The NOAA Chemical Sciences Laboratory Airborne Research Program

Measurement Capabilities, Emerging Technologies and Needs for Air Quality and Climate Research

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NOAA CHEMICAL SCIENCES LABORATORY

CIRES

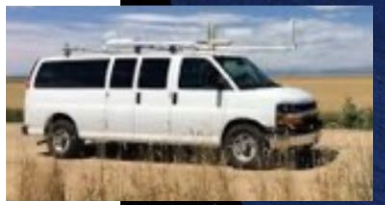
NOAA Chemical Sciences Laboratory

NOAA CSL Mission: To advance scientific understanding of the chemical and physical processes that affect Earth's atmospheric composition and climate

NOAA CSL Vision: A nation with the best scientific understanding and information about atmospheric chemistry and composition necessary to make optimal decisions for current and future generations

NOAA CSL Method: Field observations, Instrument development, Modeling, Laboratory studies

North American Tropospheric Airborne Campaigns

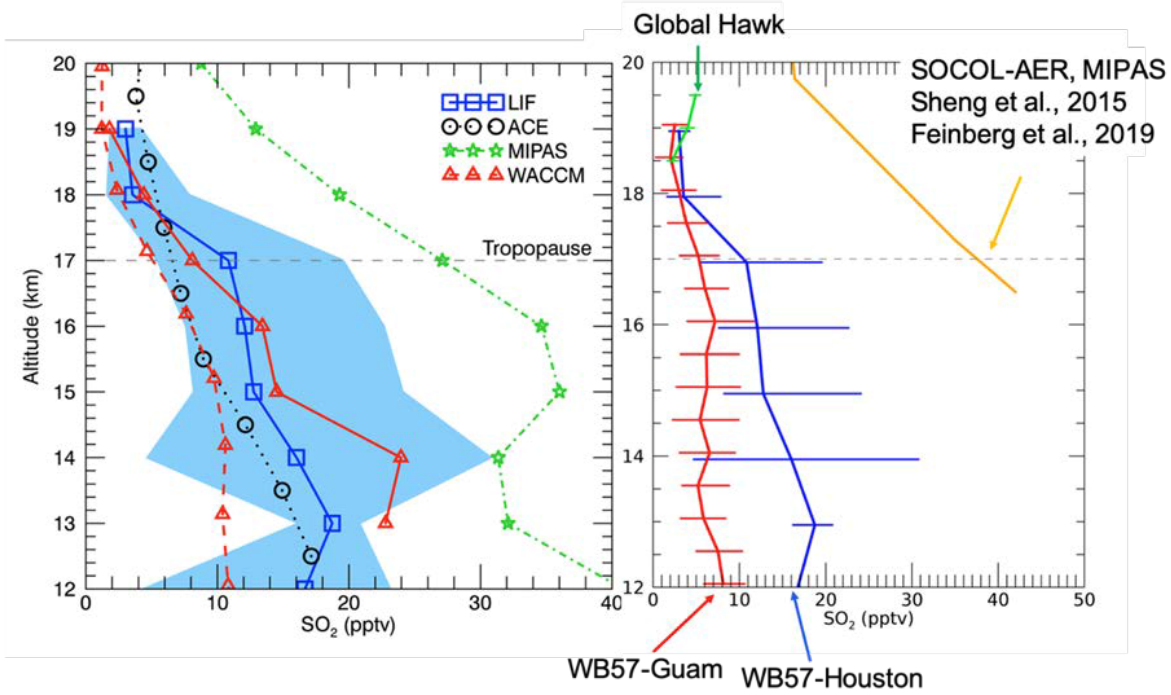


- NOAA CSL airborne program spanning decades & sampling locations multiple times
- Changing science focus over time
  - Urban air quality
  - Agriculture
  - Oil and gas
  - The Arctic
  - Biomass burning
  - Biogenic emissions
  - Boundary layer met

Stratospheric Airborne Research

CSL makes observations of trace species from aircraft to guide the understanding of physical, chemical and dynamical processes affecting stratospheric composition.

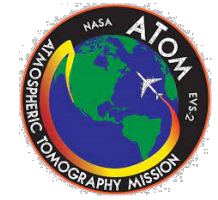
Existing and well exercised CSL instruments include: water vapor & ozone; SO_2 (LIF) was developed recently and flew during VIRGAS and POSIDON, providing the first survey of SO_2 in the tropics up to the lower stratosphere.

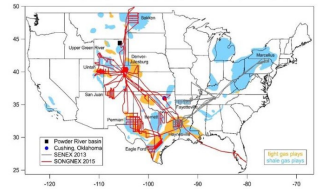


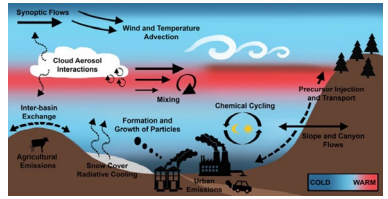
Slide Courtesy of Karen Rosenlof, NOAA CSL

Scientific Goals & Recent Airborne Field Intensives

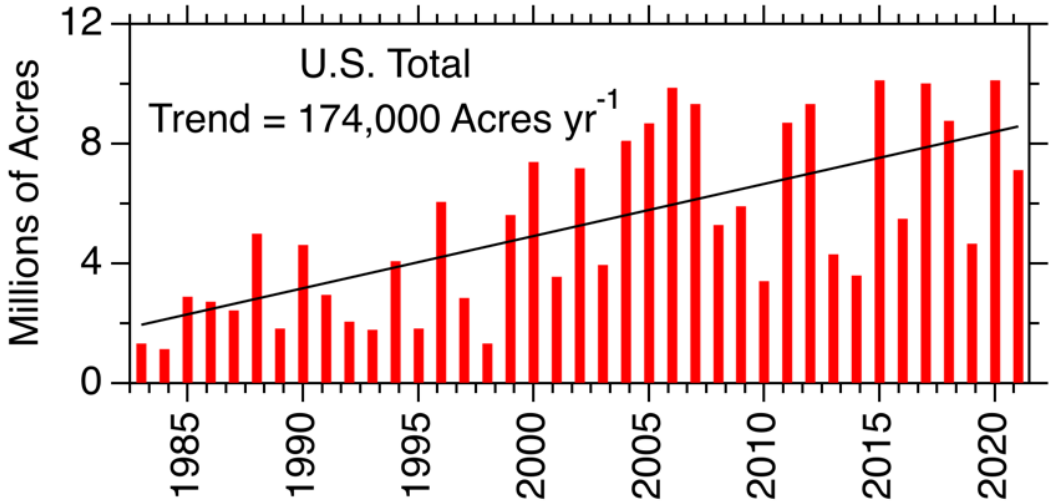
- Biomass Burning
  - Fire Influence on Regional to Global Environments Experiment (FIREX-AQ 2019)
- Urban Air Quality, Geostationary Remote Sensing, BL Dynamics
  - Atmospheric Emissions and Reactivity Observed from Megacities to Marine Areas (AEROMMA) & Coastal Urban Plume Dynamics Study (CUPiDS) 2023
- Global Atmospheric Composition, Remote Atmosphere
  - Atmospheric Tomography (ATom, 2016-2018)
- Oil and Gas, Greenhouse Gas Emissions
  - Shale Oil and Natural Gas Nexus (SONGNex, 2015)
- Stratospheric Composition, Solar Radiation Management
  - Stratospheric Aerosol Processes, Budget and Radiative Effects (SABRE, 2023)
- Air Quality Research in the Western U.S. (AQUARIUS, 2026)

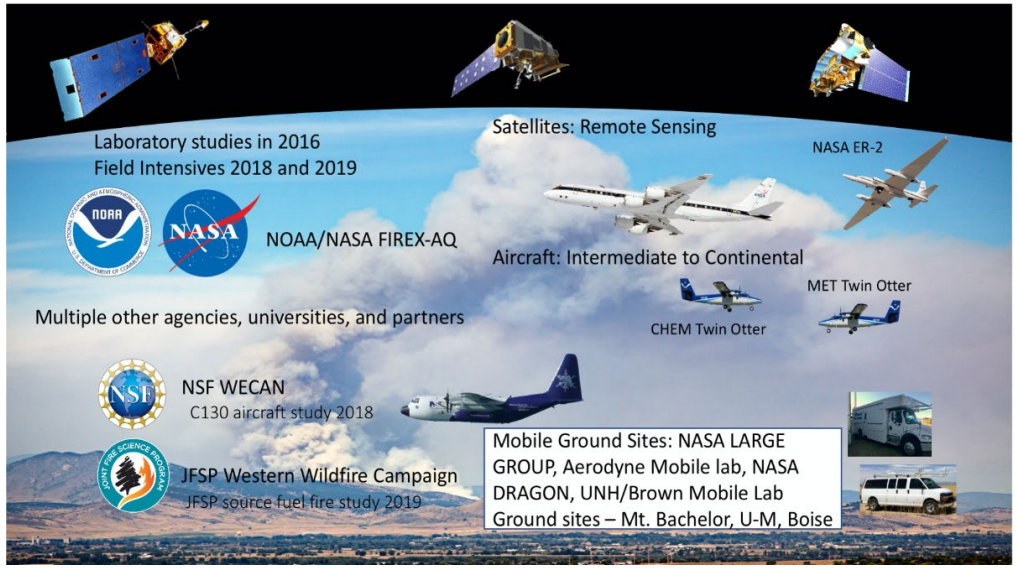




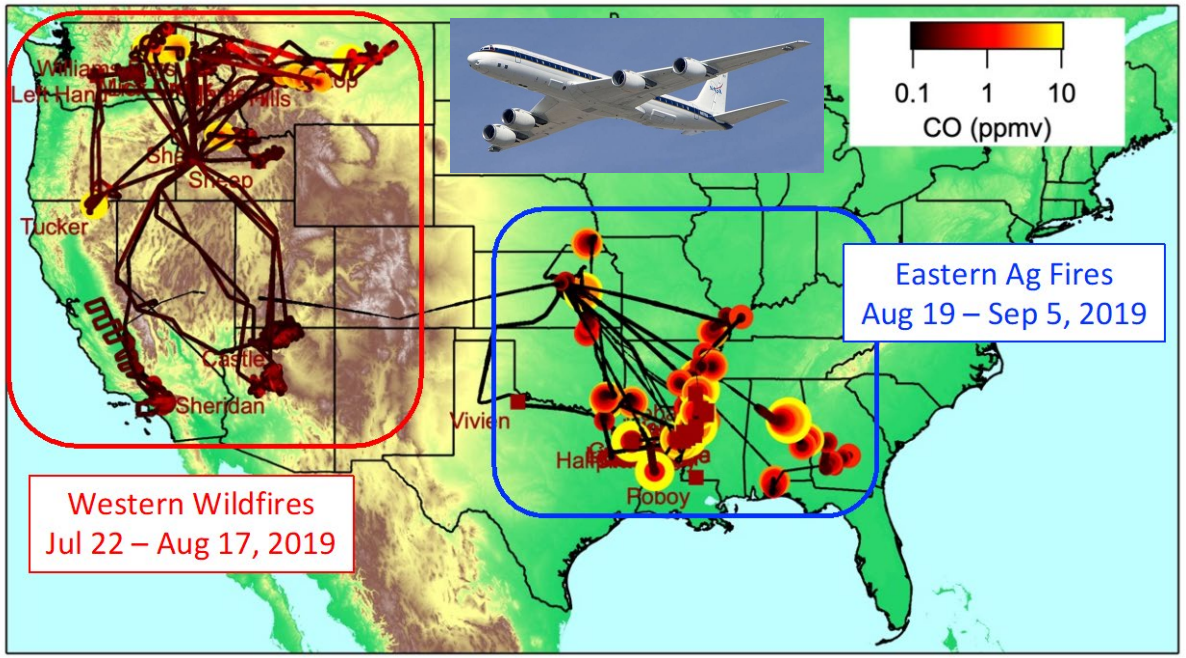


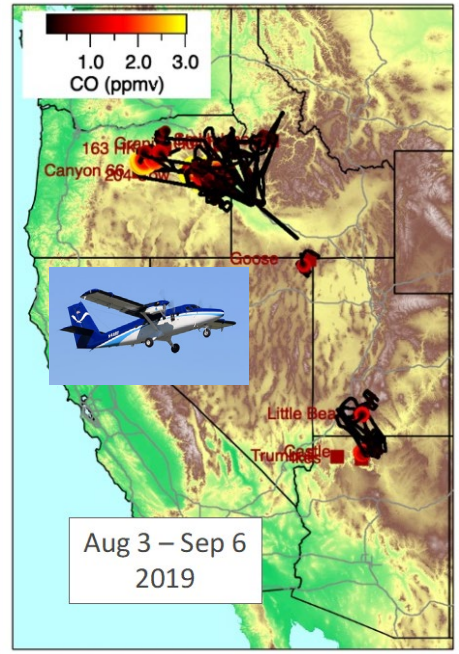
Fire Influence on Regional to Global Environments (FIREX-AQ)





- U.S. wildfire frequency, severity and area burned has increased over 4 decades
- Trend has motivated multiple fire research efforts (e.g., WE-CAN)
- NOAA - NASA FIREX-AQ 2019 involved multiple aircraft to sample wildfire and agricultural burning





AEROMMA, STAQS & CUPiDS (AGES+) 2023

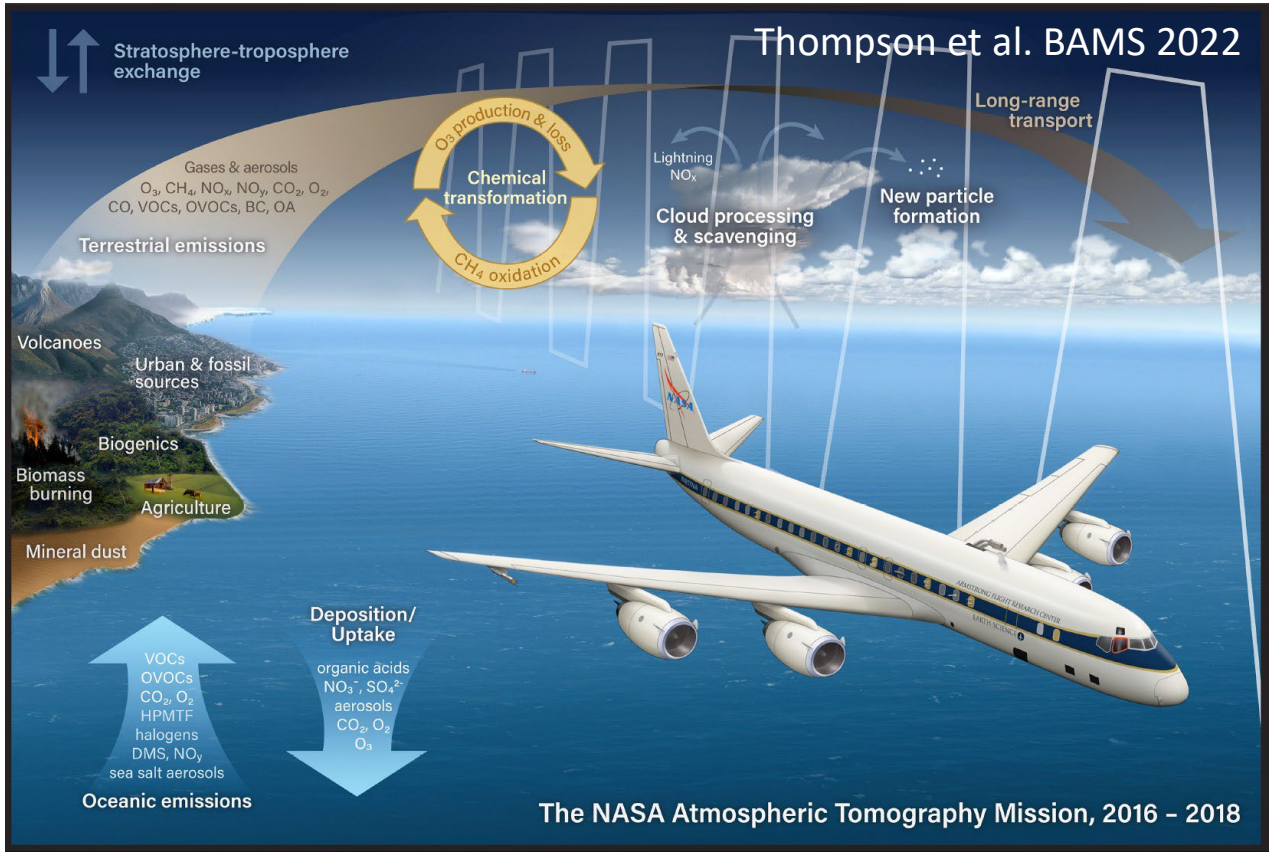
AEROMMA: NOAA campaign on DC-8 supported by NESDIS GeoXO

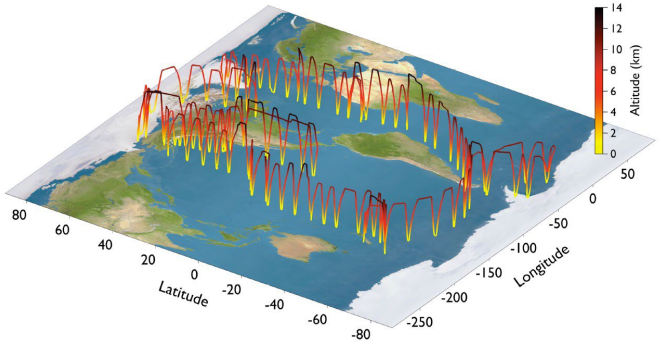
STAQS: NASA G-V & G-III remote sensing coordinated with DC-8

CUPiDS: NOAA Twin Otter, NYC Focus, Boundary Layer Dynamics

- New paradigms in emissions and the future of urban air quality
- Recent discoveries of the marine atmosphere, sulfur cycle
- Geostationary remote sensing of atmospheric composition

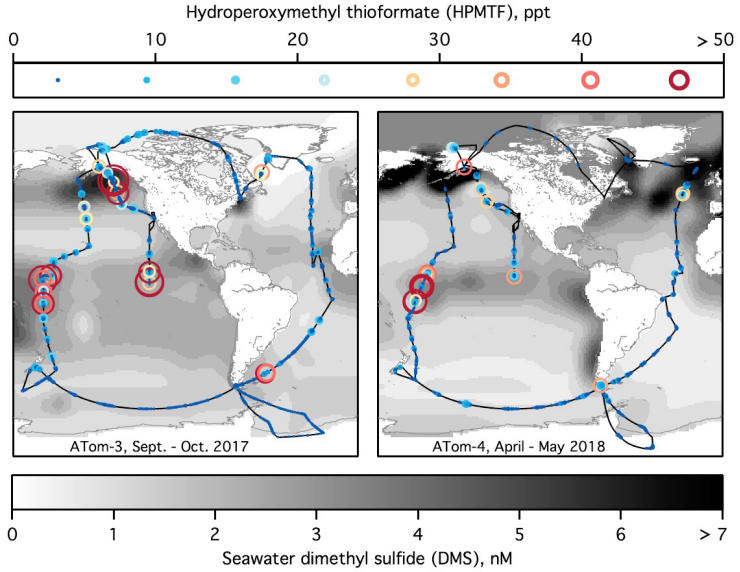
Atmospheric Tomography (ATom)



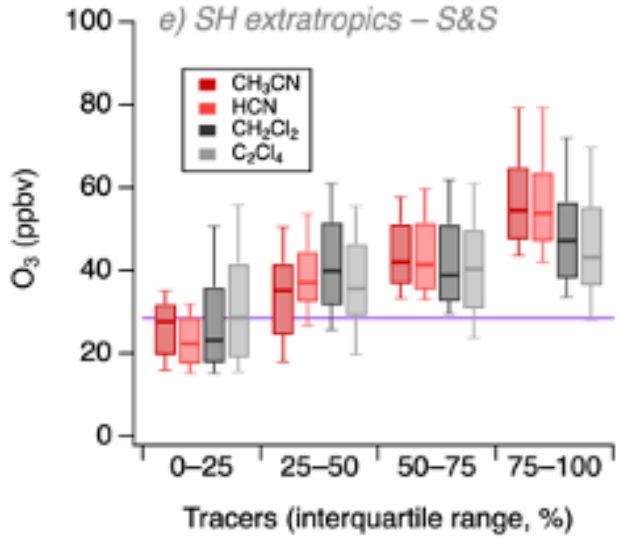


- Sampling of remote atmosphere to provide constraints for global models
- Highly collaborative effort – NASA; NOAA CSL, GML; NCAR; Academic
- Numerous high profile results

Veres et al., PNAS 2020: Discovery of HPMTF rewrites understanding of global marine sulfur cycle

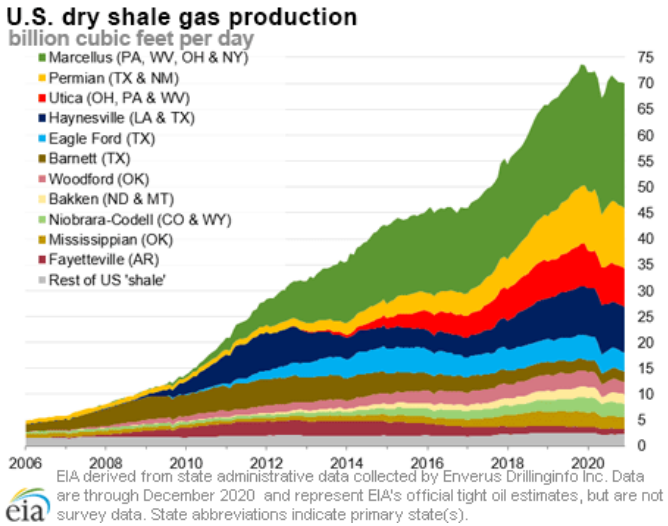


Bourgeois et al., PNAS 2021: Widespread influence of biomass burning on ozone at global scale

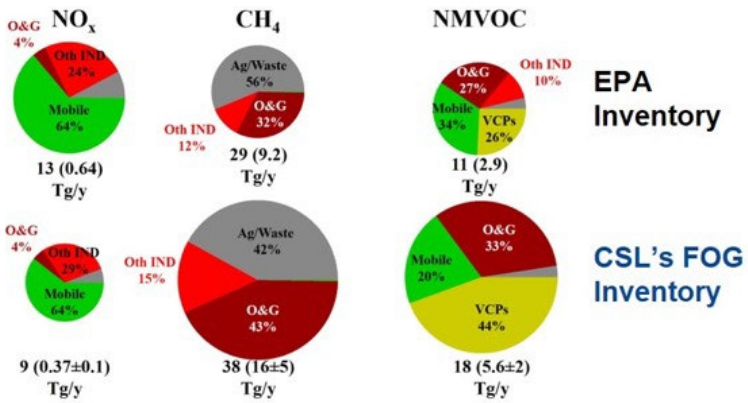


Shale Oil and Natural Gas Nexus (SONGNEx 2015)

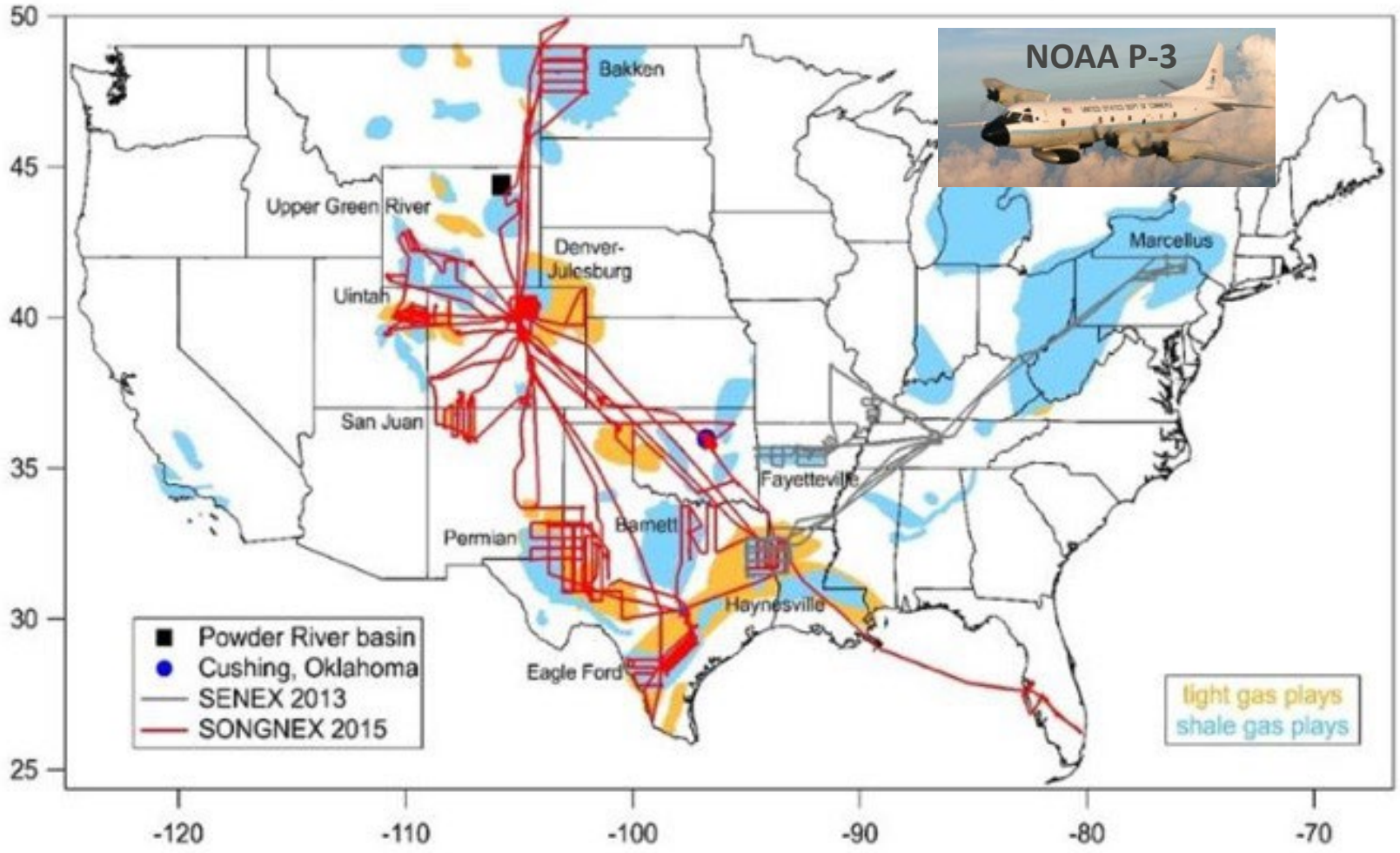
Dramatic increase in U.S. oil and gas production



Measurements Inform Inventories

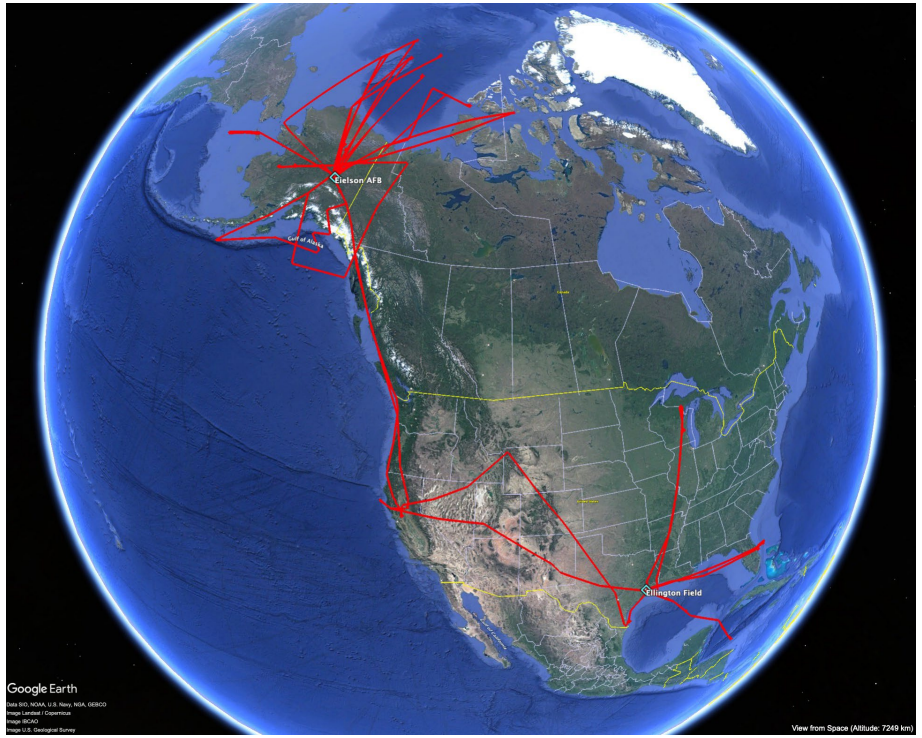


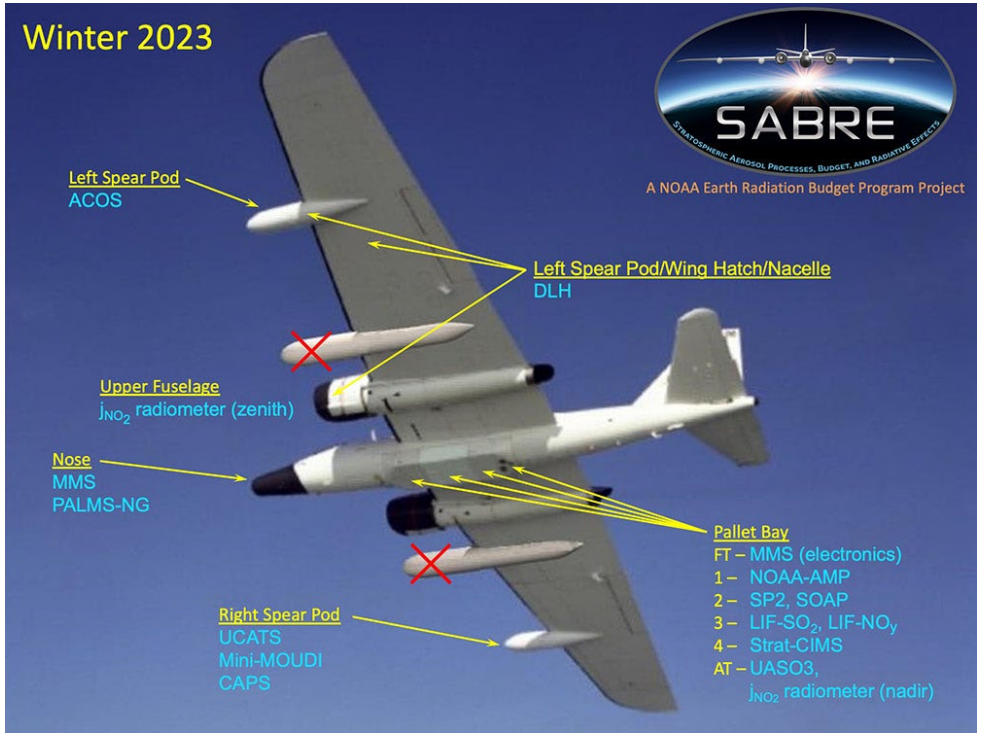
NOAA CSL campaigns sample >70% and 83% of U.S. Shale Oil and Gas Production



SONGNex 2015, SENex 2013, TOPDOWN 2014

Stratospheric Aerosol Budget, Processes and Radiative Effects (SABRE 2023)





SABRE
Stratospheric Aerosol Processes, Budget, and Radiative Effects

- Transport, chemistry, microphysics and radiative properties of aerosols in the upper troposphere and lower stratosphere (UTLS).
- Aerosol size distributions, composition and radiative properties along with relevant trace gas species in different regions and seasons.
- Improve global models of the radiative, dynamical and chemical impacts of changes to stratospheric aerosol loading

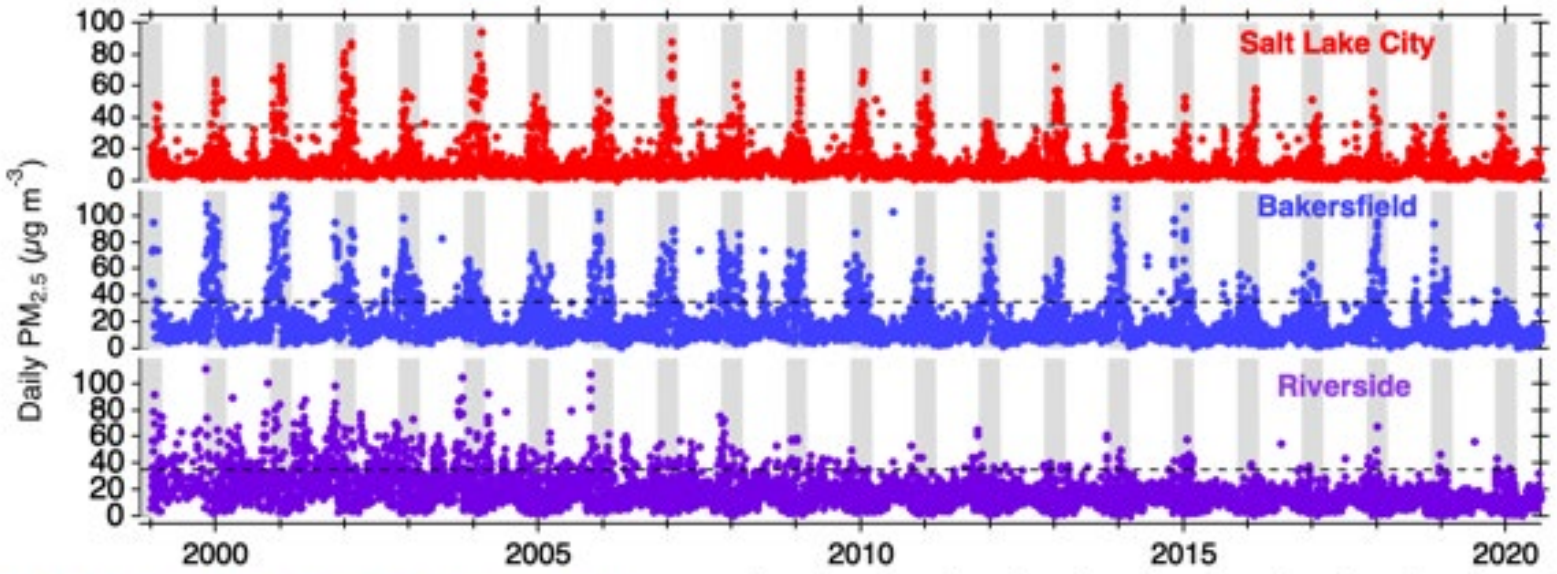
Air Quality Research in the Western U.S. (AQUARIIUS 2026)

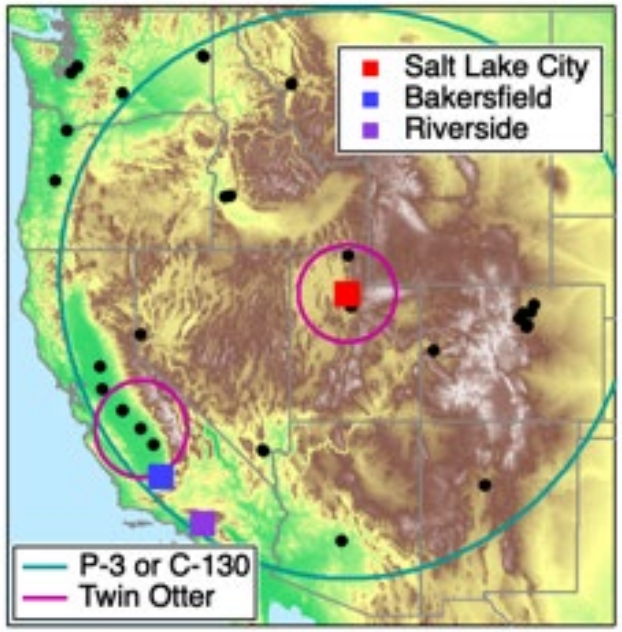
Workshop, Salt Lake City 2019

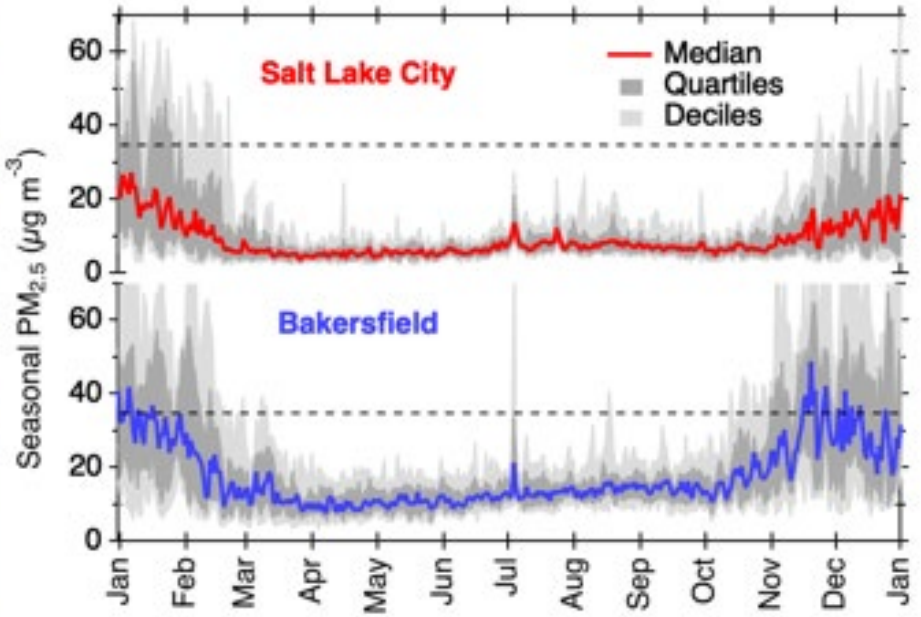
Major Scientific Questions

- Meteorology – chemistry Interactions
- Wintertime chemical processes
- $PM_{2.5}$ formation & thermodynamics
- Emissions and pollutant transport
- Seasonality in remote sensing

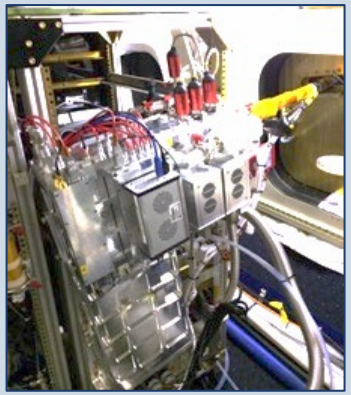
Now planned for winter (Jan – Mar) 2026







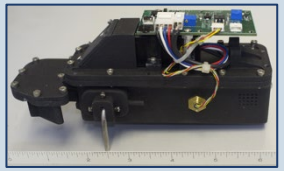
Instrument Development



Mass spectrometers

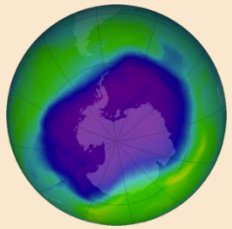
Optical and laser-based instruments

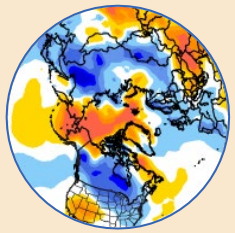
Miniaturized, 3-D printed instruments for UAVs

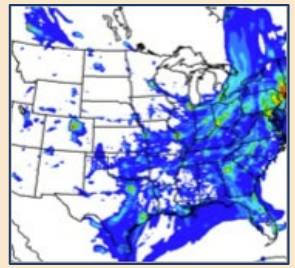


Global chemistry & climate models

Regional chemistry & transport models







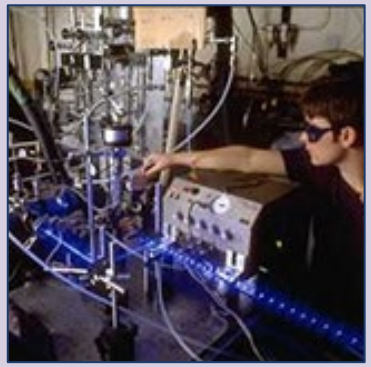
NOAA P-3 Orion

NOAA Twin Otter

Airborne missions

Ground sites

Ship cruises

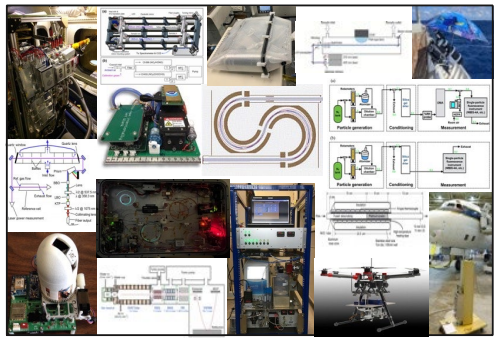


Chemical kinetics

Characterization of fundamental atmospheric chemical processes

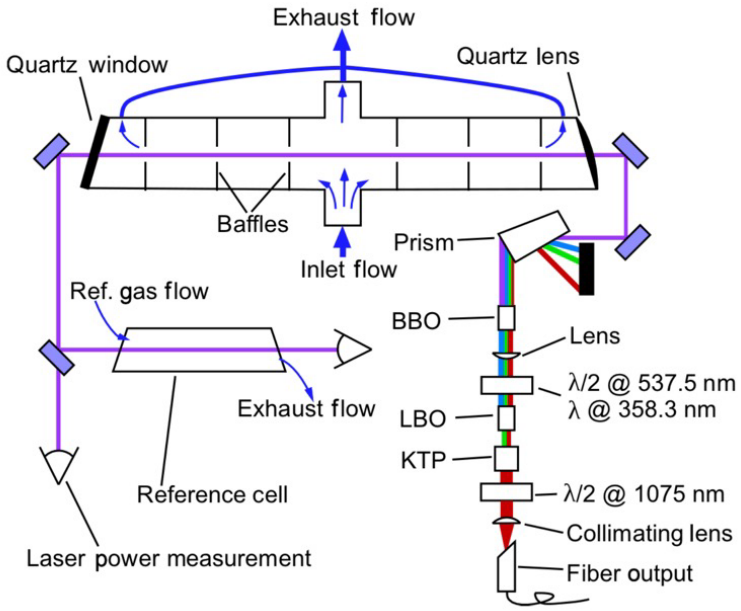
Theoretical computations

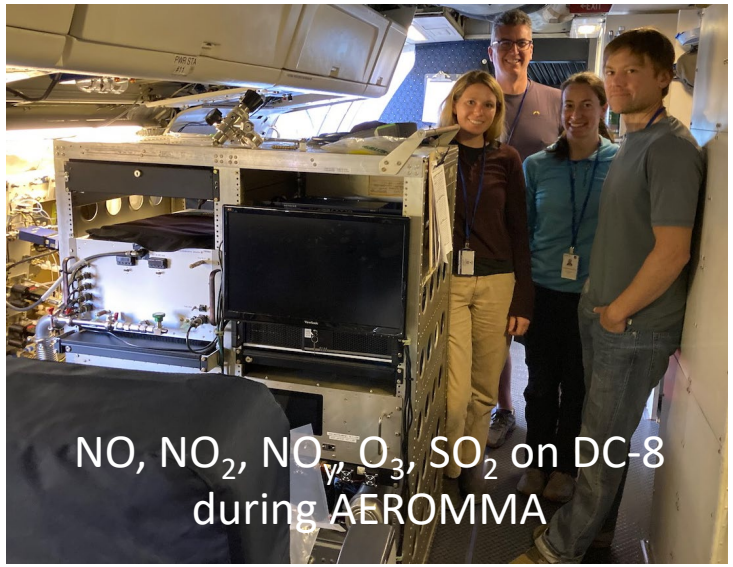
Fun with lasers



- NOAA CSL has developed many instrument concepts, including 21 between 2015 – 2021
- Instrument development, refinement and calibration is an essential part of an aircraft research program

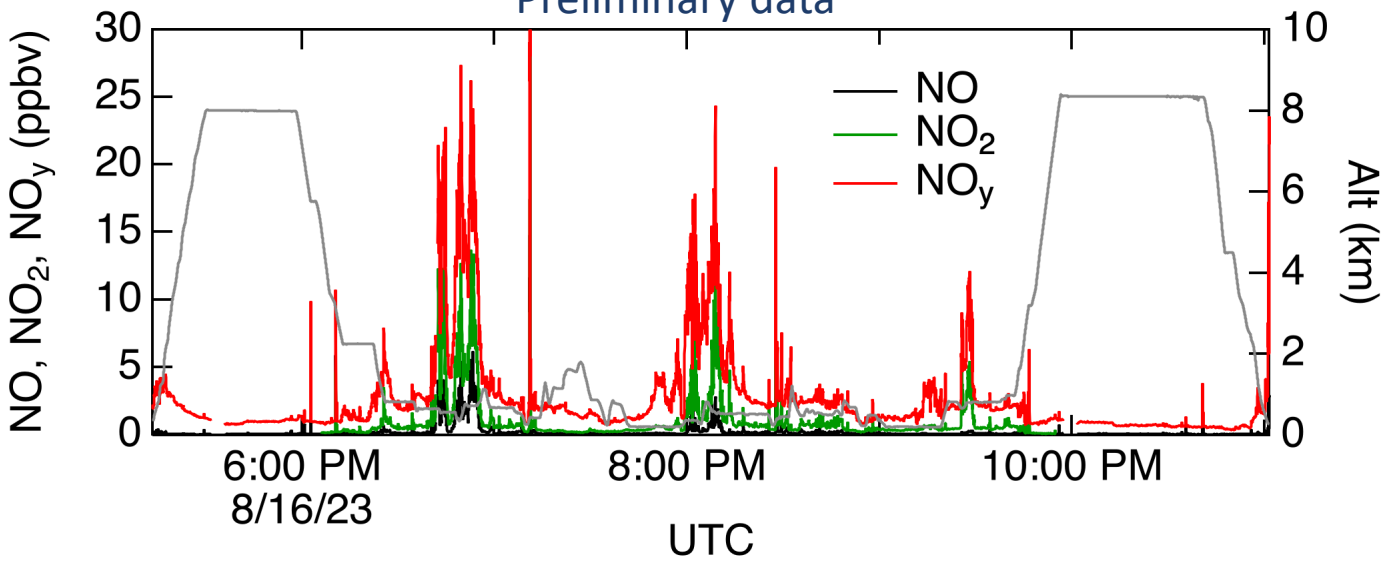
Laser Induced Fluorescence – NO_x & NO_y

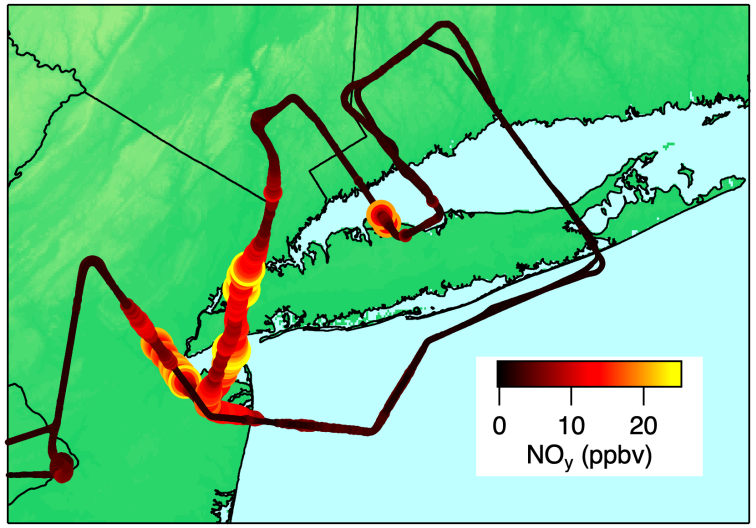




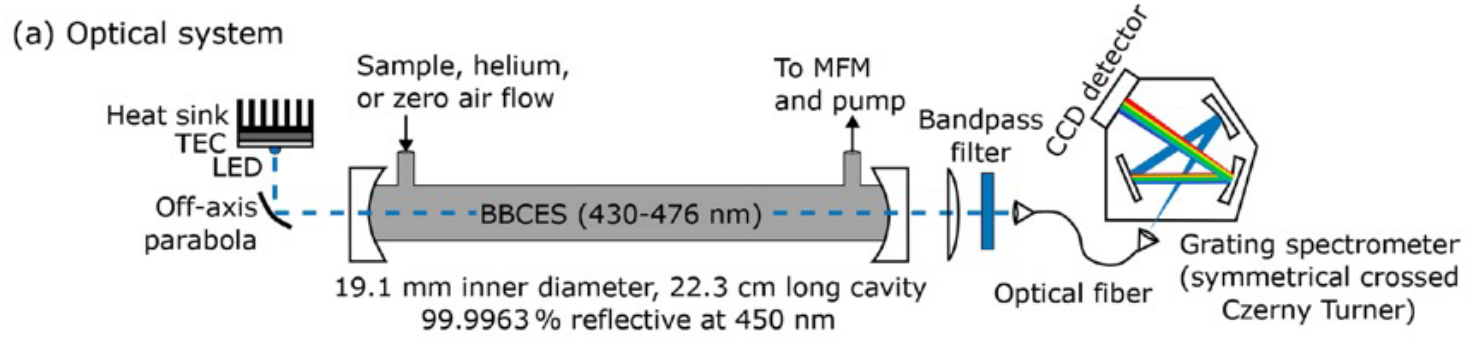
- Rollins et al., AMT 2020: NO LIF < 1 pptv / 1 Hz precision
- Photolytic conversion of NO_2 to NO in LED based window mounted cell
- Catalytic conversion of NO_y to NO

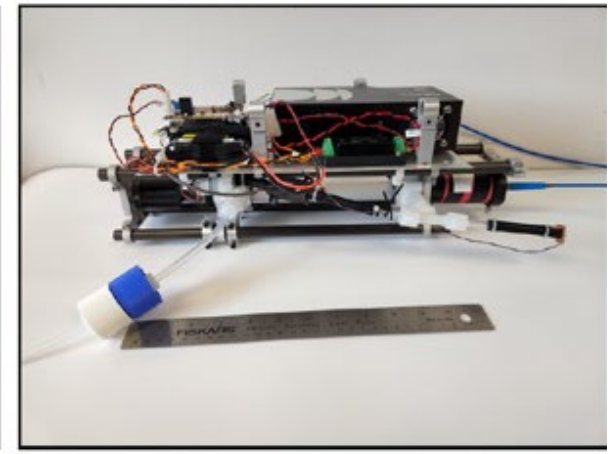
Preliminary data

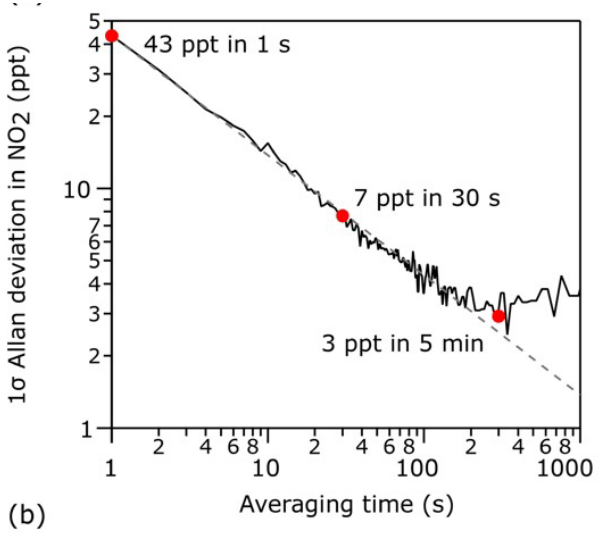


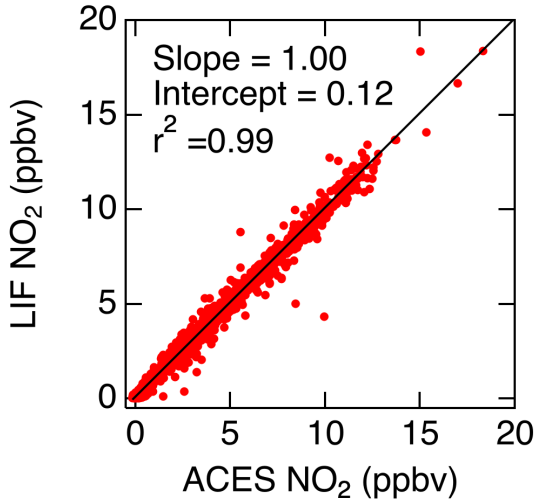


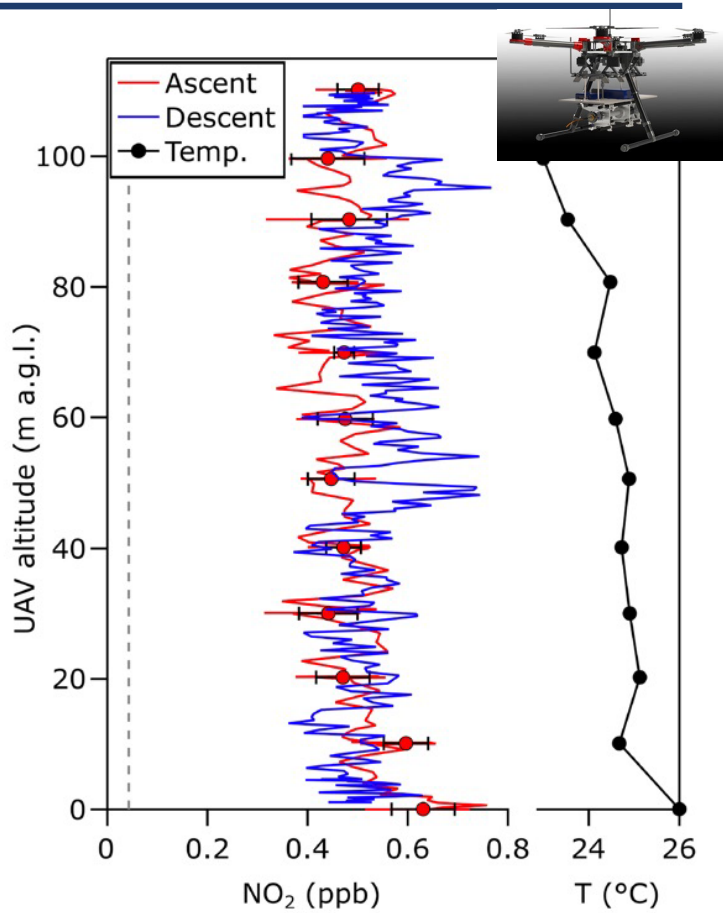
Miniature Airborne Cavity Enhanced Spectrometer (m-ACES)



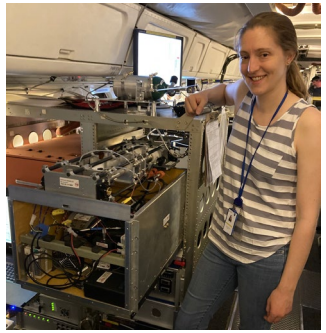






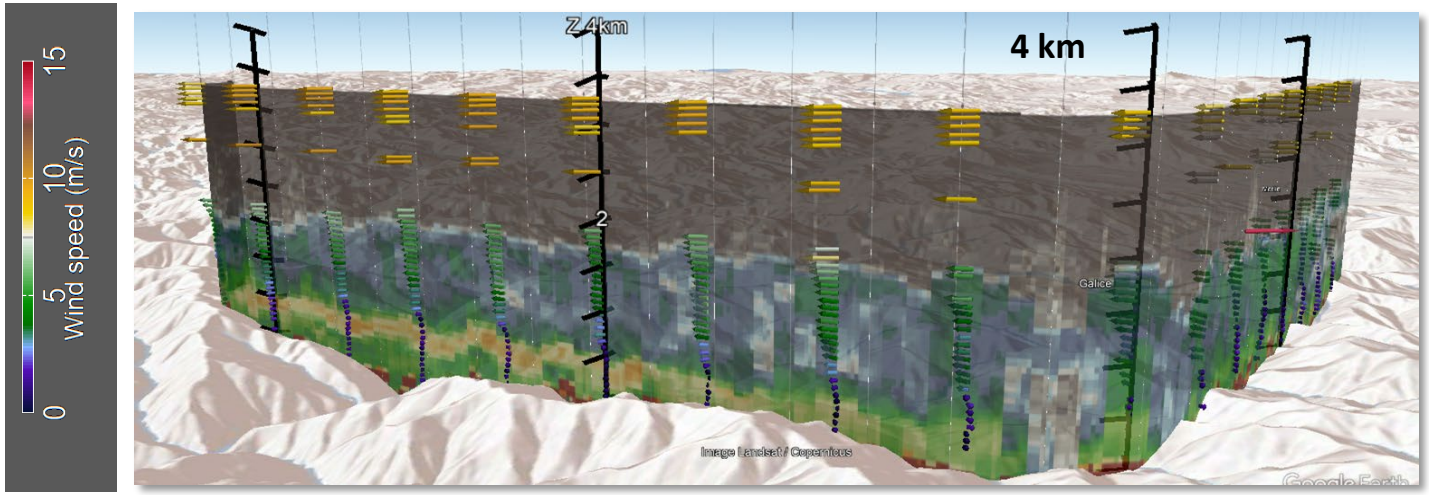


- Womack et al., AMT 2023: 3 kg, 25 watt, optical NO_2 instrument suitable for drone, other applications
- Large (DC-8) and small (UAH Sea Ray) aircraft deployments during AEROMMA
- Potential for other trace gases, satellite validation, personal monitoring, etc.

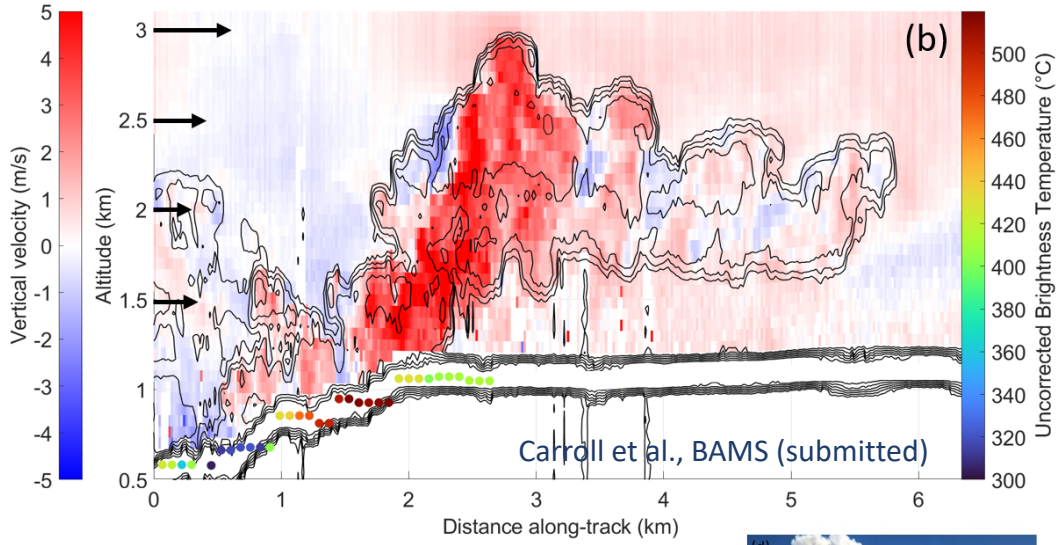


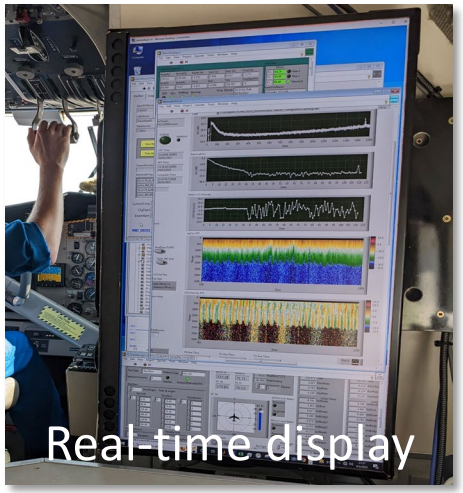
Airborne Doppler Lidar

- Operation from the NOAA Twin Otter and Orion P3
- Horizontal wind, vertical wind / turbulence, aerosol backscatter profiles
- Atmospheric dynamics & transport - complements composition



CalFiDE Vertical Winds




Real-time display


Twin Otter Scanner

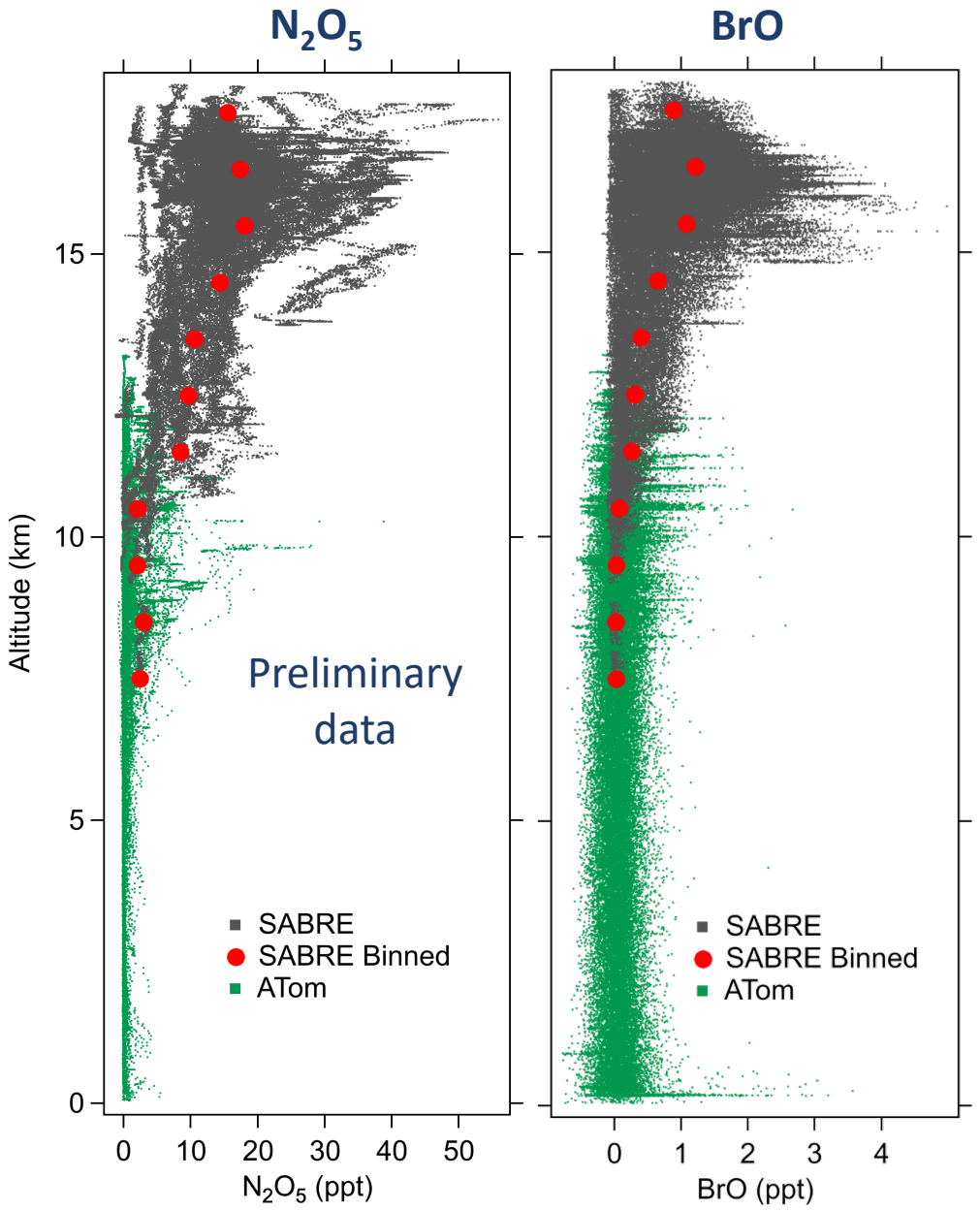

Alan Brewer

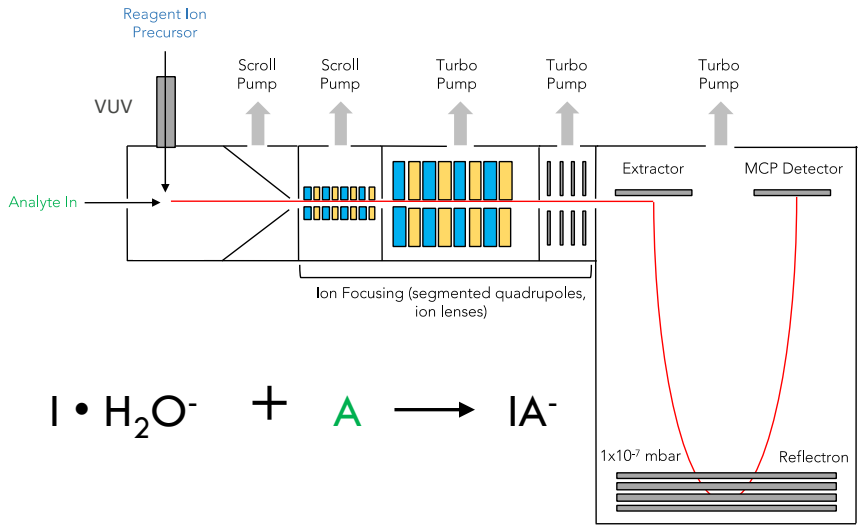

Twin Otter


Orion P3


Mosquito Fire
Sept 2022

Stratospheric Chemical Ionization Mass Spectrometer





- Commercial Aerodyne time of flight chemical ionization mass spectrometer (CIMS) re-engineered for autonomous operation at low pressure on the NASA WB-57
- Investigation of reactive nitrogen and halogen species to characterize stratospheric heterogeneous chemistry in support of Earth's Radiation Budget program


Thanks !
NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE
CSL
NOAA CHEMICAL SCIENCES LABORATORY
CIRES
Facilities for Atmospheric Research and Education Workshop (FARE)
NCAR Earth Observing Laboratory, September 2023