Reflections on aerosols and climate and the future

by

David W. Fahey
Acting Director, Chemical Sciences Division
Earth System Research Laboratory
National Oceanic and Atmospheric Administration
Boulder, CO USA
Reflections on aerosols and climate and the future

Research theme: Invest in instruments, observations, and interpretation related to aerosols
Motivation: To serve the atmospheric science, aerosol modeling and policy worlds
Reflections on aerosols and climate and the future

Research theme: Invest in instruments, observations, and interpretation related to aerosols
Motivation: To serve the atmospheric science, aerosol modeling and policy worlds

Outline
• Black carbon and the Bounding BC assessment
• GOA²HEAD initiative
• ATom project
• Bioaerosol measurements
• Geoengineering
• Summary
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
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.
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, …..

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


---

**Guiding Principles: Comprehensive, quantitative, policy neutral**


- 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.

- Other initiatives needed (e.g., dust, SOA, …)
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
GOA^2HEAD: 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 GOA²HEAD 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.
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

<table>
<thead>
<tr>
<th>Species</th>
<th>Instrument(s)</th>
<th>Sampling interval</th>
<th>Data quality†</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aerosol composition and microphysics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Particle distribution (4–1000 nm)</td>
<td>AMP</td>
<td>1 s</td>
<td>14 cm(^{-1}) + 9%</td>
</tr>
<tr>
<td>Cloud drop distribution (2–50 μm)</td>
<td>AMP</td>
<td>1 s</td>
<td>20%</td>
</tr>
<tr>
<td>Black carbon mass and coating state</td>
<td>SP2</td>
<td>1 s</td>
<td>12 ng/kg + 30%</td>
</tr>
<tr>
<td>(\text{SO}_4^{2-}, \text{NO}_3^-, \text{Cl}^-, \text{NH}_4^+)</td>
<td>HR-AMS</td>
<td>1 s</td>
<td>0.1 μg/m(^3) + 35%</td>
</tr>
<tr>
<td>Organic aerosol</td>
<td>HR-AMS</td>
<td>1 s</td>
<td>0.5 μg/m(^3) + 35%</td>
</tr>
<tr>
<td>Particle O/C, H/C, and OM/OC</td>
<td>HR-AMS</td>
<td>1 s</td>
<td>0.1 μg/m(^3) + 40%</td>
</tr>
<tr>
<td>(\text{Cl}^-, \text{Na}^+, \text{Ca}^{2+})</td>
<td>SAGA filters</td>
<td>5 - 15 min</td>
<td>0.05 μg/m(^3) + 10%</td>
</tr>
<tr>
<td>(\text{SO}_4^{2-}, \text{NO}_3^-, \text{Br}^-, \text{C}_2\text{O}_4^{2-}, \text{NH}_4^+, \text{K}^+, \text{Mg}^{2+})</td>
<td>SAGA filters</td>
<td>5 - 15 min</td>
<td>0.02 μg/m(^3) + 10%</td>
</tr>
<tr>
<td>(^{7}\text{Be})</td>
<td>SAGA filters</td>
<td>5 – 15 min</td>
<td>25 fCi/m(^3) + 5%</td>
</tr>
<tr>
<td>(^{210}\text{Pb})</td>
<td>SAGA filters</td>
<td>5 – 15 min</td>
<td>0.5 fCi/m(^3) + 10%</td>
</tr>
</tbody>
</table>

- ATom aerosol observations will far exceed the HIPPO payload
Global model simulations of new particle nucleation rates

(a) ion-assisted nucleation rates

(b) neutral 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

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

Hoose 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;

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.

Burrows et al., 2013
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
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

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)