Summer School on Extreme Temperature and Precipitation Events

Session 3: Floods

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Organization: Justus Liebig University Giessen - JLU

Cluj-Napoca, Romania
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UNIVERSITATEA BABEȘ-BOLYAI
cmcc Centro Euro-Mediterraneo sui Cambiamenti Climatici
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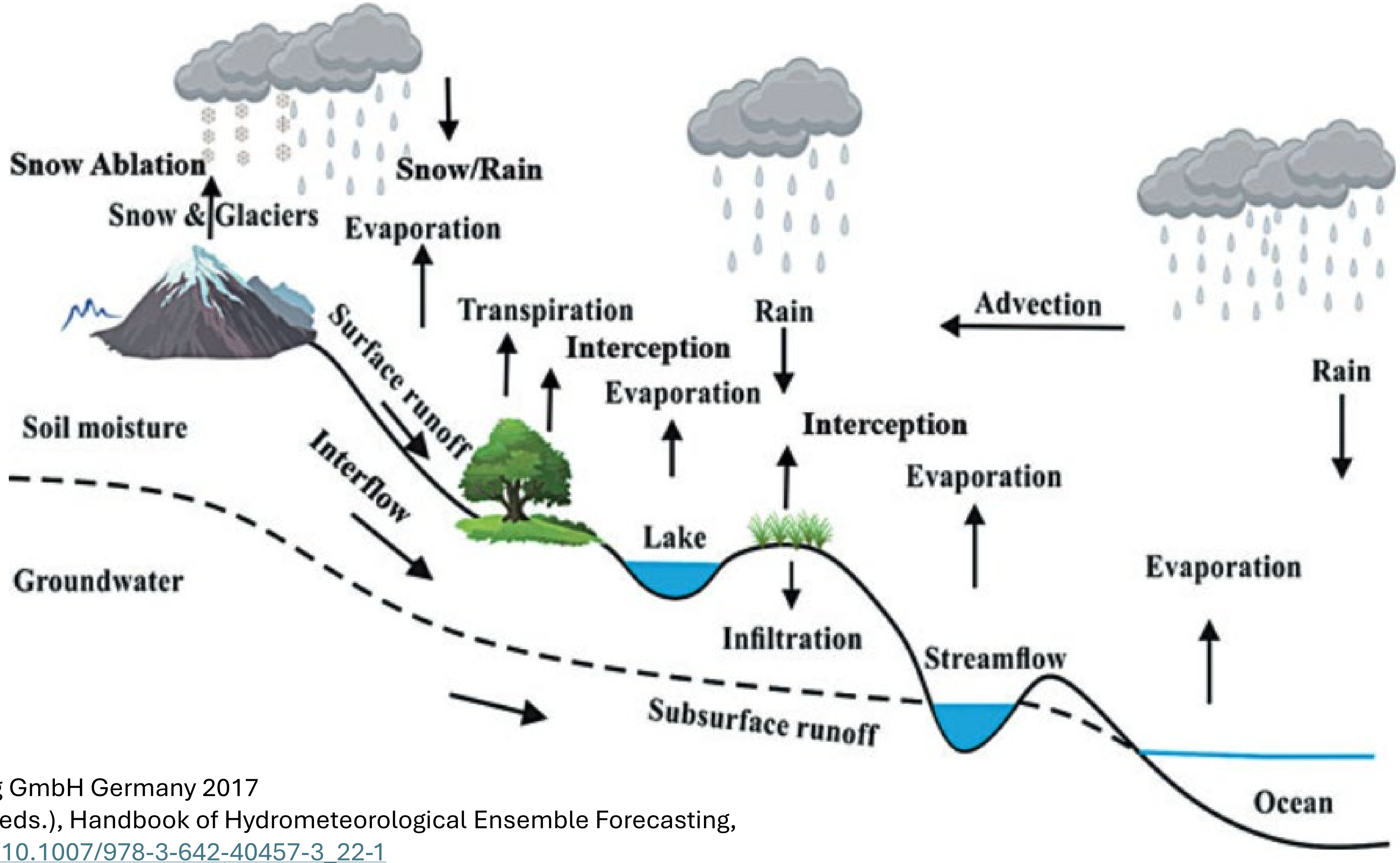
Grant Agreement 101159497

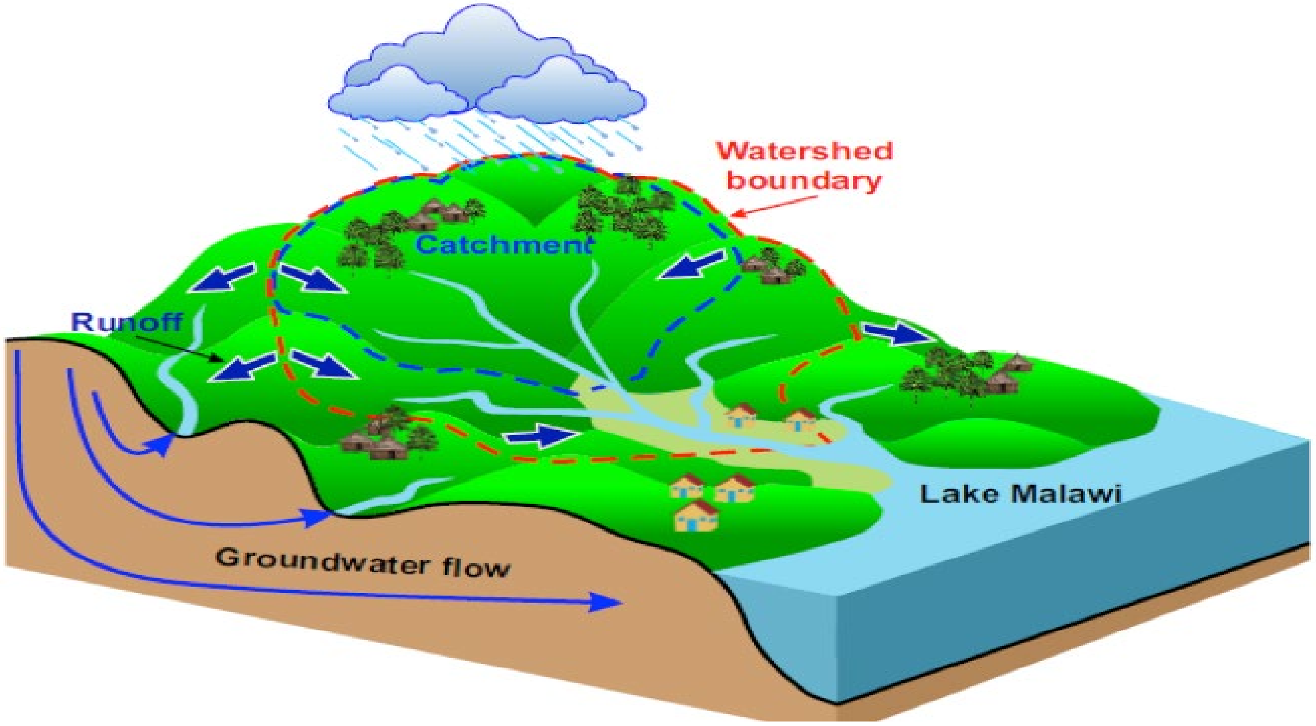
1. Water cycle

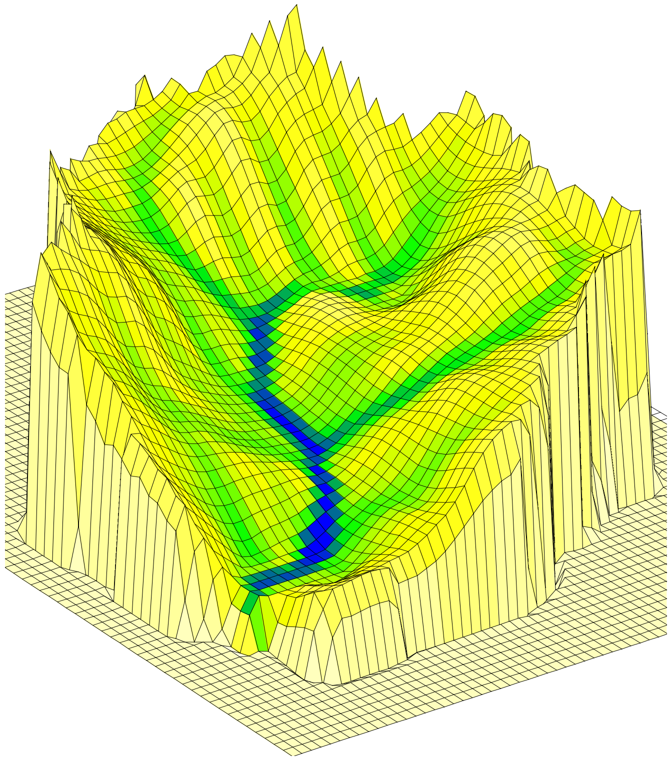


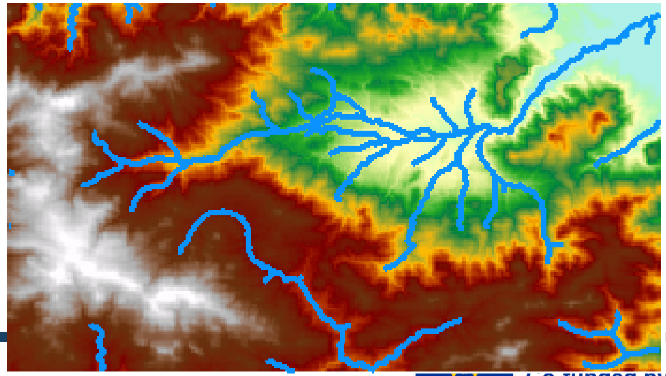
Springer-Verlag GmbH Germany 2017
Q. Duan et al. (eds.), Handbook of Hydrometeorological Ensemble Forecasting,
https://doi.org/10.1007/978-3-642-40457-3_22-1

Catchment

Catchment is area where all water, drains to same outlet.







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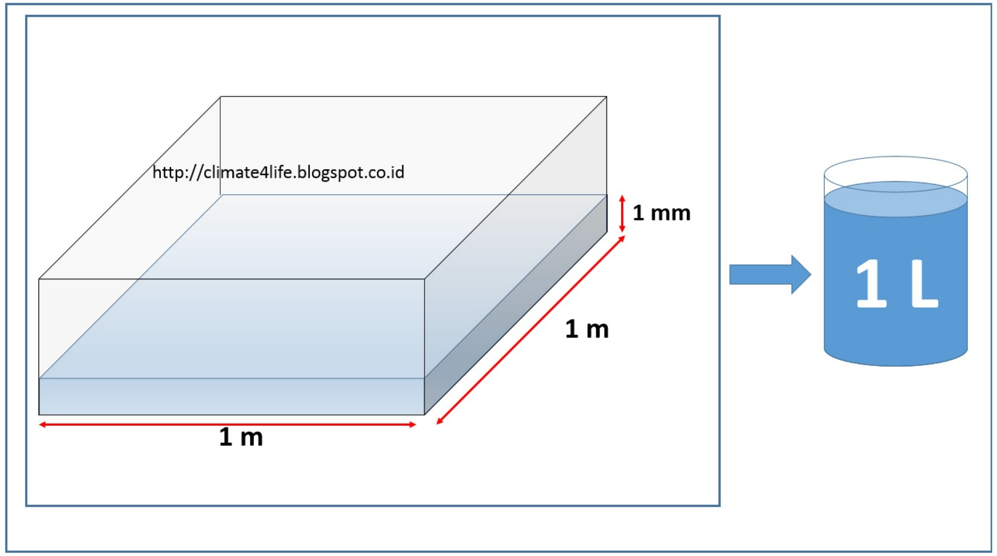
Precipitation

Measuring **rainfall** as a depth is an international standard mainly because it is very easy to convert depth to volume; The conversion factor is **1 mm** of **rainfall = 1 Liter** of water/**m²**



1 **mm** -> 1 mm/day

$$i = \frac{\Delta P}{\Delta t} \quad \left[\frac{mm}{hr}\right]$$

$$i = \frac{5\ mm}{1\ day} = 0.208\frac{mm}{hr}$$

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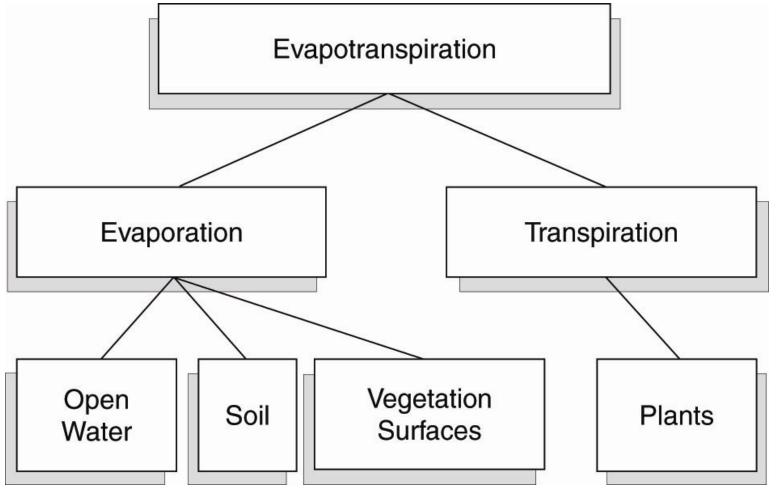
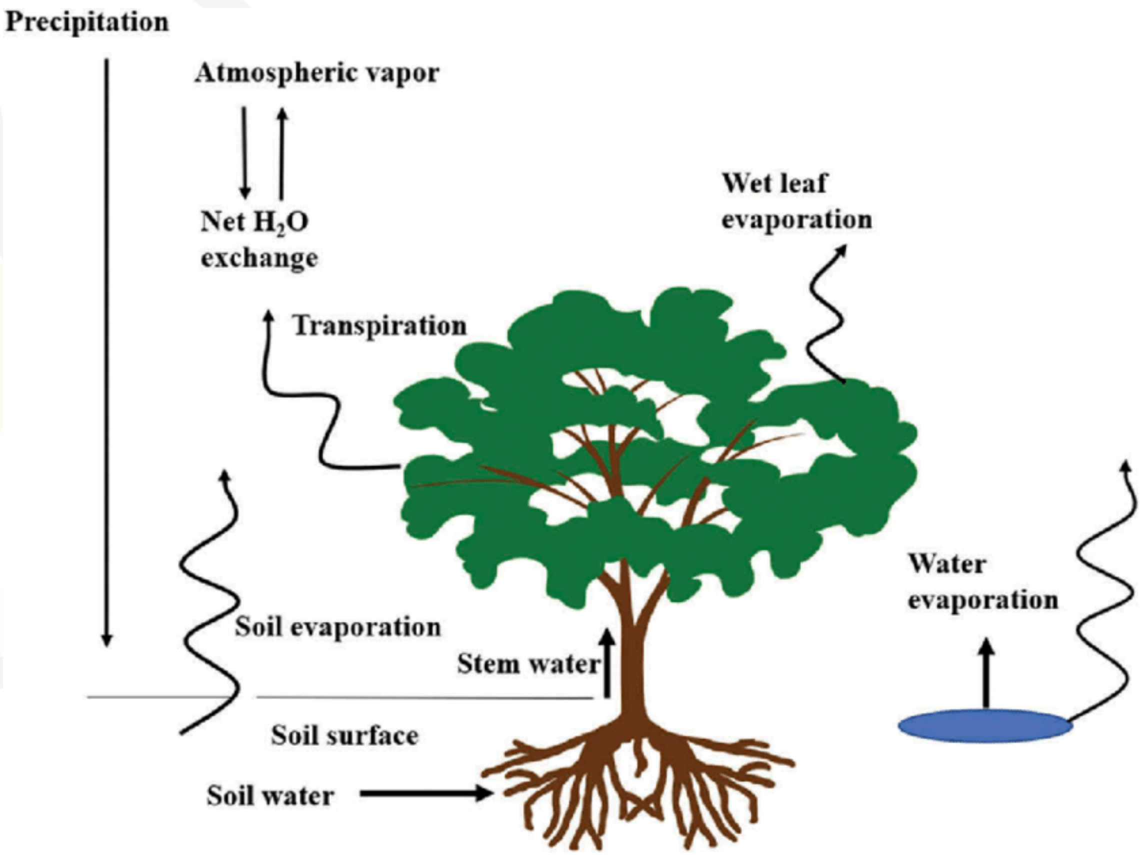
Evaporation, transpiration, and evapotranspiration





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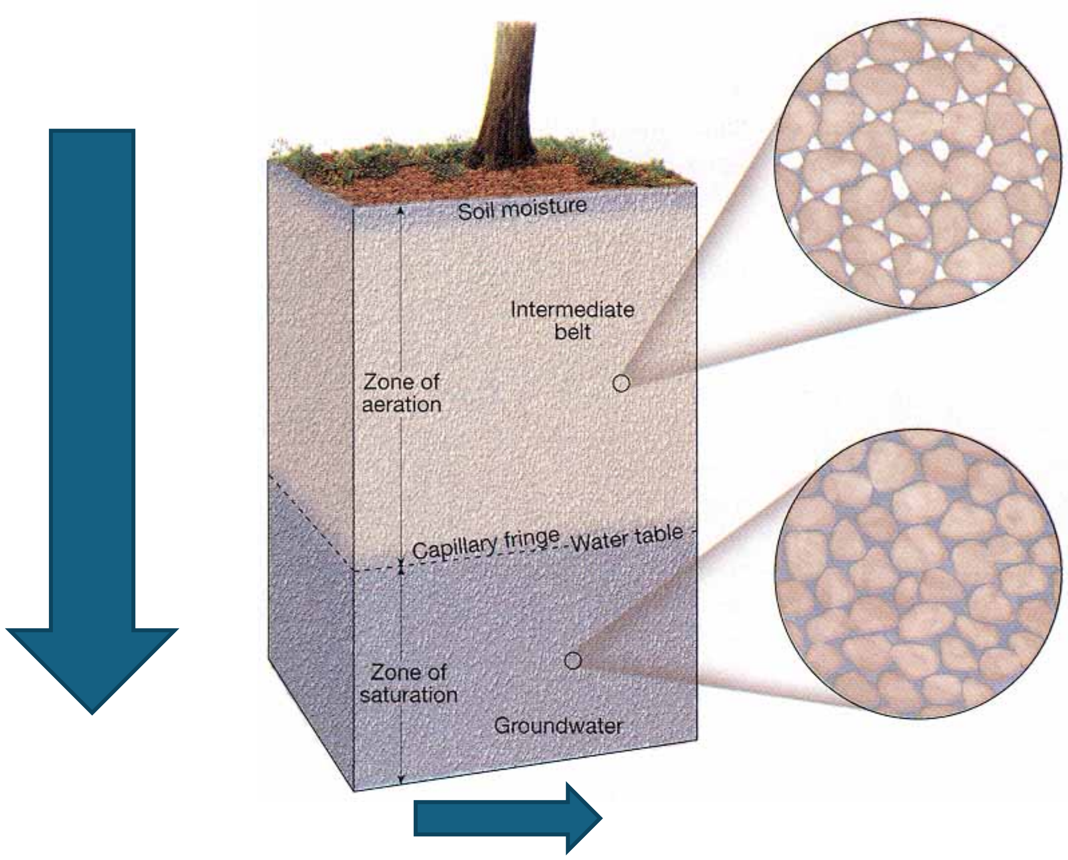
Infiltration



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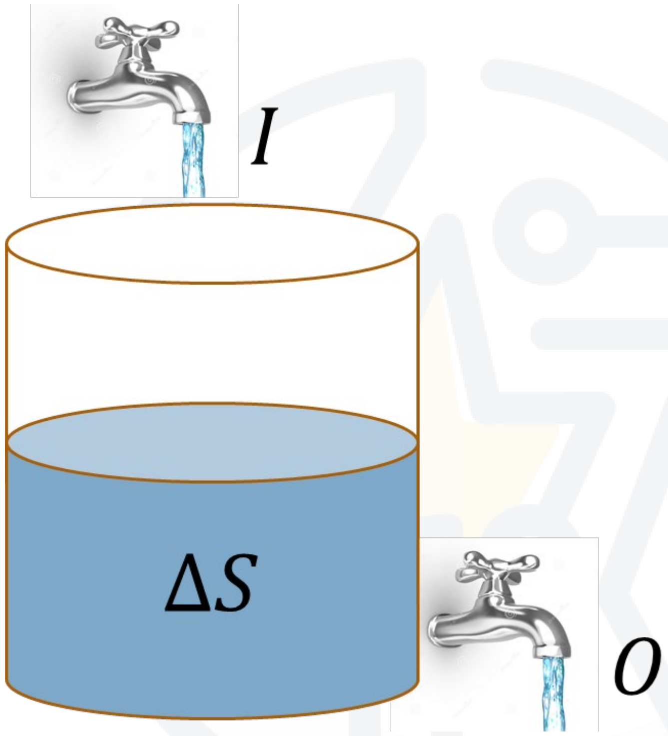
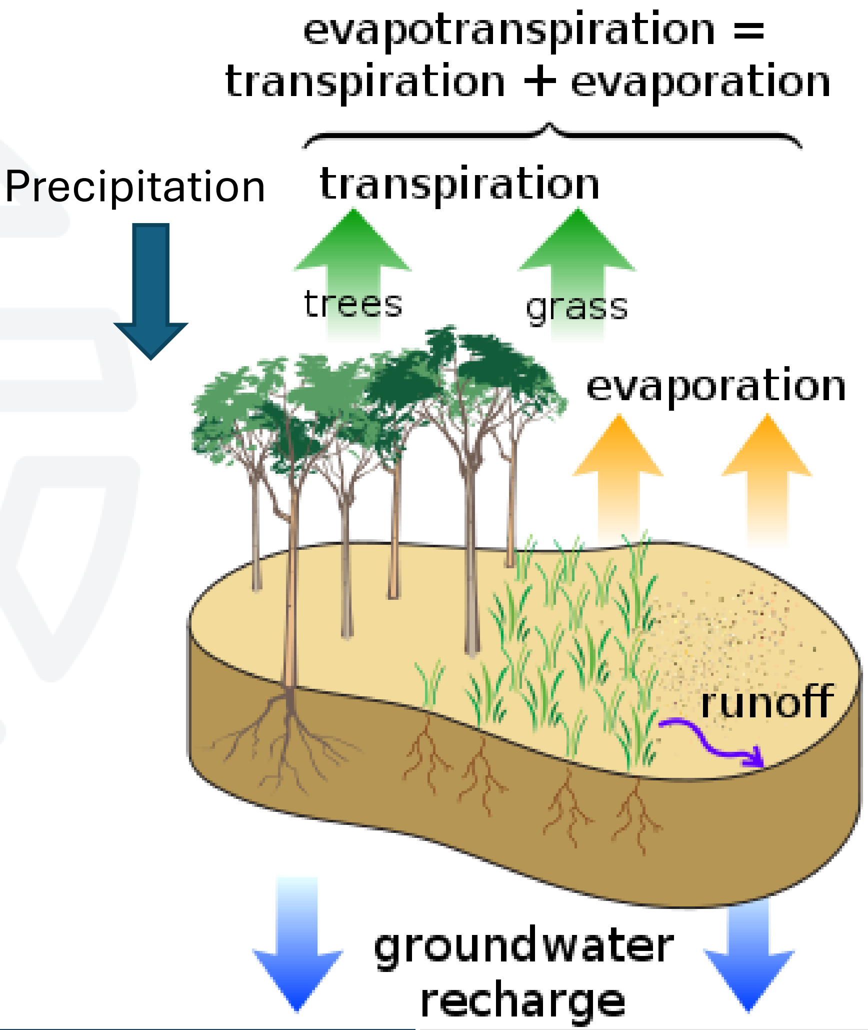
Water Balance

$$I - O = \Delta S$$





On basis Reynolds transport theorem (Law of **conservation mass**, law of conservation of **linear momentum**, law of **conservation energy**)

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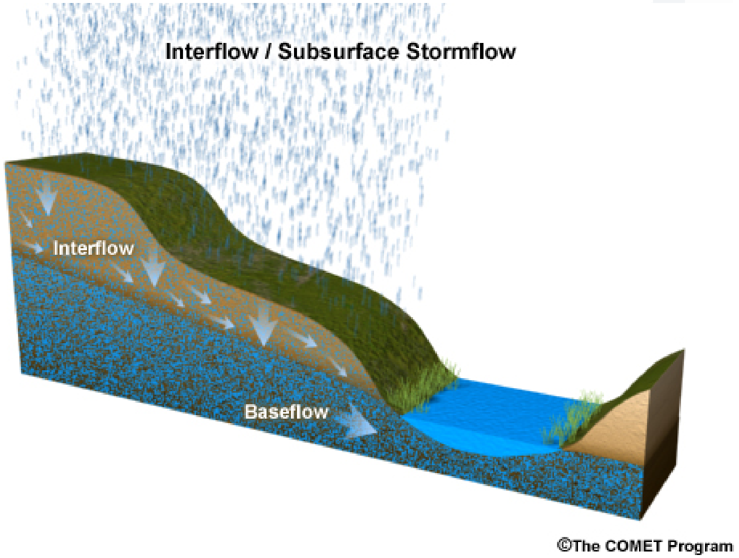
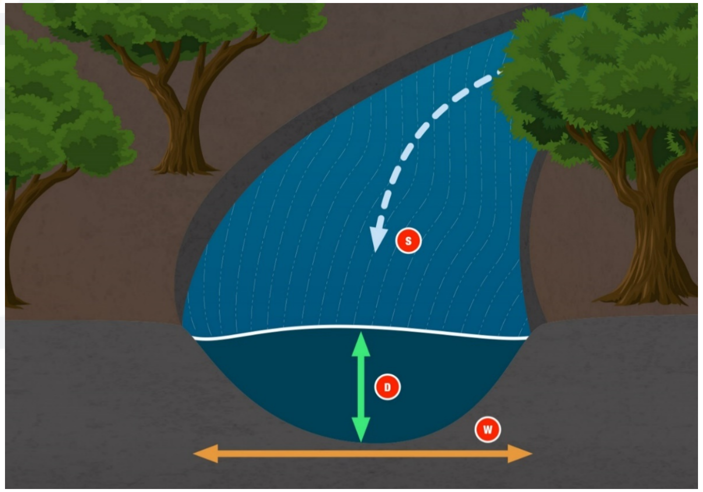
Streamflow

Streamflow, discharge, or runoff is the portion of raifall, snowmelt or irrigation water that runs over the soil surface toward the stream channel.

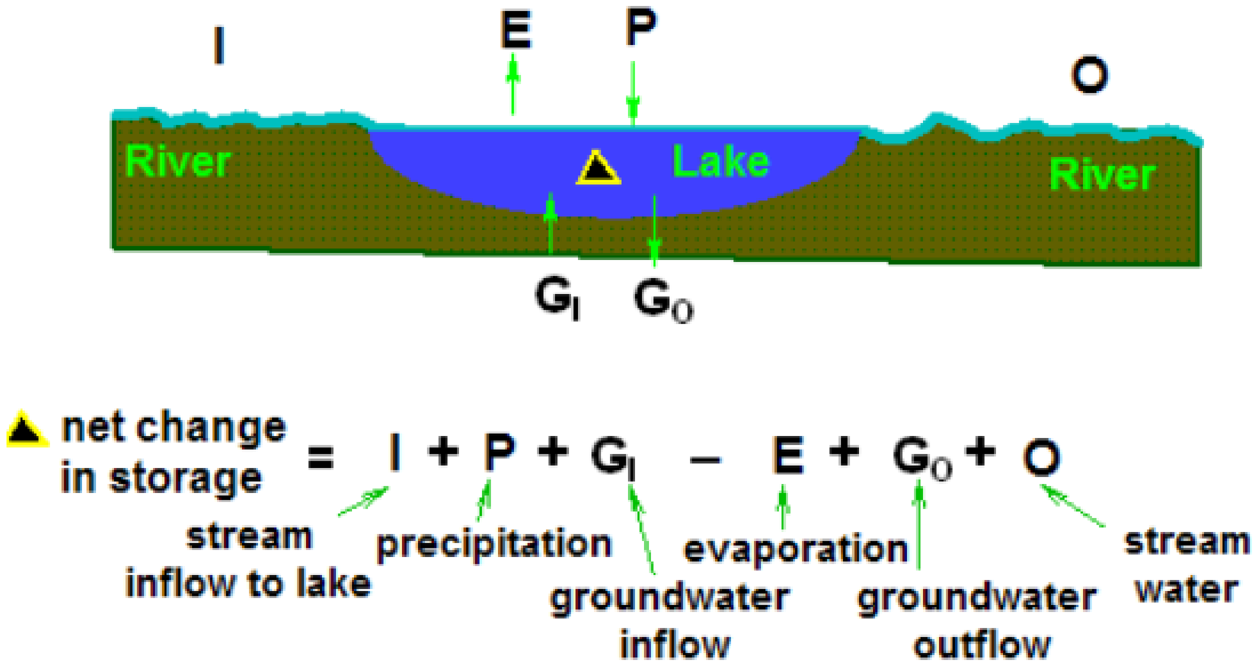


$$Q = A\,\bar{u}$$

- **Q** is the discharge ($[L^3T^{-1}]$; m^3/s or ft^3/s)
- **A** is the cross-sectional area of the portion of the channel occupied by the flow ($[L^2]$; m^2 or ft^2)
- **u** is the average flow velocity ($[LT^{-1}]$; m/s or ft/s)



Water Balance



2. Hydrological modelling

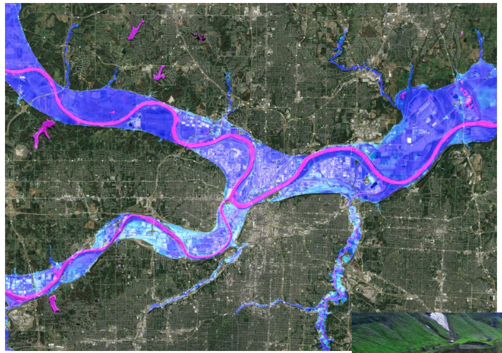
Why modelling ?

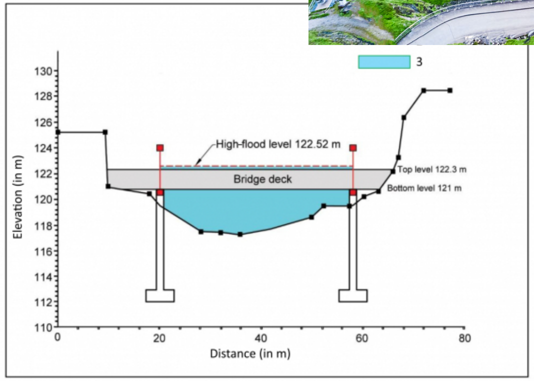
The use of models allows the stakeholder and decision makers to take descions on basis of limited measurements and qualitative predictions in space and time of the hydrological procceses.

Modelling is a fundamental and quantitative way to understand and analyze complex systems and phenomena.

Modelling is a complement to theory and experiments.

For example: evaluating the water availabilty for human consumption, floods, droughts, irrigation, water contamination and others.





https://www.hydrotech-group.com/blog/the-10-most-beautiful-water-dams-from-around-the-world

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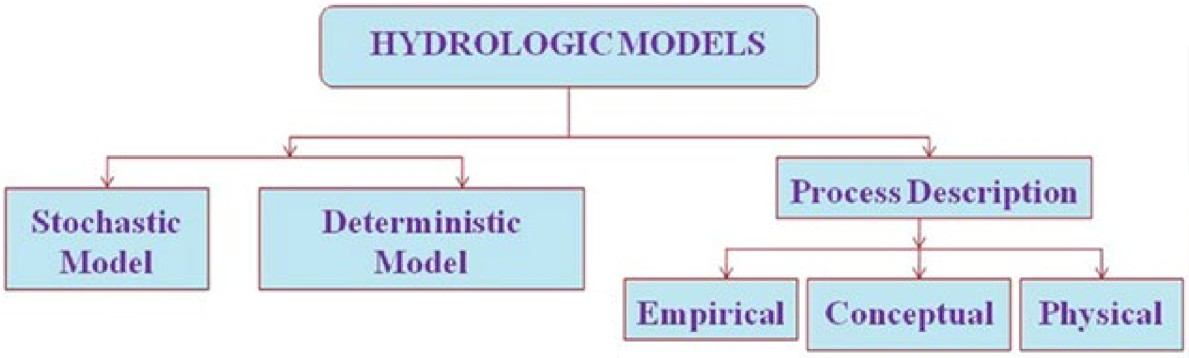
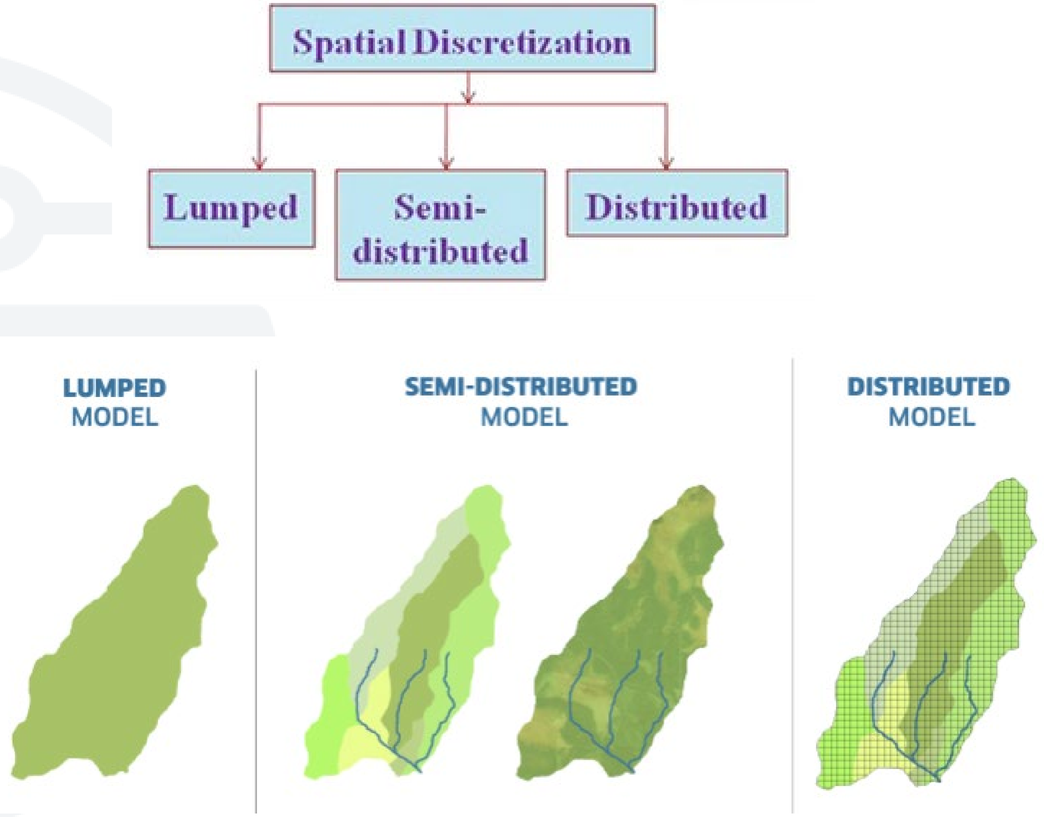
Type of models





Ochoa-Tocachi, Cuadros-Adriazola, Arapa, Aste, Ochoa-Tocachi, & Bonnesoeur. (2022). *Guide to Hydrologic Modeling*. Forest Trends Association. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.forest-trends.org/wp-content/uploads/2022/08/Guide-to-Hydrologic-Modeling-of-NI.pdf

The GR4J Hydrological model

Si $P_k \geq E$, alors $P_n = P_k - E$ et $E_n = 0$,
Si $P_k < E$, alors $P_n = 0$ et $E_n = E - P_k$

$$Ps = \frac{X1\left(1-\left(\frac{S_k}{X1}\right)^2\right).\tanh\left(\frac{Pn}{X1}\right)}{1+\frac{S_k}{X1}\tanh\left(\frac{Pn}{X1}\right)} \quad \text{et} \quad Es = \frac{S_k.\left(2-\frac{S_k}{X1}\right).\tanh\left(\frac{En}{X1}\right)}{1+\left(1-\frac{S_k}{X1}\right).\tanh\left(\frac{En}{X1}\right)}$$

$S' = S_k + Ps - Es,$

$$Perc = S'\left\{1-\left[1+\left(\frac{4}{9}.\frac{S'}{X1}\right)^4\right]^{-\frac{1}{4}}\right\}, \quad S_{k+1} = S' - Perc$$

$Perc + (Pn - Ps)$

Si $0 \leq j \leq X_4. SH1(j) = \left(\frac{j}{X_4}\right)^{\frac{5}{2}}$; Si $j > X_4. SH1(j) = 1$

Si $0 \leq j \leq X_4. SH2(j) = \frac{1}{2}\left(\frac{j}{X_4}\right)^{\frac{5}{2}}$;

Si $X_4 \leq j \leq 2X_4. \; SH2(j) = 1 - \frac{1}{2}\left(2-\frac{j}{X_4}\right)^{\frac{5}{2}}$;

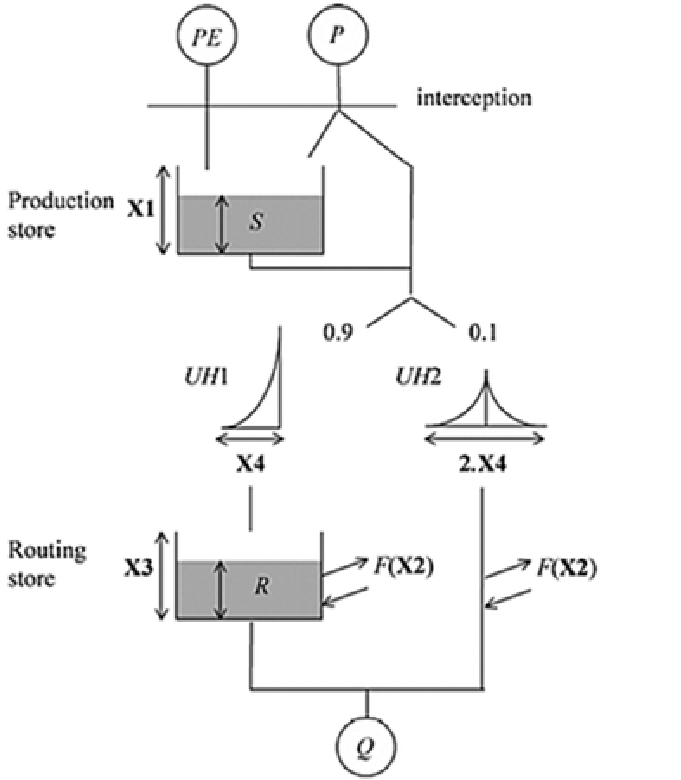
Si $j > 2X_4. \; SH2(j) = 1$

$$UH1(j) = SH1(j) - SH1(j-1)$$
$$UH2(j) = SH2(j) - SH2(j-1)$$

$Q9(k) = 0,9.\sum_{j=1}^{l} UH1(j).Pr(k-j+1),$
$Q1(k) = 0,1.\sum_{j=1}^{m} UH2(j).Pr(k-j+1)$

$F = X2.\left(\frac{R_k}{X3}\right)^{\frac{7}{2}}$; $R' = \max(0 ; R_k + Q9(k) + F)$

$$(DP)\begin{cases} Qr = R'.\left\{1-\left[1+\left(\frac{R'}{X3}\right)^4\right]^{-\frac{1}{4}}\right\} ; \quad R_{k+1} = R' - Qr \\ Qd = \max(0; Q1(k) + F); \\ Q(k) = Qr + Qd \end{cases}$$



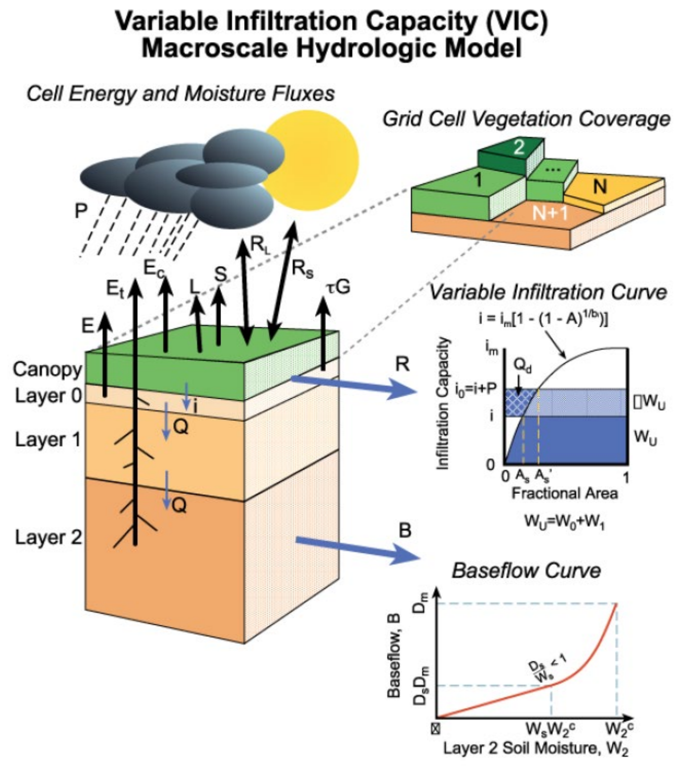
X1 Capacity of the production store (mm)
X2 Water exchange coefficient (mm)
X3 Capacity of the nonlinear routing store (mm)
X4 Unit hydrograph time base (day)

Perrin, C., Michel, C., & Andréassian, V. (2003). Improvement of a parsimonious model for streamflow simulation. *Journal of Hydrology*, *279*(1–4), 275–289. https://doi.org/10.1016/S0022-1694(03)00225-7

2. Hydrological modelling

VIC-WUR

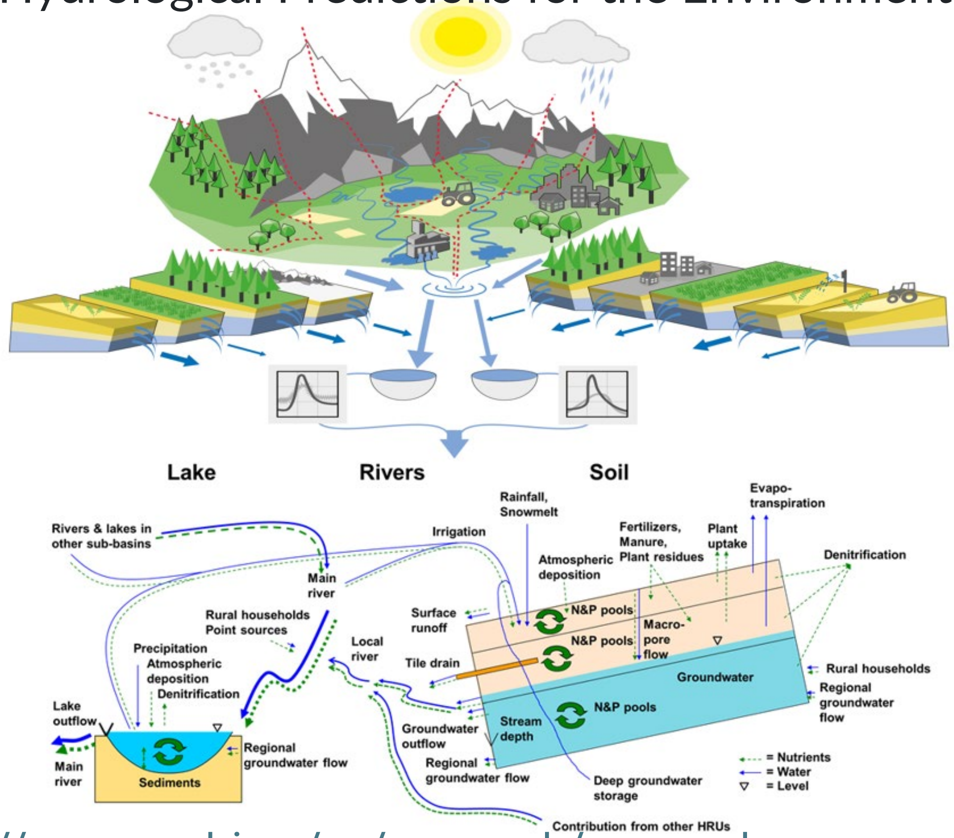
https://vicwur.readthedocs.io/en/latest/index_vicwur/



https://www.wur.nl/en/research-results/chair-groups/environmental-sciences/earth-systems-and-global-change-group/research/water-climate-food/vic-wur.htm

HYPE

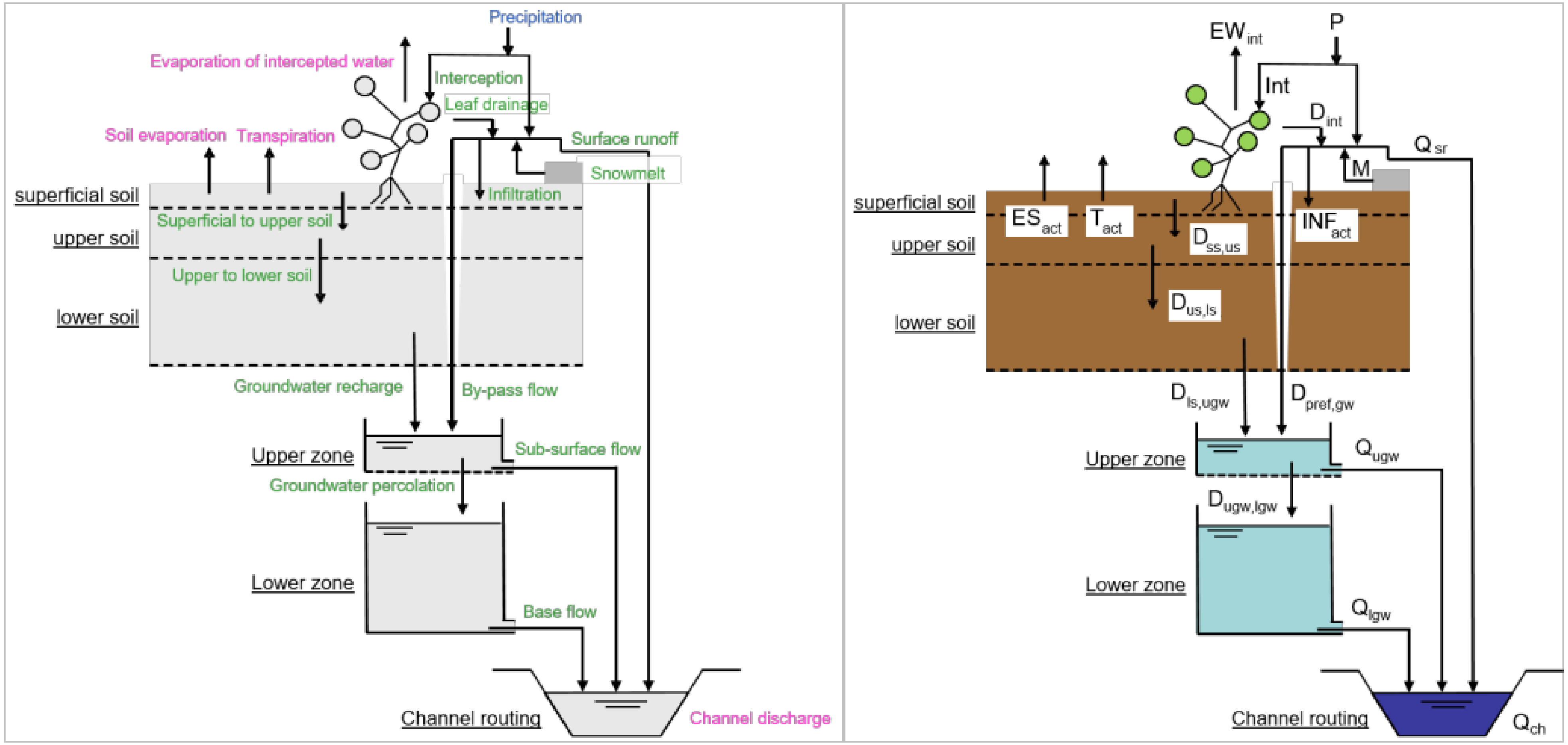
The Hydrological Predictions for the Environment (HYPE)



https://www.smhi.se/en/research/research-units/hydrology/hype---our-hydrological-model

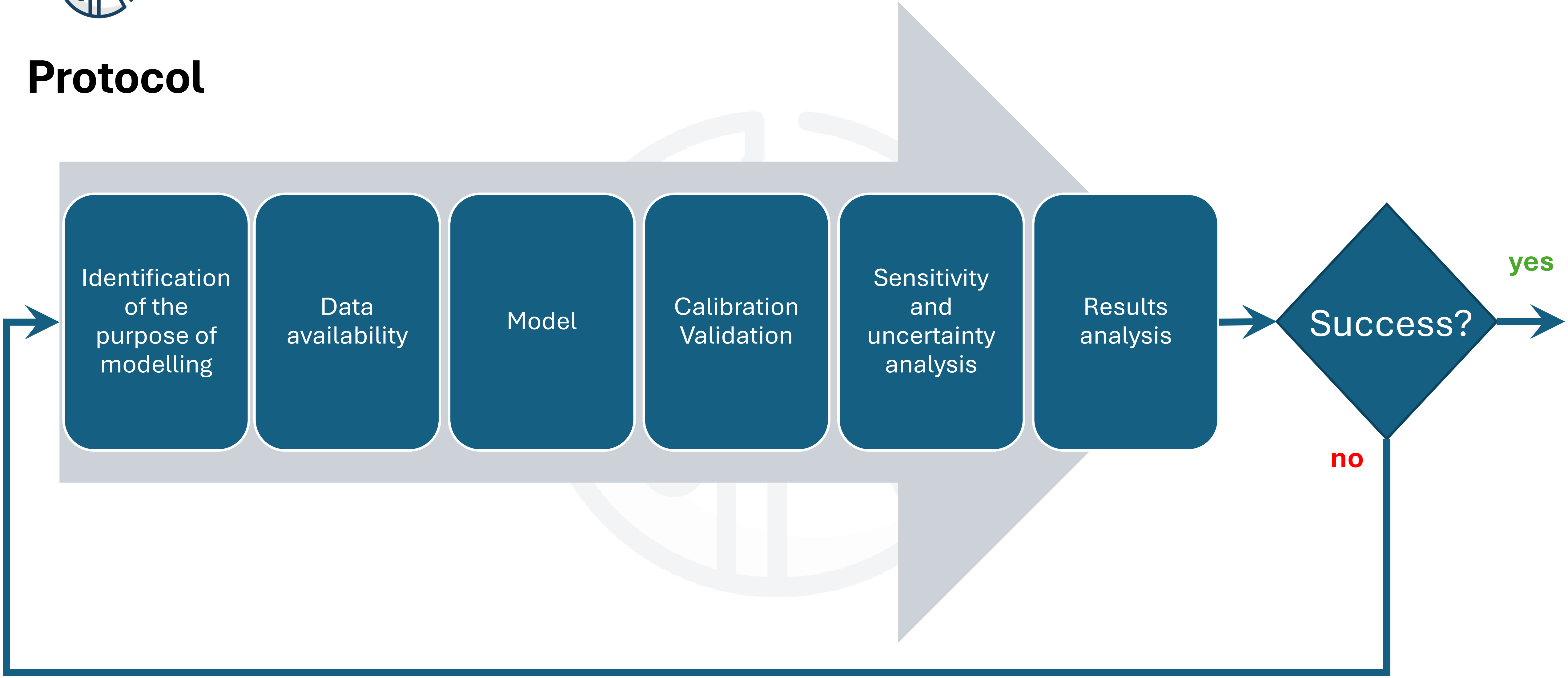
2. Hydrological modelling

LISFLOOD



https://ec-jrc.github.io/lisflood-model/2_01_stdLISFLOOD_overview/

Protocol



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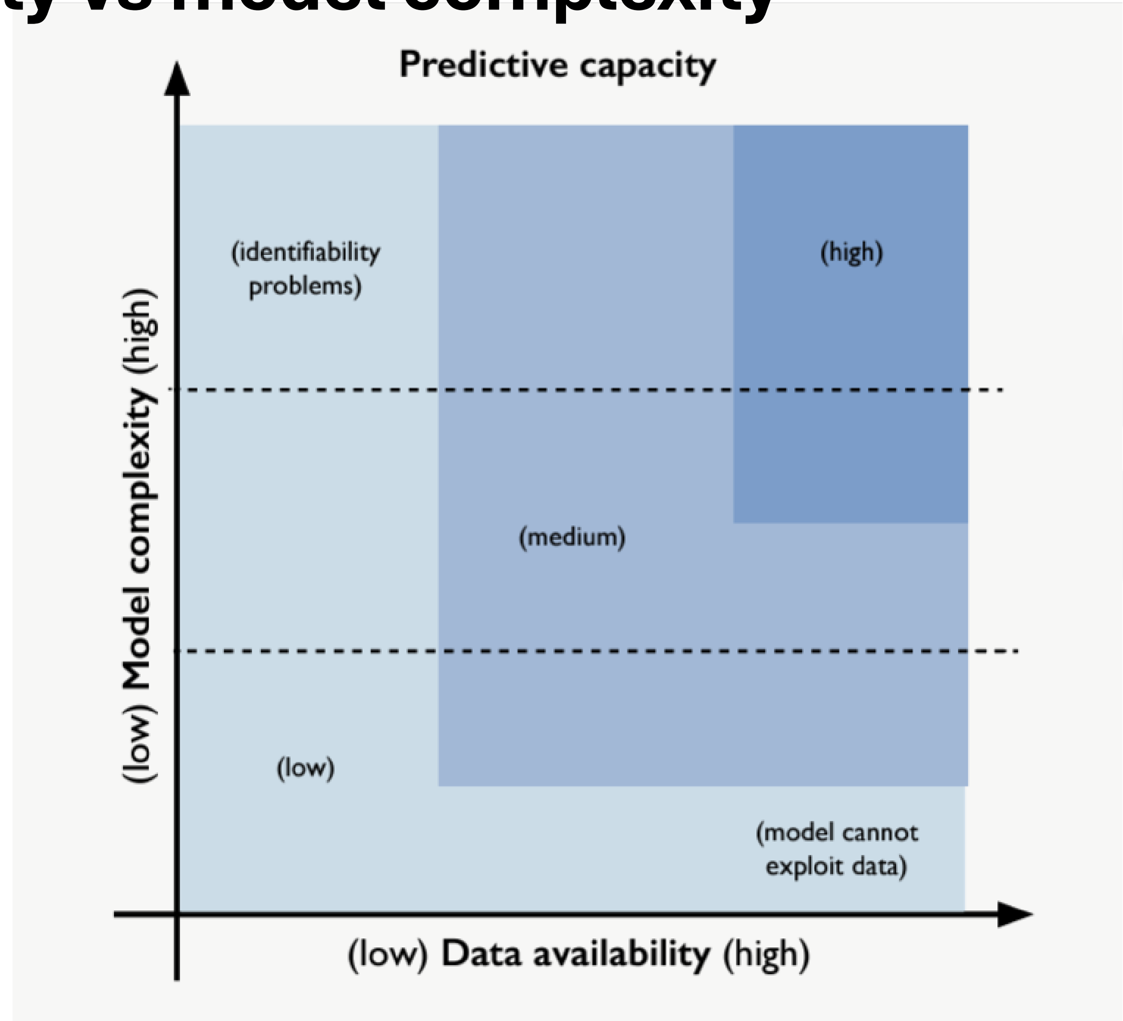
Data availability vs model complexity



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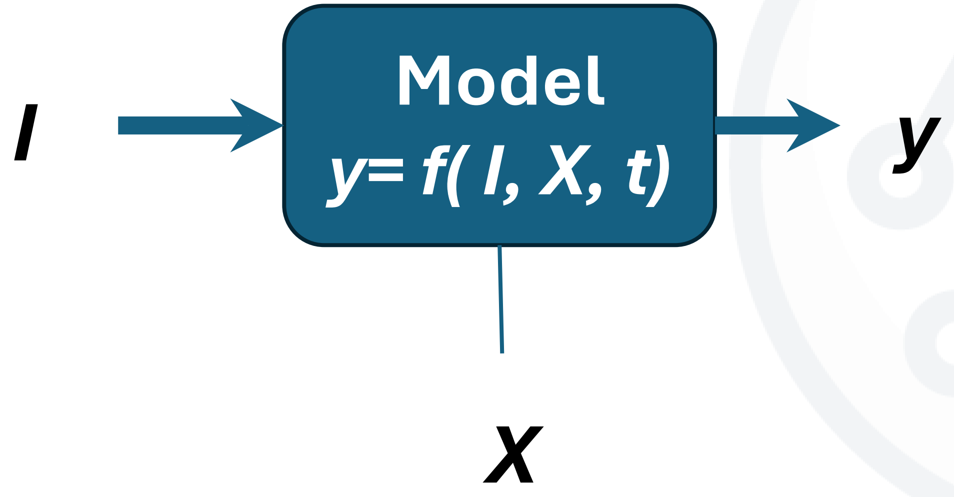
The inverse problem



$$y = f(I, X, t)$$

We know X, and the inputs so we are interested to know the outputs

$$y = x_1 I + x_2$$

$$y = f(I, X, t)$$

We know the inputs I, and the outputs y, so we are interested in the parameters.

$$y = x_1 I + x_2$$

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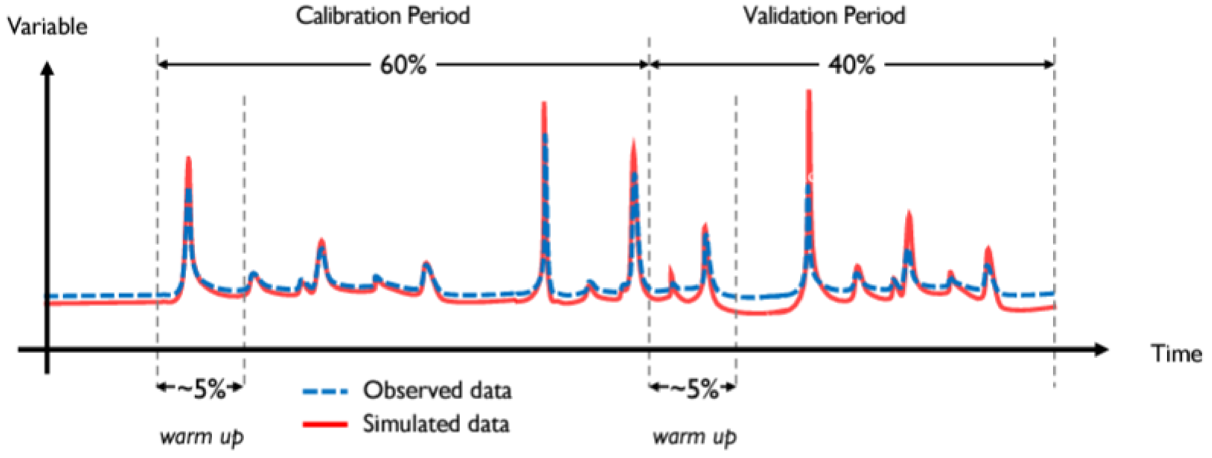
Calibration, validation and performance evaluation



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Performance metric	Expression
Mean Absolute Error (MAE)	$F_1 = \frac{1}{N}\sum_{t=1}^{N}\lvert y_{s,t} - y_{o,t}\rvert$
Mean Square Error (MSE)	$F_2 = \frac{1}{N}\sum_{t=1}^{N}\lvert y_{s,t} - y_{o,t}\rvert^2$
Root Mean Square Error (RMSE)	$F_3 = \left[\frac{1}{N}\sum_{t=1}^{N}\lvert y_{s,t} - y_{o,t}\rvert^2\right]^{1/2}$
Minimax objective function	$F_4 = \frac{1}{N}\max\lvert y_{s,t} - y_{o,t}\rvert$
Average Absolute Percentage Error (AAPE)	$F_5 = 100\frac{1}{N}\sum_{t=1}^{N}\left\lvert\frac{y_{s,t}-y_{o,t}}{y_{o,t}}\right\rvert$
Mean Square Relative Error (MSRE)	$F_6 = 100\frac{1}{N}\sum_{t=1}^{N}\left\lvert\frac{y_{s,t}-y_{o,t}}{y_{o,t}}\right\rvert^2$
Coefficient of determination (R^2)	$F_7 = \left\{\frac{\sum_{t=1}^{N}(y_{o,t}-\overline{y_o})(y_{s,t}-\overline{y_s})}{\left[\sum_{t=1}^{N}(y_{o,t}-\overline{y_o})^2\right]^{0.5}\left[\sum_{t=1}^{N}(y_{s,t}-\overline{y_s})^2\right]^{0.5}}\right\}^2$
Index of agreement (D)	$F_8 = 1 - \frac{\sum_{t=1}^{N}(y_{s,t}-y_{o,t})^2}{\sum_{t=1}^{N}(\lvert y_{s,t}-\overline{y_o}\rvert+\lvert y_{o,t}-\overline{y_o}\rvert)^2}$
Nash–Sutcliffe Efficiency coefficient (NSE)	$F_9 = 1 - \frac{\sum_{t=1}^{N}(y_{s,t}-y_{o,t})^2}{\sum_{t=1}^{N}(y_{o,t}-\overline{y_o})^2}$

Biondi, D., Freni, G., Iacobellis, V., Mascaro, G., & Montanari, A. (2012). Validation of hydrological models: Conceptual basis, methodological approaches and a proposal for a code of practice. Physics and Chemistry of the Earth, Parts A/B/C, 42–44, 70–76. https://doi.org/10.1016/j.pce.2011.07.037

Modified Kling–Gupta efficiency $\mathrm{KGE}' = 1 - \sqrt{(\gamma - 1)^2 + (\beta - 1)^2 + (r - 1)^2}$

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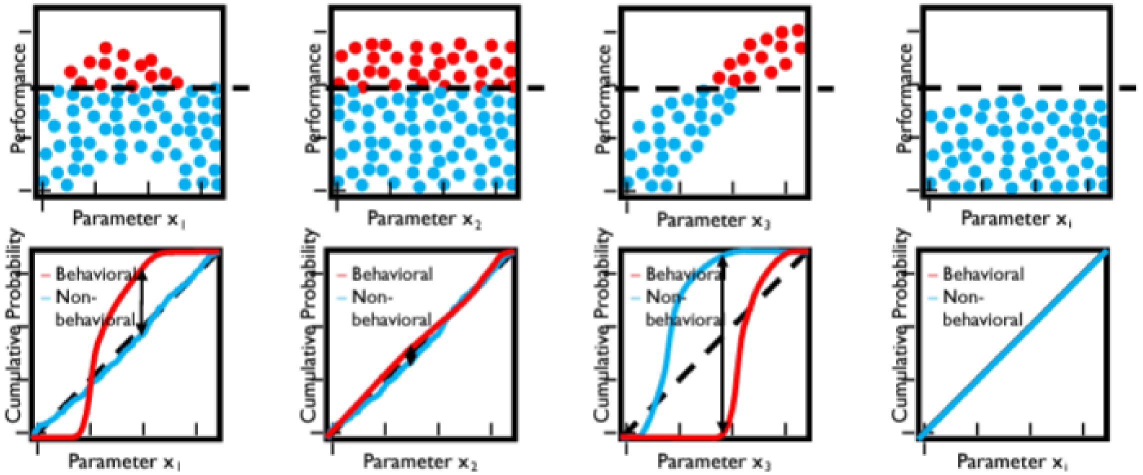
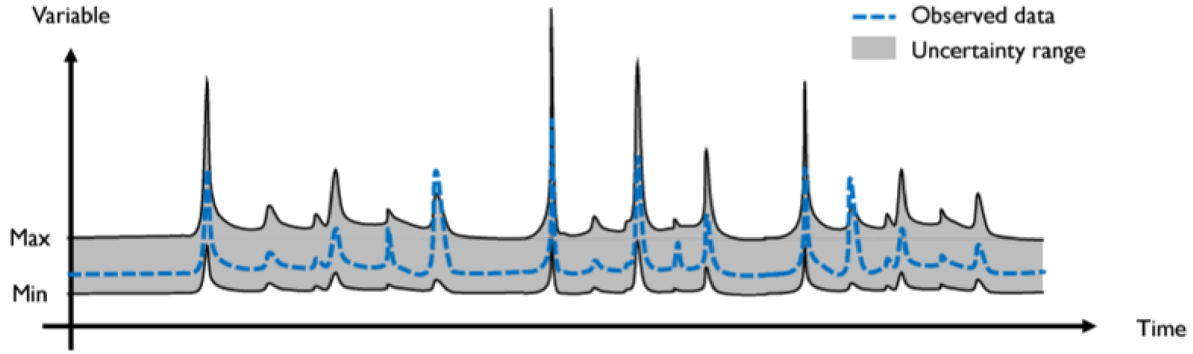
Sensitivity and uncertainty analysis





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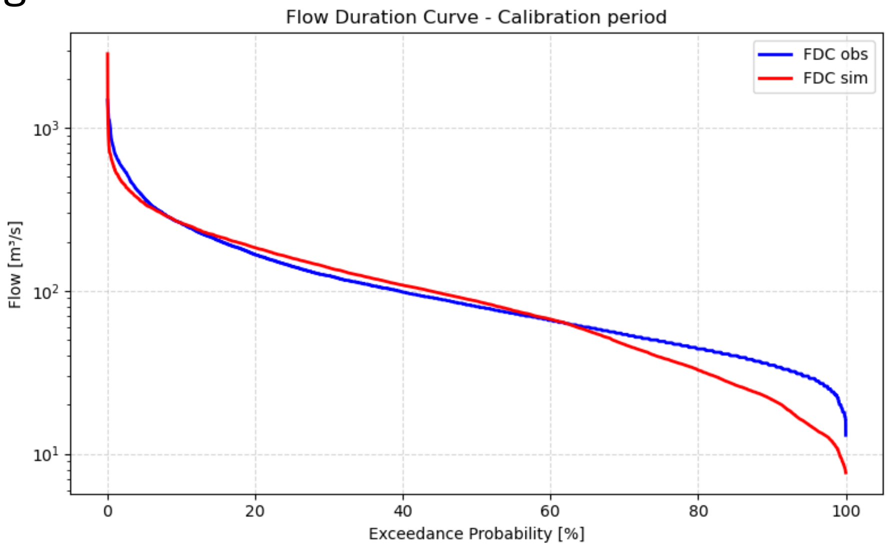
Flow duration curves

A cumulative frequency curve that shows the percentage of time that specified discharges are equaled or exceeded

- Arrange flows in chronological order
- Find the number of records (N)
- Sort the data from highest to lowest
- Rank the data (m=1 for the highest value and m=N for the lowest value)
- Compute exceedance probability for each value using the following formula
- Plot p on x axis and Q (sorted) on y axis



PDF fitting: Gumbel

$$Pr = 1/Tr$$

Pr [%]	Tr [Years]
66.67	1.5
50	2
20	5
10	10
5	20
2	50
1	100
0.2	500
0.1	1 000
0.01	10 000

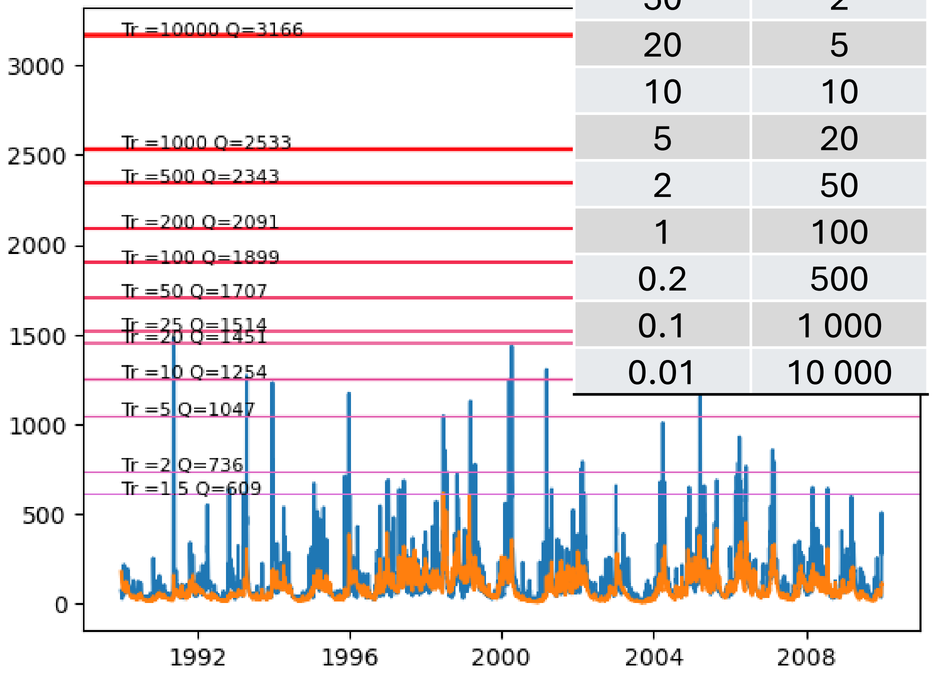
- **Extreme Value Distribution:** Extreme value distributions are widely used in hydrology. Storm rainfalls are most commonly modeled by the **Extreme Value Type I distribution**. Below is the "cumulative" probability distribution version of the function.

$$F(x) = e^{-e^{\left[-\frac{x-u}{\alpha}\right]}} \quad -\infty \le x \le \infty$$

$$\alpha = \frac{\sqrt{6}s_x}{\pi}$$

$$u = \bar{x} - 0.5772\alpha$$

$$Let\_y = \frac{x-u}{\alpha}$$



- Correlating "y" with Return Period (T), the Extreme Value Distribution can be simplified to:

$$x_T = u + \alpha y_T$$

$$y_T = -\ln\left[\ln\left(\frac{T}{T-1}\right)\right]$$

$$(x-u)/\alpha = -\ln(-\ln(F(x)))$$

$$x = -\ln(-\ln(F(x))) \cdot \alpha + u$$

$$\mu_y = 0{,}5772; \; \sigma_y = 1{,}2825$$

$$\alpha = s_x / \sigma_y$$

$$u = \bar{x} - \mu_y \cdot \alpha$$

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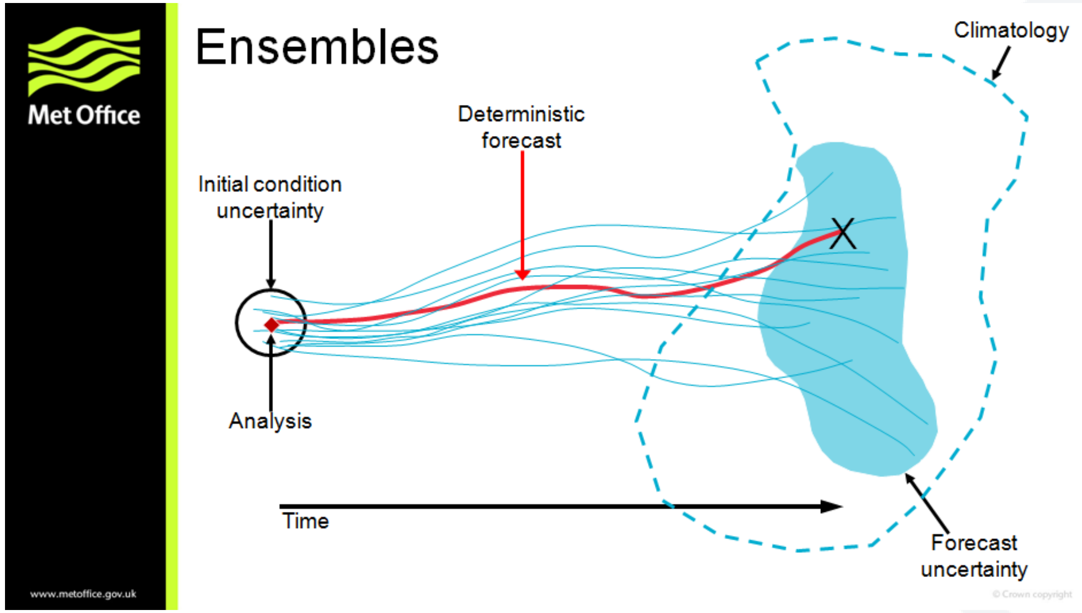
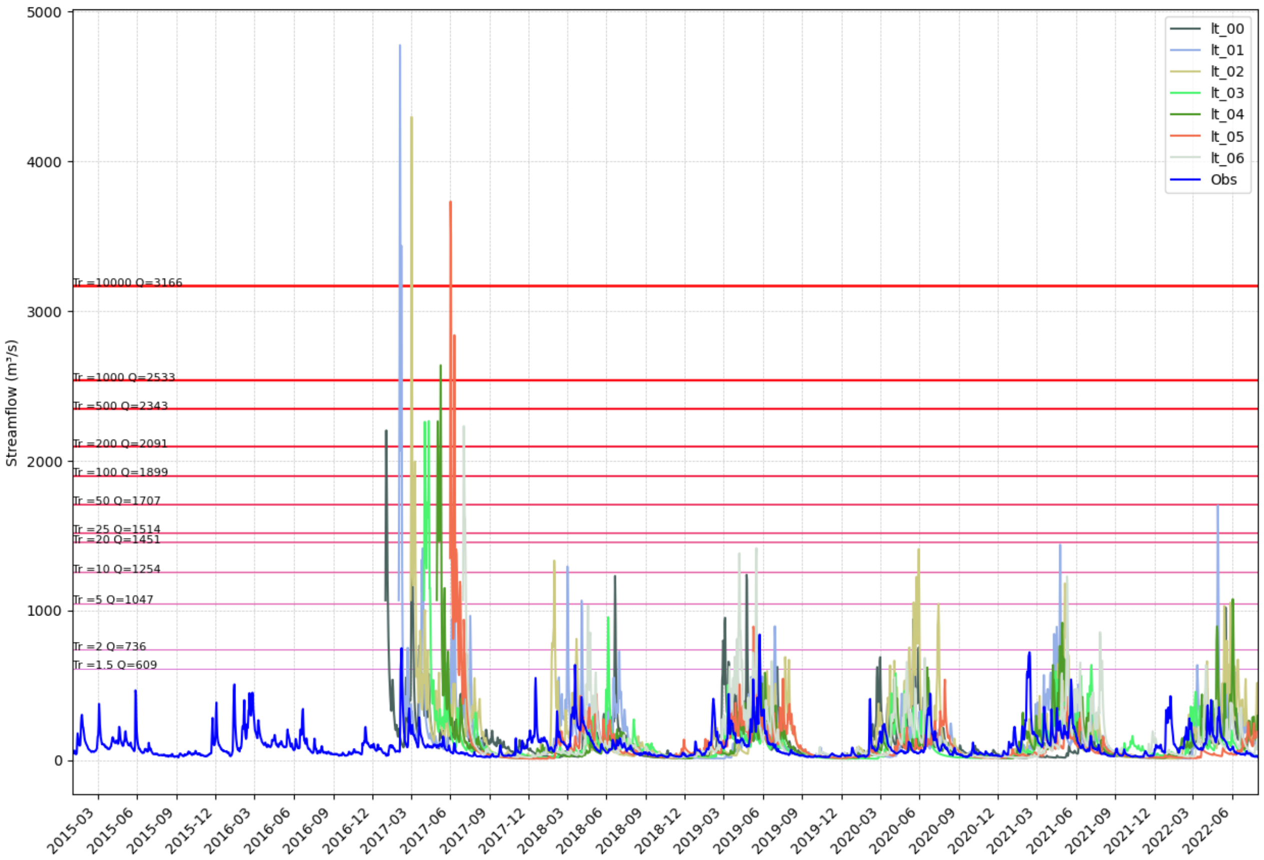
Ensemble forecasting



https://www.rmets.org/metmatters/ensembles-how-forecast-comes-together



Understanding the lead time

issued on

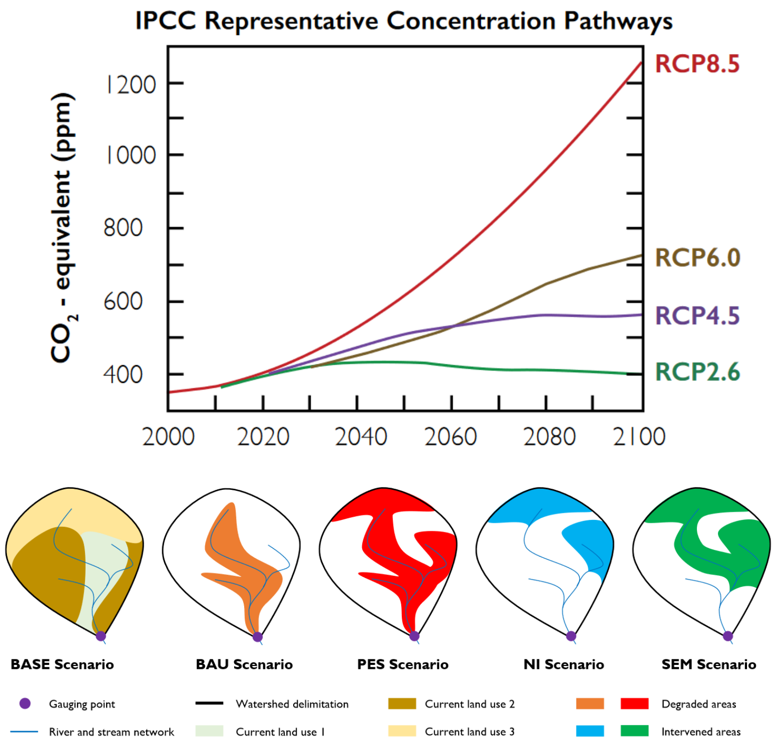
valid for

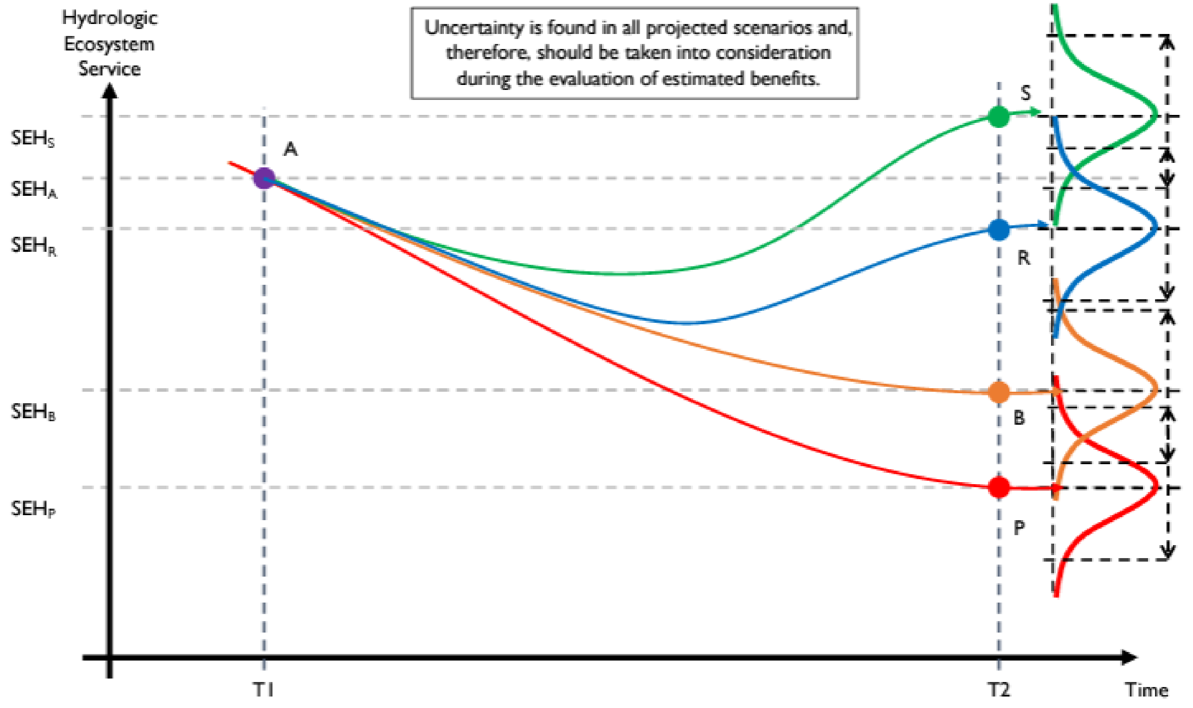
		2017-01-01	2017-01-02	2017-01-03	2017-01-04	2017-01-05	2017-01-06	2017-01-07
Predictions	1-day lead time		312	335	358	342	NaN	NaN
	2-day lead time		NaN	341	364	351	332	NaN
	3-day lead time		NaN	NaN	361	358	327	327
Observations			351	367	377	378	330	324

Hallouin, T., Bourgin, F., Perrin, C., Ramos, M.-H., & Andréassian, V. (2024). EvalHyd v0.1.2: A polyglot tool for the evaluation of deterministic and probabilistic streamflow predictions. *Geoscientific Model Development*, *17*(11), 4561–4578. https://doi.org/10.5194/gmd-17-4561-2024

Results analysis

What if …





Ochoa-Tocachi, Cuadros-Adriazola, Arapa, Aste, Ochoa-Tocachi, & Bonnesoeur. (2022). *Guide to Hydrologic Modeling*. Forest Trends Association. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.forest-trends.org/wp-content/uploads/2022/08/Guide-to-Hydrologic-Modeling-of-NI.pdf

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Performance metrics for ensemble forecasting

Brier Score (BS)

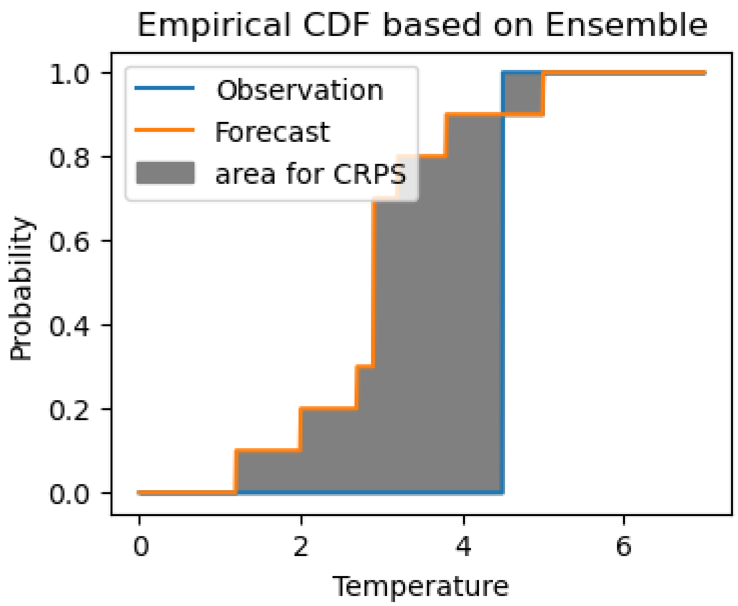
$$BS = \overline{(p - o)^2}$$

Brier Skill Score (BSS)

Rank Probability Scores (RPS)

Continuous Ranked Probability Scores (CRPS)

Continuous Ranked Probability Skill Score (CRPSS)



https://confluence.ecmwf.int/display/FUG/Section+12.B+Statistical+Concepts+-+Probabilistic+Data

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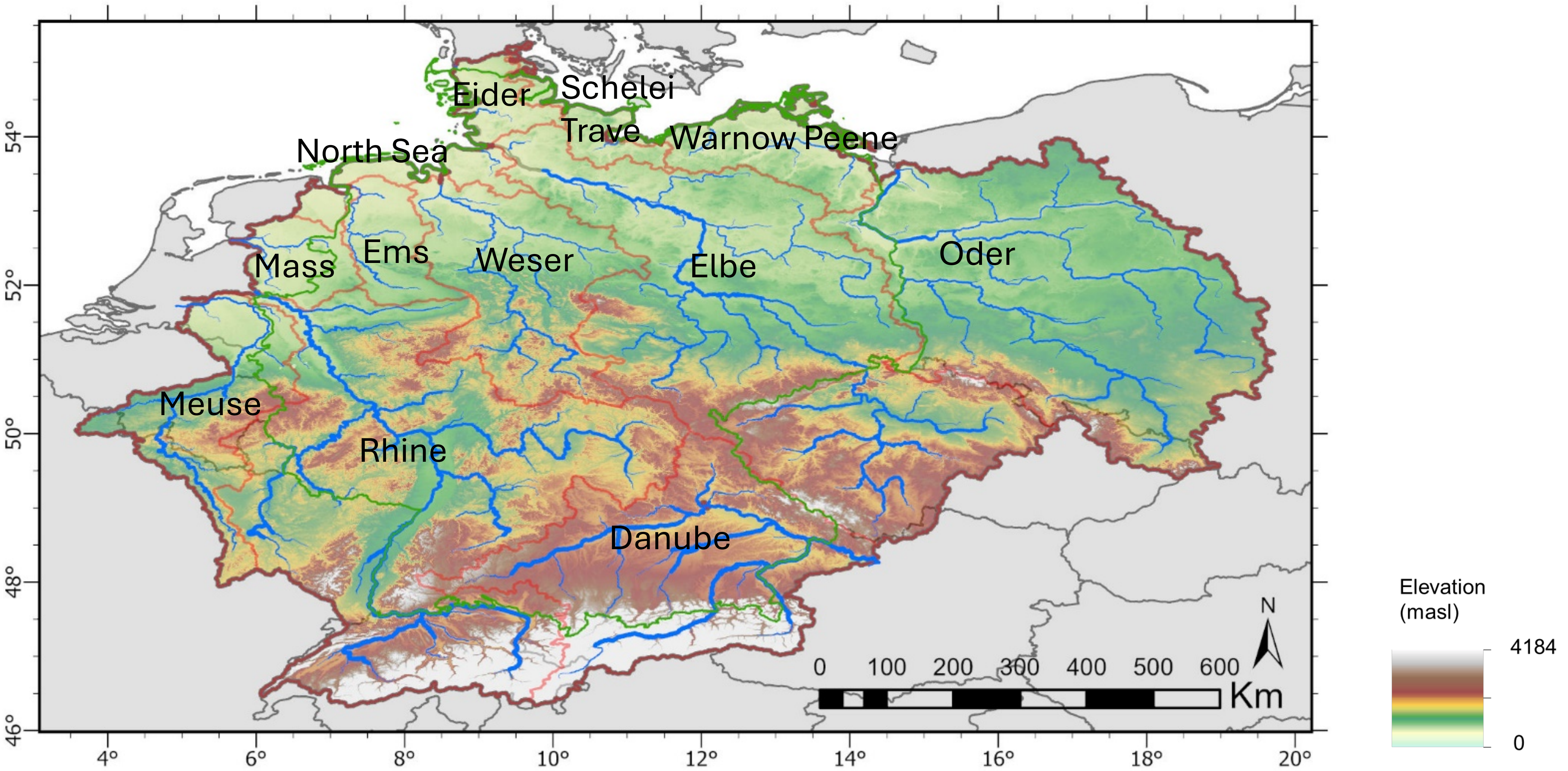
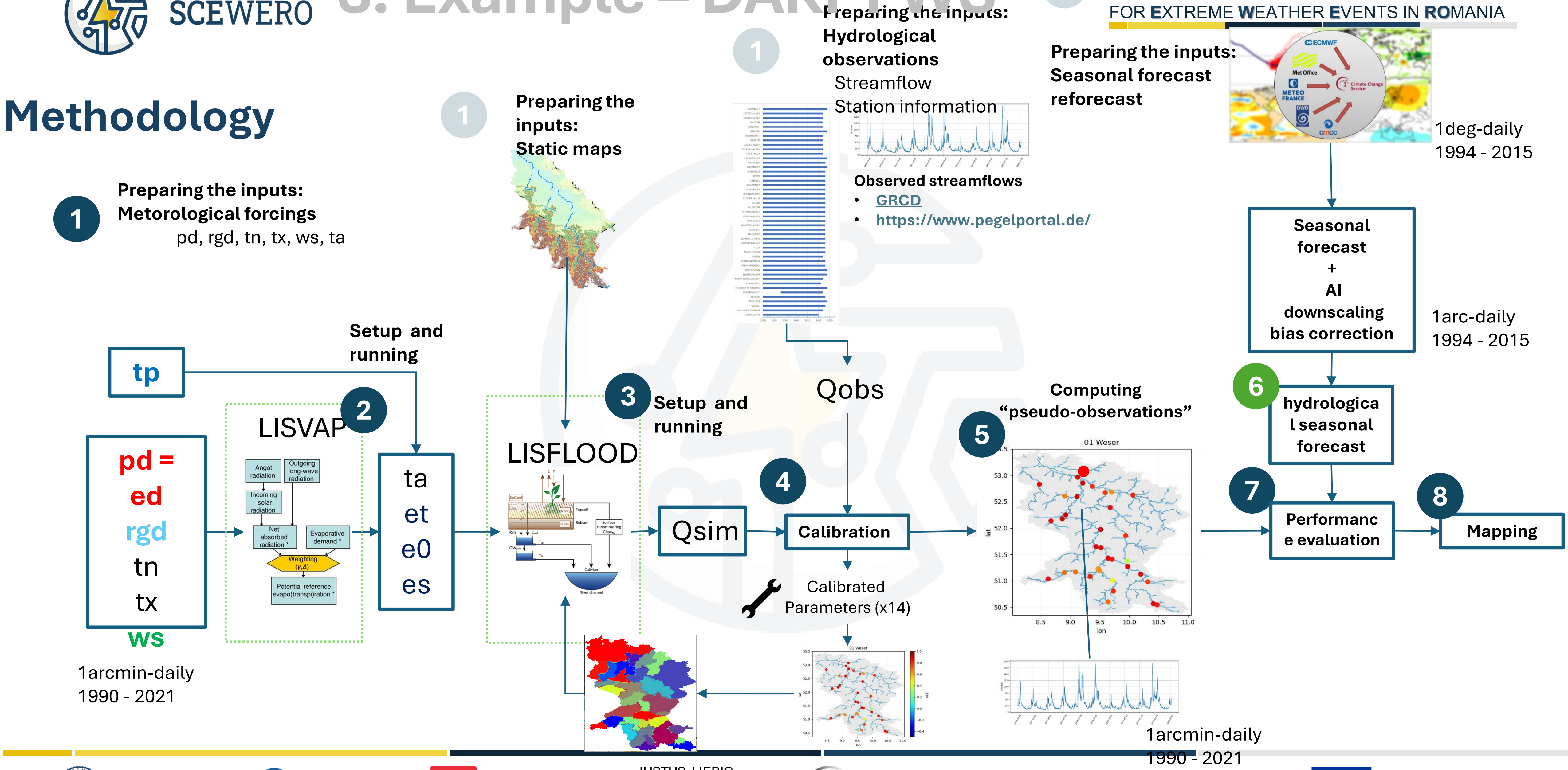
3. Example – DAKI-FWS



3. Example – DAKI-FWS

Methodology



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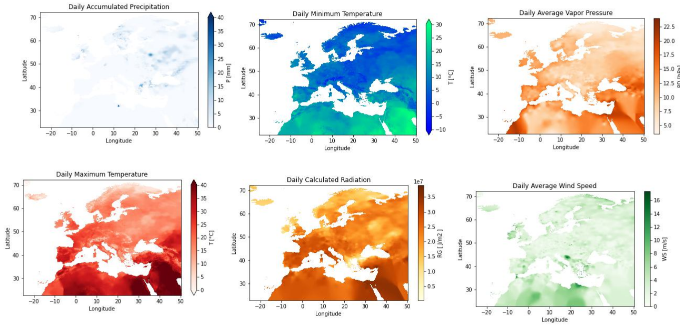
3. Example – DAKI-FWS

Meteorological forcing's

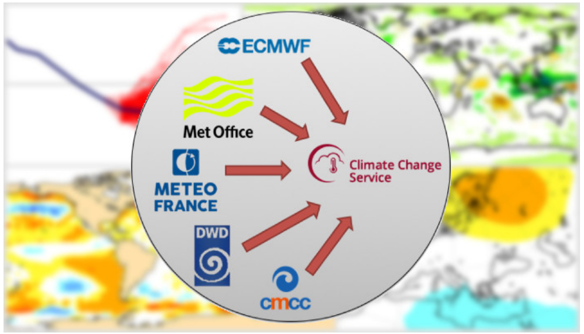
Observations

EFAS



EMO – 1
Spatial resolution 1arcmin
Time resolution daily
Period 1990-2021

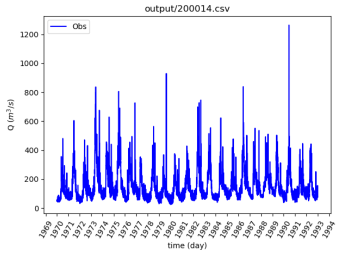
Seasonal forecast re-forecast

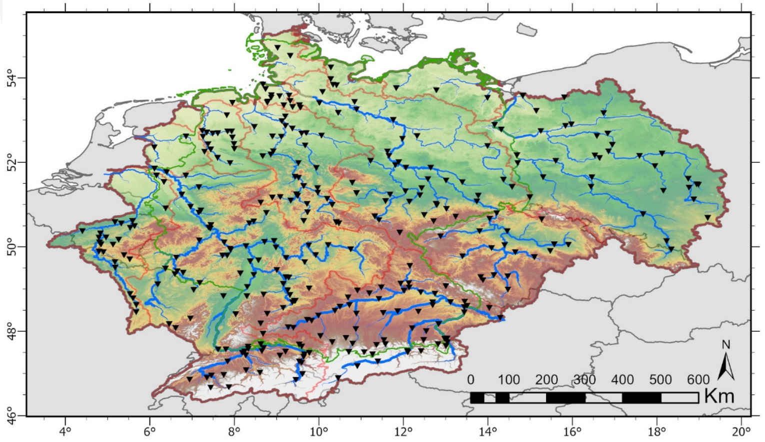


Hydrological

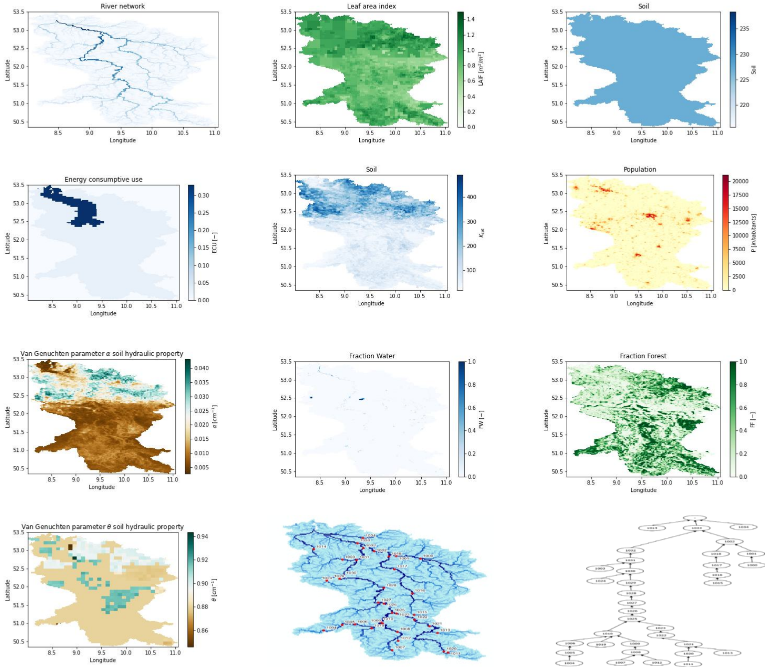
Pegelportal

GRDC





Morphological, physical, soil, and land use properties



EFAS

Francesca Moschini; Margarita Choulga; Cinzia Mazzetti; Disperati, Juliana; Grimaldi, Stefania; Salamon, Peter; Prudhomme, Christel (2023): LISFLOOD static and parameter maps for Europe. European Commission, Joint Research Centre (JRC) [Dataset] PID: http://data.europa.eu/89h/f572c443-7466-4adf-87aa-c0847a169f23

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3. Example – DAKI-FWS

Pre-processor LISVAL

LISVAP Installed and tested in Levante HPC

1. Installing/initializing git for large file
   `git lfs install`
2. clone LISVAP from the respository
   `git clone https://github.com/ec-jrc/lisflood-lisvap.git`
   `cd lisflood-lisvap`
3. Creating a conda enviromment for lisvap
   `conda create --name lisvap python=3.8 --no-default-packages`
   `source activate lisvap`
4. Installing and checking lisvap
   `pip install -r requirements.txt`
5. Installing and checking pcraster
   `conda install -c conda-forge pcraster`
6. Running LISVAP from scr folder
   `python lisvap1.py /my_system/lisflood-lisvap/tests/data/tests_efas.xml -v -t`

```
<!--
#######################################################

  ##       ####  ######  ##     ##    ###    ########
  ##        ##  ##    ## ##     ##   ## ##   ##     ##
  ##        ##  ##       ##     ##  ##   ##  ##     ##
  ##        ##   ######  ##     ## ##     ## ########
  ##        ##        ##  ##   ##  ######### ##
  ##        ##  ##    ##   ## ##   ##     ## ##
  ######## ####  ######     ###    ##     ## ##

#######################################################

TIP:
You can use $(ProjectDir) or $(ProjectPath) as built-in variable to use in this XML settings, to refer Lisvap project folder (in cas
You can use $(SettingsDir) or $(SettingsPath) to refer directory containing the XML settings.
-->

<lfsettings>

    <lfuser>

        <group>

            <comment>
                **************************************************************
                TIME-RELATED CONSTANTS
                **************************************************************
            </comment>

            <textvar name="CalendarDayStart" value="01/01/1995 00:00">
                <comment>
                    calendar day number of 1st day in model run
                    e.g. 1st of January: 1; 1st of June: 151 (or 152 in leap year)
                </comment>
            </textvar>

            <textvar name="DtSec" value="86400">
                <comment>
                    time step [seconds] ALWAYS USE 86400!!
                </comment>
            </textvar>

            <textvar name="StepStart" value="01/01/1995 06:00">
                <comment>
                    Number of first time step in simulation
                </comment>
            </textvar>

            <textvar name="StepEnd" value="31/12/1995 06:00">
                <comment>
                    Number of last time step
                </comment>
            </textvar>

            <textvar name="ReportSteps" value="1..14">
                <comment>
                </comment>
```


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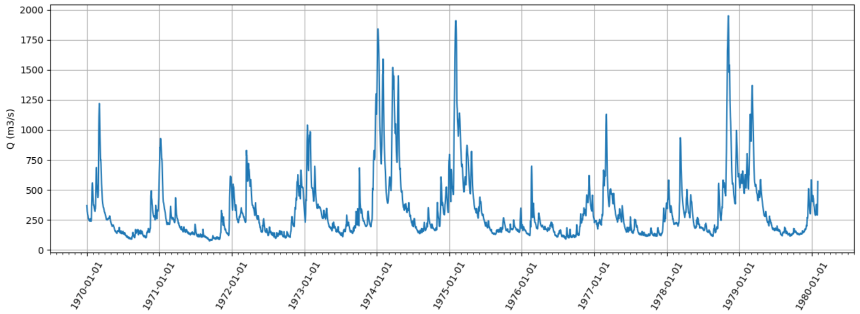
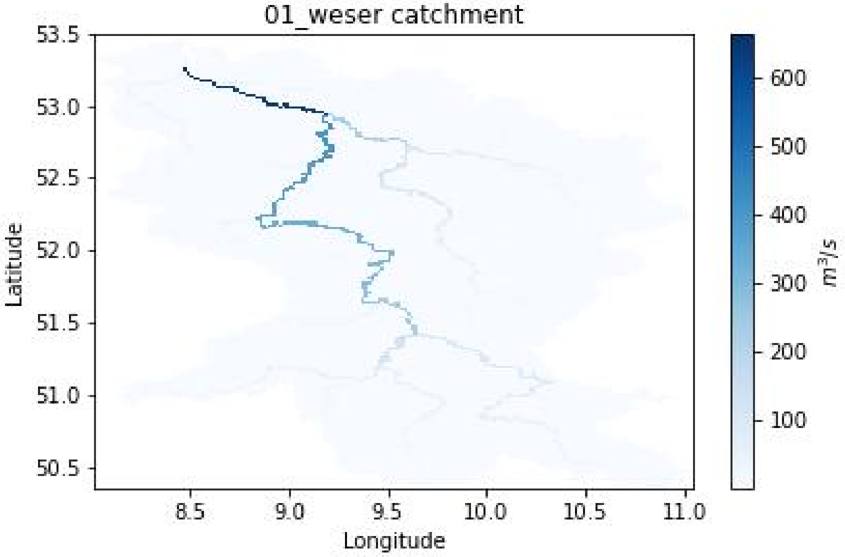
Hydrological Model LISFLOOD

LISFLOOD, LISFLOOD-Utilities and LISFLOOD-Calibration tools installed and tested in Levante HPC. (Working in serie and in parallel).

```
# 2023-05-05 Installing Lisflood Calibration tool
# installation for solving the multiprocessing problems attemp 1


module load python3
module load git

conda create --name lisflood_calibration_2 python=3.7 -c conda-forge

git clone --single-branch https://github.com/ec-jrc/lisflood-calibration.git

source activate lisflood_calibration_2
conda install -c conda-forge pcraster gdal
pip install lisflood-model==4.1.2

# pip show lisflood-model # allows you to know where is the source code of lisflo
# /work/bb1245/hydromodelling/conda_venvs/lisflood_calibration_2/lib/python3.7/si
# After installing lisflood compile the  cython module kinematic_wave_parallel_to
# To compile this Cython module to enable OpenMP multithreading (parallel kinemat
# Delete the files *.so (if any) in directory hydrological-modules
# Inside the hydrological_modules folder, execute "python compile_kinematic_wave_

# For get rid of the errors in related with hdf5
conda remove hdf5
conda install -c conda-forge hdf5==1.12.1


# other tools
pip install pandas
pip install numpy
pip install matplotlib
pip install netCDF4
pip install deap
conda install -c conda-forge deap

pip install -r requirements.txt # run it in the lisflood_code folder
pip install . # run it in the lisflood_calibration folder

pip install tbb # For parallelization
```

```
#######################################################################

##       ####  ######  ######## ##       #######   #######  ########
##        ##  ##    ## ##       ##      ##     ## ##     ## ##     ##
##        ##  ##       ##       ##      ##     ## ##     ## ##     ##
##        ##   ######  ######   ##      ##     ## ##     ## ##     ##
##        ##        ## ##       ##      ##     ## ##     ## ##     ##
##        ##  ##    ## ##       ##      ##     ## ##     ## ##     ##
######## ####  ######  ##       ######## #######   #######  ########

#######################################################################
-->

<lfsettings>

  <lfoptions>
    #----------------------------------------------------------
    # modelling and reporting options
    #----------------------------------------------------------
  <setoption choice="0" name="TemperatureInKelvin"/>
  <setoption choice="1" name="gridSizeUserDefined"/>

    # options to turn hydrological modules on/off
    <setoption choice="0" name="cropsEPIC"/>

    <setoption choice="1" name="wateruse"/>
    <setoption choice="1" name="TransientWaterDemandChange"/>
    <setoption choice="0" name="useWaterDemandAveYear"/>
    <setoption choice="1" name="wateruseRegion"/>

    <setoption choice="0" name="groundwaterSmooth"/>
    <setoption choice="1" name="wateruseRegion"/>
    <setoption choice="1" name="drainedIrrigation"/>
    <setoption choice="1" name="riceIrrigation"/>
    <setoption choice="0" name="indicator"/>

    <setoption choice="1" name="openwaterevapo"/>
    <setoption choice="0" name="simulateLakes"/>
    <setoption choice="0" name="simulateReservoirs"/>

    <setoption choice="0" name="simulateReservoirs"/>

    <setoption choice="1" name="SplitRouting"/>

    # use inflow data
    <setoption choice="0" name="inflow"/>

    # option to initialize Lisflood
    <setoption choice="0" name="InitLisflood"/>
```





3. Example – DAKI-FWS

Calibration - Validation

Non-dominated Sorting Genetic Algorithm-II (NSGA-II)

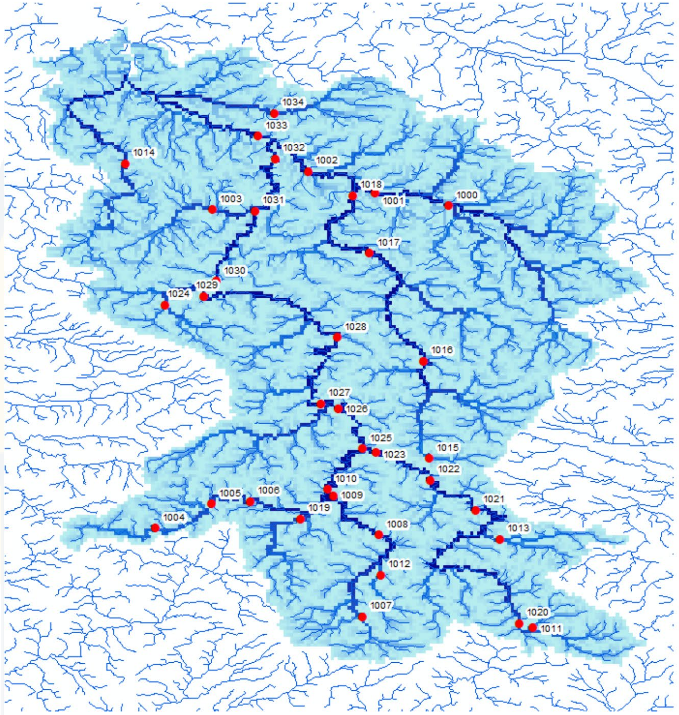
Modified Kling-Gupta Efficiency

$$KGE' = 1 - \sqrt{(r-1)^2 + (\beta-1)^2 + (\gamma-1)^2}$$

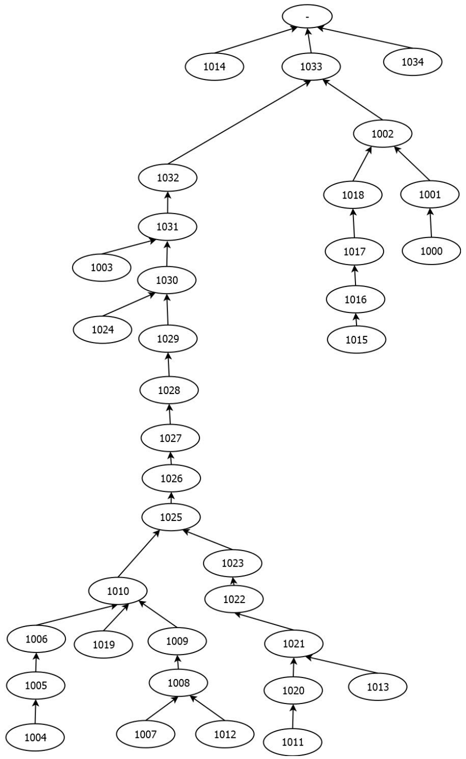
$$r_{xy} = \frac{\sum_i x_i y_i - n\bar{x}\bar{y}}{\sqrt{\sum_i x_i^2 - n\bar{x}^2}\,\sqrt{\sum_i y_i^2 - n\bar{y}^2}}$$

$$\beta = \frac{\mu_s}{\mu_o} \qquad \gamma = \frac{\sigma_s/\mu_s}{\sigma_o/\mu_o}$$

KGE'	Description
1.0 - 0.8	Very good
0.8 - 0.6	Good
0.6 - 0.4	Medium
0.4 - 0.2	Poor
< 0.2	Bad



01_wesser



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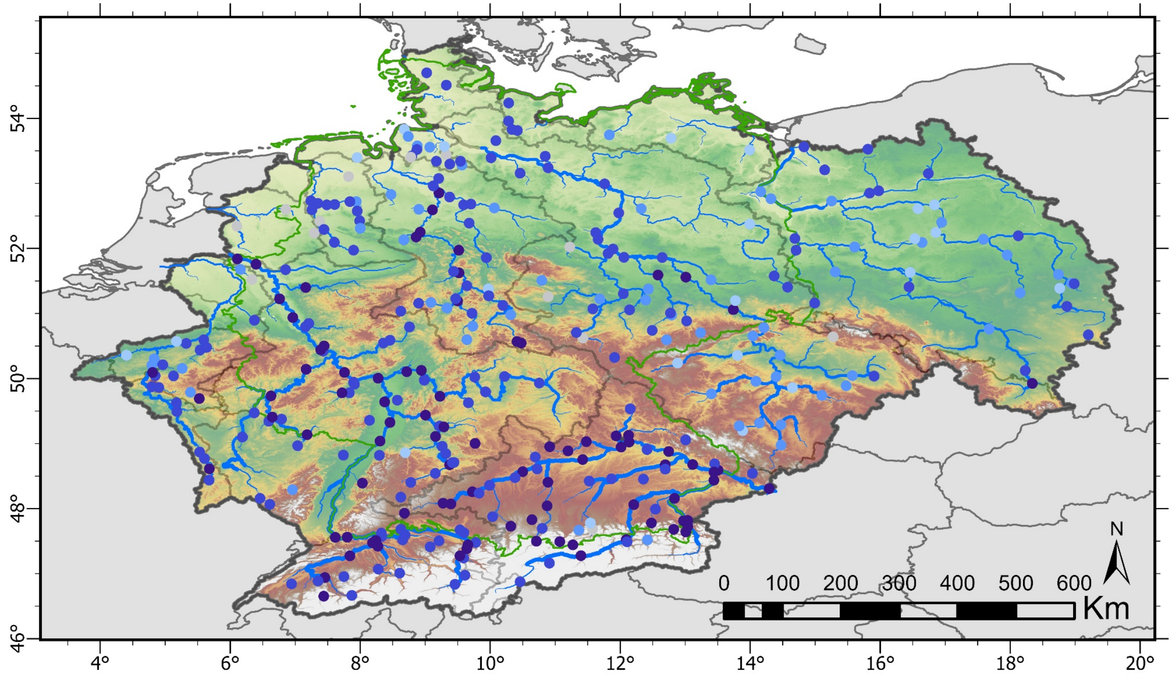
3. Example – DAKI-FWS

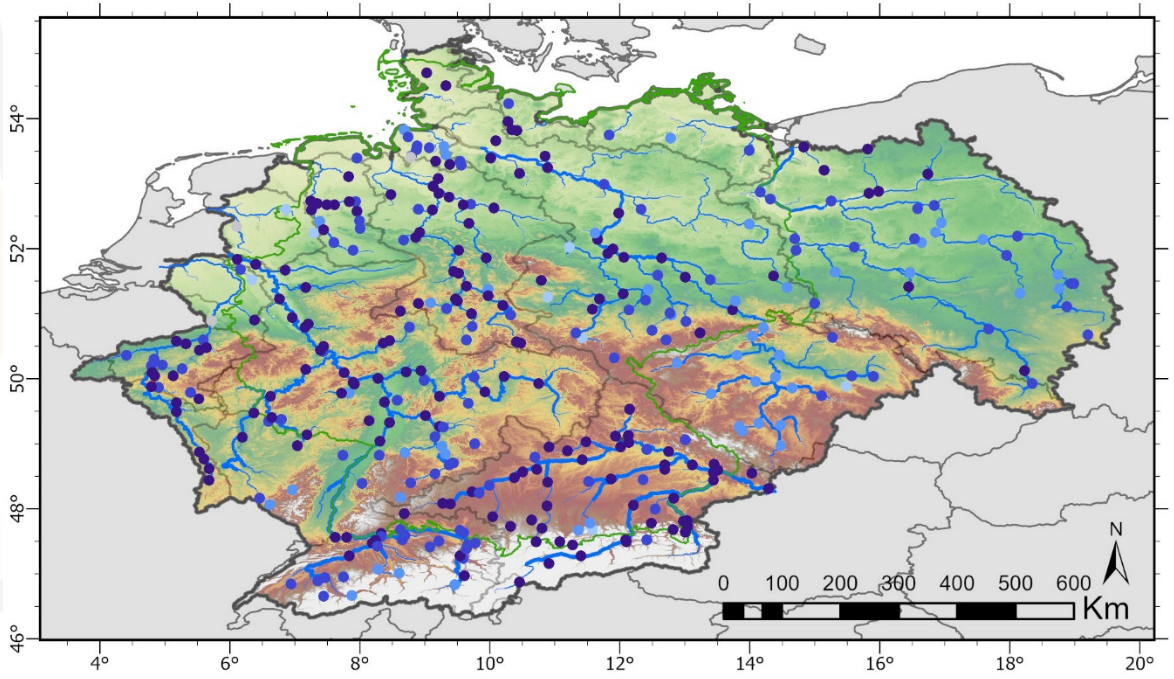
Calibration - Validation

KGE'	Description
1.0 - 0.8	Excellent
0.8 - 0.6	Good
0.6 - 0.4	Acceptable
0.4 - 0.2	Low
< 0.2	very low

Calibration



Validation



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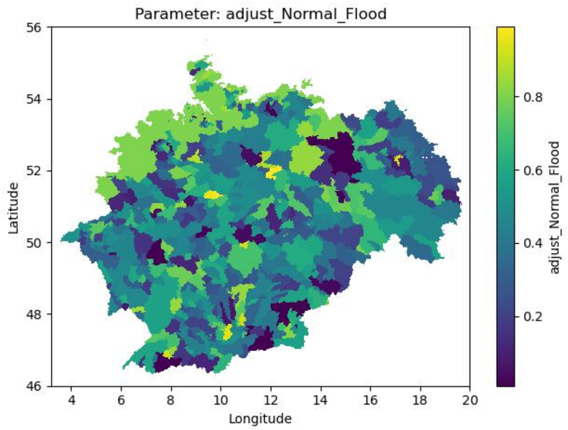
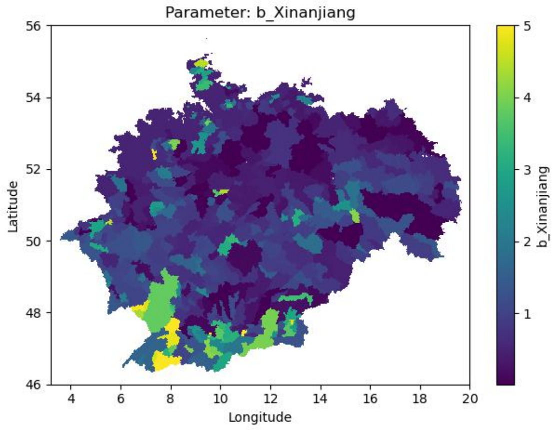
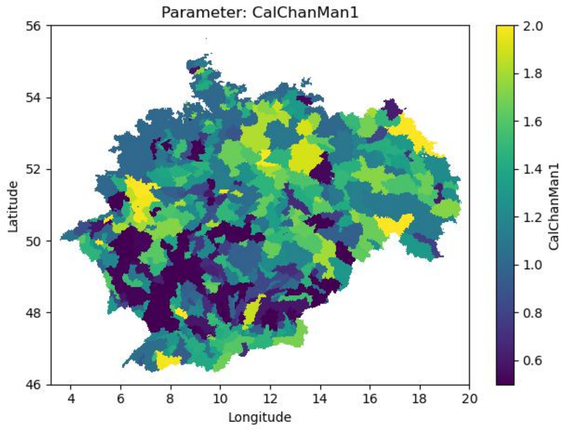
3. Example – DAKI-FWS

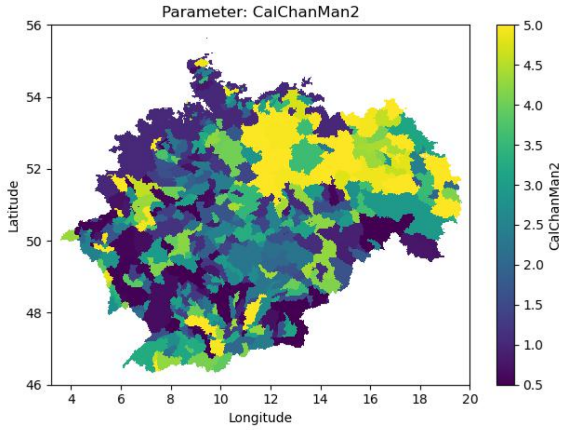
Parameters maps for the study region

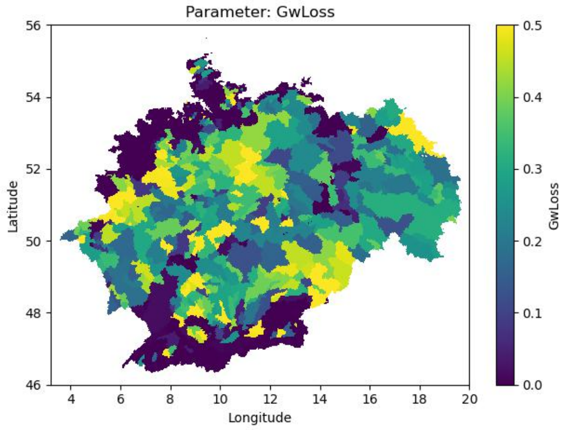
… a total of 14 maps

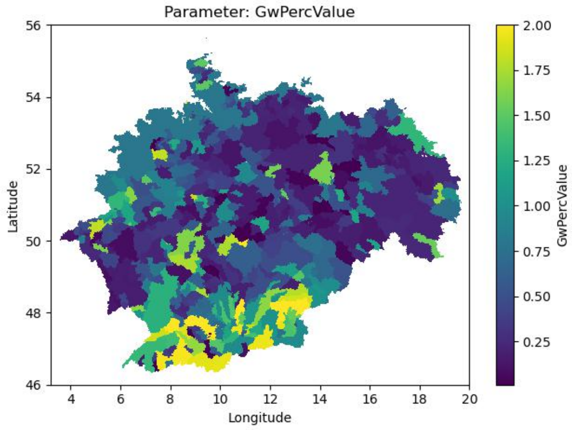












3. Example – DAKI-FWS

Dashboard

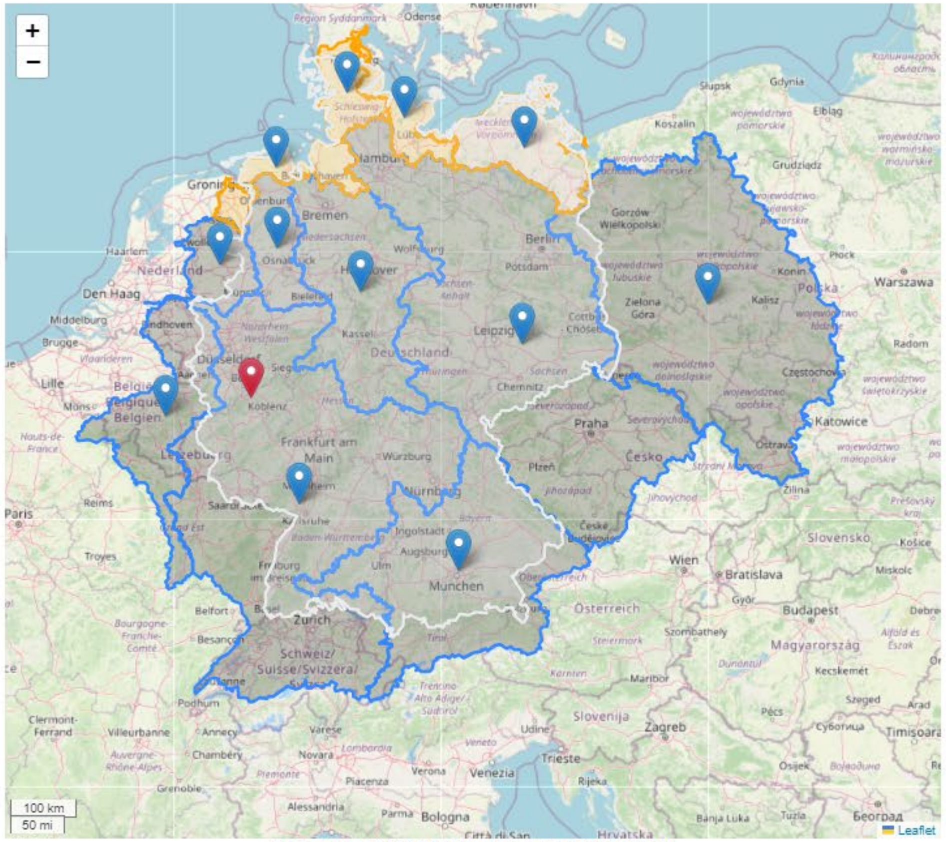
Hydrological seasonal forecast

DAKI-FWS

Catchments of interest

List of catchments

Select...

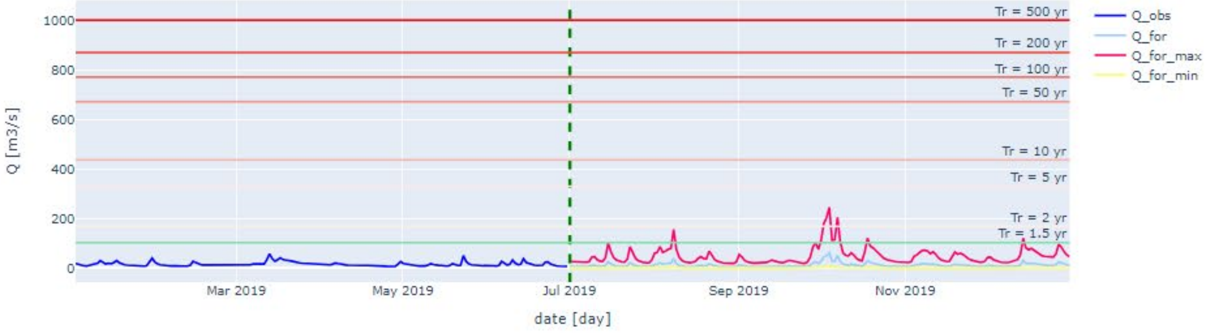


Clicked Point 7.184211526660529, 50.54654466503386

Selected catchment: None

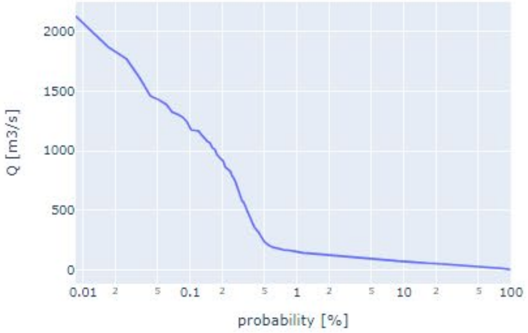
Information about the calibration

Hydrograph



Flow duration curve

Observed period

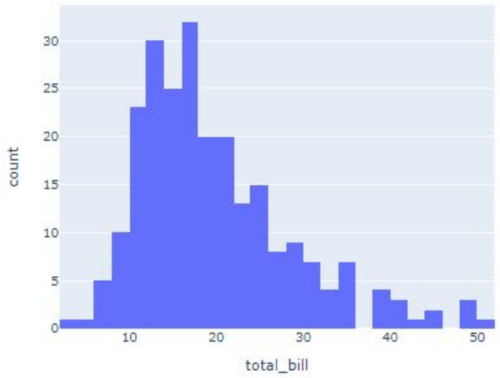


(12.47, 65.30) means pr(Q>65.30 m3/s) = 12.78 %

(p, q) means pr(Q>q)=p

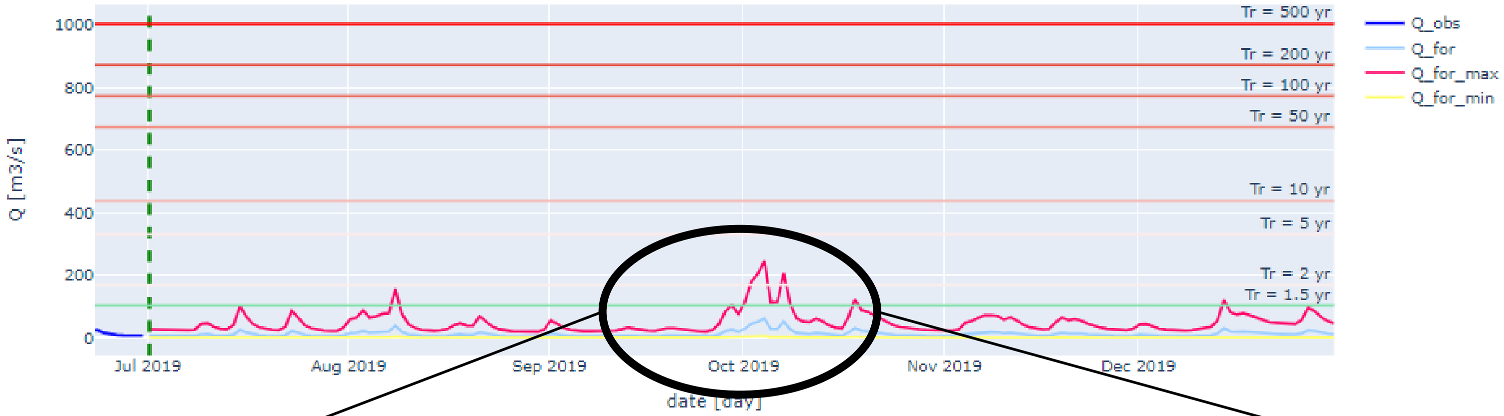
Probability of excedence

Forecast period



3. Example – DAKI-FWS

Lon = 10.063°
Lat = 52.622°

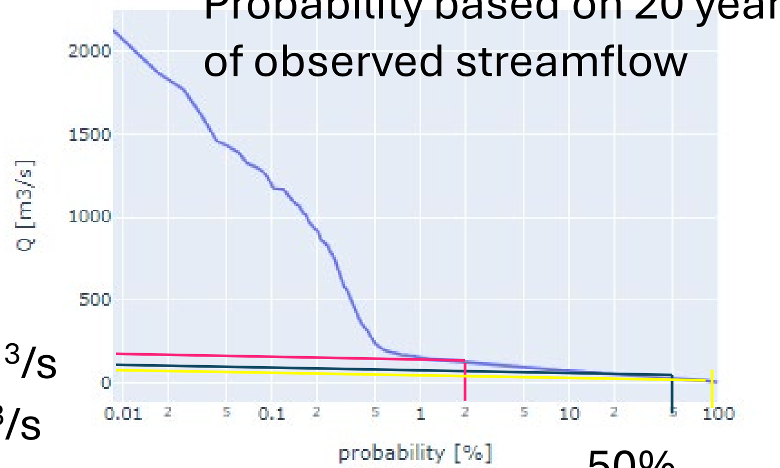


Probability based on 20 years of observed streamflow

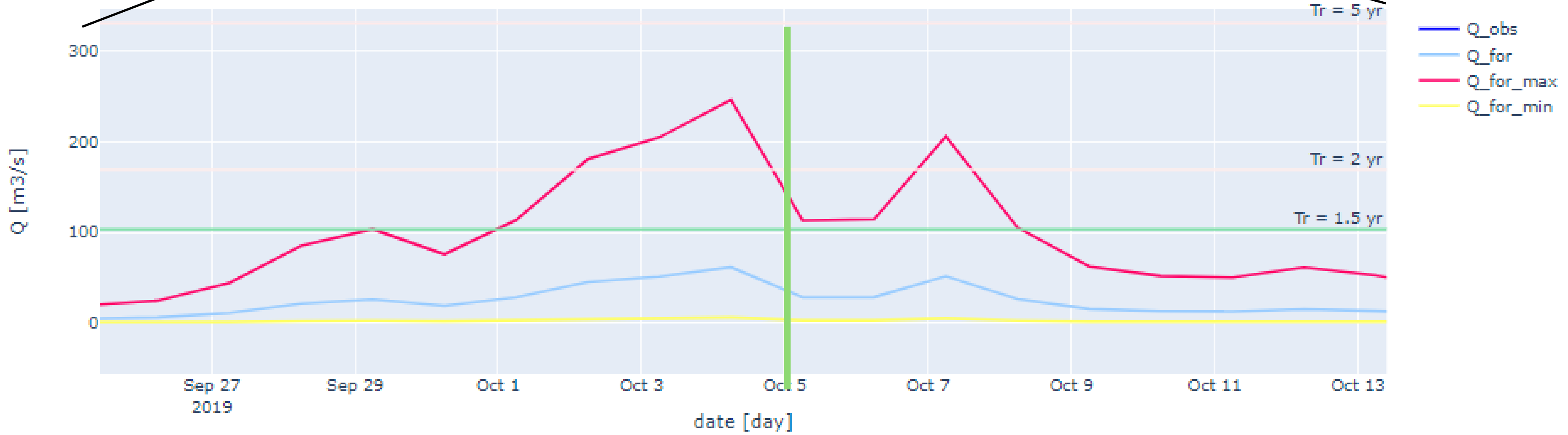
$113 m^3/s$

$28.31 m^3/s$

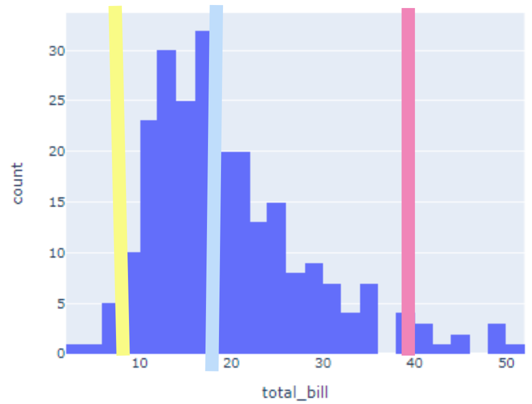
$2.8 m^3/s$



2%
50%
99.9%



$Q_{max}=113 m^3/s$
$Q_{mean}=28.31 m^3/s$
$Q_{min} = 2.83 m^3/s$



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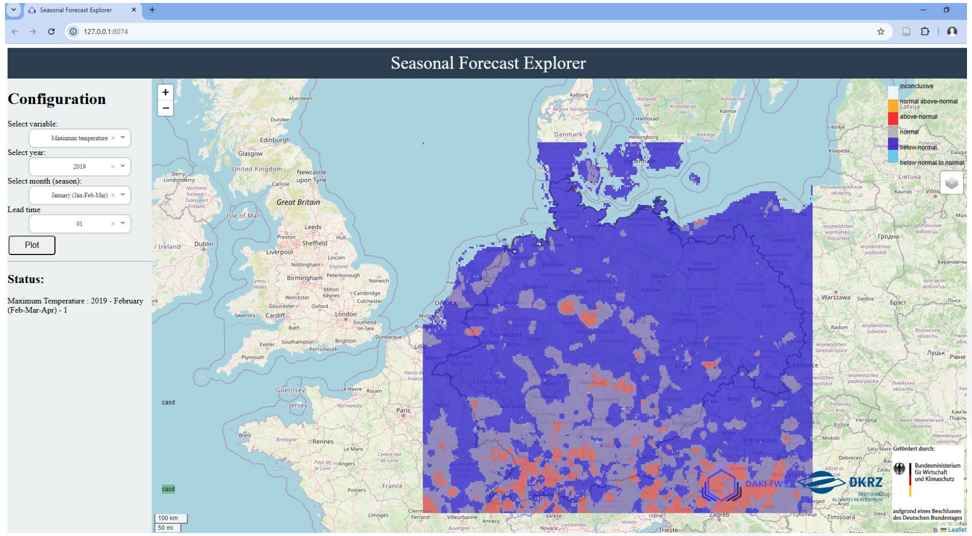
SCEWERO

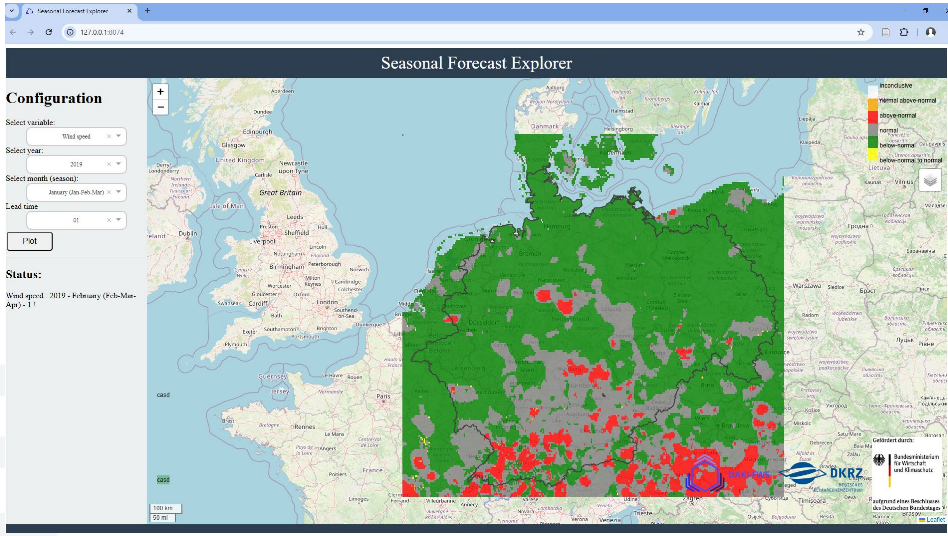
3. Example – DAKI-FWS

STRENGTHENING THE RESEARCH CAPACITIES FOR EXTREME WEATHER EVENTS IN ROMANIA

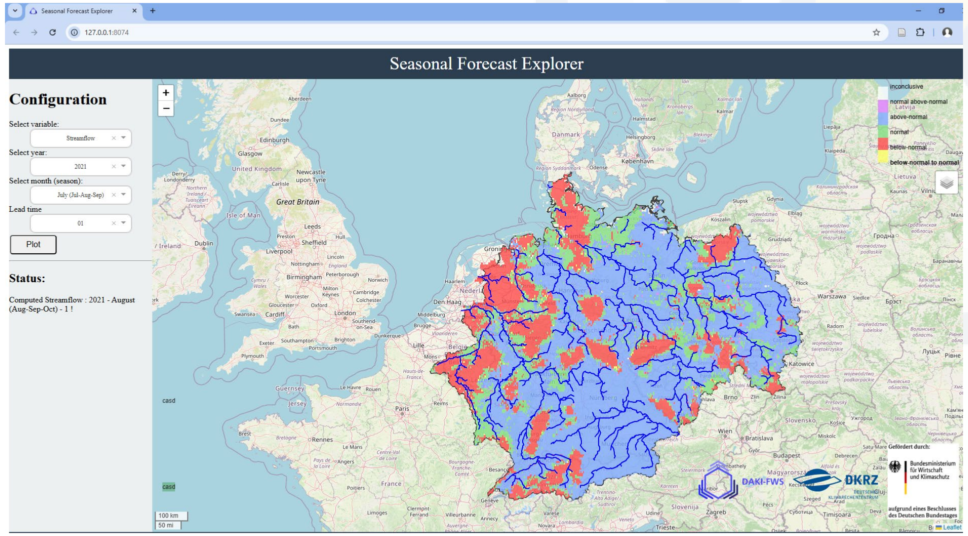
Temperature



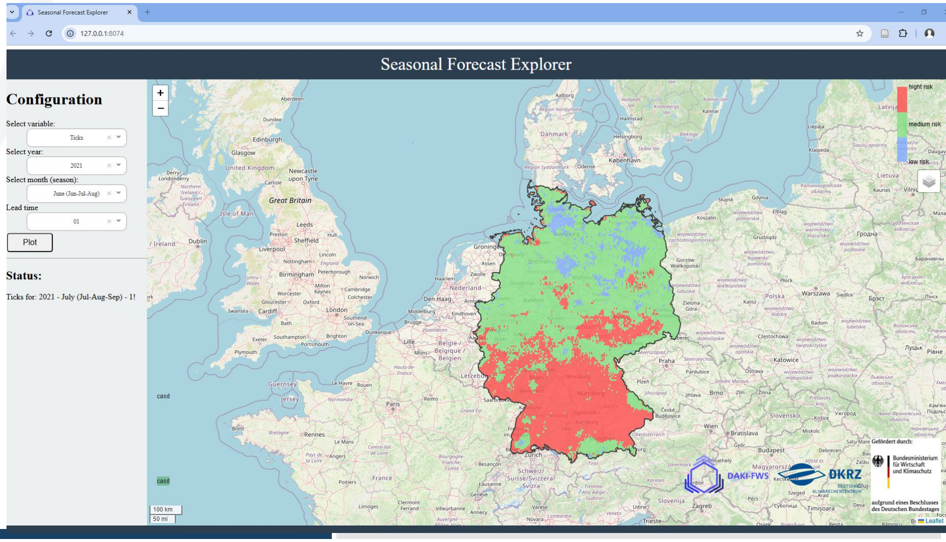
Wind speed



Streamflows



Ticks



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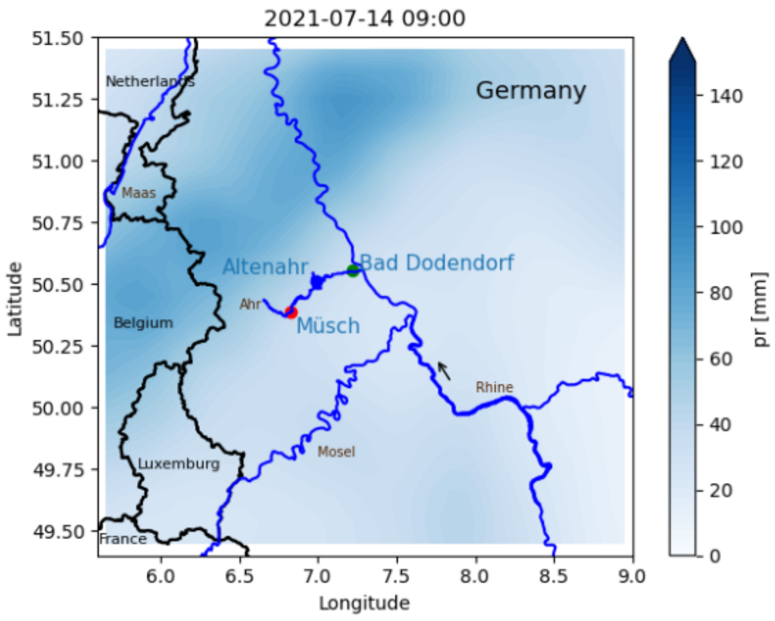
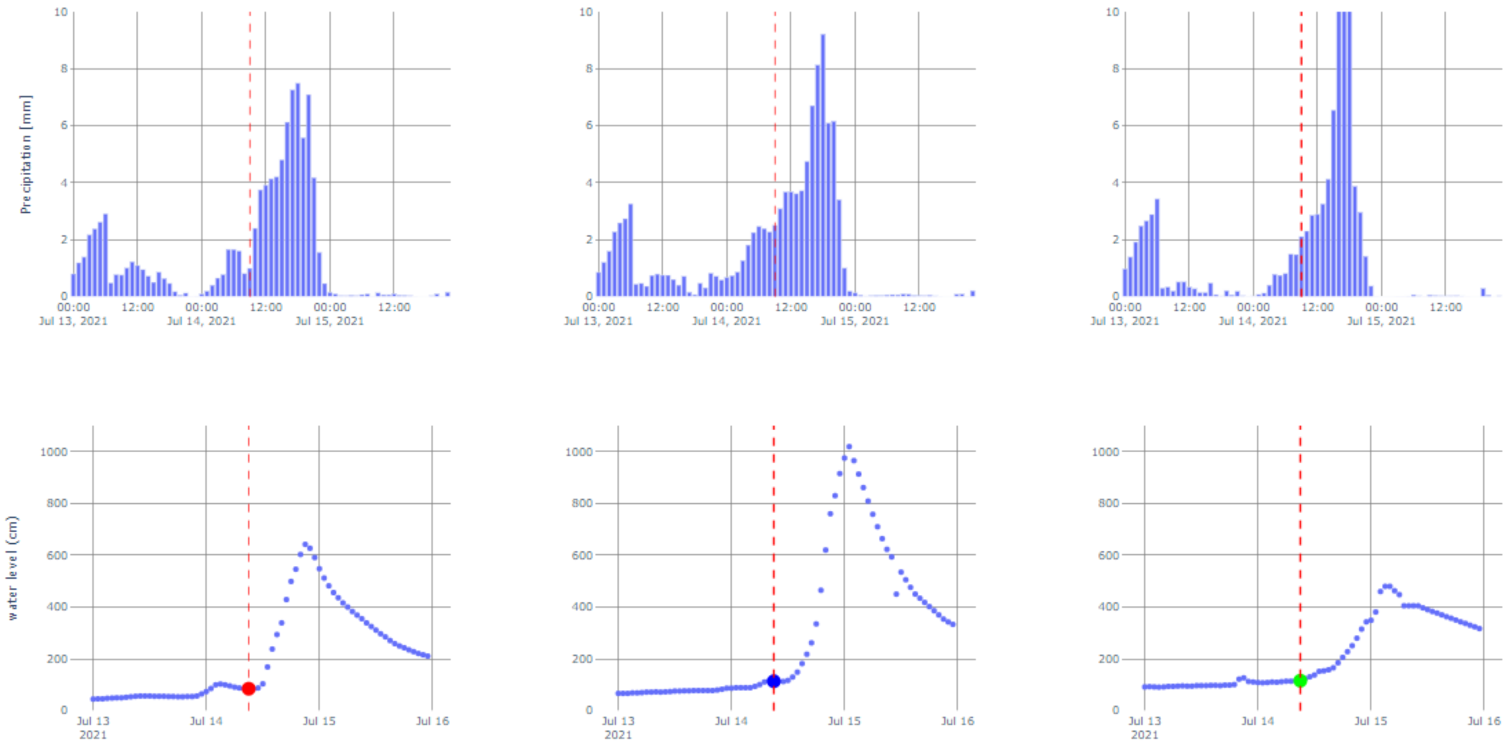
3. Example – DAKI-FWS

Propagation of the Ahrtal flood in 2021

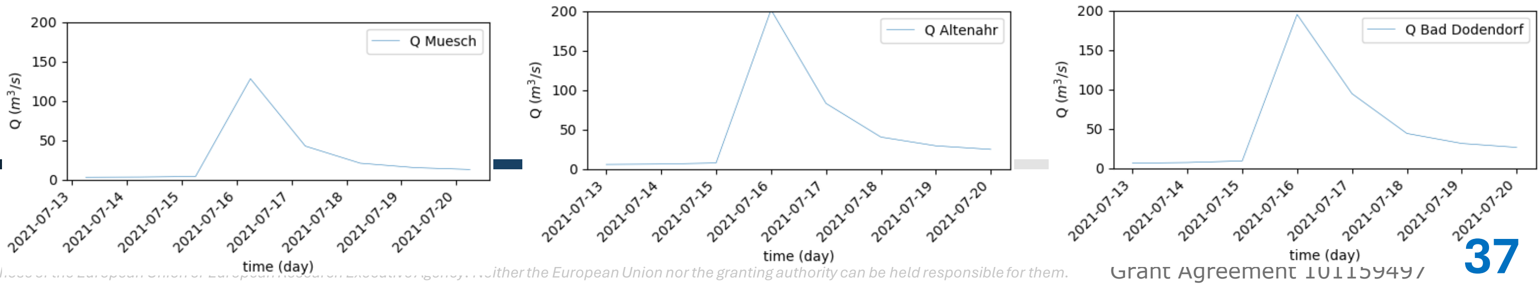
Cumulative rainfall in the region:



Müsch
Altenahr
Bad Dodendorf



Observed precipitation and water level



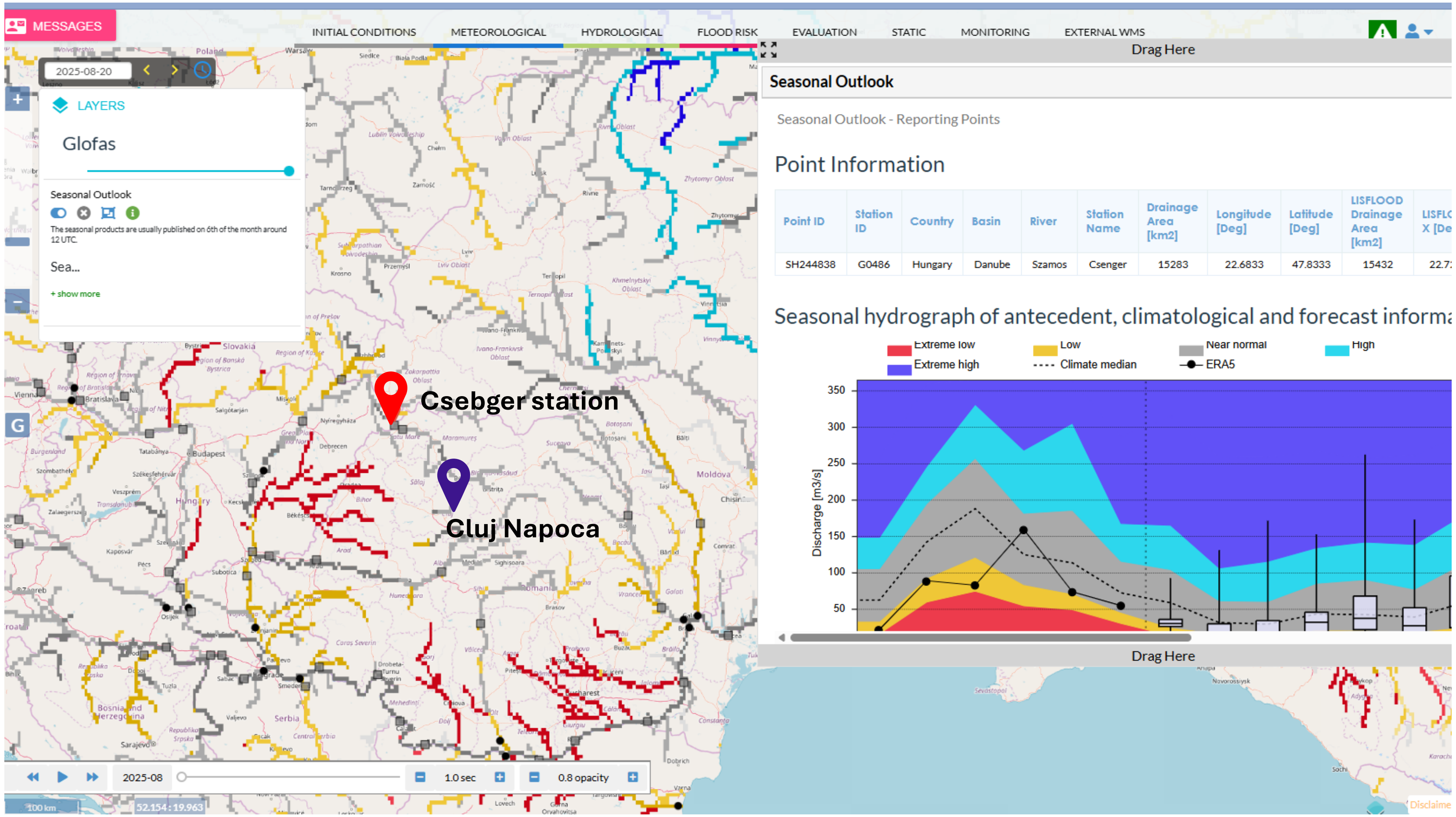
4. Operating FEWS

Global Flood Awareness System - GLOFAS

https://global-flood.emergency.copernicus.eu/

European Flood Awareness System - EFAS

https://european-flood.emergency.copernicus.eu/en



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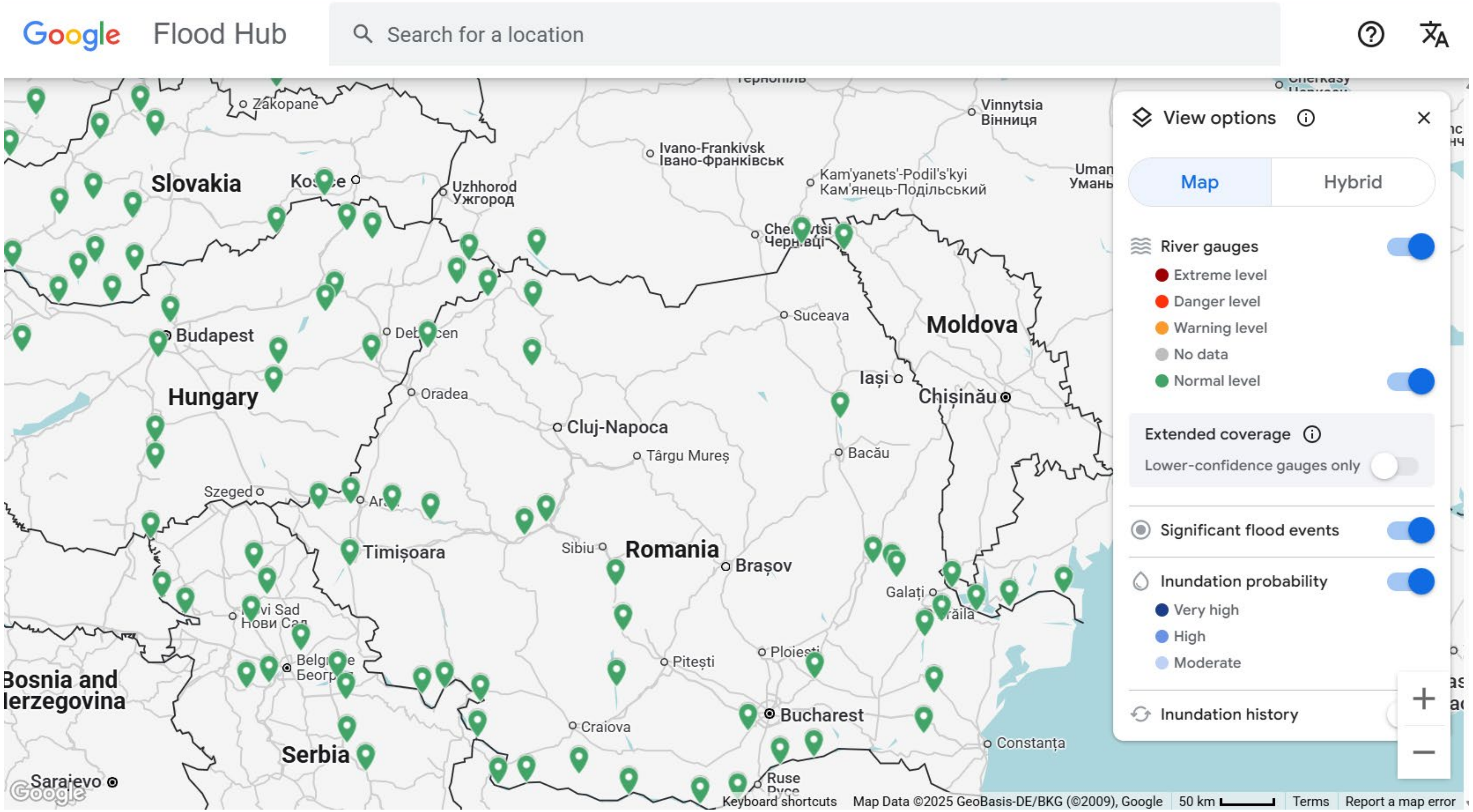
4. Operating FEWS

AI – Google Flood Hub

https://g.co/floodhub



Nearing, G., Cohen, D., Dube, V. *et al.* Global prediction of extreme floods in ungauged watersheds. *Nature* **627**, 559–563 (2024). https://doi.org/10.1038/s41586-024-07145-1

5. Summary

Hydrological cycle

Hydrological modelling

Models

Protocol

Application

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Thank you!

Questions ?

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Hands on: Hydrological modelling

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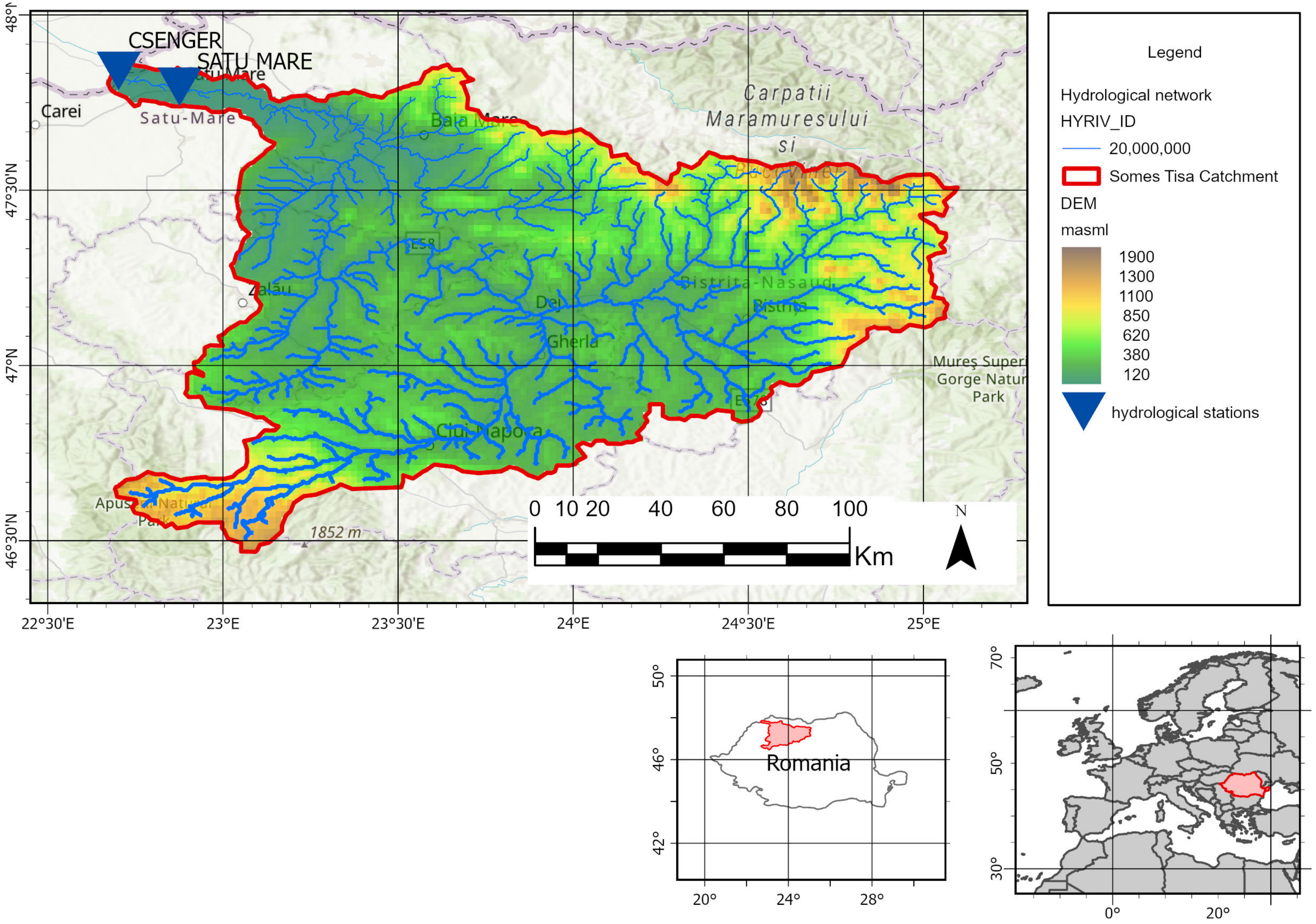
1. Define model goals

Somes-Tisa Watershed Area

Somes-Tisa watershed area is located to the North and North-Western part of the country, being delineated to the North by the natural border – Tisa river with Ukraine on a length of 61 km, to the West by the border with the Hungarian Republic, and on the national territory, it borders on Siret Basin to the East, Mures Basin to the South and Crisuri Basin to the South-West.

https://inundatii.ro/en/river-basins/somes-tisa-watershed-area/



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Flood records

The maximum quantities of precipitations are recorded during spring-summer, in particular during the period March-June and in August. One can remember several maximum historical values of precipitations occurred during serious floods across the entire river basin as those recorded in May 1970 (over 150 mm/24 hours and even 200 mm/24 hours in Baia Sprie).

Serious floods, with significant maximum discharges, come from rainfalls recorded on large areas of the basin or from mixed source (snowmelt and rain). The maximum historical flood over the last 50-60 years was that occurred in 1970, having a mixed source. An analysis of the series of floods over around the last 50 years shows that the most significant floods occurred in: 1970, 1974, 1975, 1978, 1979, 1980, 1981, 1989, 1993, 1995, 1998, 2000, 2001, 2005 and 2008.

The first half of 1970 was characterized by catastrophic floods. The most serious floods occurred on the rivers Somes, Tisa, Tur, Viseu, Iza, Lapus, Sieu, Crasna, Almas, Somesul Mic and their tributaries. Discharges exceeding the insurance of 1% were recorded on the rivers Somes (downstream Dej) and Viseu, on the other water courses, there were discharges recorded with the insurance ranging between 5– 10%. There was a breach of dikes on rivers Somes and Tur (Satu Mare county), which caused the flooding of many urban and rural localities. Floods were caused by long-lasting heavy rainfalls accompanied by snowmelt resulting in floods that exceeded the flood level, on most rivers in Somes-Tisa river basin. Important urban localities were affected, such as Nasaud, Beclean, Gherla, Dej, Zalau, Jibou, Simleu, Satu Mare, as well as many rural localities (over 200).

https://inundatii.ro/en/river-basins/somes-tisa-watershed-area/

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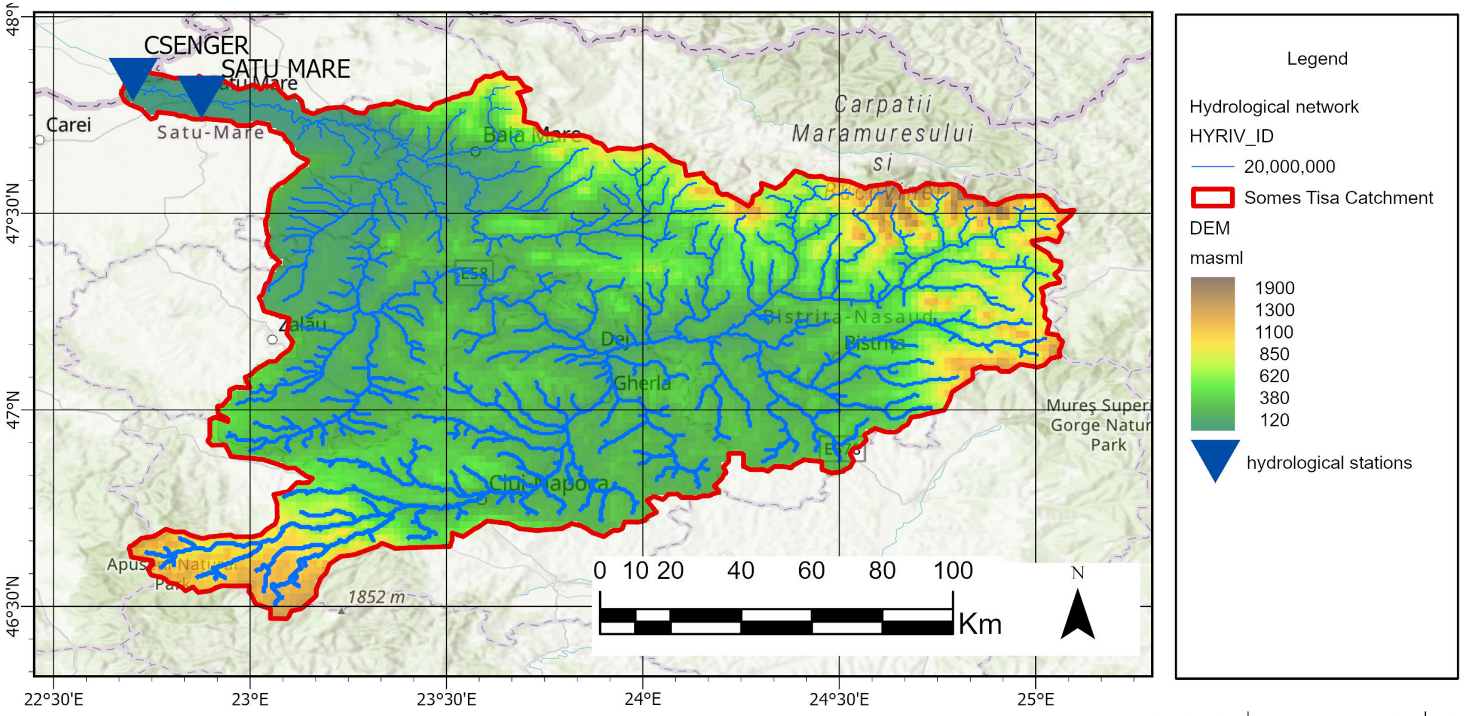
2. Implementing, validating and analyzing models

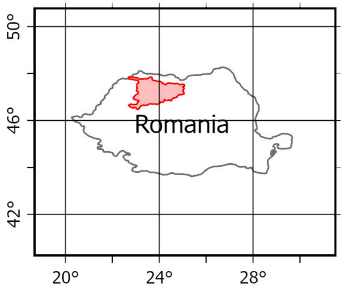
Floods

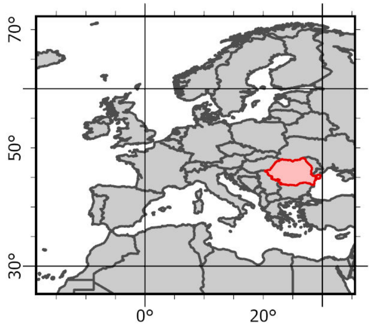
Meteorological forcings
https://jeodpp.jrc.ec.europa.eu/ftp/jrc-opendata/CEMS-EFAS/meteorological_forcings/EMO-1arcmin/

Discharge
https://portal.grdc.bafg.de/applications/public.html?publicuser=PublicUser#dataDownload/Stations



Geographical information
DEM 30 meter resolution
1arcmin EFAS
https://jeodpp.jrc.ec.europa.eu/ftp/jrc-opendata/CEMS-EFAS/LISFLOOD_static_and_parameter_maps_for_EFAS/





https://inundatii.ro/en/river-basins/somes-tisa-watershed-a

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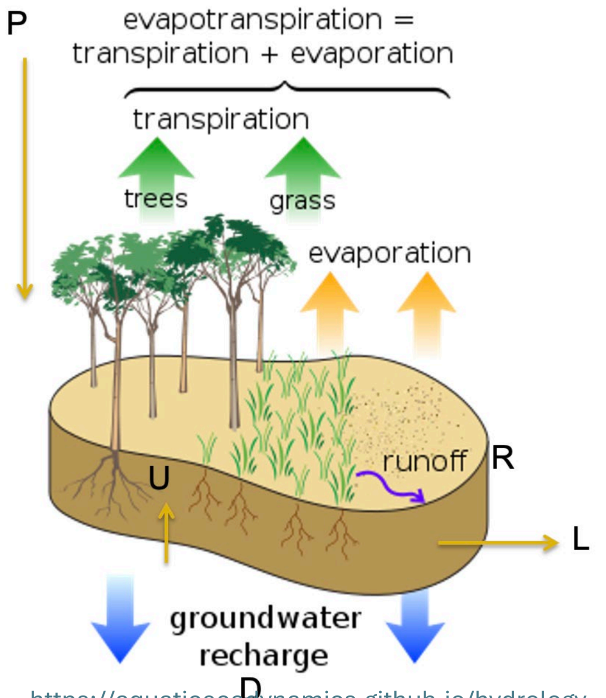
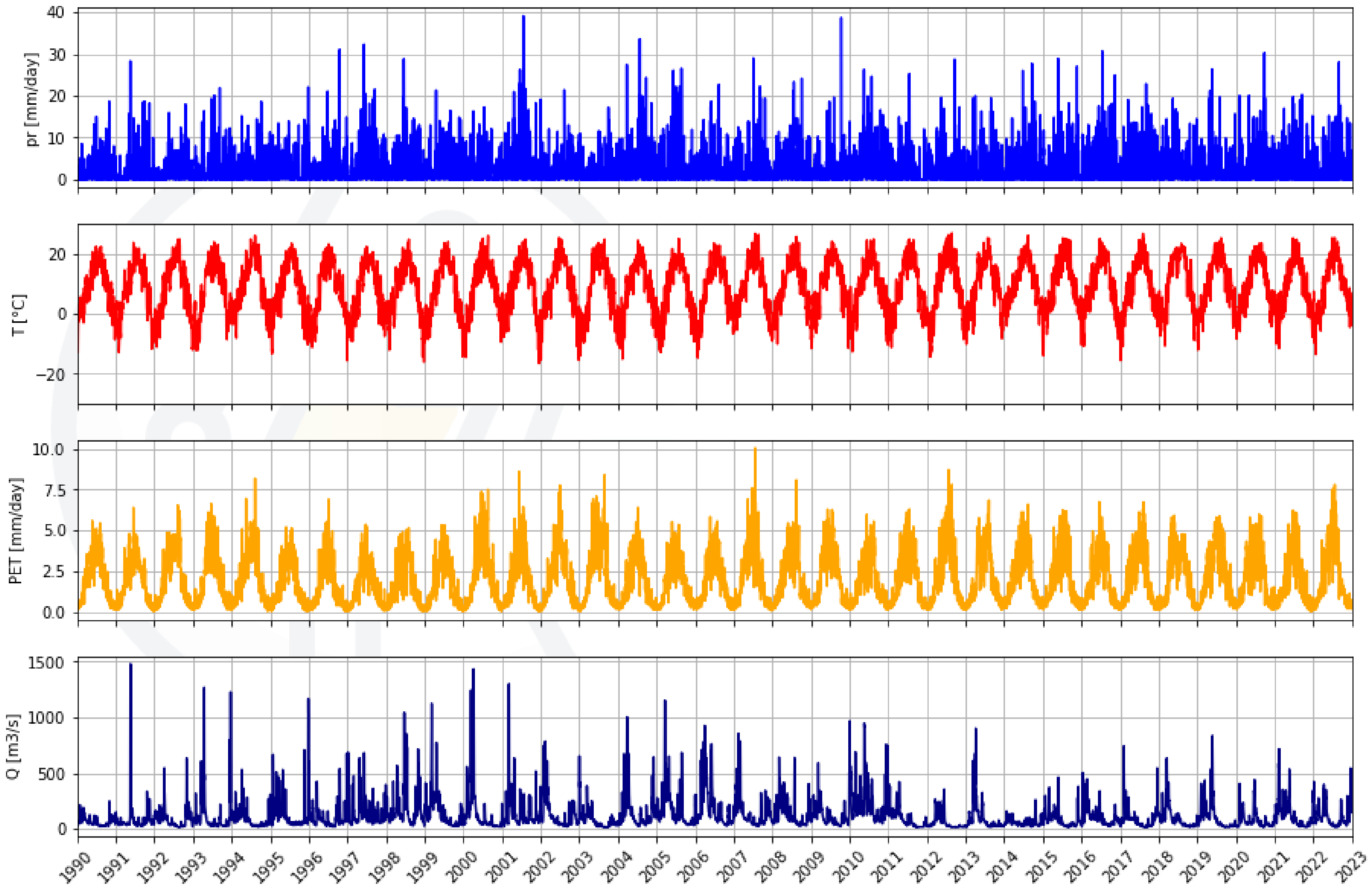
1. Data preparation

01_data_preparation_example



https://aquaticecodynamics.github.io/hydrology-workbook/E5.html



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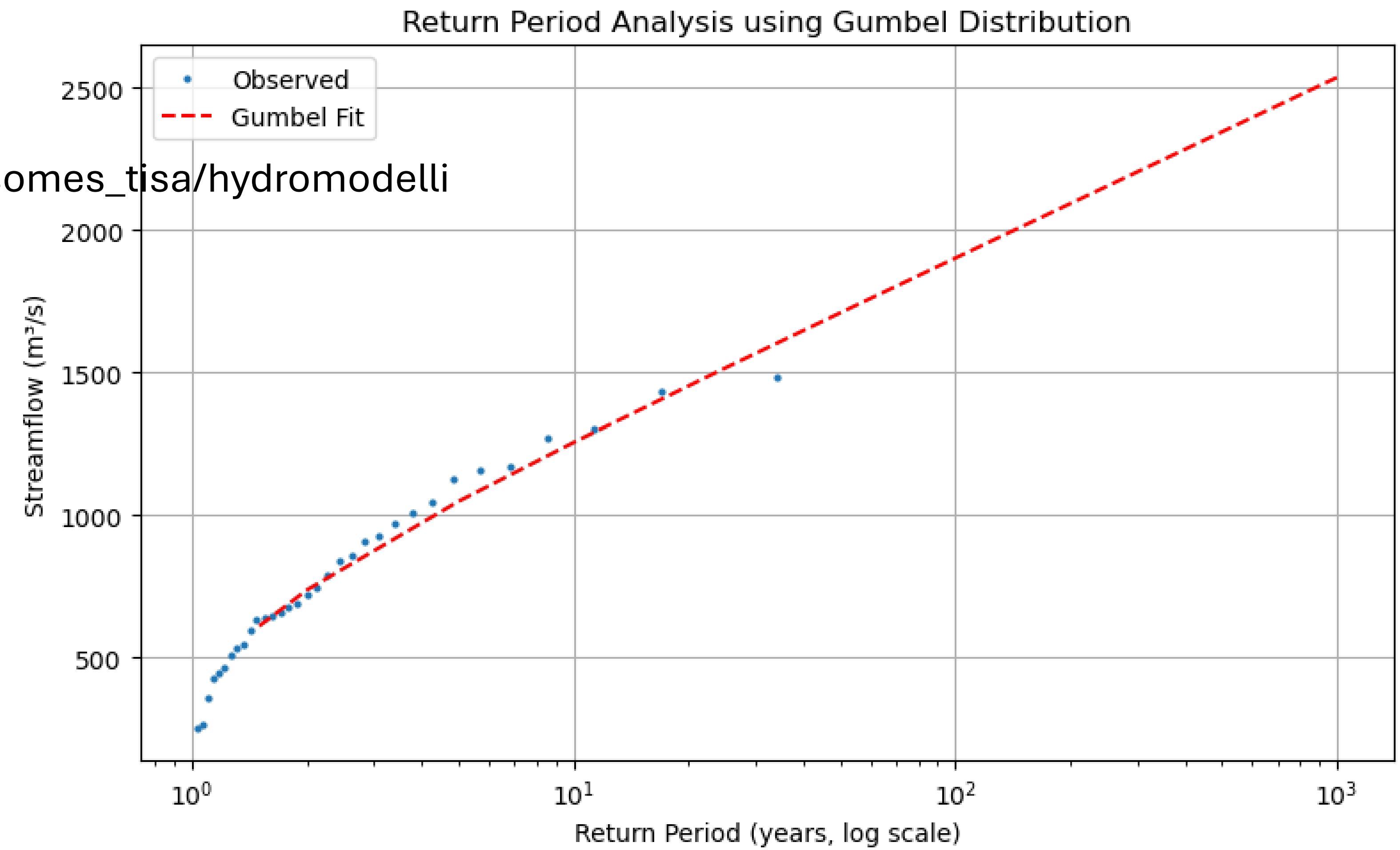
Extreme events

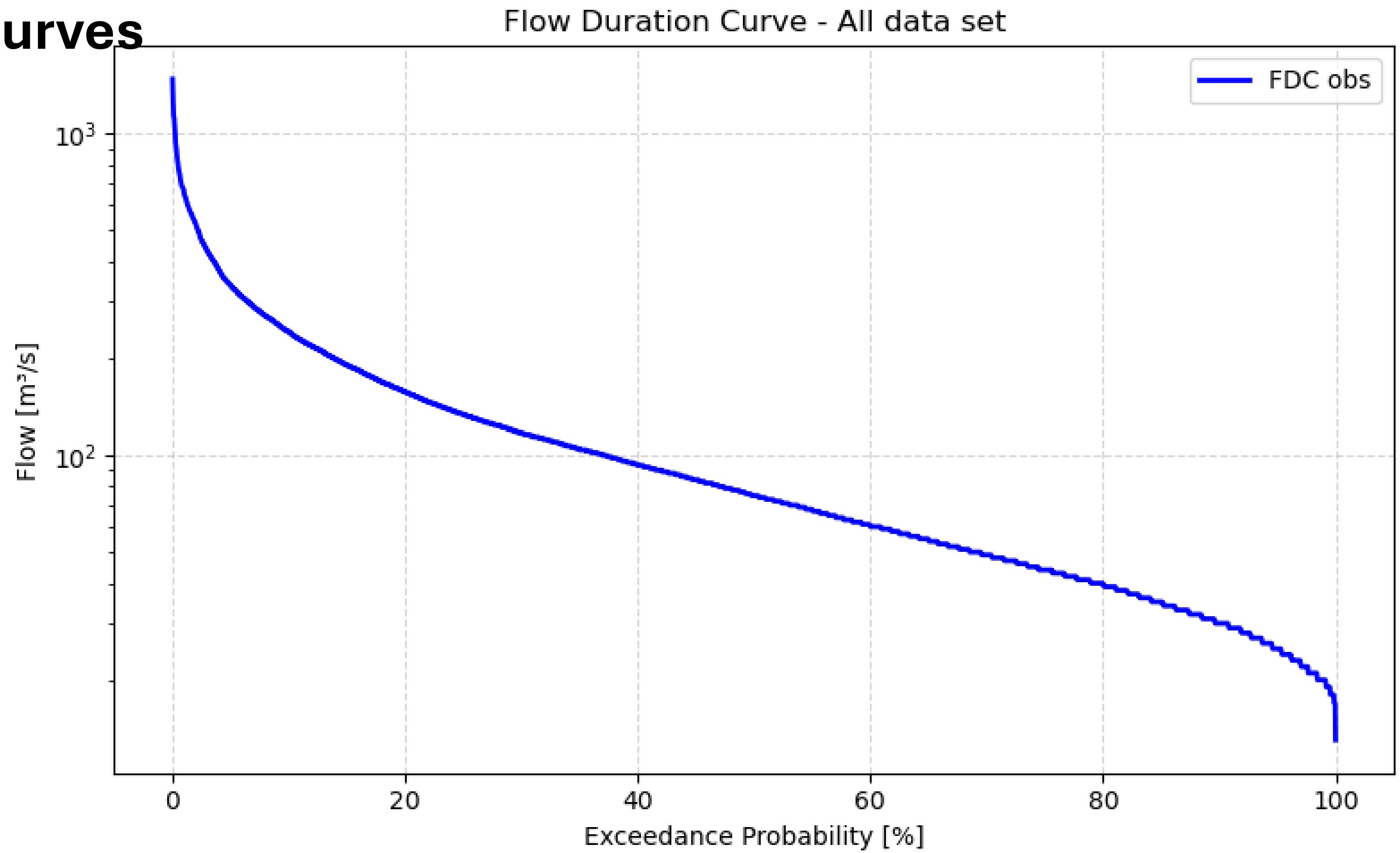
/work/bb1480/b381840/scewero/somes_tisa/hydromodelling/somes_tisa_extrems.ipynb

Gumbel Distribution

Return period	**Streamflow**
Tr [Years]	**Q** [m^3/s]
1.5	610
2	736
5	1048
10	1254
25	1515
50	1708
100	1900
200	2091
500	2343
1000	2534



Flow duration curves



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Hydrological model

GR4J

Si $P_k \geq E$, alors $P_n = P_k - E$ et $E_n = 0$,
Si $P_k < E$, alors $P_n = 0$ et $E_n = E - P_k$

$$Ps = \frac{X1\left(1-\left(\frac{S_k}{X1}\right)^2\right).\tanh\left(\frac{Pn}{X1}\right)}{1+\frac{S_k}{X1}\tanh\left(\frac{Pn}{X1}\right)} \quad \text{et} \quad Es = \frac{S_k\left(2-\frac{S_k}{X1}\right).\tanh\left(\frac{En}{X1}\right)}{1+\left(1-\frac{S_k}{X1}\right).\tanh\left(\frac{En}{X1}\right)}$$

$S' = S_k + Ps - Es$,

$$Perc = S'\left\{1-\left[1+\left(\frac{4}{9}.\frac{S'}{X1}\right)^4\right]^{-\frac{1}{4}}\right\}, \quad S_{k+1} = S' - Perc$$

$Perc + (Pn - Ps)$

Si $0 \leq j \leq X_4 . SH1(j) = \left(\frac{j}{X_4}\right)^{\frac{5}{2}}$; Si $j > X_4 .\ SH1(j) = 1$

Si $0 \leq j \leq X_4 . SH2(j) = \frac{1}{2}\left(\frac{j}{X_4}\right)^{\frac{5}{2}}$;

Si $X_4 \leq j \leq 2X_4 .\ SH2(j) = 1 - \frac{1}{2}\left(2-\frac{j}{X_4}\right)^{\frac{5}{2}}$;

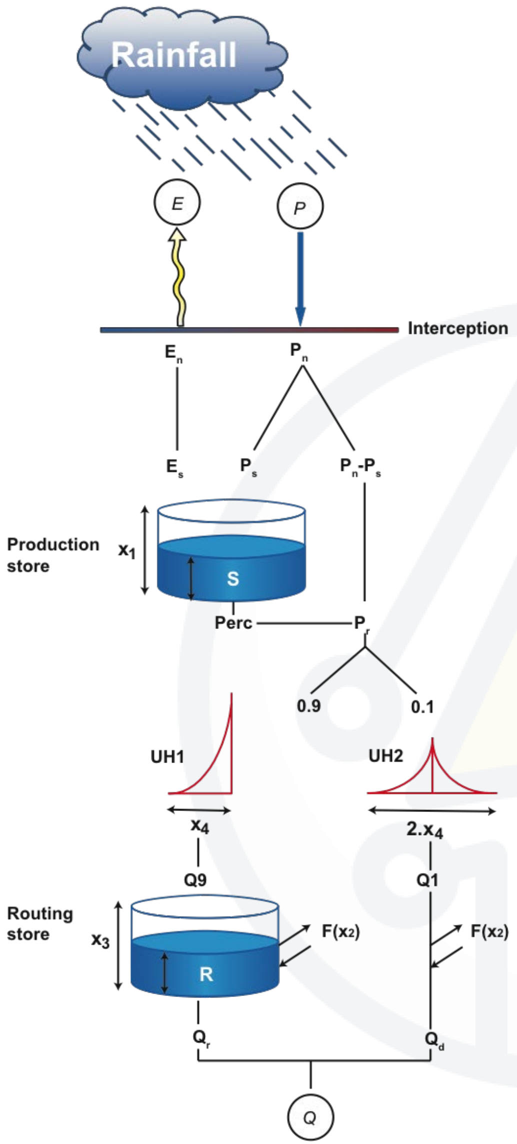
Si $j > 2X_4 .\ SH2(j) = 1$

$$UH1(j) = SH1(j) - SH1(j-1)$$
$$UH2(j) = SH2(j) - SH2(j-1)$$

$$Q9(k) = 0,9.\sum_{j=1}^{l} UH1(j).Pr(k-j+1),$$
$$Q1(k) = 0,1.\sum_{j=1}^{m} UH2(j).Pr(k-j+1)$$

$$F = X2.\left(\frac{R_k}{X3}\right)^{\frac{7}{2}} ; \quad R' = \max(0 ; R_k + Q9(k) + F)$$

$$(DP) \begin{cases} Qr = R'.\left\{1-\left[1+\left(\frac{R'}{X3}\right)^4\right]^{-\frac{1}{4}}\right\} ; \quad R_{k+1} = R' - Qr \\ Qd = max(0 ; Q1(k) + F) ; \\ Q(k) = Qr + Qd \end{cases}$$



Perrin, C., Michel, C., & Andréassian, V. (2003). Improvement of a parsimonious model for streamflow simulation. *Journal of Hydrology*, *279*(1–4), 275–289. https://doi.org/10.1016/S0022-1694(03)00225-7

Implementation in python

```python
import numpy as np

'''
This class modelate a proccess rainfall-runoff

Perrin, C., C. Michel, et al. (2003). "Improvement of a parsimonious model for streamflow simula

http://www.cemagref.fr/webgr/Modelesgb/gr4j/fonctionnement_gr4jgb.htm
'''

class GR4J:
    'Class hydrological model GR4J'

    def __init__(self, PEQ, A, X, S0, R0):
        self.set_PEQ(PEQ)
        self.a = np.copy(A) # Area of basin in km2
        n = PEQ.shape[0] # Get the lenght of data series
        self.X =  np.copy(X)  # Parameters of model
        self.Pn = np.zeros((n))
        self.En = np.zeros((n))
        self.R_ = np.copy(R0)
        self.S_ = np.copy(S0)

    # Define the imputs
    def set_PEQ(self, PEQ):
        self.P = np.copy(PEQ[:,1])
        self.E = np.copy(PEQ[:,2])
        self.Q = np.copy(PEQ[:,3])
```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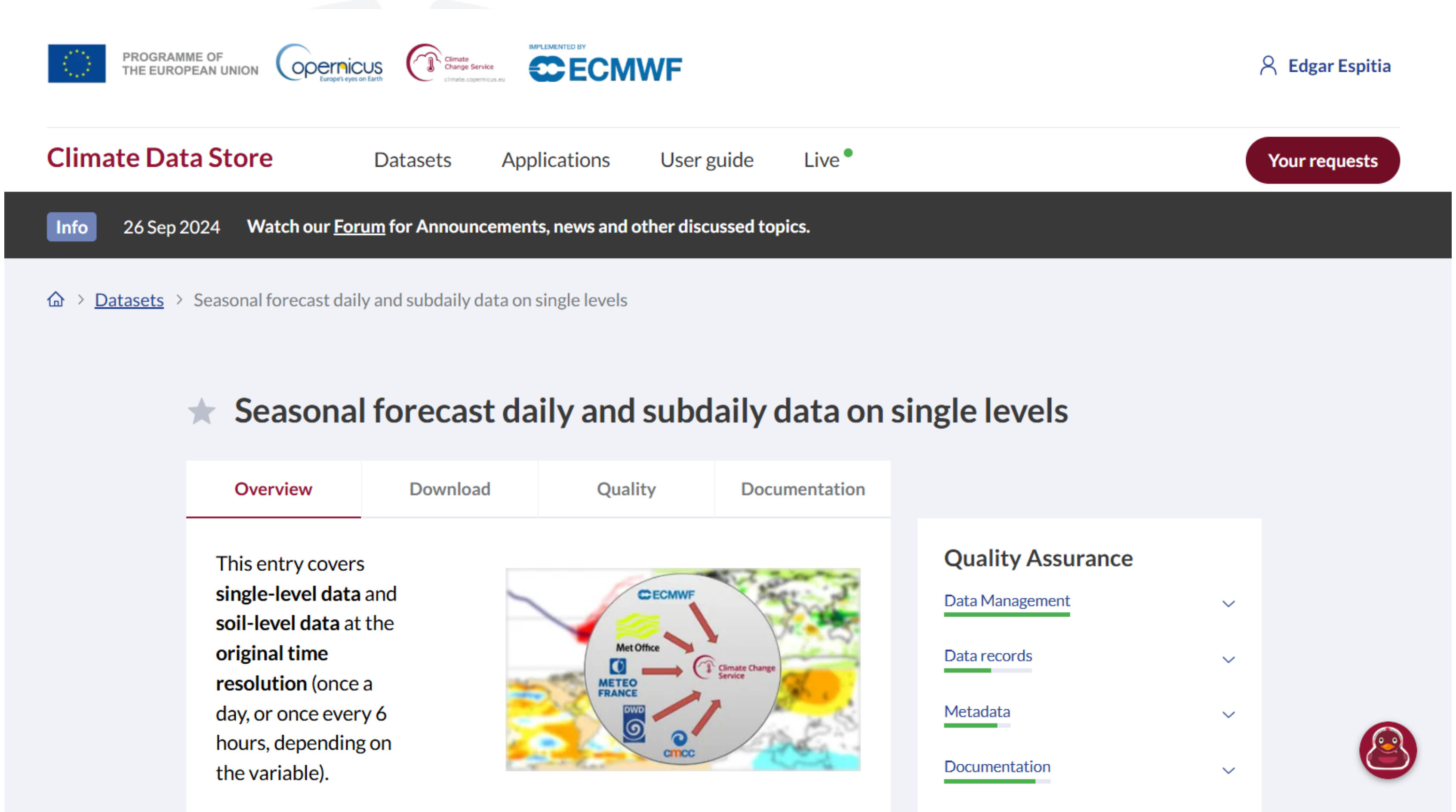
https://cds.climate.copernicus.eu/datasets/seasonal-original-single-levels?tab=overview

Meteorological forcings



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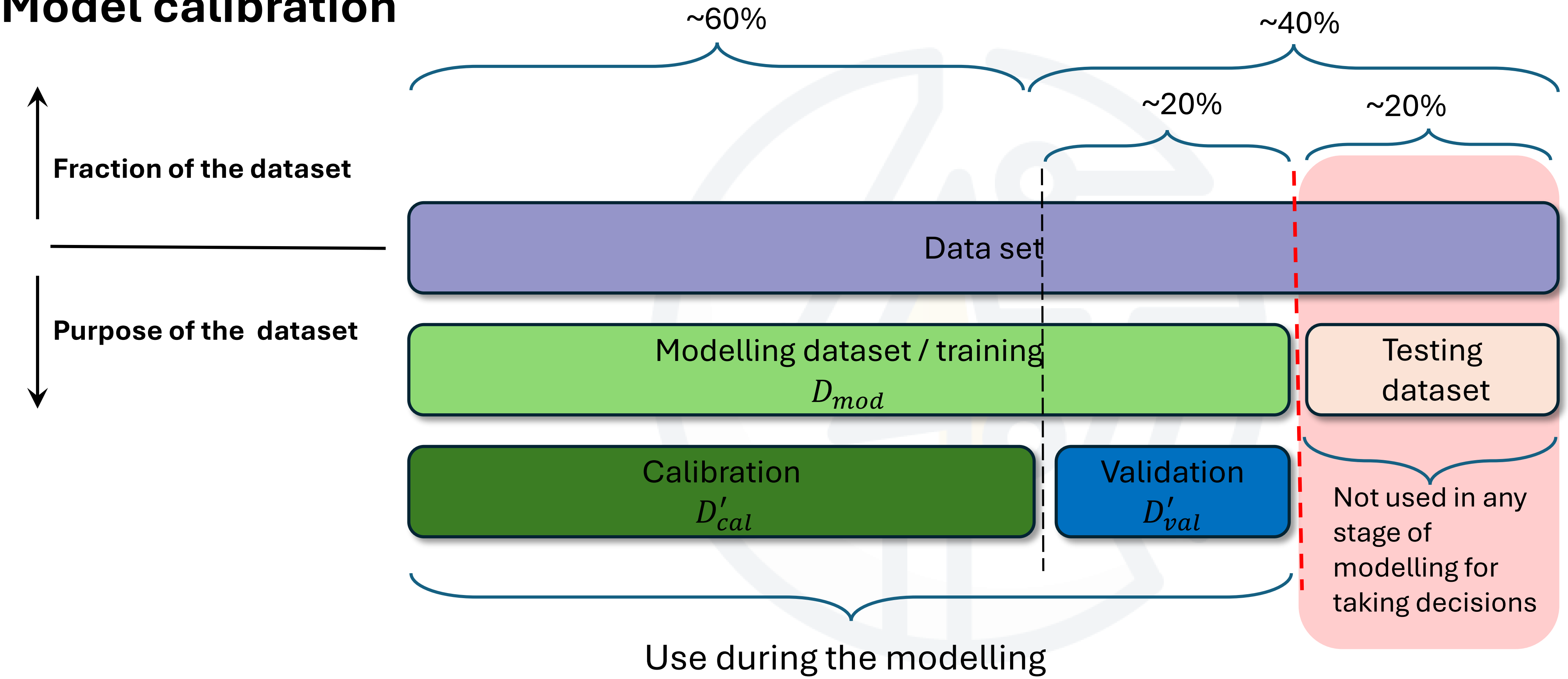
Model calibration



% based on modeler experience

Based on: Shen, H., Tolson, B. A., & Mai, J. (2022). Time to Update the Split-Sample Approach in Hydrological Model Calibration. *Water Resources Research*, *58*(3), e2021WR031523. https://doi.org/10.1029/2021WR031523

Model calibration

$$KGE' = 1 - \sqrt{(r-1)^2 + (\beta-1)^2 + (\gamma-1)^2}$$

$$r_{OS} = \frac{\sum_{i=1}^{n} (O_i - \bar{O})(S_i - \bar{S})}{\sqrt{\sum_{i=1}^{n} (O_i - \bar{O})^2}\sqrt{\sum_{i=1}^{n} (S_i - \bar{S})^2}}$$

bias ratio $\beta = \frac{\mu_s}{\mu_o}$

Variability ratio $\gamma = \frac{\sigma_s/\mu_s}{\sigma_o/\mu_o}$

	KGE'	Description
	0.8 - 1.0	Excellent
	0.6 - 0.8	Good
	0.4 - 0.6	Aceptable
	0.2 - 0.4	Low
	< 0.2	Very low

	r
	0.8 - 1.0
	0.6 - 0.8
	0.4 - 0.6
	0.2 - 0.4
	< 0.2

	bias ratio β
	> 1.5
	1.3 - 1.5
	1.1 - 1.3
	0.9 - 1.1
	0.7 - 0.9
	0.5 - 0.7
	< 0.5

	variability ratio γ
	> 1.5
	1.3 - 1.5
	1.1 - 1.3
	0.9 - 1.1
	0.7 - 0.9
	0.5 - 0.7
	< 0.5

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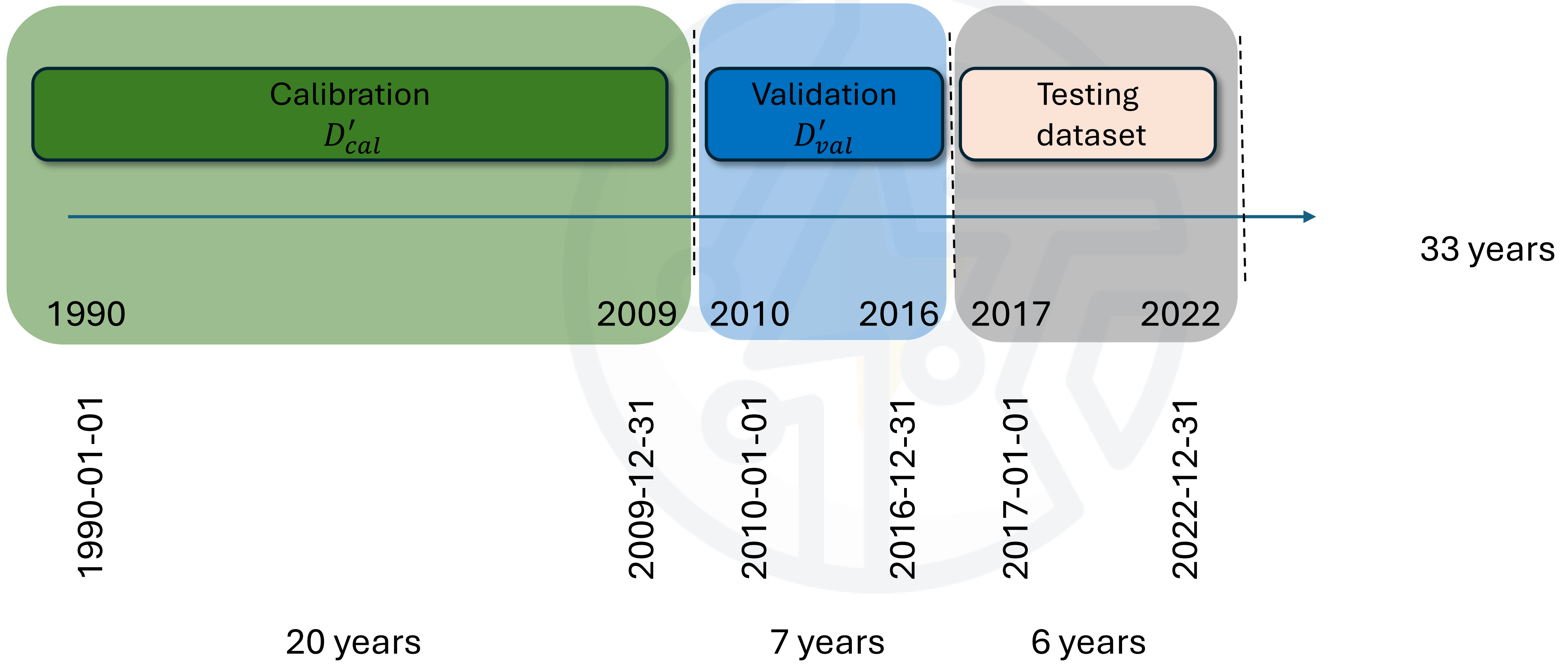
Model calibration

/work/bb1480/b381840/scewero/somes_tisa/hydromodelling/somes_tisa_hydromodelling.ipynb



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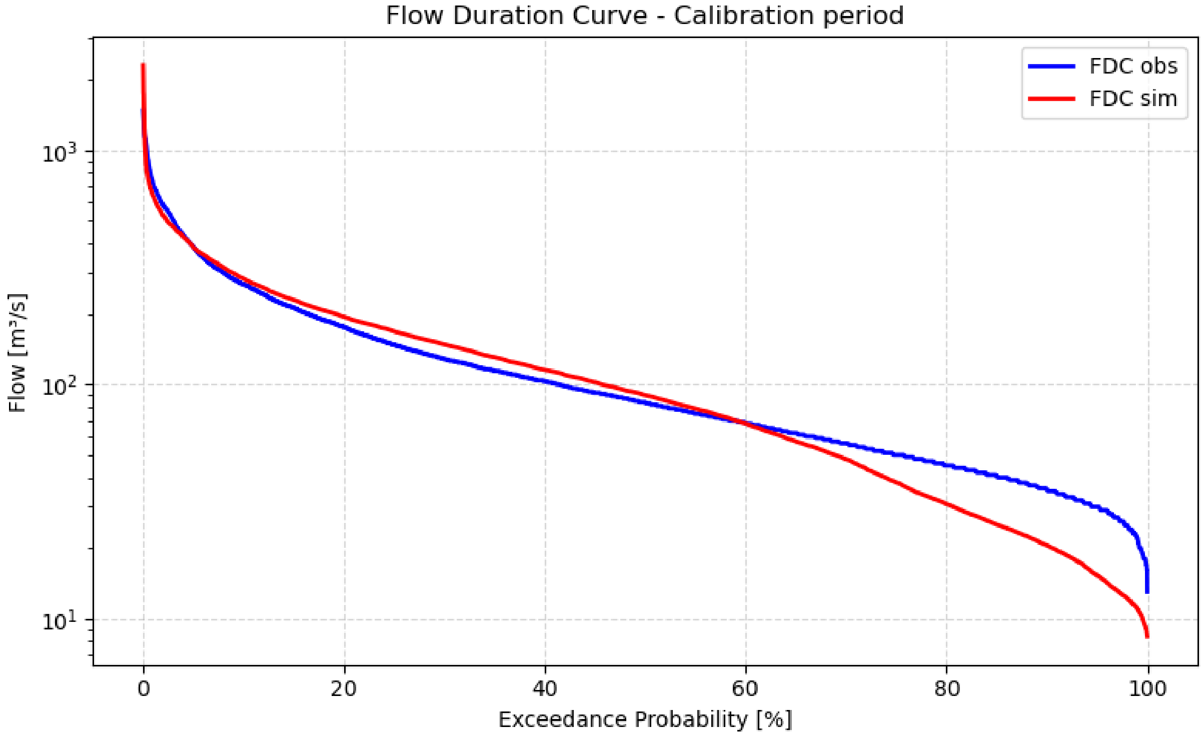
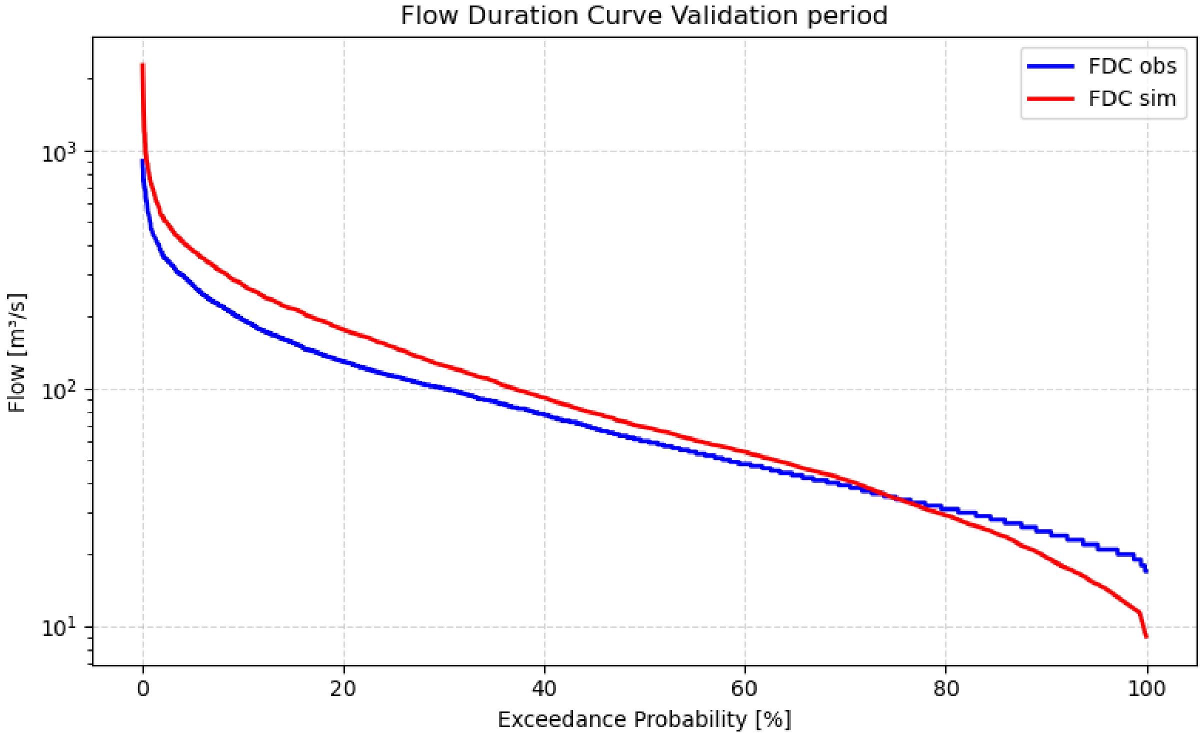
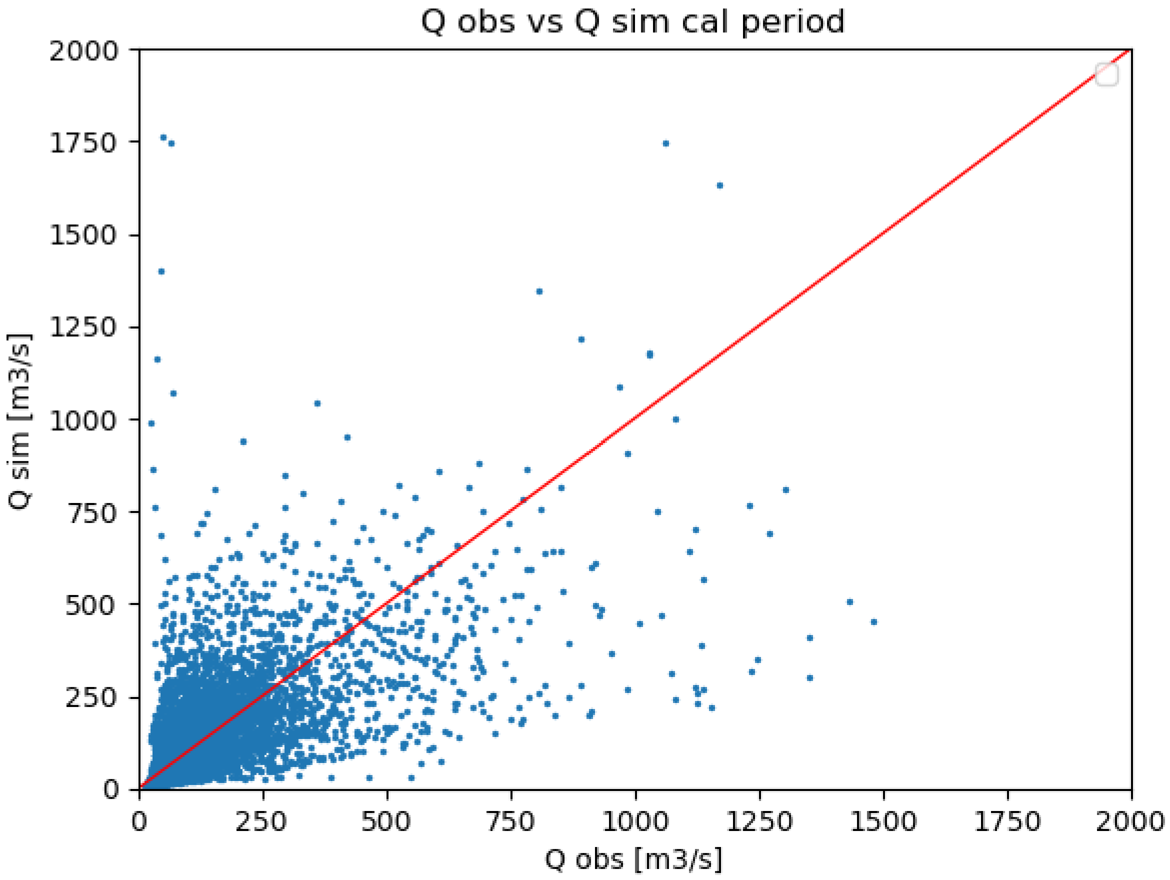
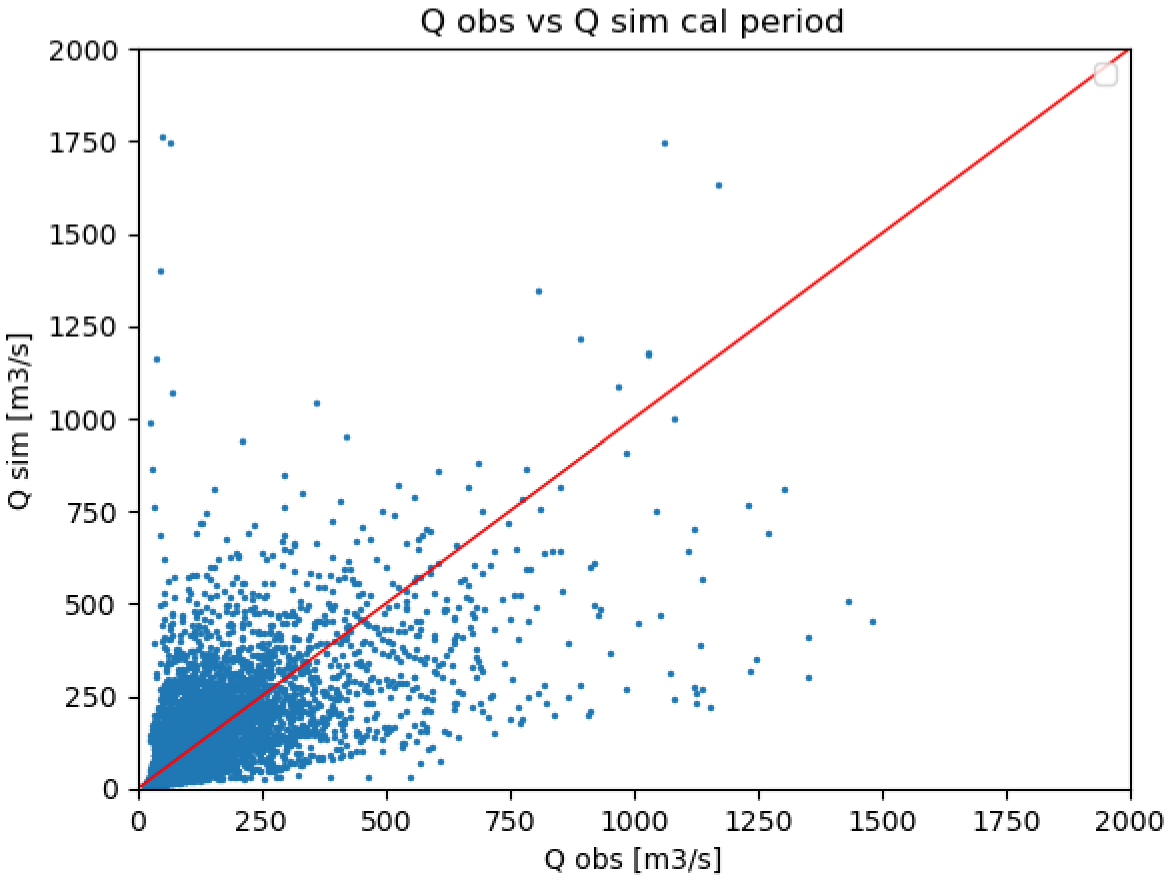
Flow duration curves





Scatter plots





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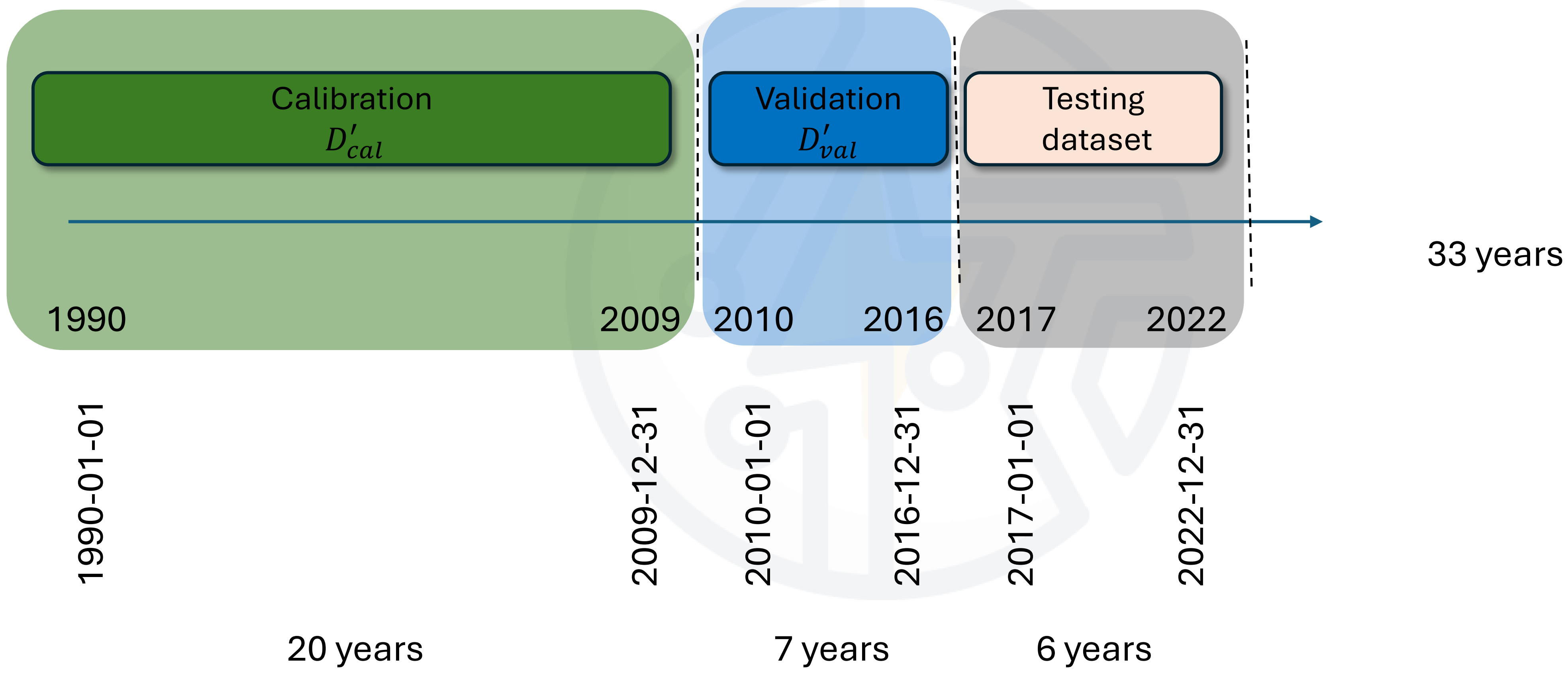
Testing /work/bb1480/b381840/scewero/somes_tisa/hydromodelling/somes_tisa_generate_Q.ipynb



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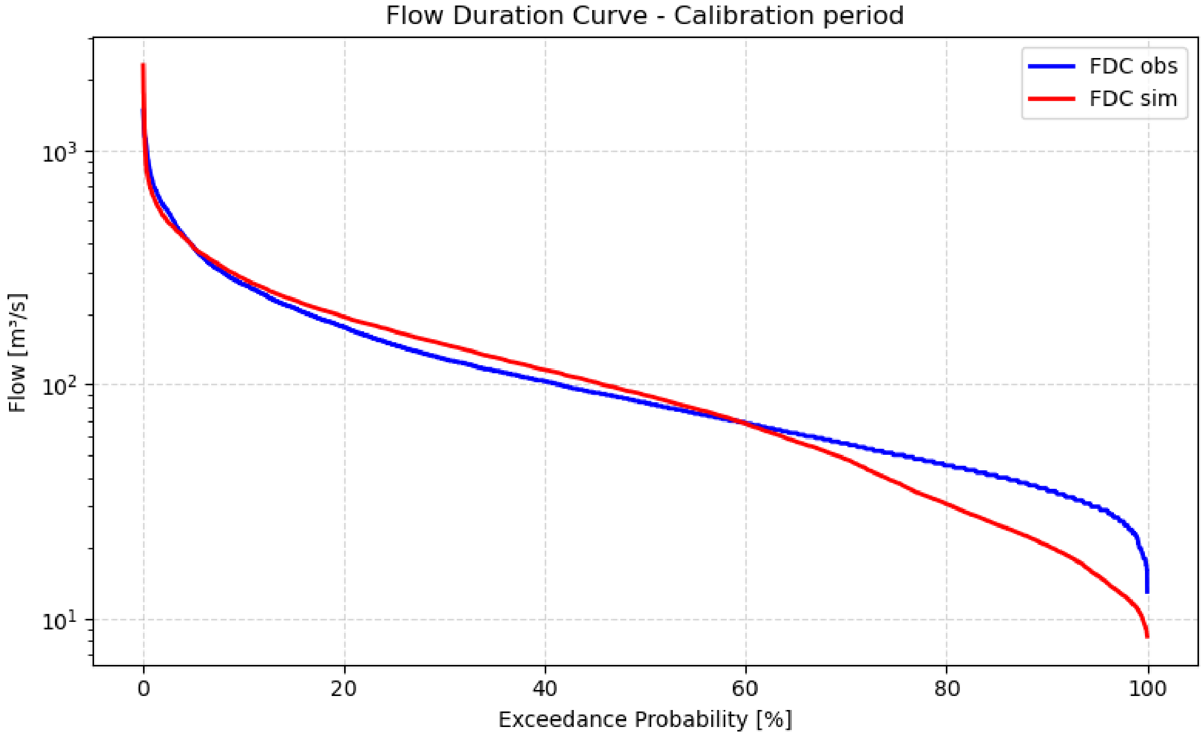
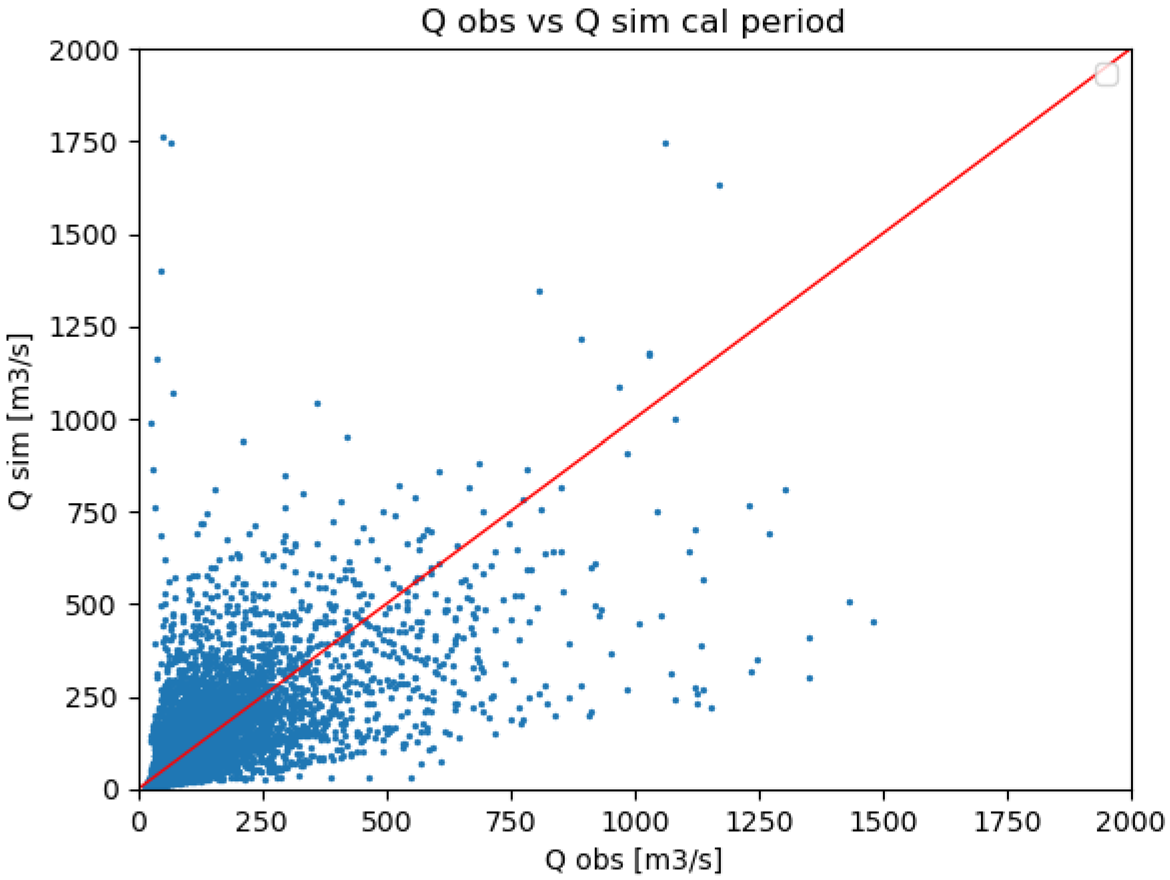
Testing





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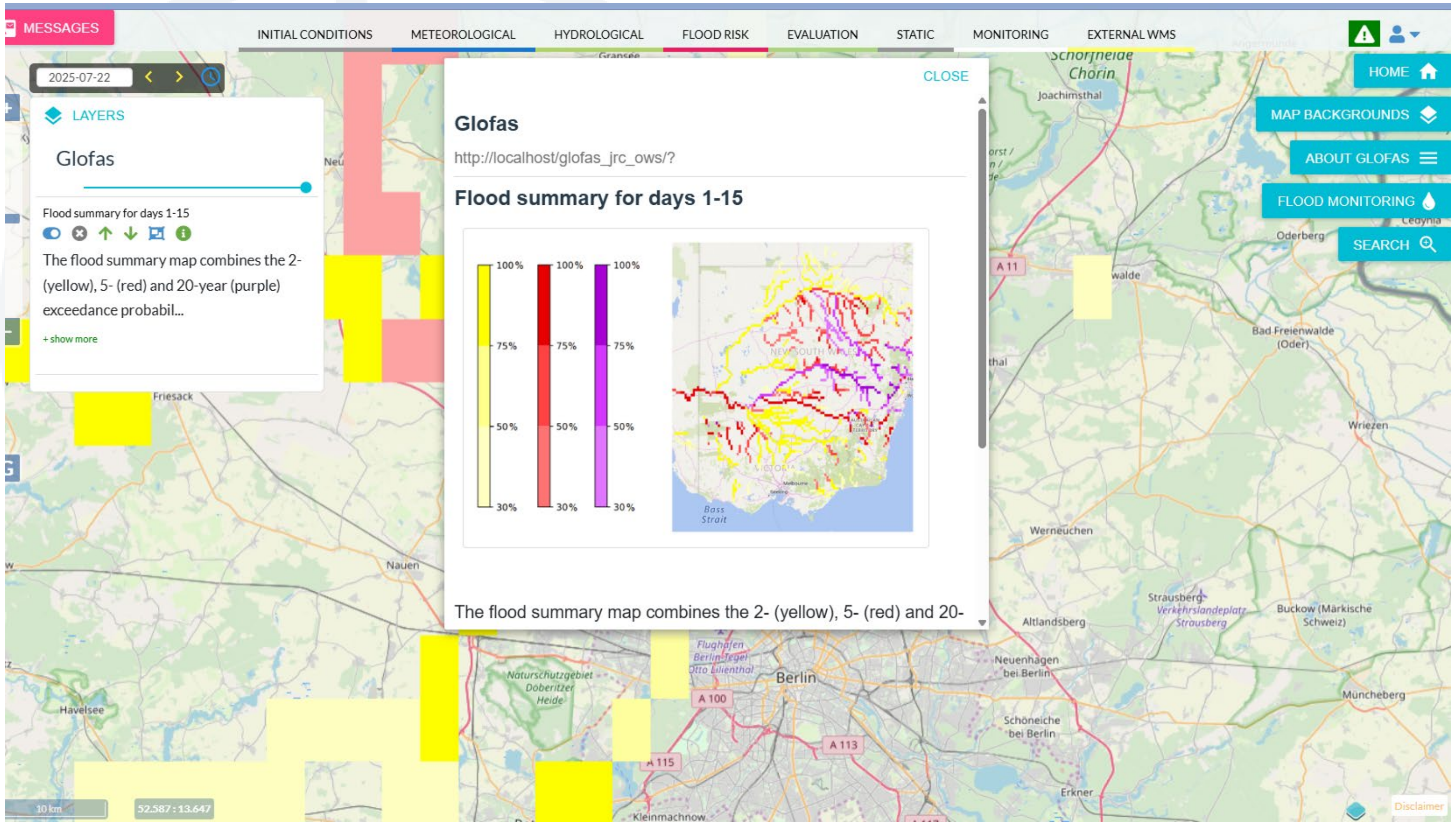
Short term flood summary

https://global-flood.emergency.copernicus.eu/



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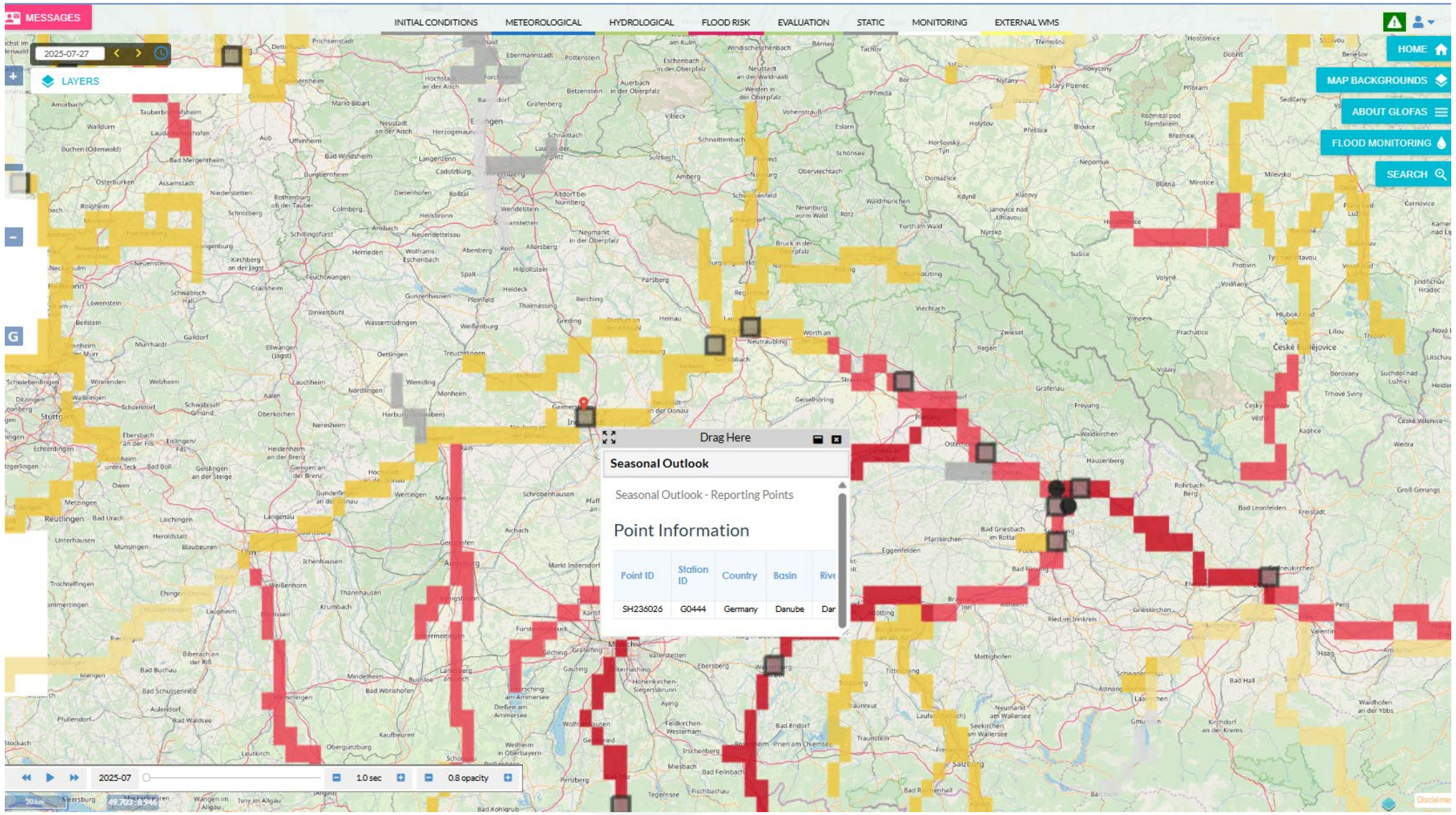
Seasonal forecast



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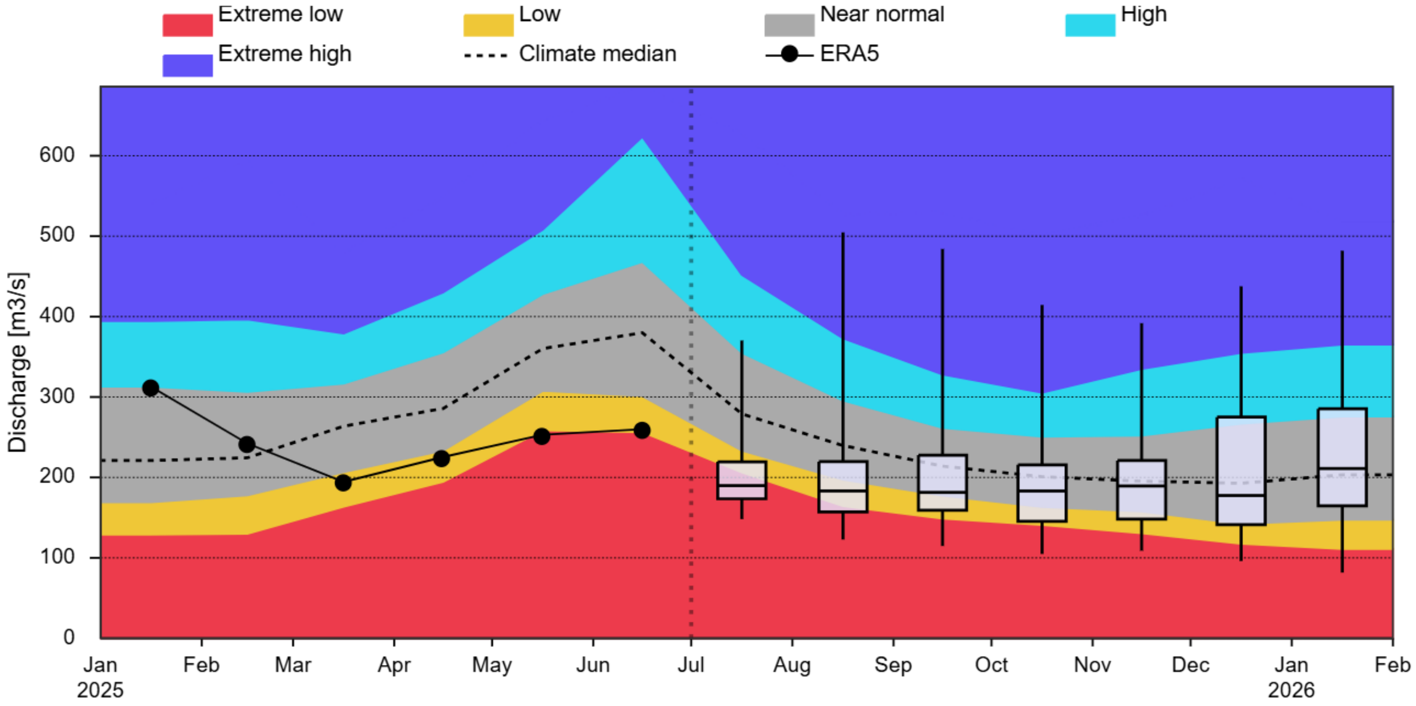
Seasonal forecast

Seasonal Outlook - Reporting Points

Point Information

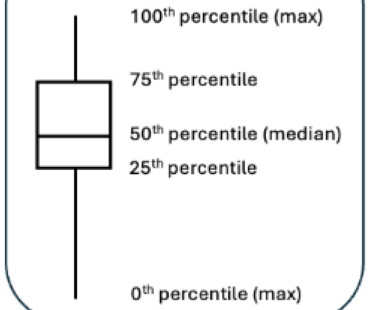
Point ID	Station ID	Country	Basin	River	Station Name	Drainage Area [km2]	Longitude [Deg]	Latitude [Deg]	LISFLOOD Drainage Area [km2]	LISFLOOD X [Deg]	LISFLOOD Y [Deg]
SH236026	G0444	Germany	Danube	Danube	Ingolstadt	20001	11.4220	48.7540	20419	11.4250	48.7750

Seasonal hydrograph of antecedent, climatological and forecast information



Climatological thresholds
From extreme low to extreme high (red to blue), derived from range-dependent model climatologies

Ensemble forecast boxplot



Anomaly category		Rank	Description
Extreme low		1-10	Bottom 10% of the climatological distribution
Low		10-25	15% from the 1st decile to the 1st quartile
Bit low	Near normal (25-75)	25-40	15% from the 1st quartile to the 2nd quintile
Normal		40-60	20% from the 2nd quintile to the 3rd quintile
Bit high		60-75	15% from the 3rd quintile to the 3rd quartile
High		75-90	15% from the 3rd quartile to the 9th decile
Extreme high		90-100	Top 10% of the climatological distribution

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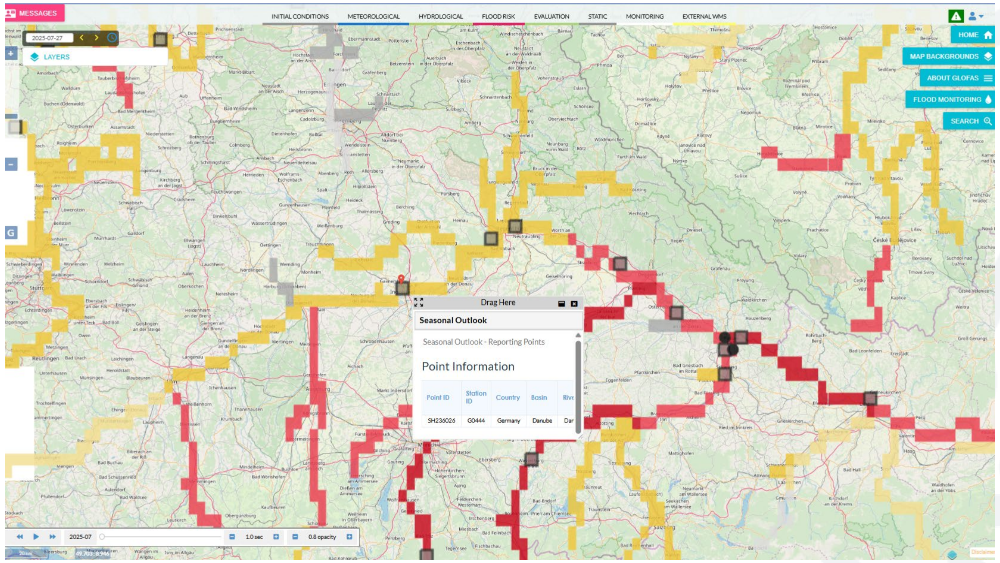
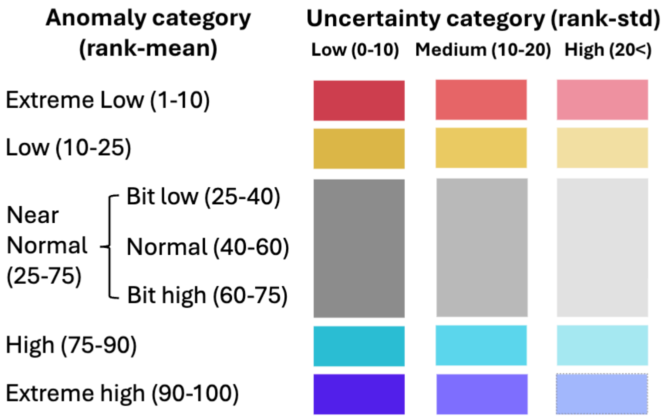
Seasonal forecast





Uncertainty category	Rank STD	Description
Low uncertainty	<10	The standard deviation of the ensemble member ranks is less than 10
Medium uncertainty	10-20	The standard deviation of the ensemble member ranks is between 10 and 20
High uncertainty	20<	The standard deviation of the ensemble member ranks is higher than 20

Seasonal forecast probability (numbers) and expected anomaly category (coloured cells) [2025-07-01]

	July 2025							August 2025							September 2025						
	EL	L	BL	N	BH	H	EH	EL	L	BL	N	BH	H	EH	EL	L	BL	N	BH	H	EH
July 2025	65	**27**	4	0	2	2	0	33	31	**12**	10	8	4	2	16	29	**16**	15	8	8	8
June 2025	22	21	**14**	21	14	2	6	14	31	**19**	16	10	6	4	12	14	18	**17**	16	17	6
May 2025	12	23	16	**21**	20	8	0	12	21	14	**21**	10	16	6	6	14	14	**33**	17	10	6
April 2025	12	12	19	**14**	21	12	10	8	12	16	**14**	21	19	10	6	19	18	**23**	8	10	16
March 2025	6	21	14	**12**	19	20	8	6	14	21	**20**	16	19	4	4	21	16	**27**	12	16	4
February 2025	10	15	14	**25**	14	16	6	6	12	14	**27**	19	6	16							
January 2025	8	12	18	**14**	25	17	6														

	October 2025							November 2025							December 2025							January 2026						
	EL	L	BL	N	BH	H	EH	EL	L	BL	N	BH	H	EH	EL	L	BL	N	BH	H	EH	EL	L	BL	N	BH	H	EH
July 2025	23	10	**18**	23	12	12	2	10	19	16	**27**	12	14	2	14	16	17	**12**	10	23	8	12	10	16	**21**	12	23	6
June 2025	17	14	14	**19**	14	12	10	16	17	12	**23**	14	6	12	8	19	12	**19**	20	14	8							
May 2025	18	16	17	**21**	14	8	6	16	14	14	**10**	19	25	2														
April 2025	12	15	21	**14**	12	14	12																					
March 2025																												
February 2025																												
January 2025																												

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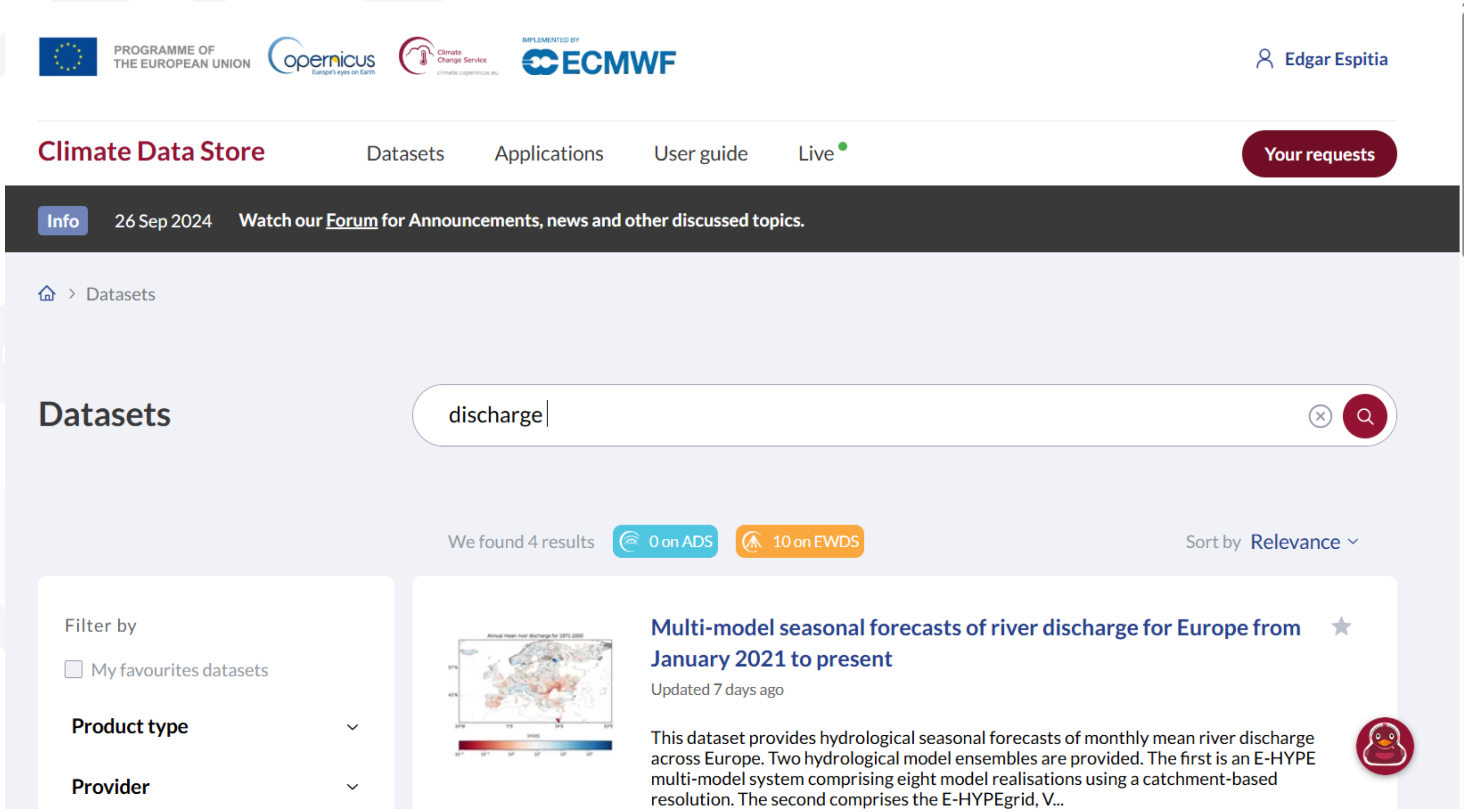

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Thank you!

Questions ?

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