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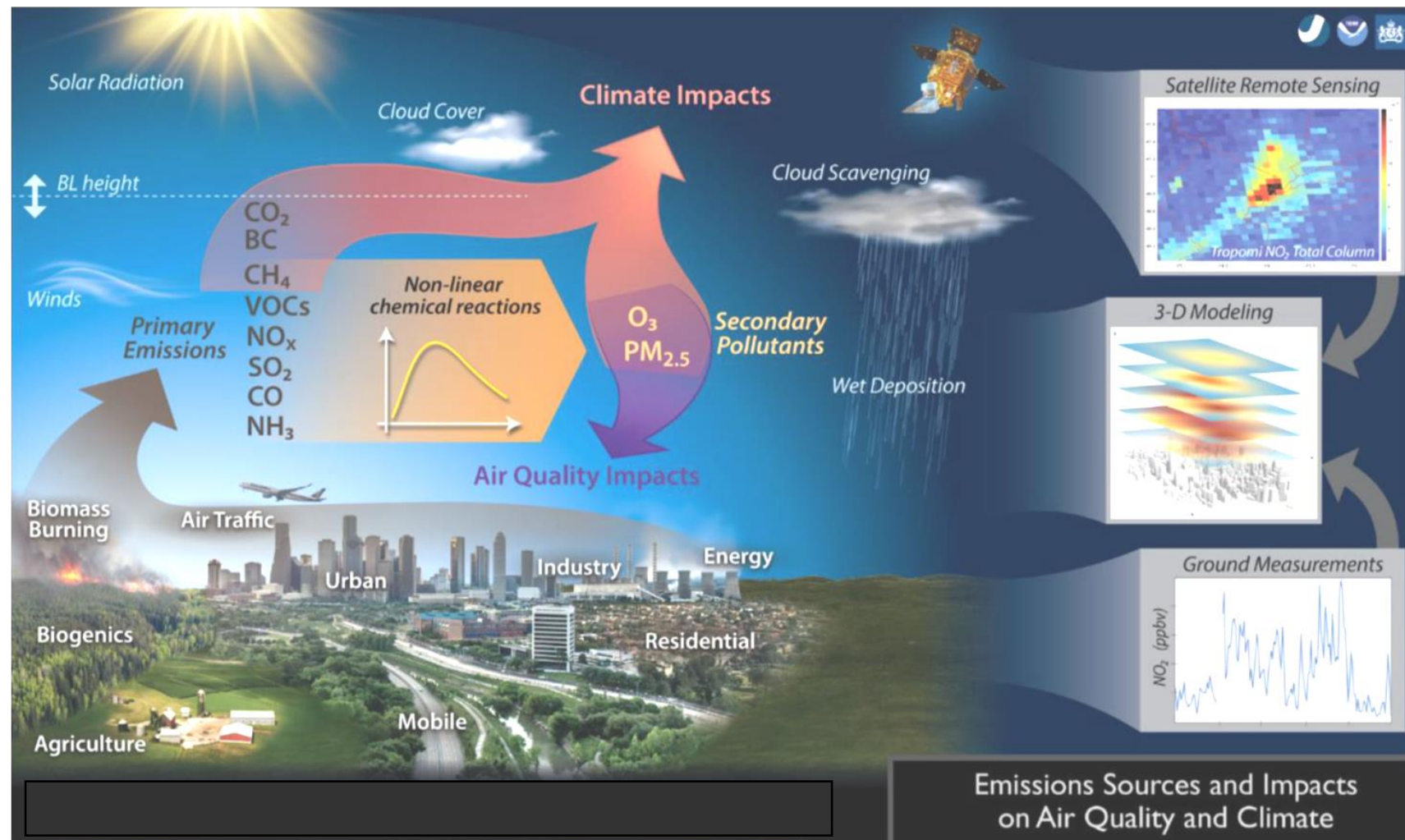


air quality from space: indicator of human activity

Pieter Levelt^{1,2,3}, Pepijn Veefkind^{2,3}

NCAR, KNMI, TU-Delft





- Ozone layer
- Air quality
- Climate
- Biodiversity

Figure 1. Schematic of major emission sectors and primary emissions, meteorological and chemical processes, impacts to air quality and climate, and measurement and analysis tools used to analyze the effects of emissions changes. DOI: <https://doi.org/10.1525/elementa.2021.00176.f1>

Carbon and Nitrogen Cycle



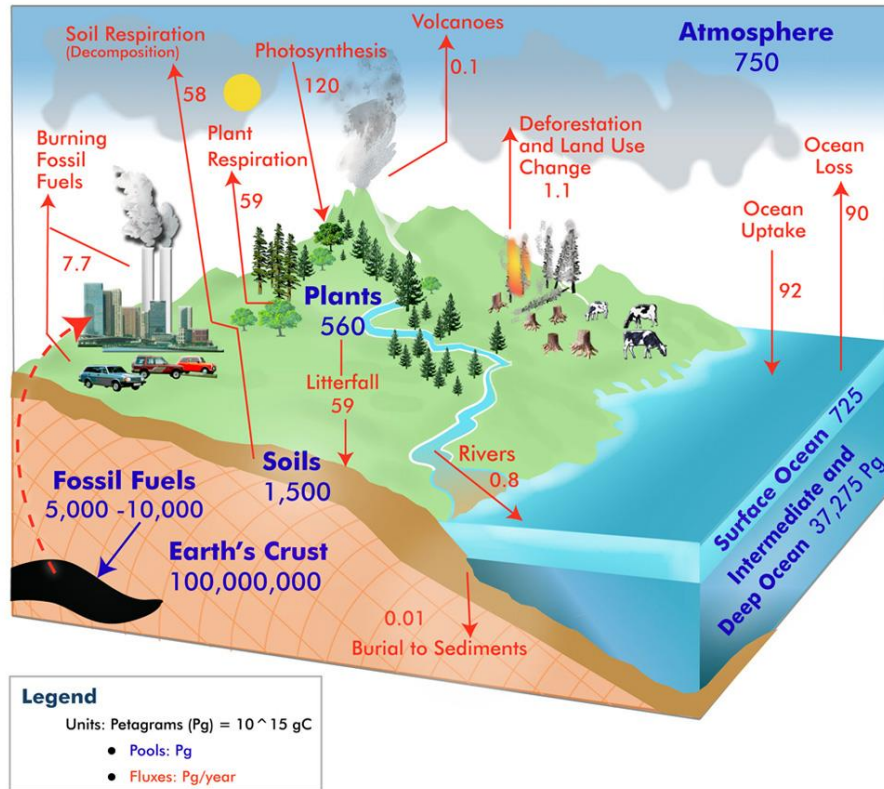
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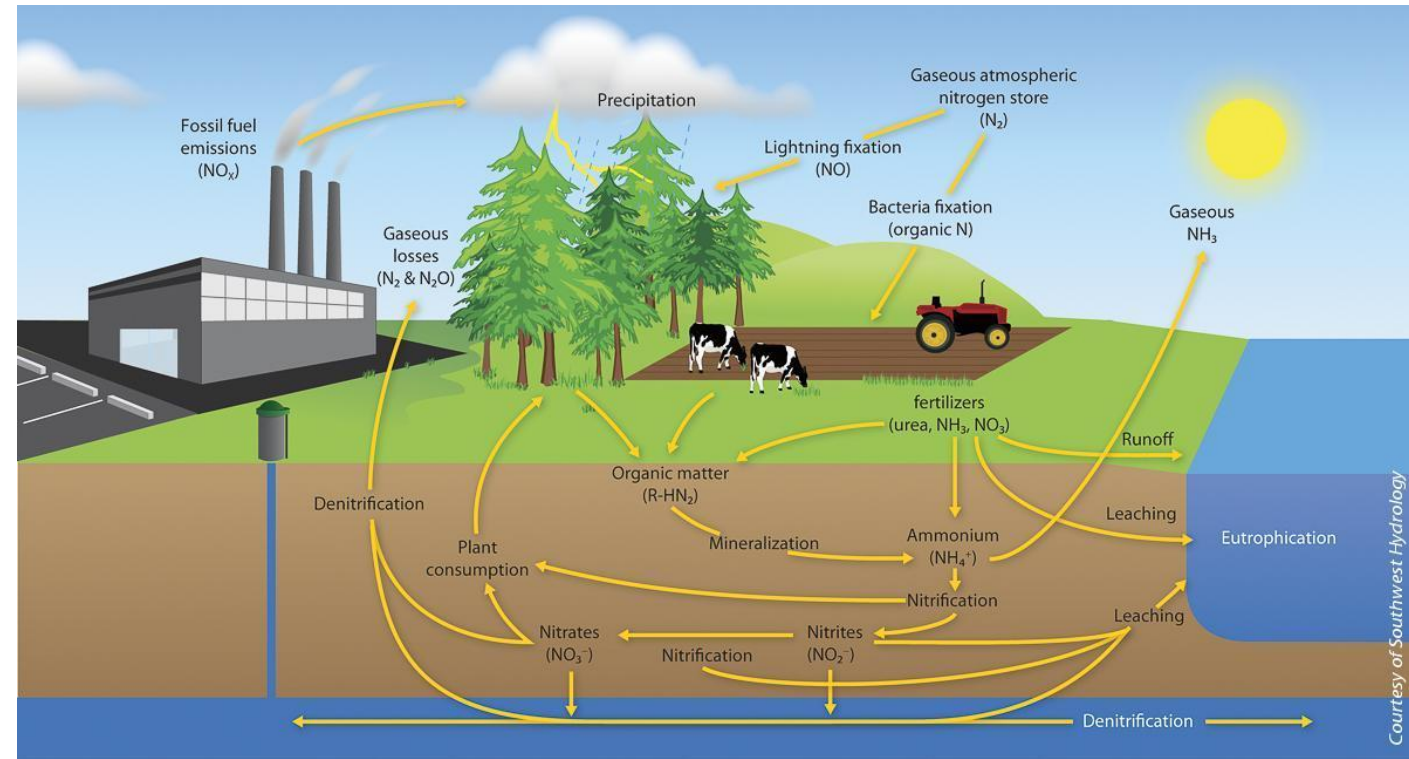
Carbon Cycle



Copyright 2010 GLOBE Carbon Cycle Project, a collaborative project between the University of New Hampshire, Charles University and the GLOBE Program Office.
 Data Sources: Adapted from Houghton, R.A. Balancing the Global Carbon Budget. Annu. Rev. Earth Planet. Sci. 007.35:313-347, updated emissions values are from the Global Carbon Project: Carbon Budget 2009.



Nitrogen Cycle



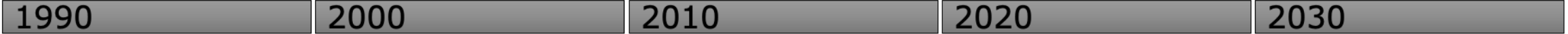
Global Missions



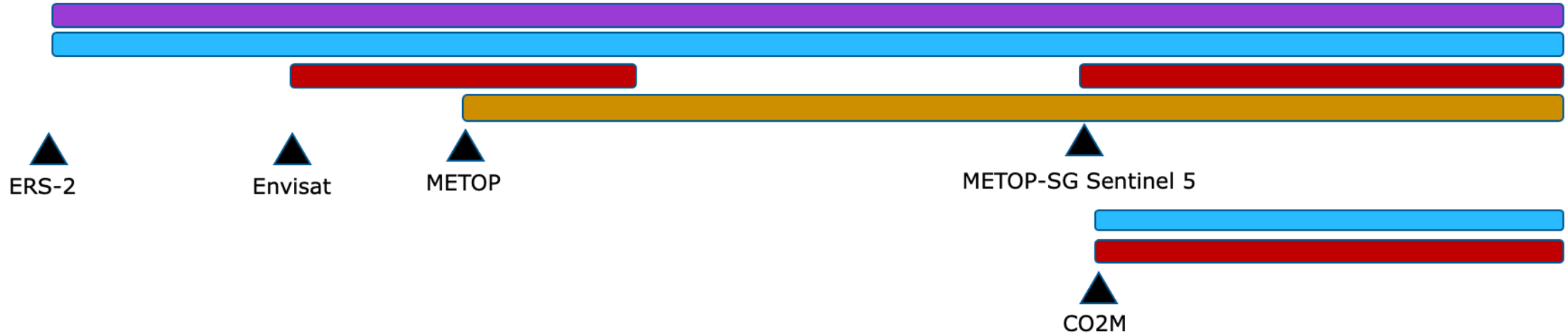
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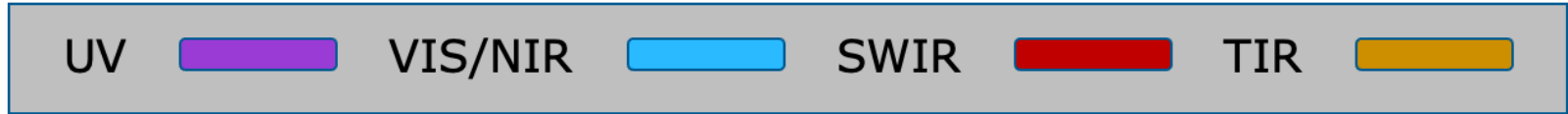
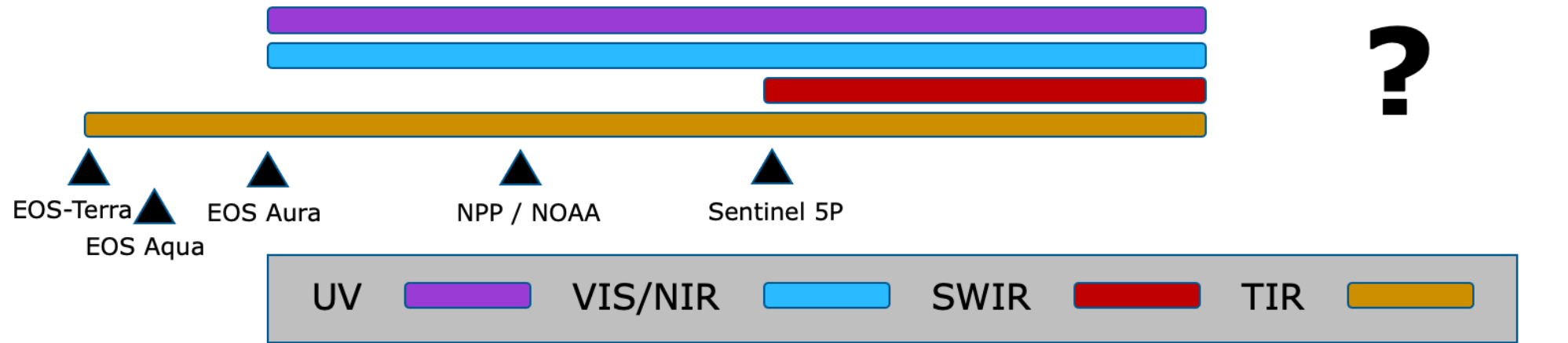
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AM



PM



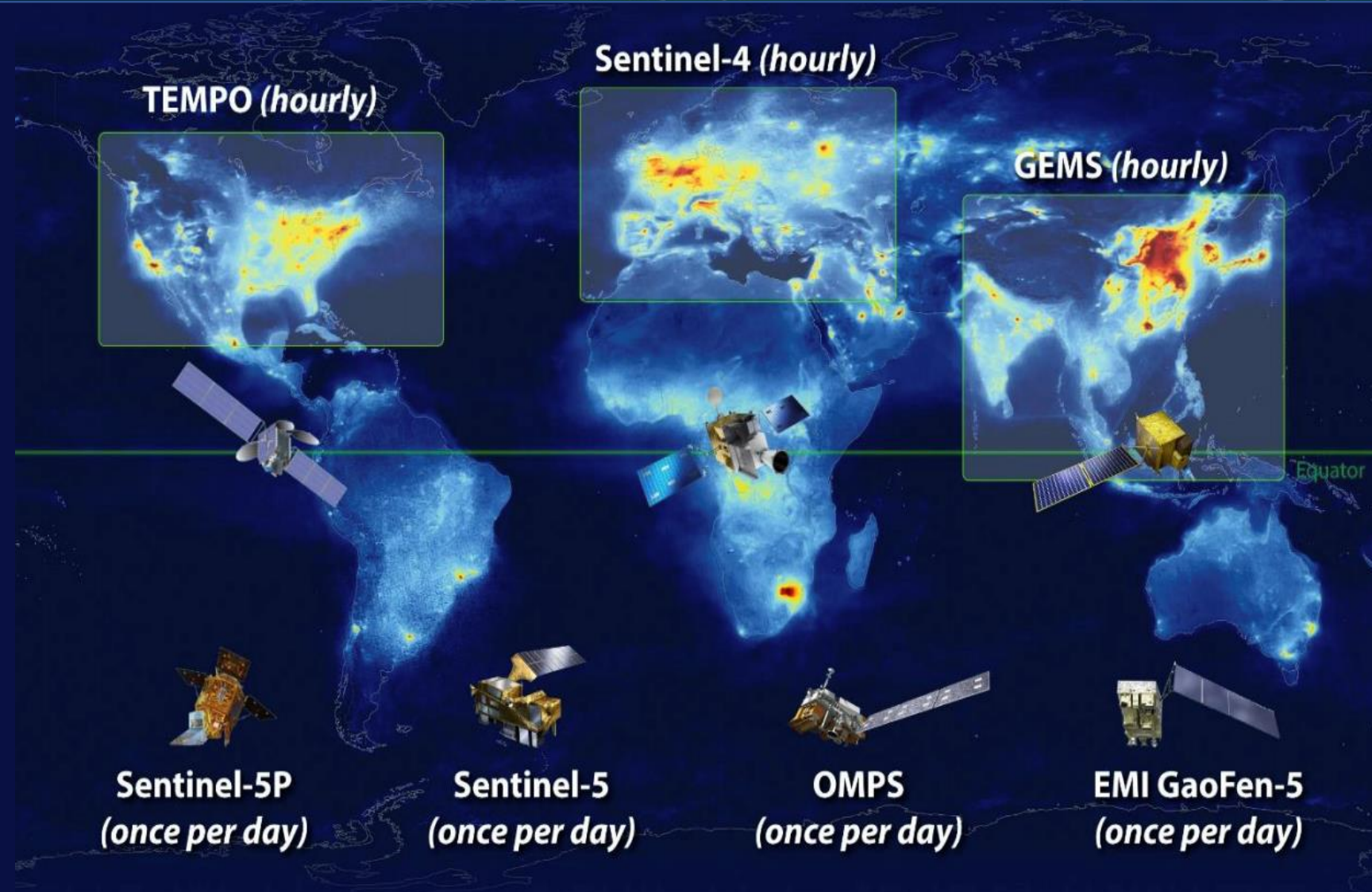
GEO Constellation



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Focus on Africa: GEO

CO



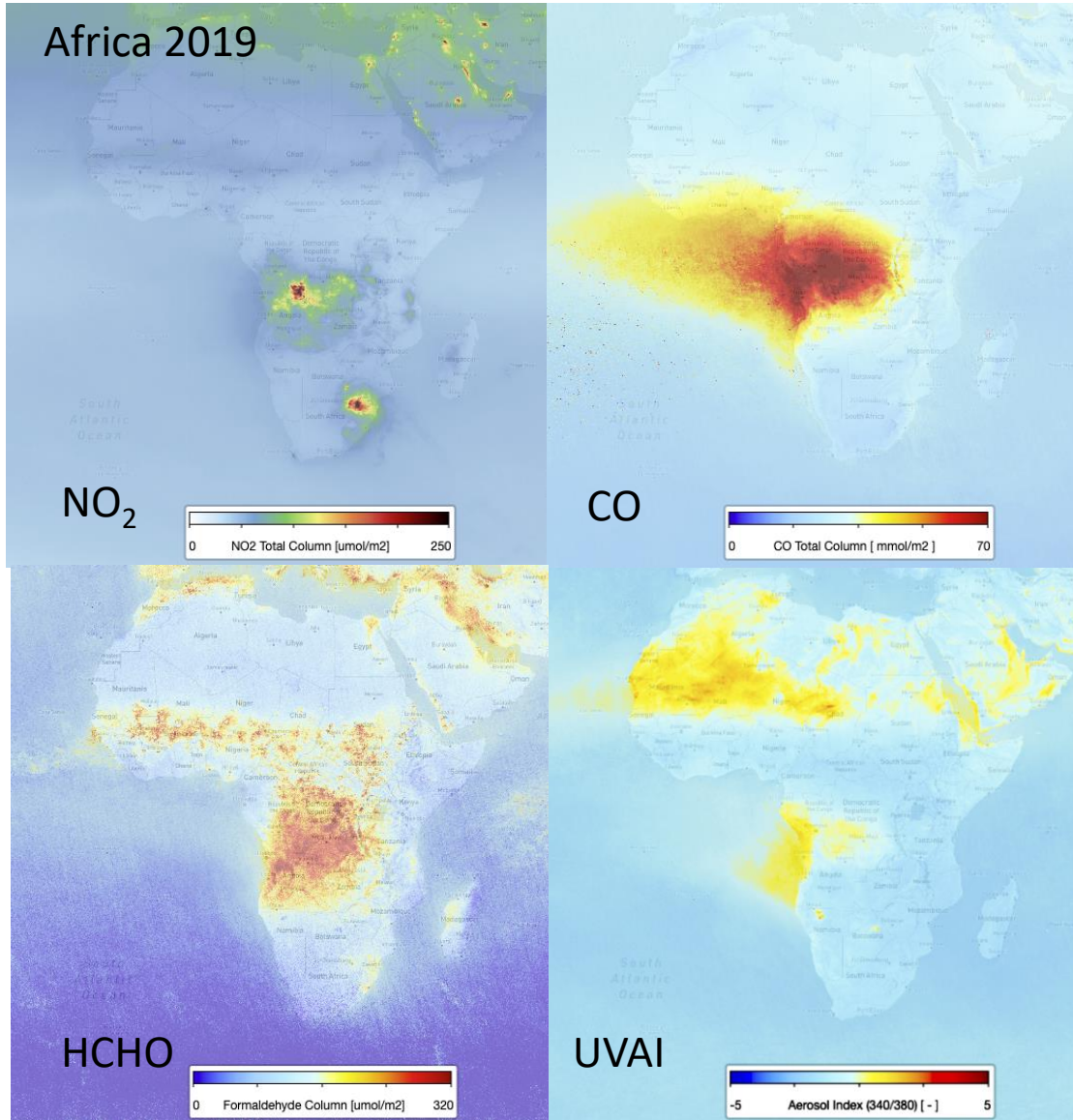
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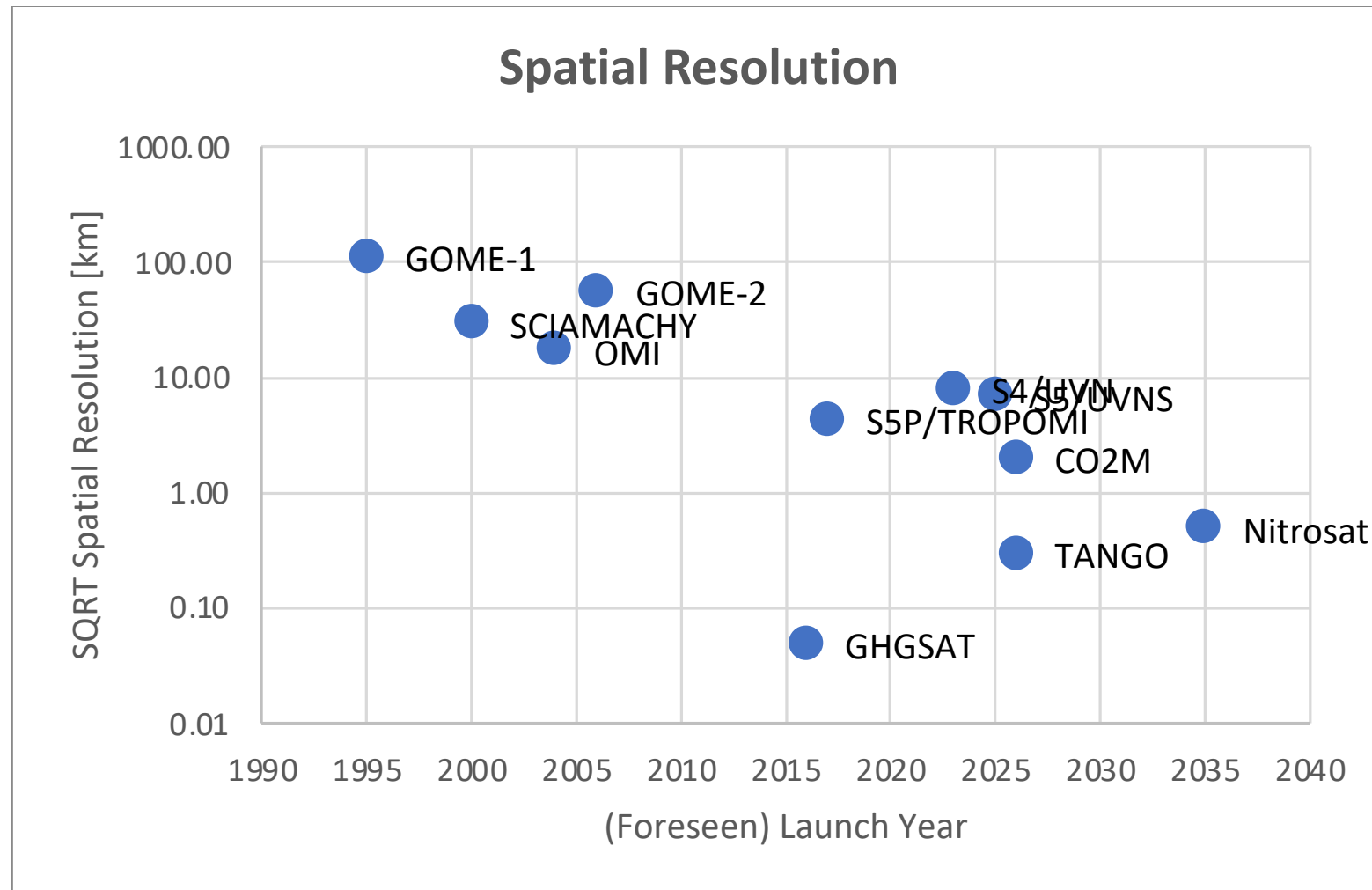


Africa 2019



Population is expected to double in 2050
(now 1.1 billion)

4th industrial revolution: will lead to large
increases in air pollutants and greenhouse
gases



Y-axis has logarithmic scale!



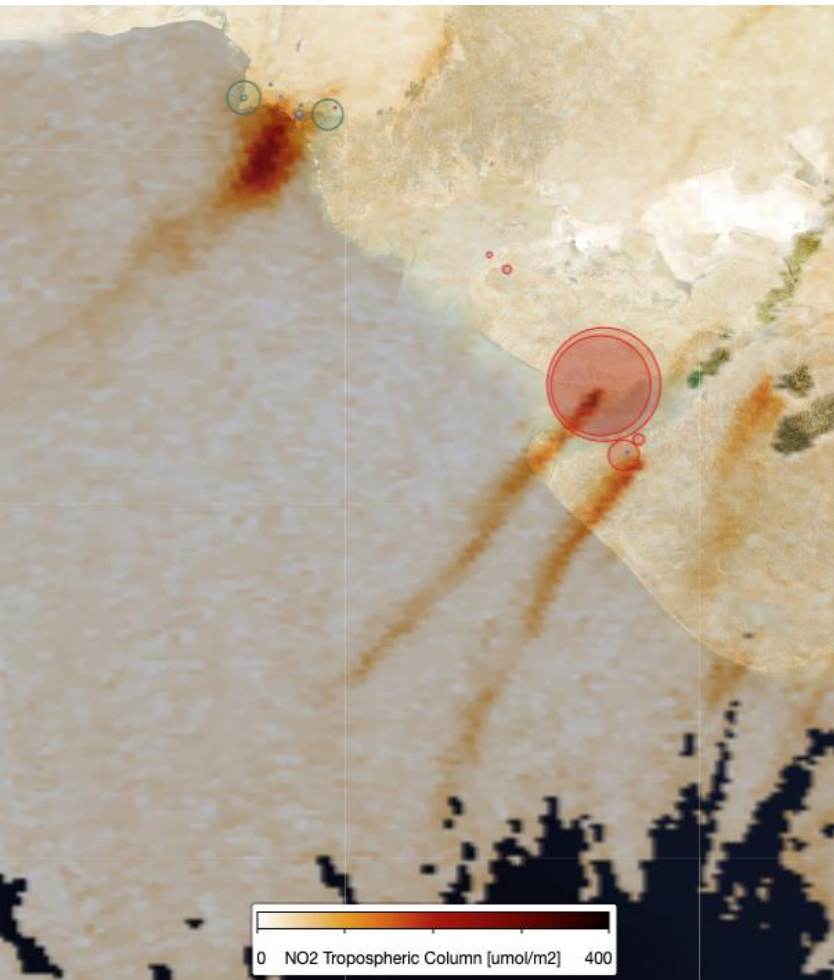
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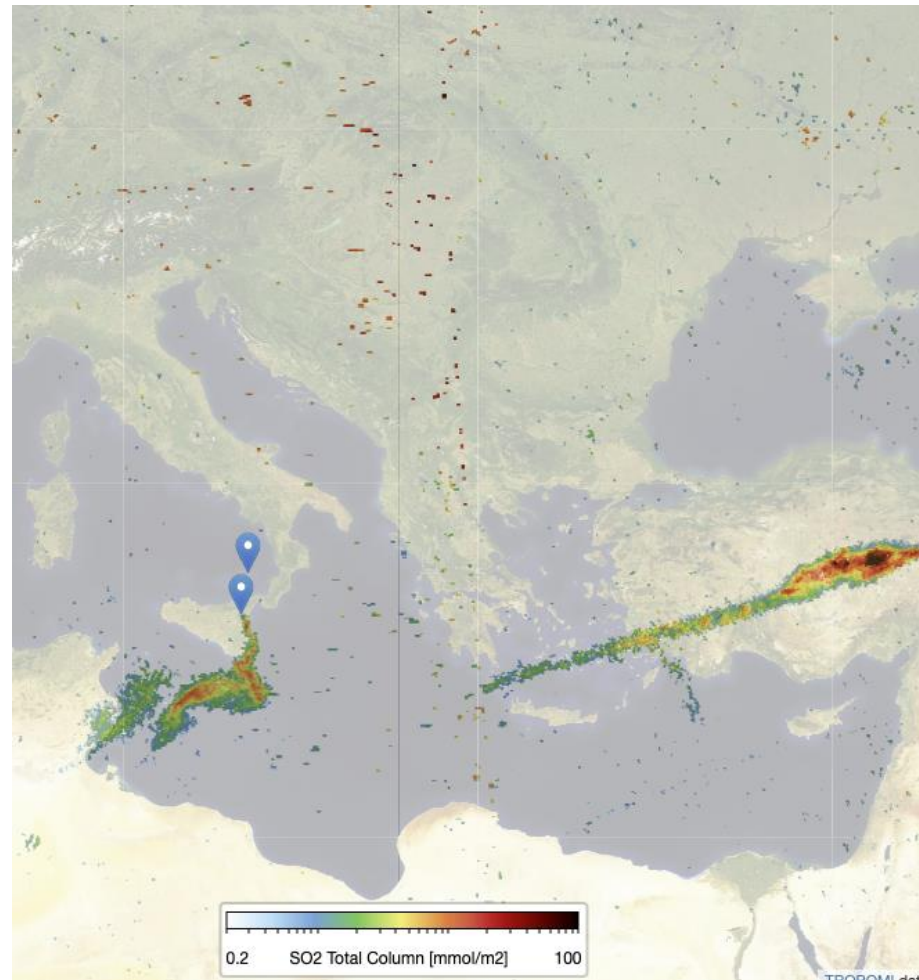
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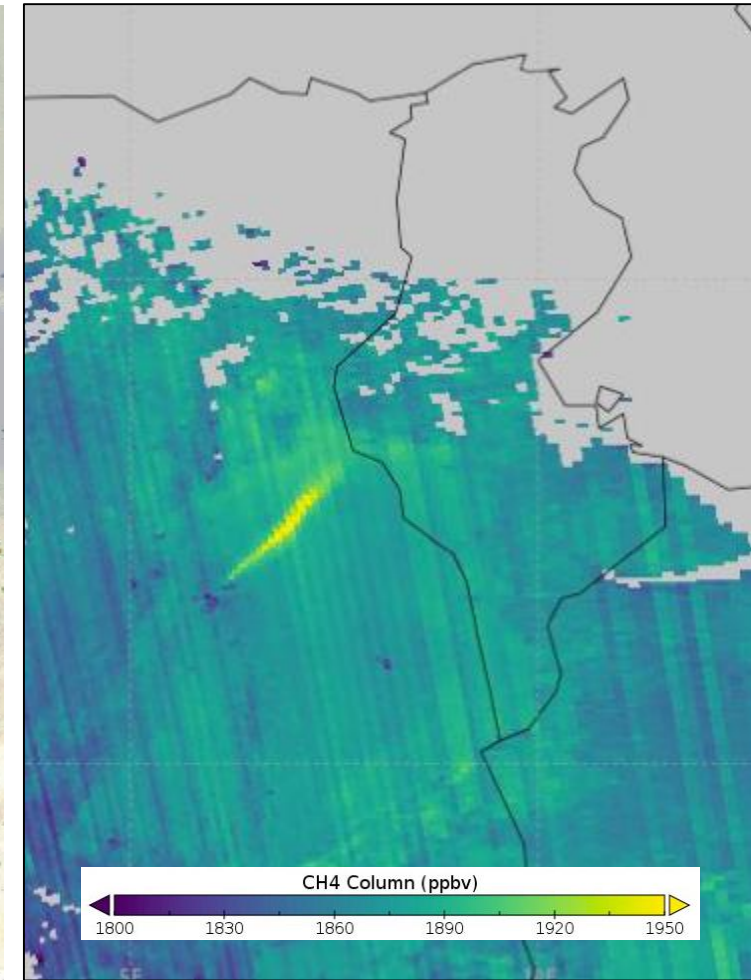
NO₂, India & Pakistan 2021-01-10



SO₂, Etna Volcano 2020-12-22



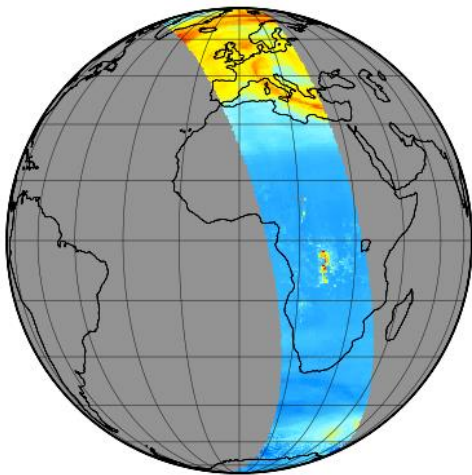
CH₄, Algeria, 2020-01-04





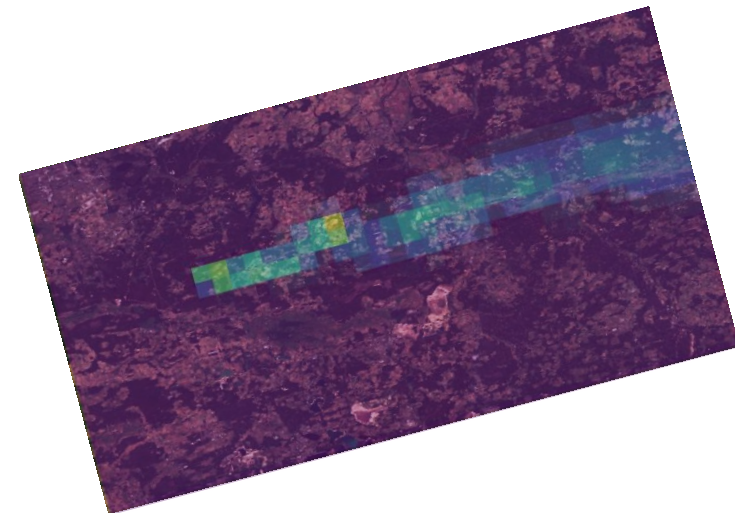
LOW/MEDIUM RESOLUTION

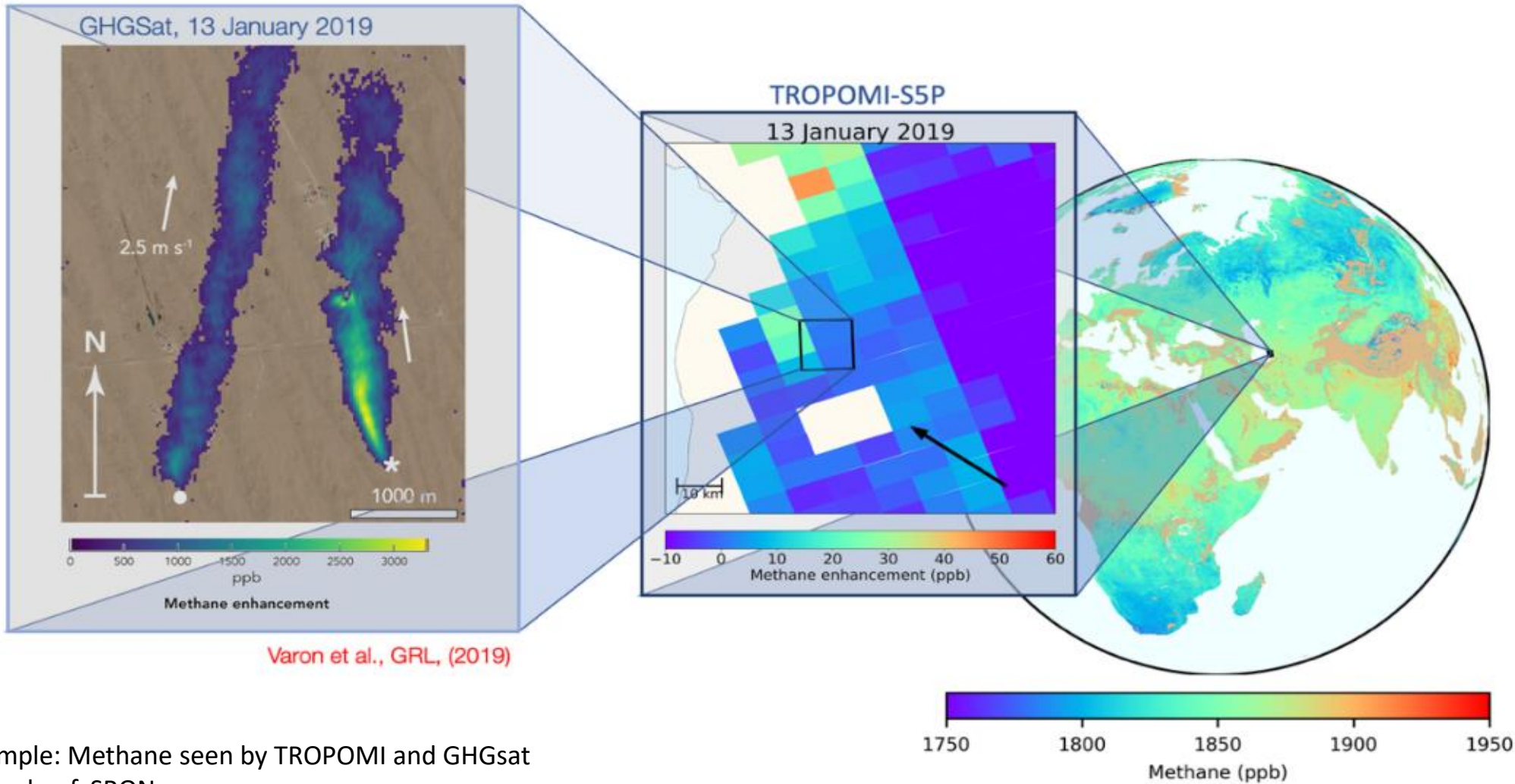
- Wide swath
- Concentration mapping
- Backbone missions



HIGH RESOLUTION

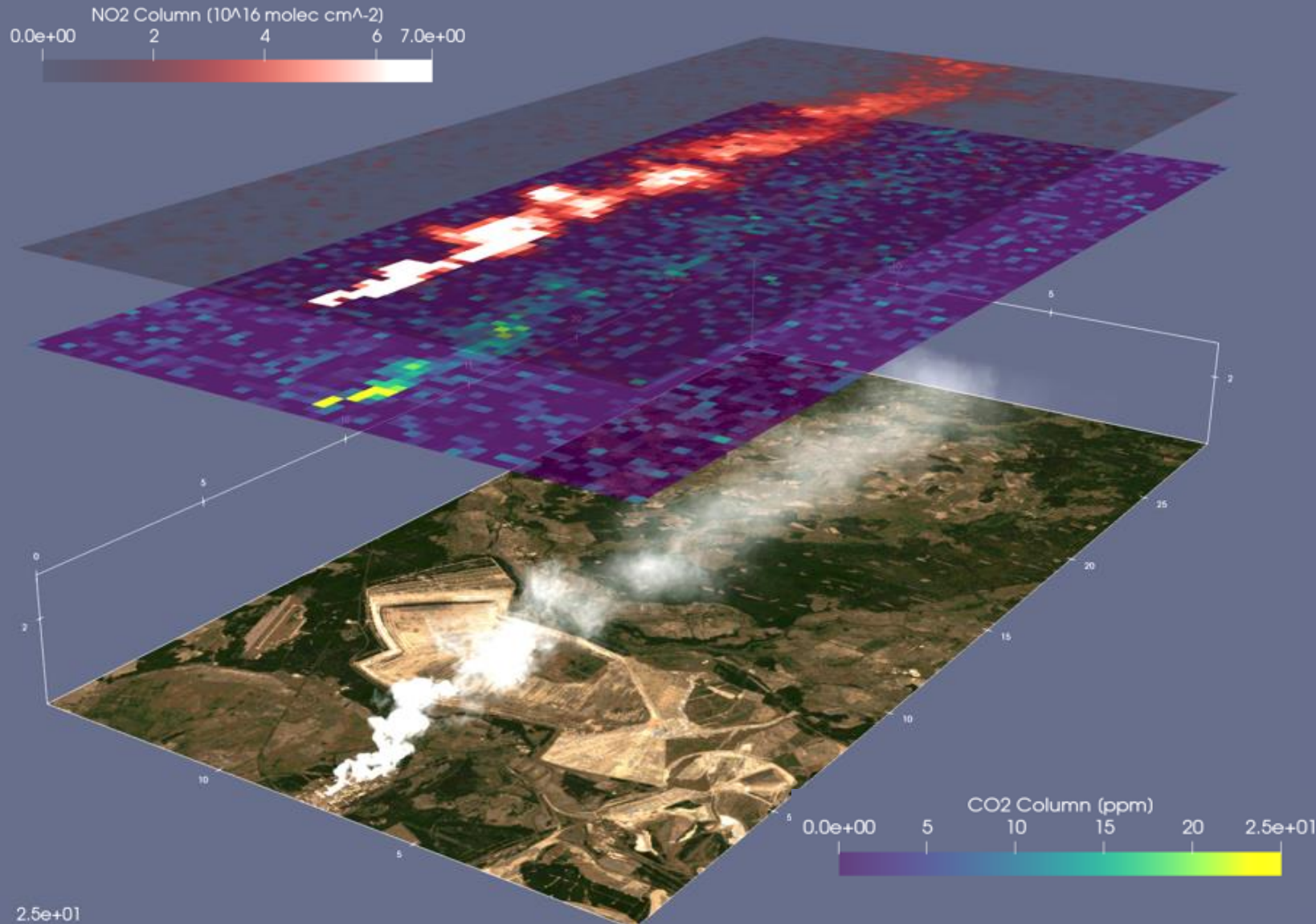
- Limited swath
- Target modes
- Agile platforms
- Add zoom-in capabilities
- Satellite constellations





Varon et al., GRL, (2019)

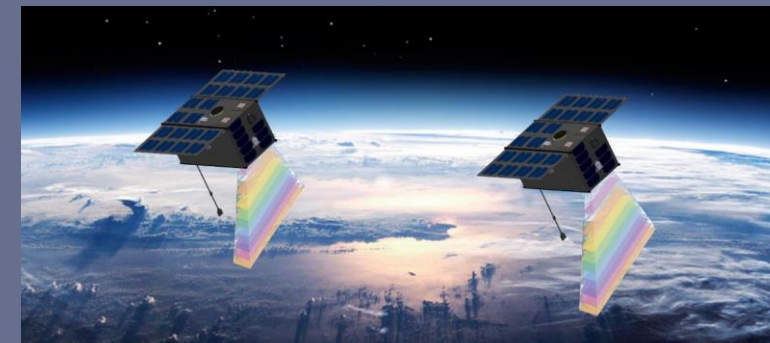
Example: Methane seen by TROPOMI and GHGSat
J. Landgraf, SRON



TANGO:

- ESA-Scout candidate that provides zoom-in functionality to CO2M.
- Demonstrator for a cubesat constellation.
- CO₂ and CH₄ total column concentrations at spatial resolutions of individual industrial facilities worldwide (<300 m).
- Collocated NO₂ tropospheric column concentrations to detect the plume air masses
- Agile platforms that allow pointing and staring.

Science Leads: Jochen Landgraf (SRON) & Pepijn Veeftink (KNMI/TU-Delft)



Nitrosat *mapping reactive nitrogen at the landscape scale* EE-11 Candidate



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Pis: Pierre Coheur (ULB) & Pieternel Levelt (UCAR/KNMI/TU-delft)

Excess reactive nitrogen affects:

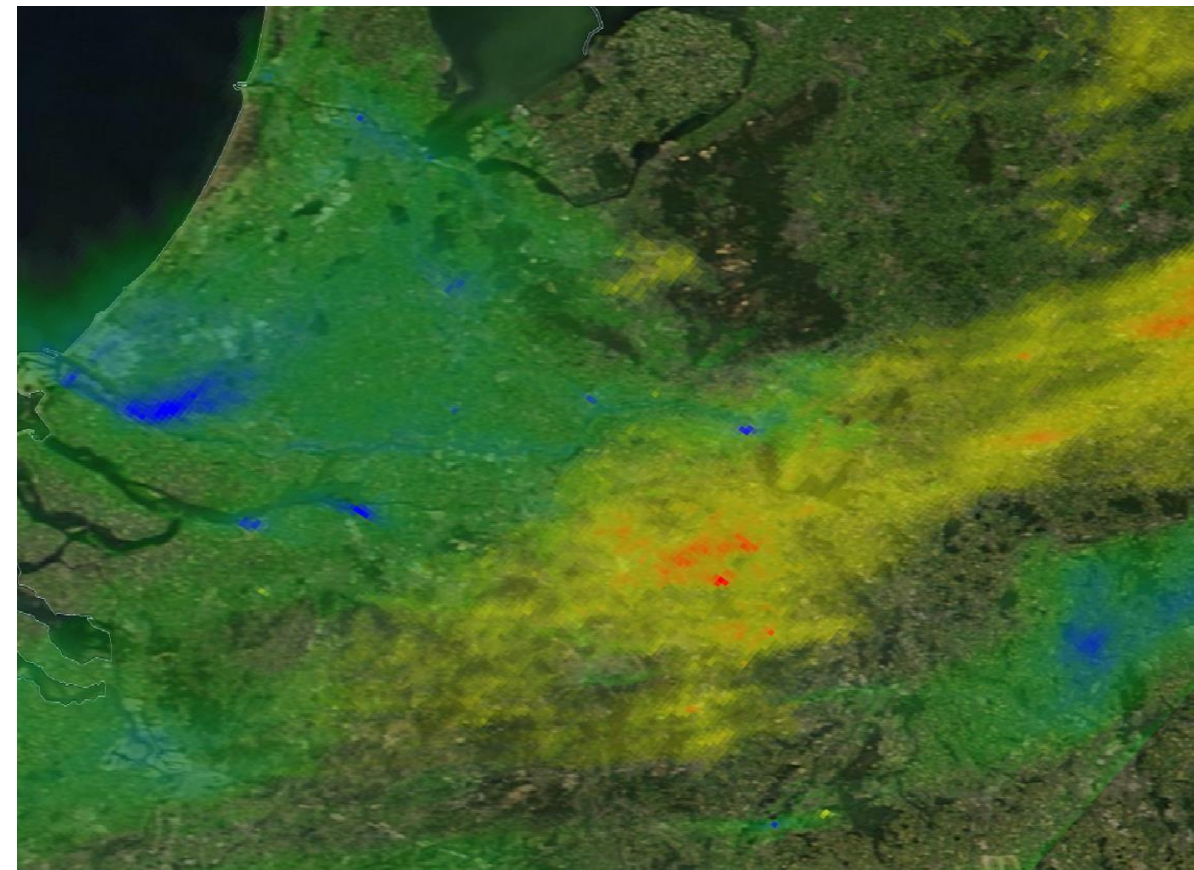
- Air quality
- Biodiversity
- Soil and water quality
- Climate

Observing NH_3 and NO_2 on high spatial resolution

- Swath width >80 km (NH_3) and >160 km (NO_2).
- Spatial resolution better than 500 m.
- Sun synchronous or inclined (drifting) orbits.

Status

- Phase 0 studies started First aircraft campaigns

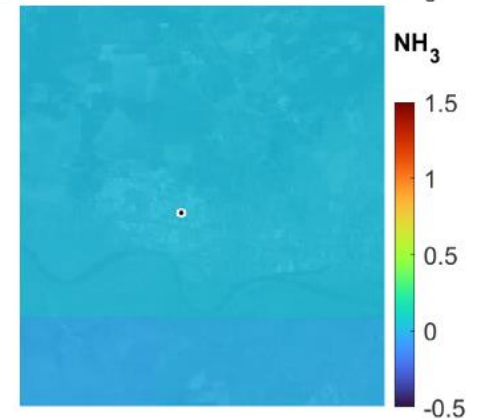
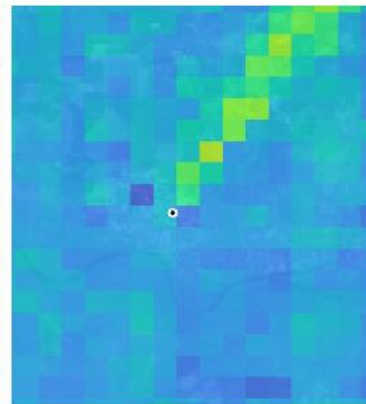
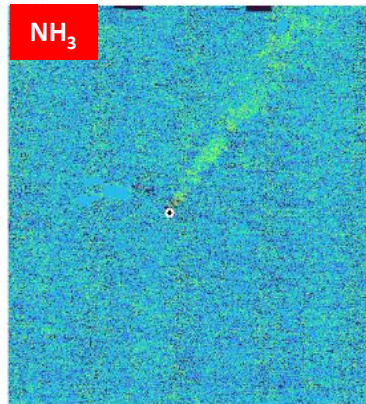
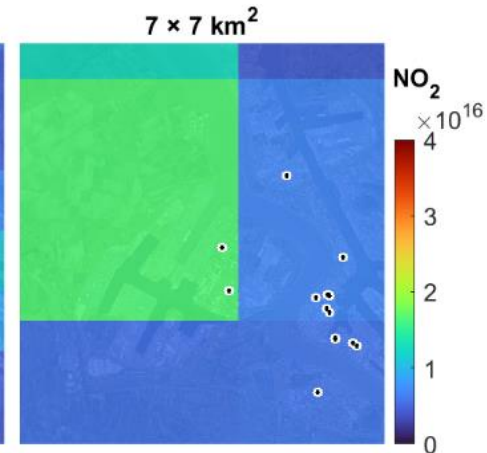
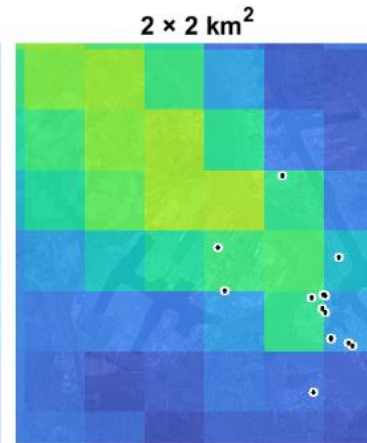
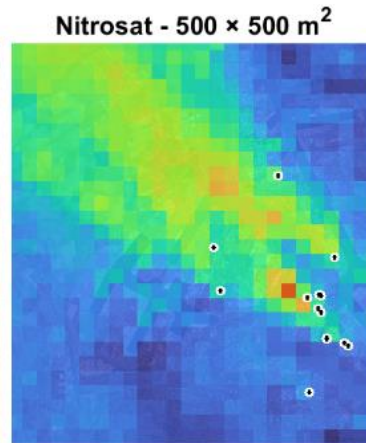
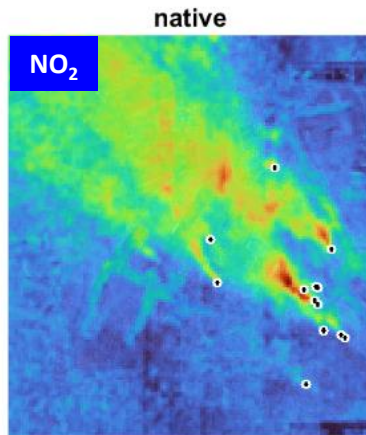
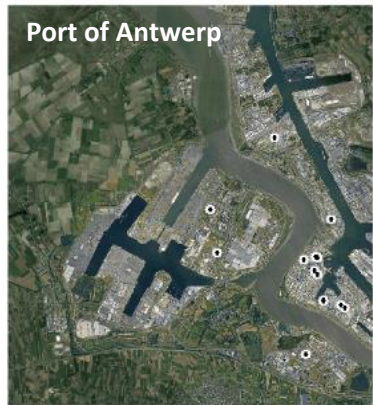


NH_3 (yellow to red) and NO_2 (green to blue) boundary layer concentration at $1 \times 1 \text{ km}^2$ resolution overlaid on a MODIS land imagery over the Netherlands.

Nitrosat

Measurements at the landscape scale

Industrial point sources



Take-home messages



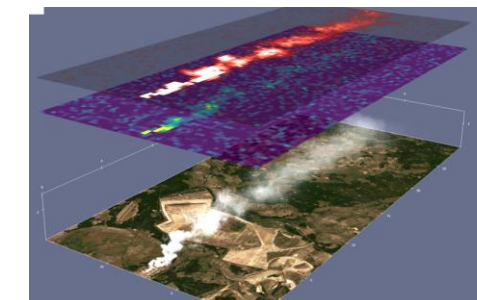
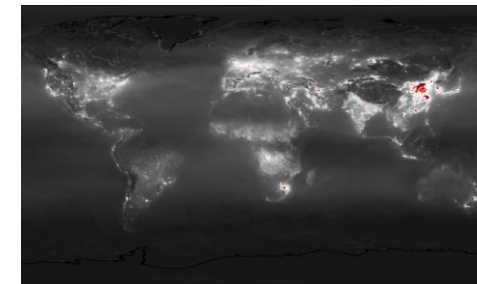
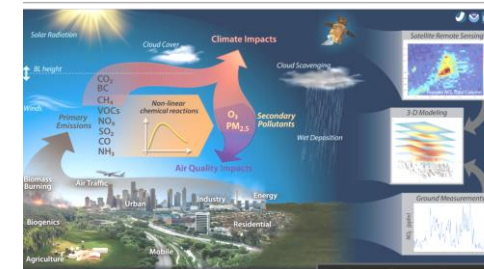
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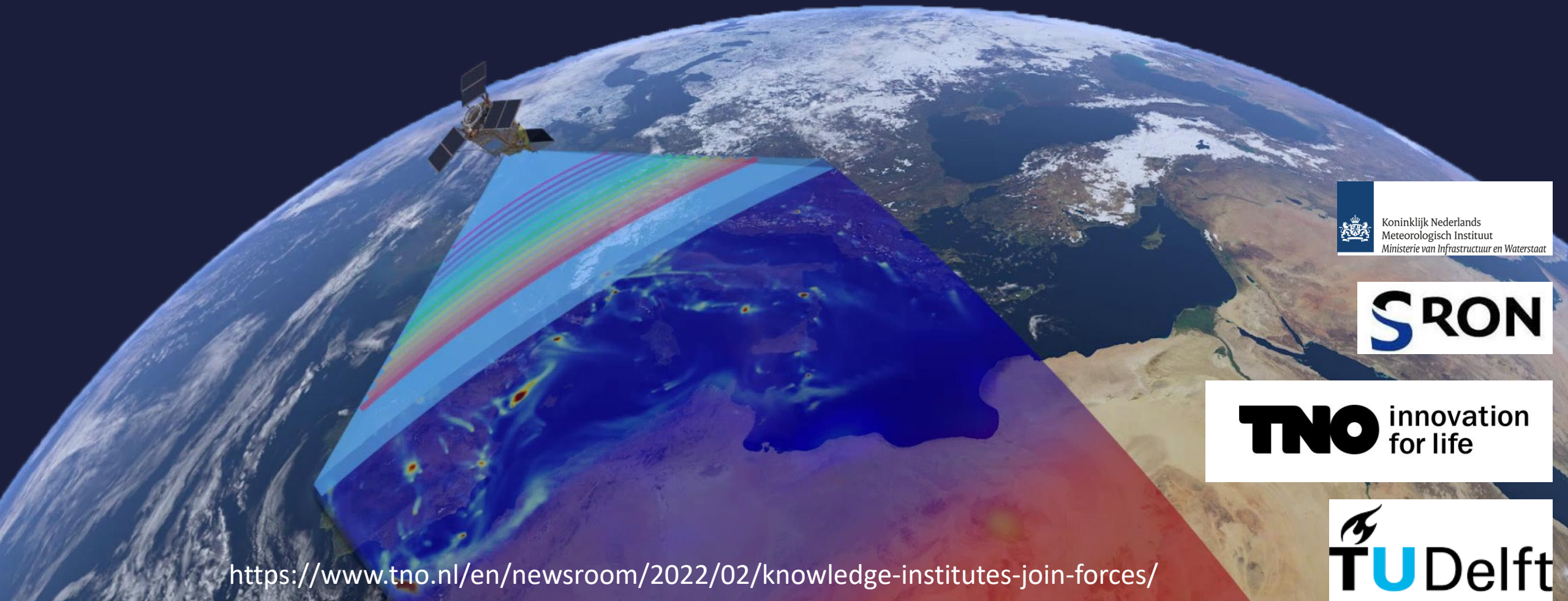
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- Future satellite missions for air quality, climate and biodiversity: focus on carbon cycle & nitrogen cycle.
- Observations should focus on understanding the processes and monitoring the emission changes.
 - Focus on Africa
- Observing system combining global backbone missions and high spatial resolution targeted missions.
 - Global missions: risk that the OMI-TROPOMI data record is discontinued.
 - Tango & Nitrosat
 - Small satellite missions can be developed much faster



Clear Air Consortium



<https://www.tno.nl/en/newsroom/2022/02/knowledge-institutes-join-forces/>