PROGRAMME OF THE EUROPEAN UNION

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Advances in satellite-derived emissions using Sentinel-5p

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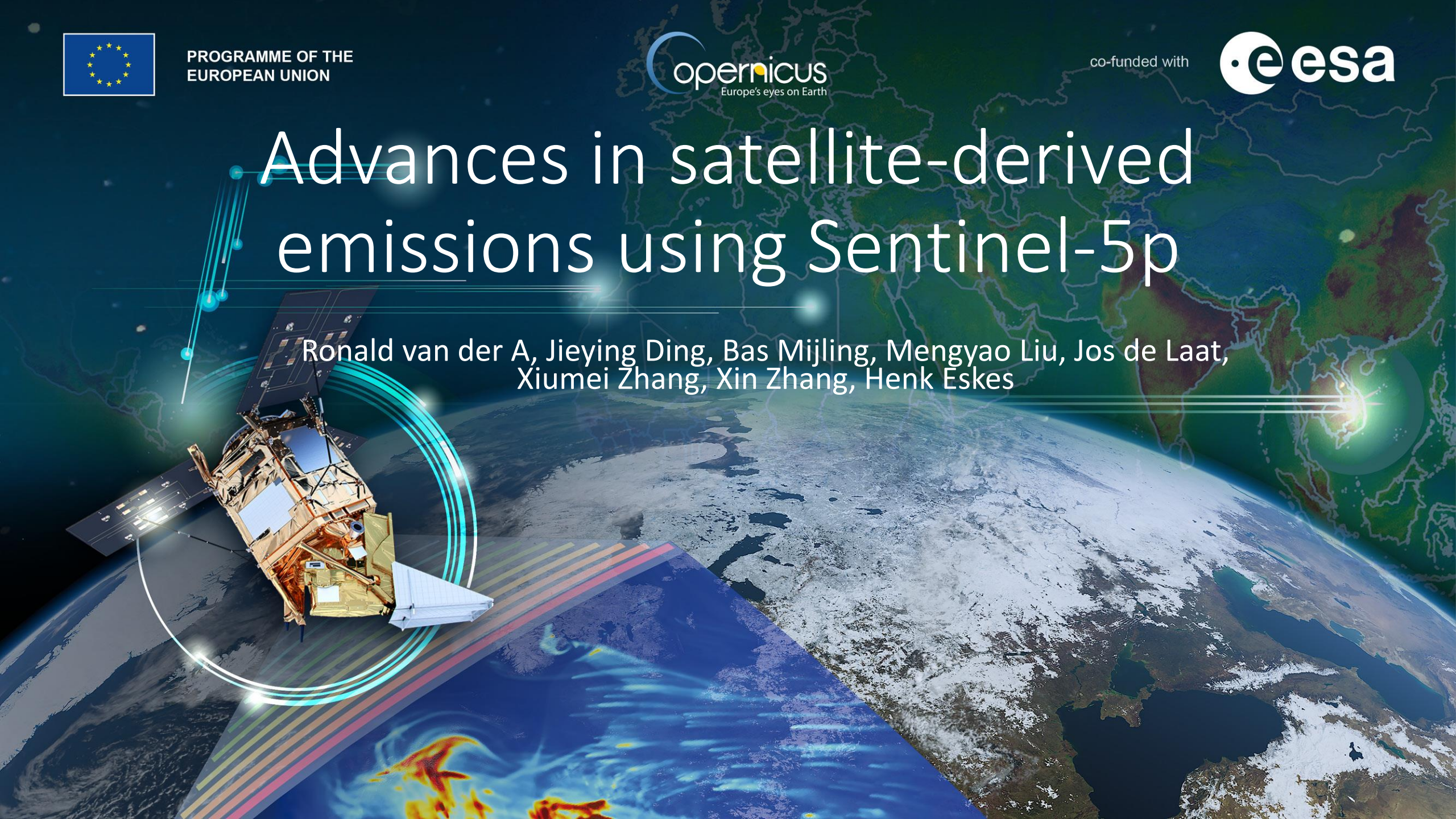


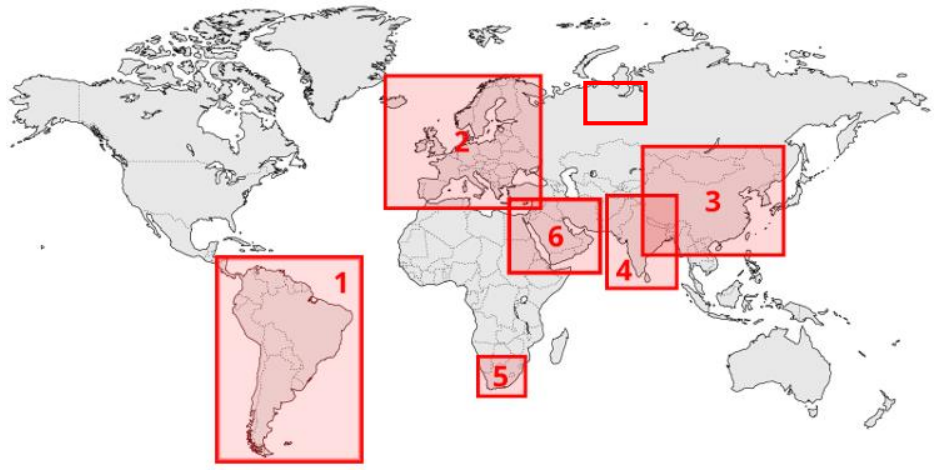
Introduction

- TROPOMI has given a boost to the retrieval of emissions.
- This overview is incomplete, because only inversions developed at KNMI will be shown.
- Emissions of
  - NO_x (full inversion with DECSO)
  - NH_3 (in parallel to NOx using DECSO)
  - CO_2 (ratio method)
  - CH_4 (mass balance divergence method)
  - SO_2 (plume fitting, DECSO)

DECSO
Daily Estimates Constrained by Satellite Observations

State vector forecast	$\mathbf{x}^f(t_{i+1}) = M_i\,[\mathbf{x}^a(t_i)]$
Error covariance forecast	$\mathbf{P}^f(t_{i+1}) = \mathbf{M}_i\mathbf{P}^a(t_i)\mathbf{M}_i^T + \mathbf{Q}(t_i)$
Kalman gain matrix	$\mathbf{K}_i = \mathbf{P}^f(t_i)\mathbf{H}_i^T[\mathbf{H}_i\mathbf{P}^f(t_i)\mathbf{H}_i^T + \mathbf{R}_i]^{-1}$
State vector analysis	$\mathbf{x}^a(t_i) = \mathbf{x}^f(t_i) + \mathbf{K}_i(\mathbf{y}_i^o - H_i\,[\mathbf{x}^f(t_i)])$
Error covariance analysis	$\mathbf{P}^a(t_i) = (\mathbf{I} - \mathbf{K}_i\mathbf{H}_i)\,\mathbf{P}^f(t_i)$

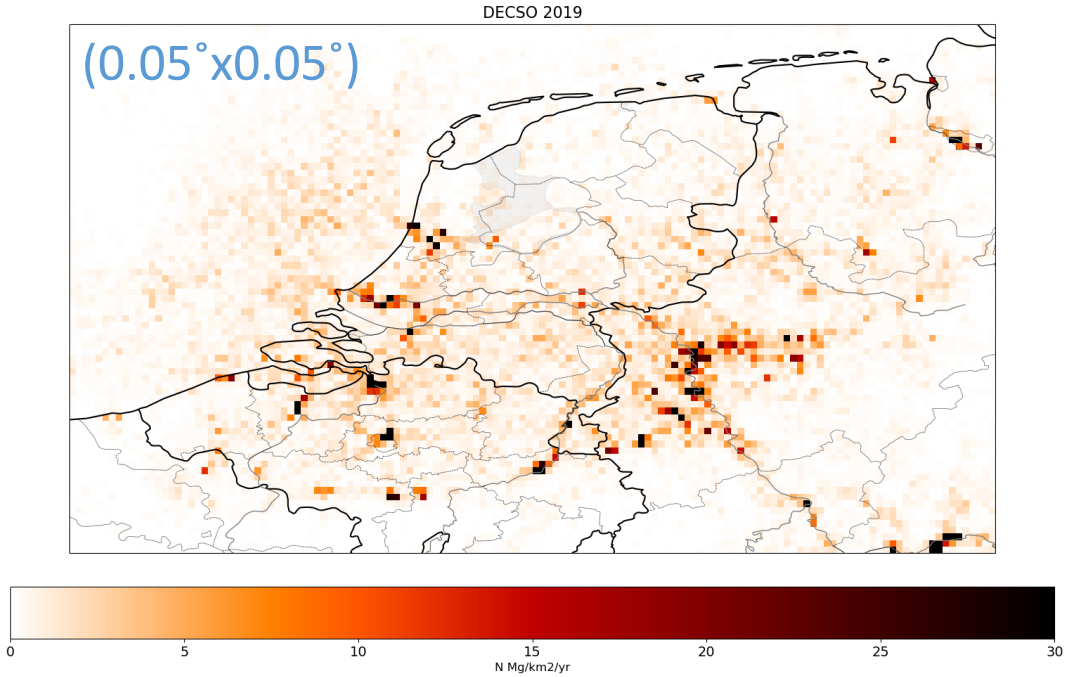
- It is fast: one model run per assimilation step of 1 day
- No *a priori* information needed: unknown sources will become visible.
- Full error estimation of new emission inventory
- Used for <u>daily</u> NO_x and NH_3 emissions

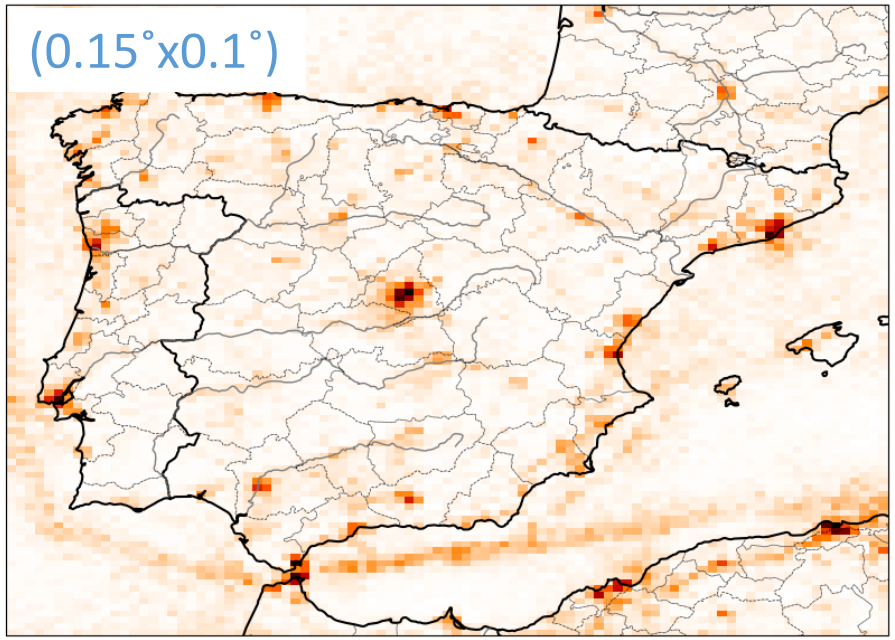


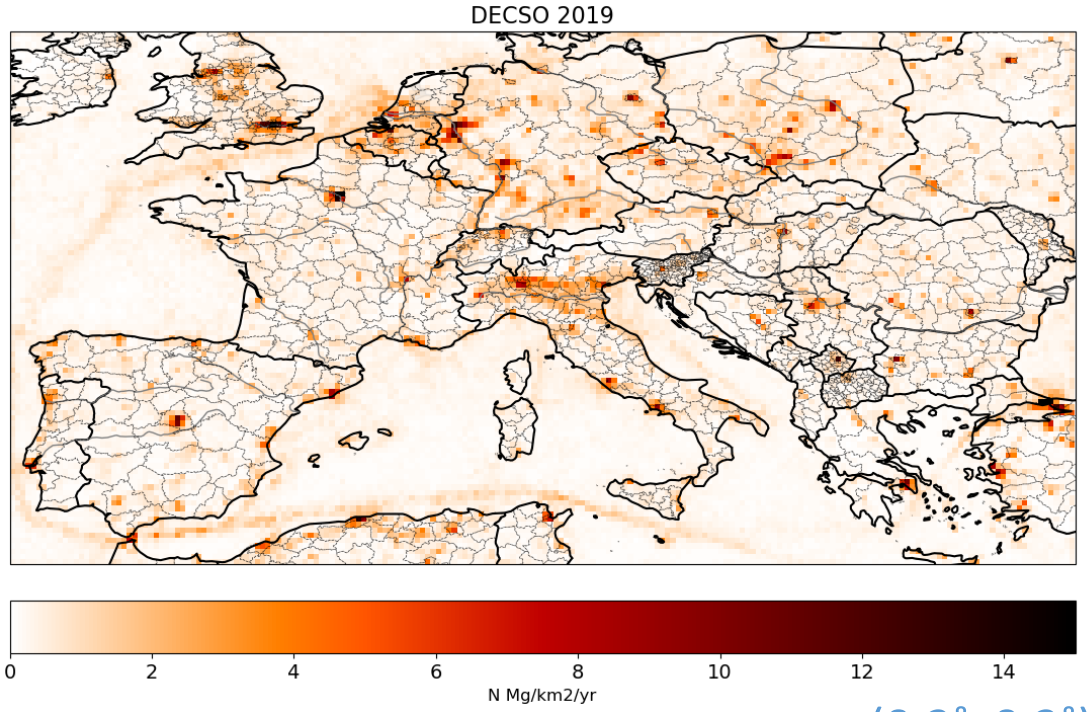
This work is part of the H2020 project SEEDS. SEEDS develops pollutant emissions and depositions to support CAMS.

SEEDS
Sentinel EO-based Emission and Deposition Service

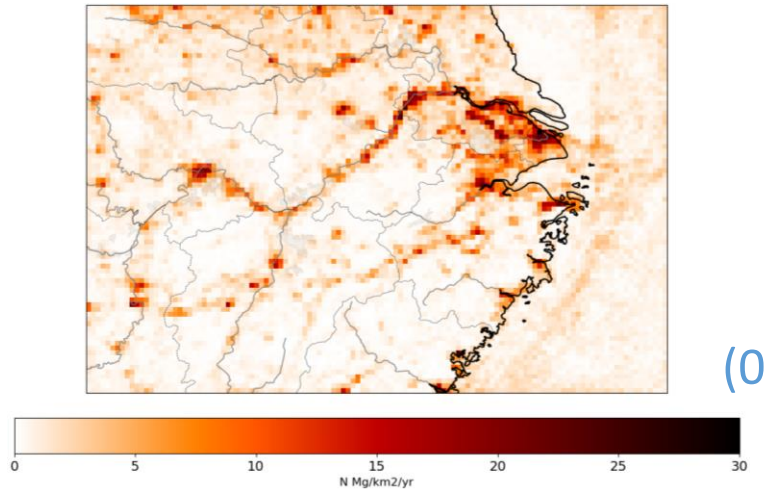
Regions at various resolutions





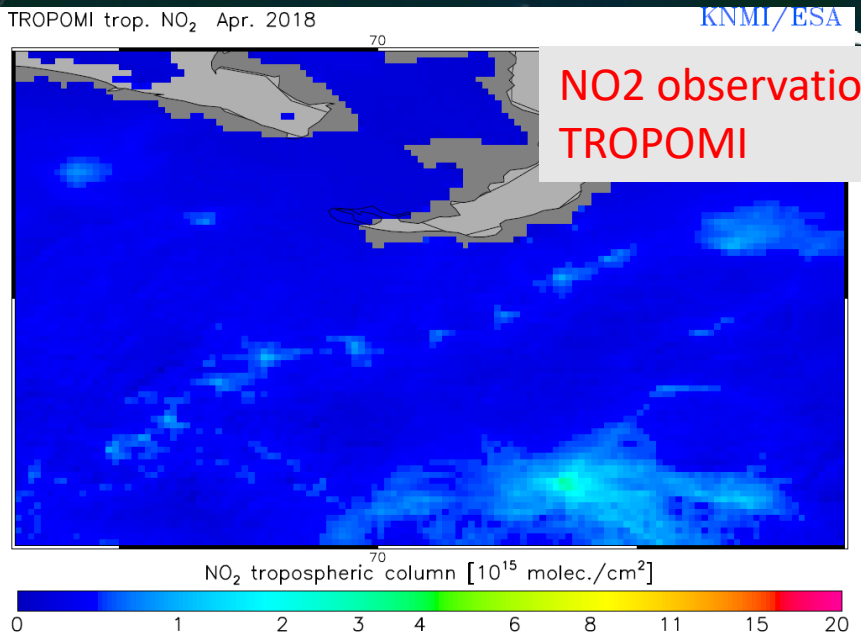


(0.2˚x0.2˚)



(0.1˚x0.1˚)

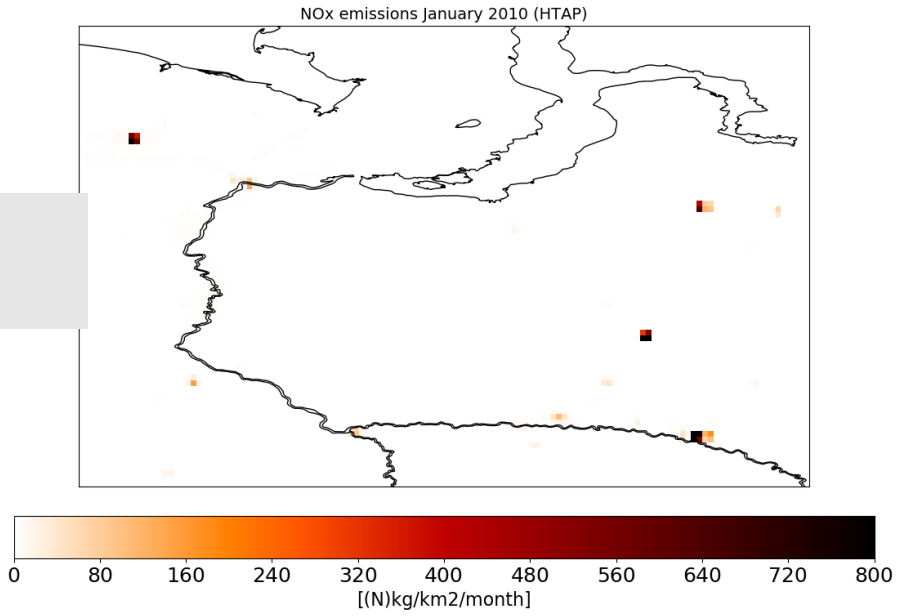
West Siberia: gas compressor stations along pipeline to transport gas to Europe show up in map of NOx emissions

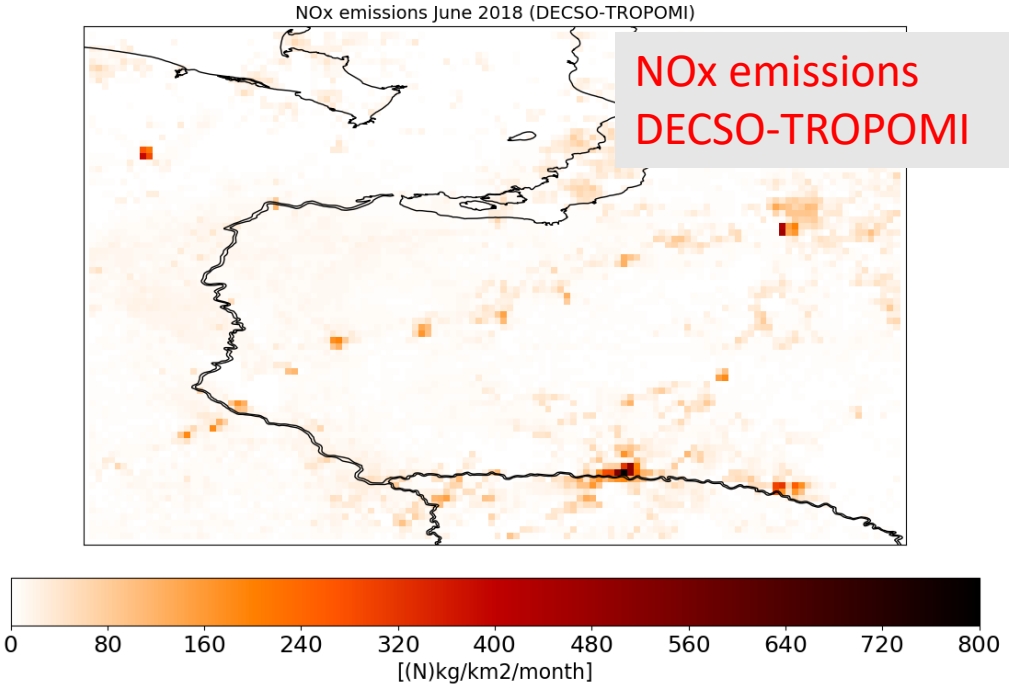


NO2 observations TROPOMI

Van der A et al., npj Clim. Atmos. Sci., 2020

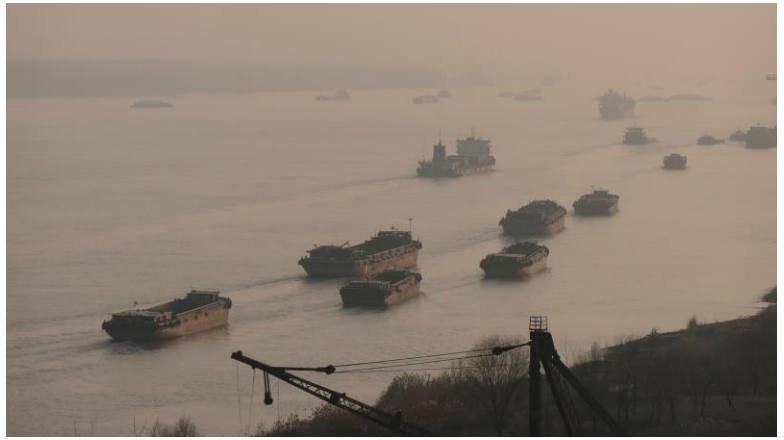
NOx emissions HTAP





NOx emissions DECSO-TROPOMI

Emissions from inland ships on the Yangtze river

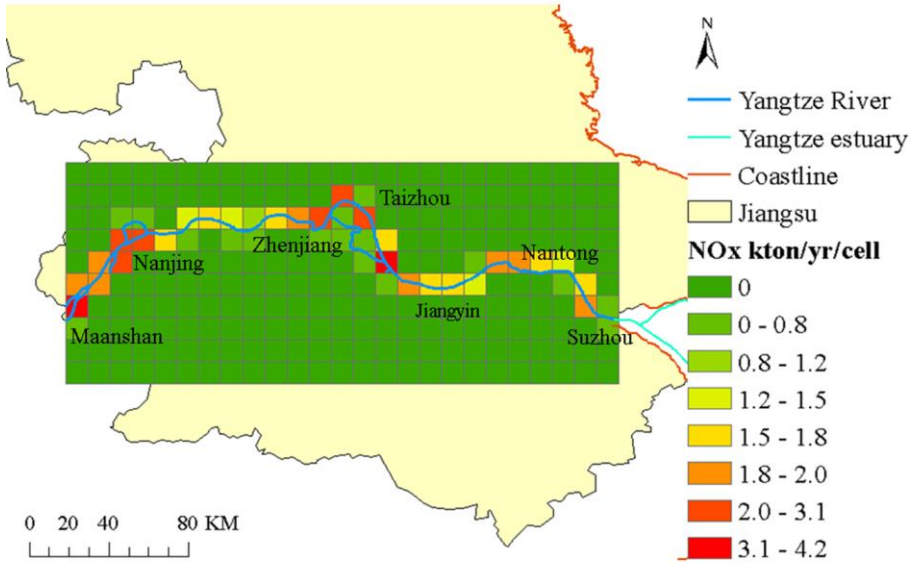


Data from AIS signals that we use:

- Type of ship
- Speed
- Size

=> Emissions calculated per ship or per km

AIS signals received at NUIST, Nanjing.

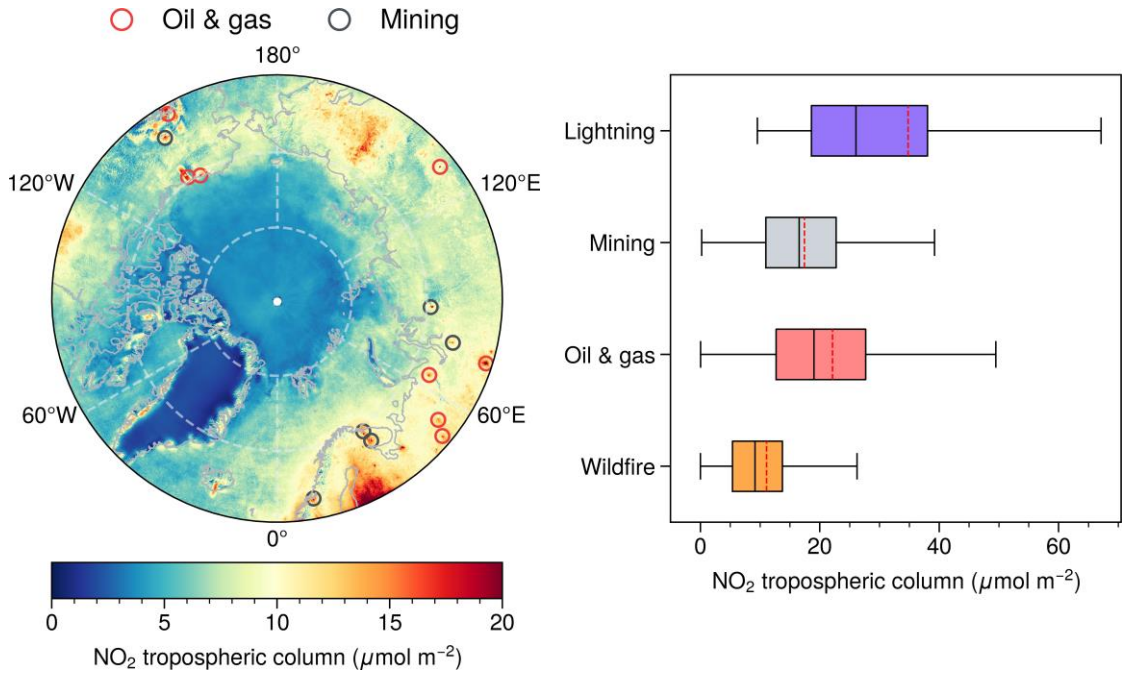


See poster by Xiumei Zhang (#21)

Arctic Lightning NO2

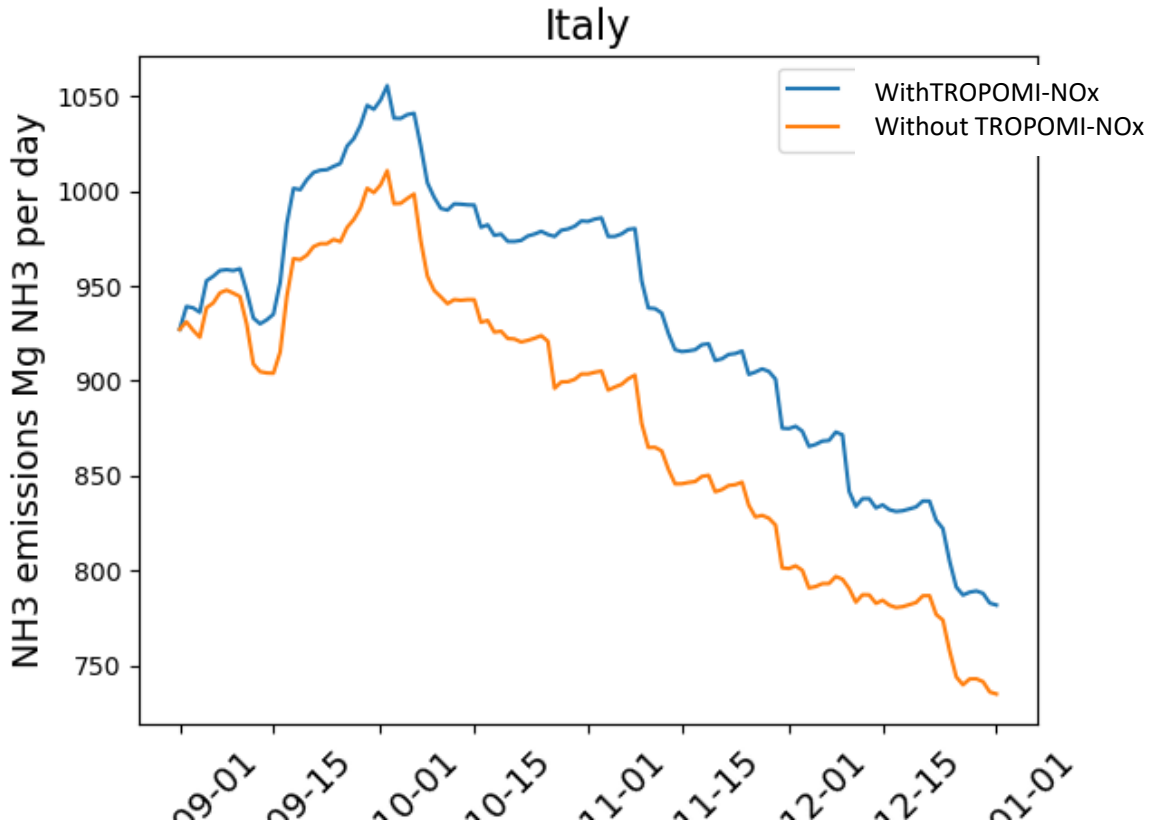
- NO2 emissions from lightning in the Arctic region derived from TROPOMI observations

by Xin Zhang (NUIST-KNMI centre in Nanjing)

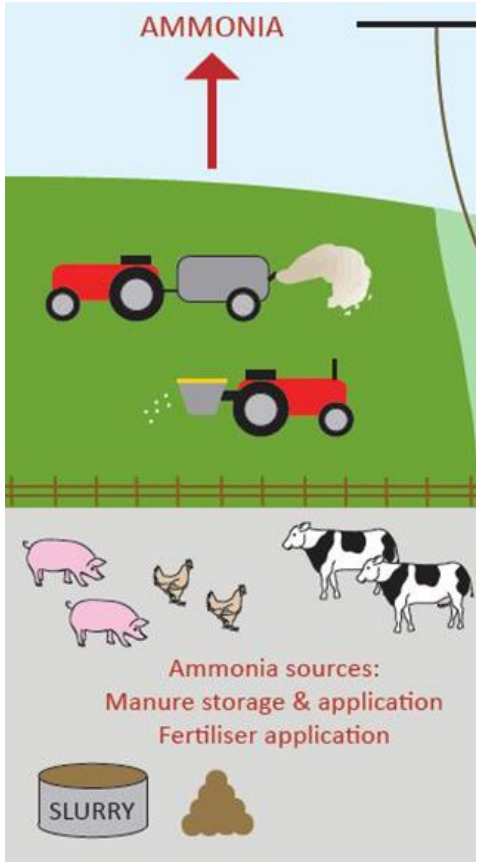


Ammonia (NH3) emissions

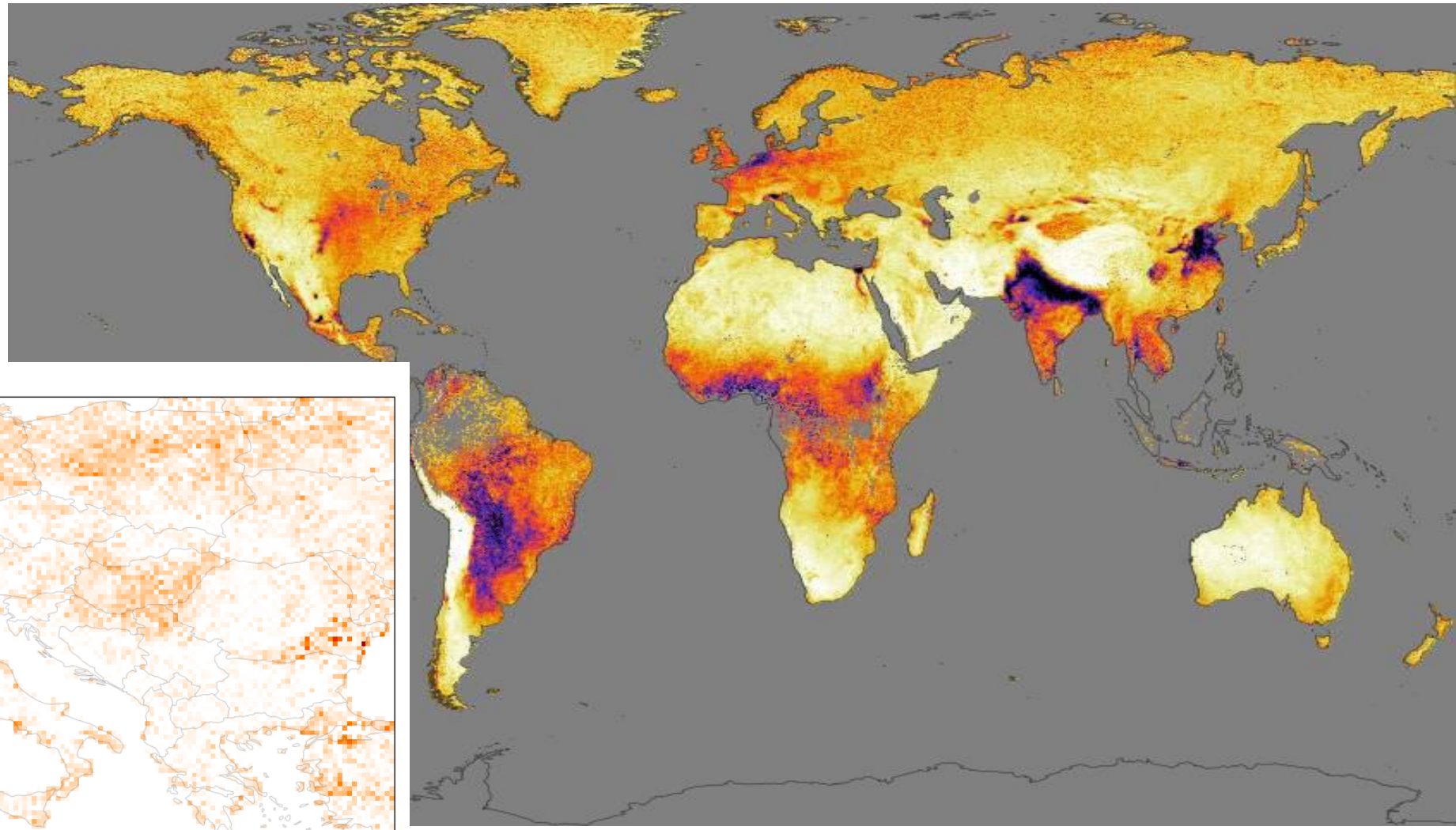
- Cross-track Infrared Sounder (CrIS) observations in combination with TROPOMI
- DECSO version of NH3, run in parallel to NOx.



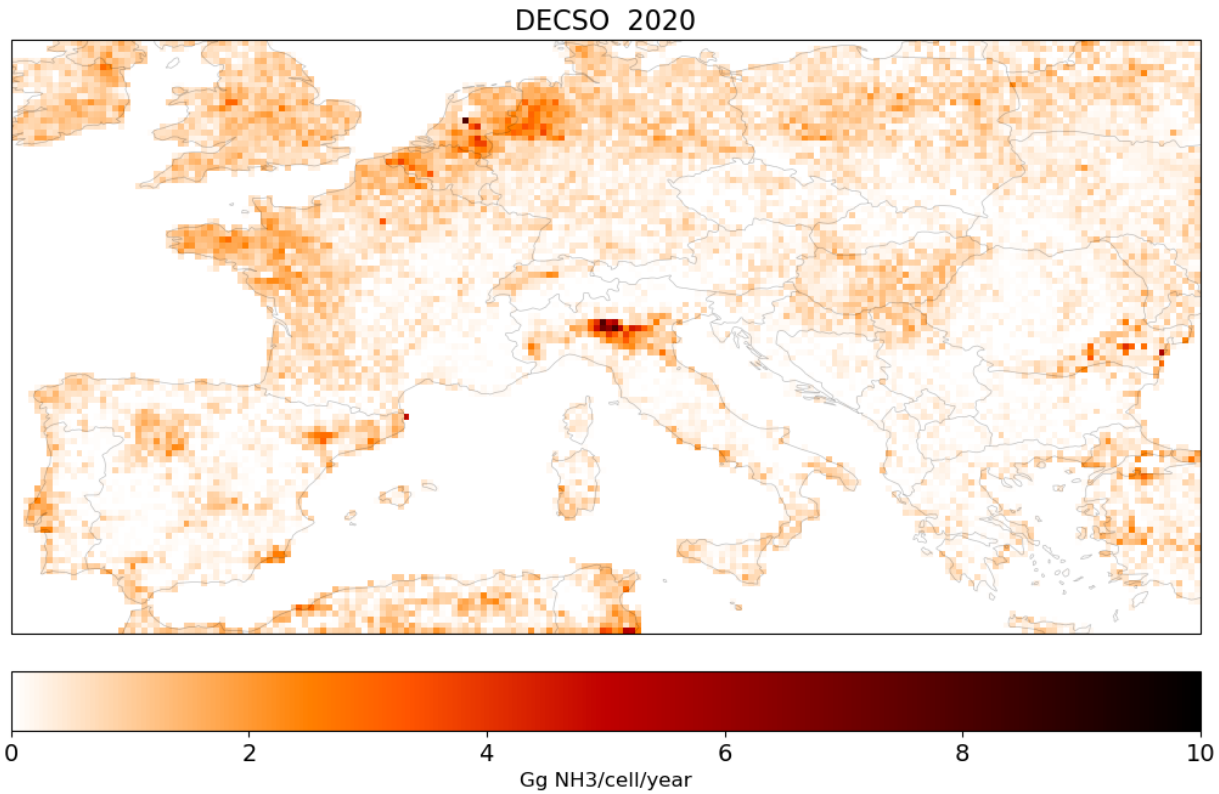
Sources of NH3



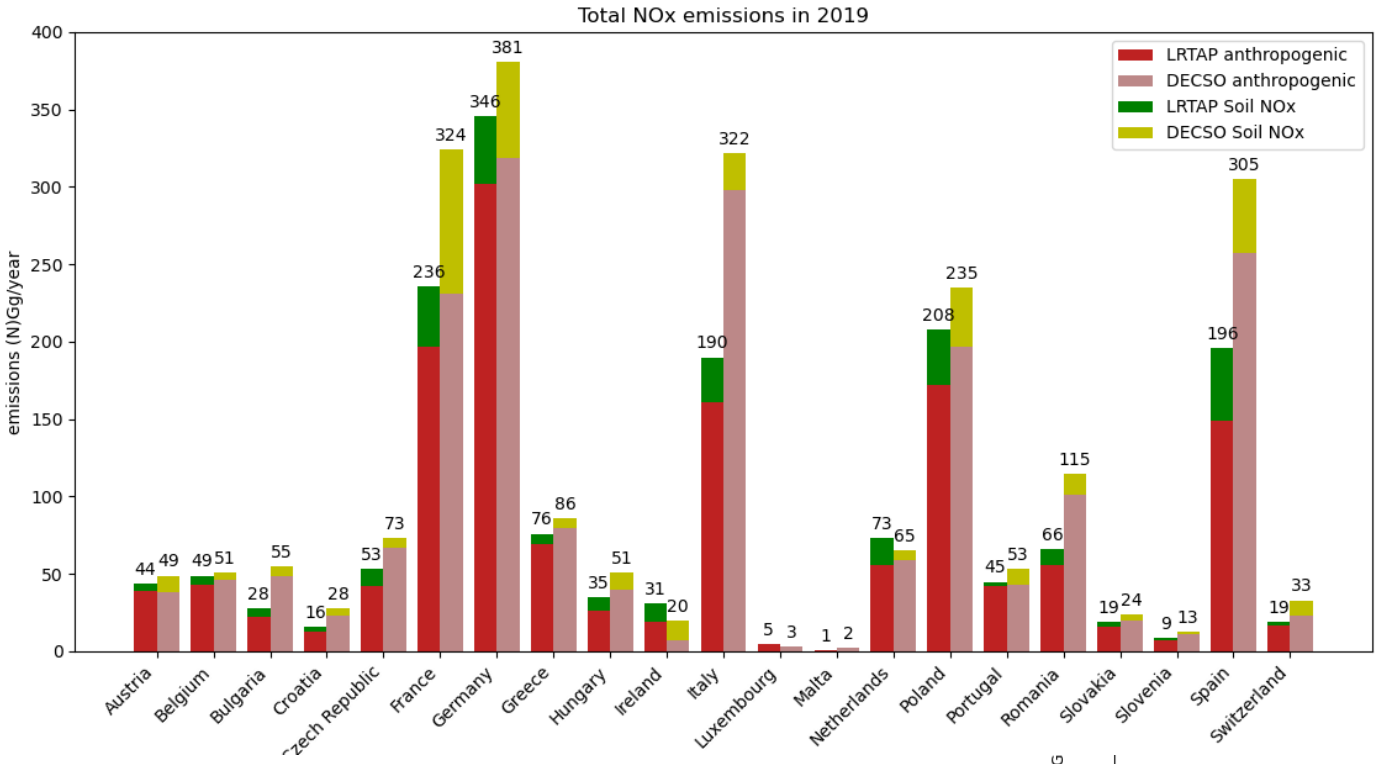
NH3 concentrations for 2020 (CrIS)



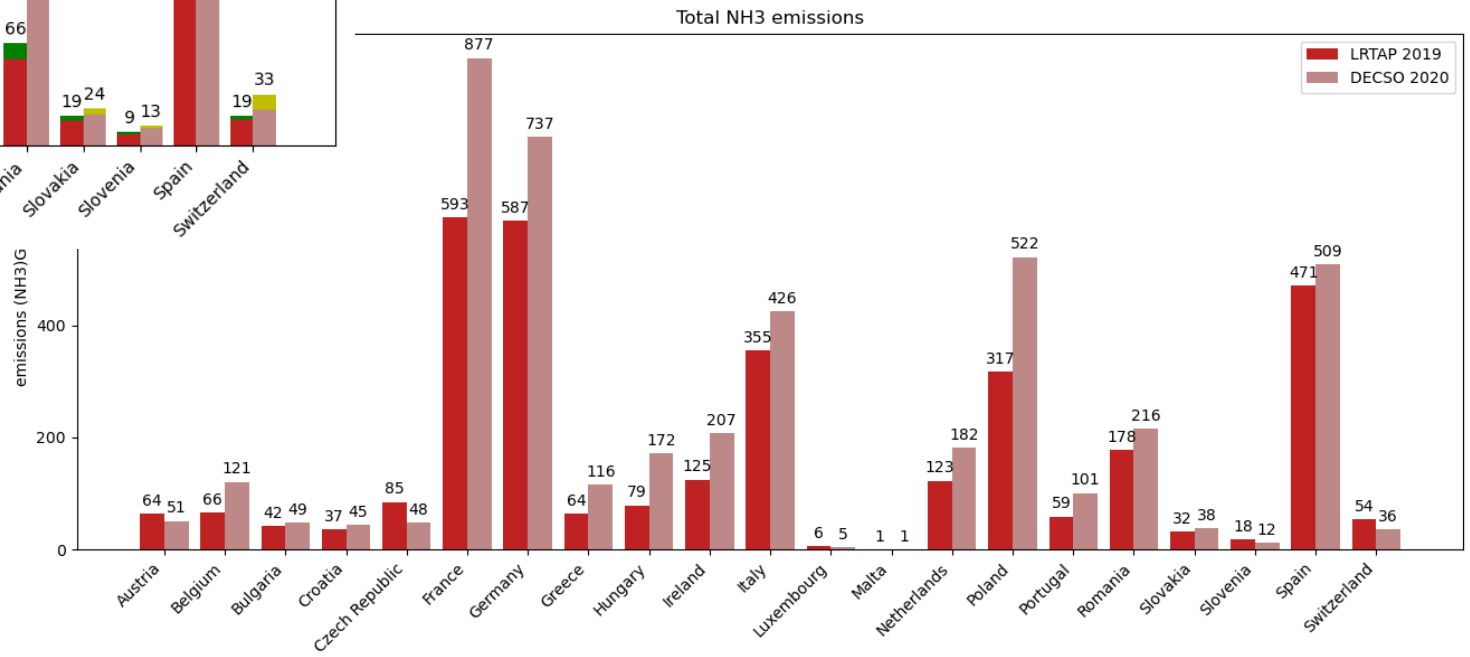
NH3 emissions for 2020 (DECSO)



Country totals of NOx and NH3 (vs. LRTAP)



- DECSO: light color bars
- LRTAP (EEA): dark color bars



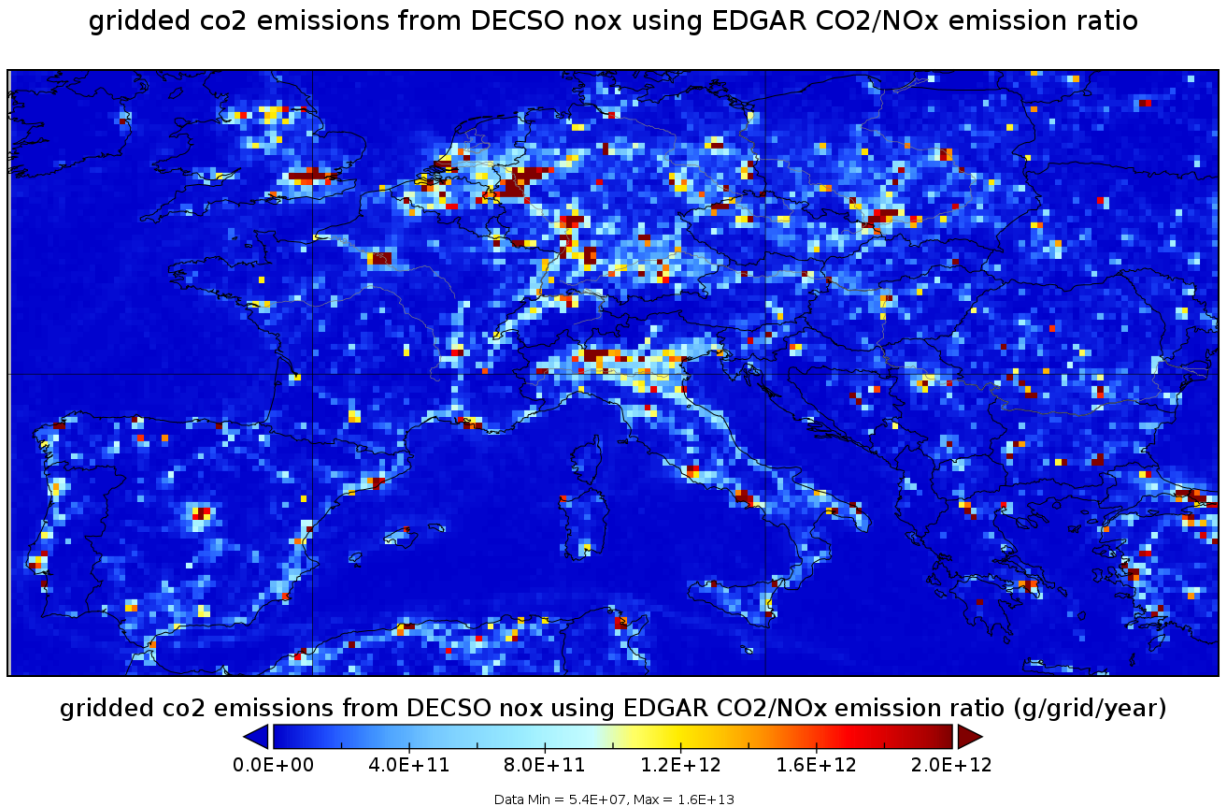
More details on NOx and NH3 emissions:
Presentation by Jieying Ding on Tuesday, 12:00

CO_2 emissions

Method:

- NOx emissions are split into anthropogenic and biogenic emissions
- DECSO => only <u>anthropogenic</u> NO_x emissions from TROPOMI
- Ratio of CO2/NOx from e.g. EDGAR on the same grid as DECSO
- Apply ratio to NOx emissions

  => CO2 emissions



Methane emissions - method

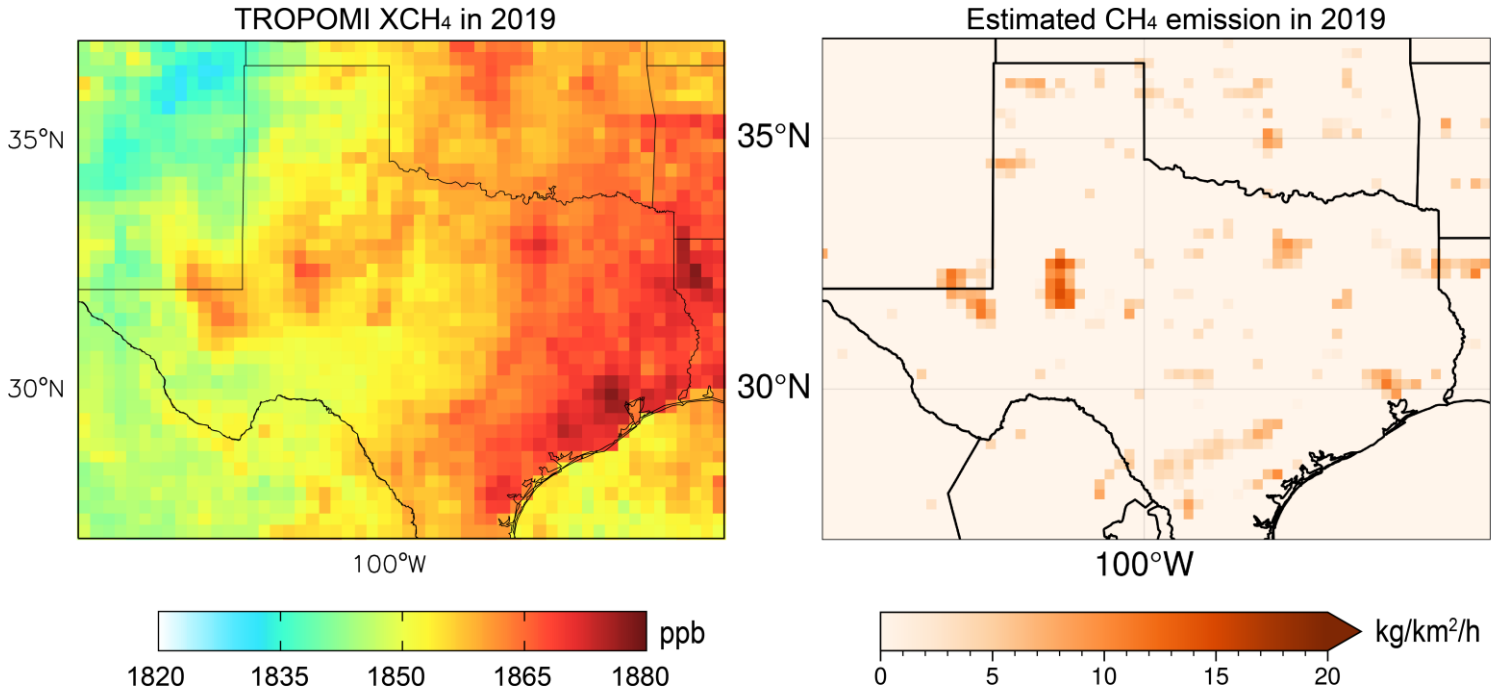
- Long living gases -

Mass balance incl. transport: $E = \cancel{C / \tau} + \nabla F$

$C / \tau = 0$

$F = \nabla F(background) + \nabla F(emissions)$

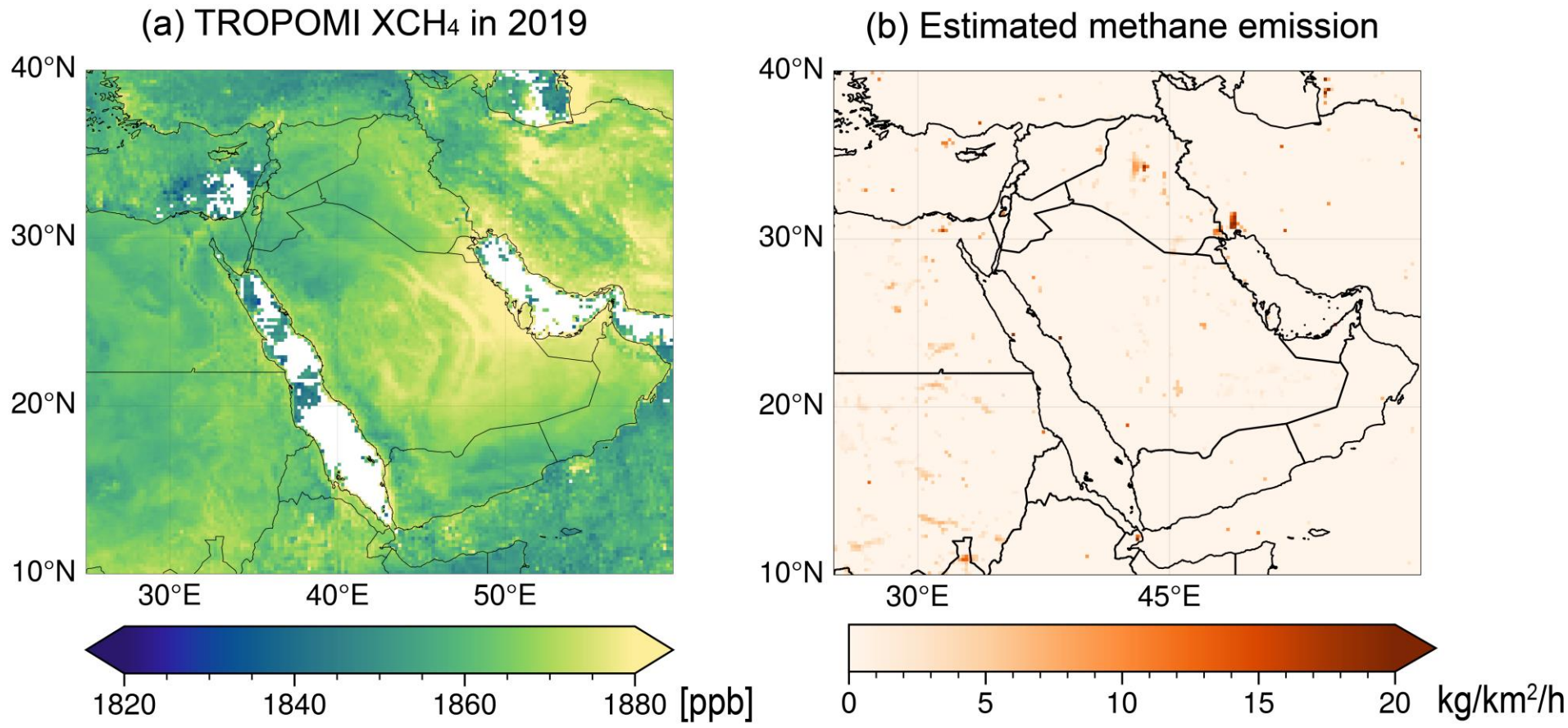
Includes a correction for false signals due to (1) albedo and (2) orography



Methane emissions from the oil/gas industry in Texas (2019) based on TROPOMI

Published in Liu et al. (GRL, 2021)

Methane emissions derived for the Middle East

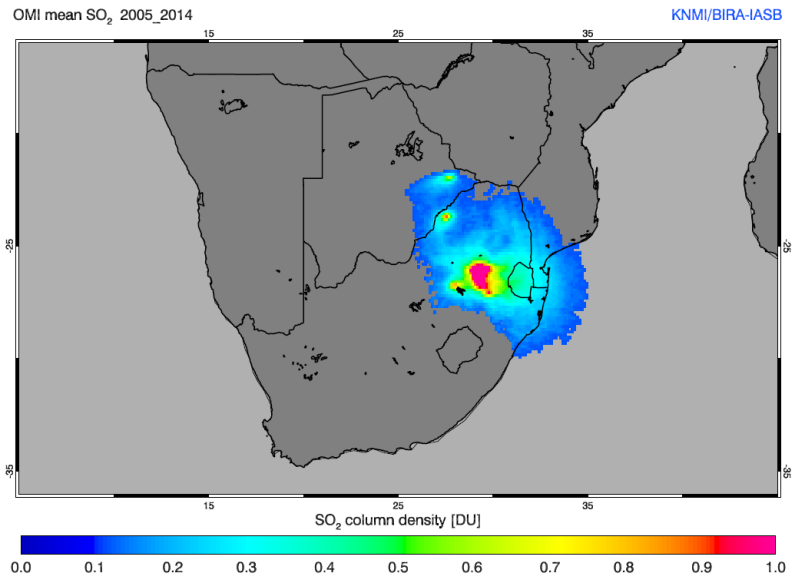


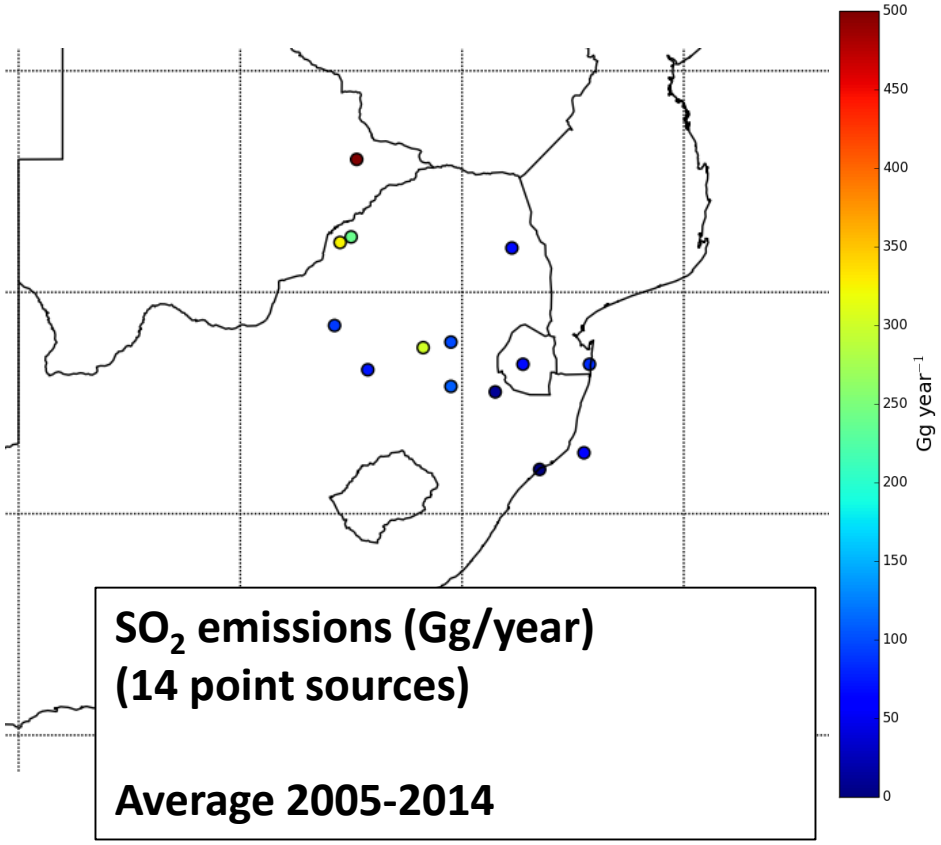
See Poster by Mengyao Liu (#55)

SO2 emissions using OMI

Results using the OMI observations

Plume fitting technique



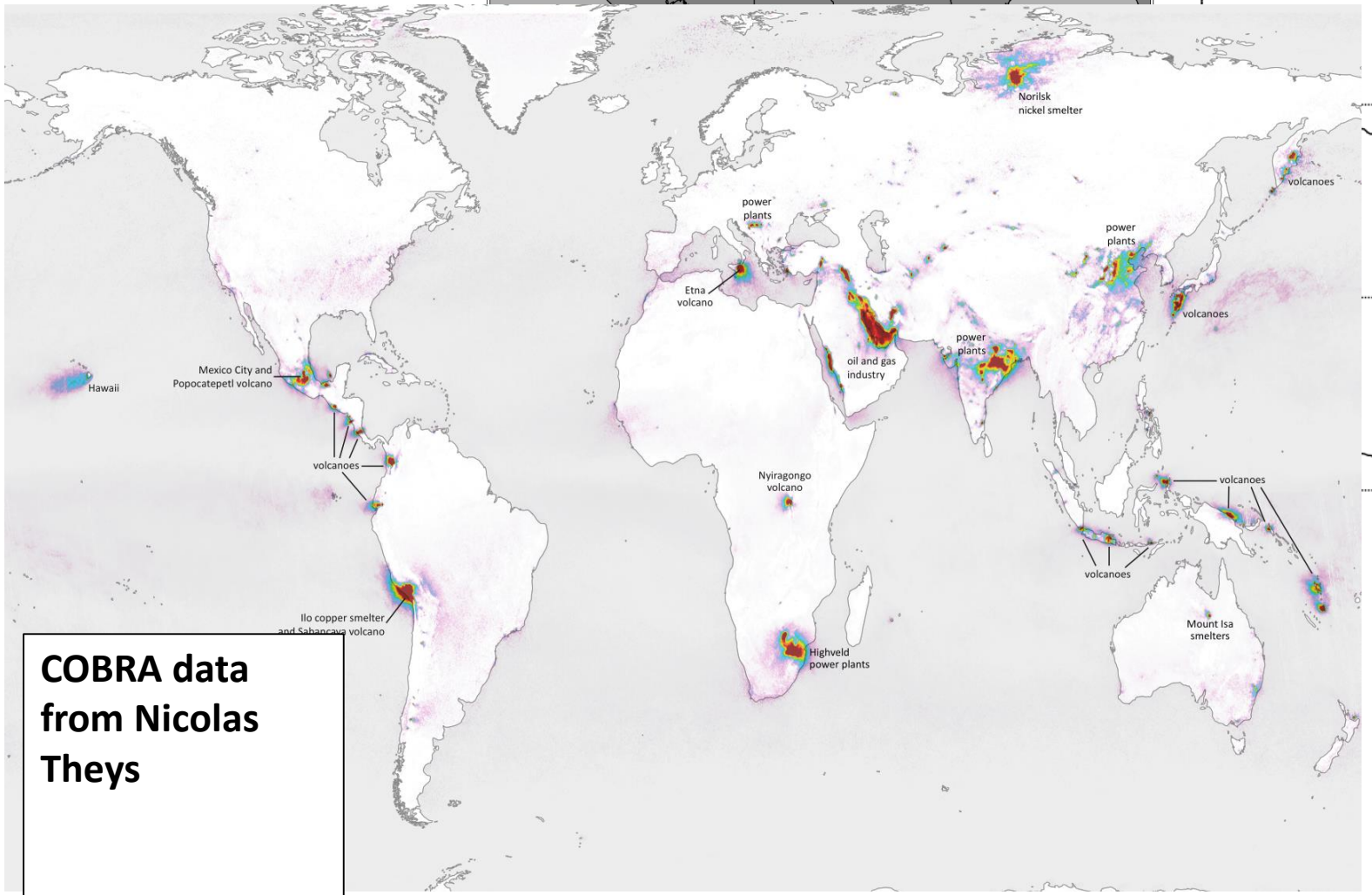


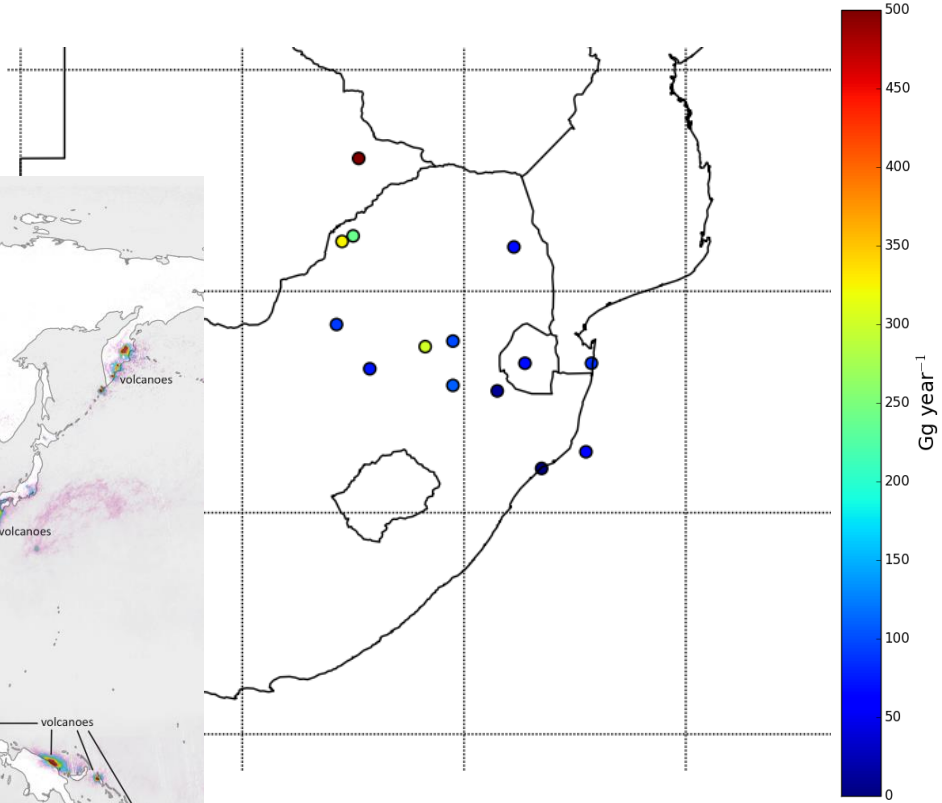
SO_2 emissions (Gg/year)
(14 point sources)

Average 2005-2014

SO2 concentrations

TROPOMI observations





COBRA data from Nicolas Theys

Summary

NOx and NH3 and CO2 emissions

- Improved daily NOx emissions on a resolution of 5-20 km for anthropogenic and biogenic source sectors.
- In parallel to NOx also NH3 emissions are derived.
- Good agreement with bottom-up inventories but also with differences.
- From anthropogenic NOx emissions the CO2 emissions are derived.

CH4 emissions

- Global annual emissions possible gridded on 0.2 degree resolution

SO2 emissions

- Can be included in DECSO for the anthropogenic emissions. PhD study just started.

Operational emission products ?

- All shown inversions are fast enough to deliver operational emission products.

Further info

Species	Method	Detailed presentation
CH4	Mass balance/Divergence method	Poster by Mengyao Liu (#55) Poster by Pepijn Veefkind (#57)
CO2	Scaling NOx by emission factor	-
NH3	DECSO (Kalman Filter)	Presentation by Jieying Ding Tuesday 12:00
NOx	DECSO Ship emissions Lightning NO2	Presentation by Jieying Ding (Tuesday) Poster by Xiumei Zhang (#21) -
SO2	DECSO, plume fitting	-