ESA-ECMWF Workshop 2021

SMARTRIVER: Artificial Intelligence for effective Water Resources Forecast & Management

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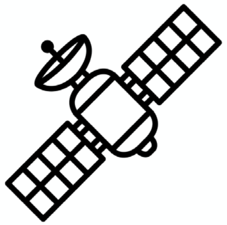
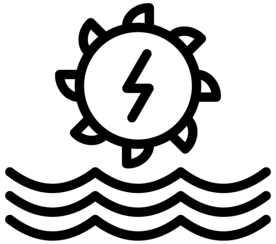
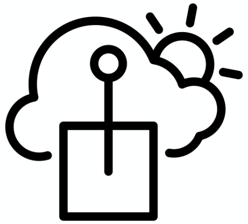
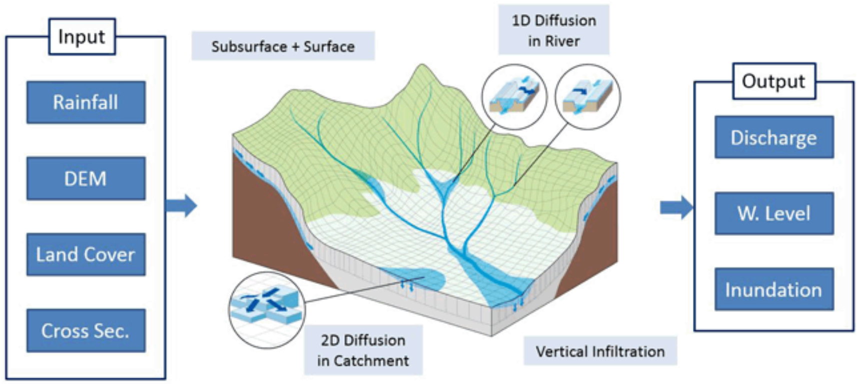
AI for Downstreaming and Tailoring Hydrological Forecast Intelligence to final Users

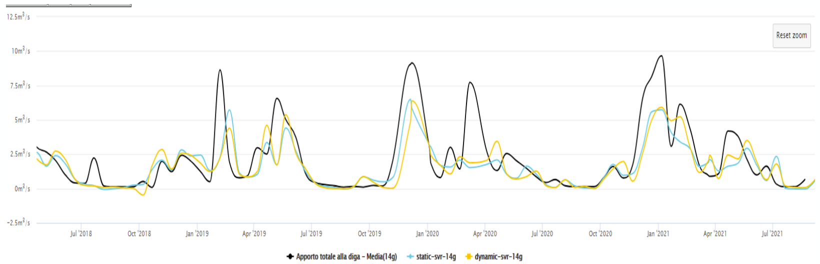
- NEEDS: Energy and Water Management requires forecast for optimal usage of the resource

- A Data Centric approach : Copernicus CDS, EOBS, Forecast Datasets are GROWING

- The *Business as usual* Way to *Go* : Feed complex hydrological Deterministic Models (Eventually adding AI on top or at the bottom of the CHAIN) with EOBS, ground station data , DTM, Soil …. And forecast

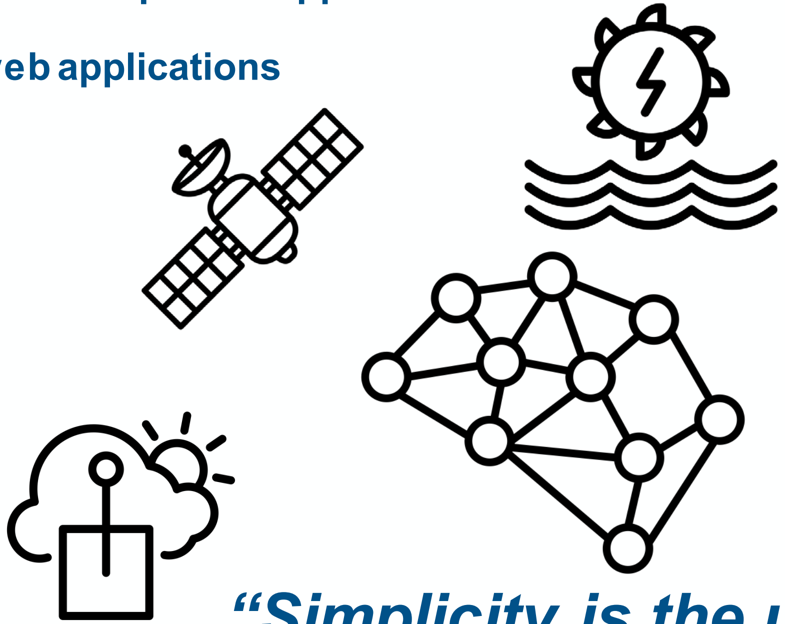
  - Time and data consuming (topo, landuse, soil)
  - Requires the involvement of hydrological modeling expert
  - Multiple sites = Multiple Models
  - Many companies already offer service / software– NO INNOVATION

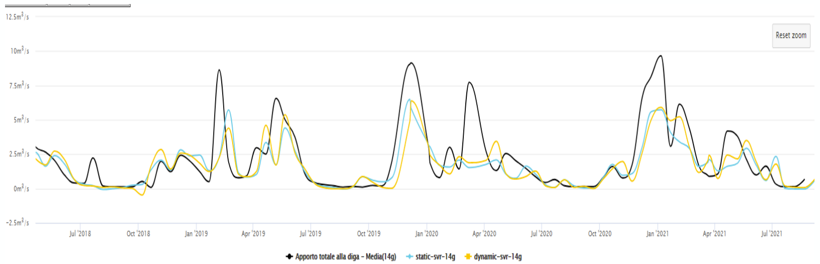





AI for Downstreaming and Tailoring Hydrological Forecast Intelligence to final Users

- **AI for *DATA* DRIVEN forecast : Combination <u>Operational Forecast , EOBS, and</u> Data Science (AI and ML) for ana effective down streaming of forecast intelligence**
  - **<u>Democratize</u> the practical use of seasonal-forecast-based climate services**
  - **Less time and data requirements – No background in hydraulics requested Only local discharge data needed (rainfall/ temperature station if available)**
  - **Suitable for multiple site applications**
  - **And for web applications**

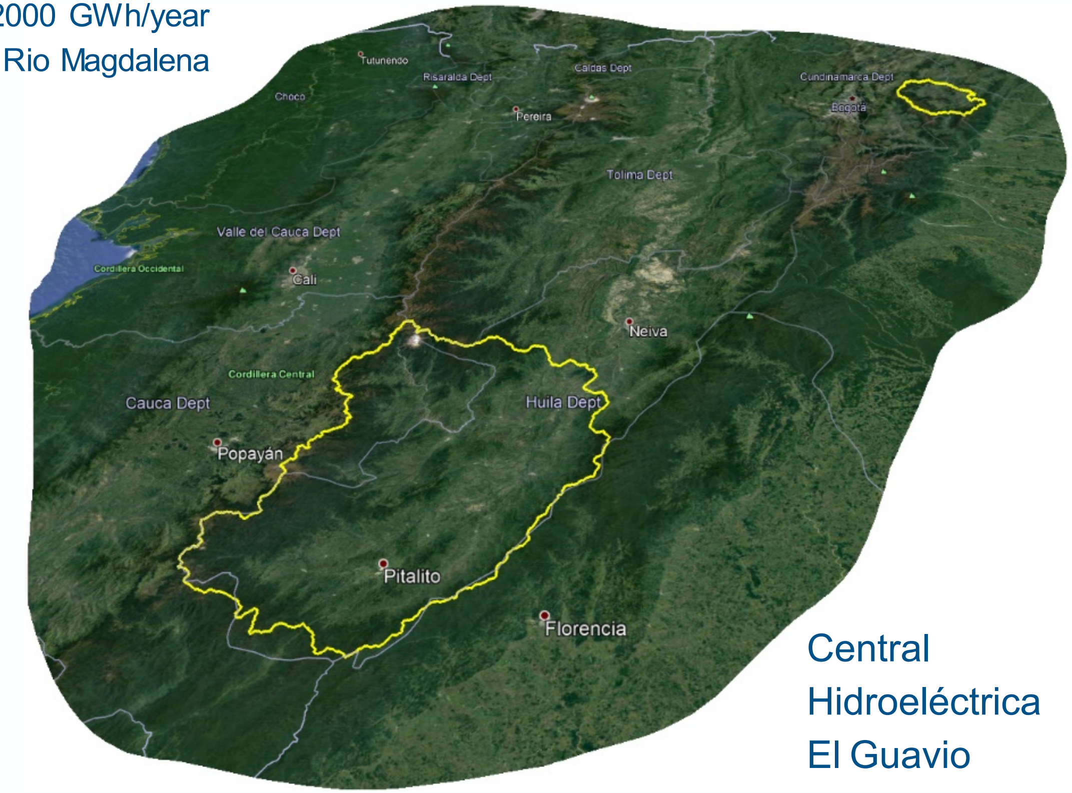




"Simplicity is the ultimate sophistication "

Where is the value in forecasting for HP ?

Central Hidroeléctrica
Betania
2000 GWh/year
Rio Magdalena



Central
Hidroeléctrica
El Guavio
5500 GWh/year
Rio Guavio

Locla used data are monthly iucoming disharge to the 2 reservoirs recorded in the last 20 years

First application – Hydropower for EGP
Where is the value of AI forecasting for HP ?

Problems

- **Technical** : Knowing in advance means planning **management** of the reservoir to increase production

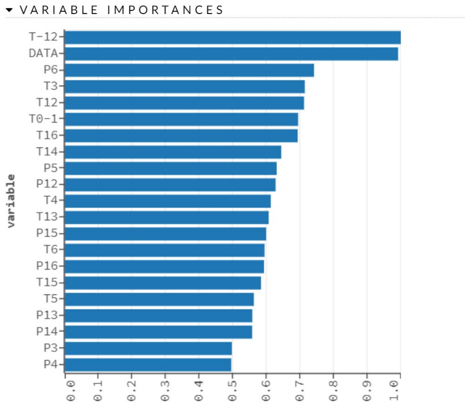
- **Financial** = Deviation between the scheduled annual production and actually achievable production requires:
    - Corrective sales / purchase of energy
        - If you buy increasing unit costs during the year
        - If you sell redundancies have decreasing benefits in the year round.

Objective

- Knowing as early as possible deviation at the year end between budget producibility and final production to be able to undertake the most advantageous corrective actions.

AI lightweight workflow setup

Selecting most informative FEATURES available operationally
(i.e. P,T Seasonla FORECAST from Copernicus CDS)



Tree based relative variable importance

And cross correlation

Exploiting power of AUTOML

model_id	mean_residual_deviance	rmse
GBM_grid_1_AutoML_20190404_203847_model_91	751935.437897656	867.14
DRF_1_AutoML_20190404_203847	812327.561287064	901.29
XRT_1_AutoML_20190404_203847	851252.1116687973	922.63
GBM_grid_1_AutoML_20190404_203847_model_71	851279.4798175697	922.64
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GBM_grid_1_AutoML_20190404_203847_model_78	872708.6184079287	934.18
StackedEnsemble_BestOfFamily_AutoML_20190404_203847	881258.2452519641	938.75
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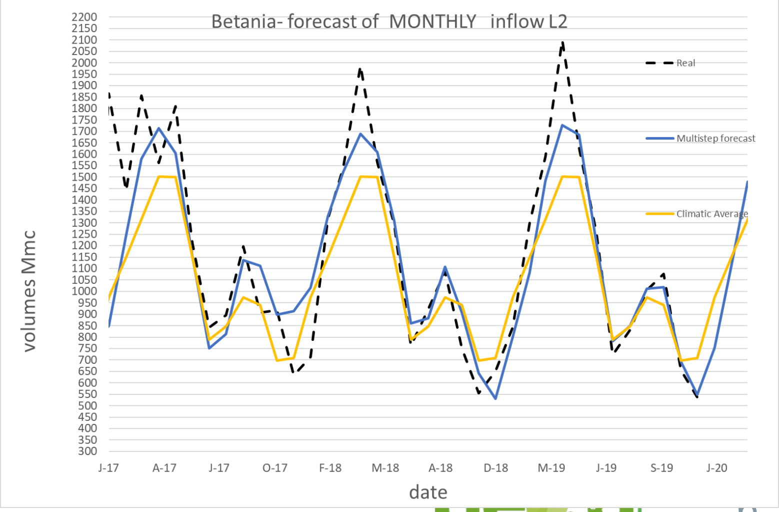
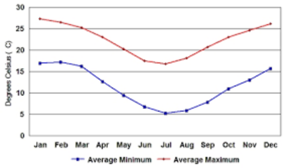
GBM_grid_1_AutoML_20190404_203847_model_50	904389.176157908	950.99
GBM_grid_1_AutoML_201904		

Using AI to get consistently forecast performances improvements over benchmarks

(i.e. Climatic average or alternative simple regeressors setup by EGP)

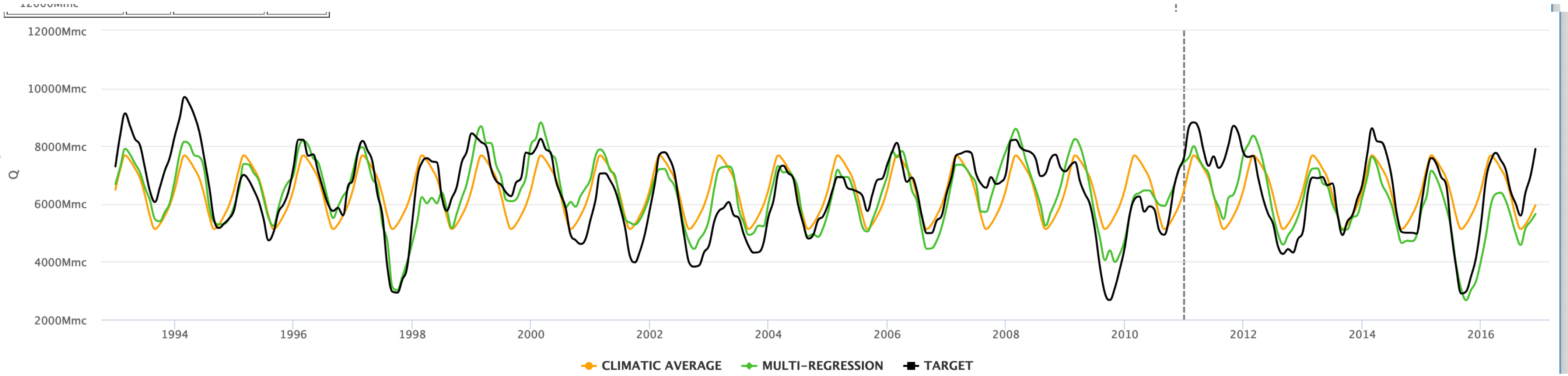


Baseline and Benchmark



BASELINE : What you have for free : trivial bench - climatic average

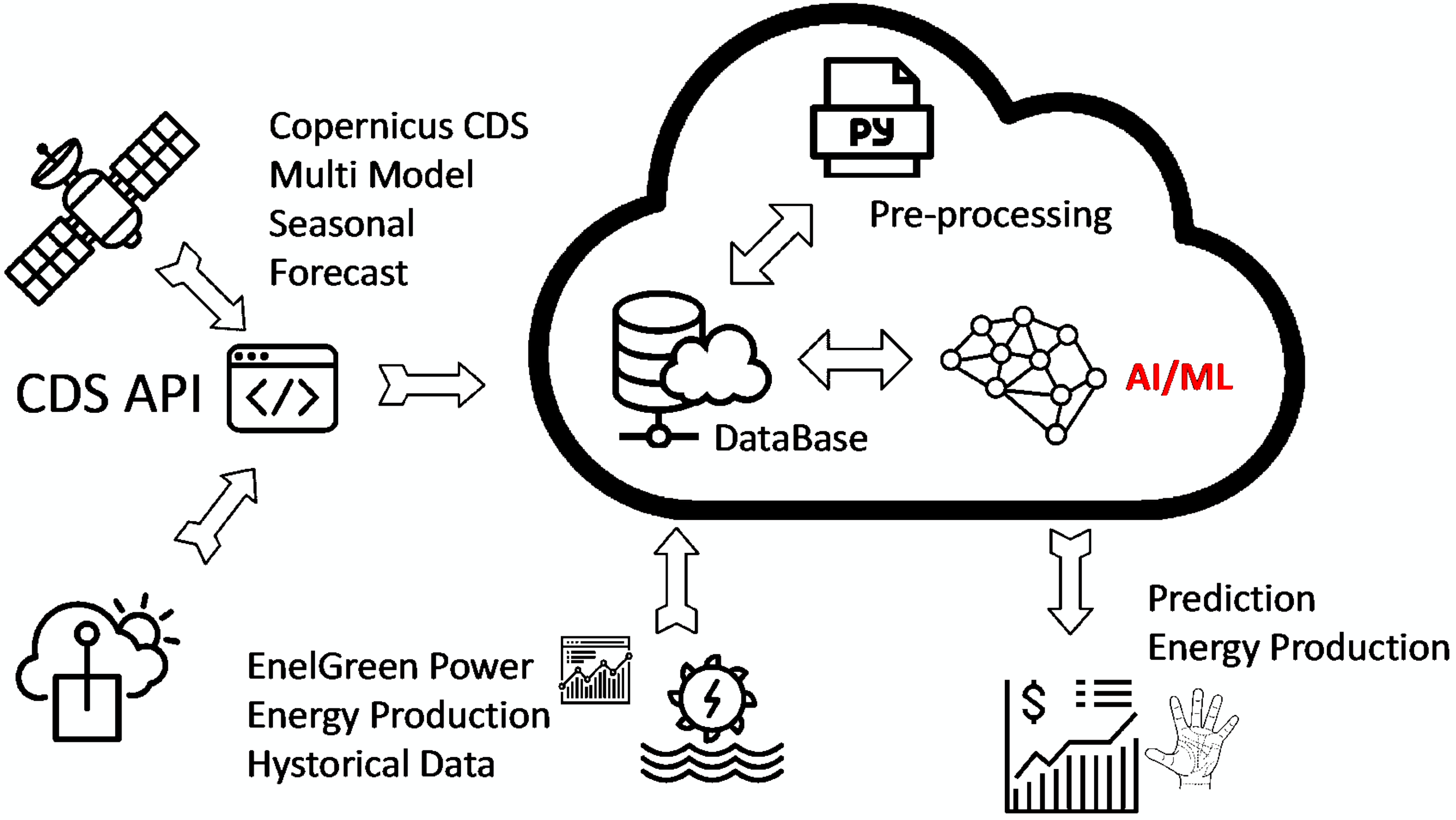
BENCHMARK: What you can setup with an excel spreadsheet - multiregression with same input features - EGP



Best Model Results Vs Baselines- RMSE

	BETANIA 6 Months RMSE (1E6 mc) Cum. Vol 6 Months	GUAVIO 3 Months RMSE (1E6 mc) Cum. Vol 3 Months
Deep Learning (LSTM)	697	116
SVR	819	116
Multi-regression (by EGP)	960	135
Climatic Average	1000	136

Translating forecast intelligence into Operational Cloud-Web CS



A web service that shows forecast and performances

The added value example for HPIS the provide intelligence good "Enough"?

	NO SEASONAL FORECAST	SCHT AI-based CS	PERFECT FORECAST
Years 2000-2016	100.0%	101.7%	103.1%
Years 2011-2016	106.0%	106.6%	108.3%

A simple test made with EGP :
Simulation of expected benefits on annual producibility for budget adjustment twice a year, considering actual and perfect forecast

And current management reservoir rules

(*) with low energy price oh 4 $c/Kwh (PRE-COVID market condition…)

Second application – Forecast intelligence for Water distribution

Ridracoli Resevoir

- Over 33 Mm3 of capacity
- Small 80km2 mountain catchment
- Distributing drinking water to 3 Provinces in Emilia Romagna – Italy

Second application – Forecast intelligence for Water distribution

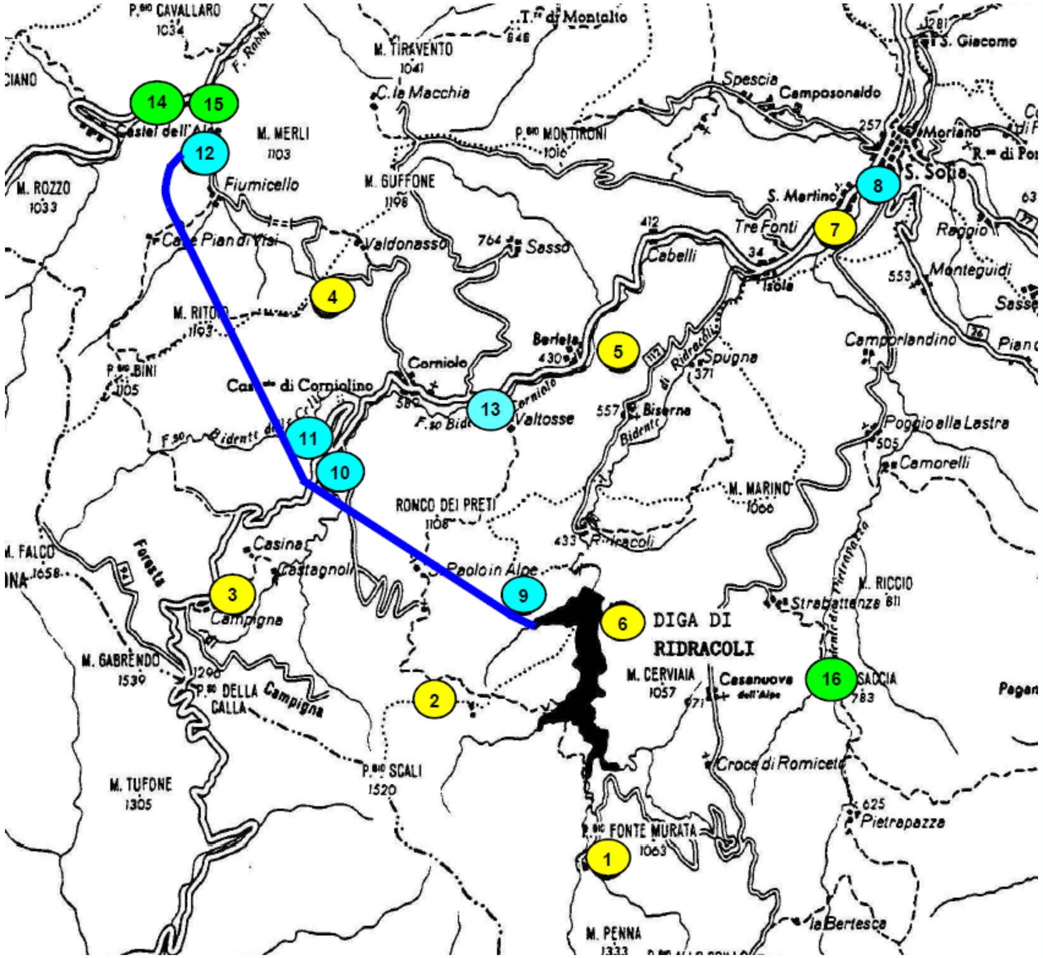
Problems

- **Technical** : Knowing in advance means planning **a mix of water resources to be exploited efficiently**
- A small, impulsive and very challenging catchment

Objective

- Reducing uncertainty in the average discharge coming to the reservoir for the next 14 days and the next month and testing operational forecast twice a month.

Getting a few Local data for effective downstreaming



Temperature/prec.

Discharge

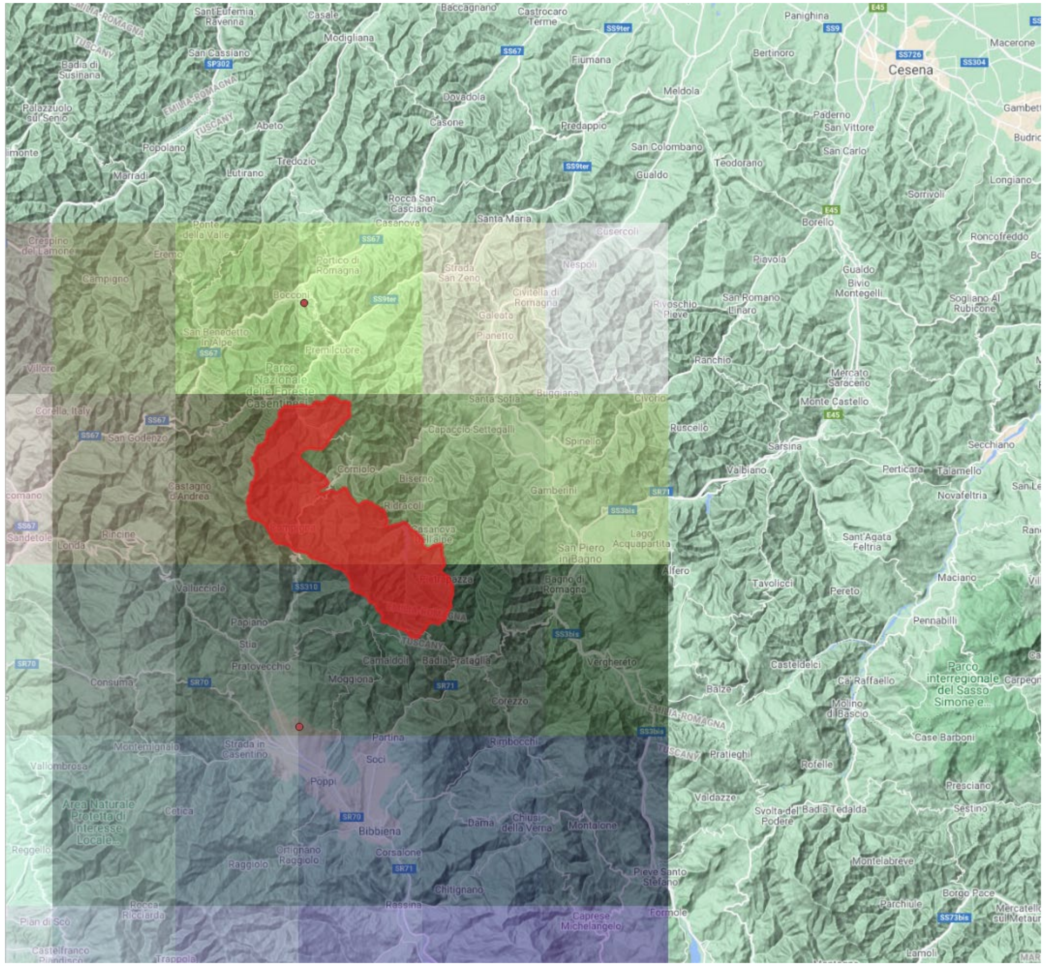
Testing ECMWF TIGGE forecast dataset Precipitation and temperature

Nearly operational meteo forecast (48 hours delay)

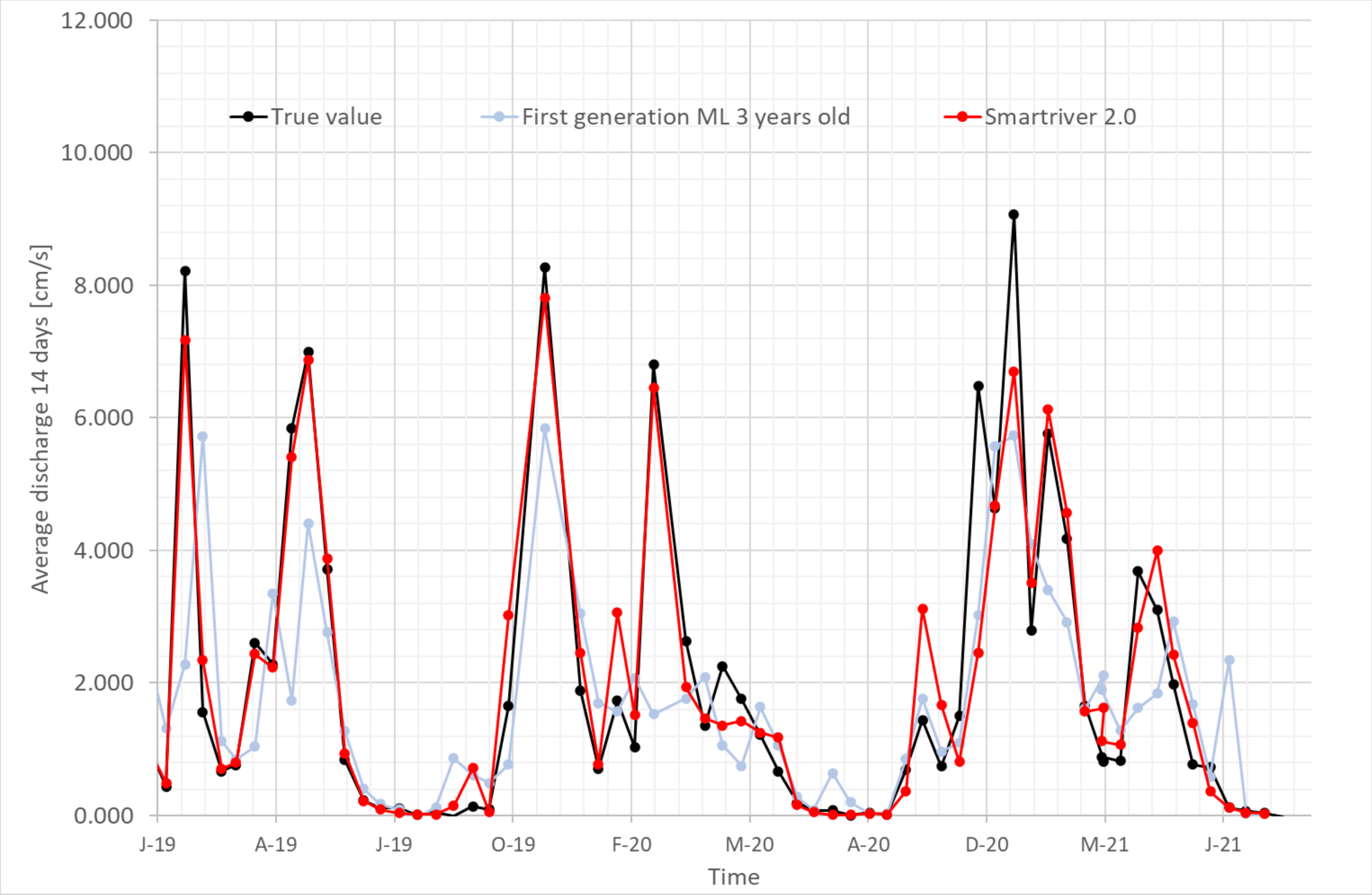
@ 10-25 km

P,T,SDWE

Leadtime upt to 10-15 days



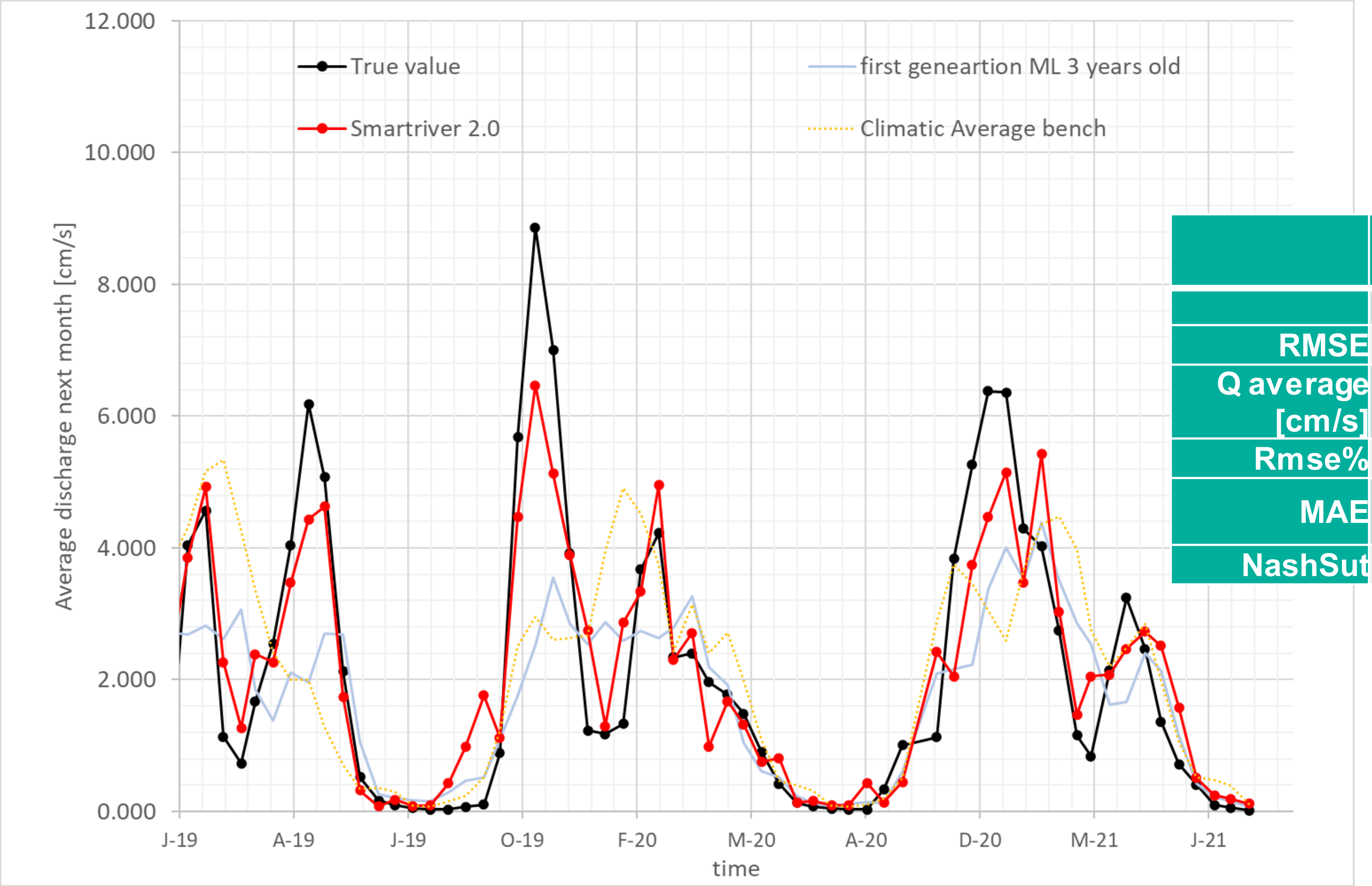
The improved forecast – next 14 days



Serious improvement over first generation forecast with simple ML models

	First genration ML	SMARTRIVER 2.0
	19-21	19-21
RMSE	1.42	0.89
Q average [cm/s]	1.84	1.84
Rmse%	77%	48%
MAE	0.95	0.53
NashSut	0.6	0.84

The improved forecast – next month

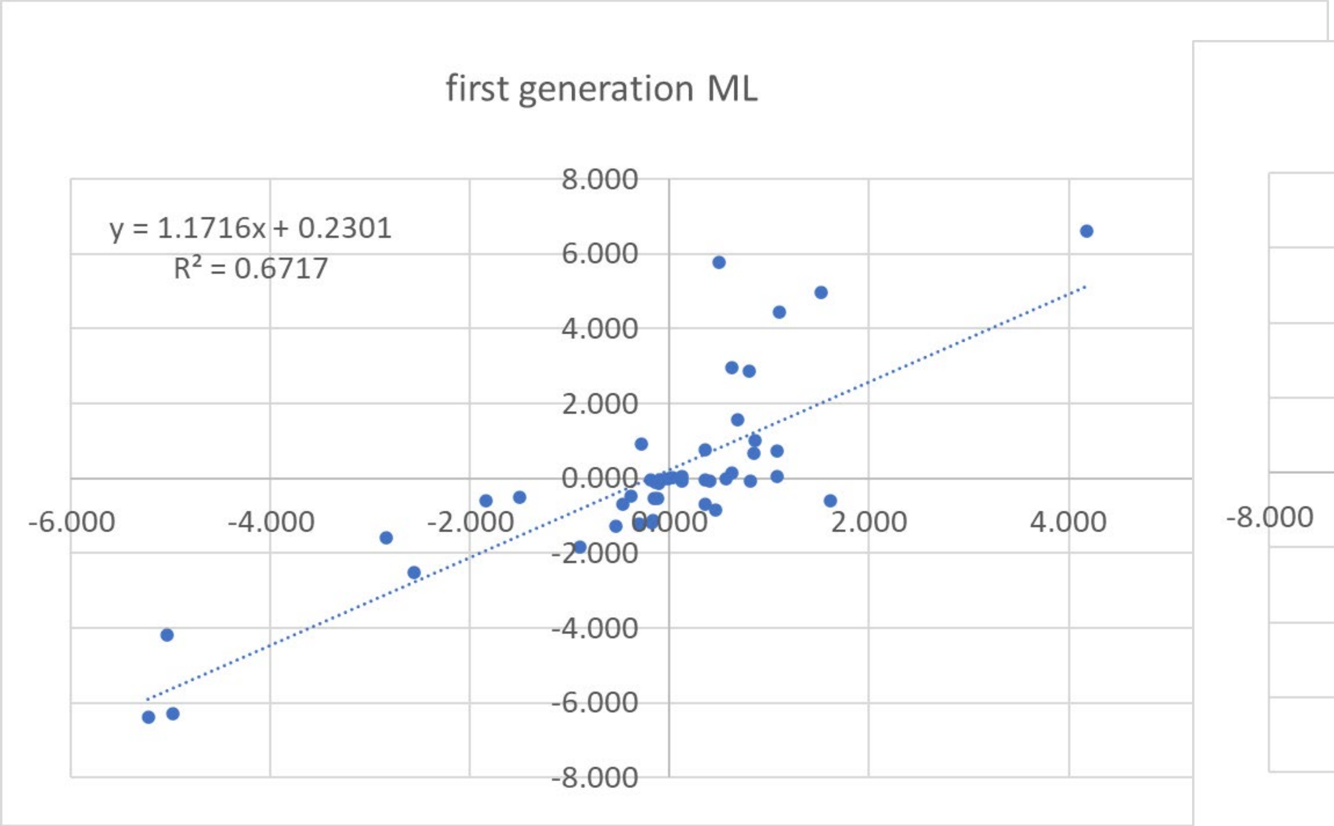


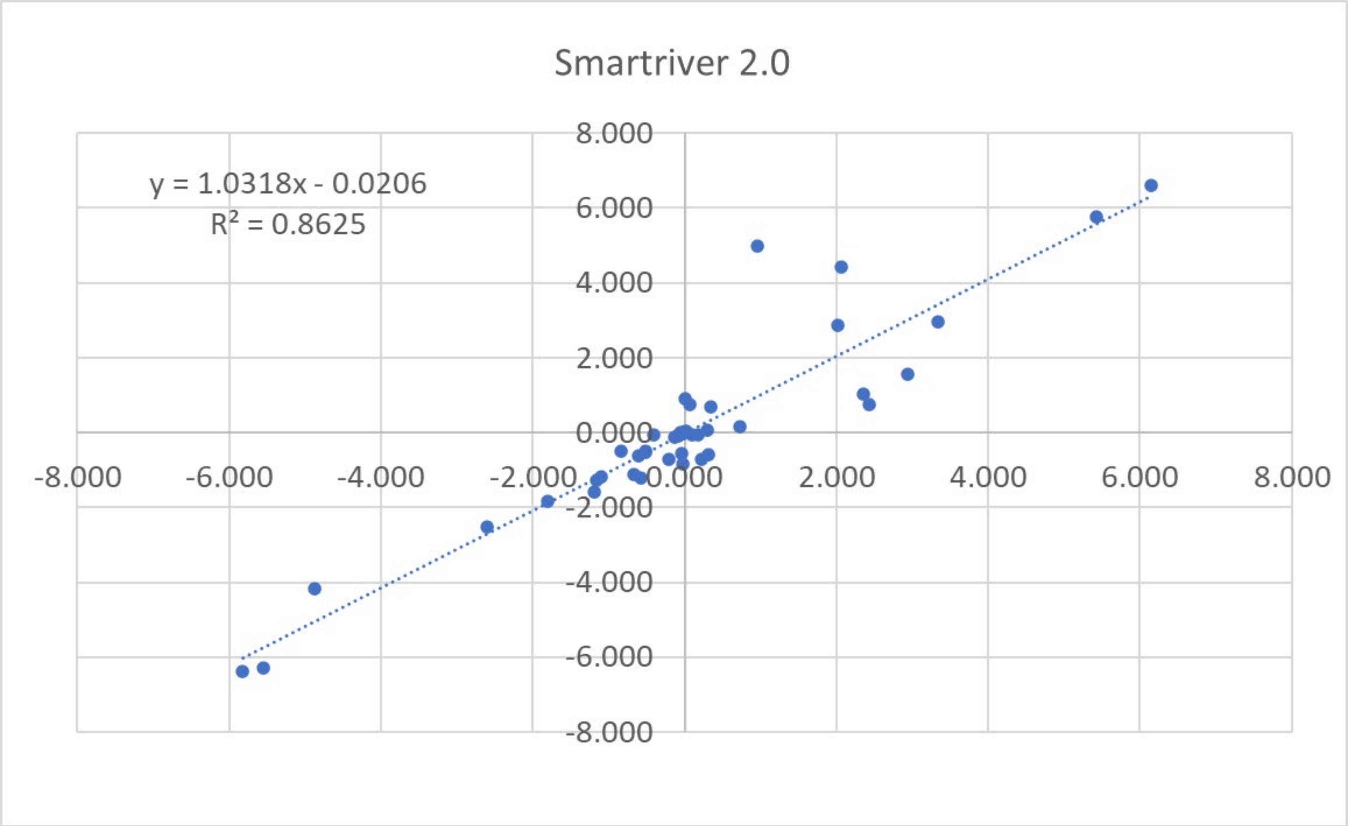
Serious improvement over first generation forecast with simple ML models

	First gen. ML	Climatic average	SMARTRIVER 2.0
		19-21	
RMSE	**1.59**	**1.73**	**0.93**
Q average [cm/s]	2.079	2.079	2.079
Rmse%	76%	83%	45%
MAE	0.99	1.07	0.68
NashSut	0.47	0.37	0.82

Predictive power added by SMARTRIVER

Showing predicted the time-differenced data (next precited time step minus previous recorded one) VS recorded time differenced data is a robust indication of the predictive power :





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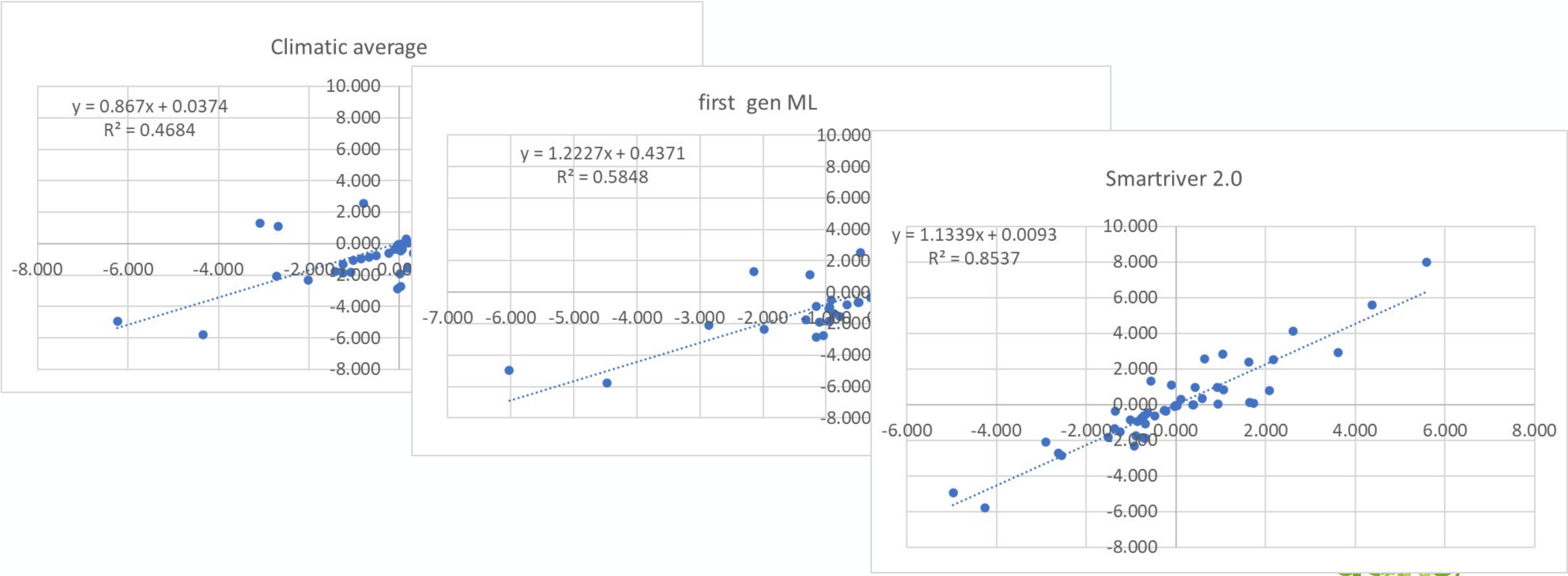

The added value example for HP

- SMARTRIVER AI-based forecast can **improve** water forecast to **usable** figures for different target users
- IT's **low time and resource consuming** and can be replicated in multiple sites virtually **WORLDWIDE**
  - No needs of complex hydrological models
  - Purely "data" driven
- SMARTIRIVER AI-based forecast realizes effective **Downstream Services** <u>from actual global and growing datastores data stores</u>