# Validation of the IUP Bremen TROPOMI tropospheric $NO_2$ product and comparison to the operational TROPOMI product

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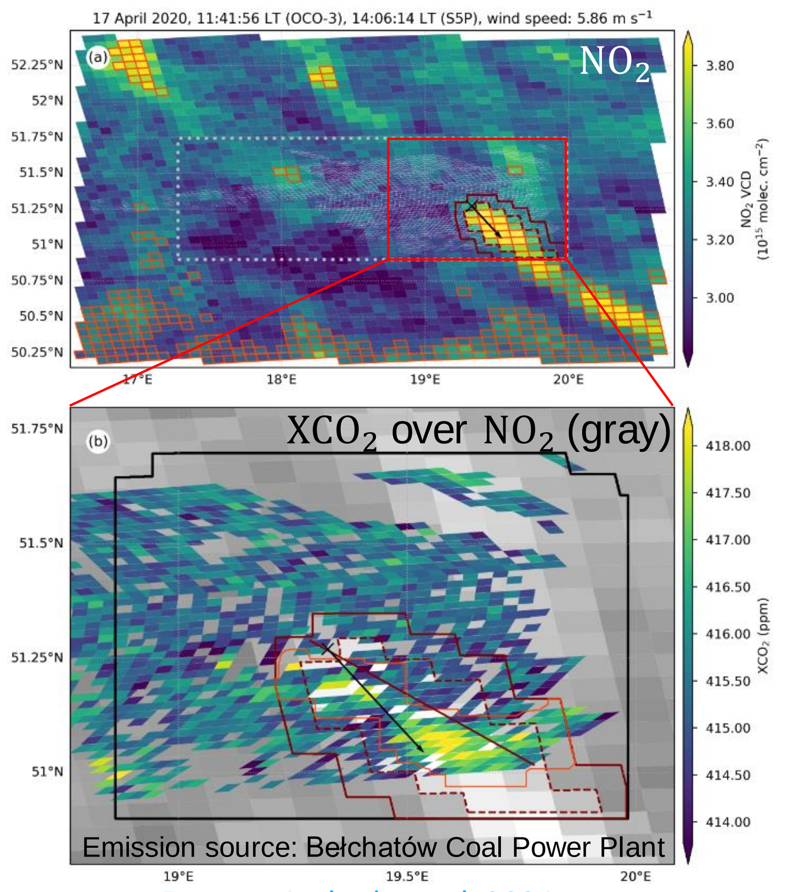
## 1. Motivation

$CO_2$ is the most important anthropogenic greenhouse gas. Detecting and quantifying $CO_2$ emission sources is an important task, but difficult to achieve, using satellite data. $NO_2$ is co-emitted with $CO_2$ during combustion processes and has short lifetime. Therefore, $NO_2$ plumes have a stronger gradient to surroundings, making $NO_2$ a useful proxy for $CO_2$ emissions.

The objective of this study is to establish a high resolution TROPOMI $NO_2$ product for Europe, optimised for small scale processes.




Fuentes Andrade et al. 2024

## 2. From spectrum to tropospheric vertical column

- Measure spectra using TROPOMI
- Fit spectra using DOAS method
  → total slant column (SC)
- Use STREAM to estimate strat. SC, subtract from total SC
  → tropospheric SC
- Transform into tropospheric VC using **A**ir **M**ass **F**actor (**AMF**)
- $AMF \stackrel{\text{def}}{=} \frac{SC}{VC}$, depends on a priori and surface reflectivity
- Use MODIS **B**i-directional **R**eflectance **D**istribution **F**unction (**BRDF**) data for reflectivity (e.g. Zhou et al. 2010) to determine box-AMF (BAMF) using LUT
- Use CAMS-REG/CAMS global as $NO_2$ a priori to calculate AMF

$$AMF = \frac{\sum_i BAMF_i \cdot m_i \cdot c_i}{\sum_i m_i}$$

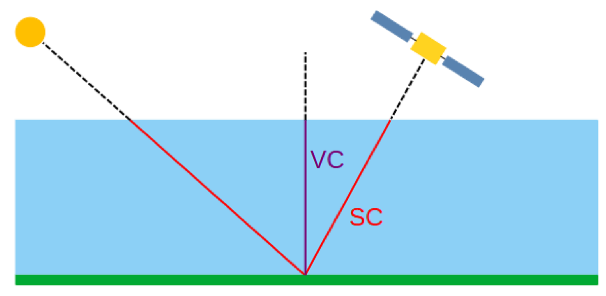
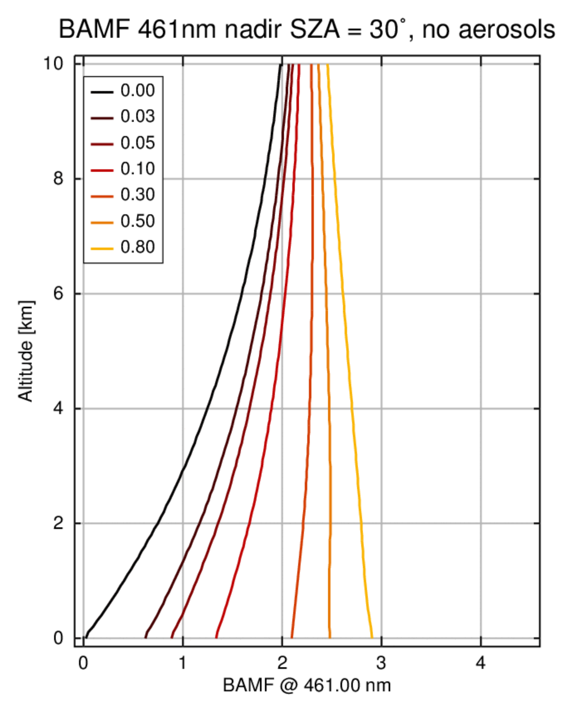
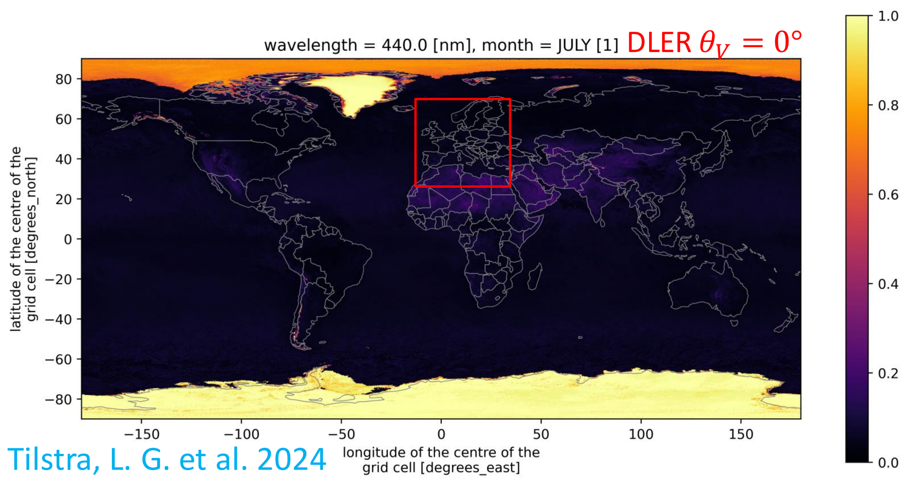



Illustration of slant and vertical columns.




Dependency of the Box AMF (BAMF) on the surface reflectivity. Small changes in reflectivity at low reflectivities lead to big changes in BAMF.

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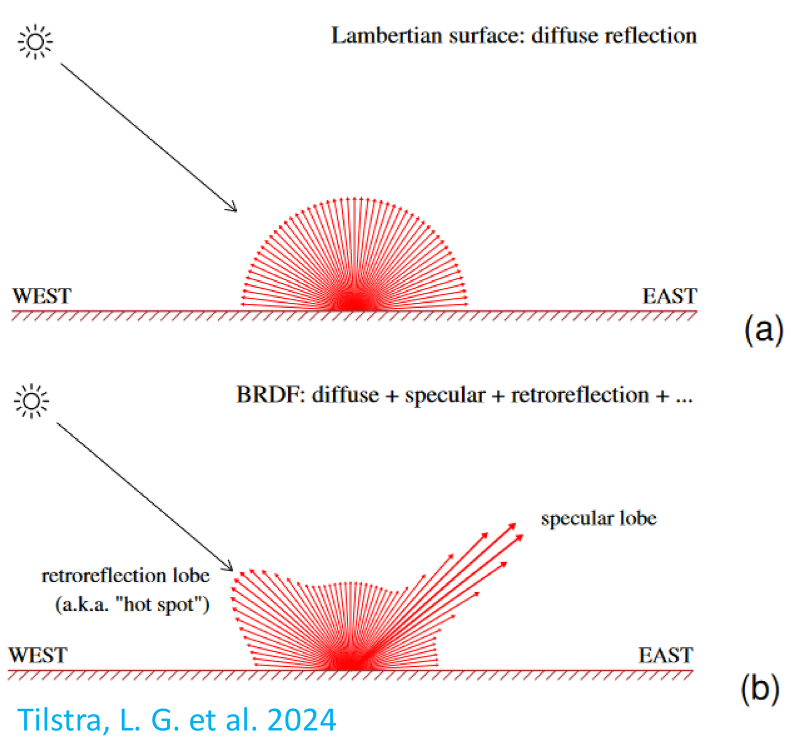
Surface reflectivity of DLER product shows low reflectivities in target area (red)

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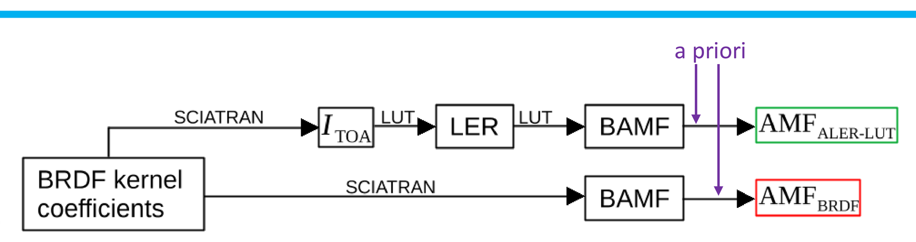
a) Lambertian equivalent reflectivity (LER) reflected radiance in all directions the same

b) Bi-directional reflectance distribution function (BRDF), describes angle-dependent reflectivity of surfaces

## 3. AMF calculation

- AMF calculation using SCIATRAN and the BRDF for all TROPOMI pixels and orbits takes too long
- Shortcut: determine LER corresponding to TOA radiance of the BRDF case using LUT, as described by Vasilkov et al. (2017)




Flow chart for different AMF data sets

**Legende**
TOA… top of atmosphere
LUT… look-up table
ALER-LUT … angular LER-LUT

## 4. Results

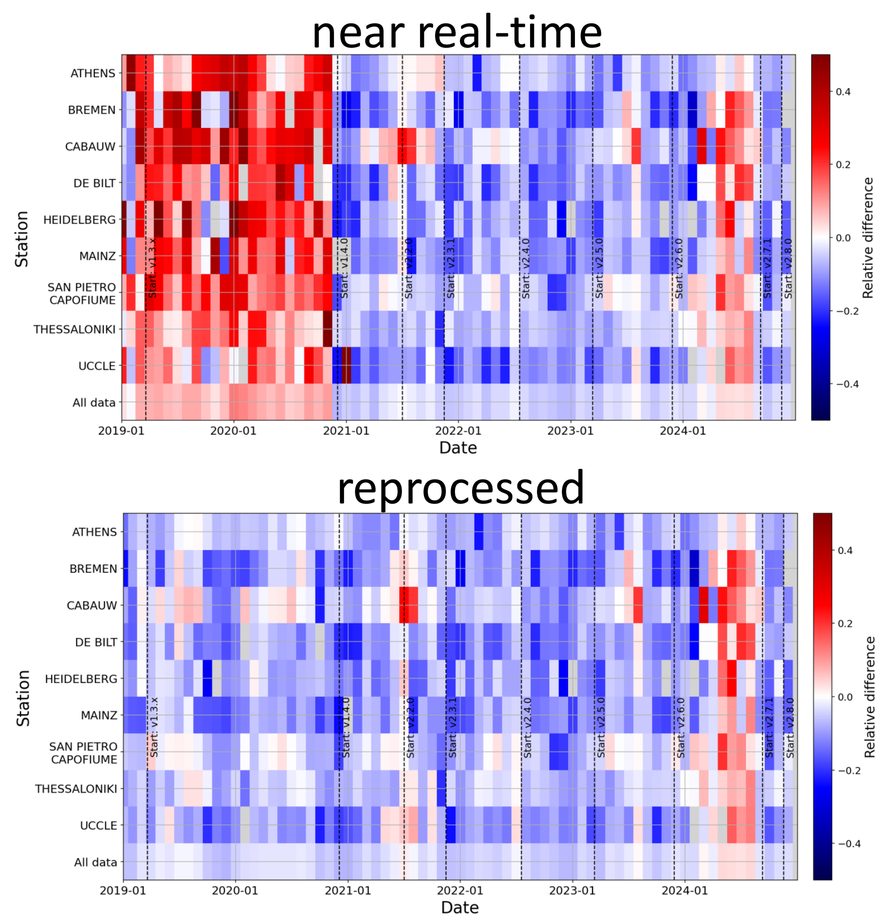
### 4.1 TROPOMI cloud data NRT vs RPRO

- Operational cloud data used in retrieval
- **N**ear **r**eal-**t**ime (**NRT**) cloud data **rep**r**o**cessed (**RPRO**) until 25.7.2022 → influence on retrieval?
- Calculate relative difference in VC

$$\Delta VC = \frac{VC^{ncc} - VC^{cc}}{VC^{cc}}$$

ncc – no cloud correction used
cc – cloud correction used

- Large differences for NRT → gone for RPRO
- v2.6.0 difference due to change in FRESCO leading to unintended consequences → reverted
- Use RPRO cloud data in addition to NRT



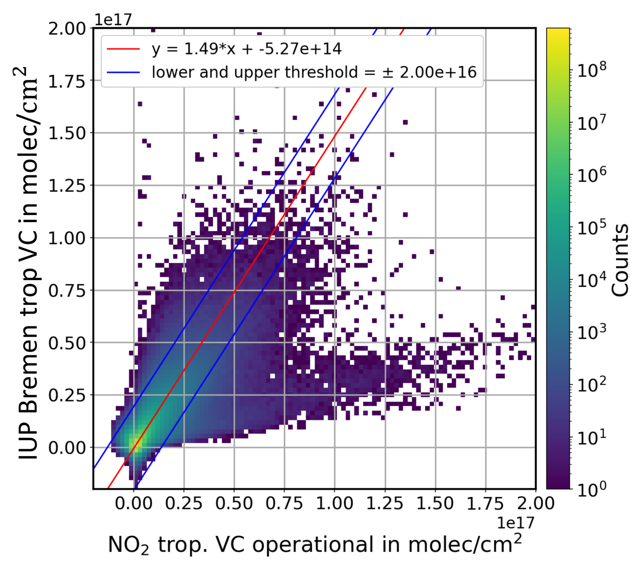

### 4.2 Operational vs IUP Bremen trop. VC

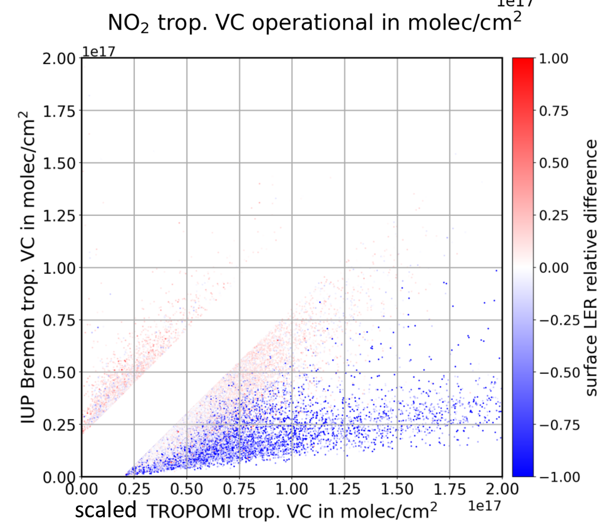
- Correlation plot using 6 years of data
  - IUP Bremen product ~50% larger trop. VC
  - Large additional branch → Why?
- Filter data using threshold of $2 * 10^{16}$ molec/cm$^2$
- Calculate relative difference in scene LER used in retrieval

$$\Delta LER = \frac{LER_{oper} - LER_{UB}}{LER_{oper}}$$

$LER_{oper}$ – scene LER operational
$LER_{UB}$ – scene LER IUP Bremen

- Large differences correlate with additional branch
- Operational TROPOMI modifies scene LER, if cloud fraction would lie outside [0, 1]

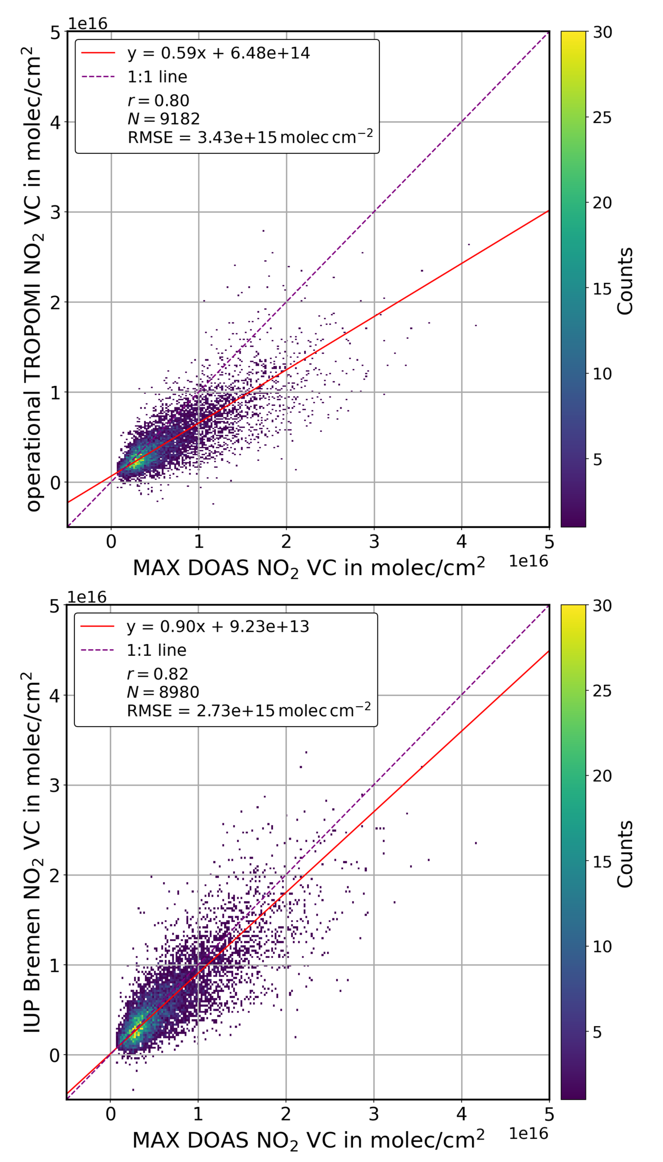



### 4.3 Validation using MAX-DOAS data

- MAX-DOAS data (VIS) of FRM4DOAS project used for validation
- Average MAX-DOAS data for ±30 minutes around TROPOMI overpass
- For IUP Bremen and operational product, pixel above MAX-DOAS station used only
- IUP Bremen product shows clear improvement over operational product

| Product | IUP Bremen | | | operational | | |
|---|---|---|---|---|---|---|
| year | points | slope | corr. | points | slope | corr. |
| 2019 | 1237 | 0.86 | 0.81 | 1283 | 0.57 | 0.81 |
| 2020 | 1579 | 0.86 | 0.81 | 1639 | 0.55 | 0.79 |
| 2021 | 1532 | 0.92 | 0.81 | 1538 | 0.63 | 0.79 |
| 2022 | 1697 | 0.94 | 0.82 | 1775 | 0.62 | 0.80 |
| 2023 | 1549 | 0.96 | 0.82 | 1583 | 0.59 | 0.78 |
| 2024 | 1386 | 0.83 | 0.80 | 1364 | 0.56 | 0.76 |
| all | 8980 | 0.90 | 0.82 | 9182 | 0.59 | 0.80 |




## 5. Conclusions and outlook

- IUP Bremen TROPOMI $NO_2$ VC product created for 2019 – 2025, (2025 not shown)
- Importance of using RPRO cloud data confirmed
- Additional branch found → operational product adjusts scene LER
- Validation with MAX-DOAS clear improvements over operational product
  - $s = 0.59 \rightarrow s = 0.90$
  - r = 0.80 → r = 0.82

**References**

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**Zhou** et al. (2010), Accounting for surface reflectance anisotropy in satellite retrievals of tropospheric $NO_2$, https://doi.org/10.5194/amt-3-1185-2010

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