



Air quality – climate connections research overview

Daniel Murphy



Air quality policies affect climate....

Climate change and climate policy affect air quality....

- What do we do and why?

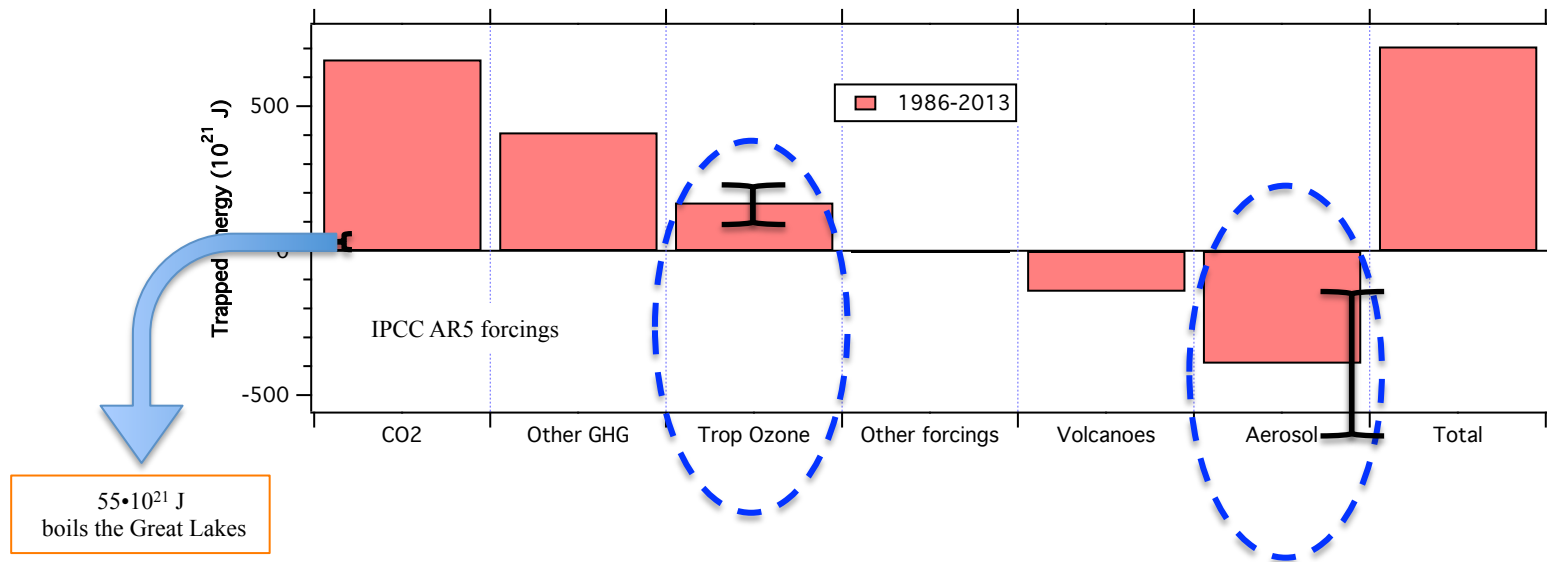
A range of scales from local to global

Examples of the role of process studies:

- › Apportion pollution by cause
- › Meld with large-scale data
- › Inform future research

- How do air quality – climate connections help set research priorities?

Context:



- Aerosols and ozone are being controlled because of their health impacts.
- They are significant parts of the climate system.
- They also have large uncertainties.

(most of my time on aerosol-climate connections)

Updated from Murphy et al., 2009

Ozone → climate: what we do

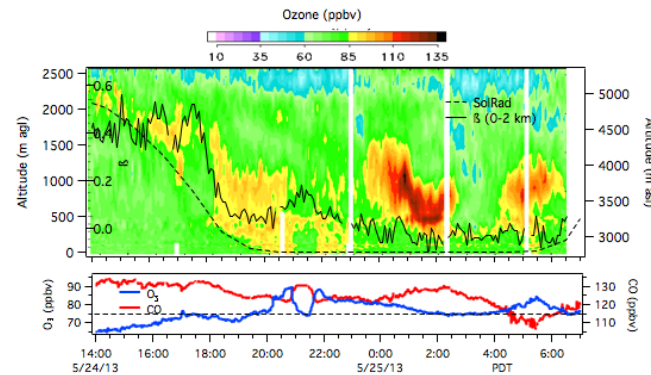
Two complementary goals:

Understand trends in ozone

(for example, Owen Cooper yesterday)

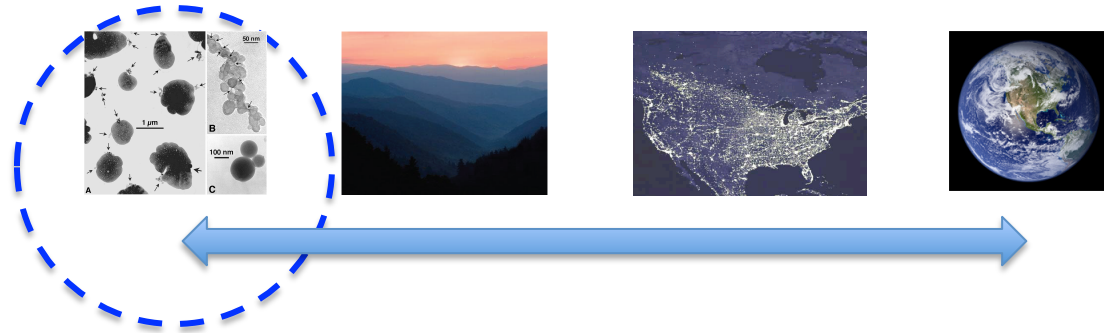
Apportion the ozone by source

- necessary for both air quality control and radiative forcing
- requires detailed process studies (Andy Langford)
- requires emission inventories (Greg Frost)

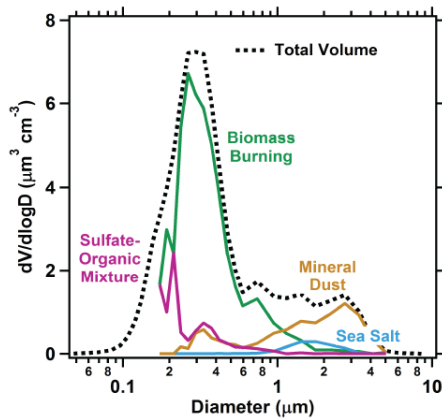


Cooper et al., Increasing springtime ozone mixing ratios in the free troposphere over western North America, Nature, 2010
Langford et al., An overview of the Las Vegas Ozone Study.... Atmos. Environ., 2014

Aerosols → climate



Composition can **apportion** aerosol to pollution or natural sources



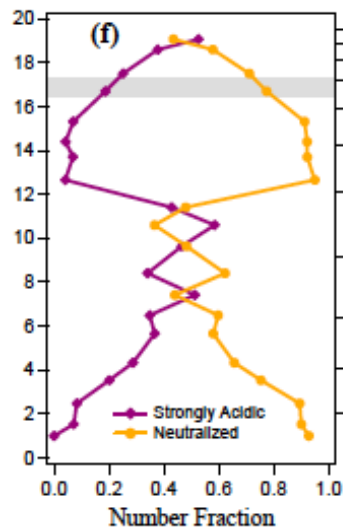
Unique capabilities with PALMS:
(laser ionization single particle mass spectrometer)

← *Arctic haze: Identify biomass burning plume with dust*

Tropics: Distinguish sources of sulfate:

- stratosphere
- oceanic DMS
- troposphere including anthropogenic

(Ann Middlebrook, Effect of composition on aerosol properties)

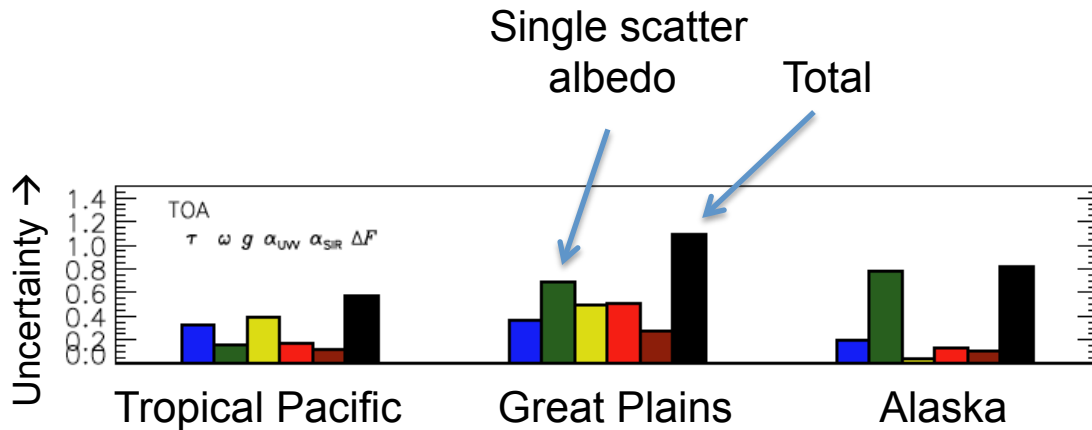


Burton et al. (Froyd), *Aerosol classification using airborne HSRL measurements...*, AMT, 2012
Froyd et al., *Aerosol composition of the upper troposphere*, ACP, 2009
Murphy et al., *Observations of the chemical composition of stratospheric aerosol particles*, QJRMS, 2014

Aerosols → climate



Regional studies identify important variables.



Single scatter albedo aircraft instrument



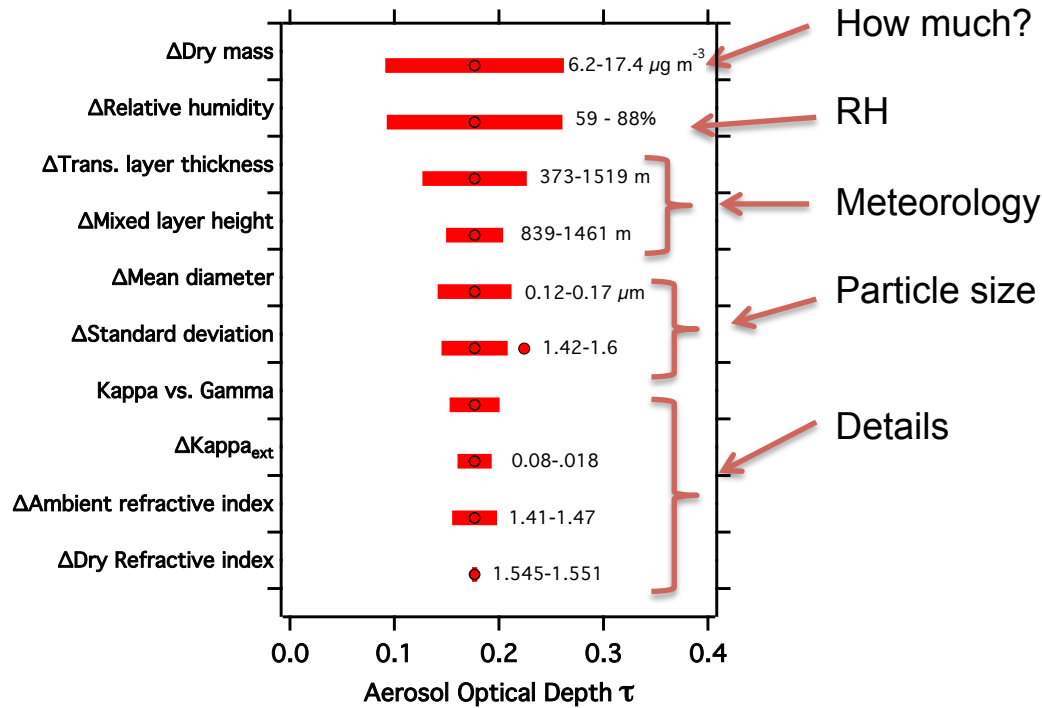
Where is the uncertainty in the direct effect?

McComiskey et al., Direct aerosol forcing: Calculation from observables and sensitivities to inputs, JGR, 2008

Aerosols → climate



Regional studies identify important variables.



- **Simple things matter.**
(But that does not mean they are easy)
- **A big role for relative humidity.**

“Sulfate residing near the surface gives the strongest [radiative forcing] due to the effects of relative humidity” (GFDL, 1998)

⇒ Effects of RH is a research priority.

⇒ A lot of instruments went into this graph.
Other locations around the world?

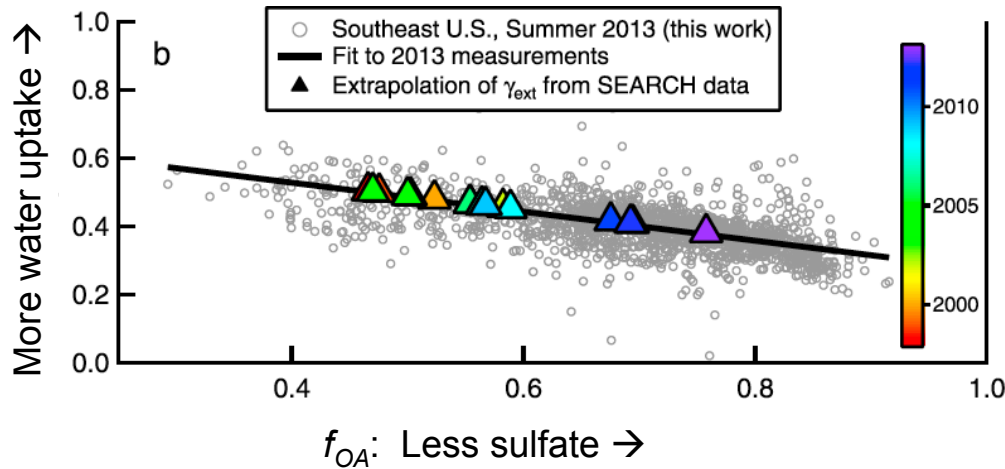
Day-to-day variability in the Southeast US

Brock, in preparation

Aerosols → climate



Regional studies connect to long-term changes.



- Less sulfate => less water uptake (*our data, dots*)
- Sulfate has been declining (*network data, triangles*)

That big RH effect has been changing.

- *Water uptake has multiplied the impact of sulfate controls on climate by about 1.2.*
- *Process studies add value to network data.*

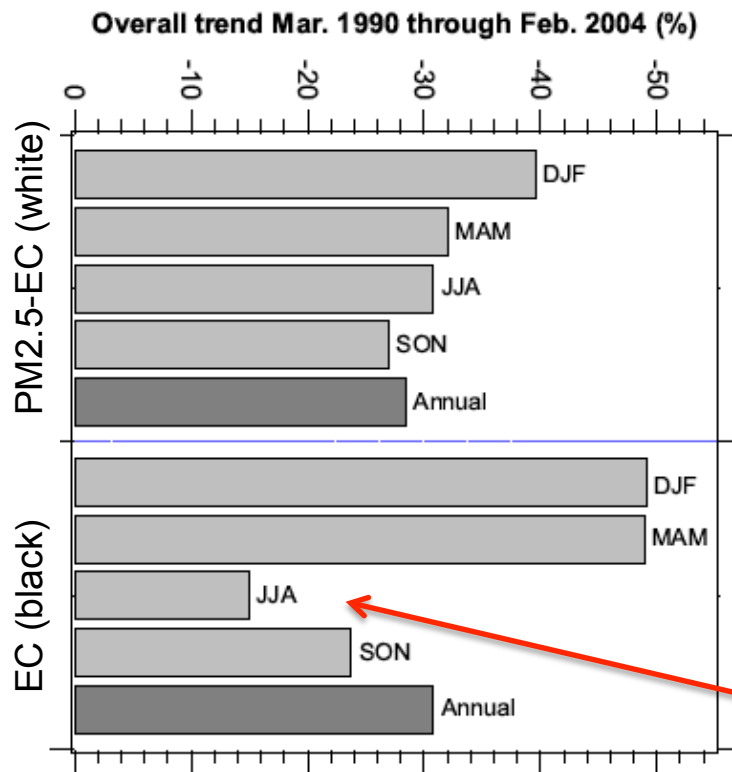
Trends in the Southeast US

Attwood et al., Trends in sulfate and organic aerosol mass in the Southeast U.S.: Impact on aerosol optical depth and radiative forcing, GRL, 2014

Aerosols → climate



Long-term changes in the United States

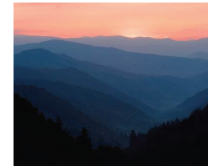
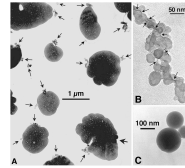


- 20 to 40% decreases in US particulate pollution between 1990 and 2004 (IMPROVE data)
- *First use of this multi-agency haze database for a climate forcing calculation.*
- **BOTH** white and black particles decreased
- Net climate result was toward warming
- Lessons for black carbon as a short-term response

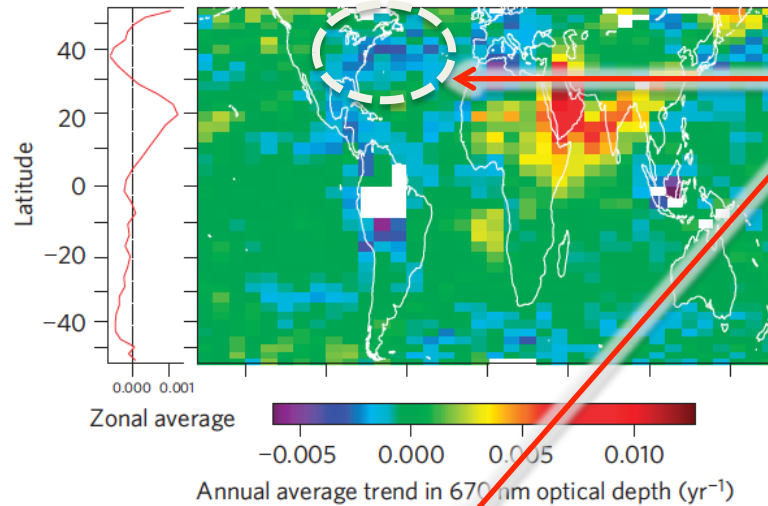
A sign of things to come? Wildfires in western US.

Murphy et al., Decreases in elemental carbon and fine particle mass in the United States, ACP, 2011

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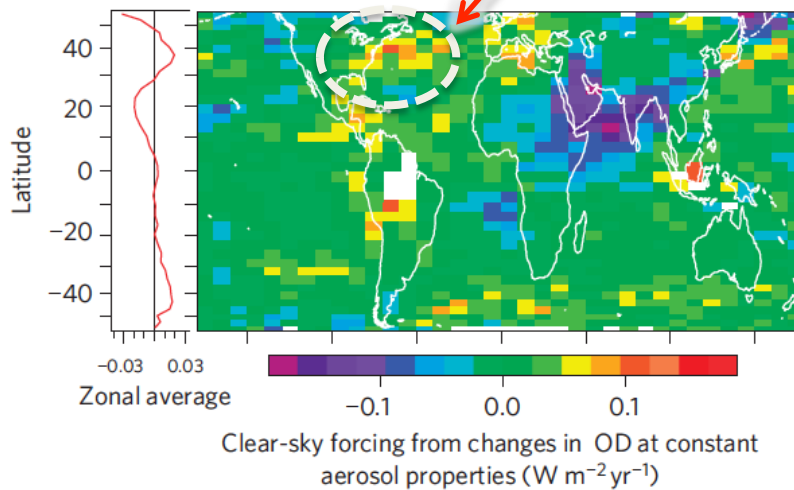
Global trends



Pollution control in the US: climate impact is measurable from space.

- Optical depth increases and decreases around the world
- The first straightforward calculation of the direct climate impact of these trends
- Regional changes largely cancel.

(Satellite stability is not sufficient for global average forcing calculation.)



Murphy, Little net clear-sky radiative forcing from recent regional redistribution of aerosols, Nature Geoscience, 2013

Some implications for our research

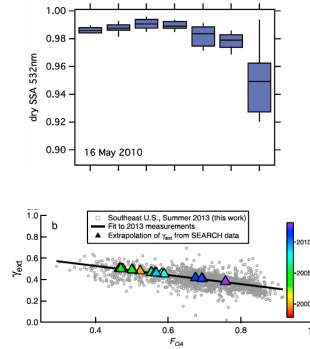
1) Aerosol optical properties and how they relate to remote sensing



Single scatter albedo at 3 wavelengths, humidity dependence



Extinction at ambient conditions

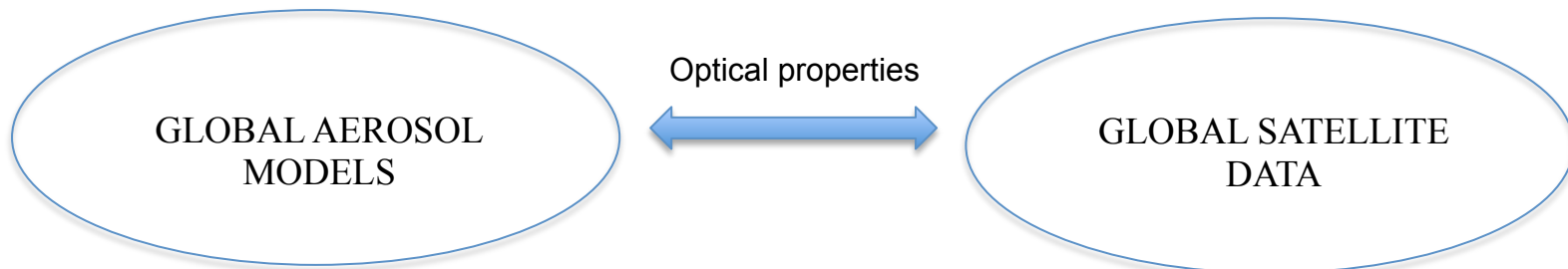


Climate-focused analysis



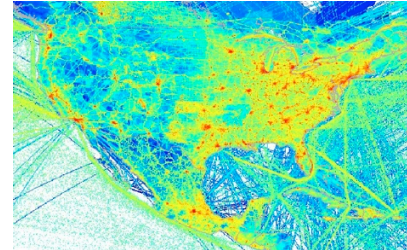
New collaborations relating to satellite observations

- ***Optical properties connect with climate forcing.***
- ***Optical properties connect models to satellite observations.***



Some implications for our research

2) Connect emissions science from local to global scales. (Greg Frost, Eric Williams)



- *Emissions are a crucial input to climate models.*
- ***Emissions are the main tool policy makers have.***

3) Pursue process-level understanding of key uncertainties

- *How pollution affects cloud systems (yesterday afternoon)*
- *Air quality budgets and apportionment*
(Andy Langford, Jeff Peischl, Bob Banta)
- *Clouds in the Southern Hemisphere (SOCRATES)*



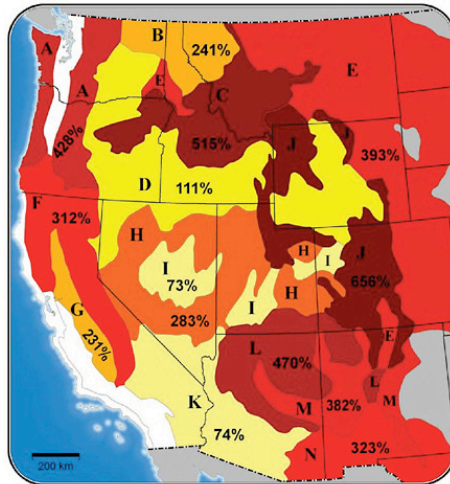
Some implications for our research

4) How will climate change affect air pollution?

We cannot anticipate all effects ...



but some are likely:



*Climate Stabilization Targets,
National Academies Press, 2011*

- ***Huge projected increases in fires in the western US***
- ***Continue to develop instrumentation to measure coated soot, brown carbon, and other climate characteristics of smoke***





Air quality – climate connections research overview

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- NOAA's objectives for "science informing decisions" means we must study the climate implications of air quality policies.
- Ozone and aerosols are two major areas with air quality – climate connections.
- Process studies and chemical information provide
 - apportionment between sources
 - research priorities
- We make connections from the process studies to large-scale issues