Improved Soil Moisture Variability in CLM 3.5

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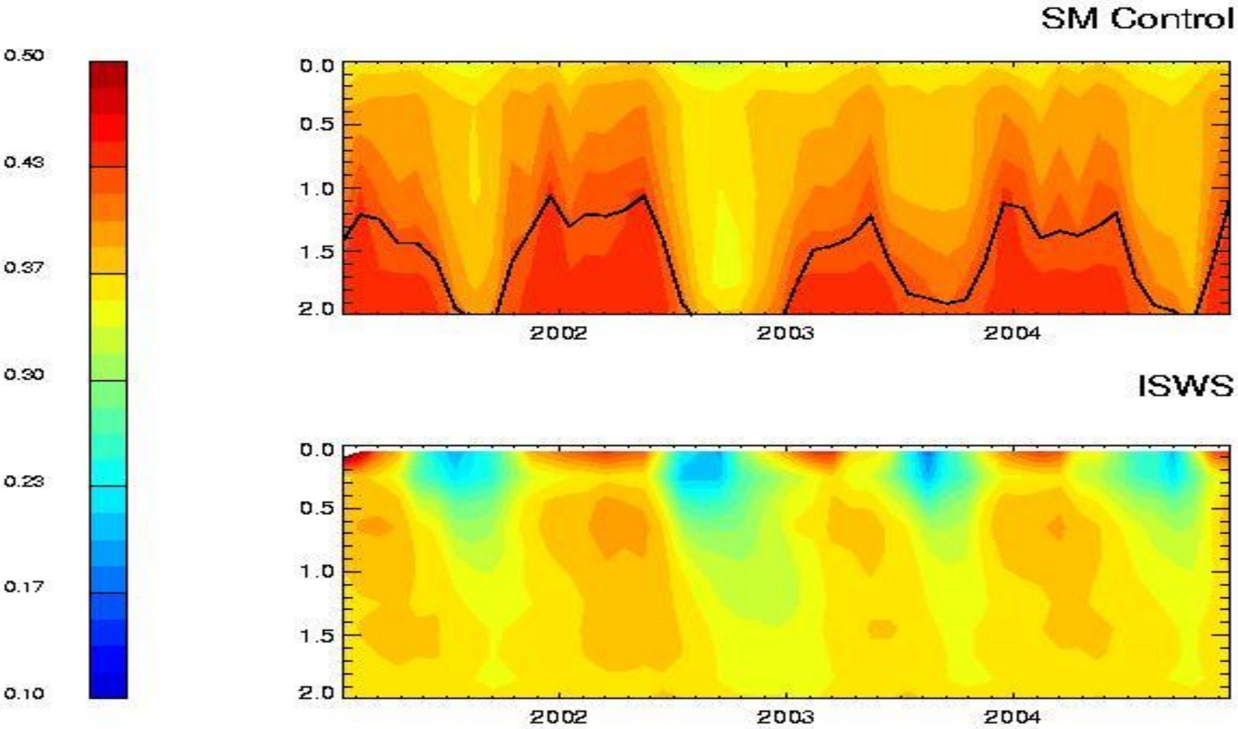
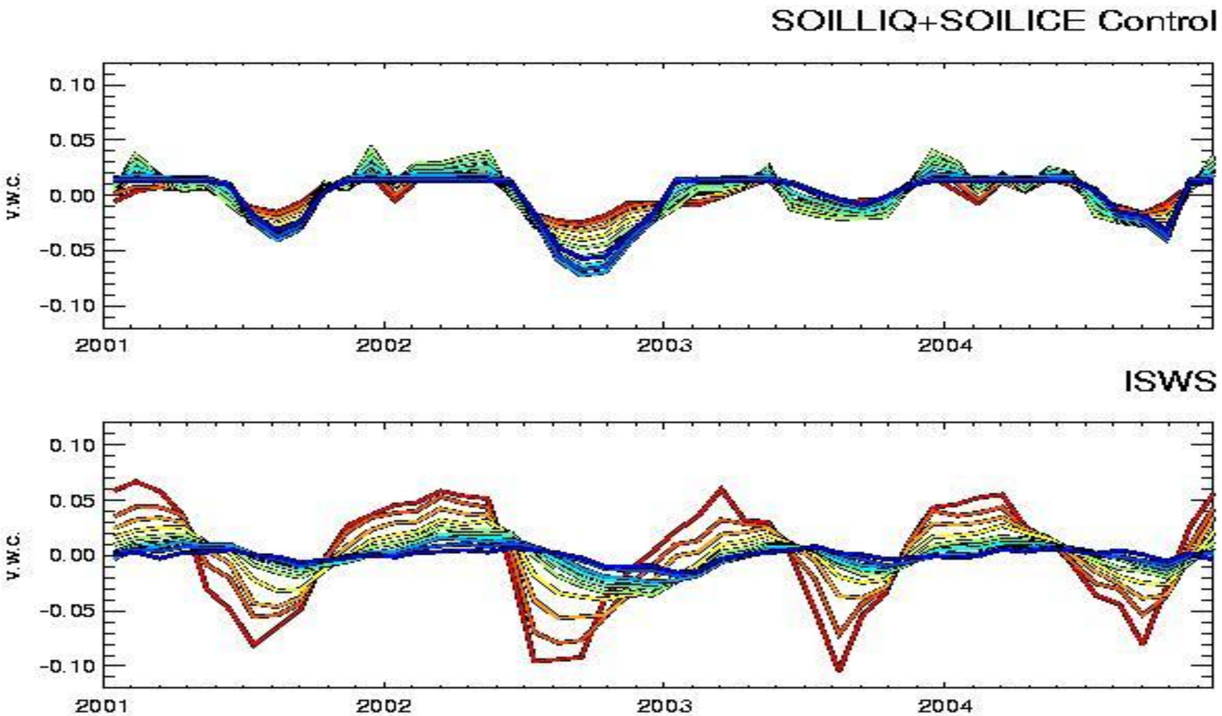
in collaboration with Keith Oleson and David Lawrence

Outline

- **Simulating soil moisture in Illinois with validation by Illinois State Water Survey observations.**
- Simulation of a site in Brazil (ABRACOS).
- Incorporating the water table into the soil water equations.
- Recommendations.
- Current and Future work.



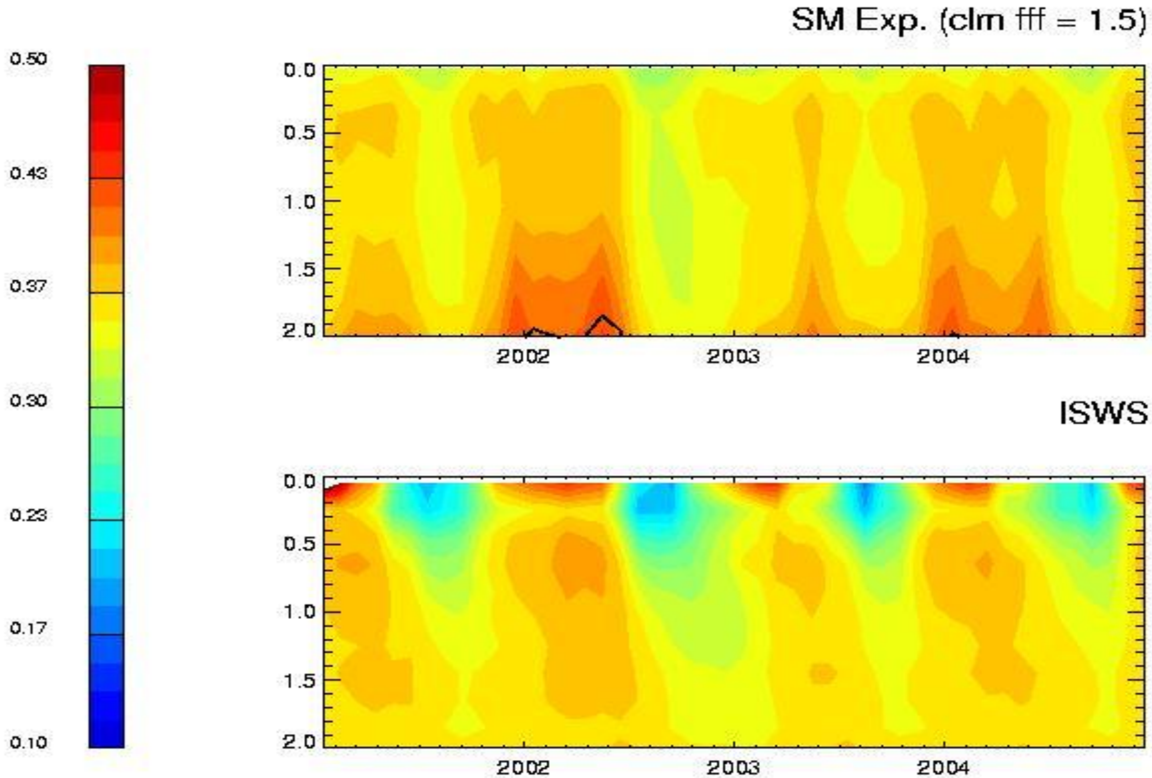
Water table is not apparent in observed soil moisture data.

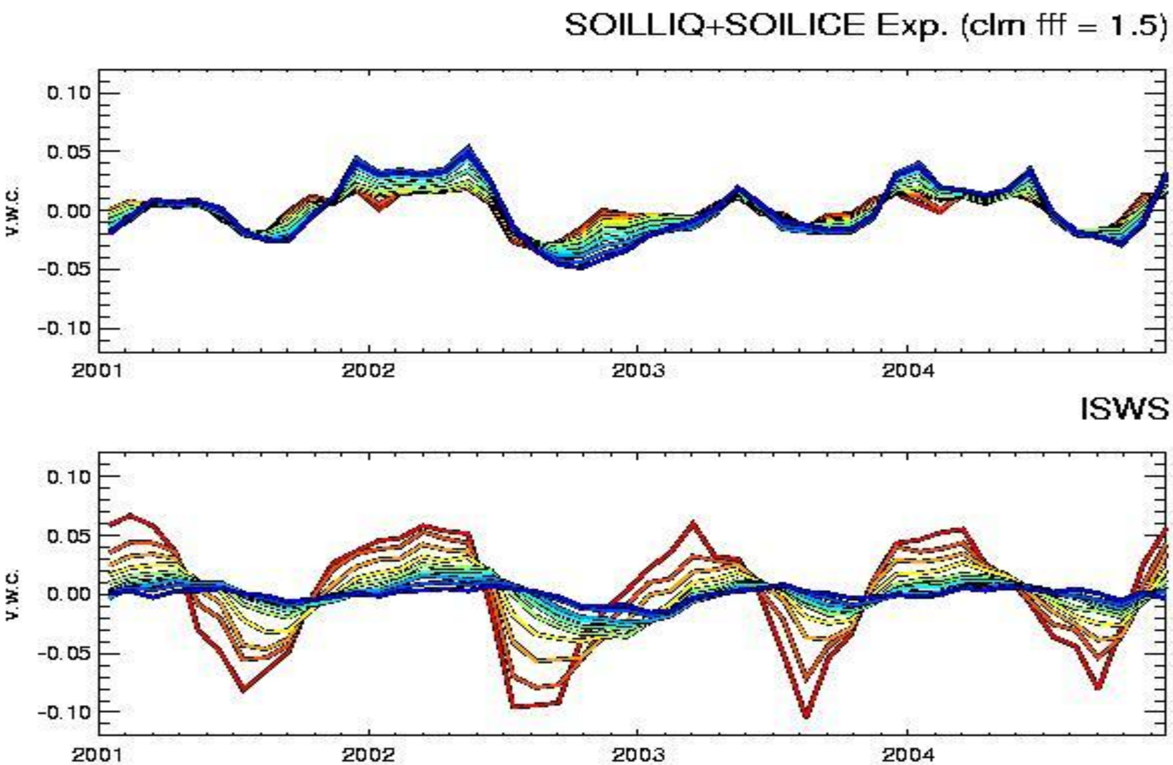


Red: shallowest layer
Blue: deepest layer

•**Control** shows most variability at **depth**.

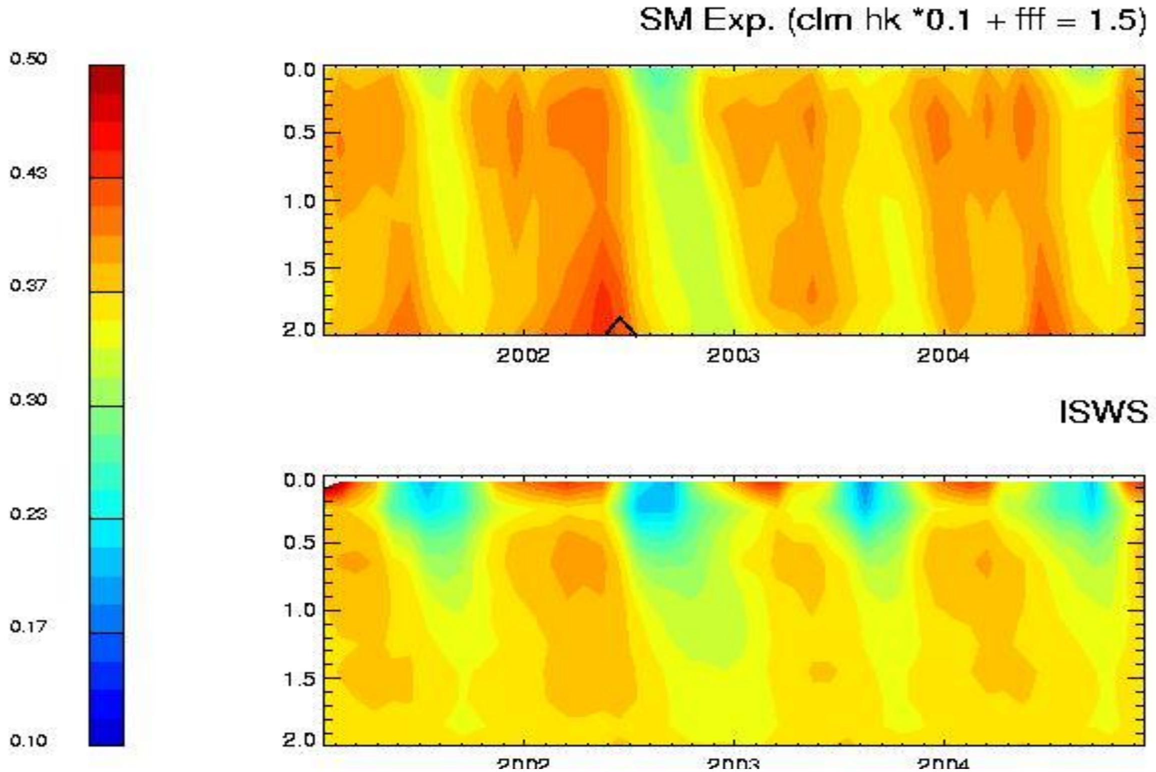
•**Observations** show most variability near the **surface**.

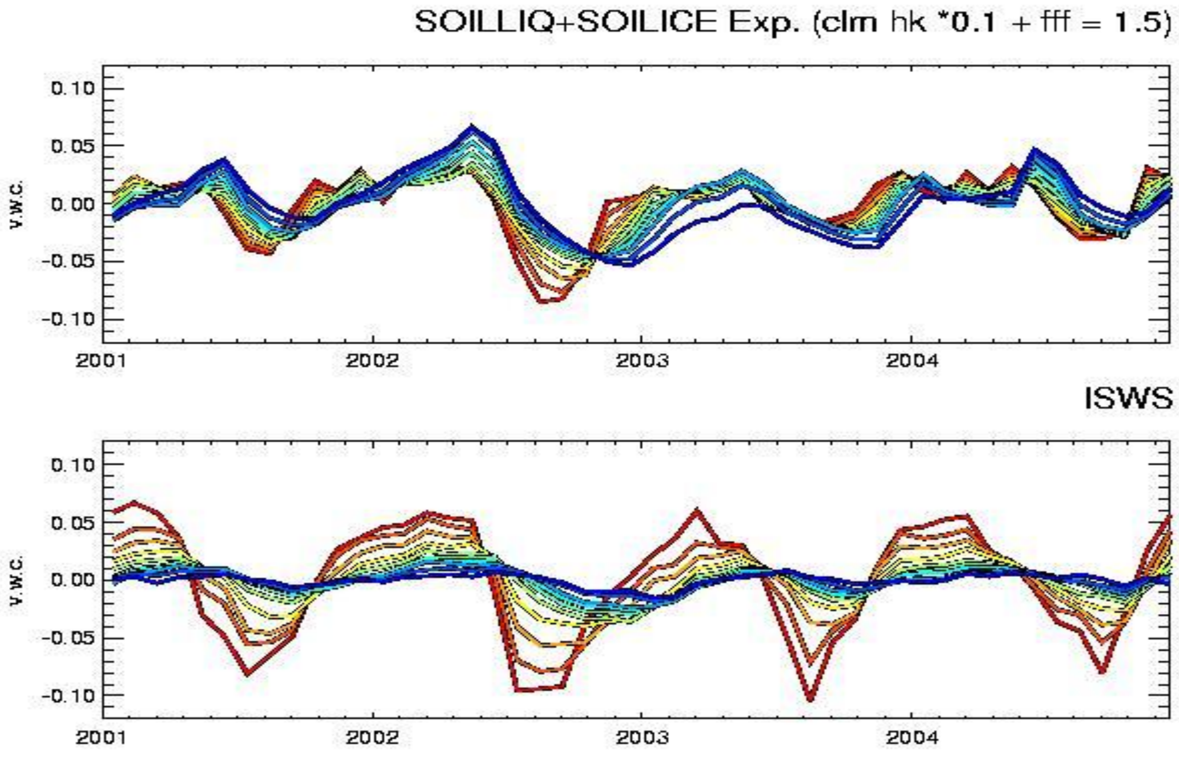




Decreasing the **f** parameter (Q ✪ $e^{(-f\cdot z)}$) causes equilibrium baseflow to occur at greater depth, pushing the water table below 2 meters.

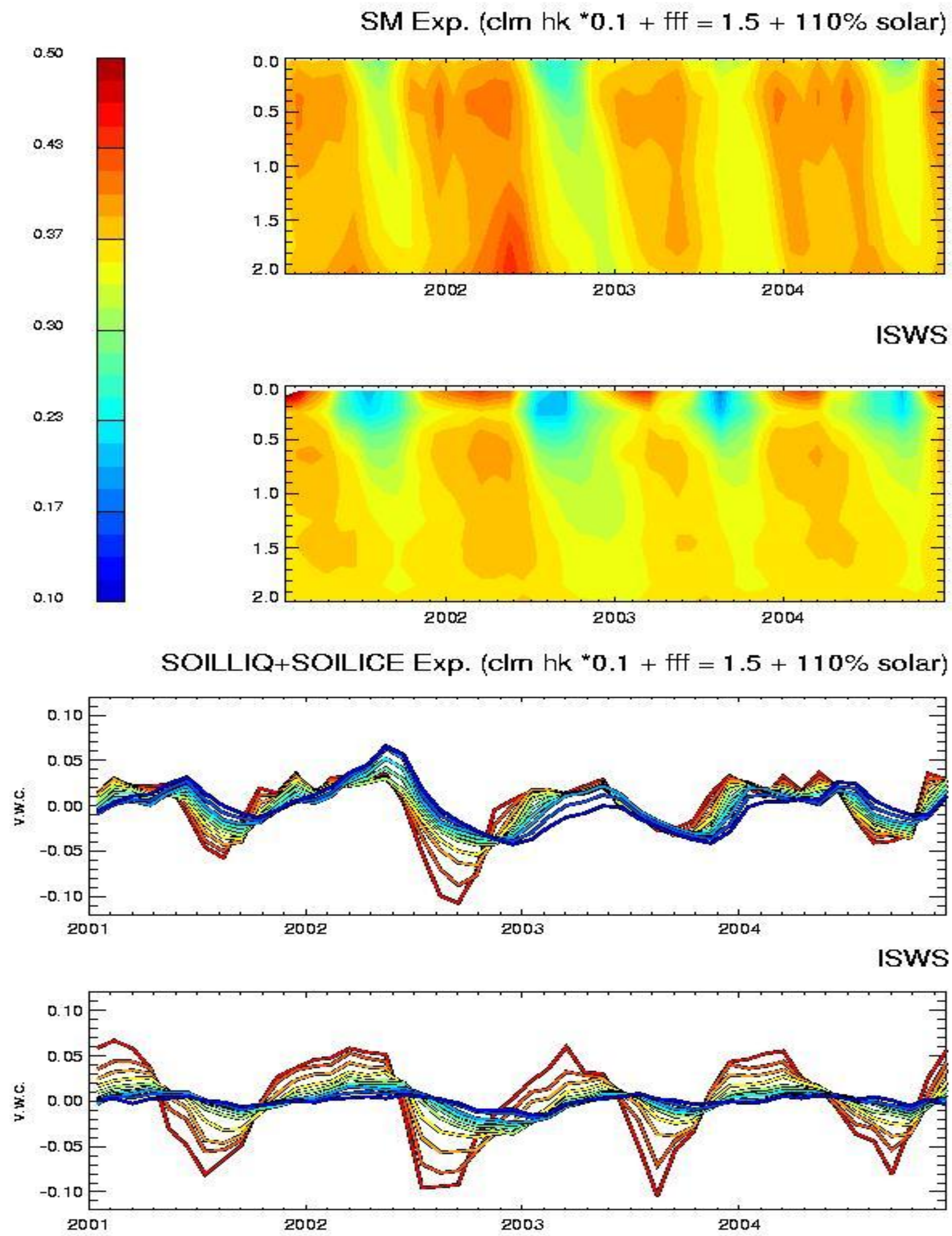
Variability is roughly uniform with depth.





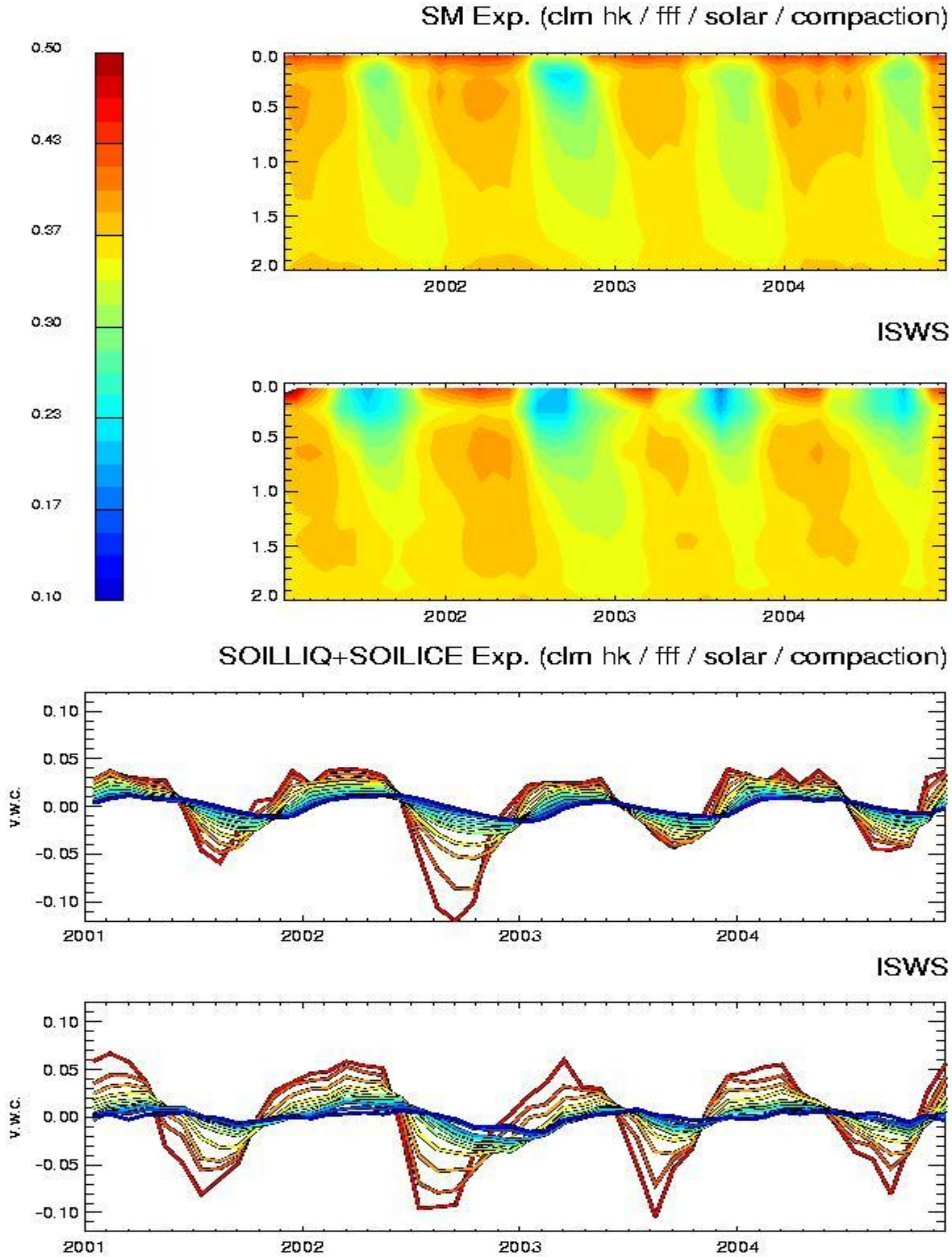
Decreasing the **saturated hydraulic conductivity** by an order of magnitude reproduces the phase lag with depth.

This **increases variability**, especially near the surface.



Insolation is increased by 10% to match climatological values from other studies.

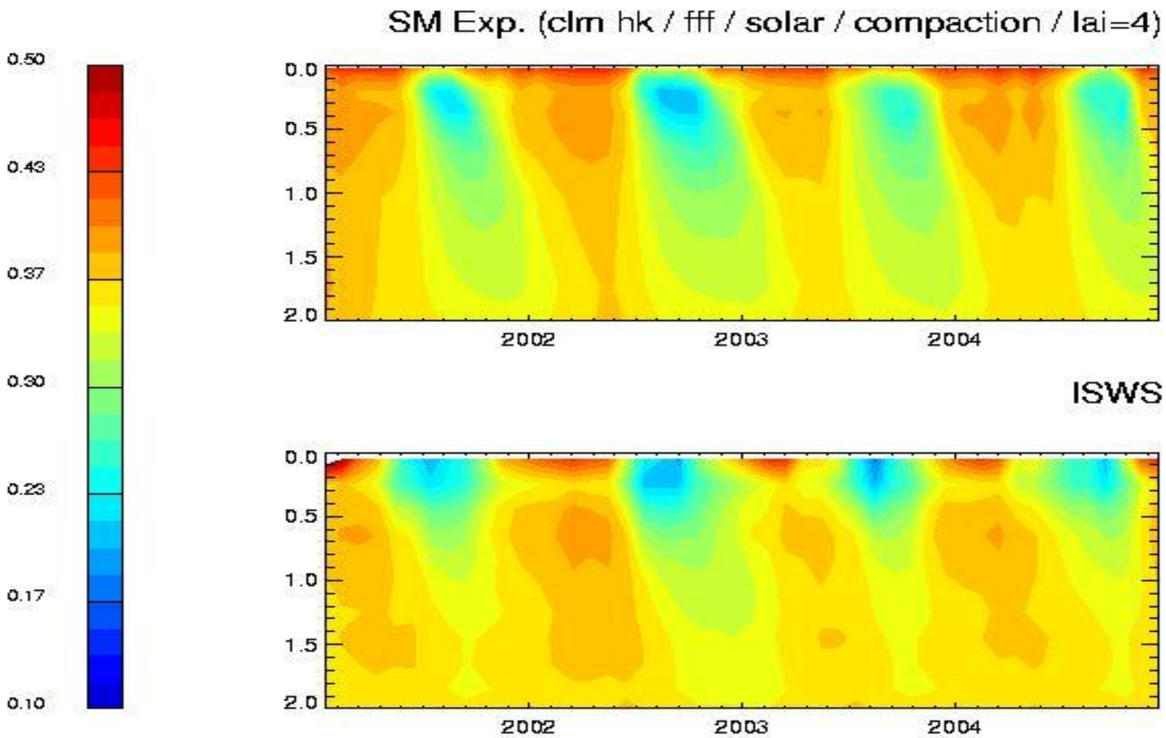
This is likely due to the linear interpolation currently used, which results in a poor diurnal cycle.

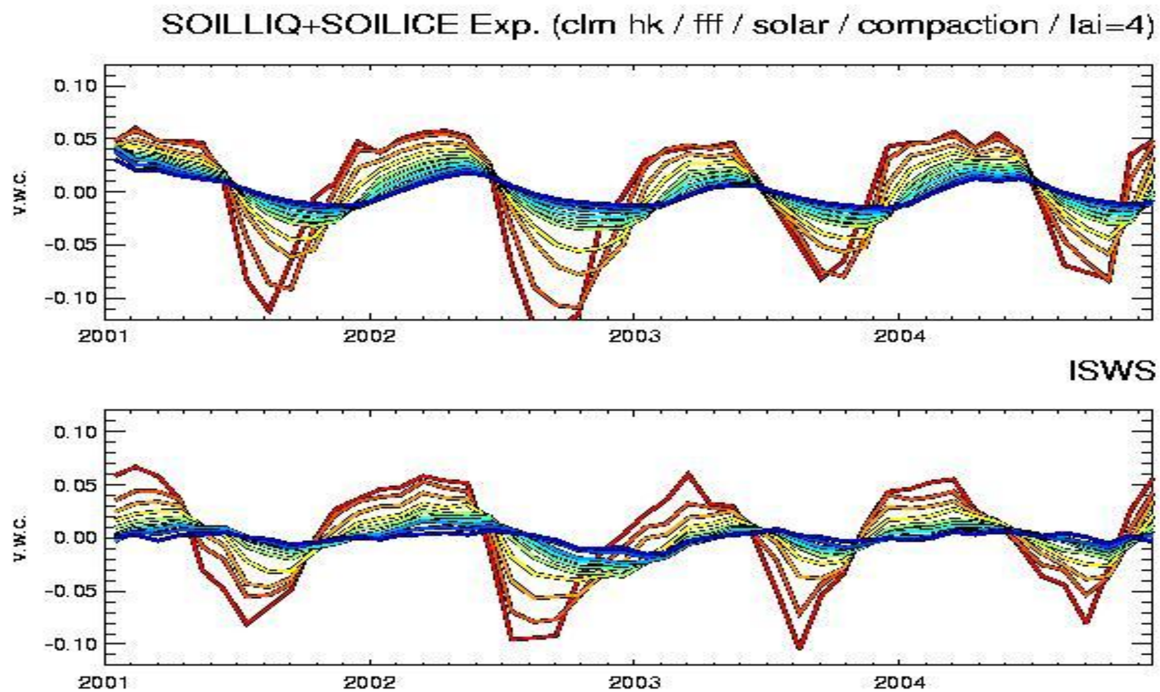


The **upper 10 cm** of the observations exhibit anomalously **wet** conditions during the **winter**.

This can be modeled by a **“compacted” layer** by increasing the ratio of **clay** to **sand**.

This increases **field capacity** and **decreases infiltration,** further increasing variability near the surface.





Finally, increasing **Leaf Area Index** (LAI) to **4** boosts transpiration.

The final simulation shows similar variability that is consistent with the observations in both **amplitude**, **phase**, and **depth dependence**.

The **water table** in this simulation is at a depth of about **3.5** meters.

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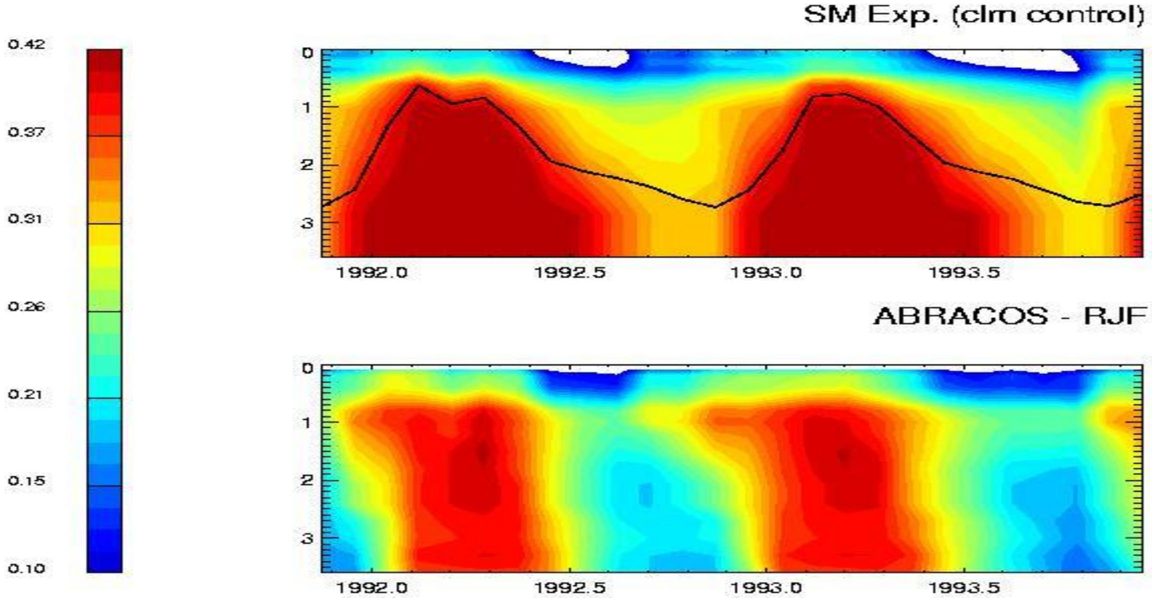
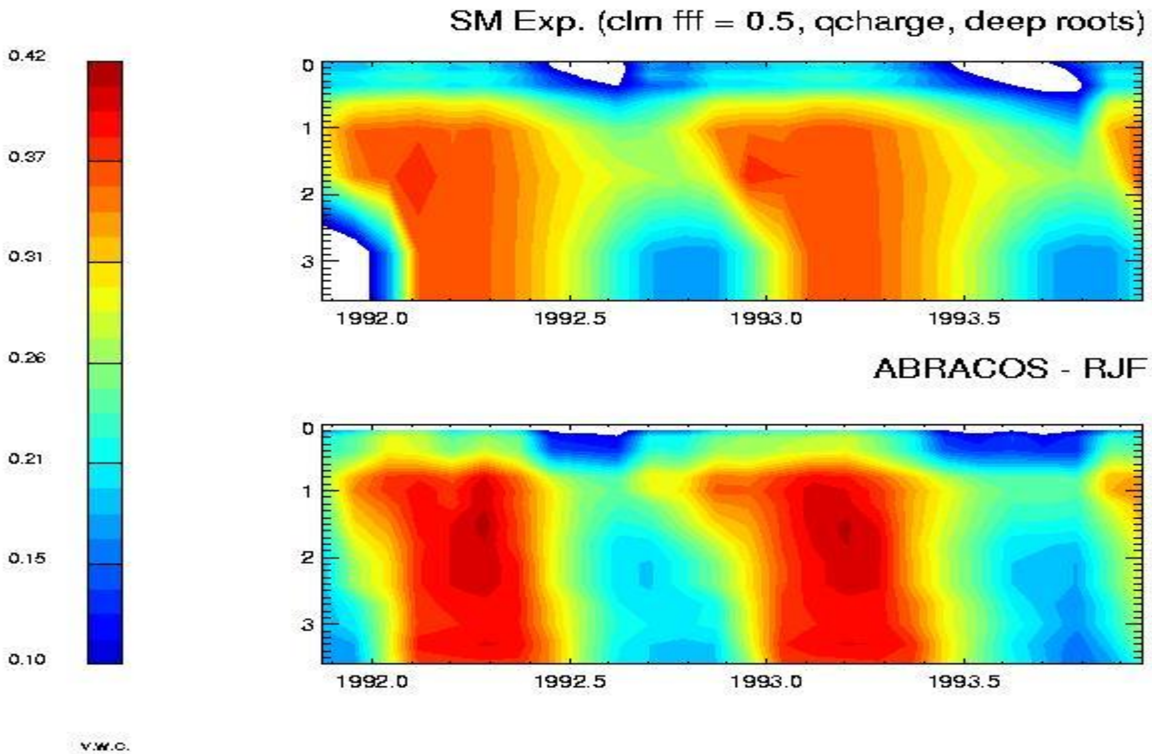
Other sites: Brazil/ABRACOS/Reserva Jaru Forest Flux Tower



Control shows high soil wetness due to **shallow water table**.



New simulation is also wet, but due to **high infiltration rates**. Water table is much deeper, 6-8 meters.

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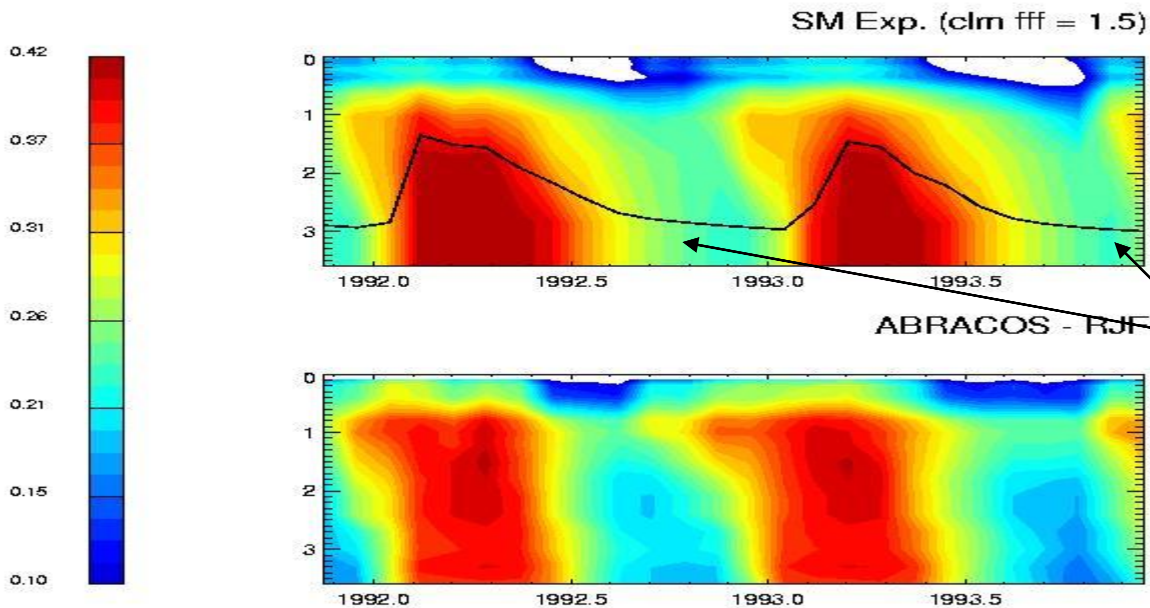
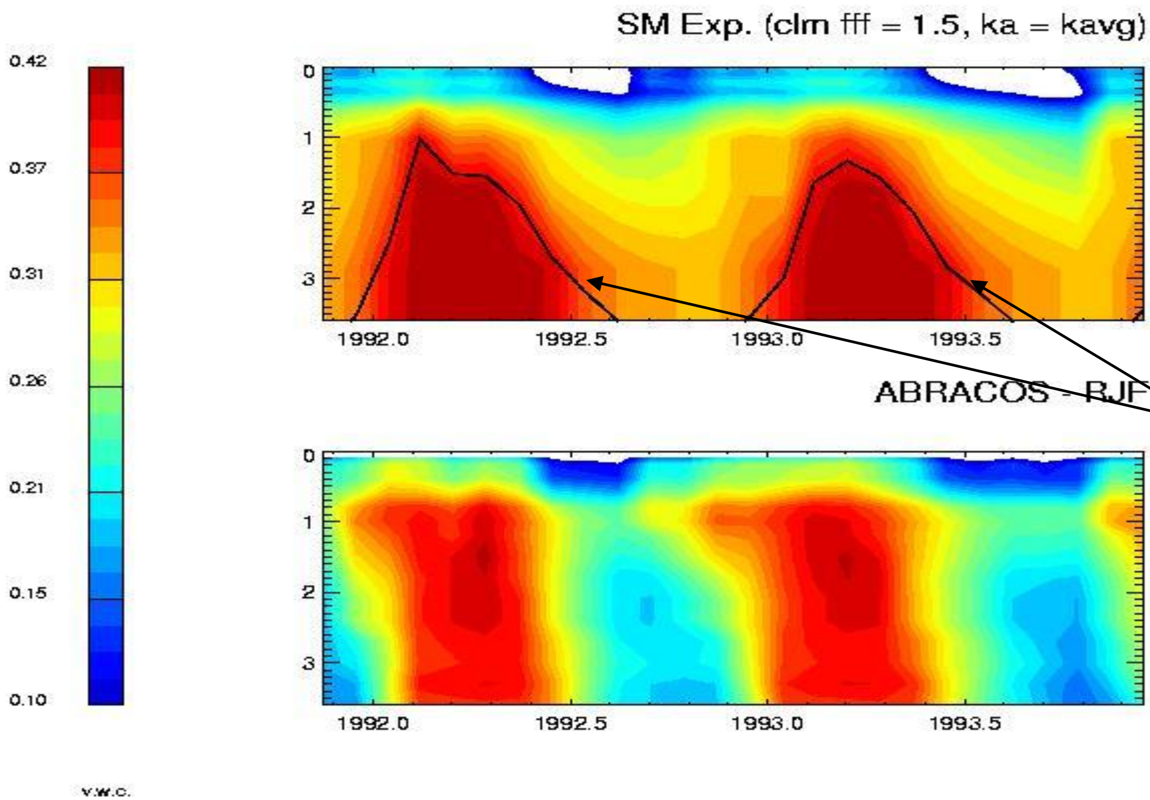
The current water table formulation can exhibit pathological behavior.

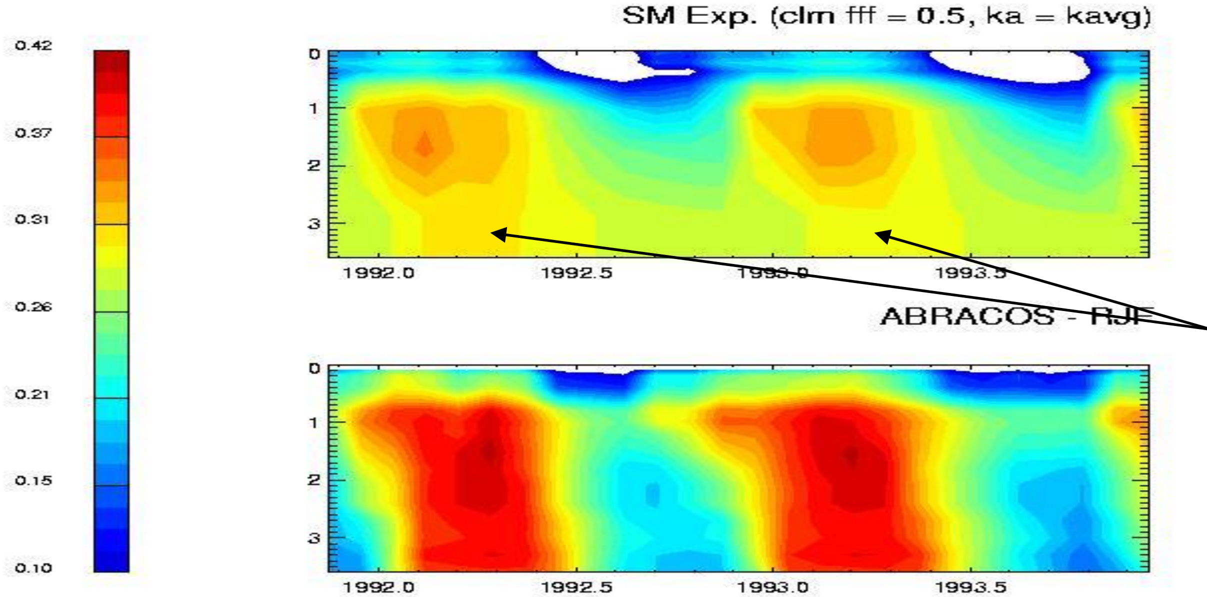


The **hydraulic conductivity** used in the QCHARGE calculation is **too low**. During drying events, the water table fails to track the saturated contours.

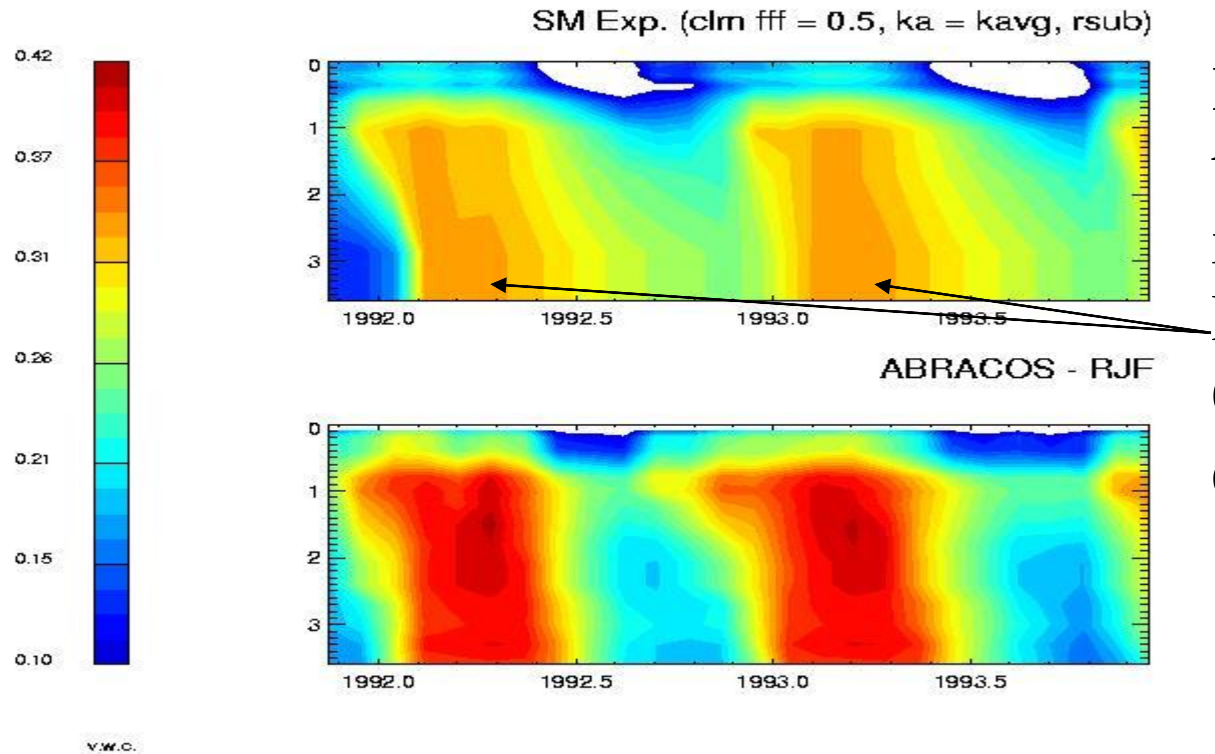


Using a hydraulic conductivity based on the **average soil moisture** between the water table and the layer above it causes the water table to better track the saturated contours.

"Fixing" the QCHARGE calculation reveals a second problem.



The **"two-step"** aquifer formulation **decouples** the flux of water from the soil column to the aquifer. This can result in unrealistic **drying at depth**.



Incorporating the water table as the **lower boundary condition** in the soil water equations leads to a **consistent** QCHARGE calculation, and eliminates these drying events.

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Summary & Recommendations

CLM 3.5 is demonstrated to possess the ability to simulate soil moisture observations with **great detail**.

Significant **improvements** to the simulation of **soil moisture variability** in CLM 3.5 can be obtained by a model formulation change combined with parameter calibration:

- Incorporate the **exchange of water** between the **soil column** and the **aquifer** (QCHARGE) into the **soil water equations**.
- **Correct** the **hydraulic conductivity** used to compute QCHARGE.
- **Deepen** the water table, by adjusting parameters controlling baseflow.
- Re-examine the values of **saturated** hydraulic conductivity (KSAT).

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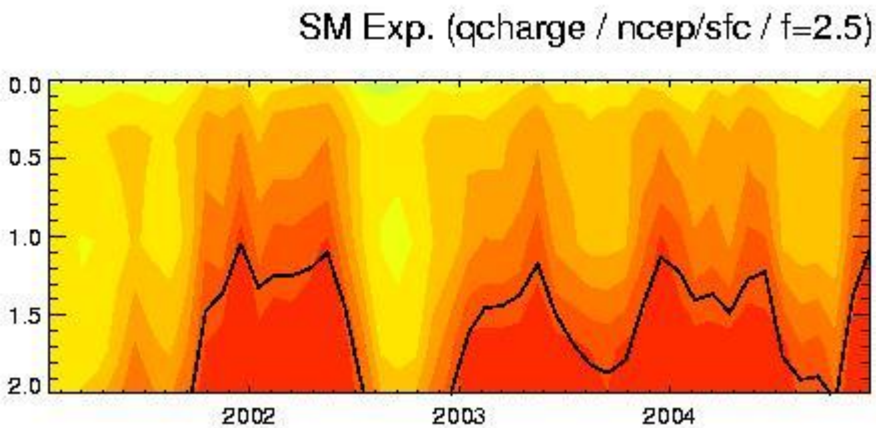
Current and Future Work

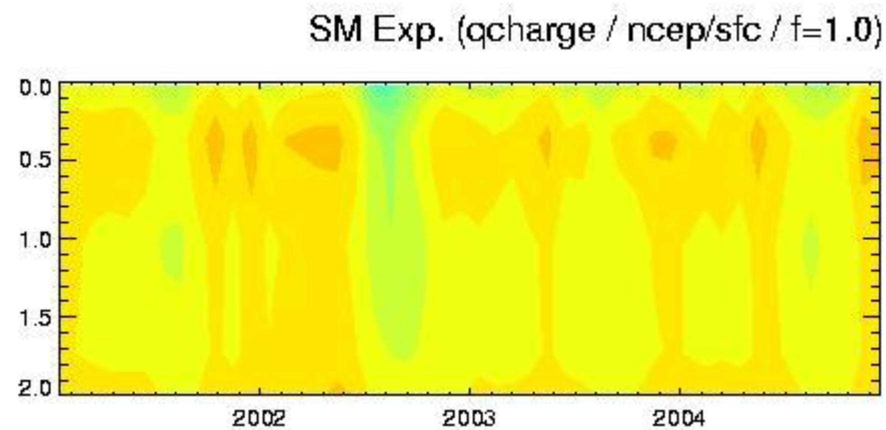
- Model calibration:
    - are global parameter values adequate?
    - can regional parameter values be determined?
    - what is the appropriate ratio of surface runoff to baseflow?
        - deepening the water table will further reduce surface runoff.

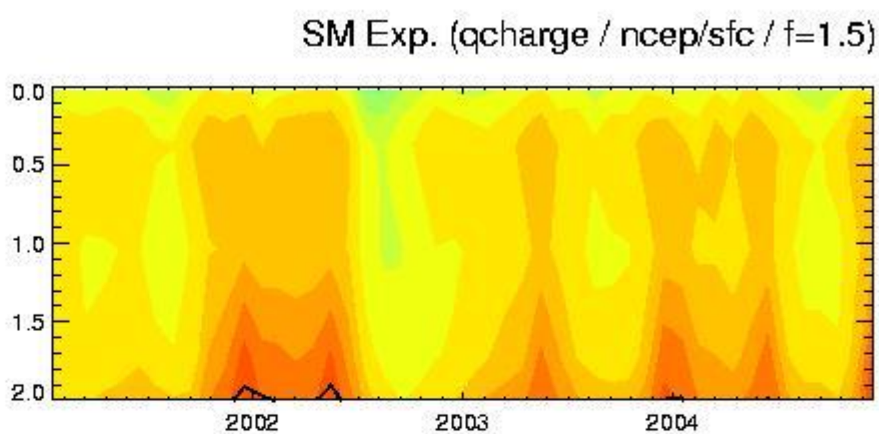
- Model validation:
    - use combined constraints of GRACE and river discharge.
    - use flux tower observations.
    - obtain additional soil moisture and well level observations.

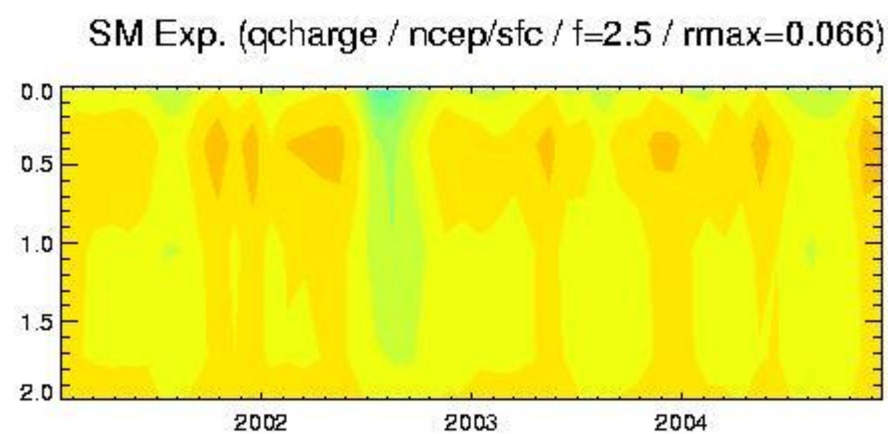
Deepening the Water Table

- f versus rtop_max (q ~ rtop_max·exp(-f·zwt):
  - both deepen the water table by increasing drainage for a given depth
  - decreasing f dampens the variability, increasing rtop_max does not









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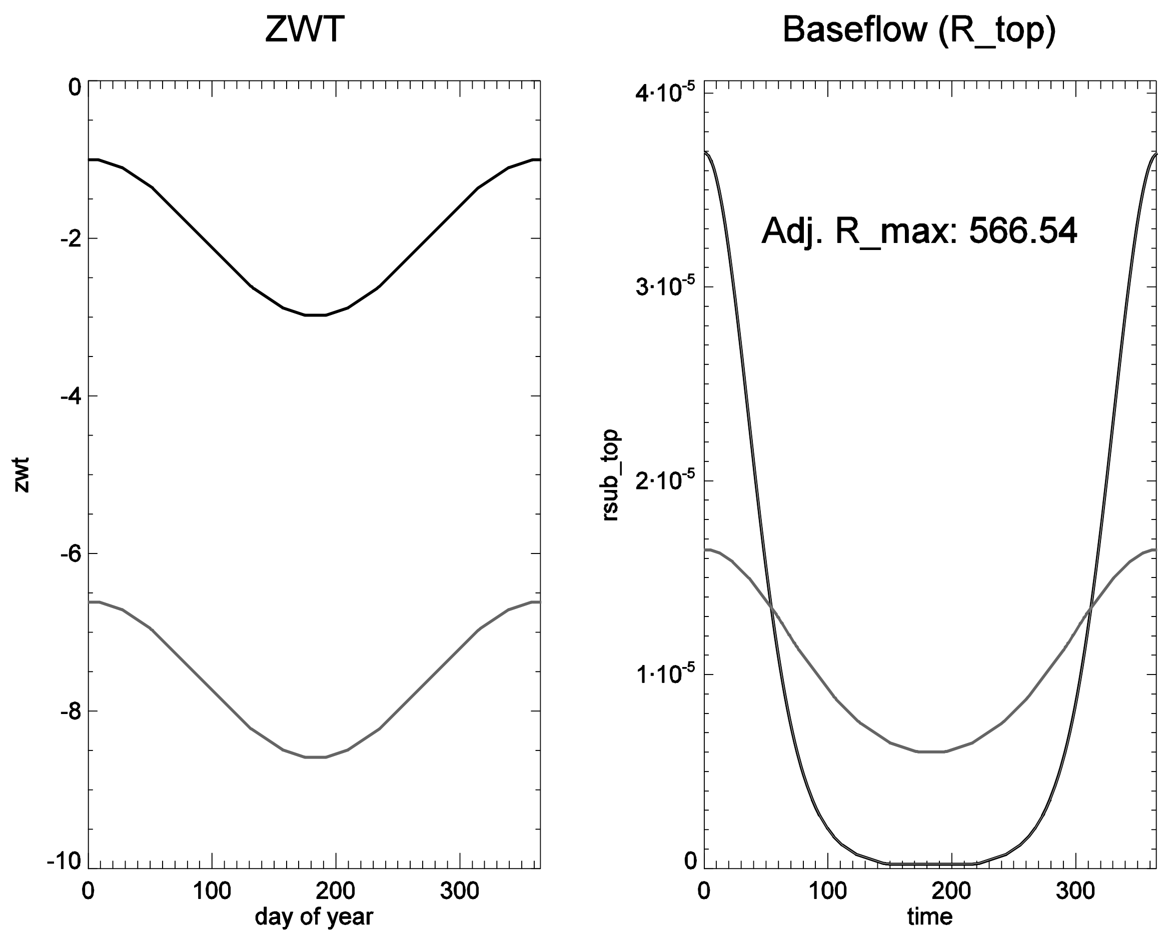

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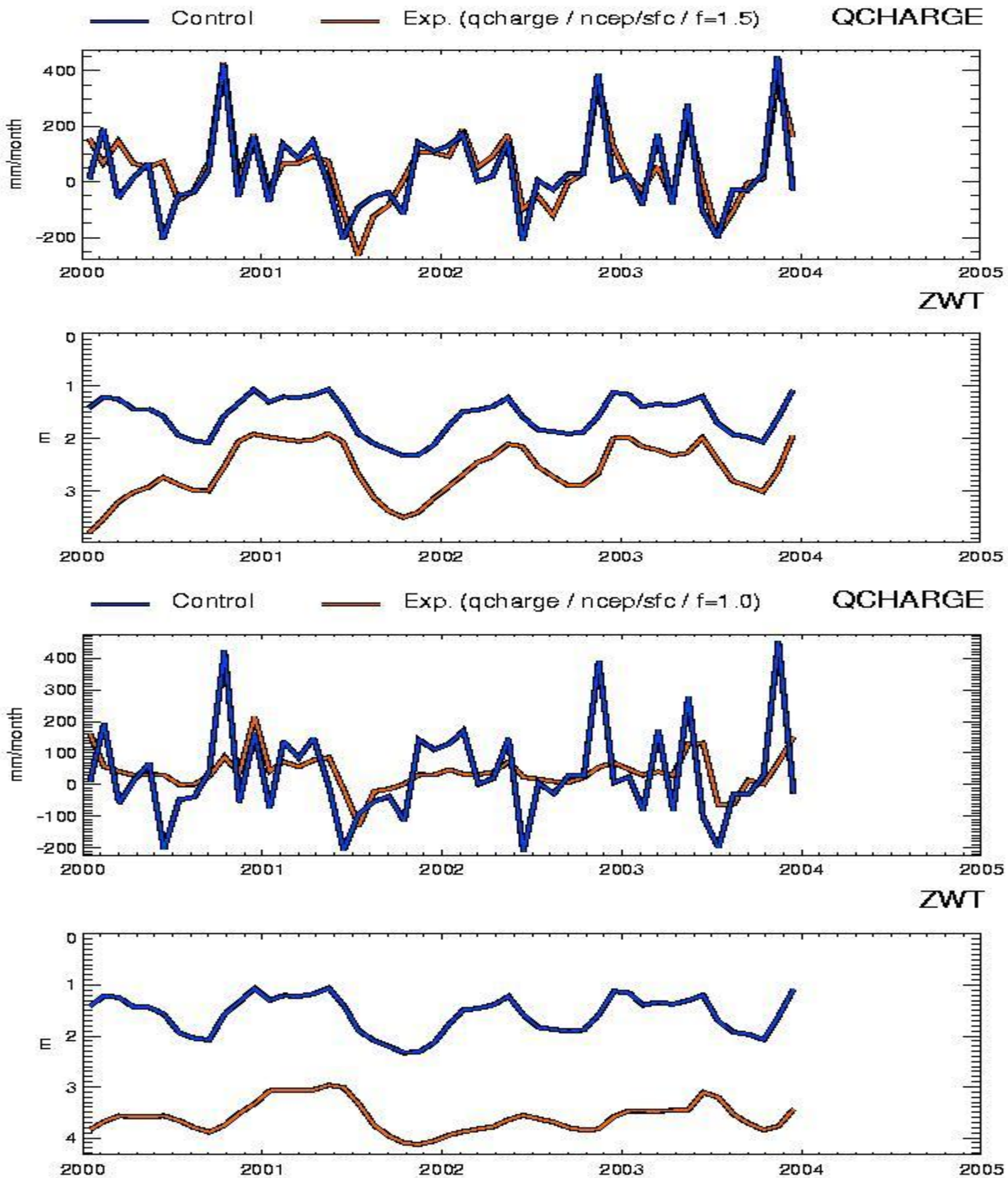

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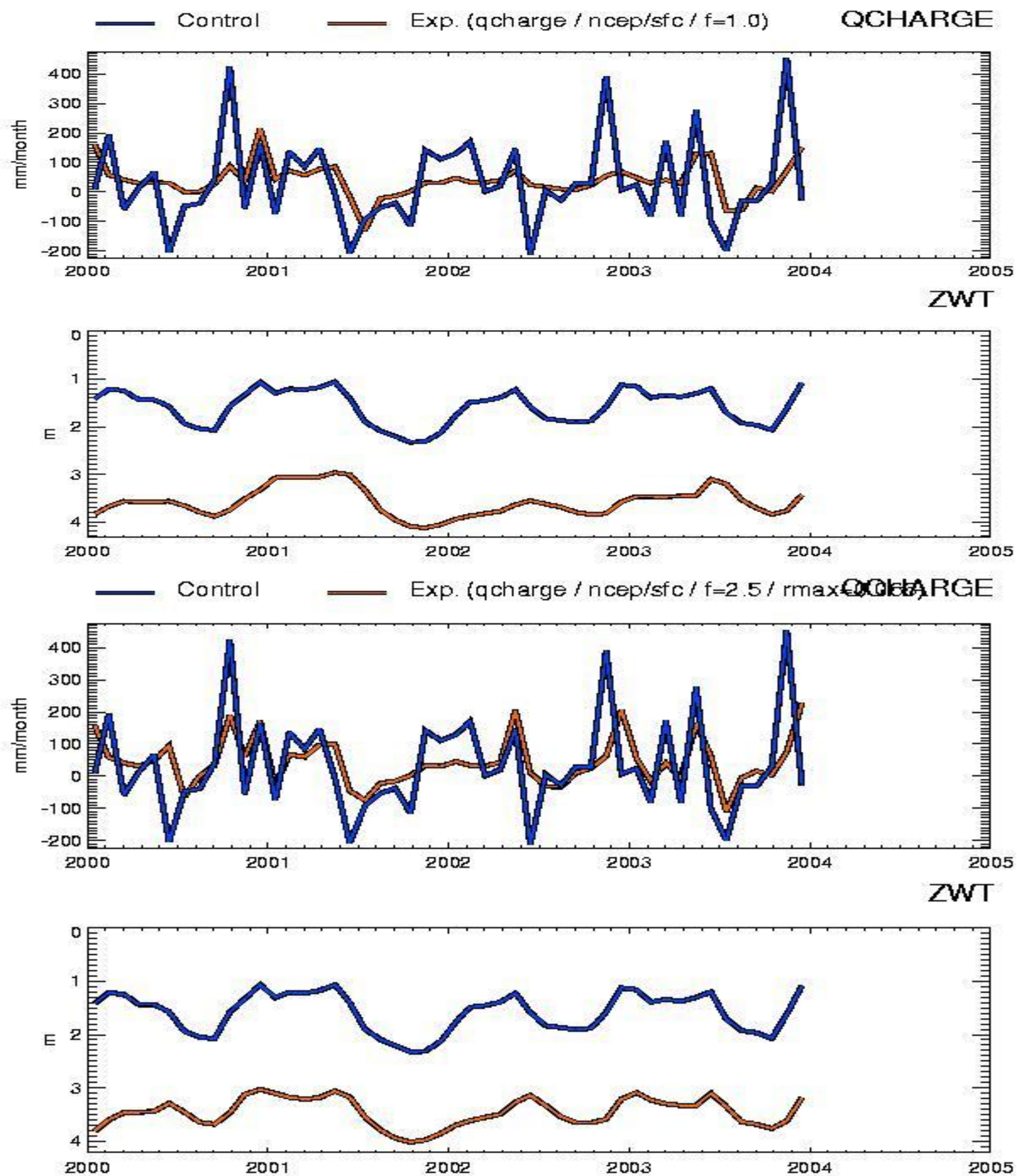

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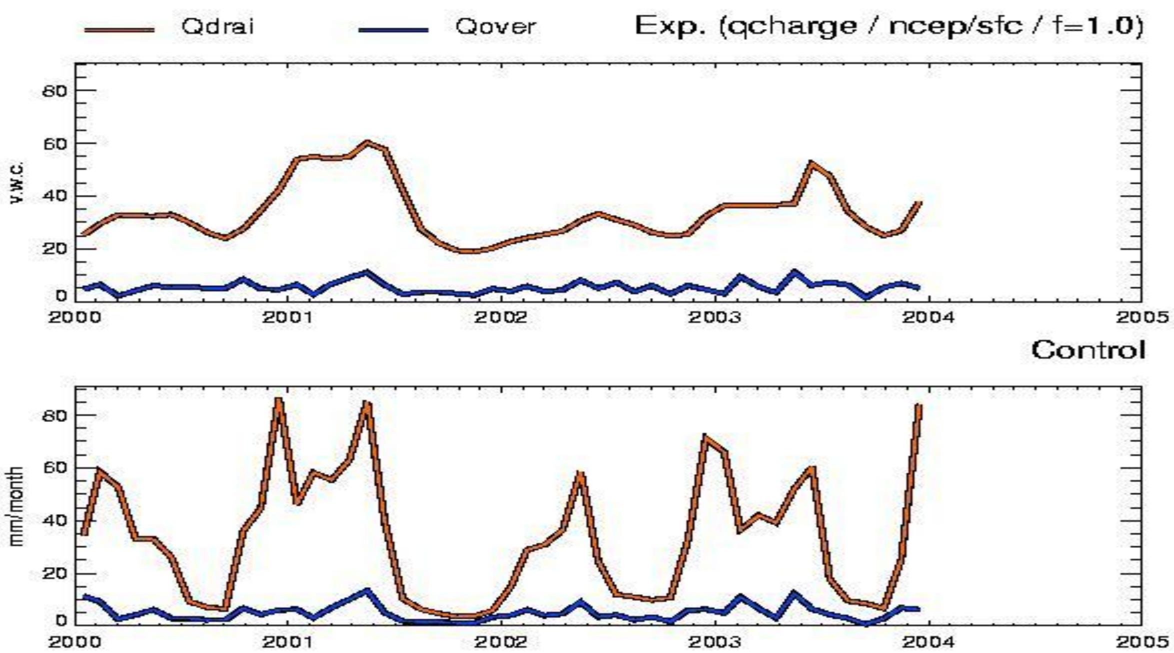

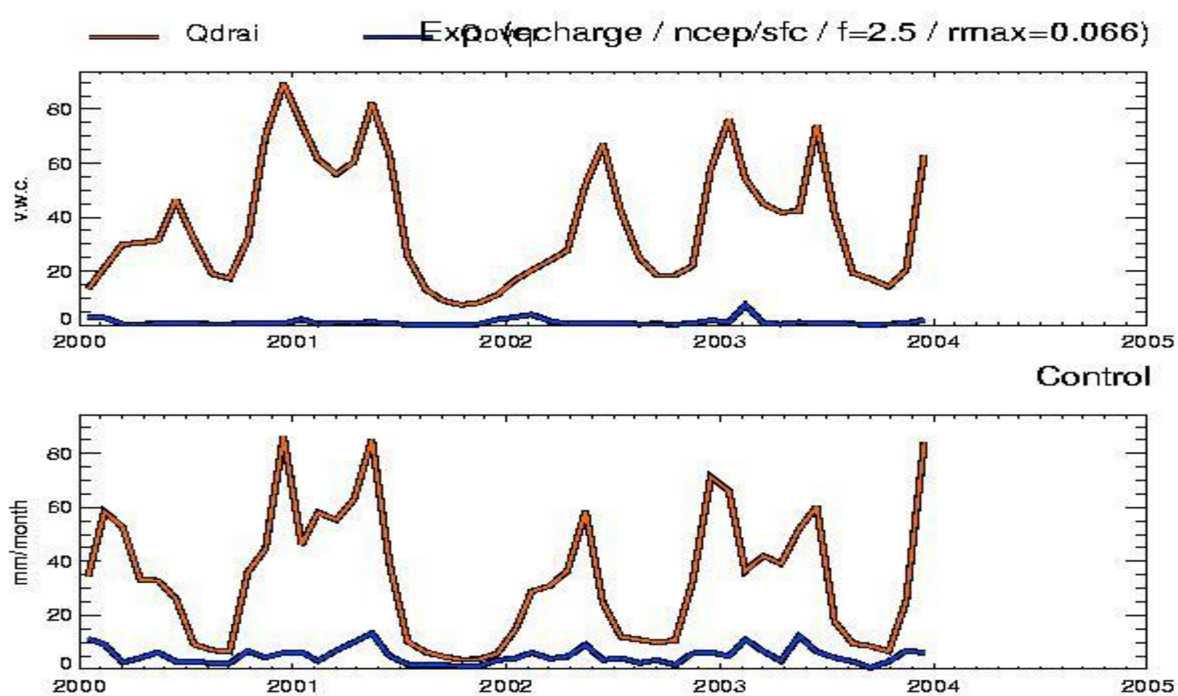

Partitioning Runoff

• in the topmodel formulation, surface runoff is a function of water table depth

• deepening the water table will further decrease surface runoff, and increase baseflow