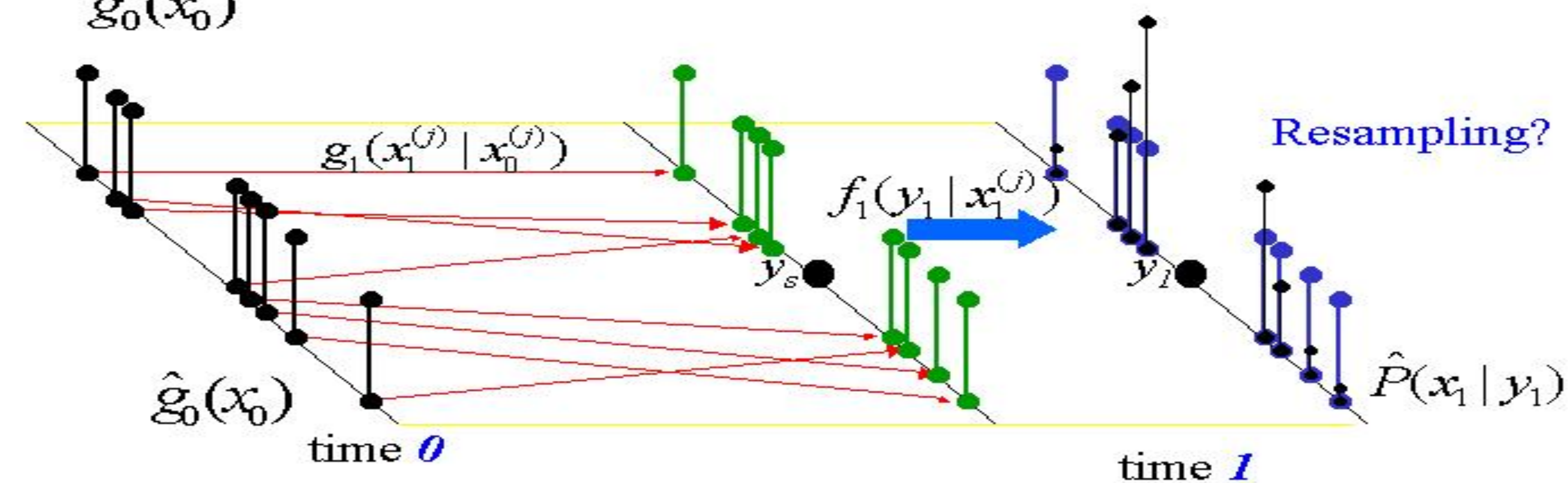


Prof Jun S. Liu
Stats @ Harvard Uni.,
www.people.fas.harvard.edu/~junliu/

www.csiro.au

Model-Data Fusion in Water Balance Modelling: Examples from Water for a Healthy Country Flagship

Luigi Renzullo,
Albert van Dijk,
Ben Gouweleeuw,
Julien Lerat, et al.

National Research FLAGSHIPS
Water for a Healthy Country

CSIRO

Presentation overview

Overview some of the different flavours of MDF work tried / tested / used in research under CSIRO's Water for a Healthy Country Flagship & WIRADA

Model development, optimisation, parameter selection/ estimation, calibration, tuning, fitting; data assimilation, state updating; model-data integration, image fusion; statistical blending; data merging; model selection, …

- **Talk outline**
  - Choice of MDF Techniques for Water Balance studies
  - Some examples from WfHC Flagship & WIRADA
  - Issues for Water Balance MDF
  - Conclusions & Recommendations

Choice of MDF Techniques

1. Nature of the systems we are modelling governs the appropriateness of the MDF techniques employed
   - System dynamics: e.g. stochastic dynamic, deterministic static, …

2. Use of Observations

   "**Observations**" includes **measured direct / indirect (retrieved) or modelled quantities**

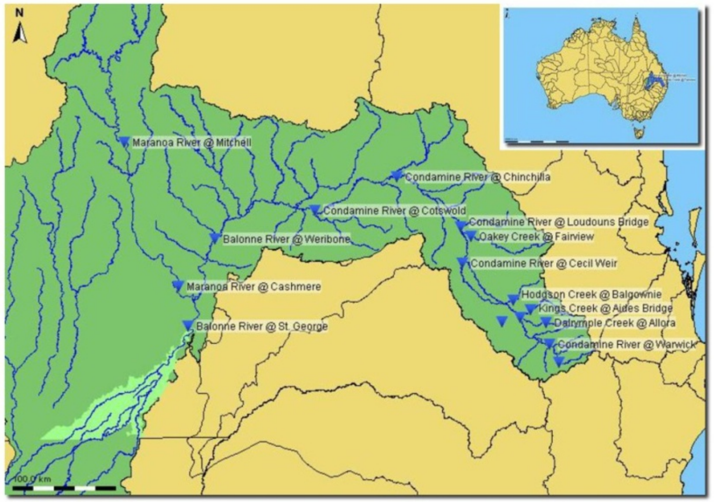
   - **Constraint** *e.g. sequentially update model trajectory; batch parameter estimation for time series of data*
   - **Model development & evaluation** *e.g. inferring model structure, parameterisation, model selection/development, verification*
   - **Model forcing & input** *e.g. driver data propagating model from one time step to next; spatially varying land surface variable*

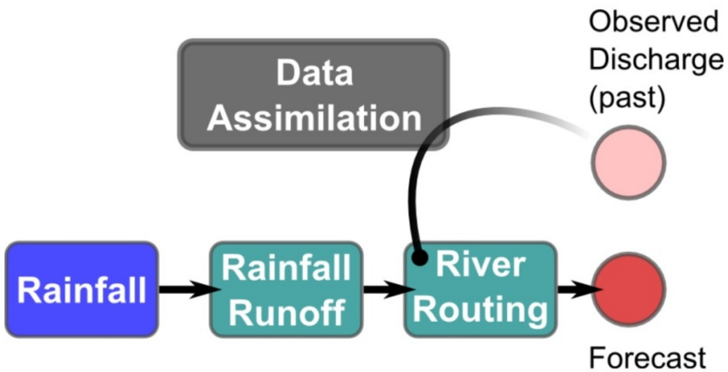
3. Application space & time frames
   - Real-time *e.g. flash flood forecasting,*
   - Retrospective / historical *e.g. medium- and long-term predictions, climate change studies*

Some examples from WfHC and WIRADA

Real time	Retrospective
• **Rainfall-runoff modelling** *Parameter estimation, state updating & forcing adjustment using stream gauges observations* • **Open water fraction** *Integrating multiple sources of remotely-sensed observations to map extent of flooding* • **Precipitation blending** *Statistical blending of gridded estimates & point measurements of precipitation*	• **Landscape water balance model development** *Using flux tower & stream flow observations to determine optimal level of model complexity* • **Spatial modelling of water stores & fluxes** *Spatial water balance estimation constrained by remote sensing in reanalysis*

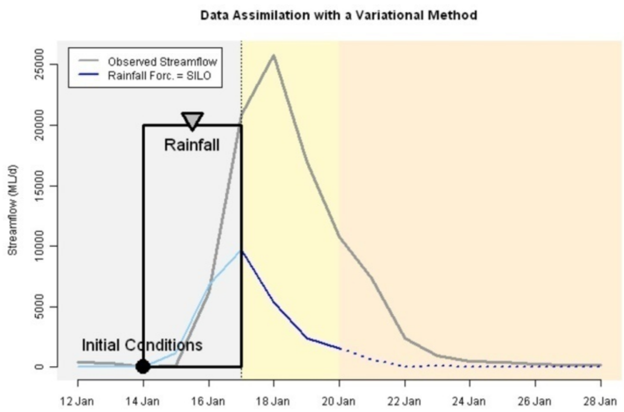
Real-time flow forecast on the Condamine-Balonne

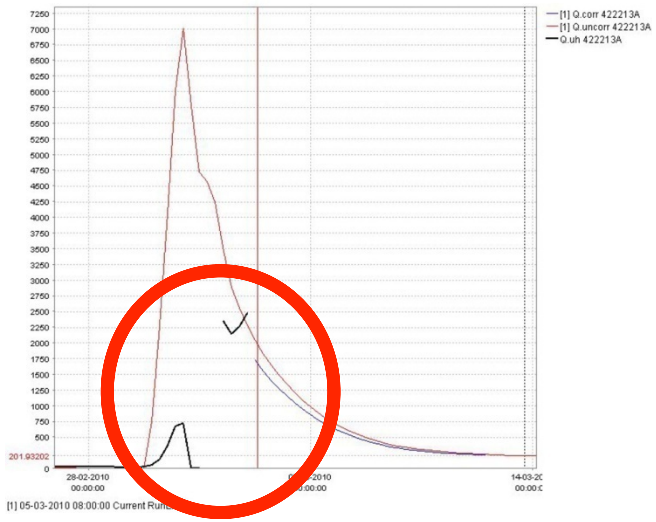




- System
  - 6 hourly
  - 20 forecasting points
  - Total area of 80 000 km2
- Models
  - Rainfall-runoff
  - River Routing
  - Data Assimillation to update Routing

Real-time flow forecast on the Condamine-Balonne



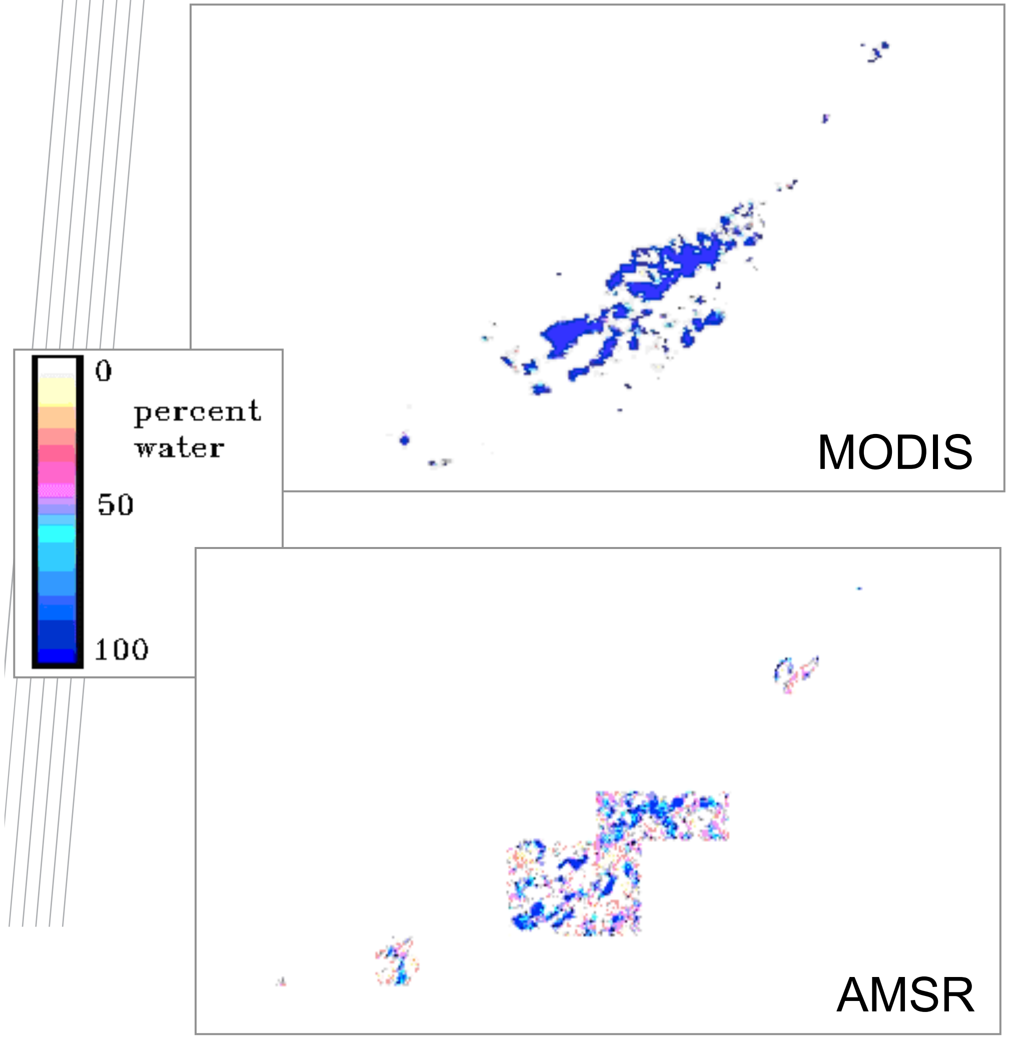


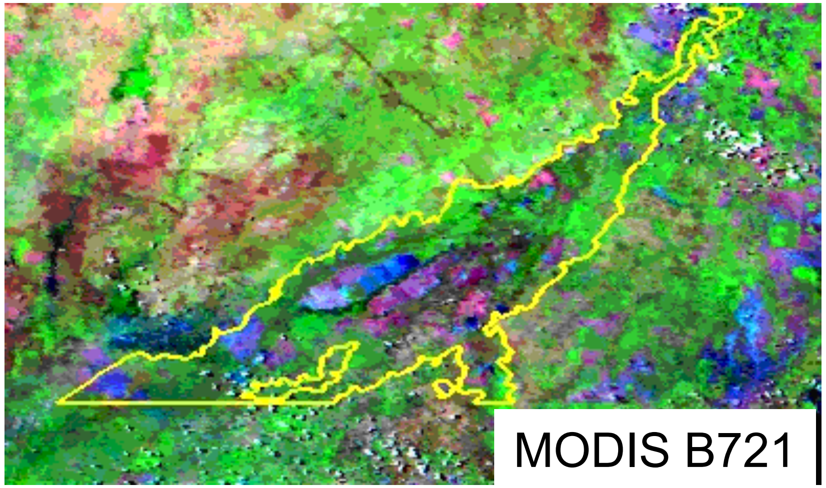
- Variational DA
  - Assimilation window of 7 days
  - Updating correction factors on
    - rainfall
    - model states
- Issues
  - Raw input data
  - DA not compensating structural errors

National Research FLAGSHIPS
Water for a Healthy Country
CSIRO

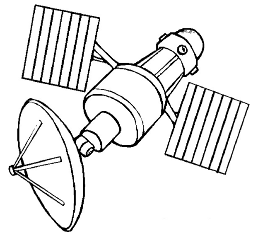
Estimating flooded area by blending satellite imagery

Flood extent estimation





MODIS
- 500 m resolution
- cloud affected
- twice daily

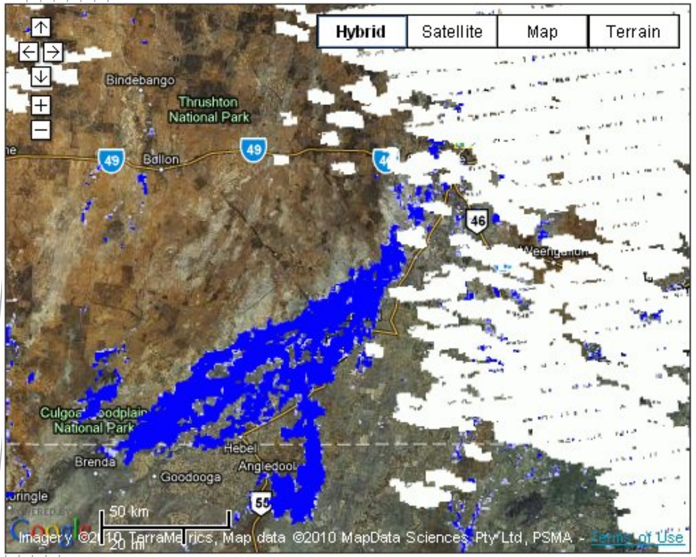


AMSR
- 14x8 km resolution
- affected by rain
- 1-2 times daily

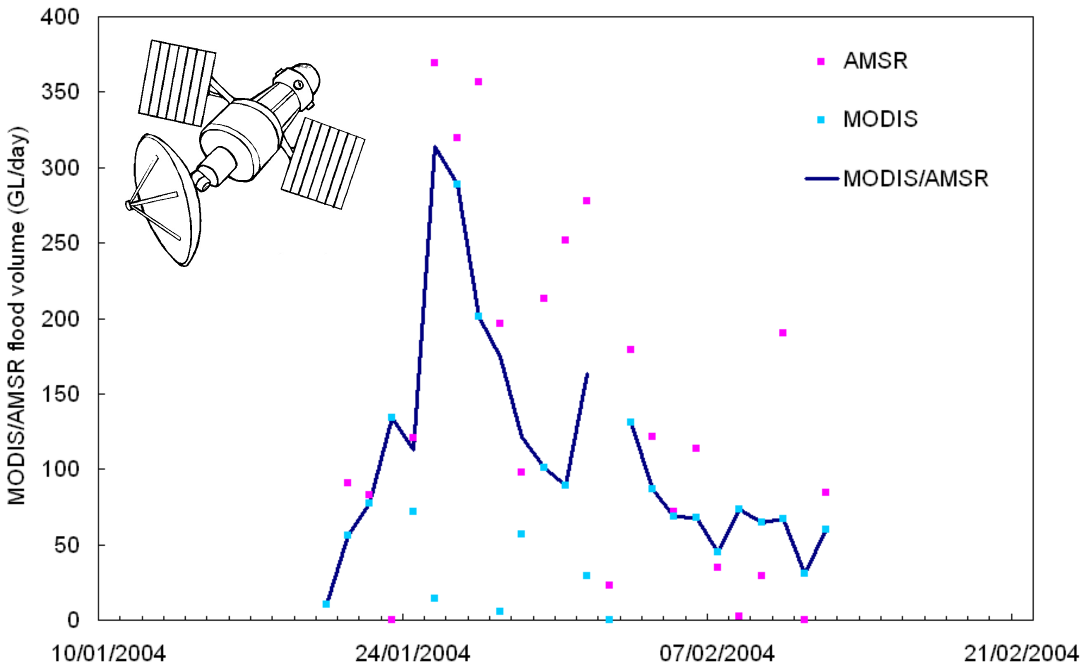
National Research FLAGSHIPS Water for a Healthy Country

CSIRO

Estimating flooded area by blending satellite imagery

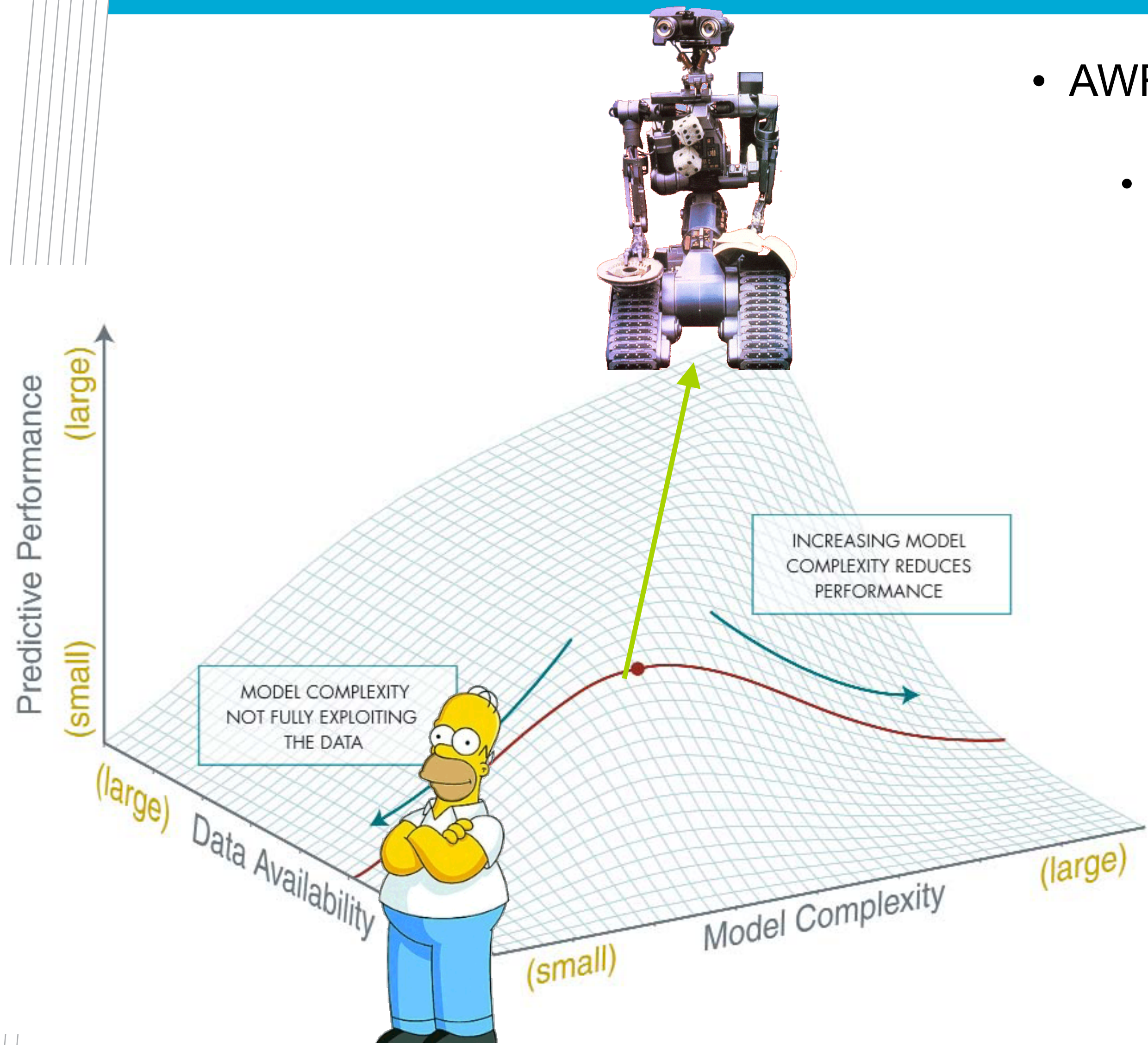


Frame: 180
Date: Wed Mar 17 2010
Volume: 1989.3 Gl



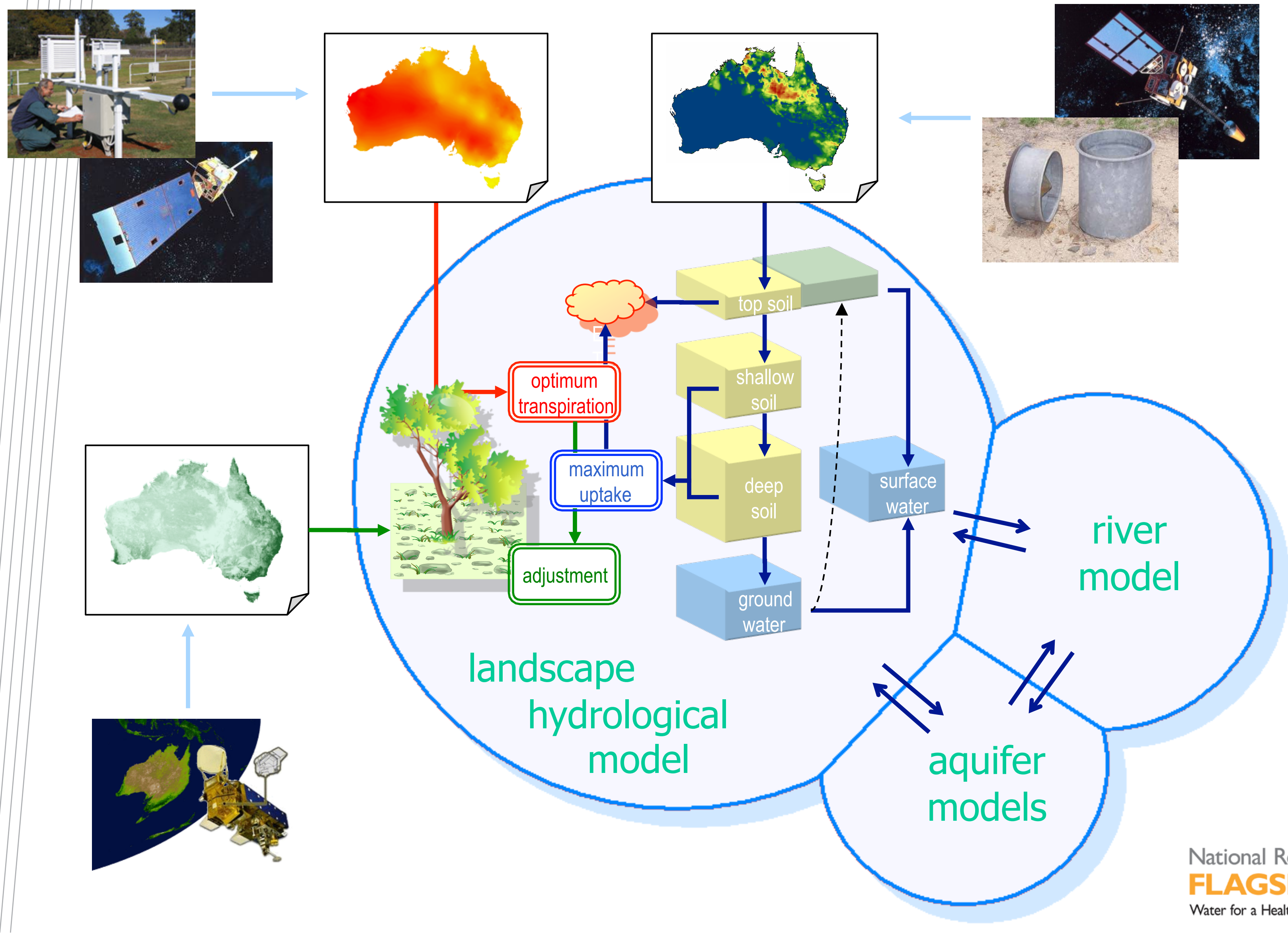
Weight of sensor based on cloud cover fraction

The Australian Water Resources Assessment (AWRA) system



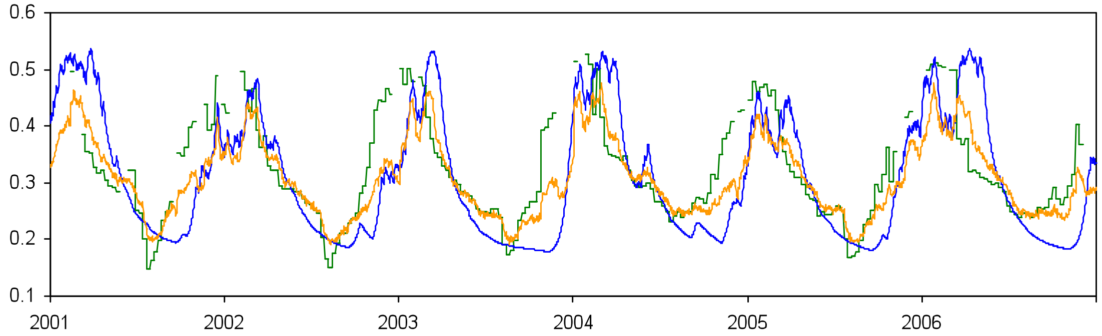
- AWRA model development
  - Surface obs from **flux** towers & **stream flow** observations were used to derive a model of Australian water balance of optimal complexity

The Australian Water Resources Assessment (AWRA) system

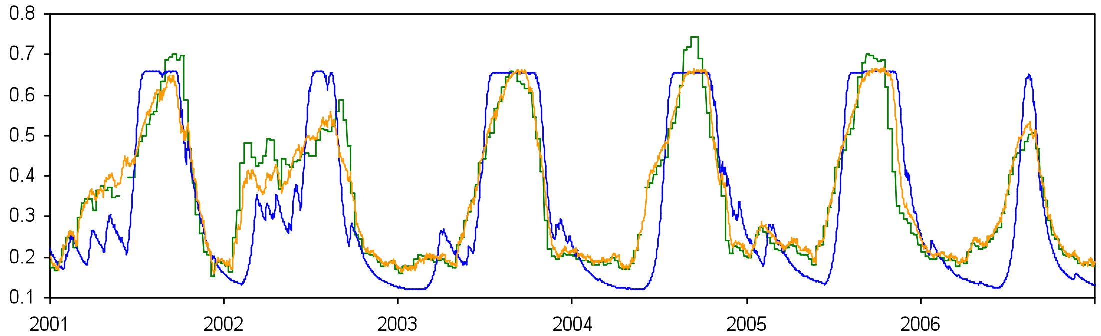


Data assimilation: MODIS EVI

Howard Springs savanna



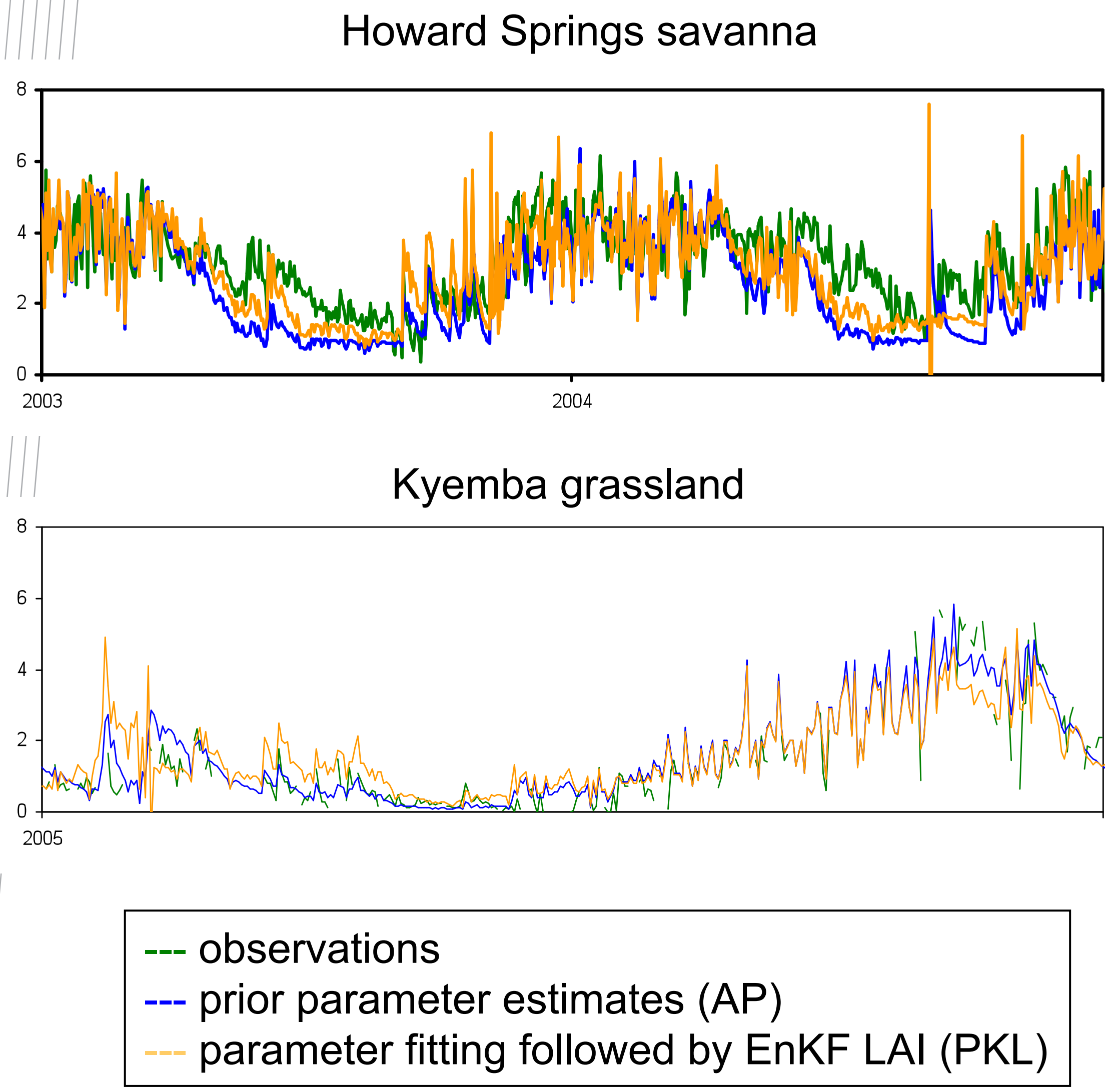
Kyemba grassland



--- MODIS greenness (EVI) observations
--- prior parameter estimates
--- parameter fitting followed by EnKF LAI

Data courtesy Lindsay Hutley, Jason Beringer, Jeff Walker and Robert Pipunic

Result: comparison against flux tower ET



- Prior parameters reproduce ET patterns reasonably well.
- Ensemble Kalman filter to update LAI occasionally leads to improvements, but also degradation at times.
- Much of the recalcitrant differences can be attributed to errors in rainfall (kriging product).

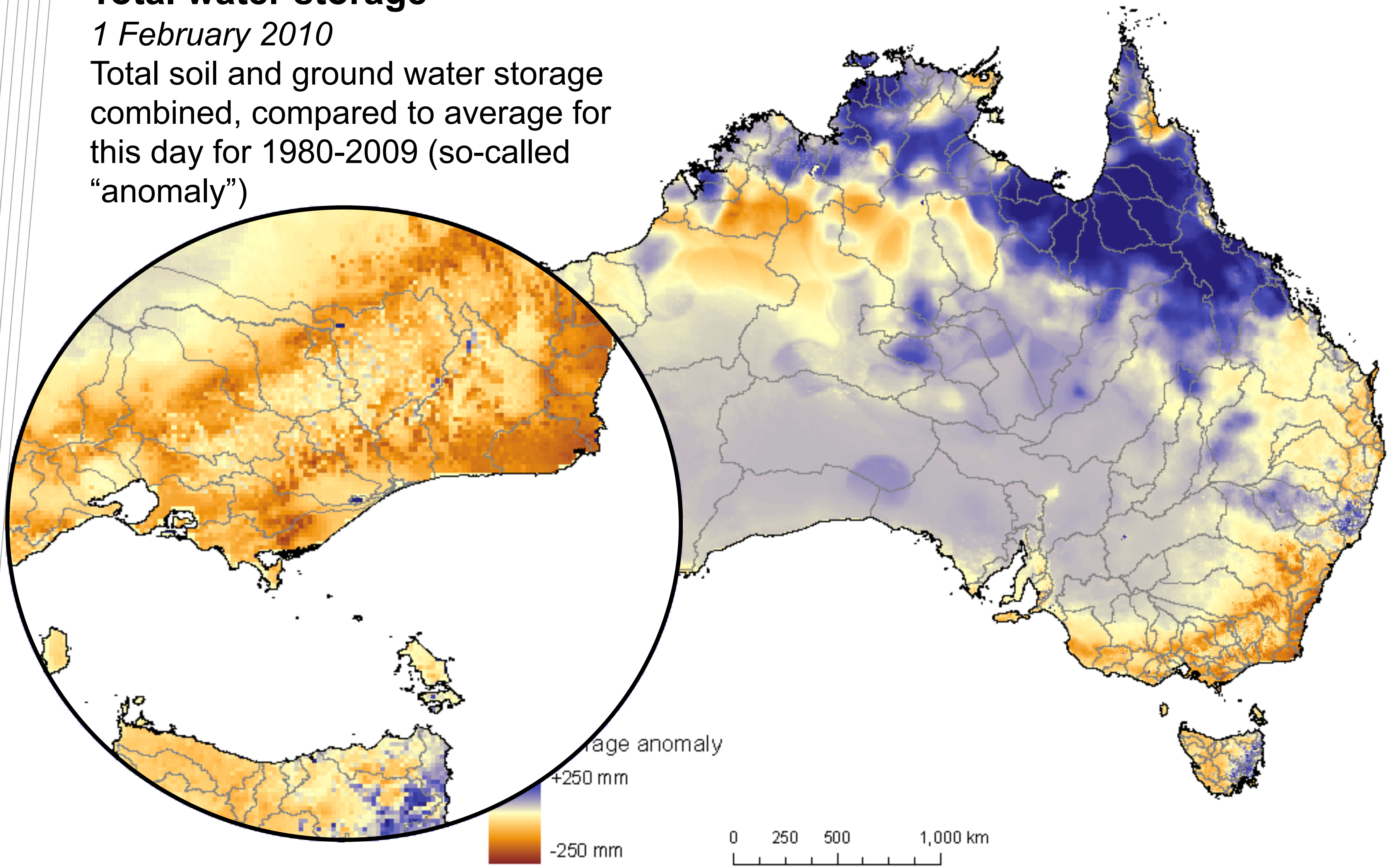
National Research FLAGSHIPS Water for a Healthy Country CSIRO

Example AWRA reports

Total water storage

1 February 2010

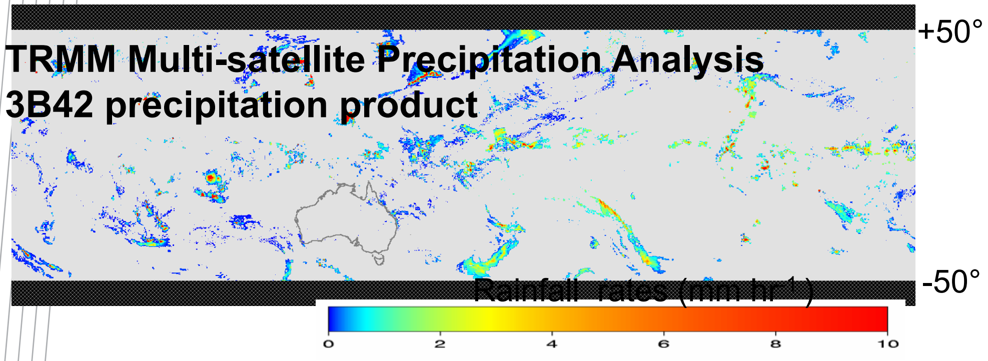
Total soil and ground water storage combined, compared to average for this day for 1980-2009 (so-called "anomaly")

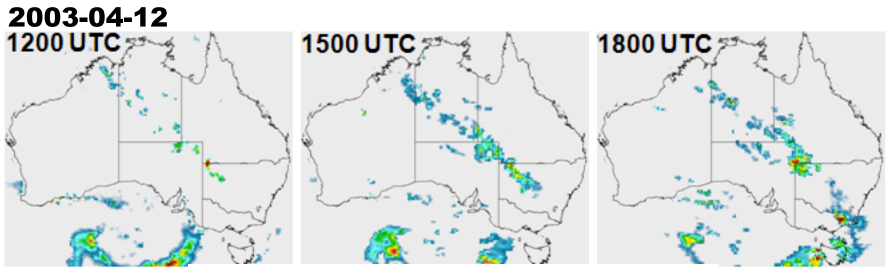


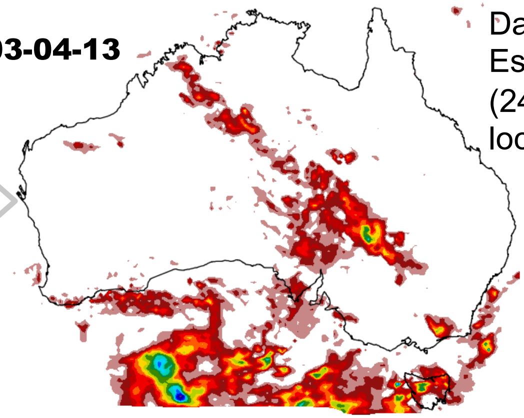
Blending gauge and satellite-based precipitation

Statistical blending of gauge & gridded precipitation data (Li & Shao, *J Hydrol*. 2010)

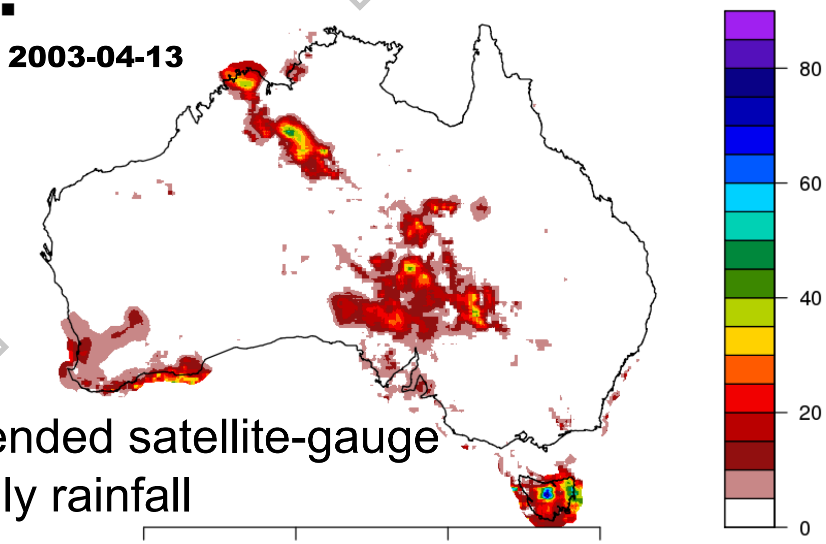
NCC Daily rainfall observations







Daily Rainfall Estimates (24 hr to 9am local time)

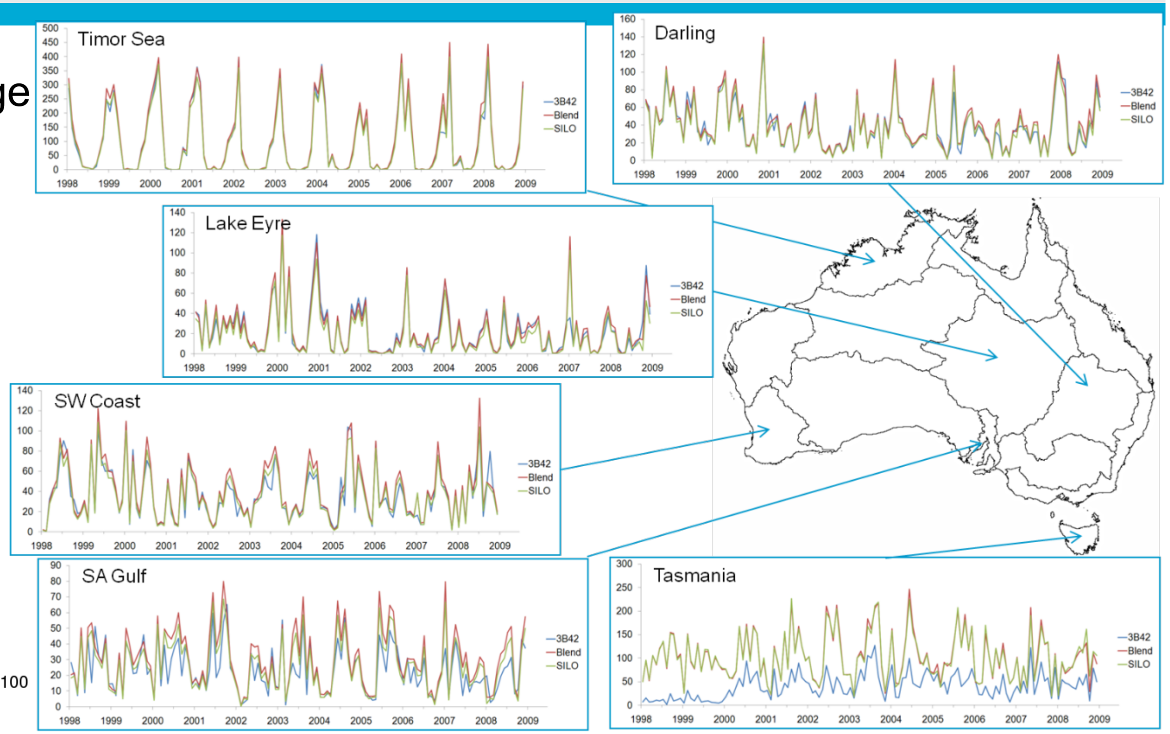


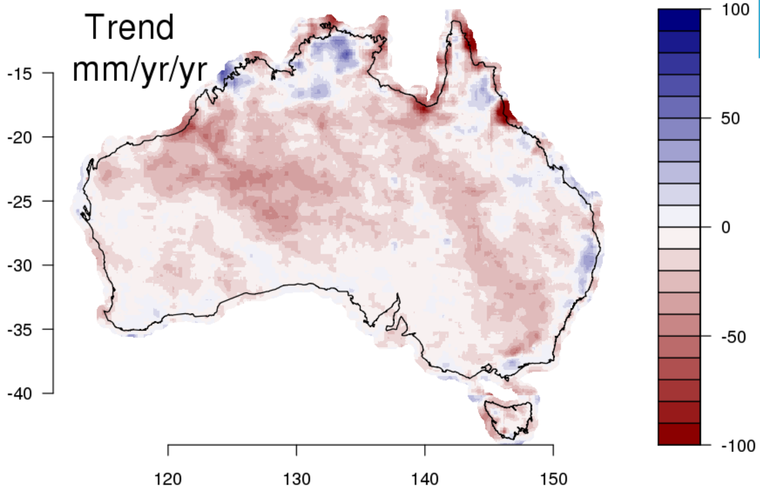
Blended satellite-gauge daily rainfall

Historical blended gauge and satellite-based precipitation

- Historical archives of rain gauge obs & satellite (TMPA 3B42) retrievals

- Displayed are time series of monthly precip average for 13 drainage divisions
  Jan 1998 – Dec 2008





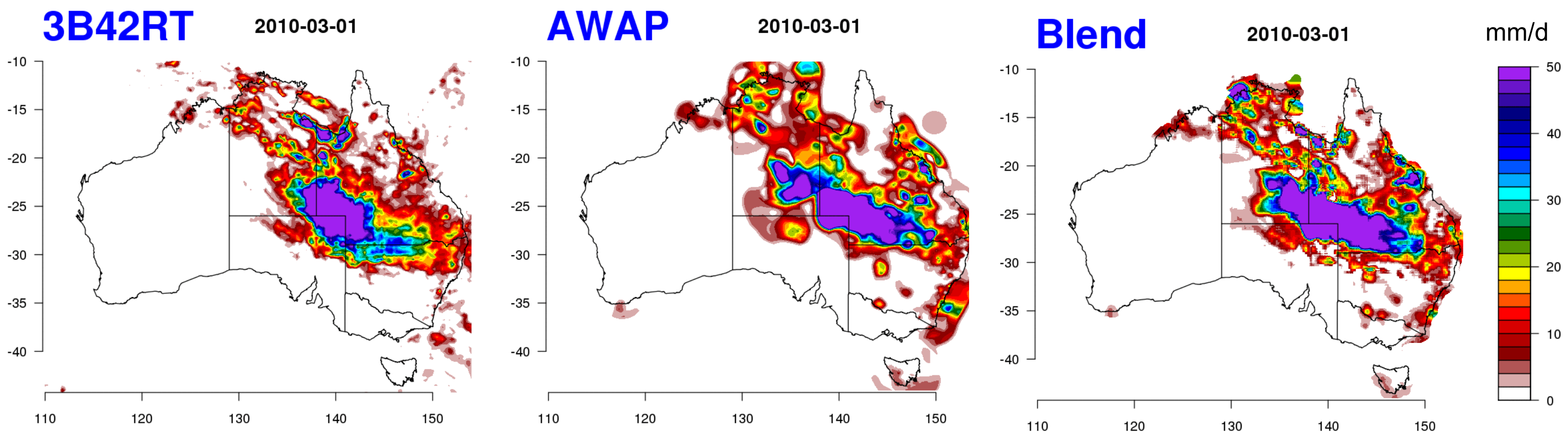
- Trend in annual precipitation from the blended product for Jan 1998 – Dec 2008

- ***Note***
  - * Number of gauge obs ~6000 per day (as opposed to ~1000 per day in Real Time)
  - * Satellite image history to short for most climate studies

National Research FLAGSHIPS Water for a Healthy Country CSIRO

Near real-time blended gauge and satellite-based precipitation

- Sequences of daily rainfall for 1-24 March 2010
- Blended satellite and NRT gauge generated ~9pm on day of interest



- ***Some issues***
  - * Not very “real-time” – but is 12 hr latency acceptable for most applications? (probably not for flood warning)
  - * Alternative blending approaches & data sets need to be tried
  - * Needs objective quantitative assessment of accuracy

National Research FLAGSHIPS Water for a Healthy Country CSIRO

Issues

- Nature of the systems
  - Modelling states difficult/impossible
    - e.g. Ground water dynamics
  - Makes development of observation operator challenging
    - Conceptualisation
  - No connection in space (e.g. adjacent catchments)
- Observations
  - Quality control – what/where are the error bars on the observations?
  - Timeliness – what level of latency is acceptable/unacceptable?
- …

Conclusions & recommendations

- *"Models without observations are misguided; observations without models are uninteresting…"*
- Observations are essential for determining appropriate level of model complexity, constraining model estimates & evaluating model performance
- Better characterisation of observation errors is needed
  - Obs error needed for assimilation; ensemble modelling; model verification
  - Greater support for field campaigns
- Ask the questions:
  - Are we making the most of the data we *currently* have?
  - What more data would we like to have & where?

Conclusions & recommendations

- MDF techniques abound – not all techniques appropriate for certain applications
  - *"When all you have is a hammer, all problems start to look like a nail"*
- However, some challenges are ubiquitous to all field
  - Encourage dialogue between the communities gathered here
- What would be good to have is …
  - Access to toolsets/existing algorithms
    - LIS, OpenDA tools, software libraries, …
  - Access to expertise/capabilities
    - Tap into this community; foster linkages & promote cross-divisional/institutional collaborations
  - Performance testing infrastructure
    - e.g. web-based interface to submit algorithms / outputs to be objectively assessed against alternative approaches. (ET-ICE)
  - Ability to interrogate / develop model structure
    - e.g. revisit rainfall-runoff model paradigm