What process drives groundwater discharge in hard rock basement of West Africa?

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1. Context

- To anticipate the sustainability of groundwater uptake in hard rock aquifers requires comparison to recharge and discharge
- In a context of global changes, both recharge AND discharge are relevant because departure from equilibrium may rapidly impact water storage and the sustainability of groundwater uptake.
- Numerous work is focused on estimating recharge (e.g. [1],[2], [3], [4] and IAH session 2.c contributions, but very few adress discharge processes

2. Concept: Estimation of baseflow

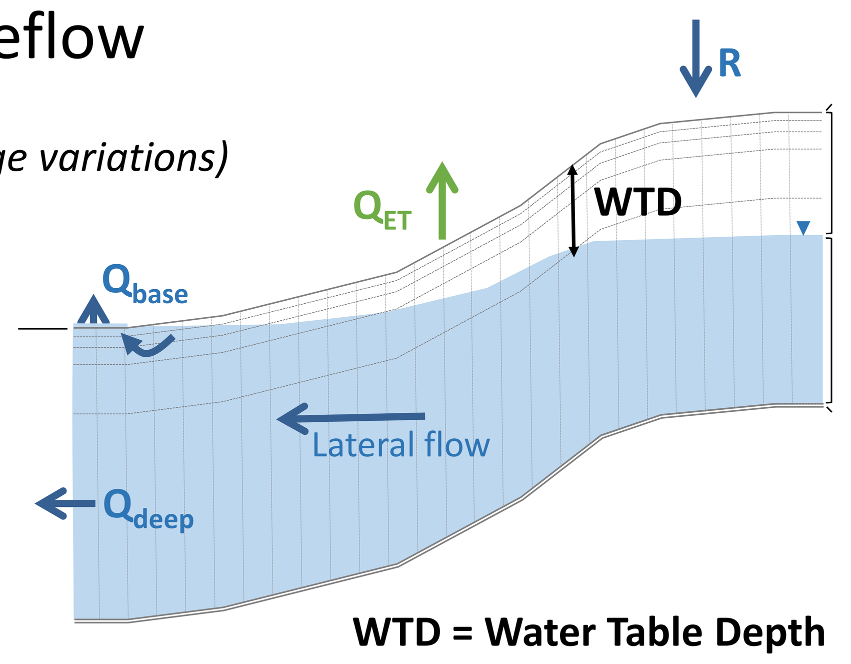
Groundwater budget: *(inflow = outflow + storage variations)*

$R = Q + \Delta Stock$

Ou

$R = Q_{ET} + Q_{base} + Q_{profond} + \Delta Stock$

R : Recharge,
Q_{ET} : Groundwater evapotranspiration,
Q_{base} : River baseflow,
Q_{deep} : regional groundwater flow



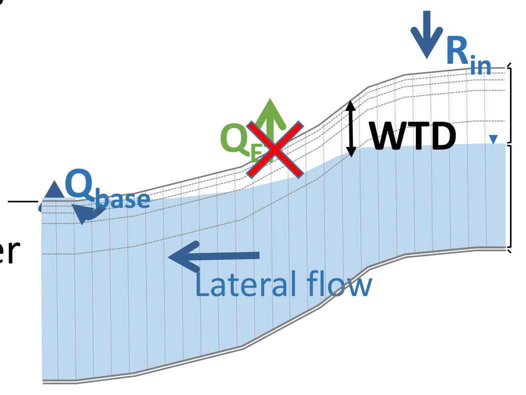
Hypotheses:

- In steady state regime and stationnary climate/uses/soils/vegetation: $\Delta stock \sim 0$
- $Q_{deep} \sim 0$ No observations of geochemical signature in large rivers

$\Rightarrow R = Q_{ET} + Q_{base}$

Approach to estimate Q_{base} :

In a numerical flow model that does not simulate ET,
It is possible to adjust forcing (R_{in}) to simulate observed water Levels, allowing to derive $R_{in} = Q_{base}$



3. Methods

- A porous-media flow model (ParFlow) is applied over the whole West Africa
- Applied recharge flux is adjusted so as to match observed water table depths
- This applied recharge corresponds to baseflow and can be compared to total discharge as estimated from recharge values found in the littérature.

Data

- A drill logs database allows to know the water table depth (N = 31549)

4. ParFlow model configuration

- ParFlow: Richards equations [5], [6], [7]
- Resolution 1km², daily time step
- 11 cells in depth (**Fig. 1**)
- Hydrodynamic parameters:
  - 0-2.5m: SoilGrids [8] and pedotransfer functions [9]
  - 2.5-100m: GLHYMPS [10] modified ($Ks_{aq.\ socle} = 6.10^{-5}$ m/s, **Fig. 2**)
- Forcings (**Fig. 3**):
  - R = α * (Precipitation (P) – Evapotranspiration (ET))
  - P and ET derived from GLDAS
  - α = 1/50 obtained with manual calibration
- Steady state regime (2000 years)

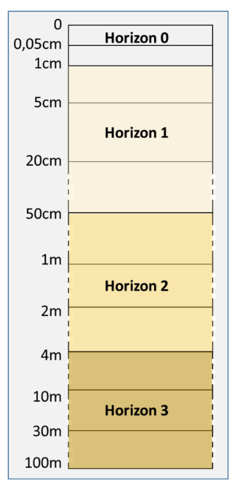


Fig.1: Vertical mesh

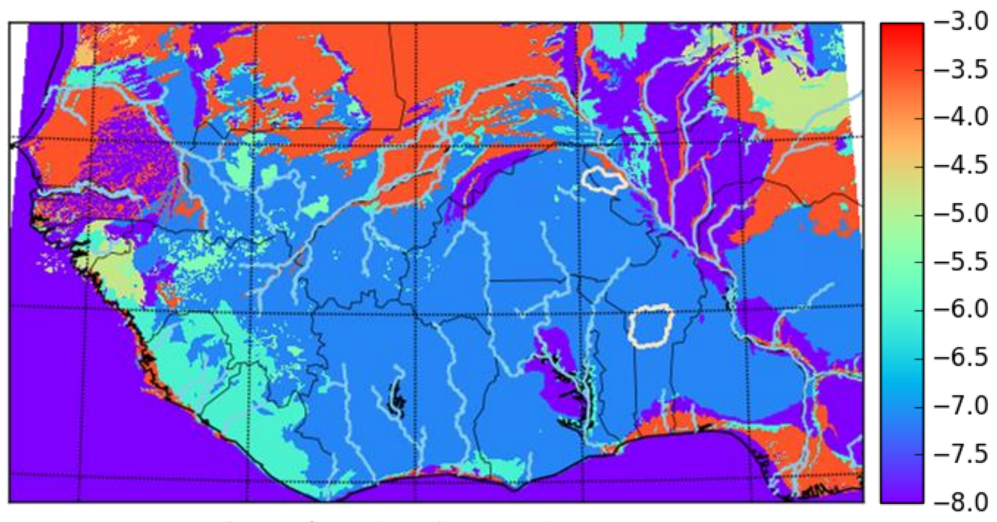


Fig.2: Logarithm of Hydraulic Conductivity

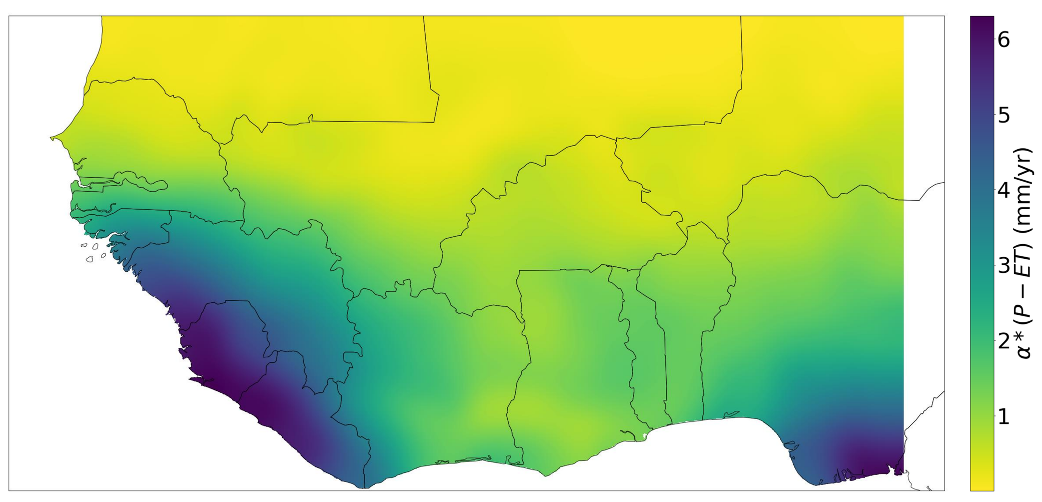


Fig.3: Model forcing

5. Resultats:

- Homogeneous behavior in hard rock areas (**Fig. 4**)
- Simulated water levels match observed ones for most of imposed forcings (**Fig. 5**)
- Spatial distribution of water levels show regional variations that could be better simulated (**Fig. 6**)
- Q_{base} remains below 3mm/year

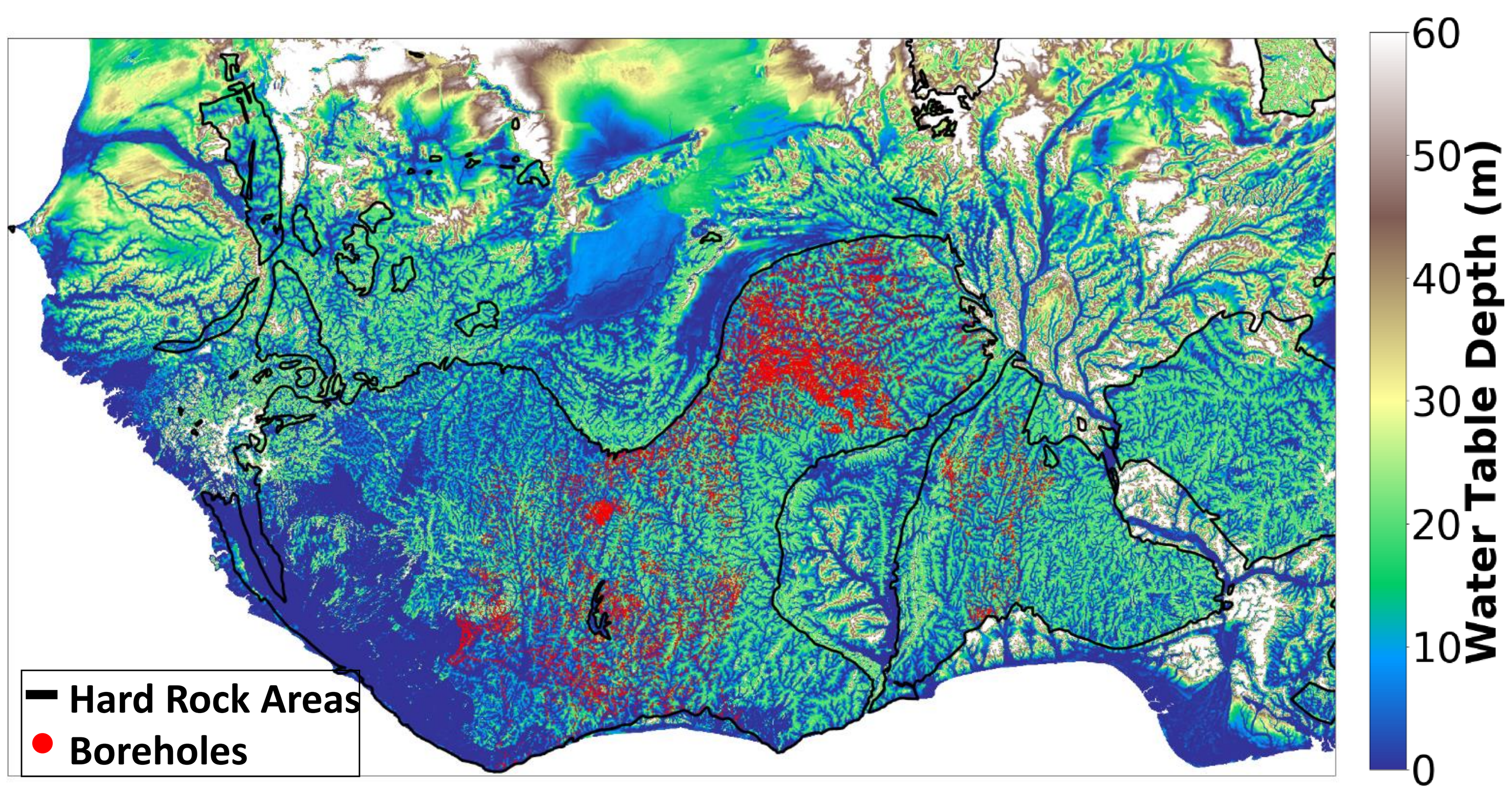


Fig.4: Simulated water table depths and drillings locations

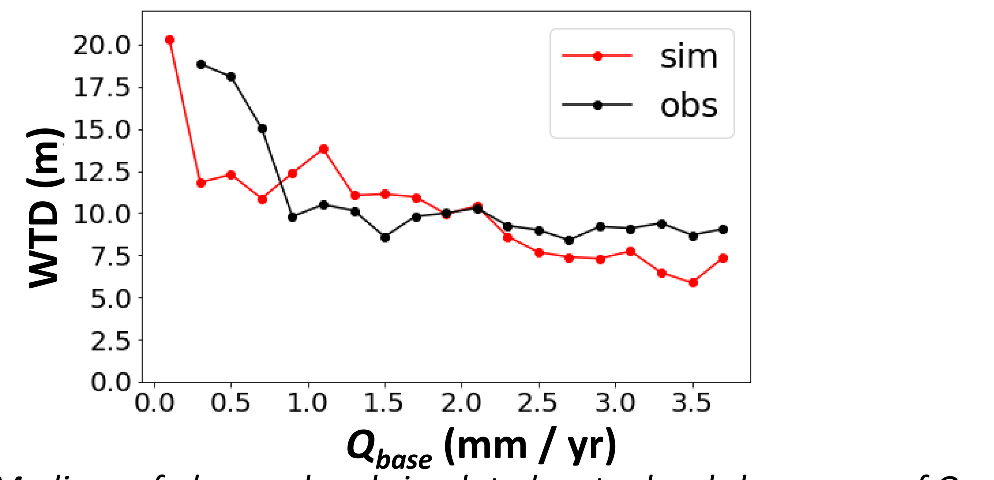


Fig.5: Medians of observed and simulated water levels by ranges of Q_{base}

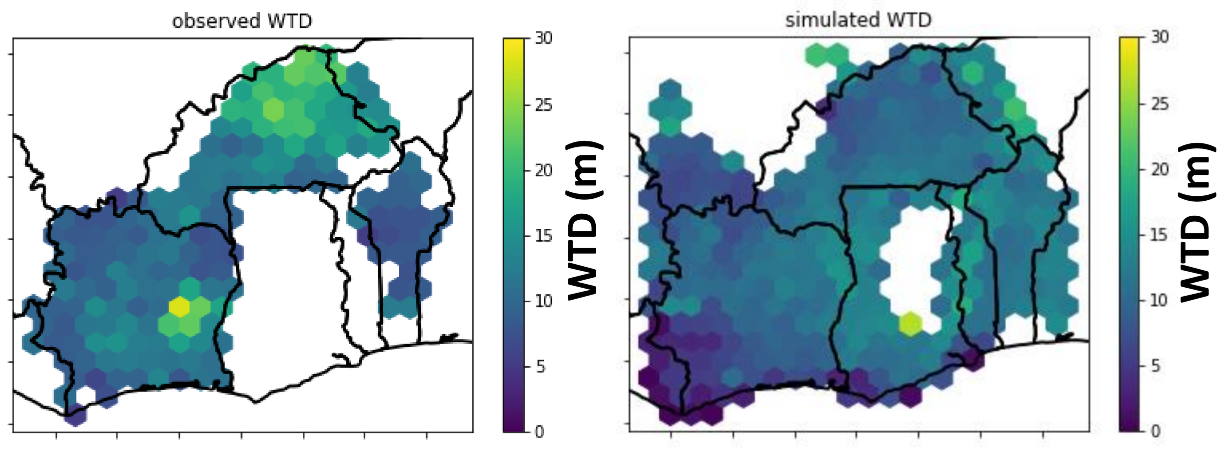


Fig.6: spatial means of agregated water level observed (left) and simulated (right)

6. Discussion

- From the total recharge (=total discharge Q) map from [2], one may estimate the ratio Q_{base} / Q (**Fig. 7**)
- Baseflow discharge is less than 4% of total discharge and often less than 2%
- This agrees with the absence of observation of geochemical signature of permanent water table in rivers (e.g. [11]) and previous modeling experiment results [12]

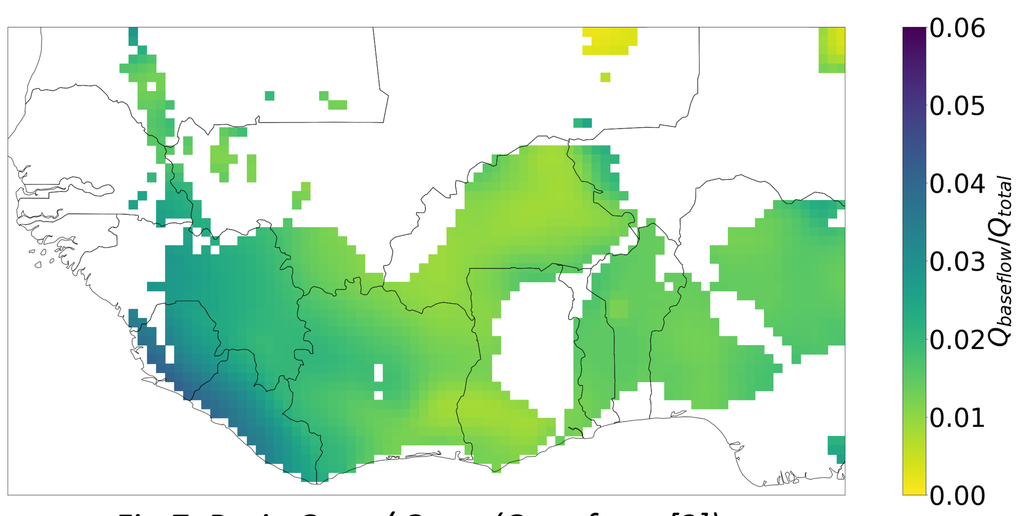


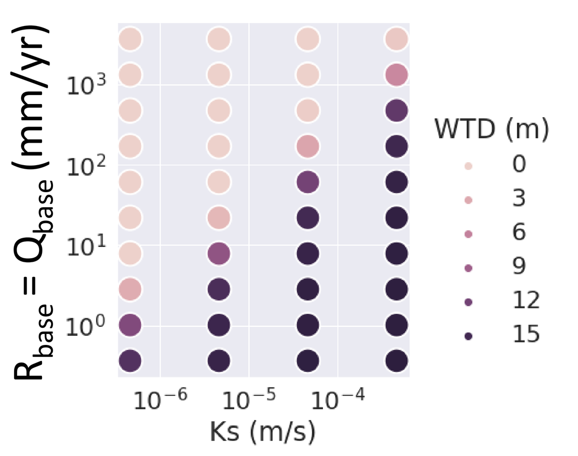
Fig.7: Ratio Q_{base} / Q_{total} (Q_{total} from [2])

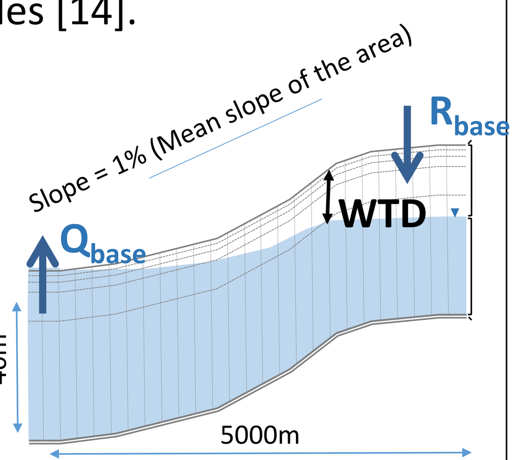
These estimates are maximums because:

- Aquifer Ks in the model are overestimated (~1 order of magnitude) as compared to a littérature review [13] ($8.10^{-7} – 1.7.10^{-5}$ m/s)
- Riparian areas have high transpiration rates and may contribute to the lateral gradients in the water tables [14].

Sensitivity analysis:

- Simulations of a typical hillslope help understand the model sensitivity
- Results are highly sensitive to Ks, which need to be better constrained through other approaches.





Conclusion

- Groundwater in hard rock is most likely discharged through evapotranspiration
- These results are consistent with a weak contribution of groundwater to rivers, depending on the climate.
- Such results imply to explicitely account for land use and land cover change and climate change that will impact evapotranspiration, but also to strengthen the knowledge of groundwater evapotranspiration .

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