Exploring NO_2 spatiotemporal patterns and the impact of pixel size on Pandora comparisons

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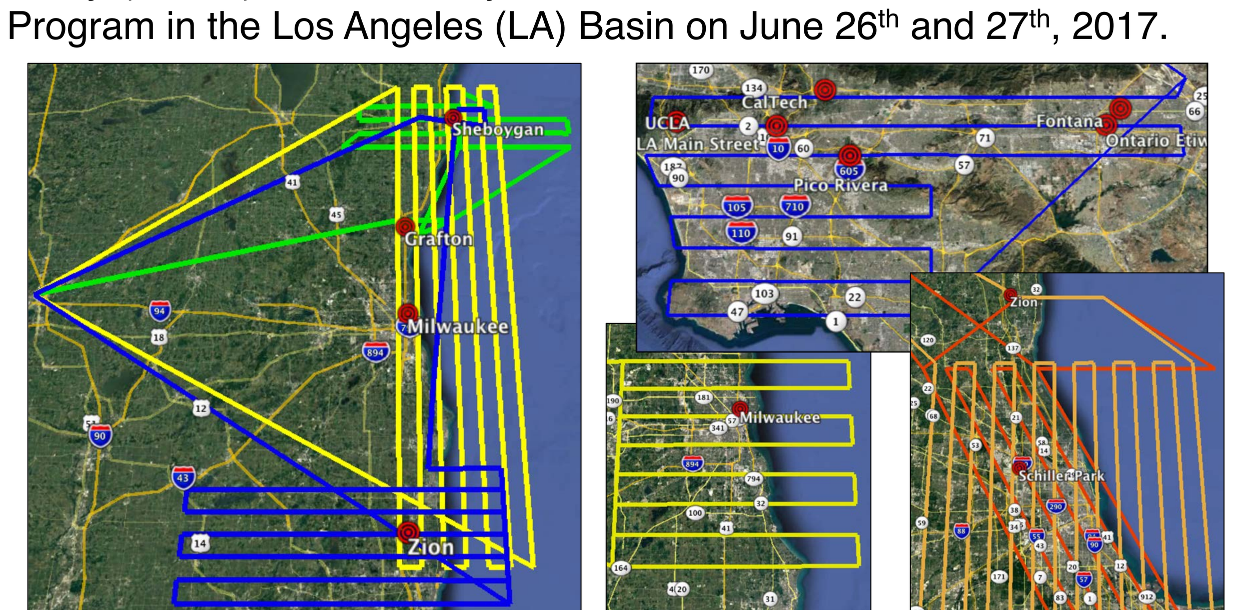
Introduction and Data

The **GeoTASO** hyperspectral mapping spectrometer was deployed aboard the NASA LaRC UC-12 in support of the KORUS-AQ Field Study in South Korea during May-June 2016, the Lake Michigan Ozone Study (LMOS) between May 22nd and June 22nd, 2017, and the SARP Program in the Los Angeles (LA) Basin on June 26th and 27th, 2017.



Flight plans playbook for LMOS/SARP 2017

Gapless maps (**Rasters**) were created by flying parallel flight lines spaced so there were no gaps between adjacent swaths considering the 45° FOV of GeoTASO and the nominal flight altitude of 7-8.5km.

Flight objectives were to map over emission source regions **multiple times per day** over several days in **urban areas** like Seoul (KORUS-AQ), Chicago (LMOS), and Los Angeles (SARP) including **point sources** (power plants) along the ozone-polluted western shore of Lake Michigan.

Preflight in Madison, WI during LMOS.

This poster shows NO_2 raster datasets from a subset of GeoTASO flights to demonstrate how NO_2 signatures appear during diurnal sampling, weekend/weekday sampling, and point source mapping/pollution transport events.

The GeoTASO retrievals from LMOS and SARP are spatially binned to demonstrate how spatial resolution influences mapping of NO_2 features and how GeoTASO compares to Pandora Spectrometers at different spatial scales.

NO_2 Differential Slant Column (DSC) Process

L1B spectra: Spatially binned to ~ 250 m x 250 m pixels

→ Retrieve **NO_2 Differential Slant Columns (DSCs)** relative to an unpolluted reference spectrum taken in flight with QDOAS in the 435-460 nm window

→ Bin data spatially to **750 m x 750 m**: Decreases noise approximately 50%

→ Estimate and subtract difference in **stratospheric slant column** between reference and observation to create a 'below aircraft' DSC: (OMI, OMPS, **PRATMO Box Model**)

→ Spatially **upscale** to desired areal resolution (e.g. 3 km x 3 km for TEMPO, 5 km x 5 km for TROPOMI, or 18 km x 18 km for OMI)

[Future Work] Calculate and apply AMFs to derive VCs
LMOS AMF a priori will include 4-km WRF-Chem output from U. Iowa (stratospheric components from RAQMS and PRATMO) and MODIS BRDF.

Comparing GeoTASO to Pandora

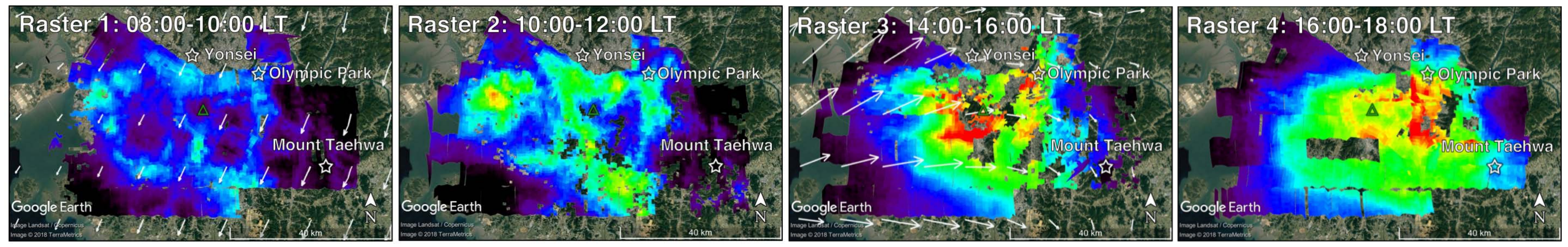
- 10 Pandoras were installed over the Lake Michigan and LA Basin areas in 2017.
- Pandora data are filtered for errors greater than 0.05 DU and Norm RMS greater than 0.005.
- Pandora vertical columns are converted to slant columns (SCs) via the air mass factor (AMF_{PAN}) and the stratospheric SC is estimated and subtracted to create a tropospheric SC (SC_T):

$$Pandora\ SC_T = (VC \times AMF_{PAN}) - (VC_{strat} \times AMF_{PAN})$$

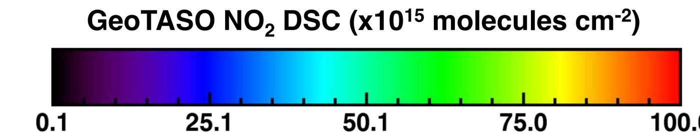
- Pandora data is averaged ± 5 min from the GeoTASO overpass.
- At GeoTASO's nominal resolution, airborne data is averaged within a 750 m radius of the Pandora. At upscaled resolutions, the value is taken for the pixel in which Pandora resides.

High-resolution Case Study Examples

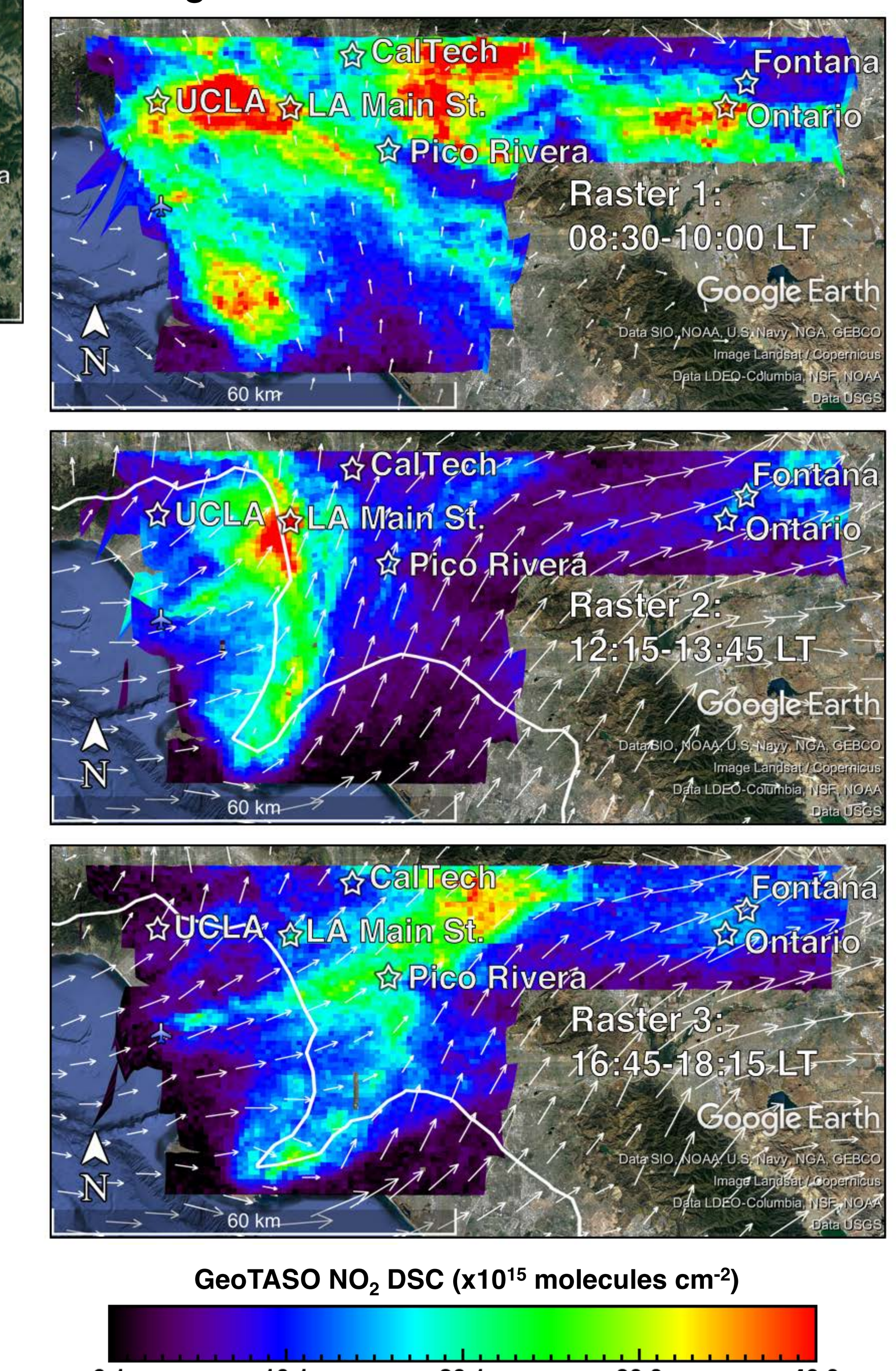
Diurnal Evolution: Seoul, South Korea on June 9th, 2016



Maps of NO_2 DSCs measured four times on June 9th, 2016 over Seoul, South Korea. Rasters 1 and 3 includes wind vectors averaged through the lowest 500 m agl from the full resolution Global Data Assimilation System (GDAS) at 09:00 LT and 15:00 LT.



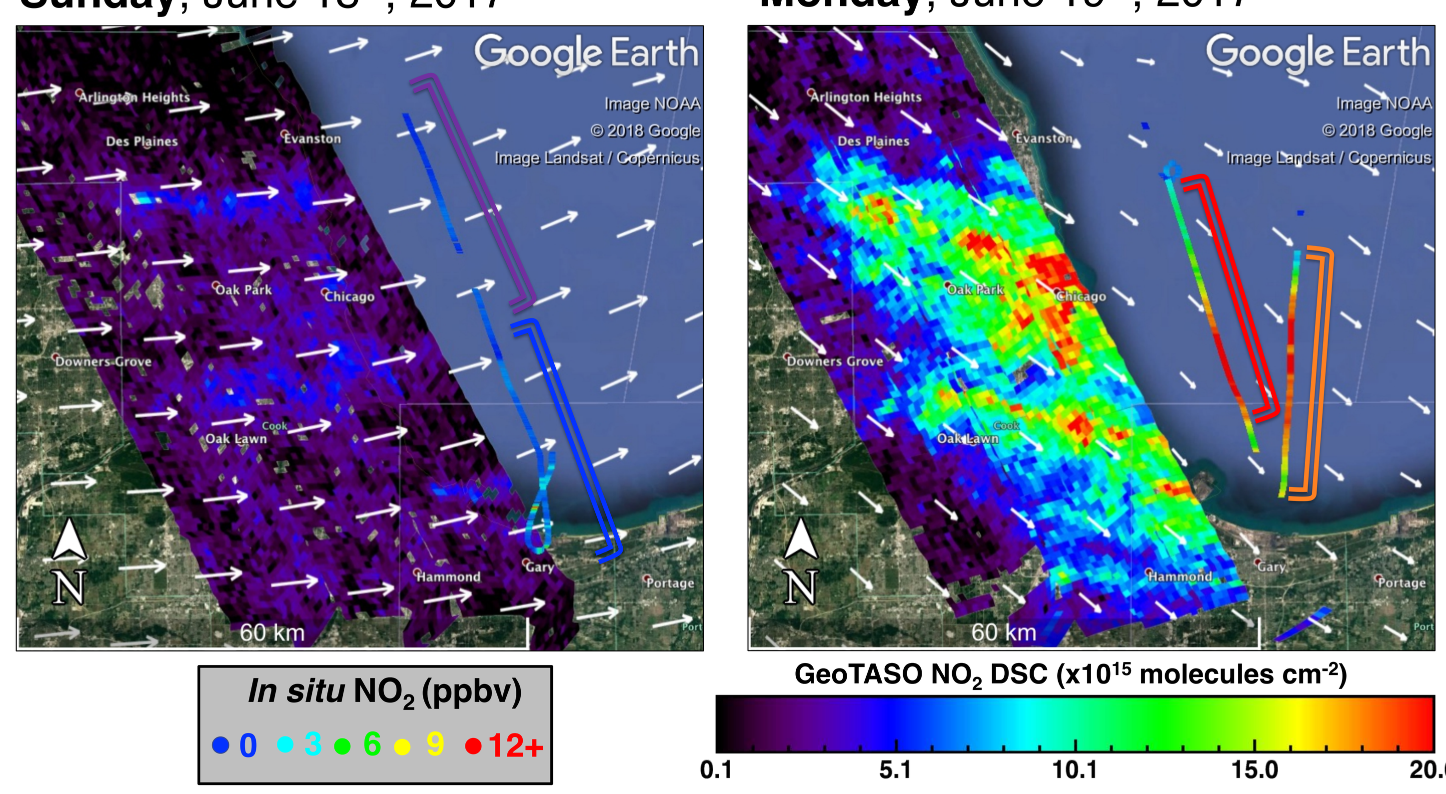
Diurnal Evolution: Los Angeles on June 27th, 2017



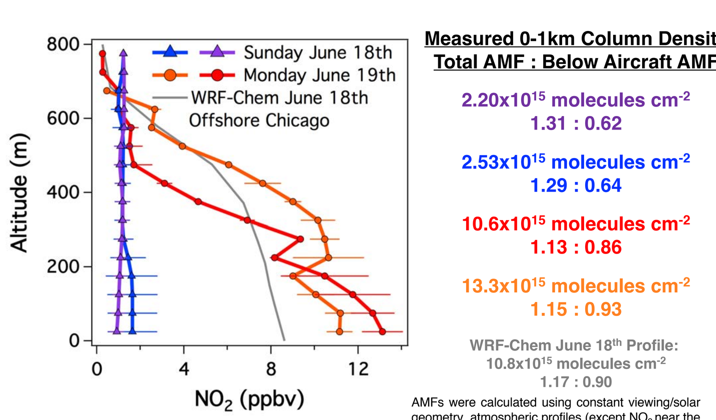
Maps of NO_2 DSCs over Los Angeles during the three rasters sampled on June 27th, 2017. Boundary layer averaged wind vectors from the NAM-CONUS 3-km analysis for 09:00 LT (top), 13:00 LT (middle), and 17:00 LT (bottom) are overlaid. Raster 2 and 3 have a white contour indicating the estimated sea breeze front location within the LA Basin.

Weekend/Weekday Comparisons: 08:00-10:00 LT

Sunday, June 18th, 2017 — **Monday**, June 19th, 2017

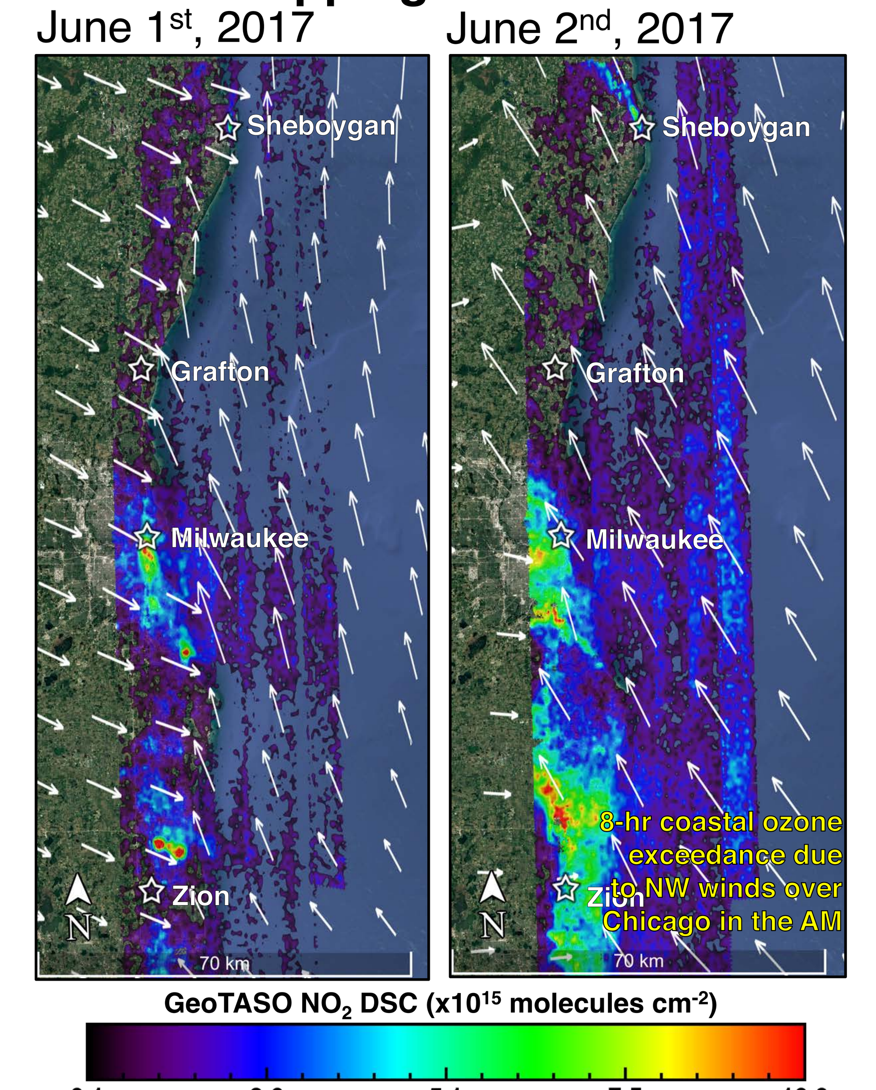


Maps of NO_2 DSCs over Chicago, IL between 08:00-10:00 LT on Sunday, June 18th and Monday, June 19th. Boundary layer averaged wind vectors from the NAM-CONUS 3-km nest analysis for 09:00 LT are overlaid. Temporally coincident in situ NO_2 profiles from Scientific Aviation occurred offshore from the GeoTASO rasters. These vertical profiles are plotted to the right, as well as the annotated column densities and calculated AMFs.



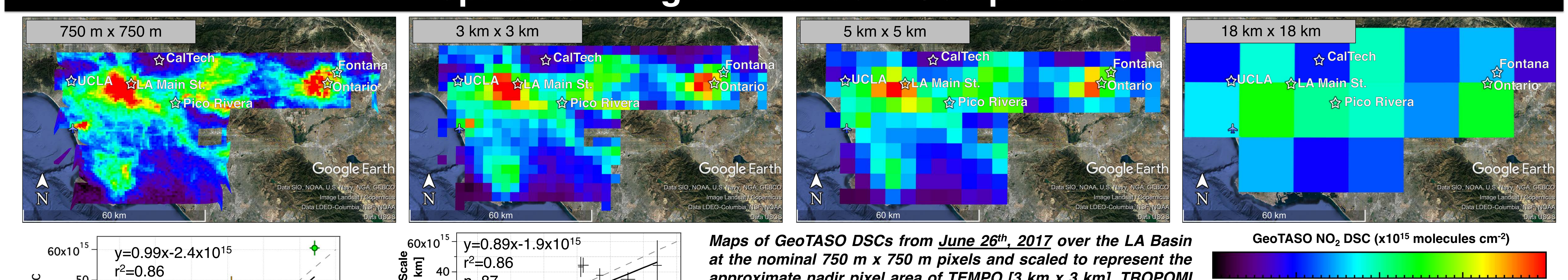
Coastal Mapping: 14:00-18:00 LT

June 1st, 2017 — June 2nd, 2017

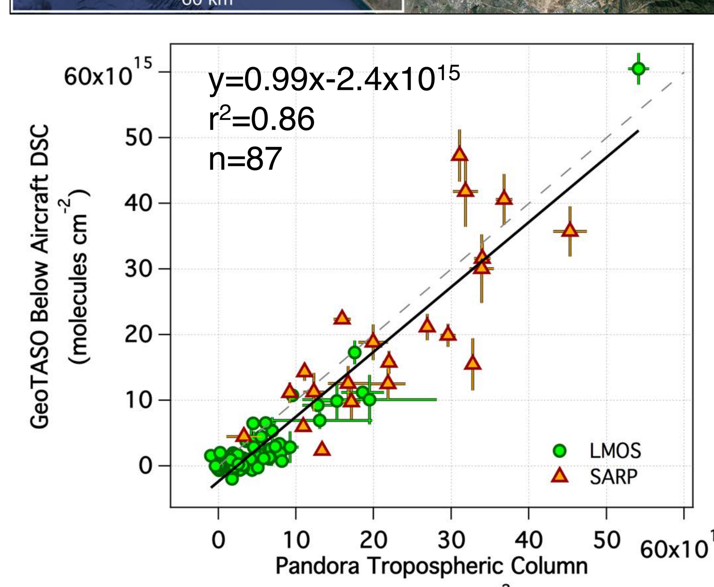


Maps of NO_2 DSCs along the western shore of Lake Michigan on June 1st (left) and June 2nd (right) between 14:00-18:00 LT. The boundary layer averaged wind vectors from the NAM-CONUS 3-km nest analysis for 15:00 LT are overlaid.

Spatial Scaling and Pandora Comparisons

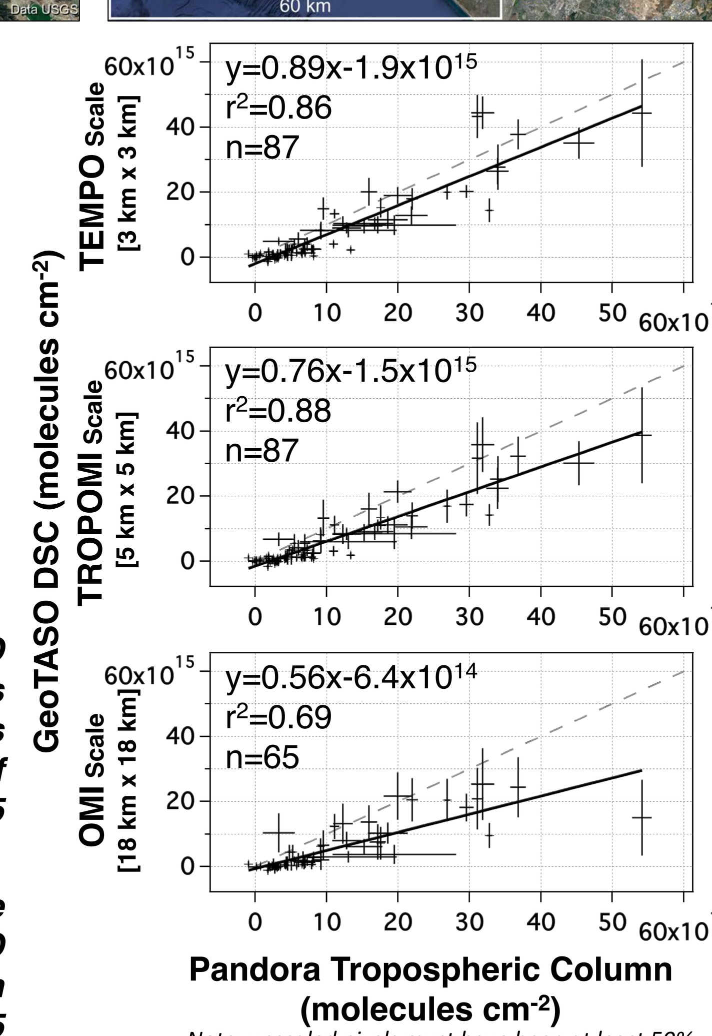


Maps of GeoTASO DSCs from June 26th, 2017 over the LA Basin at the nominal 750 m x 750 m pixels and scaled to represent the approximate nadir pixel area of TEMPO [3 km x 3 km], TROPOMI [5 km x 5 km], and OMI [18 km x 18 km] to demonstrate how spatial resolution influences resolved spatial features.



(Above) Scatter plots comparing GeoTASO DSCs to Pandora tropospheric slant columns during LMOS (green) and SARP (orange). Bars indicate the spatial variability (750 m radius) of GeoTASO and the temporal variability (±5 minutes) of Pandora at the time overpass.

(Right): Scatter plots indicating how the comparison to Pandora changes as GeoTASO is upscaled to the near-nadir areal resolution of TEMPO [3 km x 3 km], TROPOMI [5 km x 5 km], and OMI [18 km x 18 km].



Note: upscaled pixels must have been at least 50% sampled by GeoTASO for consideration

Looking Ahead…

Summer 2018 includes participating in the Long Island Sound Tropospheric Ozone Study (LISTOS), which is a collaborative effort with NASA, EPA, local/state air quality agencies, and local research institutions.

Fifteen flight days are planned in the New York City /Long Island Sound (LIS) region to map emissions and their transport over LIS and inland, including temporally coincident measurements with TROPOMI.

Future Validation Strategy: GeoTASO columns can be binned over the area of the footprint of space-based sensor retrievals. The airborne mappers provide information on the sub-pixel variability to help link the broader satellite footprint to the more local Pandora measurement.

Instrument References:

Nowlan, C. R., et al. (2016). Nitrogen dioxide observations from the Geostationary Trace gas and Aerosol Sensor Optimization (GeoTASO) airborne instrument: Retrieval algorithm and measurements during DISCOVER-AQ Texas 2013. doi:10.5194/amt-9-2647-2016.

Leitch, J. W., et al. (2014). The GeoTASO airborne spectrometer project. doi:10.1117/12.2063763.

Herman, J., et al. (2009). NO_2 column amounts from ground-based Pandora and MFDOAS spectrometers using the direct-sun DOAS technique: Intercomparisons and application to OMI validation. doi:10.1029/2009JD011848.

Data sources: GeoTASO data publically available after June 2018: https://www-air.larc.nasa.gov/missions/lmos/index.html
Pandora: data.pandonia.net

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