Advanced, high spatial resolution PACE OCI nitrogen dioxide (NO_2) product and potential applications

***Paper submitted to ERL

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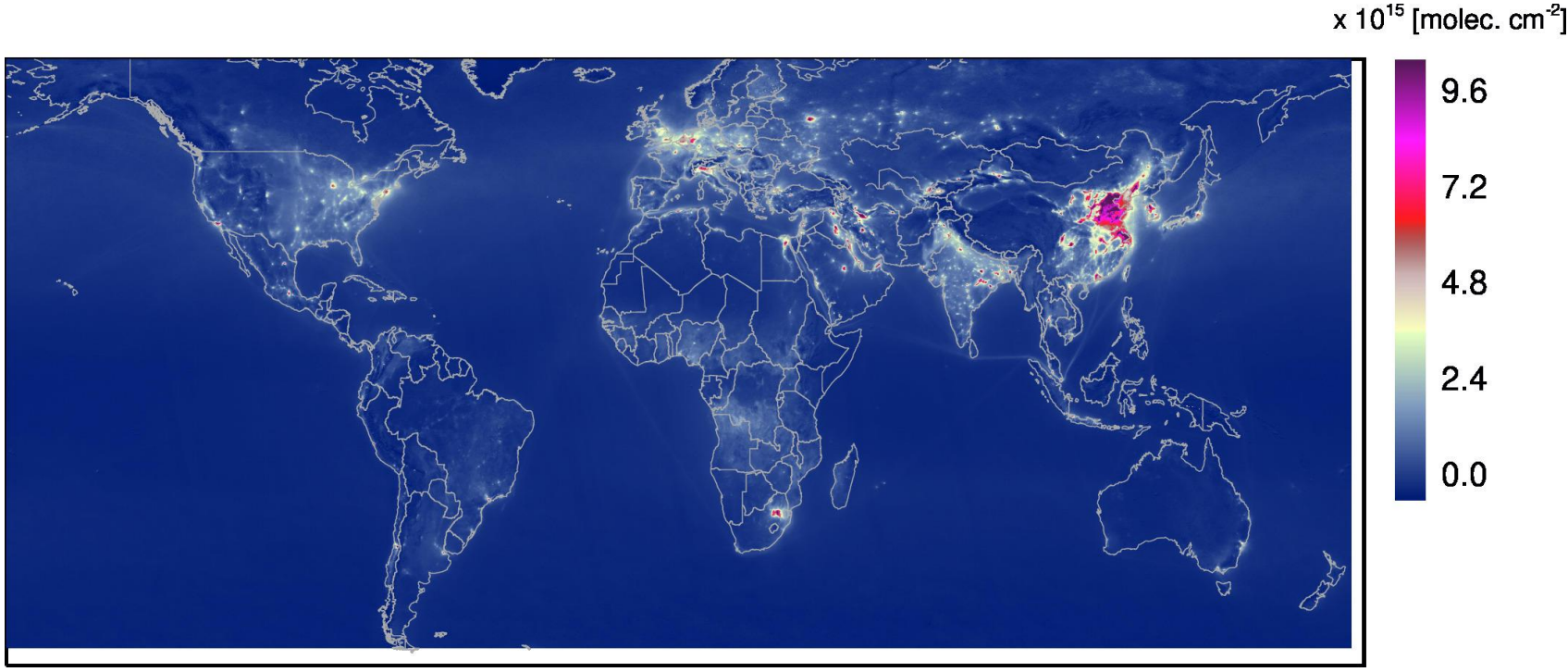
Motivation

- NO_2 sources are both natural (wildfires, soil, lightning) and anthropogenic (burning of fossil fuels, biomass burning)
- NO_2 has adverse health effects and contributes to the formation of aerosols and tropospheric ozone
- NO_2 impacts ocean color algorithms. Errors under high loading ($1x10^{16}$ mol cm^{-2}) of 10-20% in water leaving radiance (Ahmad et al., 2007).



2021 annual averaged TROPOMI troposphere NO_2 column (courtesy Lok Lamsal)

Can we retrieve NO_2 accurately with PACE OCI and if so, can it provide value-added data for the atmospheric chemistry community (for downscaling emissions, etc)?

Heritage Trace Gas (NO_2) Instruments

- Traditional trace gas satellite instruments (OMI, TROPOMI, TEMPO) have lower spatial resolution (at least 10x coarser) than PACE OCI, but higher spectral resolution
- Previous ocean color multi-spectral instruments such as MODIS and VIIRS have spectral resolution of 20nm+, too coarse for NO_2 retrievals

	Spatial Res.	Spectral Res.	Spectral Range	Orbit
OMI	13x24km^2	0.42-0.63nm	290-500nm	Polar
TROPOMI	3.5x5.5km^2	0.25-0.55nm	267-499nm 661-786nm 2.3-2.389um	Polar
TEMPO	2x4.7km^2	0.6nm	290-490nm 540-740nm	Geo
PACE OCI	1km^2	5nm	315-895nm	Polar

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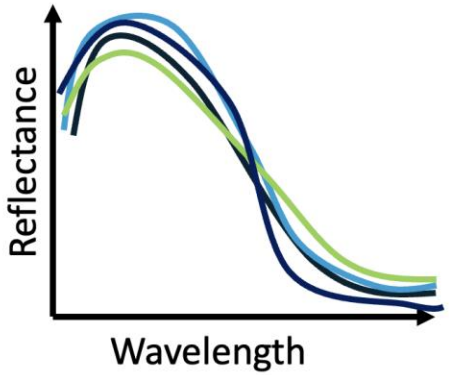
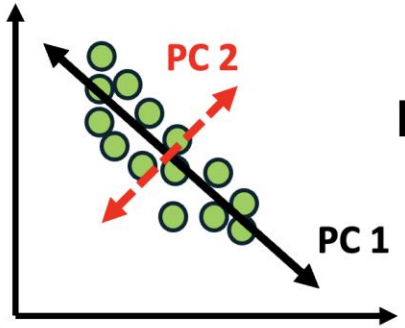
Basic approach

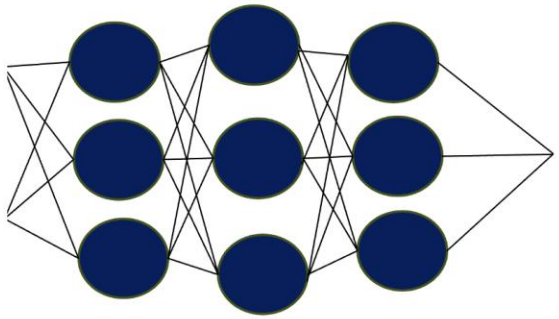
Measured Reflectances Decomposed into PCs





Neural Network Trained to Learn Relationships between PCs and Co-located NO_2

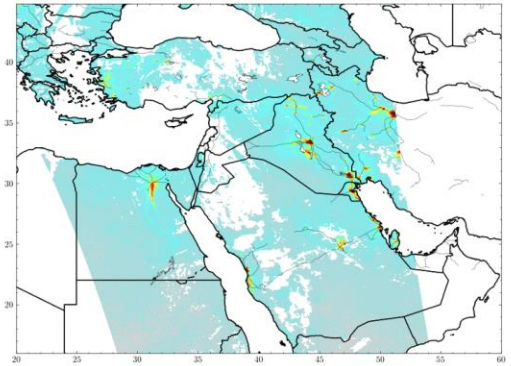
- Solar/View Angles
- Coefficients of PCs

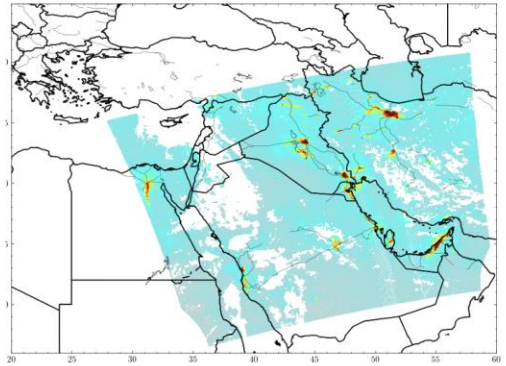


Optionally profile data can be used, but not currently used

TROPOMI NO_2 Co-located to PACE

PACE OCI 5km reflectances co-located with TROPOMI Total Vertical Column NO_2 retrievals binned to ~5km





Apply to 1km PACE OCI L1b data

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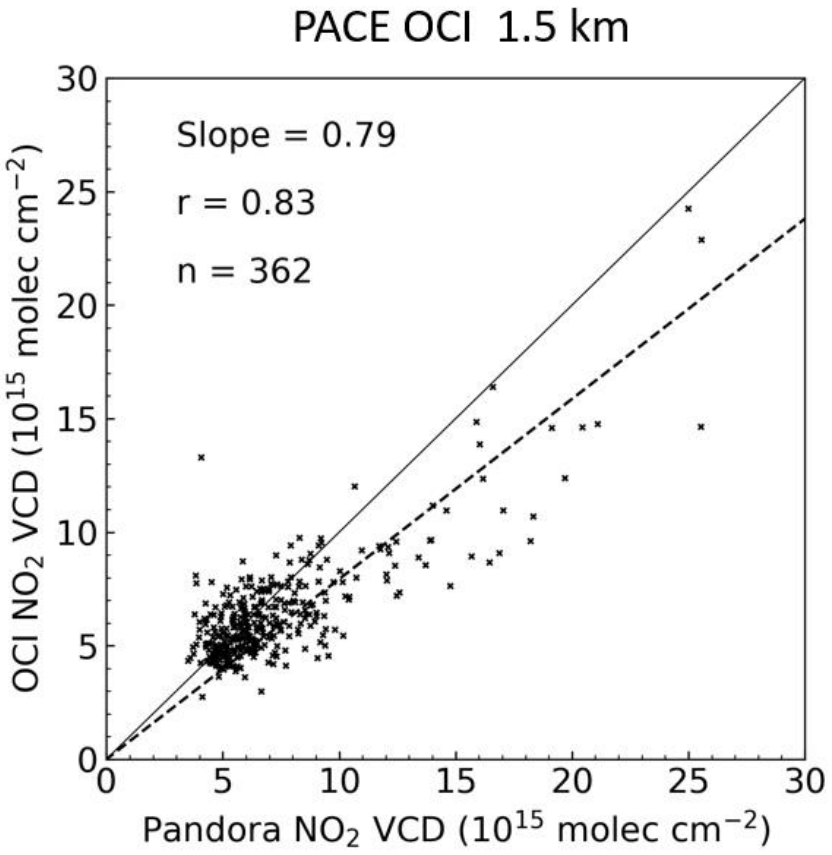
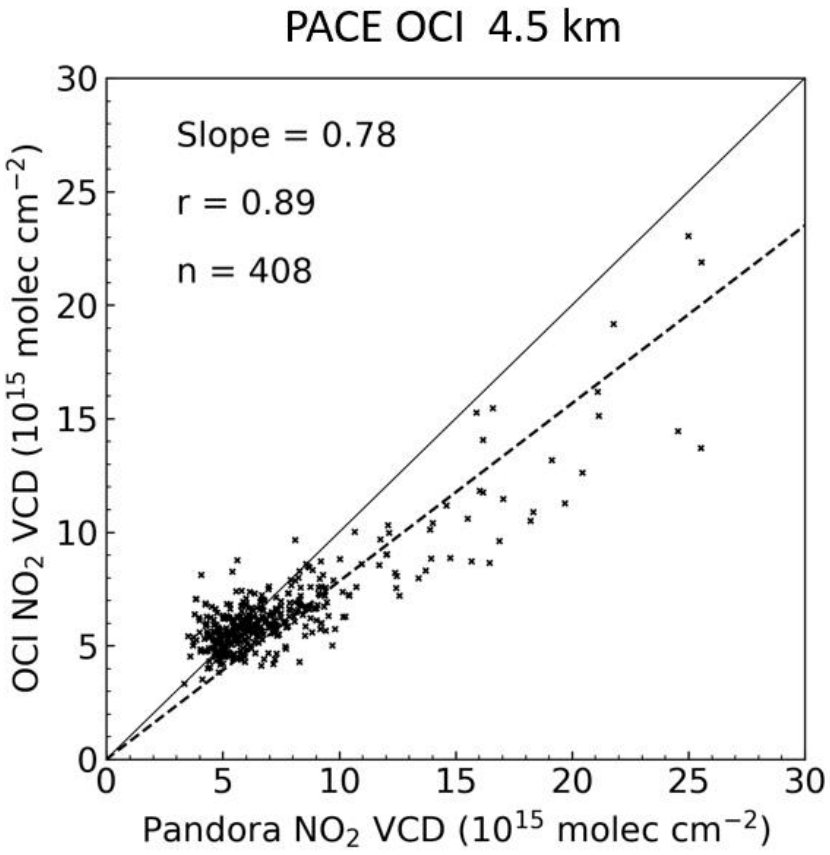
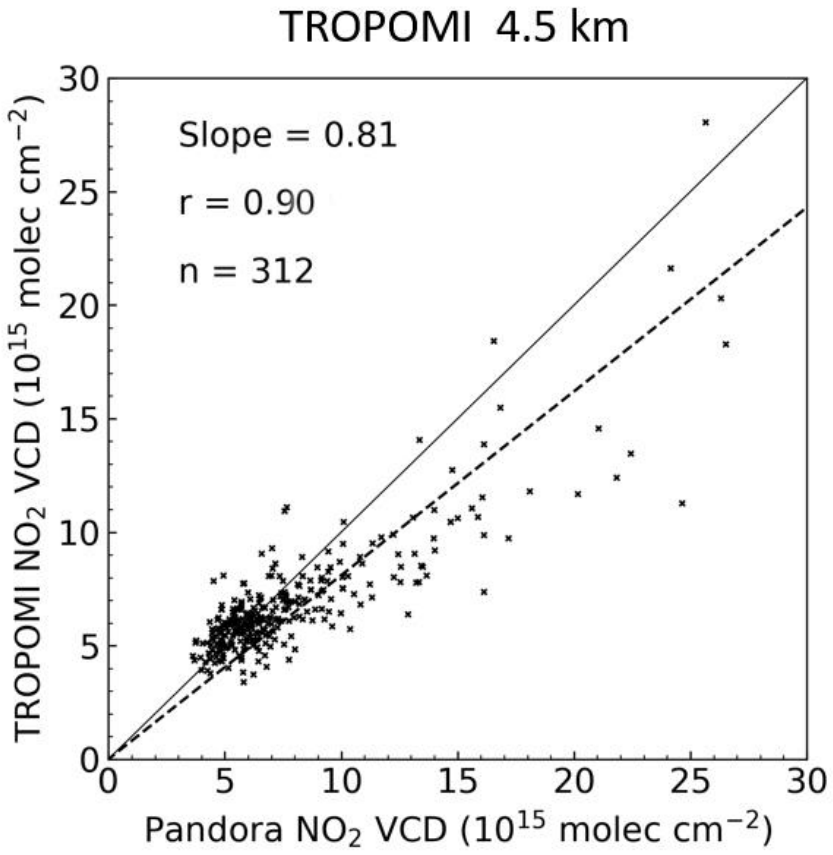
Comparison with Pandora NO_2







- Comparisons with Pandoras from U.S. sites shows similar results as the TROPOMI comparison (ML model will only do as well as the data it's trained on)

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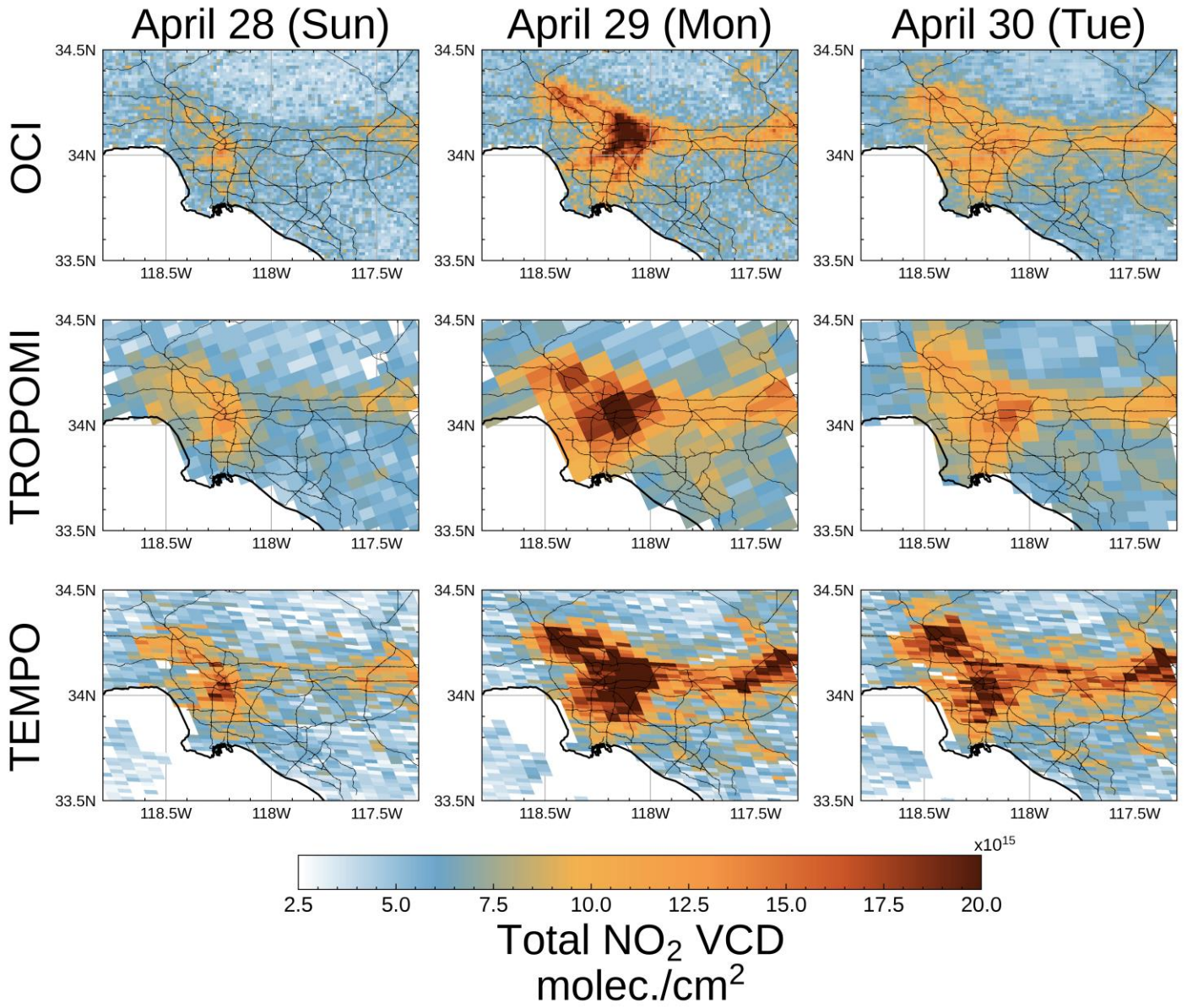
Provided by Eric Buscela

Weekend vs Weekday NO_2 in LA Metro

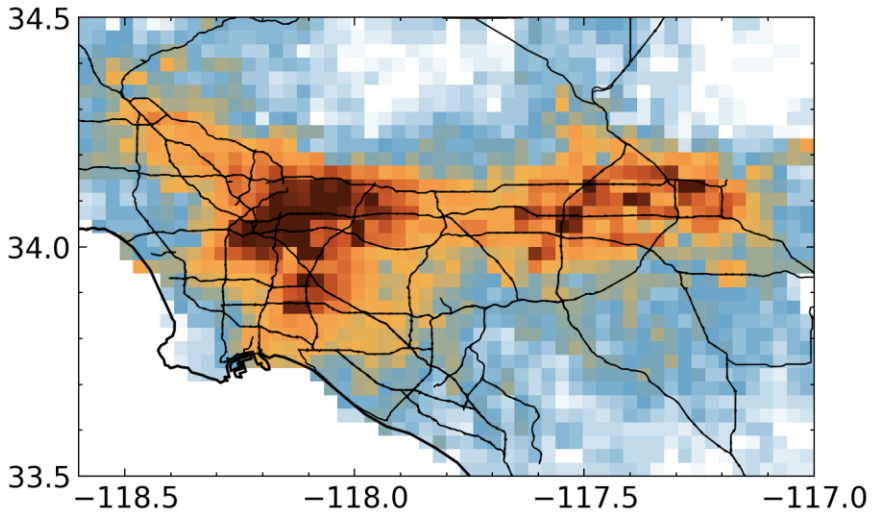
- Air quality in LA region is heavily dominated by vehicular traffic leading to a significant weekend/weekday effect as seen in NO_2 retrievals on right
- Unlike TROPOMI and TEMPO, with PACE OCI spatial resolution we can begin to see individual highways, particularly in heavy vehicular traffic such as Monday April 29



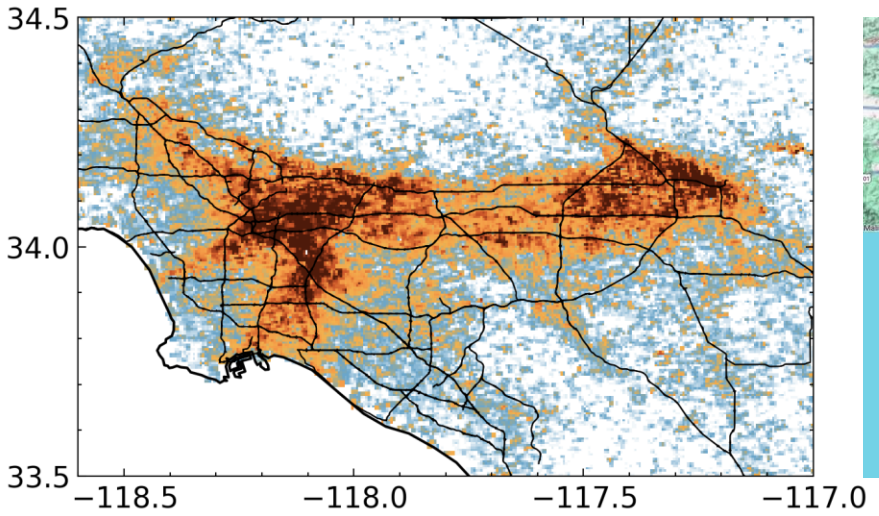
Multi-Day Average for Downscaling

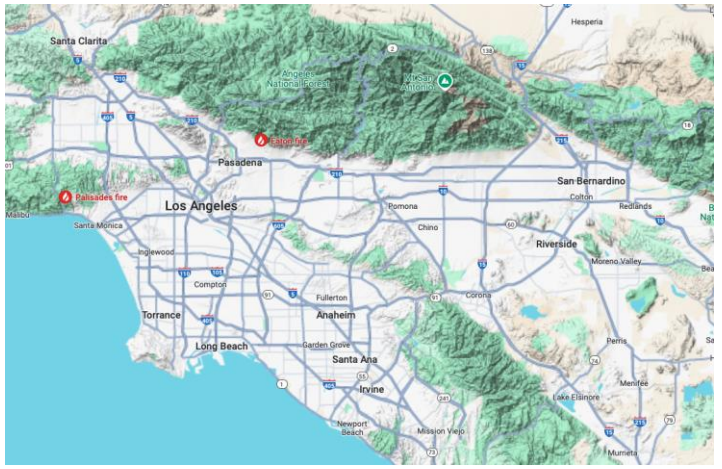
Thu Sep 26-28

TROPOMI ~3km Resolution

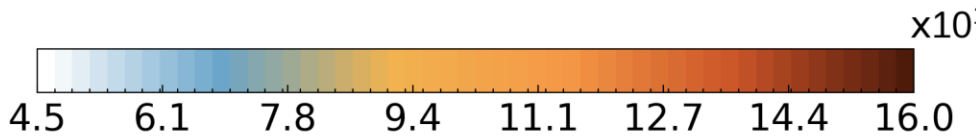


PACE OCI ~500m Resolution





Credit: Google Maps

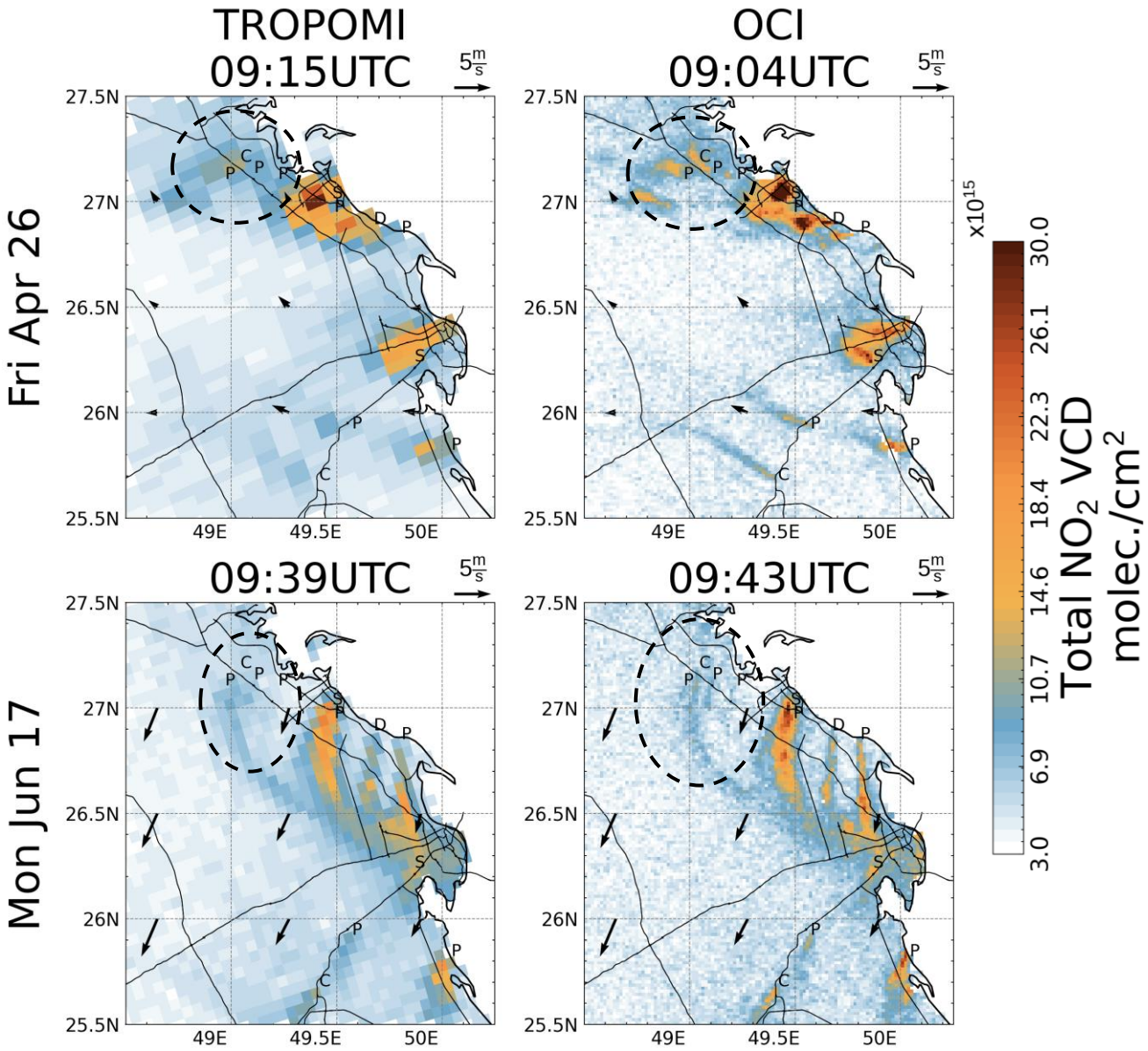


Total NO_2 VCD
molec./cm^2

- High resolution measurements from PACE allow for upscaling of NO_2 within a few days to spatial resolution < 500m
- Example above from LA shows many localized features such as mountain ranges and highways not as clear in TROPOMI

NO_2 in Eastern Saudi Arabia

- NO_2 in eastern Saudia Arabia is elevated due to many power plants and manufacturing plants in the region
  - P: Power Plant
  - C: Cement Factory
  - D: Desalination Plant
  - S: Steel Factory
- PACE OCI shows better defined NO_2 plumes such as to the north where there are two power plants and a cement factory (dashed circle)



Potential Applications and Future Work

Applications

- Improved spatially resolved emissions estimates
- Better resolved exposure estimates
- Improved ocean color retrievals
- Improved chemistry-transport modeling
- Spatial downscaling of TEMPO hourly measurements (complementary)

Future Work

- Finetuning the training and integration into PACE processing system
- More validation with aircraft as well as ground-based

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Applying Approach to Retrieve Ozone from PACE
May 21, 2024