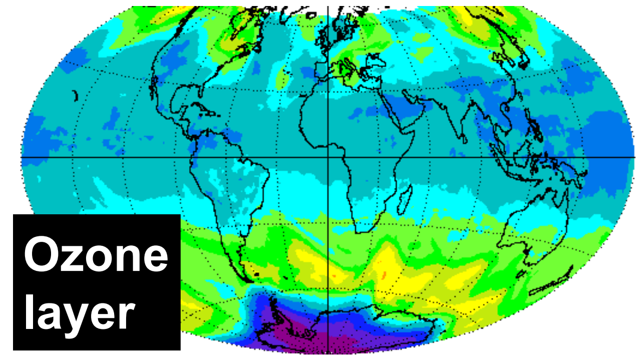
Airborne platforms as part of the Earth observing system for air quality and atmospheric chemistry–coupled to dynamics

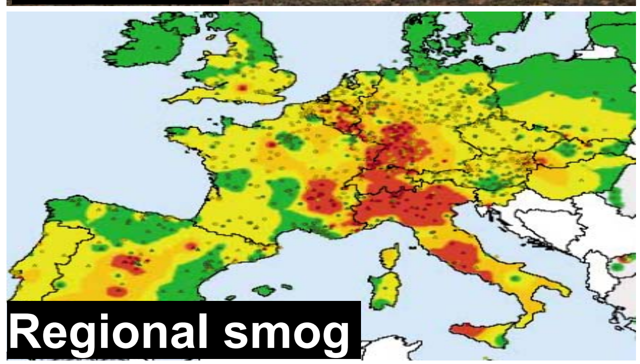
Daniel J. Jacob

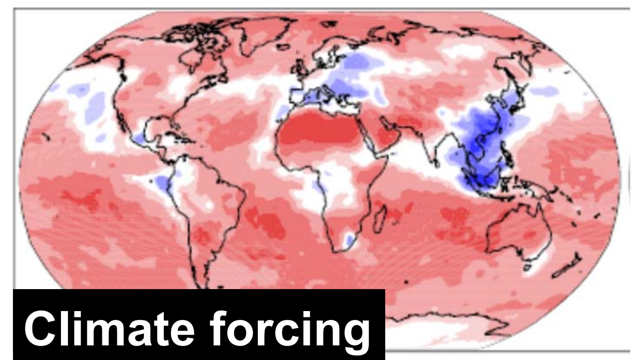
NASA DC-8 in ARCTAS

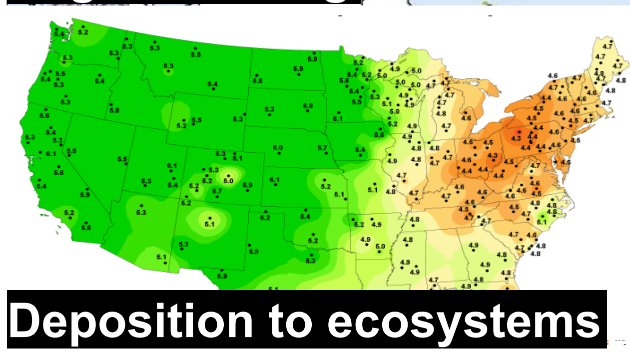
Atmospheric chemists are interested in a wide range of problems

LOCAL	REGIONAL	GLOBAL










Thriving on Our Changing Planet
A Decadal Strategy for Earth Observation from Space
#EarthDecadal
The National Academies of
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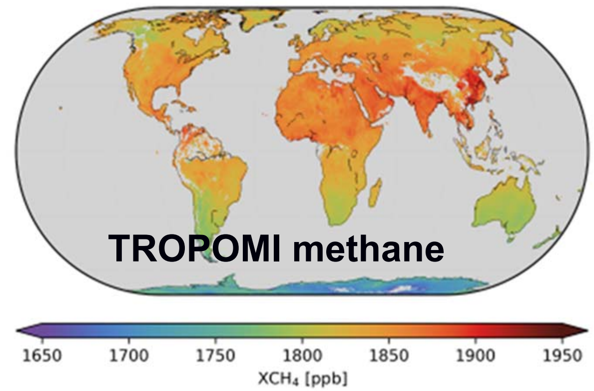
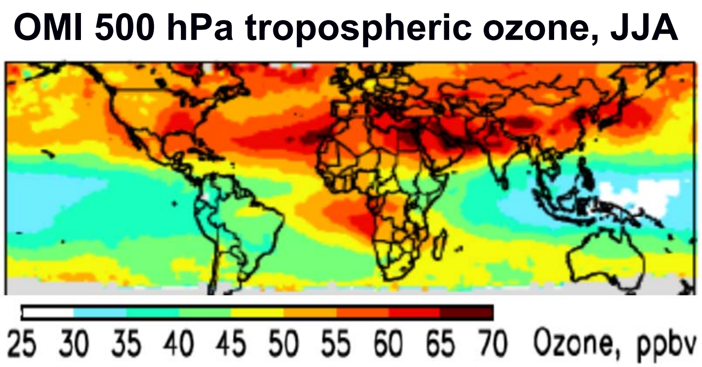
Big questions in atmospheric chemistry

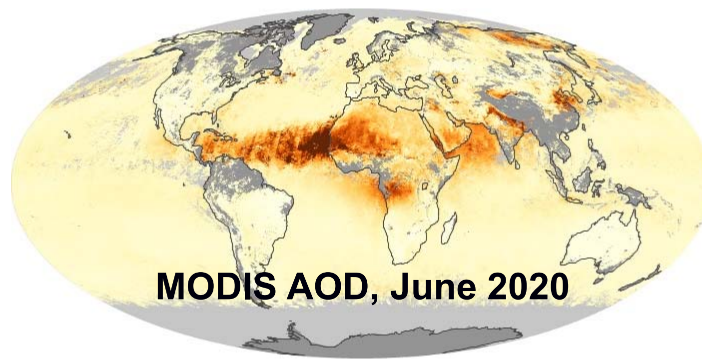
1. What are the carbon fluxes from the global scale down to point sources?

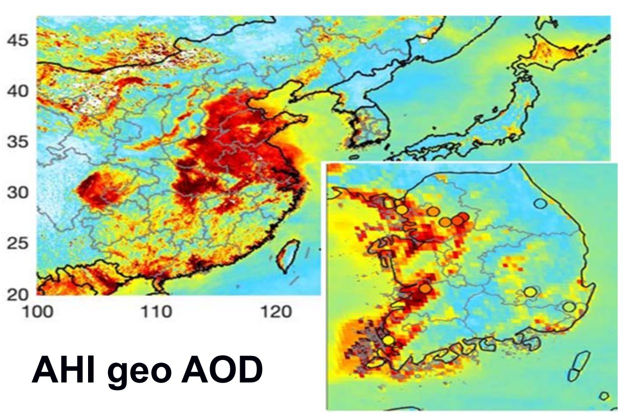




2. What controls the concentrations of atmospheric oxidants?

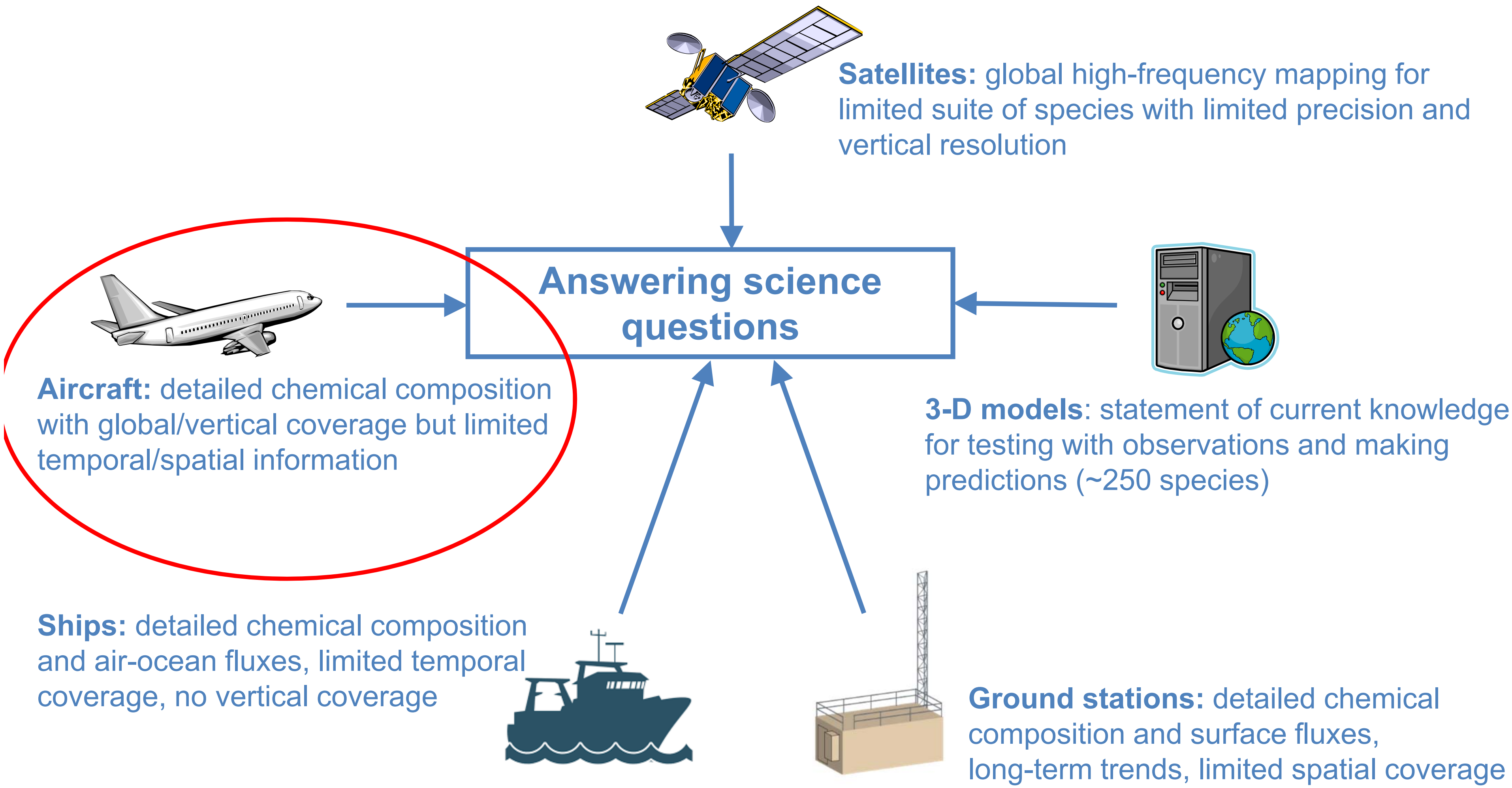
3. What are the sources and properties of aerosols in relation to climate forcing?





4. What are the levels and drivers of air pollution in different regions of the world?

Observing system for atmospheric chemistry



Different NASA aircraft to serve atmospheric chemistry needs

Large aircraft (DC-8, P-3)
Comprehensive payload, 12-km ceiling

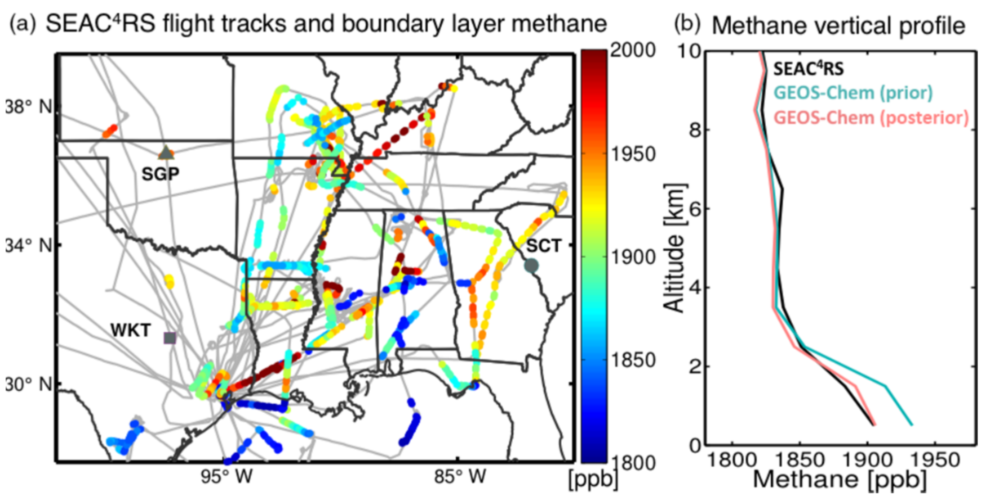
High-altitude aircraft (ER-2, WB-57, GS V)
21-km ceiling

Small aircraft (e.g., Twin Otter)
Slow low-altitude flying

UAVs (e.g., Global Hawk, drones)
Range of capabilities

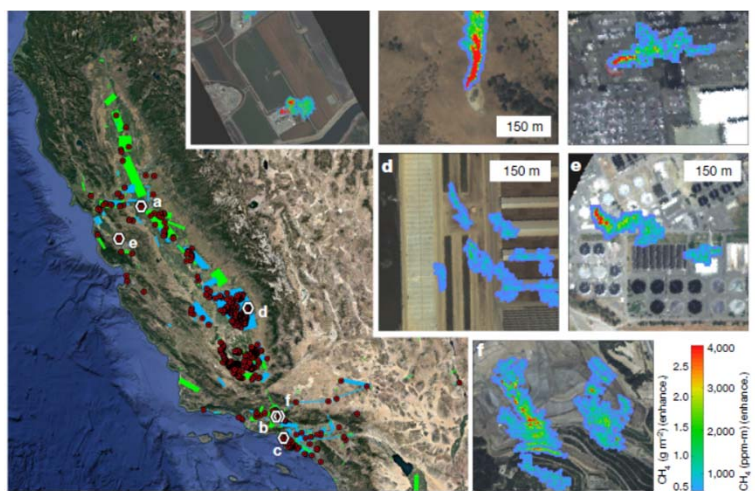
Quantifying carbon fluxes: unique role of aircraft

1. Mapping surface fluxes at landscape/regional scales directly (eddy-correlation) or indirectly (inversion of in situ data): small aircraft, flux capability, correlative tracers



Sheng et al., 2018

2. Quantification of point sources by remote sensing of plumes or upstream/downstream sampling: small aircraft

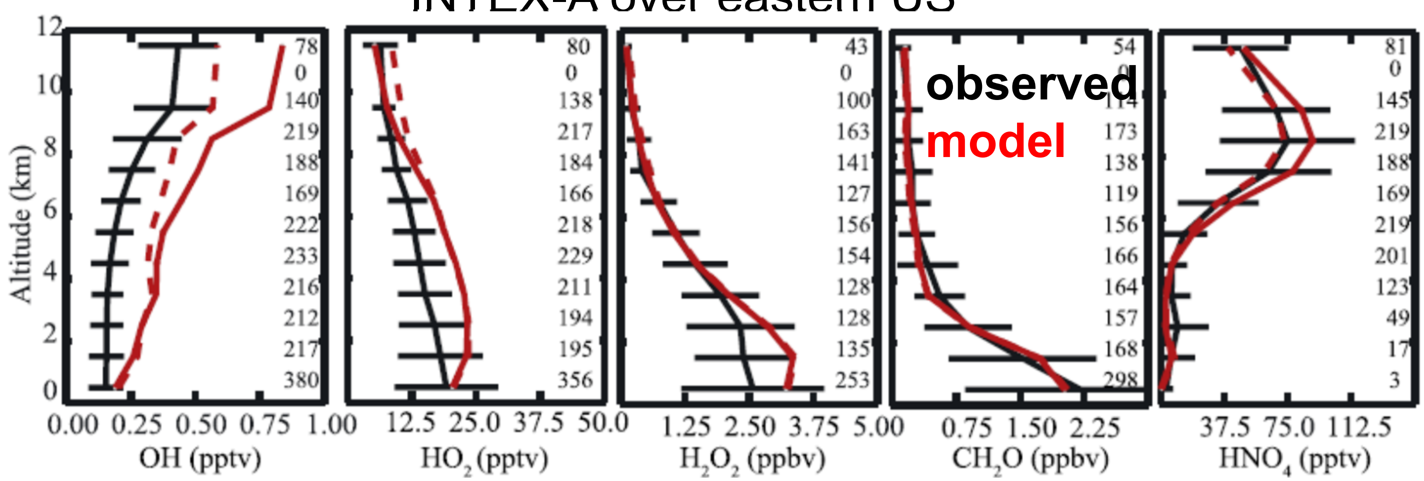


Duren et al., 2019

Understanding atmospheric oxidants: unique role of aircraft

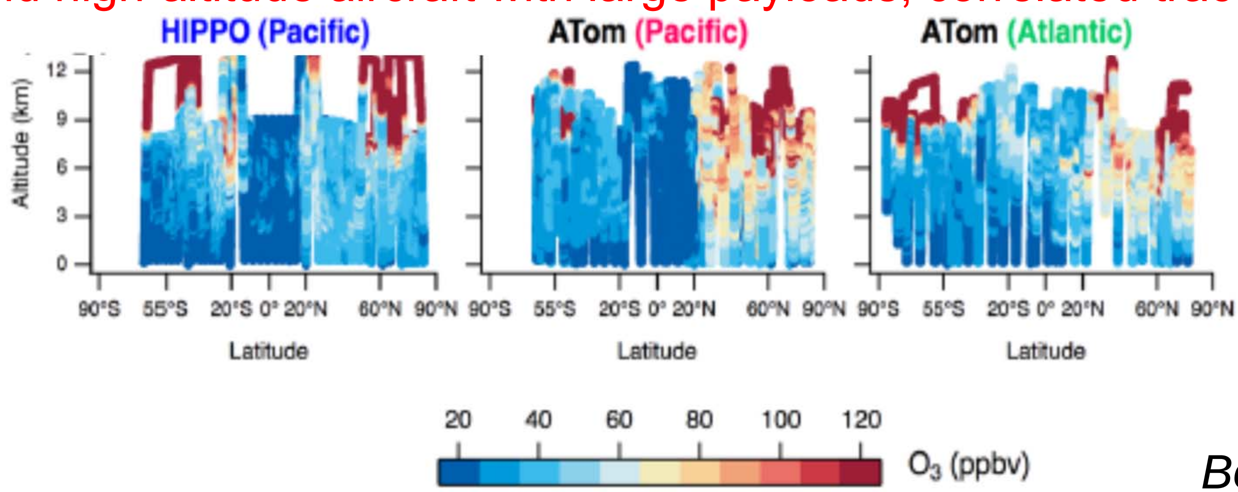
1. Test fast chemistry governing radical concentrations in range of environments: large and high-altitude aircraft with large payloads, redundancy

INTEX-A over eastern US



Hudman et al., 2007

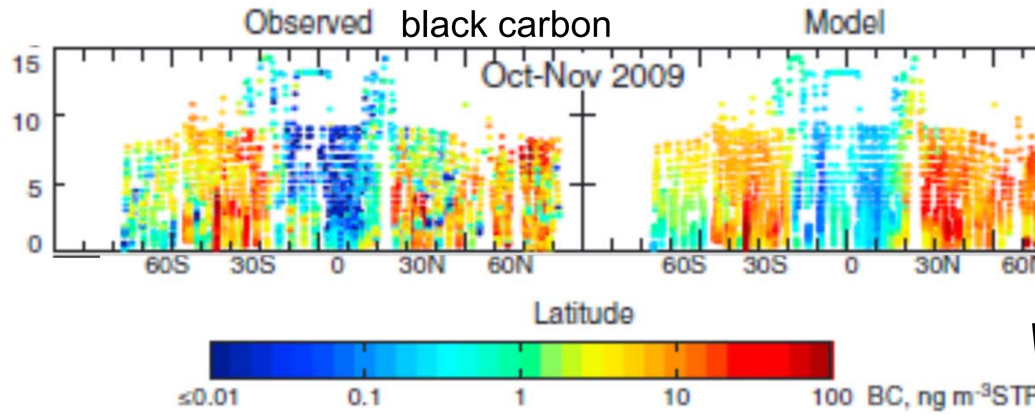
2. Test slower chemistry controlling tropospheric ozone and coupling to transport: large and high-altitude aircraft with large payloads, correlated tracers



Bourgeois et al., 2020

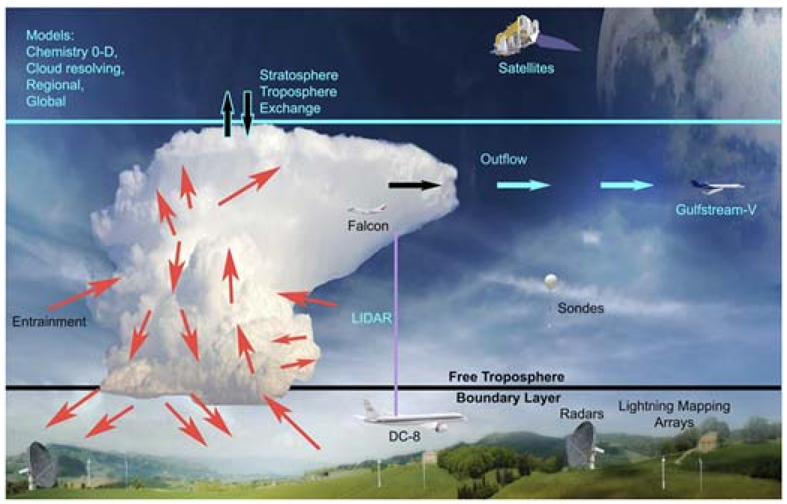
Aerosol composition and properties: unique role of aircraft

1. Global 3-D aerosol characterization in relation to sources and radiative forcing: large aircraft with large payloads, aerosol microphysics + chemistry



Wang et al., 2014

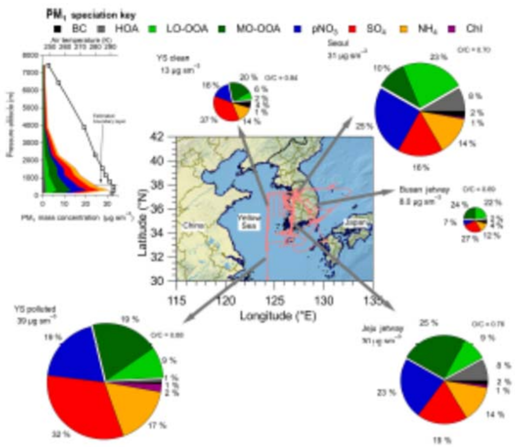
2. Understand aerosol-cloud interactions and scavenging: multi-aircraft with large payloads, remote sensing



Barth et al. [2015]

Air quality processes: unique role of aircraft

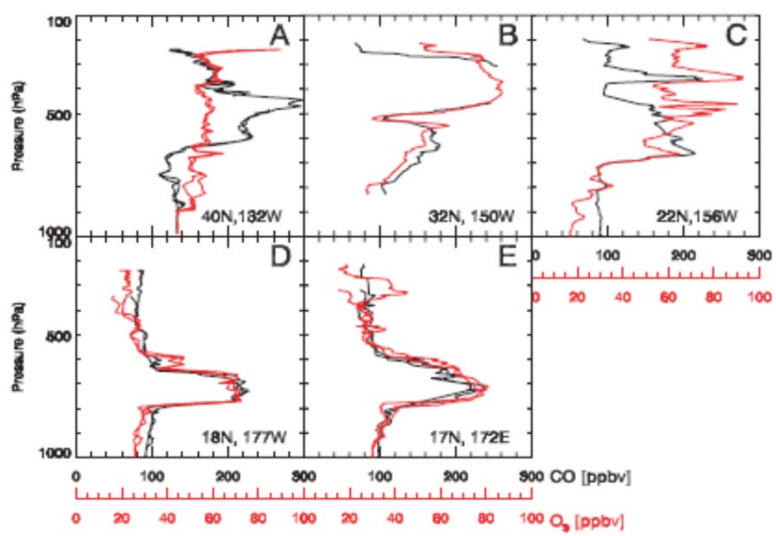
1. Understand sources, chemical processing, transport of $PM_{2.5}$ and ozone pollution: large aircraft with large payloads, low-altitude capability + vertical profiling, also small aircraft for coupling to transport



Nault et al., 2018

2. Characterize intercontinental transport and aging of pollution: large aircraft with large payloads, remote sensing

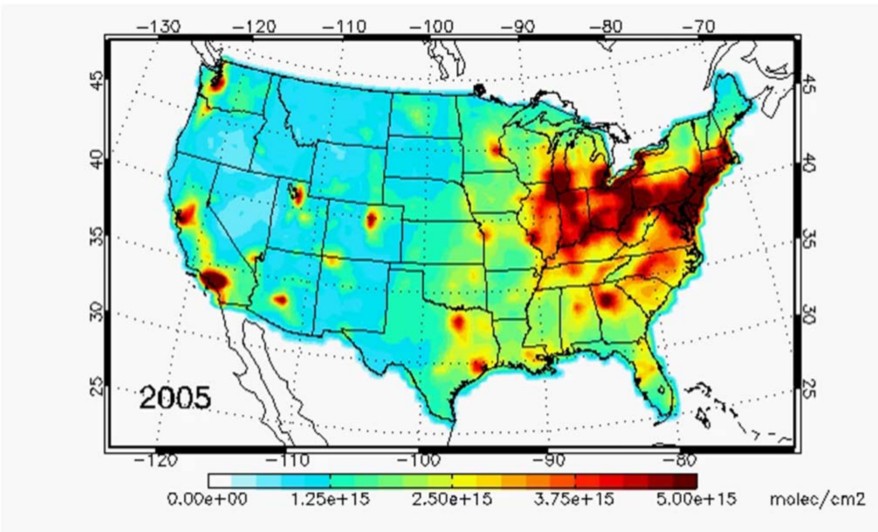
Ozone and CO over N. Pacific: Asian pollution plumes



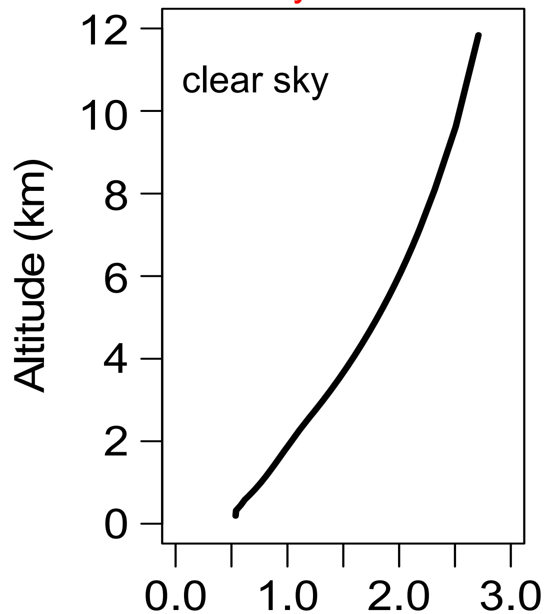
Heald et al., 2003

Need large and high-altitude aircraft in interpretation of satellite data

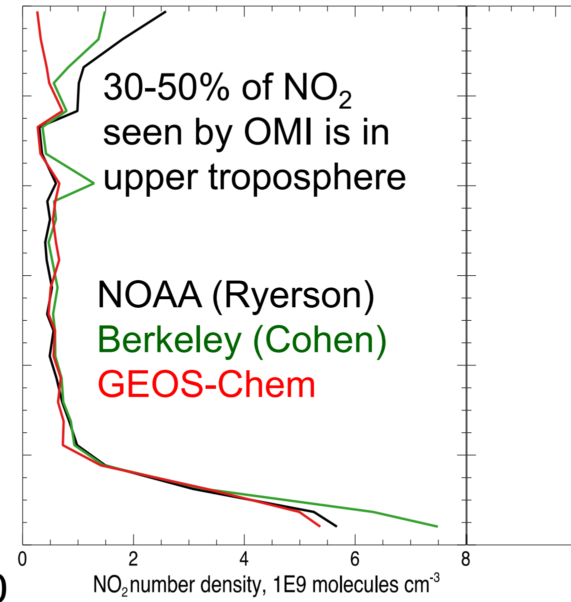
OMI annual tropospheric NO_2 column trends over US, 2005-2017



sensitivity vs. altitude



Mean SEAC^{4}RS NO_2 vertical profile, Southeast US



- Independent vertical profiling is essential for attribution of satellite data/trends and testing models
- Vertical profiling should extend to lower stratosphere
- Detailed chemical payload is necessary to resolve model errors
- Aircraft data must be high-quality – else raise more questions than answers

Silvern et al. [2019]

Summary: needs for aircraft to support research in atmospheric chemistry/air quality in relation to dynamics

- Need large platforms that can carry comprehensive instrument payloads on continental/global scales and from the surface to the lower stratosphere
  - Also need small aircraft for surface fluxes, air quality

- Payload needs:
  - high-frequency, validated measurements;
  - redundancy and intercomparison of important but uncertain measurements;
  - automatization and footprint/weight reduction.

- Payloads should include both in situ and remote capabilities:
  - In situ most important for local and correlative characterization of air masses
  - Remote sensing for enhanced vertical profiling and surface mapping

Research directions in the group (from our research webpage)

AIR QUALITY (subgroup leaders:Ke Li, Shixian Zhai)

- **Air quality in China** *(Ke Li, Jonathan Moch, Shixian Zhai, Drew Pendergrass)*
- **Air quality in Korea** *(Shixian Zhai, Nadia Colombi, Jared Brewer, Drew Pendergrass, Haipeng Lin, Ellie Beaudry)*
- **Background contributions to air quality** *(Viral Shah, Nadia Colombi, Zhen Qu, Elise Penn)*

CHEMISTRY (subgroup leaders: Kelvin Bates, Viral Shah)

- **Tropospheric oxidants** *(Kelvin Bates, Elise Penn, Xiao Lu)*
- **Tropospheric halogen chemistry** *(Xuan Wang, Will Downs)*
- **Organic chemistry** *(Kelvin Bates, Ke Li, Ivan Specht)*
- **Mercury chemistry** *(Viral Shah)*
- **Cloud and rain acidity** *(Viral Shah, Jonathan Moch)*

CLIMATE AND HEALTH (subgroup leader: Loretta Mickley)

- See **Loretta Mickley's research page**. Students/postdocs working on chemistry/climate interactions, effects of fires on air quality, and connections to public health generally have Loretta Mickley as primary research advisor. (*Eimy Bonilla, Pengfei Liu, Tianjia (Tina) Liu, Jonathan Moch, Miah Caine, Kent Toshima*)

METHANE (subgroup leaders: Xiao Lu, Zhen Qu)

- **Methane emission inventories** *(Tia Scarpelli, Melissa Sulprizio, Shayna Grossman)*
- **Inverse analyses of atmospheric methane observations** *(Xiao Lu, Bram Maasakkers, Melissa Sulprizio, Yuzhong Zhang, Hannah Nesser, Elise Penn, Lu Shen, Zhen Qu, Jiawei Zhuang, Daniel Varon, Margaux Winter)*
- **Detecting methane point sources from satellites** *(Daniel Varon, Dan Cusworth, Jack Bruno)*

MODEL DEVELOPMENT (subgroup leader: Sebastian Eastham)

- **GEOS-Chem as chemical module for weather/climate models and data assimilation** *(Lizzie Lundgren, Jonathan Moch, Haipeng Lin, Drew Pendergrass, GEOS-Chem Support Team)*
- **Adaptive methods and machine learning for chemistry solvers** *(Lu Shen, Makoto Kelp)*
- **High-performance GEOS-Chem (GCHP) for massively parallel applications** *(Lizzie Lundgren, Jiawei Zhuang, GEOS-Chem Support Team)*
- **GEOS-Chem on the cloud** *(Jiawei Zhuang,Will Downs, Judit Flo-Gaya, Haipeng Lin)*
- **Development and management of GEOS-Chem for its worldwide user community** *(Bob Yantosca, Melissa Sulprizio, Lizzie Lundgren,, Will Downs).*