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
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.
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
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

- 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

<table>
<thead>
<tr>
<th>Landscape water flows</th>
<th>Australian average</th>
<th>Difference from 1911–2012 annual mean</th>
<th>Decile ranking with respect to the 1911–2012 record average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall</td>
<td>567 mm</td>
<td>+33%</td>
<td>10th – very much above average</td>
</tr>
<tr>
<td>Evapotranspiration</td>
<td>483 mm</td>
<td>+30%</td>
<td>10th – very much above average</td>
</tr>
<tr>
<td>Landscape water yield</td>
<td>83 mm</td>
<td>+57%</td>
<td>10th – very much above average</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>2011–12</th>
<th>2010–11</th>
<th>Relative</th>
</tr>
</thead>
<tbody>
<tr>
<td>10th – very much above average</td>
<td>10th – very much above average</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Total accessible capacity</th>
<th>30 June 2012</th>
<th>30 June 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>accessible volume</td>
<td>% of total capacity</td>
<td>accessible volume</td>
</tr>
<tr>
<td>79,700 GL</td>
<td>66,300 GL</td>
<td>75%</td>
</tr>
</tbody>
</table>

Urban water use (of the eight capitals of the Australian States and Territories)

<table>
<thead>
<tr>
<th>Total use in 2011–12</th>
<th>Total use in 2010–11</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,781 GL</td>
<td>1,736 GL</td>
</tr>
</tbody>
</table>

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

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

Guerschman et al. (in prep.)
Remotely sensing canopy conductance (using FLUXNET)

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

<table>
<thead>
<tr>
<th>Index</th>
<th>Formulation</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normalized difference vegetation index</td>
<td>$NDVI = \frac{\rho_2 - \rho_1}{\rho_2 + \rho_1}$</td>
<td>Rouse et al. (1974)</td>
</tr>
<tr>
<td>Enhanced vegetation index</td>
<td>$EVI = \frac{2.5 \times (\rho_2 - \rho_1)}{(\rho_2 + 6 \times \rho_1 - 7.5 \times \rho_3 + 1)}$</td>
<td>Huete et al. (2002b)</td>
</tr>
<tr>
<td>Normalized difference water index</td>
<td>$NDWI = \frac{\rho_2 - \rho_5}{\rho_2 + \rho_5}$</td>
<td>Gao (1996)</td>
</tr>
</tbody>
</table>
| Crop factor                                | $K_c = K_{c_{max}} \times \left[1 - \exp\left(-a \times EVI_r^{\infty} - b \times RMI^3\right)\right]$,  
where $K_{c_{max}} = 0.68$, $a = 14.12$,  
$\alpha = 2.482$, $b = 7.991$, $\beta = 0.890$,  
$EVI_r = \frac{EVI - EVI_{min}}{EVI_{max} - EVI_{min}}$, $K_{RMI} = 0.775$ 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 \((S_{in} > 5 \, \text{W m}^{-2})\)
- No precipitation in previous 3 days
- Effective daytime dry canopy \(G_c\) averaged over 16 days
NDVI  EVI  Kc  LAI  FPAR

\[ R = 0.63 \]
\[ y = 0.002 \times \exp(4.11x) \]
\[ R = 0.66 \]
\[ y = 2.5 \times \exp(3.15x) \]
\[ R = 0.58 \]
\[ y = 1.2 \times \exp(6.13x) \]
\[ R = 0.56 \]
\[ y = 0.3 \times \exp(5.14x) \]
\[ R = 0.30 \]
\[ y = 4.3 \times \exp(0.18x) \]
\[ R = 0.28 \]
\[ y = 2.7 \times \exp(1.45x) \]

Summary

<table>
<thead>
<tr>
<th>N. Sites</th>
<th>NDVI</th>
<th>EVI</th>
<th>Kc</th>
<th>NDWI</th>
</tr>
</thead>
</table>

WSA  ENF  EBF  DBF  GRA  CRO

Graphs showing the relationship between different vegetation indices and soil moisture indices.
• 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)
Model simulates seasonal vegetation dynamics

Model forced with LAI, EVI and albedo climatology

Weighting based on RMSE with MODIS EVI time series

Best estimate ET and GPP

\[ y_b = \frac{\alpha_o}{\alpha_o + \alpha_c} y_o + \frac{\alpha_c}{\alpha_o + \alpha_c} y_c \]

\[ \alpha = \sigma^{-2} \]

Van Dijk, 2009

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

January 2009

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)
Combining open and short-intake closed path to measure $E_i$

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?