Status Update on EPA Pandora Activities

Lukas Valin, Jim Szykman, David Williams + many others with NASA Pandora Project and U.S. state and local AQ agencies

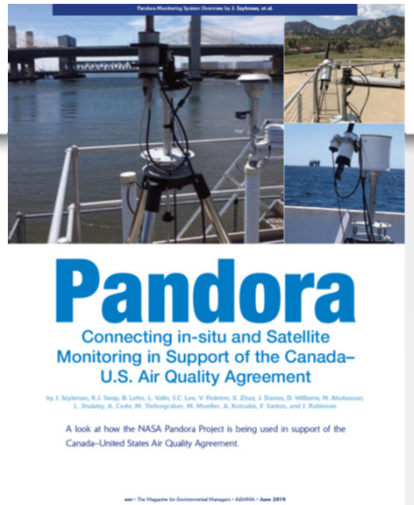
CASTNET Monitoring Meeting
September 26, 2019
EPA Campus
RTP, NC

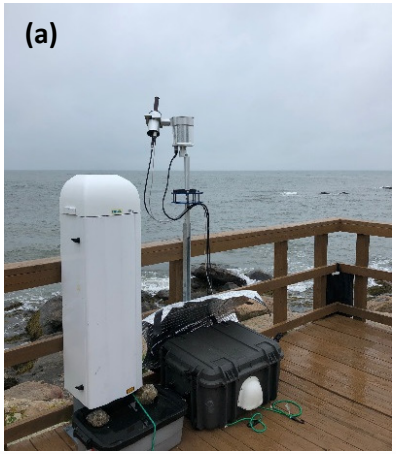
Pandora's Box

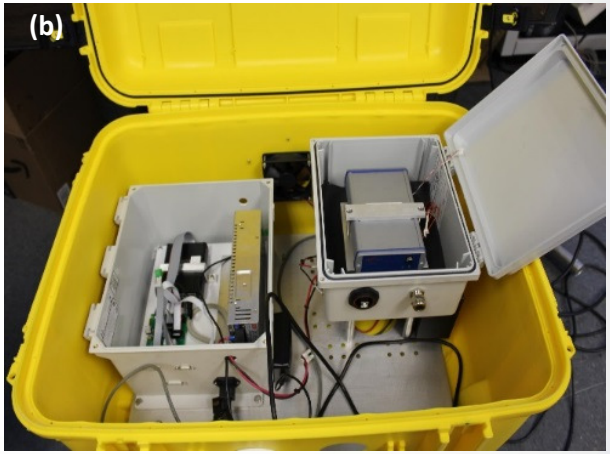
Pandora Ground-Based Spectrometer

- System developed at NASA Goddard by Herman, Cede, and Abuhassan with a focus on satellite validation. Supported and maintained by NASA and ESA.
- Ground-based direct sun/moon & sky scanning remote sensing for air quality and atmospheric composition (1S - ~270 – 530 nm, 0.6 nm; 2S – 400 – 900 nm, 1 nm) provides slant column measurements.
- NRT Standard Operational Products at high frequency (~ 2 mins): Total Column Ozone (+/-15 DU, ~5%); Total Column NO2 (+/-0.05 DU, ~10%) **Optimistically awaiting total column formaldehyde**
- Research products: HCHO column, SO2 column & near surface NO2
- Successfully deployed for multiple field campaigns (e.g. DISCOVER-AQ, KORUS-AQ, LMOS and OWLETS) as well as long-term monitoring.

June 2019 AWMA EM Article →





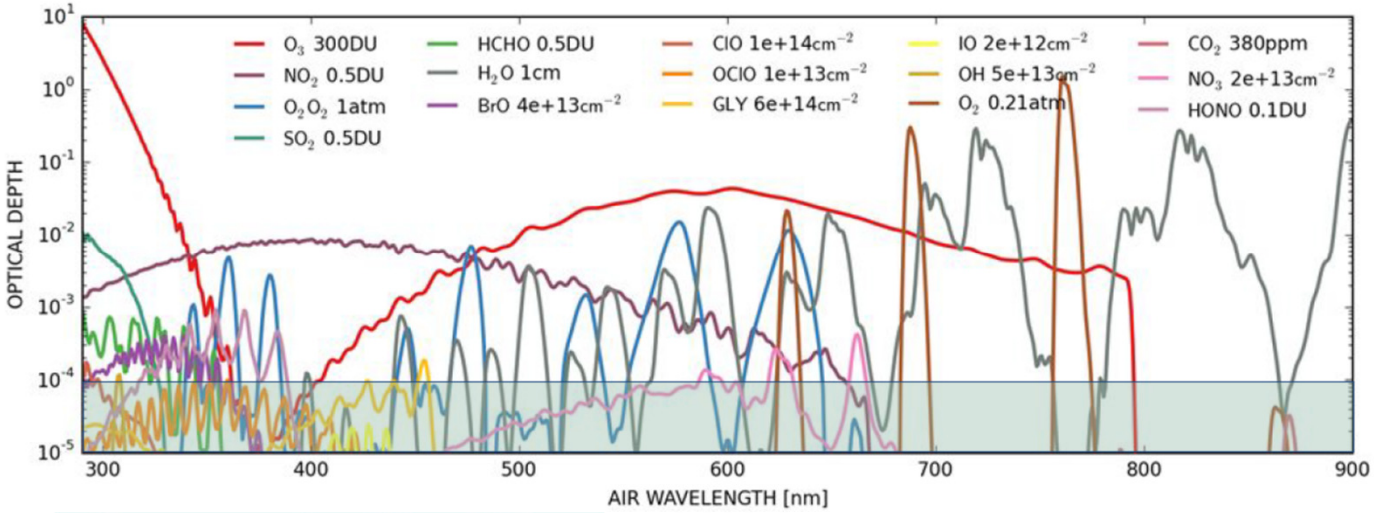


Pandora Pictures: (a) enhanced sun tracker; Pan55 deployment at FWS Outer Island in LIS (b) redesigned integrated layout

Current efforts focused on development of operational capacity and standard products of O3, NO2, HCHO, and SO2, but opportunity is there to provide information on range of atmospheric constituents and novel data products such as Zenith-Sky for NO2 profile or near surface NO2 (MAX-DOAS) vs. Direct Sun (total optical absorption spectroscopy (TOAS) measurements.

Courtesy
Alexander Cede,
LuftBlick

LUFTBLICK



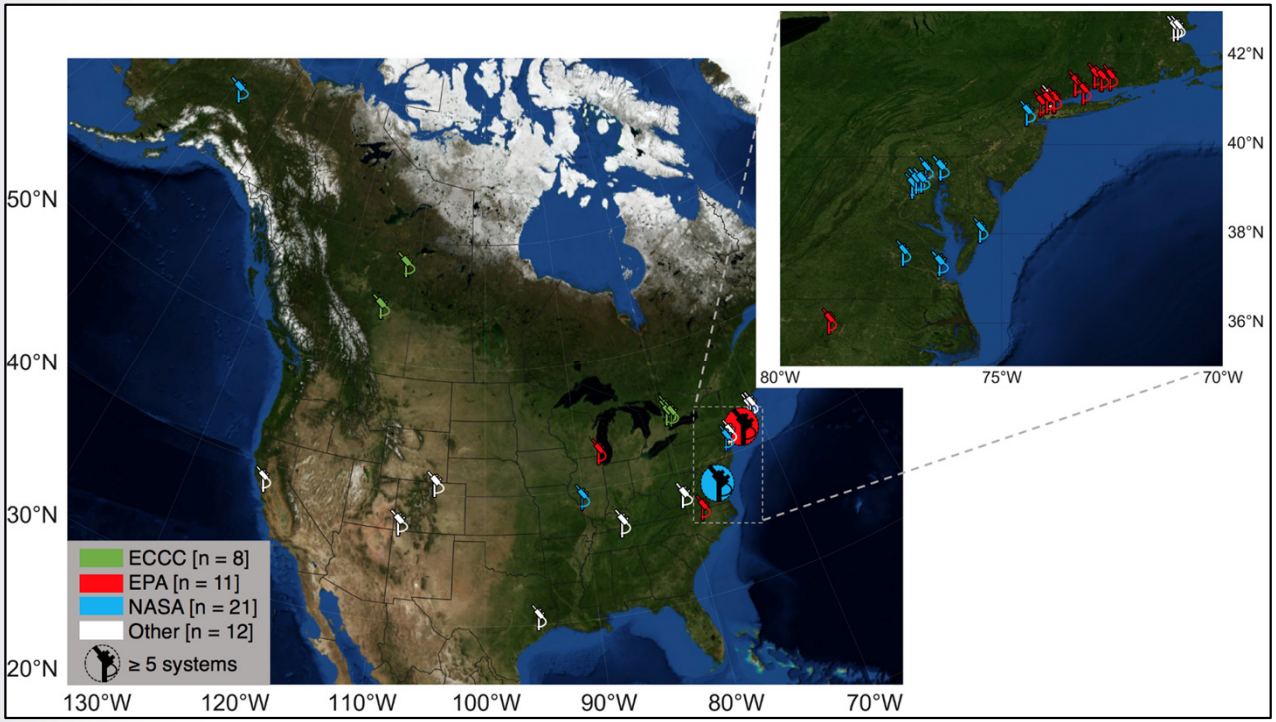
Spectrometer 1, 270 to 530 nm
0.12 nm step, 0.6 nm resolution

Spectrometer 2, 400 to 900 nm
0.24 nm step, 1.1 nm resolution

Pandonia Global Network (PGN) Collaboration

- As a member of the TEMPO Science Team and TropOMI S5PV Team , EPA is collaborating with NASA, ESA, and Luftblick to develop a subset surface air quality sites to host Pandora spectrometer instruments and contribute to larger Pandonia Global Network.
- Pandonia Global Network (PGN) developed by ESA and NASA to provide global community with standardized long-term measurements for validation of more than a dozen low-earth orbit and geostationary orbit UV-visible sensors, most notably Sentinel 5P, TEMPO, GEMS and Sentinel 4.
- Initial EPA deployment ~10 long-term instruments across the Ozone Transport Region started in May 2018. Effort directly supports new requirement under National Photochemical Assessment Monitoring Station (PAMS) Program Enhanced Monitoring Instrument under the re-designed PAMS Program.

EPA-NASA PAMS-EMP Pandora Network: September 2019



- May 2018 - Initial set of long-term sites establish in collaboration with state air agencies as part of Long Island Sound Tropospheric Ozone Study
- Sept 2019 - All older generation units removed and five new generation units reintegrated:
  - Rutgers, NJ
  - Bronx, NY
  - Queens College, NY
  - Flax Pond, NY
  - New Haven, CT
- Data processed via PGN in near-real-time

Rutgers, NJ PGN site - September 2019

EPA-NASA PAMS-EMP Pandoras with the PGN: Forthcoming Additions

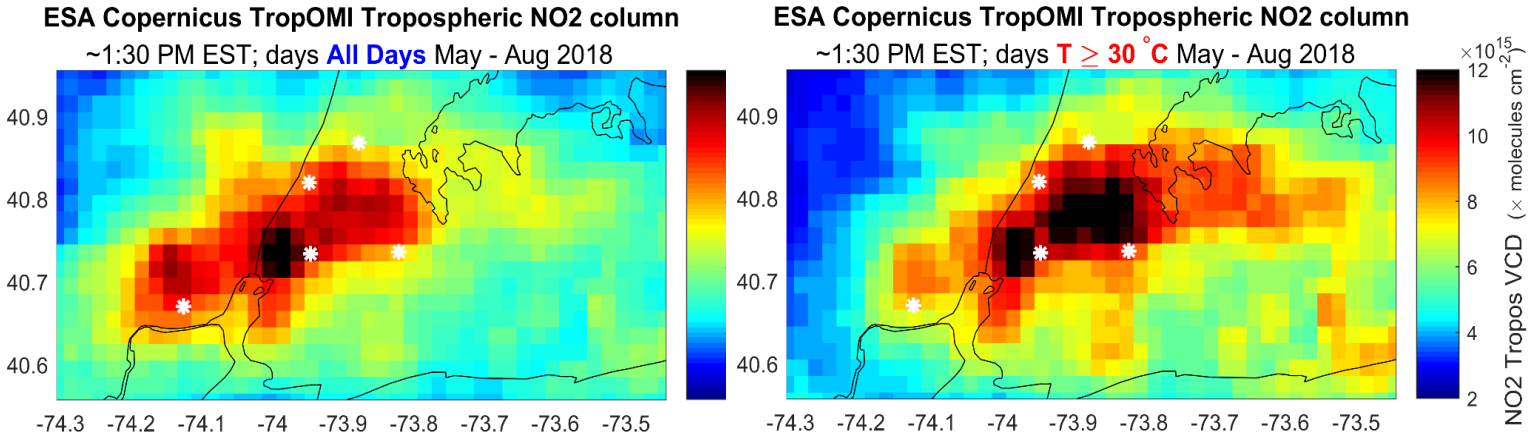
- Pandora 2S installation at EPA Duke Forecast Research Site Sept 2019
  - TropOMI Satellite Validation
  - NO2 dry deposition in conjunction with CASTNet Program
  - NO3, HONO, & NO2 profiles

- Upgrade all nine 1S-units removed from Greater Long Island Sound Area and redeploy to prior and new sites within the Ozone Transport Regions (Mid-Atlantic and NE U.S.) – Early 2020
  - Bayonne, NJ; Westport, CT; Madison, CT; East Providence, RI; Londonderry, NH; Cape Elizabeth, ME; Bristol, PA (and/or City of Philadelphia); Lawrenceville (Pittsburg, PA); McMillian Reservoir, DC

- Seven new 1S-units under procurement. Target deployments include CASTNet, and Western Lake Michigan Area and western U.S. – Expect delivery around December 2019

- 22 upgraded units to be placed into the PGN Network NLT the end of 2020.

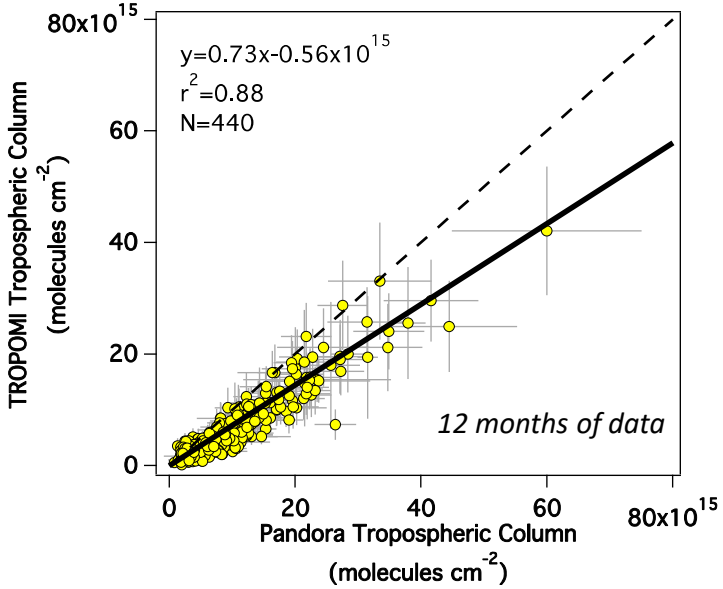
Doing "experiments" with satellite measurements – one opportunity of many

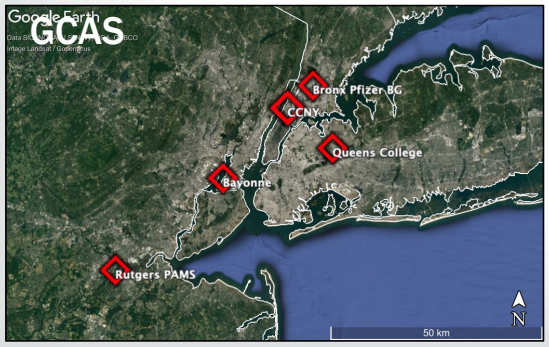


- Satellite NO_2 measurements indicate a large NO_2 enhancement over Queens and the East River on hot days (T > 30 C). There is no conventional trace gas monitoring network near these sites.

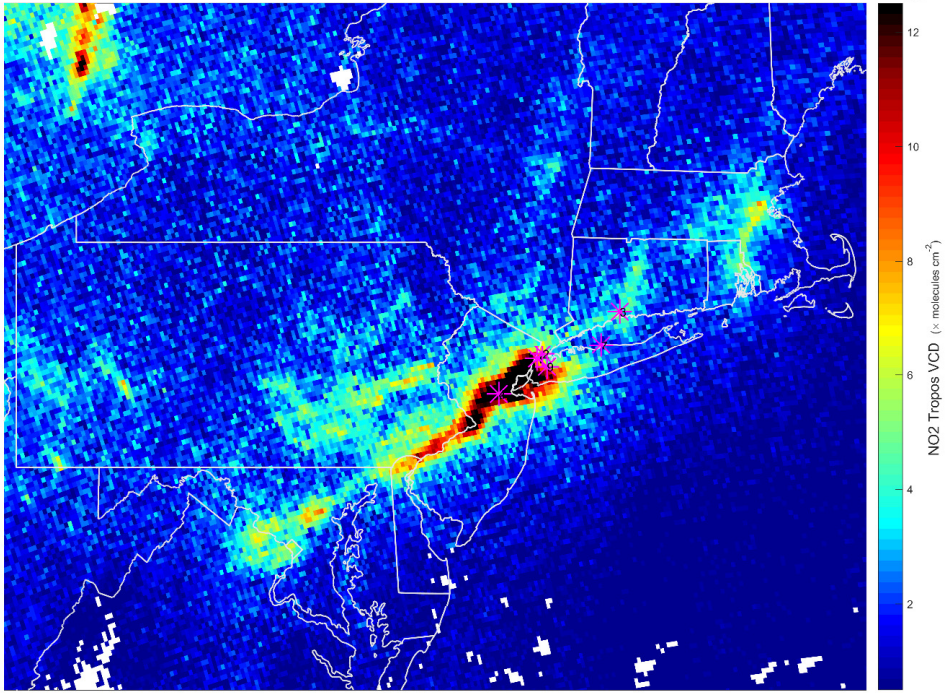
- Pandora network at air quality sites around Long Island Sound will help assess uncertainty in satellite based NO_2 columns. Goal is to improved understanding of emission sources through a more integrated spatial and temporal analysis of NO_2.

Pandora a key measurement for validation of ESA TropOMI NO2 over the NYS/LIS domain





TropOMI Trop.NO2 VCD – 19 Sept 2019

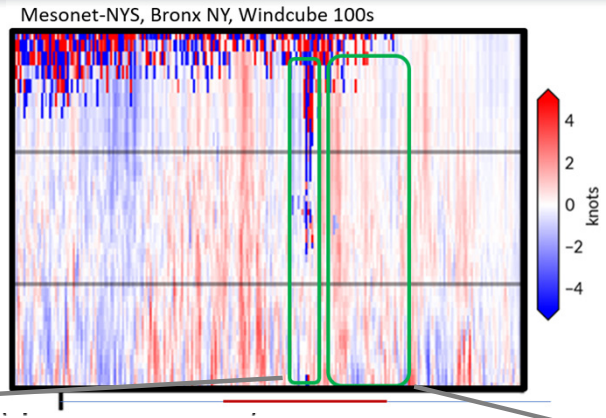


TROPOMI

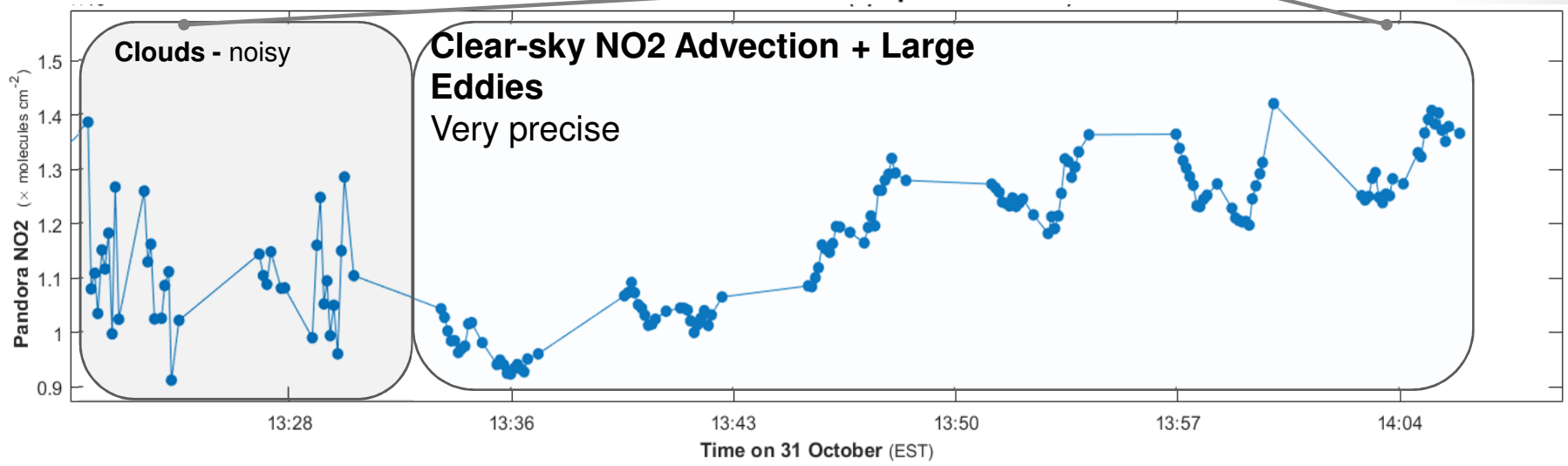
Scatter plot courtesy Laura Judd, NASA LaRC

Precise measurement of NO_2 column @5 seconds

Pandora is sensitive enough (**1σ = 5×10^{13} in 10 s**) to capture variations driven by large boundary layer eddies **(up to ±1×10^{15} molecule cm^{-2} over 1-minute,** or ~10%-20% of tropospheric column).



Bronx NY Pandora



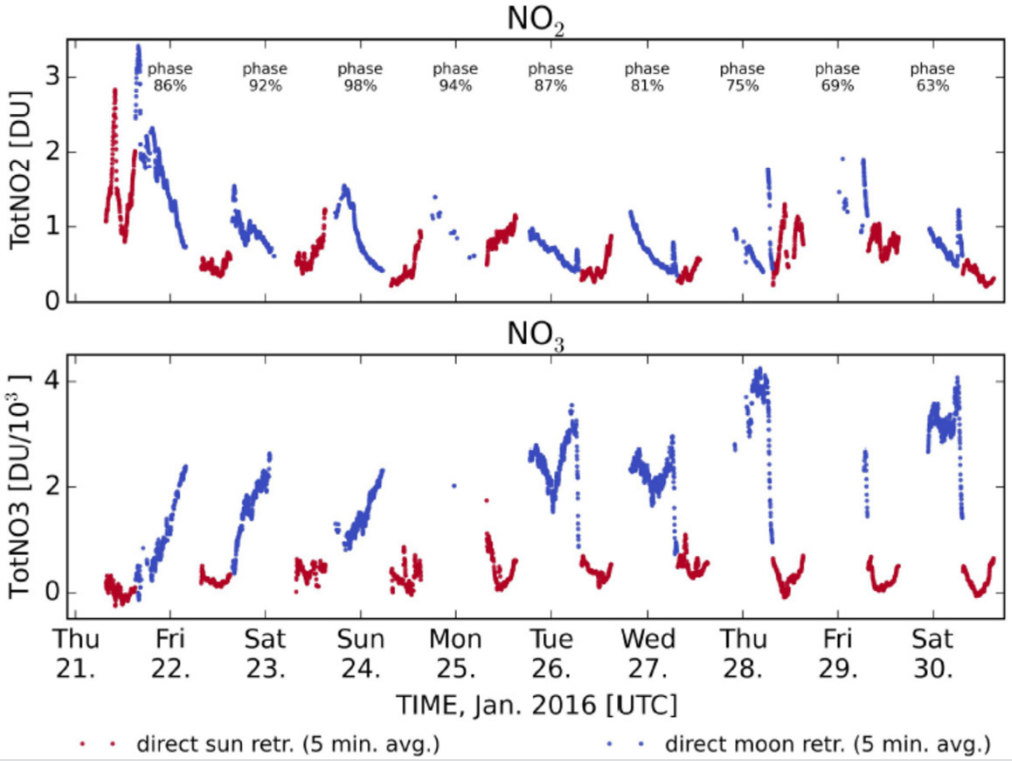
Again, development of robust operations is currently highest priority of the PGN, but direct-moon measurements, when more than half-full, offer the potential for unique datasets.

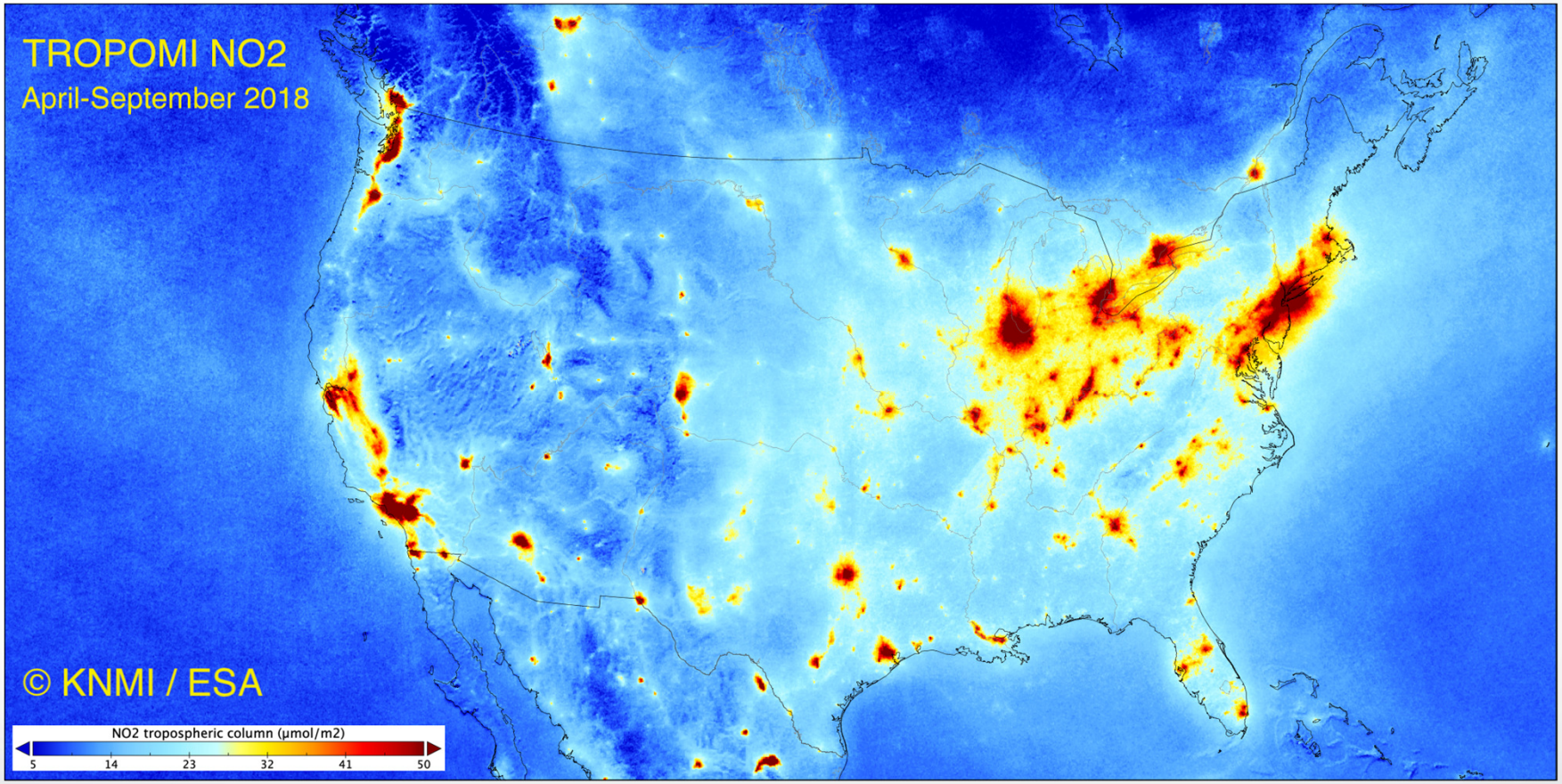
Courtesy
Alexander Cede,
LuftBlick

LUFTBLICK

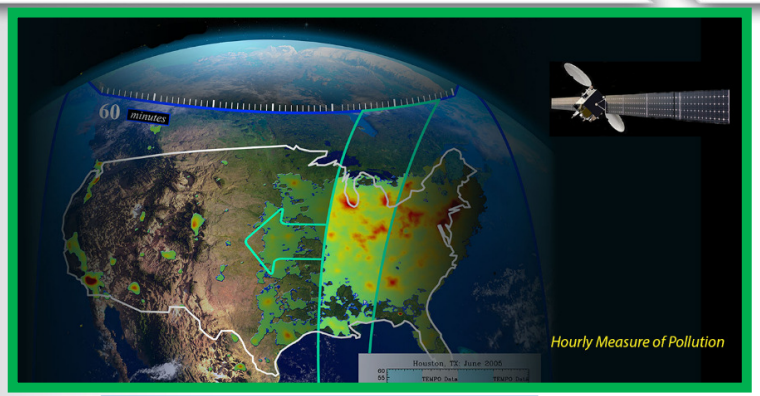
Moon measurements

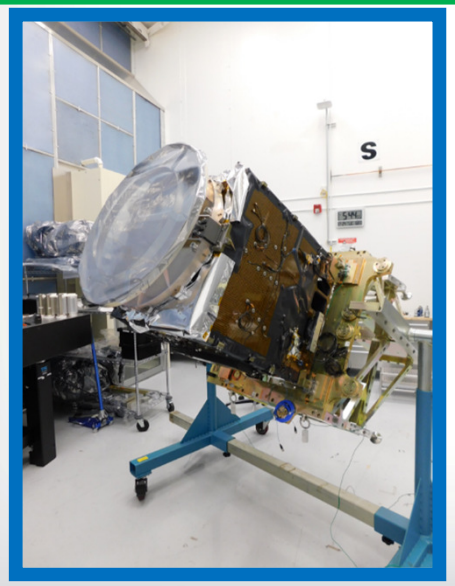
Sun / moon NO_2 and NO_3




TROPOMI NO2
April-September 2018
© KNMI / ESA
NO2 tropospheric column (µmol/m2)
5
14
23
32
41
50

Tropospheric Emissions: Monitoring of Pollution





Picture of TEMPO UV/VIS Spectrometer instrument; current schedule for instrument delivery to NASA - December 2018

PI: Kelly Chance, Smithsonian Astrophysical Observatory
Current other Institutions: EPA, NASA LaRC, NASA GSFC, NOAA, NCAR, Harvard, UC Berkeley, St. Louis U, U Alabama Huntsville, U Nebraska

International collaboration: Korea, Mexico, Canada, Europe

Selected Nov. 2012

- UV/VIS grating spectrometer (290-490 nm; 500-700 nm)
- Instrument completed December 2018.
- NASA arranging for launch via host instrument on commercial geostationary communications satellite with launch expected late 2020-2022.

NASA and USAF awarded a commercial services contract in June, 2019 for TEMPO satellite hosting services

- Maxar Technologies (formerly Space Systems Loral) is the host spacecraft service provider and prime contractor
- Proposed Launch Date: February 2022
- Anticiapted Orbital Location: 92.85 degrees West Longitude

Collaboration Opportunities with CASTNET

- CASTNet high elevation remote sites offer good opportunity for satellite validation in remote rural areas: low tropospheric column densities $<10^{15}$ molec-cm^{-2}
- Potential to help with research on lightening NOx and stratospheric/tropospheric NO_2 separation
- Dry Deposition of oxidized N – NO2 and TDep CMAQ modeling
- Stratospheric Intrusions Western U.S.
- Validation of satellite trends of NO2 over areas of interest
- Evaluation of CMAQ modeling of prescribed (ag) burns (pandora+satellite+ceilometer)
- Field Studies Oppoturnities – DISCOVER-AQ/FRAPPE', KORUS-AQ, UWFPS, LMOS, LISTOS,
- New Project NASA funded project with Sitting Bull College south-central ND Standing Rock Reservation to establish research air quality site – TEMPO Validation site

Understanding trends in OH radical and its impacts on O3 and PM

- For a 90% reduction of anthropogenic NOx emissions from 2005 baseline level, isoprene abundance in the eastern US was 2.5-fold that of baseline levels a reflection of reduced OH radical abundance (Valin et al., 2016).

- The changes in OH concentration (~2.5-fold) has a very large impact on regional ozone and secondary PM formation rates in the East US boundary layer.

- Mountain-top sites in the east US monitor airflow that interacts with a larger spatial area, particularly at nighttime when downslope flows effectively sample the residual boundary layer atmosphere, unaffected by surface exchange processes (e.g., ozone concentrations are maximum at nighttime at mountain-top sites)

- Monitor isoprene concentrations at mountain top sites in East US (???)

Acknowledgements

PGN Participants

LuftBlick and NASA GSFC Pandora teams (Alexander Cede, Bob Swap, Nader Abuhassan)

Shared Slides

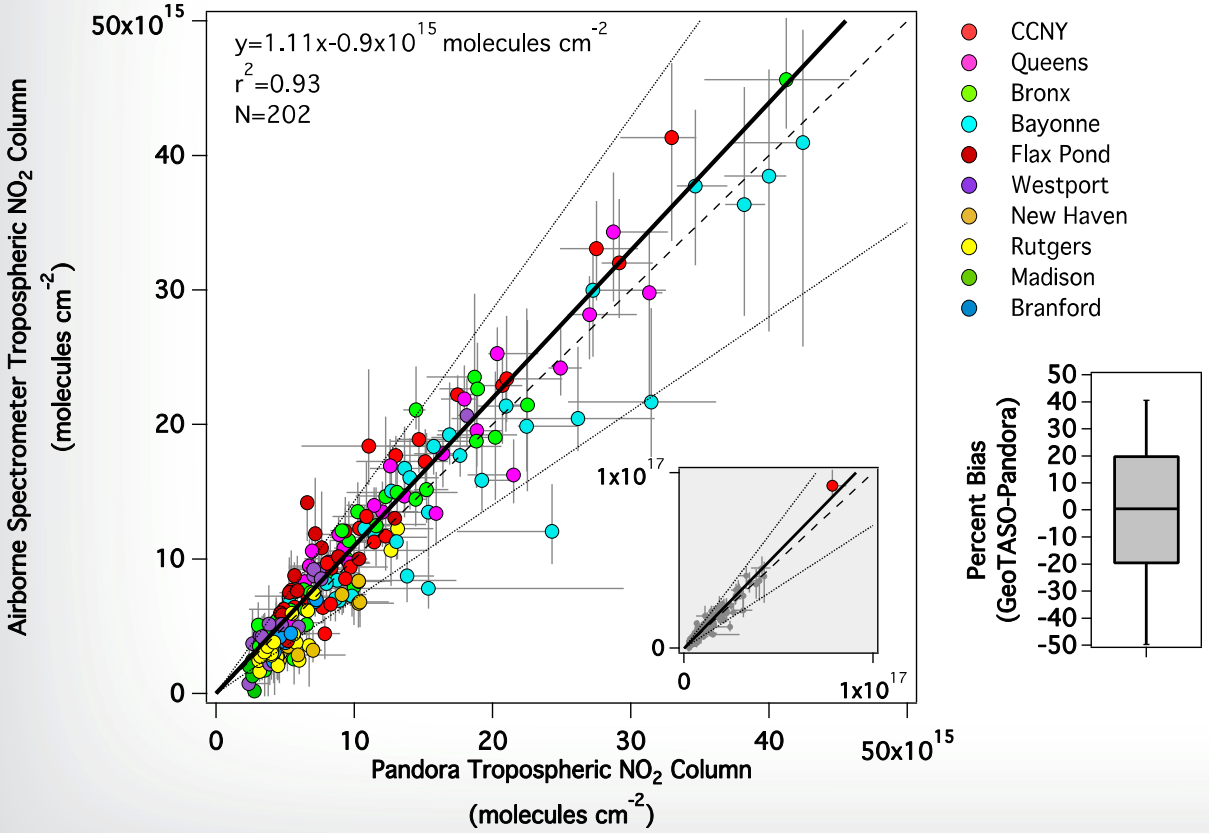
Laura Judd (NASA LaRC), Alexander Cede (LuftBlick)

Funding: U.S. EPA Air-Energy Research Program and TEMPO Project

High Priority Topics: EPA-NASA PAMS-EMP Pandoras within the PGN

- Increased operational performance – Sept 2019 installs much improved from prior year. Upgrades to Blick-O and sun trackers appear to have made a difference.
- DS Formaldehyde retrieval critical to PAMS program - co-location of pandoras at several sites with in-situ HCHO and PBLH profiling for continuous evaluation.
- Shorten time to get initial field calibration done.
- Increase reliability of internet connection.
- Development of a dummy installation kit and protocol that can be sent out to site monitoring staff (EPA and GSFC led)
- Creation of quarterly site status reports to key personnel.

Pandora provides excellent validation resource
NASA GeoTASO Airborne Spectrometer vs. Pandora (LISTOS 2018)



Courtesy Laura Judd et al., In preparation

See also:

- Judd et al., *Frontiers in Environmental Science* 2018 10.3389/fenvs.2018.00085
- Judd et al., *AMTD, in review* 10.5194/amt-2019-161

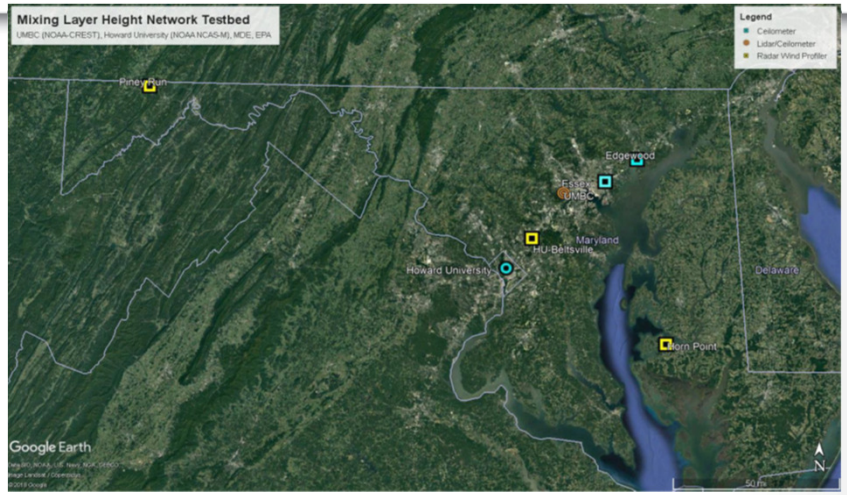
Development of PAMS profiling network

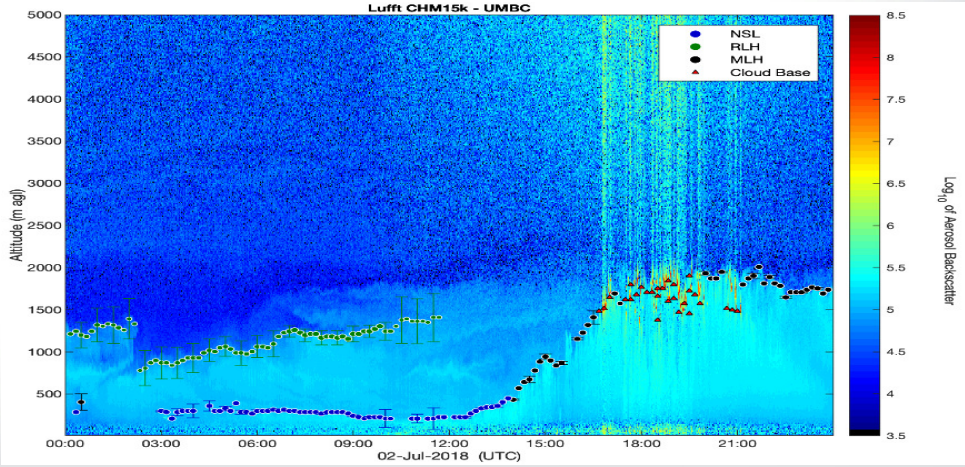
EPA is working with UMBC Atmospheric Lidar Group to establish a prototype Aerosol Profiling Network in support of PAMS mixing height requirements:
Maryland is the initial focus area via MDE:

- Data transfer of raw data from ceilometers (new) and existing wind profilers into data archive.

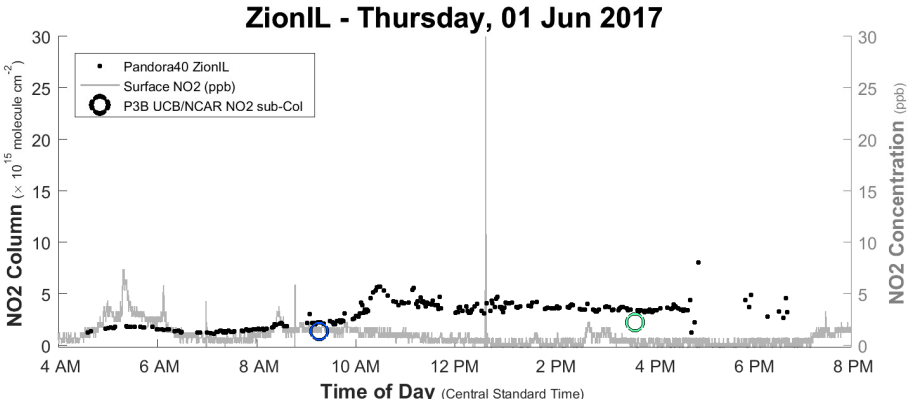
- Development and implementation of a common algorithm (Haar wavelet) with site specific settings.
  - Signal corrections (noise, artifacts, overlap, etc.)
  - Continuity of diurnal evolution of boundary layer (transtions)
  - Calculation of MLH uncertainties in retrievals
  - Cloud identification and classification in order to include convective cloud-topped boundary layers and cloud cover information
- Near real-time (1 hr.) web-based display.

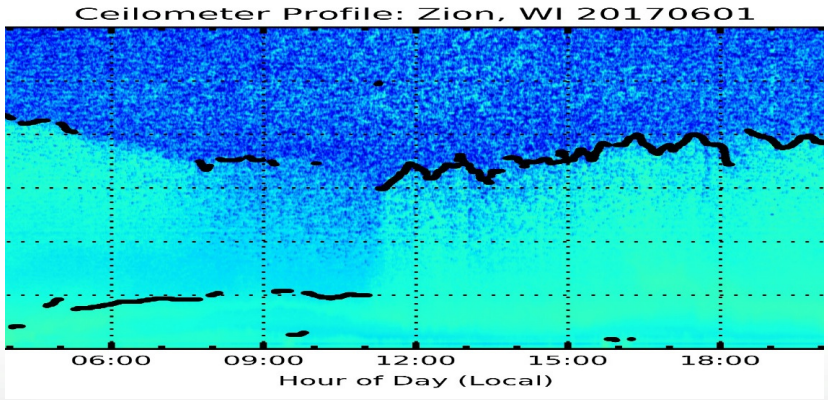
- Data retrieval of archive.

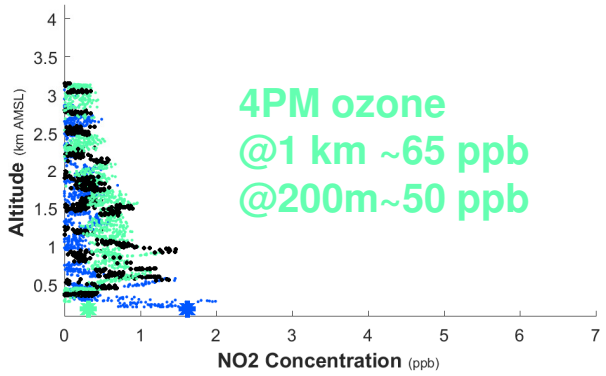




CL-51 Provides Additional Information





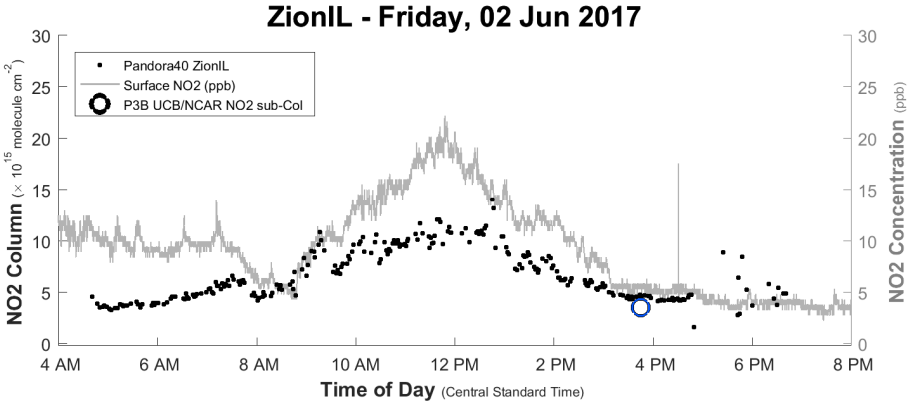


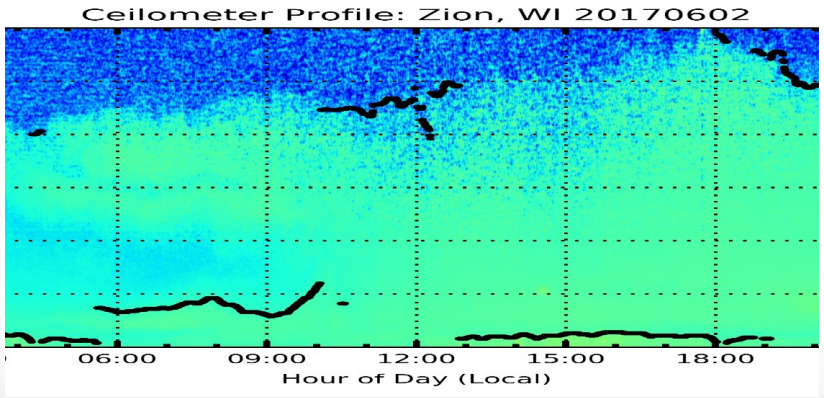
4PM ozone
@1 km ~65 ppb
@200m~50 ppb

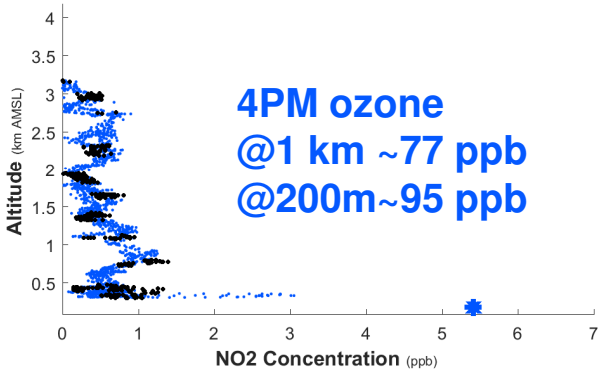
CL51 observes a deeper polluted layer passing over at 11 AM, and a descending cleaner airmass near the surface.

The polluted layer aloft is sufficient to maintain or generate high O_3 background of 65 ppb.

CL-51 Provides Additional Information







4PM ozone
@1 km ~77 ppb
@200m~95 ppb

On the next day, CL51 again observes a deep polluted layer, but observes a more polluted layer near the surface instead of the cleaner conditions of the previous day. The ozone profile is consistent with NOx profile: a deep polluted layer and more extreme values occurring at

Measured column to surface ratio helps us understand how deep pollution is mixed aloft

Regress NO2 column vs surface concentration for each hour (colors)

- Maximum observed slope at BAO Tower is 2.3×10^{15} / 1ppb and occurs at 12 noon. → 1 km average PBL
- Maximum R2 is 0.71 and also occurs at 12 PM. This is when mixing is most vigorous.