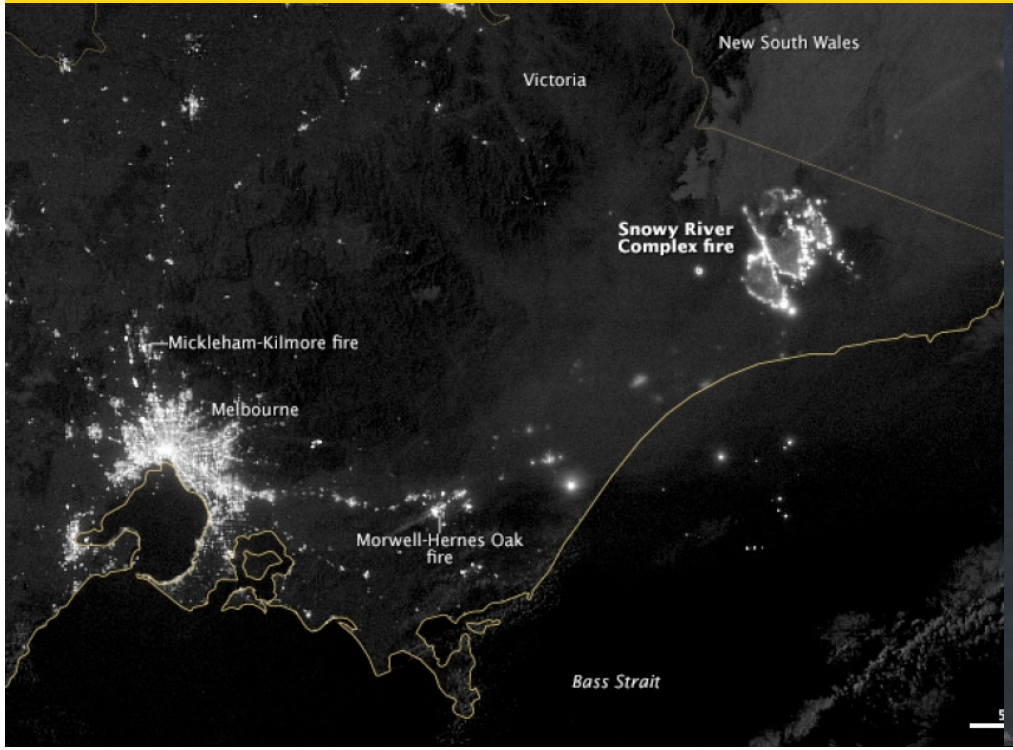
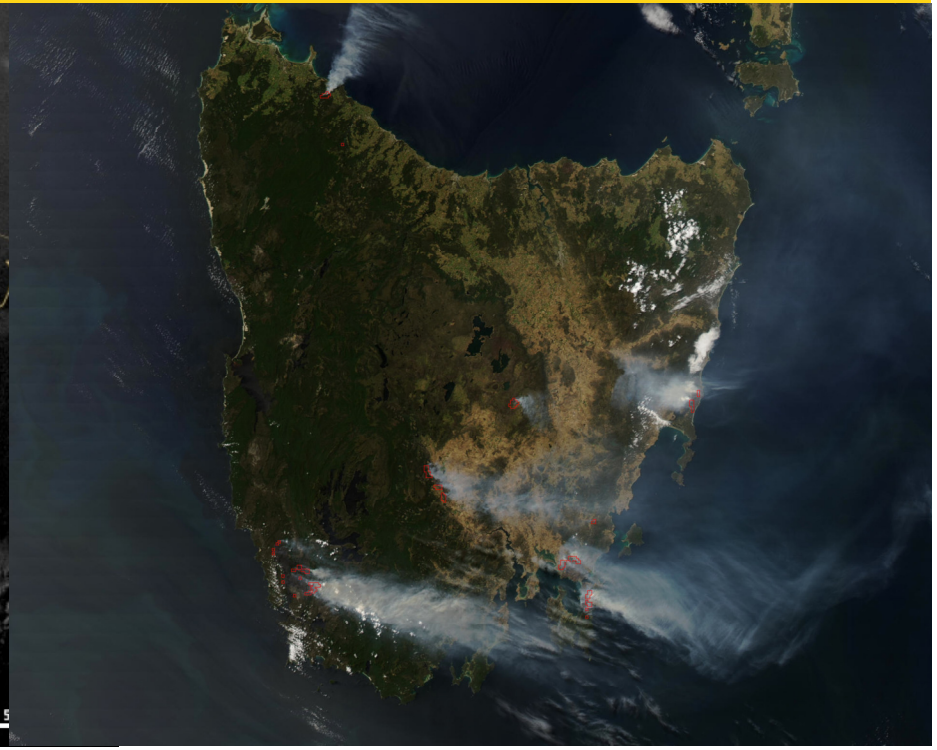
bushfire&natural HAZARDSCRC

TOWARDS AN IMPROVED LAND DRYNESS ESTIMATE FOR FIRE PREDICTION

Vinodkumar & Imtiaz Dharssi
Bureau of Meteorology, Melbourne





Picture courtesy: NASA

An Australian Government Initiative

CRC AUSTRALIA

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

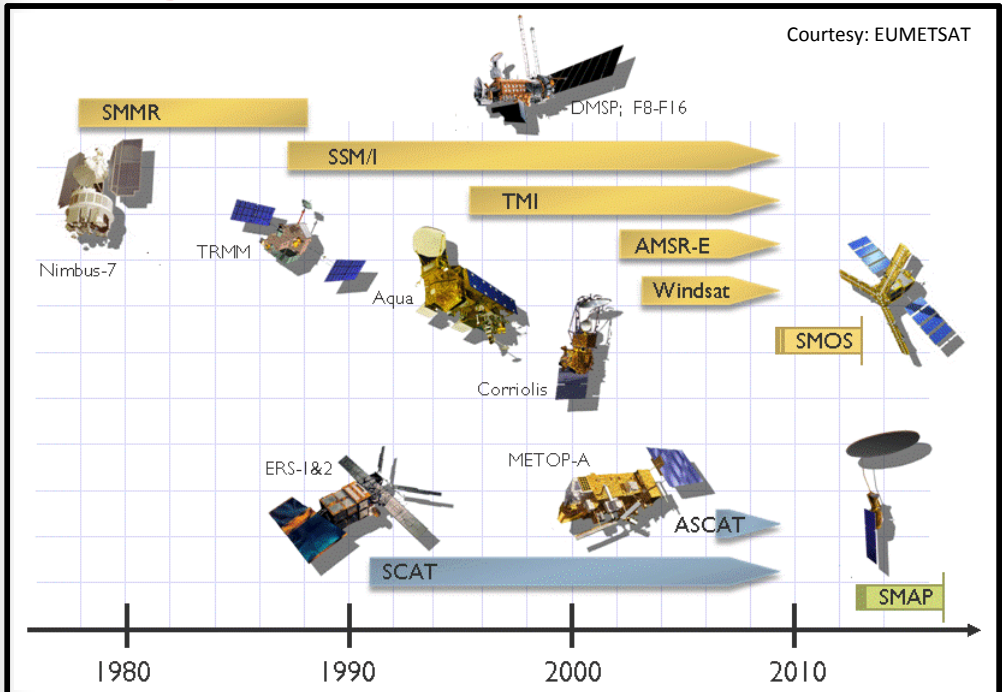
- Forest Fire Danger Index (FFDI; McArthur, 1958).
- No major science update since first design!
- $FFDI = 2e^{(-0.45+0.987 \ln(DF)-0.0345RH+0.0338T+0.0234V)}$

  DF - 'Drought Factor'
- DF represent 'fuel availability'.
- DF $= fn(soil\ moisture\ deficit)$
- Current soil moisture deficit models:
  - Keetch-Byram Drought Index (KBDI; Keetch & Byram 1968)
  - Mount's Soil Dryness Index (SDI; Mount 1972)

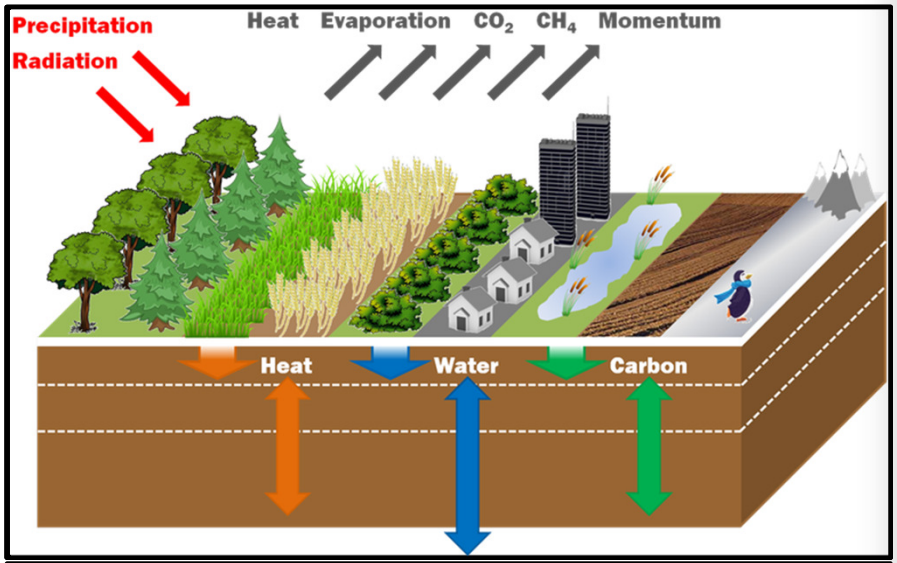
Background

- "*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



- Microwave remote sensing (~1 – 5 GHz).
- Measures top 2 – 5 cm soil layer.
- ASCAT operationally received in BoM.

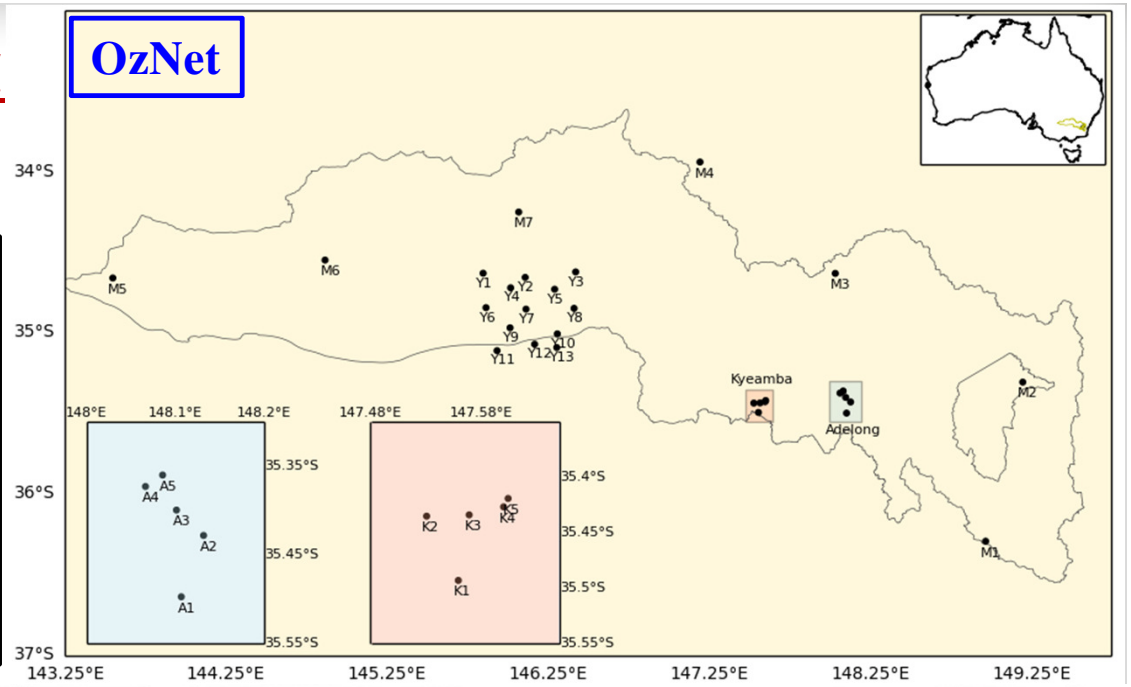


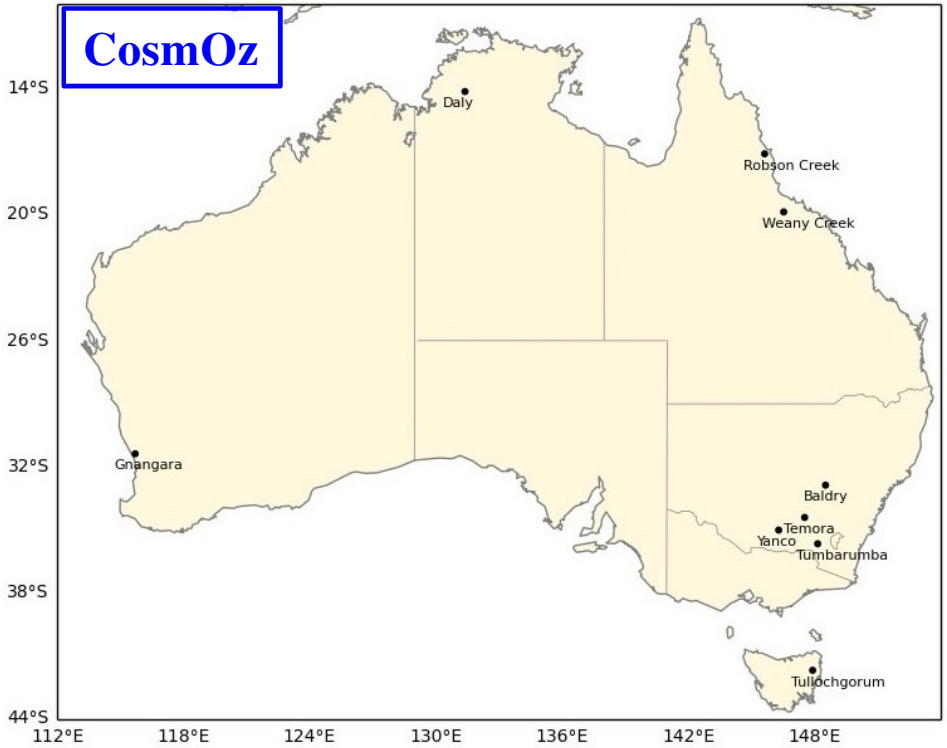
- Example for LSMs: JULES, CABLE.
- JULES used in ACCESS NWP & Seasonal forecasting models.
- ACCESS NWP has a Land Data Assimilation scheme.

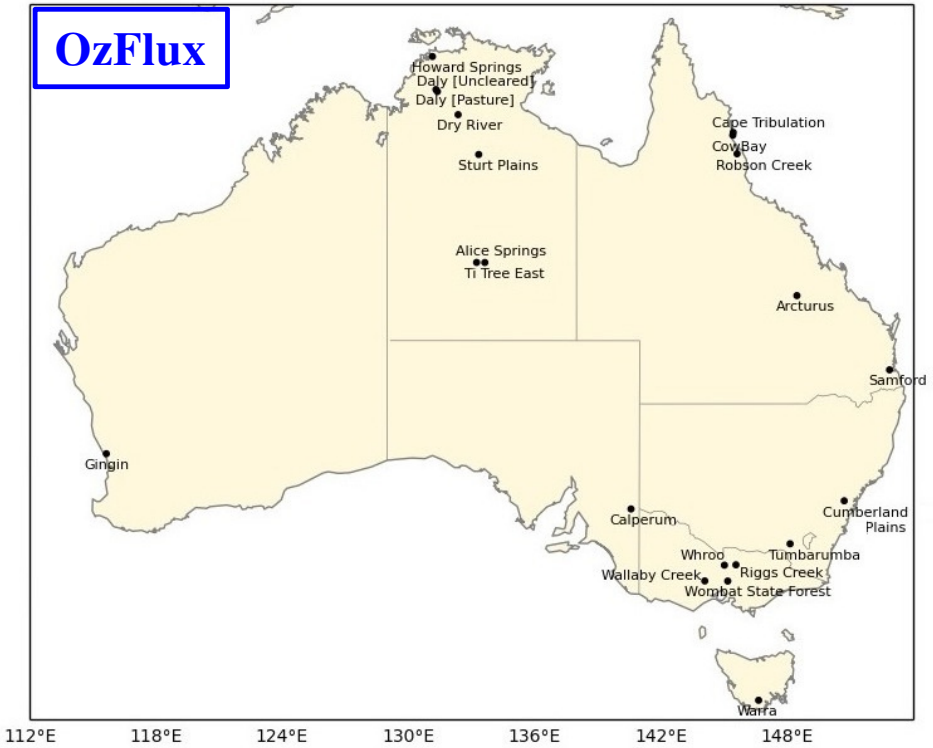
LSM – Land Surface Model
JULES – Joint UK Land Environment Simulator
CABLE - Community Atmosphere Biosphere Land Exchange
ACCESS – Australian Community Climate & Earth System Simulator
NWP – Numerical Weather Prediction

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

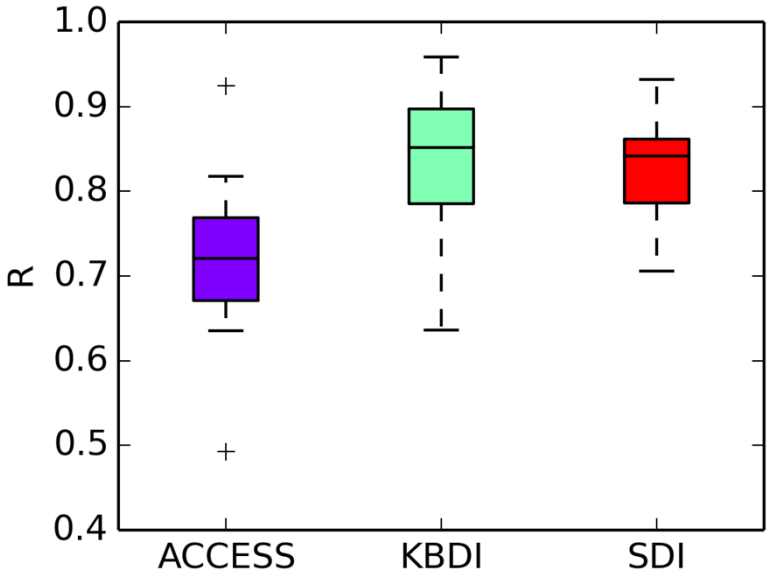
OzFlux	Correlation [-]		Bias [-]		RMSD [-]	
	Forested (12 sites)	*Non-forested (6 sites)*	*Forested*	*Non-forested*	*Forested*	*Non-forested*
ACCESS_40km	**0.76**	**0.73**	-0.09	-0.04	0.20	0.22
KBDI	**0.72**	**0.67**	**-0.24**	**-0.16**	**0.33**	**0.26**
SDI	0.75	0.70	-0.10	**-0.02**	0.22	0.23
ASCAT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

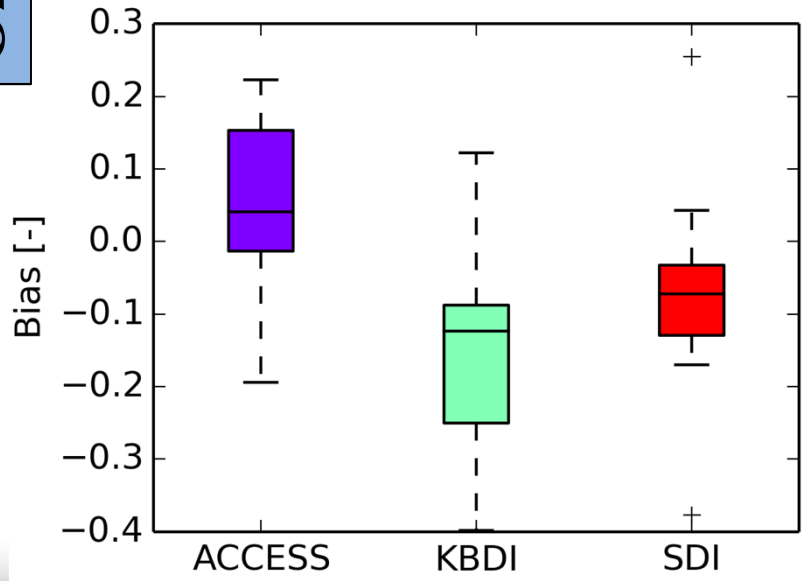
* 5 sites

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

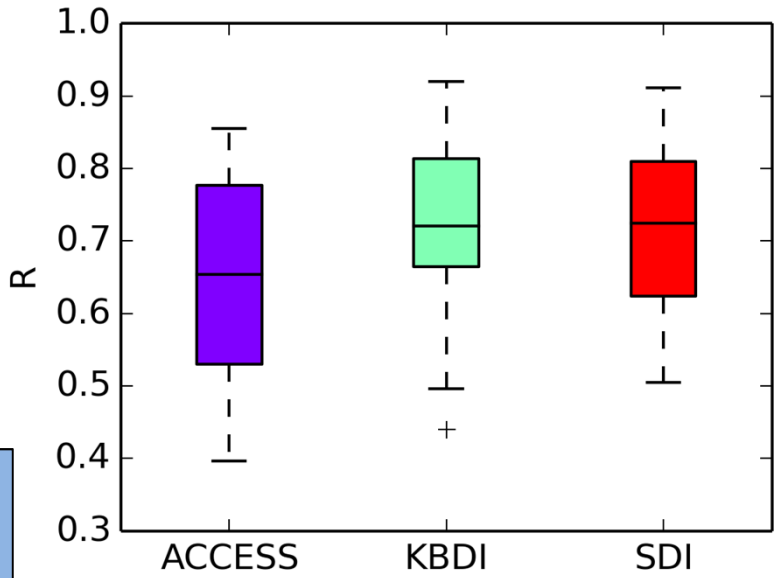
Deeper (~ 100 cm) Soil Moisture

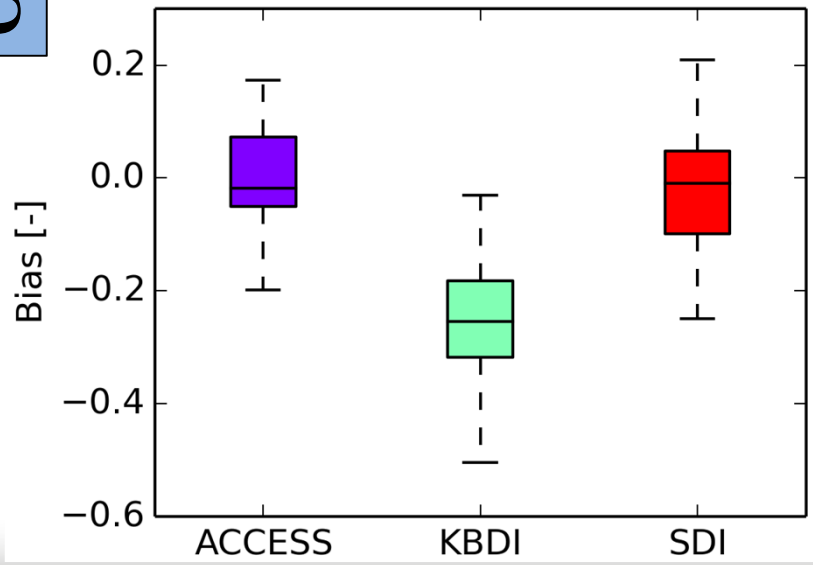
OzFlux





OzNet

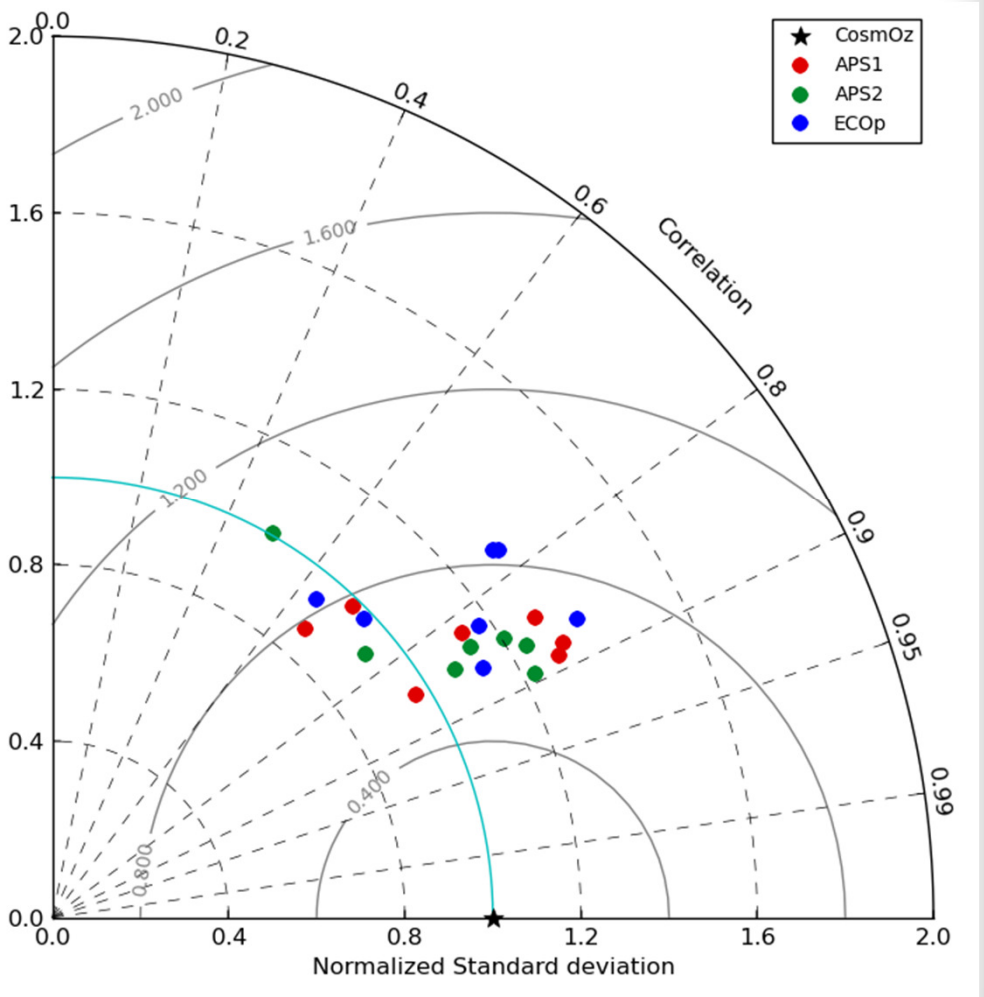




ACCESS vs. ECMWF

- 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?

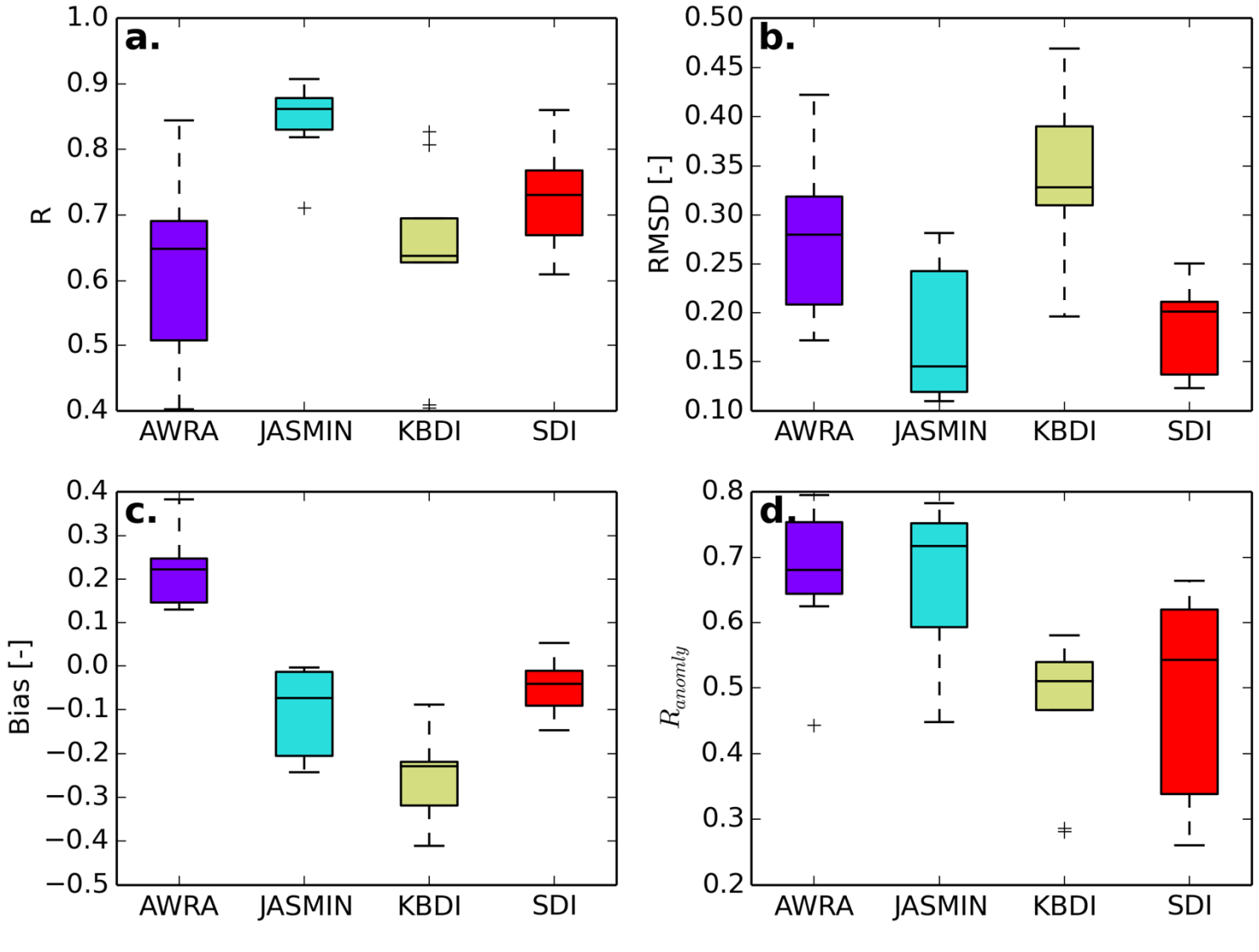
A high resolution soil moisture analyses

- 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.

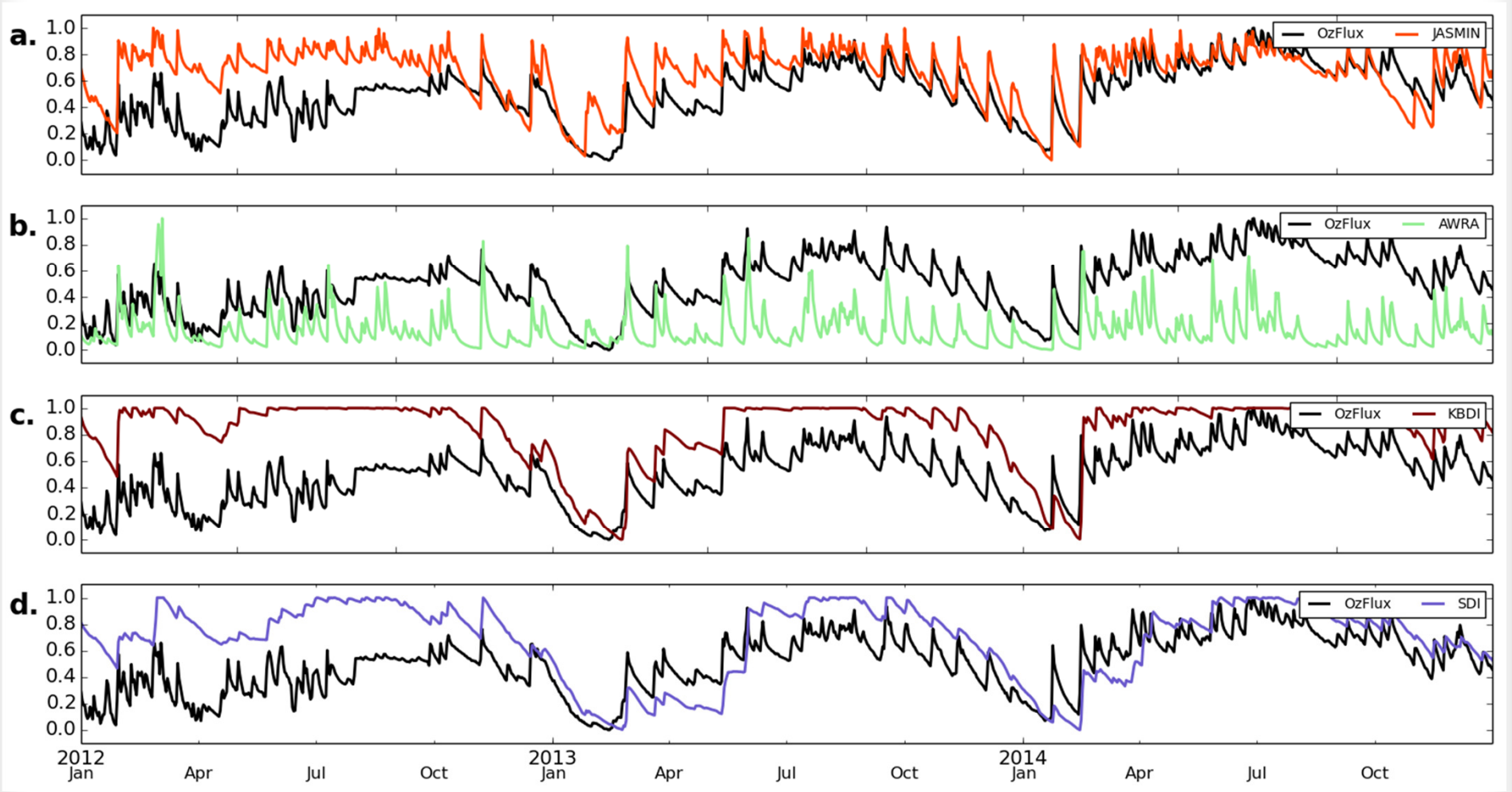
More about JASMIN

- 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]

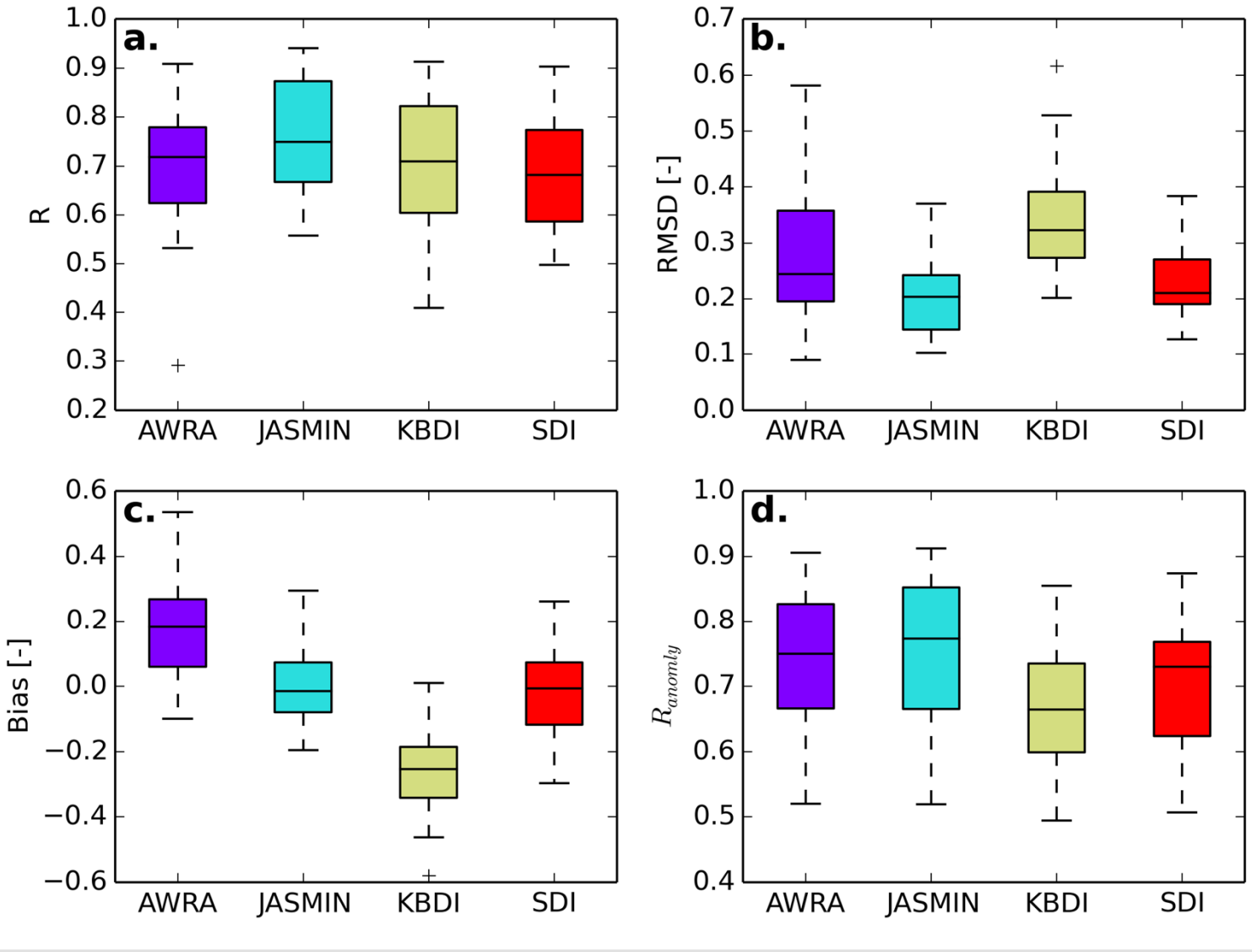


OzFlux surface: Tumbarumba, NSW



1 = Very wet, 0 = Very dry

OzNet [0-90 cm]


a.
R
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
AWRA
JASMIN
KBDI
SDI
b.
RMSD [-]
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
AWRA
JASMIN
KBDI
SDI
c.
Bias [-]
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
AWRA
JASMIN
KBDI
SDI
d.
R_{anomly}
1.0
0.9
0.8
0.7
0.6
0.5
0.4
AWRA
JASMIN
KBDI
SDI

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 ($\vartheta_{min} = 0$, $\vartheta_{max} = 200$).

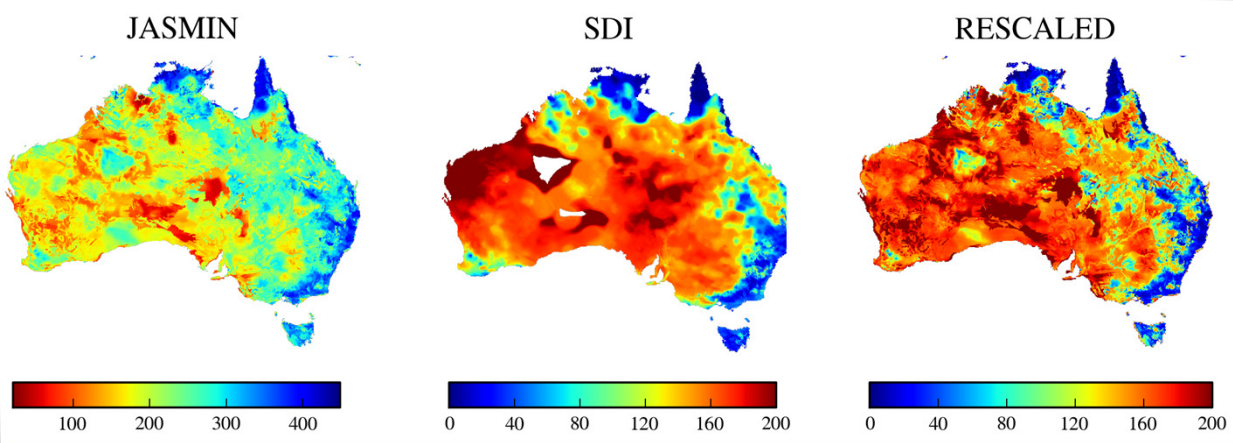
- **$\mu - \sigma$ MATCHING**

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

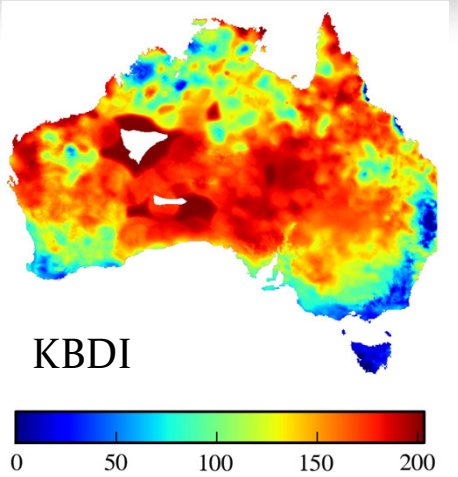
Θ – JASMIN soil moisture, $\hat{\Theta}$ – Normalized Θ,
μ – Mean, σ – Standard Deviation, ϑ – KBDI / SDI

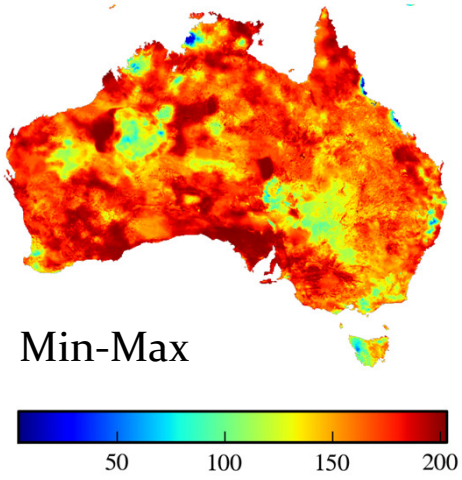
- **CDF MATCHING**

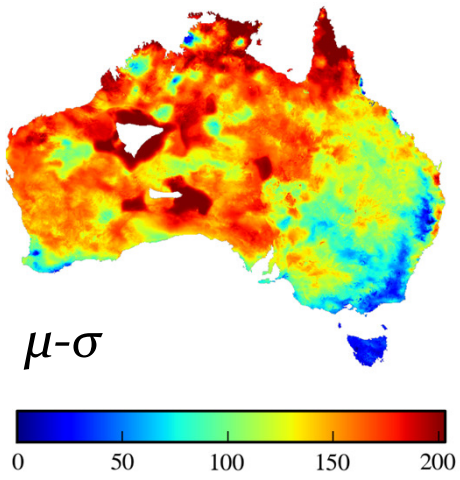
$$F(x) = \Pr[X \leq x]$$

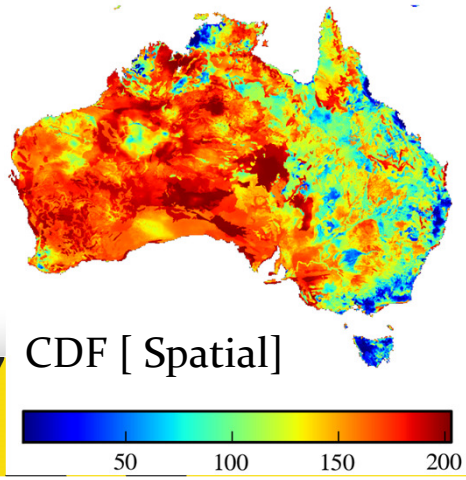


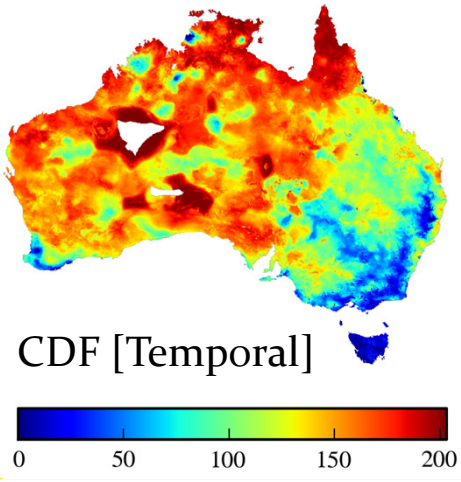
Re-scaling JASMIN to KBDI on 1st Jan 2013

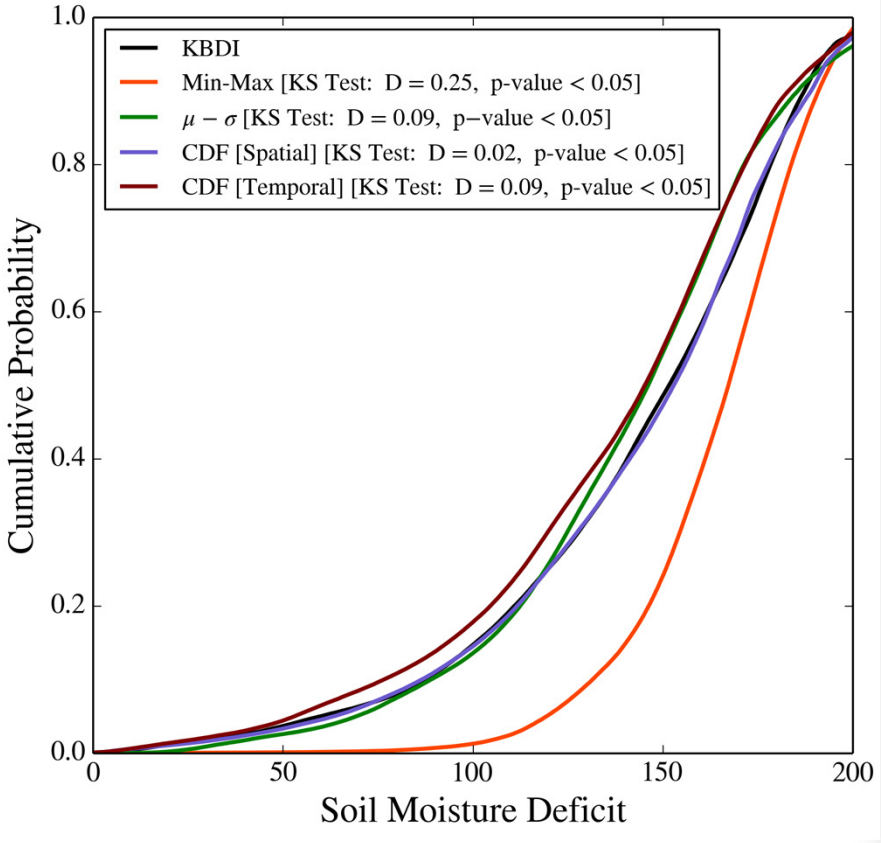












Correlation [with *in-situ*]

0–35 cm model soil profile

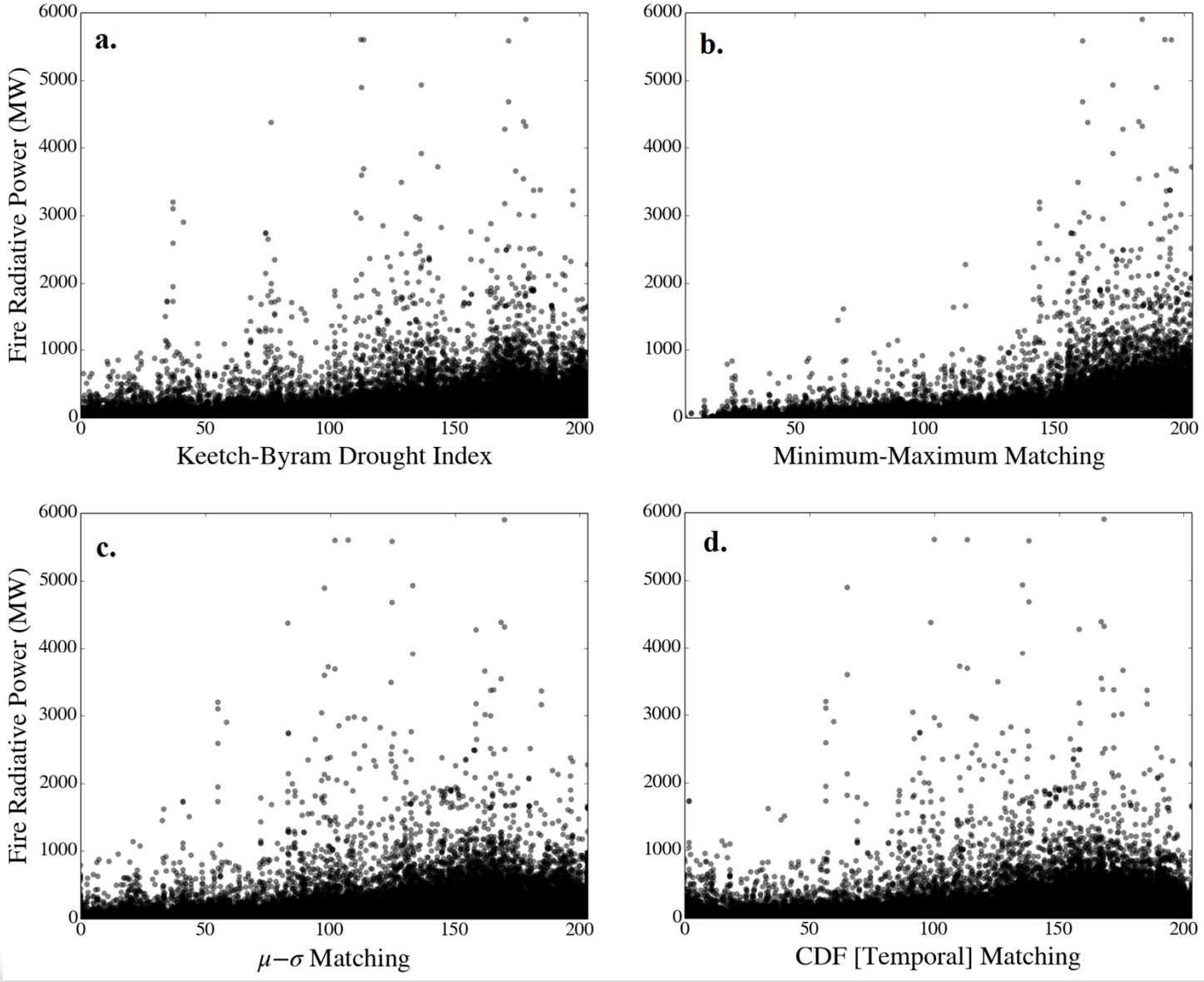
In situ network	Correlation					Anomaly correlation				
	KBDI	MM	μ – σ	CDF		KBDI	MM	μ – σ	CDF	
				Spatial	Temporal				Spatial	Temporal
CosmOz	0.72	0.85	0.84	0.79	0.82	0.46	0.66	0.60	0.49	0.55
OzFlux (surface)	0.76	0.84	0.83	0.75	0.82	0.58	0.74	0.71	0.60	0.69
OzFlux (root zone)	0.85	0.86	0.86	0.77	0.85	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	μ – σ	CDF		KBDI	MM	μ – σ	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:

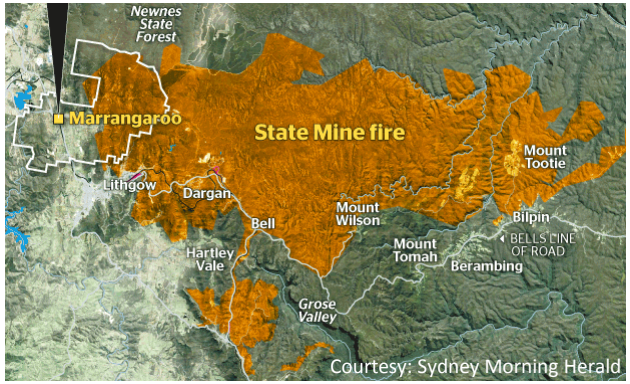
Bushfire cases

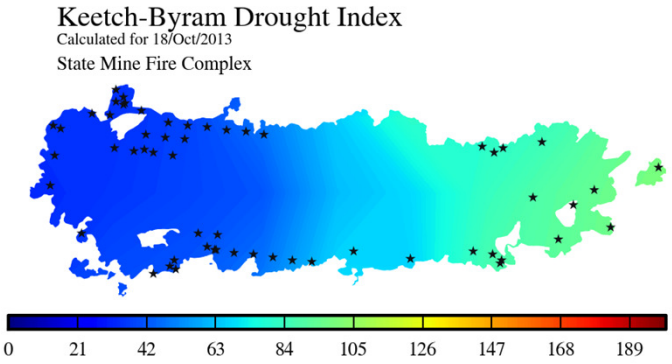
State Mine Fire, NSW, Oct 2013
Dunalley Fire, TAS, Jan 2013
Wuthering Heights Fire, TAS, Jan 2016
Lake Mackenzie fire, TAS, Jan 2016
Ballandean fire, QLD, Oct 2014

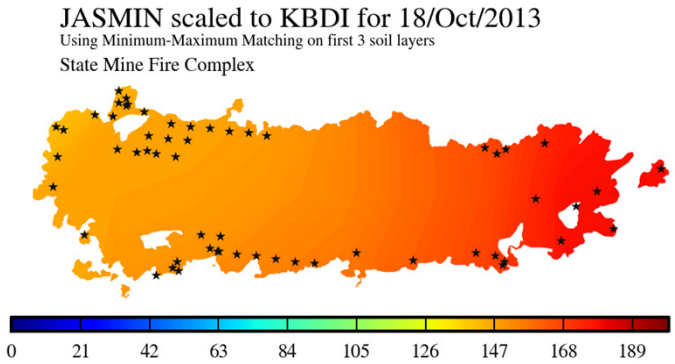
Fuel reduction burns

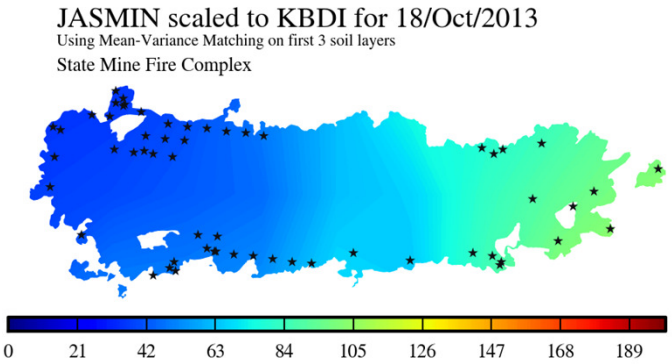
Lancefield, VIC, Sep 2015
NE Victoria, Mar 2017
Orbost, VIC, Mar 2017

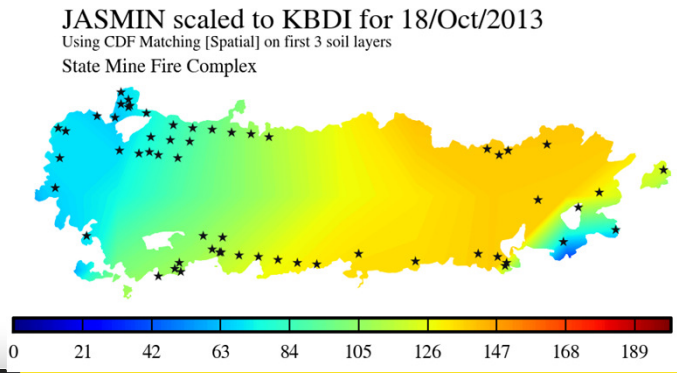
State Mine Fire, NSW

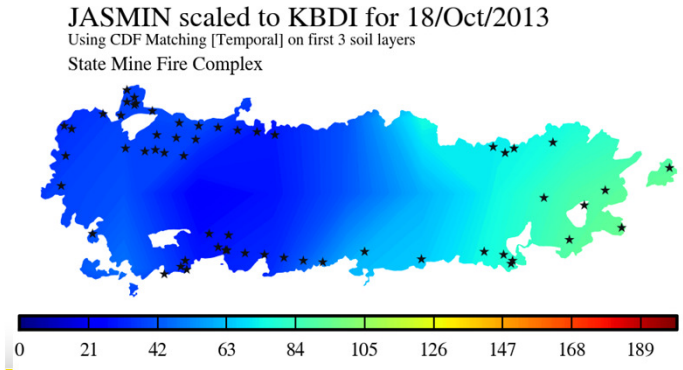










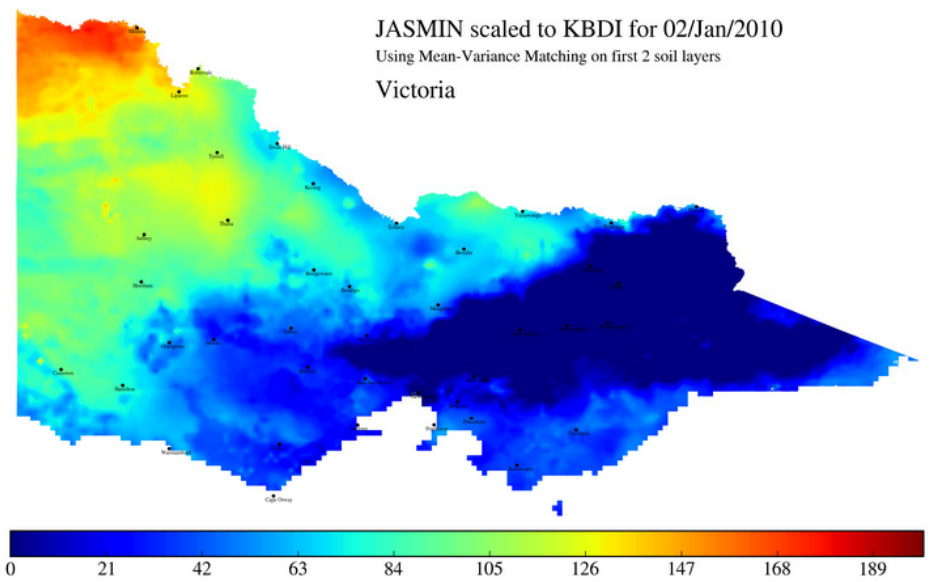


Webpage development in progress

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

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

JASMIN rescaled to KBDI



SAMPLE

Select Date: 2 Jan 2010

Select Method: Mean-Variance Matching

Select Layer: 0-35 cm layer

Select Region: Victoria

- Contact
- Home Page

Partner Organizations

bushfire&natural HAZARDSCRC

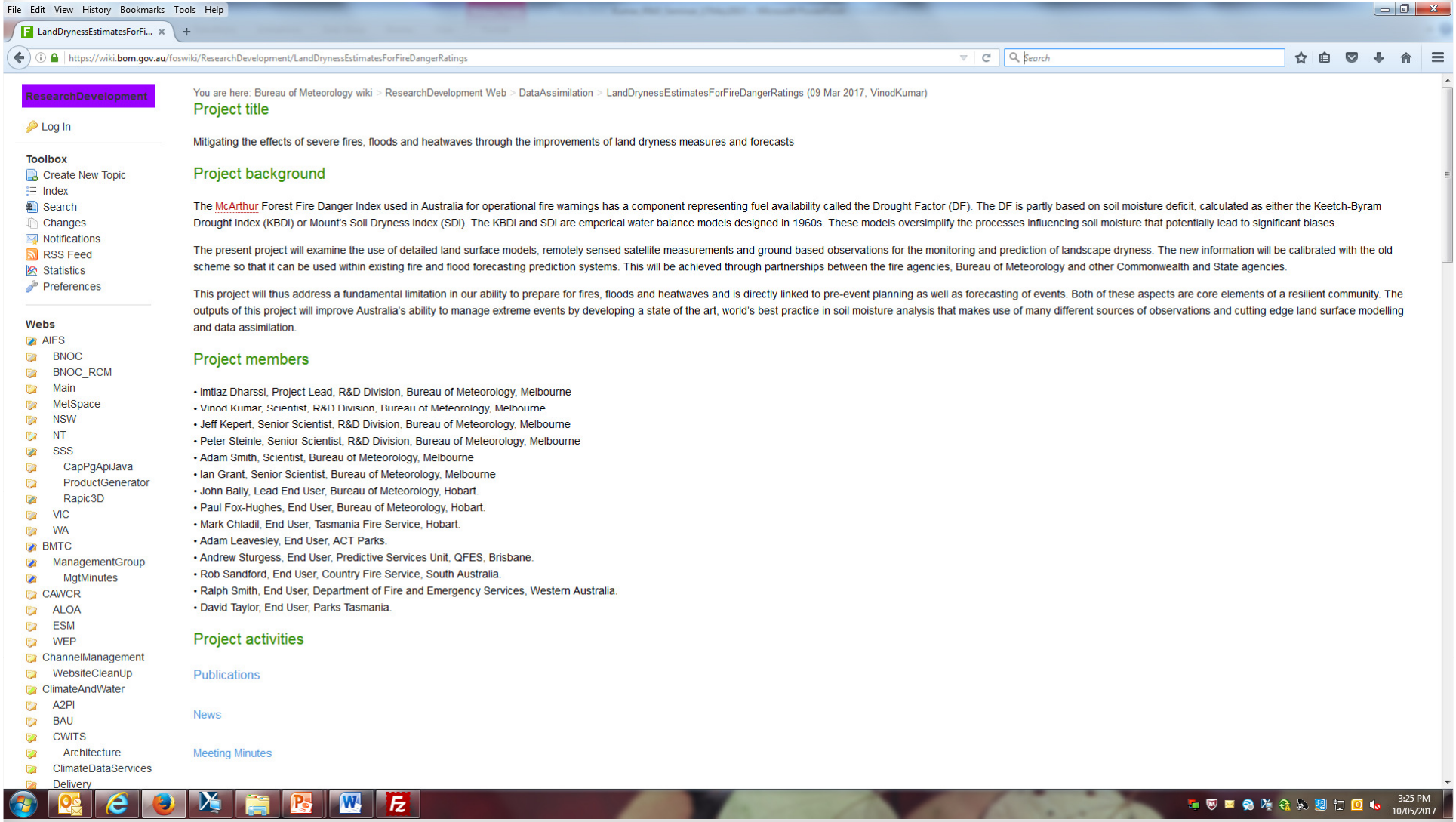
Australian Government
Bureau of Meteorology

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.

Follow project updates

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



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 Uniersity & University of Melbourne for OzNet
- CSIRO for CosmOz
- OzFlux team

THANKS, ANY QUESTIONS?

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