Climate Change

C3S Energy Webinar
Global Hydro Power and Electricity Demand Indicators

10 July 2024

“The global hydro power indicator”

Giovanni Aldrigo (ICS)

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Outline

- The need of a statistical model
- The approach over Europe
- The approach for the Global domain
- Latest developments for the Global domain
- Next steps

HYDROPOWER

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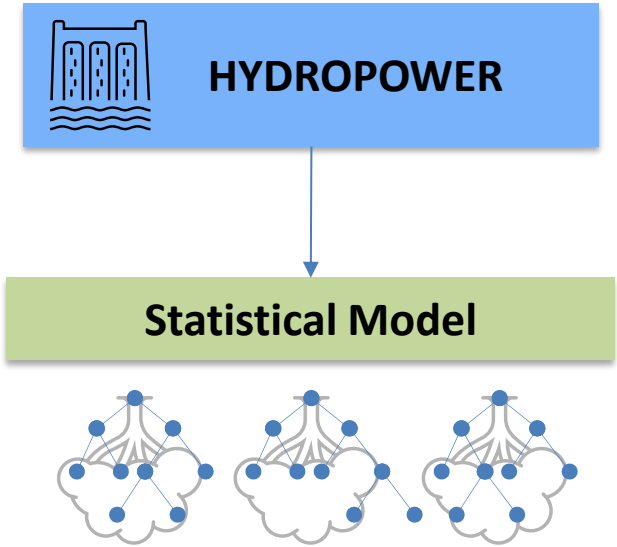
Why a statistical model?

- Scarcity of detailed plant-level data
- Big domain: high computational resources
- Satisfactory results obtained in the past* with statistical models at country level



* 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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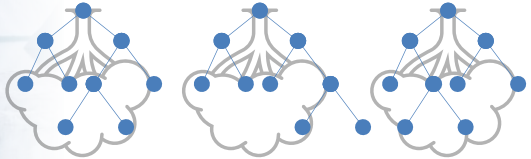
Two approaches

HYDRO POWER

Europe

Random Forest (RF) Model

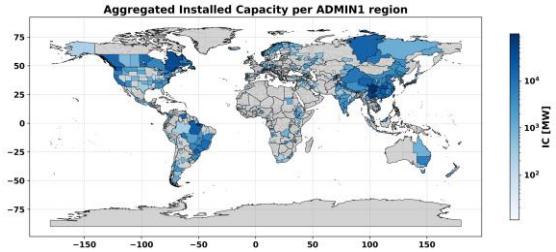


Generation data:

- ENTSO-E TP → hourly resolution

Globe

IC-W-TP (or IWP)



Generation data:

- IEA and EMBER → monthly resolution

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Two approaches

HYDRO POWER

Europe

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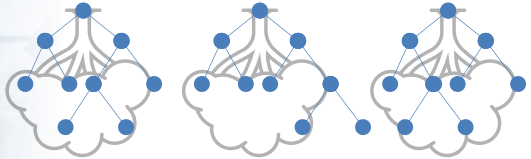

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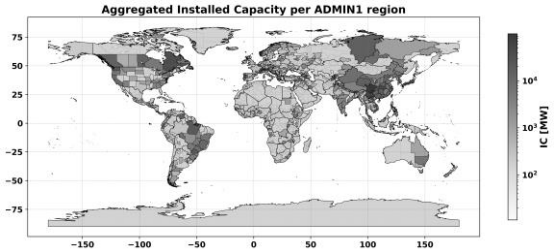

Generation data:

- IEA and EMBER → monthly resolution

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Europe – Hydropower generation data

HYDRO POWER

- **Reservoir (HRE)** ➢ Generation
- **Run-of-River and pondage (HRO)** ➢ Generation

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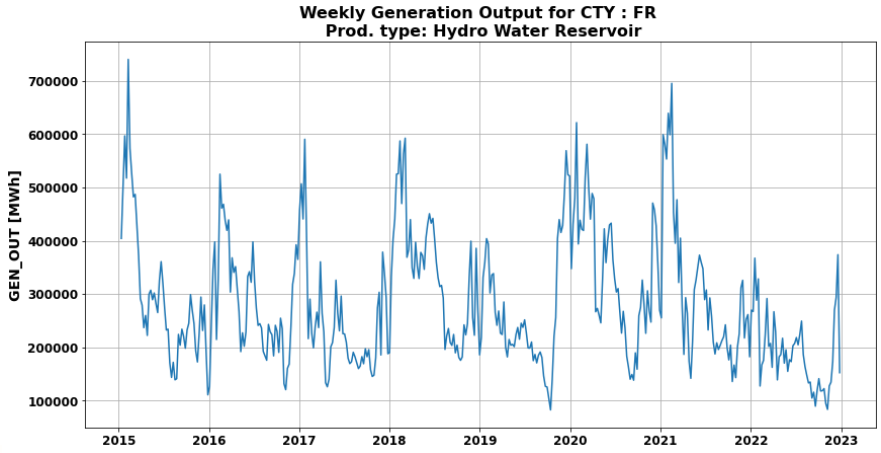
Transparency Platform*

Target resolution:

- ➢ Country
- ➢ Weekly



*https://transparency.entsoe.eu/

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Europe – Random Forest Regression Model

ERA5 2015-2023

- 2-m Temperature
- Precipitation

(country-level aggregates and **lagged**)

Transparency Platform

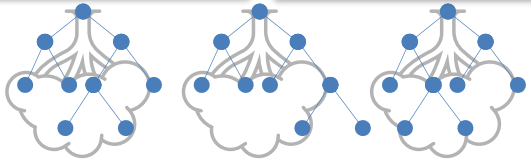
- Generation data

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	...	...	...	...		...	...

RF Model validated and trained on ERA5

RF Model driven by new climate data



HIST reconstruction

PROJ estimates

SEAS estimates

- Generation estimates

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Europe – Random Forest Regression Model

ERA5 2015-2023

- 2-m Temperature
- Precipitation

(country-level aggregates and **lagged**)

ERA5 1950-2023

CMIP6 2015-2065

SEAS FORECASTS

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Transparency Platform

- Generation data

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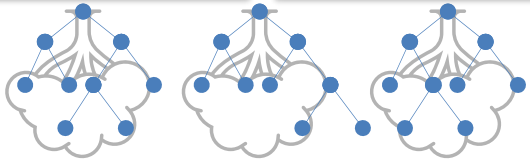

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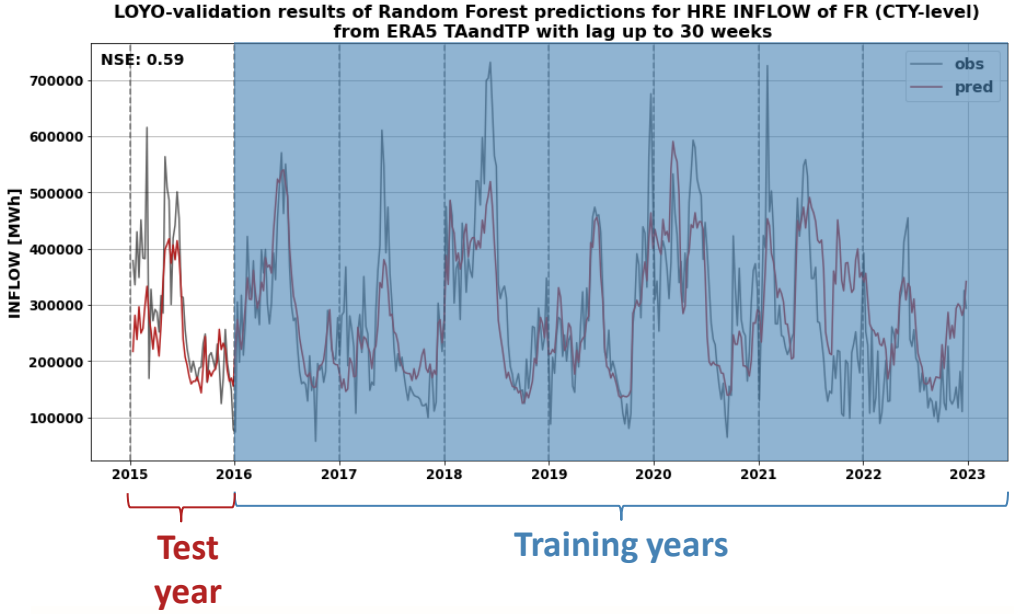
Europe – RF Leave-One-Year-Out Validation

Validation : L-O-Y-O

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



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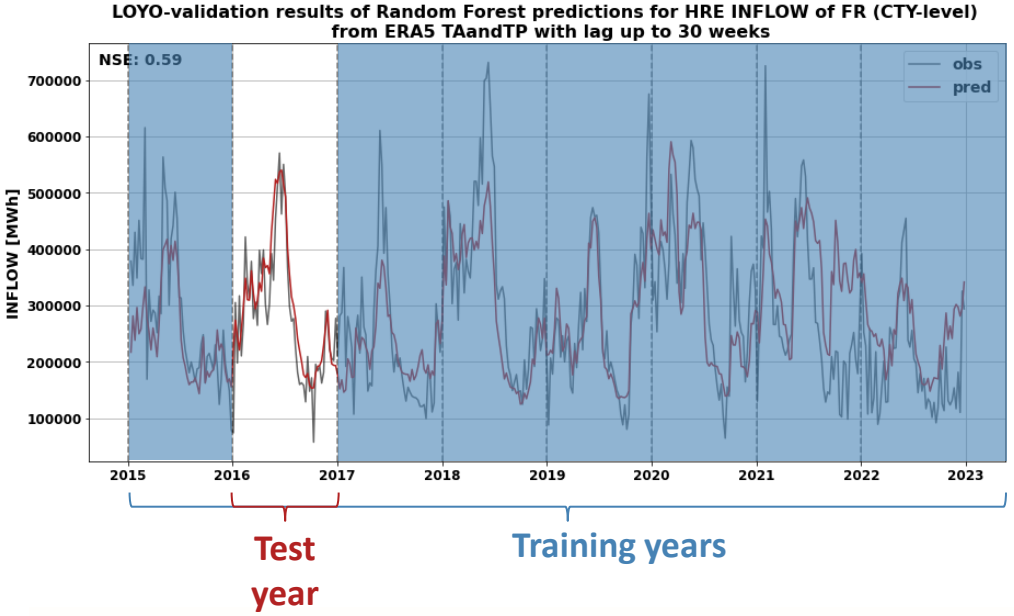

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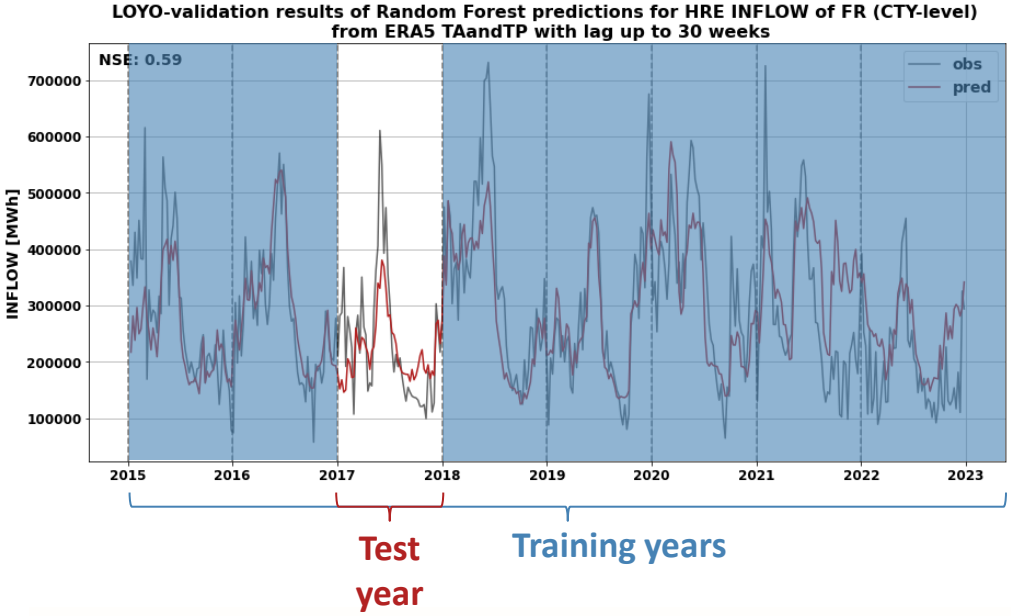

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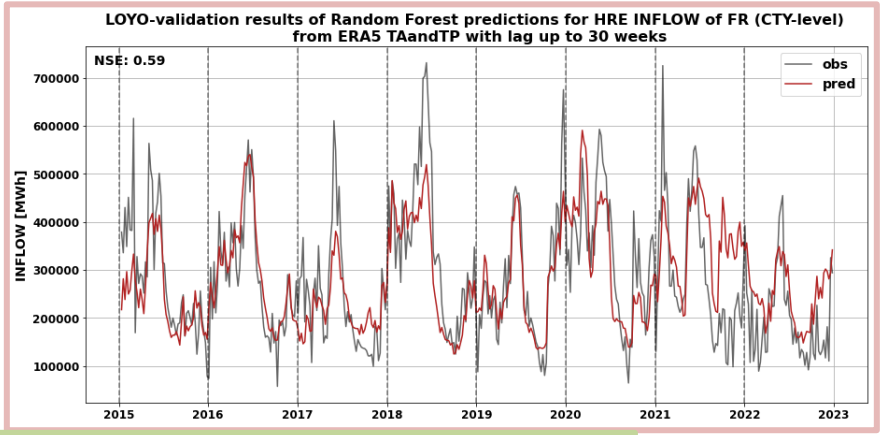
Europe – RF for HIST and PROJ streams

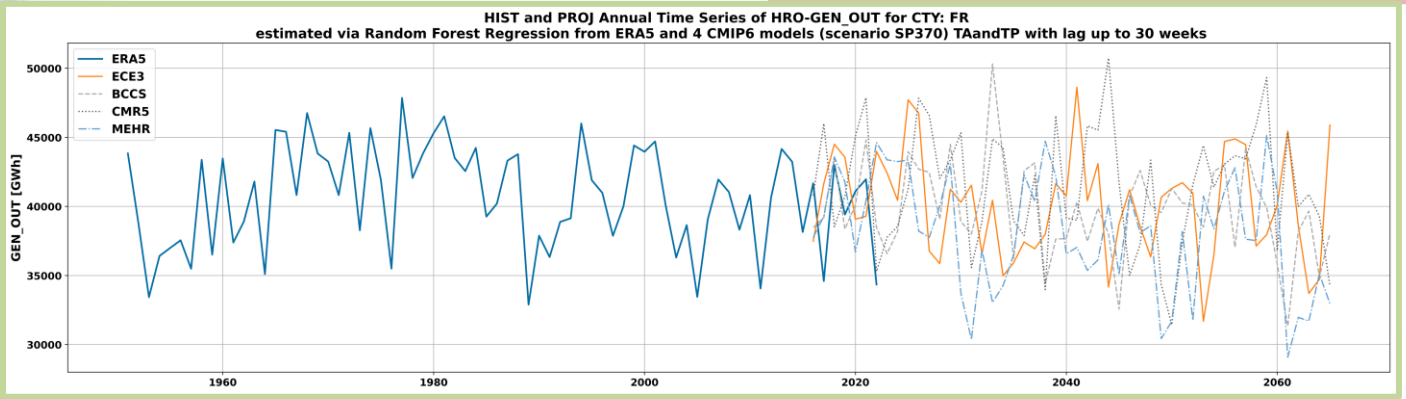
RF model validated and trained on ERA5

Result of the Leave-One-Year-Out Validation: Inflow to reservoirs (HRE) estimate over 8 years for France.

RF model driven by ERA5 and CMIP6 data

Reconstructed and projected time series are plotted in the same figure as annual aggregates. The addressed scenario is the SSP370. Mind: CMIP6 input data are first bias-adjusted wrt ERA5.





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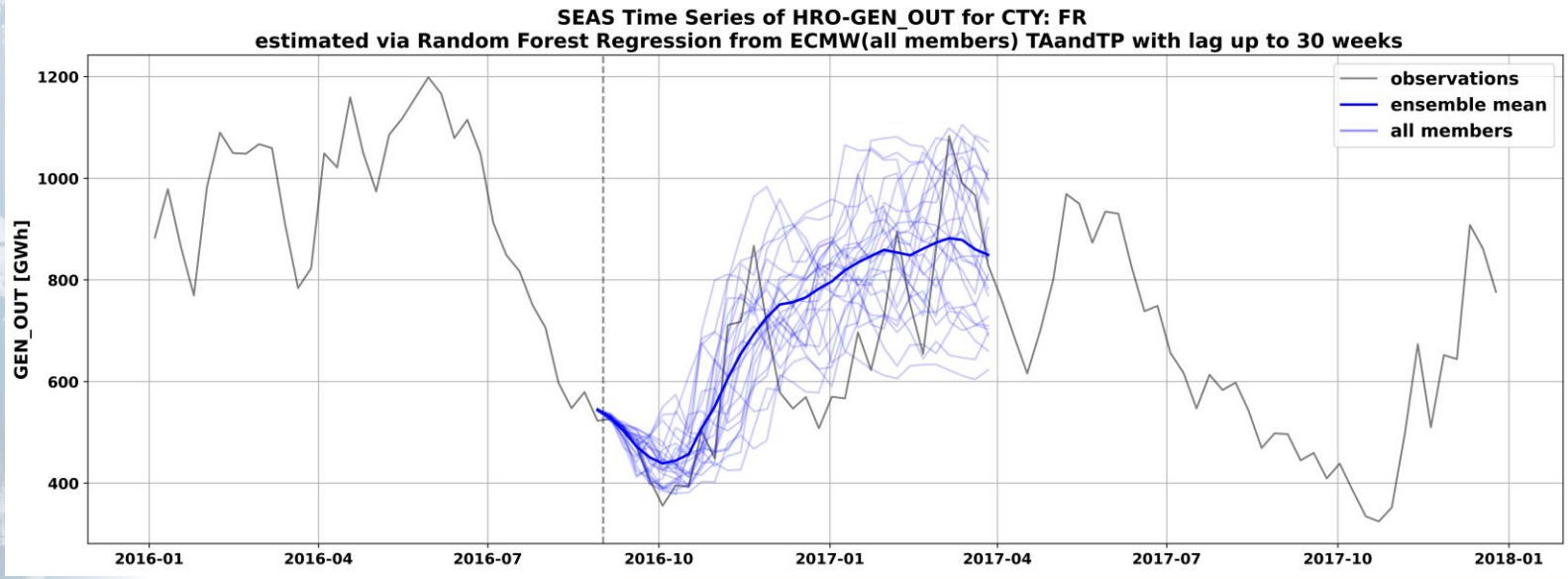
Europe – RF for SEAS stream

RF model validated and trained on ERA5 → **RF model driven by Seasonal Hind/Forecasts**

Model driven by ECMWF Seasonal hindcast of September 2016 + ERA5 data to fill in for lags computation. Mind: SH/SF are first bias adjusted wrt ERA5.



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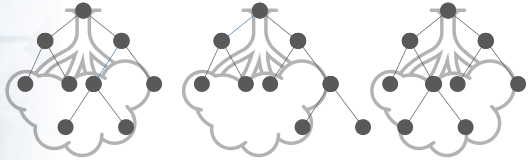
Two approaches

HYDRO POWER

Europe

Random Forest (RF) Model

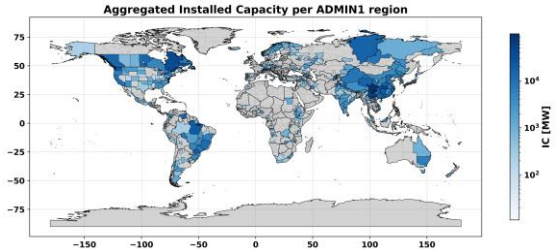


Generation data:

- ENTSO-E TP → hourly resolution

Globe

IC-W-TP (or IWP)



Generation data:

- IEA and EMBER → monthly resolution

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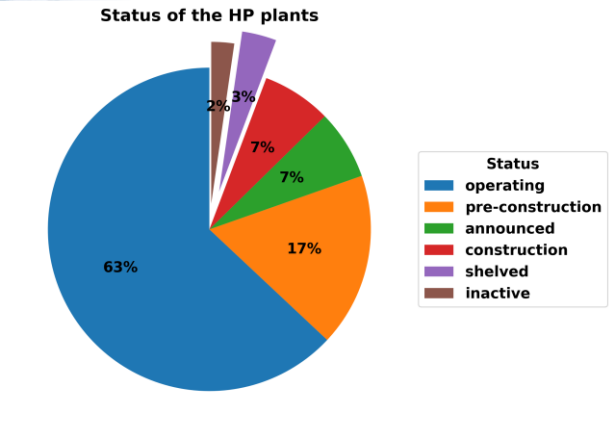
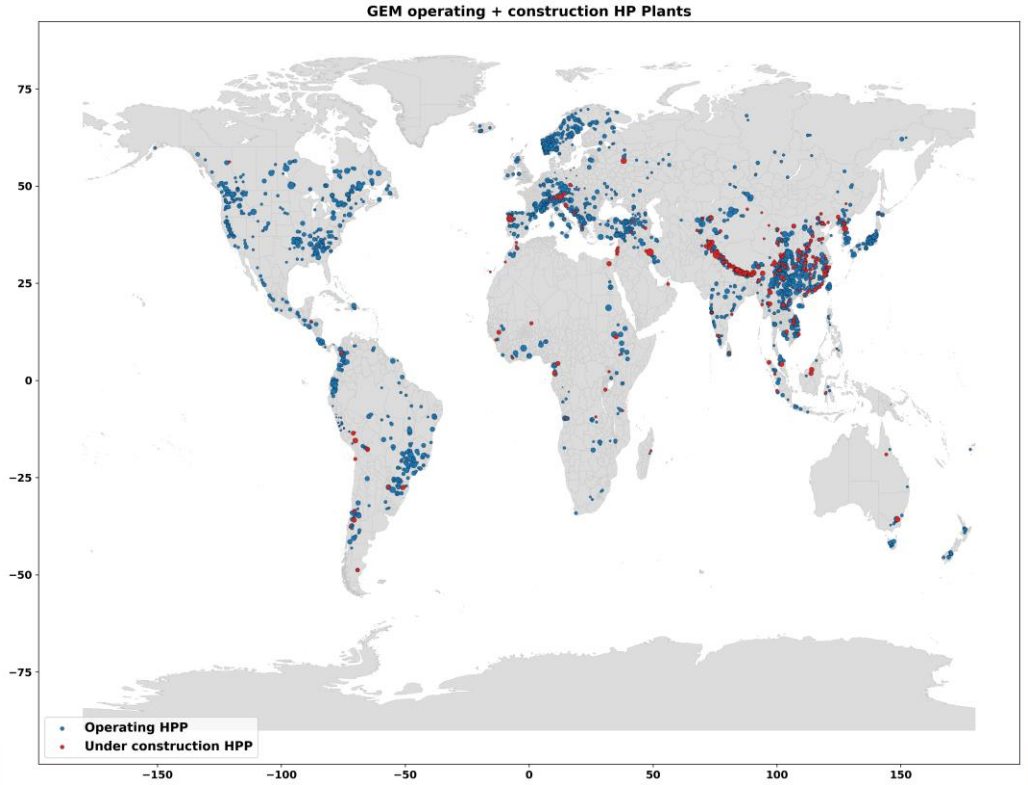
Globe – Hydropower Installed Capacity data

Global Energy Monitor

Installed Capacity (**IC**) data on HP plants **operating** and **in construction**





*https://globalenergymonitor.org/projects/global-hydropower-tracker/

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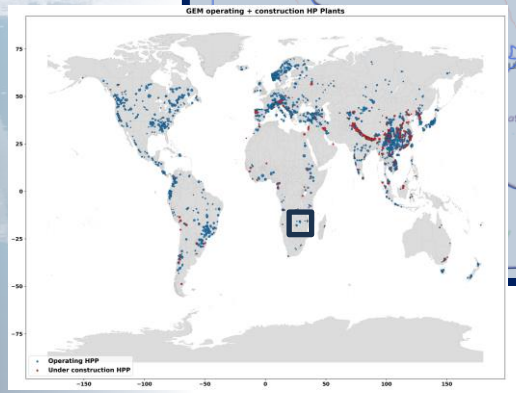
Globe – Hydropower Installed Capacity data

1) ICs are assigned to a specific Country/Countries based on HP plants' location and GEM metadata.
2) ICs are assigned to a specific region based on plants' location.

Global_energy_monitor_HYDRO_complete	
Project Name	Kariba Dam hydroelect...
(Derived)	
(Actions)	
Country 1	Zambia
Country 2	Zimbabwe
Project Name	Kariba Dam hydroelect...
Project Name (local lang/scr...	NULL
Other name(s)	NULL
Capacity (MW)	2130
Binational	Yes
Country 1 Capacity (MW)	1080
Country 2 Capacity (MW)	1050
Turbines	14
Status	operating
Complex	NULL
Start Year	1959
Retired Year	NULL
Owner	ZESCO LTD, Zimbabwe...
Owner Name (local lang/scri...	NULL
Operator	Zambezi River Authority
Operator Name (local lang/s...	NULL
Technology Type	conventional storage
River / Watercourse	Zambezi River
Latitude	-16,5225
Longitude	28,7621
Location Accuracy	exact
City 1	NULL
Local Area 1	Kariba
Major Area 1	Siavonga District



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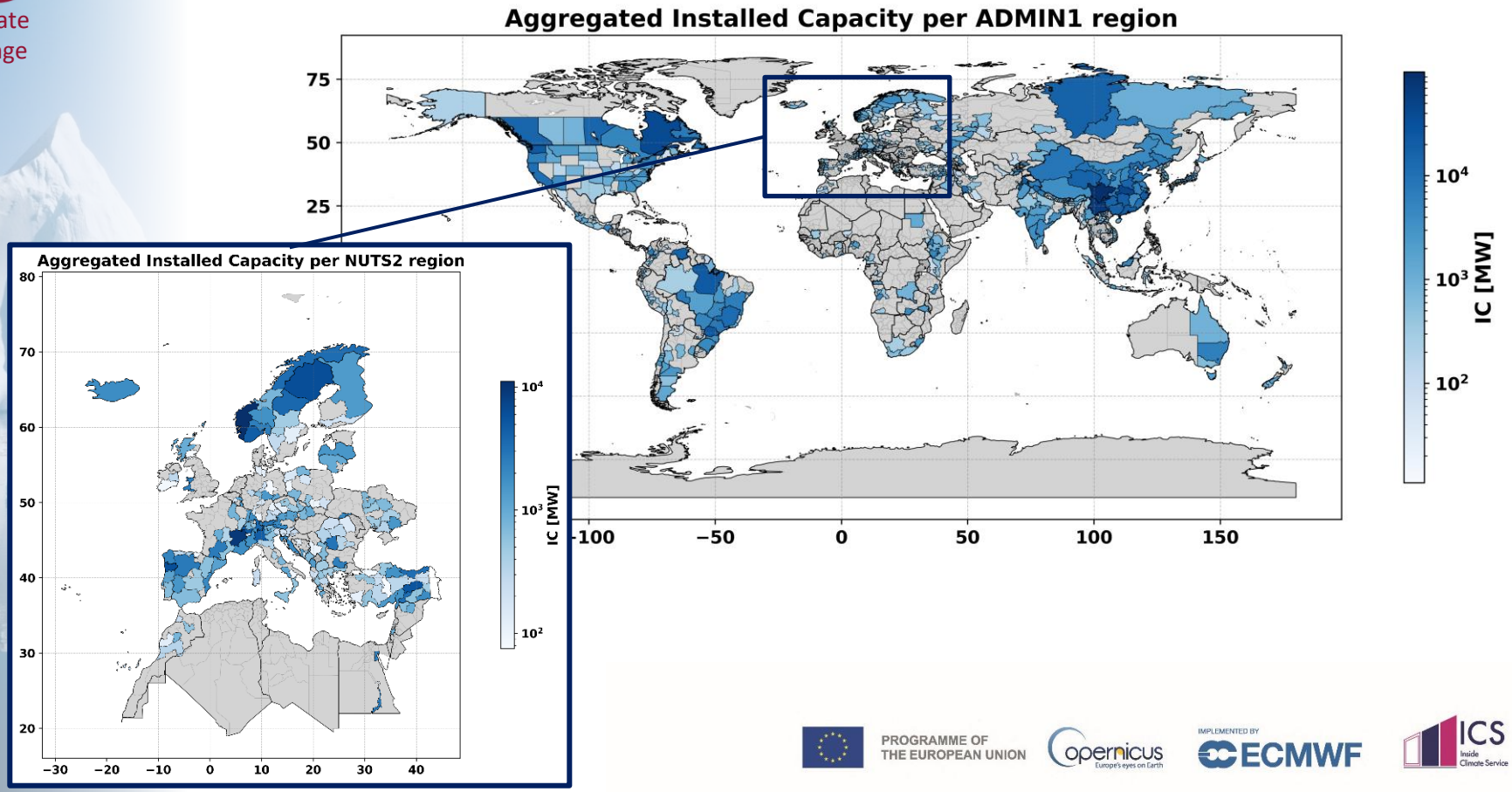
Globe – Installed Capacity – Weighted – Precipitation (IC-W-TP or IWP)



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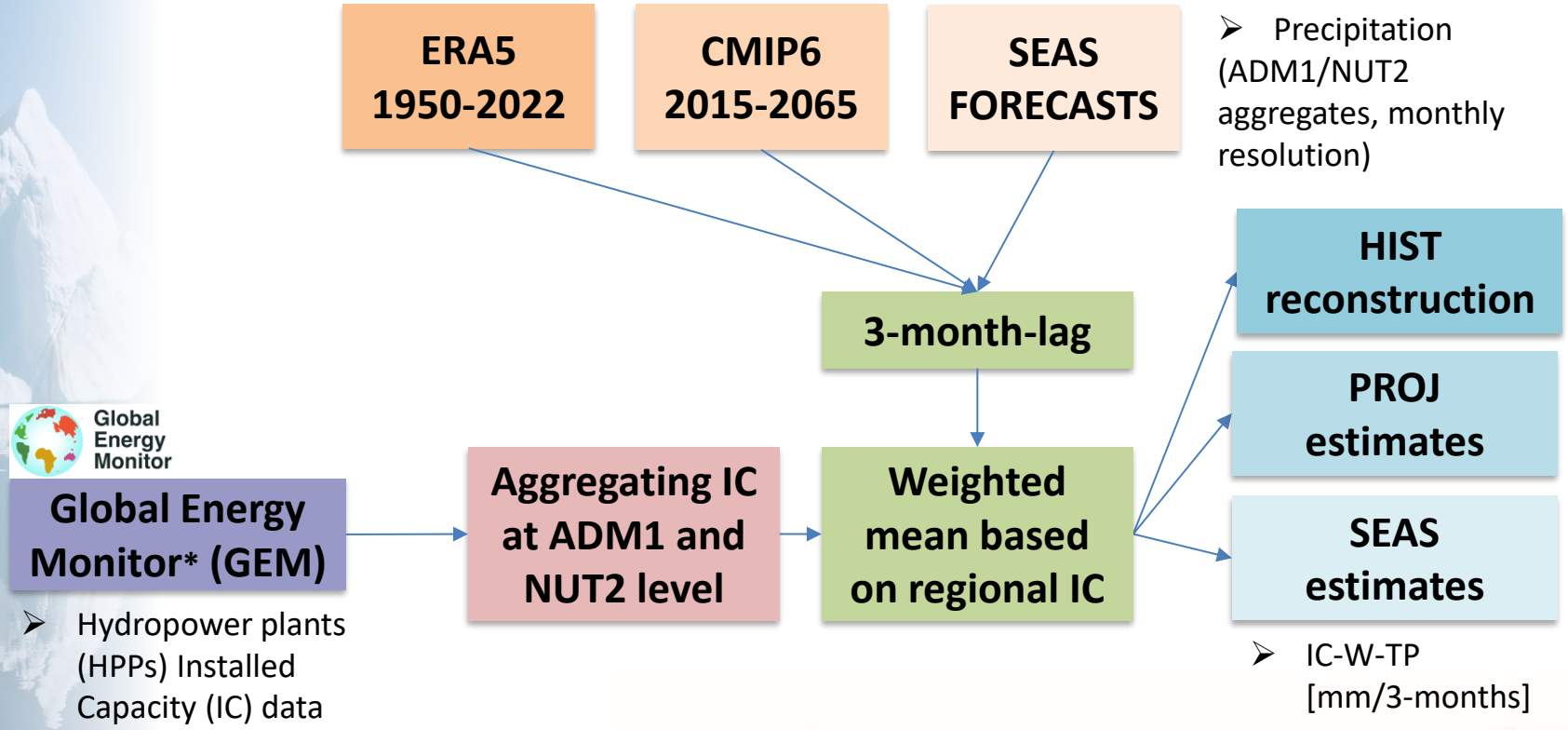

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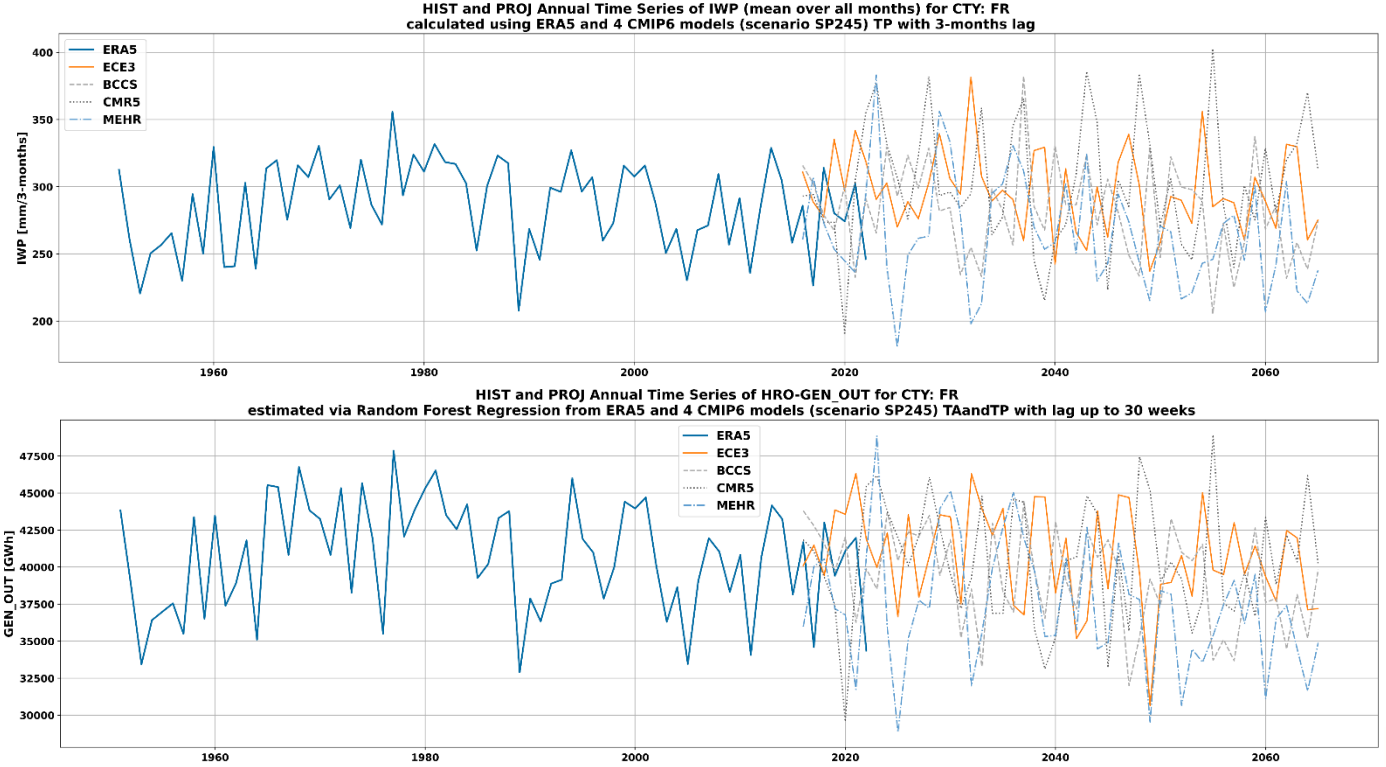
Globe – IWP for HIST and PROJ streams

Input: ERA5 and CMIP6 data

Reconstructed and projected time series are plotted in the same figure as annual aggregates. The addressed scenario is the SSP245.

Comparing RF (only HRO gen) and IWP French annual time series (HIST + PROJ-SP245)



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Input: Seasonal Hind/Forecast

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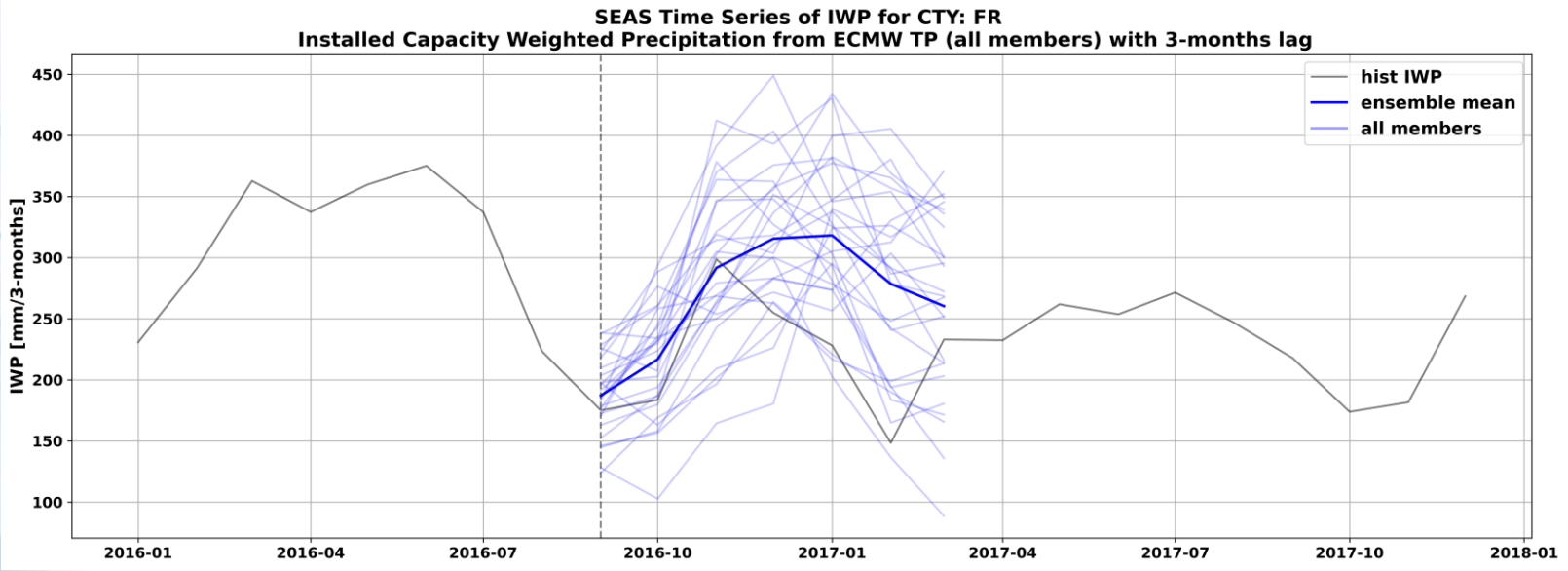

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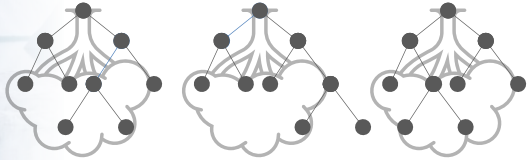
Globe – latest developments

HYDRO POWER

Europe

Random Forest (RF) Model



Generation data:

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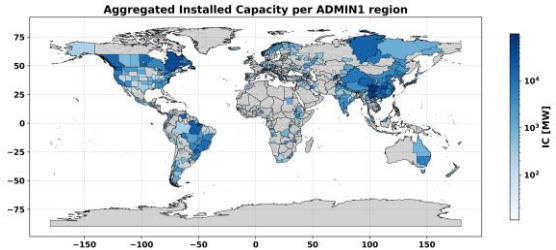
Globe

IC-W-TP (or IWP)



Generation data:

- IEA and EMBER → monthly resolution

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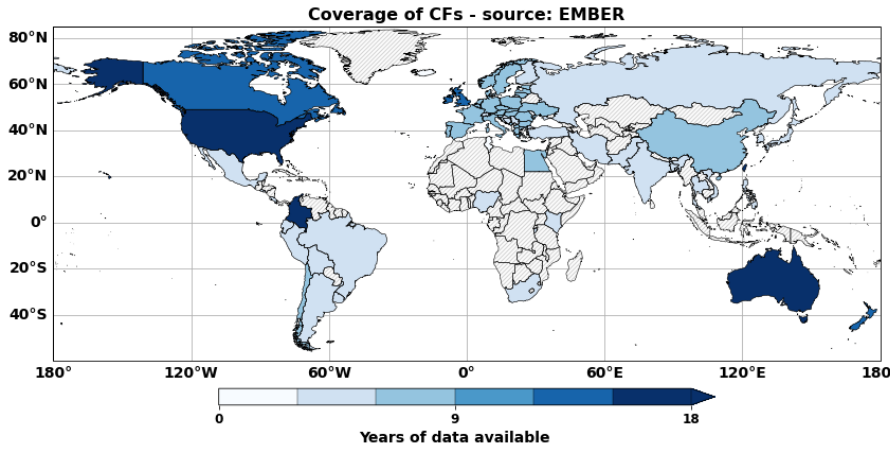
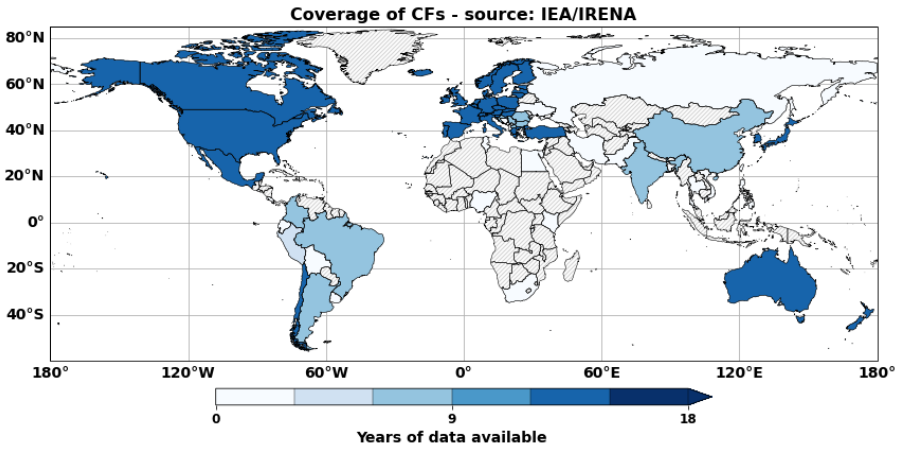
Globe – coverage of global monthly generation data (EMBER and IEA)





Global data coverage for Hydropower capacity factors (CFs) calculated as generation divided by installed capacity where both datasets are available. To normalize IEA generation data, IRENA installed capacity data are being considered for cases where annual generation between the two sources are close.

https://www.irena.org/Data
https://www.iea.org/data-and-statistics/data-tools/hydropower-data-explorer
https://ember-climate.org/data/data-tools/data-explorer/

*EMBER does not include HPS, IEA/IRENA do

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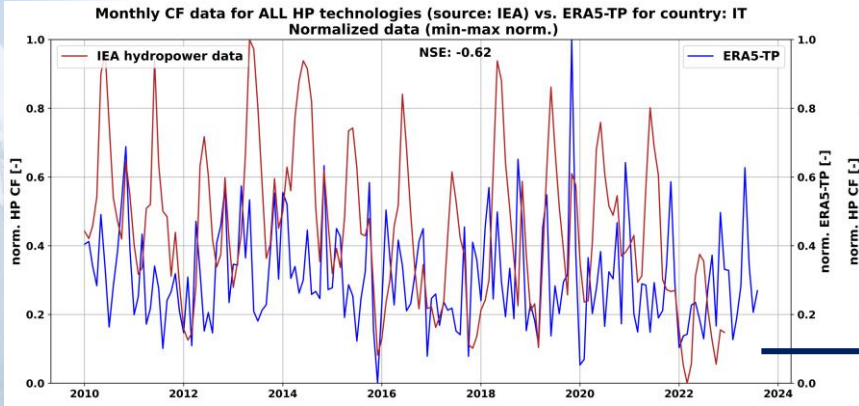
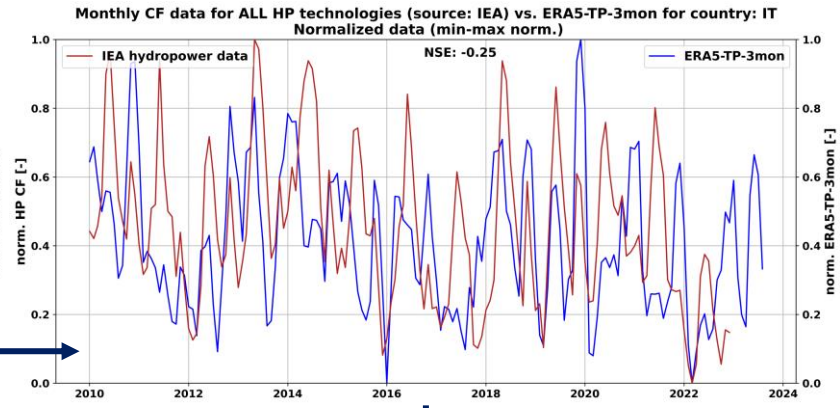
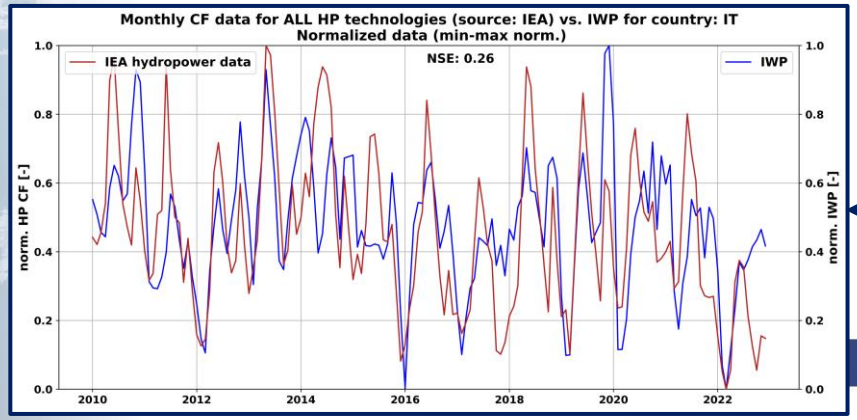
Globe – IWP vs ERA5 TP

Italy – improvement considering first simple **TP**, then **cumulated TP**, then adding weighting based on HHPs distribution within the country (**IWP**).







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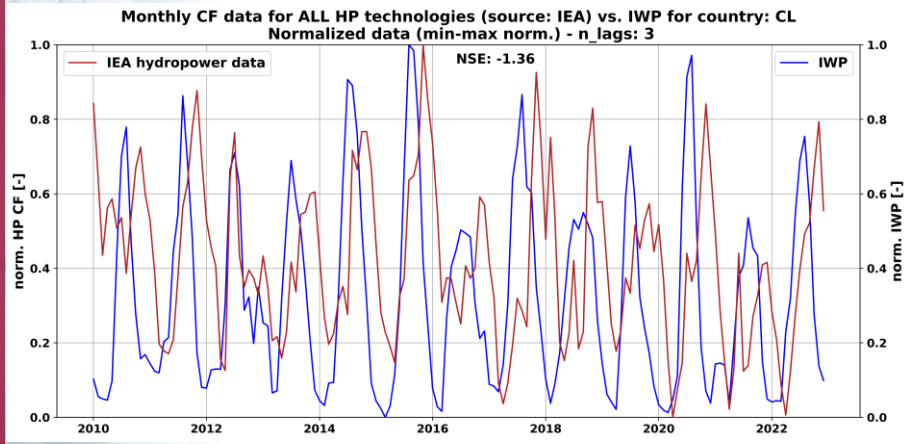
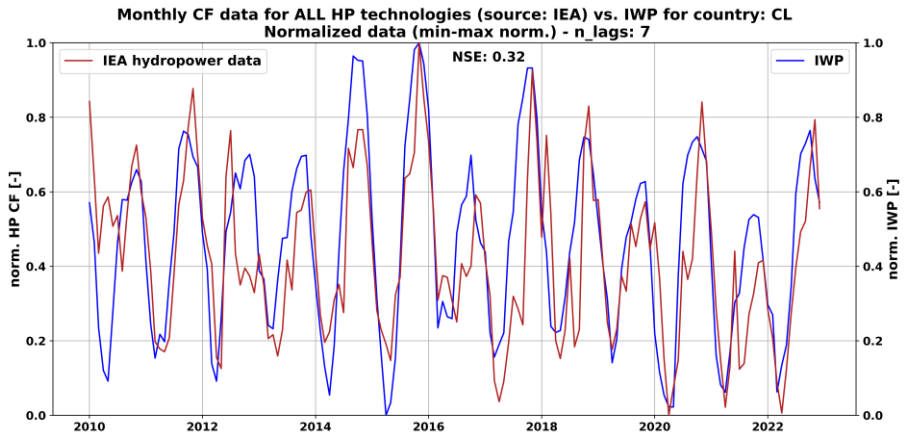
Globe – IWP with different lags

IWP tests with **different lags** comparing results to IEA/EMBER global monthly datasets.
A lag of **2-3 months** is still the one that globally works better, but for some countries considering a **longer time** span brings to a more informative proxy.





Chile – tests computing cumulated weighted TP over different number of months: **lag_7** yields best results

Possibility : considering a different lag for each country where we have generation data?

Globe – IWP vs RF-monthly

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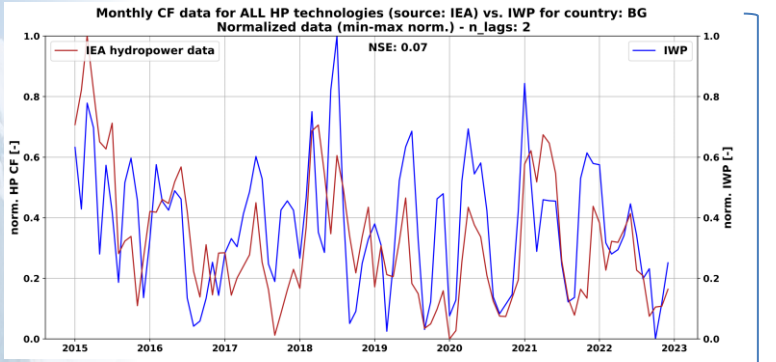
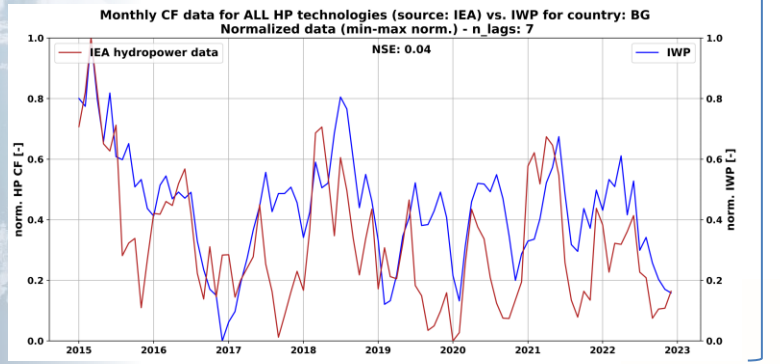
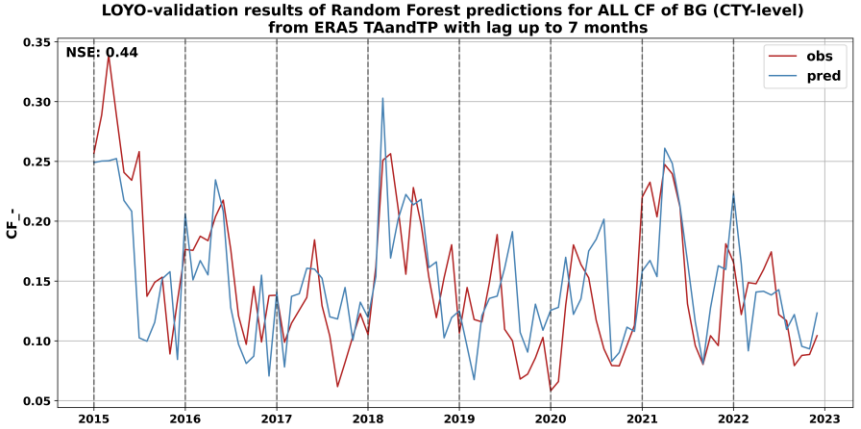
Bulgaria: different lags are important (e.g. 2 and 7) → advantage of RF: taking into account several lags







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Hydropower – next steps

- Testing different lags with **IWP** for different countries
- Understanding **differences among global datasets** (IEA, EMBER, Carbon Monitor Power) and deciding which one(s) to use outside of Europe: probably a mix of them
- Implementing **RF model with monthly data** where data are available