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Fachbereich 01
Physik/Elektrotechnik

Improved tropospheric NO_2 columns retrieved from TROPOMI on board the Sentinel-5P satellite

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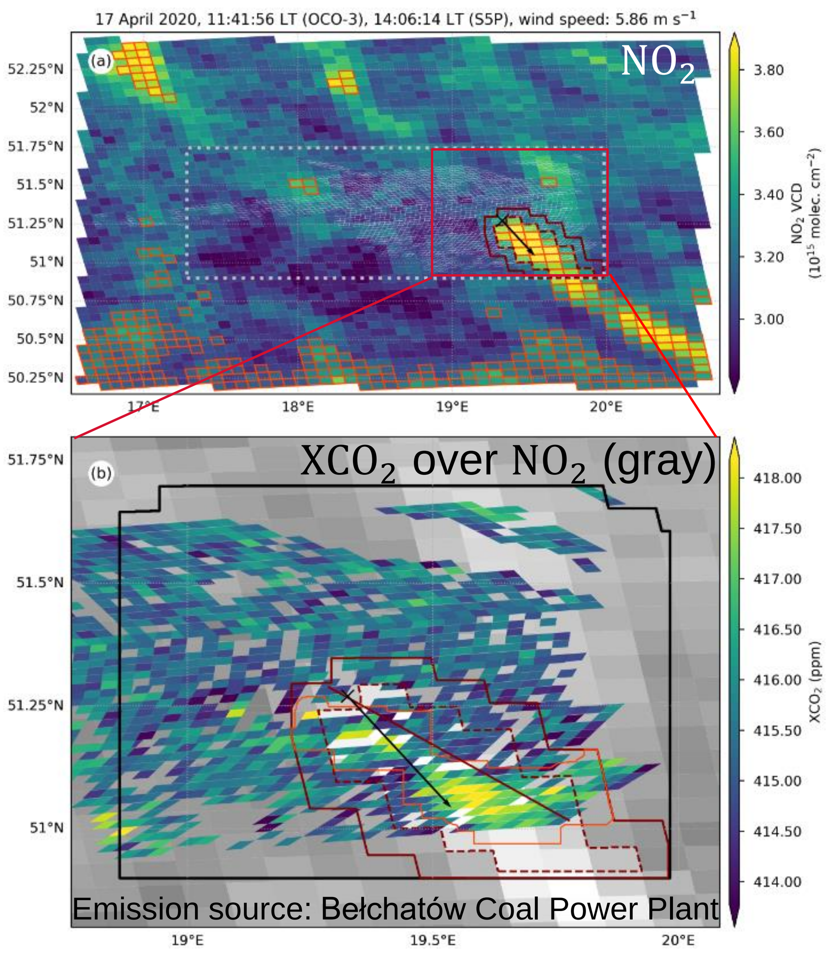
1. Motivation

CO_2 is the most important anthropogenic greenhouse gas. Detecting and quantifying CO_2 emission sources is important but difficult using satellite data. NO_2 is co-emitted with CO_2 during combustion processes and is much easier to detect. Therefore, it can be used as a proxy for CO_2 emissions. The objective is to establish a high resolution TROPOMI NO_2 for Europe, optimised for small scale processes, like emission plumes.



Fuentes Andrade et al. 2023

2. NO_2 columns and AMF

- Spectra measured by TROPOMI
- Analysed using DOAS
→ slant columns (SC)
- Stratospheric SC substracted to obtain tropospheric SC
- Transformed into vertical columns using air mass factor (AMF)
- $AMF \stackrel{\text{def}}{=} \frac{SC}{VC}$, a priori information for calculation used e.g. surface reflectivity
- Has influence on BAMF

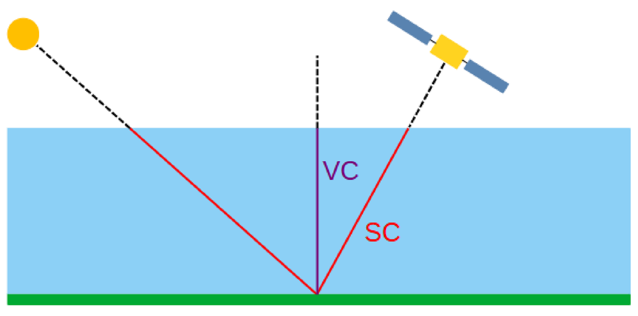
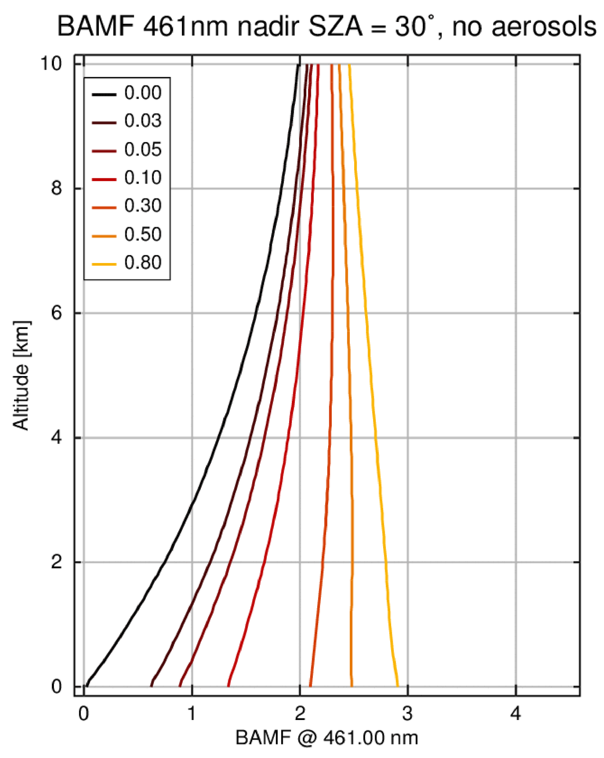
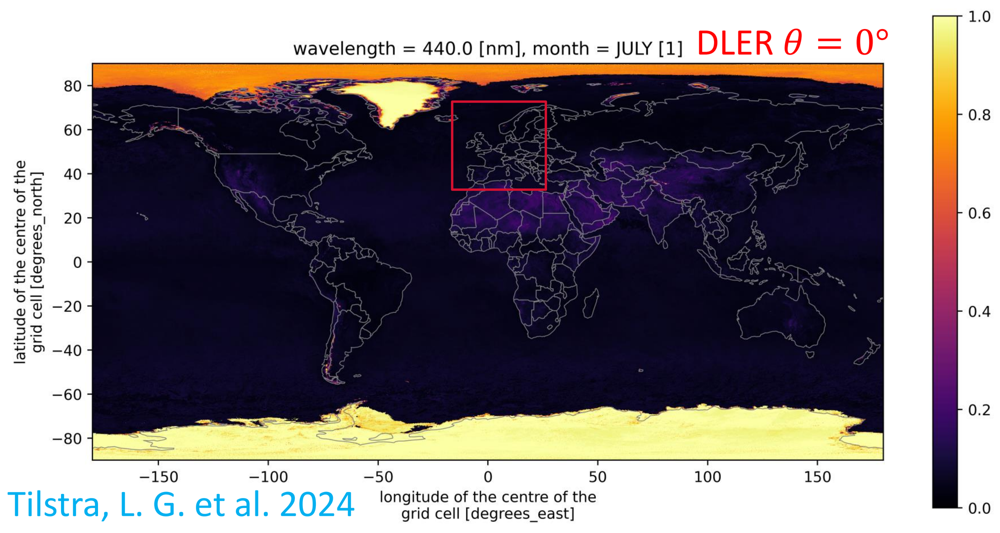


Illustration of slant and vertical columns.



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

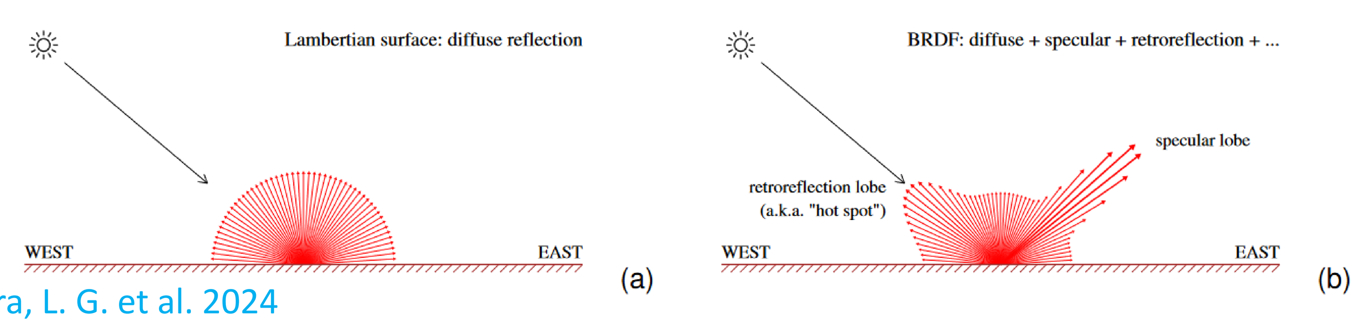
- Idea: replace operational DLER reflectivity product from TROPOMI with BRDF product from MODIS
- MODIS dataset has higher temporal and spatial resolution



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

$$BRDF(\lambda, \theta, \theta_0, \varphi - \varphi_0) = f_{iso}(\lambda) + f_{vol}(\lambda) * k_{vol}(\theta, \theta_0, \varphi - \varphi_0) + f_{geo}(\lambda) * k_{geo}(\theta, \theta_0, \varphi - \varphi_0)$$

f_{iso}, f_{geo} and f_{vol} obtained from MODIS



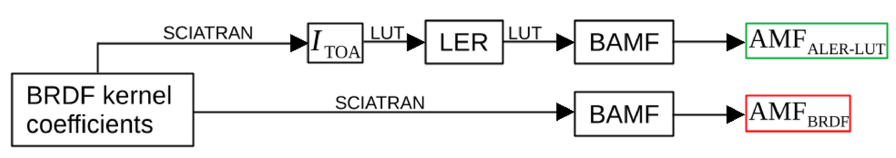
Tilstra, L. G. et al. 2024

a) Lambertian equivalent reflectivity (LER) amount of reflected light in all directions the same

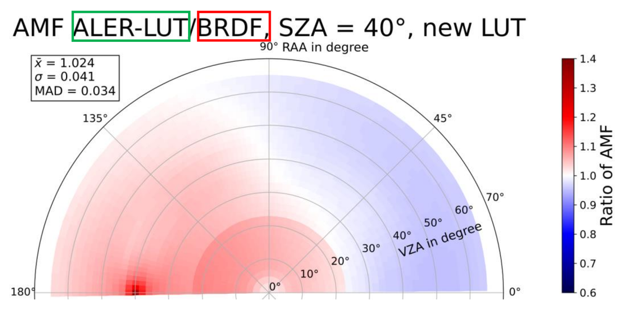
b) Bi-directional reflectance distribution function (BRDF), describes angle-dependent reflectivity of surfaces

3. Results

- AMF calculation using SCIATRAN for the AMF calculation using the BRDF for all TROPOMI pixels and orbits takes too long
- Shortcut: use LUT and interpolation, as described by Vasilkov et al. (2017)

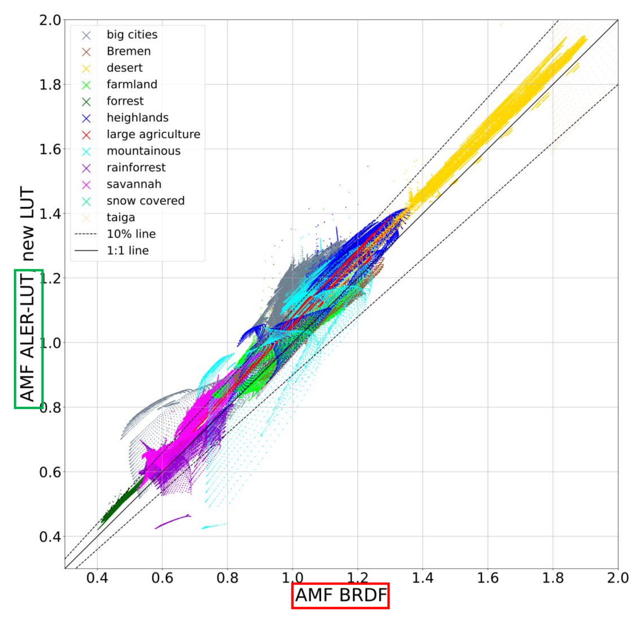


Flow chart for different AMF data sets

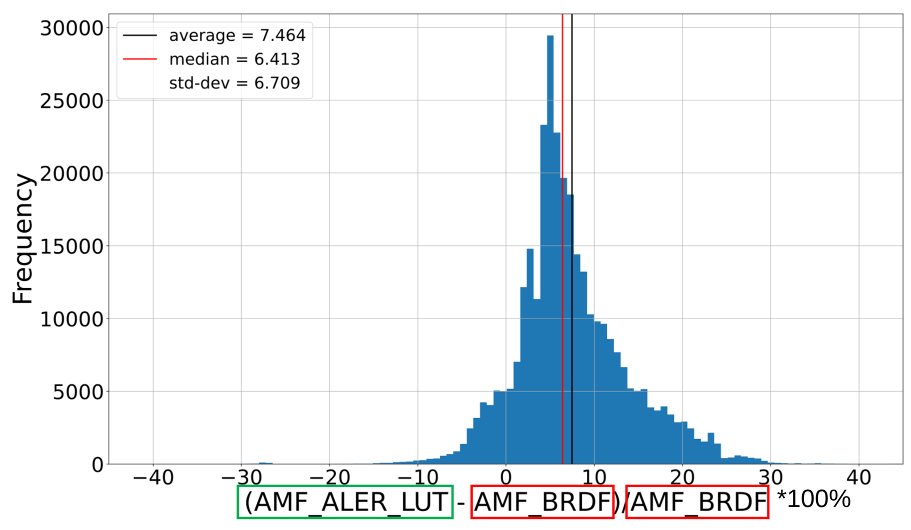


Pixel by pixel ratio of the AMF for Vasilkovs method and using the BRDF.

- AMF_BRDF and AMF_ALER-LUT comparison shows problems:
  - Ring structure around VZA ~4° - ~22°
  - Hotspot at retroreflection
  - Ratio is RAA dependent
- Check more than one scene in a scatter plot

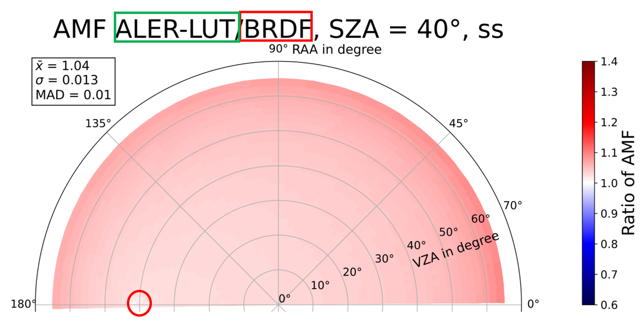


Scatter plot of AMFs shows systematic structures and large spread at low AMF.

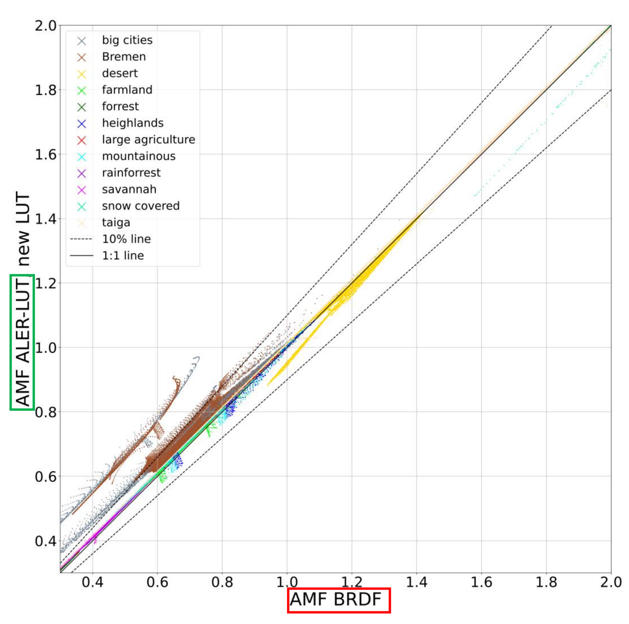


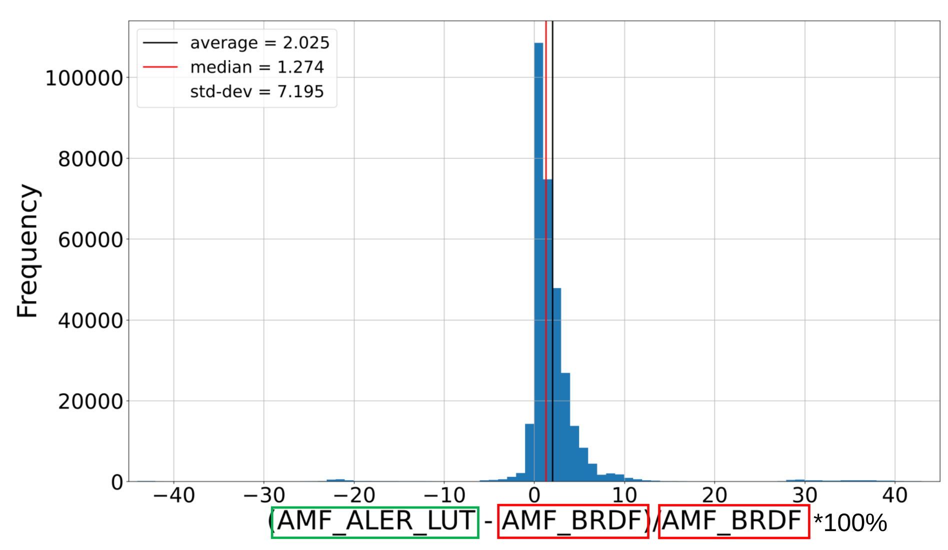
Quantifying the scatter shows spread up to ~40% and an offset of ~7.5%

- Testing single scattering (ss) instead of multiple scattering



- Only a slight hotspot is visible
- statistics is closer to what is hoped for





- Statistics is better, but problems at low AMF (not shown, reason not known)
- ss is not realistic in the atmosphere
- Shows that ms introduced problems

4. Conclusion

- BRDF has significant influence on the AMF
- Comparison of BRDF and method of Vasilkov showed problems:
  - Offset between AMF datasets
  - Ring structure around VZA ~4° - ~22°
  - Hotspot at retroreflection
- Better results obtained using single scattering, but problems occurred for some geometries

References

Fuentes Andrade et al. (2023), A method for estimating localized CO_2 emissions from co-located satellite XCO_2 and NO_2 images, https://doi.org/10.5194/egusphere-2023-2085 (Preprint)

Tilstra, L.G. et al. (2024), TROPOMI ATBD of the directionally dependent surface Lambertian-equivalent reflectivity