



Organic Aerosol:

Making complicated particles seem simple

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**Colorado
State
University**

Photo courtesy: Cam McNaughton (taken from NASA's DC-8)

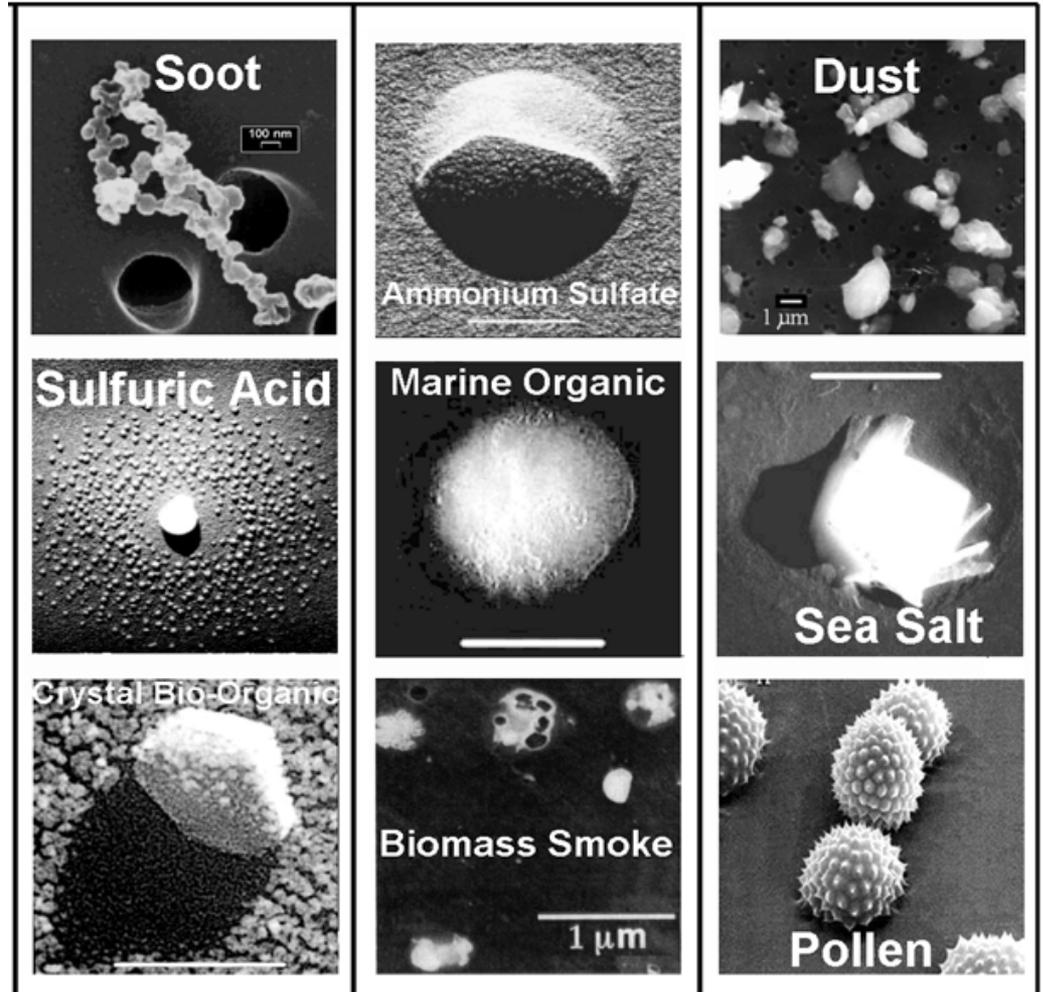
*20th Anniversary Celebration: NOAA Climate and Global Change Postdoctoral Program
April 14, 2011*

WHAT IS AN AEROSOL?

(my first communication challenge!)



Not just paint,
deodorant or
hairspray!



AEROSOL: CONNECTION TO BIG RESEARCH TOPICS IN ENVIRONMENTAL SCIENCE...A MOTIVATION TO GET IT RIGHT!

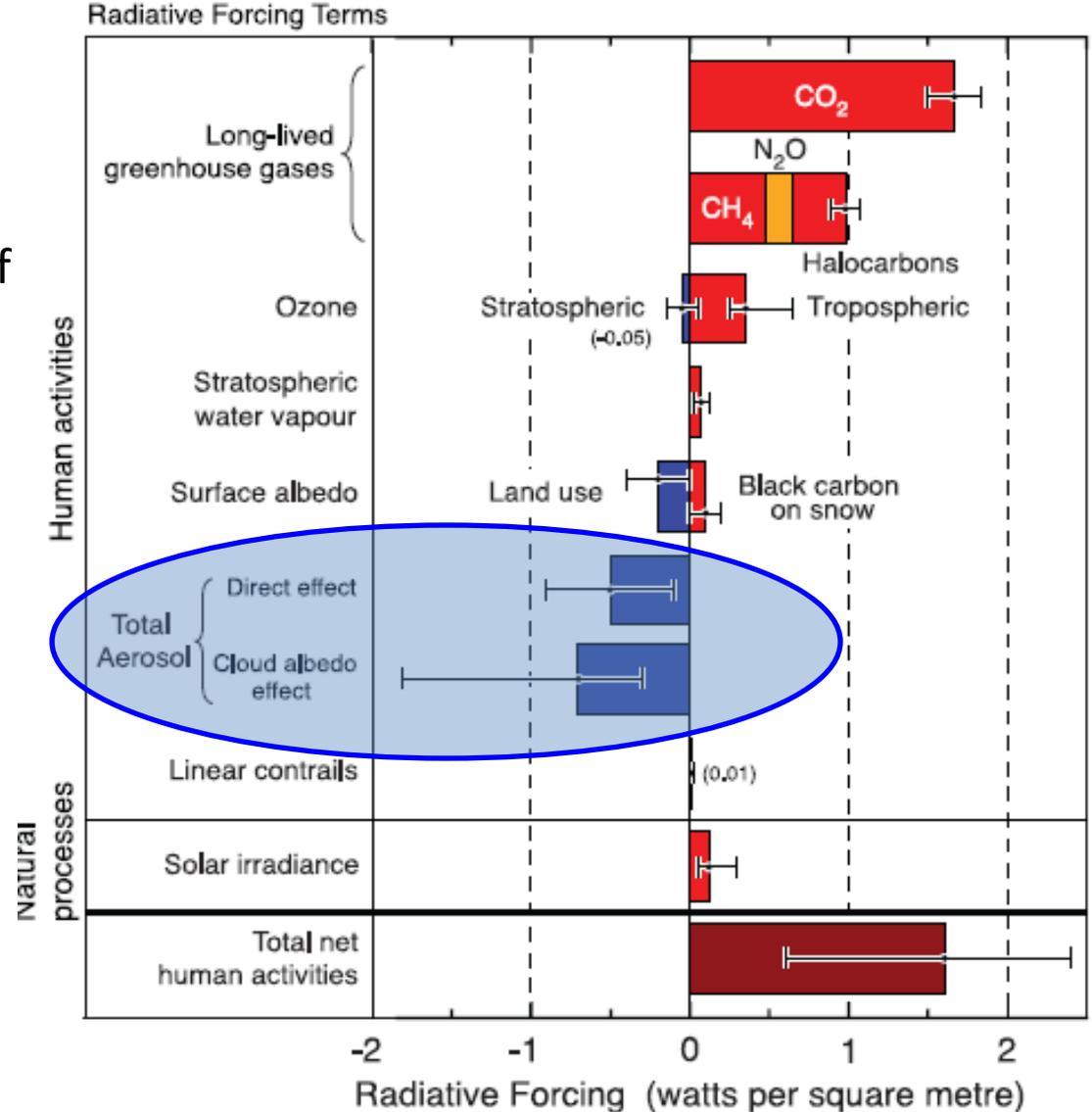


AEROSOLS AND CLIMATE

Radiative forcing of climate between 1750 and 2005

Three main **SCIENTIFIC** questions relevant to climate change:

1. How is the radiative balance of the Earth changing?
2. How much of this change is human-caused?
3. What is the impact of this change?

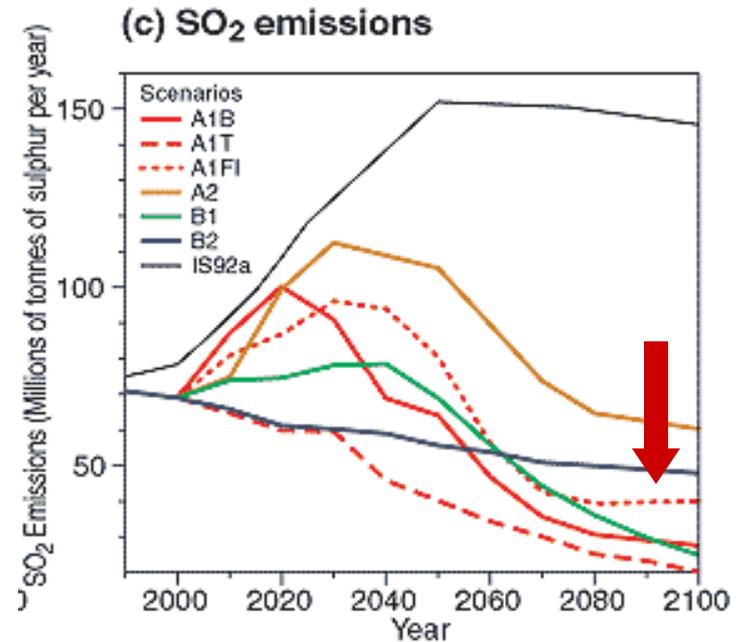


[IPCC 2007]

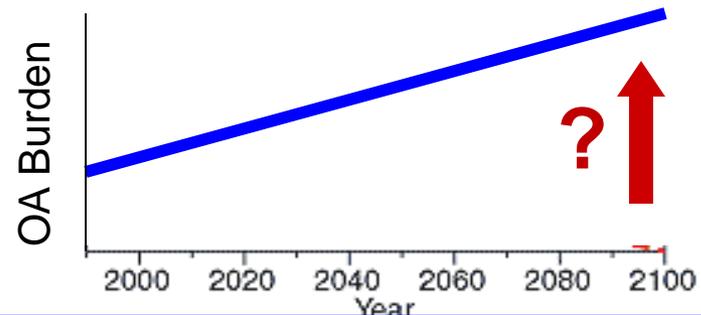
Aerosols are the most uncertain component of Question #1 (and possibly #2)

ATMOSPHERIC AEROSOLS IN THE FUTURE?

SULFATE

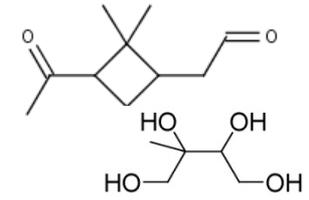
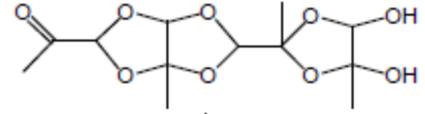
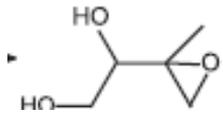


ORGANIC AEROSOL

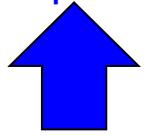


The “climate penalty” of air quality clean-up:
Andreae et al. [2005] suggest ↓ sulfate will accelerate greenhouse gas warming.
Could organics compensate?

BUT ORGANIC AEROSOL ARE POORLY UNDERSTOOD



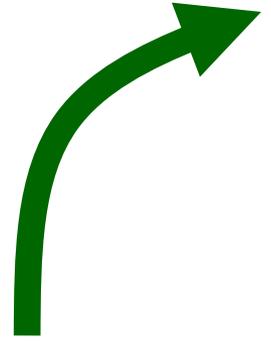
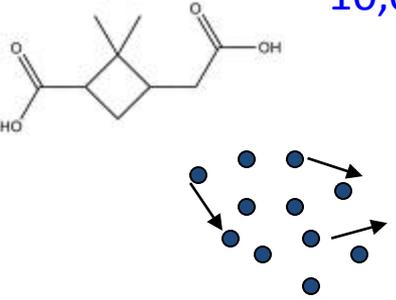
10,000's of (unidentified?) compounds with variable properties



Continuing Oxidation/Partitioning in the Atmosphere



Uncertain Formation (Missing sources? Poorly understood processes?)



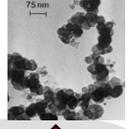
PBAP



Terpenes
(gas-phase)

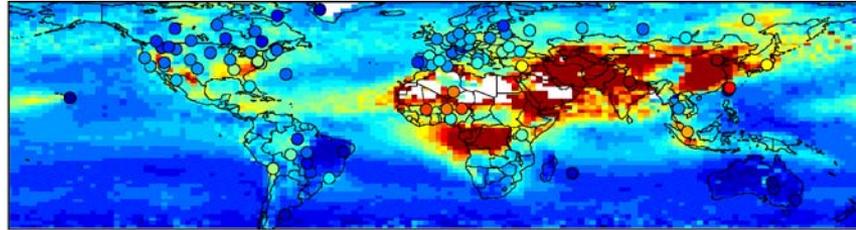


Hydrocarbons
(gas-phase & particulate)

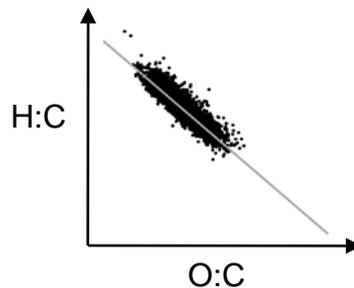


TWO QUESTIONS

(1) How much organic aerosol is in the atmosphere??

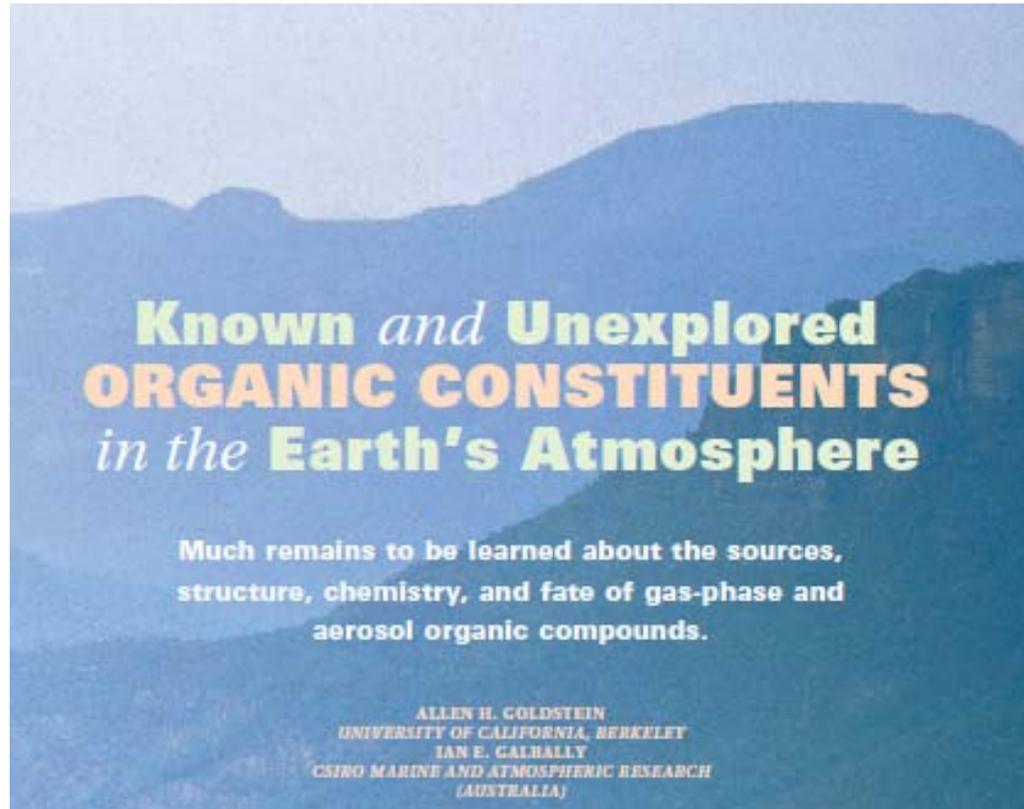


(2) How do/can we describe a system that consists of 10,000's of molecules in a simple way for models?



A LARGE MISSING SOURCE OF ORGANIC AEROSOL?

Goldstein and Galbally [2007] suggest that OA source may be anywhere from 140-910 TgC/yr.



For comparison, current global model estimates total ~50 TgC/yr

Can satellite measurements shed any light on the total budget of OA?

CAN SATELLITE OBSERVATIONS SHED ANY LIGHT ON THE BUDGET OF OA?

ADVANTAGE: Global view of total atmospheric column

CHALLENGE: Aerosol Optical Depth (AOD) is an integrated measure of ALL aerosols – uncertainty on any single derived particle type will be high.

**SATELLITE
AOD**

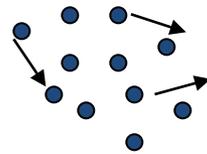


Assumptions:
Optical Properties
Size Distributions
Aerosol Distributions

AEROSOL SPECIATED MASS CONCENTRATIONS

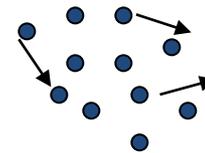
Organic
aerosol

Soot



Sulfate

Nitrate



Dust

Sea Salt

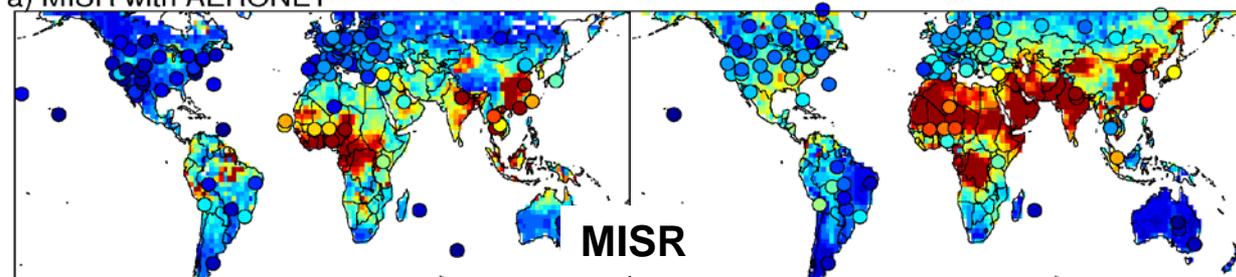
SURFACE REFLECTANCE

ATTRIBUTE ENTIRE MODEL UNDERESTIMATE OF AOD TO ORGANICS

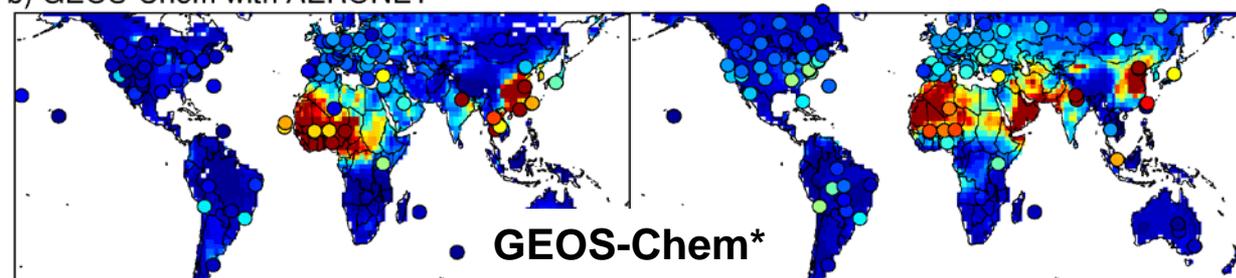
WINTER

SUMMER

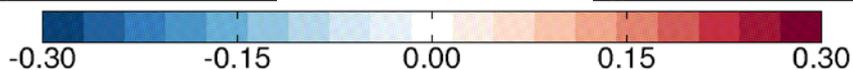
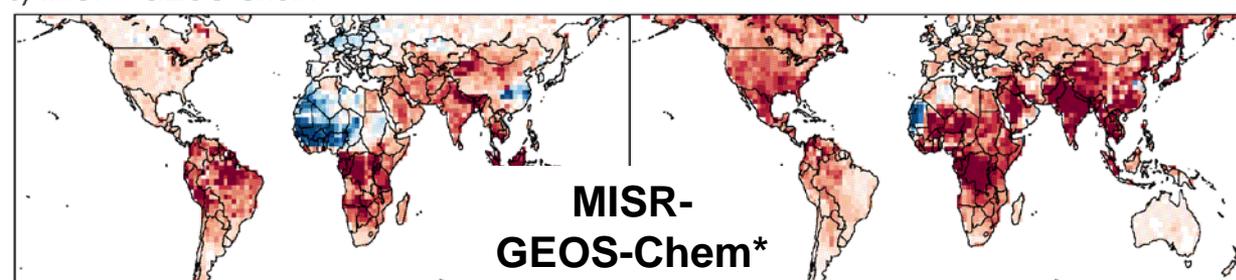
a) MISR with AERONET



b) GEOS-Chem with AERONET



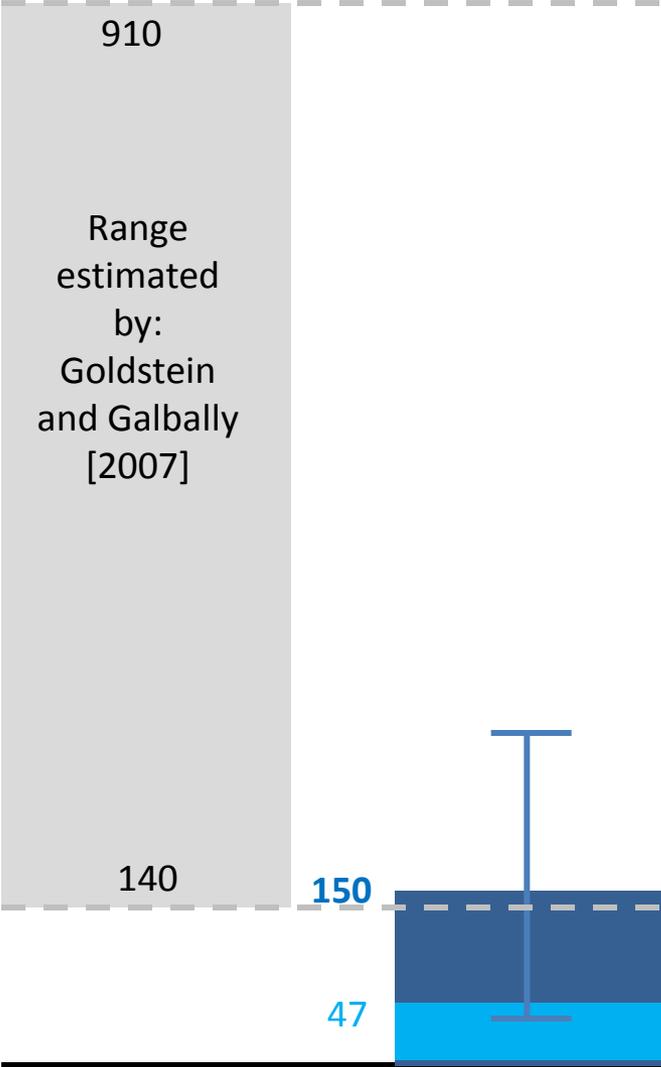
c) MISR - GEOS-Chem



Estimate that ~ 150 TgC/yr source is required to close the MISR-GEOS-Chem* discrepancy.

*excluding OA

HAVE WE REDUCED THE UNCERTAINTY ON THE OA BUDGET?



YES!

150 TgC/yr is more than **THREE TIMES** what is currently included in global models....

BUT at the low end of Goldstein & Gallbally [2007] range.

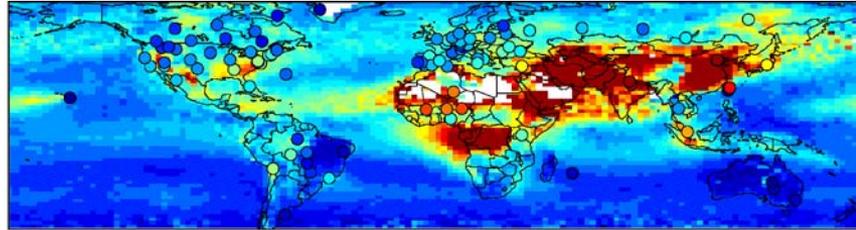
Our satellite top-down estimate

Existing GEOS-Chem sources

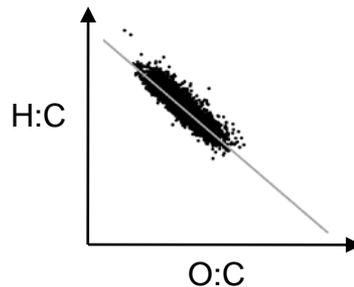
All units in TgCyr⁻¹

TWO QUESTIONS

(1) How much organic aerosol is in the atmosphere??

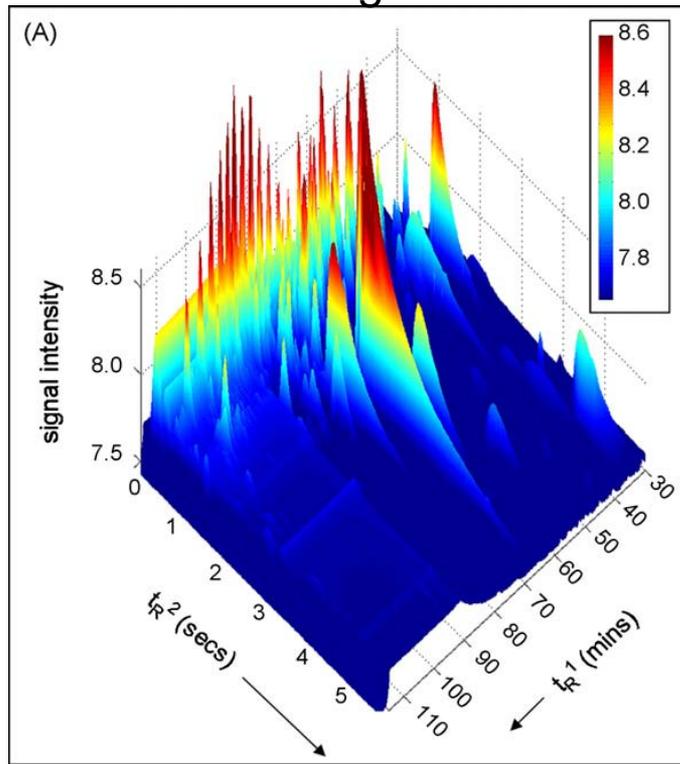


(2) How do/can we describe a system that consists of 10,000's of molecules in a simple way for models?



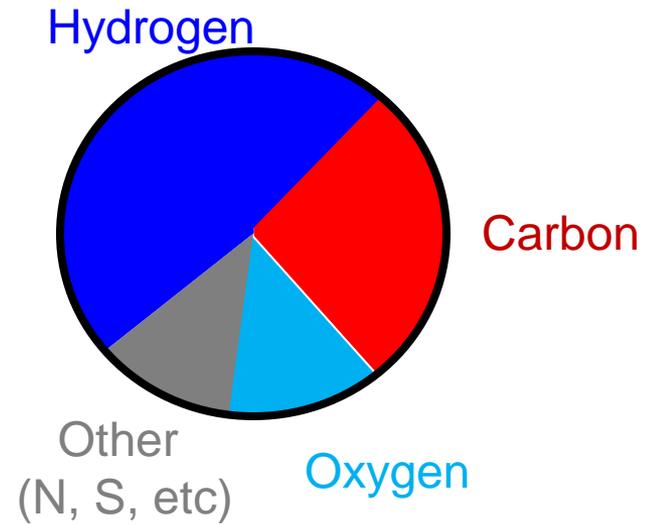
A SIMPLIFIED DESCRIPTION OF ORGANIC AEROSOL COMPOSITION

2D chromatogram of OA



[Goldstein et al., 2008]

Alternate: Look at bulk elemental composition of aerosol



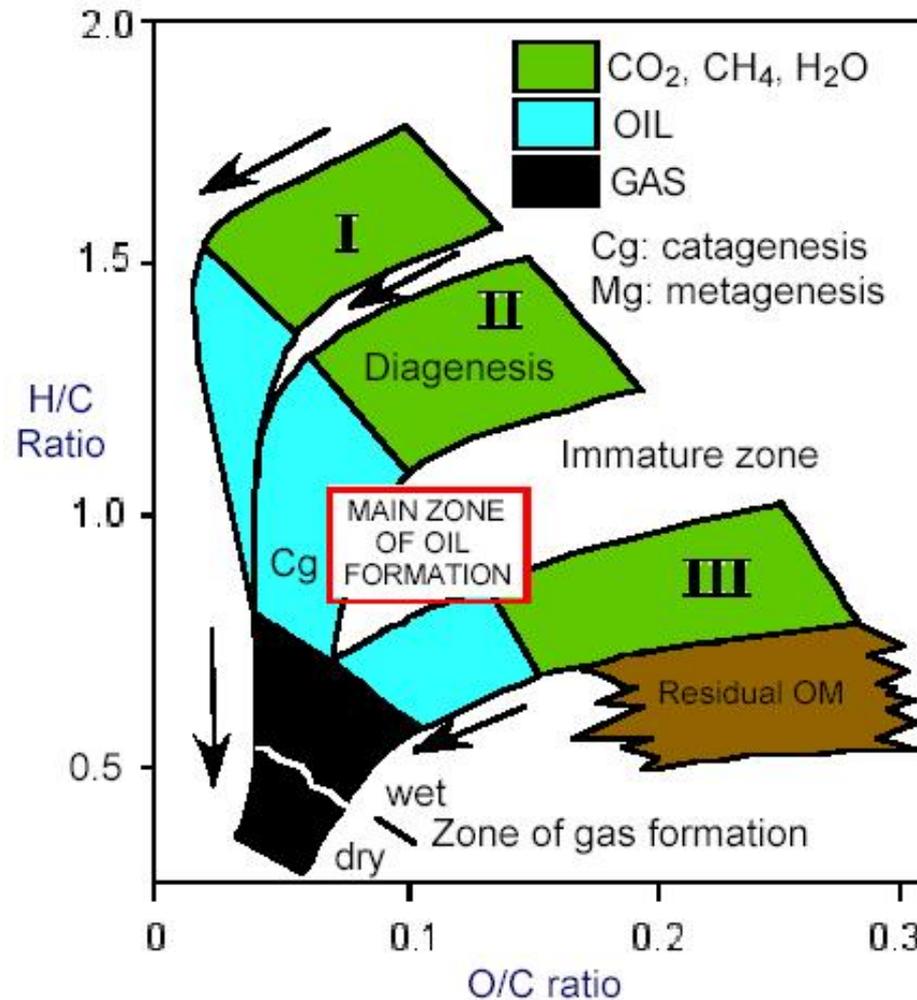
Typically < 20% of OA mass can be identified
[Williams et al., 2007].

Even if we could identify these species, global models couldn't handle this complexity!

Need a framework to compare composition & track changes...

THE VAN KREVELEN DIAGRAM

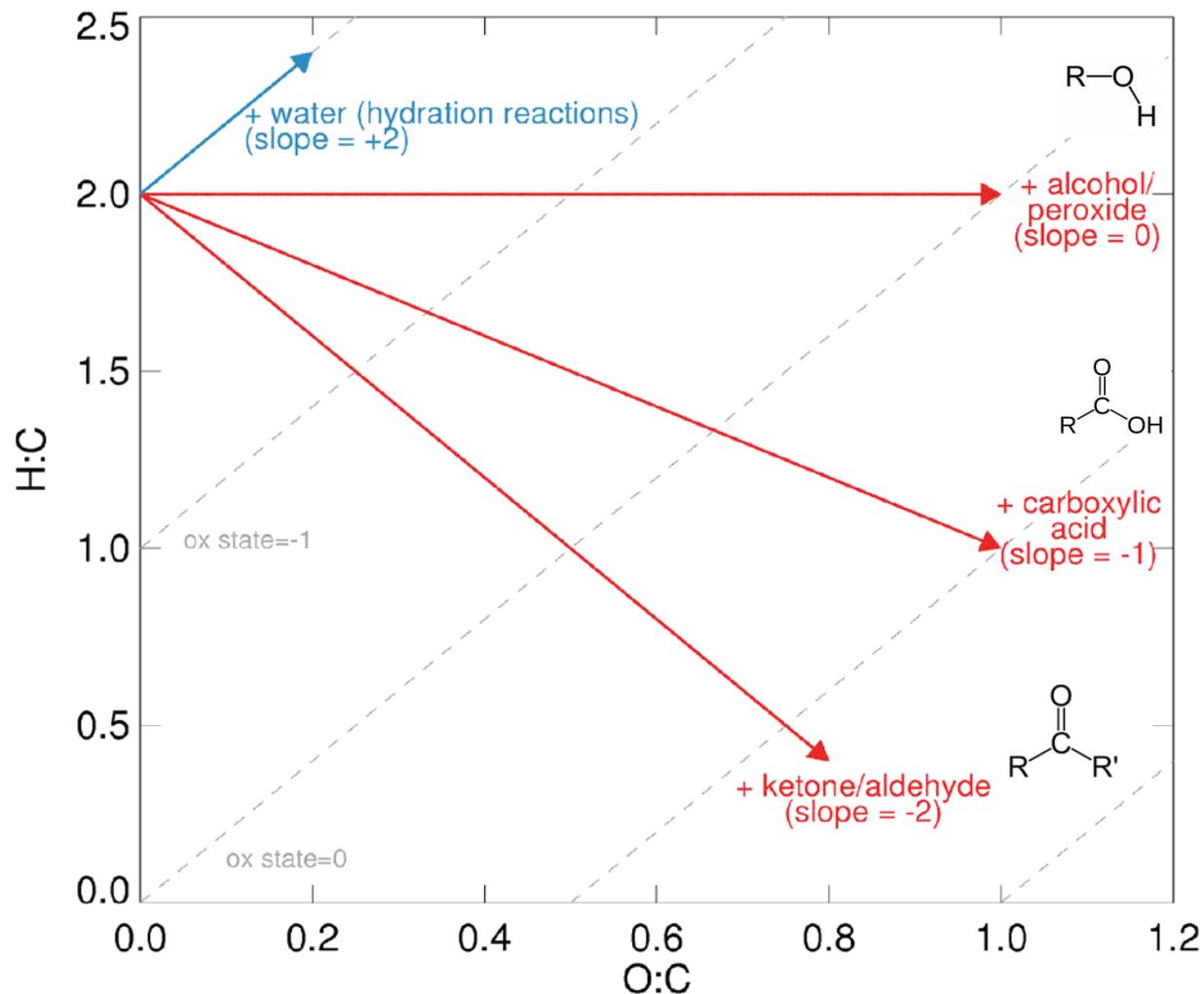
Developed by Van Krevelen in 1950's to describe oil formation



Simple way to visualize changing composition

HOW DOES FUNCTIONALIZATION CHANGE AEROSOL COMPOSITION?

If replace aliphatic carbon ($-\text{CH}_2-$) with functional group, composition changes as follows:

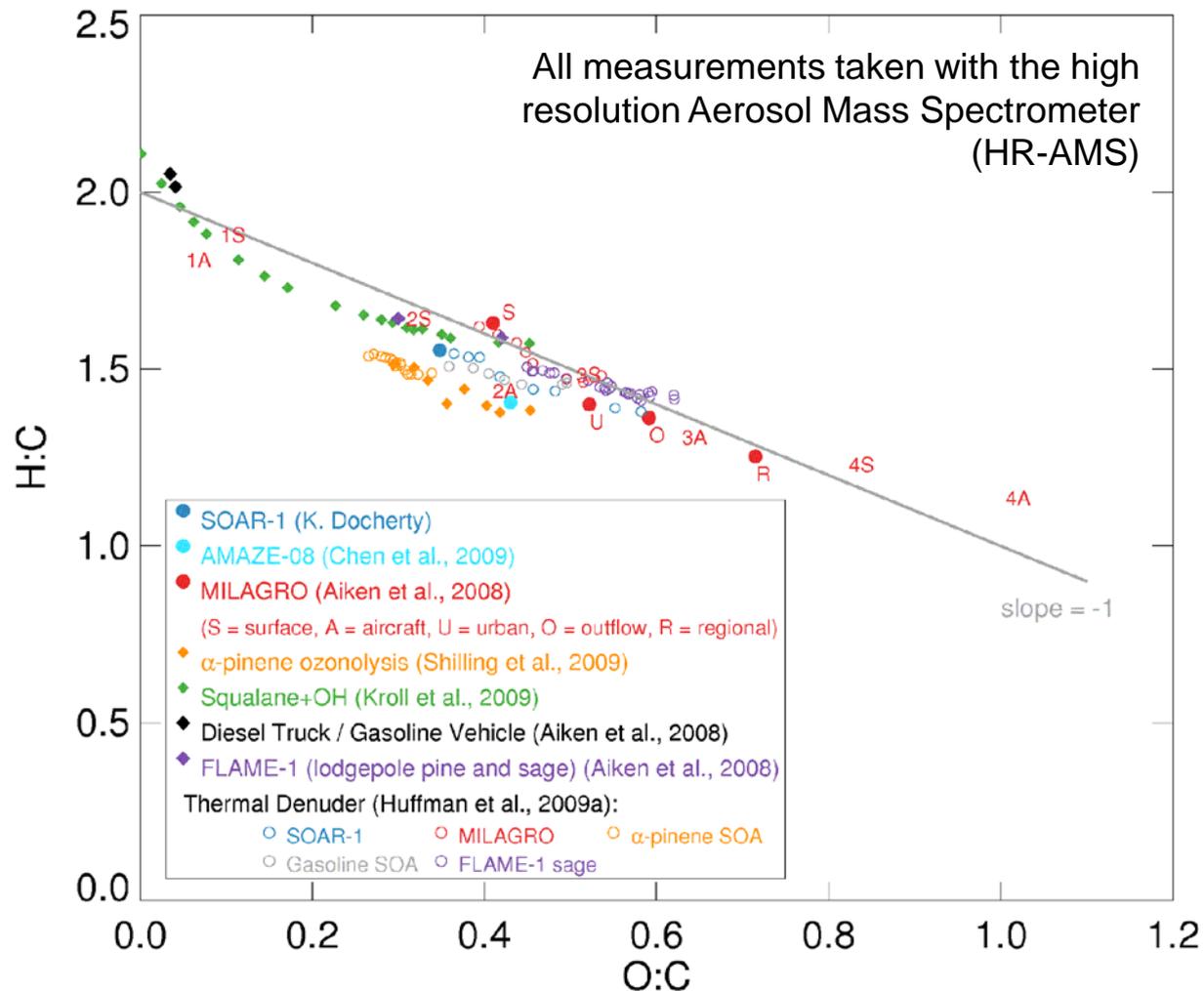


Example:

Replace $-\text{CH}_2-$ with a carbonyl group $-\text{C}(=\text{O})-$

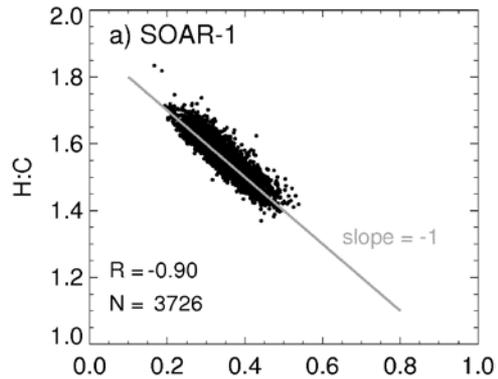
→ Add 1O, lose 2H, slope = -2

LAB & FIELD ORGANIC AEROSOL LINE UP IN A VAN KREVELEN DIAGRAM!

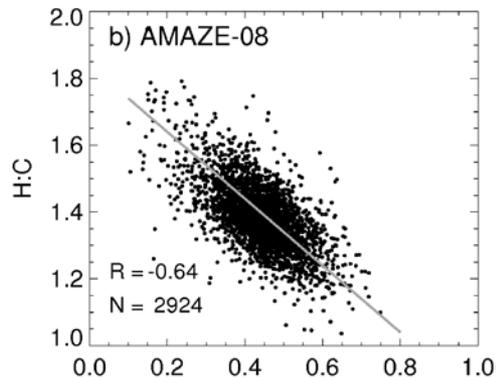


Surprisingly, despite complexity, aerosol composition changes during aging are consistent with carboxylation!

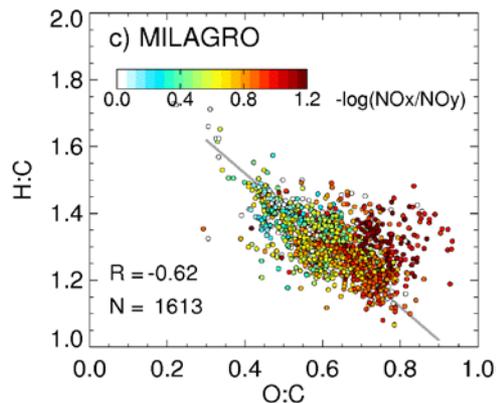
EXAMPLES FROM THREE FIELD CAMPAIGNS...



Riverside, California: dominated by urban sources



Amazon basin: clean, low loadings, more oxygenated

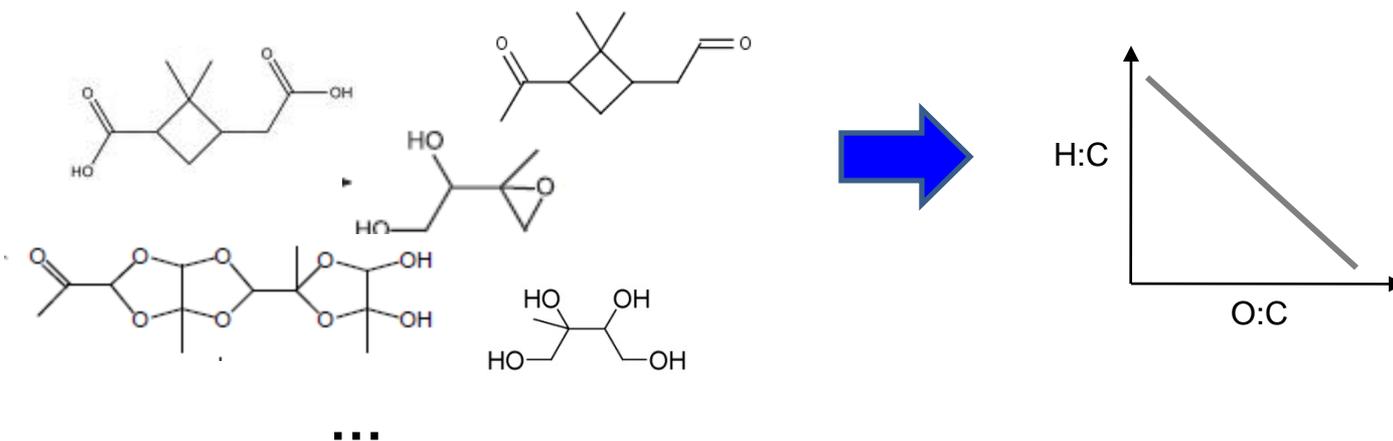


Mexico city (aircraft): regional sampling (clean & polluted)

Photochemical clock shows moves "down" the line with aging.

IMPLICATIONS

1. **From a modeling perspective:** hope for a simple parameterization!



→ Need to understand aging timescale better

2. **From a lab perspective:** why does bulk OA “collapse” to this composition? What are the details of fragmentation & functionalization reactions in the atmosphere that result in net carboxylation?

STRATEGIES, SUCCESSES, CHALLENGES IN COMMUNICATION...



Giving scientific talks is much easier than being interviewed by the local FOX News affiliate!

Discovery Simplifies View of Atmospheric Aerosols, a Factor in Climate Change

ScienceDaily (May 28, 2010) — The large number of tiny organic aerosols floating in the atmosphere -- emitted from tailpipes and trees alike -- share enough common characteristics as a group that scientists can generalize their makeup and how they change in the atmosphere.

See Also:

Earth & Climate

- [Air Pollution](#)
- [Atmosphere](#)

The groundbreaking research by Colette Heald, assistant professor in the Department of Atmospheric Science at Colorado State University, was highlighted this



ACKNOWLEDGEMENTS



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