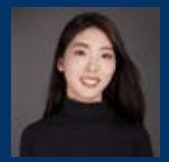
Integrating Scientific and Local Data

Enhancing Streamflow Predictions At Local Scale With Hybrid Modelling



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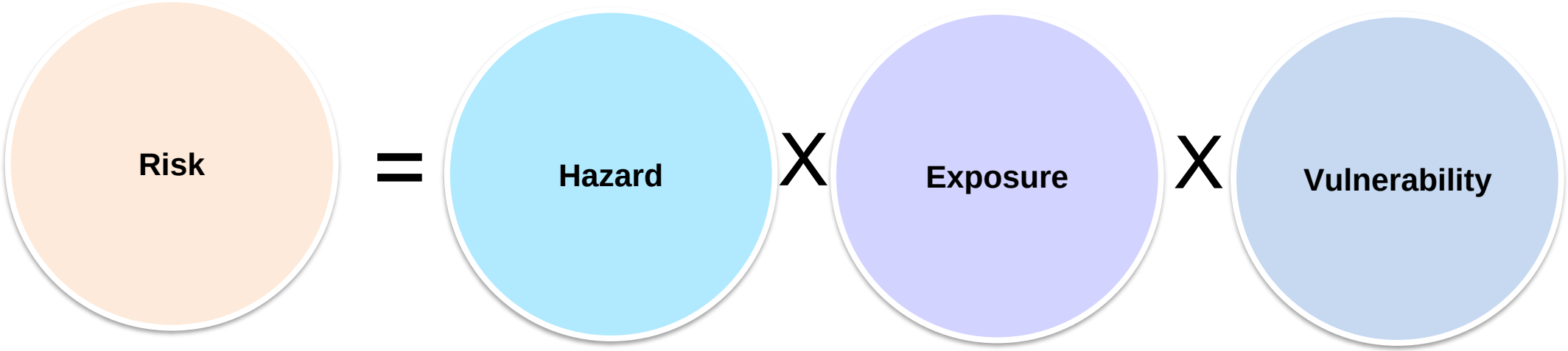
Challenge –Hydrological Modelling at Local Scale



Intensified extreme events
IPCC Sixth Assessment Report has noted increase of different extreme events, with high confidence level.

Heatwave, heave precipitation, river flood, drought, compound extremes.

Population Growth and Urbanization
More than 4 billion people – more than half of the world – live in urban areas.
Two third by 2050

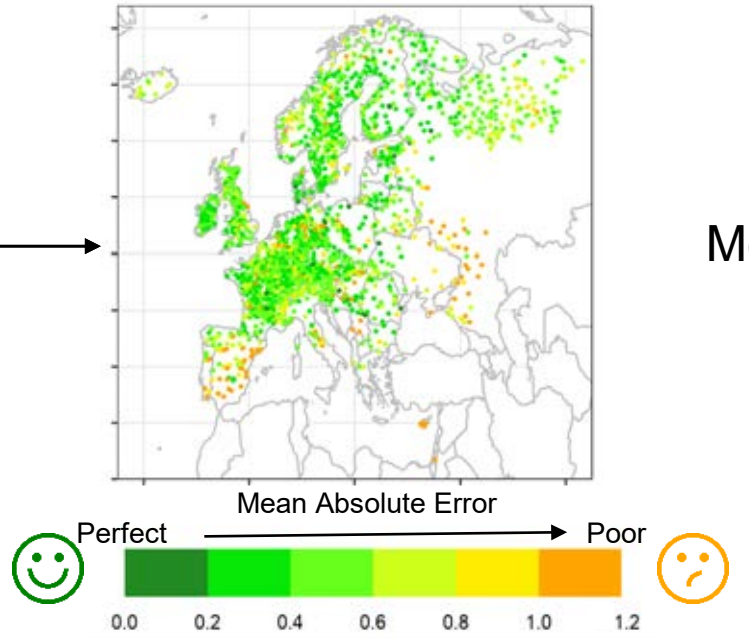
Concentrated population, infrastructure, water demand

Prepareness
Include:
Accurate forecasts of the hazards

Challenge –Hydrological Modelling at Local Scale

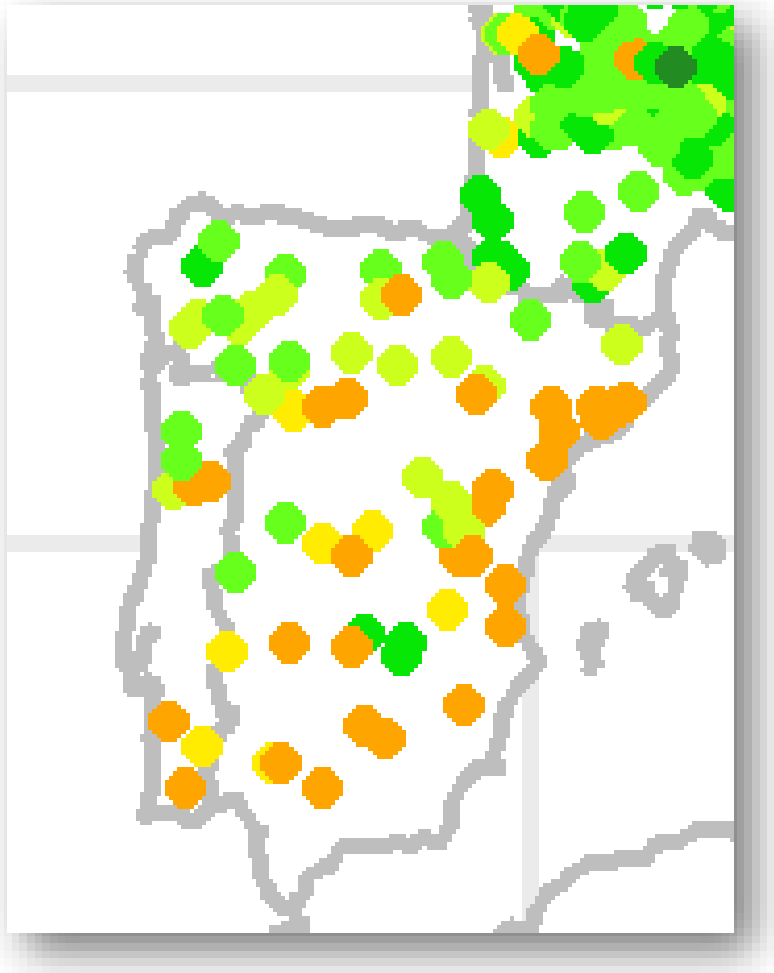
Simulation

Observation



Model imperfection

Challenge –Hydrological Modelling at Local Scale

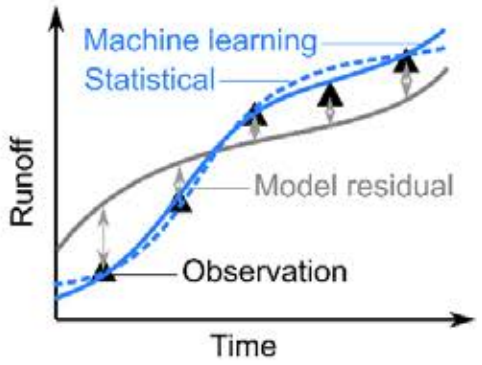


- Uncertainties and errors
  in model setup and parameter identification
- hydro-climatic gradient
- Anthropogenic influence

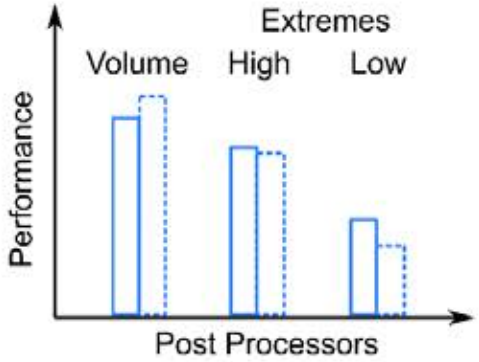
Solution – Hybrid Framework at Gauged Basins

Process-Based Model (Hydrological model)

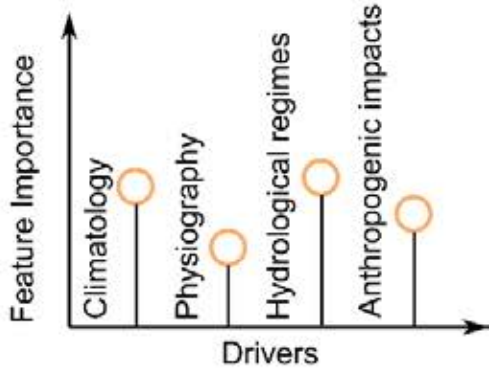
Post Processing



Evaluation



Performance Attribution



Observed and modelled data	Post-processing to local data	Evaluation and causation
• Inputs: Simulated streamflow • Outputs: Observed streamflow • OR • Residuals	• Generalized Linear Model (**GLM**) • Quantile Mapping (**QM**) • Random Forest (**RF**) • Long Short-Term Memory (**LSTM**)	• Compare performance • Identify patterns and drivers

Individually Trained

80% Training
20% Testing

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(Du and Pechlivanidis, 2025)

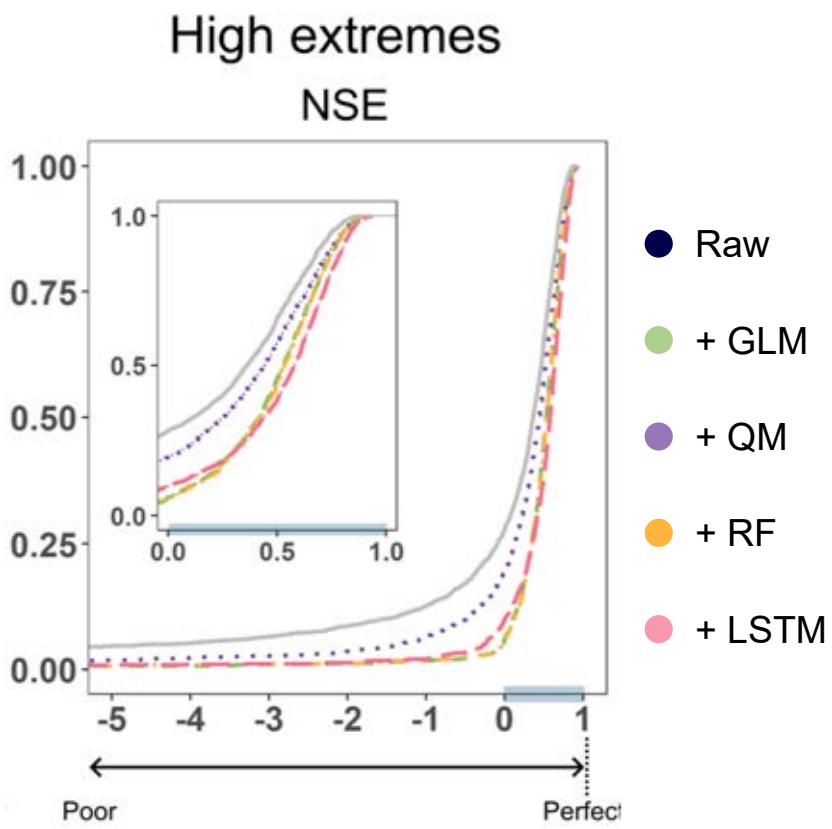
Performance – Hybrid Framework at Gauged Basins

High extremes:
NSE
Nash-Sutcliffe coefficient

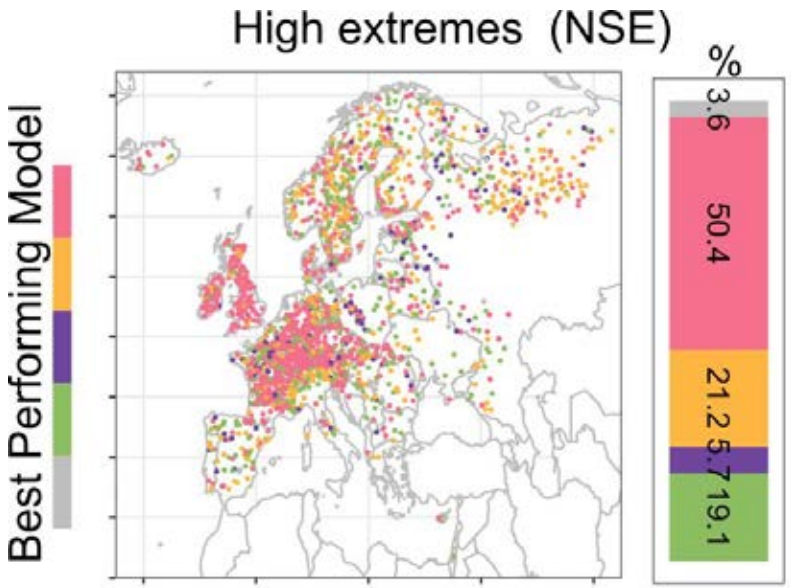
Low extremes:
logNSE
Logarithmic NSE

Total volume:
SMAE
Scaled Mean Absolute Error

Overall



Spatially



Hybrid modelling improves representation of streamflow characteristics at local scale

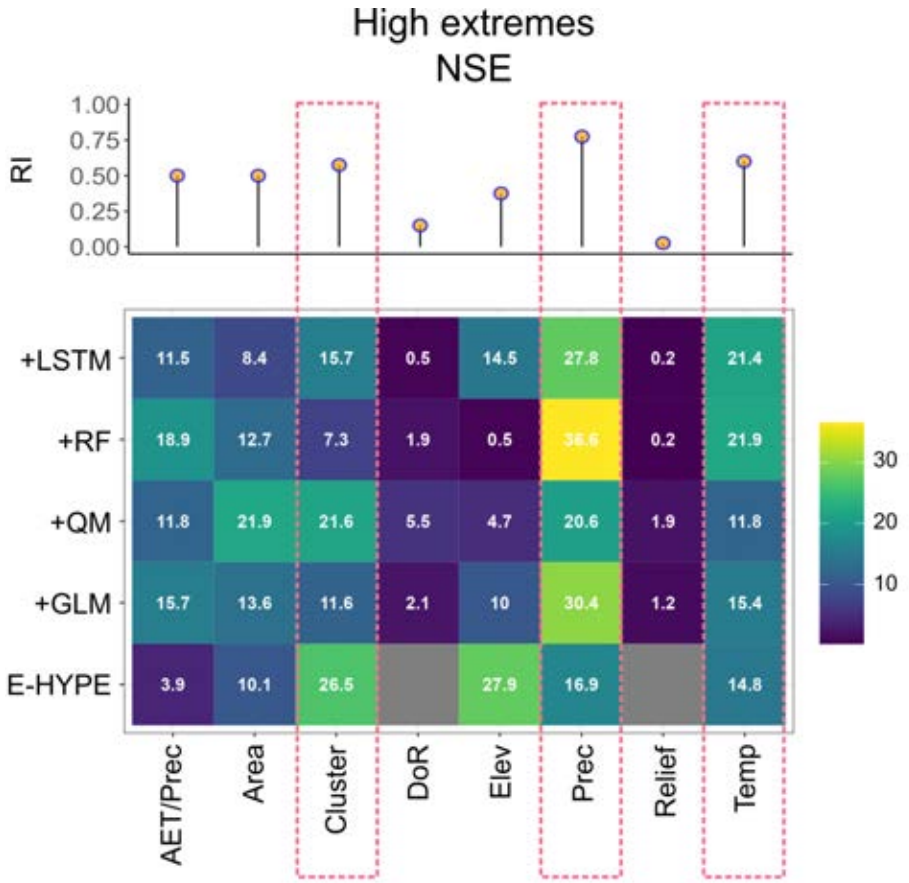
(Du and Pechlivanidis, 2025)

Understanding – Hybrid Framework at Gauged Basins

Potential drivers:

- Climatology
- Topography
- Human impact
- Hydrological regimes (Cluster)

CART
Classification and Regression Trees



(Du and Pechlivanidis, 2025)

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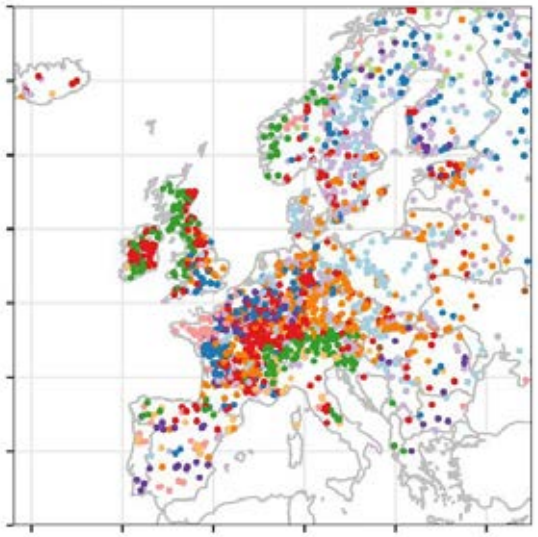
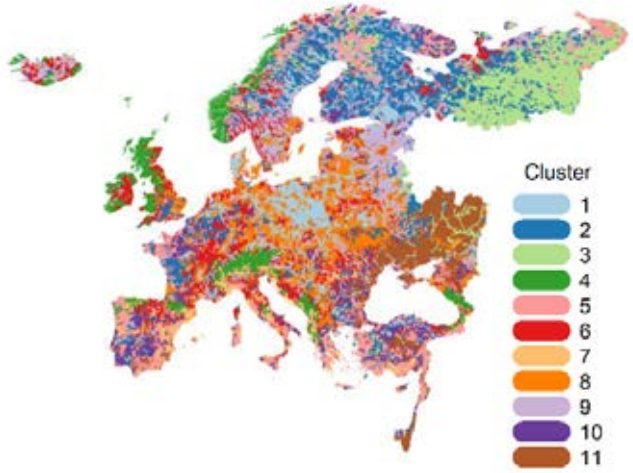
Hydrological Regime Is Within The Leading Drivers To Model Performance Enhancement

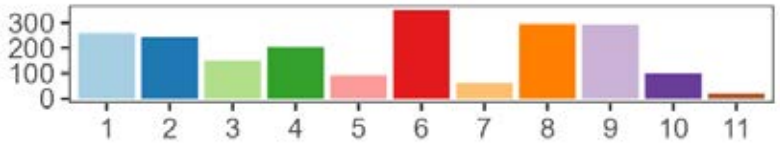
Solution – Hybrid Framework at Ungauged Basins

Regionalization - Hydrological similarity





Station Numbers

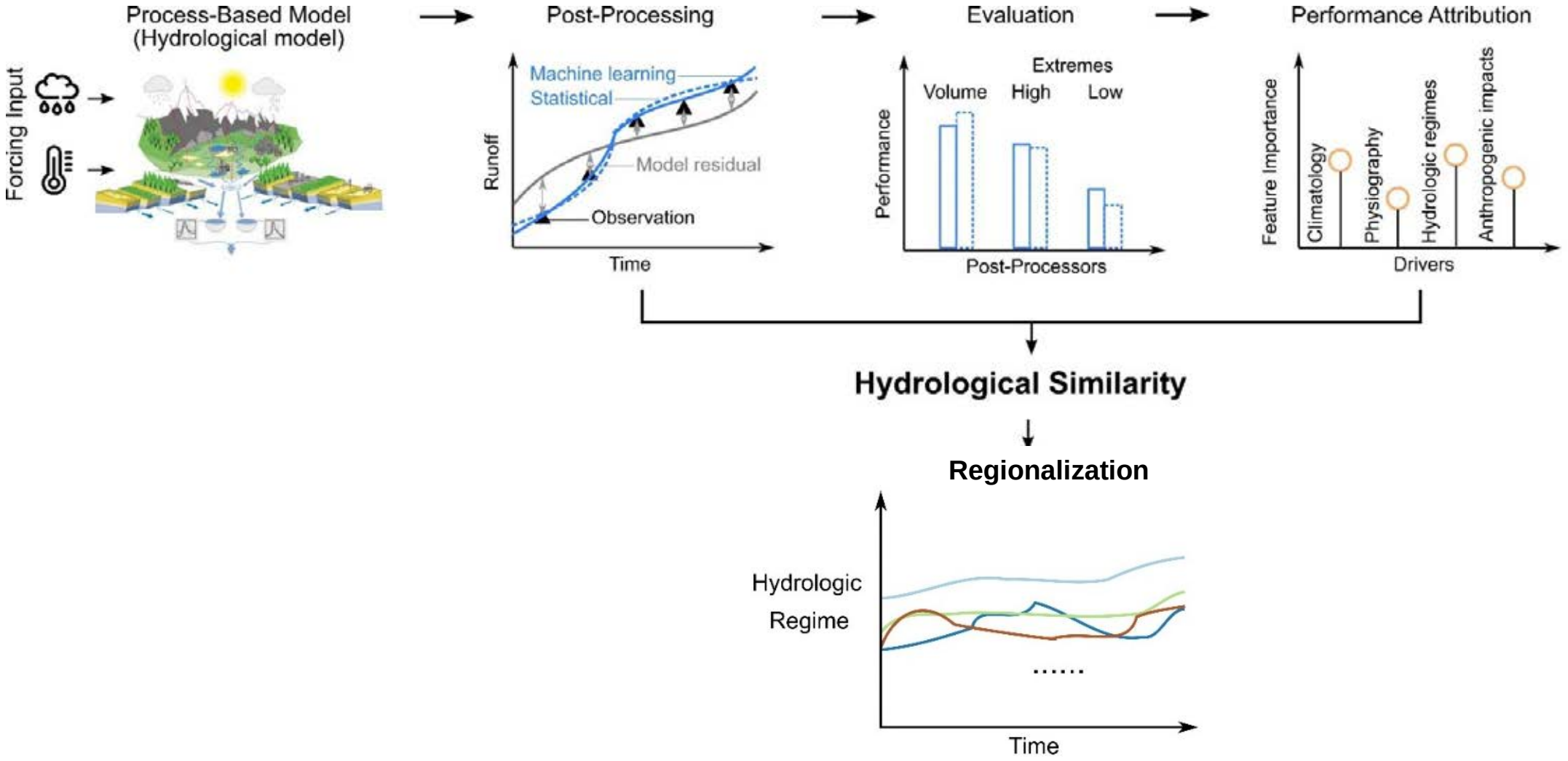


Cluster

Regionalization: from ~2000 stations to ~35400 sub-catchments based on clusters

(Pechlivanidis et al, 2020)

Solution – Hybrid Framework at Ungauged Basins



Solution – Hybrid Framework at Ungauged Basins

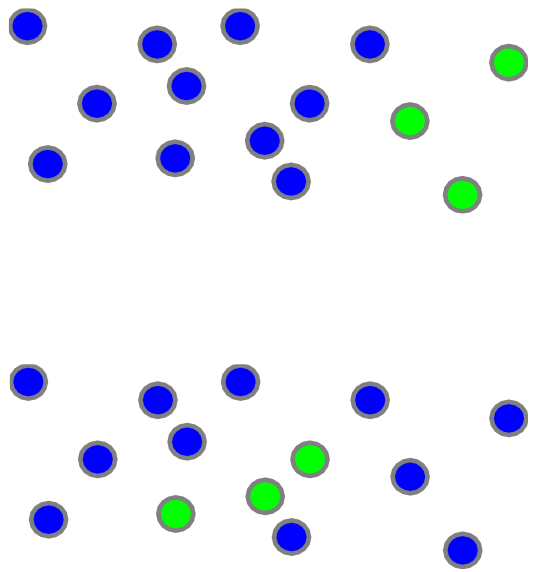
Static variables:

Climatology
Topography
Hydrological regimes

Name	Abbr.
Precipitation	Prec
Temperature	Temp
Snow depth	Snow
Actual evapotranspiration	AET
Potential evapotranspiration	PET
Dryness index	PET/Prec
Evaporative index	AET/Prec
Upstream Area	Area
Elevation	Elev
Relief ratio	Relief
Slope	Slope
Hydrological regime	Cluster

Dynamic variables:

Precipitation
Temperature
Simulated runoff

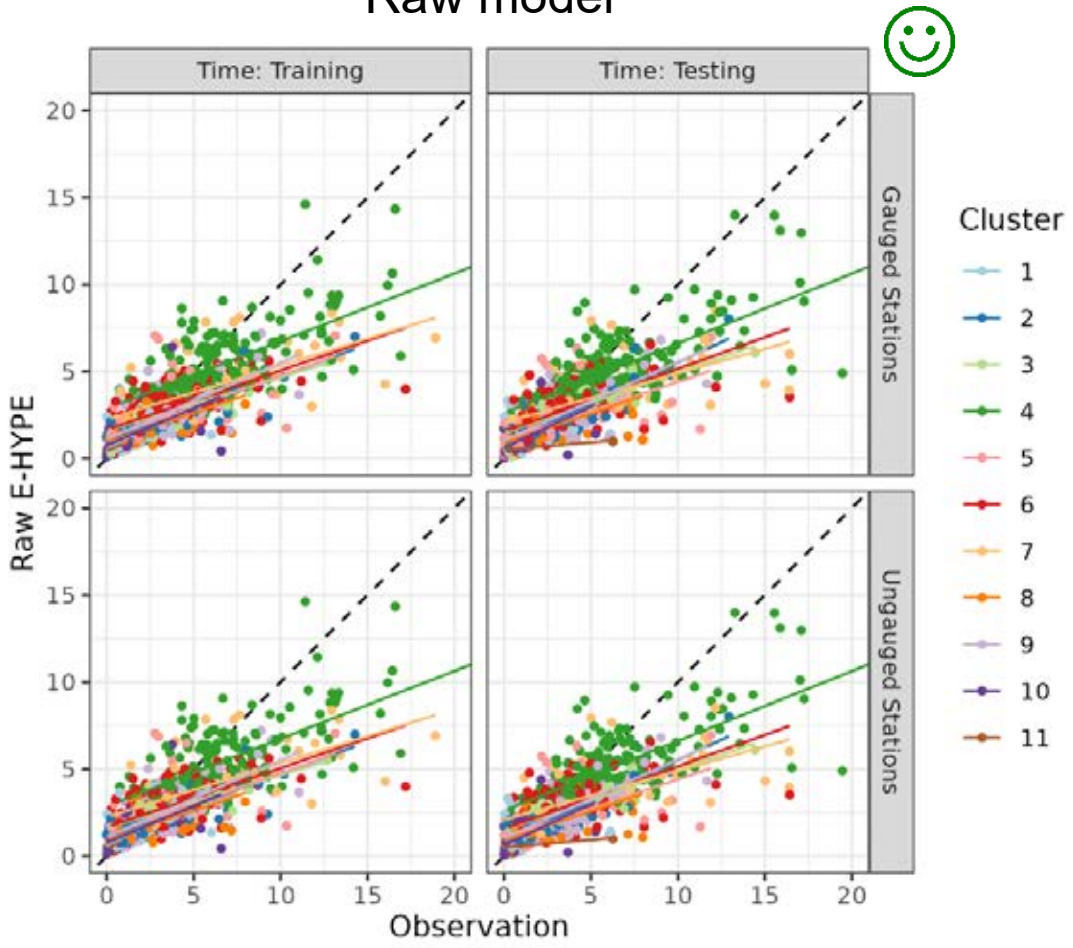


Cross Validation

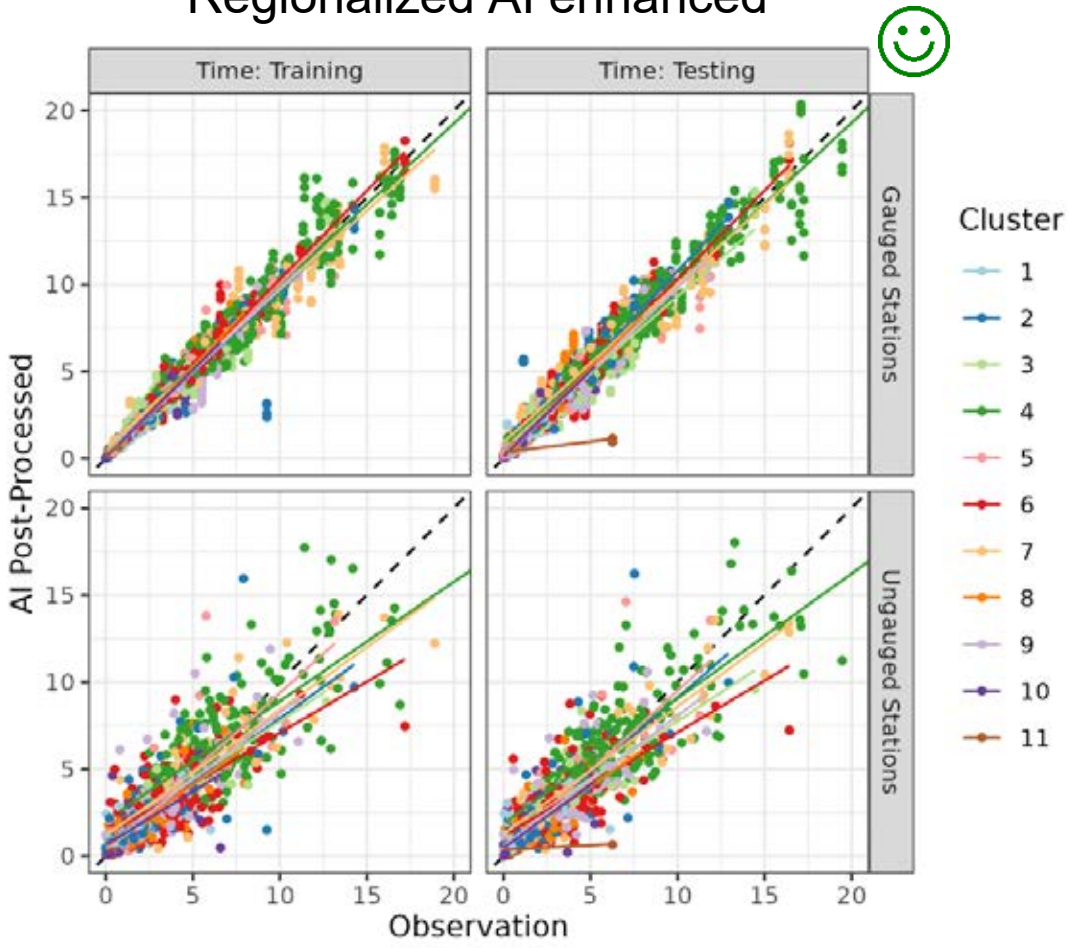
Performance – Hybrid Framework at Ungauged Basins

High extreme, Q90

Raw model



Regionalized AI enhanced



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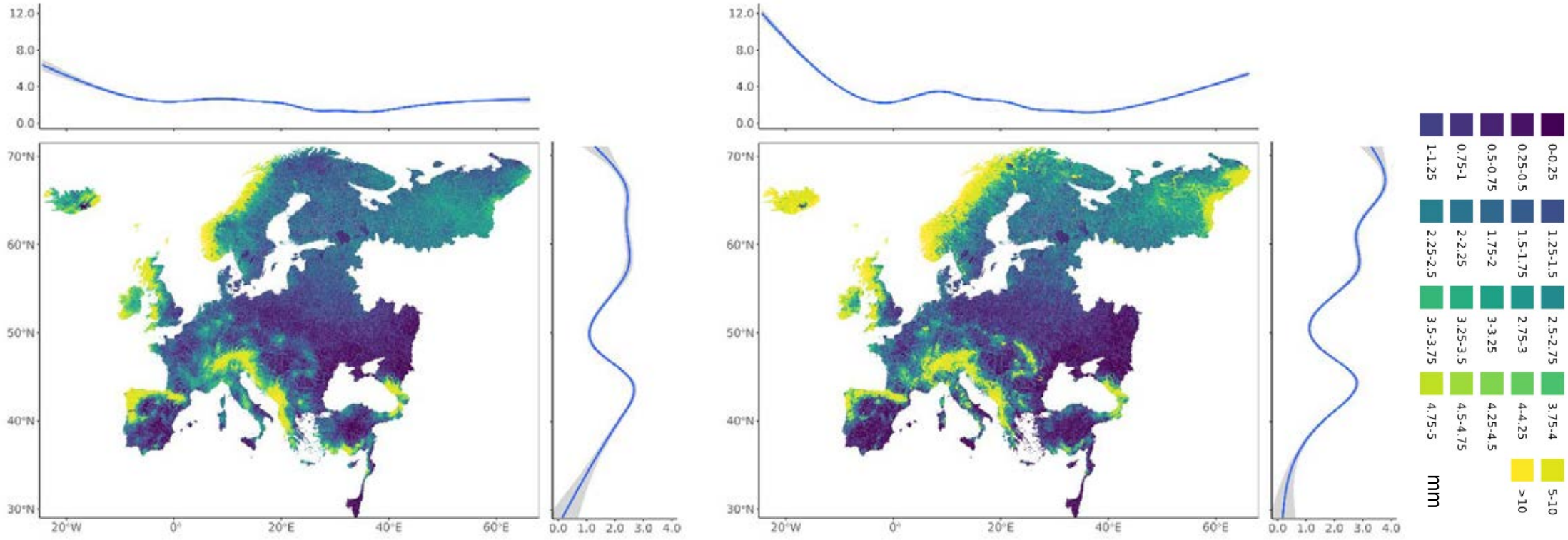
AI-enhancement have added values for both gauged and ungauged basins, also varies across hydrological regimes

Application – Hybrid Framework at Pan European Domain

High extreme, Q90

Raw model

Regionalized AI-enhanced



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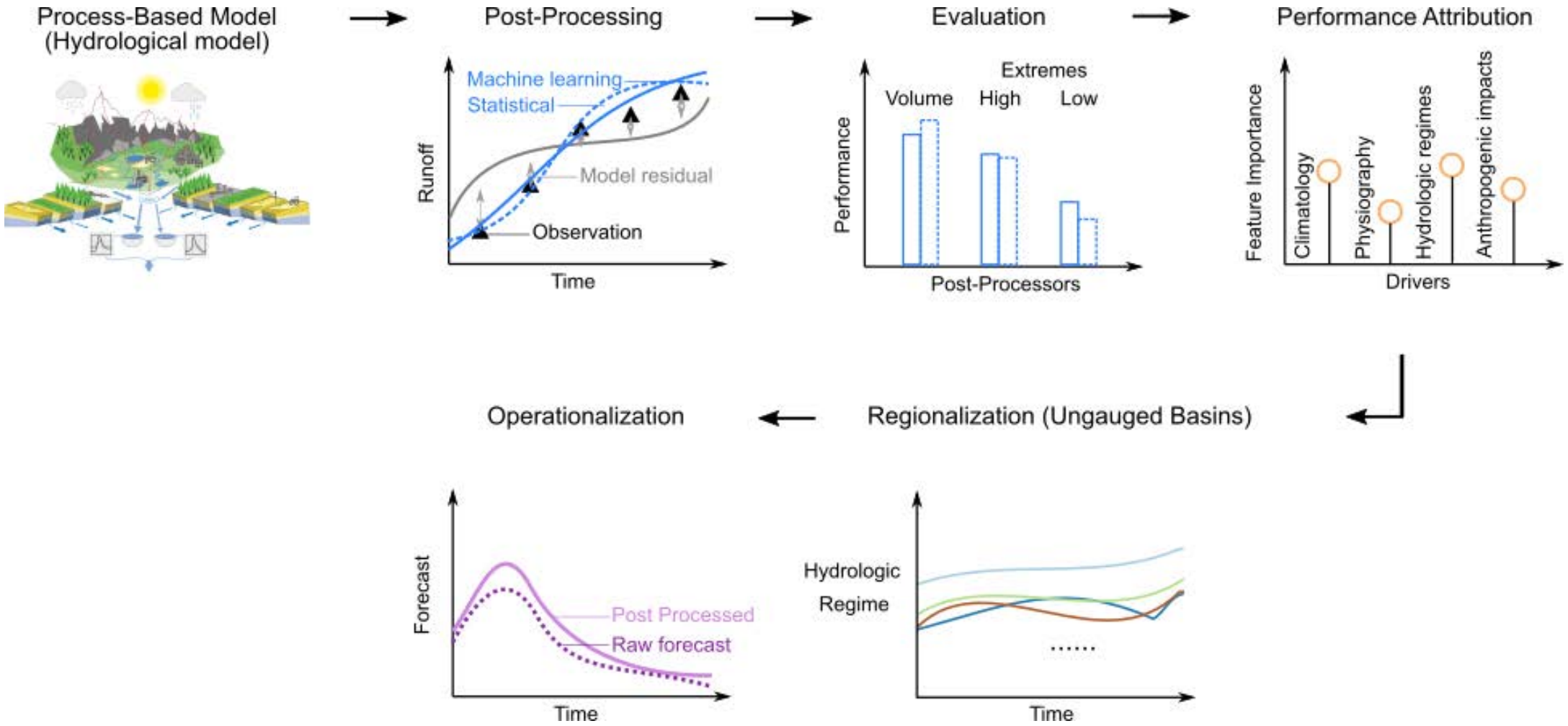
AI-enhancement provides updated pattern of hydrological signatures

Application – Hybrid Framework in Operational Forecast



Take home messages

- **Large-scale hydrological models** are important tools to support equitable access to climate services.
- However, they often face challenges **at the local scale**, where critical decisions are made.
- **A hybrid framework** that integrates post-processing techniques can improve their performance.
- **A regionalized approach** can even enhance predictions in ungauged basins by using information from gauged ones.
- These methods show strong potential to be **operationalized** in climate and hydrological forecast products.

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