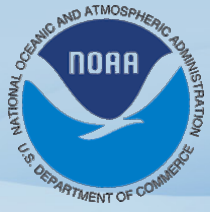


PMEL

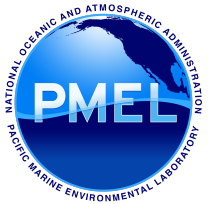
Pacific Marine Environmental Laboratory

Climate

Atmospheric Chemistry

Trish Quinn

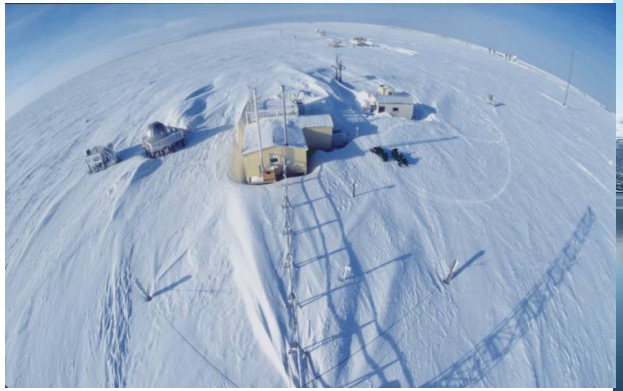
Tim Bates, Co-PI (JISAO)
Derek Coffman and Kristen Schulz
Jim Johnson and Drew Hamilton (JISAO)
Langley deWitt (NRC Post Doc 2010 – 2012)
Priya Murthy, Maria Zatko, Megan Haserodt (Hollings Scholars)



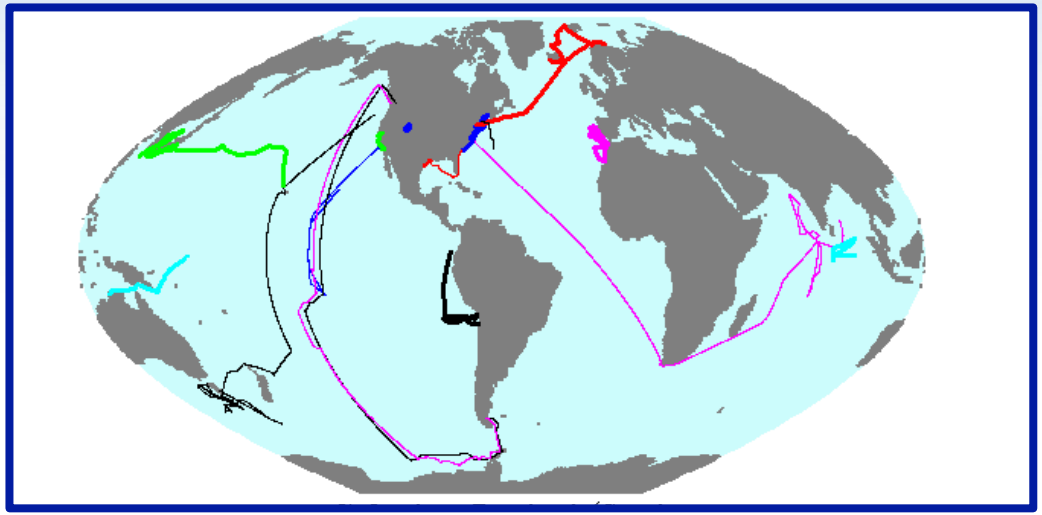
Background

Atmospheric Chemistry Group's Primary Objective:

Lead and participate in intensive field campaigns and long term monitoring to determine the impact of atmospheric aerosol particles on climate and air quality.



Atmospheric Chemistry Cruises and Land-Based Measurements 1992 - 2012



19 Cruises
5 since 2008

- Process oriented, intensive field experiments

12 Land-Based Experiments
4 since 2008

- Process oriented, intensive field experiments
- Long-term monitoring observations

NOAA's Long-Term Goals

Climate Adaptation and Mitigation

Objective: Improved scientific understanding of the changing climate system and its impacts

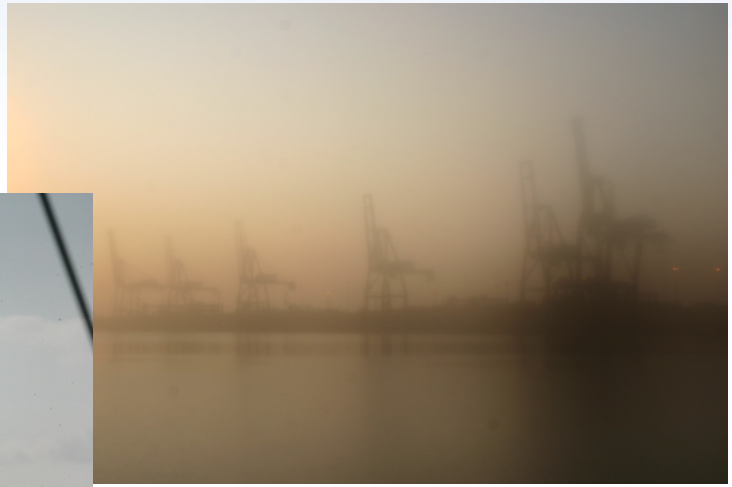
"This will require answering key questions that limit scientific understanding of … atmospheric composition (clouds, aerosols, precipitation)…. NOAA must integrate this knowledge into models to improve predictive capabilities…"

IPCC 2013

"Clouds and aerosol continue to contribute the largest uncertainty to estimates and interpretations of the Earth's changing energy budget."

Weather Ready Nation

Objective: Healthy people and communities due to improved air and water quality services

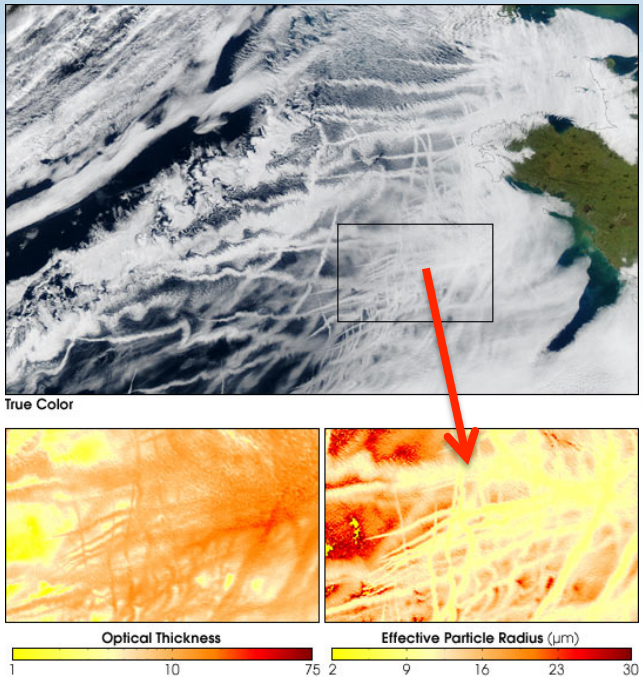


Primary Objectives since 2008

Relevance

- **Objective #1**: Provide data to improve the parameterization of the sources and climate impacts of ocean-derived aerosol in global models.
- **Objective #2**: Characterize sources of atmospheric aerosols, atmospheric processing and removal of those aerosols, and their impact air quality.
- **Objective** #3: Assess properties, trends, and climate impacts of short-lived climate forcers that are transported from the mid-latitudes to the Arctic.

Objective #1: Provide data to improve the parameterization of the sources and climate impacts of ocean-derived aerosol in global models

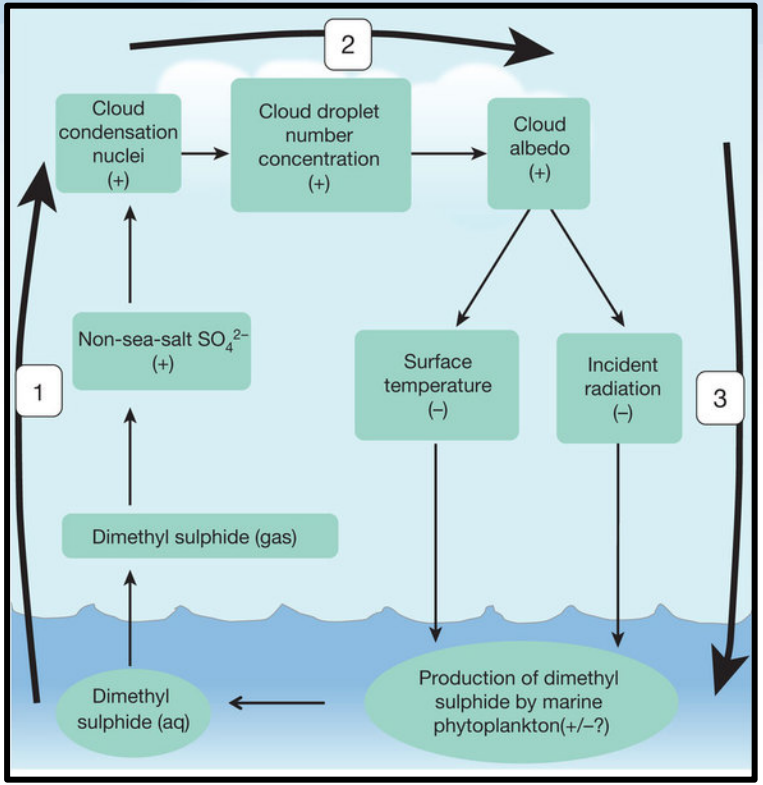


Cloud drop radius

Accurate modeling of the impact of aerosols on clouds in marine regions requires knowing the sources and properties of cloud condensation nuclei in the marine boundary layer.

Credit: NASA GSFC

1980s view of the source of cloud condensation nuclei to the marine atmosphere

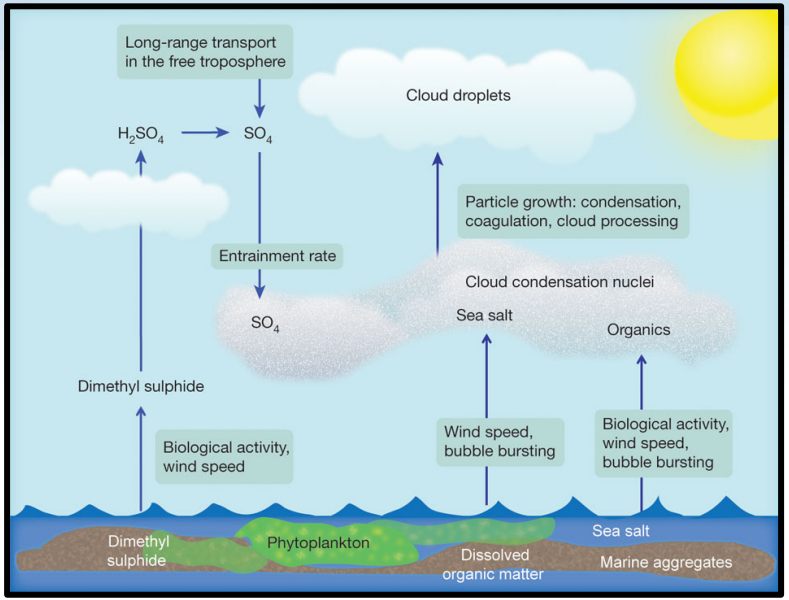


Hypothesized bio-regulation of climate:

- Proposed in 1987 as a climate feedback loop between cloud albedo and surface ocean dimethylsulfide (DMS) concentrations
- Relies on DMS being the primary source of cloud condensation nuclei to the marine atmosphere
- Relies on local production of particles from the gas phase oxidation of DMS

Charlson et al., *Nature*, 1987

Paradigm shift: Updated View of Sources of Cloud Condensation Nuclei to the Atmosphere

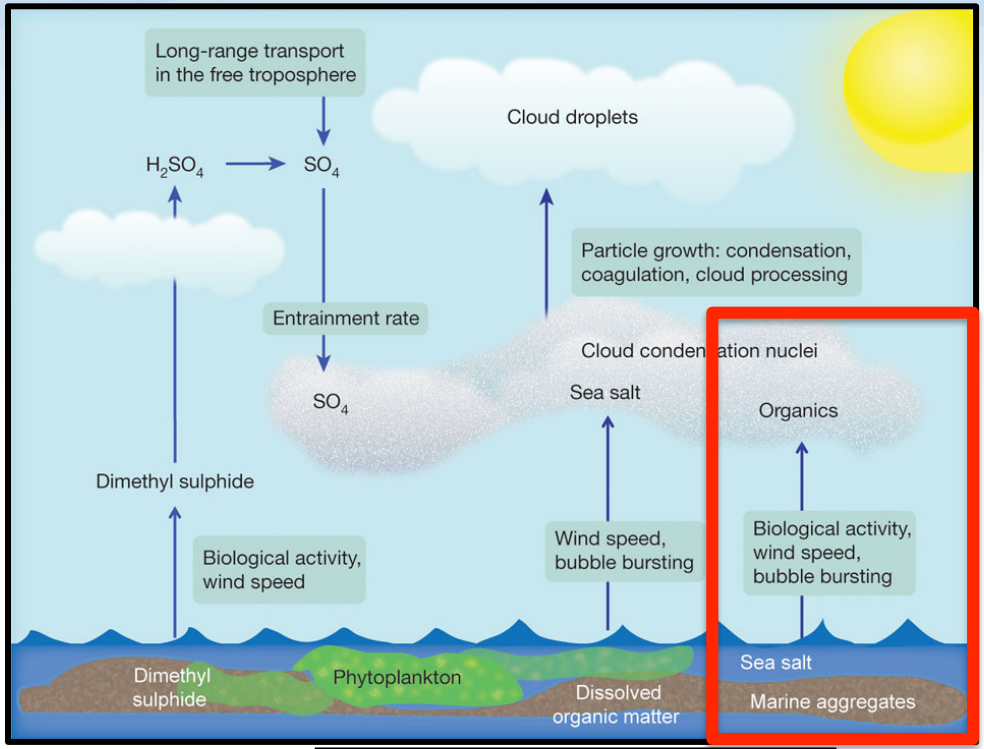


Quinn and Bates, The case against climate regulation via oceanic phytoplankton sulfur emissions, *Nature*, 2011.

Observations in the marine boundary layer over the past 25 years have shown:

- Sources of marine boundary layer CCN are much more complex than previously thought
- Local production of particles from DMS oxidation is rare in the marine boundary layer
- Sea spray aerosol and long range transport of continental emissions prevent DMS from being the primary CCN source

Sources of Cloud Condensation Nuclei to the Atmosphere

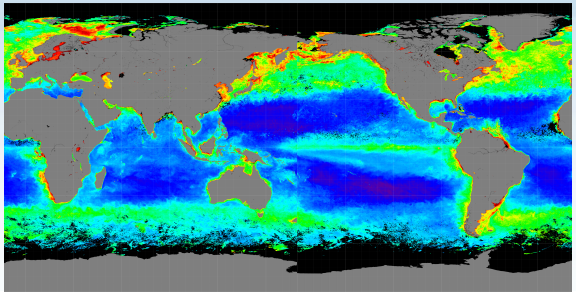


Quinn and Bates, *Nature*, 2011.

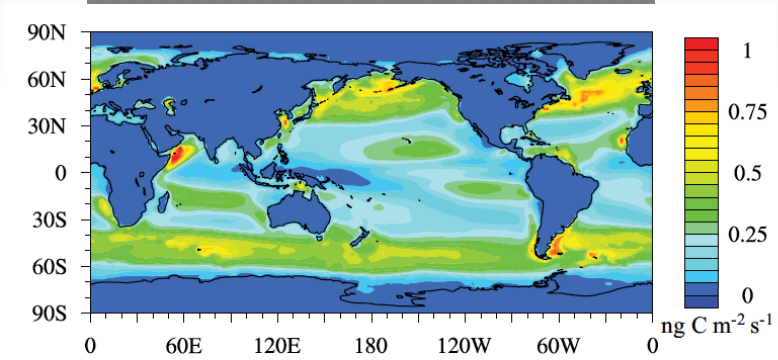
- Organic matter affects the ability of a particle to nucleate a cloud droplet
- Requires that global models are able to accurately parameterize the emission of the organic fraction of sea spray aerosol

Parameterizing the Sources of Cloud Condensation Nuclei to the Marine Atmosphere

MODIS composite image of Chl *a* for Spring 2010



Emission rate of sea spray organics based on Chl *a*



Gantt et al., ACP, 2011

- Currently, all models use an emission parameterization for sea spray aerosol organics based on surface seawater chlorophyll-a concentrations
- Lack of *in situ* measurements to assess the validity of chlorophyll-a as a proxy for sea spray aerosol organics

Sea Sweep

Sampling of freshly emitted sea spray aerosol

Inlet to sampling mast

Bates et al., *JGR*, 2012

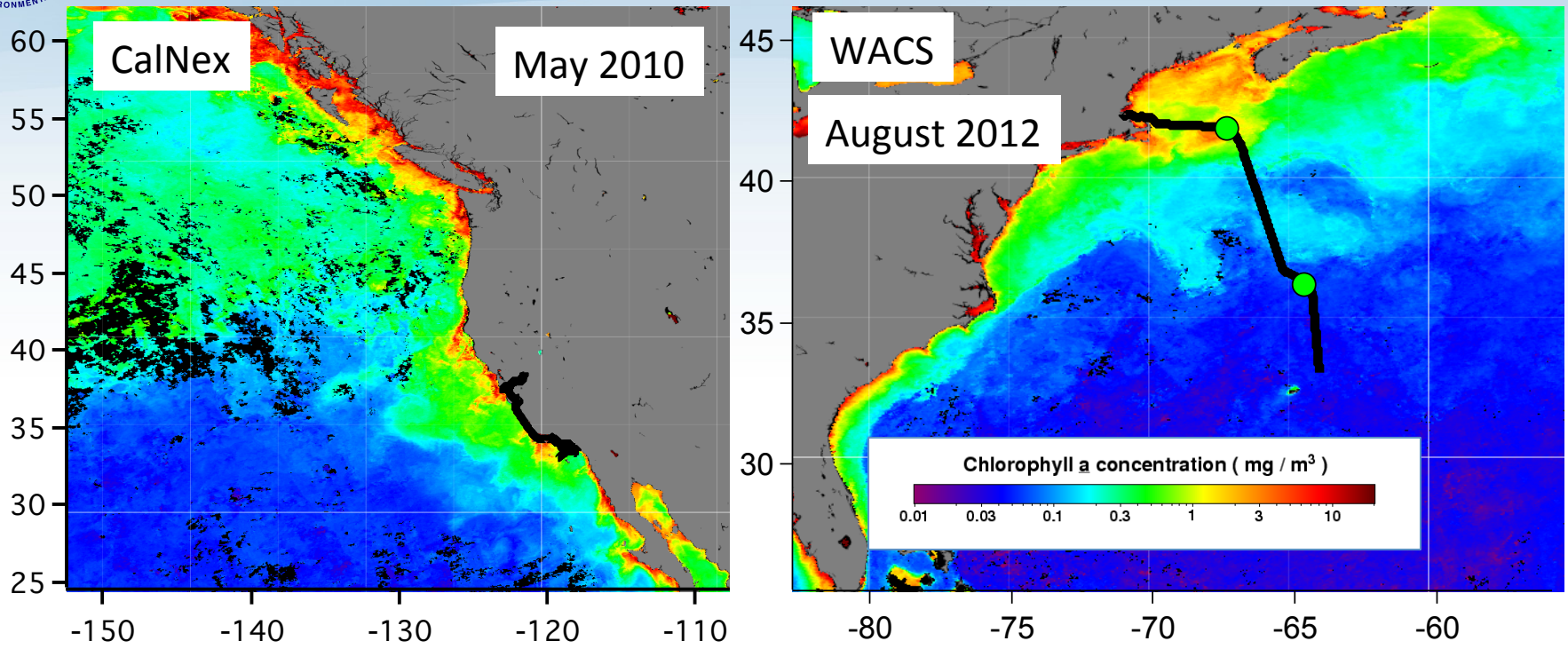
Particle-free air

Air Curtain

Air Curtain to seal off nascent sea spray aerosol from ambient particles and gases

Frits 1 m below surface

CalNex and WACS: Measurements of freshly emitted sea spray aerosol properties in regions of high and low chlorophyll seawater



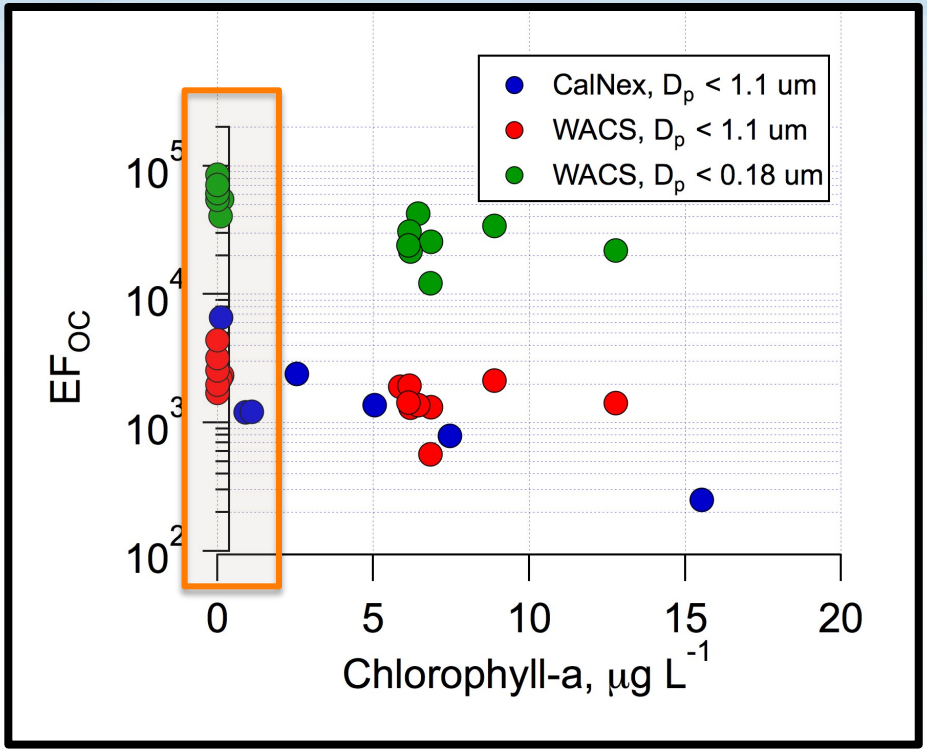
Source MODIS Data Credit: NASA/GSFC/OBPG
http://oceancolor.gsfc.nasa.gov/cgi/l3

Do strong regional differences in phytoplankton biomass, as represented by Chl *a,* impact the properties of freshly emitted sea spray aerosol?

Organic Carbon Enrichment Factor for Sea Spray Aerosol Relative to Seawater:

$$EF_{OC} = \frac{[(OC \text{ as } C) / Na^{+}]_{SSA}}{[(OC \text{ as } C) / Na^{+}]_{seawater}}$$

Organic Enrichment in Sea Spray Aerosol and Chlorophyll-a Concentration



Paradigm shift: Large organic enrichments in low-chlorophyll Sargasso Seawater reveals a pool of surface seawater organic matter that is not directly associated with Chl *a* and phytoplankton biomass, but is available for incorporation into nascent SSA.

Quinn et al., Contribution of sea surface carbon to organic matter enrichment in sea spray aerosol, *Nature Geoscience*, 2014

Objective #2: Characterize sources of atmospheric aerosols, atmospheric processing and removal of those aerosols, and their impact on air quality.

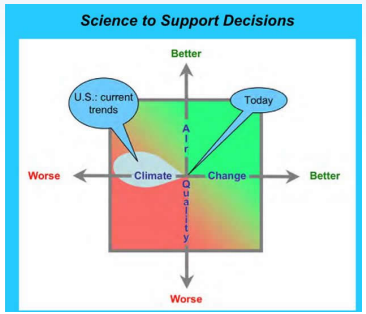
2002, 2004

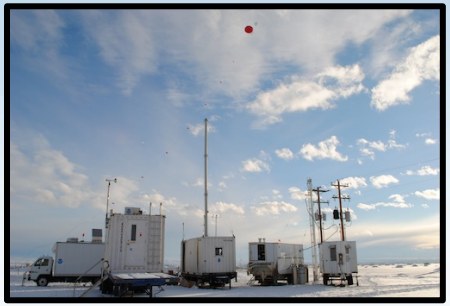
NEW ENGLAND AIR QUALITY STUDY

INTERNATIONAL 2007 2008 POLAR YEAR

2006 The Texas Air Quality Study

CalNex 2010



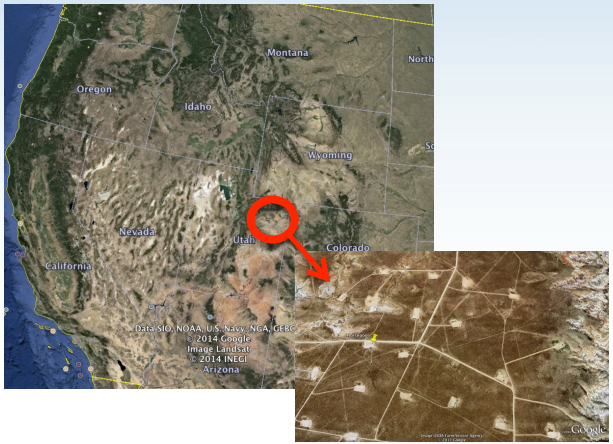


UBWOS
2012, 2013, 2014

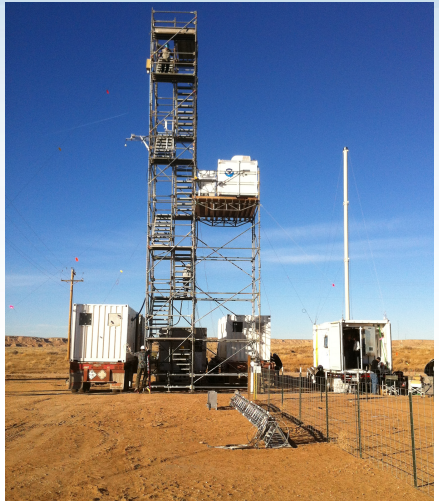
Series of bi-annual climate and air quality experiments conducted in partnership with NOAA OAR's Earth System Research Laboratory

Uintah Basin Wintertime Ozone Study (UBWOS)

Oil and Gas Fields



2012



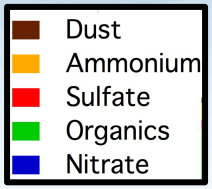
2013

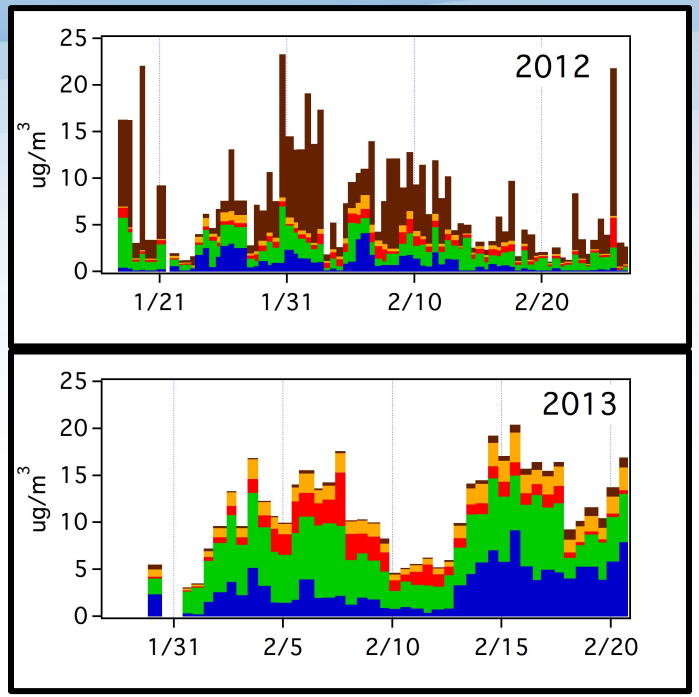
- Conducted in 2012, 2013, and 2014 to determine the causes of high wintertime ozone observed in the oil and gas fields of the Uintah Basin in northeast Utah

- In partnership with NOAA ESRL, U. Utah, U. Colorado, and U. Washington

Contrast in UBWOS 2012 and 2013 reveals information about O_3 formation

Aerosol Chemical Composition

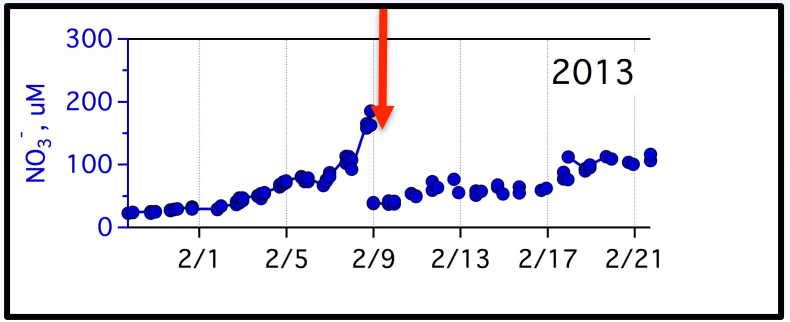




- Snow -> temperature inversion
- High aerosol NO3 and organic levels
- Ozone 8 hr average >> 75 ppbv

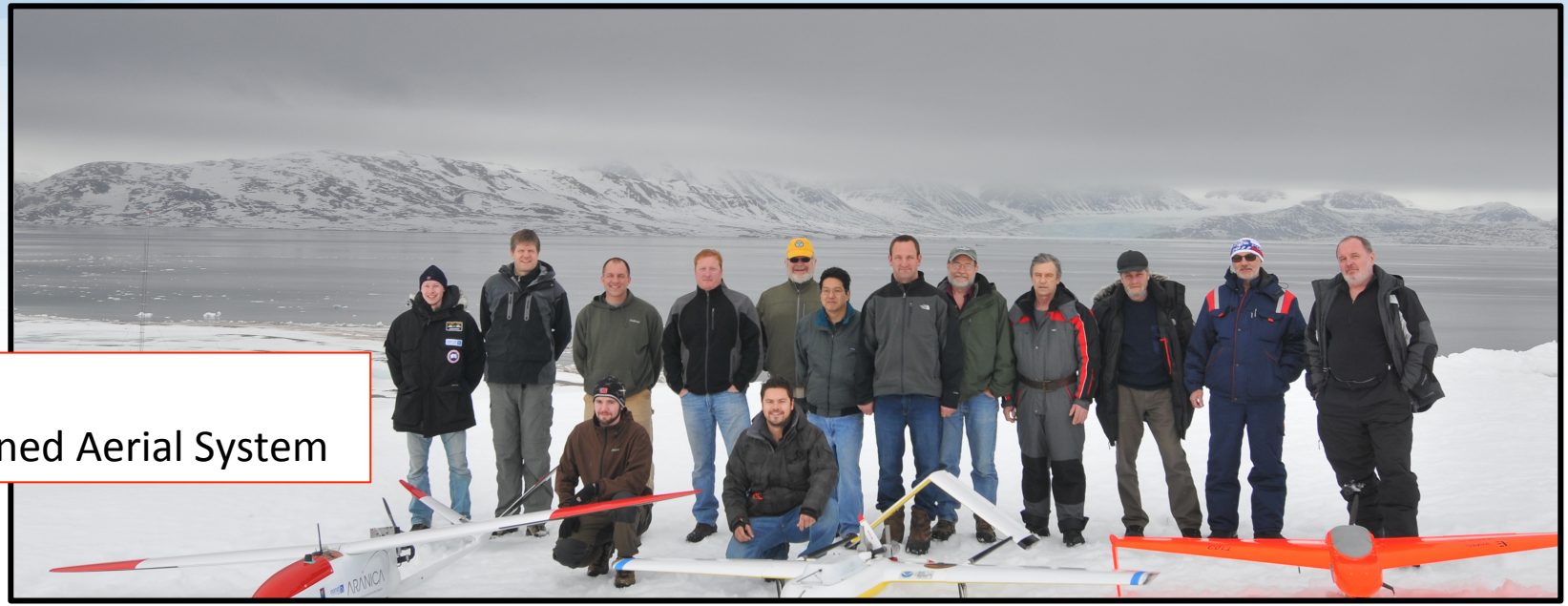
- No snow -> no temperature inversion
- Relatively low aerosol NO3 levels
- No ozone exceedances
  (8 hr average << 75 ppbv)

Fresh Snow



- Build up of NO3 in surface snow
- Increase in atmospheric O3 due to NO3 photochemistry in snow

Objective #3: Assess properties, trends, and climate impacts of short-lived climate forcers that are transported from the mid-latitudes to the Arctic



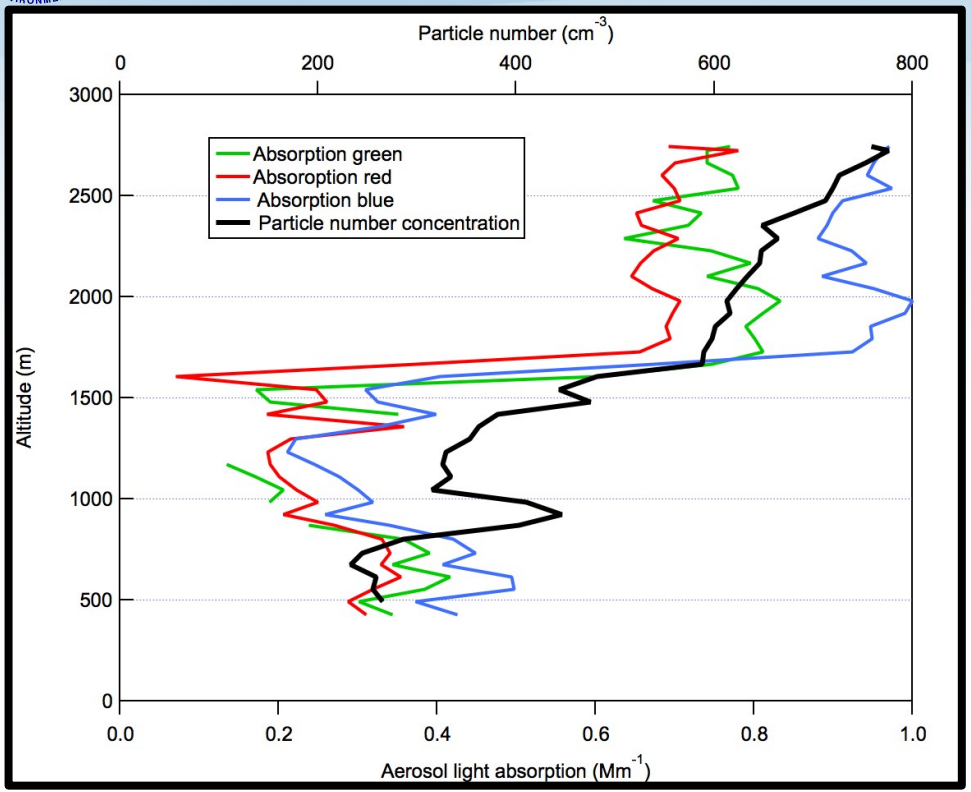
UAS:
Unmanned Aerial System

CICCI 2011: Cooperative Investigation of Climate-Cryosphere Interaction

Norwegian, Russian, Italian, and German partners

CICCI: UAS vertical profiles of aerosol number concentration and absorption

19 flights, 40 flight hours



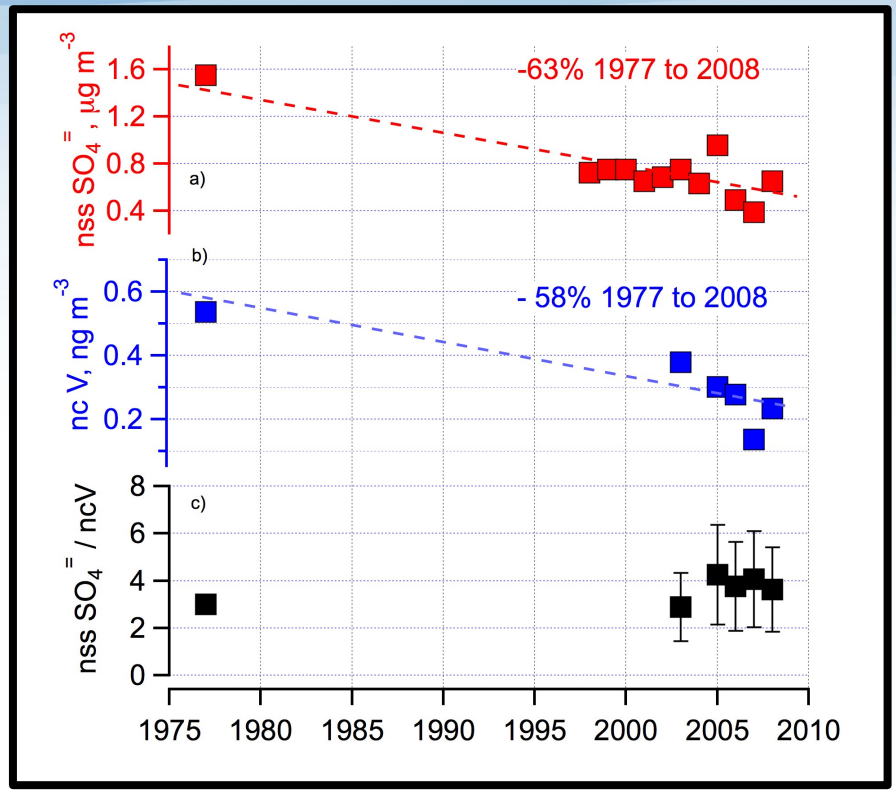
- Proof of concept
- Potential for routine observations of aerosol vertical profiles in the Arctic

Layer of enhanced particle concentration and absorption

Layer of enhanced particle concentration but no absorption

Bates et al., *AMT*, 2013

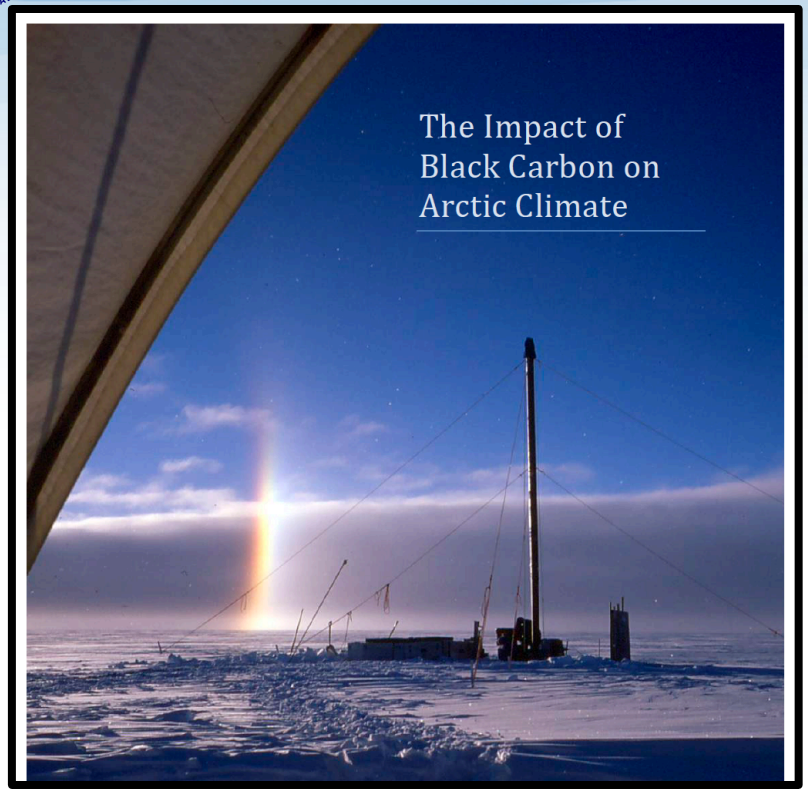
Decadal Trends in Short-Lived Climate Forcers in the Arctic



- One of the longest records of sulfate aerosol concentrations in the Arctic.
- Concentrations have decreased but source regions have remained the same.
- Measurements made in partnership with NOAA ESRL GMD and U. Alaska.

Quinn et al., *ACP*, 2009.

Arctic Monitoring and Assessment Programme's first Assessment of the Impacts of Black Carbon on Arctic Climate



- Background information on BC (emission regions and sectors, properties, transport pathways to the Arctic, etc.)
- Trends in Arctic BC in snow and aerosol
- Model simulated radiative forcing

Quinn et al., *AMAP*, 2011.

Summary

Quality and Performance

Results:

- *In situ* measurements of aerosol properties revealed complexity of sources of CCN to the marine boundary layer
- New Sea Sweep technology revealed an unrecognized ocean carbon pool available for incorporation into sea spray aerosol
- Improved understanding of the causes of ozone build-up and poor air quality in the oil and gas fields of the Uintah Basin
- Developed UAS technology for vertical profiling of aerosol properties in the Arctic
- Assessed trends of short-lived climate forcers in the Arctic
- Produced AMAP's 1st assessment on the impact of BC on Arctic climate

Summary

Quality and Performance

Beneficiaries:

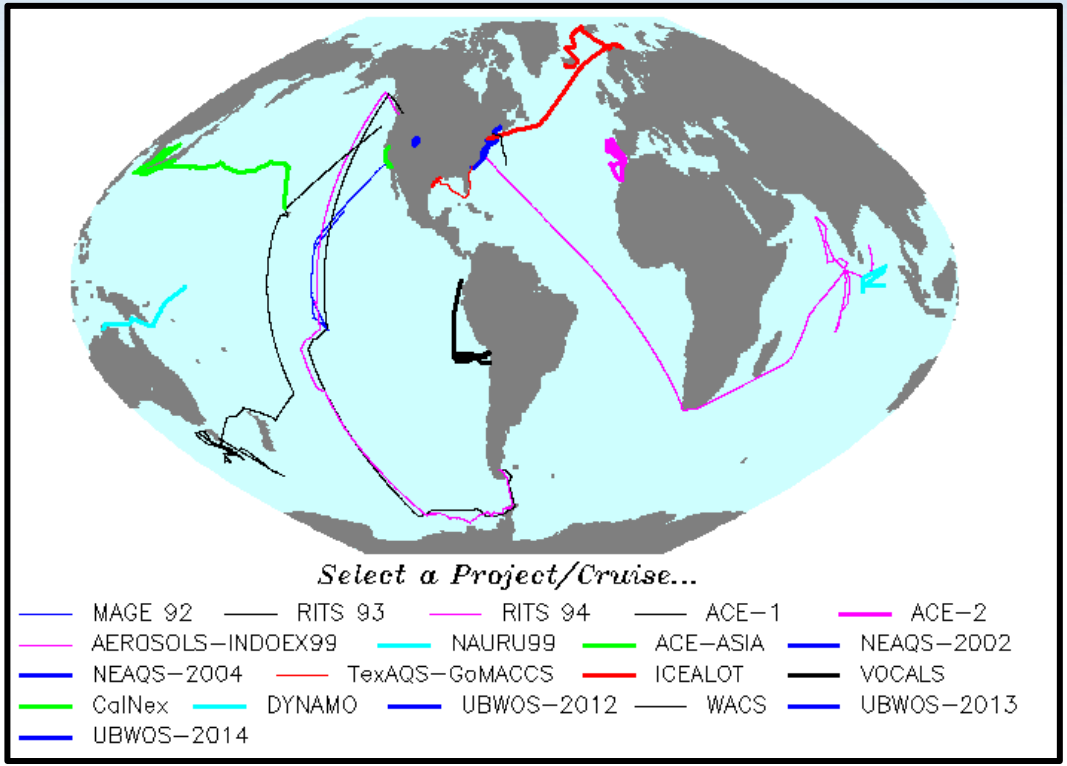
- Climate and air quality modeling, regulatory, policy making, and assessment communities

Products:

- 75 peer reviewed articles since 2008
- 5,690 citations since 2008 (Web of Science)
- Largest global data base of marine boundary layer aerosol properties

Global data base of aerosol properties
saga.pmel.noaa.gov/data/

Quality and Performance



Future Directions

- Ocean-derived aerosol
  - WACS2 2014
  - SOCRATES 2018
- Arctic aerosol
  - Svalbard 2015
  - AMAP 2nd Assessment on "The Impact of BC and Tropospheric Ozone on Arctic Climate" to be completed 2015