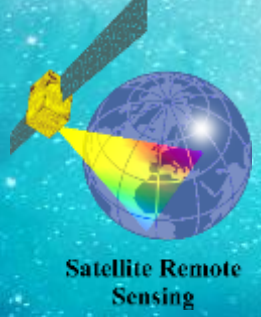



# Using TROPOMI L2 $NO_2$ Measurements to Fine-Tune a High Resolution Regional Atmospheric Chemistry Model and Inter-Comparison Procedure

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# Motivation

- High spatial resolution atmospheric chemistry models achieve comparable spatial resolution as that of new generation satellite instruments.

- These models provide crucial supporting information for processing of satellite data as well as extending the scientific outcome through supporting data:
  - Air quality monitoring and study of health effects.
  - Estimation of primary emissions and its change.
  - Estimation of surface concentration and profiles.

- Performance of such models have been rarely evaluated at day-to-day basis with respect to satellite observations.

- Regional atmospheric chemistry transport model WRF Chem was set–up at 3×3 $km^2$ spatial resolution over western Europe and evaluated with respect to individual TROPOMI orbits as well as temporal means.

# Model set up

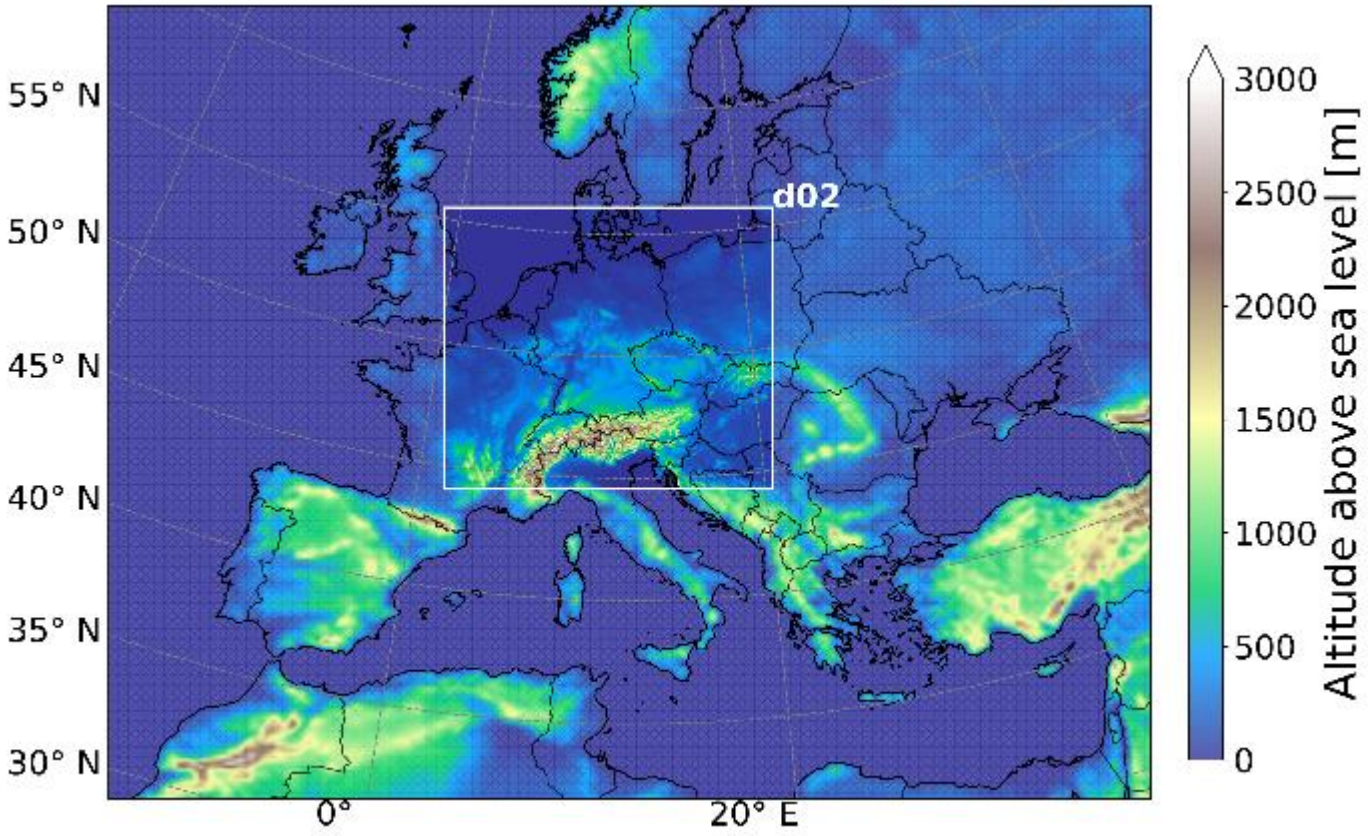



Fig: WRF Chem simulation domain showing the orography for the coarse resolution (15km ) and nested fine resolution (3km) domain.

- WRF Chem model with two one way nested domains :
  - **d02** (3 km) coupled online to d01(15 km).
- Meteorological boundary conditions from ERA5
  - ~25km resolution, every 3 hours
  - Spectral nudging in domain d01 (u, v and T).
- Chemical boundary condition from the global model CAM-Chem (0.9x1.25°, every 6 hours).
- MOZART-4 gas phase chemistry .
- Biogenic emissions and soil $NO_x$ from MEGAN v 2.0 (Online).
- Anthropogenic emissions – Next slide.
- Simulations for May 2018 performed at MPCDF Raven.

# Anthropogenic emissions

- EDGAR v.5.0 monthly resolved anthropogenic emissions (2015) worldwide and UBA emissions (2018) of $NO_x$, CO, $SO_2$ and VOCs Germany.
- Spatial resolution:
  - EDGAR – 0.1 × 0.1°
  - UBA – 1km × 1km

- Processed using HERMES[1] to apply **country** and **sector** specific temporal profiles (local time) and conservative remapping over model domain.
  - The relative temporal profiles of emissions from road transport (TRA), energy industries (ENE), non industrial combustion (RCO) and other industries (IND)are shown in the figure on right.

[1]Guevara et al., GMD 2019

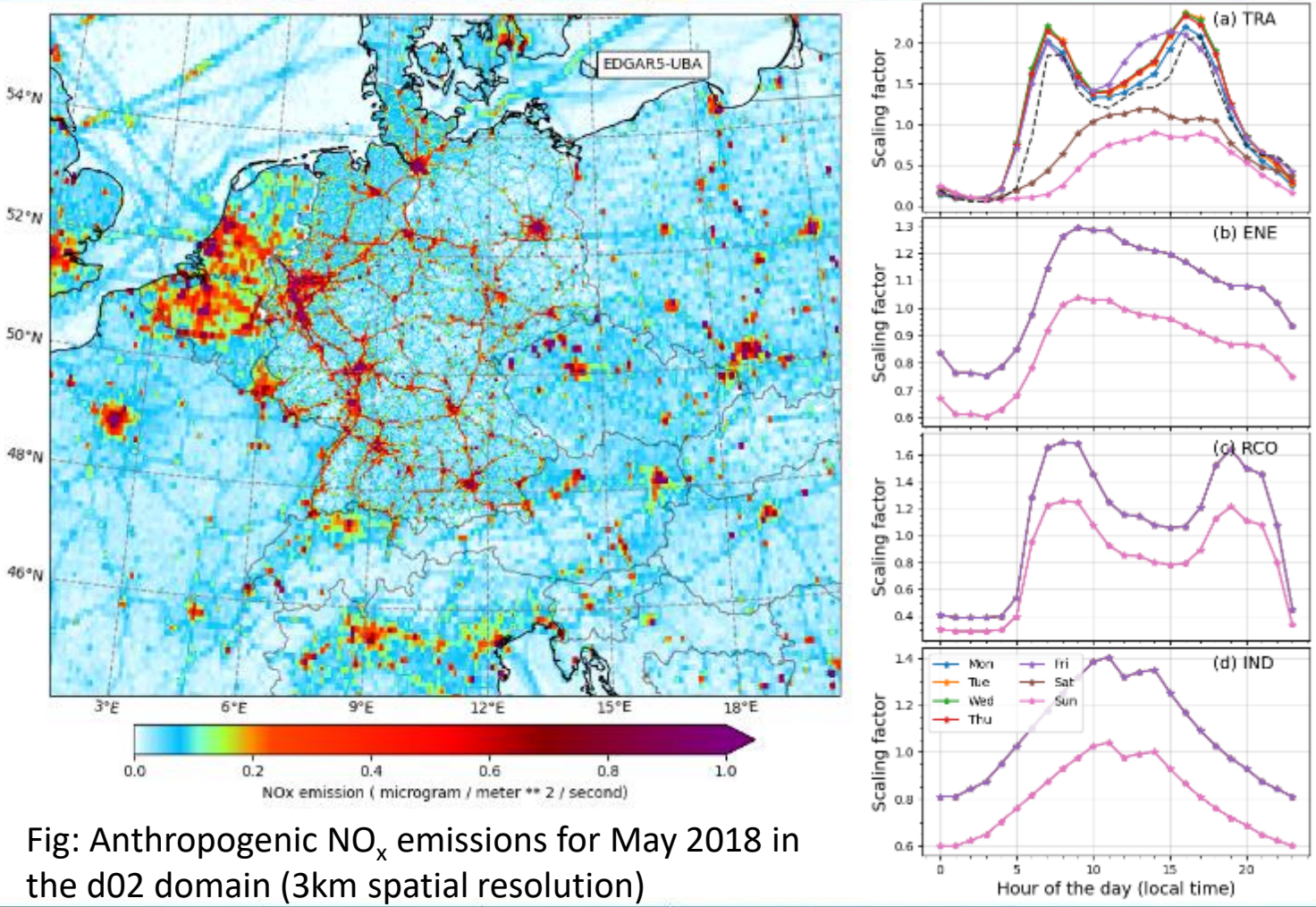



Fig: Anthropogenic $NO_x$ emissions for May 2018 in the d02 domain (3km spatial resolution)

# Sampling of model output at TROPOMI overpass

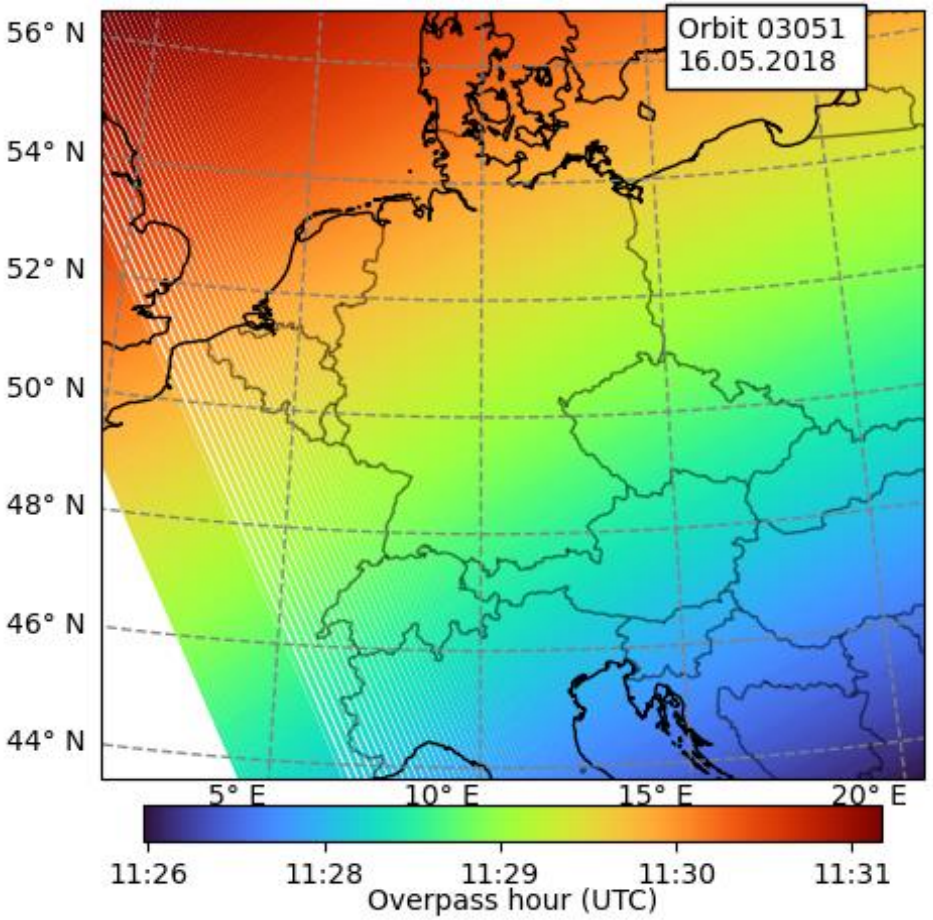



Fig: Overpass time of TROPOMI at various pixels for one illustrative orbit.

- Model output was written at hourly time resolution.
- For each TROPOMI orbit encompassing the model domain, model outputs of nearest hours corresponding to overpass times are selected.
- For each TROPOMI pixel, model output of nearest overpass hour is linearly interpolated at the center of the pixel.
- Maximum difference between the sensing time and simulated model output is 30 min.
- TROPOMI tropospheric AMFs are calculated using WRF Chem a priori profiles to derive tropospheric VCDs

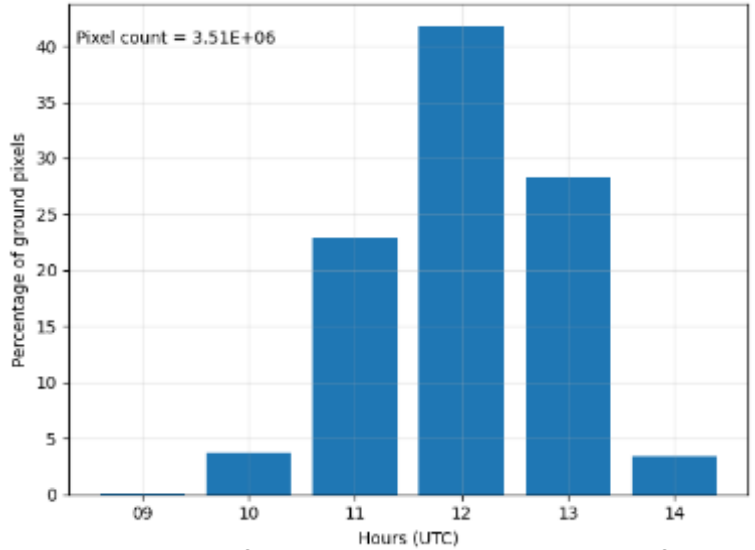
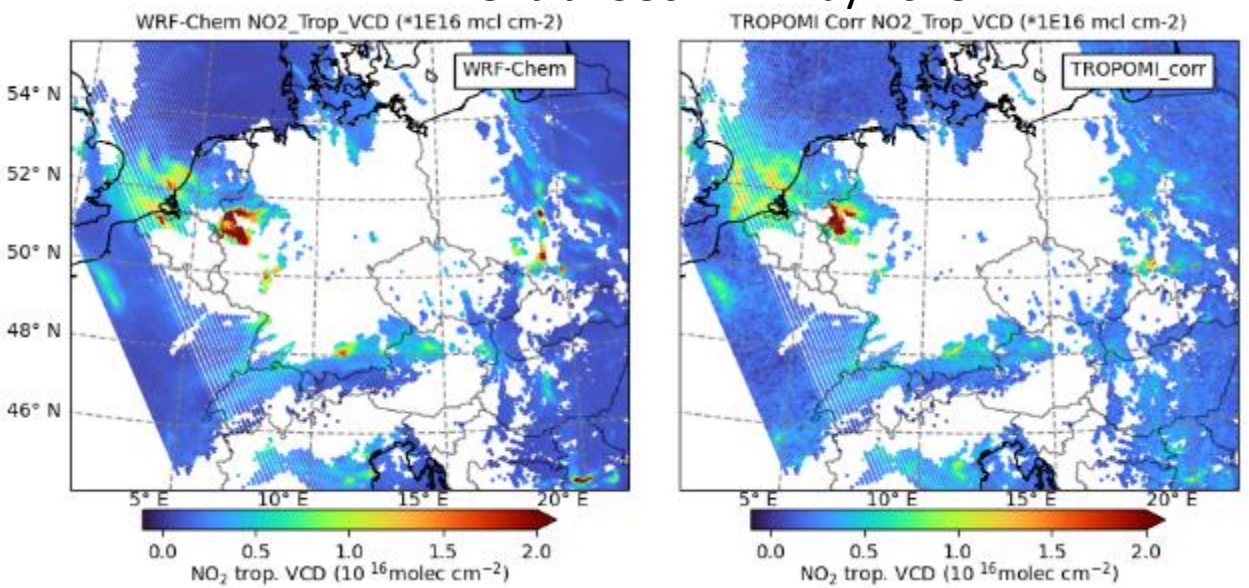



Fig: Relative frequency distribution of the number of pixels corresponding to an hour for one month in the model domain.

# Sampling of model output around TROPOMI overpass

Orbit 2980 : 11 May 2018




Orbit 2981 : 11 May 2018

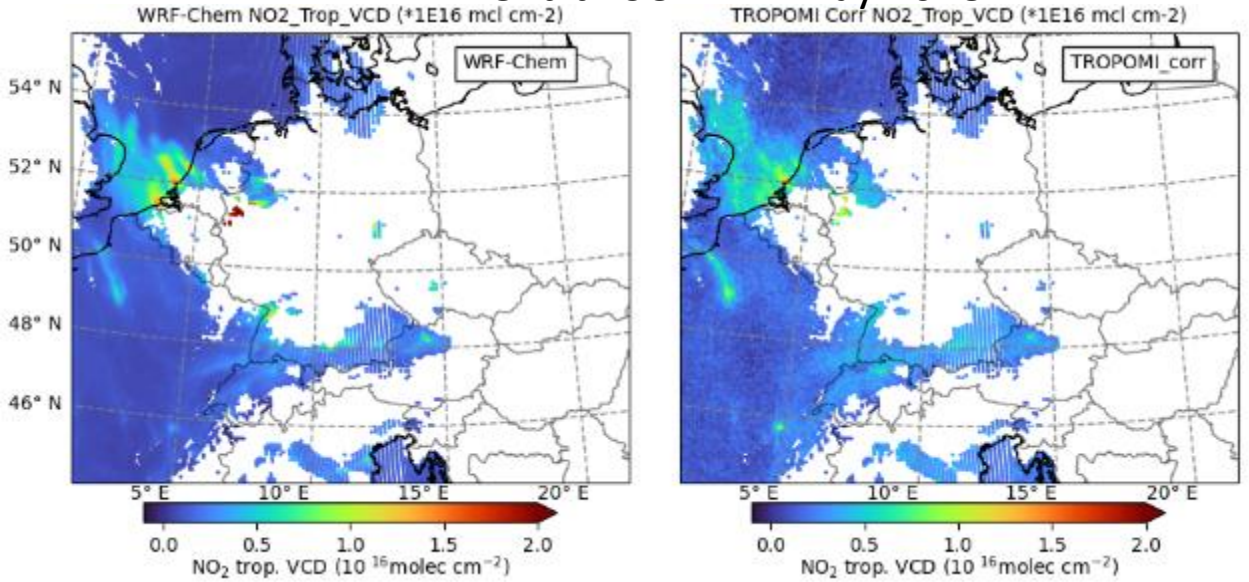
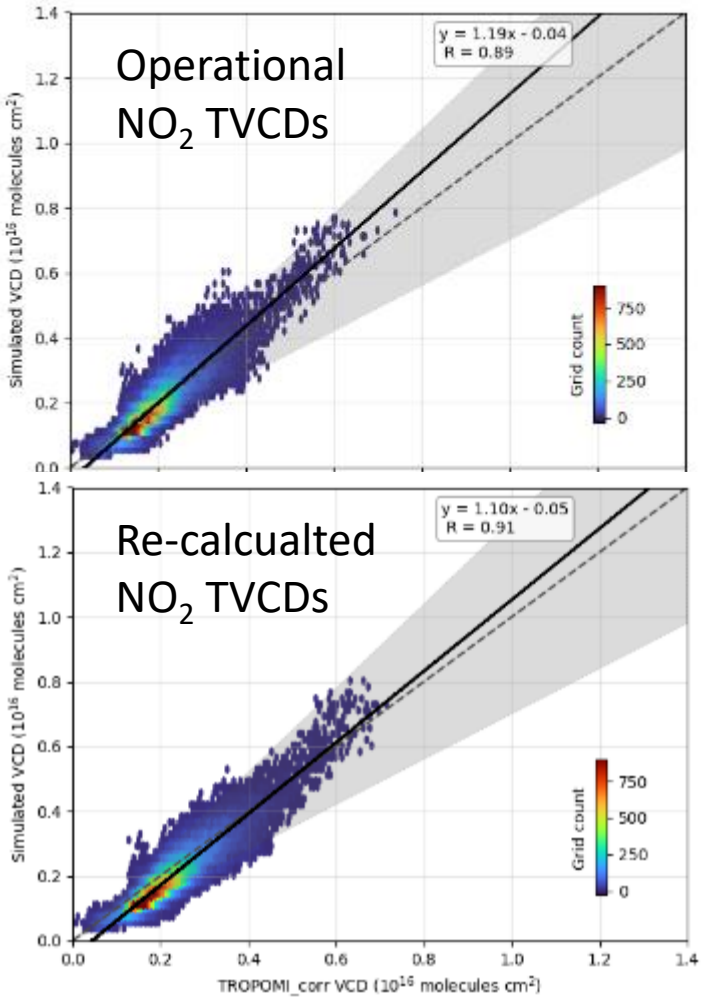



Fig: Spatial maps of $NO_2$ tropospheric VCDs over the d02 domain for orbit 2980 (left panel) and orbit 2981 (right panel) on 11 May 2018. The gaps in maps are due to cloud filter and quality assurance filter.

- The spatial patterns of short lived species (e.g. $NO_2$) can change significantly between two orbits.
  - For the example orbit shown above, $NO_2$ VCDs over the coast of the Netherlands and Belgium decreased by more than 30%. The comparison maps show that the model was able to capture these short temporal scale variabilities.

# Reprocessing of TROPOMI tropospheric VCDs

- A coarse a priori $NO_2$ profile ( as used in operational product) can result in high airmass factors (AMF) at pollution hotspots and subsequently smaller biased tropospheric VCDs.
  - $SCD_{trop} = VCD_{trop} \times AMF_{trop}$
- Using the total airmass factors, averaging kernels and the high resolved (3 × 3 km²) a priori profiles from WRF Chem, tropospheric air mass factors are calculated according to:
  - $AMF_{trop}(x_m) = AMF_{tot}(x_a) \frac{\sum_{l=1}^{L} A_l x_{m,l}}{\sum_{l=1}^{L} x_{m,l}}$
- Replacing the TM5 a priori by that of WRF-Chem increases the mean VCD over the domain by ~10% and by 20-25% over the hotspots.
- The regional CAMS reprocessed product increased the $NO_2$ tropospheric VCD by ~30% over the entire domain. Replacing the CAMS a priori by WRF-Chem yields similar modified VCDs from TROPOMI.



# Comparison of monthly mean $NO_2$ tropospheric VCDs

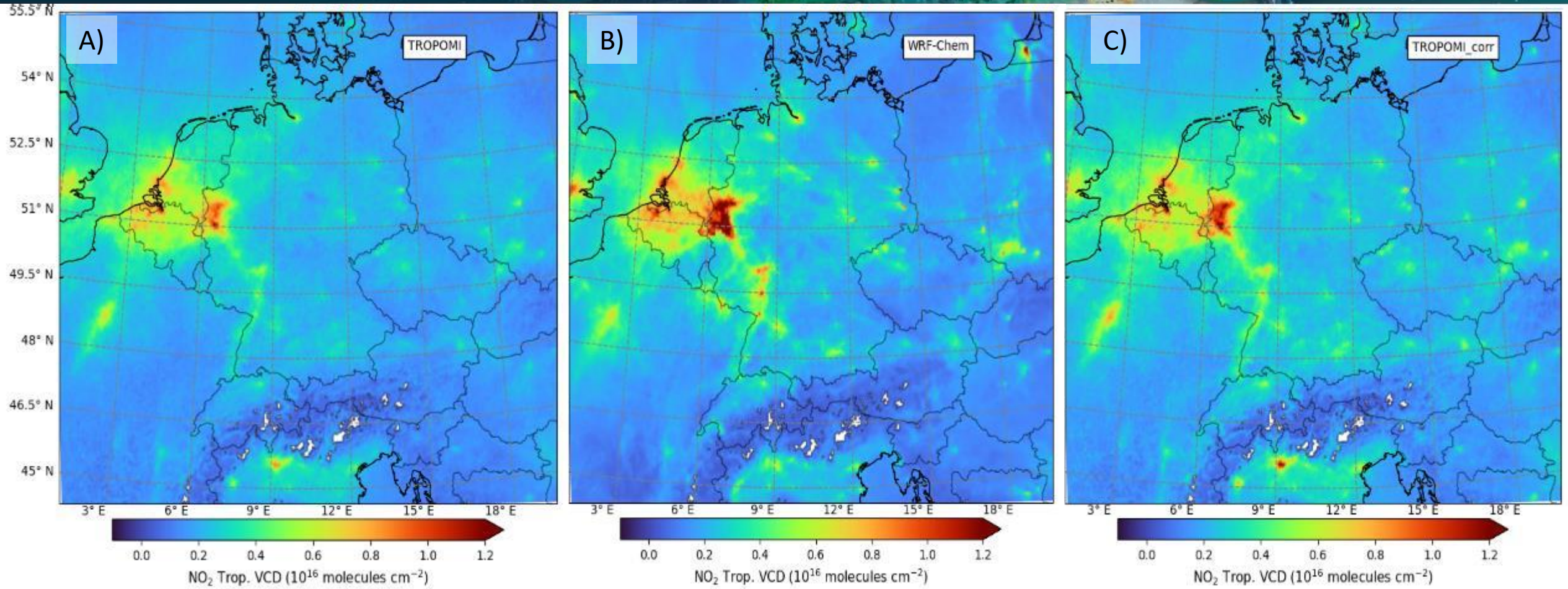



Fig: Monthly mean $NO_2$ tropospheric VCDs over the d02 domain for A)TROPOMI operational product, B)WRF Chem and C) TROPOMI with a priori from WRF Chem.

# Model performance for one orbit: effect of spectral nudging

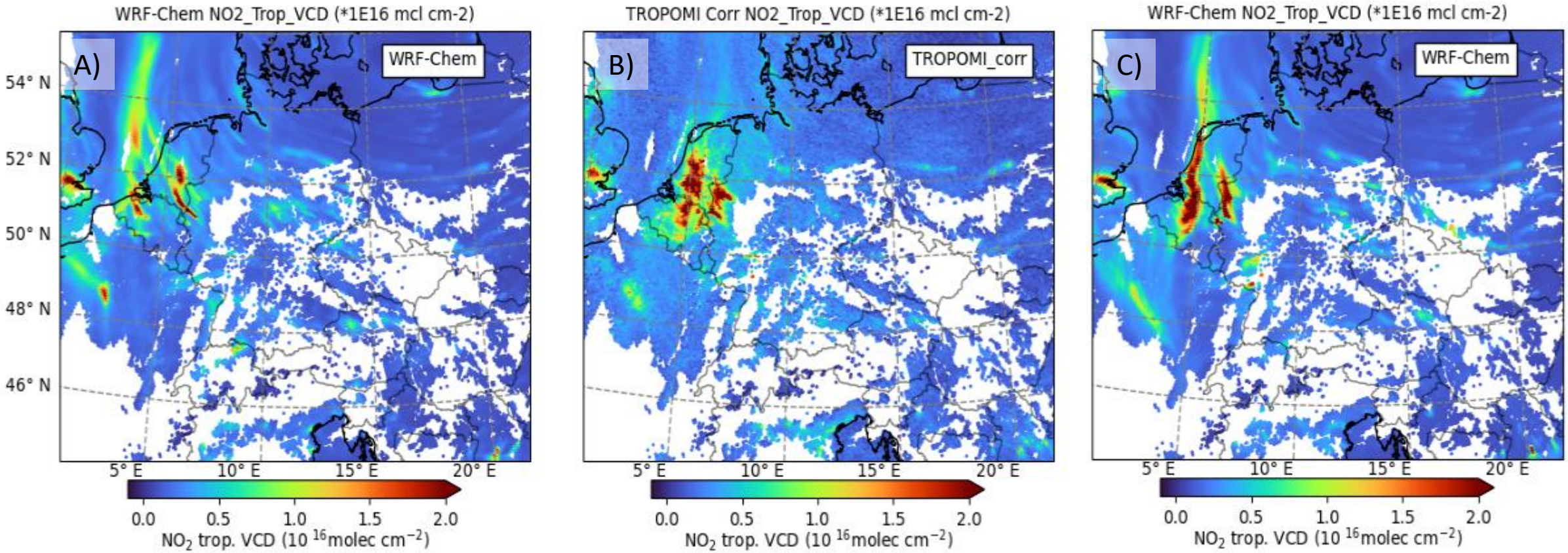



Fig: Spatial maps of $NO_2$ tropospheric VCDs over the d02 domain for orbit 2952 on 09 May 2018 for A) WRF Chem simulation without spectral nudging, B)TROPOMI (reprocessed with WRF Chem a priori profiles) and C)WRF Chem with spectral nudging. The gaps in maps are due to cloud filter and quality assurance filter.