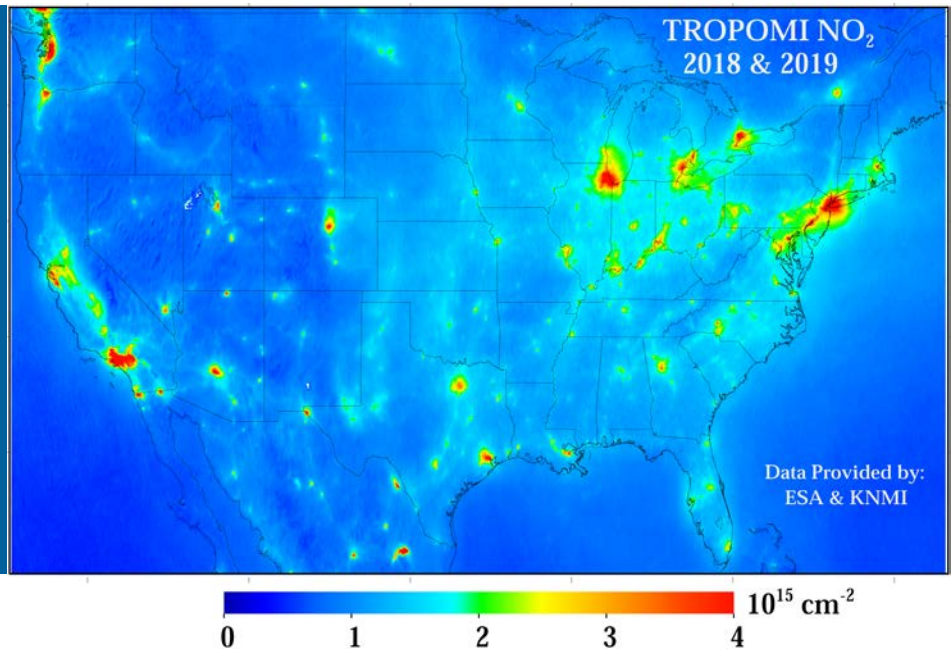
Applications of Satellite NO_2 Data



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Washington, DC

Air & Waste Management:
Regional Air Quality Symposium
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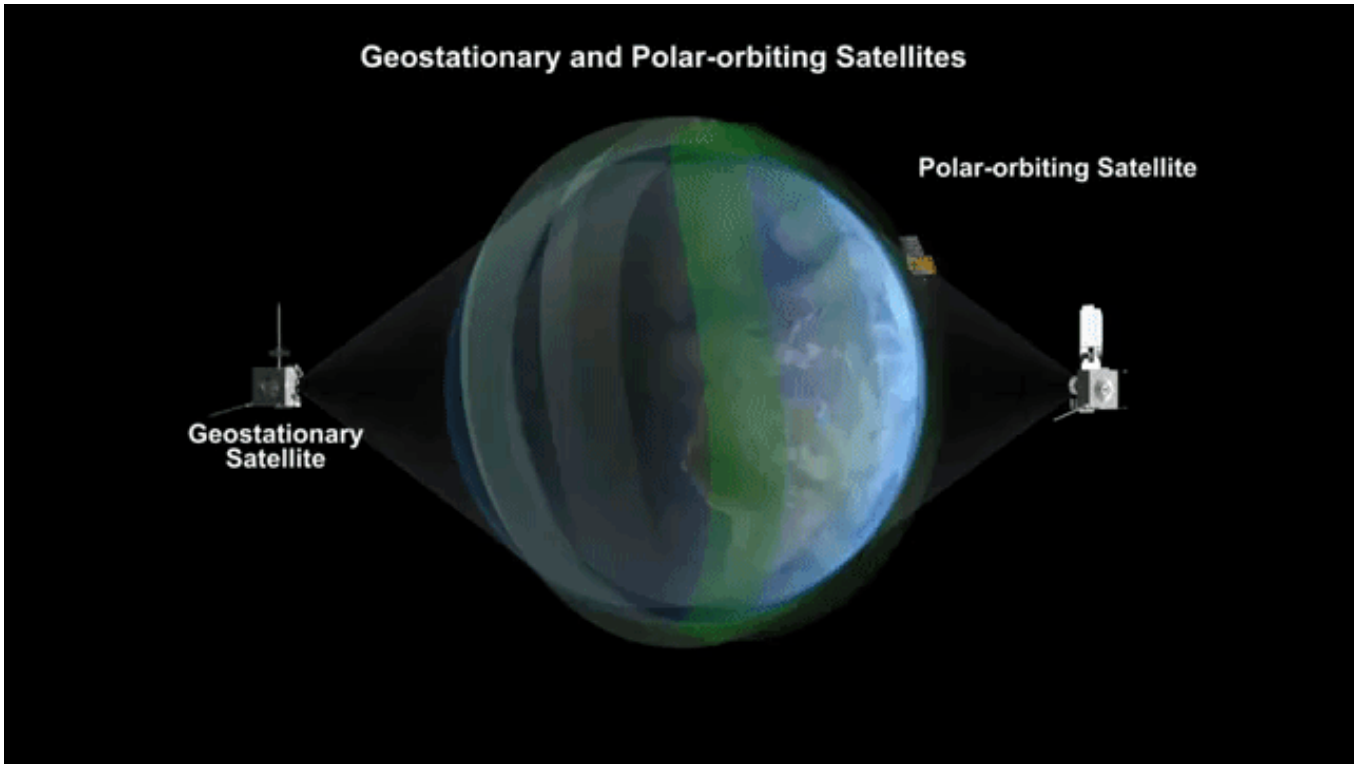
POLAR-ORBITING SATELLITES VS. GEOSTATIONARY SATELLITES



Animation from UCAR COMET

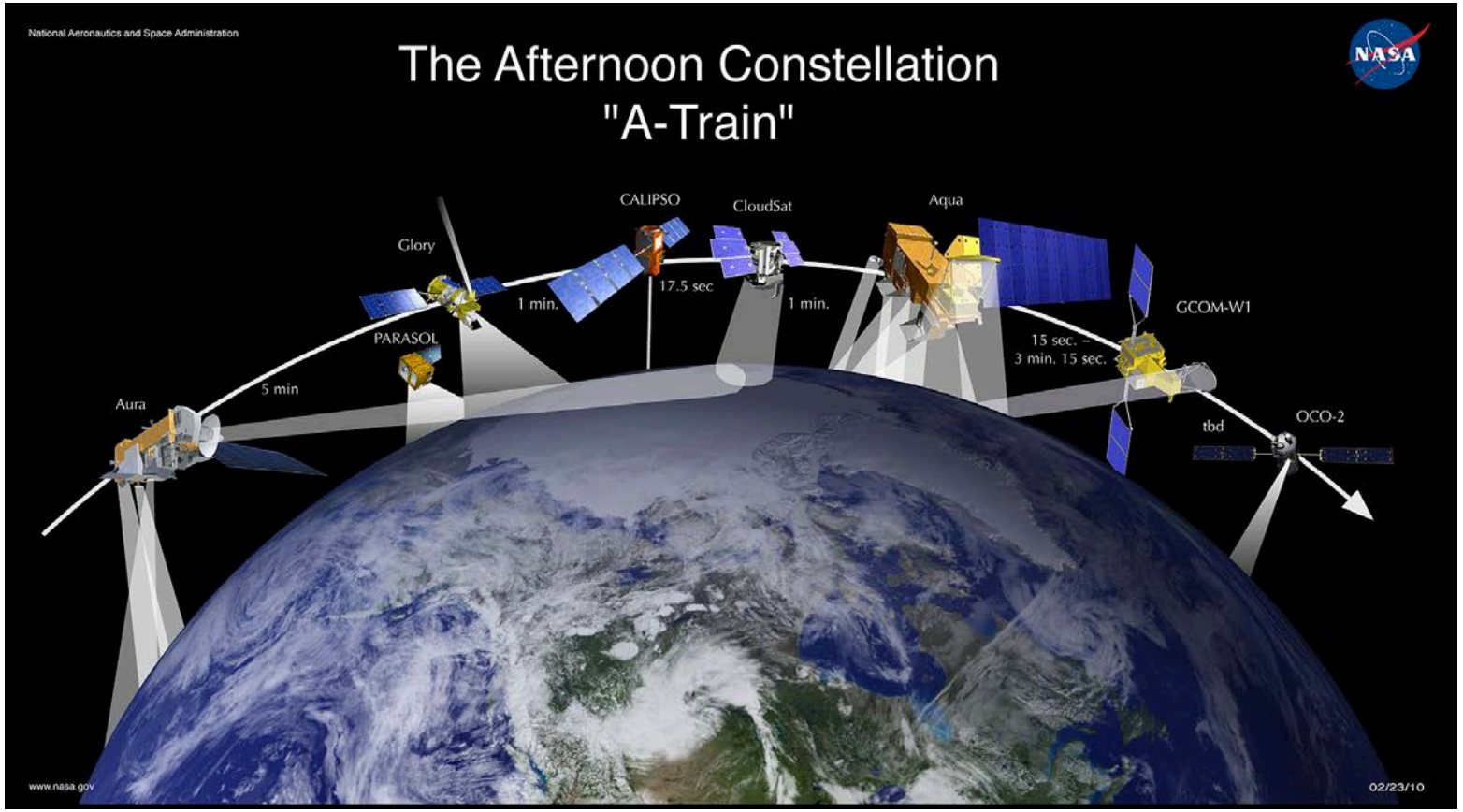
Polar-orbiting, or low-earth-orbiting, satellites have global coverage *but* only one snapshot (sometimes fewer) per day.

Geostationary satellites have partial global coverage, but many snapshots (100x, 1000x) per day. Coming in 2022!

← All current air quality monitoring satellites are these.

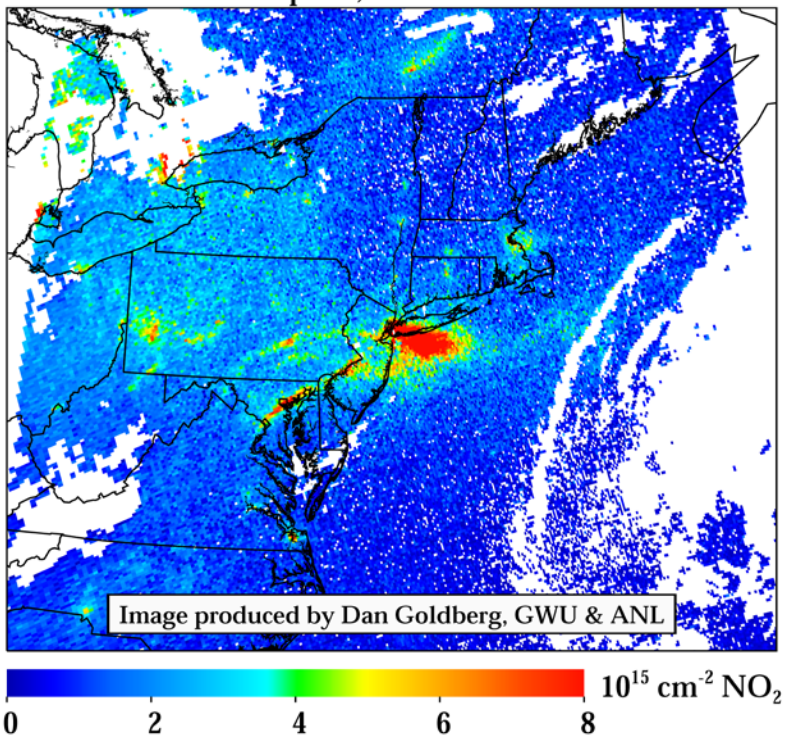
NAMES OF THE SATELLITES

- OMI = Ozone Monitoring Instrument (launched Summer 2004)
- TROPOMI = Tropospheric Monitoring Instrument (launched Fall 2017)

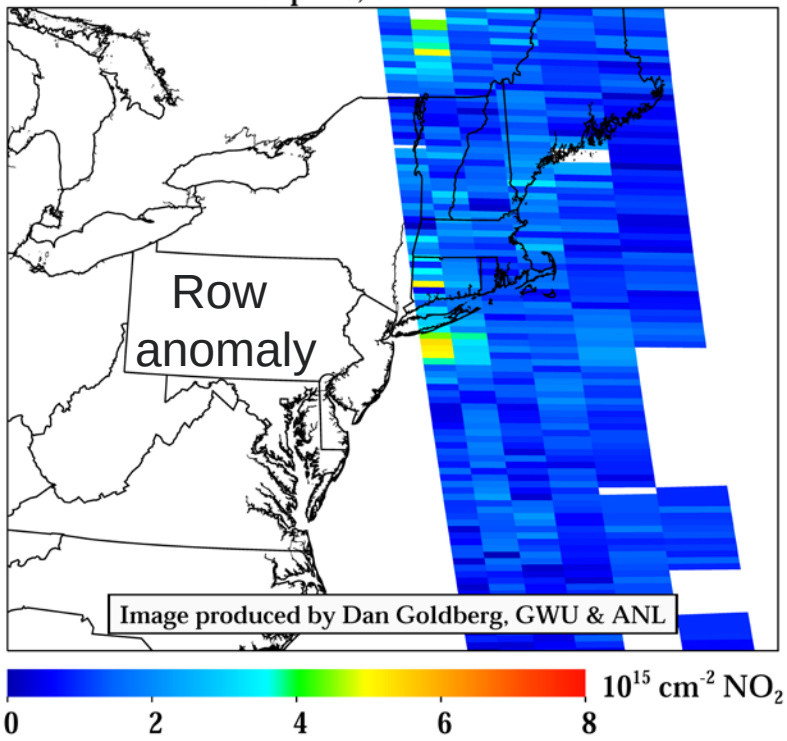


SINGLE DAY OF NO_2 FROM TROPOMI & OMI

NRT Tropomi NO_2 (Source: https://scihub.copernicus.eu/)
Sept 20, 2019 17:43Z

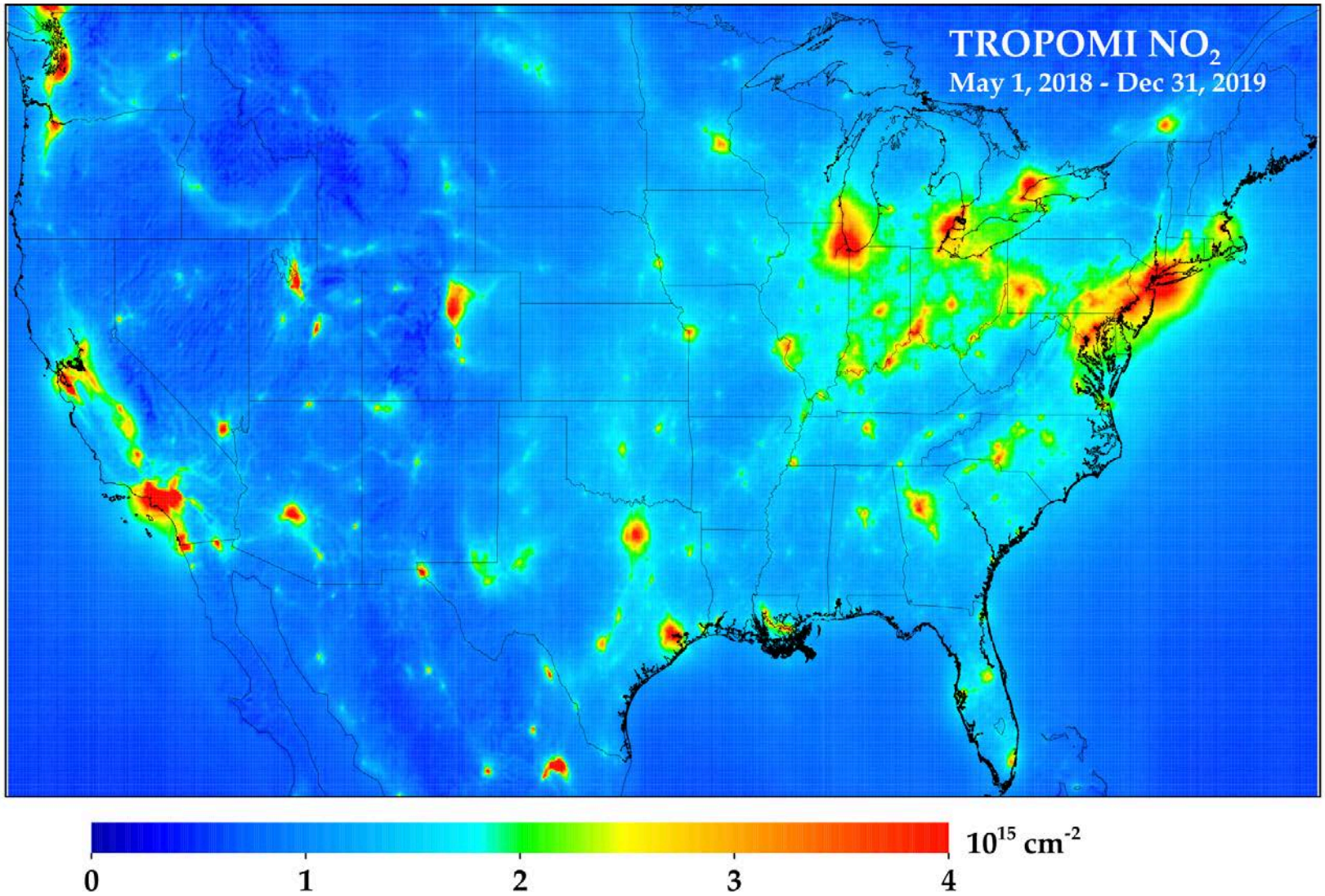


OMI NO_2 (Source: https://earthdata.nasa.gov/)
Sept 20, 2019 17:47Z



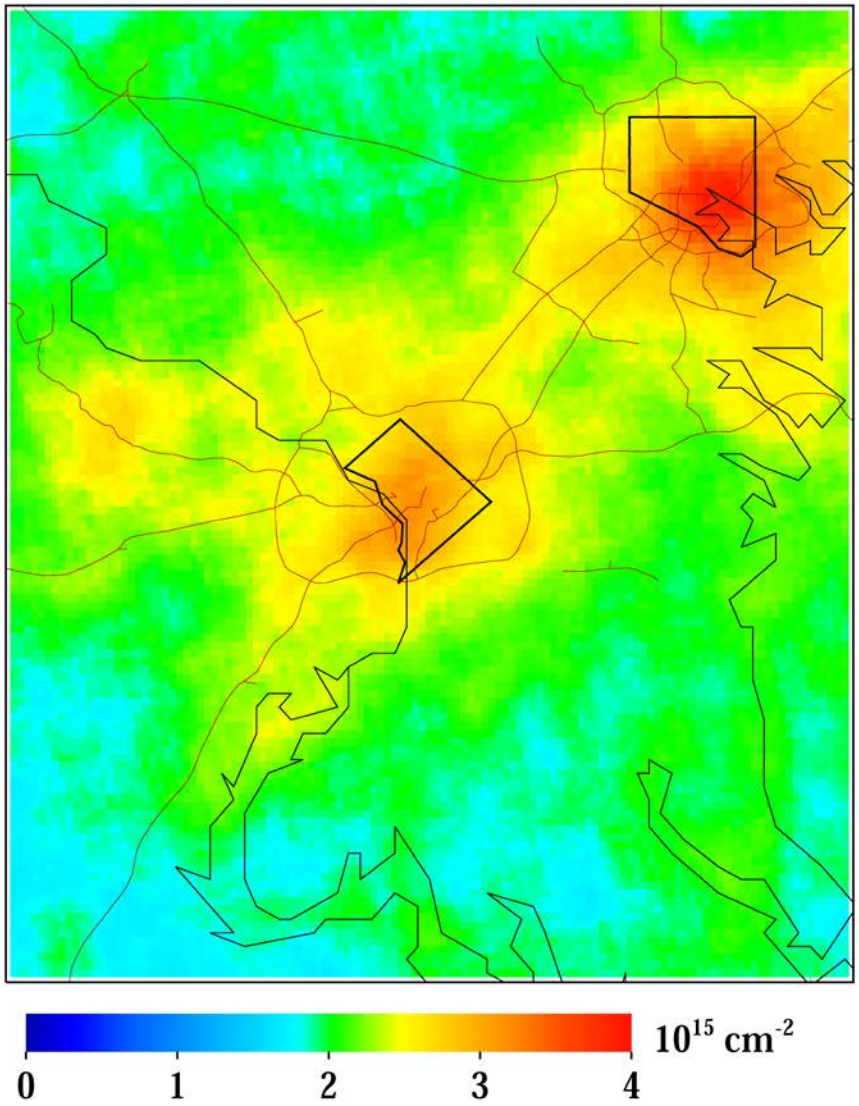
Units are molecules per cm^2; Red is high concentrations, Blue is low concentrations

ENTIRE RECORD OF TROPOMI NO_2 OVER THE US



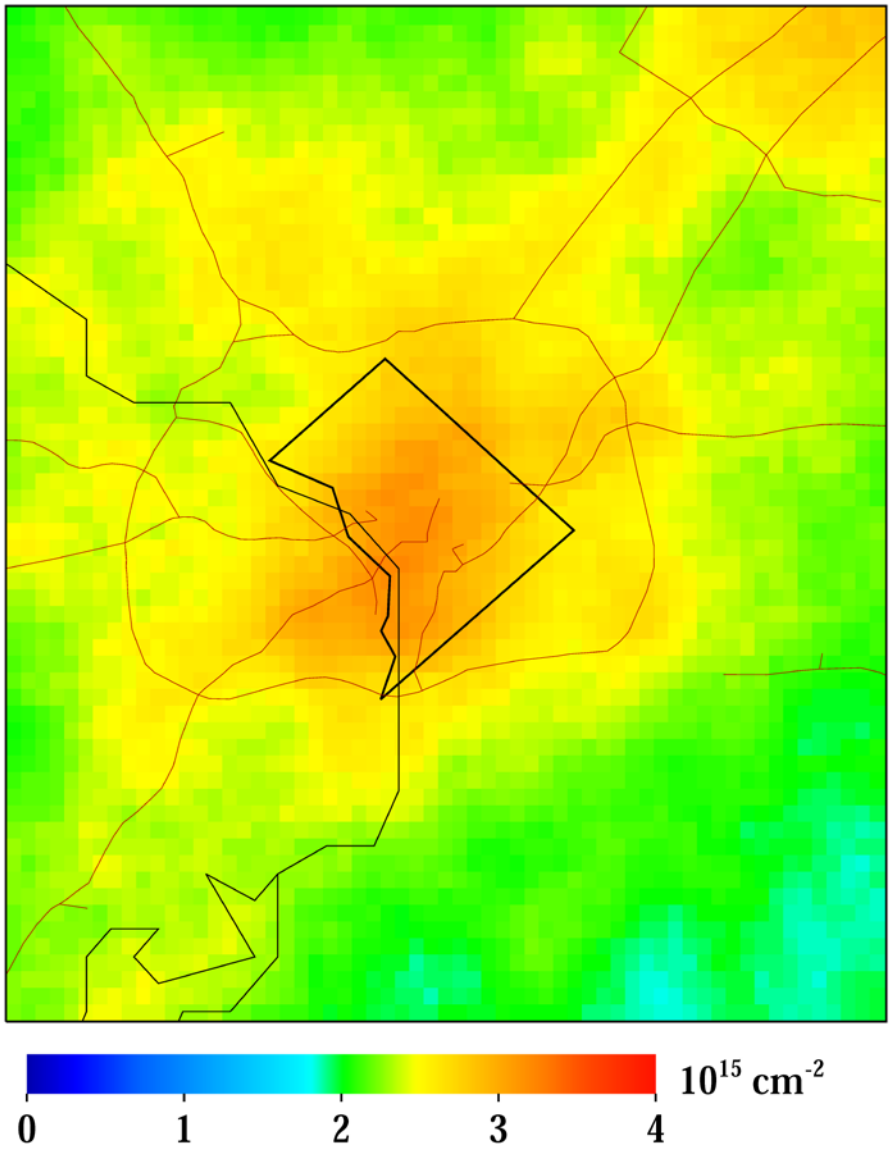
Units are molecules per cm^2; Red is high concentrations, Blue is low concentrations

TROPOMI NO_2 AVG FOR BALTIMORE & DC (MAY – SEPT ONLY)



Highest value is in SE Federal Hill, Baltimore, MD

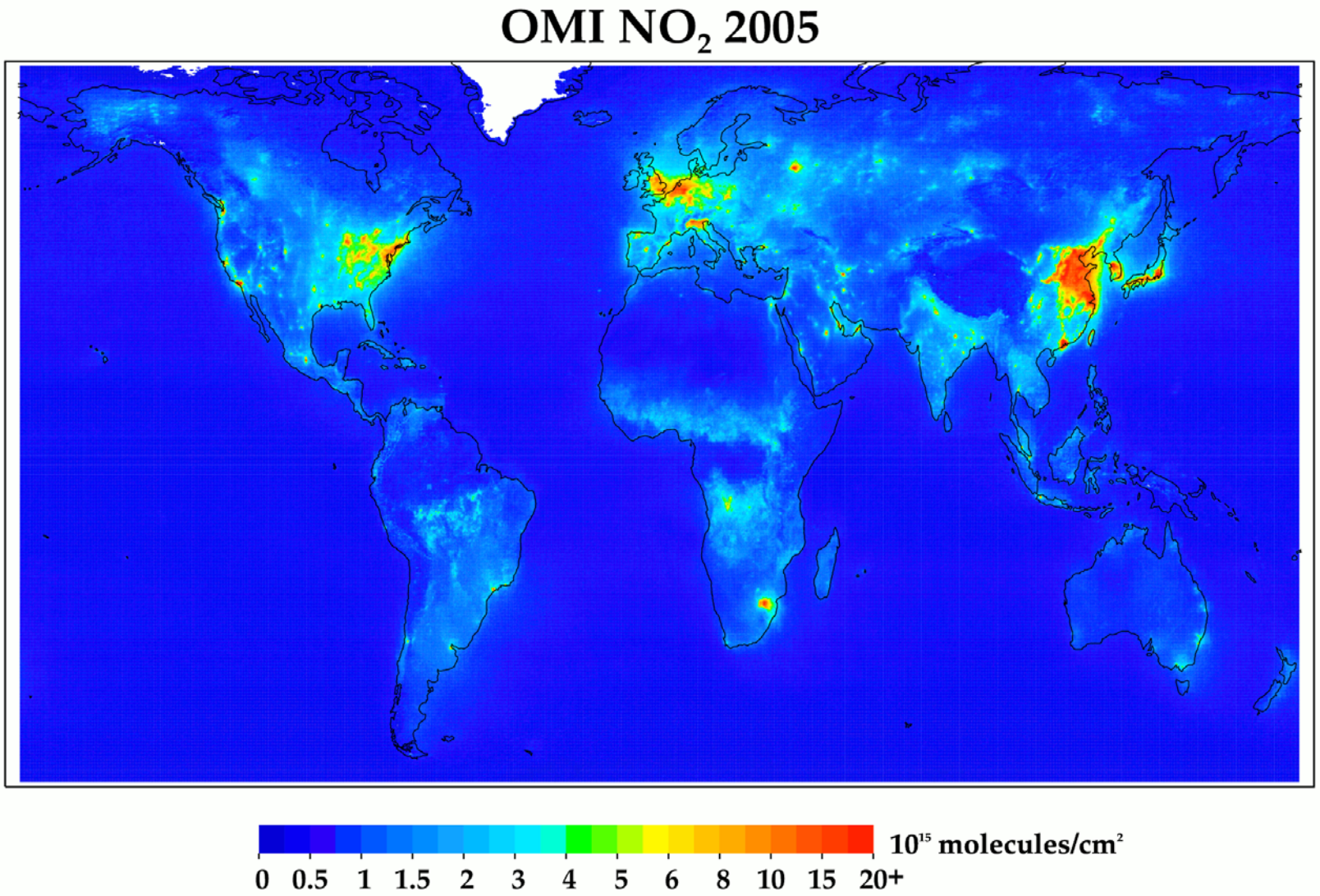
TROPOMI NO_2 AVG FOR DC (MAY – SEPT ONLY)



Highest value is at East Potomac Golf Course (downwind of Reagan)

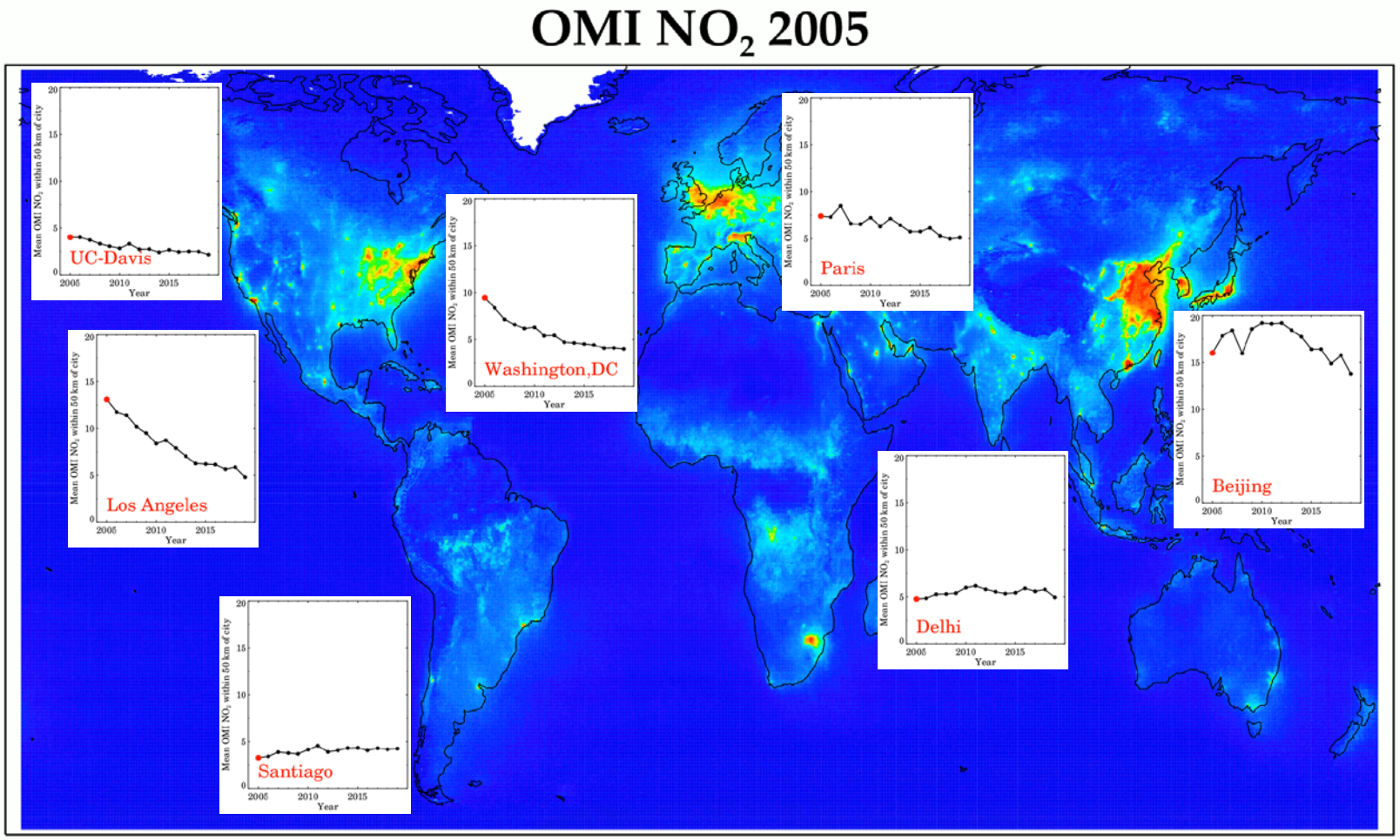
WHAT CAN WE DO WITH SATELLITE DATA?

1. Investigate trends of NO_2 and its emissions sources



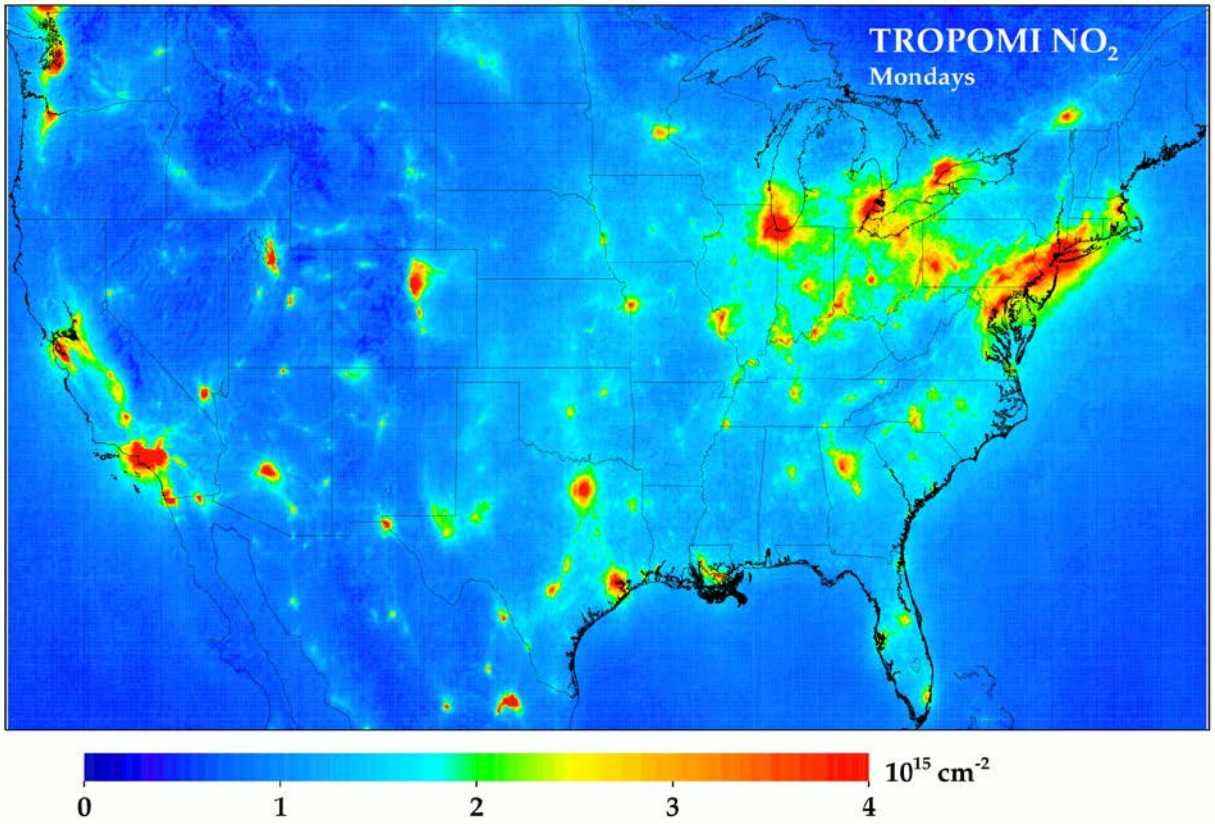
WHAT CAN WE DO WITH SATELLITE DATA?

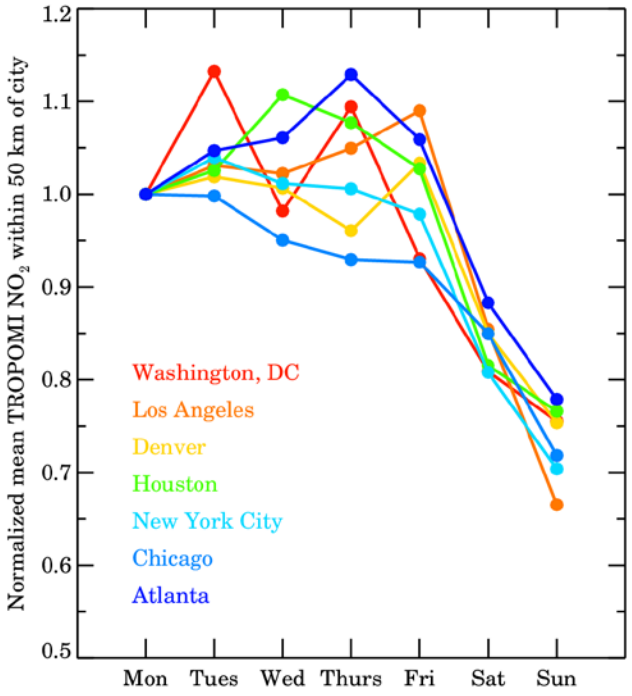
1. Investigate trends of NO_2 and its emissions sources



WHAT CAN WE DO WITH SATELLITE DATA?

2. Investigate anthropogenic and "natural" cycles of NO_2

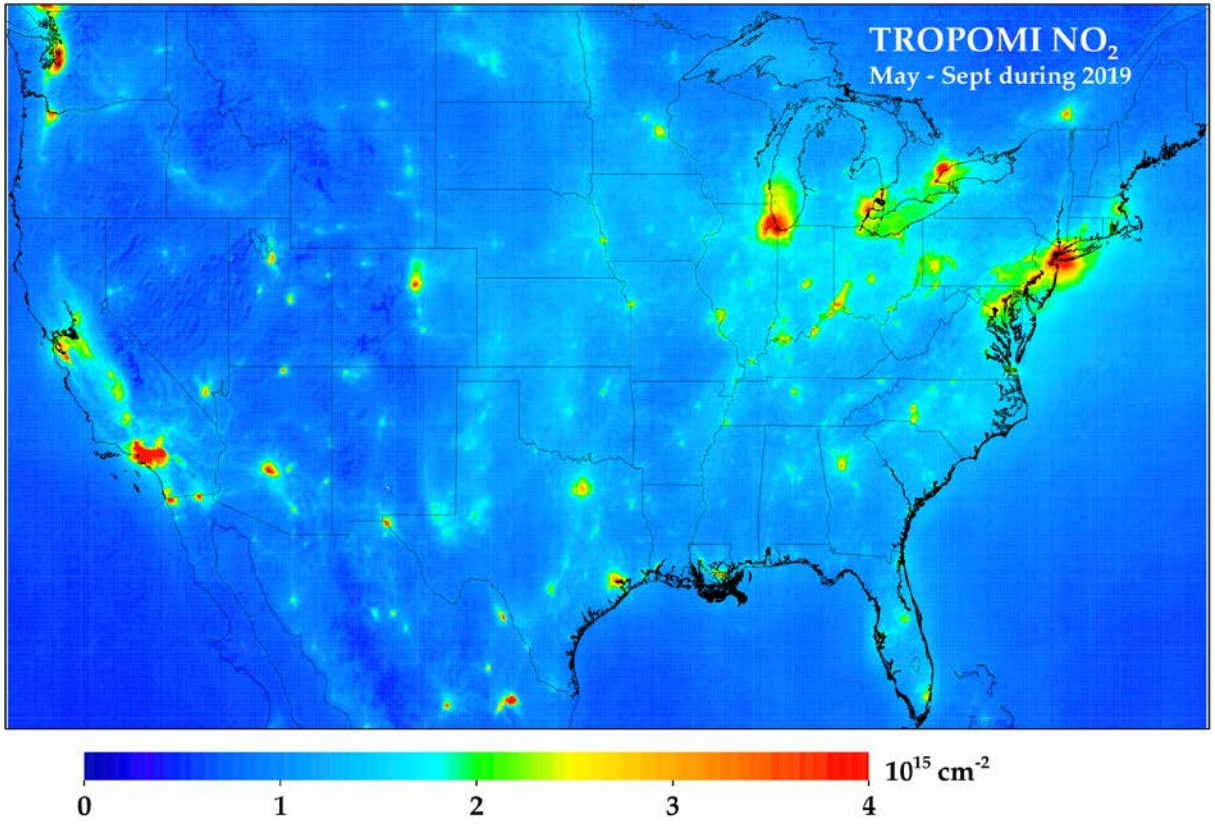


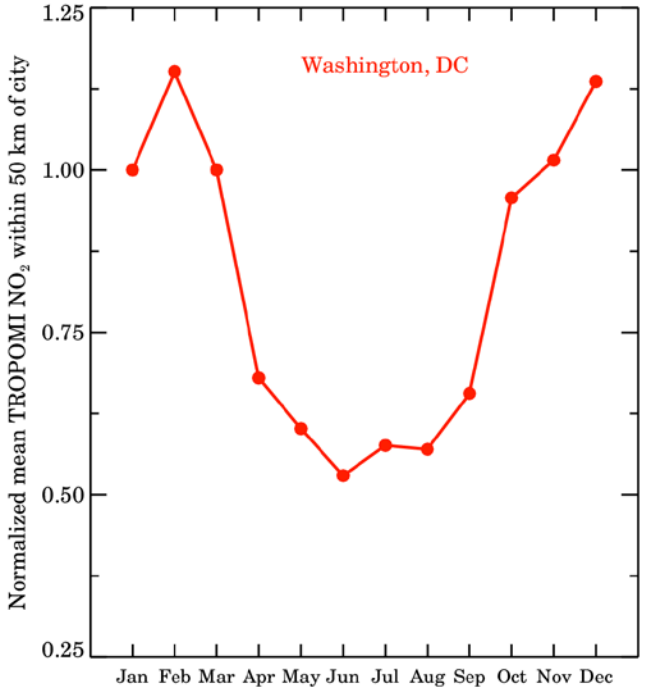


- NO_2 highest on weekdays; lower on Saturdays; lowest on Sundays
- Some interesting unexpected city-specific trends

WHAT CAN WE DO WITH SATELLITE DATA?

2. Investigate anthropogenic and "natural" cycles of NO_2

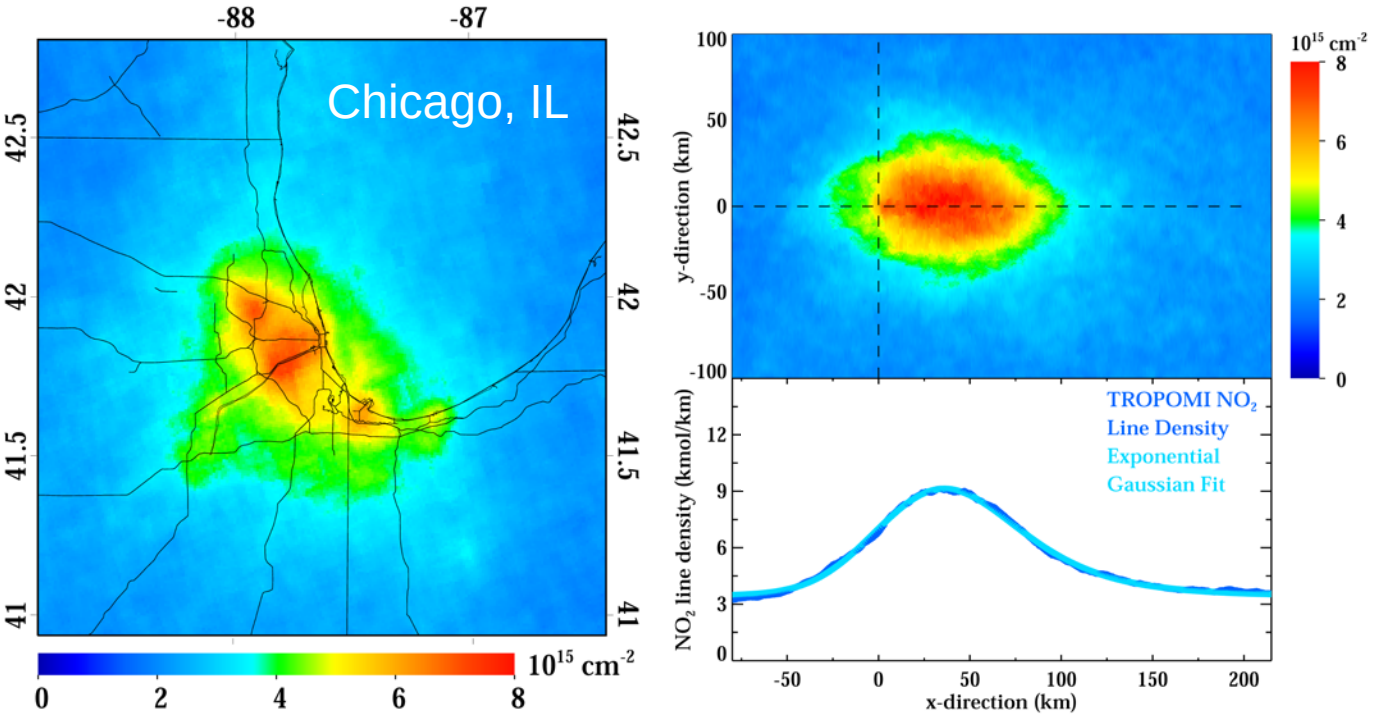




- NO_2 larger during winter (longer NO_2 lifetime) even though emissions are likely larger during summer
- NO_2 concentrations ≠ NO_x emissions
- In many cases, NO_2 concentrations ~ NO_x emissions

WHAT CAN WE DO WITH SATELLITE DATA?

3. Derive NO_x emissions rates (when combined with wind data)



NO_x emissions as derived from the satellite data: **19 ± 5 Mg/hr**

For context, EPA reports NO_x emissions to be: **~18 Mg/hr**

Goldberg et al., 2019a

Advantages of satellite-based "top-down" estimates:

- Completely independent of EPA "bottom-up" estimates
- Can provide timely estimates before EPA estimates are released

Disadvantages:

- Satellite estimates are aggregated across an entire urban area
- If there are discrepancies, it's difficult to ascertain which source is responsible)

WHAT CAN WE DO WITH SATELLITE DATA?

3. Derive NO_x emissions rates (when combined with wind data)

Location	Satellite-derived NOx emissions rate	Stack-measured NOx emissions rate
Four Corners Power Plant Complex, NM	1.04 ± 0.29 Mg/hr	1.18 Mg/hr
Colstrip Power Plant, MT	1.17 ± 0.31 Mg/hr	1.21 Mg/hr

Location	Satellite-derived NOx emissions rate	Gov't-reported NOx emissions rate
Chicago, IL	19 ± 5 Mg/hr	18 Mg/hr
New York City, NY	18 ± 5 Mg/hr	22 Mg/hr
Toronto, ON	14 ± 5 Mg/hr	11 Mg/hr

Goldberg et al., 2019a

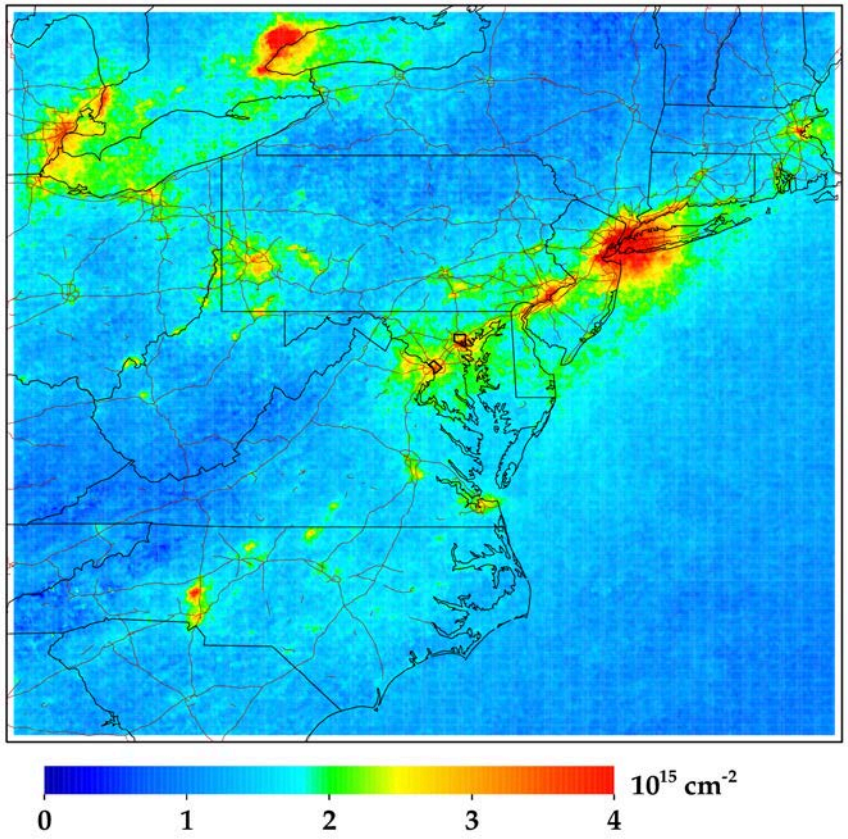
Location	Satellite-derived NOx emissions rate	Gov't-reported NOx emissions rate
Seoul, Korea	55 ± 23 Mg/hr	26 Mg/hr

Goldberg et al., 2019b

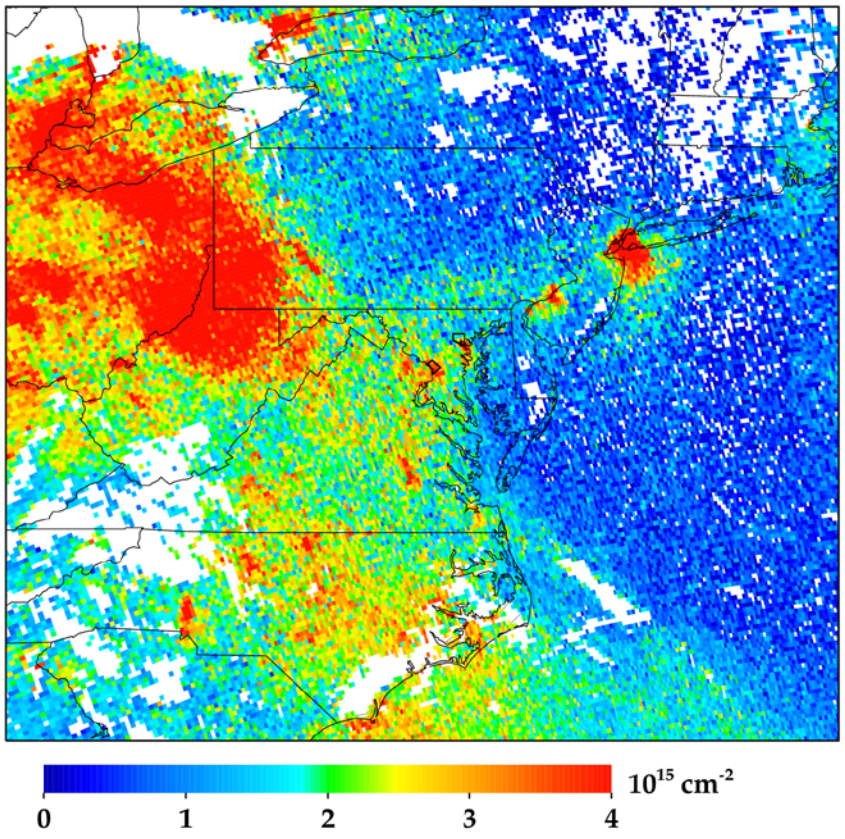
WHAT CAN WE DO WITH SATELLITE DATA?

3. Use it as a tool in air quality forecasting

JULY 2019 AVG



MONDAY
JULY 1, 2019 ONLY

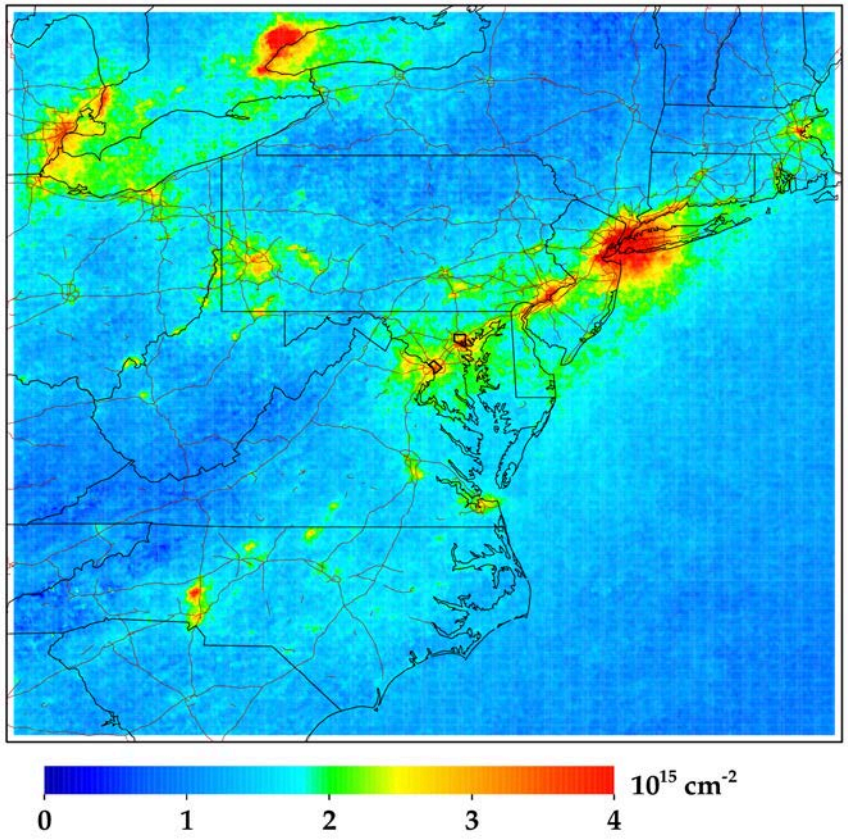


Column NO_2 is 2 – 5 times larger than “average” during the worst ozone AQ days!

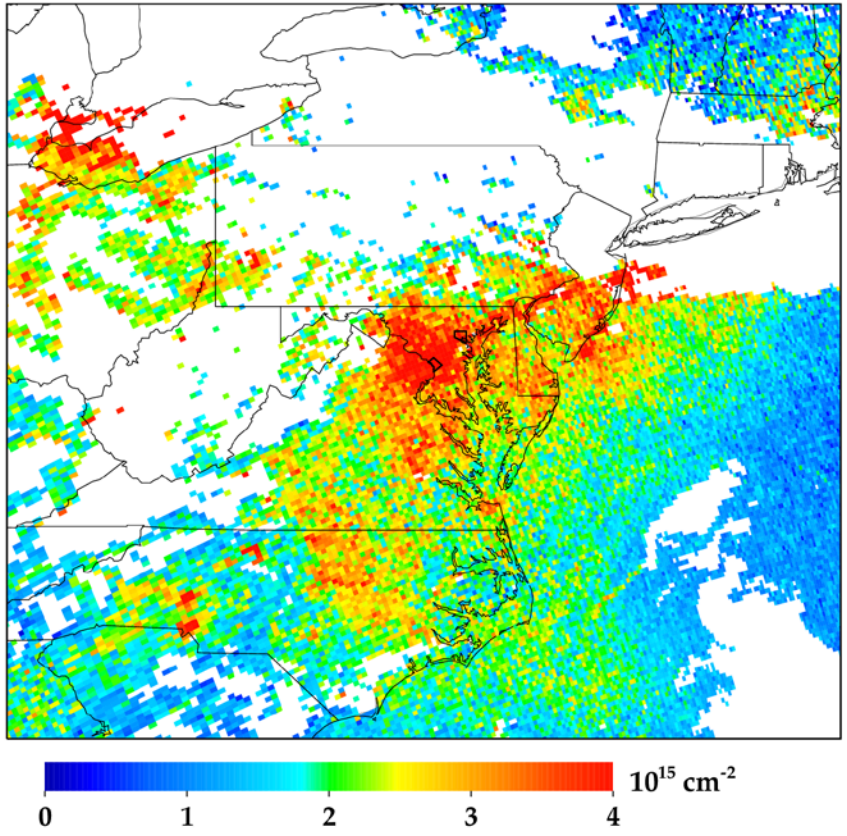
WHAT CAN WE DO WITH SATELLITE DATA?

3. Use it as a tool in air quality forecasting

JULY 2019 AVG



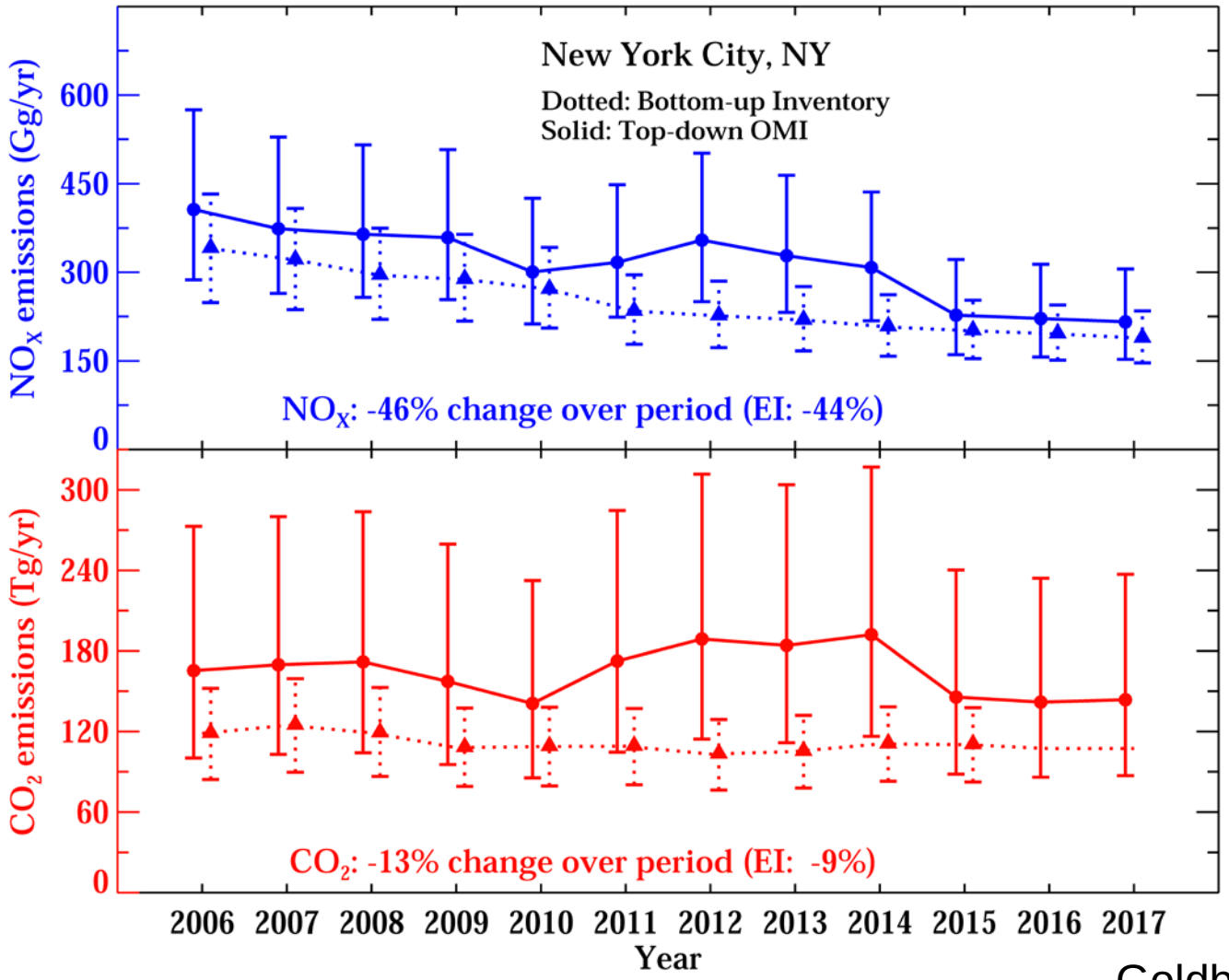
TUESDAY
JULY 2, 2019 ONLY



Column NO_2 is 2 – 5 times larger than “average” during the worst ozone AQ days!

WHAT CAN WE DO WITH SATELLITE DATA?

5. Infer CO_2 emission rates (NO_2 is co-emitted with CO_2)

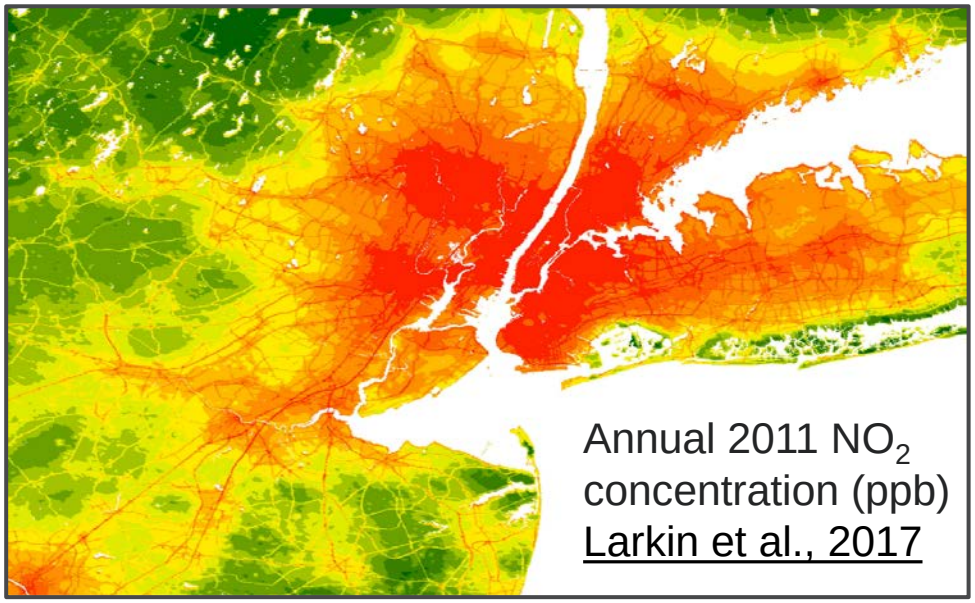


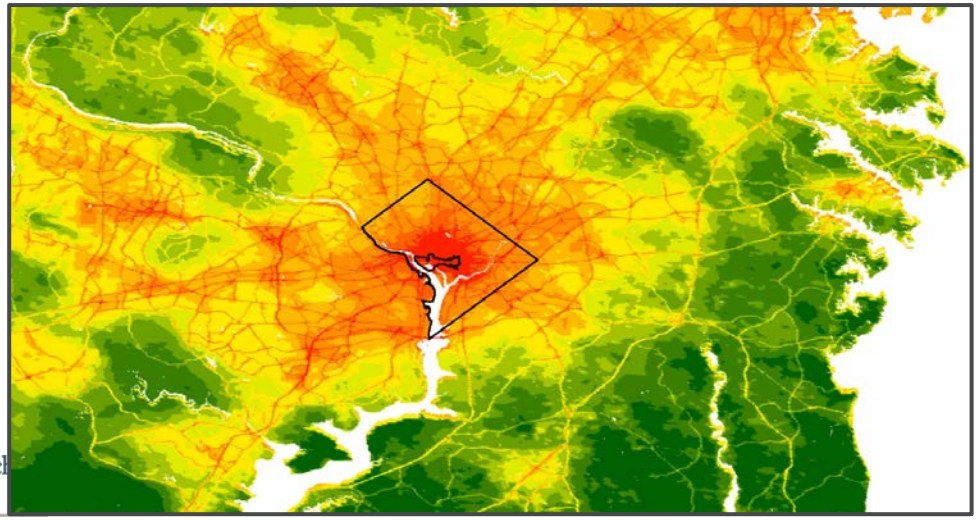
Use NO_X-to-CO_2 ratio as reported by the state to convert to fossil-fuel CO_2 emissions

Goldberg et al., 2019c

WHAT CAN WE DO WITH SATELLITE DATA?

6. Use as an input to estimate surface-level concentrations





HAQAST

HEI
HEALTH EFFECTS INSTITUTE

COMING SOON: TEMPO & GEMS

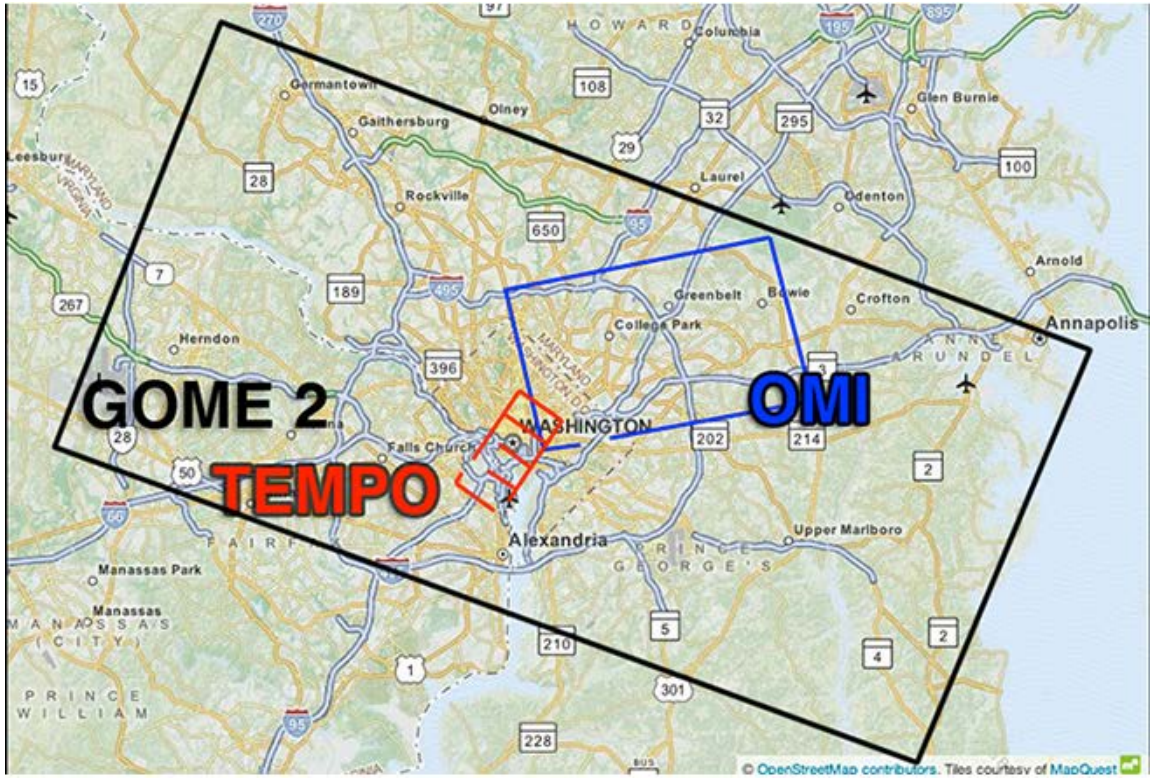


Image: TEMPO Science Team

Characteristics:

- Geostationary orbit
  - TEMPO: North America
  - GEMS: East Asia
- Hourly resolution that can show diurnal variability of emissions!
- Spatial resolution:
  - TEMPO: 2 km x 4.5 km
  - GEMS: 7 km x 8 km

CONCLUSIONS

- Satellite data can be useful in many different ways. Some examples discussed:

1. To estimate trends of pollution anywhere across the globe
2. Investigate seasonal, monthly, and weekly cycles of pollution
3. To derive emissions rates from cities and power plants without the use of a global model simulation
4. To help forecast air quality on a day-to-day basis
5. To account for GHG emissions, since NOx is co-emitted with CO_2
6. To use as an input for estimation of surface-level concentrations

LET'S CONNECT ON TWITTER!
@DGOLDBERGAQ

OR EMAIL:
DGOLDBERG@GWU.EDU

THANK YOU!