Using satellite soil moisture in large-scale water resources estimation

an Australian perspective

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THE AUSTRALIAN NATIONAL UNIVERSITY

Australia: the largest country without an earth observation program

13) Australia

14) Mexico *

35) Colombia*

50) Qatar

WRESAT, 1967

"... the Australian Government does not see an Australian satellite manufacturing or launch capability as an essential element of its approach to assured access to critical space-enabled services. "

Australian Government Space Policy Unit

From satellite to product to decision

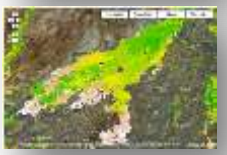
~~Mission design and operation~~

Sensor calibration

Satellite data products

Product validation

Information services



Use in decision making

Water Resources Account & Assessments

2.2.2 Key information

National water flows, stores and use indicators for 2011–12

Landscape water flows

	Australian average	Difference from 1911–2012 annual mean	Decile ranking wit 201
Rainfall	567 mm	+33%	10th – very mu
Evapotranspiration	483 mm	+30%	10th – very m
Landscape water yield	83 mm	+57%	10th – very m

Mean annual soil moisture (decile ranking with respect to the 1911–2012 record avera

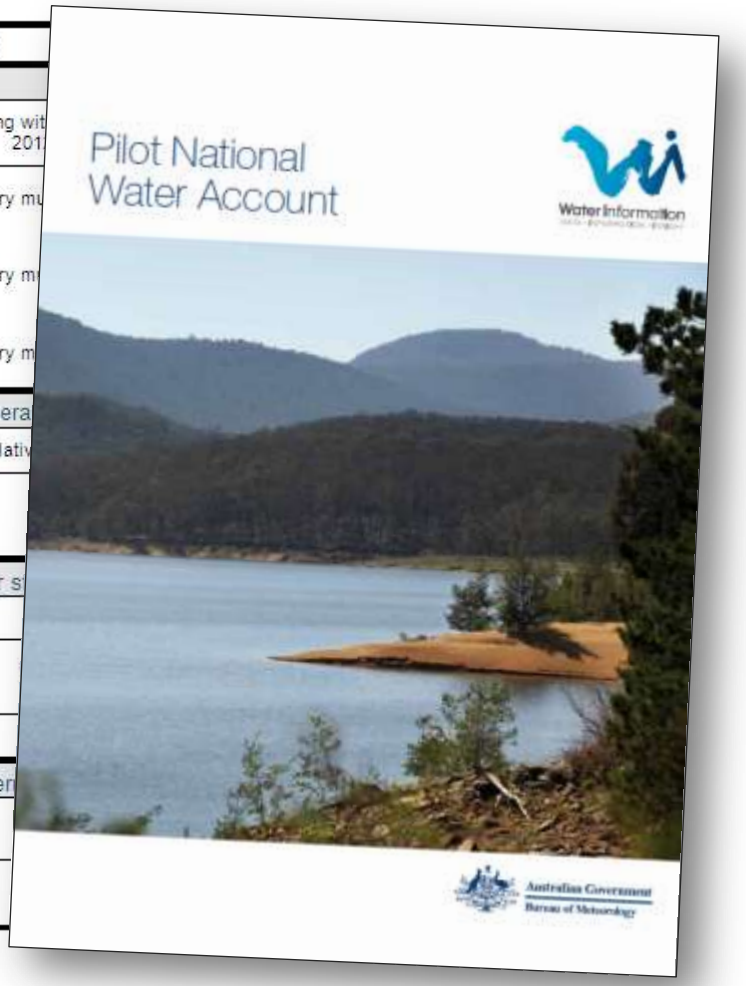
2011–12	2010–11	Relati
10th – very much above average	10th – very much above average	

Surface water storage (comprising about 94% of Australia's total surface water s

Total accessible capacity	30 June 2012		30 June 2011	
	accessible volume	% of total capacity	accessible volume	% of total capacity
79,700 GL	66,300 GL	75%	60,100 GL	83%

Urban water use (of the eight capitals of the Australian States and Ter

Total use in 2011–12	Total use in 2010–11
1,751 GL	1,736 GL



absolute SSM % not of interest

http://www.bom.gov.au/water/

Australian Government
Bureau of Meteorology

Water Resources Account & Assessments

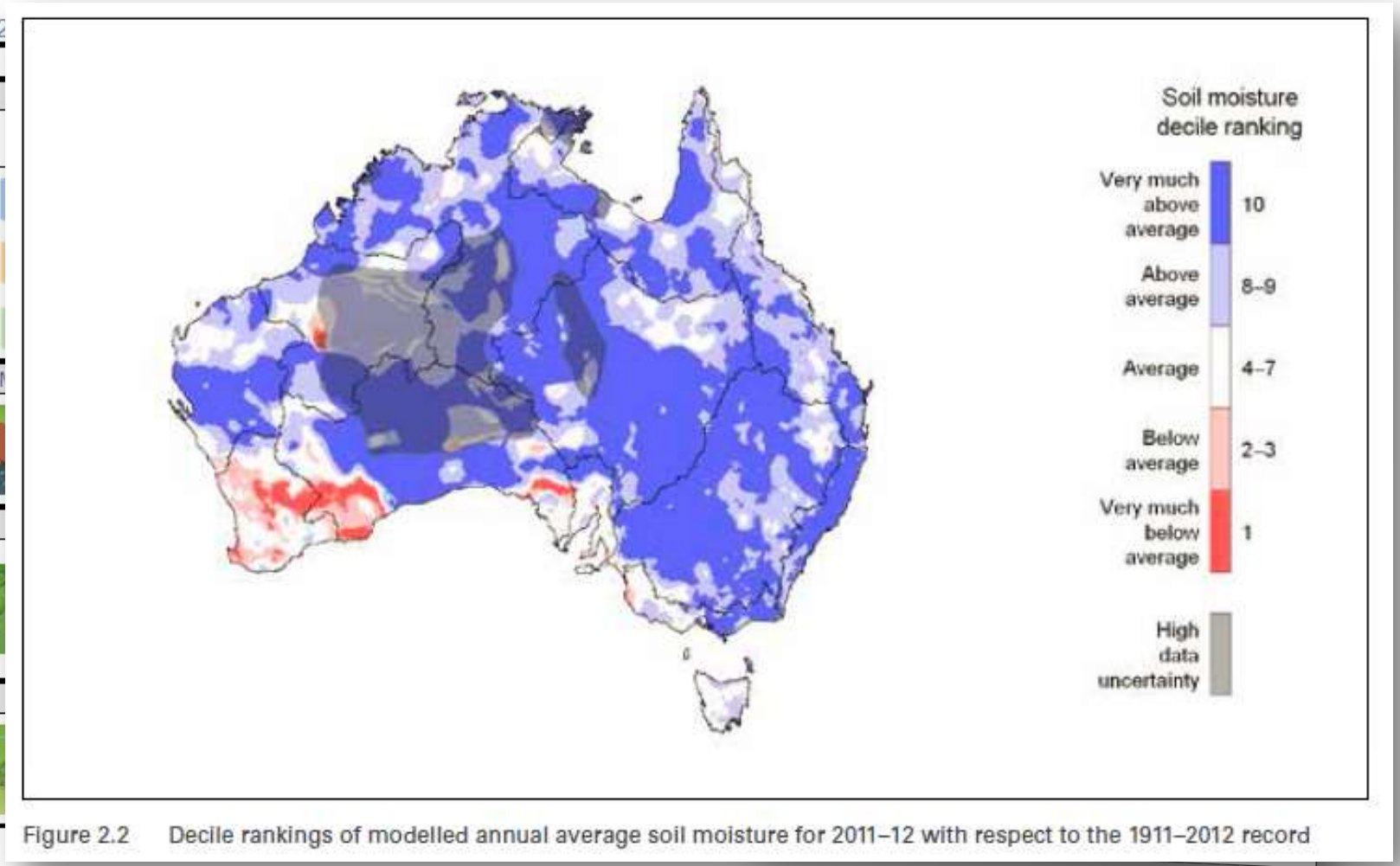


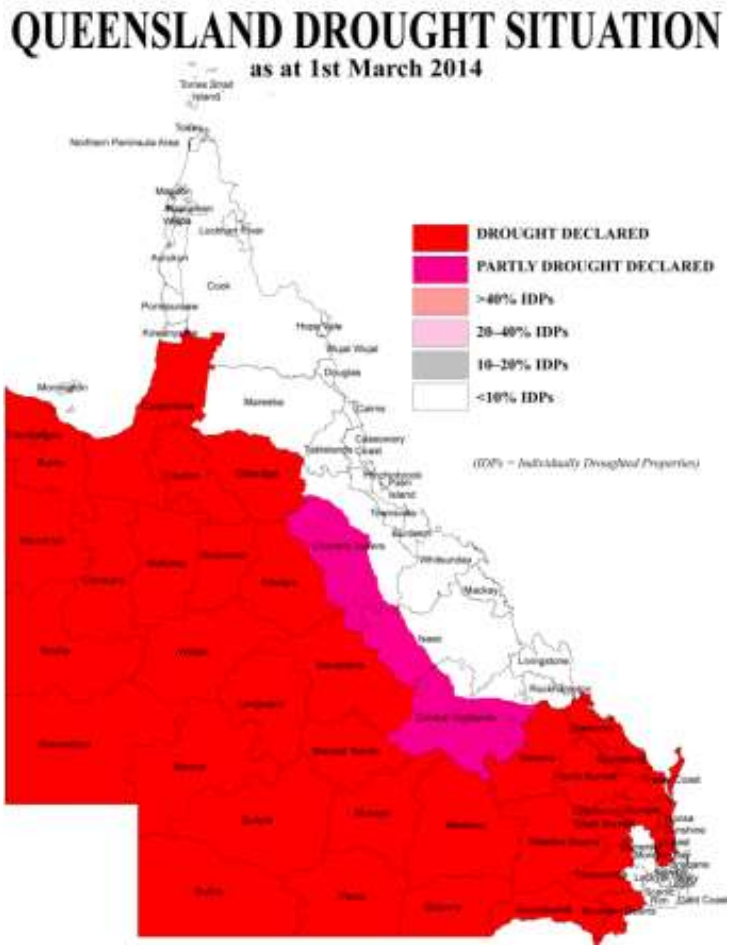
Figure 2.2 Decile rankings of modelled annual average soil moisture for 2011–12 with respect to the 1911–2012 record

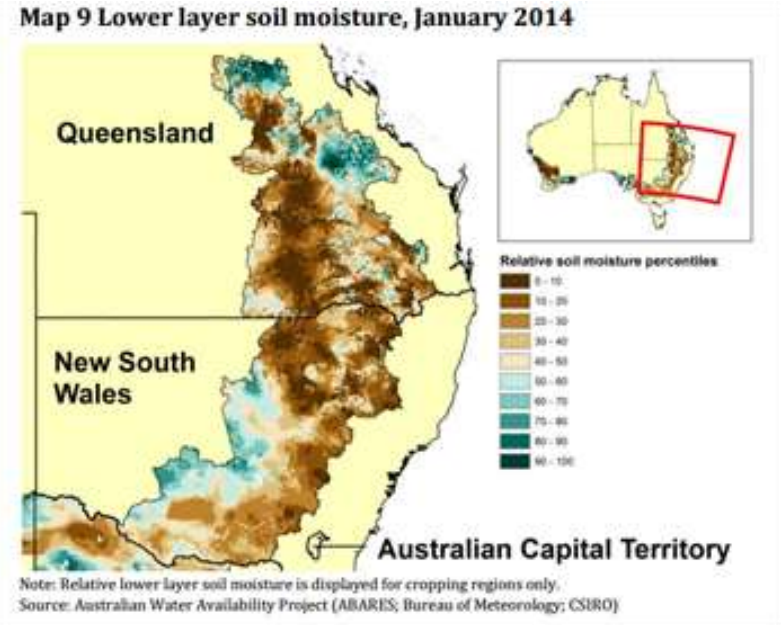
absolute SSM % not of interest

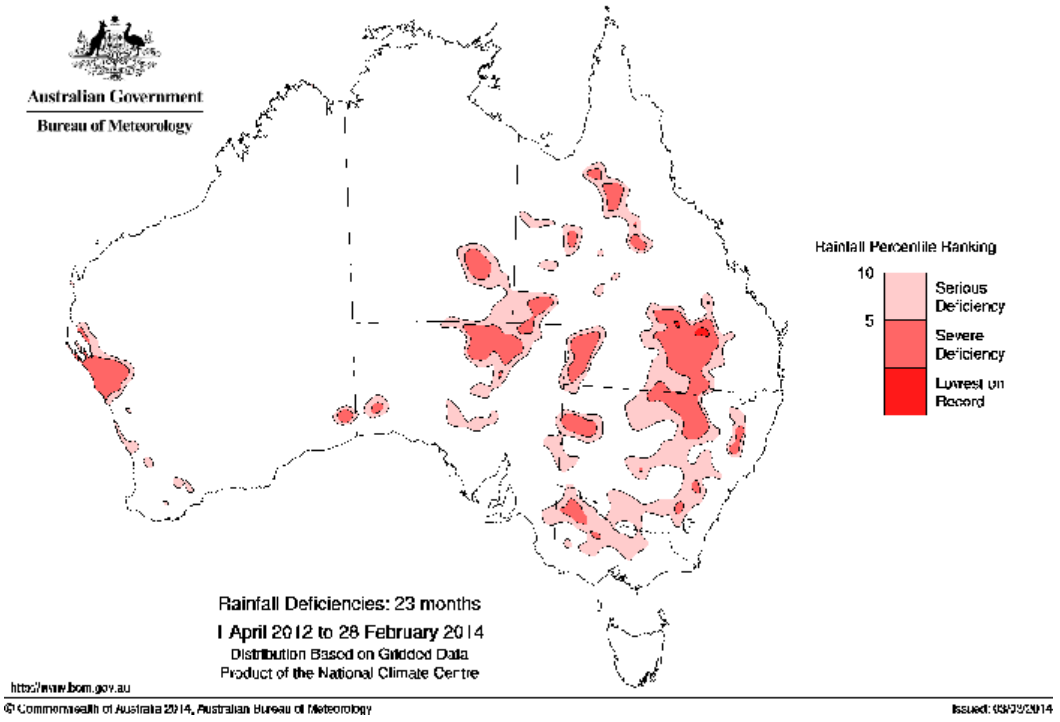
http://www.bom.gov.au/water/

Australian Government
Bureau of Meteorology

Drought declaration

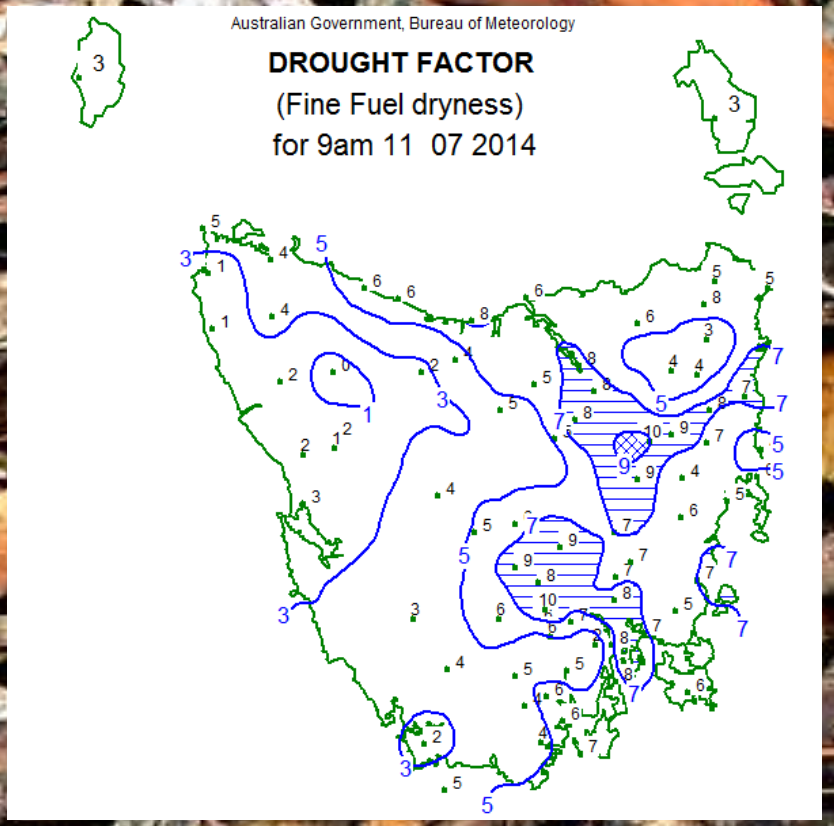






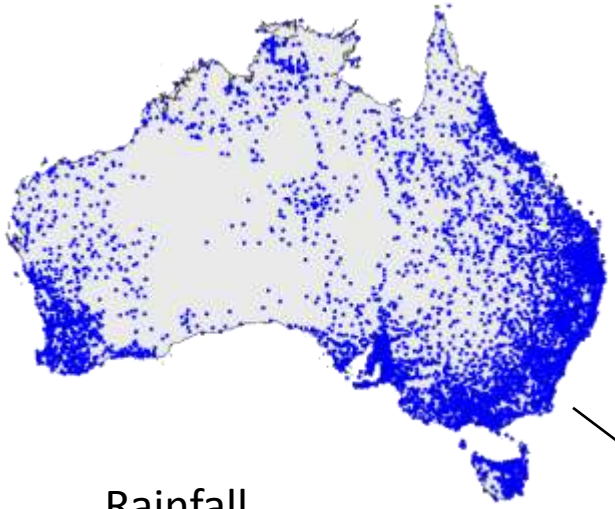
absolute SSM not of interest

Fire danger rating



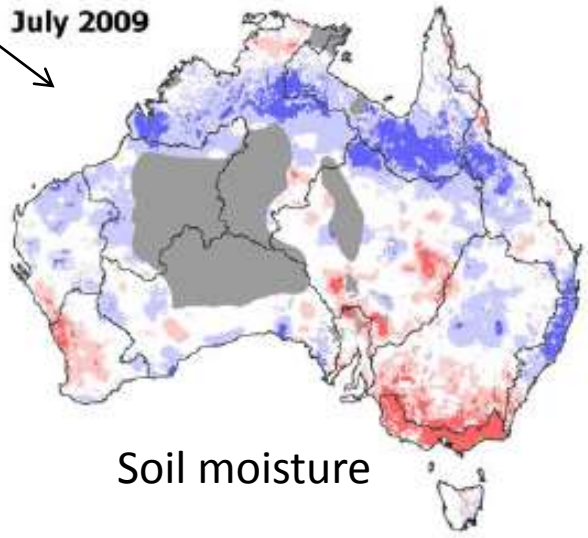
Focus on existing scoring scheme, absolute SSM not of interest (it's about litter moisture)

The on-ground hydrometric network is sparse

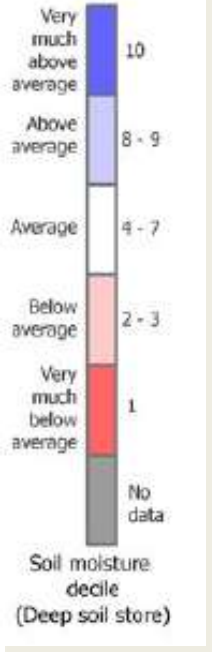


Rainfall gauging network

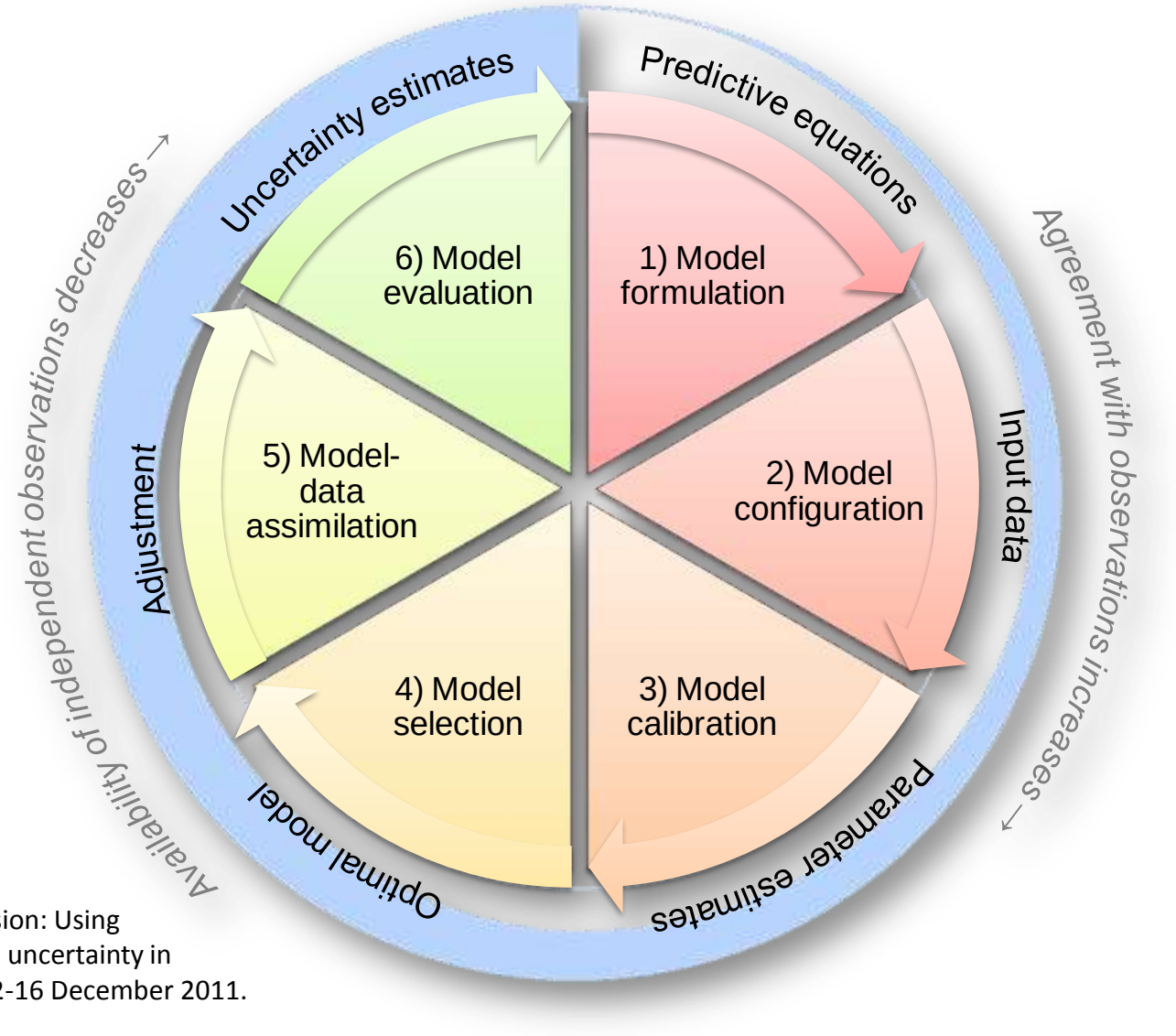
Hydrological model



Soil moisture

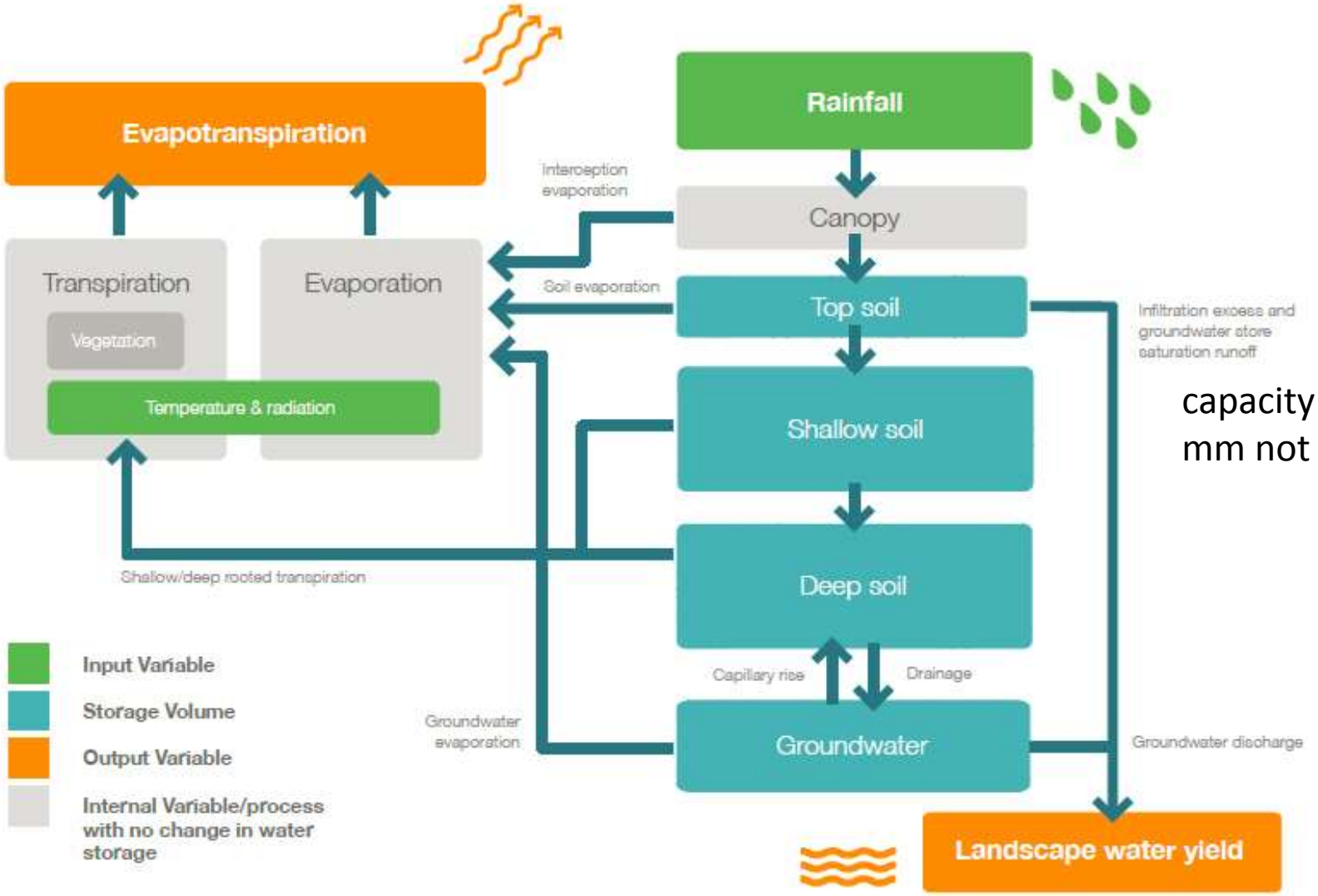


Model-data fusion:
using observations to improve models in 6 easy steps



Van Dijk, A.I.J.M., 2011. Model-data fusion: Using observations to understand and reduce uncertainty in hydrological models, MODSIM 2011, 12-16 December 2011. MSSANZ, Perth.

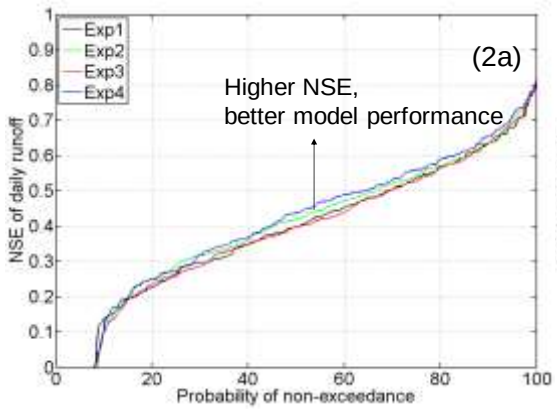
Australian Water Resources Assessment (AWRA) model



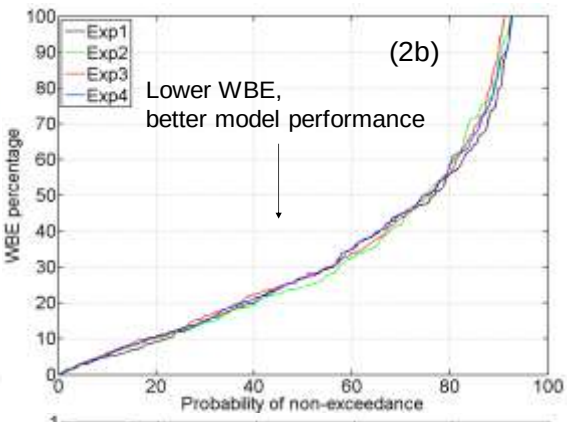
capacity in mm not vol%

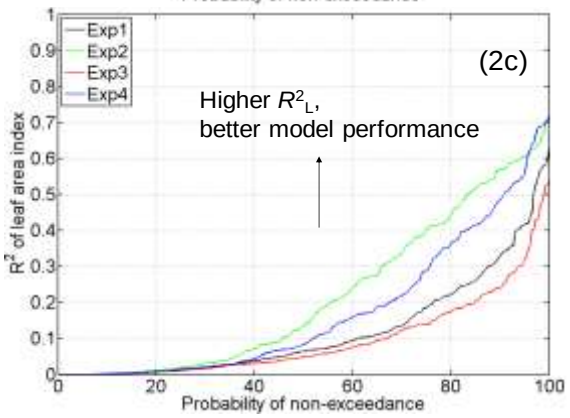
Step 3) Model calibration

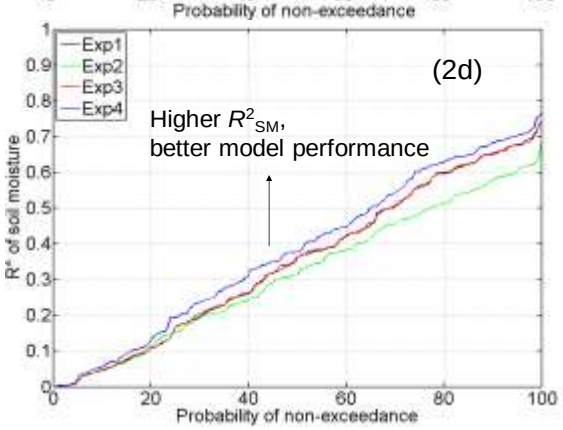
NSE of streamflow



streamflow water balance error (%)







R^2 of monthly leaf area index

R^2 of daily soil moisture

AWRA-L model parameter calibration against multiple observation types simultaneously helps find the overall 'best behaved' parameter set

Experiments:

1. against daily recorded runoff (Q)
2. against Q and monthly NOAA-AVHRR leaf area index (LAI)
3. against Q and daily TRMM-TMI surface soil moisture (SSM)
4. against Q, LAI and SSM

Zhang, Y.Q., Viney, N.R., Chiew, F.H.S., Van Dijk, A.I.J.M. and Liu, Y.Y., 2011. Improving hydrological and vegetation modelling using regional model calibration schemes together with remote sensing data, MODSIM 2011. MSSANZ, Perth, Australia.

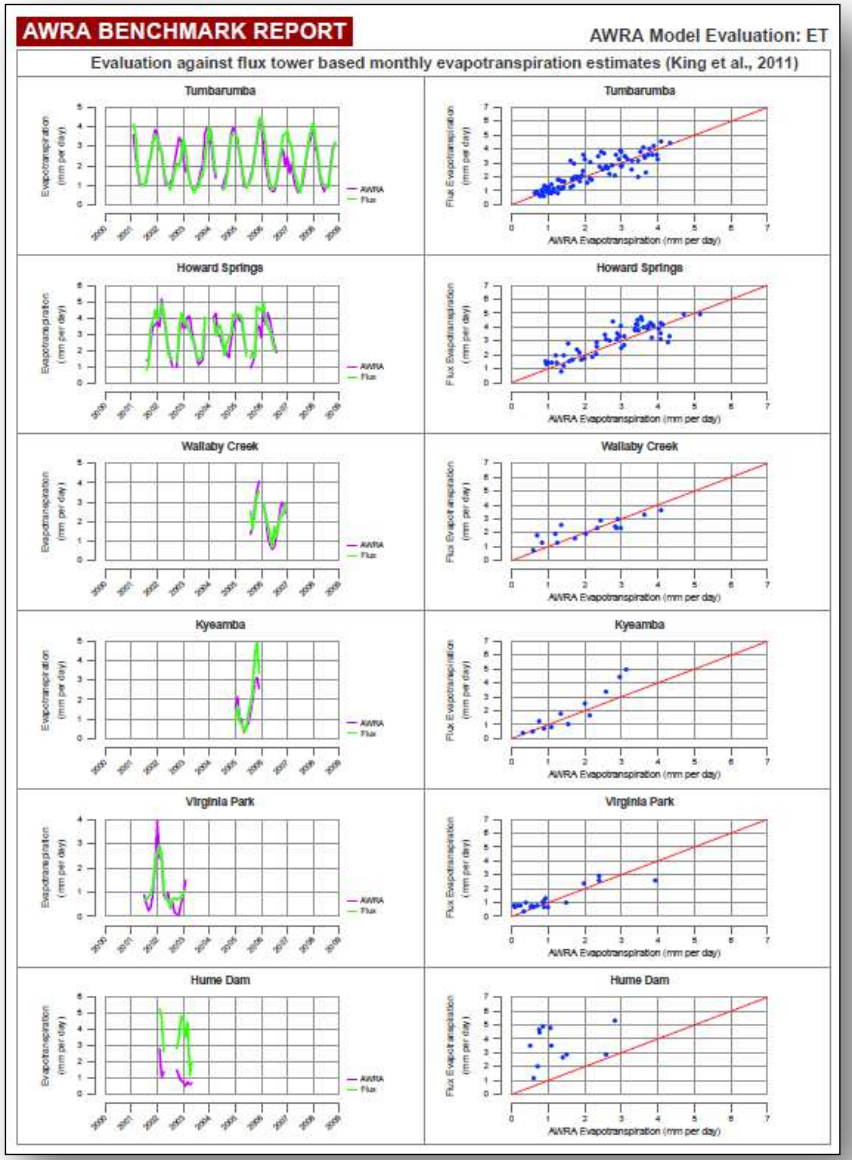
Step 4) Model selection

AWRA benchmarking system

Designed to assist in performance assessment, version acceptance and operational testing

Includes automated reporting against:

- Streamflow from 786 small catchments
- Recharge estimates from several 100s sites
- Remotely sensed LAI (MODIS)
- Remotely sensed soil moisture (AMSR-E, NASA/VUA LPRM)
- ET from flux towers



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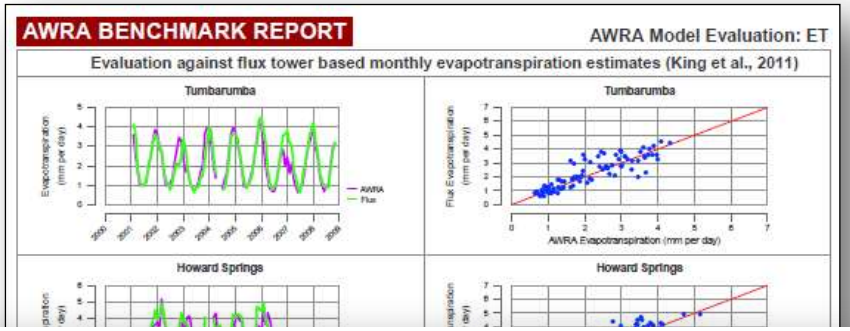
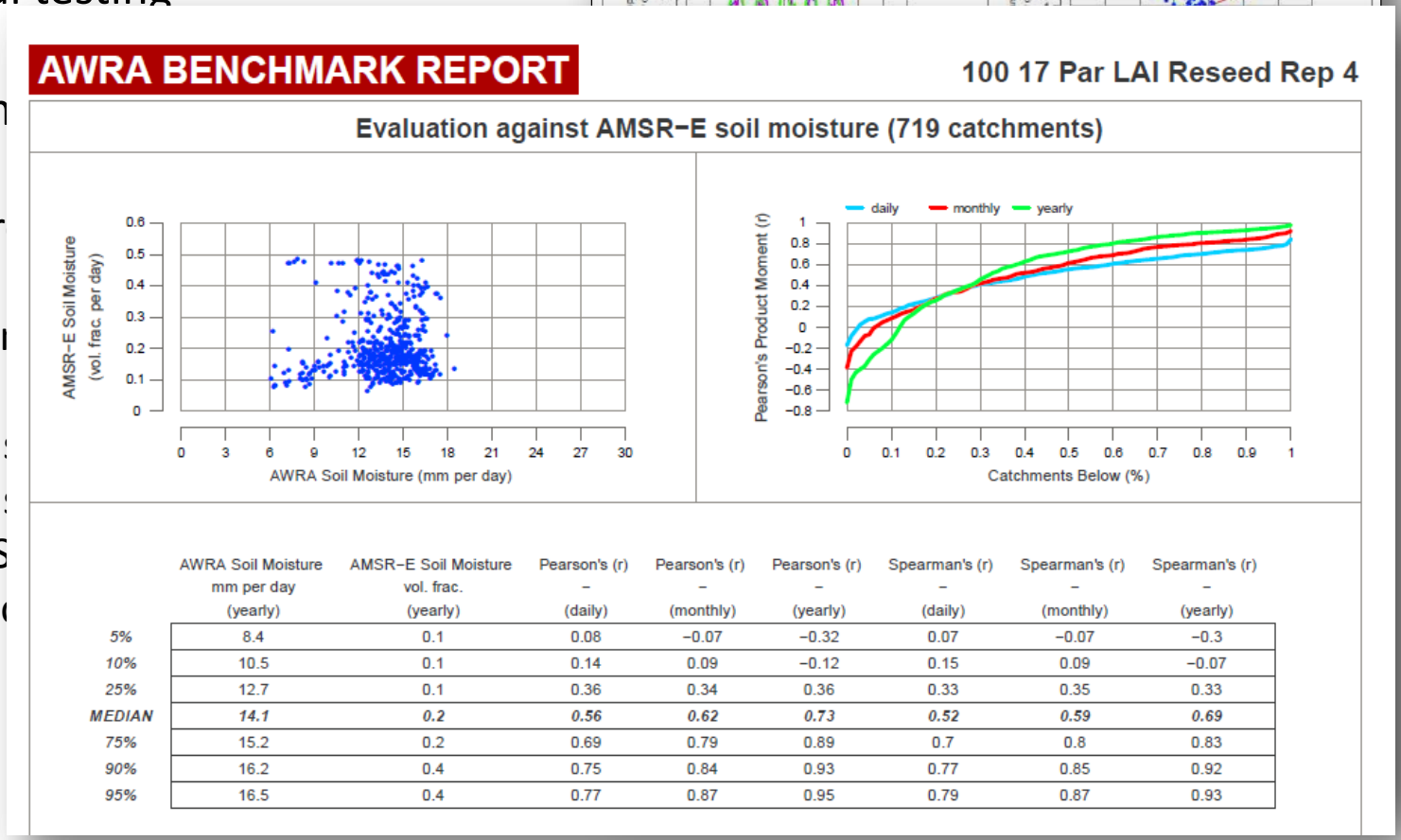


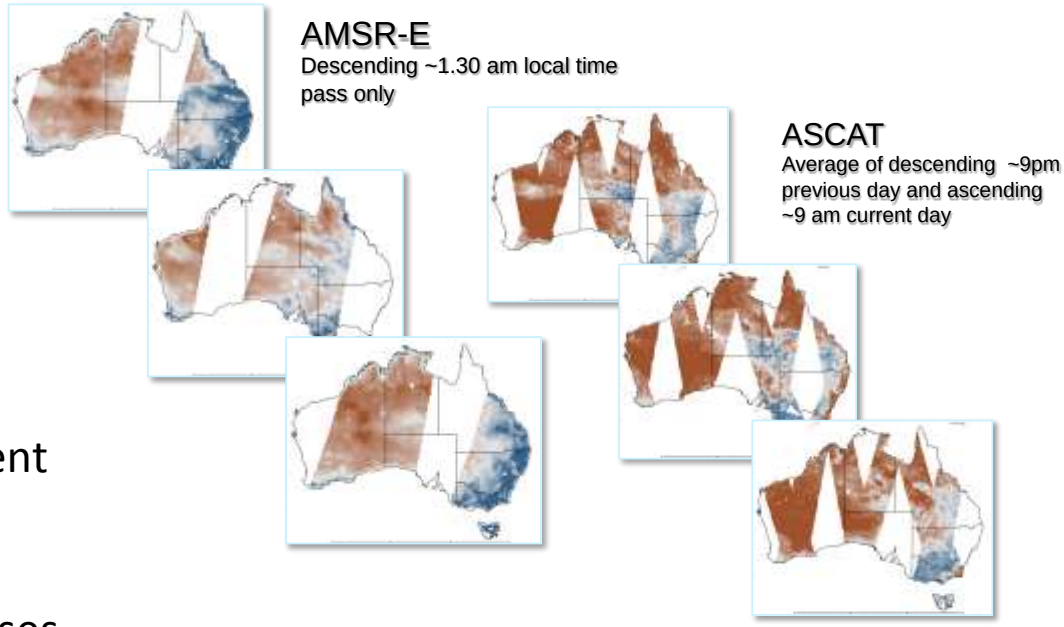


	AWRA Soil Moisture mm per day (yearly)	AMSR−E Soil Moisture vol. frac. (yearly)	Pearson's (r) – (daily)	Pearson's (r) – (monthly)	Pearson's (r) – (yearly)	Spearman's (r) – (daily)	Spearman's (r) – (monthly)	Spearman's (r) – (yearly)
5%	8.4	0.1	0.08	−0.07	−0.32	0.07	−0.07	−0.3
10%	10.5	0.1	0.14	0.09	−0.12	0.15	0.09	−0.07
25%	12.7	0.1	0.36	0.34	0.36	0.33	0.35	0.33
MEDIAN	***14.1***	***0.2***	***0.56***	***0.62***	***0.73***	***0.52***	***0.59***	***0.69***
75%	15.2	0.2	0.69	0.79	0.89	0.7	0.8	0.83
90%	16.2	0.4	0.75	0.84	0.93	0.77	0.85	0.92
95%	16.5	0.4	0.77	0.87	0.95	0.79	0.87	0.93

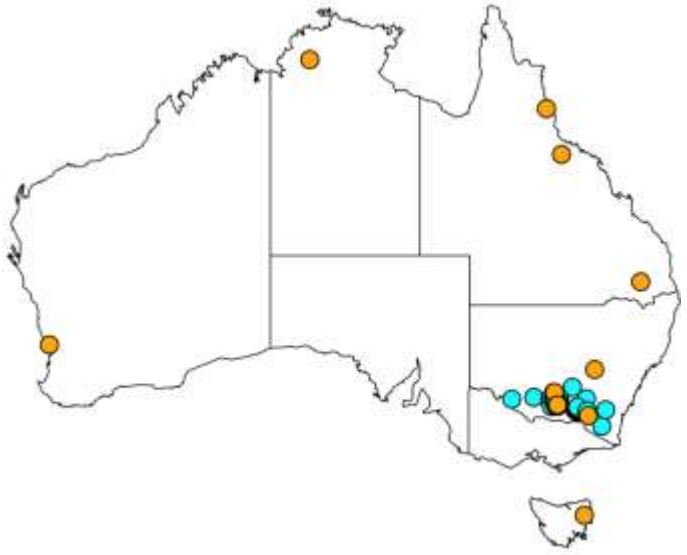
Step 5) Data assimilation

Continental satellite soil moisture assimilation for Australia:

- Perturbed meteorological forcing
- ensemble Kalman filter
- AMSR-E and ASCAT-derived NSSM products
- Australian Water Resources Assessment system (AWRA-L) model
- ensembles of daily top-layer and shallow root-zone soil moisture analyses for Australia at 0.05°

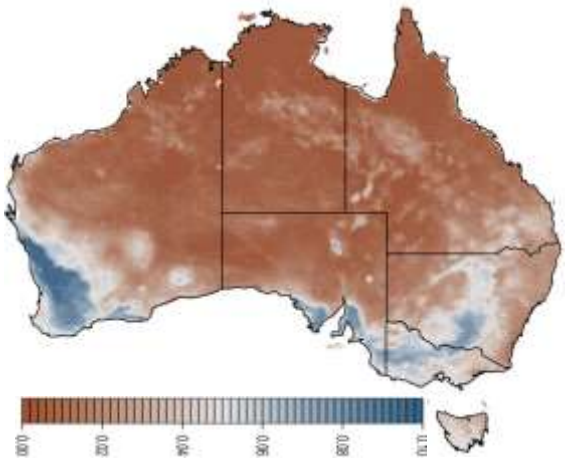


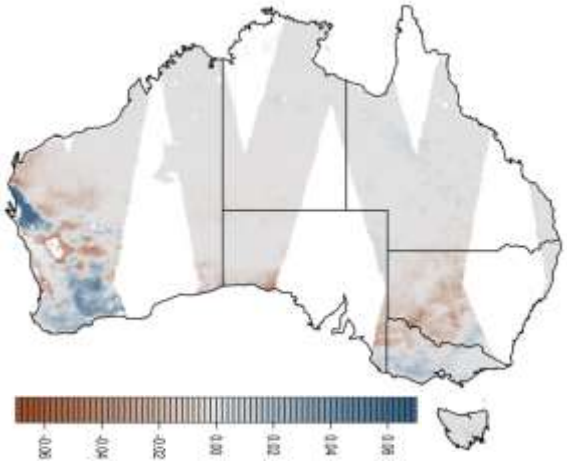
Evaluated against in situ moisture measurements in southeast Australia (OzNet), as well as against a new network of cosmic ray moisture probes (CosmOz).



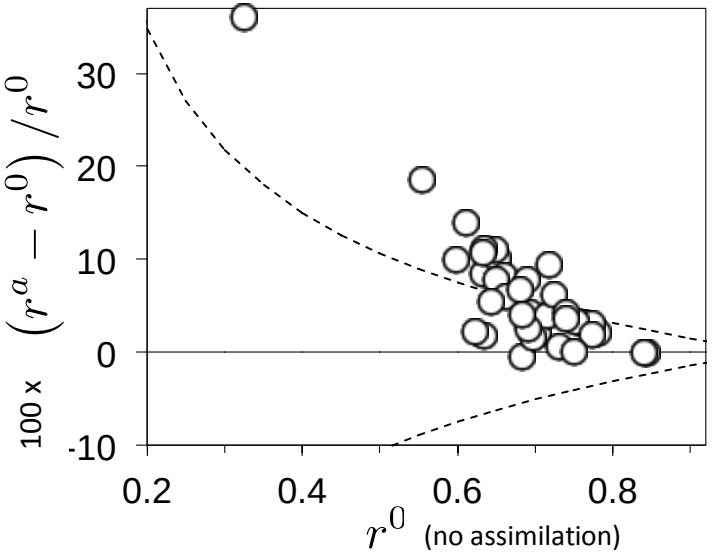
Renzullo et al. (2014) Continental satellite soil moisture data assimilation improves root-zone moisture analysis for water resources assessment. *Journal of Hydrology* (revised)

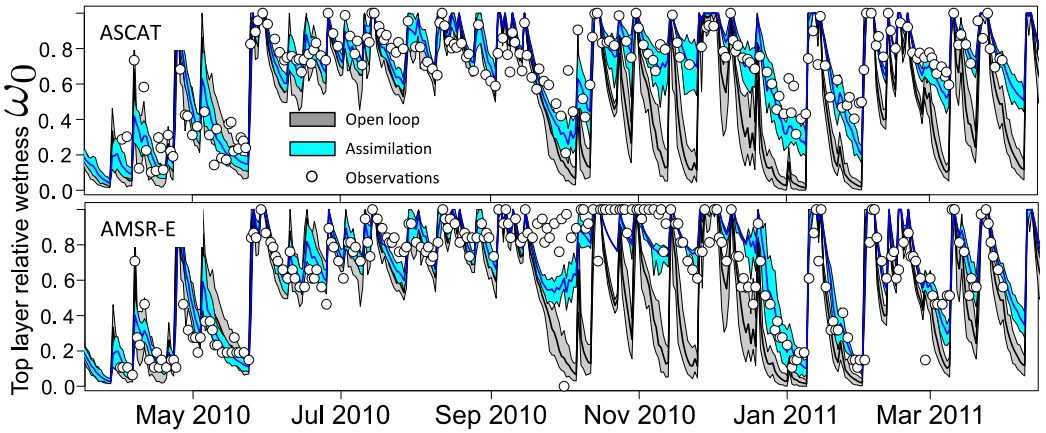
Relative wetness for 7 July 2009 (median)





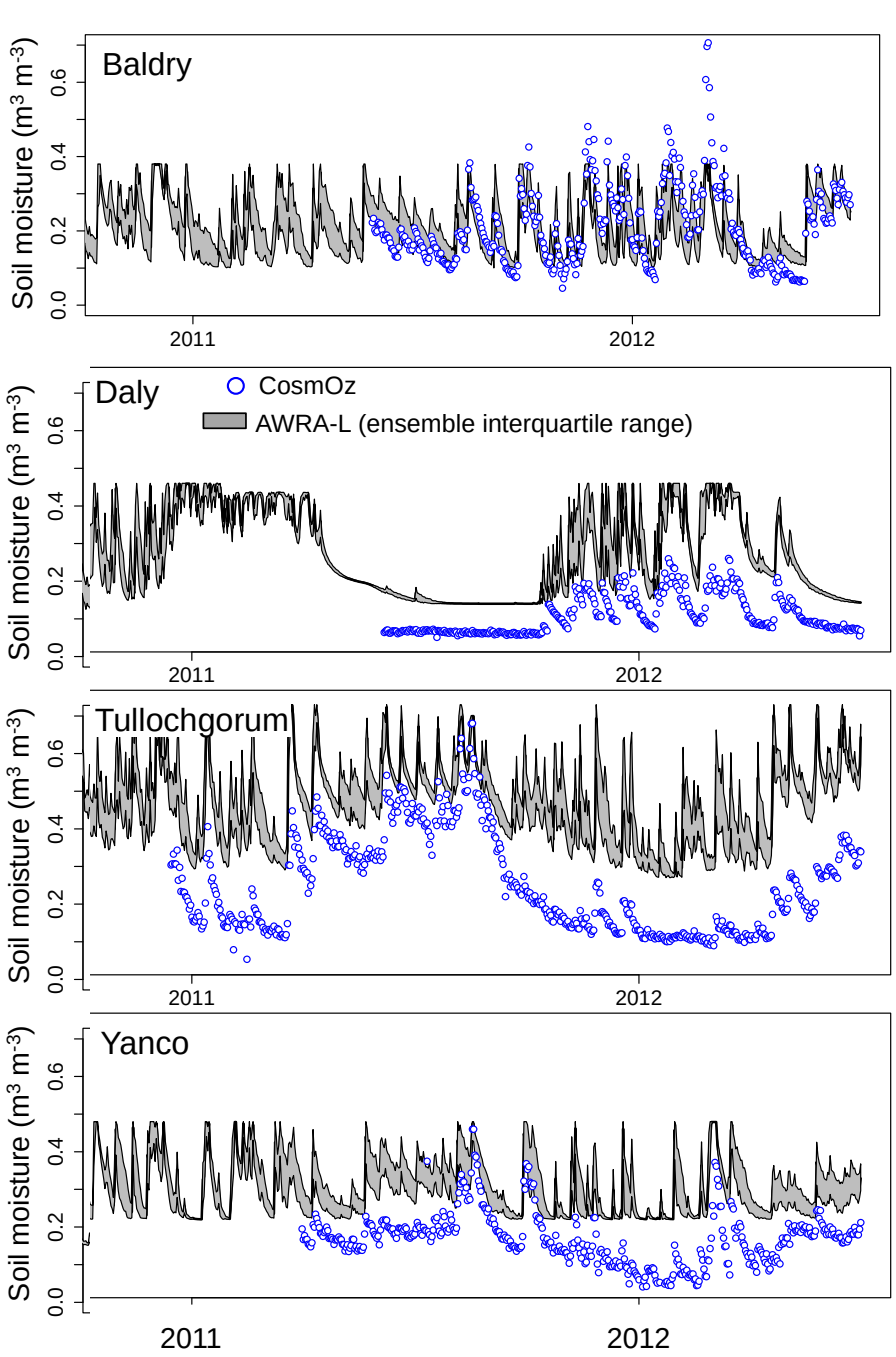
Analysis increment





AWRA root-zone moisture estimates correlation against *in situ* probes increases (r^a) as a result of assimilating ASCAT soil moisture data

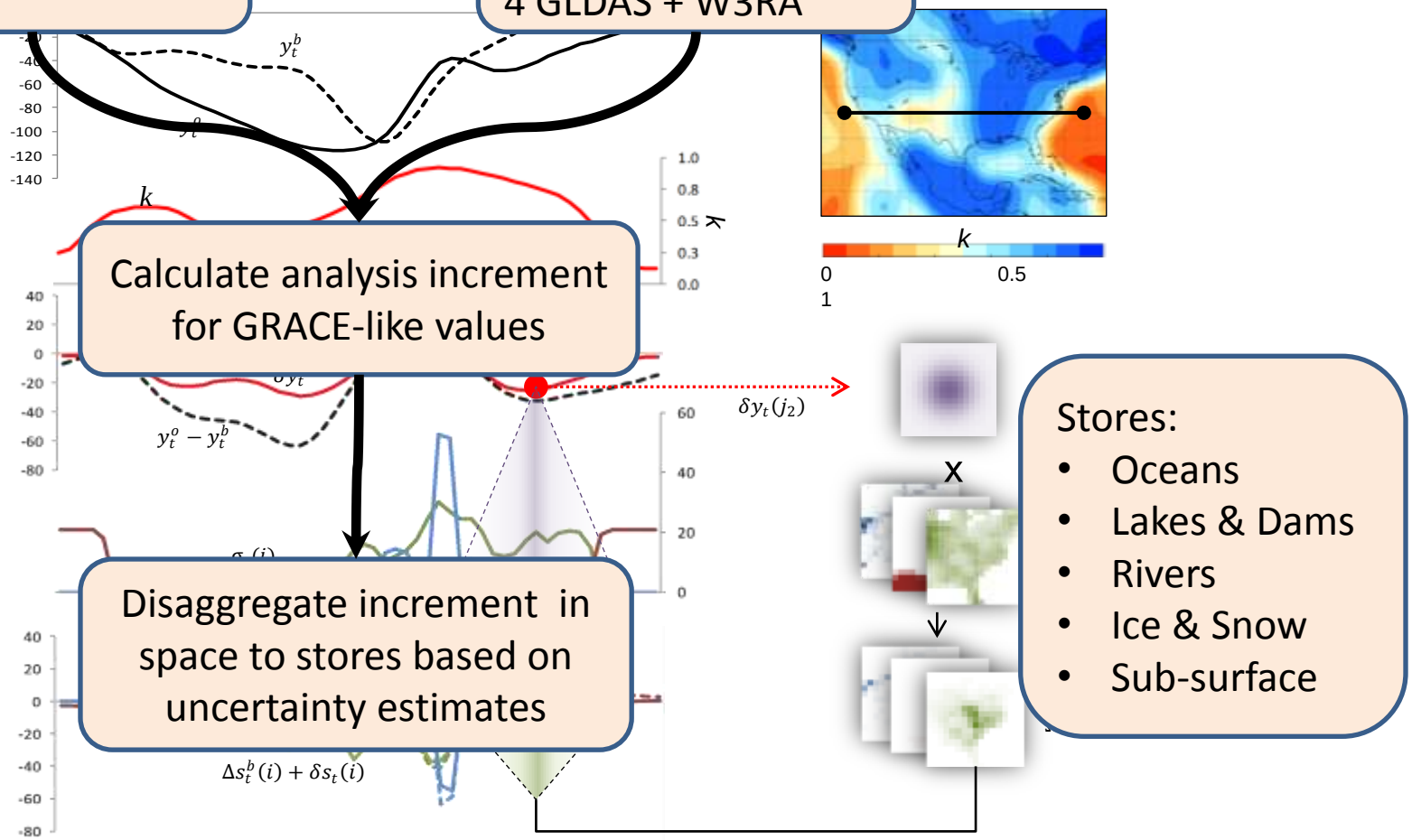
AWRA root-zone moisture comparison with cosmic-ray probe



Step 6) Model evaluation

GRACE ensemble:
(4 Tellus + GRGS)

Satellite altimetry &
model ensemble:
4 GLDAS + W3RA



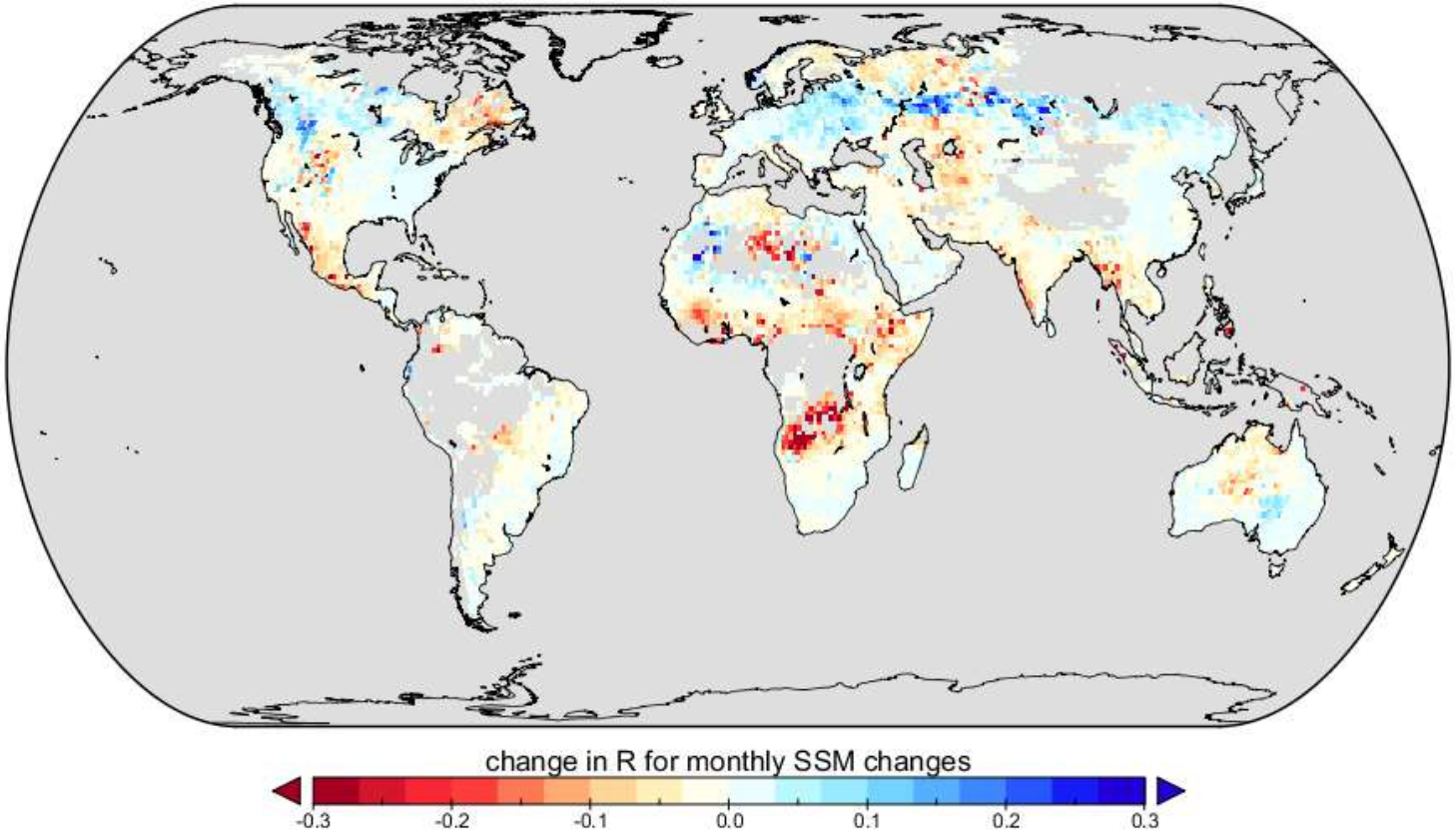
Calculate analysis increment
for GRACE-like values

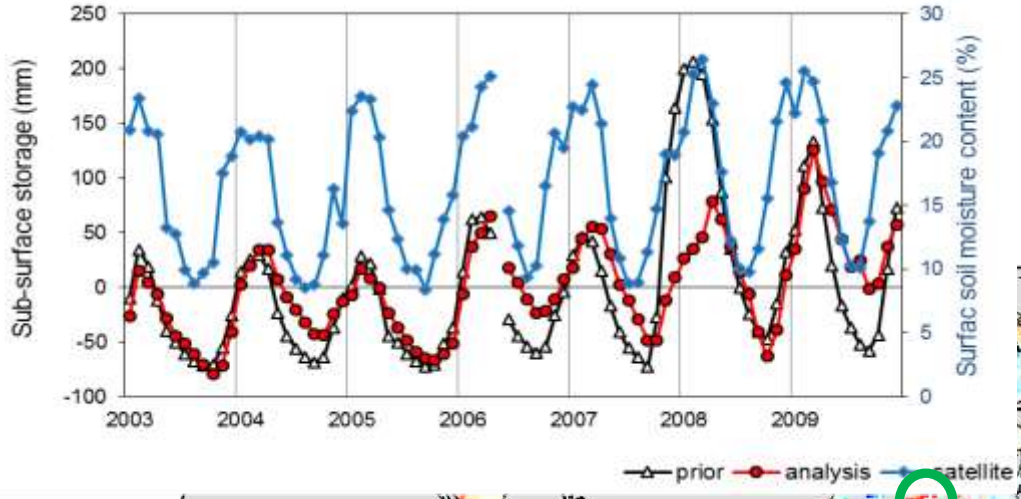
Disaggregate increment in
space to stores based on
uncertainty estimates

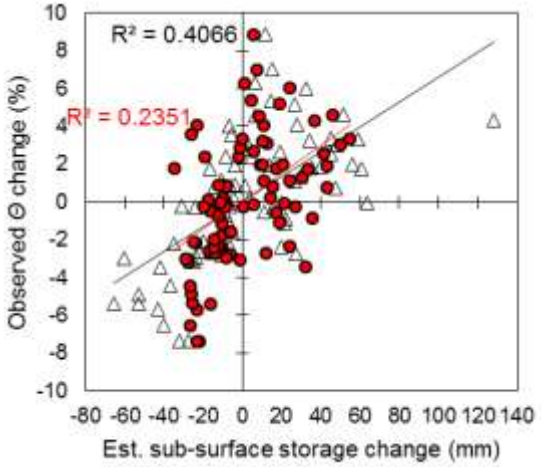
Stores:
- Oceans
- Lakes & Dams
- Rivers
- Ice & Snow
- Sub-surface

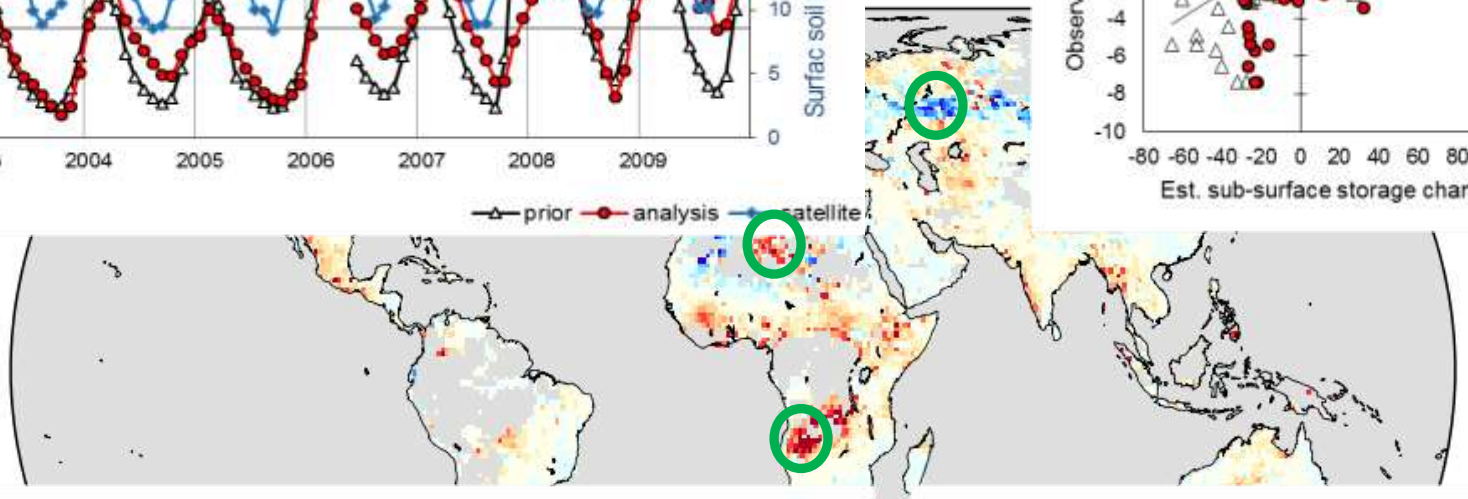
van Dijk, A. I. J. M., Renzullo, L. J., Wada, Y., and Tregoning, P.: A global water cycle reanalysis (2003–2012) reconciling satellite gravimetry and altimetry observations with a hydrological model ensemble, Hydrol. Earth Syst. Sci. (in press)

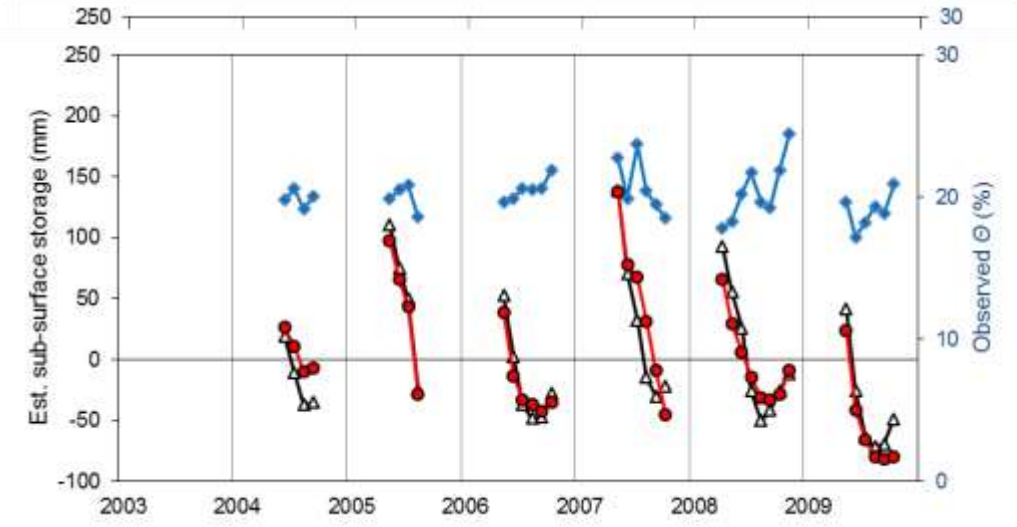
R between monthly changes in sub-surface water storage (reanalysis) and in NASA/VUA LPRM AMSR-E soil moisture

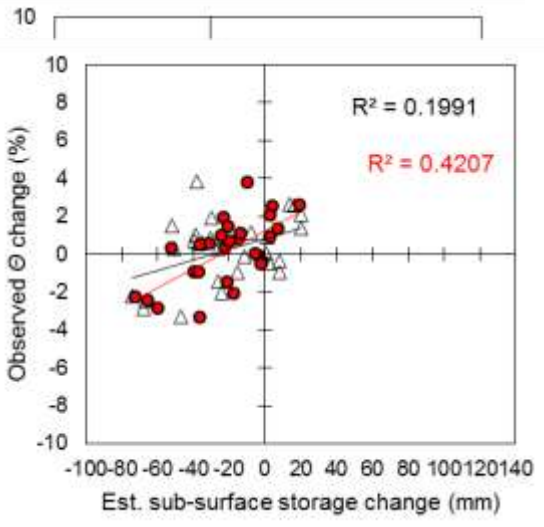



Sub-surface storage (mm)
Surfac soil moisture content (%)
prior
analysis
satellite

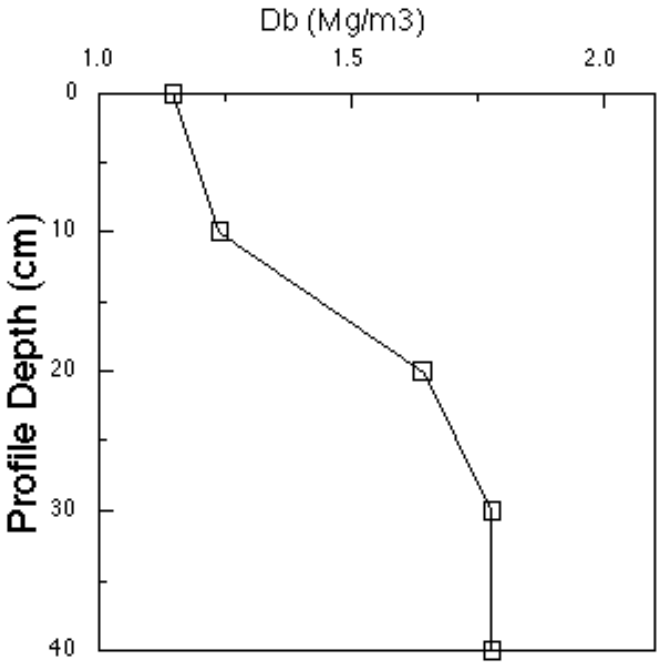

R² = 0.4066
R² = 0.2351
Observed Θ change (%)
Est. sub-surface storage change (mm)




Est. sub-surface storage (mm)
Observed Θ (%)


R² = 0.1991
R² = 0.4207
Observed Θ change (%)
Est. sub-surface storage change (mm)

What does satellite soil moisture represent exactly?



What does satellite soil moisture represent exactly?

Conclusions

- Several **good potential applications** for SSM
- Most require a **harmonised historic record** at least a decade or two
- So far no application requires **absolute accuracy**
- **Data continuity, consistency, and latency data supply** is the main barrier to uptake
- Most applications do not really need **higher spatial resolution**
- Unidentified **contamination** (open water, ocean, salt, RFI, topography, vegetation dynamics) remain issues.
- There is no obvious need for **new missions** (just more of the same please!).
- **'Validation' tends to be biased** towards favourable environments
- **Cosmic ray sensors** are taking off as a means of bridging scales