Runoff and Evaporation in the WRF Regional Climate Model

Rachel White

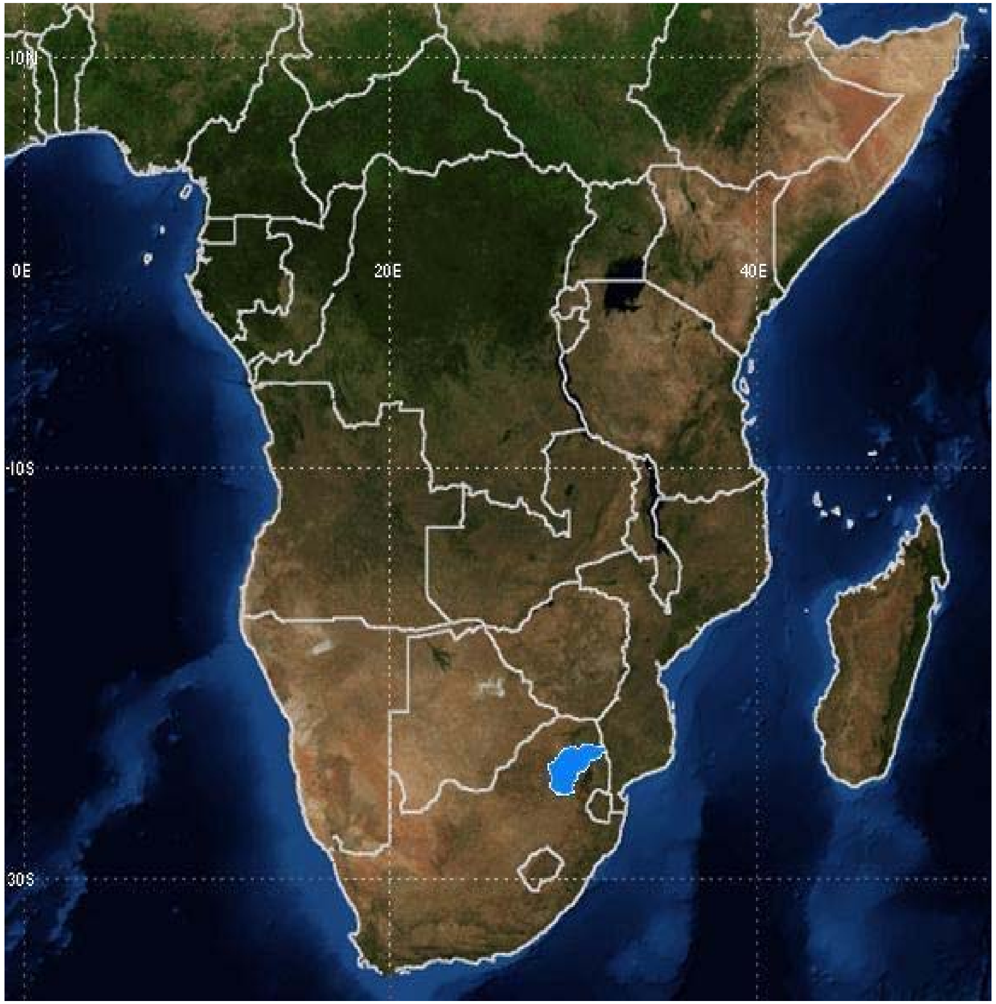
Imperial College London, UK

Prof. Ralf Toumi

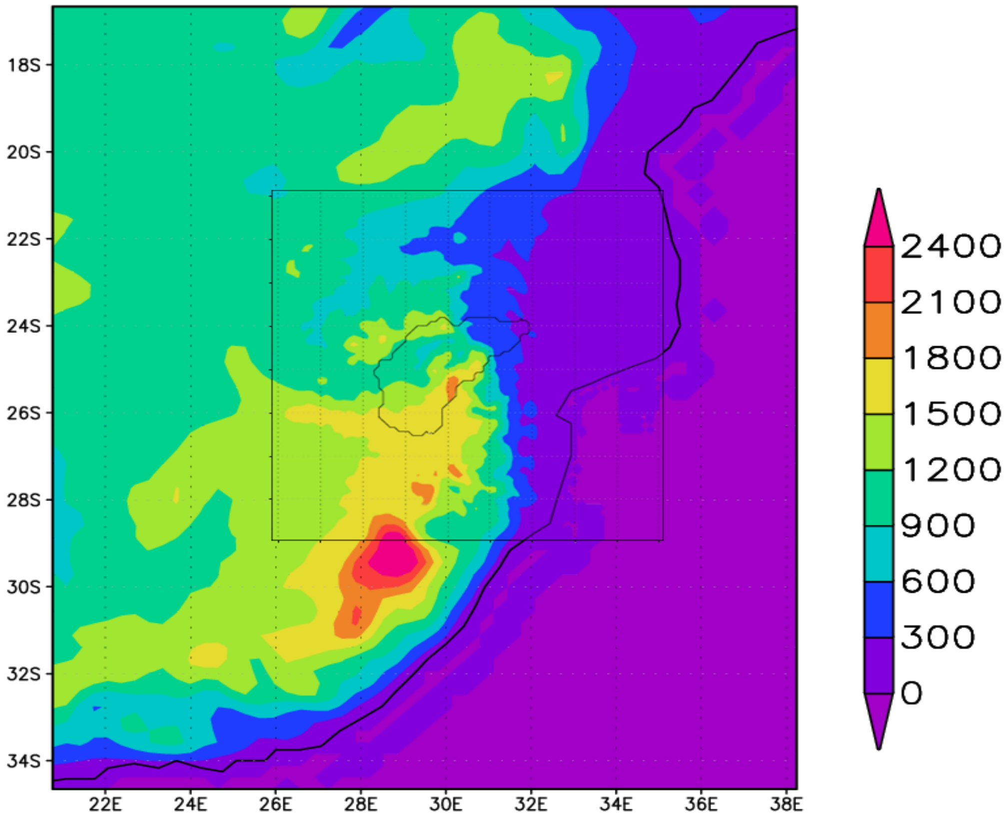
- Regional climate model and domain
  - The Olifants basin in South Africa
- Standard model of soil water physics
- Evidence for a better model?
  - Brooks et al. 2010
- Implementation of new physics in NOAH-WRF
- Results – validation of new scheme

WRF Regional Climate Model

- Designed for high resolutions and research purposes
- Has previously been shown to successfully simulate precipitation on regional scales.
- Many different options for physical schemes/ parameterisations



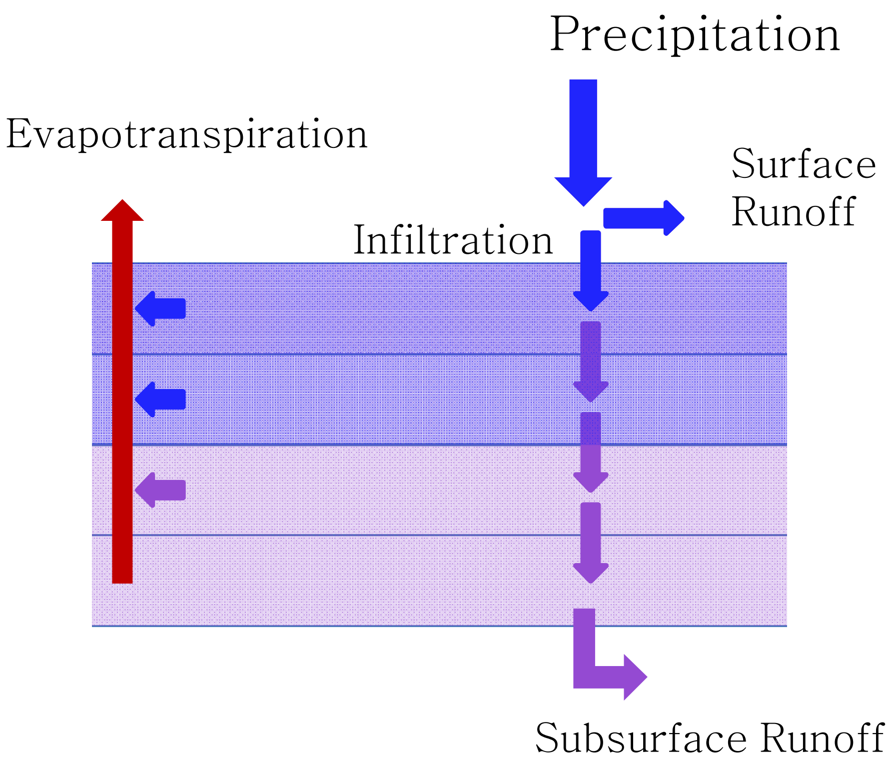
Olifants Basin, South Africa



- Water-stressed region
- Local population, agriculture and mining economy dependent on water resources
- Runoff important for future water security

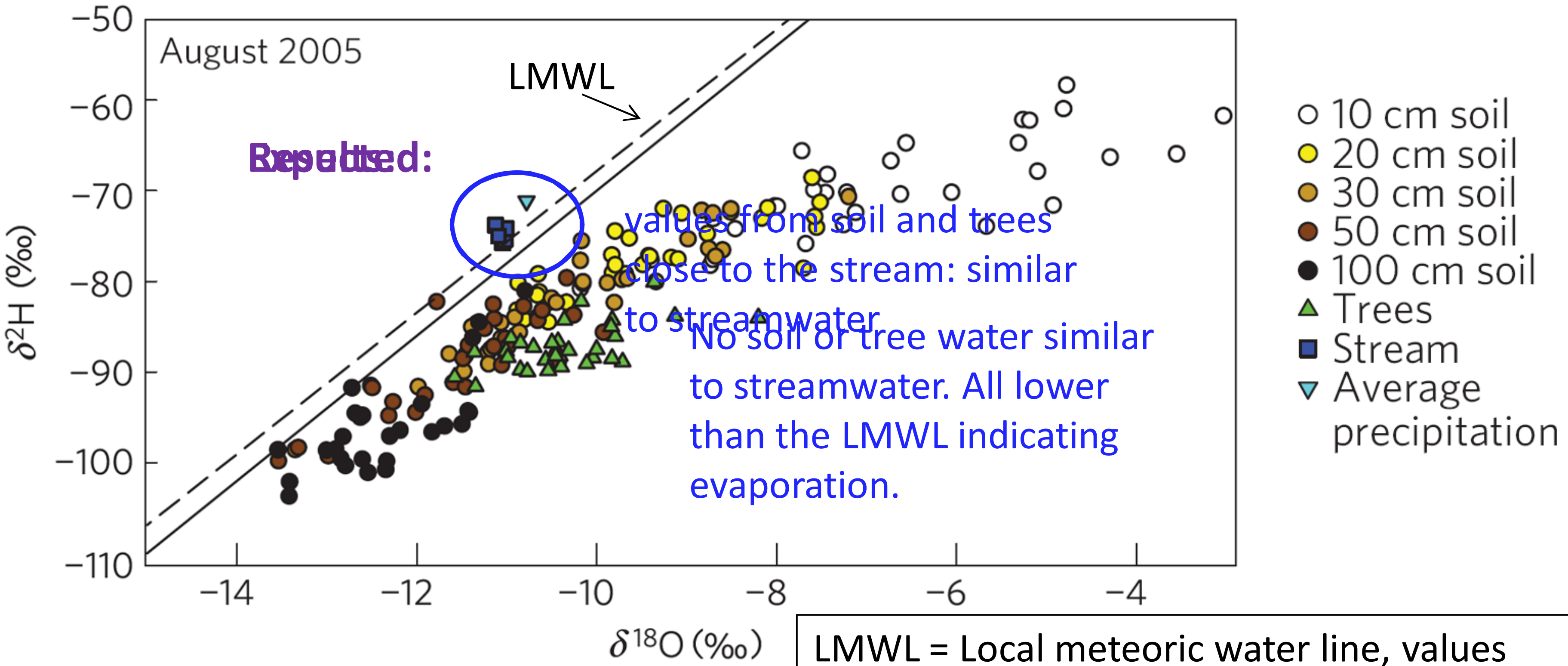
WRF V3.2.1
Nested domain, 12km resolution inner domain (36km outer)
Forcing from ERA40

Standard Soil Water Physics



- New infiltration displaces existing soil water downwards
- Subsurface runoff is oldest soil water
- Evaporation and transpiration occur from soil
- In reality this occurs on sloping terrain – lateral movement within soil.
- Expect water in soil close to a stream to be similar to water within the stream.

Brooks et al. 2010: Ecohydrologic separation of water between trees and streams

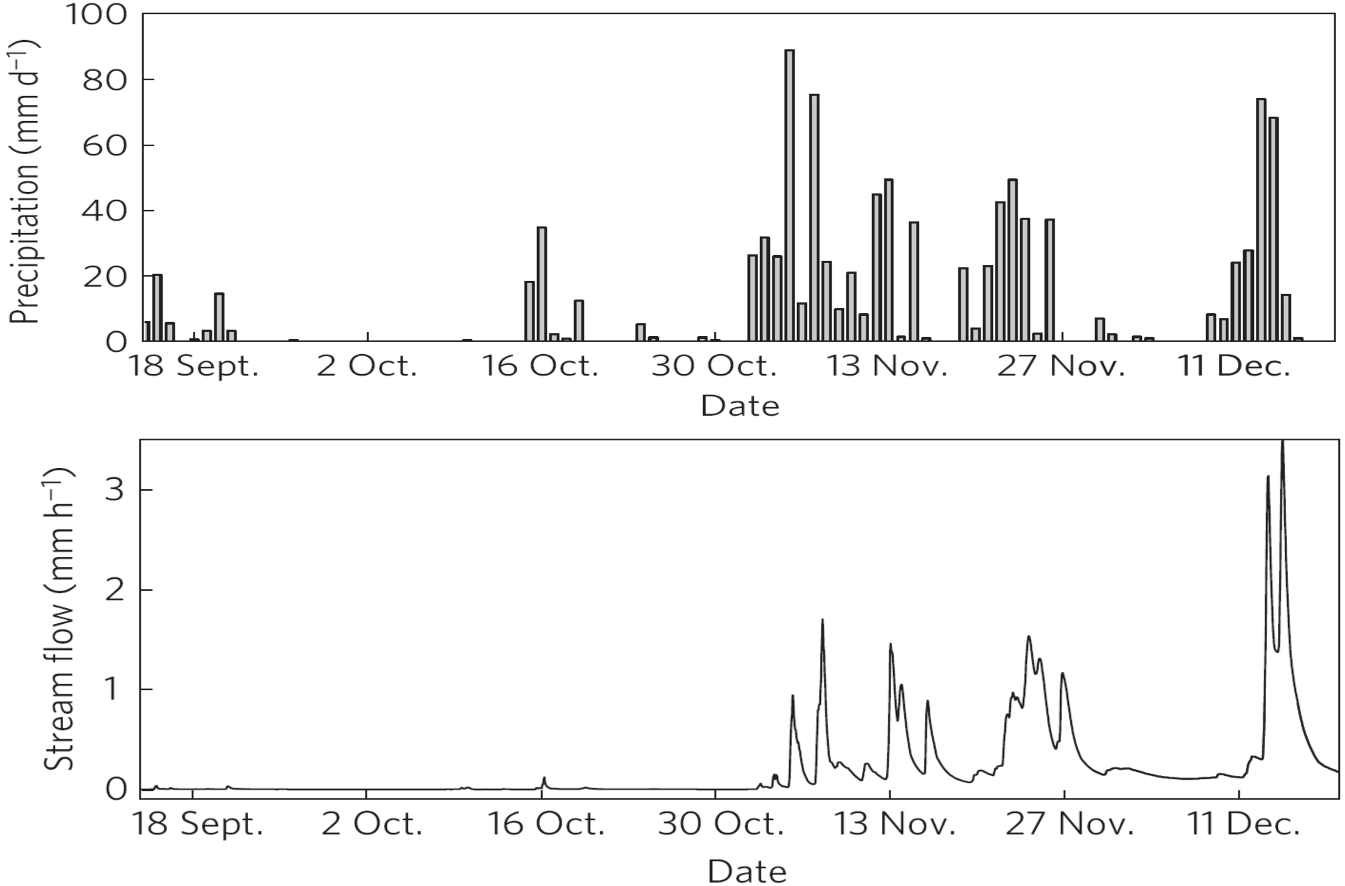


LMWL = Local meteoric water line, values below this indicate evaporation has occurred

Brooks, J. R., Barnard, H. R., Coulombe, R., and McDonnell, J. J., 2010. Ecohydrologic separation of water between trees and streams in a Mediterranean climate. Nature Geoscience, 3(2):100104.

Brooks et al. 2010: Ecohydrologic separation of water between trees and streams

Initial wet season rain events had little impact on streamflow

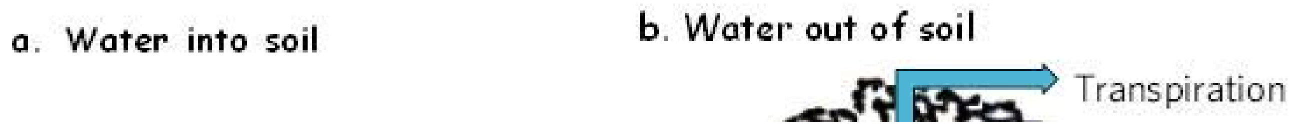


Brooks et al. conclusions:

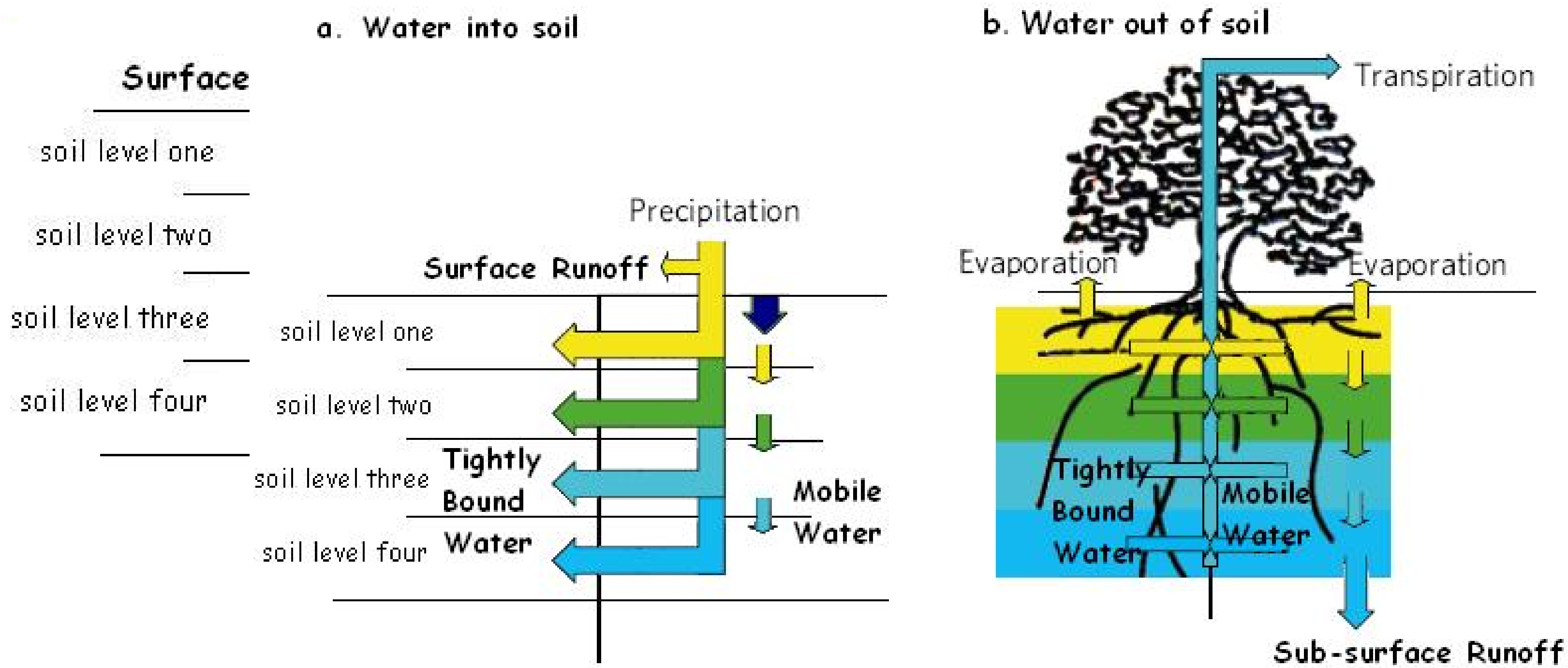
- There are two distinct reservoirs within the soil:
  - Mobile water expressed in the stream
  - Tightly bound water represented by plant water
  - Agrees with Dawson and Ehleringer (1991)
- The tightly bound reservoir refills in the first rain events of the wet season – little response of streamflow to precipitation during this refill time.
- The tightly bound water does not move within the soil – it is removed by tensions exerted by plant roots or direct soil evaporation

Modeling the Tightly Bound Water Scheme in the NOAH LSM

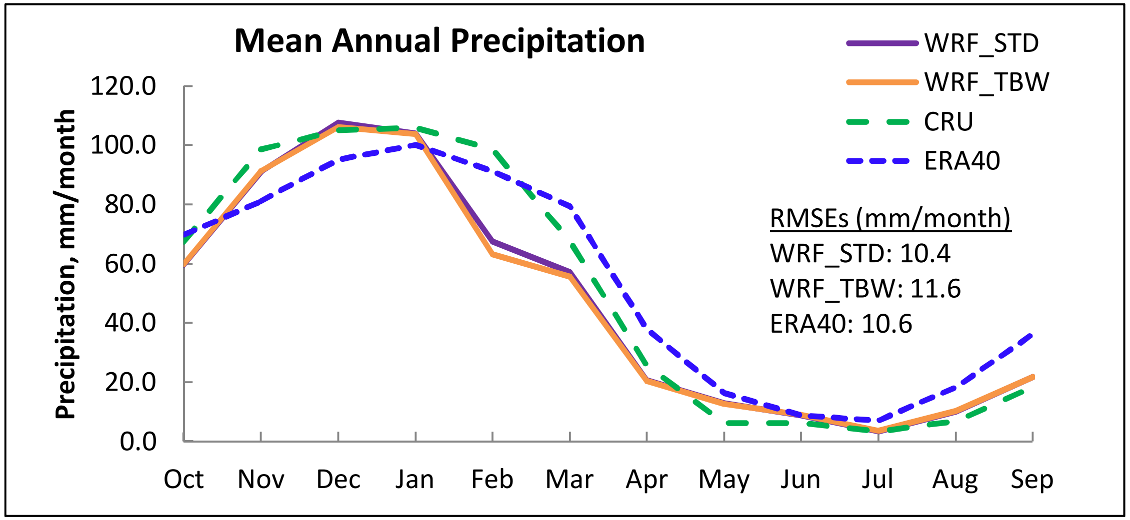
NOAH Standard Scheme

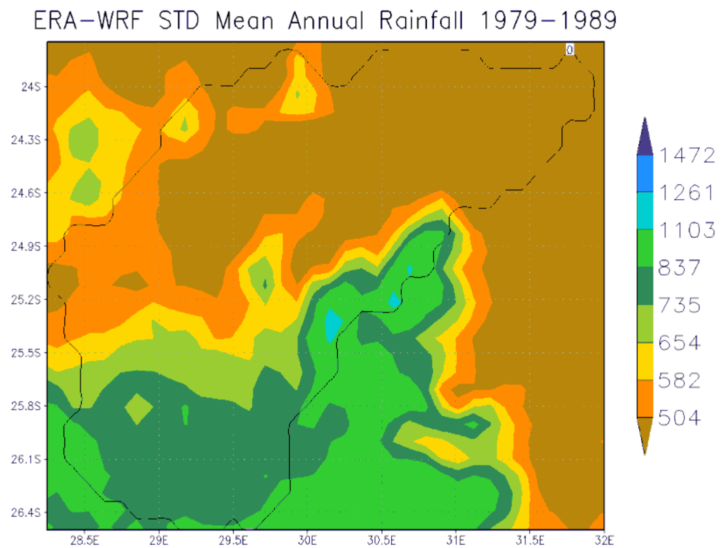


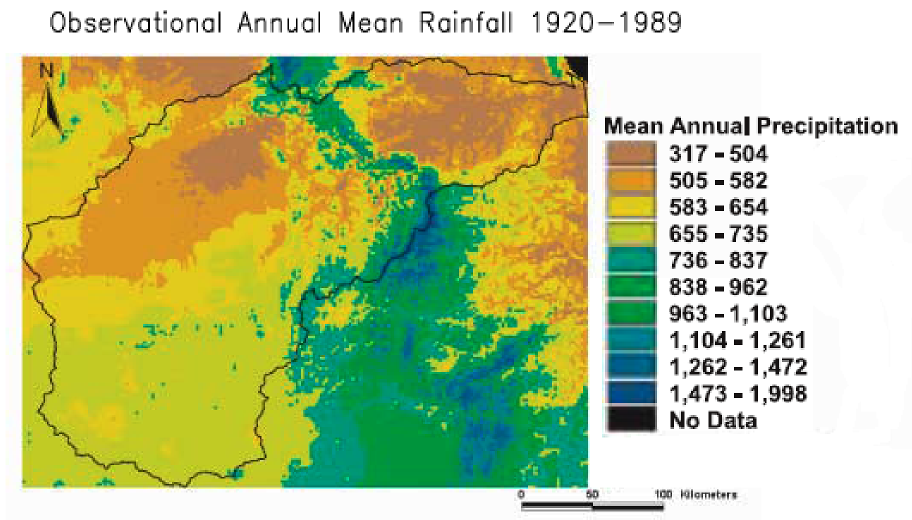
NOAH TBW Scheme



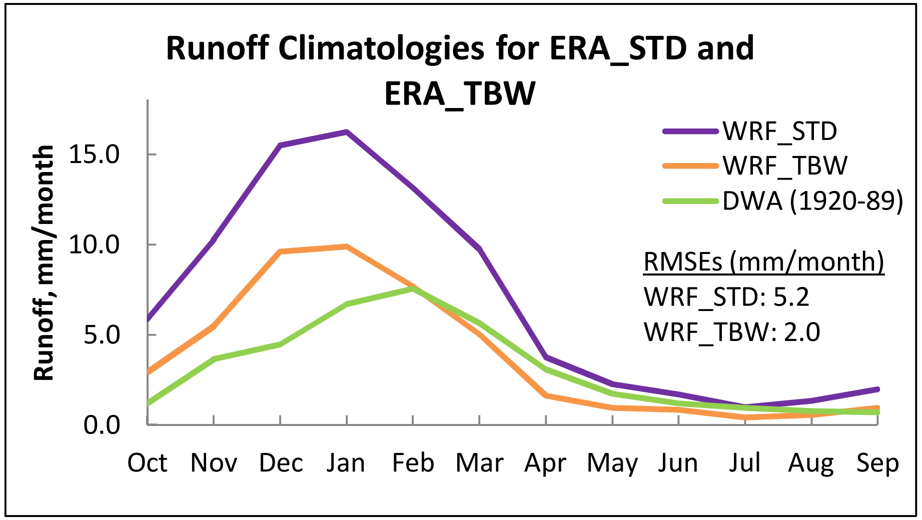
10yr Simulation Results: Precipitation

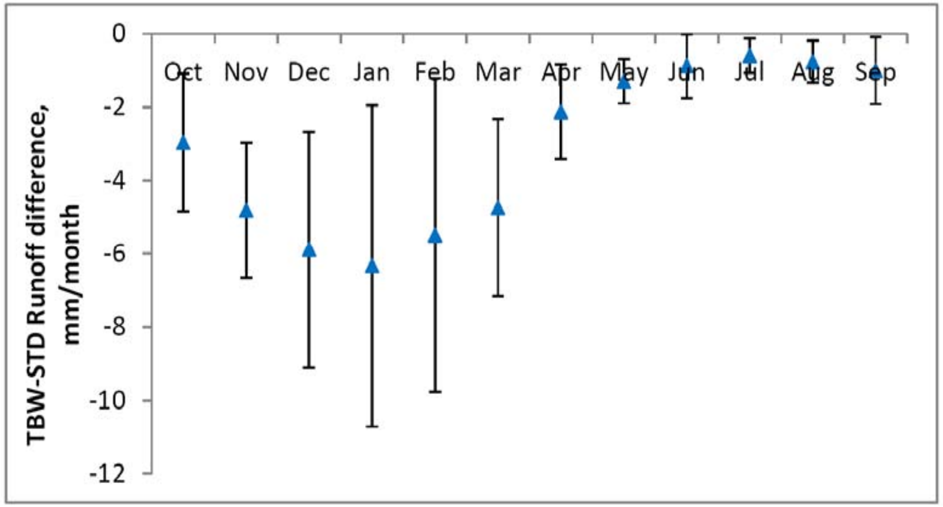






10yr Simulation Results: Runoff



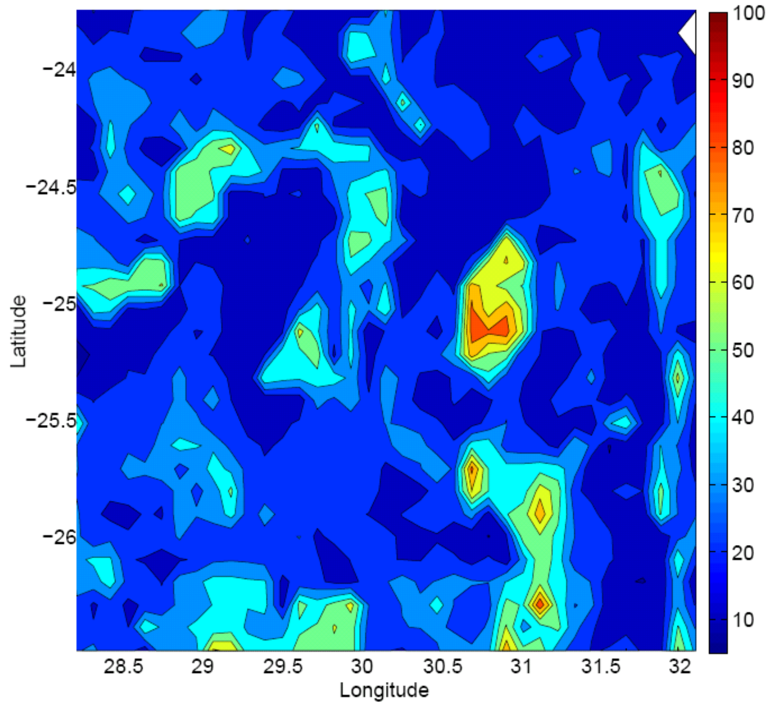


- Yearly bias reduced from +120% to +22%
- Reduction significant at 0.99 confidence (Student's paired T-test)
- Such reduction in error not achievable by changing existing parameters within the NOAH Land Surface Model

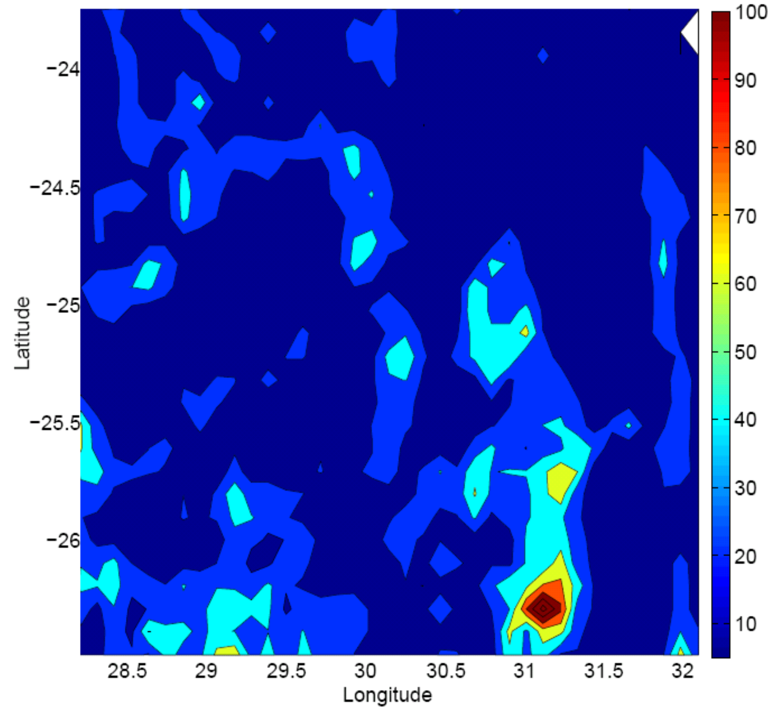
Impact of TBW scheme

- Modelling present day extremes

Standard 100-yr return value for surface runoff (mm/day)



TBW 100-yr return value for surface runoff (mm/day)



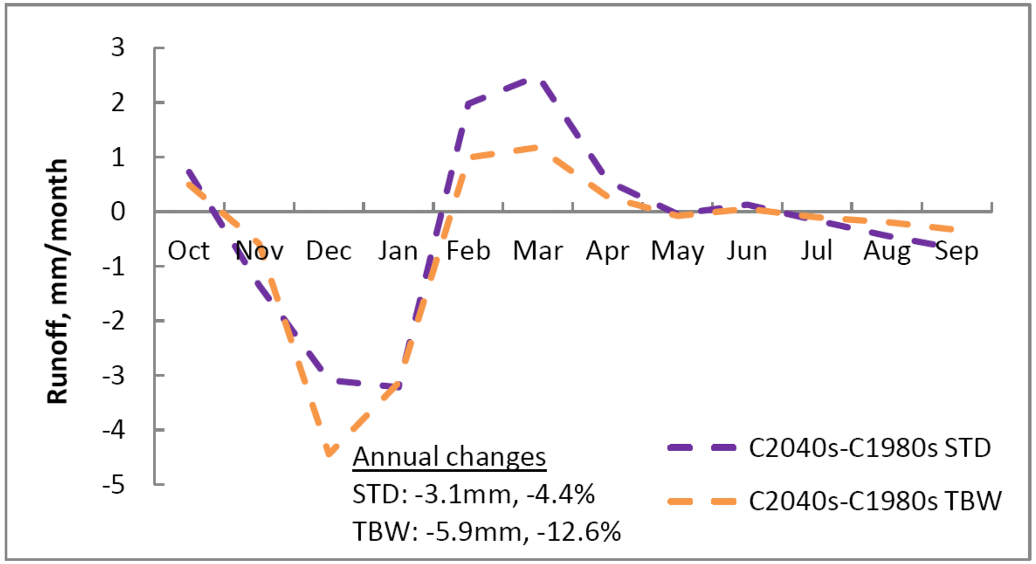
Impact of TBW scheme

- Modelling future changes
  - Force WRF with CCSM3 data 1979-1999; 2039-2059

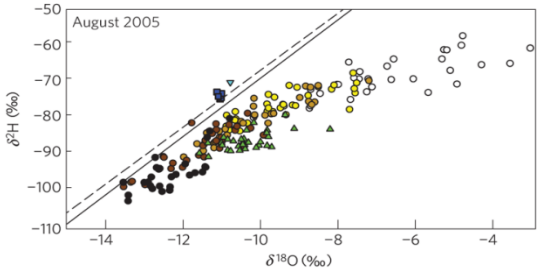
- TBW scheme simulates greater decreases
-TBW scheme simulates smaller increases

- Overall the TBW scheme simulates a greater decrease in runoff for the future.

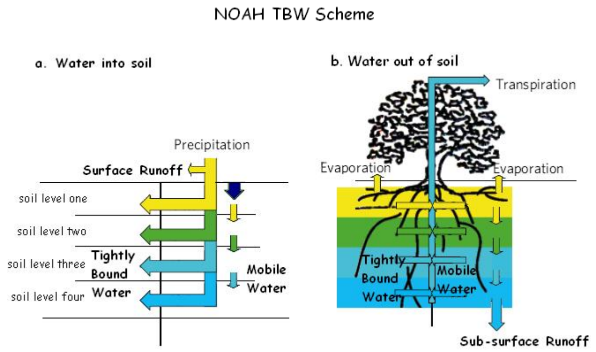
Changes to Climatological Runoff:
2040s – 1980s.



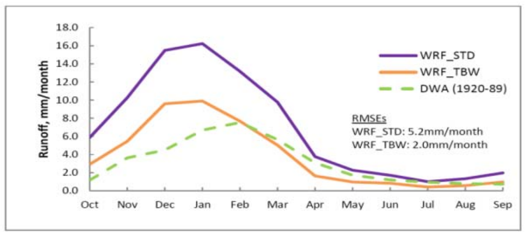
Conclusions



- Evidence that soil water exists in two distinct reservoirs – tightly bound and mobile soil water.



- This new physics has been implemented into the NOAH land surface model within the WRF regional model.



- Results show a highly significant improvement in the simulation of runoff in a semi-arid climate.
- Likely to improve runoff simulation in regions with similar climate: significant moisture-controlled evaporation during rain season.
- No significant impact on precipitation in this region despite increase in evaporation – may vary in other areas.

White, R. and Toumi, R., 2012. A Tightly Bound Soil-Water Scheme within an Atmosphere-Land-Surface model. Journal of Hydrology, accepted.

Thank You!

WRF V3.2.1 Model Set-up

- WRF double-moment 6-class scheme
- Betts-Miller-Janjic scheme convection
- Longwave radiation using the RRTM
- Shortwave radiation using the Dudhia scheme
- Planetary boundary layer by MYNN Level 2.5
- Surface layer physics by the corresponding MYNN surface layer scheme.
- NOAH Land Surface Model.
- SSTs updated every 6 hours