Identifying and quantifying the impact of climatic and non-climatic effects on river discharge in Europe

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Dr. Pere Quintana Segui (Observatori de l'Ebre, Universitat Ramon Llull - CSIC)

Context

- LIAISE Project : Impact of human water usage on evaporation
  → contrast between natural and irrigated area

- More generally :
  → **Effect of climate change**:
  changes in P and E, drought events, intensification of P leading to flood events…
  → **Human water management:**
  changes in river functionning and water redistribution

Questions

Integration at the catchment level:
→ Discharge
→ Closed water budget

Which significance of impact **of human management** on the availability of the **water resource**, in contrast to **climate change ?**

Context

Separate climat vs direct human effect

- Work from observations, define « natural catchments »
  → limited in number and size, or case studies

- Use of models
  - Parsimonious parametric models
  - Complex Land Suface Models (LSM)

Idea of our method

Combine both types of models

→ simplicity of use of parcimonious model, few parameters to interprete
→ LSM = « natural » reference, accounting for physical processes

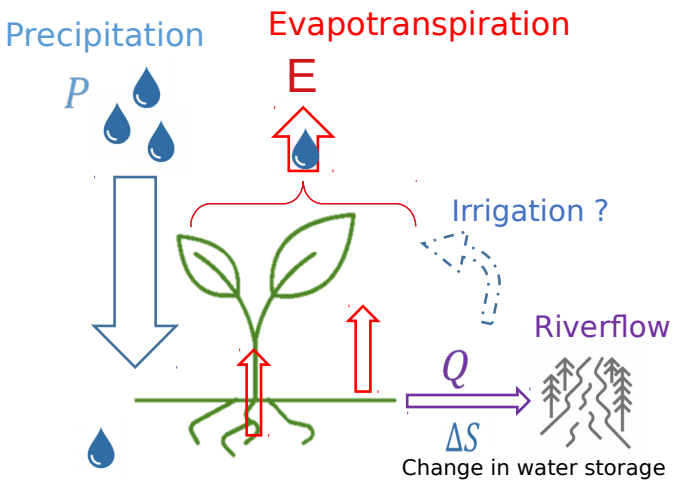
Method

General Presentation

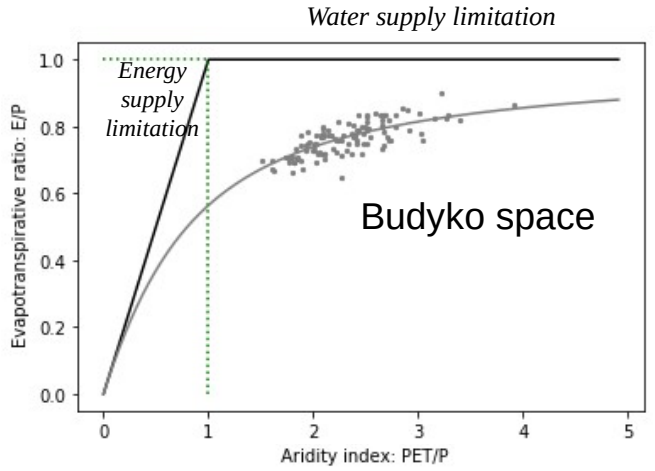
The Budyko framework: a simple river discharge model

- Parcimonious model:
  → based on long term water balance equilibrium

Water balance equation $Q = P - E - \Delta S$ *Considered negligible*



- Two factors limiting evapotranspiration: **Energy** and **Water** supply



Annual mean over hydrological years, then decadal period considered

From E to discharge Q through water balance, neglecting storage

The Budyko framework: a simple river discharge model

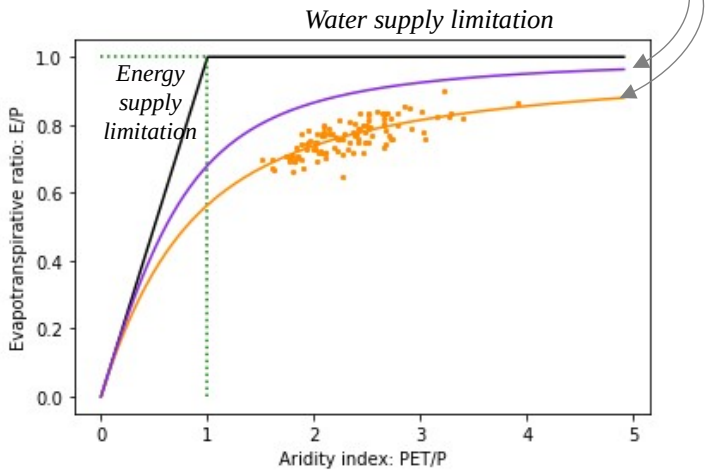
- Adjustement **over specific catchment:** parametric equations:

> Empirical parameter adjusted **over each catchment**, for **given time period**

> Reflecting specific **watershed evaporation efficiency** (vegetation cover, soils, slopes, some climatic characteristics…)

Analytical approximation: *(Fu equation)*

$$\frac{E}{P} = 1 + \frac{PET}{P} - \left(1 + \left(\frac{PET}{P}\right)^{\omega}\right)^{\frac{1}{\omega}}$$



→ One parameter, represents **how water is partitionned** over a specific catchment at equilibrium

The Budyko framework: a simple river discharge model

At equilibrium

For given watershed with
constant characteristics
+ no long term trends in climate

→ Dispersion around **average curve**

Analytical approximation: *(Fu equation)*

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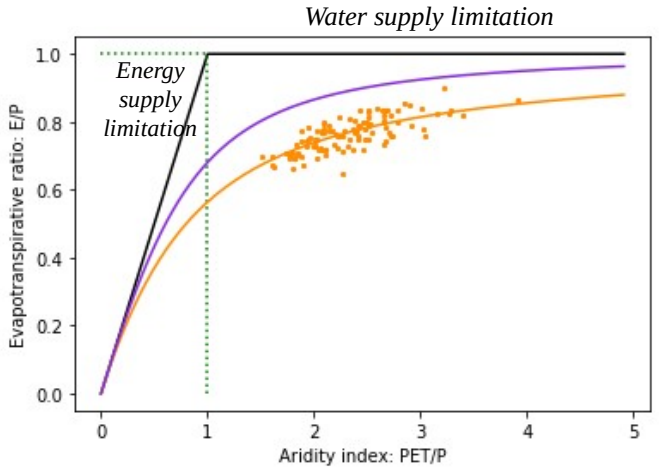

What if the equilibrium is disrupted ?

The Budyko framework: a simple river discharge model

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For given watershed with
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→ Dispersion around **average curve**

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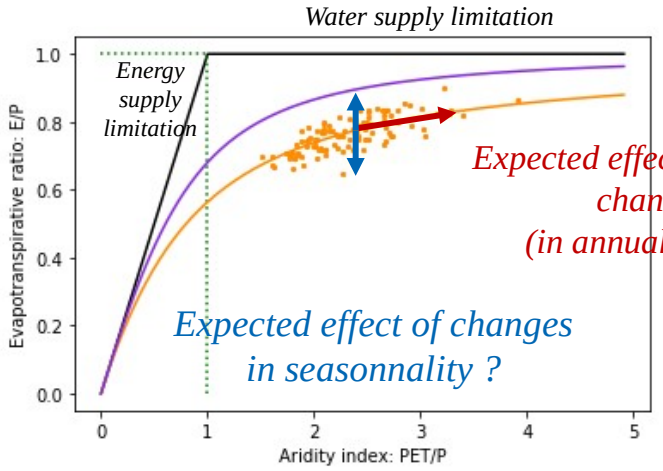

Disruption

- Changes in **annual mean of climate variables ?** → Climat → Included in the framework
- Changes in **evaporation efficiency ?** → Climat → Change in synchronization between P (water available) and PET (energy demand from the atmosphere)

The Budyko framework: a simple river discharge model

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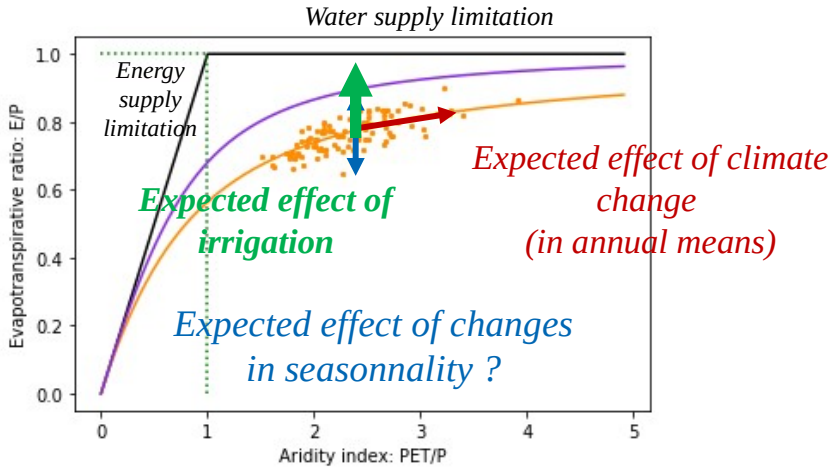

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  ↓ Varying parameter

  Human activities, Vegetation changes → Change in the land surface characteristics ?

The Budyko framework: Quantifying discharge changes

« Natural reference »

Calculation of the watershed parameter for basin with **constant** **surface characteristics**

1

Land Surface Model ORCHIDEE

Calculate ET and Q over each watershed

GSWP3 **Forcing dataset**

Precipitation (P), Potential Evapotranspiration (PET)

$$\frac{E}{P} = 1 + \frac{PET}{P} - \left(1 + \left(\frac{PET}{P}\right)^{\omega}\right)^{\frac{1}{\omega}}$$

Best fit when looking at E/P ~ PET/P

Only includes climate data and climatic/ atmospheric processes

Changes due to climate

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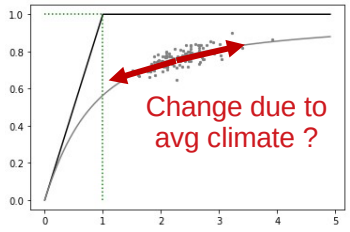
Avg ω — *Best fit when looking at E/P ~ PET/P*



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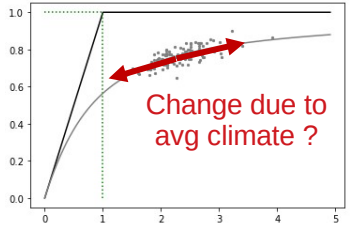
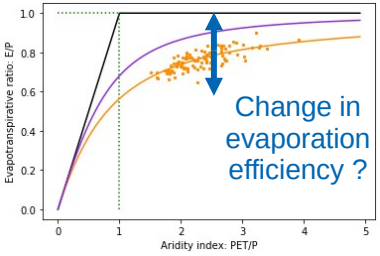


Successive fit with 11-year moving window ω



Includes expected effects of seasonality trends

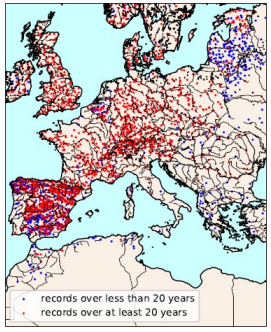
The Budyko framework: Quantifying discharge changes

« Actual system »

Calculation of the watershed parameter for basin with **variant** **surface characteristics**

2

Discharge from observation stations



All GRDC stations (1806-2019) 11182 Stations, 7144 with records over more than 20 years

- GRDC database
-Specific database over Spain

E = P-Q

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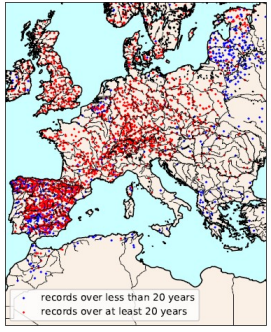

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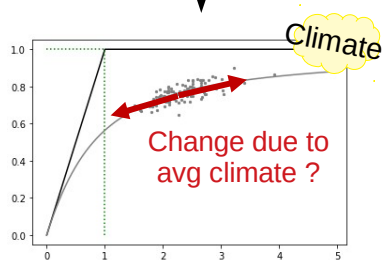

Changes due to all factors

The Budyko framework: Quantifying discharge changes

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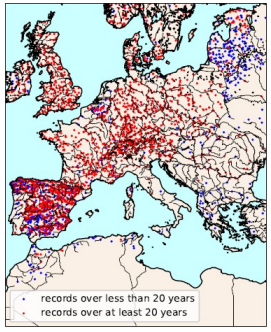

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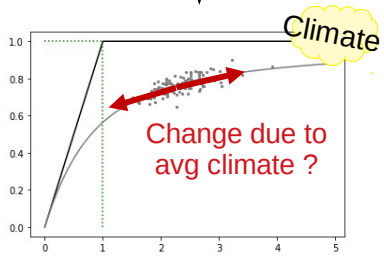
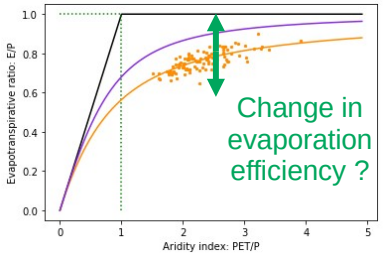




All factors involved

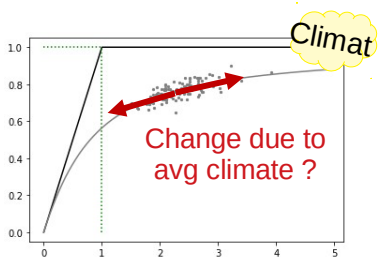
Results

Discharge trends across Europe

1 « Natural reference »

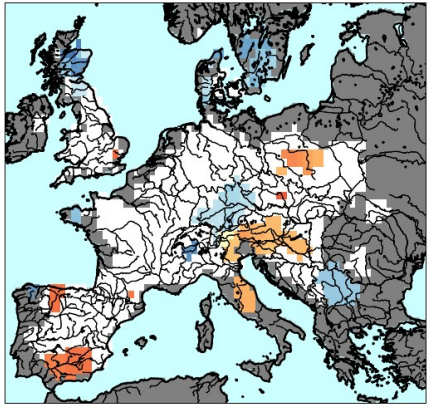
Dominance of ***mean annual climate*** on streamflow Q variations

ORCHIDEE
LAND SURFACE MODEL



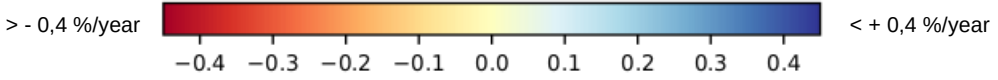
Relative discharge trends

(significant)



- **High inter-annual variability**
→ Few significant trends

- Trends and variability in discharge mostly related to **average precipitation** (primary driver)



% of change in Q per year over the past century

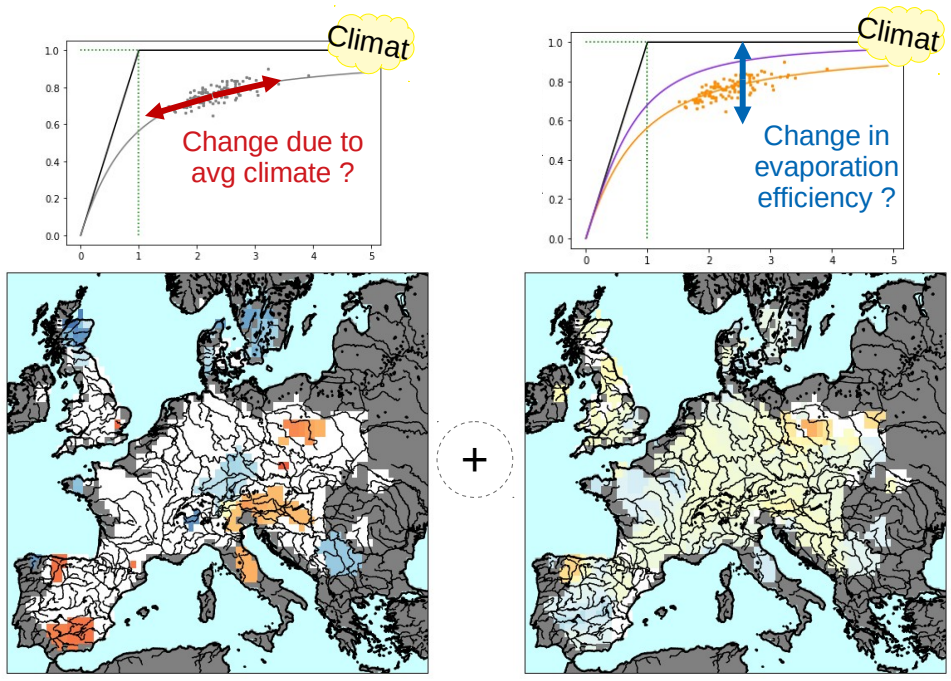
1 « Natural reference »

Dominance of ***mean annual climate*** on streamflow Q variations

ORCHIDEE
LAND SURFACE MODEL

Relative discharge trends

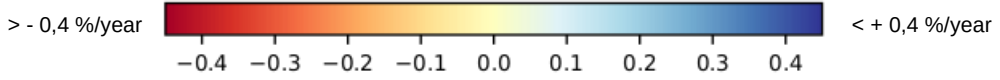
(significant)



- Less variability

- Climatic changes in **evaporation efficiency** mostly due to **intra-annual distribution of P**

- Second climatic driver :
  - > PET over most of Europe
  - > changes in evaporation efficiency over Mediterranean area



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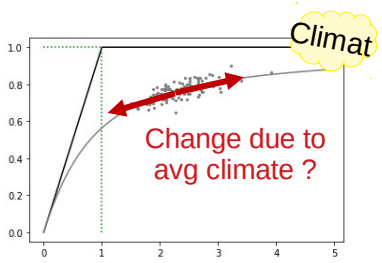
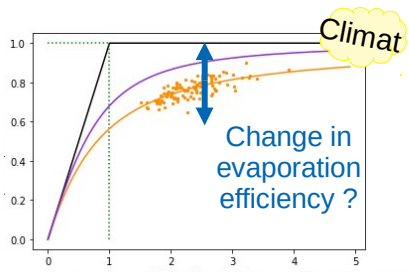


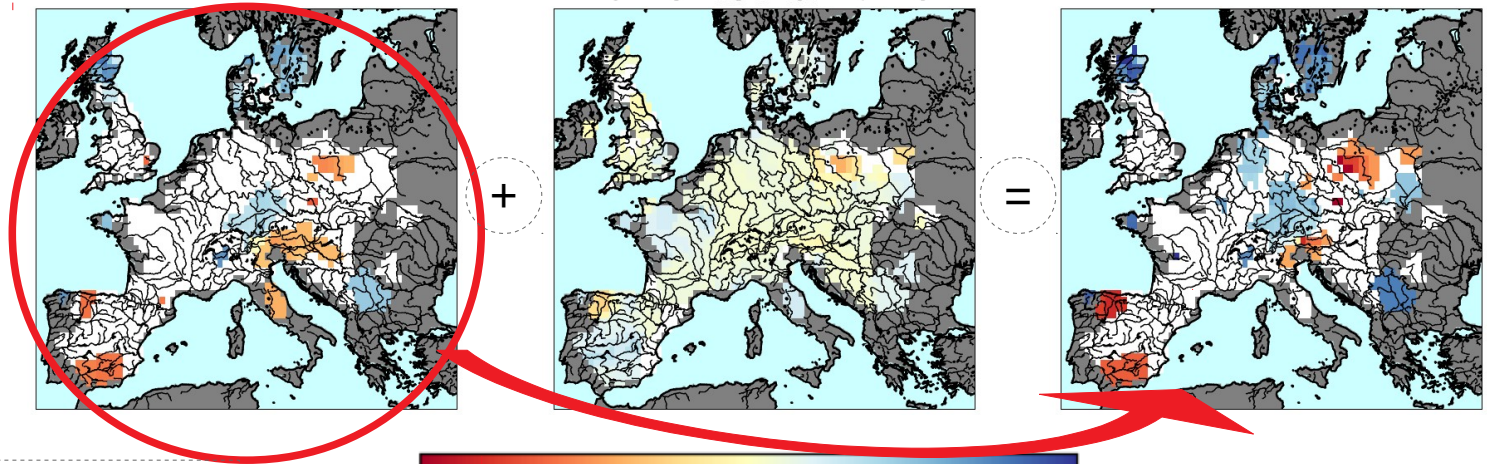


Climat

Total discharge **trends** over the century

Relative discharge trends

(significant)

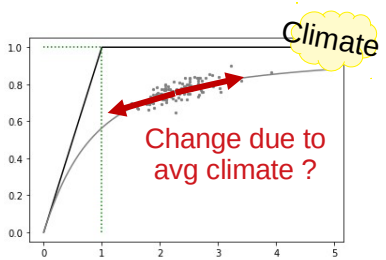


% of change in Q per year over the past century

→ Main climatic driver = **evolution of annual averages of climate variables**

2 « Actual system »

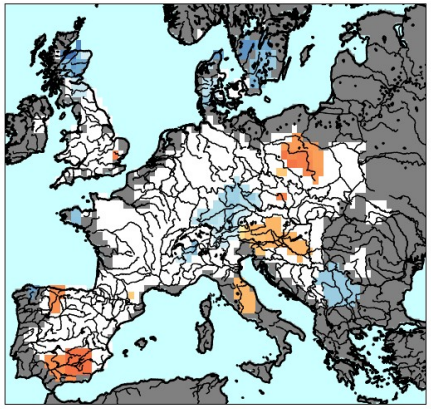
Dominance of **un-attributed factors** on streamflow Q variations

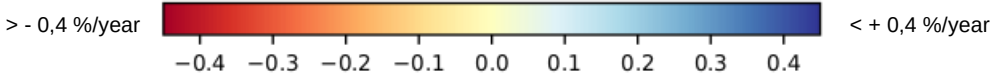


- Same changes due to the average of climate variables P and PET

Relative discharge trends

(significant)





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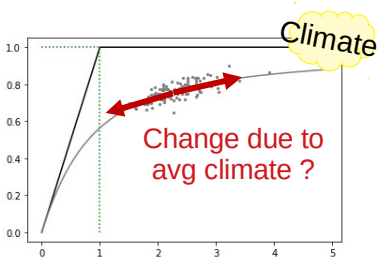
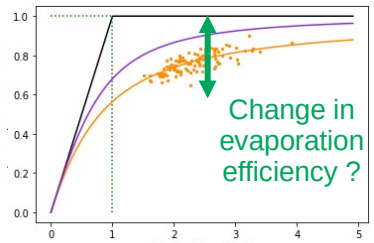
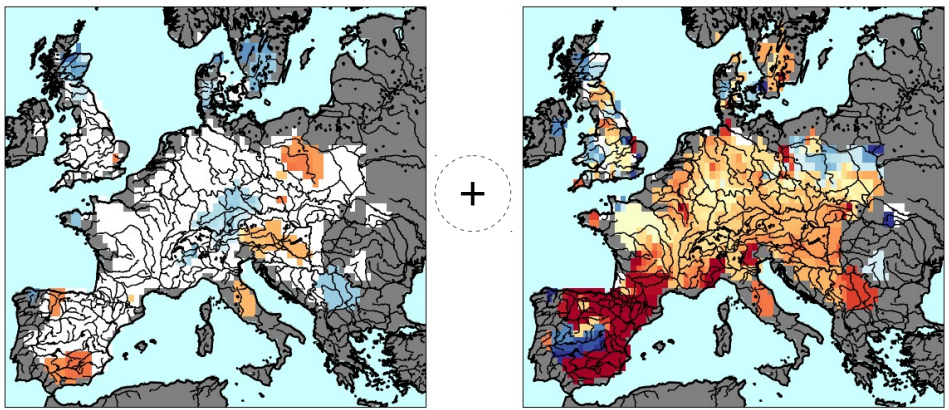




Changes due to all factors

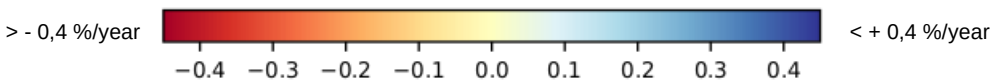
Relative discharge trends

(significant)



- Less variability

- **High trends**, up to 10 times higher than climate trends, especially over Spain



% of change in Q per year over the past century

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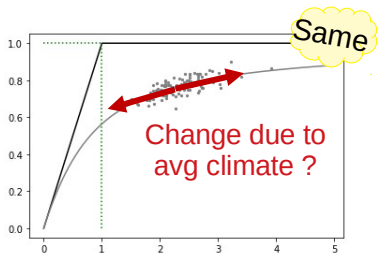
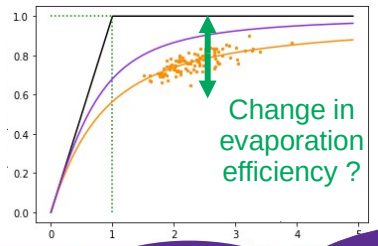


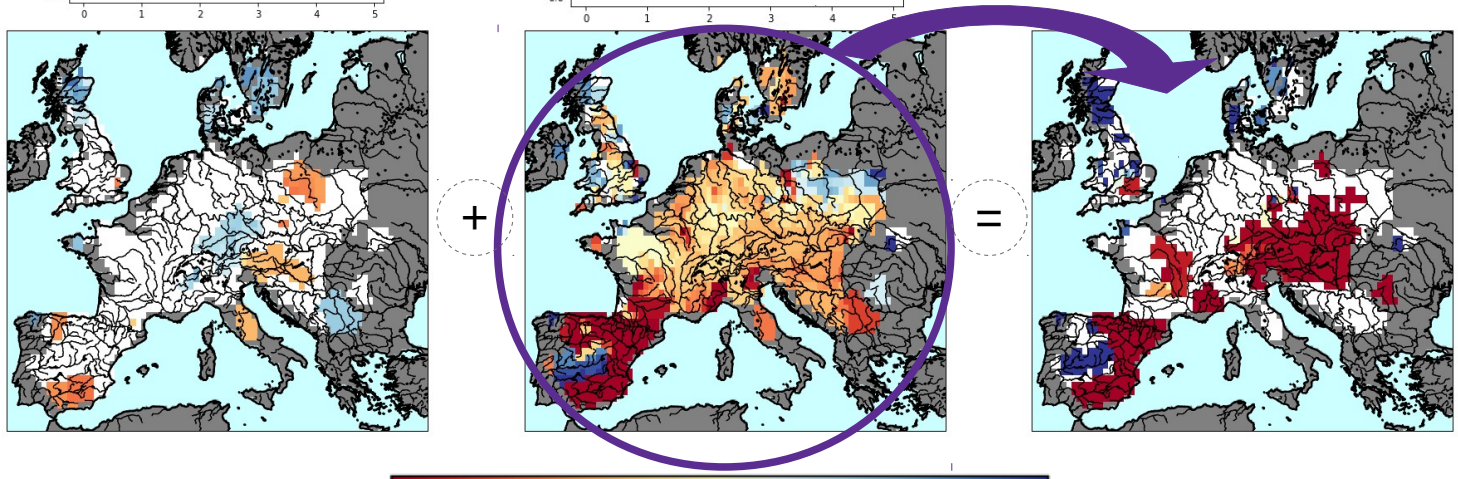


Changes due to all factors

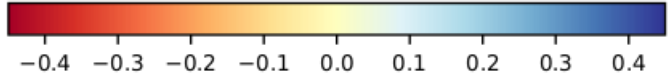
Total discharge **trends** over the century

Relative discharge trends

(significant)



> - 0,4 %/year



< + 0,4 %/year

% of change in Q per year over the past century

→ Main driver =
evolution of watersheds characteristics

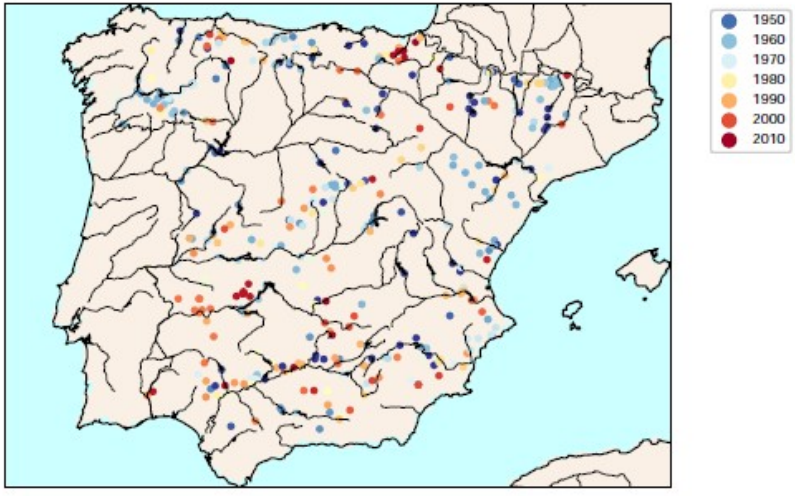
Summary

- Main results :
  - **Climate impact** on streamflow
    → mainly through changes in **annual averages of precipitation**
    → also through seasonnality changes : seasonnality of P
    second driver of Q before average PET over Spain
  - **Higher impact** on actual streamflow of **other factors** (probably anthropic factors) over the past century, especially over Spain

- Next step : how to attribute these detected changes ?
  - Higher resolution models to study sub-basins
  - test model with irrigation

Dams and associated stored water volumes

Dams over Spain with building date



Example for one basin over Spain

6298318.0: Jarama

Rivas-Vaciamadrid,