Improved AMF for tropospheric NO_2 columns retrieved from TROPOMI using MODIS BRDF kernel coefficients

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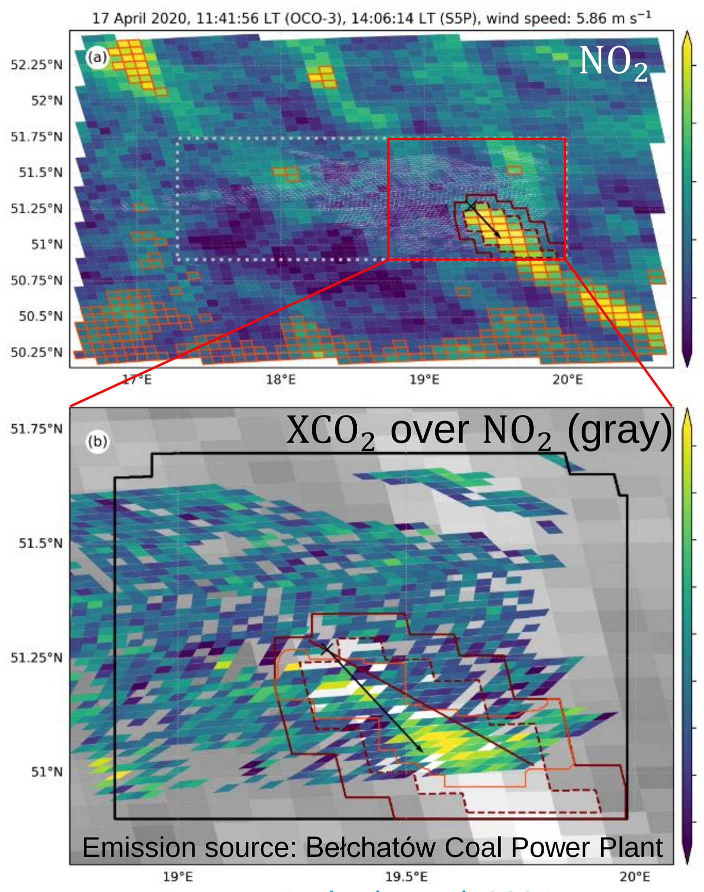
1. Motivation

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 of this study is to establish a high resolution TROPOMI NO_2 for Europe, optimised for small scale processes, like emission plumes.



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2. NO_2 columns and AMF

- Spectra measured by TROPOMI
- Analysed using DOAS

→ slant columns (SC)

- Stratospheric SC subtracted 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
- Idea: replace operational **D**irectional **L**ambertian **E**quivalent **R**eflectivity (**DLER**) product from TROPOMI with **B**i-derectional **R**eflectance **D**istribution **F**unction (**BRDF**) product from MODIS
- MODIS dataset has higher temporal

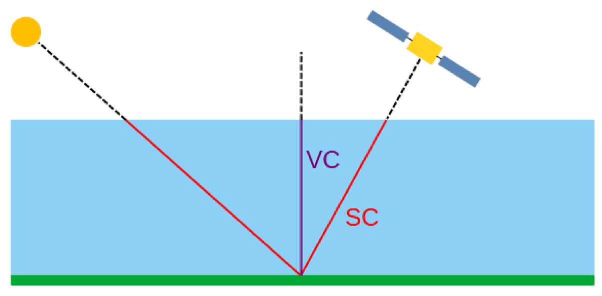
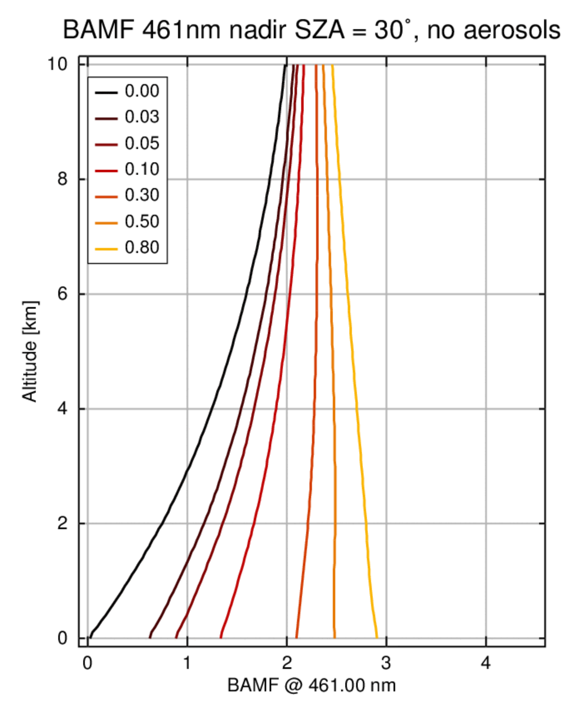
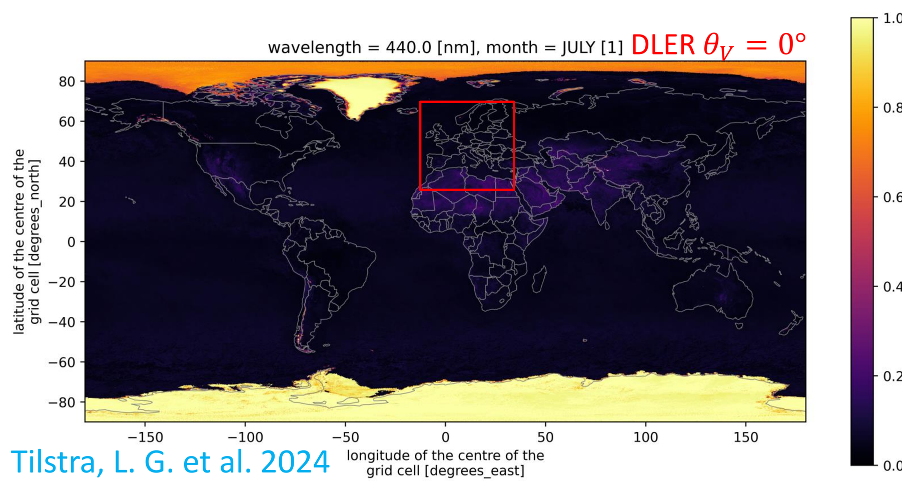


Illustration of slant and vertical columns.



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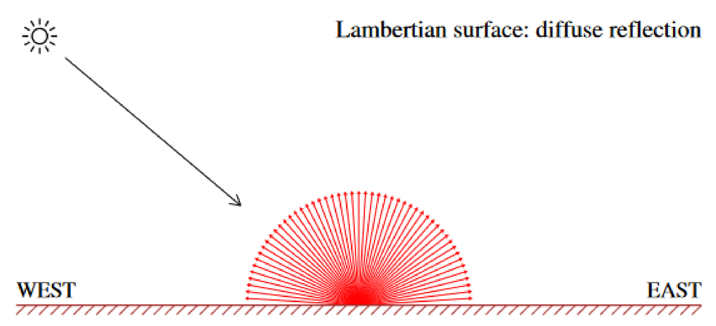
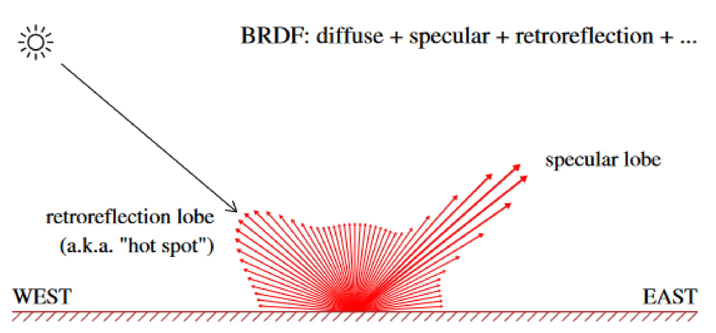
Surface reflectivity of DLER product shows low reflectivities in target area (red)



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



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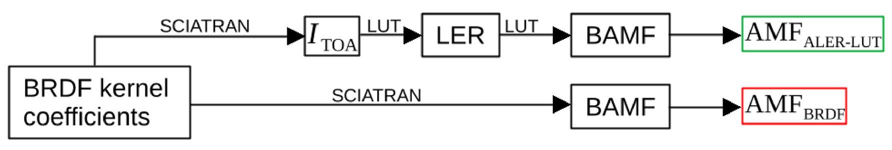
(b) b) Bi-directional reflectance distribution function (BRDF), describes angle-dependent reflectivity of surfaces

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

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

3. Results

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



Flow chart for different AMF data sets

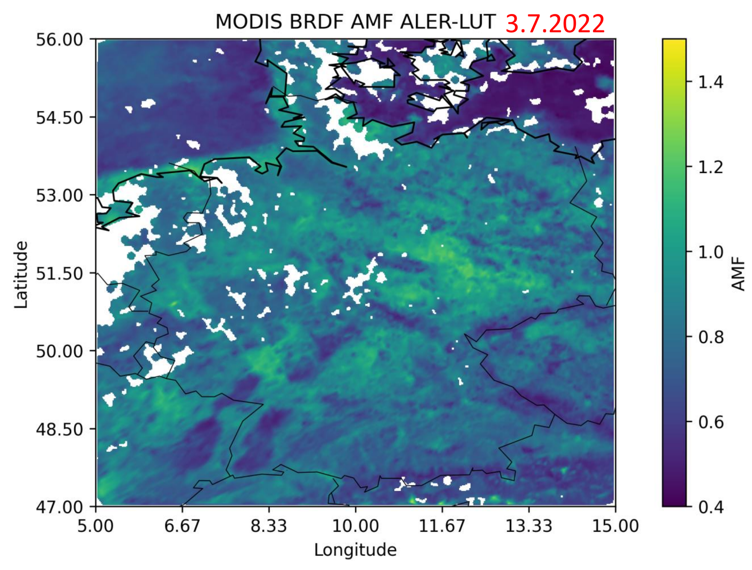
Legende

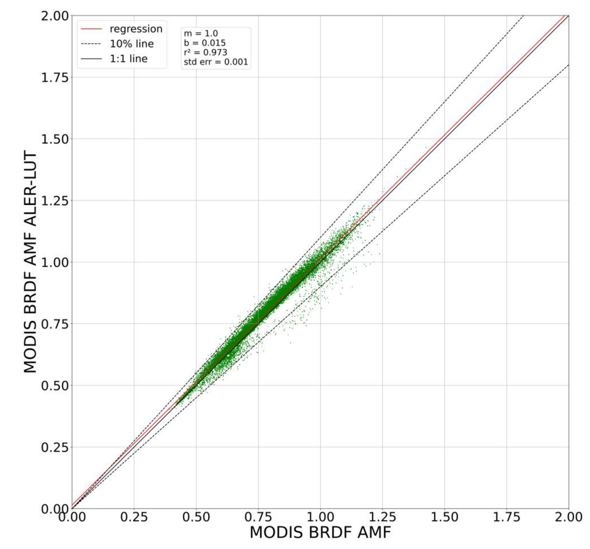
TOA… top of atmosphere

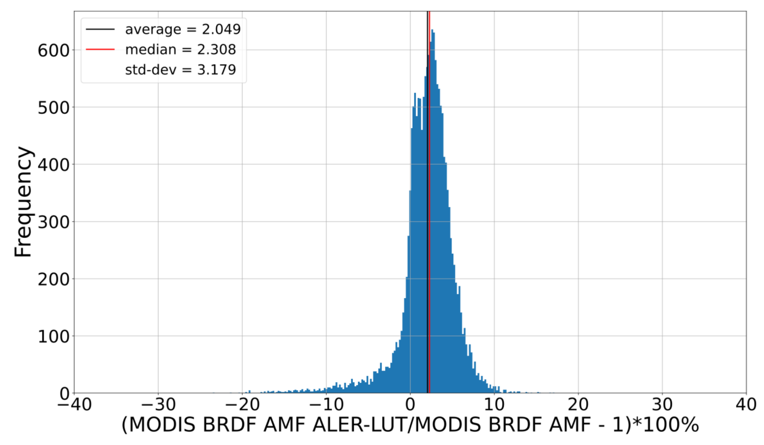
LUT… look-up table

ALER-LUT … angular LER-LUT

- AMF for parts of an TROPOMI orbit using a constant NO_2 profile

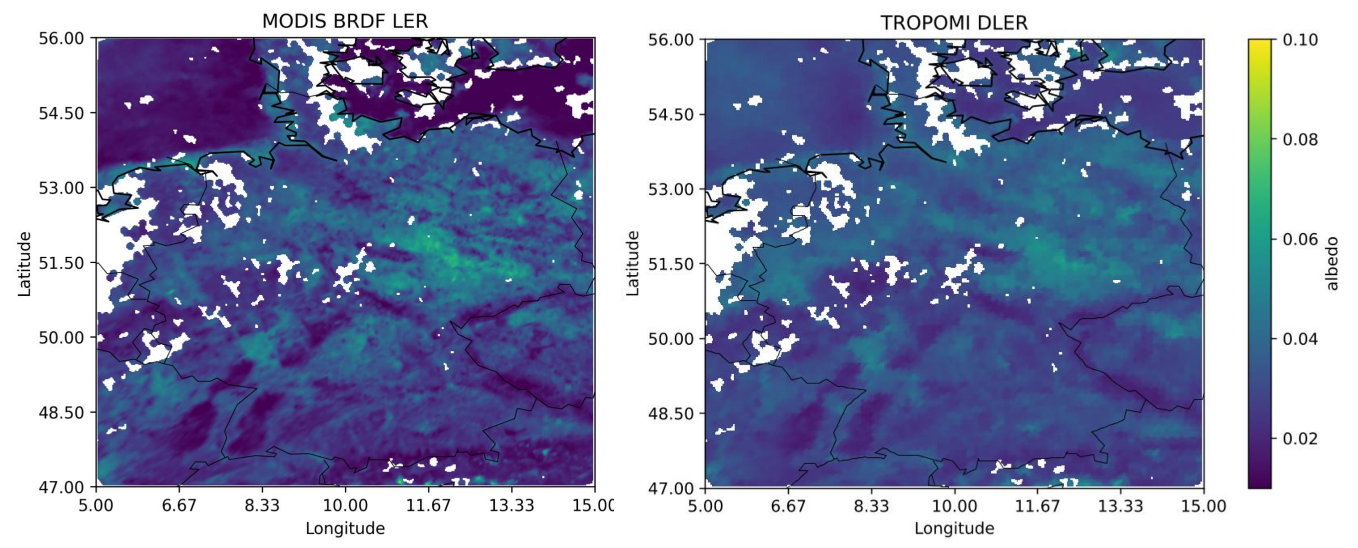




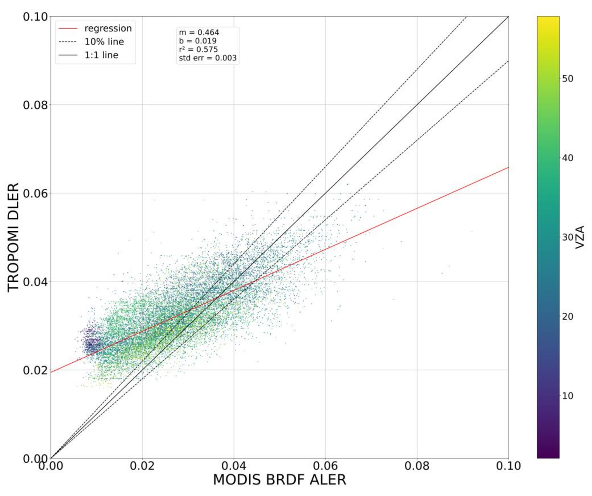


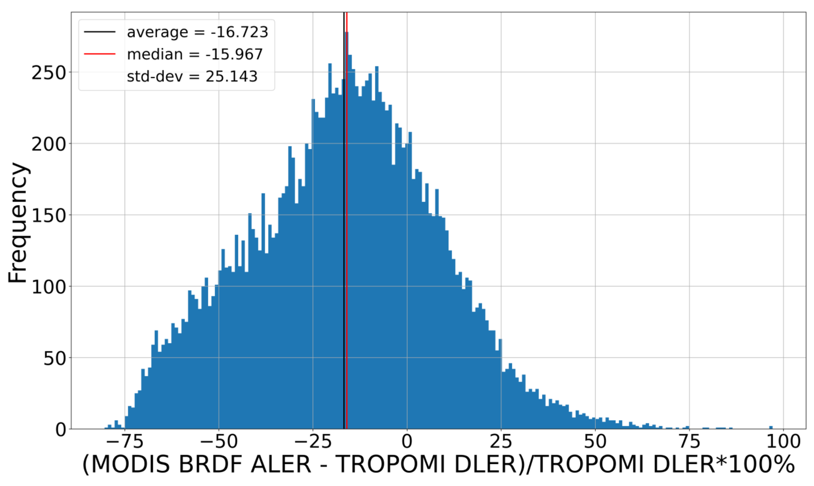
- Comparison of explicit AMF calculation using MODIS BRDF kernel coefficients with AMF using method of Vasilkov et al.
- Good agreement between MODIS BRDF AMF ALER-LUT and MODIS BRDF AMF
- Scatter mostly within 10%
- Slight overestimation of AMF by MODIS BRDF AMF ALER-LUT

- Comparison of TROPOMI DLER with obtained ALER



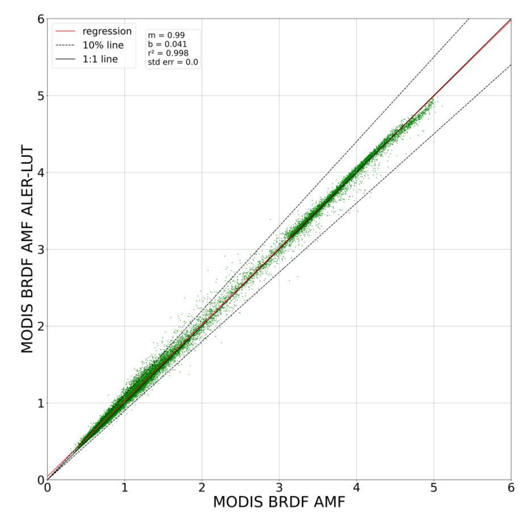
MODIS BRDF LER shows higher variability of LER and is darker on average.

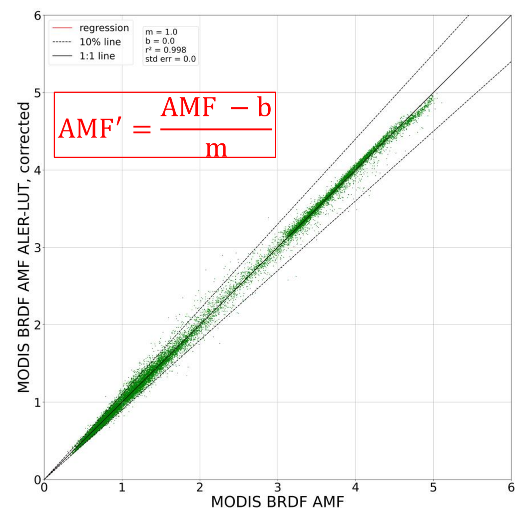


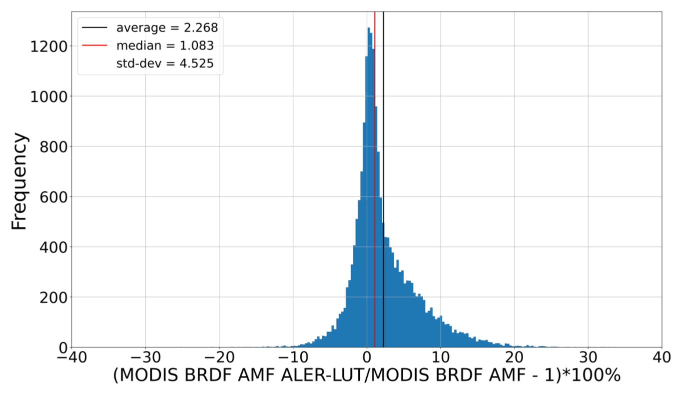


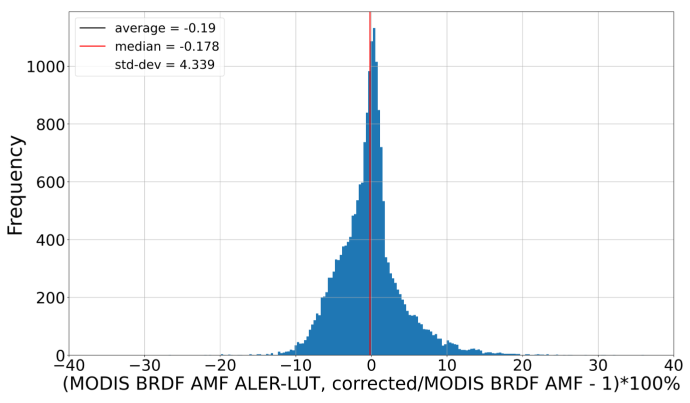
A large scatter of up to 75% and slope of 0.46 was found, partly explained by using a monthly climatology as a comparison.

- Using random MODIS pixel and viewing geometry and correction









Uncorrected data shows a good correlation between AMF ALLER-LUT and AMF BRDF. Correcting the AMF using linear regression through random MODIS pixel data improves statistics slightly.

4. Conclusion

- Preliminary AMF map of Germany using method by Vasilkov et al. created
- Good agreement between MODIS BRDF AMF ALER-LUT and MODIS BRDF AMF found (mostly within 10% deviation)
- Large number of random MODIS pixels and geometries used to find a first and easy correction
- Large scatter of up to 75% deviation between MODIS BRDF ALER and TROPOMI DLER product found, partly explained by using a monthly climatology as a comparison

References

Fuentes Andrade et al. (2024), A method for estimating localized CO_2 emissions from co-located satellite XCO_2 and NO_2 images, https://doi.org/10.5194/amt-17-1145-2024

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

Vasilkov et al. (2017), Accounting for the effects of surface BRDF on satellite cloud and trace-gas retrievals: a new approach based on geometry-dependent Lambertian equivalent reflectivity applied to OMI algorithms, https://doi.org/10.5194/amt-10-333-2017