

# meteoblue learning multi-model (MLM)

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A quick introduction

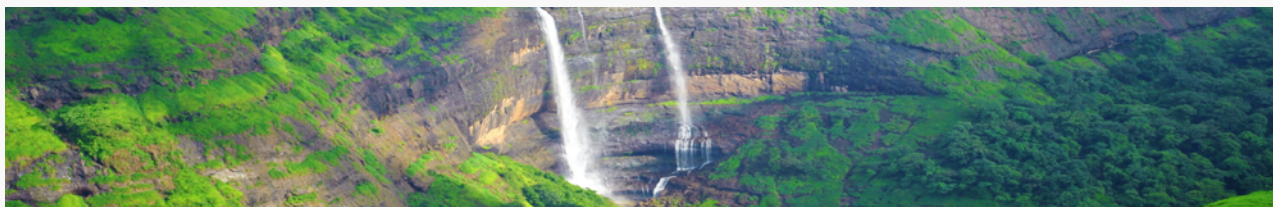
## INTRODUCTION

Numerical weather forecast models have been continuously improved in the last decades to e.g. improve the forecast of the 2 m air temperature.

Probabilistic methods based on ensemble predictions, model output statistics (MOS) and multi-model approaches have been developed to increase the model skill.

Multi-model approaches or MOS typically have a larger skill than raw models as they benefit from an error cancellation of the raw models.

Artificial intelligence is further used to increase the model skill by weighting and selecting different forecast models depending on region, season, forecast lead time and weather conditions.



## METHODS

The meteoblue learning multi-model (MLM) uses machine learning approaches to operationally forecast the 2 m air temperature.

Analysis of model performance of 2 m air temperature at worldwide 35'777 meteorological stations for 61 days (26.08.2018 – 25.10.2018).

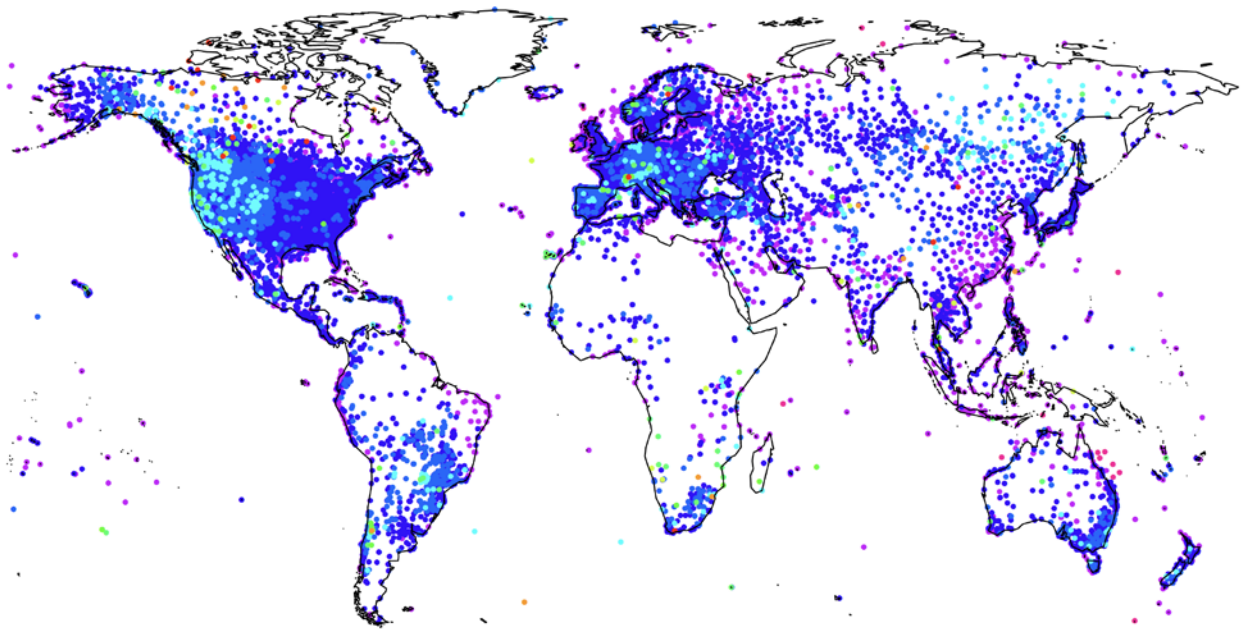
Comparison with five different weather forecast models, MOS and historical climate analysis (ERA5).

Analysis of the model skill as a function of forecast hour.

## RESULTS

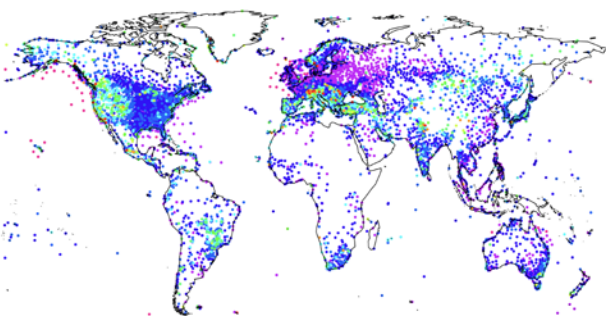
### Comparison of temperature errors as computed by different modeling approaches

Mean Absolute Error (MAE) - MLM (34701 stations)



• < 0.5 K • 0.5 - 1.0 K • 1.0 - 1.5 K • 1.5 - 2.0 K • 2.0 - 2.5 K • 2.5 - 3.0 K • 3.0 - 3.5 K • 3.5 - 4.0 K • 4.0 - 4.5 K • 4.5 - 5.0 K

MAE [K] - ERA5 (11601 stations)



MAE [K] - GFS (11601 stations)

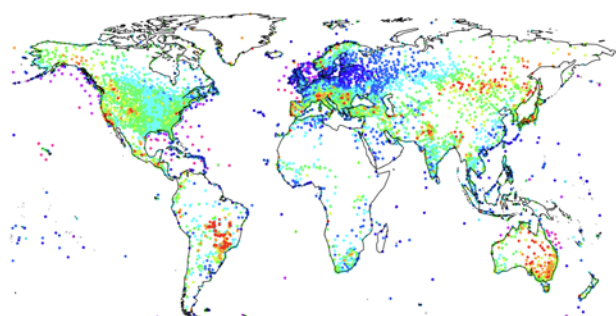


Fig. 1: Spatial distribution of Mean Absolute Error (MAE) of the Day 1 hourly temperature forecast as computed with MLM (top panel), the climate reanalysis ERA5 (bottom left) and the numerical weather forecast model GFS (bottom right) for September – October 2018.

RESULTS

Comparison of temperature errors as computed by different modeling approaches

model approach	MAE [K]
meteoblue learning multi-model (MLM)	1.2 K
Model output statistics (MOS)	1.5 K
Reanalysis model (ERA5)	1.5 K
5 Different weather forecast models (RAW)	1.7 - 2.2 K

Table 1: Mean Absolute Error [K] of the day-1 hourly temperature forecasts for different modeling approaches as evaluated at more than 11'000 observation sites.

Temperature error growth with forecast lead time

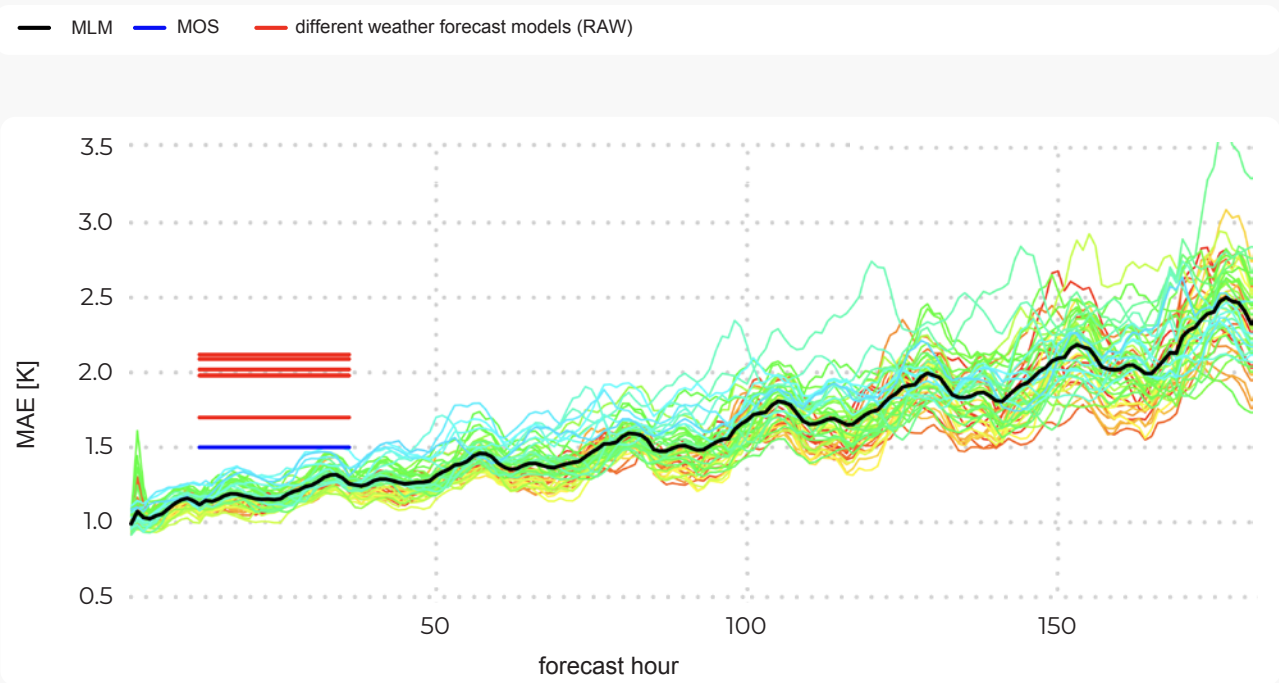


Fig. 1: Mean Absolute Error [K] as a function of forecast hour as computed by MLM for 60 consecutive 7-day forecasts (colored) and the average (black). The 12-36h forecast error for MOS (blue) and 5 different numerical weather forecast models (red) are also shown.



## RESULTS

### Sensitivity of the MLM temperature error to the forecast lead time

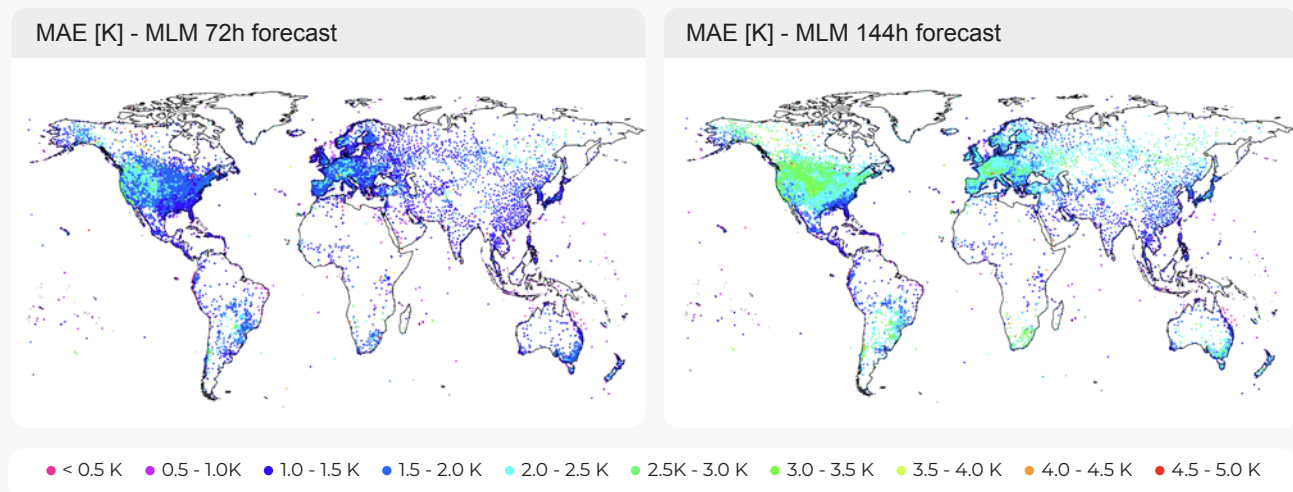


Fig. 3: Mean Absolute Error [K] of the MLM 72h forecast (left) and the 144h forecast (right), respectively.

## SUMMARY

MLM is an artificial intelligence based approach to optimally combine/select the best forecast models at any particular location and forecast lead time.

MLM performs significantly better than the climate reanalysis model ERA5, MOS based post-processing or stand-alone/RAW numerical weather forecast models (e.g. GFS) → Table 1.

A 6 day forecast of the MLM is as good as a 1 day forecast of global weather forecast models (Fig. 2).

Development of MLM for several other meteorological parameters (e.g. wind speed, humidity, radiation).

MLM is also available for precipitation.

## ABOUT US

### Precision weather company

- Provider of precision weather information every place in the world
- Founded in 2006, as spin-off from University of Basel in Switzerland
- Private company, debt-free, growing
- Customers in more than 50 countries by 2017

Delivers automated precision weather info:

- Worldwide - any point on land or sea
- Forecast and history, hourly since 1985
- High precision and consistency
- Multiple output: data, diagrams, services
- Easy to access - web, app, API, others

### Innovation leader

- Proprietary weather simulation technology
- Partnerships with Universities, NOAA, others
- Track record of innovation (with 100% green electricity)

First private company to provide:

- High resolution (<12 km) data for Europe, South America, China, India and Africa
- Own global hourly weather forecast model
- Detailed accuracy reports worldwide
- Hourly weather data - global coverage since 1985

### meteoblue offer

Designed for:

- Individuals having special interests in meteorology
- Business customers that depend on high precision weather and climate data
- Business customers requiring interactive analysis of environmental big data
- General public using our free high resolution weather forecast

Own high speed computer cluster and dedicated web servers

- High-performance weather models
- Proprietary visualisation
- Several output channels