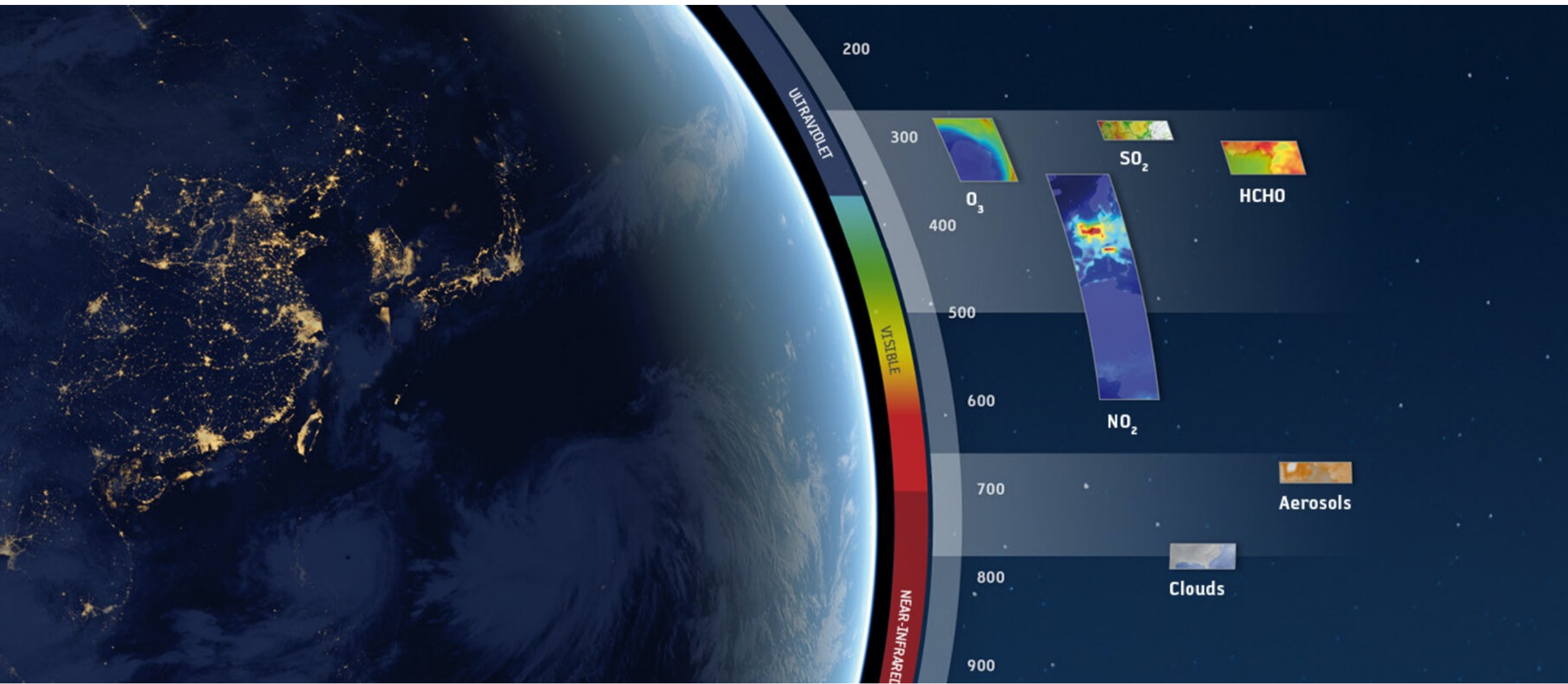
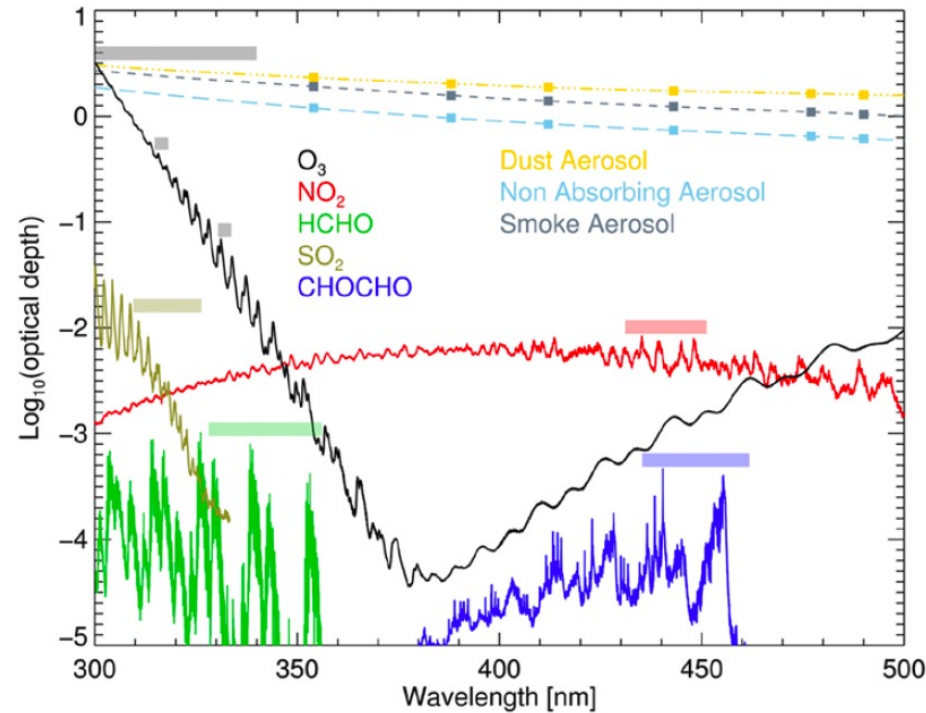


The future of EO for monitoring and assessing air quality



Absorption spectra of air pollutants measured from space

UV-visible

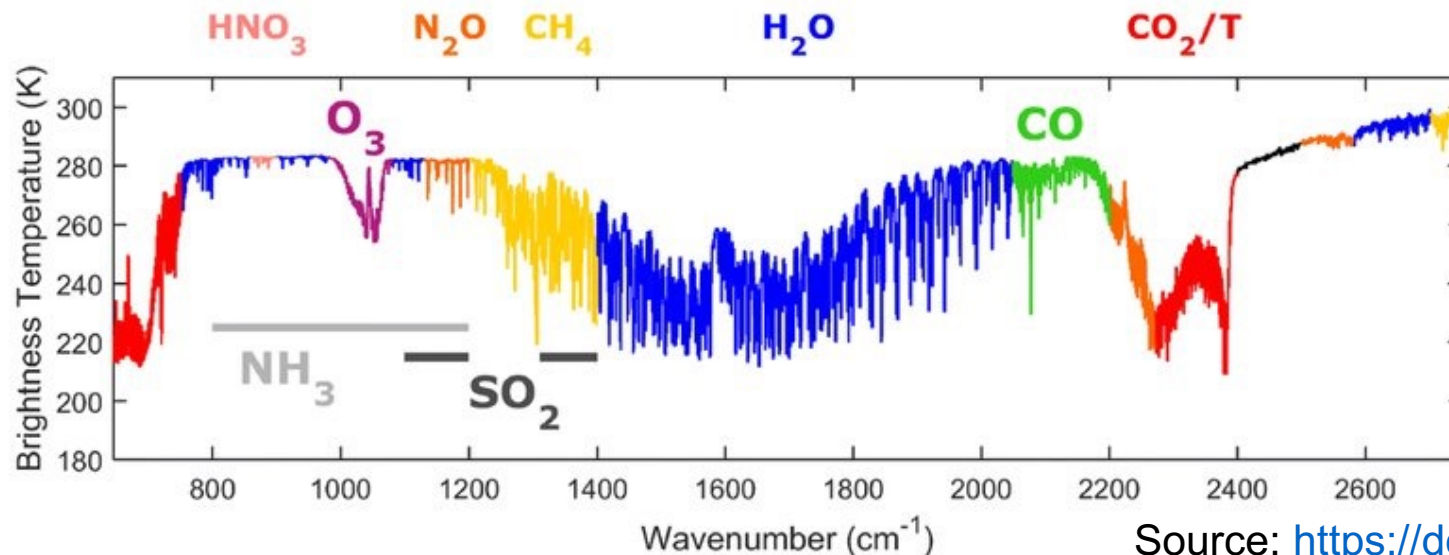


Nitrogen dioxide (NO₂)
Formaldehyde (HCHO)
Glyoxal (CHOCHO)
Sulfur dioxide (SO₂)
Ozone (O₃)

Also Aerosol Optical
Depth (AOD)

Source: <https://doi.org/10.1175/BAMS-D-18-0013.1>

Infrared (IR)



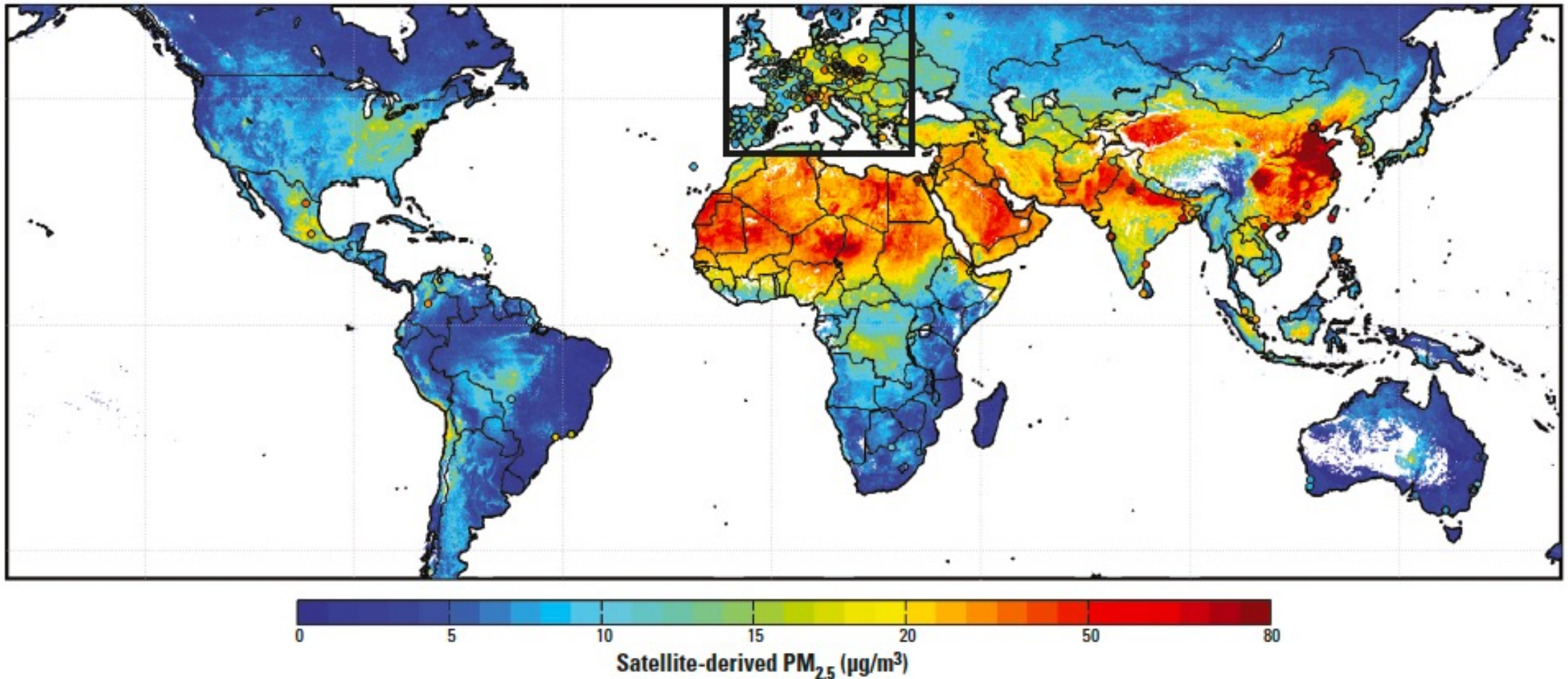
Ammonia (NH₃)
Methane (CH₄)
Carbon monoxide (CO)

Source: <https://doi.org/10.1117/12.2584500>

Success of Current and Past Space-Based Measurements

Convert aerosol optical depth (AOD) to surface concentrations of $\text{PM}_{2.5}$ using a model

Validate with surface observations. Determine global burden of disease due to exposure to air pollution



Source: Van Donkelaar et al. (2010)

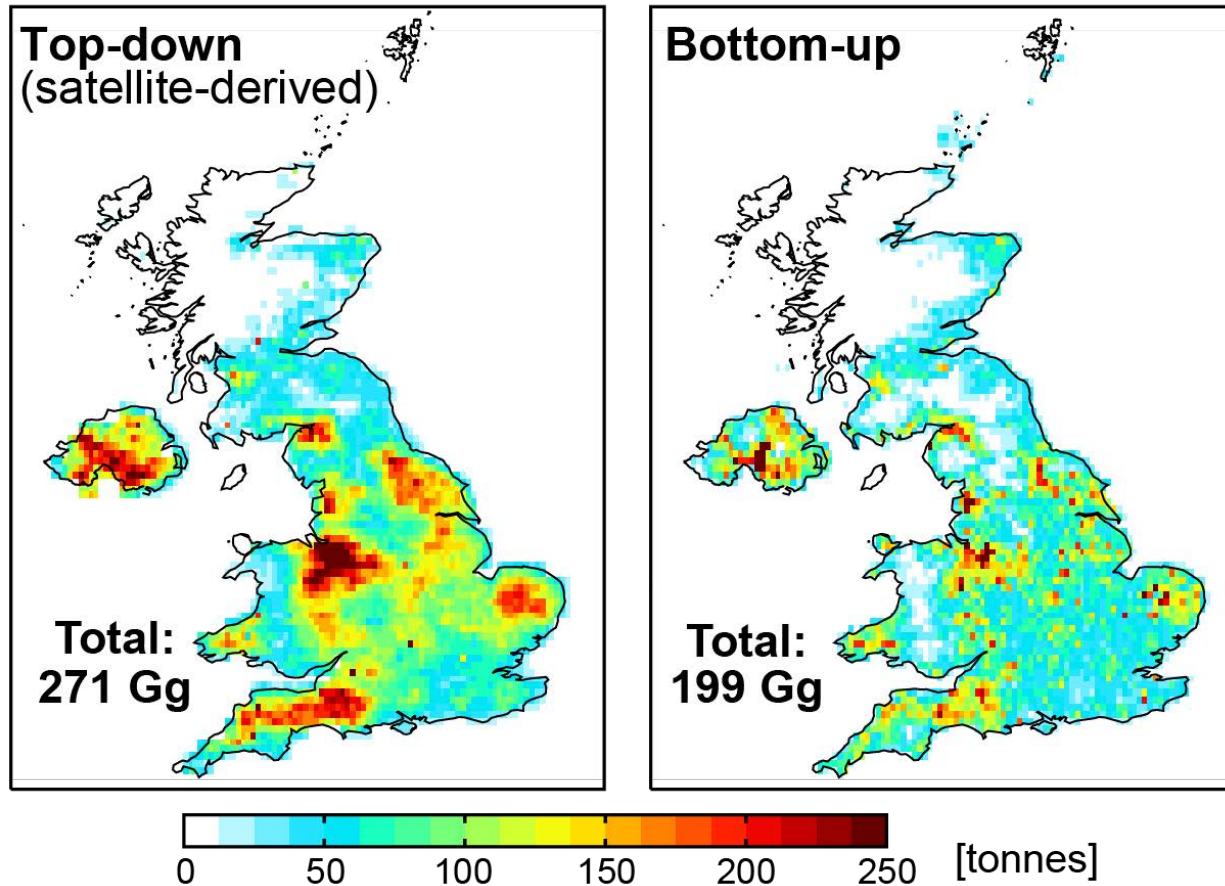
Success of Current and Past Space-Based Measurements

Estimate top-down emissions of air pollution precursors with a model

Use to evaluate bottom-up emission inventories. Where feasible, independently evaluate

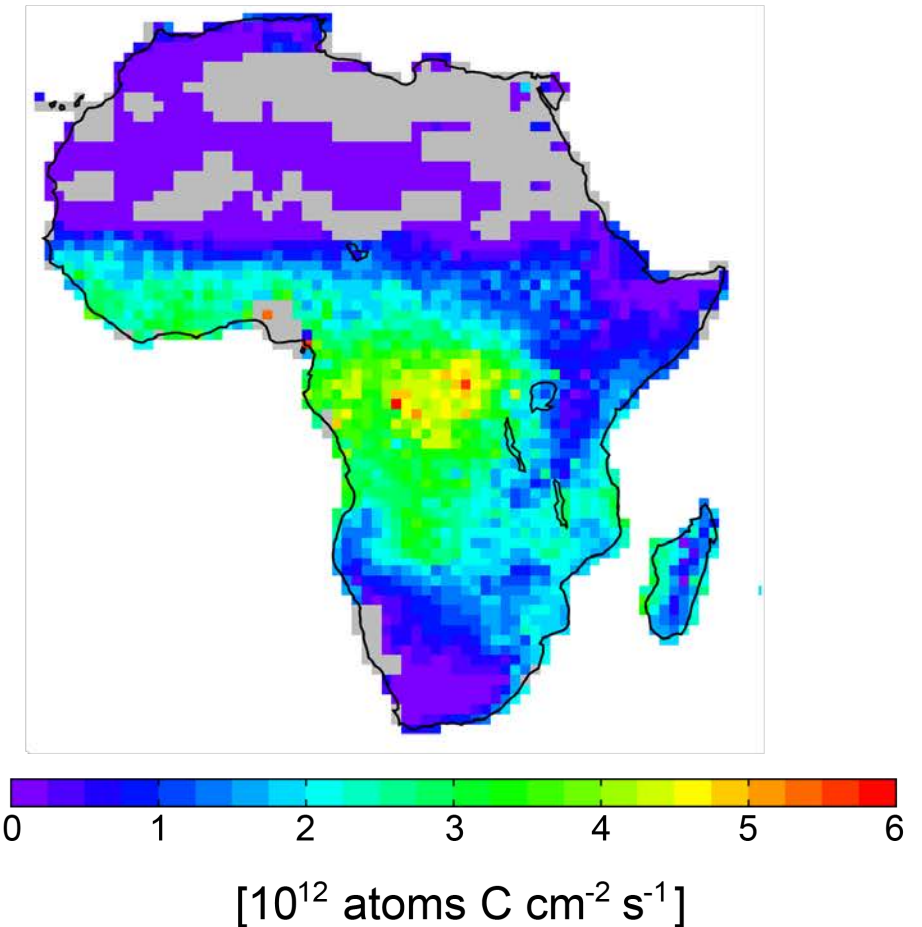
UK Ammonia (NH_3) Emissions

Top-down vs bottom-up total spring-summer UK ammonia emissions



Source: Marais et al. (2021)

Africa Biogenic Isoprene Emissions

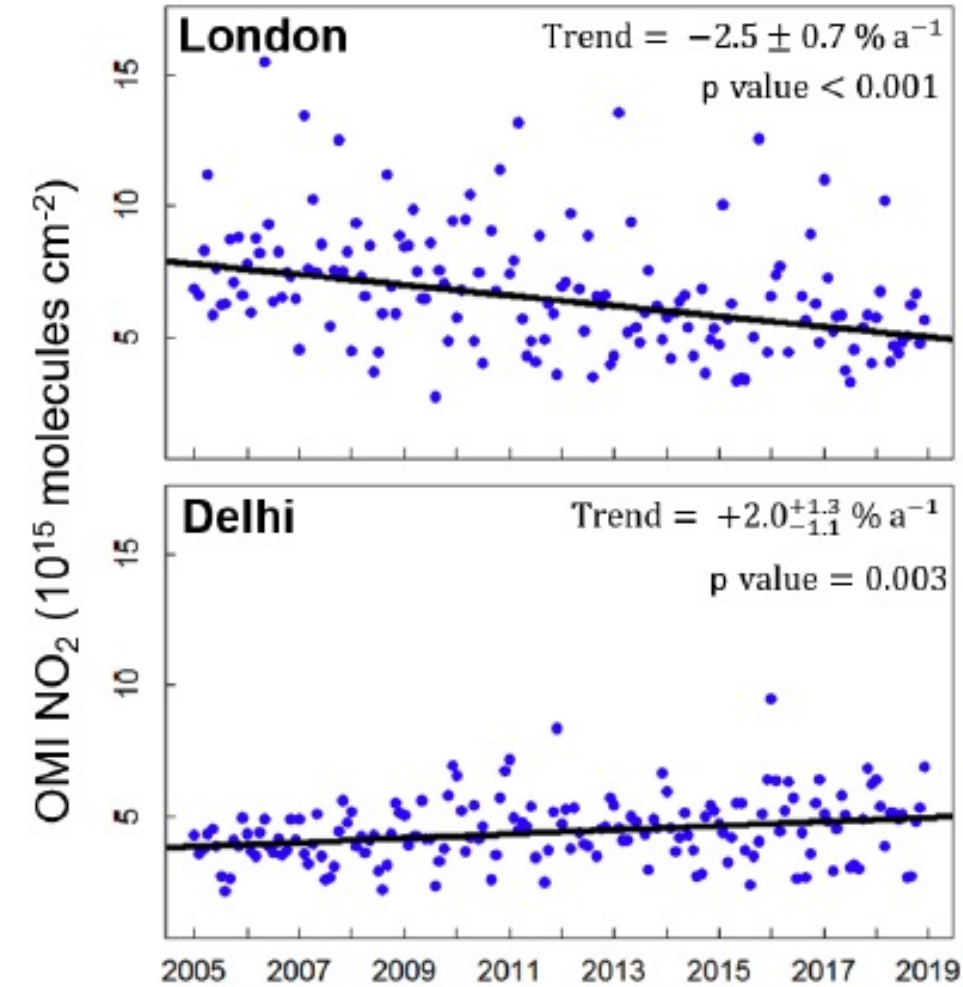
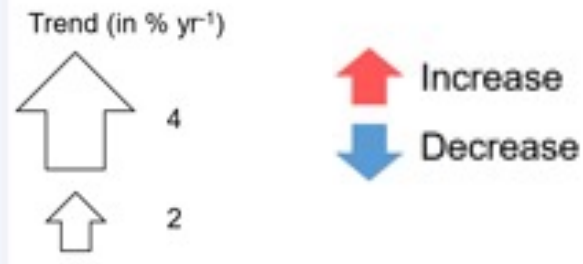
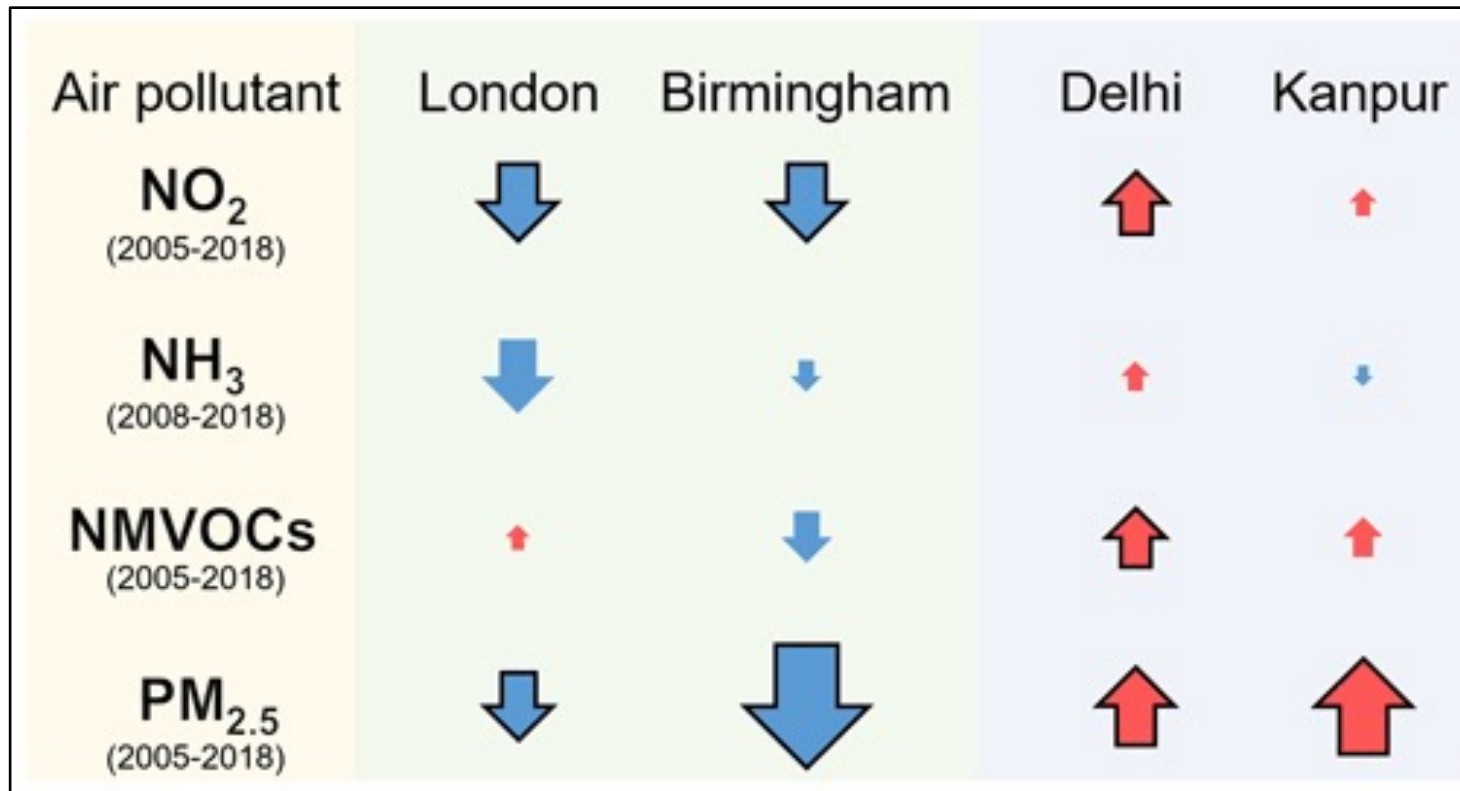


Source: Marais et al. (2012)

Success of Current and Past Space-Based Measurements

Long-term trends in air pollution and precursor emissions for policy assessment and development

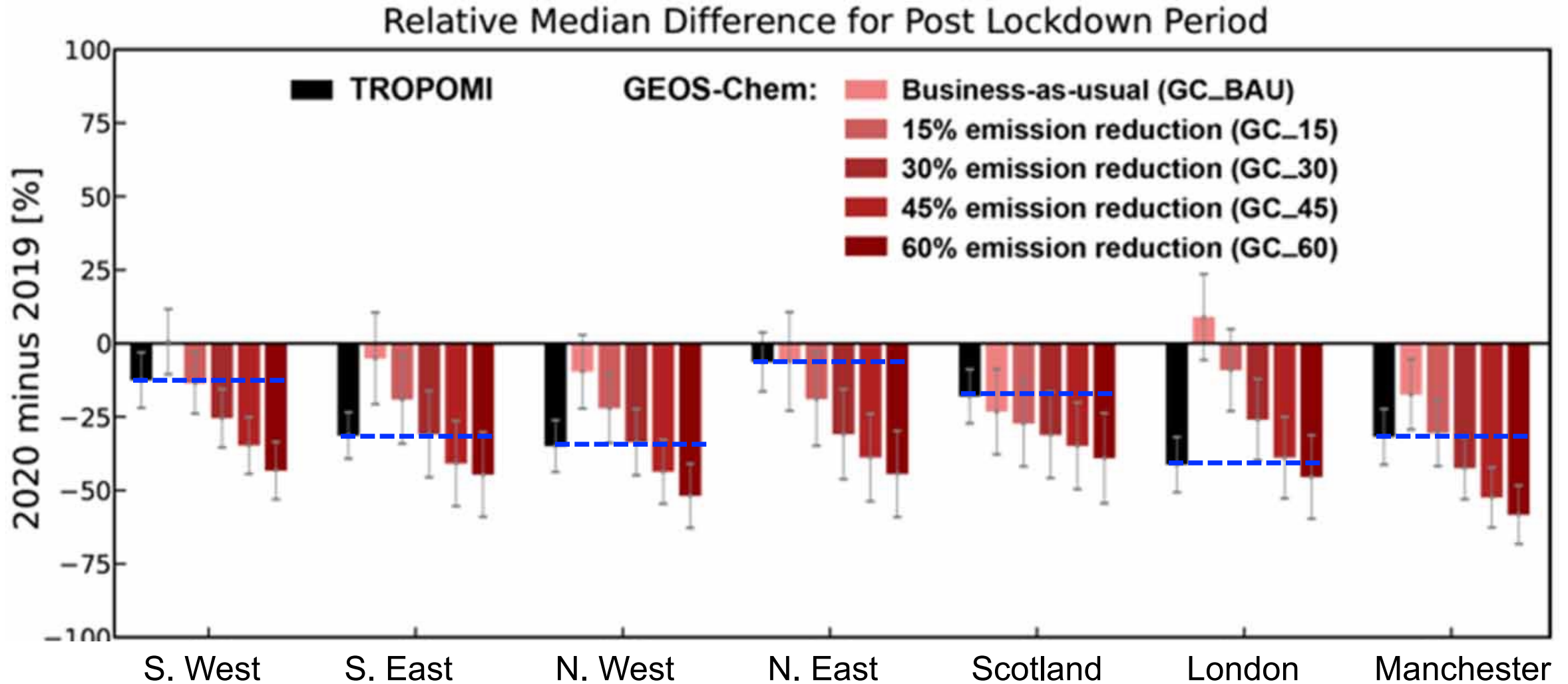
Long-term trends for cities in the UK and India



Source: Vohra et al. (2021)

Success of Current and Past Space-Based Measurements

Extensive application of TROPOMI to identify changes in air quality due to lockdown measures



Source: Potts et al. (2021)

Sustained Low-Earth Orbiting Instruments

MetOp-SG (Second Generation) A Series. 3 launches: 2024, 2031, 2037

3MI

Multi-angle, multi-polarization imager
Improved retrieval of aerosols
~4 km² ground pixel resolution
(POLDER heritage)



Morning overpass
(09h30)

IASI-NG

Monitor NH₃
Improved spectral resolution
Same spatial resolution as IASI
(IASI heritage)

Sentinel-5

NO₂, SO₂, HCHO, CHOCHO, O₃, CO, CH₄
~7 km ground pixel resolution
(TROPOMI/OMI/GOME/SCIAMACHY heritage)

For more information: <https://www.eumetsat.int/metop-sg>

Sustained Low-Earth Orbiting Instruments

JPSS (Joint Polar Satellite System) Series. 3 launches: 2022, 2027, 2032

Builds on heritage of NOAA-22 and Suomi NPP missions

CrIS
Monitor NH_3



OMPS
Monitor NO_2 , SO_2 , HCHO , O_3

Midday overpass ensures it sustains a consistency record provided by the midday overpass instruments OMI and TROPOMI

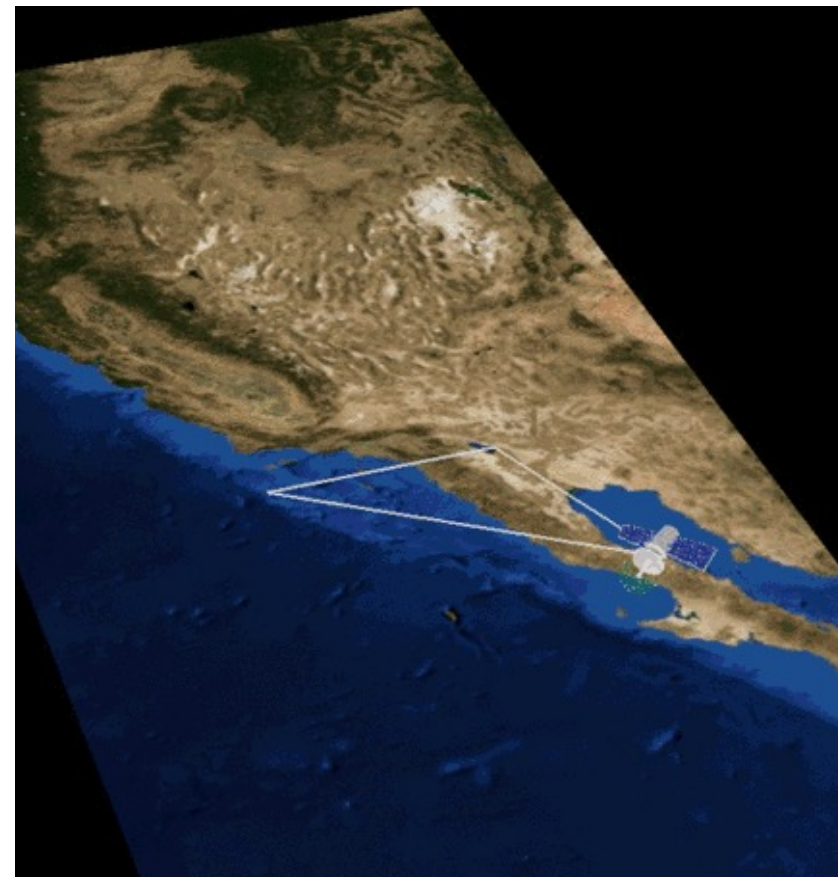
For more information: <https://www.jpss.noaa.gov/about.html>

Multi-Angle Imager for Aerosols (MAIA)

NASA partnership with epidemiologists and health organizations to study human health and improve lives.



Blue: **primary**; Green: **secondary**; Orange: **calibration/validation**



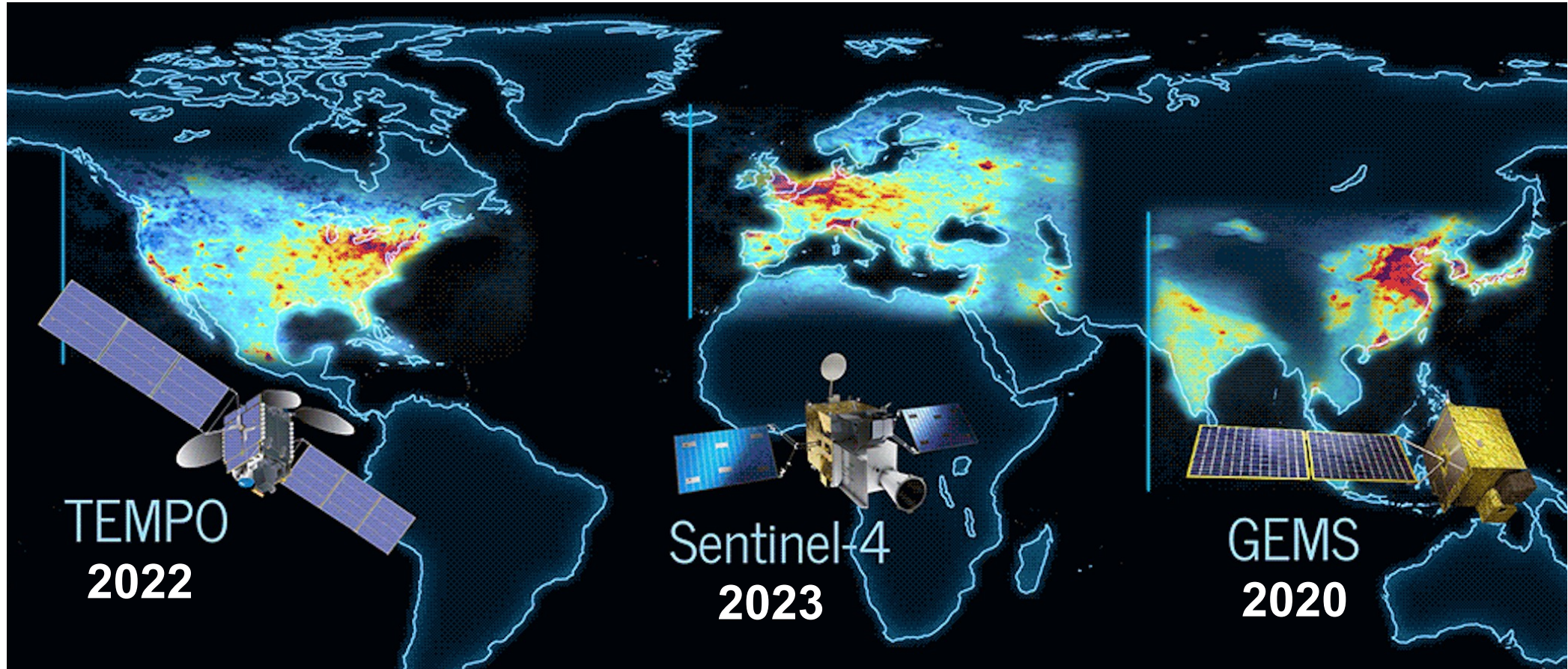
Innovation: Step-and-stare, 5-9 viewing angles (improves aerosol retrieval)

Specs: 1 km spatial resolution

Launch date: 2022

For more details: <https://maia.jpl.nasa.gov/>

The Dawn of the Geostationary Observing Network



Near-hourly observations throughout daylight hours at 2.1-9 km resolution

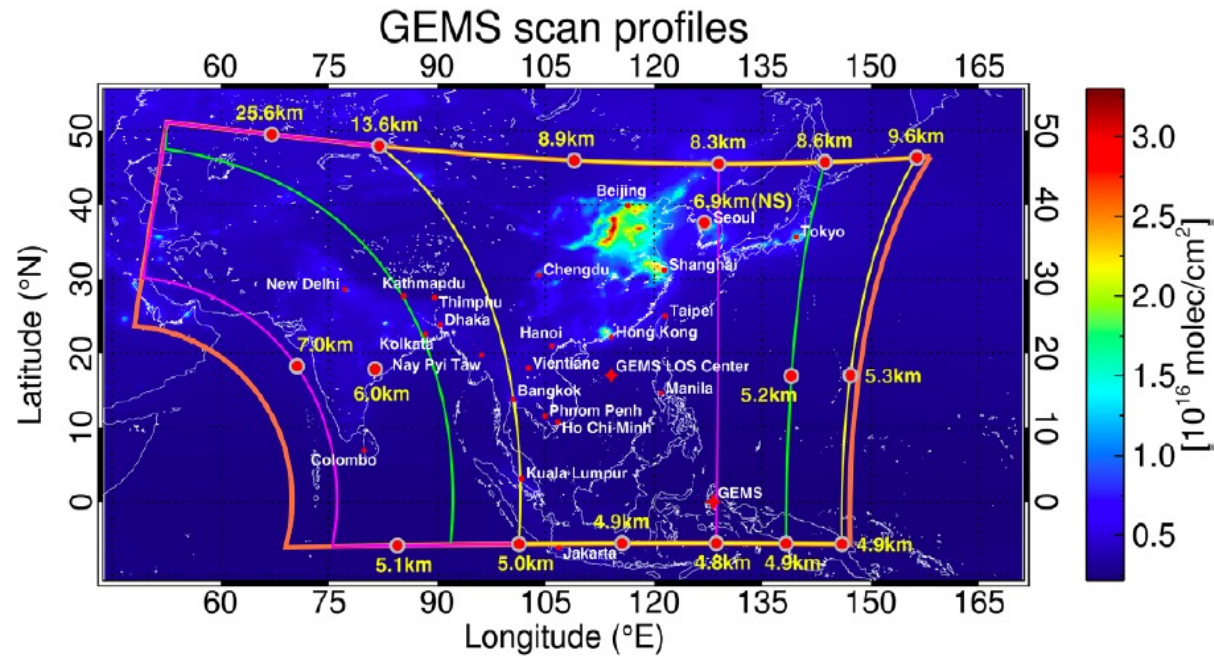
GEMS (UV/vis) and TEMPO (UV/vis-NIR) built together

Sentinel-4 includes UV-visible-NIR and IR instrument (collocation of multiple pollutants)

TEMPO: Includes NIR to improve sensitivity to ozone near surface

GEMS Product Development and Validation Underway

GEMS: Geostationary Environment Monitoring Spectrometer

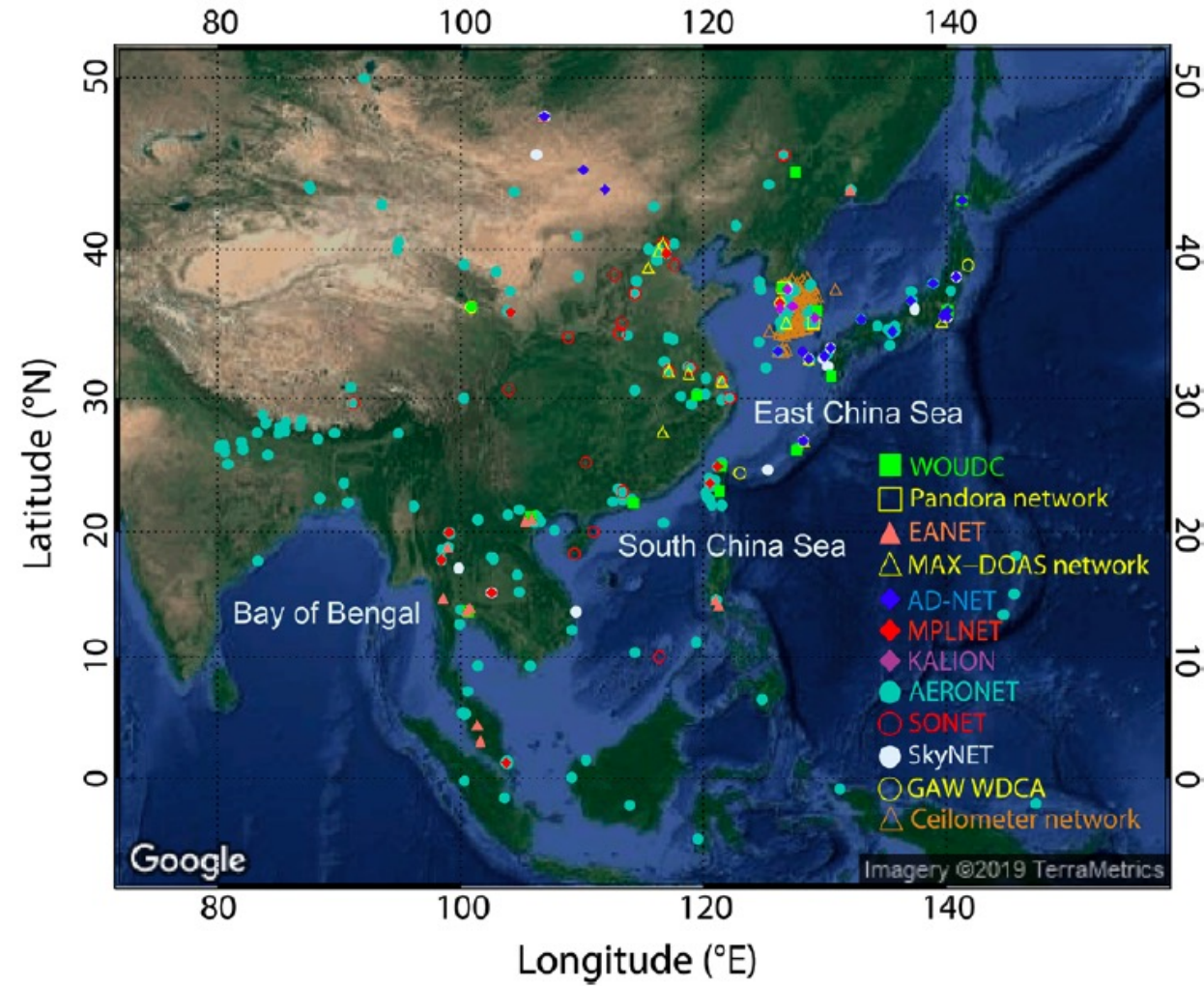


GEMS already launched and in use

10 year lifetime

Data planned for public release in mid-2022

Spatial resolution of 7 km x 8 km



Source: <https://doi.org/10.1175/BAMS-D-18-0013.1>

Other Aspects Relevant to AQ monitoring

- Sensors measuring the abundance of the ozone precursor and potent greenhouse gas methane (CH_4): GHGSat (low cost), MethaneSat (high precision)
- The many other infrared-active air pollutants that can be retrieved from IR instruments
- Complementary observations to aid in understanding air pollutant abundances and sources:
 - fires, lightning flashes, very high-resolution images, leaf area indices, vegetation cover, ocean color, incident sunlight and so on.

Helpful Resources

- OSCAR (Observing Systems Capability Analysis and Review Tool):
<https://space.oscar.wmo.int/instruments/>
- ESA Earth Observation Portal: <https://directory.eoportal.org/web/eoportal/satellite-missions/a>
- NASA MAIA early adopters network: <https://maia.jpl.nasa.gov/resources/data-and-applications/>
- TEMPO early adopters network: <https://weather.msfc.nasa.gov/tempo/>
- For more on my research group's use of Earth observations and models:
<https://maraisresearchgroup.co.uk/publications.html>