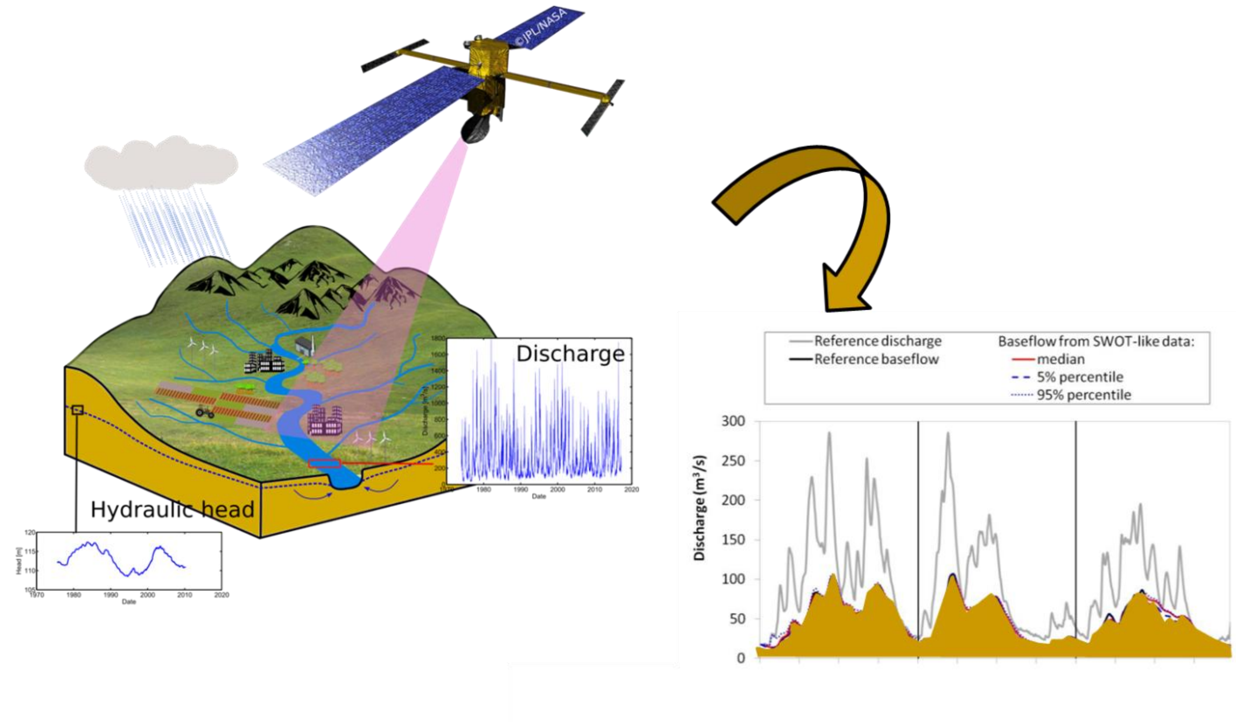
Retrieving baseflow of large rivers from space with the future SWOT mission



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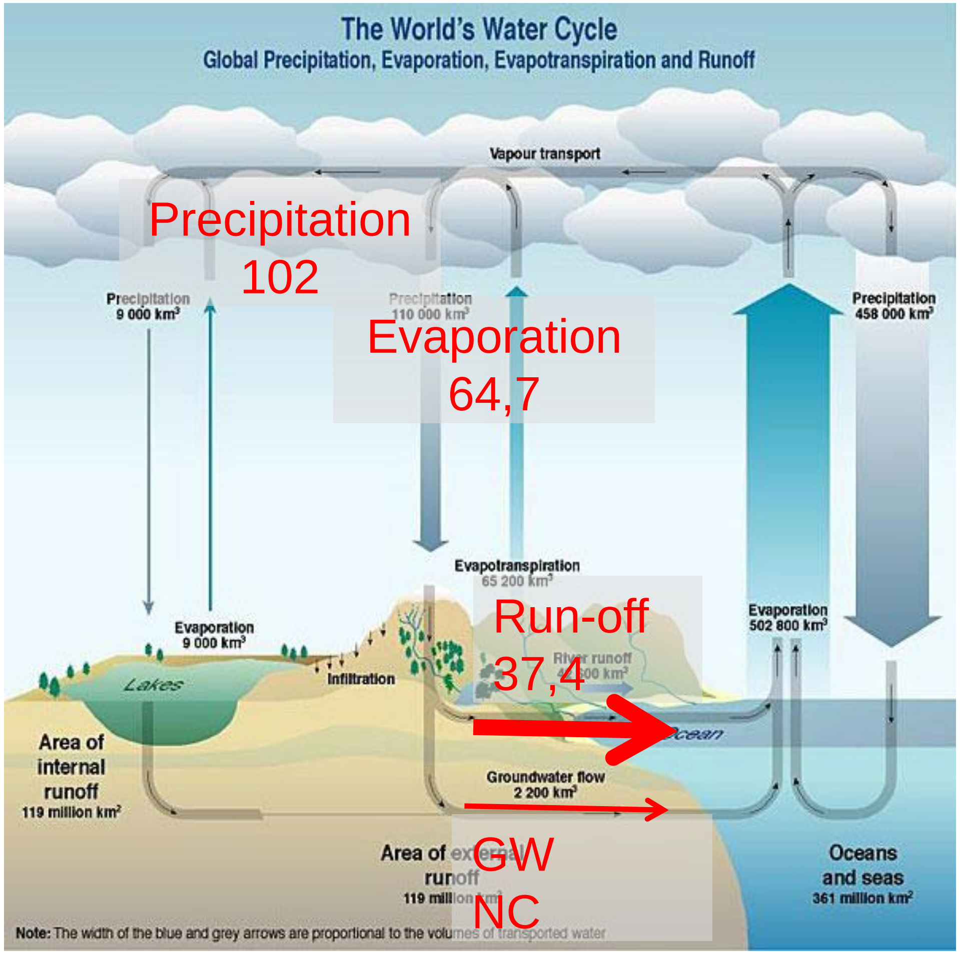
LEGOS

Water Cycle

- **From observations and coarse approximations[1] …**



Fluxes in 10^3 $km^3.a^{-1}$

[1]Synthesis by Lvovitch 1978 World Water Balance

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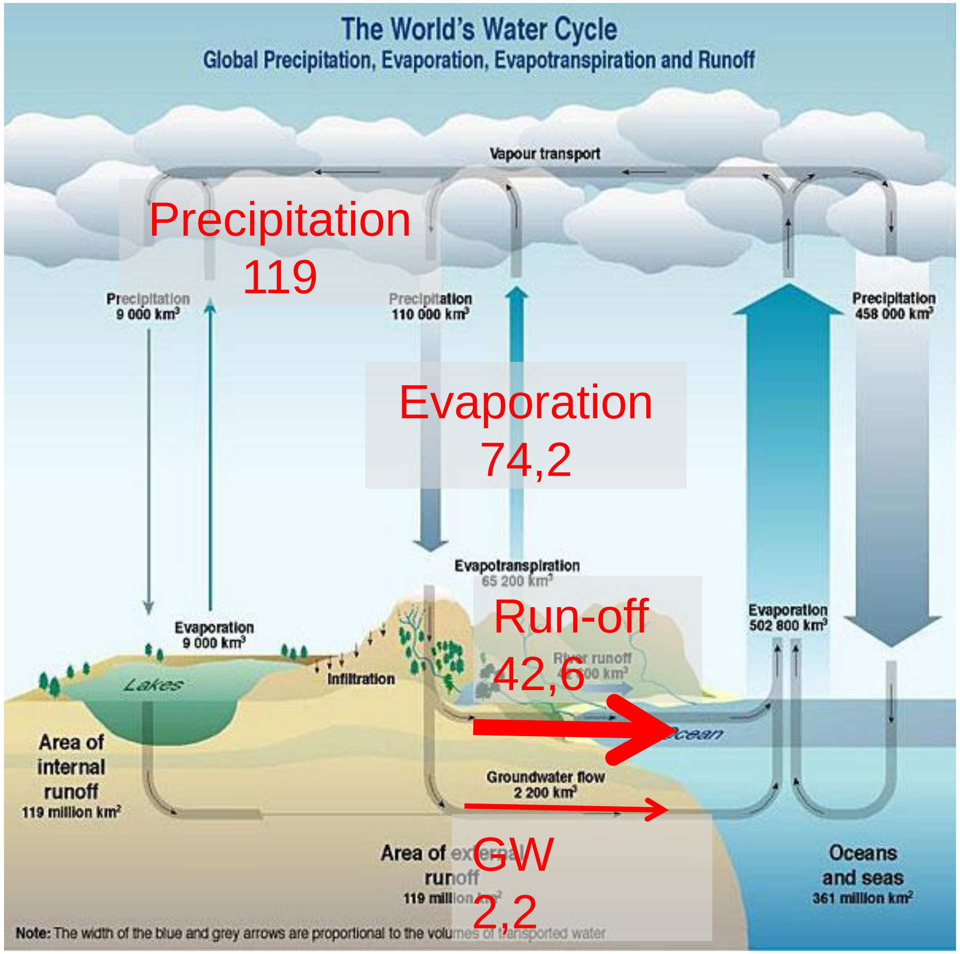
Water Cycle

- **From observations and coarse approximations[1] …**



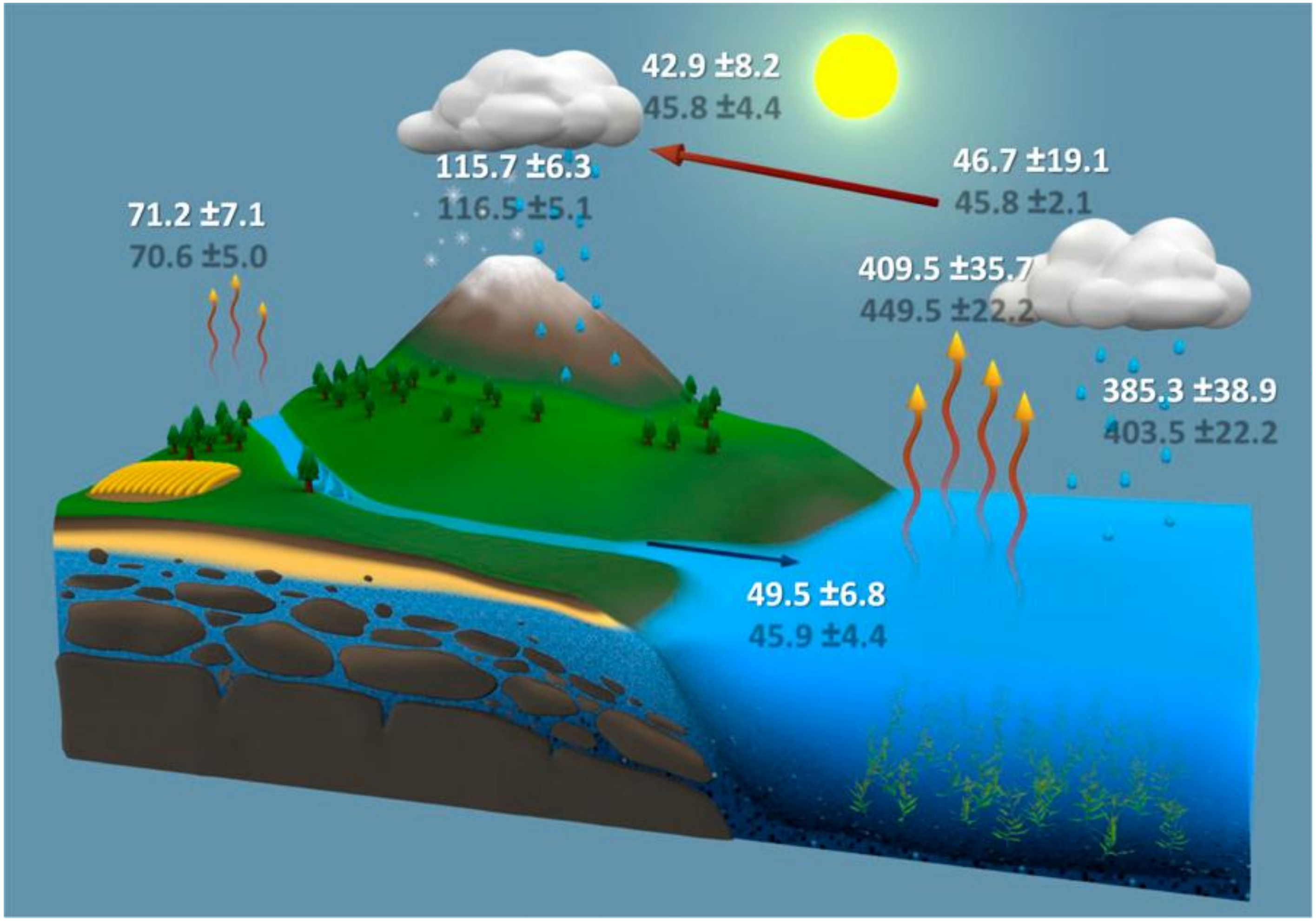
Fluxes in 10^3 $km^3.a^{-1}$

[1]Synthesis by Shiklomanov 1994 for UNESCO based on earlier studies

Water Cycle

Fluxes in $10^3\ km^3.a^{-1}$

- **To remote sensing and models**[2]

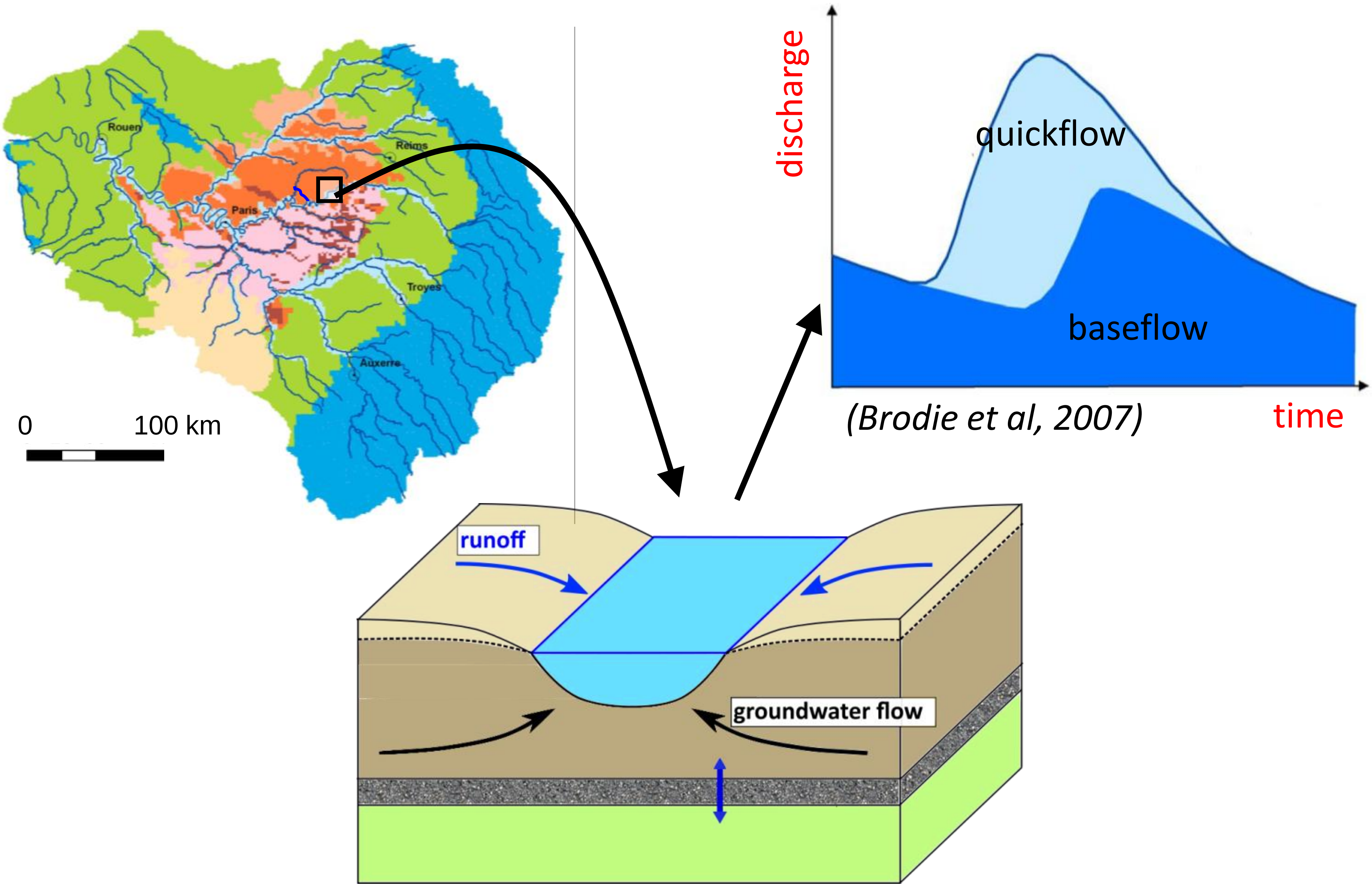


[2]Synthesis by Rodell et al. 2015 Journal of Climate

How to assess groundwater contribution to river flow?

- **Estimate surface-groundwater exchanges**
  - No direct measurements in most of the cases even at the local scale
    - Seepage meter
- **Remote sensing : gravimetry with GRACE (Tapley et al, 2004, GRL)**
  - Difficult to deconvoluate various processes (lake, soil, river floodplain, aquifer units) but feasible for large basins → Amazon River Basin (Tourian et al., 2018, WRR)
- **Model needs a proper conceptualisation and validation**
  - Flux data is the most valuable information for GW system calibration (Hunt et al 2006, JH)

River baseflow in a river basin



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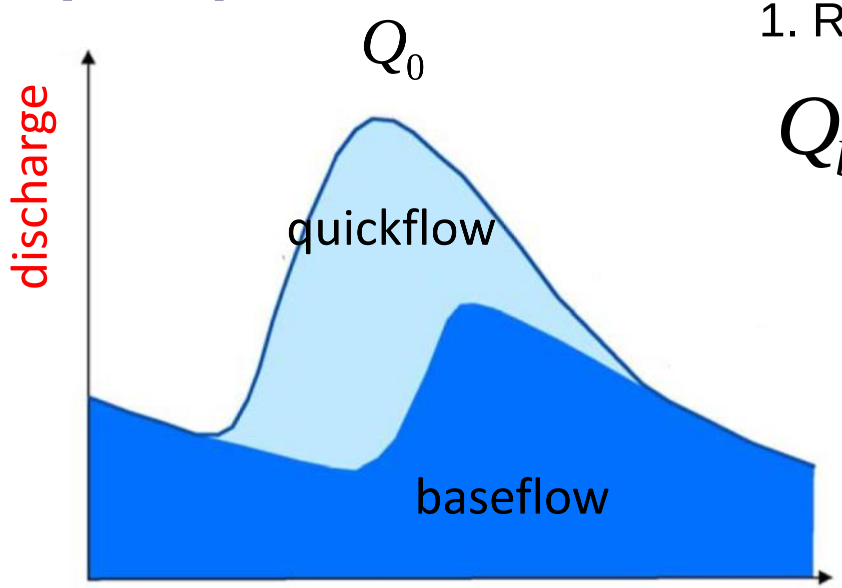
River baseflow

- **Use of the Chapman filter as a proof of concept (Chapman 1999, HP) based on Lyne and Hollick (1979)**



(Brodie et al, 2007)

1. Recession time

$$Q_b(t) = Q_0 e^{-t/\tau} = Q_0 k^t$$

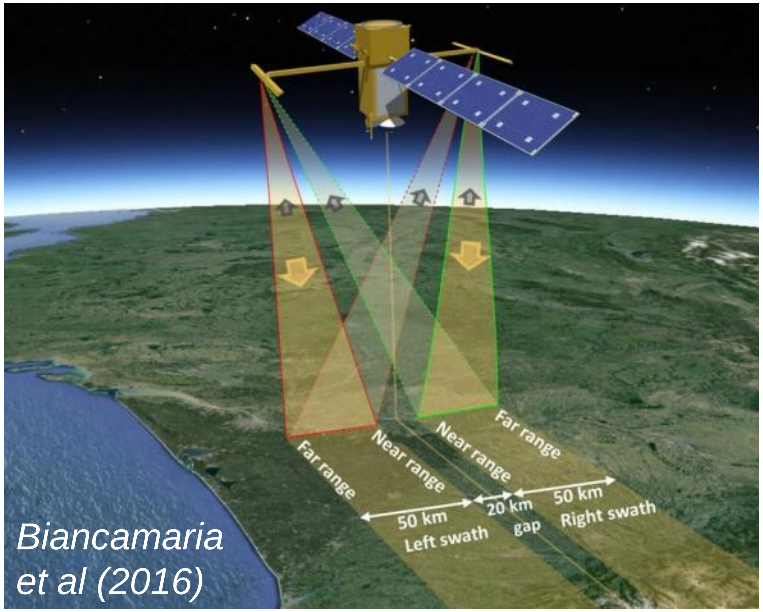
2. Recursive filter

$$Q_b(t) = \frac{k}{2-k} Q_b(t-1) + \frac{1-k}{2-k} Q(t)$$

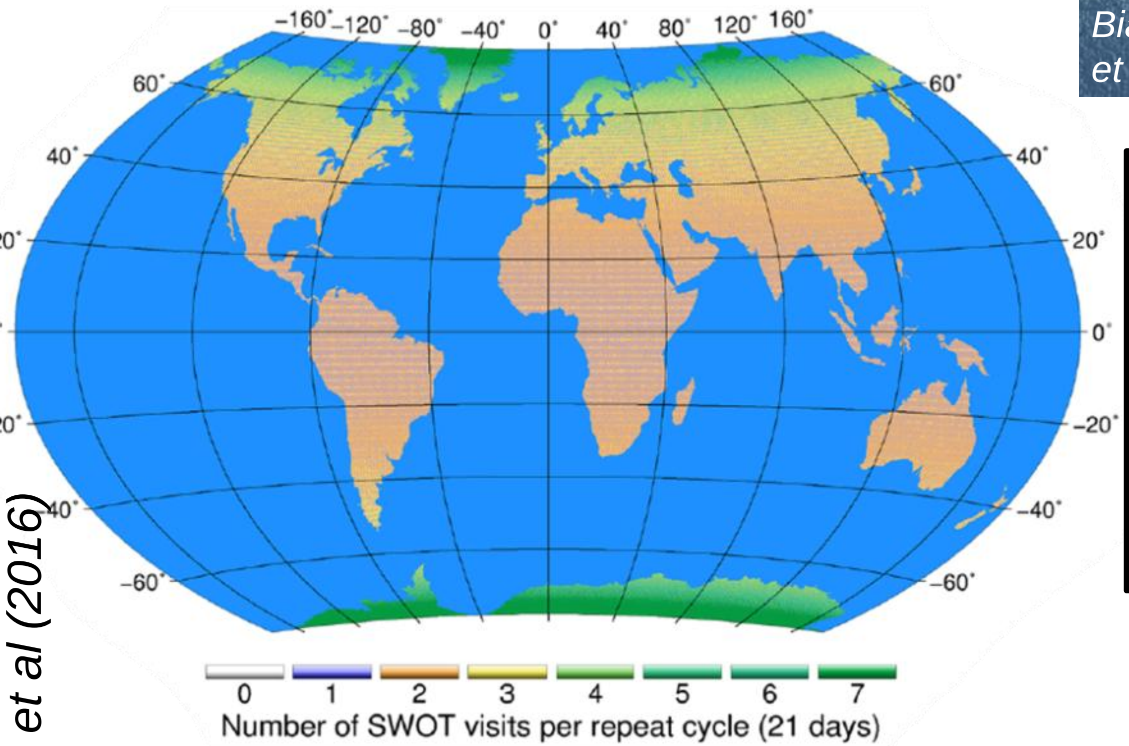
River discharge from SWOT

SWOT (Surface Water and Ocean Topography)

- oceans - land surface water topography
- **river discharge**
- river width > 100 m
- improves GRDC observation extent



Biancamaria et al (2016)



Biancamaria et al (2016)

➔ Can **baseflow** be estimated at **global** scale from **SWOT** observations during the mission lifetime?

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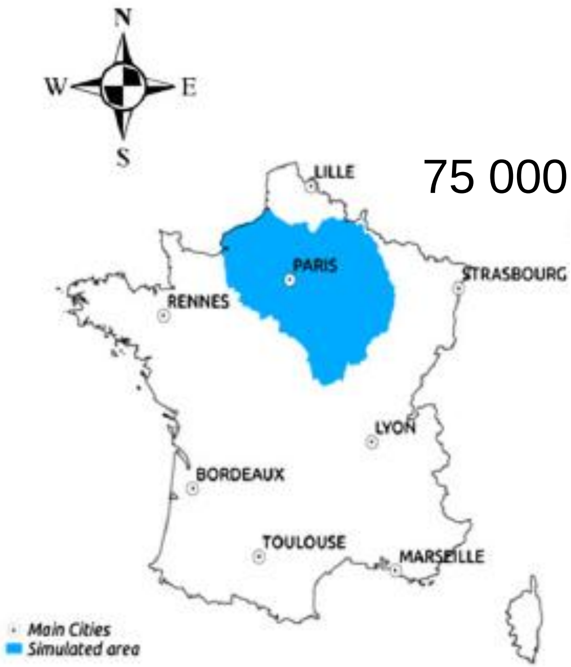
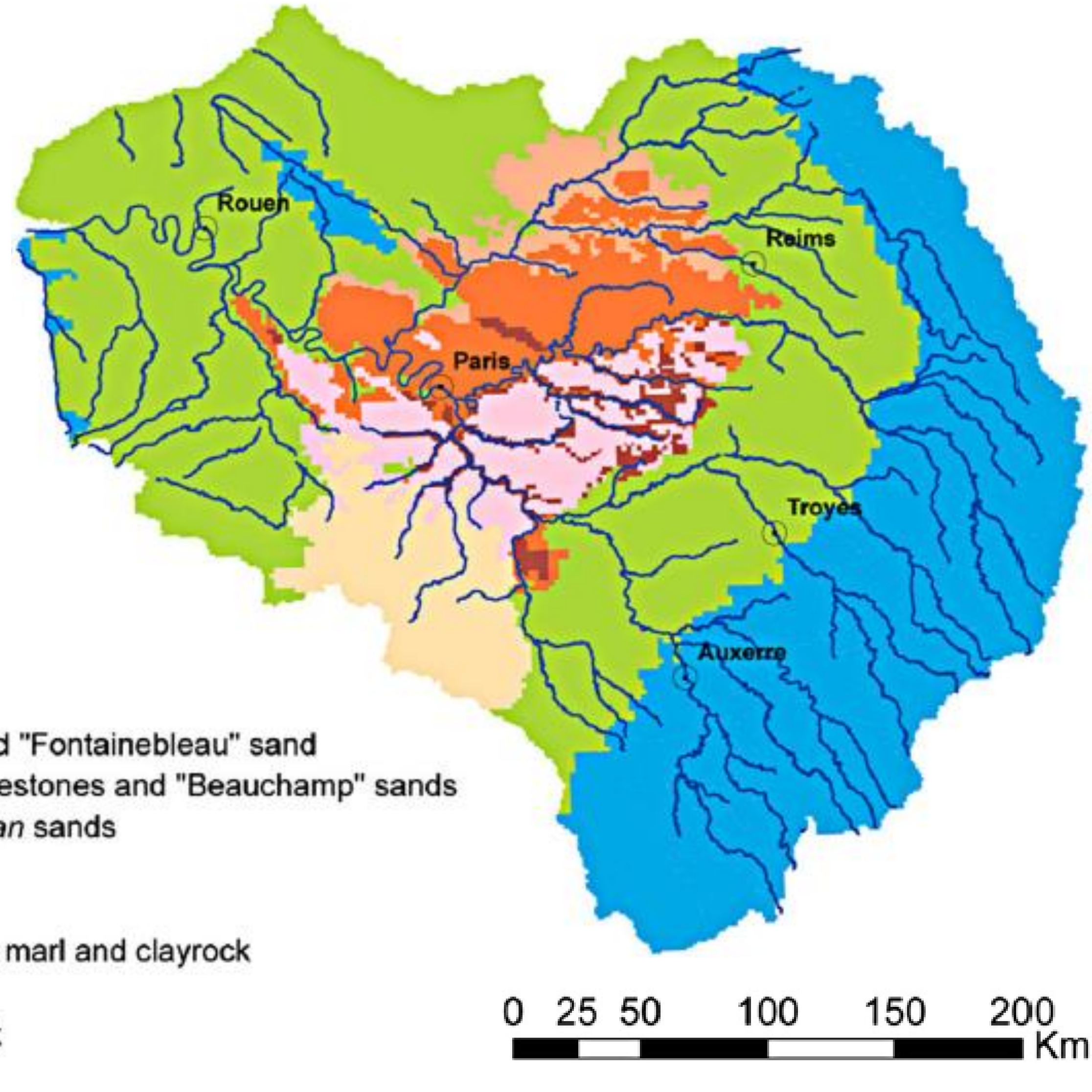
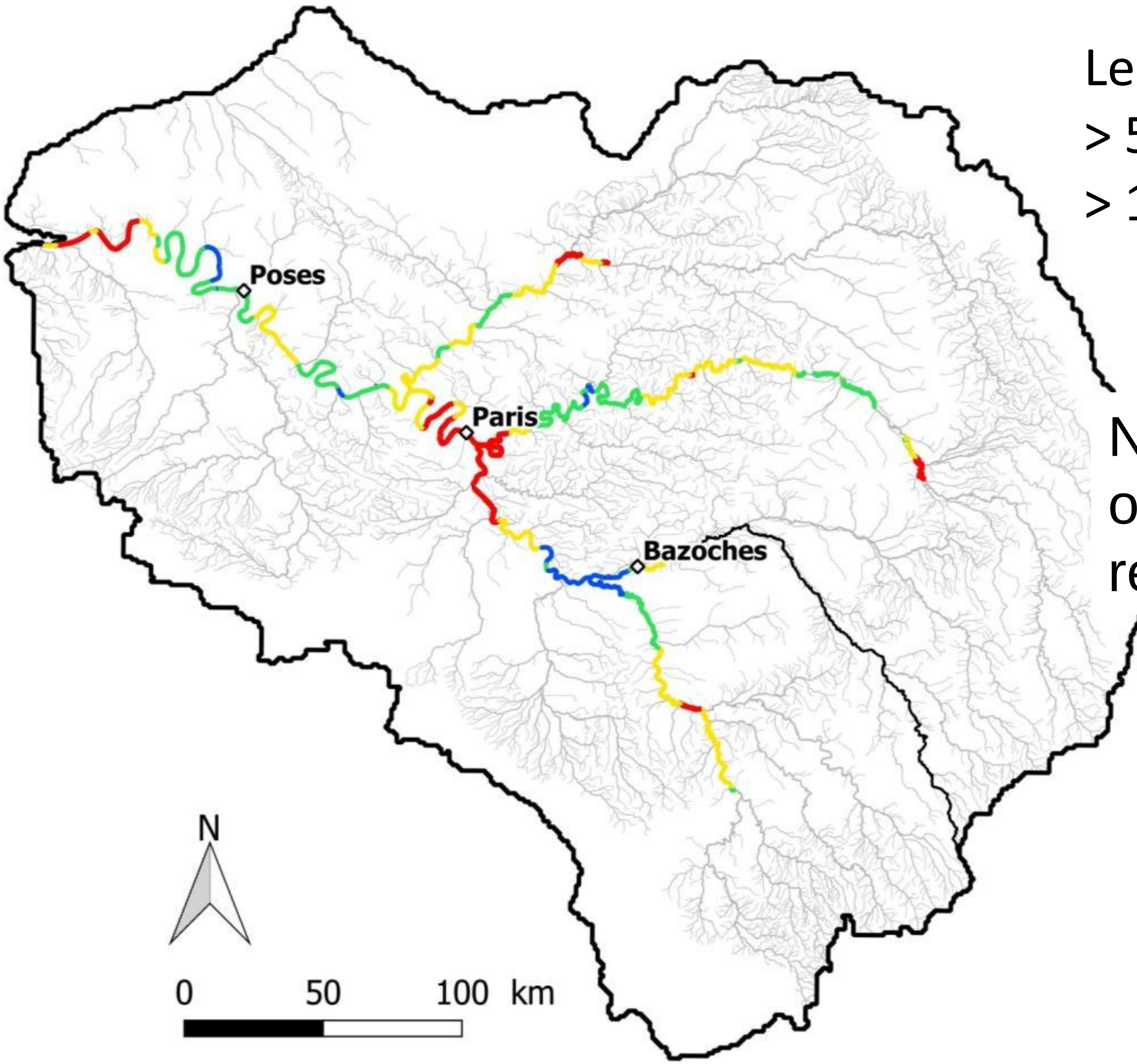
The Seine River Basin

75 000 km^2





Observation by SWOT



Length	28 000 km
> 50 m	1060 km
> 100 m	600 km

Number of SWOT observations per repeat cycle (21 days)

- 1 (16 %)
- 2 (43 %)
- 3 (30 %)
- 4 (9 %)

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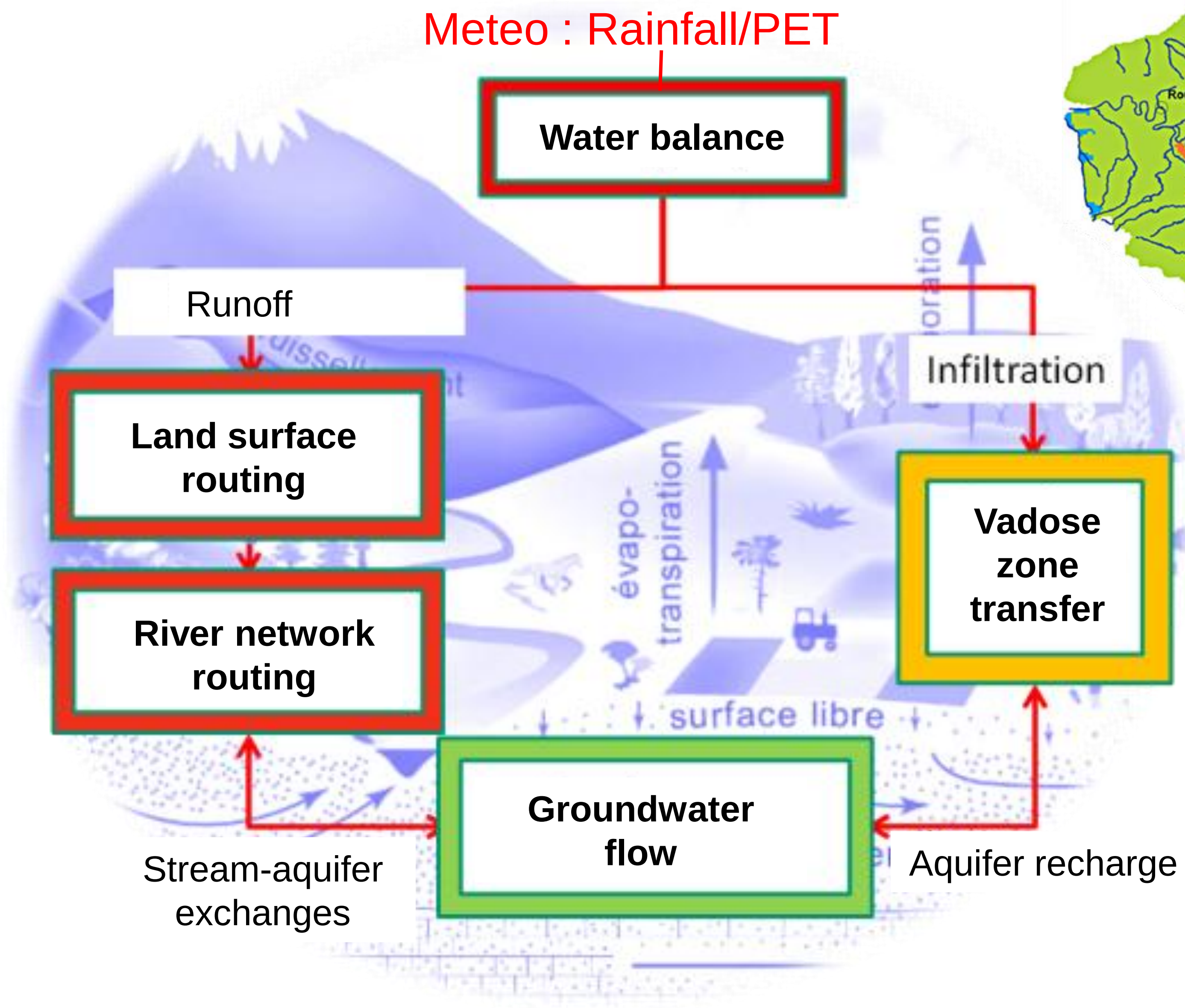
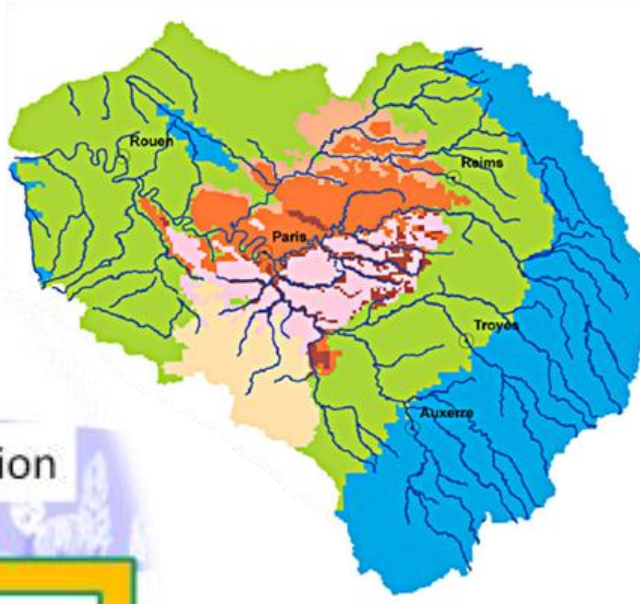
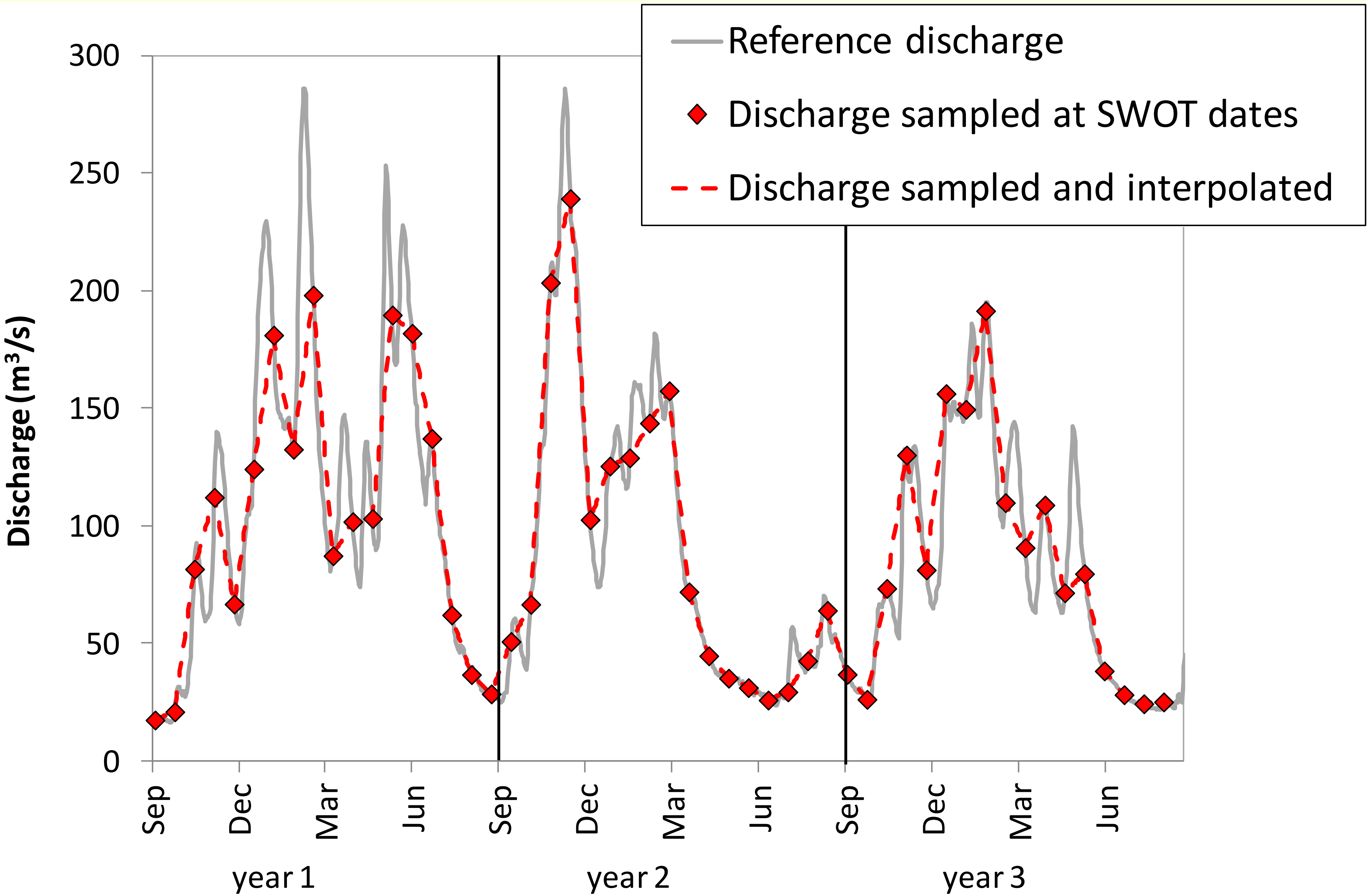
Data simulation with the CaWaQS model





Pryet et al 2015, WRM
Flipo et al. 2012, WRR

SWOT sampling effect



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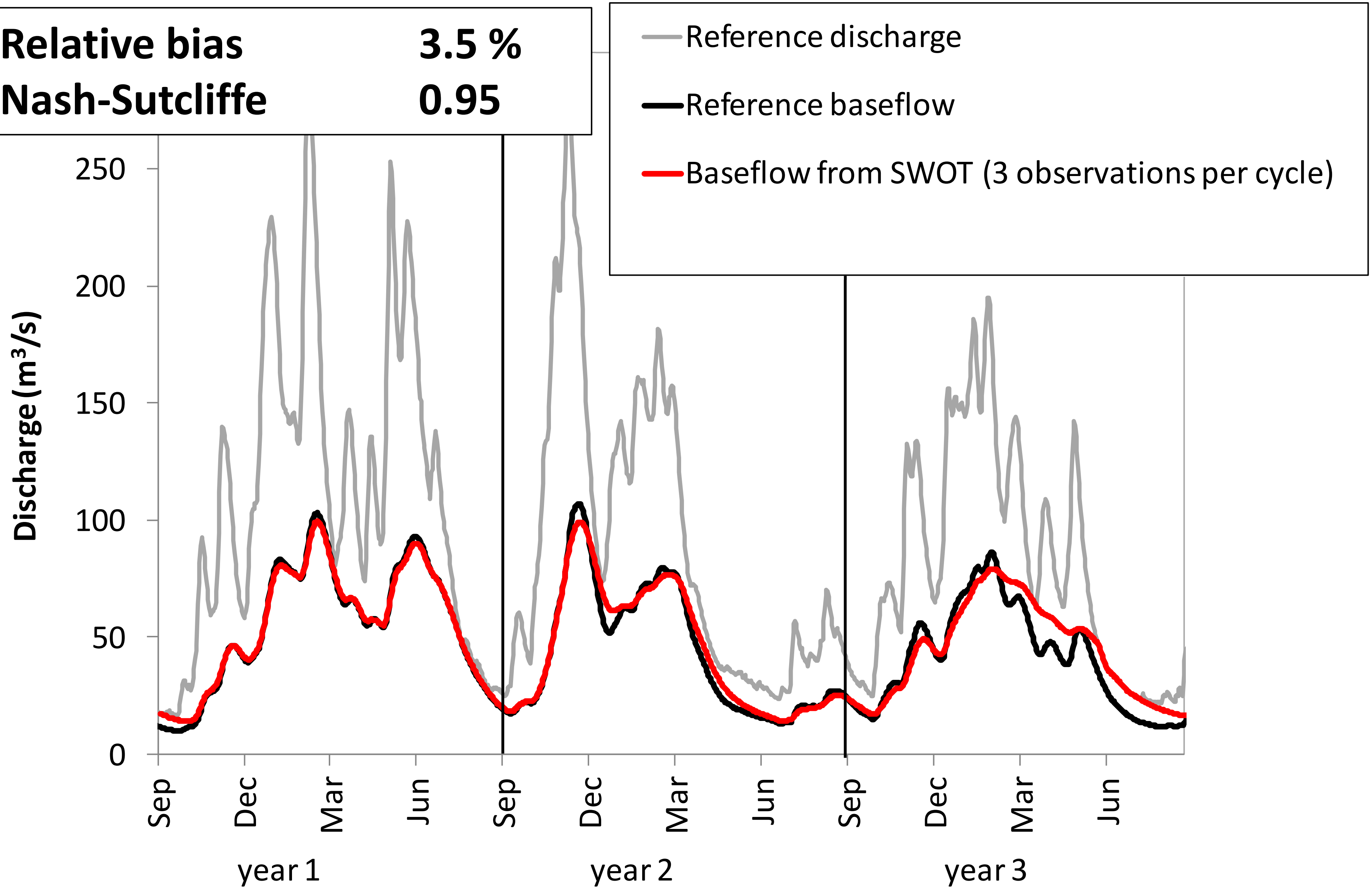
Baseflow estimate – SWOT sampling effect

Relative bias	**3.5 %**
Nash-Sutcliffe	**0.95**



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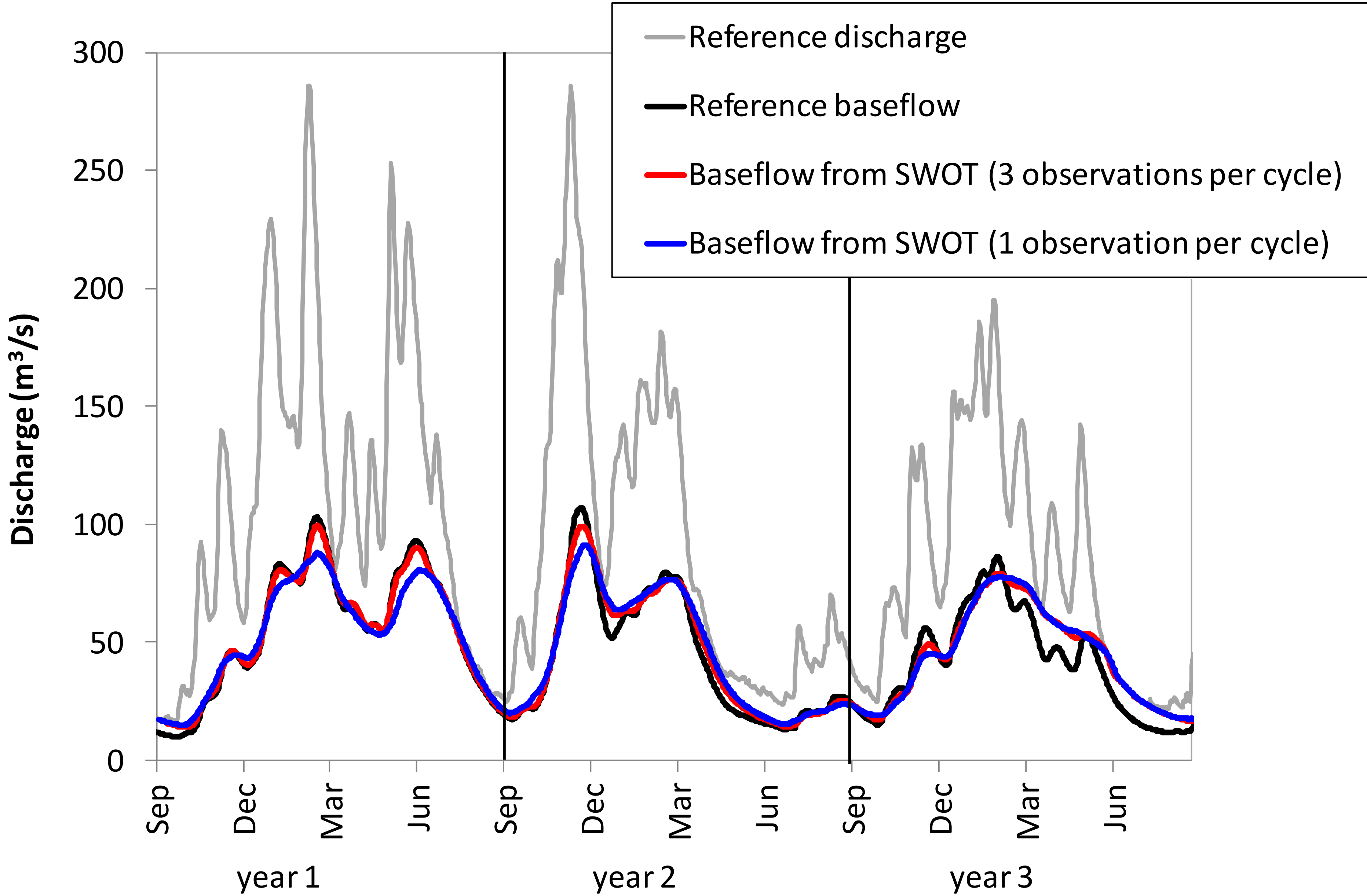
Baseflow estimate – SWOT sampling effect



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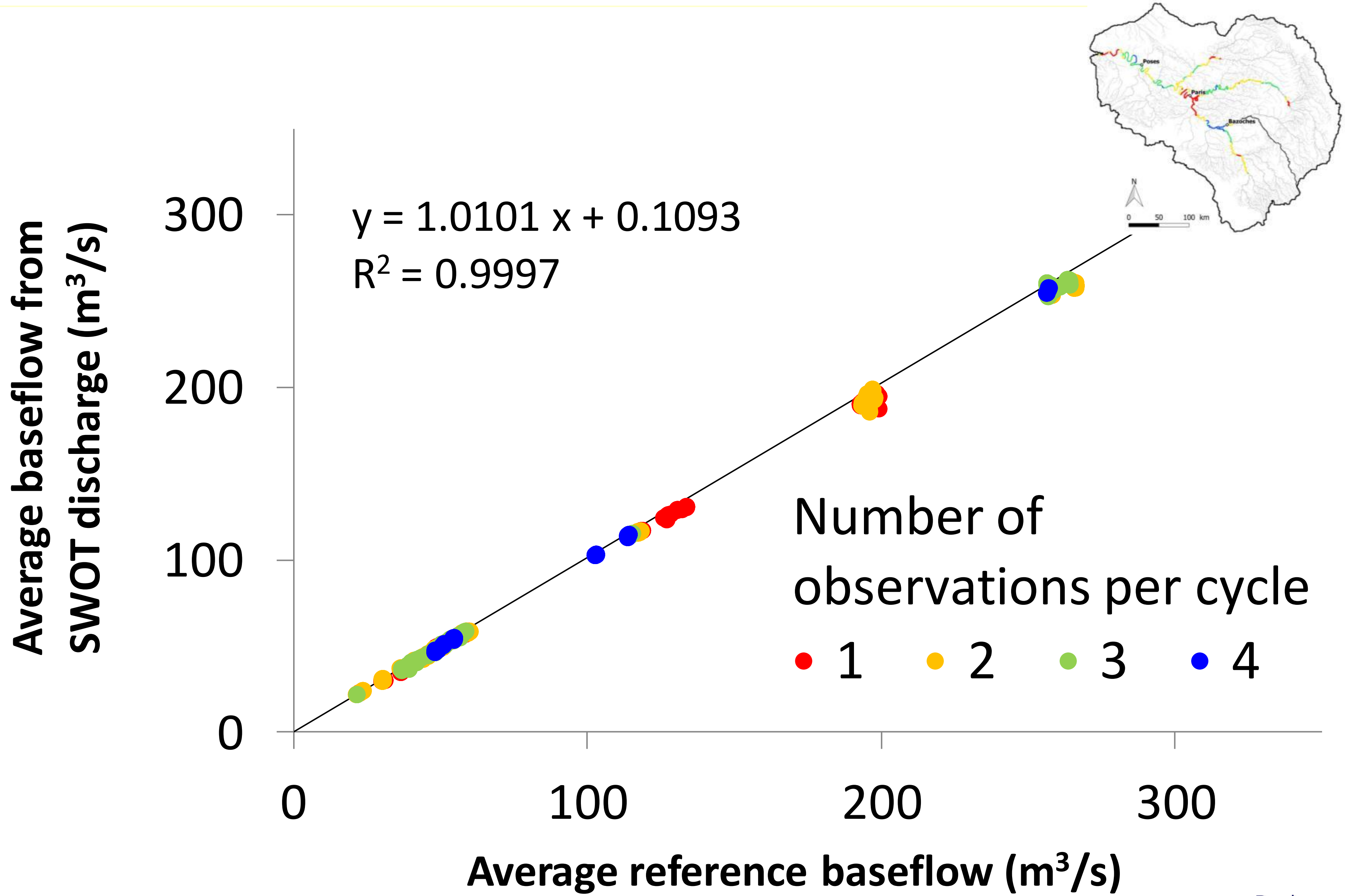
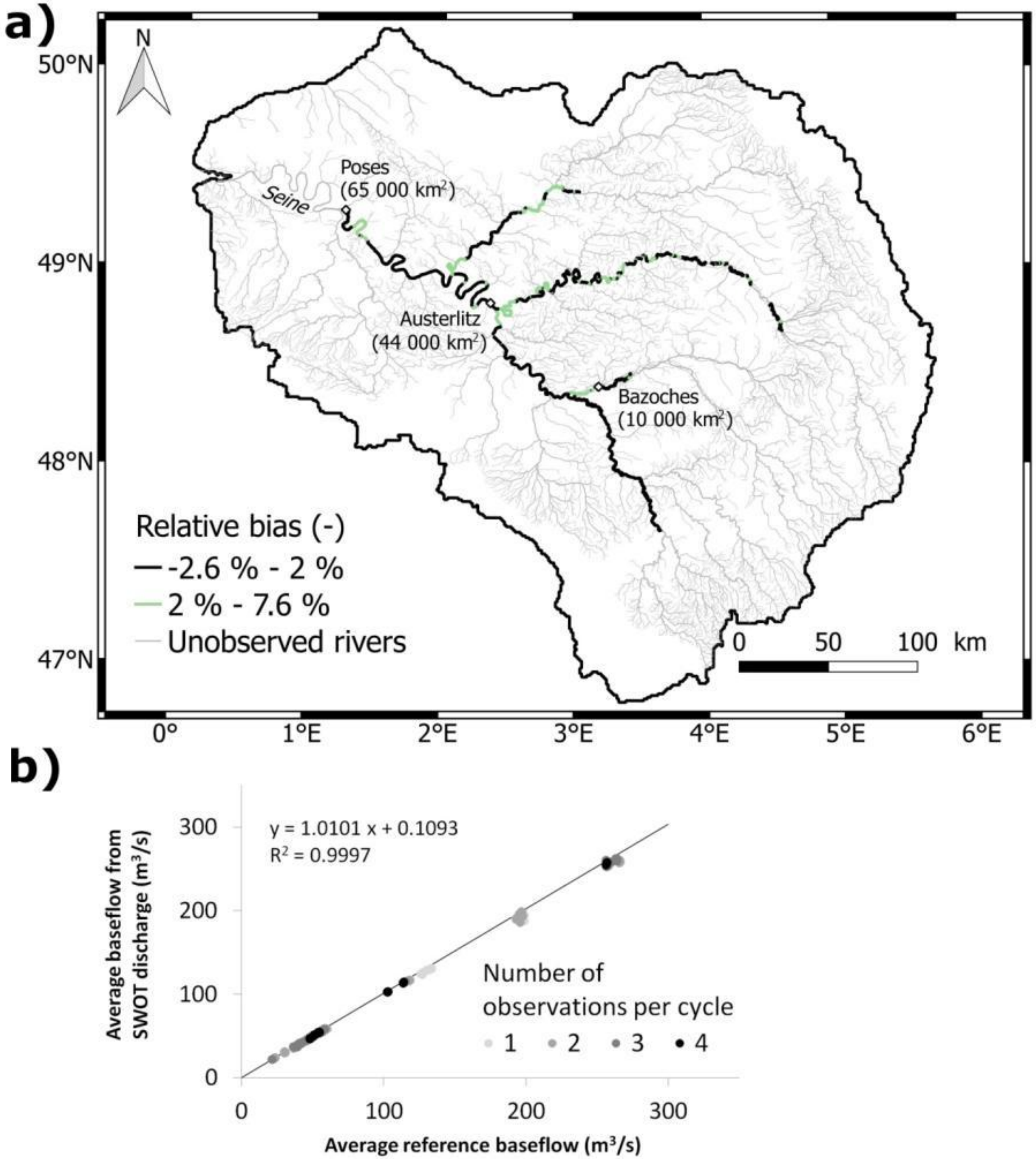
Retrieving river baseflow at the bassin scale



Bordeaux

- Very good estimates of the average baseflow, even with only 1 observation per cycle



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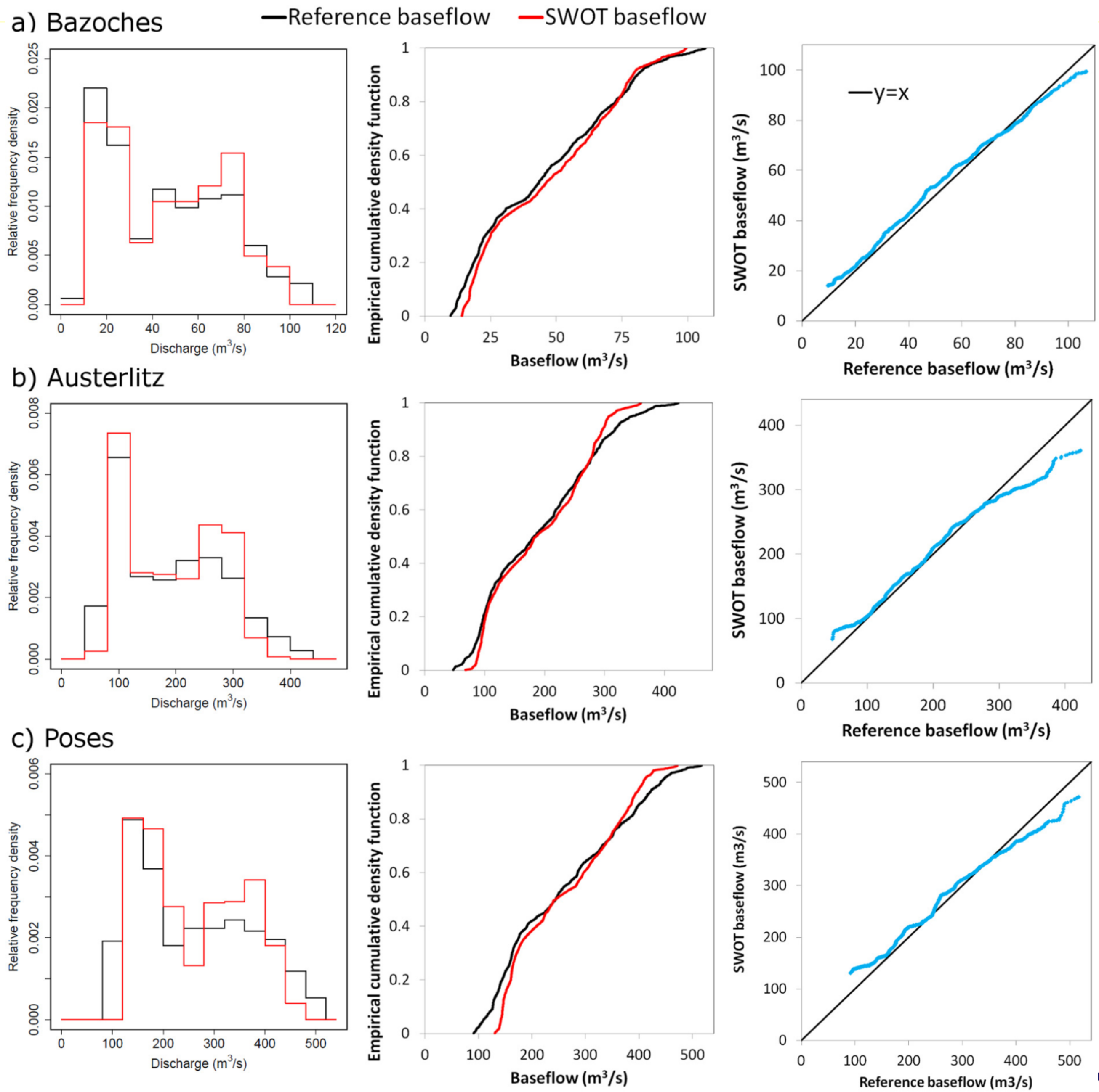
From upstream to downstream

10 000 km2

45 000 km2

65 000 km2

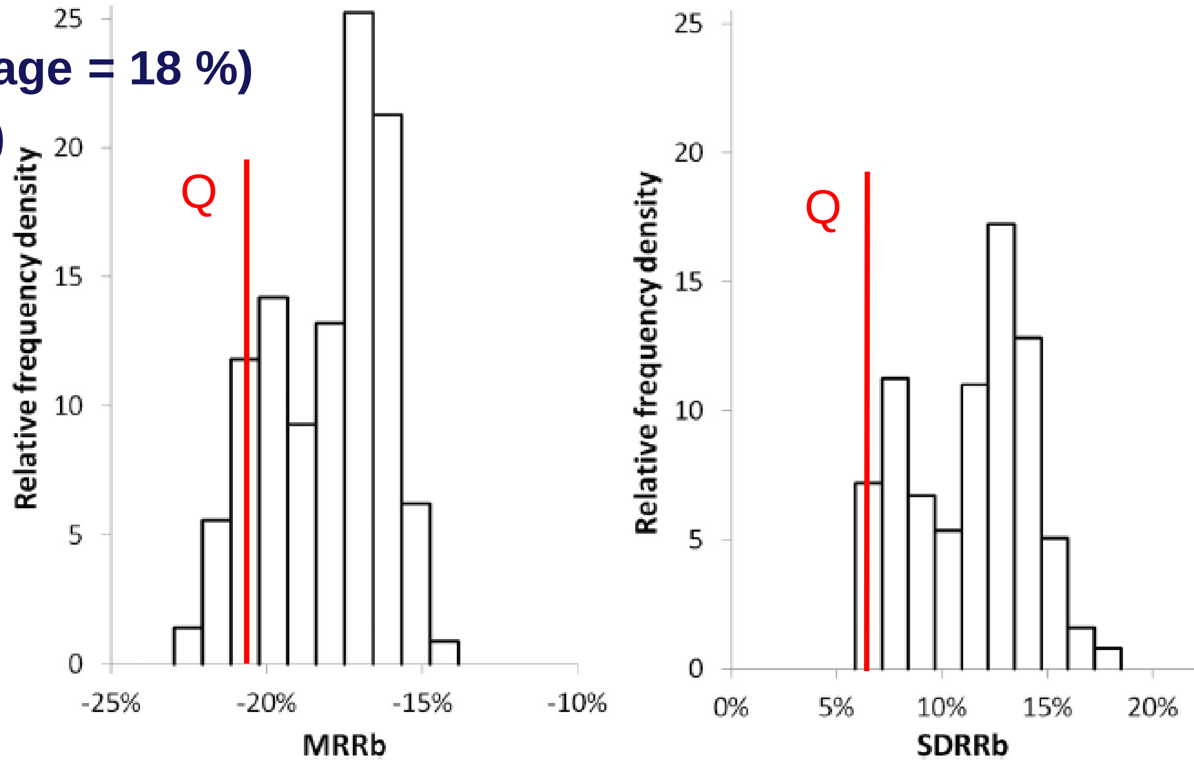


Discharge error propagation

- **Cumulates error on discharge estimate and SWOT sampling**
- **Lognormal error Y (Hagemann, 2017) on discharge estimate Q* for the Seine from Durand et al., 2016**

$$Q^*(t) = y(t)Q(t) \qquad RR = \frac{Q^* - Q}{Q} \longrightarrow y(t) = 1 + RR(t)$$

- **Errors on discharge :**
  - MRR = 21,2%, SDRR = 6.6%
- **MRRb is dampened (average = 18 %)**
- **SDRRb is larger (av=11%)**



Baratelli et al., 2018

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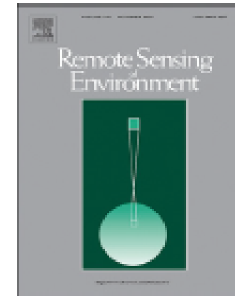
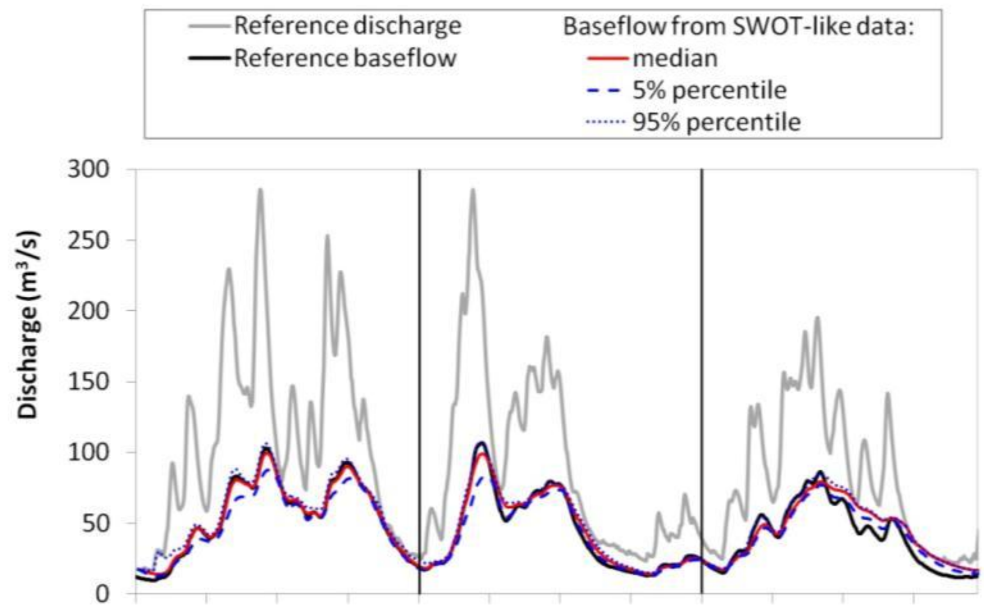


Retrieving river baseflow from SWOT spaceborne mission

Fulvia Baratelli[a,*], Nicolas Flipo[a,*], Agnès Rivière[a], Sylvain Biancamaria[b]

Remote Sensing of Environment 218 (2018) 44–54

- **SWOT** spaceborne mission will provide uncertain **river discharge at global scale**
- We **estimate baseflow** applying a filter to SWOT-like river discharge
- Baseflow is retrieved from SWOT-like data in the Seine river basin **with good accuracy**
- **Uncertainties** on baseflow estimates are always slightly **lower than those on discharge**
- SWOT will potentially provide baseflow estimates with unprecedented **global coverage**



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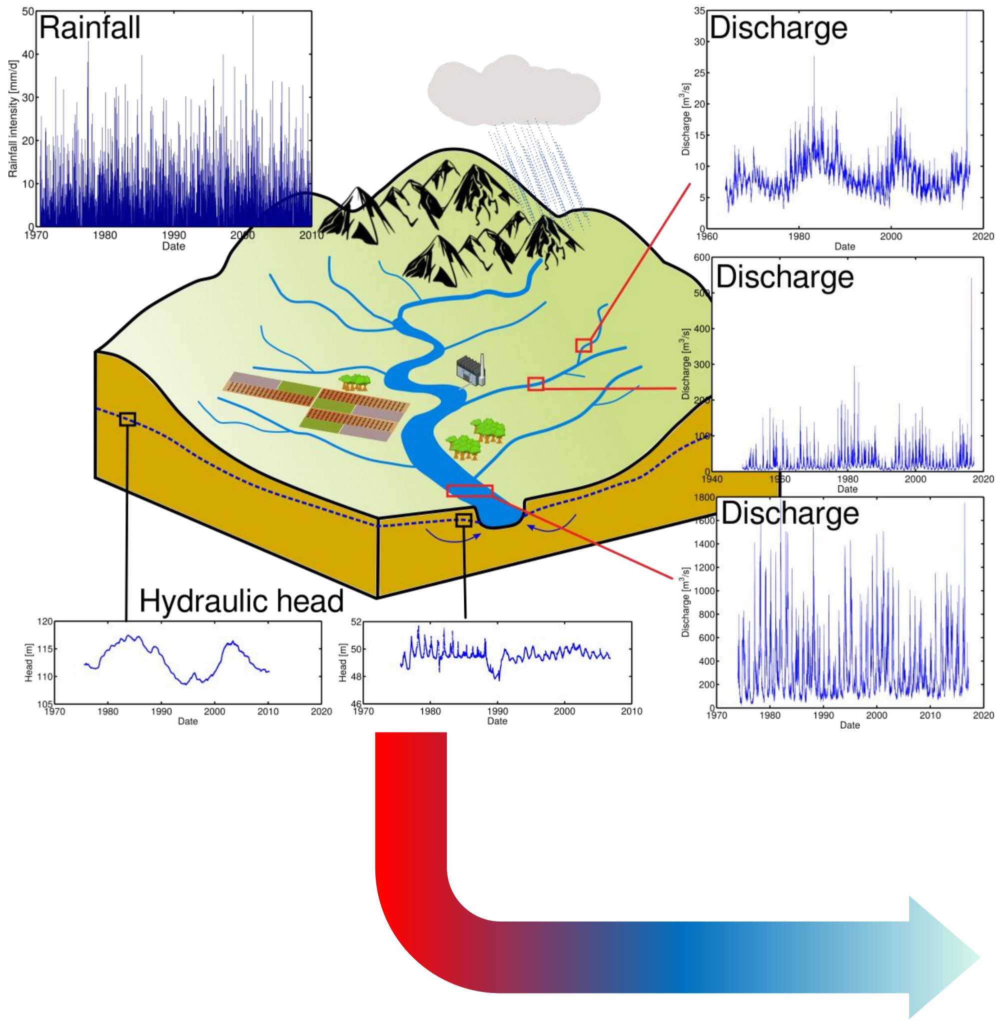
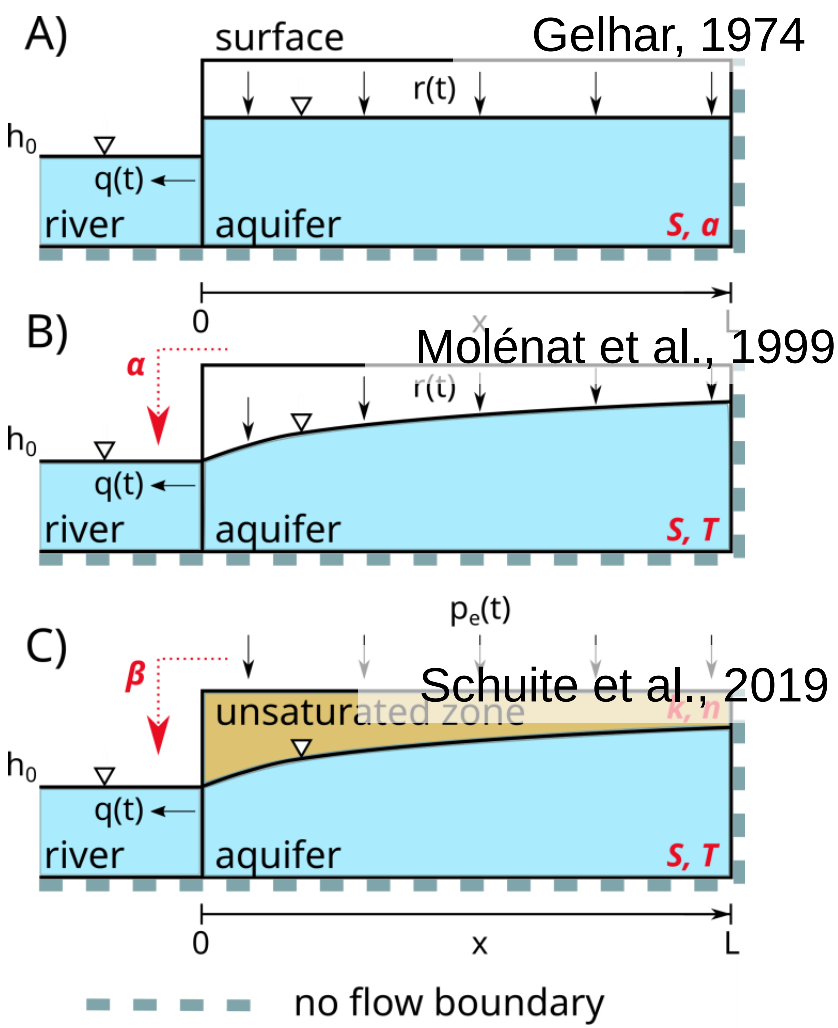
Hydrological Minimalist Transfer function HYMIT

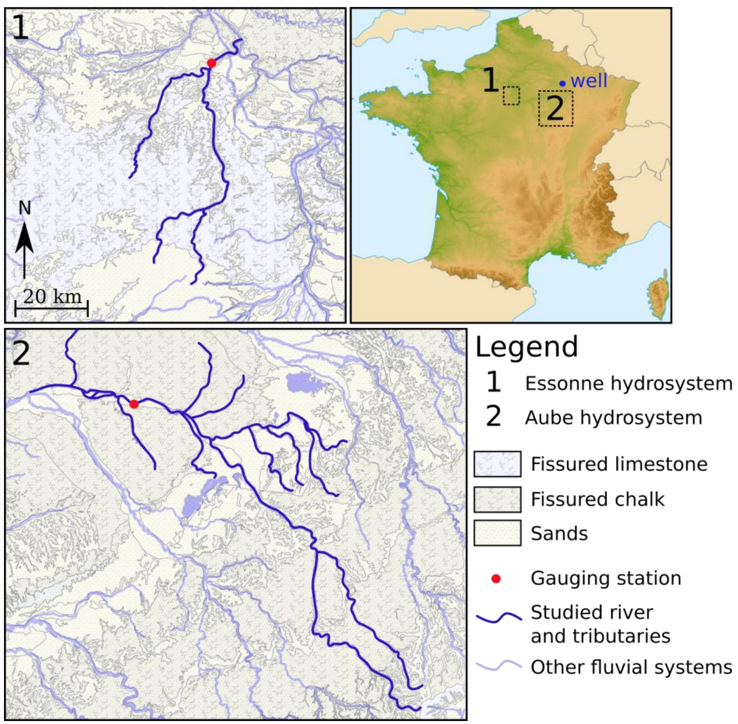


Fourier Transform (Schuite et al., 2019 WRR)



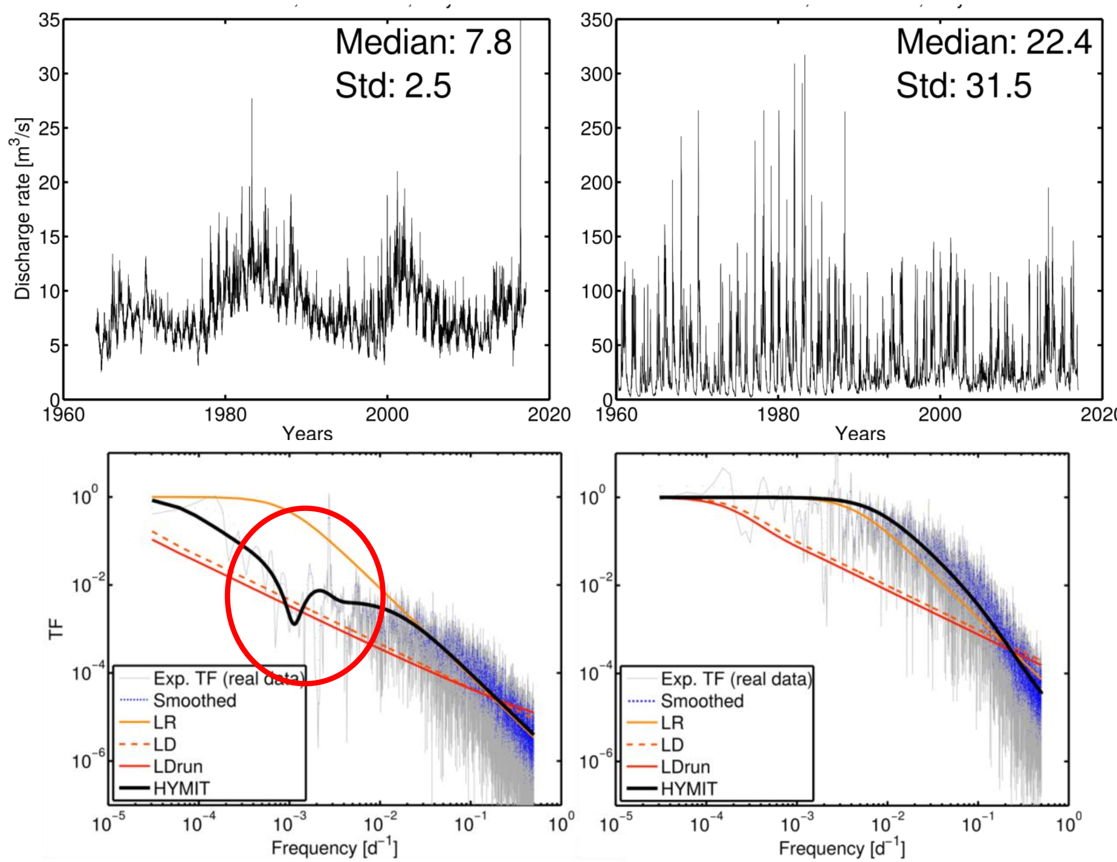
Hydrological Minimalist Transfer function HYMIT

- **Retrieve parameters for the interpretation of discharge data (Schuite et al., 2019, WRR)**



Essonne: ~1900 km²

Aube: ~3600 km²



- Very low hydraulic diffusivity
- Thick vadose zone
- Low fraction of overflow (7%)

Thick vadose zone

- Very high hydraulic diffusivity
- Thin vadose zone
- High fraction of overflow (24%), very diffuse

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Water Resources Research

2019

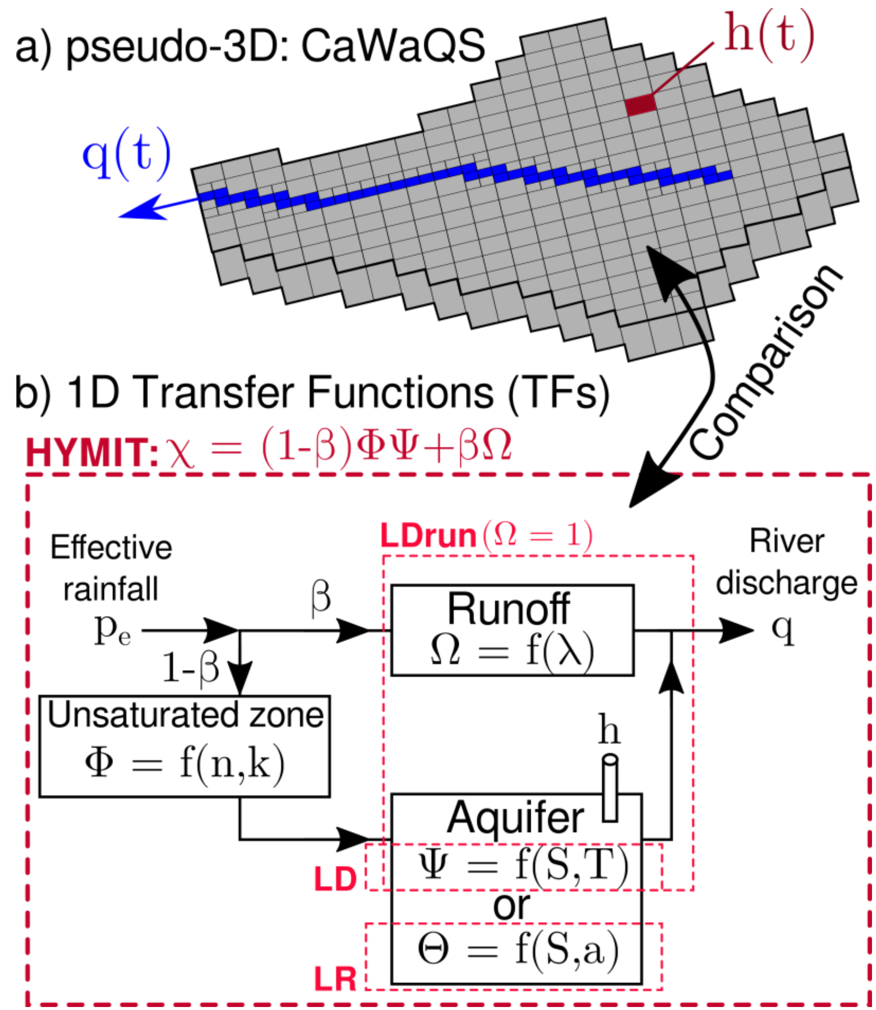
RESEARCH ARTICLE
10.1029/2018WR024579

Improving the Spectral Analysis of Hydrological Signals to Efficiently Constrain Watershed Properties

J. Schuite[1], N. Flipo[1], N. Massei[2], A. Rivière[1], and F. Baratelli[1]

Key Points:
- Hydrological responses to climatic forcing can be described more

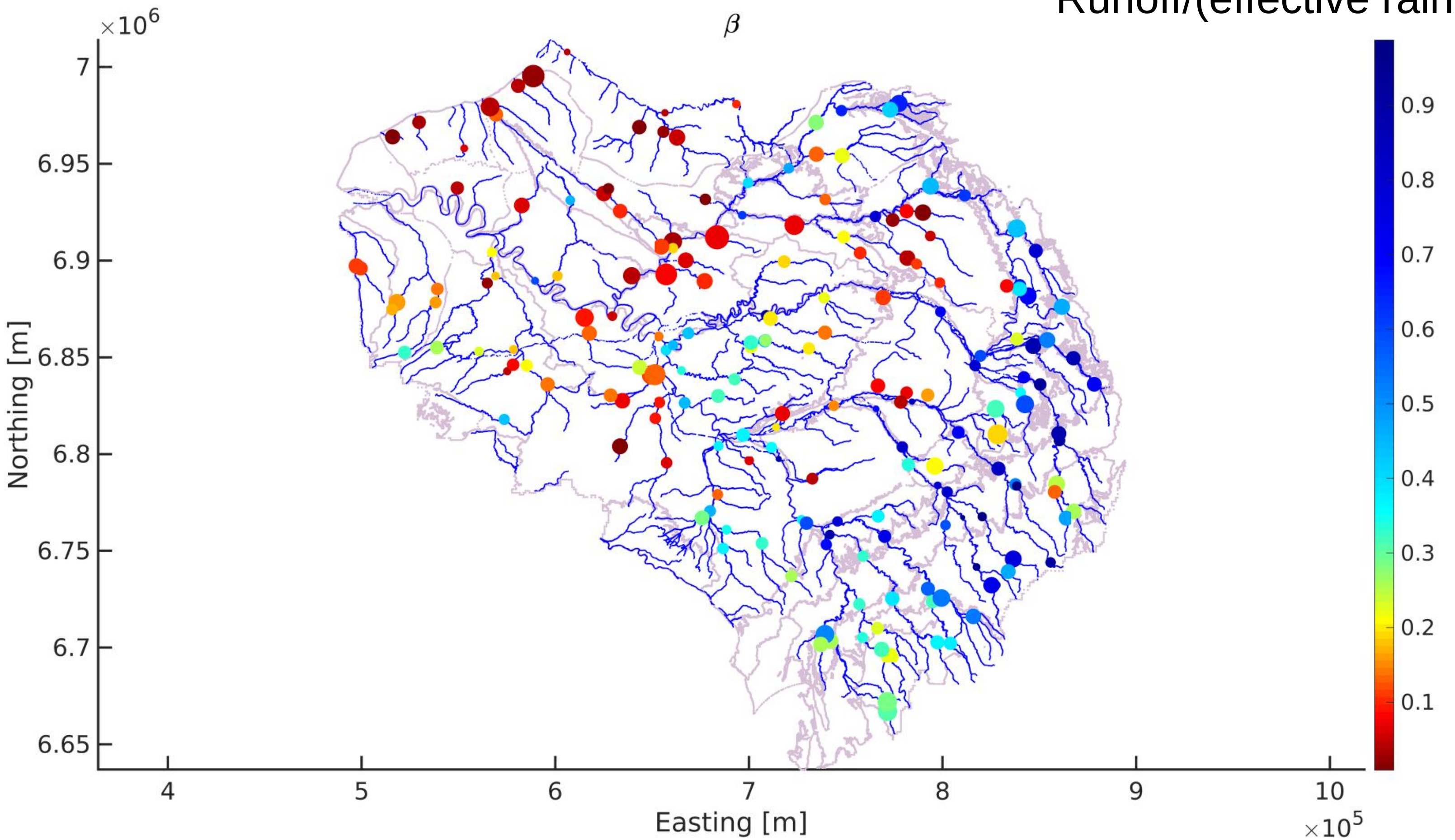
- **HYMIT : HYdrological MInialist Transfer function**
- **Fast Estimate of the general physical properties** and behavior of a **catchment** from commonly used data in hydrology: **Q, Effective Rainfall**
- Subsurface fluxes are vertical in the unsaturated zone, horizontal in aquifers → **Adapt LSM structure ?**



Runoff/infiltration partitioning on the Seine basin

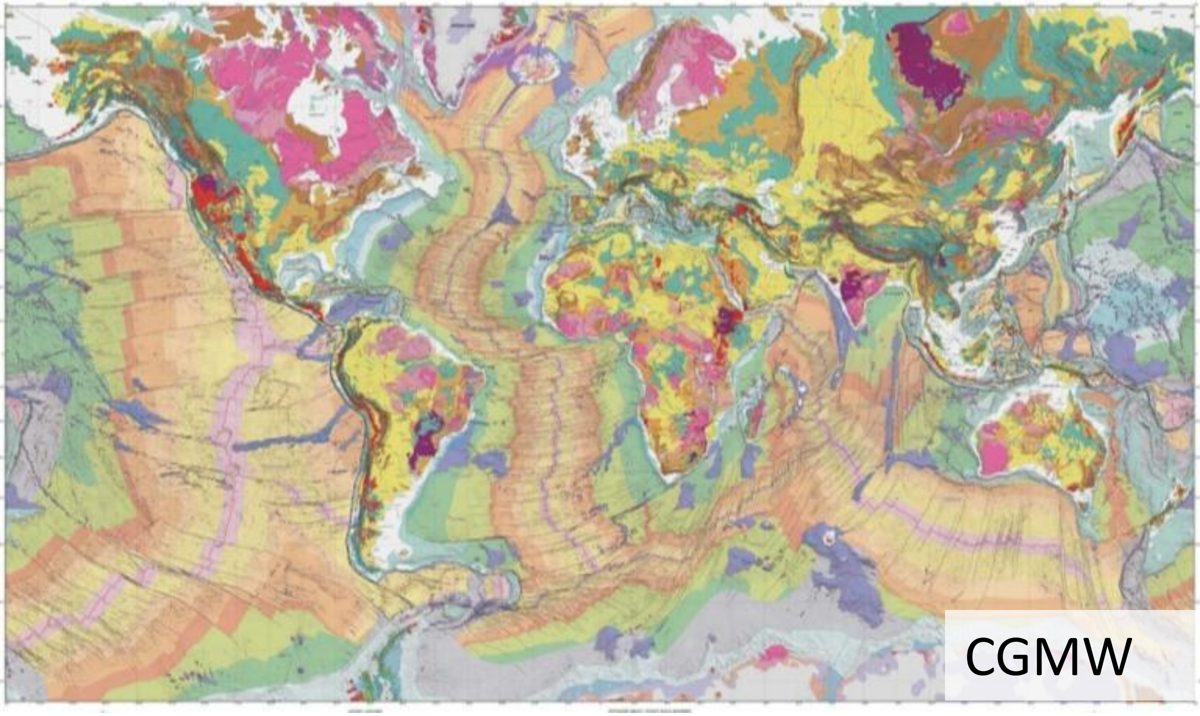
- **Calibrated conceptual surface model of CaWaQS (Flipo et al., 2012, WRR; Pryet et al, 2015, WRM; Baratelli et al., 2016 JH) + HYMIT**

Runoff/(effective rainfall)



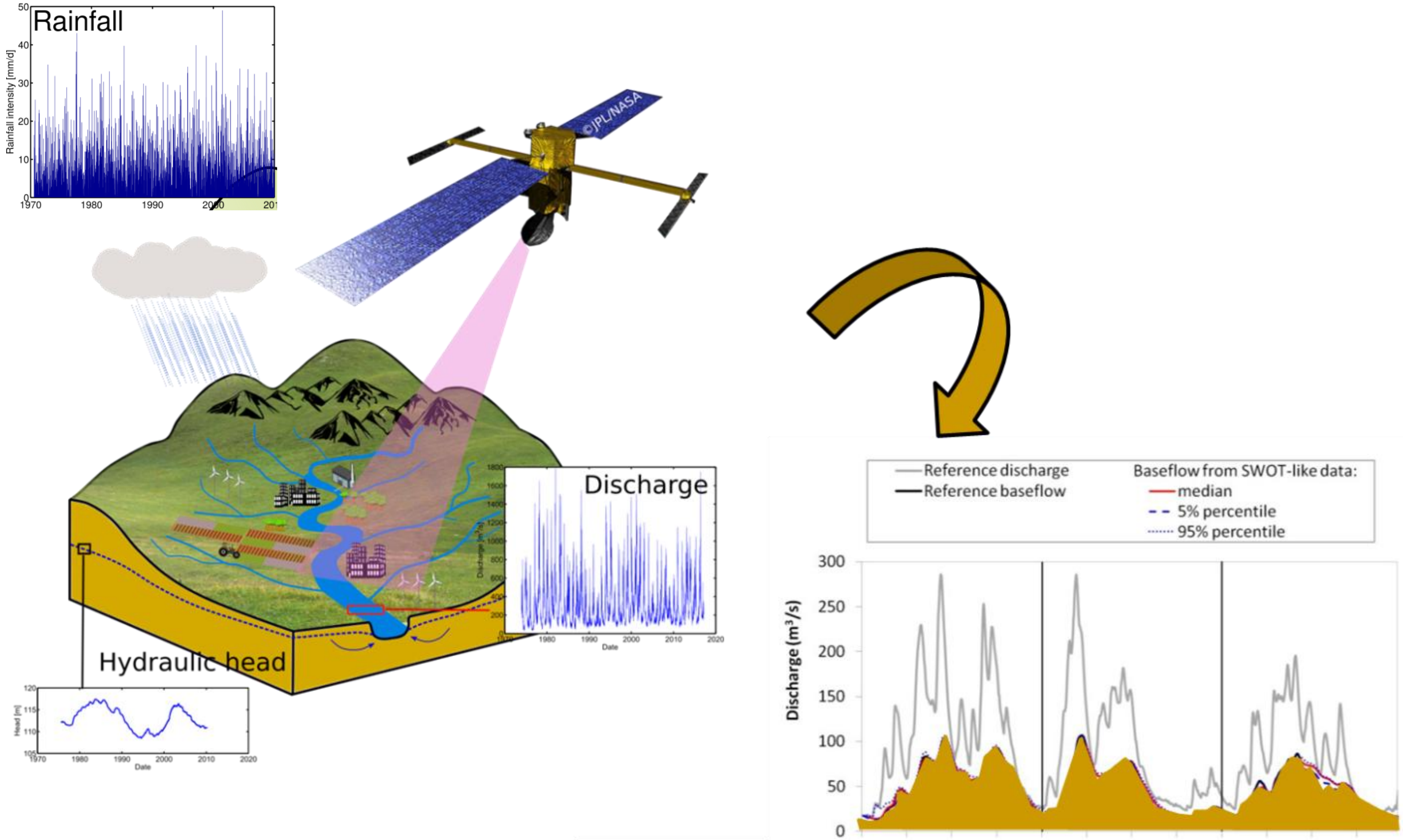
Perspectives

- **Test more geological settings and larger basins**



- **Use TF approaches to guide calibration procedures of distriuted hydrological model given a proper model structure**
- **Refine hydrograph separation methods based on spectral analysis**

Thank you



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