# Seasonal forecasts of discharge in the Upper Danube upstream of Vienna

**Session HS4.4:** Ensemble and probabilistic hydro-meteorological forecasts: predictive uncertainty, verification and decision making


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# Overview

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- Study area
- Hydrological model – COSERO
- Seasonal discharge forecast system
  - Methodology
  - Bias correction
  - Forecast outputs
- Seasonal forecasts assessment
  - Ensemble spread
  - Forecast skill
- Conclusions

# Introduction – Climate services

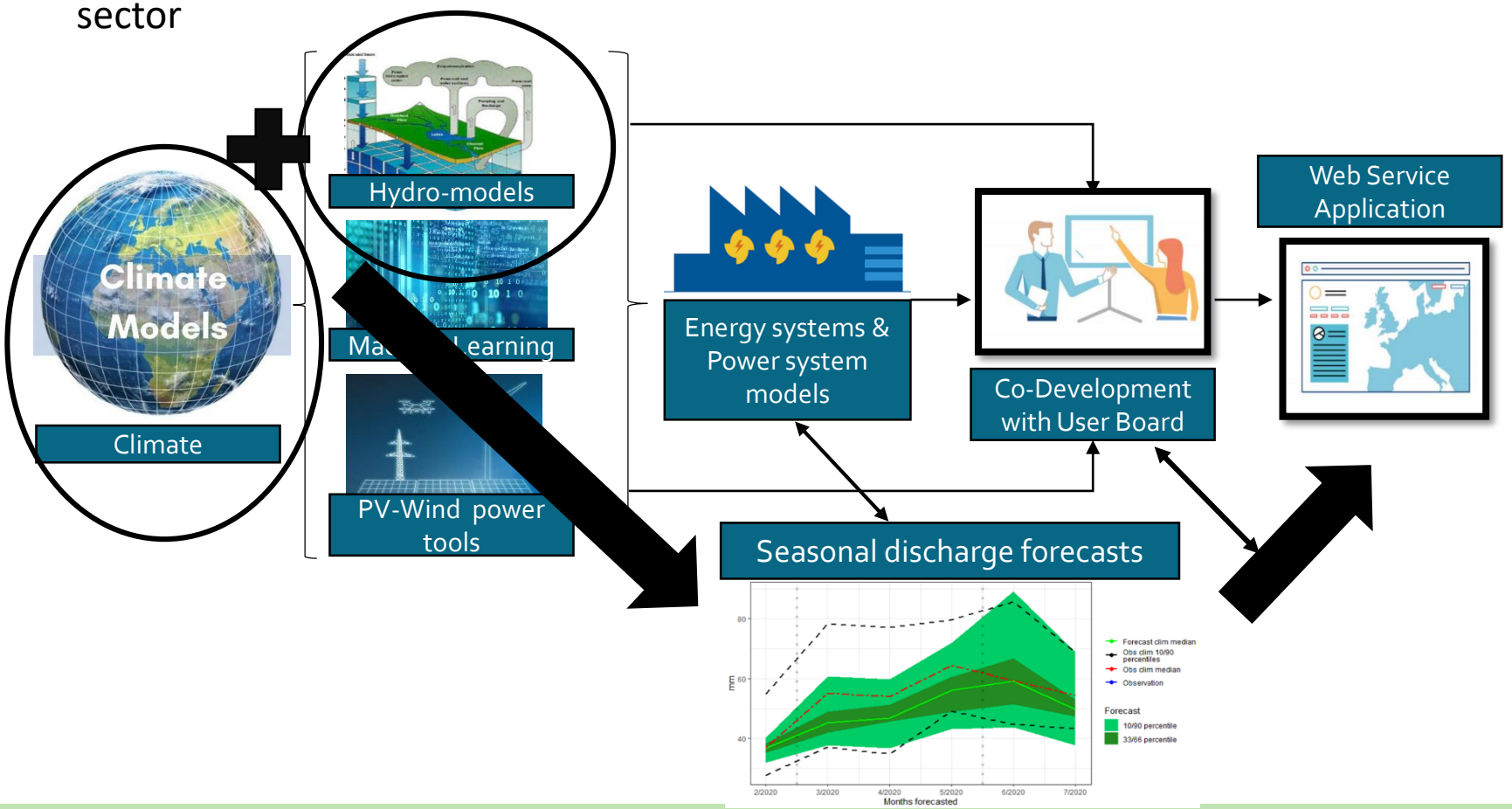
CLIM2POWER

Translating Climate Data into Power Plant Operational Guidance

www.clim2power.com

- Increasing needs for transferring the advances in climate research into hydrological applications within the framework of climate services

- Clim2Power is a research project building a bridge between complex seasonal & long-term climate data and targeted, usable information for decision making in the energy sector



# Introduction - Seasonal discharge forecasting

- Seasonal forecasts are becoming one of the most important elements in some policy/decision making systems (e.g. energy sector). Reliable forecasts can result in better anticipation of water related risks in the near months

- Seasonal time scale typically up to a year ahead (chaotic nature of climate system will always limit our ability to predict the weather beyond a few days). Seasonal forecasts offer guidance on large-scale weather patterns and whether a given location will more likely behave above-normal or below normal over a month, referring to a variable of interest

- Dynamical predictions (used since mid 1990s) vs statistical predictions (used since the late 1800s)

- The more sophisticated models typically contain atmospheric, oceanic, land surface and sea ice modules at a relatively high level of complexity. Once forecasts have been produced by models, the process is far from finished ( bias correction, downscaling techniques, verification assessments needed)

Seasonal discharge forecasting valuable for water sector


Reservoir management


Hydropower generation

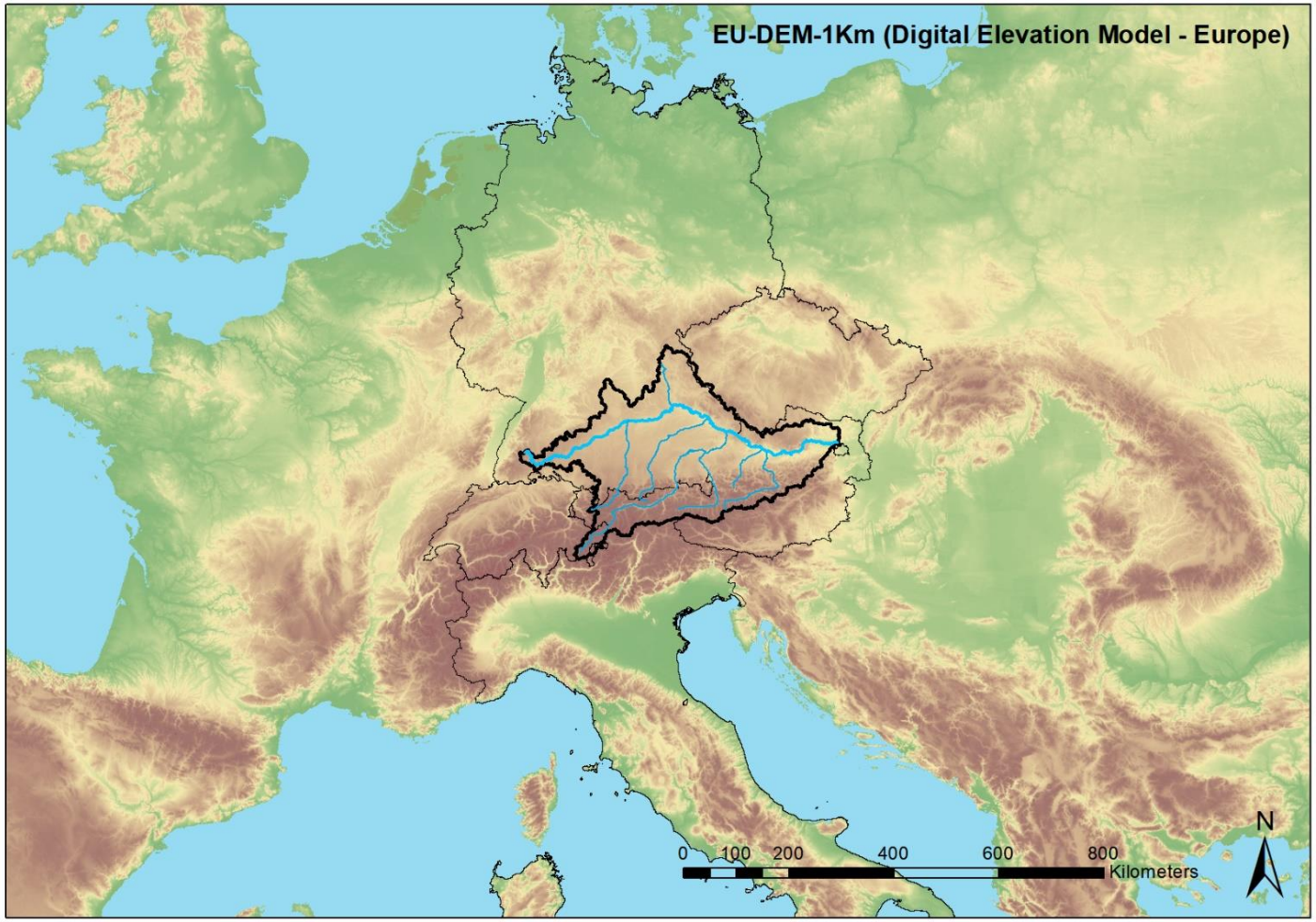

Navigation

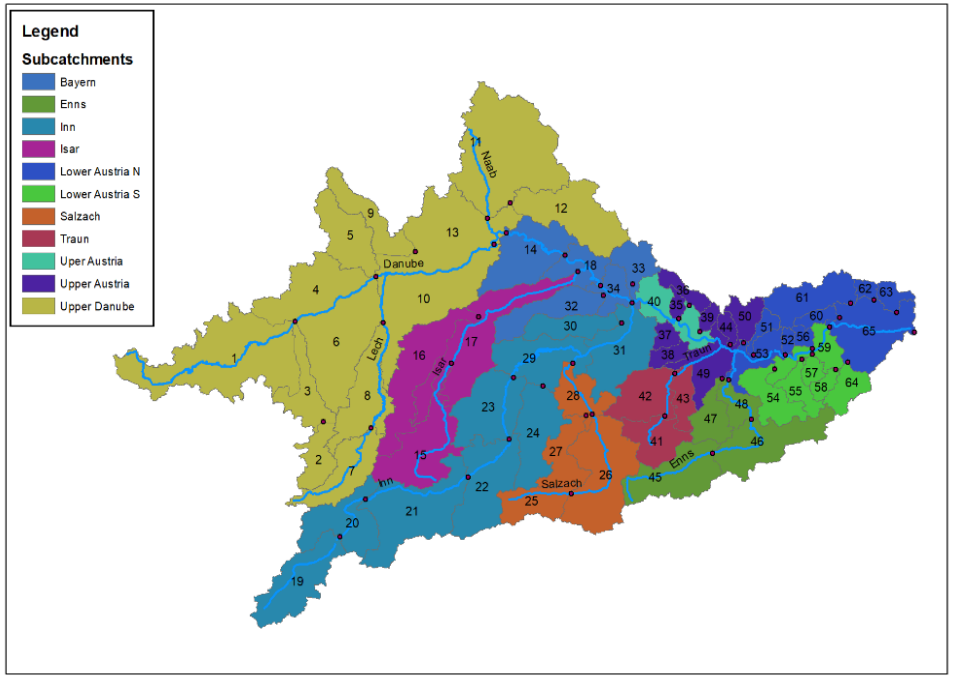

Agriculture


Drough risk management

# Study Area

UPPER DANUBE BASIN upstream of Vienna (Korneuburg)




- Total Area: 101.204 km²
- Spatial discretization:
  - 65 Sub-basins
  - 3777 HRUs
- Elevation range: ~150m to 4000m
- Mean annual prec.: 1100 mm
- Mean annual discharge: 1923 m³/s

# Hydrological model

- COSERO model is a continuous, semi-distributed, conceptual rainfall-runoff model (developed HyWa BOKU)

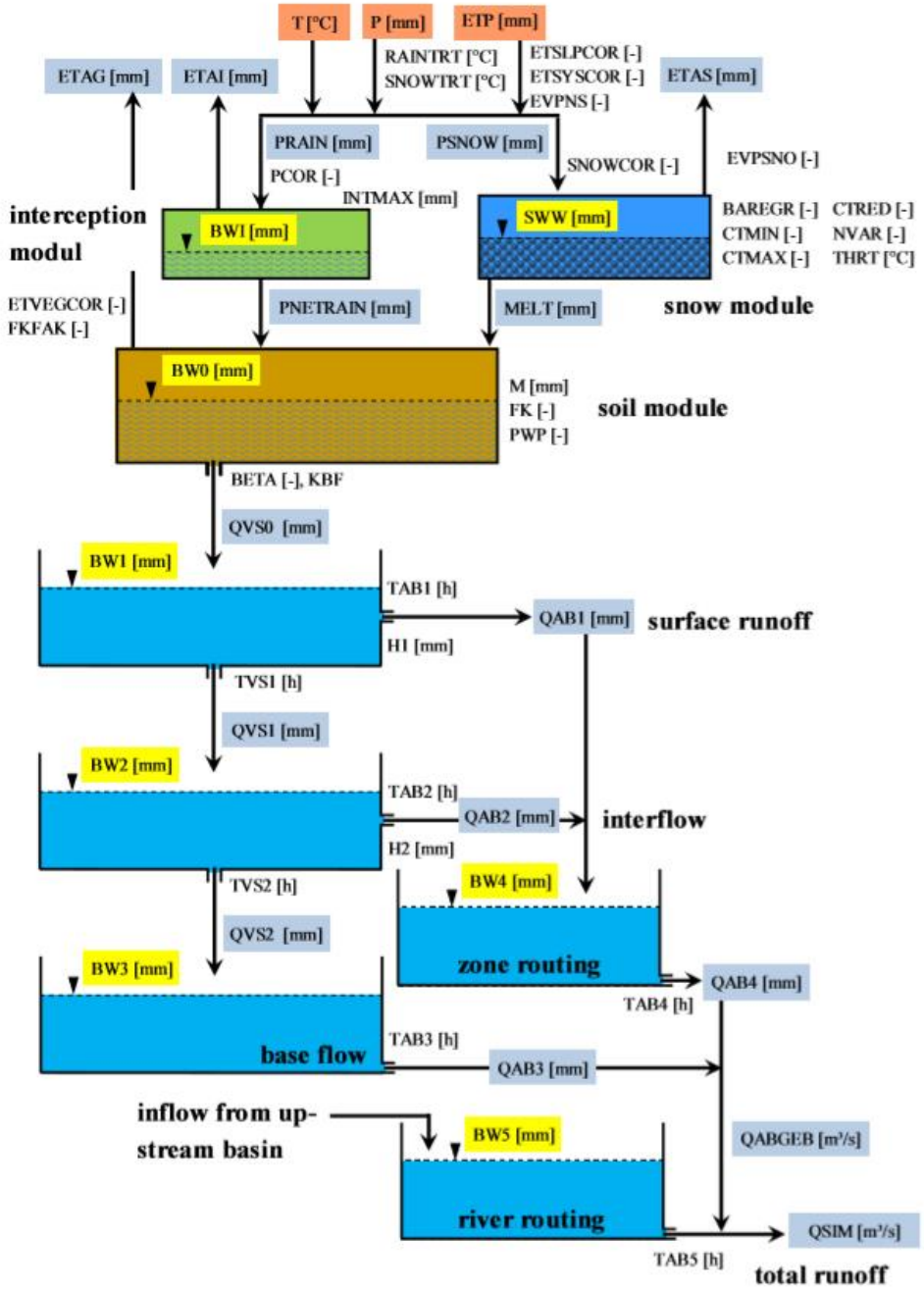
- It accounts for:

  - Accumulation and melting of snow
  - Actual evapotranspiration from interception
  - Snow and soil layer
  - Storage of water in the soil
  - Separation runoff into different runoff components

  by means of a cascade of linear and non linear reservoirs

- Ability for automatic parameter calibration

- Spatial modelling : river basin divided into several subbasin, simulated discharge computed at outlet.



# Seasonal discharge forecasting - Methodology

## Calibration/Validation Hydrological model

Reanalysis COSMO-REA6
(daily, ~6km) (1999-2015)

Temperature
Precipitation

↓

Hydrological Model
COSERO
(continuous, semi-distributed)

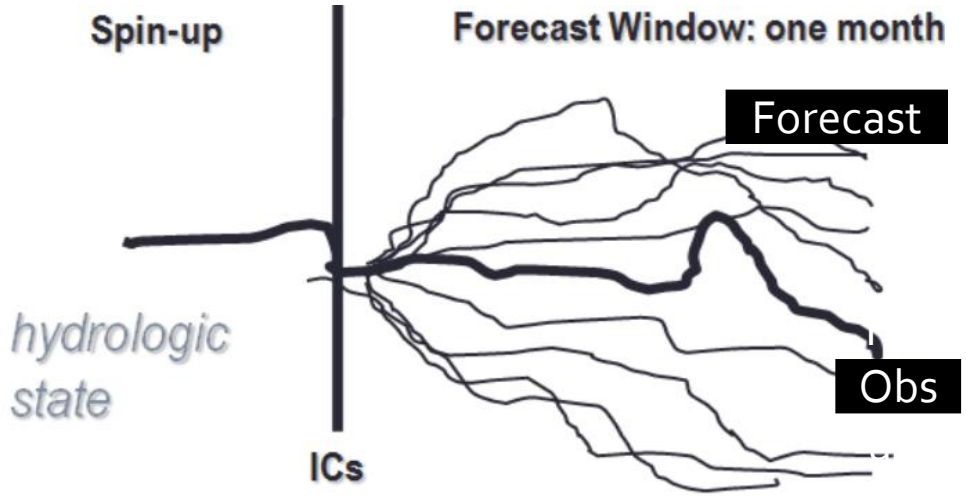
↓

Discharge simulation ← Discharge from Gauges (validation)

## Seasonal Forecasting System

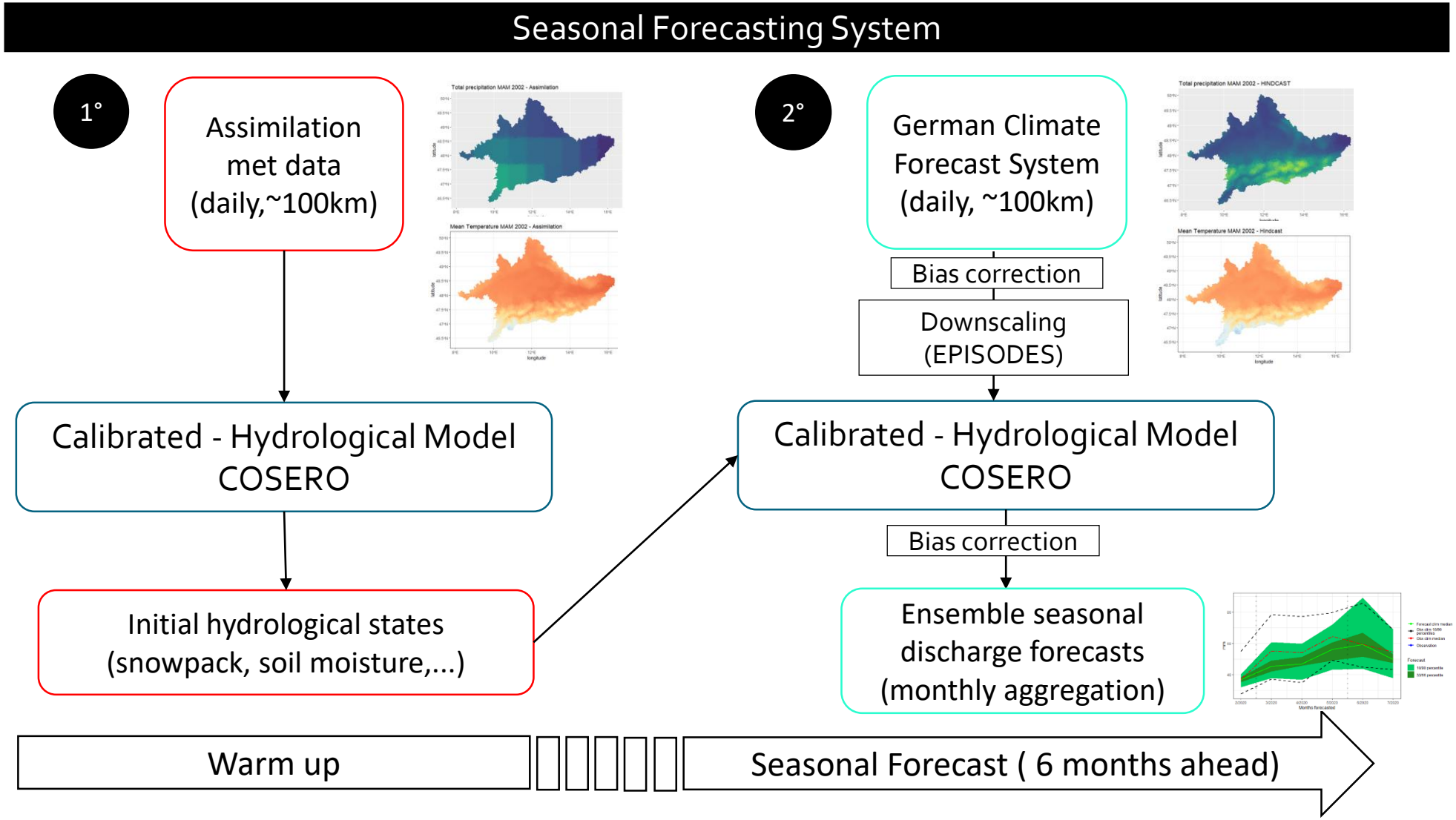
Assimilation met data (daily,~100km)

Ensemble of met data generated from GCM to generate esemble forecast




Current hydrologic states: soil moisture, snowpack,...

# Seasonal discharge forecasting - Methodology



# Seasonal discharge forecasting - Methodology

German Climate Forecast System (daily, ~100km)

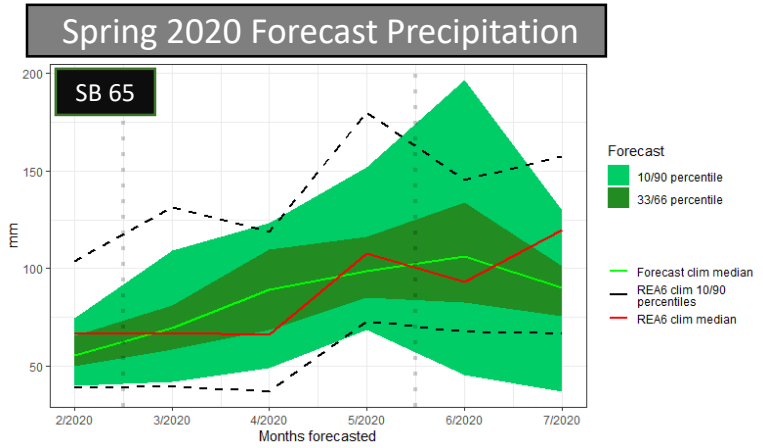
Downscaling (EPISODES)

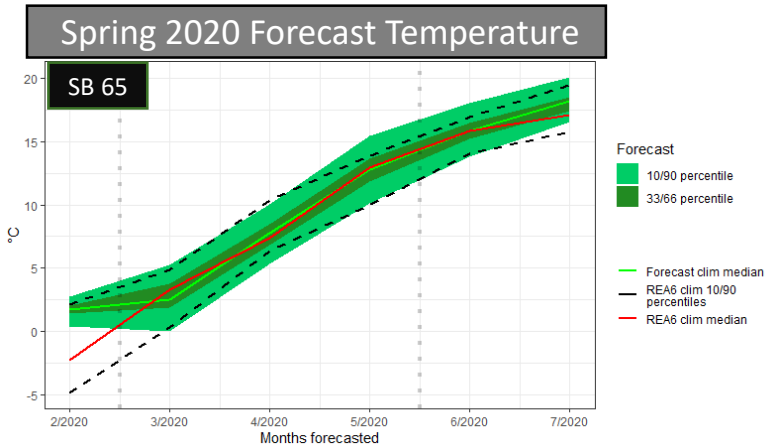
Bias correction

Calibrated - Hydrological Model COSERO (Updated Initial State)

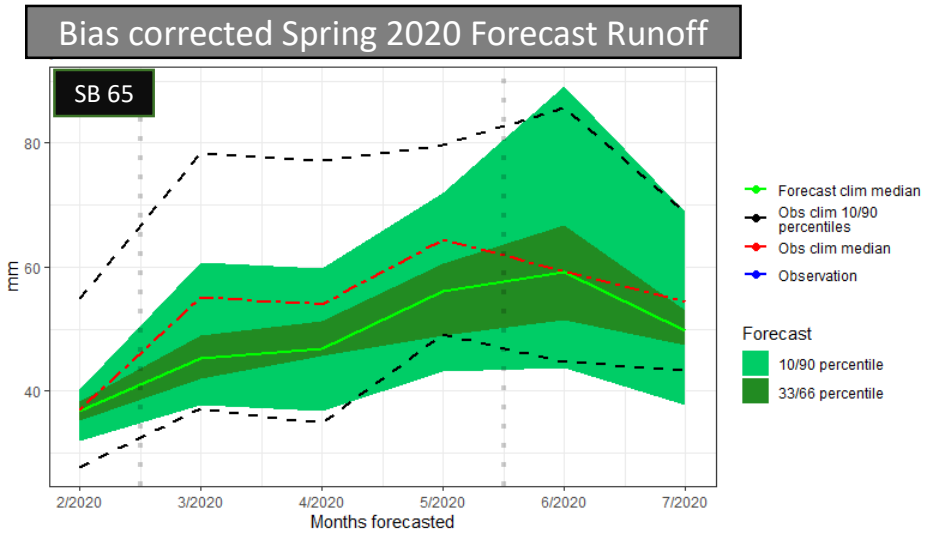
Bias correction (scale factor)

Ensemble seasonal discharge forecasts (monthly aggregated)



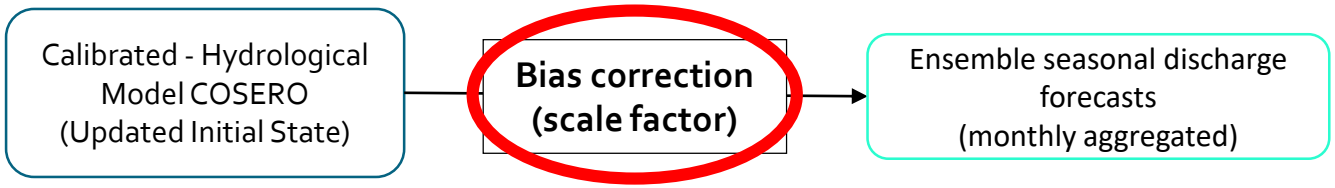




COSERO

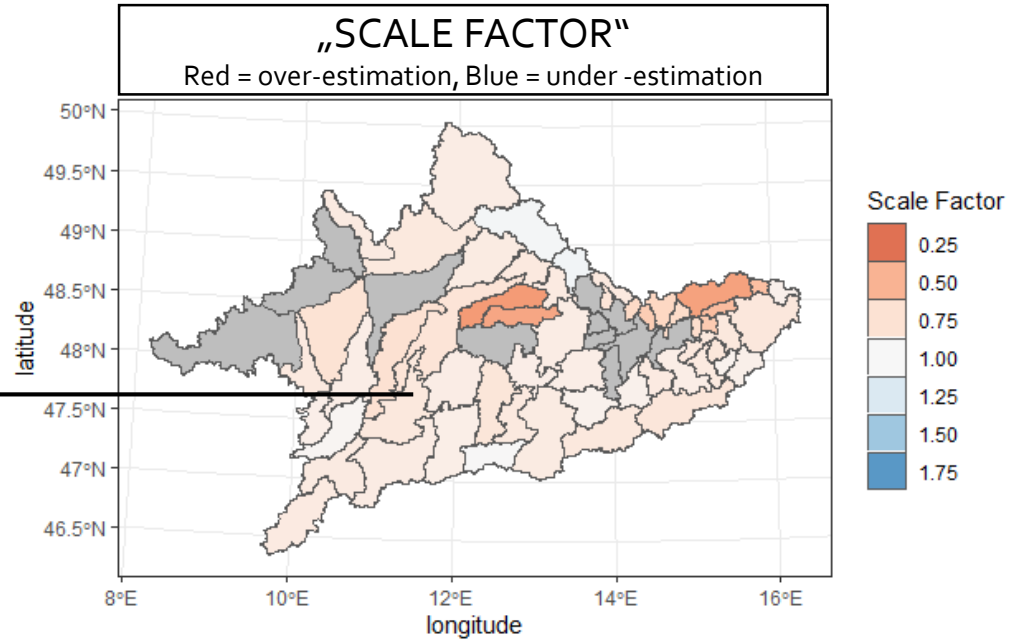


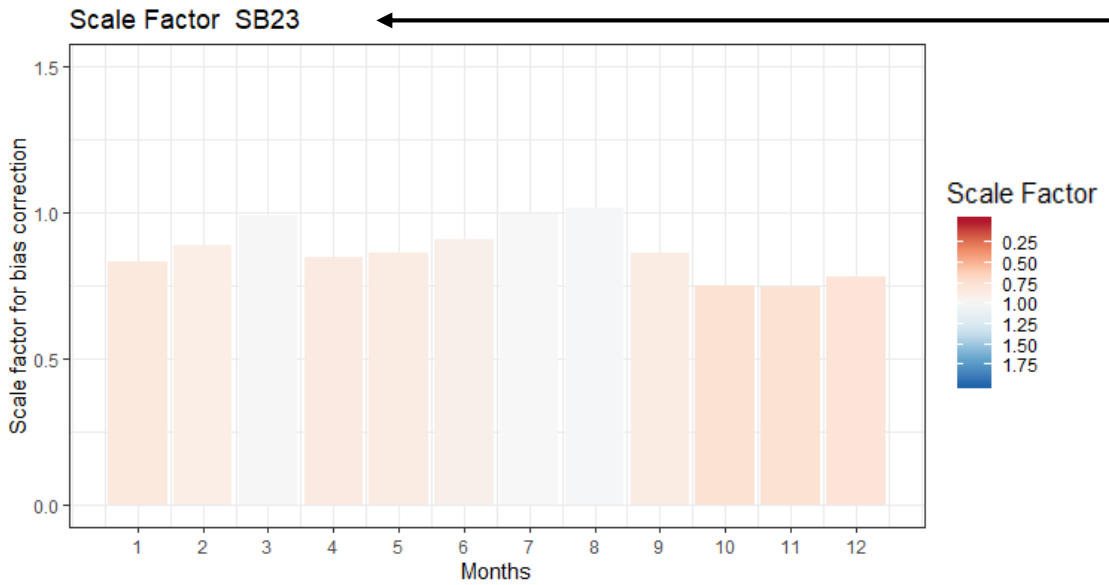

- Spring forecast 2020 (current season)
- SB-65 (Korneuburg – Danube)

# Seasonal discharge forecasting – Bias correction




- Hindcasts (1999-2014): Forecasted discharge generally shows an overall over-estimation over the whole catchment
- To solve this issue: Bias correction based on the long-term mean observed discharges using a „Scale factor“



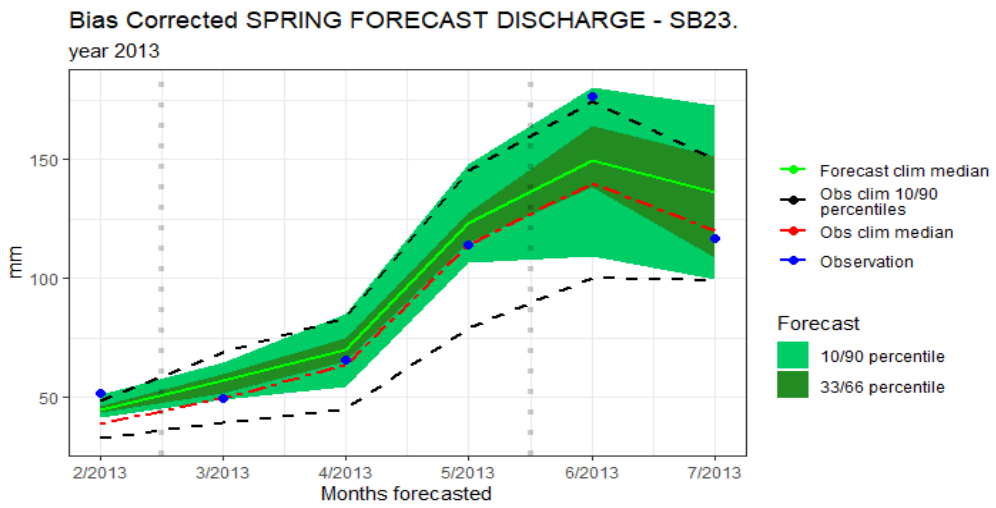



# Seasonal discharge forecasting - display

Calibrated - Hydrological Model COSERO (Updated Initial State)

Bias correction (scale factor)

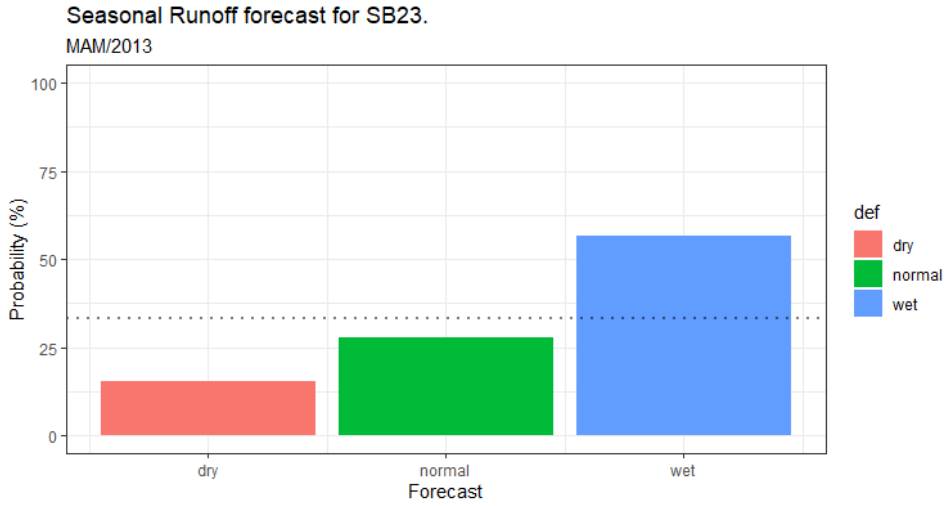
**Ensemble seasonal discharge forecasts (monthly aggregated)**

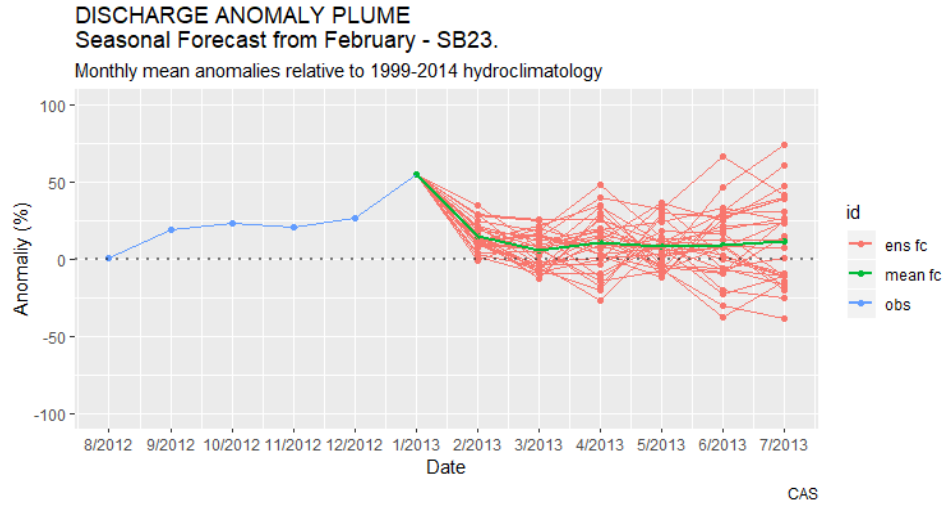



- Shaded quantile and anomaly plume charts give an overview of the spread and uncertainty of the discharge forecasts

- Probability forecasts can be aggregated to terciles, classifying each individual ensemble forecast according to pre-defined thresholds computed for the whole reference period (1999-2014)

- Spring forecast 2013 (excepcionally wet season)
- SB-23 (Wasserburg – Inn)

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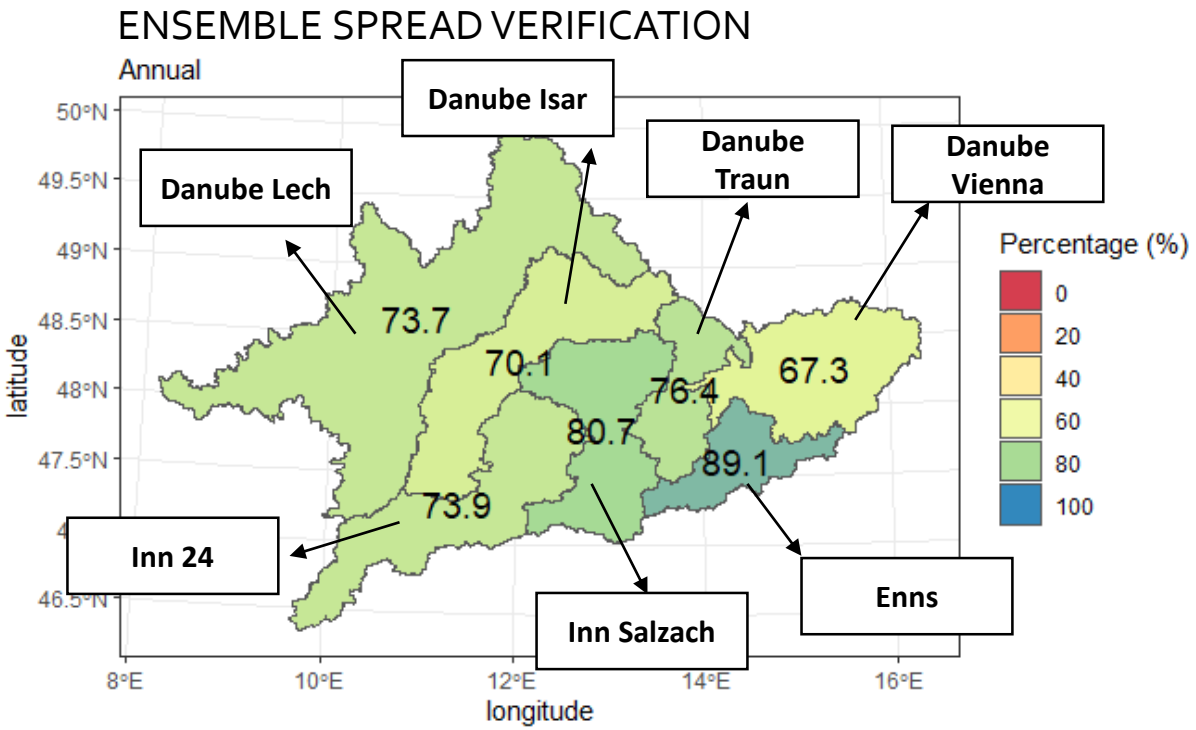
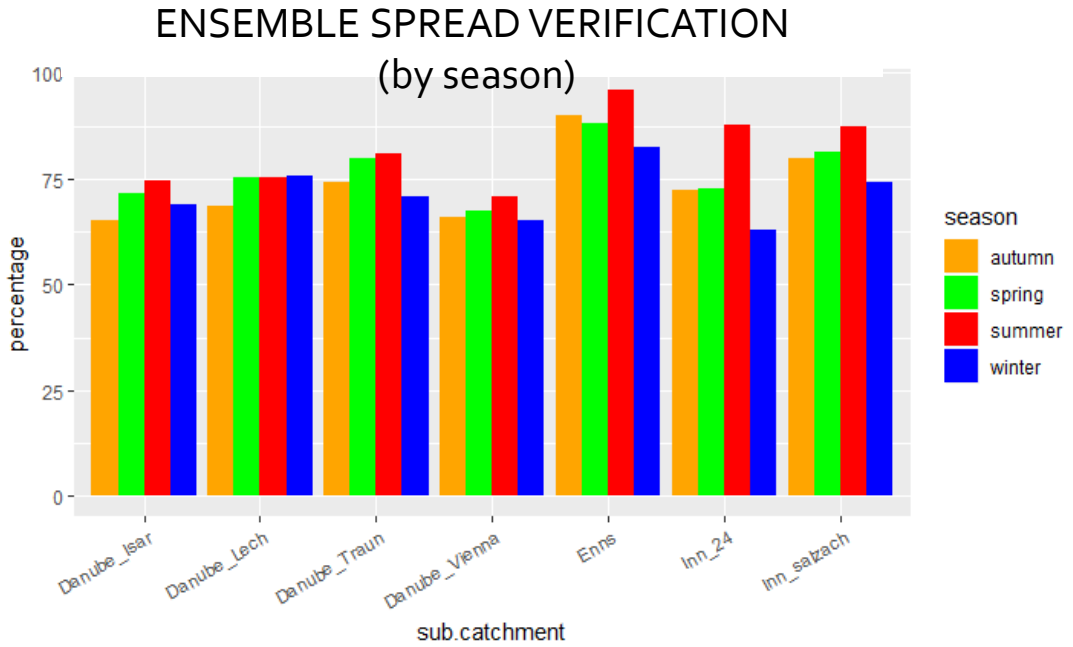
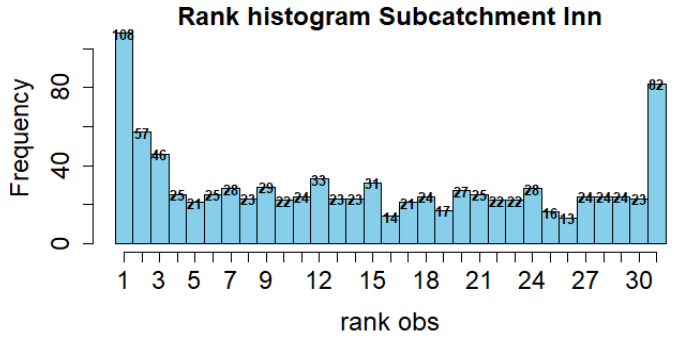
# Seasonal forecasts assessment – Ensemble spread

- Ensemble spread not able to capture discharge in some basins, particularly in Winter (spread too narrow)
- Evaluation: Averaged-percentage of cases, where the observation fell within the ensemble spread over the hindcast period for each sub-basin
- Aggregated to 7 defined sub-catchment (see plots)

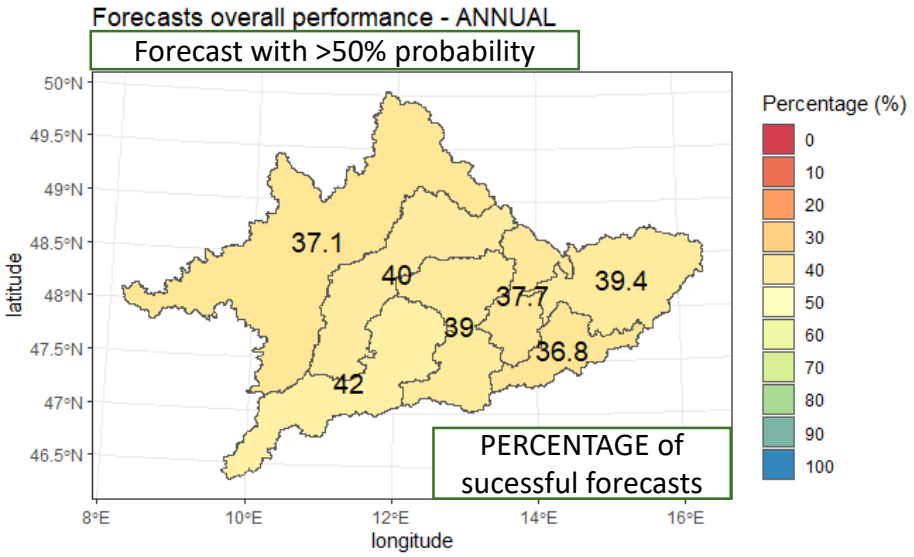


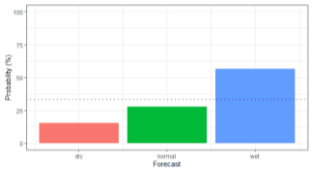



# Seasonal forecasts assessment – overall performance

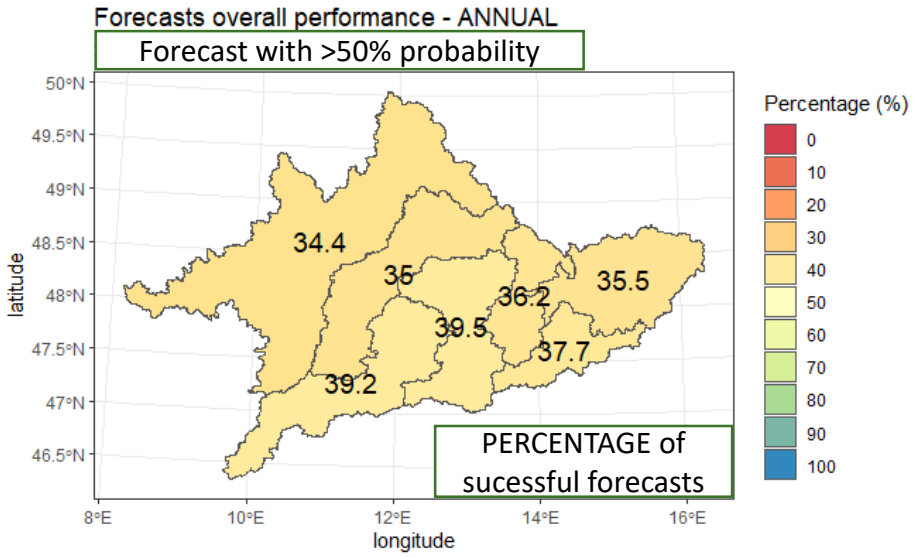
## Theorical skill (based on hindcast forecasts)

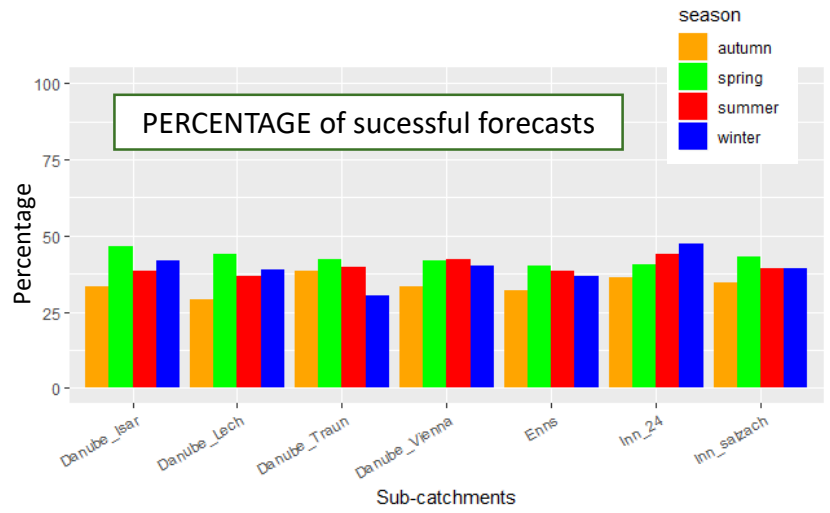


Only months where forecasts show >50% probability of being drier, normal or wetter are considered for the verification

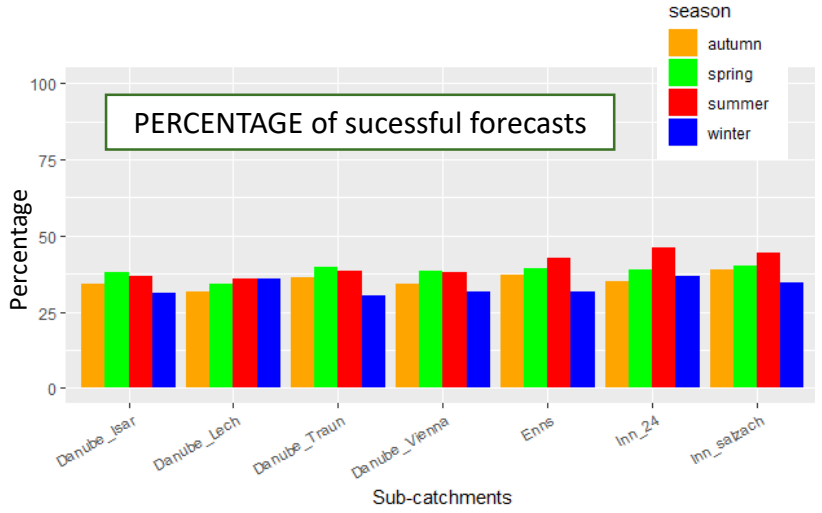
## Actual skill (based on observations)




Percentage of cases where the observation matched the forecasts (dry, wet or normal) for the hindcast period

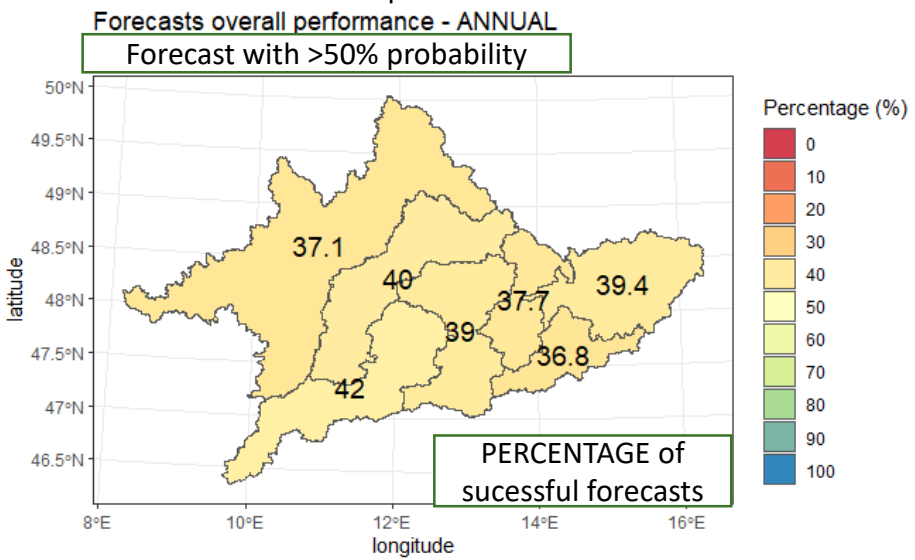
Aggregated by season and sub-catchment



# Seasonal forecasts assessment - issues

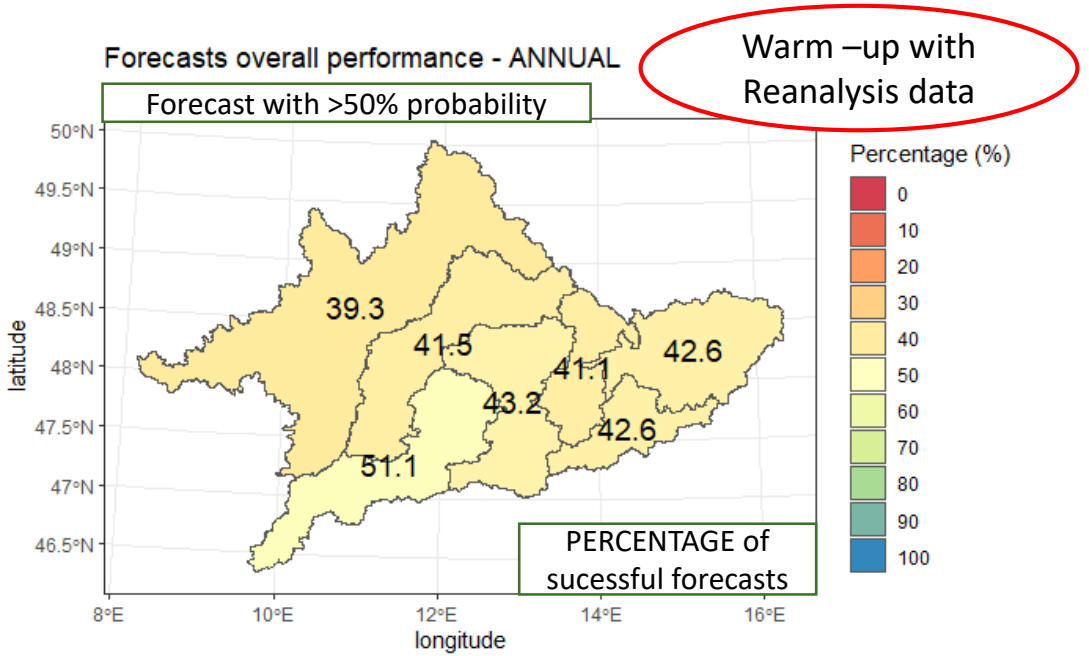
How can we improve the forecast skill?

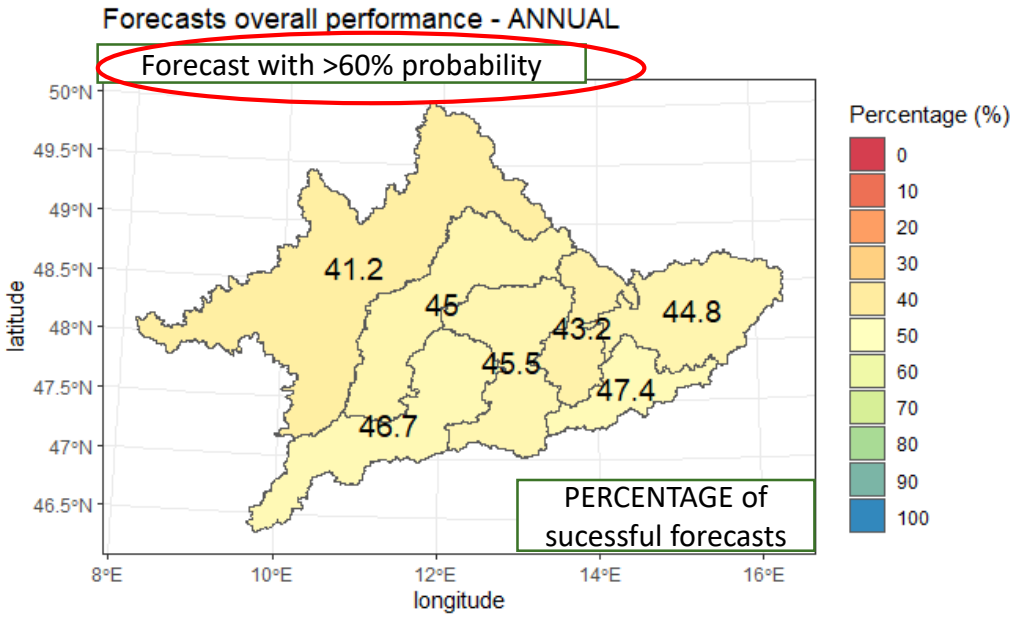
- **Warm-up with finer meteorological input data** (e.g. using reanalysis instead of assimilation datasets)




- Considering **only high probability forecast situations** (at least >60% probabily of ocurrence)

Warm –up with Reanalysis data



# Conclusions

- The applied bias correction partially compensate errors introduced  by using low resolution assimilation data (in comparison to using COSMO-REA6) for initiating system states)
- Observed discharge values are frequently outside of the ensemble spread, especially in Winter
- In summary, the seasonal forecasts show a very low skill regarding discharge predictions. However, in high probability forecast situations (i.e. many ensemble members agree on dry, normal or wet conditions) acceptable skill is achieved in some sub-catchments
- Improvement potentials and challenges: Finer spatial resolution of meteorological data / forecasts  (especially for assimilation data)

# THANK YOU FOR YOUR ATTENTION

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