AEROMMA assets for TEMPO validation

Owen Cooper (CIRES) and Brian McDonald

Regional Chemical Modeling Group

CEOS AC-VC-19 / ACSG Joint Meeting 2023
Brussels, Belgium / Hybrid
October 24 to 27, 2023

NOAA CHEMICAL SCIENCES LABORATORY

CIRES

Key TEMPO retrievals for air quality research:

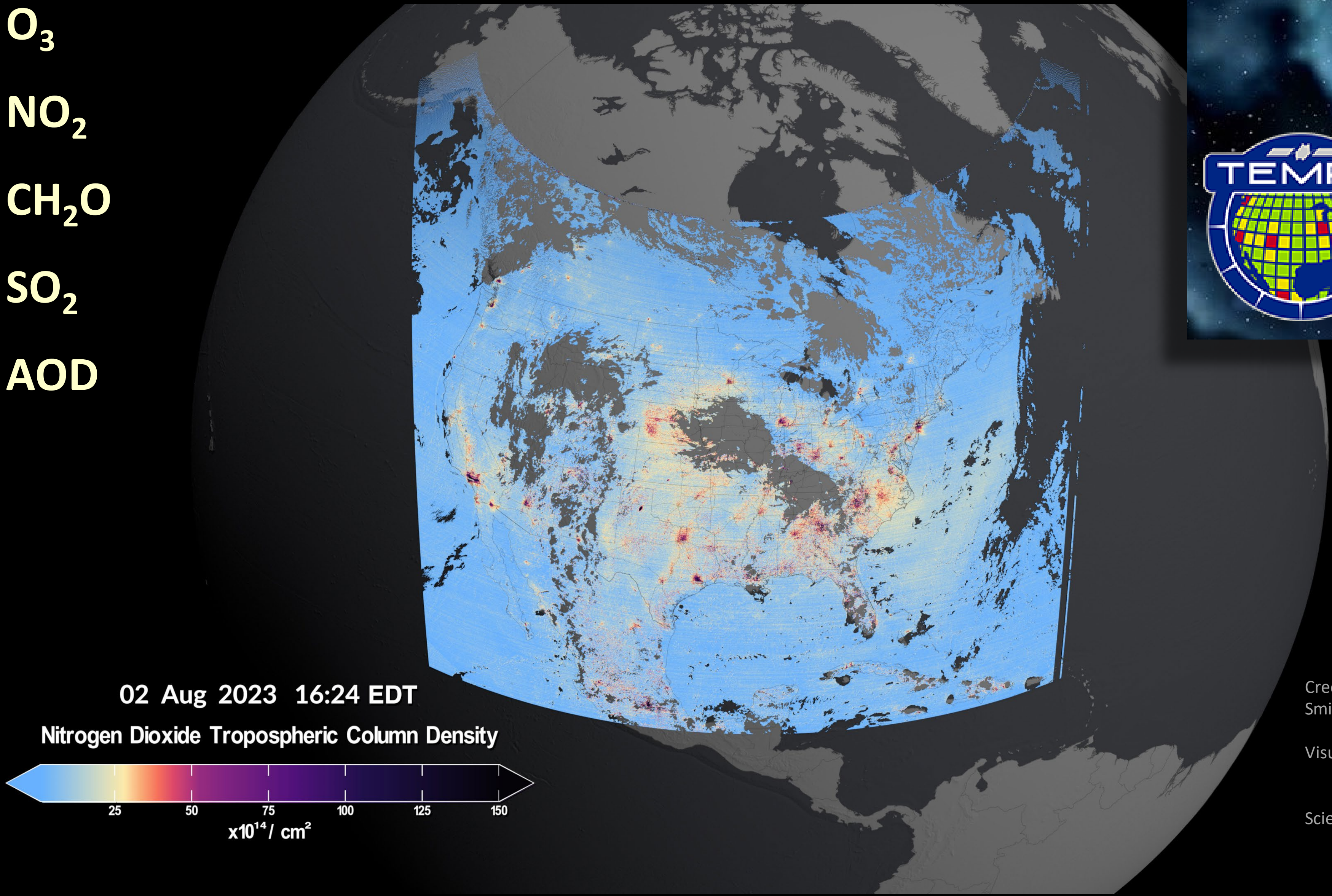
O_3

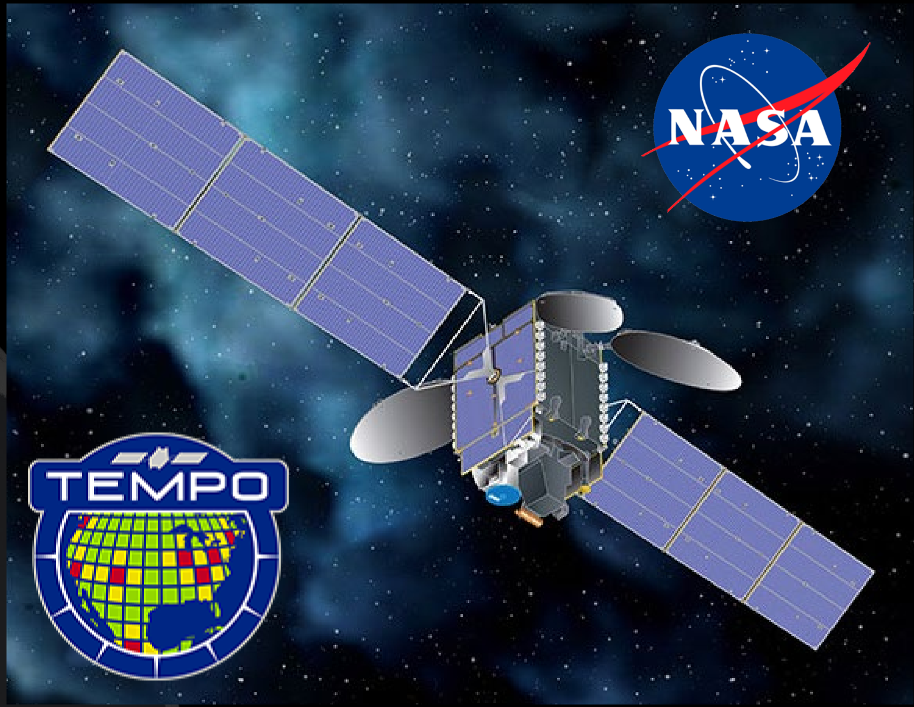
NO_2

CH_2O

SO_2

AOD



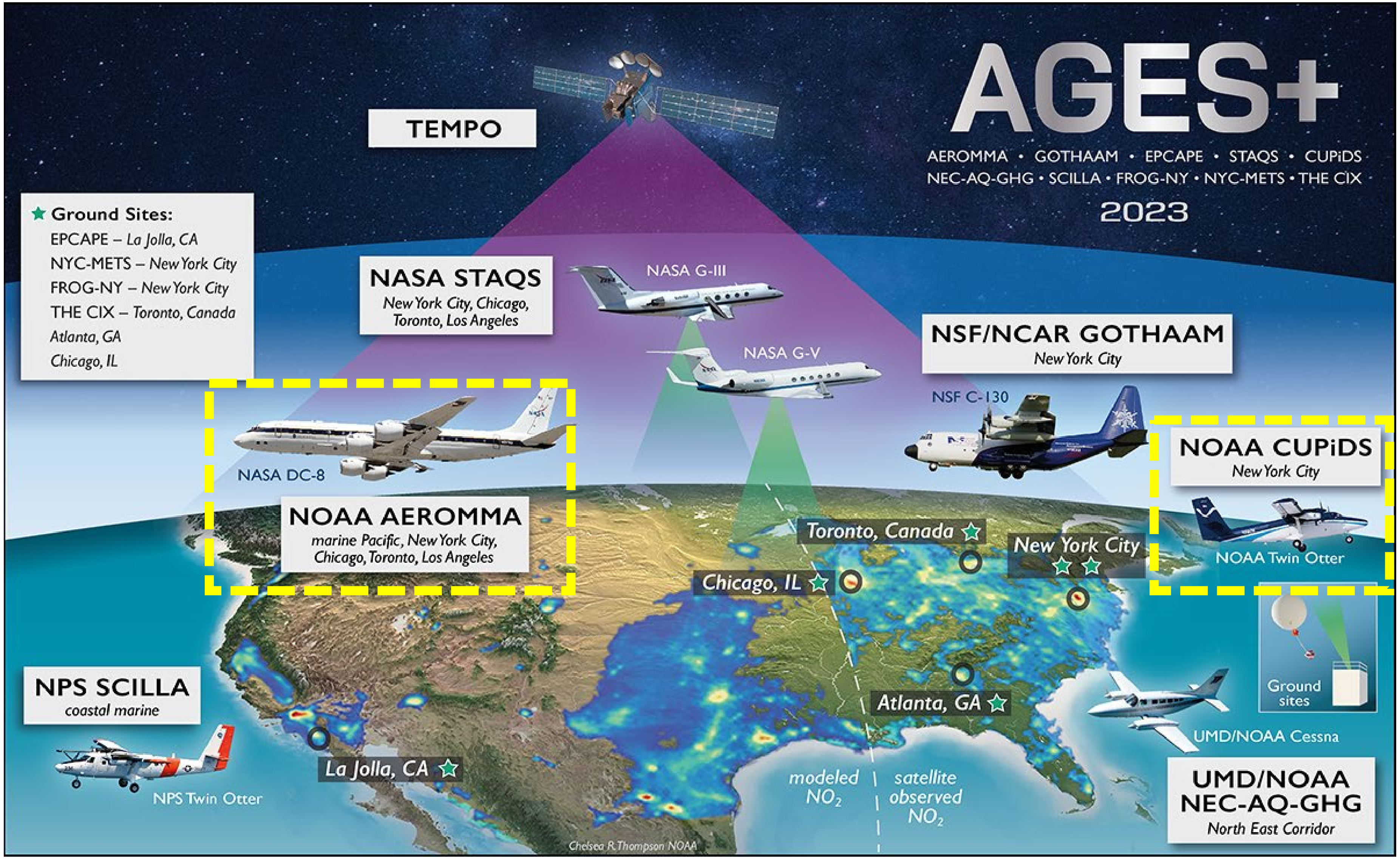


Credit: NASA's Scientific Visualization Studio; Data provided by the Smithsonian Astrophysical Observatory | Harvard & Smithsonian.

Visualizers
Cindy Starr (Global Science and Technology, Inc.)
Kel Elkins (USRA) and Trent L. Schindler (USRA)

Scientists
Caroline Nowlan and Xiong Liu
Center for Astrophysics | Harvard & Smithsonian

Airborne Field Campaigns in Summer 2023



https://csl.noaa.gov/projects/ages/

AEROMMA DC-8 Field Campaign Calendar

2023

TEMPO "first light"

April

Su	M	Tu	W	Th	F	Sa
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

May

Su	M	Tu	W	Th	F	Sa
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

June

Su	M	Tu	W	Th	F	Sa
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

July

Su	M	Tu	W	Th	F	Sa
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

August

Su	M	Tu	W	Th	F	Sa
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

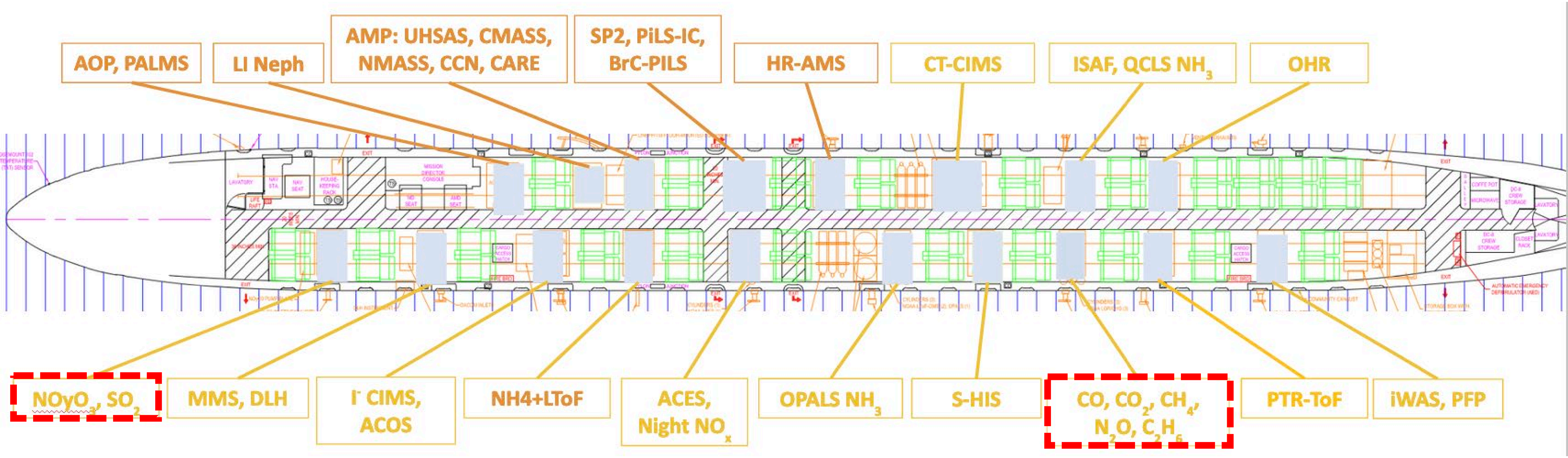
September

Su	M	Tu	W	Th	F	Sa
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

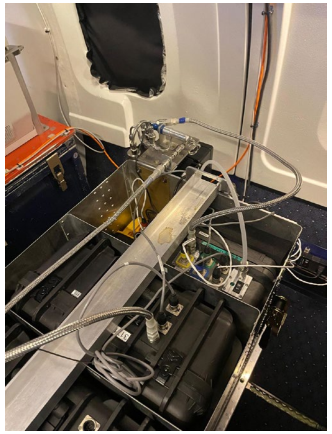
- Truck Boulder to Palmdale
- Integration / De-Integration
- Weight & Balance
- config+testflights Palmdale
- Marine Palmdale
- SARP Palmdale (3 flights: LA, Central Valley)
- Urban Palmdale (3 flights: LA)
- Urban Dayton (10 flights: NYC, CHI, TOR)
- Transits
- Packing Palmdale

Twin Otter / CUPiDS: July 17 – August 18 New York
Up to 175 Flight hours / 18 flight days

NOAA AEROMMA In-Situ Payload (GHGs, Trace Gases, Aerosols)



Programmable Flask Package (PFPs)

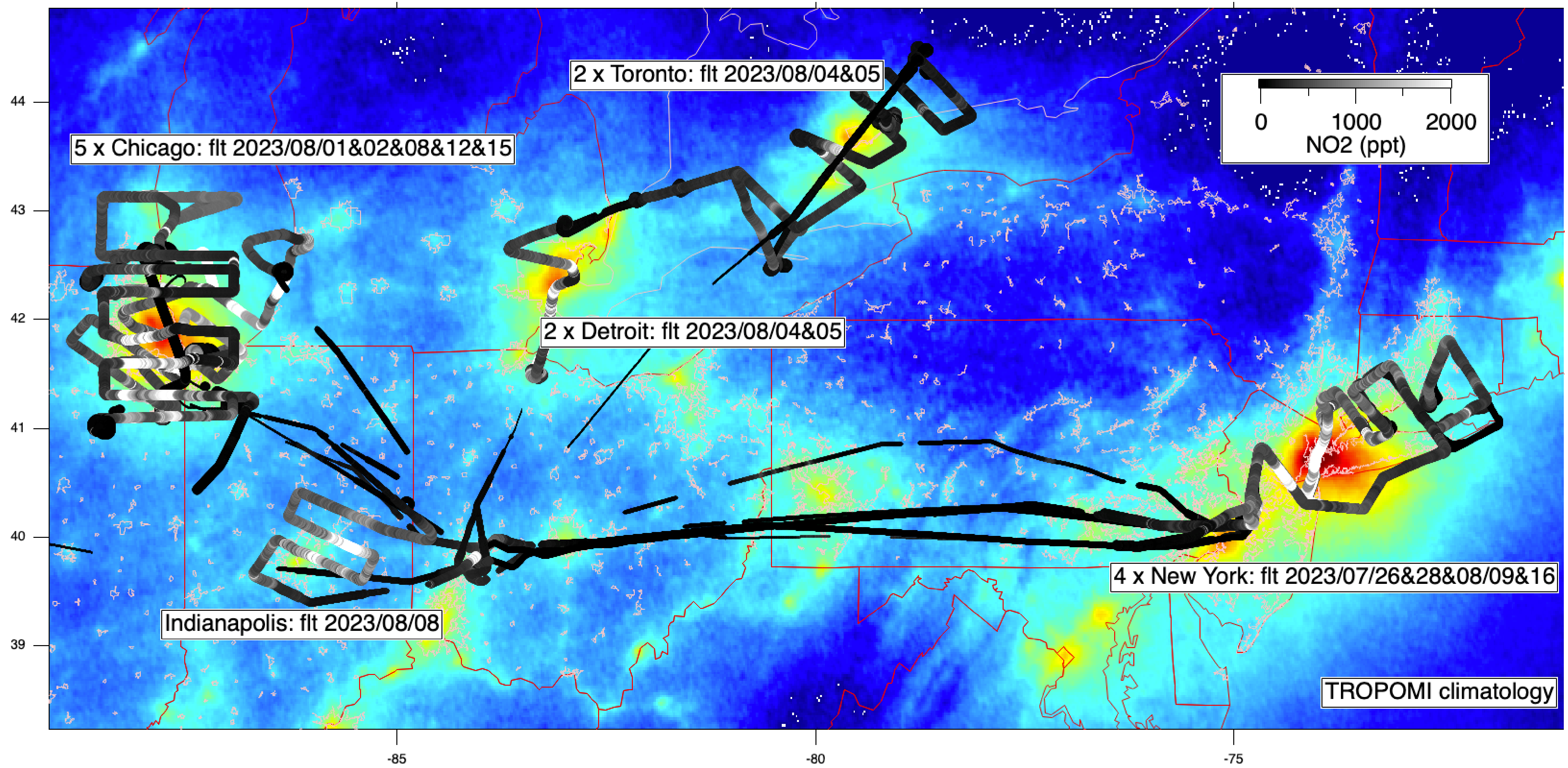


~250 samples will be analyzed for ^{14}C

John Miller (NOAA GML)

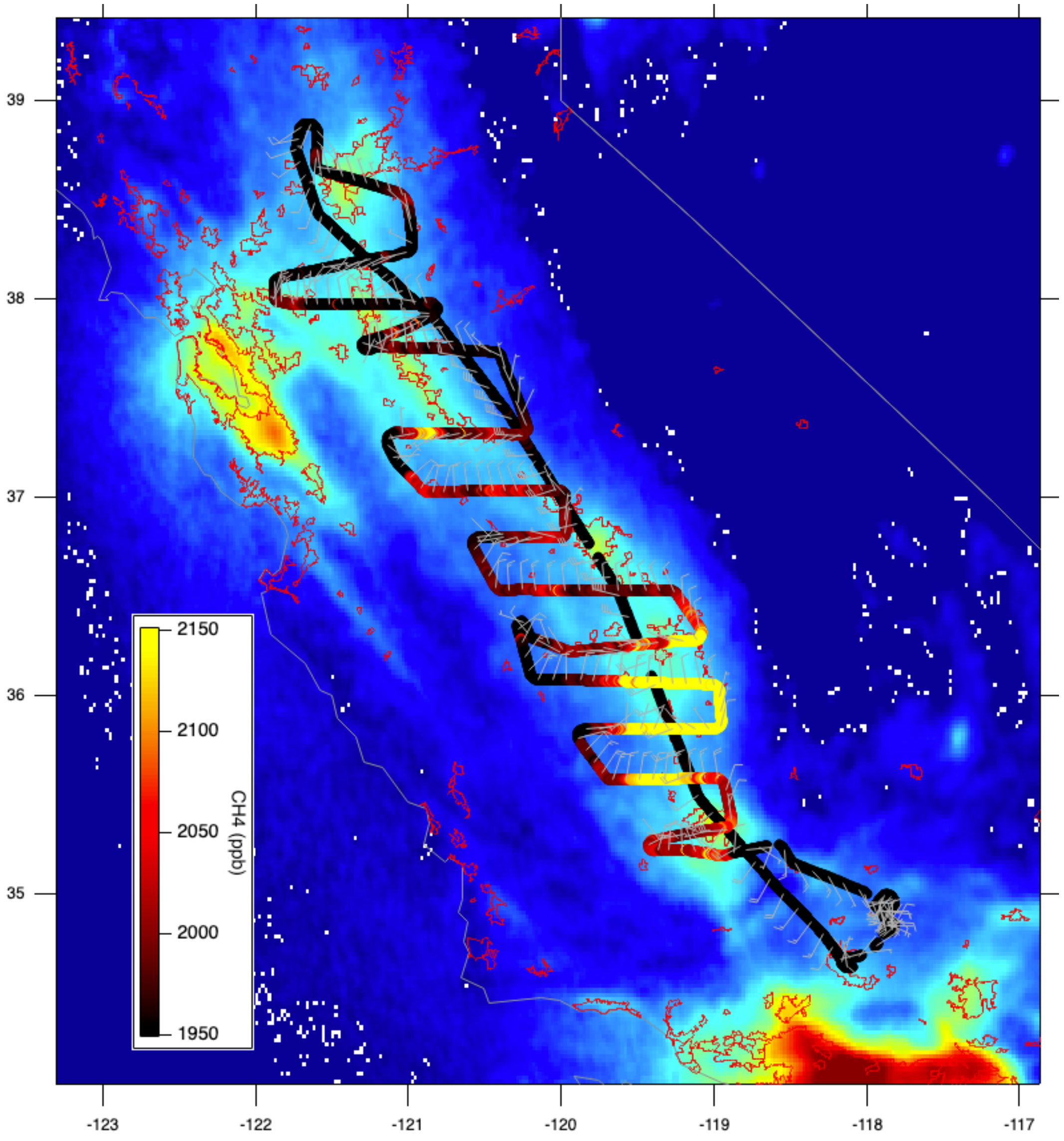
Colby Francoeur (NOAA CSL)

AEROMMA DC-8 Flights East: July-Aug 2023

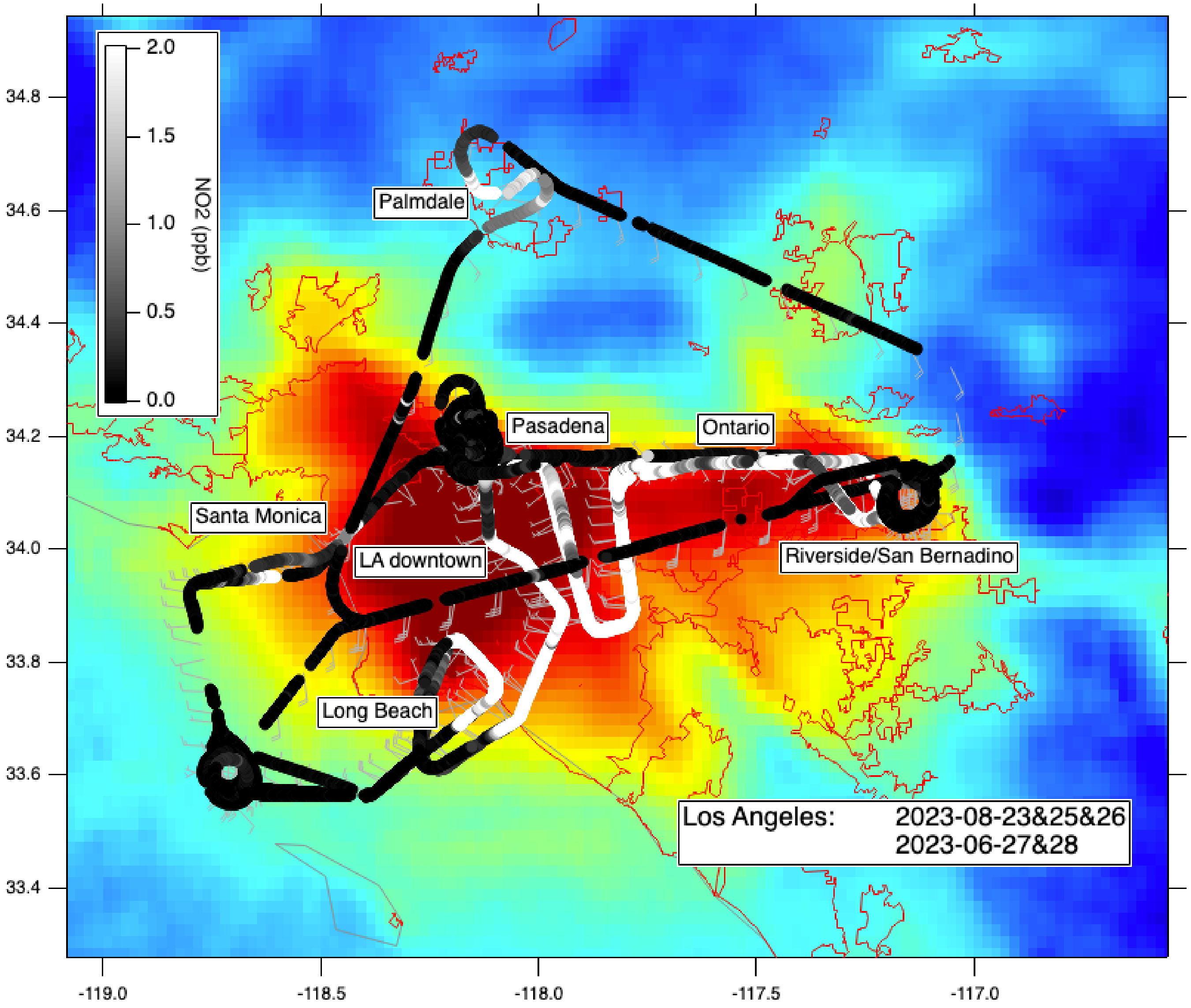


early afternoon, late afternoon repeats

AEROMMA DC-8 Flights West: Aug 2023



After Hurricane Hilary

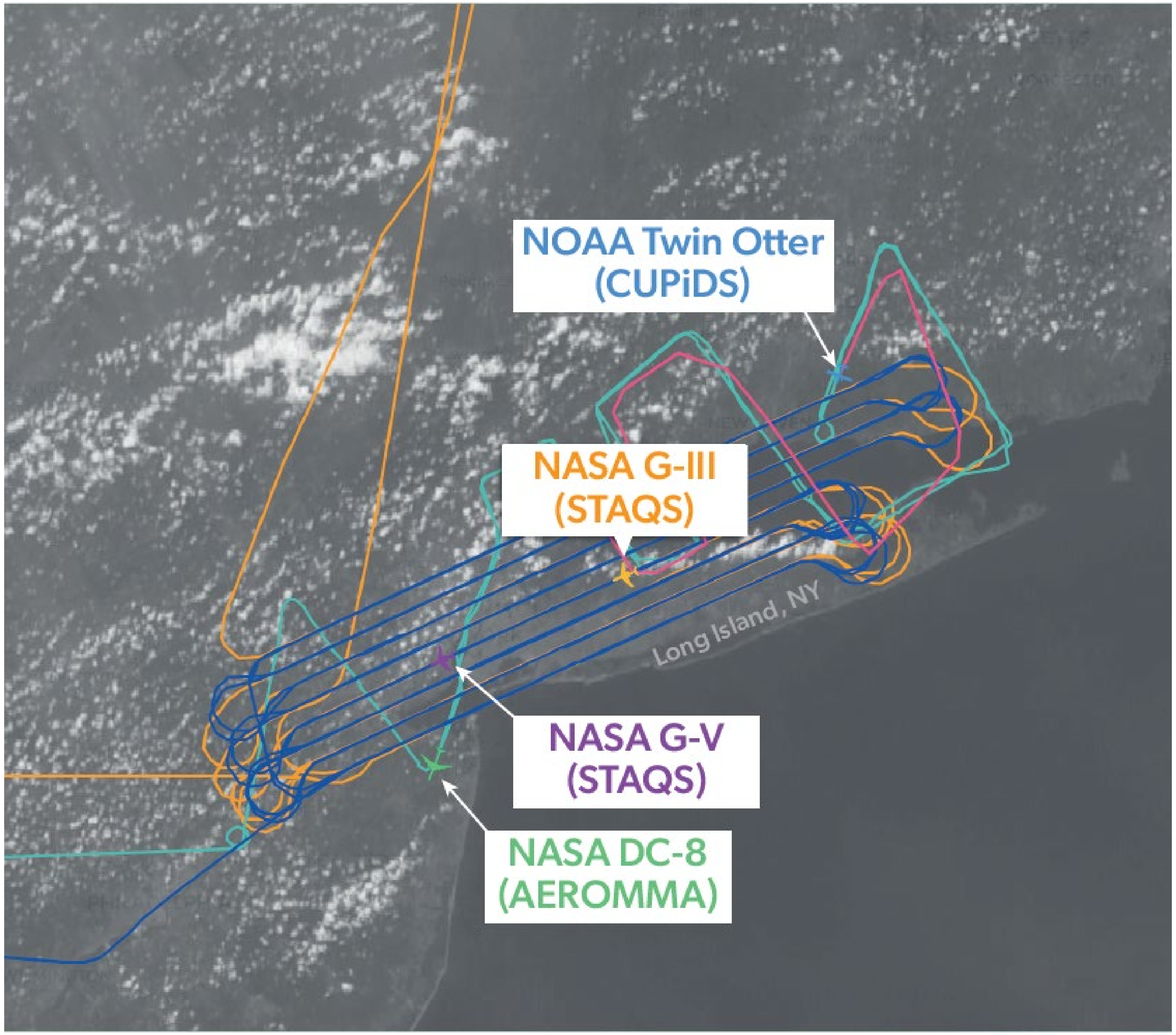


Morning, early afternoon, late afternoon

AEROMMA phase 2: Urban flights over major cities

JUNE – AUGUST 2023

The second phase of AEROMMA investigated urban pollutants that lead to production of ozone and $PM_{2.5}$. This includes volatile chemical products (VCPs), a subset of volatile organic compounds (VOCs) that come from commonly used consumer goods.



Live flight tracking of coordinated research flights by NOAA and NASA aircraft over New York City, captured on July 26, 2023 **(first AEROMMA urban flight!)**

AEROMMA DC-8 Flight Description

Tier	City	# of flights
Tier 1	Los Angeles	3 + SARP (4)
	New York	4
	Chicago	5
Tier 2	Toronto / Detroit	2
Tier 3	Central Valley	1 + SARP (1)
	Indianapolis	1
	Salt Lake City	1

Preliminary Thoughts on Successes

- ~110 flight hours for AEROMMA urban + ~20 flight hours for NASA SARP
- Sampled all three Eastern cities (New York City, Toronto/Detroit, & Chicago) under TEMPO with all three aircraft together (DC8, G3, & G5)
- Sampled Los Angeles under TEMPO with two of the aircraft (DC8, G3)
- Sampled low and higher urban air pollution conditions under TEMPO
- Sampled as many cloud free conditions under TEMPO as possible
- Sampled heavy, moderate, and light wildfire smoke aloft and near the surface under TEMPO
- All flights after TEMPO started to collect data were coordinated to occur when TEMPO was collecting measurements

Integrating Aerosol Optical, Microphysical, and Chemical In-Situ Measurements for Comparison with Satellite Observations and Models

Dr. Charles Brock, charles.a.brock@noaa.gov

NOAA Chemical Sciences Laboratory (CSL) Boulder, CO

NASA GSFC Climate and Radiation Laboratory
18 October 2022

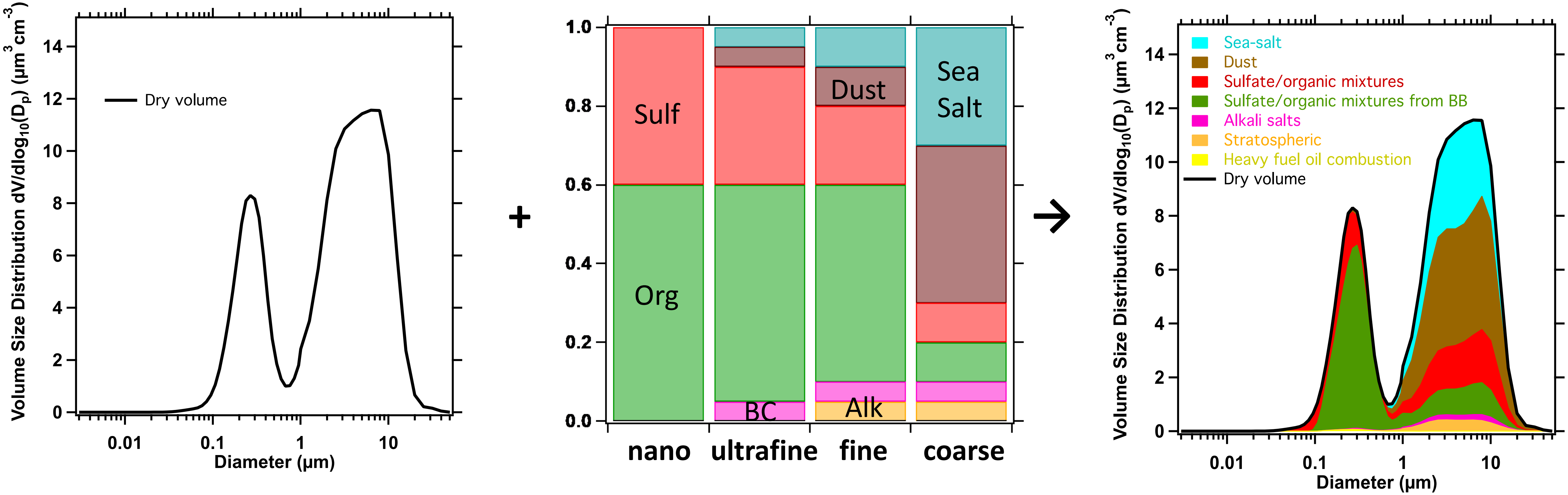
NOAA

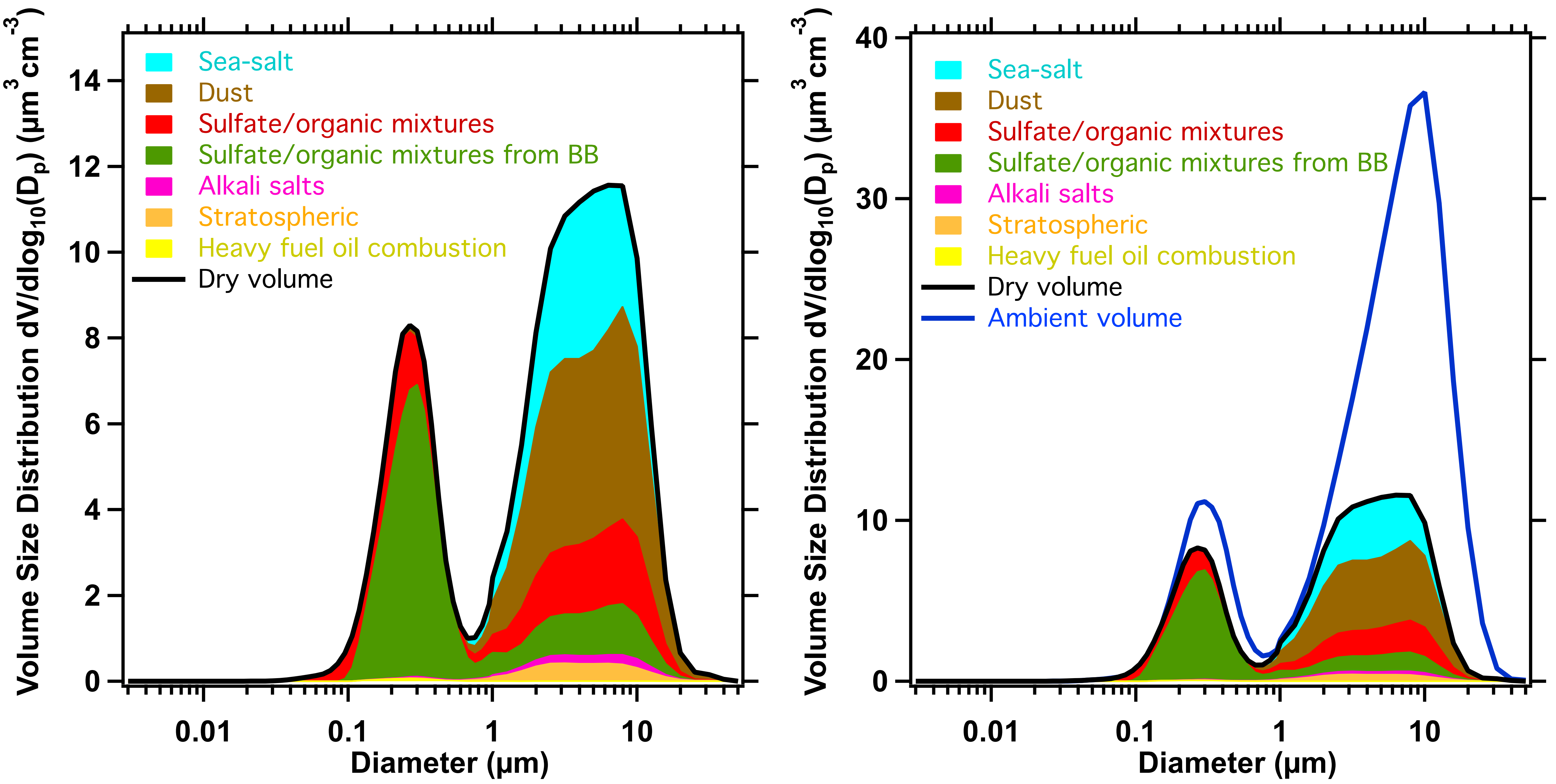
NASA ATom ATMOSPHERIC TOMOGRAPHY MISSION EVS-2

CSL NOAA CHEMICAL SCIENCES LABORATORY

CIRES
Cooperative Institute for Research in Environmental Sciences

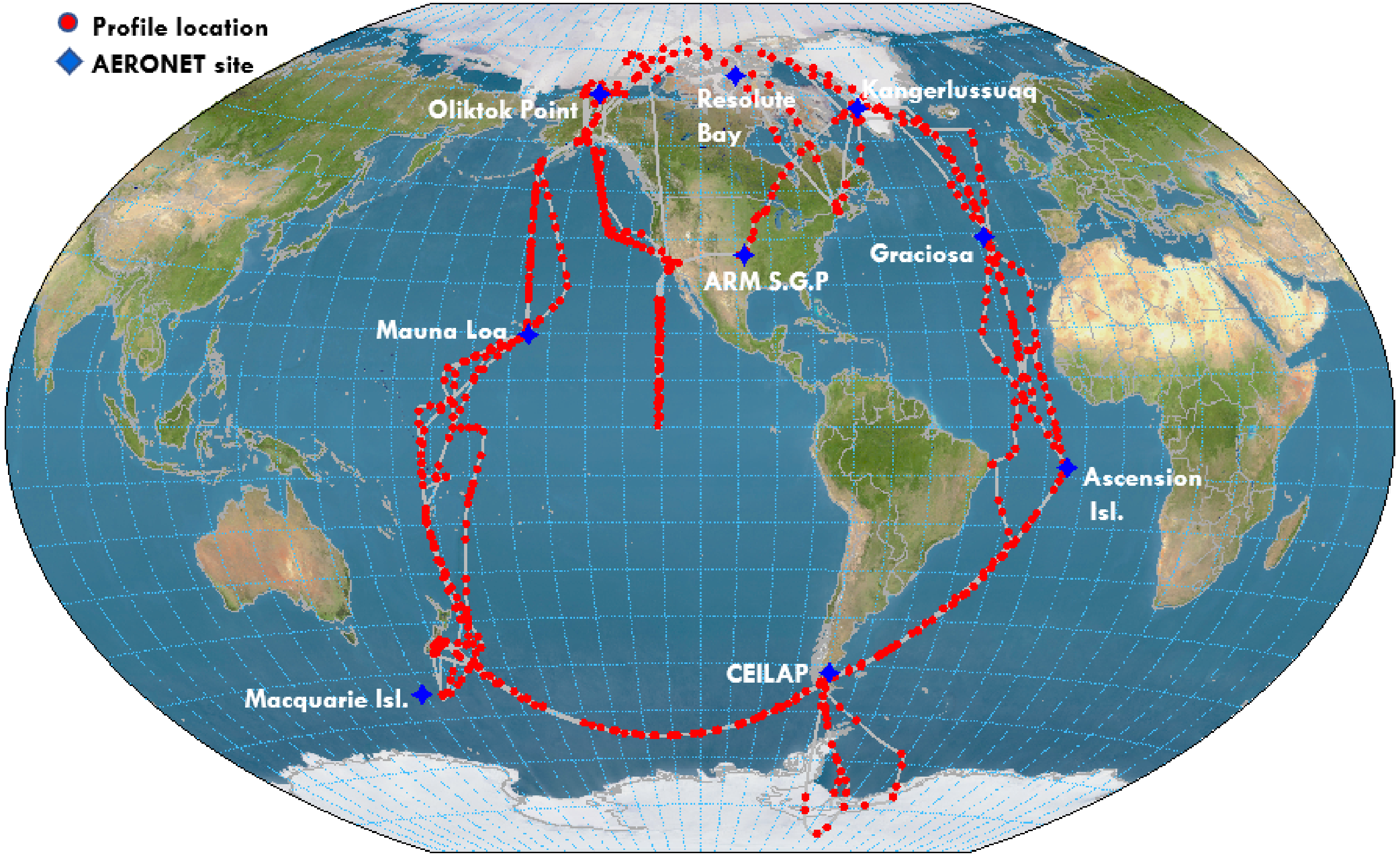
A new approach: Merge all the compositional, optical, and microphysical in situ measurements and produce a unified description (model) of the aerosol that is optimized and self-consistent. Value-added (Level 4) products like AOD, and the contribution of aerosol types to AOD, can be calculated from this model.





Sea-salt
Dust
Sulfate/organic mixtures
Sulfate/organic mixtures from BB
Alkali salts
Stratospheric
Heavy fuel oil combustion
Dry volume
Ambient volume
Volume Size Distribution dV/dlog10(Dp) (µm3 cm-3)
Diameter (µm)
0
2
4
6
8
10
12
14
10
20
30
40
0.01
0.1
1
10

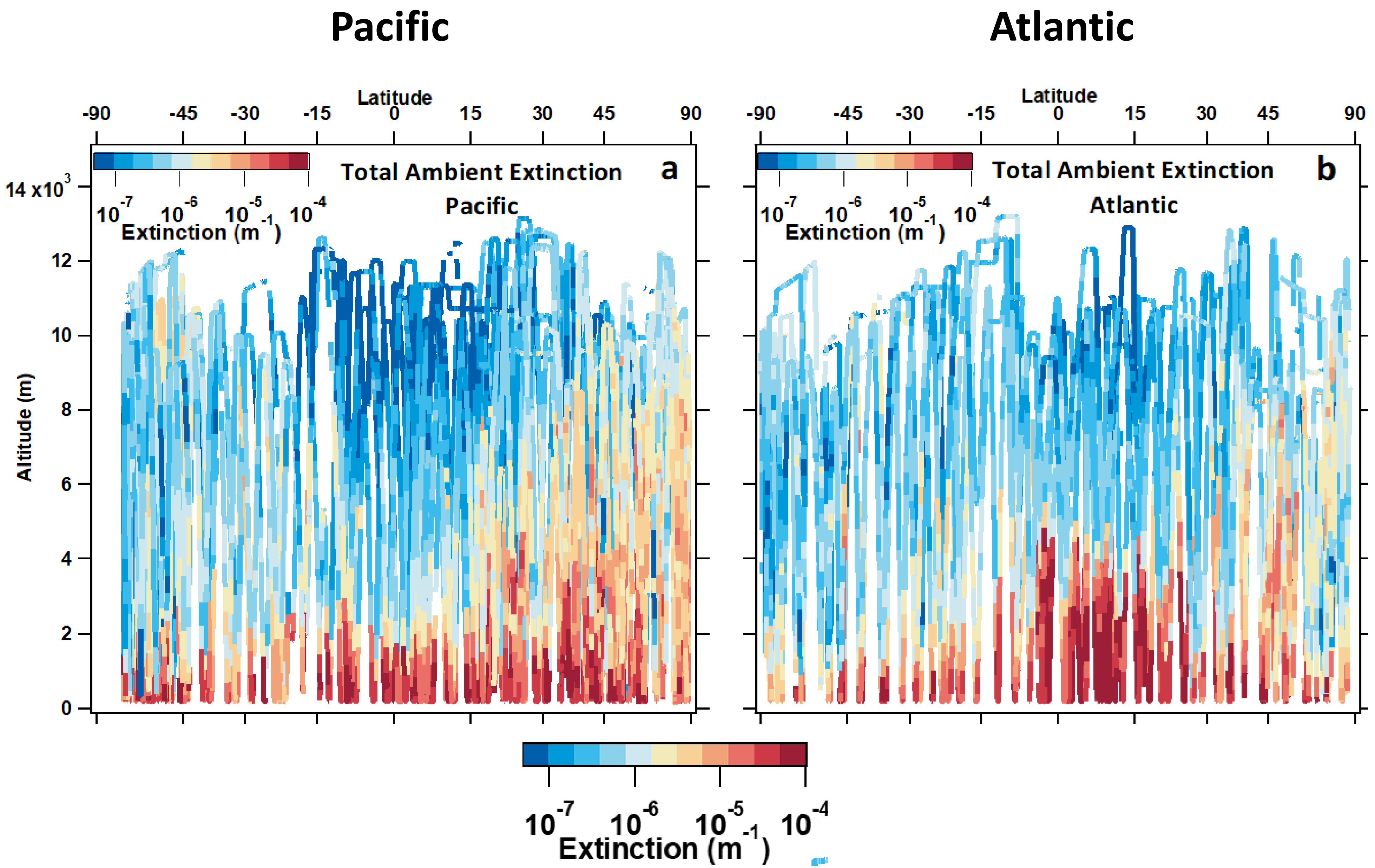
The Atmospheric Tomography Mission (ATom)



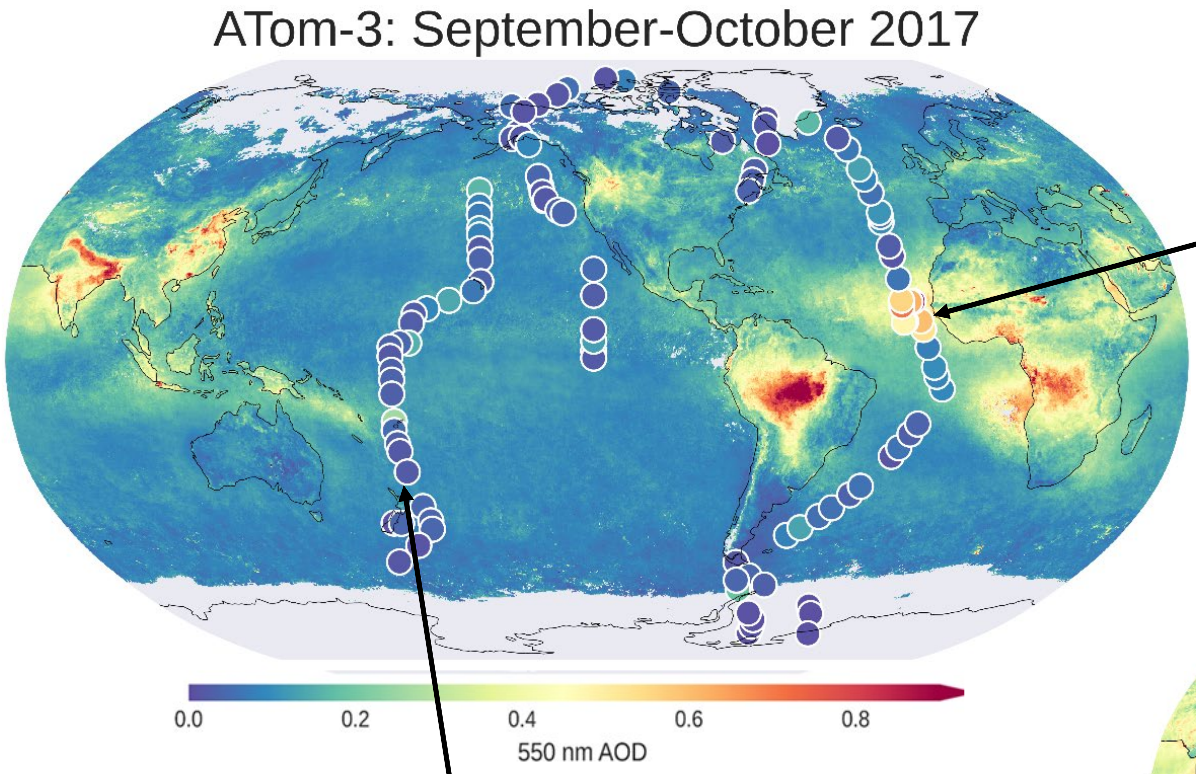
ATom-1 Aug 2016
ATom-2 Feb 2017
ATom-3 Oct 2017
ATom-4 May 2018

- **Global-scale snapshots of atmospheric composition in 4 seasons**
- **Near-continuous profiling from ~160 m to >12 km**
- **Non-targeted sampling (flight plans pre-determined)**
- **Avoided hazards (deep convection, air traffic, low clouds)**
- **Many opportunities for model-in situ-satellite collaboration**

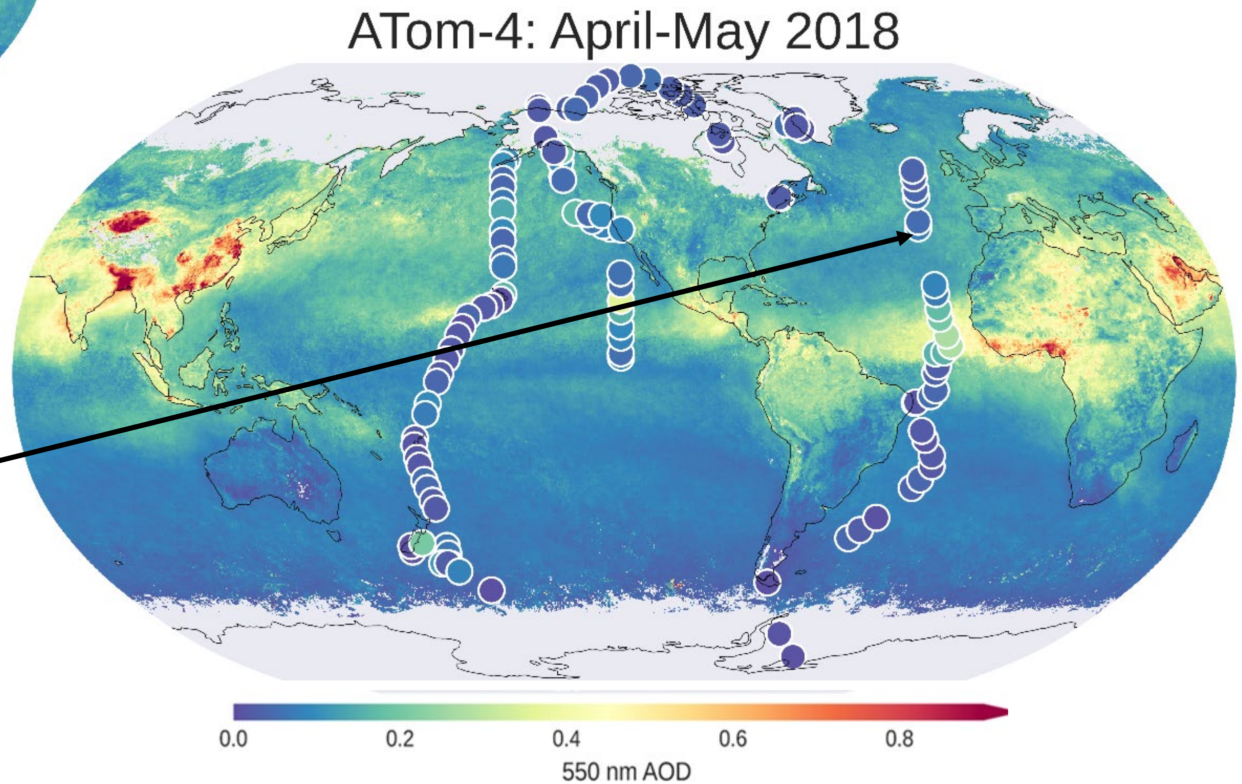
Distribution of total extinction at ambient RH



Compare profile AODs with VIIRS satellite data product



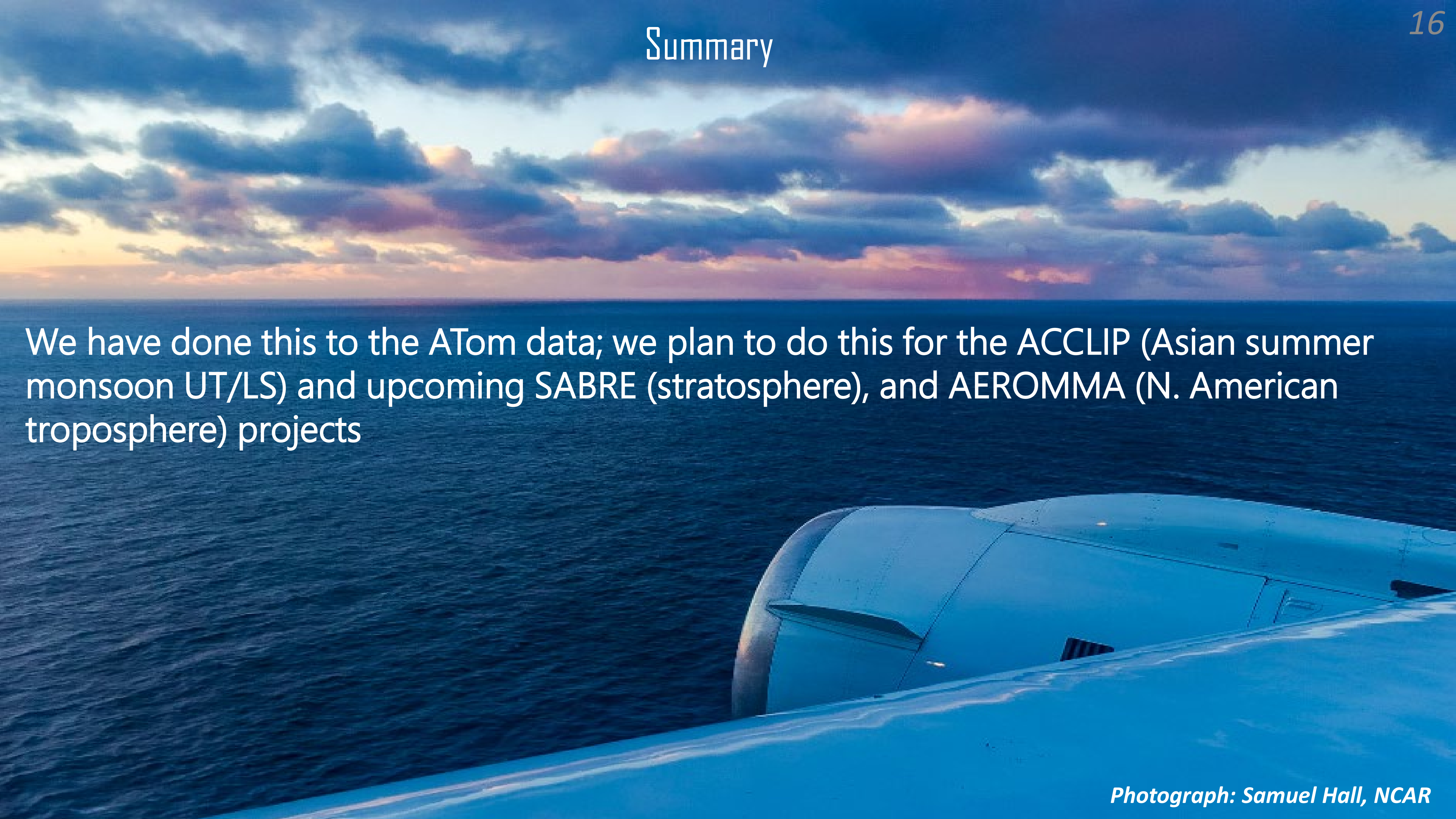
Agree well at high AOD values



Persistent bias (ATom<VIIRS) at low AOD values

Summary

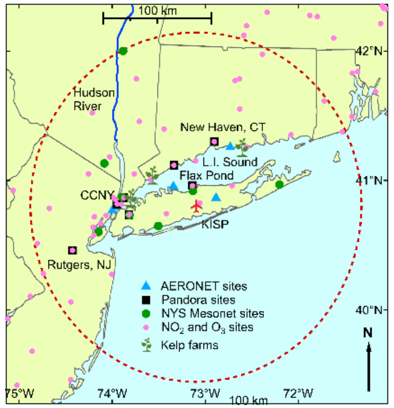
We have done this to the ATom data; we plan to do this for the ACCLIP (Asian summer monsoon UT/LS) and upcoming SABRE (stratosphere), and AEROMMA (N. American troposphere) projects

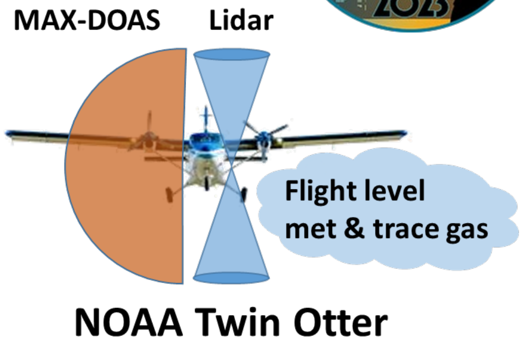


Photograph: Samuel Hall, NCAR

CUPiDS: Coastal Urban Plume Dynamics Study

- Platform: NOAA Twin Otter
  ~60 m/s, 4 hr endurance, up to 4km altitude
- MacArthur Airport, Long Island,
- 18 Jul – 16 Aug 2023 (24 days in the field)
- 31 science flights (~100 science flight hours)





<u>Science Goals:</u>

- Study the role of dynamics on air quality in the New York City region
- Quantify NOx emissions from the NYC metro area
- Determine Ozone production efficiency in the NYC metro area
- Evaluate TEMPO products

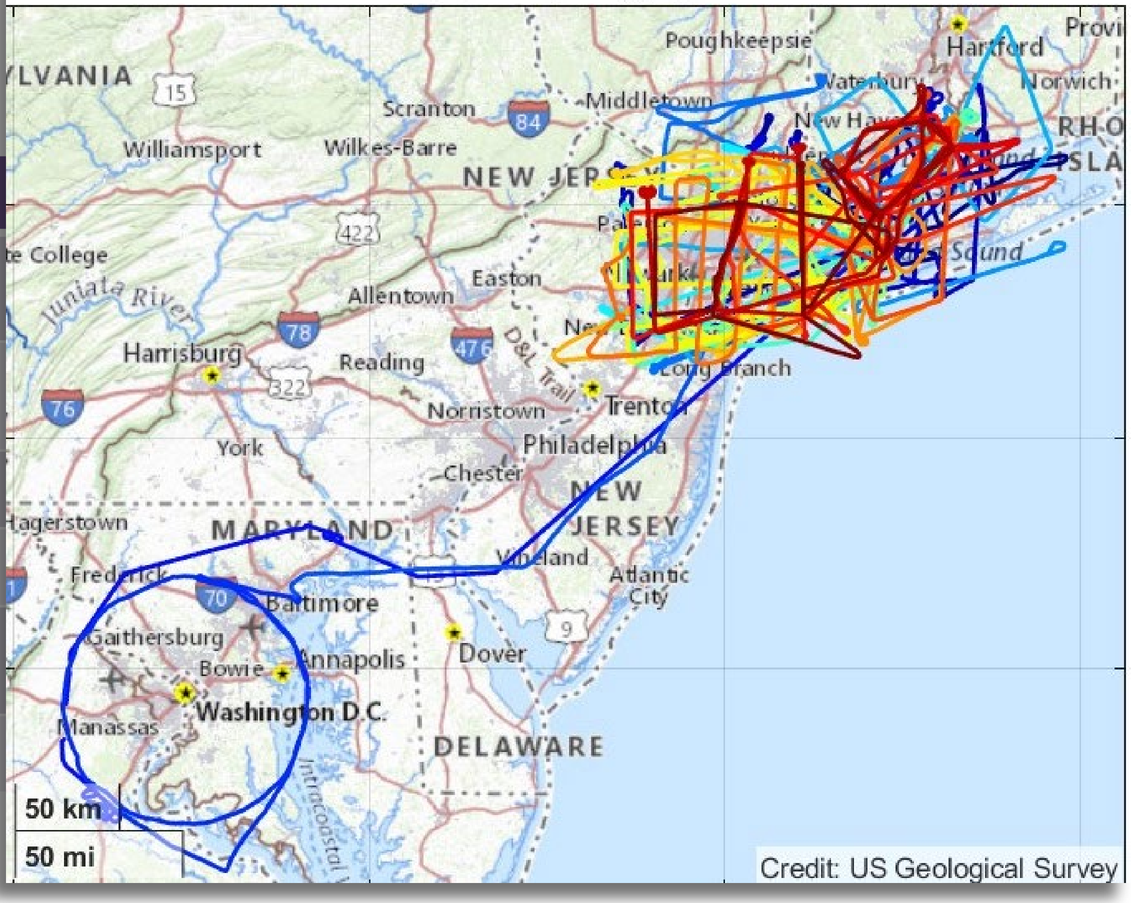
Photo: Chelsea Thompson

CUPiDS: Instrumentation

- Remote sensing + insitu measurements
- Active + Passive remote sensing instruments

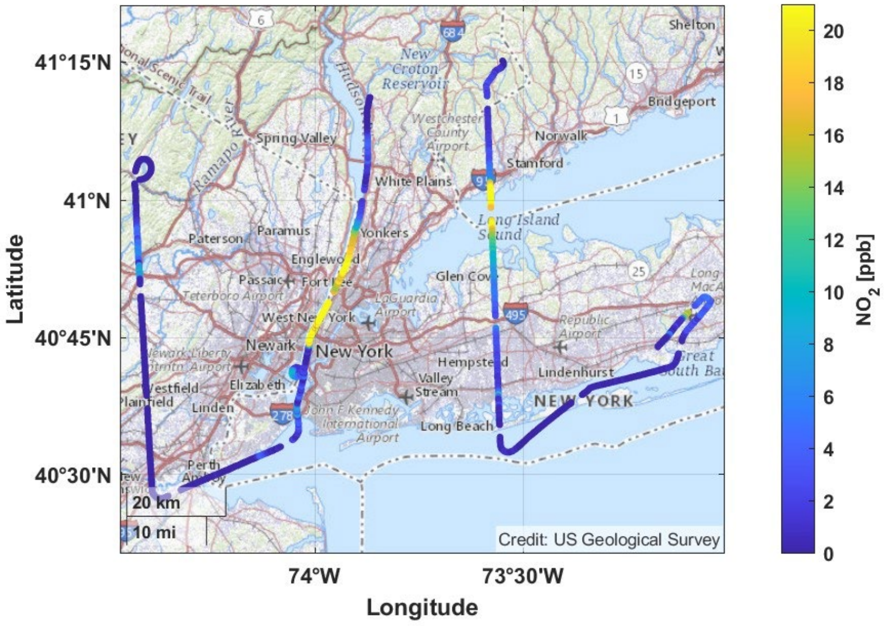
CUPiDS instruments	Measured Species
Scanning Doppler Lidar	Wind, turbulence and aerosol profiles Boundary layer height
MAX-DOAS	NO_2, formaldehyde, glyoxal columns Profiles during missed approaches
NO_xCaRD	In-situ NO, NO_2, NO_y, O_3
Picarro	In-situ CO_2, CH_4, CO, H_2O
Radiometer	Surface albedo at 360, 477, 577, and 630 nm Surface temperature
Filter radiometer	Up and downwelling NO_2 photolysis rate (jNO_2)

CUPiDS Flights

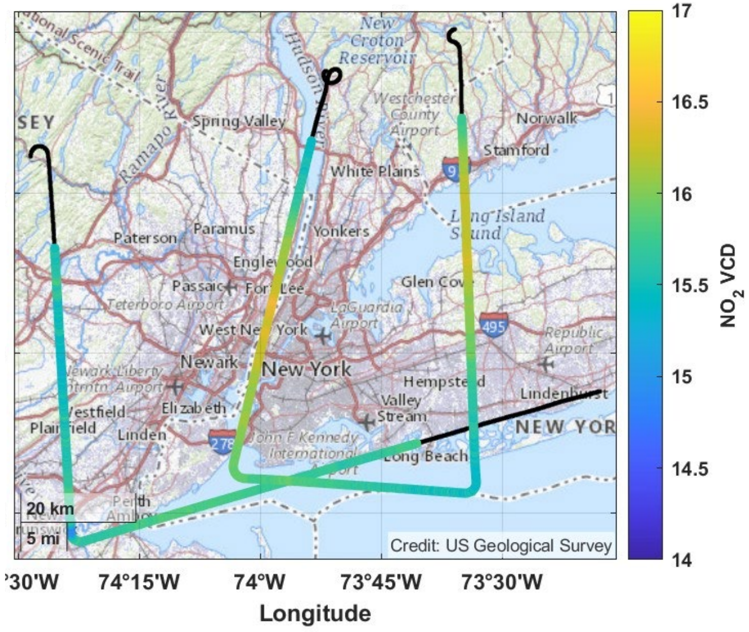


CUPiDS: Data example

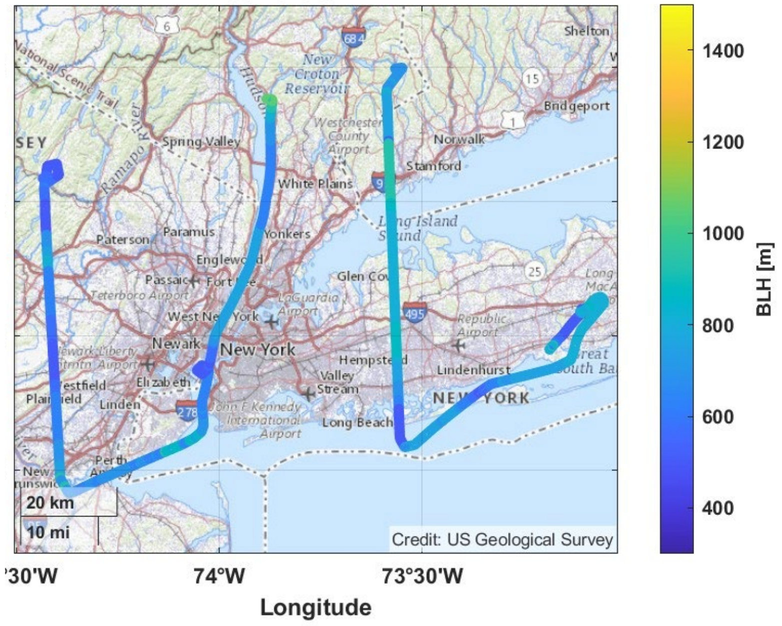
Insitu NO_2



Column NO_2



Boundary Layer Height



NOAA TOPAZ O_3 lidar and Doppler wind lidar @ YCFS

R. Alvarez II, S. Baidar, A. Brewer, A. Langford, B. McCarty, S. Sandberg, C. Senff, M. Zucker

- <u>Where</u>: Yale Coastal Field Station (YCFS) near New Haven, CT
- <u>When</u>: 3 Jul – 15 Aug (on station)
- <u>What</u>: TOPAZ - O_3 and aerosol backscatter profiles
  Doppler lidar - wind speed & direction profiles, turbulence,
  2-d surface winds (over water)
- <u>Main Science Objectives</u>:
  - Document the effect of the land - sea breeze circulation on distribution of O_3 and aerosol concentrations in the urban outflow downwind of NYC.
  - Evaluate the capabilities of high-resolution air quality models to replicate observed O_3 concentrations in the NYC area.
  - Validate TEMPO O_3 observations. Assess the accuracy of the 0-2 km AGL O_3 column product and study O_3 variability within individual TEMPO ground pixels.

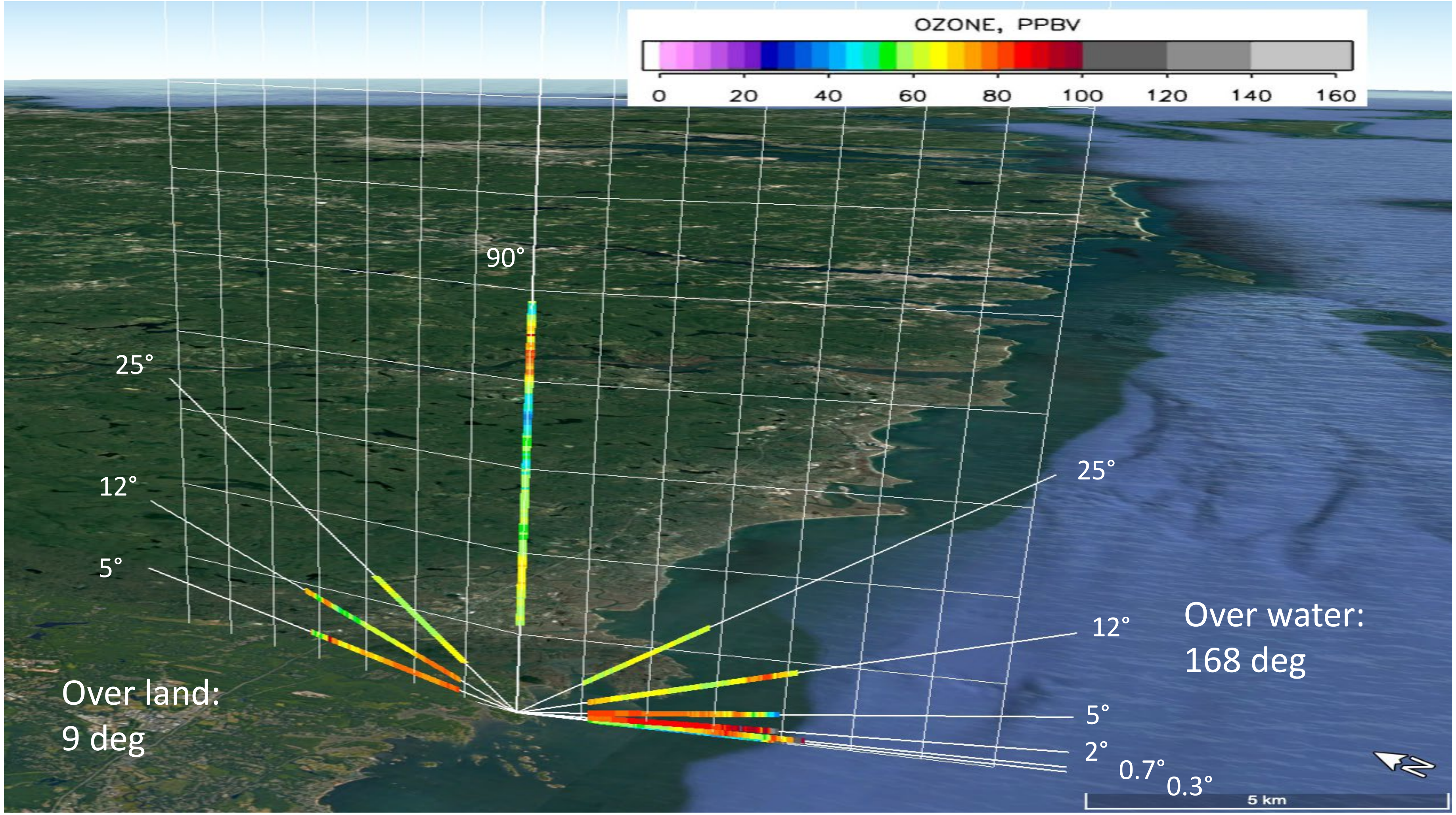
Preliminary data images:
https://csl.noaa.gov/groups/csl3/measurements/2023cupids/

NOAA Doppler lidar and TOPAZ O_3 lidar trailer at YCFS (photo: A. Langford)

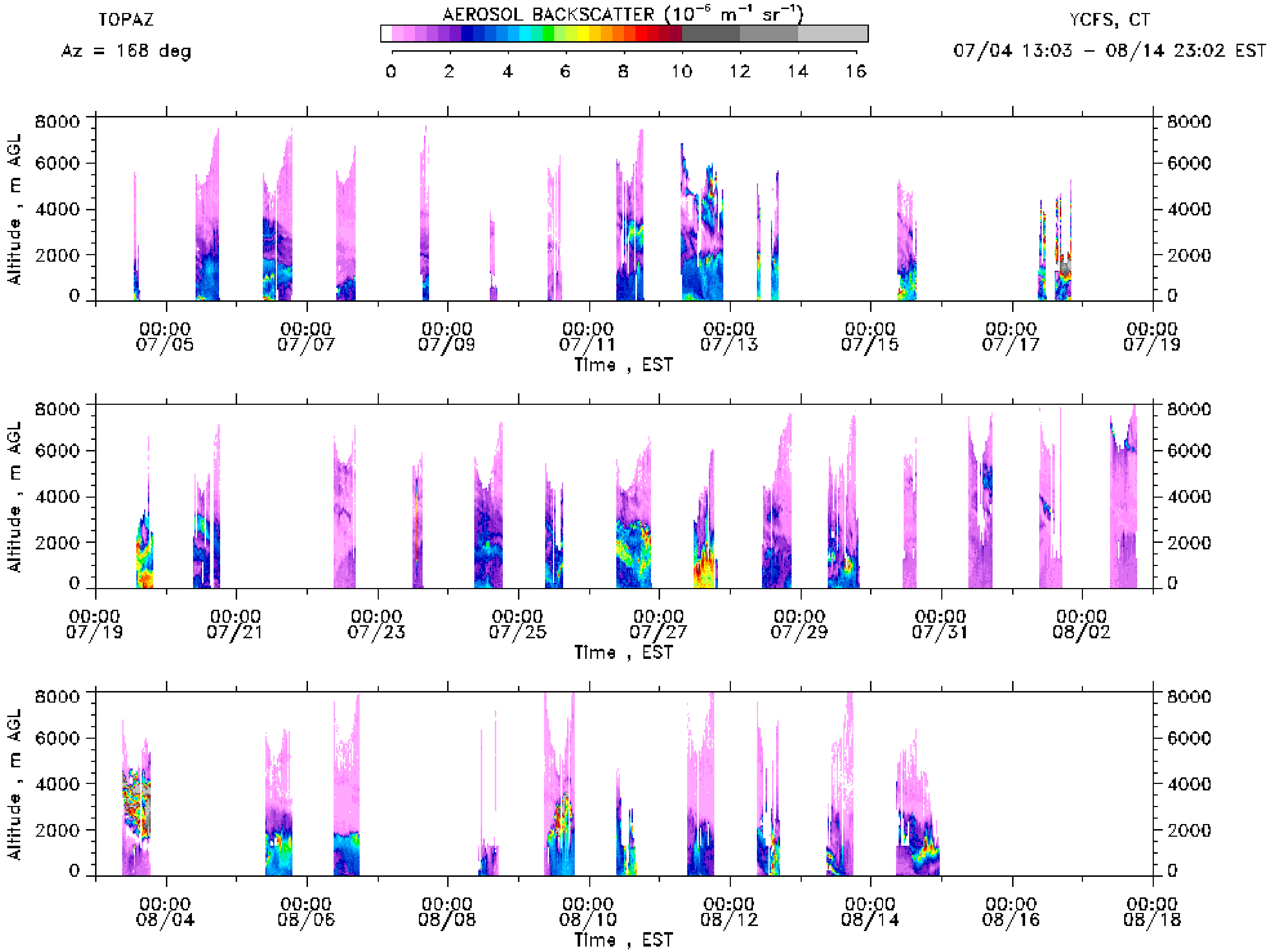
4 TOLNet O_3 lidars around the Long Island Sound

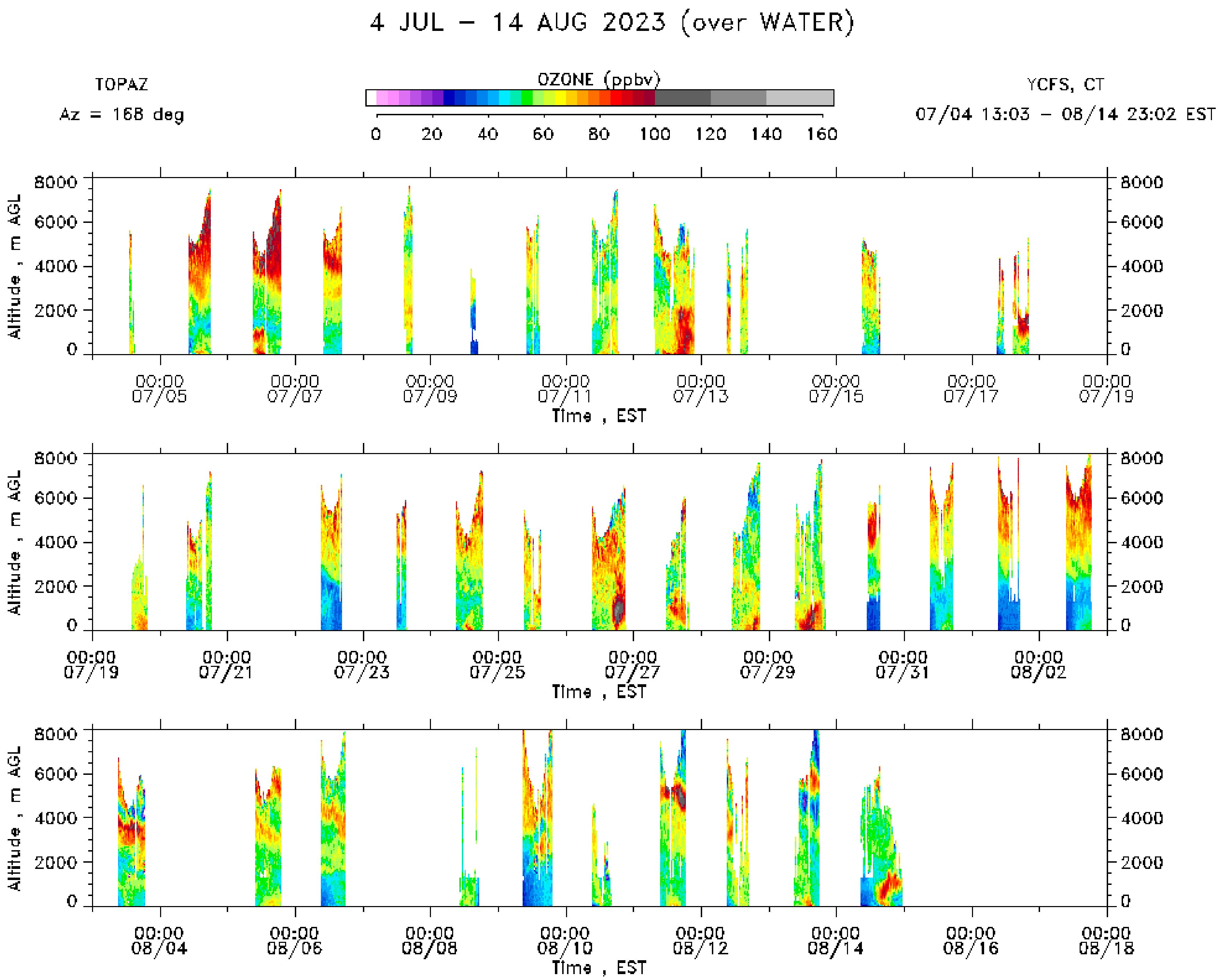
TOPAZ scan sequence (~ every 20 min)

Example: 12 JUL 2023, 9:55 – 10:15 EST

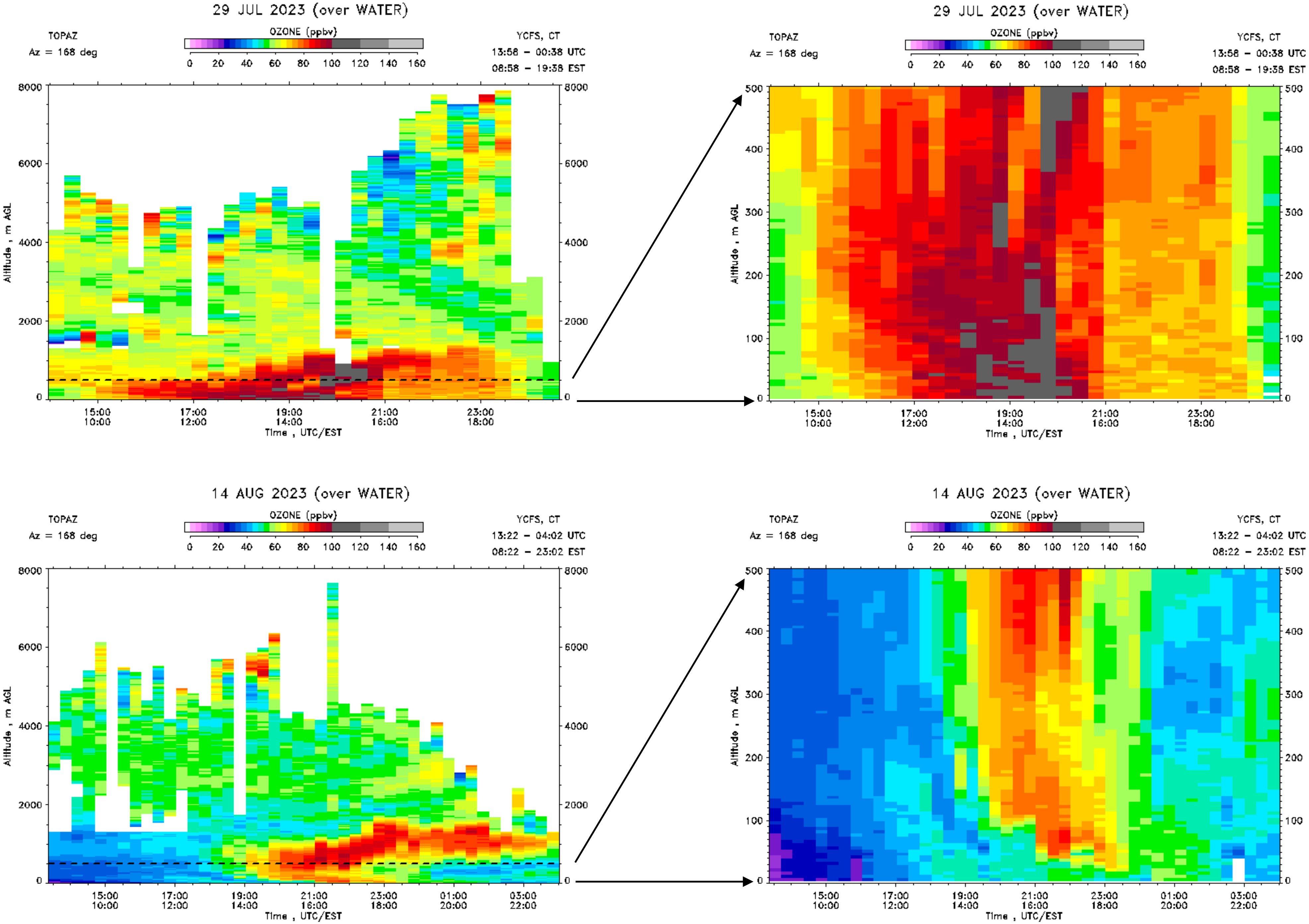


4 JUL – 14 AUG 2023 (over WATER)



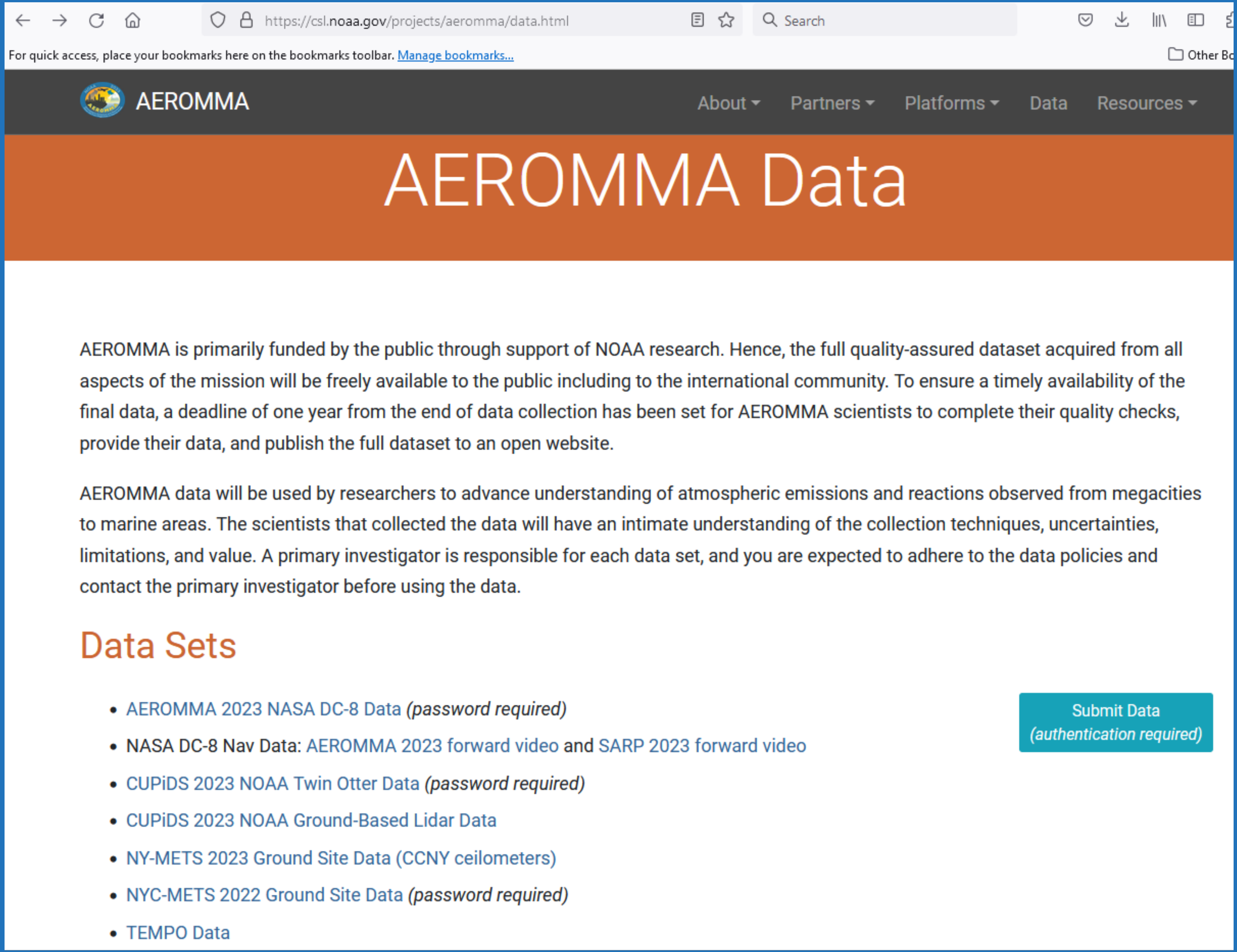


4 JUL – 14 AUG 2023 (over WATER)
TOPAZ
Az = 168 deg
OZONE (ppbv)
0 20 40 60 80 100 120 140 160
YCFS, CT
07/04 13:03 – 08/14 23:02 EST
Altitude , m AGL
8000
6000
4000
2000
0
00:00 07/05
00:00 07/07
00:00 07/09
00:00 07/11
00:00 07/13
00:00 07/15
00:00 07/17
00:00 07/19
Time , EST
00:00 07/19
00:00 07/21
00:00 07/23
00:00 07/25
00:00 07/27
00:00 07/29
00:00 07/31
00:00 08/02
Time , EST
00:00 08/04
00:00 08/06
00:00 08/08
00:00 08/10
00:00 08/12
00:00 08/14
00:00 08/16
00:00 08/18
Time , EST



29 JUL 2023 (over WATER)
TOPAZ
Az = 168 deg
OZONE (ppbv)
0 20 40 60 80 100 120 140 160
YCFS, CT
13:58 – 00:38 UTC
08:58 – 19:38 EST
Altitude , m AGL
Time , UTC/EST
15:00 10:00
17:00 12:00
19:00 14:00
21:00 16:00
23:00 18:00
14 AUG 2023 (over WATER)
13:22 – 04:02 UTC
08:22 – 23:02 EST
01:00 20:00
03:00 22:00

AEROMMA and CUPIDS data will be publicly available before September 2024



https://csl.noaa.gov/projects/aeromma/data.html

For quick access, place your bookmarks here on the bookmarks toolbar. Manage bookmarks...

AEROMMA — About · Partners · Platforms · Data · Resources

AEROMMA Data

AEROMMA is primarily funded by the public through support of NOAA research. Hence, the full quality-assured dataset acquired from all aspects of the mission will be freely available to the public including to the international community. To ensure a timely availability of the final data, a deadline of one year from the end of data collection has been set for AEROMMA scientists to complete their quality checks, provide their data, and publish the full dataset to an open website.

AEROMMA data will be used by researchers to advance understanding of atmospheric emissions and reactions observed from megacities to marine areas. The scientists that collected the data will have an intimate understanding of the collection techniques, uncertainties, limitations, and value. A primary investigator is responsible for each data set, and you are expected to adhere to the data policies and contact the primary investigator before using the data.

Data Sets

- AEROMMA 2023 NASA DC-8 Data *(password required)*
- NASA DC-8 Nav Data: AEROMMA 2023 forward video and SARP 2023 forward video
- CUPiDS 2023 NOAA Twin Otter Data *(password required)*
- CUPiDS 2023 NOAA Ground-Based Lidar Data
- NY-METS 2023 Ground Site Data (CCNY ceilometers)
- NYC-METS 2022 Ground Site Data *(password required)*
- TEMPO Data

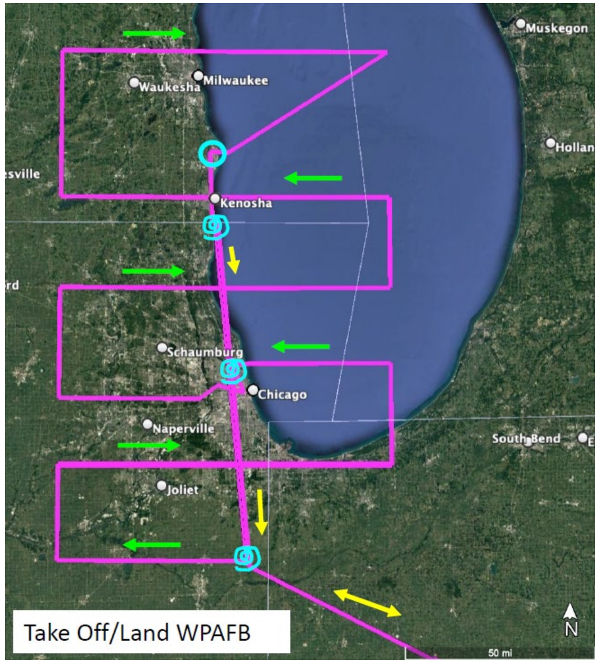
Submit Data *(authentication required)*

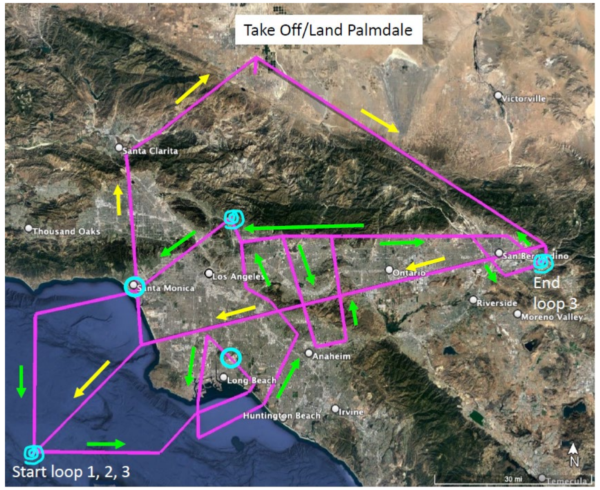
https://csl.noaa.gov/projects/aeromma/data.html

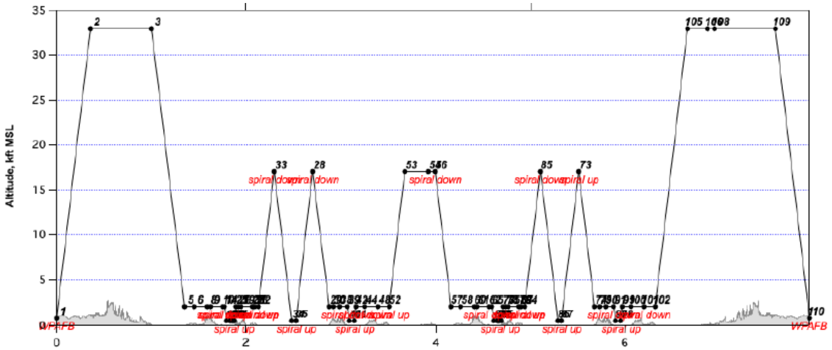
End of presentation

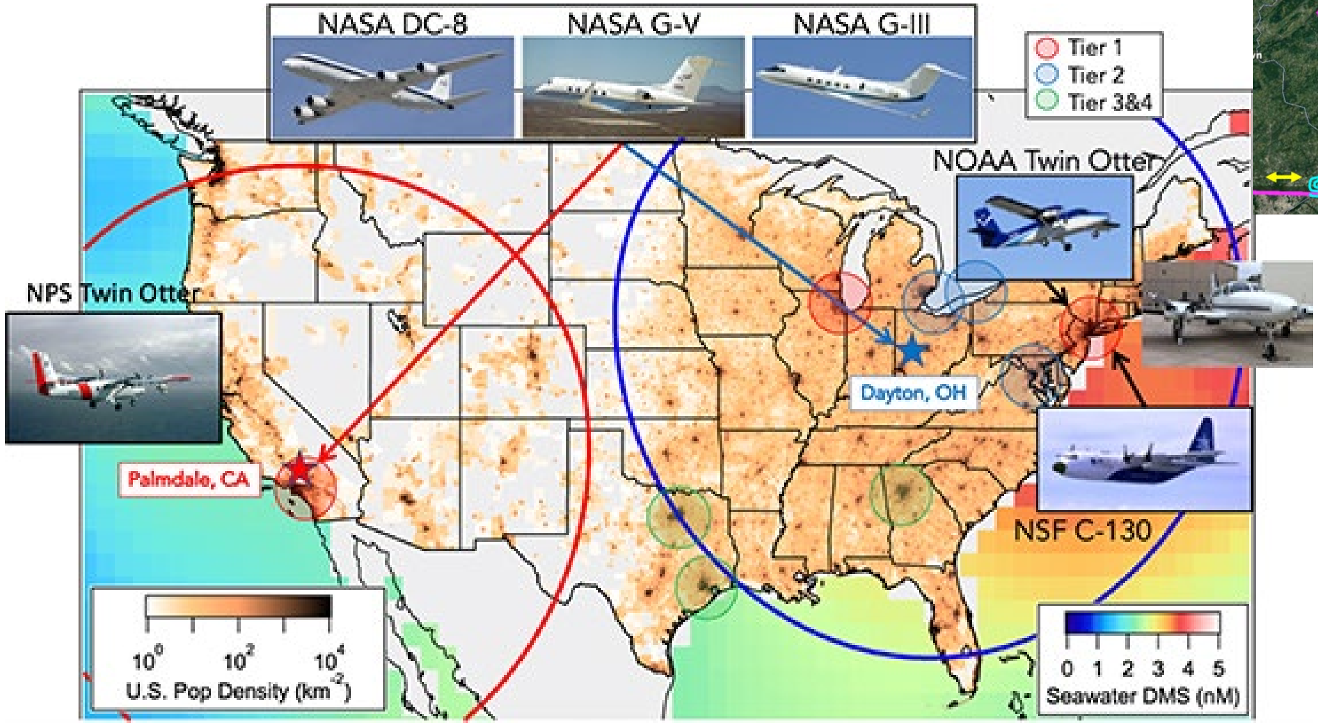
NOAA / NASA Field Campaigns Help Evaluate Satellite Obs

4 flights x 2 patterns per day



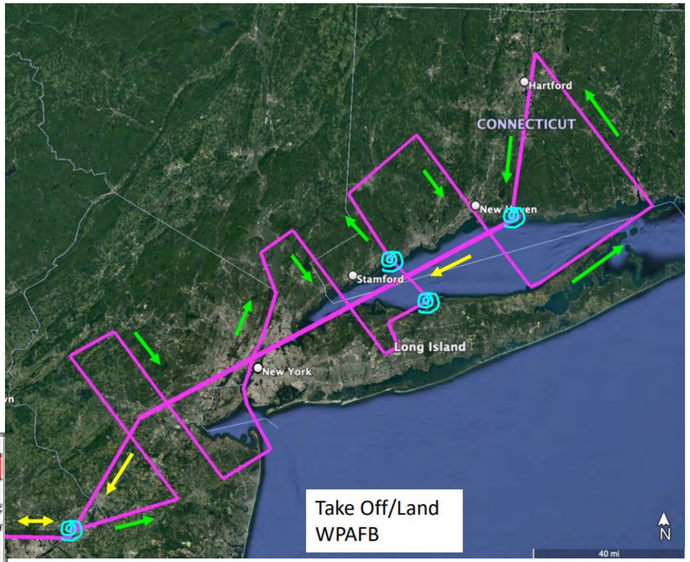






3 flights x 3 patterns per day

4 flights x 2 patterns per day



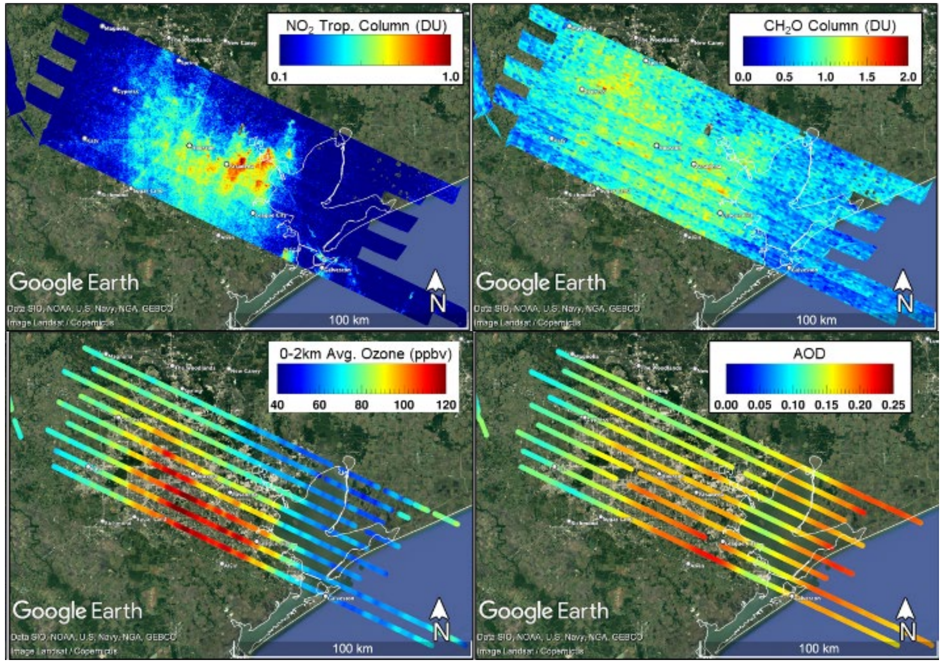
NASA STAQS Airborne Remote Sensing

NASA GV
GCAS
HSRL-2
O_3 DIAL

NASA GIII
AVIRIS-NG
HALO

NO_2

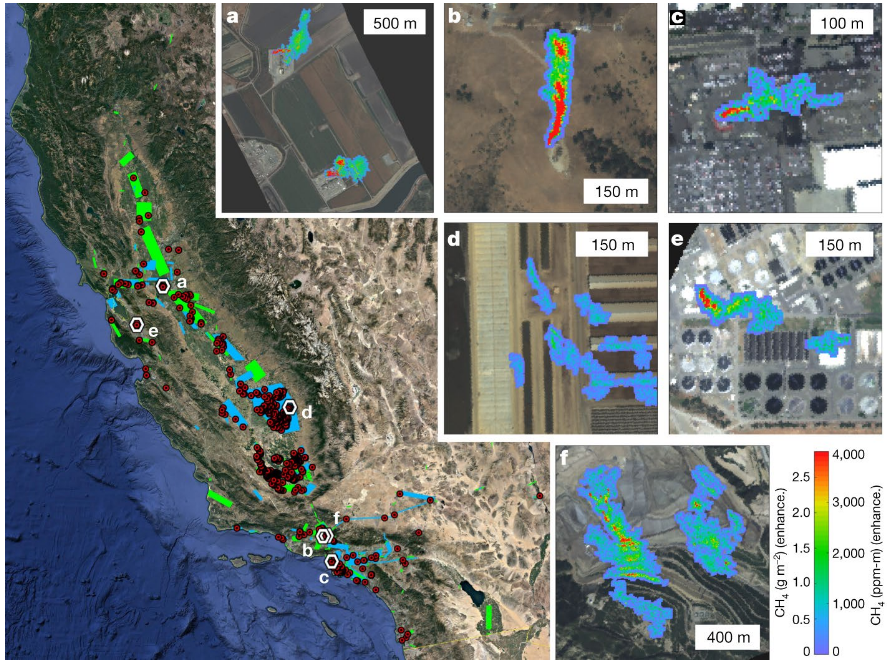
Trop. O_3



HCHO

AOD

Figure from Laura Judd (NASA LaRC)



CH_4

Duren et al. (Nature, 2019)

S-HIS: Scanning High-resolution Interferometer Sounder

Joe Taylor
with material from Dave Tobin and David Loveless
2023-10-03

THE UNIVERSITY of WISCONSIN MADISON

SSEC

S-HIS: Scanning High-resolution Interferometer Sounder

Instrument characteristics

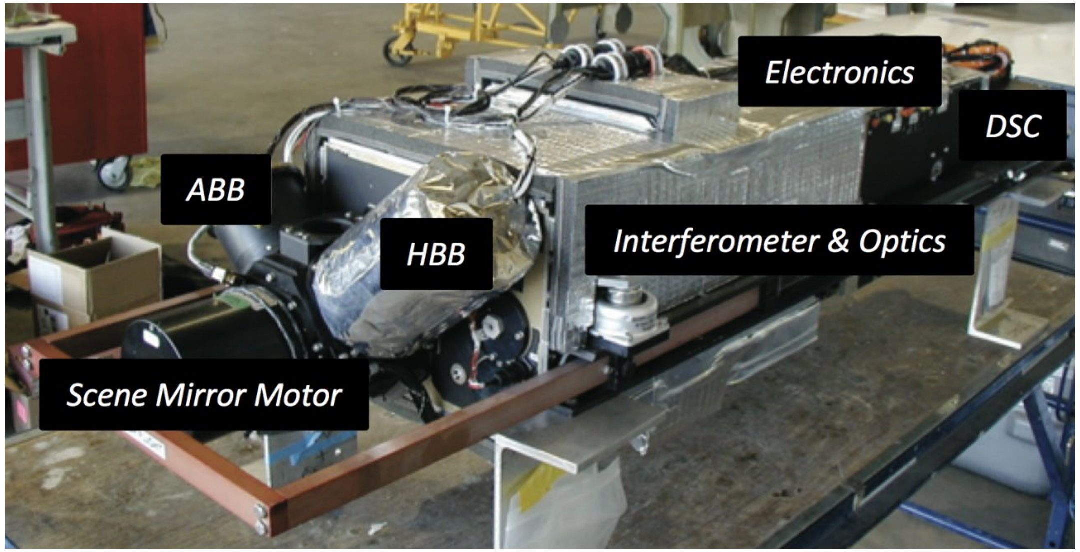
Spectral range	580 – 2850 cm^{-1} 3.5 – 17.3 µm
Spectral resolution	0.5 cm^{-1}
Vertical resolution (Sounding)	2 km
Footprint Size at nadir	2 km from 20 km 100m from 1km
Swath	ER-2: 40 km (20 km altitude)

Dynamically aligned FTS
Programmable cross-track scan coverage
UW-SSEC designed Michelson mirror assembly
4-band detector option for extended LW IR coverage
Zenith view on Proteus and WB-57

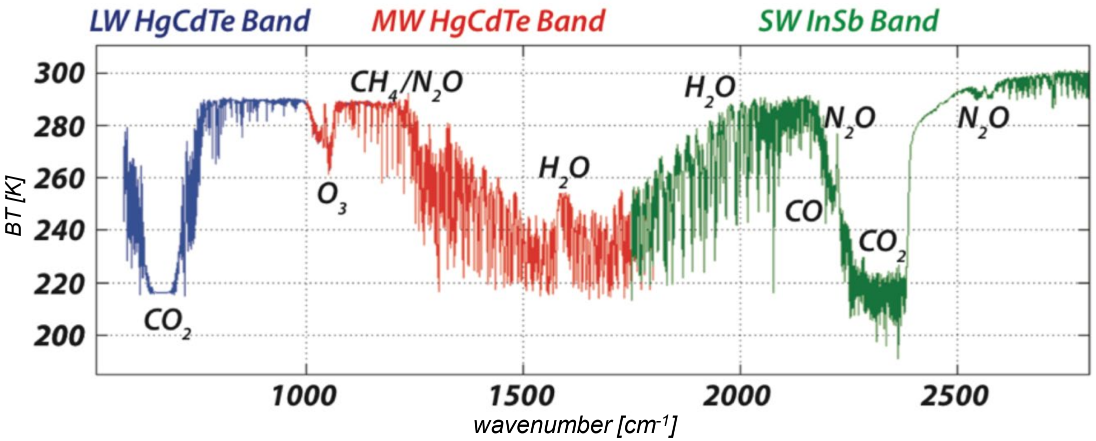
36 missions on 5 aircraft (ER-2, Global Hawk, WB-57, Proteus, DC-8) since 1998
20+ years since our last DC-8 mission in 2002
Extremely dependable, with preliminary products typically available within a few hours after data download
Near real-time products available within 1-minute of observation when a high bandwidth downlink is available

Geophysical Retrievals (Dual Regression)
Temperature Profiles
Water Vapor Profiles (RH, Mix Ratio)
CO, N_2O, CH_4, O_3 Profiles
Total Column CO_2 concentration
Surface temperature and emissivity

Past Measurement Application Examples
Radiative transfer model assessment
Trace gas retrievals
Cloud radiative properties
Cloud top retrievals
Fire characterization
Thermodynamic environment around hurricane and tropical storms
Saharan air layer studies
Calibration validation (L1b and L2)

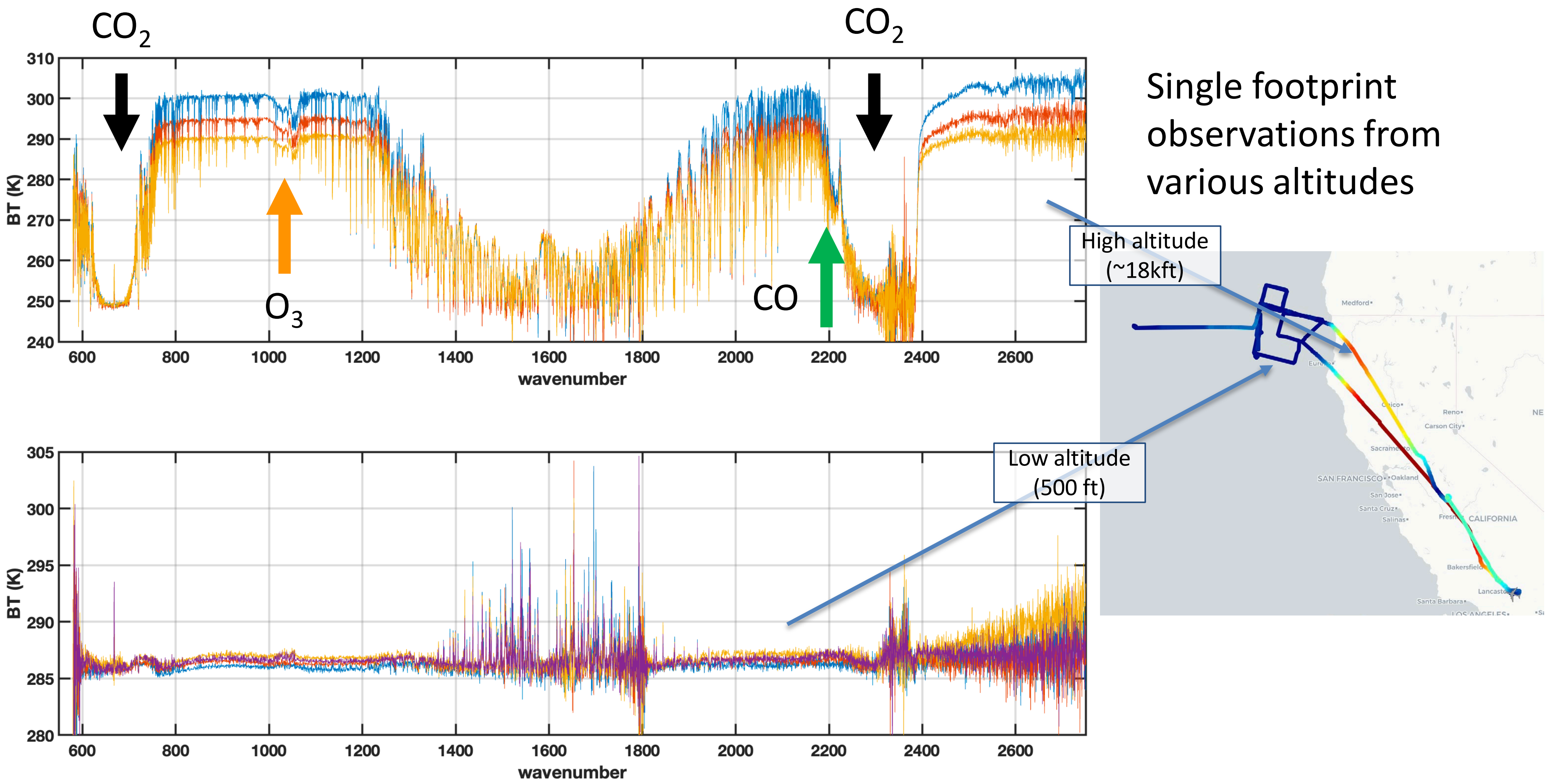


S-HIS key subsystems



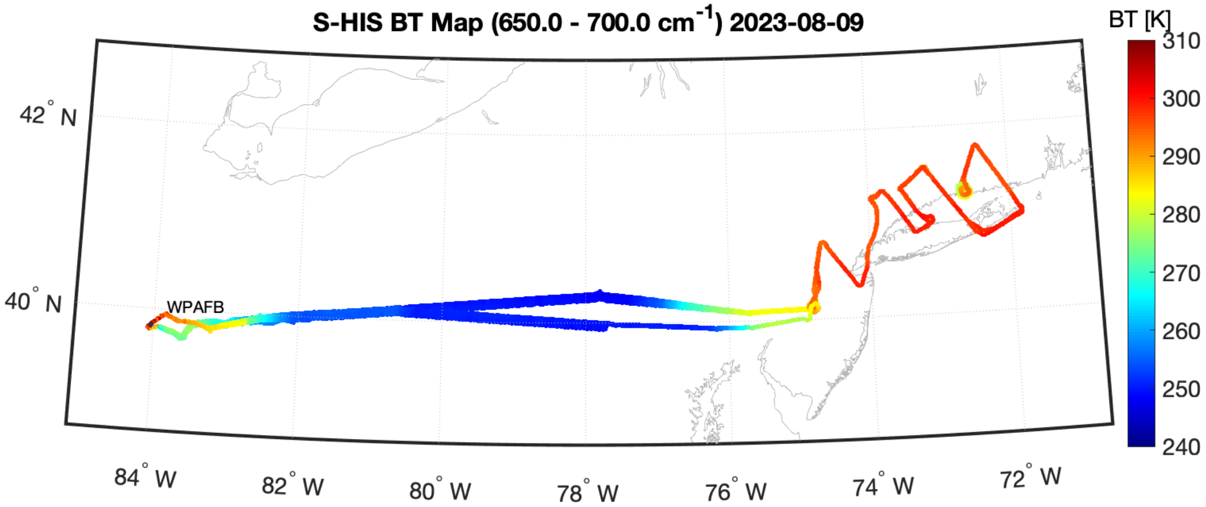
3-band detector coverage

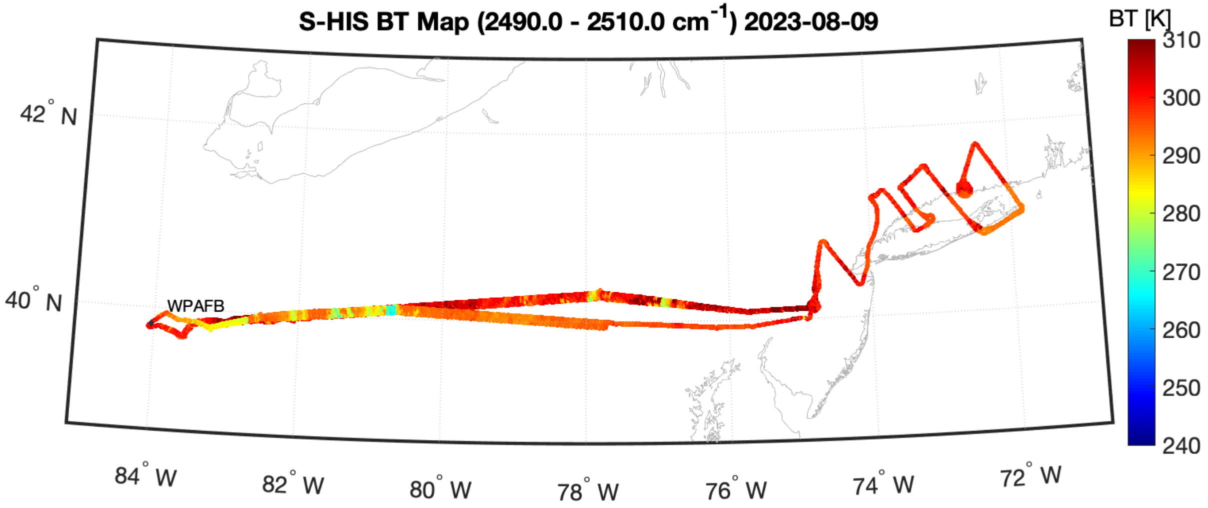
Preliminary Sample Brightness Temperature Spectra from 2023-06-21 AEROMMA Marine Flight



Low level legs have low information content (small difference between absorption channels and window channels), but have the information content needed to explain atmospheric variability over that small layer

NJ/NYC Flight (09-Aug-2023)

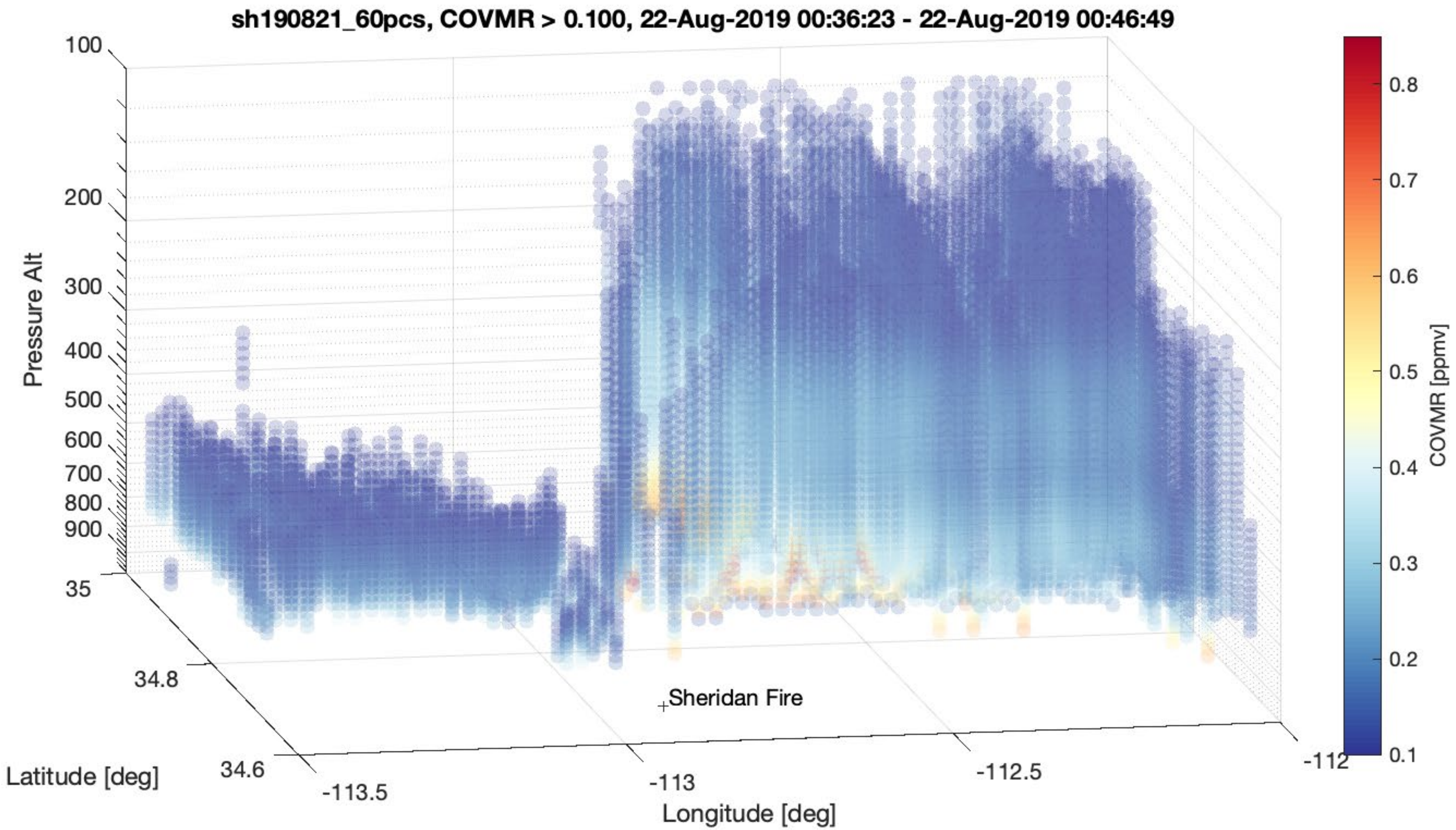




Map of entire 9 Aug. 2023 NJ/NYC Flight

- Top figure: brightness temperatures in CO_2 absorption region
  - indicates flight level temperatures
- Bottom figure: brightness temperatures in shortwave window region
  - indicates skin temperatures (or cloud top temperatures)
- Swath width increases with higher altitude
- Smaller footprint with low-level legs in NJ, NY, CT.

Example CO retrieval from FIREX-AQ



2019-08-21 Flight

- Retrieved (Dual Regression) CO VMR (ppmv) for the 5th pass near the Sheridan fire
- Plotting values with CO VMR > 0.100 ppmv