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Improving estimates of riverine fresh water into the Mediterranean sea

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Outline

- Question and objective
- Methodology, study region, datasets
- Result (1): intercomparison of the estimated riverine fresh water
  (2): Trend analysis
- Conclusions & future directions

Background and objective

- The Mediterranean sea: semi-closed, one of the most vulnerable regions to climate change
- River discharge: couples the continents and oceans in the climate system; important source of fresh water; sustaining the marine productivity and overturning circulation
- Accurate estimates of riverine freshwater inputs into the Mediterranean sea is essentially important

	Previous study		This study
	Hydrology	**Land Surface Model**	**Assimilation**
Method	Observation (gauged); water balance (ungauged)	LSM forced by atmospheric conditions	LSM + Observations (GRDC)
Advantage	Simple to implement	Daily scale	Compensate systematic errors/missing processes; High temporal/spatial resolution
Disadvantage	Annual mean values	Uncertainties (missing processes)	Computationally expensive

Assimilating river discharge observations in a model

$$\frac{dW}{dt} = P - E - x \cdot (R + D)$$

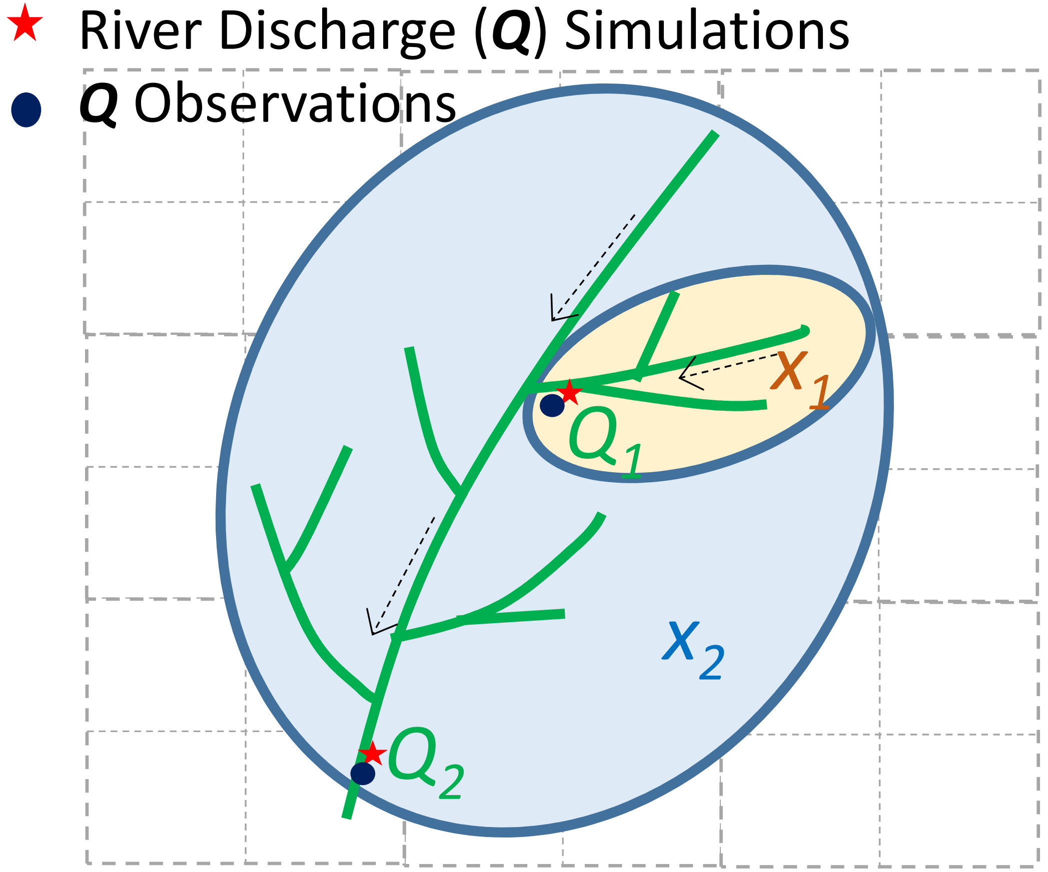
$$Q = f(R, D)$$

Correction factor

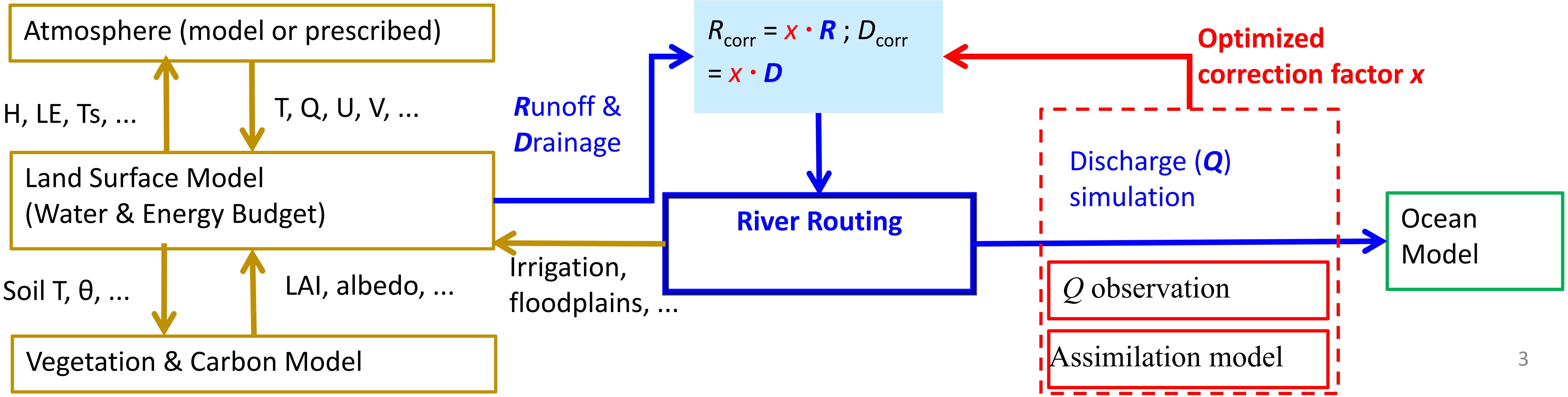
Observations available

Conceptual variable

- $\frac{dW}{dt} \approx 0$, *P* & *E* errors end up in ***R***unoff + ***D***rainage
- Bias in *Q* → correct model ***R*** & ***D*** (by *x*)
- Apply each *x* to its upstream basin, *N* of *x* depends on *N* of stations
- Improve ***Q*** simulation → Q_{corr} high temporal/spatial resolution; available when observations missing (climatology)



Wang, F., Polcher, J., et al., HESS., review, 2018.



Atmosphere (model or prescribed)

H, LE, Ts, ...

T, Q, U, V, ...

Land Surface Model
(Water & Energy Budget)

Soil T, θ, ...

LAI, albedo, ...

Vegetation & Carbon Model

Runoff &
Drainage

Irrigation,
floodplains, ...

$R_{corr} = x \cdot \boldsymbol{R}$; $D_{corr} = x \cdot \boldsymbol{D}$

River Routing

Optimized correction factor *x*

Discharge (***Q***) simulation

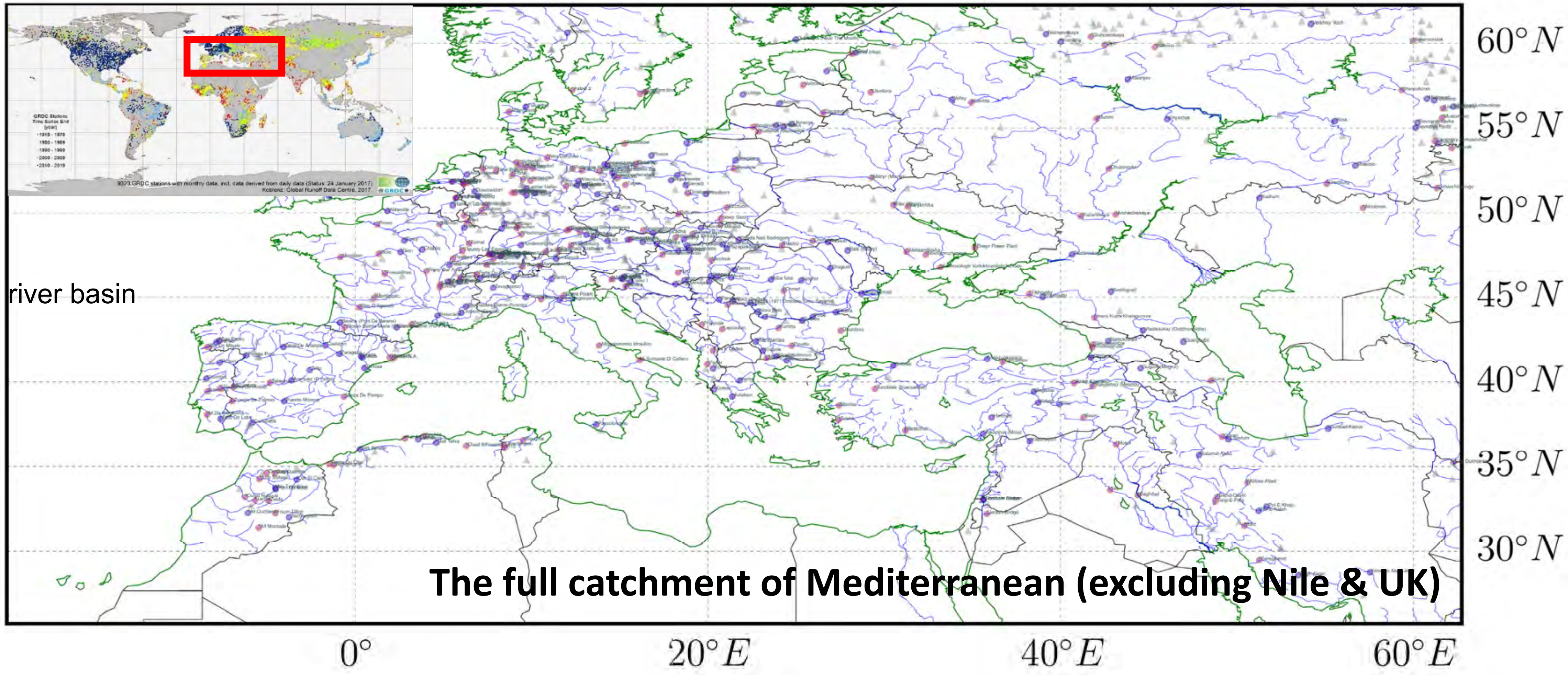
Q observation

Assimilation model

Ocean Model

Datasets and study region

- **ORCHIDEE forcing data:** WFDEI with precipitation corrected by GPCC, 0.5°
- **River discharge observations:** Global Runoff Data Centre (GRDC).
  - ✓ GRDC selection creteria: the difference of upstream area and distance between GRDC and ORCHIDEE model subbasin < 10% and < 25 km.
  - ✓ UK and Nile river basin are excluded to accelerate the assimilation.
  - ✓ **338**/792 GRDC observation stations can be used (19.7°W-62.7°E, 25°N-62°N)
- **Previous freshwater datasets:** CEFREM, Low (Ludwig et al., 2009) and High Resolution



Nile river basin

The full catchment of Mediterranean (excluding Nile & UK)

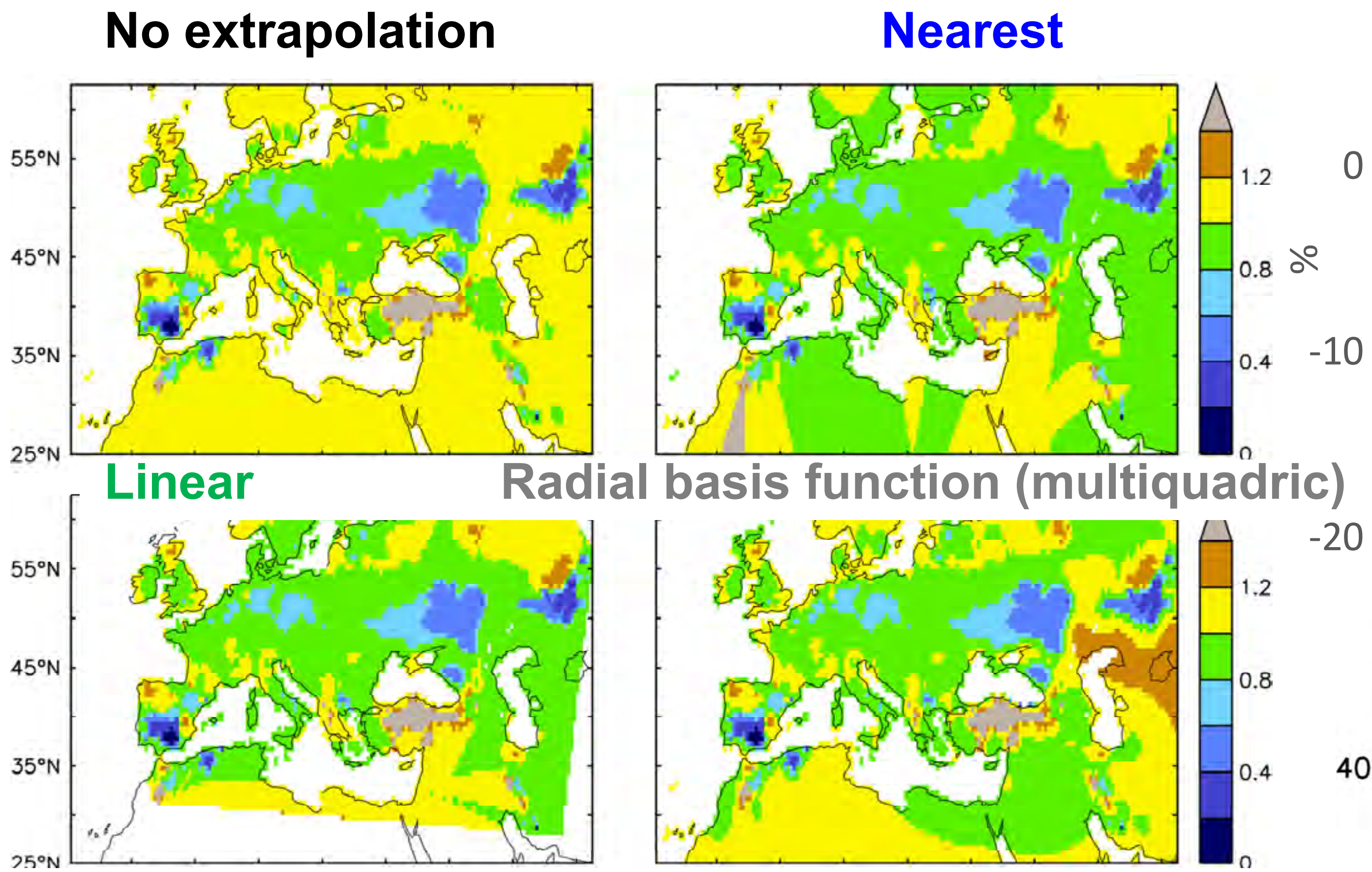
Uncertainty linked to the extrapolation methods for the correction factor

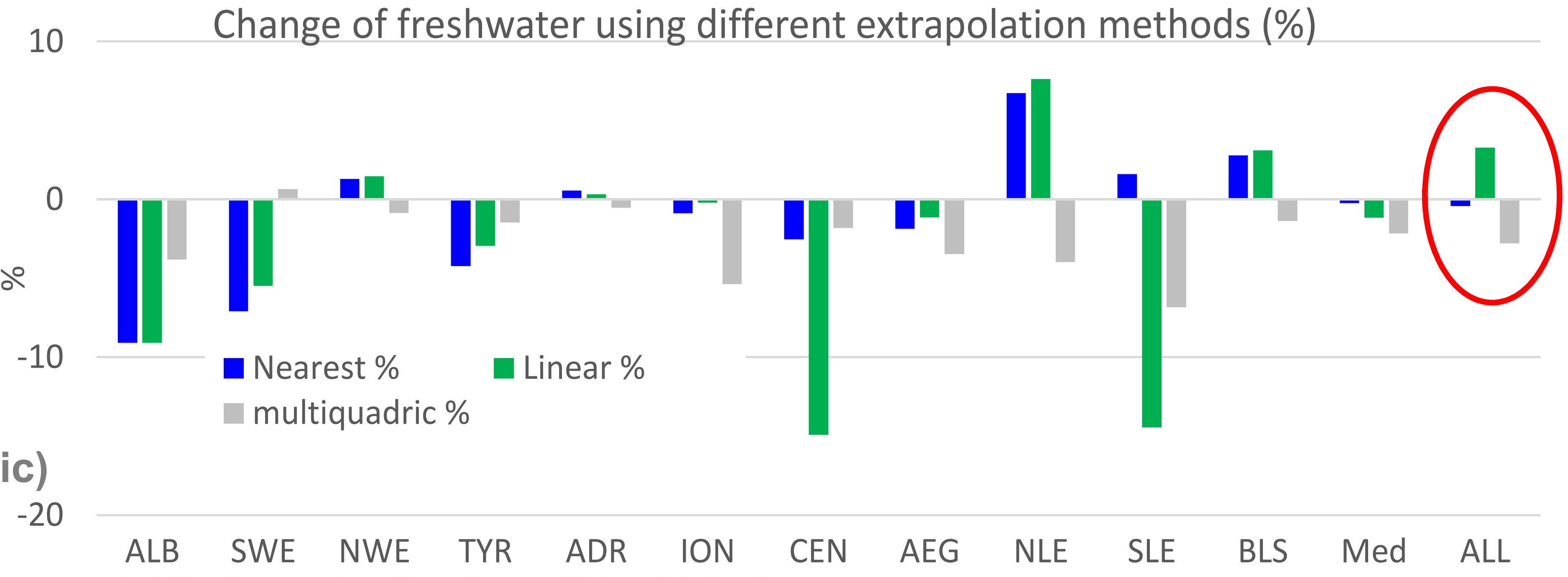
Extrapolation of the correction factor **from gauged to un-gauged basins**.

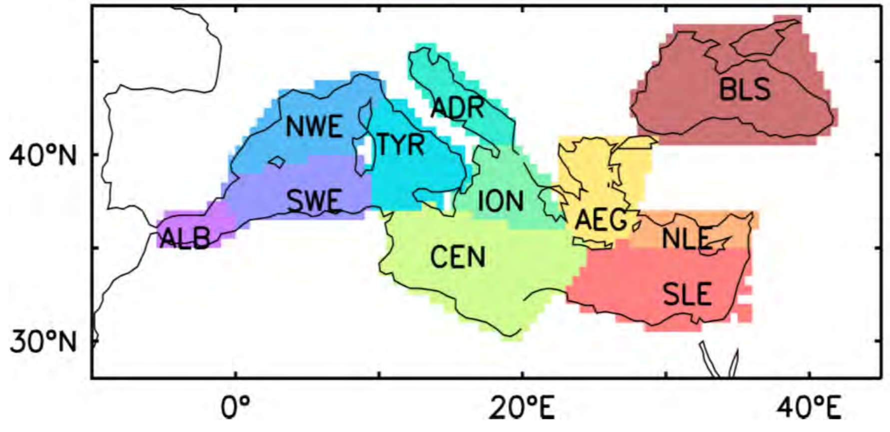
- Linear ≈ Nearest ≈ radial basis function (multiquadric)

Conclusion: the extrapolation accounts for at most 5% of the total discharge.

Correction factor *x*







River discharge bias correction by assimilation

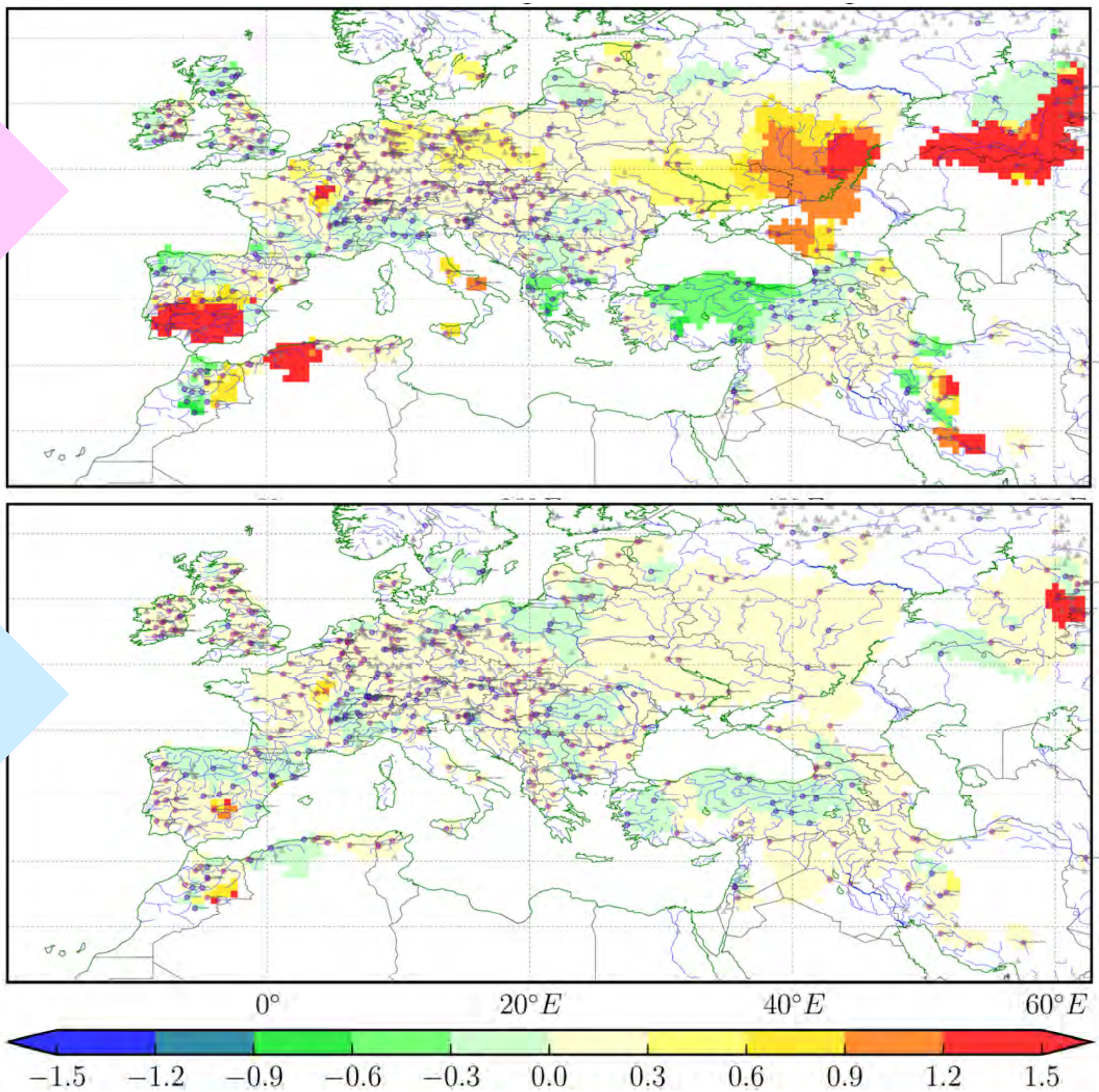
Bias of discharge: $(Q_{sim} - Q_{obs})/Q_{obs}$

Forcing: WFDEI-GPCC

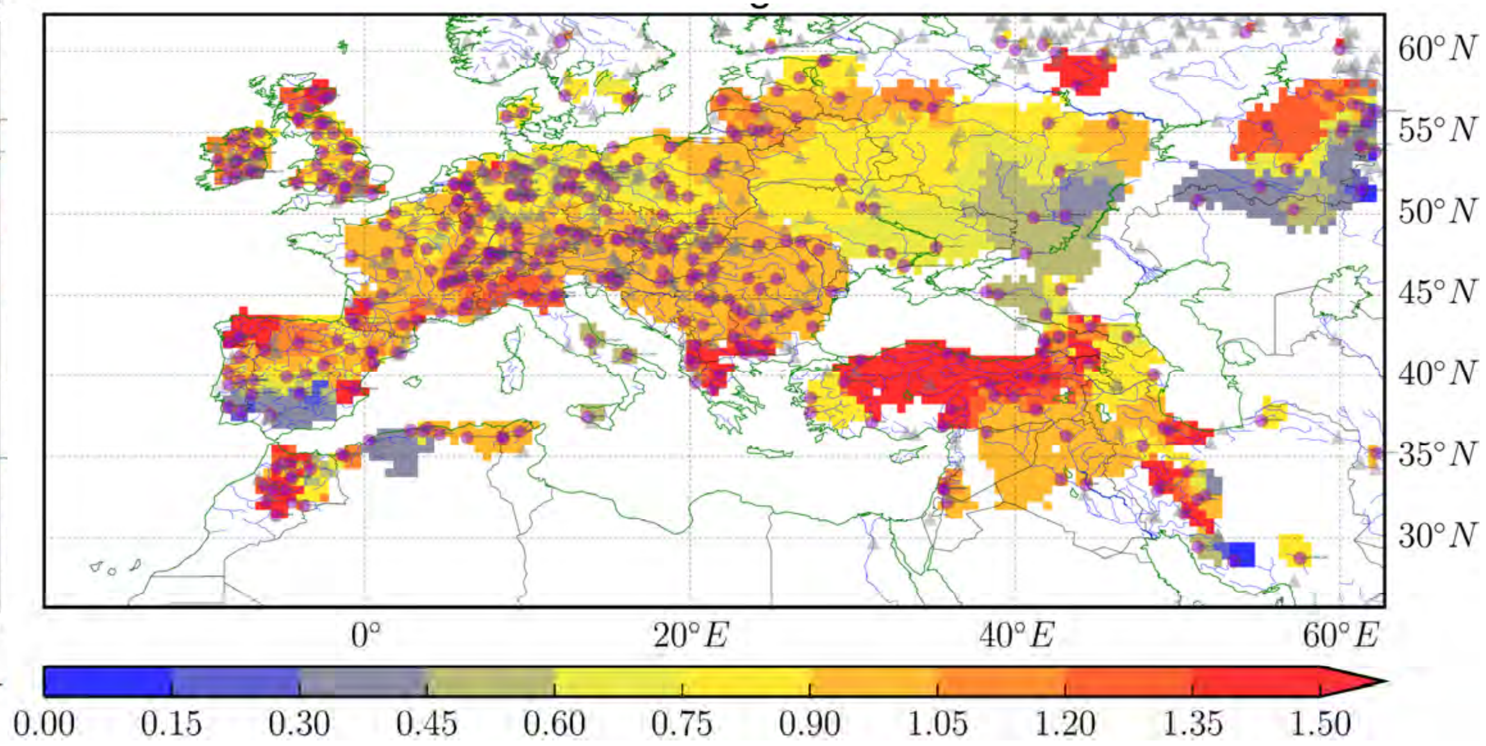
Before Assimilation

After Assimilation

Lower BIAS

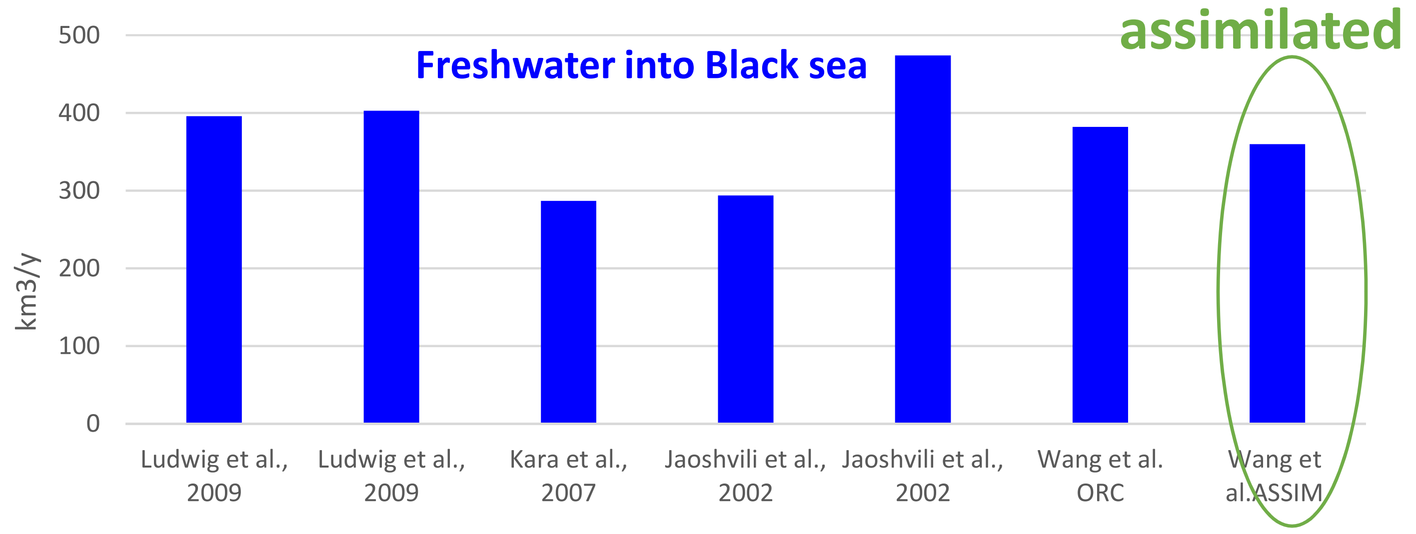


Correction factor *x*



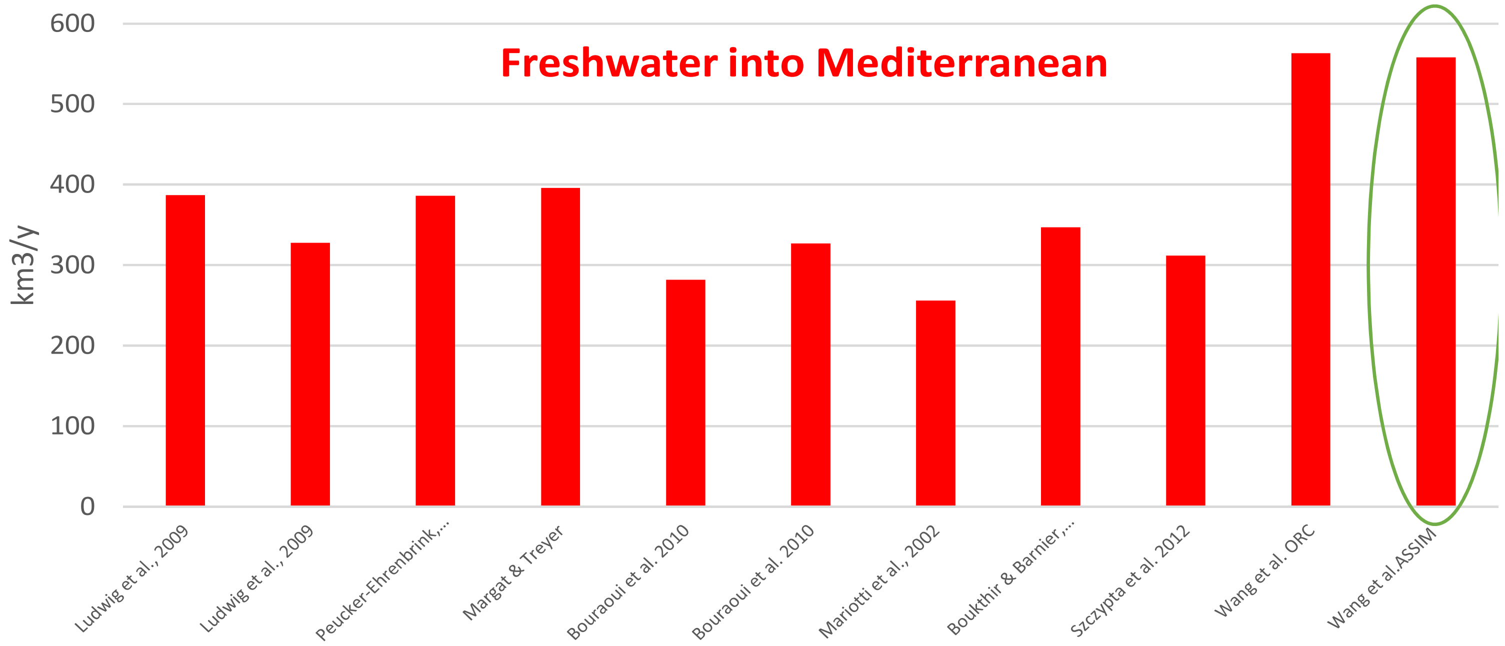
Estimated riverine input into the Black sea and the Mediterranean sea

Source	Water (km³/y)	Method	Period
Ludwig et al., 2009	**396 (LR), 403 (HR)**	**GRDC + water balance**	**1960-1969 (LR), 1991-2000 (HR)**
Kara et al., 2007	287	Model + obs.	1952-1984
Jaoshvili et al., 2002	294 to 474	Literature review	Various periods
Wang & Polcher, 2018	**389 (ORCHIDEE); 367 (Assimilated)**		**1980 - 2013**



Black sea: assimilated value ≈ previous studies.

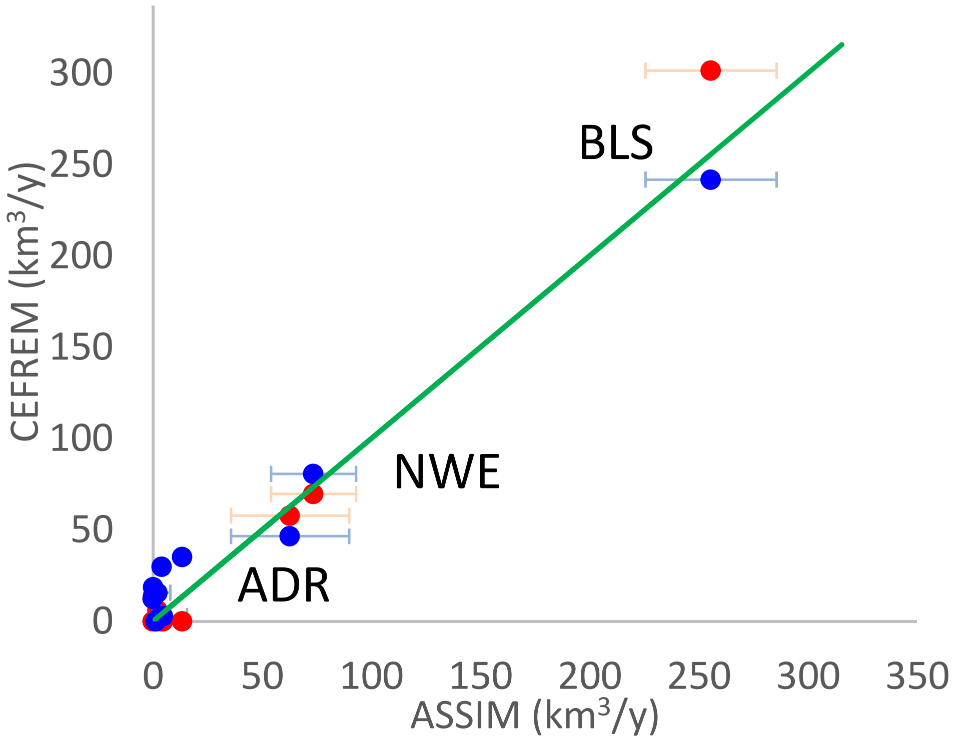
Source	Water (km³/y)	Method	Period
Ludwig et al., 2009	**387 (LR), 328 (HR)**	**GRDC + water balance**	**1960-1969 (LR), 1991-2000 (HR)**
Peucker-Ehrenbrink, 2009	386	Land2Sea data	--
Margat & Treyer	396		
Bouraoui et al. 2010	282-327	model	1980-2000
Mariotti et al., 2002; Struglia et al. 2004	256, <=328	GRDC,MED-HYCOS	>10 years
Boukthir & Barnier, 2000	347	UNESCO	various
Szczypta et al. 2012 (HESS)	312	GRDC	1991-2000
Wang & Polcher, 2018	**575 (ORCHIDEE); 569 (Assimilated)**		**1980 - 2013**



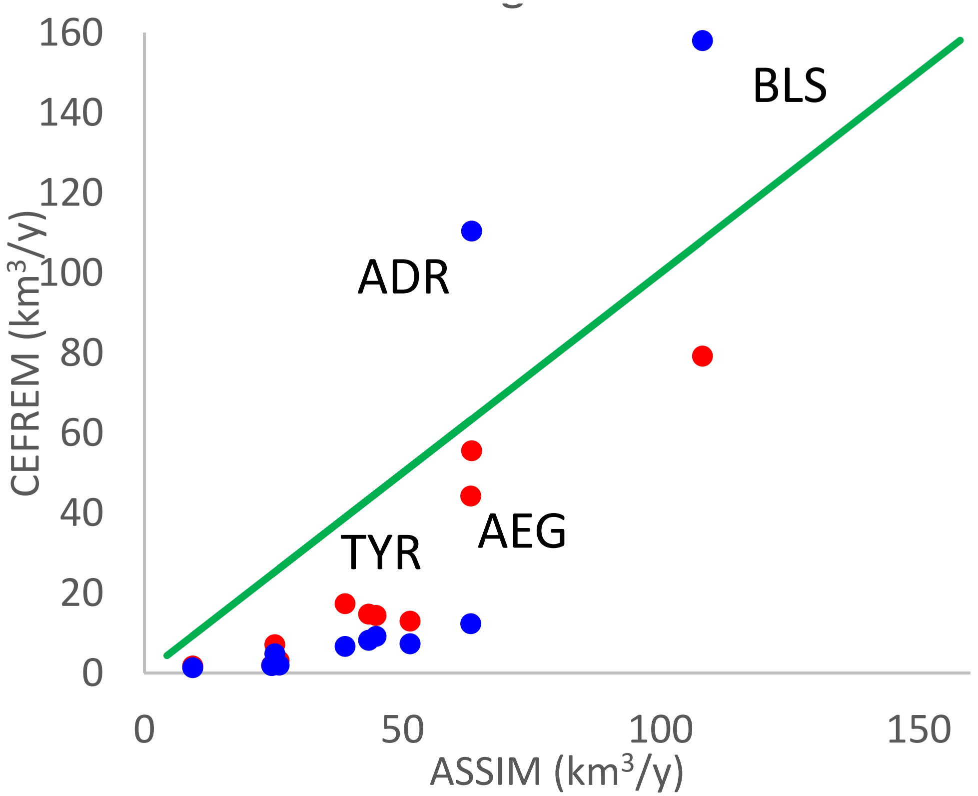
- Nile: same value for ORCHIDEE & CEFREM
- **Mediterranean**: **Assimilated >> others** (e.g., 170-230 km³/y higher than Ludwig et al., 2009). **Why ???**

Separating total discharge coastal points with and without observations

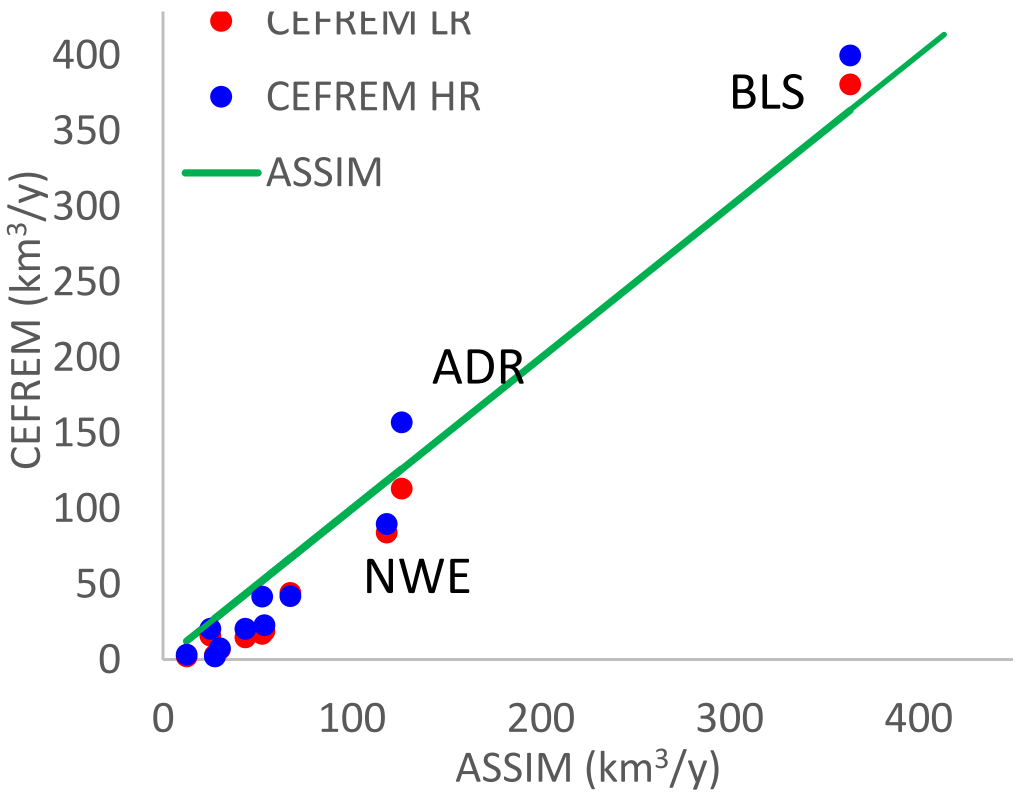
CEFREM vs ASSIM: coastal points WITH observations



CEFREM vs ASSIM: coastal points WITHOUT observations



CEFREM vs ASSIM: Total flux



- Discharge on coastal points with observations:

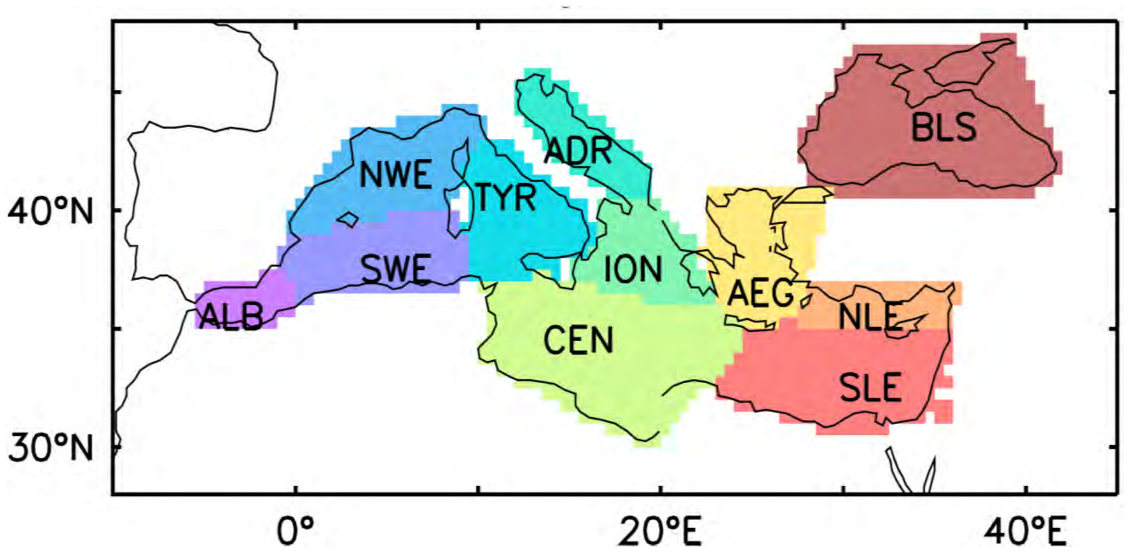
  ASSIM ≈ CEFREM (LR) ≈ CEFREM (HR)

- Non-observed coastal points:

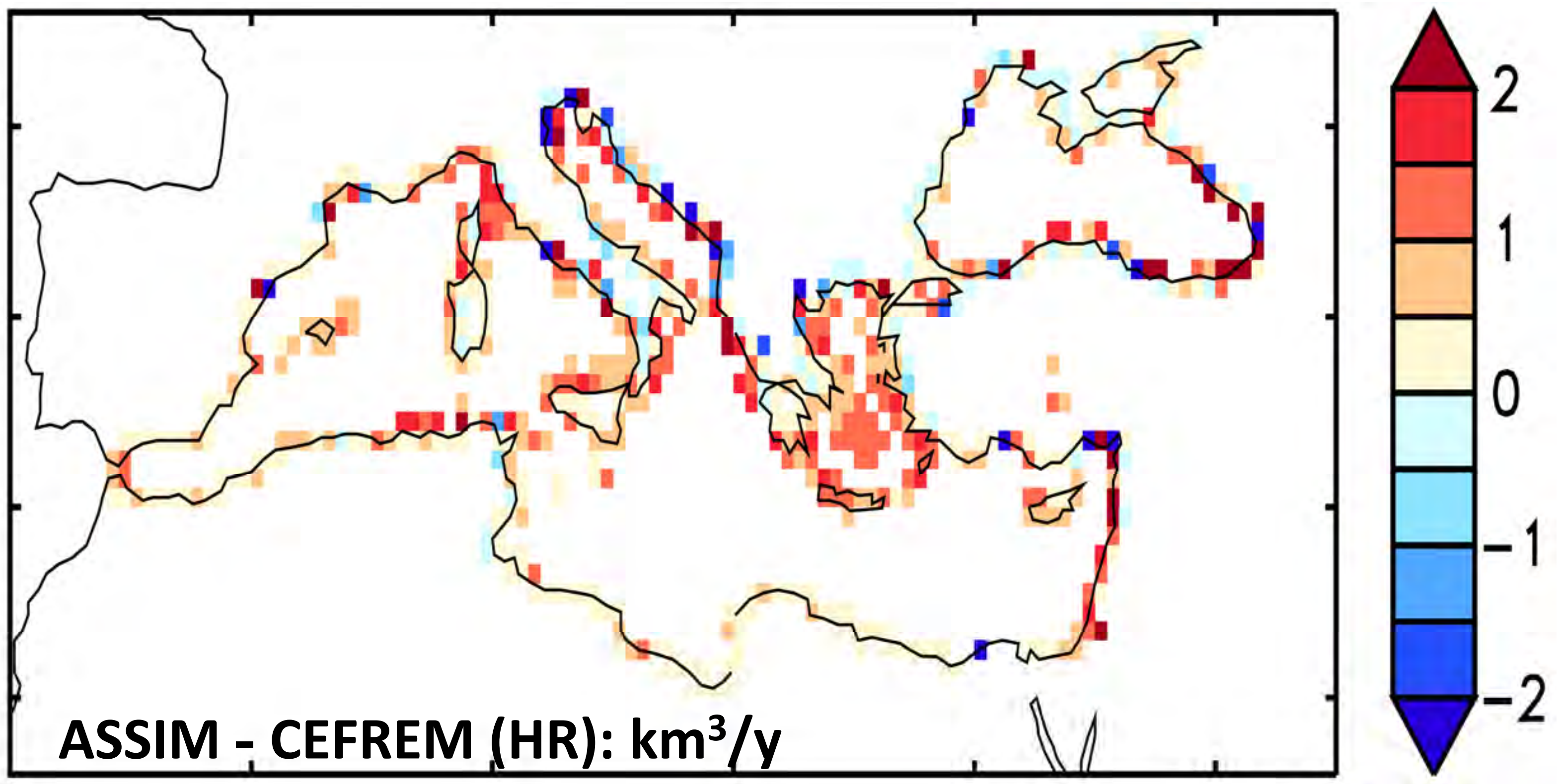
  ASSIM ≠ CEFREM (LR HR)

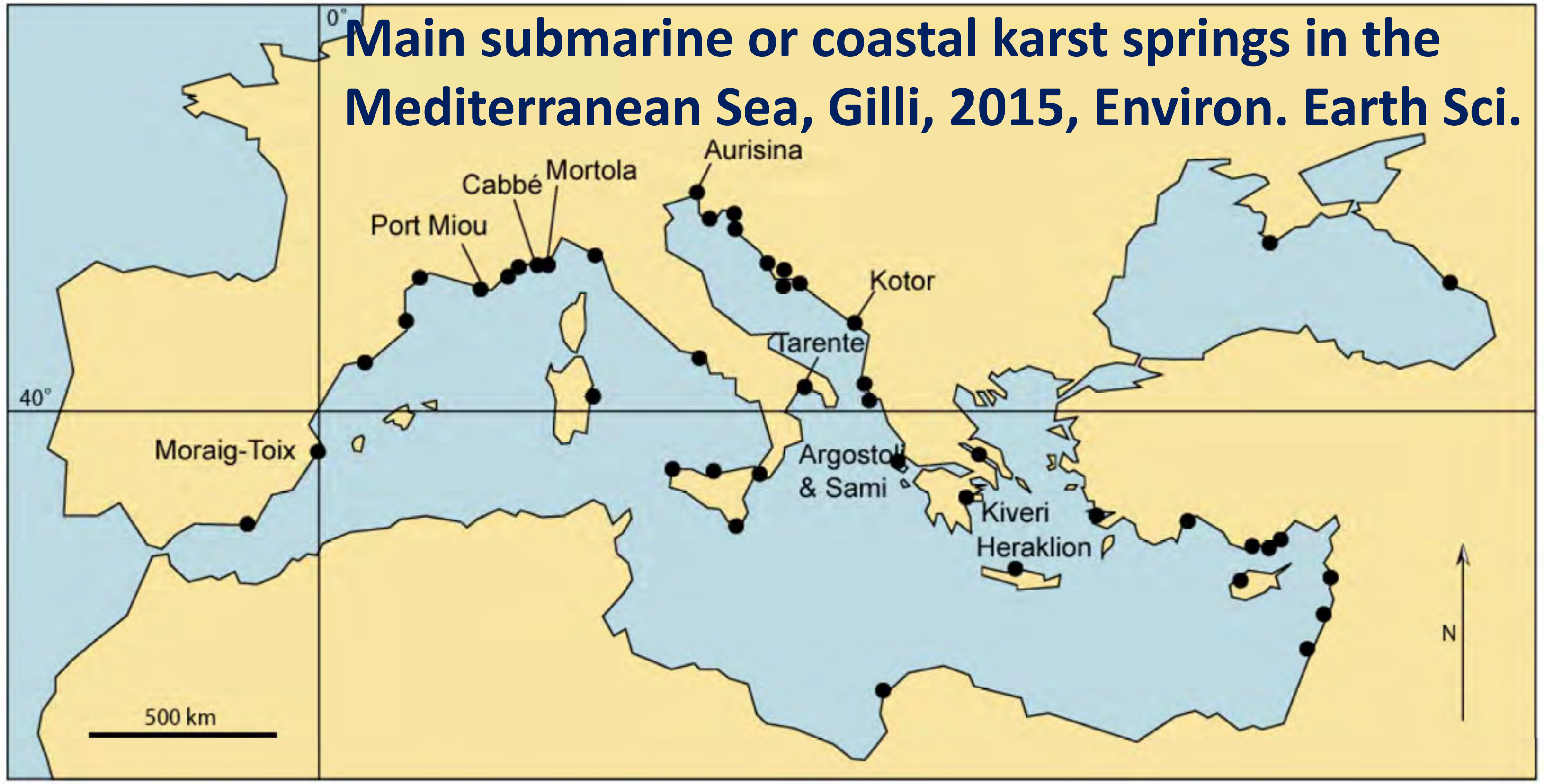
- Total discharge (= obs + nonobs):

  ASSIM > CEFREM (LR HR) **(by nonobserved discharges ?)**



Possible sources of excess freshwater flows into the Mediterranean




Main submarine or coastal karst springs in the Mediterranean Sea, Gilli, 2015, Environ. Earth Sci.

The largest differences are in regions with complex coastlines: Agean, Balkan and Italy.

Some explanations are:

- Small un-gauged rivers.
- Submarine groundwater discharge (SGD) and kastic systems

Some extimates of SGD to the Mediterranean sea:

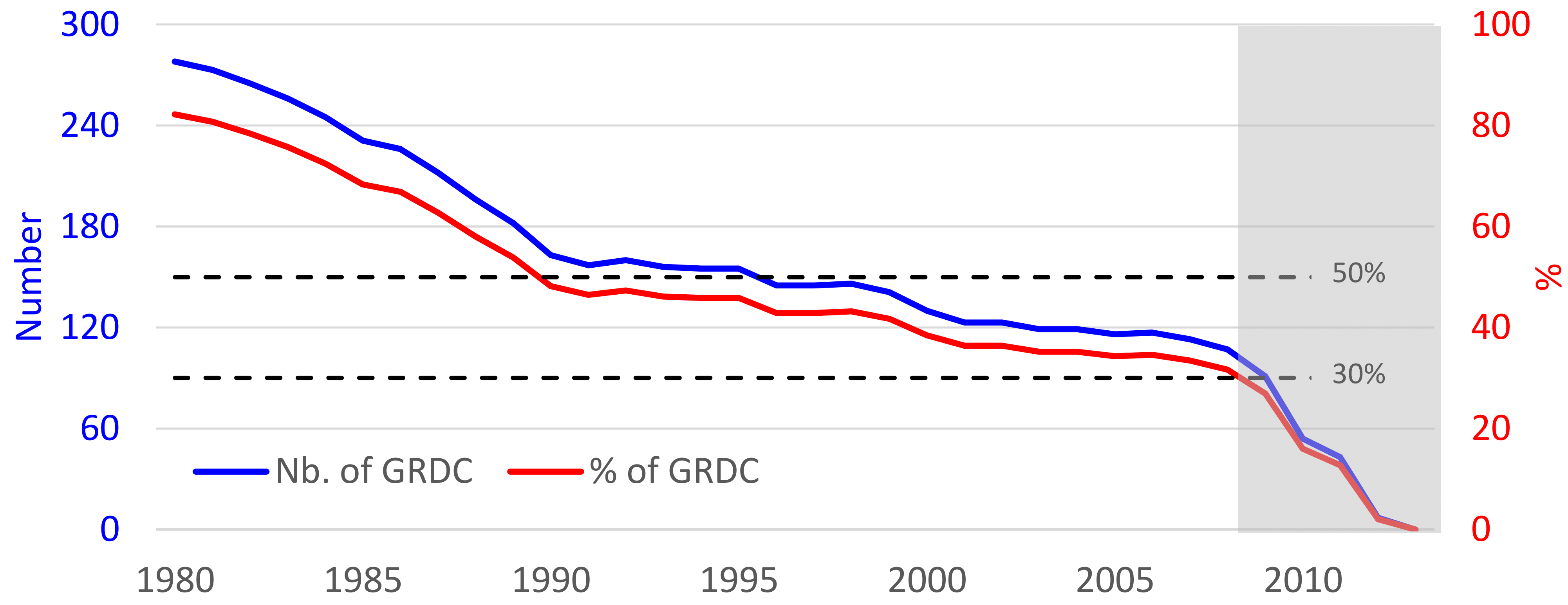
- 52 km^3/y by UNESCO (2004),
- 68 km^3/y by Zektser et al. (2007),
- 300-4800 km^3/y (fresh+saline), Rodellas et al. (2015)
- Karst: Nearly 75% of total freshwater (UNESCO)

SGD of Black sea: 16 km^3/y Schubert et al. (2017)

Why SGD is important ?

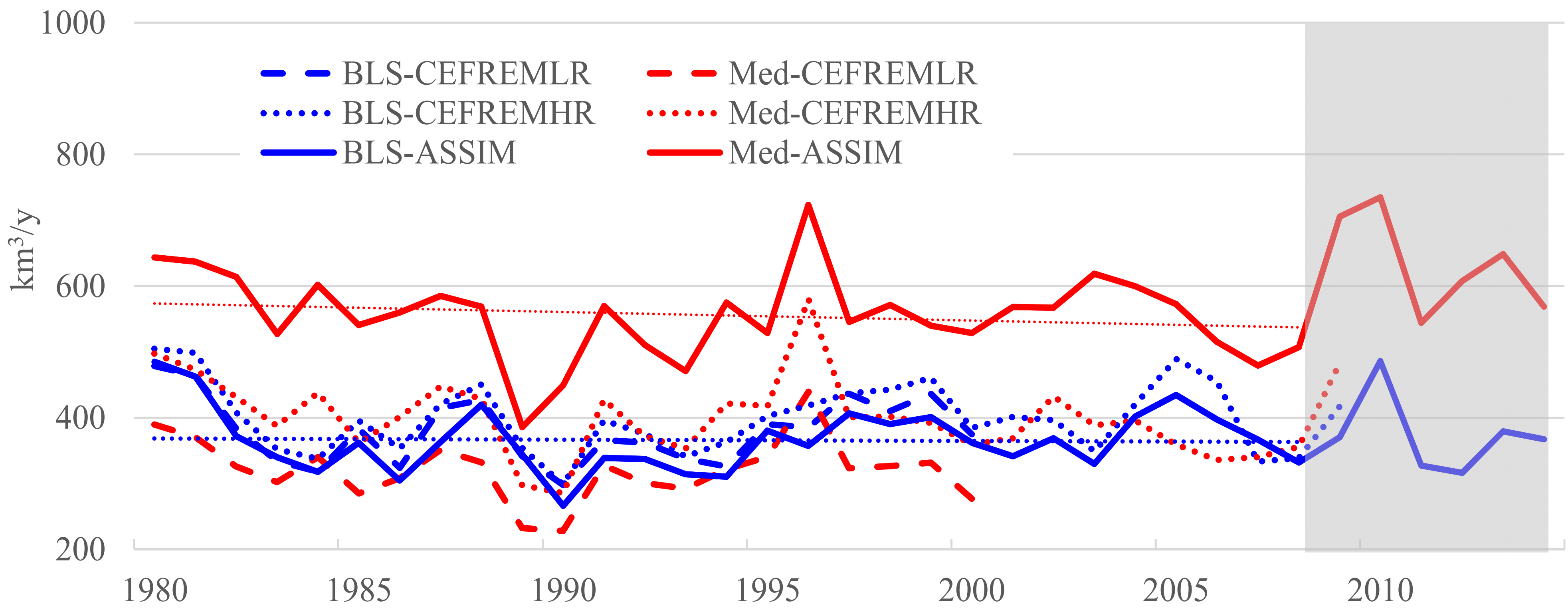
- Strategic freshwater resources
- Important source of nutrients (eutrophication)
- Water cycle

Trend of riverine fresh water (1980-2008)



← **Number** and **percentage** of assimilated GRDC stations:

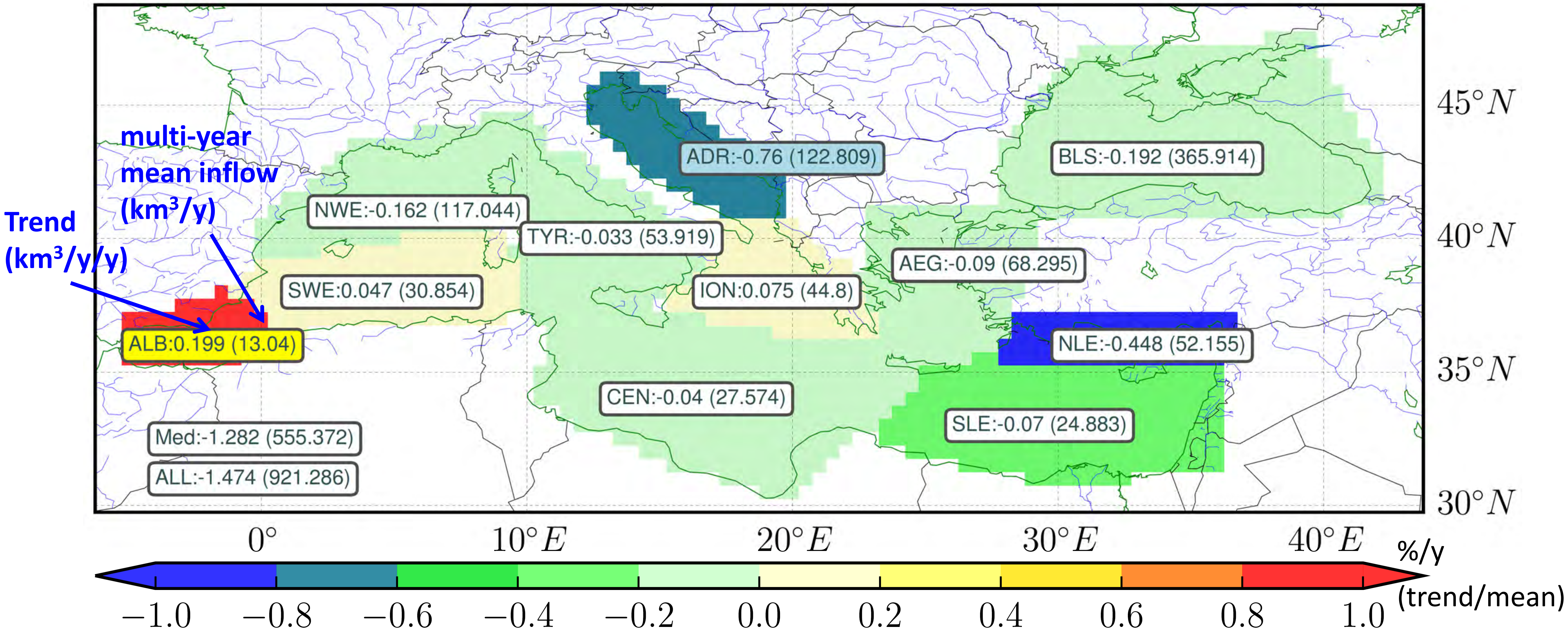
- Decrease from 1980 to 2013
- <50% (after 1990), <30% (after 2008)



← **Trend** of fresh water into **the Mediterranean** and **the Black** sea

- Period dependent;
- Not significant 1980-2008.

Trend of assimilated fresh water over each sub-basin (1980-2008)



multi-year mean inflow (km^3/y)

Trend ($km^3/y/y$)

%/y (trend/mean)

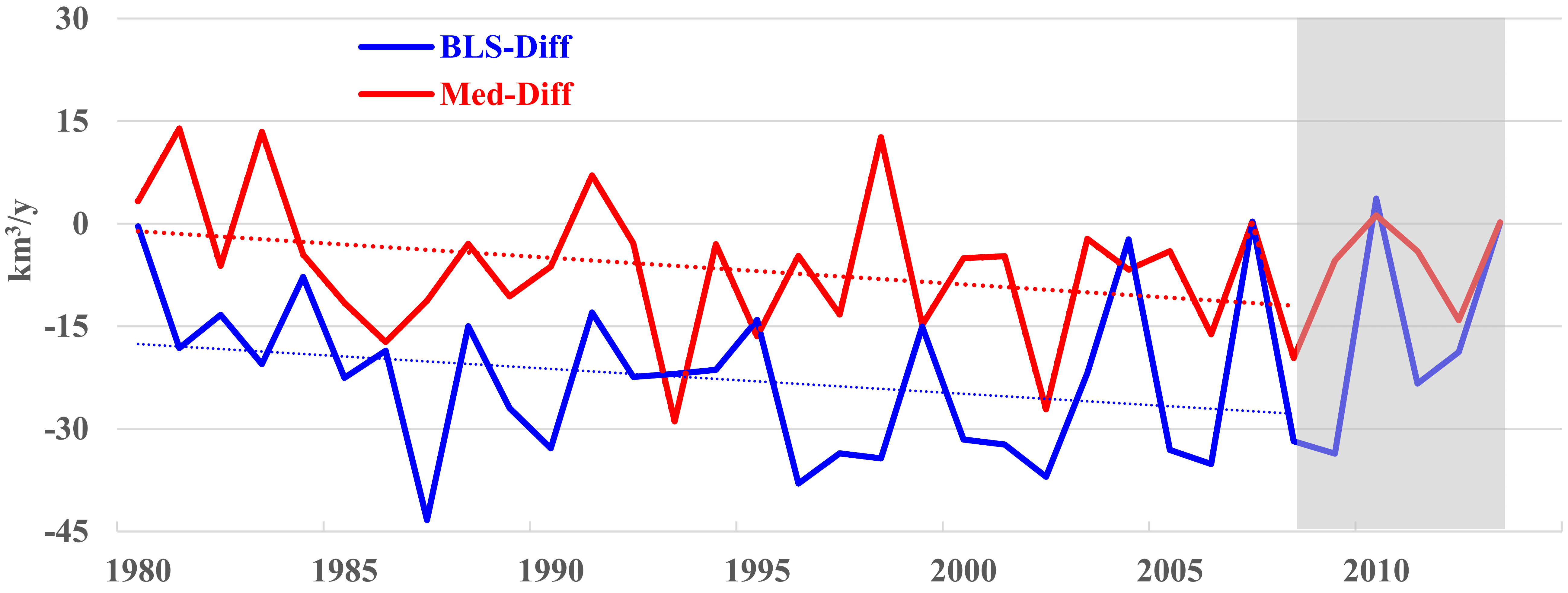
Statistical significant: Increase | No change | Decrease

Increasing trend over the Alboran (ALB) basin

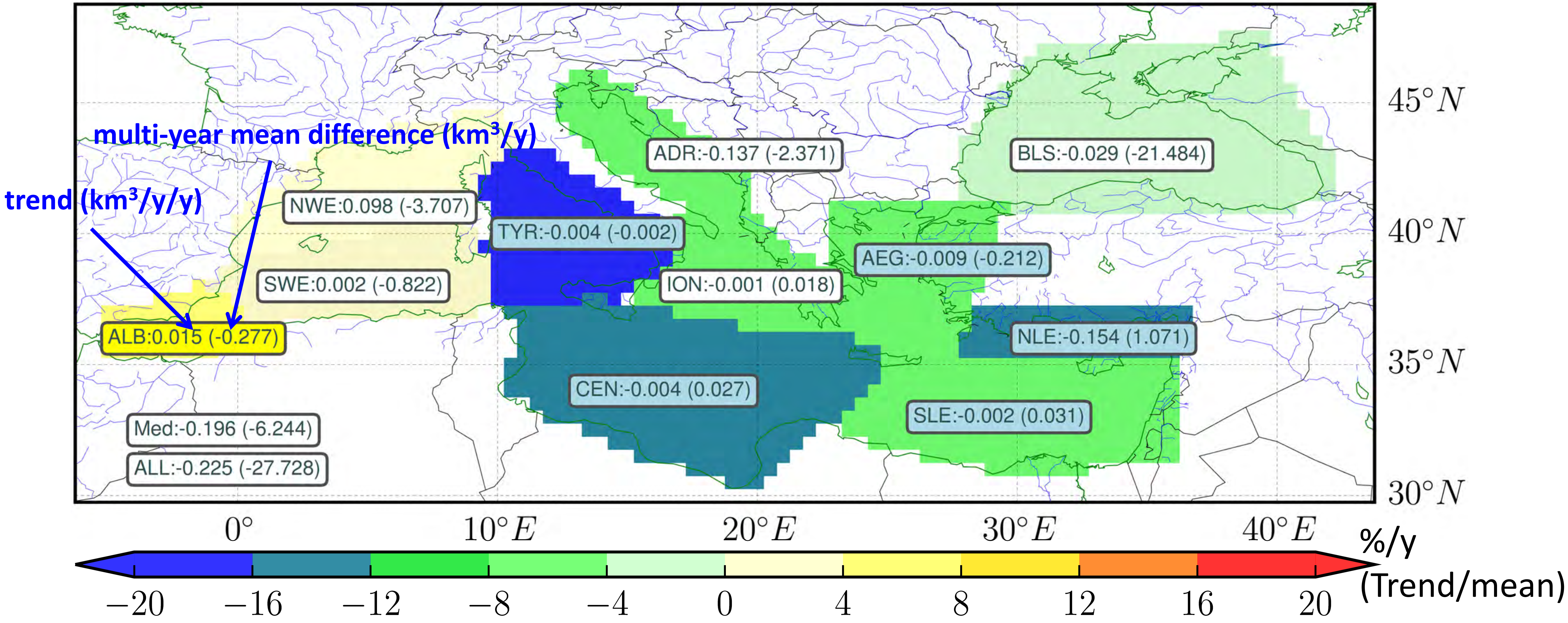
Decreasing trend over the Adriatic (ADR) basin

Trend of the diffrence between assimilated values (ASSIM) & LSM (1980-2008)

- LSM: estimation of the freshwater flux where only climate changes.
- ASSIM: a time varying correction includes different processes: (1) Climate dependent bias of LSM. (2) bias in atmospheric forcing. (3) Model missing processes (e.g., water usage).
- Diff = ASSIM-LSM only retain the time evolution of climate independent trends.
- Changes in 'Diff' → changes in water usage and their impact on the freshwater flux to the ocean.
- **Significant decrease (1980-2008), associated to non climatic factors (-0.39 km^3/y/y for Med, -0.75 km^3/y/y for Black sea).**



Trend of ‘ASSIM – LSM’ over each sub-basin (1980-2008)



Statistical significant: Increase | No change | Decrease

Increasing trend over ALB basin

Decreasing trend over TYR, CEN, AEG, NLE, SLE basins

Conclusions and future directions

- **Conclusions:** freshwater estimated by assimilation (338 GRDC): 1980-2013, daily scale.
  - The Mediterranean: assimilated values (558 km^3/y) > previous (300-400 km^3/y; e.g., 328-387 km^3/y by Ludwig et al., 2009)

    -- Difference in non-observed regions

    -- Submarine groundwater discharge (e.g., 300-4800 km^3/y, Rodellas et al., 2015)
  - Trend (1980-2008): 'Assim-LSM' decreases (non climatic factors).
- **Future direction:**
  - Uncertainty (perturb correction factor → ensemble fresh water).
  - Larger domain (e.g., global)
  - Impacts on ocean circulaiton.

Thank you !