Improving river discharge simulations using high-resolution topography and hydrogeology informations

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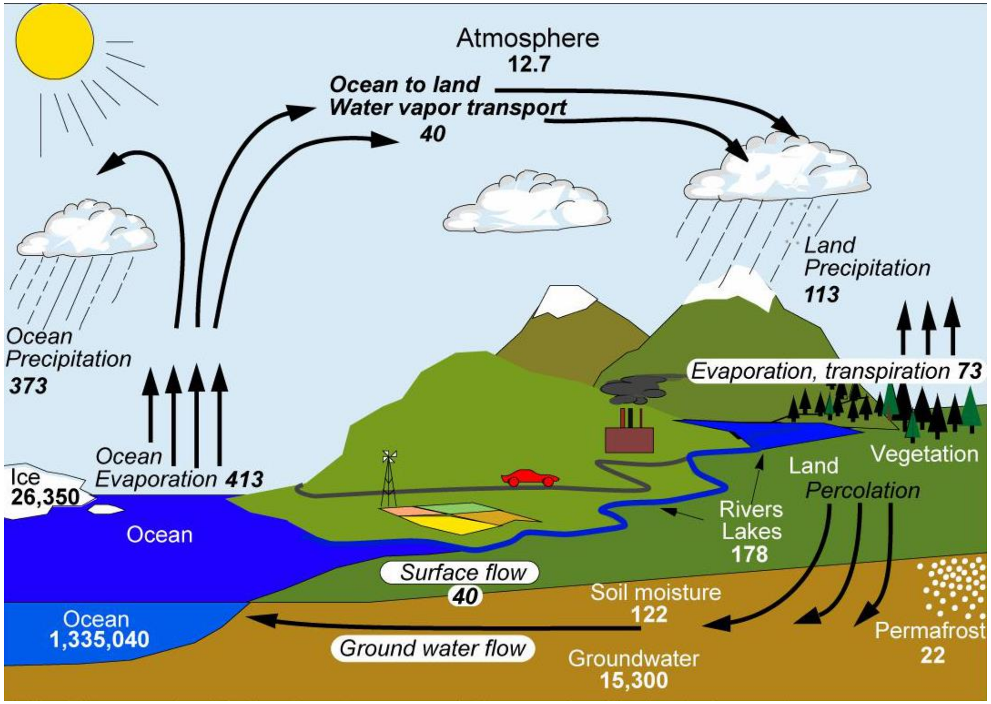
Introduction

Groundwater can impact the simulated climate, and can be connected to the soil moisture (Lo and Famiglietti, 2010).

Soil moisture has important role on climate, and is connected to water table dynamics (Lo et al., 2010) affecting river flow variability by the total runoff.

Depending on water table depth, groundwater can influence land surface processes (Kollet and Maxwell, 2008).



Trenberth et al. (2007)

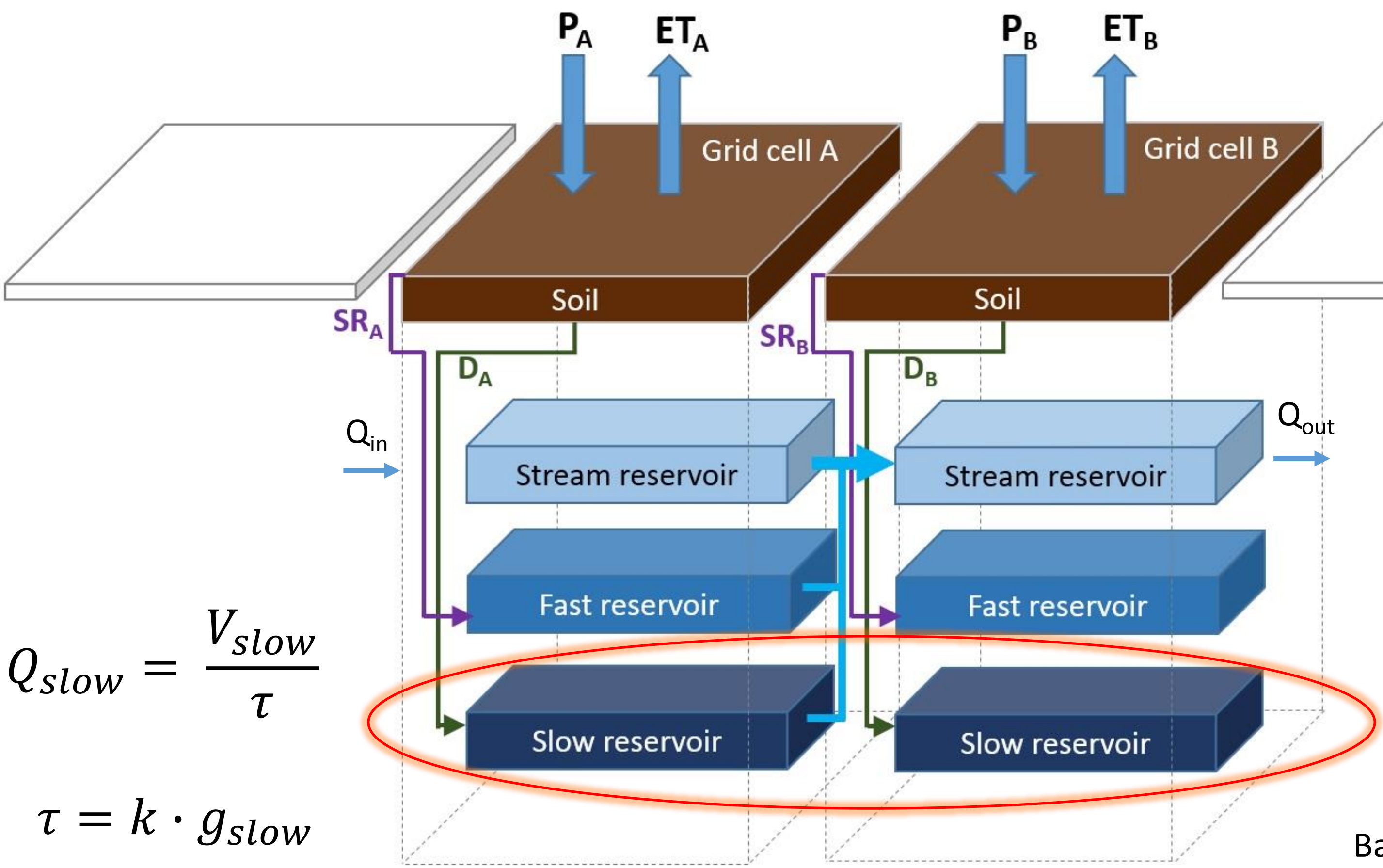
Introduction

- Gascoin et al. (2009) added a new groundwater reservoir in CLSM to better represent water transfers.

- Vergnes et al. (2012) proposed a new groundwater implemented on TRIP model, scheme based on MODCOU hydrogeological model and geological, lithological, and aquifers data.

- Vergnes and Decharme (2012) validated this new groundwater scheme based on GRACE TWS and GRDC river discharge data.

Introduction



$$Q_{slow} = \frac{V_{slow}}{\tau}$$

$$\tau = k \cdot g_{slow}$$

g_{stream} = 24E-3 d/km

g_{fast} = 3E-3 d/km

g_{slow} = 0.25E-3 d/km

Based on calibration of Senegal river (Ngo-Duc, 2007)

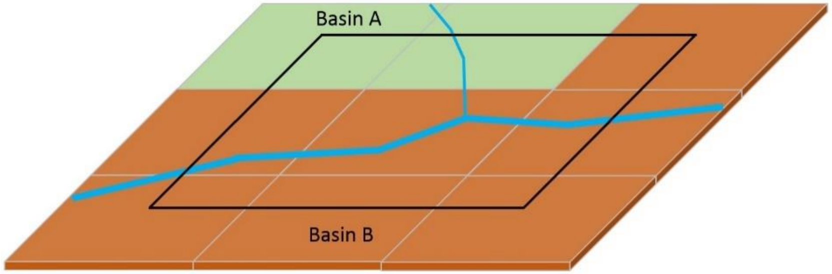
Introduction

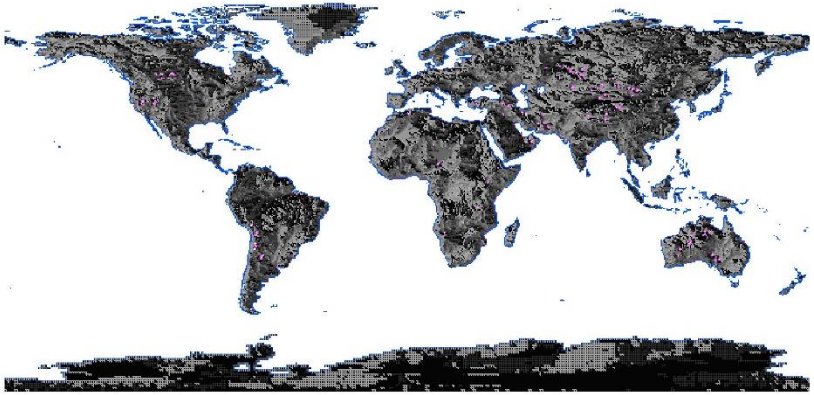
Routing topographic parameters:

- Flow direction (*trip*)
  - 8 single flow directions
  - River flow into the oceans
  - Coastal flow
  - Lake inflow
- Topographic index (k)

$$k = \frac{d}{\sqrt{S}}$$

- Basins





Introduction

- Eng and Milly (2008): exponential-decay model for base flow $\frac{dQ}{dt} = -aQ^b$ $\quad Q_{t+\Delta t} = Q_t e^{-\Delta t/\tau}$

Statistical method to determine τ

- Brutsaert (2008): $\tau = 0.1 n_e / D_d^2 T_e \quad D_d = L/A$

Dd is insensitive to A in regions with homogeneous lithology; τ in similar climates = low variation

Objectives

Improve ORCHIDEE's routing scheme by finding a better description of the groundwater and its interactions with the land surface.

- Create a new high resolution topographical parameters data to ORCHIDEE's routing scheme.
- Improve ORCHIDEE's base flow equation to better represent groundwater at global scale.
- Improve ORCHIDEE's drainage simulation via soil texture data at global scale.

New topographical parameters

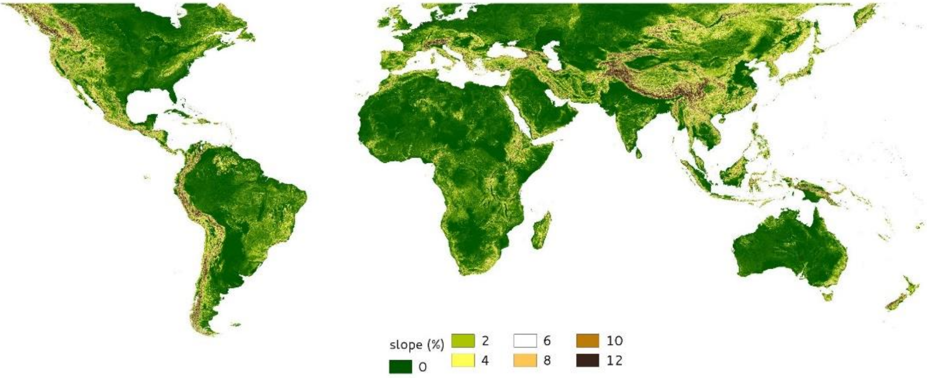
- Create a new high resolution topographical parameters data to use on ORCHIDEE's routing scheme.

Global data	Advantages	Problems
Hydro1K (Verdin and Greenlee, 1998)	1 km; global coverage; complete dataset; hydrologically conditioned corrections	Lack of data in Australia; separated files; flow directions
HydroSHEDS (Lehner et al., 2008)	3 arc-sec up to 5 min; complete dataset; hydrologically conditioned corrections	56°S – 60°N*
Wu et al. (2012)	1/16° up to 2°; merged HydroSHEDS and Hydro1K data; global coverage	Large amount of sinks; flow directions can't be reproduced; no basins information

* It will be updated to global coverage

New topographical parameters

- HydroSHEDS data:
  - 30 arc-seconds (1 km)
  - Flow directions: converted to *trip* (FAC and basins)
  - Topographic index *k* (km): $$k = \frac{d}{\sqrt{S}}$$
  - Slope: based on hydrologically corrected elevations



New topographical parameters

Parameter	ORCHIDEE (0.5°)	New parameter (0.5°)
trip=97 (% in area)	0.18%	0.17%
trip=99 (pixels)	166	249
k_{min} *and* k_{max} (km)	17 and 9 860	14 and 7 090
Basins (amount)	6 930	7 000

- Collaboration with Jan Polcher and Trung Nguyen for implementation in ORCHIDEE
- Update when global coverage is available

Base flow equation improvement

- Improve ORCHIDEE's base flow equation to better represent groundwater at global scale.

- Lithology global data from Hartmann and Moosdorf (2012)
- Porosity (-) and permeability (m^2) global data from Gleeson et al. (2014)

$$K = \frac{k \cdot \rho_w \cdot g}{\mu_w}$$

(m/s)

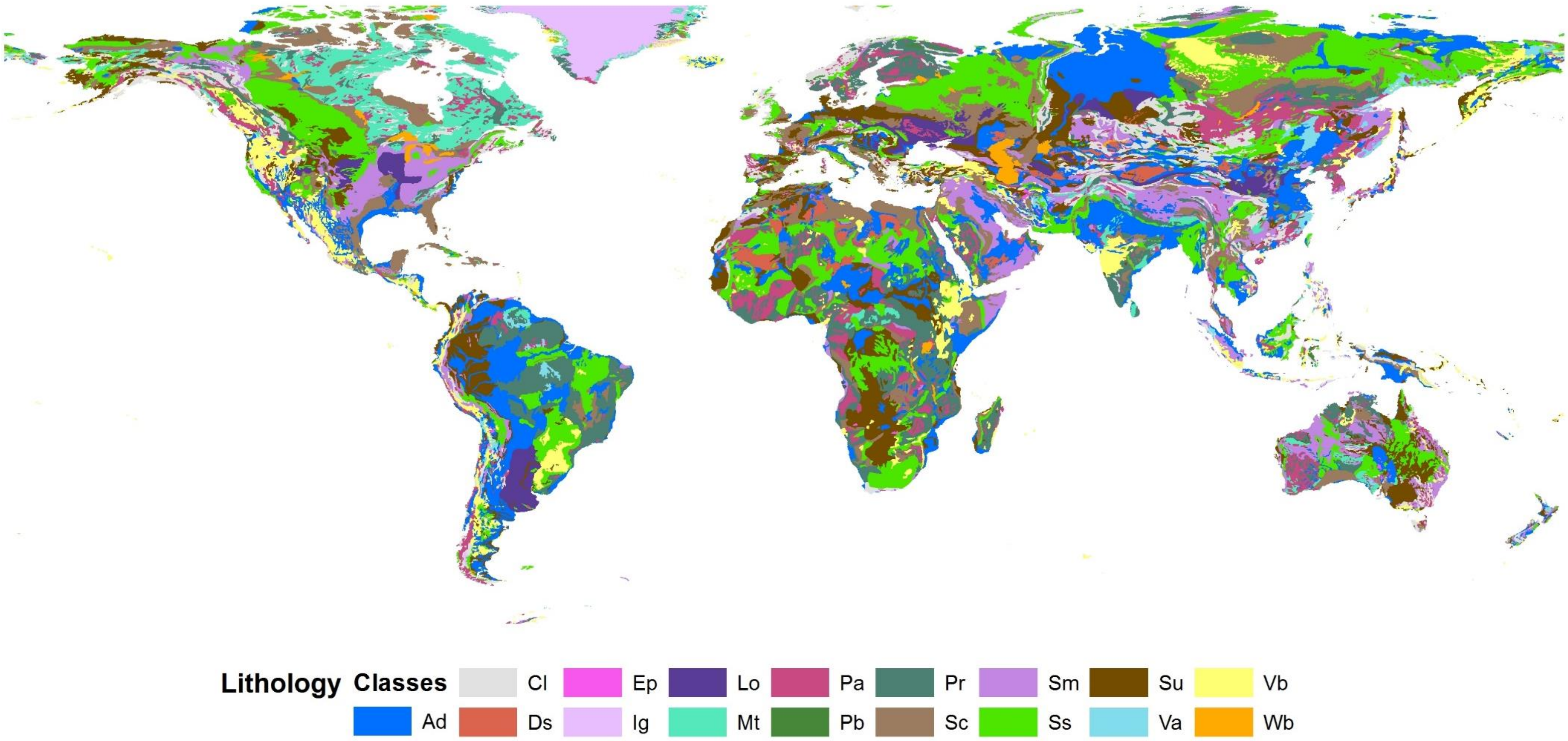
$$T = \mathrm{K} \cdot b$$

(m^2/s)

$$\mathrm{D} = \frac{T}{\eta}$$

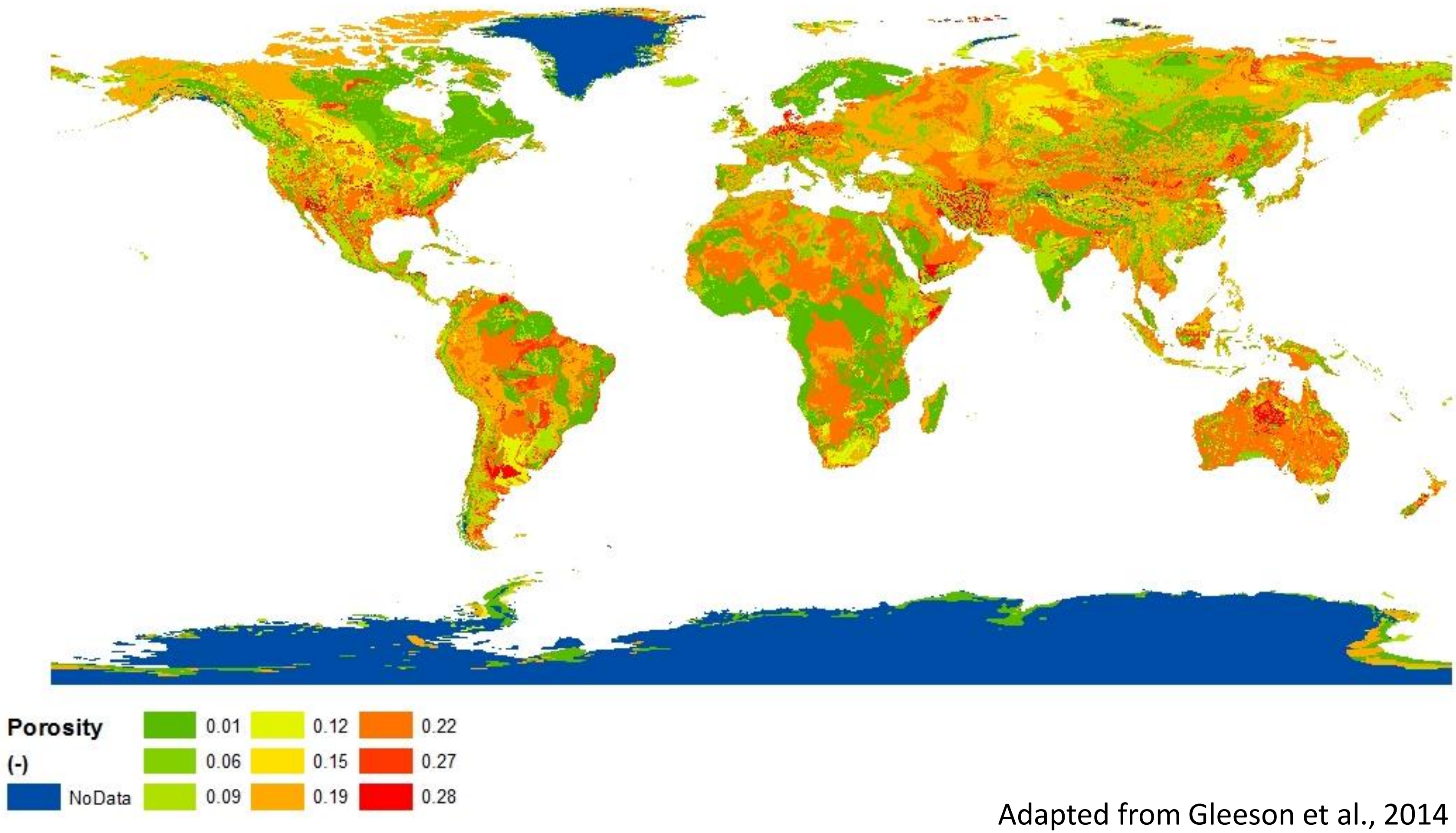
(m^2/s)

Base flow equation improvement



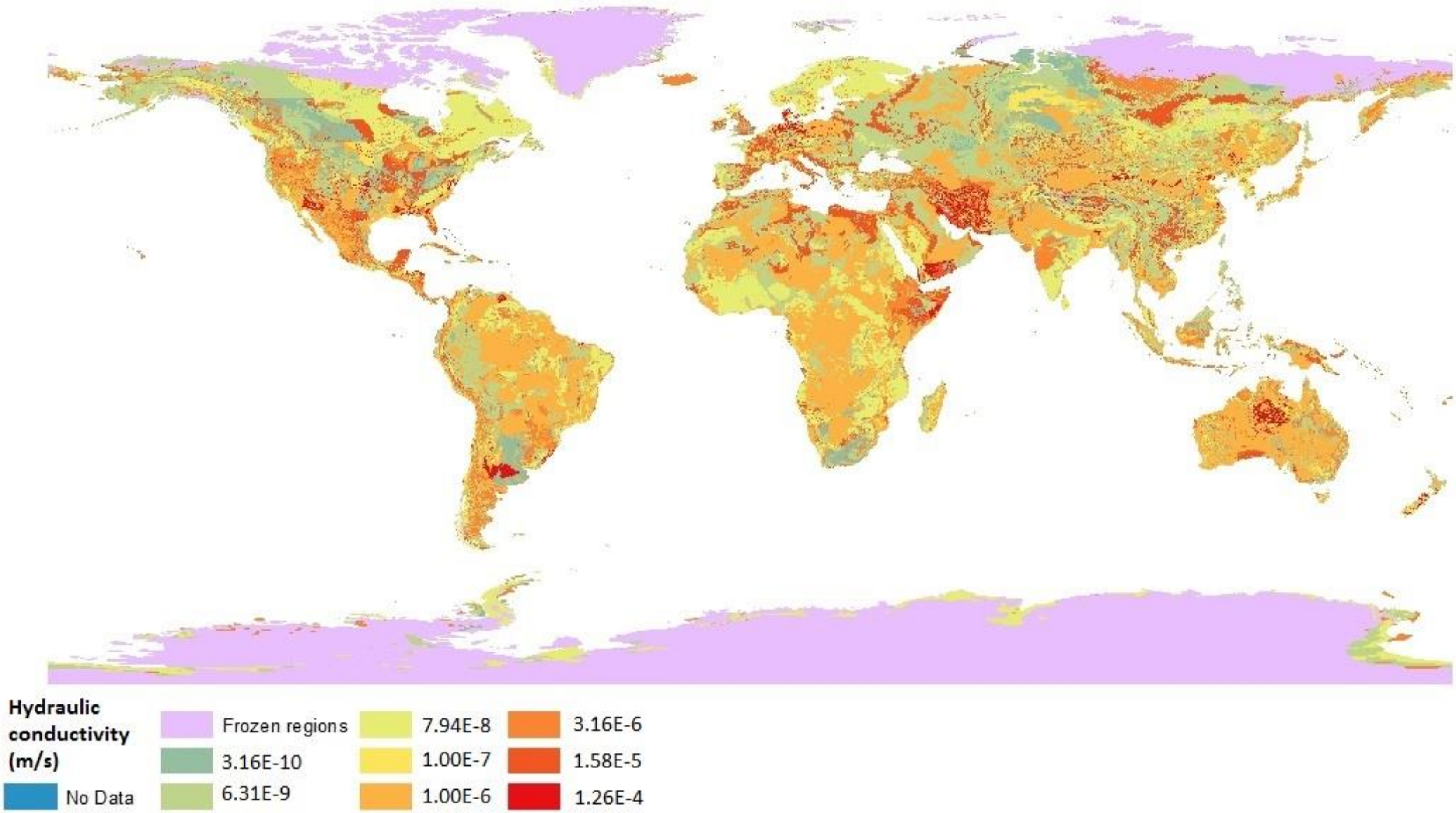
Adapted from Hartmann and Moosdorf, 2012

Base flow equation improvement



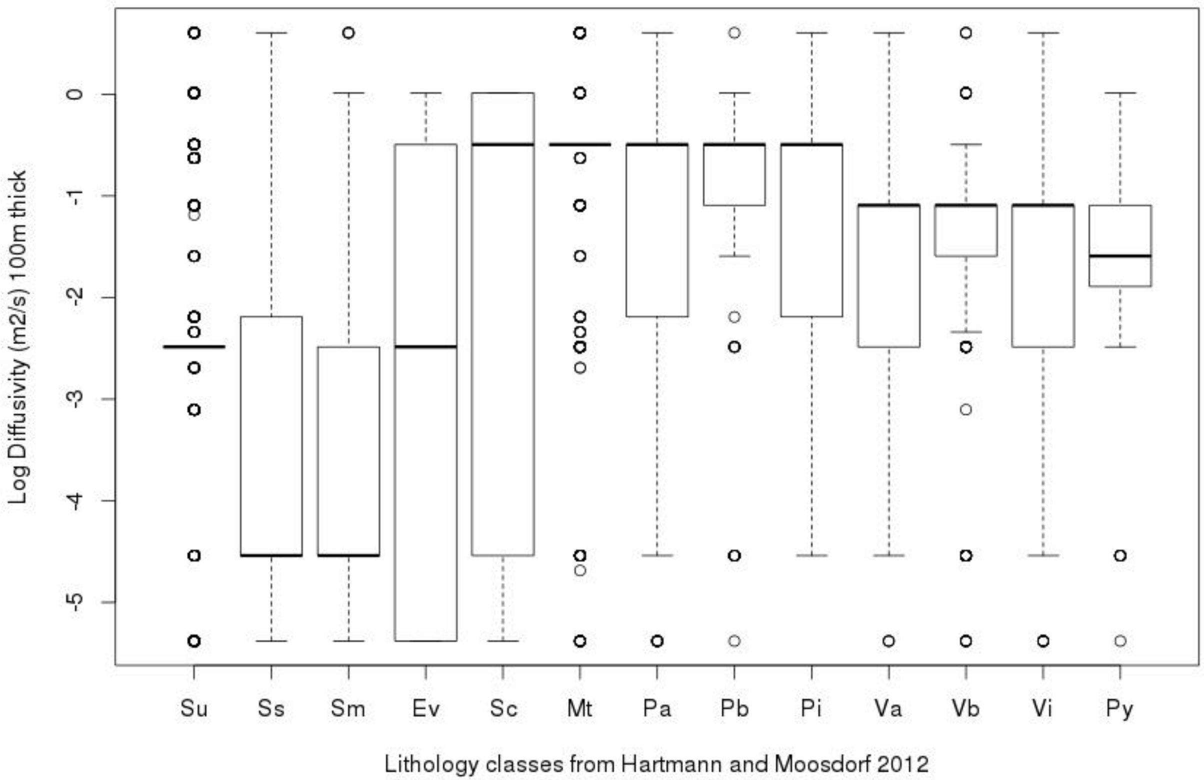
Adapted from Gleeson et al., 2014

Base flow equation improvement



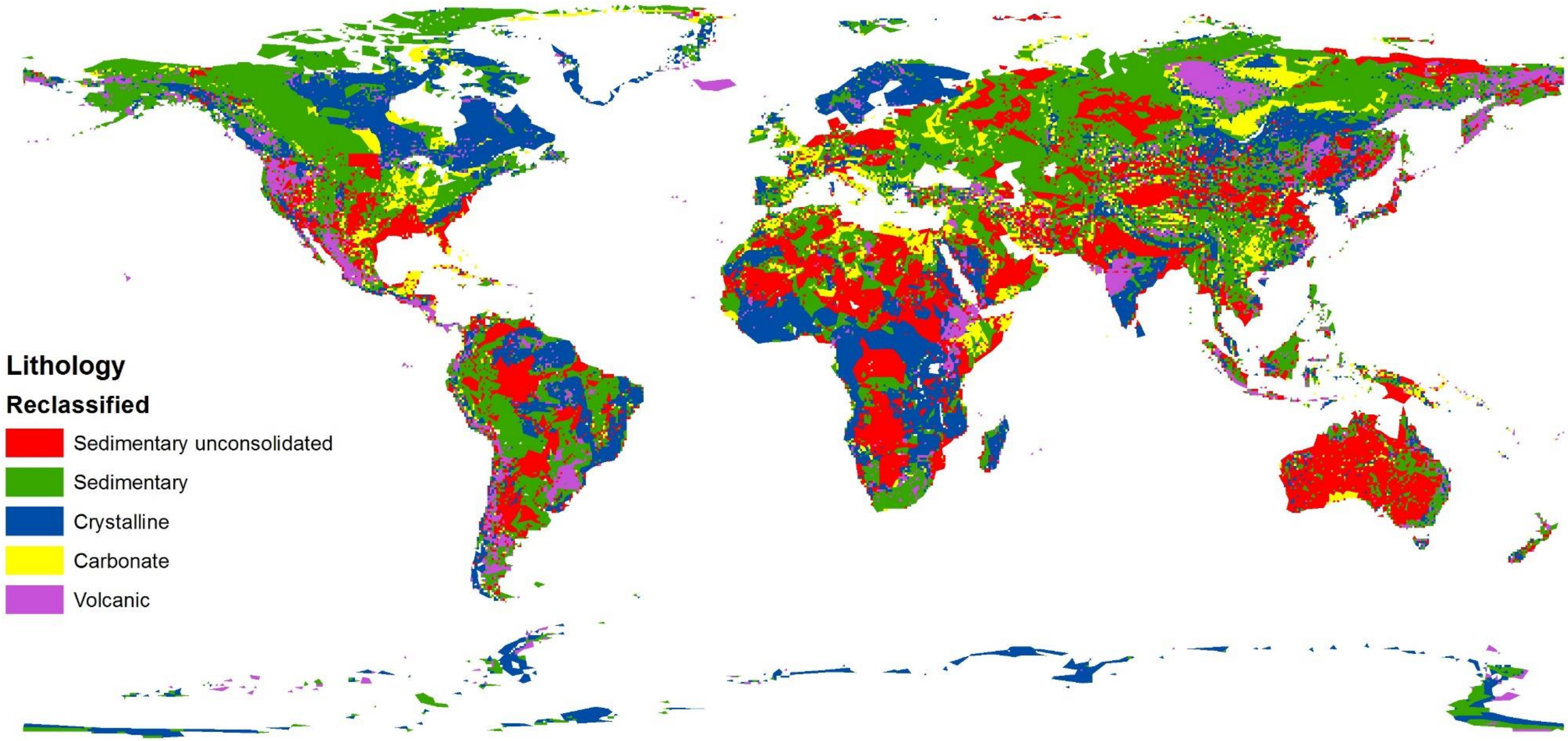
Calculated from Gleeson et al., 2014 permeability data

Base flow equation improvement



Lithology class (% in area)
Su – unconsolidated sedimentary (24%)
Ss – Sedimenary (19%)
Sm – mixed sedimentary rocks (19%)
Ev – evaporates (0%)
Sc – siliciclastic sedimentary rocks (8%)
Mt – metamorphic rocks (15%)
Pa – acid plutonic rocks (7%)
Pb – basic plutonic rocks (1%)
Pi – intermediate plutonic rocks (0%)
Va – acid volcanic rocks (1%)
Vb – basic volcanic rocks (4%)
Vi – intermediate volcanic rocks (2%)
Py – pyroclastics (1%)

Base flow equation improvement



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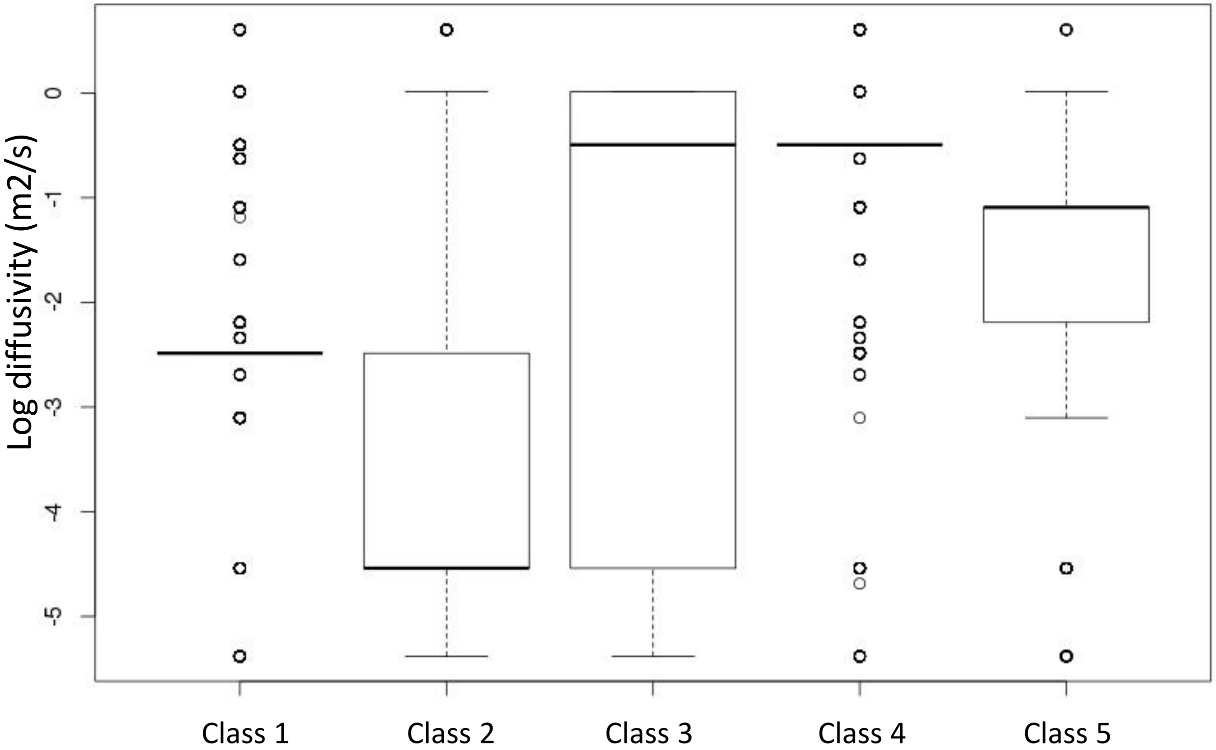
Base flow equation improvement



Lithology class (% in area)

Class 1 - unconsolidated sedimentary (24%)

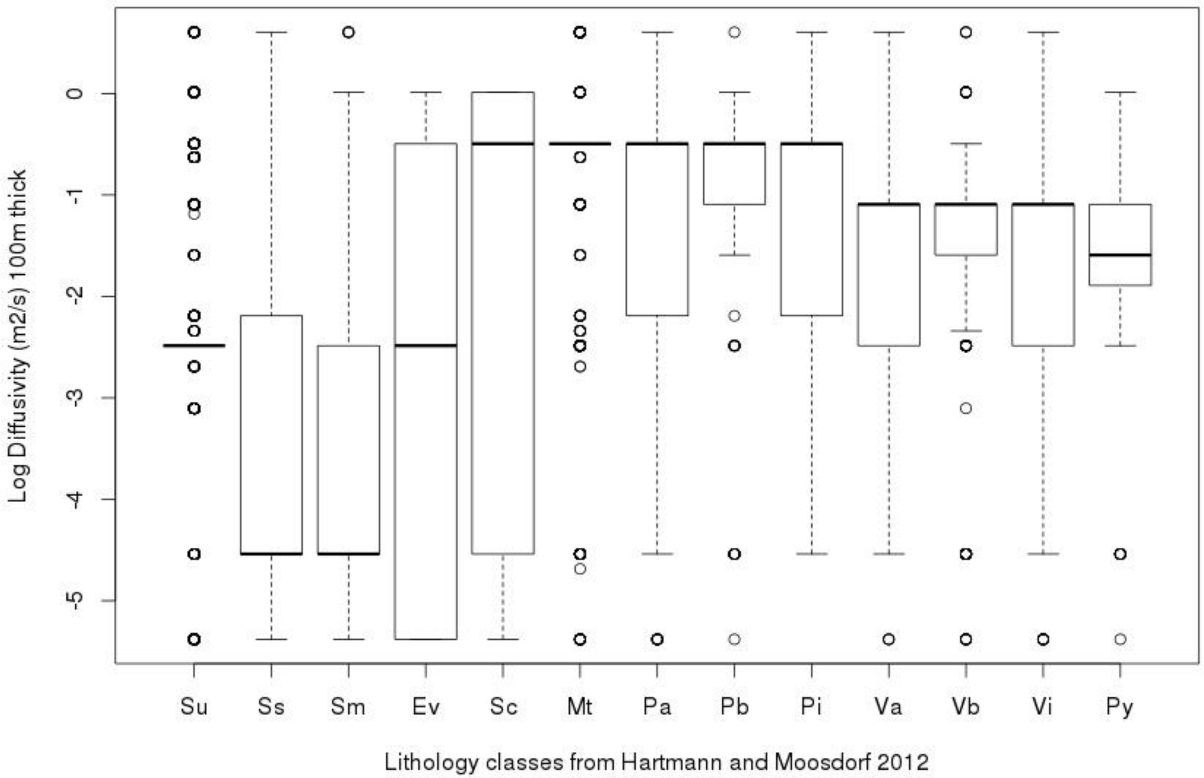
Class 2 - sedimentary + mixed sedimentary rocks + evaporites (38%)

Class 3 - siliciclastic sedimentary rocks (8%)

Class 4 - metamorphic rocks + acid plutonic rocks + basic plutonic rocks + intermediate plutonic rocks (23%)

Class 5 - acid volcanic rocks + basic volcanic rocks + intermediate volcanic rocks + pyroclastics (7%)

Base flow equation improvement



Lithology class (% in area)

Su – unconsolidated sedimentary (24%)
Ss – sedimentary (19%)
Sm – mixed sedimentary rocks (19%)
Ev – evaporites (0%)
Sc – siliciclastic sedimentary rocks (8%)
Mt – metamorphic rocks (15%)
Pa – acid plutonic rocks (7%)
Pb – basic plutonic rocks (1%)
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Va – acid volcanic rocks (1%)
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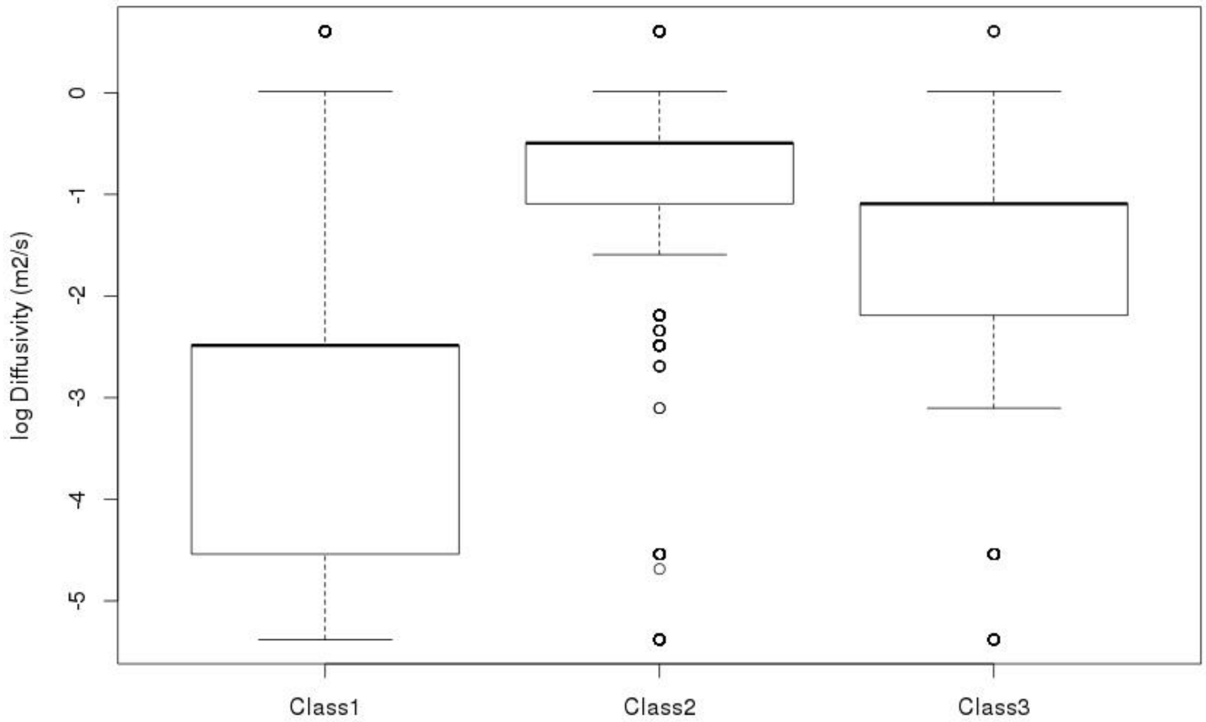
Base flow equation improvement



Lithology class (% in area)
Class 1 - unconsolidated sedimentary + sedimentary + mixed sedimentary rocks + evaporites (62%)
Class 2 - siliciclastic sedimentary rocks + metamorphic rocks + acid plutonic rocks + basic plutonic rocks + intermediate plutonic rocks (31%)
Class 3 - acid volcanic rocks + basic volcanic rocks + intermediate volcanic rocks + pyroclastics (7%)

Next steps and perspectives

- Test ORCHIDEE's sensibility to changes on the time constant;
- Decide: new time constant or new base flow equation?
- Validation of changes in ORCHIDEE
  - GRACE TWS
  - GRDC river discharge
- Drainage analysis:
  - new soil texture
  - parametrization