OzFlux for water cycle studies

Albert van Dijk

THE AUSTRALIAN NATIONAL UNIVERSITY

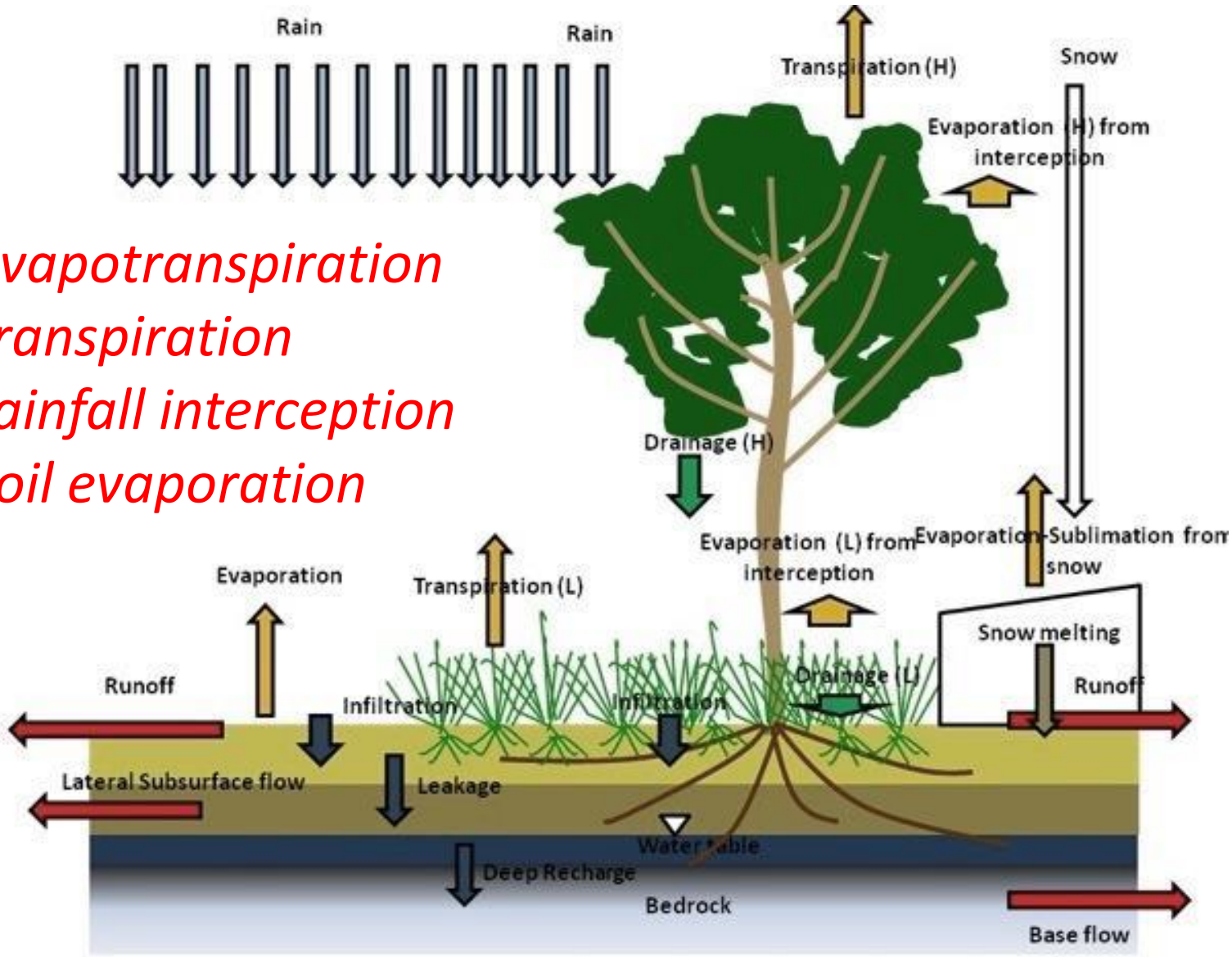
OzFlux for water cycle studies

ET = *evapotranspiration*

Et *transpiration*

+ Ei *rainfall interception*

+ Es *soil evaporation*



Outline

- GEWEX OzEWEX
- Flux tower measurements to develop and evaluate spatio-temporal ET (and GPP) estimates
- Opportunities to increase hydrological value of OzFlux sites
  - Soil hydrology, groundwater, runoff
  - Large area soil moisture (CosmOz)
  - Physics of Ei

www.ozewex.org

OzEWEX

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What is OzEWEX?

OzeWEX is the **Australian Energy and Water Exchange initiative**. We are a non-profit volunteer organisation that is part of the international Global and regional Energy and Water Exchanges project (GEWEX). *Our goal is to promote and increase measurement, understanding and prediction of the water and energy cycles and related variables over the Australian continent.* Examples of important related variables include vegetation dynamics and ecosystem carbon fluxes.

OZEWEX aims to achieve its goal by promoting and facilitating data collection and sharing; collaborative research activities across organisations, and engagement between researchers, research users and research managers. Data brokering, collaborative research experiments, and workshops are considered important means.

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OzEWEX

WG1 - Observational Data

Co-chairs:

- Dr Juan Pablo Guerschman, CSIRO Land and Water
- Dr Sandra Monerris-Belda, Monash University

Members

- Mark Adams, University of Sydney
- James Cleverly, University of Technology Sydney
- Derek Eamus, University of Technology Sydney
- Rachel Gilmore, Bureau of Meteorology
- Alfredo Huete, University of Technology Sydney
- David McJannet, CSIRO Land and Water
- Stuart Phinn, University of Queensland
- Natalia Restrepo-Coupe, University of Technology Sydney
- Bellie Sivakumar, University of New South Wales
- Albert van Dijk, Australian National University
- Eva van Gorsel, CSIRO Marine and Atmospheric Research
- Jeff Walker, Monash University
- Andrew Western, Melbourne University
- Marta Yebra, CSIRO Land and Water

WG5 - Vegetation Processes

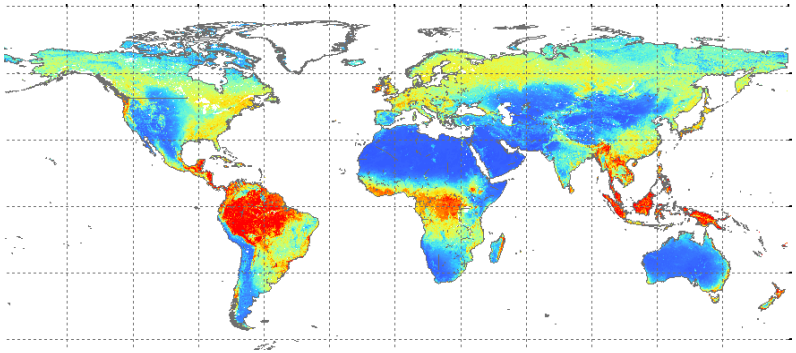
Co-chairs:

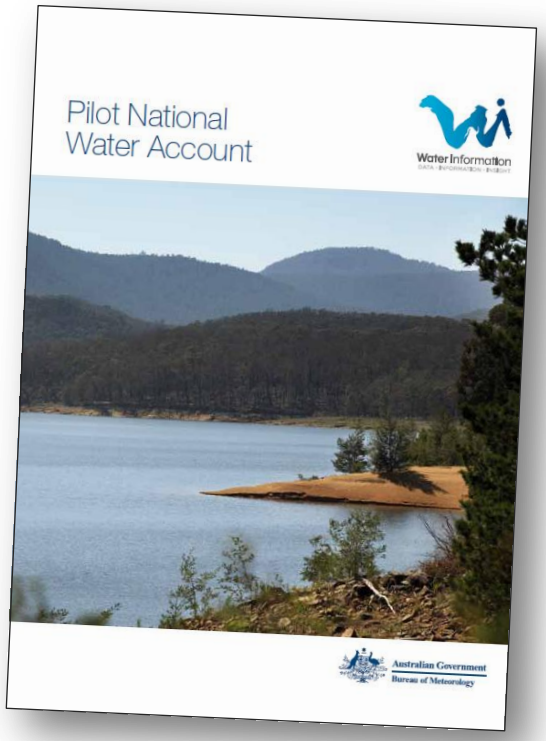
- Tim McVicar, CSIRO Land and Water
- Brad Evans, Macquarie University

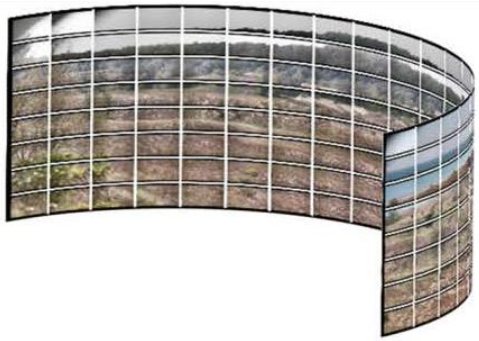
Members:

- Mark Adams, University of Sydney
- Nicolas Boulain, University of Technology Sydney
- James Cleverly, University of Technology Sydney
- Edoardo Daly, Monash University
- Derek Eamus, University of Technology Sydney
- Rachel Gilmore, Bureau of Meteorology
- Eva van Gorsel, CSIRO Marine and Atmospheric Research
- Huade Guan, Flinders University
- Juan Guerschman, CSIRO Land and Water
- Alfredo Huete, University of Technology Sydney
- Mirko Karan, James Cook University
- Mike Liddell, James Cook University
- Dave McJannet, CSIRO Land and Water
- Belinda Medlyn, Macquarie University
- Colin Prentice, Macquarie University
- Natalia Restrepo-Coupe, University of Technology Sydney
- Alison Specht, University of Queensland
- Albert van Dijk, Australian National University
- Willem Vervoort, University of Sydney
- Randol Villalobos-Vega, University of Technology Sydney
- Marta Yebra, CSIRO Land and Water

Some new developments

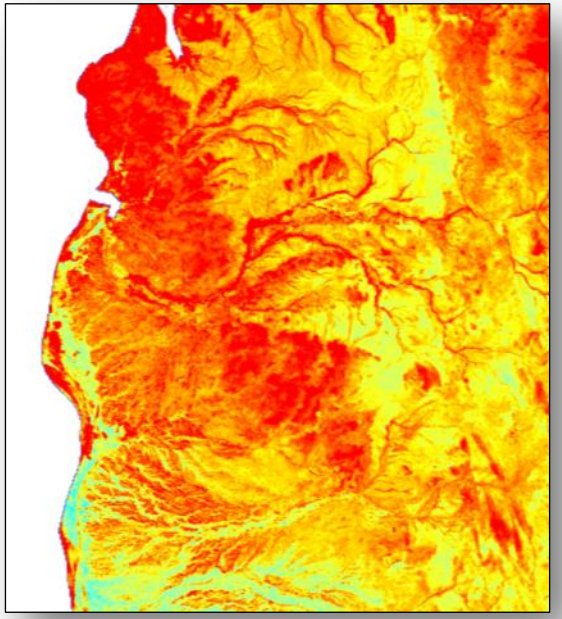






CMRSET evapotranspiration product

Guerschman J.P., van Dijk, A.I.J.M., Mattersdorf, G., Beringer, J., Hutley, L.B., Leuning, R., Pipunic, R.C. and Sherman, B.S. (2009), *Scaling of potential evapotranspiration with MODIS data reproduces flux observations and catchment water balance observations across Australia.* Journal of Hydrology, **369**, 107-119.



- 8-day, 250 m resolution, 2000 onwards - via eos.csiro.au or www.ozewex.org

Example uses:

- Murray-Darling Sustainable Yields Project
- BoM Australian Water Resources Assessments
- Groundwater Dependent Ecosystem Atlas (http://www.bom.gov.au/water/)

Australian Water Resources Assessment system

2.2.2 Key information

National water flows, stores and use indicators for 2011–12

Landscape water flows

	Australian average	Difference from 1911–2012 annual mean	Decile ranking wit 201
Rainfall	567 mm	+33%	10th – very mu
Evapotranspiration	483 mm	+30%	10th – very m
Landscape water yield	83 mm	+57%	10th – very m

Mean annual soil moisture (decile ranking with respect to the 1911–2012 record avera

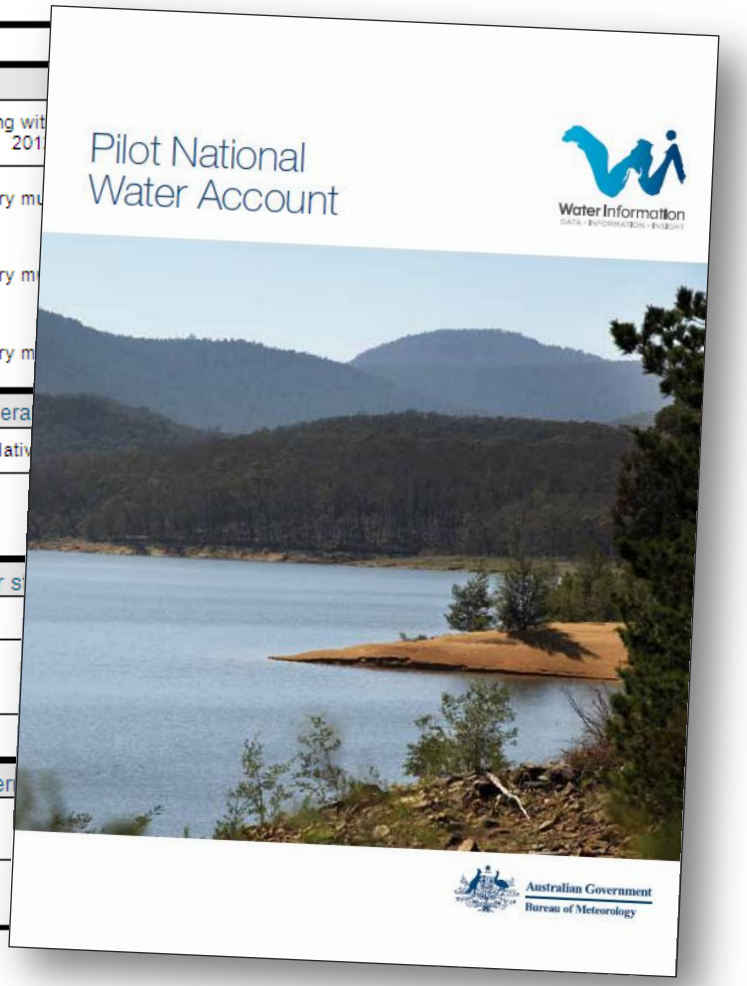
2011–12	2010–11	Relati
10th – very much above average	10th – very much above average	

Surface water storage (comprising about 94% of Australia's total surface water s

Total accessible capacity	30 June 2012		30 June 2011	
	accessible volume	% of total capacity	accessible volume	% of total capacity
79,700 GL	66,300 GL	75%	60,100 GL	83%

Urban water use (of the eight capitals of the Australian States and Ter

Total use in 2011–12	Total use in 2010–11
1,751 GL	1,736 GL



http://www.bom.gov.au/water/)

Australian Government
Bureau of Meteorology

Water Information
DATA › INFORMATION › INSIGHT

National Research FLAGSHIPS
Water for a Healthy Country
CSIRO

AWRA benchmarking system

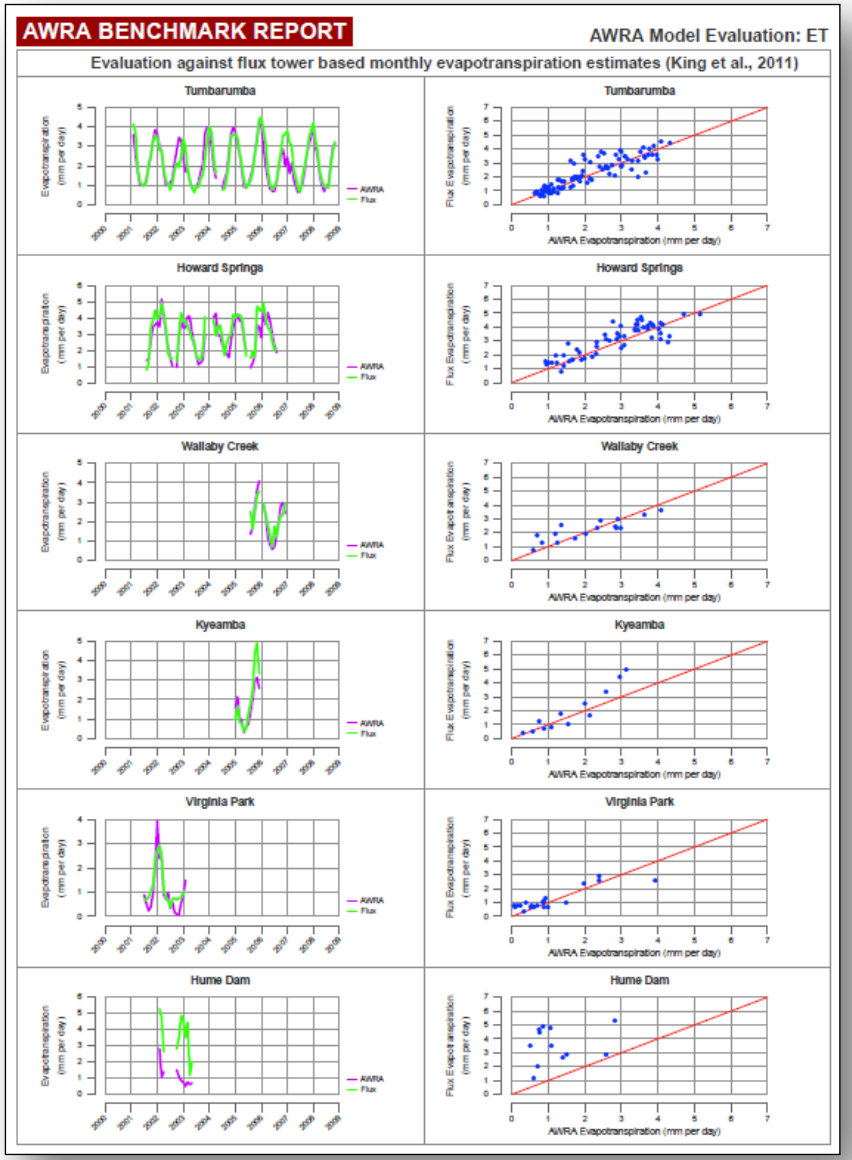
Designed to assist in performance assessment, version acceptance and operational testing

Includes automated reporting against:

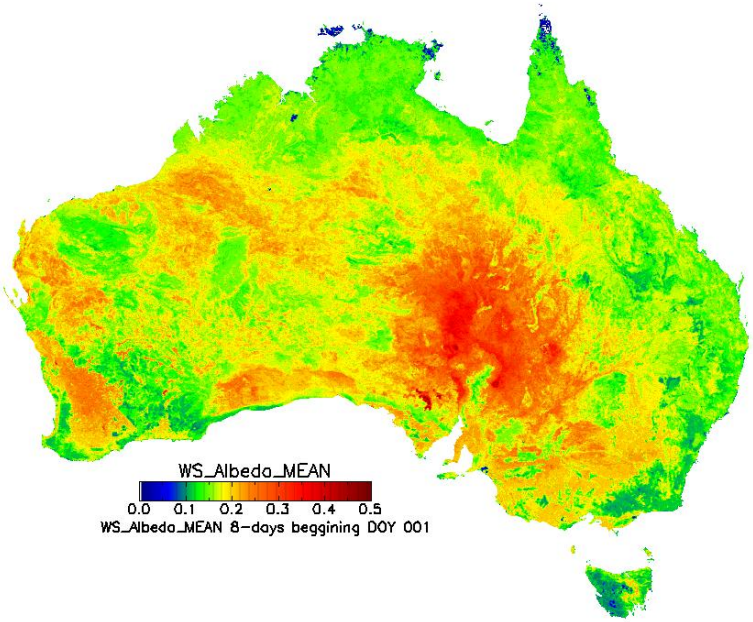
- Streamflow from 786 small catchments
- Recharge estimates from several 100s sites
- Remotely sensed LAI and soil moisture
- ET from 6 flux towers (Tumb, HoSp, Wall, Kyem, ViPa, Hume)

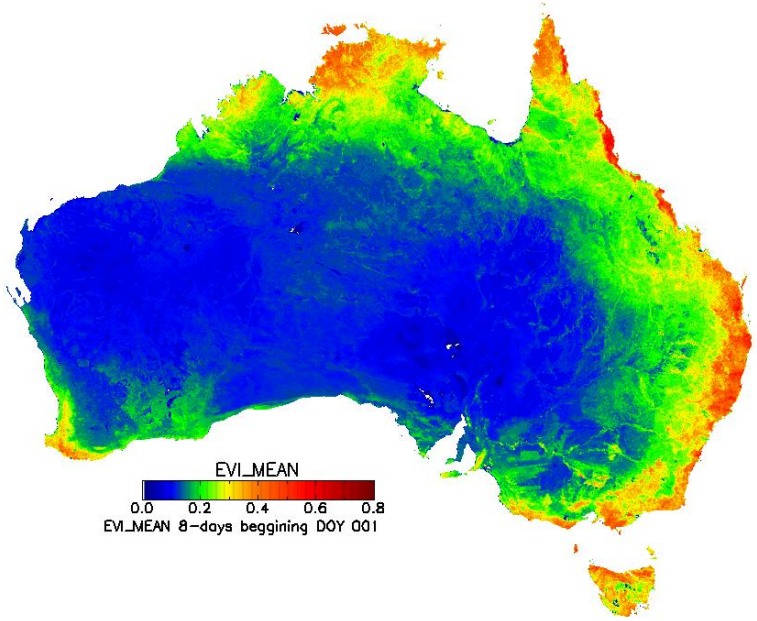
Great opportunity to expand the ET evidence base with OzFlux

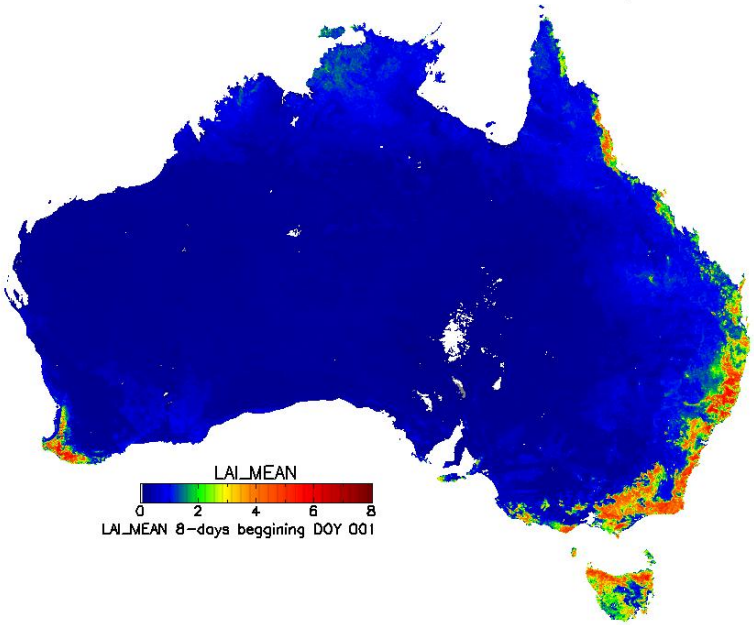
Warren et al. (in press)



Example of version testing: AWRA parameterised with MODIS vegetation data





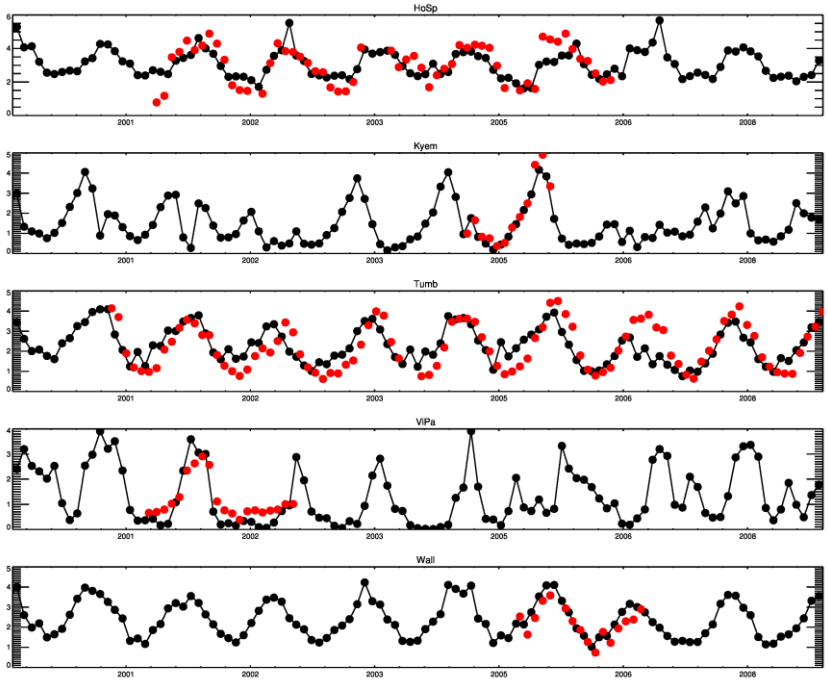


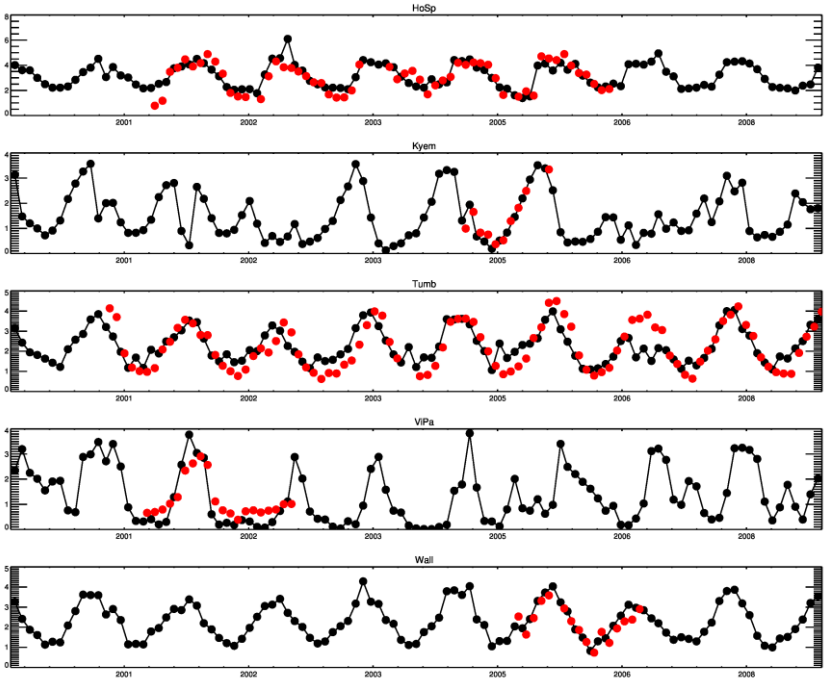
Guerschman et al. (in prep.)

Performance test

Table 1: Pearson correlation coefficients (r) between observed and modelled mean monthly evapotranspiration

site	n	%Forest	Default	LAI	EVI	Alb	LAI+EVI+Alb
HoSp	56		0.731	0.800	0.794	0.738	0.830
Kyem	12		0.951	0.905	0.973	0.983	0.946
Tumb	93		0.802	0.858	0.810	0.798	0.850
ViPa	20		0.974	0.971	0.979	0.971	0.969
Wall	16		0.942	0.929	0.945	0.940	0.929





Guerschman et al. (in prep.)

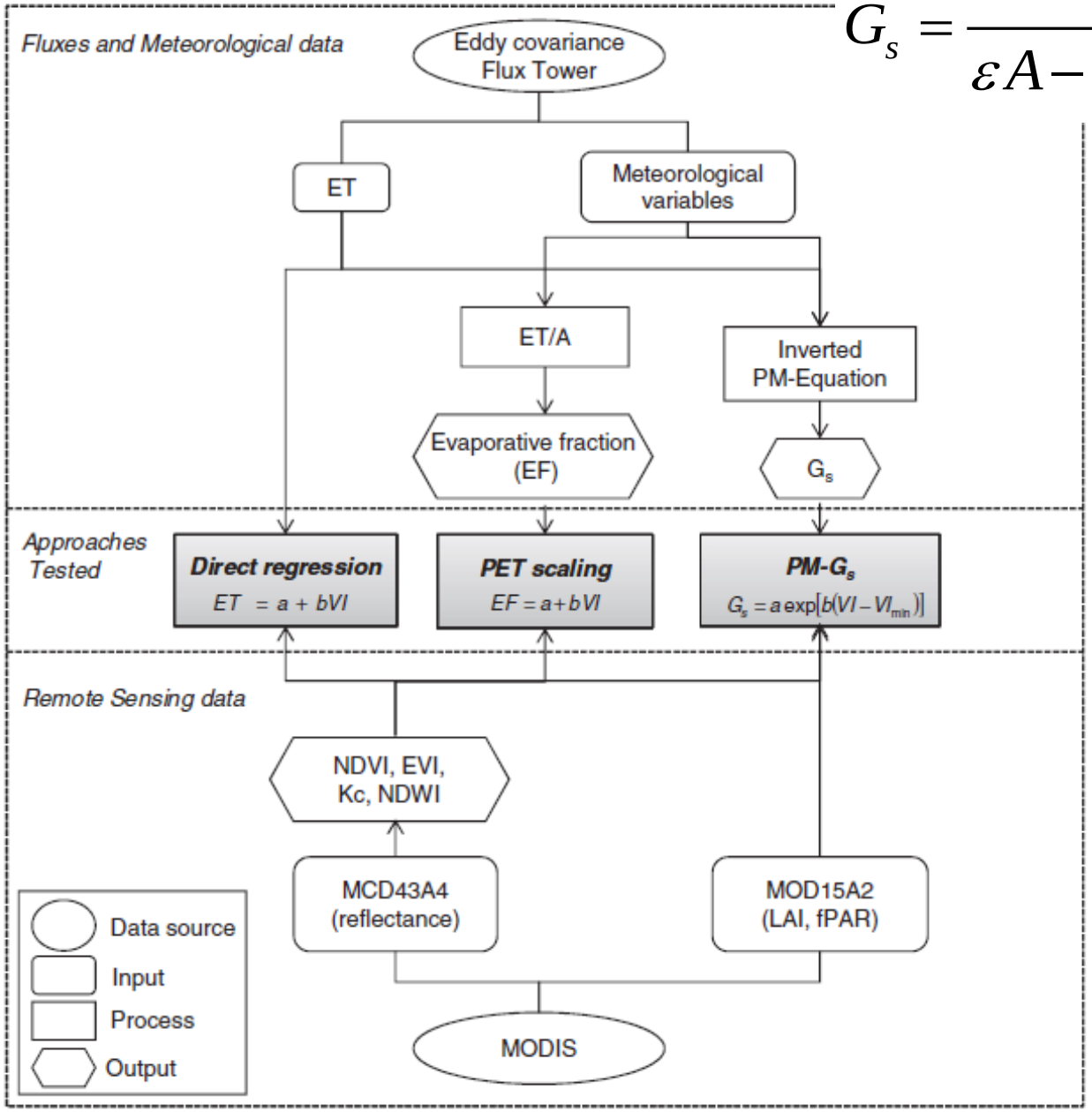
Remotely sensing canopy conductance (using FLUXNET)

Spectral indices calculated from MODIS including their shortened acronym, mathematical formulation and reference. ρ_x is the reflectance in MODIS band × (1 to 7).

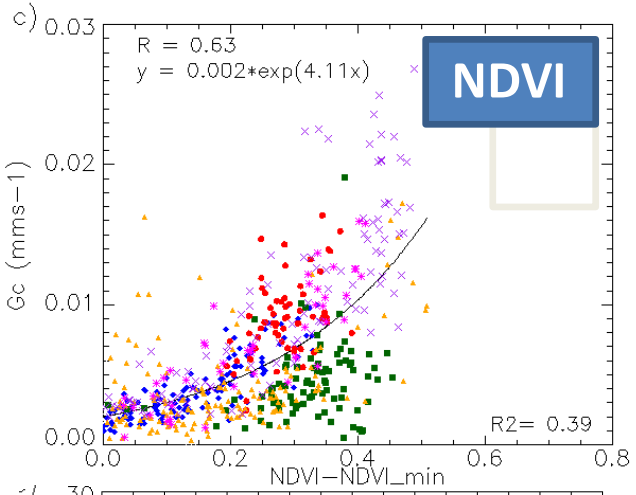
Index	Formulation	Reference
Normalized difference vegetation index	$NDVI = \frac{\rho_2 - \rho_1}{\rho_2 + \rho_1}$	Rouse et al. (1974)
Enhanced vegetation index	$EVI = \frac{2.5 \times (\rho_2 - \rho_1)}{(\rho_2 + 6 \times \rho_1 - 7.5 \times \rho_3 + 1)}$	Huete et al. (2002b)
Normalized difference water index	$NDWI = \frac{\rho_2 - \rho_5}{\rho_2 + \rho_5}$	Gao (1996)
Crop factor	$K_c = K_{c\_max} \times [1 - exp(-a \times EVI_r^{\alpha} - b \times RMI^{\beta})]$, where $K_{c\_max} = 0.68$, $a = 14.12$, $\alpha = 2.482$, $b = 7.991$, $ß = 0.890$, $EVI_r = \frac{EVI - EVI_{min}}{EVI_{max} - EVI_{min}}$, $K_{RMI} = 0.775$ and $C_{RMI} = -0.076$	Guerschman et al. (2009), Model 2b
Global vegetation moisture index	$GVMI = \frac{(\rho_2 + 0.1) - (\rho_6 + 0.02)}{(\rho_2 + 0.1) + (\rho_6 + 0.02)}$	Ceccato et al. (2002)

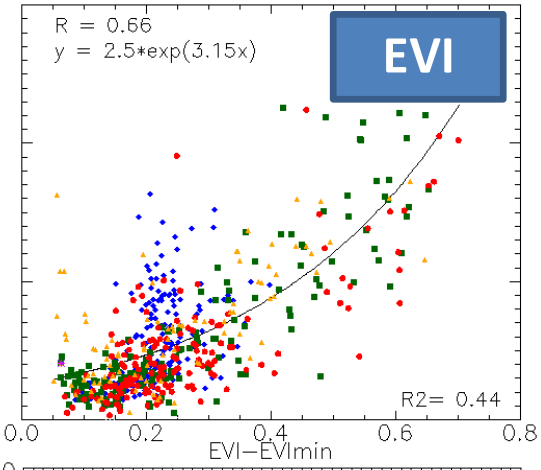
Yebra, Van Dijk, Leuning, Huete & Guerschman (RSE, 2013)

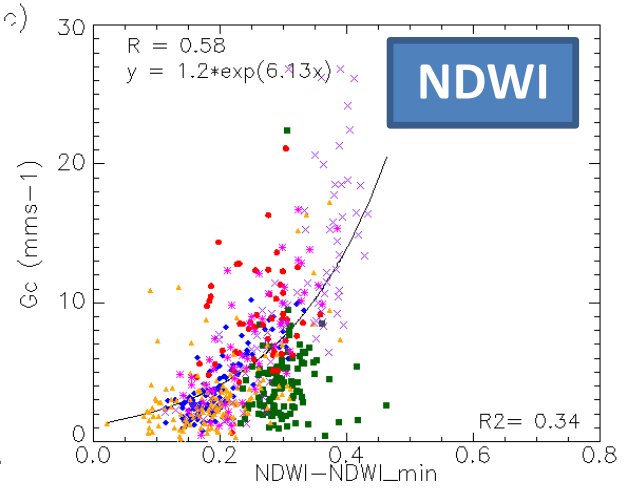
$$G_s = \frac{\lambda E\, G_a}{\varepsilon A - (\varepsilon + 1)\lambda E + \rho c_p D / \gamma}$$

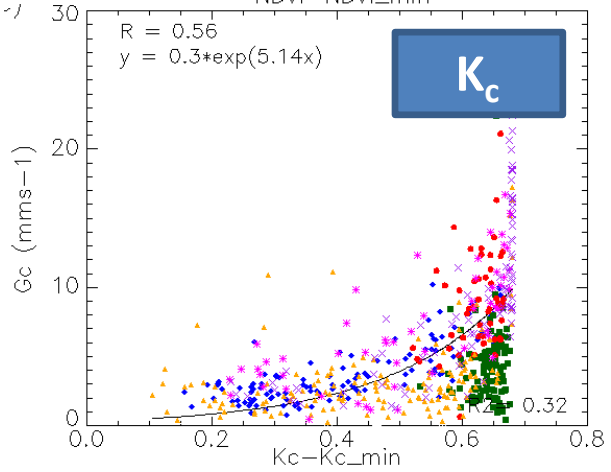


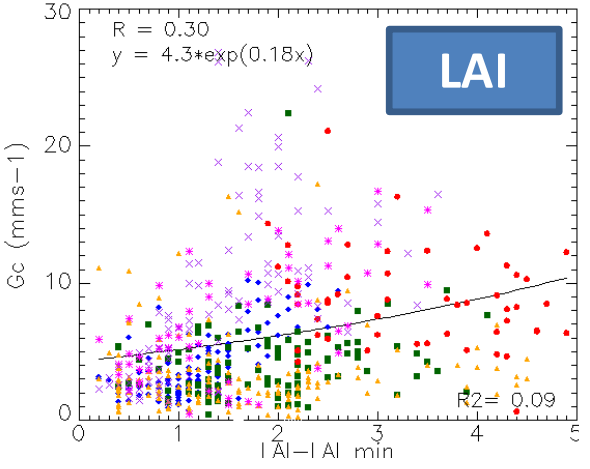
- 15 homogenous sites globally
- Daylight hours (S_{in} > 5 W m^{-2})
- No precipitation in previous 3 days
- Effective daytime dry canopy G_c averaged over 16 days

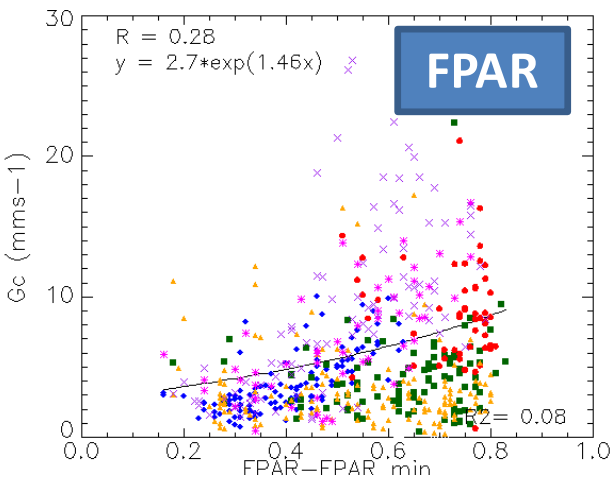

c)
R = 0.63
y = 0.002*exp(4.11x)
NDVI
R2= 0.39
Gc (mms−1)
NDVI−NDVI_min


R = 0.66
y = 2.5*exp(3.15x)
EVI
R2= 0.44
EVI−EVImin

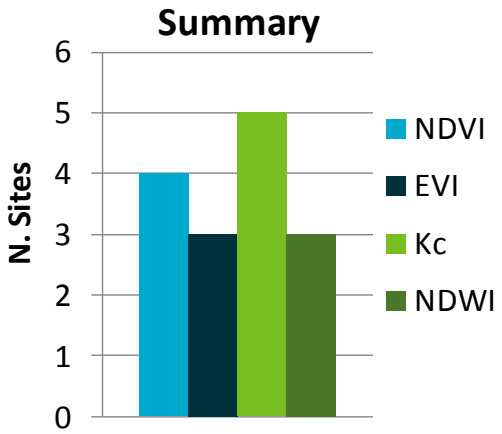

c)
R = 0.58
y = 1.2*exp(6.13x)
NDWI
R2= 0.34
Gc (mms−1)
NDWI−NDWI_min


R = 0.56
y = 0.3*exp(5.14x)
Kc
R2= 0.32
Gc (mms−1)
Kc−Kc_min

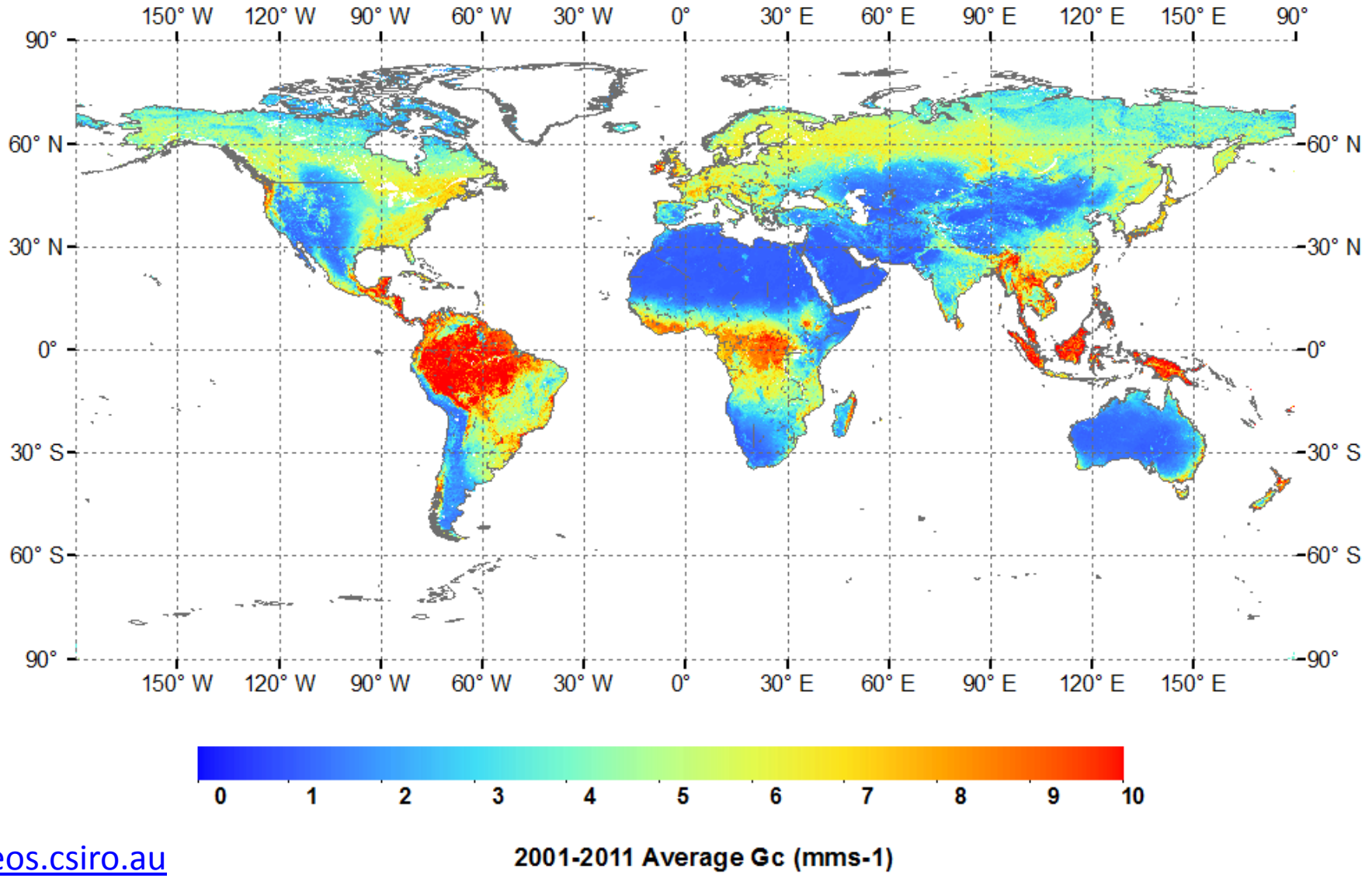

R = 0.30
y = 4.3*exp(0.18x)
LAI
R2= 0.09
Gc (mms−1)
LAI−LAI_min


R = 0.28
y = 2.7*exp(1.46x)
FPAR
R2= 0.08
Gc (mms−1)
FPAR−FPAR_min

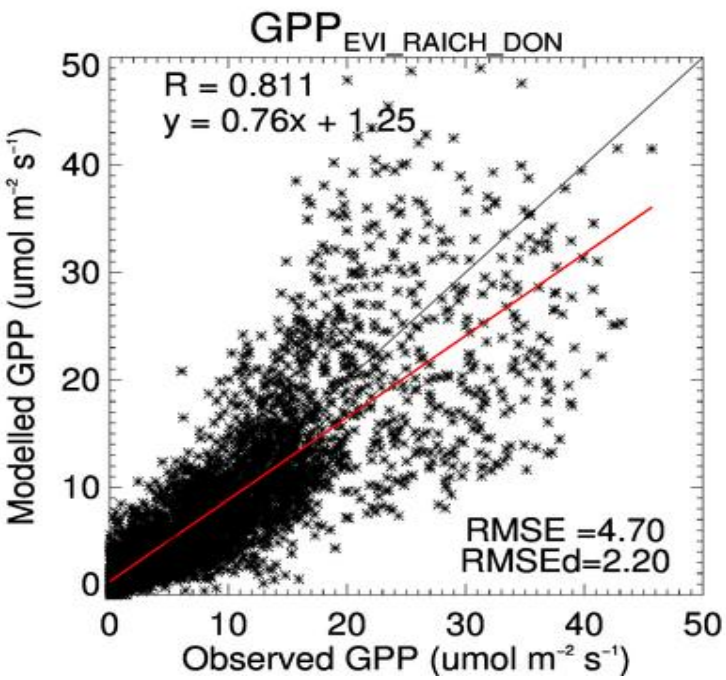

WSA
ENF
EBF
DBF
GRA
CRO


Summary
N. Sites
NDVI
EVI
Kc
NDWI

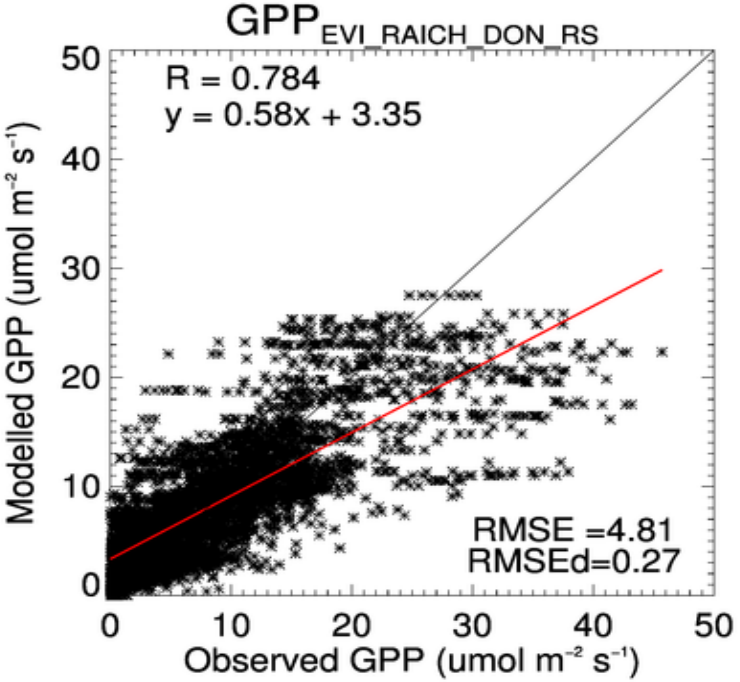
- NDVI, EVI and K_c produce similarly good G_c estimates; better than LAI or FPAR
- G_c estimates provided in grids and tabular data for modelling

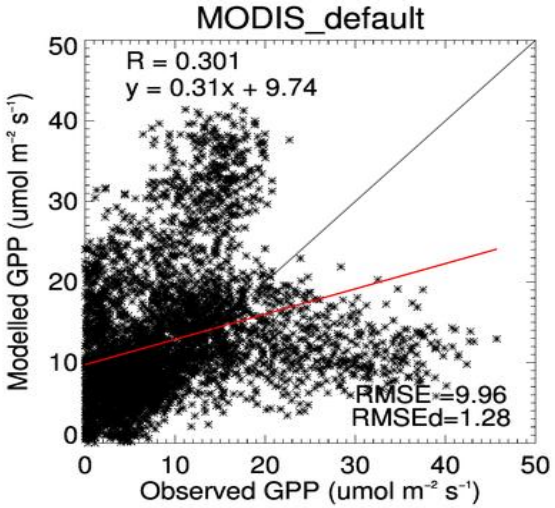


Using Gc from flux tower data



Using Gc from MODIS





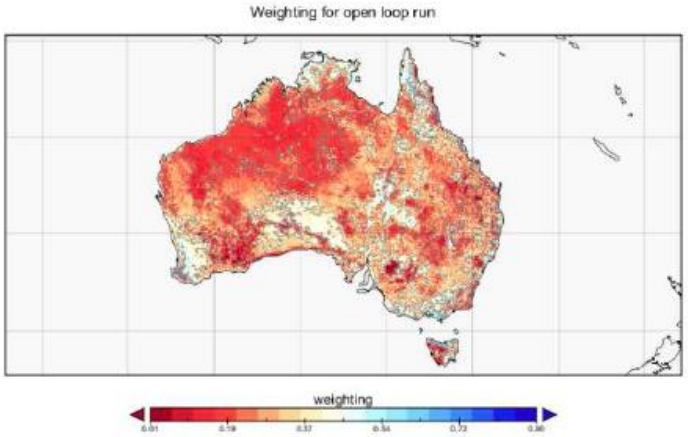
Using Gc for GPP estimation

Yebra et al. (in prep)

AWRA-LC carbon (GPP/NPP) product version 0.5, data assimilation / blending

Model simulates seasonal vegetation dynamics

Model forced with LAI, EVI and albedo climatology



Weighting based on RMSE with MODIS EVI time series

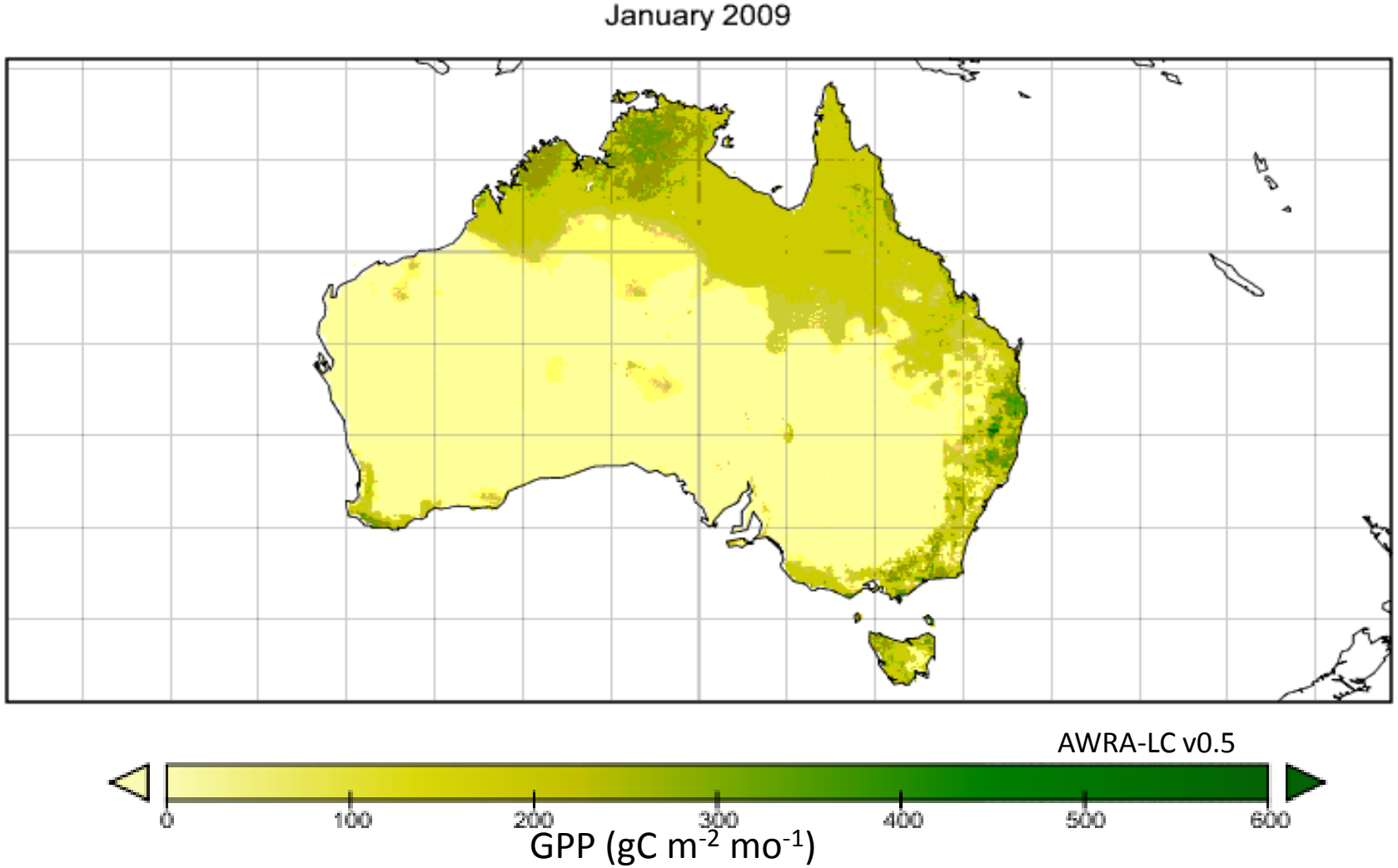
$$y_b = \frac{\propto_o}{\propto_o + \propto_c} y_o + \frac{\propto_c}{\propto_o + \propto_c} y_c$$

$$\alpha = \sigma^{-2}$$

Best estimate ET and GPP

Van Dijk, 2009

Carbon exchange estimates



Has been compared to GPP and NEE data from flux towers and other data cf. Roxburgh et al. (2007) (Van Dijk, 2009; Haverd, unpublished)

Opportunity?

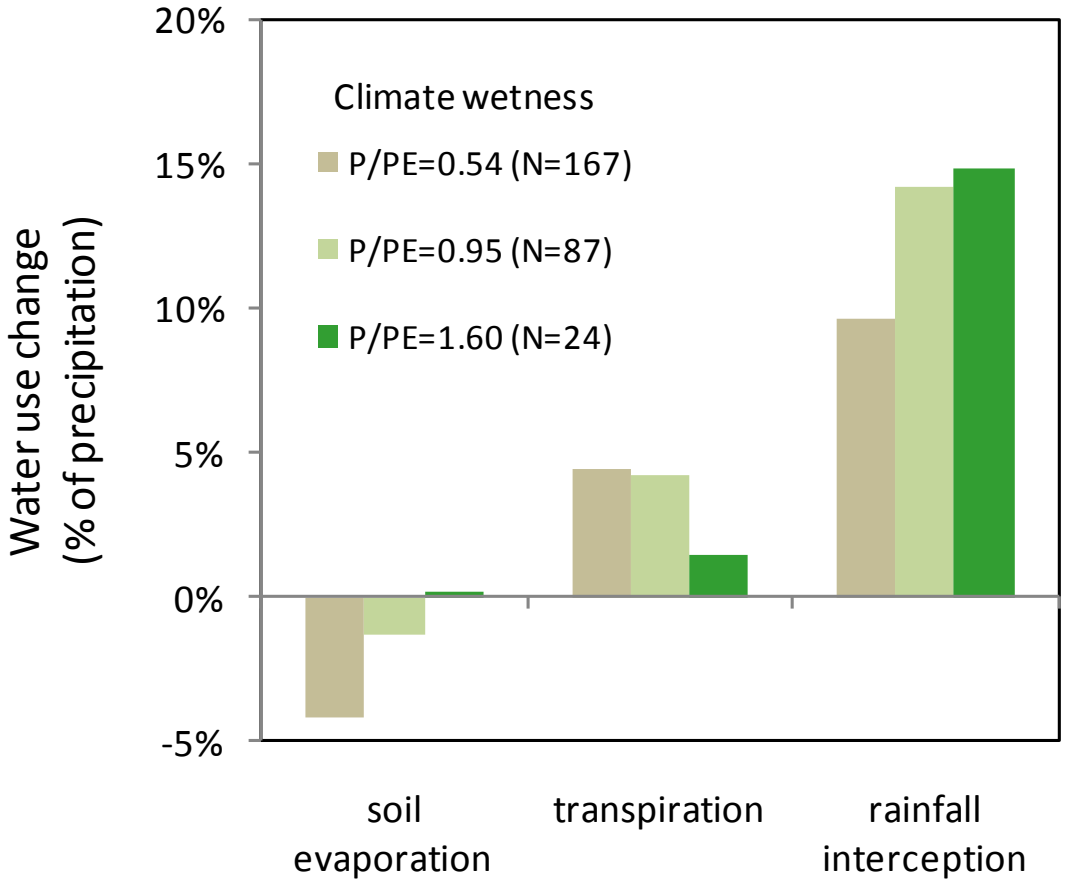
- There appears to be an opportunity for an GEWEX-OzEWEX/OzFlux/eMast experiment to evaluate satellite/model-derived vegetation, water and carbon data?
- Or should we wait until November 2014?

- *Using spatial data for National Environmental Accounts* (ARC Linkage - ANU, BoM, CMAR, CLW, ABS, VU Amsterdam, U Nottingham)
  - (1) satellite data harmonisation (2) data assimilation, (3) what can accounts be used for?
  - Will involve CABLE, AWRA-L, CMRSET, int'l products..
  - Water, carbon and landscape 'integrity'

Rainfall interception – a weakness in flux tower measurement?

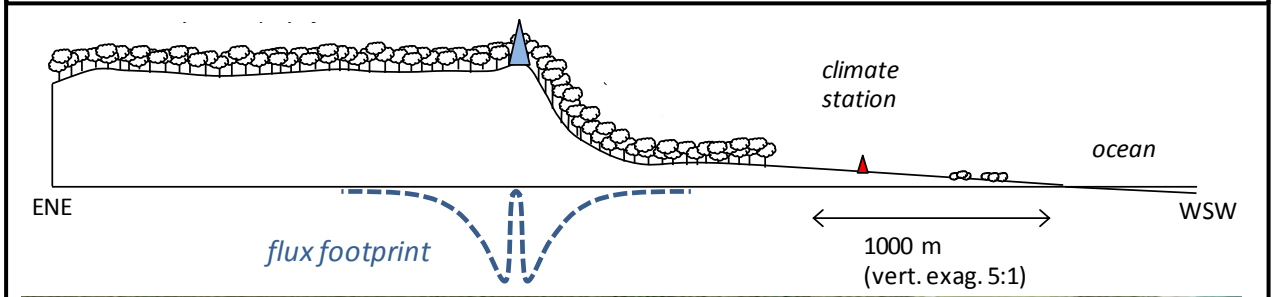
Estimated changes in evapotranspiration components after afforestation

(Van Dijk *et al.*, HESSD, 2012)



Understanding wet canopy evaporation physics

Analysing wind vector and fluxes as a function of wind direction



Combining open and short-intake closed path to measure Ei

Usual vegetation water balance instruments

Stem compression technique to measure canopy water balance (Friesen et al., WRR 2008)

Van Dijk et al. (ARC Disc., pending)

Kioloa Coastal Campus

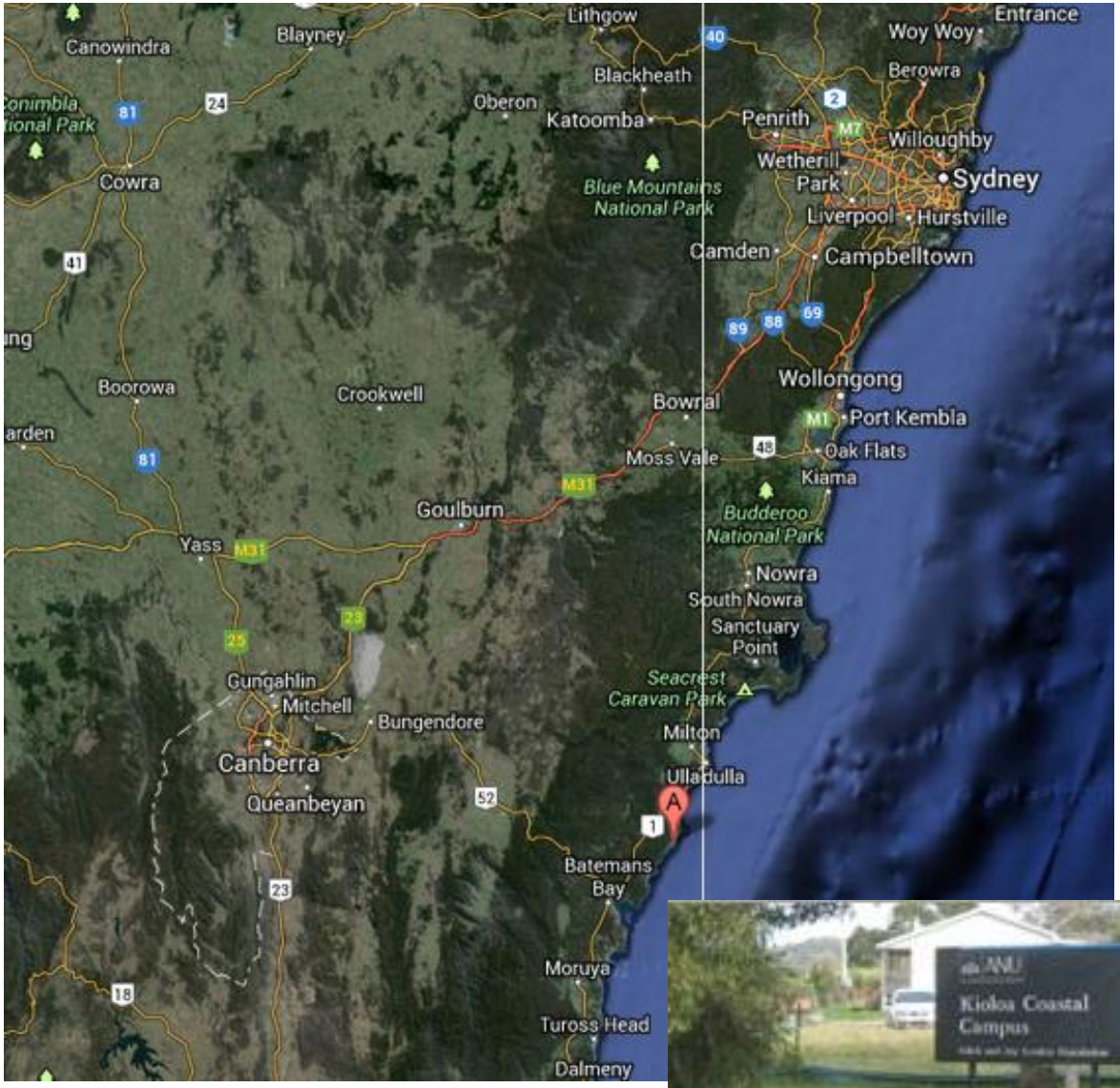
strategy to 'digitally enable' long-term ANU research station

Key issues:
Interactions between physical environment (weather, water) and ecology

Spatial scaling from leaf to landscape

Instruments

- streamflow gauges
- climate station
- flux tower(s)
- hyper-res phenology camera network
- cosmic ray sensors
- bush.fm site
- etc.

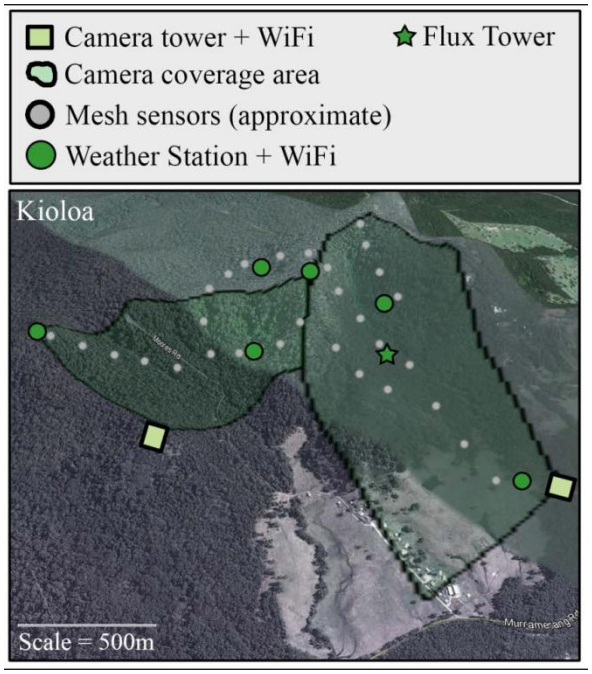


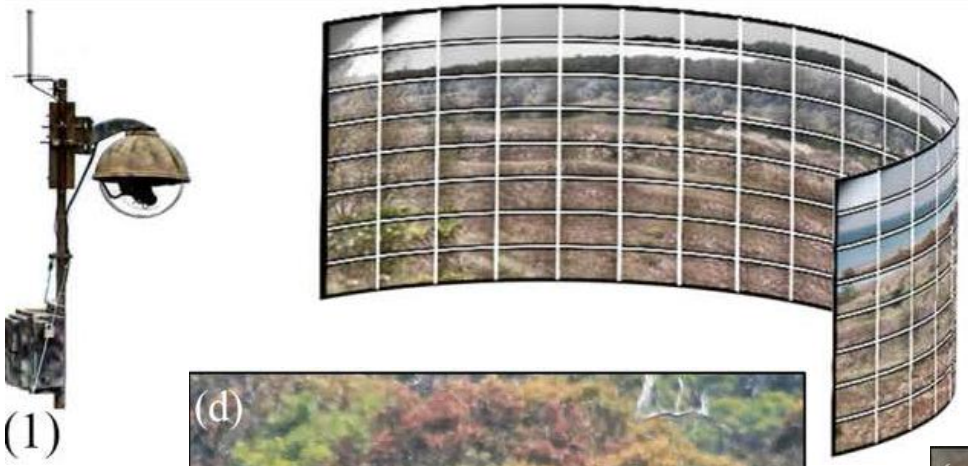
OzFlux / TERN affiliate status may be requested

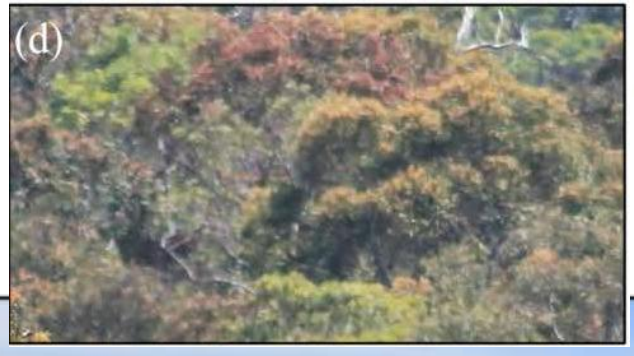
Integrated multi-scale sensor array for phenomic studies of climate adaptation

Brack, Borevitz, Brown, Van Dijk et al. (ARC LIEF pending)

2 sites (Kioloa & National Arboretum)







In summary: some ideas for collaboration:

- Collaborating to evaluating satellite/model water/carbon/biomass data (eMast/OzEWEX?)
- Sharing ET/GPP/R data for BoM water/carbon model benchmarking (acknowledgement via TERN?)
- Multi-site ET partitioning and rainfall interception research (ARC?)
- Developing new phenology-flux technologies and applications
- Develop GEWEX projects through OzEWEX?