Experience in Northern Italy with ammonia (NH_3) emissions: using in situ observations and satellite derived products

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Summary

Model input parameters

- Ammonia emissions in Northen Italy – Bottom up inventory
- In situ measurements sites concentrations and atmospheric turbulence parameters

Methodology

- Iterative ML – Methodology to fit concentrations and calculate emission rates

Discussion

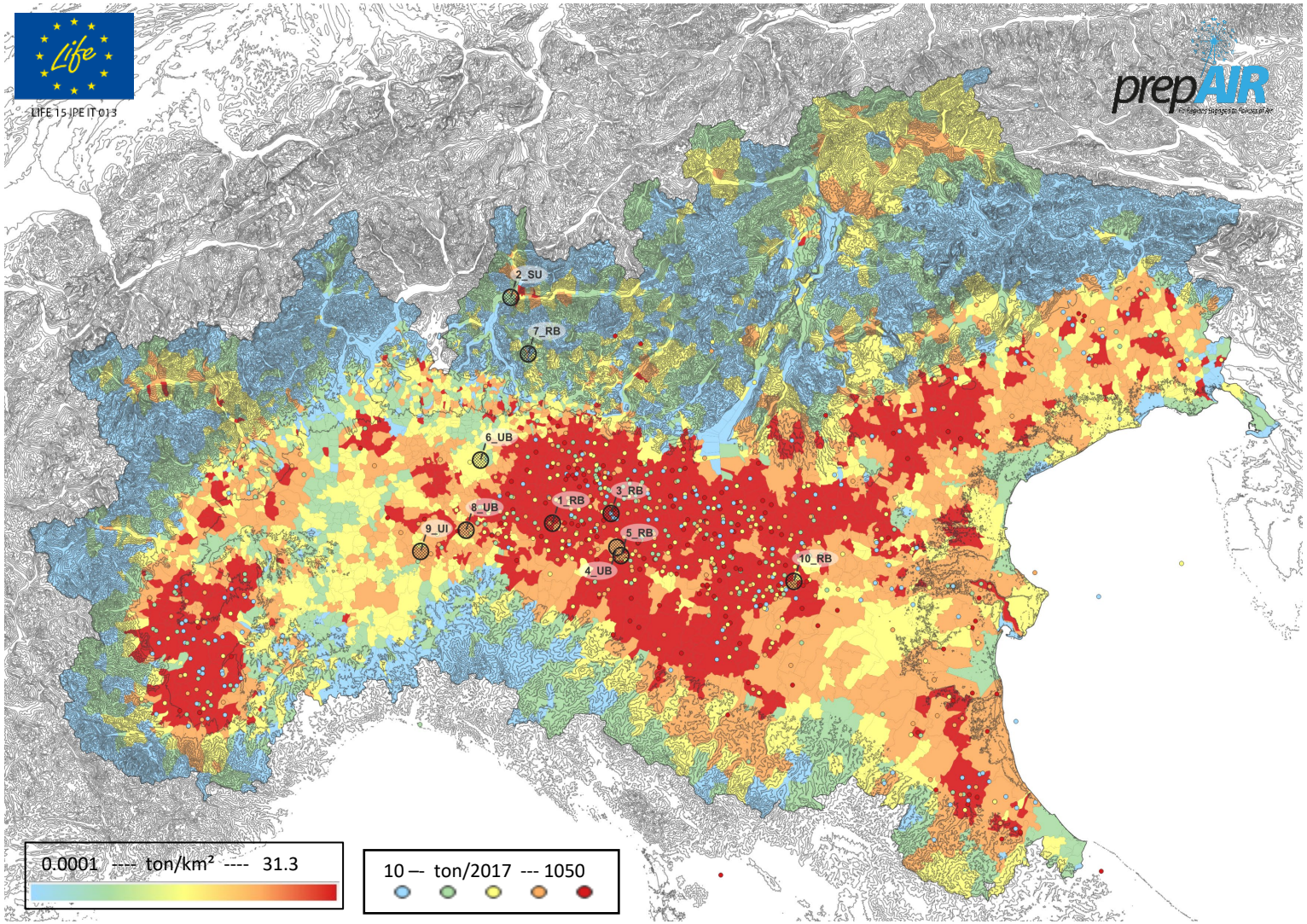
- Relationship of concentrations, meteorology and emission rates

Comparison with SEEDS

- Comparison of the emission rates profiles

Conclusions

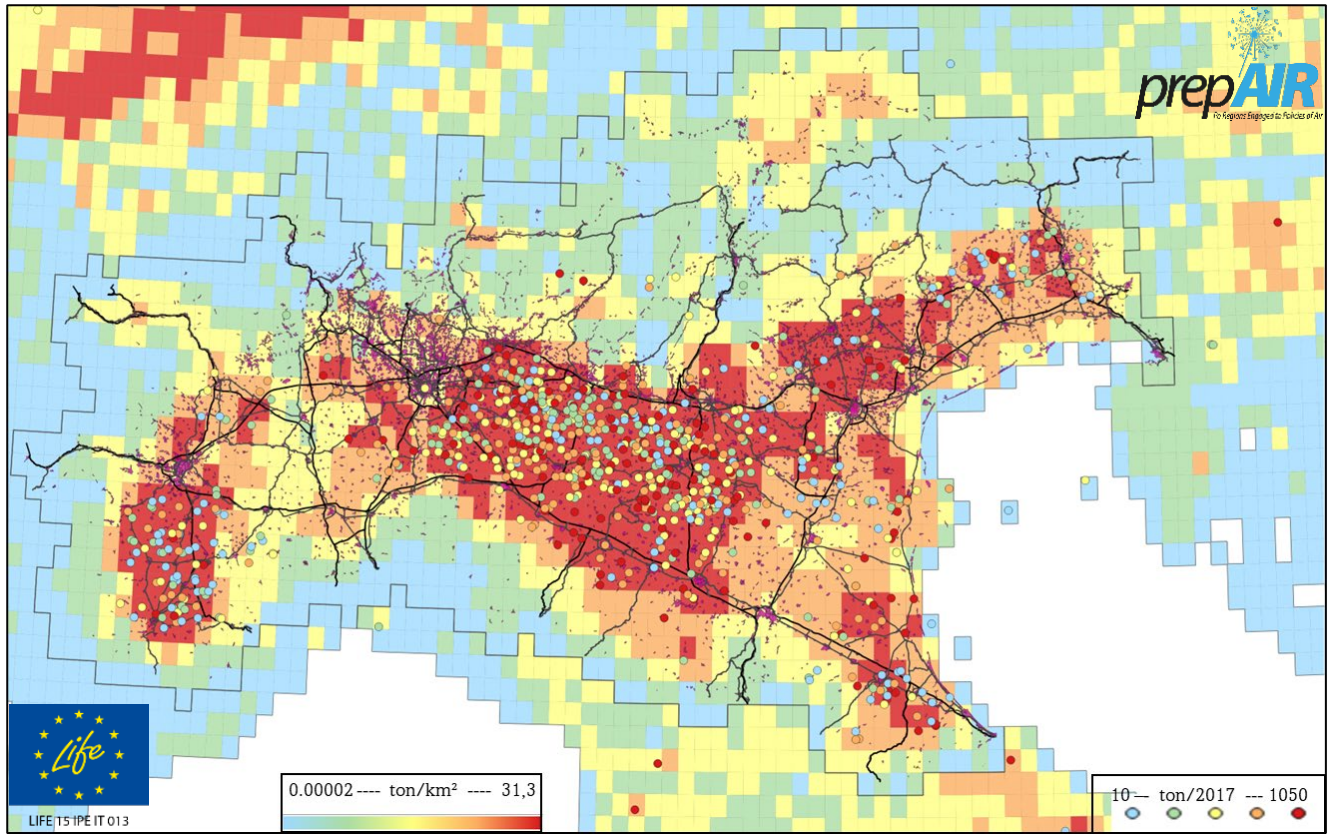
Bottom-up emission inventory for NH_3

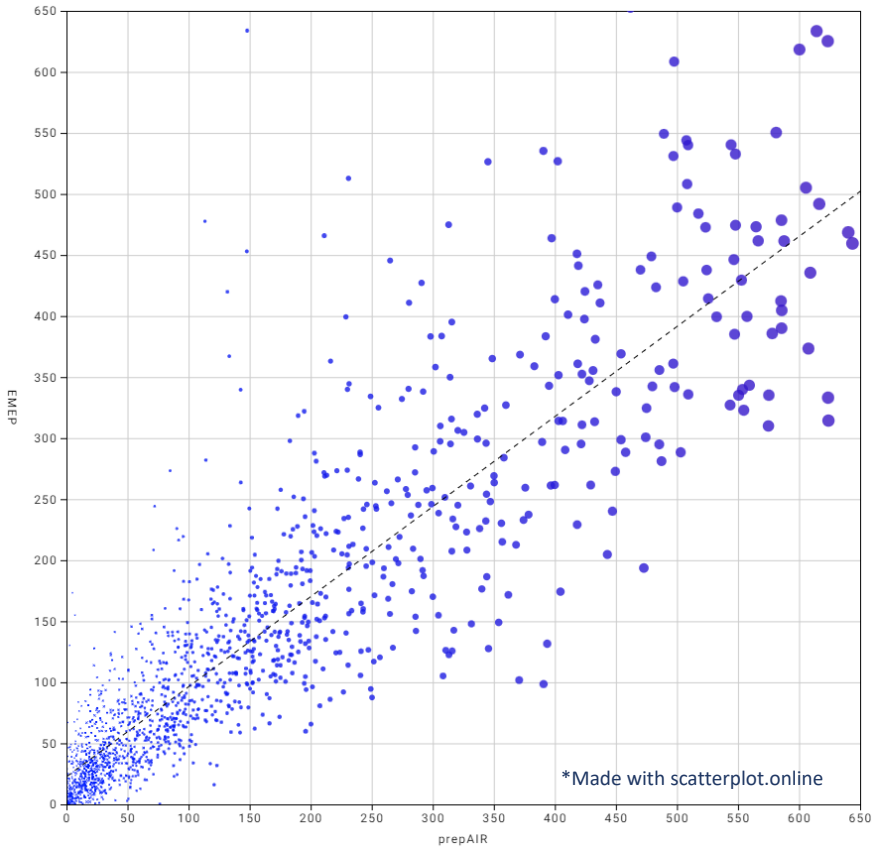


In the frame of the EU LIFE PREPAIR project, ARPA Lombardia developed a common emission dataset on the Po-basin and Slovenia (domain of 135000 Km2 and population of 28 million inhabitants).

- **Detail**: Year, Pollutant, Municipality, SNAP (3 levels for Italian regions), Fuel (for the Italian regions)
- **Approach:** Bottom – Up with details on point emissions sources
- **Three updates: 2013, 2017 and 2019**

Emission mapping of NH3 in Northern Italy





Composite map of emission data (2017) from LIFE PREPAIR:

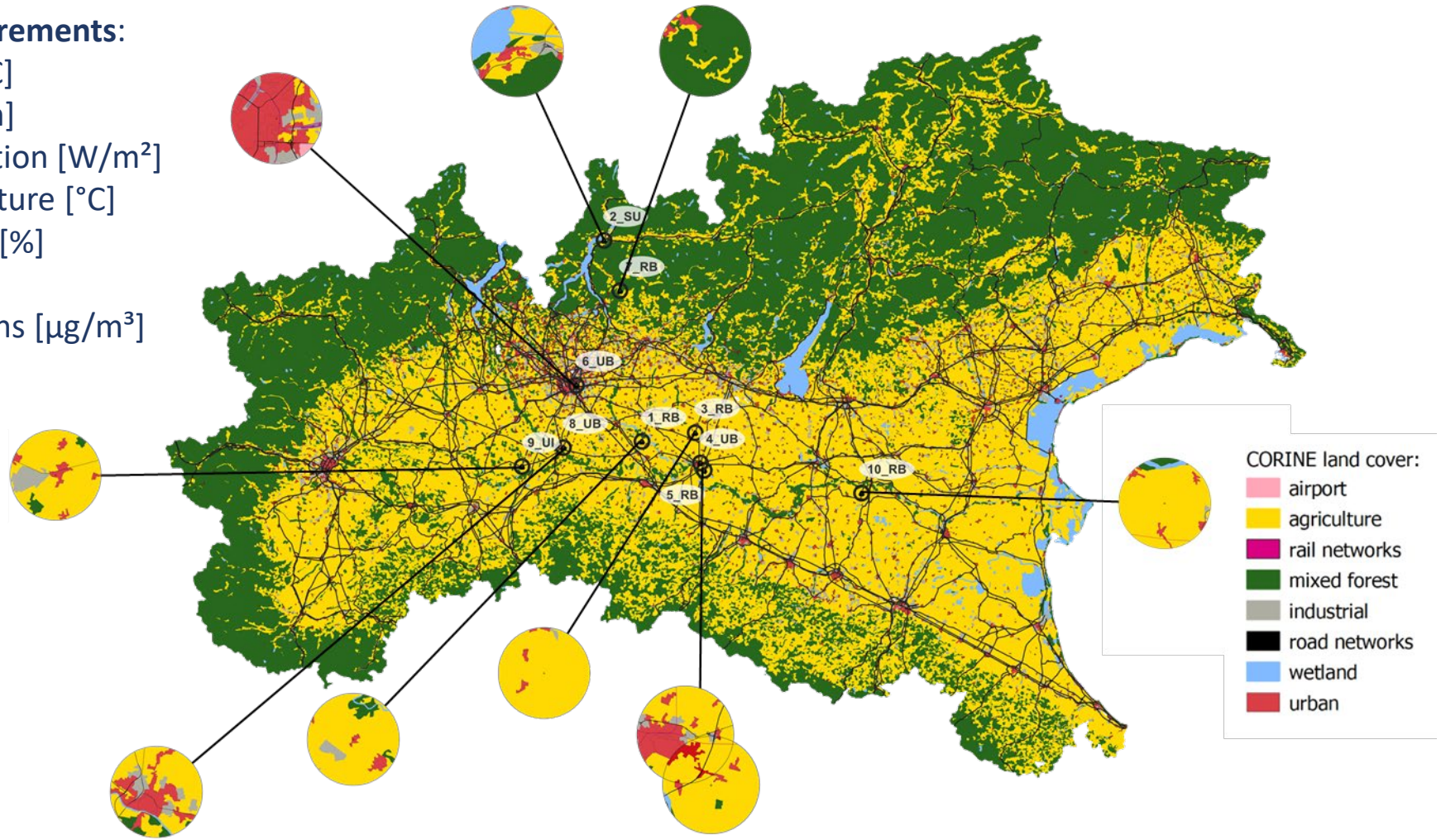
- data in the outline from ceip.at/the-emep-grid;
- 945-point emission sources in Italy from 10 tonnes of NH_3 from intensive rearing of poultry or swine reported in E-PRTR database v.18 (industry.eea.europa.eu)

Each point of the scatter plot represents the ammonia emitted in tons in 2017 for each cell according to PREPAIR and EMEP estimates (95-percentile)

NH_3 concentrations and meteorological parameters

Hourly based measurements:

- wind direction [°C]
- precipitation [mm]
- global solar radiation [W/m²]
- ambient temperature [°C]
- relative humidity [%]
- wind speed [m/s]
- NH_3 concentrations [µg/m³]



Monitoring sites: RB: rural background; UB: urban background; SU: suburban background; UI: urban industrial

Model goal and main hypothesis

Goal: estimate ammonia concentrations and emissions with high accuracy

- We consider an area with a radius of 3.6 km around the site (maximum distance in an hour with a wind velocity of 1 m/s).
- Training and testing of Random Forest on the measured hourly ammonia concentrations and turbulence parameters and with a first guess value of the emission rate of NH_3 from the inventory.
- Reiteration of test and training of the Random Forest model correcting the hourly emissions by the ratio between measured and estimated concentrations.

Marongiu, A.; Collalto, A.G.; Distefano, G.G.; Angelino, E. Application of Machine Learning to Estimate Ammonia Atmospheric Emissions. *Preprints* **2023**, 2023090607. https://doi.org/10.20944/preprints202309.0607.v1

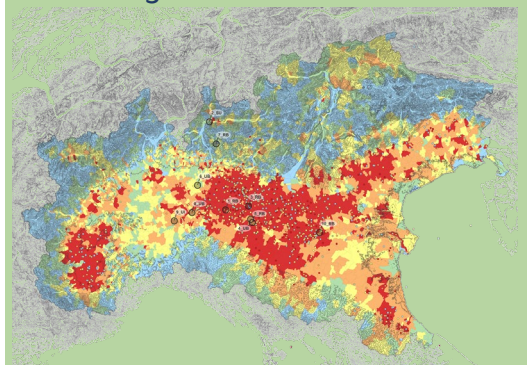
Iteration on Random Forest correcting emission rates

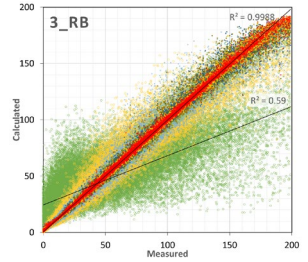
Hourly based measurements:

- wind direction (WD) [°]
- precipitation (PR) [mm]
- global solar radiation (GSR) [W/
- ambient temperature (AT) [°C]
- relative humidity (RH) [%]
- wind speed (WS) [m/s]
- NH_3 concentrations (NH3) [µg/m³]

Annual based estimates from inventory:

- NH_3 emission [t/year]

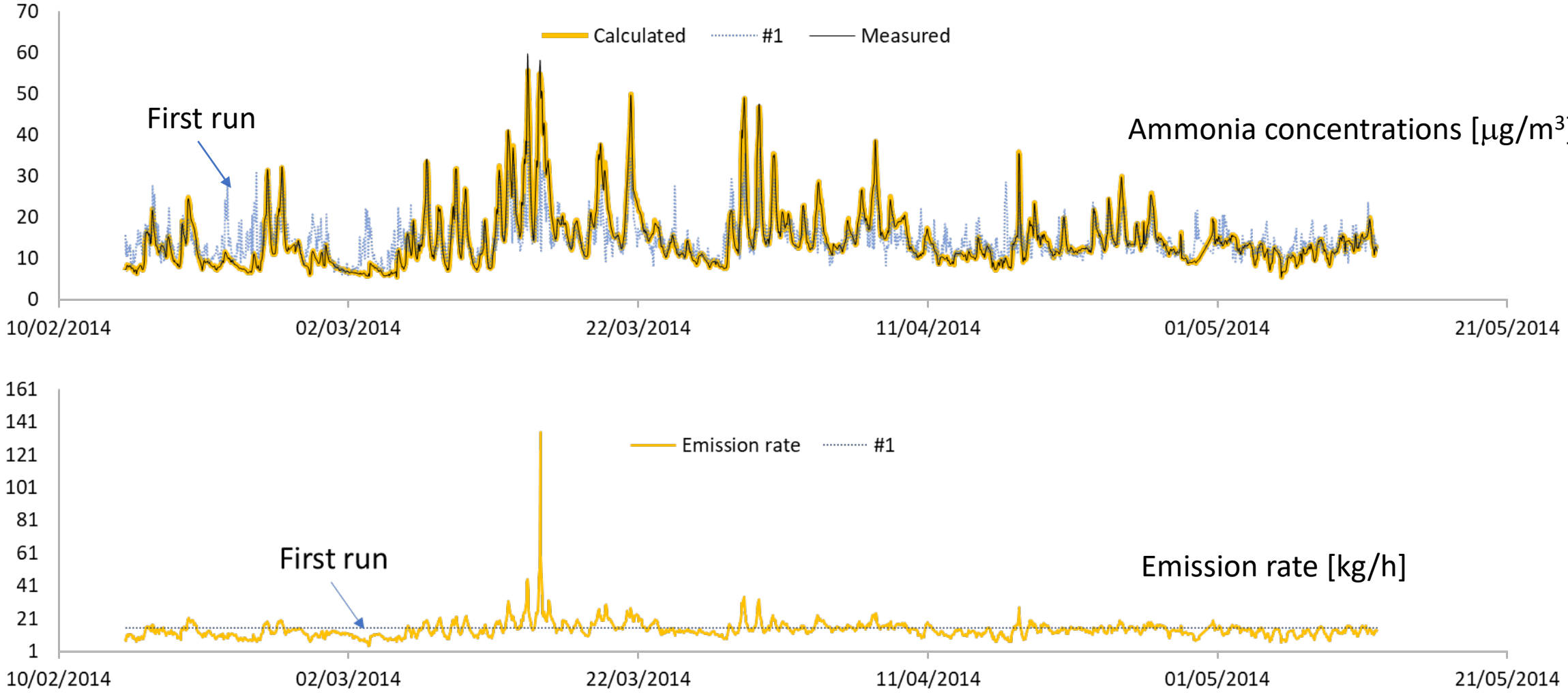




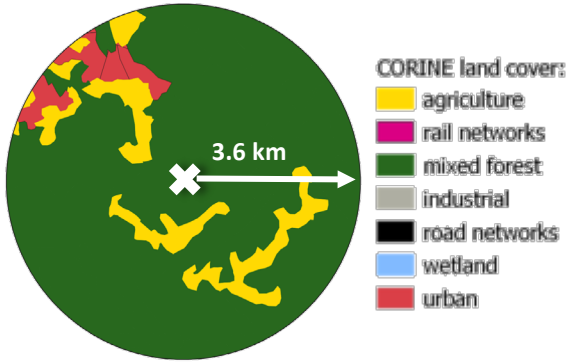
ML Random Forest (train and test) → NH_3 concentrations prediction → Prediction vs Measurements

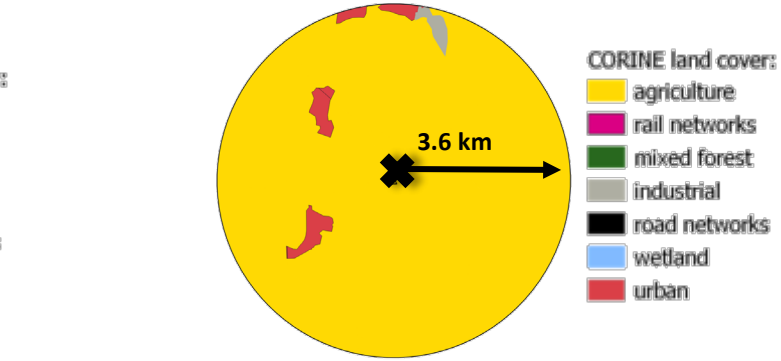
Prediction vs Measurements → Correction of Hourly emission rate → **Hourly emission rate**: • NH_3 emission [kg/h] → ML Random Forest (train and test)

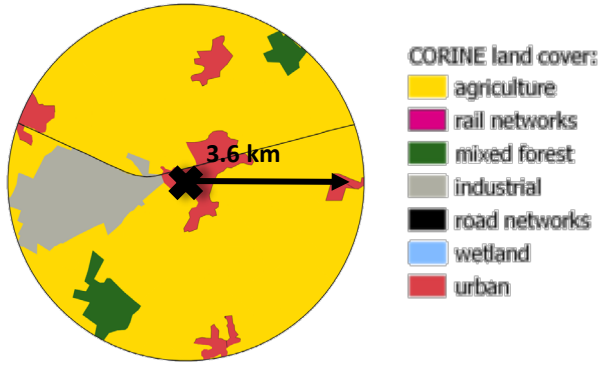
Iterative application of Random Forest

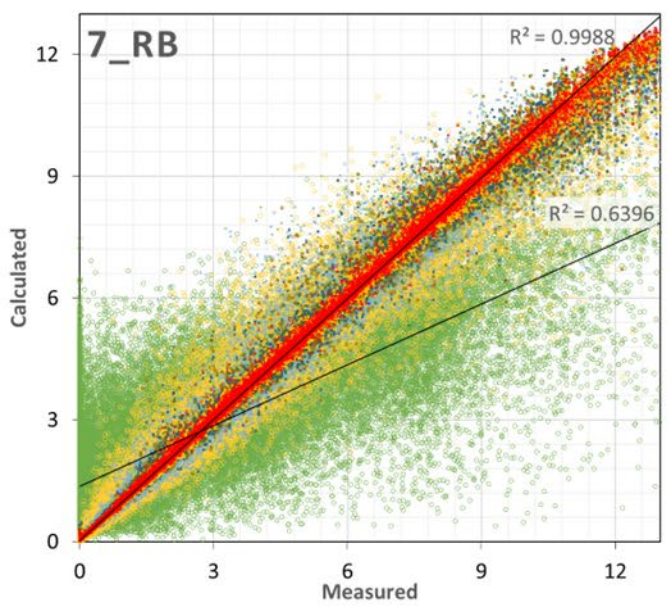


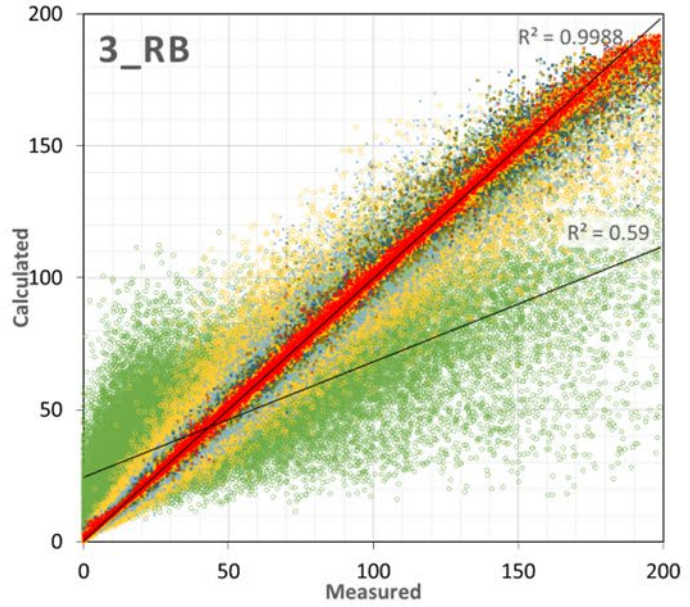
Convergence of the model

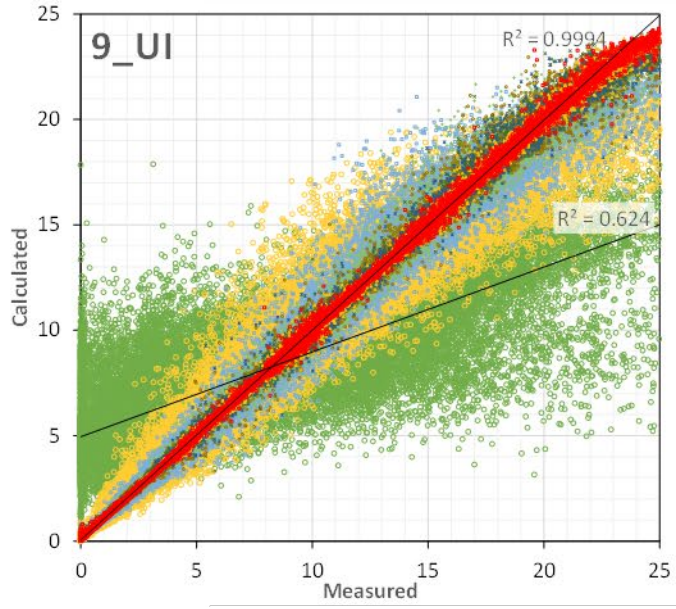




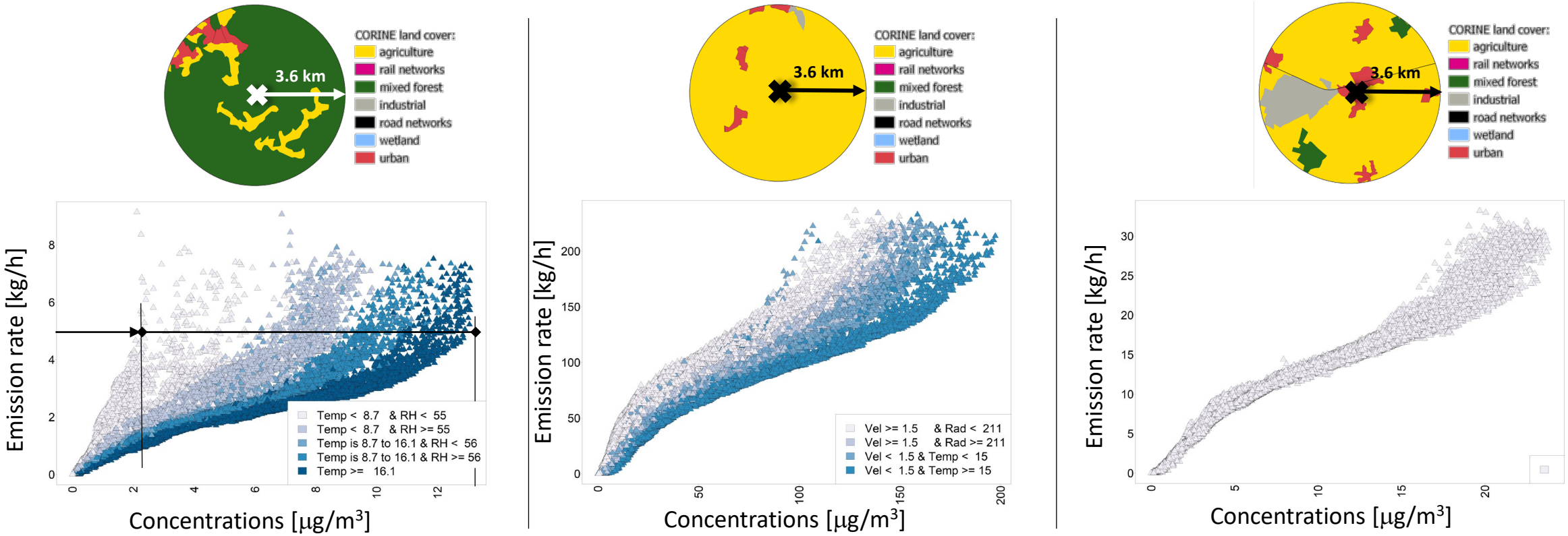








Emission rates and Concentrations of Ammonia



0.2 0.6 0.9

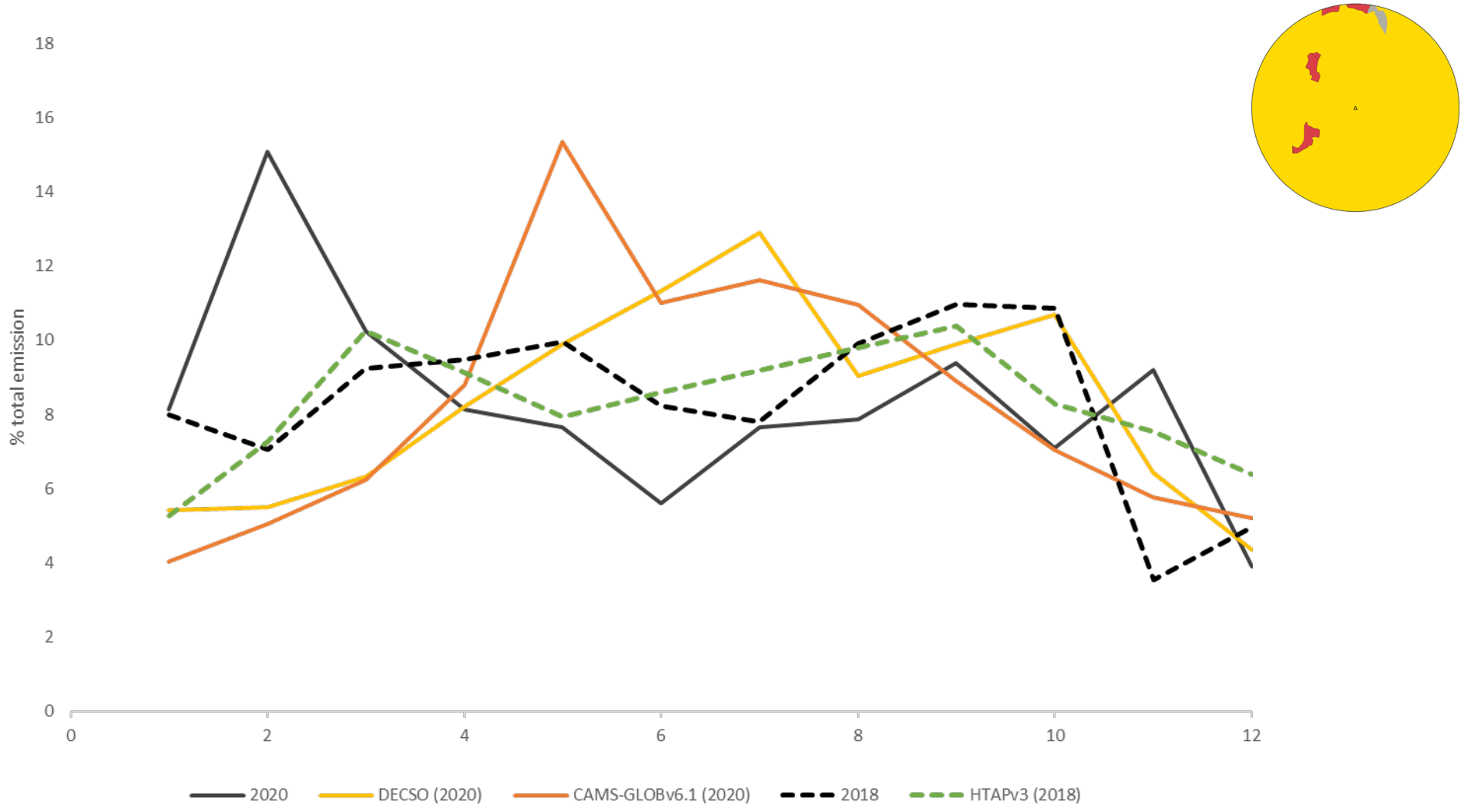
Impact of emission rates to concentrations (R^2)

0.3 0.2 < 0.2

Impact of meteorological parameters to concentrations (R^2)

Emission rates of NH3 from SEEDS

NH3 monthly emissions variability



Conclusions (I)

ARPA LO is the Environmental Protection Agency of Lombardy Region.

Specifically, the AEI Unit deals with the **following main tasks**:

- manages and update the Atmospheric Emission Inventory
- collaborates with emission scenarios and projections in National/International projects
- supports regional authority AQ action plan evaluation assessment
- has been updating and developing for 20 years the emission modelling system according to International Protocols and GB

For our needs **potentialities from the use of satellite data/CAMS/SEEDS products** can be found in:

- Relating activity indicators with data from independent sources
- Comparing with Bottom-up AEI results
- Improving emission estimation methods and algorithms

Conclusions (II)

The presentation has shown examples of use **NH3 emissions** from SEEDS and how they have been used to improve the ML implemented approach.

We are also interested to **other pollutants (example NOX)** and **other sources,** as traffic related emissions, industrial plume emissions, biogenic (NOx soil and BVOCs).

In relation to **spatial resolution**, we are primarily interested to urban pattern scale, facility level scale, but for AEI intercomparison goal also to larger scale ones (regional, national)

For our needs **temporal resolution** could be potentially useful from hourly to annual base:

- hourly for modelling purposes;
- annual for benchmarking bottom-up data;
- monthly for temporal profiles updating and improving.

The **preferable type of access** to satellite data would be automatic web-based download procedures (e.g.: API)

Conclusions (III)

As coming from the results of this study, the **combined use of estimation techniques and models, satellite data and measurements** certainly offers a great opportunity to improve inventories, to build up more detailed temporal emission profiles and more accurate high resolution emission estimates, to investigate atmospheric phenomena seasonability.