Estimating high resolution daily surface $PM_{2.5}$ over Europe using CAMS PM forecast, satellite AOD and a Machine Learning model

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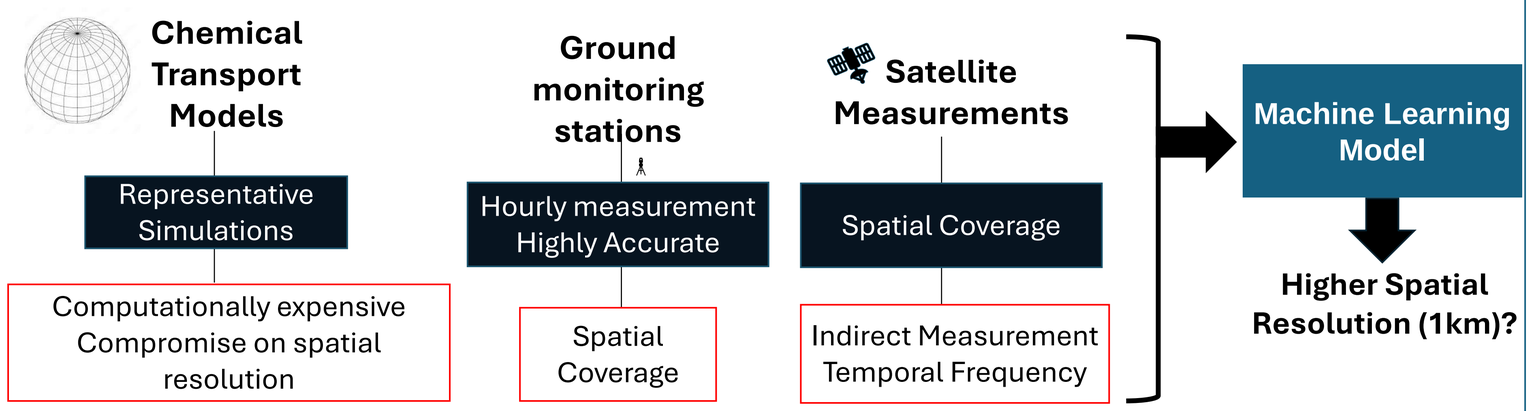
1. MOTIVATION

- Negative health impacts from $PM_{2.5}$
- High spatial resolution surface information required for assessment (Chen et al, 2021)

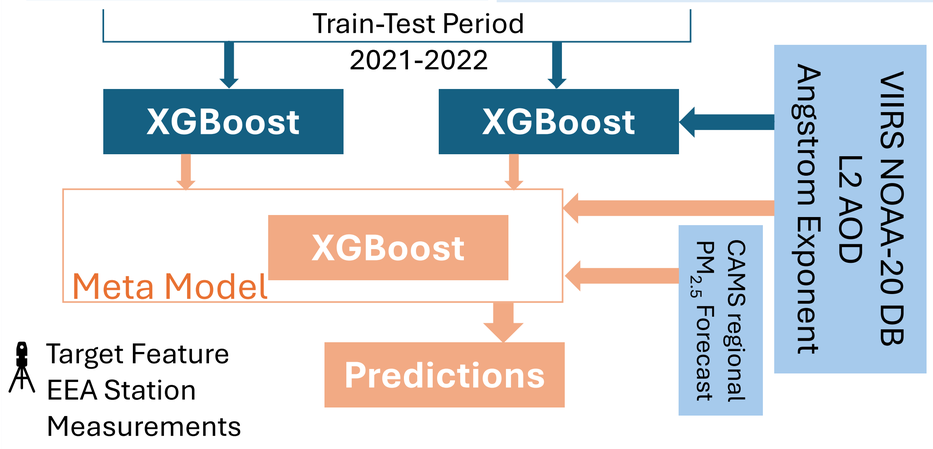
2. OBJECTIVE



A synergistic approach entitled S-MESH (Satellite- and ML-based Estimation of Surface air quality at High resolution) using chemical transport models, satellites and ML to derive daily averaged surface $PM_{2.5}$

3. METHODOLOGY

CAMS regional $PM_{2.5}$ Forecast	Population Density
SRTM Elevation and Change	ERA5 PBLH
ERA5 Wind Speed, Direction	ERA5 Land temperature
ERA5 Land total precipitation	ERA5 Land dew point temperature
ERA5 Land surface pressure	TROPOMI AAI

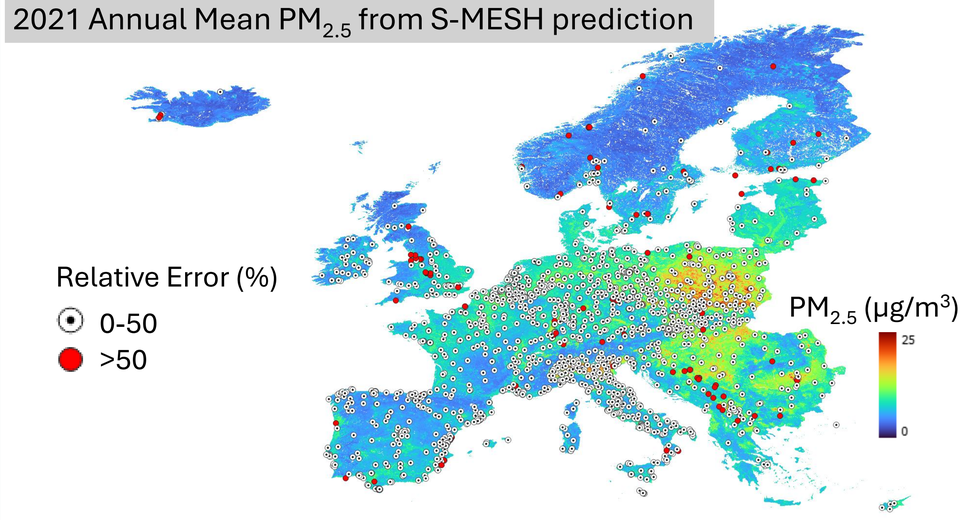


4. EVALUATION

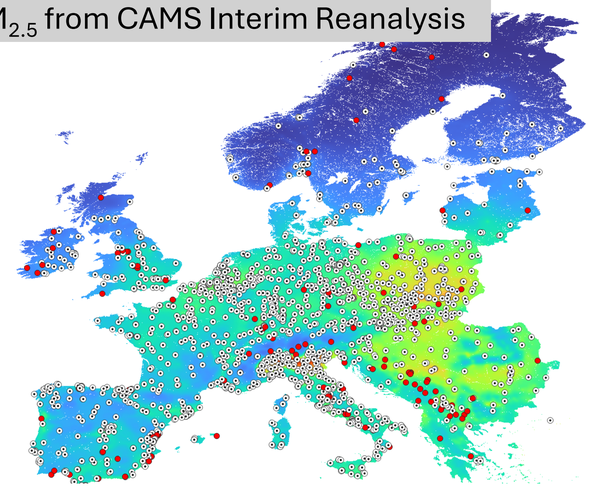
Evaluation and comparison of $PM_{2.5}$ from CAMS regional Forecast, ML prediction and CAMS interim reanalysis

	CAMS Forecast	S-MESH Prediction	CAMS Interim Reanalysis
MAE	4.36	3.62	3.4
RMSE	7.58	6.18	6.51
R^2	0.37	0.58	0.54

2021 Annual Mean $PM_{2.5}$ from S-MESH prediction



2021 Annual Mean $PM_{2.5}$ from CAMS Interim Reanalysis

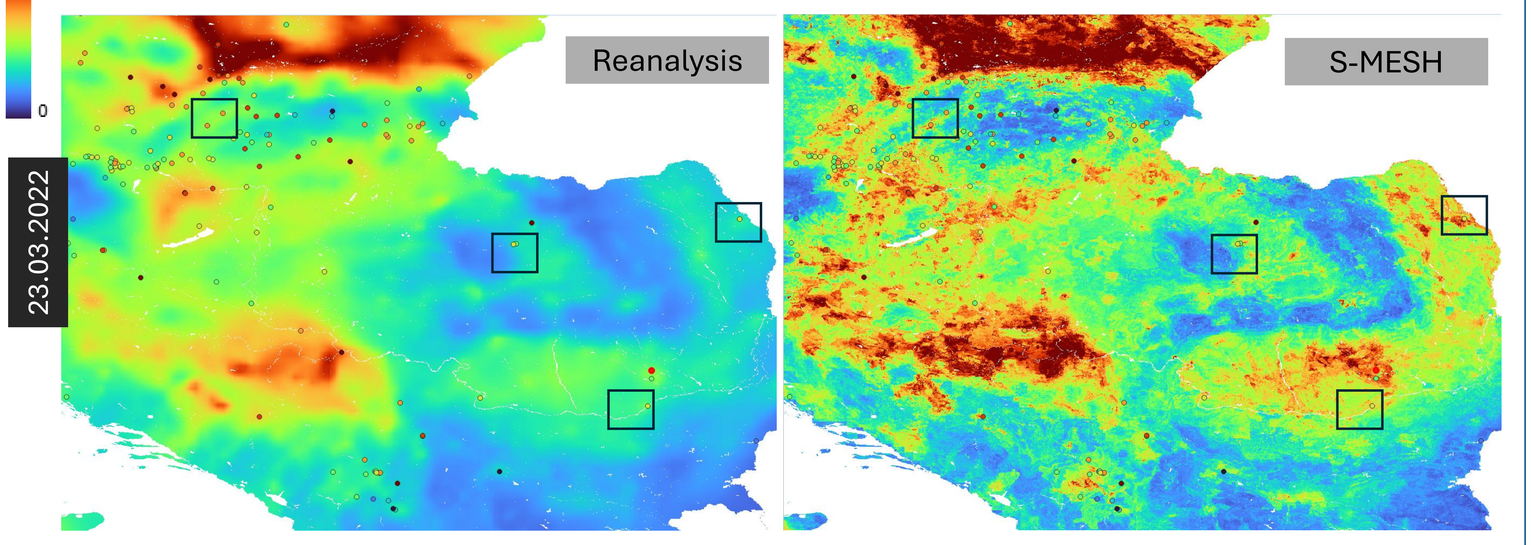


Validation against station measurement shows comparatively lesser >50% errors in ML predictions, especially over Poland and Italy

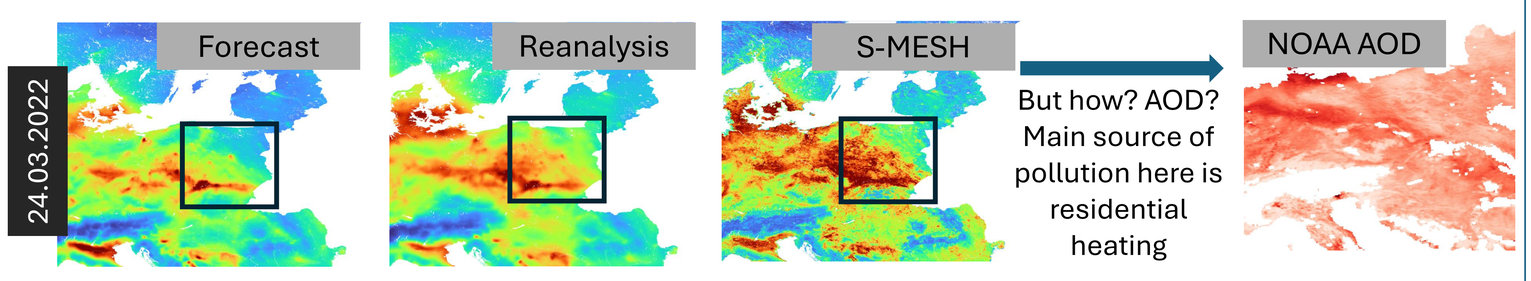
5. POLLUTION EPISODE – Comparison with Interim Reanalysis

$PM_{2.5}$ (µg/m³) — Daily averaged station observation

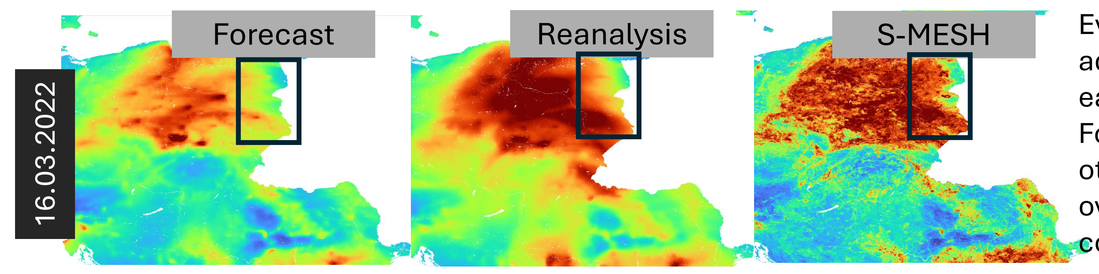
More detailed spatial patterns from S-MESH that closely matches station observation



Additional information derived from S-MESH that matches Reanalysis but is not present in Forecast

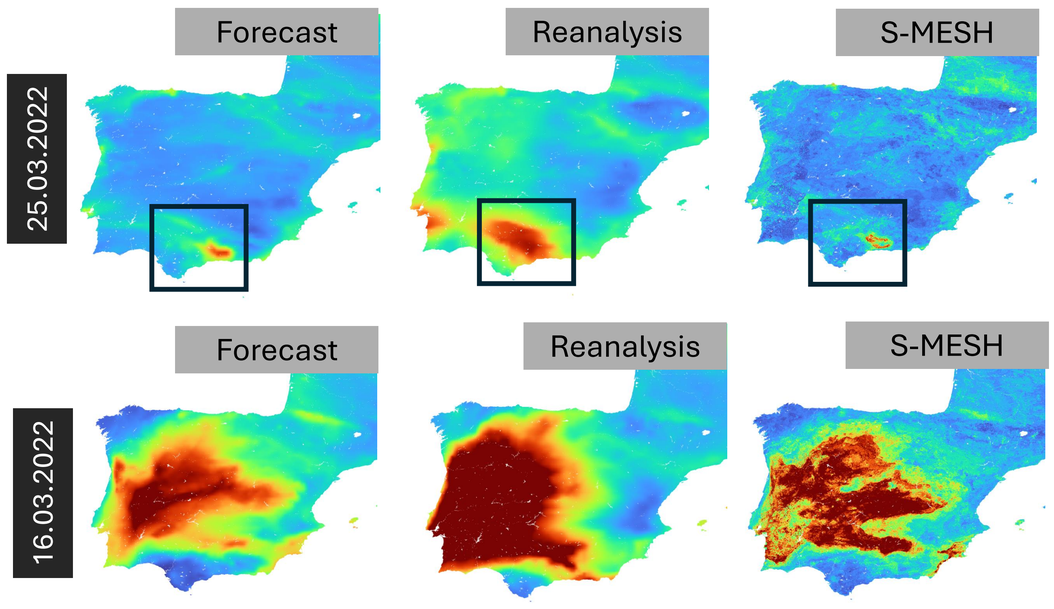


Improved predictions and spatial patterns over Eastern Europe compared to Forecast



Even in the absence of AOD data, additional information over eastern Europe, that is missing in Forecast is derived in ML using other parameters. The model over these regions acts as a bias corrector for Forecast

But over events of dust intrusion, model predictions can fail in certain scenario



Saharan dust intrusion not present in Forecast and when AOD data is missing, will not be captured by S-MESH model

Saharan dust intrusion episode captured by Forecast and hence all seen in S-MESH model, matching reanalysis

CONCLUSION

- S-MESH model derives downscaled high-resolution surface $PM_{2.5}$ information from CAMS regional $PM_{2.5}$ forecast using other input predictors and machine learning model
- S-MESH model spatial predictions matches that of CAMS regional interim reanalysis
- Improvements in surface $PM_{2.5}$ estimations over eastern Europe are observed in S-MESH compared to CAMS regional interim reanalysis
- S-MESH fails to capture certain pollution episodes such as dust in the absence of AOD or if not present in CAMS Forecast

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