AeroCom – 2014 Workshop
Steamboat Springs, Colorado
29 September – 3 October 2014

Reflections on aerosols and climate and the future

by

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Research theme: Invest in instruments, observations, and interpretation related to aerosols

Motivation: To serve the atmospheric science, aerosol modeling and policy worlds

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Outline

- Black carbon and the Bounding BC assessment
- GOA^{2}HEAD initiative
- ATom project
- Bioaerosol measurements
- Geoengineering
- Summary

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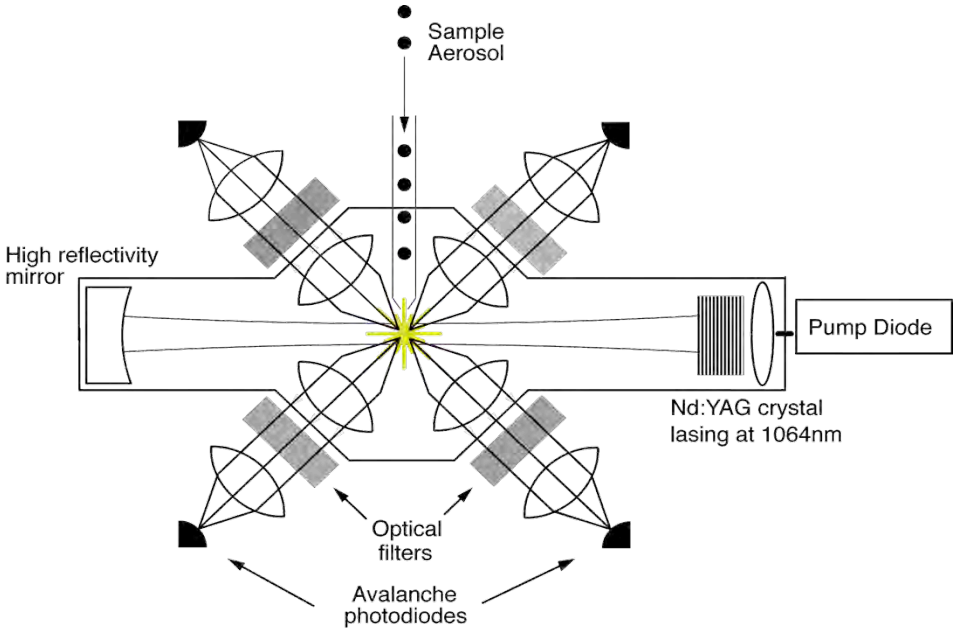
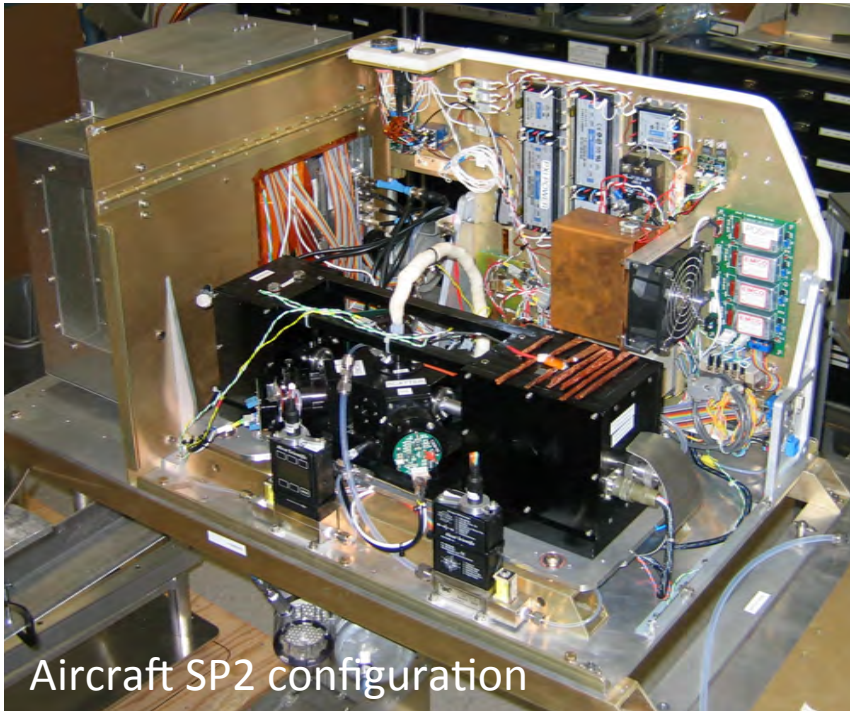
Single-particle soot photometer (SP2)

- The SP2 detects refractory black-carbon mass component of individual particles via laser-induced incandescence.



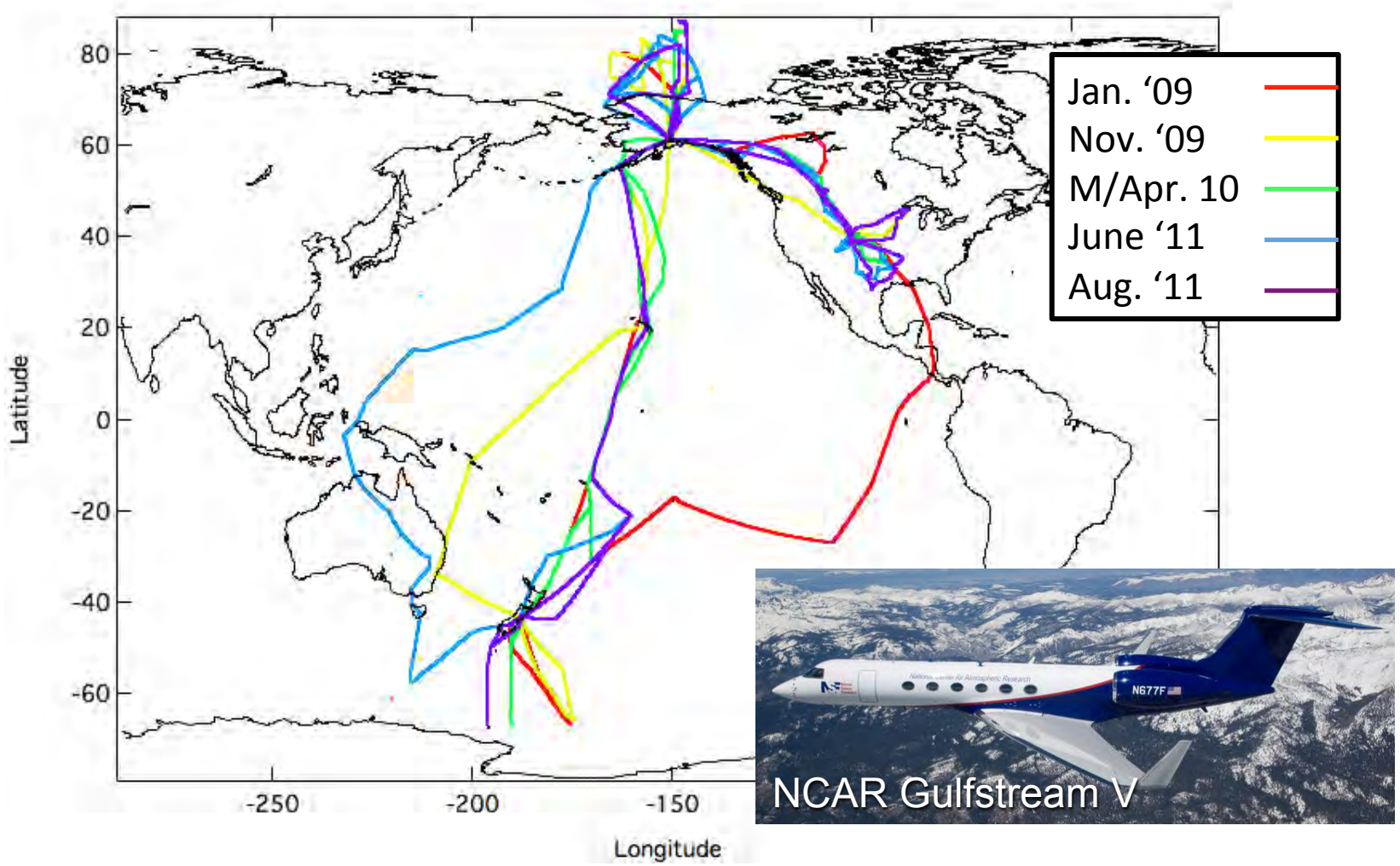


- NOAA made a significant investment in evaluating and improving the analytical quality of the SP2 measurement.
- SP2 measurements have revolutionized BC research

Schwarz *et al.*, *JGR*, 2006; Manufactured by Droplet Measurement Technology, Inc., Boulder CO

Sampling black carbon in the remote Pacific Region (HIPPO)

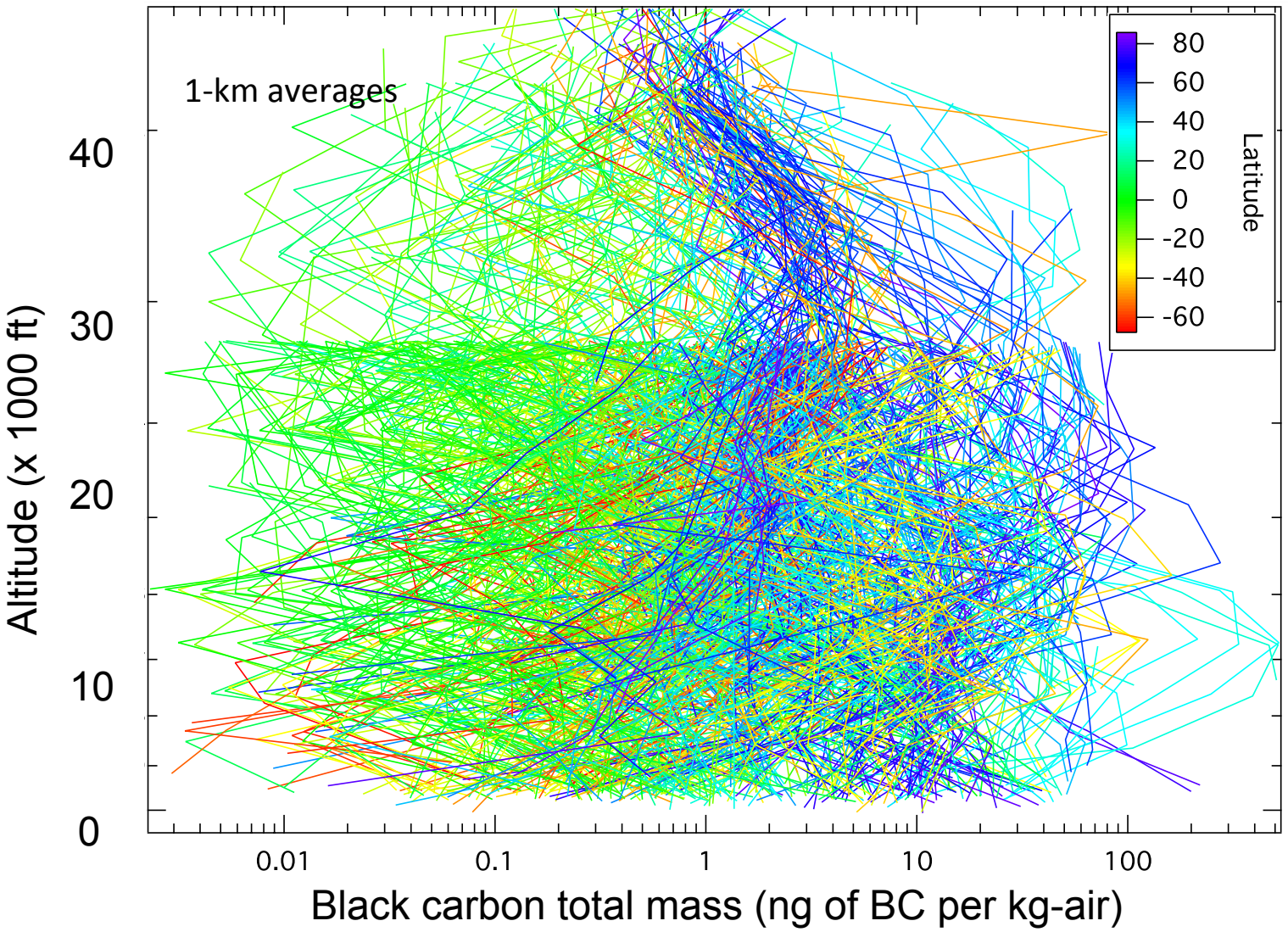
Continuous vertical profiling (85°N – 65°S) in all seasons with the SP2



- HIPPO represents a sea change in airborne sampling

Supported by NSF

HIPPO black carbon dataset summary

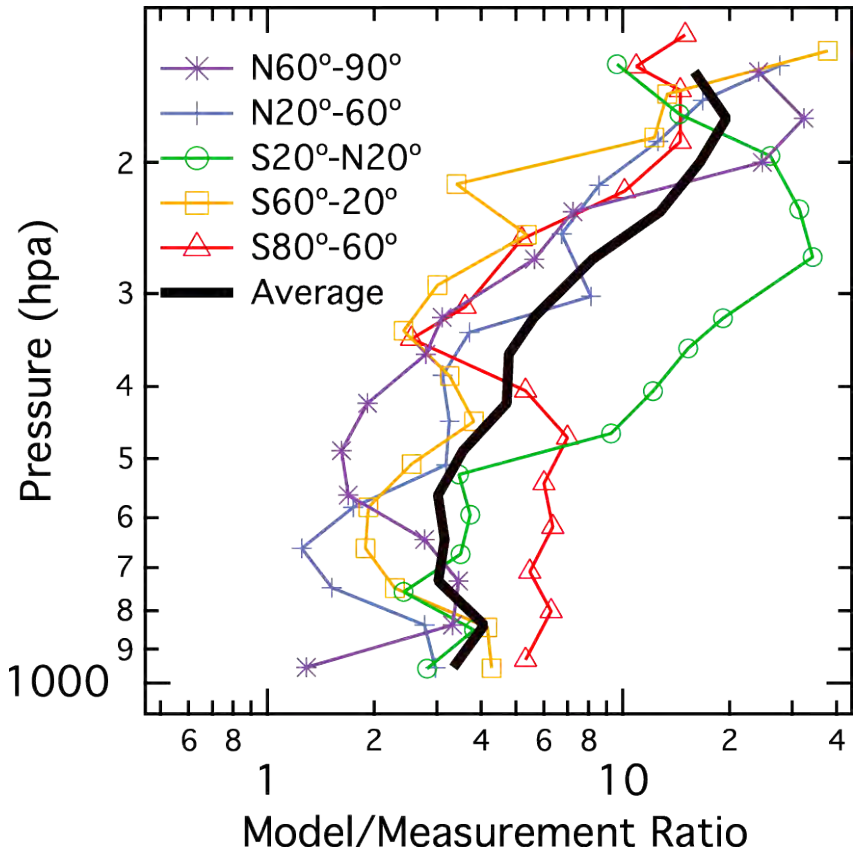


- Over 250K kms and 700 profiles
- 12 million particles sampled = 24 ng

➢ HIPPO provides a new fundamental perspective on BC in the atmosphere

Derived from Schwarz *et al.*, 2013

BC Intercomparison: All HIPPO vs AeroCom

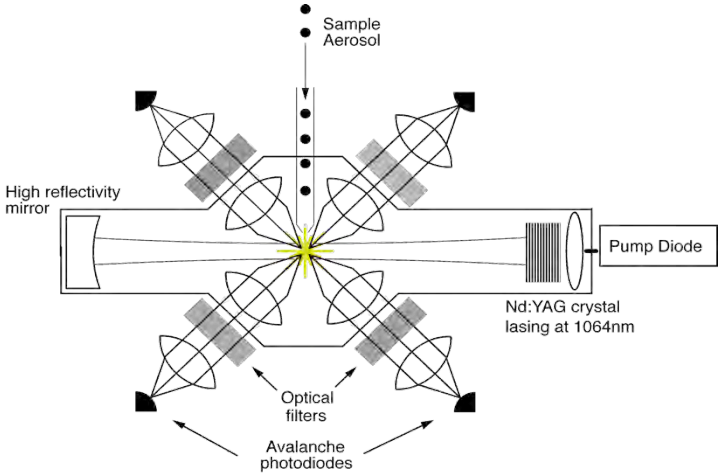


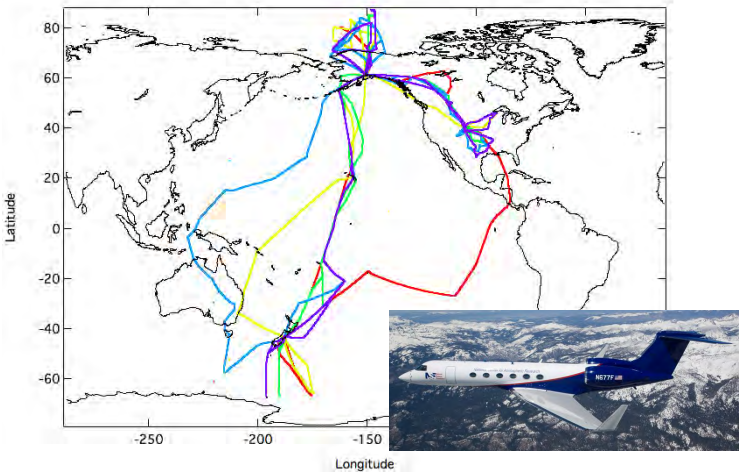
• AeroCom models systematically overestimates BC in the free troposphere.

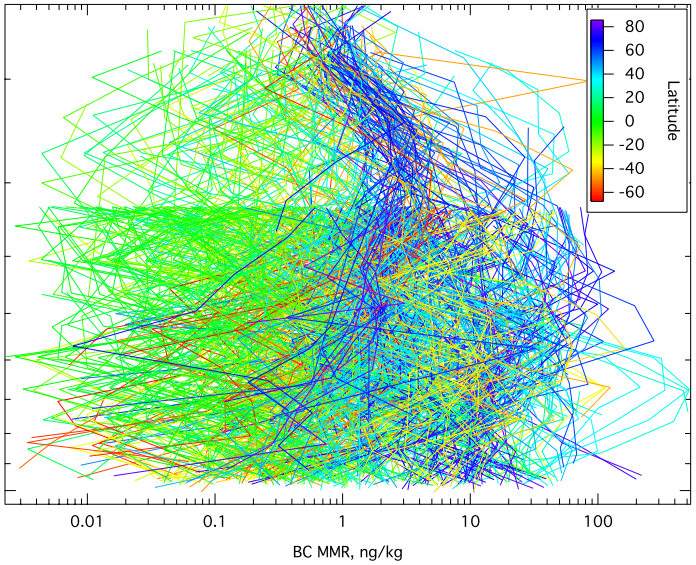
• This result has influenced or initiated many follow on studies, in part, to improve model simulations.

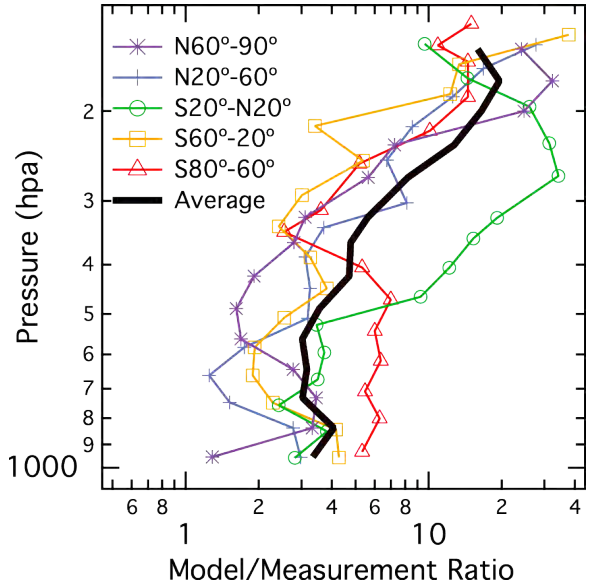
Schwarz et al., GRL, 2013

What if it didn't happen?





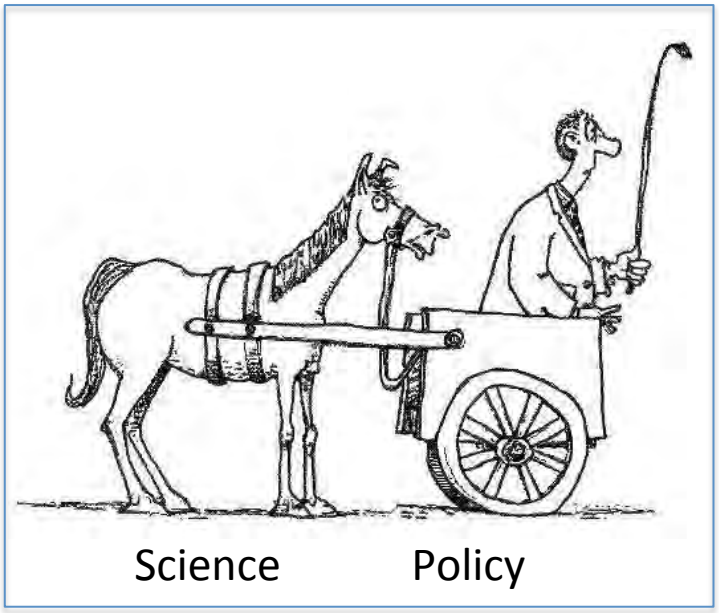




- Be vigilant about opportunities and committed to finishing what we start

Motivation for an assessment of black carbon and climate

• A real concern exists about the lack of adequate scientific foundation for black carbon's role in climate forcing from regulators, policy makers, non-governmental organizations (NGOs), advocates, …..



http://www.metronetiq.com

• A stronger scientific foundation required an international assessment given:

- ➢ the complexity of BC emissions and climate processes and
- ➢ the incomplete state of the existing scientific literature.

iStockPhoto.com

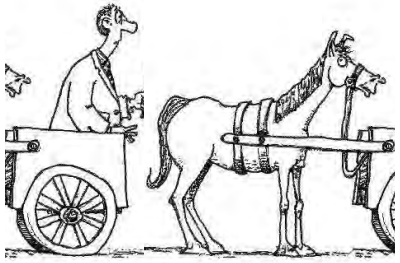
Bounding the Role of Black Carbon in the Climate System: A Scientific Assessment

T. Bond, S. Doherty, D. Fahey, P. Forster (CLAs), T. Berntsen, O. Boucher, B. J. DeAngelo, M. G. Flanner, S. Ghan, B. Kärcher, D. Koch, S. Kinne, Y. Kondo, P. K. Quinn, M. C. Sarofim, M. G. Schultz, M. Schulz, C. Venkataraman, H. Zhang, S. Zhang, N. Bellouin, S. K. Guttikunda, P. K. Hopke, M. Z. Jacobson, J. W. Kaiser, Z. Klimont, U. Lohmann, J. P. Schwarz, D. Shindell, T. Storelvmo, S. G. Warren, C. S. Zender

Guiding Principles: Comprehensive, quantitative, policy neutral

- *Journal of Geophysical Research – Atmospheres*, published June 2013.

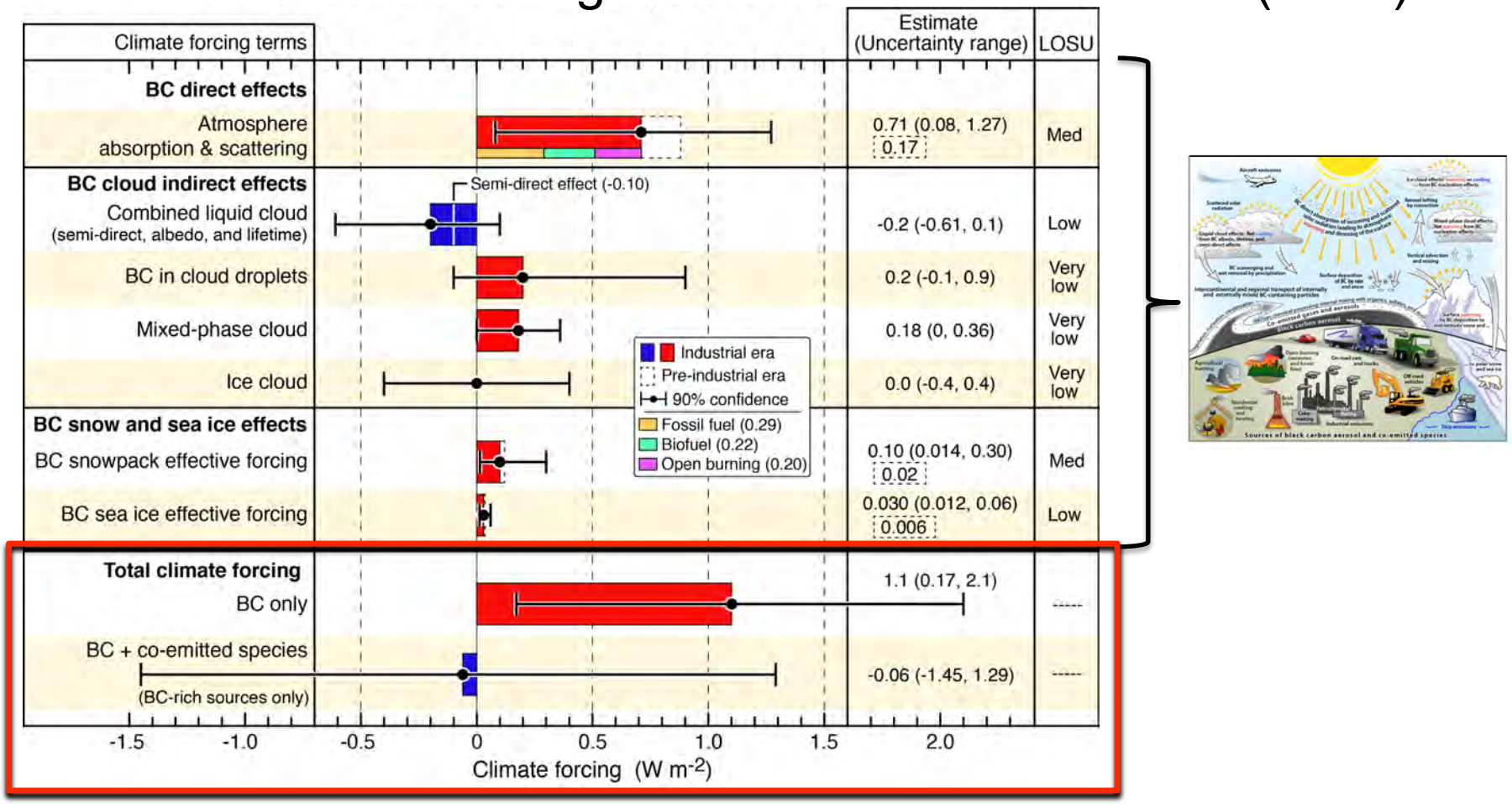
- Bounding BC has provided a needed scientific foundation and changed science and policy discussions of BC…..
.….but it is a living document that needs to evolve with new understanding.



Policy Science
Improved

- Other initiatives needed (e.g., dust, SOA, …)

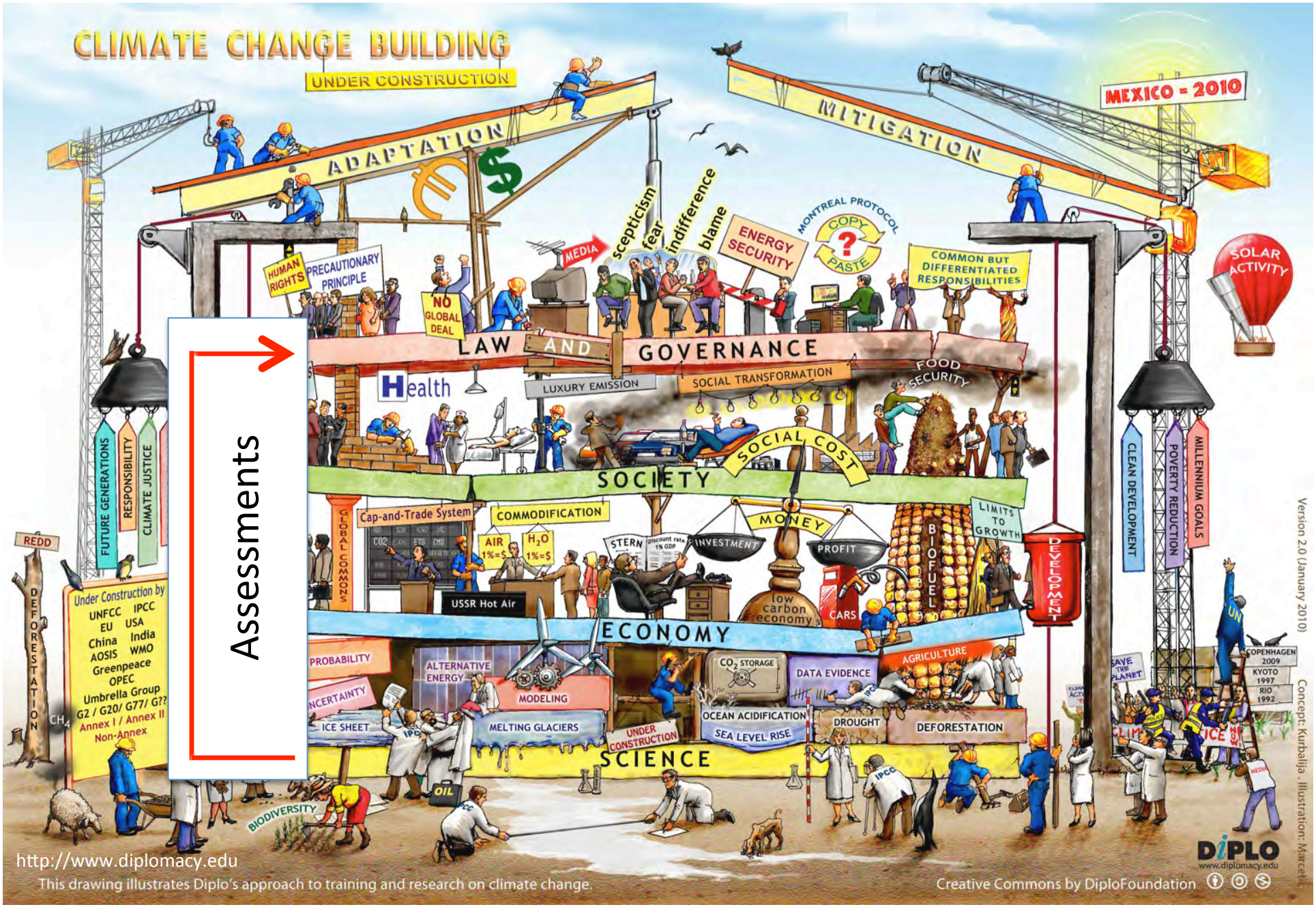
Global climate forcing of black carbon emissions (2005)



- Black carbon is the 2nd most important climate forcing agent from human activities
- These results added value to the IPCC AR5 assessment of aerosol effects
- The large uncertainty warrants focused research efforts to improve our understanding of BC processes

Bond *et al.*, JGR, 2013

The Climate Change Building as a framework for assessments



GOA²HEAD: A new initiative to address global aerosol data gaps

Global Ozone and Aerosol profiles and Aerosol Hygroscopic Effect and Absorption optical Depth

Ru-Shan Gao, Jim Elkins, Greg Frost, Allison McComiskey,
Daniel Murphy, John Ogren, Irina Petropavlovskikh,
Karen Rosenlof
NOAA Earth System Research Laboratory

- Use new lightweight, semi-disposable instruments
- Routine profiles from surface up to 20+ km altitude

on small balloons or small UAS aircraft platforms

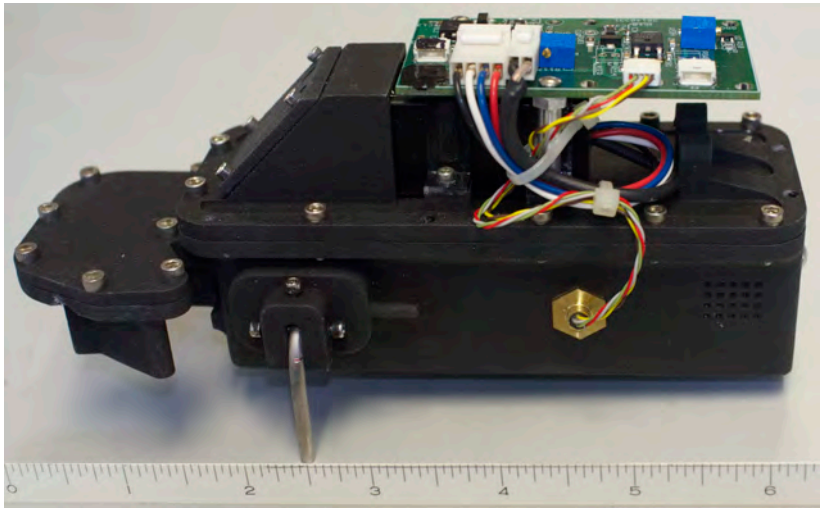
- Measurements: aerosol AOD, AAOD, size distribution, hygroscopic growth, ozone

New instruments developed at NOAA Chemical Science Division

- **Optical Particle Counter (OPC)**

- single-particle detection
- 150 - 2500nm diameter range
- 800 g, 7 Watts
- Semi-disposable (use of 3D printing)

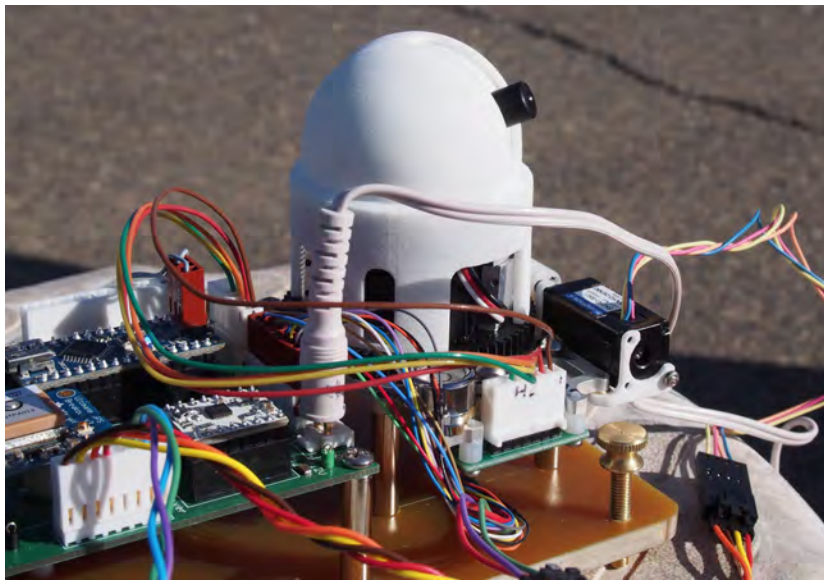
Rushan Gao et al.



- **Upward Looking Radiometer (ULR)**

- 4 wavelength (460, 550, 670, 860 nm)
- 0.02 AOD detection limit
- 350 g, 2 Watts
- Semi-disposable (use of 3D printing, Arduino processor)

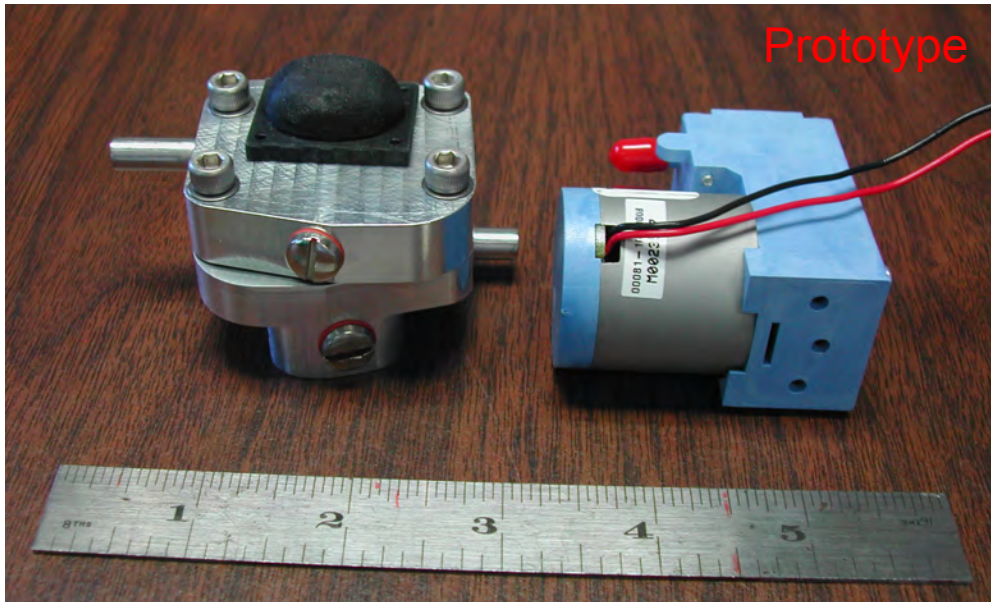
Dan Murphy et al.



New instruments developed at NOAA Chemical Science Division

- **Mini-Continuous Light Absorption Photometer (CLAP)**

- Particle absorption detection
- 3 wavelengths (467, 528, 652 nm)
- Precision < 0.2 Mm^{-1} (estimated)
- 1000 g, 10 Watts (estimated)
- Semi-disposable



Rushan Gao, Alex Ting et al.
(Based on John Ogren design)

➢ But what about the deployment platform?

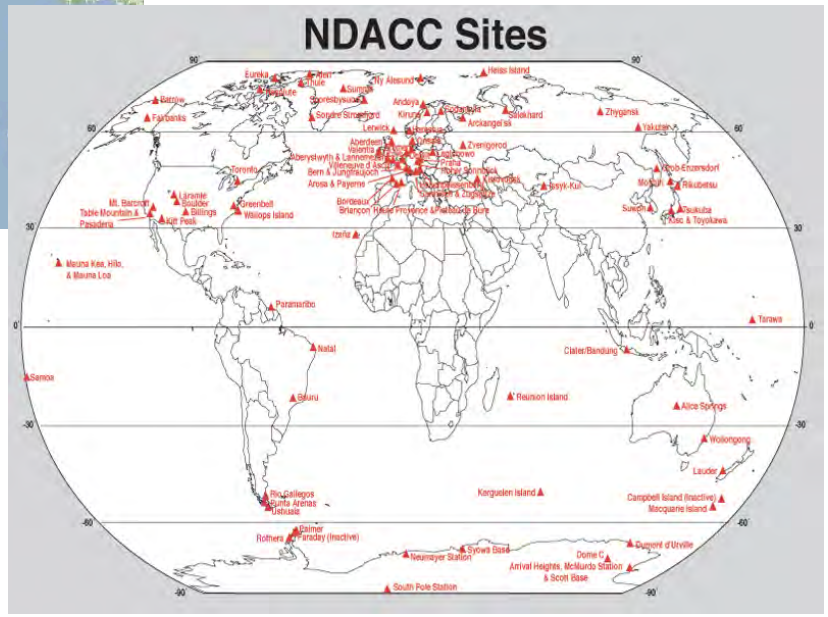
MANTA UAS platform with prototype GOA^{2}HEAD payload

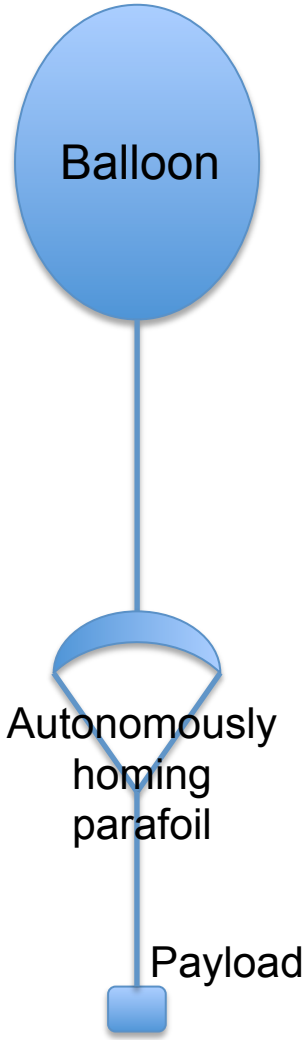
NOAA Pacific Marine Environment Laboratory Yakima WA April 2014
(with Tim Bates and Trish Quinn)

Altitude ceiling 3km
Payload 5 kg
Endurance 2 hr
Wingspan 2.7 m

GOA²HEAD global deployment options

NOAA Network Stations



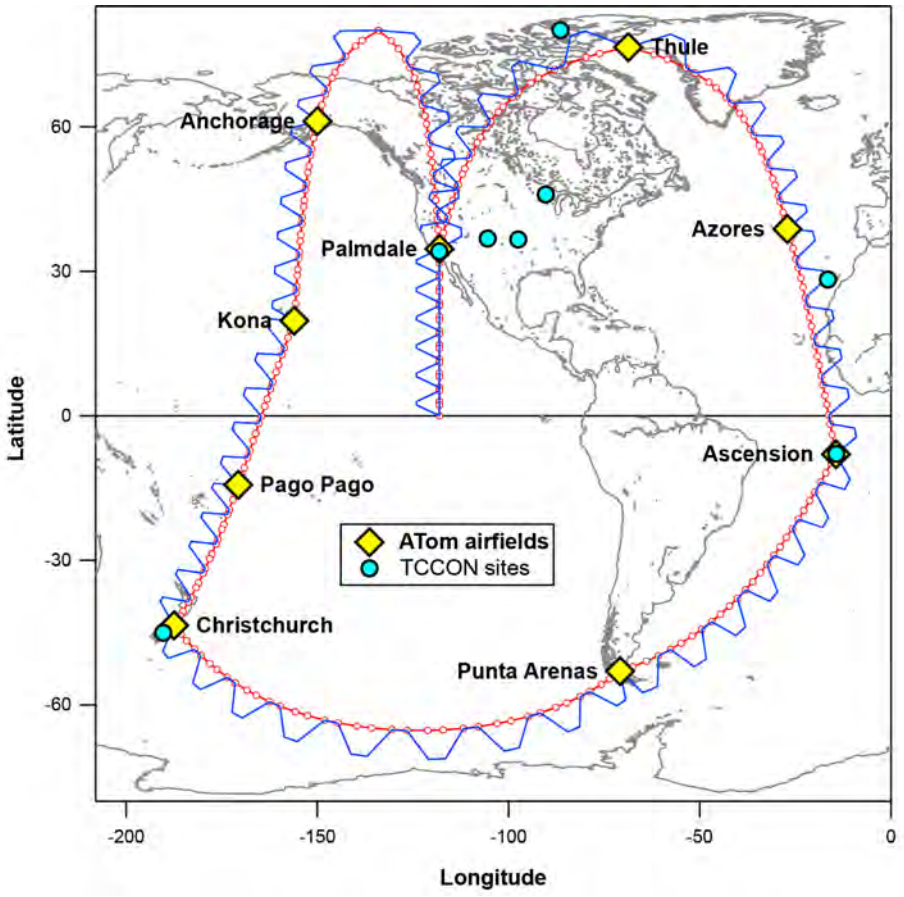


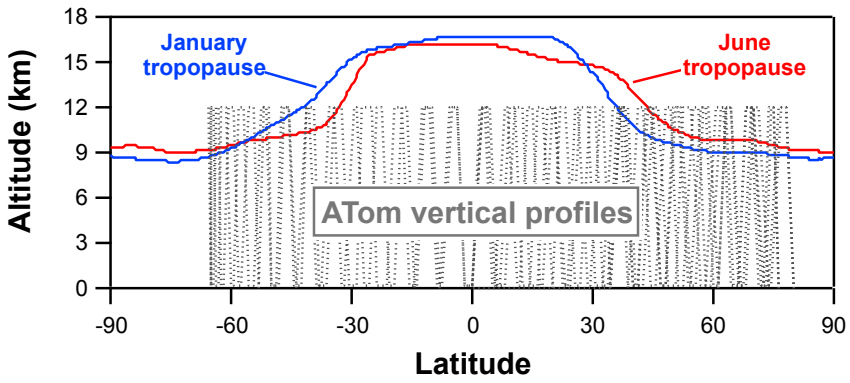
- Strategic global deployment of GOA²HEAD instruments could provide essential information for satellite retrievals and model simulations.

NASA Atmospheric Tomography Mission (ATom) (In review)

Imaging the Chemistry of the Global Atmosphere (2015-2020)

Steve Wofsy and Michael Prather, Principal Investigators





The payload has 15 proven instruments for in situ measurements of reactive and long-lived gases, diagnostic chemical tracers, and aerosol size, number, and composition, plus spectrally resolved solar radiation and meteorological parameters.

NASA Atmospheric Tomography Mission (ATom) (In review)

Imaging the Chemistry of the Global Atmosphere

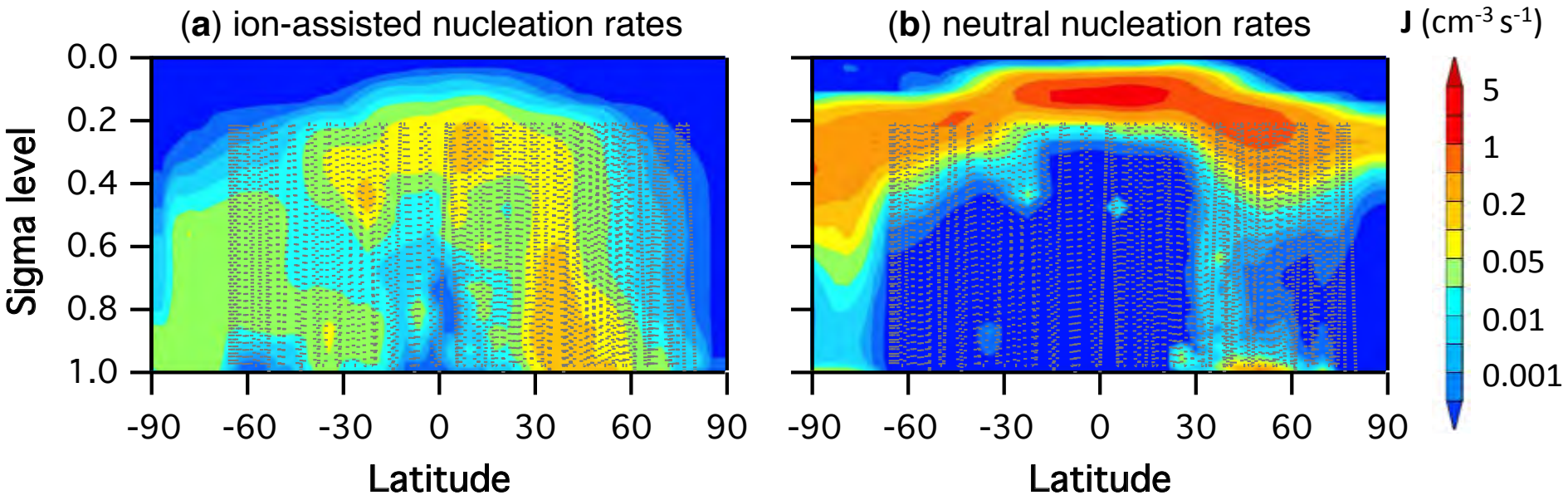
Species	Instrument(s)	Sampling interval	Data quality†
Aerosol composition and microphysics			
Particle distribution (4–1000 nm)	AMP	1 s	14 cm^{-1} + 9%
Cloud drop distribution (2–50 µm)	AMP	1 s	20%
Black carbon mass and coating state	SP2	1 s	12 ng/kg + 30%
SO_4^{2-}, NO_3^-, Cl^-, NH_4^+	HR-AMS	1 s	0.1 µg/m^3 + 35%
Organic aerosol	HR-AMS	1 s	0.5 µg/m^3 + 35%
Particle O/C, H/C, and OM/OC	HR-AMS	1 s	0.1 µg/m^3 + 40%
Cl^-, Na^+, Ca^{2+}	SAGA filters	5 - 15 min	0.05 µg/m^3 + 10%
SO_4^{2-}, NO_3^-, Br^-, $C_2O_4^{2-}$, NH_4^+, K^+, Mg^{2+}	SAGA filters	5 - 15 min	0.02 µg/m^3 + 10%
^7Be	SAGA filters	5 – 15 min	25 fCi/m^3 + 5%
^{210}Pb	SAGA filters	5 – 15 min	0.5 fCi/m^3 + 10%

- ATom aerosol observations will far exceed the HIPPO payload

NASA Atmospheric Tomography Mission (ATom) (In review)

Imaging the Chemistry of the Global Atmosphere

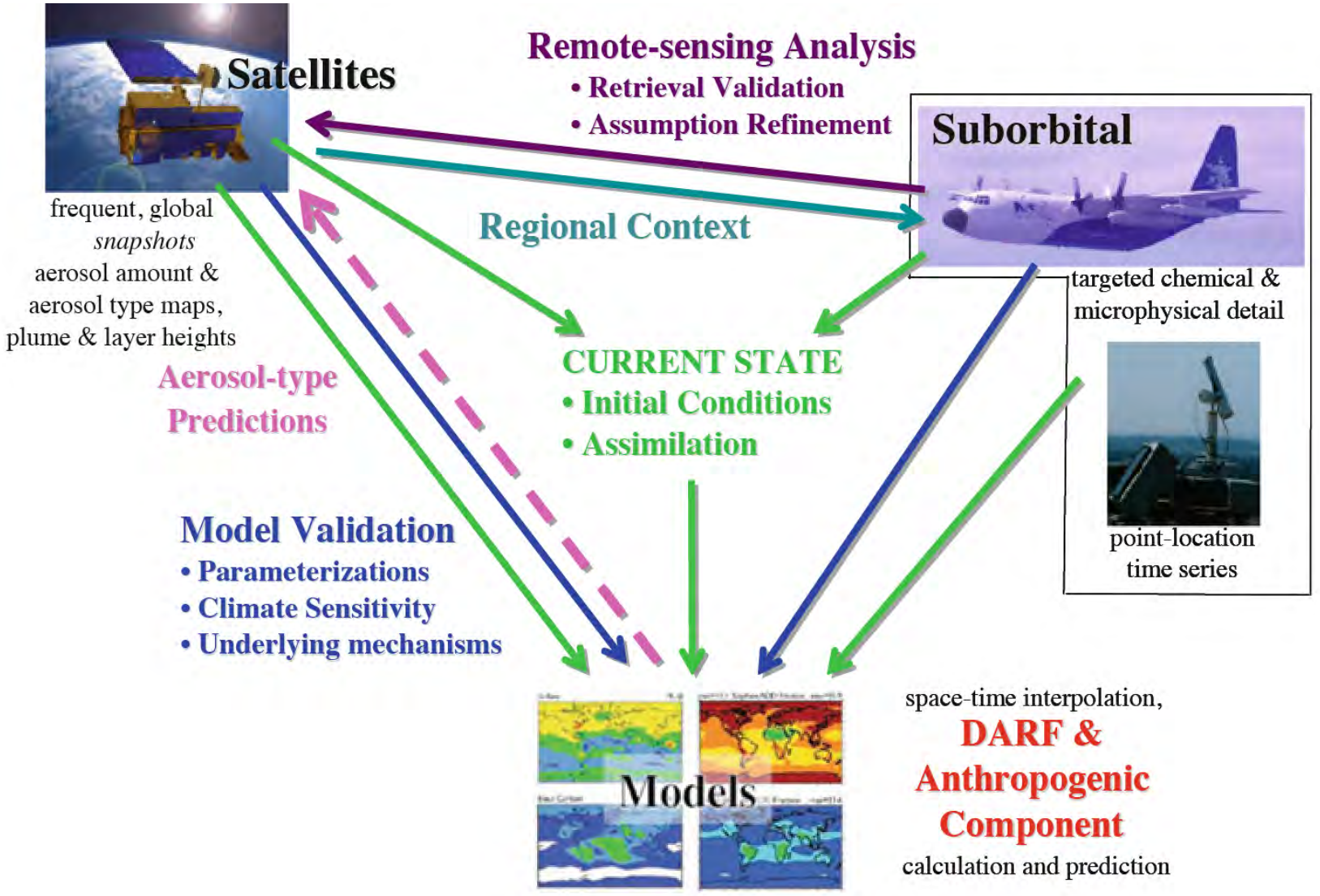
Global model simulations of new particle nucleation rates



- Observations of new particle formation can help identify the role of different mechanisms

Yu *et al.*, 2010

Relationship between satellite and suborbital measurements and models for constraining DARF

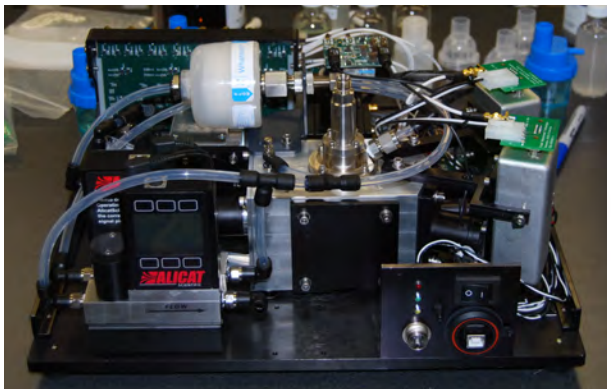


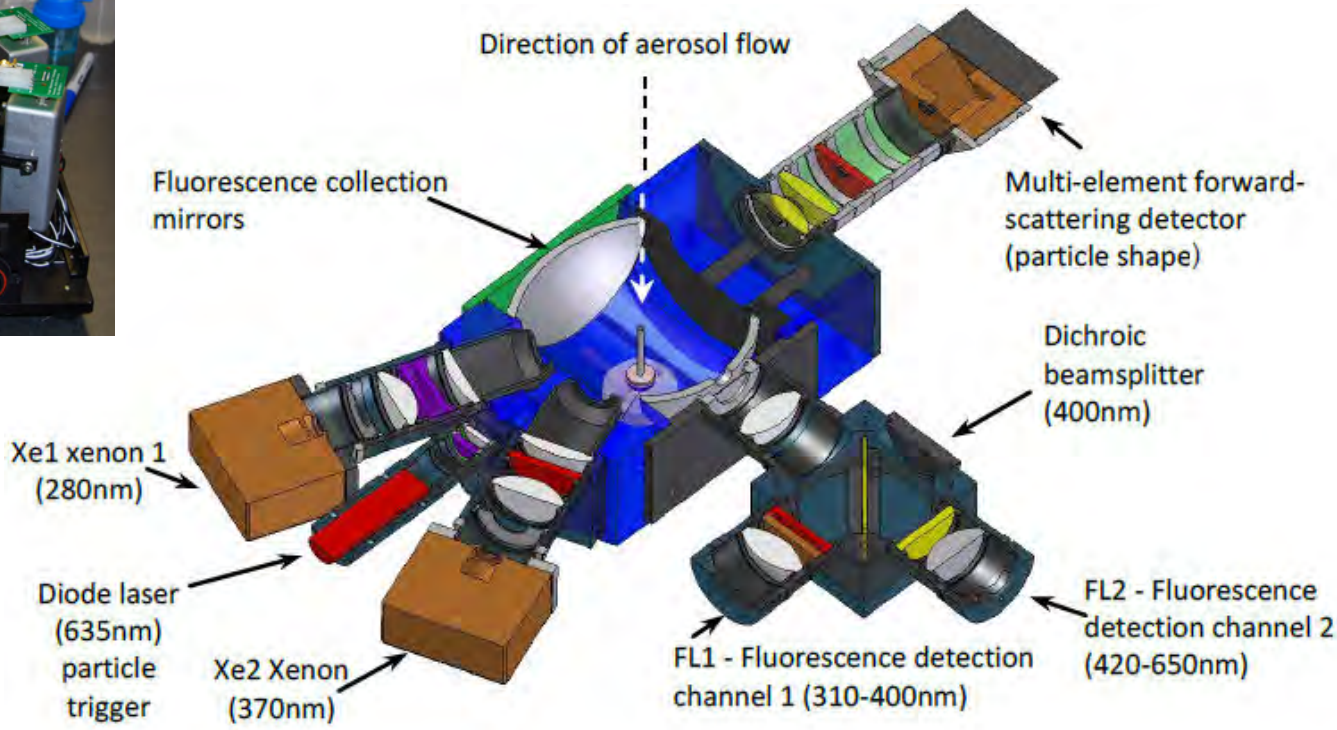
Kahn *et al.*, *Surv Geophys*, 2012

The Wide-band Integrated Bioaerosol Sensor (WIBS): A new generation in bioaerosol detection.

Anne Perring/NOAA, PI

- Continuously counts and sizes single particles > 0.8 um diameter
- 2 excitation wavelengths and 3 pieces of fluorescent information per particle

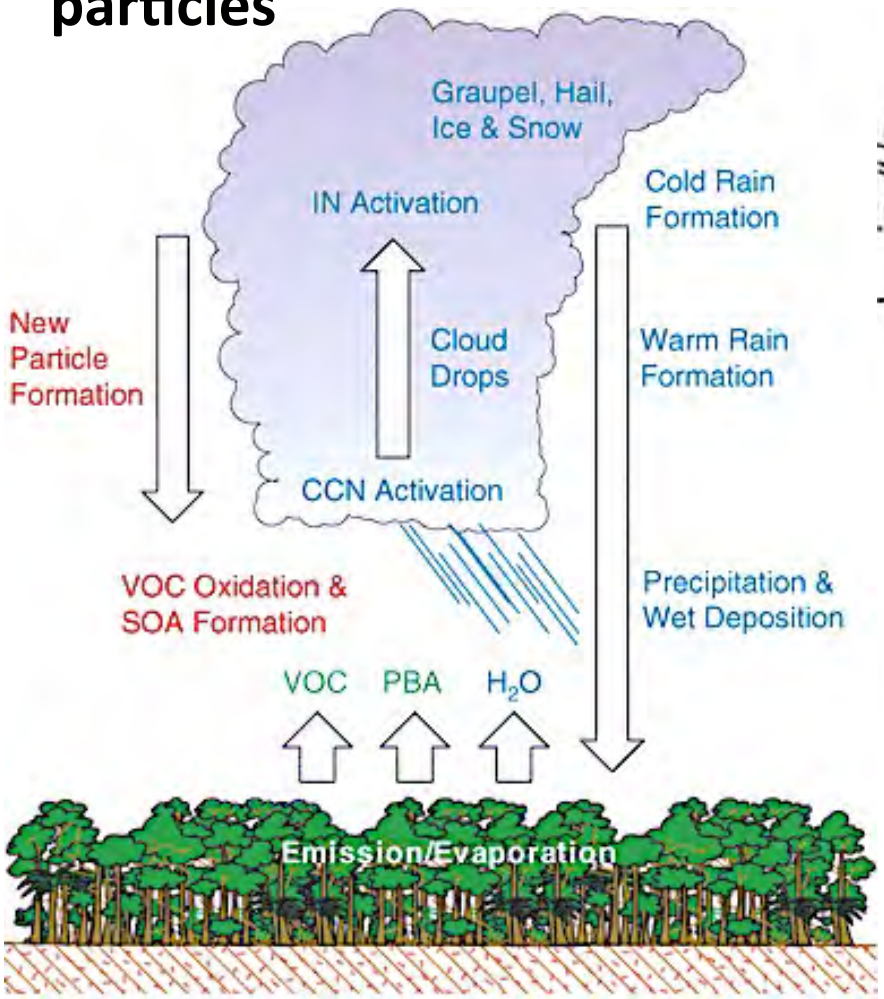


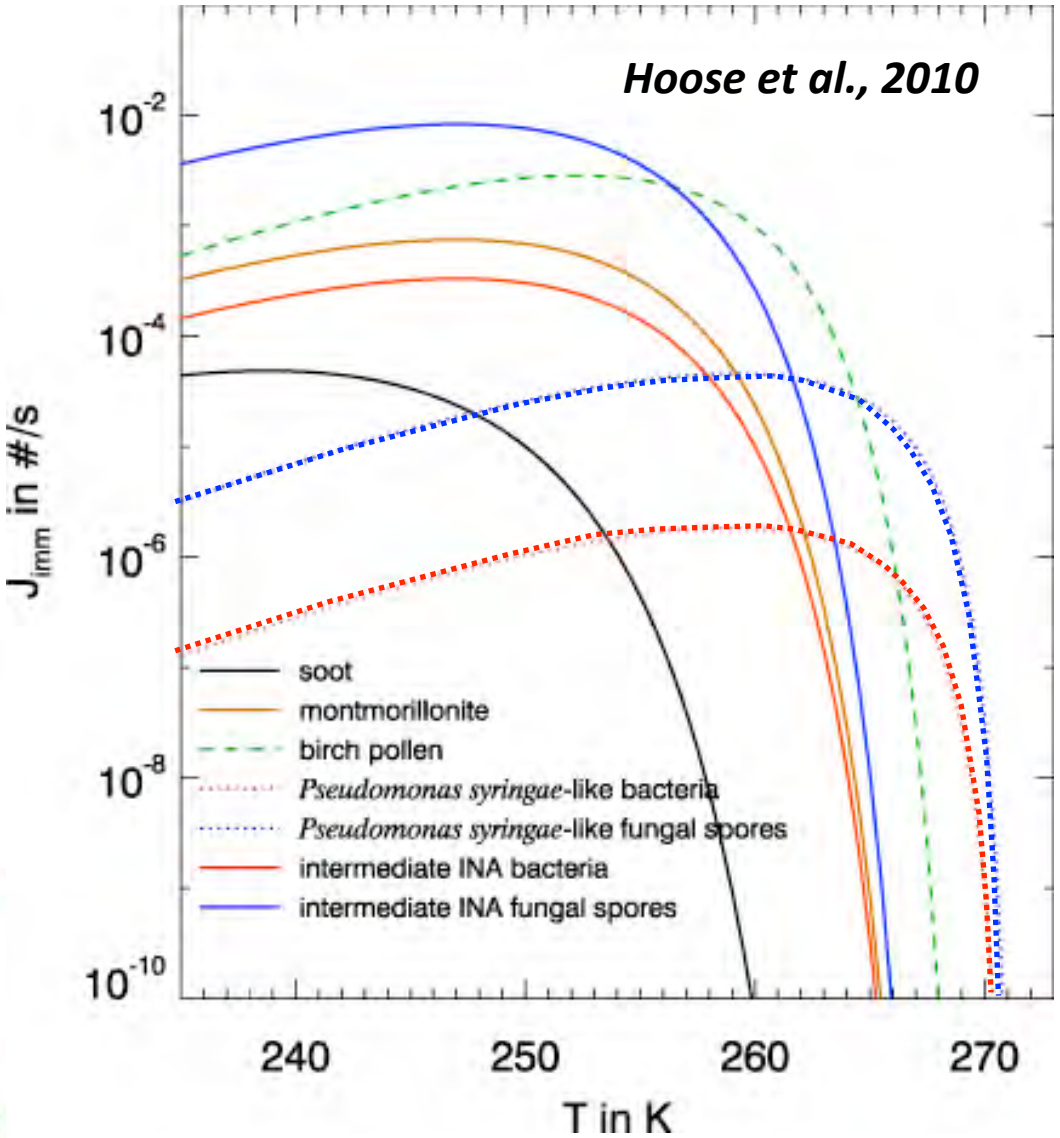


Manufactured by Droplet Measurement Technology, Inc., Boulder CO

Bioaerosol in the atmosphere

Bioaerosol can *nucleate ice* at warmer temperatures than many other atmospheric particles

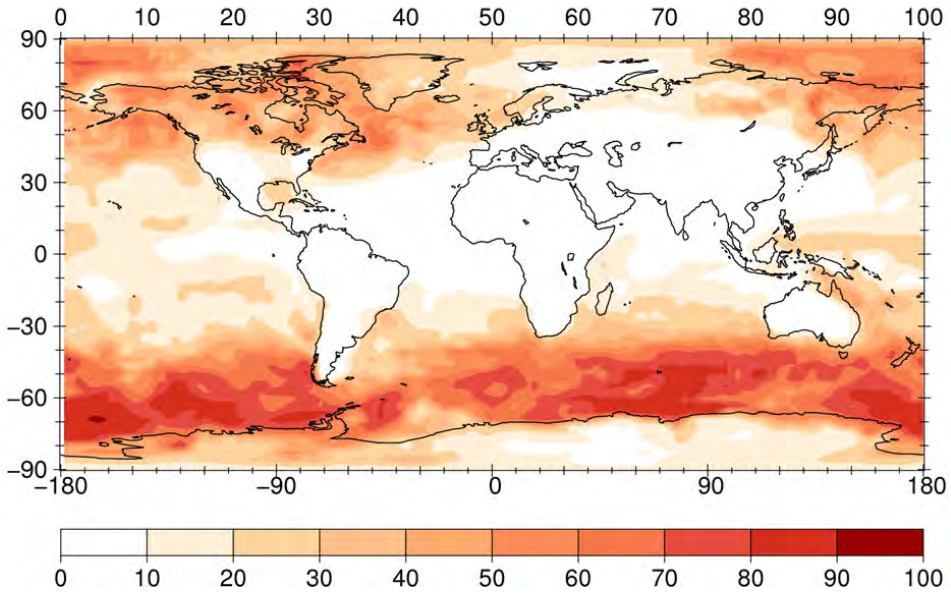




Poschl et al., 2010

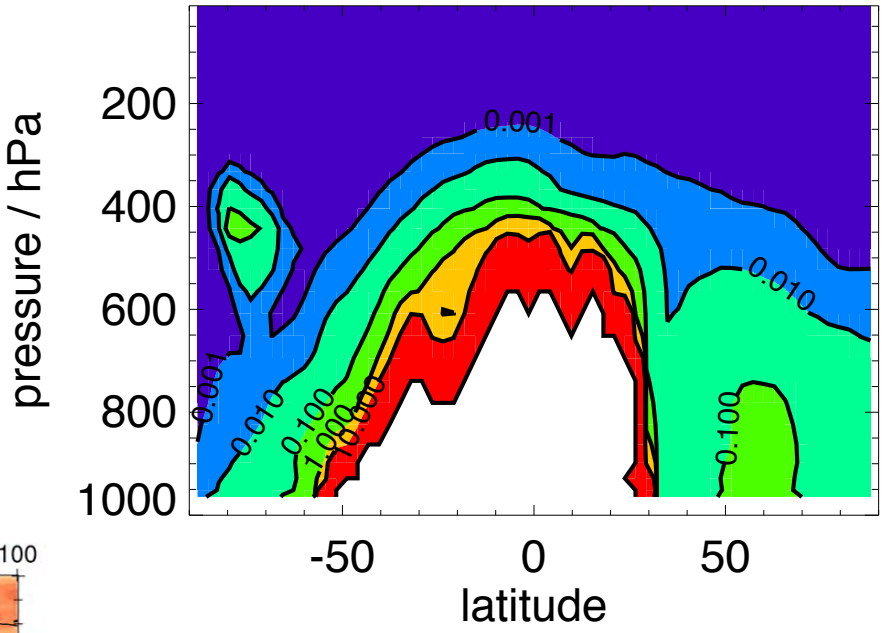
Modeled impacts

Modeled bioaerosol can be hugely important IN in certain regions (even though they are only a tiny fraction of global IN.)



Simulated relative contribution of marine biogenic IN to marine boundary layer IN concentrations at −15 C, as a percent of annual mean dust IN and marine biogenic IN. Estimate using "control" dust IN concentrations and "best" biogenic IN concentrations;

Burrows et al., 2013



Spracklen and Heald, 2014

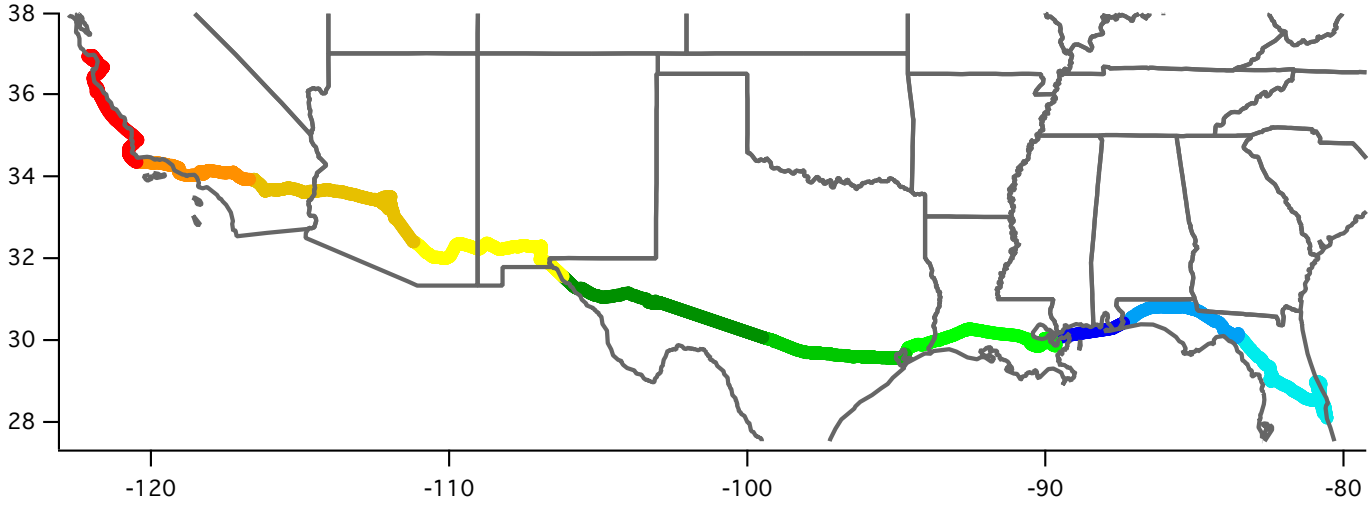
Percentage contribution of PBAP (bacteria and fungal spores) to zonal annual mean immersion freezing rates.

Observations, especially in the vertical, are sparse however.

The BBC Two CloudLab Project, Fall 2013

WIBS bioaerosol, SP2 (BC), PAS (absorbing aerosol), cloud probe

Led by Jim McQuaid, Univ of Leeds, UK

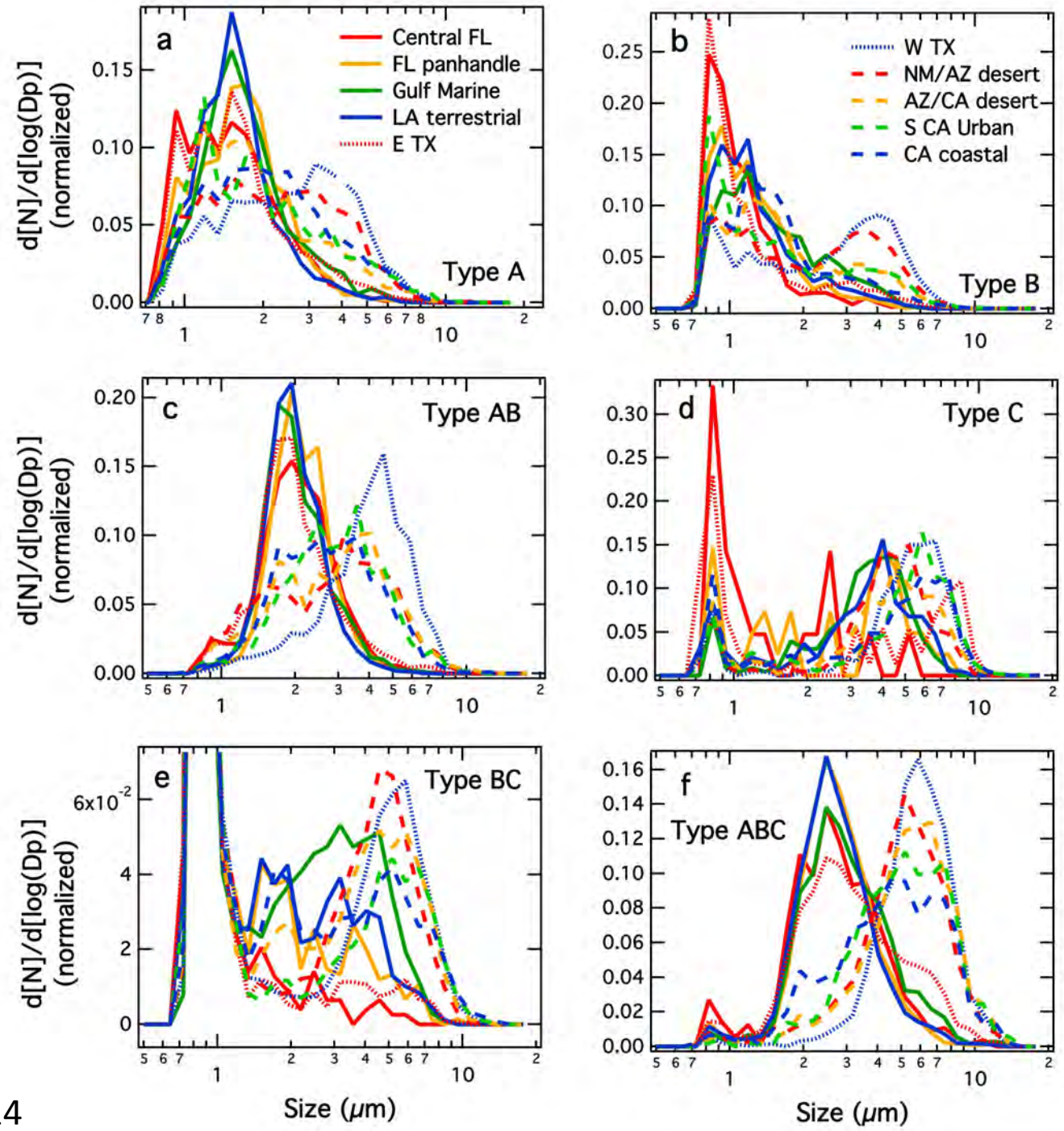


Results

General E-W trends

Shown are # distributions for each type in each region

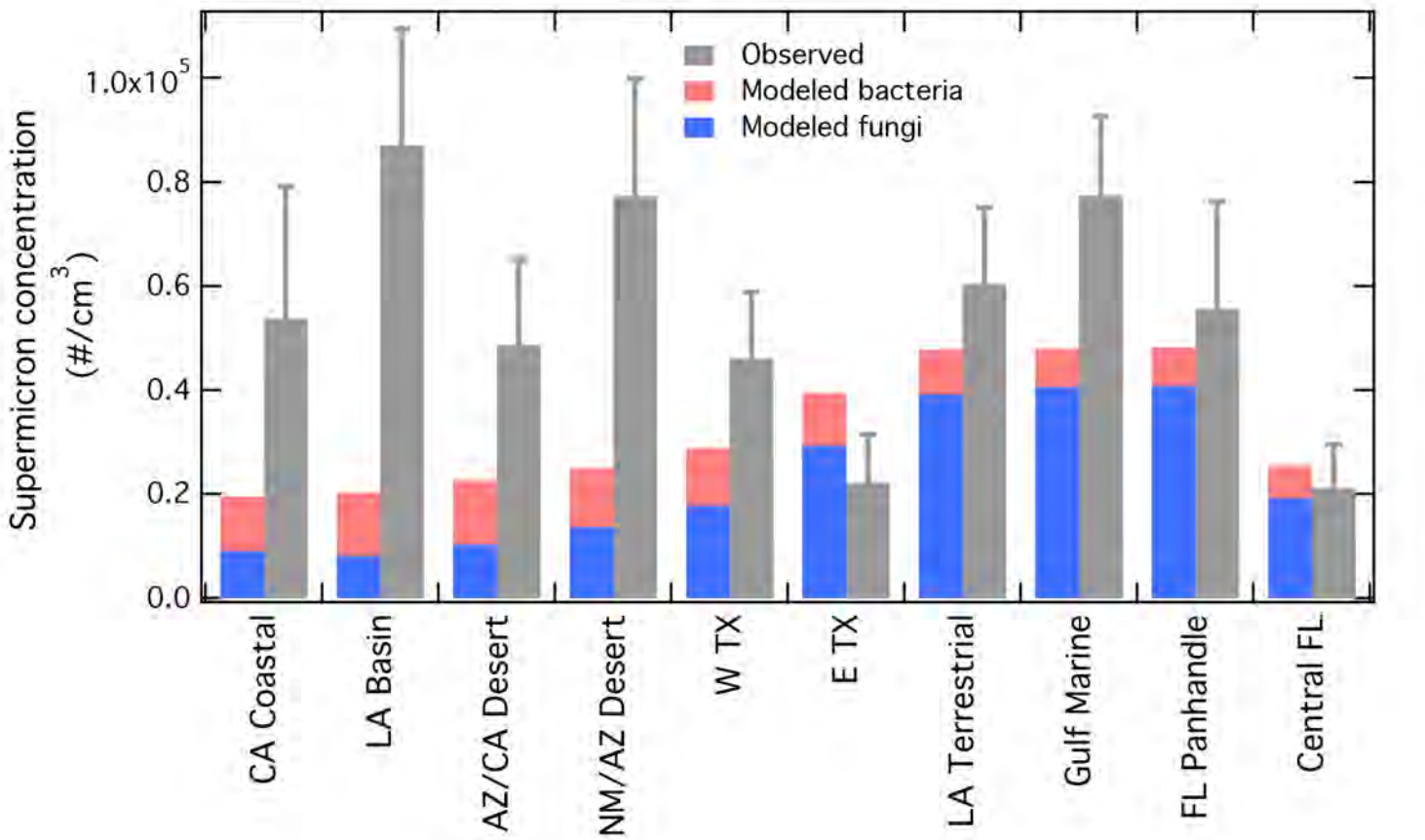
- Trend to larger sizes in the West
- Type switches from AB and ABC w/mold-spore-like sizes in the east to B, BC and ABC at sizes akin to mushroom spores or pollen fragments in the west



Perring et al., submitted, 2014

Model comparison of CloudLab bioaerosol concentrations

Anne Perring *et al.*, submitted to *JGR*, September 2014



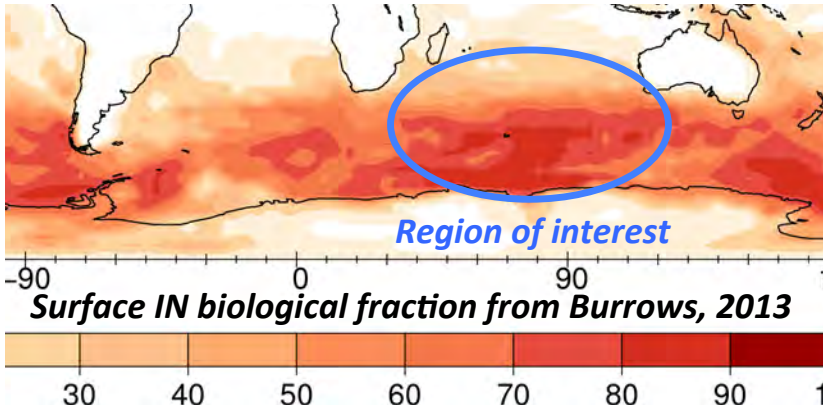
• Comparison between observed supermicron fluorescent concentrations and modeled supermicron bacteria and fungi from Spracklen and Heald (2014) sampled along the airship coordinates at an altitude of 300m.

• Aerocom's next challenge?

Fluorescent bioaerosol at Reunion Island

March 2015 (austral summer)

Anne Perring/NOAA and Mark Hernandez/CU, PIs



WIBS provides:

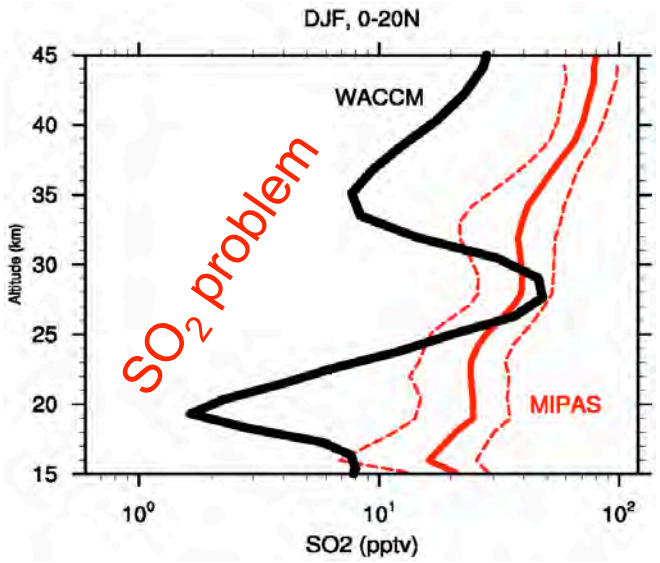
- Real-time supermicron fluorescent concentration and number distribution
- Total supermicron concentration and number distribution

Liquid impinger collection for:

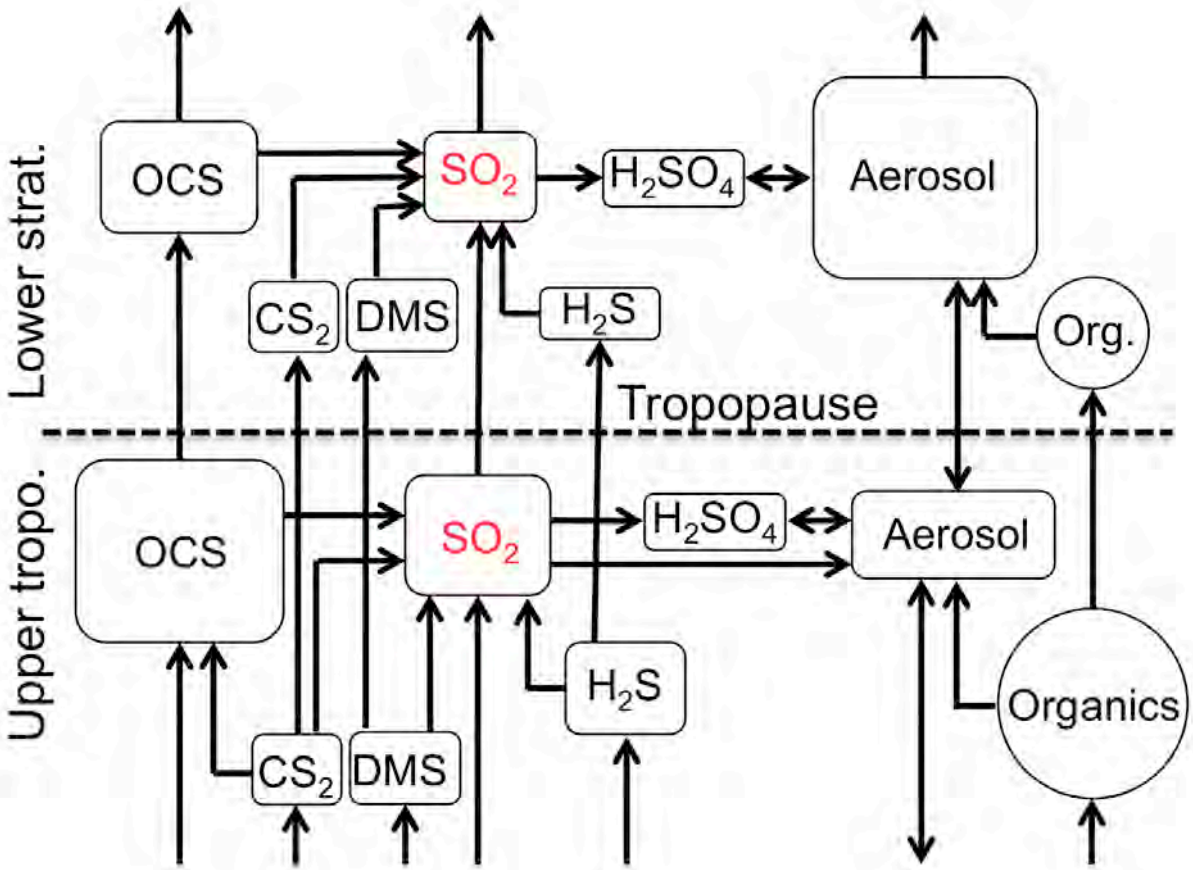
- Optical microscopy bioaerosol counts
- Microbial genetic analyses
- Bulk biological component analysis

White paper: Inventory of Sulfur and Aerosol Composition in the Upper Troposphere and Lower Stratosphere (ISAC-UTLS), Gao et al.

- Solar radiation management (SRM) is widely discussed option
- UT/LS sulfur budget is not well understood: Current SO_2 problem
- Propose new NOAA SO_2 instrument and WB-57F or Global Hawk aircraft survey mission



Höpfner et al., 2013;
Neely et al. unpublished, 2014



T. Peter, unpublished, 2014

Summary remarks

- In situ instruments have high value in shaping and guiding our understanding of the atmosphere

- Strategic measurements can transform our understanding of atmospheric issues (e.g., BC/HIPPO)

- Strategic assessments of atmospheric issues are essential to document our understanding of atmospheric issues (e.g., Bounding BC).

- New deployable instruments for AOD and AAOD could fill important observational gaps and enhance confidence in satellite retrievals and models (e.g., GOA2HEAD vertical profiles)

- ATom project will be a great leap forward

- Bioaerosol is an exciting new frontier for measurements and models.

- AeroCom is essential 'connective tissue' in our atmospheric modeling and measurements community and has a permanent role in future research (e.g., AerChemMIP)