Estimating Evapotranspiration for Australian Seasonally Water-limited Ecosystems Based Solely on Remote Sensing Data

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2017-08-17

Importance of ET

Evapotranspiration (ET) is the sum of soil evaporation, canopy evaporation, and canopy transpiration transferred to the atmosphere.

- ❖ major link between the global energy budgets and hydrological cycles
- ❖ important for management of water resource, particularly in semi-arid and arid regions

Remote sensing estimation of ET

Remote sensing methods for estimating ET with various complexity and applicability can be grouped into:

- those models using the coupling between ET and vegetation photosynthesis through canopy conductance
- empirical models employing vegetation index (e.g., enhanced vegetation index, EVI), land surface temperature (LST) or meteorological observations
- surface energy balance models incorporating satellite retrievals of thermal temperature
- physical models based on the Penman-Monteith or Priestley-Taylor equations with terms parameterized using remote sensing data

Remote sensing estimation of ET

1. $$ET = \frac{GPP}{WUE}$$

$$WUE = f(VIs, T_A, \ldots,).$$

2. VI

Direct regression	PET scaling	PM-G_s
$ET = a + bVI$	$EF = a + bVI$	$G_s = a\exp[b(VI - VI_{min})]$

$$G = R_n \cdot (a \cdot VI + b)$$

3.

$$LE = R_n - H - G \qquad (1)$$

where LE is the latent heat of evaporation due to ET; R_n is net radiation absorbed by the land surface, equal to incoming solar radiation (R_s) minus outgoing shortwave and long-wave radiation; H is sensible heat flux to the atmosphere; and G is heat flux to the soil. In

4.

$$\lambda E = \frac{s \times A + \rho \times C_p \times (e_{sat} - e)/r_a}{s + \gamma \times (1 + r_s/r_a)} \qquad (1)$$

where λE is the latent heat flux and λ is the latent heat of evaporation; $s = d(e_{sat})/dT$, the slope of the curve relating saturated water vapor pressure (e_{sat}) to temperature; A is available energy partitioned between sensible heat, latent heat and soil heat fluxes on land surface; ρ is air density; C_p is the specific heat capacity of air; and r_a is the aerodynamic resistance. The psychrometric constant γ is given by $\gamma = C_p \times P_a \times M_a/(\lambda \times M_w)$, where M_a and M_w are the molecular masses of dry air and wet air, respectively, and P_a is atmospheric pressure (Maidment, 1993). Surface resistance (r_s) is an effective resistance to evaporation from land surface and transpiration from the plant canopy. See ref 11

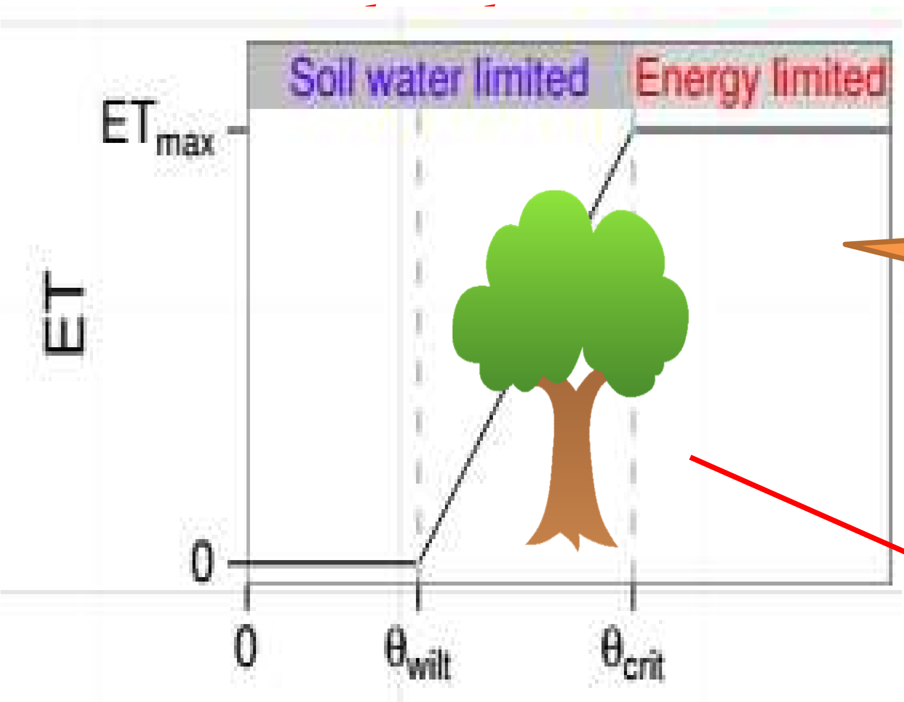
Review:

- *Uncertainty with GPP and WUE estimation and cannot effectively account for soil evaporation, which will become a critical problem over barely to moderately vegetated regions*
- *lack support of theoretical framework or needs ground based meteorological observations*
- *sensitive to the accuracy of remotely sensed surface temperature*
- *Need complex parameterization and is often limited by coarse resolution meteorological inputs*

Review of classical framework

Aims:

- ❖ *develop a new VI model to estimate monthly ET based solely on remote sensing data*
- ❖ *evaluate this new model both across- and within-sites and at the*

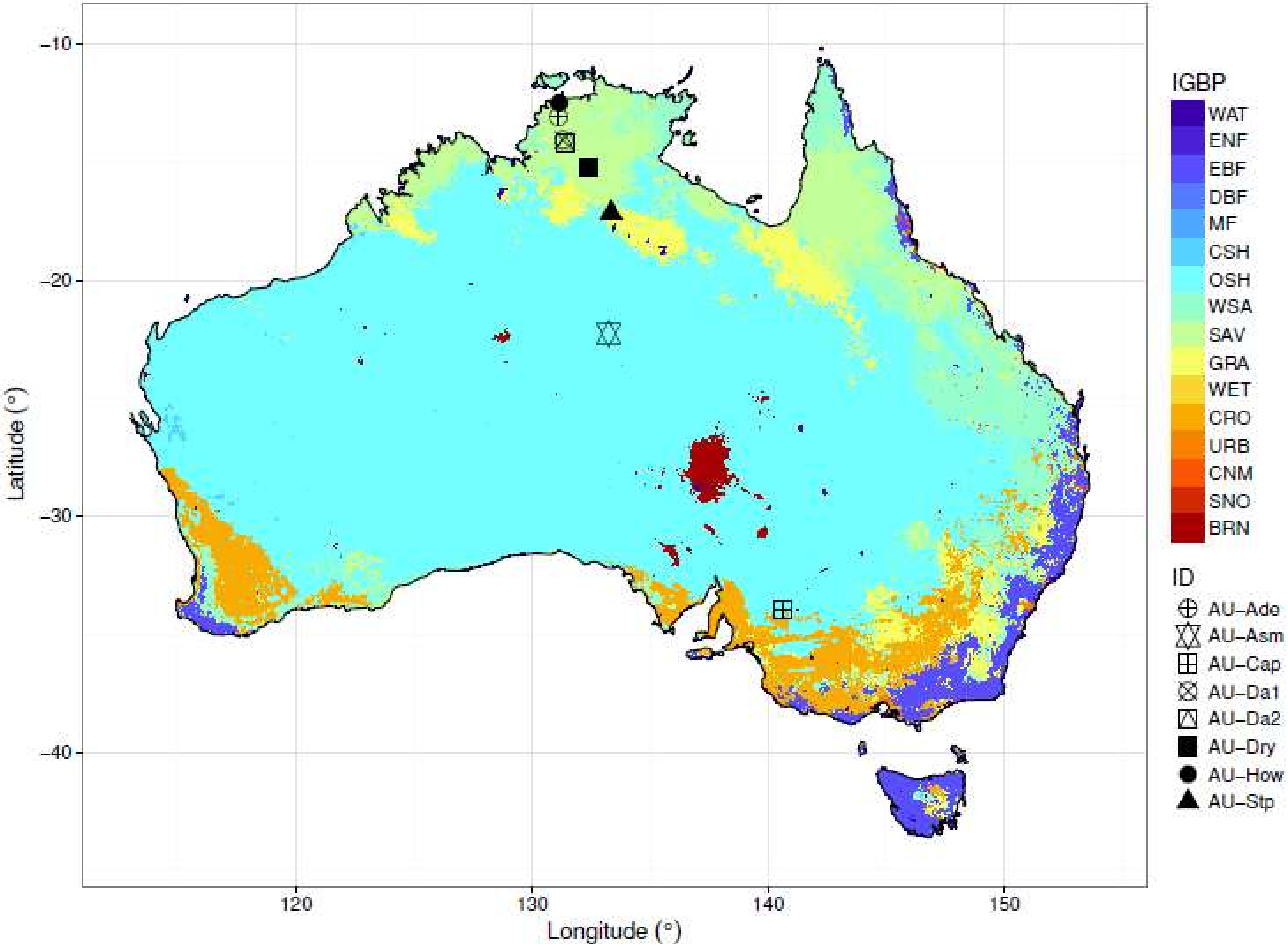


Classical framework defines energy-limited and water-limited ET regimes as a function of soil water.

However…

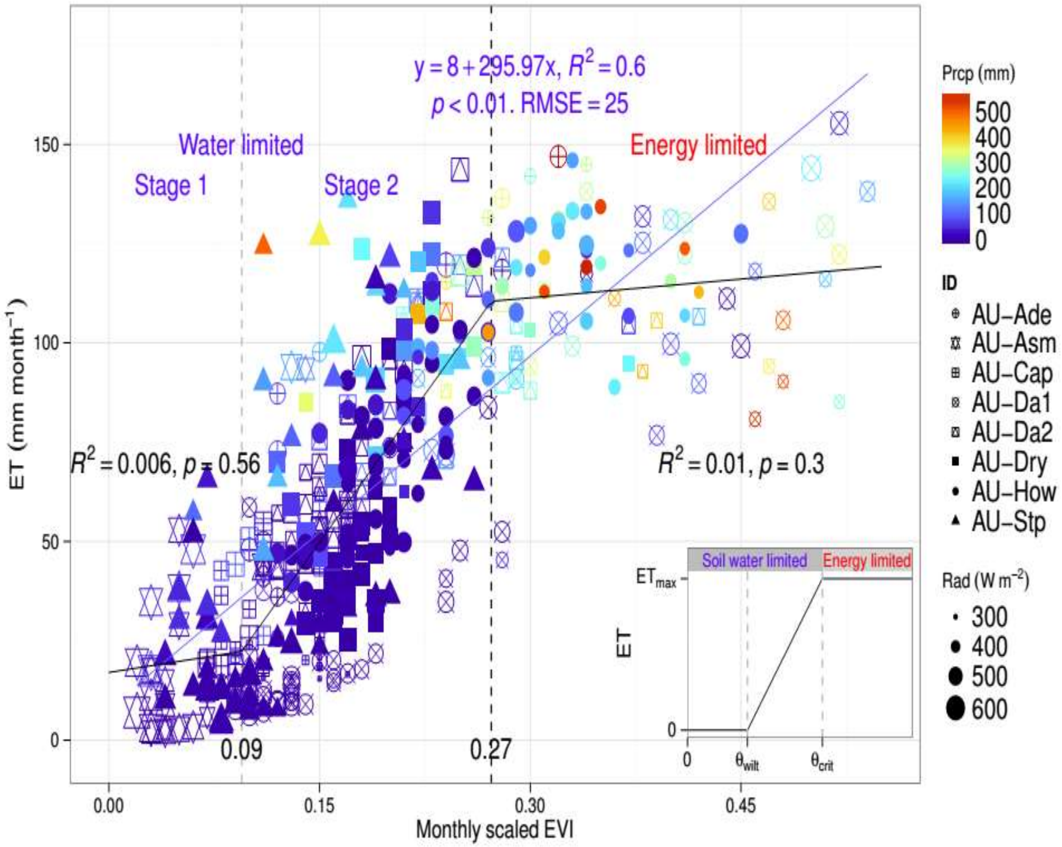
The role of vegetation is missing!

Flux sites



-10
-20
-30
-40
120
130
140
150
Latitude (°)
Longitude (°)
IGBP
WAT
ENF
EBF
DBF
MF
CSH
OSH
WSA
SAV
GRA
WET
CRO
URB
CNM
SNO
BRN
ID
AU–Ade
AU–Asm
AU–Cap
AU–Da1
AU–Da2
AU–Dry
AU–How
AU–Stp

ET-EVI relationship



Australia is largely arid to semi-arid and retains large areas of seasonally water limited ecosystems. Eddy covariance observations over these ecosystems provide a unique opportunity to check ET-EVI relationship in differed hydrothermal conditions.

EC data: Eight seasonally water-limited ecosystems covering savannas, woody savannas, grasslands and open shrublands.
RS data: MODIS EVI and land cover map (0.05° × 0.05°). ECV microwave soil moisture product (0.25° × 0.25°) from 2000 to 2011.
Benchmark data: MODIS ET product, ET-MTE (0.5° × 0.5°) and CABLE modelled ET

Development of new ET model

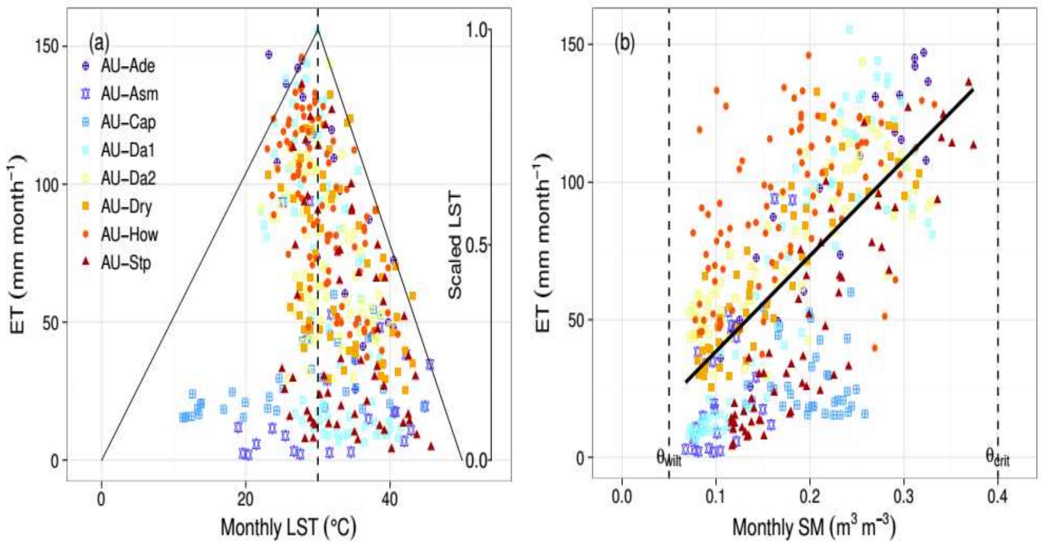
$$ET = f(scaled\_EVI, e) + E \qquad (1)$$

where $scaled\_EVI = EVI - 0.08$, e is the energy constraint factor, $f(scaled\_EVI, e)$ indicates transpiration and E indicates soil evaporation. This equation takes the same

$$E = f(A_s, f) \qquad (2)$$

where A_s indicates the available energy at the soil surface and f indicates a fraction constraint on A_s. An advantage of this form is that it allows us to use separate but unique

Development of new ET model



$$e = \min[(\frac{LST}{30}), (2.5 - 0.05 \times LST)] \quad (3)$$

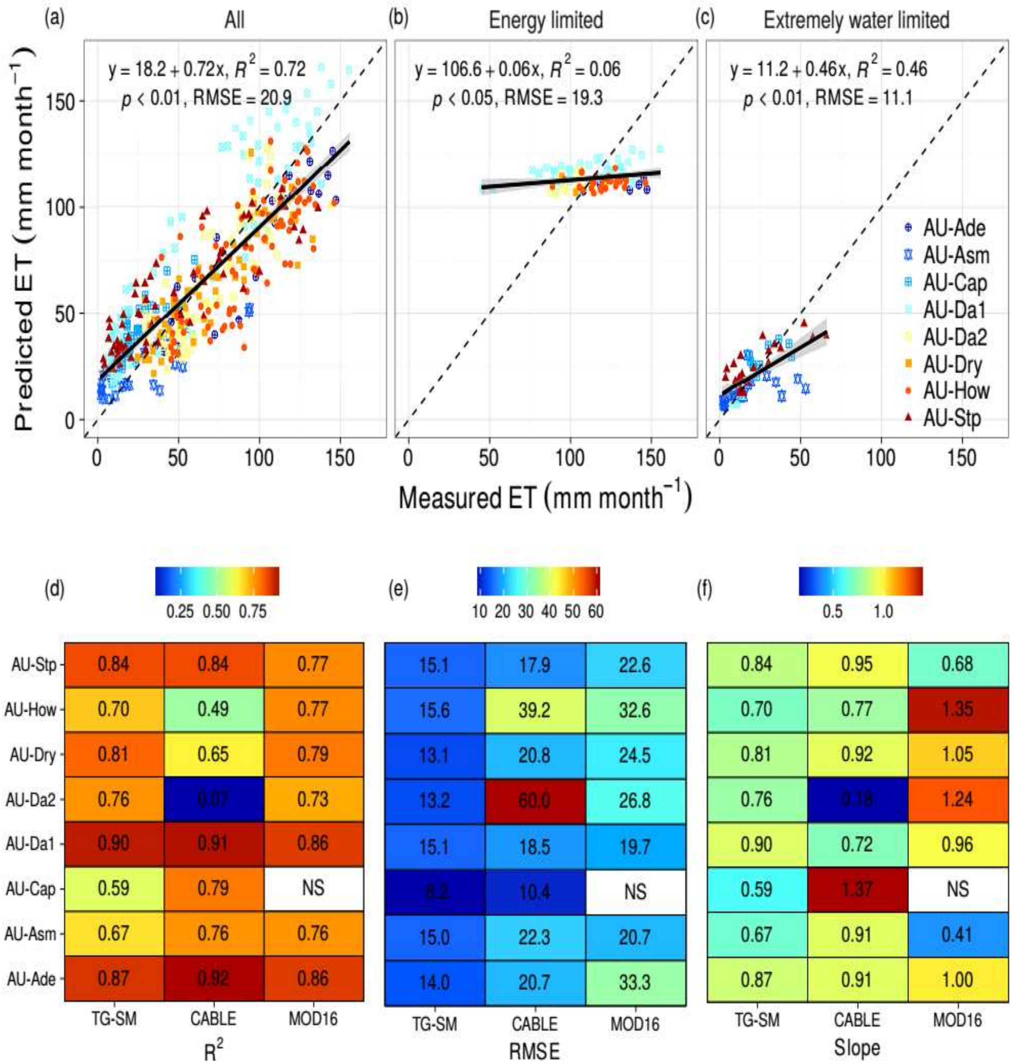
where e obtains a maximum value of 1 at 30 °C and minimum value of 0 at 0 °C and 50 °C.

$$f = \begin{cases} 0, \theta < \theta_{wilt} \\ \frac{\theta - \theta_{wilt}}{\theta_{crit} - \theta_{wilt}}, \theta_{wilt} < \theta < \theta_{crit} \\ 1, \theta > \theta_{crit} \end{cases} \quad (4)$$

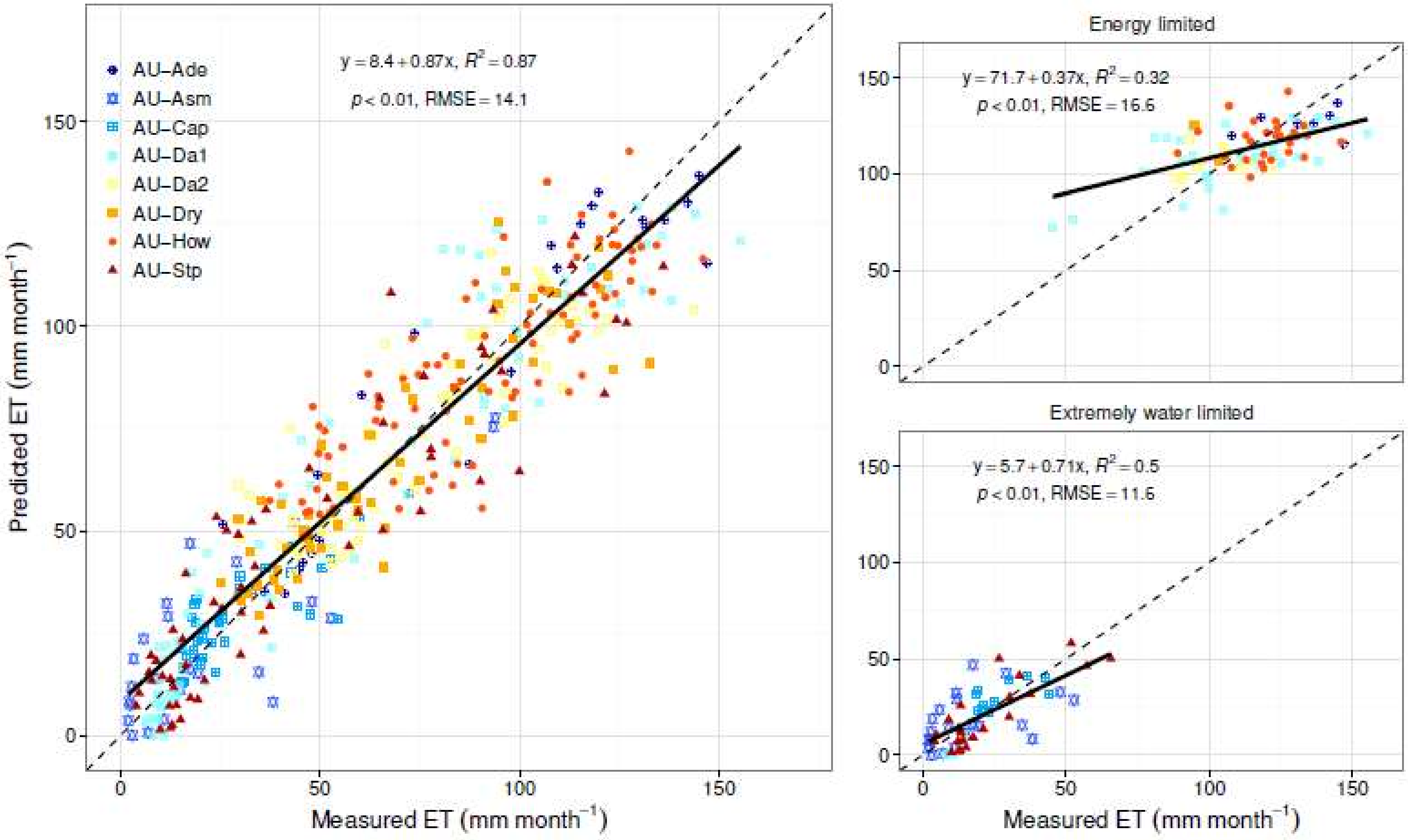
where θ indicates microwave soil moisture, $\theta_{wilt} = 0.05\ m^3m^{-3}$ and $\theta_{crit} = 0.40\ m^3m^{-3}$. θ was scaled to $0 \sim 1$ where it is between θ_{wilt} and θ_{crit}.

Parameterization across sites

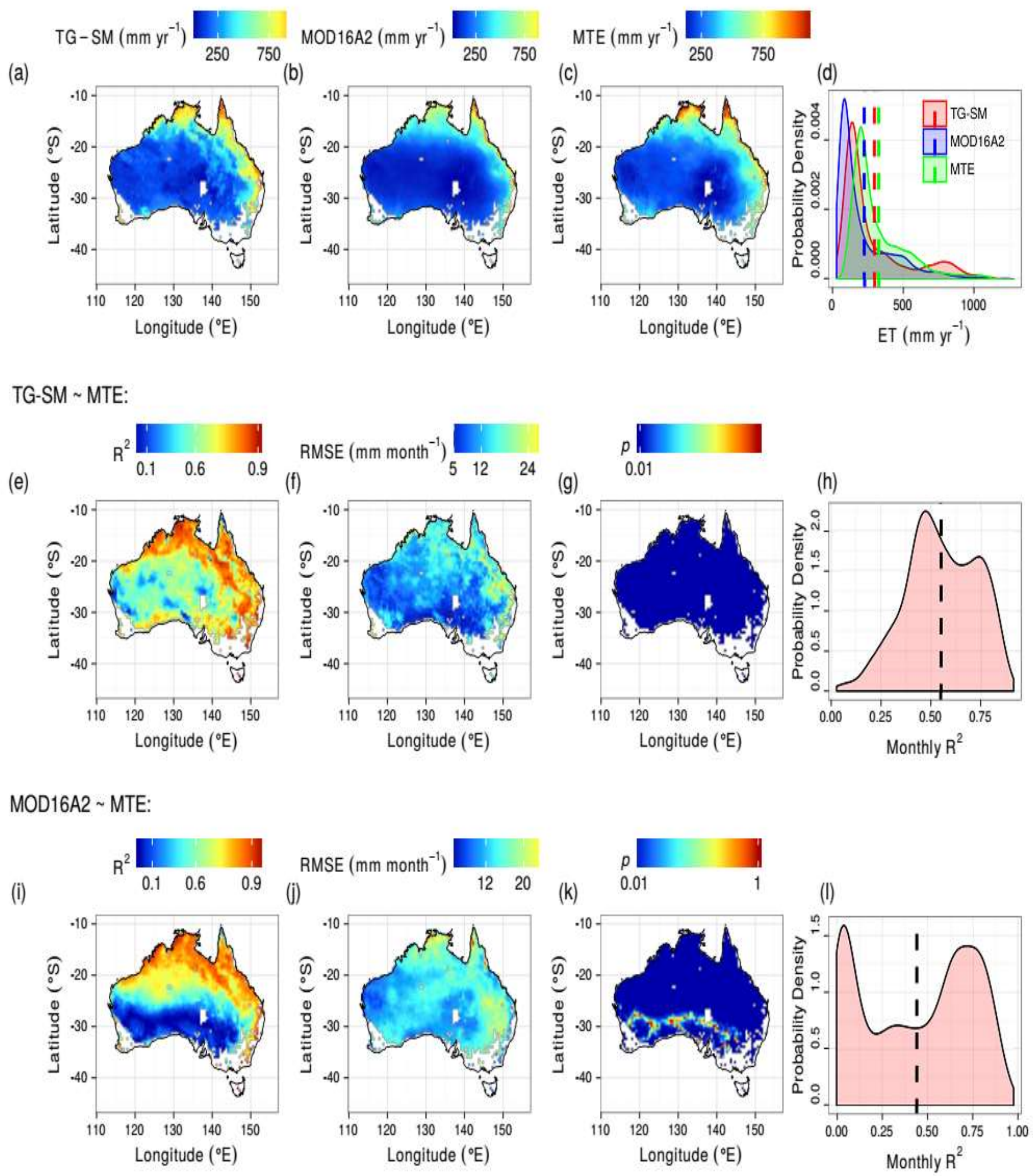
$$ET = max(0, a \times scaled\_EVI \times e + b \times LST \times f + \epsilon) \quad (5)$$



Parameterization within each site



Regional benchmark



Implications:

- *One limitation is that it cannot apply over short time-scales, because changes in EVI are not rapid enough to capture short-term fluctuations in vegetation activity and structure.*
- *Failure to partition trees and grasses at those sites where both trees and grasses grow also introduces uncertainty due to their distinct access to soil moisture reserves and differential contribution to fluctuations in leaf area (finished in another work)*
- *Though developed using seasonally water-limited sites, the model has potential to be applied in non-water limited ecosystems of other types, such as forests and crops*

Thank you!