4TH INTERNATIONAL WORKSHOP ON WAVES, STORM SURGES, AND COASTAL HAZARDS
Incorporating the 18th International Waves Workshop

AI Storm Surge Forecasting: Foundation models sensitivity analysis

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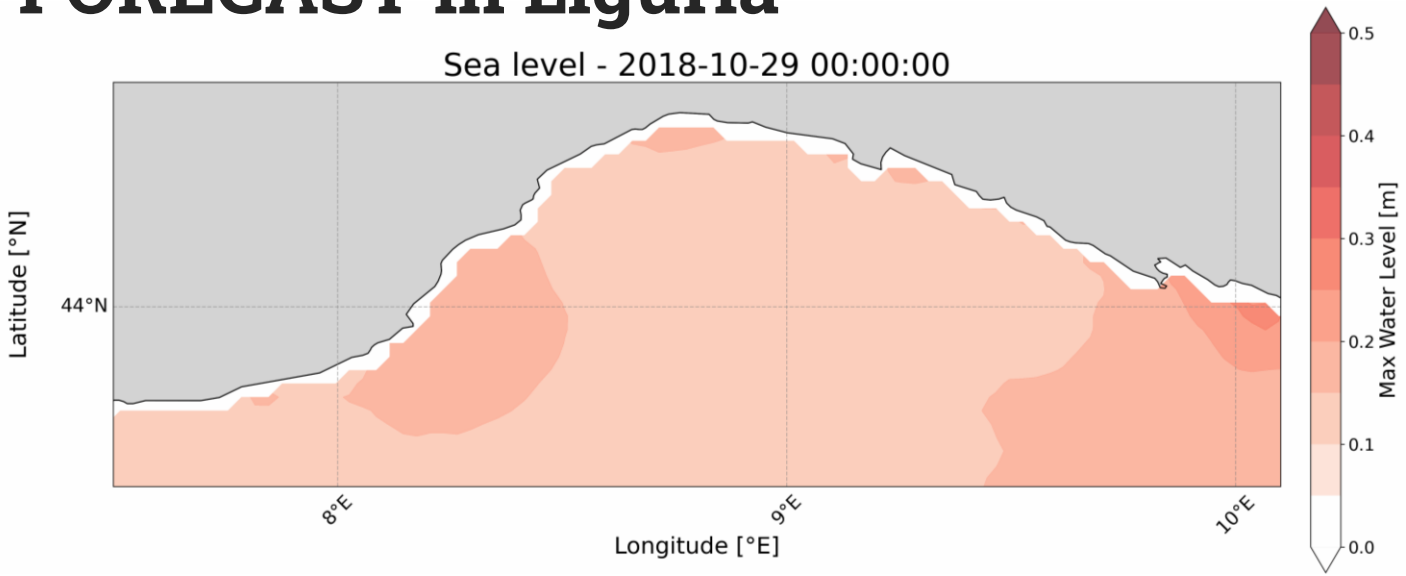
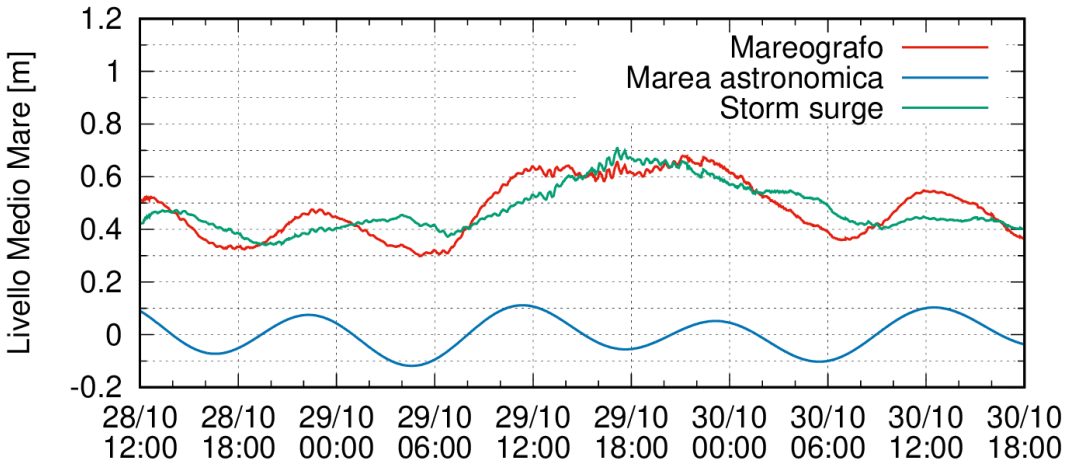
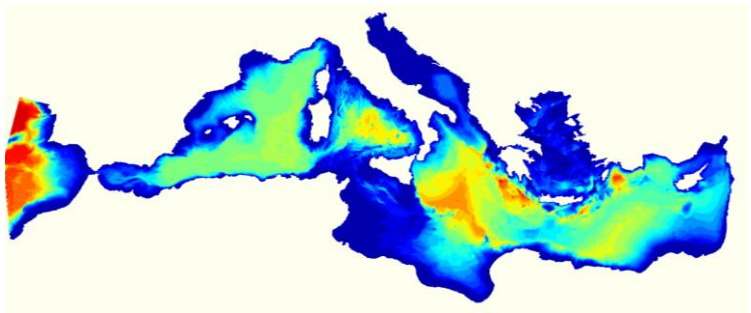
FORECAST in Liguria





Delft3D



→ MeteOcean DICCA (hindcast, 1979-2023)

→ Climate Models (projections, up to 2100)

→ Need for storm surge forecast

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Artificial Intelligence

Is the field of study

Machine Learning

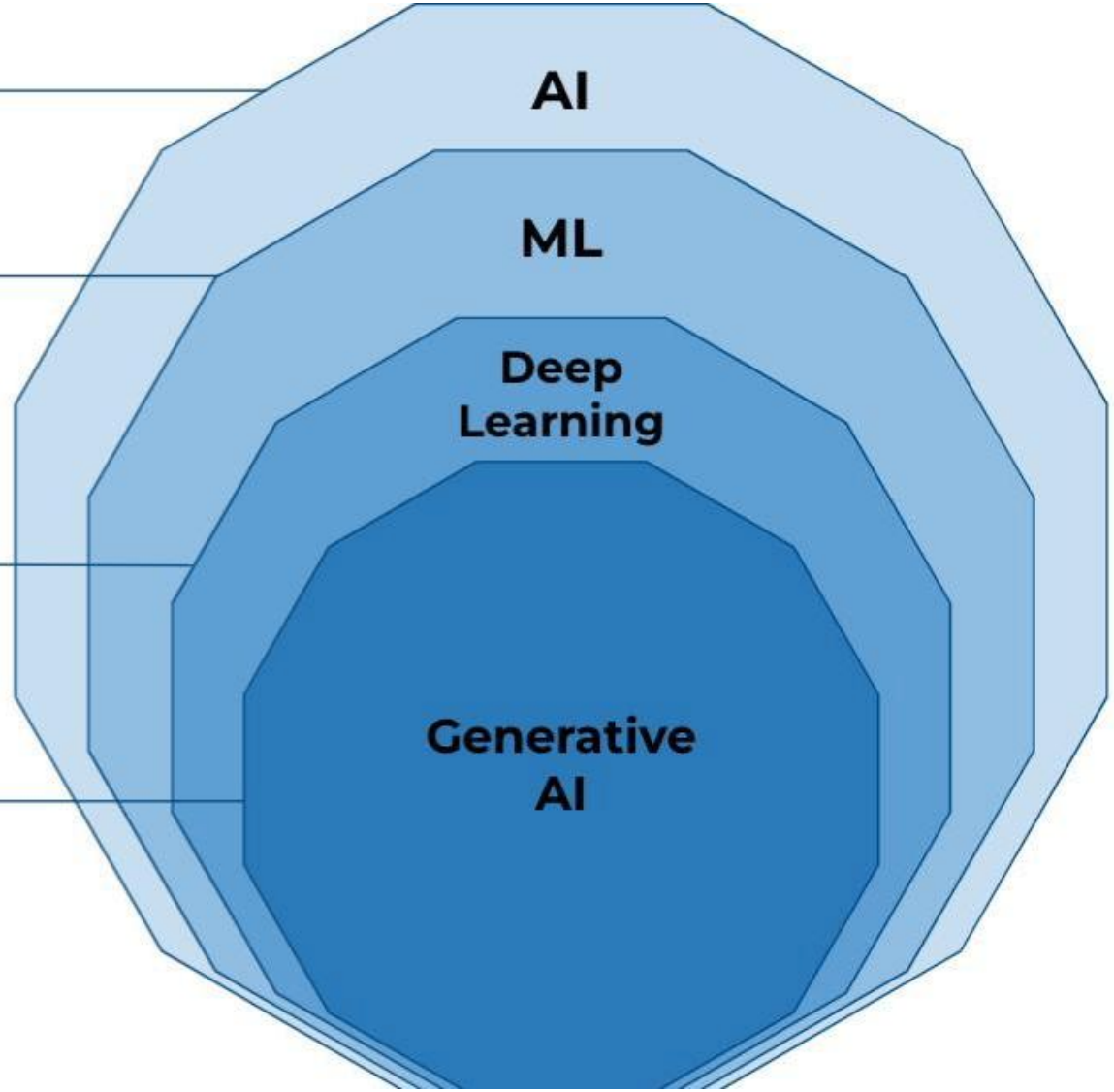
Is a branch of AI that focus on the creation of intelligent machines that learn from data. Another very well know branch inside AI is **Optimization**.

Deep Learning

Is a subset of Machine Learning methods, based on **Artificial Neural Networks.** Examples: CNNs, RNNs

Generative AI

A type of ANNs that generate data that is similar to the data it was trained on. Examples: GANs, LLMs

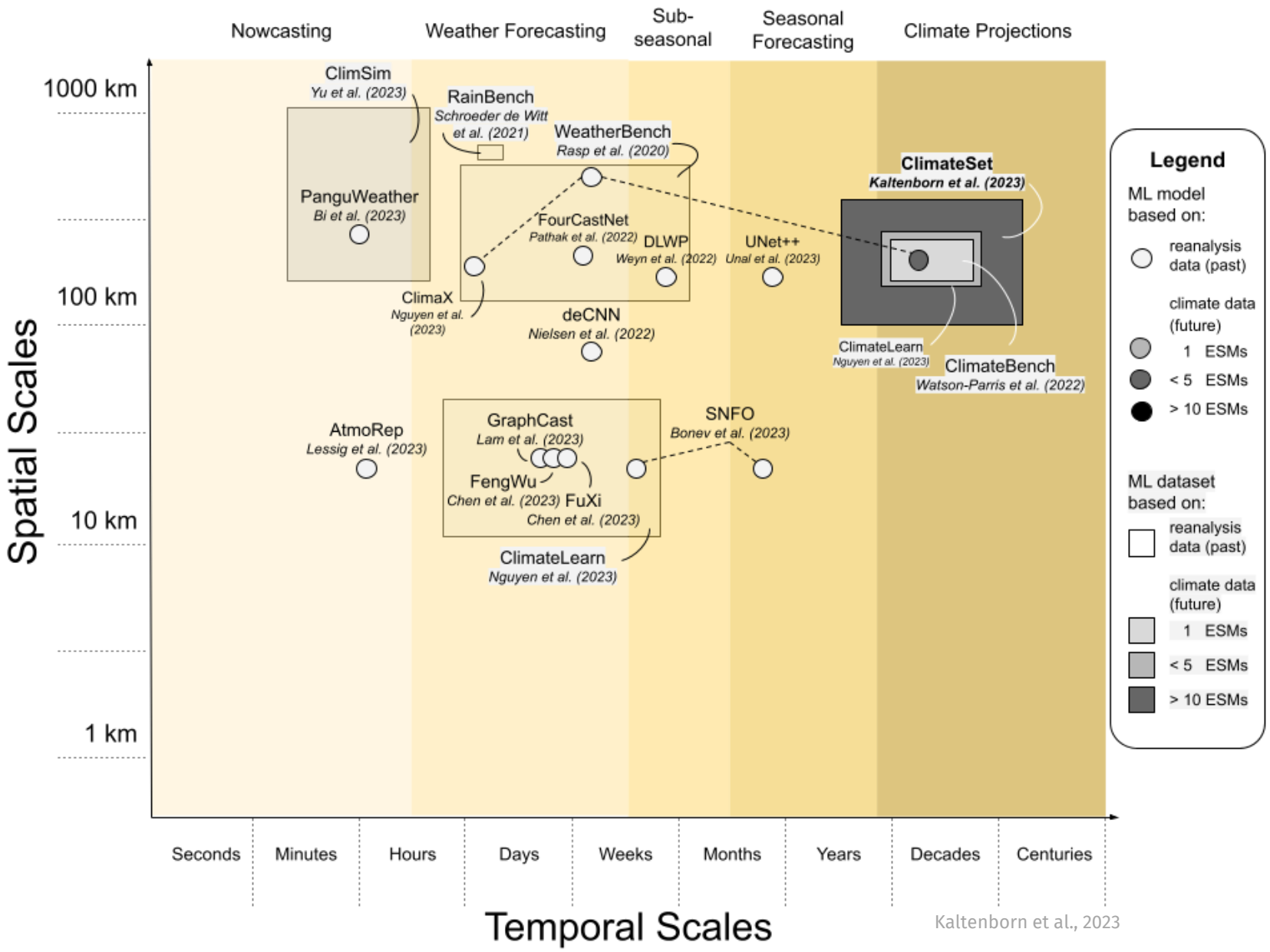


www.devoteam.com

Earth system GenAI

2023→ PanguWeather breakthrough in outperforming dynamical systems.

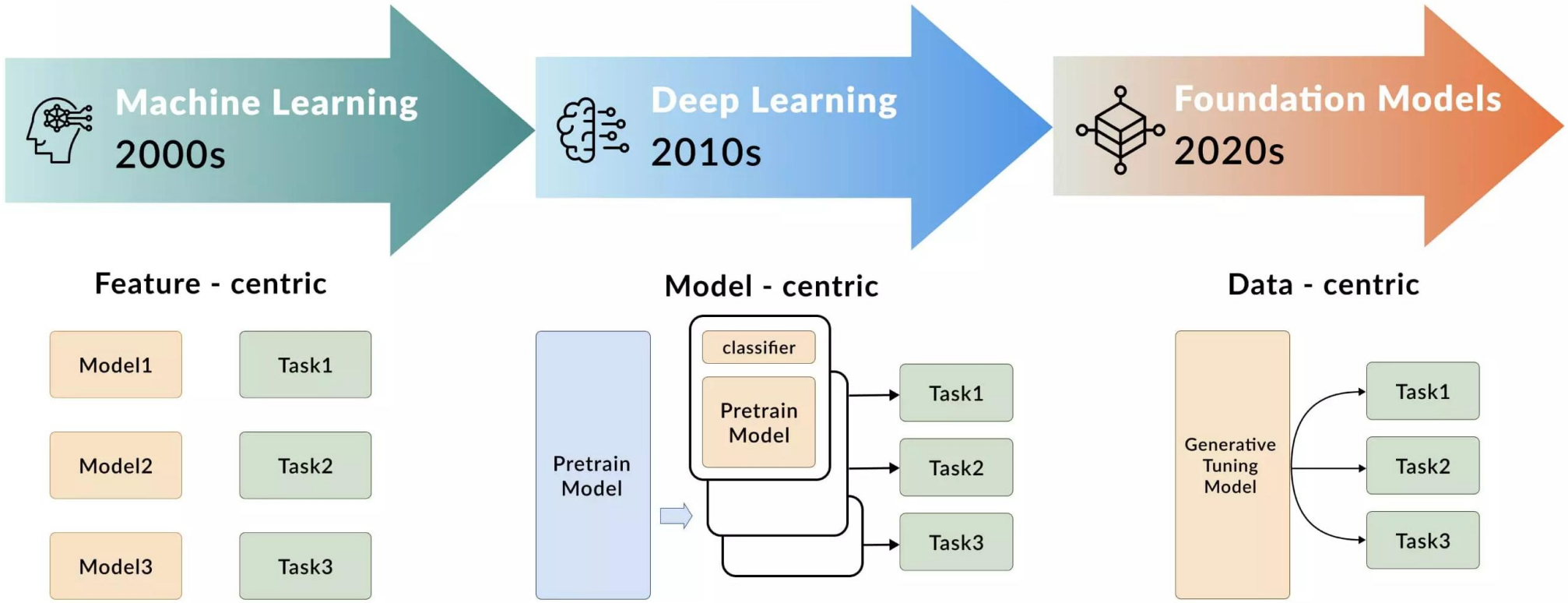
Focus on global medium-range weather → missing ocean dynamics and waves.



Kaltenborn et al., 2023

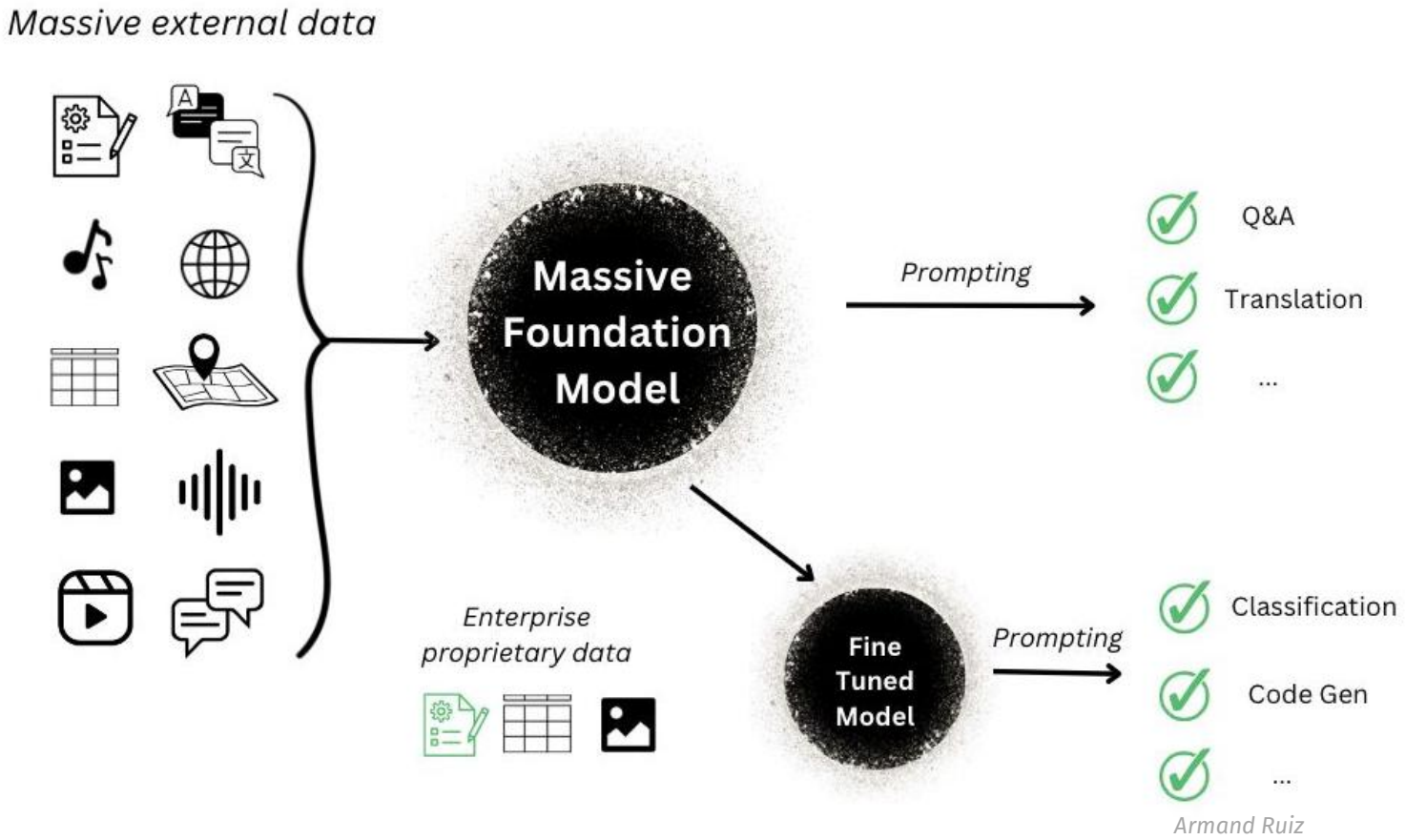
A New Era of AI: Foundation Models

Step function improvements over legacy AI technologies



Dataforest

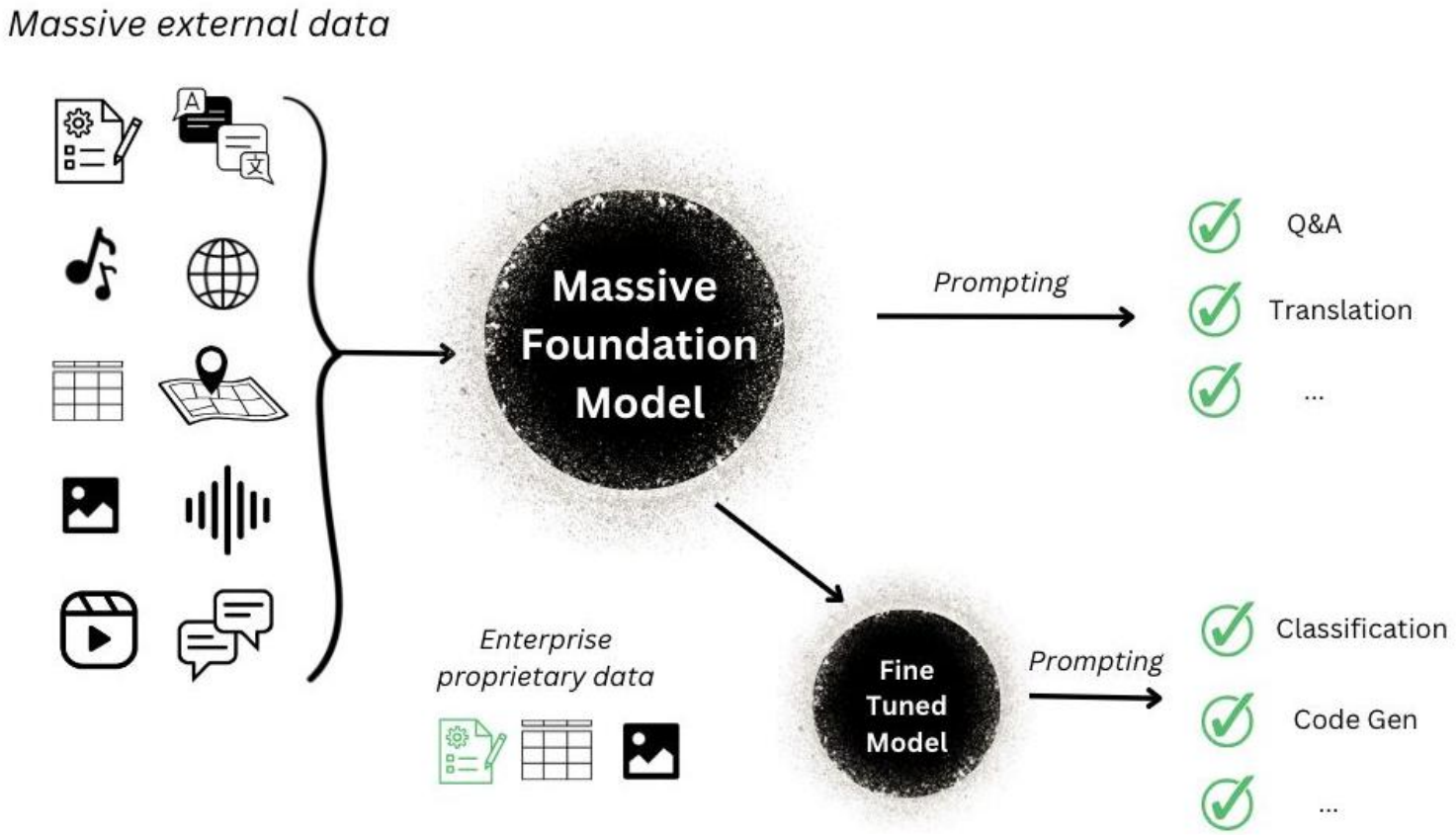
Foundation models



- Large-scale pre-trained model
- Adaptable with little or no training

- Enhanced performance
- Low cost to deploy (AI knoweldge)
- Reduced development time
- Cutting-edge technology
- Innovation

Foundation models



Time series FM:

TimeGPT (Aug-2023)
top accuracy and fastest inference

Lag-Llama (*Feb-2024*)
probabilistic forecasting

Chronos (*Mar-2024*)

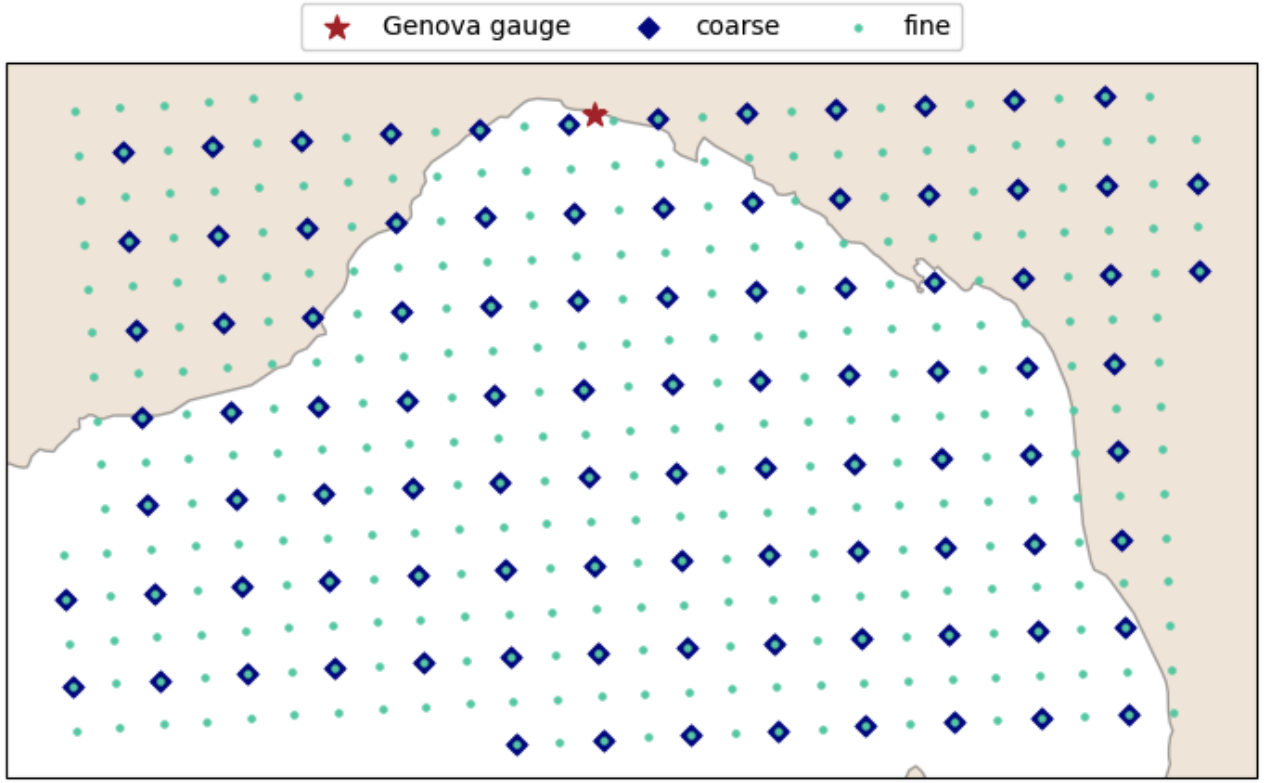
TimesFM (*May-2024*)
pretrained on ~100 billion points

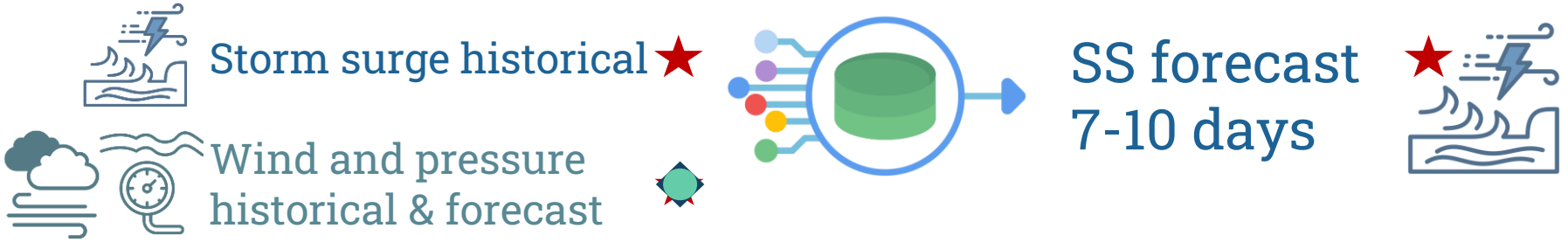
Earth system time series FM:

Aurora (Nov-2024 | May-2025)
state-of-the-art performance:
5-day global air pollution
10-day global ocean wave
5-day tropical cyclone track
10-day global weather forecasts

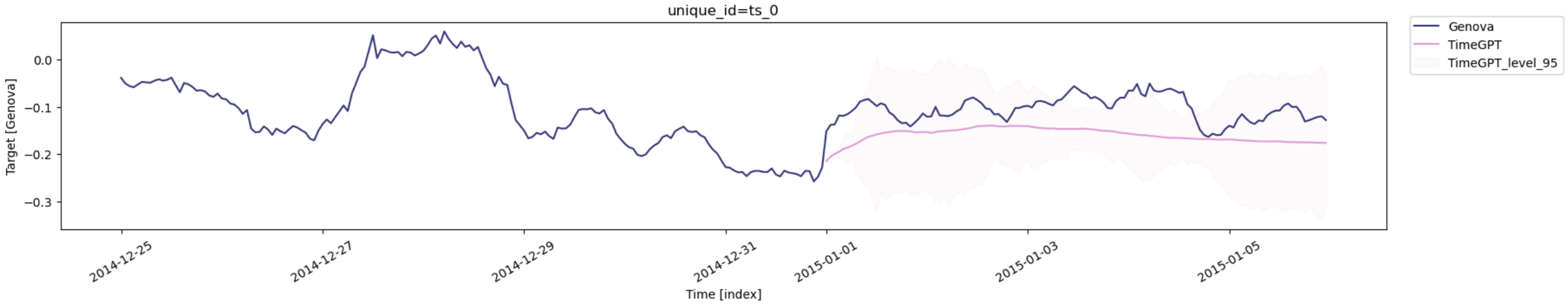
Foundation model capabilities

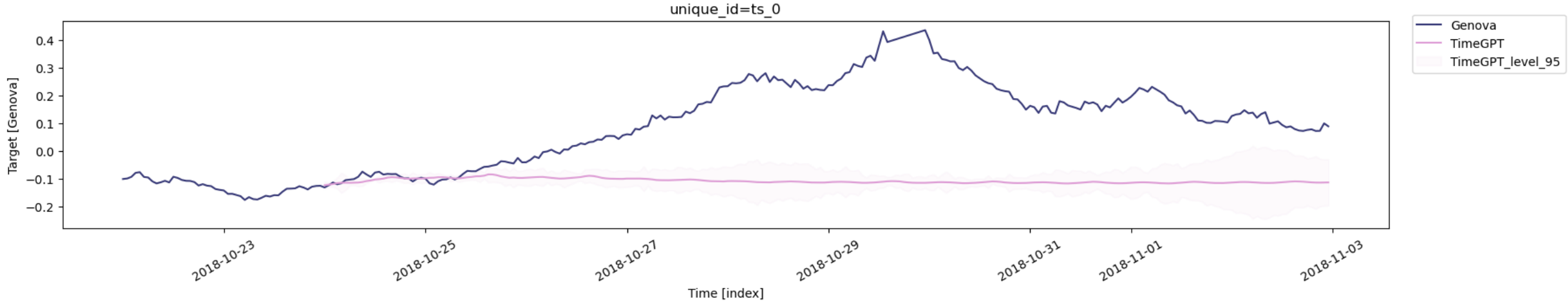
1. Benchmark forecast
2. Point forcings
3. Coarse-area forcing
4. Fine-area forcing





Benchmark Forecast nixtla TimeGPT





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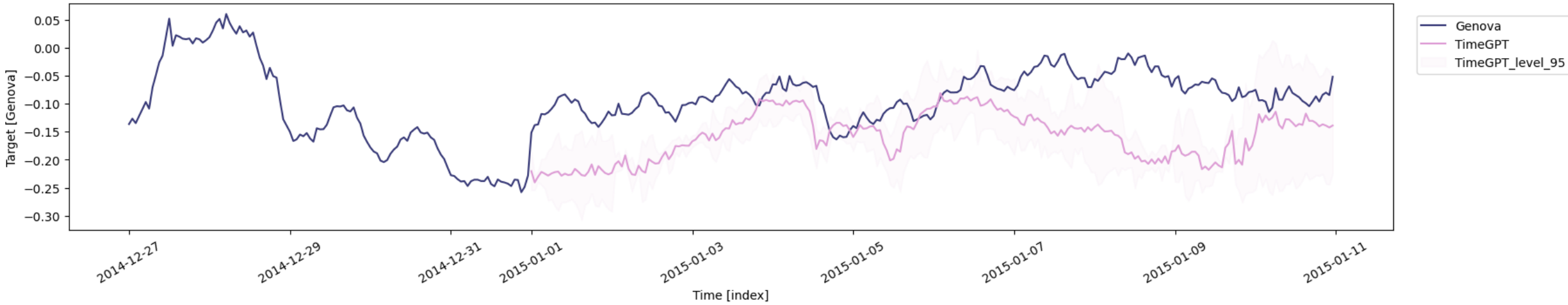
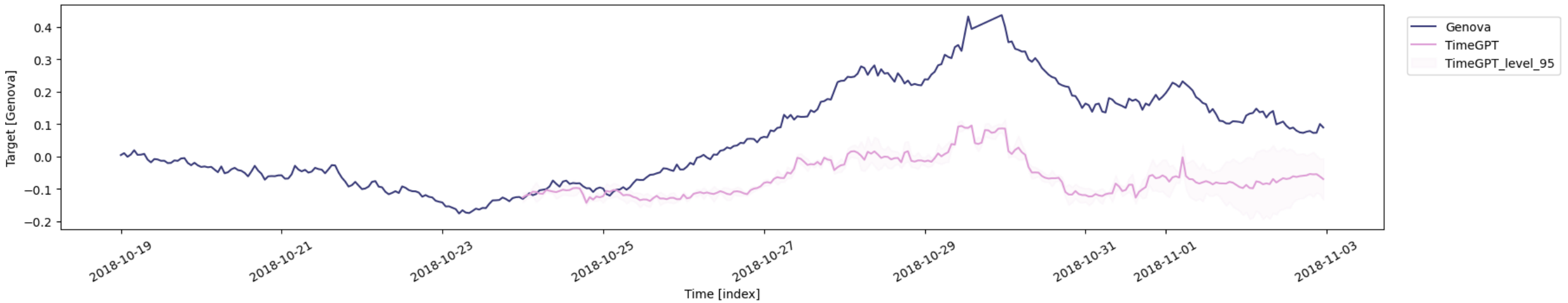
Point forcing

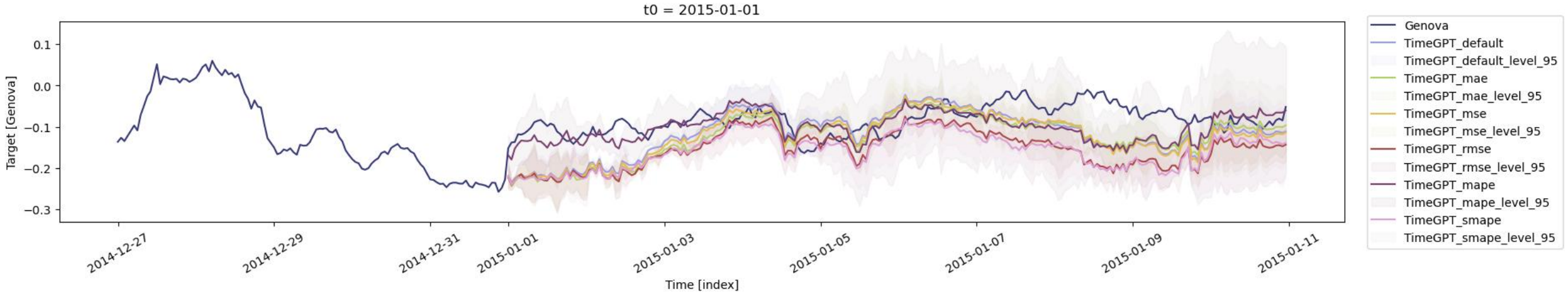
Fine-tune train 8 days
< 1 min



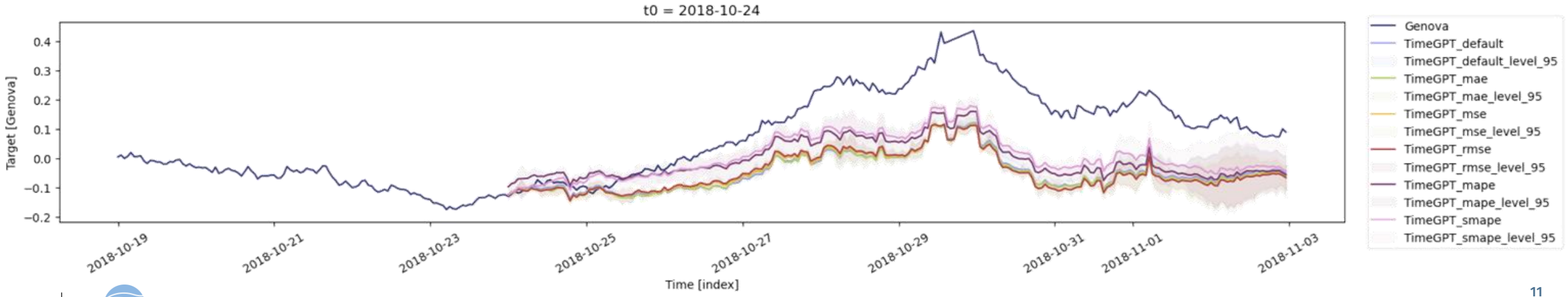


Point-forcing – Loss functions

metric	TimeGPT_default	TimeGPT_mae	TimeGPT_mse	TimeGPT_rmse	TimeGPT_mape	TimeGPT_smape
mae	0.05	0.06	0.06	0.07	0.04	0.08
rmse	0.07	0.07	0.07	0.09	0.05	0.09

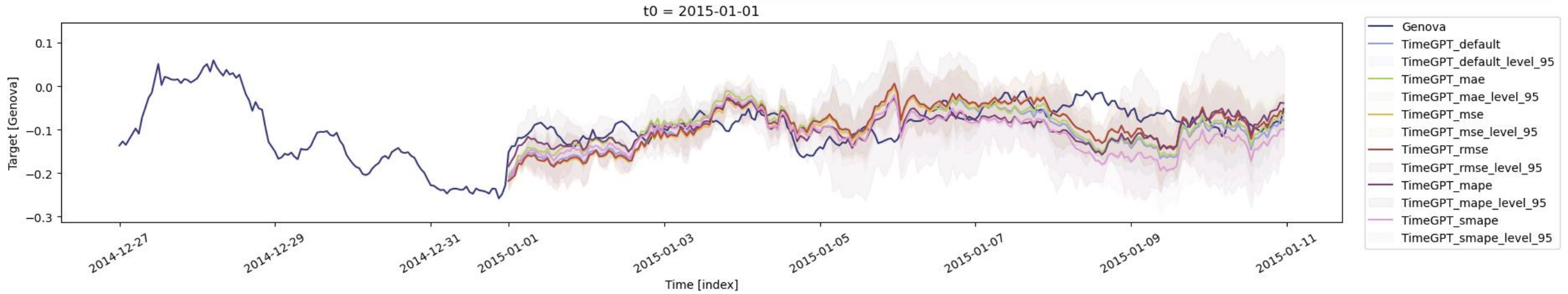


metric	TimeGPT_default	TimeGPT_mae	TimeGPT_mse	TimeGPT_rmse	TimeGPT_mape	TimeGPT_smape
mae	0.18	0.18	0.18	0.18	0.14	0.13
rmse	0.20	0.20	0.20	0.20	0.17	0.15

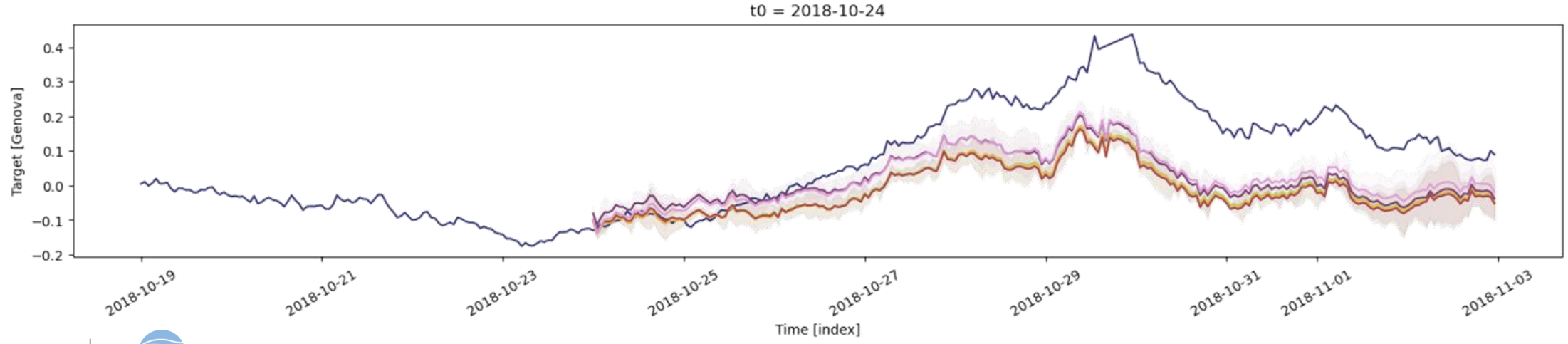


Area forcing - coarse

metric	TimeGPT_default	TimeGPT_mae	TimeGPT_mse	TimeGPT_rmse	TimeGPT_mape	TimeGPT_smape
mae	0.04	0.04	0.04	0.04	0.03	0.07
rmse	0.05	0.05	0.05	0.05	0.04	0.08



metric	TimeGPT_default	TimeGPT_mae	TimeGPT_mse	TimeGPT_rmse	TimeGPT_mape	TimeGPT_smape
mae	0.14	0.14	0.14	0.15	0.12	0.11
rmse	0.17	0.16	0.17	0.17	0.14	0.13



Area forcing – 2018 storm event

Finetune 13 days
< 1 min

t0 = 2018-10-27

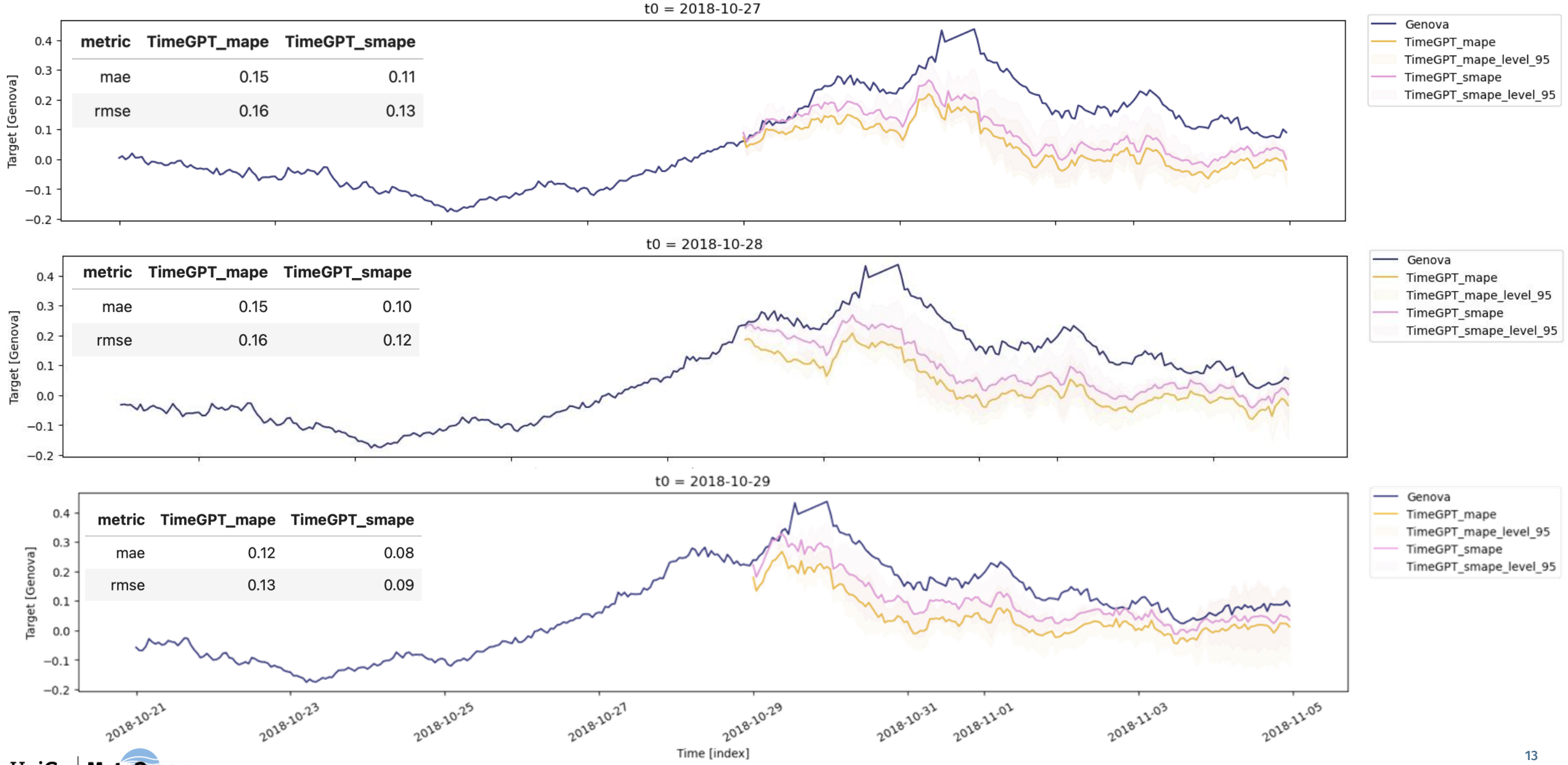
metric	TimeGPT_mape	TimeGPT_smape
mae	0.15	0.11
rmse	0.16	0.13

t0 = 2018-10-28

metric	TimeGPT_mape	TimeGPT_smape
mae	0.15	0.10
rmse	0.16	0.12

t0 = 2018-10-29

metric	TimeGPT_mape	TimeGPT_smape
mae	0.12	0.08
rmse	0.13	0.09



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Conclusions & discussion

- Promising alternative for storm surge forecasting
- Bridge expertise gaps: challenges keeping up with the rapid evolution of AI → cutting-edge architectures
- Performance gains: Preliminary results suggest good skill | limitations extremes (peaks)
- Models trained across diverse domains (finance, energy, transportation) → interpretability and reliability for physical ocean processes

→ Complement, not a replacement, to physics-based modeling
→ Potential for rapid application
→ Lots of work to do

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