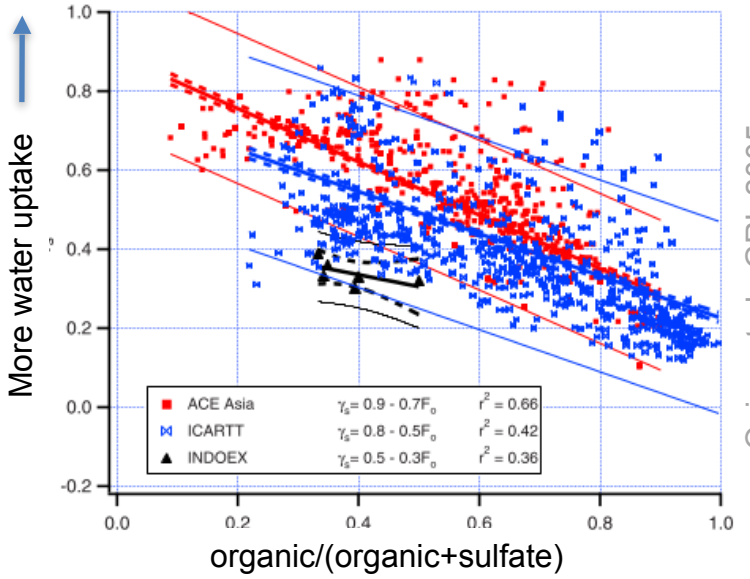


Sampling conditions

GAW protocol for in-situ observations is to measure at low RH (RH<40%).
→easy to compare properties across sites
→the sample T/RH ≠ ambient T/RH inside a building/instrument
→Modelers and experimentalists have different definitions of 'dry'

Use measurements of scattering as f(RH) if exist (e.g., Burgos et al., 2020)
Use parameterization based on chemistry (e.g., Quinn et al., 2005)
Typically assume absorption doesn't change with RH… is that correct?

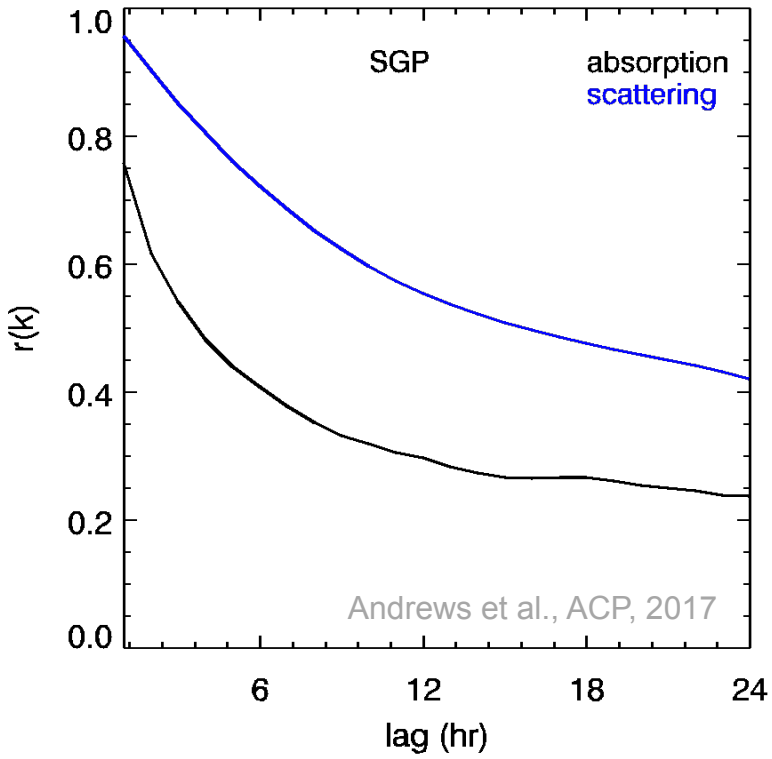




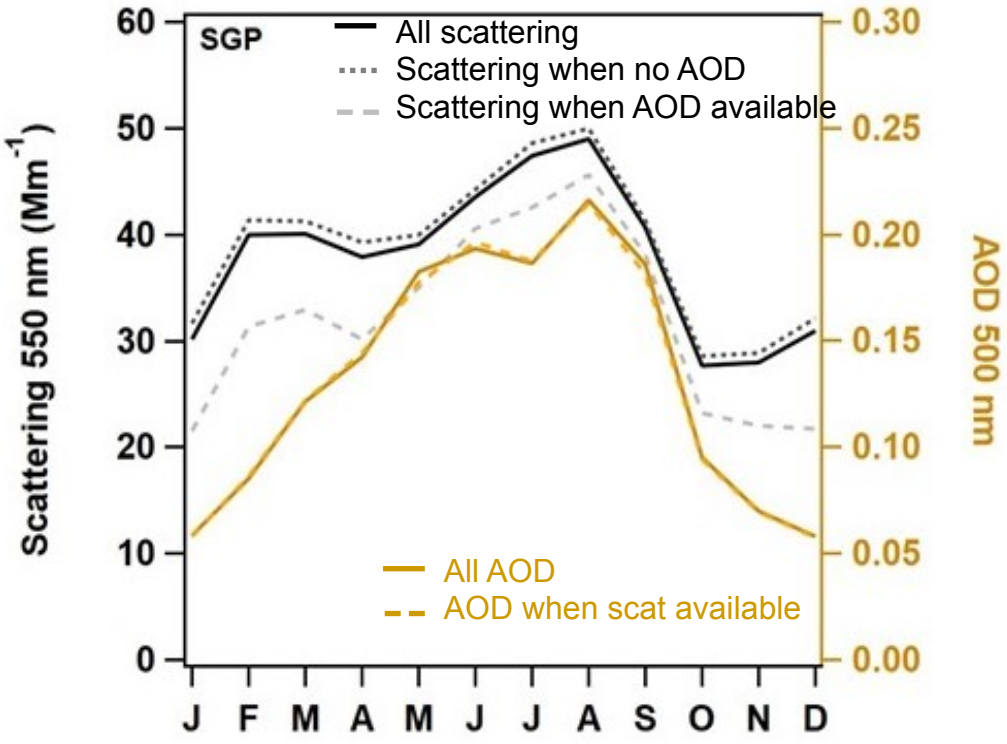
Temporal/spatial matching

--How close in time or space is acceptable/necessary?
--What about climatological comparisons?

Lag correlation plot – persistence



Climatological comparisons - IS and AERONET



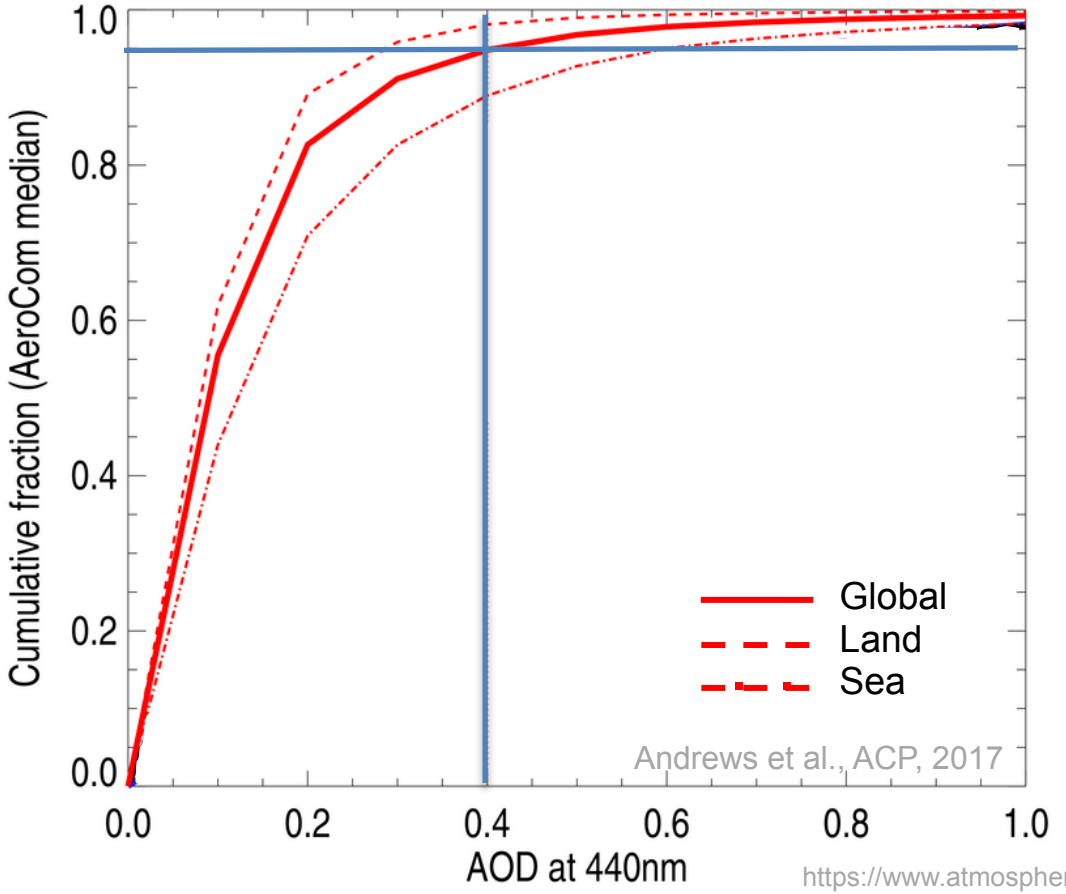
Boedicker et al., in prep

Nick Schutgens has some lovely papers in ACP

Uncertainties, sensitivities and constraints

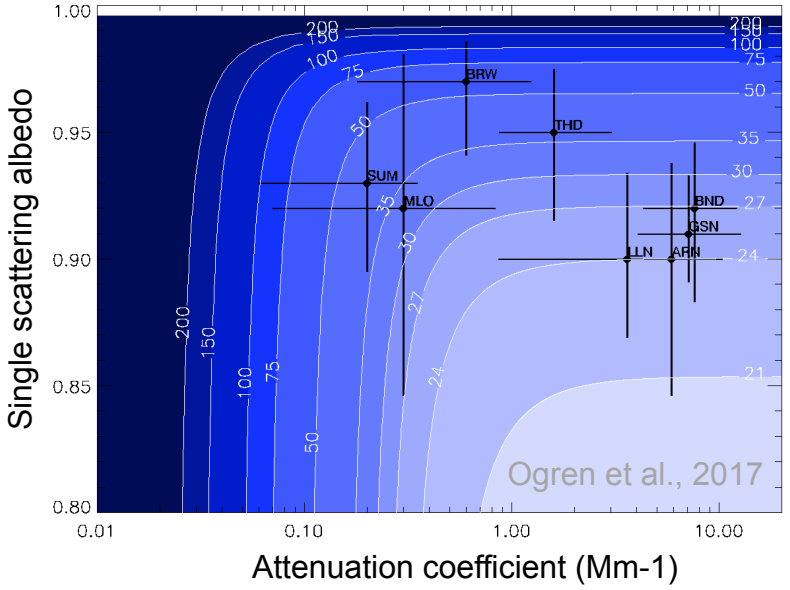
AERONET level 2 retrieval of SSA requires $AOD_{440} > 0.4$

- Models suggest that only ~5% of Earth's surface has $AOD_{440} > 0.4$



In situ instrument uncertainty can depend on particle characteristics.

- Scattering uncertainty increases with size
- Absorption uncertainty from CLAP changes with SSA.



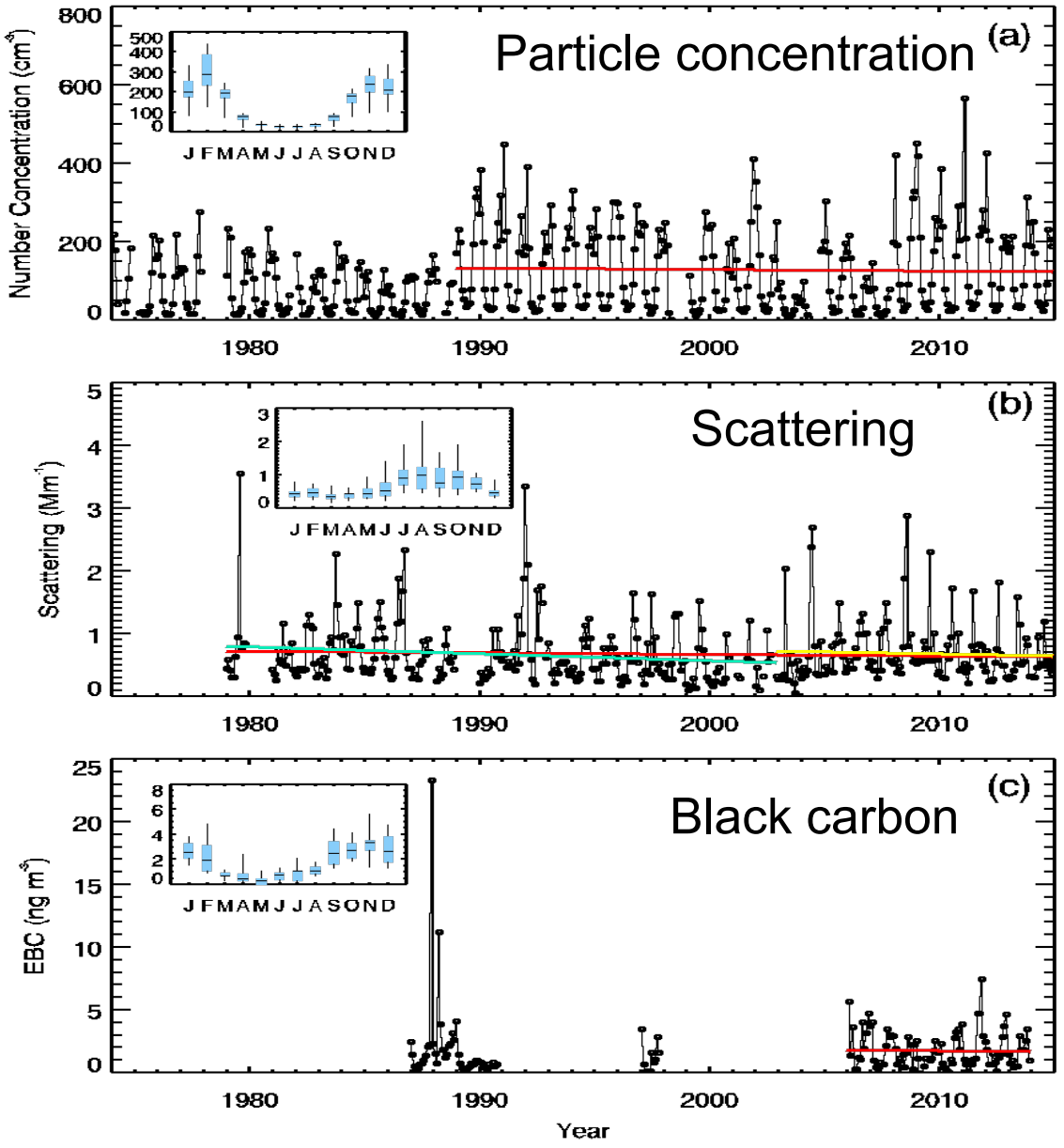
With care, you can turn those apples and oranges into something more delicious!

Cute fruit cake with unknown copyright protections.

https://www.bakingo.com/fruit-cakes

Climatology and Trends – South Pole: 1974 - 2014

- No statistically significant trends
- Annual cycle in the different aerosol properties
- Different parameters have different annual cycles → different sources/types of particles??



Sheridan et al., AAQR, 2015

Climatology and Trends – Arctic Sites

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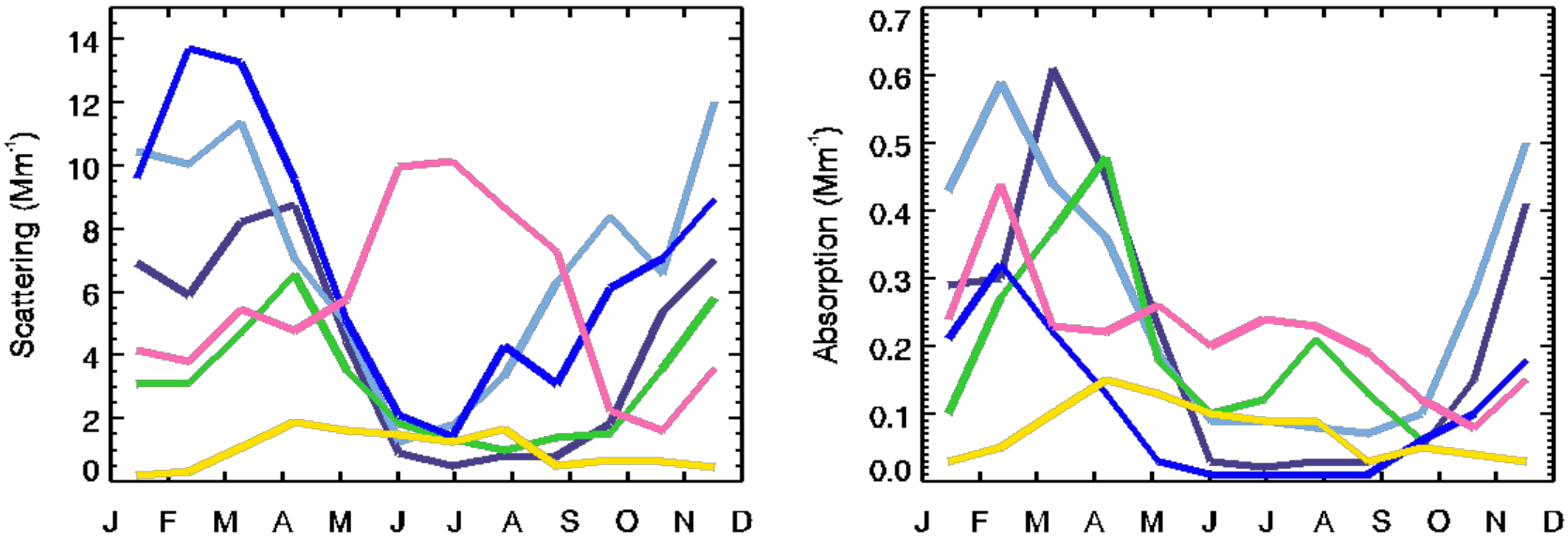


Schmeisser et al., ACP ,2018

→The Arctic cannot be treated as a uniform region, spatially or temporally, in climate models or in remote sensing retrieval algorithms.

→Surface measurements in Arctic critical for evaluating models – 24/7, all year.

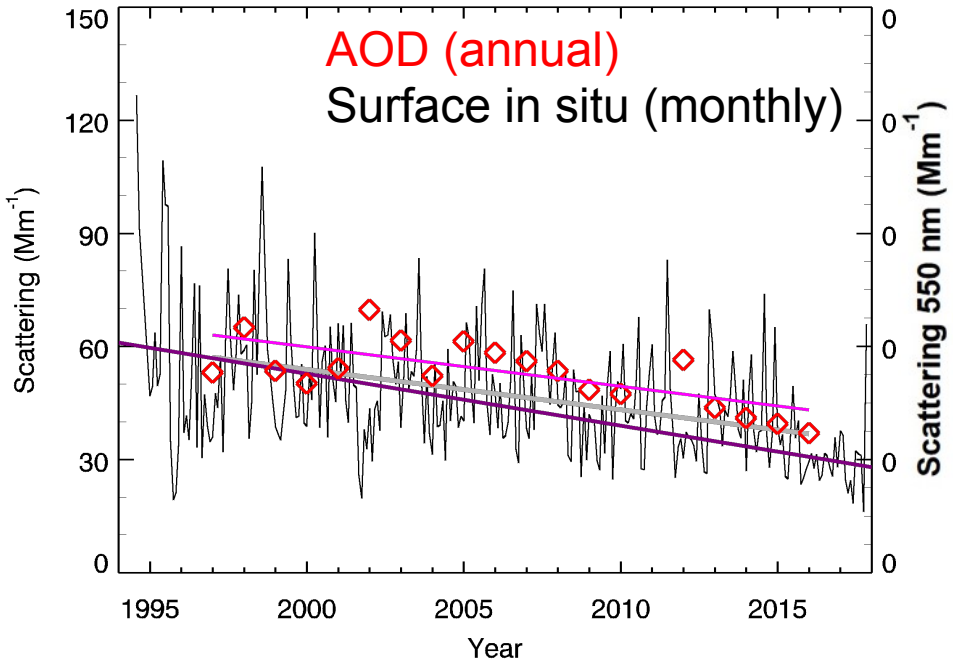
Satellites have issues with high latitudes, clouds,..

Surface remote sensing have issues with no sun, clouds…

Aircraft campaigns in past have primarily occurred in Arctic haze season (spring)

Climatology and trends – Bondville (1994-2017)

In-situ scattering and AOD trends



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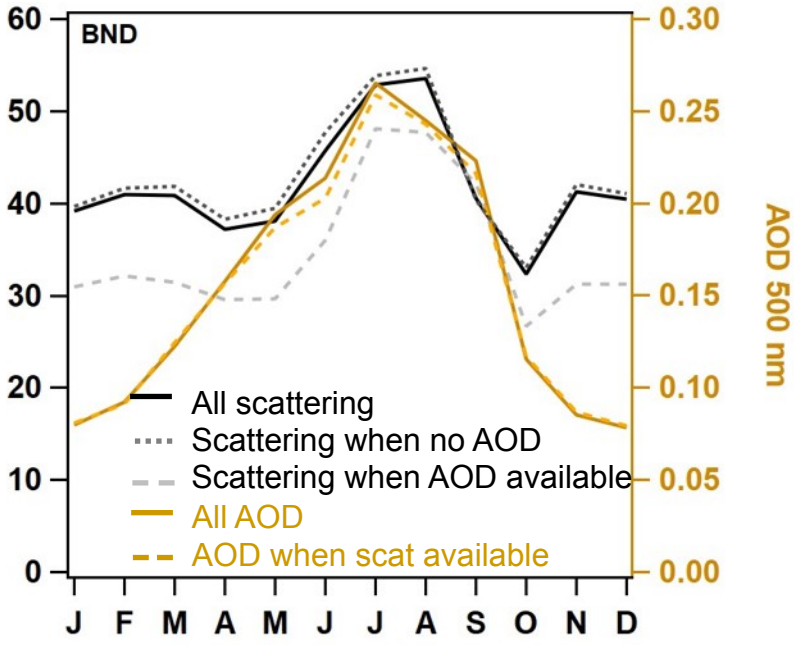


Boedicker et al., in prep

Bondville aerosol loading has been decreasing over the last 2 decades.

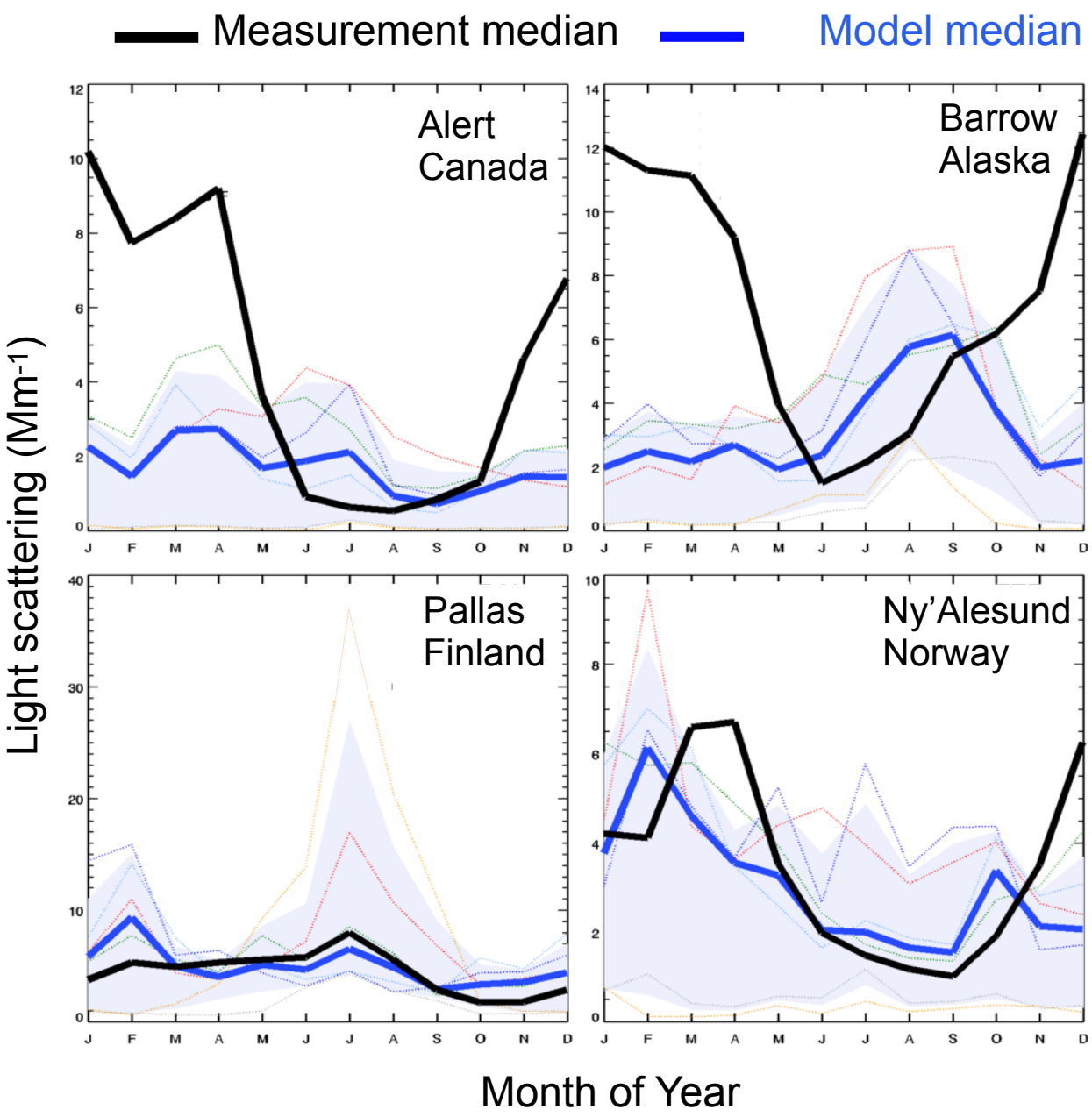
→Consistent with literature (e.g., Collaud Coen et al., 2020; 2020; Hand et al., 2013)

→Decrease occurring across all months

→Observed at surface and in vertical column

Andrews et al., BAMS, 2019

Model Evaluation – Arctic Sites



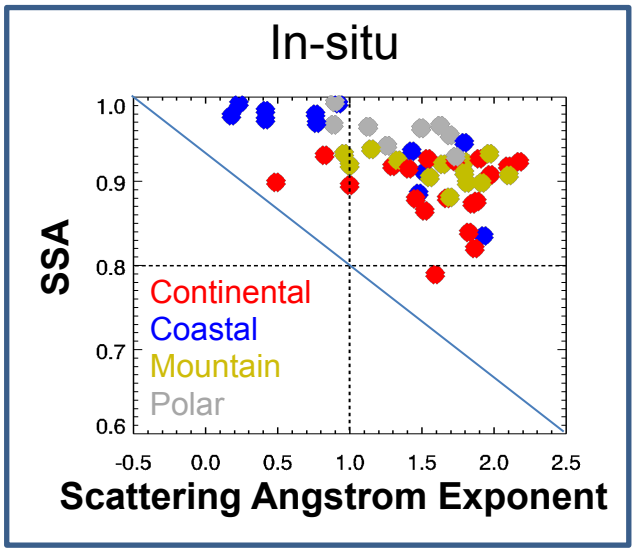
Model/measurement discrepancies can suggest model processes to focus on.

What causes the model peak in summer at Barrow?
→Overestimating forest fire emissions?
→Underestimating removal processes such as wet deposition?

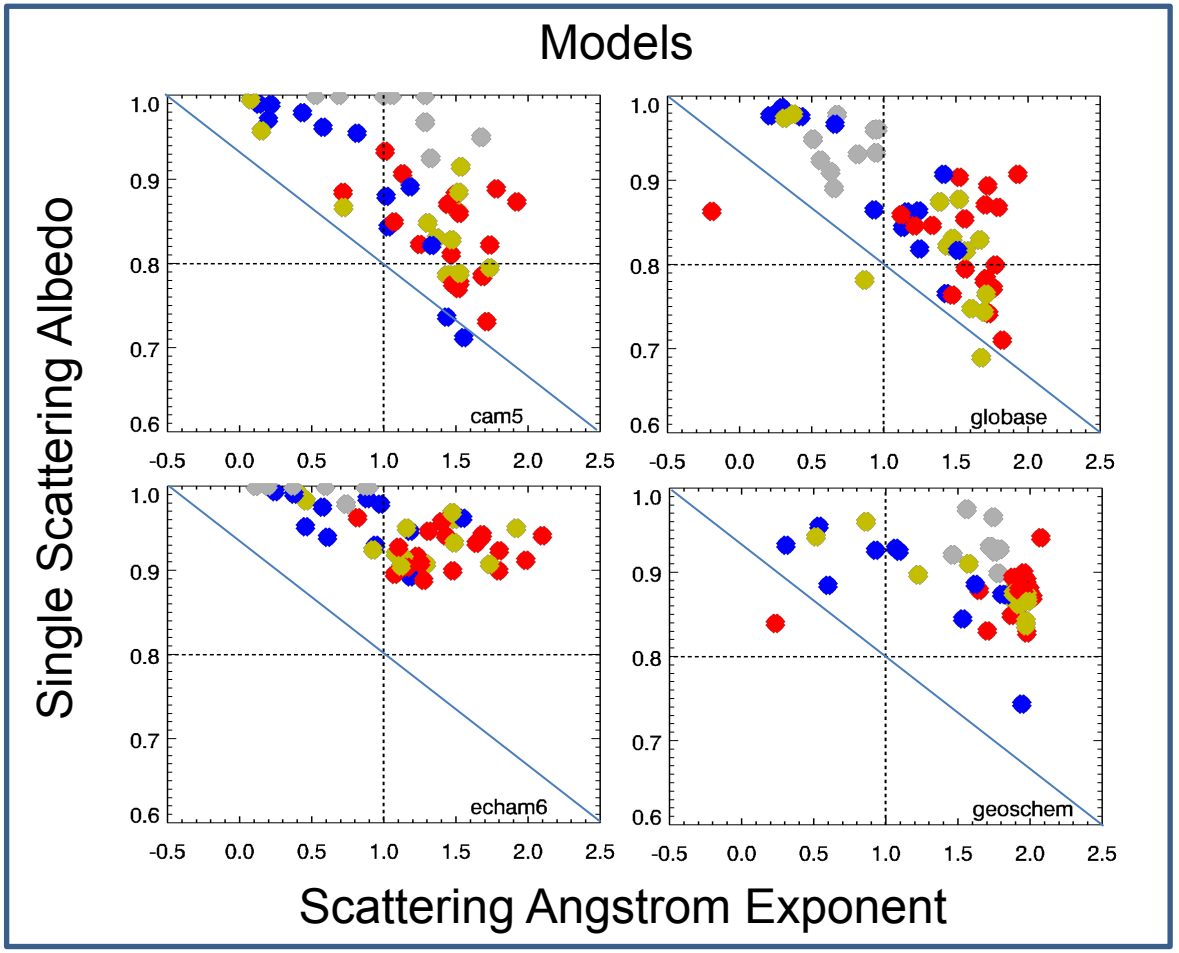
Why is model/meas. agreement better in the European Arctic than the North American Arctic?

Andrews et al., in prep

Model Evaluation – Aerosol property co-variance



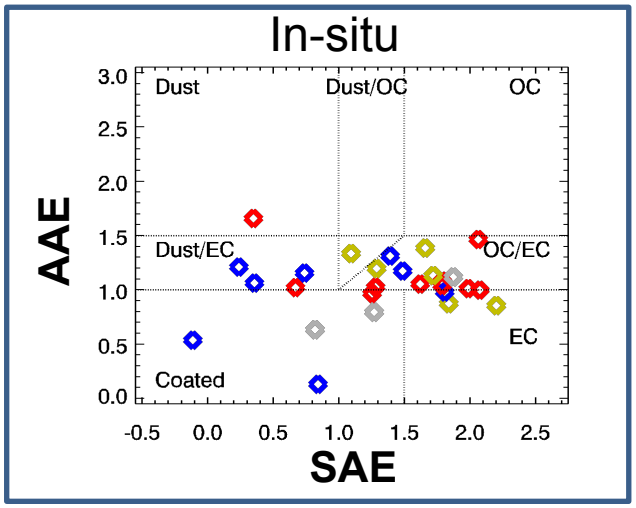
Each point represents annual median for 1 GAW site



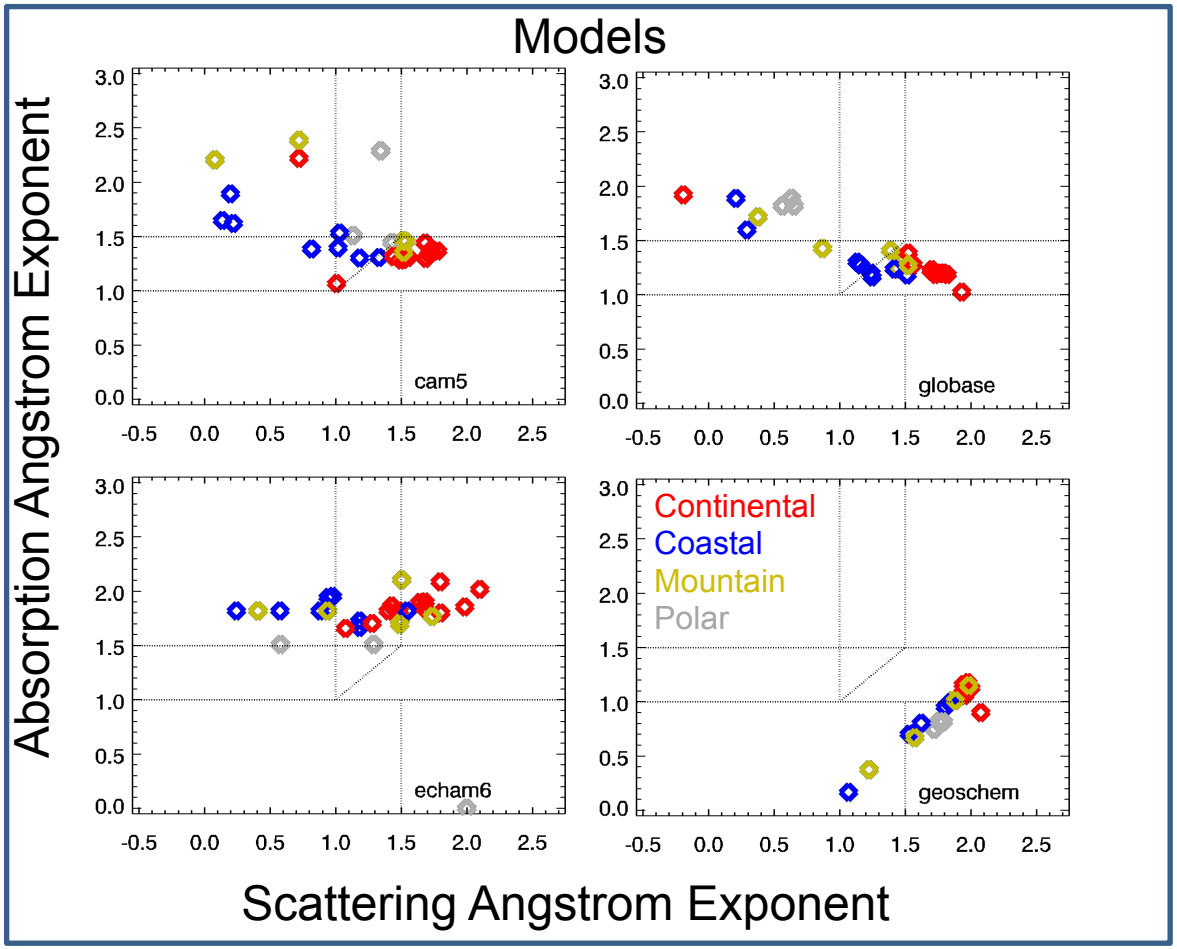
Similar model/measurement relationships between SSA (chem) and SAE (size)
→Pattern of decreasing SSA with increasing SAE

Andrews et al., in prep

Model Evaluation – Aerosol property co-variance



Each point represents annual median for 1 NFAN site



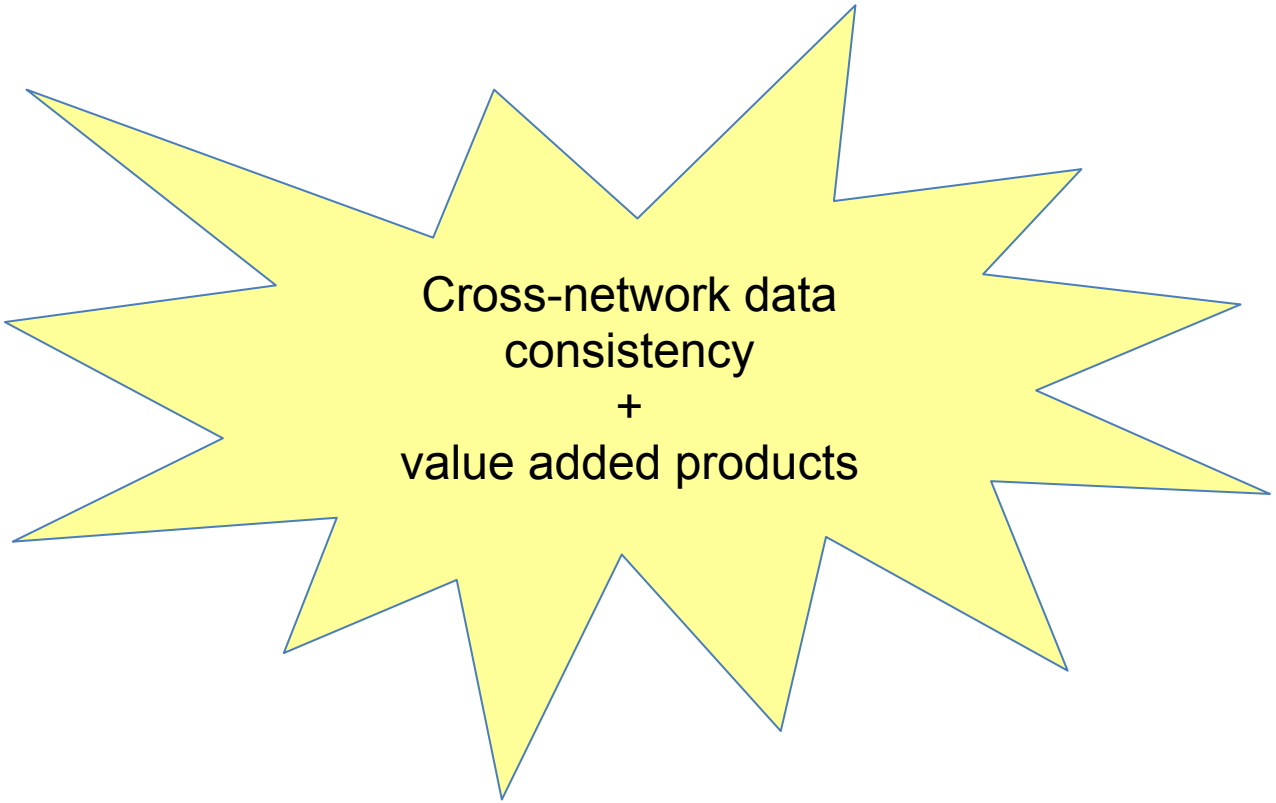
Very different relationships between AAE and SAE
→differences amongst models
→differences between models and in-situ

Andrews et al., in prep

What's next – Improved cross-network consistency

CARGO-ACT*
EU infrastructure development proposal
ACTRIS institutes + NASA, NOAA, and DOE in US

→**Roadmap for sustainable global cooperation between EU and US networks**
→**Provide users with the best possible services for accessing and using data**



***C**ooperation and **A**g**R**eements enhancing **G**lobal inter**O**perability for **A**erosol, **C**loud and **T**race ga**s** research infrastructures

Conclusions

Surface in-situ networks make long term measurements of aerosol optical properties

→24/7 high temporal resolution data

→Some parameters difficult to retrieve with remote sensing

→Measurements are comparable across many of the GAW sites

→Must consider sampling methods/constraints for cross-platform comparison

EU infrastructure proposal:

→More collaboration

→Harmonization of methods and data processing chain

➡ More science

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THANK YOU!