The Importance of Water Below Ground in Convection Permitting Models for Climate Simulations

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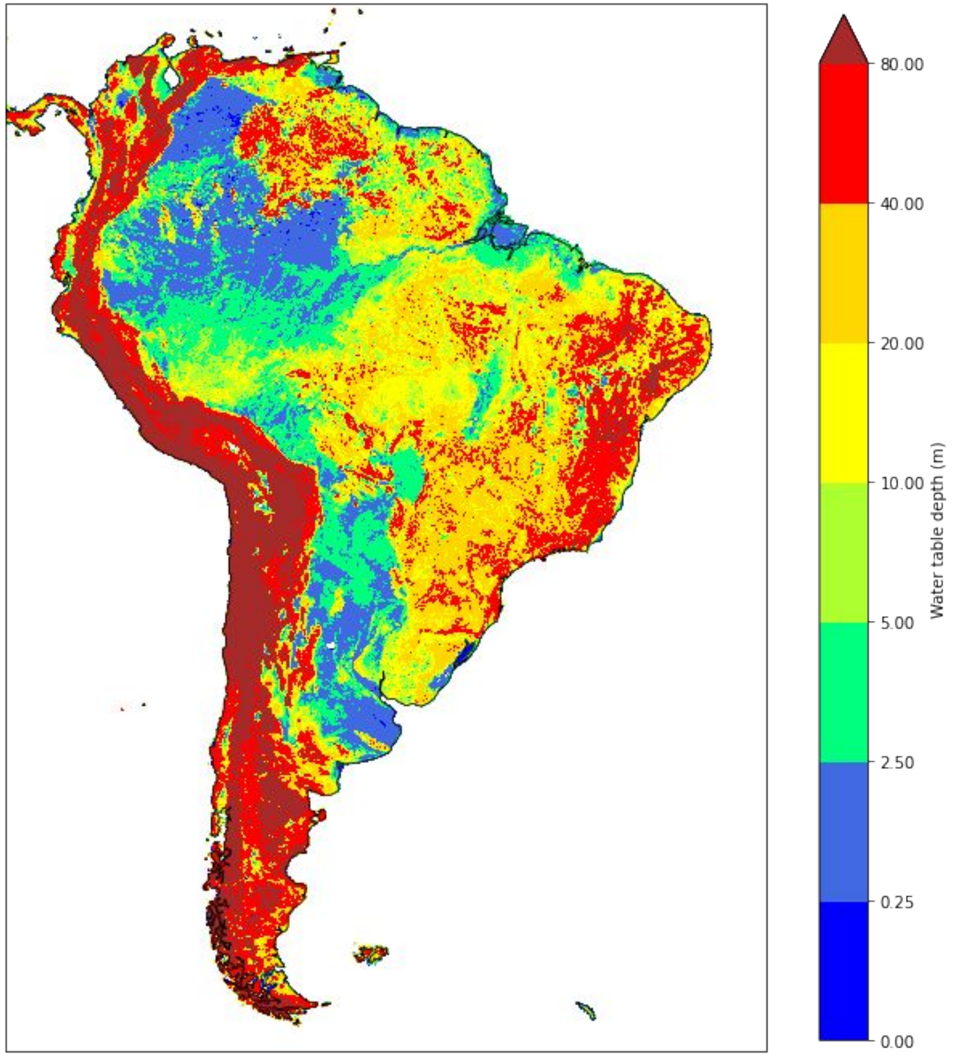
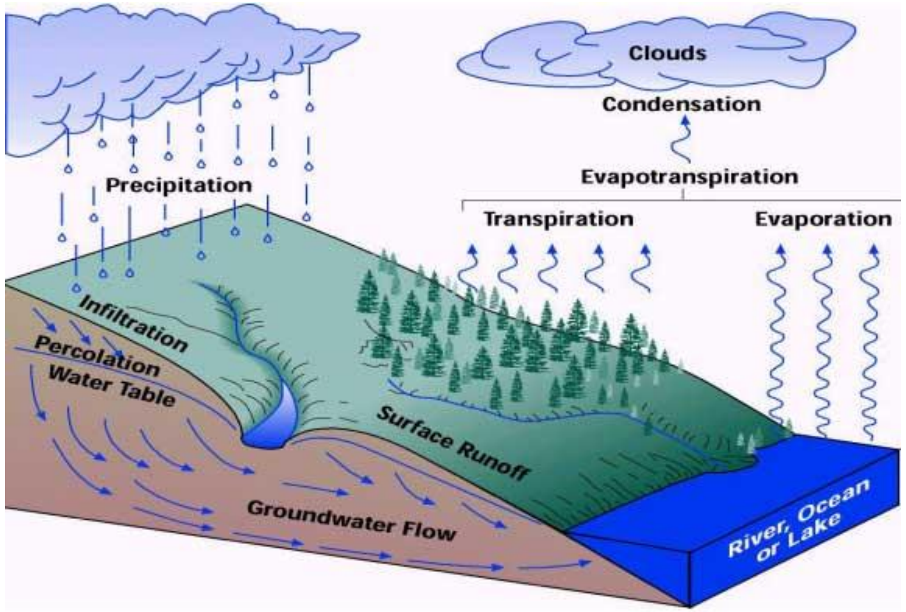


"Similar to the oceans, which can store heat and thus induce persistence ("memory") in the climate system, land represents a water storage for the climate system, with associated persistence features." Seneviratne et al. 2010



https://www.spokaneaquifer.org/

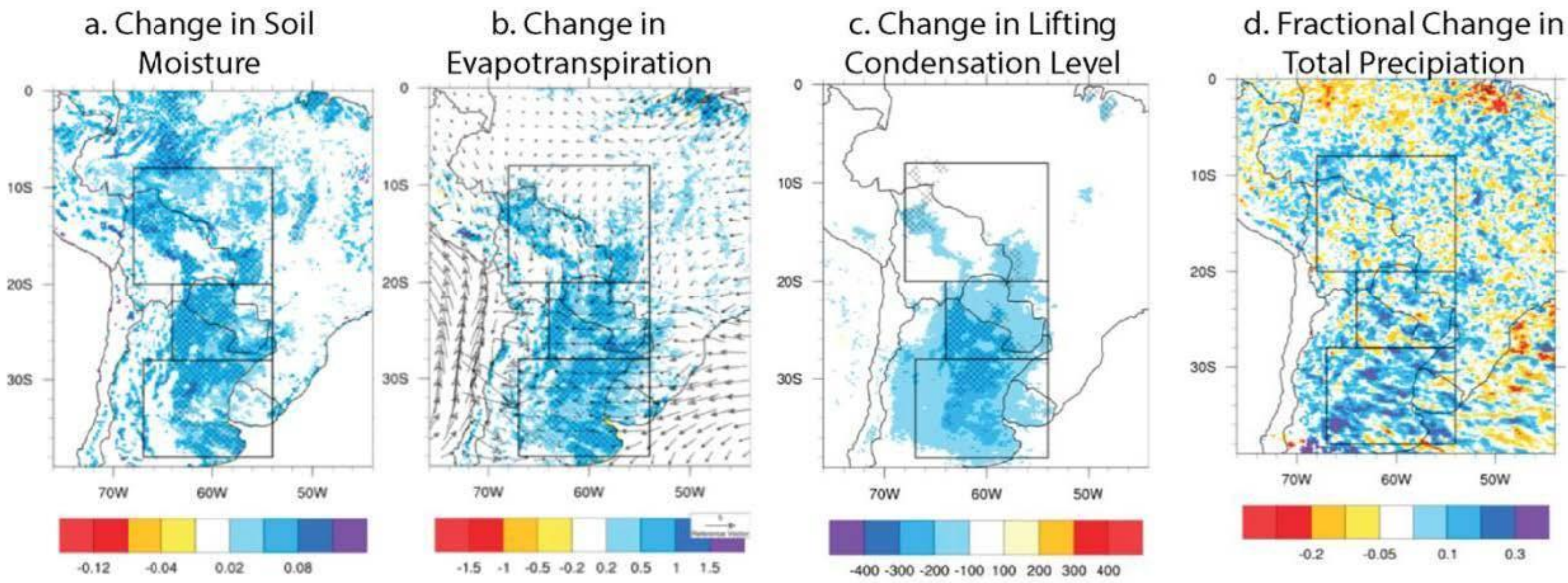
Shallow groundwater reduces soil moisture drainage.

Soil moisture can be replenished from below in regions of shallow groundwater.

Lateral flow re-distributes shallow groundwater.

For example, in the forest of the Amazon, the water table reaches its peak up to 4 months after the peak rainy season, so that the water table under the plateaus is shallower in the dry season.

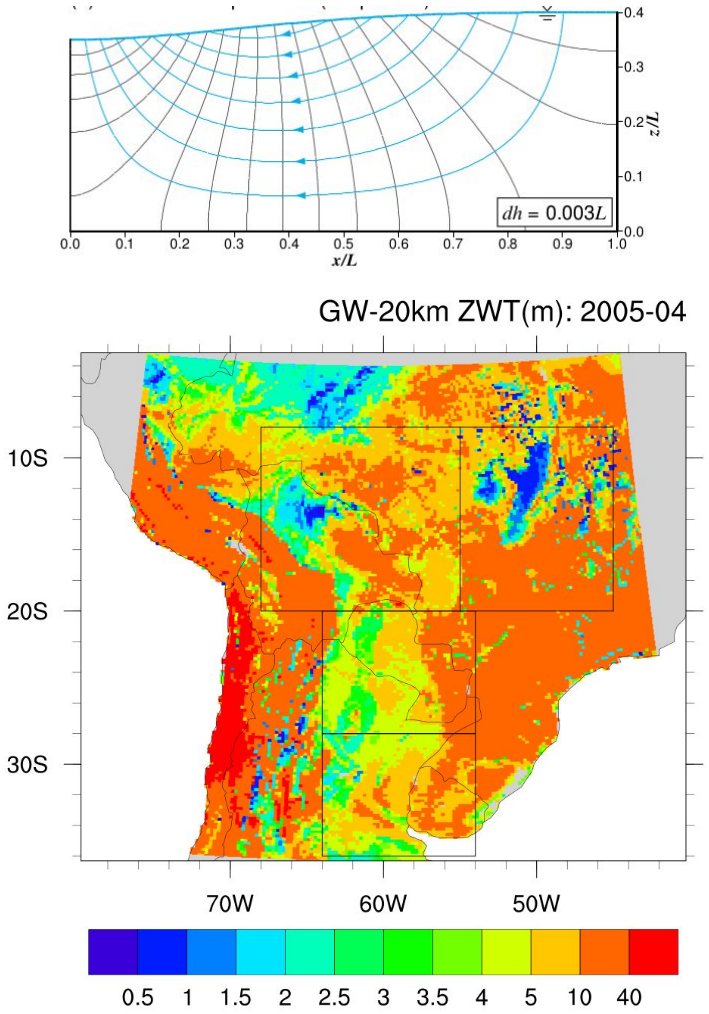
When including groundwater in WRF, the higher ET and surface humidity in water-limited places/times lead to enhanced convective and total precipitation.

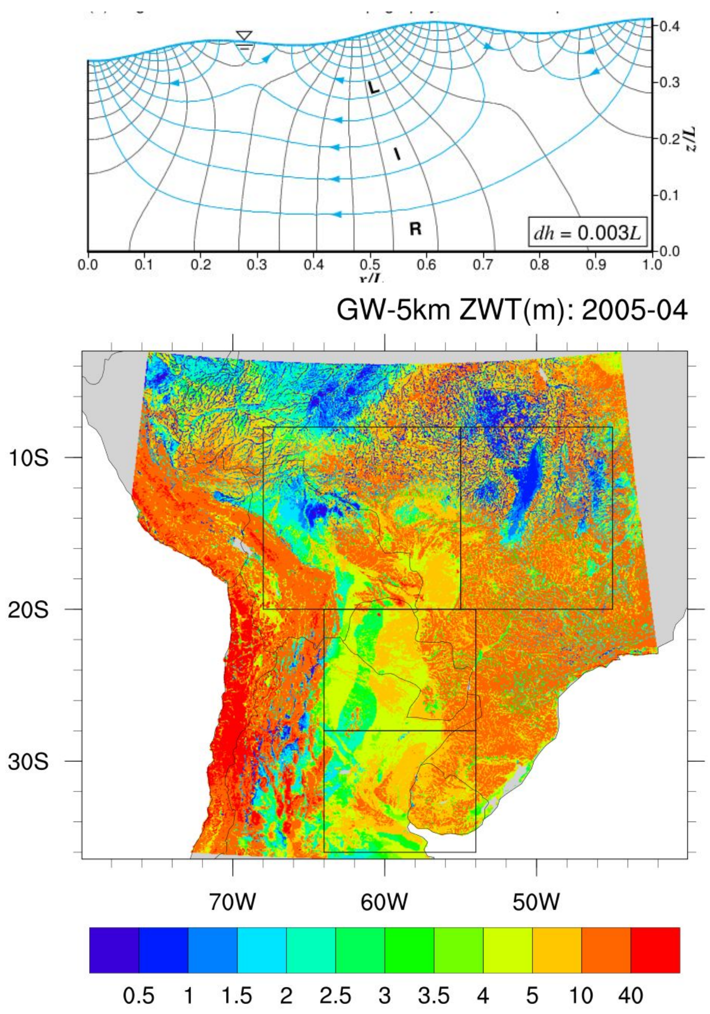


The extra precipitation comes from direct recycling and from enhanced instability of local and upstream atmosphere.

Martinez et al. *J. Hydromet*, 2016

At higher horizontal resolution, there is larger convergence of GW in small depressions – raising water table.





Barlage et al. (2021) find that high-resolution GW: “reduces (1) 2-m temperature warm biases from 5–6 to 2–3 °C and (2) the low precipitation bias by half.”

“3 km or smaller is necessary to capture small-scale river and stream networks and associated shallow water tables, which supplies additional root-zone water”… which leads to more evapotranspiration.

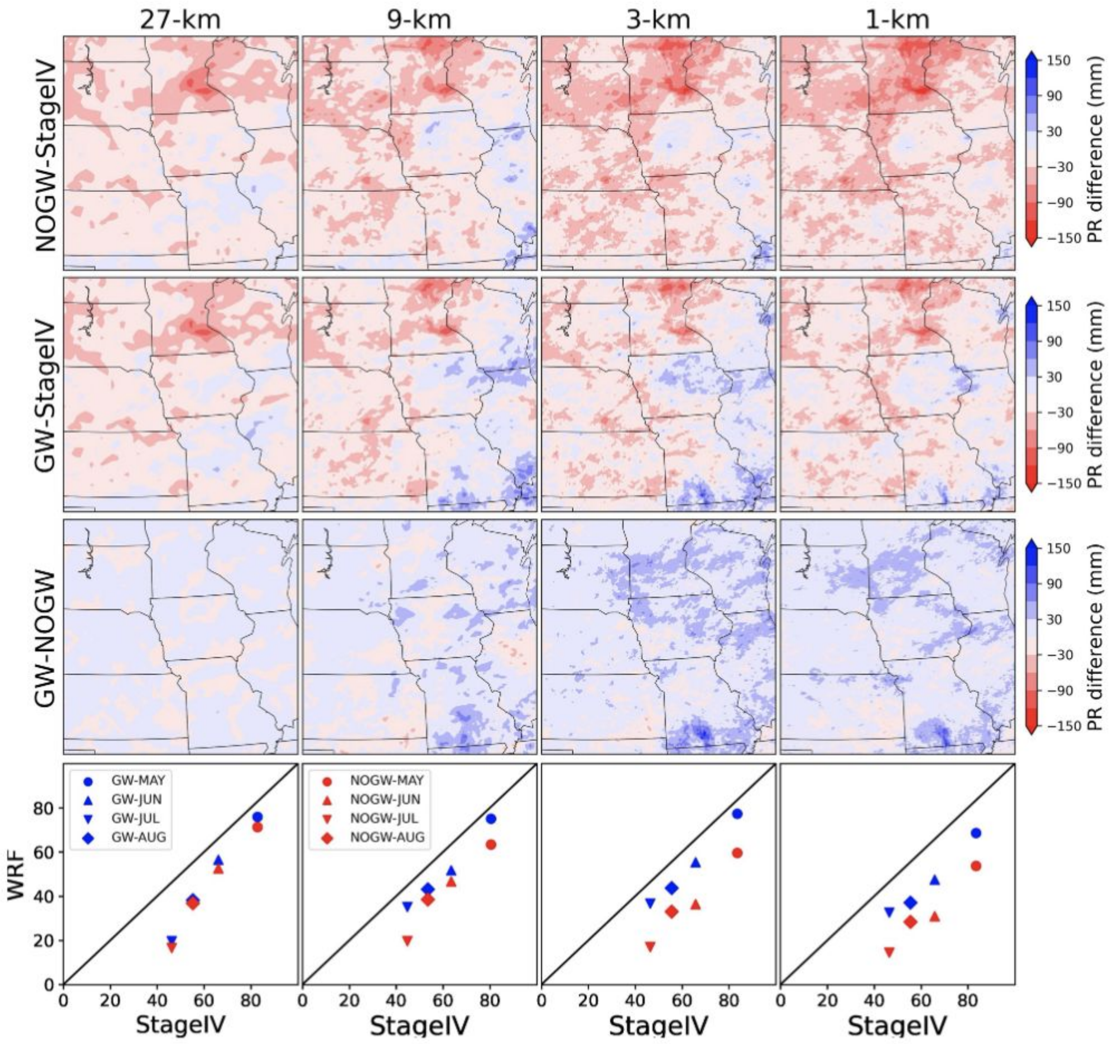
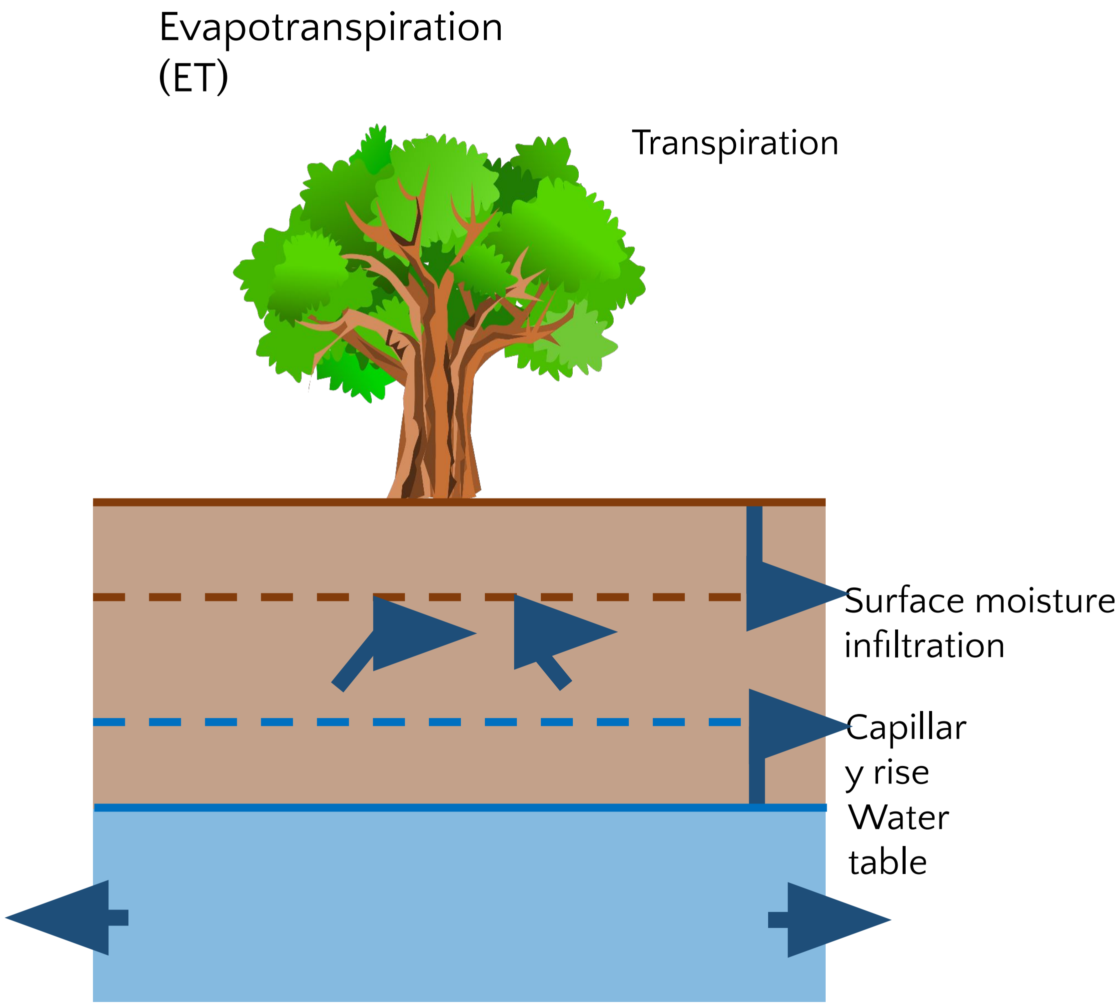


Figure 3. Spatial distribution of May–August 2012 average precipitation bias (mm), verified against Stage IV observations, for WRF simulations with 27-km, 9-km, 3-km, and 1-km grid spacing. The three rows represent simulations with the groundwater scheme (GW), without the groundwater scheme (NOGW), and differences between these two simulations (GW-NOGW). The bottom scatter plots present domain-averaged precipitation bias of 27-km, 9-km, 3-km, and 1-km WRF simulations for May, June, July, and August 2012. WRF, Weather Research and Forecasting.



Despite significant advances in the representation of groundwater, our current conceptualization of land-atmosphere interactions lacks an appropriate representation of deep roots to access the slowest-varying moisture reservoir on land.

Rooting depth is strongly linked to local soil moisture profiles influenced by infiltration from the surface and by groundwater from below.

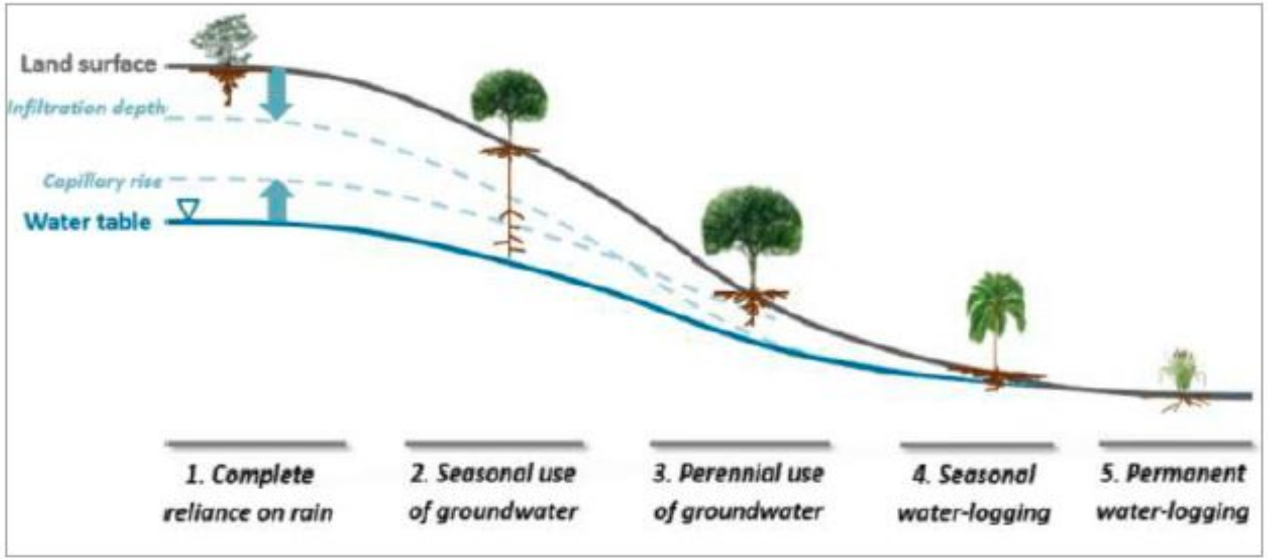


Figure 1 *Rooting depth driven by local soil moisture profile along a hill slope. At position-1, GW is too deep to be useful to plants. At p-2, roots can be pulled deeper in the dry season. At p-4, roots are limited to the aerated shallow soil above the water table (Fan et al 2017).*

How will groundwater – rooting depth interactions manifest themselves in land-atmosphere interactions and affect the persistence in the hydroclimate system?