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Comparison of TROPOMI tropospheric NO_2 observations with airborne, stationary ground-based and car DOAS measurements during the S5Pval-DE-Ruhr campaign

Sentinel-5P 5 years anniversary meeting
11 October 2022
Taormina, Italy

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S5P-VAL-DE-Ruhr campaign

→ Validation of TROPOMI tropospheric NO_2 VCD

→ Campaign activities took place in North Rhine-Westphalia
- Rhine-Ruhr Metropolitan area
- 10 million inhabitants
- Several highways
- Energy intensive industrial areas
- Large power plants

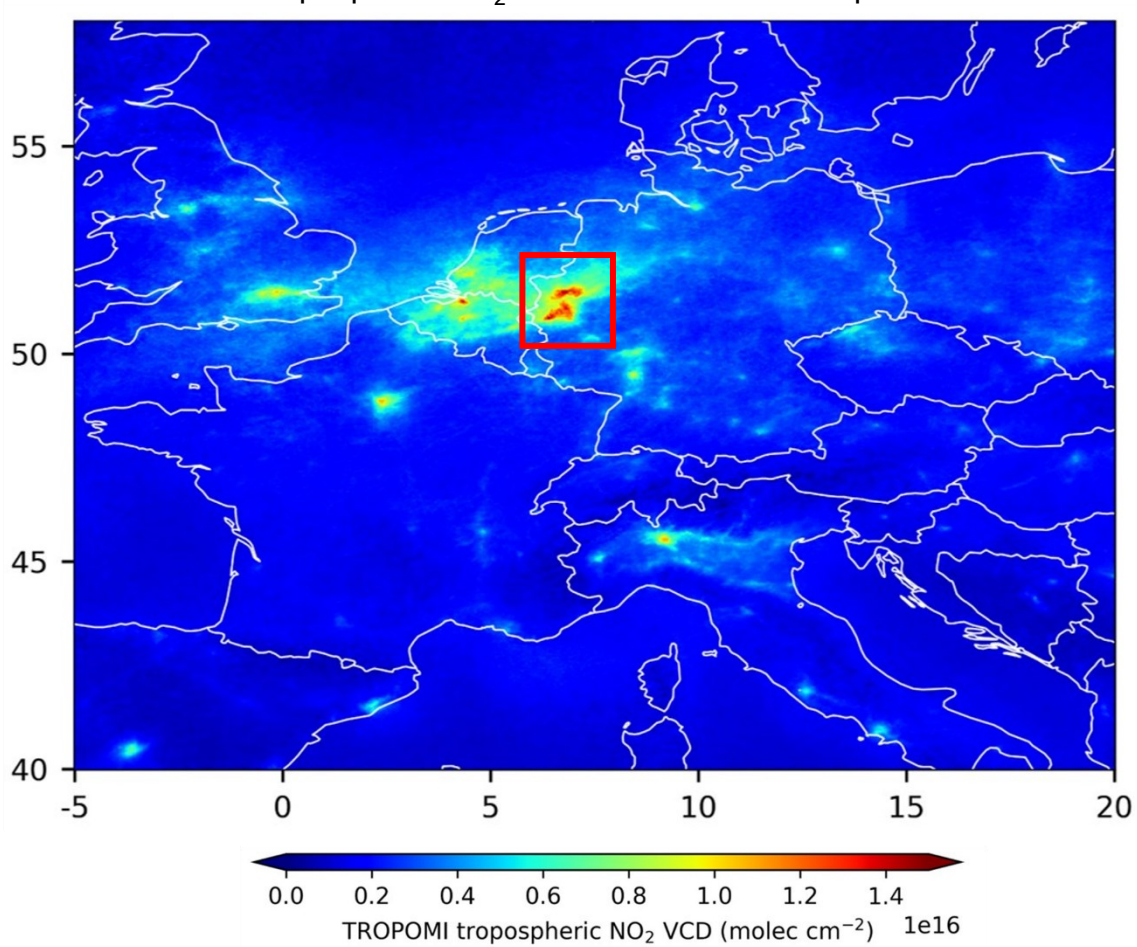
→ NO_2 pollution hotspot clearly visible in TROPOMI NO_2 maps

→ Airborne imaging, ground-based stationary and mobile car DOAS measurements

→ Seven research flight days from 12 – 18 September 2020

→ Part of the QA4EO project

TROPOMI tropospheric NO_2 VCD PAL V02.03.01 September 2020



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Instruments

→ Mobile component
- IUP-AirMAP imaging DOAS onboard of the Cessna
- 3 car DOAS instruments: MPIC, BIRA, and IUP-Bremen

FU Berlin Cessna T207A (D-EAFU)

→ Ground-based component
- 6 ground-based spectrometers at 5 locations
  - 2 zenith-sky Avantes: Jülich and Gelsenkirchen
  - 2 MAX-DOAS: Duisburg and Airport Dinslaken
  - 2 Pandora: Jülich and Cologne


Pandora Jülich


MPIC car DOAS

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Research flight areas

→ Three research flight areas

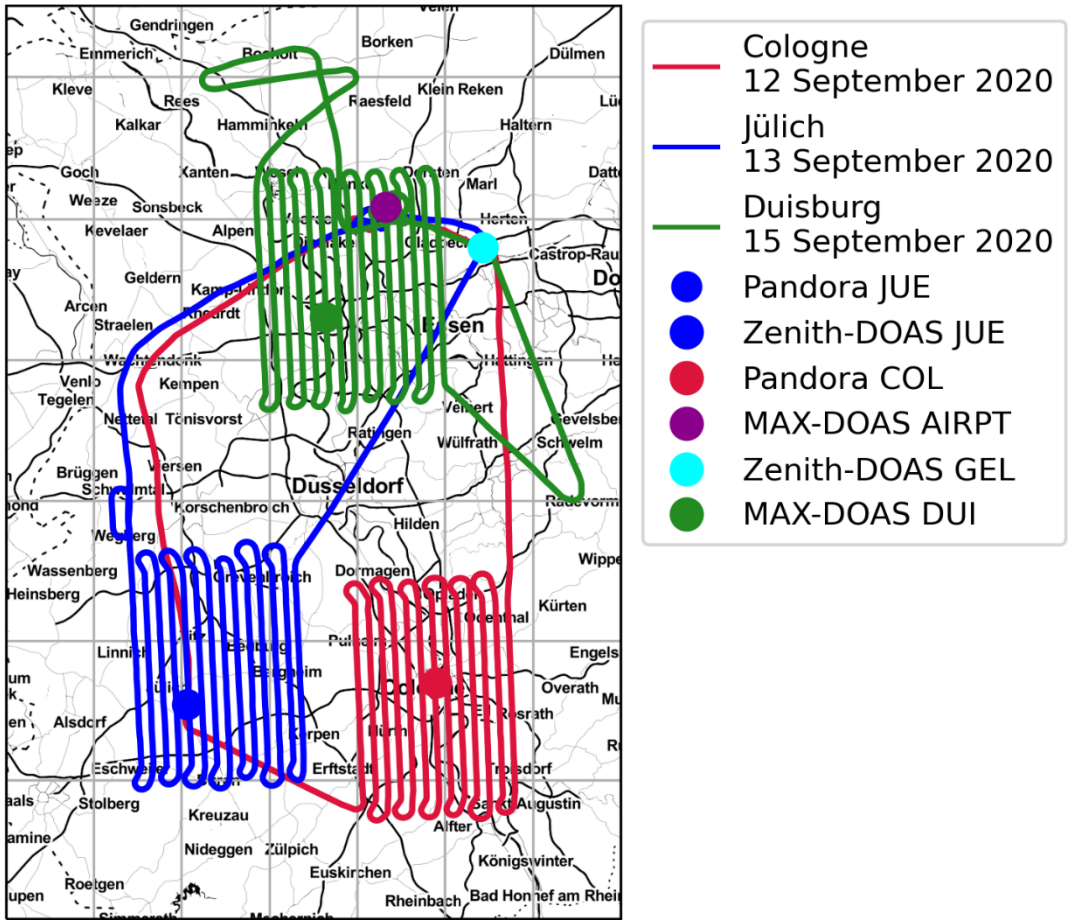
→ Flight area **Jülich**
- Three large coal fired power plants

→ Flight area **Cologne**
- Mixed urban and industrial area

→ Flight area **Duisburg**
- Mixture of urban and industrial emitters, includes the central metropolitan Ruhr area

→ Each flight 13-15 flight tracks in an area of 30 km x 35 km

→ Overpass of ground-based measurement sites



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Comparison of TROPOMI NO_2 observations with the S5P-VAL-DE-Ruhr campaign dataset

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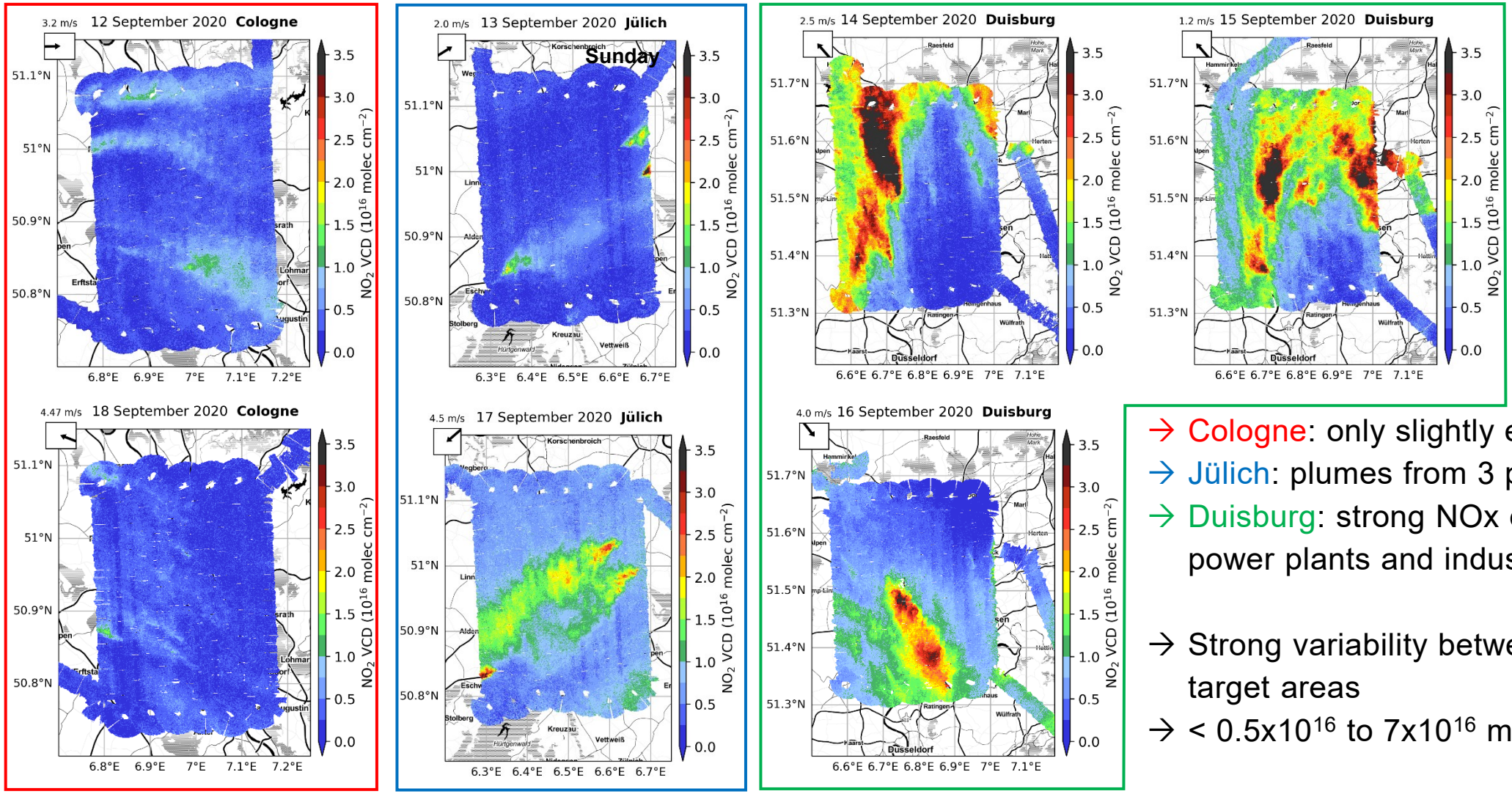
AirMAP NO_2 maps



→ Cologne: only slightly enhanced NO_2

→ Jülich: plumes from 3 power plants visible

→ Duisburg: strong NOx emissions from power plants and industrial area

→ Strong variability between the different target areas

→ < 0.5×10^{16} to 7×10^{16} molec cm^{-2}

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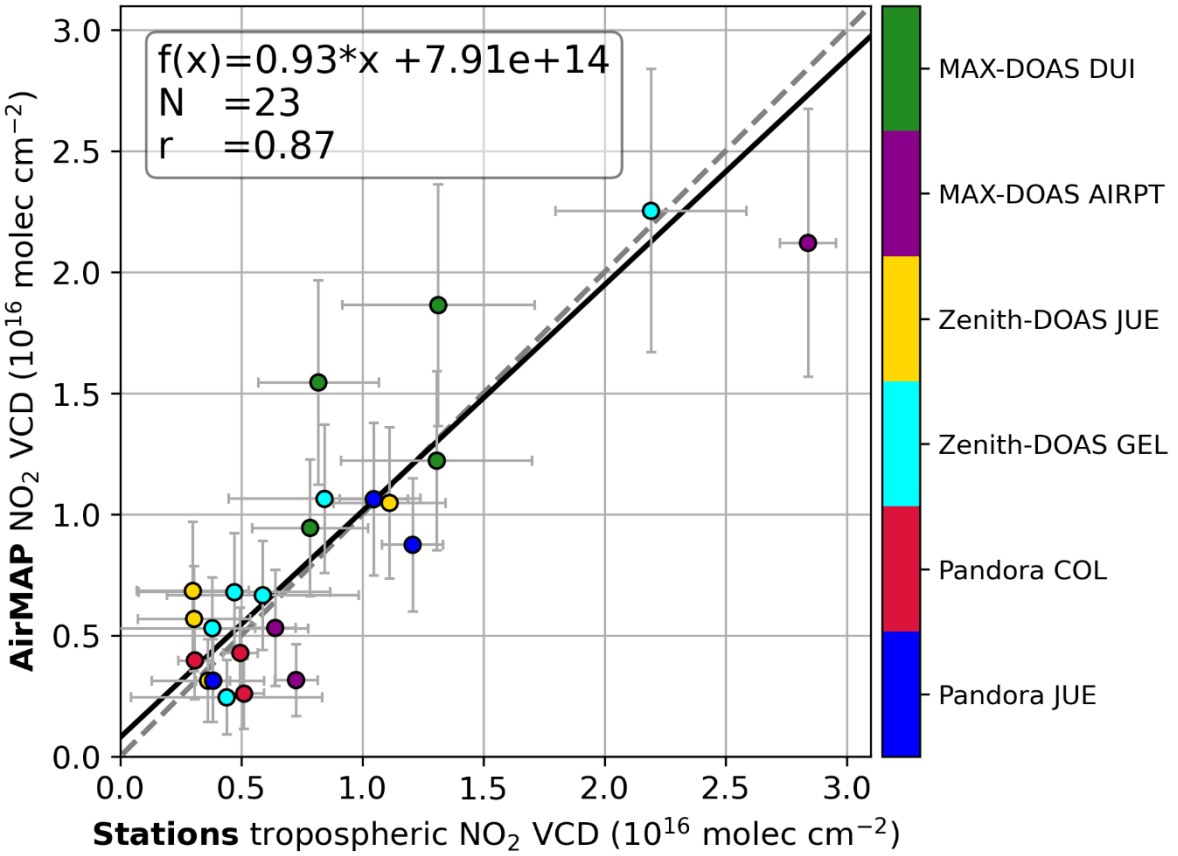
Evaluating AirMAP NO_2 VCD with stationary data

→ AirMAP data averaged over a **500 m x 500 m** box around the station sites

→ Stationary ground-based data averaged over a time interval of **20 min** closest to the AirMAP overpass

→ 23 coincident measurements

→ AirMAP and ground-based tropospheric NO_2 VCDs are highly correlated and show good agreement



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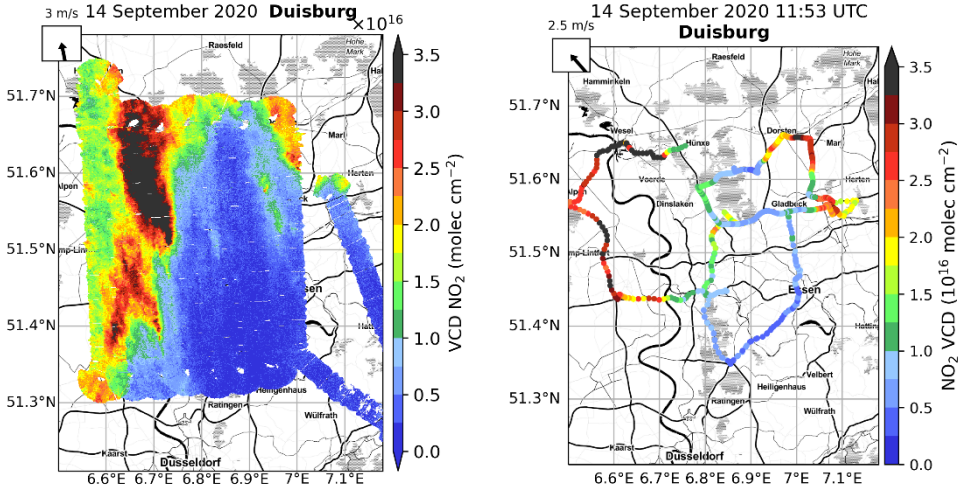
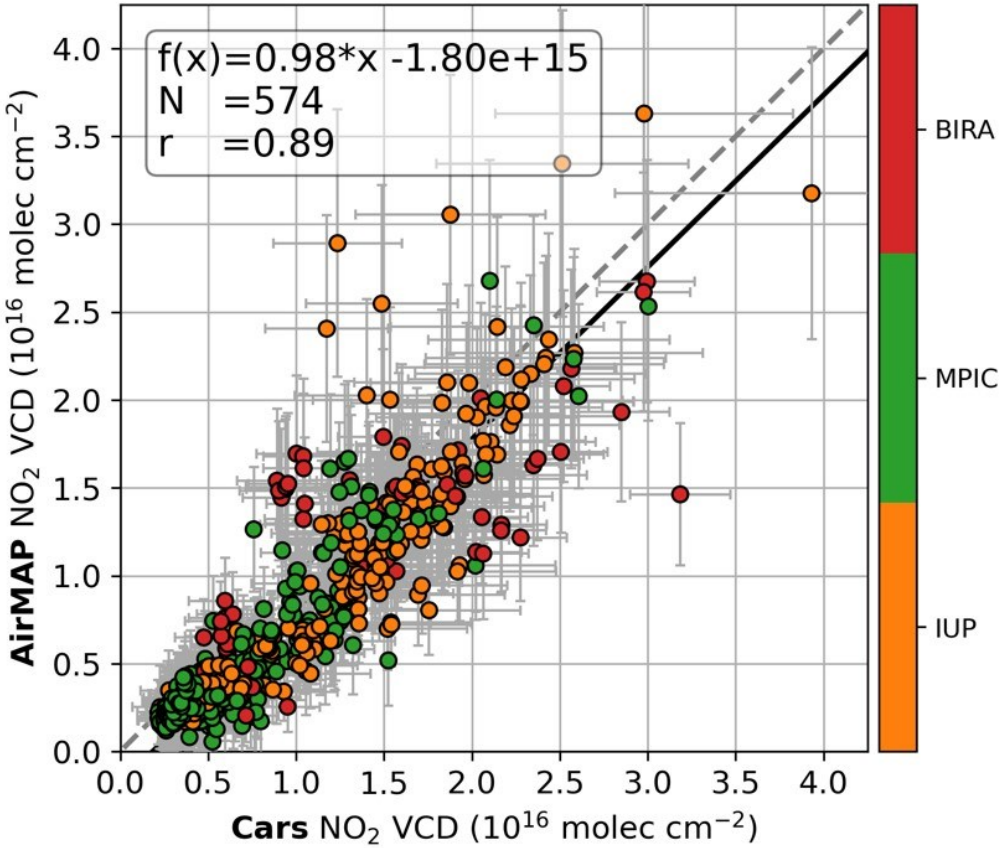
Evaluating AirMAP NO_2 VCD with car DOAS data

→ Advantages of car DOAS:
- high temporal resolution & coordinated to AirMAP flights



→ AirMAP and car DOAS measurements are averaged over **500 m x 500 m** boxes and in time intervals of **15 min**

→ 574 coincident measurements (car DOAS **± 15 min** window from AirMAP overpass)



→ Collocated measurements show good agreement

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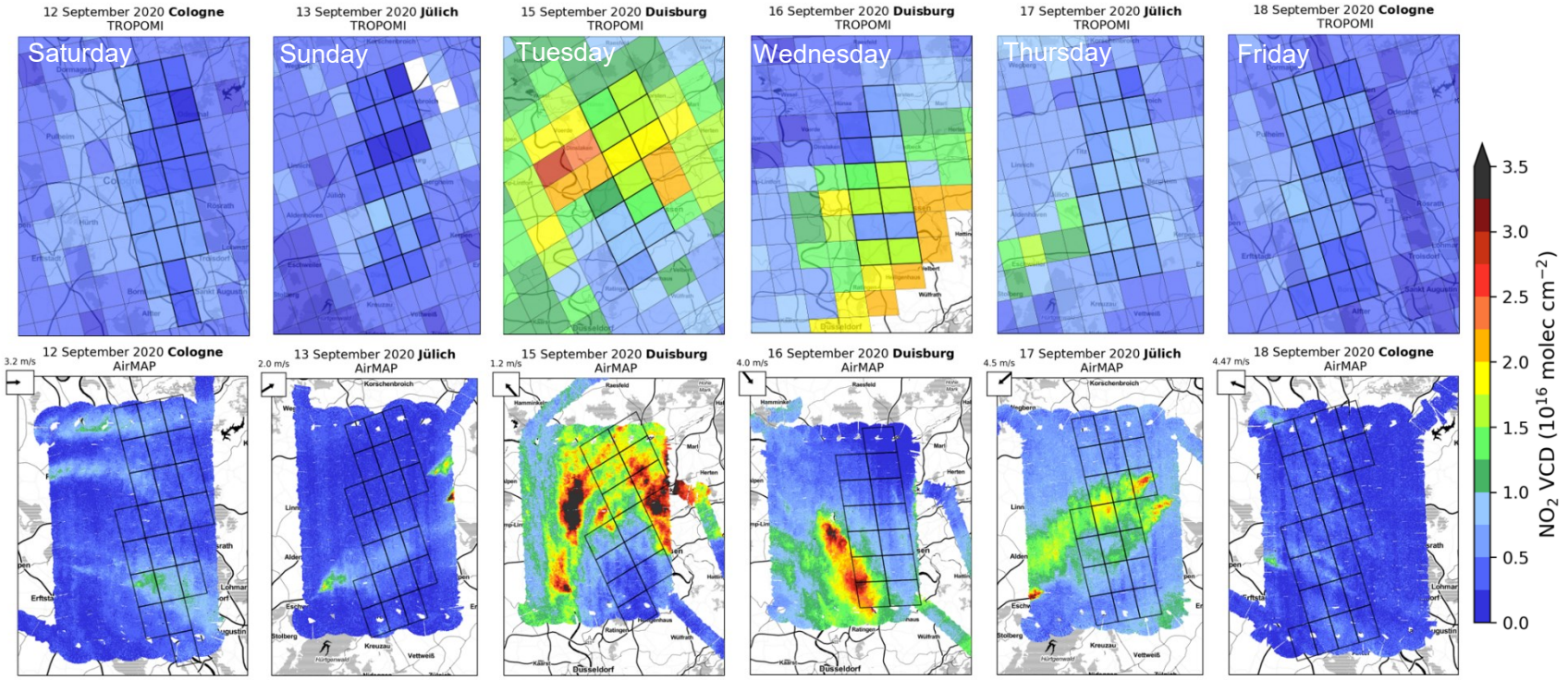
Evaluating TROPOMI NO_2 VCD with AirMAP data



→ 6 measurement days with TROPOMI and AirMAP observations

→ Nearly cloud free days

→ Collocation criteria:
- TROPOMI pixel mapped >75%
- ± 30 min time difference

→ 117 TROPOMI pixels coinciding with AirMAP measurements

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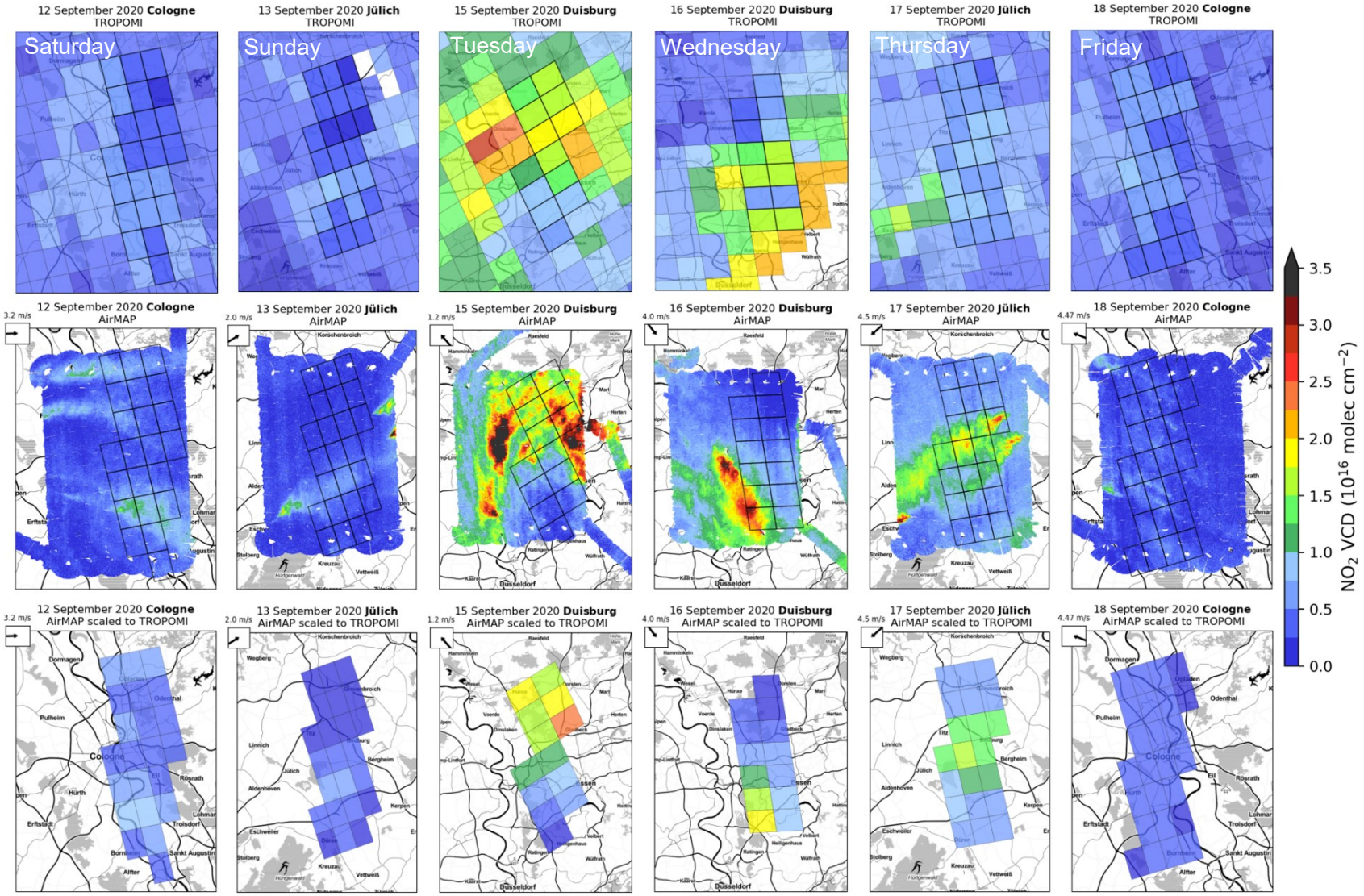
Evaluating TROPOMI NO_2 VCD with AirMAP data



→ 6 measurement days with TROPOMI and AirMAP observations

→ Nearly cloud free days

→ Collocation criteria:
- TROPOMI pixel mapped >75%
- ± 30 min time difference

→ 117 TROPOMI pixels coinciding with AirMAP measurements

→ AirMAP tropospheric NO_2 VCDs are scaled to the TROPOMI pixel

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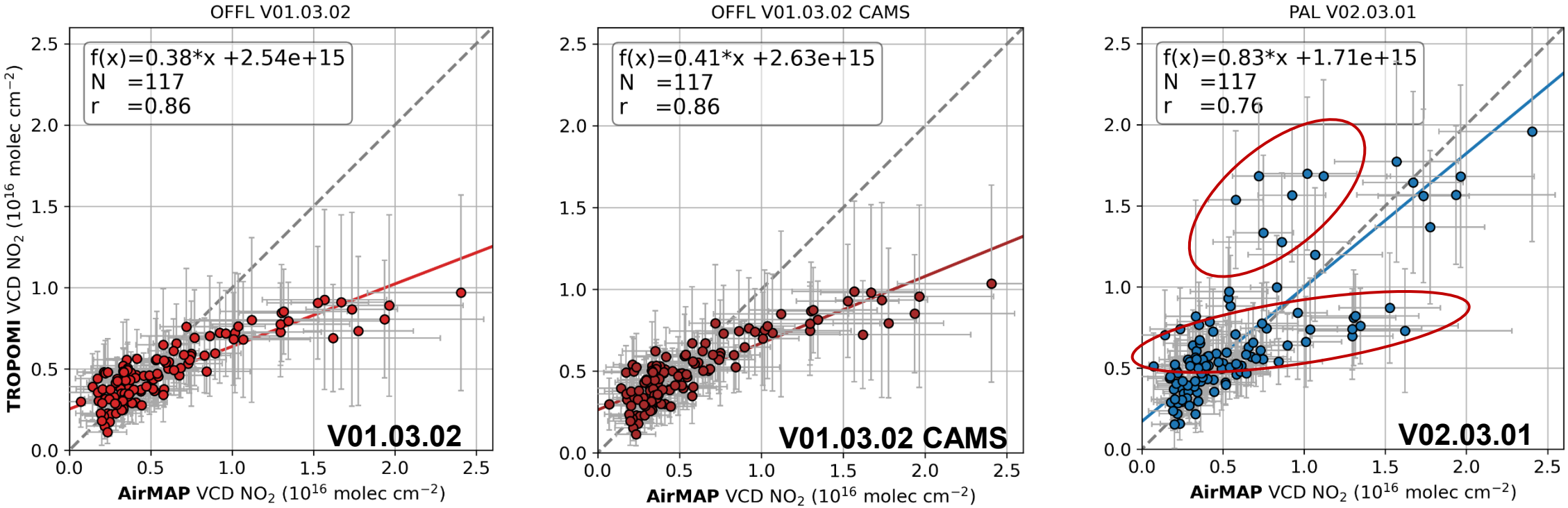
Evaluating TROPOMI NO_2 VCD with AirMAP data

→ OFFL V01.03.02: good correlation 0.86 with slope of 0.38
→ OFFL V01.03.02 CAMS: correlations unchanged, slope slightly improved to 0.41
→ PAL V02.03.01: Larger scatter → reduced correlation but better slope of 0.83



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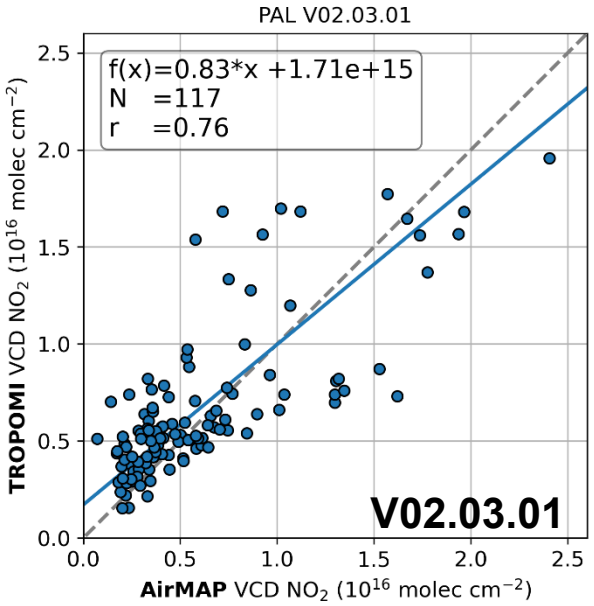
Evaluating TROPOMI NO_2 VCD – Cloud effects

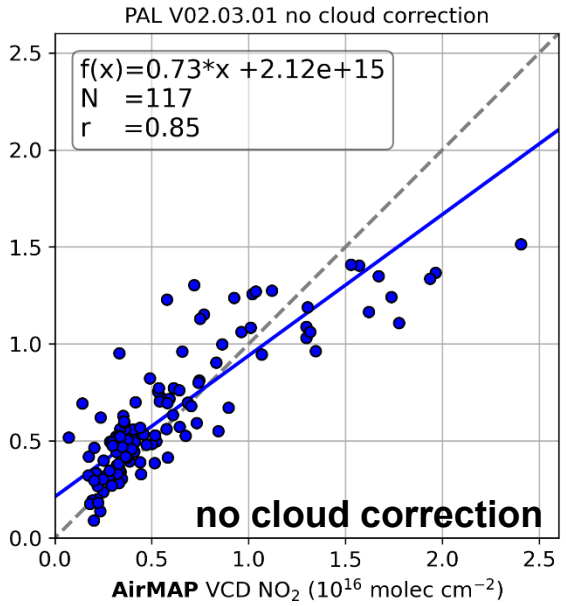
→ Without cloud correction
- Lower branch gone
- Upper branch much reduced
- Better correlation 0.76 → 0.85

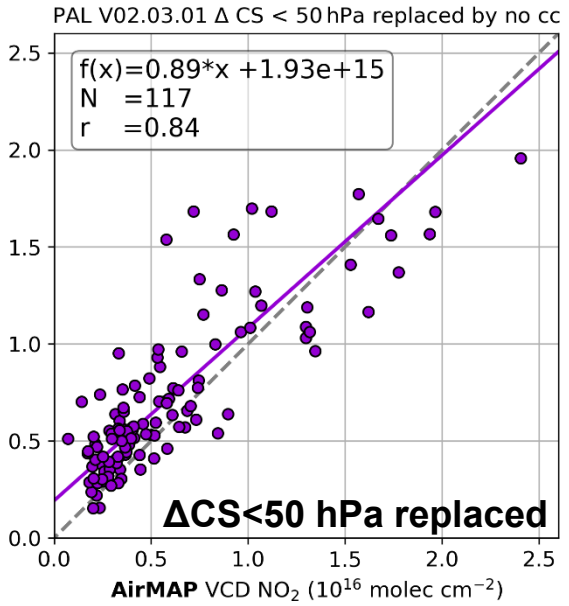
→ Two branches caused by cloud correction

→ Cloud pressure filter
- Detecting pixels with clouds close to the surface
- cloud pressure – surface pressure ΔCS < 50 hPa
- 28 out of 117 pixel replaced with no cloud correction
- Lower branch gone → better correlation

→ High cloud pressures might be caused by aerosol loads







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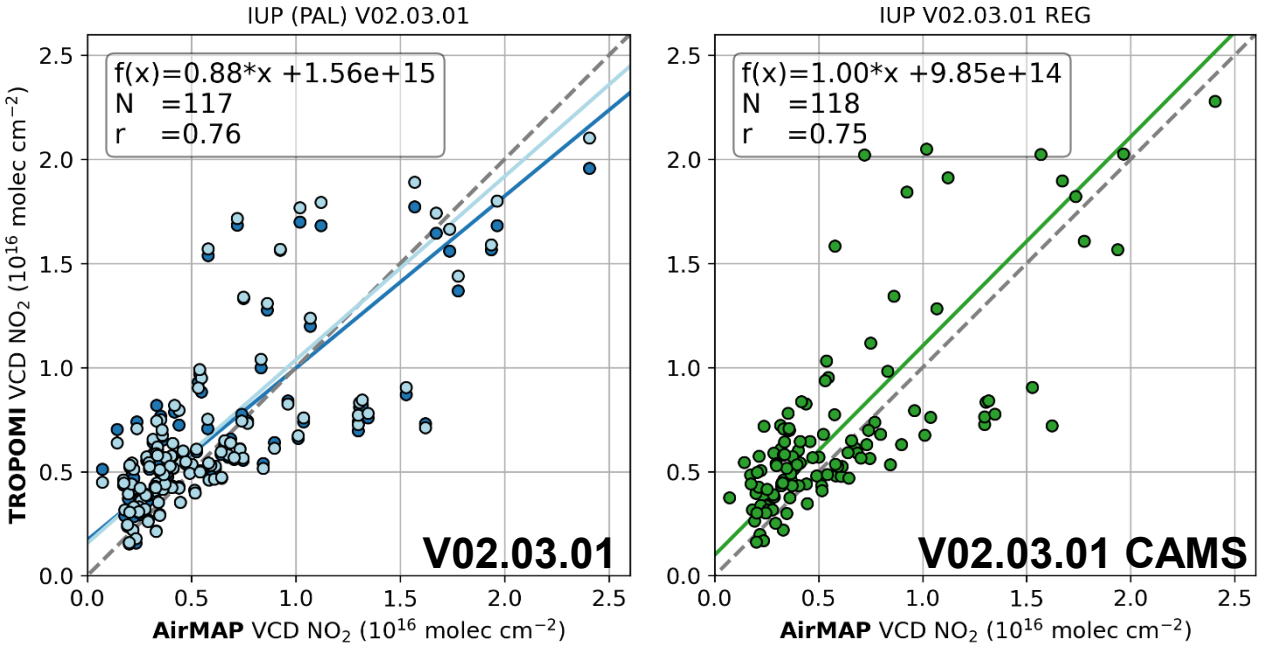
Evaluating TROPOMI NO_2 VCD - NO_2 profile



→ Custom TROPOMI NO_2 product based on V02.03.01
- Possibility to change auxiliary data

→ Higher resolved a priori NO_2 vertical profile
- 0.1° x 0.1° CAMS regional analyses below 3 km
- Recalculating AMFs and tropospheric NO_2 VCDs
- Correlation nearly unchanged
- TROPOMI data closer to AirMAP data 0.88 → 1.00

→ Higher resolved NO_2 profiles have a larger effect than for the old version
- only for the more realistic lower cloud pressures
- Lower branch in V02.03.01 remains

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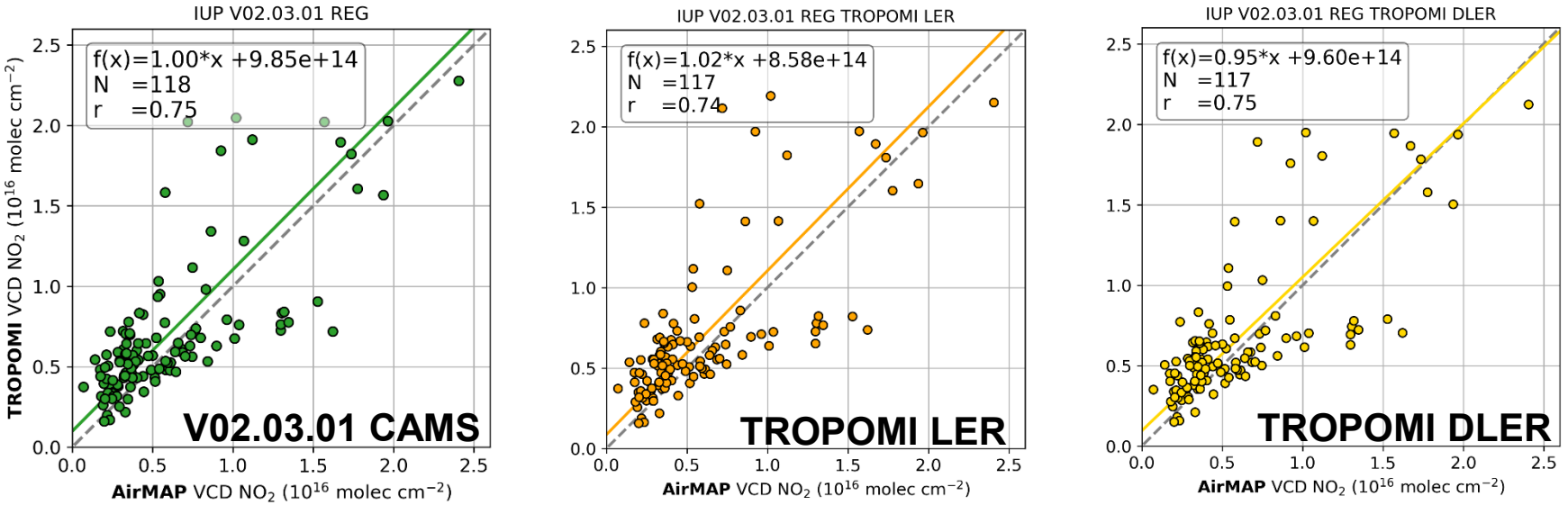
Evaluating TROPOMI NO_2 VCD - surface reflectivity

→ Replacing OMI LER with TROPOMI LER (Tilstra, 2022)
- Slope increased slightly 1 → 1.02
- Correlation nearly unchanged 0.75 → 0.74

→ Replacing OMI LER with TROPOMI DLER (Tilstra, 2022)
- Slope decreased 1 → 0.95
- Correlation unchanged

→ TROPOMI LER/DLER only small effect



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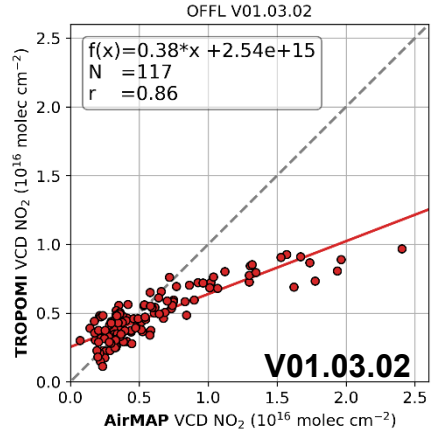
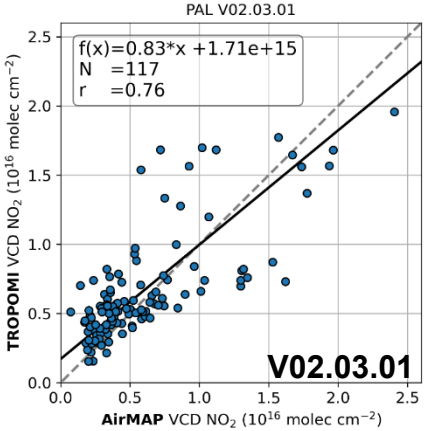
Conclusions

→ Evaluation of different TROPOMI tropospheric NO_2 VCD products

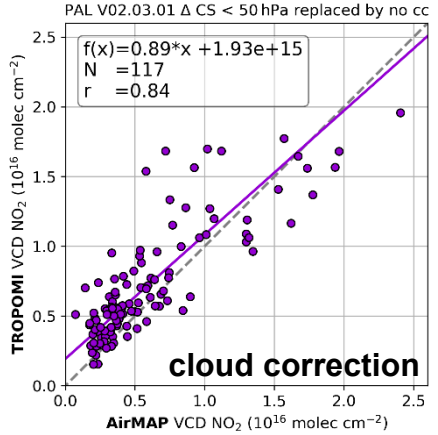
→ Old version OFFL V01.03.02:
- Strong negative bias but good correlation
- Replacing TM5 with CAMS regional NO_2 profiles only small impact



→ New version PAL V02.03.01:
- Slope increased but correlation got worse



→ Sensitivity test showed that problems are caused by cloud correction
- Aerosol loads



→ CAMS regional NO_2 profiles larger impact than for old version

→ TROPOMI LER/DLER plays a minor role for the campaign dataset

→ Paper submitted to AMT

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Thank you for your attention!