MURRAY DARLING BASIN
Water Budget Project

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Participating Agencies:
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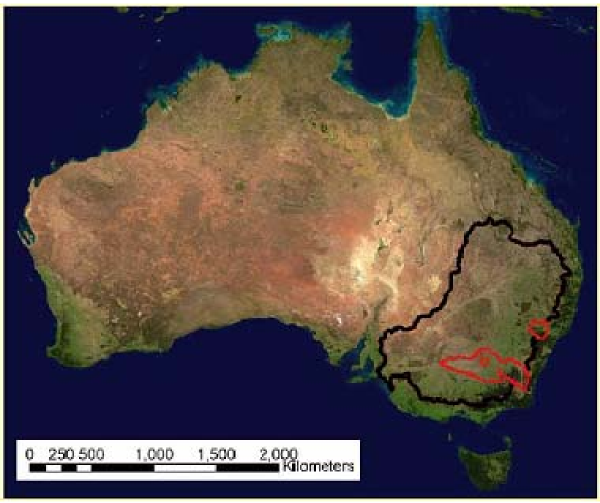
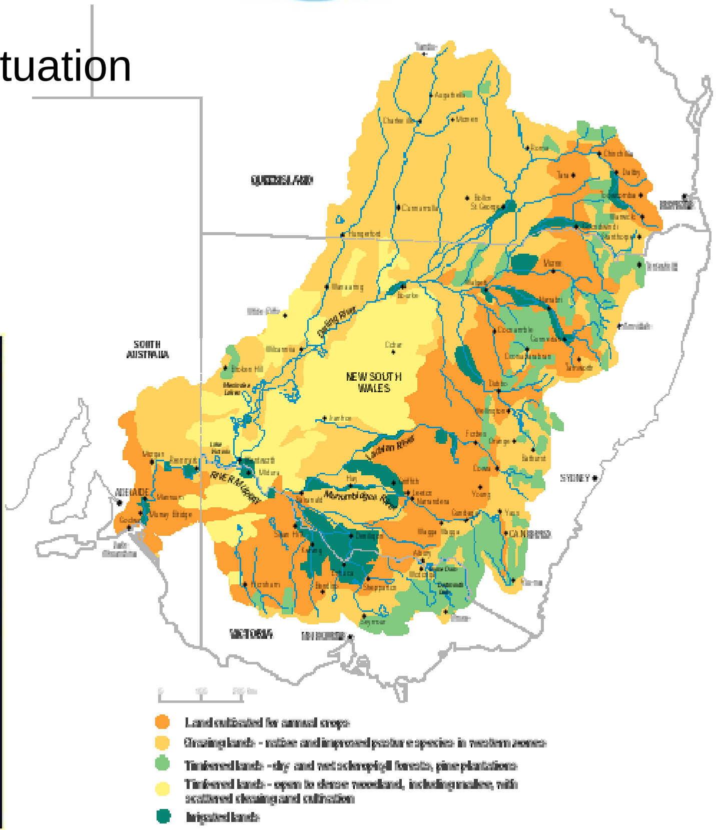
University of Melbourne
Macquarie University

Outline

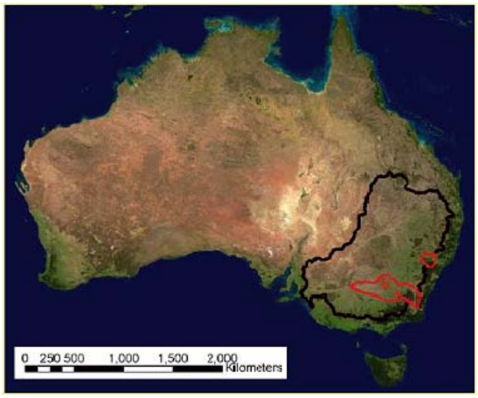
MURRAY DARLING BASIN
Water Budget Project

- Background and current situation
- Objectives and status
- Research highlights
- New opportunities





The Murray Darling Basin Background



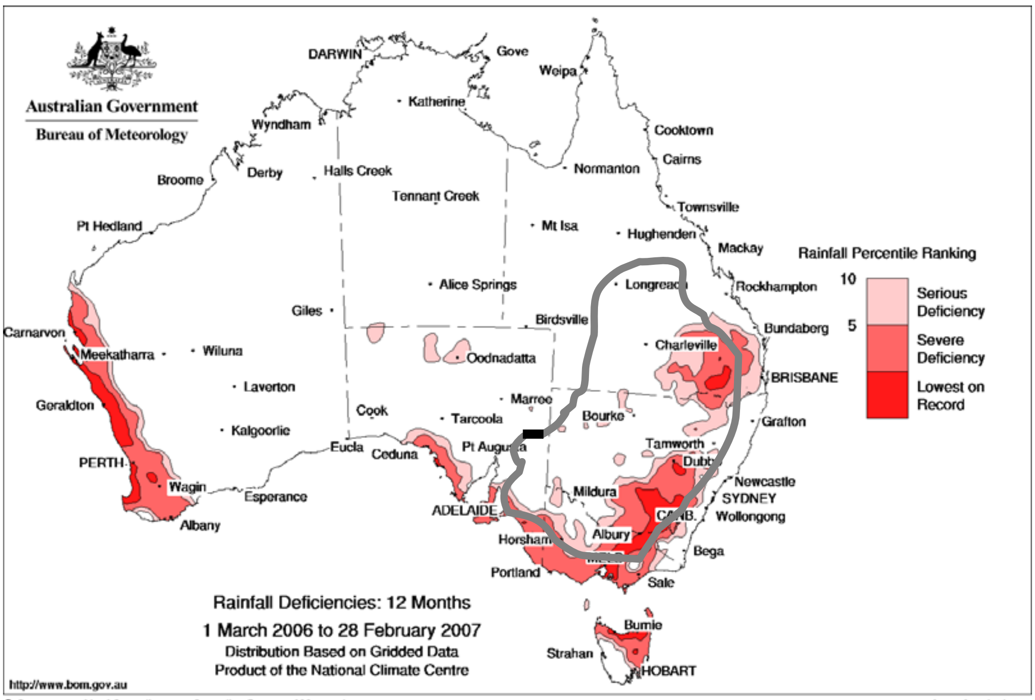
- Semi-arid **climate** characterised by:
  - Low ratio of discharge to precipitation (< 5%)
  - High potential evaporation rate
  - Large interannual variability of the rainfall, due to ENSO

- Variability in rainfall is amplified in the annual **runoff:**
  - Annual average is 10,000 GL, ranging from 1,600 GL to 54,000 GL

- Important region for Australia's **population and productivity**
  - Catchment area of 1 million km^2 or about 14% of Australia
  - The food bowl of Australia, accounting for 40% of agricultural production
  - Home to 2 million people - about 10% of the population
  - Manufacturing industries with an annual turnover of more than $10 billion

The Murray Darling Basin: Current Situation

Rainfall deficiencies in last 12 months (Mar 2006 – Feb 2007)



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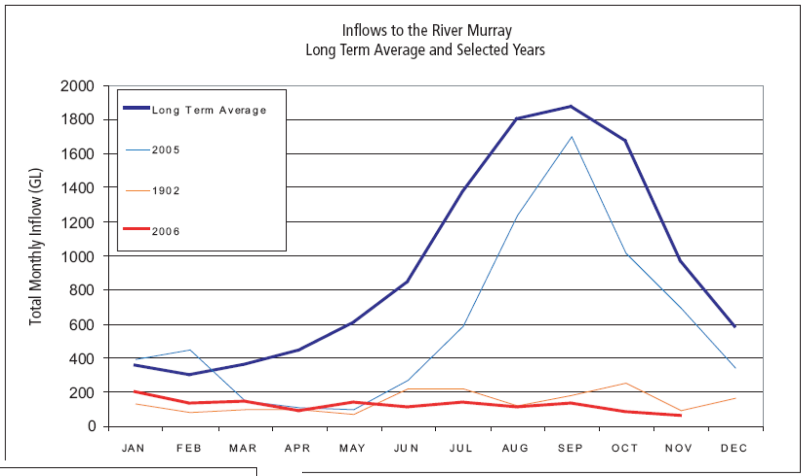
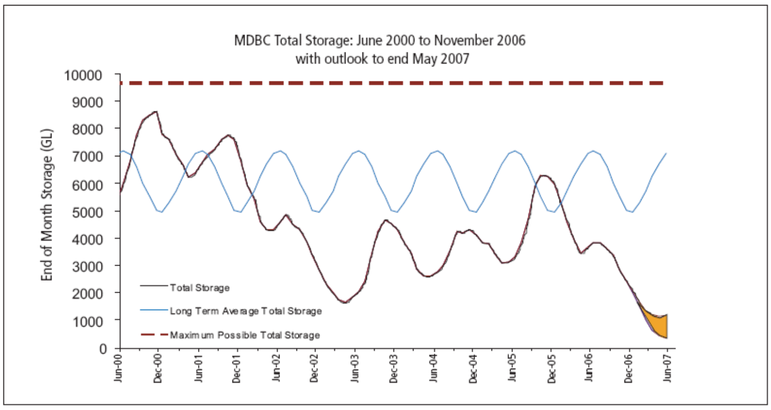
The Murray Darling Basin: Current Situation

Inflows to the River Murray:

- Average
- 1902, 2005, 2006





MDB total water storages

Both figures from Murray Darling Basin Commission

The Murray Darling Basin: Current Situation

- Currently in one of the worst droughts on record, which has focussed attention on:
  - The links between water availability and climate
  - Assessing and predicting water availability: soil moisture store, river flows and storages
  - Information and institutional arrangements needed to better manage water resources
  - Likely impacts of climate change

- Its an exciting time to be engaged in water – climate research in the MDB!

MDB Water Budget Project: Objectives

Motivation:

The critical role of moisture availability and the stress that a lack of rainfall imposes on socio-economic and biophysical systems demands improved water balance diagnoses and predictions

- Observe, understand and model the dynamics of the coupled water, energy and carbon cycles
- Improve predictive tools for water management, including real-time forecasting products for use by water agencies in the MDB
- Strengthen interaction between the climate research community and decision-makers
- Promote education and international exchange to improve global change science capability and innovation in Australia and worldwide

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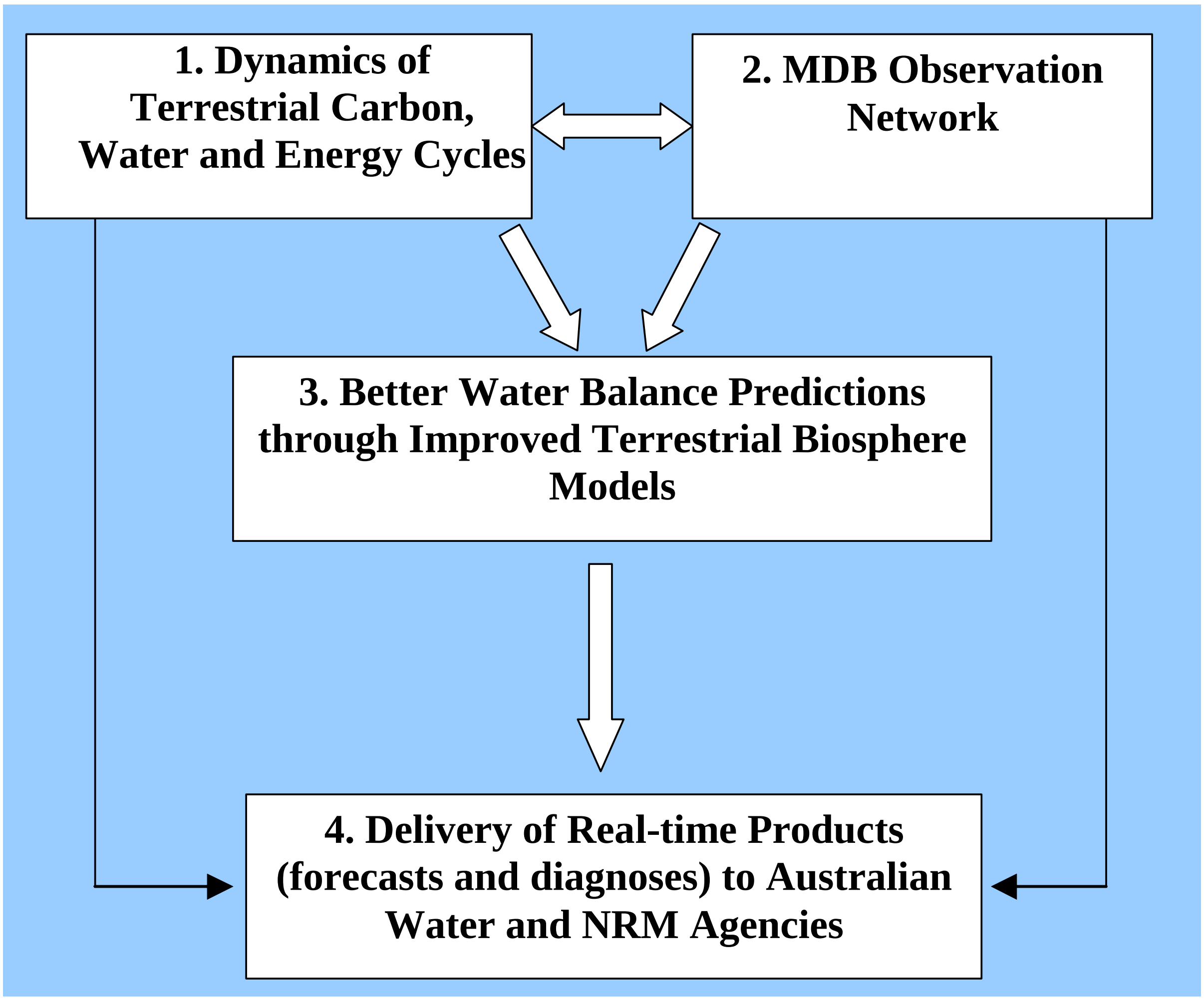
Water Budget Project



MDB Water Budget Project: Status

The following highlights some activities that:

a) contribute to these objectives, and

b) will contribute to future GEWEX – CEOP objectives:

1. Research quality datasets … of the Earth's energy and water cycles and their variability and trends on interannual – decadal timescales
2. Enhance the understanding of, and quantify how, energy and water cycle processes contribute to climate feedbacks
3. Improve predictive capability (especially via assimilating remotely-sensed observations)
4. Undertake joint activities with operational hydromet. services; ESSP projects …. to demonstrate the value of GEWEX research, data sets and tools..

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Water Budget Project

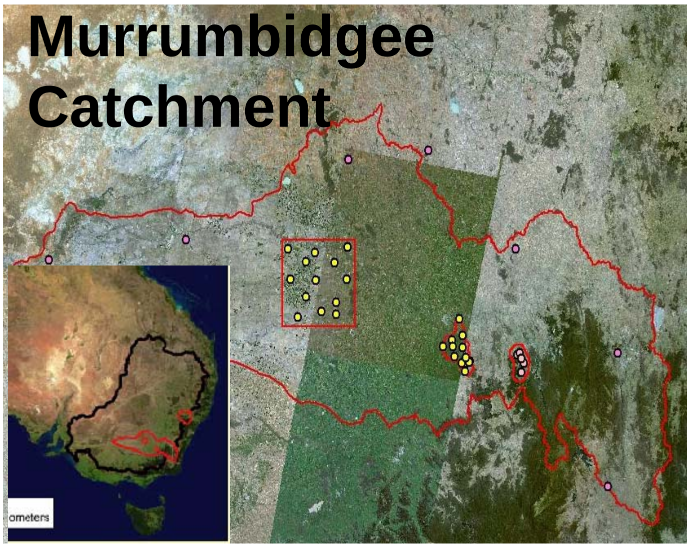
1. Observe, understand and model water, energy and carbon cycles

Observations

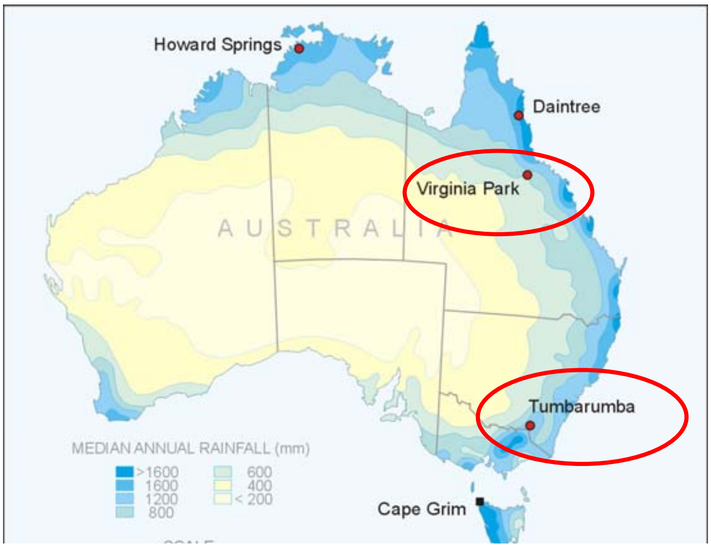
- In situ observations of soil moisture and water fluxes
  - Murrumbidgee soil moisture network: long-term observations and field campaigns (NAFE)
  - Tumbarumba flux tower:
    - Long-term water, carbon, energy fluxes
    - Field campaigns – complex terrain; isotopes in carbon and water; atmospheric chemistry and aerosol formation
- Global Network for Isotopes in Precipitation (GNIP) sampling network extended
- Regional water balance assessments via remote sensing:
  - GRACE satellite observations of terrestrial water storage
  - MODIS evaporation estimates for Australia

Murrumbidgee soil moisture network

- Network continues and has been expanded
- Mapping high resolution surface and root zone soil moisture
- 38 soil moisture and rainfall sites
- 26 groundwater monitoring wells
- 1 flux tower



Energy, water and carbon fluxes: Australia's flux tower network (Ozflux)



Flux tower measurements:

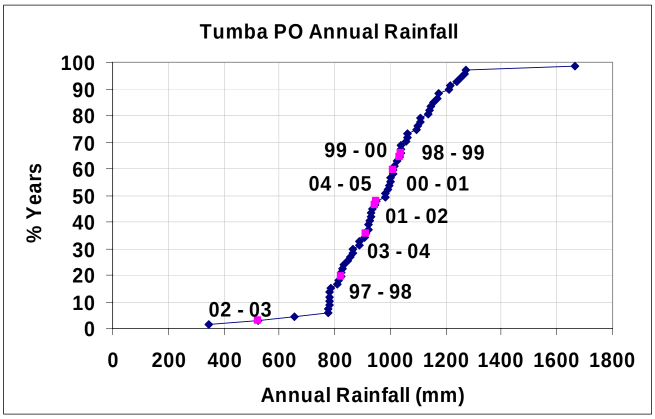
Hourly carbon, water fluxes

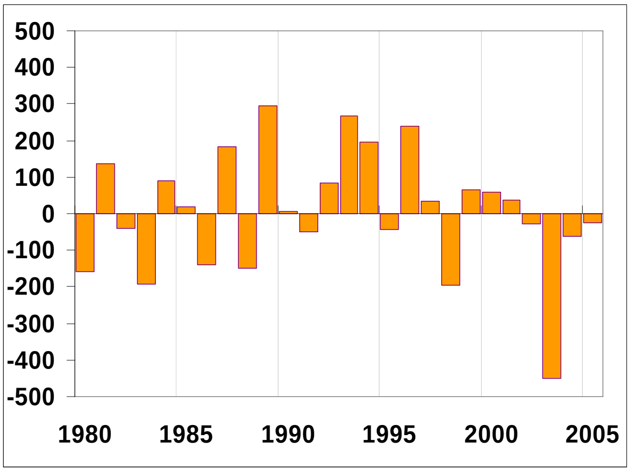
Net all-wave radiation, soil heat fluxes

Temperature, humidity and wind speed

Rainfall

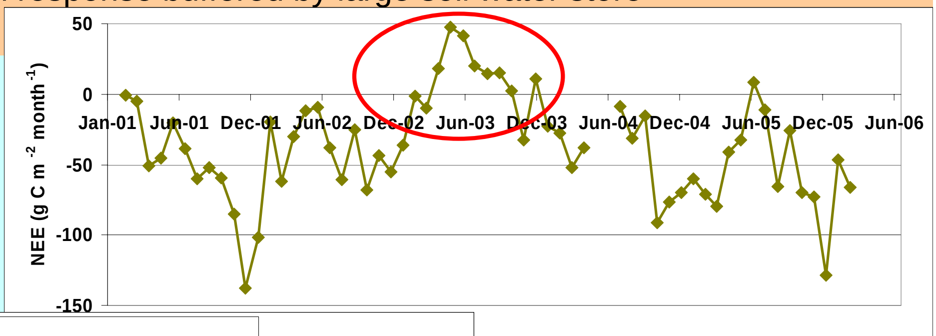
Tumbarumba flux tower

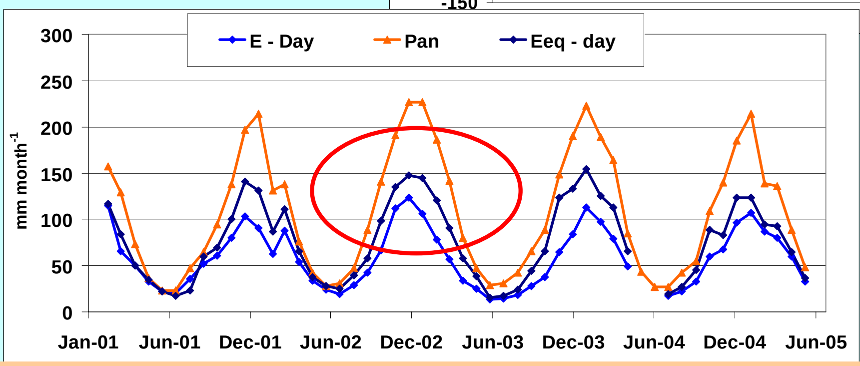




- **Continuous carbon, energy, water fluxes and stored soil water, rainfall from 2000 – 2006**
  - Plan to continue measurements
- **Eucalypt forest:**
  - Broad-leaf and evergreen
  - Highly productive (NEE ~ 6 t C ha^{-1})
  - Fairly sparse (LAI ~ 2.5)
- **Temperate, mesic climate**
  - Annual average rainfall ~ 1100 mm
  - Record spans 5^{th} – 70^{th} percentiles using long-term (65 y) record
- **Annual rainfall anomalies in last decade illustrate the drying trend**
  - Plus higher temperatures and humidity deficits

- Large inter-annual variability in rainfall and increasing “evaporative demand”
  - Causes large variability in net exchange of carbon (large sink to small source)
  - Evapotranspiration response buffered by large soil water store





- Tumbarumba is being used to parameterise CABLE – the land surface scheme in ACCESS [Australia’s NWP and next generation climate model]
  - Wang et al (2006); Abramowitz et al (2006)

Regional water balance assessments via remote sensing

1. Evapotranspiration (ET) estimates by combining flux tower and MODIS remote sensing

2. HydroGRACE – estimating terrestrial water storage in the MDB by assimilating ground- and satellite-based gravity measurements at the point- and regional-scale, respectively, into a land surface model:
   - NASA's GRACE satellite observations of Earth's gravity field
   - *in situ* soil moisture measurements (Murrumbidgee network)
   - near-surface soil moisture measurements from AMSR-E (Advanced Microwave Scanning Radiometer for the Earth observing system)

Regional scale evaporation

- Monitoring of ET using MODIS remote sensing (Cleugh et al, 2007)
  - Continuous estimates at weekly – monthly intervals
  - Fine spatial resolution (1 km) – implemented continentally and globally

- Model specification:
  - Inputs: routinely available over large regions (e.g. Australia)
  - Robust: estimates constrained and insensitive to cloud screening and compositing aspects of multi-temporal remote sensing
  - Use: Penman Monteith: an "old but new" ET model, and MODIS LAI to estimate surface conductance:

$$\lambda E_{PM} = \frac{sA + (\rho C_p G_A D_a)}{s + \gamma(1 + G_A / G_S)}$$

$$G_S = c_L \, LAI + G_{s\min}$$

  - Validated: using Fluxnet ET (diverse range of bioclimates and ecosystems) and annual ET from gauged catchments in MDB

Land surface evaporation from remote sensing

3 coupled surface energy balance equations

$$A = R_n - G = H + \lambda E$$

$$H = \rho C_p \frac{T_{sA} - T_a}{R_a}$$

$$\lambda E = \frac{\rho C_p}{\gamma} \frac{e_s - e_a}{R_a + R_s}$$

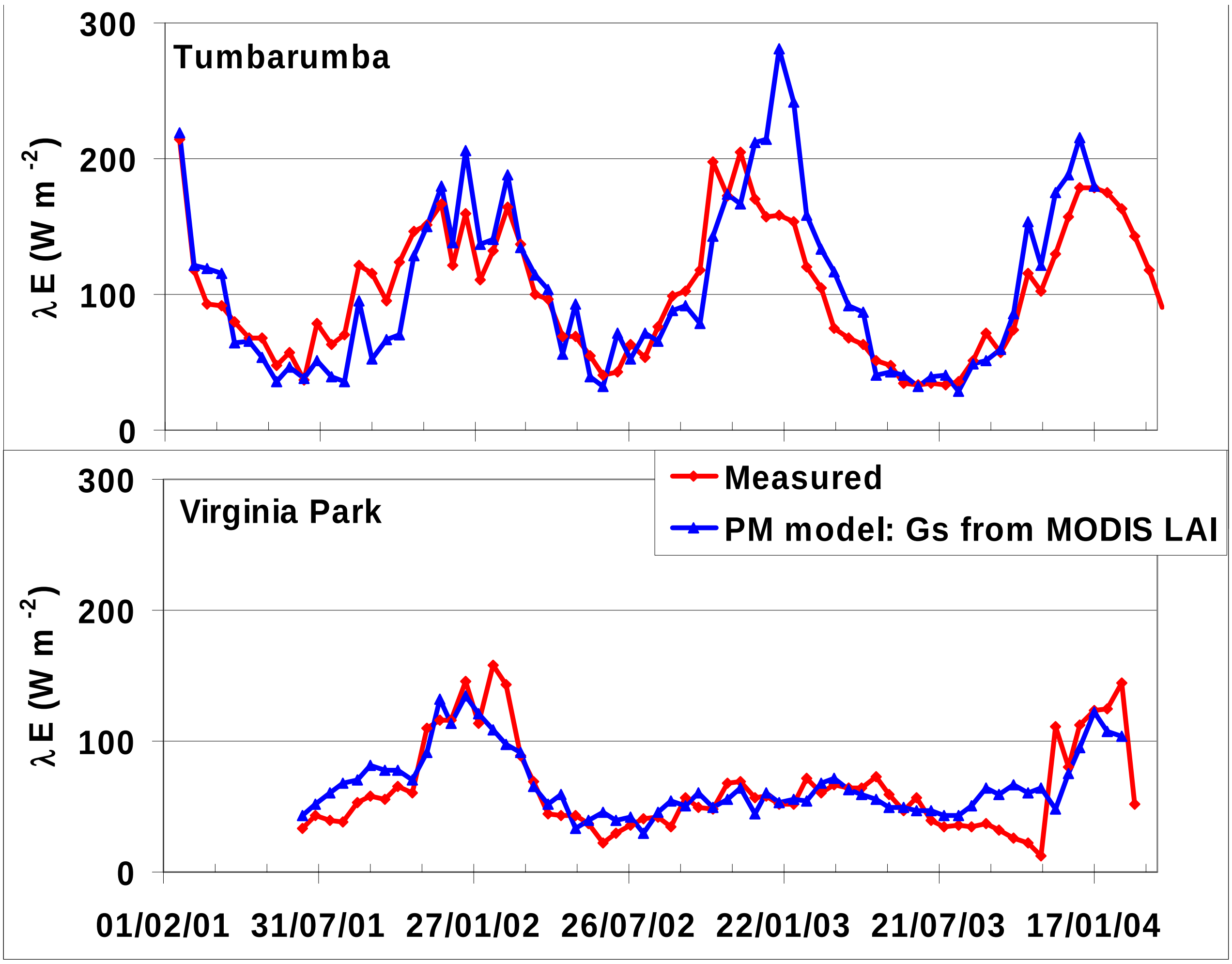
$A = R_n - G$ = available energy

$H + \lambda E$ = sensible and latent heat fluxes

R_s and R_a = surface and aerodynamic resistances

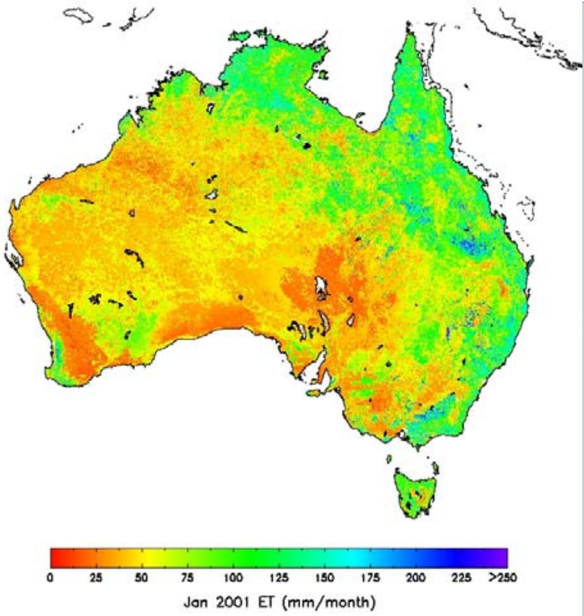
T_{sA} and T_a = aerodynamic surface and air temperatures

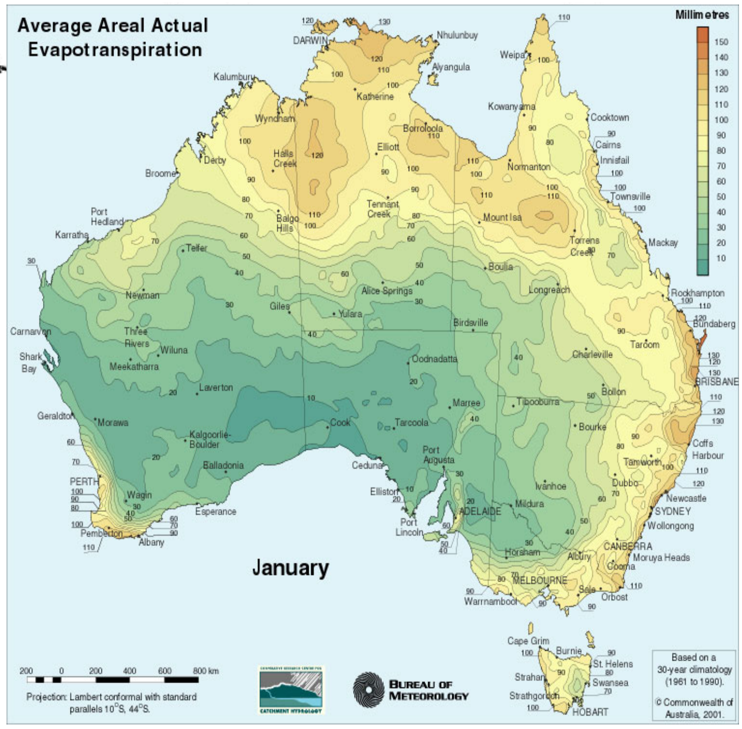
e_s and e_a = vapour pressure at surface and in air



Continental evaporation climatologies

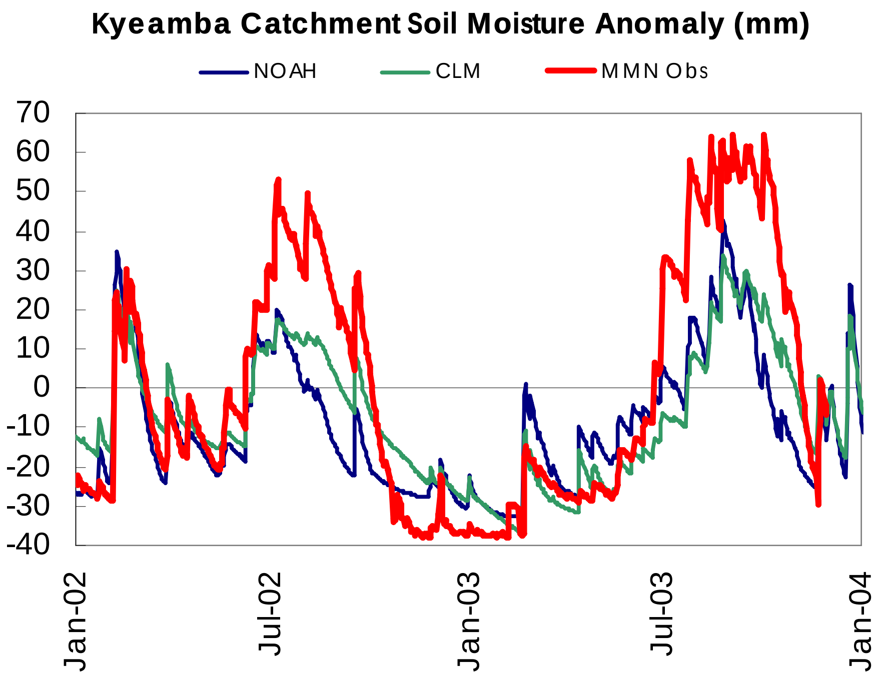
Mid Summer, Monthly ET





2001 – average year

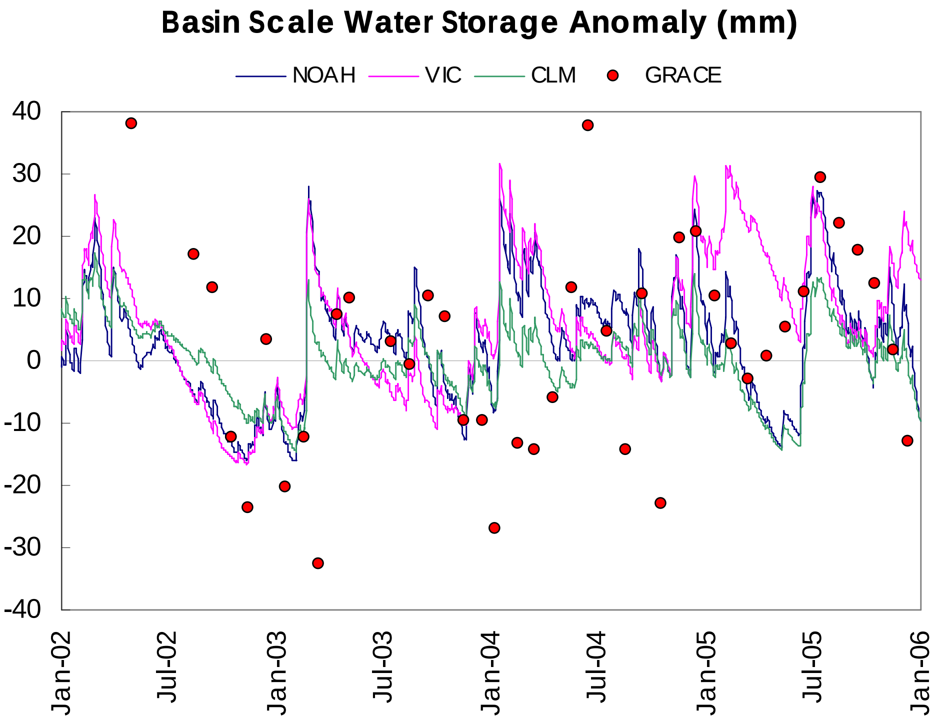
HydroGRACE component of the MDB:
Model evaluation of soil moisture at various scales (Walker et al)



- Grid cell and catchment-scale comparisons to in-situ observations (Murrumbidgee)
- Soil moisture is underestimated
- Dry bias, with initialisation effects persisting for several years

HydroGRACE component of the MDB:

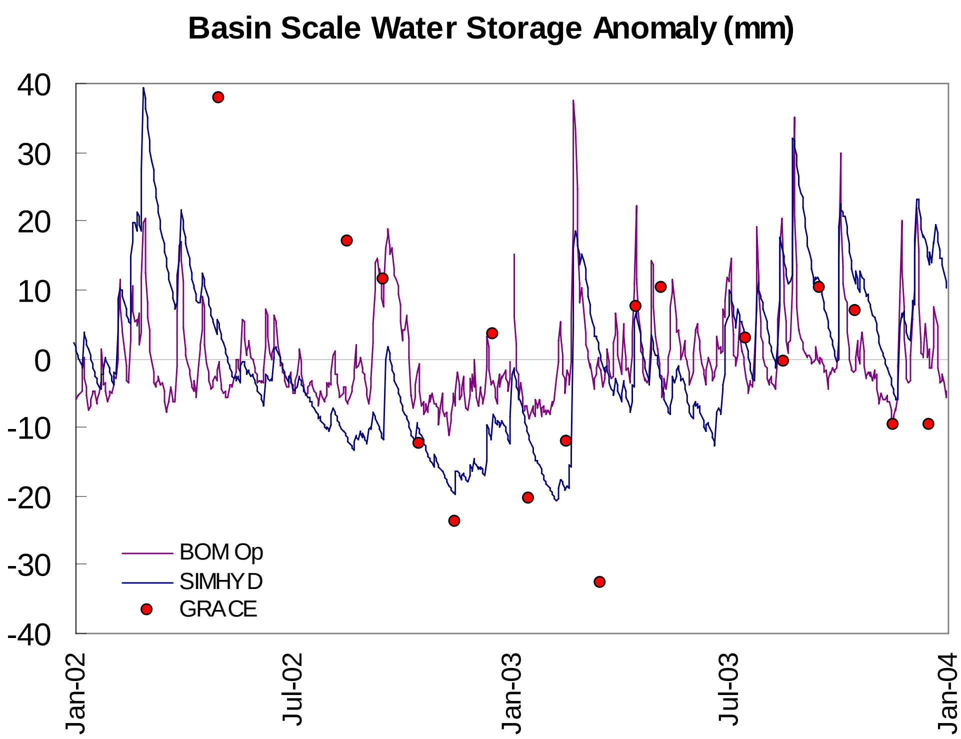
Model evaluation of soil moisture at various scales (Walker et al)



- Seasonal evolution of modelled soil moisture also damped compared to GRACE estimates
- Water storage estimates (amplitude and phase) from GRACE are sensitive to processing methods
- Further work underway to validate GRACE signal

HydroGRACE component of the MDB:

Model evaluation of soil moisture at various scales



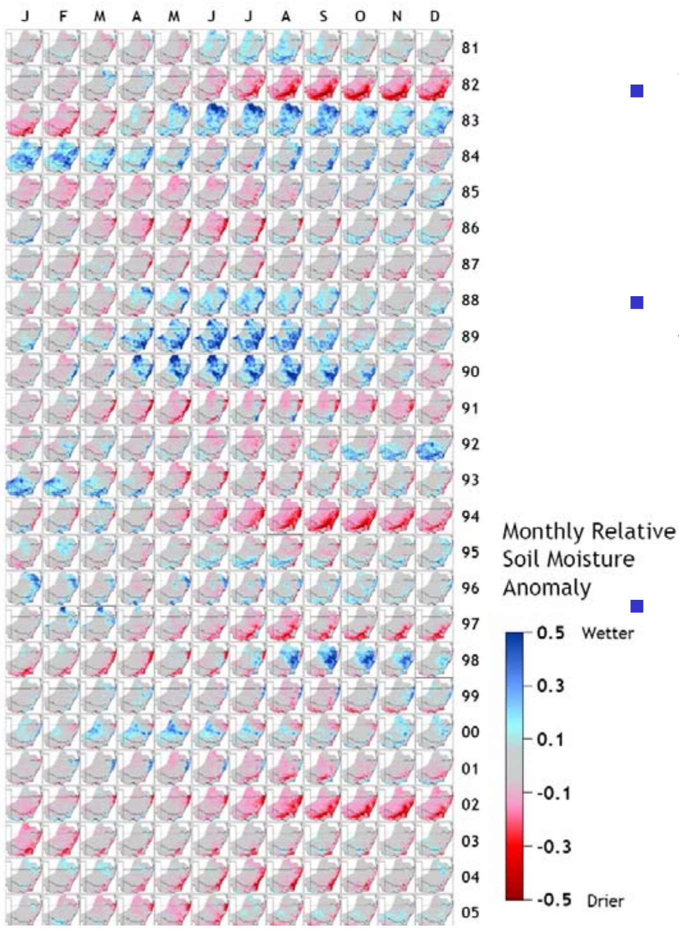
- NOAH, CLM and VIC are similar to SIMHYD rainfall-runoff model
- BOM operational model damped and noisy due to initialisation routine and nudging scheme

1. Observe, understand and model water, energy and carbon cycles

Water Balance Assessments

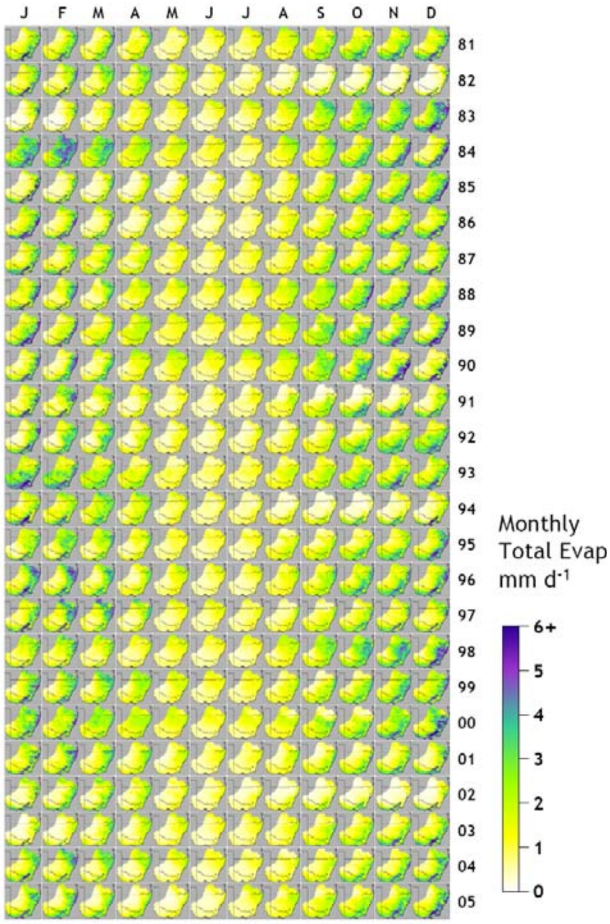
- An initial hydrological water budget for the MDB using:
  - Analyses of rainfall and streamflow data
  - Engagement with river management agencies
  - New methods developed to account for unknown sources and sinks
- Australia Water Availability Project: a "model – data fusion' approach to assessing the terrestrial water balance, for SE Australia
  - A collaboration between Bureau of Meteorology, Bureau of Resource Sciences and CSIRO

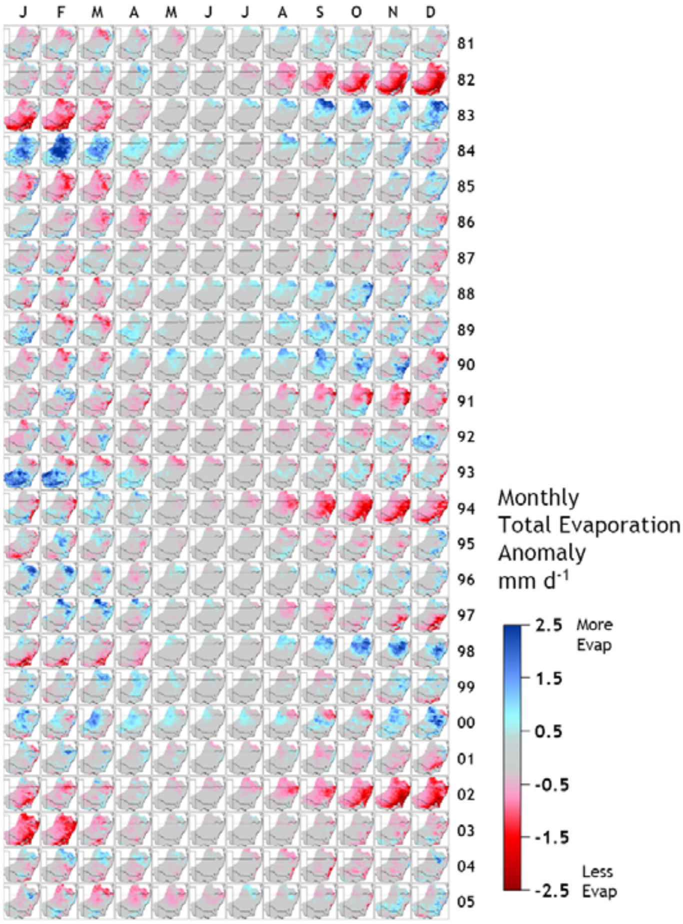
Water balance for SE Australia



- Water balance assessments:
  - Main output is soil water availability
  - In the past and in near real-time
- *WaterDyn* – a terrestrial carbon and water balance model
  - Grid: 5 km
  - Domain: SE Australia; continent
  - Time step: daily
- Data assimilation
  - Ensemble Kalman filter
  - Runoff from gauged catchments
  - NDVI (carbon)
  - Surface temperature
  - ET (Cleugh et al 2007; others)

Water Balance for SE Australia





2. Improve predictive tools for water management

- A pilot project to provide forecasts of rainfall and evaporation directly to two catchment authorities continues

- The “Water and the Land” web site (http://www.bom.gov.au/watl/) has been developed to distribute hydro-meteorological observations and forecasts to the water industry

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3. New Opportunities

- 1. Complementary initiatives that will benefit the MDB Project:
  - SEACI (South East Australia Climate Initiative)
  - CSIRO's Water Resource Observation Network (WRON)
  - Terrestrial Ecosystem Research Network (TERN)

- 2. Federal changes to water resource management (in response to current drought):
  - Bureau of Meteorology now will provide data and predictive capability

- 3. Australian Community Climate & Earth System Simulator (ACCESS)
  - Australia's NWP and next generation global climate model
  - Joint initiative between Bureau of Meteorology, CSIRO, Universities
  - Hydrometeorology needs to be strengthened

Strategy for RHP (1)

- 1. Data needs – from whom and purpose?
  - Most data needs met by Australian agencies – current or planned
  - Need to enhance flux tower observations and network is understood:
    - More secure funding base
    - Expand network
    - Additional observations at Tumbarumba (e.g. hydrology, …)?

    TERN will potentially solve this post 2008

- 2. Data infrastructure needs – what purpose?
  - tbd

- 3. Climate region commonality, which can be shared:
  - MDB is a semi-arid basin
  - Aerosols - in situ measurements for both biogenic, burning and dust sources (not all in MDB)
  - Extremes
  - Coupled water – carbon emphasis

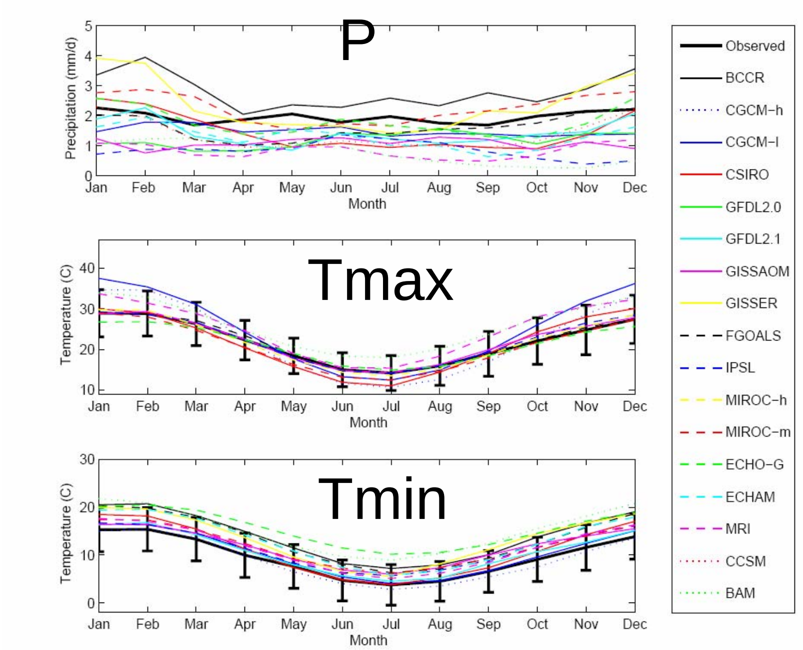
Strategy for RHP (2)

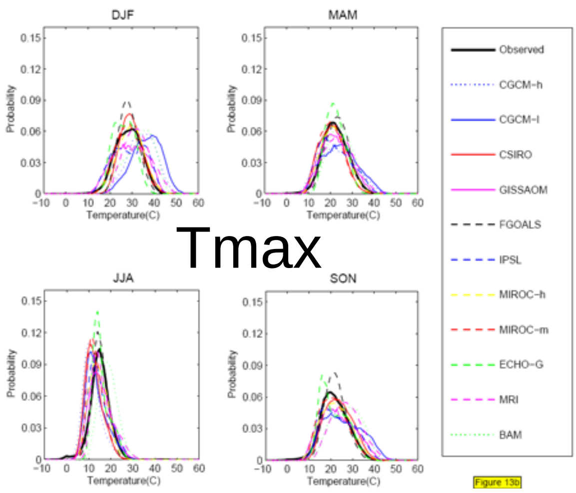
- 4. Needs for up-scaling and down-scaling
  - Met by model – data fusion approach (combining models, remotely-sensed and in-situ data)
- 5. Needs for pilot demonstrations
- 6. Clarification of limitations

Simulation of the Murray-Darling Basin climate by the AR4 models

Clare Maxino and Andy Pitman

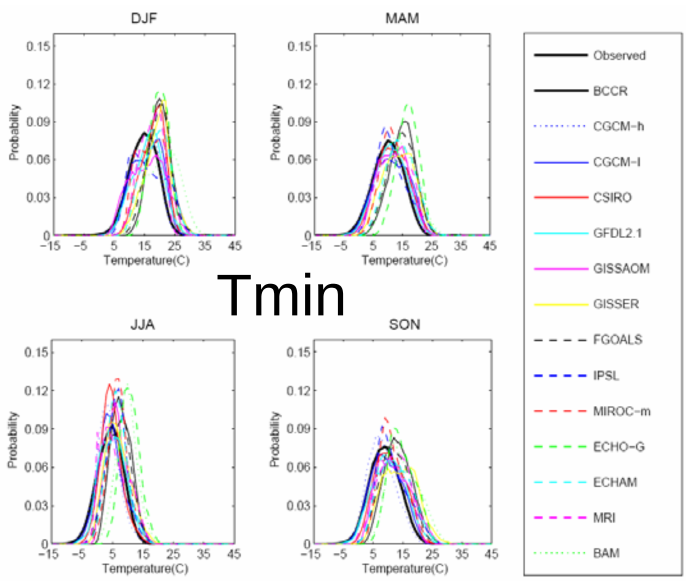
- Many of the AR4 models have significant skill in simulating the rainfall, maximum and minimum temperatures over the MDB
- But it is not the mean seasonal climate that really matters – what about extremes?
- Calculate PDFs *from AR4 daily data* of P, Tmin and Tmax



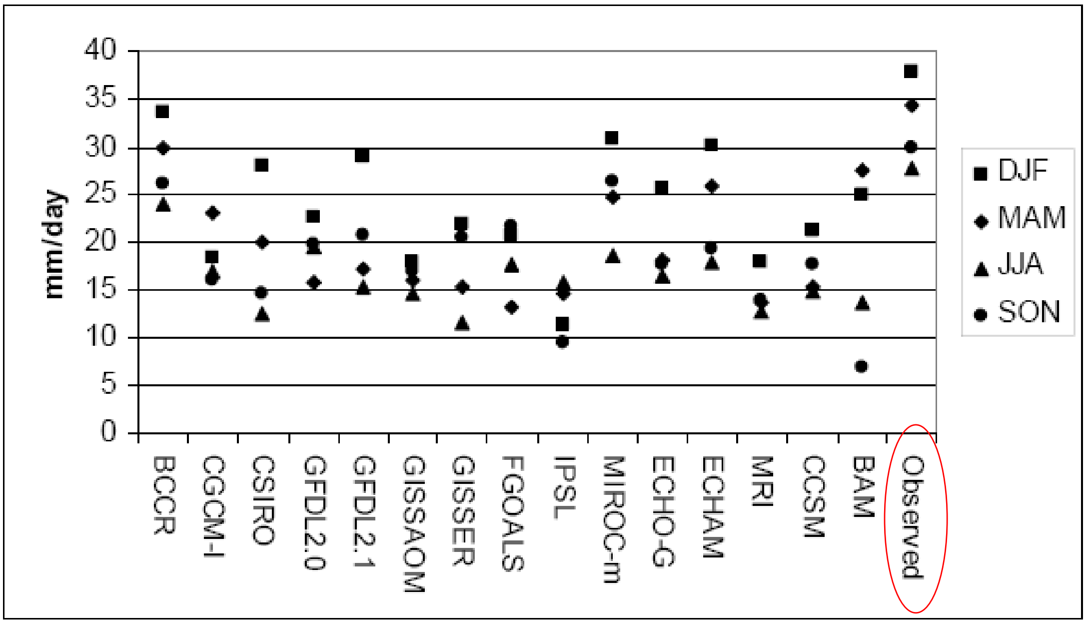


- At regional scales, many of the AR4 models have real skill in simulating Tmax and Tmin
- In most cases, the shapes of the PDF match the observations

- This is using daily data – this is impressive and suggests the AR4 models have regional skill
- But its not perfect – particularly at the tails of the distributions



What about rainfall extremes?



Most models badly underestimate the magnitude of the 95th rainfall percentile every month