Groundwater – SM – climate interactions: Lessons from idealized model experiments with forced water table depth

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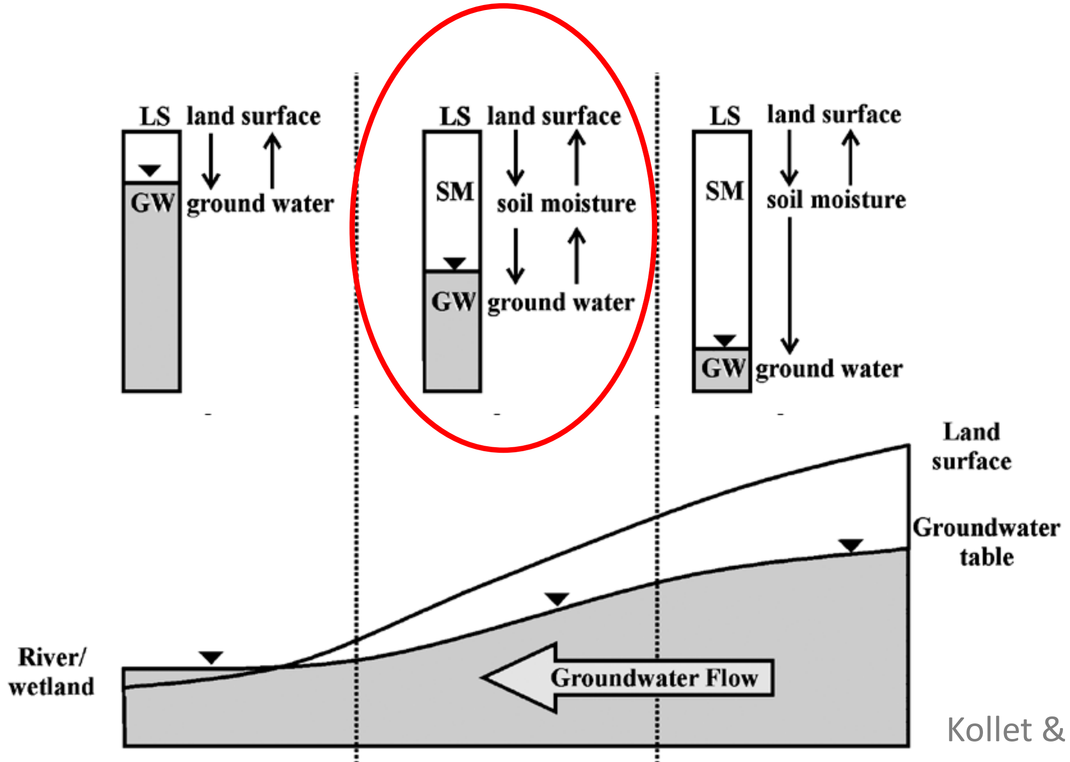
The IGEM project

- **Jointly funded by France (ANR) and Taiwan (MoST) for 2014-2018**
- **Three research teams and climate models**: IPSL, CNRM, NTU
- **Research goals:**
  - Explore the impacts of GW on regional and global climate, and its links to water resources availability, through model analyses
  - Compare the sensitivity of simulated climate to different GW parametrizations within 3 different climate models
- **Four model intercomparisons:**
  1. **Sensitivity to fixed water table depths (WTD)**
  2. With dynamic WTD over the recent period, to assess the potential of realistic GW parametrizations to improve the simulated climate
  3. With dynamic WTD and climate change, with 2 complementary questions:
     (a) What is the influence of GW on the climate change trajectory?
     (b) What is the impact of climate change on water resources (including GW)?
  4. With dynamic WTD and withdrawals, with potential impacts on climate until water resources get exhausted.

1. Introduction



Kollet & Maxwell, 2008

GW with long residence times → buffering effects

on stream flow

on SM and LA coupling where the water table is close enough to the surface

Objective

Identify **where** the WT can influence SM, ET, and LA coupling through idealized model experiments

2. The numerical experiment

3 state-of-the-art LSMs: CLM4, ISBA/SURFEX, ORCHIDEE

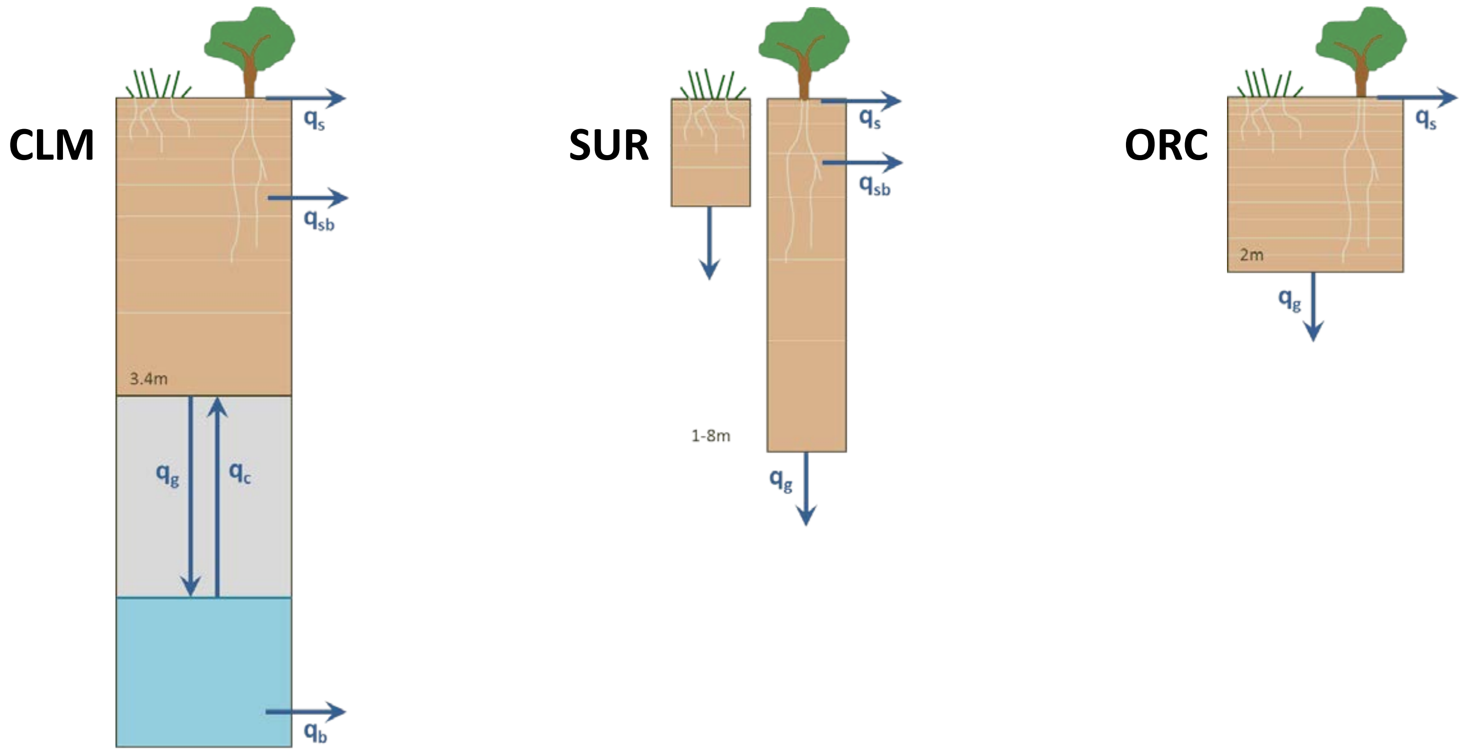
Off-line or coupled to their parent climate model

following LMIP/AMIP-like protocols for intercomparability

Off-line forcing = PGF (1°, 3-hourly, 1979-2010 , Sheffield et al. 2006) + GPCC bias corrrection

Reference simulations with standard configuration

+ 7 simulations with forced water table depth (WTD) between 0.5 and 10 m



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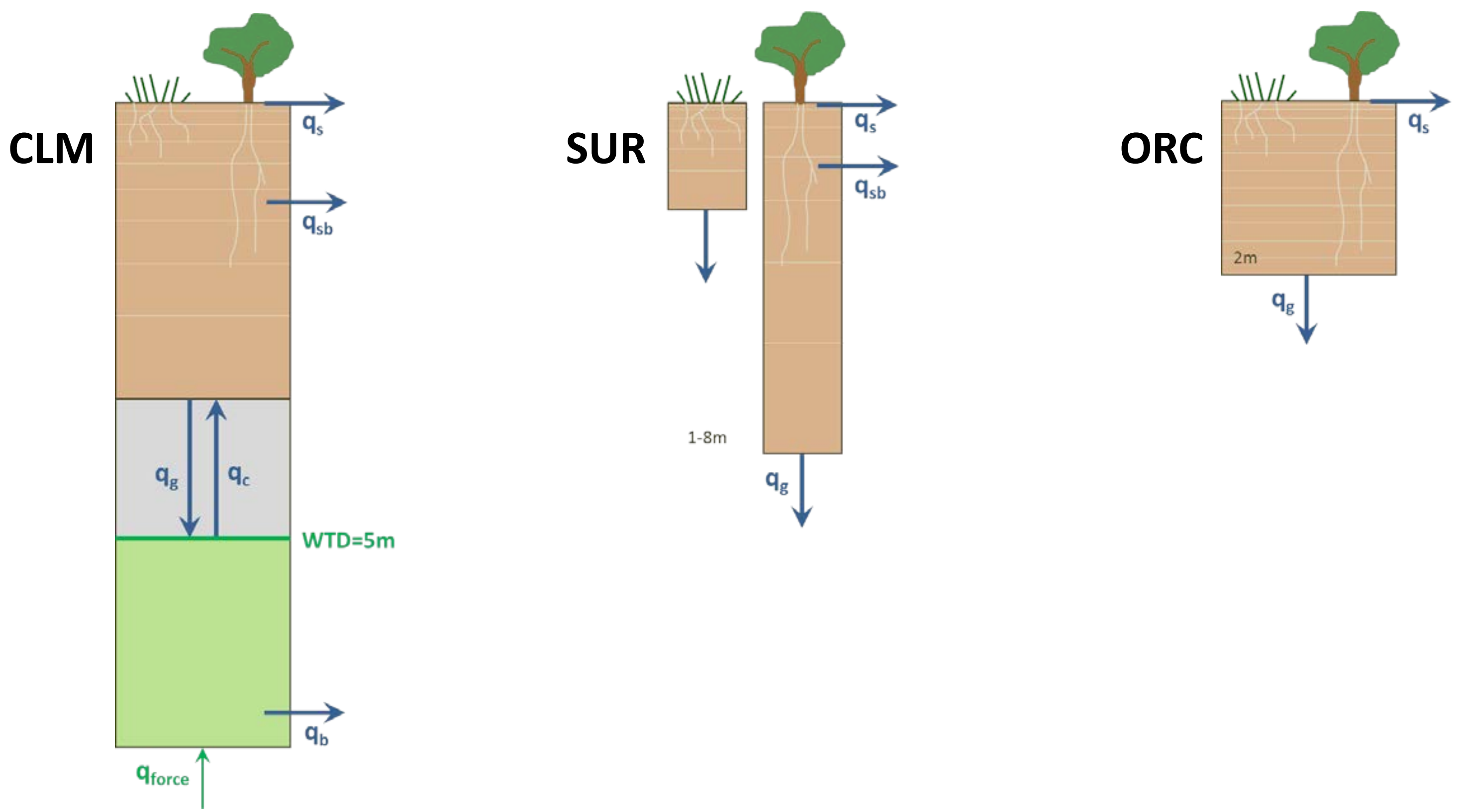

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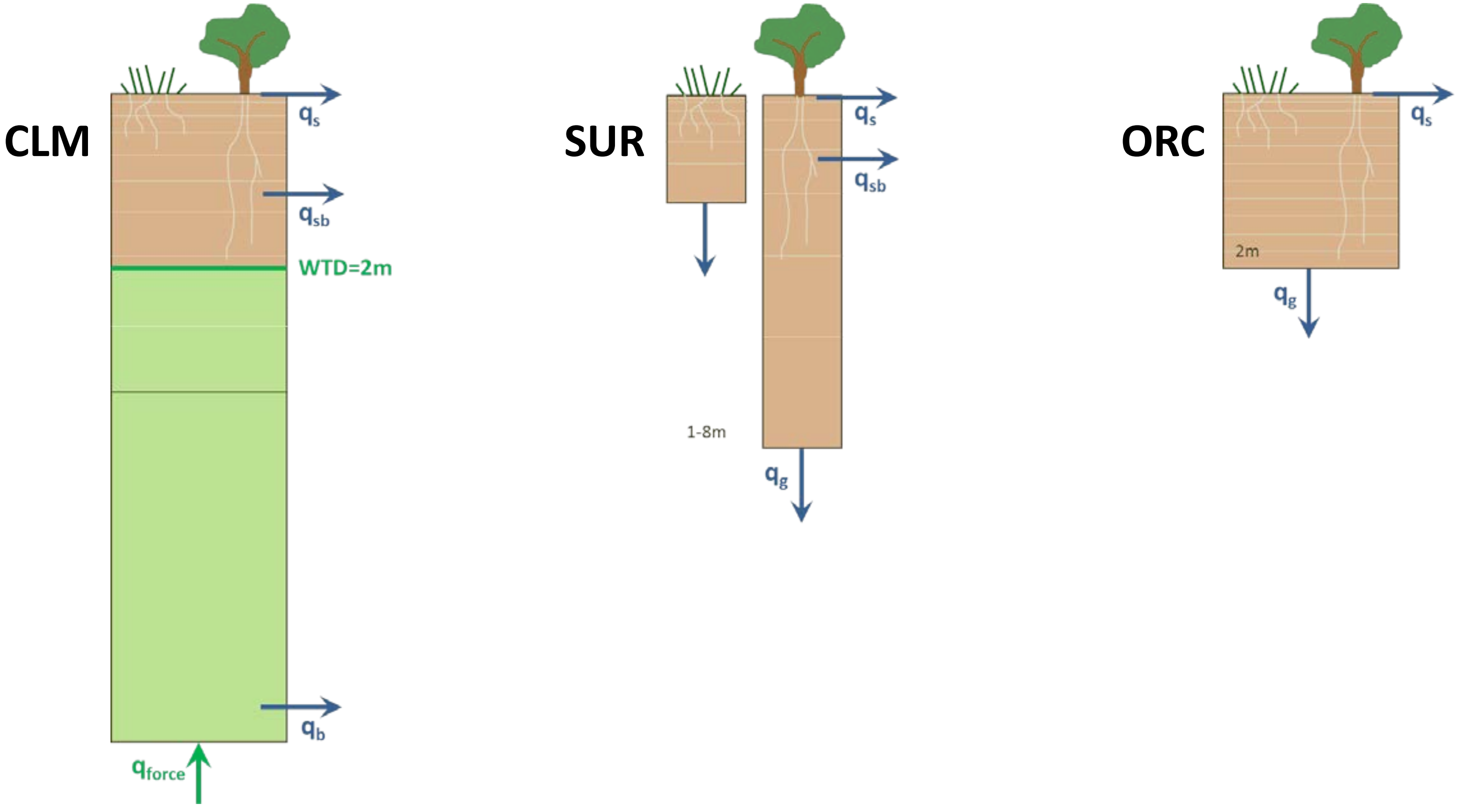

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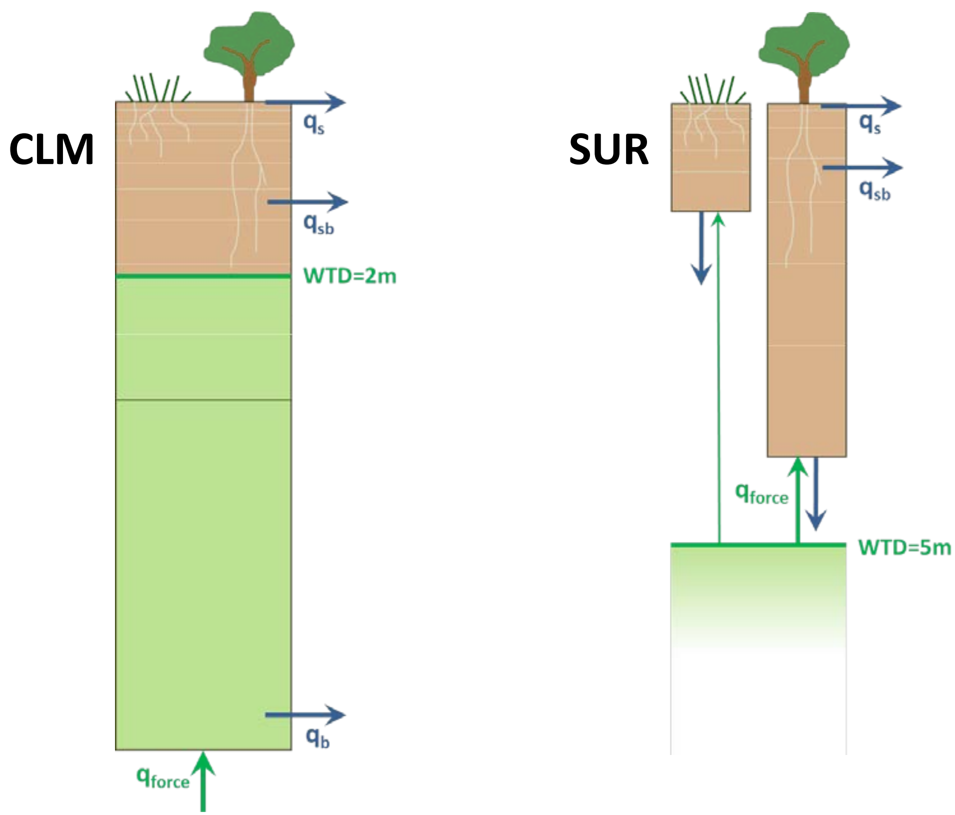

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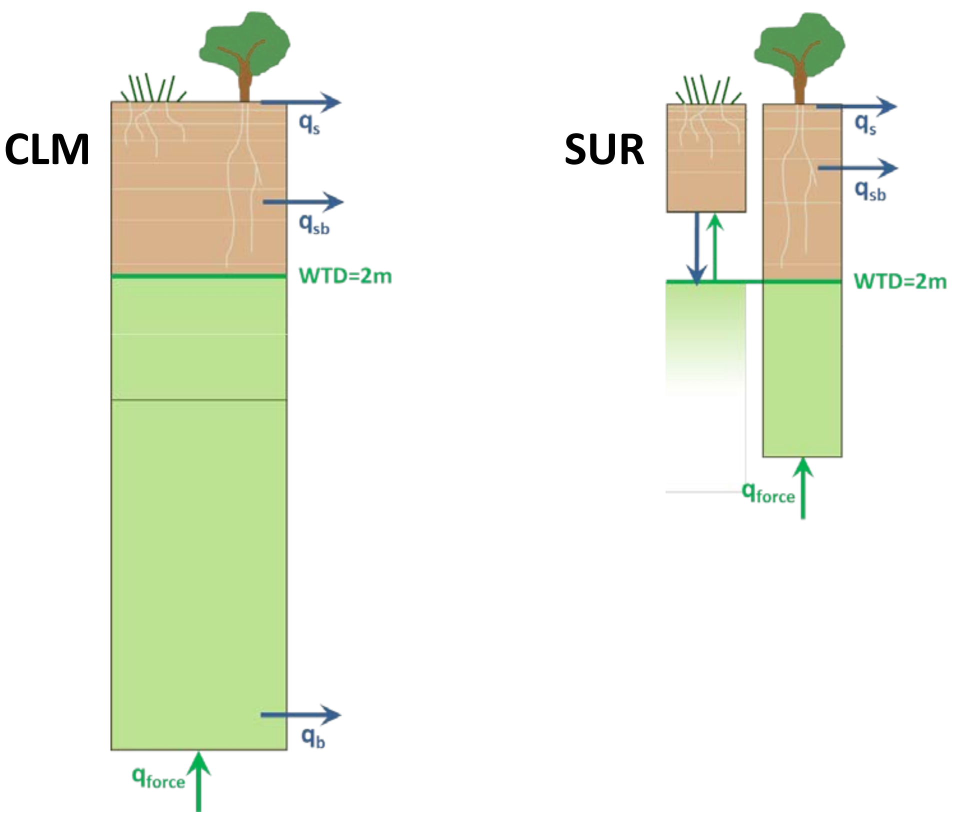

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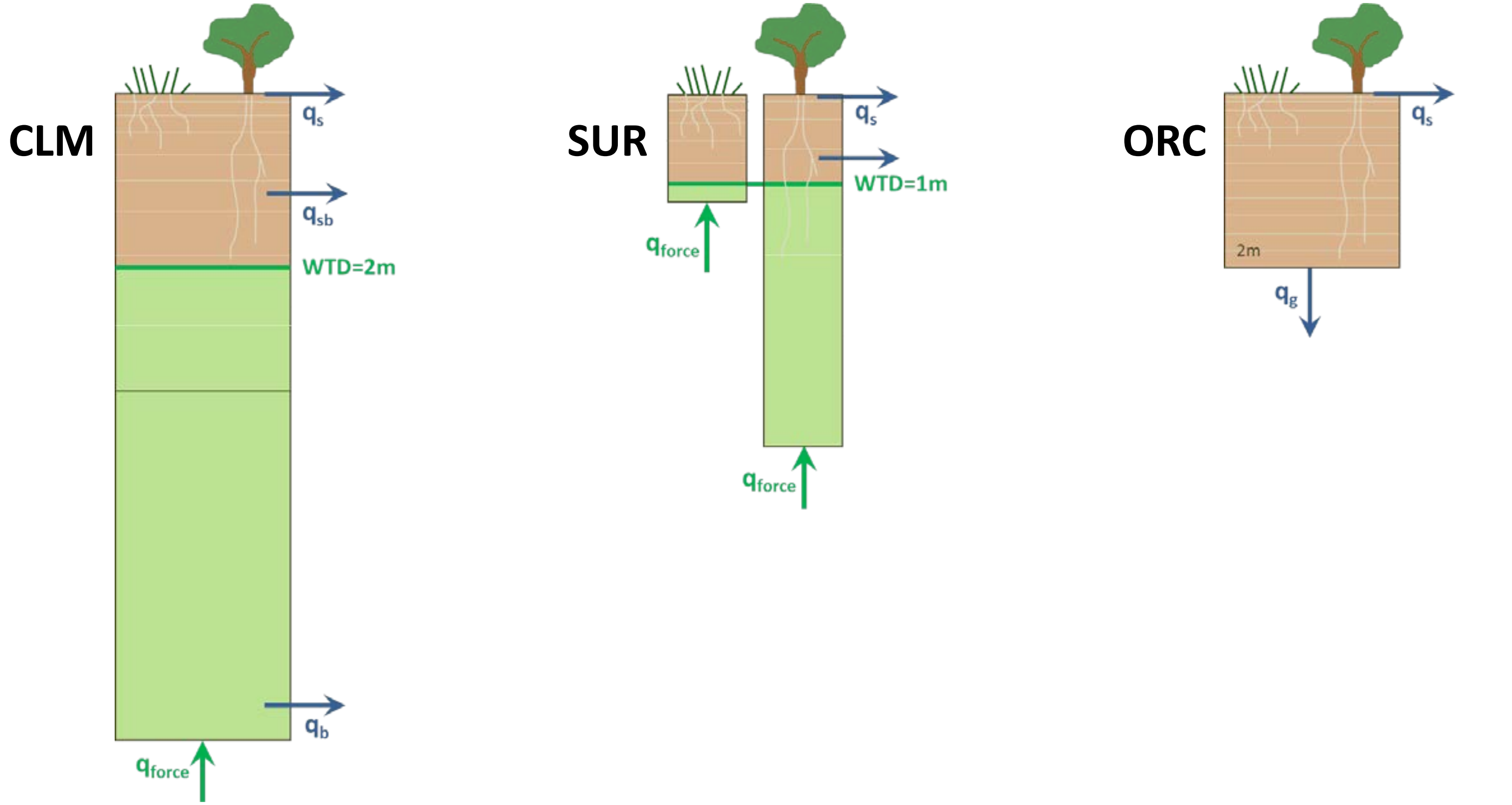

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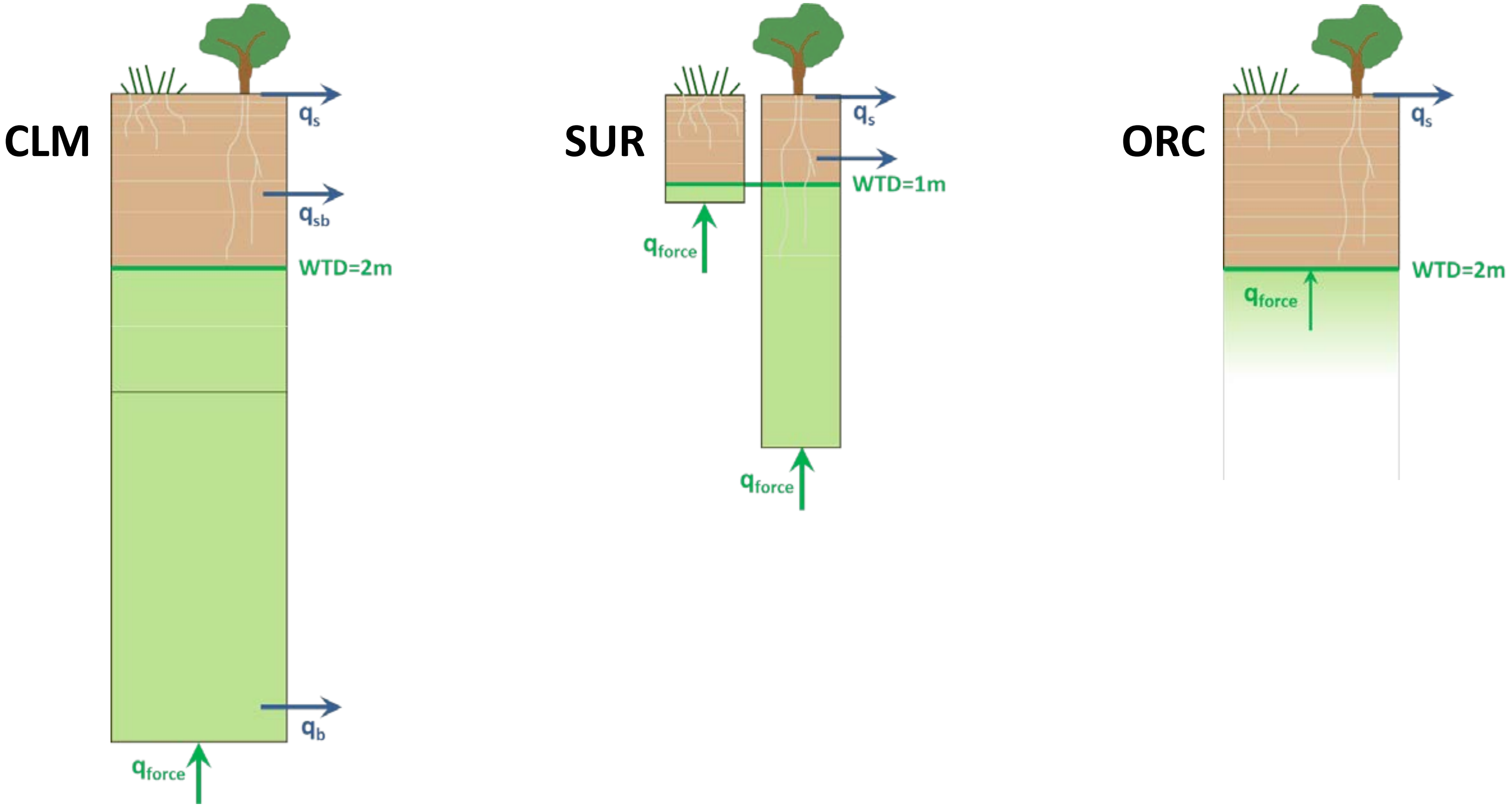

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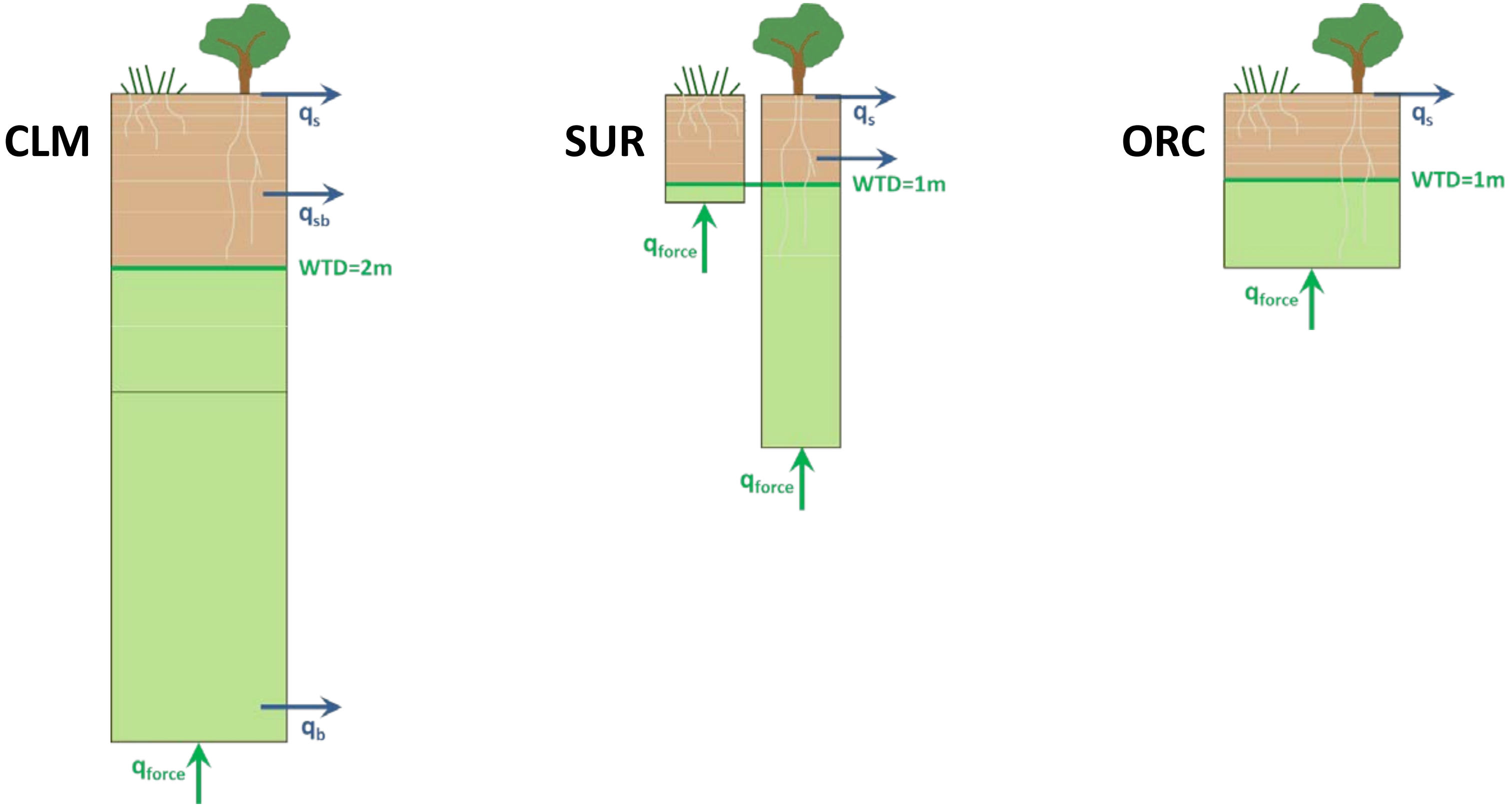

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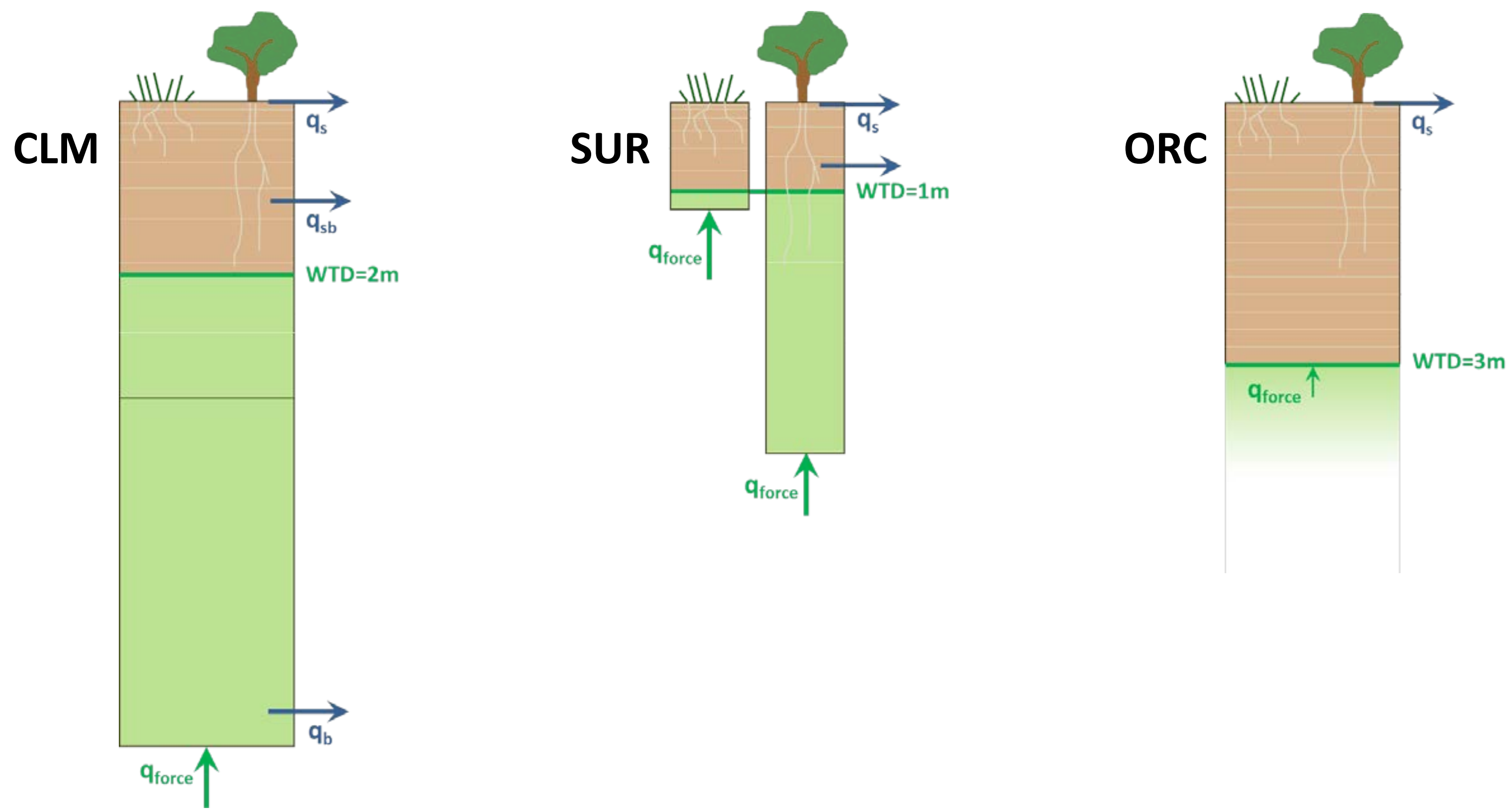
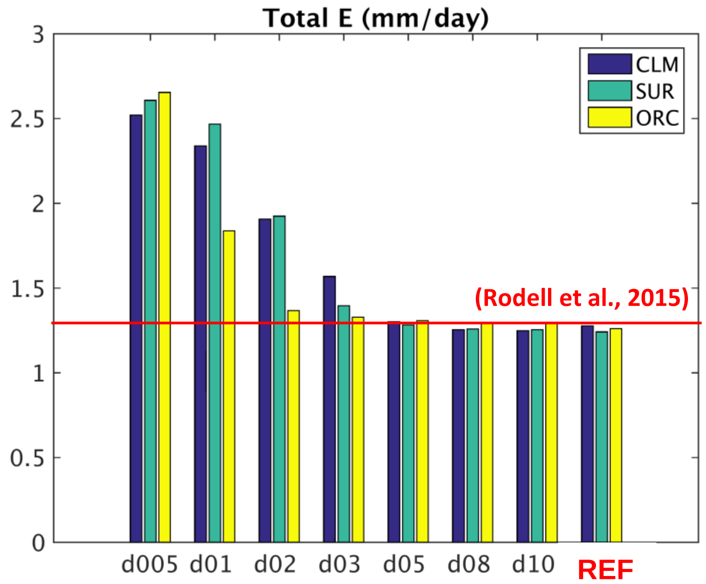
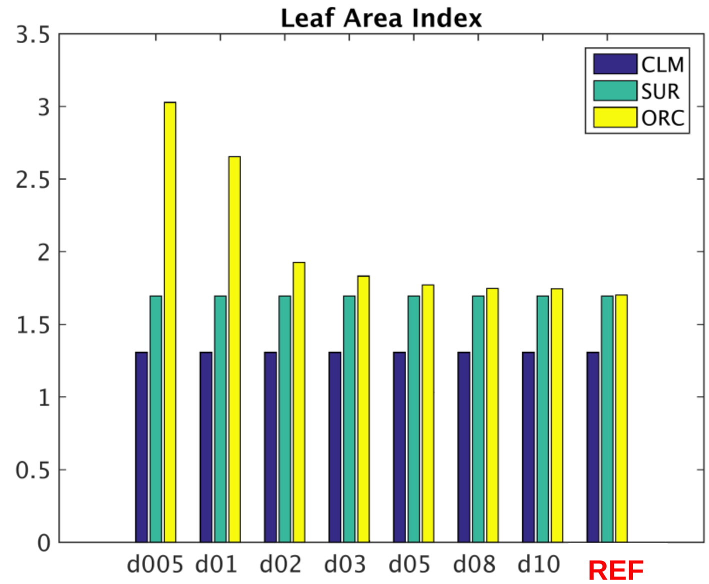
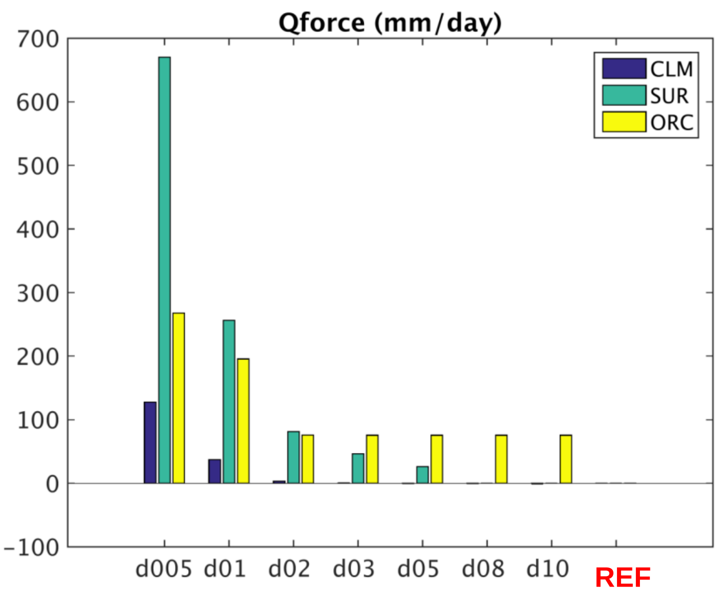
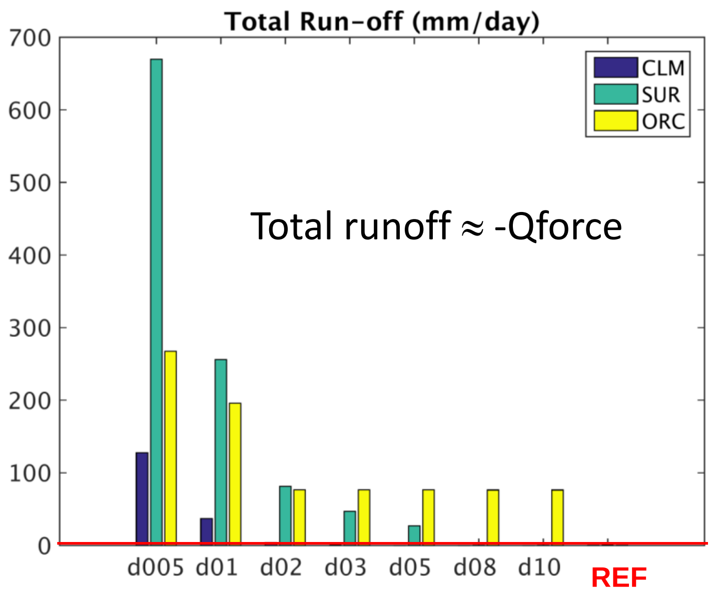


Land averages – Sensitivity to WTD



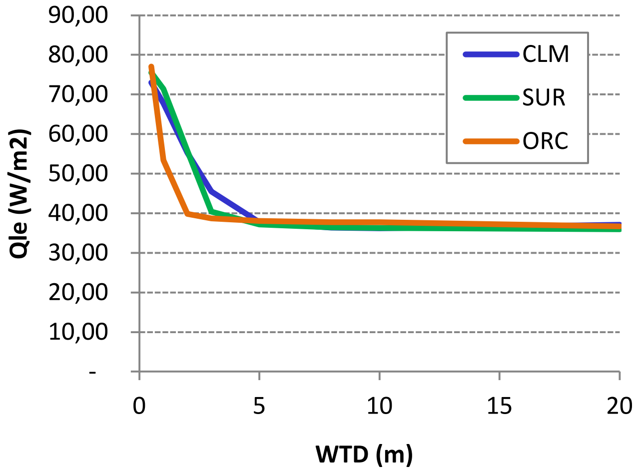




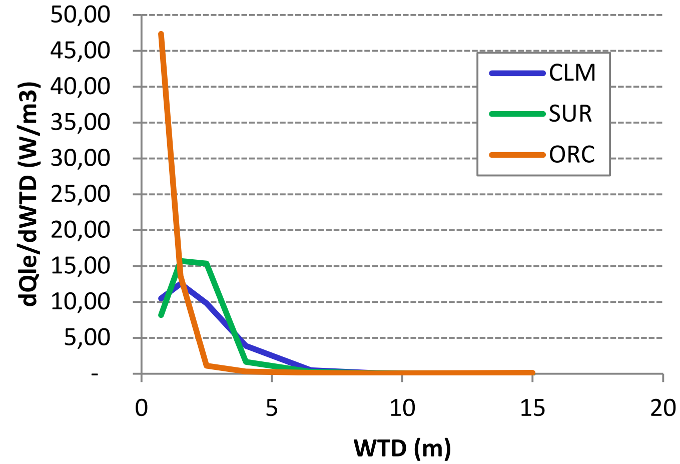


The critical WTD

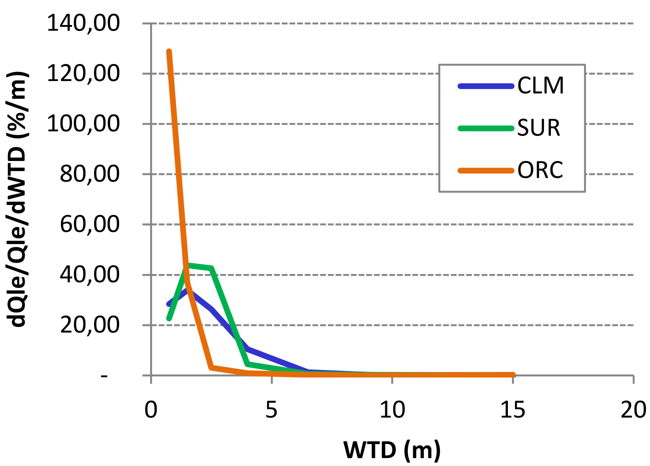
Qle = f(WTD)



Variation rate

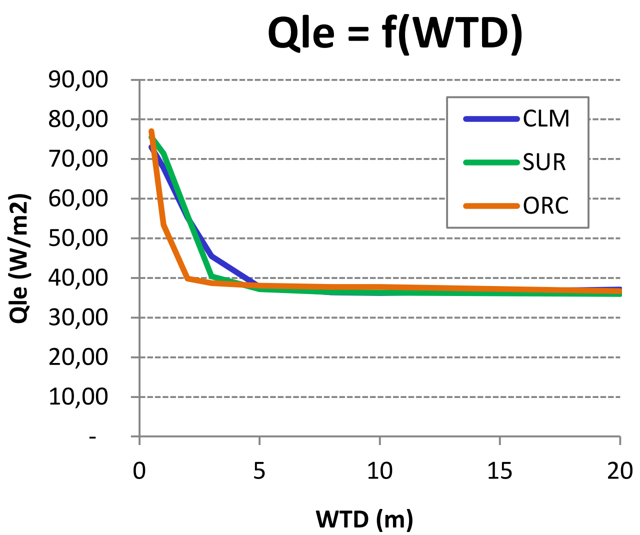


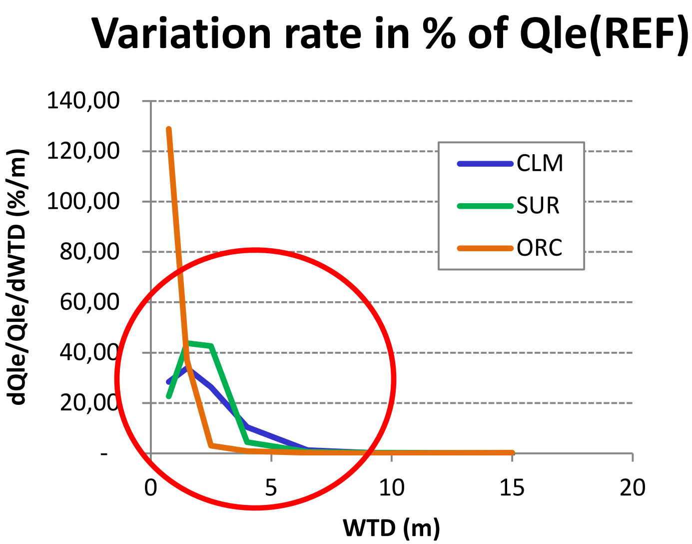
Variation rate in % of Qle(REF)



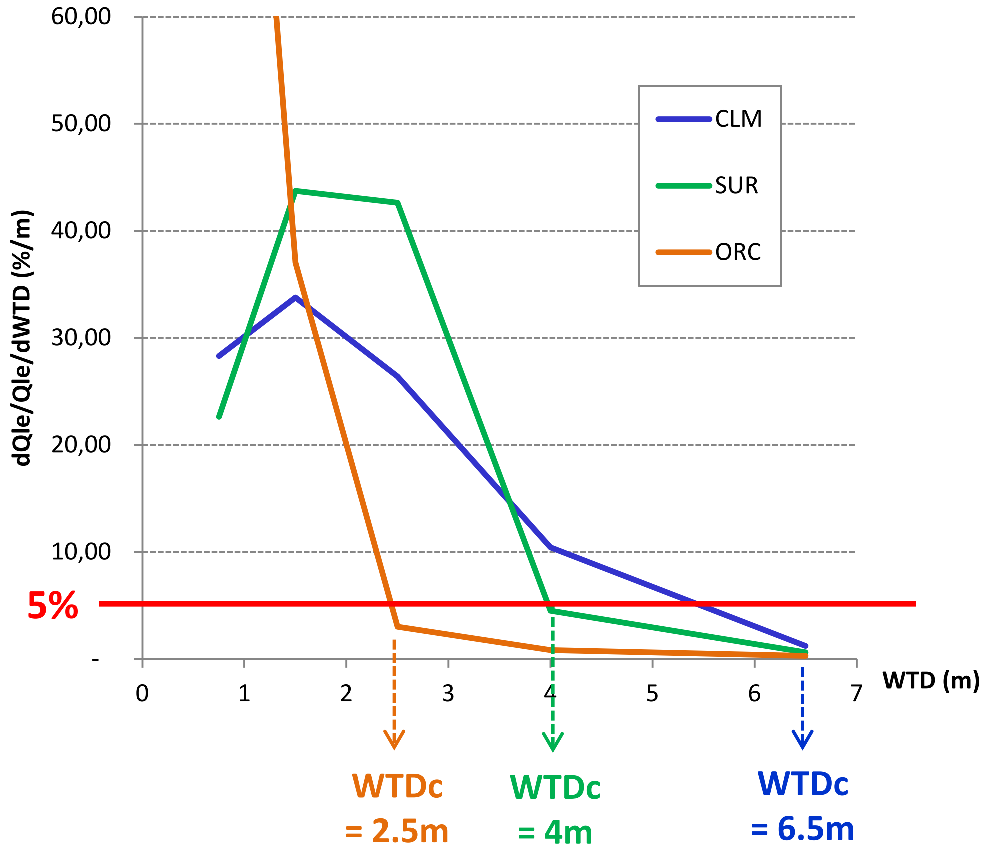
All values are land averages

The critical WTD





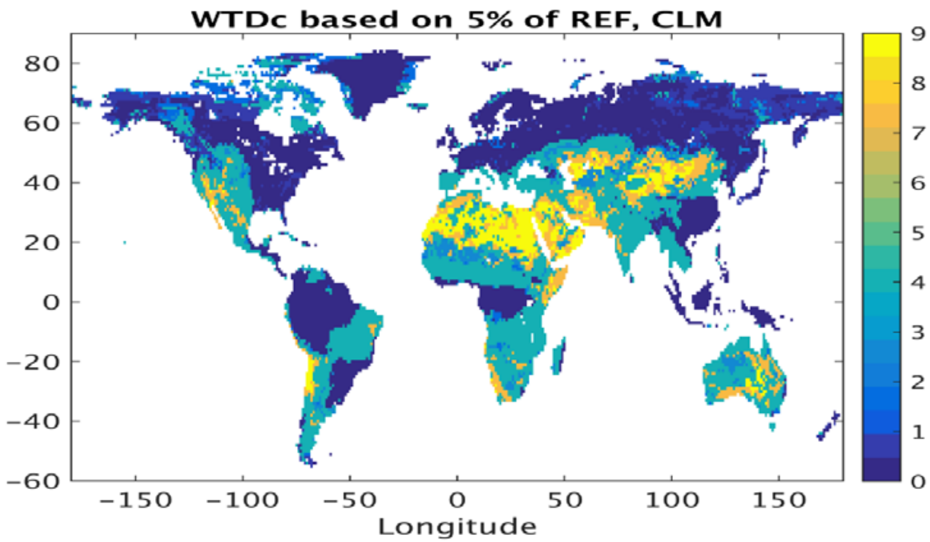
WTDc = depth at which Qle response becomes small

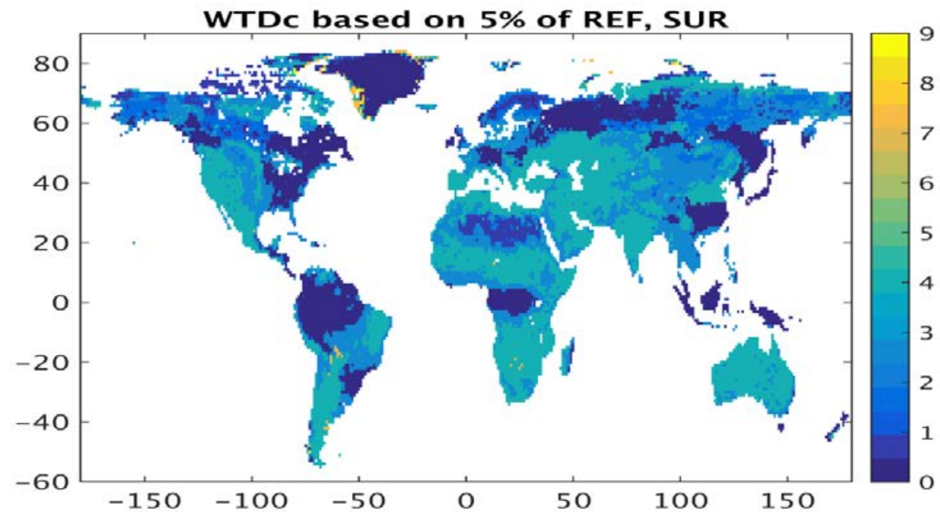


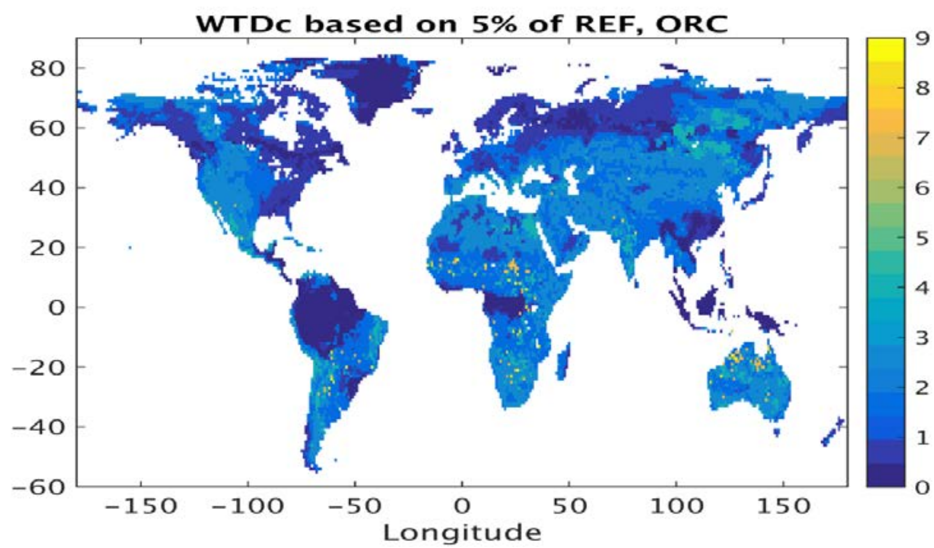
Deeper WTDc → higher sensitivity to WTD

All values are land averages

The critical WTD : 5% threshold

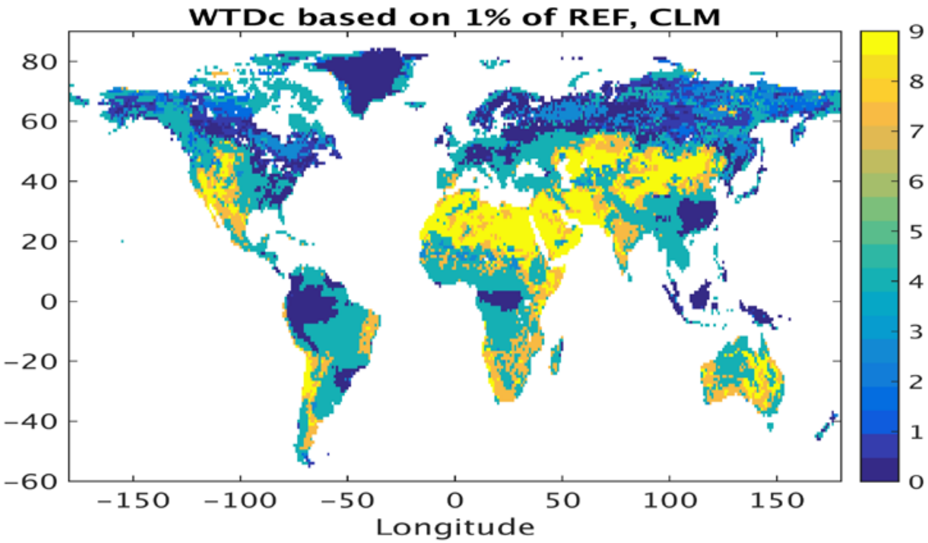


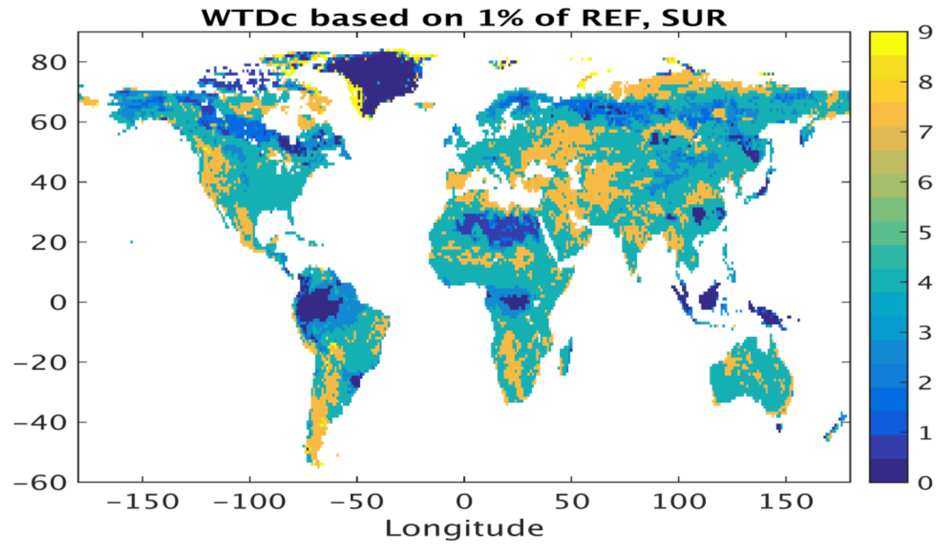


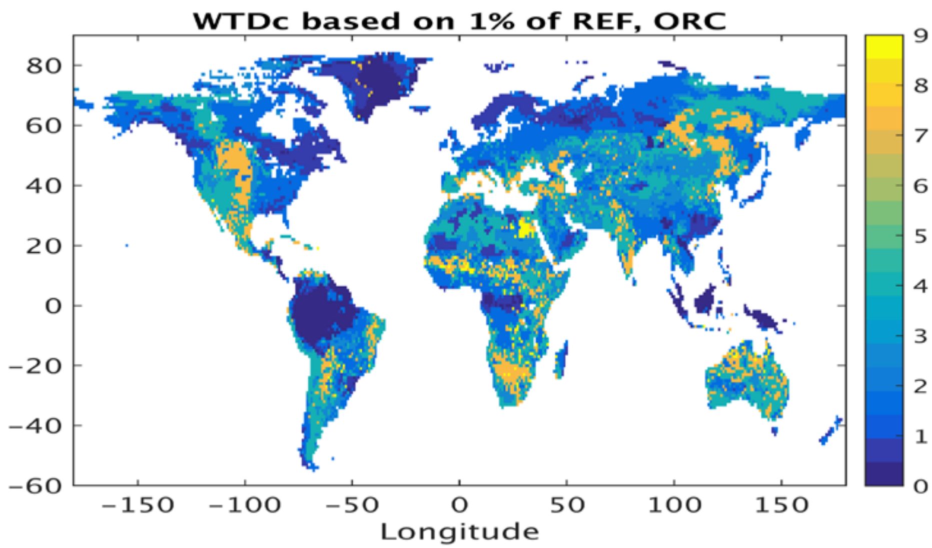


Patterns // aridity
Strong inter-model difference

The critical WTD : 1% threshold







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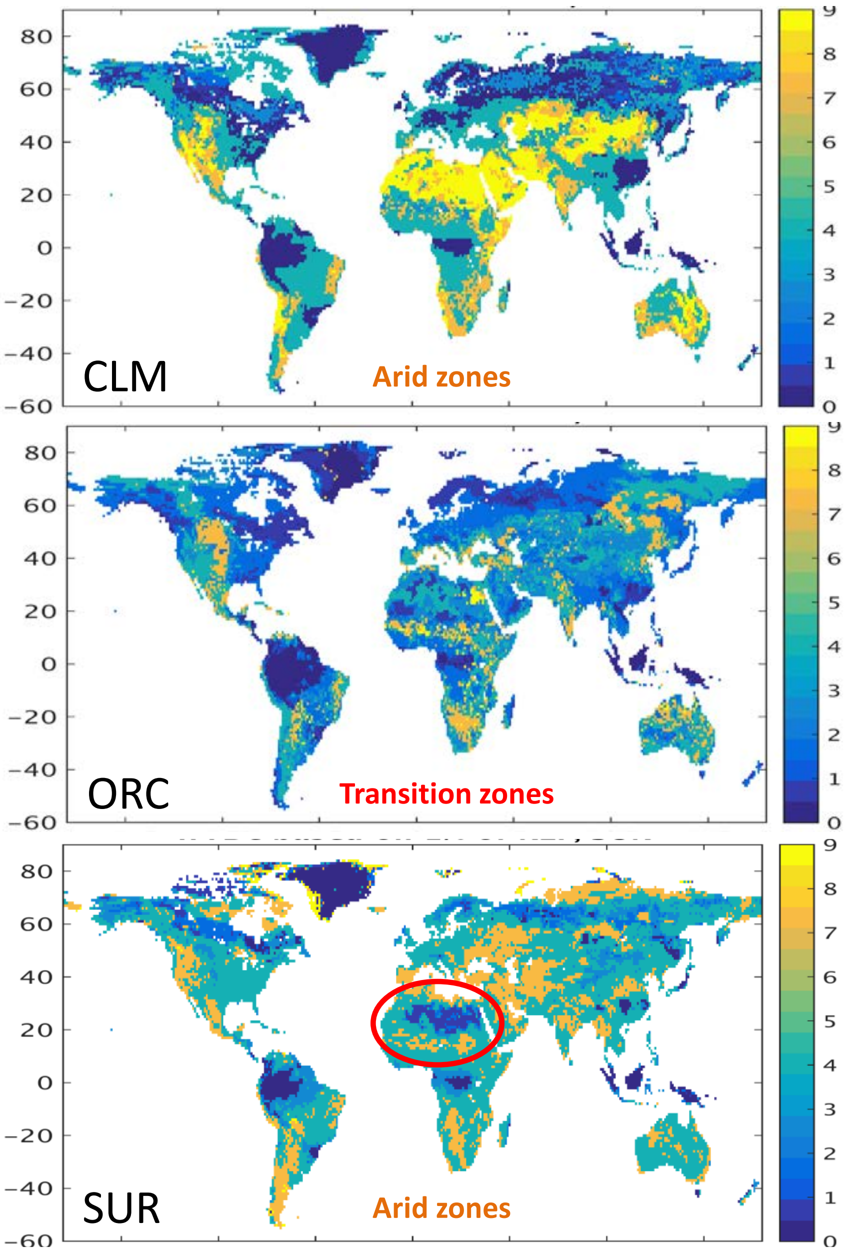
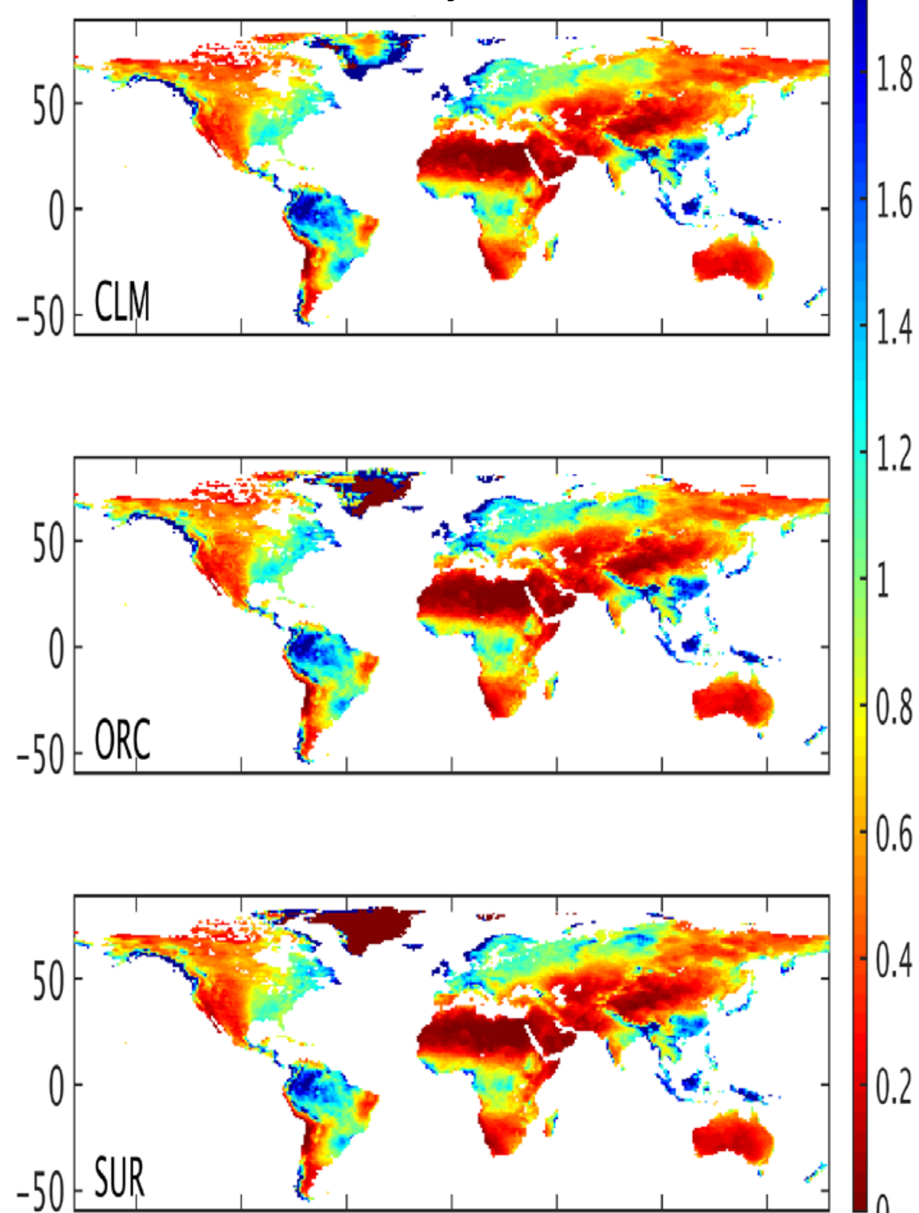
3. Off-line results

1% WTDc



REF: Aridity index $\lambda P/Rn$



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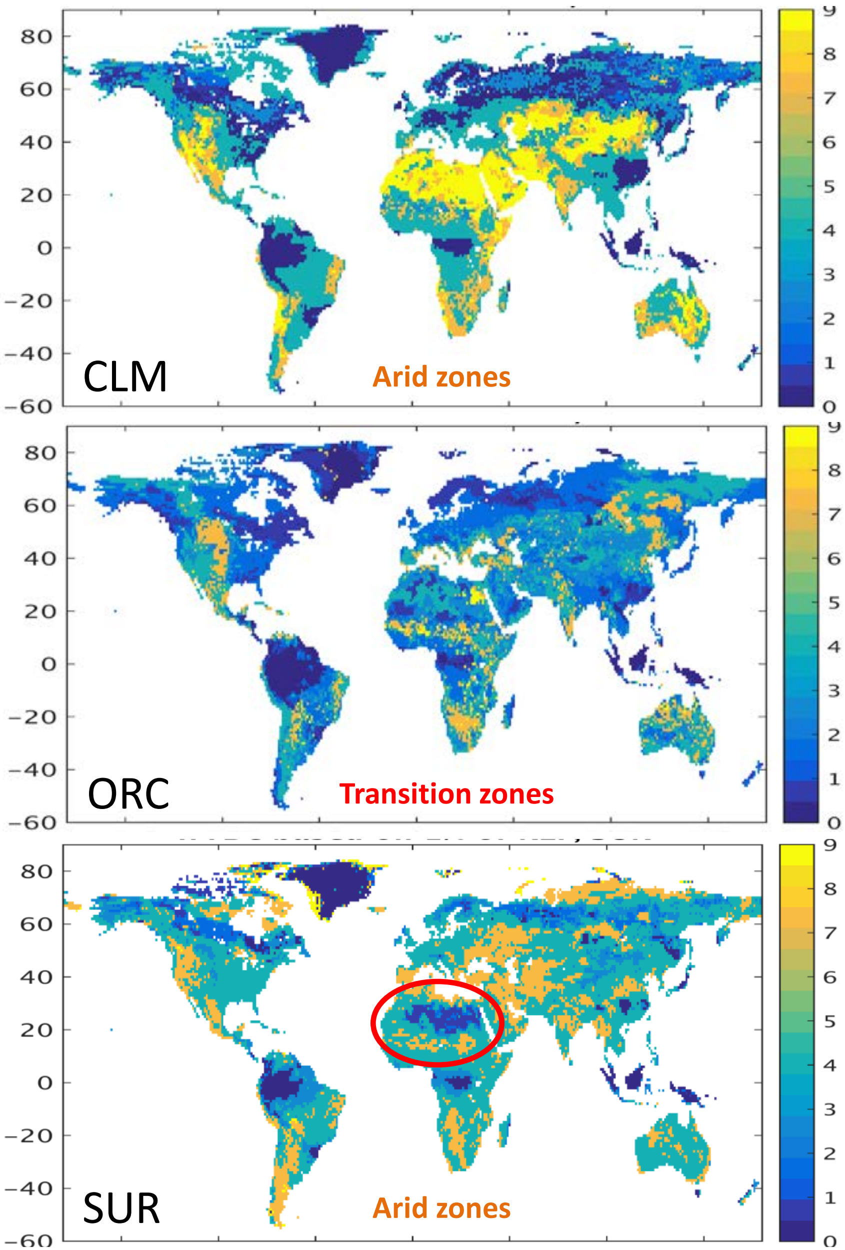
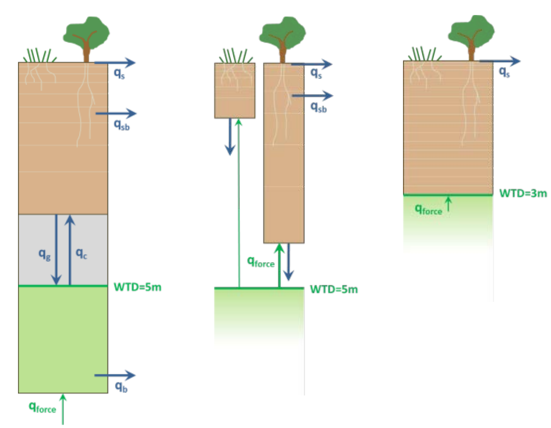
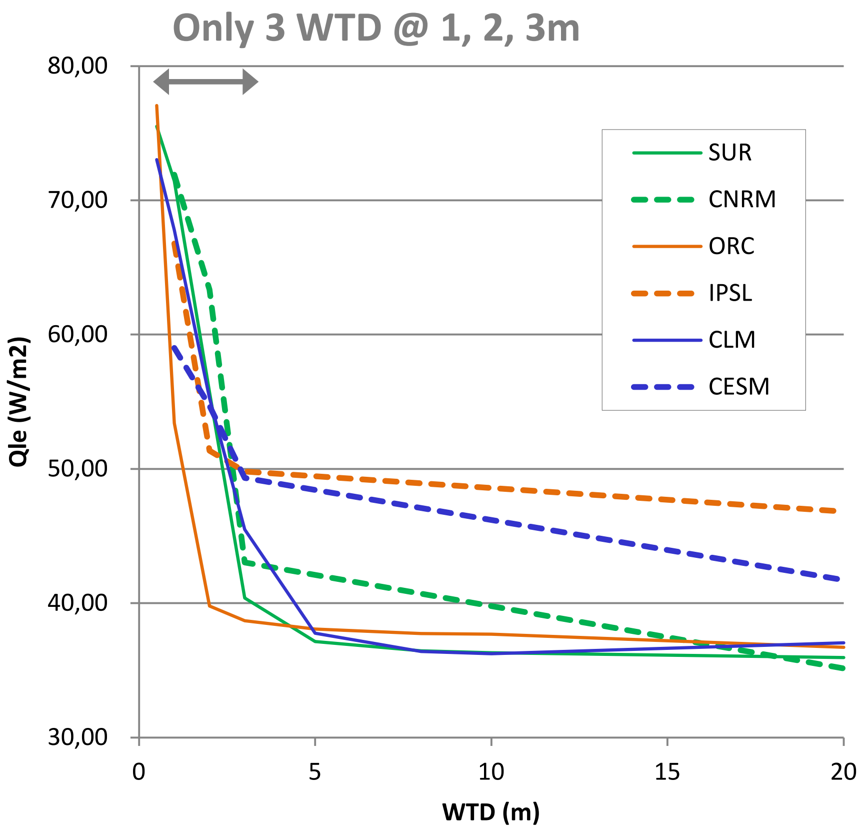


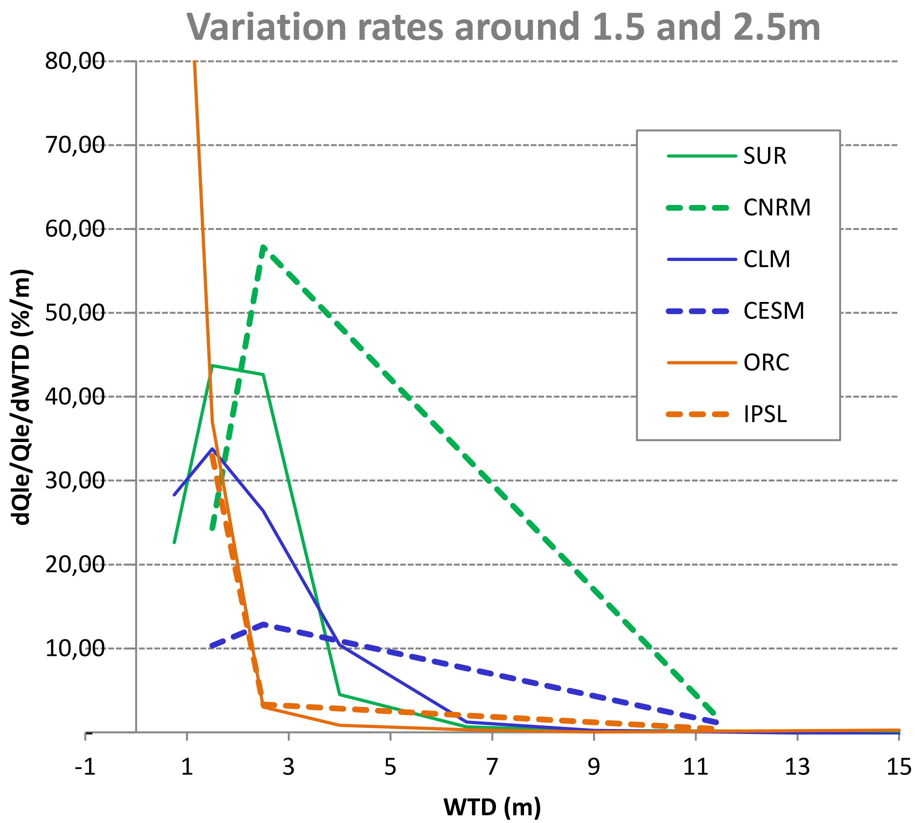
The reasons for inter-model differences are not clear yet but may involve:

- Dynamic LAI in ORC, combined with different sensitivities of soil evaporation and transpiration
- Different models of unsaturated hydraulic parameters (BC for CLM & SUR, VG for ORC) *cf. Decharme et al. 2011*
- Different ways to link the soil and deep WTs



Land averages: ET

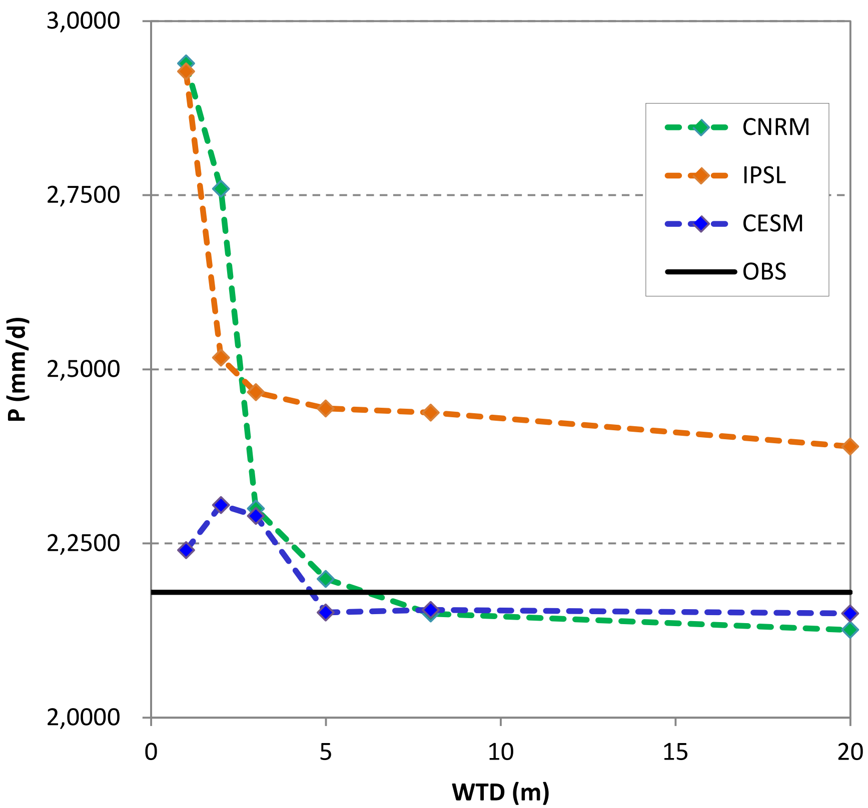


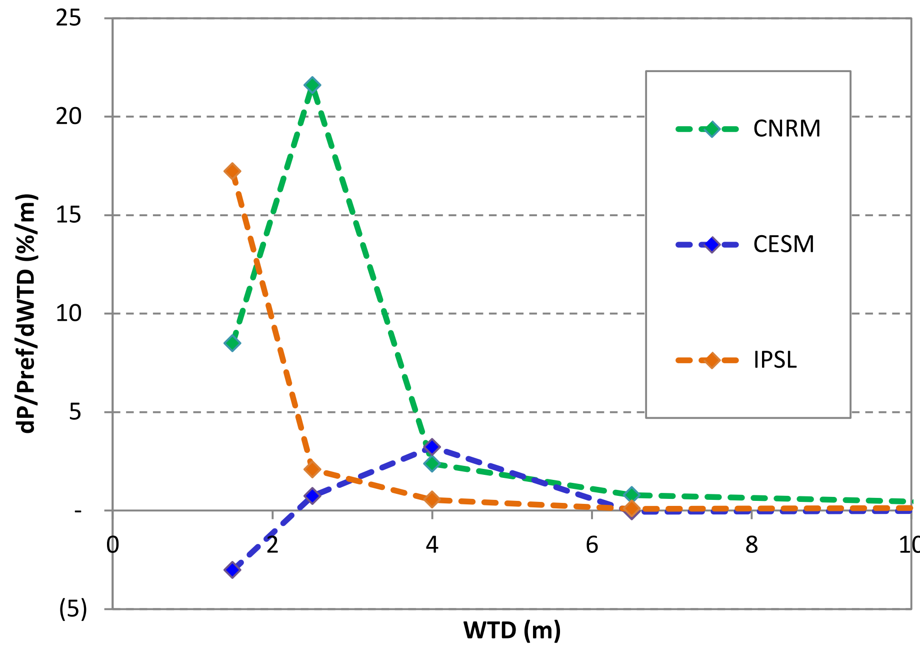


CLM and ORC have a larger reference Qle in coupled mode than offline

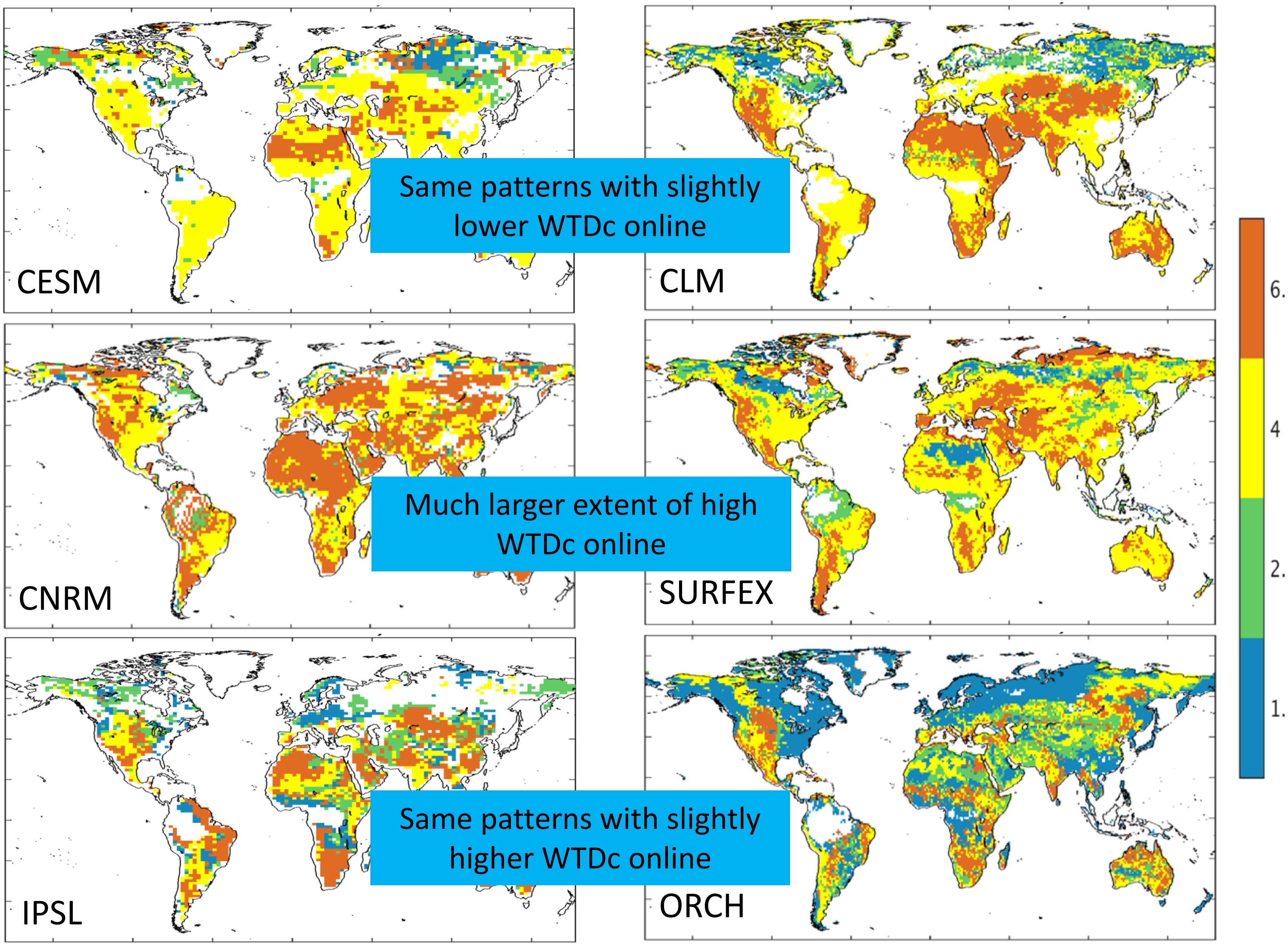
CLM shows smaller variations rates to shallow WTD in coupled mode

Land averages: Precipitation

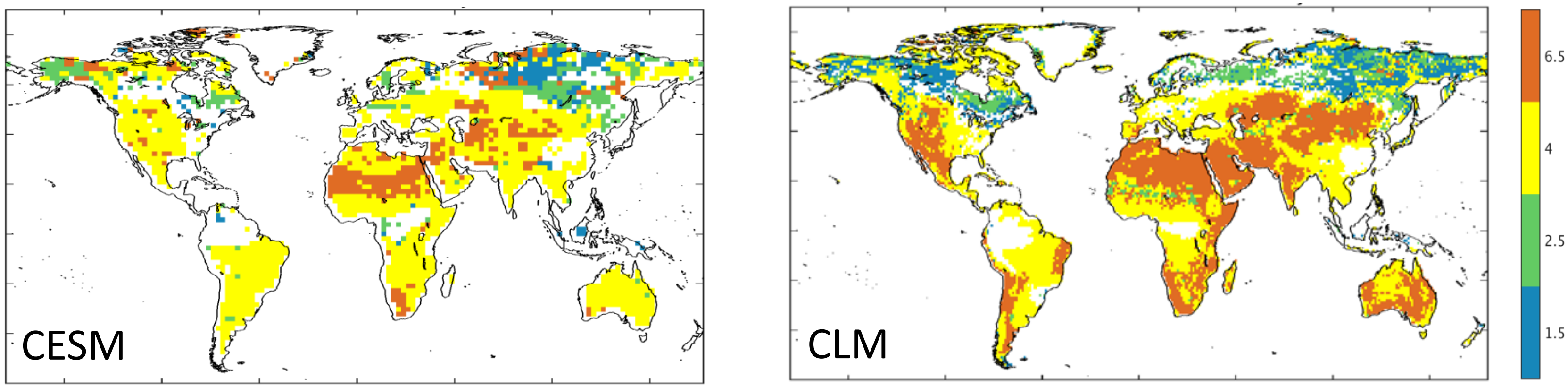




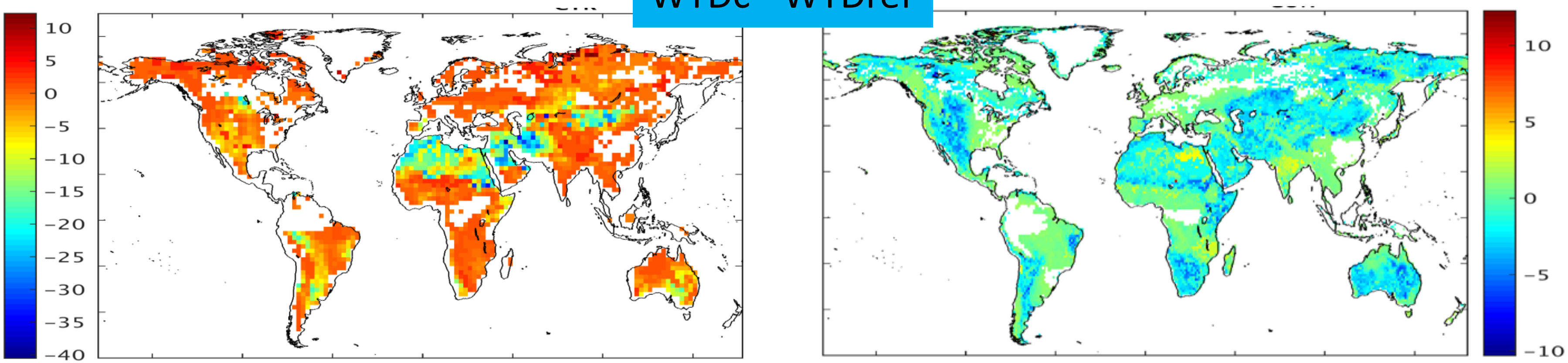
WTDc at 1%: Coupled v. off-line



Comparison with actual WTD in CLM



WTDc - WTDref



Where blue, WTDref>WTDc, and there is no/low WTD impact on ET

- Arid zones for CESM
- Transitional zones for CLM

5. Conclusion and perspectives

Off-line results

- The critical WTD helps comparing the sensitivity of surface fluxes to GW between different regions and models
- **Models need WTDs down to 5 - 10 m to represent the effect of GW on SM and ET in arid and semi-arid zones**

Coupled results

- **Same overall WTDc patterns as from off-line simulations** (no major change in aridity patterns because of WTD/atmosphere coupling)
- « Deeper » analysis is needed

Limits and perspectives

- Fixed WTD over the entire grid-cells → highly unrealistic
- Same experiments with forced WTD over fractions of grid-cells (coupled mode)
- Comparison of the three LSMs with dynamic WTD parametrization

Thank you for your attention

Whymap 2008