Testing the CO2M NO_2 Retrieval Algorithm using TROPOMI Spatial Zoom Data

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Introduction

The future Copernicus Anthropogenic CO_2 Monitoring Mission (CO2M) will provide CO_2 data at a high resolution of 2x2 km^2 with unprecedented accuracy and precision. In addition to bands in the near-infrared and shortwave infrared, the CO2I spectrometer on board of CO2M also contains a visible band for the retrieval of NO_2 tropospheric columns. NO_2 observations will be performed to aid the detection and identification of CO_2 emission plumes, as NO_2 is co-emitted during combustion processes and acts as a tracer of CO_2. Due to its relatively low tropospheric background value and biospheric influence, local enhancements of tropospheric NO_2 are better detectable than those of CO_2 and allow for more accurate CO_2 emission estimates. Furthermore, this NO_2 product will be very valuable for air quality applications, especially emission source quantification.

Algorithm improvements

To fully exploit the high resolution of the NO_2 measurements, five times higher than the operational resolution of the TROPOMI instrument, improvements on multiple aspects of the air-mass correction in the tropospheric NO_2 retrieval algorithm are considered (see also Figure 1):

- **anisotropic surface treatment at high spatial resolution using BRDF products and models**
- effective cloud/aerosol parameter retrieval as a scattering layer (Henyey-Greenstein) using co-registered cloud information provided by the on-board cloud imager instrument (CLIM) and the measured O_2-O_2 (and O_2-A) absorption bands. This algorithm will be based on the OMCLDO2 cloud algorithm (Veefkind et al., 2016).
- high resolution NO_2 a-priori profiles from the CAMS global/regional model forecasts.

BRDF and DLER

Over land a kernel-based BRDF model is used (Ross-Thick/Li-Sparse reciprocal RTLS model (Lucht et al., 2000)) to describe the land surface reflection anisotropy and estimates the BRDF using a linear combination of three terms: an isotropic parameter, the volumetric kernel describing the scattering of dense vegetation canopy, the geometric kernel describing surface scattering and geometric shadow effects. Operationally the BRDF kernel coefficients will be obtained from the 3MI instrument (Metop-SG).

The BRDF for water surfaces can be modelled by an air-water interface (Fresnel) in combination with water surface roughness by wind-driven waves (Cox and Munck, 1954). The water leaving radiance or ocean albedo can be described by a Lambertian reflectance (Morel and Maritorena, 2001), dependent on chlorophyll concentration. An example is shown in Figure 2.

The BRDF surface would ideally be directly implemented into radiative transfer calculations, however, due to computational and practical constraints, we opted for an intermediate step: to calculate a directional Lambertian equivalent reflectivity (DLER) as function of the BRDF model parameters and solar/viewing geometry and store this in look-up tables using the DAK model (de Haan et al, 1987) and the ocean reflectance model from Trees et al. (2019).

TROPOMI spatial zoom data

The TROPOMI instrument produced a limited data set during the commissioning phase, where measurements were performed with increased spatial sampling of 2.4x1.8 km^2 at the cost of reduced SNR. This data set captures typical scenes showing NO_2 emission plumes at a similar spatial resolution as the planned CO2M measurements, allowing for the CO2M NO_2 retrieval algorithm to be tested on real data.

In Figure 3 the BRDF/DLER method is demonstrated over clear-sky land, using BRDF coefficients from the MODIS BRDF product MCD43GF at 470 nm. The DLER is used as input for the calculation of the NO_2 AMF at 440 nm. For qualitative comparison, the parameters are also calculated using the OMI LER database, which until recently was used as surface albedo source in the S5P NO_2 processor. The LER for 477 nm was used to minimize spectral dependency effects in the comparison with the DLER, however, this causes an overestimation in the cloud fraction. Note that the original AMF calculation and cloud correction from the S5P NO_2 algorithm are used for both versions, using the original TM5 NO_2 profile shape.

When using the OMI LER database, the lack of inclusion in surface albedo is partly compensated for in the cloud fraction, resulting in similar structures in the tropospheric AMF when comparing the DLER to the LER version. The different magnitude of the (D)LERs propagates into the AMF and NO_2 VCD.

Outlook

As the planned CO2M NO2 algorithm improvements are being developed, new methods will be tested using the TROPOMI spatial zoom data-set, alongside the CO2M synthetic test data-set.

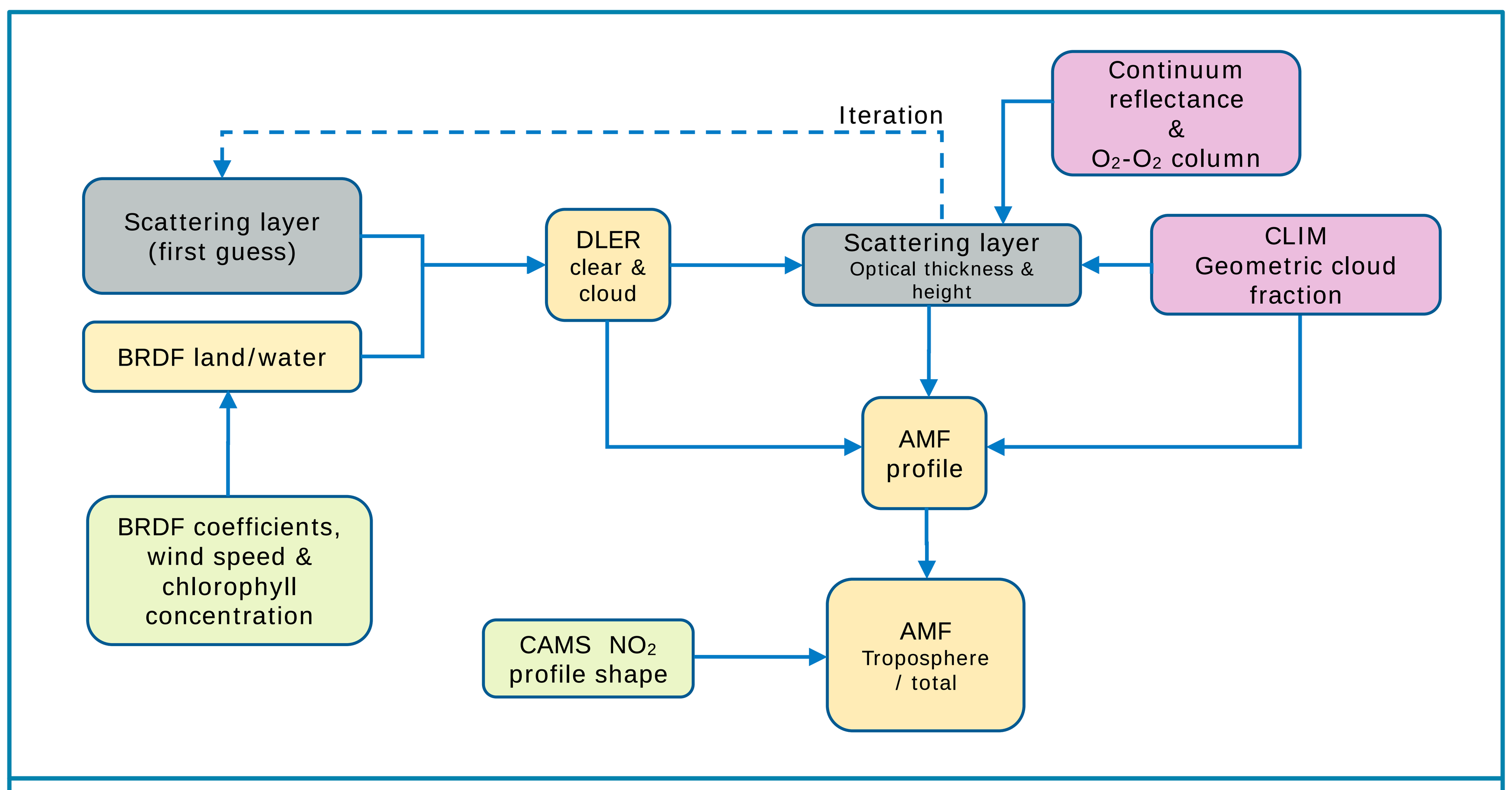

Figure 1: Simplified schematic overview of planned NO2 air-mass factor algorithm for CO2M.

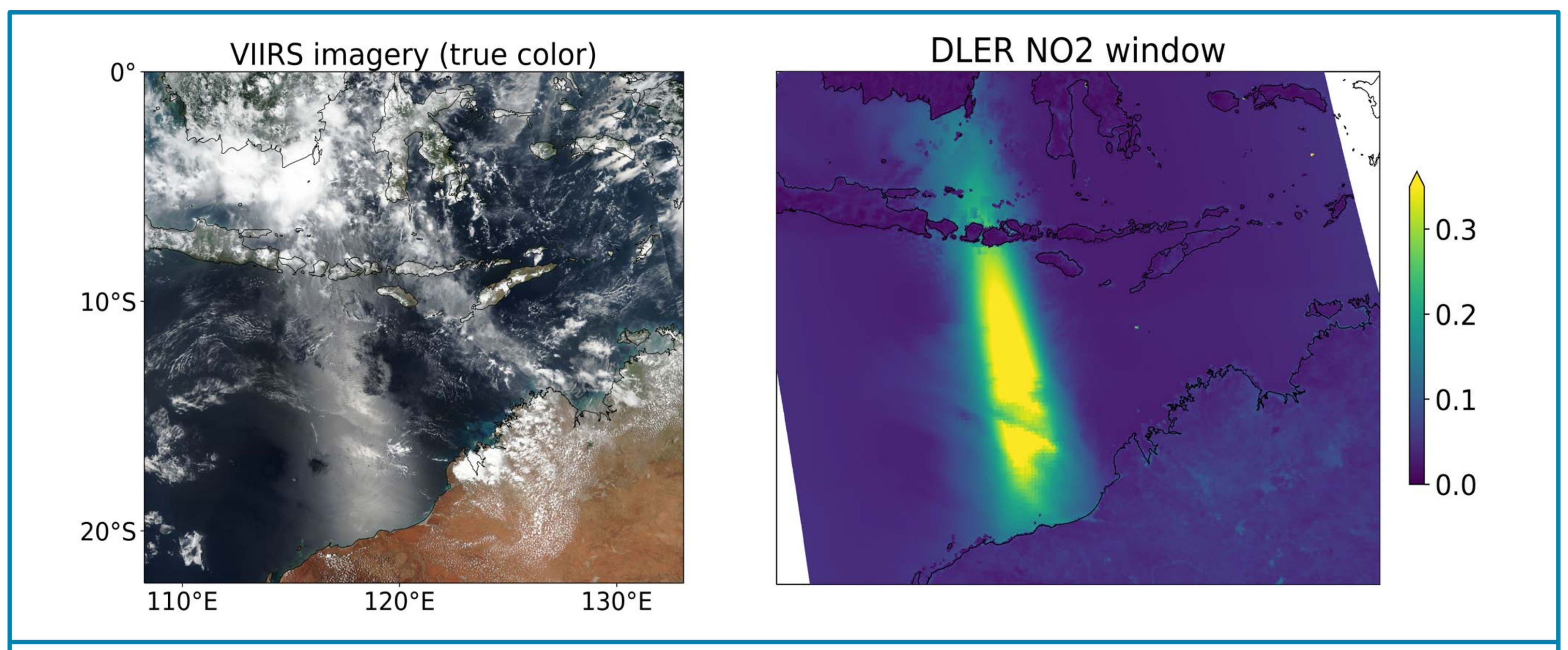

Figure 2: Sun glint on the Indian Ocean at 04-12-2019 as seen by VIIRS (left). DLER (right) calculated from TROPOMI measurement geometry, ECMWF wind speed, CMEMS chlorophyll concentration and MODIS BRDF (MCD43GF).

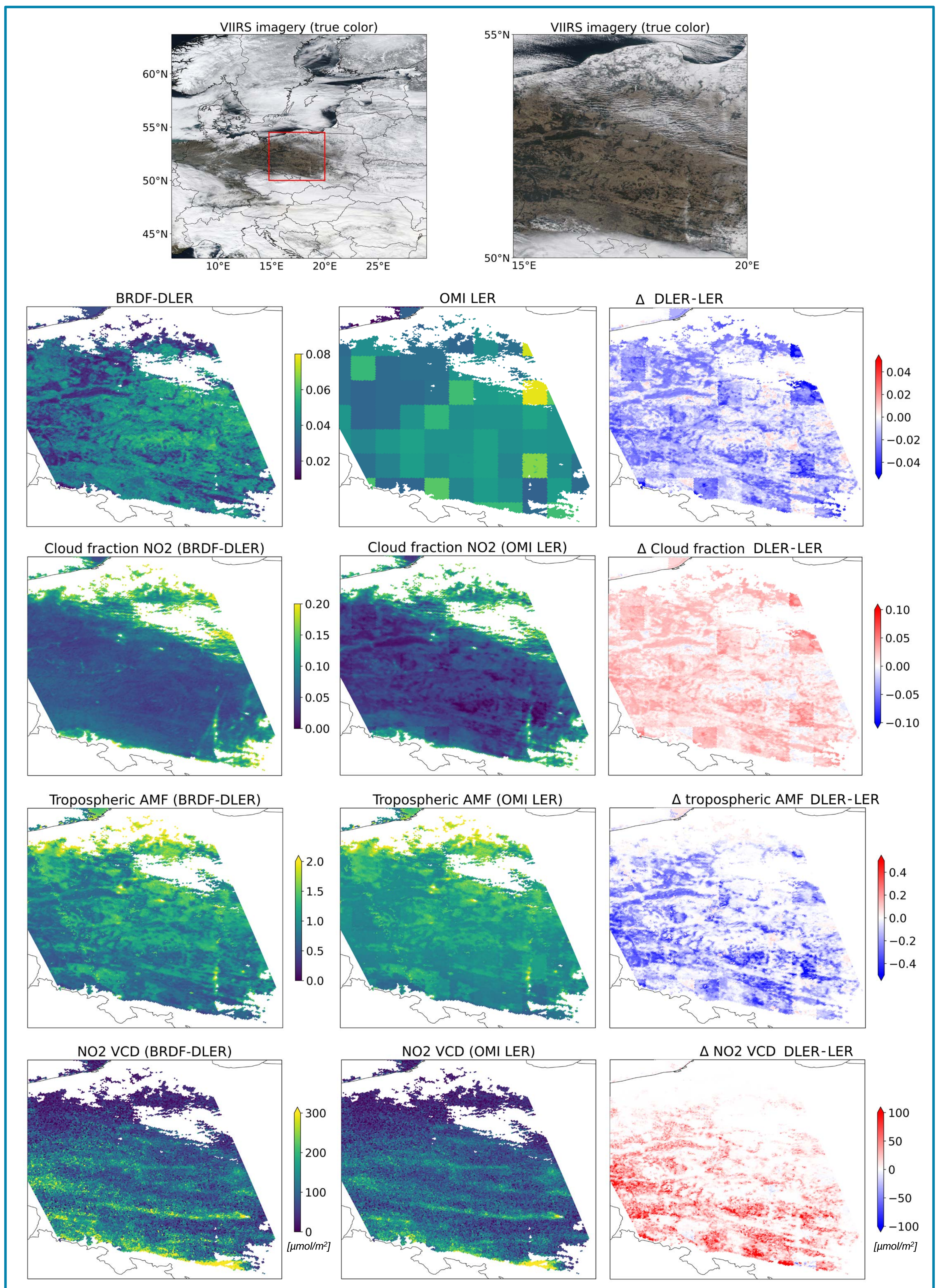

Figure 3: TROPOMI spatial zoom data on 02-03-2018 of Poland. The NO_2 plume originates from the Bełchatów power plant. The BRDF-DLER method is qualitatively compared to the OMI LER database in calculation of the cloud fraction, AMF and NO_2 VCD.