The CLM Groundwater Scheme: Insight from Semiarid Regions

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Synopsis

• Recent changes to the CLM parameterization of soil evaporation lead to significant changes to the hydrologic cycle in semiarid regions

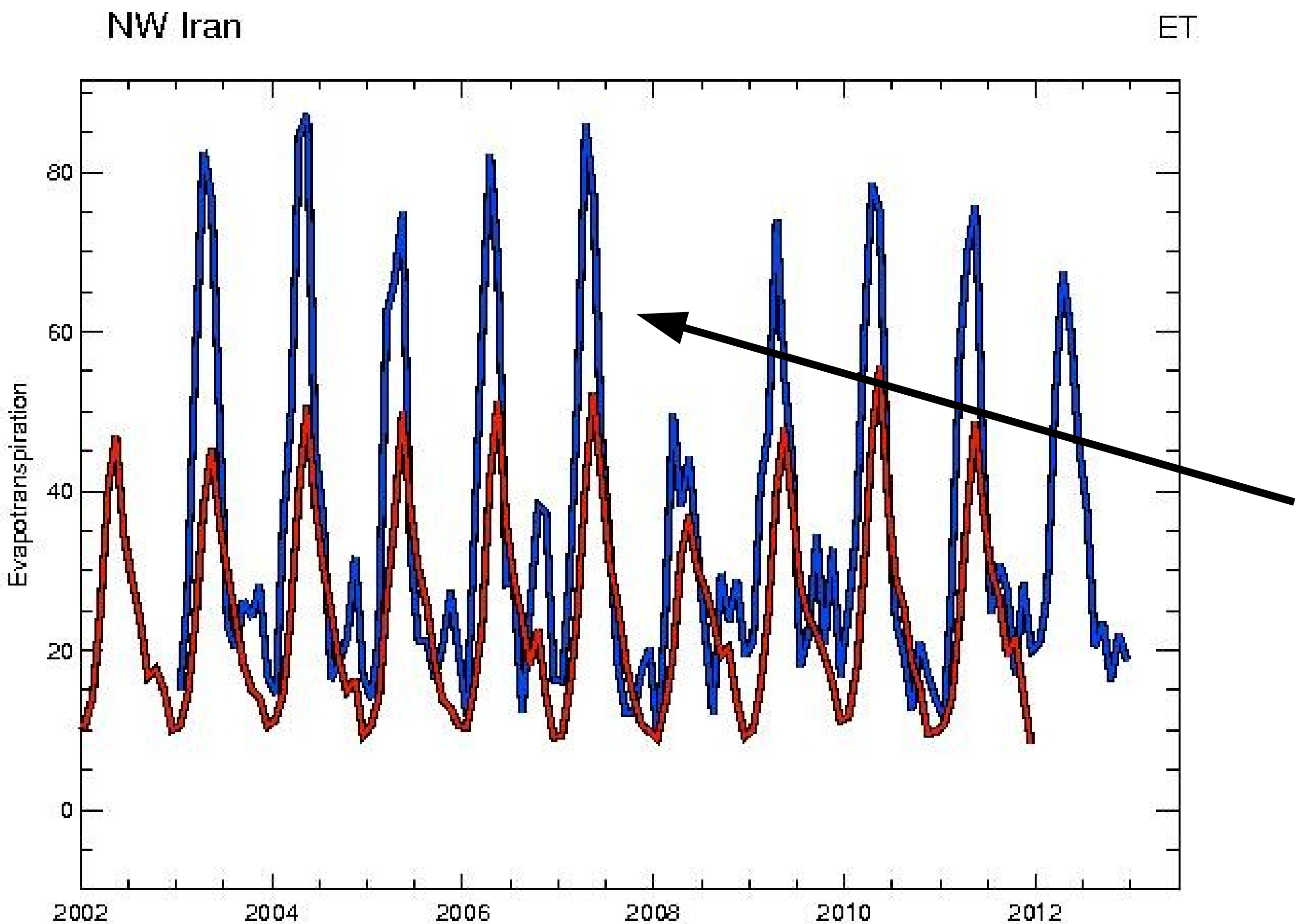
• In most semiarid regions, the new soil evaporation scheme brings the simulated latent heat fluxes closer to observations

• However, in some areas, simulated total water storage is degraded.

• This response can be traced to the behavior of the groundwater module; specifically, its quasi-infinite lower boundary

• Adding a finite lower boundary results in good agreement with both total water storage and latent heat flux observations

New Soil Evaporation Parameterization



CLM evapotranspiration too large and too variable compared to observations

Swenson, S.C., and D. M. Lawrence, Assessing a dry surface layer-based soil resistance parameterization for the Community Land Model using GRACE and FLUXNET-MTE data, J. Geophys. Res. Atmos., 119, 10,299–10,312, doi:10.1002/2014JD022314, 2014

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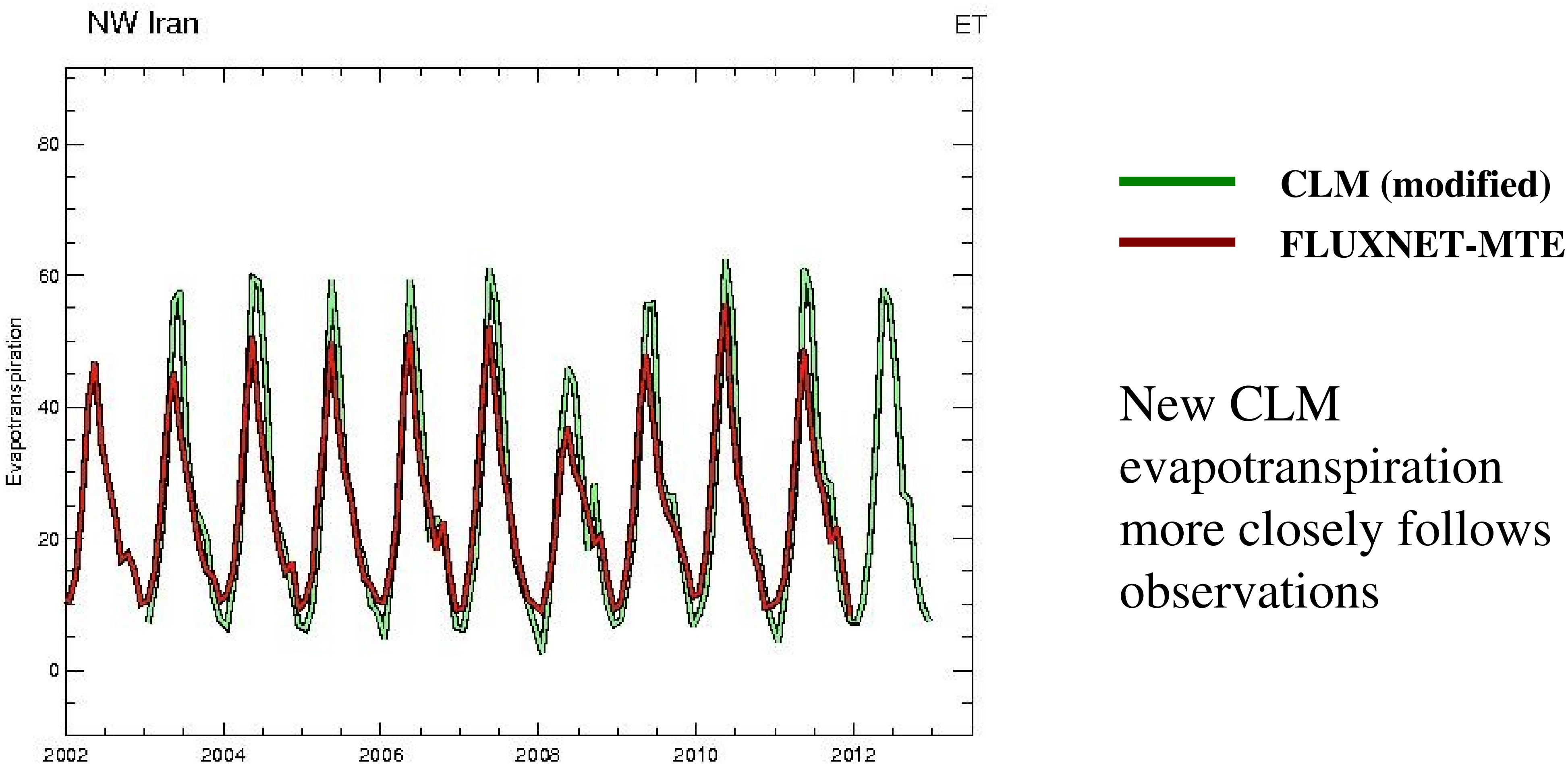

New CLM evapotranspiration more closely follows observations

Swenson, S.C., and D. M. Lawrence, Assessing a dry surface layer-based soil resistance parameterization for the Community Land Model using GRACE and FLUXNET-MTE data, J. Geophys. Res. Atmos., 119, 10,299–10,312, doi:10.1002/2014JD022314, 2014

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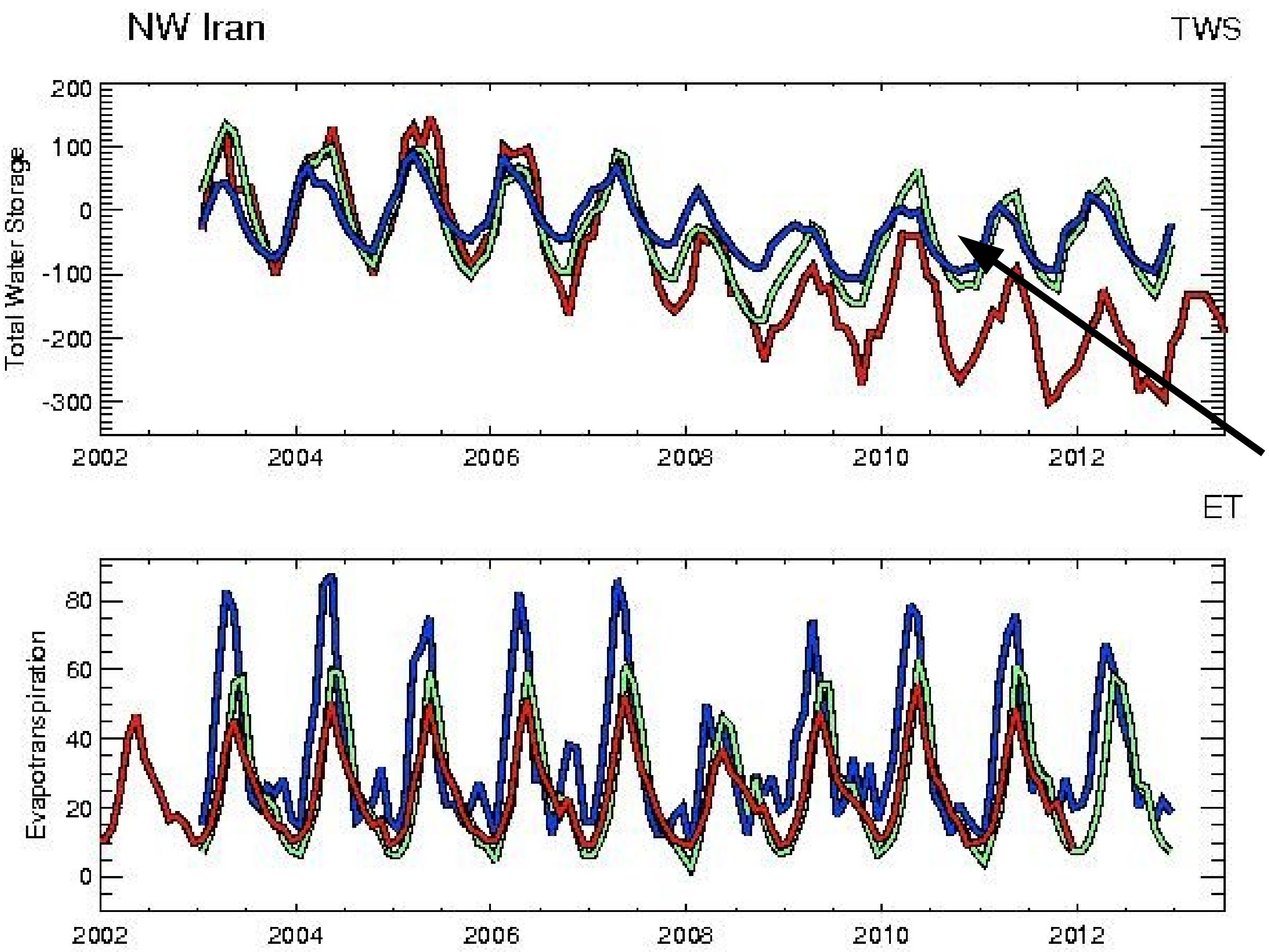

New CLM total water storage has larger seasonal cycle, closer to observations

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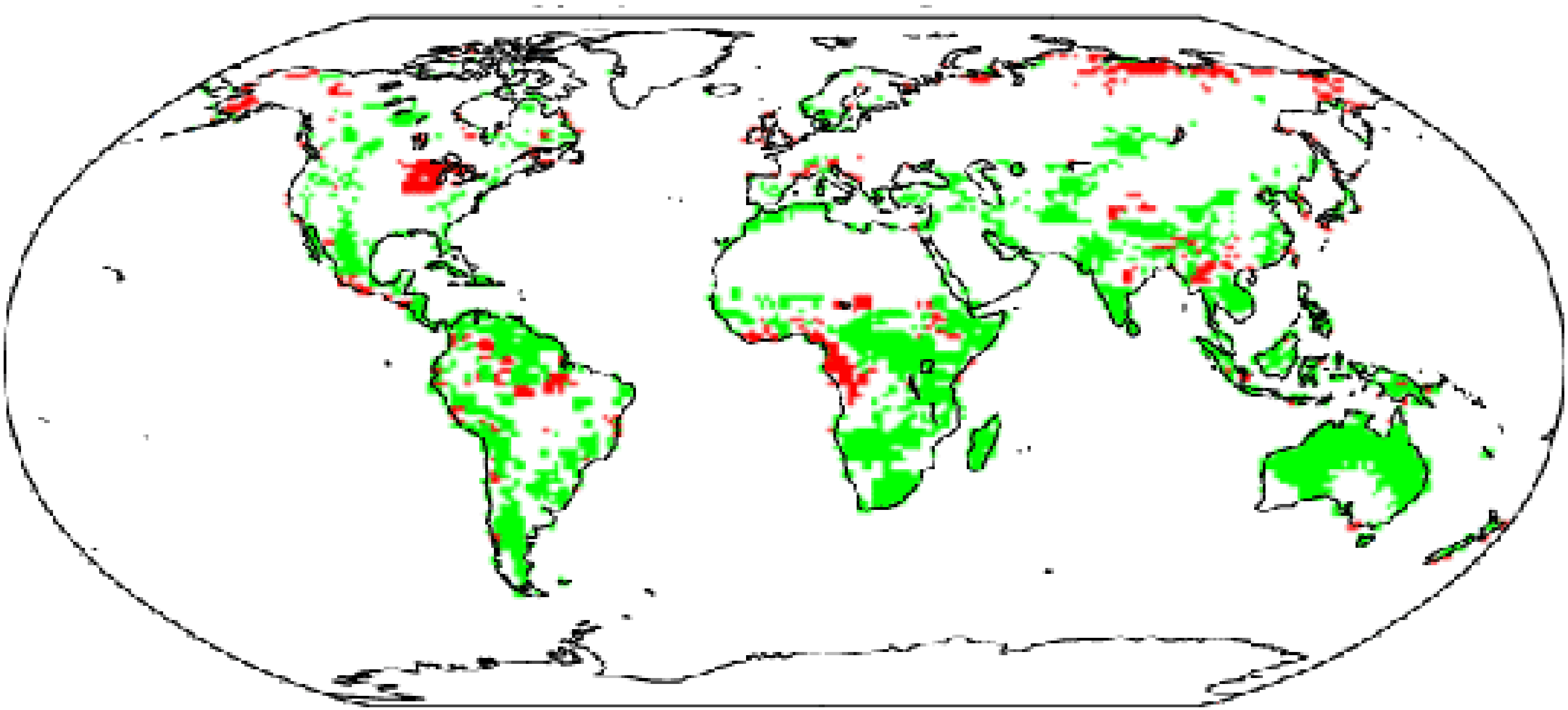
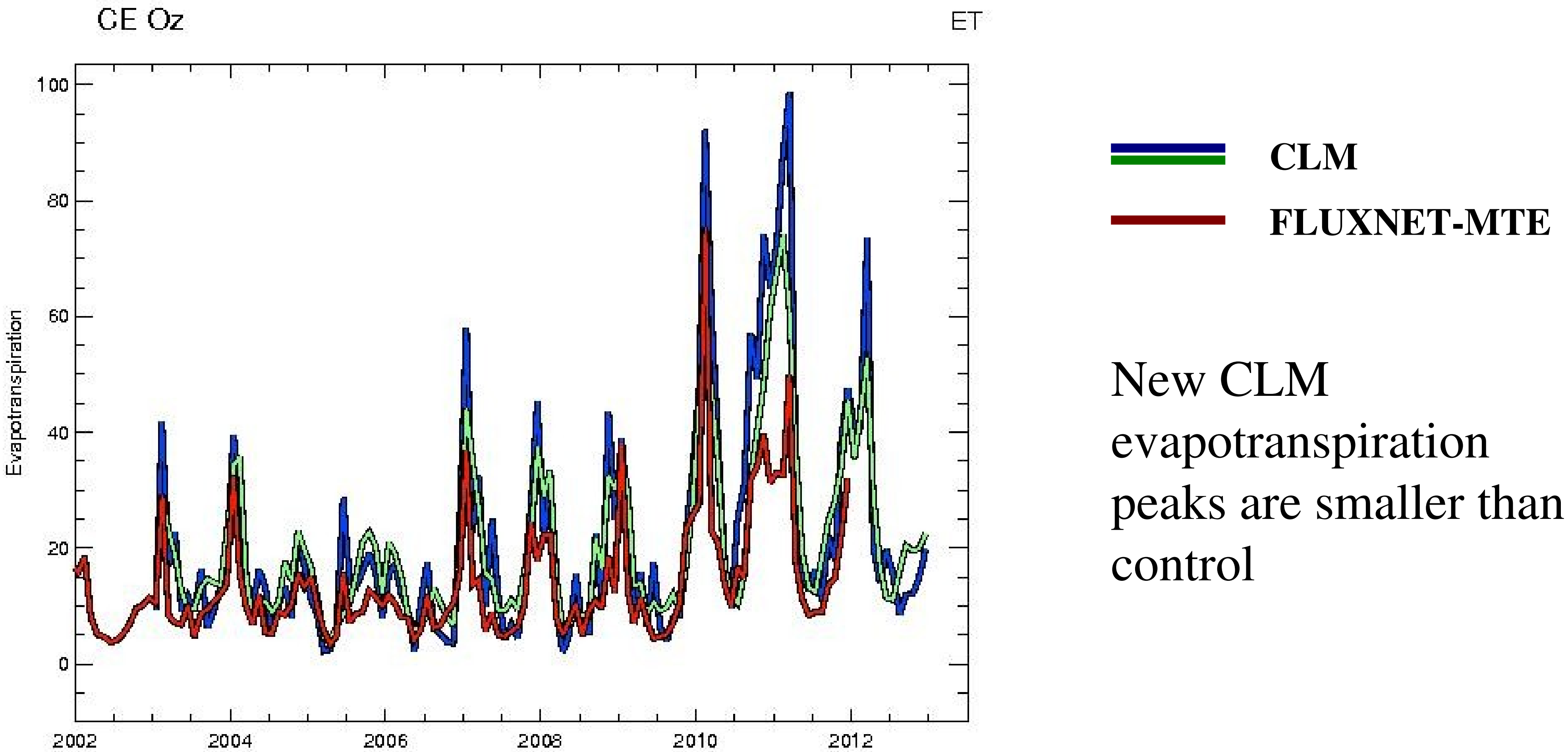
Latent Heat Global Comparison



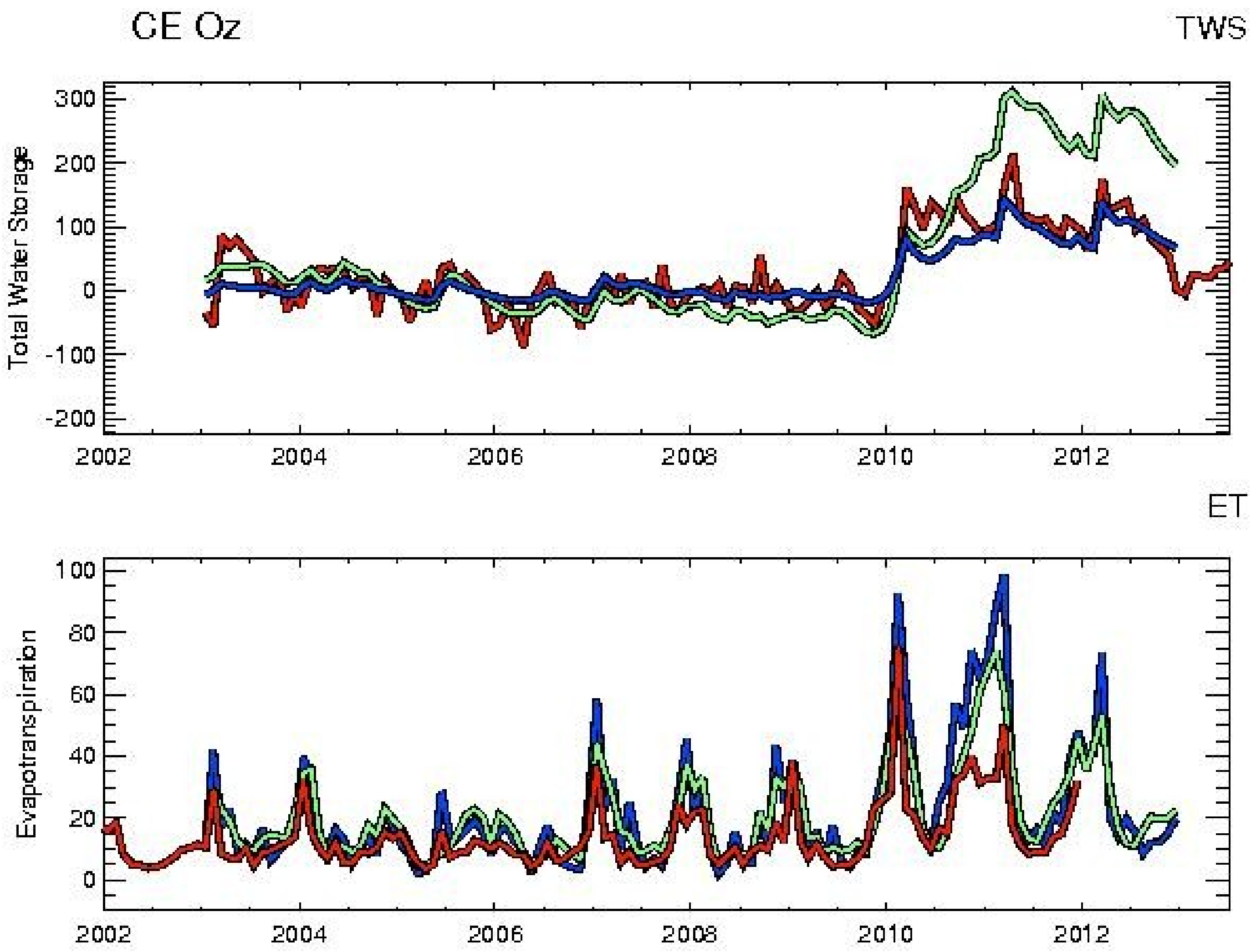
From CLM diagnostics package: red = control has lower RMSE relative to observations, green = modified model has lower RMSE relative to observations

Another location: central Australia



New CLM evapotranspiration peaks are smaller than control

Central Australia

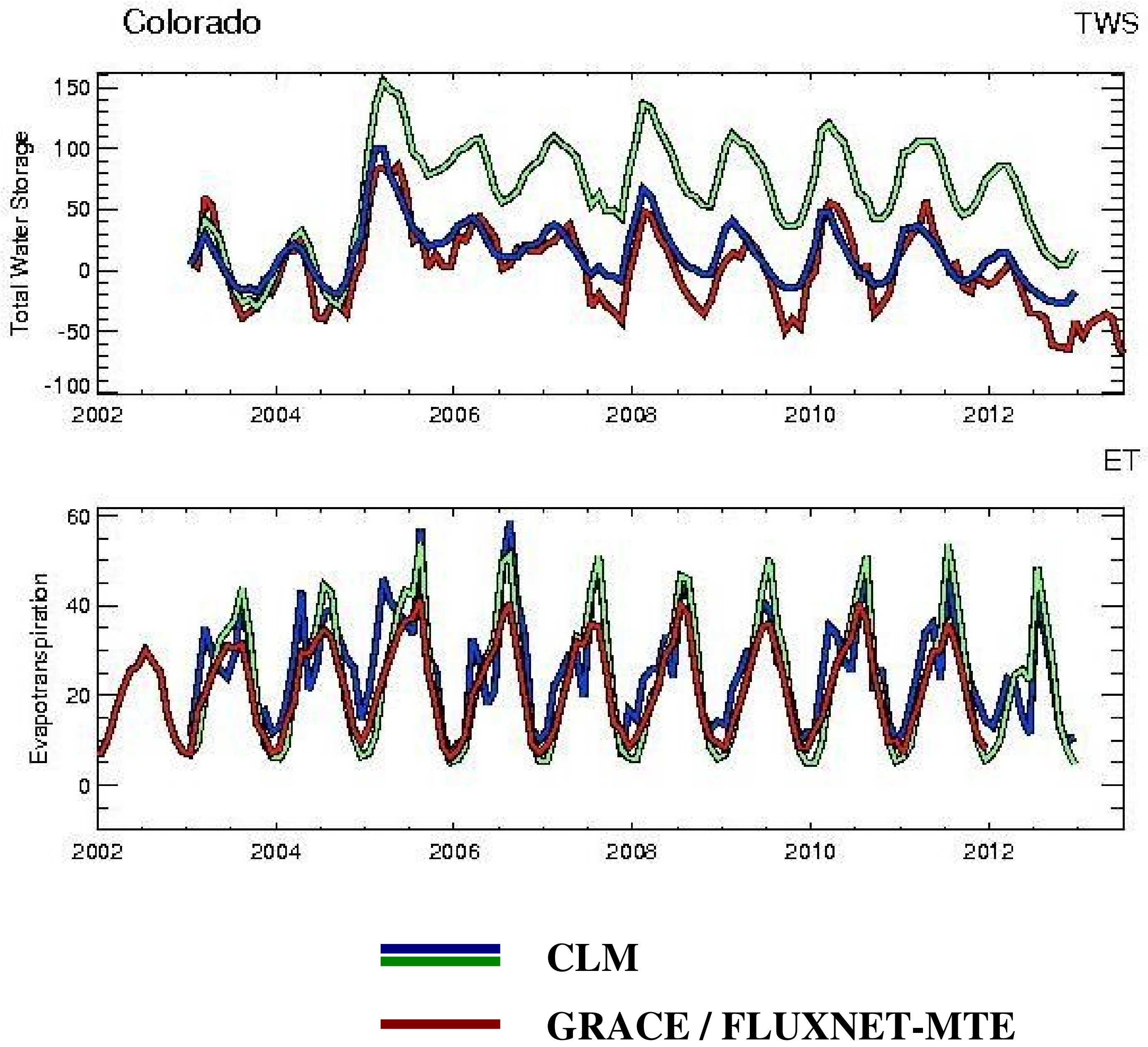


While ET closer to observations, total water storage develops a huge bias after a large wet period

CLM

GRACE / FLUXNET-MTE

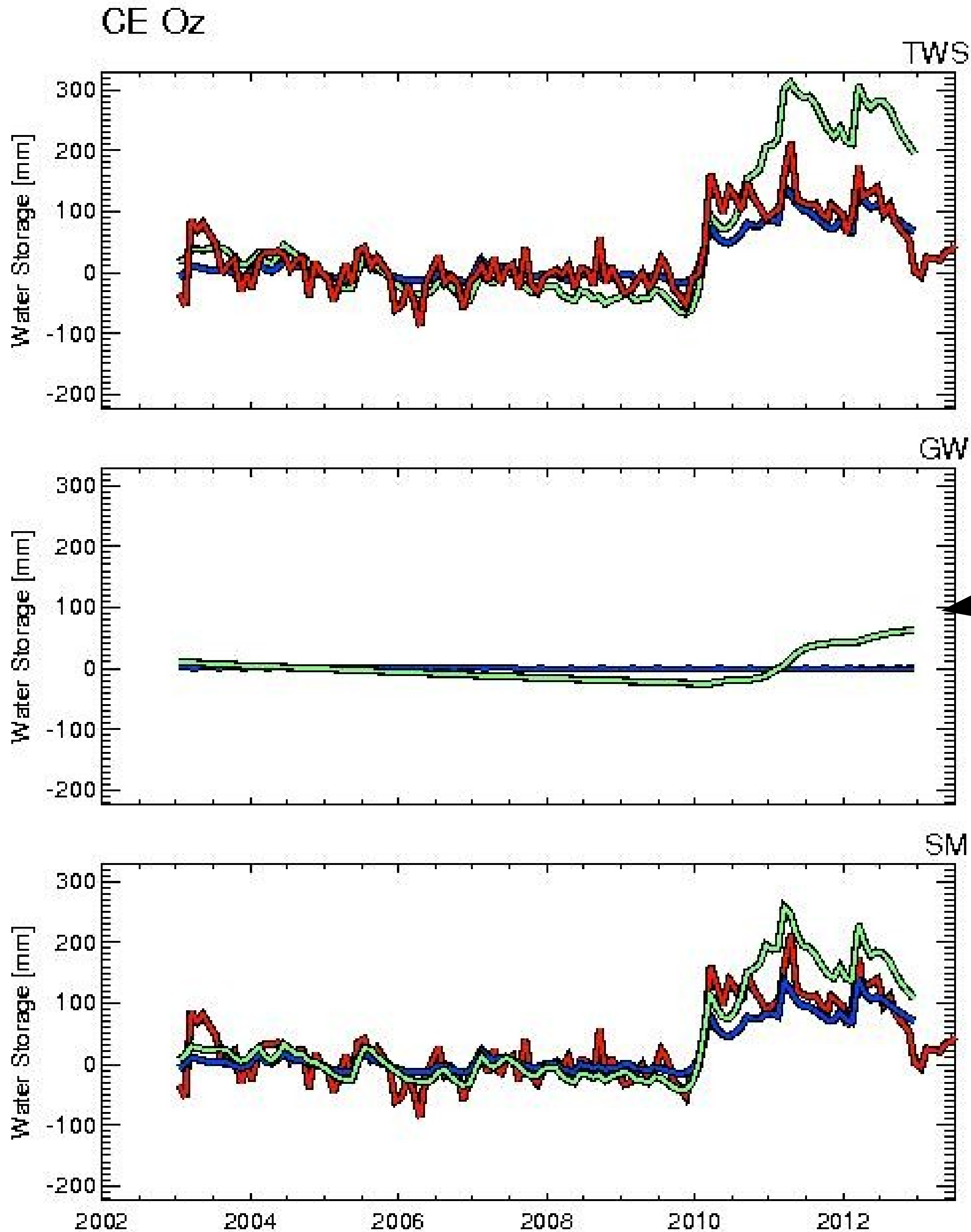
Colorado River Basin



New model eliminates spurious winter/spring ET spikes.

Seasonal cycle of total water storage is larger and closer to obs, but again develops a large bias after a wet period

Water Storage Components: C. Australia

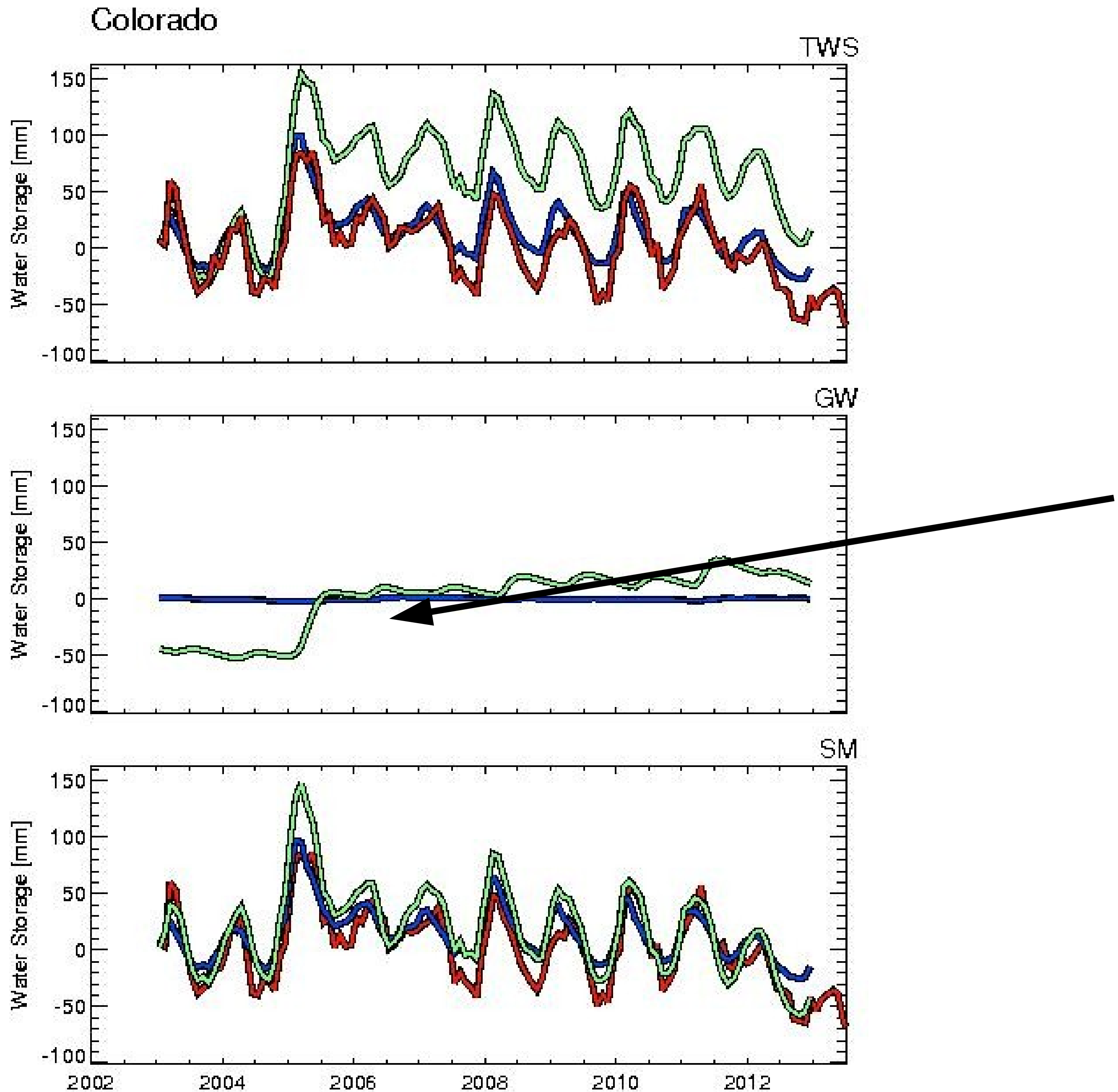


Top: Total Water Storage
Middle: Groundwater
Bottom: Soil Moisture

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

Soil moisture alone agrees better with observations

Water Storage Components: Colorado



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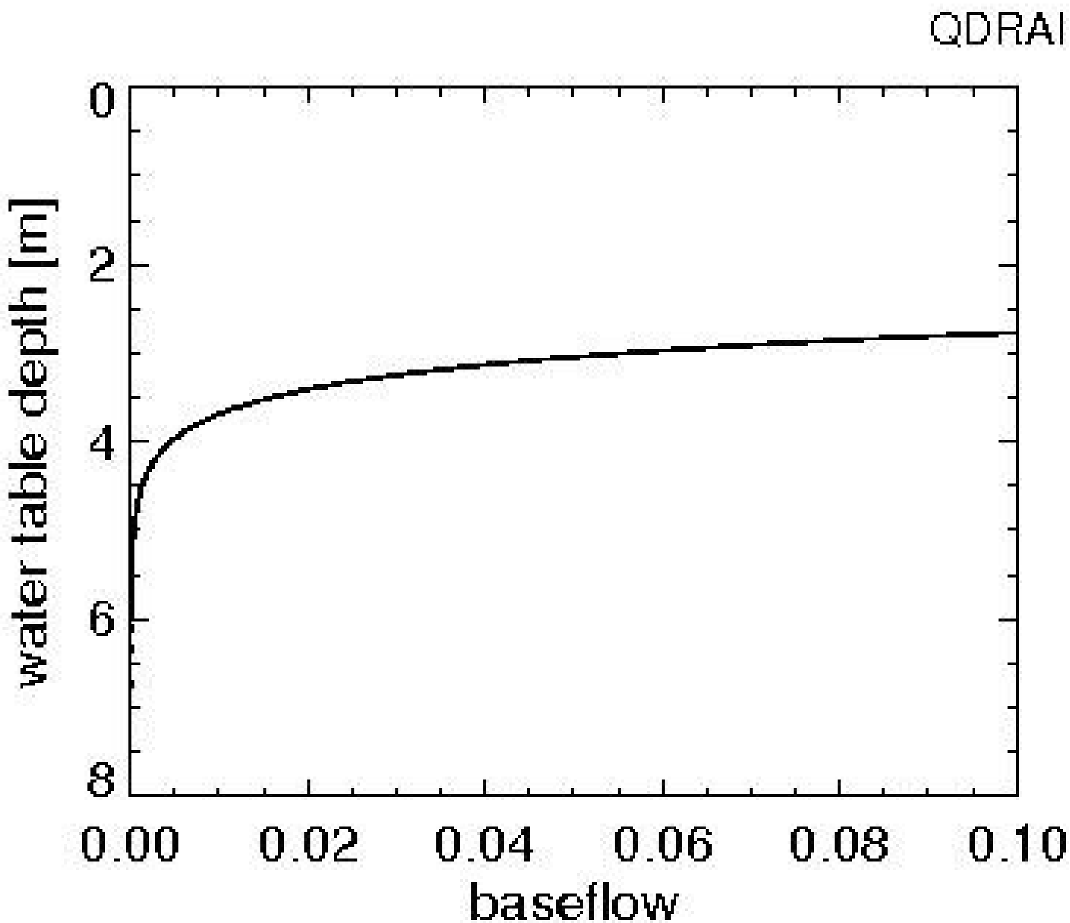
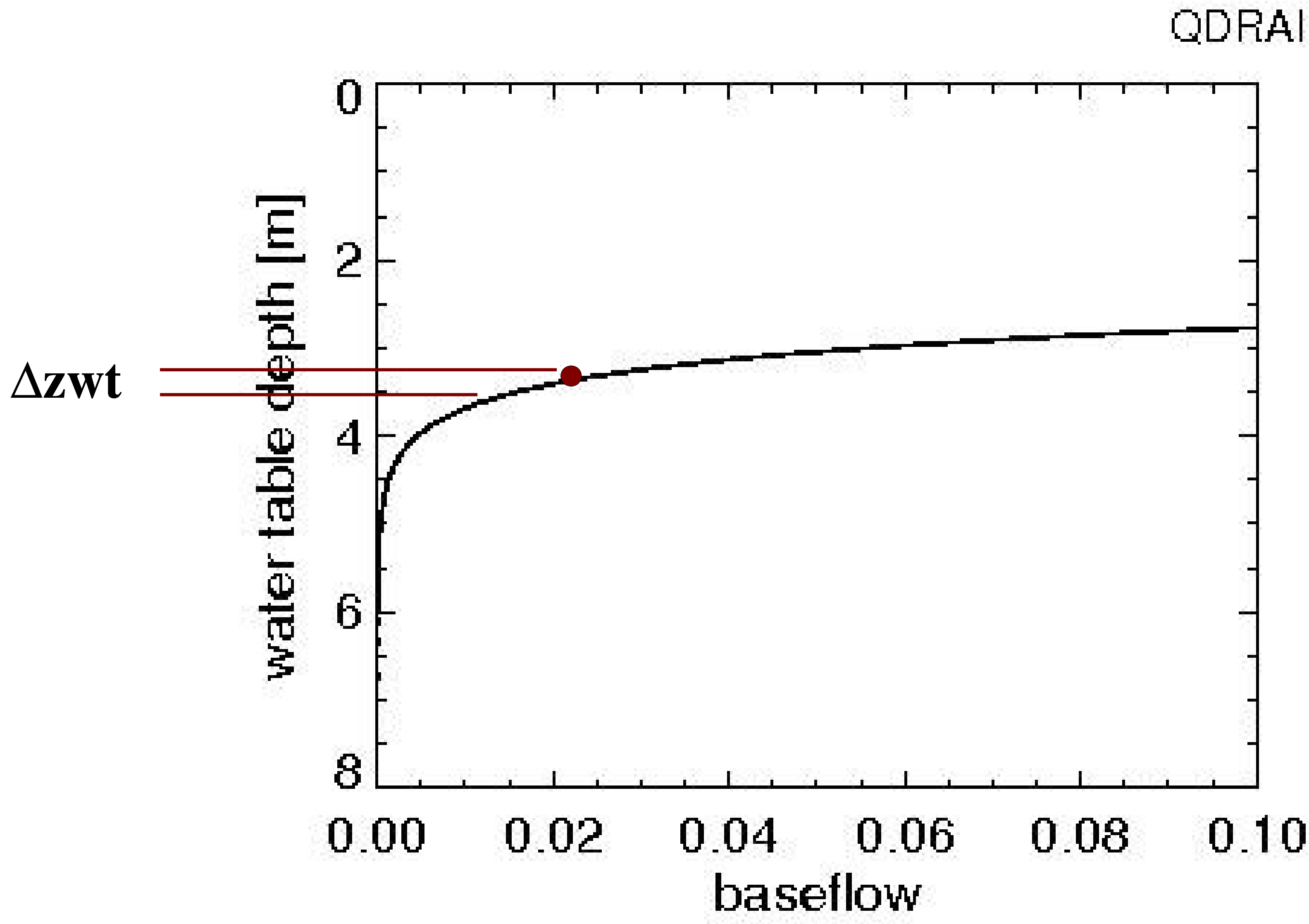
CLM Baseflow / Drainage Parameterization

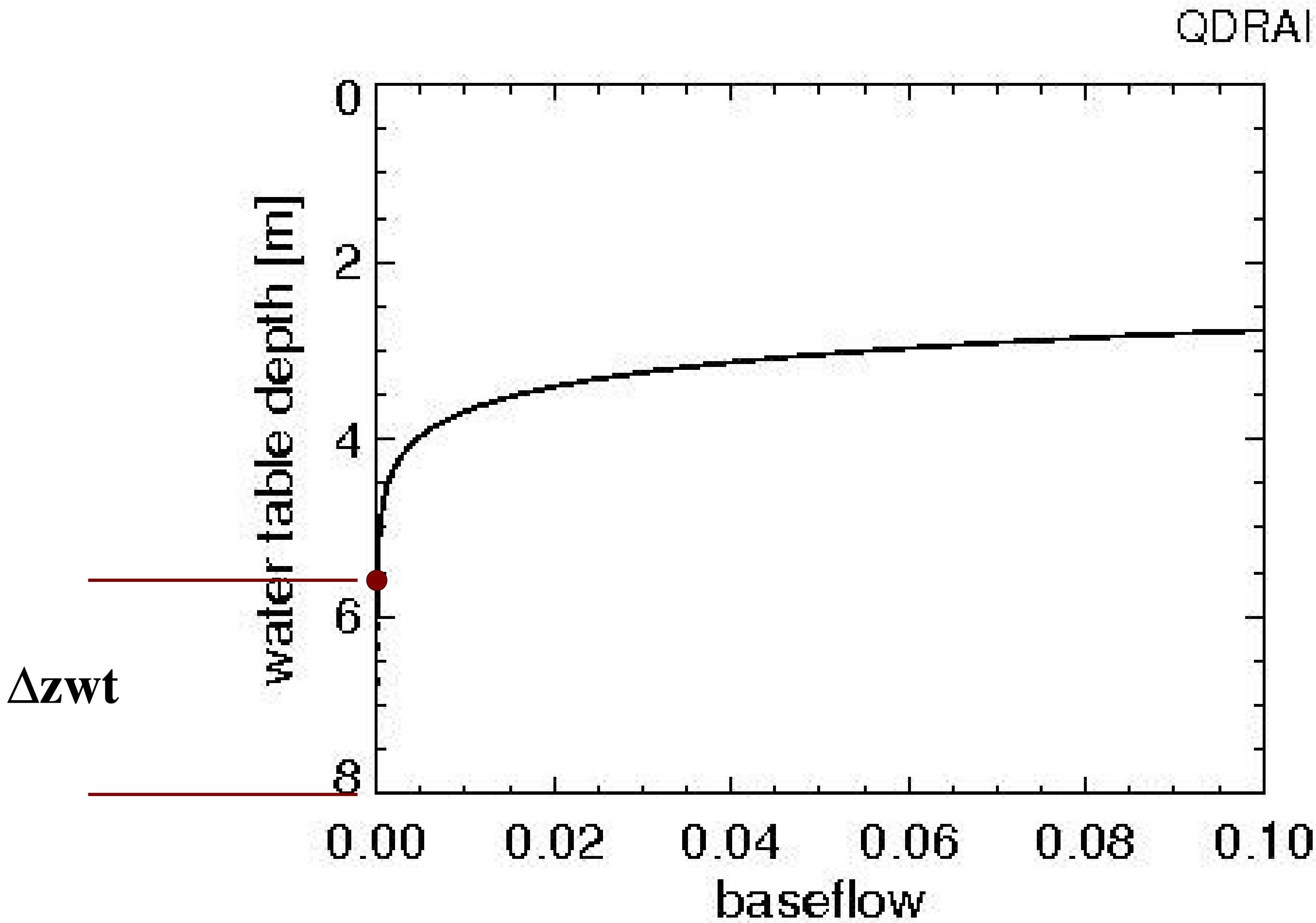


$$Q_{baseflow} = R_{top} * \exp(-fff * zwt)$$

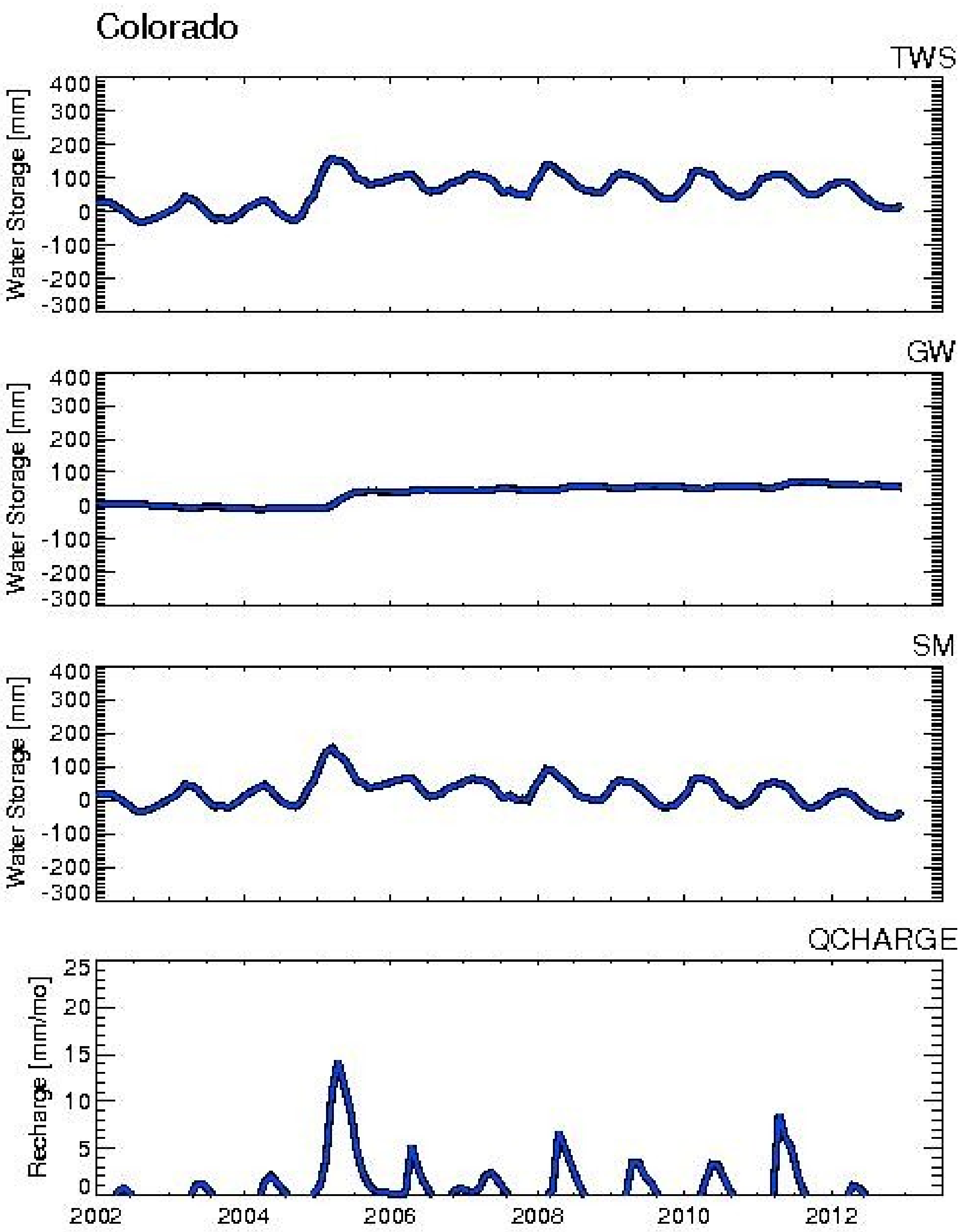
Is it a matter of tuning, i.e. Parameter choice?



Starting point affects the response



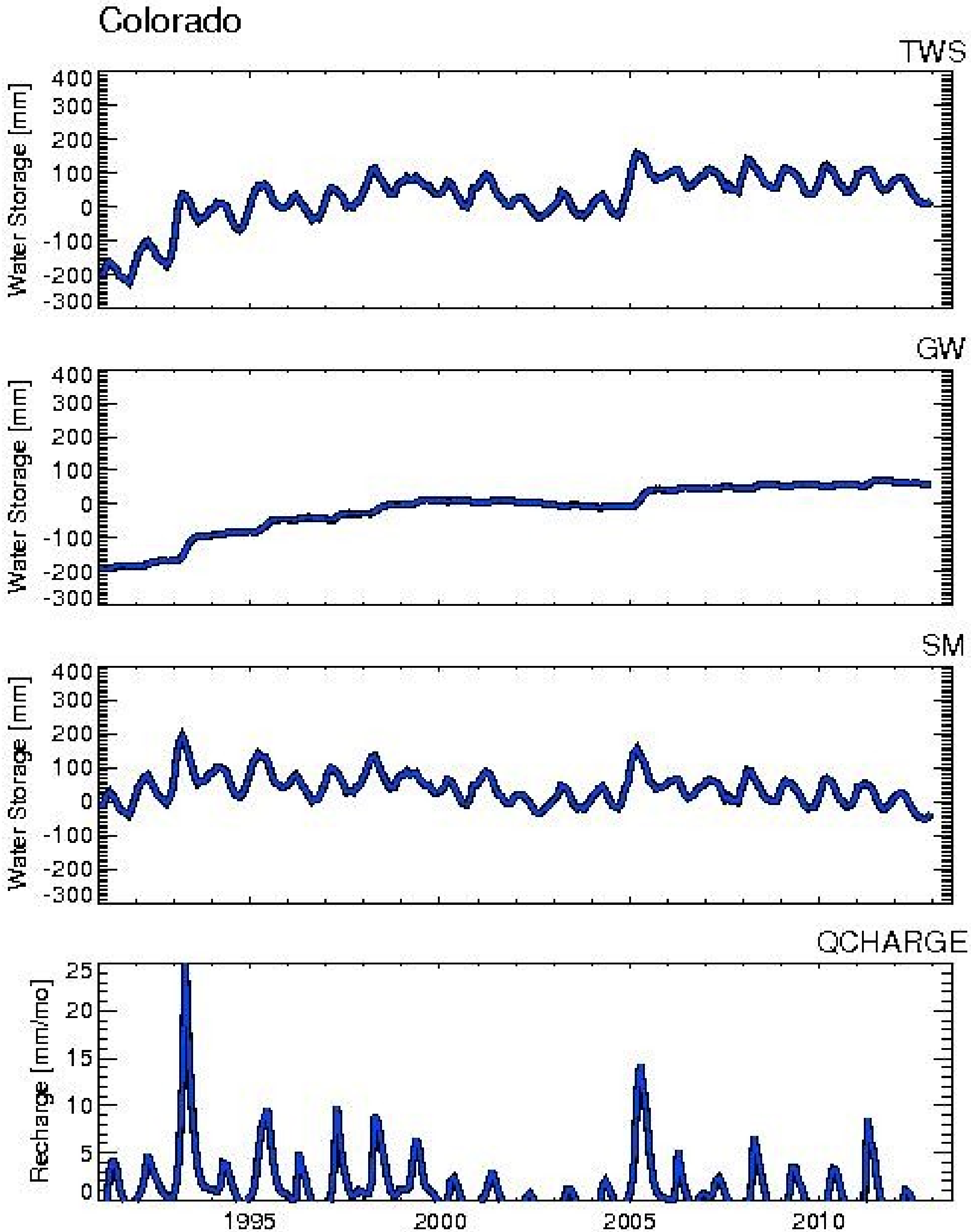
Groundwater response to different recharge regimes



Water storage in near equilibrium state during end of simulation

Groundwater response is will take a decade or more to drain large recharge events

Groundwater response to different recharge regimes



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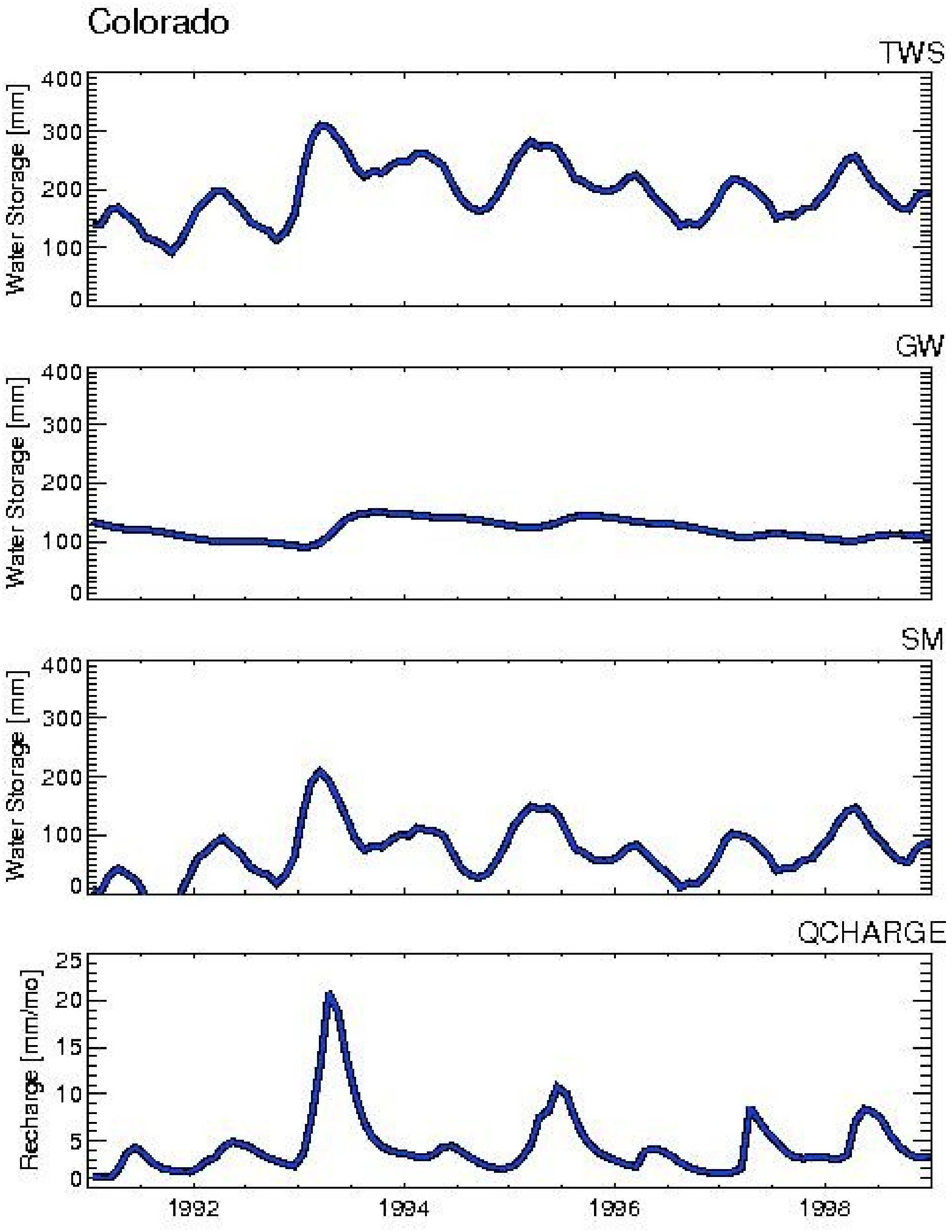
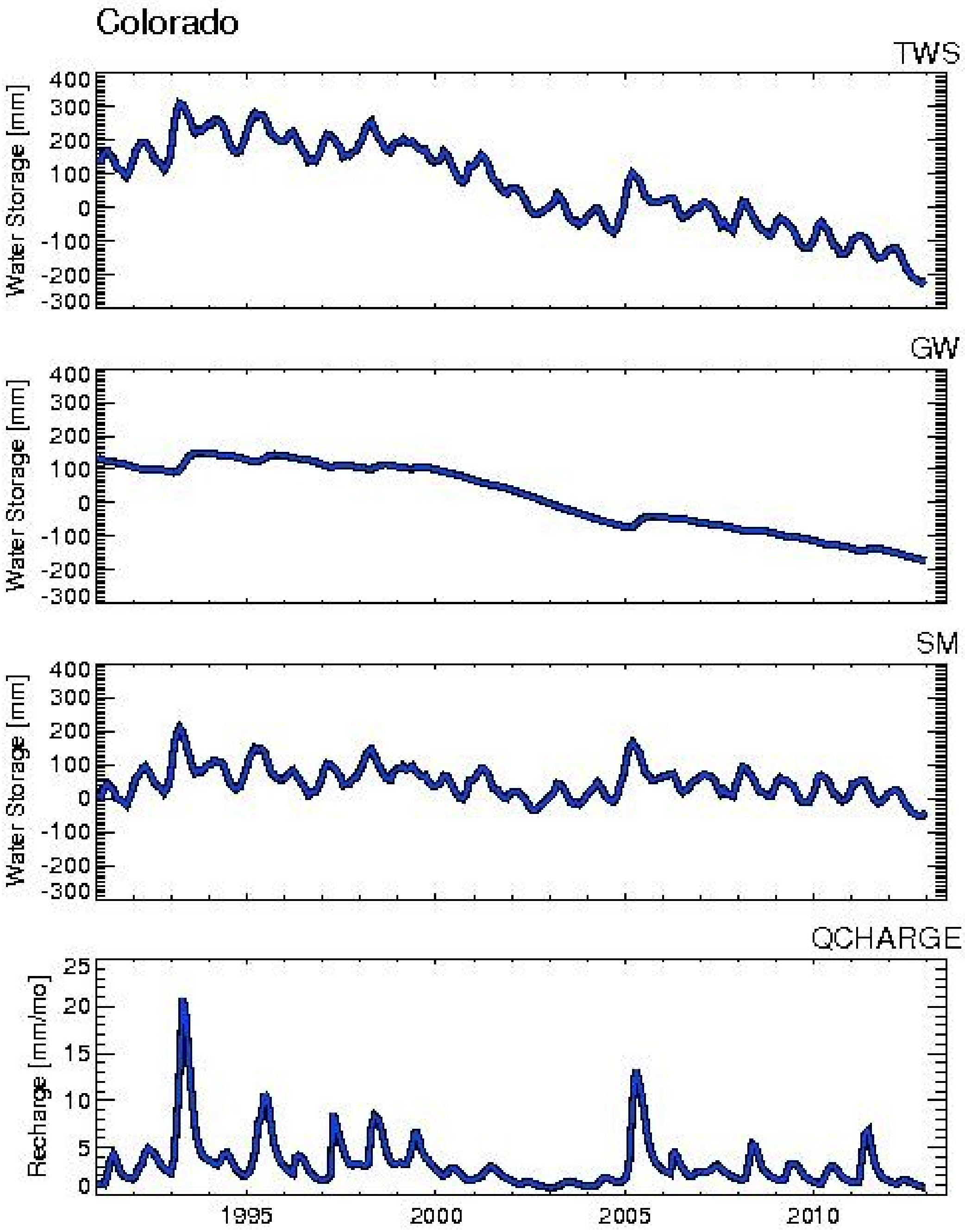
Example of Different fff Parameter Behavior



Water storage in near equilibrium state

Groundwater response is rapid enough to drain large recharge events in a couple of years

Example of Different fff Parameter Behavior



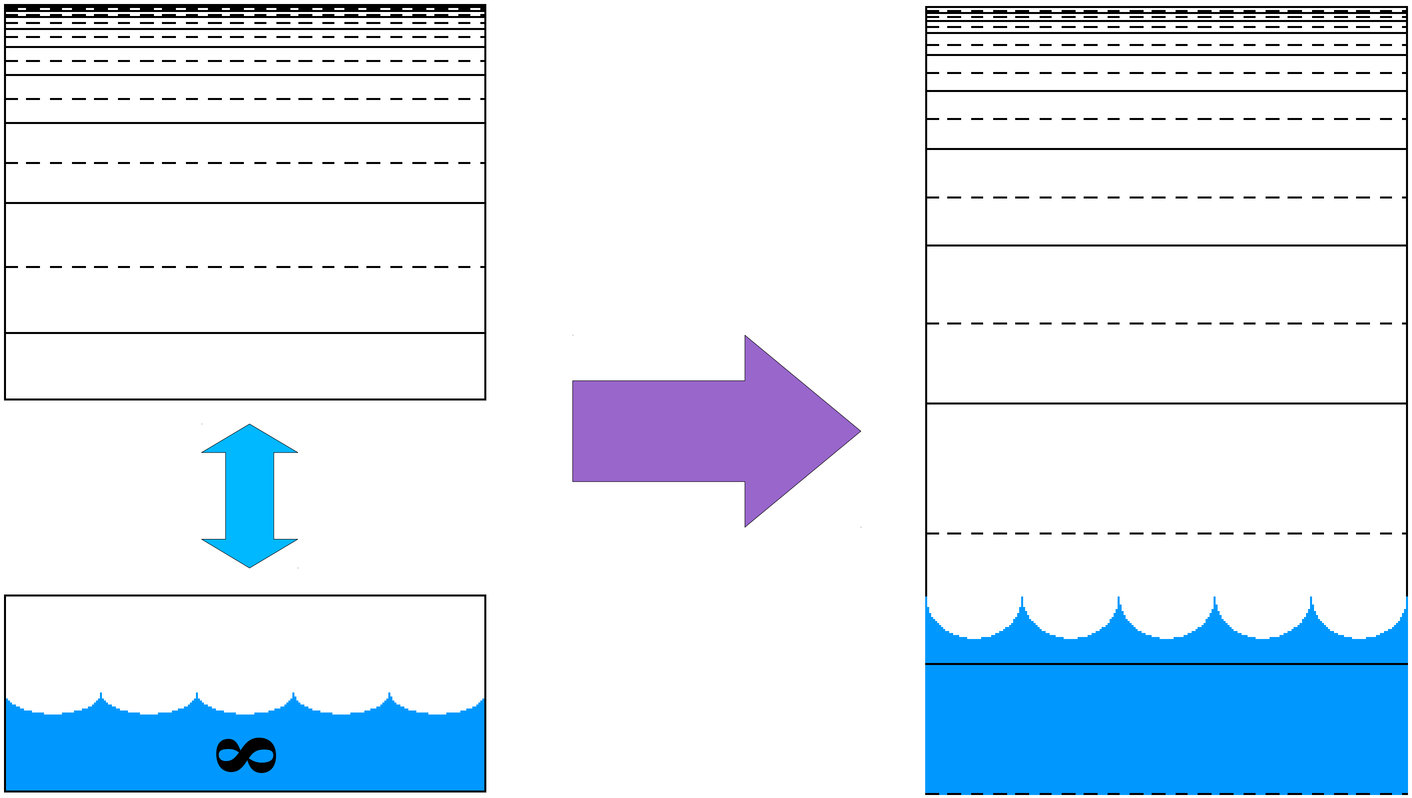
Water storage in later years drops rapidly

Groundwater response is out of balance with low recharge events during drought

Solution: Add a Finite Lower Boundary

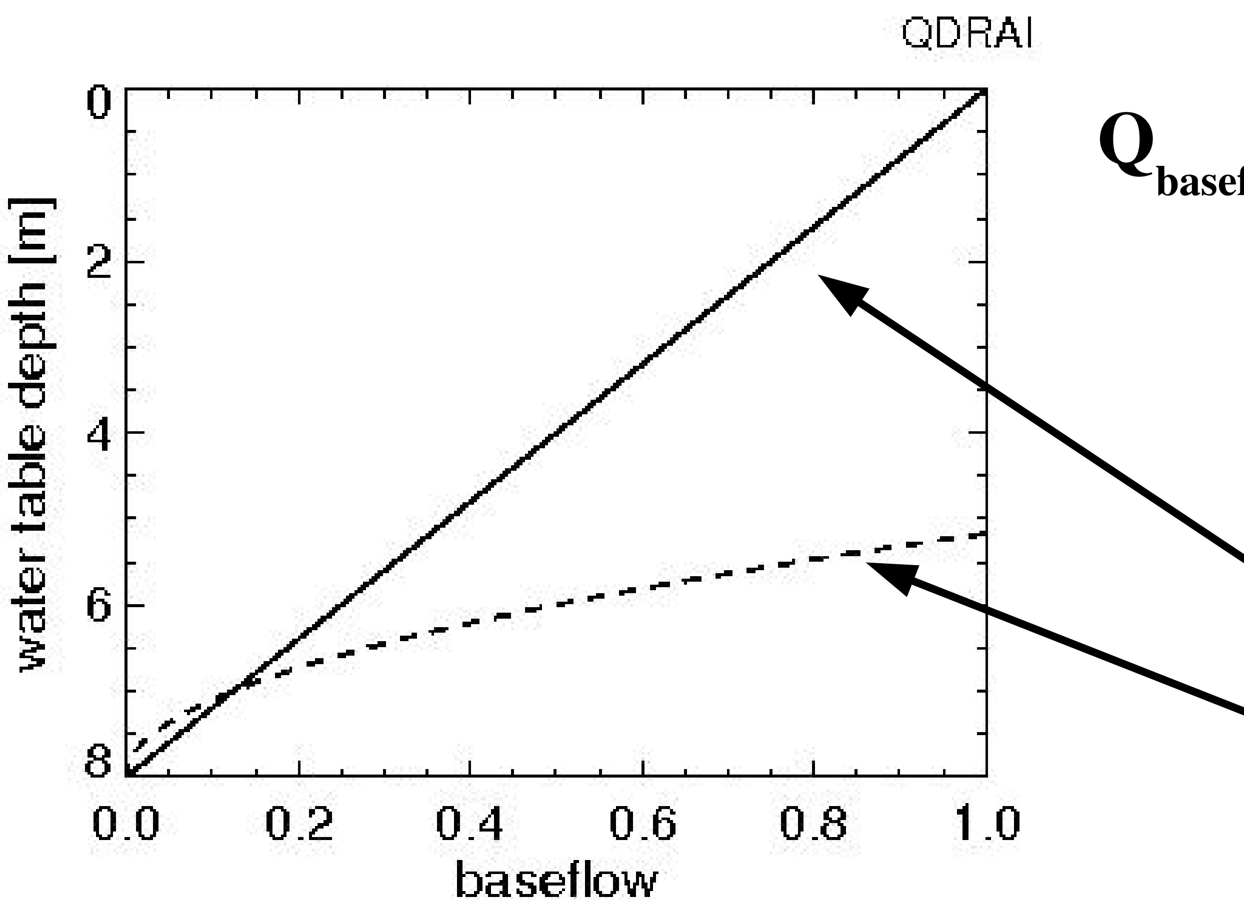
Aquifer Layer

Water Table



zero flux boundary condition

Power Law Baseflow Equation w/ Lower Boundary



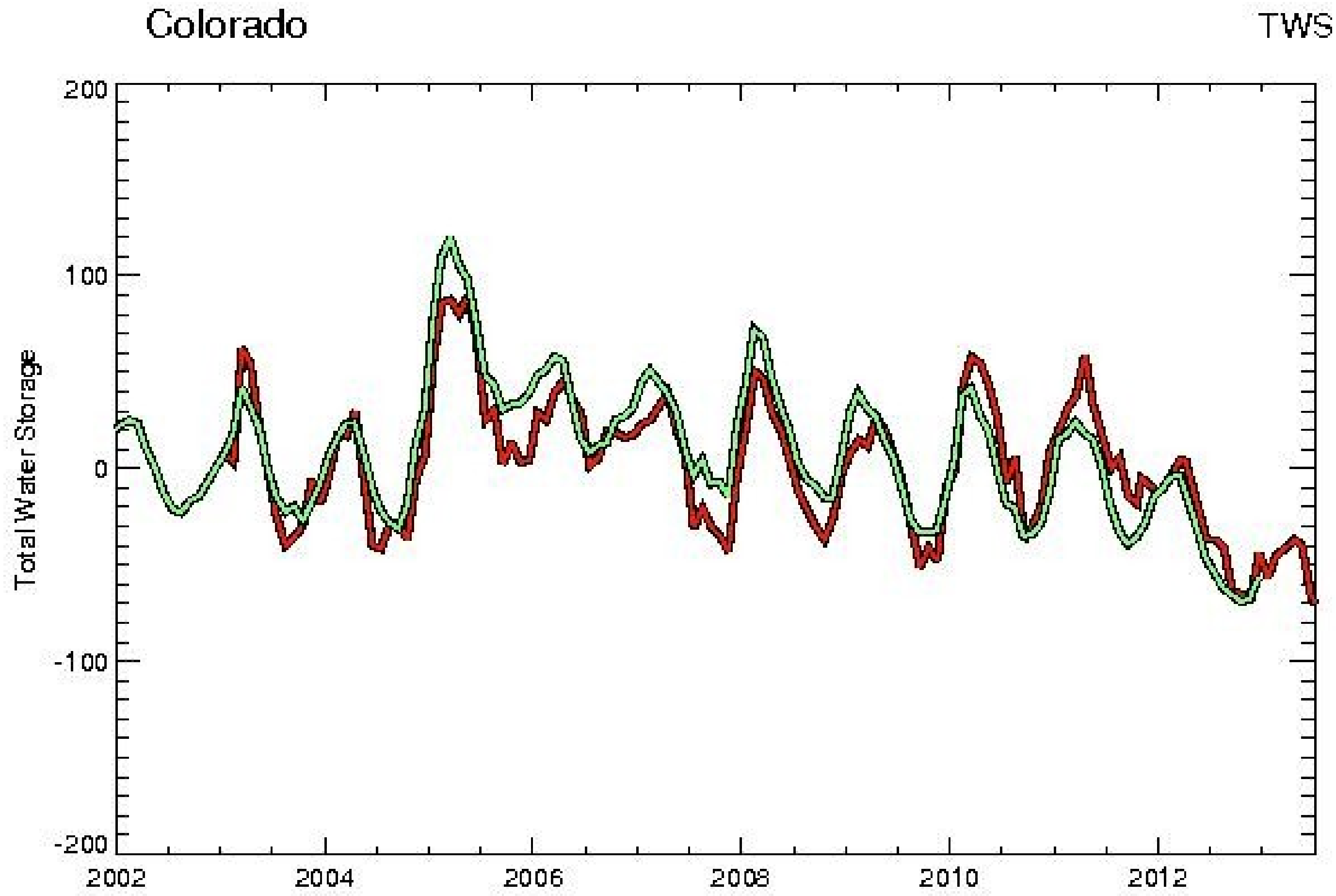
$$Q_{baseflow} = K * (zbot - zwt)^{n}$$

Example w/ lower boundary at 8 meters

Linear (n = 1)

Quadratic (n = 2)

Colorado River Basin



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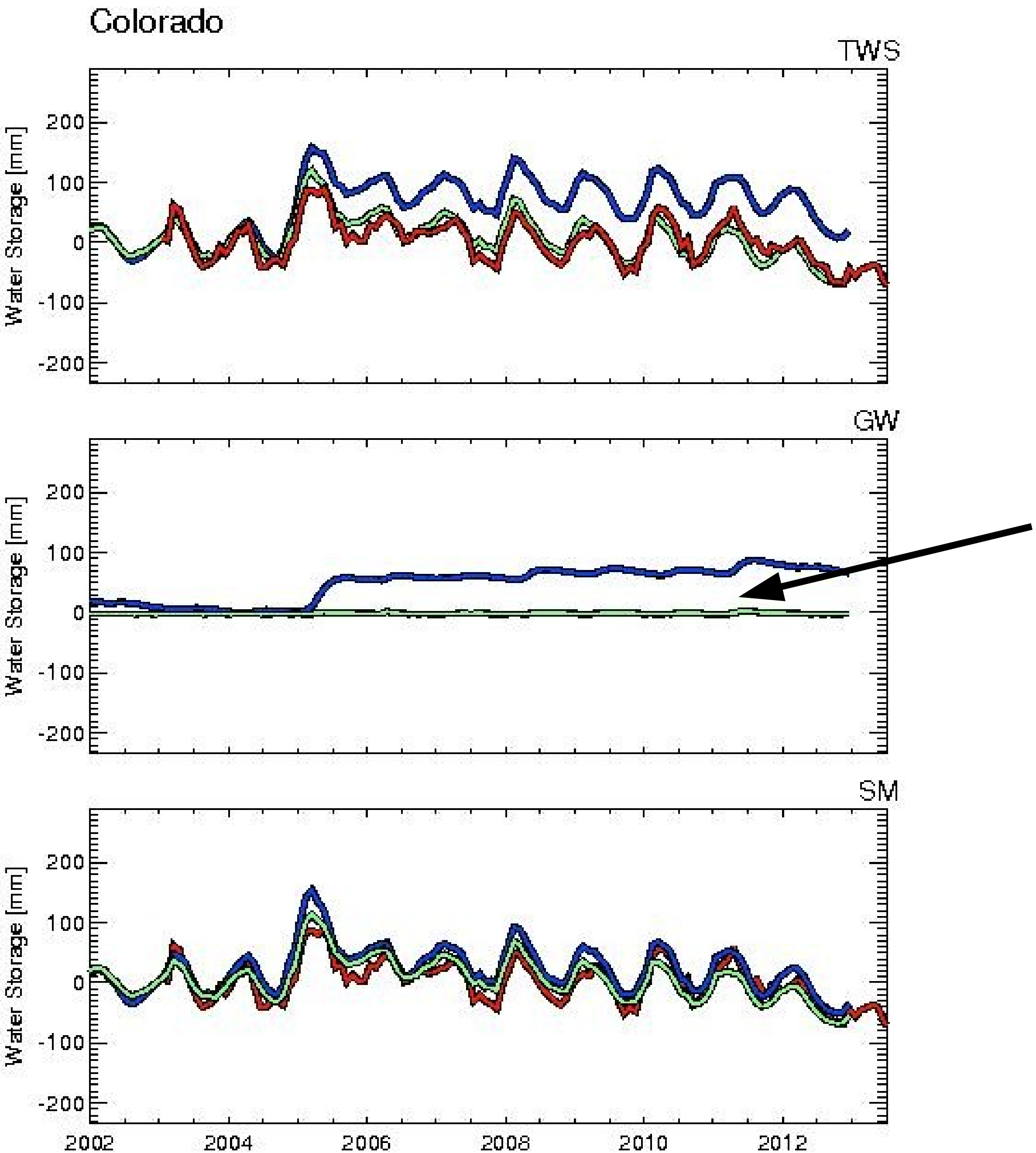
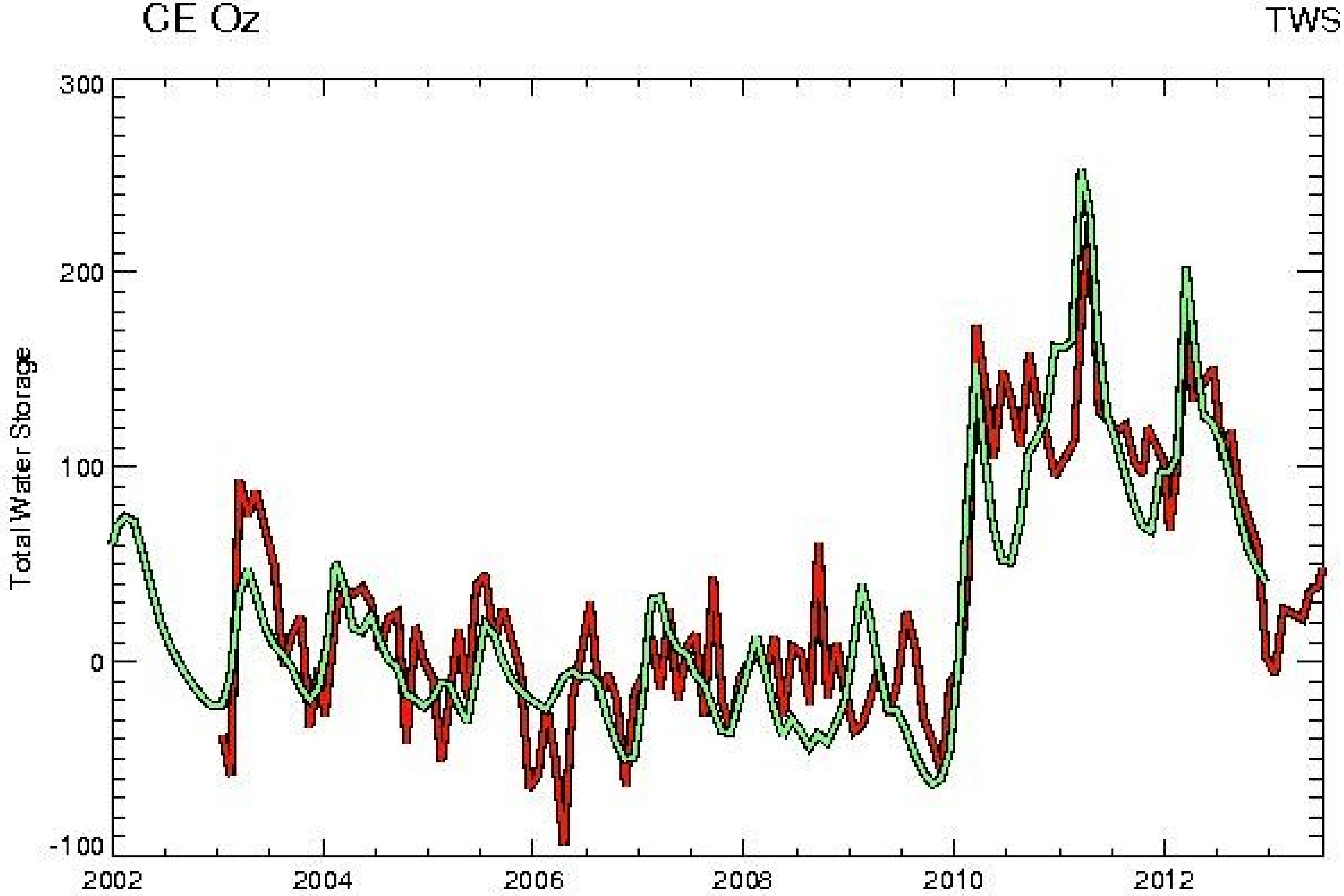
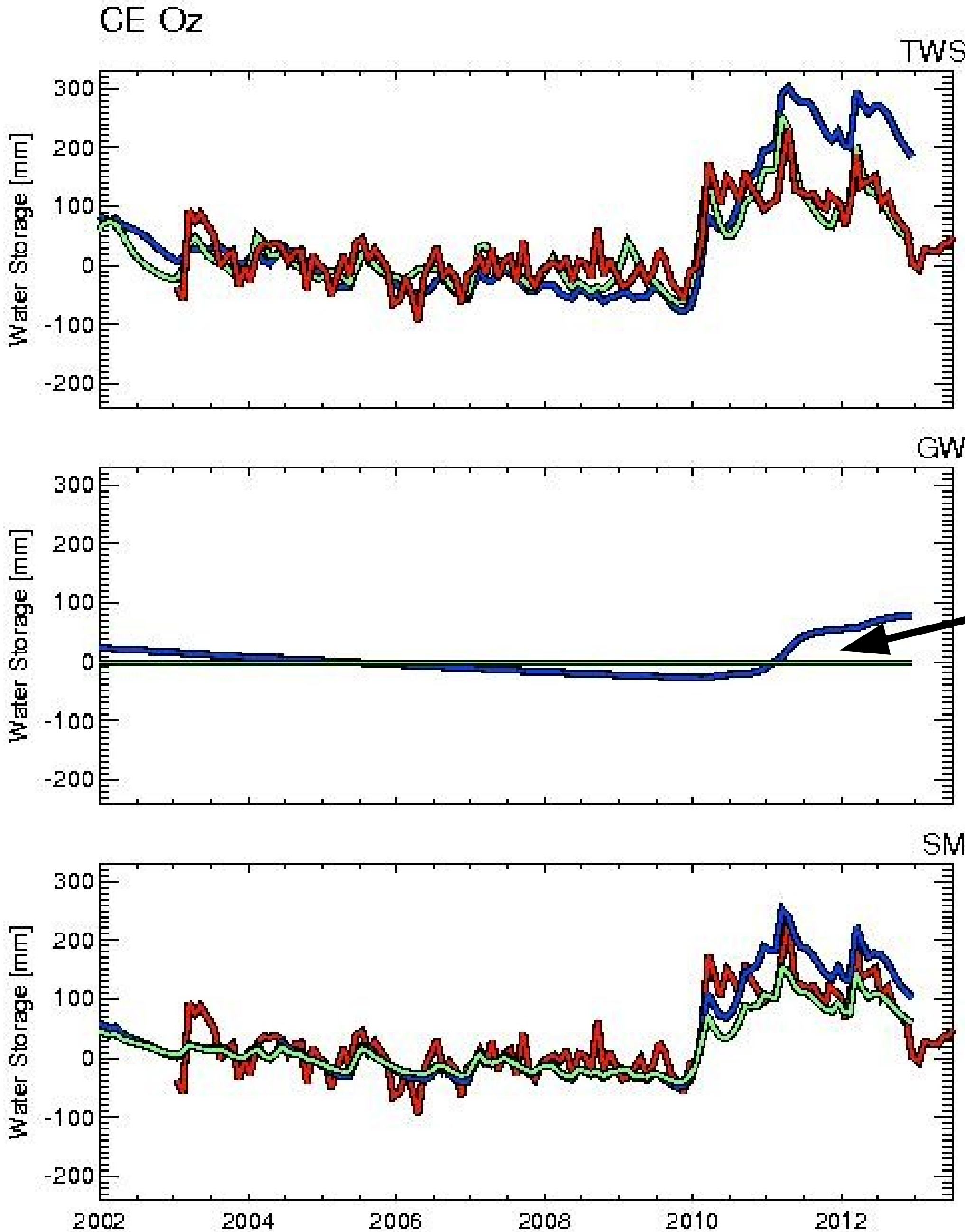


Groundwater response is more rapid (order few months)

Central Australia

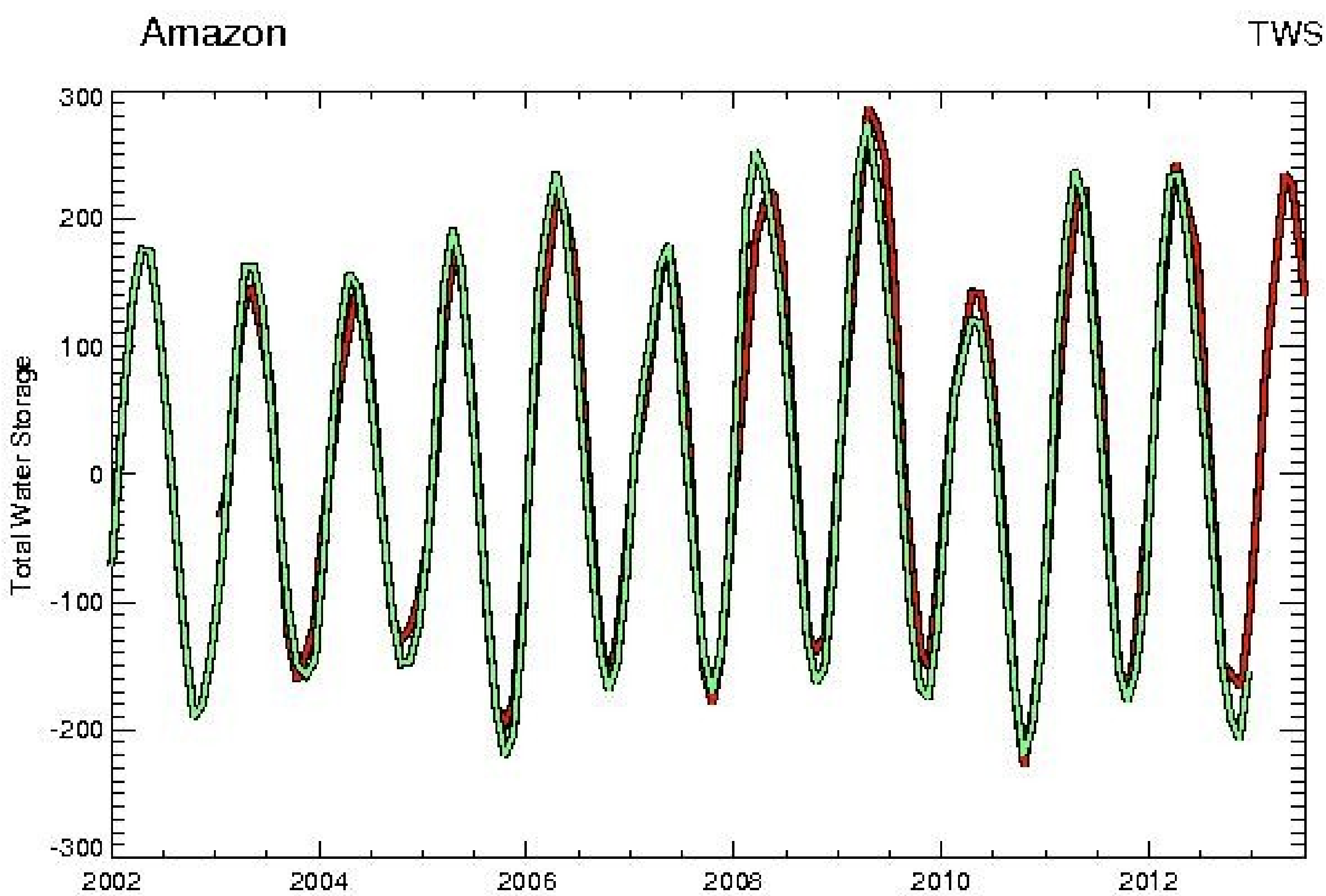


Central Australia



Groundwater storage quite small, main components are soil moisture and river storage

A Non-Semiarid region: the Amazon



Summary

• Greater recharge in semiarid regions (via reduced soil evaporation) exposes unrealistic groundwater behavior

• Removing "limitless" groundwater parameterization and implementing a finite lower boundary improves water storage agreement with observations

• Modified model works well in more humid regions also

Current/Future Work

- Studying sensitivity to different soil column thicknesses
- Studying sensitivity to different baseflow parameterizations
- Reconciling optimal lower boundary depth with observations