New Hydrological Parameterizations in CLM5

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Synopsis

CLM5 includes a number of new parameterizations related to hydrology:

- Soil evaporation
- Canopy evaporation
- Soil water redistribution (Richards equation)
- Lateral subsurface flow (Baseflow)

Synopsis

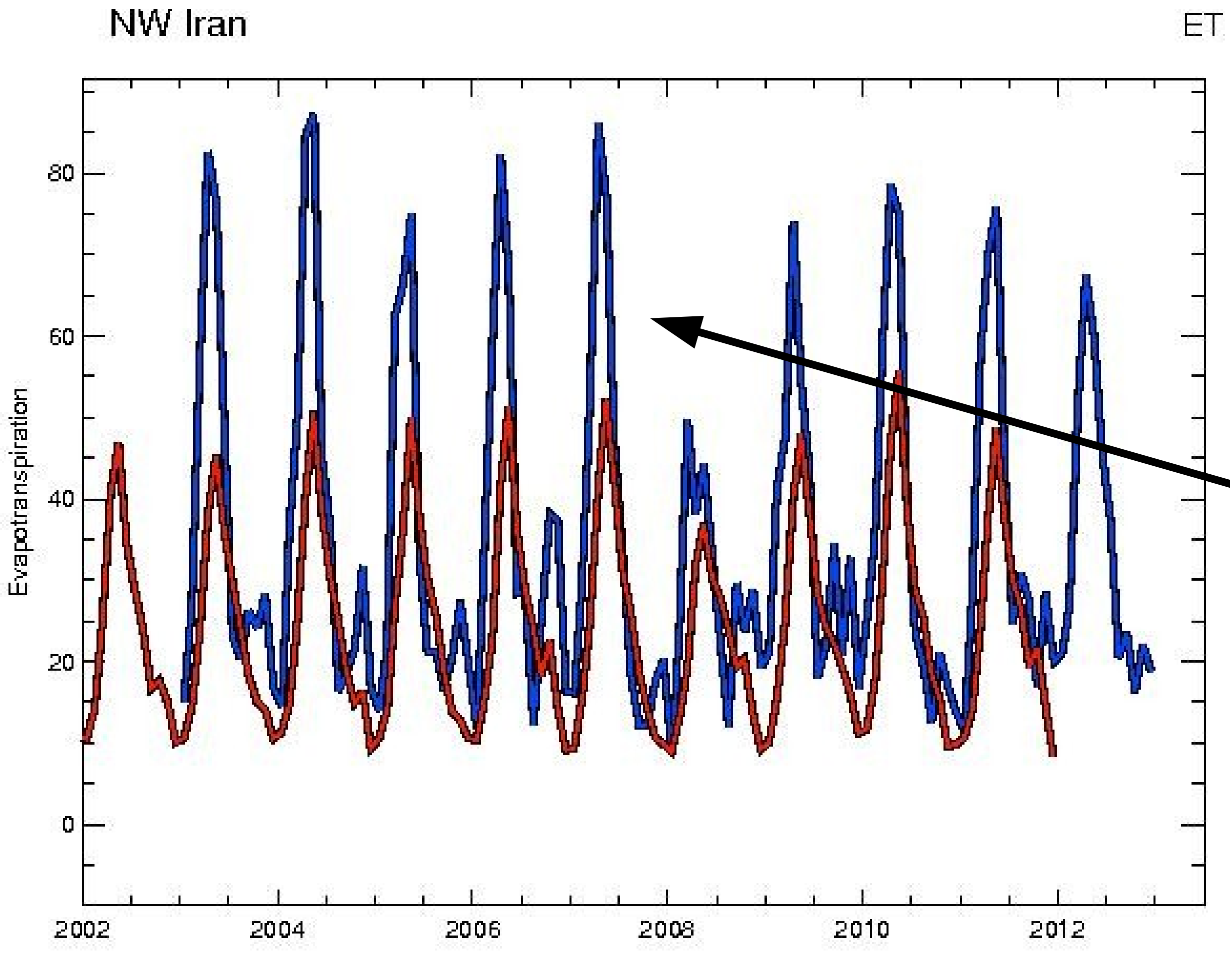
In addition, there are changes to the vertical structural of the soil column and the lower boundary condition:

- Deeper soil column (8.5 m default)
- Spatially variable soil thickness
- Elimination of “aquifer” layer

Soil Evaporation

- Based on observations of a dry surface layer
- Meant to represent transition to vapor diffusion dominated transport
- Function of soil moisture

New Soil Evaporation Parameterization

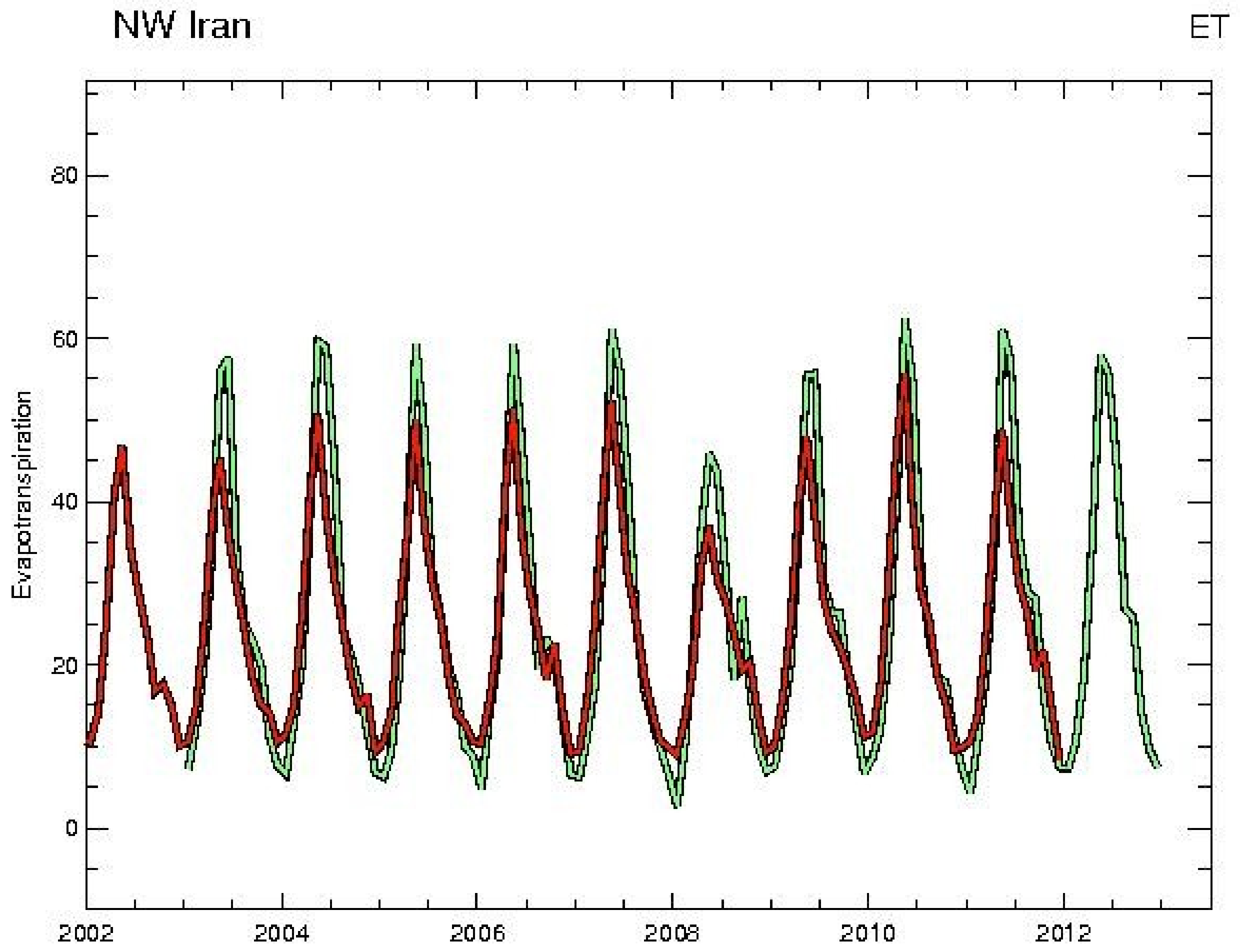


CLM

FLUXNET-MTE

CLM evapotranspiration too large and too variable compared to observations

New Soil Evaporation Parameterization

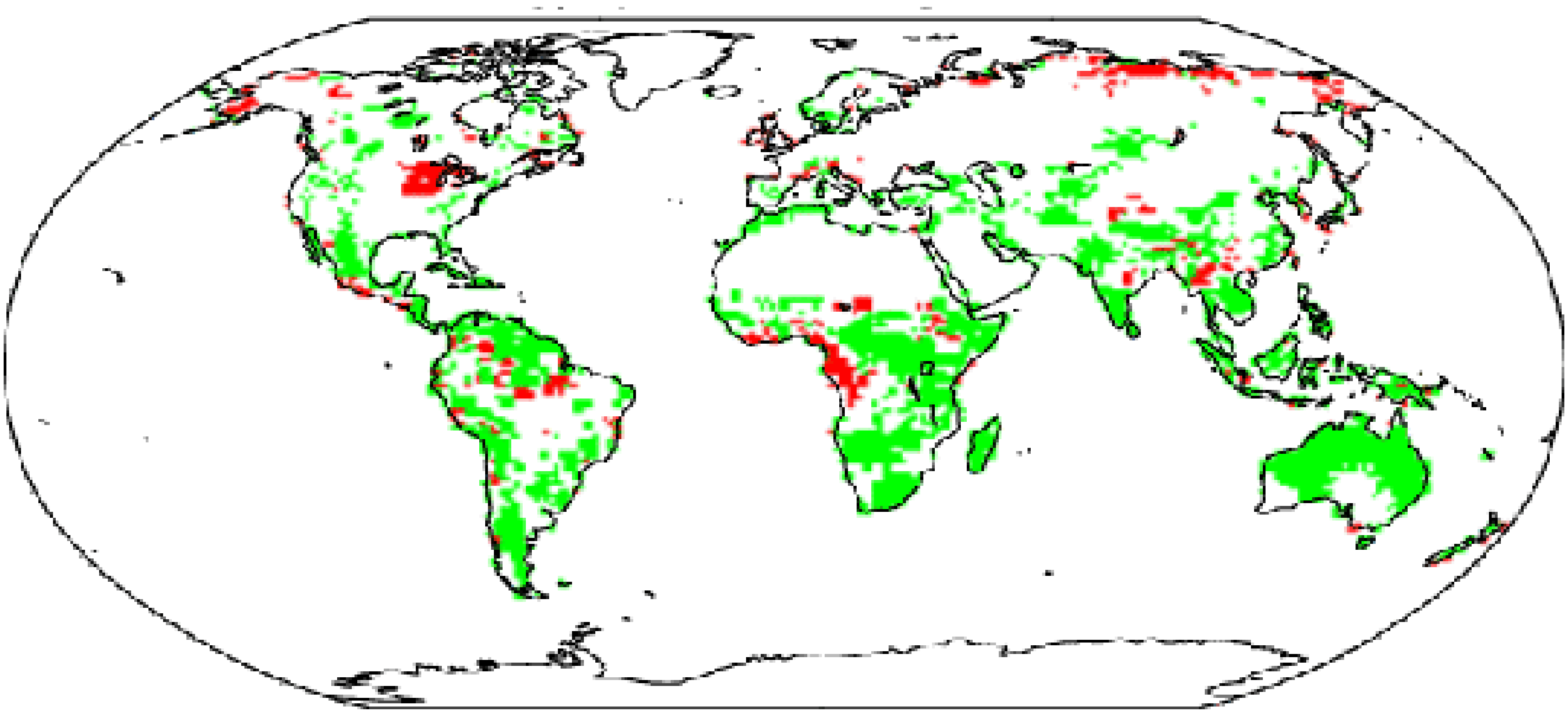


CLM (modified)

FLUXNET-MTE

New CLM evapotranspiration more closely follows observations

Latent Heat Global Comparison

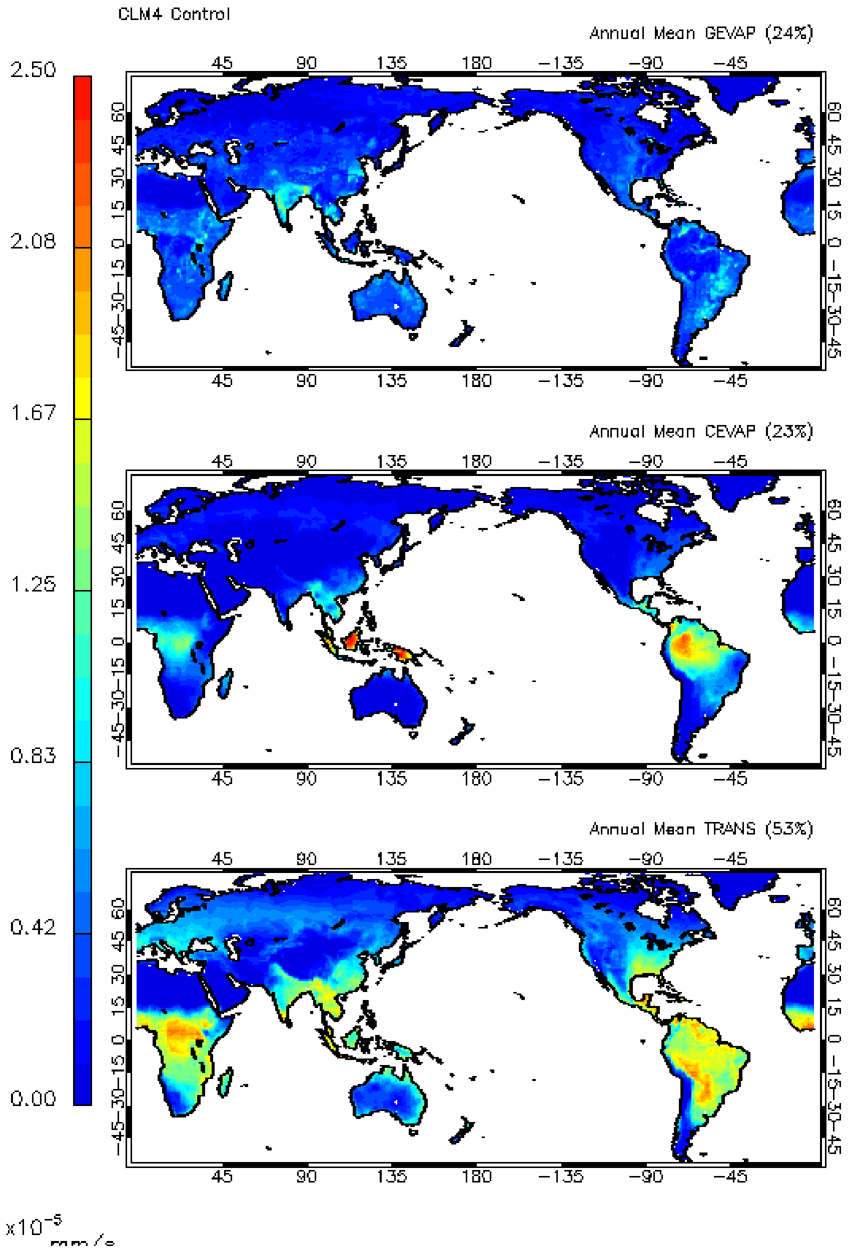


From CLM diagnostics package: red = control has lower RMSE relative to observations, green = modified model has lower RMSE relative to observations

Canopy Hydrology

- Interception / throughfall
- Leaf water storage and wetted fraction
- Evaporation from leaf surfaces

Canopy Hydrology And Evapotranspiration Partitioning

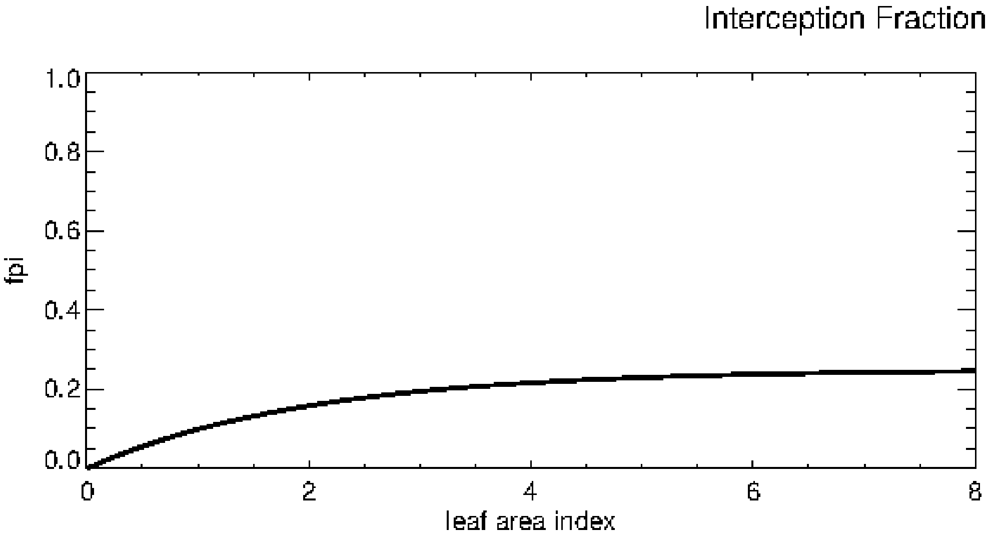


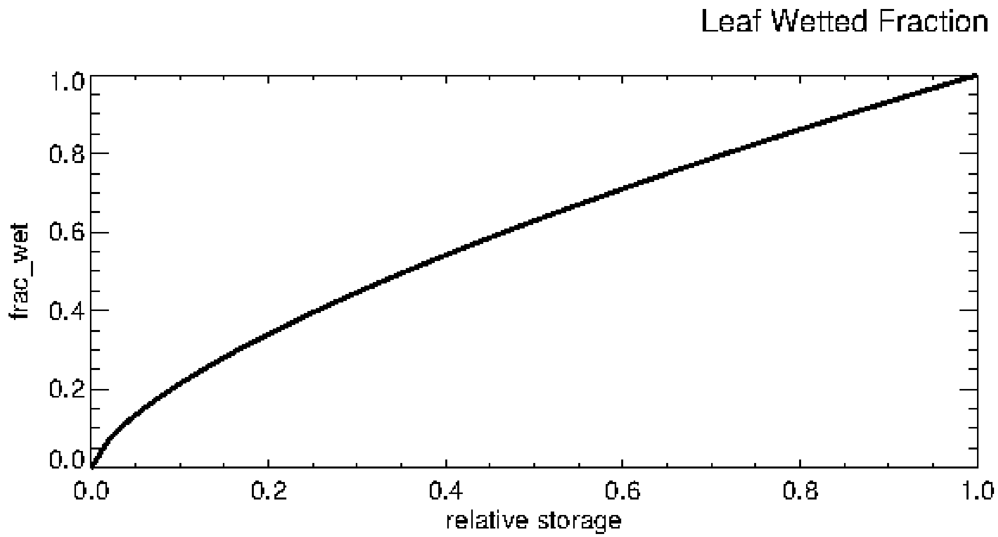
Ground Evaporation: 24%

Canopy Evaporation: 23%

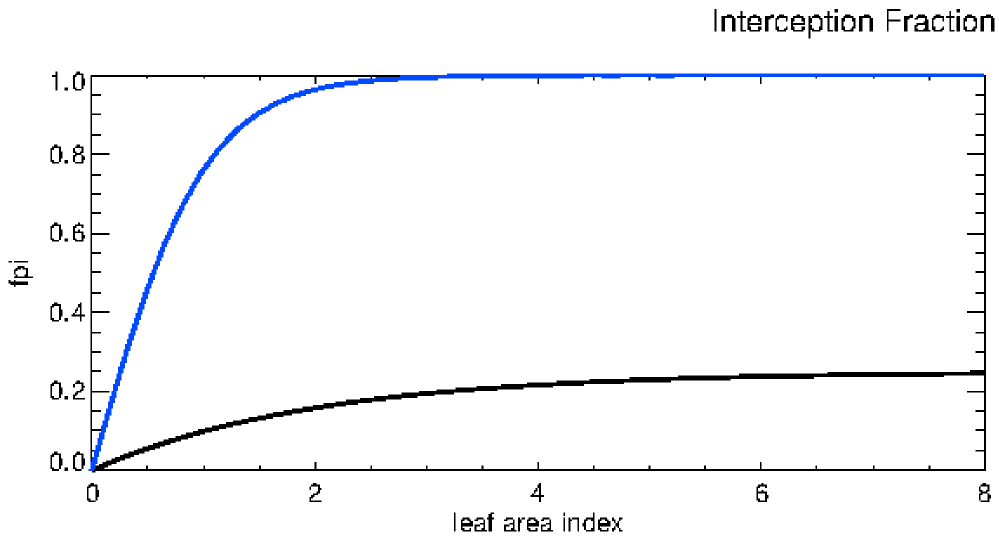
Transpiration: 53%

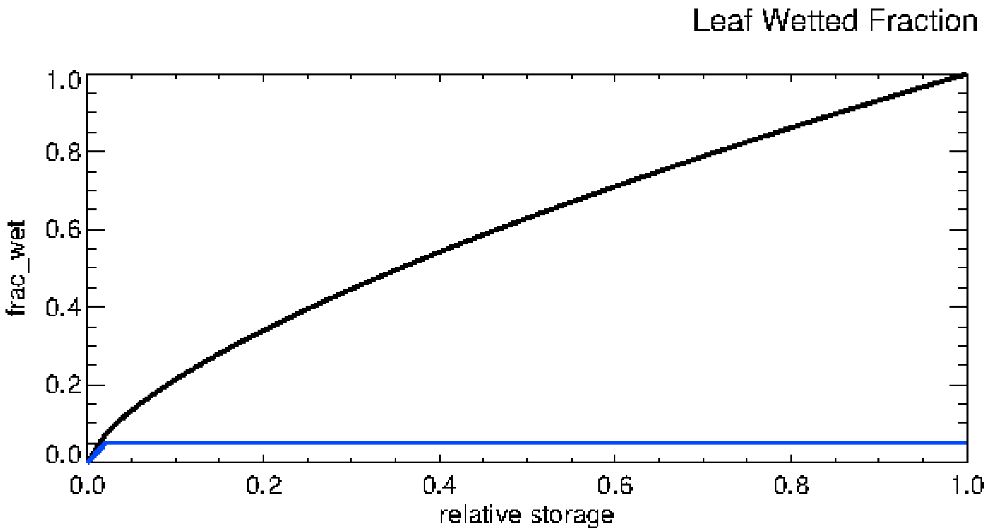
Precipitation Interception and Leaf Wetted Area





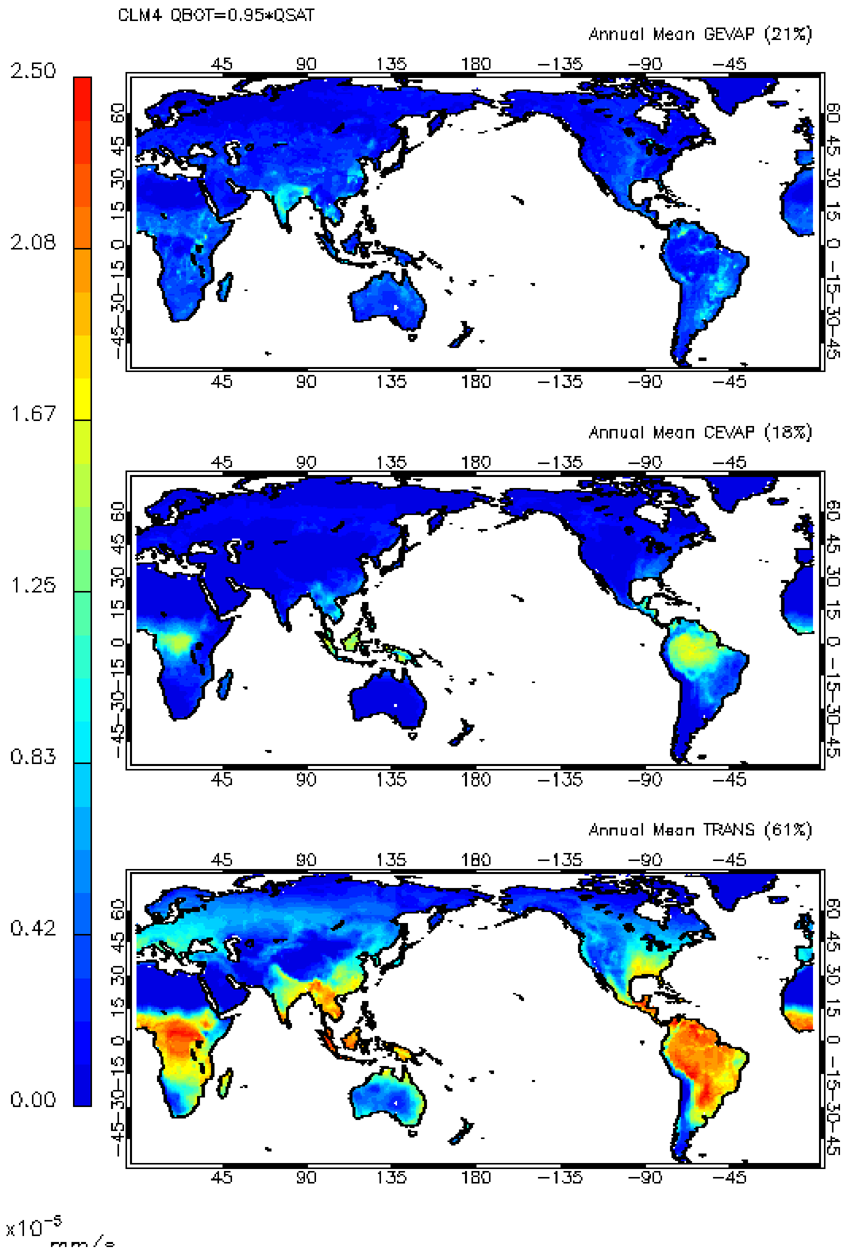
Precipitation Interception and Leaf Wetted Area





CLM5 default in blue

Canopy Hydrology And Evapotranspiration Partitioning



Ground Evaporation: 21%

Canopy Evaporation: 18%

Transpiration: 61%

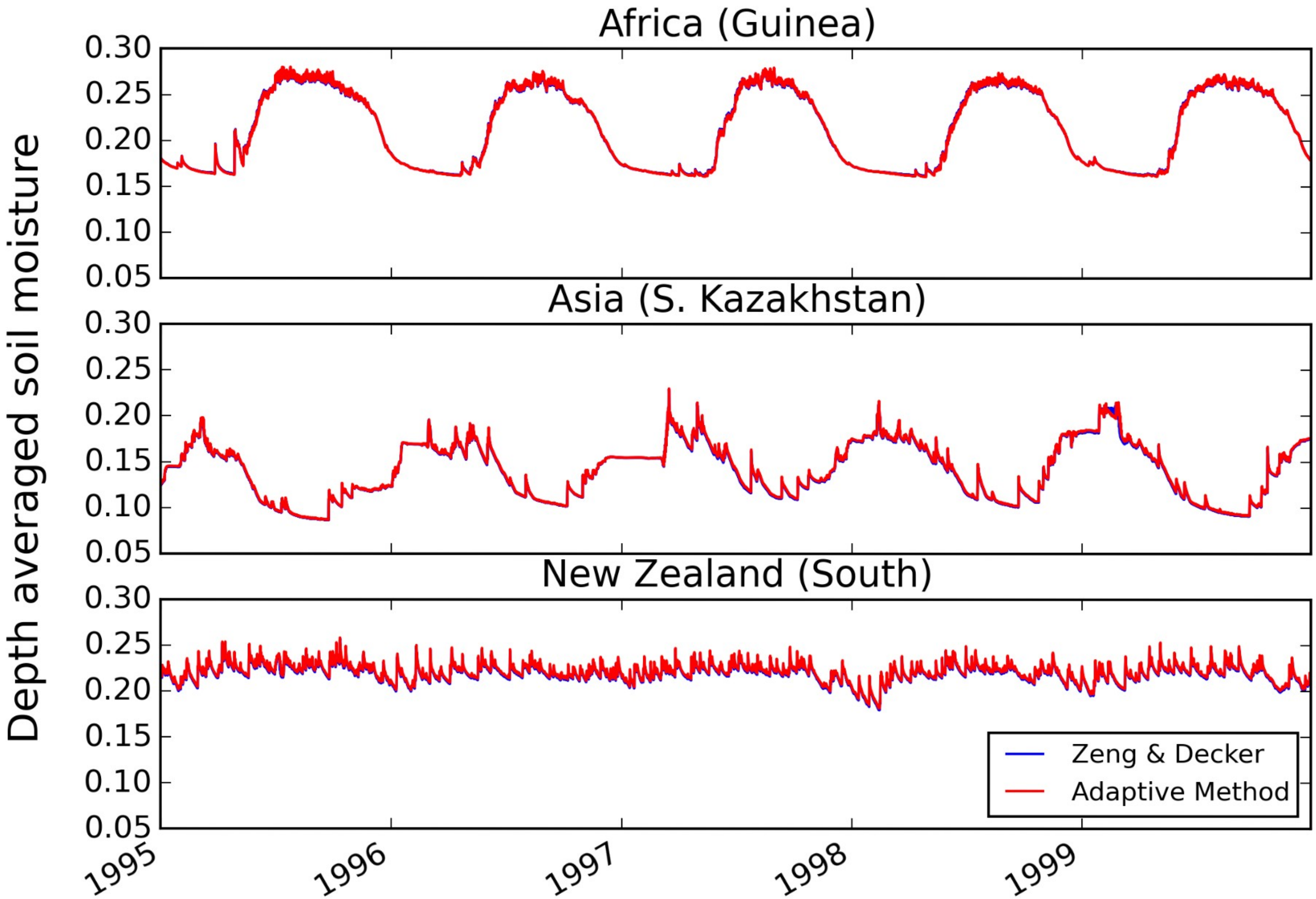
Richards Equation

- describes the vertical redistribution of water through soil
- currently implemented the moisture-based form of Richards equation
- adaptive time stepping

Adaptive time stepping method for soil water distribution

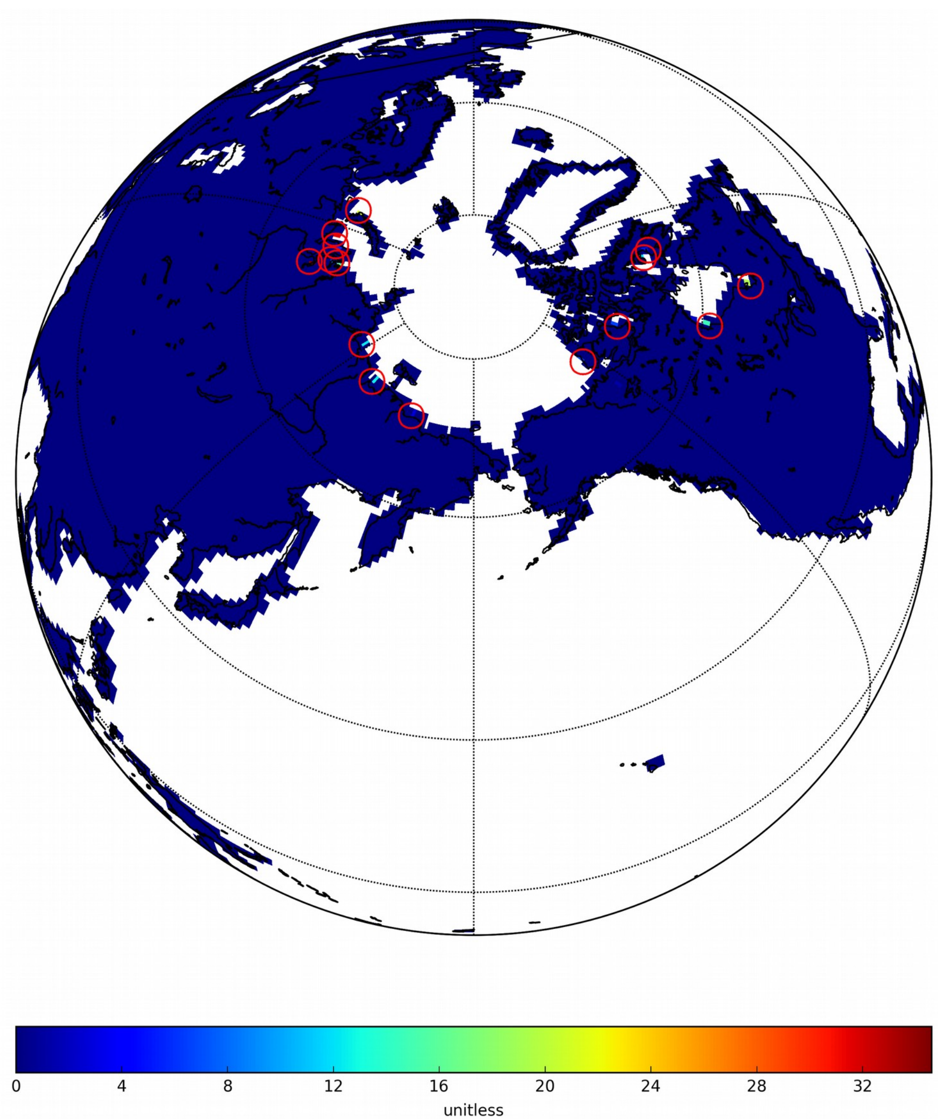
- Similar results to Zeng & Decker method

- Tested globally and at points with relatively high numerical error



Slide courtesy of John Volk

Adaptive scheme removed numerical errors in soil water



- (Left) Locations with negative soil moisture using Zeng & Decker method in 1990-2000, 1° simulation.
- Error tolerance was adjusted to remove any instance of significant numerical error (< -0.5 kg/m^2) for twenty year simulation, at small computational cost.

Numerical Scheme	Error tolerance (kg/m^2) water	Max no. of neg. moisture per column	CLM run time in seconds
Zeng & Decker	NA	32	1759
Adaptive	1e9	720	1802
Adaptive	5	0	1791
Adaptive	1e-2	0	1815

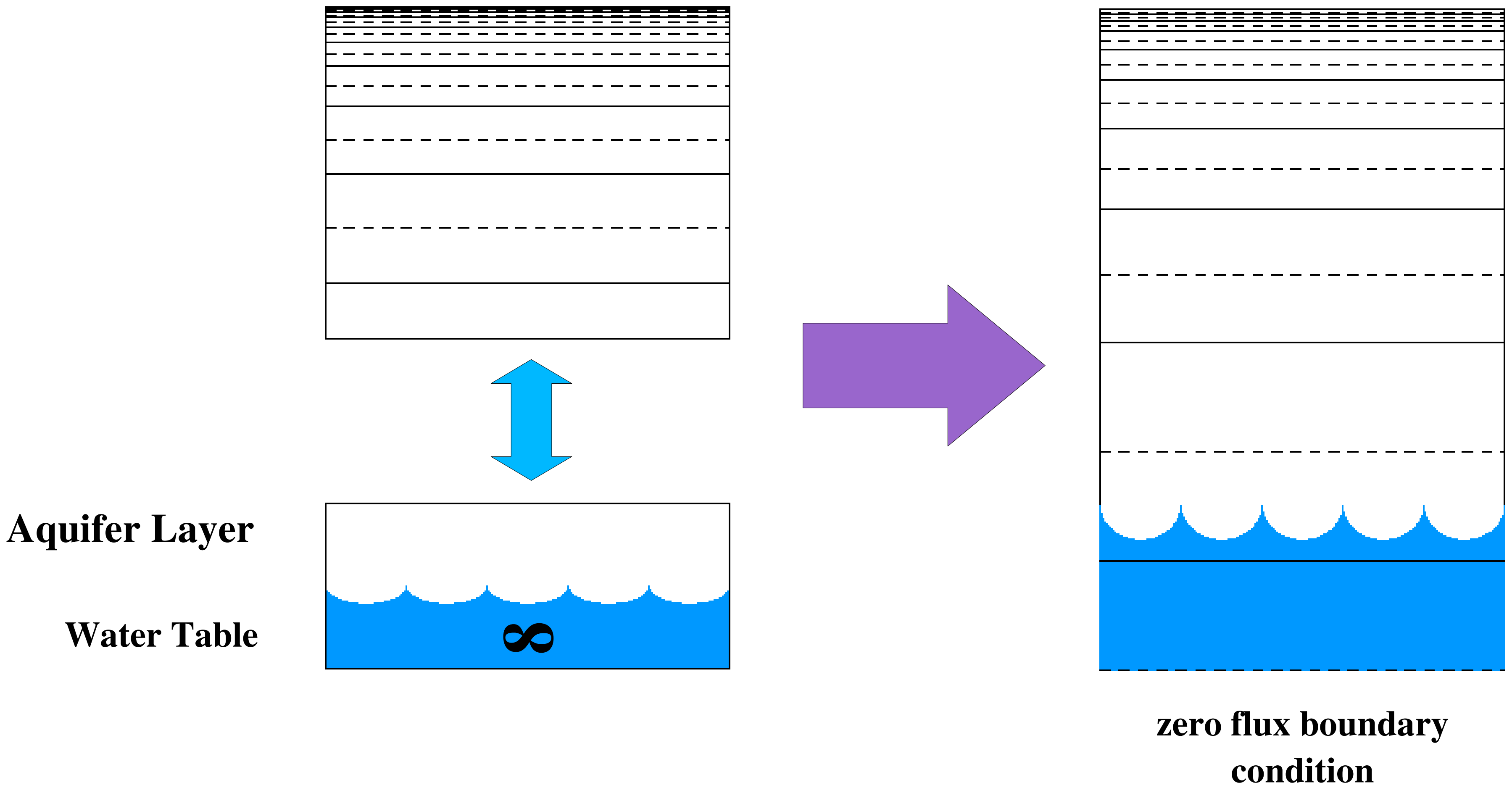
Table data for 1° resolution, 10 year (1990-2000) global runs.

Slide courtesy of John Volk

Groundwater and Water Table Dynamics

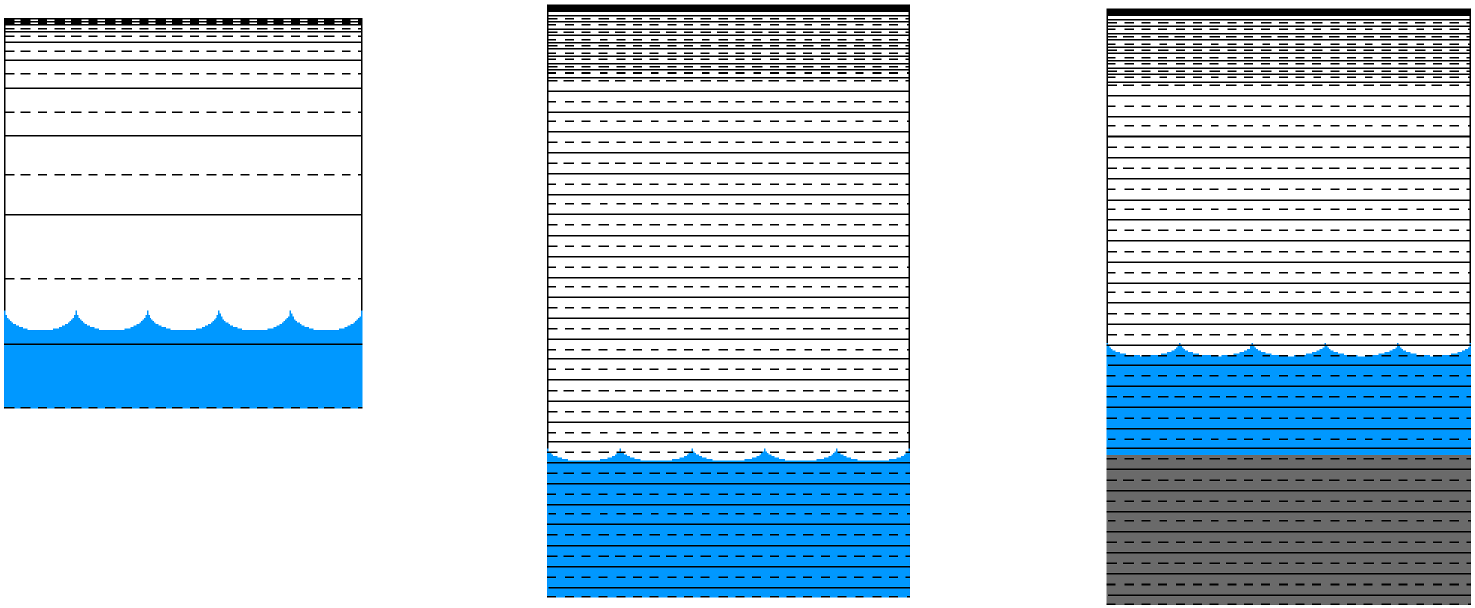
- deeper soil column
- bedrock (zero vertical flux) lower boundary
- removed bulk aquifer layer
- modified baseflow equation

Removing the Aquifer: Finite Lower Boundary

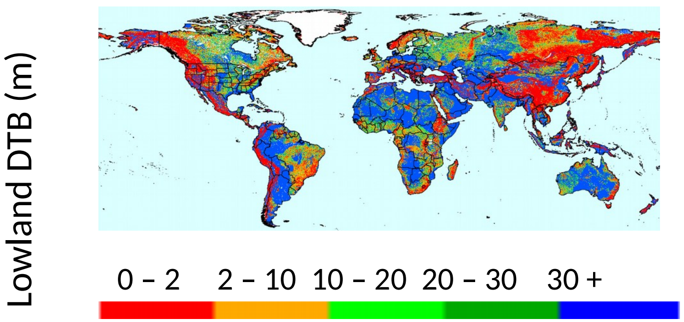


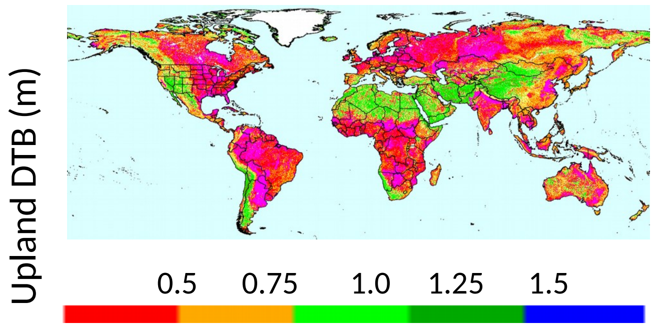
Soil Depth

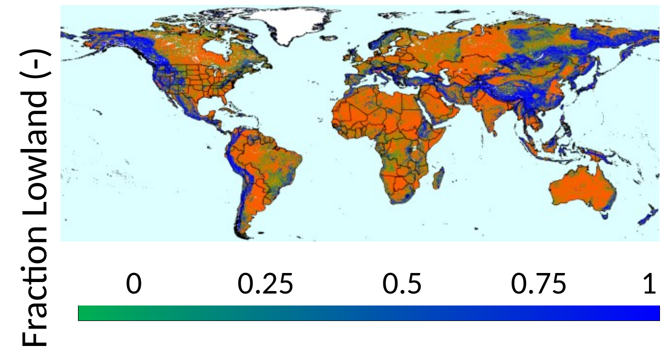
- deep soil / variable soil depth
- high vertical resolution soil



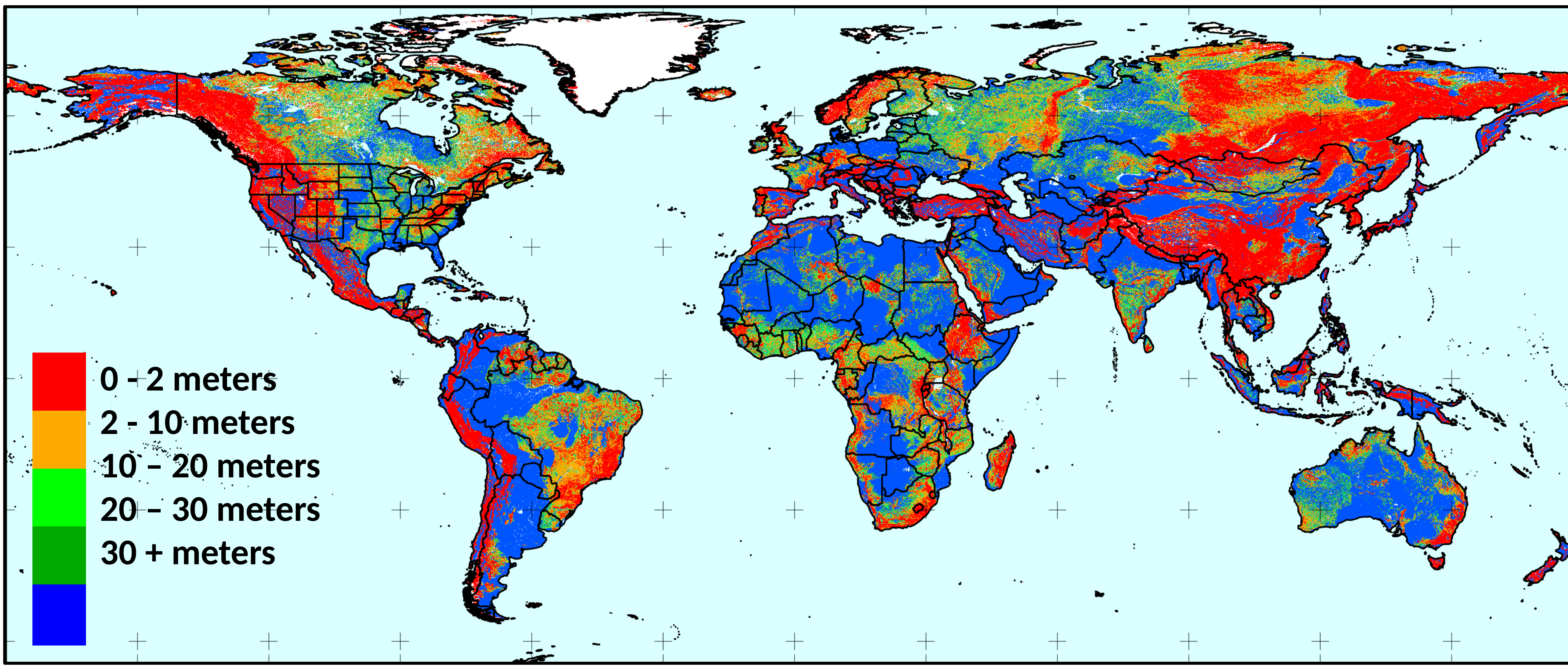
PRELIMINARY GLOBAL MAP OF DTB ESTIMATES





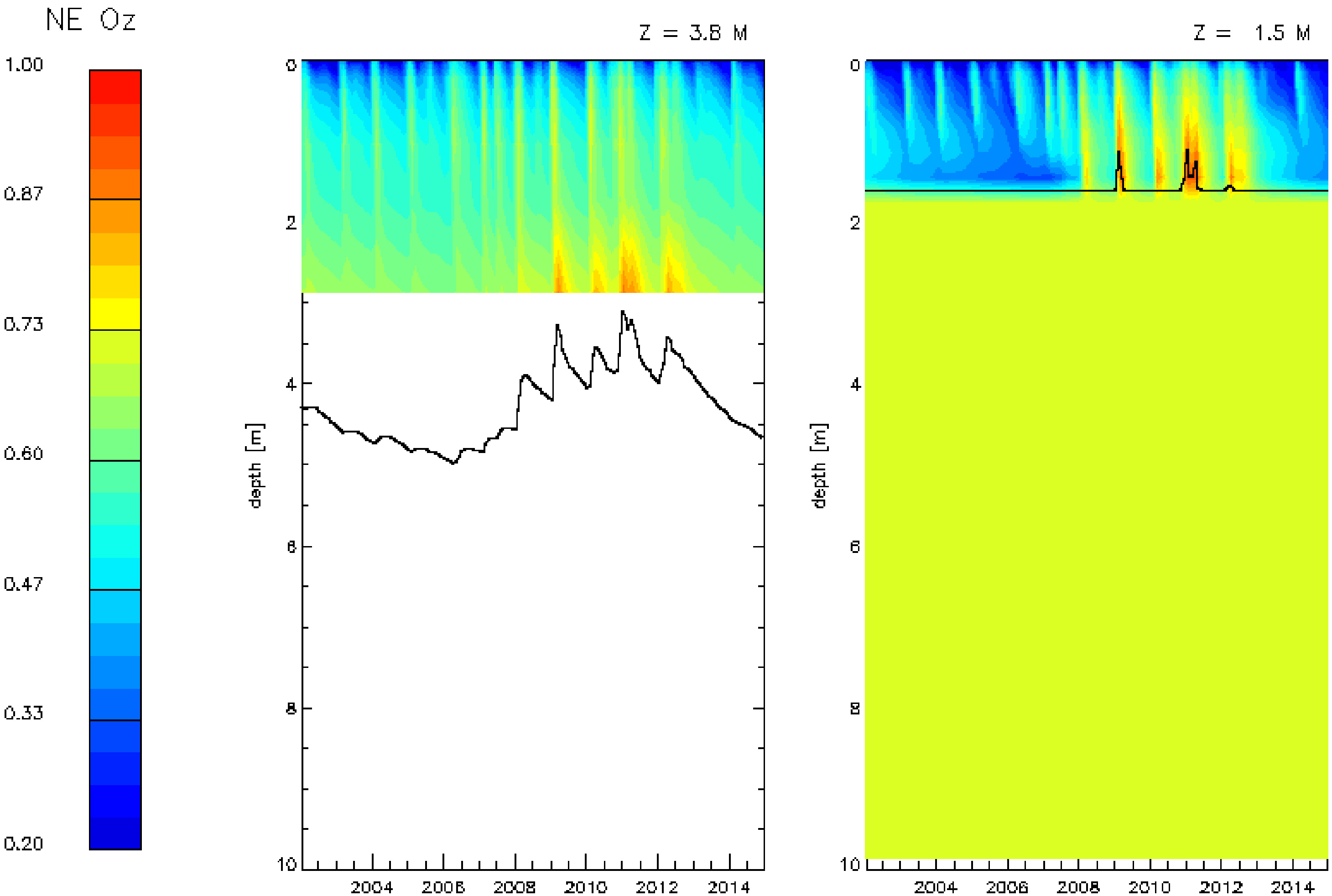


Overall Depth to Bedrock (~1 km resolution)

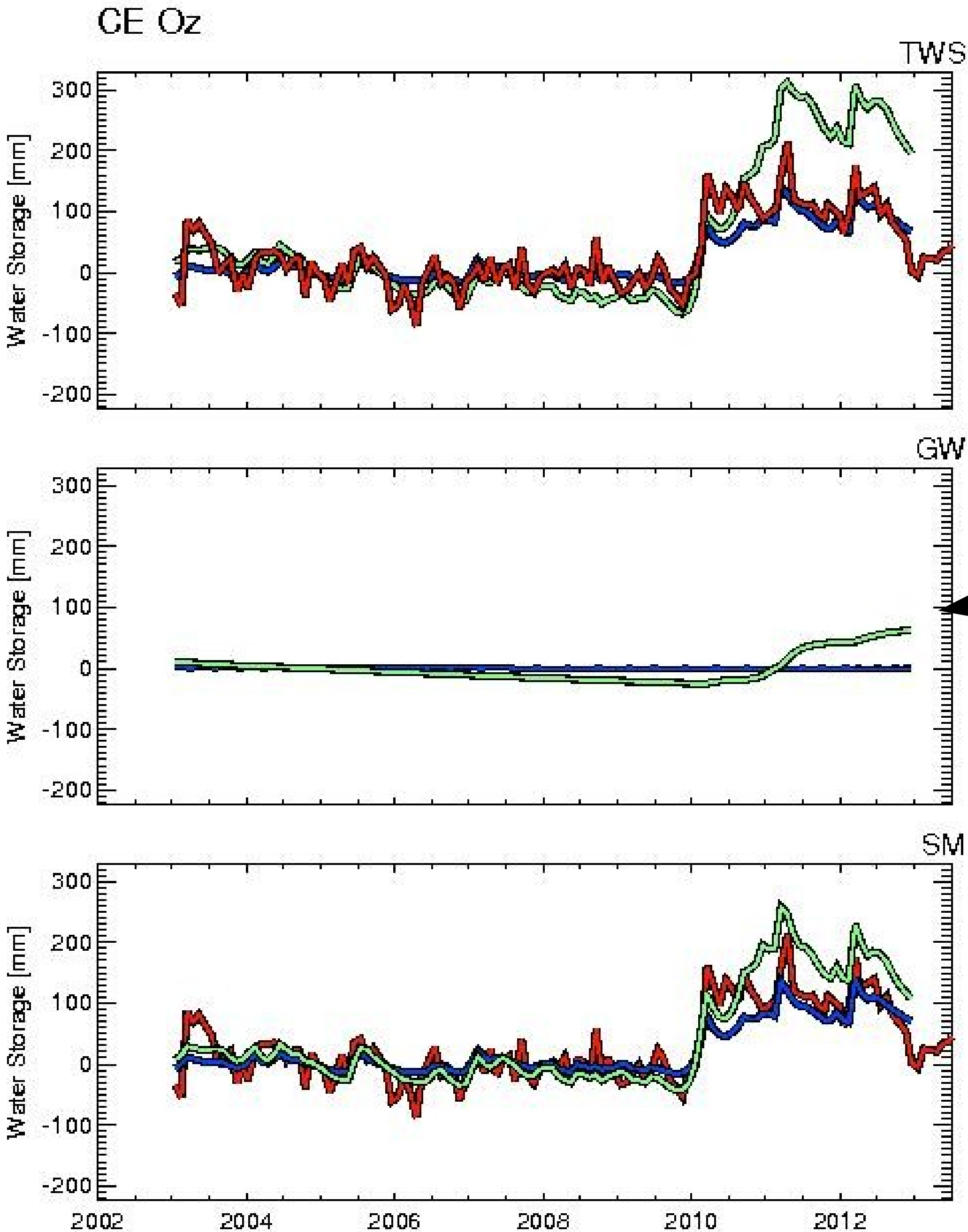


Slide courtesy M.Brunke, U. Arizona

Spatially Variable Soil Depth



Water Storage Components

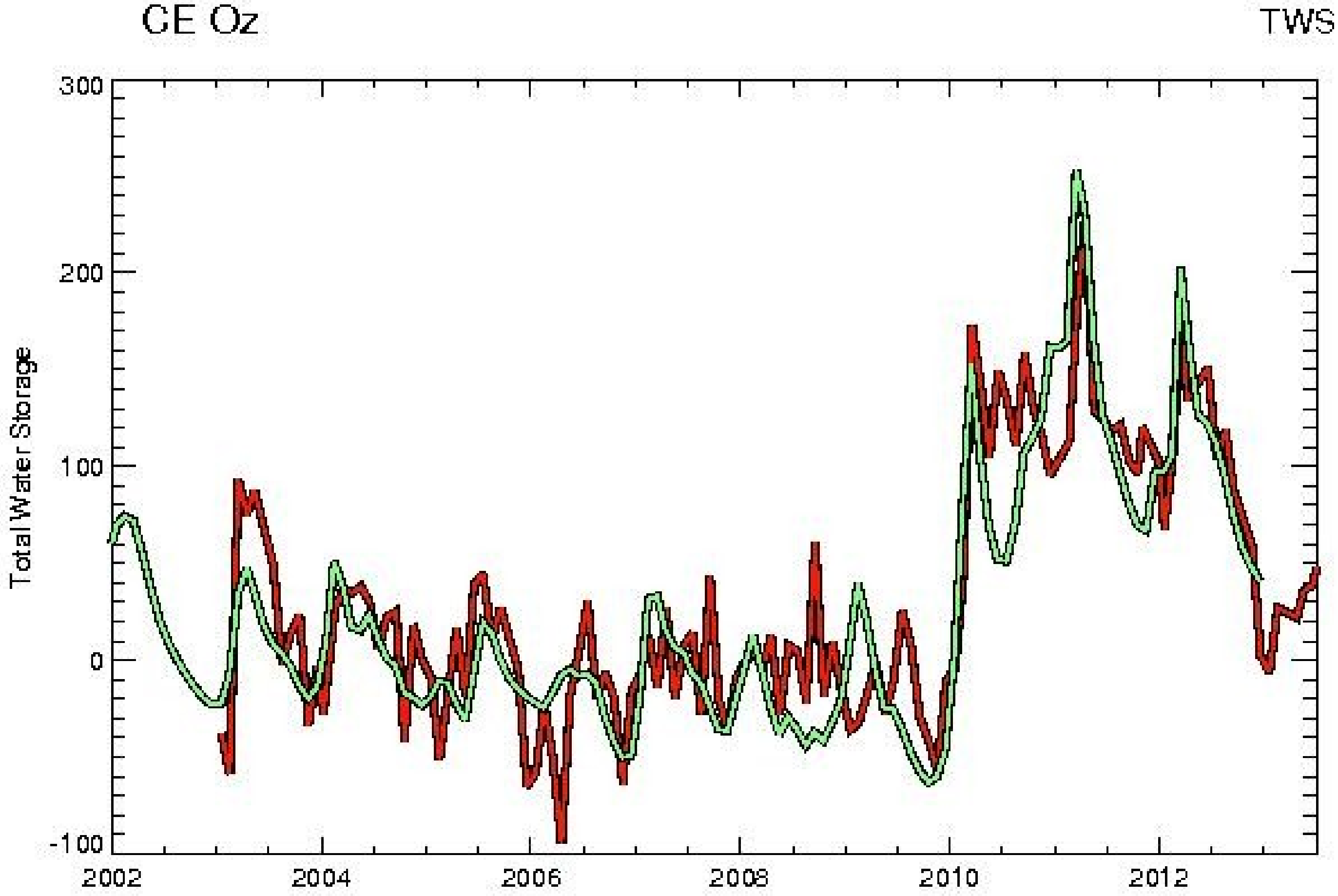


Top: Total Water Storage
Middle: Groundwater
Bottom: Soil Moisture

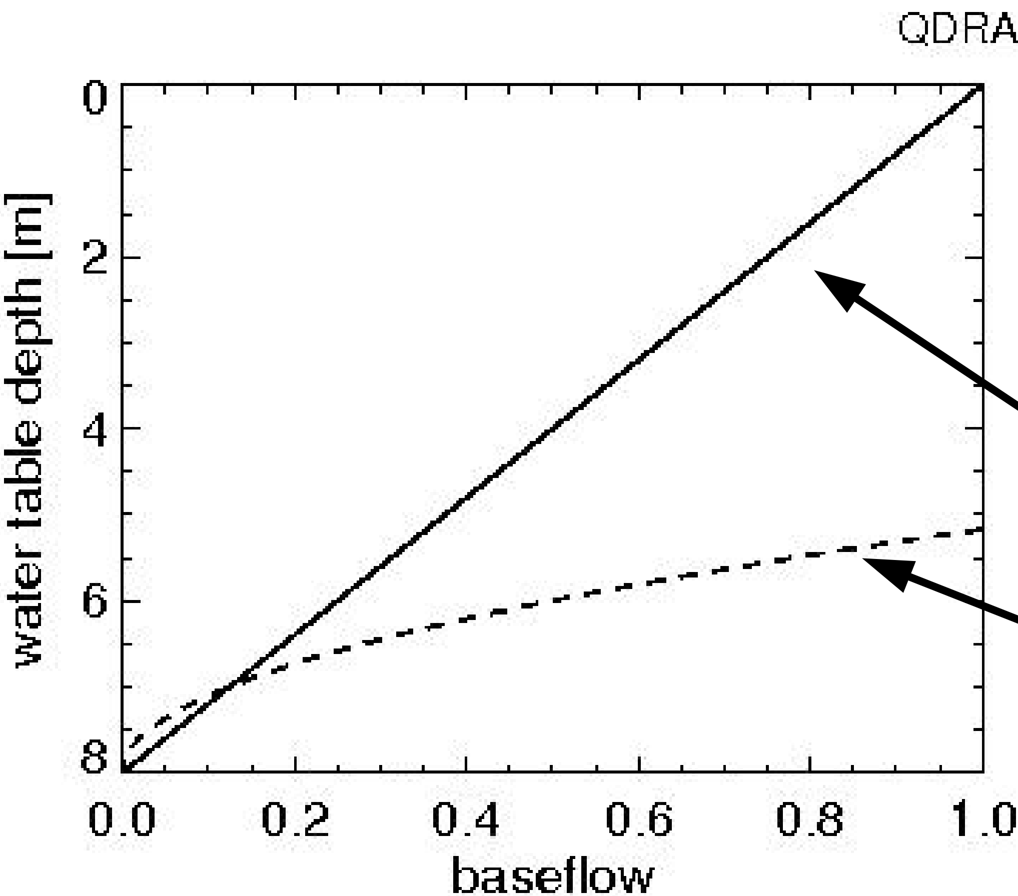
After a wet period, groundwater does not drain fast enough to match GRACE observations

Soil moisture alone agrees better with observations

Total Water Storage: Central Australia



Power Law Baseflow Equation w/ Lower Boundary



$$Q_{baseflow} = K * (zbot - zwt)^n$$

Example w/ lower boundary at 8 meters

Linear (n = 1)

Quadratic (n = 2)

Summary

- In most semiarid regions, the new soil evaporation scheme brings the simulated latent heat fluxes closer to observations

- Changes to canopy interception and leaf wetted fraction improve the partitioning of ET between canopy evaporation and transpiration

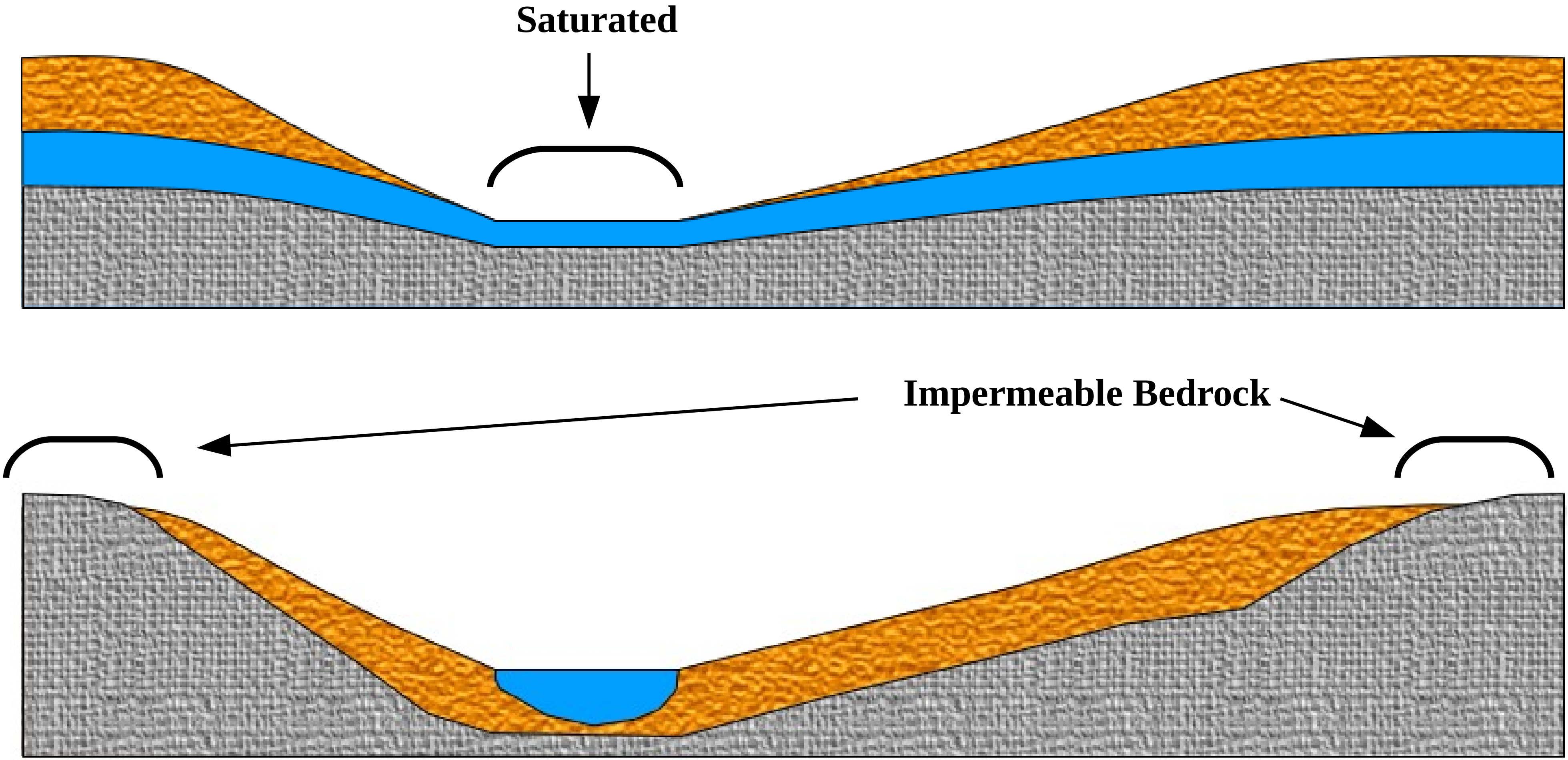
- Moisture-based Richards equation with adaptive time-stepping reduces occurances of instabilities (i.e. negative soil moisture)

- Removing “limitless” groundwater parameterization and implementing a finite lower boundary improves water storage agreement with observations

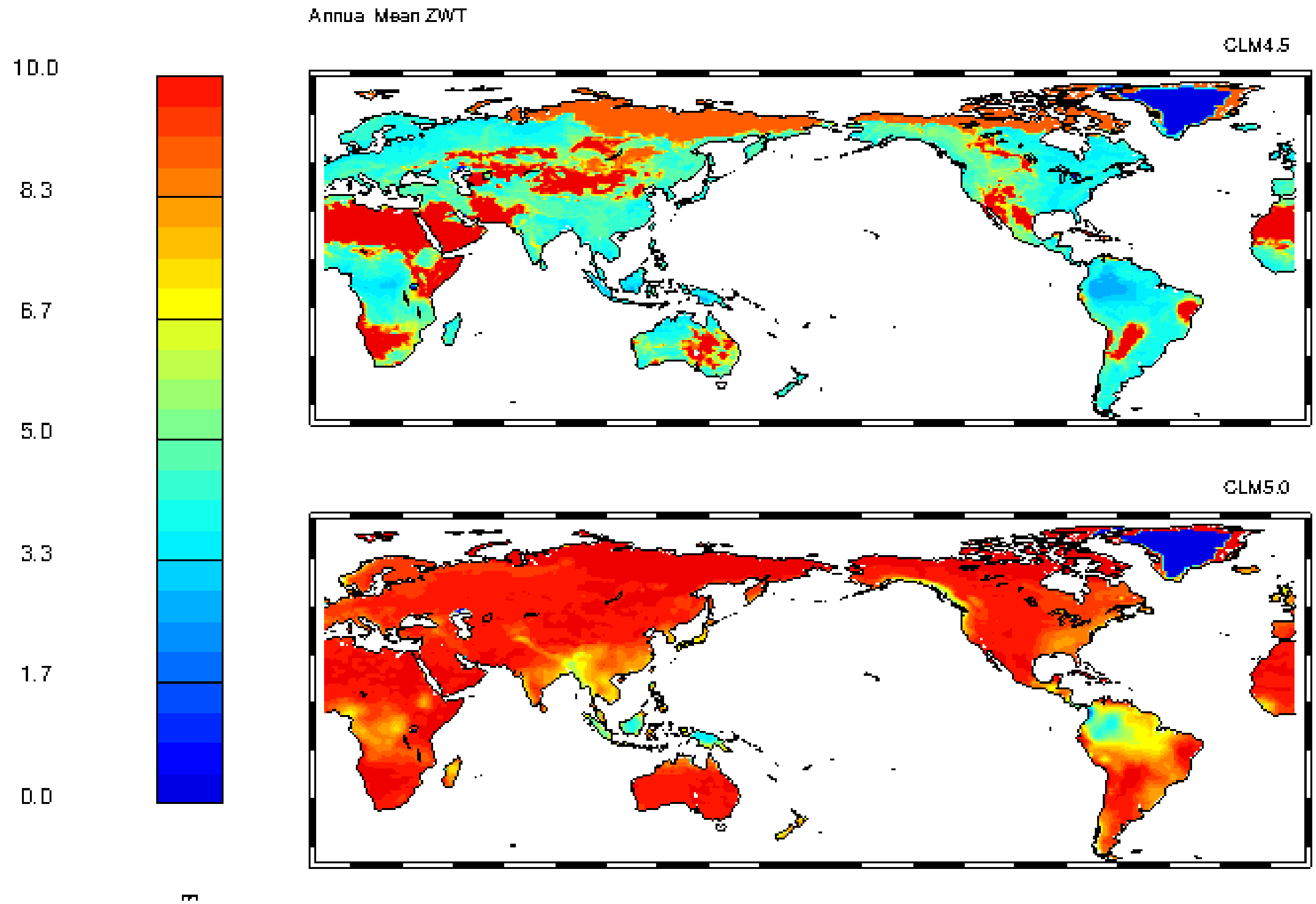
Further Work / Caveats

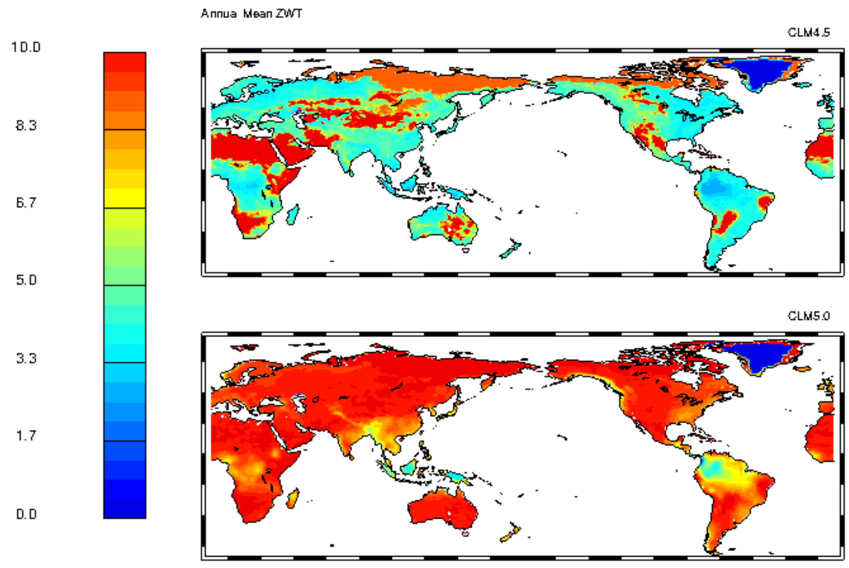
- Saturated areas, impermeable areas, and infiltration
- Parameter tuning
- Further assessments

Impermeable Areas

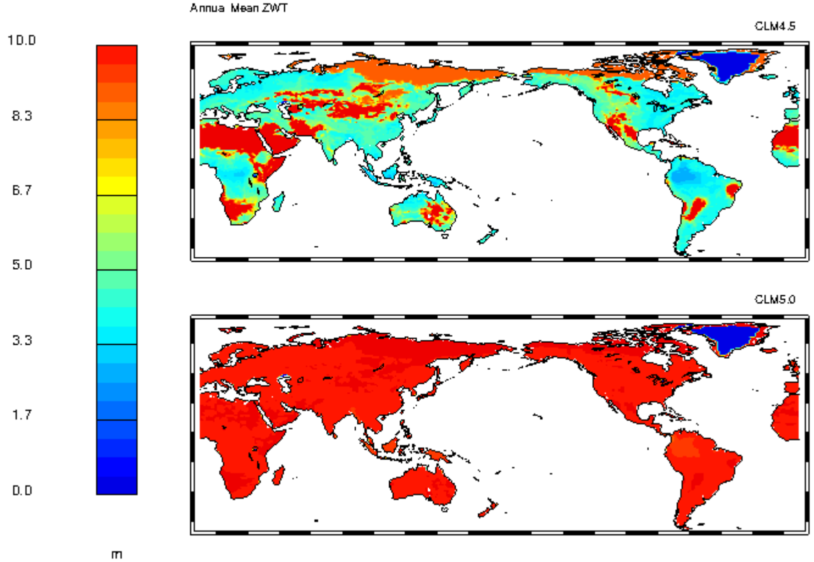


Mean Water Table





Larger Baseflow Coefficient



Smaller Baseflow Coefficient