Machine learning weather normalization in estimating lockdown induced European NO_2 changes

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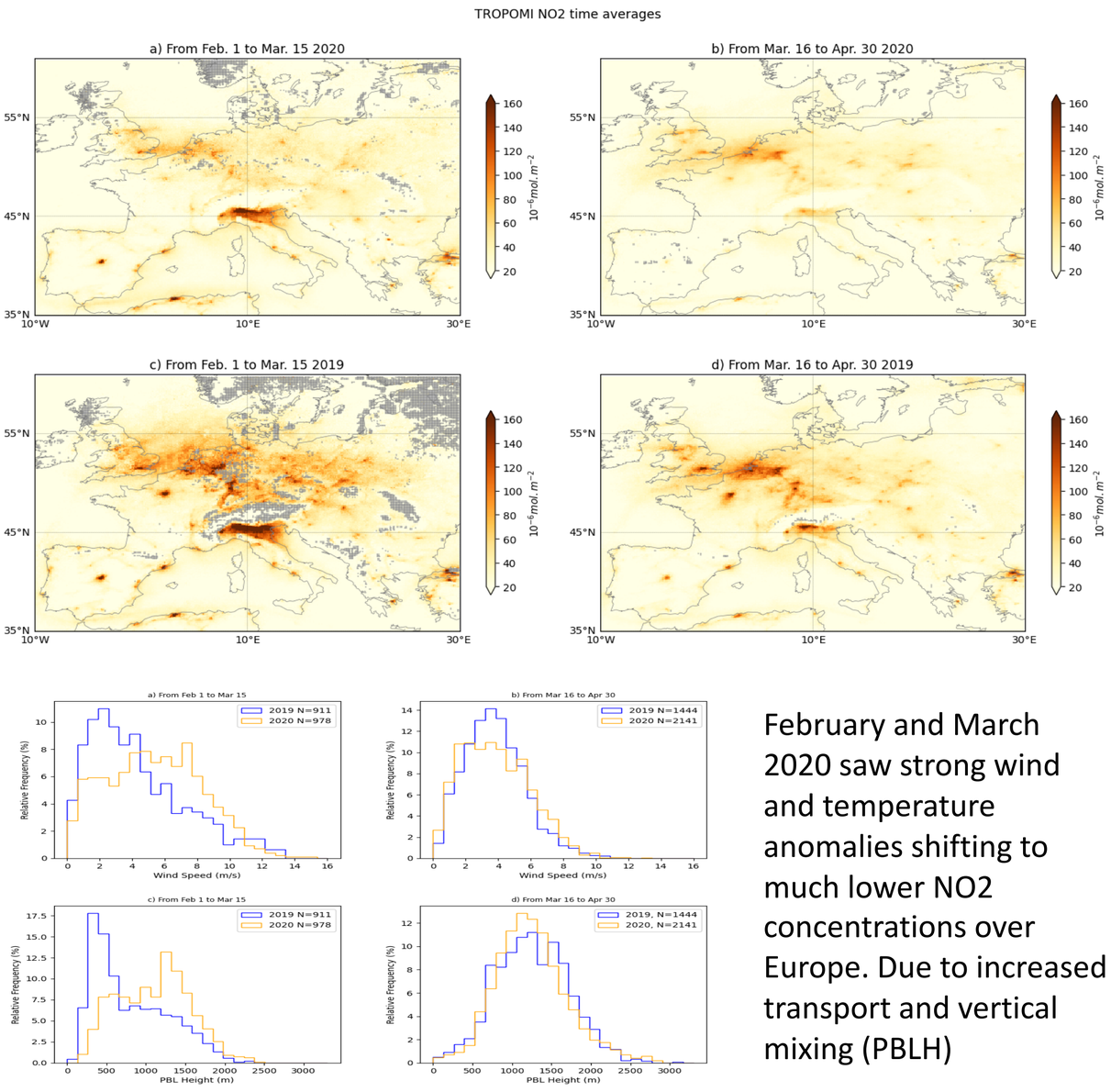
Abstract. We provide weather-normalized estimates based on a machine learning method (gradient boosting) along with an assessment of the biases that can be expected from methods that omit the influence of weather. We also compare the weather-normalized satellite NO_2 column changes with both weather-normalized surface NO_2 concentration changes and simulated changes by the CAMS regional ensemble, composed of 11 models, using recently published emission reductions induced by the lockdown. We show that all estimates show the same tendency on NO_2 reductions. Locations where the lockdown was stricter show stronger reductions and conversely locations where softer measures were implemented show milder reductions on NO_2 pollution levels. On average reduction estimates whether using satellite observations (-23%) surface stations (-43%) or models (-32%) are presented, showing the importance of vertical sampling but also the horizontal representativeness. Surface station estimates are significantly changed when sampled to the TROPOMI overpasses (-37%) pointing out the importance of the variability in time of such estimates. Observation based machine learning estimates show a stronger time variability than the model-based estimates.

Weather variability on Air Quality



February and March 2020 saw strong wind and temperature anomalies shifting to much lower NO2 concentrations over Europe. Due to increased transport and vertical mixing (PBLH)

S5P Weather Normalization Methodology

- **Training Set** (90% of Jan-May **2019**):
- ECMWF NWP operational forecasts:
  - 10m wind speed and direction,
  - planetary boundary layer height
  - 2m temperature
  - surface relative humidity
  - geopotential at 500hPa
- CAMS regional NO2 forecasts
- S5P NO2 columns (*target*)

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Gradient boosting Regressor
Hyperparameter tuning (grid search)
with cross-validation (5 k-fold)

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Simulate "business as usual" (BAU) S5P NO2 columns

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Evaluation with **Test Set** (10% of Jan-May **2019**)

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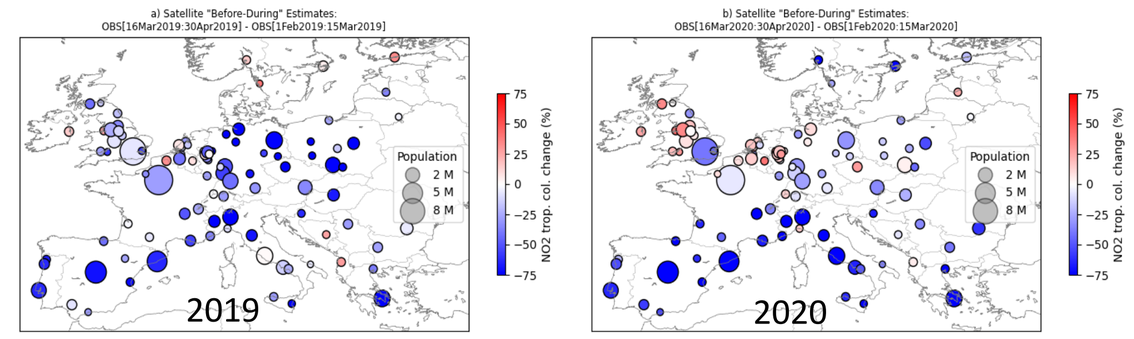
Calculate 2020 estimates:
Real S5P Columns – BAU S5P Columns

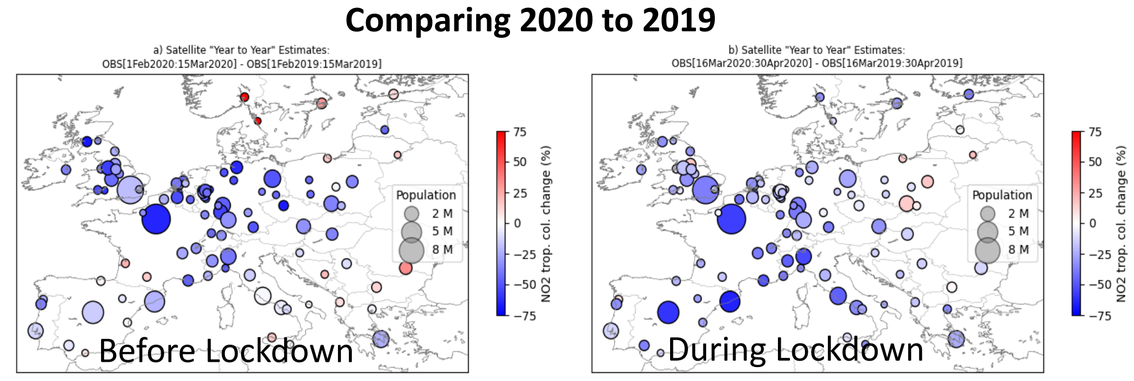
	MB [$10^{-6}mol.m^{-2}$]	nMB [%]	RMSE [$10^{-6}mol.m^{-2}$]	nRMSE [%]	PCC	N
S5P training set	0.00	+0.02	1.4	45.68	0.87	9,634
S5P test set	-0.04	-1.30	1.68	56.38	0.79	1,071

Non-Weather Normalized NO2 Changes

Comparing 45 days during to 45 days before lockdown

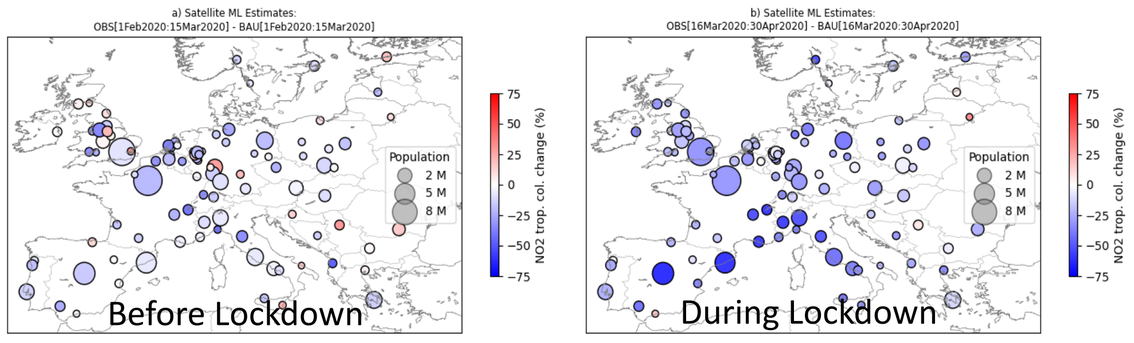


Comparing 2020 to 2019

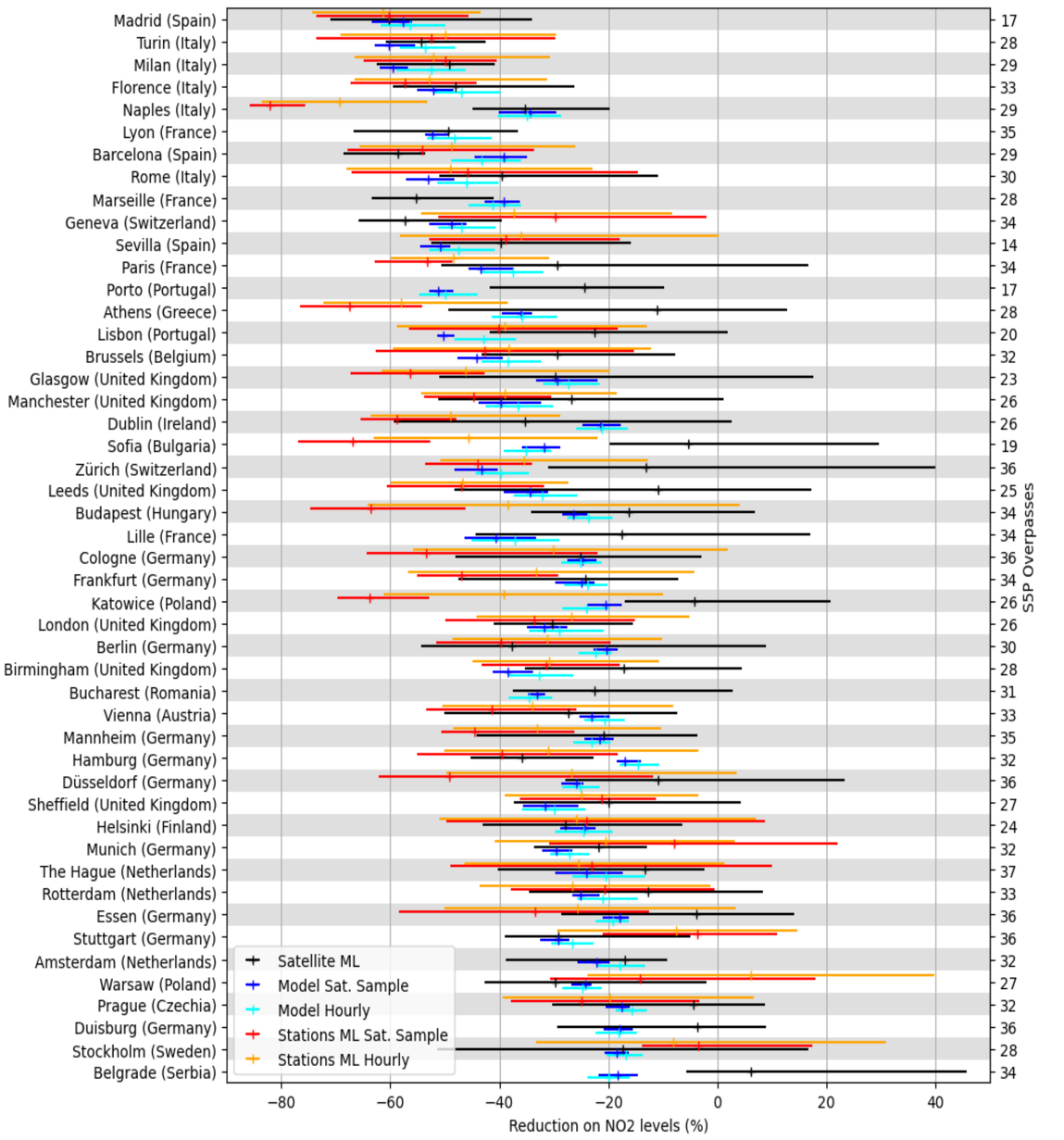


Weather Normalized NO2 Changes

Comparing Real observations to BAU observations



Comparison with other estimates



References

Jérôme Barré et al., 2020, Estimating lockdown induced European NO_2 changes, acp-2020-995, submitted to ACP

Petetin, H., et al.,.: Meteorology-normalized impact of COVID-19 lockdown upon NO_2 pollution in Spain, Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2020-446, in review, 2020.