Are we improving weather forecasts through better initialisation of the land surface state?

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Imtiaz Dharssi

OzEWEX Workshop

November 2014

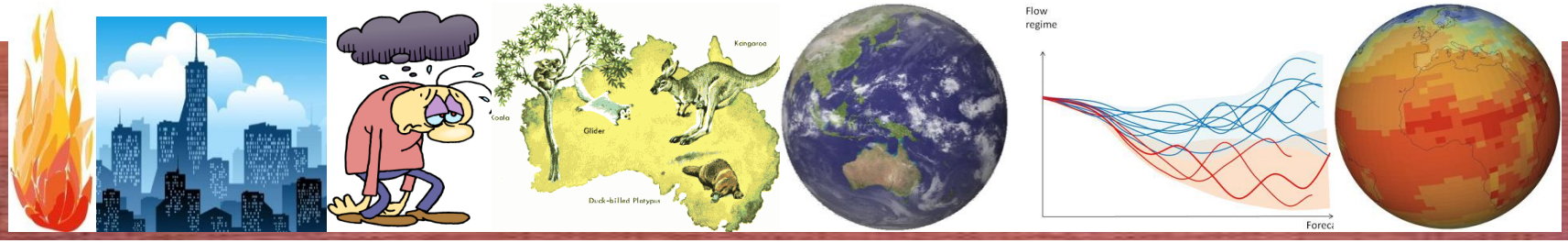
Australian Government
Bureau of Meteorology

The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

CSIRO

Seamless Modelling of Weather/Climate

Hours | Days | Weeks | Months | Decades | Centuries

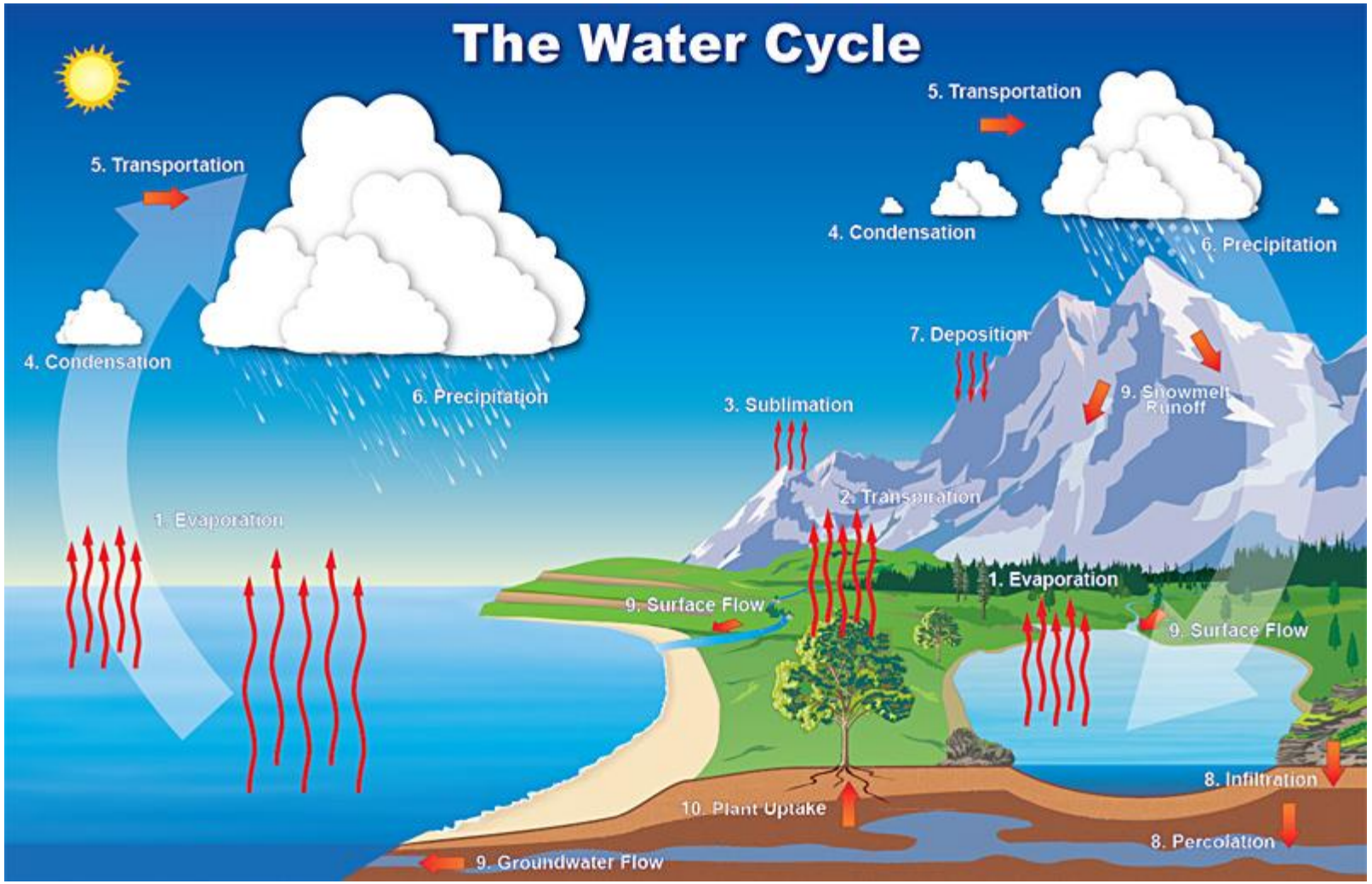


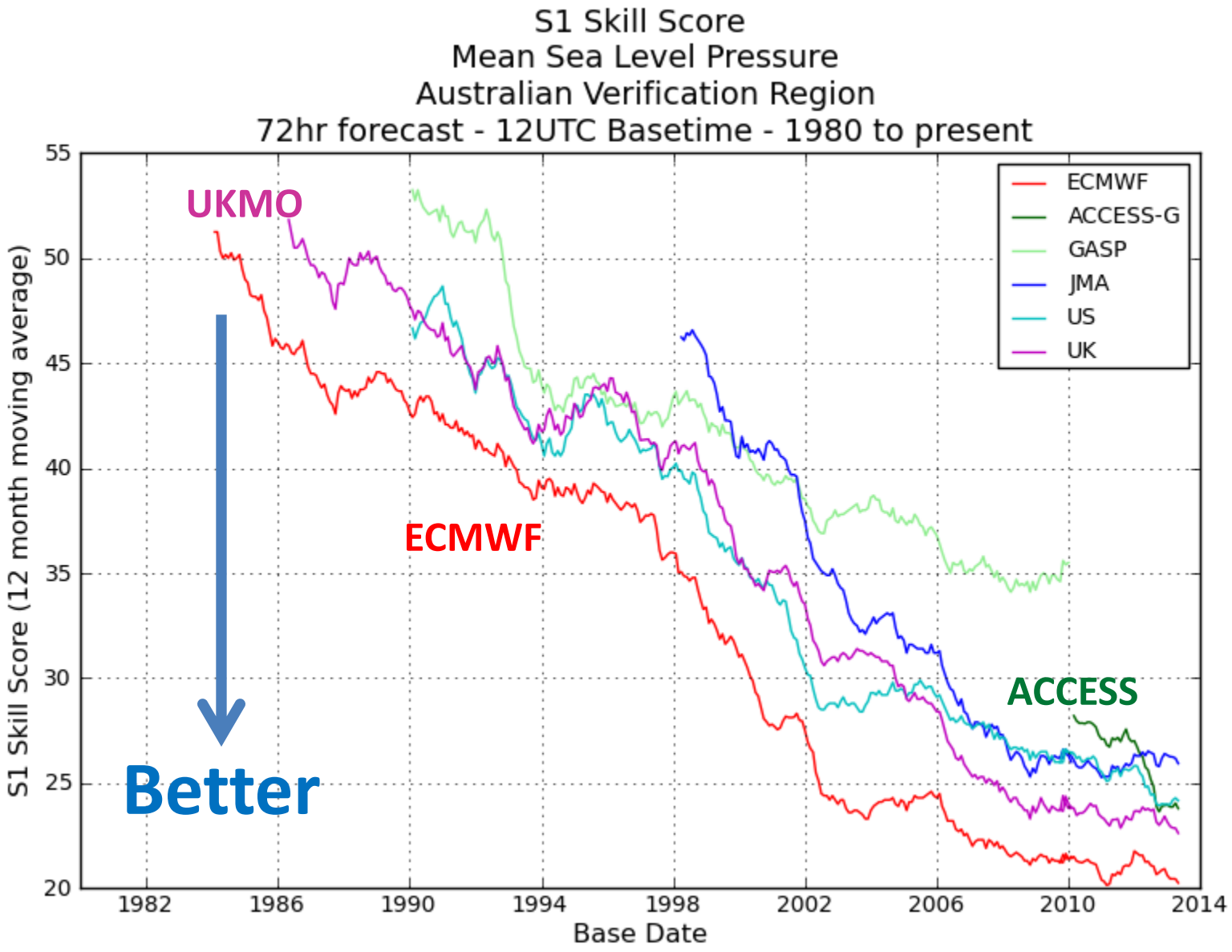
1km | 4km | 10km | 20km | 50km | 100km

Different configurations of the same model are used across all time and space scales; from very high resolution fire modelling to lower resolution climate prediction.

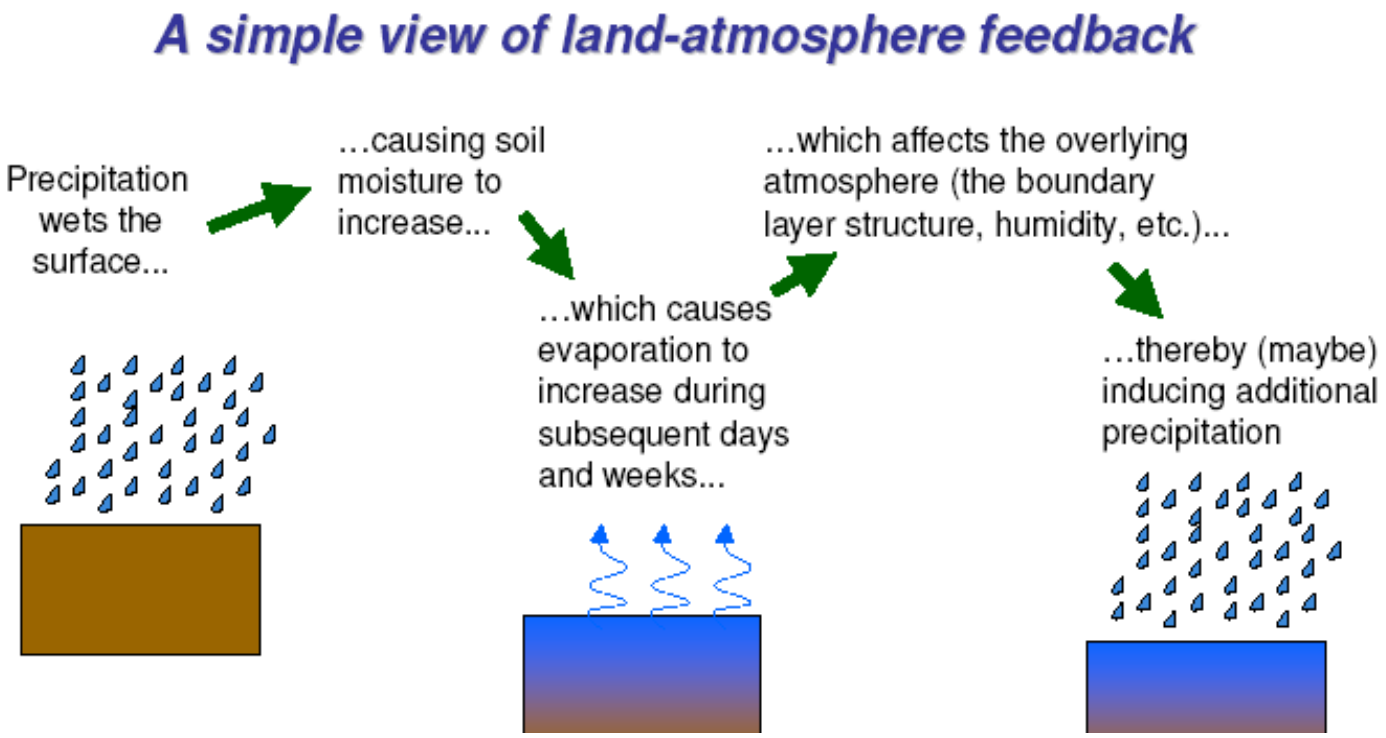
The atmosphere and land Surface are fully coupled in all configurations.

Weather/Climate Models Simulate the Energy and Water Cycles



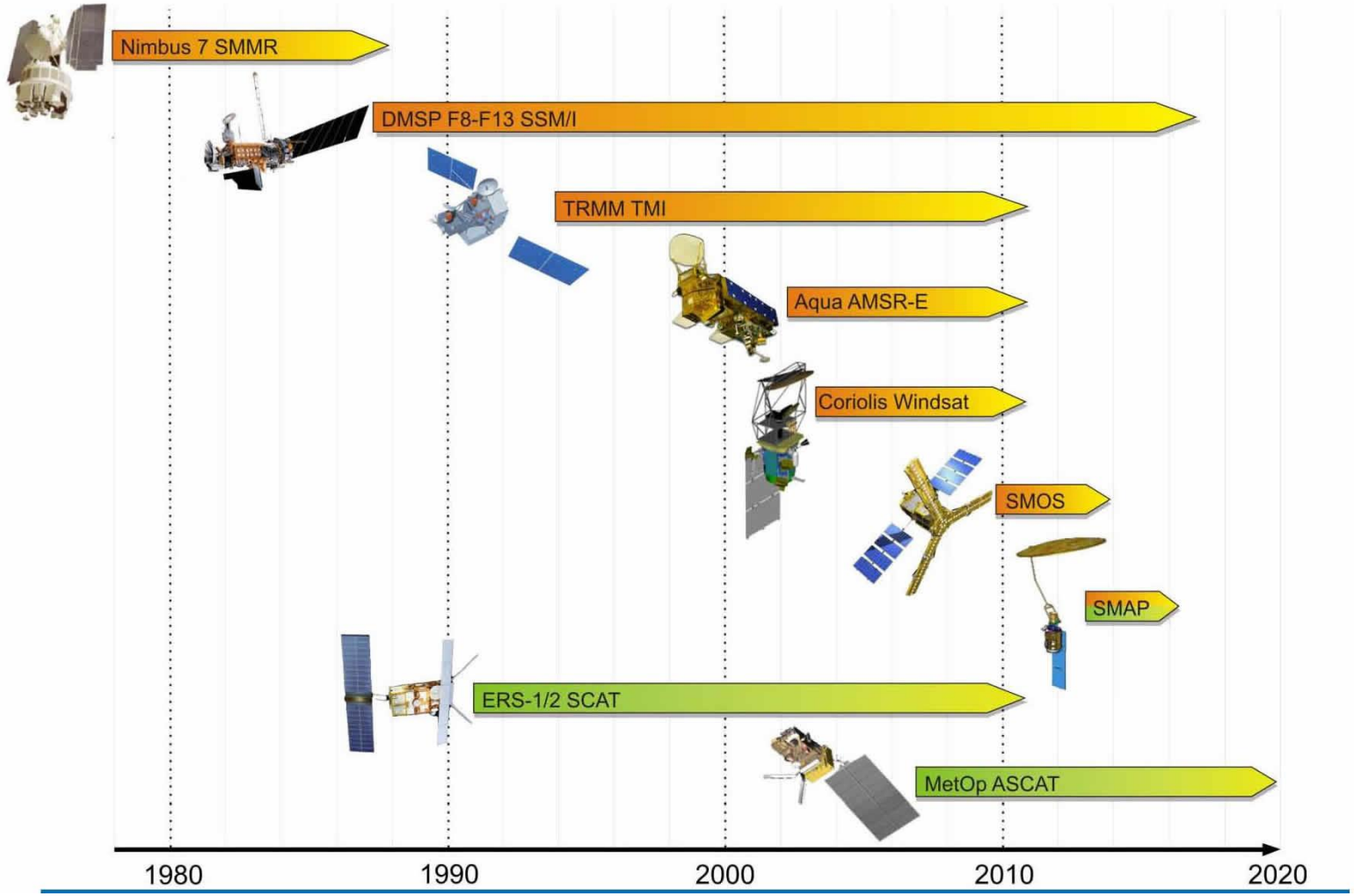

S1 Skill Score
Mean Sea Level Pressure
Australian Verification Region
72hr forecast - 12UTC Basetime - 1980 to present
S1 Skill Score (12 month moving average)
Base Date
55
50
45
40
35
30
25
20
1982
1986
1990
1994
1998
2002
2006
2010
2014
ECMWF
ACCESS-G
GASP
JMA
US
UK
UKMO
ECMWF
ACCESS
Better

Land-atmosphere feedback



From Reichle and Koster:
Land data assimilation and sub-seasonal climate prediction

30+ years of passive and active satellite microwave observations for soil moisture



http://wacmos.itc.nl/sites/default/files/pictures/Satellites.jpg

DATA ASSIMILATION EXAMPLE

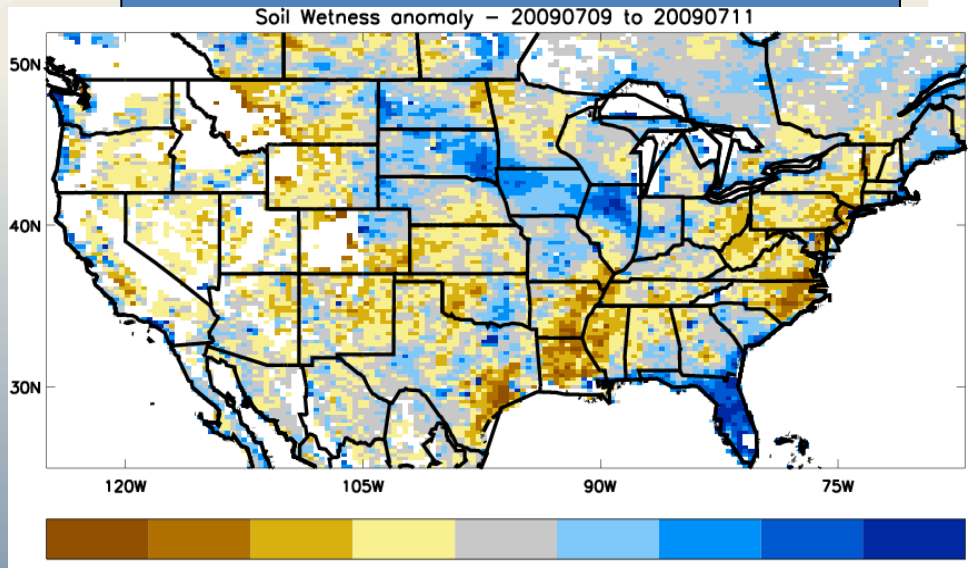
Assimilation of ASCAT surface soil wetness into a global numerical weather prediction model

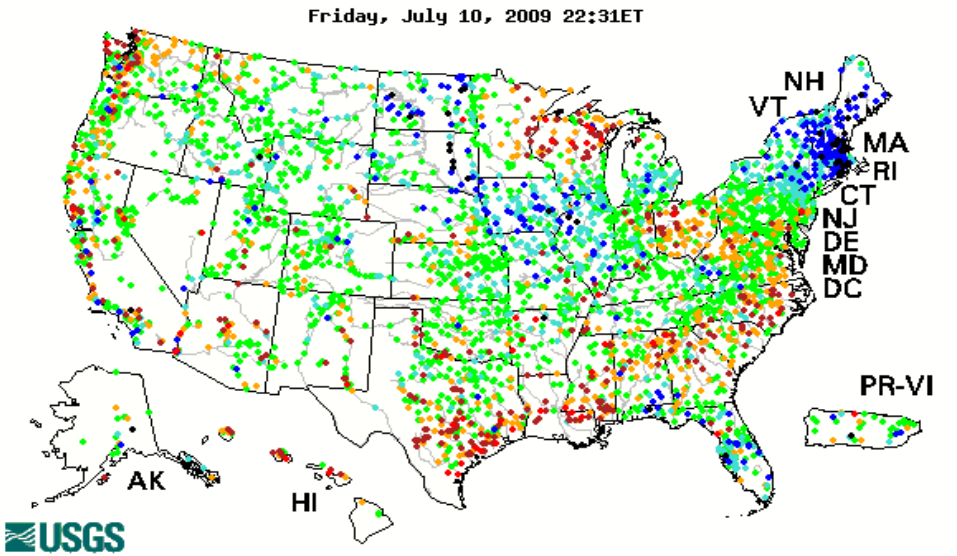
Dharssi, I., Bovis, K. J., Macpherson, B., and Jones, C. P.: Operational assimilation of ASCAT surface soil wetness at the Met Office, Hydrol. Earth Syst. Sci., 15, 2729-2746, doi:10.5194/hess-15-2729-2011, 2011.

WATER ANOMALIES: 9 TO 11 JULY 2009

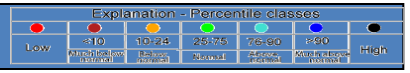
Good qualitative agreement between the two data.

ASCAT surface soil wetness anomaly



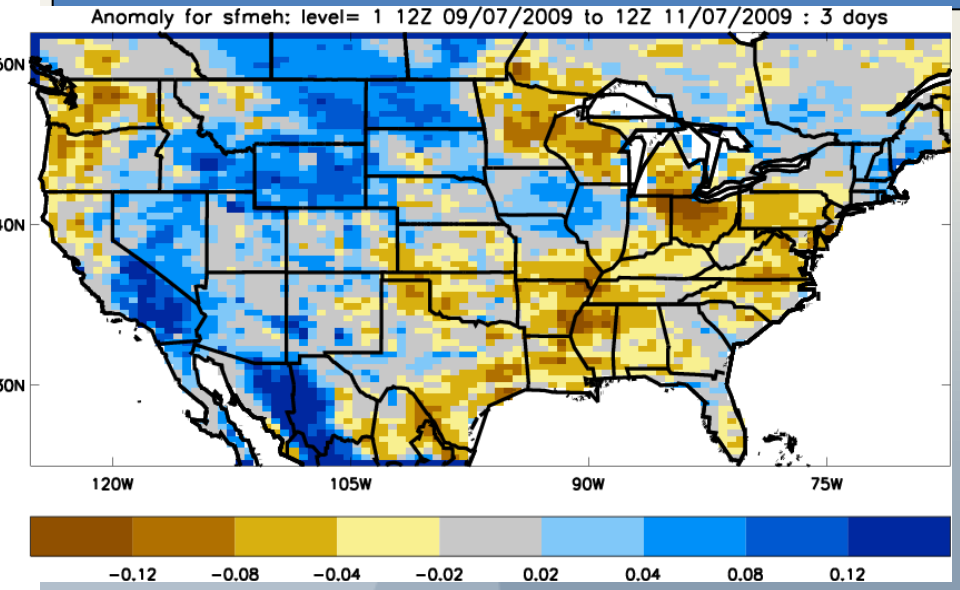


River Flow anomaly



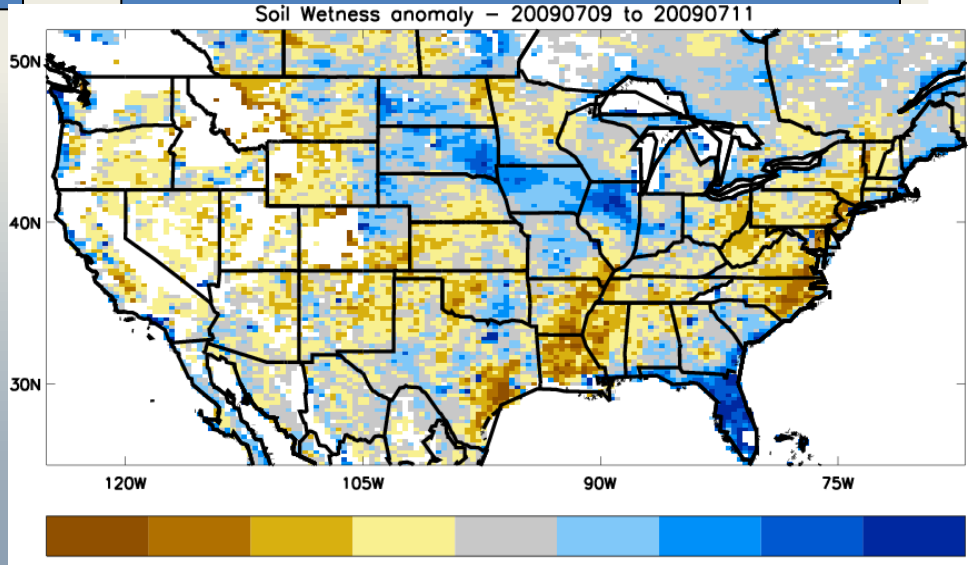
MODEL: 9 TO 11 JULY 2009

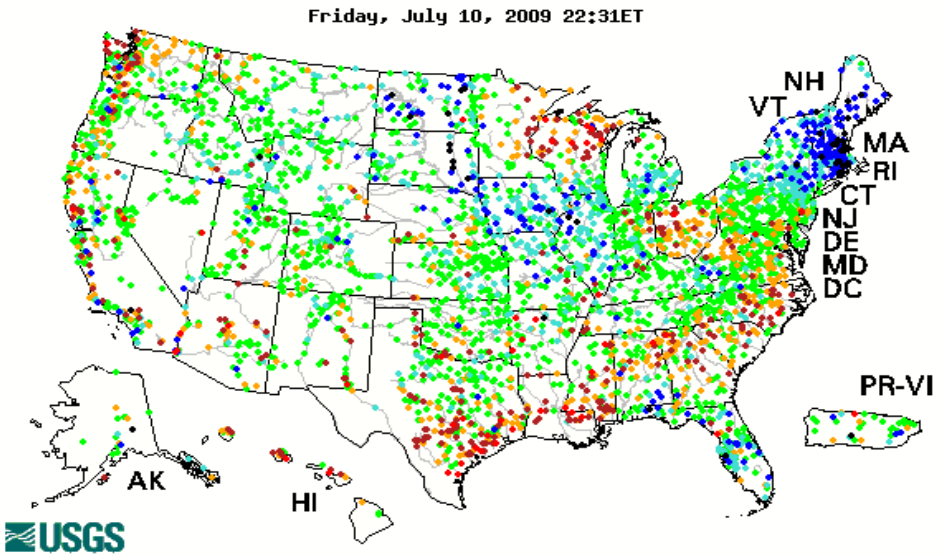
Control run: top 10cm soil moisture anomaly



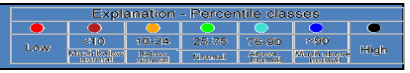
Model soil too wet in the west and possibly too dry in the east (e.g. Florida).

ASCAT surface soil wetness anomaly



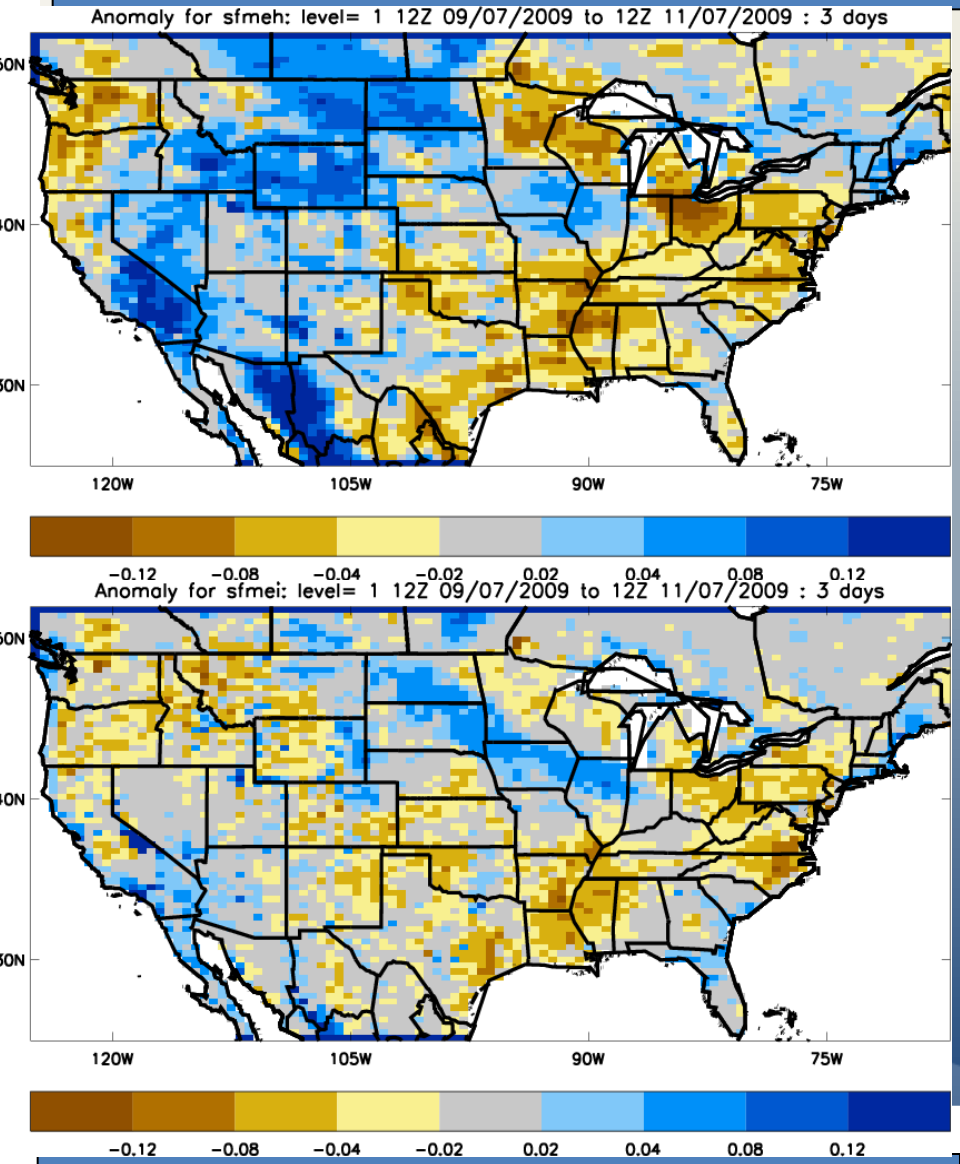


River Flow anomaly



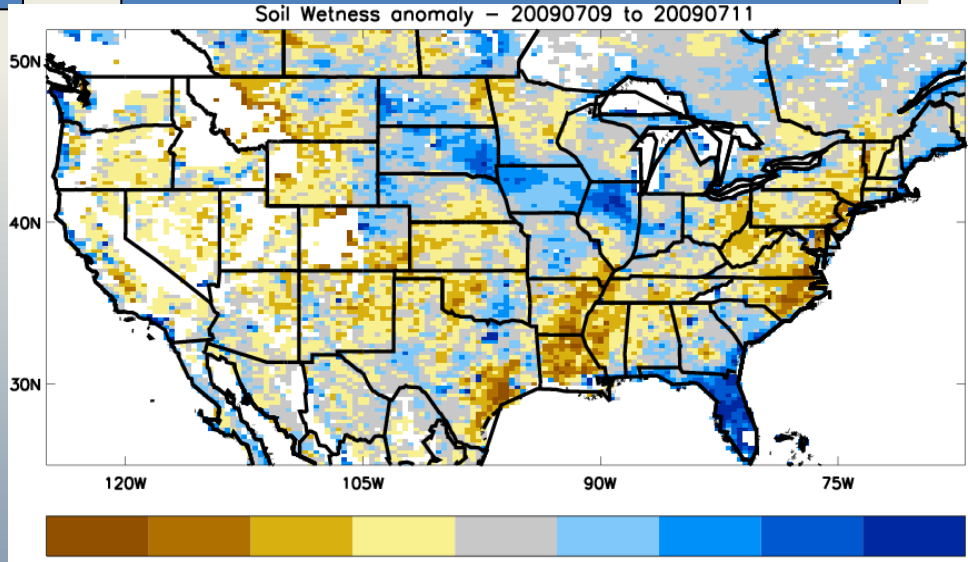
DATA ANALYSIS: 9 TO 11 JULY 2009

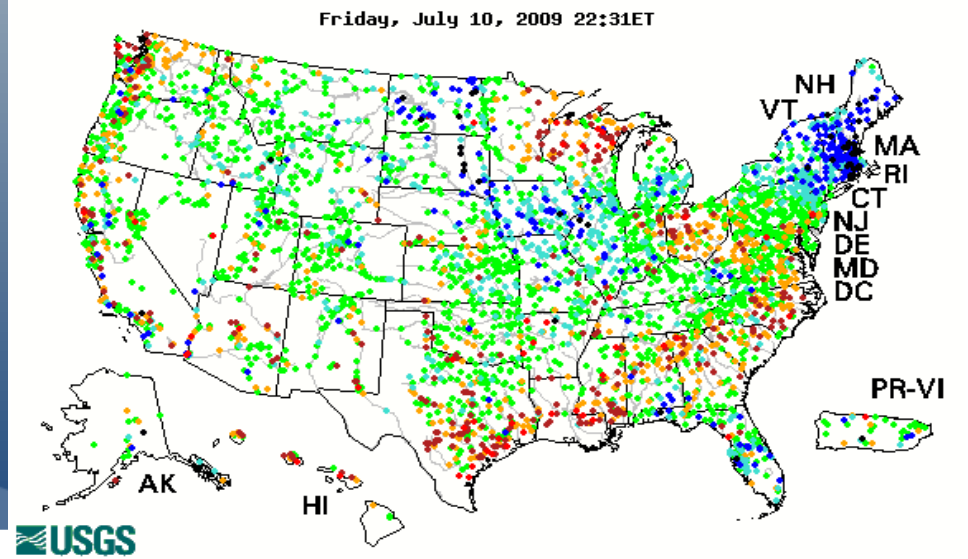
Control run: top 10cm soil moisture anomaly



Test run: top 10cm soil moisture anomaly

ASCAT surface soil wetness anomaly



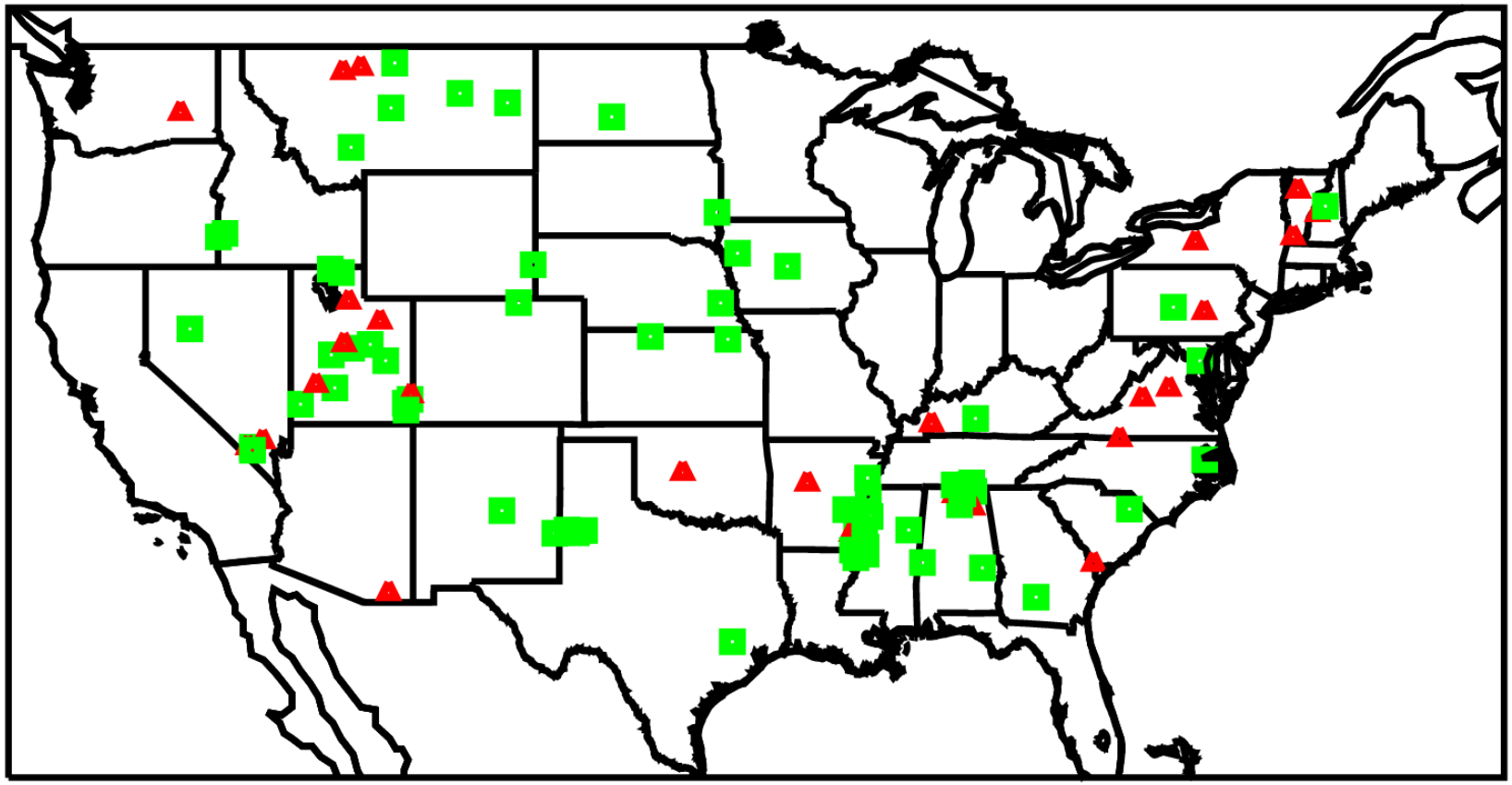


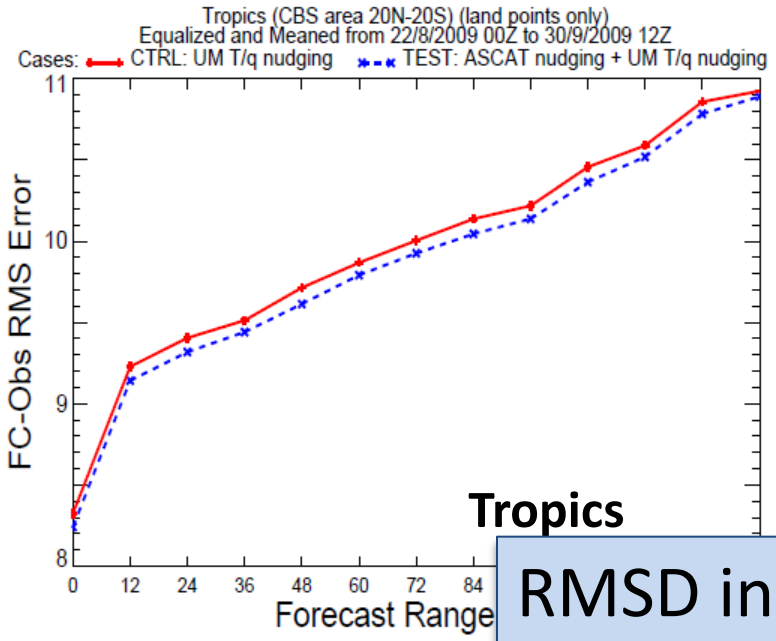
River Flow anomaly

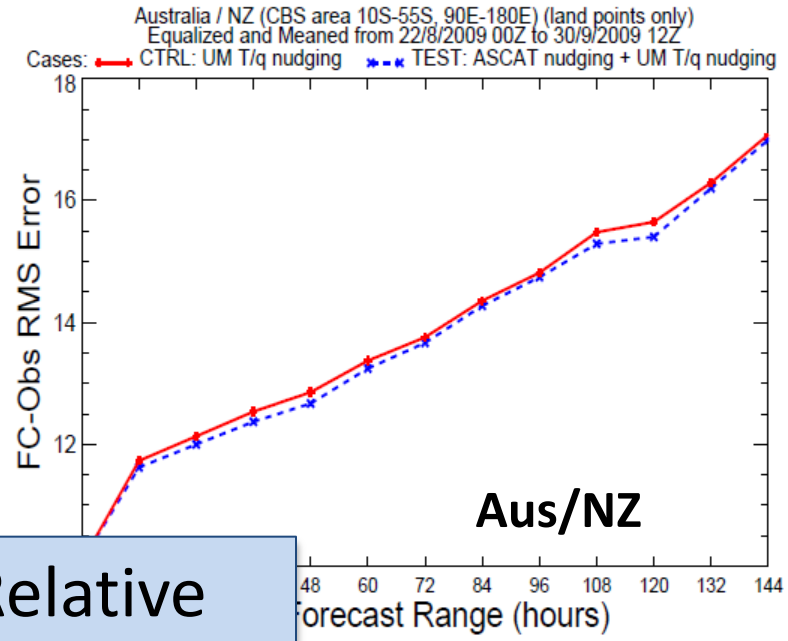
ASSIMILATION OF ASCAT SOIL WETNESS IMPROVES VERIFICATION AGAINST GROUND BASED SOIL MOISTURE MEASUREMENTS

Reduction in random errors (Better)

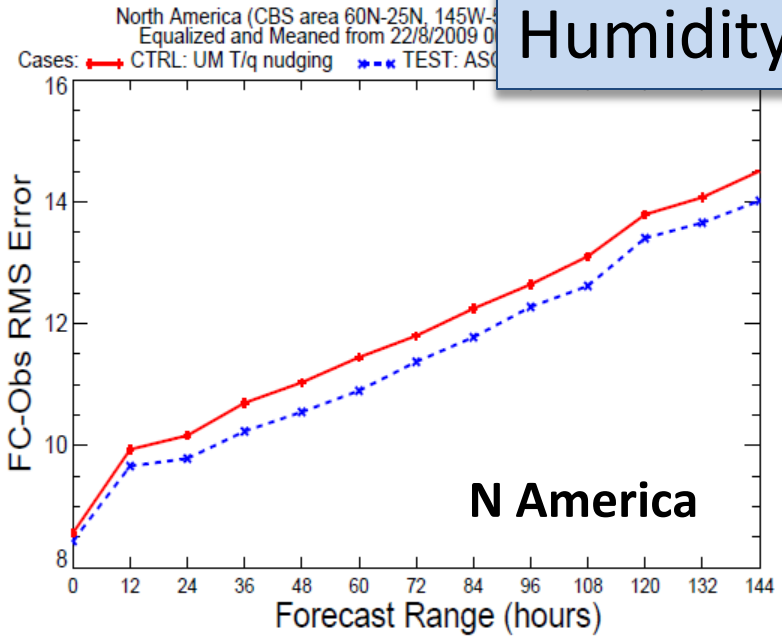
Increase in random errors (Worse)

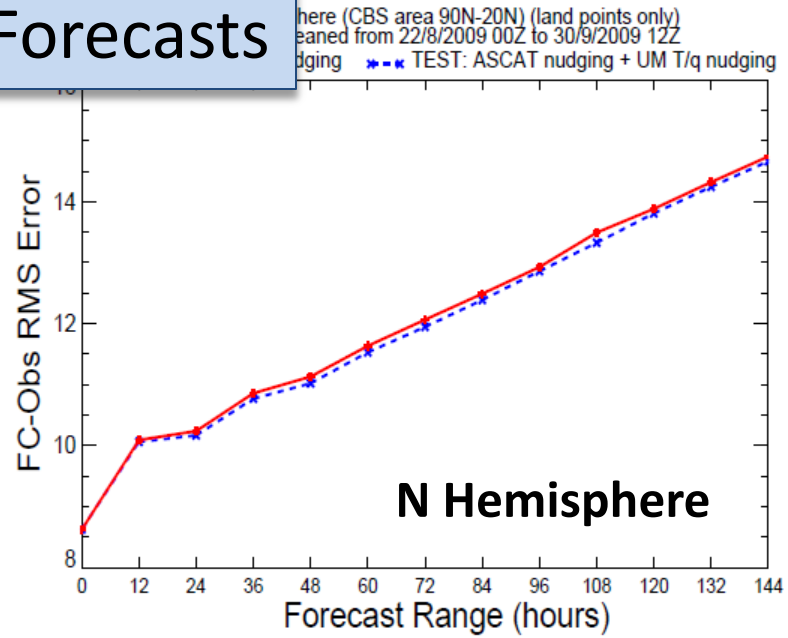






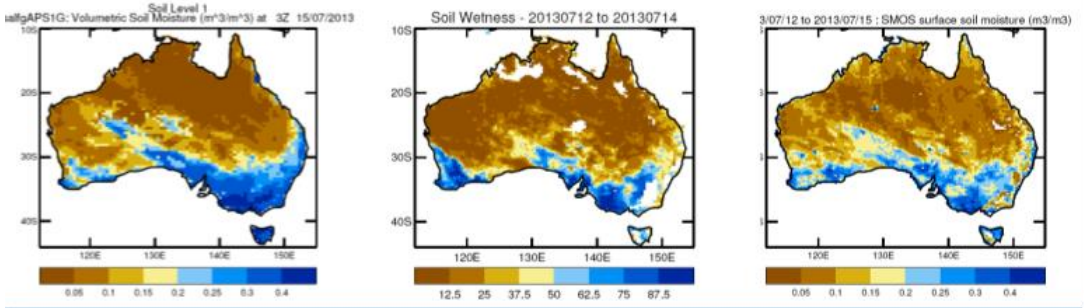
RMSD in Relative Humidity Forecasts





New Flexible Land DA scheme for NWP

- Built Around the JULES Land Surf Model (LSM)



Comparison of Model surface soil moisture (left) with ASCAT surface soil wetness (middle) and SMOS (Soil Moisture Ocean Salinity) surface soil moisture (right).

- Can Assimilate many observation types
  - 2m temperature and humidity (2m T, q)
  - Satellite derived surface soil wetness
  - Satellite derived land surface temperature (LST)
  - Satellite derived vegetation indices (e.g. NDVI, LAI)
- Atmospheric driving data is from the ACCESS Global NWP model at 25km spatial and 10min temporal resolution

Operational Implementation for NWP

- The new land DA scheme is operational at the UK Met Office
- The new land DA scheme is running in research mode at the Bureau
  - Assimilates 2m T, q and ASCAT soil wetness
- We should be able to use the new land DA scheme with CABLE LSM once CABLE is in the JULES framework
  - CABLE using same I/O interface as JULES

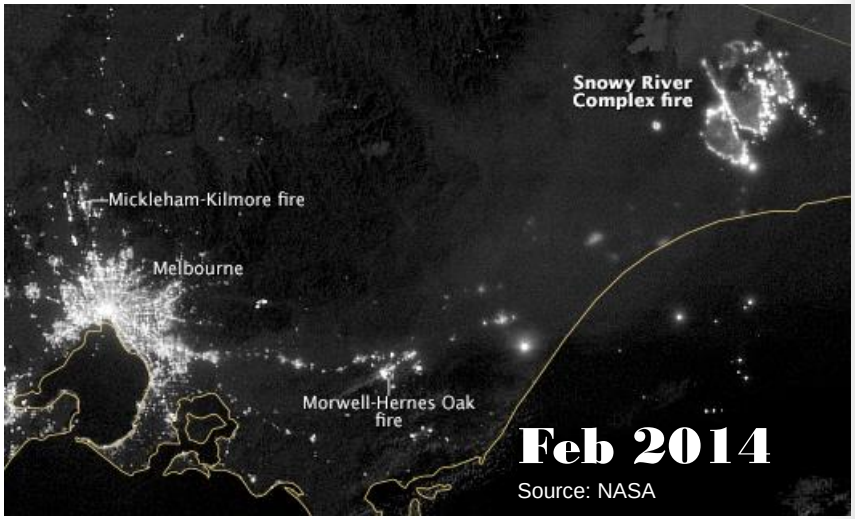
Observation Operator

Dharssi, I., Candy, B., Bovis, K., Steinle, P., & Macpherson, B. (2013). Analysis of the linearised observation operator in a land surface data assimilation scheme for numerical weather prediction. 20th International Congress on Modelling and Simulation (pp. 2862-2868). Adelaide: The Modelling and Simulation Society of Australia and New Zealand.

- The Observation operator describes the link between the observations and the model variables
- The observation operator is derived by using many JULES runs with perturbed initial conditions
  - Example; need 10 JULES runs to analyse soil moisture and soil temperature on four soil layers plus skin temperature
- The observation operator for LST is very similar to the observation operator for T2m.
  - Therefore, assimilating LST should have a similar very beneficial impact.
  - **Satellites can measure LST with high spatial resolution thus allowing the analysis of soil moisture and soil temperature at 1km resolution.**
  - Satellite derived soil moisture has a much coarser resolution of about 25km

Mitigating the effects of severe fires, floods and heatwaves through the improvements of land dryness measures and forecasts.

- Develop a high resolution (initially 5km) land DA scheme for natural hazard monitoring and prediction
- Develop Downscaling techniques to estimate landscape dryness at 1km horizontal resolution



- Use daily rainfall analyses from AWAP disaggregated to hourly fields
- Hourly analyses of T2m, q2m, 10m wind speed and surface pressure (MSAS)
- Hourly surface SW radiation generated from satellite data

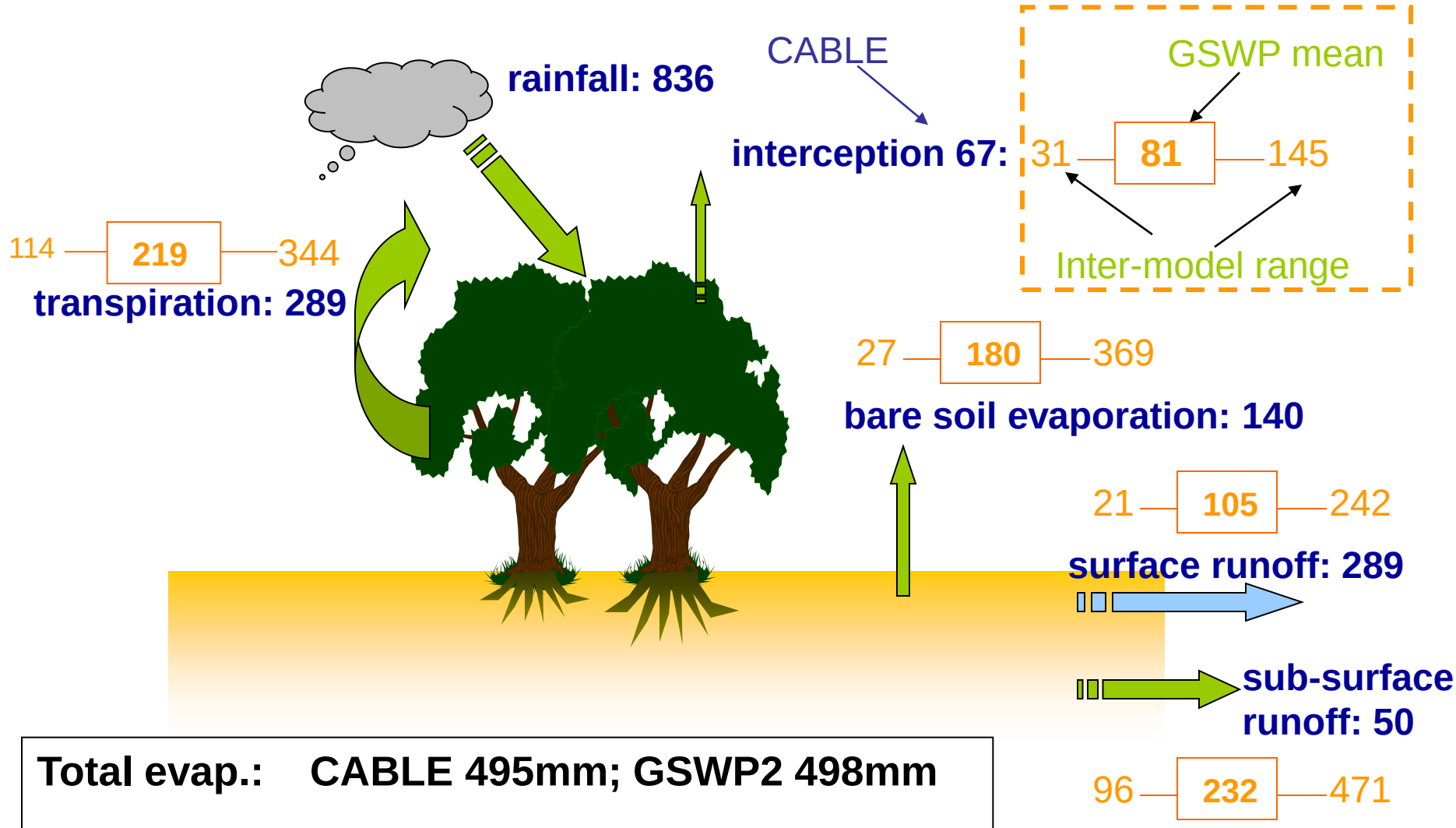
Nature of Model Soil Moisture

Koster, Randal D., et al. "On the nature of soil moisture in land surface models." Journal of Climate 22.16 (2009): 4322-4335.

- The true information in model soil moisture estimates is in the temporal variations and not the absolute magnitudes (Koster et al, 2009)
  - **"Simulated "soil moisture" does not have an unambiguous meaning. It is a strongly model-specific quantity, essentially an "index" of the moisture state, with a dynamic range defined by the specific evaporation and runoff formulations utilized by the given model"**
  - Different models have very different soil moisture climatologies. Even when driving the land models with identical precipitation and other meteorological data (e.g. GSWP2)
  - Model soil moisture is model specific. Direct transfer of soil moisture values from one land surface model to a different land surface model is inappropriate and likely to lead to problems.
  - Models tend to agree on the temporal variations of soil moisture
  - Satellite derived surface soil moisture values must be bias corrected to be consistent with the model used for assimilation.
  - For weather forecasting, the priority is to correctly model the surface fluxes of heat and moisture

Global water budget (mm yr^{-1}) against GSWP2 13-model climatology

Courtesy of Huqiang Zhang (CAWCR)

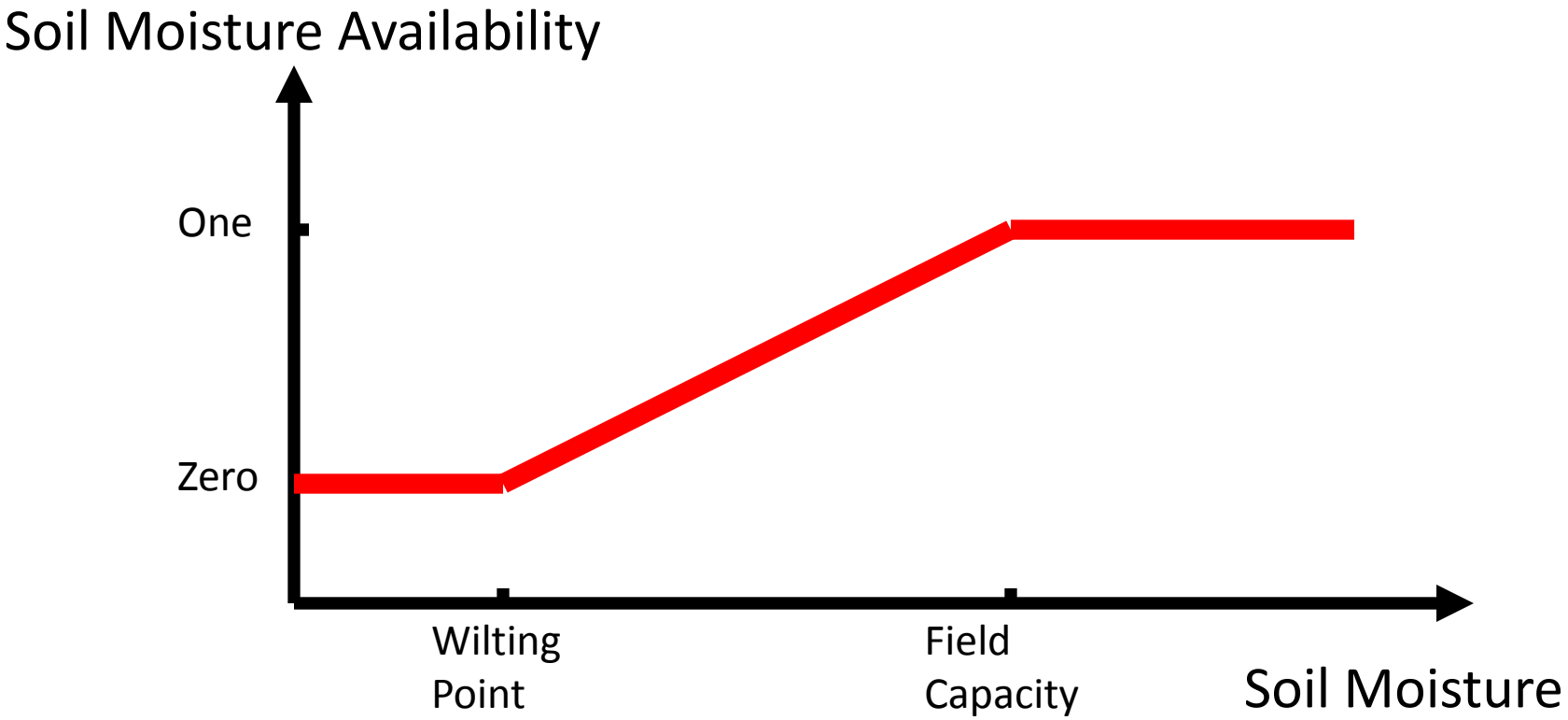


Total evap.: CABLE 495mm; GSWP2 498mm

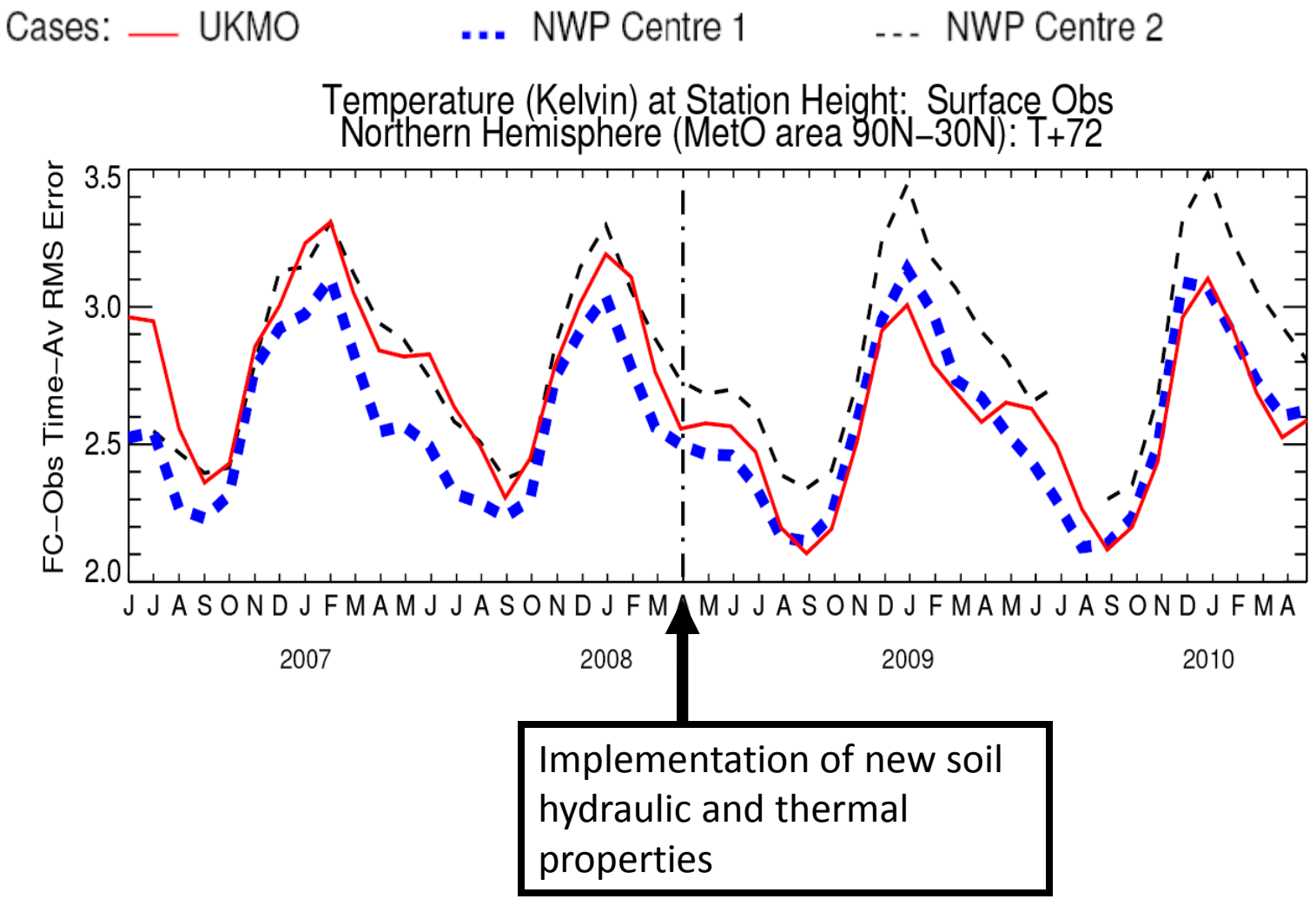
Total runoff: CABLE 338mm; GSWP2 337mm

How Does the Model Use Soil Moisture?

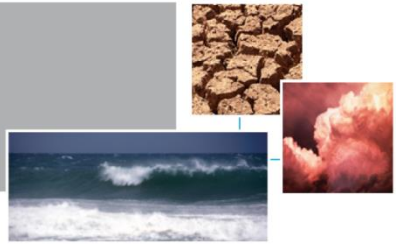
$E_{veg} \approx E_{potential}$ x Soil_Moisture_Availability



Operational Verification of T_{2m} T+72 RMS Error



How does the model use soil moisture?



- Evaporation from vegetation

$$E_{veg} = \rho \frac{\Delta q}{R_a + R_{s,veg}}$$

E	Evaporation
ρ	Density of Air
Δq	Difference in Specific Humidity between the surface and model level 1
R_a	Aerodynamic Resistance between the surface and model level 1

Calculated by a photosynthesis model and depends on vegetation type, temperature, humidity and incident solar radiation.

$$R_{s,veg} = \frac{R_s^{\min}}{\beta_{veg}}$$

The soil moisture availability depends on soil moisture, plant root fraction and soil texture.

Improvement of Urban Parameters and Tree Heights Surface verification over July 2013

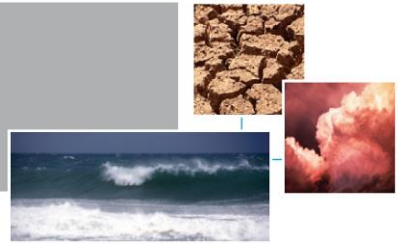
http://www.cawcr.gov.au/staff/idharss/Dharssi_urban.ppt

- Old=Control
- New=New Urban Parameters and Tree Heights

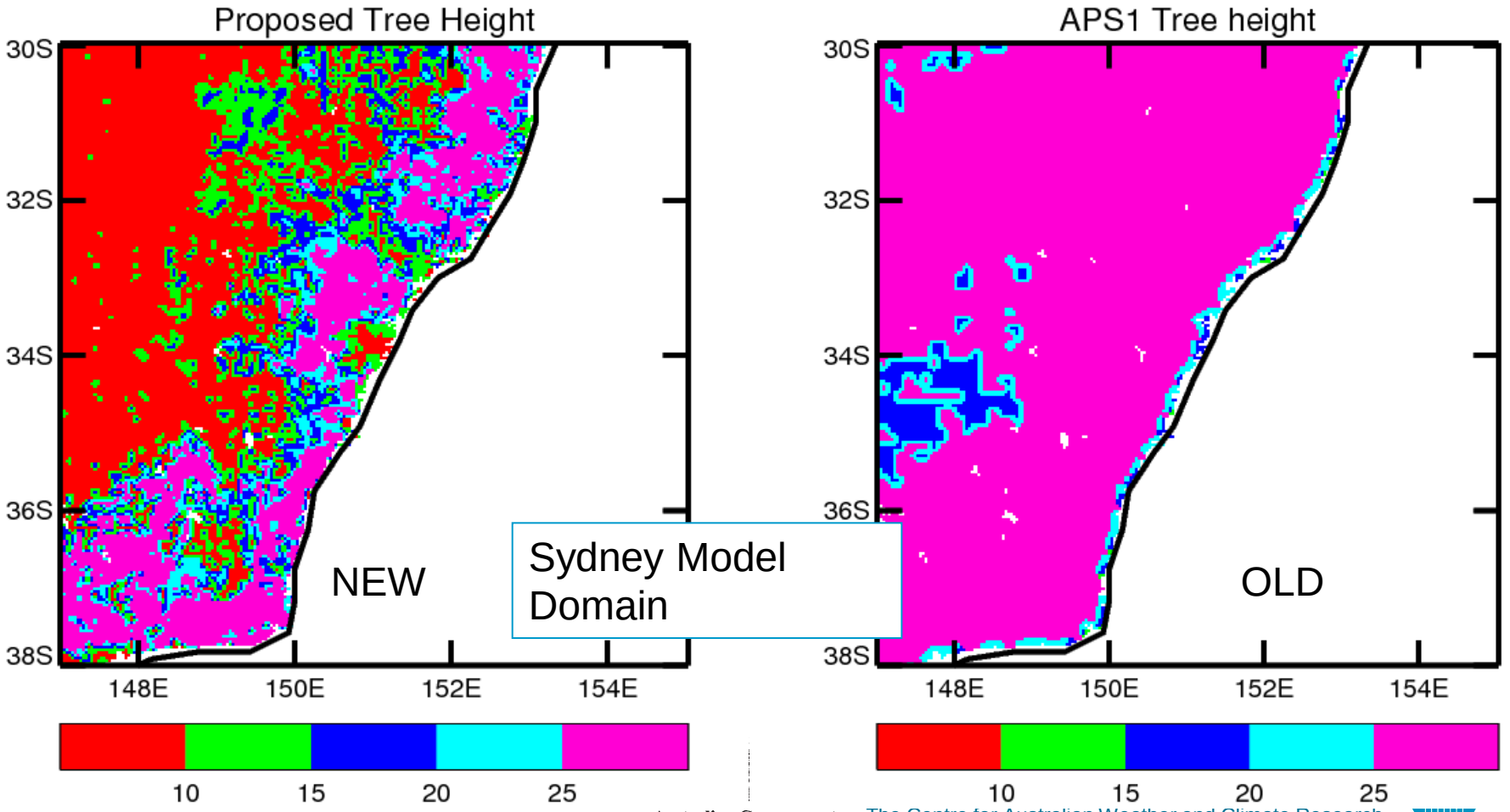
RMSD from Observed							
	Screen Temperature (K)			Screen Dew Point (K)		10m Wind Speed (m/s)	
Expermnt	Old	New	Imprv	Old	New	Old	New
Sydney	2.09	1.87	**11%**	2.00	1.98	1.98	1.93
VicTas	1.80	1.75	**3%**	1.67	1.64	2.12	2.04
Adelaide	1.60	1.57	**2%**	1.62	1.62	1.75	1.67
Perth	1.70	1.58	**7%**	2.06	2.04	1.84	1.79
Brisbane	1.92	1.67	**13%**	1.78	1.76	1.66	1.64

- **This change went operational in Winter 2014**
- We have reduced the urban heat capacity, albedo and roughness length in ACCESS NWP
- We have used a global satellite derived dataset of tree heights
- Testing in the ACCESS City models shows a significant improvement to 2m temperature forecasts, both in Winter and Summer

New Tree height ancillary

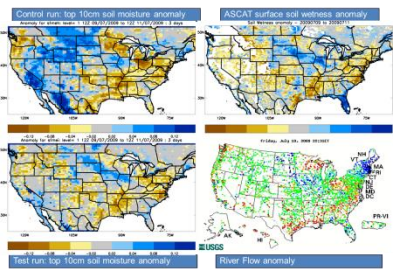


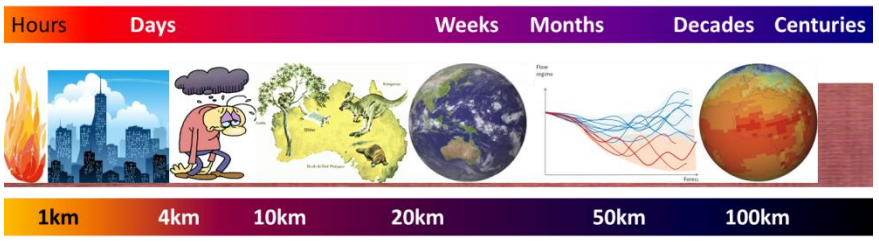
- Simard et al (2011). Mapping forest canopy height globally with spaceborne lidar, J. Geophys. Res., 116, G04021, doi:10.1029/2011JG001708

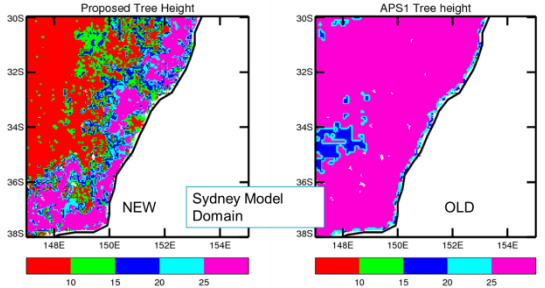


Conclusions

- We need to invest a lot more to improve the land models and land data assimilation used by Weather/Climate models
  - It is possible to improve land surface models by making greater use of remotely sensed data
- Weather/Climate models should continue to be improved so they can better simulate the energy and water cycles.
- Water in all it's forms is an essential climate variable
- **Only Weather models can forecast precipitation**
- We should use a seamless approach to modelling







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The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

CSIRO

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Questions?

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