



Climate Change

Copernicus Climate Change Service (C3S)

Energy Seminar

C3S Enhanced Operational European Service in Support to ENTSO-E



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Climate Change

Copernicus Climate Change Service (C3S)

European Hydropower Indicators for the PECD

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Inside Climate Service (ICS)



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European HP Indicators for the PECD – Target



HYDRO POWER

Reservoir (HRE)

- Generation
- Inflow*

Run-of-River (HRO)

- Generation

entsoe

**Transparency
Platform**

Resolution:

- Country
- Weekly

$$*Inflow(w) = GENOUT(w) + [FR(w) - FR(w - 1)]$$

Weekly Generation Output for CTY : FR
Prod. type: Hydro Water Reservoir



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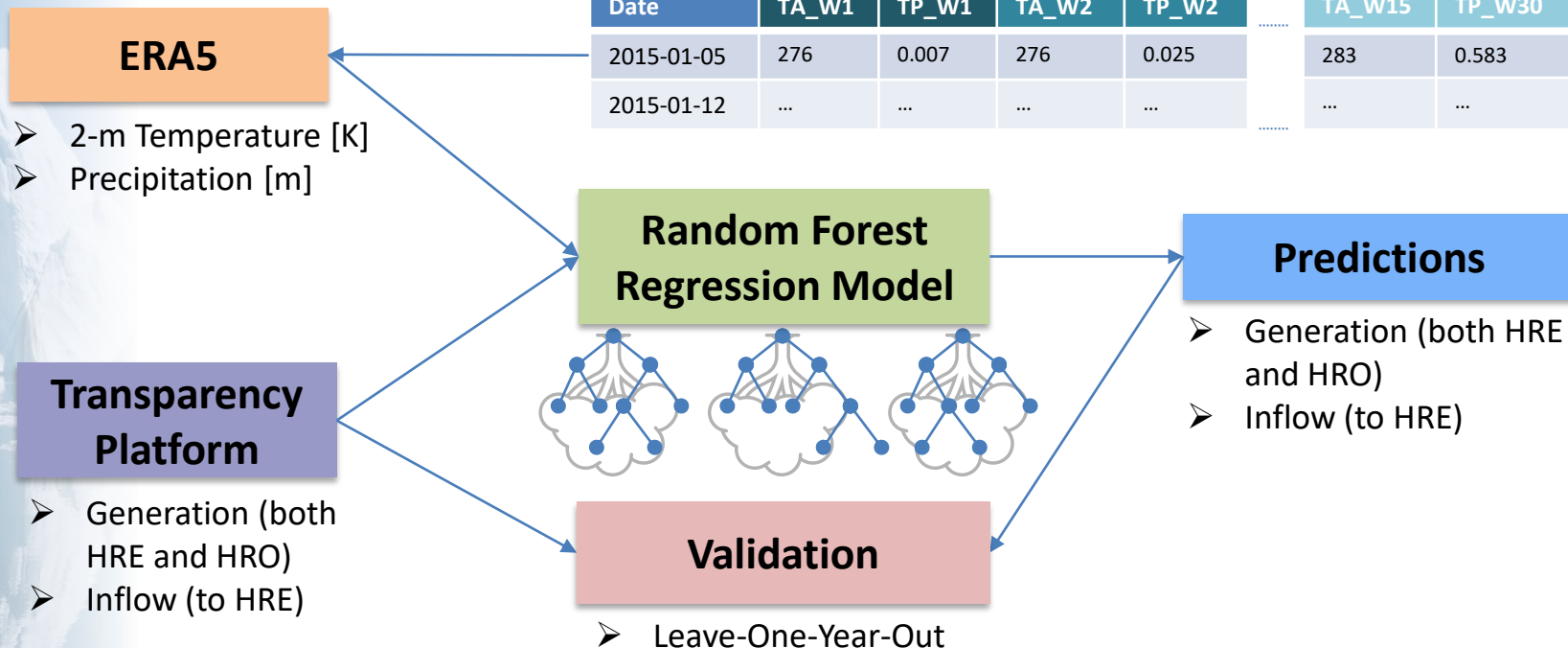


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European HP Indicators for the PECD – The Model

Calculating cumulated TP and average TA over multiple weeks

Date	TA_W1	TP_W1	TA_W2	TP_W2	.....	TA_W15	TP_W30
2015-01-05	276	0.007	276	0.025	.....	283	0.583
2015-01-12	...	...	...	...	.....	...	...



*Ho, L.T.T.; Dubus, L.; De Felice, M.; Troccoli, A. Reconstruction of Multidecadal Country-Aggregated Hydro Power Generation in Europe Based on a Random Forest Model. *Energies* 2020, 13, 1786. <https://doi.org/10.3390/en13071786>



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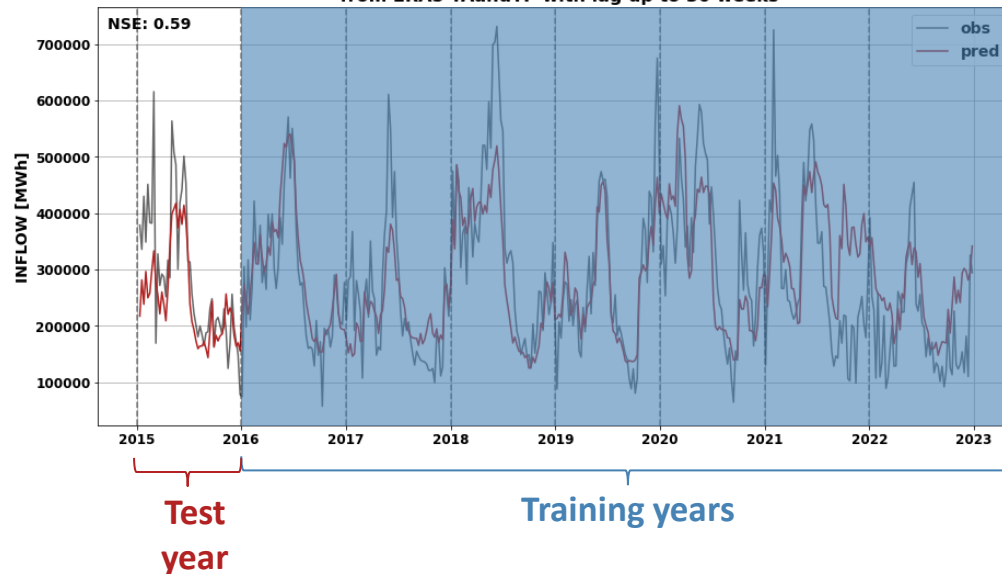
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European HP Indicators for the PECD – Leave-One-Year-Out Validation

Validation : L-O-Y-O

- Training the RF model on **all years except one (test year)**.

LOYO-validation results of Random Forest predictions for HRE INFLOW of FR (CTY-level) from ERA5 TAandTP with lag up to 30 weeks



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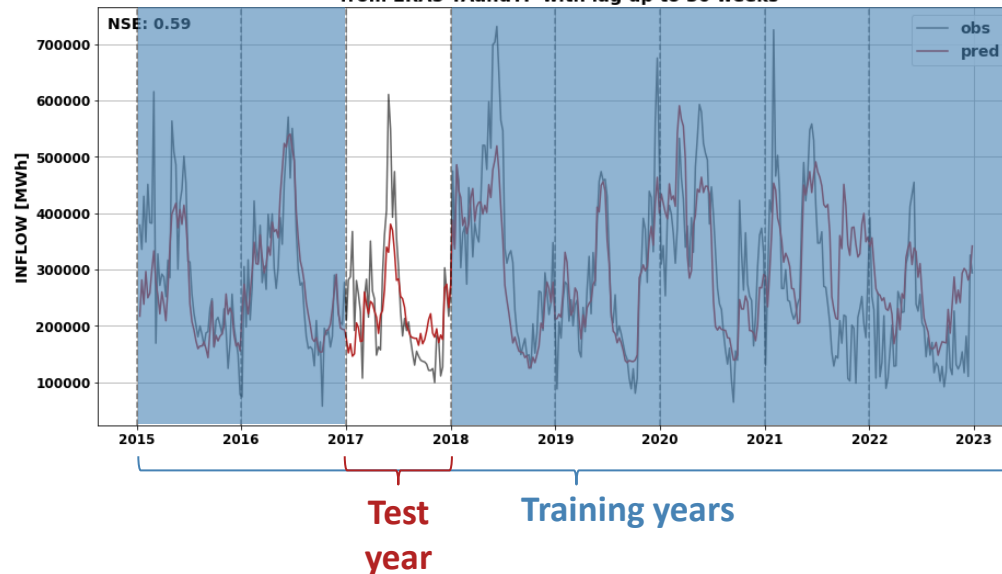
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European HP Indicators for the PECD – Leave-One-Year-Out Validation

Validation : L-O-Y-O

- Training the RF model on **all years except one (test year)**.
- Metrics evaluated:

➤ **NMAE**

➤ **RMSE**

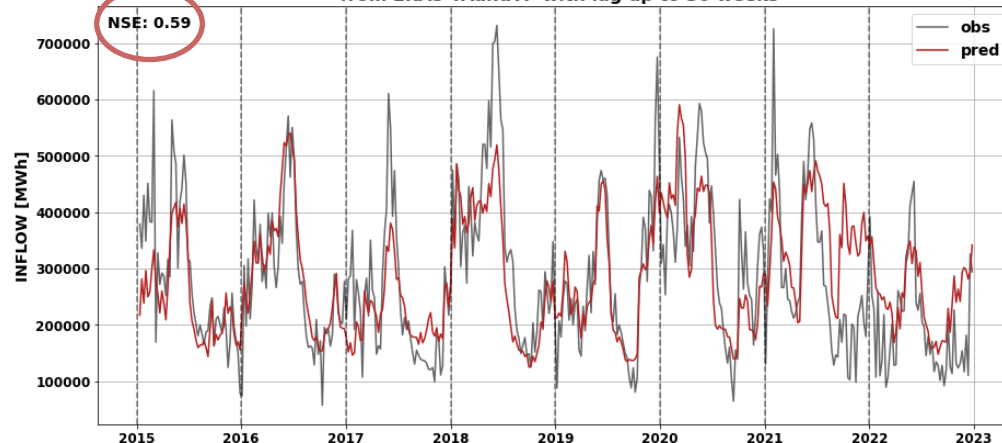
➤ **CORR**

➤ **NSE** :
$$NSE = 1 - \frac{\sum_{i=0}^n (x_m - x_o)^2}{\sum_{i=0}^n (x_o - \bar{x}_o)^2}$$

➤ **RelBias**

➤ **...**

LOYO-validation results of Random Forest predictions for HRE INFLOW of FR (CTY-level) from ERA5 TAandTP with lag up to 30 weeks



Final Inflow prediction over 8 years for France.

Optimization of RF parameters

- Maximizing combined metrics to target extremes



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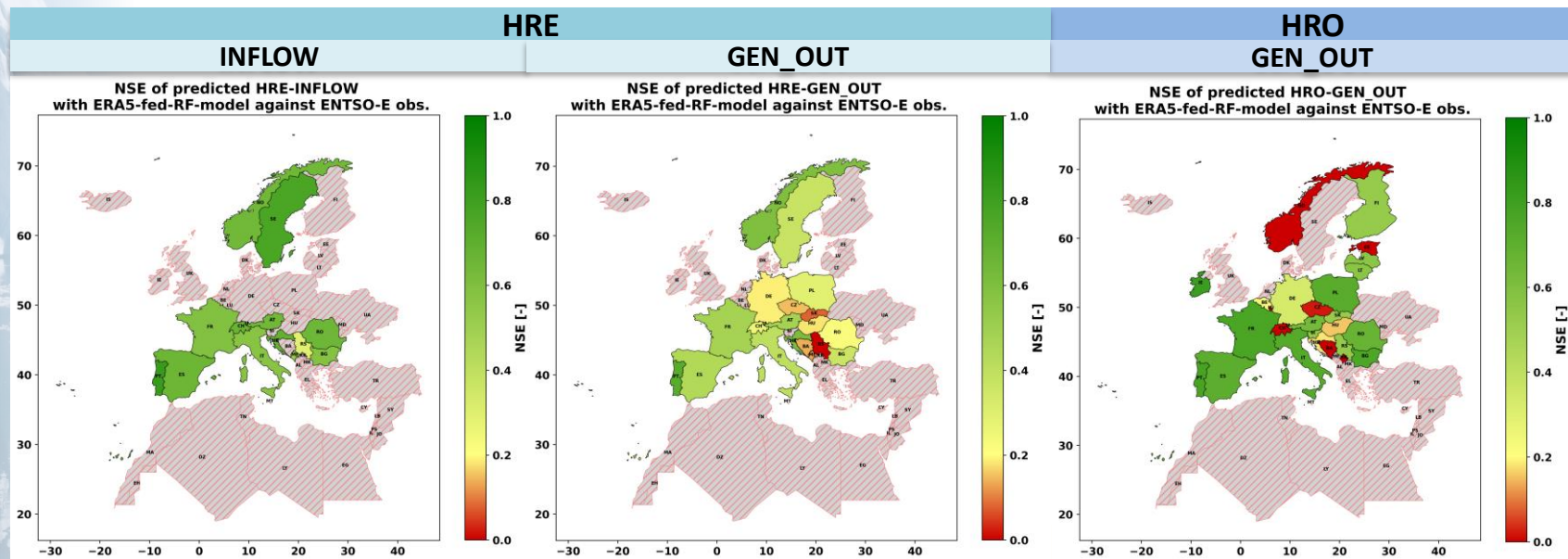




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European HP Indicators for the PECD – Validation Results

Results over Europe



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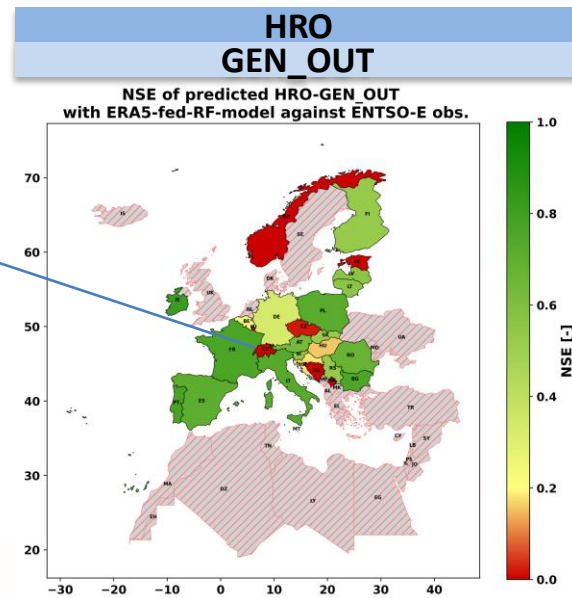
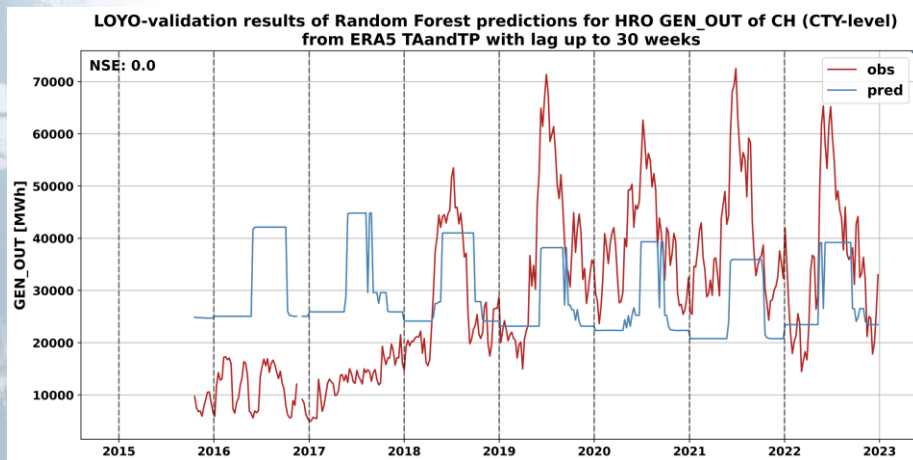


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European HP Indicators for the PECD – Validation Results

Results over Europe

- Normalizing generation data with country aggregated Installed Capacity (IC) can be beneficial (e.g. NO, CH), although IC information are only available as annual
- Presence of very irregular generation signal (e.g. EE, CZ, HU)
- Too few data for training (e.g. LU, BA, XK)



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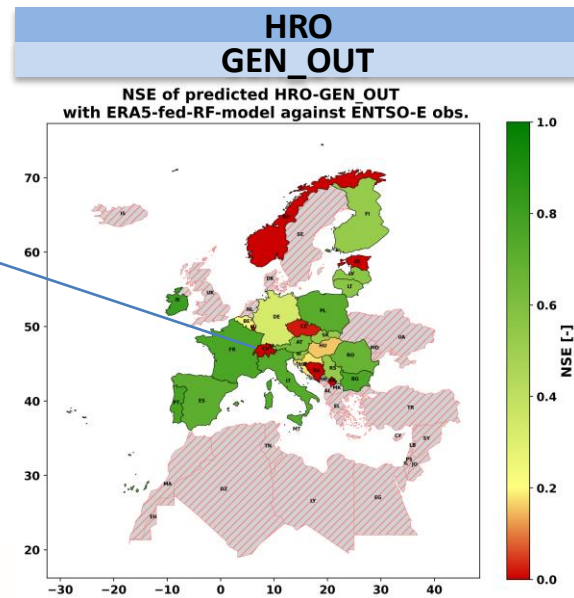
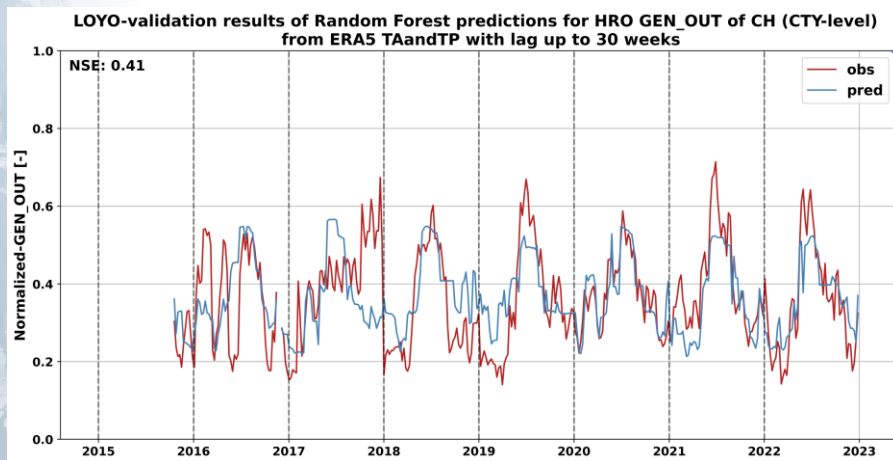


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European HP Indicators for the PECD – Validation Results

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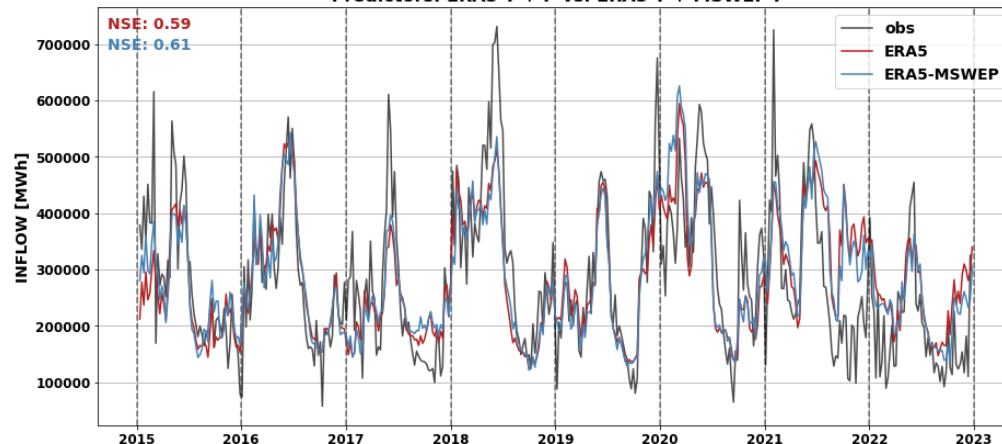
MSWEP for Precipitation

- **Multi-Source Weighted-Ensemble Precipitation***: global dataset that combines gauge, satellite, and reanalysis data [0.1°, 3h]

ERA5 - Land

- Next TA and TP datasets that will be tested

LOYO Predicted INFLOW for FR - CTY-AVG
Predictors: ERA5 T + P vs. ERA5 T + MSWEP P



*Beck, H. E., E. F. Wood, M. Pan, C. K. Fisher, D. G. Miralles, A. I. J. M. van Dijk, T. R. McVicar, and R. F. Adler, 2019: MSWEP V2 Global 3-Hourly 0.1° Precipitation: Methodology and Quantitative Assessment. *Bull. Amer. Meteor. Soc.*, 100, 473–500. <https://doi.org/10.1175/BAMS-D-17-0138.1>



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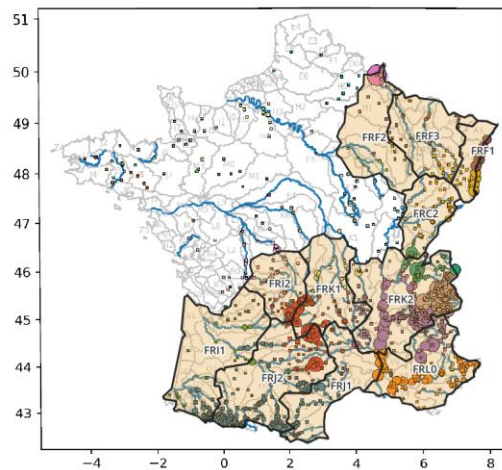




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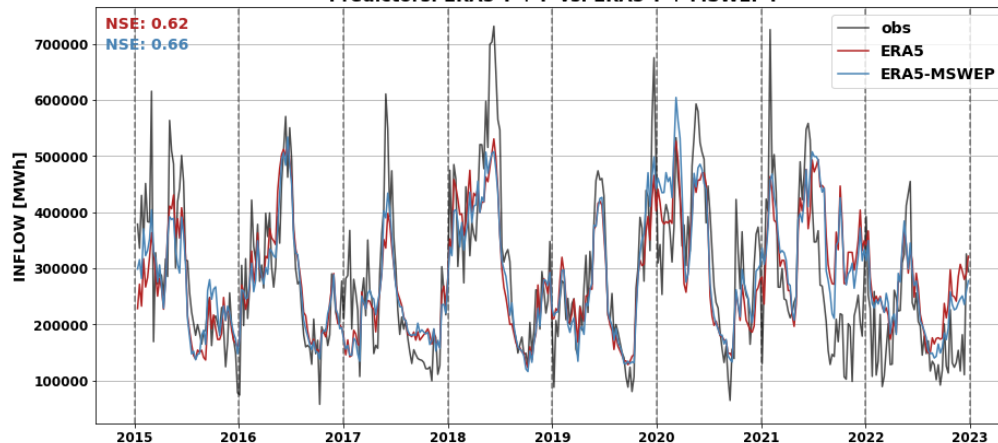
European HP Indicators for the PECD – Validation Results

NUTS2 sub-selection



Selected French regions based on locations of major HP plants (HP plants map provided by L. Dubus)

LOYO Predicted INFLOW for FR - NUTS2_SEL-AVG
Predictors: ERA5 T + P vs. ERA5 T + MSWEP P



- Temperature and Precipitation have been averaged over a subselection of NUTS2 regions.



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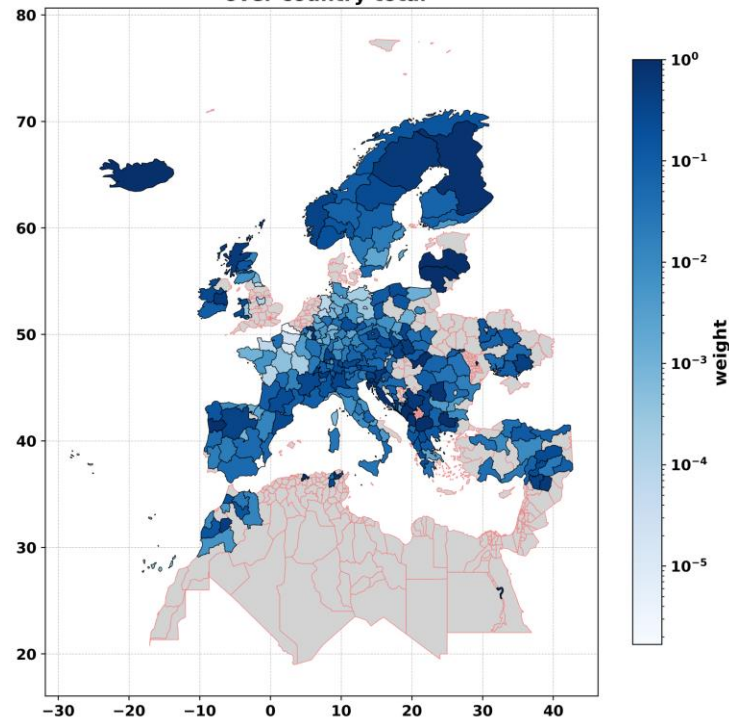
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European HP Indicators for the PECD – Weighted Average based on Aggregated Installed Capacity (IC)

NUTS2 weighting

- **Weighted average** of predictors based on the **distribution of Installed Capacity** over each country, based on the data gathered by *Elena Restivo (ICS)*.

Weights based on Aggregated Installed Capacity per NUTS2 region over country total



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European HP Indicators for the PECD – Conclusions and next steps

- Model performs well over most European Countries for the two technologies addressed (especially Inflow to Reservoirs and Run-of-river generation)
- Need to find a solution for countries showing unsatisfactory scores (big help would come from **monthly Installed Capacity** data)
- Keep improving the model in multiple directions (targeting extremes, testing ERA5 Land, testing IC-based weighted average of predictors)
- Employ model to reconstruct the **historical** generation time series and estimate the future **projections** (EURO-CORDEX and CMIP6)



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European HP Indicators for the PECD – ICEM 2023 & Hydropower

Want to hear more on **Hydropower**?

- WMO Global Energy Resilience Atlas: Climate Risk Indices for Hydropower (RICHAIHU WU)
29th, **11:05-11:20** – **Sala degli Scrovegni**
- Generation of a future-proof hydro inflow dataset for power system studies (NICHOLAS FABIO BONFANTI)
29th, **11:20-11:35** – **Sala dei Giganti**
- Building a climate service for hydropower resources: Application to Mpatamanga project in Malawi within FOCUS-Africa project (HIBA OMRANI)
29th, **11:20-11:35** – **Sala dei Giganti**
- Hydrological Seasonal Forecast as a Resource Assessment Tool for the Upper Adige Catchment (MATTIA ZARAMELLA)
29th, **11:35-11:50** – **Sala degli Scrovegni**
- Implementation of customized hydropower model for enhancing the hydropower generation in Tanzania (ALBERTO TROCCOLI)
29th, **11:50-12:20** – **Sala degli Scrovegni**
- Also give a look at the posters!

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