**Titel:**

Exploring TROPOMI NO<sub>2 </sub> observations over low clouds and fog: understanding the impact of the air-mass factor on cloudy scenes over the North Sea

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**Abstract**

This thesis investigates TROPOMI NO2 observations over low clouds and fog. Such scenes present unique opportunities due to the increased reflectivity of clouds in the lower troposphere, which enhances sensor sensitivity. However, in order to accurately estimate vertical NO2density in these scenarios, a better understanding of the retrieval process in such conditions is imperative. Two NO2 retrieval case studies, both exhibiting a spurious retrieval in the presence of low clouds and fog above the North Sea, are examined: February 14𝑡ℎ, 2023, and April 9𝑡ℎ, 2023. The main focus was on the influence of the air-mass factor on the retrieval. This factor converts measured slant column data along the satellite path into vertical tropospheric columns. Spurious spatial patterns are strongly amplified after the application of the air-mass factor. Key dependencies influencing the conversion from slant to

vertical column are identified, being the the a-priori NO2 profile, air mass factor calculation, and cloud characterization. Notably, the low spatial resolution of the a-priori model and its pronounced peak near the surface contribute to inflated NO2 values over clouds. The majority of the a-priori NO2 profile is simulated underneath the cloud field, leading the retrieval algorithm to assume it did not capture a significant portion of the concentration, thus strongly increasing retrieved NO2 densities over clouds. Furthermore, spatial reflectivity patterns in the North Sea are not always accounted for in the surface reflectivity climatology. This results in misinterpreted clouds with a low cloud fraction. Misinterpreted clouds over open sea areas, combined with low cloud pressures, result in downward corrections over clear-sky seas. These effects culminate in an exacerbated cloudy-clear contrast in NO2 densities, aligning with the outlines of low cloud fields. Additionally, the heterogeneous cloud field challenges the assumption of a fixed-height, fixed-albedo Lambertian reflector. This inflation effect is modulated by the cloud height. The uncertain height of the Lambertian cloud in the lowest troposphere, combined with an assumed NO2 profile at the same height, dominates the air-mass factor calculation . Four recommendations to enhance NO2 retrieval accuracy in the presence of low clouds and fog over the North Sea are presented, which include a Cloud-as-Layers characterization, high-resolution simulations and in-situ measurements of vertical NO2 profiles in the presence of low clouds, an a-priori correction of the NO2 profile in the presence of low clouds and implementing auxiliary data relating to spatial patterns in sea-colour of the North Sea.