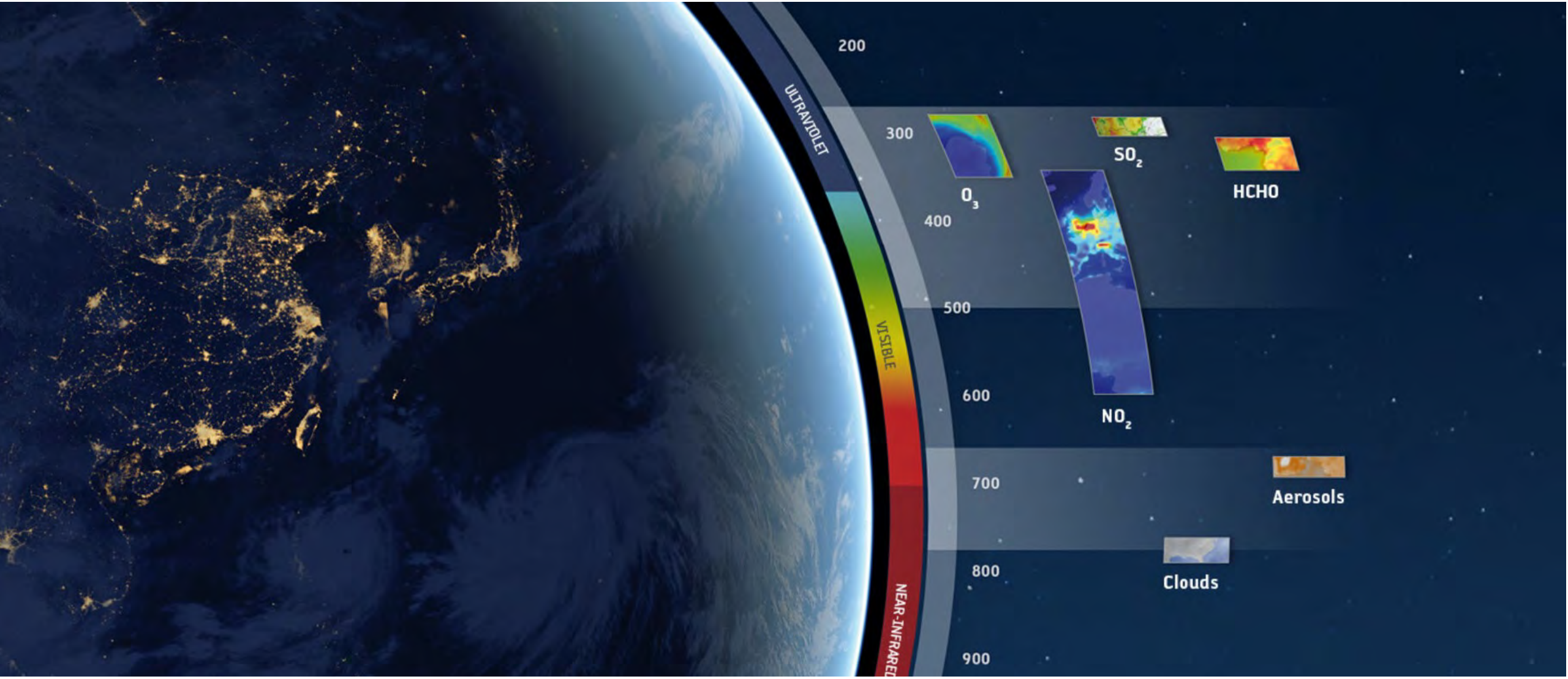
The future of EO for monitoring and assessing air quality



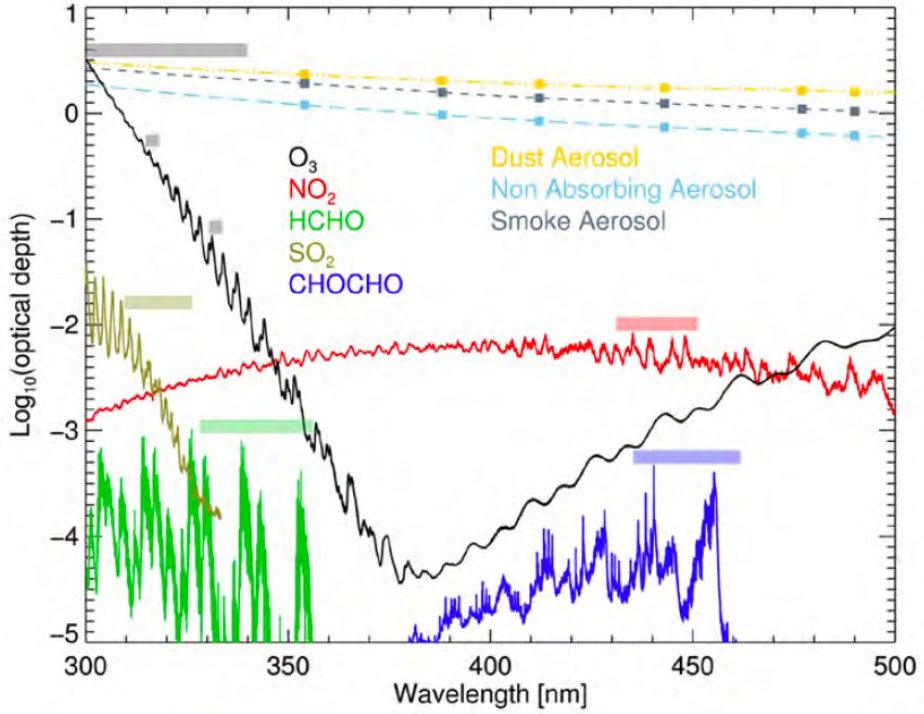
DEFRA EO CoE Workshop

Eloise A Marais (e.marais@ucl.ac.uk)
https://maraisresearchgroup.co.uk/

21 September 2021

Absorption spectra of air pollutants measured from space

UV-visible

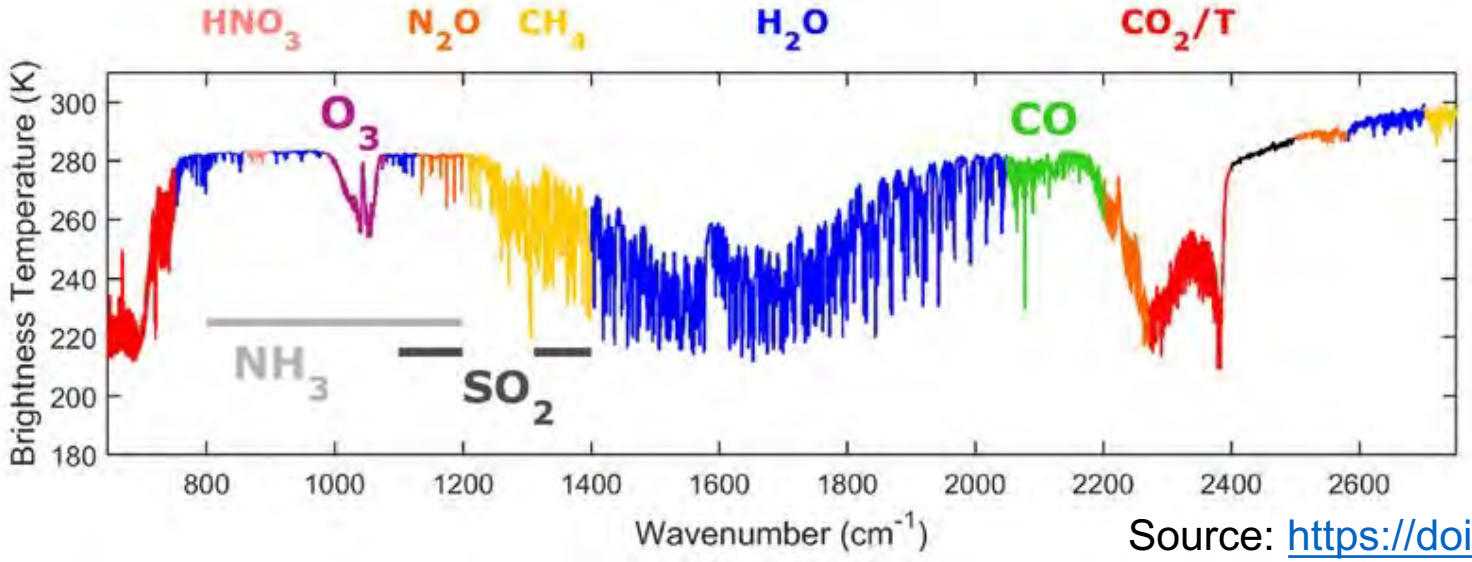


Nitrogen dioxide (NO_2)
Formaldehyde (HCHO)
Glyoxal (CHOCHO)
Sulfur dioxide (SO_2)
Ozone (O_3)

Also Aerosol Optical Depth (AOD)

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

Infrared (IR)



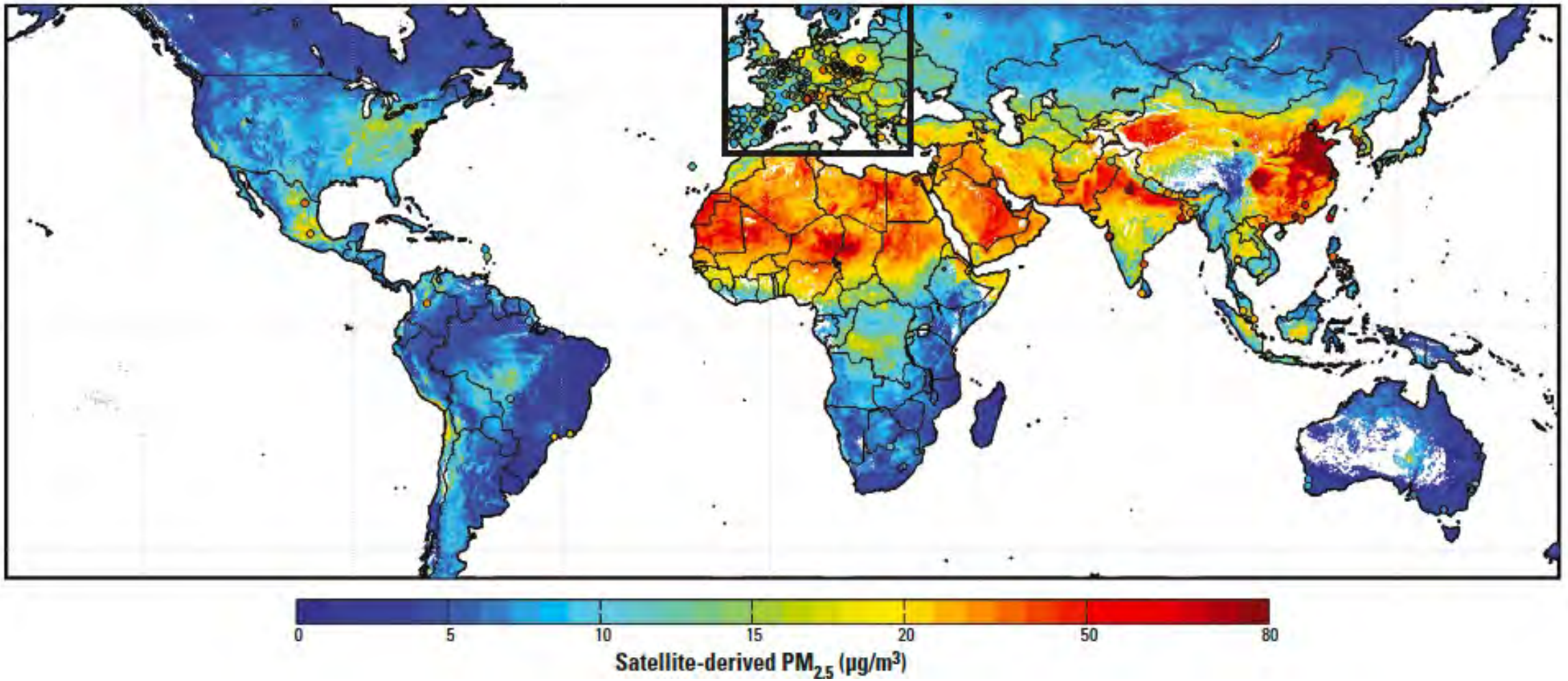
Ammonia (NH_3)
Methane (CH_4)
Carbon monoxide (CO)

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 $PM_{2.5}$ using a model

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



Source: Van Donkelaar et al. (2010)

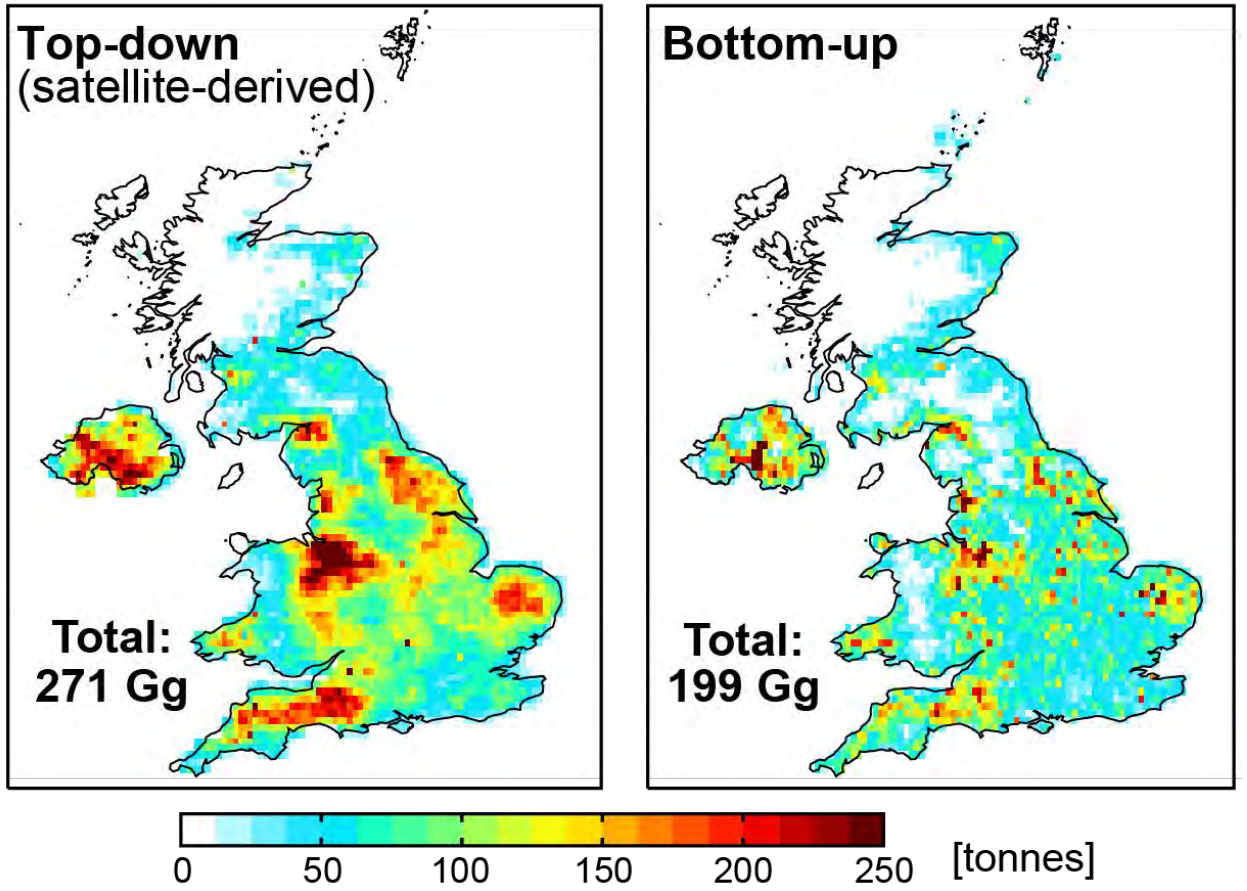
Success of Current and Past Space-Based Measurements

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

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

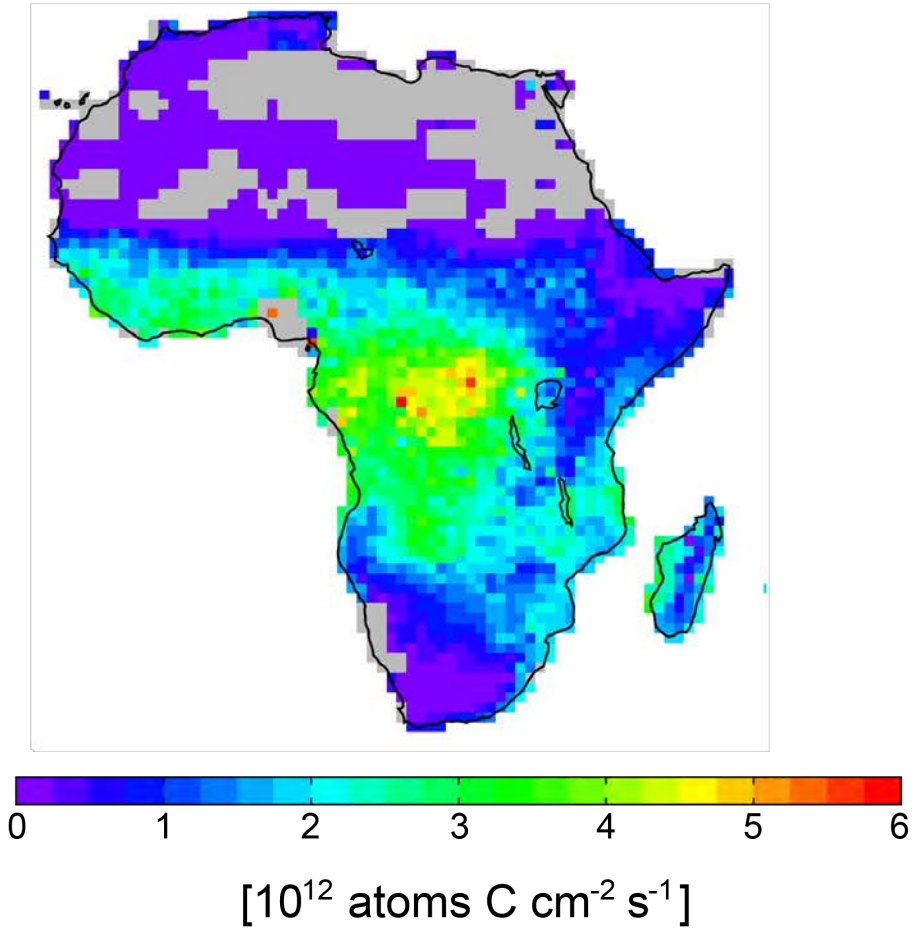
UK Ammonia (NH_3) Emissions

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

Air pollutant	London	Birmingham	Delhi	Kanpur
NO_2 (2005-2018)	↓	↓	↑	↑
NH_3 (2008-2018)	↓	↓	↑	↑
NMVOCs (2005-2018)	↑	↓	↑	↑
$PM_{2.5}$ (2005-2018)	↓	↓	↑	↑

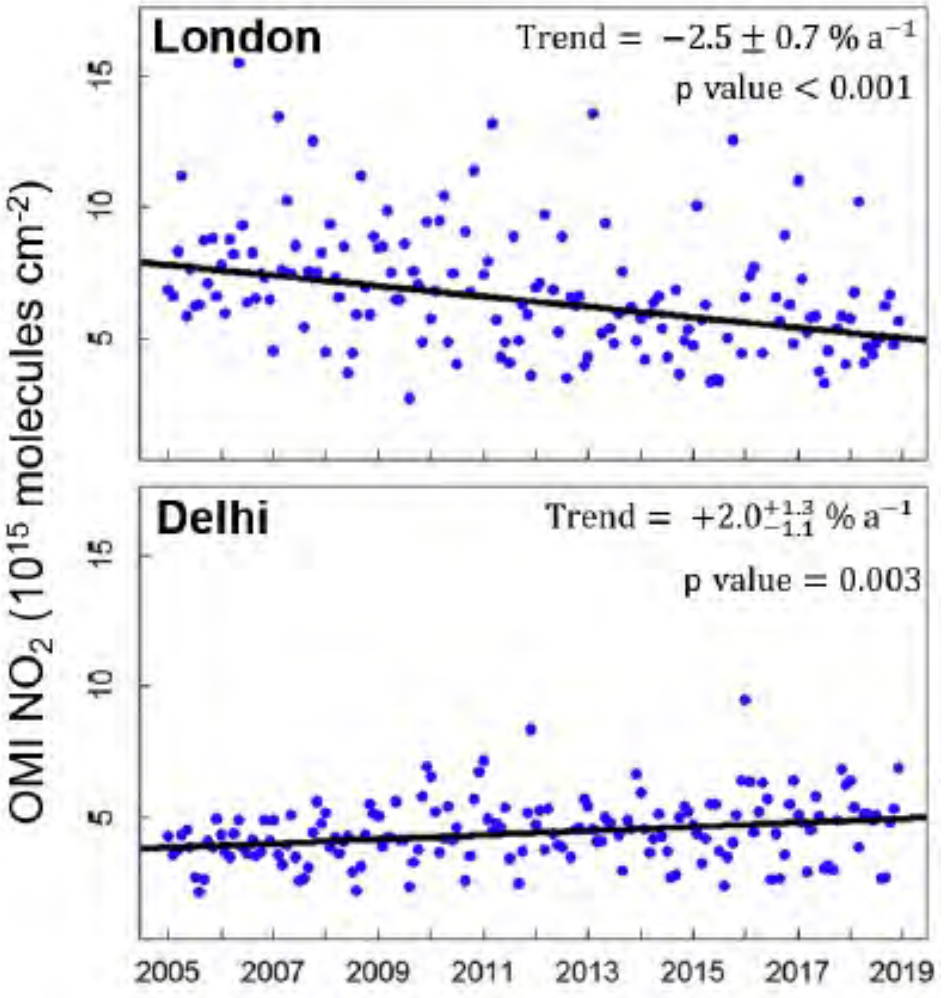
Trend (in % yr^{-1})

4

2

Increase

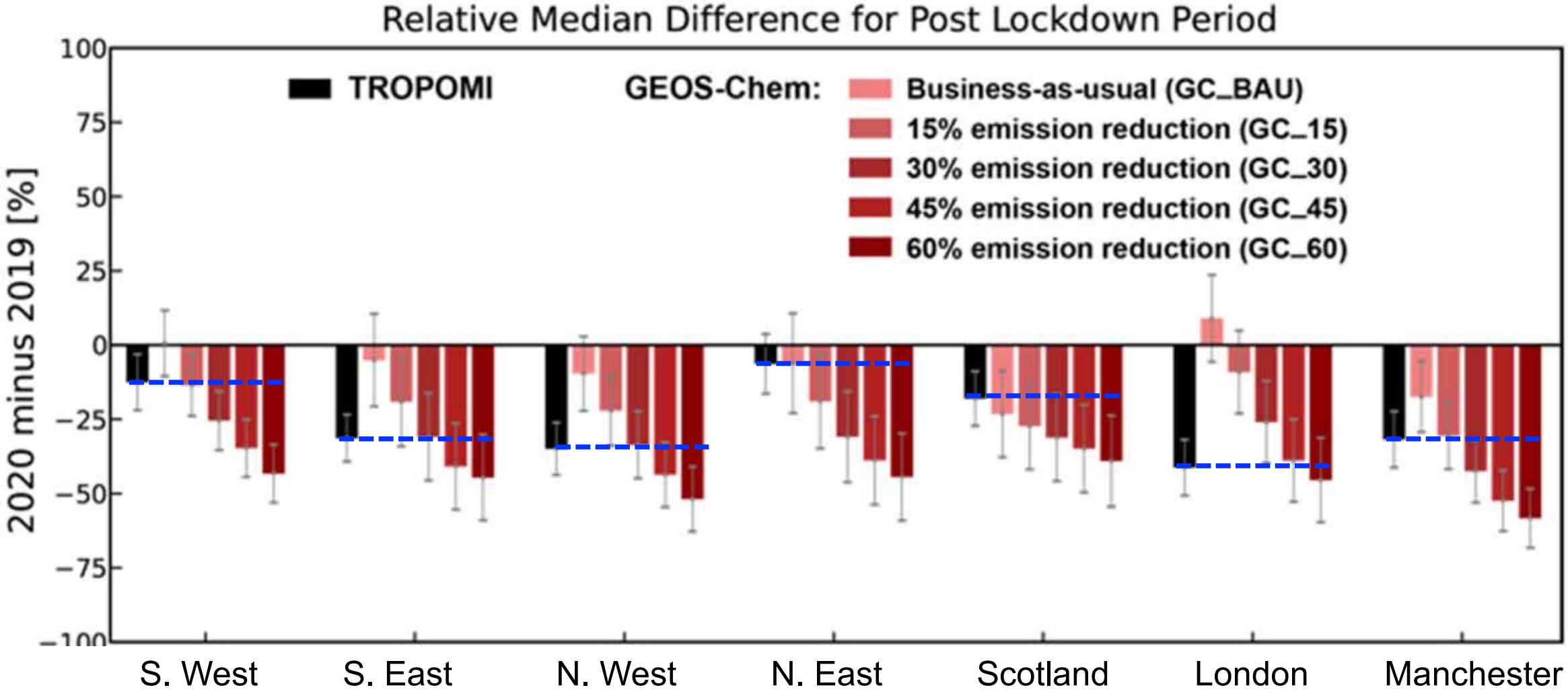
Decrease



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

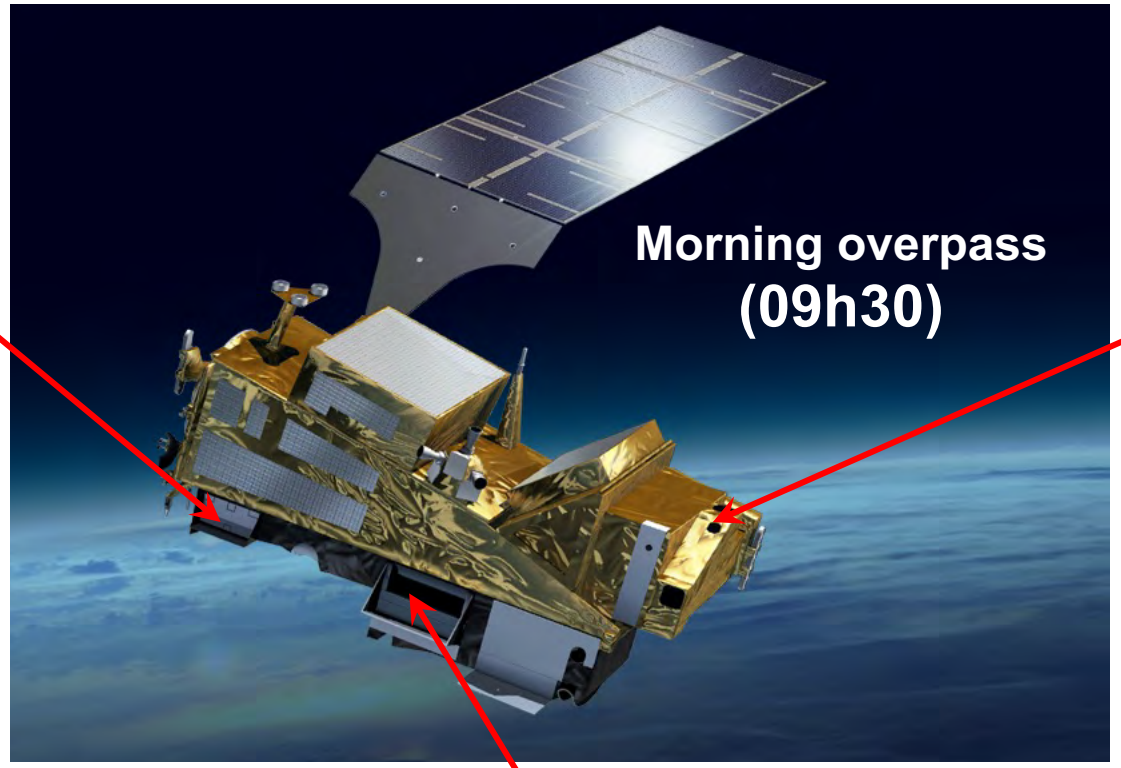


Source: Potts et al. (2021)

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 km^2 ground pixel resolution
(POLDER heritage)



IASI-NG
Monitor NH_3
Improved spectral resolution
Same spatial resolution as IASI
(IASI heritage)

Sentinel-5
NO_2, SO_2, HCHO, CHOCHO, O_3, CO, CH_4
~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

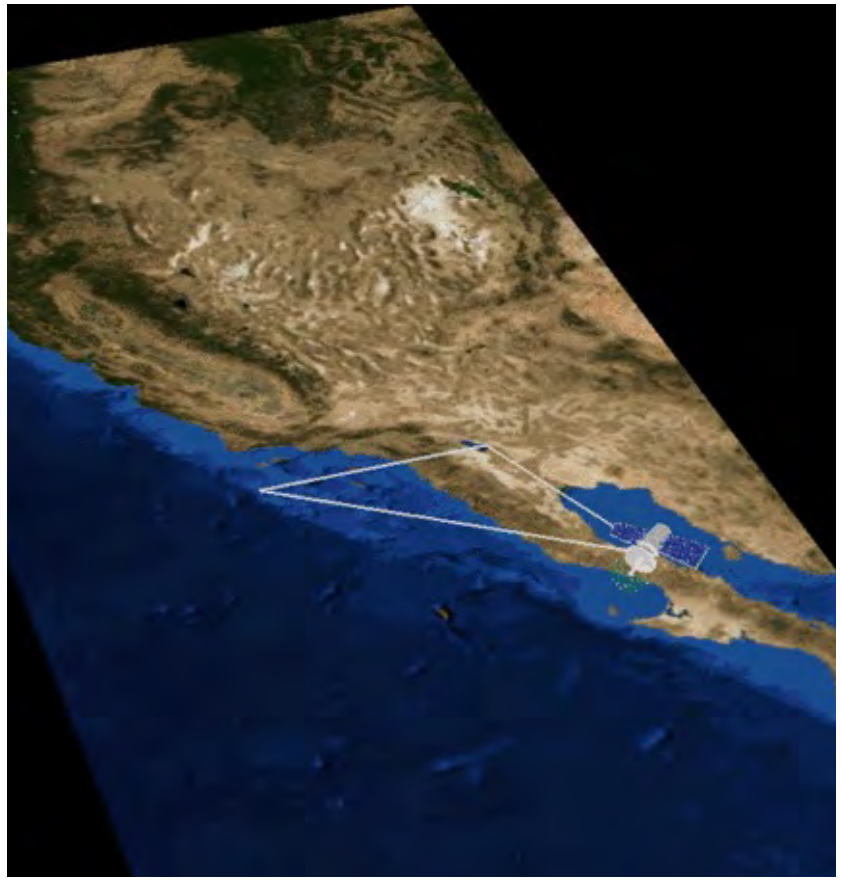
OMPS
Monitor NO_2, SO_2, HCHO, O_3

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**

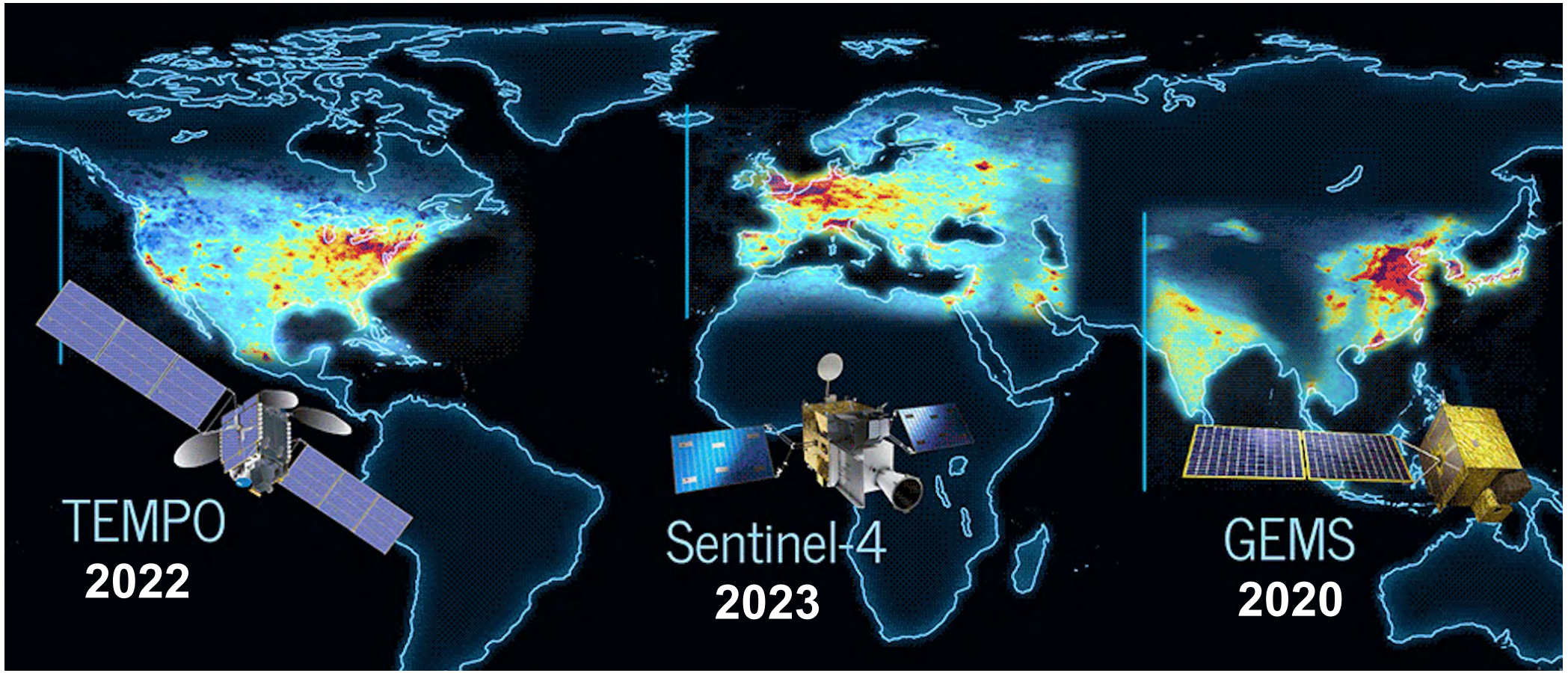
Innovation: Step-and-stare, 5-9 viewing angles (improves aerosol retrieval)

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

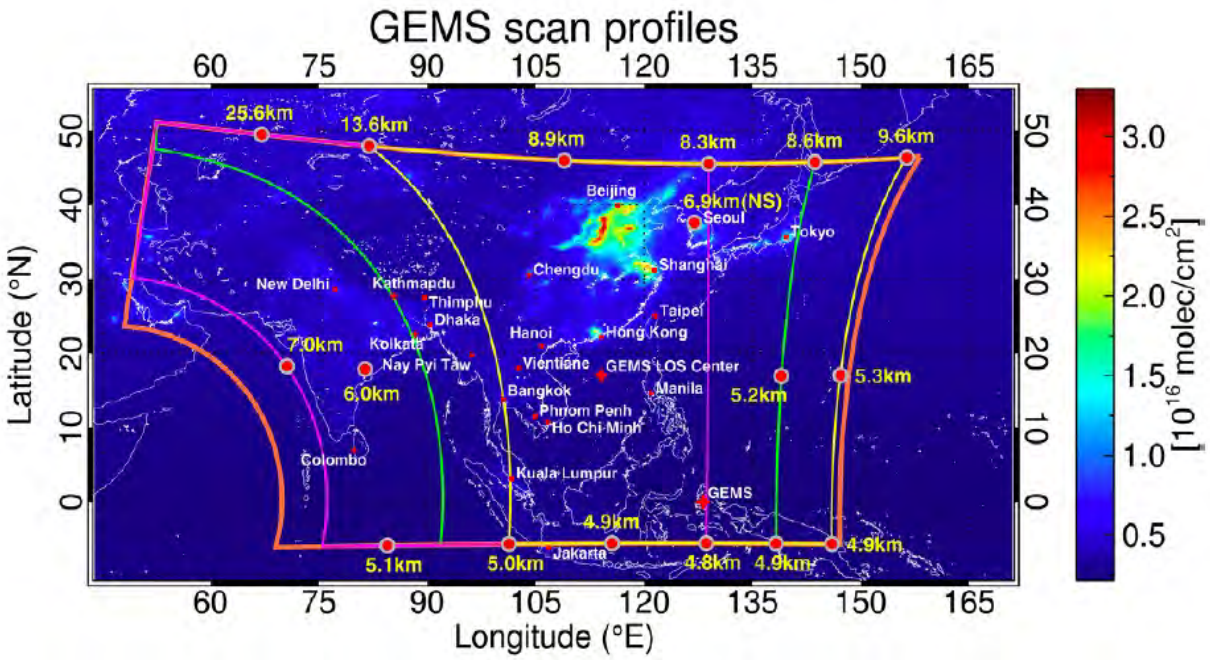
GEMS (UV/vis) and TEMPO (UV/vis-NIR) built together

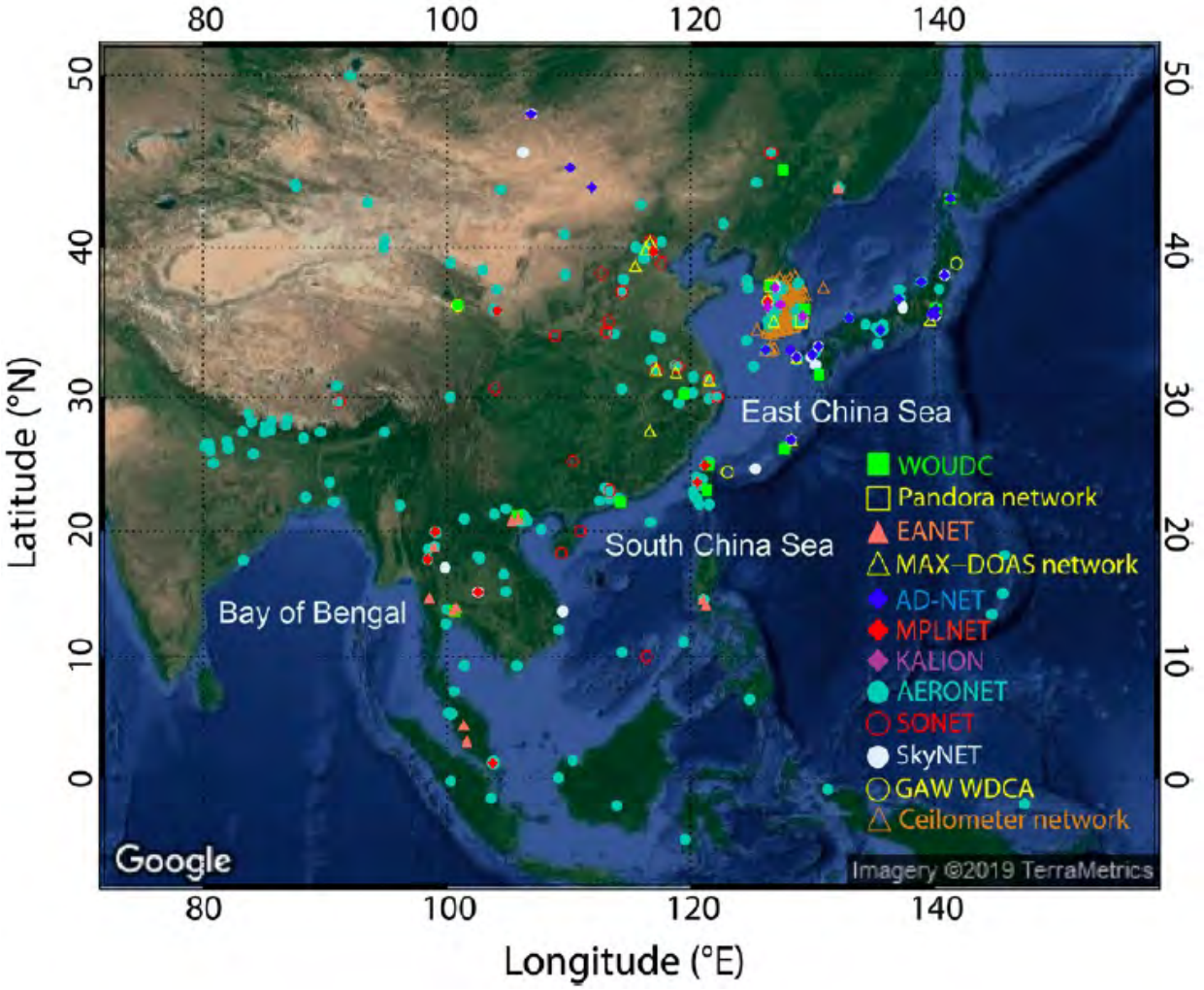
Sentinel-4 includes UV-visible-NIR and IR instrument (collocation of multiple pollutants)

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