EE-11 candidate Nitrosat

Scientific motivation, goals, and mission requirements

Pierre Coheur and Nitrosat MAG

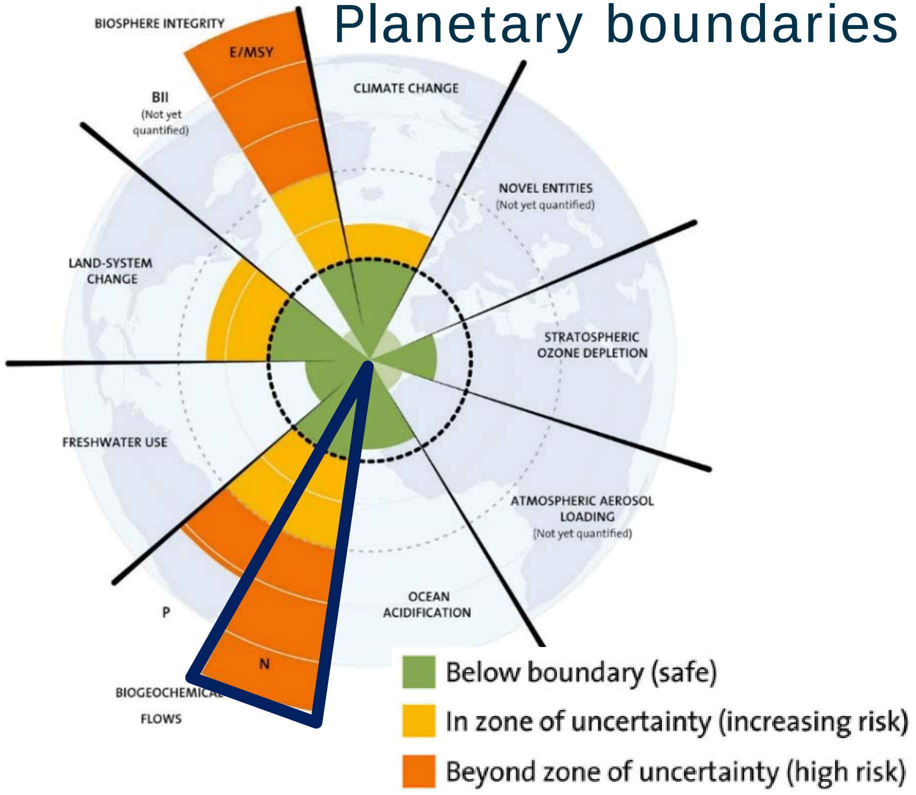
21/10/2021

Scientific motivation and goals

Nitrosat – Mapping reactive nitrogen at the landscape scale

- Emissions of reactive nitrogen have increased five to ten-fold since preindustrial times due to agriculture and energy production
- 90 % of the emissions occur in the form of NO_x and NH_3
- Excess reactive nitrogen has detrimental impacts on human and ecosystems health, as well as on the global environment (climate, biodiversity, stratospheric ozone) *on all scales*
- The current nitrogen biogeochemical flow is placing humanity in a zone of high-risk.

Planetary boundaries



adapted from Steffen et al., Science, 2015

State of the environment in Europe Report 2020

62 %

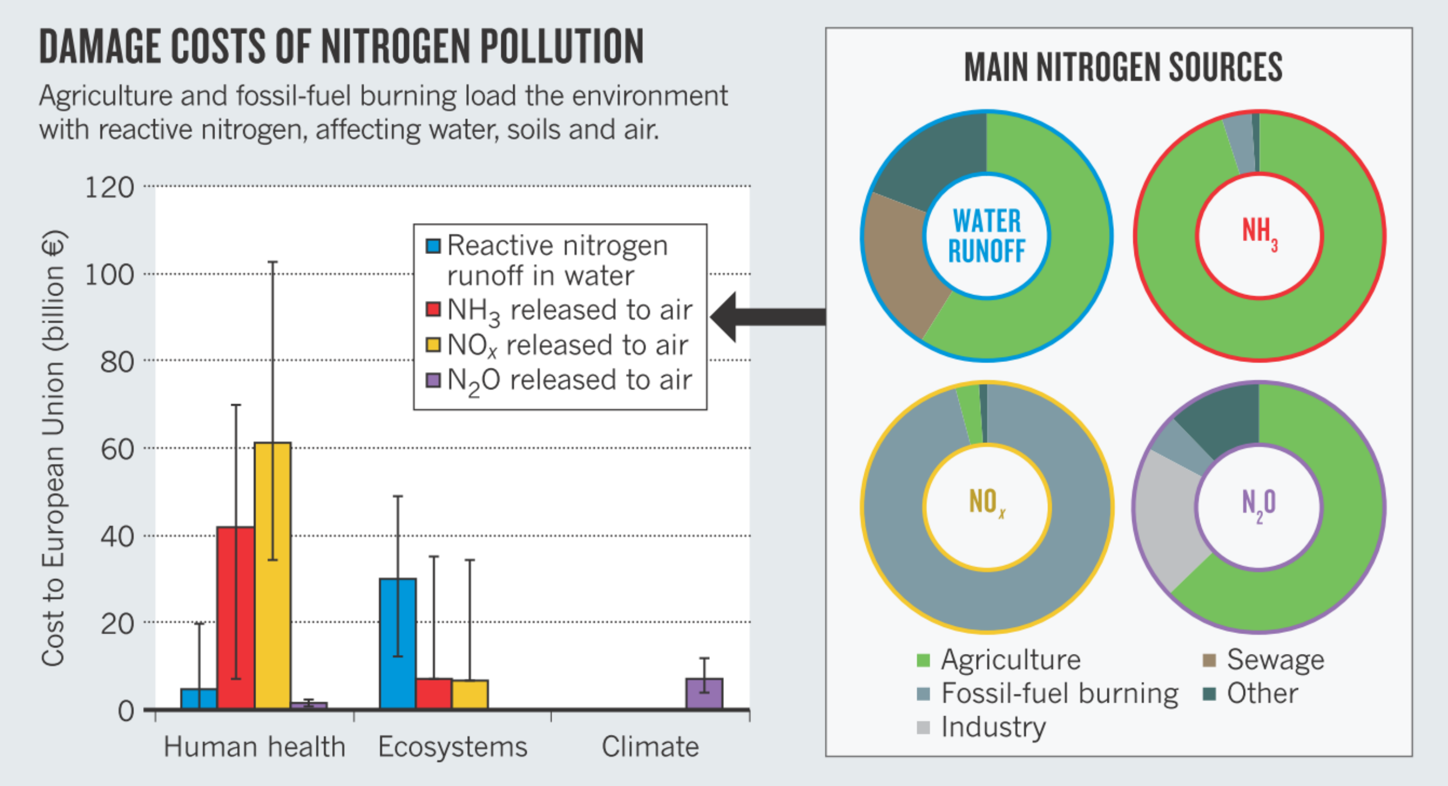
of the area of European ecosystems was exposed to levels of nitrogen beyond that which they can safely tolerate.

58 %

of all Natura 2000 areas is expected to still be at risk in 2030 due to excessive atmospheric nitrogen deposition

Nitrosat – Mapping reactive nitrogen at the landscape scale

- Emissions of reactive nitrogen have increased five to ten-fold since preindustrial times due to agriculture and energy production
- 90 % of the emissions occur in the form of NO_x and NH_3
- Excess reactive nitrogen has detrimental impacts on human and ecosystems health, as well as on the global environment (climate, biodiversity, stratospheric ozone) *on all scales*
- The current nitrogen biogeochemical flow is placing humanity in a zone of high-risk.



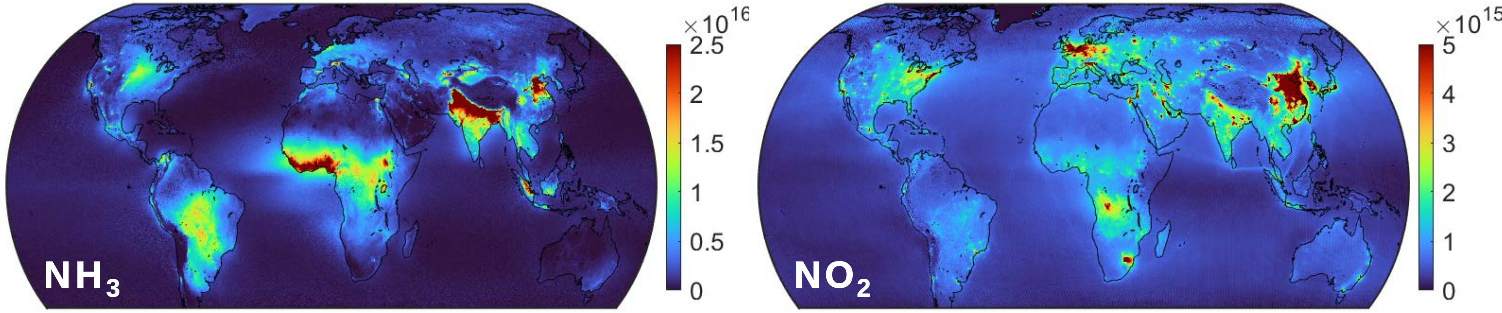
Sutton et al., Nature 2011

EU damage cost: 70-320 billion € / year

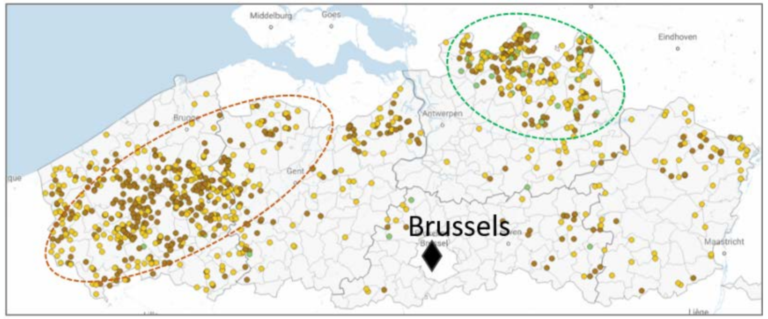
Scientific motivation and goals

Nitrosat – Mapping reactive nitrogen at the landscape scale

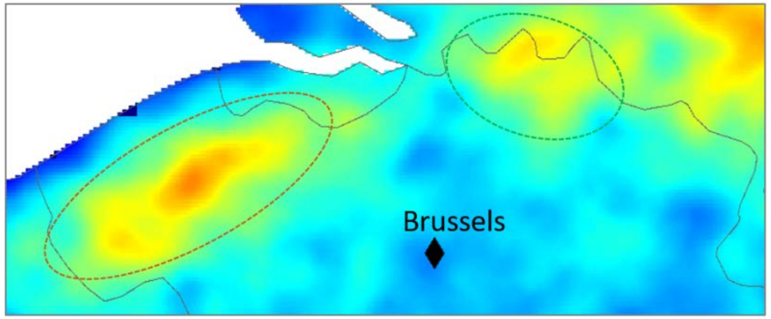
- Much is known on reactive nitrogen at the regional scale but much less is known at the landscape scale



Feedlots in Flanders



Ammonia distribution from IASI



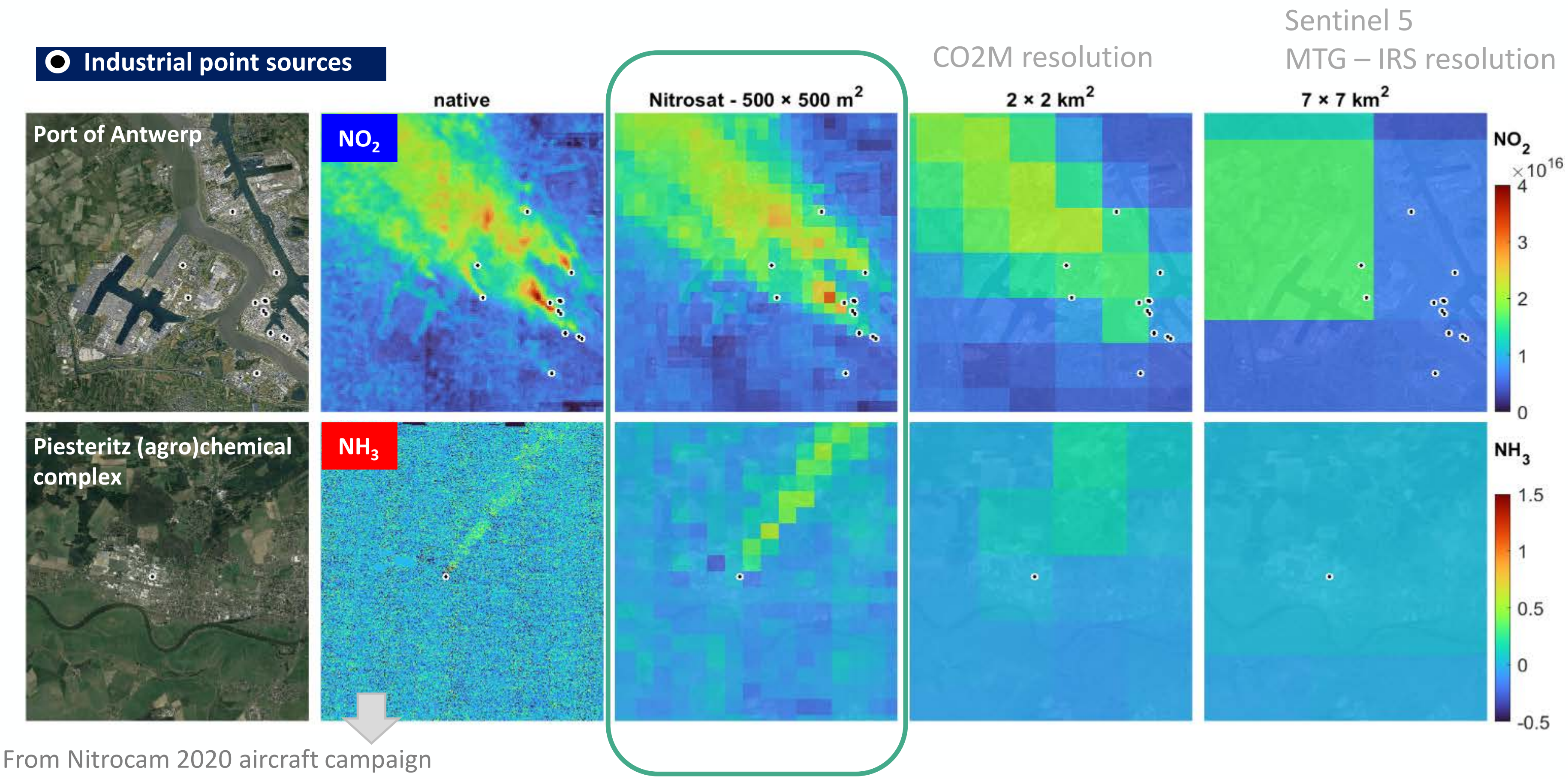
- **Landscape** is needed for:
  - o Disentangling the contribution of different sectors to the emissions
  - o Accurately linking concentrations to exposure and thereby assessing impact on human and ecosystem health
  - o Implementing suitable nitrogen management strategies

Mission Objectives

Nitrosat – Mapping reactive nitrogen at the landscape scale

Nitrosat will provide sub-km spatial resolution measurements of NO_2 and NH_3 in order to allow

- spatial discrimination of both point and area sources
- assessing the nitrogen flows and impacts on air quality and deposition at the landscape scale



Specific objectives

Nitrosat – Mapping reactive nitrogen at the landscape scale

1. Quantify the **emissions** of NH_3 and NO_2 on the landscape scales, to expose individual sources and characterize the temporal patterns of their emissions.
   - Quantify the relative contribution of agriculture, in its diversity of sectors and practices, to the total emissions of reactive nitrogen.

2. Quantify the contribution of reactive nitrogen to **air pollution** and its impact on human health.

3. Constrain the atmospheric dispersion and **surface deposition** of reactive nitrogen and its impacts on **ecosystems** and contribute to monitoring policy progress to reduce nitrogen deposition in Natura 2000 areas in Europe.

4. Reduce uncertainties in the contribution of reactive nitrogen to **climate forcing, atmospheric chemistry** and **interactions between biogeochemical cycles**.

Nitrosat will address ESA's Living Planet Scientific Challenges related to the Atmosphere (A1, A2, A3), Land Surface (L1, L2, L3, L5) and Ocean (O1, O3).

How nitrogen management can contribute to SDGs

https://www.inms.international

Key Mission Requirements

The Nitrosat higher-level mission products cover:

- **Level-1:** Earth radiances in the visible and the thermal infrared spectral domains, measured in a near-nadir viewing geometry
- **Level-2**: Observations of atmospheric NO_2 and NH_3 concentrations.

Spatial resolution and sampling

- ⇨ 500 m (T), 250m (G) resolution
- ⇨ Gapless observations are required over land and coastal areas for both NH_3 and NO_2, for the latter also coverage over major shipping routes is beneficial

The landscape scale will not be accessible with the future Sentinels and other related operational missions.

IRS	16 km²
Sentinel 4	<100 km²
IASI-NG	115-400 km²
Sentinel 5	50-400 km²
CO2M	4 km²

Key Mission Requirements

The Nitrosat higher-level mission products cover:

- **Level-1:** Earth radiances in the visible and the thermal infrared spectral domains, measured in a near-nadir viewing geometry
- **Level-2**: Observations of atmospheric NO_2 and NH_3 concentrations.

Temporal sampling

The temporal sampling of these products is driven by the need to identify seasonal patterns of NO_2 and NH_3 emissions from the different sectors, in particular those associated with

- farming practices
- changes in energy consumptions and domestic heating
- biomass burning

⇨ Target coverage **once a month** above source regions, but ideally shorter (twice a month (B) and once a week (G))

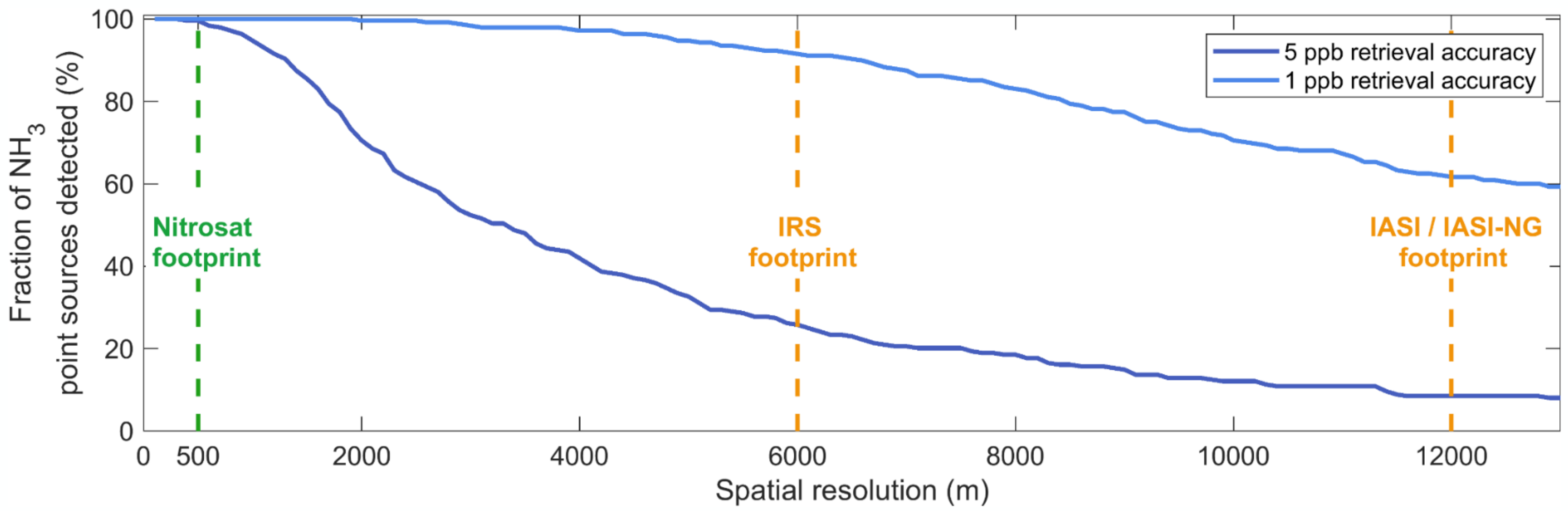
⇨ Daytime overpass between **10h30 and 15h00** local time

Earth radiance observations will be acquired during the day (VIS) and during day and night (TIR)

Key Mission Requirements

Level 2 requirements

Requirements on product uncertainty are set to satisfy the needs of the driving applications, which include monitoring the critical levels (CLEs) for impacts on vegetation (1.5-6 ppb) and air quality (0-12 ppb) *at the target resolution*



- NO_2 vertical column densities shall be observed with a Level-2 product uncertainty of **2 ppb + 25%** or better.
- NH_3 vertical column densities shall be observed with a Level-2 product uncertainty of **2 ppb + 25%** or better.

Key Mission Requirements

Principal L1 requirements

Earth radiances shall be measured in 2 bands

- A **visible band** extending from at least 400 nm to 490 nm with
  - a resolution better than 0.6 nm
  - a SNR higher than 600 (T) / 1200 (G) at a reference radiance signal level of $2.5 \cdot 10^{13}$ photons$\cdot sr^{-1} \cdot nm^{-1} \cdot cm^{-2}$

- A **thermal IR** band extending from at least 925 to 975 cm^{-1} with
  - an apodized resolution better than 1.6 cm^{-1} (T) 1.25 cm^{-1} (B), 0.5 cm^{-1} (G).
  - a NeΔT lower than 400 mK (T), 100 mK (B) and 50 mK (G) at a reference radiance signal level of 280 K

Measurement Concept Trade-Offs

- **Spatial/temporal mapping performance of the TIR sounding instrument:** a better sampling could be achieved with a wider swath but this is clearly a driver for the instrument complexity and performance.
    - Planned scientific studies will assess the sensitivity of NH_3 retrieval under different observation conditions and instrument scenarios and consolidate a baseline swath / NeΔT configuration

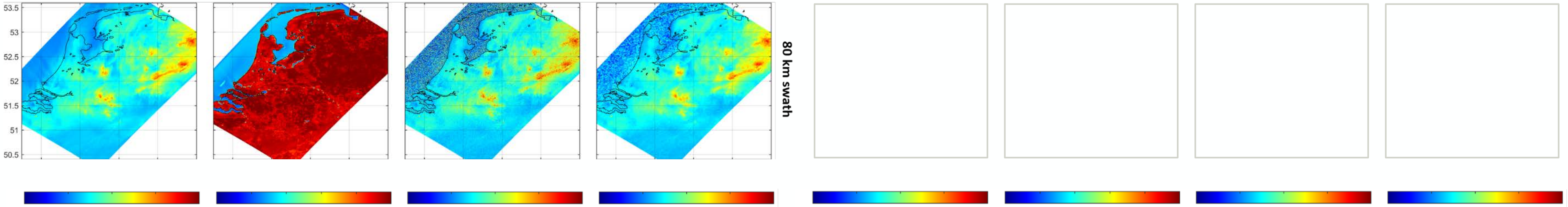
- **Spectral range** in both bands by also taking into account co-benefits (HONO; other industrial emission tracers)

- **Orbit choice** with consideration of science objectives (inclined or not) but also synergies with Sentinel 4-5 and CO2M missions

Comments from the EE11 Scientific Peer Review of the Nitrosat Proposal

- Developments of chemistry-transport models to exploit high-spatial resolution Nitrosat products
- Demonstration of the observational breakthrough of Nitrosat by data assimilation and inverse modelling studies.

Truth | Geophysical conditions | Retrieved concentrations (**L2**) | Higher level products (**L3-L4**)



Reference columns (ppb) | Thermal contrast (K) | Nitrosat 500×500 m^2 (ppb) | Nitrosat 2×2 km^2 (ppb)

Emission fluxes | **Deposition fluxes Critical levels** | **[PM]** | **[O3]**

SRL 4-5

Exposure
(population, Natura 2000 areas…)

Ecosystem / health assessments

Summary and Conclusions

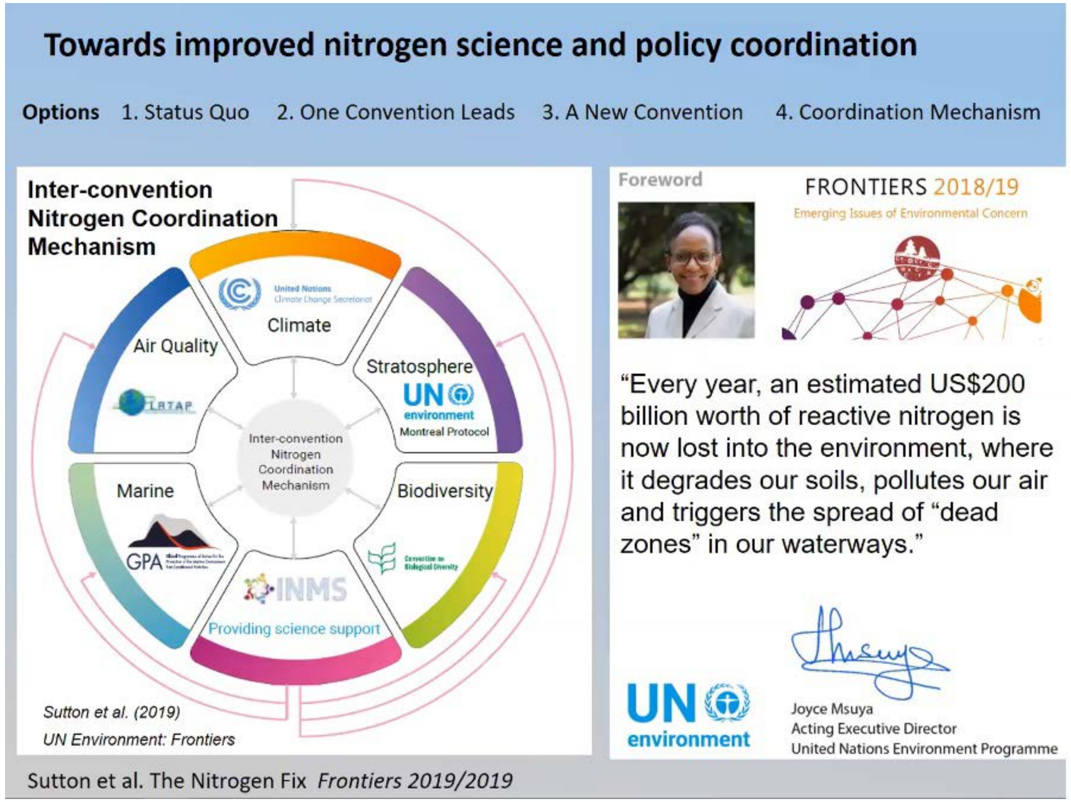
Nitrosat would be the first atmospheric sounding mission capable of addressing the global nitrogen challenge

Measurement of both oxidized and reduced nitrogen

- Coupling NO_2 and NH_3 links source sectors: agriculture, industry and transport. All sectors must be involved!

Unprecedented spatial resolution and mapping

- Capability to distinguish major sources globally
  - ⇨ towards establishing an international (compliance) monitoring system as input to emerging UN action including INMS & INCOM
- Capability to link atmospheric measurements to exposure for assessing impacts on human and ecosystems health
- Synchronized with the future CO2M mapping mission, Nitrosat will be a key element for assessing the intertwined carbon and nitrogen budgets on the landscape scale



Summary and Conclusions

esa

Relevance to international programs

- ESA Living Planet Scientific Challenges
- *The Sustainable Nitrogen Management resolution (UNEP/EA.4/Res.14) adopted by the United Nations Environment Assembly on 15 March 2019*
- The 2030 Agenda for Sustainable Development of the United-Nations (UN)
- The Geneva Convention on Long-Range Transboundary Air Pollution (CLRTAP)
- The UN Convention on Biological Diversity
- The European Bird and Habitat Directive to maintain Natura 2000 quality and protect them against excess nitrogen deposition
- The Global Atmosphere Watch (GAW) program from the World Meteorological Organization (WMO)
- The Copernicus Atmosphere Monitoring Service (CAMS)
- The International Nitrogen Management System (INMS)

United Nations
Environment Assembly of the United Nations Environment Programme

United Nations Environment Assembly of the United Nations Environment Programme
Fourth session
Nairobi, 11–15 March 2019

Resolution adopted by the United Nations Environment Assembly on 15 March 2019

4/14. Sustainable nitrogen management

The United Nations Environment Assembly,

Recognizing the multiple pollution threats resulting from anthropogenic reactive nitrogen, with adverse effects on the terrestrial, freshwater and marine environments, and to air pollution and greenhouse gas emissions, while acknowledging the benefits of nitrogen use for food and energy production,

Calls on the Executive Director of the United Nations Environment Programme to:

(a) Consider the options to facilitate better coordination of policies across the global nitrogen cycle at the national, regional and global levels, including consideration of the case to establish an intergovernmental coordination mechanism on nitrogen policies, based primarily on existing networks and platforms and consider the case for developing an integrated nitrogen policy, which could enhance the gravity of common cause between multiple policy domains.

EE-11 candidate Nitrosat

Scientific motivation, goals, and mission requirements

Pierre Coheur and Nitrosat MAG

21/10/2021