A Federated Approach to Develop Ground Validation Sites Across the United States; Closing the Gap between Surface and Satellite Air Quality

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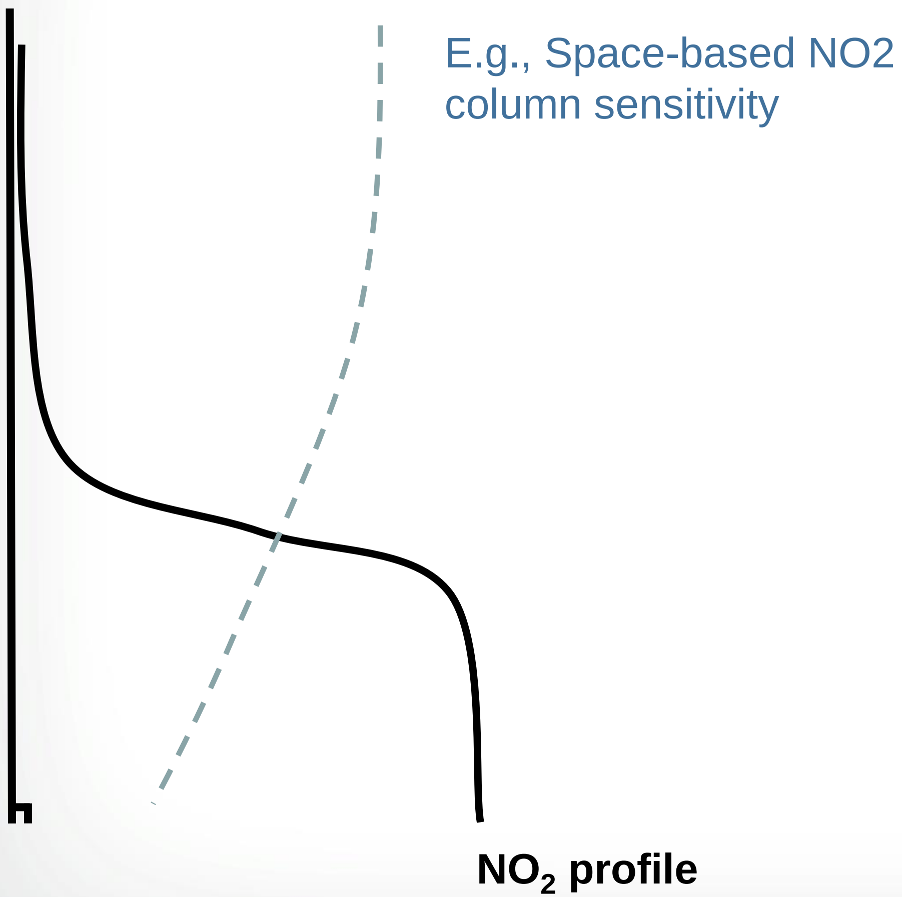
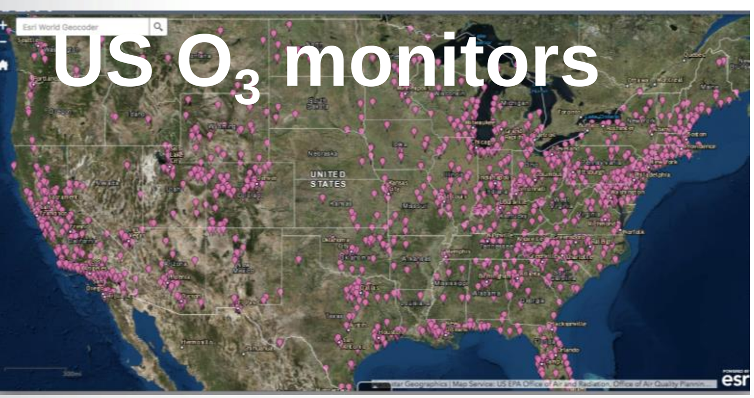
Relating the surface concentration to the column



To better understand surface-level pollution, the from space-based data products, the US EPA recognizes the need for co-located measurements of surface and column quantities

Development of a Federated Ground Validation Network across the U.S.

Monitoring Locations for combined PAMS/Ncore SItes



Upcoming changes to the U.S. EPA Photochemical Assessment Monitoring Station (PAMS) Network provides a unique opportunity to:

- **Leverage existing/expanding monitoring infrastructure to develop high quality ground-based (correlative data) validation sites across the United States in areas with the worst O_3 pollution.**
- **Provides a sustainable approach which increase the value of measurement suite at these sites to communities of interest.**
- **Promote adoption of satellite data products, especially TEMPO, to the air quality community - increasing societal benefit.**
- **Consistent with The Integrated Global Atmospheric Chemistry Observations (IGACO) Theme Report, 2004.**

Development of a Federated Ground Validation Network across the U.S.

- *Measurements at new combines Ncore and PAMS Sites:*
  - NO, NO_2, NO_y, O_3 (year round). SO_2, CO, $PM_{2.5}$ mass and speciation (At least 1-in-3 day), $PM_{2.5}$ continuous, $PM_{10-2.5}$ mass, basic met. parameters.
  - Profiling Measurements: Continue use of existing Radar wind profiler (RWP)/Radio acoustic sounding system (RASS) supplemented with use of ceilometer at new sites for hourly mixing layer heights.
  - Met measurements – Vertical wind speed, solar radiation, precipitation, baro. pressure, delta-T for 2-10m.
  - Option to add continuous in-situ CH_2O in the future as reliable commercial units are become available.

Monitoring Locations for combined PAMS/Ncore SItes

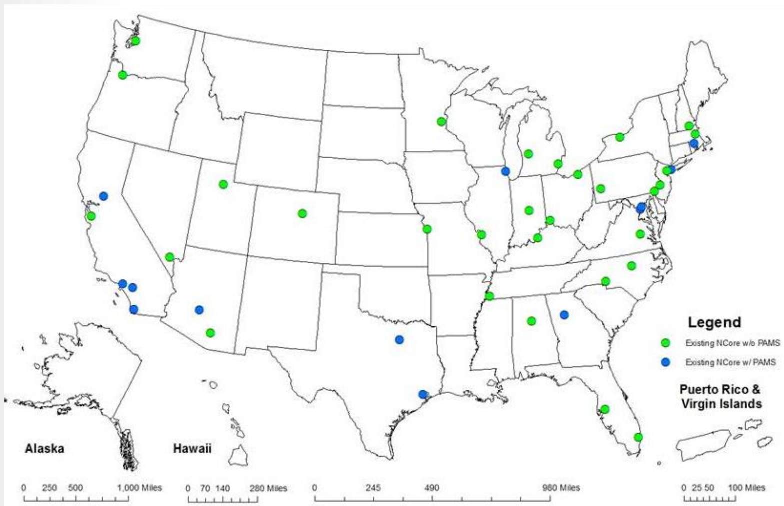
	Current PAMS Network	PAMS at NCore
Number of Sites	75	**43**
-Existing		14
-New		29

Relevant changes under PAMS Network Re-Engineering

- Relevant PAMS Changes:
  - ***Issue:*** Standard NOx measurement technology is known to have positive interferences from other non-NOx species (HNO_3, PAN, etc.) and does not measure NO_2 directly.
  - ***Proposed Solution:*** Add a "true NO2" measurement at required PAMS-NCore sites.
  - ***Issue:*** Formaldehyde (CH_2O) is now recognized as one of the most important ozone precursors
  - ***Proposed solution:*** Restart carbonyl measurements which includes CH_2O, still not very useful for TEMPO. Option to add commercial CH_2O measurements methods for high time low detection limit (ppb).
  - ***Issue:*** Existing radar profilers with RASS temperature profilers at PAMS sites are old and in need of replacement or expensive upgrades.
  - ***Proposed solution:*** Addition of ceilometers to provide continuous mixing height via aerosol backscatter (910 nm). Can also provide aerosol layer heights and cloud heights up to 15+ km.

Upcoming changes to the U.S. EPA Photochemical Assessment Monitoring Station (PAMS) Network provides a unique opportunity for CEOS Validation

Monitoring Locations for combined PAMS/Ncore Sites



- Starting in 2017 EPA will work with NASA and TEMPO to begin adding PANDORA spectrometers to a subset of PAMS/Ncore sites.

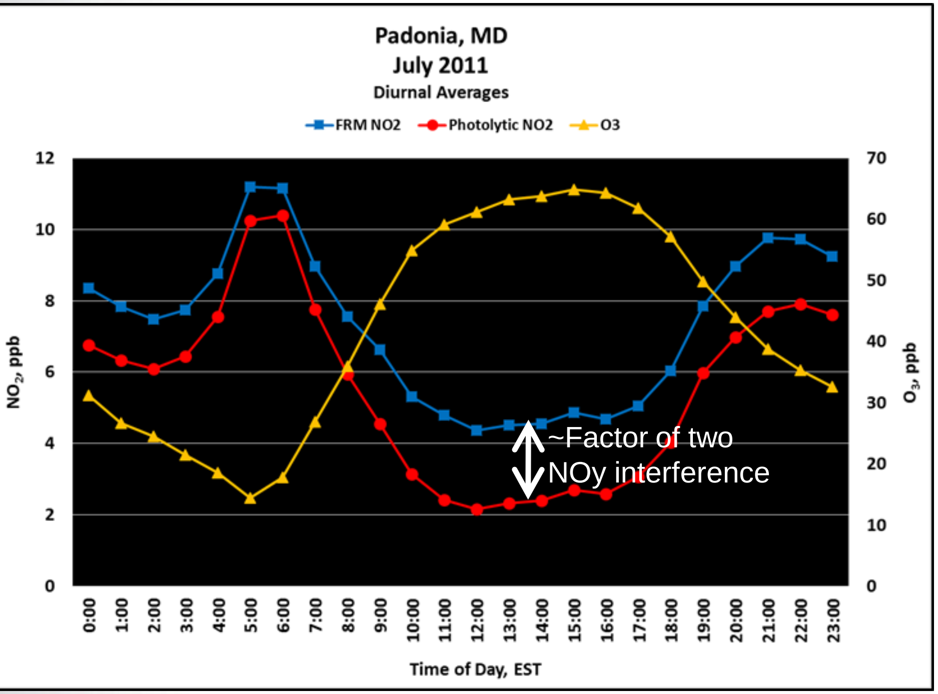
- Initial goal - 5 sites per/year with 20 network sites by 2020.

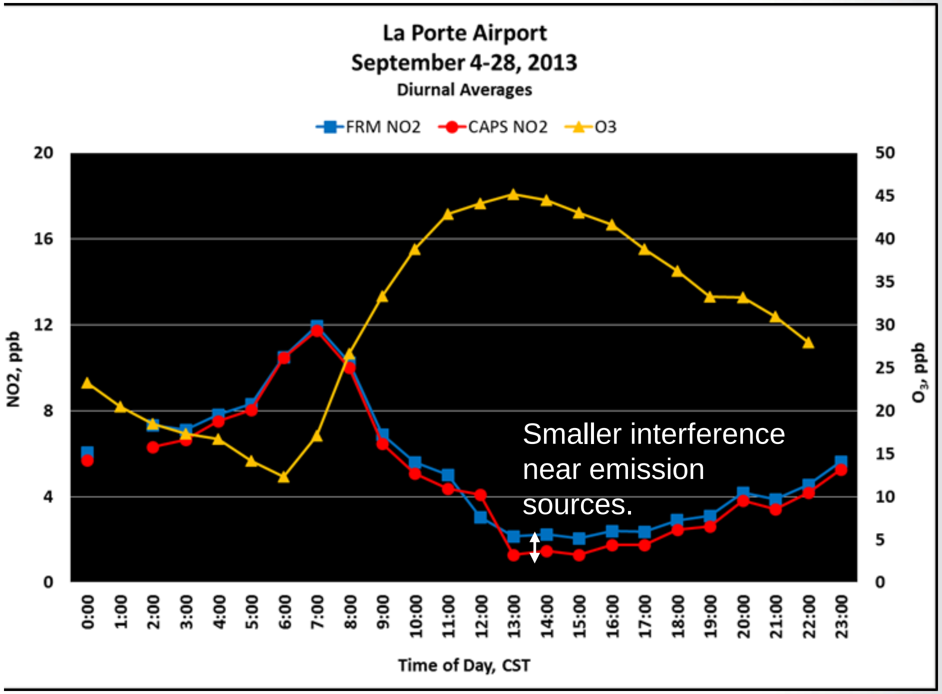
Improved Ground-based Monitors (FRM/FEM)

Ceilometer/lidar
Aerosol layers/mixing heights

Ground-based PANDORA spectrometer Column density O_3, NO_2, HCHO, and SO_2

Connecting column measurements to surface AQ
Optical/Photolytic “True” NO_2





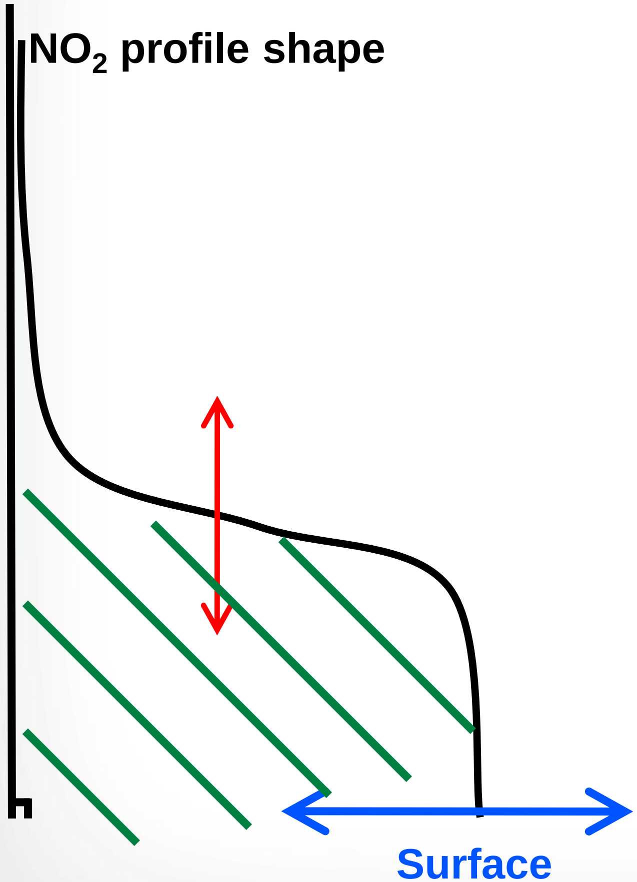
<u>Photochemically aged air</u>

- **The standard US federal reference method (FRM) for measuring NO_2 has chemical interferences due to conversion of higher-oxidized nitrogen species on the molybdenum converter (left panel)**

<u>Fresh Emissions Dominated</u>

- **At sites closer to large NOx sources (right), and in conditions where photochemistry is slow, the interference is much smaller.**

Characterizing the NO2 profile shape with only surface-based measurements

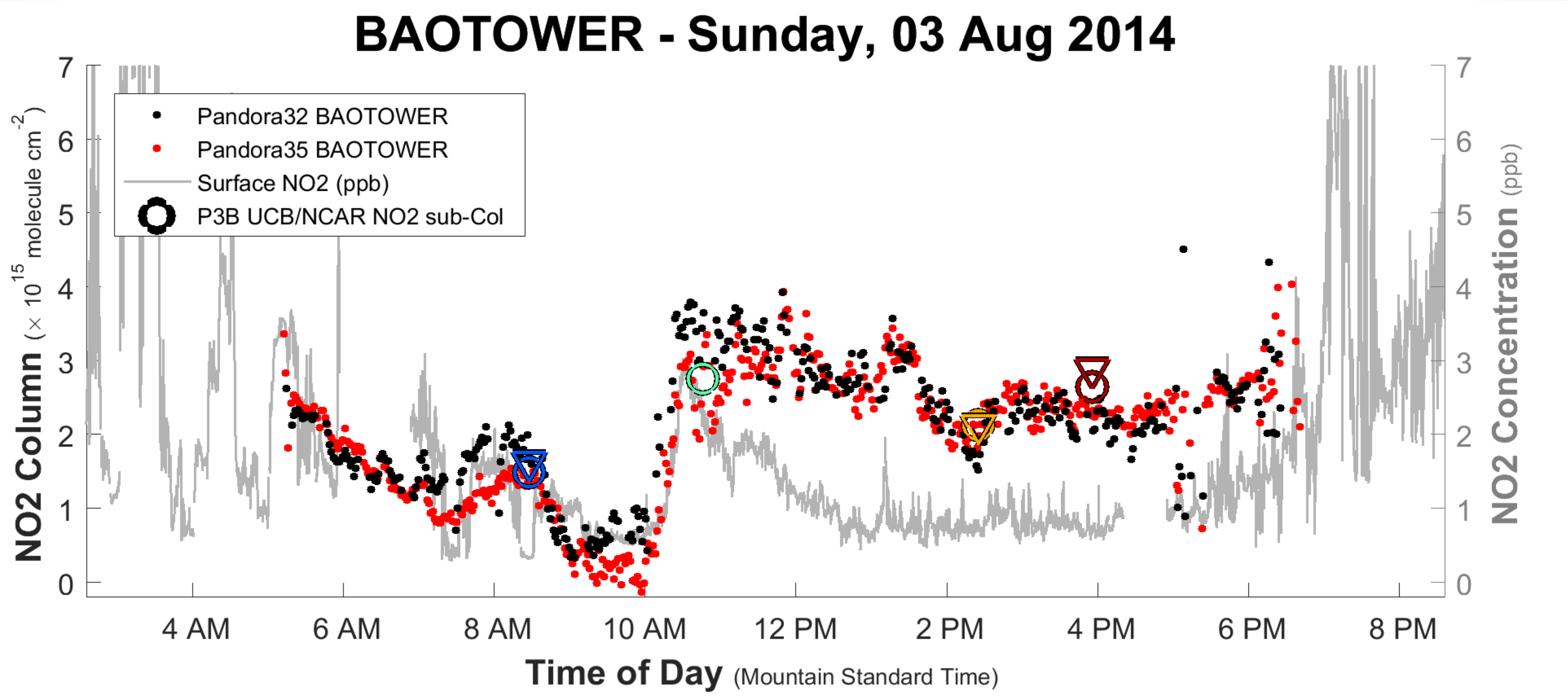


1. NO2 Surface Concentration (required by law)

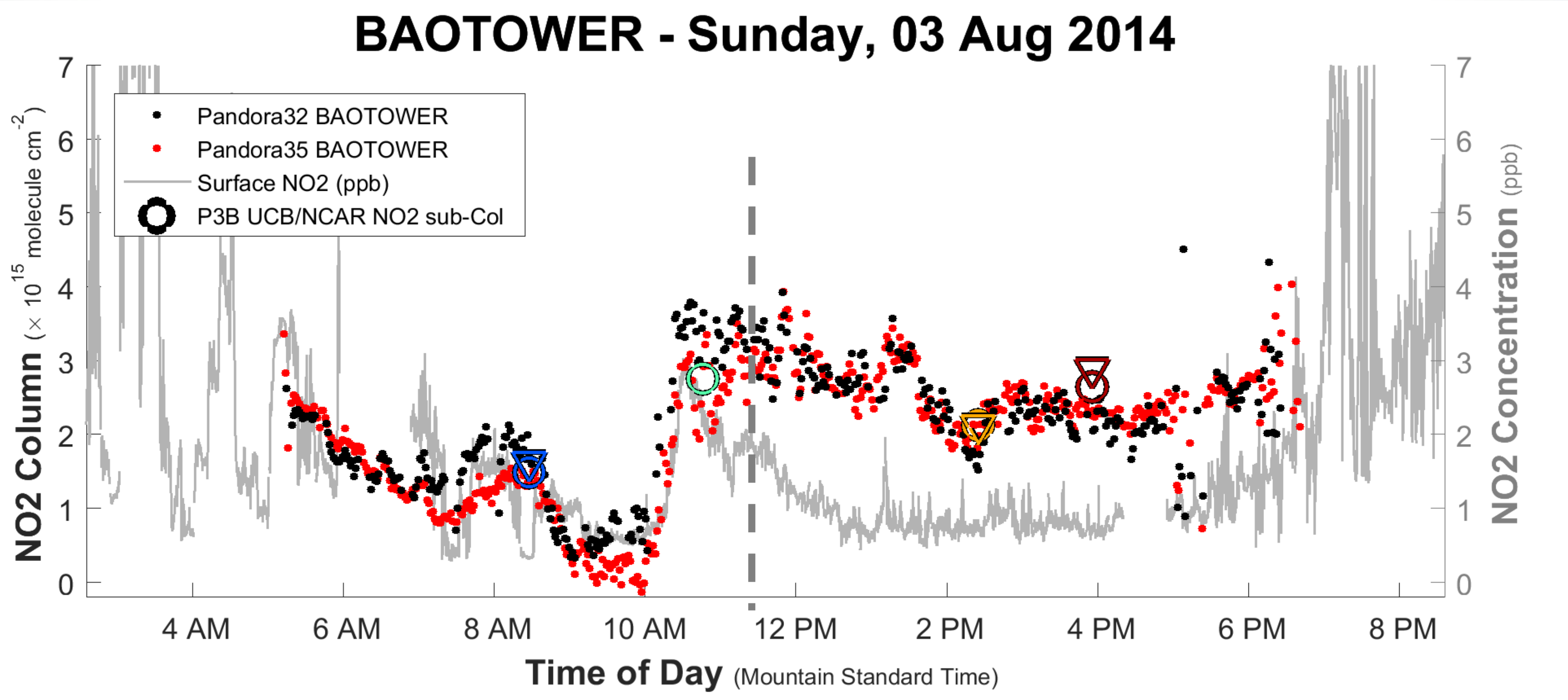
2. Total Column (stratospheric contribution subtracted) (value-added measurement)

3. Mixed layer height i.e., CL51 ceilometer (required by law)

NO2 column (red,black) and surface concentration (gray)



NO2 column (red,black) and surface concentration (gray)



<u>Before 11 AM</u>

1 ppb : 1×10^{15} cm^{-2}

-> Assume well mixed PBL:

Height ≈ **0.5 km**

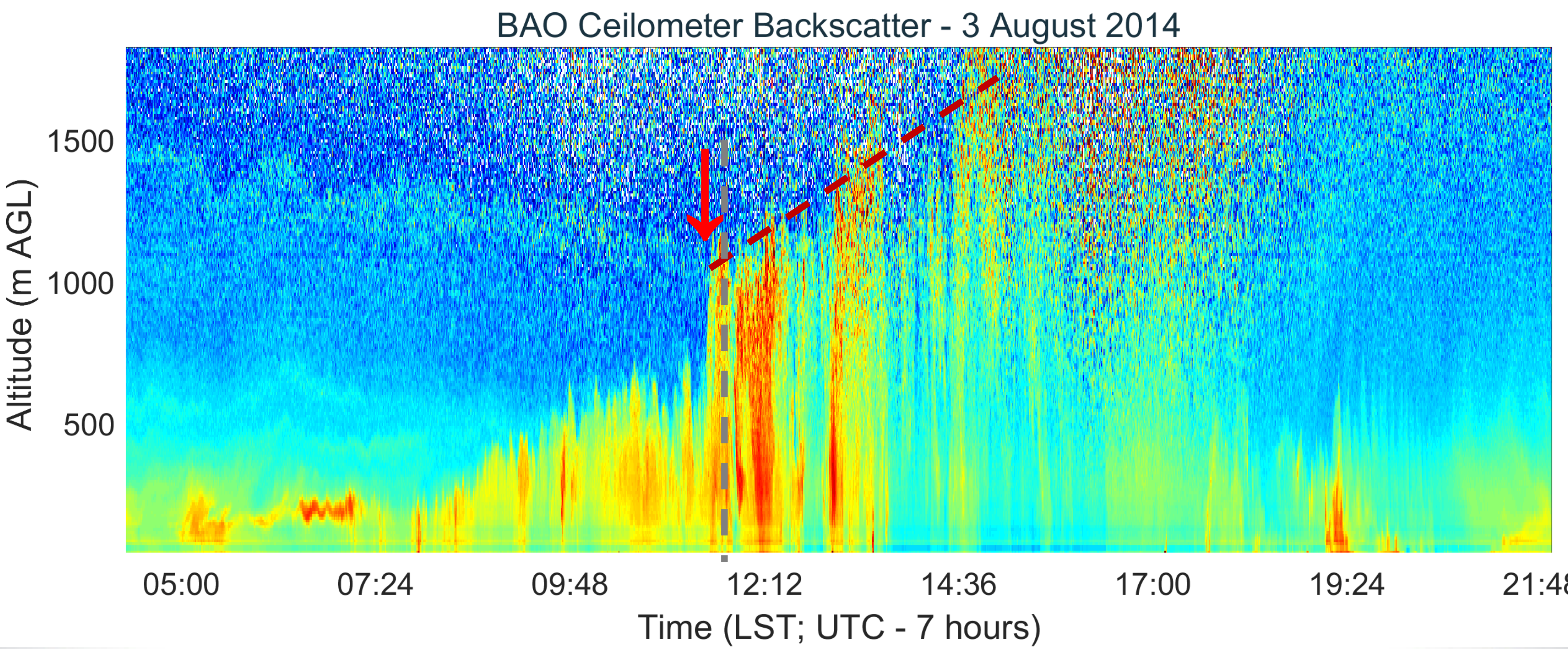
<u>After 1130 AM</u>

~1 ppb : ~3×10^{15} cm^{-2}

-> Assume well mixed PBL

Height ≈ **1.5 km**

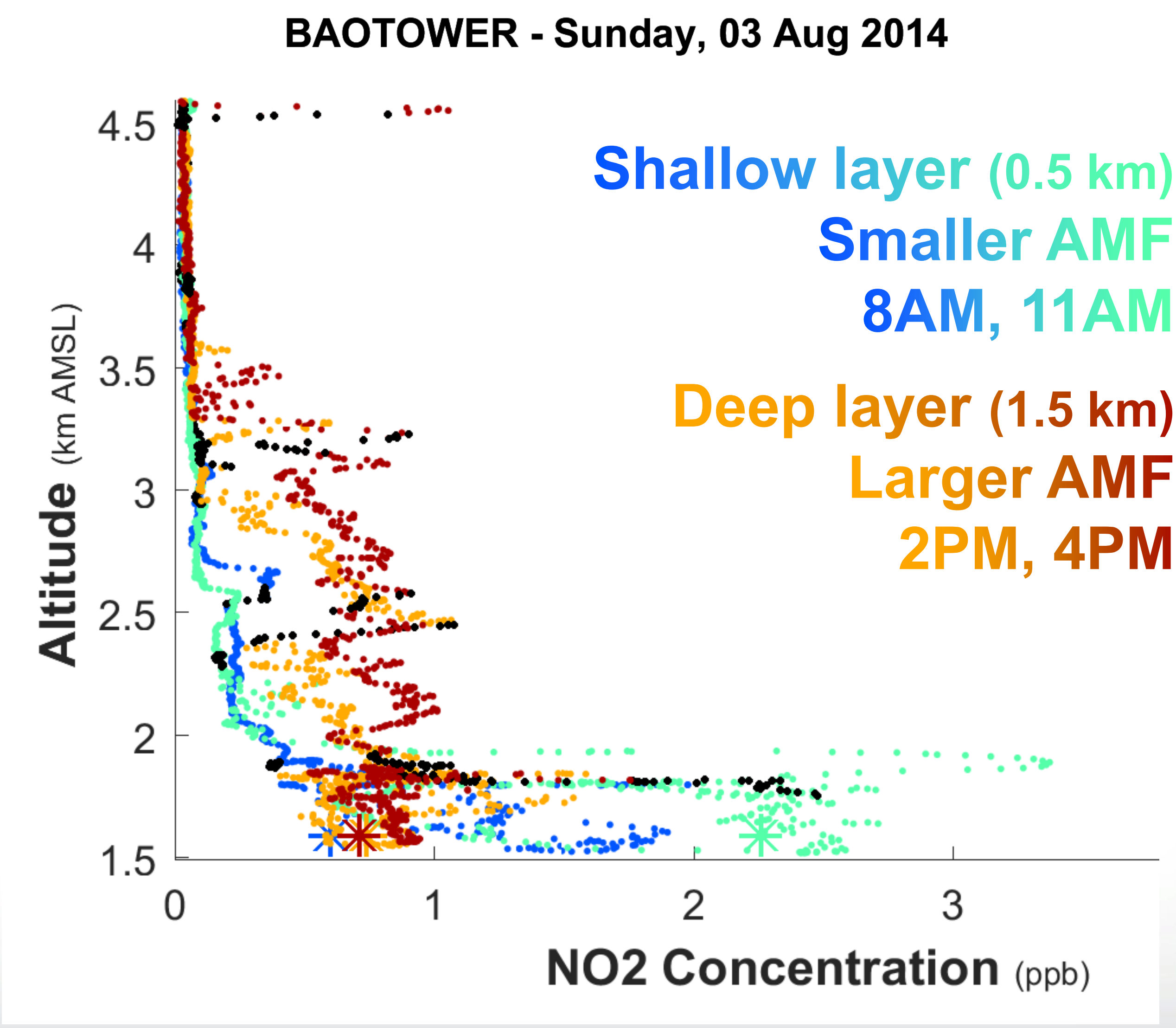
Backscatter Ceilometer observations of 3 August 2014



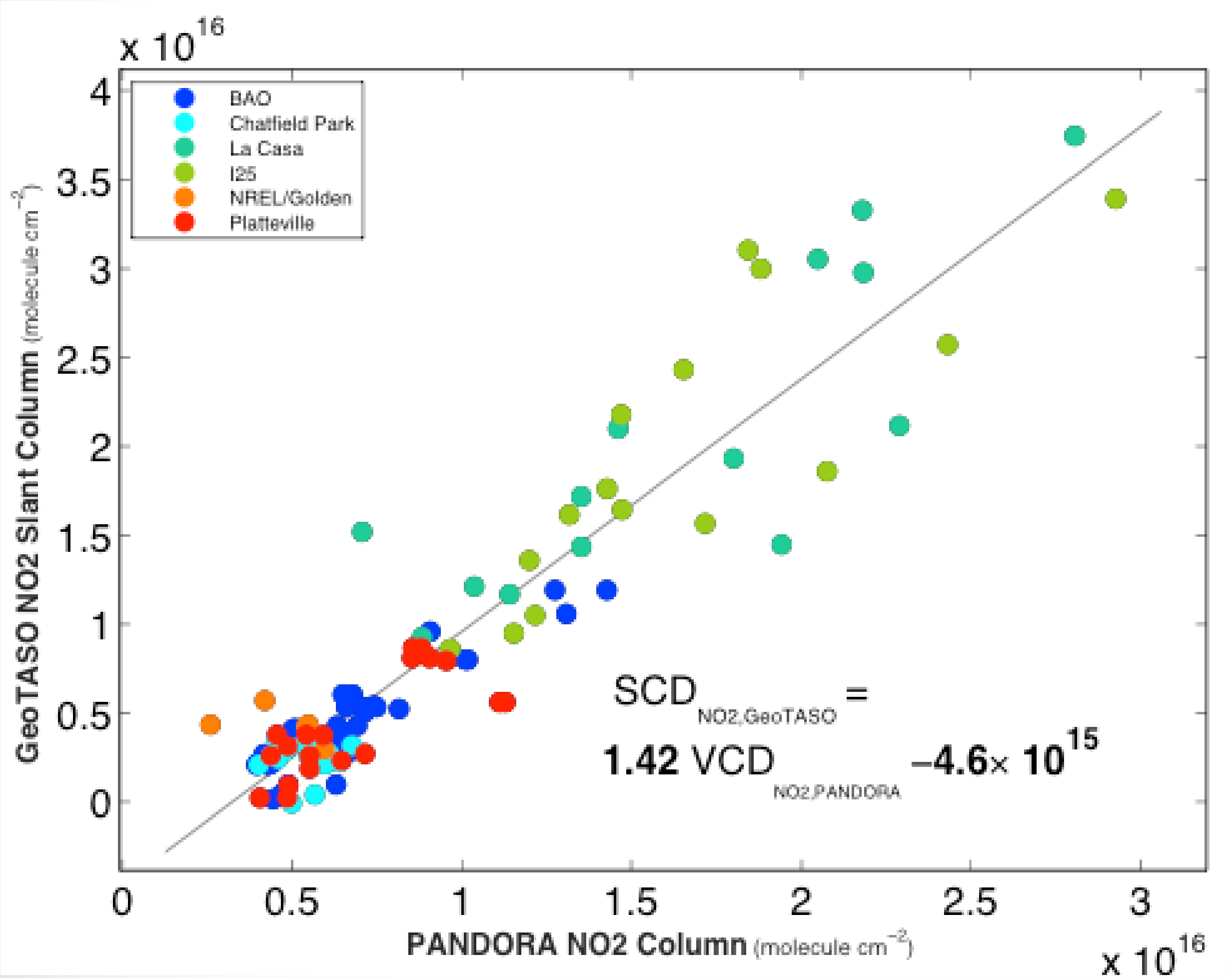
Ceilometer backscatter measurements, to be deployed across PAMS/NCORE network, capture this transition in boundary layer height at 11:30 AM followed by continued boundary layer growth until ~2:30 PM

Ground-based characterization is consistent with observed profiles

Surface NO_2 + column NO_2 + backscatter ceilometer = 3 pieces of information to describe profile shape and its diurnal evolution.



With PANDORA vertical and GeoTASO slant column measurements we can 'measure' AMF



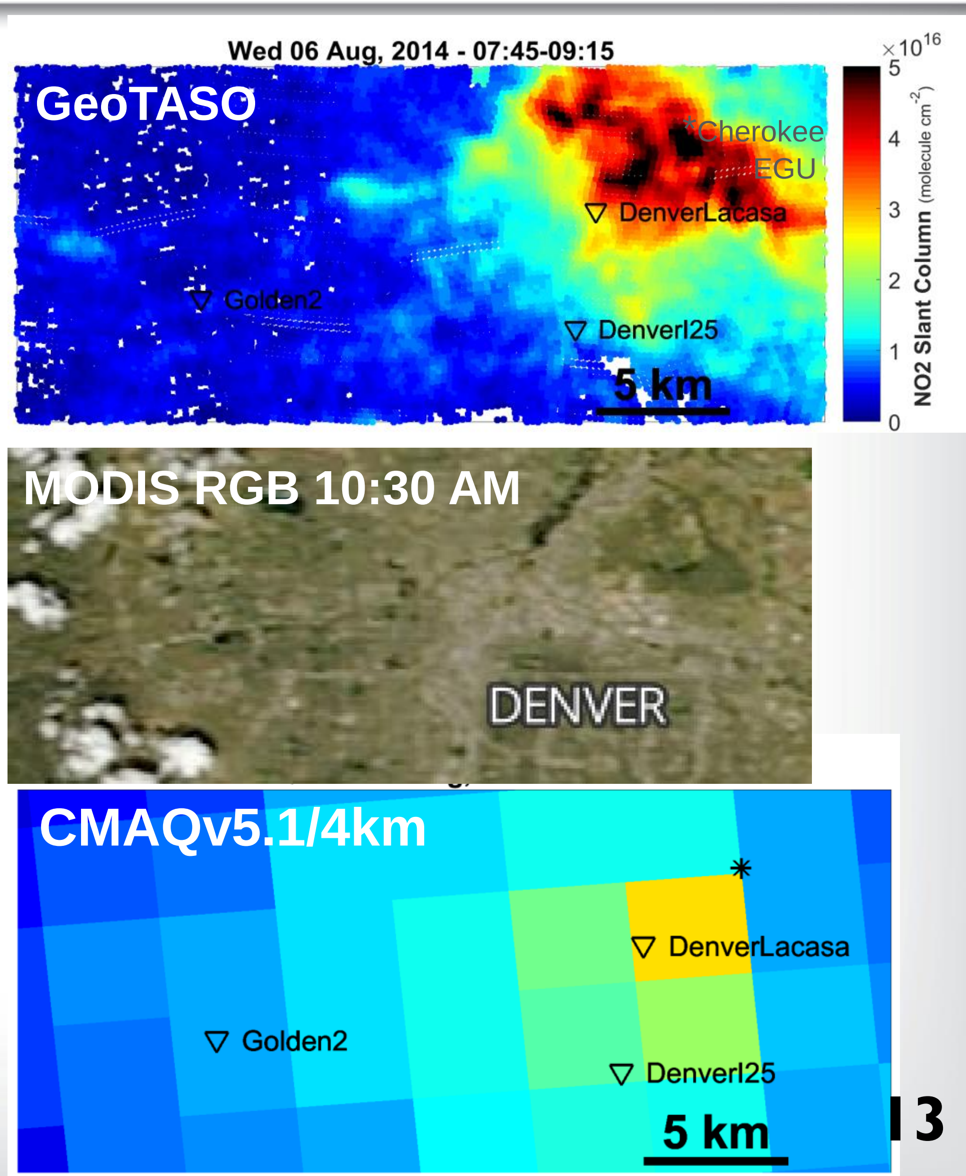
Inferred AMF over DISCOVER-AQ Colorado region is ~1.4 including all coincident measurements

Surprisingly little systematic variability immediately

Needs more investigation

Spatial detail + known emission source:
The observations test our knowledge of transport

Precise quantitative considerations aside – the spatial detail observed by the constellation will enhance our understanding of very local transport processes.



GeoTASO Data courtesy of **Caroline Nowlan**, SAO

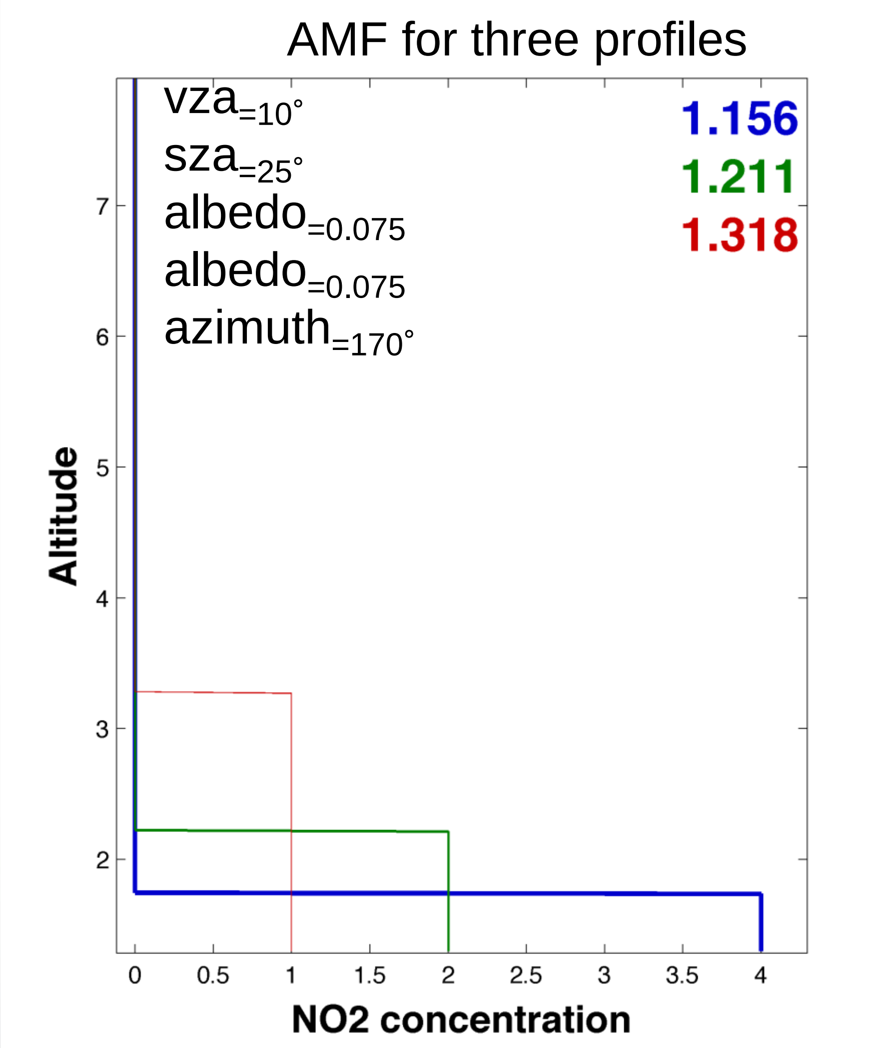
Conclusions

- Fast-time response (1-minute) in situ and total column NO2 measurements on the ground are critical link connecting CEOS mission to EPA mission (i.e., surface AQ)
- To enhance existing EPA PAMS/NCORE network with little effort, AQ managers must see direct benefit of additions for explaining surface air quality, particularly episodes.

Contributors

- EPA
  - Russell Long, Jim Szykman, Rachelle Duvall, Kevin Cavender
- NASA
  - Jim Crawford, Jay Al-Saadi, Barry Lefer
- SAO
  - Kelly Chance, Caroline Nowlan

Calculated AMF for summertime, high-altitude, grassland setting like Colorado

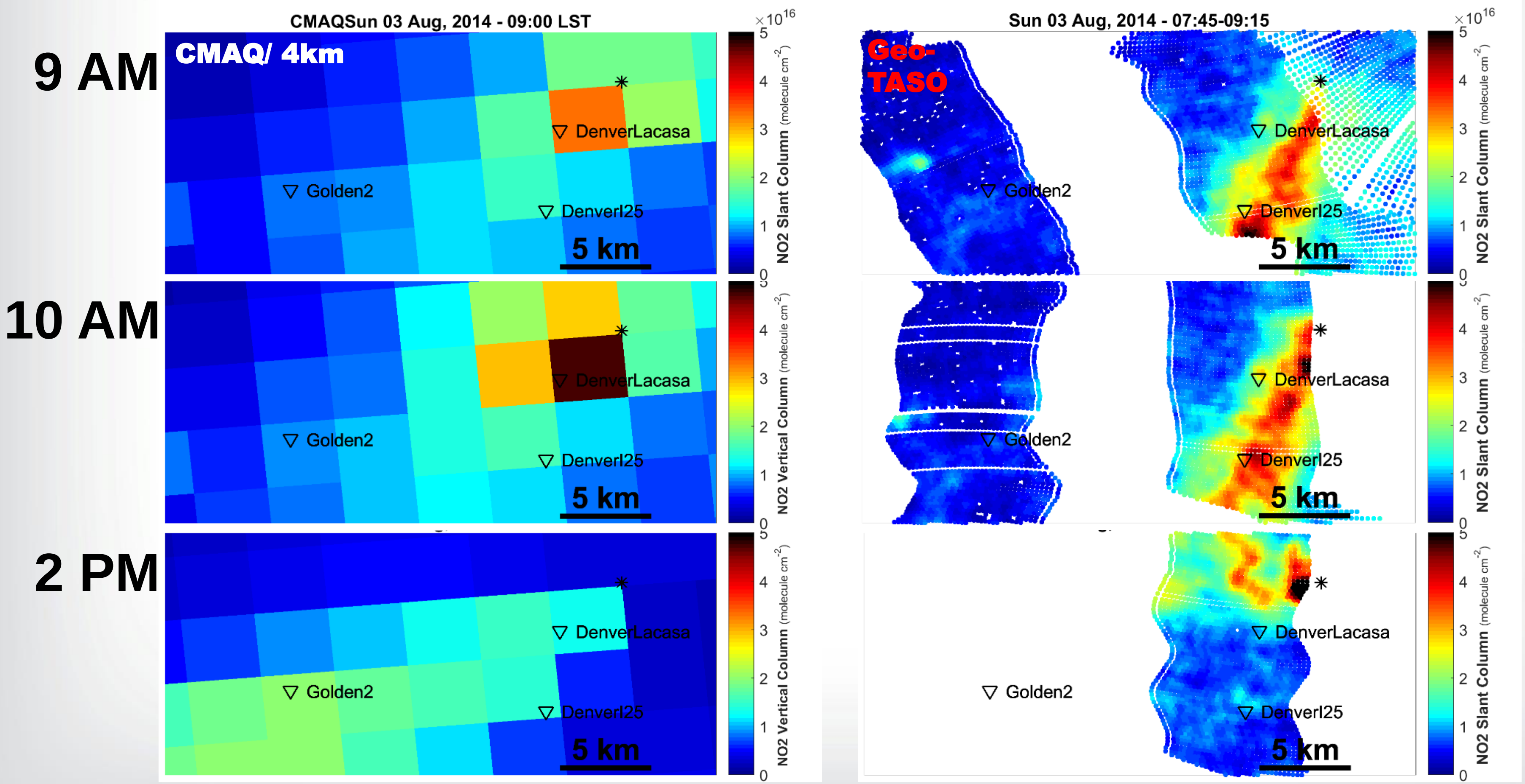


Observed AMF of ~1.4 is larger than those calculated for polluted BL and clean free troposphere.

Regardless, a factor of 4 difference in boundary layer height affects AMF less than 15% under these conditions

Summertime high pressure system
Denver, Colorado

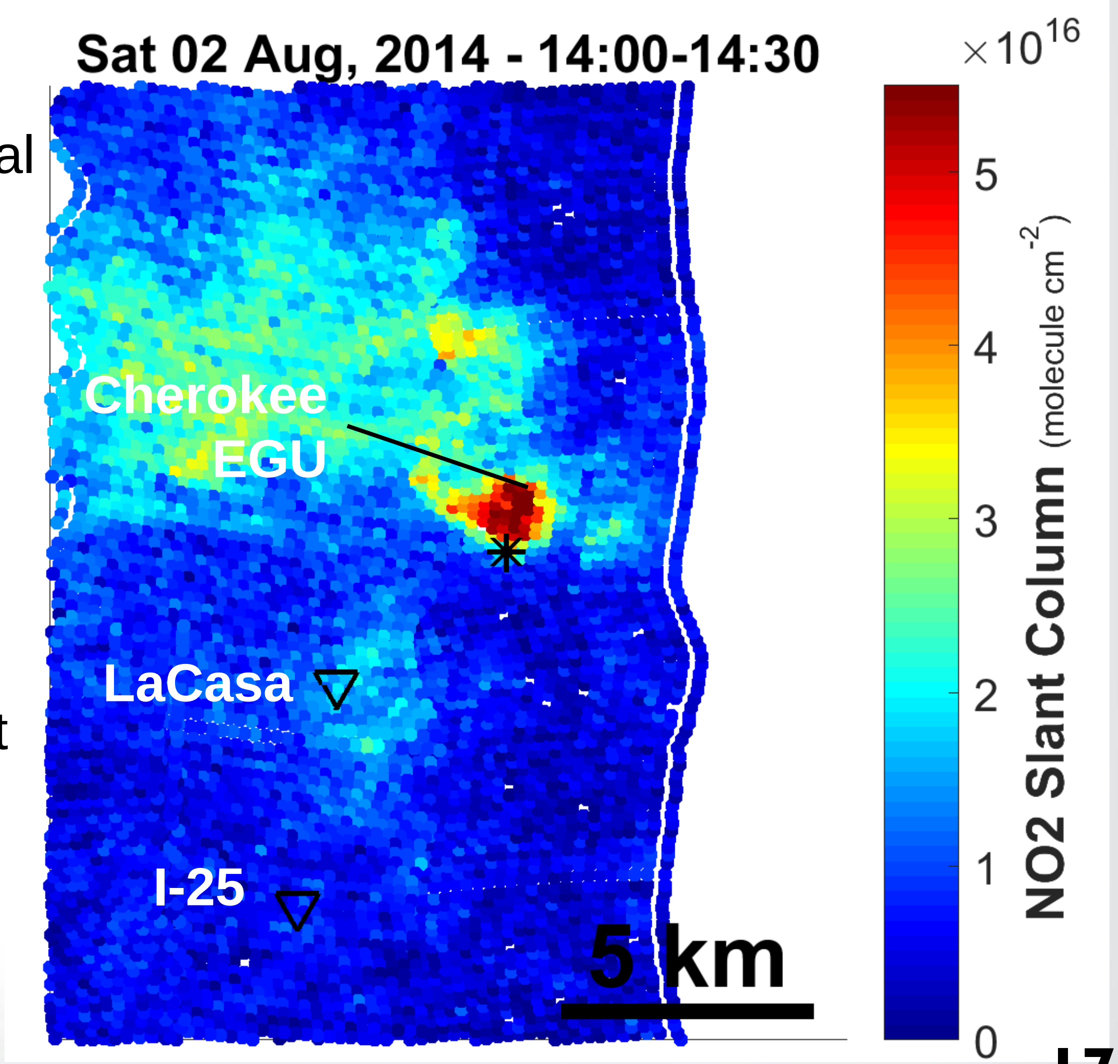
Simulation imperfect but captures essence of transport processes. **Data assimilation system involving both composition and dynamics will add tremendous value for air quality management**



Spatial detail + known sources:
The observations test our knowledge of transport

Precise quantitative considerations aside – the spatial detail observed by the constellation will enhance our understanding of very local transport processes.

The challenge is integrating this detail in to an assimilation framework or finding out when/where the model transport is broken

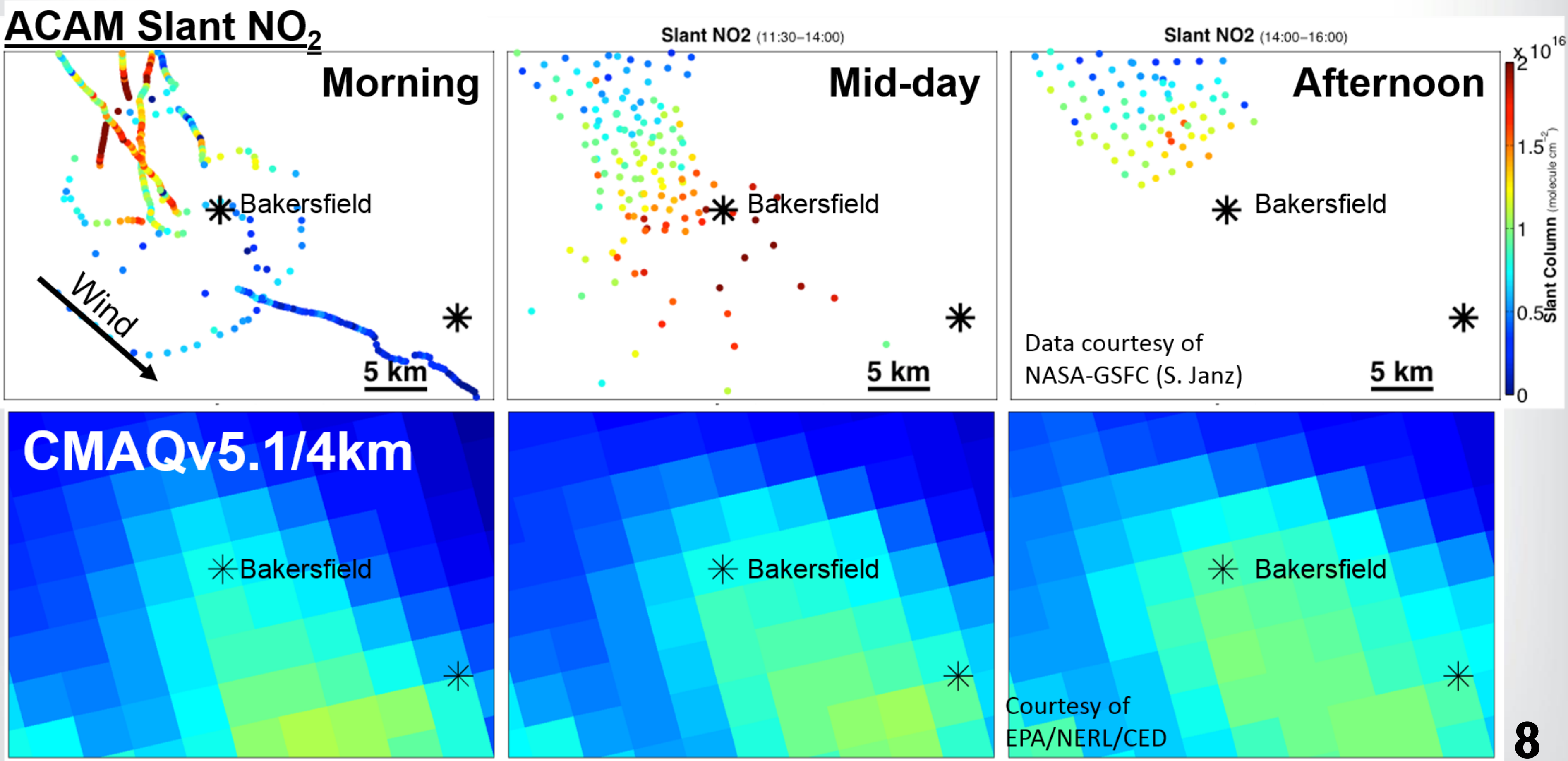


GeoTASO Data courtesy of **Caroline Nowlan**, SAO

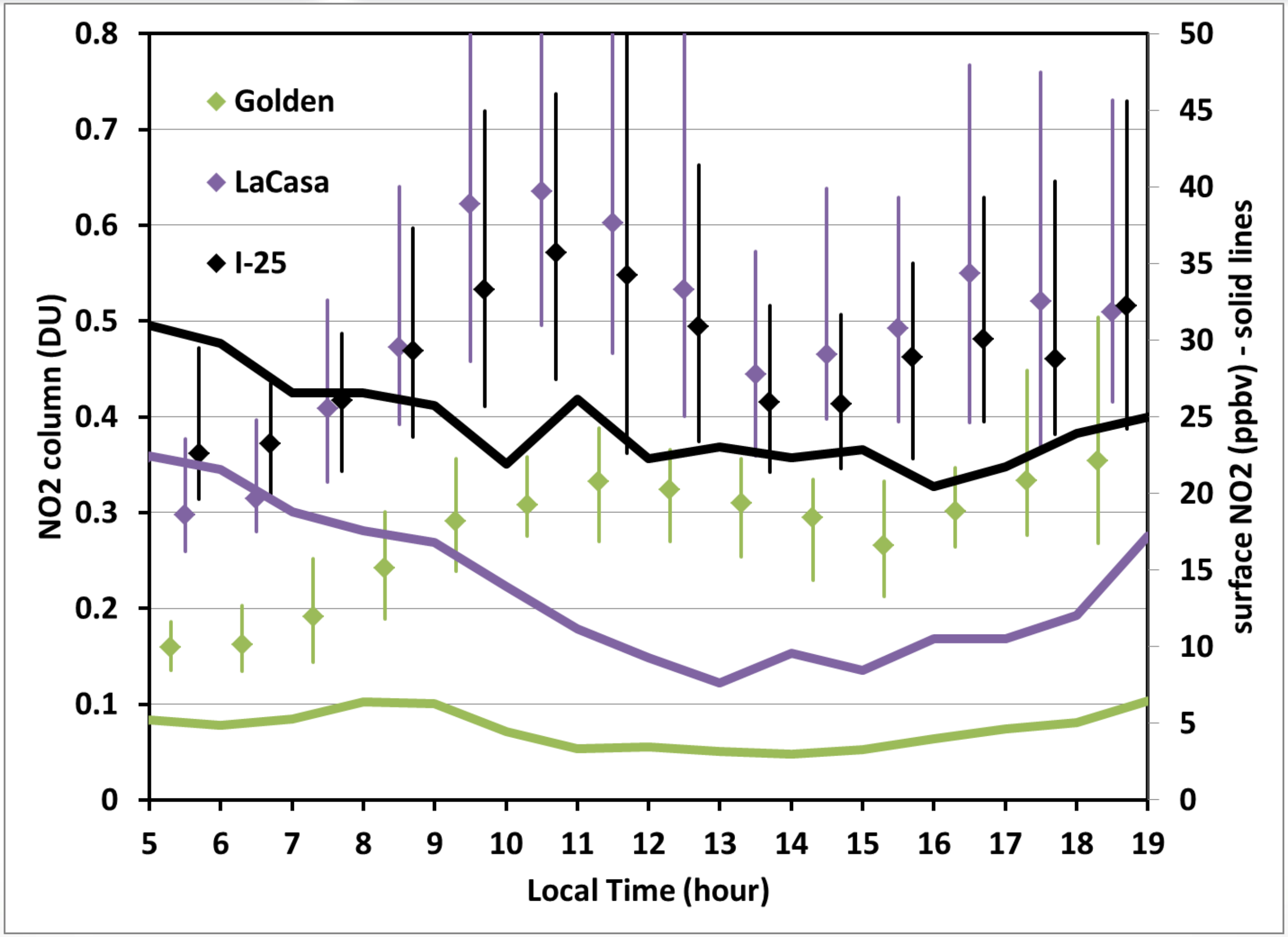
Wintertime high pressure California San Joaquin Valley

Simulation fails to capture observed spatial pattern and transport.

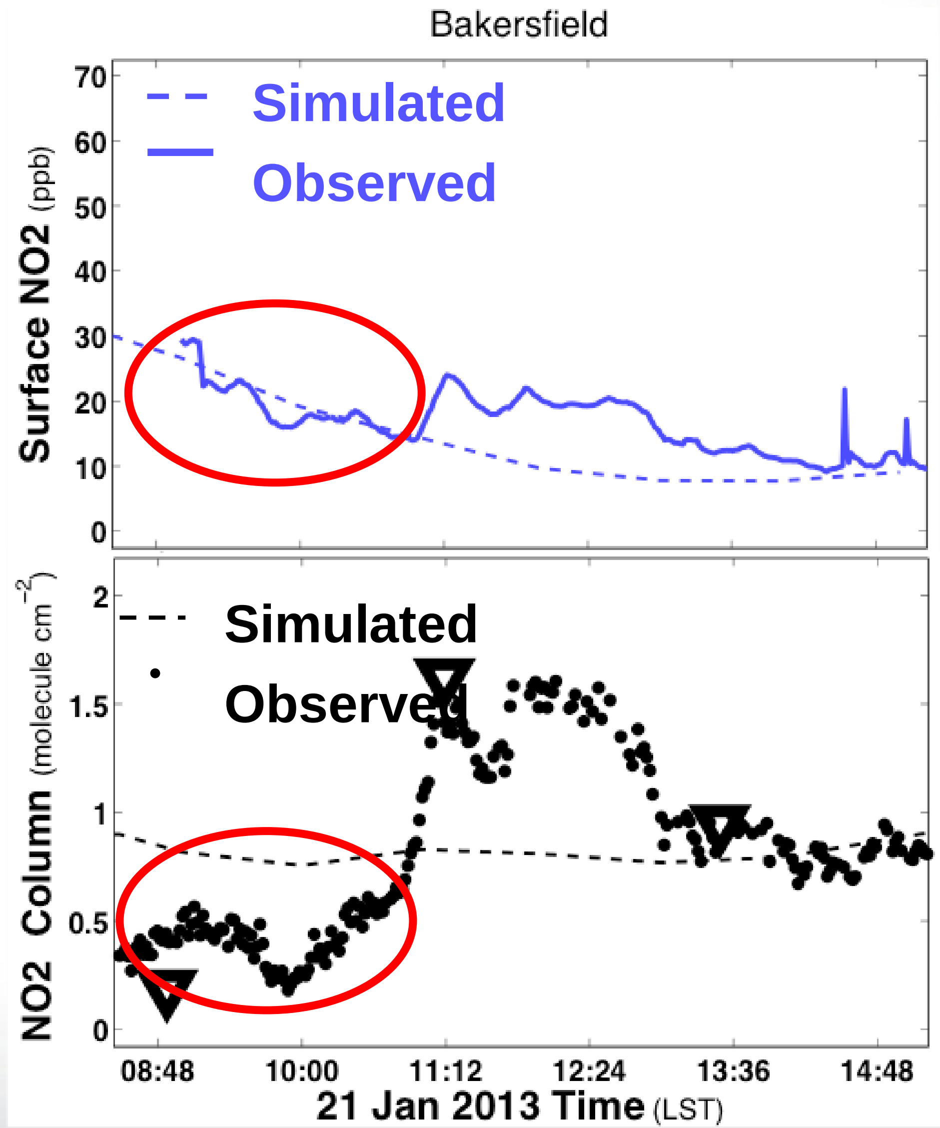
Fundamental understanding of model transport needs improvement



Pandora vs Surface-Colorado



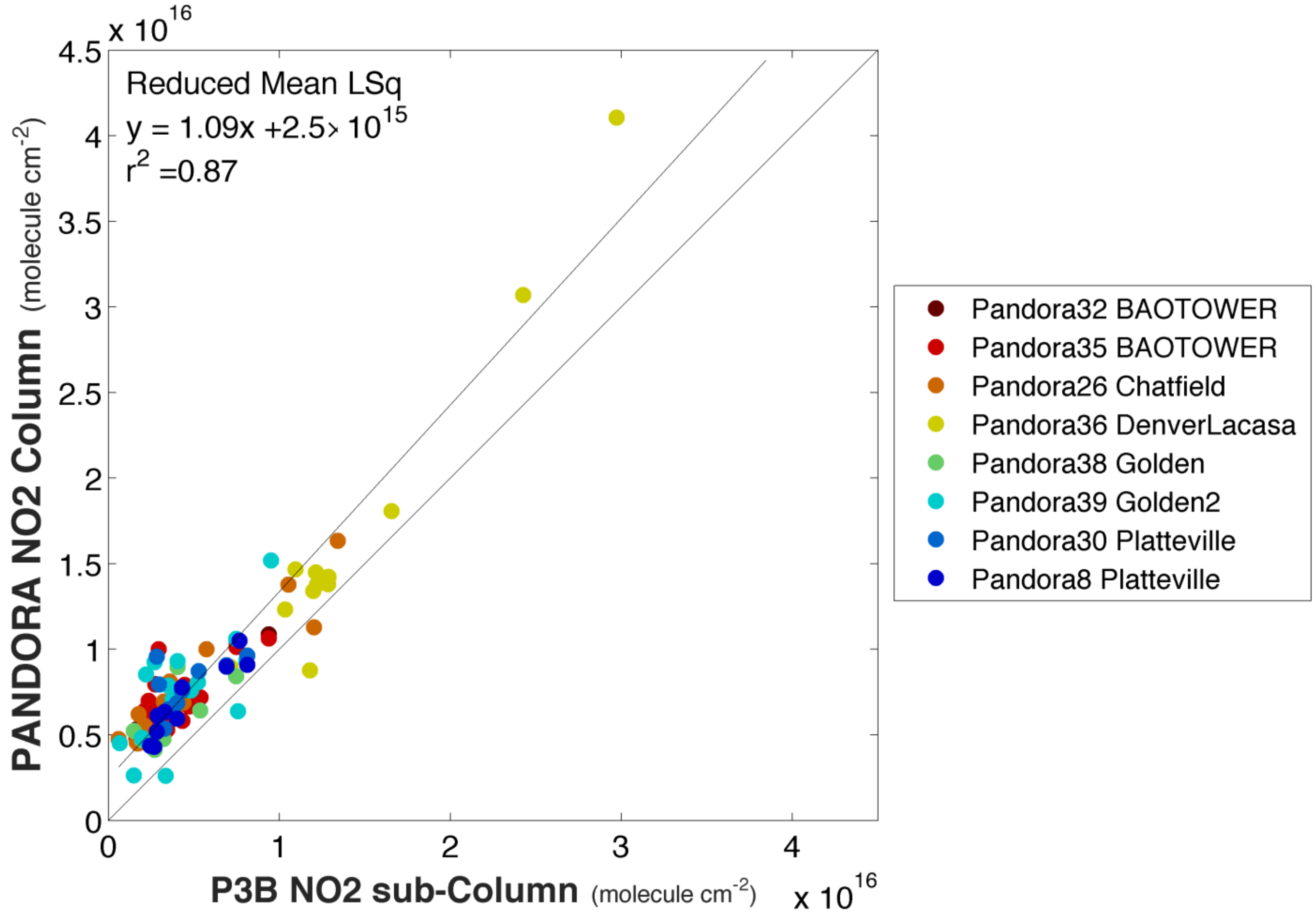
Highlights the limitations of evaluating model performance using surface data alone (top), particularly in conditions where mixing (or lack of mixing) are difficult to simulate



Preliminary PANDORA validation vs P3B/surface in situ sub-columns (< 4km)

Slight positive bias for PANDORA vertical columns (slope = 1.09)

Y-intercept = 2.5×10^{15} mol cm^{-2} reflects the column above 4 km including stratospheric contribution

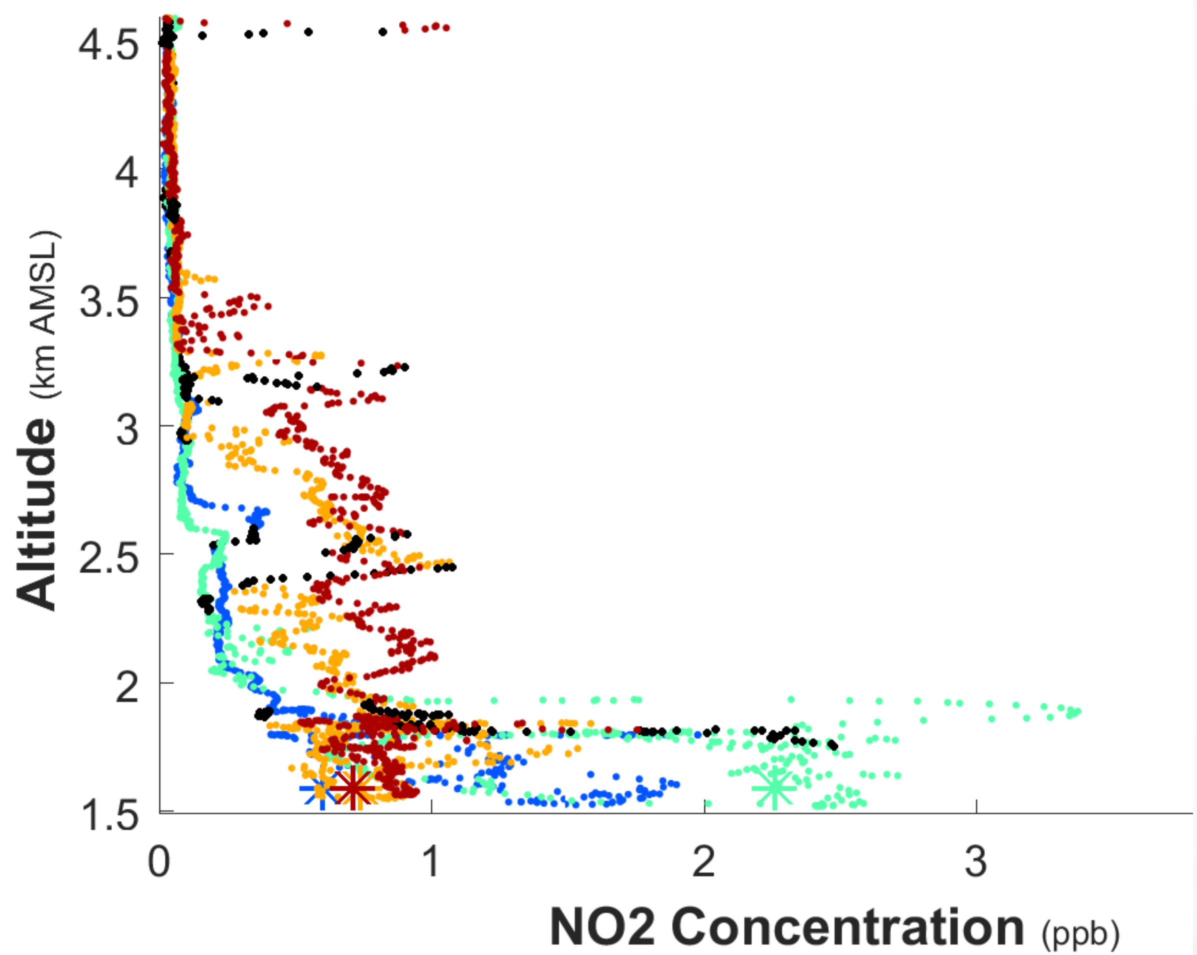


The validation of PANDORA with spiral data is imperfect

Real atmospheric variability adds noise to any analysis due to different sampling footprint

PANDORA observes within ~1 km of site.

Spirals are ~5 km-10 km (>1 km frm site is shown as black points)



The US EPA works with a diverse group of managers on US air quality

Source - http://www.aqast-media.org/

Federal
Bureau of Land Management (BLM)
Center for Disease Control (CDC)
Environmental Protection Agency (EPA)
National Oceanic and Atmospheric Admin. (NOAA)
National Park Service (NPS)

US Department of Agriculture (USDA)

Regional
Central States A
Environmental P
Environmental P
Environmental P
Environmental P
Environmental P
Michigan Air Dire
Regional Air Mar
States for Coord
Transport Commission (OTC)Southeastern Air Pollution Control Agencies (SESARM) Western Regional Air

Partnership (WRAP)

Local
Bay Area Air Quality Management District
Clark County Department of Air Quality
East-West Gateway Air Quality Advisory Committee
Maricopa County Air Quality Agency
Sacramento Air Quality District
San Joaquin Valley Air Pollution Control District South

Coast Air Quality Management District

State
Alabama Department of Environmental Management
California Air Resources Board
California Energy Commission
Colorado Department of Public Health and Environment Connecticut Dept of Energy and Environmental Protection Delaware Department of Natural Resources and Conservation Georgia Department of Natural Resources
Georgia Environmental Protection Division
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New Hampshire Department of Environmental Services
New Jersey Department of Environmental Protection
New York State Department of Environmental Conservation
New York State Energy Resources Development Admin.
North Carolina Department of Environmental Quality
Ohio Environmental Protection Agency
Oklahoma Department of Environmental Quality
Rhode Island Department of Environmental Management
Texas Commission on Environmental Quality
Utah Department of Environmental Quality
Vermont Department of Environmental Conservation
Virginia Department of Environmental Quality
Wisconsin Department of Natural Resources

Wyoming Department of Environmental Quality

Engagement with air quality managers can be a challenge, but may provide <u>additional data AND local expertise</u>

EPA

Relevant measurements for L2/L3 Geophysical Validation from a Federated Ground Network

Development of a federated correlative validation data sets would allow for:
A long-term statistical analysis and for comparisons under differing atmospheric and viewing conditions. Desirable attributes of the proposed correlative data set are;

1) **Accuracy: well-validated measurements,**
2) **Temporal coverage: e.g., comparisons with fixed sites for seasonal and longer-term studies, and,**
3) **Numerous sites over the U.S. with local technical support.**

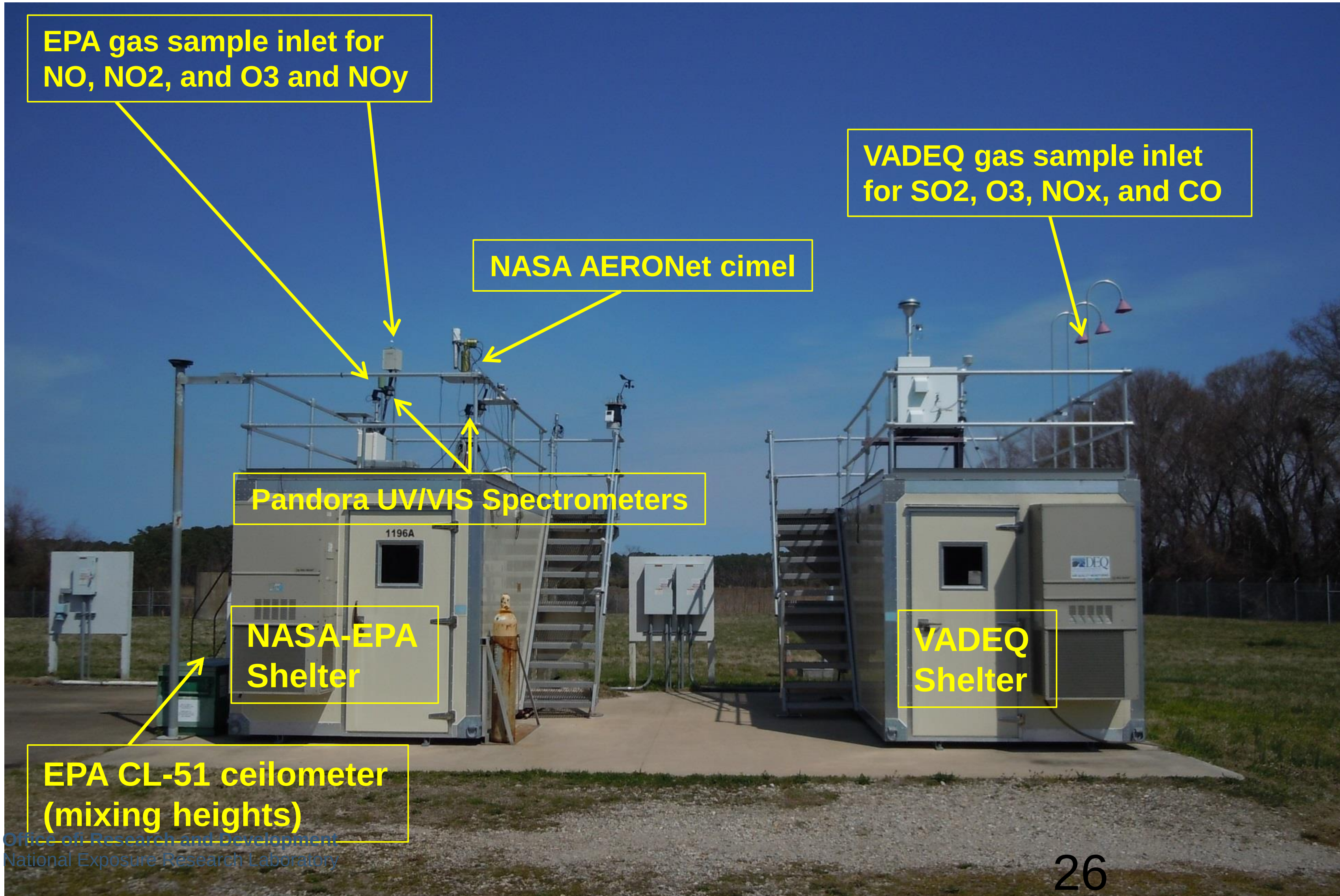
TEMPO Data Products:
Total Ozone Column - UV/VIS Spectrometer PANDORA
Tropospheric Ozone - in-situ surface O3

Total Nitrogen Dioxide Column - UV/VIS Spectrometer PANDORA
Tropospheric Nitrogen Dioxide -UV/VIS Spectrometer PANDORA, ceilometer, and in-situ surface NO2

Total Sulfur Dioxide Column - UV/VIS Spectrometer PANDORA and in-situ surface SO2 at CAPABLE and AIRS
Aerosol loading and optical properties in the UV - AERONet Cimel and aerosol height via ceilometer (920 nm)

Total Formaldehyde Columns - UV/VIS Spectrometer PANDORA, in-situ surface CH_2O

Prototype Instrument Suite for Ground Validation Sites



PAMS Network Re-Engineering

Forthcoming changes in the U.S. Photochemical Assessment Monitoring Station (PAMS) program by U.S. EPA present an opportunity to better connect air quality relevant satellite measurements with surface measurements for both aerosol and trace gases.

-The overall objective of PAMS network is to provide measurements that will assist States in understanding ozone nonattainment problems and to implement strategies to solve the problem.

-The PAMS network sites are operated by the state and local air pollution agency – not EPA.

-As a result of the changing nature of the ozone problem and the form of the standard since the start of the PAMS program, the EPA has proposed a re-engineered PAMS program.

-At numerous locations across the country, PAMS sites will be co-located, or in near proximity to, NCore sites established primarily for particulate matter (PM) monitoring.

Current PAMS Sites