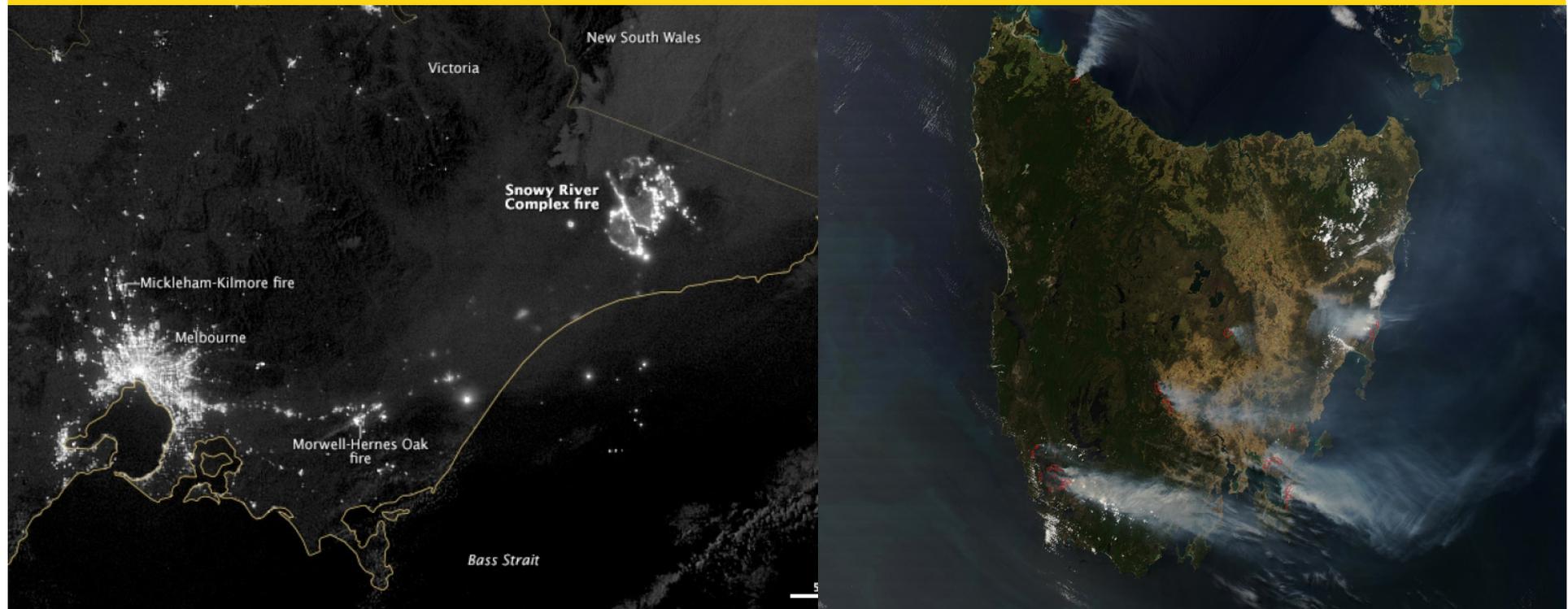




bushfire&natural
HAZARDSCRC

TOWARDS AN IMPROVED LAND DRYNESS ESTIMATE FOR FIRE PREDICTION

Vinodkumar & Imtiaz Dharssi
Bureau of Meteorology, Melbourne



Picture courtesy: NASA



An Australian Government Initiative



Project Background

Bureau researchers were awarded with a project called "*Mitigating the effects of severe fires, floods and heatwaves through the improvements of land dryness measures and forecasts*" by BNHCRC under the 'Monitoring and Prediction' theme.

Project Team Members

- Imtiaz Dharssi
- Vinod Kumar
- Peter Steinle
- Jeff Kepert
- Adam Smith
- Ian Grant
- Jeff Walker
- Claire Yeo
- John Bally
- Paul Fox-Hughes
- Mark Chladil
- Rob Sandford
- Andrew Sturgess
- Stuart Mathews
- Adam Leavesley
- David Taylor

End-users

BoM, ACT parks, Tasmania Fire Service, Parks Tasmania, South Australian Country Fire Service, Fire and Emergency Services Authority of Western Australia, NSW Rural Fire Service, Queensland Fire Service, Victorian CFA, AFAC PSG.

Fire Danger Rating in Australia

- Forest Fire Danger Index (FFDI; McArthur, 1958).

- No major science update since first design!

- $FFDI = 2e^{(-0.45 + 0.987 \ln(DF) - 0.0345RH + 0.0338T + 0.0234V)}$

DF - 'Drought Factor'

- DF represent 'fuel availability'.

- $DF = fn(\text{soil moisture deficit})$

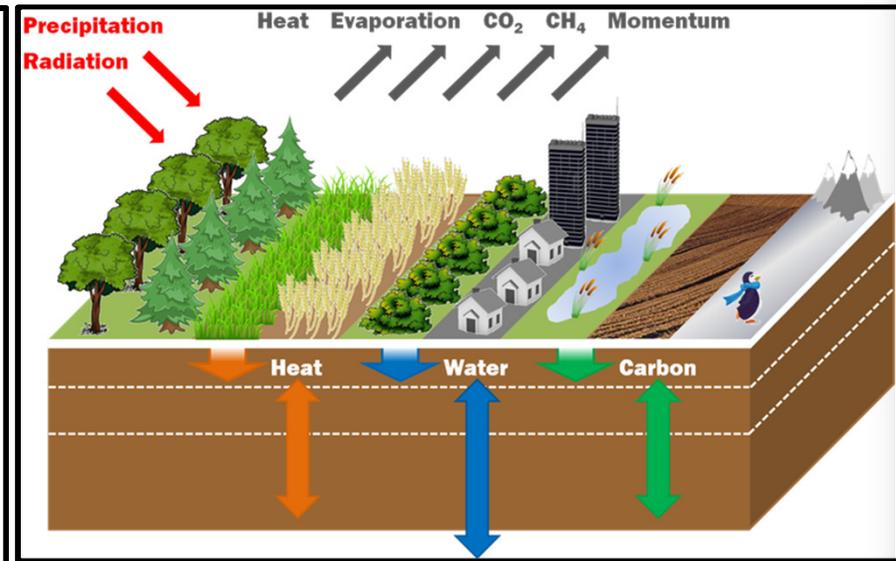
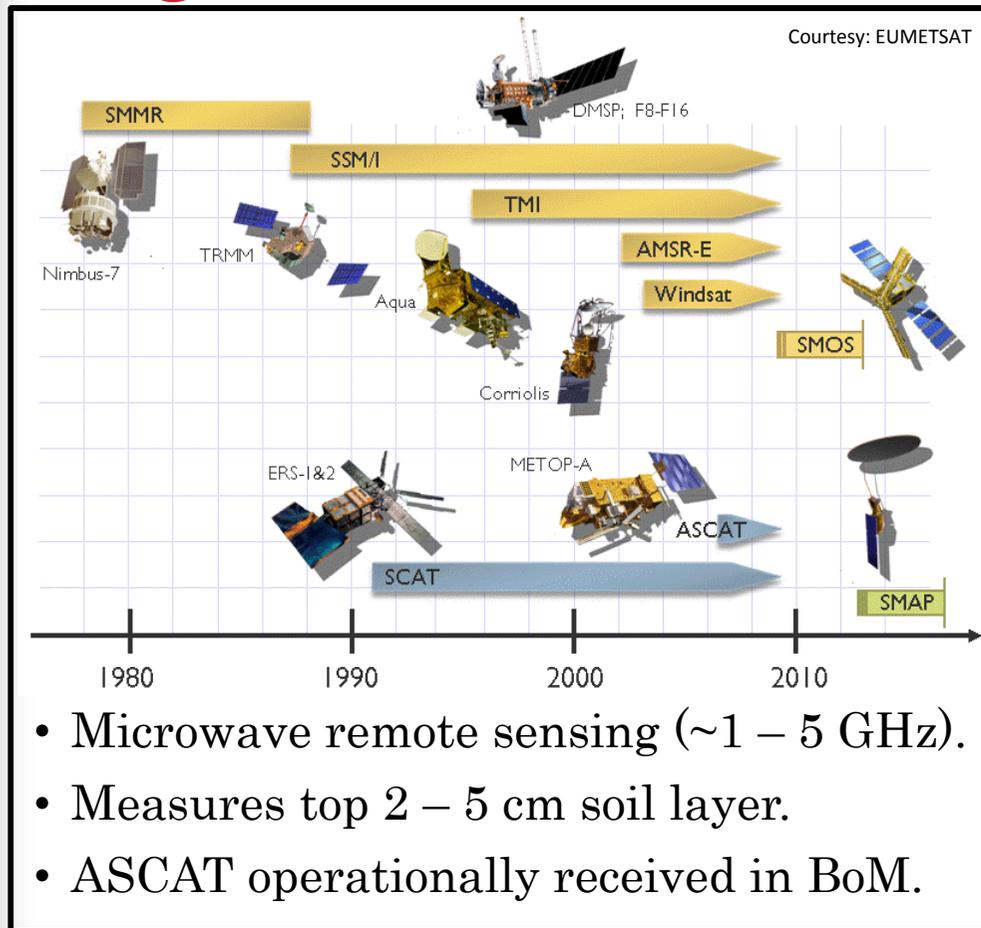
- Current soil moisture deficit models:

- ▶ Keetch-Byram Drought Index (KBDI; Keetch & Byram 1968)
- ▶ Mount's Soil Dryness Index (SDI; Mount 1972)

Background

- *"From the standpoint of fire control, the significant moisture relationships are those which exists in an upper layer of soil and a covering layer of duff. ..." (Keetch & Byram, 1968, pp 24.)*
- KBDI / SDI
 - single soil layer (~1 m)
 - Simple (very simple!) bucket model
 - 60's science
- *"... a good system that work throughout the seasons should not depend upon a fixed depth of soil horizon to indicate fire danger. A system employing multi-layer soil model is desirable..." (Haines et al., 1976).*

Progress in Soil Moisture Science



- Example for LSMs: JULES, CABLE.
- JULES used in ACCESS NWP & Seasonal forecasting models.
- ACCESS NWP has a Land Data Assimilation scheme.

LSM – Land Surface Model

JULES – Joint UK Land Environment Simulator

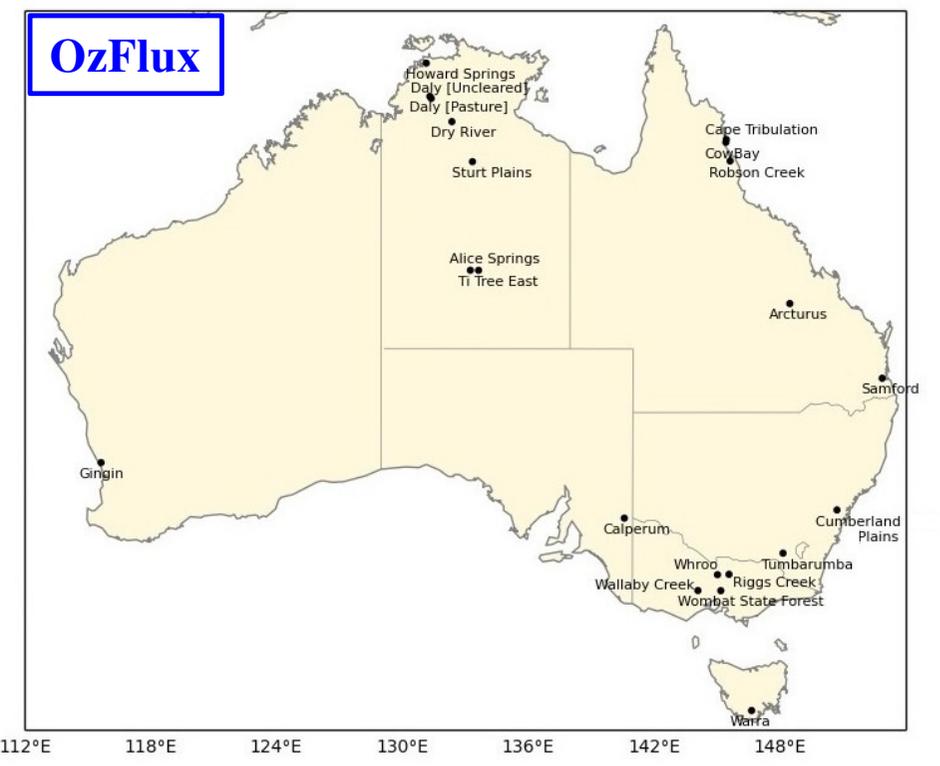
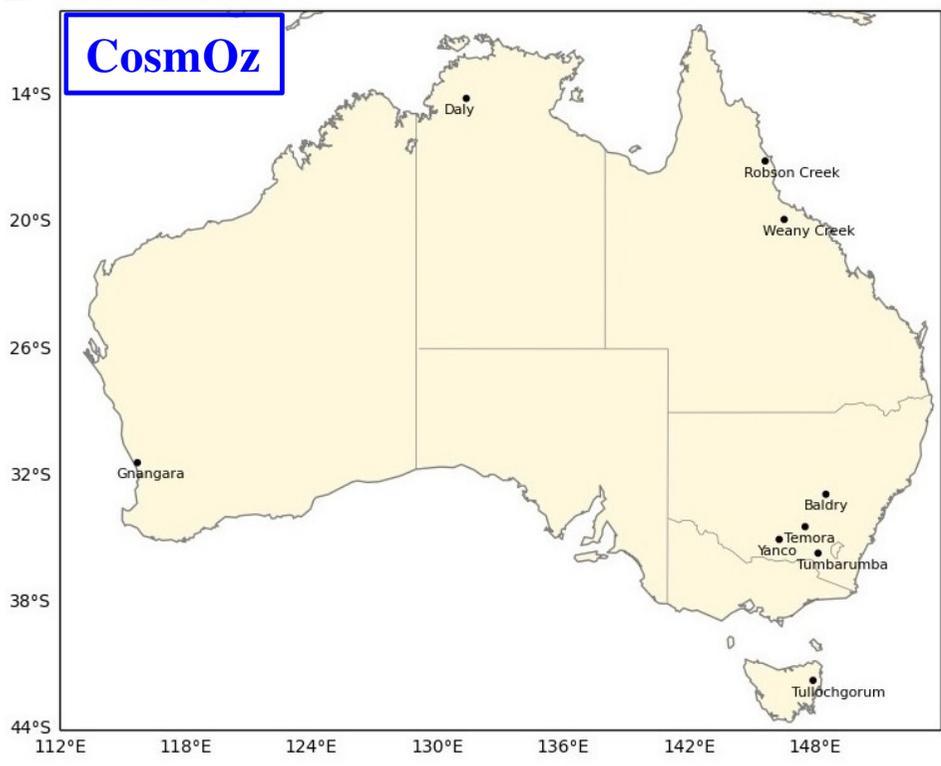
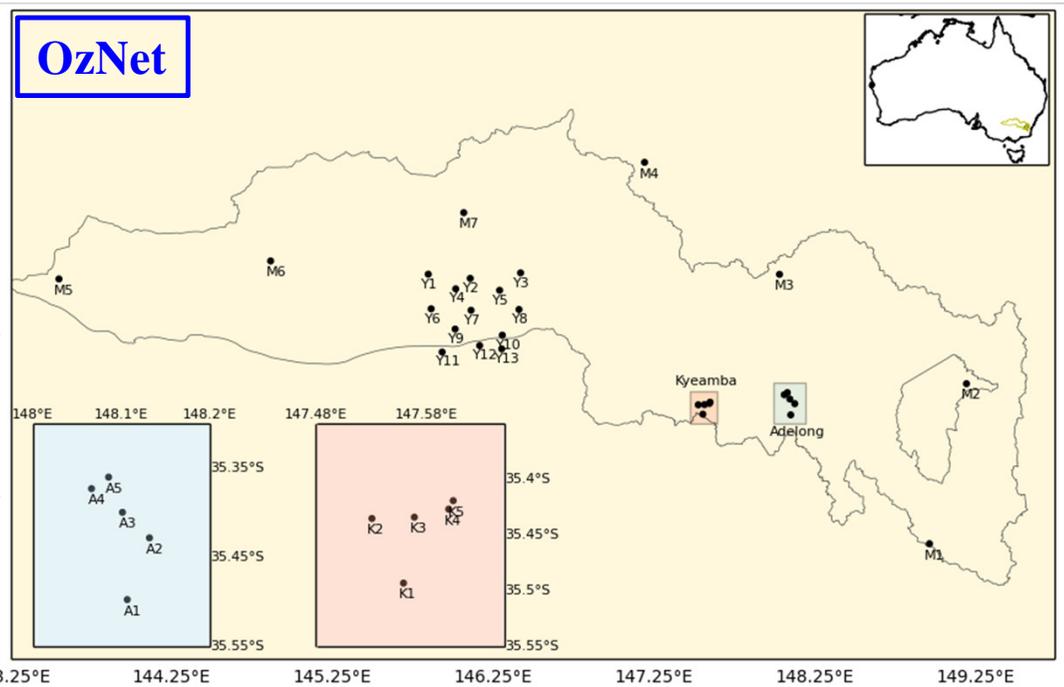
CABLE - Community Atmosphere Biosphere Land Exchange

ACCESS – Australian Community Climate & Earth System Simulator

NWP – Numerical Weather Prediction

Verification: *In situ* obs. networks

- **OzNet:** 01 Sep '09 to 31 May '11 (21 months)
- **CosmOz:** 01 May '12 to 31 Dec '14 (32 months)
- **OzFlux:** 01 Jan '12 to 14 Dec '15 (47.5 months)



Surface (~ 30 cm) Soil Moisture

Data Set	Correlation [-]			Bias [-]			RMSD [-]		
	OzNet (30 sites)	CosmOz (9 sites)	OzFlux (18 sites)	OzNet	CosmOz	OzFlux	OzNet	CosmOz	OzFlux
ACCESS_80km	0.72	-	-	0.02	-	-	0.19	-	-
ACCESS_40km	-	0.81	0.75	-	-0.03	-0.07	-	0.15	0.21
KBDI	0.64	0.63	0.70	-0.26	-0.22	-0.22	0.36	0.33	0.30
SDI	0.71	0.76	0.73	-0.02	-0.07	-0.08	0.23	0.20	0.22
ASCAT	-	0.81	0.74	-	-0.03	-0.05	-	0.18	0.22

- **ASCAT**: ~ 25 km resolution; 1–2 pass per day; Soil wetness at top ~2 cm
- **ACCESS**: Global analysis, daily average, 4 soil layers (0–10, 10–35, 35–100, 100–200 cm).
- **KBDI/SDI** - ~5 km grids; daily time steps; AWAP rainfall & T_{Max}

Surface Soil Moisture: Forest vs. Non-forest

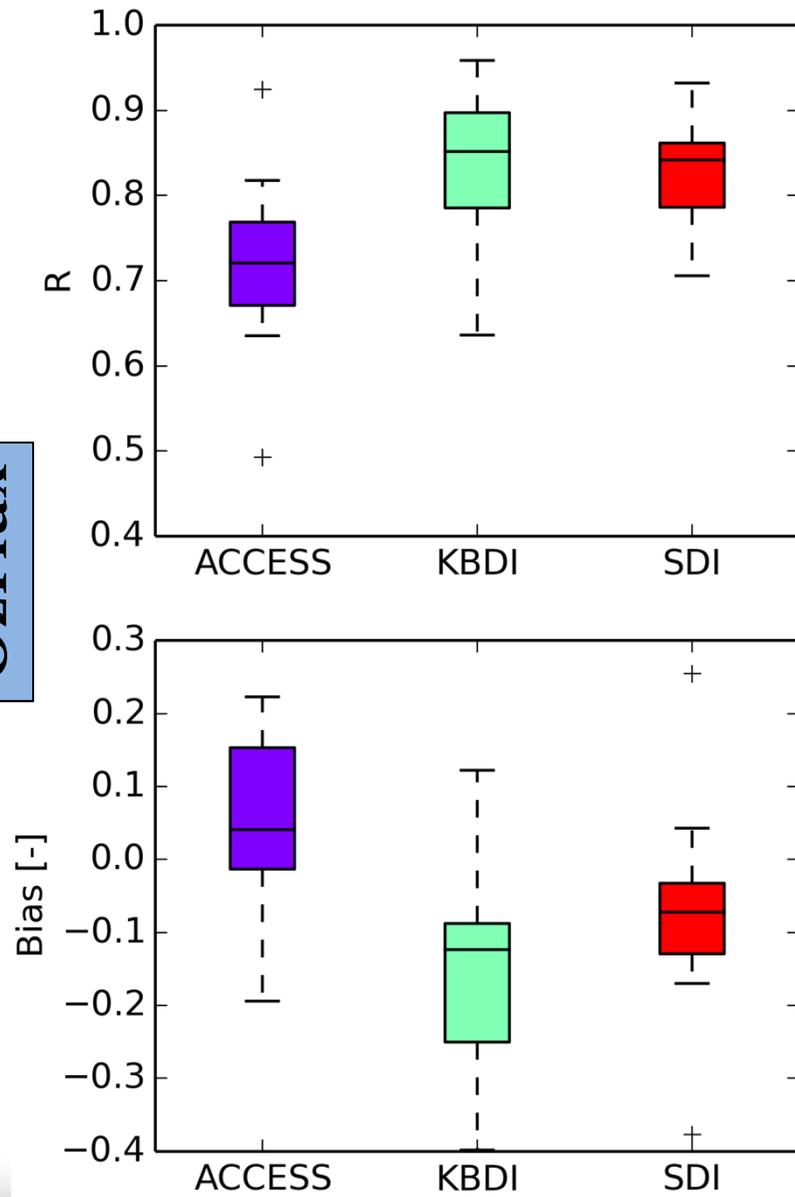
OzFlux	Correlation [-]		Bias [-]		RMSD [-]	
	Forested (12 sites)	Non-forested (6 sites)	Forested	Non-forested	Forested	Non-forested
ACCESS_40km	0.76	0.73	-0.09	-0.04	0.20	0.22
KBDI	0.72	0.67	-0.24	-0.16	0.33	0.26
SDI	0.75	0.70	-0.10	-0.02	0.22	0.23
ASCAT	0.75	0.67*	-0.04	-0.06	0.19	0.18

* 5 sites

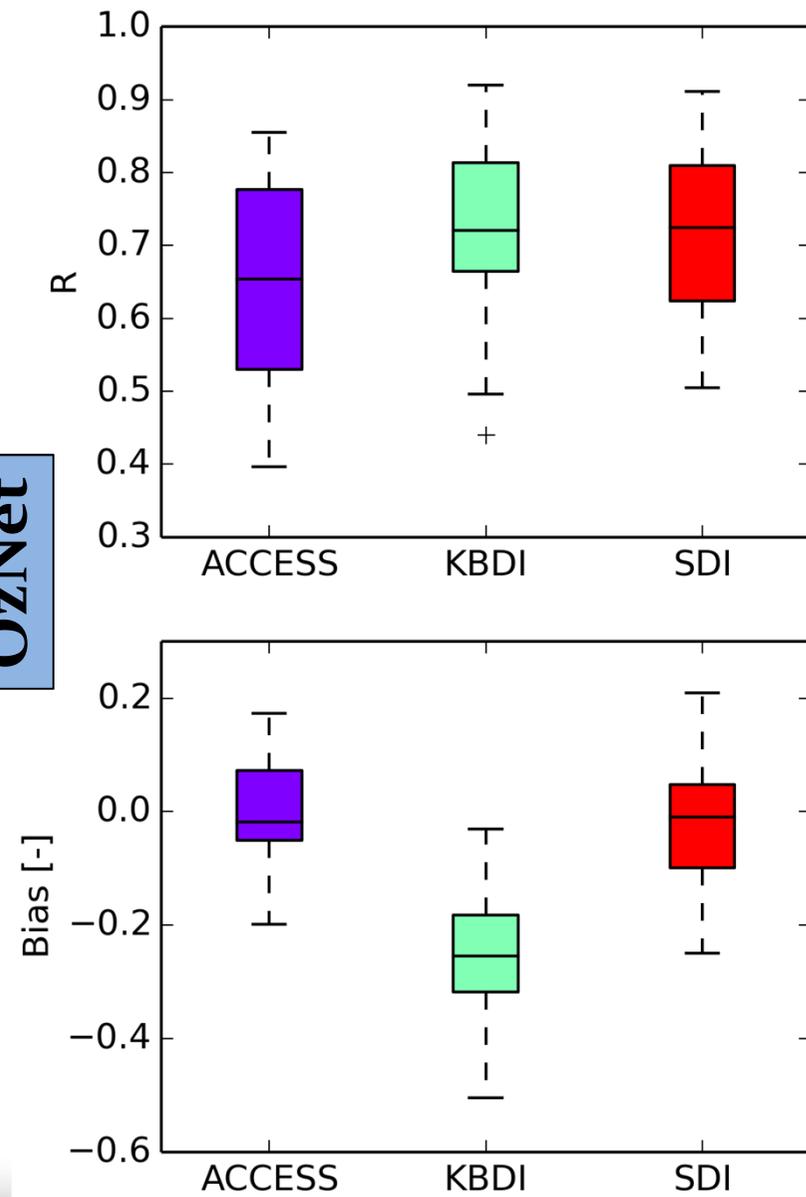
CosmOz	Correlation [-]		Bias [-]		RMSD [-]	
	Forested (5 sites)	Non-forested (4 sites)	Forested	Non-forested	Forested	Non-forested
ACCESS_40km	0.78	0.85	-0.03	-0.02	0.16	0.13
KBDI	0.74	0.50	-0.18	-0.26	0.28	0.37
SDI	0.74	0.78	-0.08	-0.12	0.21	0.21
ASCAT	0.76	0.86	0.00	-0.08	0.18	0.17

Deeper (~ 100 cm) Soil Moisture

OzFlux



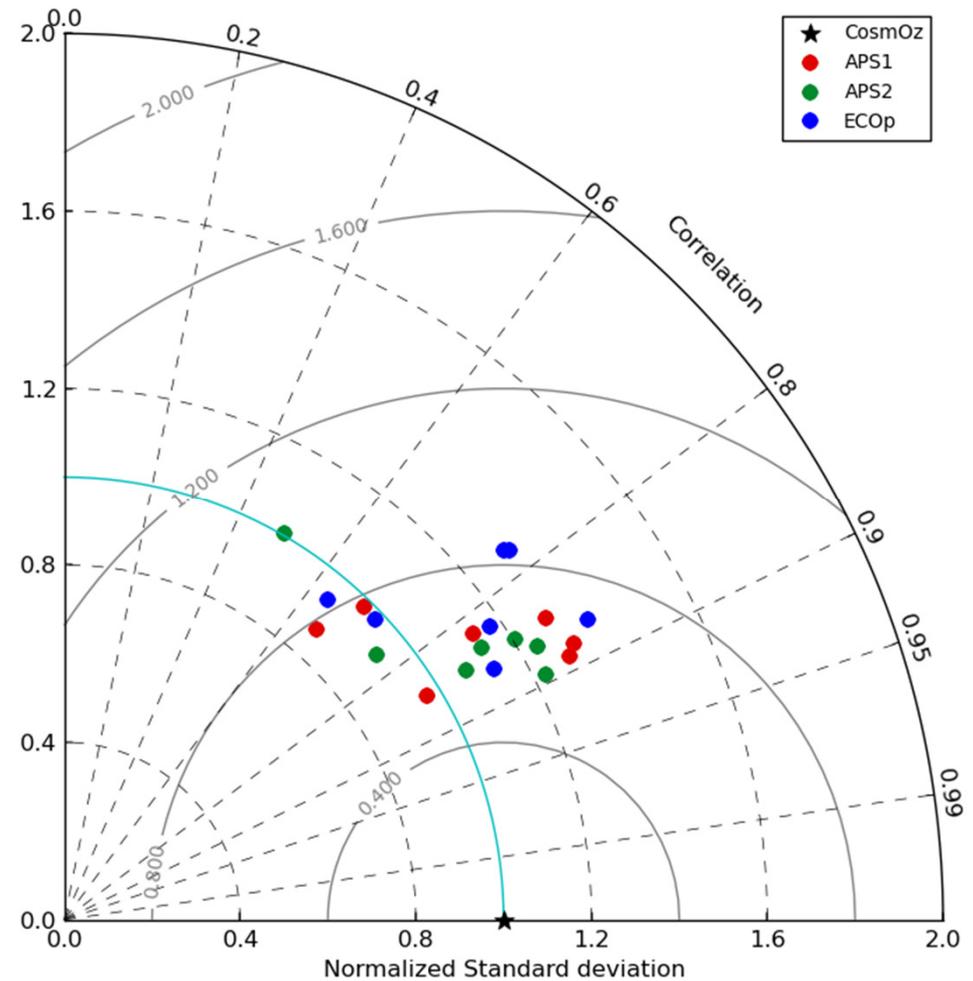
OzNet



ACCESS vs. ECMWF

- APS – Australian Parallel Suite.
- APS1 – ~40 km , APS2 - ~25km.
- 1 Dec '13 to 28 Feb '15 (14 months).

Metrics	APS1	APS2	EC-Op
Correlation	0.81	0.80	0.78
Bias	-0.08	-0.06	-0.06
RMSD	0.18	0.17	0.19
Anomaly Correlation	0.57	0.57	0.6



So far..

Traditional dryness indices

- ▶ Generally, low skill at surface.
- ▶ Good at root-zone.
- ▶ Large wet bias in KBDI.

ACCESS soil moisture

- ▶ Better skills at surface than traditional indices.
- ▶ Reasonable skill at root-zone.
- ▶ Too coarse resolution for fire applications?

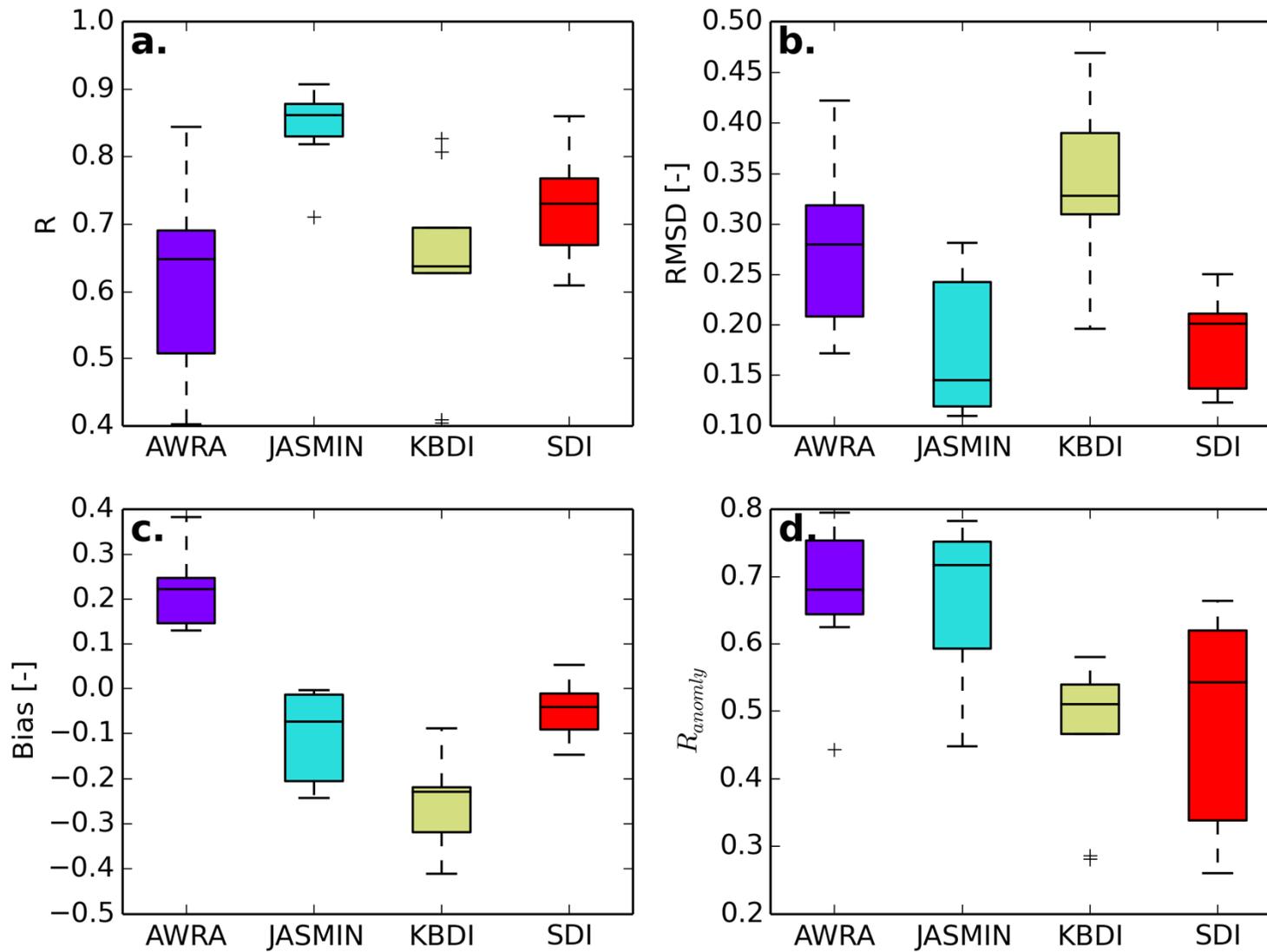
A high resolution soil moisture analyses

- a prototype system has been developed.
- called **JULES based Australian Soil Moisture Information (JASMIN)**.
- output from Jan 2010 onwards.
- driven mainly by observation based gridded analysis.

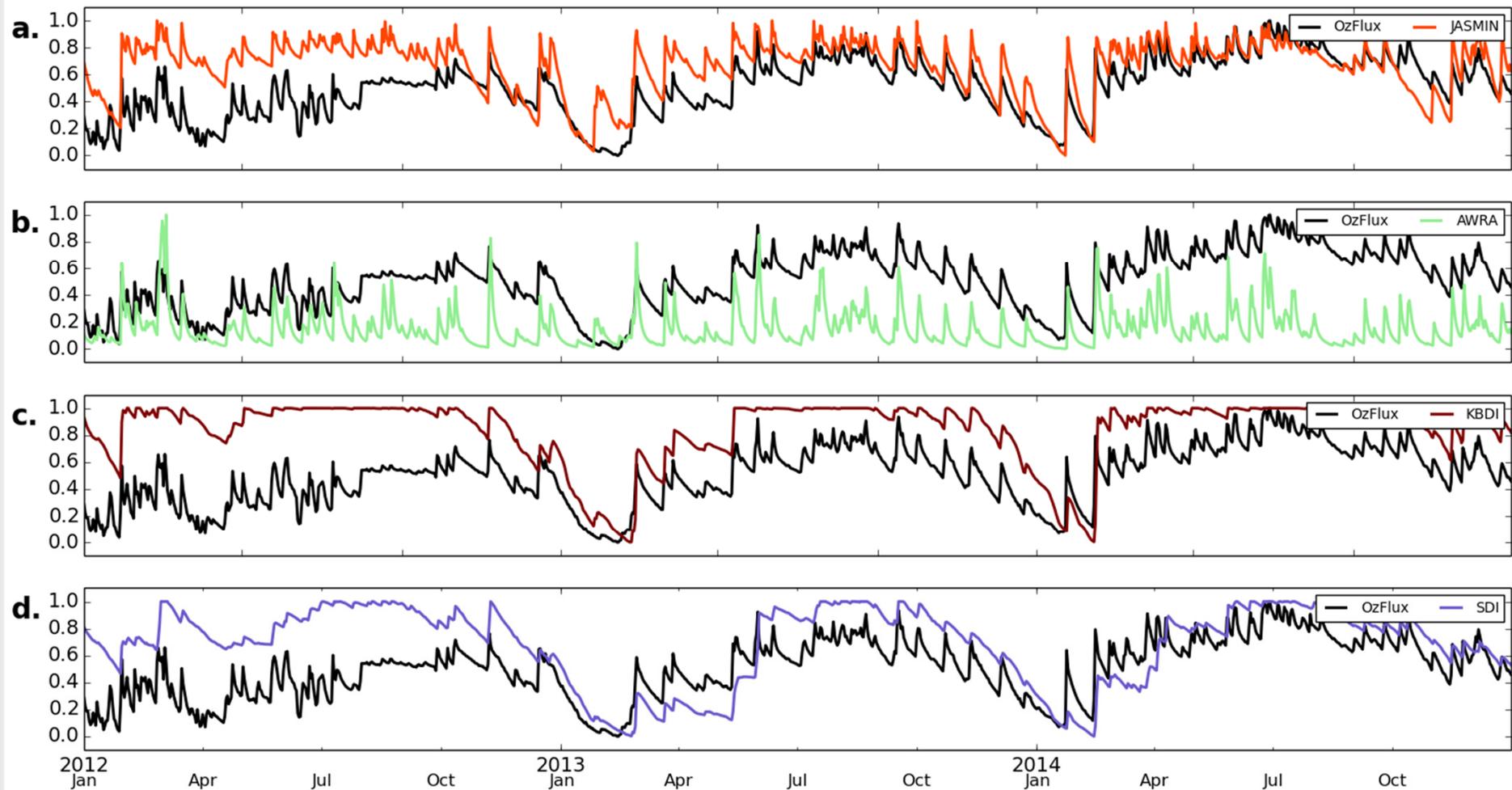
More about JASMIN

- Based on JULES offline framework.
- 5 km grids.
- Hourly time step.
- Four soil layers, to 3 m deep.
- 0~10; 10~35; 35~100; 100~300 (in cm).
- 5 plant functional types, 4 non-vegetation types.
- Provides analyses of soil moisture, soil temperature, latent and sensible heat fluxes as well as other surface variables.
- Driving data from observation based analysis (e.g., AWAP, MSAS), satellites and regional NWP.
- No DA at present, but in future plans.

CosmOz [Surface]

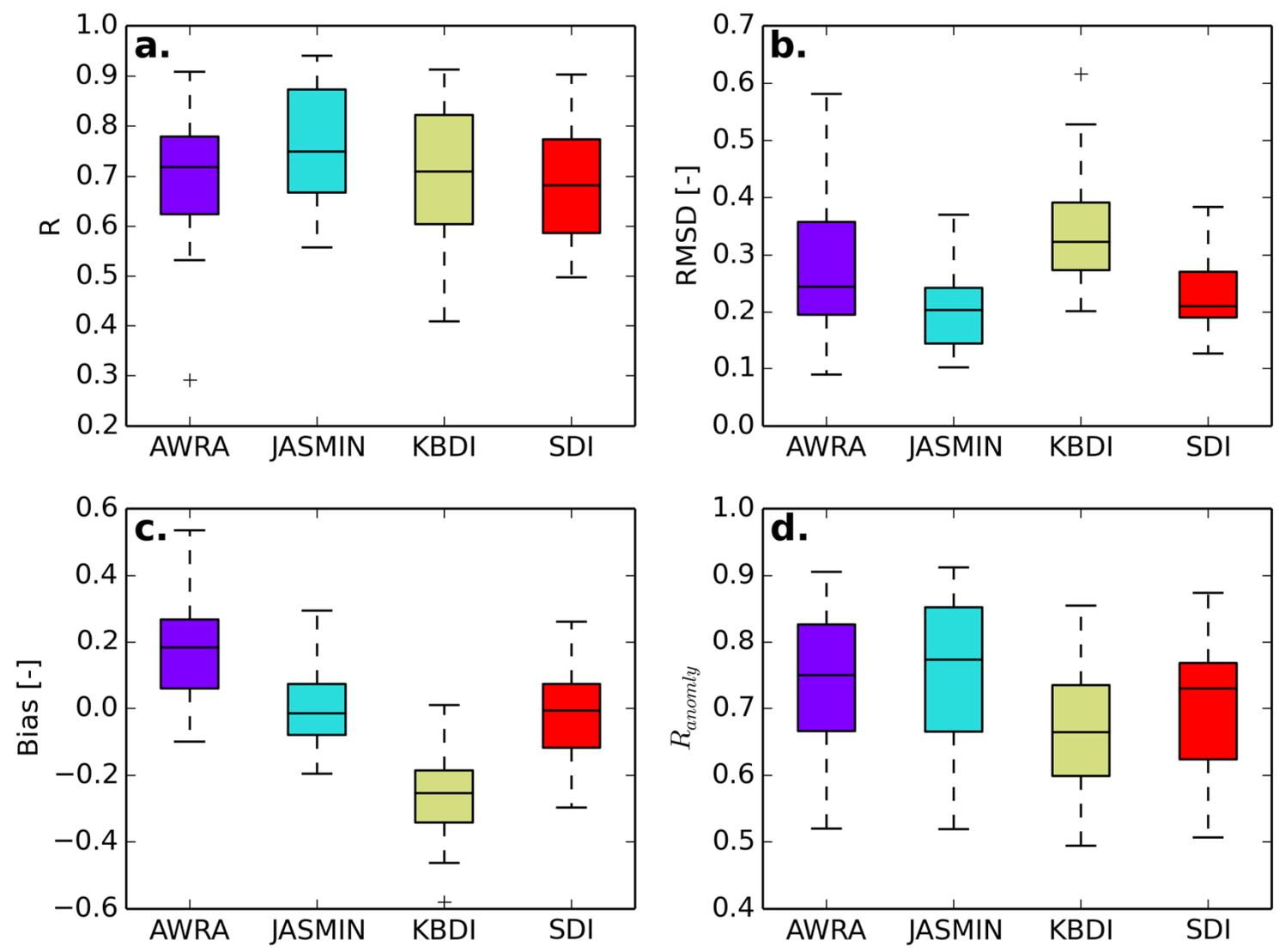


OzFlux surface: Tumbarumba, NSW



1 = Very wet, 0 = Very dry

OzNet [0-90 cm]



Re-scaling

- JASMIN output is in Kg/m²
- KBDI/SDI range from 0 – 200 mm.
- Various rescaling methods.
 - Minimum-Maximum
 - $\mu - \sigma$ Matching
 - CDF Matching
- On-going work.
- End-user involvement.
- Case studies
- Routine display of images on registered user website.

• MINIMUM-MAXIMUM MATCHING

$$\hat{\theta} = \vartheta_{min} + (\theta - \theta_{min}) \left(\frac{\vartheta_{max} - \vartheta_{min}}{\theta_{max} - \theta_{min}} \right)$$

θ – JASMIN soil moisture, ϑ – KBDI/SDI ($\vartheta_{min} = 0$, $\vartheta_{max} = 200$).

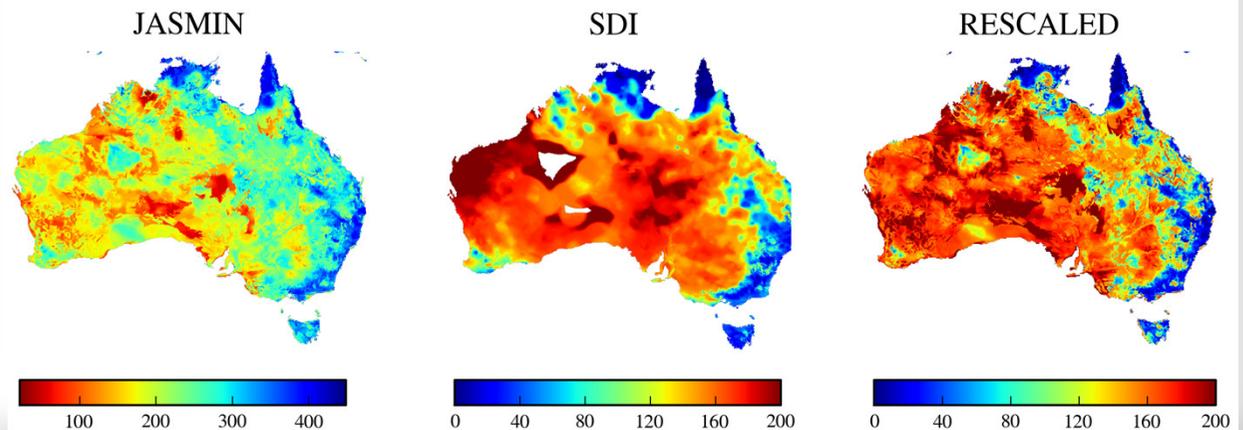
• $\mu - \sigma$ MATCHING

$$\hat{\theta} = \mu_{\vartheta} + \frac{\sigma_{\vartheta}}{\sigma_{\theta}} (\theta - \mu_{\theta})$$

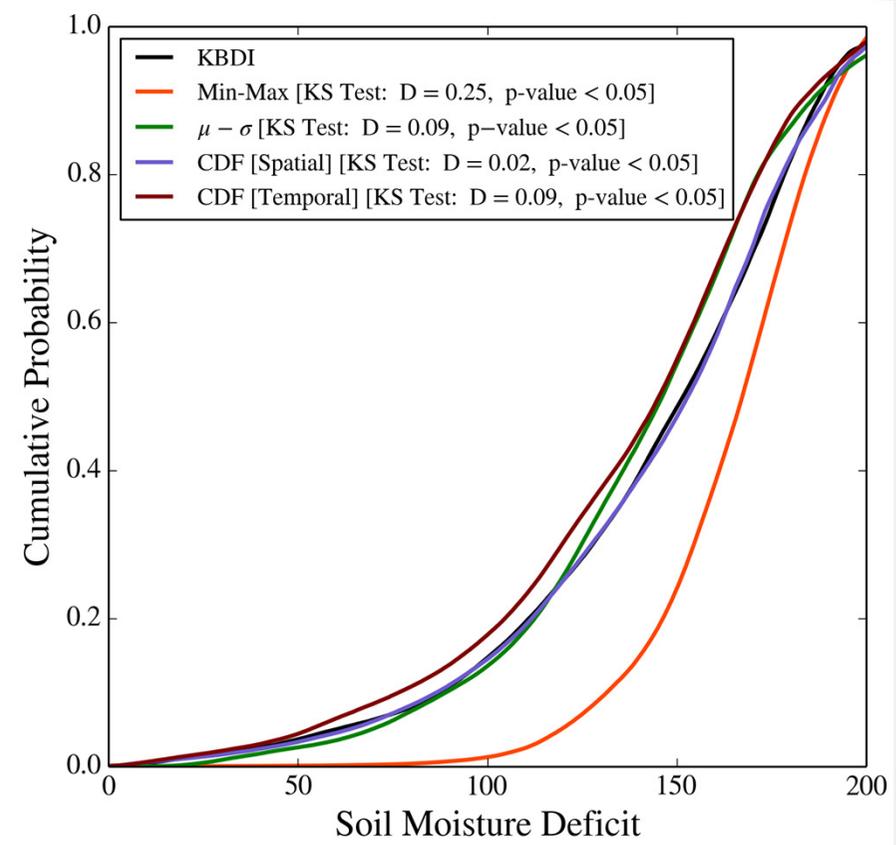
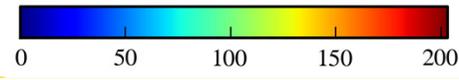
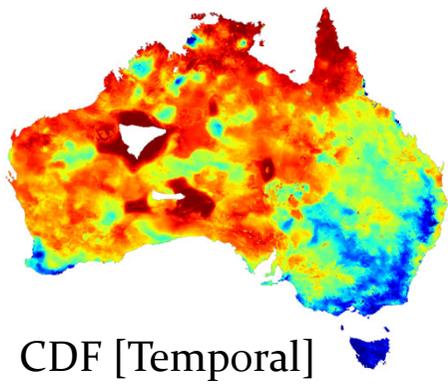
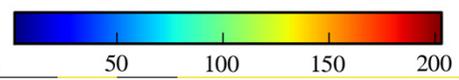
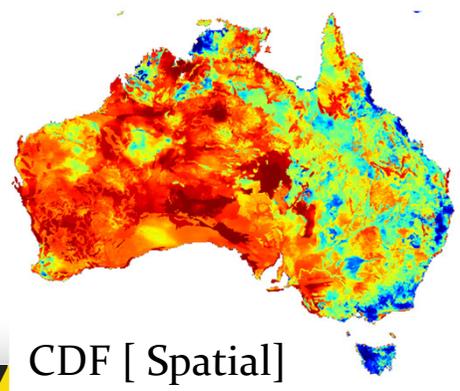
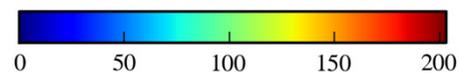
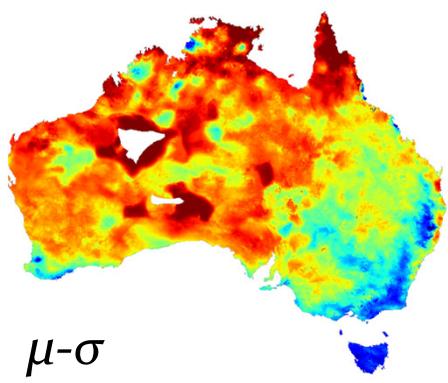
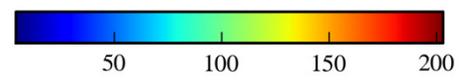
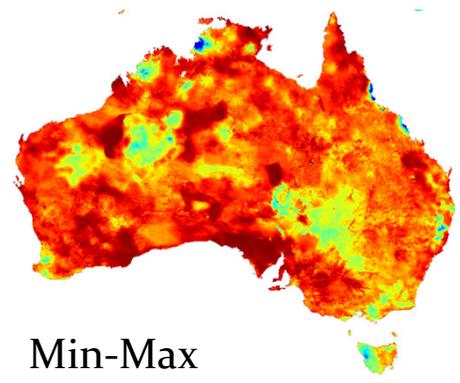
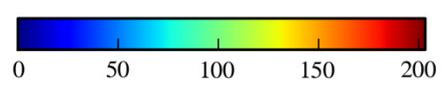
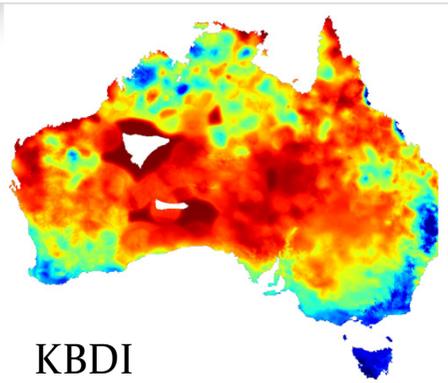
θ – JASMIN soil moisture, $\hat{\theta}$ – Normalized θ ,
 μ – Mean, σ – Standard Deviation, ϑ – KBDI / SDI

• CDF MATCHING

$$F(x) = \Pr[X \leq x]$$



**Re-scaling
JASMIN to
KBDI on 1st Jan
2013**



Correlation [with *in-situ*]

0–35 cm model soil profile

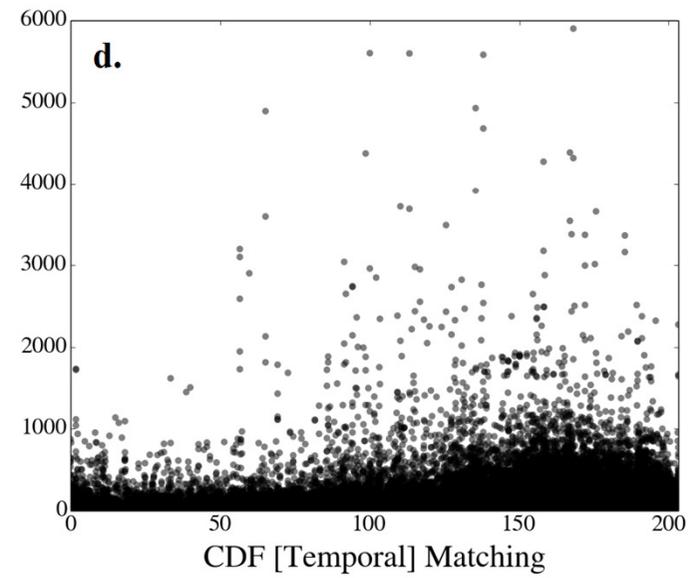
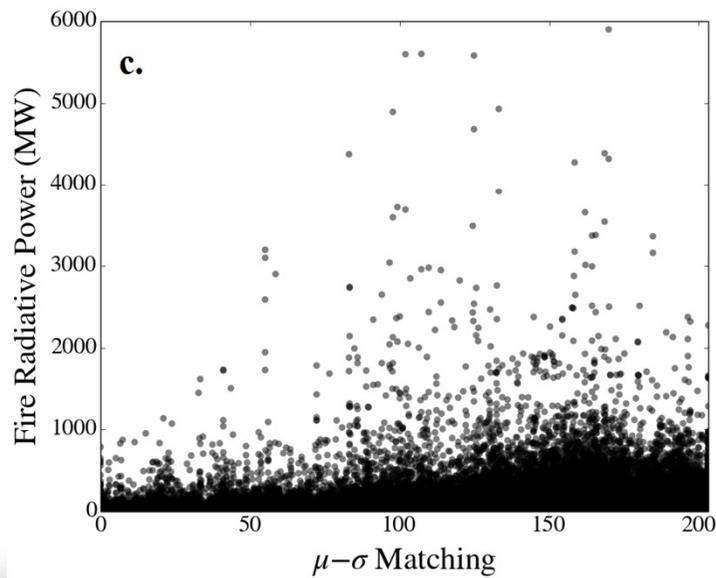
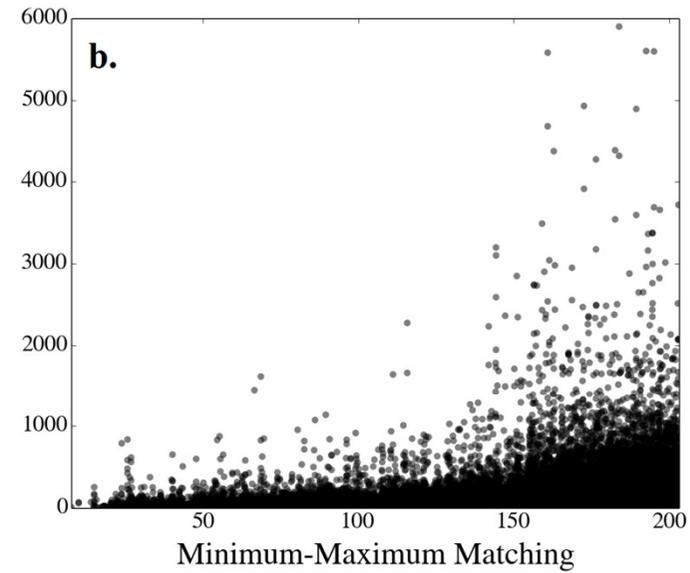
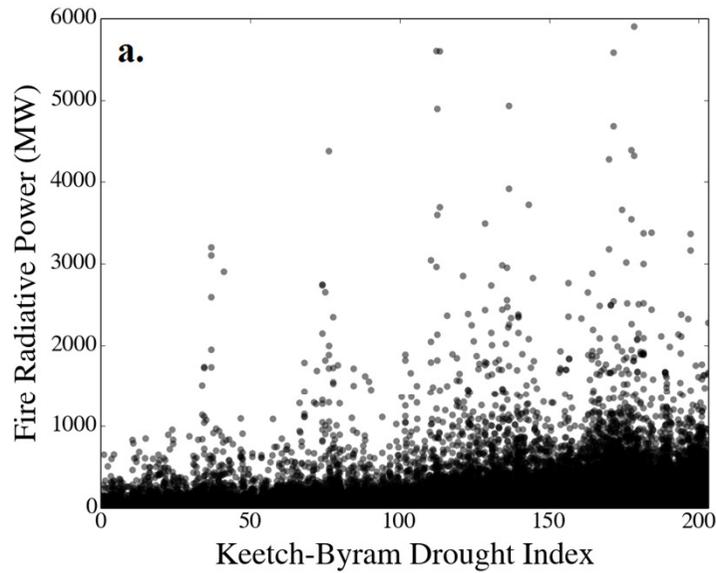
In situ network	Correlation					Anomaly correlation				
	KBDI	MM	$\mu - \sigma$	CDF		KBDI	MM	$\mu - \sigma$	CDF	
				Spatial	Temporal				Spatial	Temporal
CosmOz	0.72	0.85	0.84	0.79	0.82	0.46	0.66	0.60	0.49	0.55
OzFlux (surface)	0.76	0.84	0.83	0.75	0.82	0.58	0.74	0.71	0.60	0.69
OzFlux (root zone)	0.85	0.86	0.86	0.77	0.85	0.66	0.67	0.66	0.56	0.68

MM: Minimum-Maximum

0–100 cm model soil profile

In situ network	Correlation					Anomaly correlation				
	KBDI	MM	$\mu - \sigma$	CDF		KBDI	MM	$\mu - \sigma$	CDF	
				Spatial	Temporal				Spatial	Temporal
CosmOz	0.72	0.77	0.77	0.70	0.74	0.46	0.56	0.53	0.46	0.51
OzFlux (surface)	0.76	0.76	0.75	0.64	0.73	0.58	0.64	0.62	0.56	0.59
OzFlux (root zone)	0.85	0.84	0.84	0.72	0.83	0.66	0.65	0.64	0.53	0.64

Comparison against MODIS FRP



Fire case studies [Courtesy: Paul Fox-Hughes]

- ❑ Intend to do at least a dozen case studies.
- ❑ Include past bush fire occurrences and fuel reduction burns.
- ❑ These cases are selected and evaluated with the help of end users.
- ❑ All case studies will be documented and could be used as training documentation by fire agencies.
- ❑ Cases identified so far:

Bushfire cases

State Mine Fire, NSW, Oct 2013

Dunalley Fire, TAS, Jan 2013

Wuthering Heights Fire, TAS, Jan 2016

Lake Mackenzie fire, TAS, Jan 2016

Ballandean fire, QLD, Oct 2014

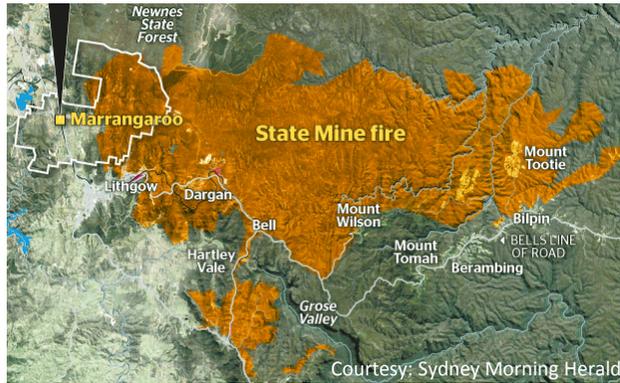
Fuel reduction burns

Lancefield, VIC, Sep 2015

NE Victoria, Mar 2017

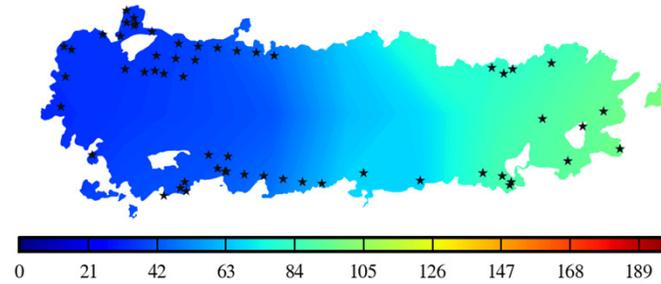
Orbost, VIC, Mar 2017

State Mine Fire, NSW



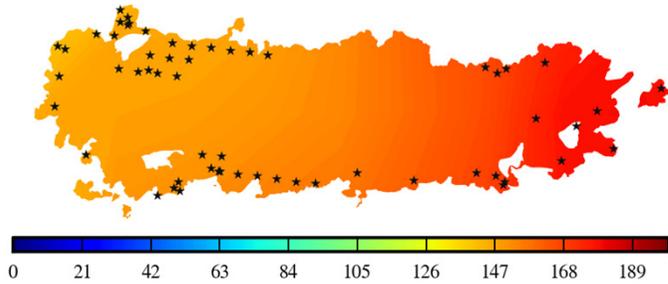
Keetch-Byram Drought Index

Calculated for 18/Oct/2013
State Mine Fire Complex



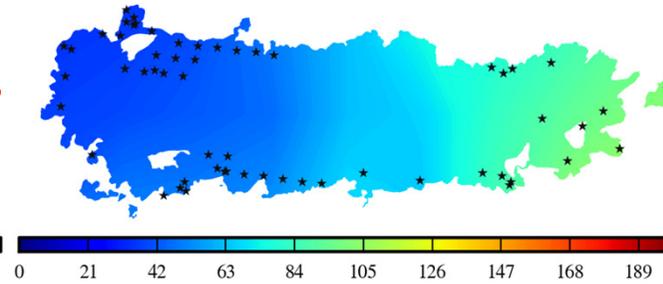
JASMIN scaled to KBDI for 18/Oct/2013

Using Minimum-Maximum Matching on first 3 soil layers
State Mine Fire Complex



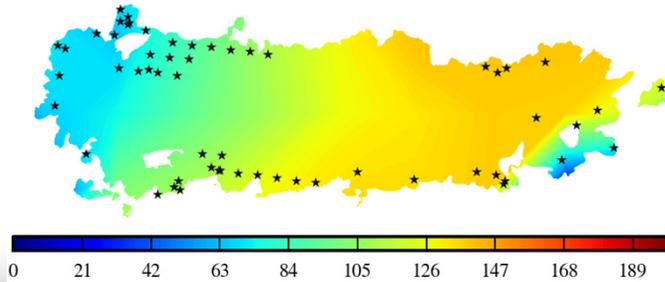
JASMIN scaled to KBDI for 18/Oct/2013

Using Mean-Variance Matching on first 3 soil layers
State Mine Fire Complex



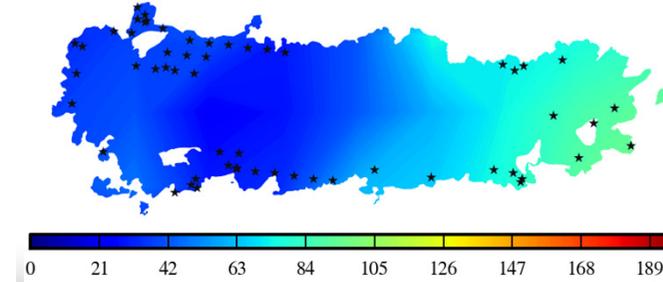
JASMIN scaled to KBDI for 18/Oct/2013

Using CDF Matching [Spatial] on first 3 soil layers
State Mine Fire Complex



JASMIN scaled to KBDI for 18/Oct/2013

Using CDF Matching [Temporal] on first 3 soil layers
State Mine Fire Complex



Webpage development in progress

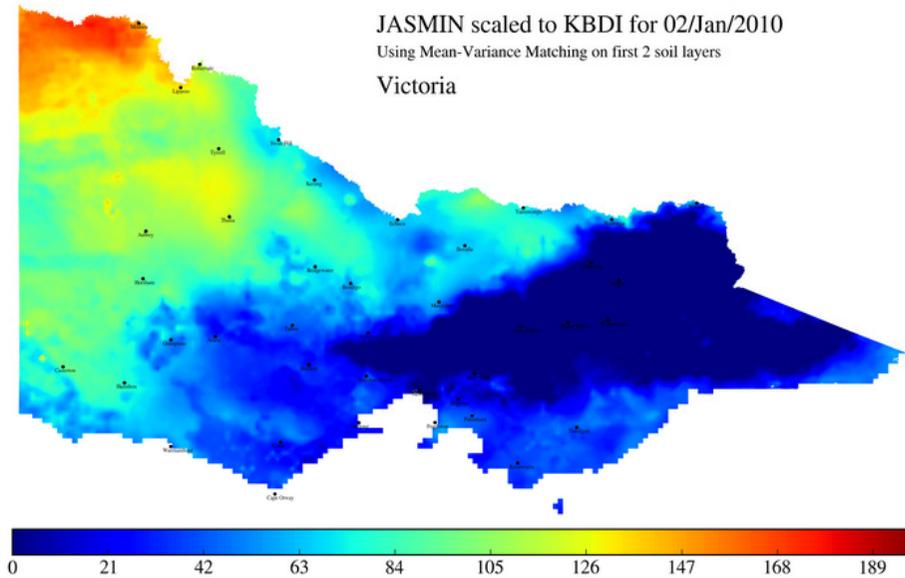
http://logan.bo...n.kbdi/jrk.html x +

logan.bom.gov.au/~vinodk/Products/JASMIN/jasmin.kbdi/jrk.html

Search

JASMIN rescaled to KBDI

JASMIN scaled to KBDI for 02/Jan/2010
Using Mean-Variance Matching on first 2 soil layers
Victoria



Partner Organizations



Select Date

2 Jan 2010

Select Method

Mean-Variance Matching

Select Layer

0-35 cm layer

Select Region

Victoria

- [Contact](#)
- [Home Page](#)

<http://logan.bom.gov.au/~vinodk/index.html>

Disclaimer: These plots are experimental. The Bureau of Meteorology accepts no responsibility for actions taken on the basis of these plots.

bnhrc.com.au

Follow project updates

<https://wiki.bom.gov.au/foswiki/ResearchDevelopment/LandDrynessEstimatesForFireDangerRatings>

The screenshot shows a web browser window with the following content:

- Browser Address Bar:** <https://wiki.bom.gov.au/foswiki/ResearchDevelopment/LandDrynessEstimatesForFireDangerRatings>
- Page Header:** You are here: Bureau of Meteorology wiki > ResearchDevelopment Web > DataAssimilation > LandDrynessEstimatesForFireDangerRatings (09 Mar 2017, VinodKumar)
- Page Title:** Project title
- Text:** Mitigating the effects of severe fires, floods and heatwaves through the improvements of land dryness measures and forecasts
- Section Header:** Project background
- Text:** The **McArthur** Forest Fire Danger Index used in Australia for operational fire warnings has a component representing fuel availability called the Drought Factor (DF). The DF is partly based on soil moisture deficit, calculated as either the Keetch-Byram Drought Index (KBDI) or Moutn's Soil Dryness Index (SDI). The KBDI and SDI are empirical water balance models designed in 1960s. These models oversimplify the processes influencing soil moisture that potentially lead to significant biases.
- Text:** The present project will examine the use of detailed land surface models, remotely sensed satellite measurements and ground based observations for the monitoring and prediction of landscape dryness. The new information will be calibrated with the old scheme so that it can be used within existing fire and flood forecasting prediction systems. This will be achieved through partnerships between the fire agencies, Bureau of Meteorology and other Commonwealth and State agencies.
- Text:** This project will thus address a fundamental limitation in our ability to prepare for fires, floods and heatwaves and is directly linked to pre-event planning as well as forecasting of events. Both of these aspects are core elements of a resilient community. The outputs of this project will improve Australia's ability to manage extreme events by developing a state of the art, world's best practice in soil moisture analysis that makes use of many different sources of observations and cutting edge land surface modelling and data assimilation.
- Section Header:** Project members
- List of Members:**
 - Imtiaz Dharssi, Project Lead, R&D Division, Bureau of Meteorology, Melbourne
 - Vinod Kumar, Scientist, R&D Division, Bureau of Meteorology, Melbourne
 - Jeff Kepert, Senior Scientist, R&D Division, Bureau of Meteorology, Melbourne
 - Peter Steinle, Senior Scientist, R&D Division, Bureau of Meteorology, Melbourne
 - Adam Smith, Scientist, Bureau of Meteorology, Melbourne
 - Ian Grant, Senior Scientist, Bureau of Meteorology, Melbourne
 - John Bally, Lead End User, Bureau of Meteorology, Hobart.
 - Paul Fox-Hughes, End User, Bureau of Meteorology, Hobart.
 - Mark Chladil, End User, Tasmania Fire Service, Hobart.
 - Adam Leavesley, End User, ACT Parks.
 - Andrew Sturgess, End User, Predictive Services Unit, QFES, Brisbane.
 - Rob Sandford, End User, Country Fire Service, South Australia.
 - Ralph Smith, End User, Department of Fire and Emergency Services, Western Australia.
 - David Taylor, End User, Parks Tasmania.
- Section Header:** Project activities
- Section Header:** Publications
- Section Header:** News
- Section Header:** Meeting Minutes

The left sidebar contains navigation menus for 'Toolbox' (Create New Topic, Index, Search, Changes, Notifications, RSS Feed, Statistics, Preferences) and 'Webs' (AIFS, BNOC, BNOC_RCM, Main, MetSpace, NSW, NT, SSS, CapPgApiJava, ProductGenerator, Raptic3D, VIC, WA, BMTC, ManagementGroup, MgtMinutes, CAWCR, ALOA, ESM, WEP, ChannelManagement, WebsiteCleanUp, ClimateAndWater, A2PI, BAU, CWITS, Architecture, ClimateDataServices, Delivery).

Conclusions

- ACCESS results are encouraging when we consider:
 - Coarser resolution (~40 – ~80 km) of NWP.
 - NWP precipitation estimates are generally erroneous.
 - Land DA in NWP is usually tuned to get fluxes correct.
- KBDI soils show large wet bias.
- SDI is better than KBDI.
- ASCAT estimates show very good skills.
- ACCESS soil moisture shows similar skill to ECMWF model.
- High resolution soil moisture analysis has been developed.

JASMIN

- Verification shows that the JASMIN has greater skill.
- Four rescaling methods for JASMIN has been implemented.
- Evaluation is on-going.

Future Work

Immediate Plans

- Compare & evaluate against the current operational system.
- Evaluation based on case studies of fire occurrence.
- The evaluations can include Drought Factor (DF) calculation.
- Raw soil moisture layers (4) could be made available.

Further Down the Road

- Downscale products to 1 km resolution.
- Bring JASMIN to NASA LIS framework.
- Assimilation of satellite products.
- Further verification.
- Links with other BNHCRC projects.

Acknowledgments

- BNHCRC
- All end-users
- Peter Steinle, Jeff Kepert, David McJannet, Jeff Walker, Adam Smith, Chun-Hsu Su, Alex Holmes
- Monash University & University of Melbourne for OzNet
- CSIRO for CosmOz
- OzFlux team

THANKS, ANY QUESTIONS?

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