Groundwater dynamics retrievals in Africa using SMOS soil moisture measurements

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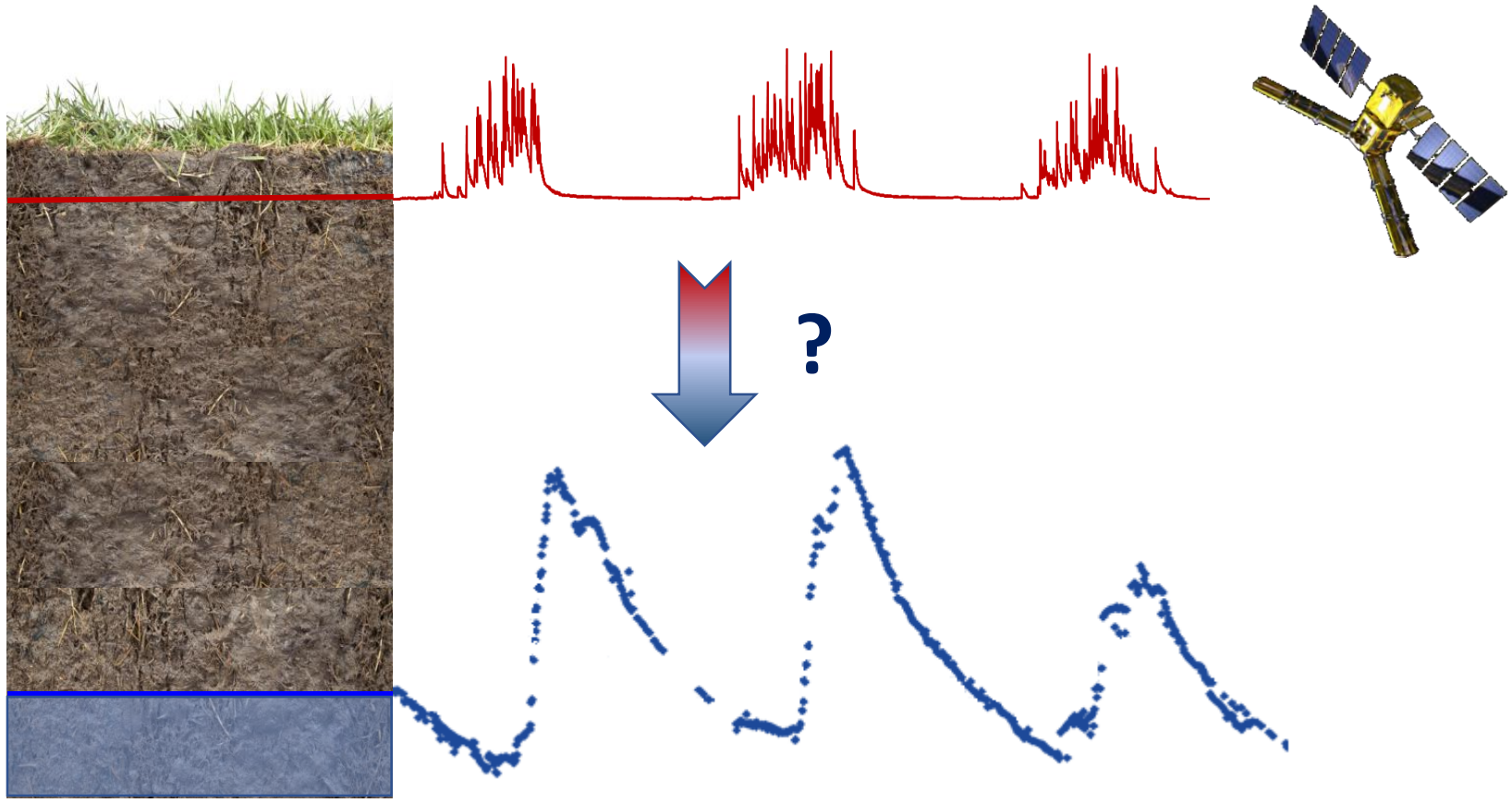

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Assumption

Soil moisture dynamics at 5 cm is a signature of water dynamics in deeper soil layers.

Methodology

1- Get accurate surface soil moisture estimates (PrISM product)
2- Force the Richards model (1D) with surface soil moisture
3- Select relevant hydraulic parameters using GRACE measurements

Soil moisture estimates

The PrISM* methodology

*Precipitation Inferred from Soil Moisture

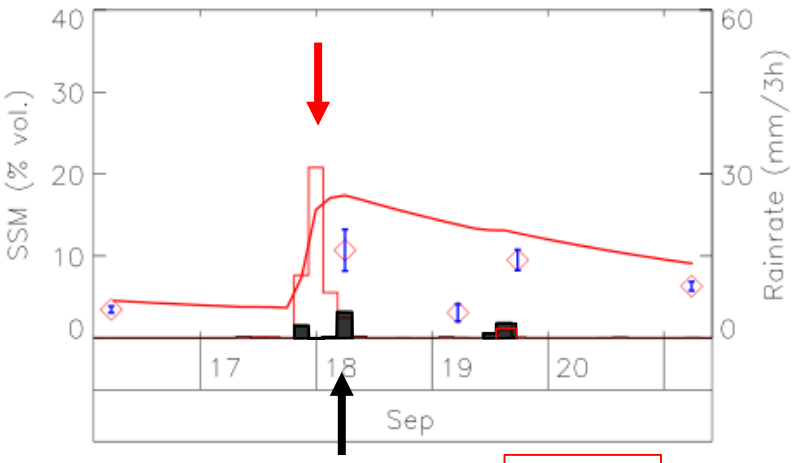
Pellarin et al. 2008, 2009, 2013, 2020; Louvet et al. 2015; Brocca et al. 2016; Román-Cascón et al. 2017 ; Zhang et al. 2019

Concept of PrISM :

Exploit the differences between satellite soil moisture measurements (SMOS/SMAP/ASCAT) and simulated soil moisture based on an existing satellite precipitation product

STEP 1

Satellite rainfall product



In situ rainfall
(Unknown)

SMOS

Simple adaptation to the Antecedent Precipitation Index (API) :

$$\theta_t = (\theta_{t-1} - \theta_{res}).e^{-\frac{\Delta t}{\tau}} + \left(\theta_{sat} - (\theta_{t-1} - \theta_{res})\right).\left(1 - e^{\frac{-P(t)}{dsoil}}\right) + \theta_{res}$$

θ_t : *soil moisture* $(m3/m3)$
θ_{res} : *residual soil moisture* $(m3/m3)$
θ_{sat} : *saturated soil moisture* $(m3/m3)$
Δt : *time step* (h)
τ : *soil moisture drying − out velocity* (h)
$dsoil$: *soil thickness* (mm)

The PrISM* methodology

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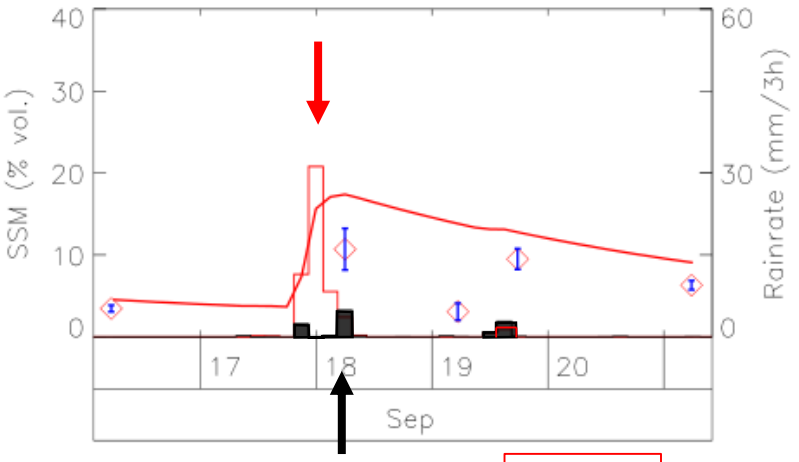

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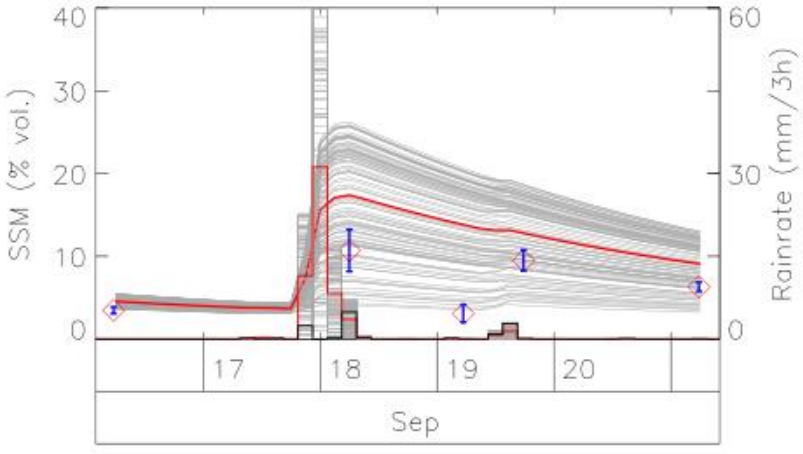
SMOS

STEP 2

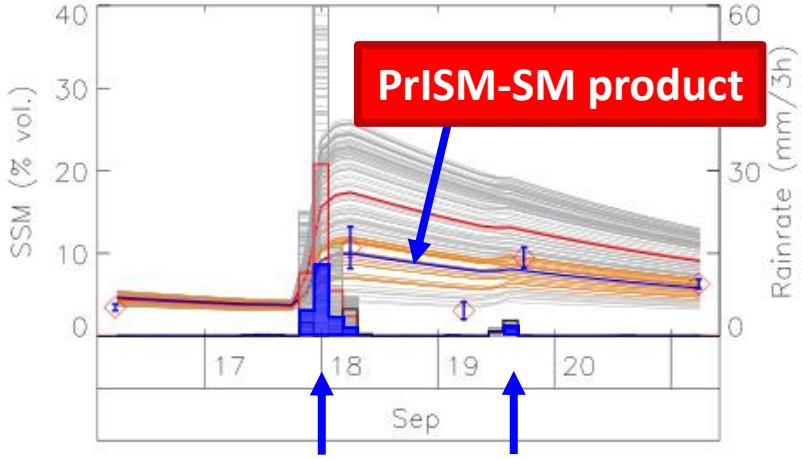
Rainfall perturbation



$$P_i^{event} = P^{event} \; x \; Random[0-2]$$

STEP 3

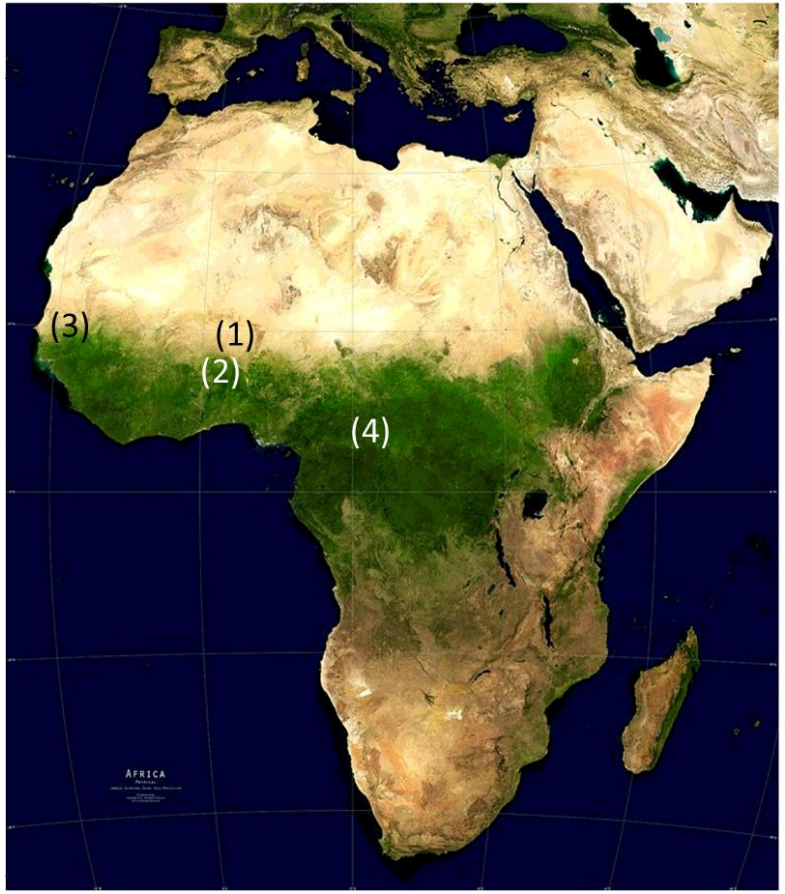
Most probable SM trajectories



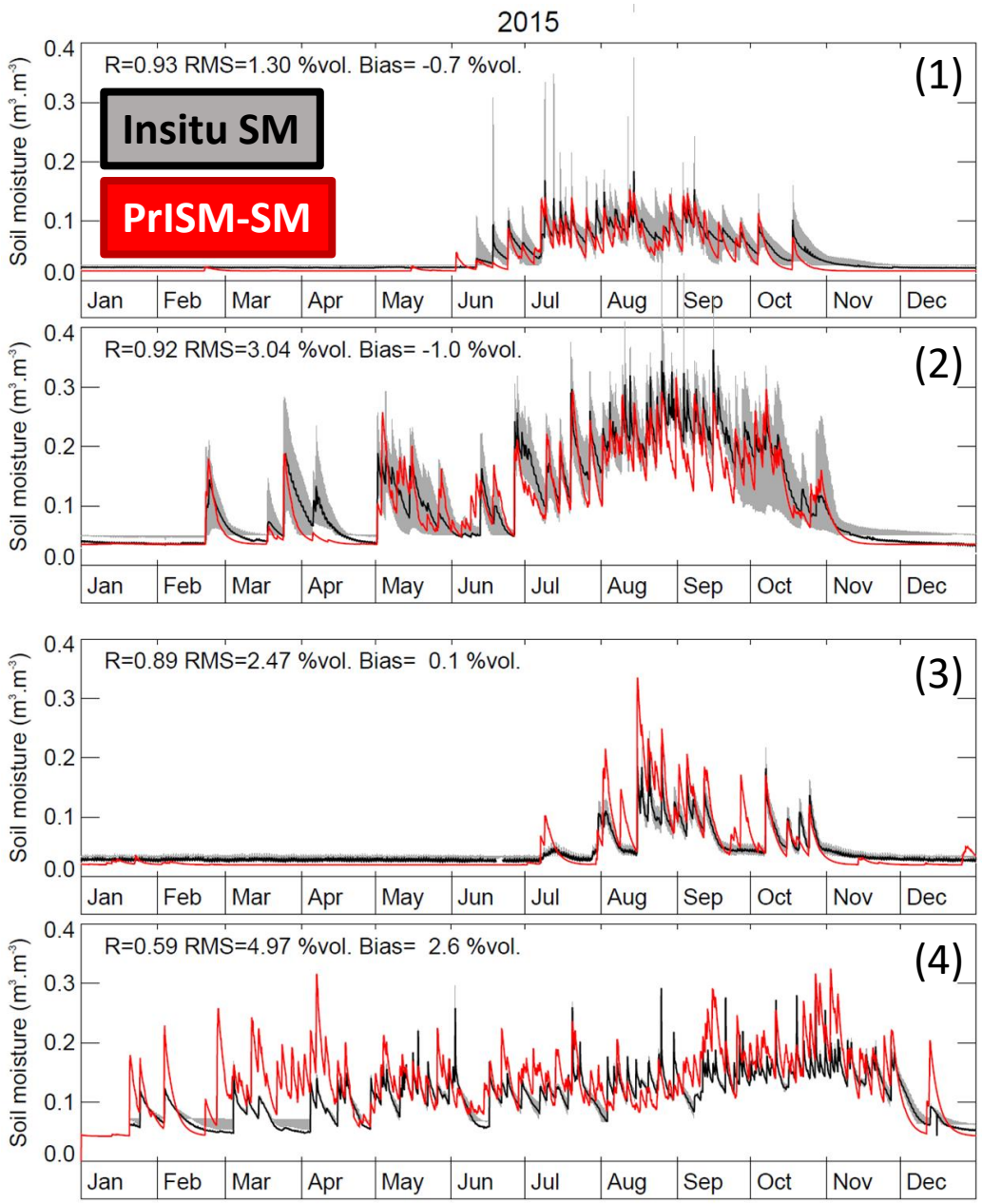
Derived PrISM rainfall product

= Particle Filter Assimilation Scheme

Evaluation of the PrISM-SM product over 4 pixels in Africa



PrISM-SM product is available on every 0.25°pixel of Africa, 3-hour temporal resolution



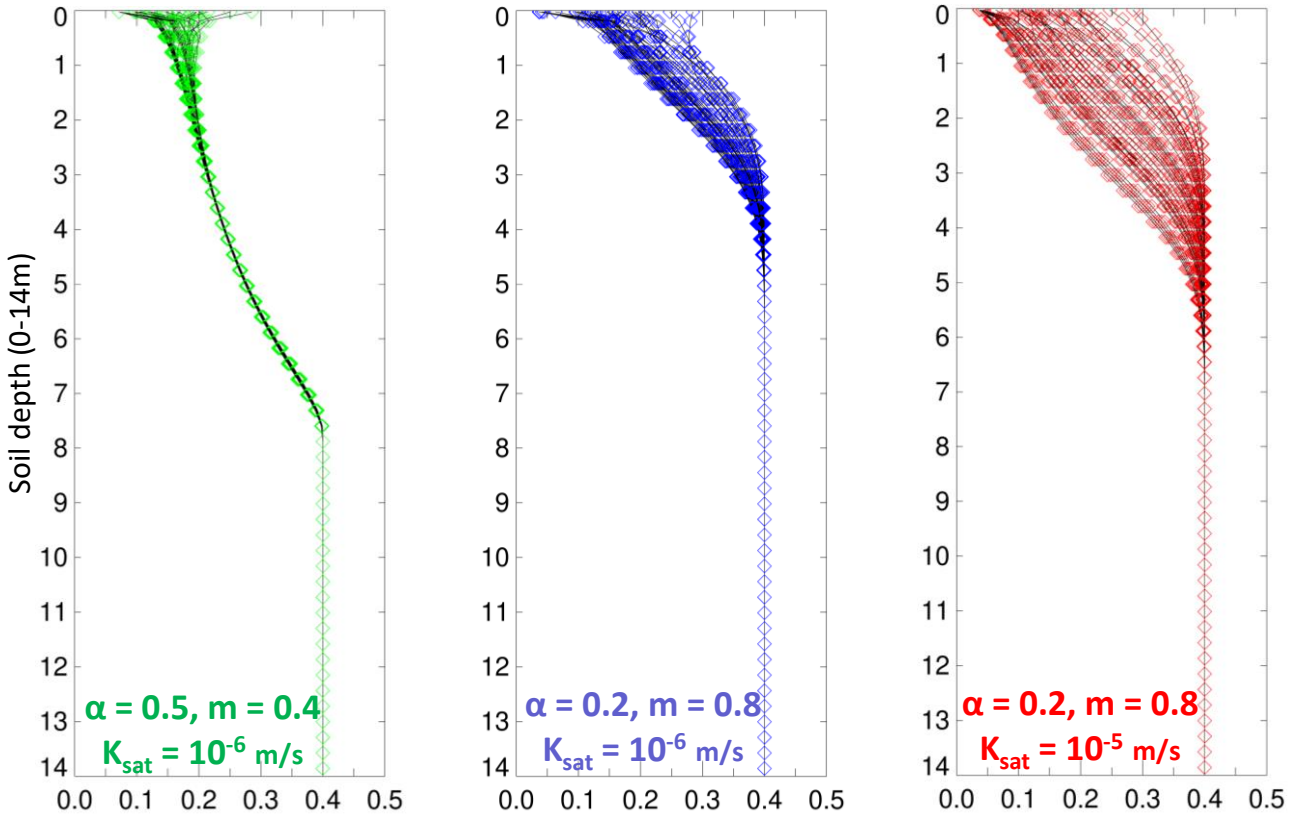
Water propagation using 1D Richards equation

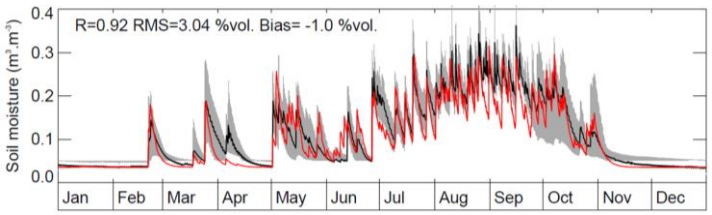
Methodology : use the Richards equation (1931) to propagate moisture from the surface to the depths.

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z}\left[K(\theta)\left(\frac{\partial h}{\partial z} + 1\right)\right]$$

K(θ) = f(Van Genuchten coefficients α, m, K_{sat})

3 examples of hydraulic parameters





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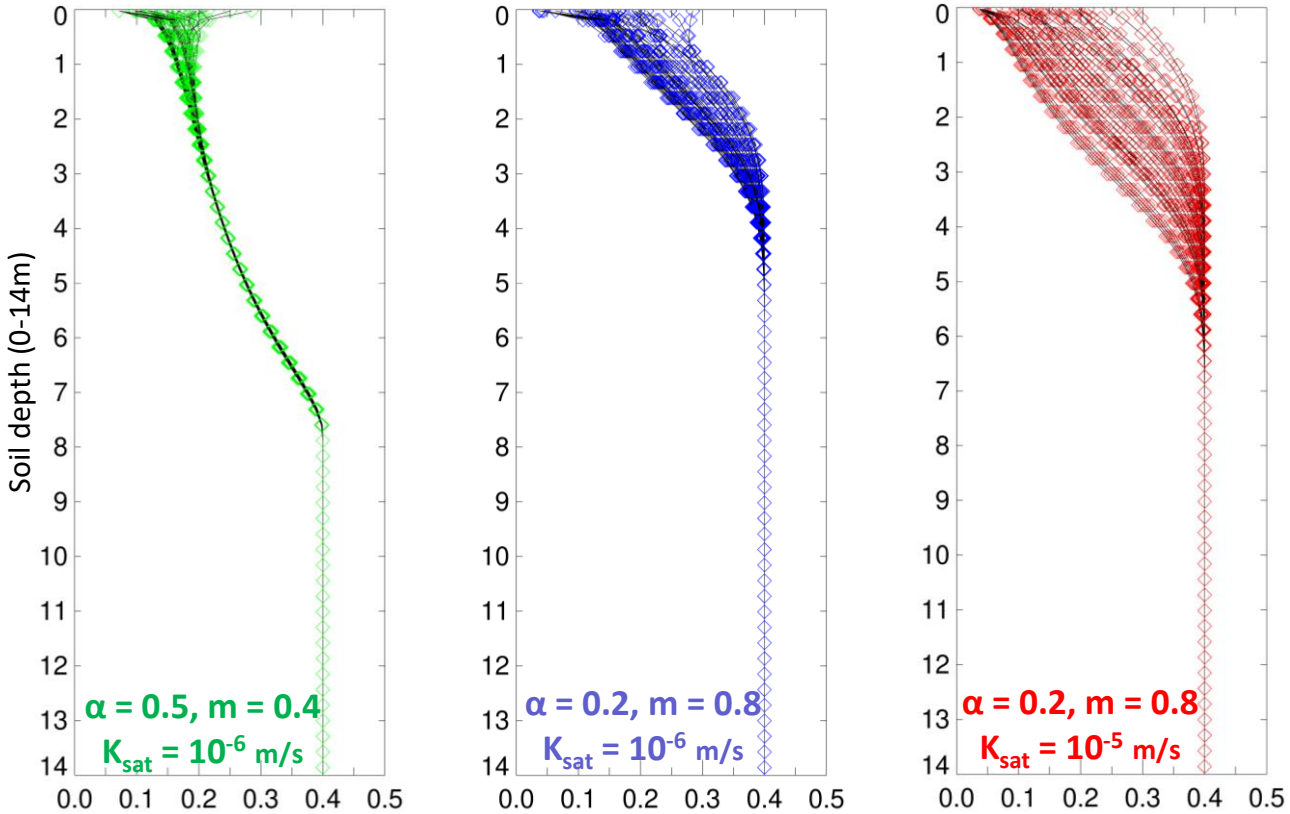

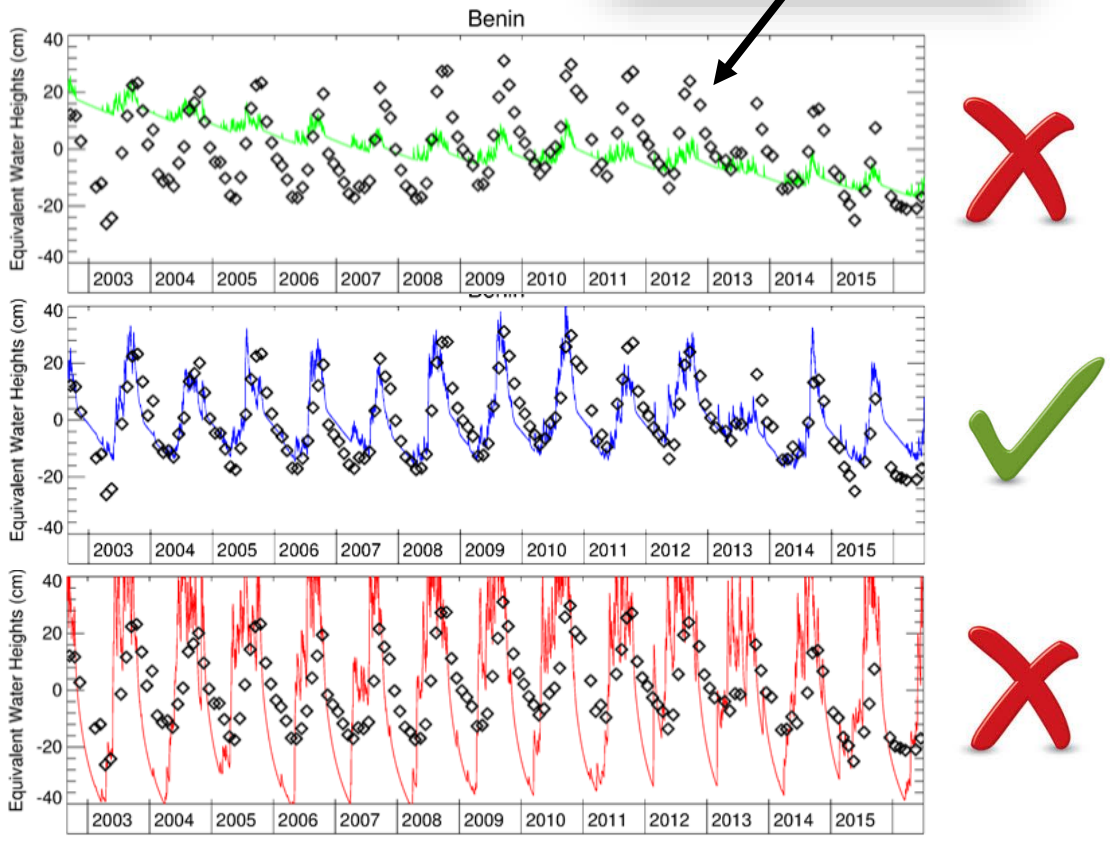

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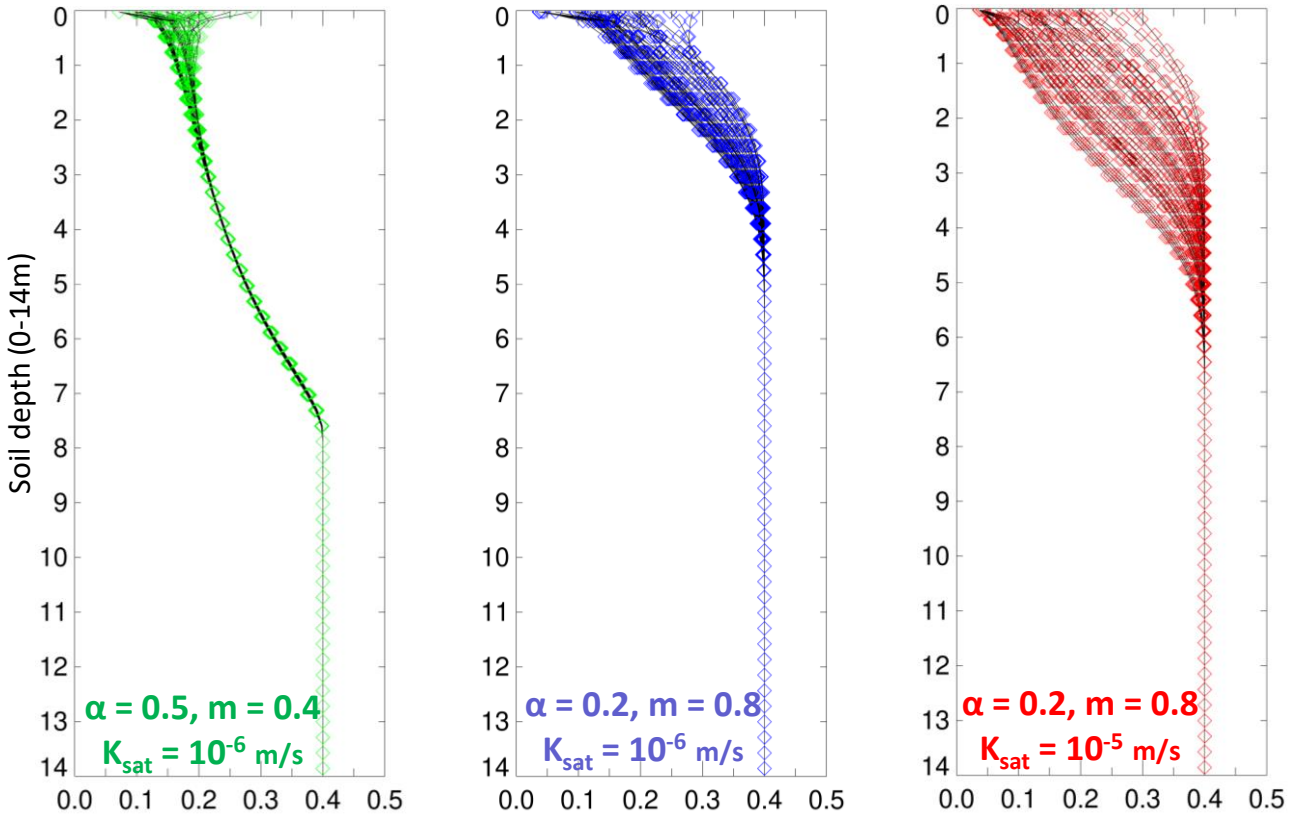


Checking with insitu water table depth

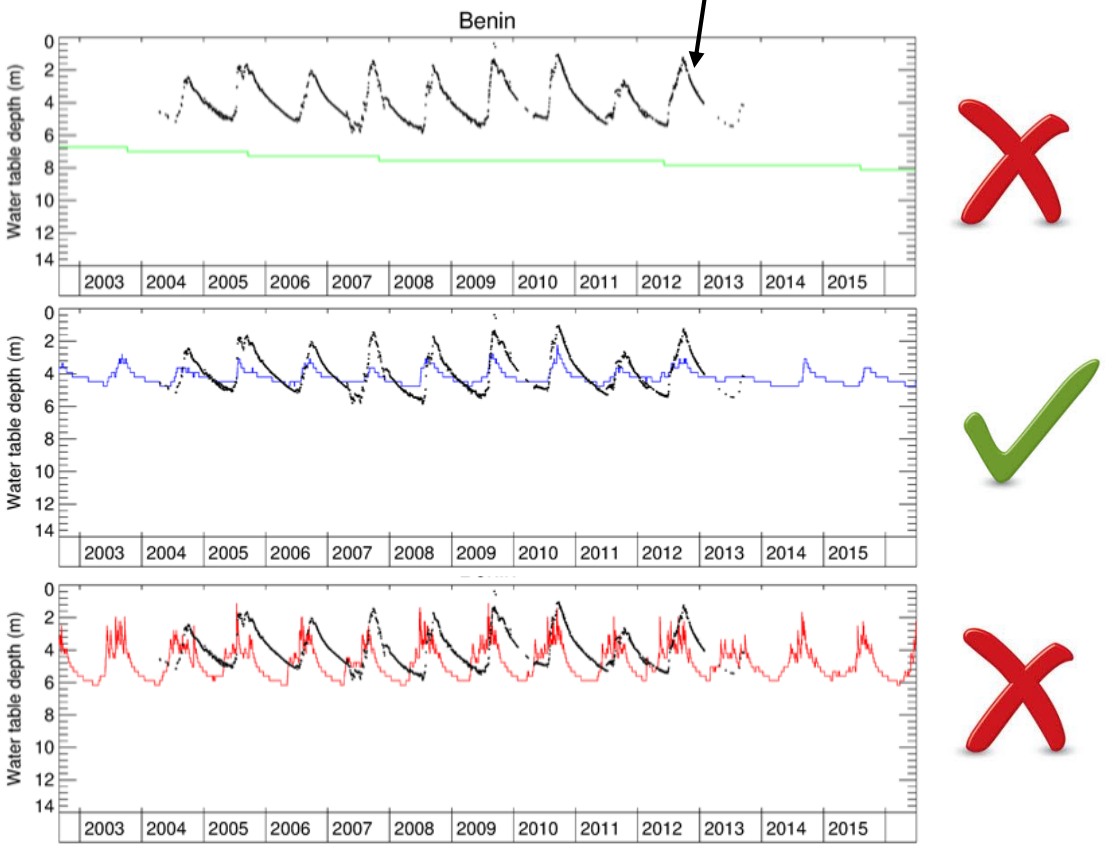
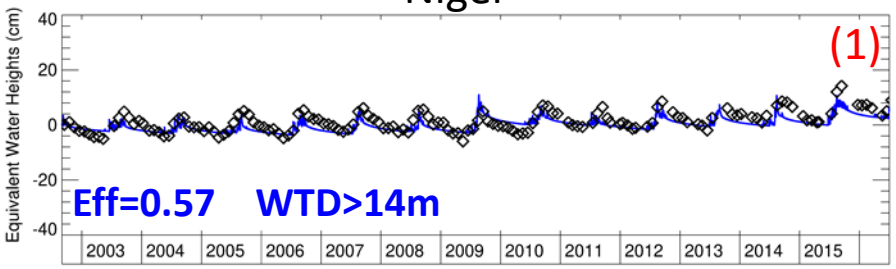
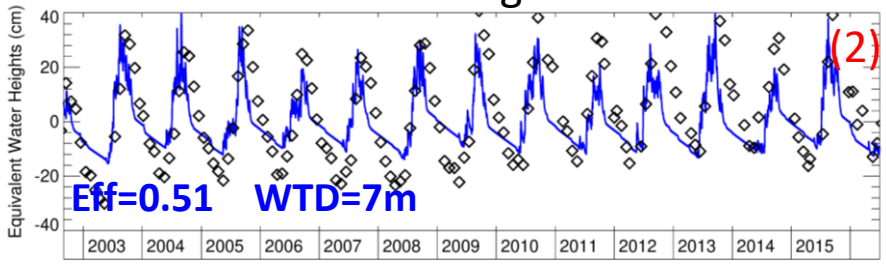


Illustration of equivalent water height variations over 6 pixels in Africa (simulation in blue, GRACE in black)

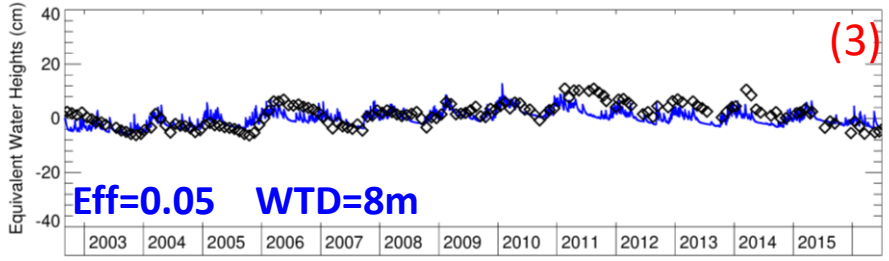
Niger

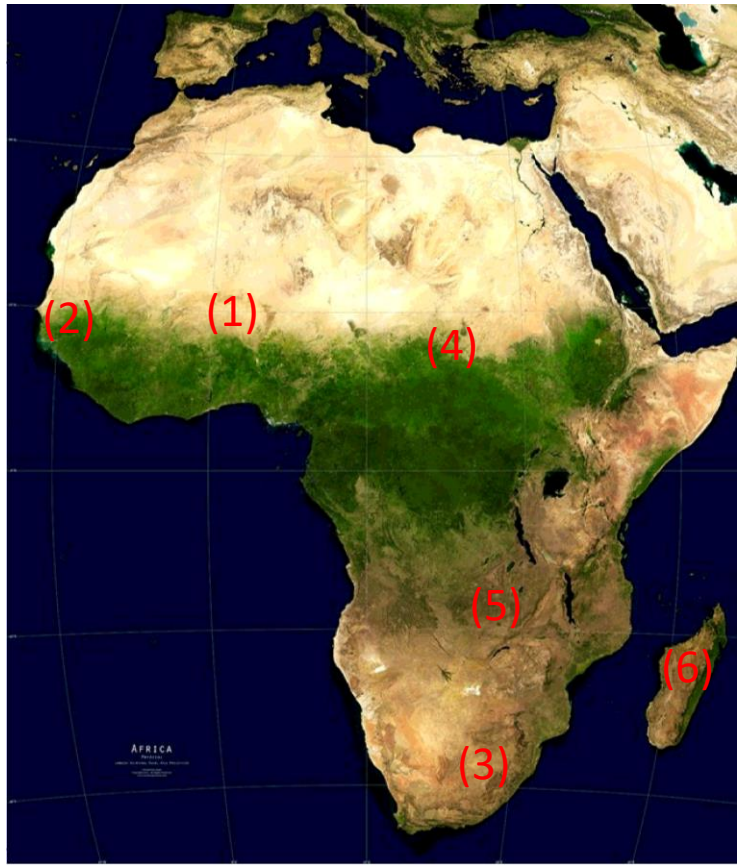


Senegal

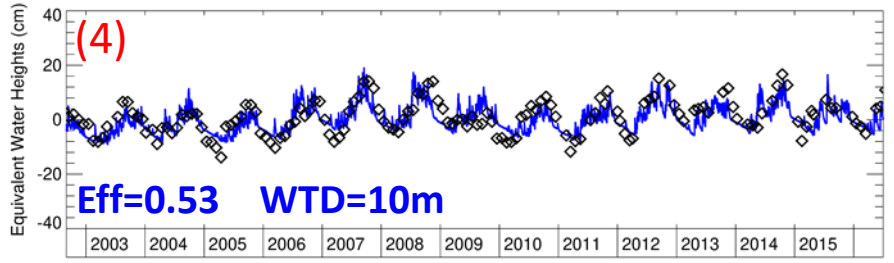


South Africa

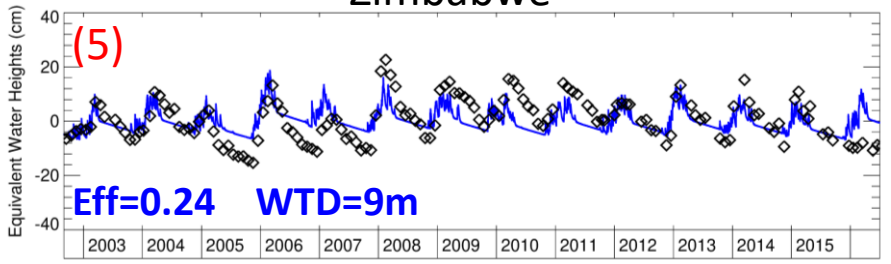




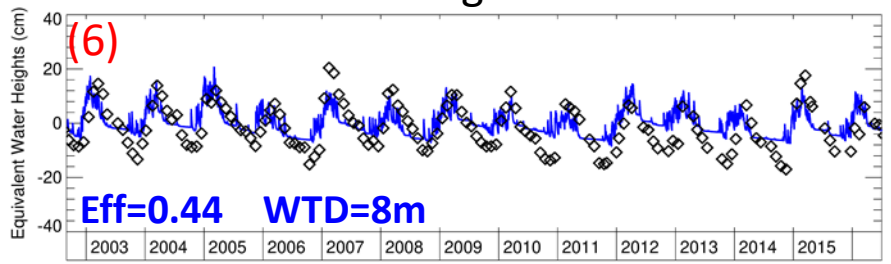
Soudan



Zimbabwe

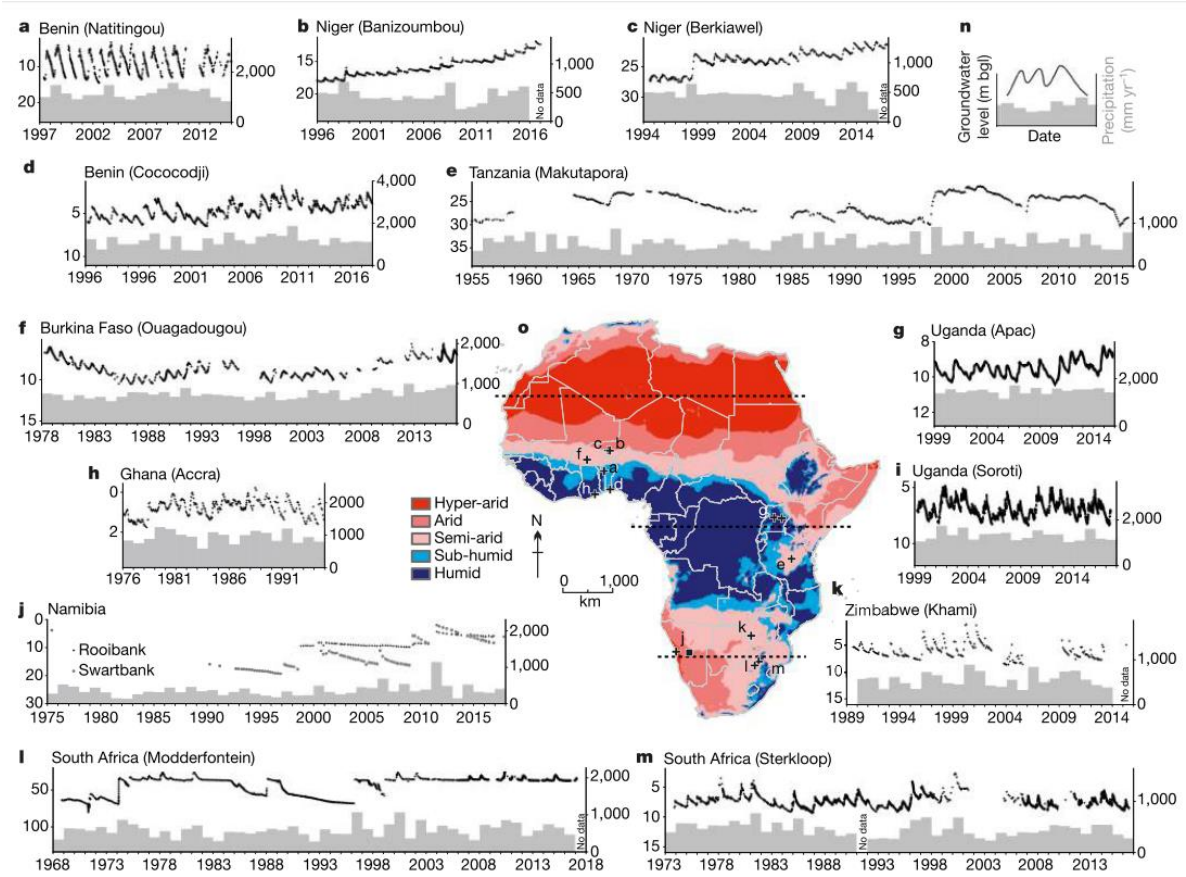


Madagascar



Conclusions & Perspectives

- Run automatic detection of hydraulic parameters over all Africa
- Assess the PrISM groundwater product using insitu aquifer measurements
- Evaluate the product on root moisture (0-2m) using field measurements.
- Inserting the algorithm into the PrISM operational processing chain



Cuthbert et al., Nature, 2019 https://doi.org/10.1038/s41586-019-1441-7