Satellite Validation of TROPOMI-SO_2 over the Balkan Region by Airborne SO_2 Measurements of Coal-Fired Power Plants

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Motivation and Objective

Recent results from spaceborne measurements (TROPOMI instrument onboard Sentinel-5P) indicate that the Balkans is a hot spot region for anthropogenic sulphur dioxide (SO_2) emissions in Europe. These emissions mainly originate from a few coal-fired power plants located in Serbia and Bosnia-Herzegovina. The Serbian power plants located near Belgrade, Nikola Tesla A and B (NTA & NTB), are ranked on position number 18 of the world´s strongest sources of SO_2 pollution. Here we report on the first airborne in situ measurements in this region carried out by the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt, DLR). The main objectives are:

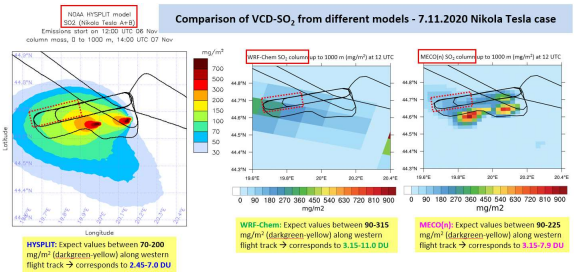
- realisation of first airborne SO_2 measurements of emissions from coal-fired power plants in Serbia and Bosnia-Herzegovina ever
- for **validation of TROPOMI-SO_2** (operational product and **COBRA*** product) with in-situ airborne measurements and models
- to improve TROPOMI-SO_2 algorithms for detection of SO_2-pollution over Europe with the focus on "hot spot" areas.

***Theys, N., et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2021-294, in review, 2021.**

The METHANE-To-Go-Europe Field Campaign

The METHANE-To-Go-Europe field experiment is the first one in a raw of planned METHANE-To-Go missions which aim to carry out airborne in situ measurements of methane (**CH_4**) and a number of further trace species (e.g. **SO_2**, CO, NO and aerosols) to gain information about **emissions from off- and on-shore natural gas and oil operations worldwide**. In addition, the quantification of **emissions from coal-fired power plants** is envisaged, as described in this study for the Balkan region with the focus on SO_2.

SO_2 Instrumentation and Modelling



Here the key instrument is an ion-trap chemical ionization mass spectrometer (IT-CIMS)** for airborne in situ measurements of SO_2. The CIMS instrument operates with a high accuracy (±20%) and a temporal resolution of 2-3 s, corresponding to a horizontal distance of ~300 m during the flight. In addition, a commercial Thermo Scientific SO_2 Analyzer (based on pulsed fluorescence technology) was operated. The data sets from both instruments were combined for the analyses.
Furthermore, simulations with the particle dispersion model HYSPLIT (DLR-developed version for SO_2), MECO(n) (MESSy-fied ECHAM and COSMO/MESSy models nested n times) and WRF-Chem were performed for flight planning and post analyses.

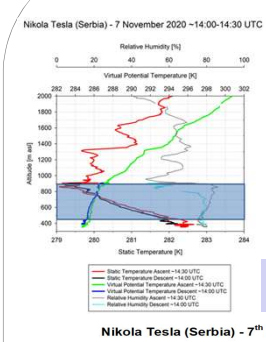
****Speidel, M., et al. (2007), Atmos. Environ., 41, 2427–2437, doi:10.1016/j.atmosenv.2006.07.047.**

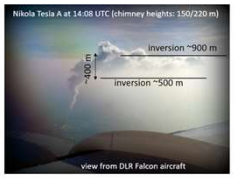
Mission Flights

13 mission flights were conducted with the research aircraft Falcon-20 of the DLR (based in Oberpfaffenhofen, Germany) during three weeks in **Oct.-Nov. 2020**. Most of the flights focused on emissions in the Adriatic Sea, yet two flights headed to Serbia and Bosnia-Herzegovina.

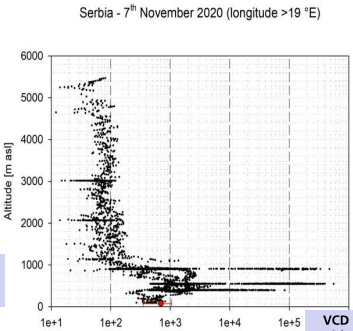
DLR research aircraft Falcon-20

DLR-Falcon flight to coal-fired power plants "Nikola Tesla" (NTA & NTB) in Serbia - 7th November 2020:

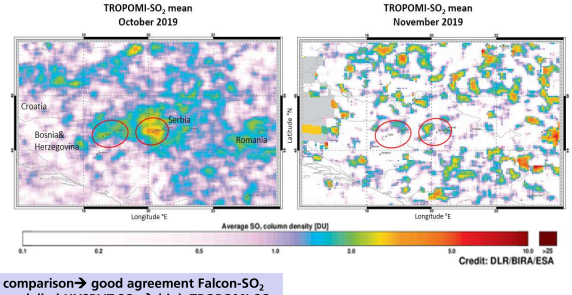


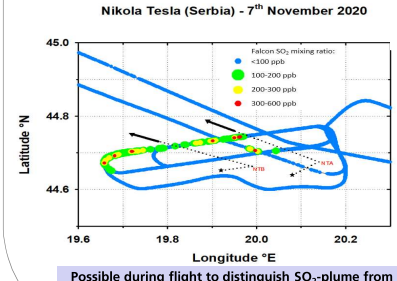


SO_2 emissions from the coal-fired power plants trapped in an inversion layer → advantage for VCD calculation

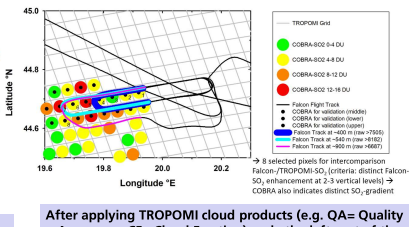


Distinct noise in TROPOMI-SO_2 signal due to lower sun position and more smoke clouds in November compared to October



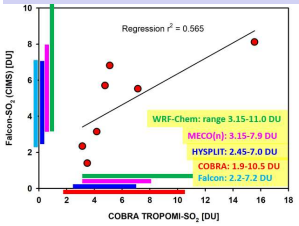


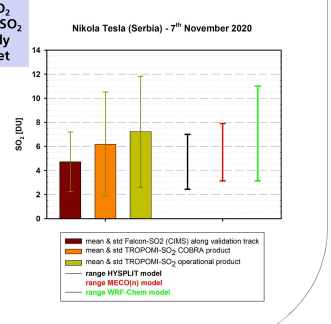
Possible during flight to distinguish SO_2-plume from both power plants (NTA & NTB) → downwind flight (20-40 km) indicates extremely high SO_2 mixing ratios



After applying TROPOMI cloud products (e.g. QA= Quality Assurance, CF= Cloud Fraction), only the left part of the flight track indicates "reliable" TROPOMI pixels → 7 pixels (number 1-6 and 8) selected for VCD estimate from Falcon-SO_2 data and validation with TROPOMI

VCD comparison→ good agreement Falcon-SO_2 with modelled HYSPLIT-SO_2 → high TROPOMI-SO_2 values possibly overestimated? → next: apply correct AK (averaging kernels) to the data set





Summary and Outlook

- For the first time successful airborne in situ measurements of SO_2-emissions from power plants in Serbia and Bosnia-Herzegovina → First TROPOMI-SO_2 validation flights for DLR → First results from Golden Day (07.11.2020 in Serbia) indicate promising case for TROPOMI-SO_2 validation with Falcon-SO_2 measurements
- Operational TROPOMI-SO_2 product 17% higher than COBRA product → COBRA ~30% higher (due to smoke clouds?) than Falcon-SO_2 → **Next: Apply correct AK**
- **Many obstacles** to overcome before successful validation flights (e.g. changing wind forecast, cloud-free conditions in target area needed, generally very difficult to receive flight permission to fly at low altitudes in these countries, support by local partners needed, limited flight duration over target area due to COVID-19 since no stopovers possible)
- Lessons learned: main SO_2 instrument (IT-CIMS) not suitable for the highest concentrations measured → replaced by measurements from less precise backup-instrument (Thermo).

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