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European Commission

Italian National Research Council

31st January 2024

Improving air quality forecast in the Arctic with machine learning

Innovative Data Solutions: Applications of a Digital Twin and AI in the Arctic – Arctic Frontiers

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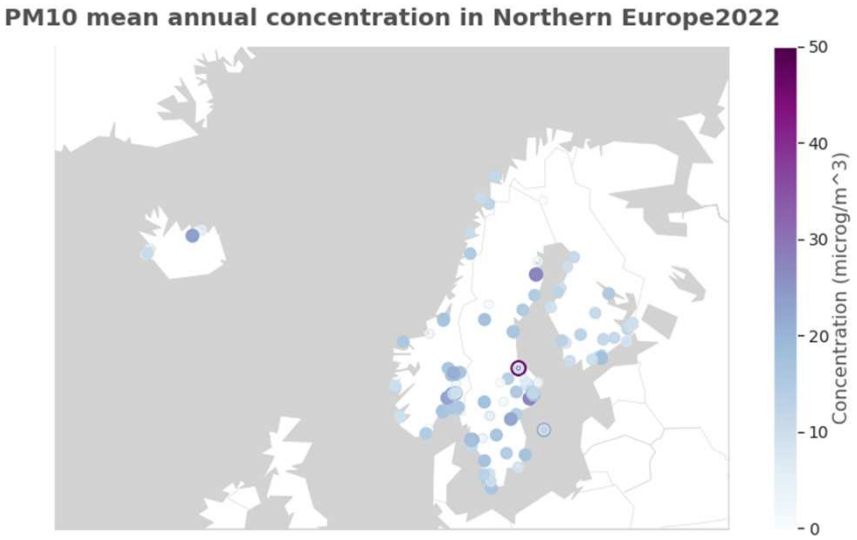
PM_{10} in North Europe

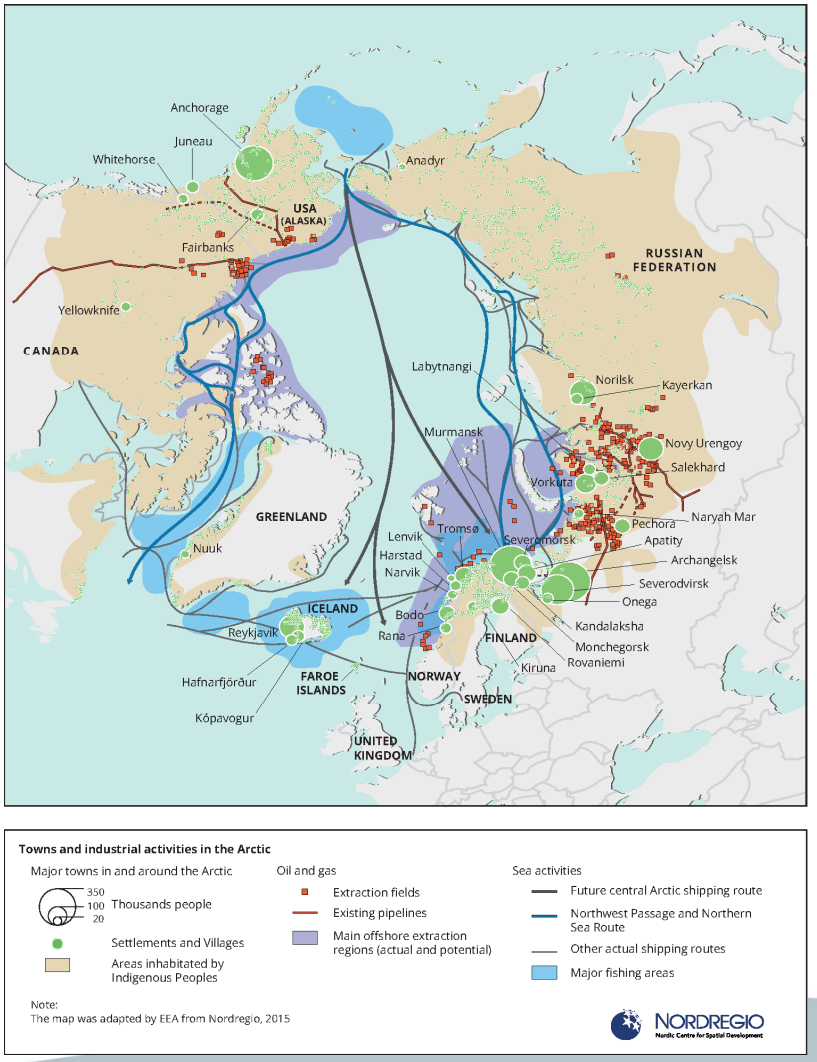
PM_{10} is a complex mixture of solids and aerosols with a diameter of 10 microns or less

It is inhalable into the lungs and can induce adverse health effects (respiratory, cardiovascular, etc.)

WHO 2021 recommendations
15 µg/m³ mean annual concentration
45 µg/m³ mean daily concentration

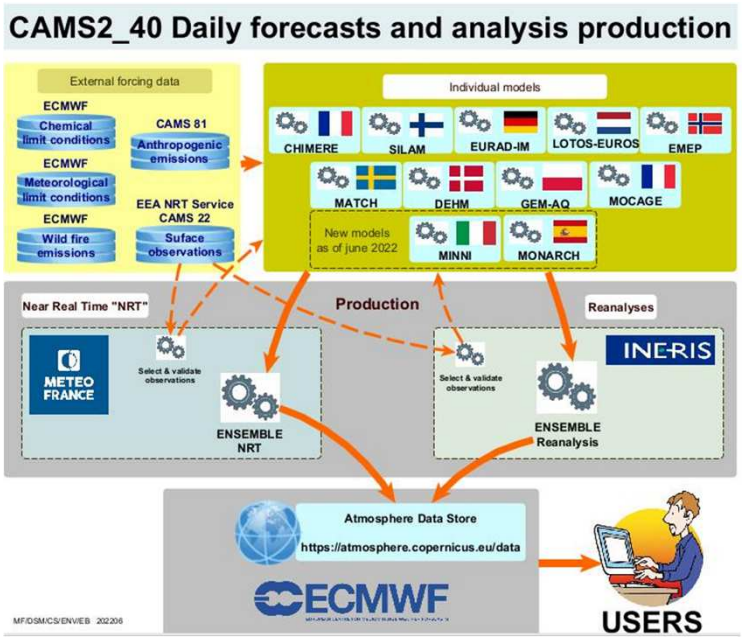


Data source: EEA

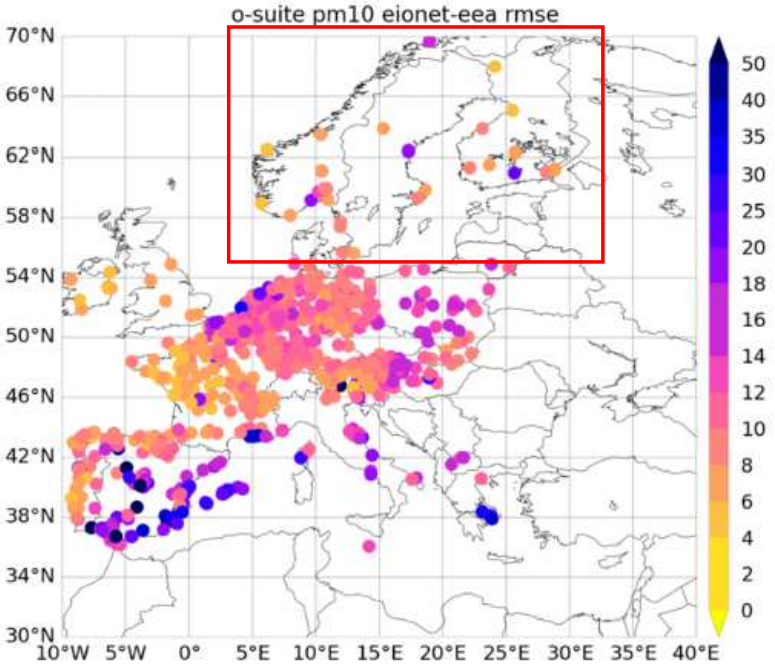


Map adapted by EEA from Nordregio, 2015

CAMS PM_{10} forecast performances

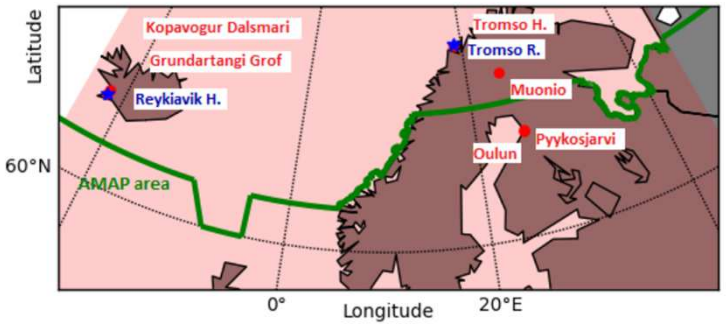


CAMS forecast and analysis scheme (https://confluence.ecmwf.int/)



RMSE for 24-hour forecasts (at 3hourly basis) of CAMS for the 1 June – 31 August 2021 and 3 hourly PM_{10} from EIONET measurements (Ramonet et al. 2021)

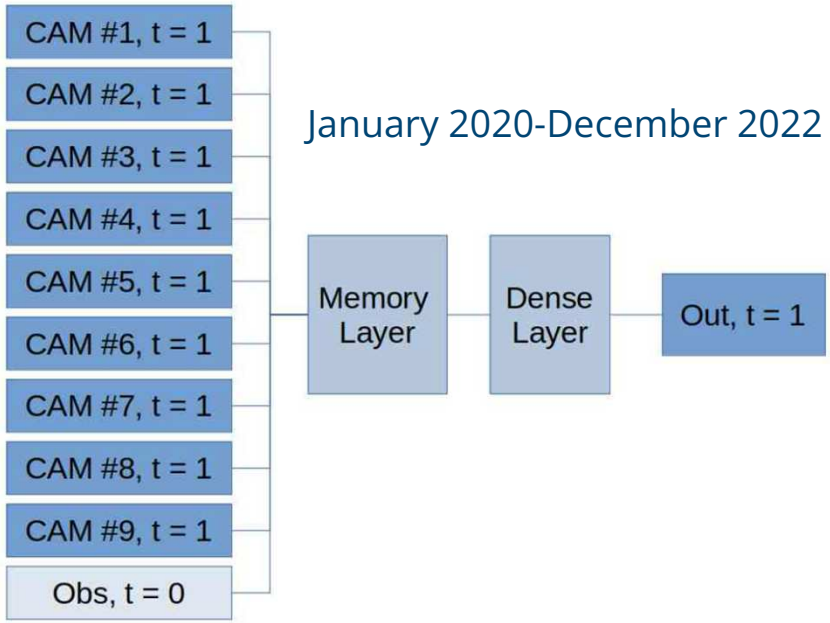
ML forecasting: a preliminary study



Article

Forecasting PM_{10} Levels Using Machine Learning Models in the Arctic: A Comparative Study

Paolo Fazzini [1,2], Marco Montuori [1,*], Antonello Pasini [2], Alice Cuzzucoli [2], Ilaria Crotti [3], Emilio Fortunato Campana [4], Francesco Petracchini [2] and Srdjan Dobricic [3]



January 2020-December 2022

Echo State Networks

Long Short Term Memory

Gated Recurrent Units

Recurrent Neural Networks

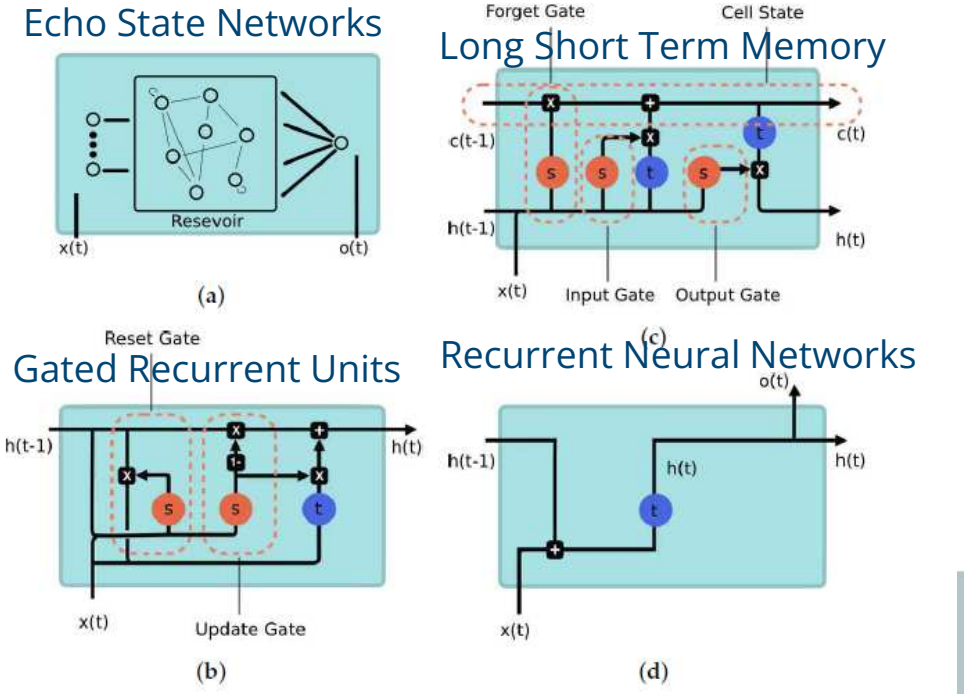
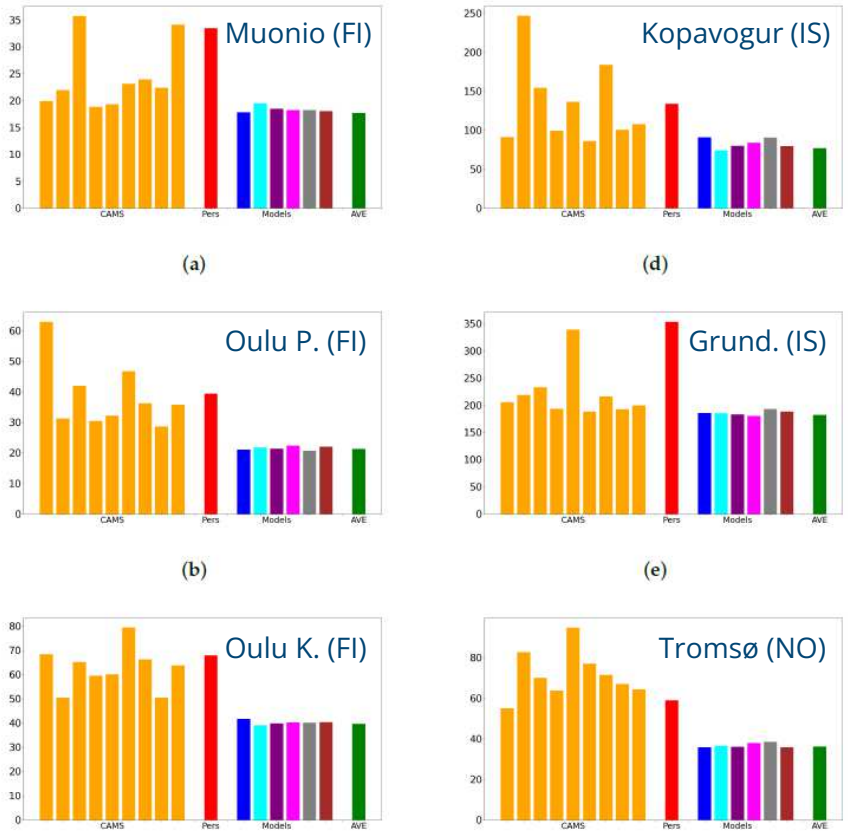


Figure 3. Various alternatives for the memory layer: (a) ESN. (b) GRU. (c) LSTM. (d) RNN.

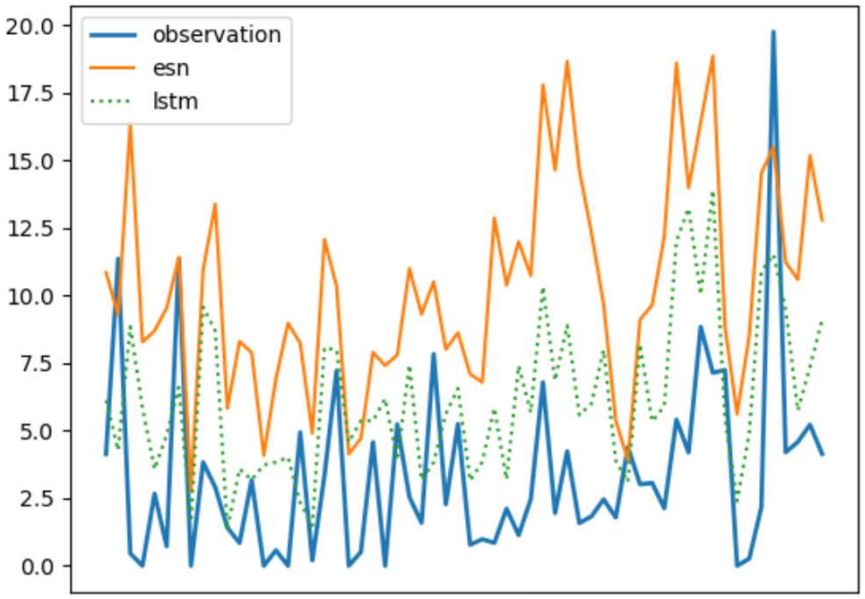
MSE ML forecasting: a preliminary study

MSE for 6 stations in the Arctic



Simulation Results MSE: CAMS 1 to 9 (orange), persistence (bar), Models ESN (blue), LSTM (light blue), GRU (purple), RNN (pink), WMP4 (gray), and WMP (dark red), models average (green) (Fazzini et al. 2023)

- ML forecasts outperforms the CAMS
- MSE improvements: 20-40%
- LSTM perform better



Comparison between measurements from Kopavogur D. (IS) station data with ESN and LSTM forecast (Fazzini et al. 2023)

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Future developments

Input data

- PM_{10} data at hourly frequency from ~ 100 monitoring stations (June 2020-June 2023)
- CAMS PM_{10} forecast (48 hours) at each station
- Meteorological variables (T, pbl, wind components, precipitation, humidity) at each station (ECMWF)

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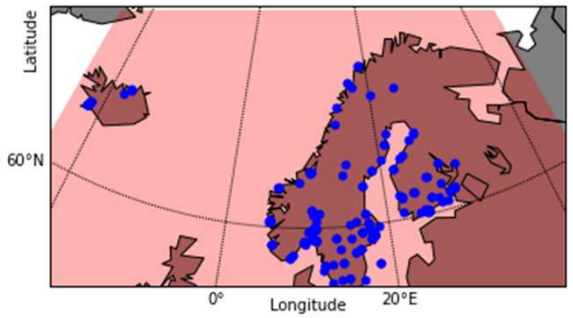
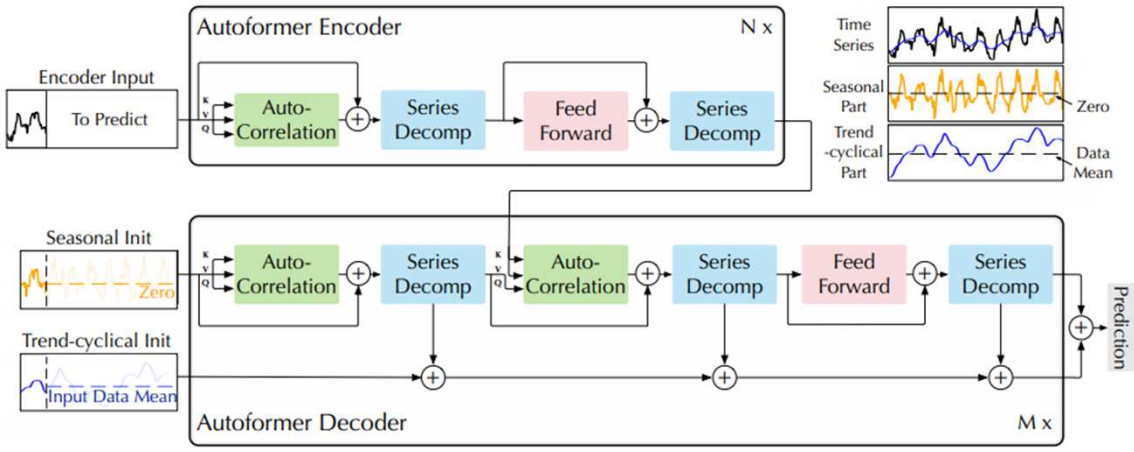


Deep learning models

- LSTM-networks used as baseline for long series forecasting
- Transformer architectures better tackle long-term dependencies exploiting time series decompositions and correlations



Source: Wu et al. 2021

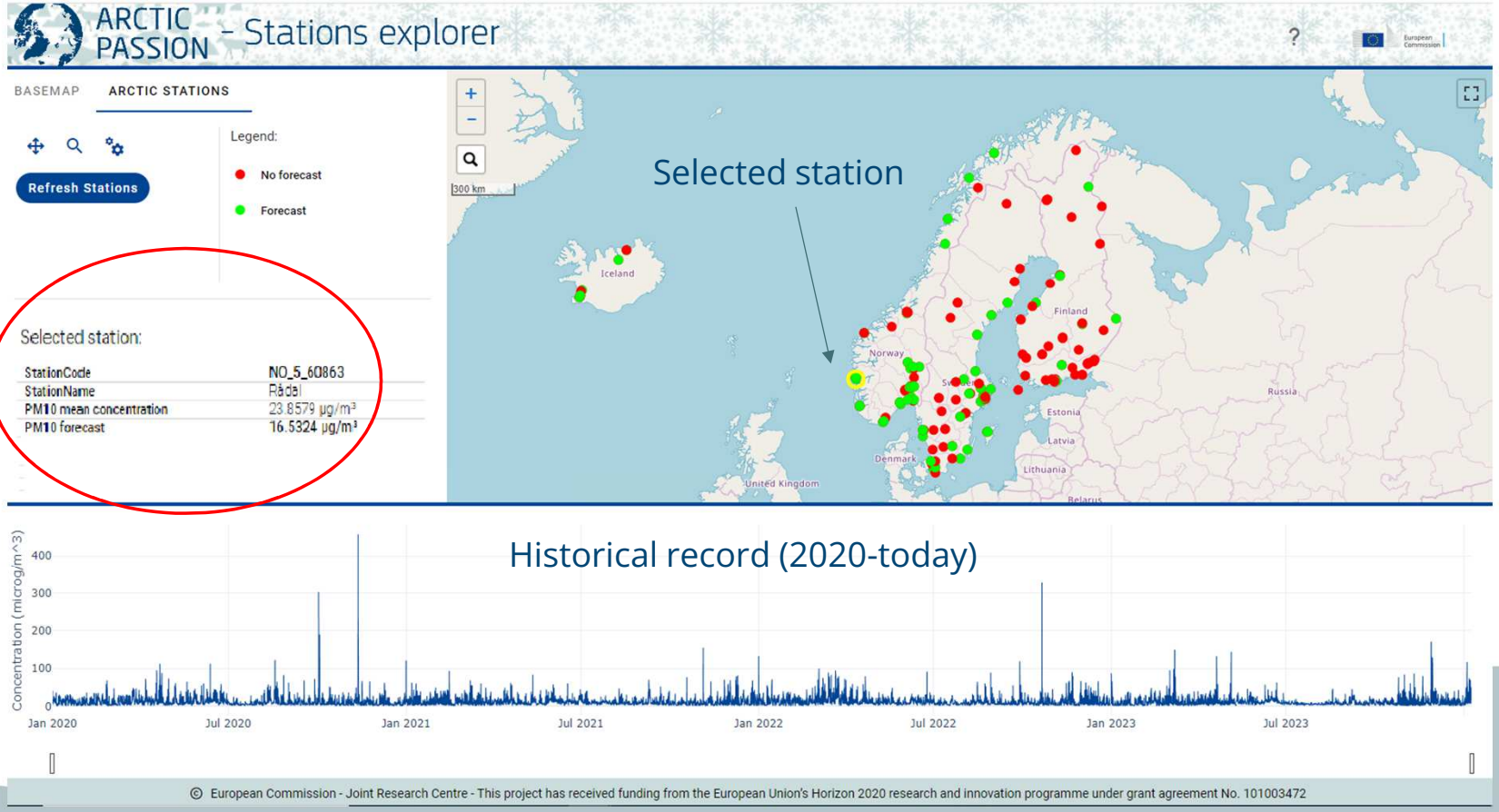
For ML contact: alice.cuzzucoli@iia.cnr.it

Dashboard for local air pollution forecast service

PRELIMINARY VERSION!

Interactive dashboard
- 200 stations (EEA and FMI networks)
- Daily PM_{10}
- 24h PM_{10} forecast

PM_{10} concentration + forecast + information on the station



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THANK YOU!
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