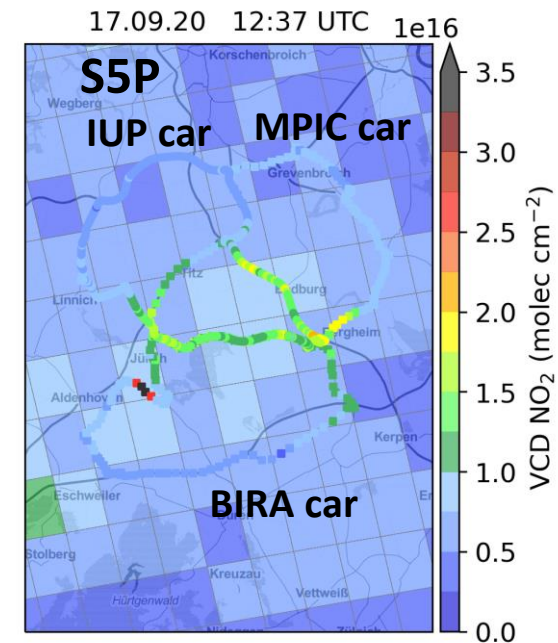
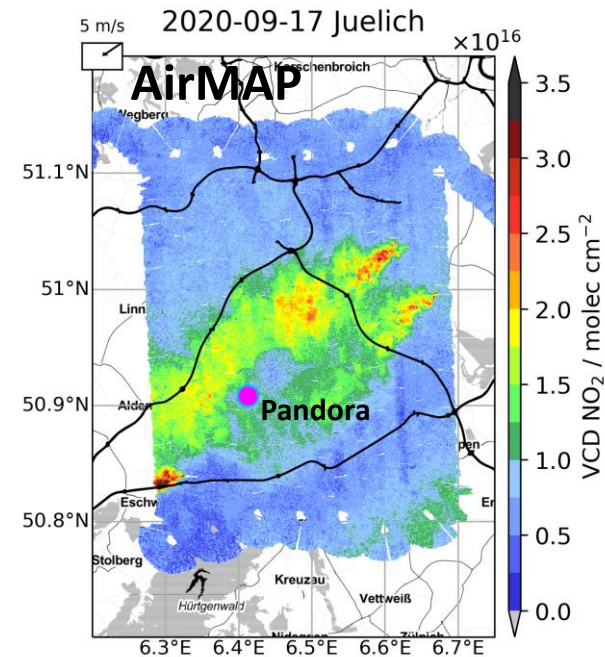


# Representativeness and variability of the ground-based measurements from the S5P-VAL-DE-Ruhr campaign



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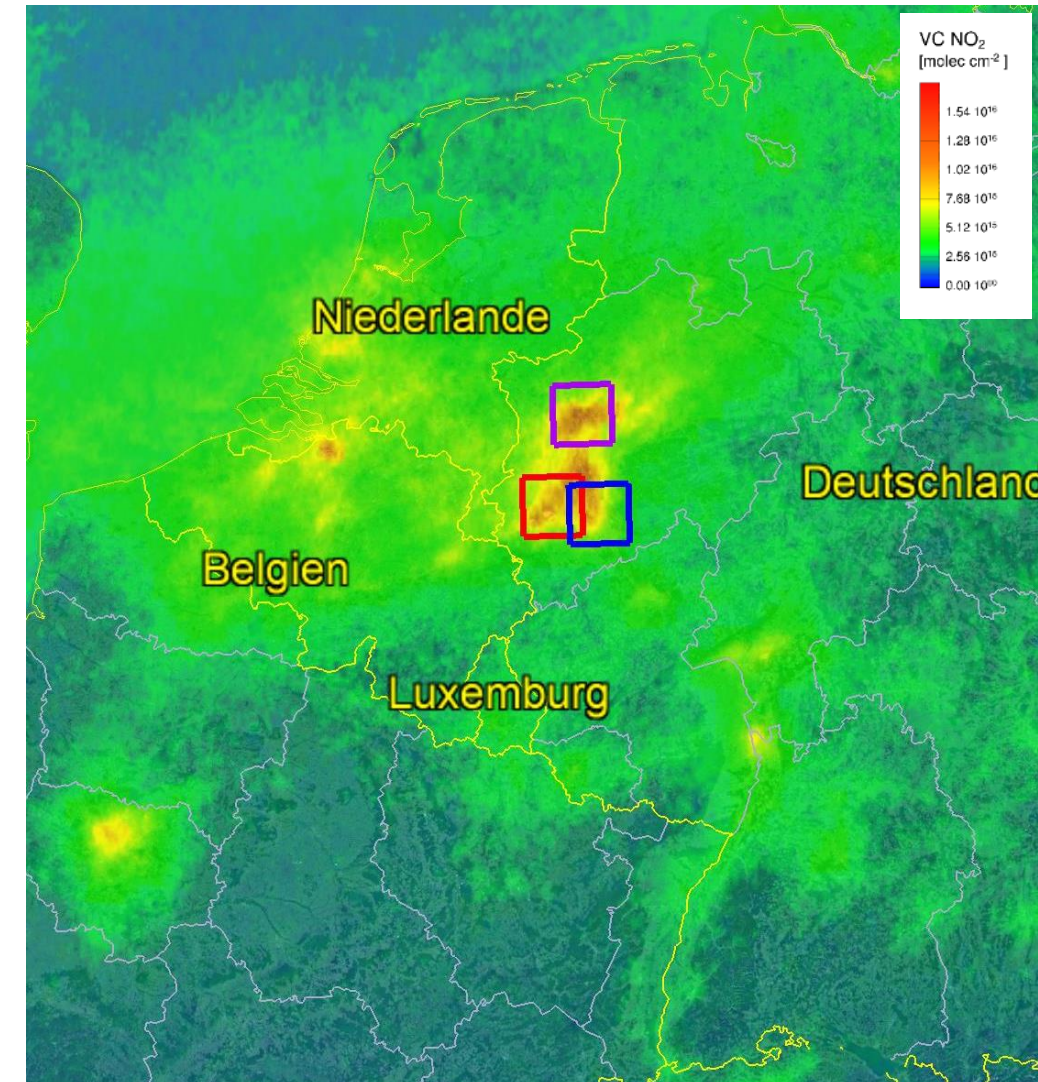
\* S5p-VAL-DE-Ruhr campaign team: Lisa Behrens (1), Birger Bohn (6), Christian Borger (3), Tim Bösch (1), Ermioni Dimitropoulou (2), Sebastian Donner (3), Steffen Dörner (3), François Hendrick (2), Kai Krause (1), Vinod Kumar(3), Bianca Lauster (3), Alexis Merlaud (2), Maria Razi (3), André Seyler (1), Frederik Tack (2), Katharina Uhlmannsiek (3), Folkard Wittrock (1)





- Validation of Sentinel-5P products ( $\text{NO}_2$ , HCHO and  $\text{SO}_2$ ) using different instruments and observation geometries
- Campaign activities took place in North Rhine-Westphalia, a pollution hotspot in Europe
  - Urban character & large industrial emitters
- Seven flight days from 12 - 18 September 2020
  - One flight per day
    - Two flights during the weekend
    - Five flights during the week
  - Three flights in the Duisburg flight sector
  - Two flights each in the Jülich and Cologne sector

Sentinel-5P VC  $\text{NO}_2$  September 2020

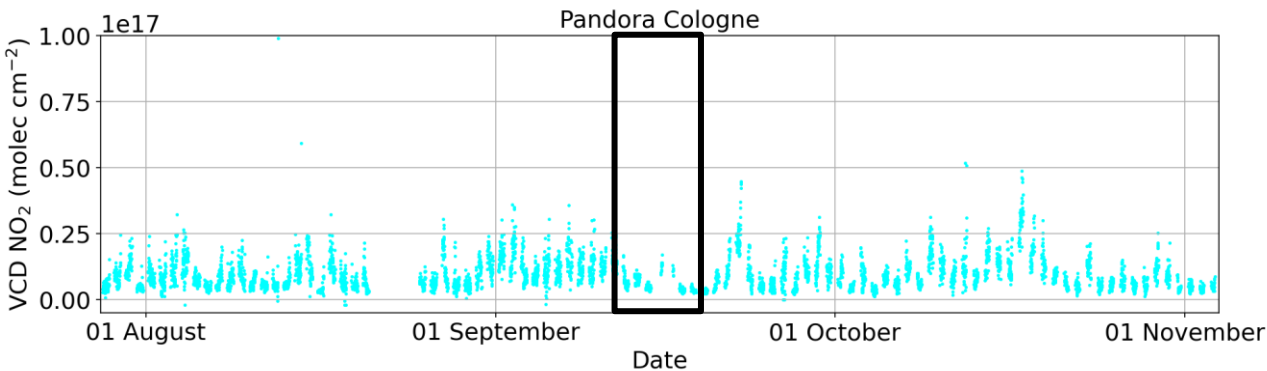
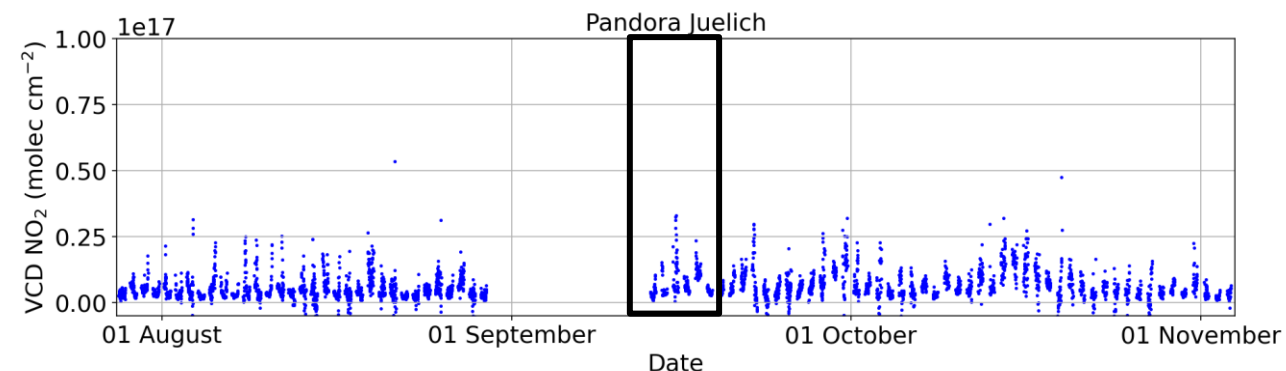
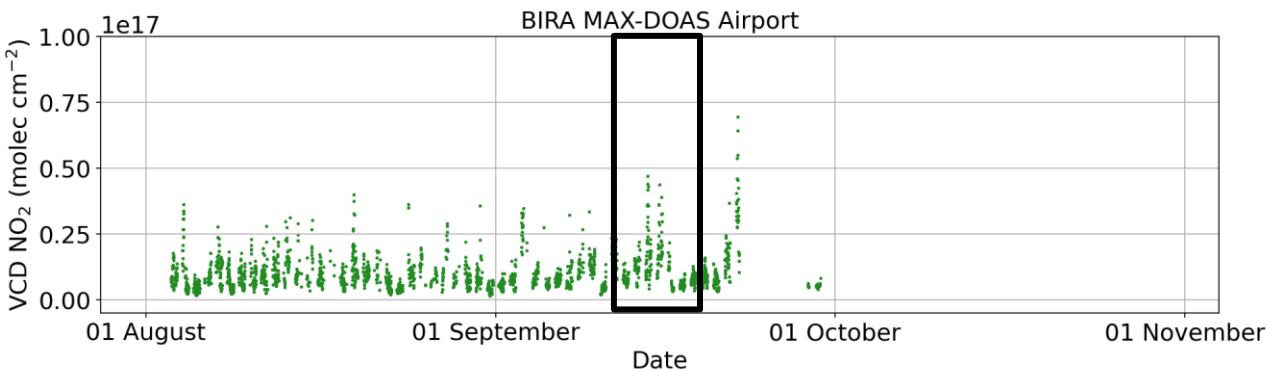
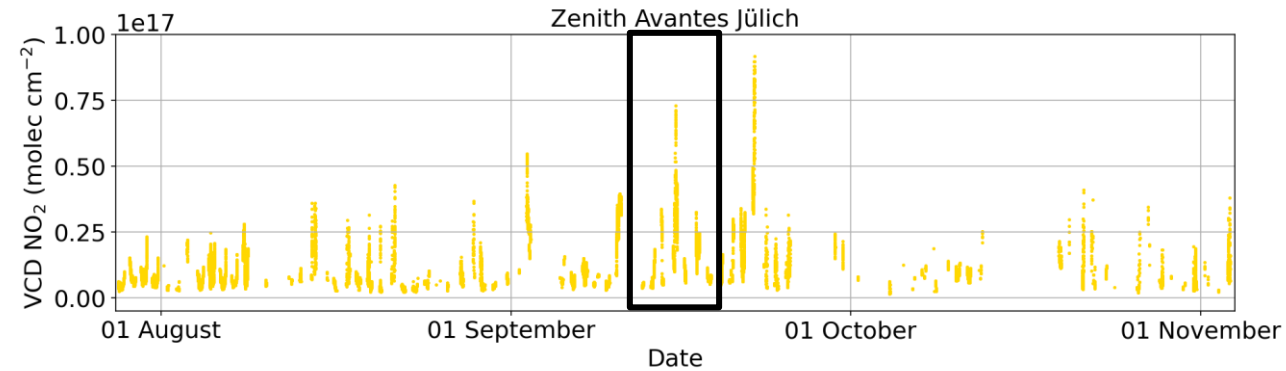
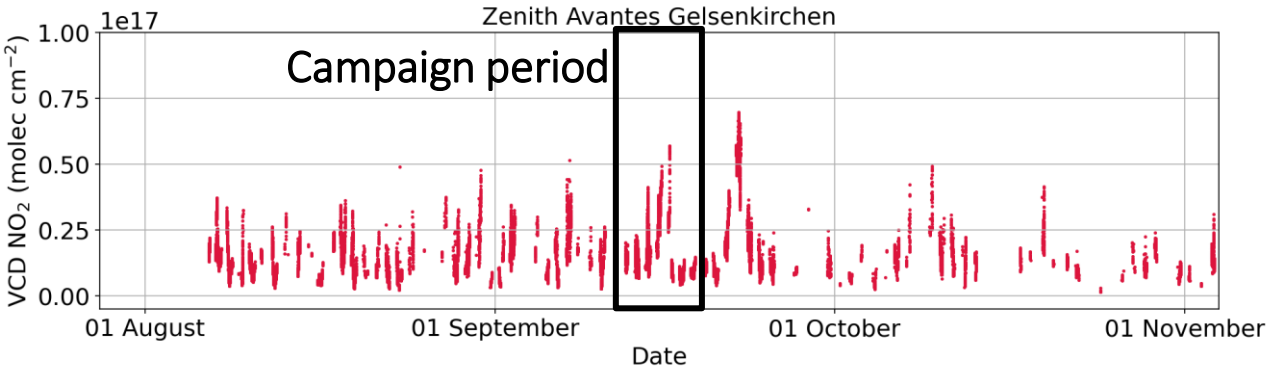


- Airborne DOAS measurements with imaging DOAS AirMAP & nadir pointing Avantes spectrometer AvaAir onboard of the Cessna on 7 days
- Car-DOAS measurements from IUP, MPIC, BIRA on all flight days (zenith-sky only)
- Stationary measurements were operational on all flight days and before/after campaign period



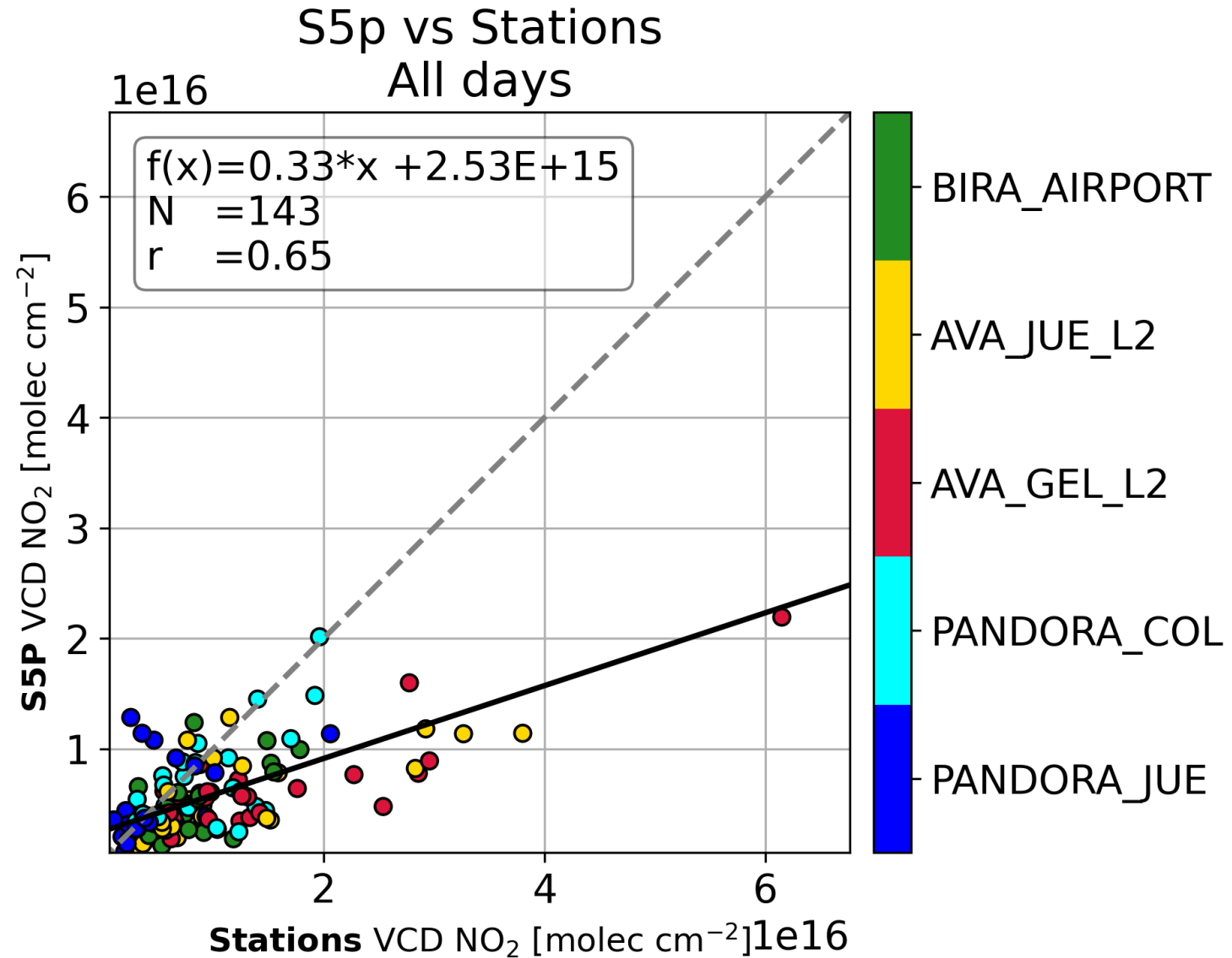
| Location          | Instrument type                           |
|-------------------|---|
| Gelsenkirchen     | IUP Zenith-sky Avantes                    |
| Jülich            | IUP Zenith-sky Avantes                    |
| Airport Dinslaken | BIRA SkySpec MAX-DOAS                     |
| Duisburg          | IUP measurement truck (MAX-DOAS, in-situ) |
| Jülich            | Pandora                                   |
| Cologne           | Pandora                                   |

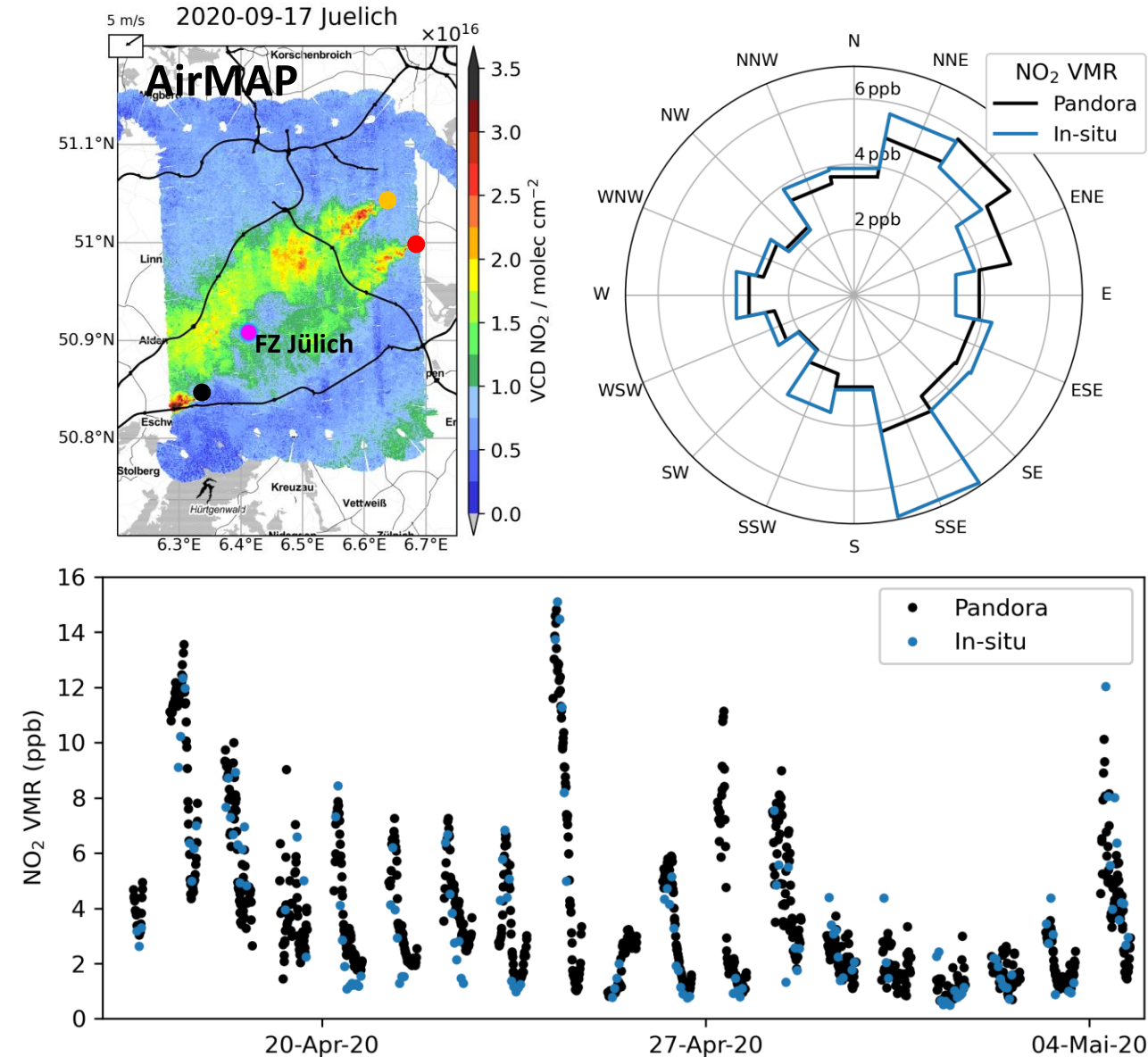




- Variability from day to day (weekly cycle) and between the different target areas but also different instruments at the same site
- Values during campaign are similar to weeks in August to October 2020

- Measurements from the 5 ground-based stations can be compared with S5P data over a longer time period than the actual campaign duration
- Data from August & September 2020 with co-location criterion:  $\pm 30$  min
- Underestimation of S5P compared to station measurements is larger here than reported in most other studies

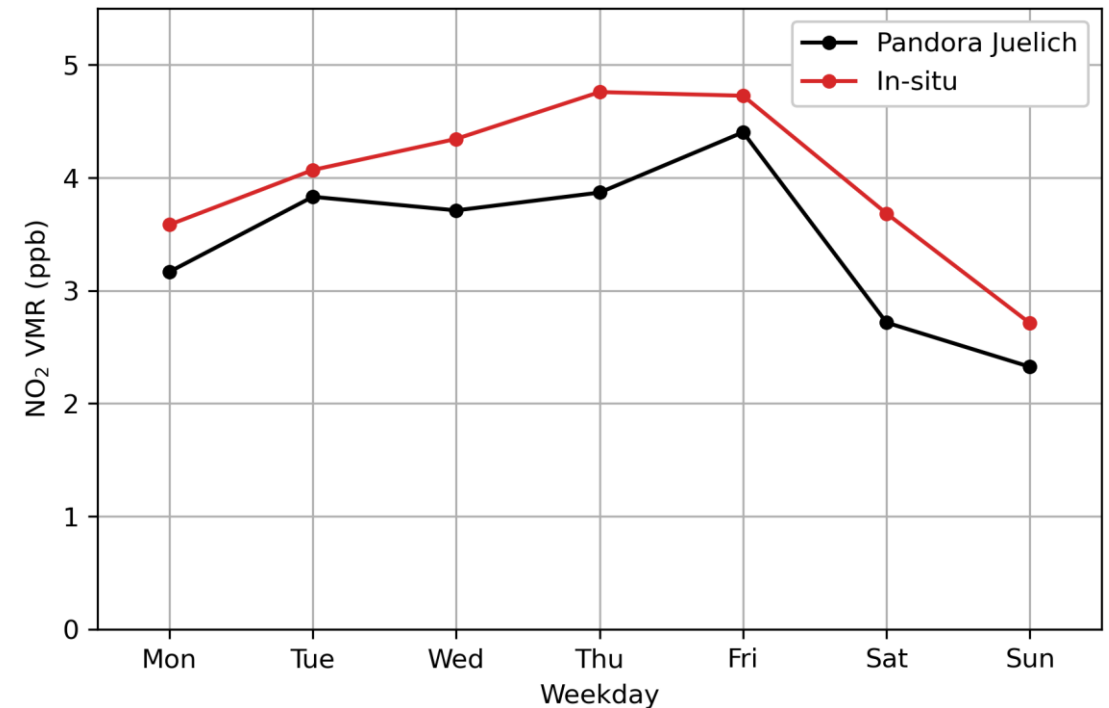
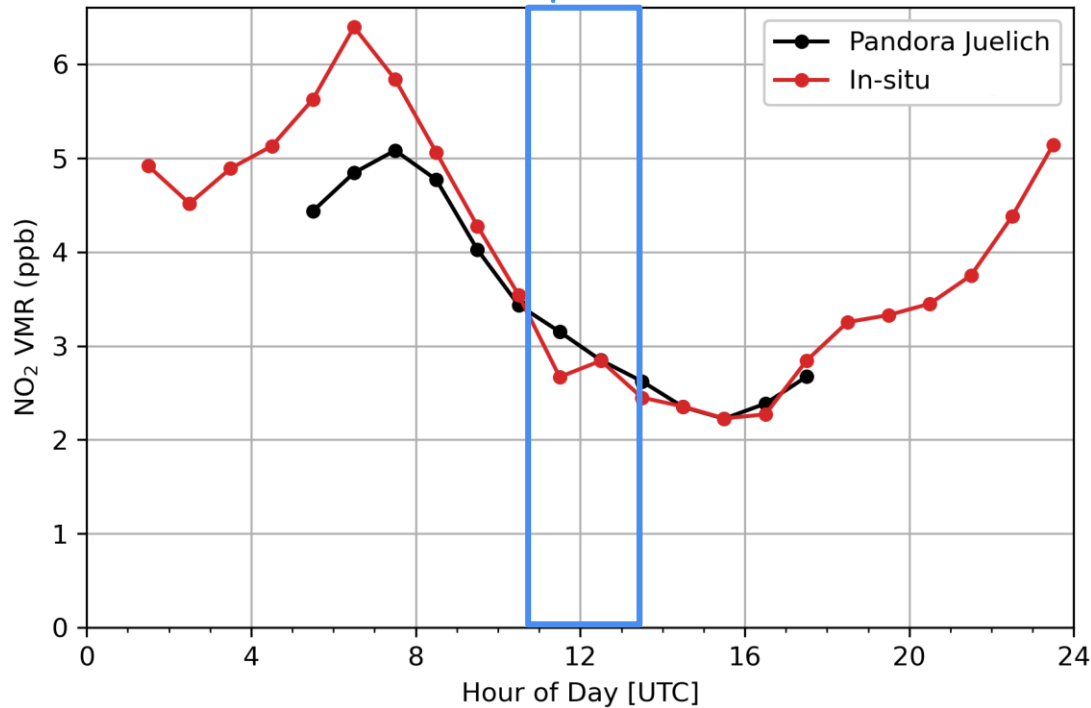




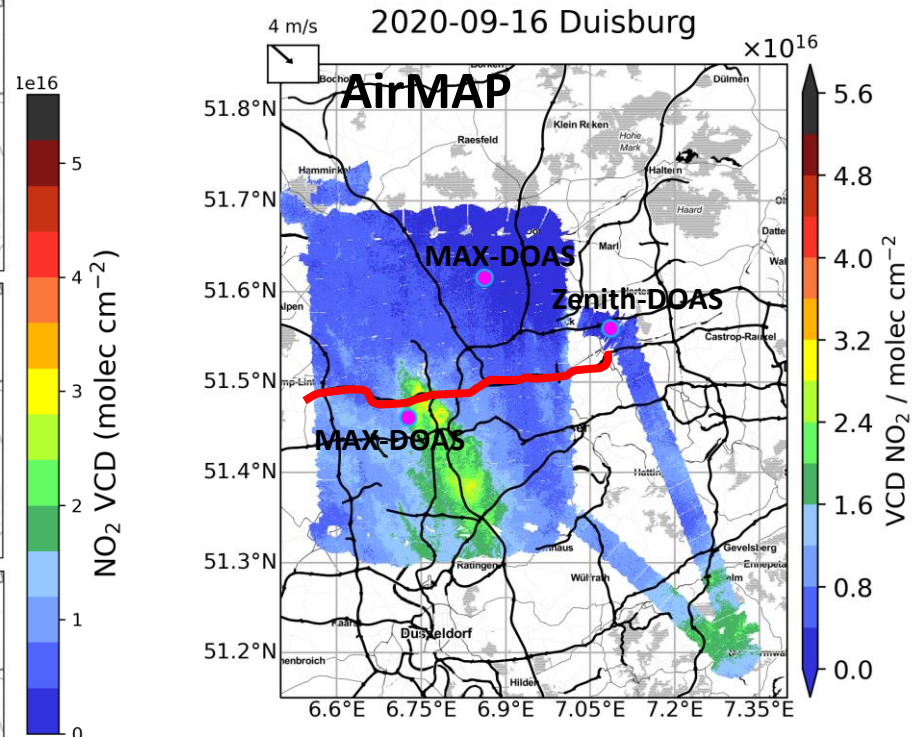
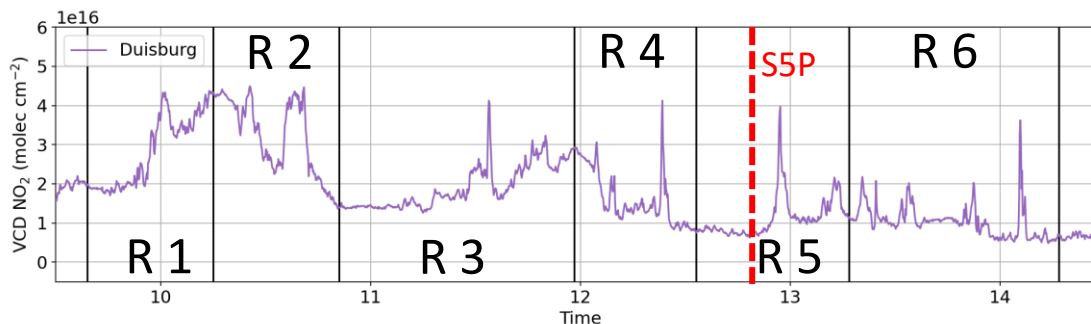
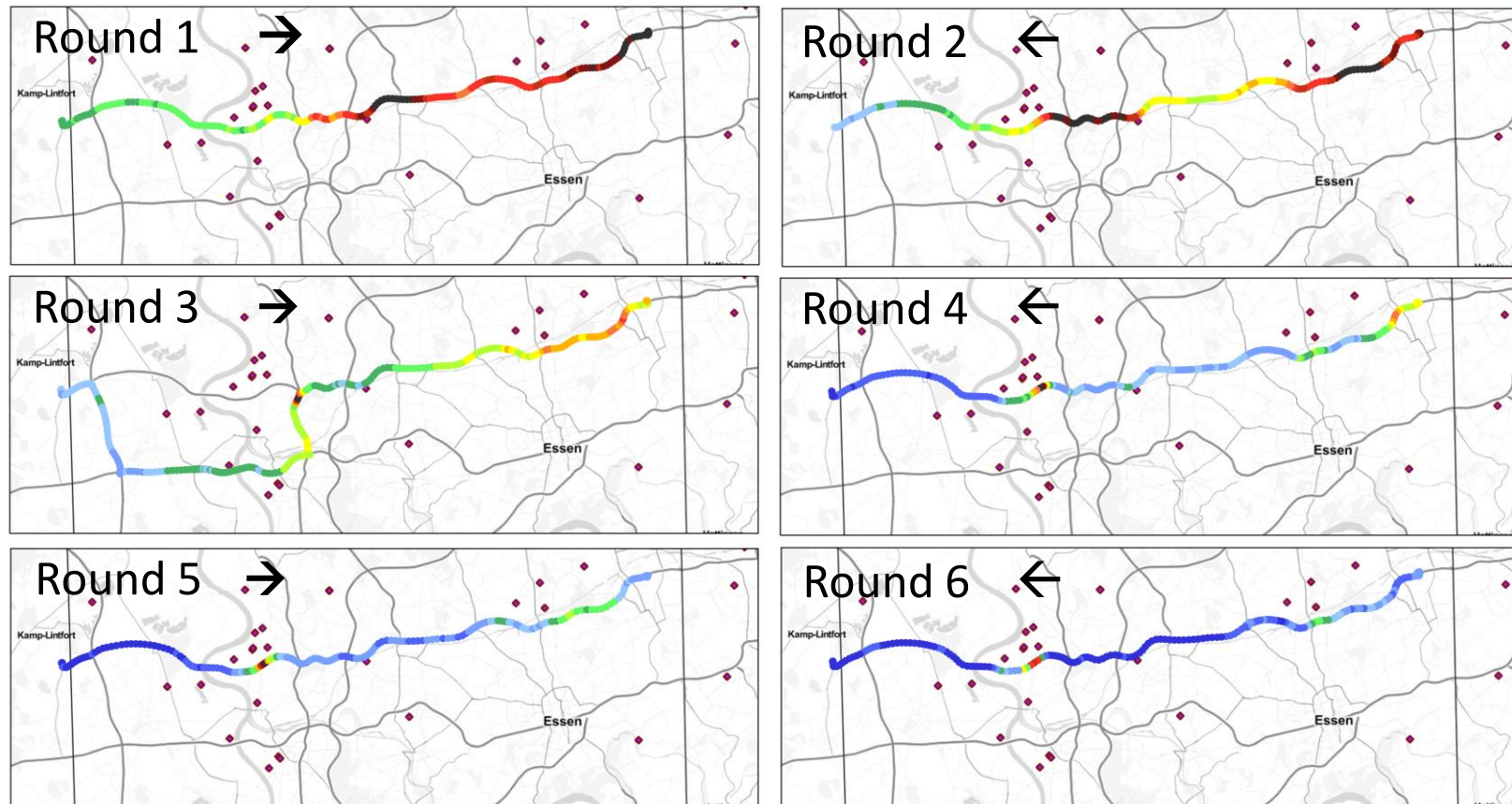
- Pandora located at **FZ Jülich** can be compared to in-situ measurements done by the FZ Jülich
- Two big power plants **Neurath** & **Niederaußem** are located NE of the measurement site
- Pandora & in-situ measurements show clear wind dependence when wind is coming from NE
- NO<sub>2</sub> VMR of Pandora and in-situ measurements show good agreement

- Pandora and in-situ measurements from 18 March to 29 August 2020 show a clear diurnal cycle
  - Underestimation of Pandora in the morning hours when boundary layer is low (already known from CINDI)
- Weekly pattern, with highest  $\text{NO}_2$  VMR on Thursday & Friday and lowest on Sunday

S5P overpass window



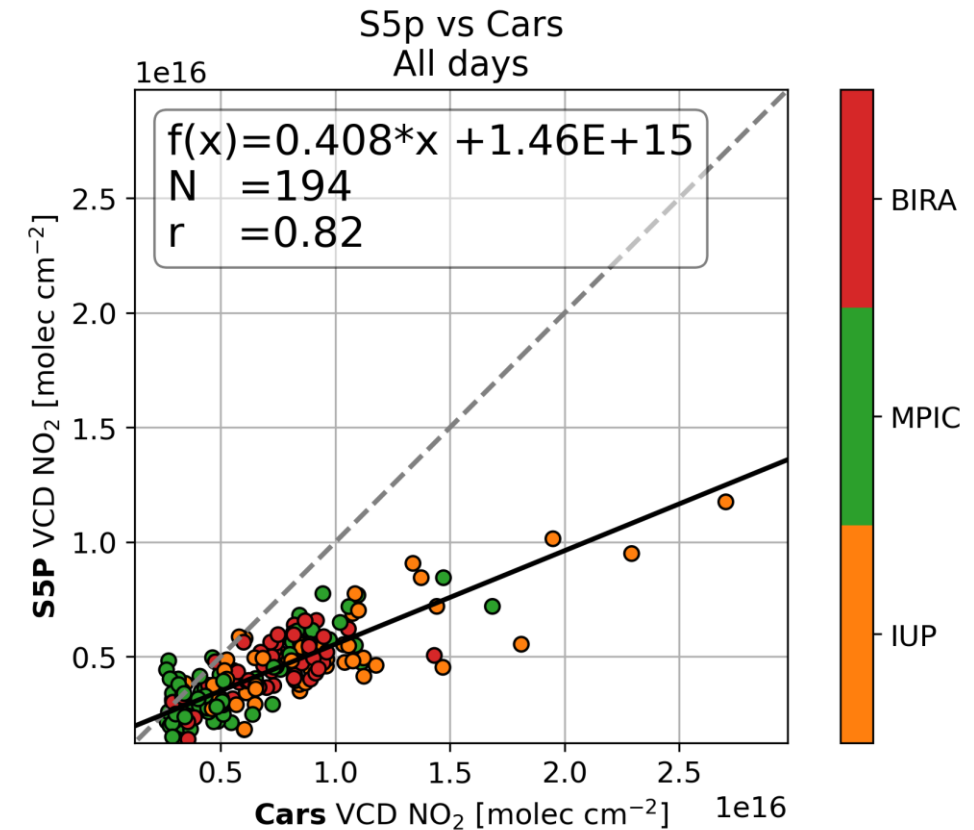
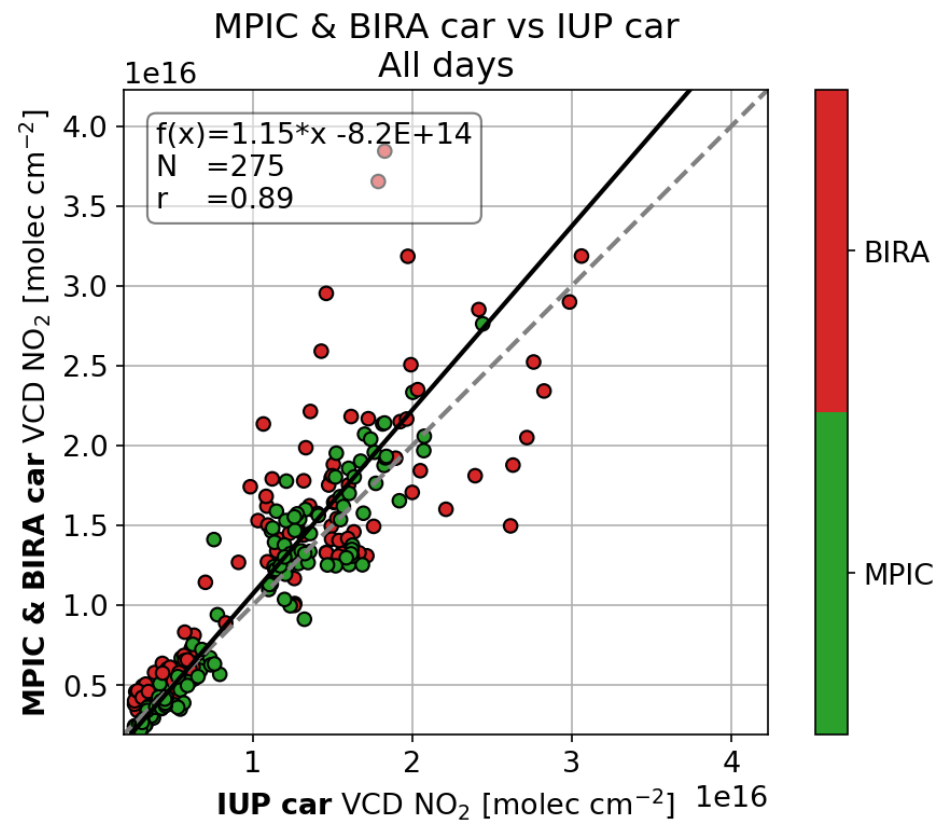




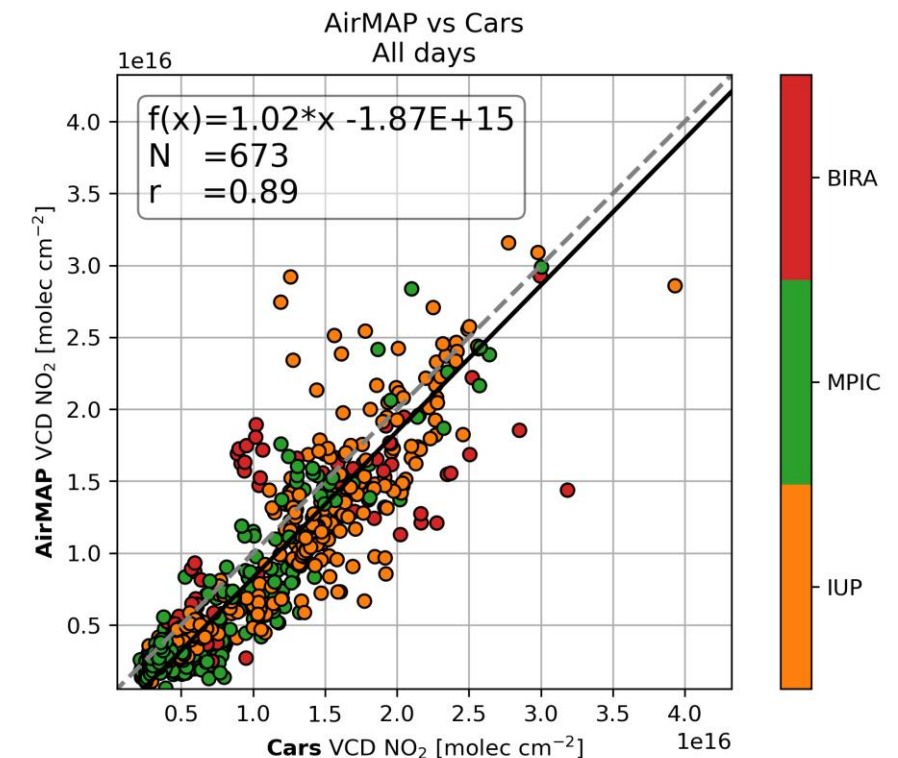
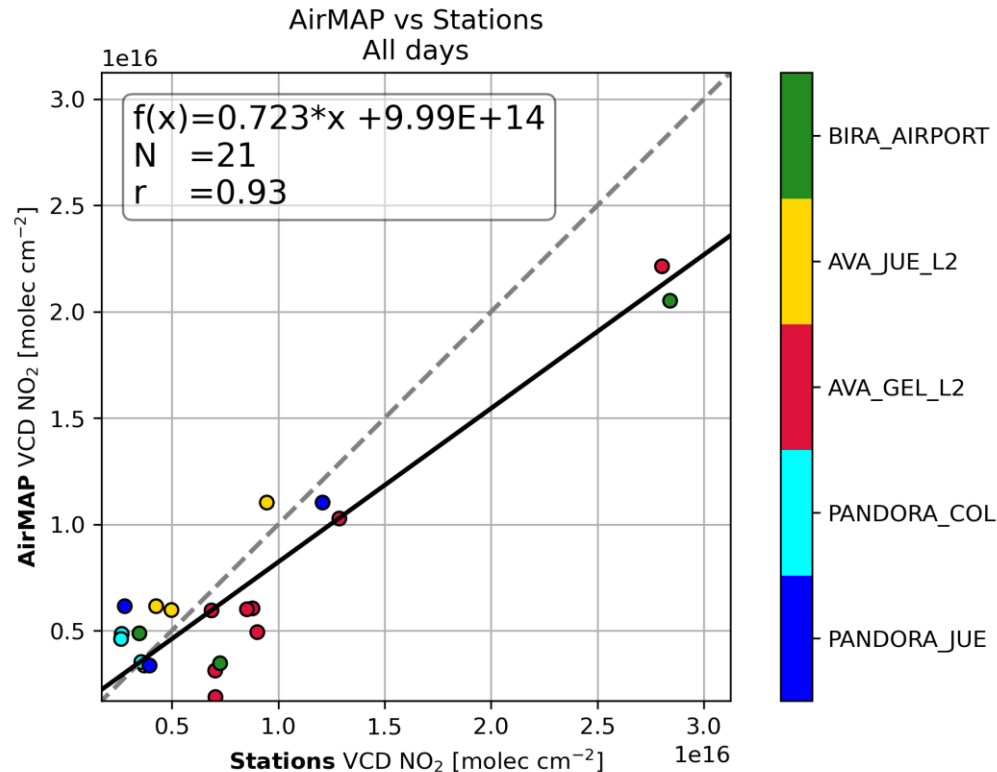
- Car measurements show high variability on the same route over the day
- Gives additional information to the AirMAP snapshot (~11 - 13:30 UTC)

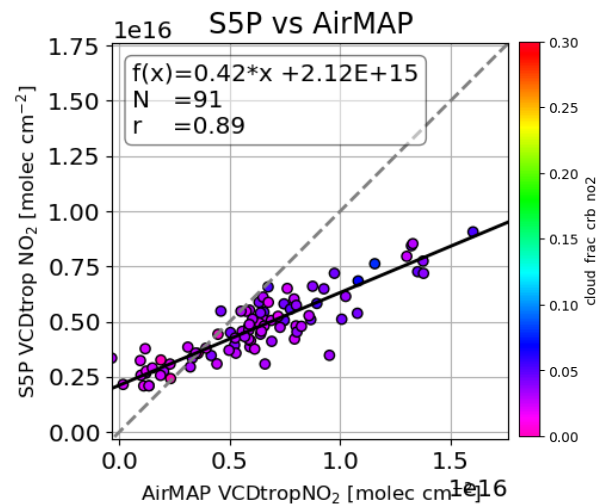
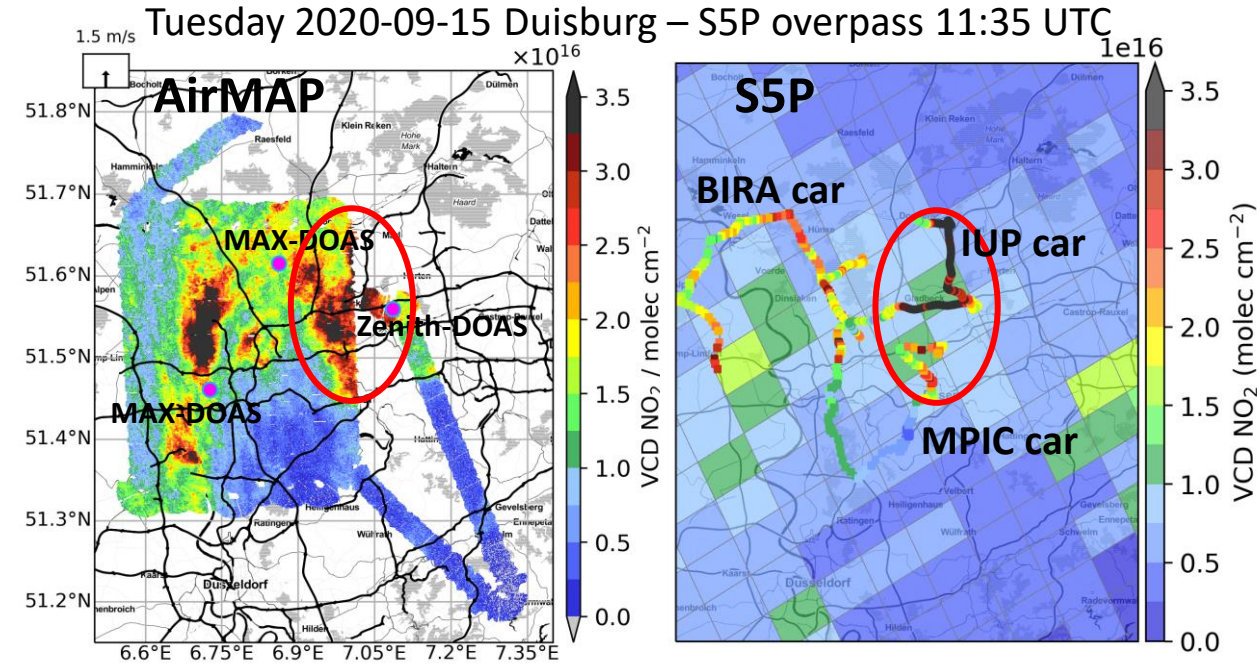
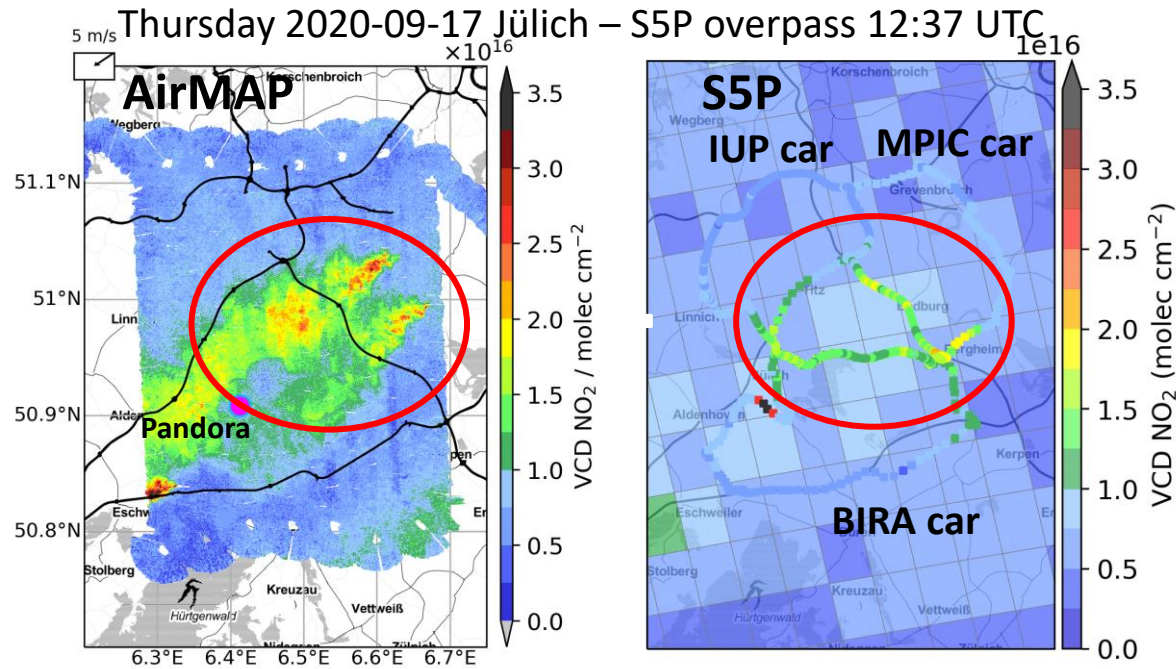


- Car DOAS measurements can be compared with each other ( $\pm 15$  min and 300m distance)
  - Good correlation of 0.89, small overestimation from the BIRA & MPIC car compared to the IUP car
- S5P vs car measurements show high correlation of 0.82 and an underestimation of S5P with 41% of car DOAS value

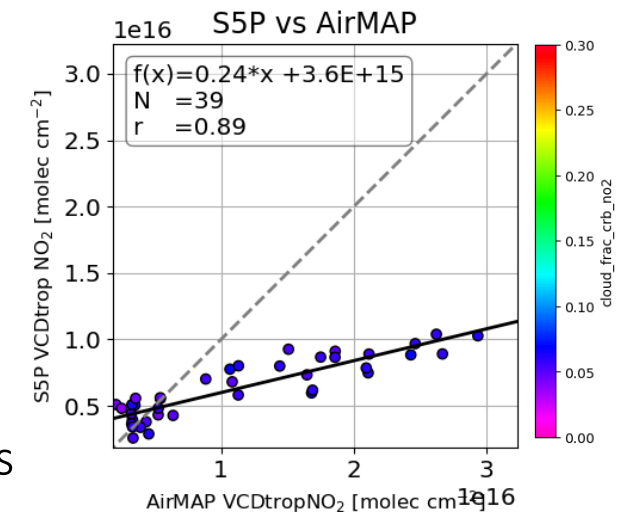


- Evaluation of AirMAP measurements to stationary and mobile car DOAS measurements
- Consistent measurements of AirMAP and stationary and mobile car DOAS measurements
  - High Correlation of 0.89 - 0.93
  - Good agreement between AirMAP and Car DOAS, underestimation of AirMAP compared to station





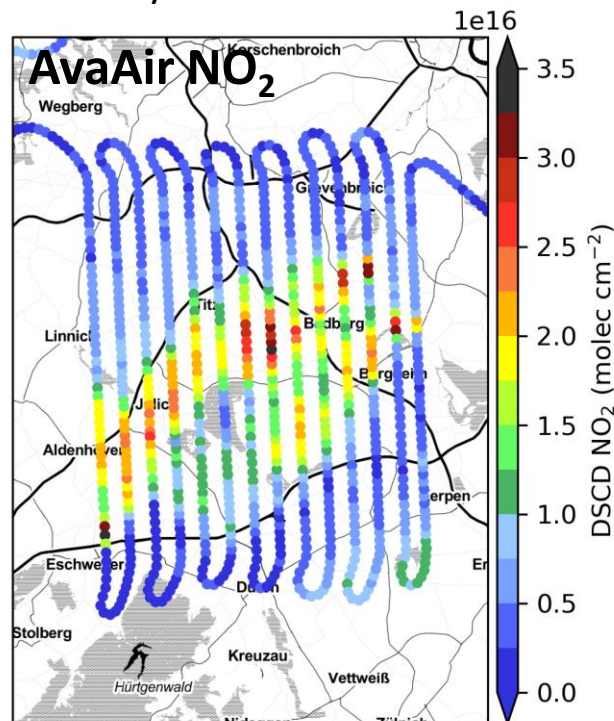
- Measurements of AirMAP and car DOAS are consistent
- Good correlation of S5P and AirMAP measurements
- Low biased S5P TROPOMI NO<sub>2</sub> data of around 25% to 45%, with varying magnitude for different days and areas



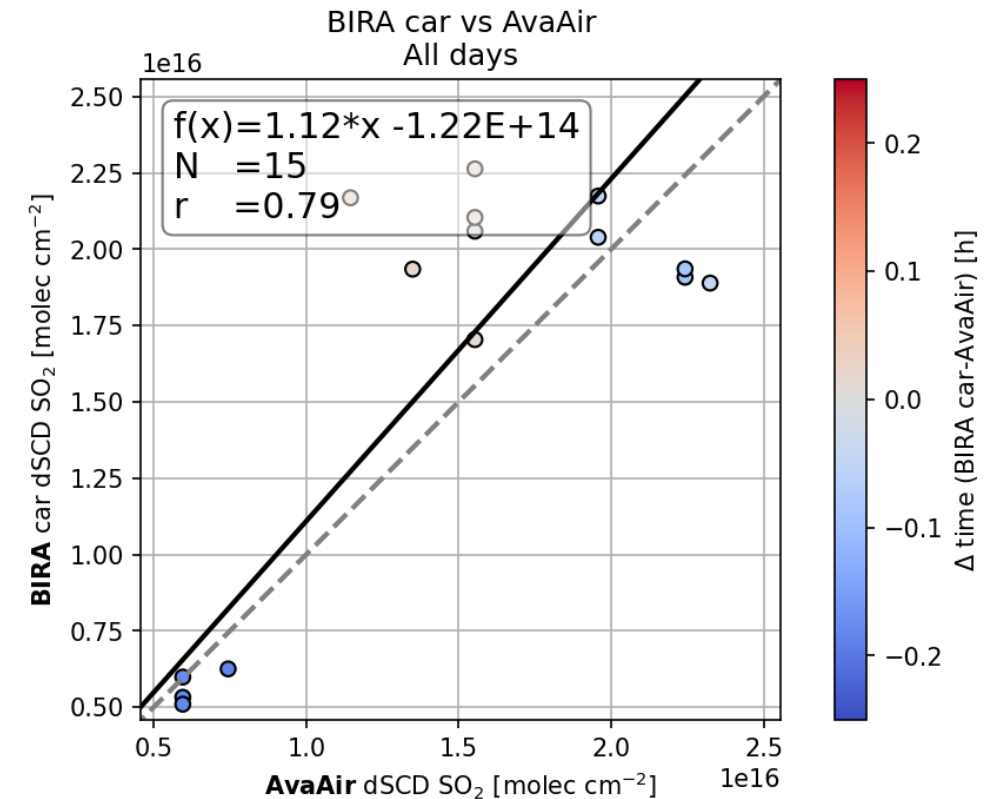
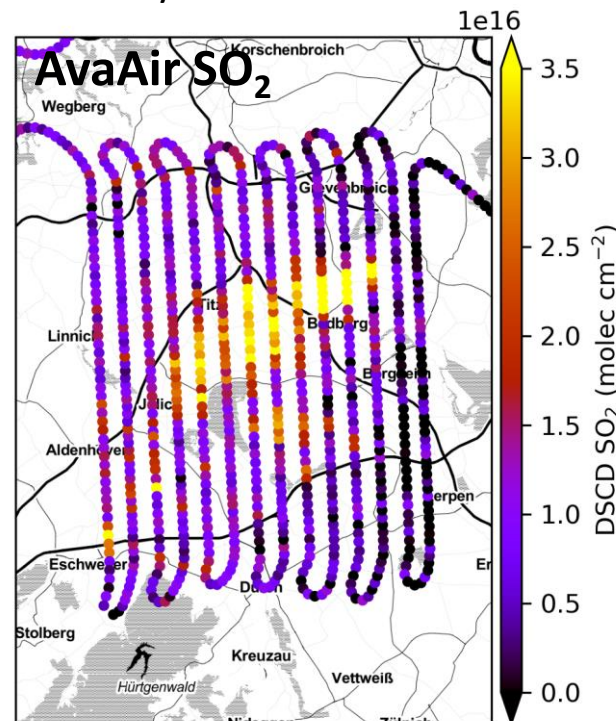


- Nadir viewing zenith Avantes AvaAir next to the AirMAP instrument on board of the Cessna
- In addition to NO<sub>2</sub> also possible to look at HCHO and SO<sub>2</sub>
- First quick looks show no signal for HCHO but strong SO<sub>2</sub> signals, for some days
- SO<sub>2</sub> measurements also possible with car DOAS instruments

Thursday 2020-09-17 Jülich



Thursday 2020-09-17 Jülich



- Measurement campaign in three different target areas in the Ruhr area
- **Stationary measurements**
  - representativeness of the campaign period
  - high variability depending on wind, weekday and time of day
  - S5P underestimates (33% of station value)
- **Car DOAS measurements**
  - high variability on the same route over one day
  - good agreement between the 3 car DOAS instruments
  - S5P underestimates (41% of car DOAS value)
- Consistent measurements of **AirMAP** and stationary and mobile car DOAS measurements
  - Low bias of S5P for all target areas, with varying magnitude for different days (40% of AirMAP value)
- **Outlook:** Custom TROPOMI NO<sub>2</sub> products, using different auxiliary data, such as albedo or a priori vertical profiles to investigate the low bias and the high spatial and temporal heterogeneity in NO<sub>2</sub>

