Aircraft Measurements in Polluted Winter Boundary Layers

Opportunities and Challenges for Western Mountain Basins

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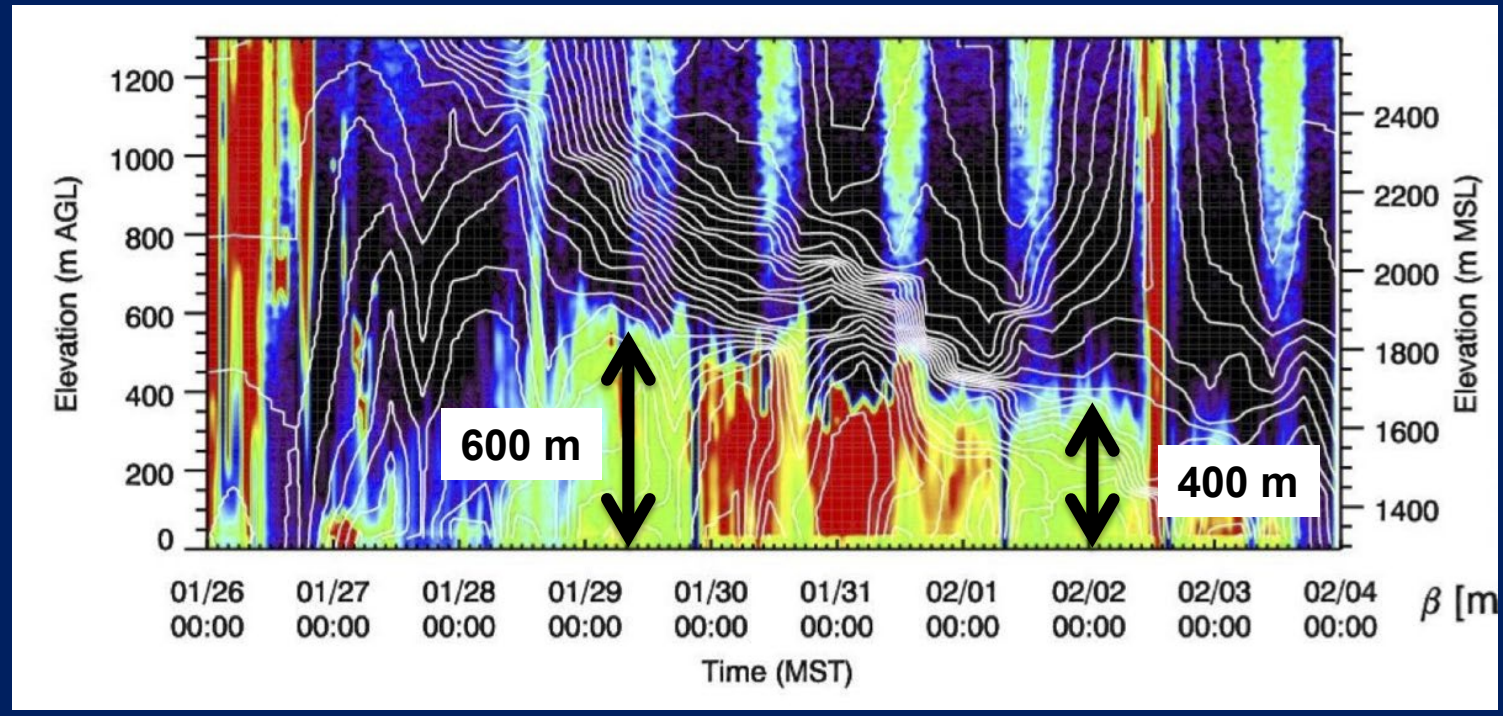
The Challenge and Opportunity

- Winter boundary layers are *shallow* : of order 100 – 800 m generally
- Characterizing composition as a function of height above ground in this range is crucial to winter air quality science
- How best to solve this challenge ?
  Are research aircraft the best / most effective way to do this ?
  If so, what is the optimum size (aircraft) and scale (spatial domain) ?

Image of inversion depth during late January – early February 2017 PCAP in Salt Lake City

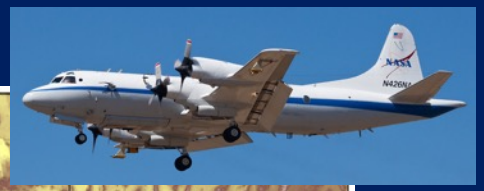
Sebastian Hoch, U. Utah



Recent U.S. Winter Aircraft Studies

DISCOVER-AQ 2013

Deriving Information on Surface Conditions from Column and Vertically Resolved Observations Relevant to Air Quality

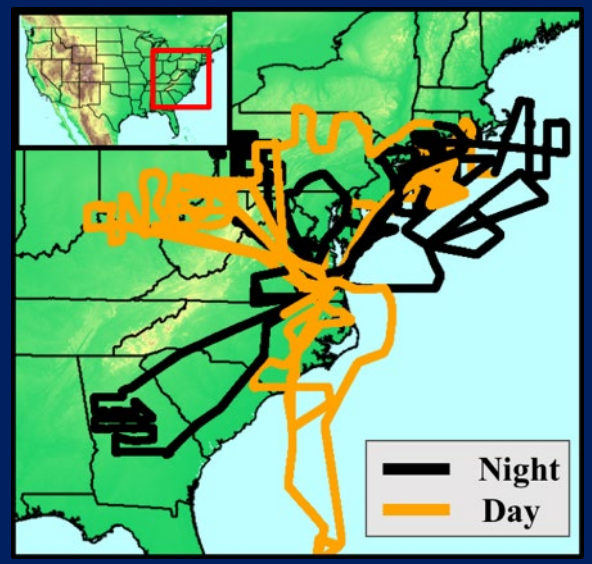


NASA
P-3

WINTER 2015

Winter Investigation of Transport Emissions and Reactivity

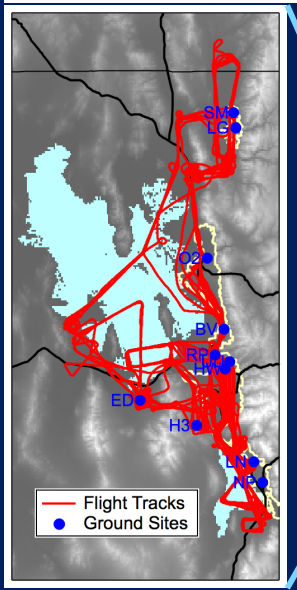
NSF
C 130



UWFPS 2017

Utah Winter Fine Particulate Study

NOAA
Twin Otter

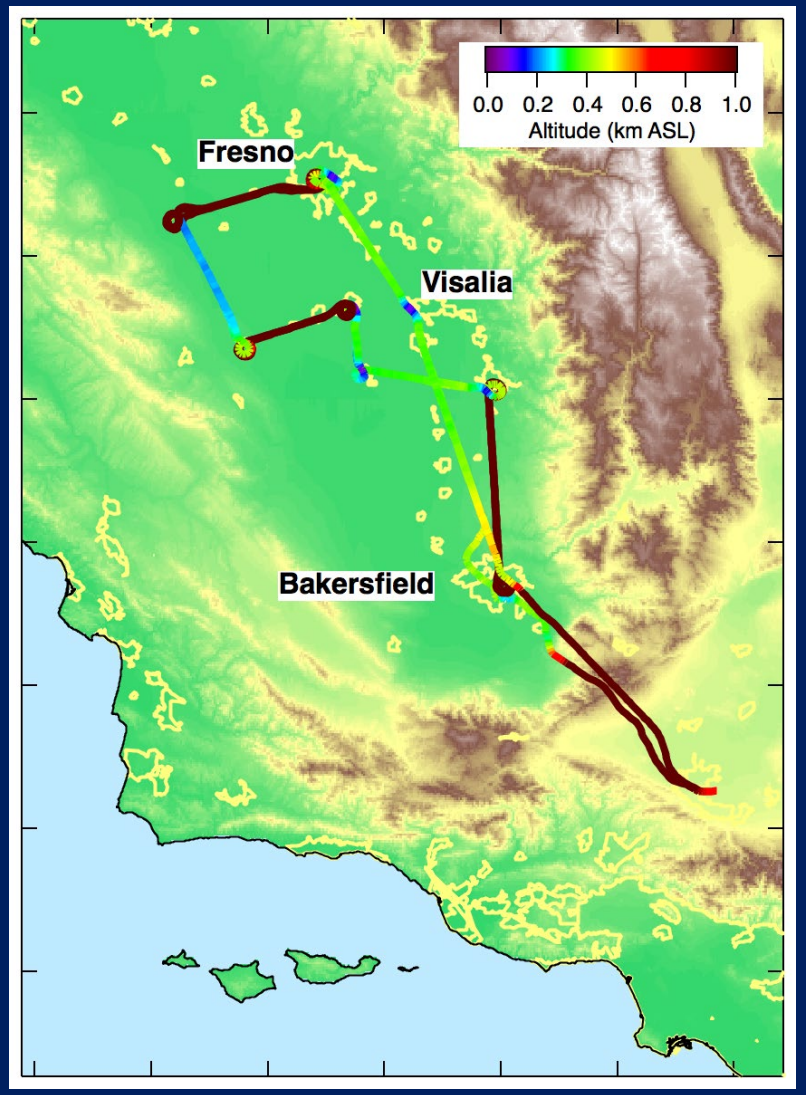


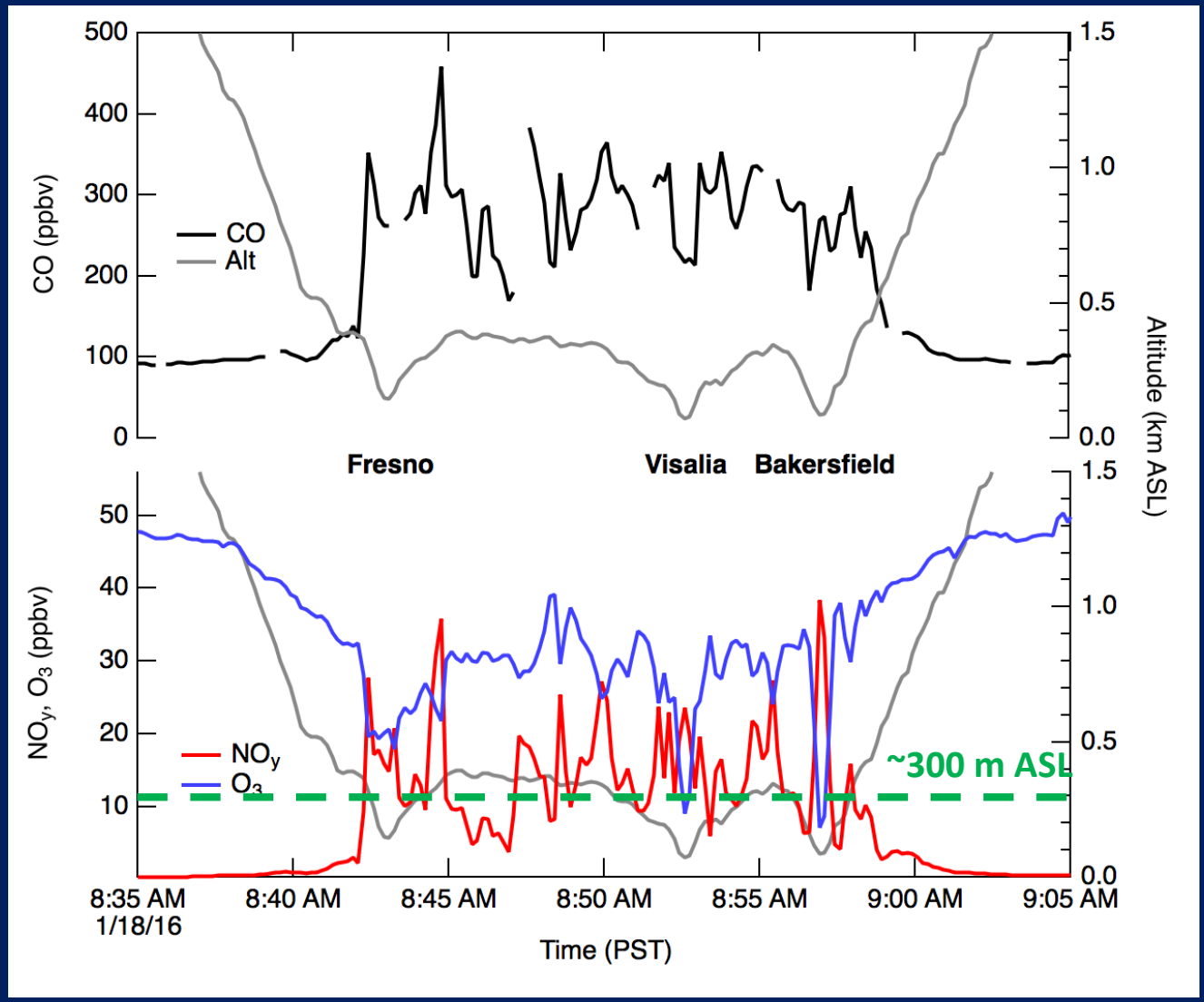
DISCOVER-AQ San Joaquin Valley

- January – February 2013
- ~ 85 Flight hours / 12 research flights / 10 flights in the SJV
- Repeated flight pattern (3x each day) across multiple days
- 9 AM takeoff time each day (no night flights)

P-3B Instruments		
+ Anderson, Bruce	LARGE (aerosols)	NASA LaRC
+ Barrick, John	PDS (met,nav)	LaRC-SSAI
+ Cohen, Ron	TD LIF (NO2, HNO3, PNs, ANs)	U of CA, Berkeley
+ Diskin, Glenn	DLH (H2O), DACOM (CO, CH4)	NASA LaRC
+ Fried, Alan	IR Absorption Spectrometer (CH2O)	U of CO, Boulder
+ Weinheimer, Andy	Chemiluminescence (O3, NO2, NO, NOy)	NCAR
+ Wisthaler, Armin	PTRMS (non-methane hydrocarbons)	University of Innsbruck
+ Yang, Melissa	AVOCET (CO2)	NASA LaRC

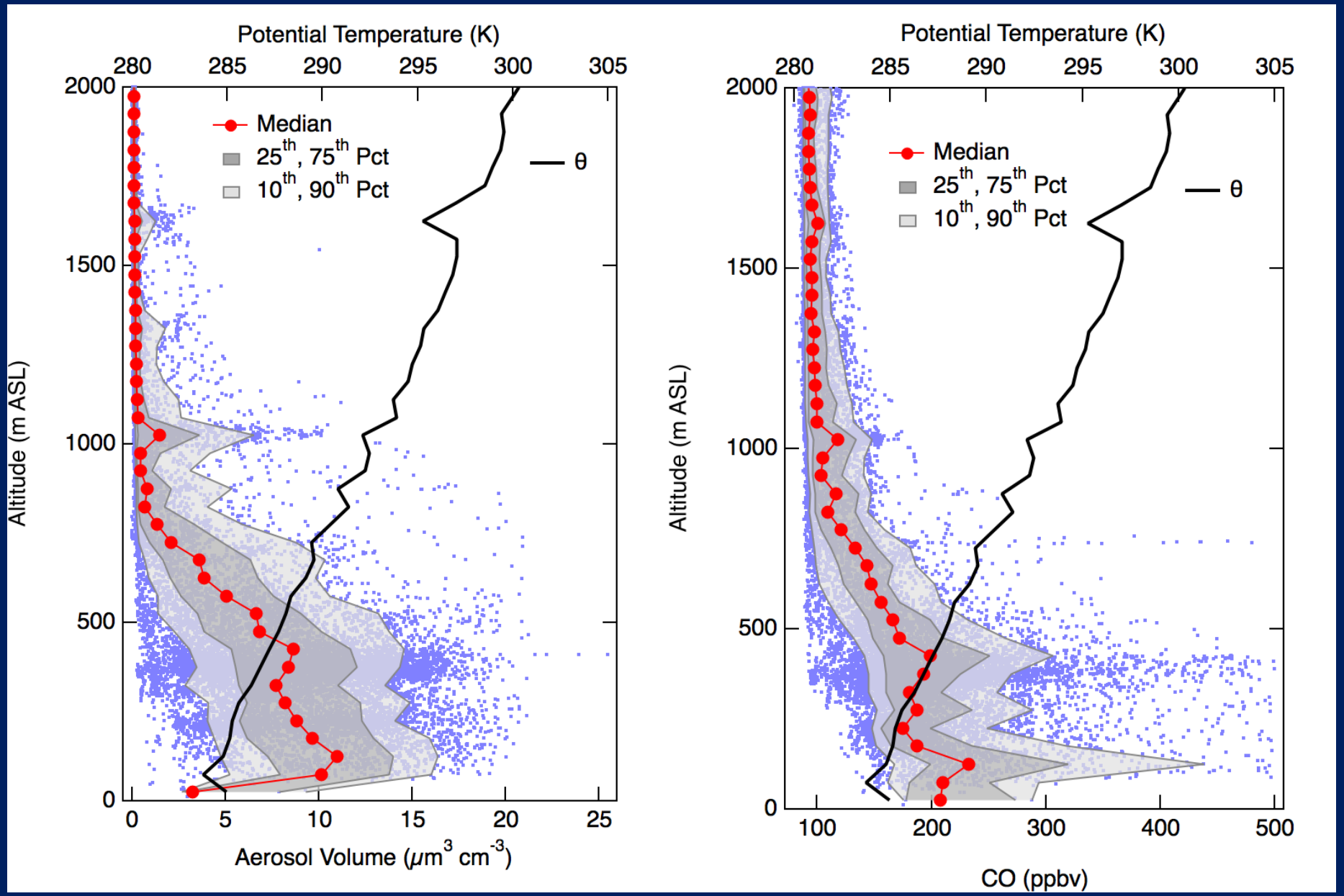
Example DISCOVER-AQ Flight – January 18, 2013





- Missed approaches / Vertical profiles to characterize boundary layer structure, depth & composition
- Level legs at 300 m ASL (≈ AGL here) are well within the polluted part of the BL

DISCOVER Vertical Distributions



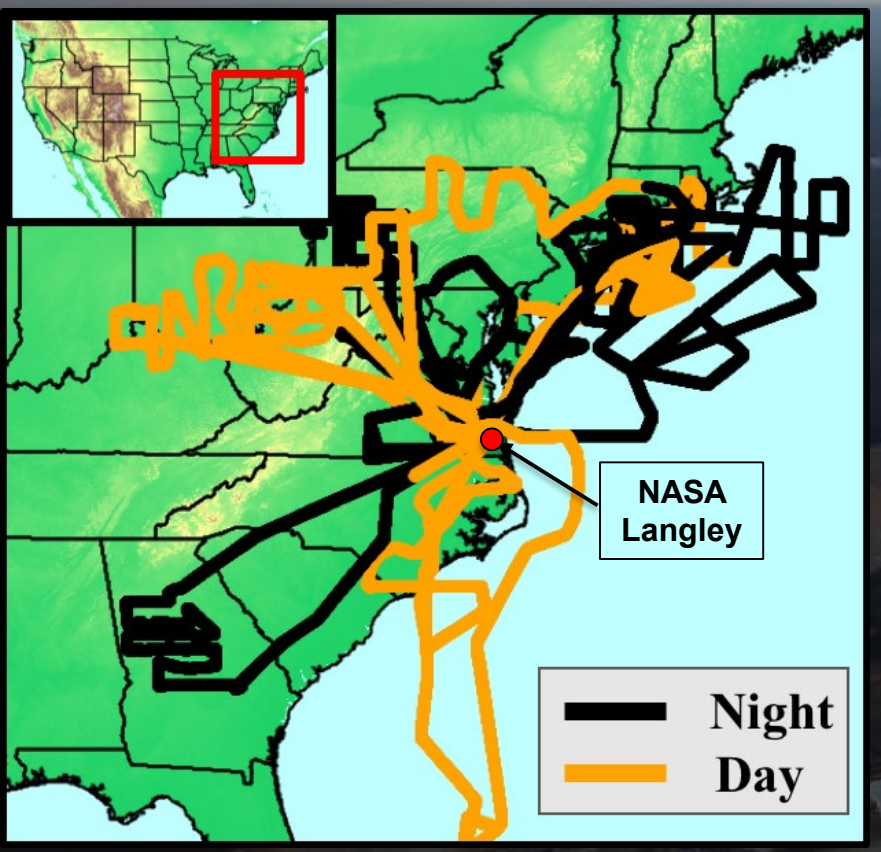
Concentrated part of the mixed layer to 400 m ASL

Max BL depth 1000 m

NASA P3 sampled routinely at 300 m ASL, with vertical profiles from the surface to 3000 m

Wintertime INvestigation of Transport, Emissions and Reactivity (WINTER)

NSF / NCAR C-130 Aircraft February 1 – March 15, 2015, United States East Coast



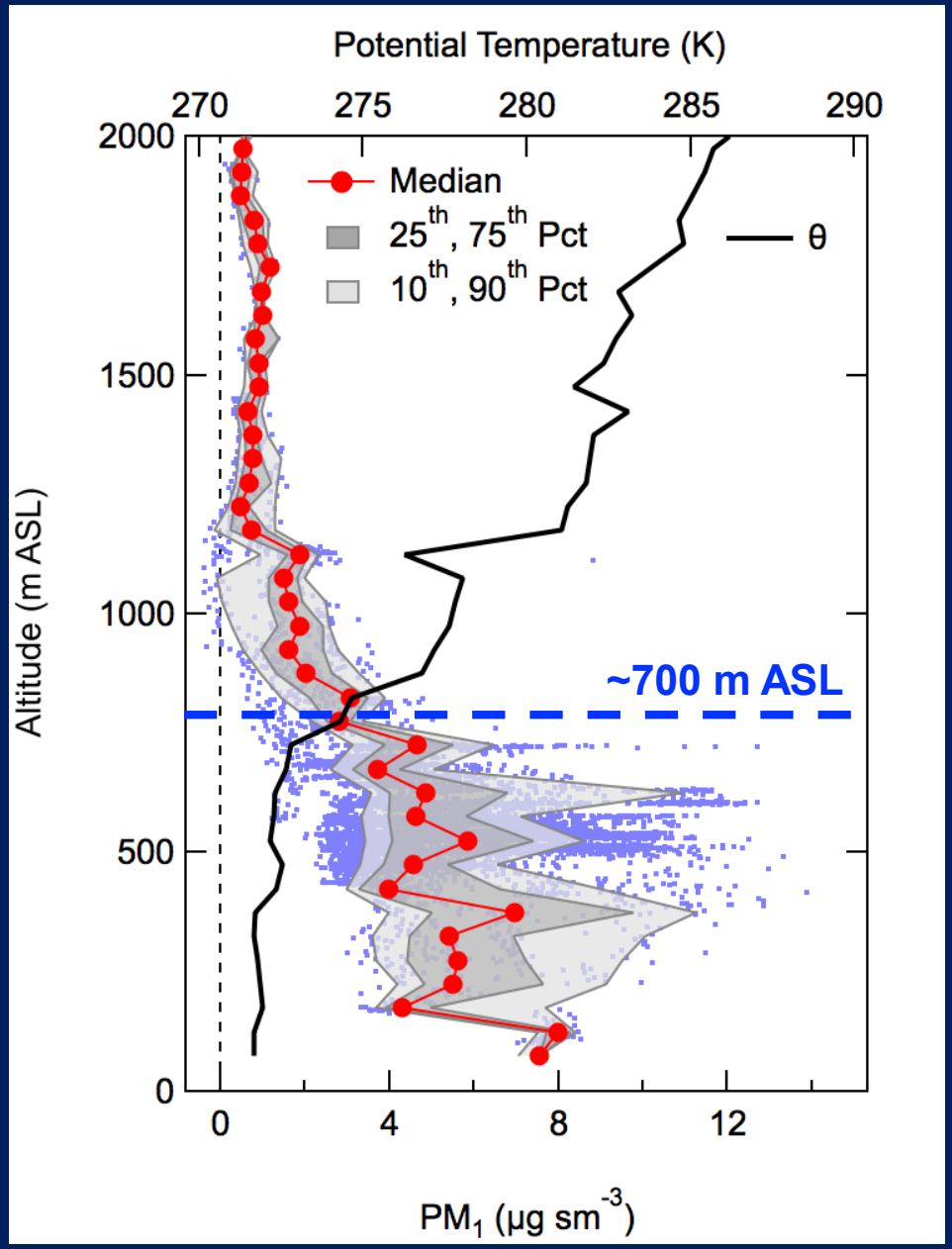
- 13 Research Flights / ~ 100 hours
- Approximately 50% of flight hours at night
- 70% within 1 km of the surface
- No two flights the same – individual goals for each research flight

Comprehensive gas and aerosol payload

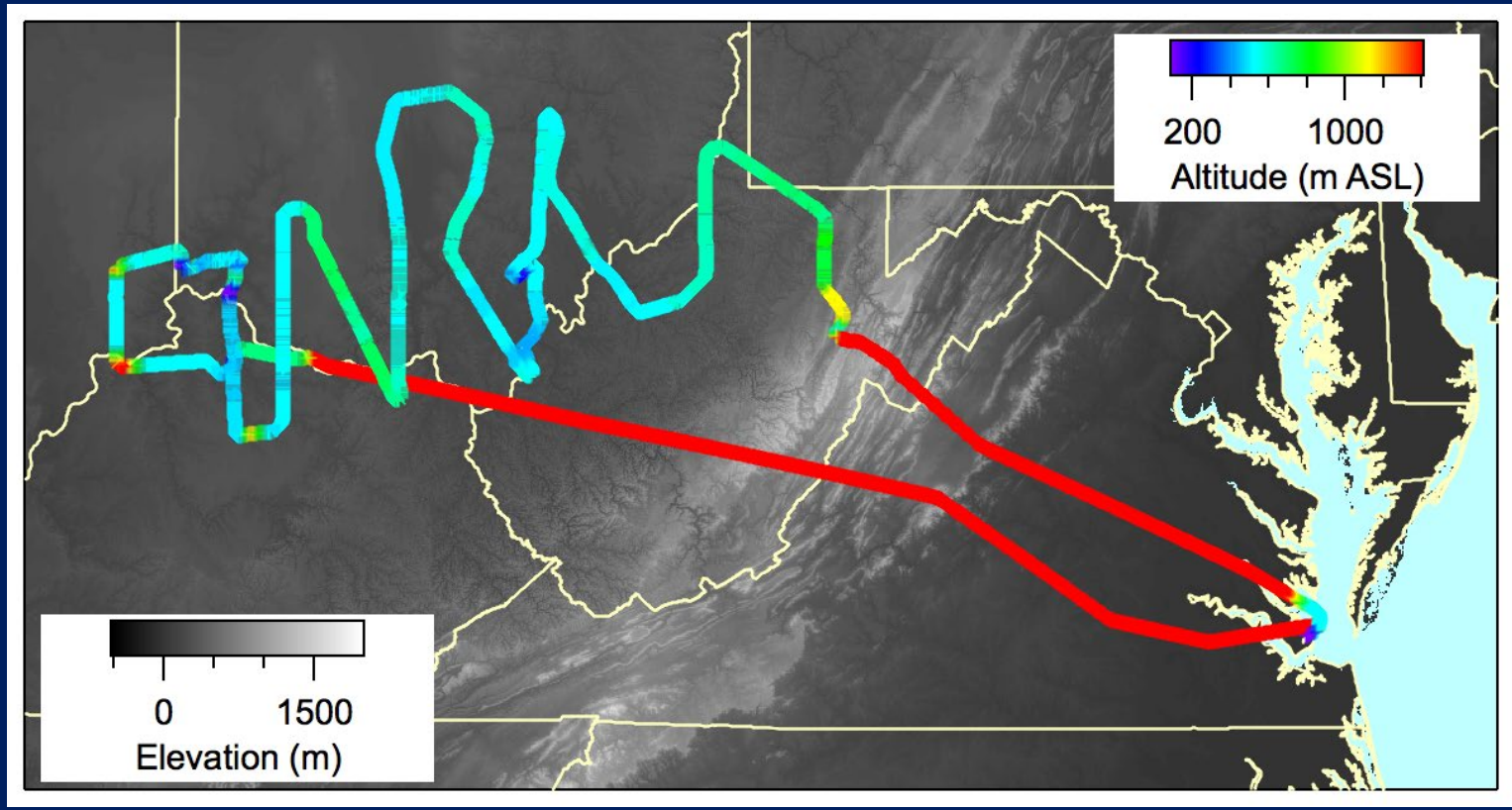
Research Goals

- Distribution and lifetime of primary pollutants
- Heterogeneous / multiphase processes
- Secondary aerosol formation mechanisms
- Wintertime oxidants

WINTER – Example Winter BL Flight



- Daytime flight to Ohio River Valley, February 6 2019
- Aircraft sampled at ~ 400 – 700 m ASL / 300 – 500 m AGL
- Missed approaches to regional airfields
- Night flights sampled in a similar altitude range – but condition dependent

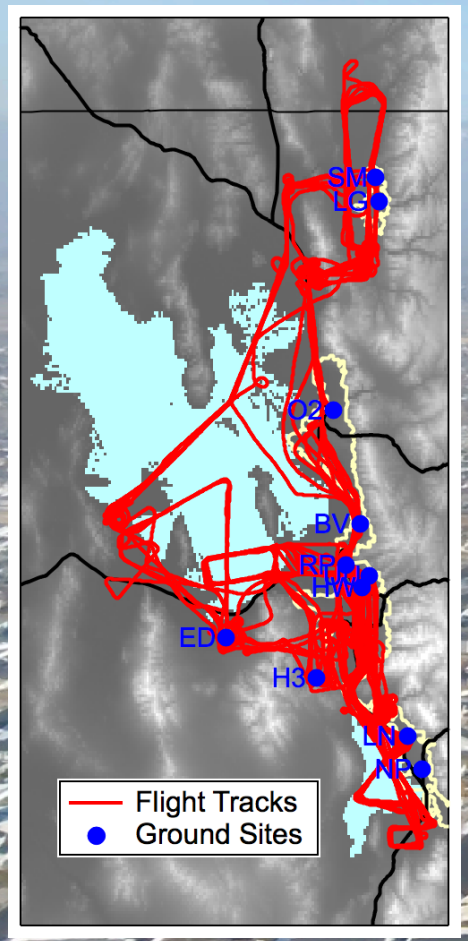


Utah Winter Fine Particulate Study (UWFPS)

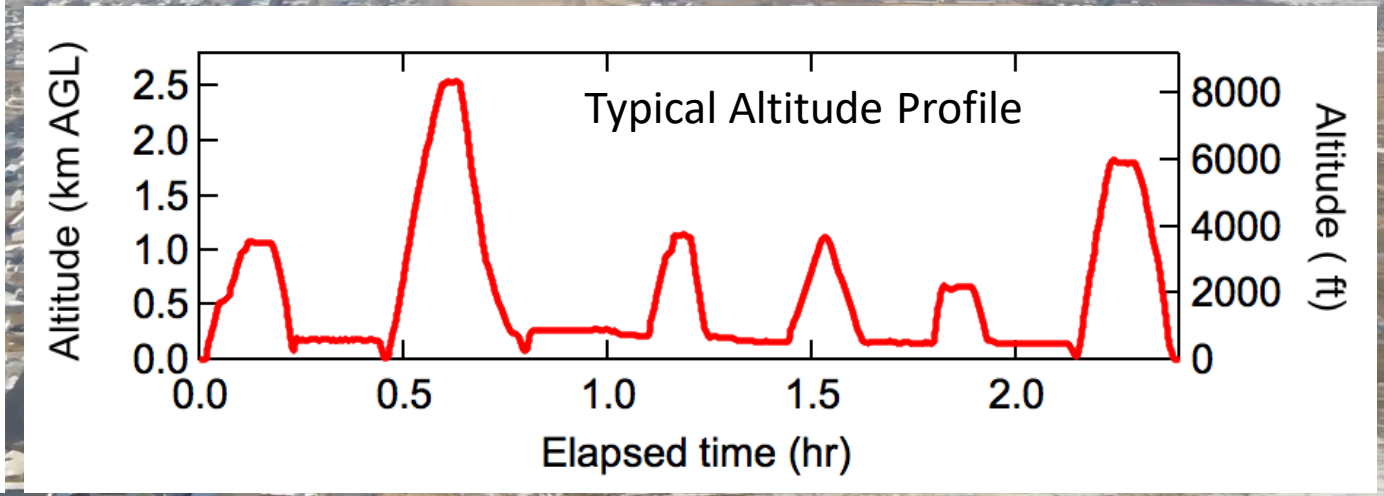
January 15 – February 14, 2017

NOAA Twin Otter

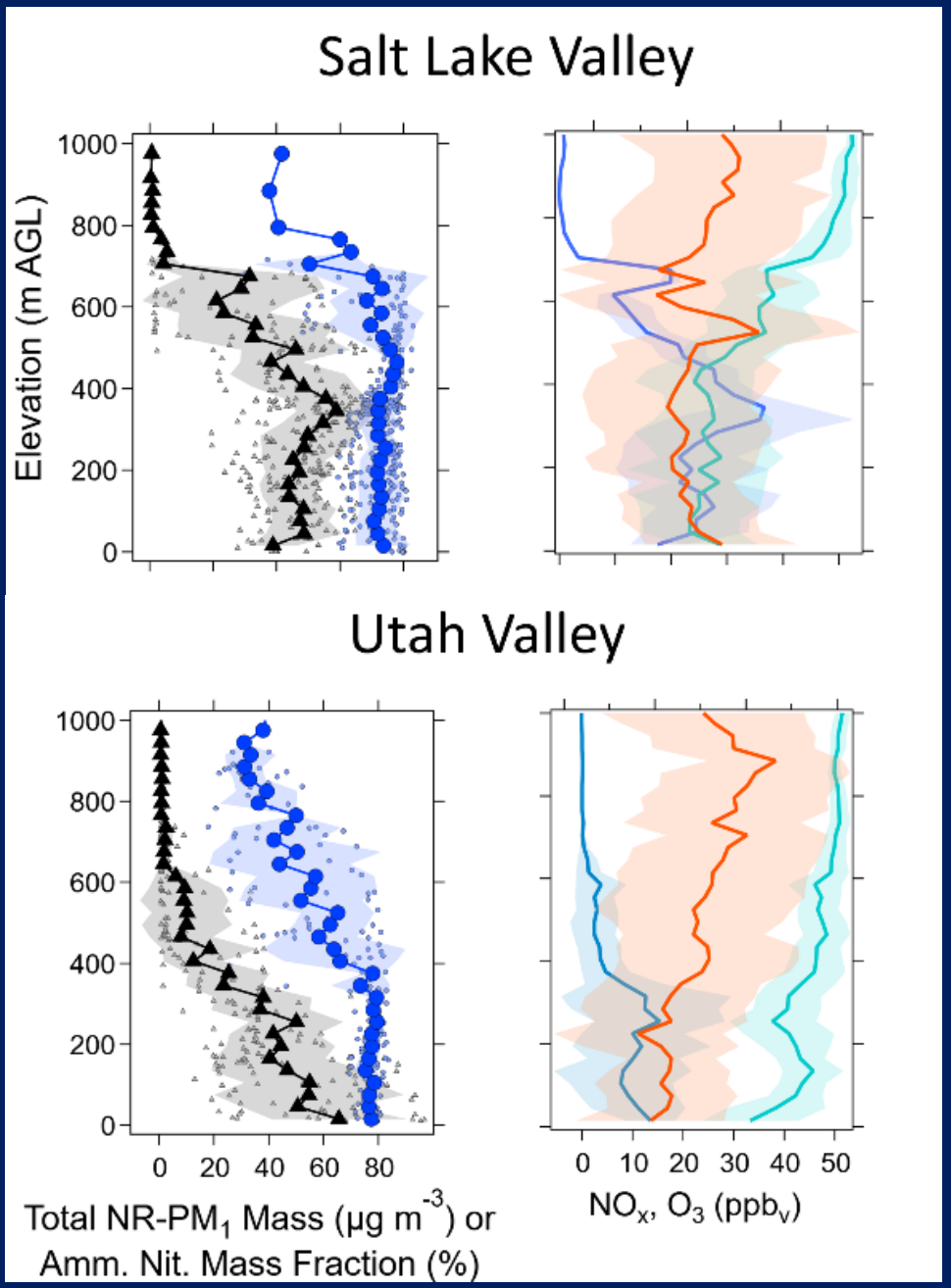
A Twin Otter aircraft and ground based investigation of high $PM_{2.5}$ events in basins of northern Utah

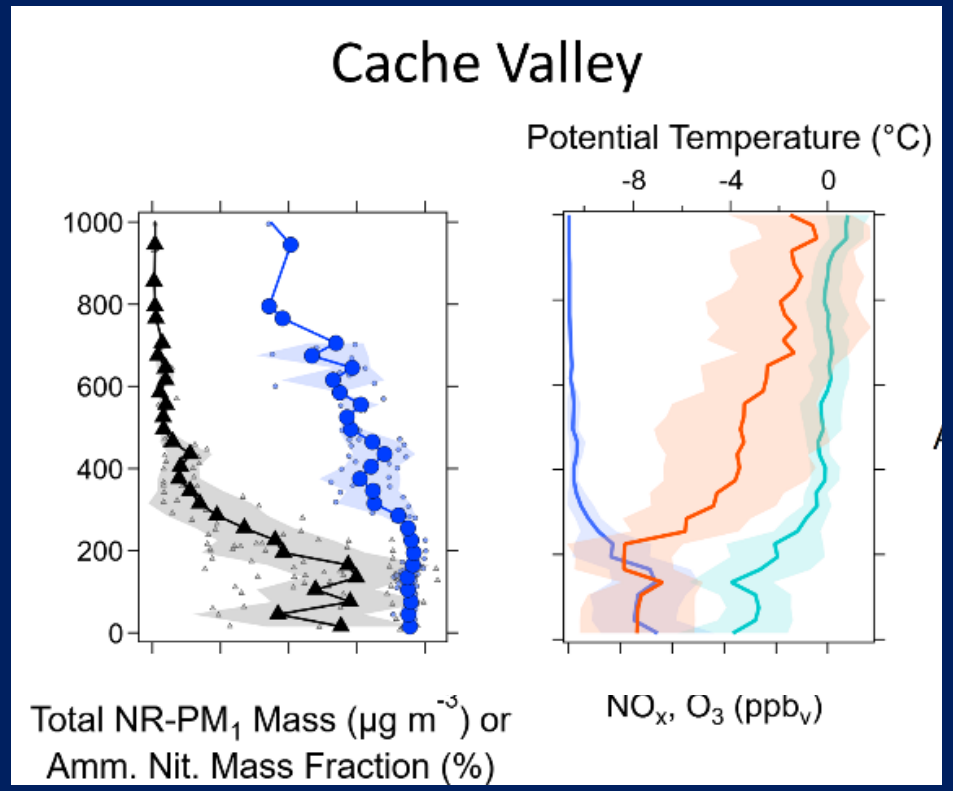


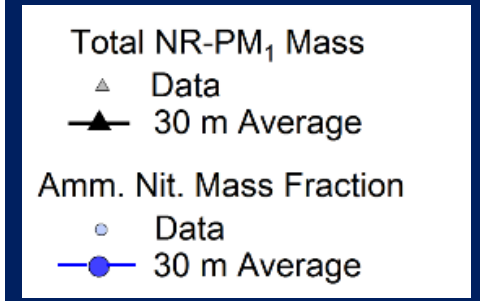
23 research flights / ~80 hours
Intensive, repeated sampling of
3 major basins + Great Salt Lake
Nighttime and daytime flights

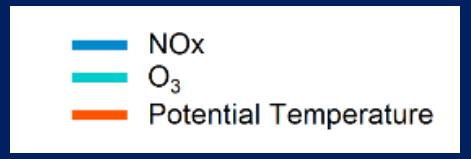


Utah Vertical Distributions & Boundary Layer Depths









Franchin ACP 2018

Twin Otter minimum cruise altitude of 500’ (150 m) over rural areas, 500 – 1000’ (150 - 300 m) over urban

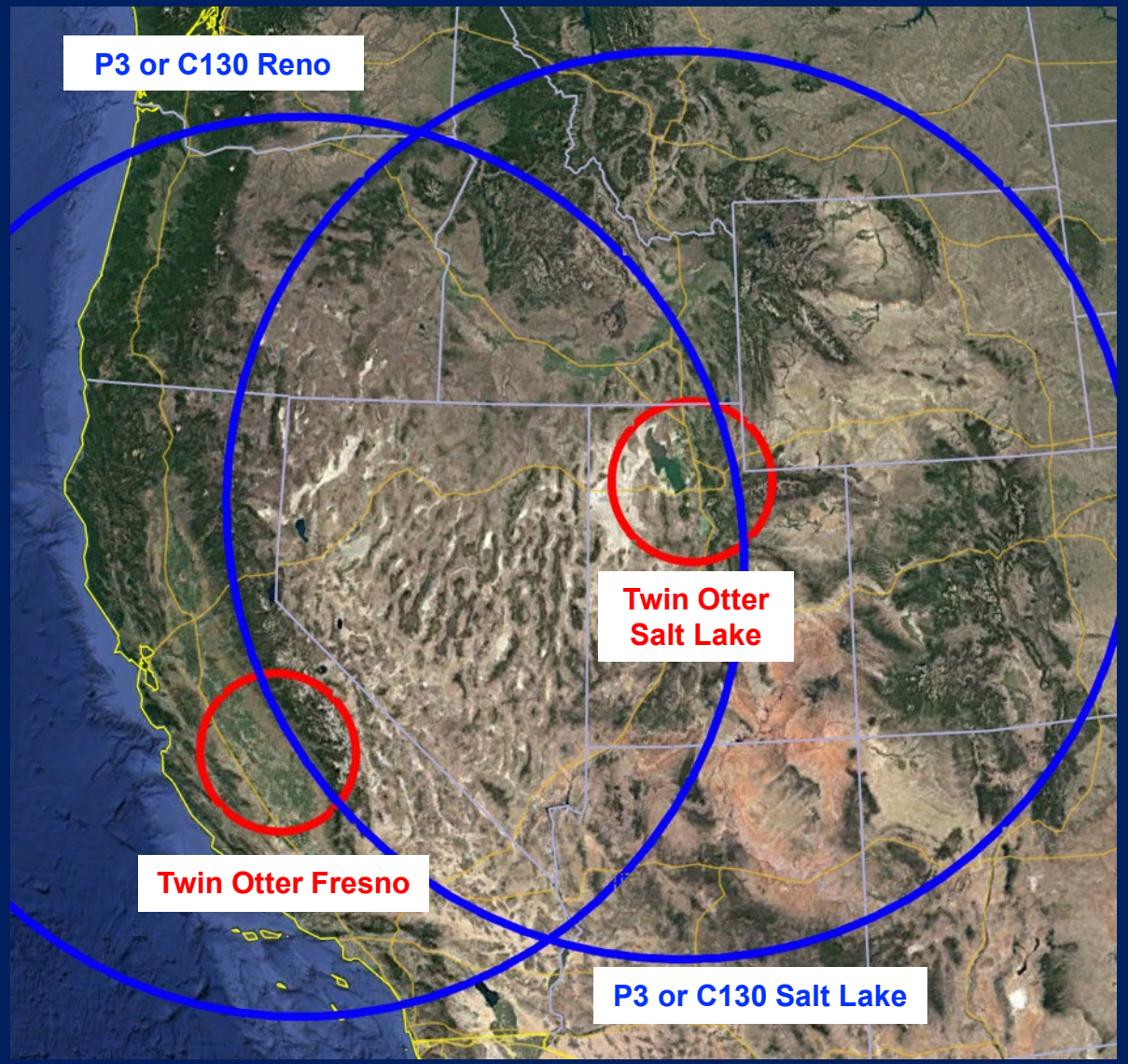
Opportunity for Future Western U.S. Winter Aircraft Study

Proven capability to fly in shallow winter boundary layers, but limited payload / scientific goals and range

Extensive payload / detailed instrumentation and ability to sample the entire western U.S. but potentially less appropriate for shallow BL

NOAA aircraft request timeline:

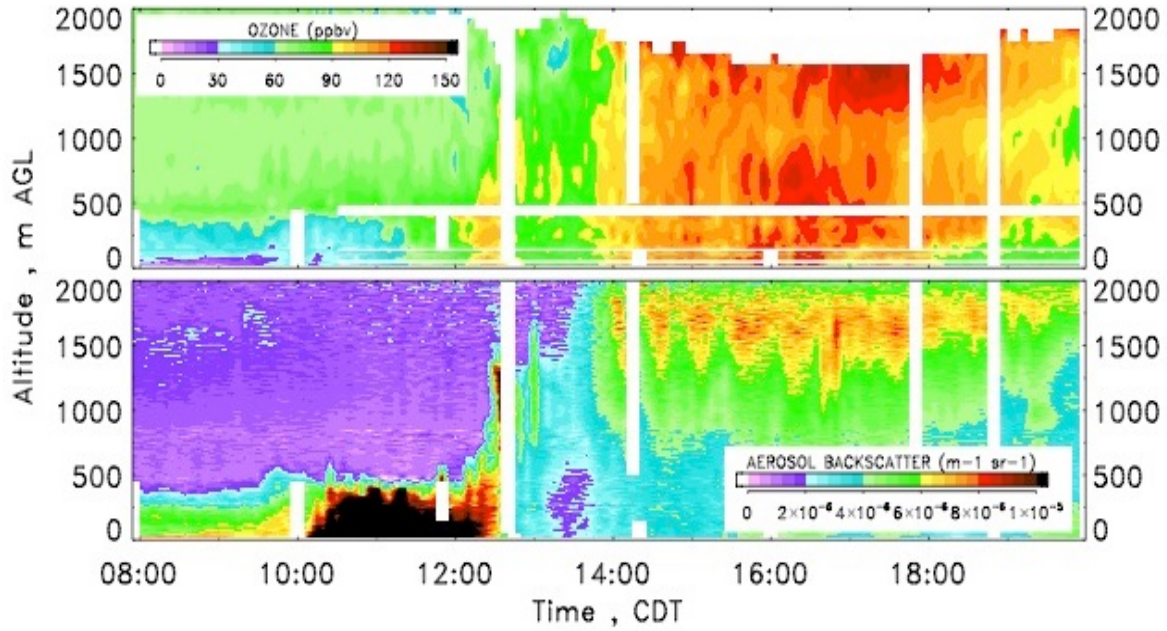
- Nov – Jan window for following year
- Discussion ongoing at NOAA CSD currently re: a winter 2022 or 2023 project

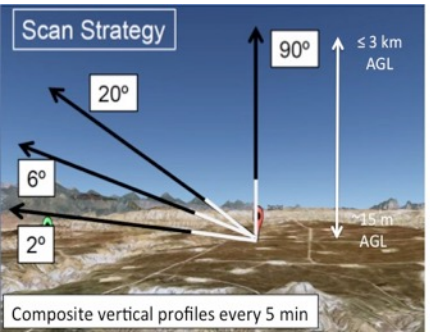


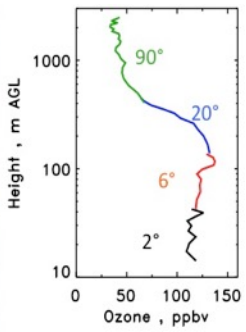
NOAA/ESRL/CSD TOPAZ Ozone and Aerosol Lidar

(TOPAZ = Tunable Optical Profiler for Aerosols and oZone)

- Ground-based scanning system permits pointing at shallow elevation angles
- Time resolution: 5 min per multi-angle scan
- Altitude coverage: 15 m – 3 km AGL
- Ozone and Aerosol Backscatter profiles

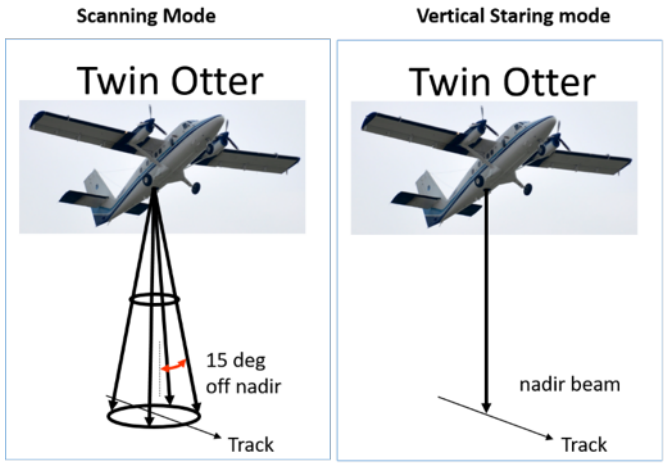






NOAA / CSD Airborne Doppler Lidar

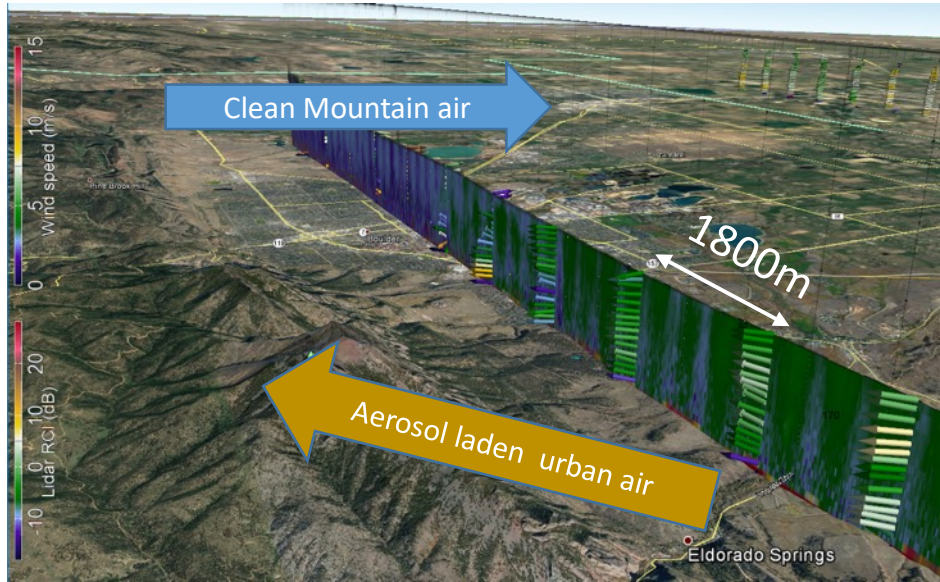
- Downward looking scanning Doppler Lidar
- Vertical and Horizontal wind and aerosol backscatter intensity
- Resolution: 60m along beam, 10Hz beam rate
- Altitude coverage: through the boundary layer



Arrows show direction / color is wind speed.

Curtain is aerosol measurement – green is higher concentration vs blue

Frontal passage over Boulder CO



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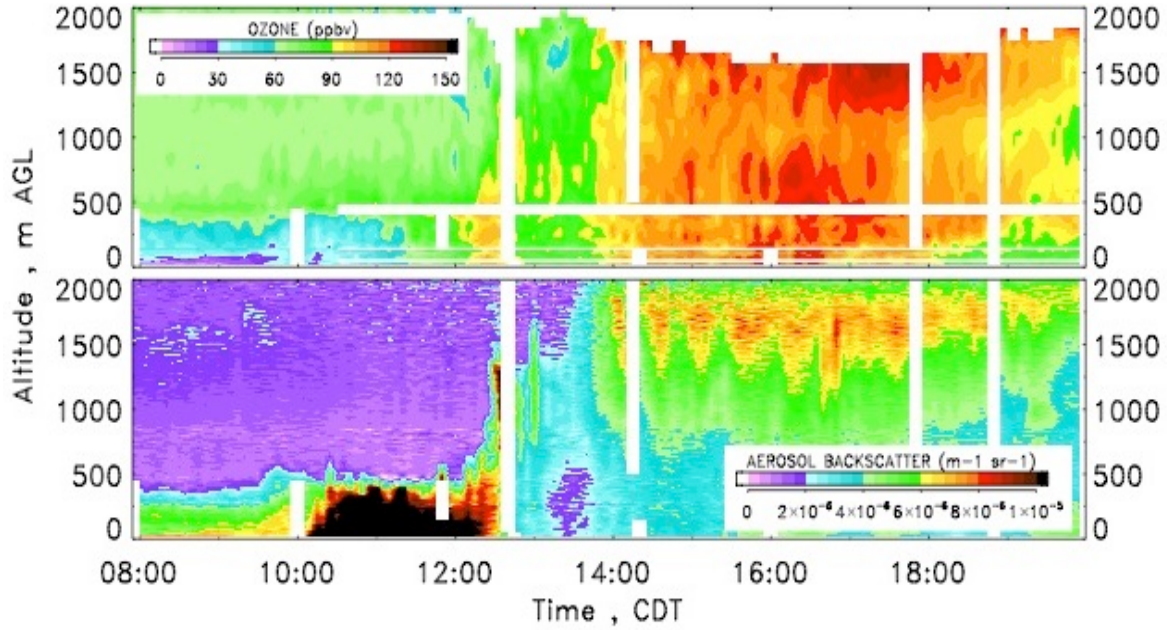
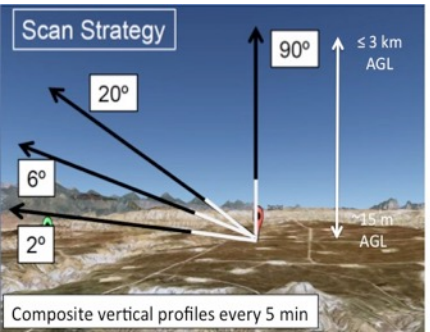
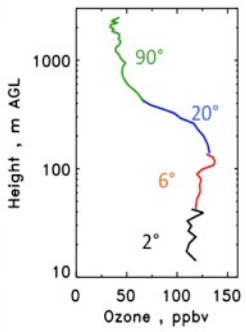


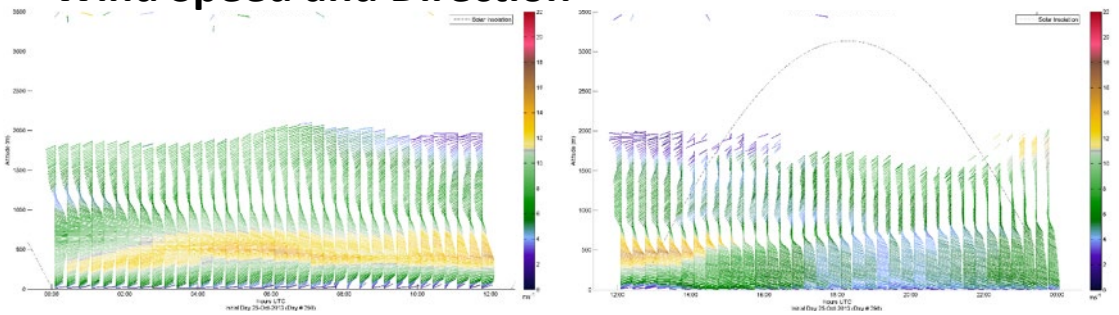




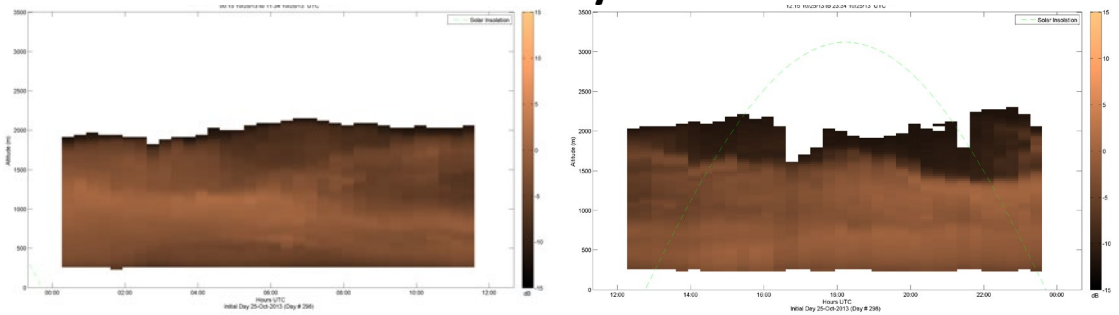
NOAA / CSD Doppler Lidar

- Ground based, scanning Doppler Lidar
- Turbulence and Horizontal wind and aerosol backscatter intensity
- Boundary layer heights

Wind Speed and Direction



Aerosol Backscatter Intensity



Vertical Velocity Variance