



# **THE USE OF SATELLITE BASED OBSERVATIONS FOR AIR QUALITY APPLICATIONS**

**USING LOTOS-EUROS MODEL | DR. R.M.A. TIMMERMANS AND  
COLLEAGUES**



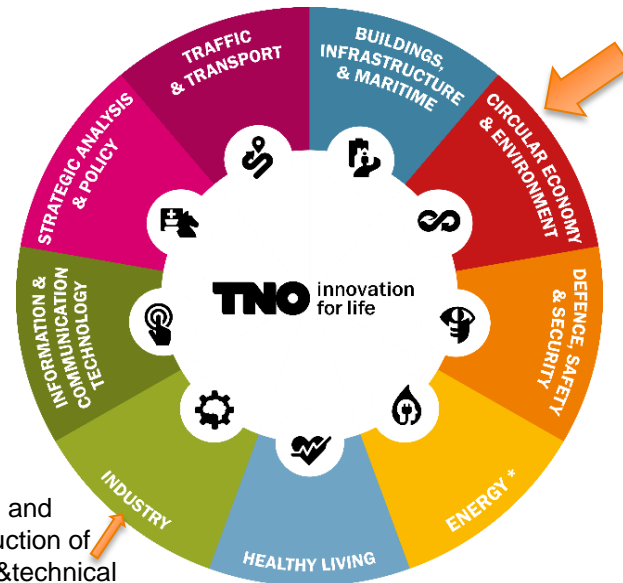
# INTRODUCTION

## TNO

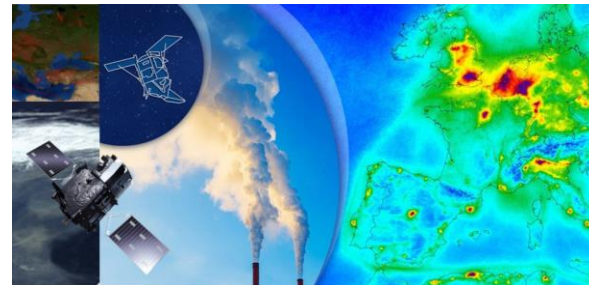
- › Netherlands Organization for Applied Scientific Research
- › Independent, not-for-profit organization
- › Technology development and consultancy
- › 14 locations NL, 9 agencies worldwide
- › Some 3,000 employees, scientists and engineers (9 units)

## Department Climate, Air and Sustainability

- › 15 years as researcher and project leader
- › Focus on air pollution modelling (in combination with observations)



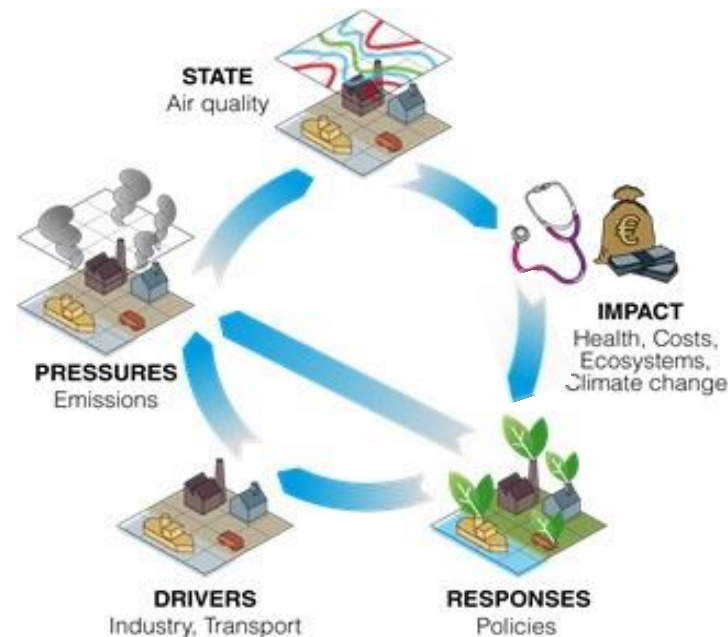
Design and construction of optical&technical parts of TROPOMI



# EMISSIONS AND AIR QUALITY TEAM

- We provide information to policy makers to underpin the development of effective strategies for air pollution abatement
- Evaluate policy measures – assessment studies

**This presentation, some examples of our experience with the use of remote sensing data to achieve these goals**

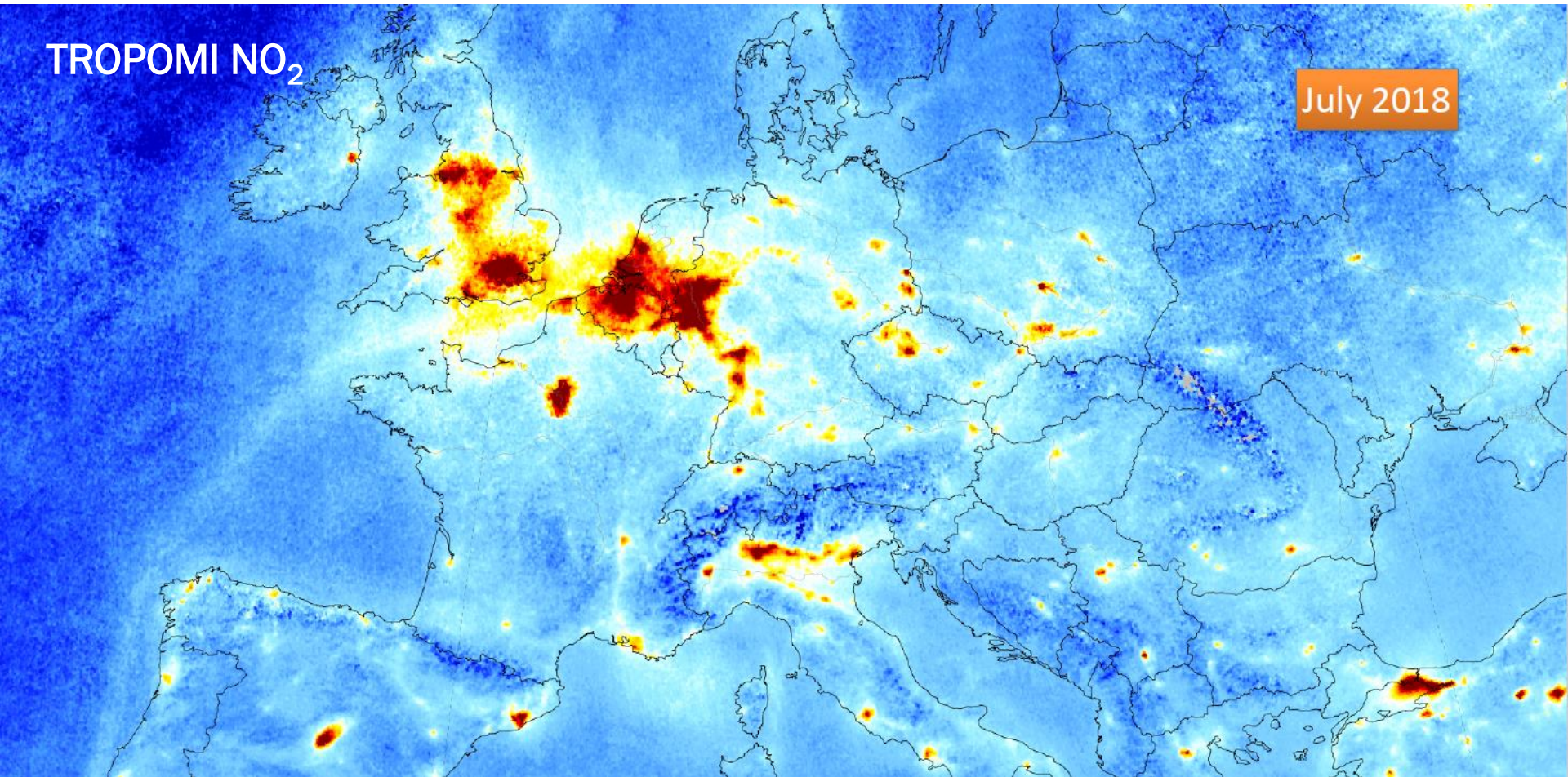




Satellite instruments provide a wealth of information on air pollution

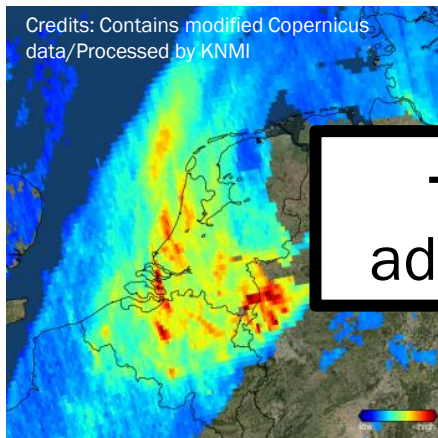
TROPOMI NO<sub>2</sub>

July 2018



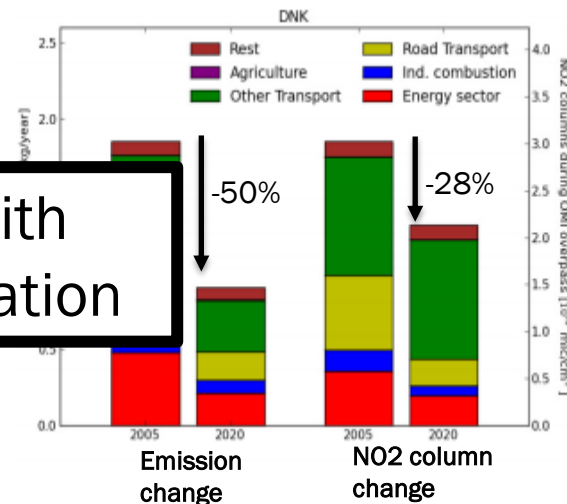
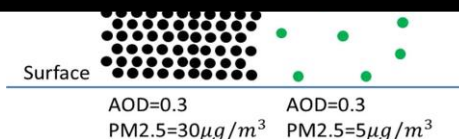
# OBSTACLES FOR USE IN AIR QUALITY APPLICATIONS

Martijn Schaap et al., 2013



Li et al., 2016

→ need for combination with additional sources of information



- **Clouds** – no data
- Temporal **resolution** – daily
- Spatial **resolution** prohibits the representation of street level concentrations where most of the exceedances occur.

Most products not directly comparable to surface variables of interest

**Columnar values** → Need profile information

**AOD versus particulate matter**

- Need composition information
- Need relative humidity information

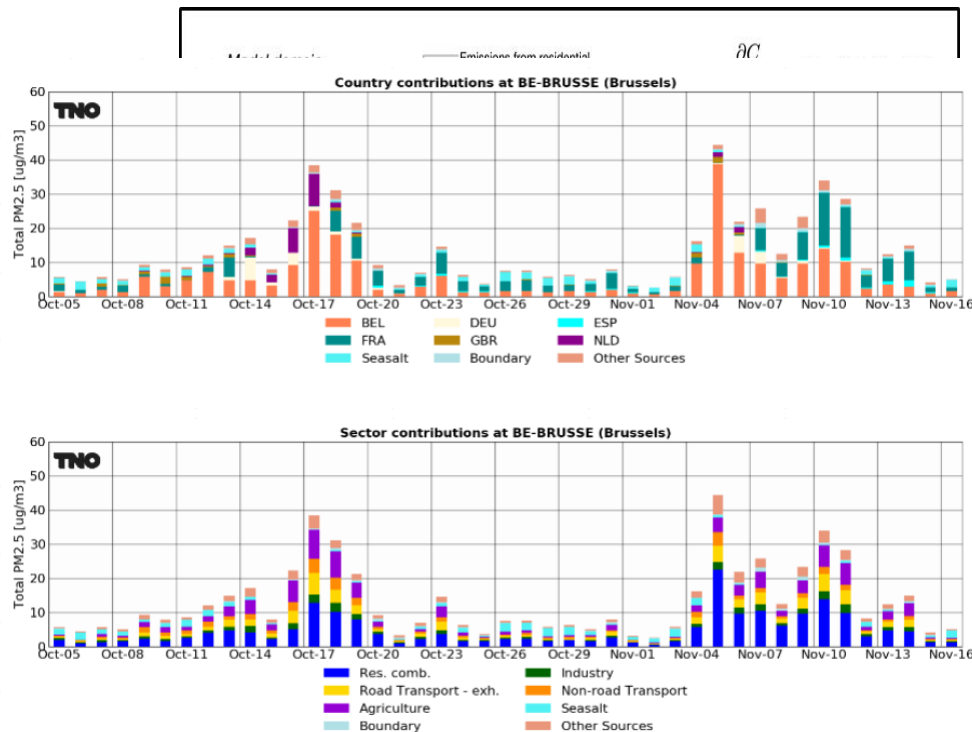
Observed concentration change in a column not directly coupled to a change in emission.

→ Need to take into account transport and chemistry

# › LOTOS-EUROS – A REGIONAL CHEMISTRY TRANSPORT MODEL

## WHAT IS IT?

- › A model that predicts **hour-by-hour** air pollution and greenhouse gas **concentration**, considering all relevant **processes** in the atmosphere
- › Particulate Matter (PM), ozone, NO<sub>2</sub>, SO<sub>2</sub>, CH<sub>4</sub>, etc.
- › Open source version available
- › Source attribution → main sources responsible for pollution

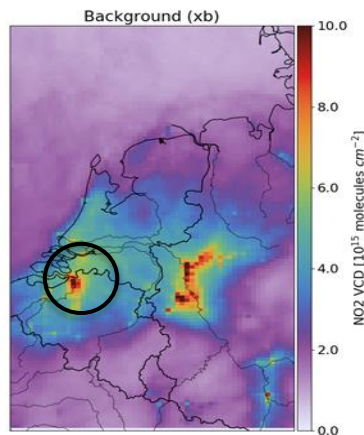




# DATA ASSIMILATION IN LOTOS-EUROS

Get the best possible estimate of the state of the atmosphere through integrated use of model and observations (data assimilation)

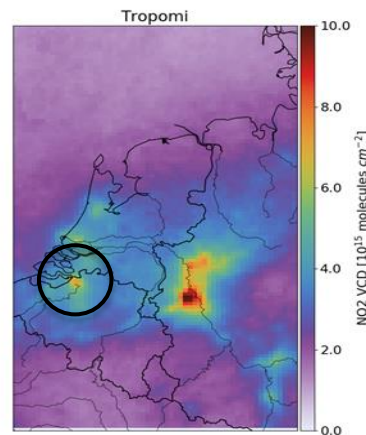
Model



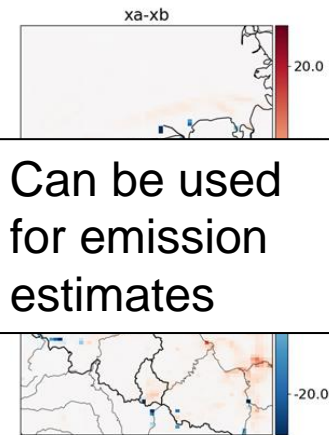
Jul/aug 2018

combined

Observations



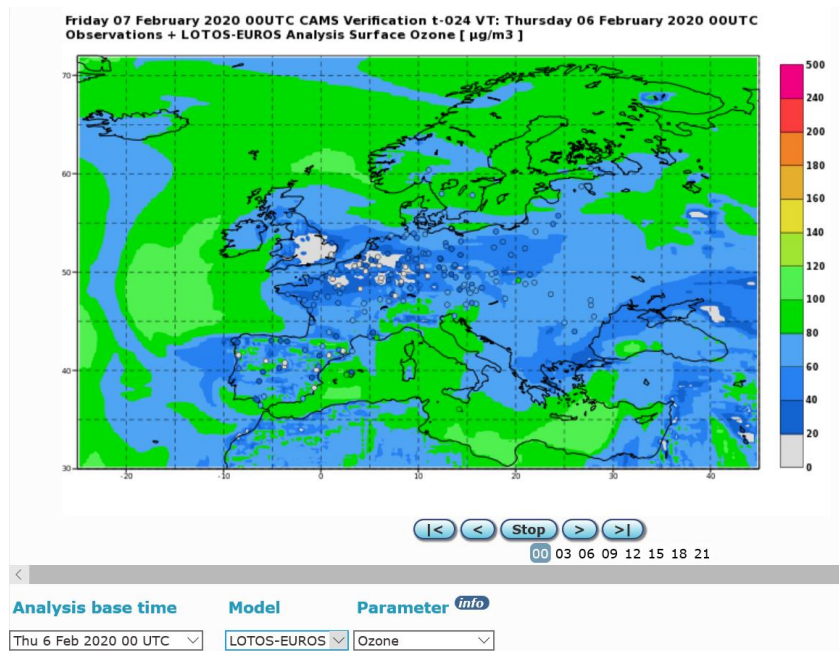
Adjusted emissions



Can be used  
for emission  
estimates

Assimilation method EnKF: active method, system provides us adjusted model parameters and inputs. In LOTOS-EUROS usually **optimisation of emissions** (and boundary conditions) to fit the gap with observations

# OPERATIONAL ANALYSES BASED ON DATA ASSIMILATION OF GROUND O3, NO2 AND OMI NO2

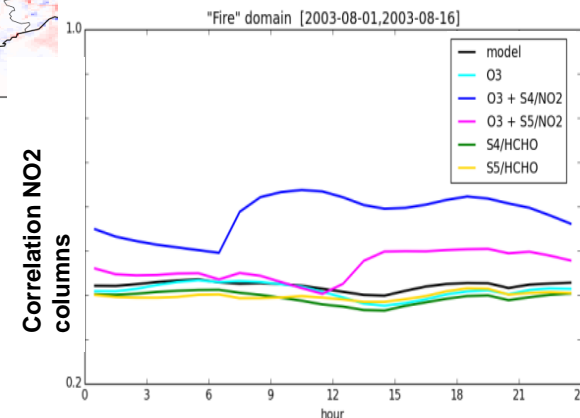
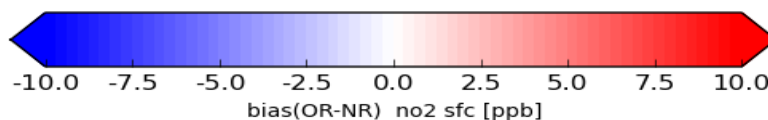
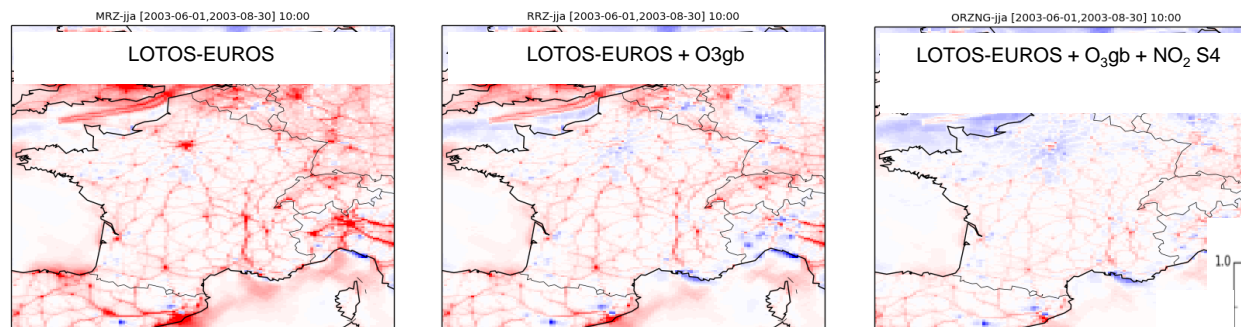




# ASSESSING ADDED VALUE FUTURE INSTRUMENTS

## OBSERVING SYSTEM SIMULATION EXPERIMENTS

### The different impact of Sentinel 4 and 5p NO<sub>2</sub> observations



# MONITORING EMISSION TRENDS

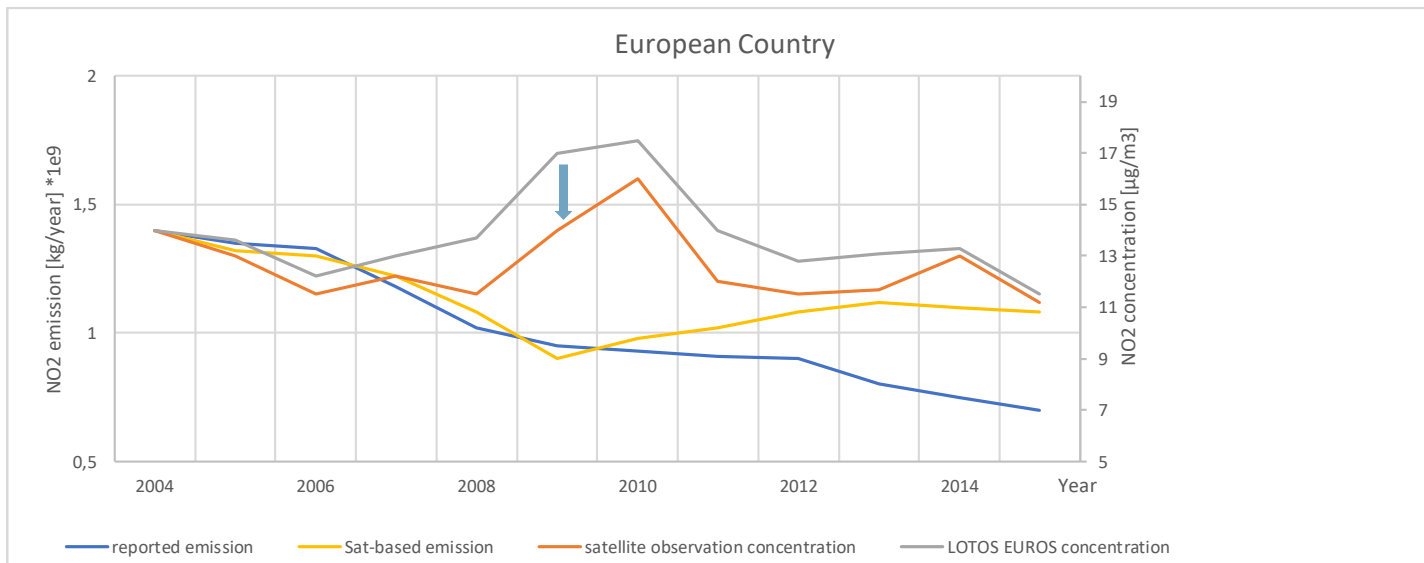


Satellite NO<sub>2</sub> tropospheric VCD is a summation of various contribution

$$\text{NO}_{2\text{instrument}} = \text{NO}_{2\text{emis}} + \underbrace{\text{NO}_{2\text{transport}} + \dots + \text{NO}_{2\text{meteo}}}_{\text{Can be modelled using a RAQ model using a fixed emission database}}$$

Can be modelled using a RAQ model using a fixed emission database

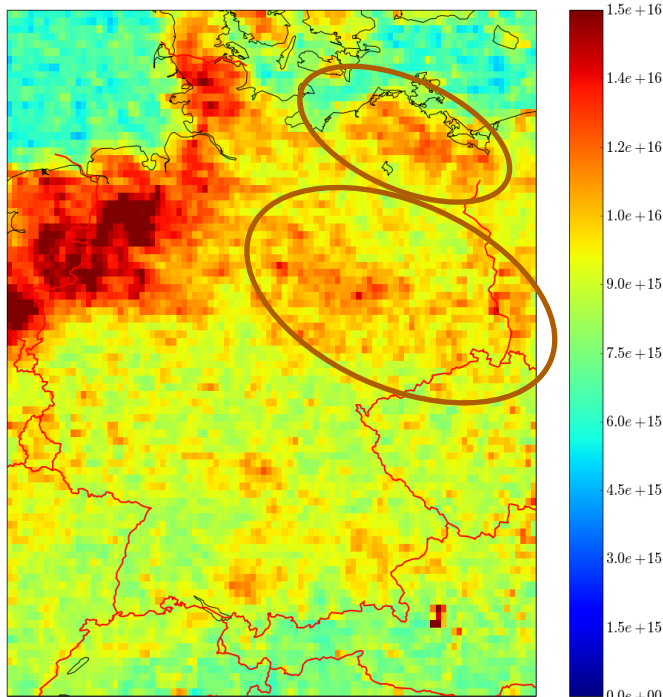
LOTOS-EUROS run for multi year period over Europe using fixed TNO MACC emission for 2004



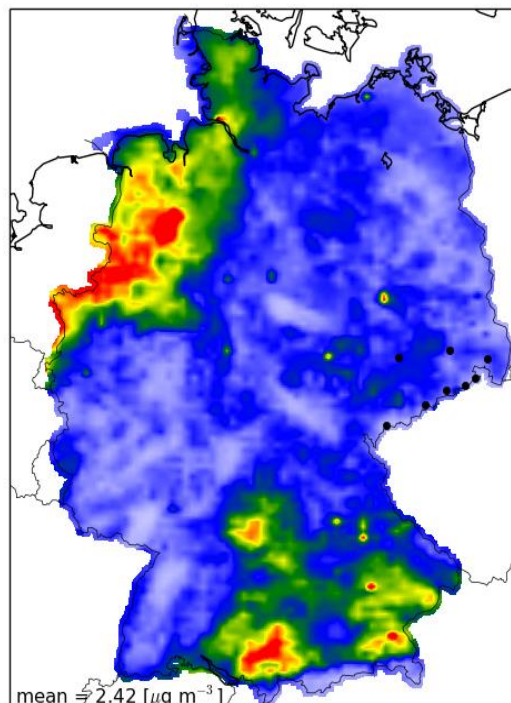
# USE OF SATELLITE DATA FOR EMISSION LOCATION VERIFICATION

SATELLITE DATA IDENTIFY REGIONS IN GERMANY WITH SUBSTANTIAL NH<sub>3</sub> LEVELS NOT PRESENT IN EMISSION INVENTORY

Satellite-IASI-NH<sub>3</sub>: 8-year average



Modelled mean surface NH<sub>3</sub>



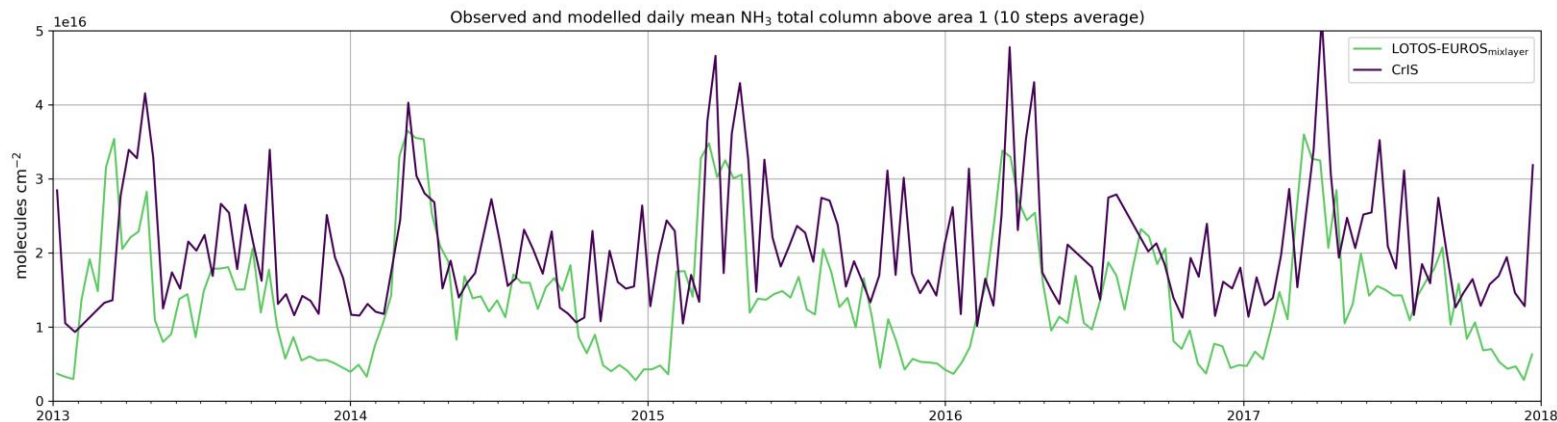
Emission inventories use proxies e.g. number of farms to distribute country totals

However in Mecklenburg-Vorpommern farmers often have larger land areas

→ Used to improve the emission inventories

# USE OF SATELLITE DATA FOR EMISSION TIMING VERIFICATION

## Time-series CrIS and Iotos-euros NH3



- › Overall, good agreement between CrIS and LOTOS-EUROS in growing season
- › Observed spring peak later than modelled in LOTOS-EUROS
- › → improve the temporal profiles used to distribute yearly NH<sub>3</sub> emissions in model



# REGIONAL TROPOMI PRODUCT Work in progress

TROPOMI-NO<sub>2</sub> product systematically **underestimates** over **polluted** areas (typically 15-30%)

**Overestimates** in **background** regions / coastal areas

*The core problem lies with a priori data used in the retrieval, the Air Mass Factors (AMFs) which are calculated at a relatively coarse resolution*

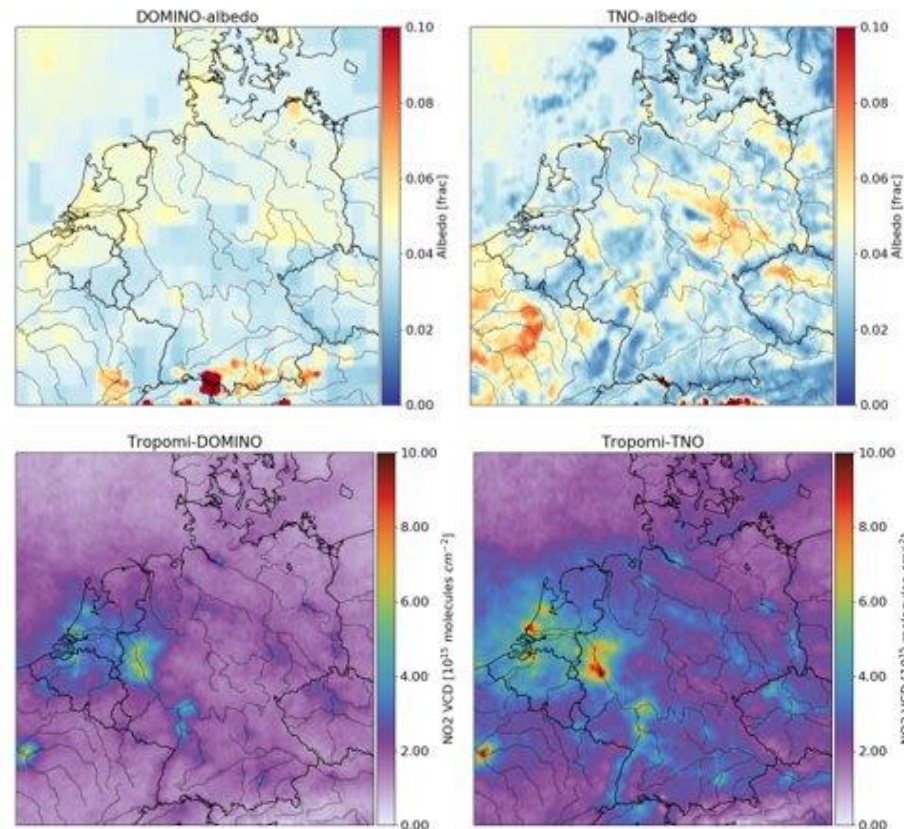
Replacement with a higher resolution AMF can drastically reduce the under and overestimation (Griffin et al 2019 / McLinden et al., 2014)

→ We use LOTOS-EUROS modelled profiles for this

References:

McLinden, C. A., <https://doi.org/10.5194/acp-14-3637-2014>, 2014.

Griffin et al., <https://doi.org/10.1029/2018GL081095>, 2018.



## › CONCLUSION

By synergetic combination of satellite observations with a chemistry transport model we provide information on:

- › Air pollutant concentrations and changes
- › Air pollution exceedances and the main sources responsible for this
- › Emissions and trends in emissions
- › Emission locations and timing
- › The added value of current and future satellite instruments
- › Regional improvements for satellite products

This information is/can be used by:

- › Policy makers to underpin the development of effective strategies for air pollution abatement, and check the effect of implemented strategies
- › Industries/agencies to support the development of new satellite instruments
- › Companies/industries to investigate their impact on the environment and possible strategies to reduce this impact

› **MERCI BEAUCOUP**

Take a look:

**TNO.NL/TNO-INSIGHTS**

**TNO** innovation  
for life

**For more information:**

**renske.timmermans@tno.nl**