Nitrosat

https://nitrosat.eu/

High Resolution

Nitrogen

Focus

Earth

Reactive nitrogen (Nr) :

- Ammonia (NH_3)
  - Ammonium (NH_4^+)
- Nitrogen oxides (NO_x)
  - Nitrous oxide (N_2O)
  - Nitric acid (HNO_3)
  - Nitrous acid (HONO)
  - Organic forms

A Satellite Mission Concept For Mapping Reactive Nitrogen At The Landscape Scale

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The Nitrosat proposing team,
The Nitrosat MAG,
The Nitrosat Scientific study team

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Simone Rafano Carná, Dirk Schüttemeyer

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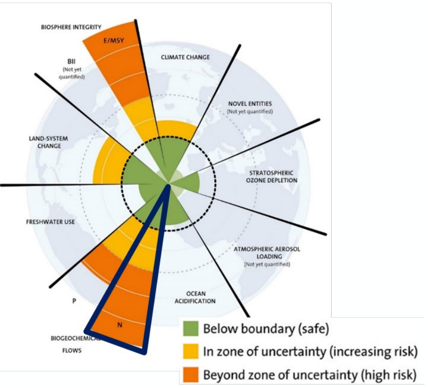
ESA Living Planet Symposium – May. 2022

Scientific motivation and goals

Anthropogenic perturbation of the reactive nitrogen cycle

- Emissions of reactive nitrogen have increased five to ten-fold since preindustrial times due to agriculture and energy production
- Excess reactive nitrogen has detrimental impacts on human and ecosystems health locally (**Air Quality, acidification / eutrophication**) , as well as on the global environment (**climate, biodiversity, stratospheric ozone**)

Planetary boundaries



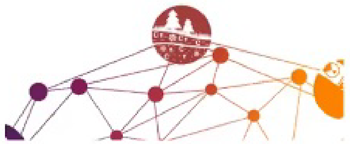
adapted from Steffen et al., Science, 2015

⇨ **The current nitrogen biogeochemical flow is placing humanity in a zone of high-risk.**

Foreword

FRONTIERS 2018/19

Emerging Issues of Environmental Concern



"Every year, an estimated US$200 billion worth of reactive nitrogen is now lost into the environment, where it degrades our soils, pollutes our air and triggers the spread of "dead zones" in our waterways."

UN environment

Joyce Msuya
Acting Executive Director
United Nations Environment Programme

« The current modification of the nitrogen cycle, mainly due to fertiliser use in agriculture, is far greater in magnitude than the modification of the global carbon cycle as a result of GHG emissions »

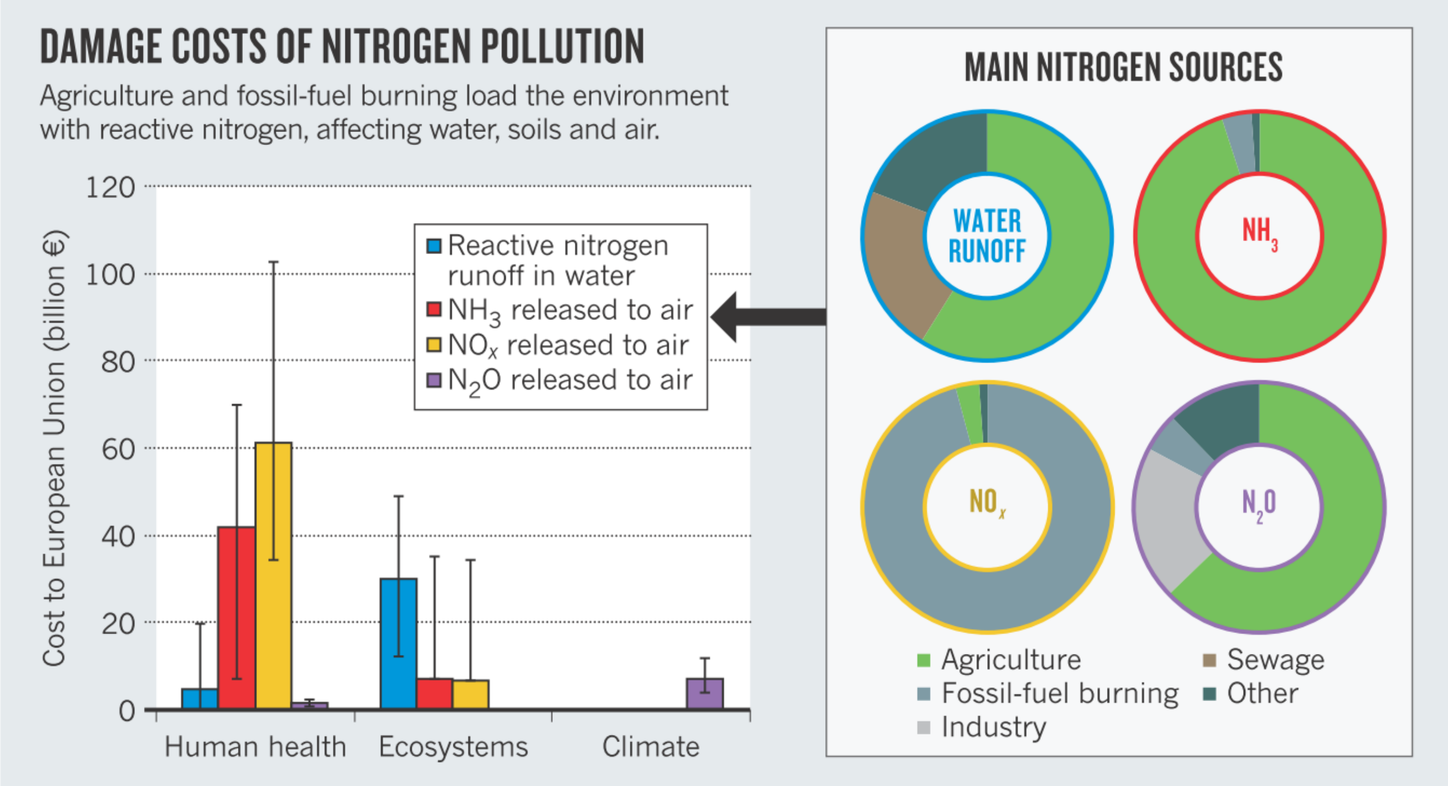
EU SOER 2020

The European environment – state and outlook

Scientific motivation and goals

Anthropogenic perturbation of the reactive nitrogen cycle

- **90 % of the emissions occur in the form of NO_x and NH_3**



Sutton et al., Nature 2011

EU damage cost: 70-320 billion € / year

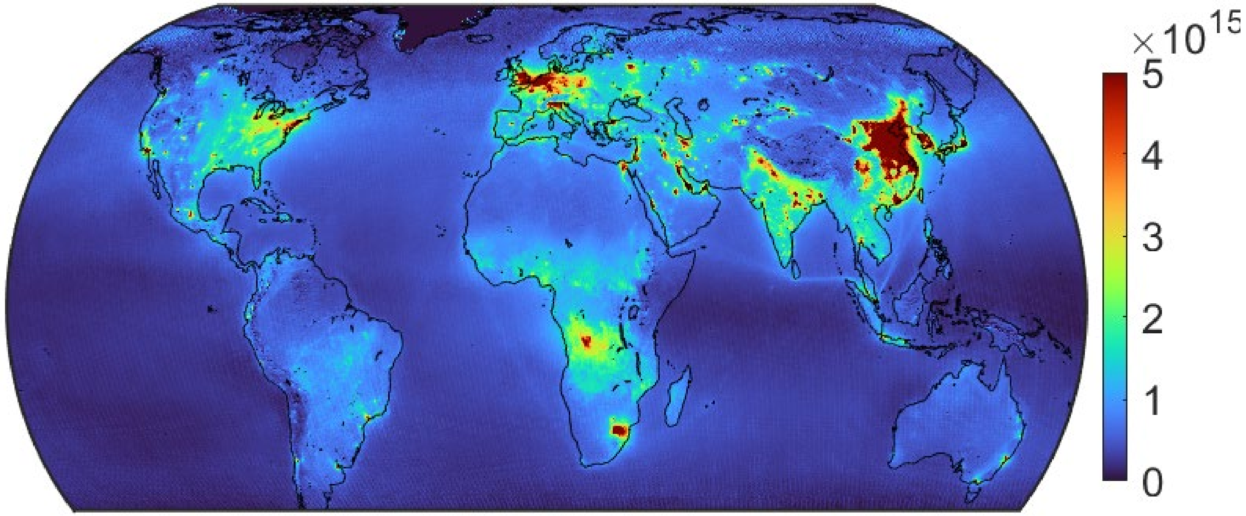
Scientific motivation and goals

Landscape scale: a remaining gap for measuring reactive nitrogen

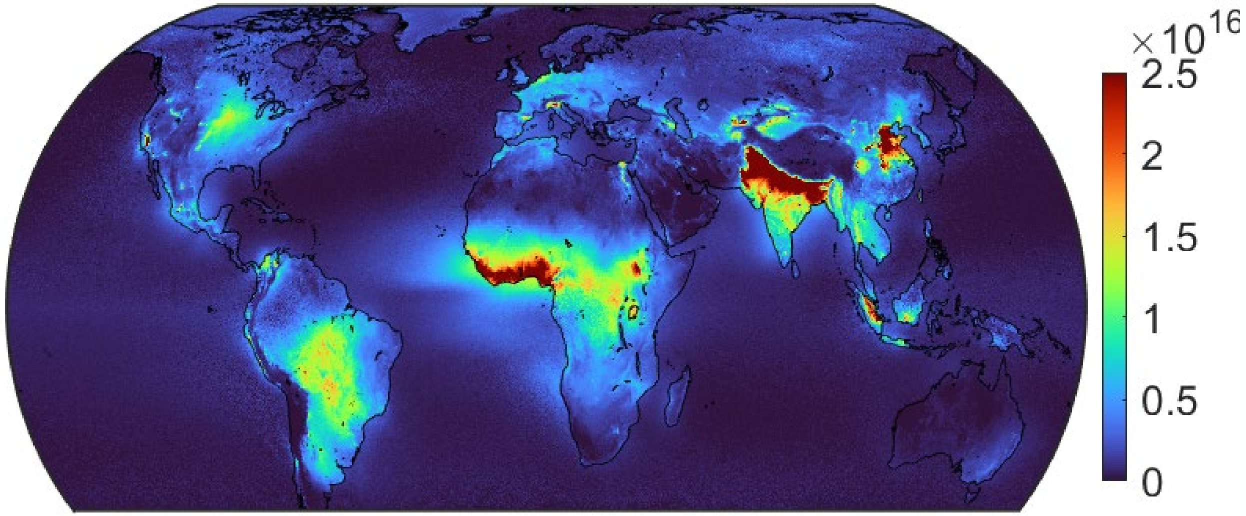
- Much is known on reactive nitrogen at the regional scale

10-year averages

Tropospheric NO_2 from OMI



Tropospheric NH_3 from IASI



Fingerprint of anthropogenic pollution (regional, country to global scale)

Energy production; transport…

Agriculture

Scientific motivation and goals

Landscape scale: a remaining gap for measuring reactive nitrogen

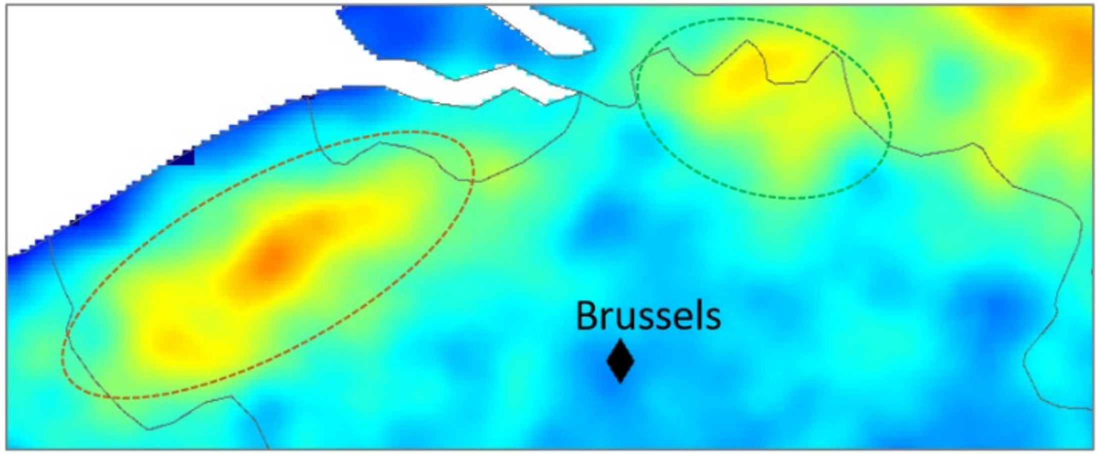
- Much is known on reactive nitrogen at the regional scale but:

  1. **Local (point source) detection only possible using long term averages and specialised imaging techniques (wind-rotated supersampling)**

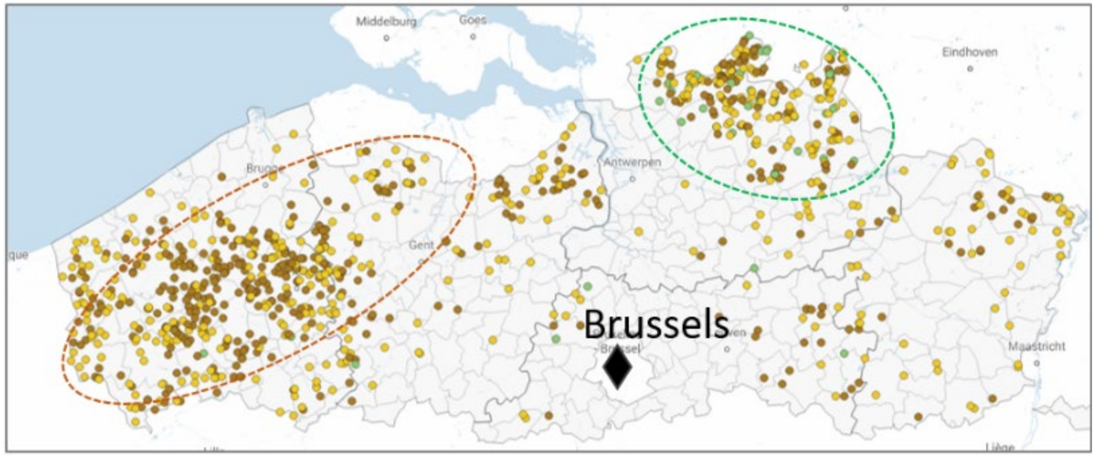
  2. **Clusters cannot be disentangled**

  3. **Extracting reliable emission / deposition fluxes and assessing the related impacts at local scale extremely challenging**

Ammonia distribution from IASI – 10 year average

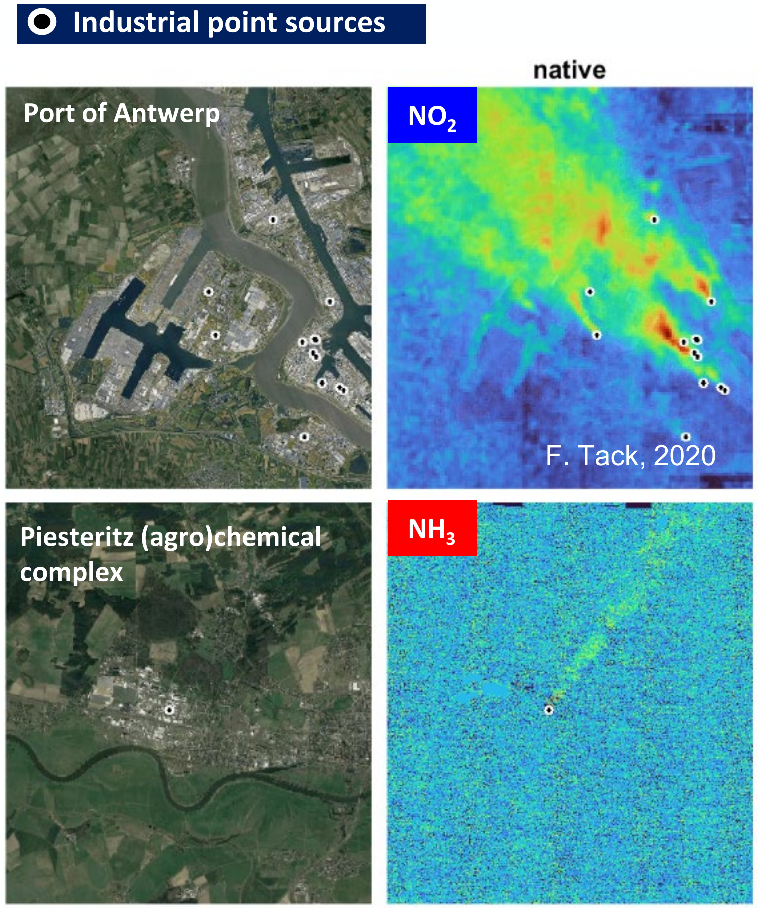


Feedlots in Flanders



Mission Objectives

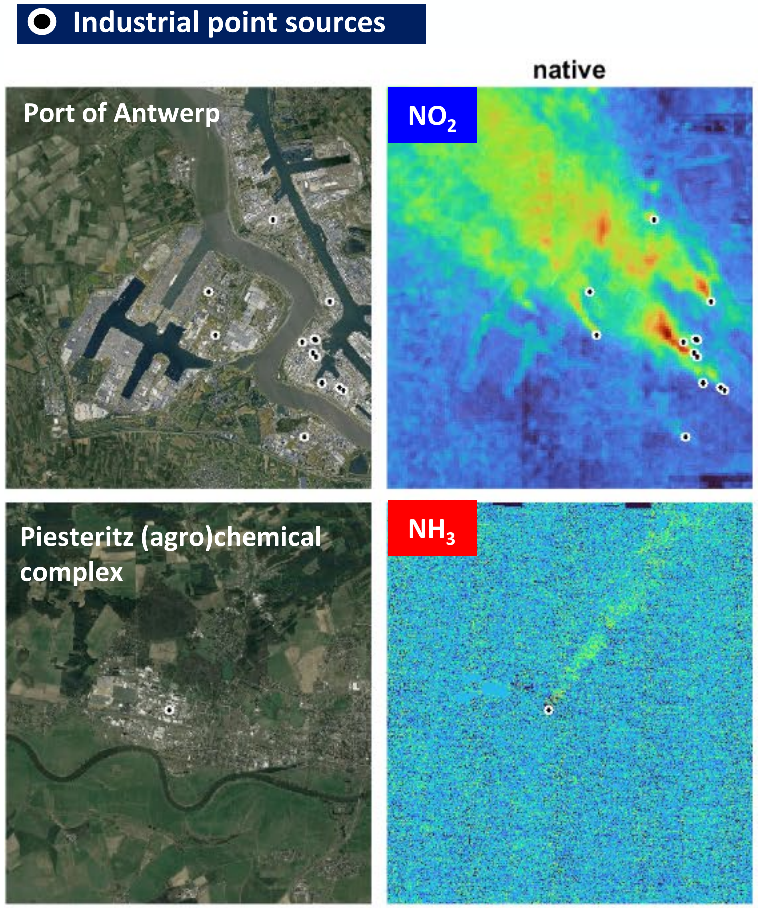
Measurements at the landscape scale

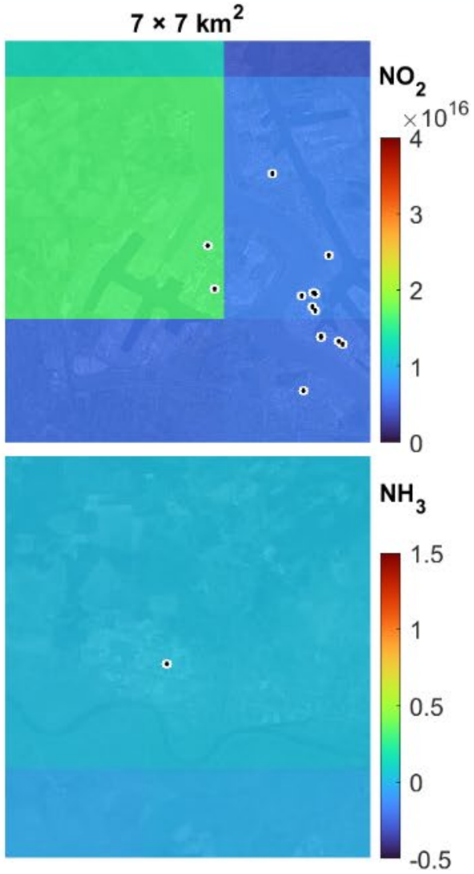


Mission Objectives

Measurements at the landscape scale

Sentinels 4, 5
IASI-NG, MTG – IRS





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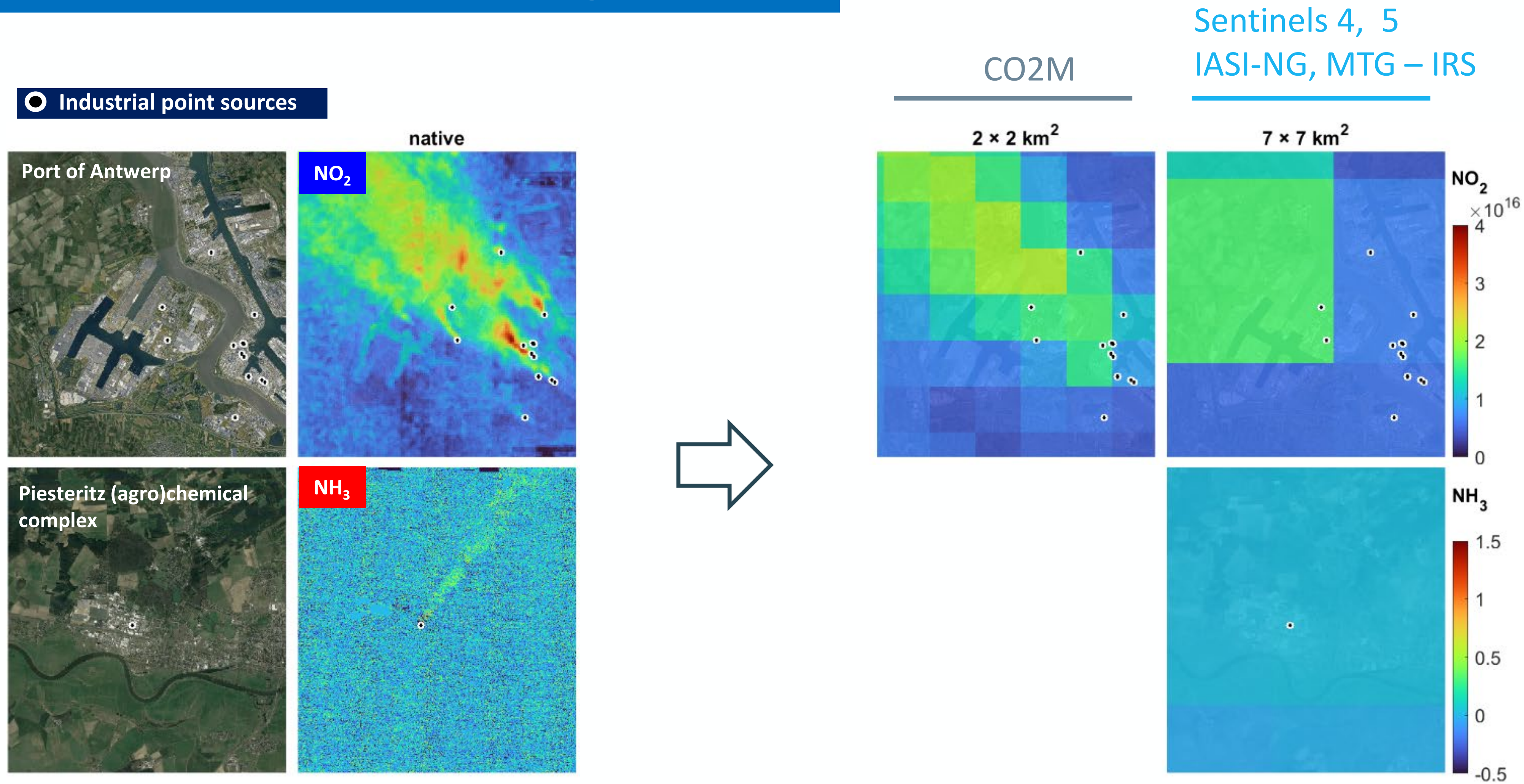


Mission Objectives

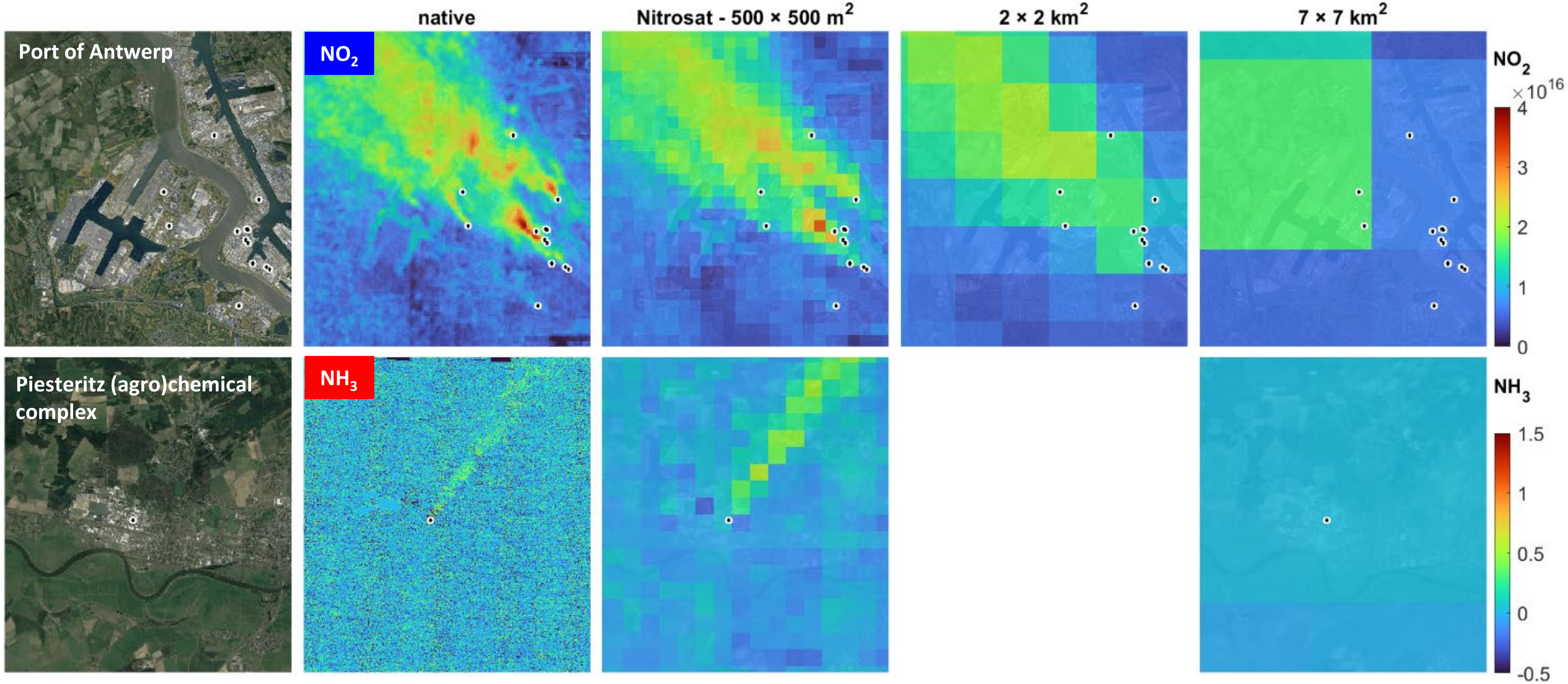
Measurements at the landscape scale

Industrial point sources

Nitrosat

CO2M

Sentinels 4, 5
IASI-NG, MTG – IRS



Mission Objectives

Four specific objectives

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:

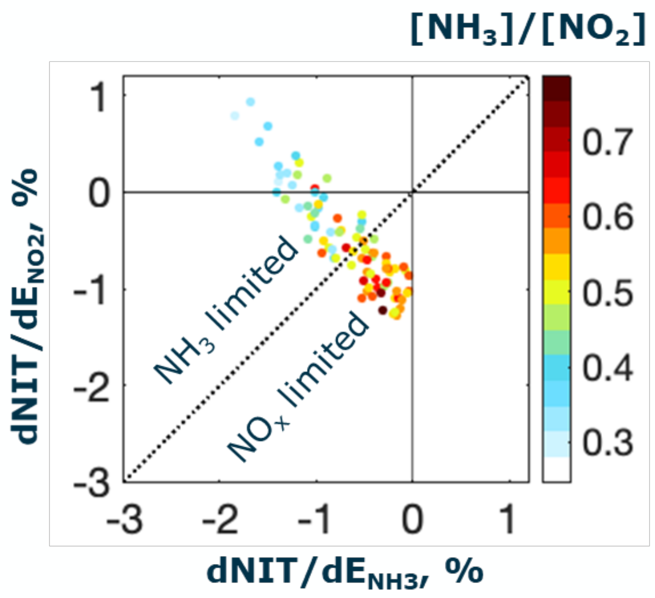
- **Level-1:** Earth radiances in the visible and the thermal infrared spectral domains, measured in a near-nadir viewing geometry
- **Level-2**: observations (co-located) of atmospheric NO_2 and NH_3 concentrations.

Spatial resolution and sampling

⇨ **500 m threshold**

⇨ **Gapless observations**

NH_3/NO_2 ratio can help to decide on suitable air quality strategies locally!



D. Jacob, Shixian Zhai
Ruijun Dang

Threshold (0.25 km²)

One to several order of magnitude better than operational missions

IRS	40 km^2
Sentinel 4	< 100 km^2
IASI-NG	>100 km^2
Sentinel 5	> 50 km^2
CO2M	4 km^2

Key Mission Requirements

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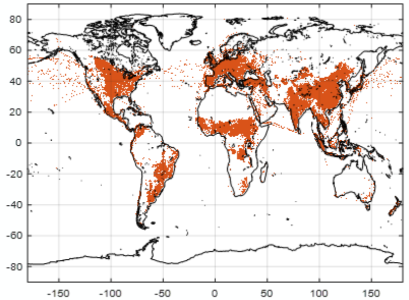
Temporal sampling

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

⇨ Revisit time **twice a month** at least over 55°S-55°N lat



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

Overpass time should include the 10h30 and 15h00 time window

Mission concept

Synchronized imaging of NH_3 and NO_2

NH_3 Infrared imaging Spectrometer

- 875-975 cm^{-1} spectral range
- >0.9 cm^{-1} spectral resolution
- NeDT < 0.2 K

NO_2 Visible Imaging Spectrometer

- 360-490 nm spectral range
- <0.6 nm spectral resolution
- SNR 600-1200 (cloud free)

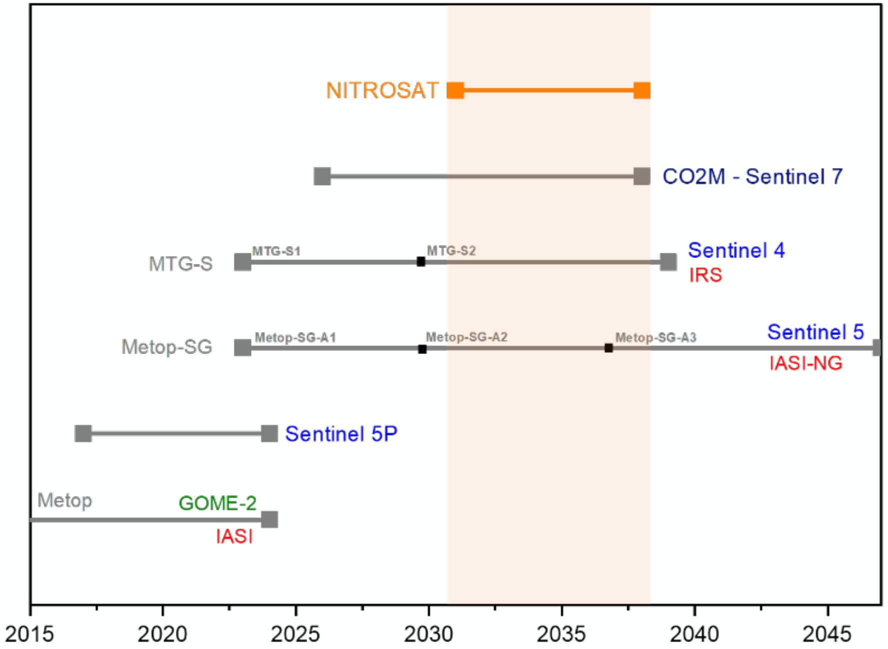
GIFOV at least 0.5×0.5 km^2

Bi-monthly revisit time

- Launch in 2031
- **7-years lifetime** (goal)
  to identify first signs of adaptations in economy and agriculture

Synergies

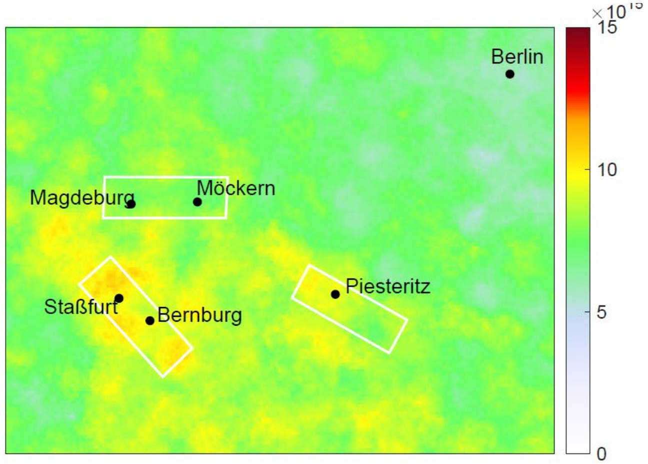
- With Sentinel 4-5: High-resolution mapping of Nitrogen on top of the operational backbone
- With CO2M: Mapping nitrogen and carbon cycle disruptions together

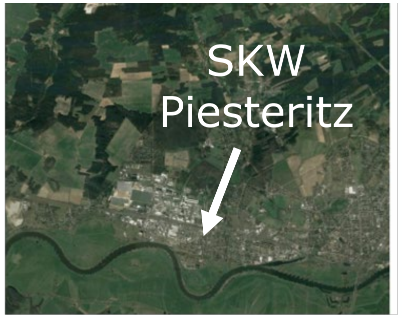


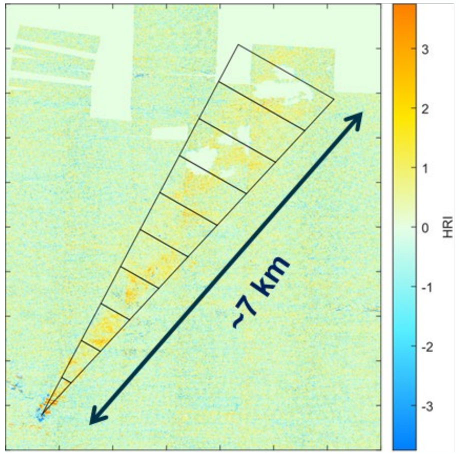
Current activities

- **Science study** kicked-off in December 2021
  ⇨Consolidation of requirements and assessment of mission performances
- **System study** kicked-off in March 2022
  ⇨ Mission concepts
- **Campaigns**
  ⇨ Demonstration from aircraft

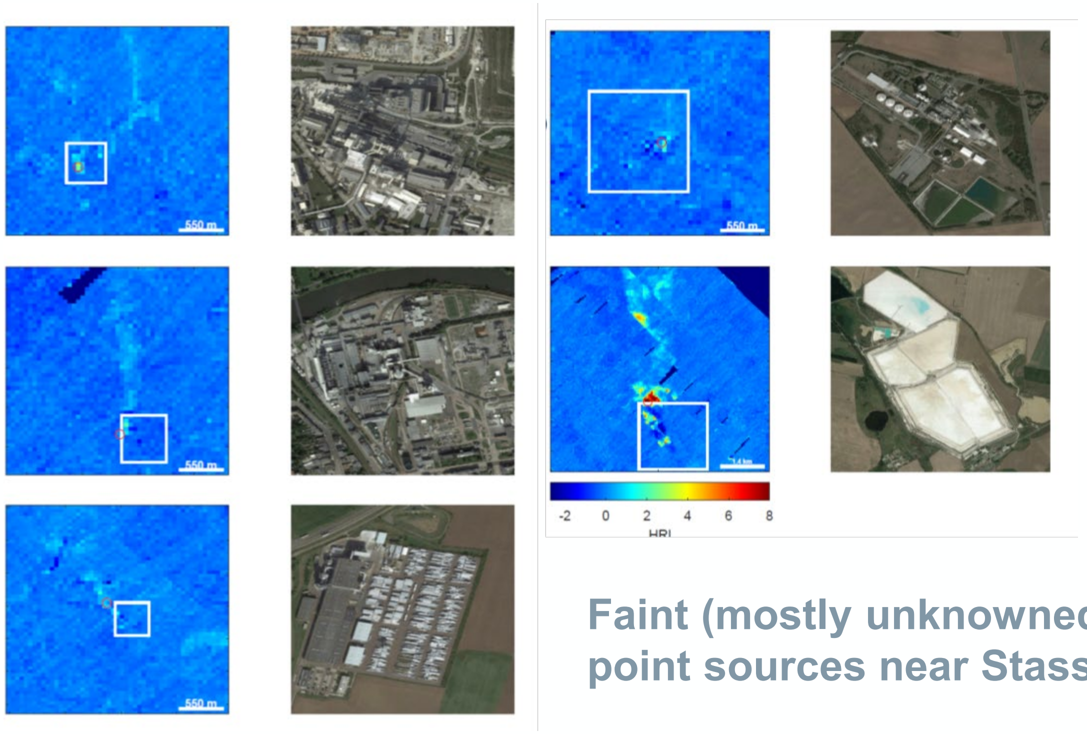
Lara Noppen Friday 10:40, Session A1.06.1 (Bangkok)







October 2020 / May 2021 Campaign in Berlin area



Faint (mostly unknowned) NH_3 point sources near Stassfurt

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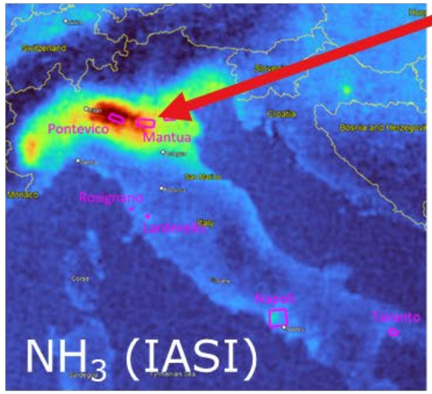
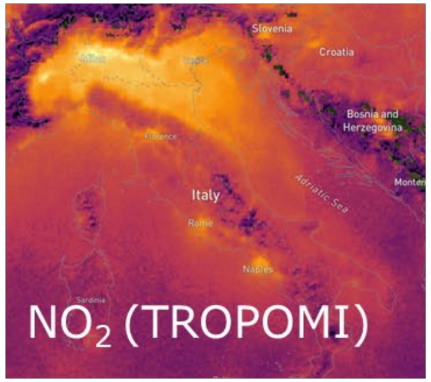
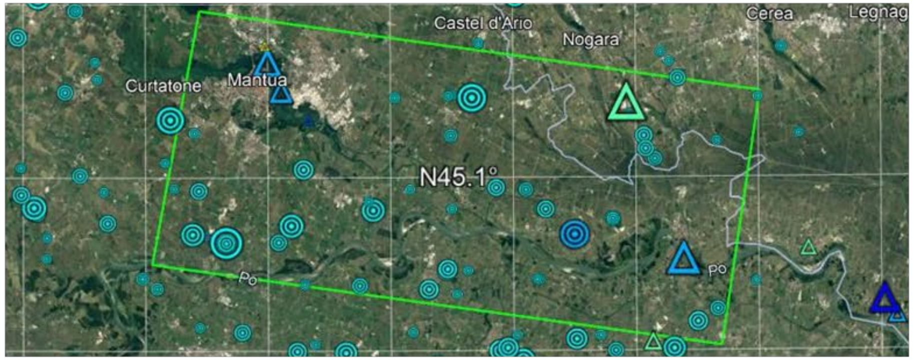
May 2022 Campaign in Italy





Mantua – Pô Valley



◎ = NH_3 point source

◎ = NO_2 point source

- Several agricultural NH_3 point sources,
- Steel plant emitting NO_2 and possibly NH_3.
- City of Mantua and other NO_2 industrial point sources (cement, energy).

Grossetto – Fertilizer experiment

Summary and Conclusions

- **With its unprecedented spatial resolution and mapping Nitrosat would be the first atmospheric sounding mission capable of addressing the global nitrogen challenge in the 21st century**

  Towards improved nitrogen and policy coordination for air quality and ecosystem health

- Synchronized with the future CO2M mapping mission: Nitrosat would provide Europe with a **unique monitoring system for carbon and nitrogen together**.

https://nitrosat.eu/

Nitrosat

NITROSAT EARTH EXPLORER CANDIDATE • SCIENCE GOALS • SCIENTIFIC TEAM • MISSION ADVISORY GROUP • ABOUT NITROGEN

Nitrosat Earth Explorer candidate

MAPPING REACTIVE NITROGEN AT THE LANDSCAPE SCALE

esa

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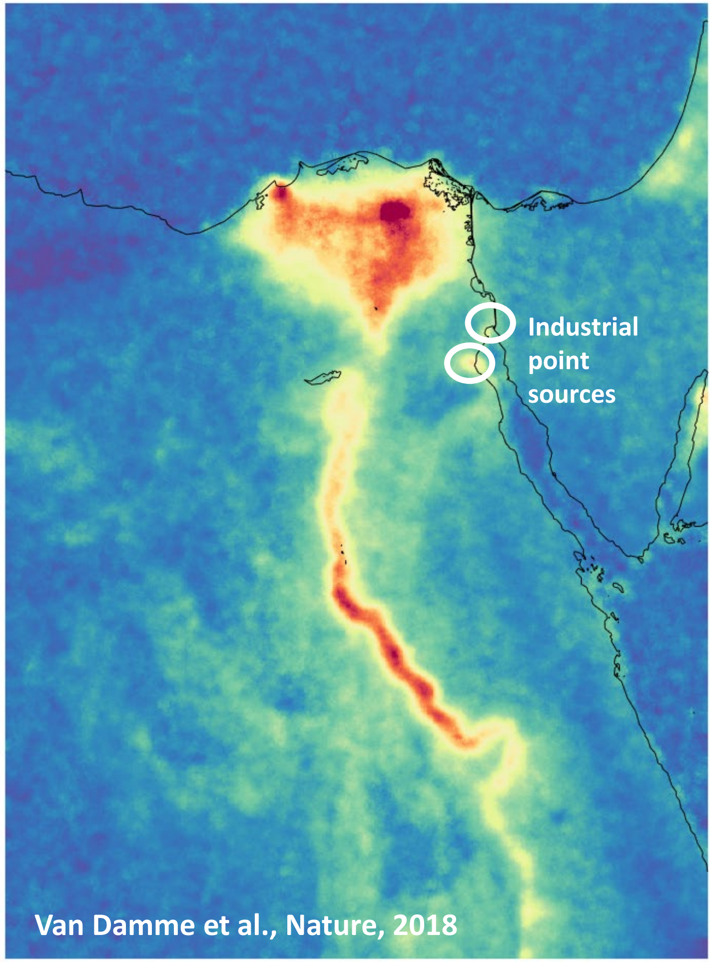

10 years

NH_3 from IASI

Van Damme et al., 2018
Sun et al., 2018
Clarisse et al., 2009