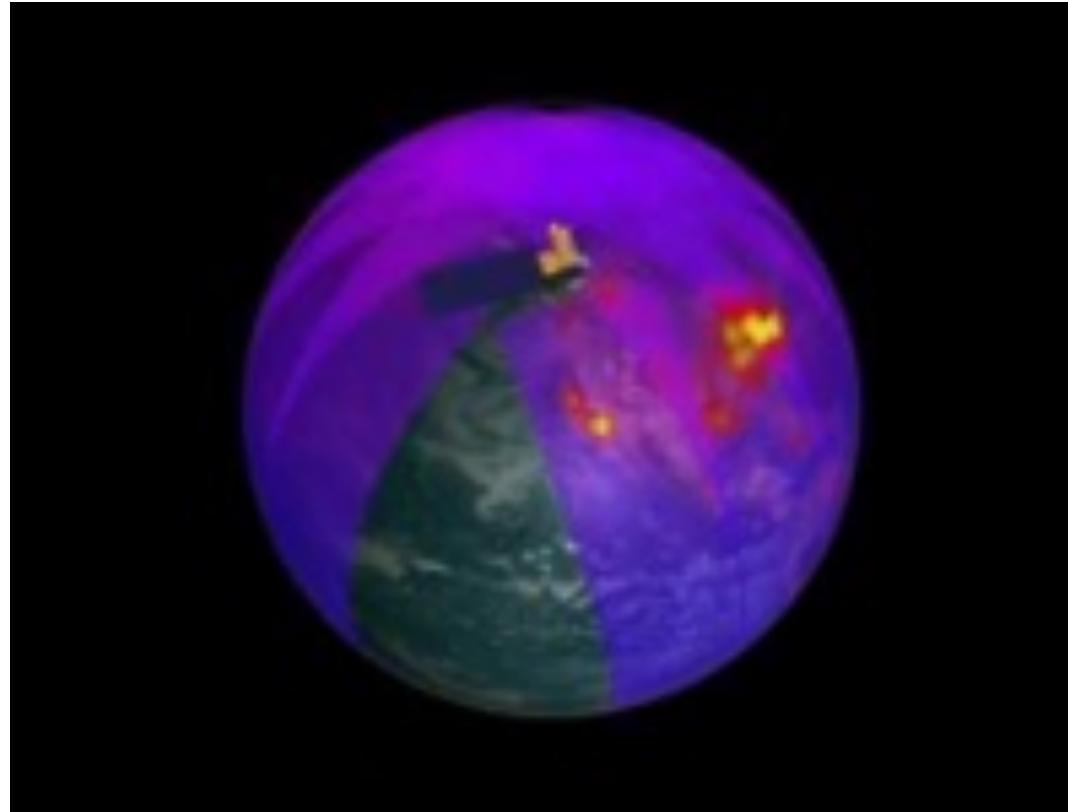


Remote Sensing of the Atmosphere

NERC London DTP Induction Week



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30 September 2022

UCL Atmospheric Composition and Air Quality Group

<https://maraisresearchgroup.co.uk/>



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Atmospheric Composition and Air Quality Group



Projects

Group Info

Publications

Datasets

Presentations

Education

Media Coverage

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.

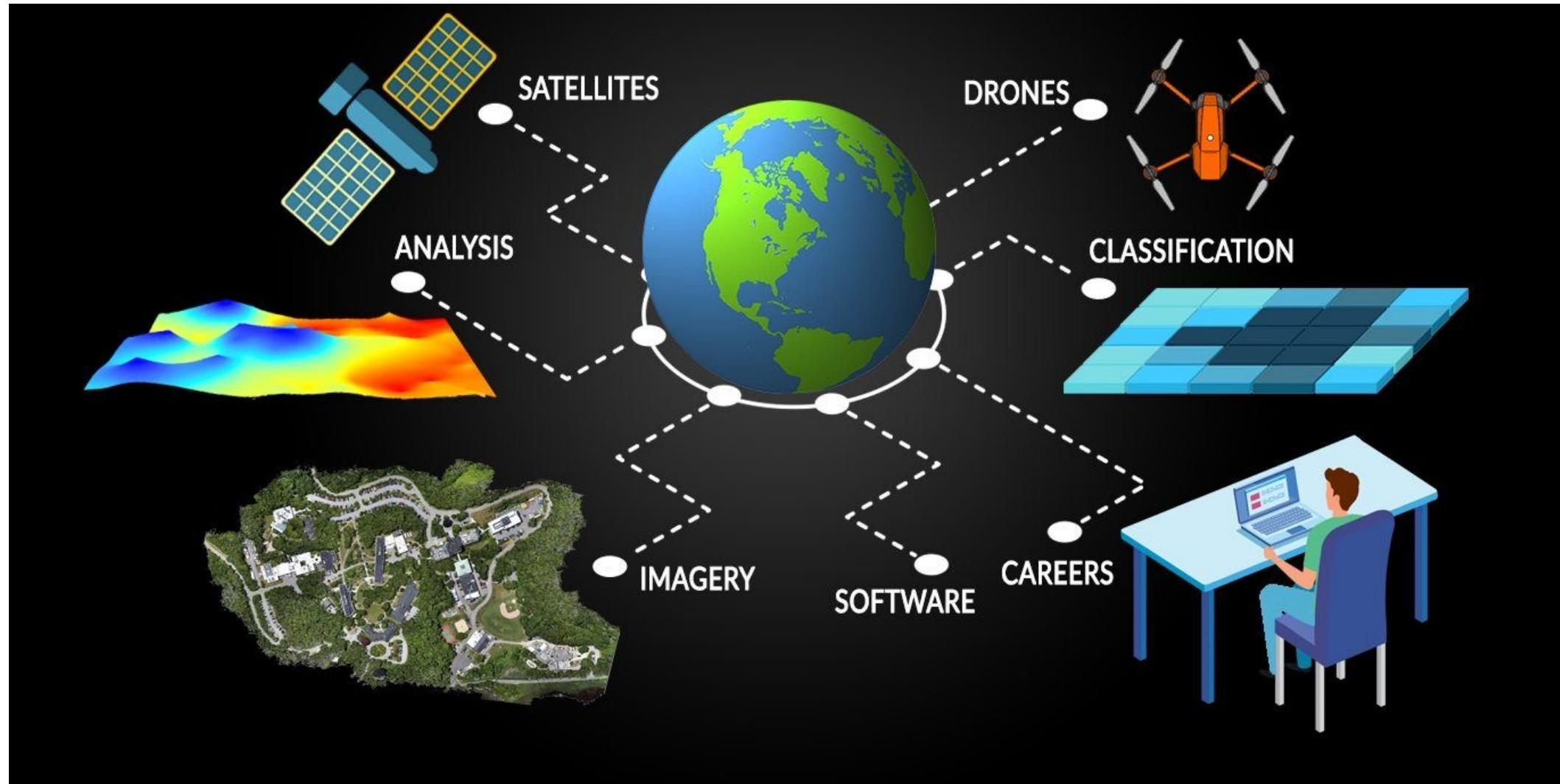
Recent news and highlights from our group:



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

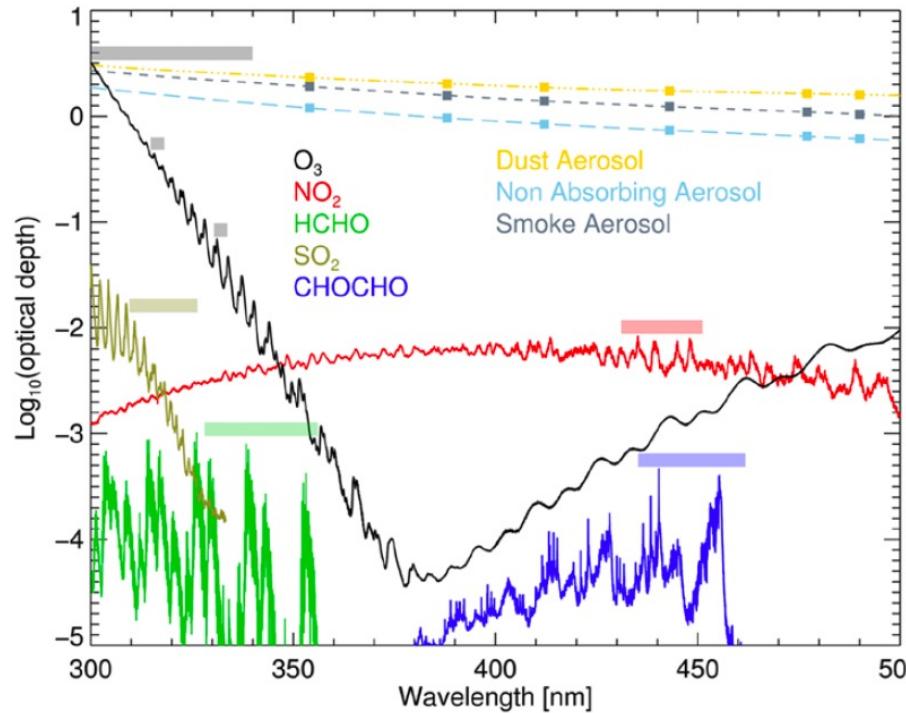
Remote Sensing

Acquire information about an object with no physical contact



Measure reflected and emitted radiation

UV-visible

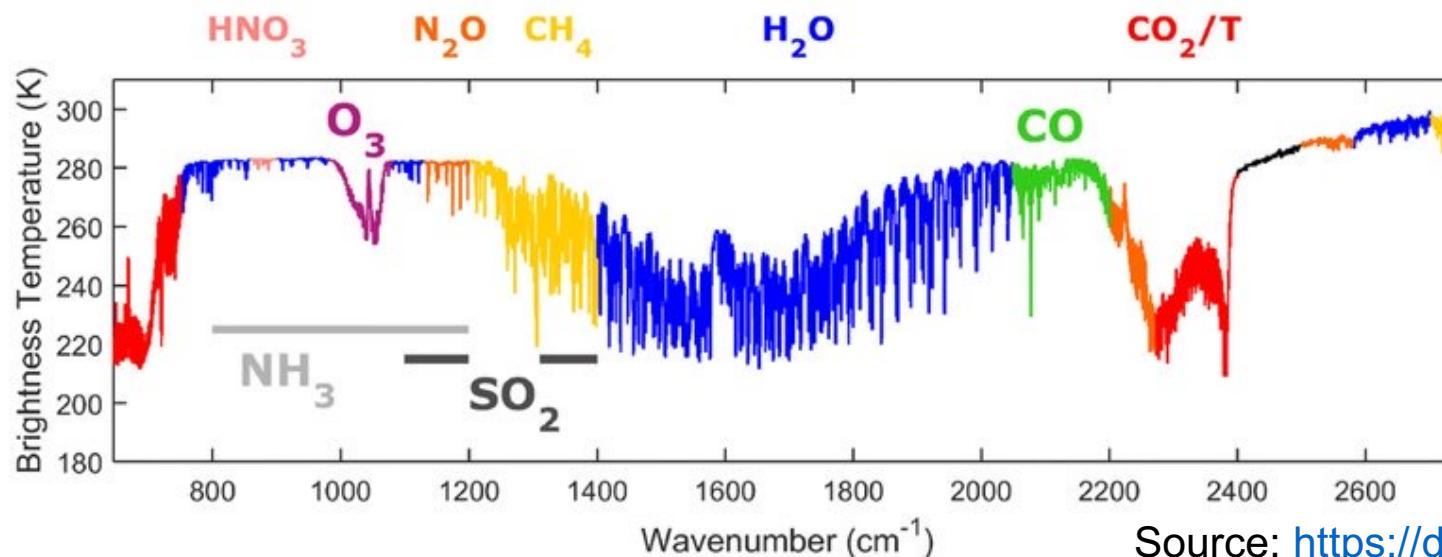


Nitrogen dioxide (NO₂)
Formaldehyde (HCHO)
Glyoxal (CHOCHO)
Sulfur dioxide (SO₂)
Ozone (O₃)

Also Aerosol Optical Depth (AOD)

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

Infrared (IR)



Ozone (O₃)
Ammonia (NH₃)
Sulfur dioxide (SO₂)
Nitric acid (HNO₃)

Source: <https://doi.org/10.1111/12.2584500>

Remote sensing of the atmosphere from the ground

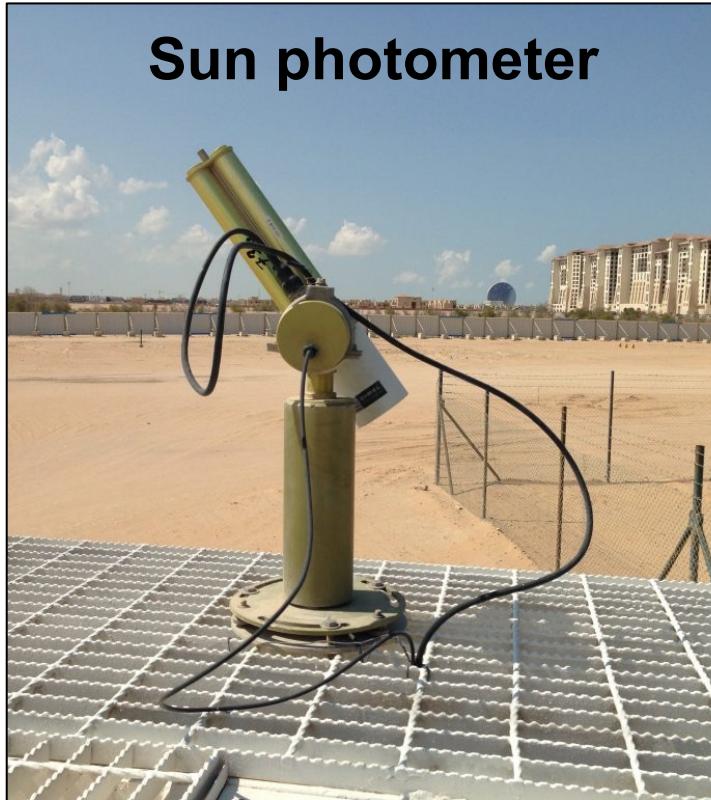
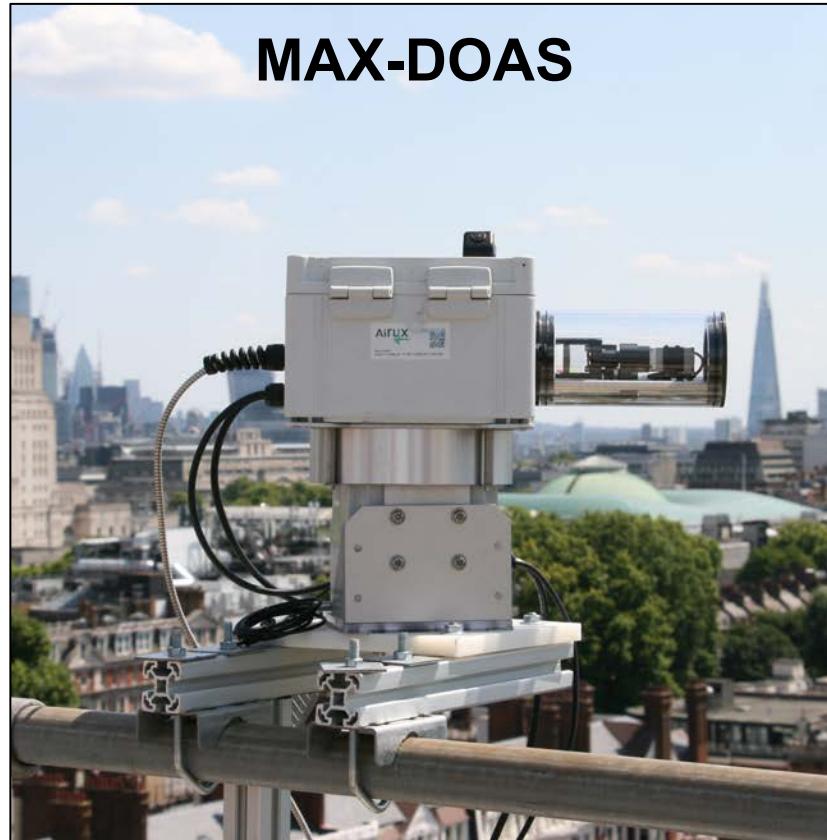
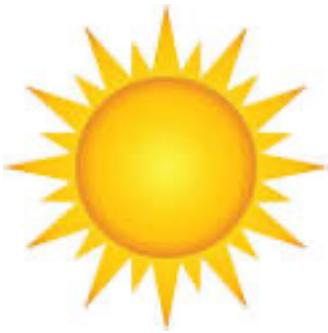
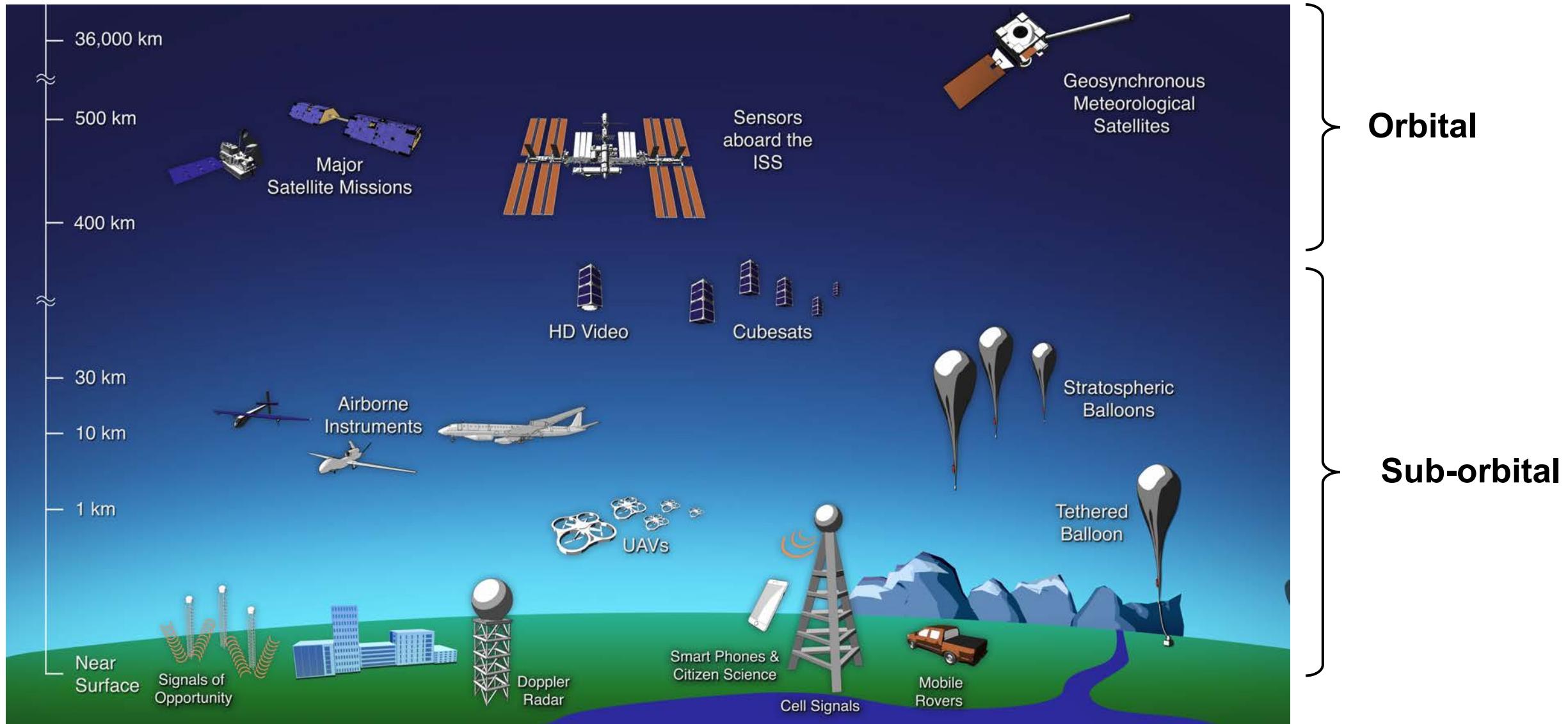


Photo of **our instrument** on the
rooftop of a 10-story UCL building

Remote sensing of the atmosphere from above





Public Health England

HCHO

Health Matters

Air pollution: sources,
impacts and actions

NMVOC

Health Matters

NH₃

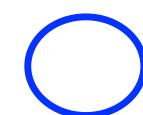
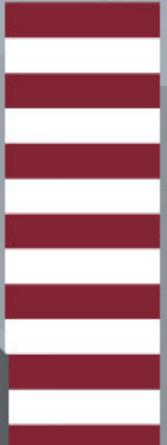
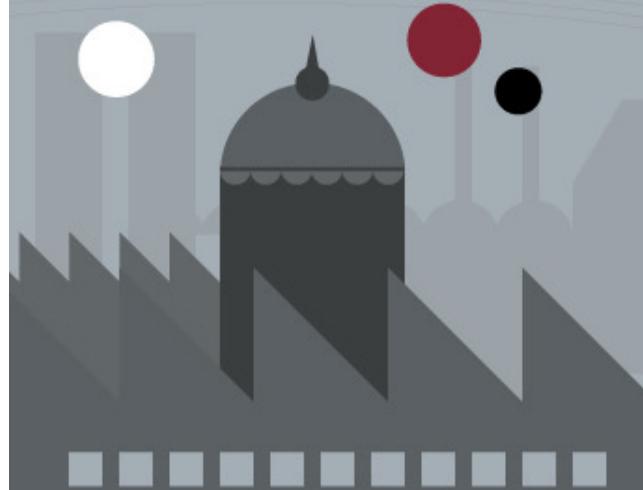
PM_{2.5}

AOD

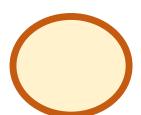
SO₂

NO_x

NO₂

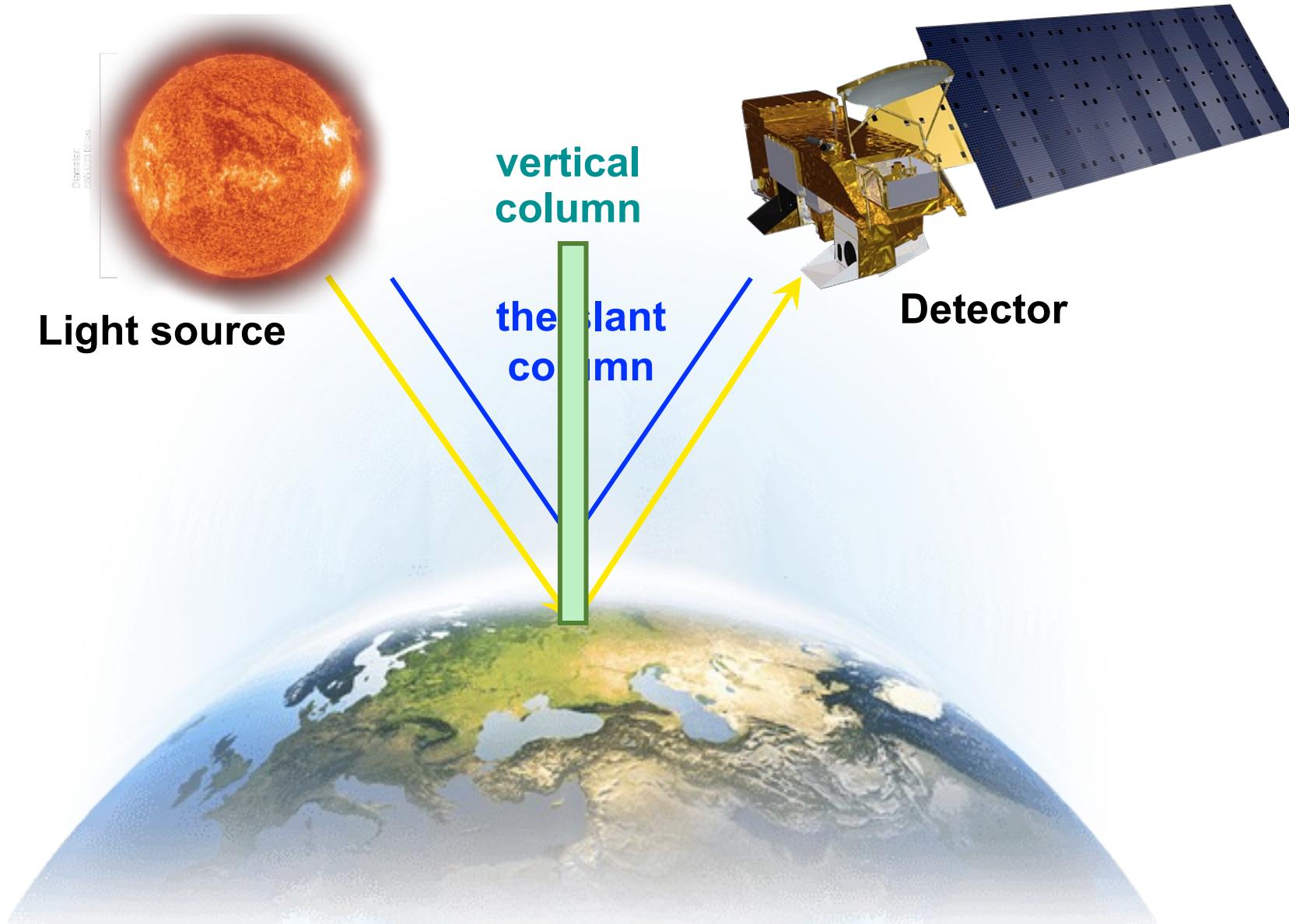


Directly detected with remote sensing



Indirect (proxy) detected

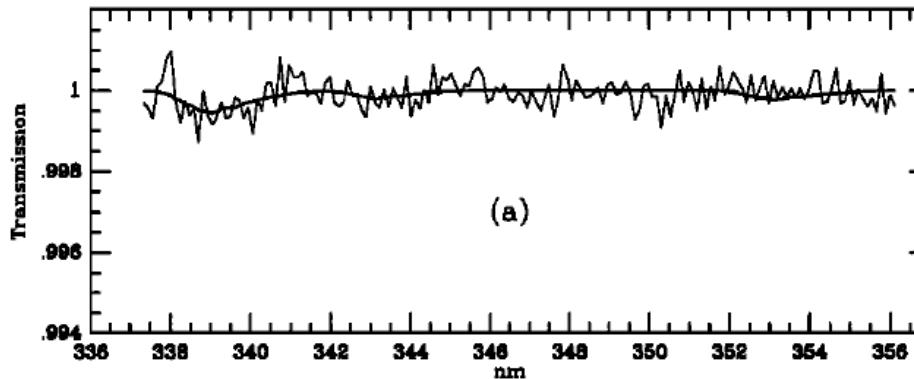
Space-based remote sensing of the atmosphere



Spectral Fit along a slant column

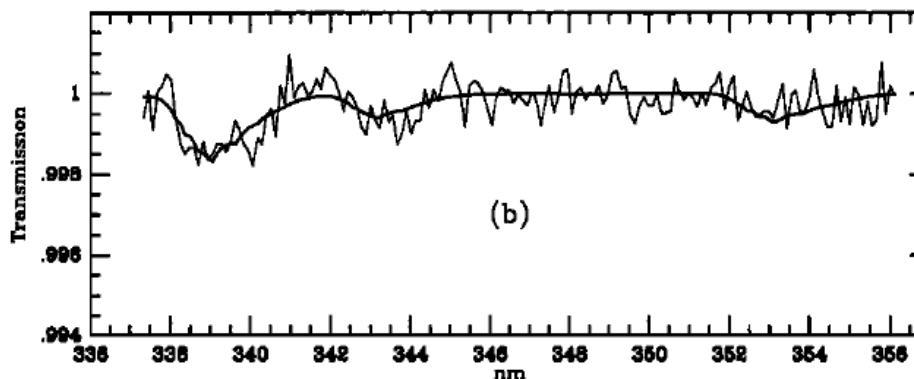
Formaldehyde (HCHO):

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



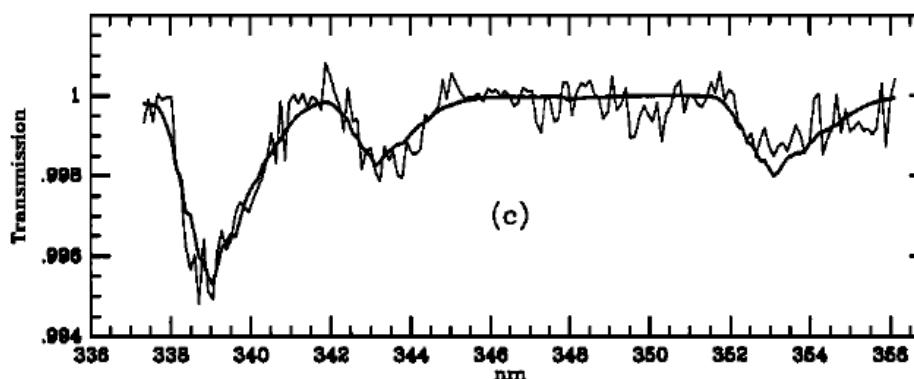
(a)

1.0×10^{16} molecules HCHO cm⁻²



(b)

3.0×10^{16} molecules HCHO cm⁻²

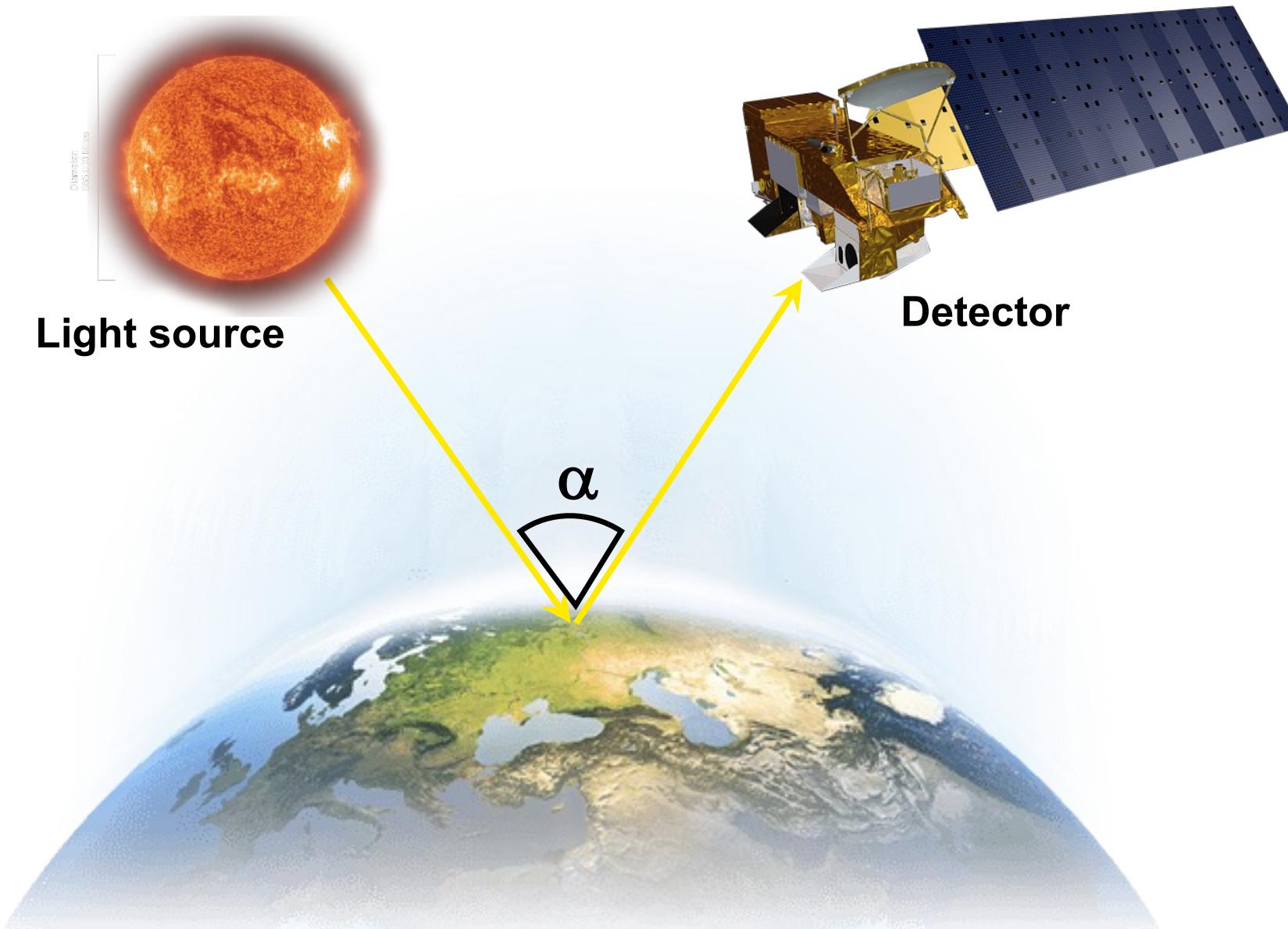


(c)

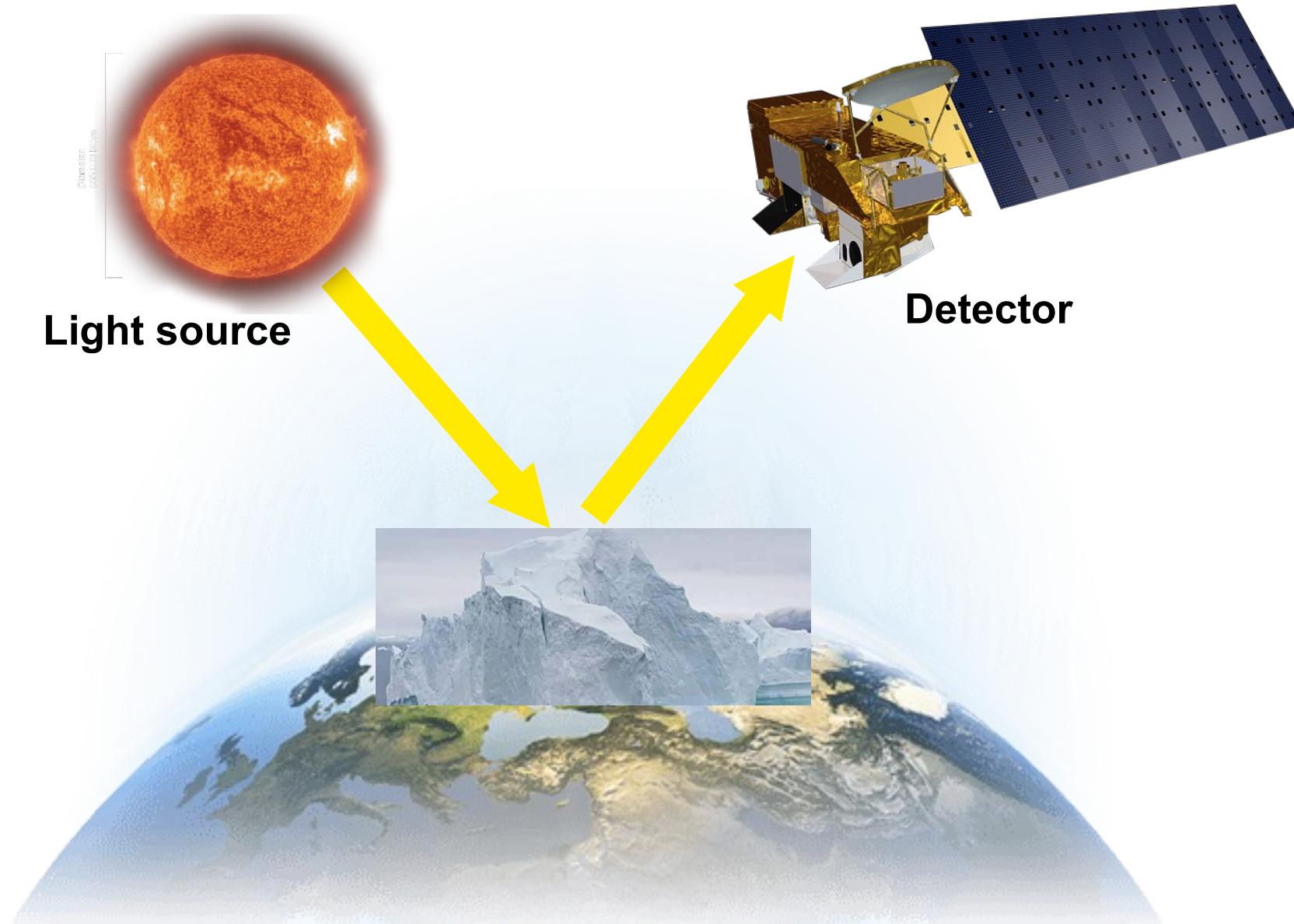
8.4×10^{16} molecules HCHO cm⁻²

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

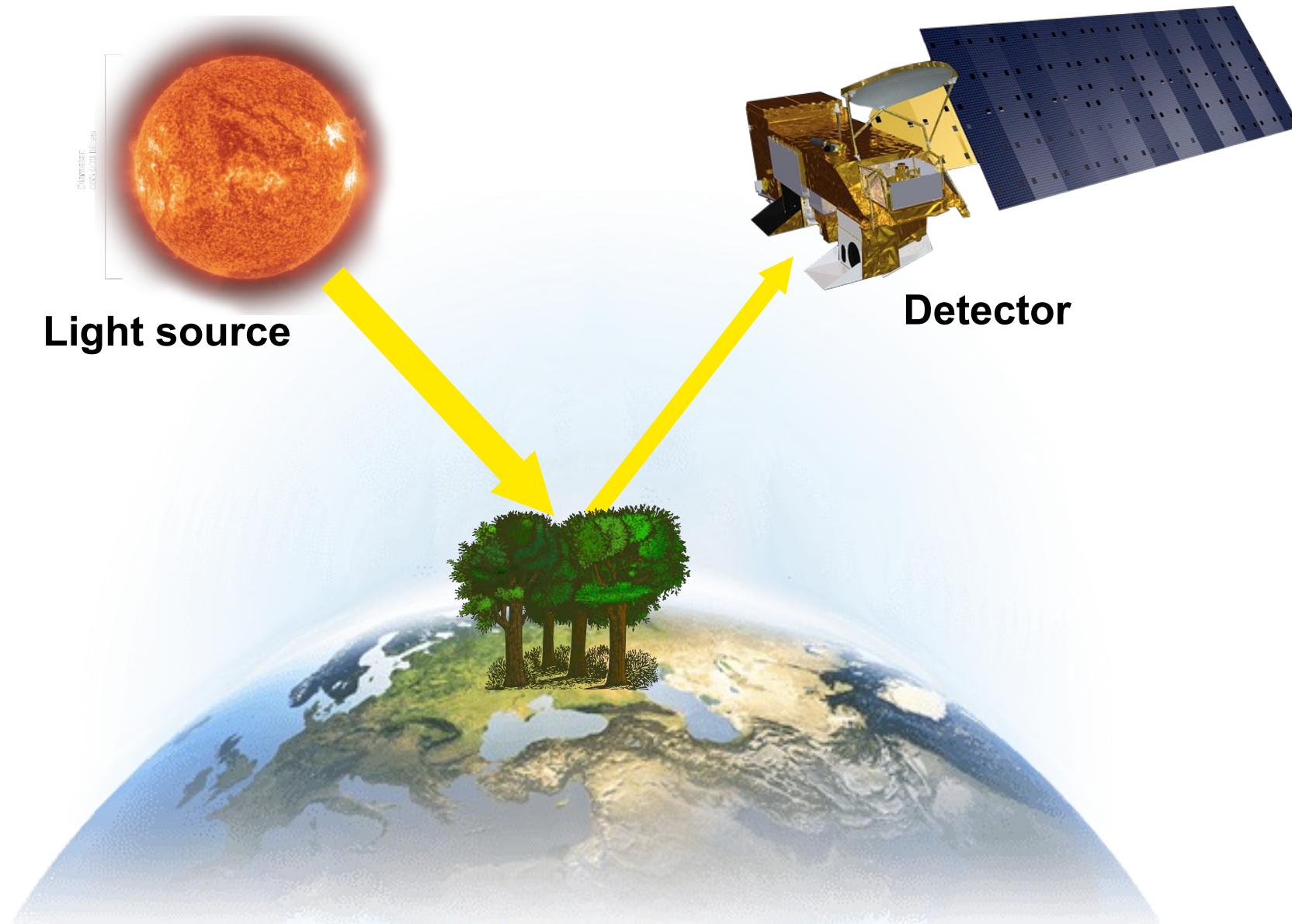
Slant Column Geometry



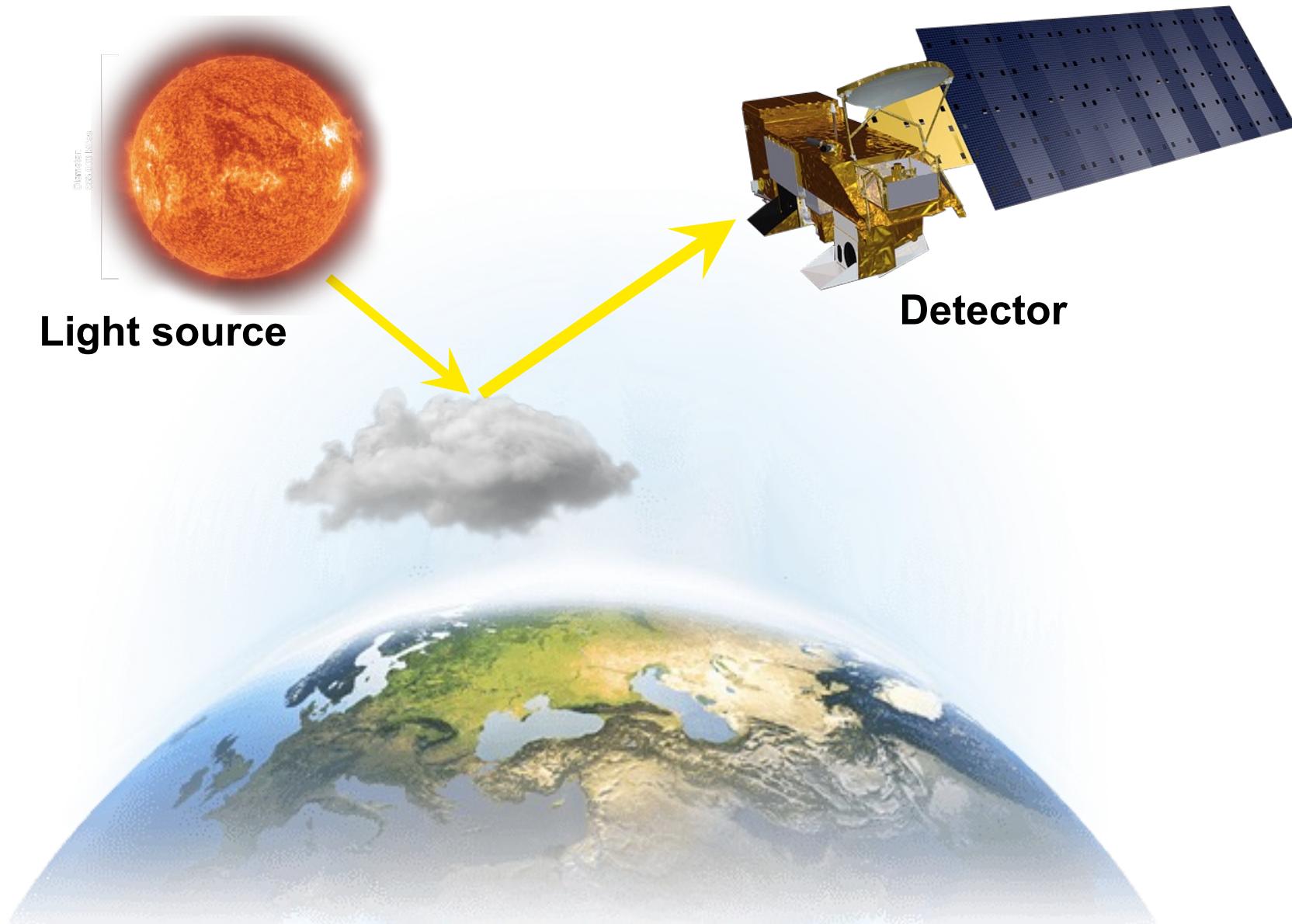
Surface Reflectivity



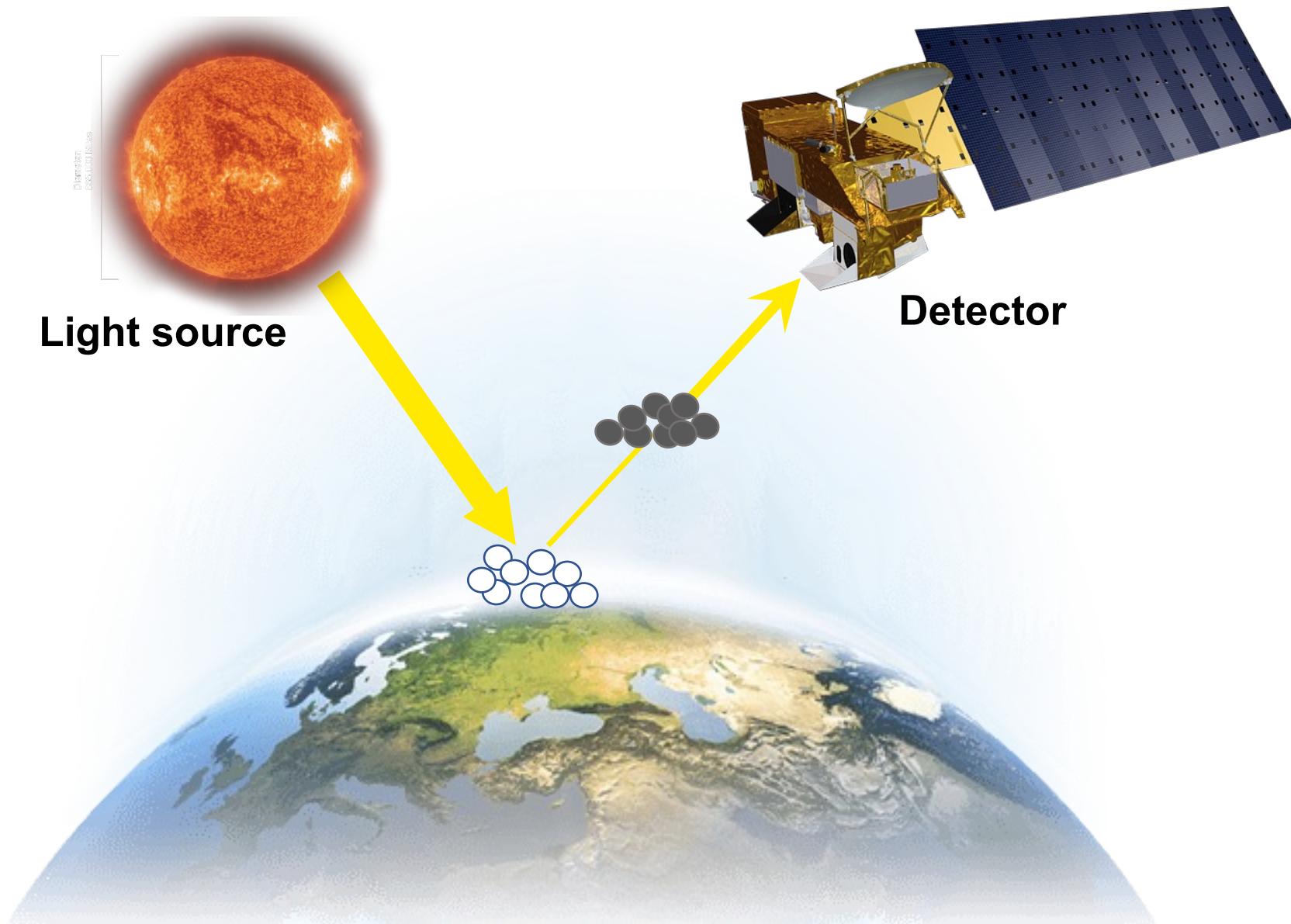
Surface Reflectivity



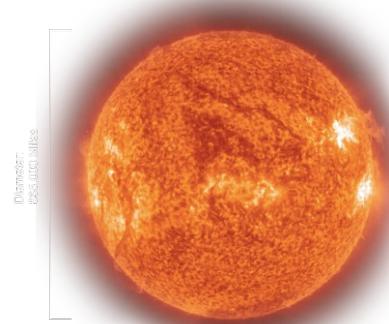
Clouds



Aerosols

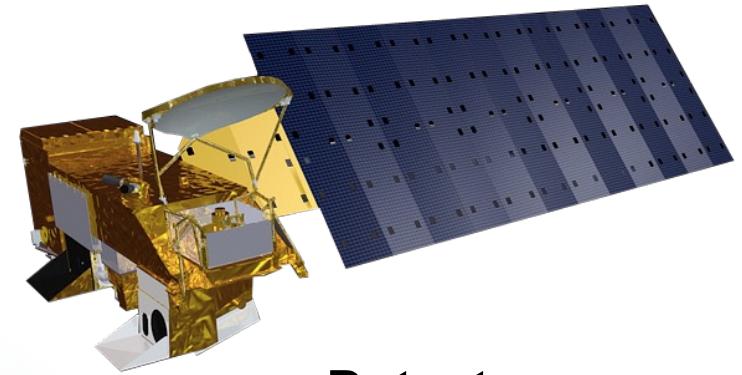
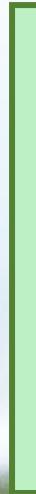


“True” Vertical Column



Light source

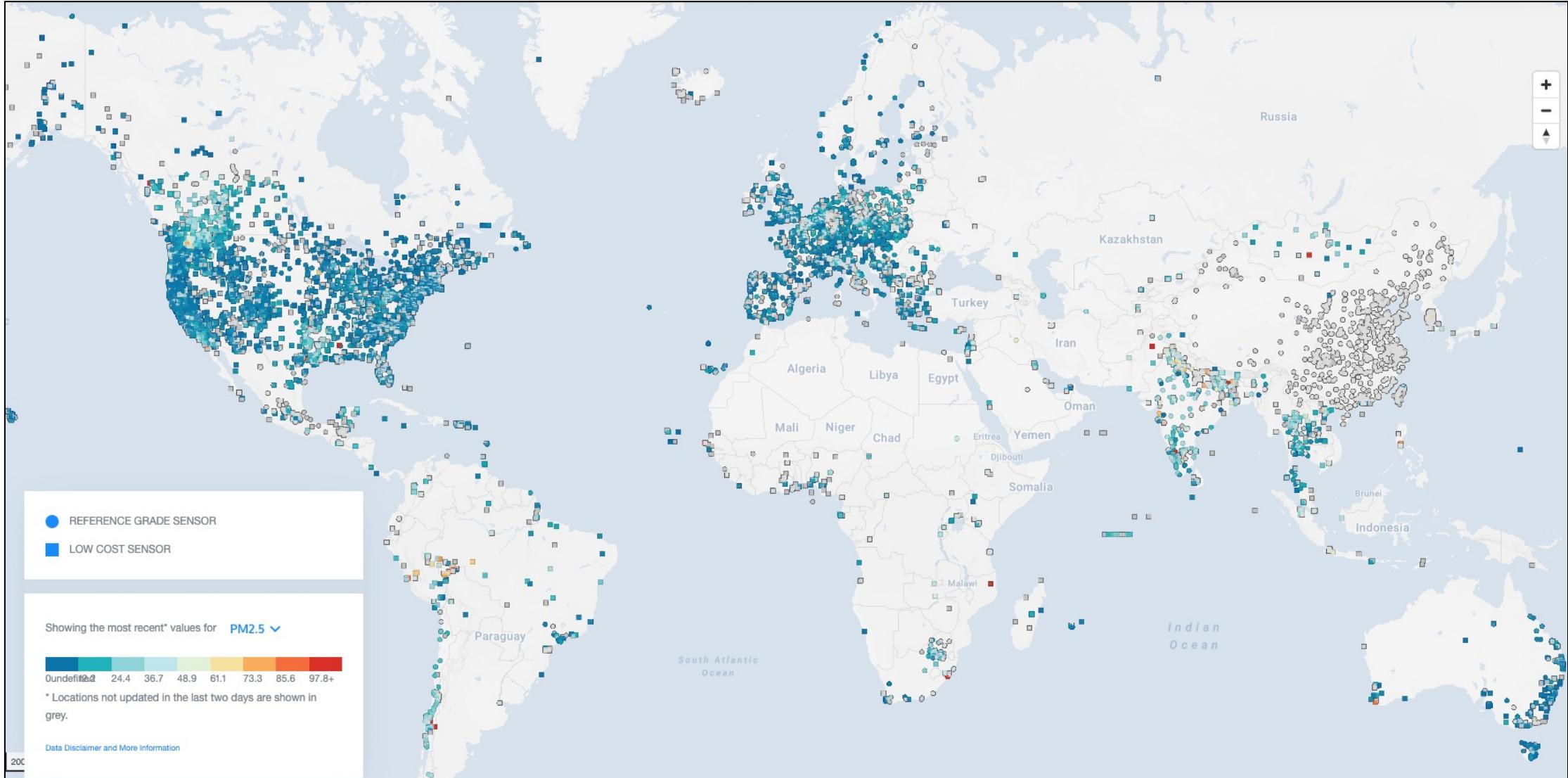
Vertical column
abundance



Detector

- Evaluate models
- Estimate emissions
- Understand air pollution
- Derive trends
- Monitor changes in air pollution

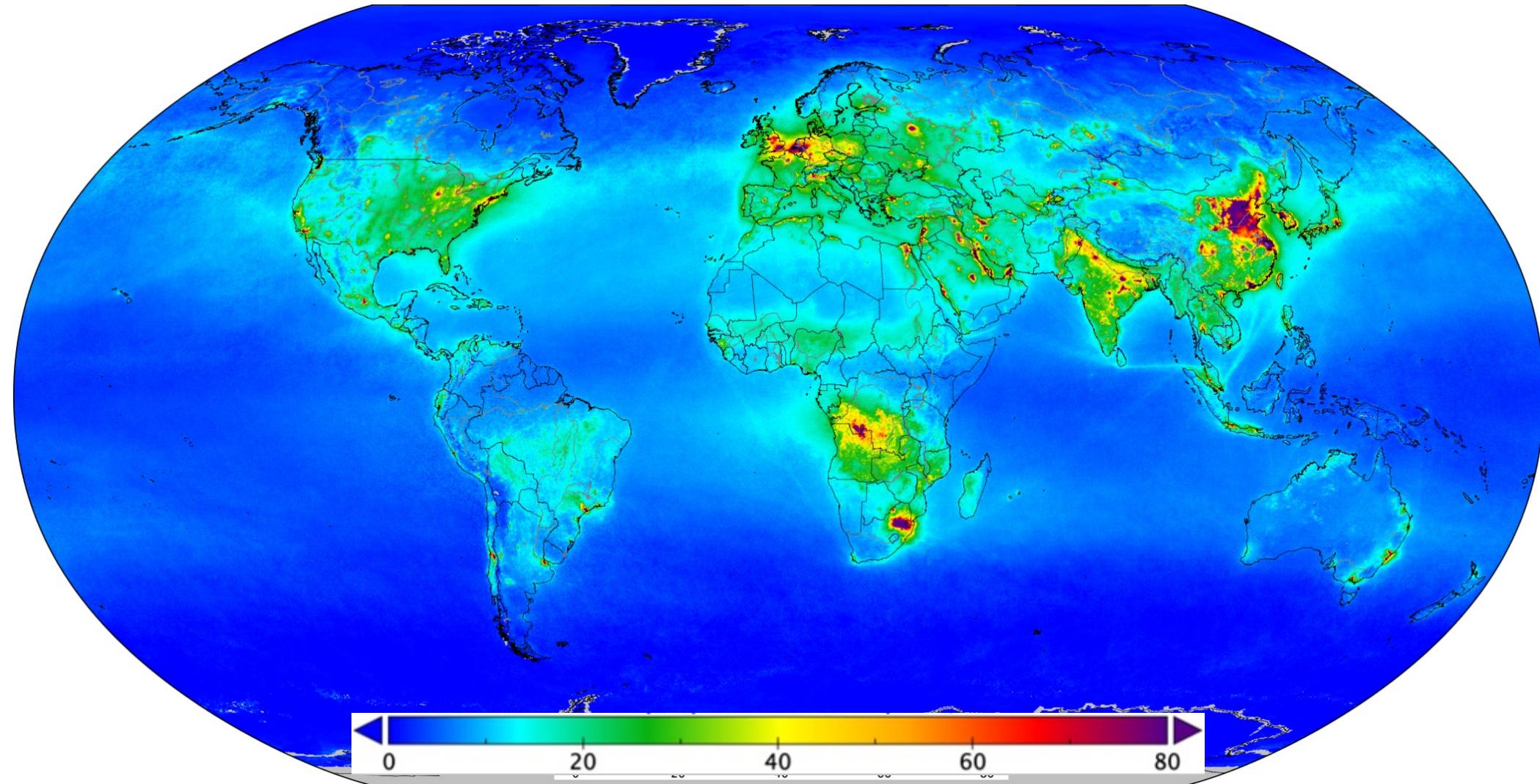
In-situ measurements have large gaps



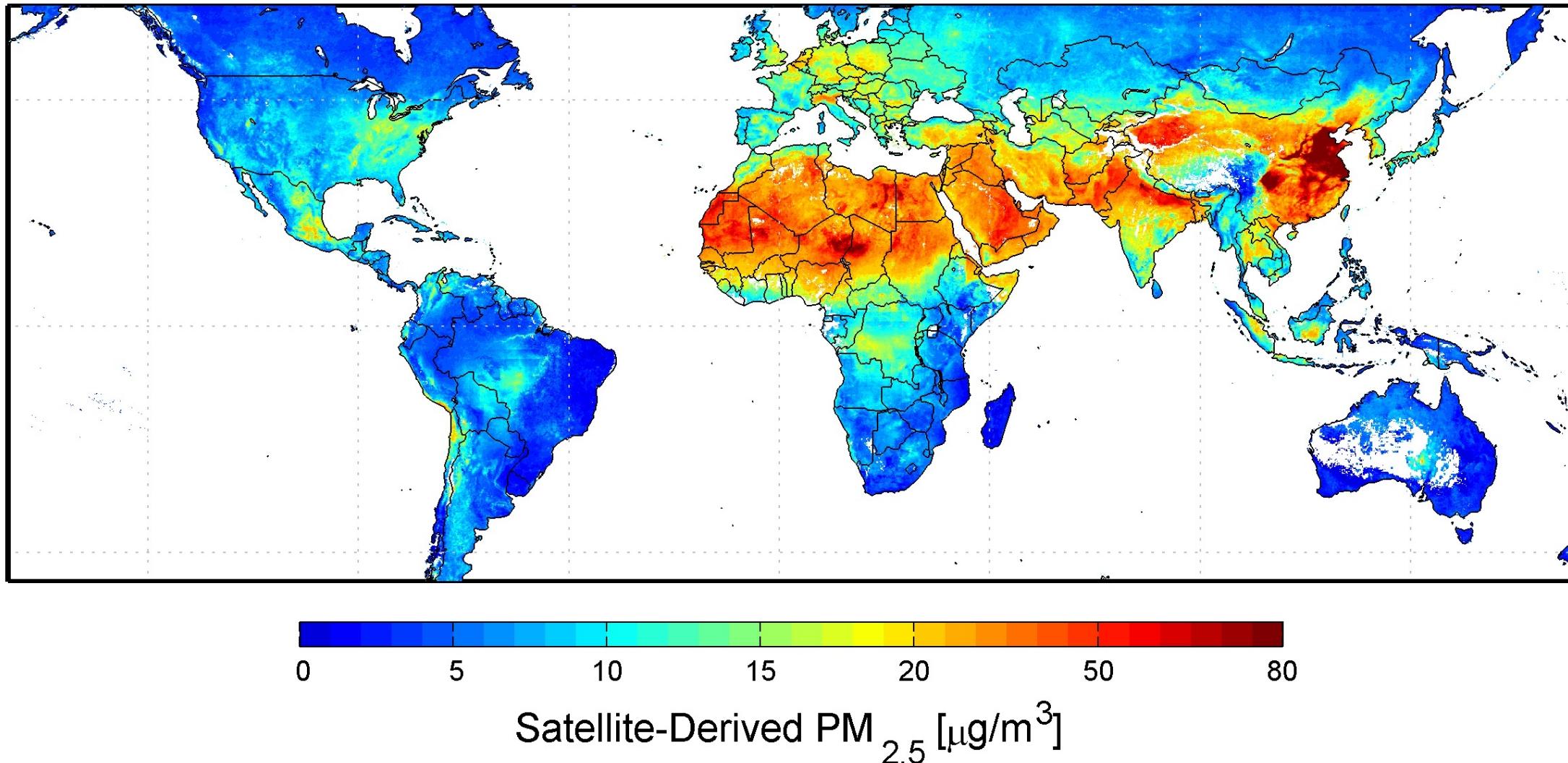
[Source: OpenAQ, <https://openaq.org/#/map>, accessed 29 Sept 2022]

Satellite observations offer global coverage

Vertical column densities of NO₂ [$\mu\text{mol m}^{-2}$]



Satellite observations used to derive PM_{2.5}

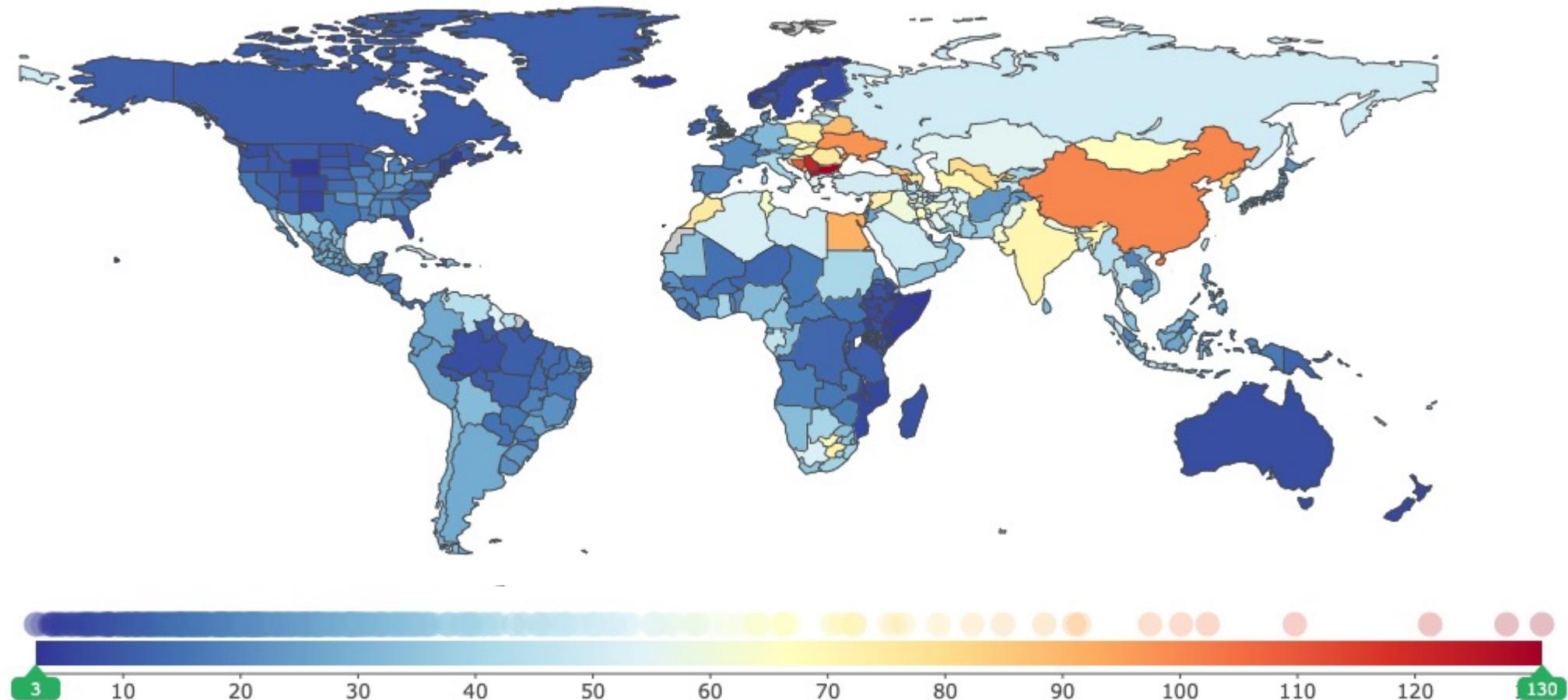


[Source: <https://doi.org/10.1016/j.envres.2012.08.005>]

Application beyond scientific research

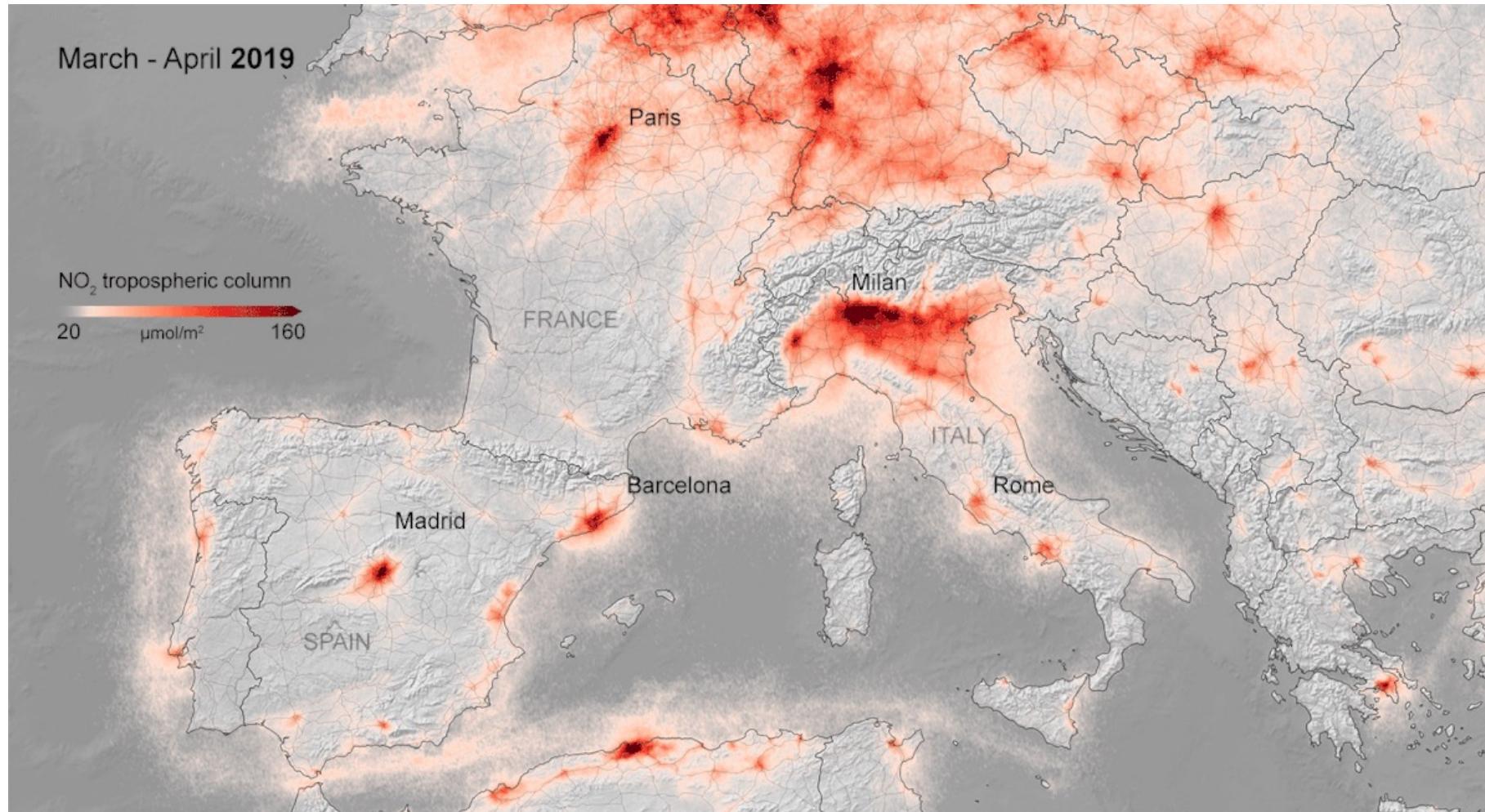
Public health burden of exposure to fine particles (PM_{2.5}): <https://vizhub.healthdata.org/gbd-compare/>

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

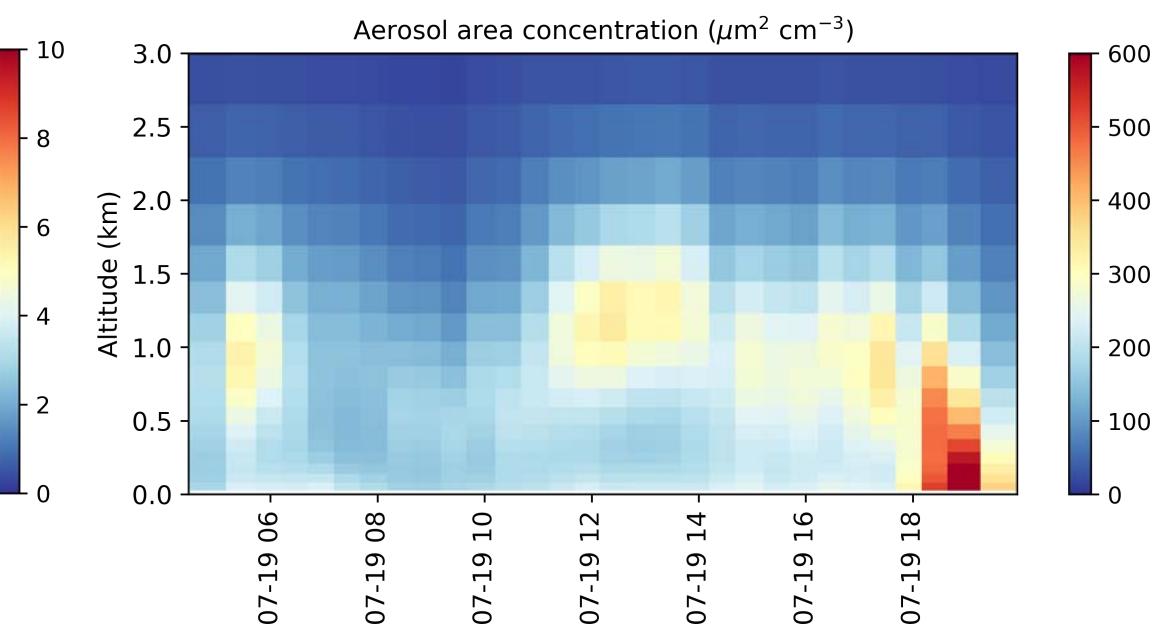
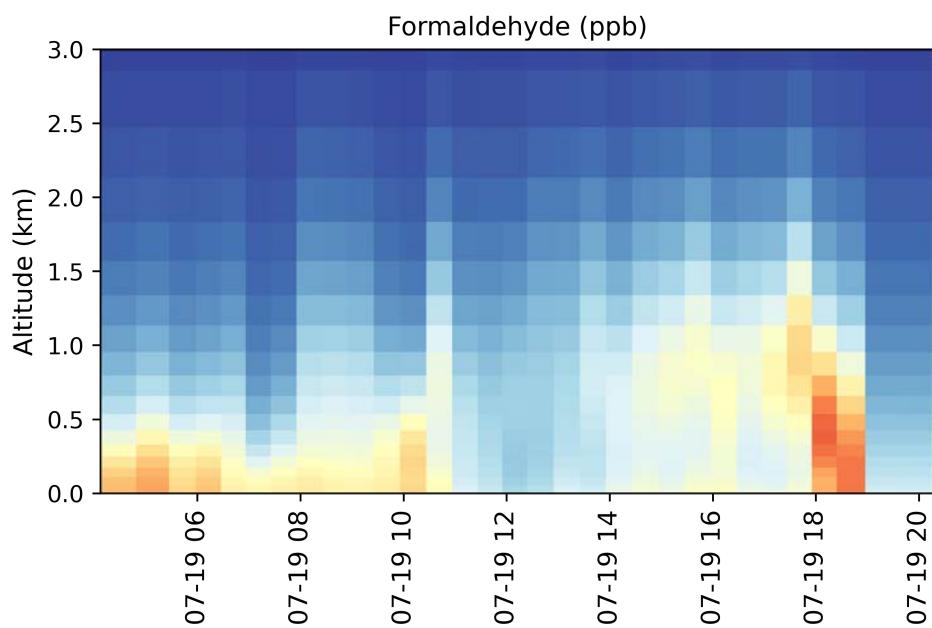


[Source: ESA]

**Research group projects using remote
sensing and related research tools**



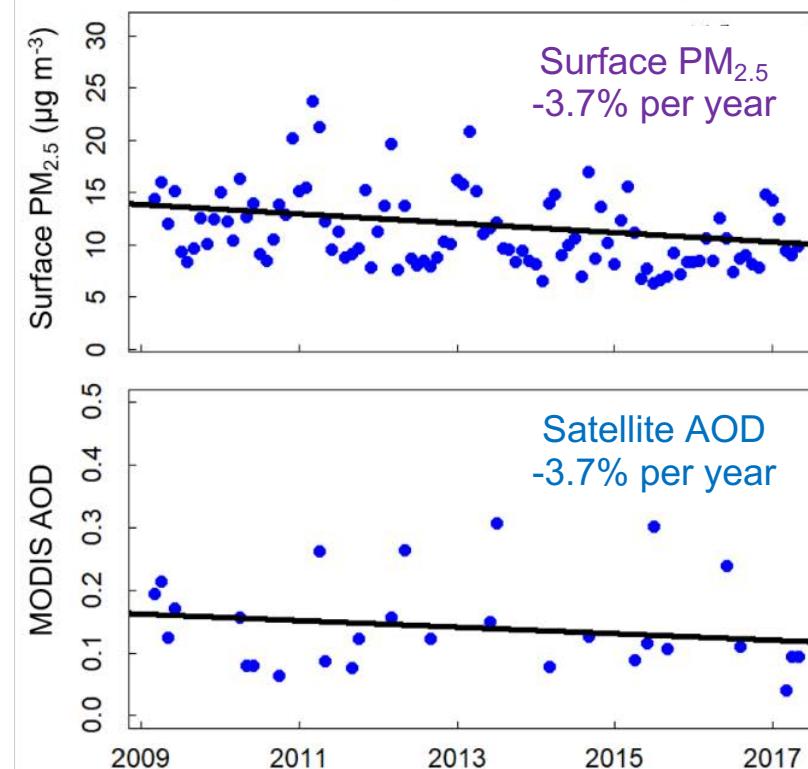
Examining the vertical extent of heatwave and wildfire pollution



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

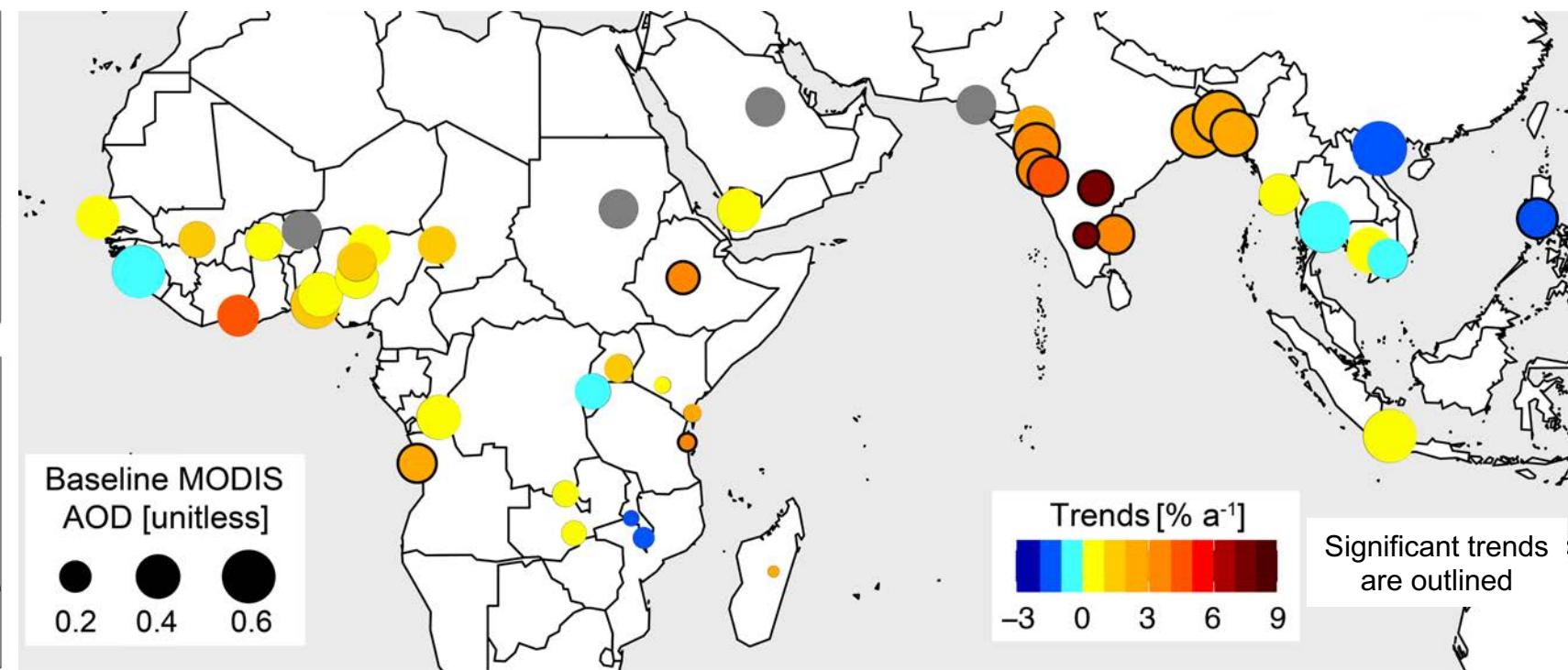
We evaluate satellite observations with surface measurements and use the quality assured data to identify rapid air quality degradation in the future megacities of the world.

Satellite AOD vs surface PM_{2.5}
Birmingham (2009-2017)



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

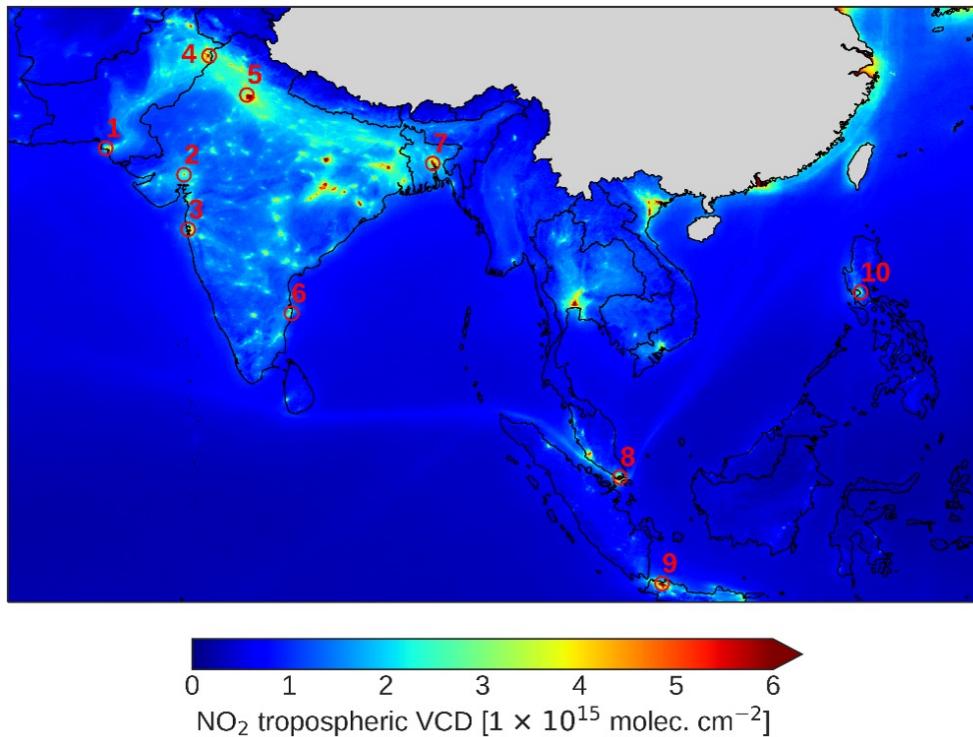
Long-term (2005-2018) trends in surface PM_{2.5} in fast-growing tropical cities



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

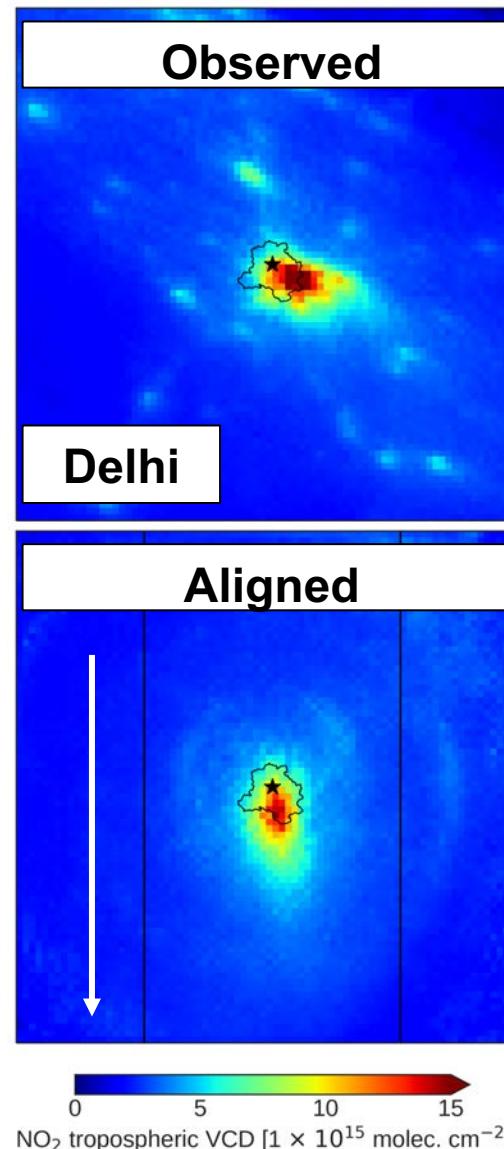
Estimating NO_x Emissions in Cities in Asia using a Plume-Rotation Technique

1. Identify NO₂ pollution hotspots



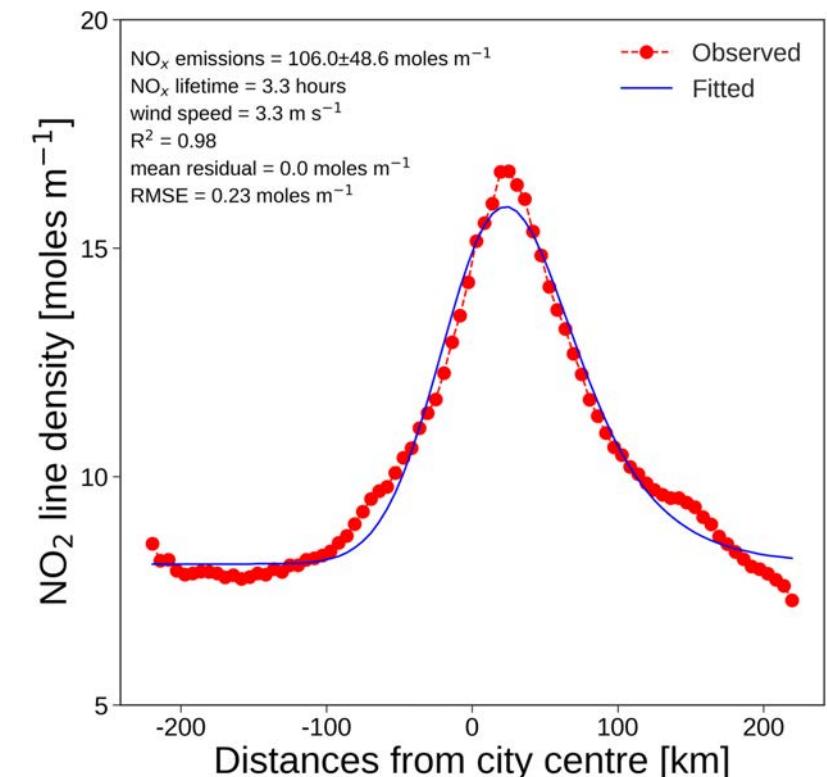
NO_x is emitted during high-temperature combustion by cars, power plants and ships

2. Align NO₂ plumes



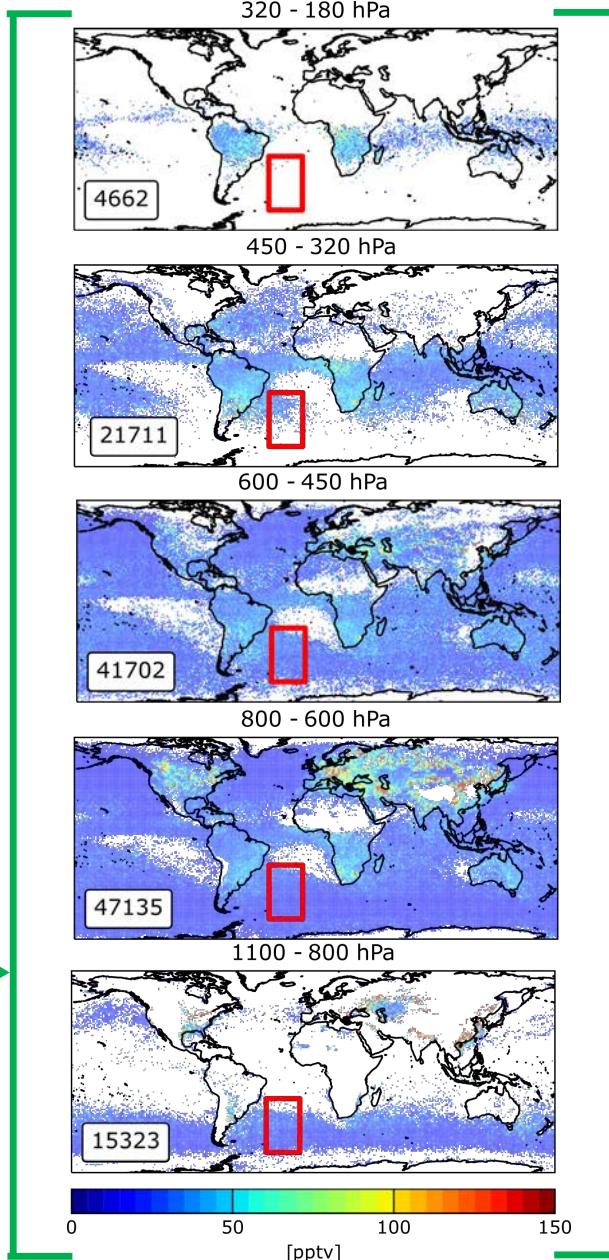
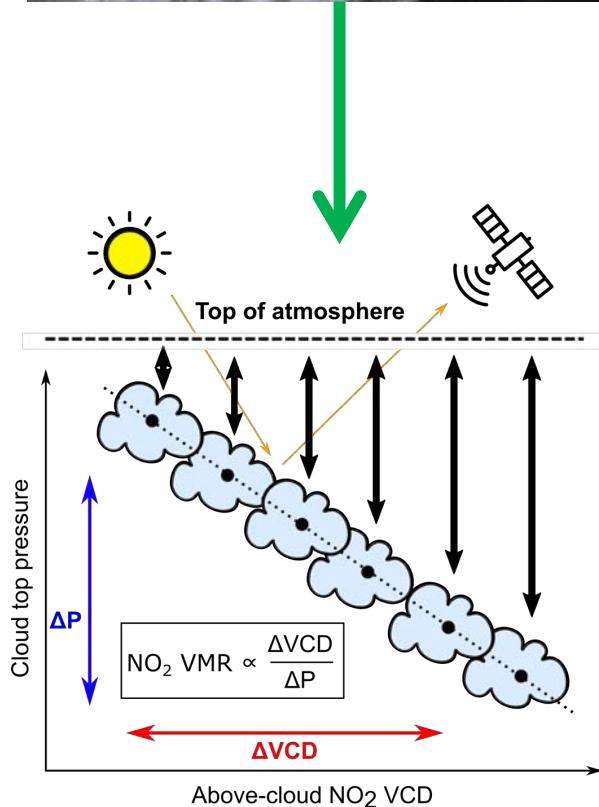
3. Estimate NO_x emissions

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

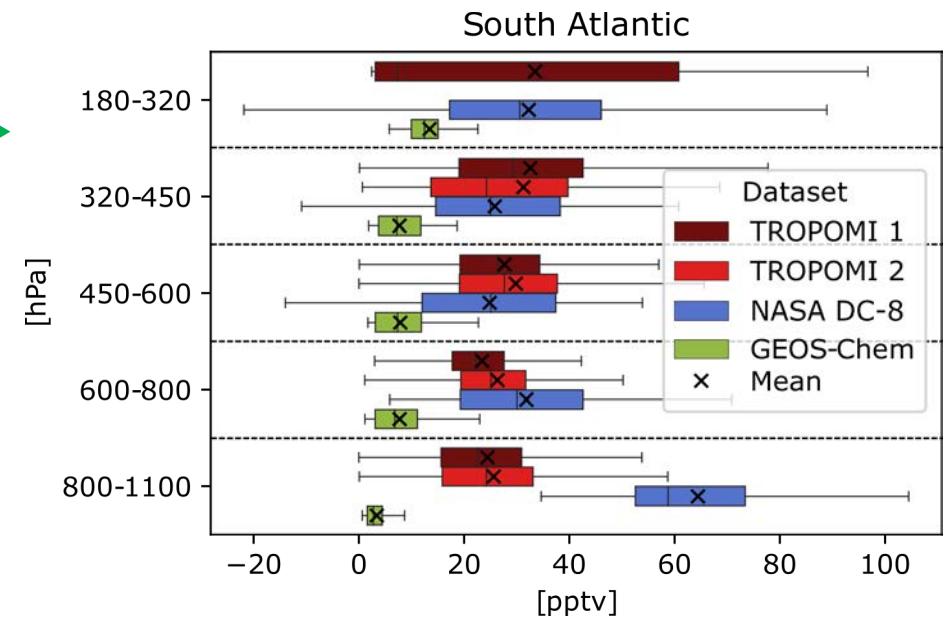


Delhi NO_x = 100 kilotonnes in 2019

Using the cloud-slicing technique to obtain NO₂ 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.

Email: rebekah.horner.20@ucl.ac.uk



Contact us to find out more about the other research we do:

- Influence of **rockets** on stratospheric ozone and climate
- 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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