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Evaluating the Potential of Satellite Measurements in Air Quality Monitoring: A Project for the Finnish Ministry of the Environment

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Project description

- **Aim**: to evaluate what potential satellite measurements have in complementing traditional *in situ* air quality measurements.
- Performance of current instruments evaluated using gridded maps and statistical comparisons with collocated *in situ* station measurements in Finland.
- Focus on NO_2 measurements done by the TROPOMI instrument; SO_2, CO, and aerosols also covered.
- Commissioned by the Finnish Ministry of the Environment.
- Study period: April 2018 to June 2019.

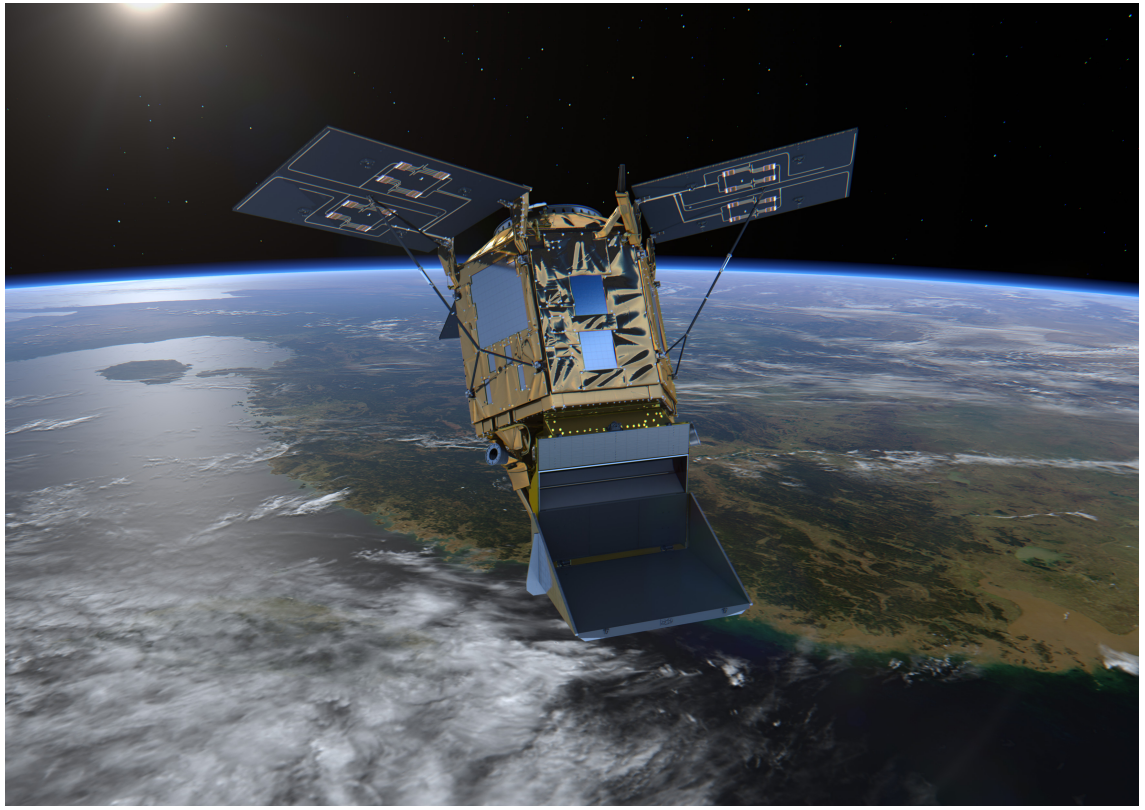
Nitrogen dioxide (NO_2)

- Internationally recognized air pollutant (WHO, EU, USA).
- Increases in concentrations linked to increased mortality.
- Concentration limits set by law.
- Mainly emitted from **combustion engines**, biomass burning, soil bacteria, and lightning.

Pixabay

TROPOMI instrument

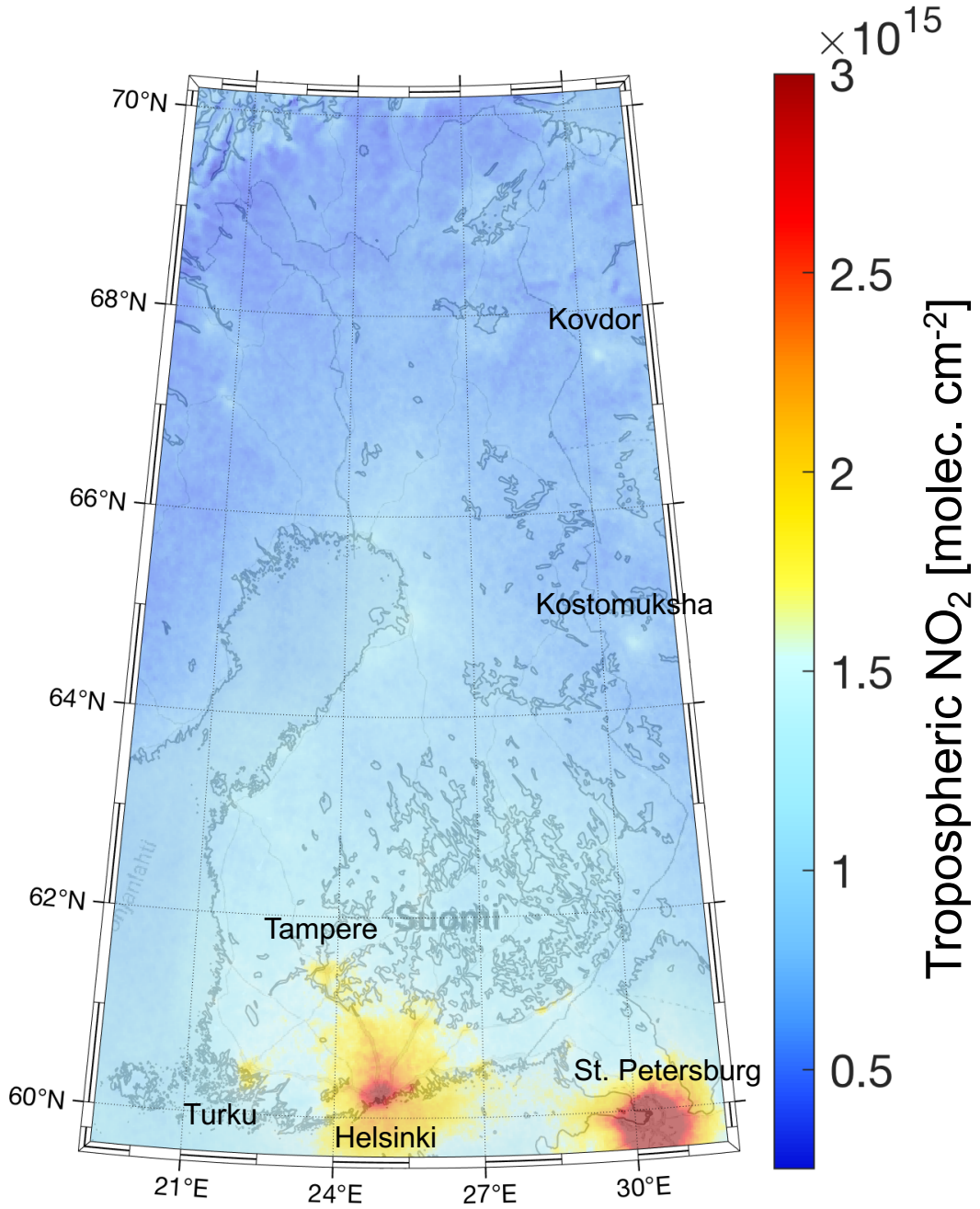
- Launched in October 2017 aboard Sentinel-5 Precursor.
- Part of EU's Copernicus Earth monitoring programme.
- Hyperspectral imager measuring **NO_2**, O_3, CH_4, CO, SO_2, CH_2O, clouds, and aerosols.
- Ground resolution 7x3.5km (5.5x3.5km as of August 2019).



Sentinel-5P. ESA/ATG medialab

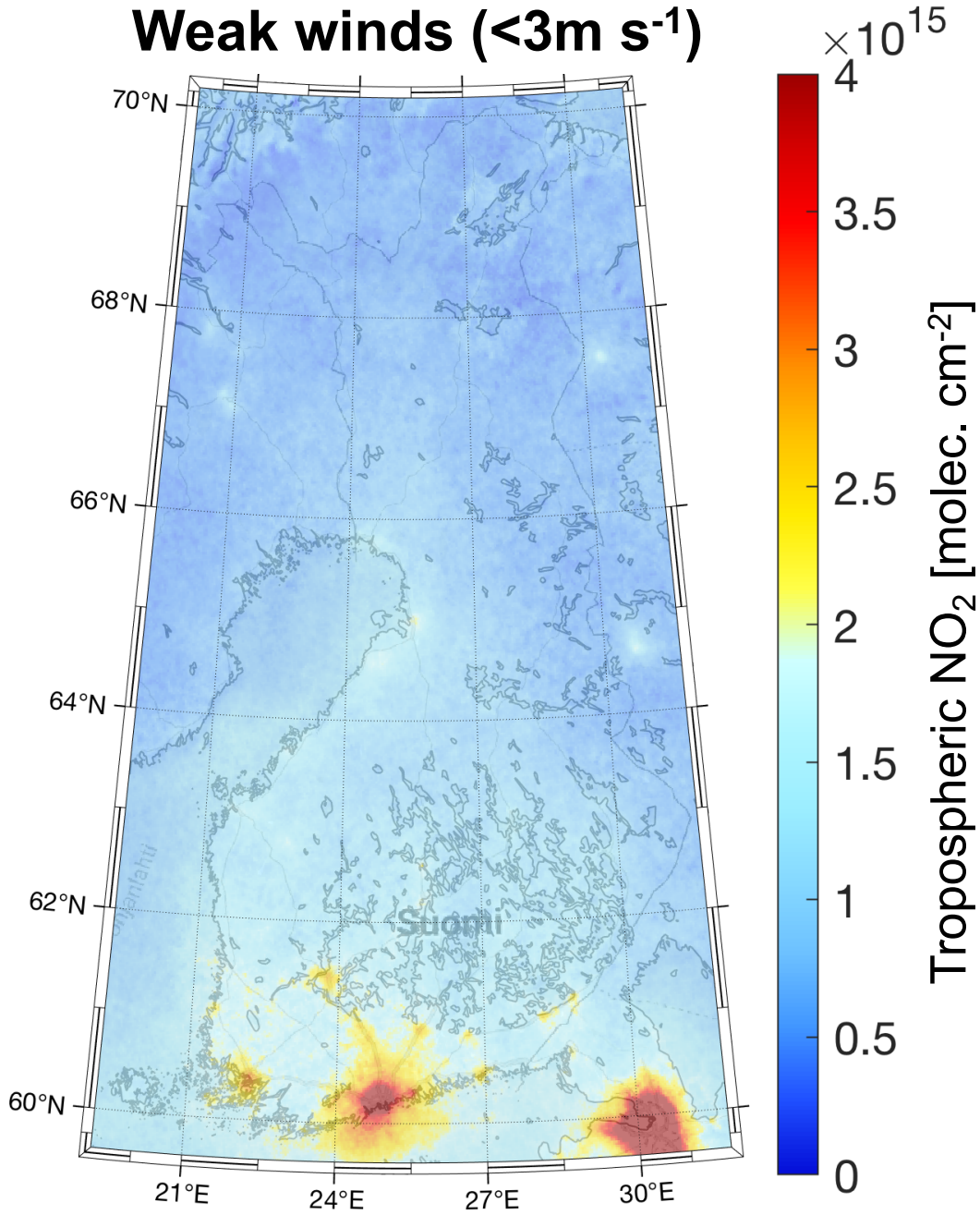
Gridded maps

- TROPOMI Tropospheric NO_2 measurements oversampled (avg.) to 2.5x2.5 km grid between 15.4.2018–30.6.2019.
- Helsinki capital region stands out, as do the cities of Turku and Tampere (among the most populous in Finland).
- Two light dots just east of northern Finland are the Russian mining towns of Kostomuksha and Kovdor.



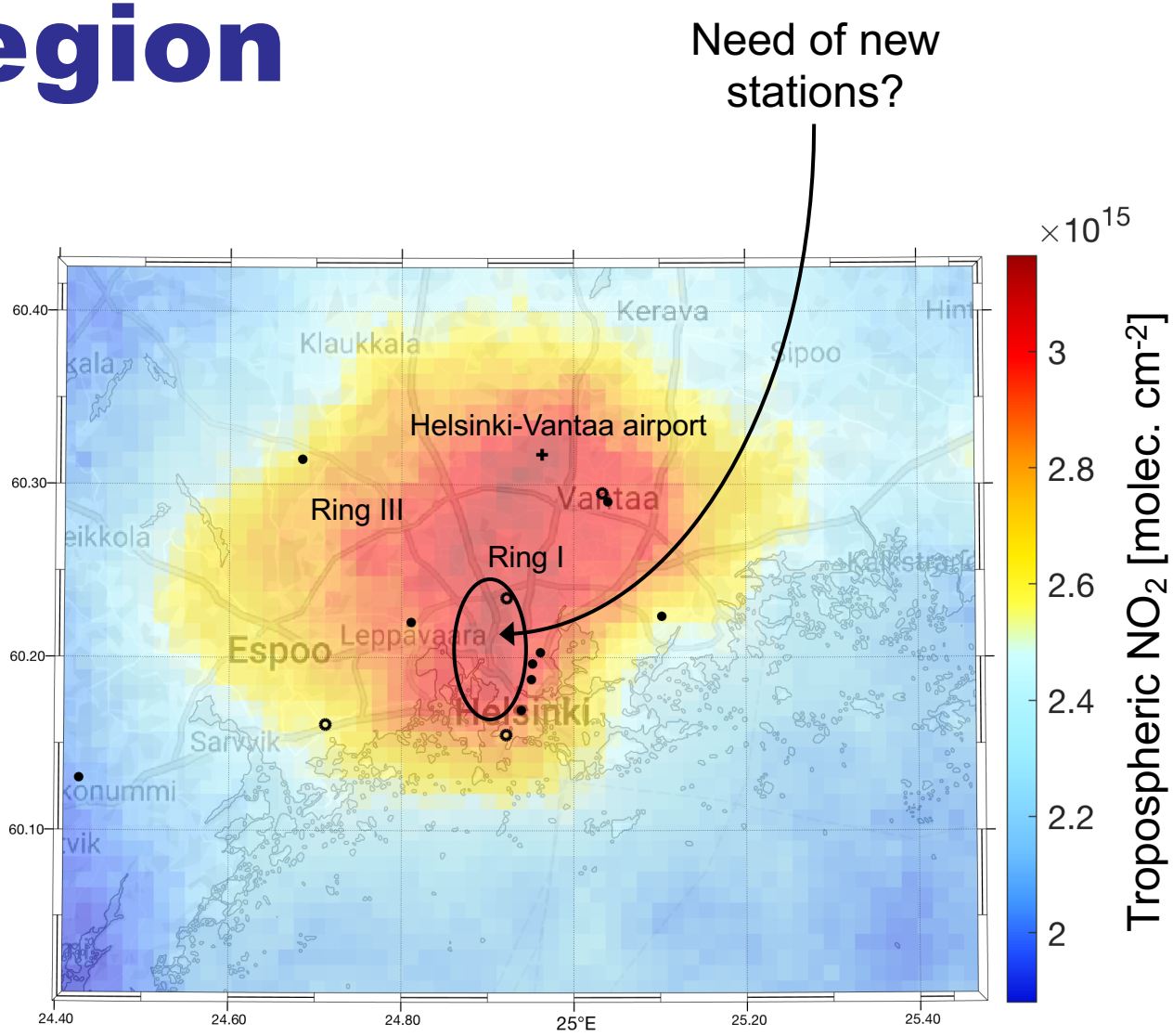
Gridded maps

- If only measurements made during weak winds are included, effect of emissions transport is reduced → sources of NO_2 more visible.
- Smaller towns now stand out, as do main highways (e.g. between Helsinki and Tampere).
- **Wind**: ERA5 reanalysis product used to calculate average boundary layer wind speed.



Helsinki capital region

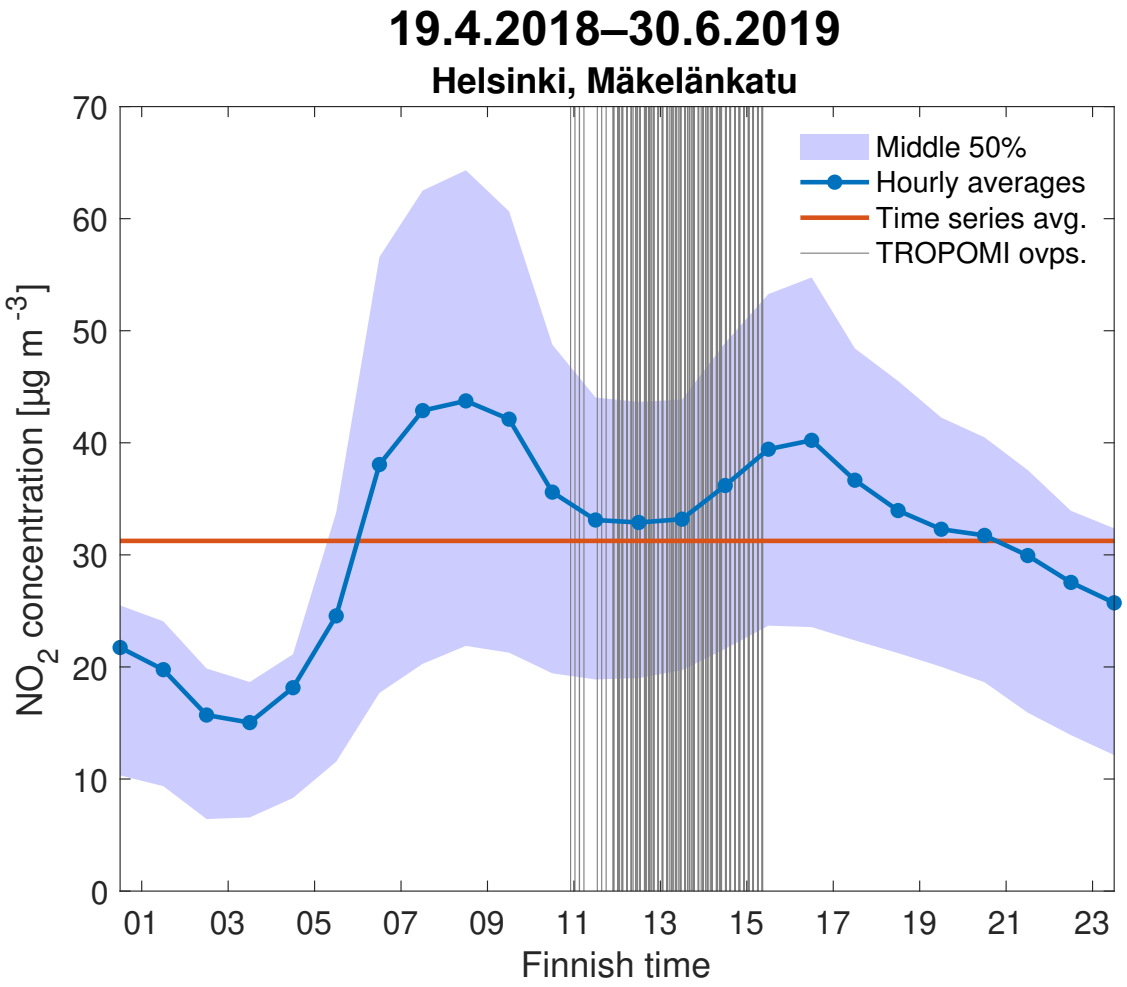
- TROPOMI Tropospheric NO_2 oversampled (averaged) to 1x1km grid.
- Highest concentrations near Helsinki-Vantaa airport and just north of Helsinki city centre.
- Ring I Finland's busiest road: not clearly visible on map → due to TROPOMI ovp time?



Permanent AQ stations marked by filled circles, temporary stations by hollow circles.

TROPOMI overpass time

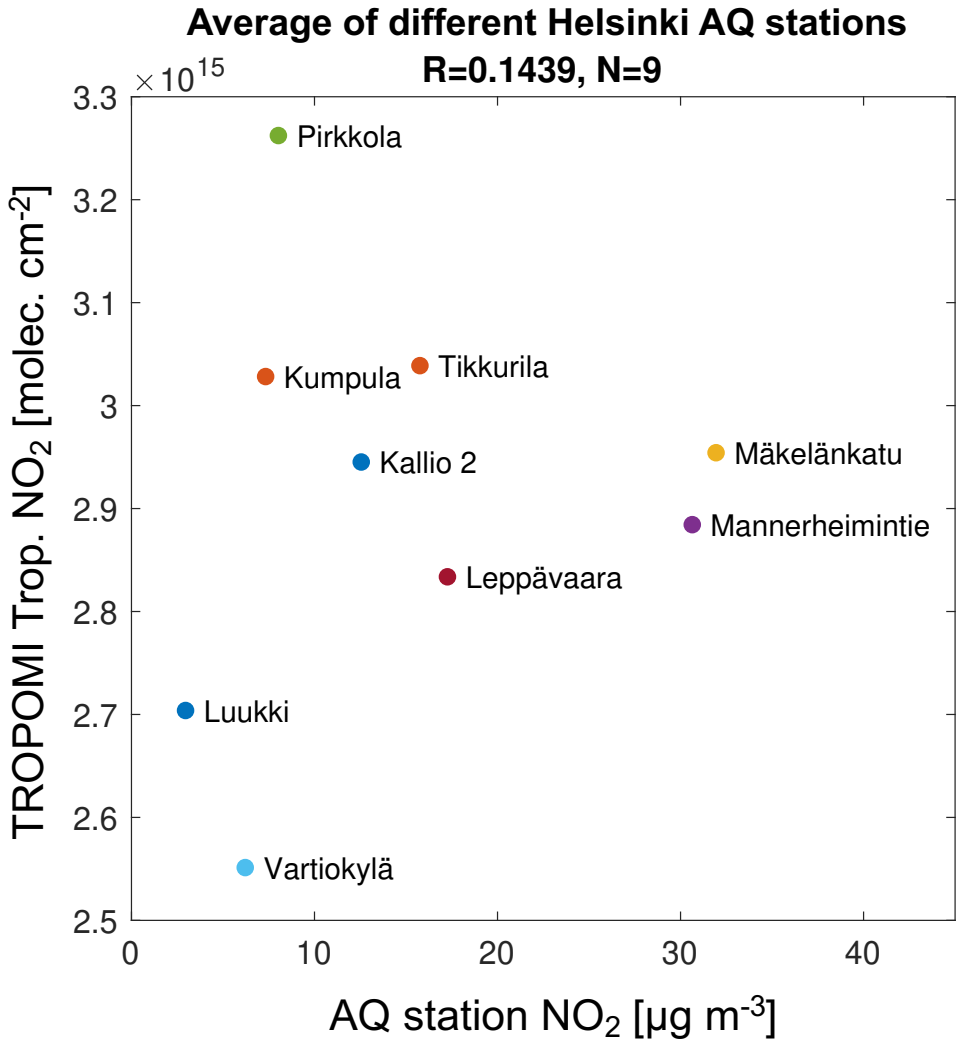
- TROPOMI on an afternoon orbit: overpasses between morning and afternoon peaks in NO_2 due to commuter traffic → highest concentrations not captured, measurements represent ~midday average.
- Important to remember when interpreting measurements!



A classic example of the NO_2 diurnal cycle from the Mäkelänkatu air quality station. TROPOMI overpass times marked with grey vertical lines.

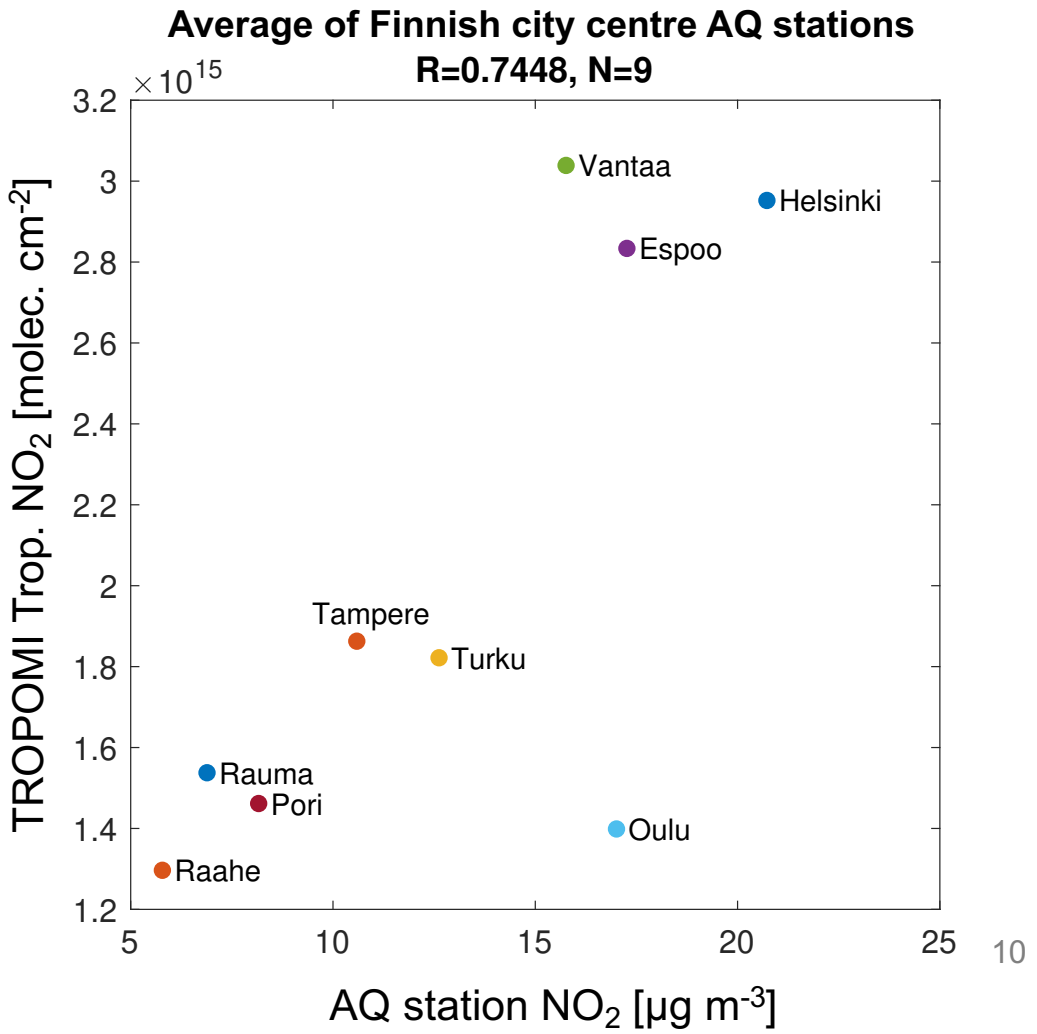
TROPOMI vs. air quality stations

- Correlation of TROPOMI and air quality station measurements evaluated using scatter plots.
- Collocation criteria: TROPOMI pixels above station chosen, station measurements linearly interpolated to overpass time.
- Poor correlation of collocated meas. averages: only ~0.14



City centre aggregation

- Measurement aggregation by averaging together all city centre stations.
- Correlation improved: ~0.74
- TROPOMI pixels cannot capture variability within a small area such as city centre → poor correlation with individual stations.
- Better correlation when comparing city centres.



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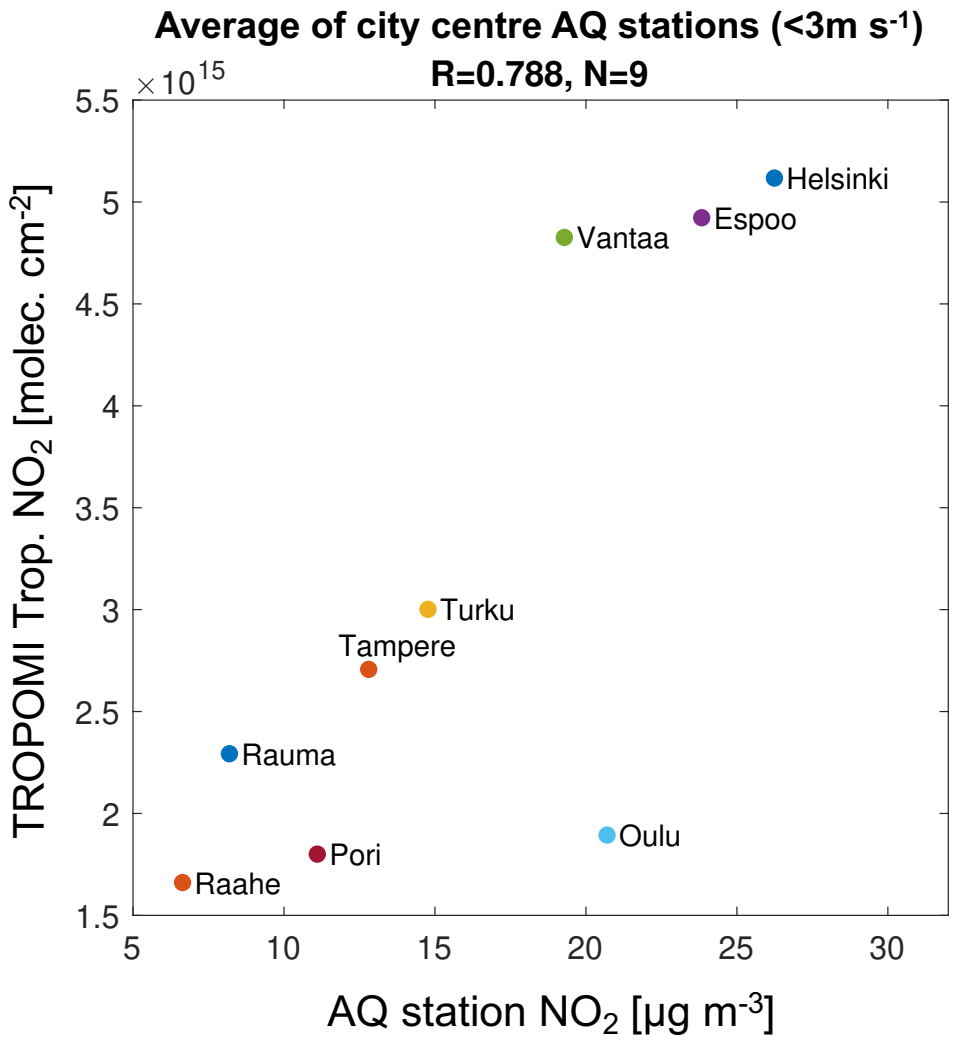
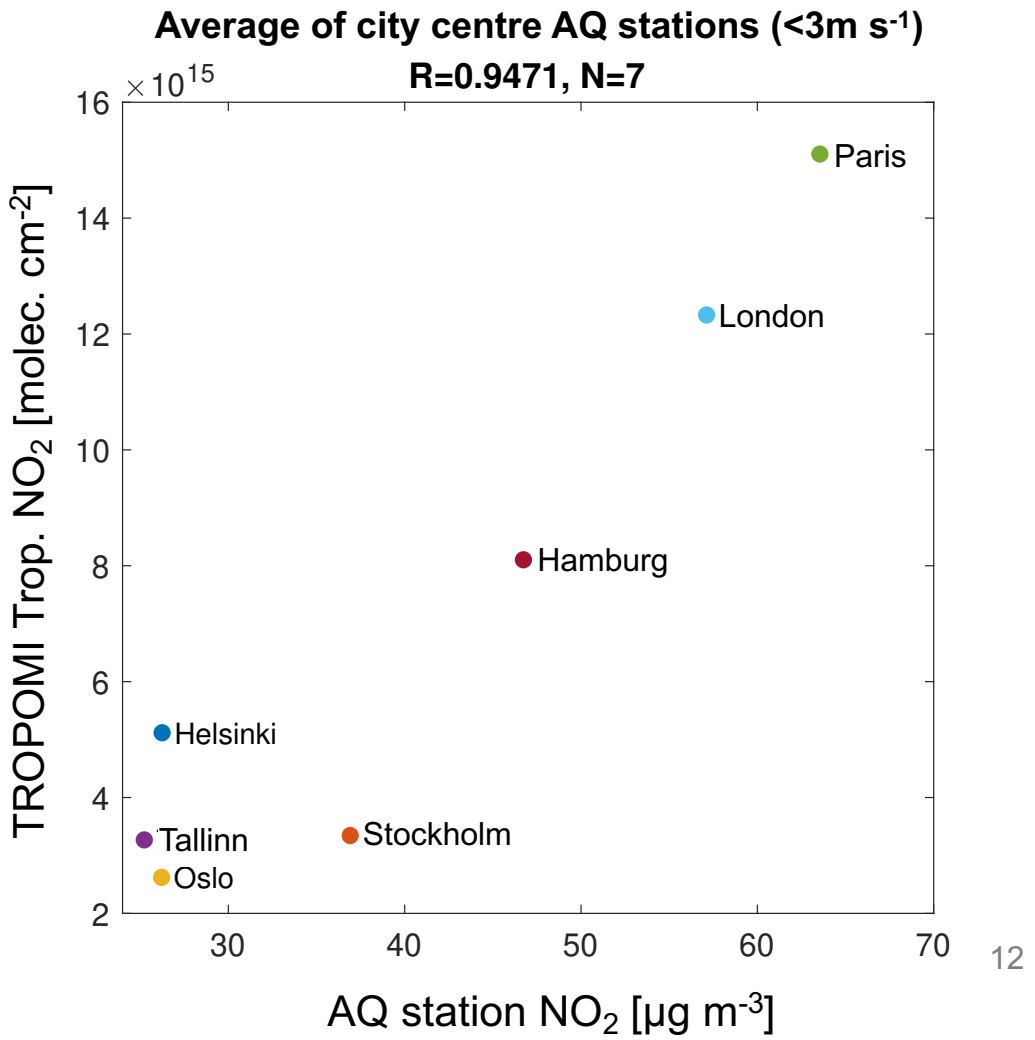
Effect of boundary layer wind

- Advection of NO_2 emissions affects correlation by dispersing emissions over a larger area.
- If only measurements during weak winds considered, correlation is improved: ~0.79
- Northernmost studied city Oulu is outlier. May be due to snow and ice cover (port city).



Comparison of European cities

- Study also extended to some European cities.
- Data from European Environment Agency.
- Data very well correlated: ~0.95
- Helsinki appears as a notable outlier. Observed *in situ* vs. TROPOMI differences require further investigation.



Conclusions

- TROPOMI oversampled grids a feasible tool to characterize regional spread of NO_2 emissions and sources.
  - Could be used to plan placement of ground stations.
  - Overpass time of TROPOMI must be accounted for.
- Correlation of TROPOMI and air quality station measurements between individual cities is good.
  - TROPOMI could be used as a tool to estimate NO_2 concentrations in cities lacking any ground stations.
- First such report delivered to the FME.
  - Societal interest in satellite measurements growing, thanks to TROPOMI's unprecedented spatial resolution.

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References

Sundström, A.-M., Virta, H., Ialongo, I., and Tamminen, J., 2020: Satelliittihavaintojen hyödyntäminen ilmanlaadun seurannassa. *Raportteja – Rapporter – Reports 2020:1*, Finnish Meteorological Institute, Helsinki, Finland. doi: 10.35614/isbn.9789523360983

See also

Ialongo, I., Virta, H., Eskes, H., Hovila, J., and Douros, J., 2020: Comparison of TROPOMI/Sentinel-5 Precursor NO2 product with ground-based observations in Helsinki and first societal applications. **EGU2020-9963** at 7 May 2020, 8:30–10:15

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