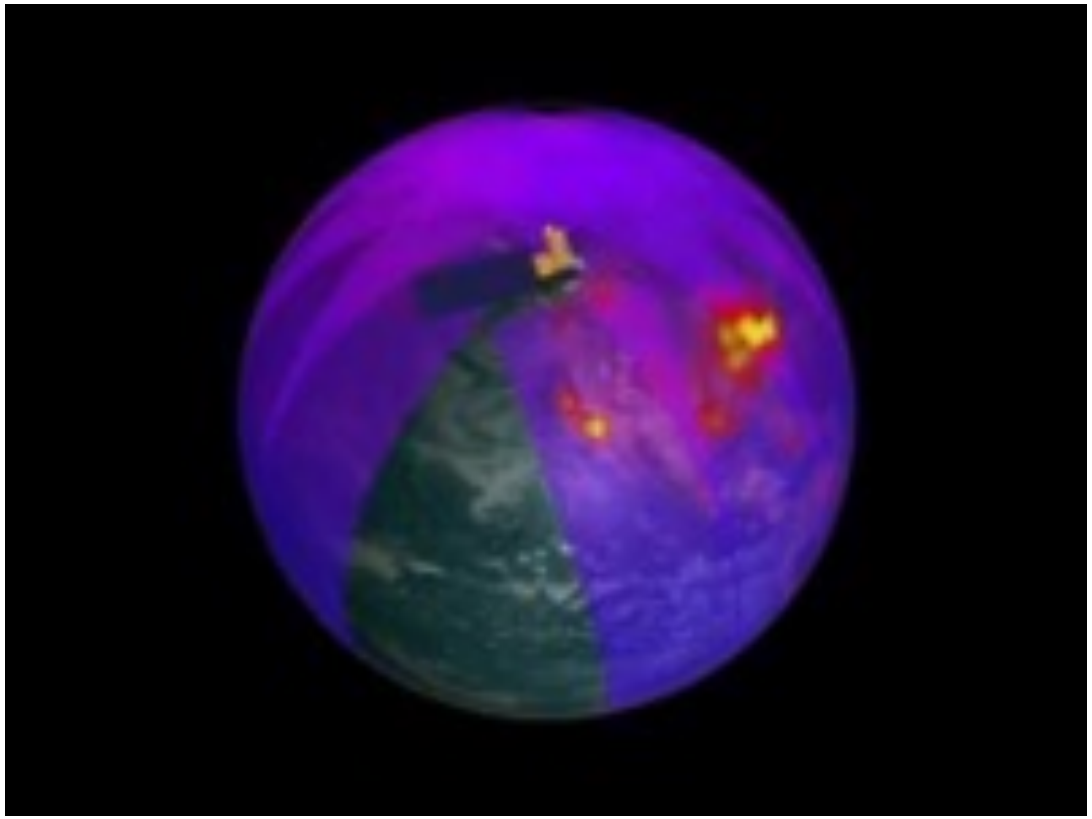
Remote Sensing of the Atmosphere

NERC London DTP Induction Week



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30 September 2022

UCL Atmospheric Composition and Air Quality Group

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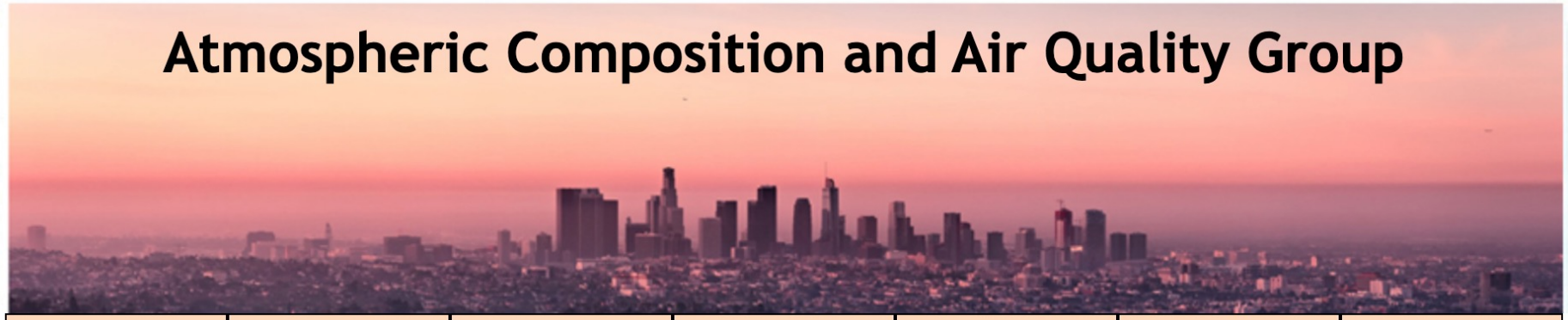
https://maraisresearchgroup.co.uk/



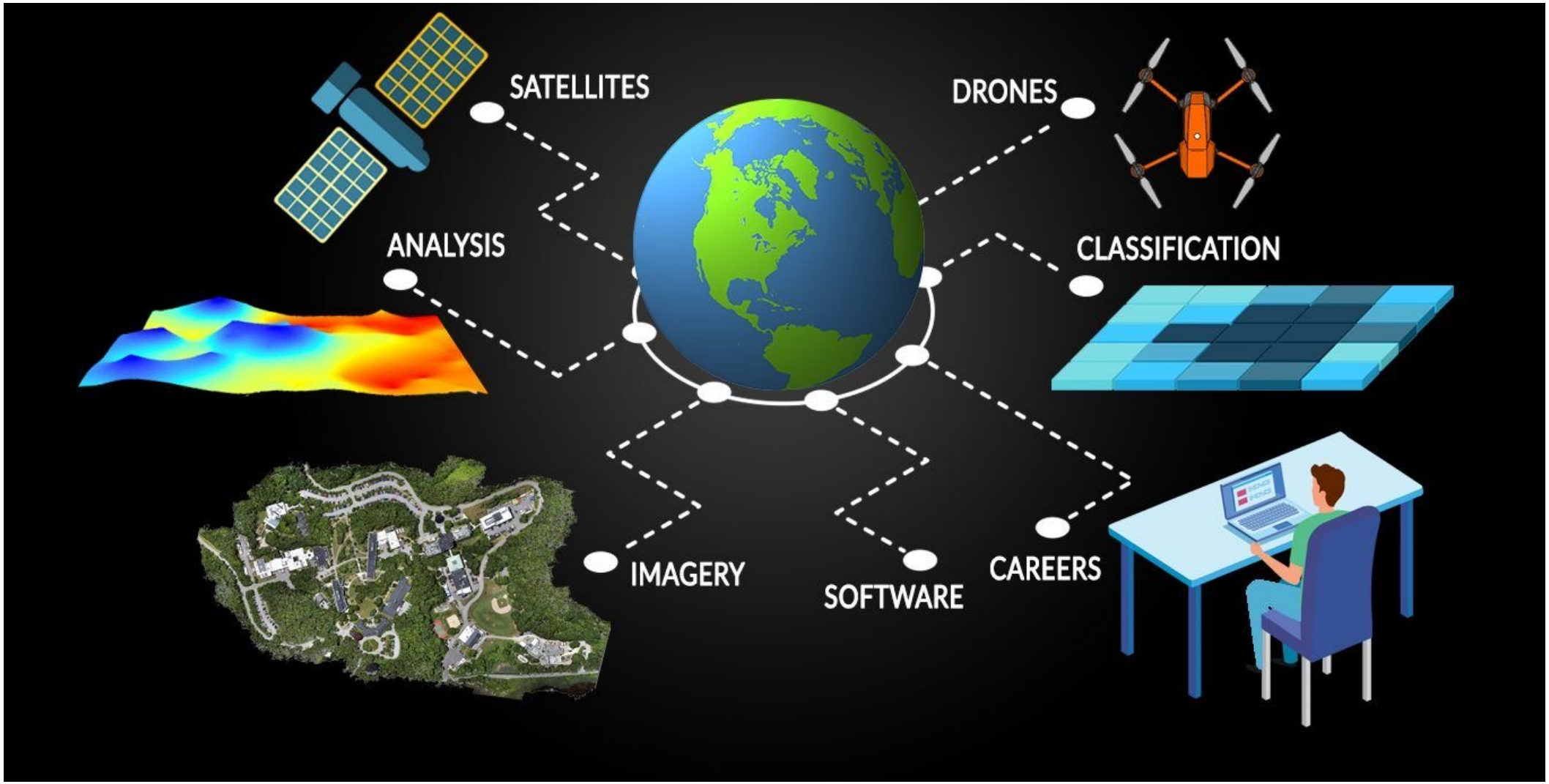
Our group combines data from multiple platforms (models, aircraft, satellites, lab and field measurements) to better understand the influence of humans on atmospheric chemistry, air quality, and climate from urban to regional to global scales.

Recent news and highlights from our group:

Our new MAX-DOAS instrument up and running on the Torrington Place rooftop at UCL

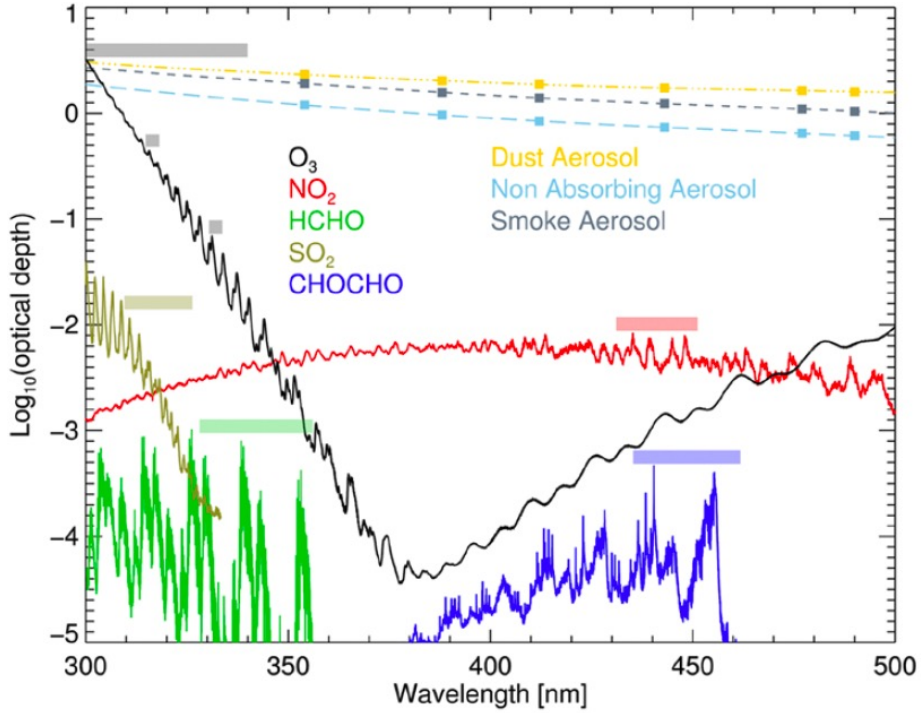
Remote Sensing

Acquire information about an object with no physical contact



Measure reflected and emitted radiation

UV-visible

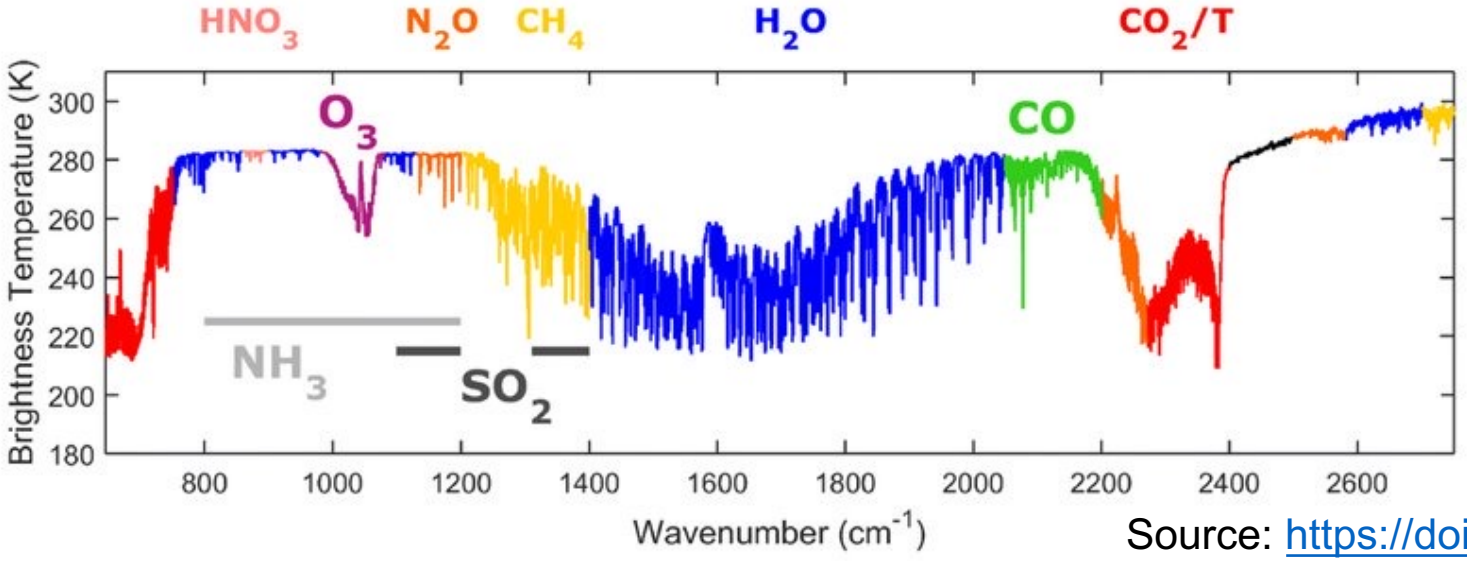


Nitrogen dioxide (NO_2)
Formaldehyde (HCHO)
Glyoxal (CHOCHO)
Sulfur dioxide (SO_2)
Ozone (O_3)

Also Aerosol Optical Depth (AOD)

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

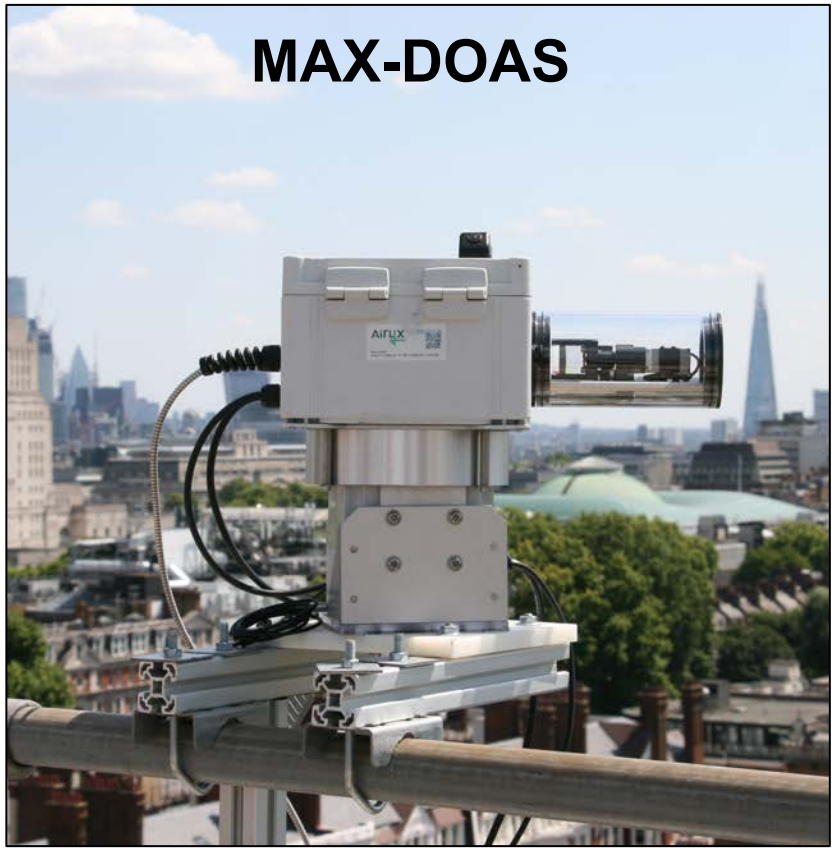
Infrared (IR)



Ozone (O_3)
Ammonia (NH_3)
Sulfur dioxide (SO_2)
Nitric acid (HNO_3)

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

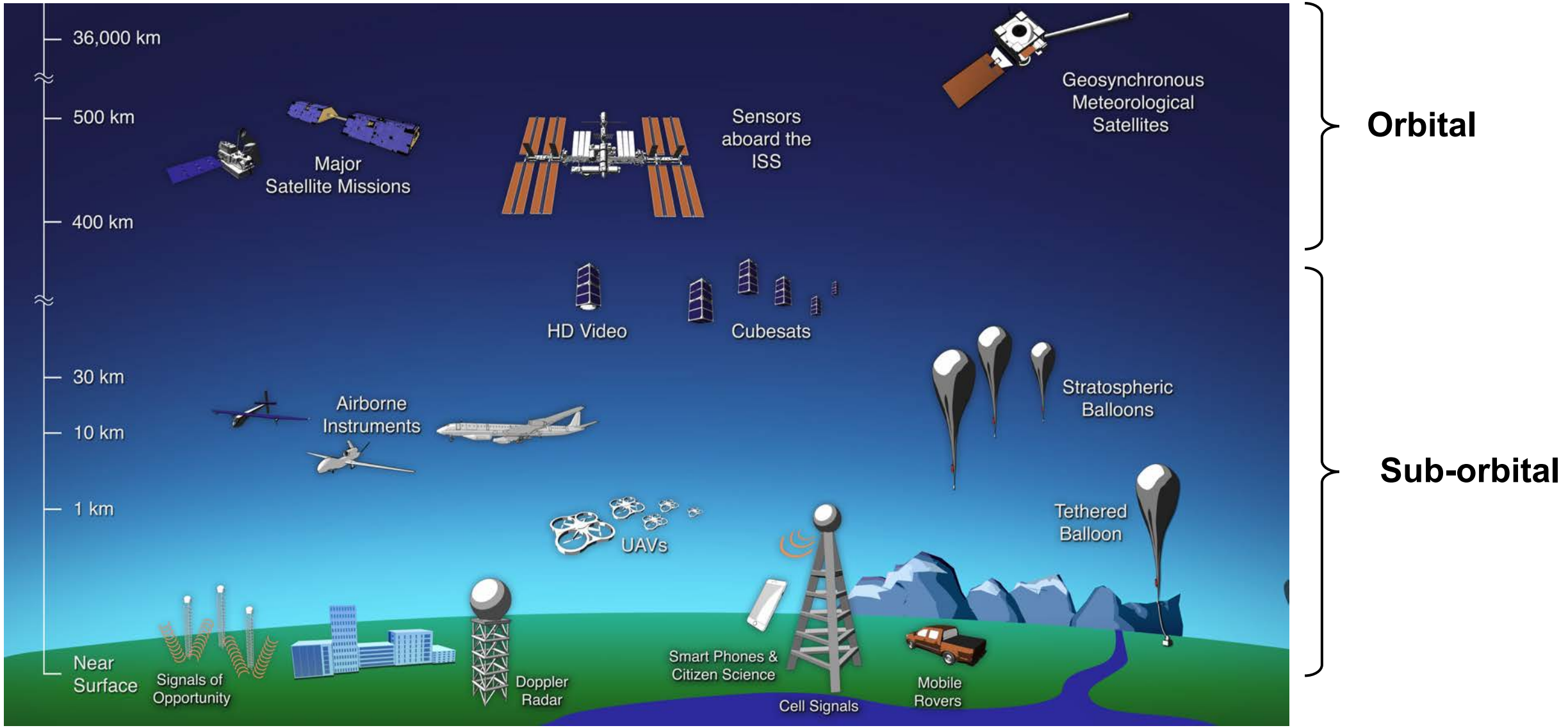
Remote sensing of the atmosphere from the ground

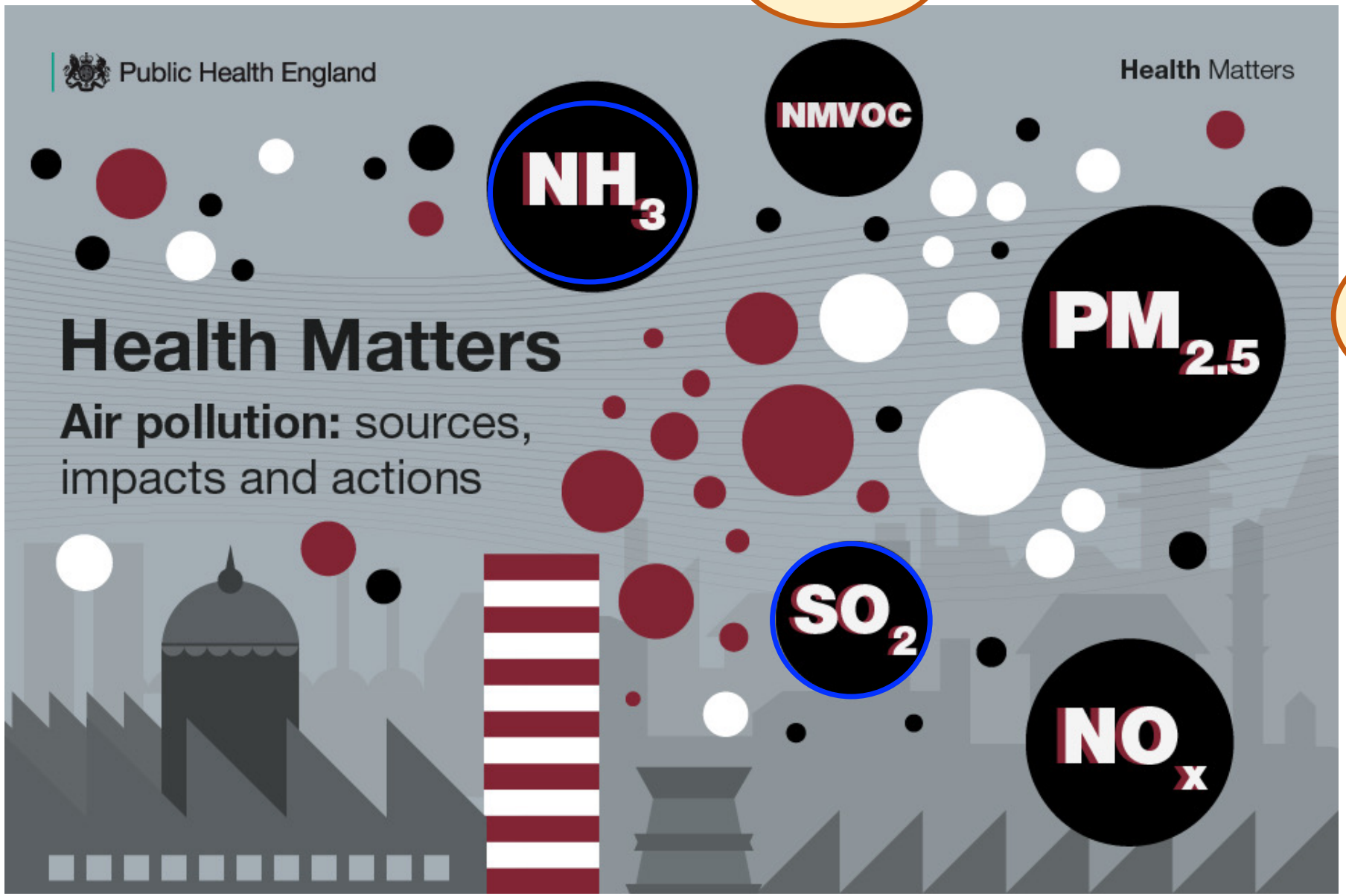


Pandora

Photo of **our instrument** on the rooftop of a 10-story UCL building

Remote sensing of the atmosphere from above





HCHO

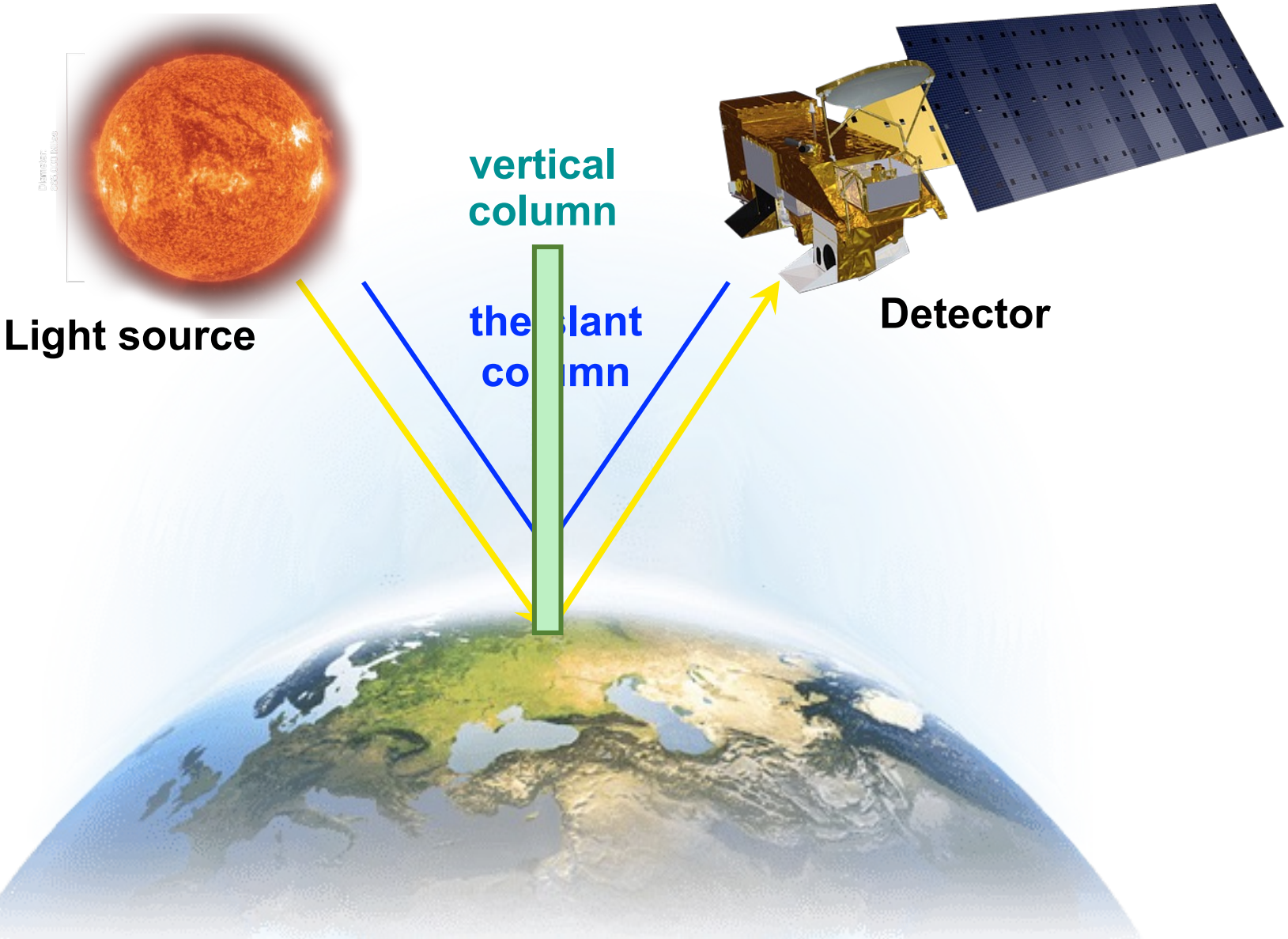
AOD

NO_2

Directly detected with remote sensing

Indirect (proxy) detected

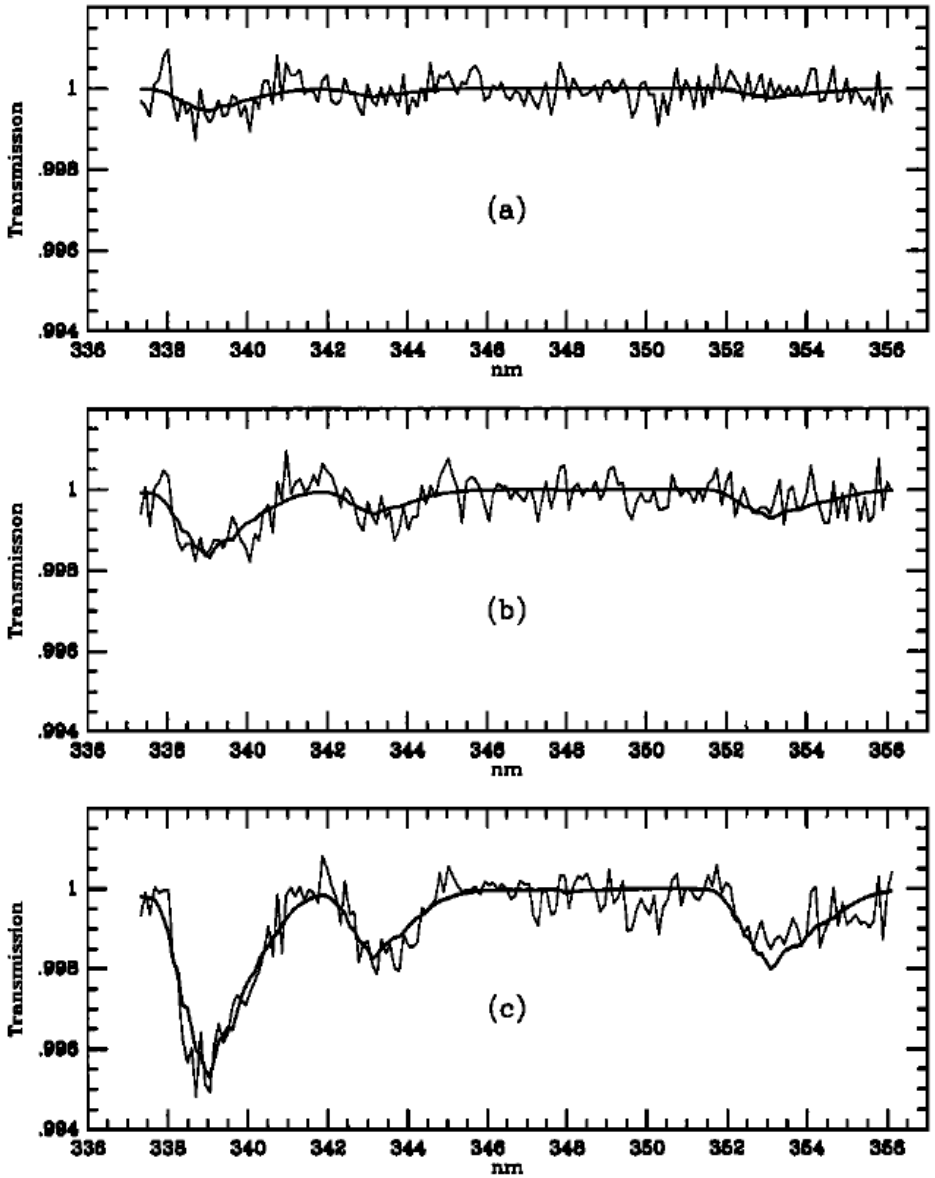
Space-based remote sensing of the atmosphere



Spectral Fit along a slant column

Formaldehyde (HCHO):

Prompt, high-yield oxidation product of non-methane volatile organic compounds



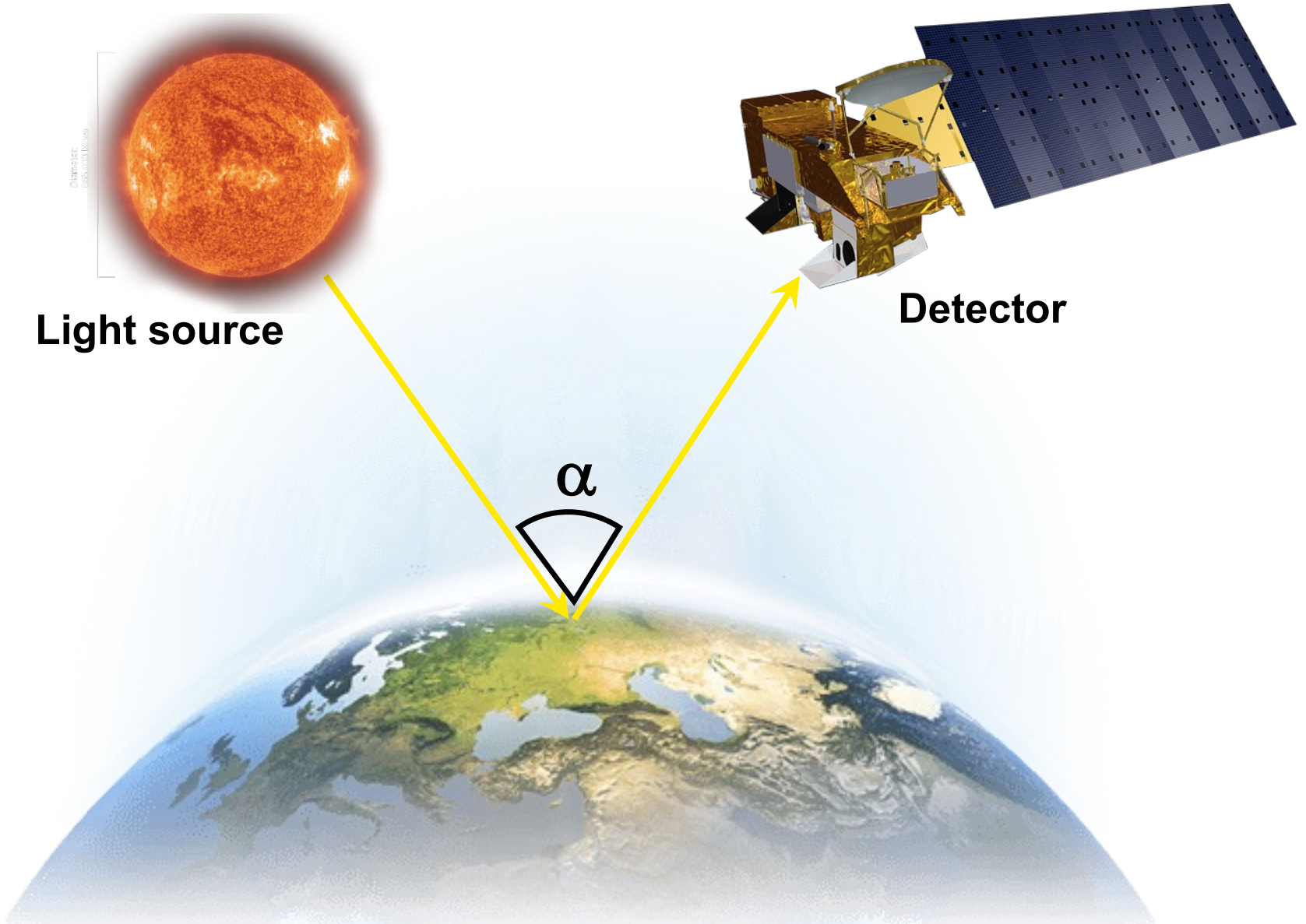
1.0 × 10^{16} molecules HCHO cm^{-2}

3.0 × 10^{16} molecules HCHO cm^{-2}

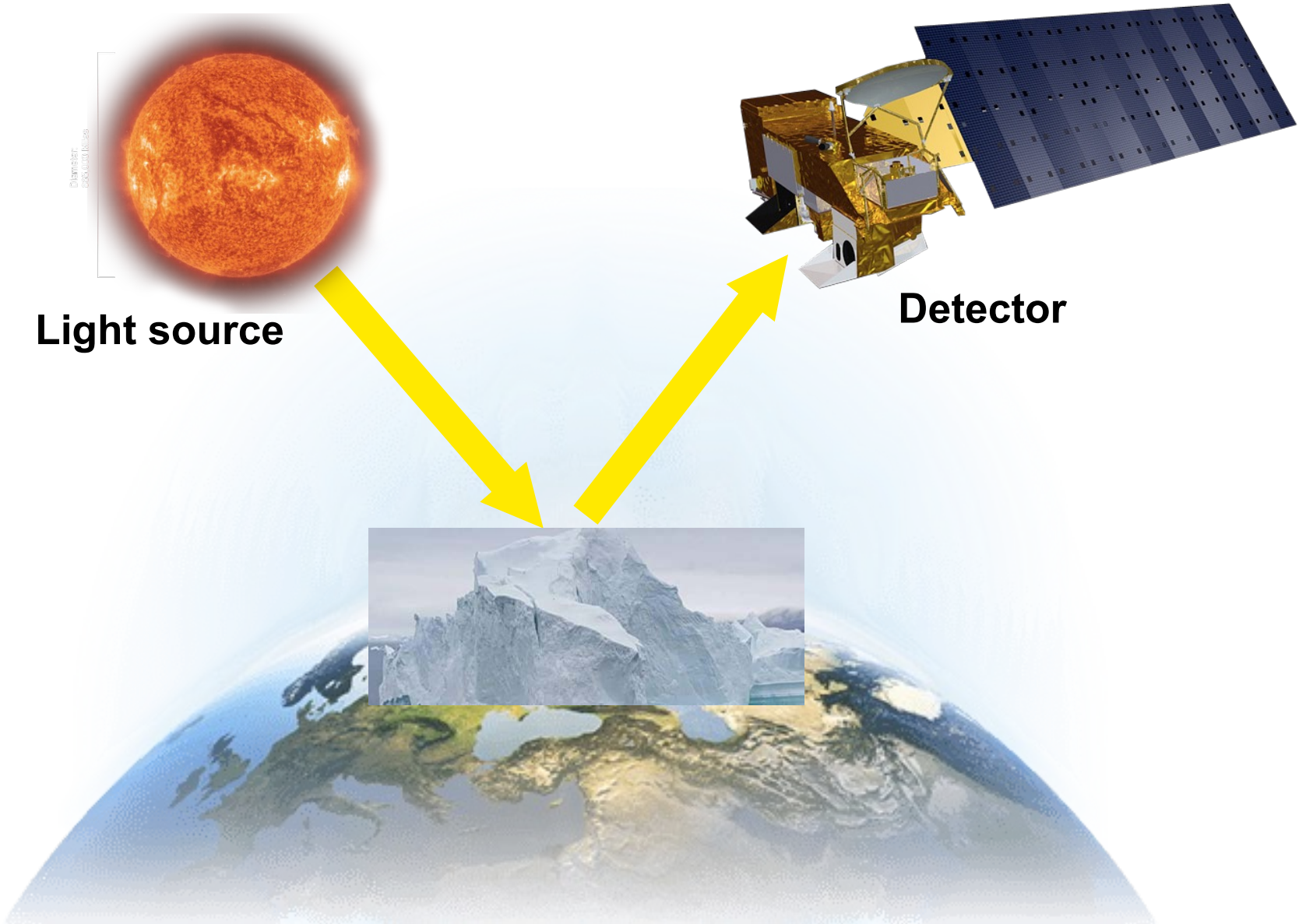
8.4 × 10^{16} molecules HCHO cm^{-2}

Source: Chance et al. 2000, https://doi.org/10.1029/2000GL011857

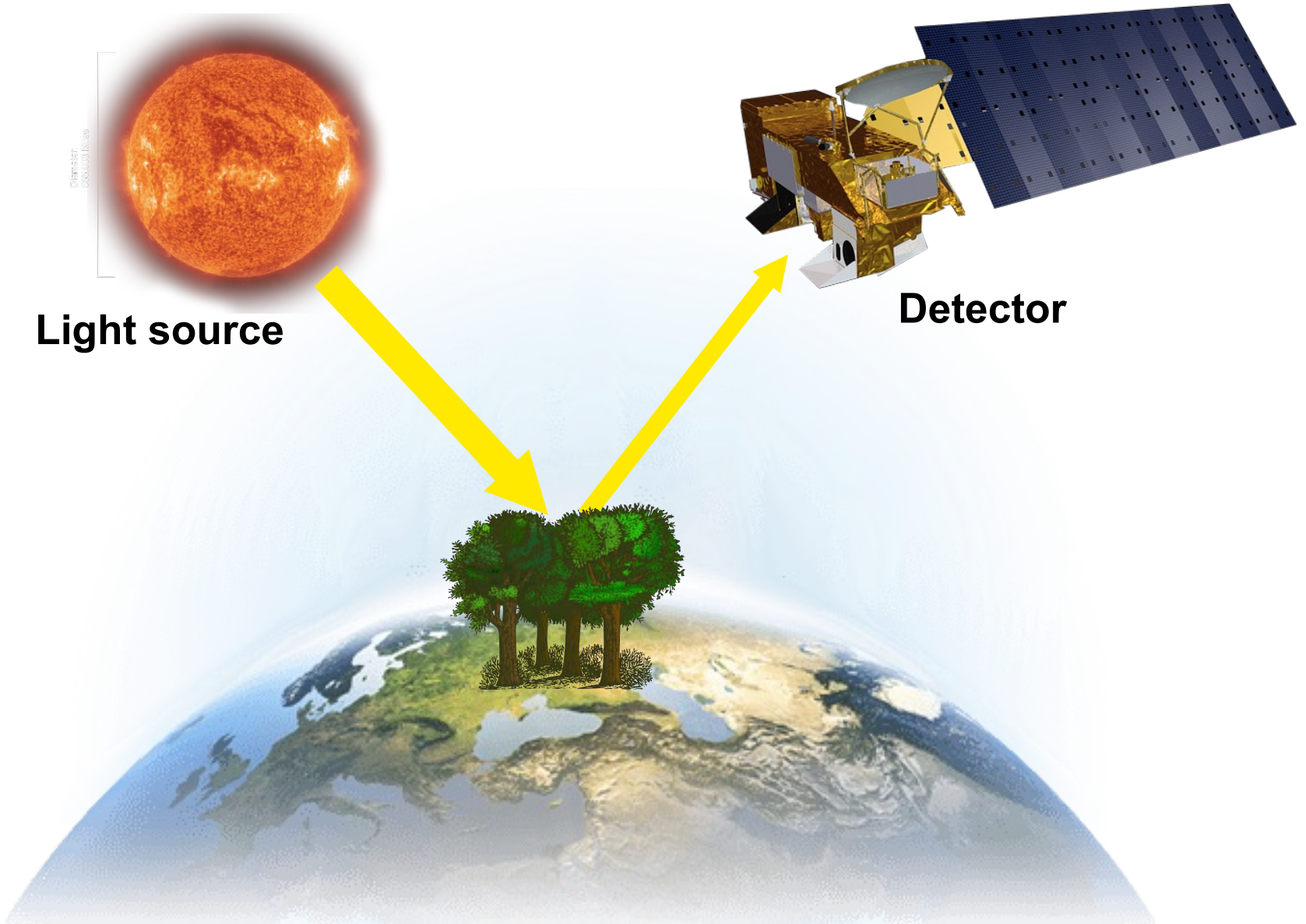
Slant Column Geometry



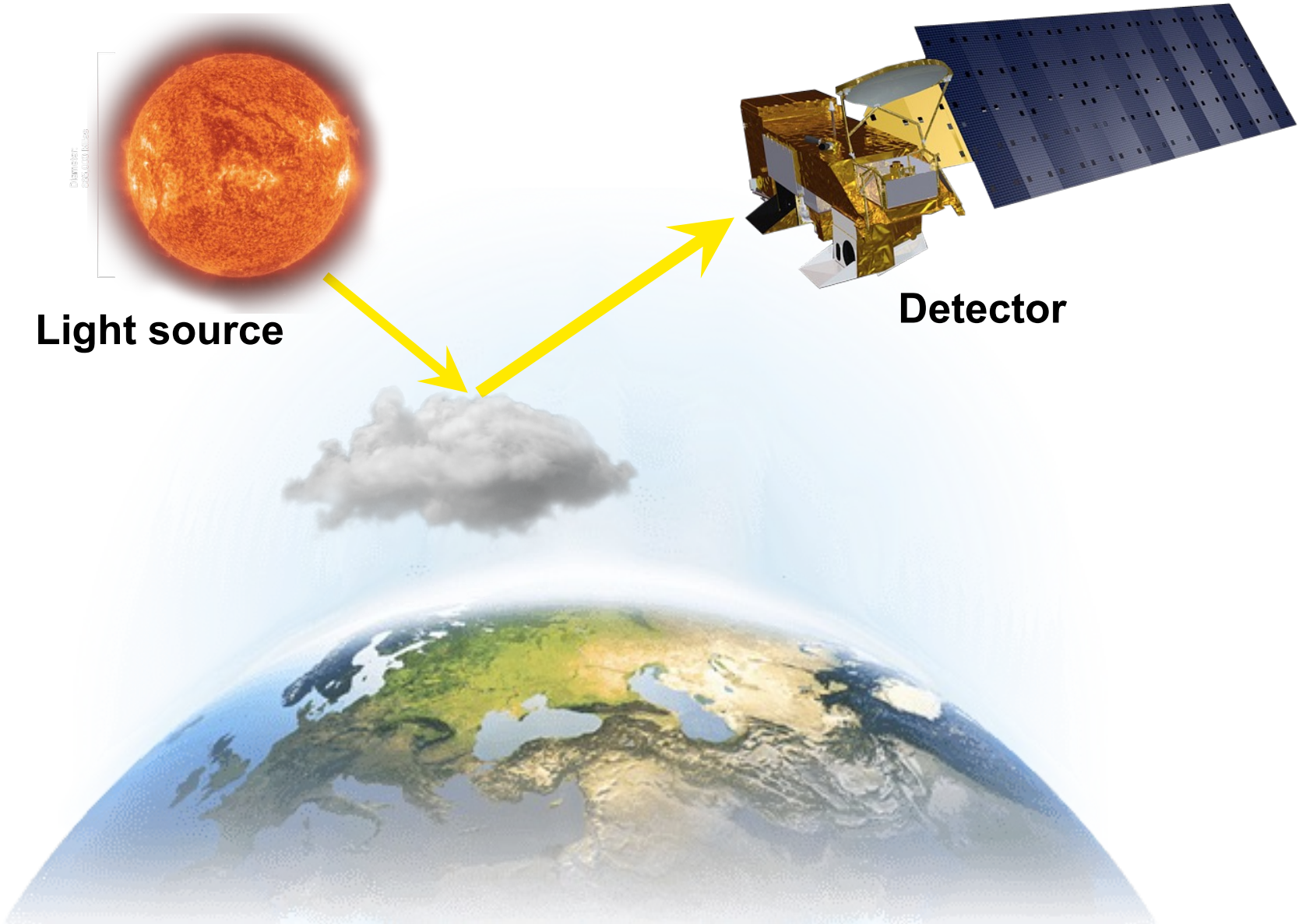
Surface Reflectivity



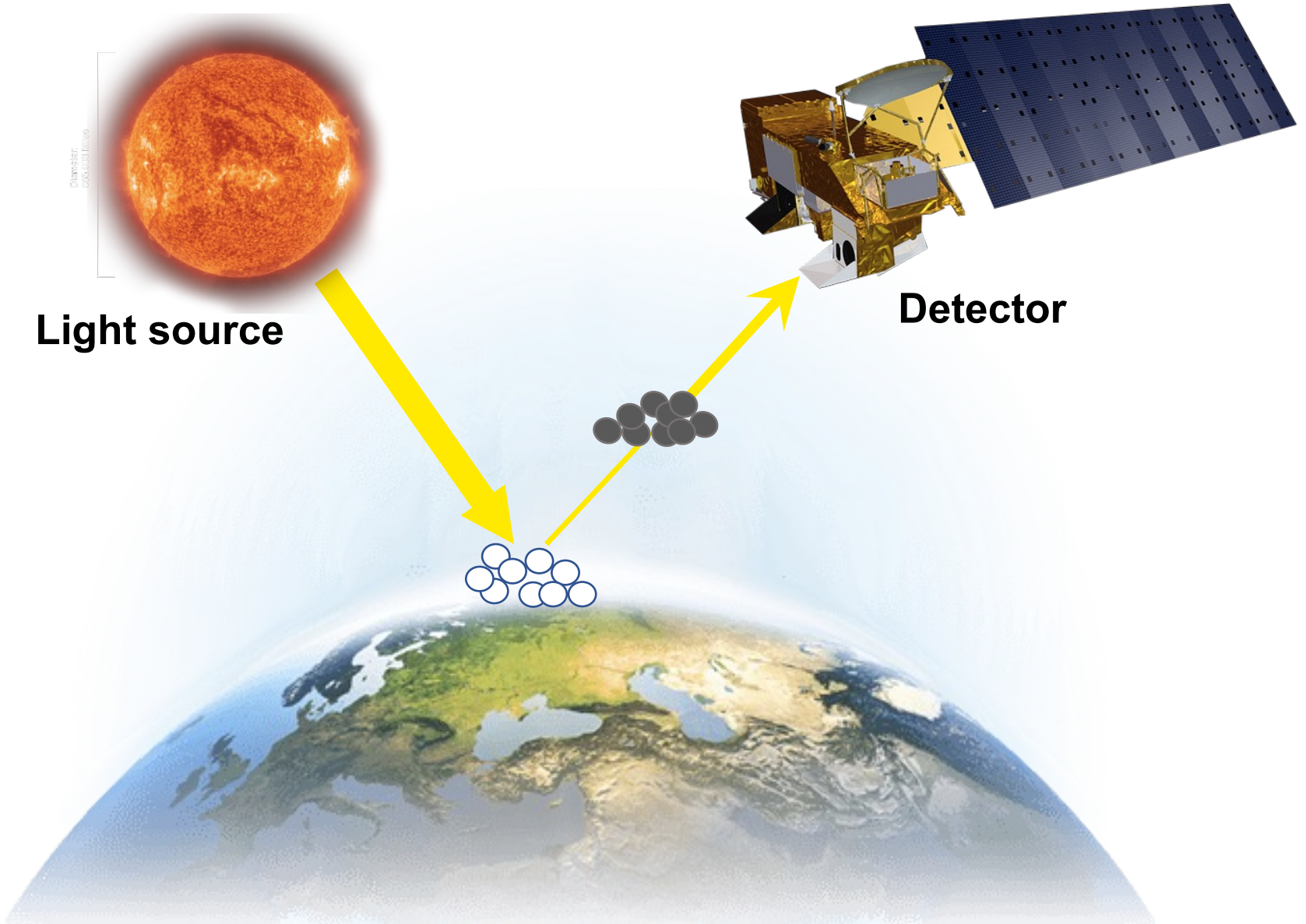
Surface Reflectivity



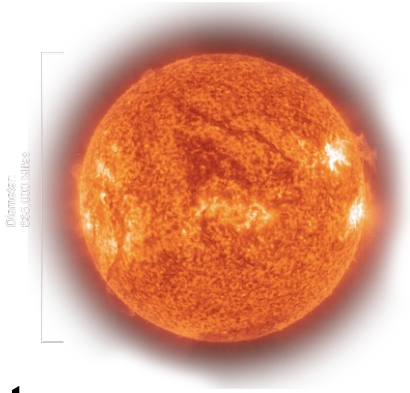
Clouds



Aerosols

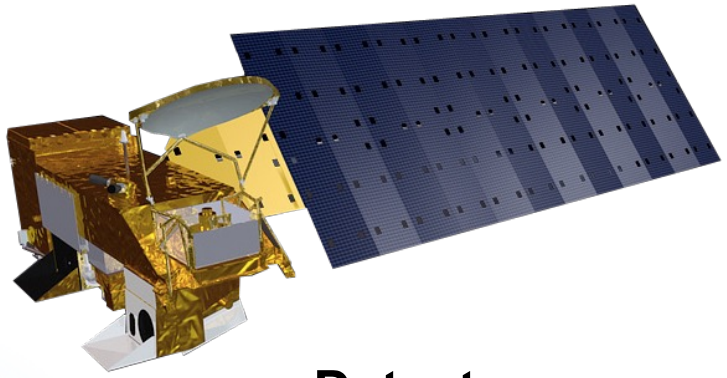


“True” Vertical Column



Light source

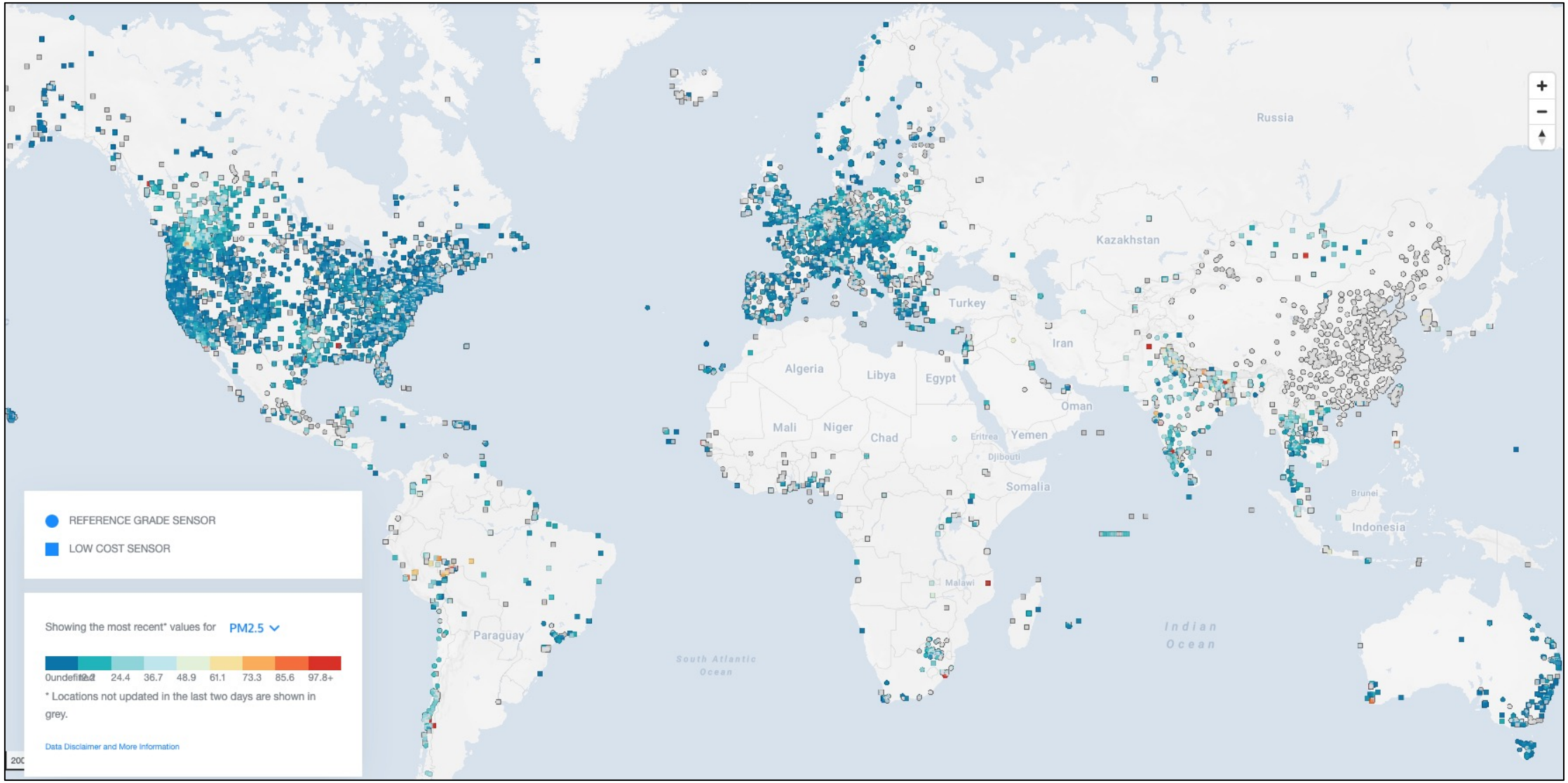
Vertical column abundance



Detector

→ Evaluate models
→ Estimate emissions
→ Understand air pollution
→ Derive trends
→ Assess year-to-year variability

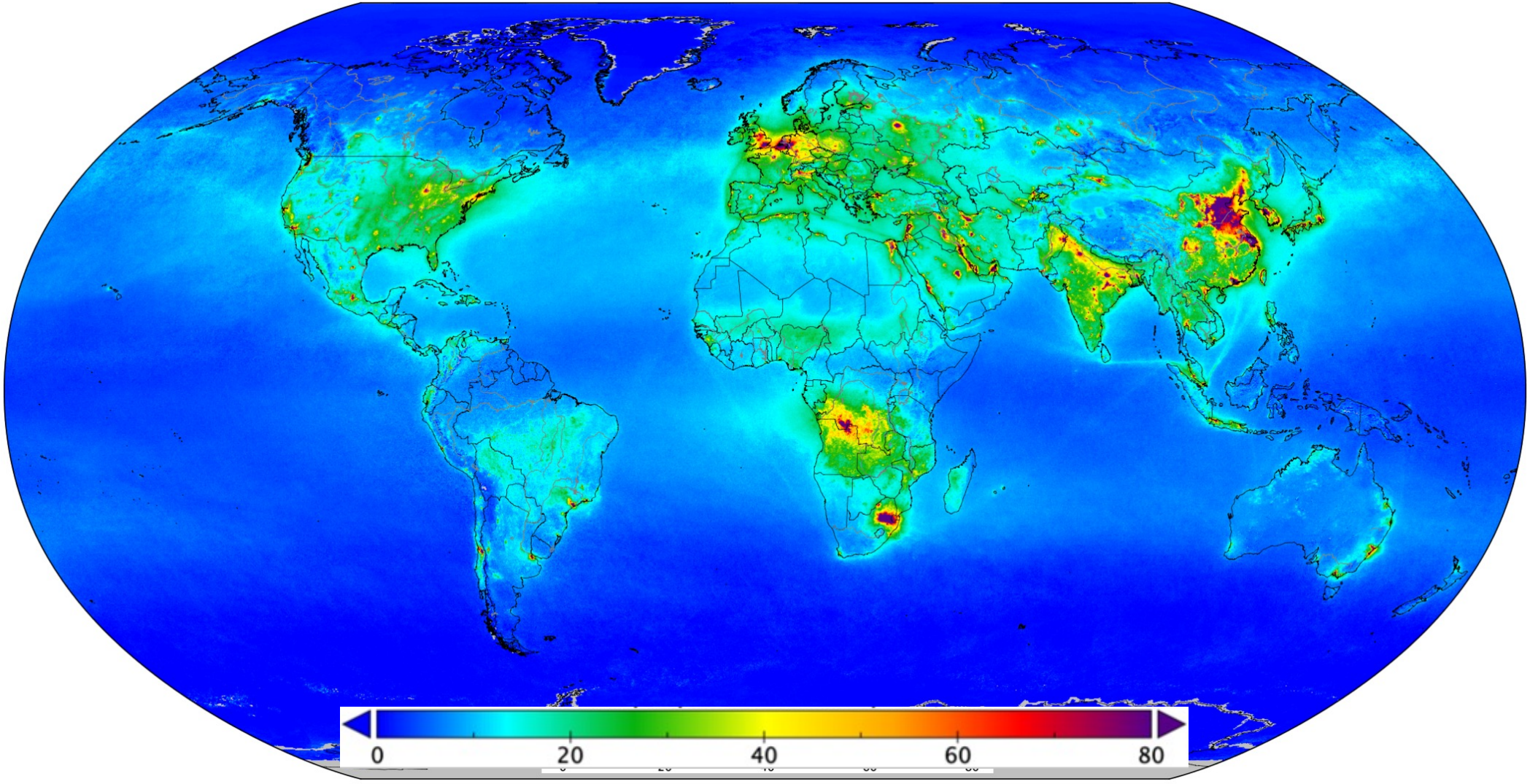
In-situ measurements have large gaps



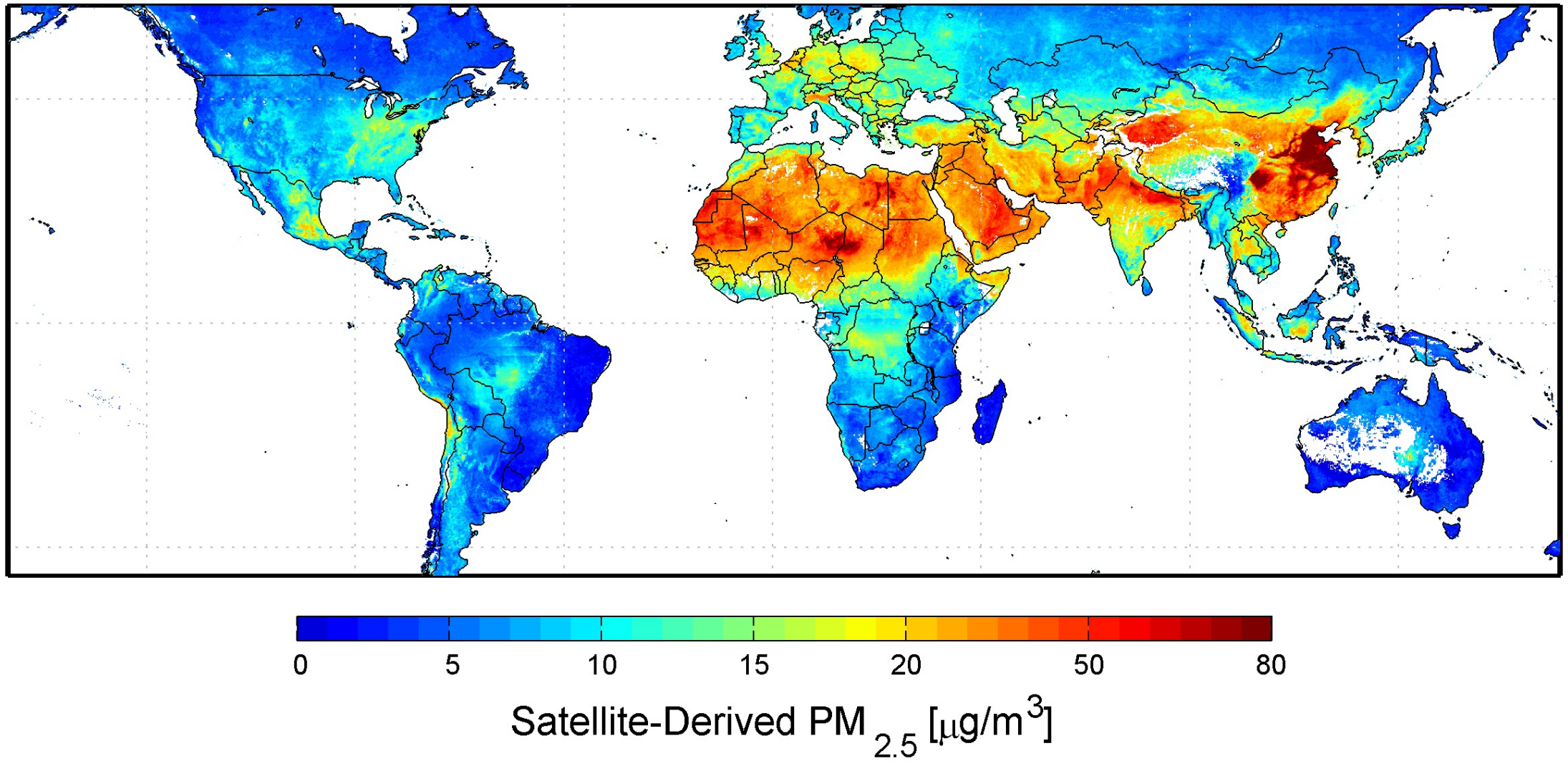
[Source: OpenAQ, https://openaq.org/#/map, accessed 29 Sept 2022]

Satellite observations offer global coverage

Vertical column densities of NO_2 [$\mu mol\ m^{-2}$]



Satellite observations used to derive $PM_{2.5}$

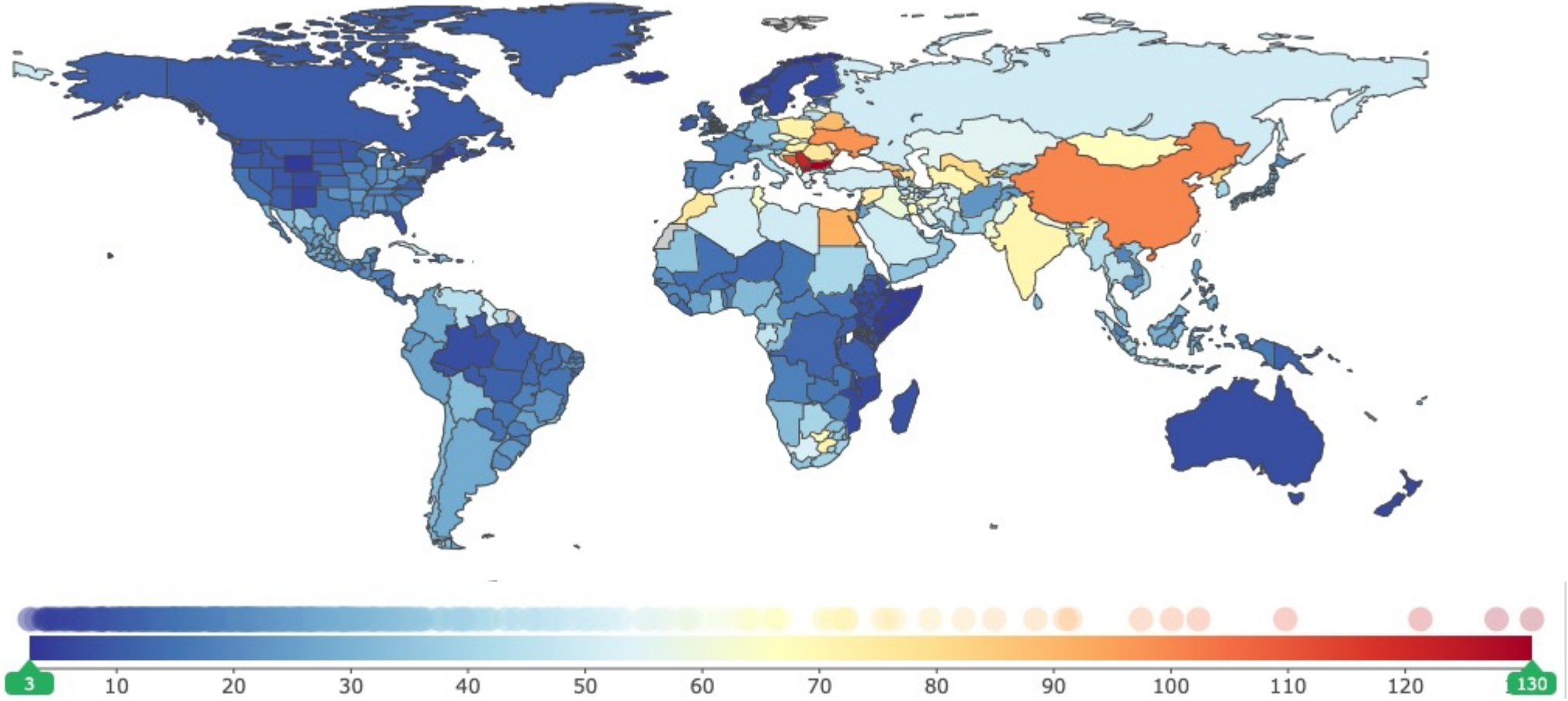


[Source: https://doi.org/10.1016/j.envres.2012.08.005]

Application beyond scientific research

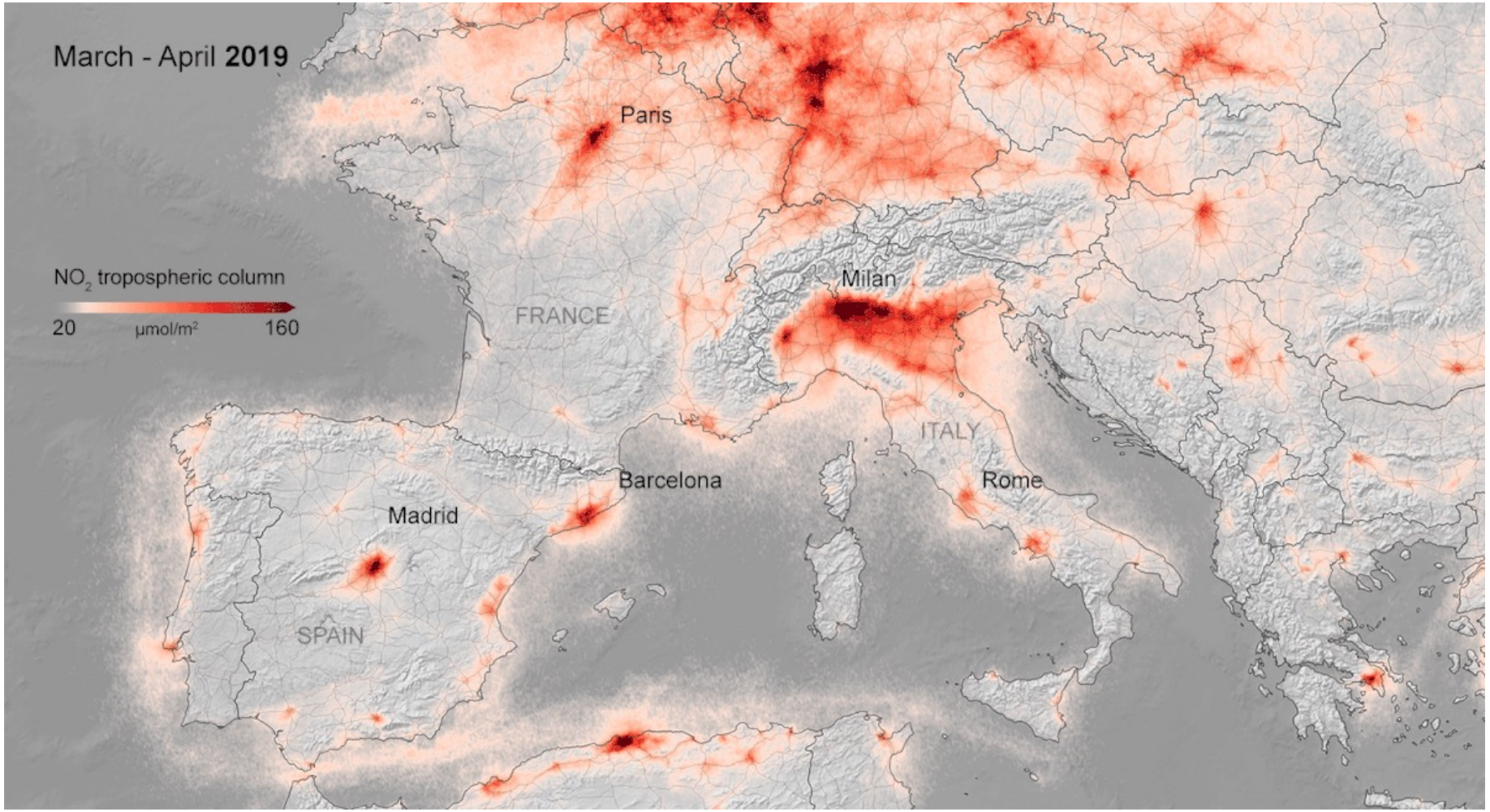
Public health burden of exposure to fine particles ($PM_{2.5}$): https://vizhub.healthdata.org/gbd-compare/

Premature deaths per 100,000 attributed to exposure to ambient (outdoor) $PM_{2.5}$



Application beyond scientific research

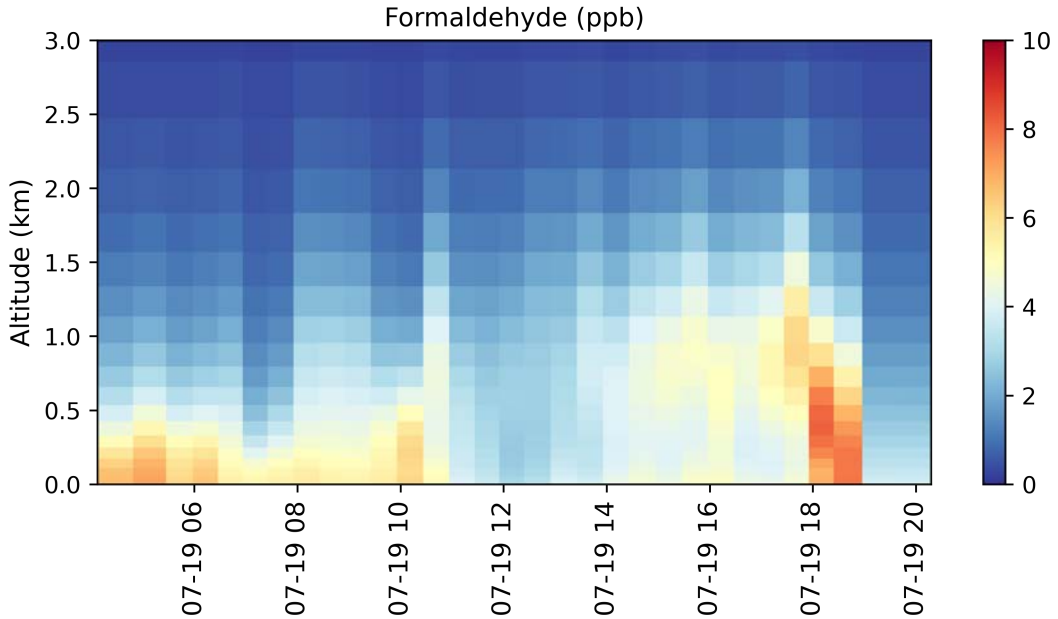
Abrupt decline in air pollution during COVID-19 lockdowns

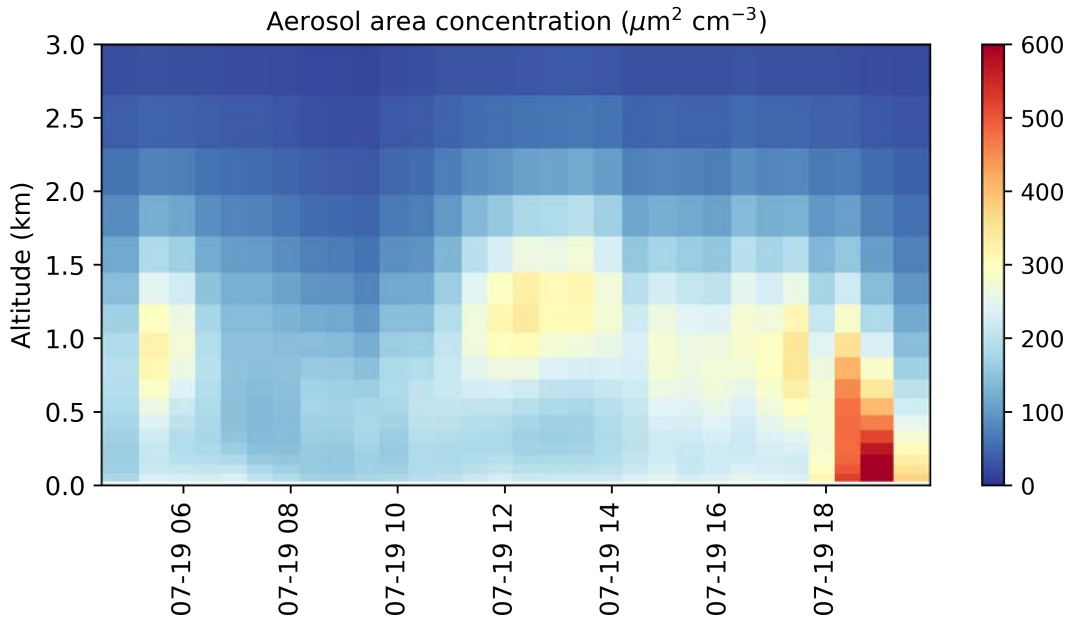


[Source: ESA]

Research group projects using remote sensing and related research tools

Examining the vertical extent of heatwave and wildfire pollution

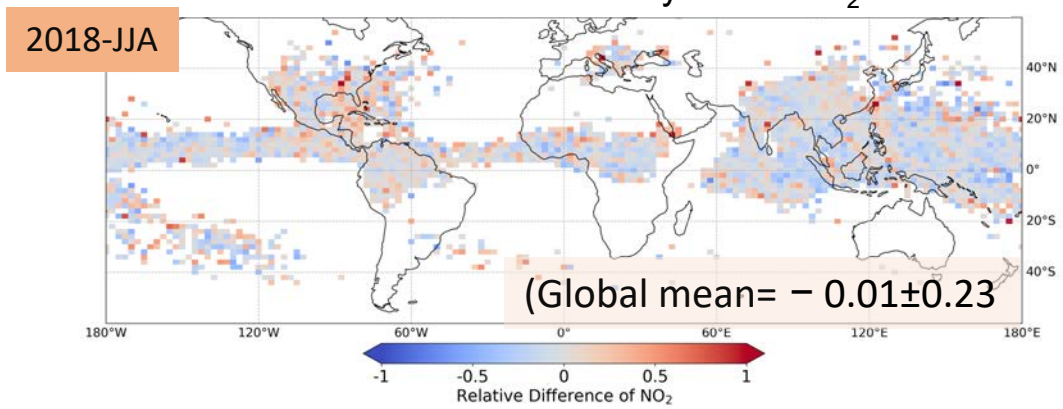




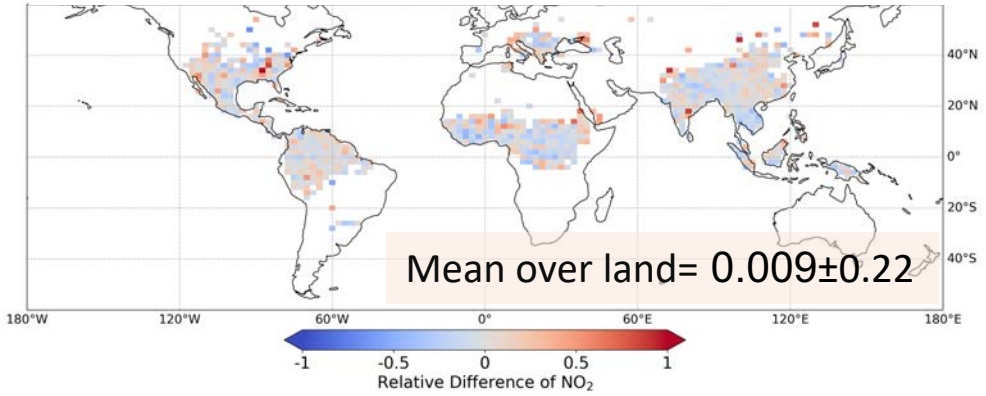
Seasonal and Interannual variability of NO_x determined with cloud-sliced TROPOMI NO_2 data

We're using new data of NO_2 concentrations to quantify for the first time year-to-year variability in NO_x in the global upper troposphere

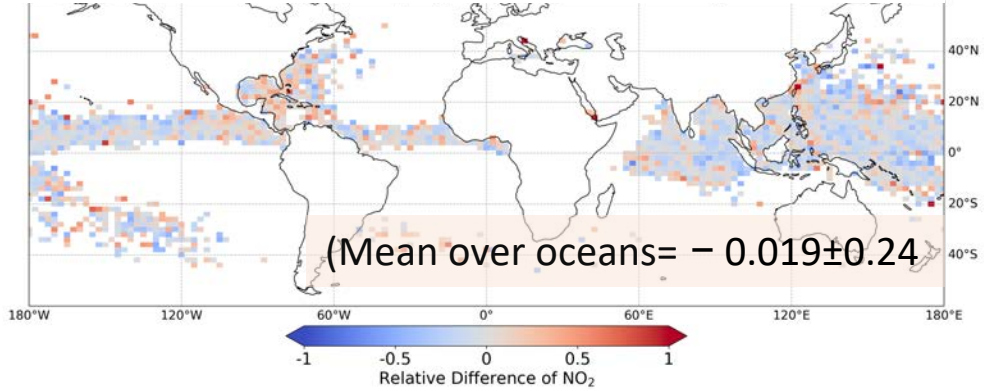
Interannual variability of UT NO_2



Interannual variability of UT NO_2 over land



Interannual variability of UT NO_2 over oceans



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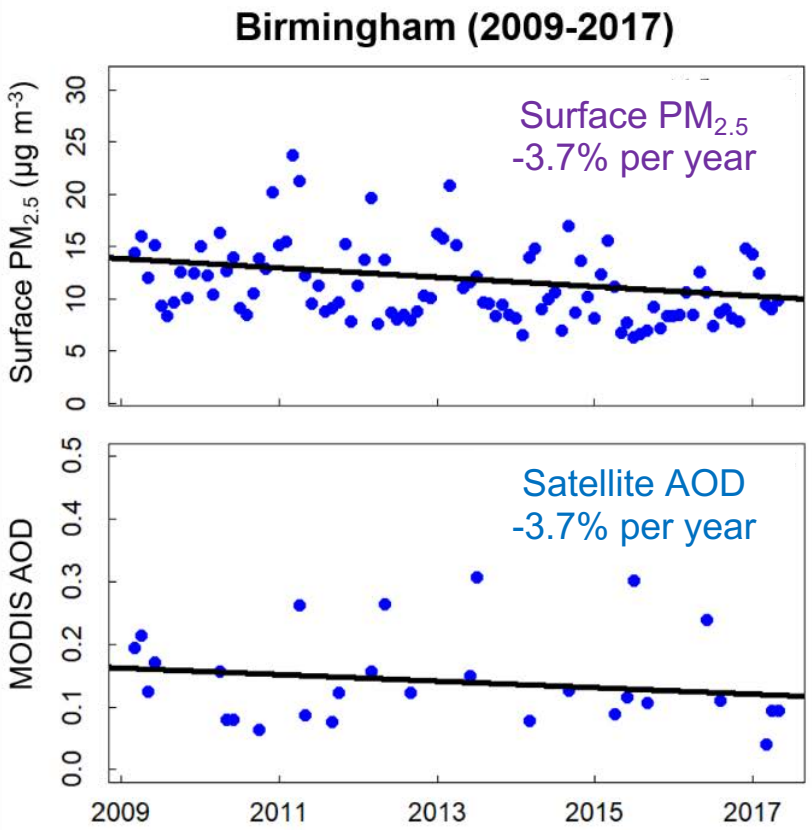
Application of remote sensing to quantify trends in air quality in cities

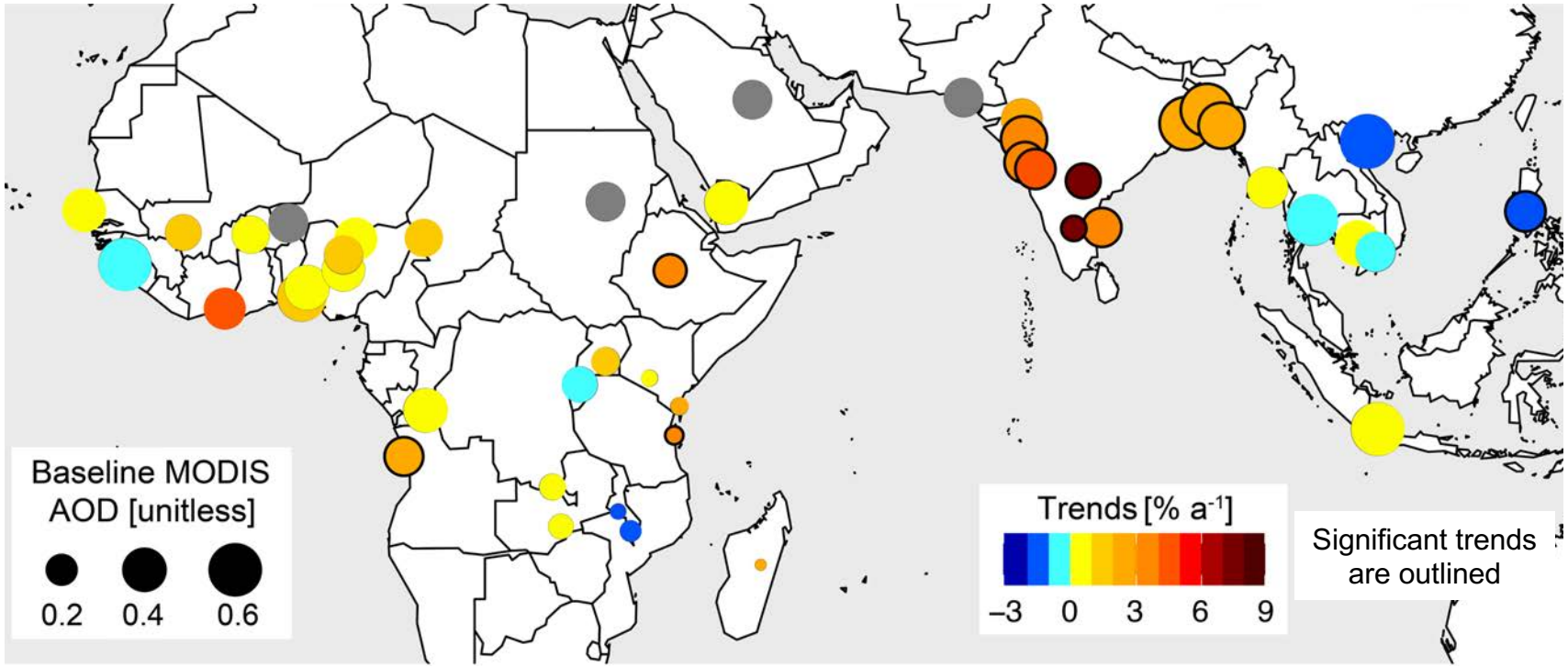
We evaluate satellite observations with surface measurements and use the quality assured data to identify rapid air quality degradation in the future megacities of the world.

Satellite AOD vs surface $PM_{2.5}$



AOD reproduces long-term trends in surface $PM_{2.5}$

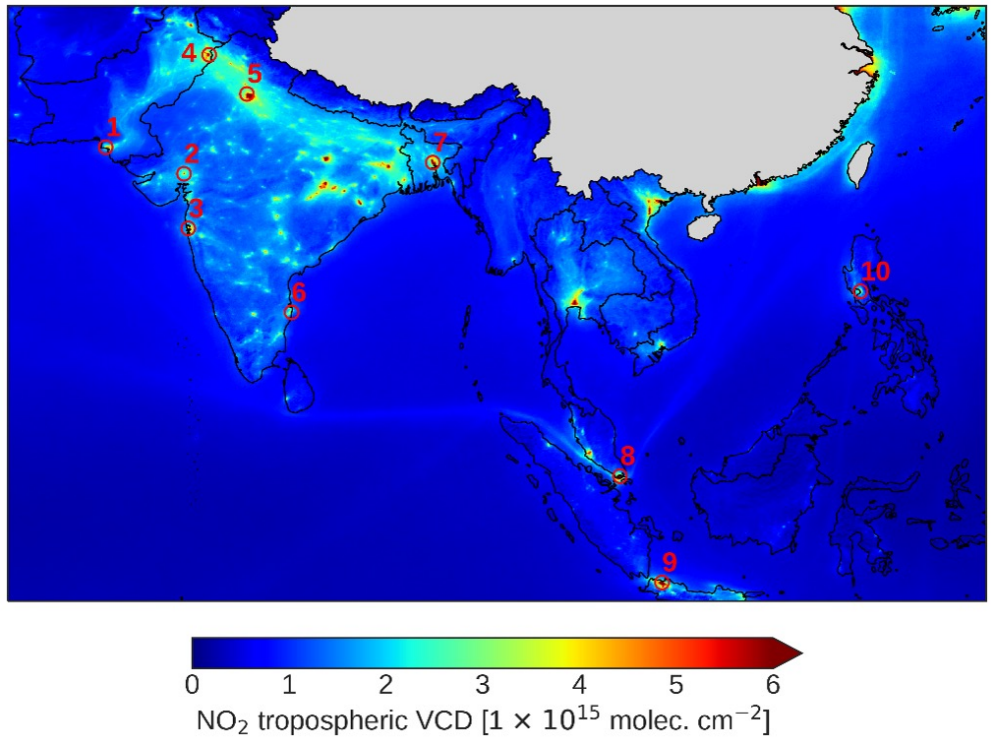
Long-term (2005-2018) trends in surface $PM_{2.5}$ in fast-growing tropical cities



Large and significant increases of 3-8 % per year in $PM_{2.5}$ over the Indian subcontinent and in 3 African cities

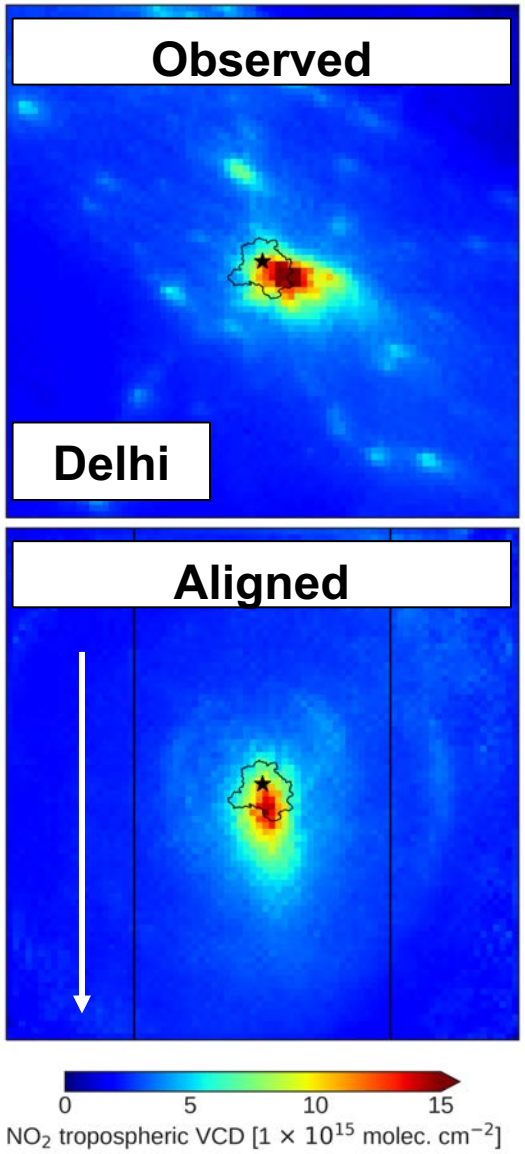
Estimating NO_x Emissions in Cities in Asia using a Plume-Rotation Technique

1. Identify NO_2 pollution hotspots



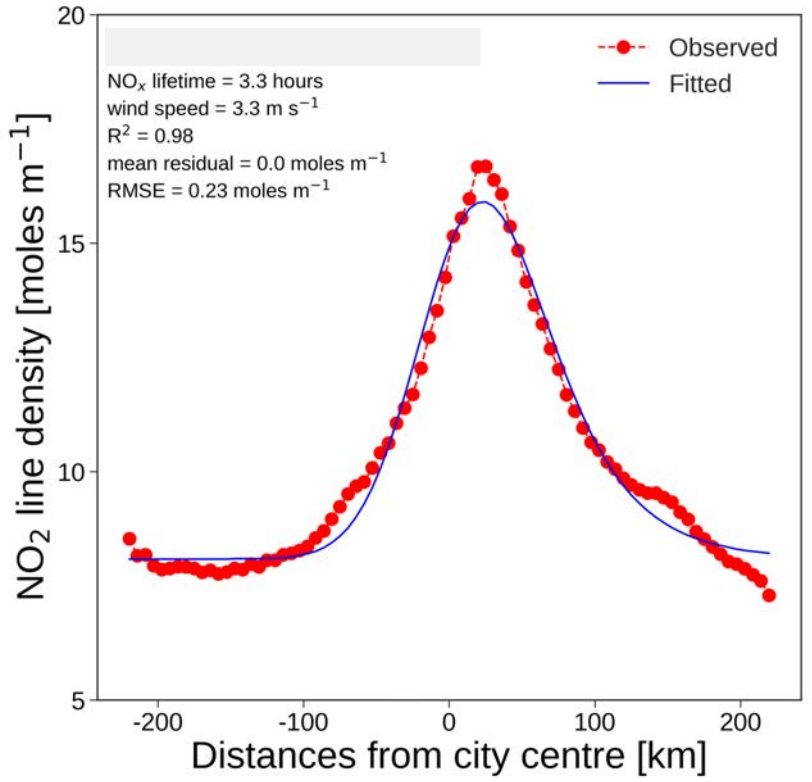
NO_x is emitted during high-temperature combustion by cars, power plants and ships

2. Align NO_2 plumes



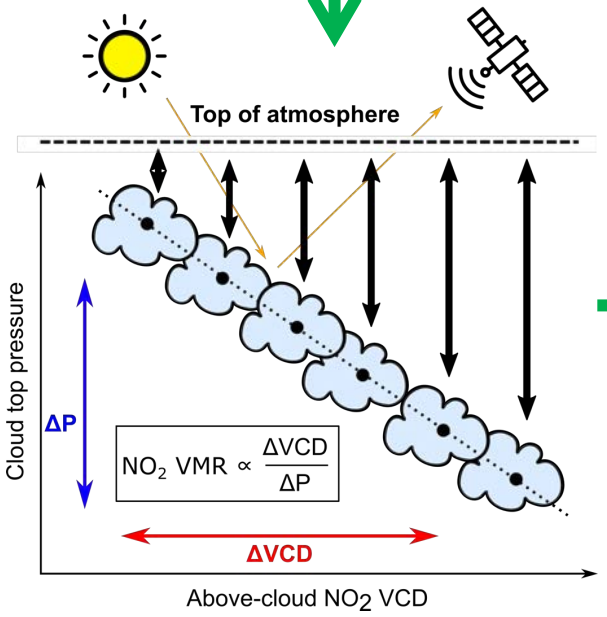
3. Estimate NO_x emissions

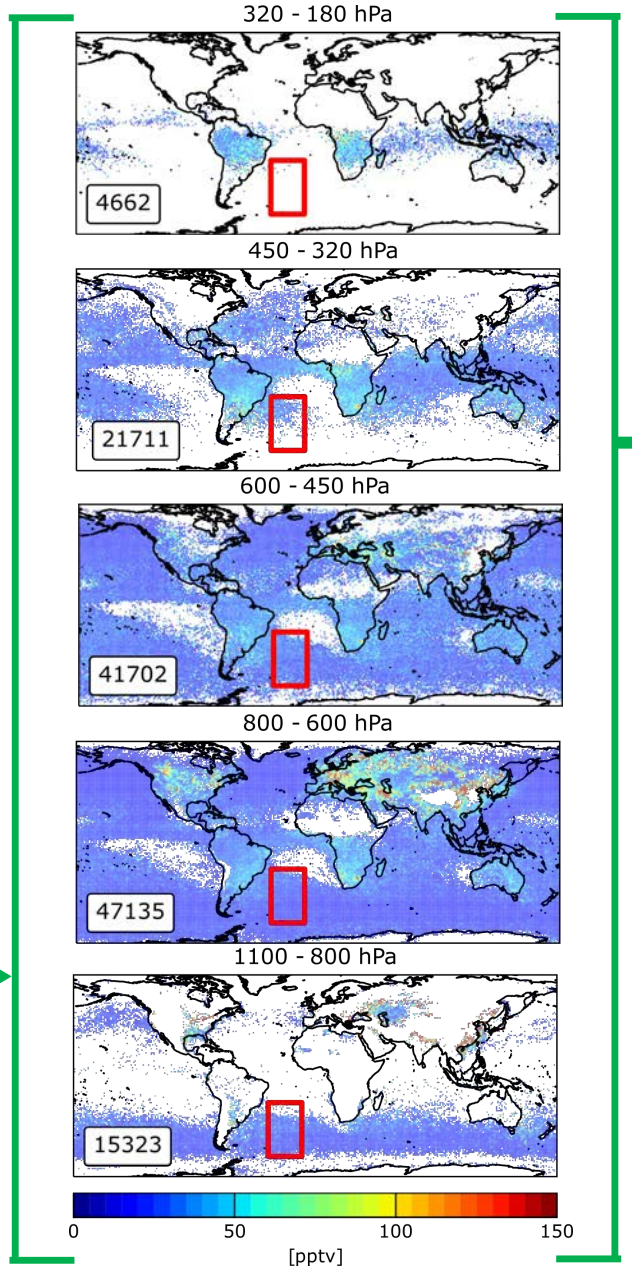
$$F(x \mid a, x_0, \mu_x, \sigma_x, B) = \frac{a}{2x_0} \exp\left(\frac{\mu_x}{x_0} + \frac{\sigma_x^2}{2x_0^2} - \frac{x}{x_0}\right) \operatorname{erfc}\left(-\frac{1}{\sqrt{2}}\left[\frac{x-\mu_x}{\sigma_x} - \frac{\sigma_x}{x_0}\right]\right) + B$$



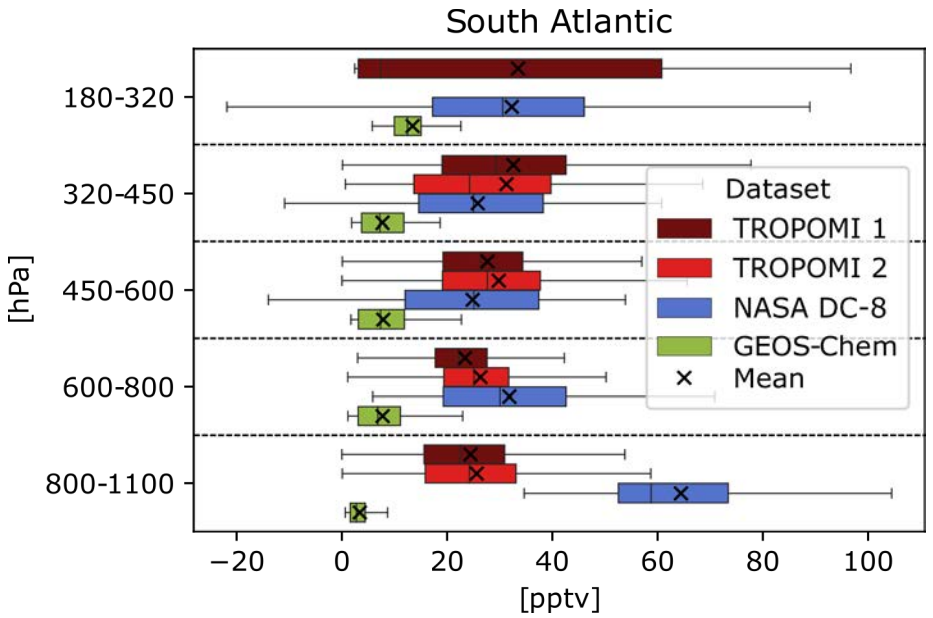
Delhi NO_x emissions in 2019: ~141 kilotonnes

Using the cloud-slicing technique to obtain NO_2 data from the TROPOMI instrument aboard the Sentinel-5P satellite





Mean and median cloud-slicing results compared to aircraft observations from NASA DC-8 and simulations from the GEOS-Chem model



Data for DJF 2018 to 2021 are shown here with the box plots representing the median value with the 5th, 25th, 75th and 95th percentiles.

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- Health burden of **fossil fuels** on global and national scales
- Ecosystem and health impact of **agricultural emissions** of ammonia in the UK
- **Urban** sources of **fine particles** in UK cities
- Emissions estimates of **emergent pollution sources** like powerships in South Africa

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