Assimilation of satellite observations into hydrological forecasting

An Australian perspective

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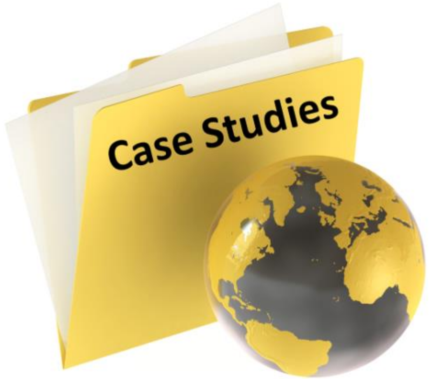
Thanks to: Luigi Renzullo, Marcela Doubkova, a.o.

H-SAF/HEPEX Workshop on Coupled Hydrology, 3-7 November, Reading

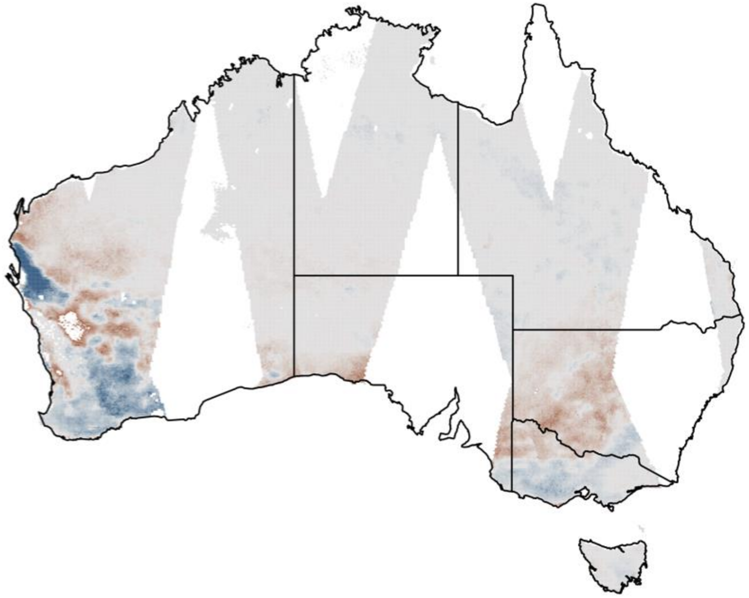

A·U·S·T·R·A·L·I·A
NO LONGER DOWN UNDER

Summary

1. Assimilating satellite observations of one hydrological variable can demonstrably ***improve analysis*** of that particular variable.
2. However, due to the sometimes loose coupling between variables, those ***benefits do not always propagate far*** (more so in land surface than atmospheric models).
3. Assimilating water balance observations can enhance hydrological forecasting skill ***provided initial hydrological state contributes to predictability***.
4. This is ***in addition to any forecast skill derived from climate system state*** (used directly or via atmospheric model forecasts)
5. ***It is possible to predict the theoretical skill contributions*** from hydrological and climate state, through model studies.
6. ***It is possible to predict the realised skill***, by combining theoretical skill with off-line model performance measured against observations.



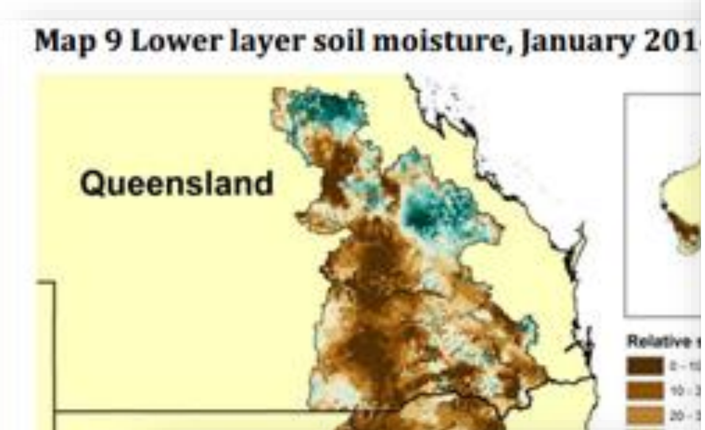
Continental satellite soil moisture data assimilation improves root-zone moisture analysis for water resources assessment

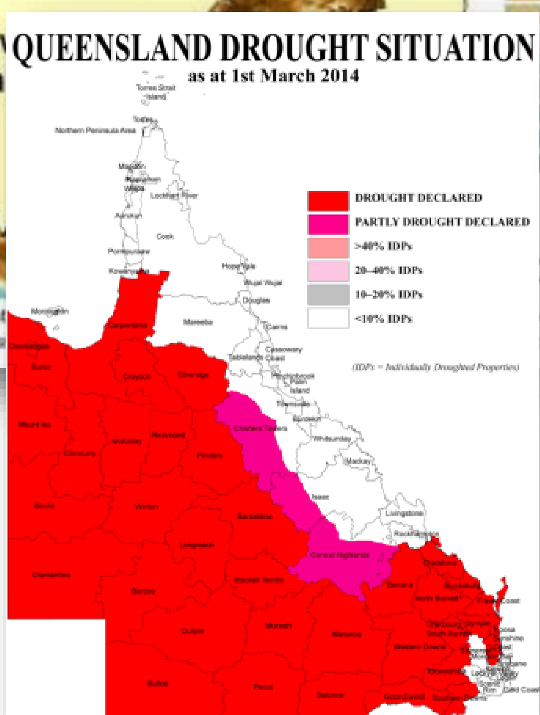


L.J. Renzullo, A.I.J.M. van Dijk, J.-M. Perraud, D. Collins, B. Henderson, H. Jin, A.B. Smith, D.L. McJannet (2014)

Journal of Hydrology (pre-published, doi: 10.1016/j.jhydrol.2014.08.008)

Soil moisture is of interest in its own right





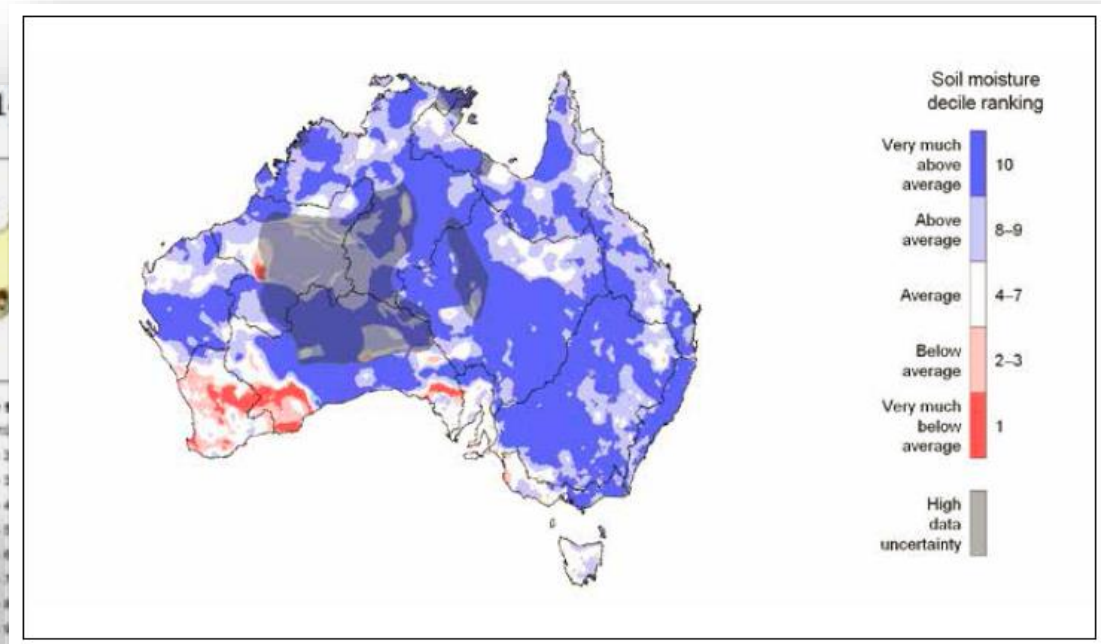
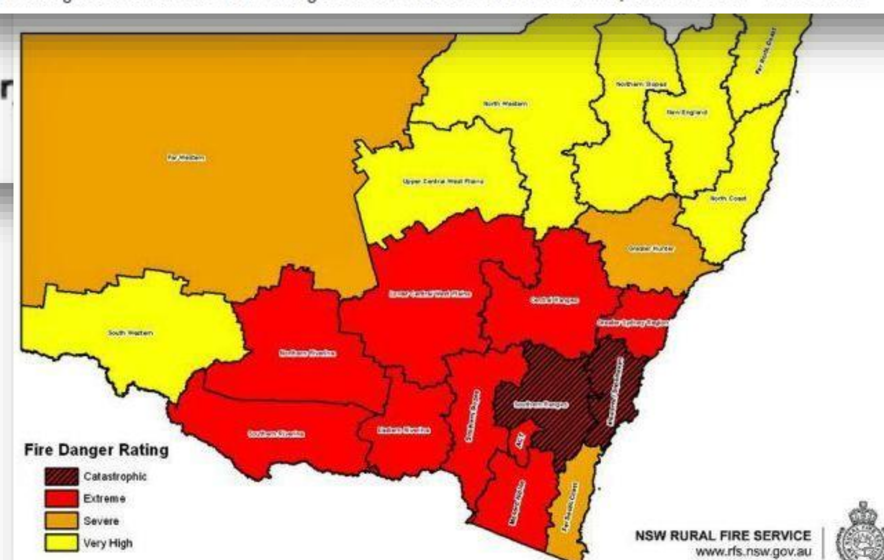
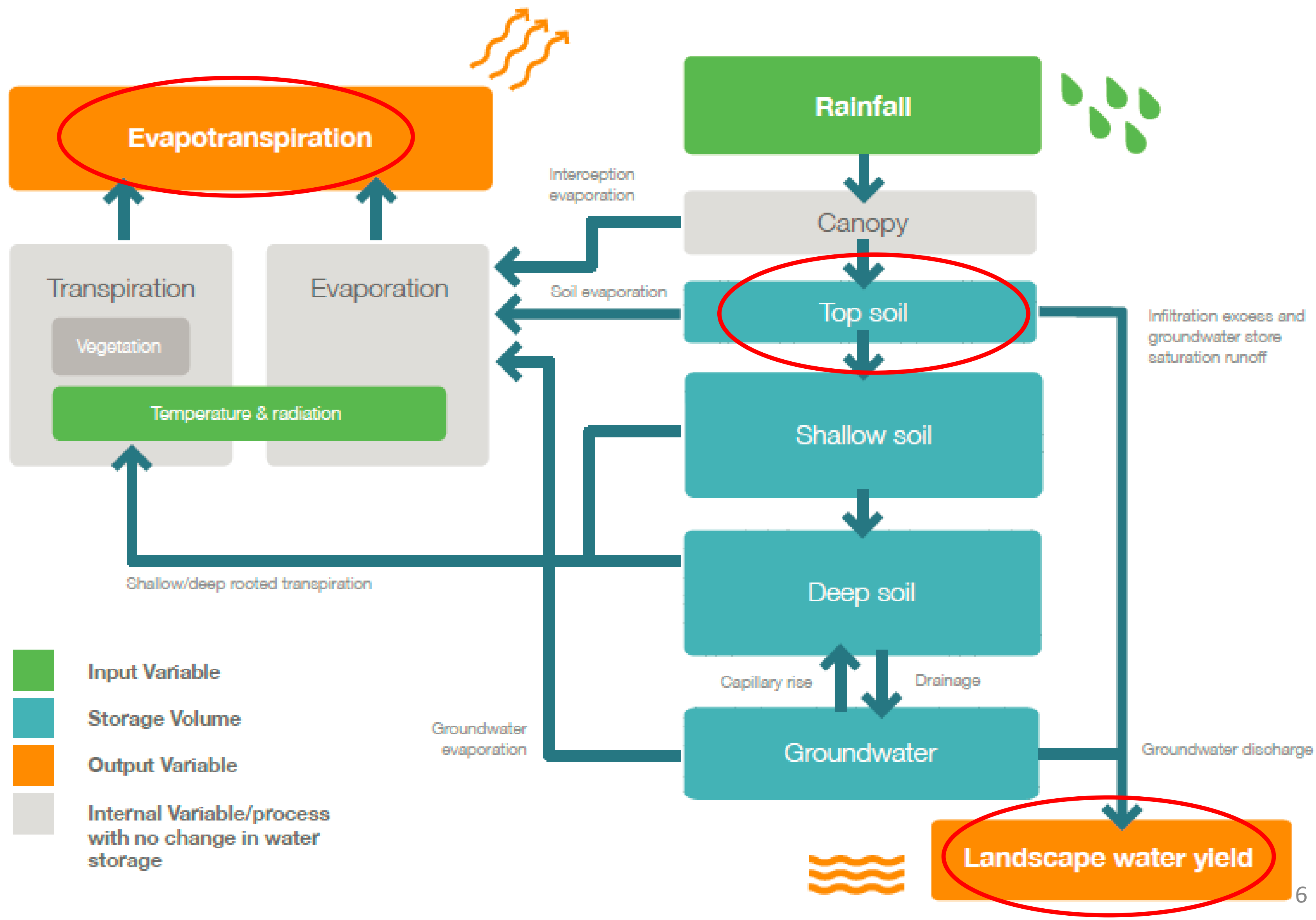


Figure 2.2 Decile rankings of modelled annual average soil moisture for 2011–12 with respect to the 1911–2012 record



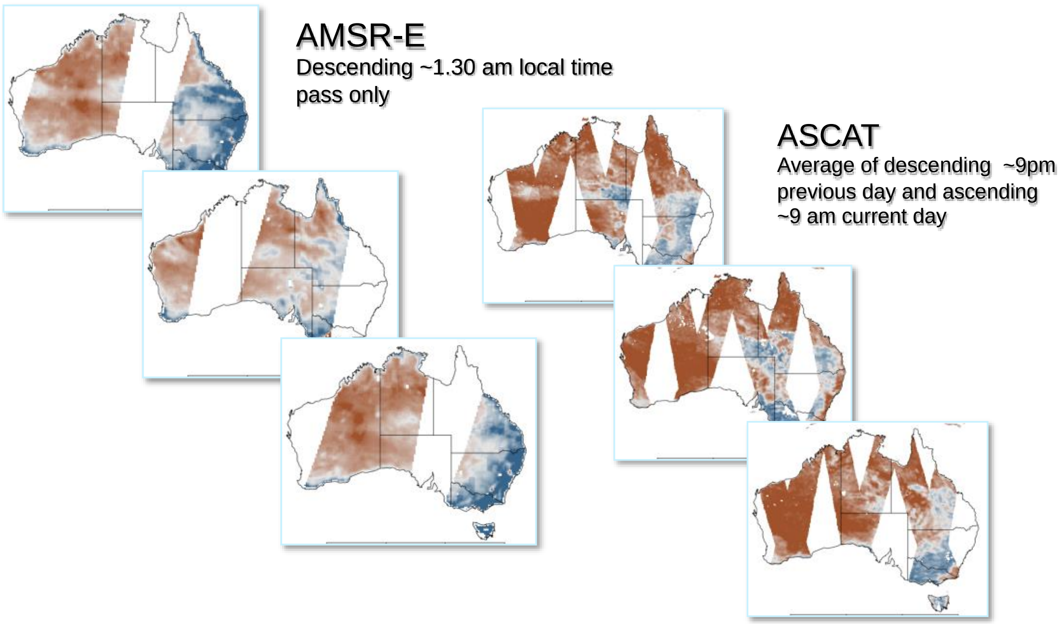
Australian Water Resources Assessment system Landscape (AWRA-L) model

CSIRO / Bureau of Meteorology



Method

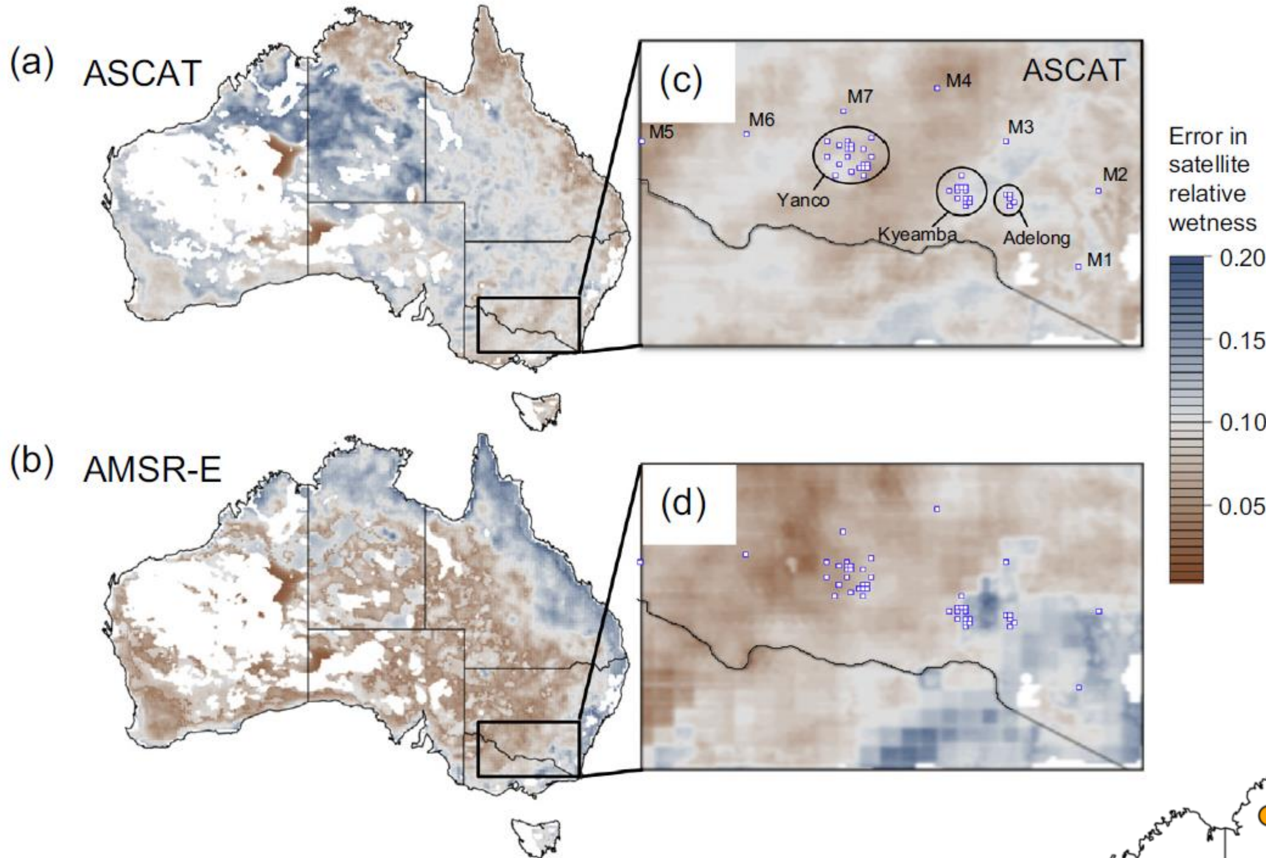
- Perturbed meteorological forcing
- ensemble Kalman filter
- AMSR-E and ASCAT-derived near-surface soil moisture
- AWRA-L model
- ensembles of daily top-layer and shallow root-zone soil moisture analyses for Australia at 0.05°

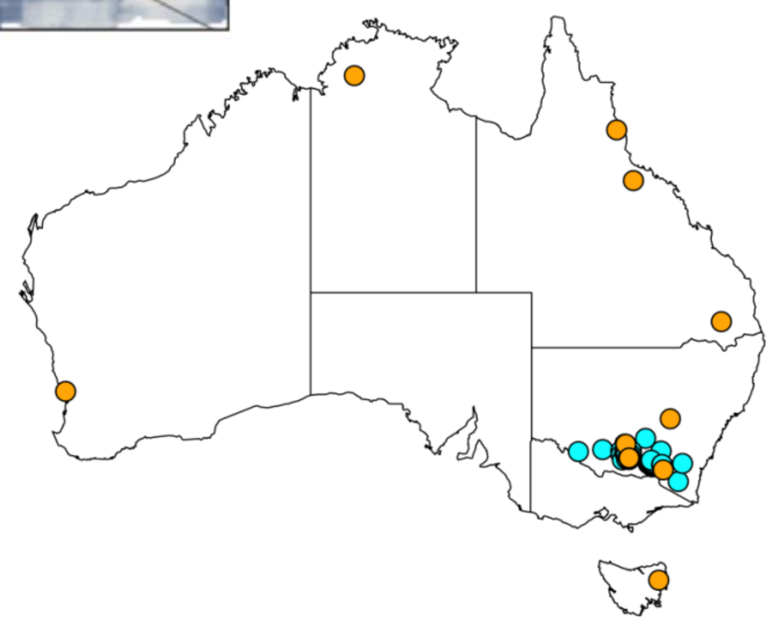


Evaluated against:

- in situ moisture measurements in southeast Australia (OzNet)
- new network of cosmic ray moisture probes (CosmOz)

Renzullo J Hyd 2014





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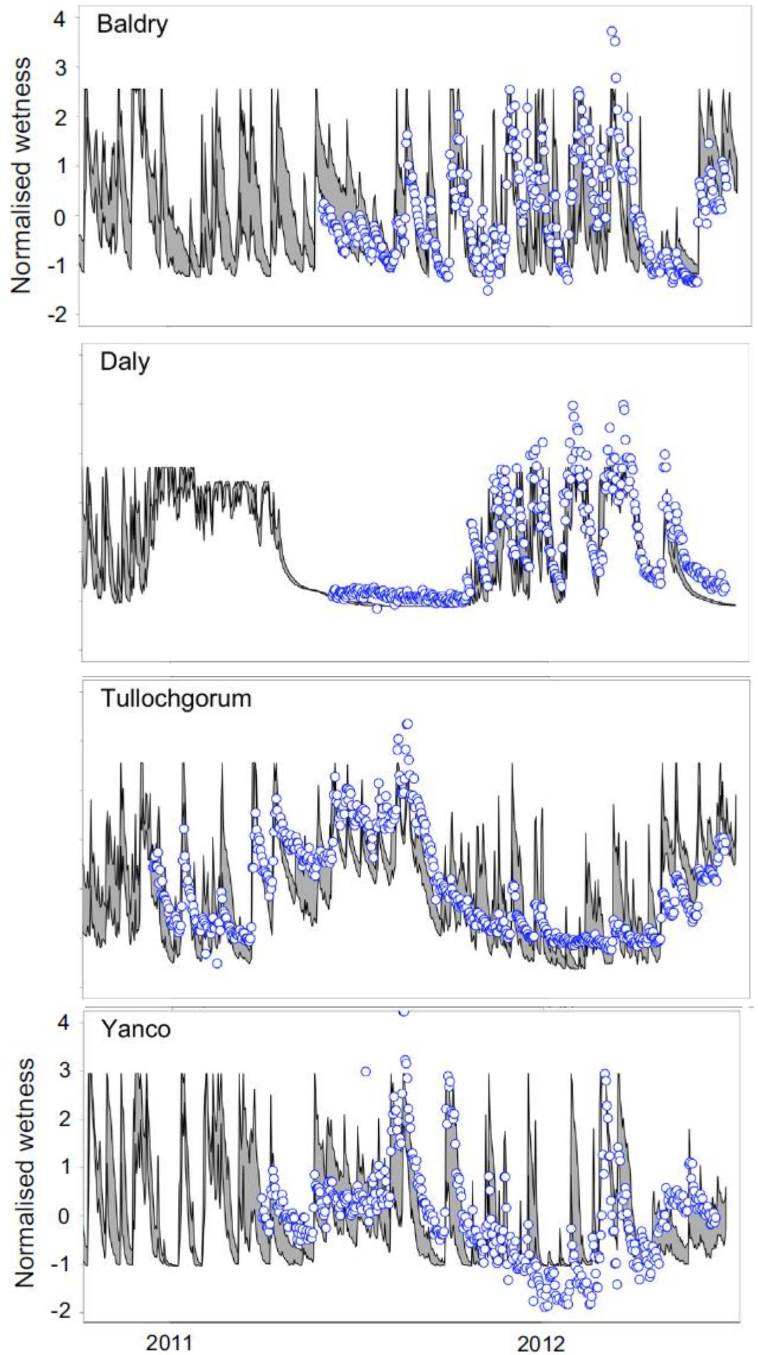
- new network of cosmic ray moisture probes (**CosmOz**)

Renzullo J Hyd 2014

AWRA root-zone moisture (open loop; shaded band)

Cosmic-ray probe soil moisture (blue dots)

- Already good agreement
- Model misses wet and sometimes dry extremes



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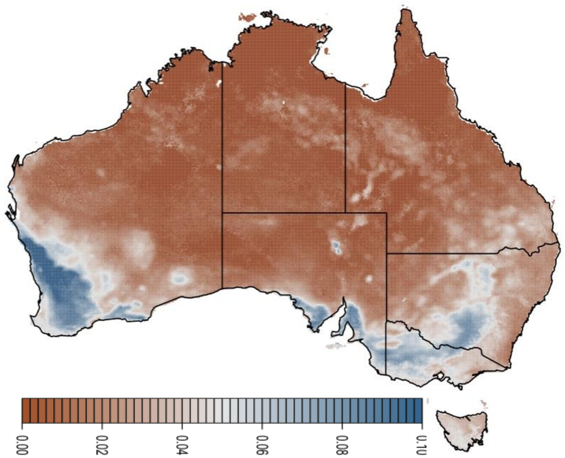
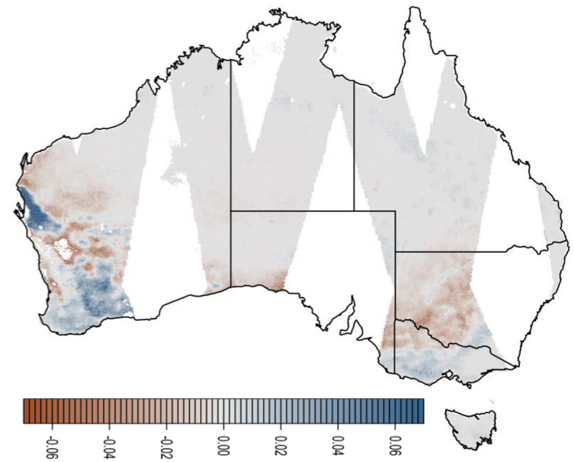
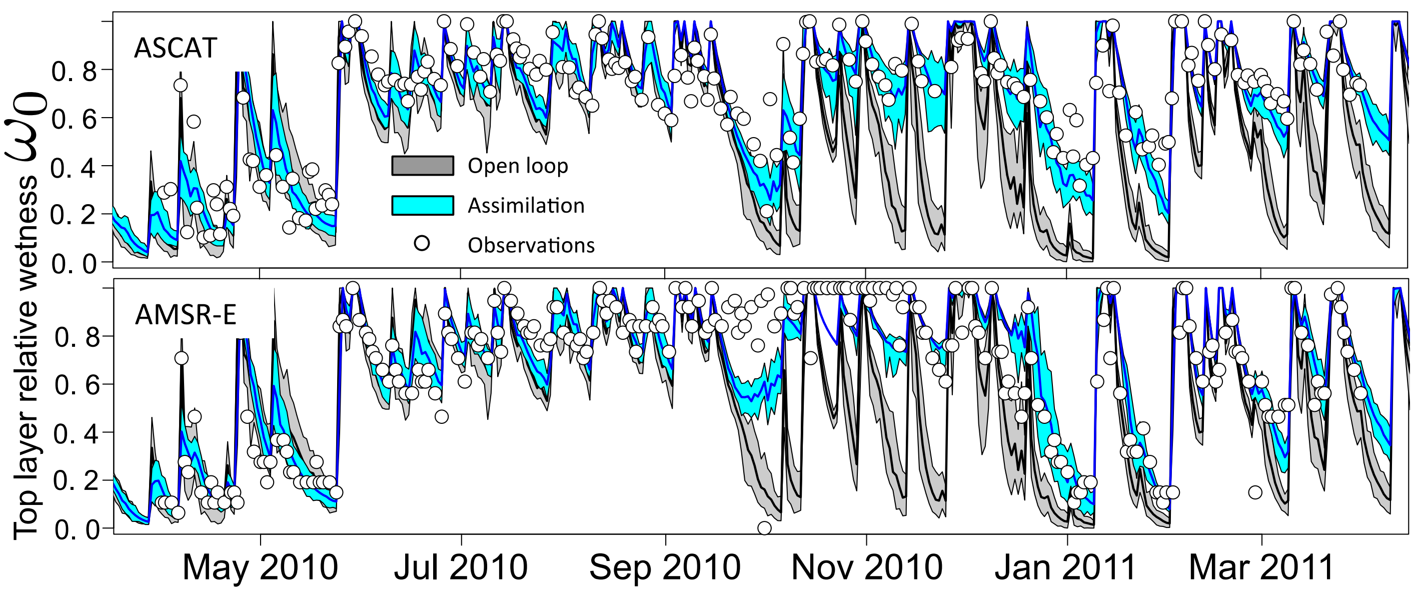
Relative wetness for 7 July 2009 (median)



Analysis increment





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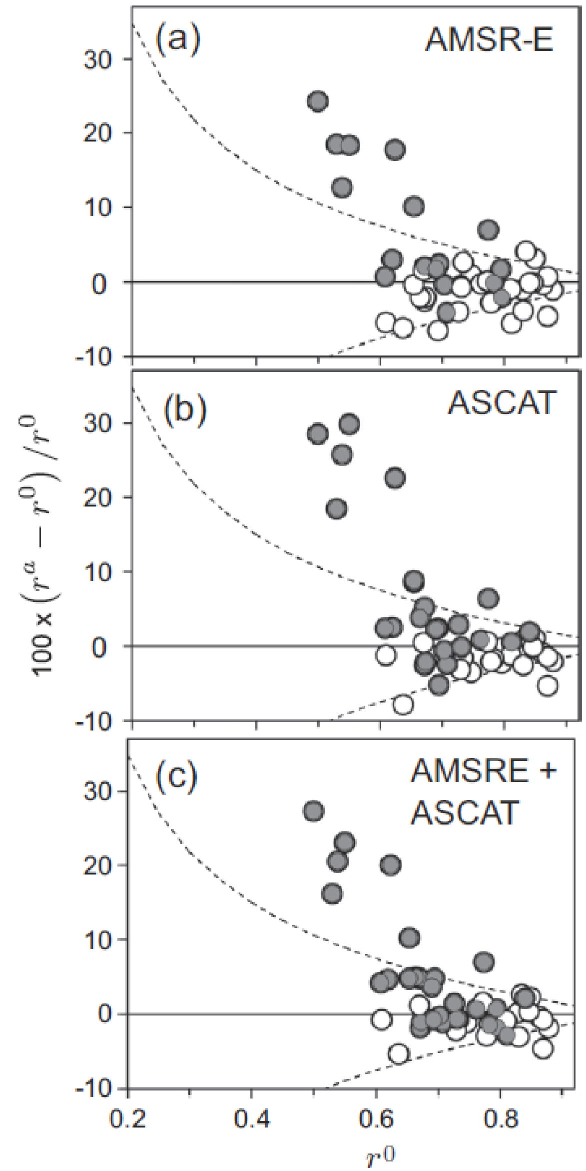
AWRA root-zone moisture estimates correlation against in situ probes increases (r^a) as a result of assimilating satellite observations



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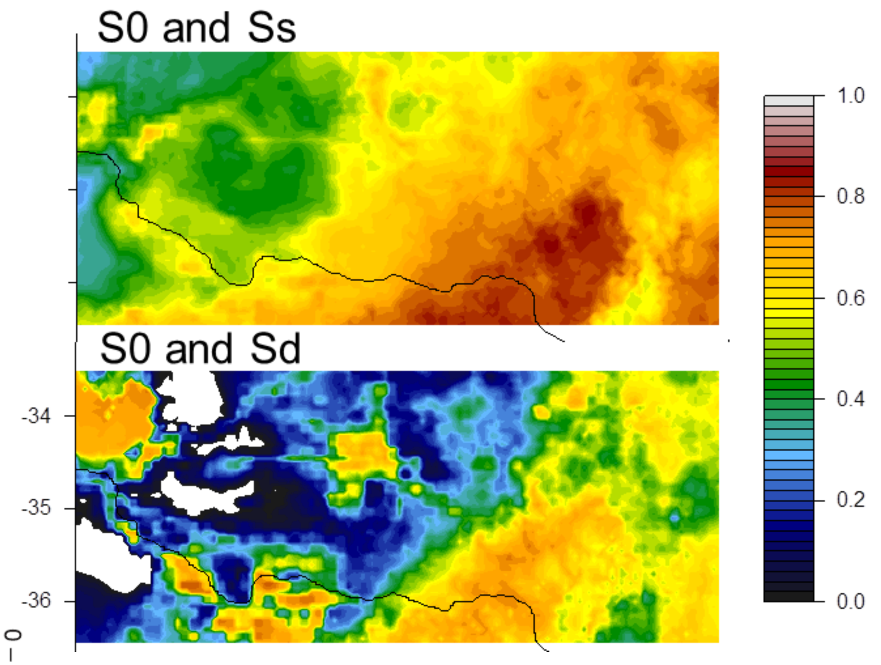
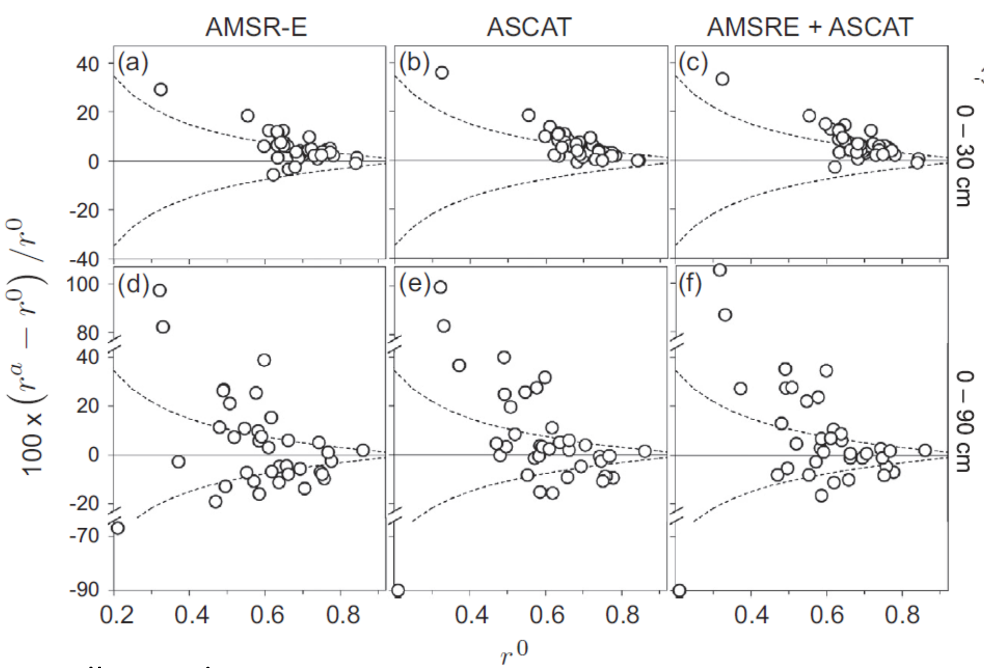
Does the benefit propagate to deeper layers?

Not really. Partly, that is a lag and temporal averaging issue.

Implications for ***temporal*** DA scheme design?

Vertical coupling





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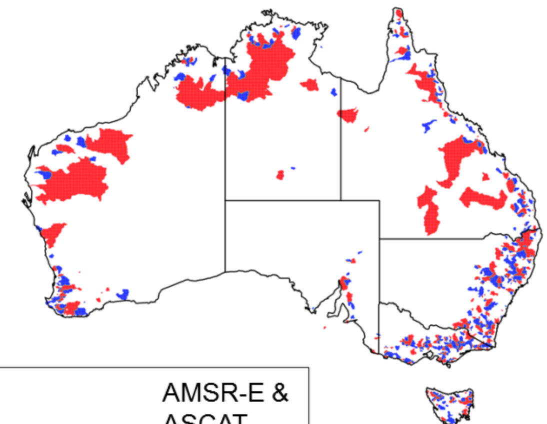
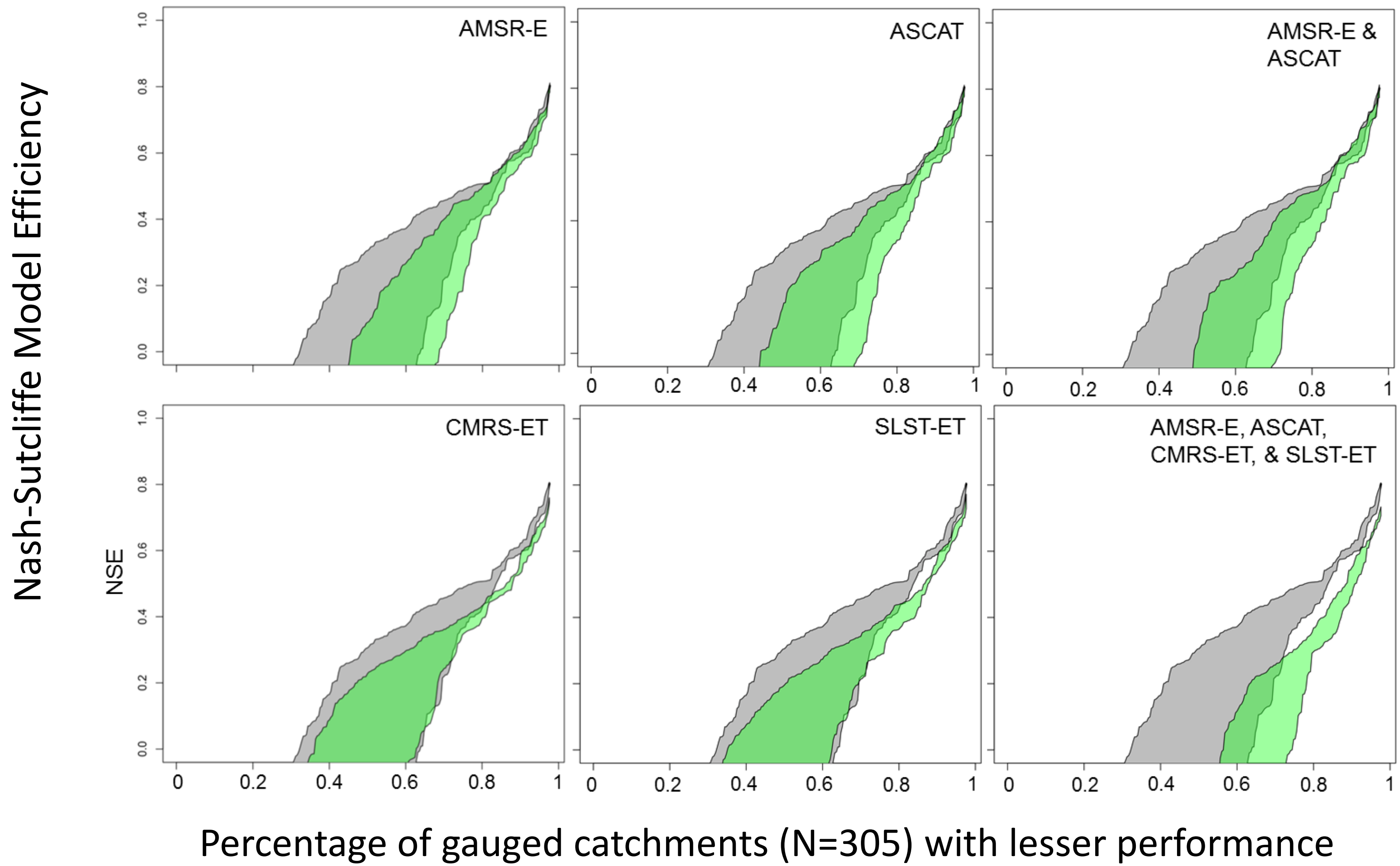
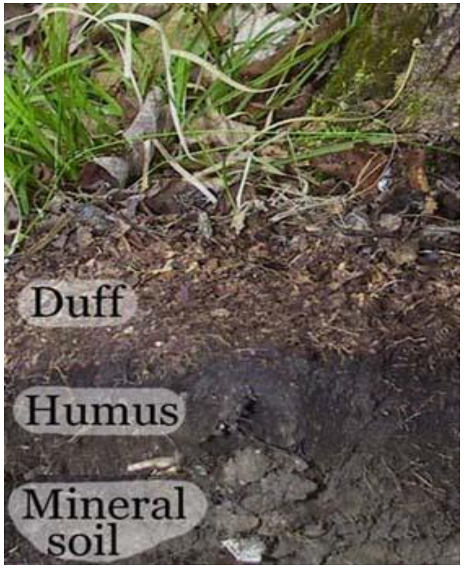
Does assimilating satellite soil moisture (AMSR-E, ASCAT) or satellite ET (CMRS-ET, SLST-ET) improve daily streamflow estimates?

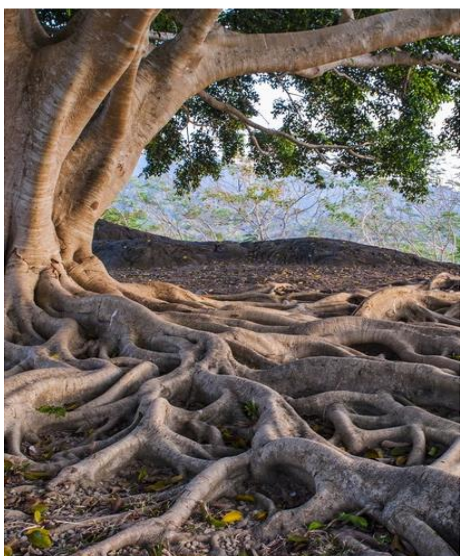
No – they are insufficiently strongly coupled.

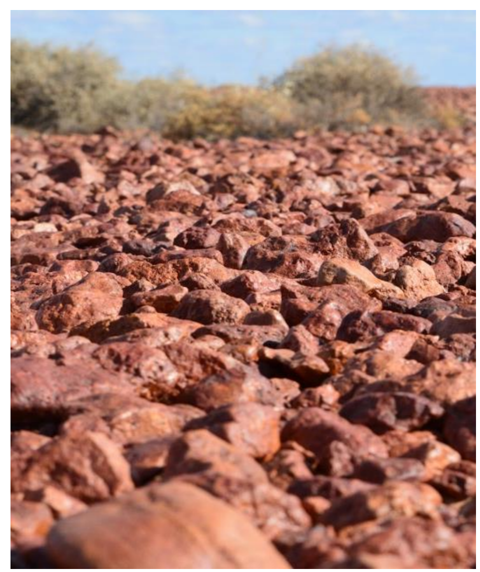


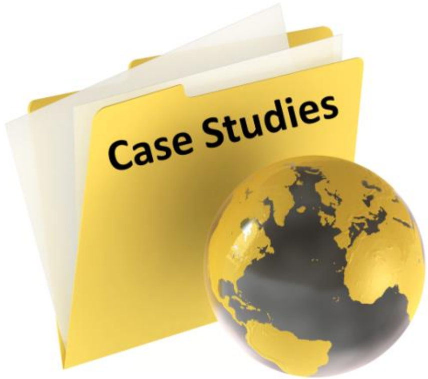


Some reasons why "absolute" soil moisture is irrelevant

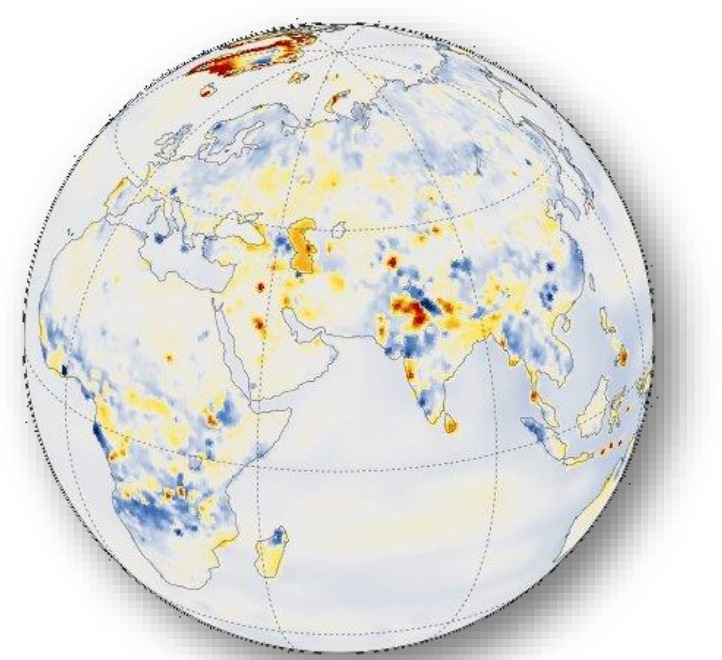






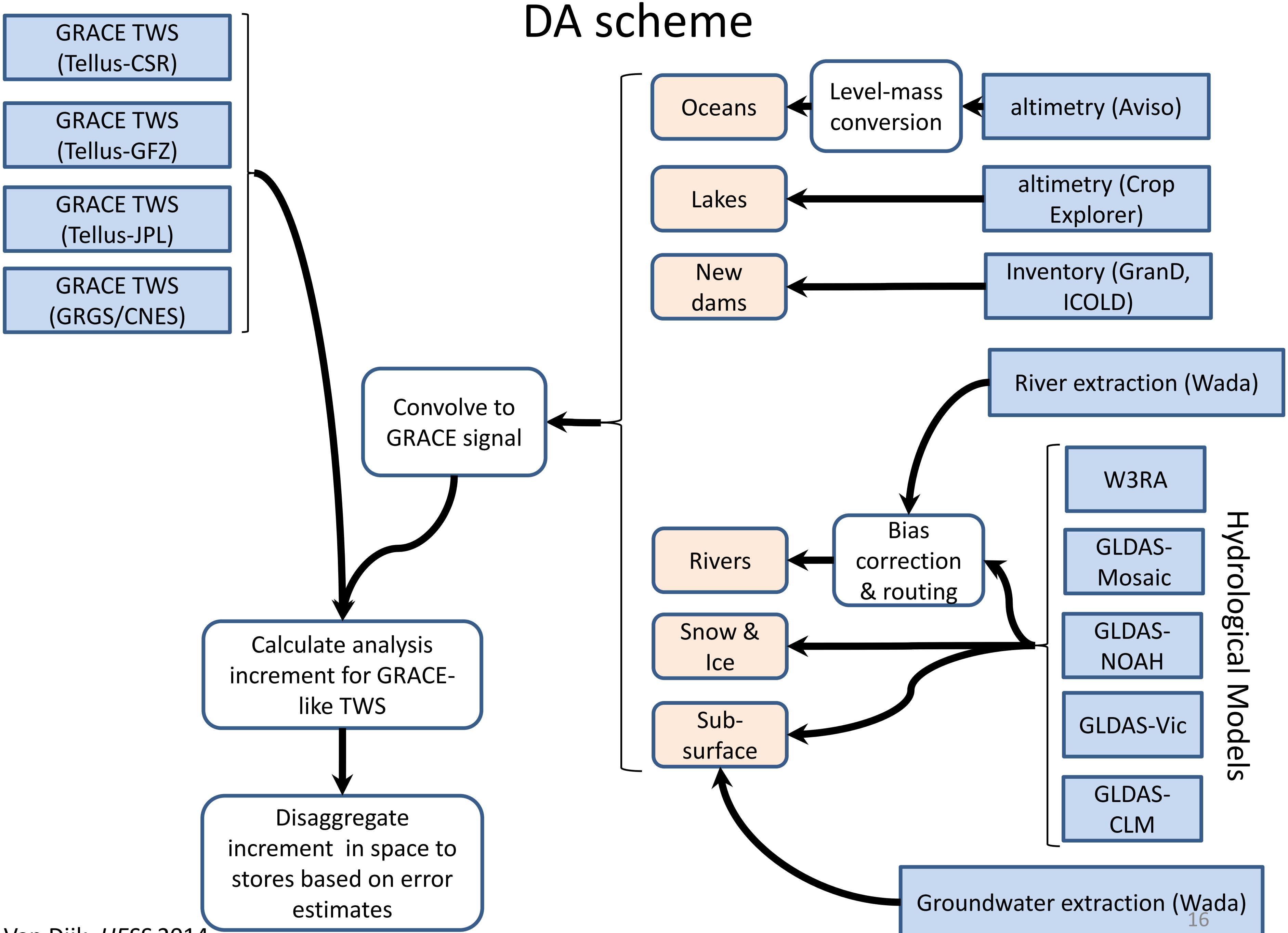


A global water cycle reanalysis (2003–2012) merging satellite gravimetry and altimetry observations with a hydrological multi-model ensemble

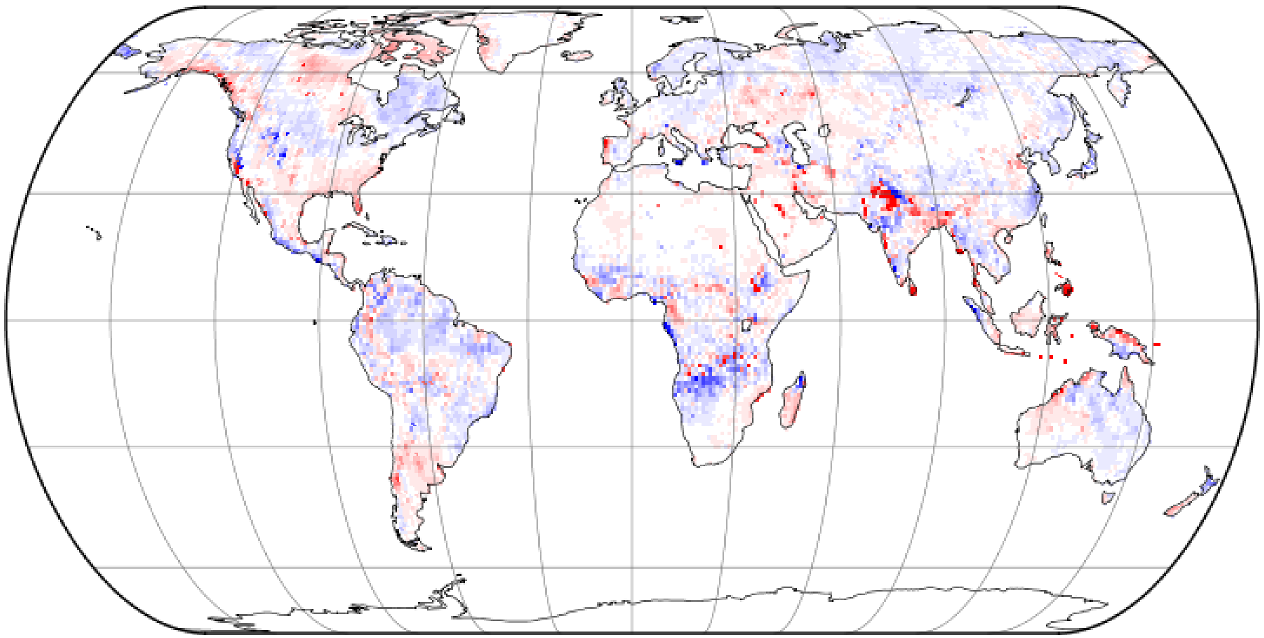


A van Dijk, LJ Renzullo, Y Wada, P Tregoning (2014). *Hydrology and Earth System Sciences* 18 (8), 2955-2973

DA scheme

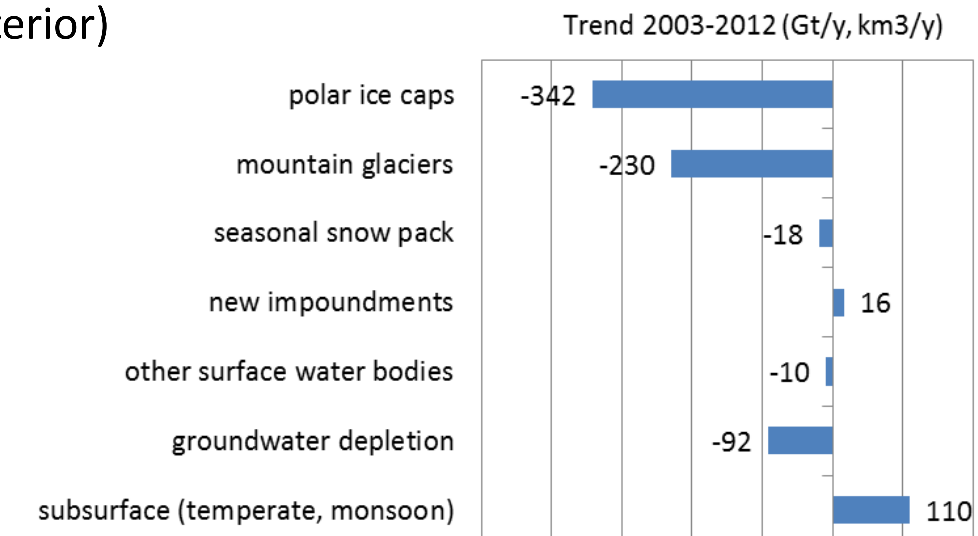


Van Dijk, *HESS* 2014



Trends in seasonal anomalies in sub-surface water storage (posterior)

Main change terms in global water budget



Van Dijk, *HESS* 2014

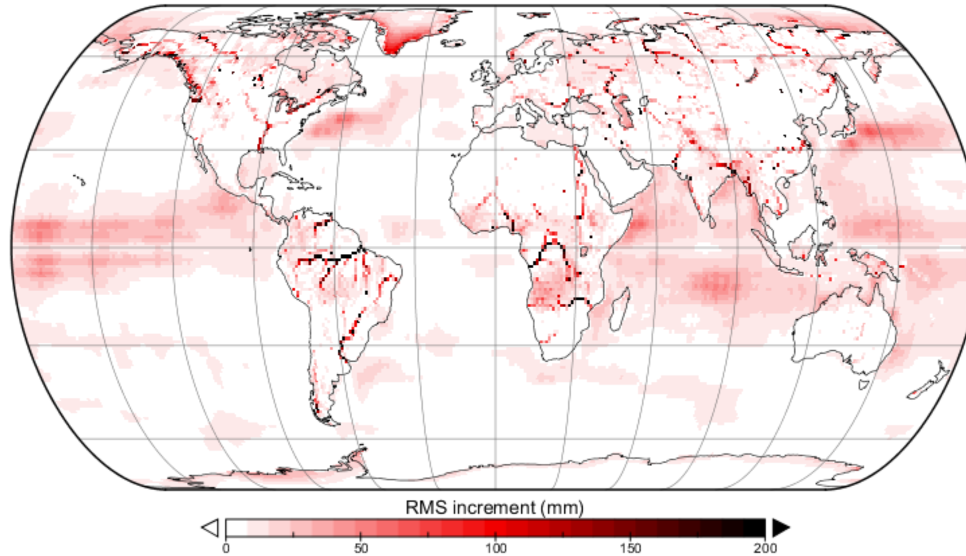
Impact of GRACE data assimilation

Greatest adjustments:
- large rivers
- ice sheets
- glaciers
- seasonal tropics

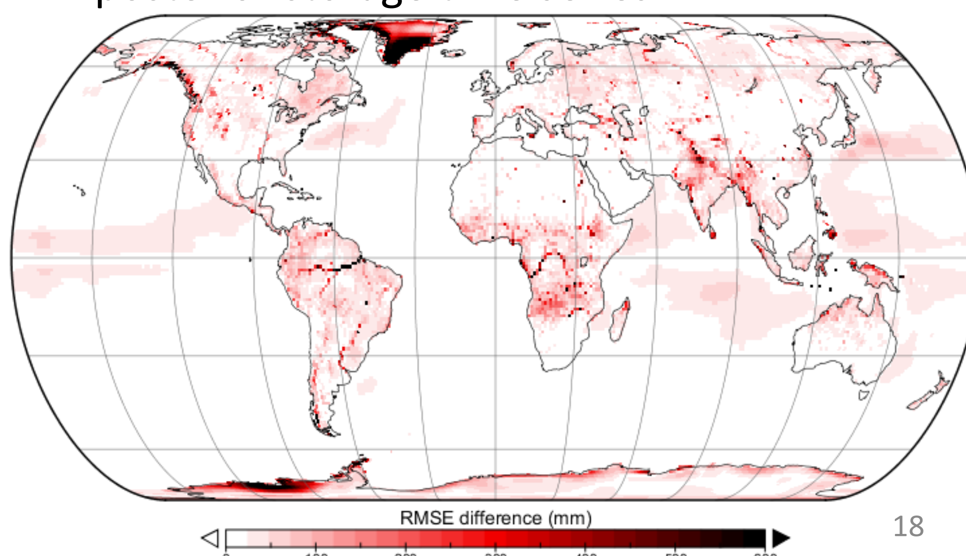
Typically, one water balance term (i.e. the least constrained) ‘sucks up’ all the innovation.

Indicative of greatest model deficiencies

root mean square (RMS) analysis increment



RMS difference between prior and posterior storage time series.



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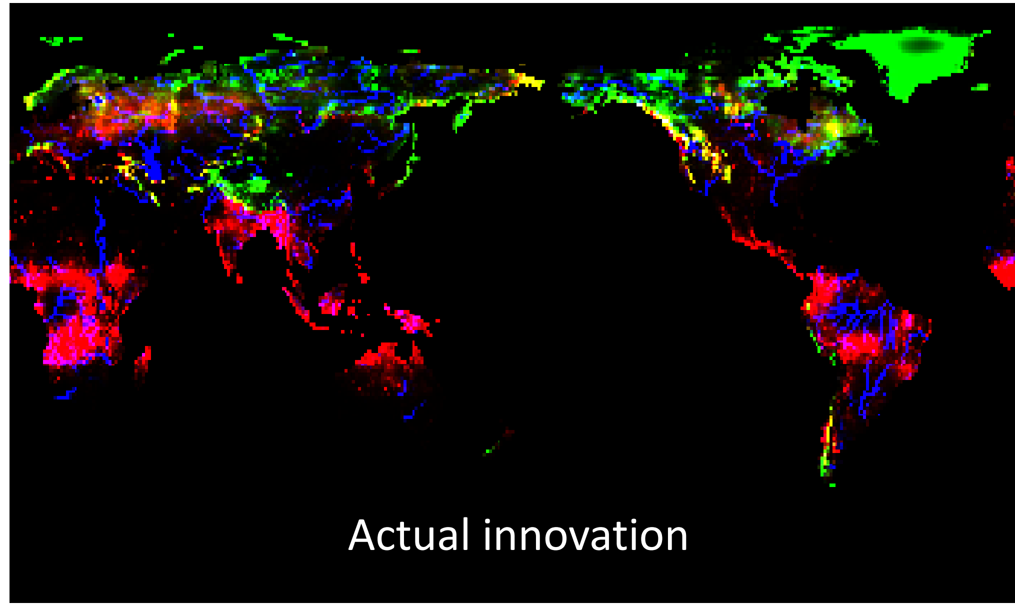

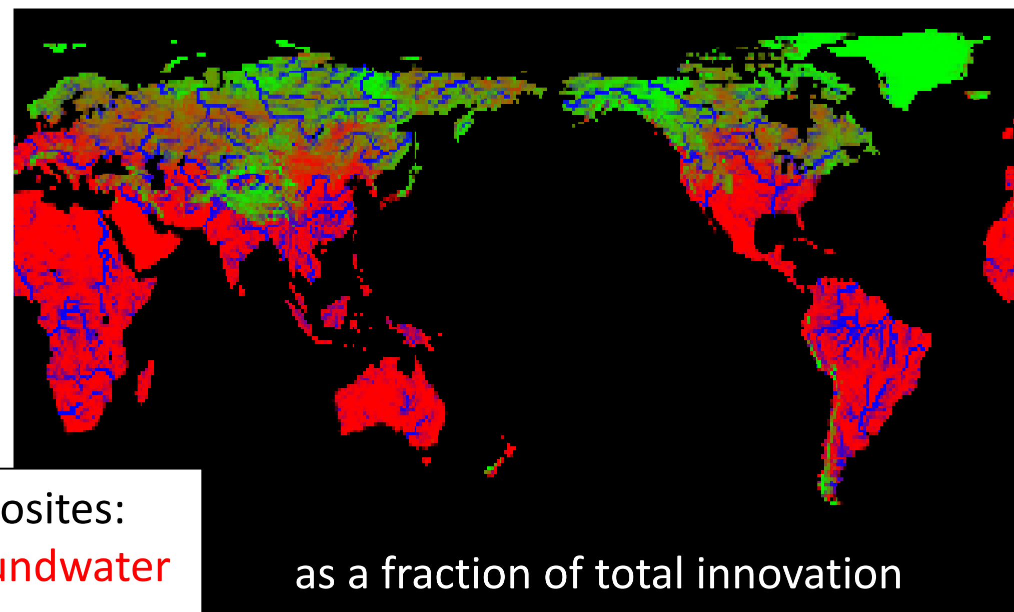

RGB composites:
soil & groundwater
snow & ice
rivers & lakes

Van Dijk, *HESS* 2014

Summary

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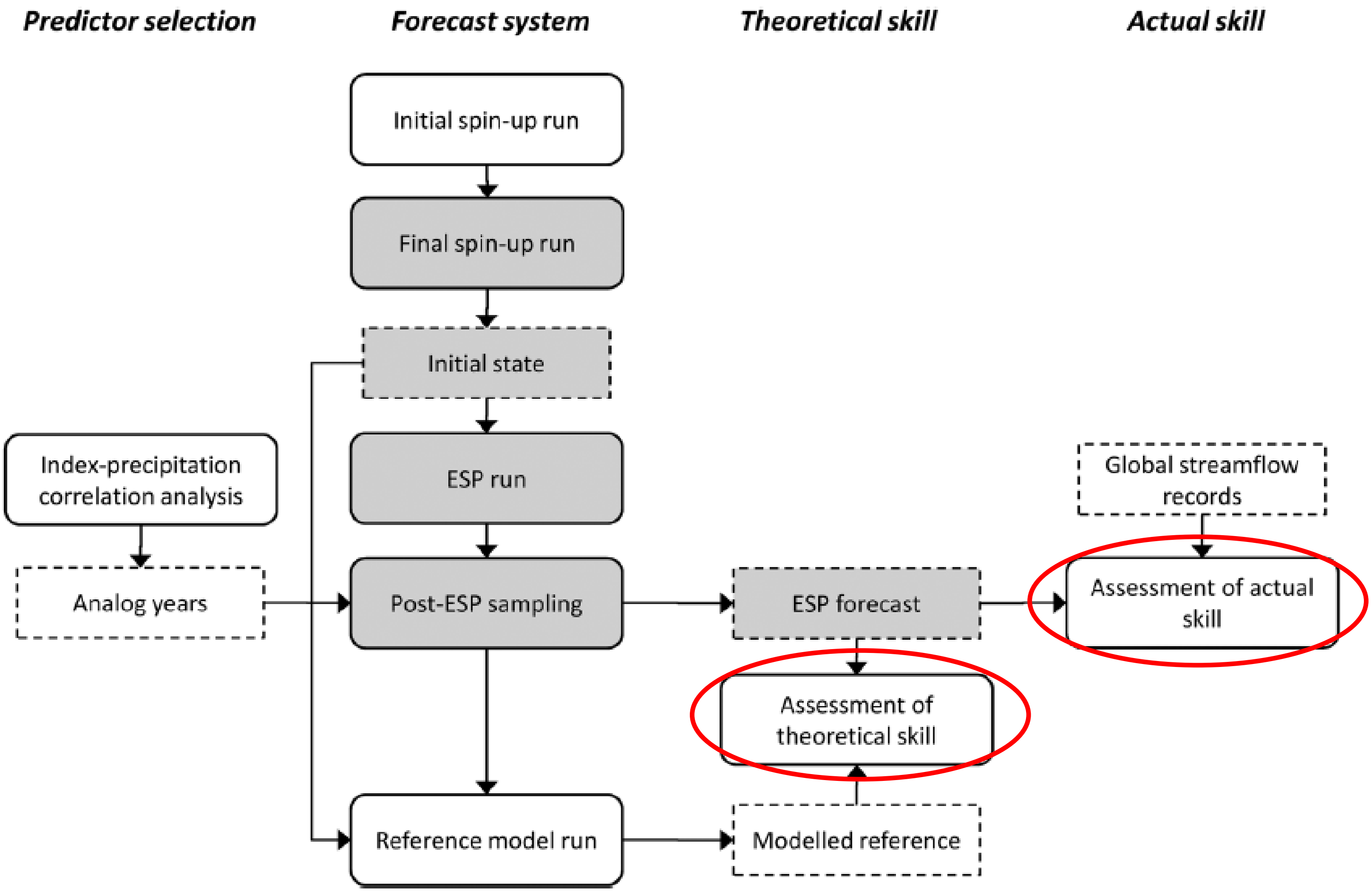
Global analysis of seasonal streamflow predictability using an ensemble prediction system and observations from 6192 small catchments worldwide

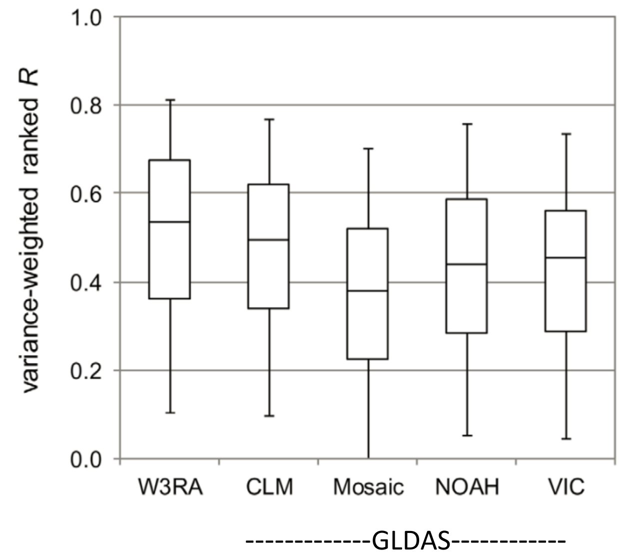
van Dijk, A. I. J. M., J. L. Peña-Arancibia, E. F. Wood, J. Sheffield, and H. E. Beck (2013)
Water Resources Research 49, 2729–2746, doi:10.1002/wrcr.20251.

Approach: conditional ESP

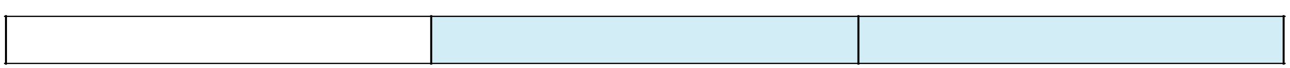


Configuration

- Meteorological forcing: 1° daily, 1948-2008 (Sheffield et al., 2006, *J Clim* 19): precipitation, incoming shortwave radiation, max and min daily temperature
- Hydrological model W3RA v1: fairly simple model based on
  - AWRA v0.5 (Van Dijk & Renzullo, 2011, *HESS* 15)
  - HBV-96 snow module (Lindström et al., 1997, *J Hyd* 201)
  - inputs: forest cover, wind speed, albedo climatologies



- Climate indices (Nino3.4, SOI, IOD, PDO, PC-NAO, STR, S-NAO,EA, WP, EP/NP, PNA, EA/WR, SCA, TNH, PL, PT, NP, SAM)
- (Re-)forecast configuration
  - two-month total streamflow
  - forecast date 1 Jan, Mar, May, Jul, Sep, Nov of years 1979-2008
  - analogues sampled from preceding 30 years



April 1980
climate index

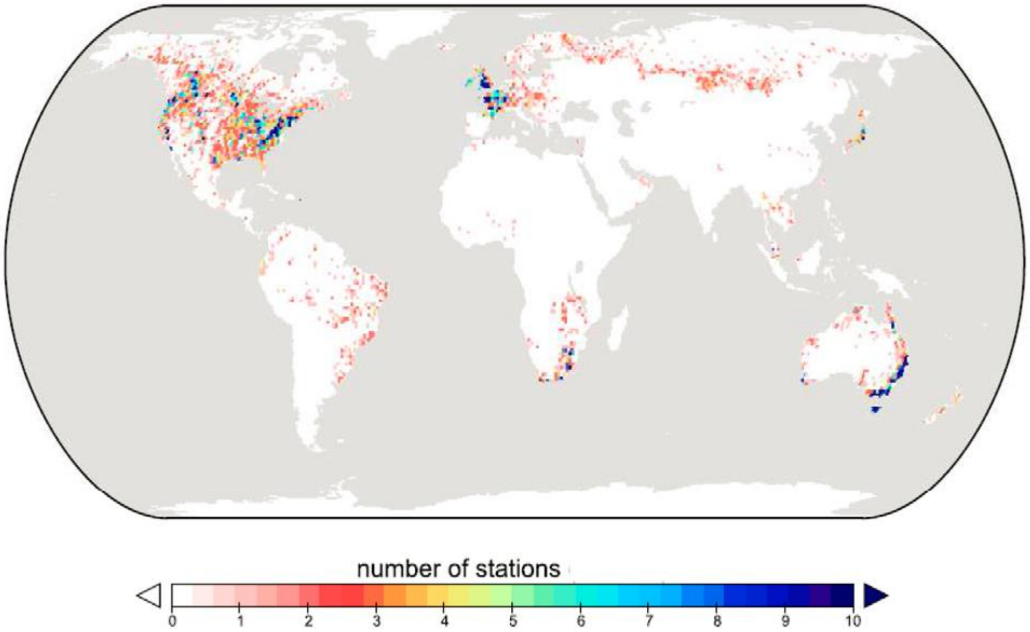
1 May 1980
forecast date
(initial state)

31 Jun 1980
end forecast period

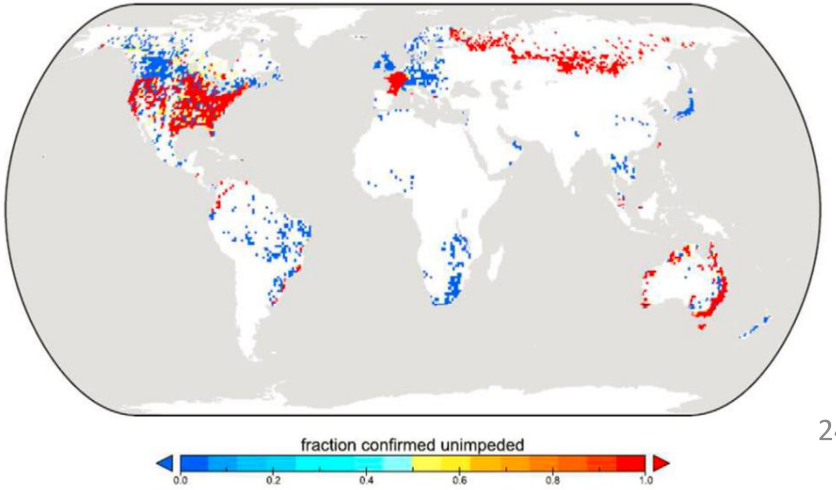
Streamflow data

- Source: GRDC, MOPEX, Min. Environment France, WIRADA
- >12 years of data
- <10,000 km^2
- 6192 catchments
- the usual bias towards OECD countries

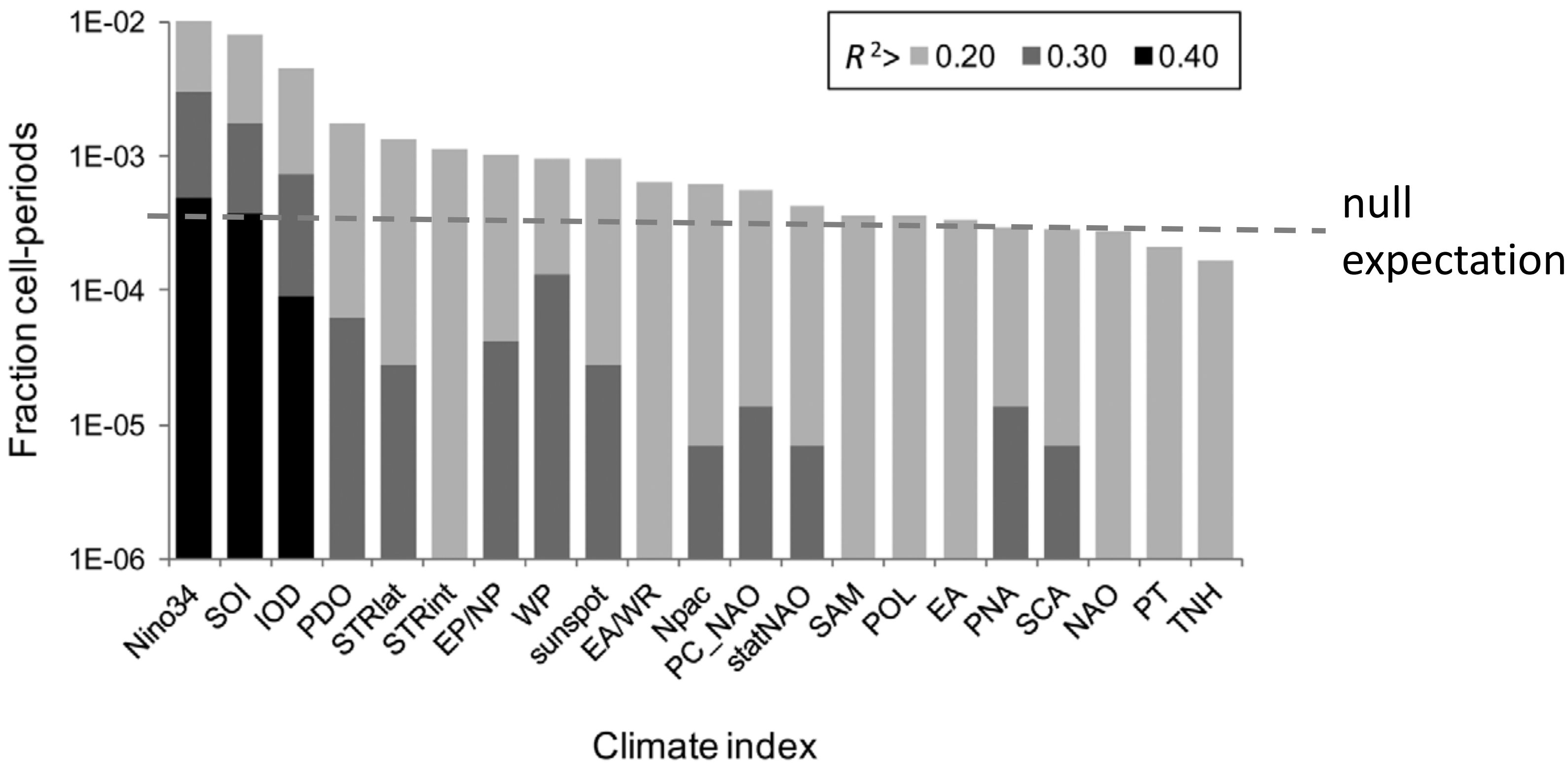
Distribution of stations



Unimpeded vs unknown

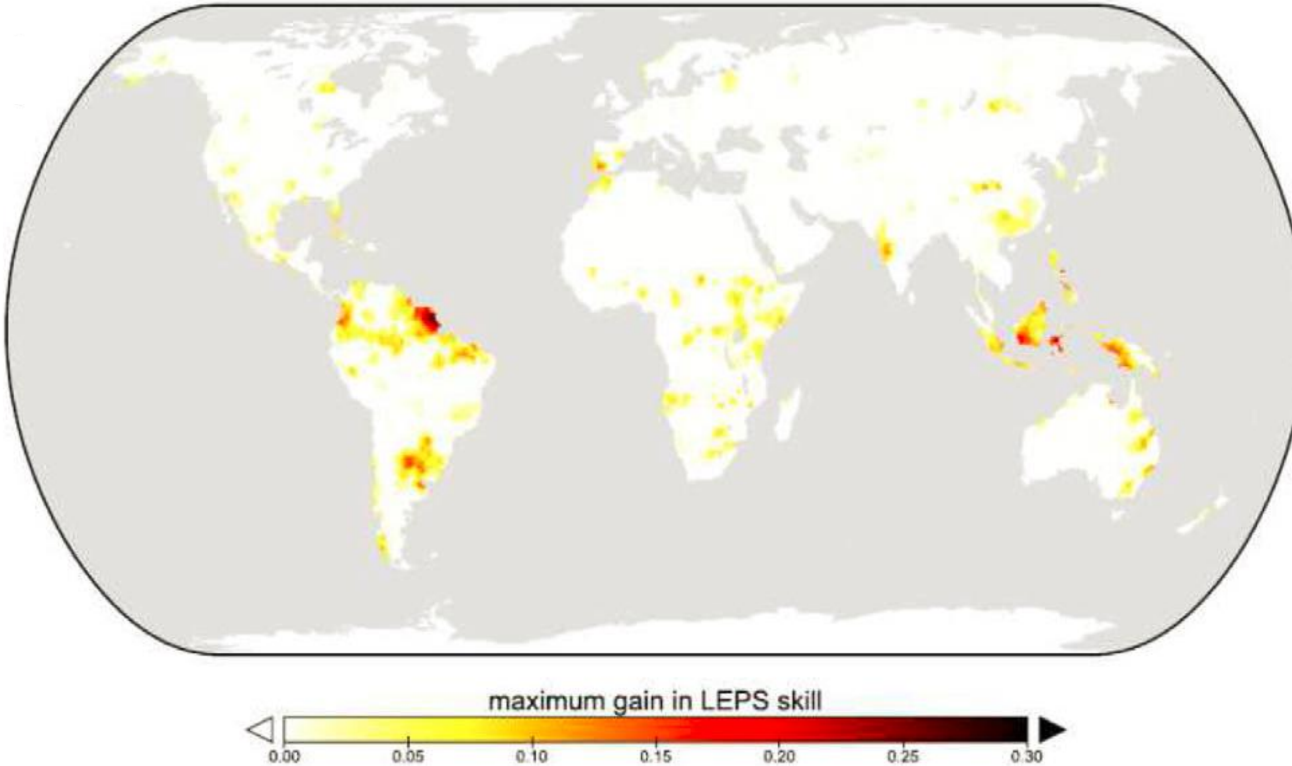


Climate predictor selection



Frequency of exceedance of different r^2 thresholds for the 21 climate mode indices tested for each grid cell forecast period combination

Climate predictor selection



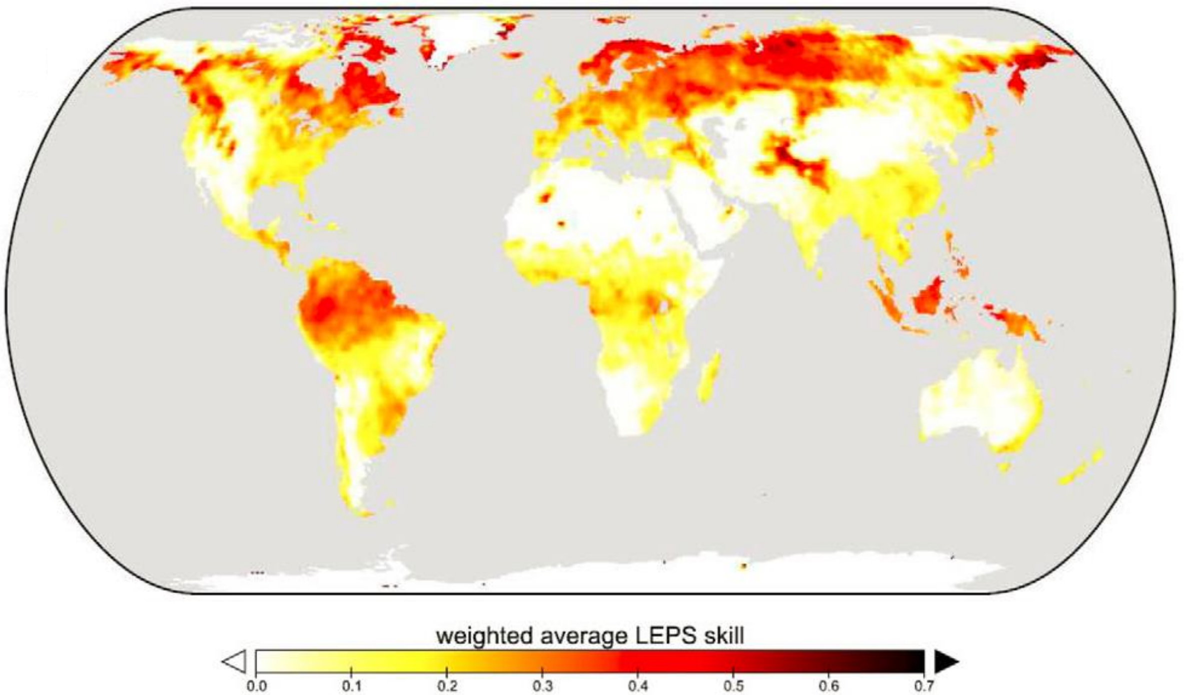
Contribution of climate indices to theoretical skill, calculated as the difference between LEPS skill with and without ensemble sampling based on climate index, resp.

Does that mean we cannot forecast streamflow 2 months out for most of the world?

Theoretical streamflow forecast skill

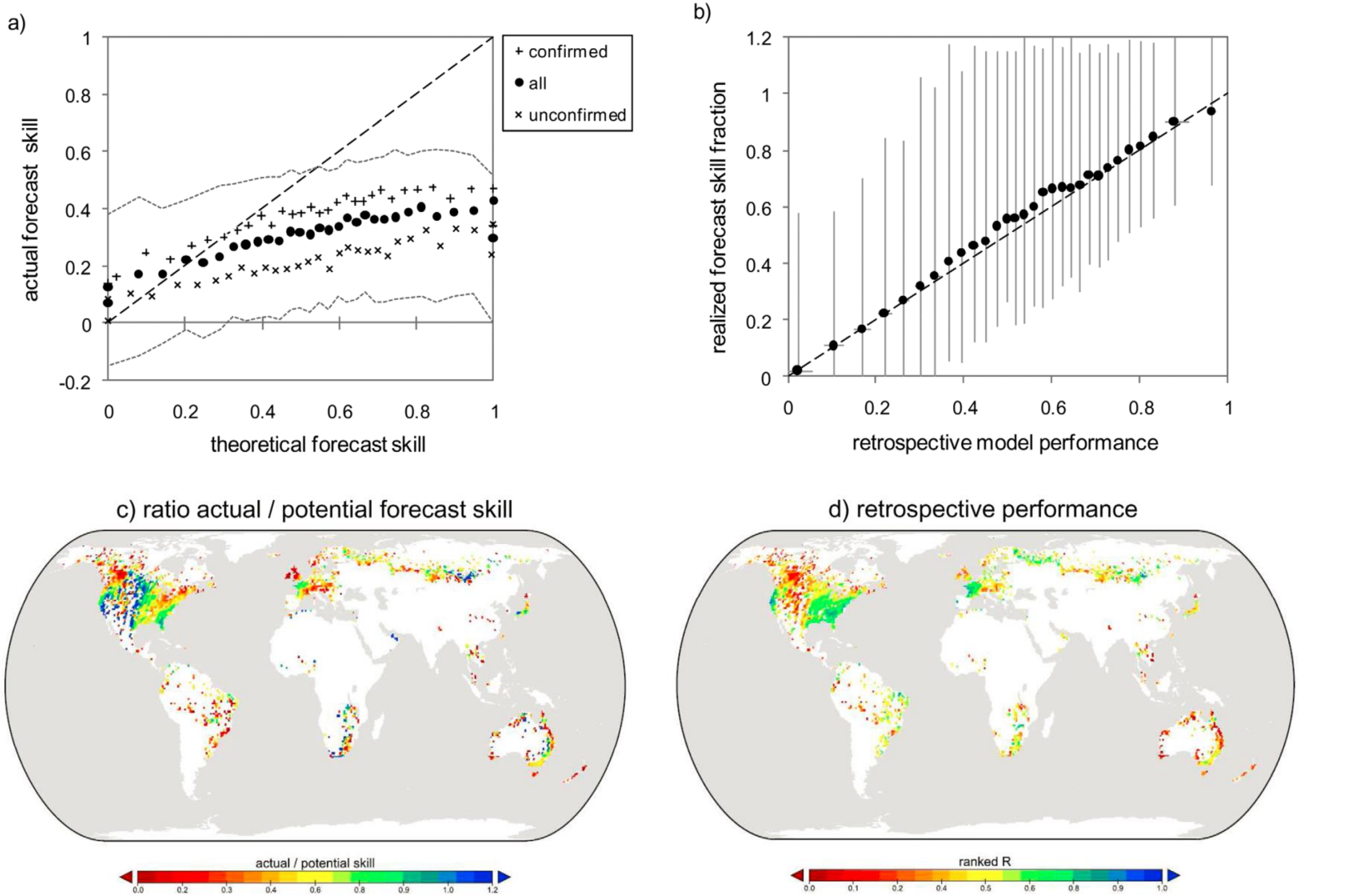
Of course not.

It does mean that hydrological initial state (water storage) typically contributes more to skill than does ESP conditioned by climate index.



Summary metrics of theoretical skill over the six forecast periods calculated as mean LEPS weighted by streamflow variance.

Verification:
How much of the theoretical skill can we realise?



Asia-Pacific Water Monitor

HOME DAILY TOTALS 30-DAY TOTALS ABOUT RELATED SITES

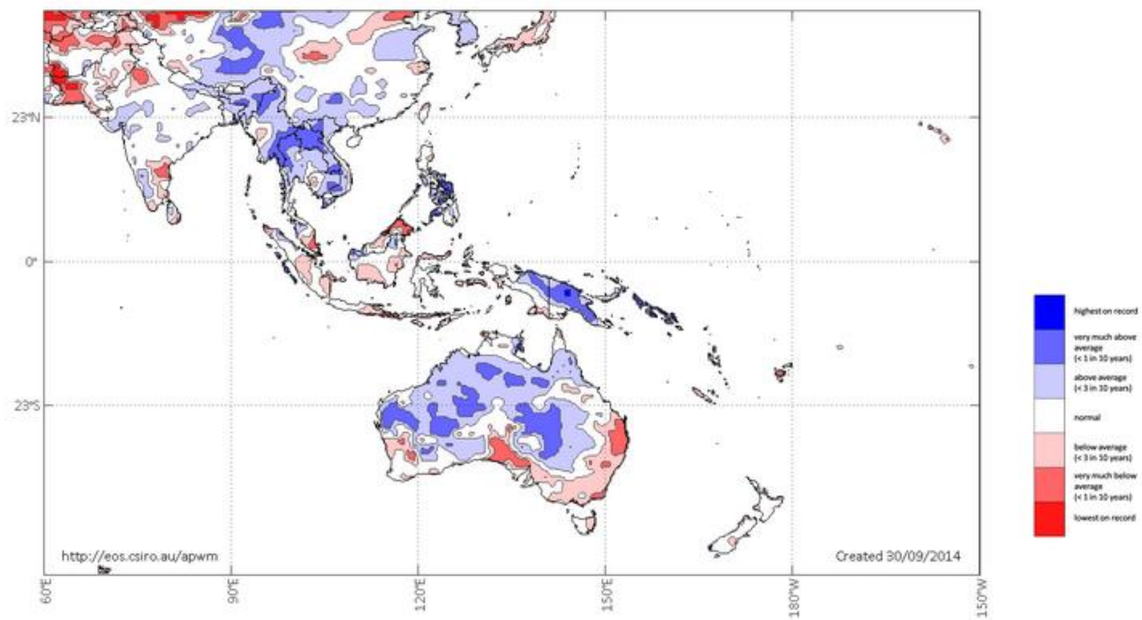
Daily Streamflow Deciles

Australian National University

CSIRO

Back to Daily Totals

Daily Streamflow Deciles
30 September 2014



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