ORCHIDEE-DEV meeting on the routing scheme
January 7, 2020

Groundwater-related developments in the ORCHIDEE routing scheme

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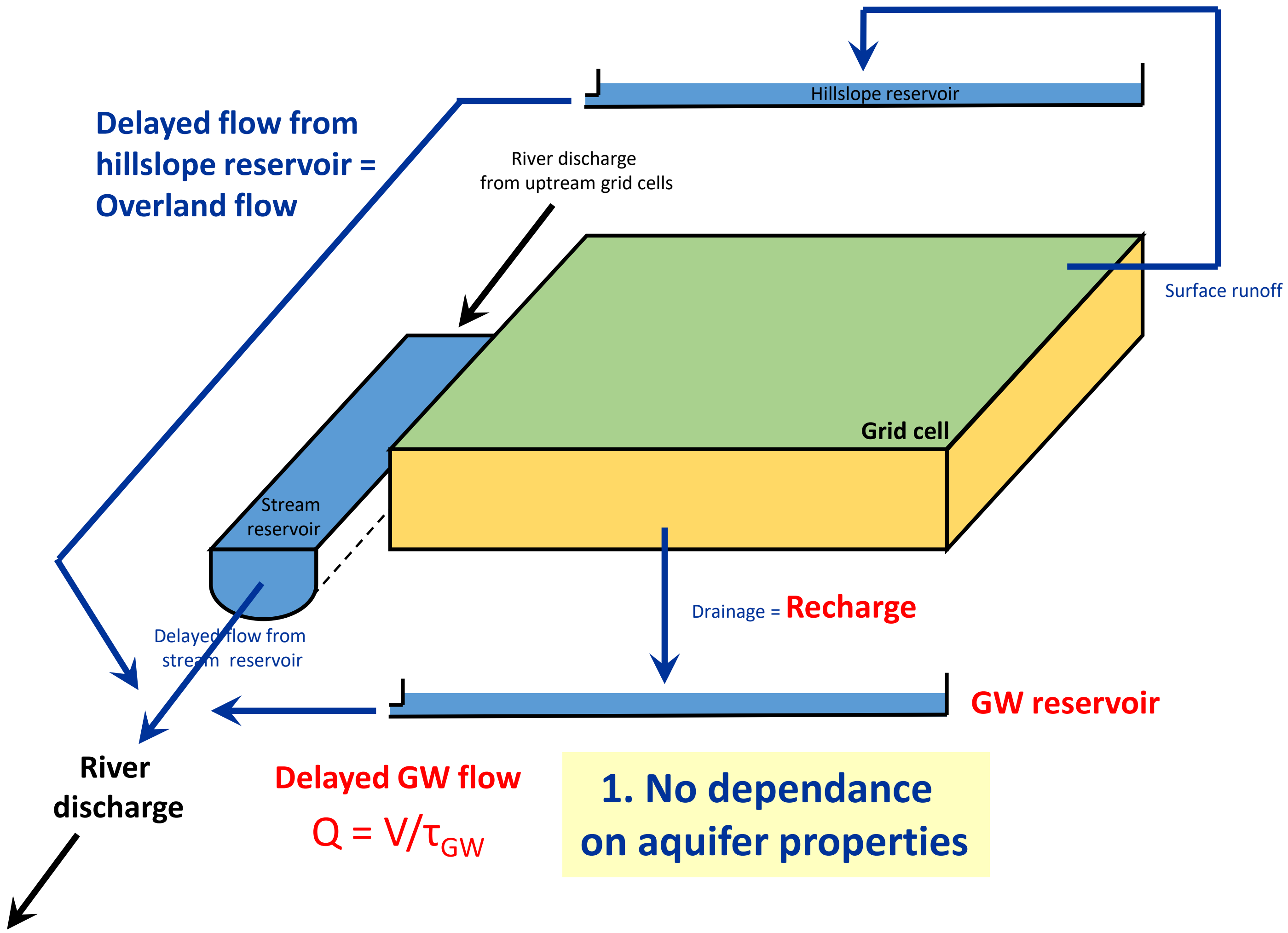
1. **Time constant of the groundwater reservoir** [trunk]
2. **Describing hillslope SM heterogeneities** [branch ORCHIDEE-GWF]
3. **Some further perspectives**

The trunk includes a very simple GW model



1. No dependance on aquifer properties

2. Assumes flat landscapes over tens to hundreds of kms

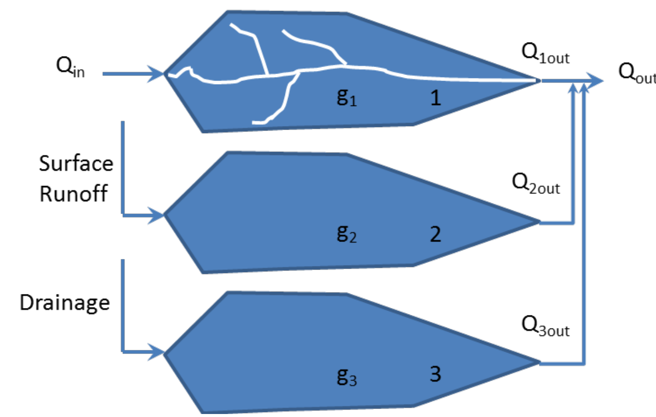
1. How to account for aquifer properties on GW discharge?

1. Standard timescales

$$\tau_i = k.g_i$$

$$k = d/\sqrt{slope}$$

Stream reservoir	$g_1 = 0.24\ 10^{-3}$ d/km
Hillslope reservoir	$g_2 = 3\ 10^{-3}$ d/km
GW reservoir	$g_3 = 25\ 10^{-3}$ d/km

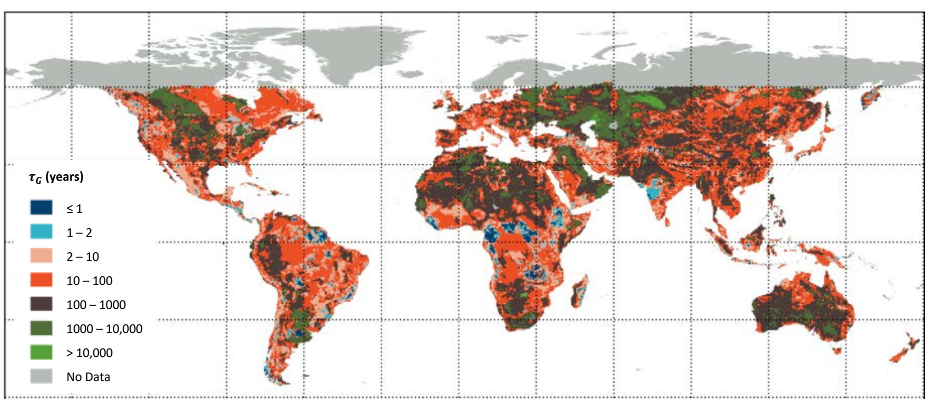


$$Q_{iout} = Vi/\tau_i$$

2. GW timescale from Boussinesq equation

$$\tau_3 = \frac{n_e}{\pi^2 \cdot \delta^2 \cdot T_e}$$

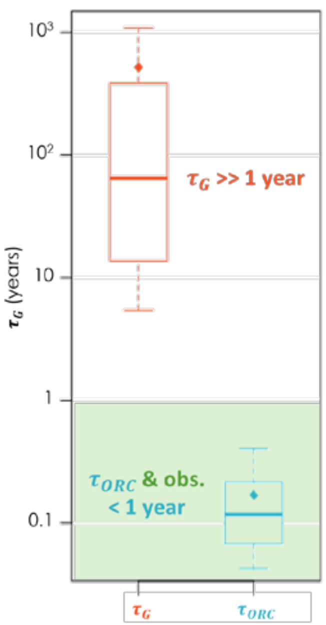
n_e: effective porosity
T_e: transmissity
δ: drainage density

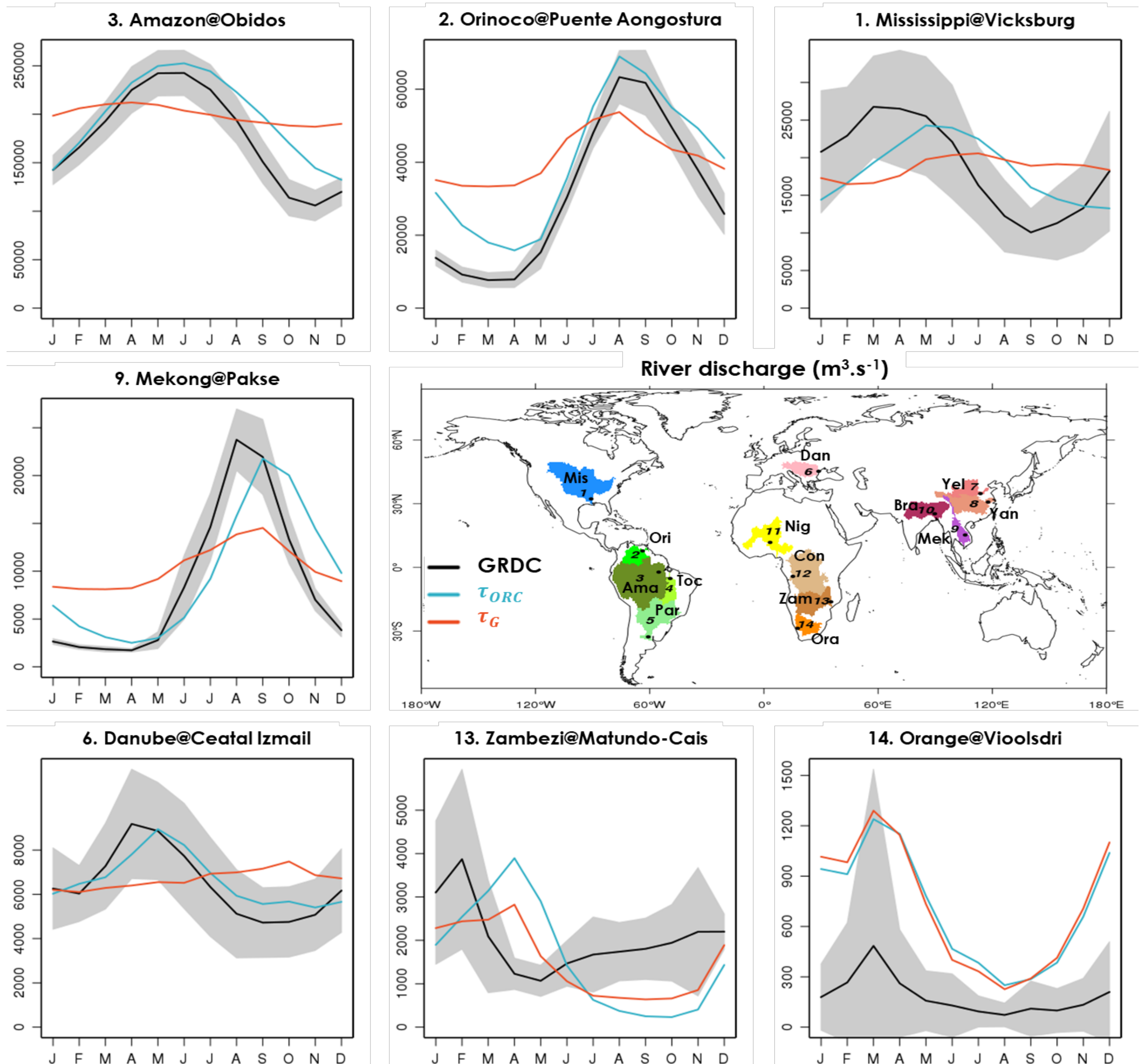


τ	Median
Streams	0.45 d
Fast/hillslopes	5 d
Slow/GW : standard	45 d
Slow/GW: new	65 y

Schneider (2017)

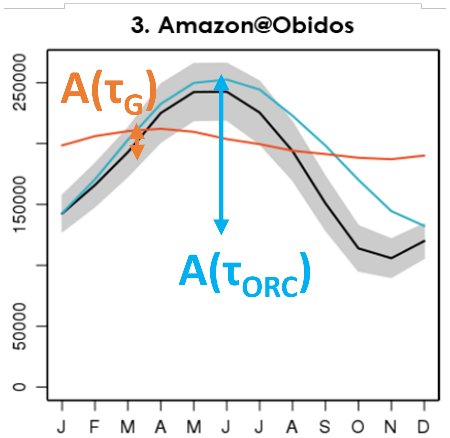
1. How to account for aquifer properties on GW discharge?



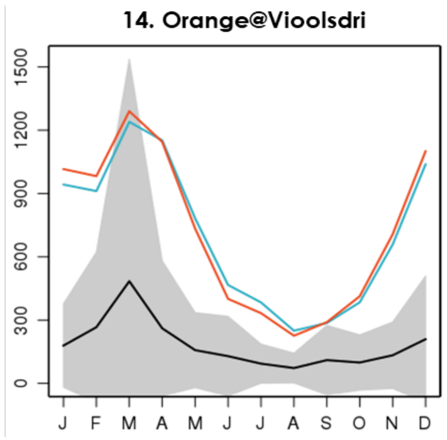


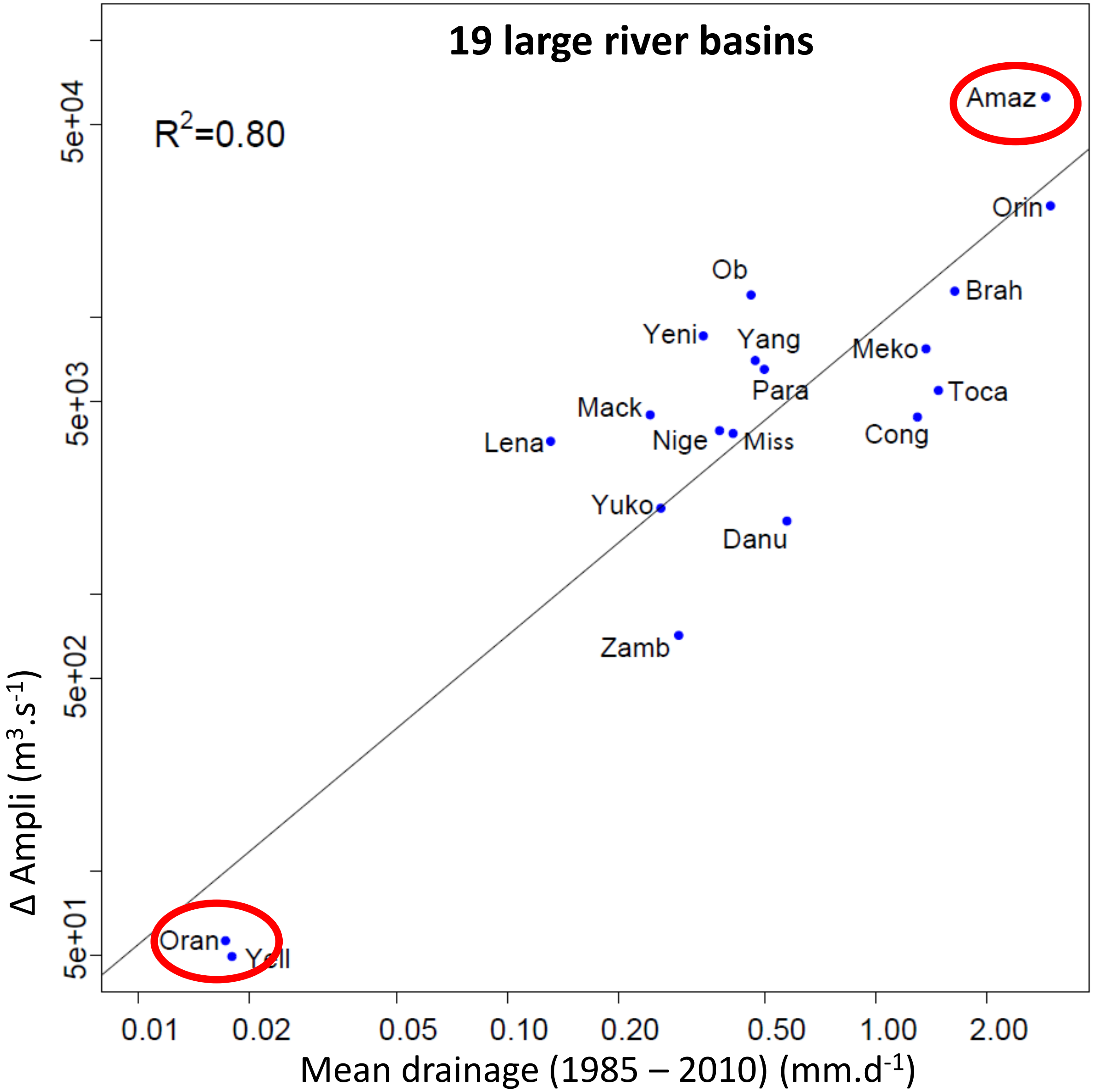
Schneider (2017)

The sensitivity to τ_{GW} depends on drainage



$$\Delta Ampli = A(\tau_{ORC}) - A(\tau_G)$$





Schneider (2017)

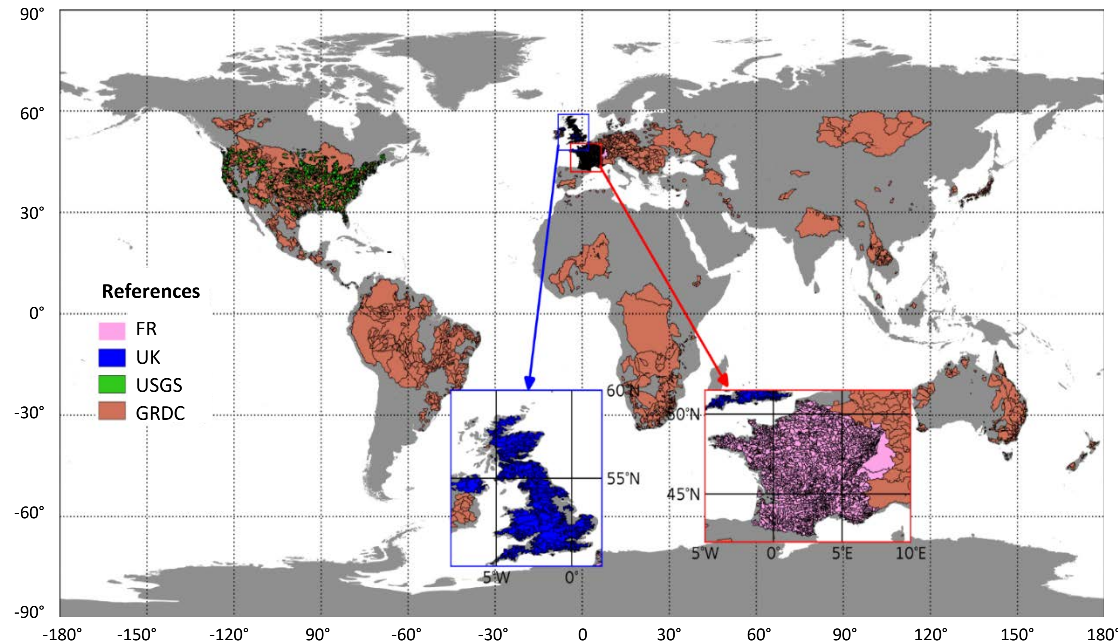
Evaluation of the two τ_{GW} against recession rates

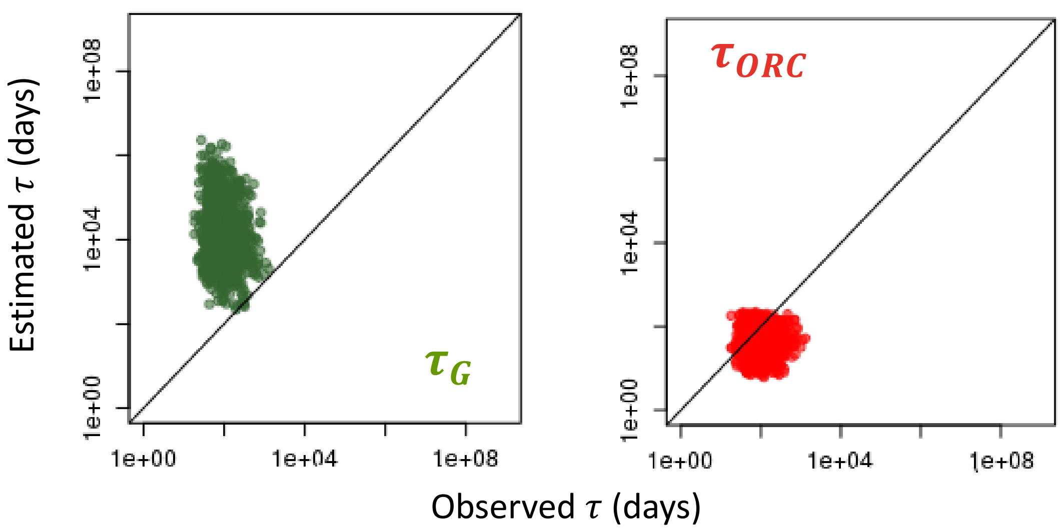
Validation dataset from recession analysis

RECESS software

Data from GRDC, France, United Kingdom and United States

τ_{obs} range from 18 days to 3.5 years



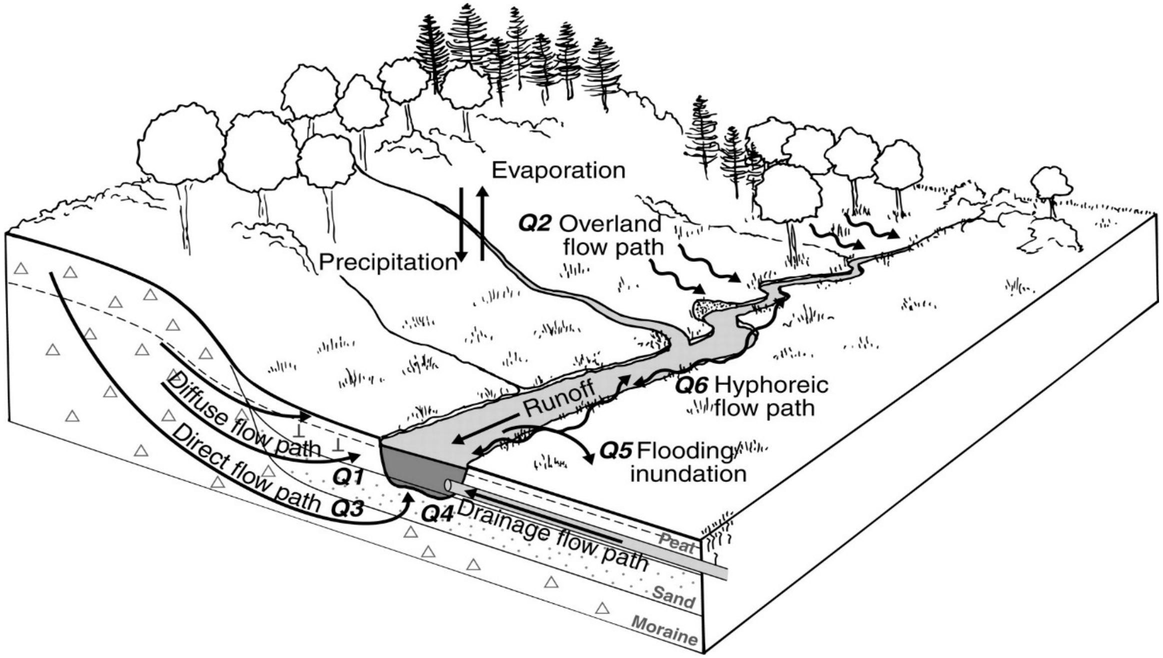


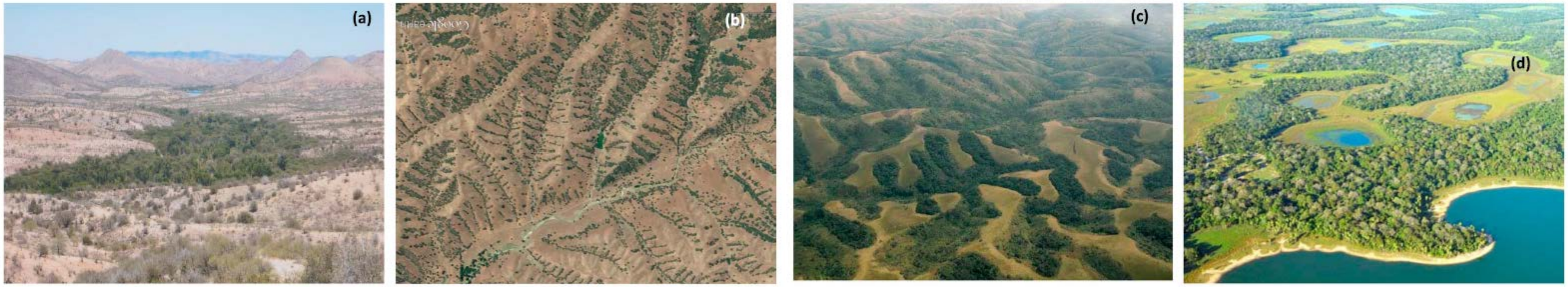
τ_G from Boussinesq is largely overestimated and not suitable for parametrization of a shallow linear groundwater reservoir

Schneider et al. 2018

2. How to account for hillslope SM heterogeneities?

since landscapes are not flat…

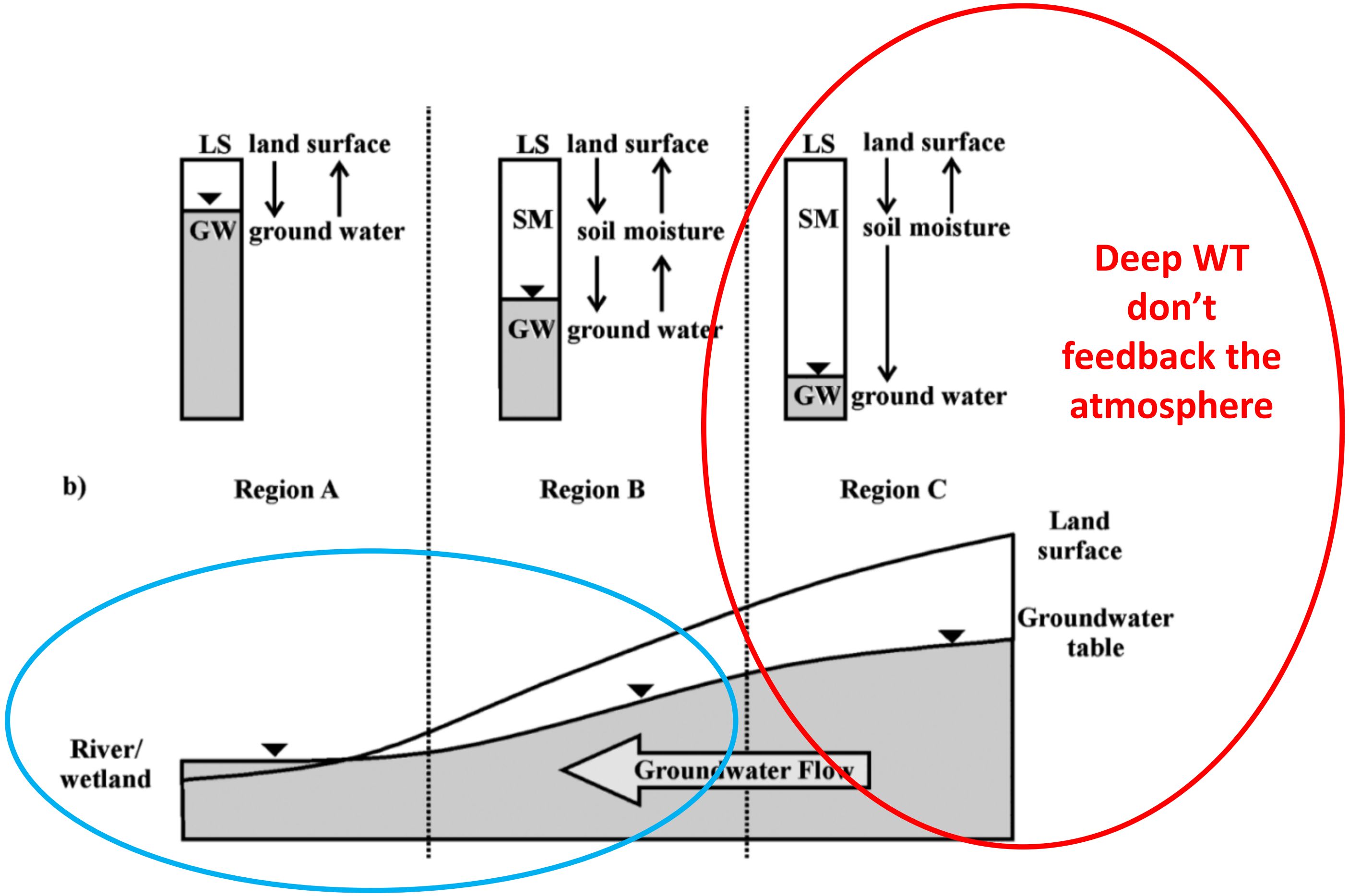




Photographs from Fan et al. 2019, WRR

2. How to account for hillslope SM heterogeneities?

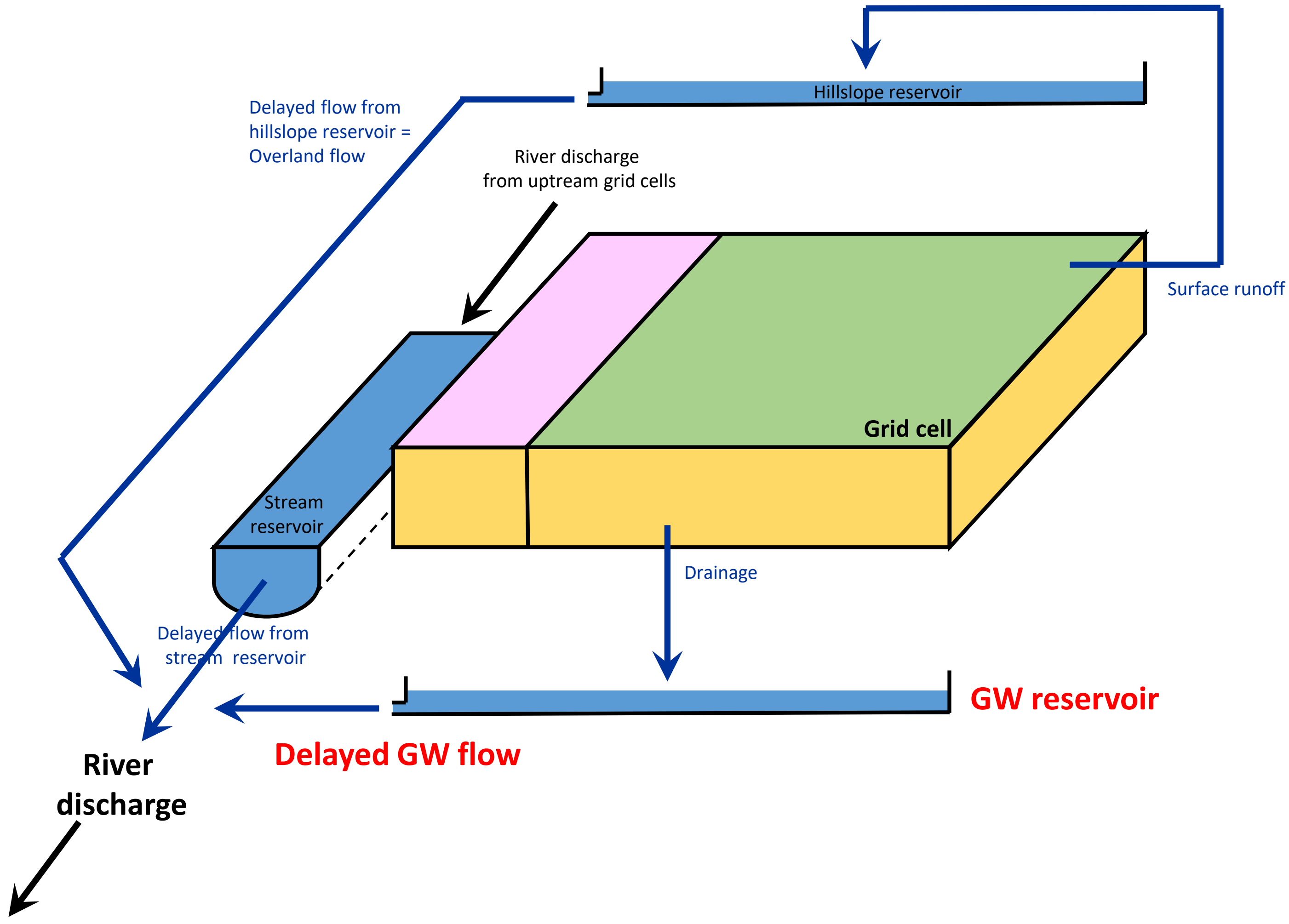
…with impacts on surface/atmosphere coupling



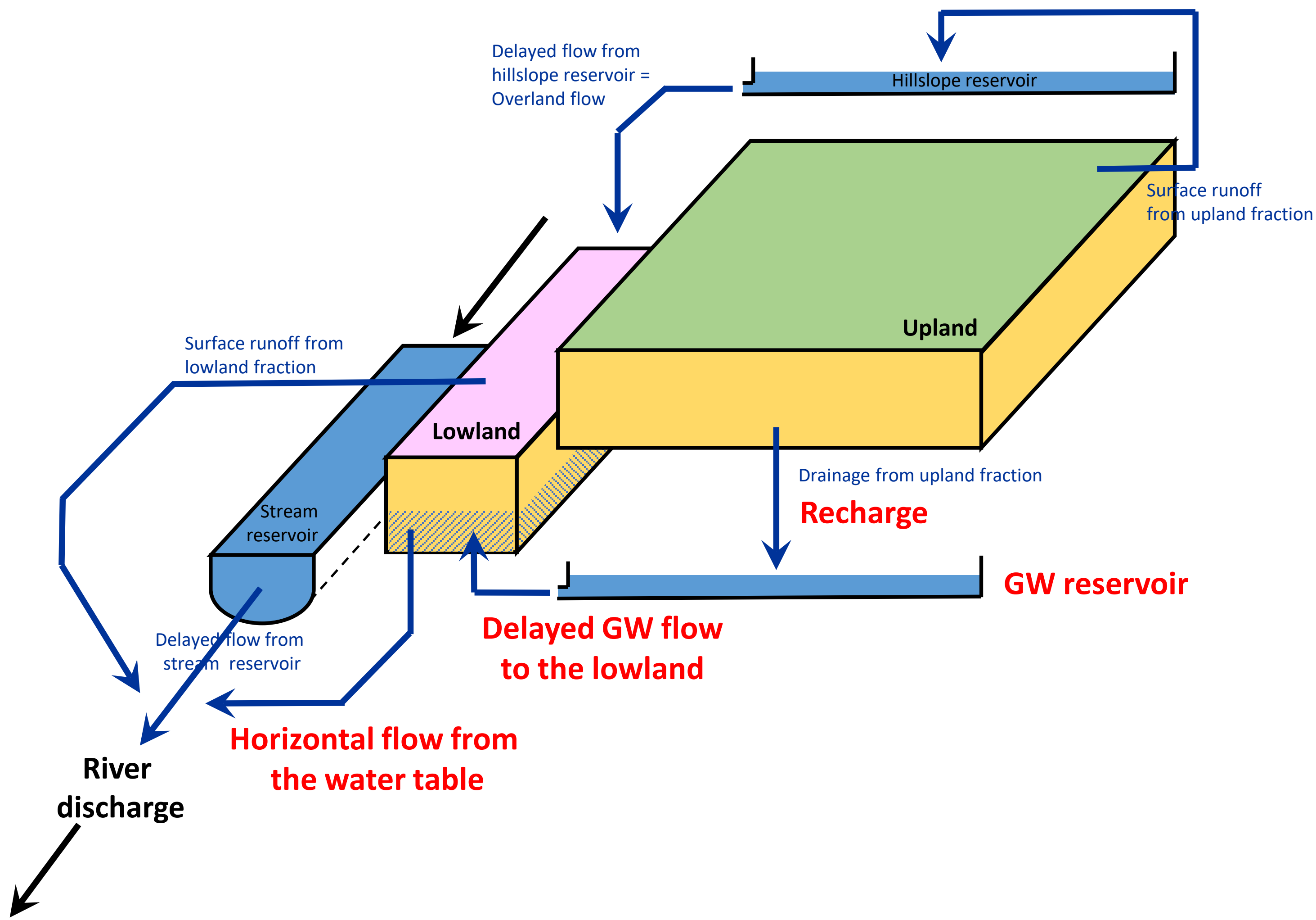
Shallow WT with strong impact on atmosphere (and specific biogeochemical processes)

Kollet & Maxwell, 2008, WRR

Introduction of a lowland fraction



Introduction of a lowland fraction



Lowland fraction prescribed from global wetland map

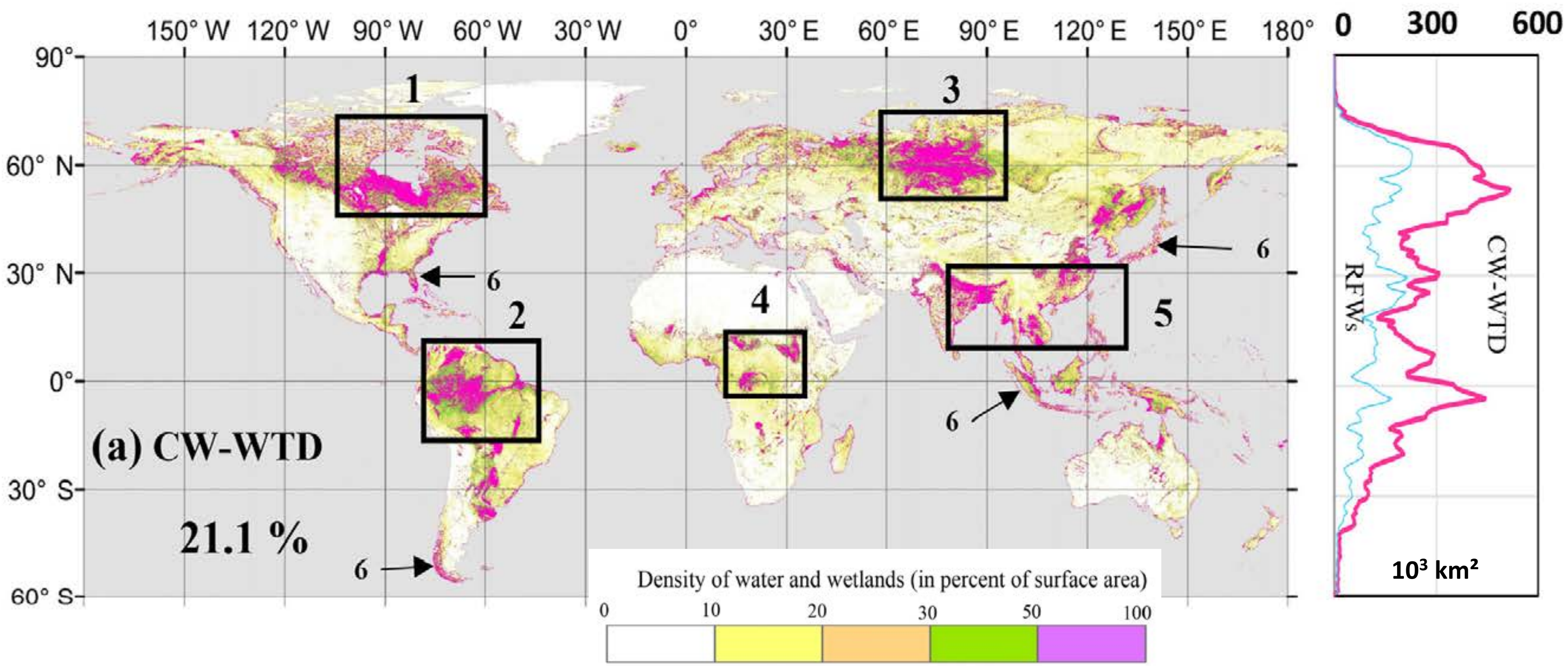
RFW
Regularly flooded wetland

GIEMS-D15 + JRC surface water + ESA CCI wetland class

15 arc-sec resolution

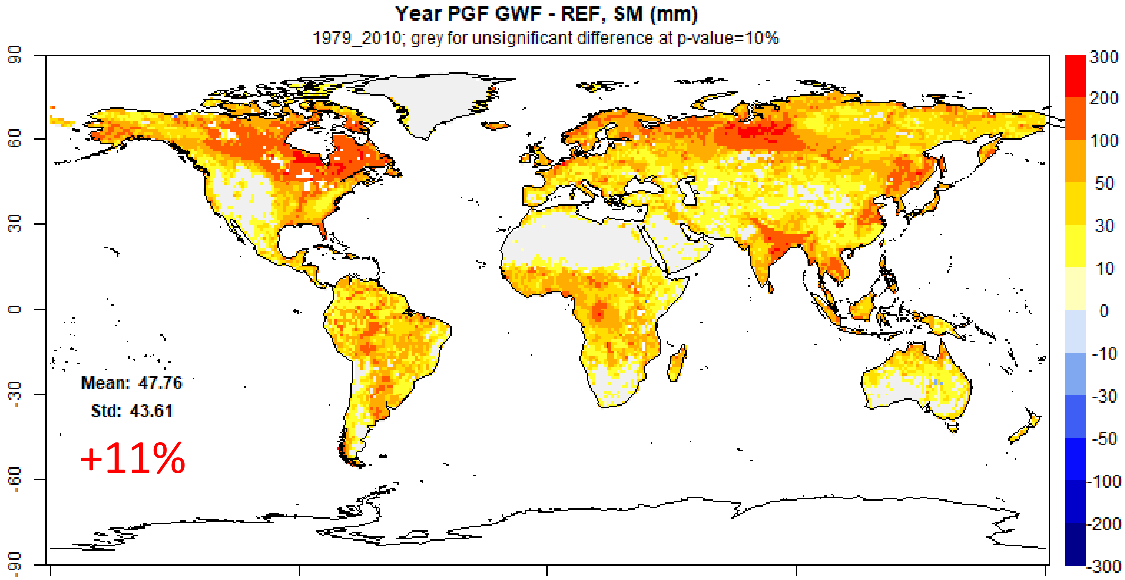
GDW
Ground-water driven wetland

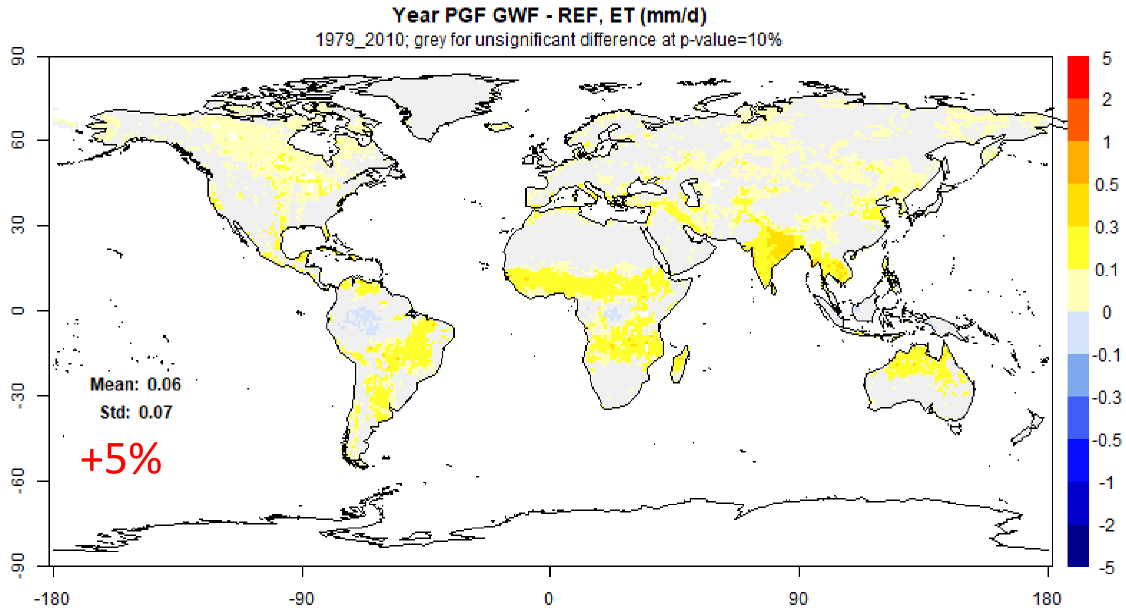
Fan et al. 2013



Tootchi et al., 2019, ESSD

Impact on SM and ET (off-line simulations)





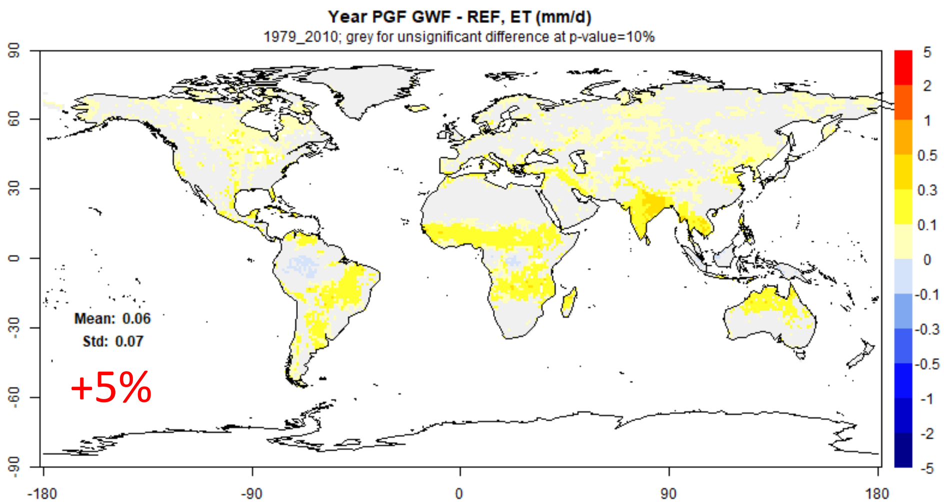
REF = 1.17 mm/d
GWF = 1.23 mm/d

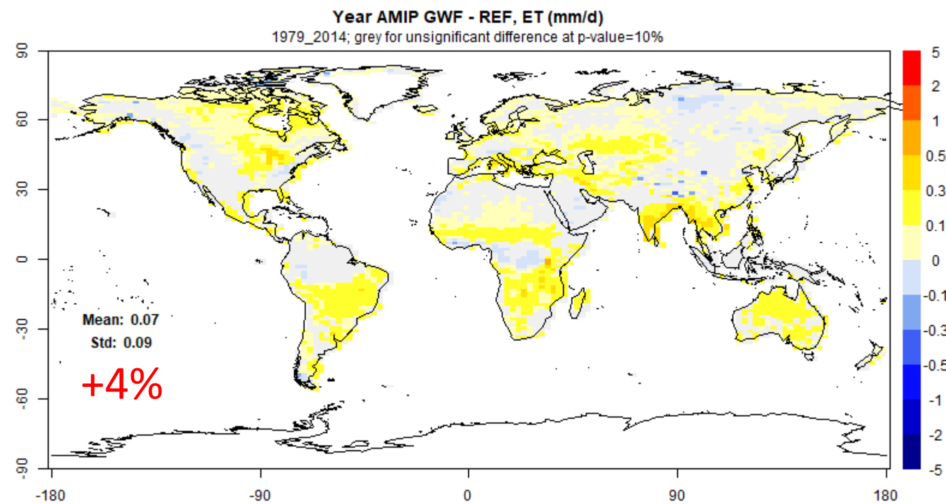
GLEAM = 1.37 mm/d
Rodell et al. 2015
= 1.45 mm/d

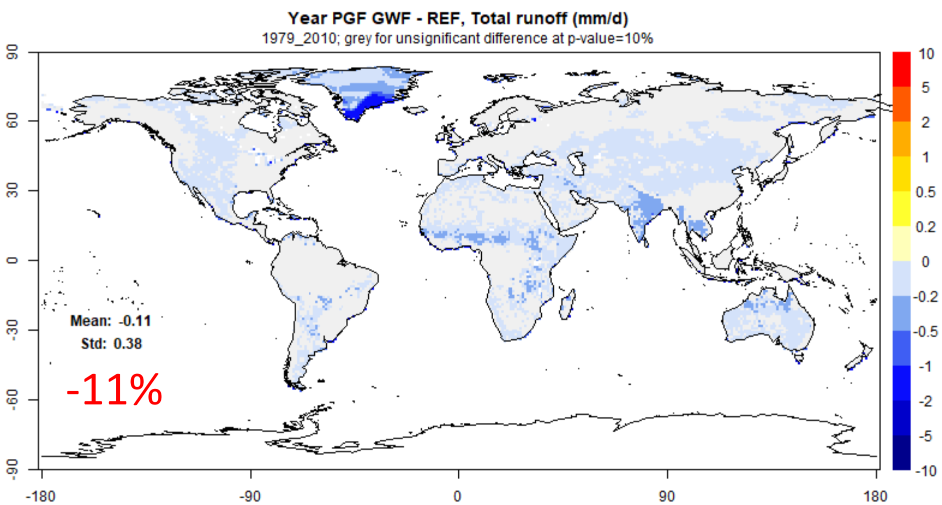
(yearly means
excluding Antartica)

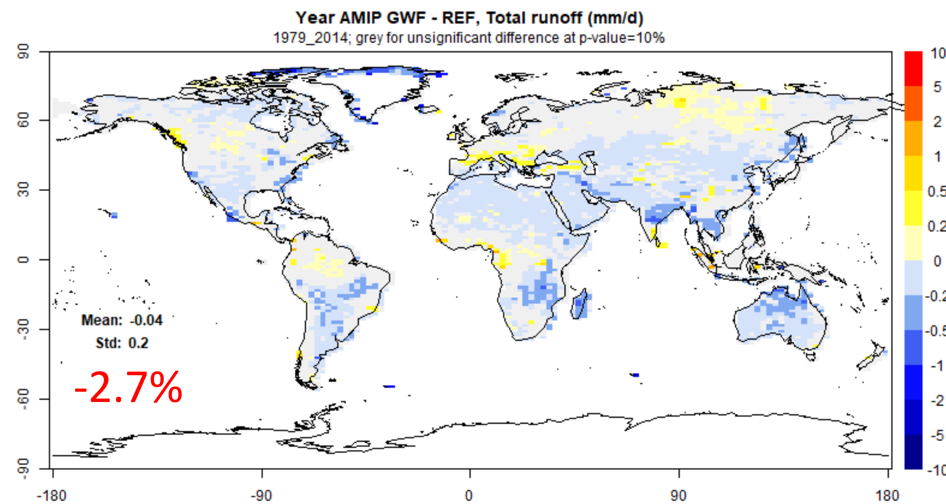
Land surface water budget

Off-line | **Coupled**

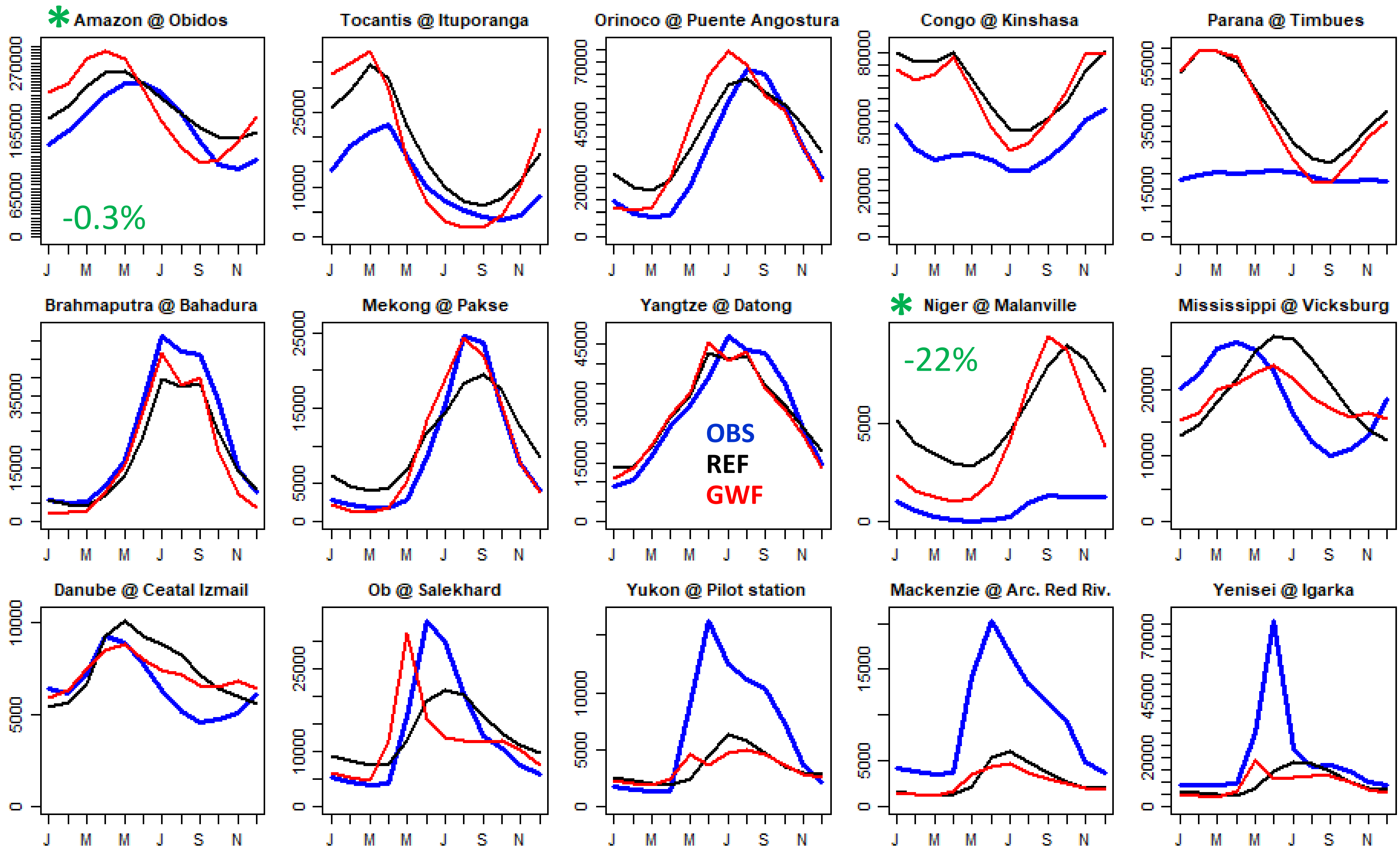




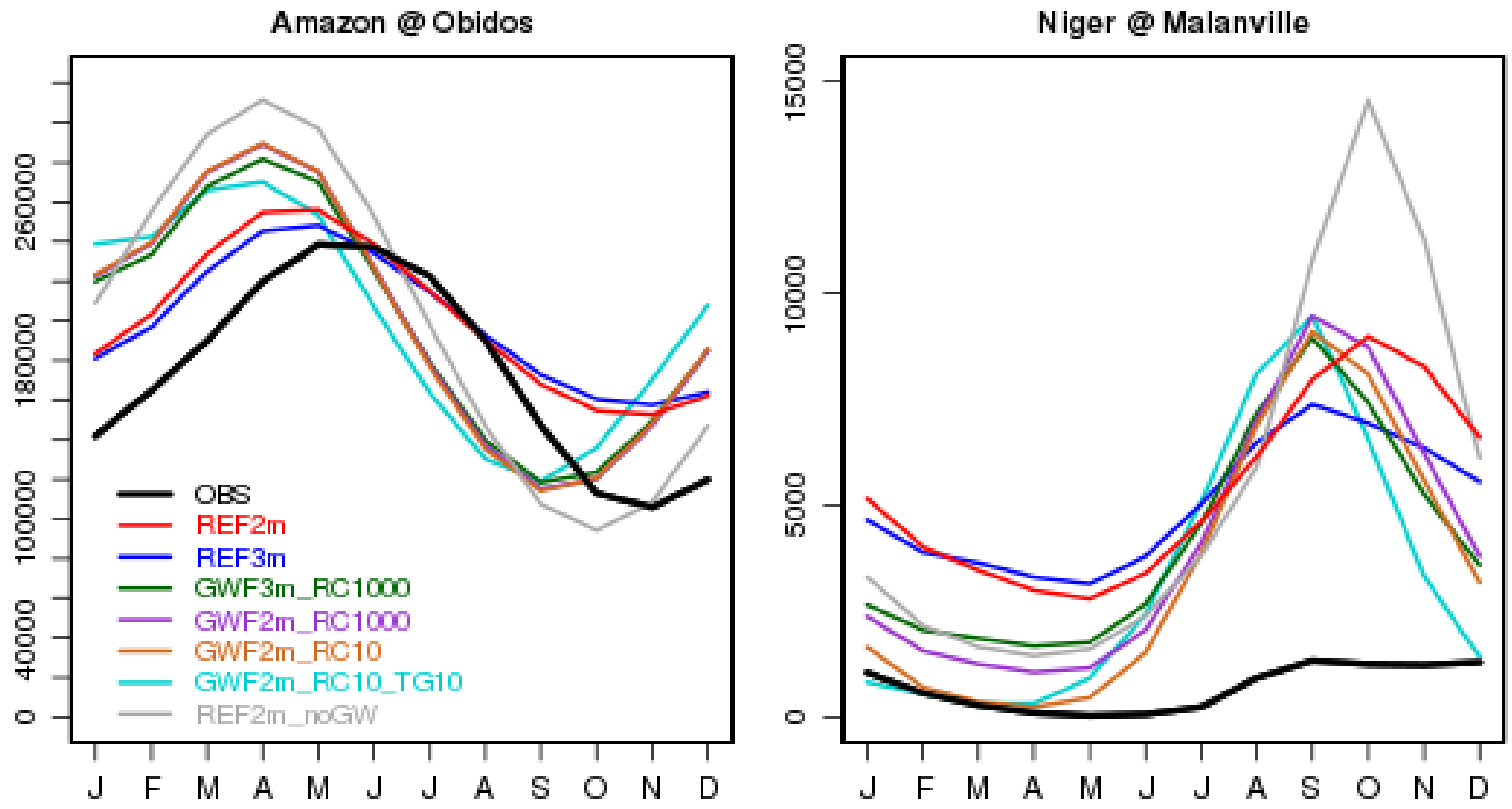




River discharge in major basins (off-line)

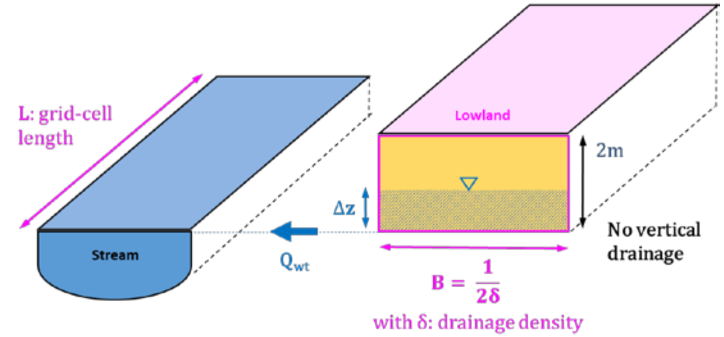


Preliminary parameter sensitivity



Tested parameters:

- **Soil depth** = max water table depth
- **RC** : adjustment factor in $Q_{wt} = L.RC.T(z)\ \Delta z/B$
- τ_{GW} : the time constant of the GW reservoir



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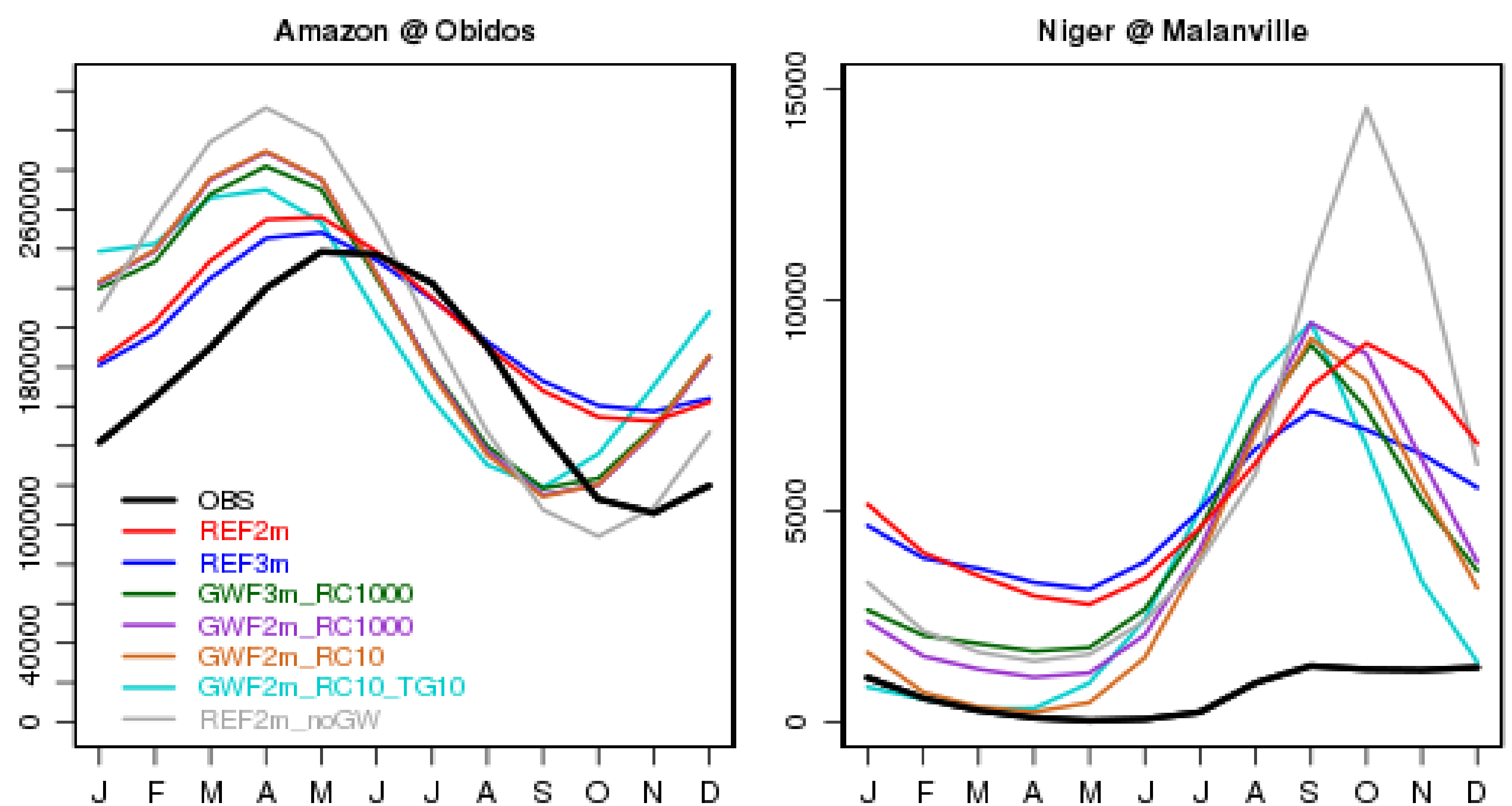


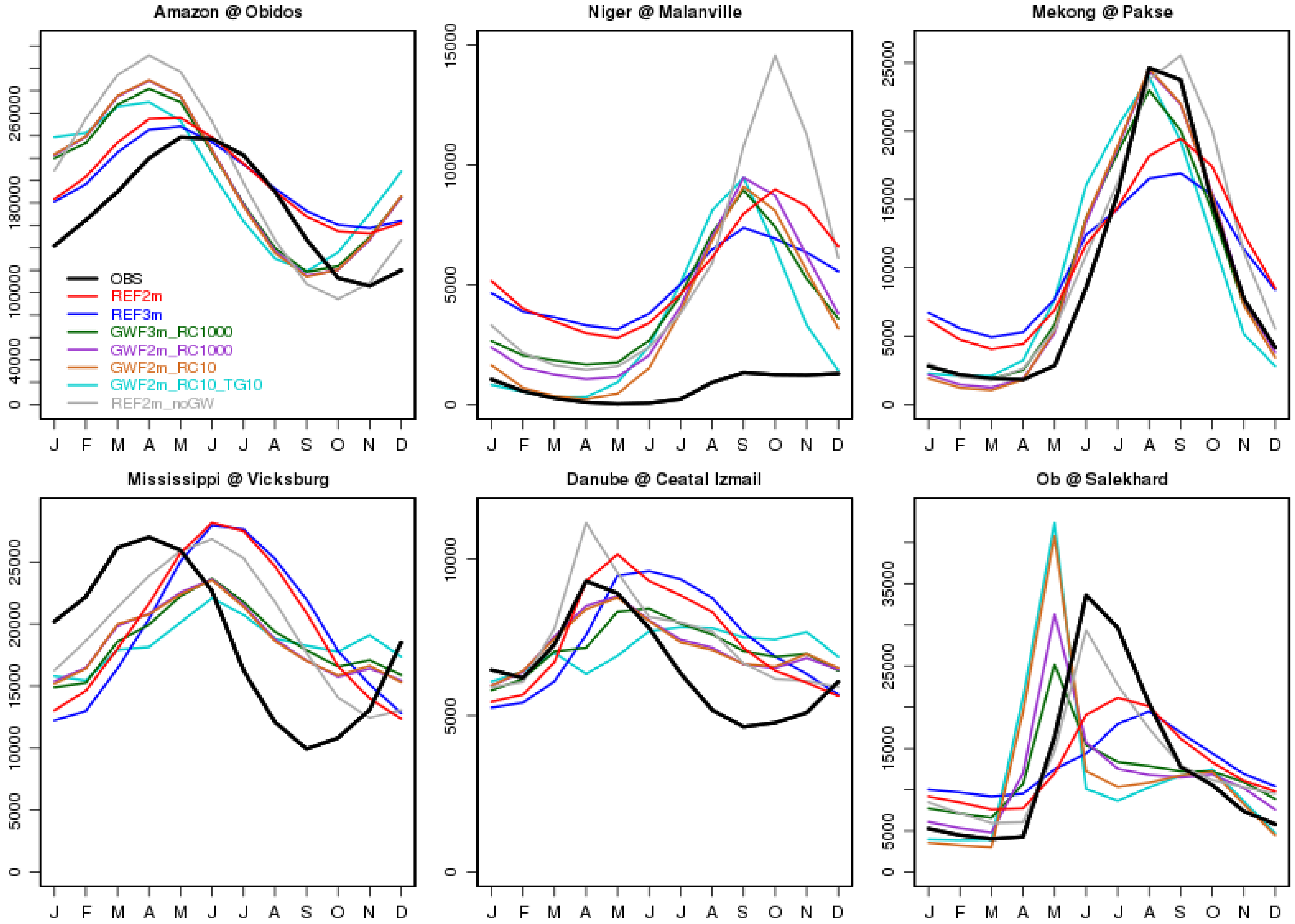
Tested parameters:

- **Soil depth** = max water table depth
- **RC** : adjustment factor in $Q_{wt} = L.RC.T(z)\ \Delta z/B$
- τ_{GW} : the time constant of the GW reservoir

These three parameters act on discharge amplitude and recession rate, τ_{GW} being the most effective.

The time of peak flow may be related to the lowland fraction extent.

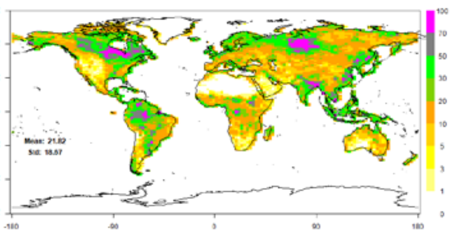
Parameter influence

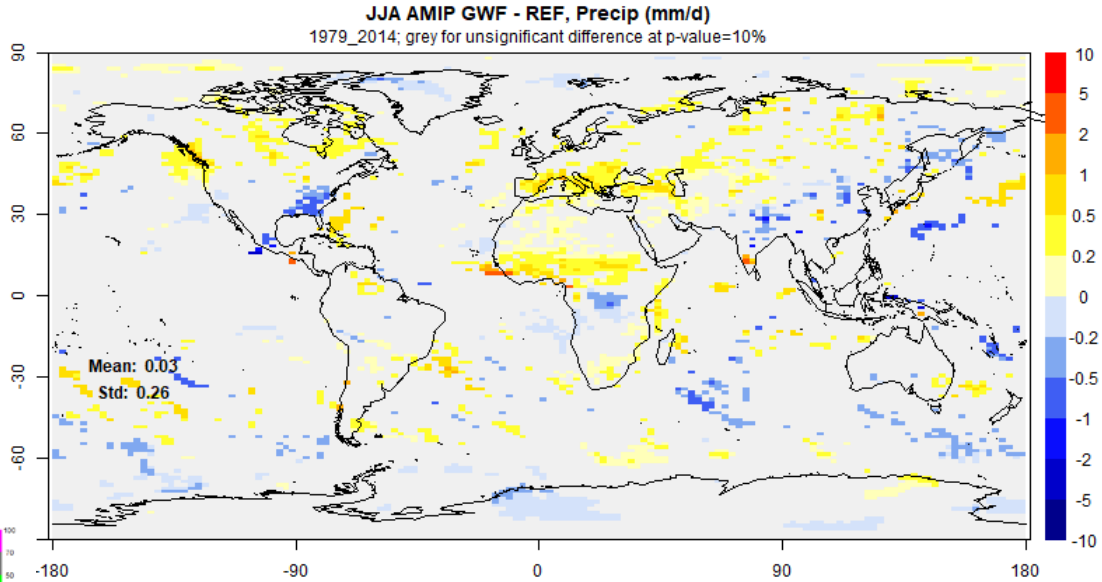


Simulated climate

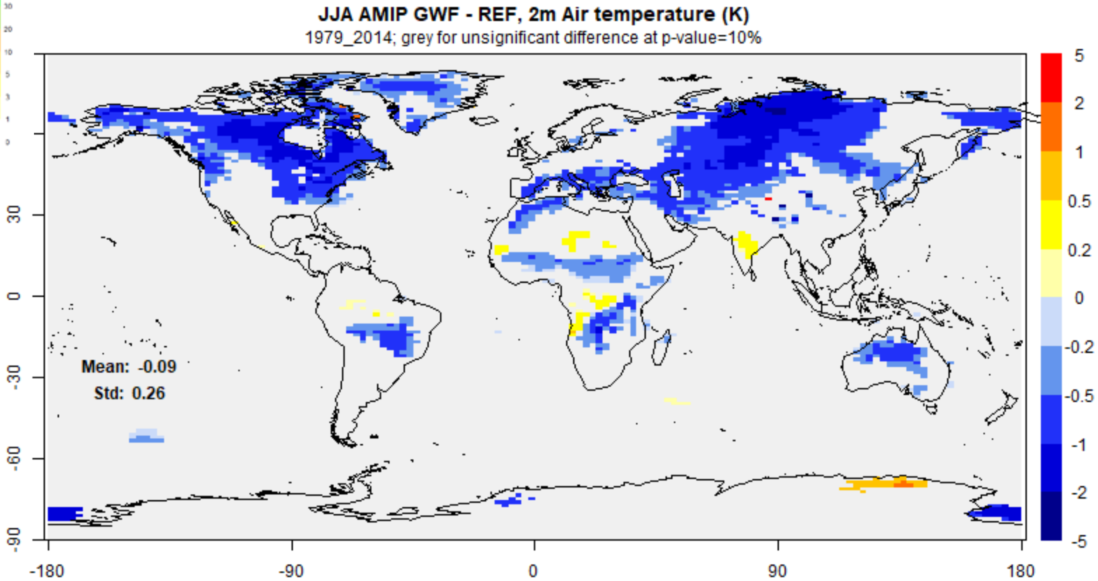
NH summer JJA

Lowland fraction





Precip
Δglob = +0.7 %
Δland = +1.3 %

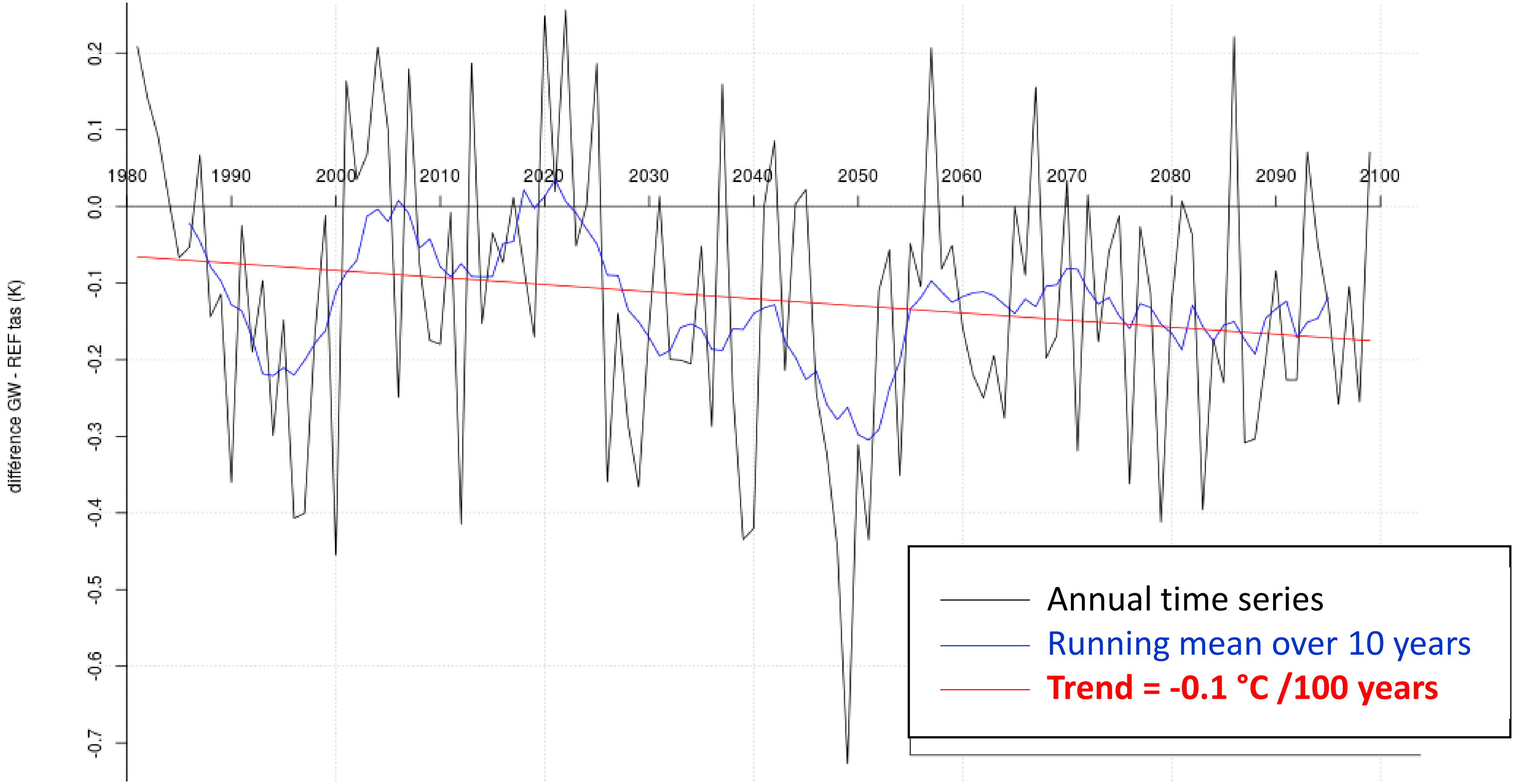


T2m
Δglob = -0.09 C
Δland = -0.27 C

A glimpse to the future…

Difference in air temperature (land average, in °C)

GWF – REF



Accounting for subgrid scale hillslope flow to a lowland fraction allows us
To mitigate some global warming manifestations

Many shortcomings

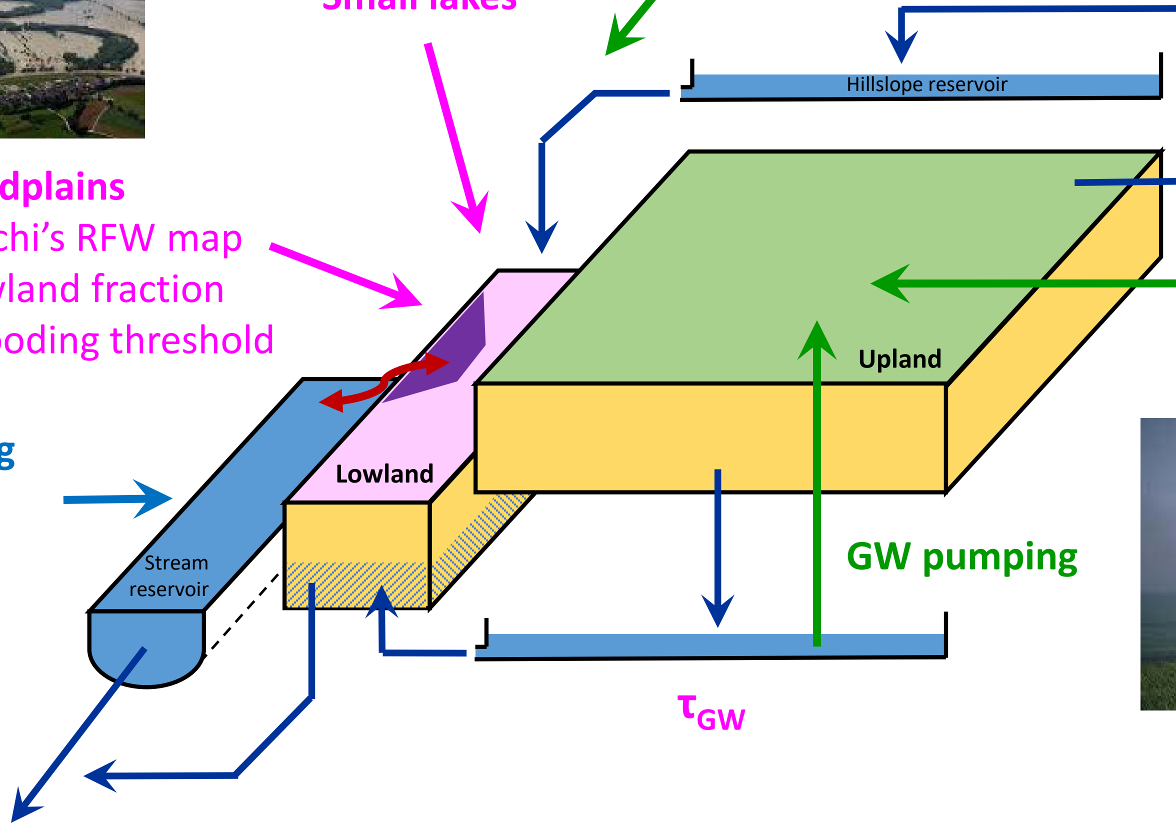
- **Simulations with ORCHIDEE2.0** $\rightarrow$ no nitrogen, no CAN, missing bug fixes, etc.
- **Many options switched off for simplicity**
  - Soil freezing
  - Floodplains and swamps
  - Irrigation
- **Need for parameter exploration / optimisation**, but…
- **Potential interactions with many developments**
  - Multi-tile energy budget
  - High-resolution routing
  - New floodplains (Ronny), wetland processes (methane, peats, etc.)
  - Lakes, reservoirs, water use
  - PFT composition, vegetation density, rooting depths

How to describe complex waterscapes without too much complexity?

Methane emission
Peat accumulation
Denitrification
Small lakes

Wetland PFTs?

Floodplains
using Tootchi's RFW map
inside lowland fraction
+ Ronny's flooding threshold



Irrigation
(mostly upland?)

High-res routing
Reservoirs
Large lakes

GW pumping

And what about including the GW and hillslope reservoirs (local) into hydrol.f90 ?

Thanks for your attention

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Other remarks on the trunk

- **There is a scale problem, since the three time constant don't follow the grid-cell size** $\rightarrow$ solution coded in the HR version of Trung, but not committed in the trunk
- **We had problems with Frédérique in zoomed mode** with the construction of the river network $\rightarrow$ can it be solved by Trung's version?
- **Can we merge all the developments to get one unified routing scheme?**
- **Then, it would be good to recalibrate the time constants** in the major river basins, with all processes activated
- **What about parallelisation?**