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

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Julie Collignan

PhD Student (2nd year)
Laboratoire de Météorologie Dynamique (LMD),
Paris, France

Co-authors :
Dr. Jan Polcher (LMD) *(supervisor)*,
Dr. Sophie Bastin (LATMOS) *(supervisor)*,
Dr. Pere Quintana Segui (Observatori de l'Ebre, Universitat Ramon Llull - CSIC)

EGU General Assembly 2022 *HS2.4.1 Understanding the links between hydrological variability and internal/natural climate variability*

Budyko framework

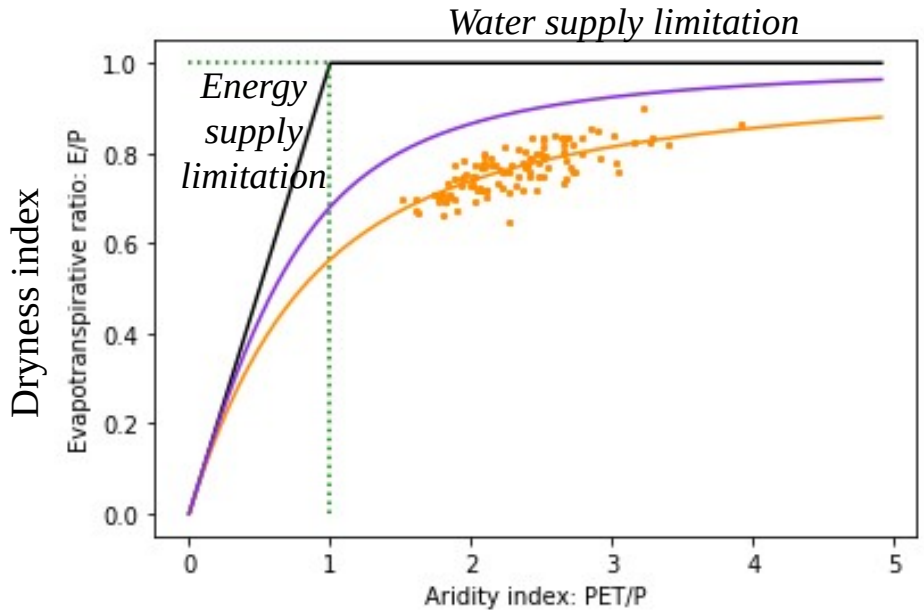
General Presentation

Budyko framework: a simple river discharge model

- Budyko framework
  - Two factors limiting evapotranspiration : **Energy** and **Water** supply
  - *Analytical approximation:* *(Fu's equation)*

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

- The watershed parameter **ν**
  - Adjusted over an **area** and a **time period**
  - Parameter reflecting **watersheds characteristics** (vegetation cover, soils, slopes, some climatic characteristics...)



Aridity index

Annual mean over hydrological years

From E to discharge Q through water balance, neglecting storage

→ Simple parameter, represents how water is **partitionned** over the catchment

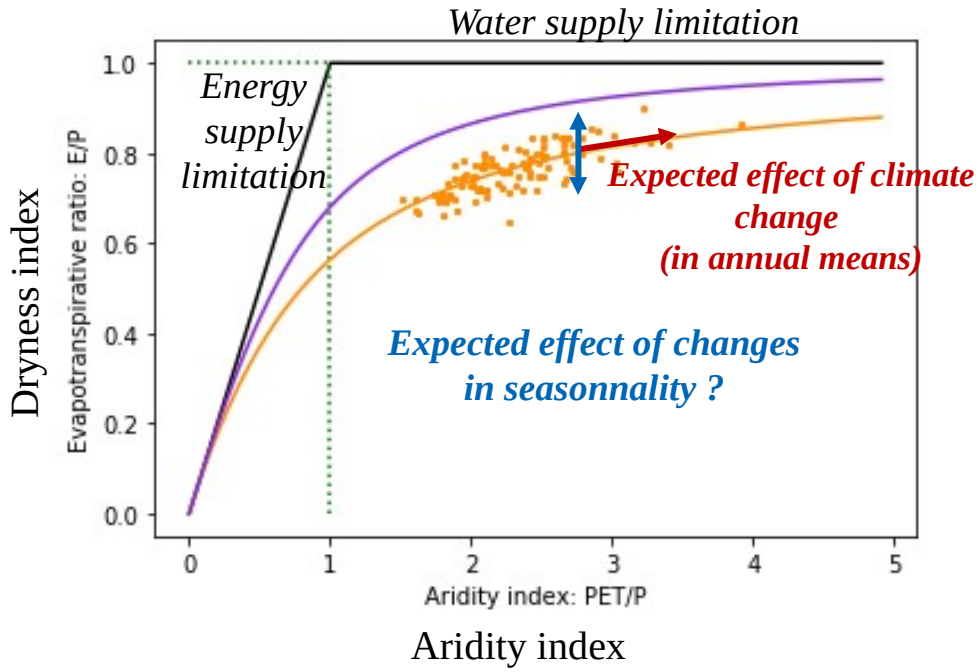
Budyko framework: evolution of the river discharge ?

- Hypothesis :
  - For given watershed with **constant characteristic**s + no long term trends in climate

    → Still **dispersion** around the curve due to **intra-annual differences** between years

⇒ Framework includes trends in annual means

⇒ Expected effect of seasonnality, trends in that effect ??



Aridity index

Budyko framework: a simple river discharge model

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

    → Still **dispersion** around the curve due to **intra-annual differences** between years

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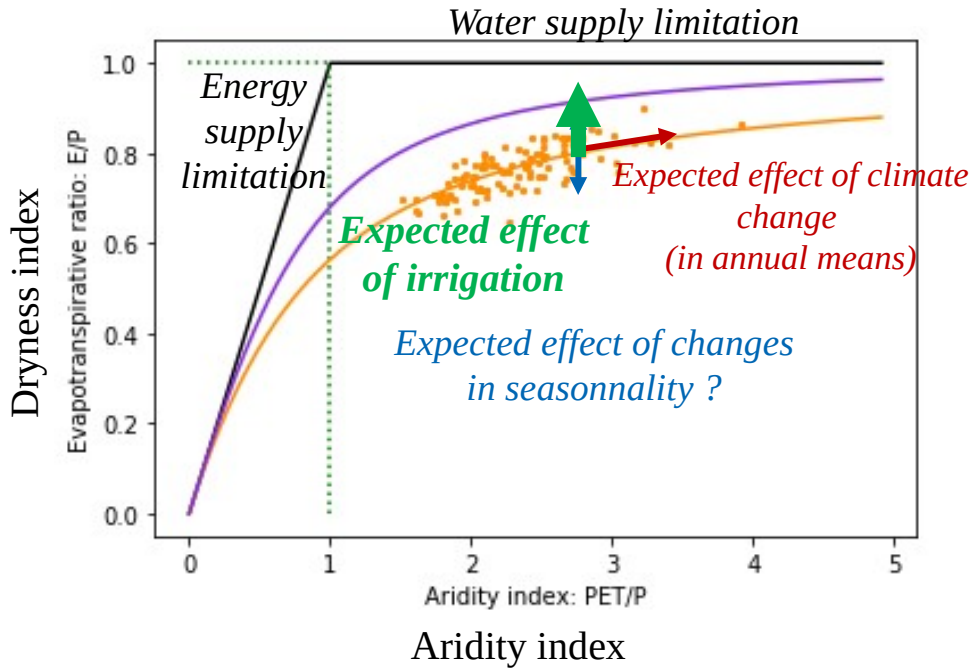
  - Watershed with **evolving characteristics** : impact of human activities



Aridity index

Changes in ν

Includes effects of human activity
Also expected effects of seasonality

Focus on climatic effect

Seasonality vs Annual averages

Budyko framework :
Fit of the watershed parameter : « Natural reference »

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

① Land Surface Model ORCHIDEE

Calculate ET and Q over each watershed

Only includes climate data and climatic/ atmospheric processes

« Climatic ν_c parameter »

Modified forcings
- **fixed intra-annual** variations
- fixed annual mean...

GSWP3
E2OFD

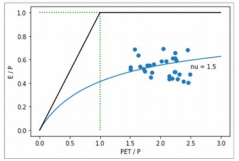
Forcing dataset
Precipitation (P), Potential Evapotranspiration (PET)

① ***Model output***
Evapotranspiration (E)

$$\frac{E}{P} = 1 + \frac{PET}{P} - \left(1 + \left(\frac{PET}{P}\right)^{nu}\right)^{\frac{1}{nu}}$$ Fu's equation

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

Scatter plot over the watershed: one point per year

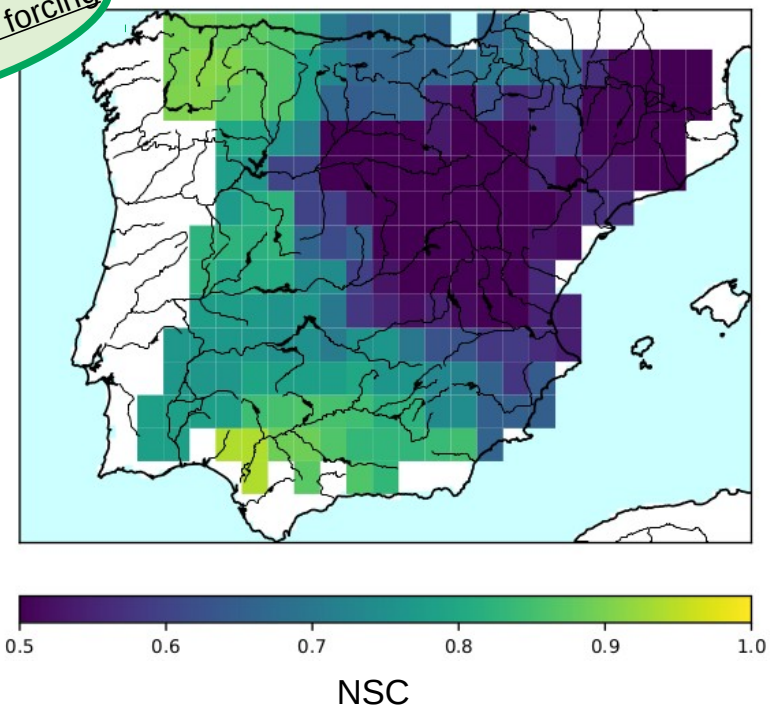


Estimated parameter for the watershed
nu_c

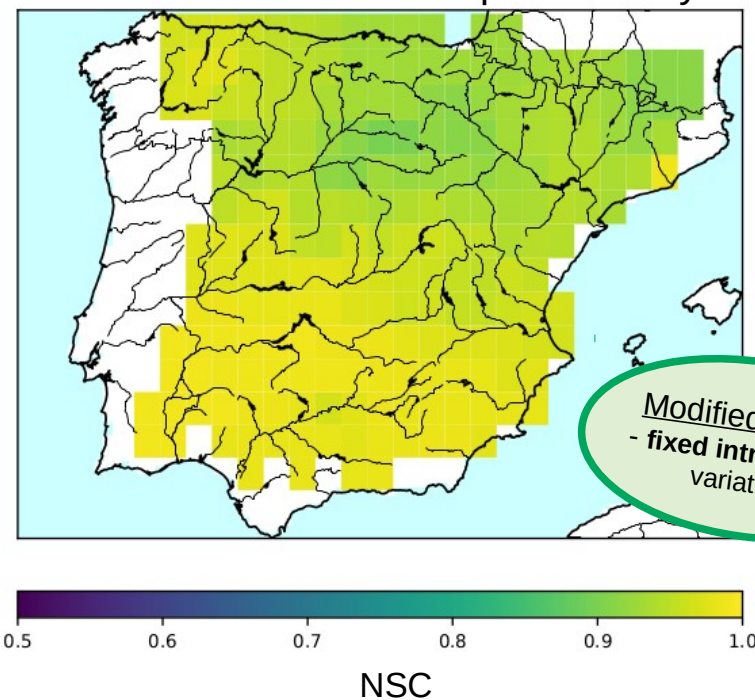
- # Nash-Sutcliffe Coefficient (NSC):
  ## performance of Budyko framework to reproduce streamflow

Applied with an historical forcing over the past century

Reference forcing



Applied with a modified forcing to keep **constant intra-annual variations** over the past century

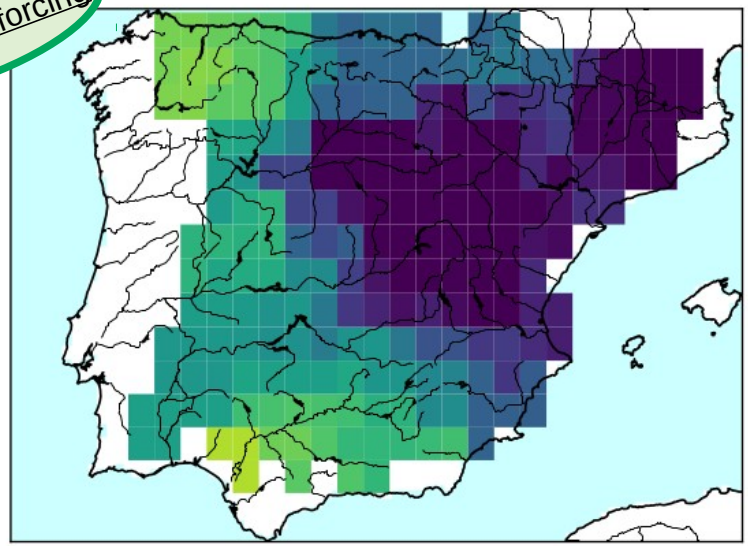


Modified forcing
- **fixed intra-annual** variations

- Nash-Sutcliffe Coefficient (NSC):
  performance of Budyko framework to reproduce streamflow

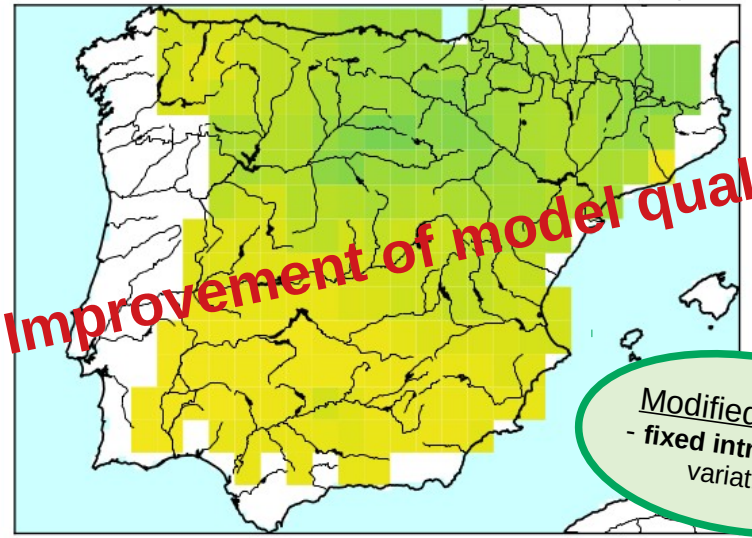
Applied with an historical forcing over the past century

Reference forcing



NSC

Applied with a modified forcing to keep **constant intra-annual variations** over the past century



Improvement of model quality

Modified forcing
- **fixed intra-annual** variations

NSC

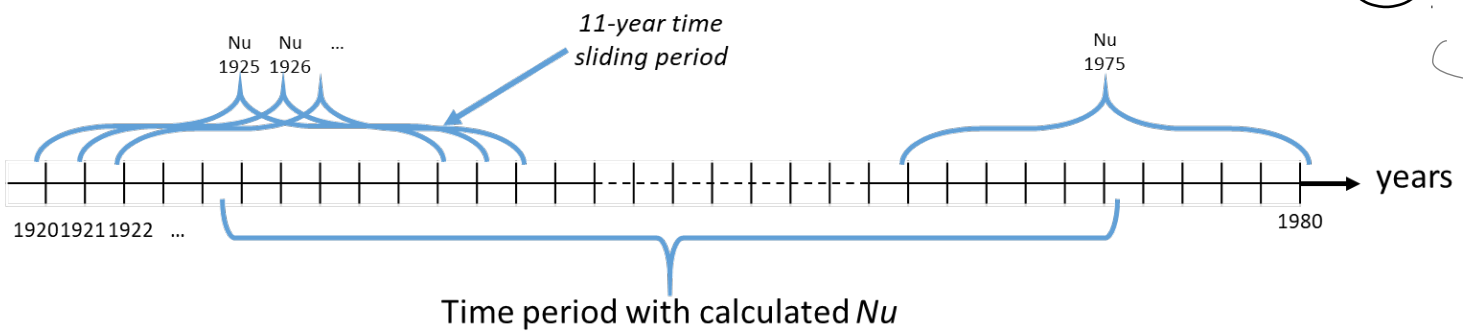
Budyko framework :
a time dependent watershed parameter

→ Includes the eventual **trend in intra-annual variations**

- One fit **over the entire time period**, with all yearly values at once → classical framework

- Fit over an **11-year sliding time-period**

→ Evolution of the parameter over the time period



« Climatic ν_c parameter »

A **Constant ν_c**

B **$\nu_c(t)$**

Includes expected effects of seasonality trends

Separate climate effects from other effects

A natural reference method

« Natural reference »

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

Relative trends

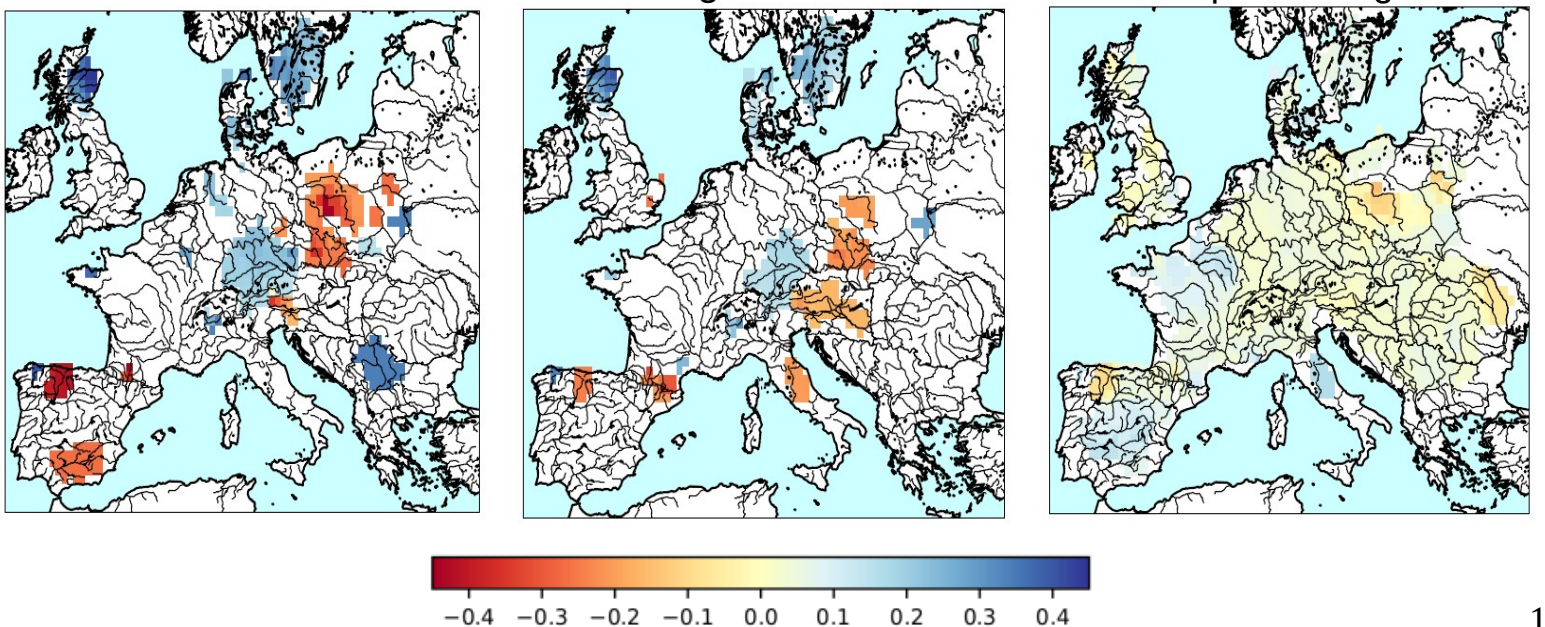
> - 0,4 %/year

< + 0,4 %/year

Total change

Change due to trends in annual average of P, PET

Change due to differences in ν_c representing water partitioning



% of significant change in Q per year over the past century

« Natural reference »

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

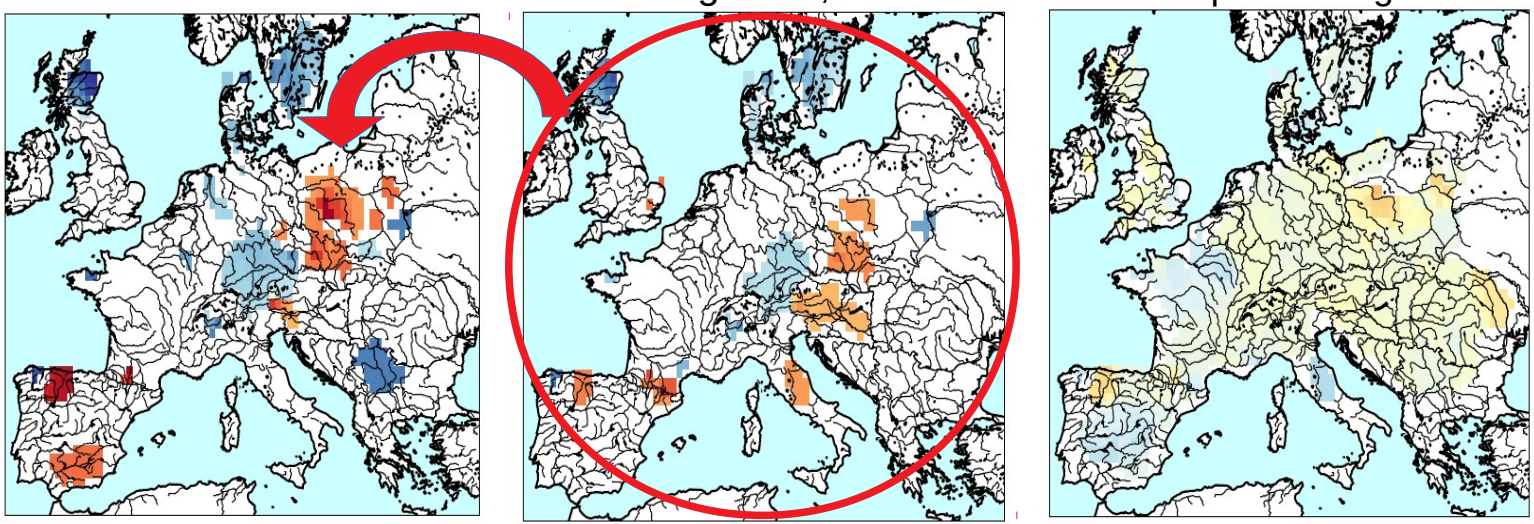
Trends of streamflow in the **natural system** :

→ mostly covered with **evolution of annual averages of climate variables**

Total change

Change due to trends in annual average of P, PET

Change due to differences in ν_c representing water partitioning



% of change in Q per year over the past century

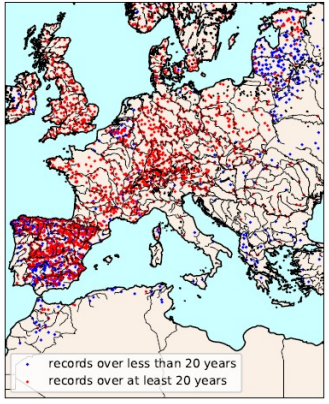
Budyko framework :
Fit of the watershed parameter : « Real system »

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

2 Streamflow from observation stations

- GRDC database
- Specific database over Spain

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



« Total ν_t parameter »

Includes effect of human activity

A **Constant ν_t** B **$\nu_t(t)$**

GSWP3
E2OFD

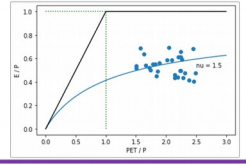
Forcing dataset
Precipitation (P), Potential Evapotranspiration (PET)

2 ***Observations***
River flow (Q) → E = P - Q

Fu's equation $Q = P * \left(1 + \left(\frac{PET}{P}\right)^{nu}\right)^{\frac{1}{nu}} - PET$

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

Scatter plot over the watershed: one point per year



Estimated parameter for the watershed
nu_t

« Real system »

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

Relative trends

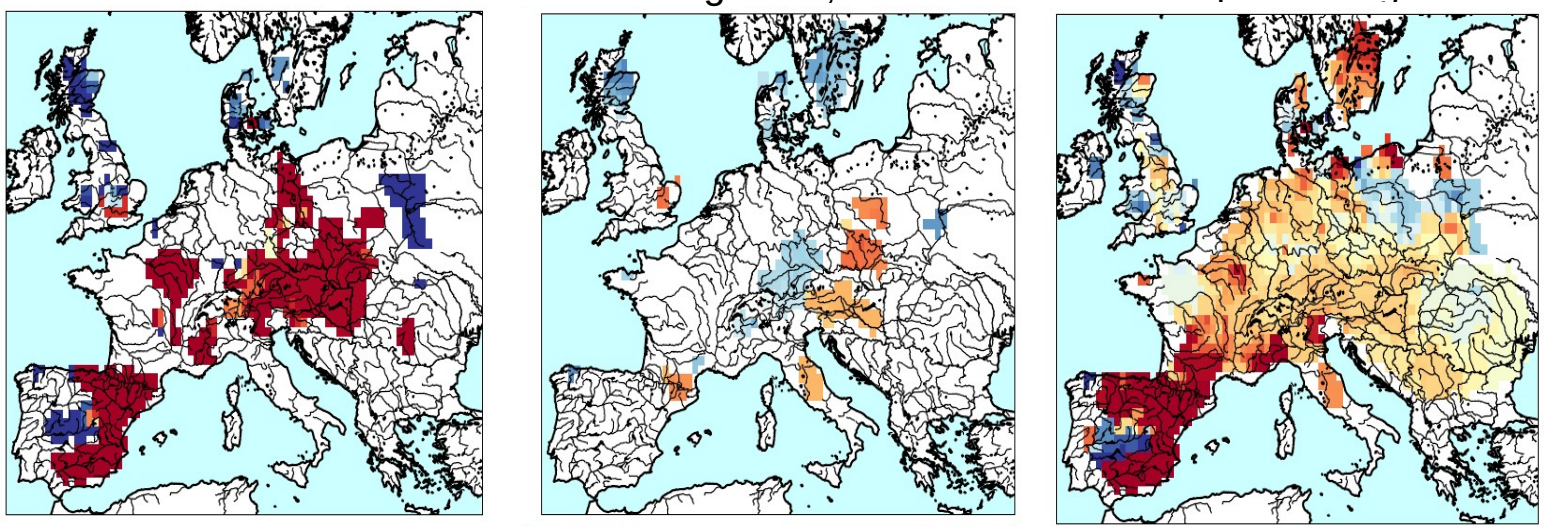
> - 0,4 %/year

< + 0,4 %/year

Total change

Change due to trends in annual average of P, PET

Change due to differences in ν_t representing water partitioning



% of change in Q per year over the past century

« Real system »

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

Trends of streamflow in the **real system** :

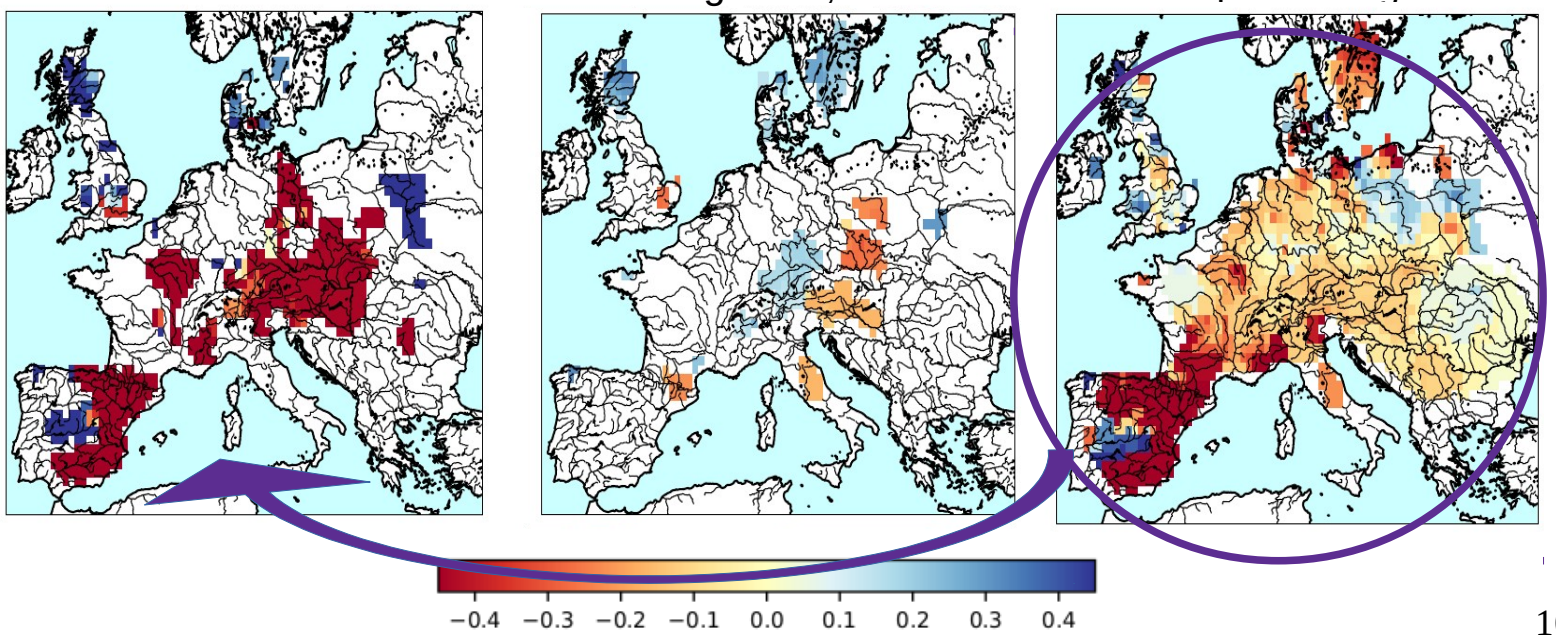
→ due to **evolution of watershed characteristics**

! Not true when looking at decadal trends !

Total change

Change due to trends in annual average of P, PET

Change due to differences in ν_t representing water partitioning



% of change in Q per year over the past century

Summary

- **Budyko framework** with time-varying parameter to include partially effect of eventual seasonnal trends
- Applied and then comparing **« natural reference »** (from Land Surface Model) to **« real system »** (from observations)
- Main results :
  - **Climate impact** on streamflow
    → mainly through changes in **annual averages of climate variable**
    → also through seasonnality changes
  - **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