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Spatial Heterogeneity of Ecosystem Fluxes over Tropical Savanna in the Late Dry Season

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Introduction

What is the question?

- What are the main drivers of spatial heterogeneity in fluxes over Tropical Savanna?
  - ❖ Surface properties or meteorology.
    - – How many leaves do we need to cover Australia?

What is the data period and why?

- 44 day period in the late dry season in the Tropical Savanna:
  - ❖ No C4 contribution, only C3 trees.
  - ❖ Very small soil evaporation.
  - ❖ Small, constant ecosystem respiration.

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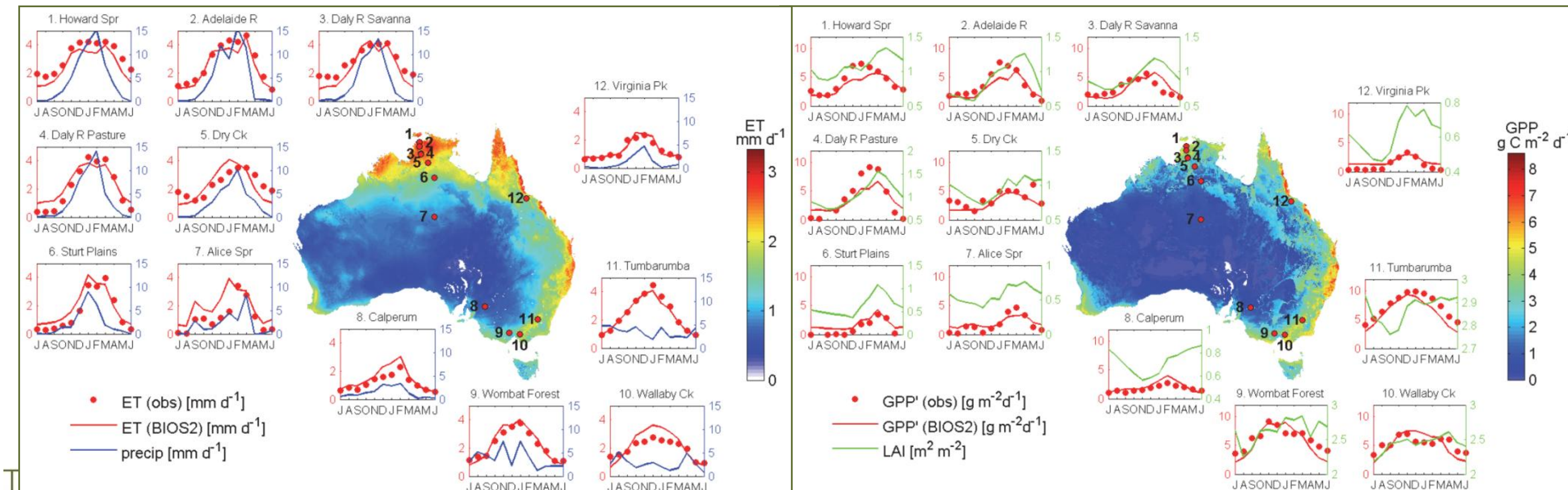
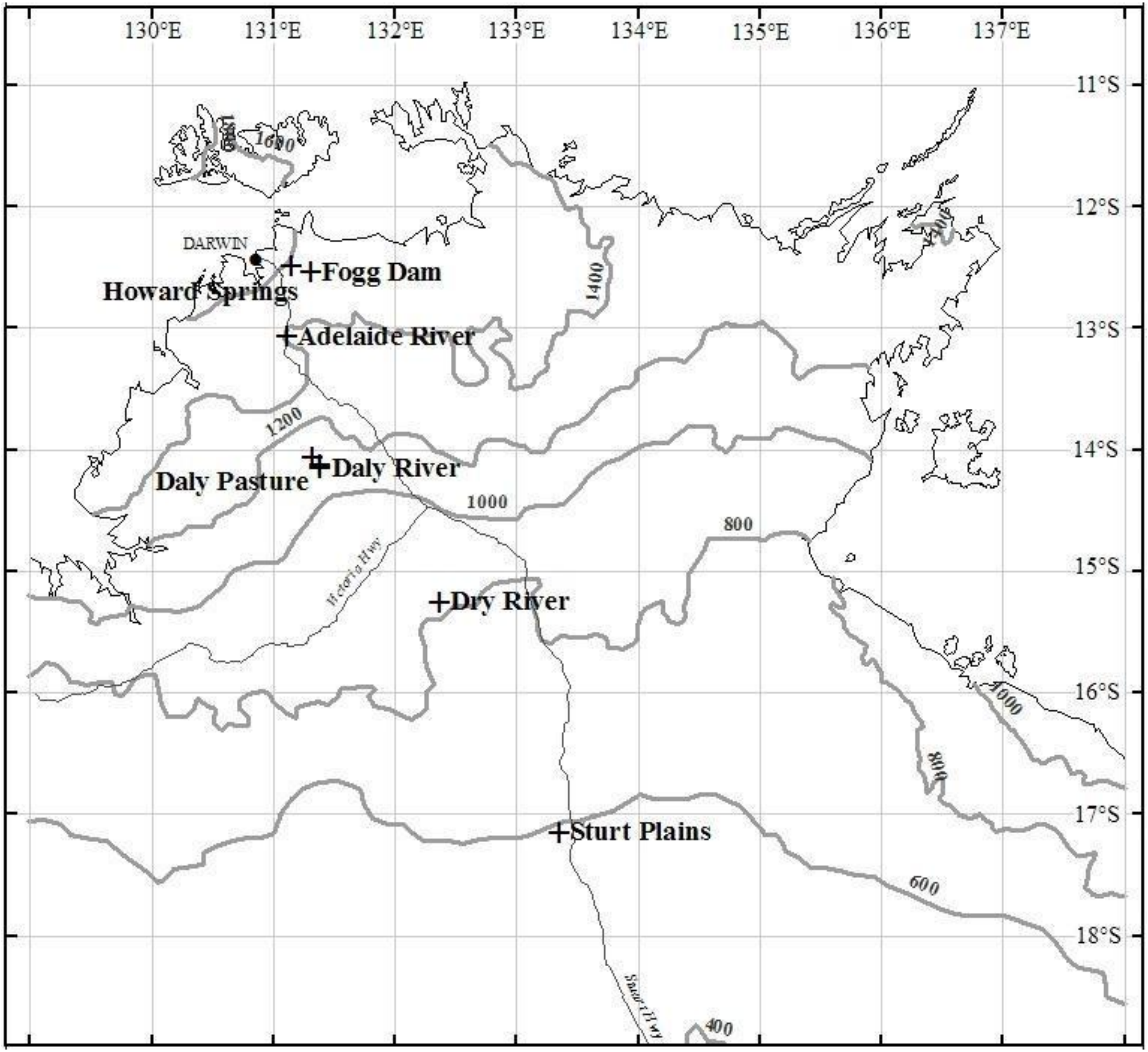
How many leaves do we need to cover Australia?

Haverd et al BIOS2 results using 6 leaves:

- “Woody” C4 sunlit and shaded.
- “Grassy” C4 sunlit and shaded.
- “Grassy” C3 sunlit and shaded.





130°E
131°E
132°E
133°E
134°E
135°E
136°E
137°E
11°S
12°S
13°S
14°S
15°S
16°S
17°S
18°S
DARWIN
Fogg Dam
Howard Springs
Adelaide River
Daly Pasture
Daly River
Dry River
Sturt Plains
1400
1200
1000
800
600
400
Victoria Hwy
Stuart Hwy

What Could be the Drivers?

Landscape

- Plant type, land use, Lai, fractional cover

Meteorology

- Fsd, Fa, Ta, D, Ws, Sws, ….

Canopy and Leaf-level properties

- Quantum efficiency
- Maximum assimilation rate (or V_{cmax})
- Response to VPD
- Respiration

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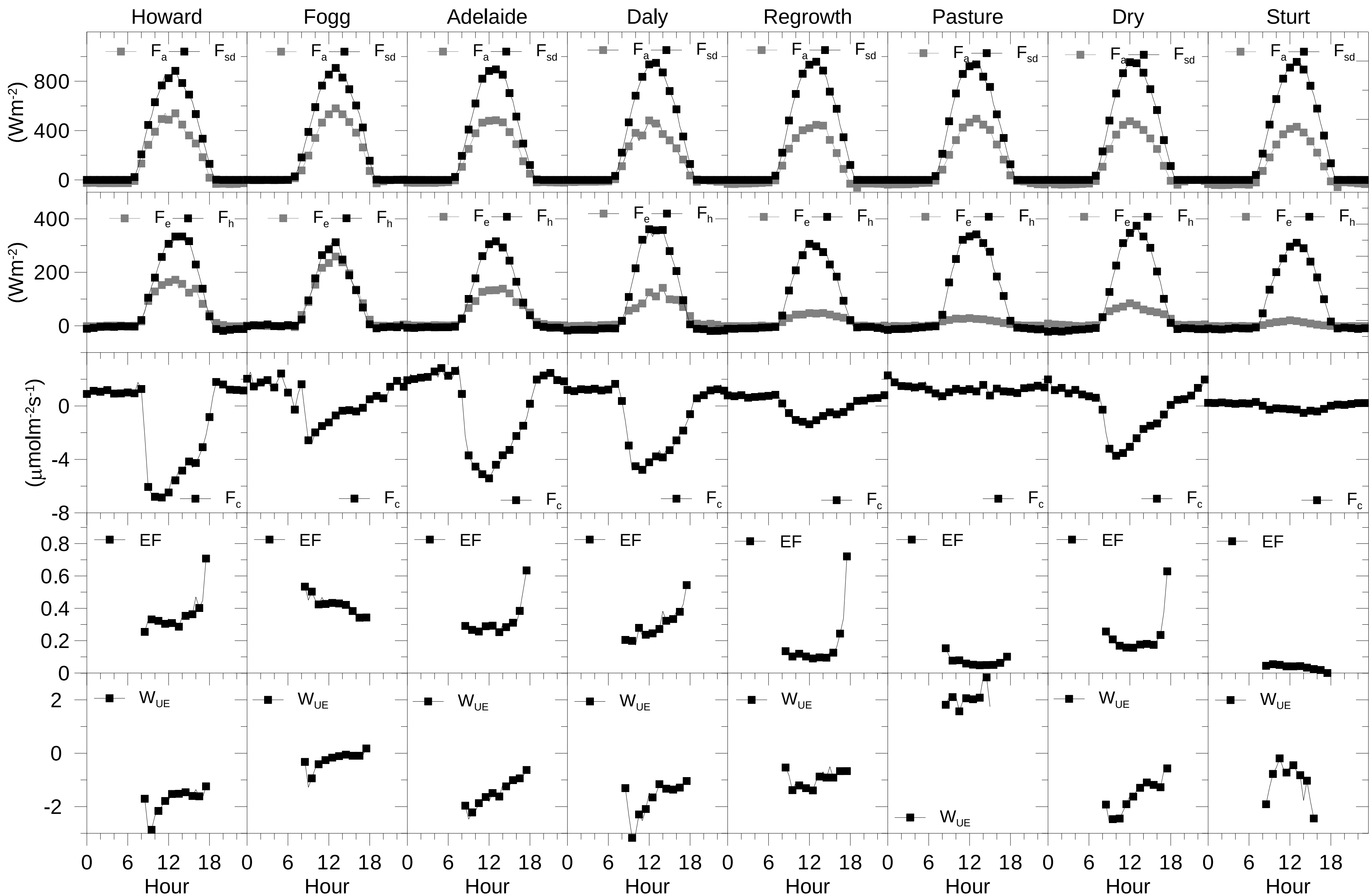

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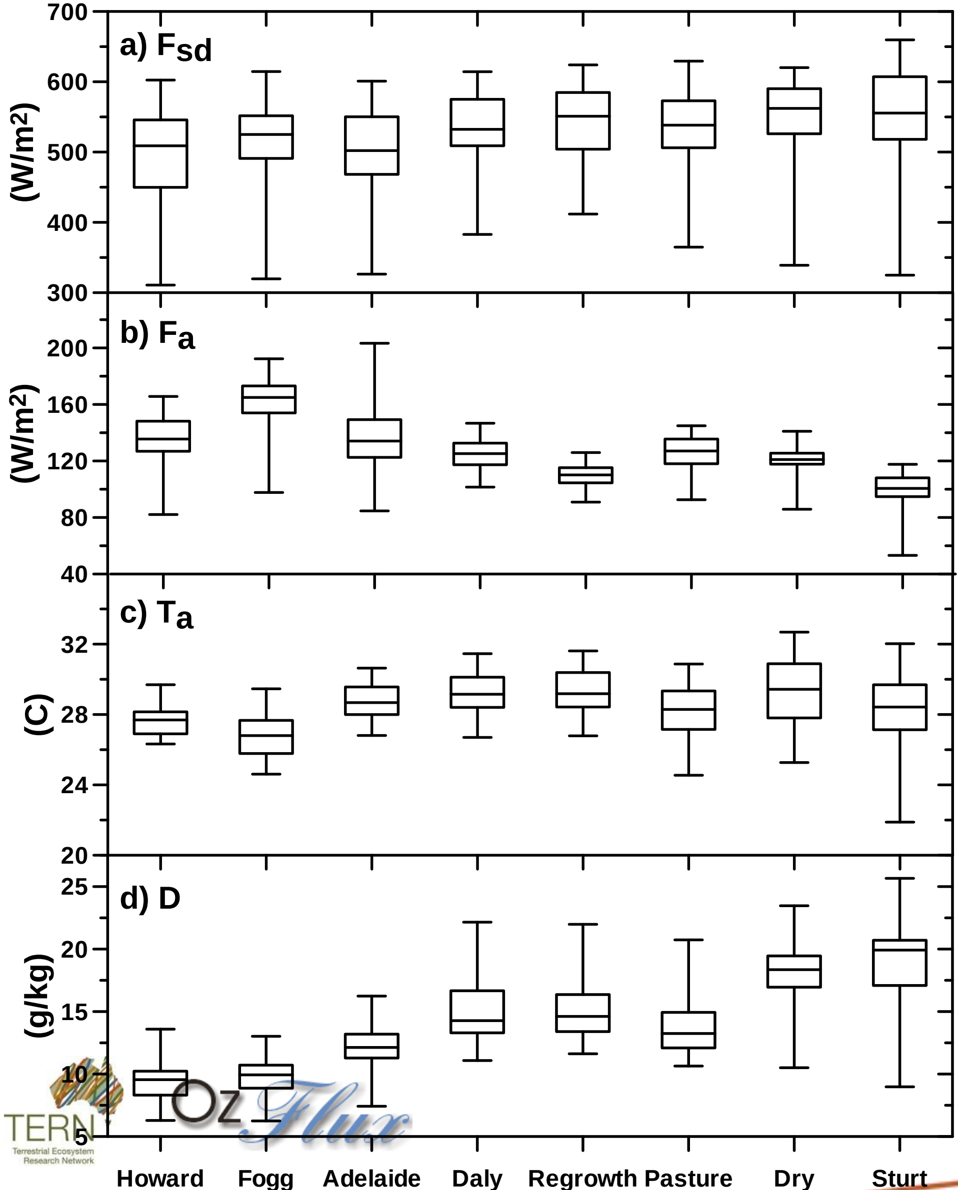
Spatial Variability along Transect



Little spatial variability in incoming shortwave, available energy and air temperature.

- Marked gradient in specific humidity deficit (D).

From the previous slide:

- Most of the spatial heterogeneity due to land use
- Concentrate on woody savanna for remainder of talk

Fluxes and Drivers along Transect

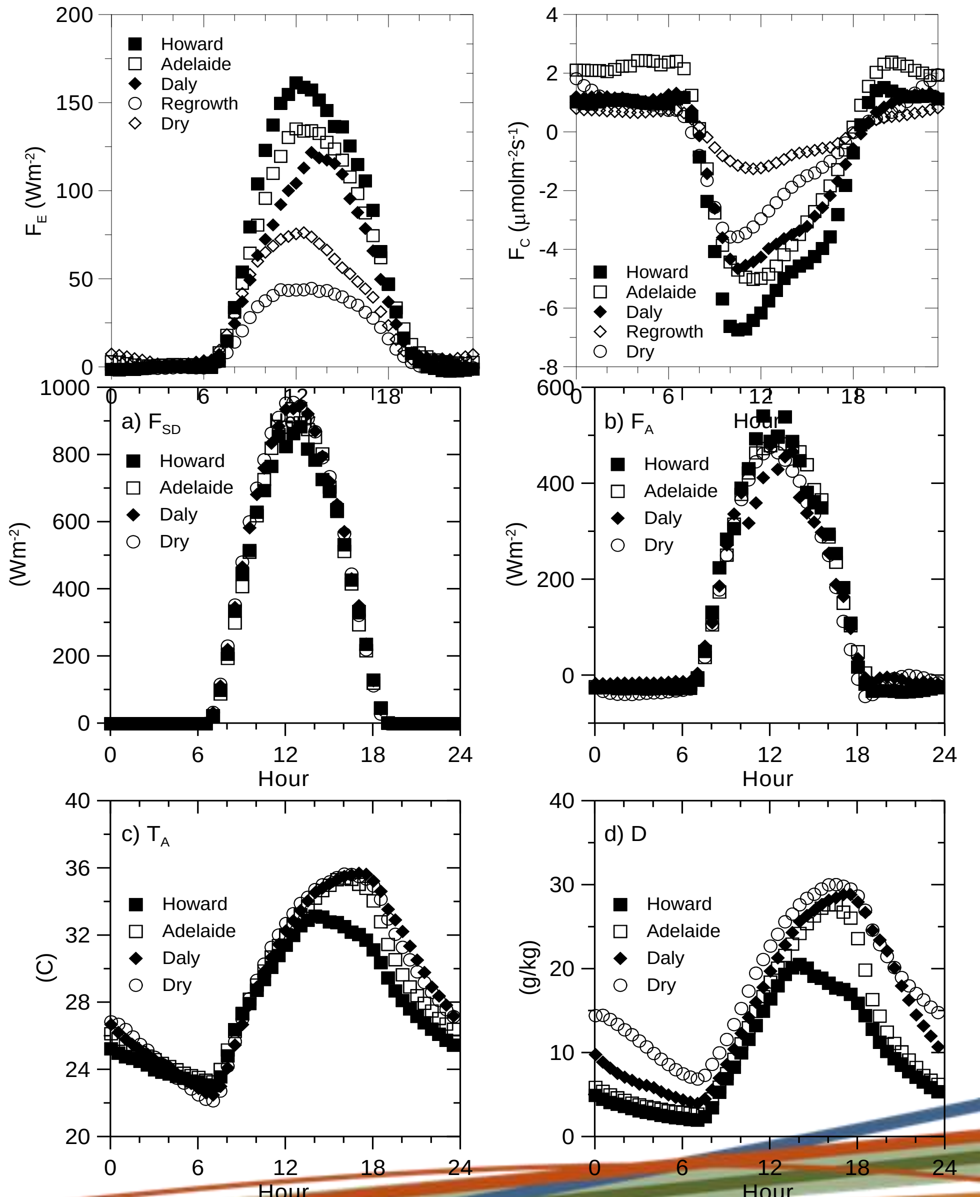
Five woody savanna sites:

- Howard Springs (1714,1.1)
- Adelaide River (1532,0.69)
- Daly Uncleared (1170,0.88)
- Daly Regrowth (1170,0.12)
- Dry River (850,0.76)

Strong gradient in fluxes.

Weak gradient in meteorology.

Daly Regrowth not used.



Comparing Response to D

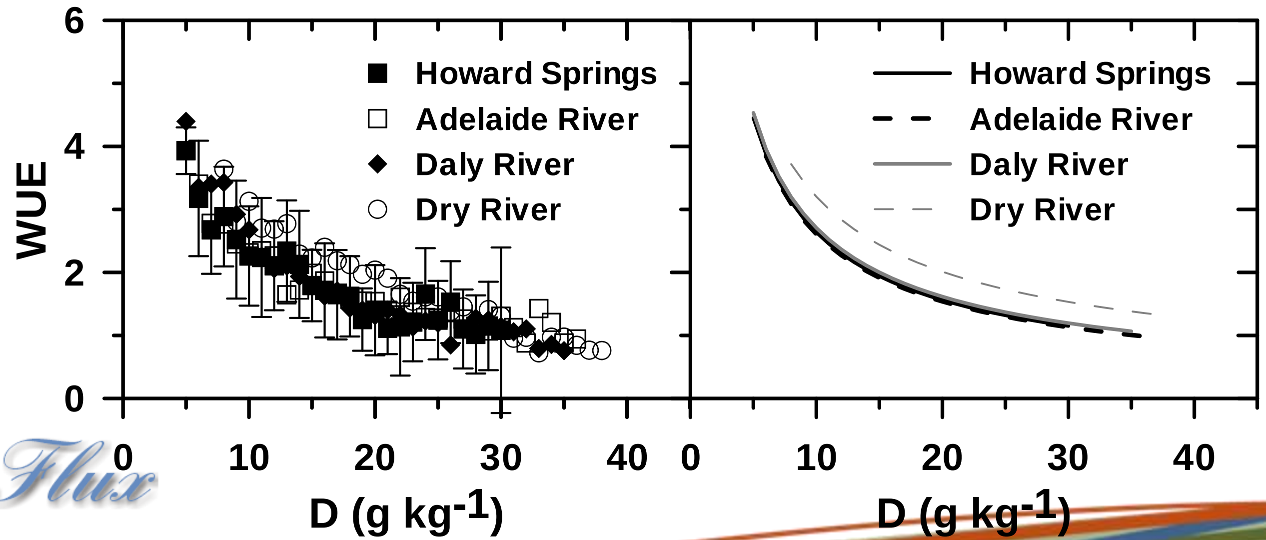
$$A = g_s(c_a - c_i) = g_s c_a (1 - c_i/c_a)$$

$$E = 1.6 g_s \left(q_s(T_{leaf}) - q_a\right)$$

$$W_{UE} = \frac{A}{E} = \frac{c_a(1 - c_i/c_a)}{1.6D} \propto \frac{1}{D}$$

$$\approx \frac{F_c - R_{eco}}{F_e} \propto \frac{1}{D}$$

Site	D exponent
Howard Springs	-0.76 ± 0.02
Adelaide River	-0.76 ± 0.02
Daly Uncleared	-0.74 ± 0.02
Dry River	-0.67 ± 0.02



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Estimating R_{eco}

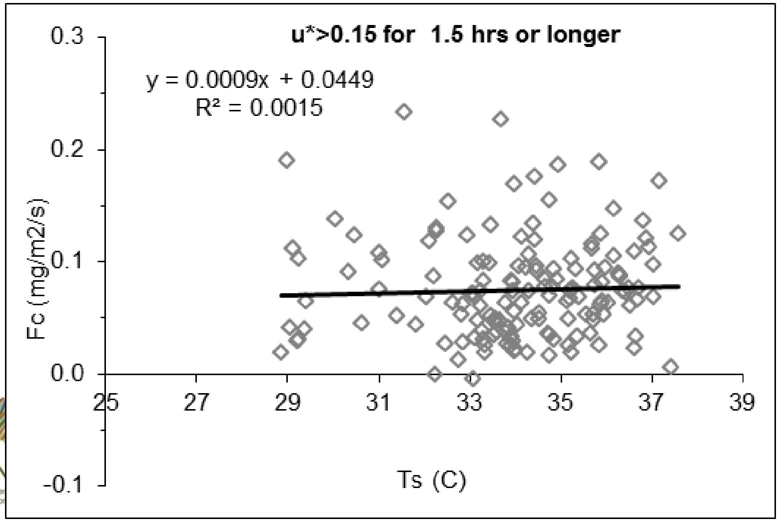
We want to partition F_c into GPP and R_{eco} so we can estimate canopy-scale quantum efficiency and A_{max} by fitting a LUE curve to day time GPP:

- Compare canopy-level parameters to leaf-level values from Lucas' work.

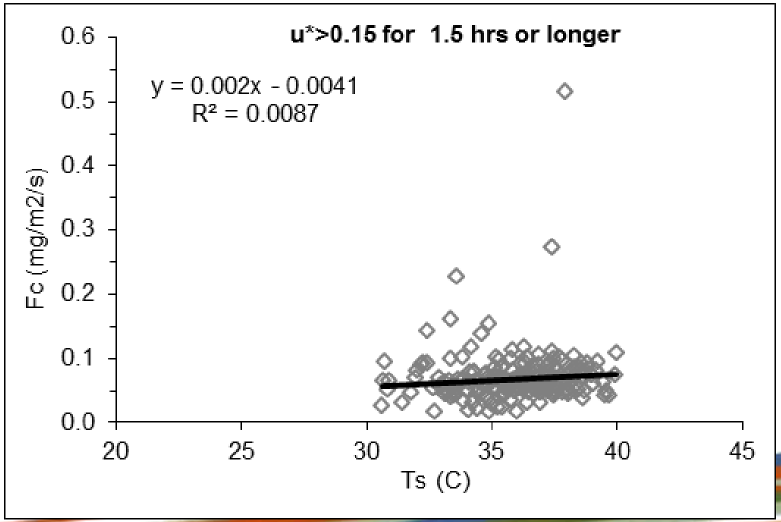
No relation found between R_{eco} with soil temperature, air temperature or soil moisture for the late dry season.

- Assumed a site-specific, constant value for 44 day period.

Howard Springs



Adelaide River



Fitting LUE Curves

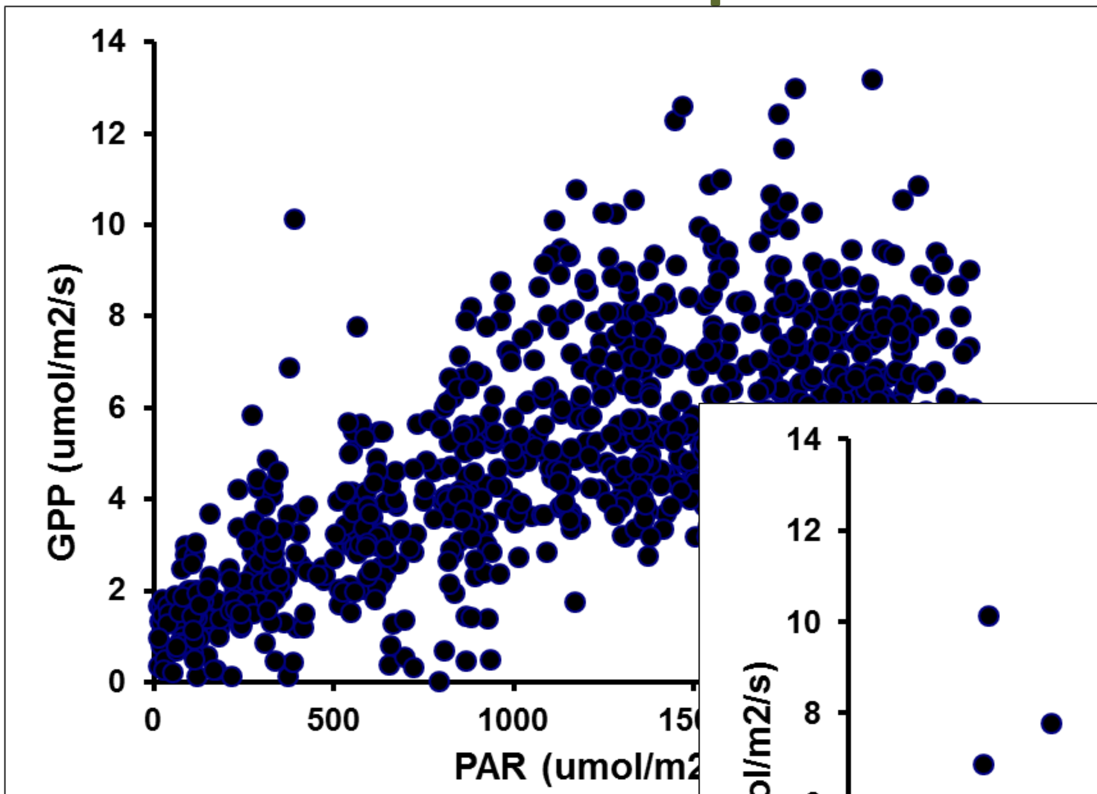
We have leaf-level photosynthetic parameters from Lucas' Li-6400 measurements:

- Quantum efficiency and A_{max}
- No observable gradient in measured parameters with MAP.

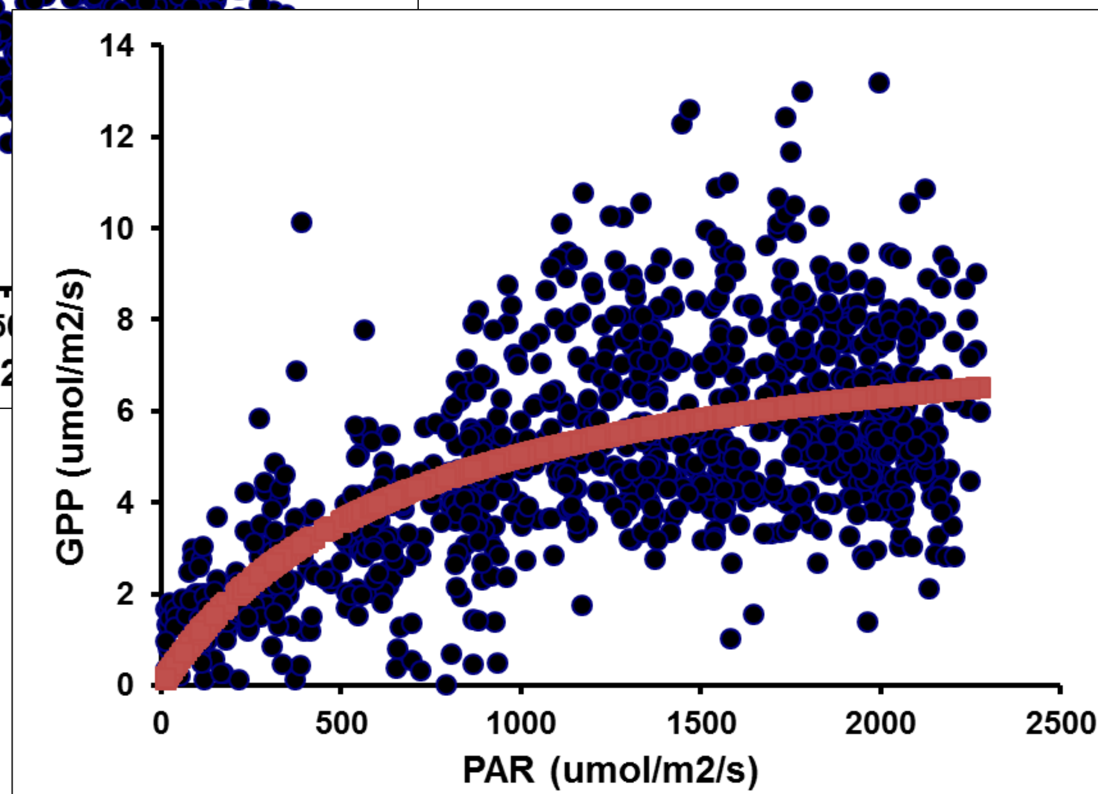
We would like to estimate the equivalent canopy-scale properties:

- Do they also show no gradient with MAP.

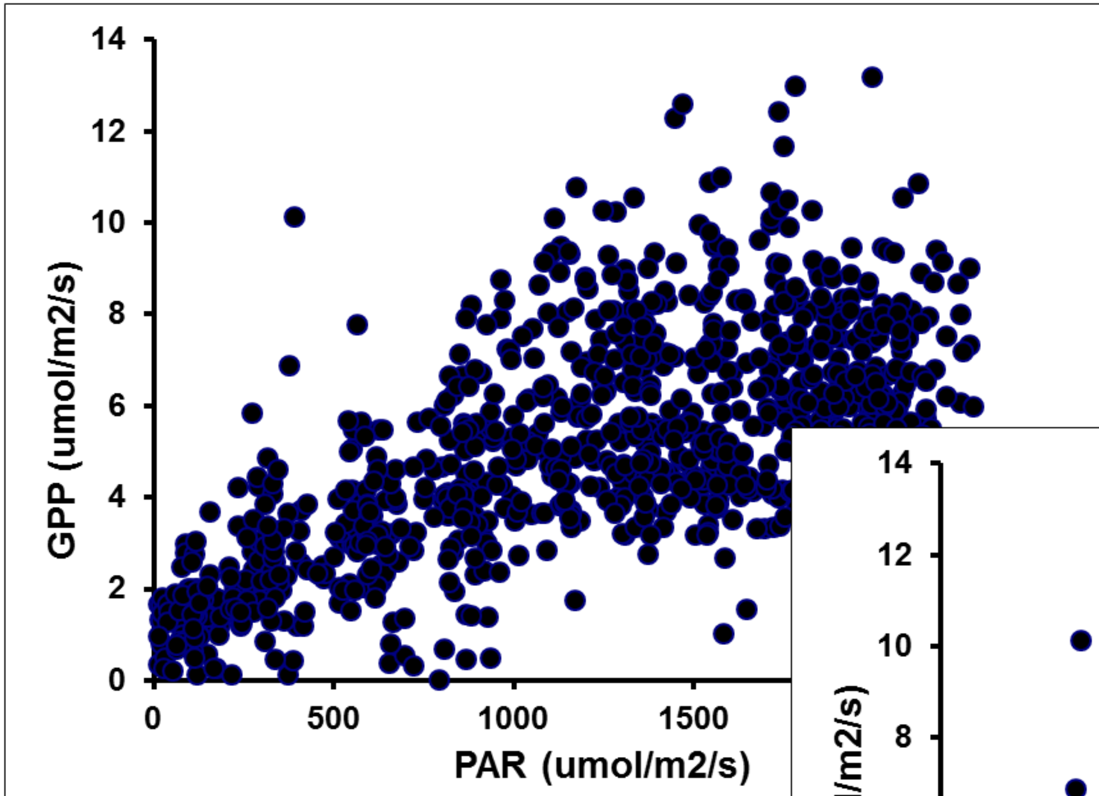
A Simple LUE Curve



$$GPP = \frac{\phi A_{\max} PAR}{\phi PAR + A_{\max}}$$



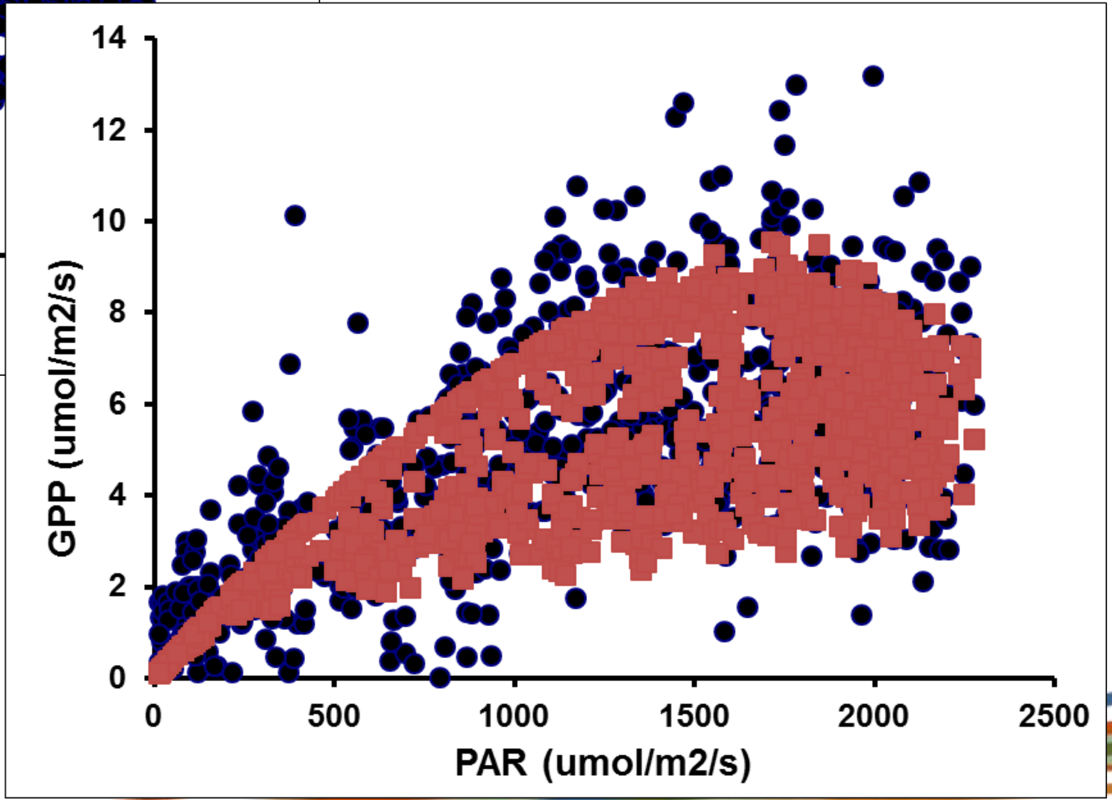
A Better Fitting LUE



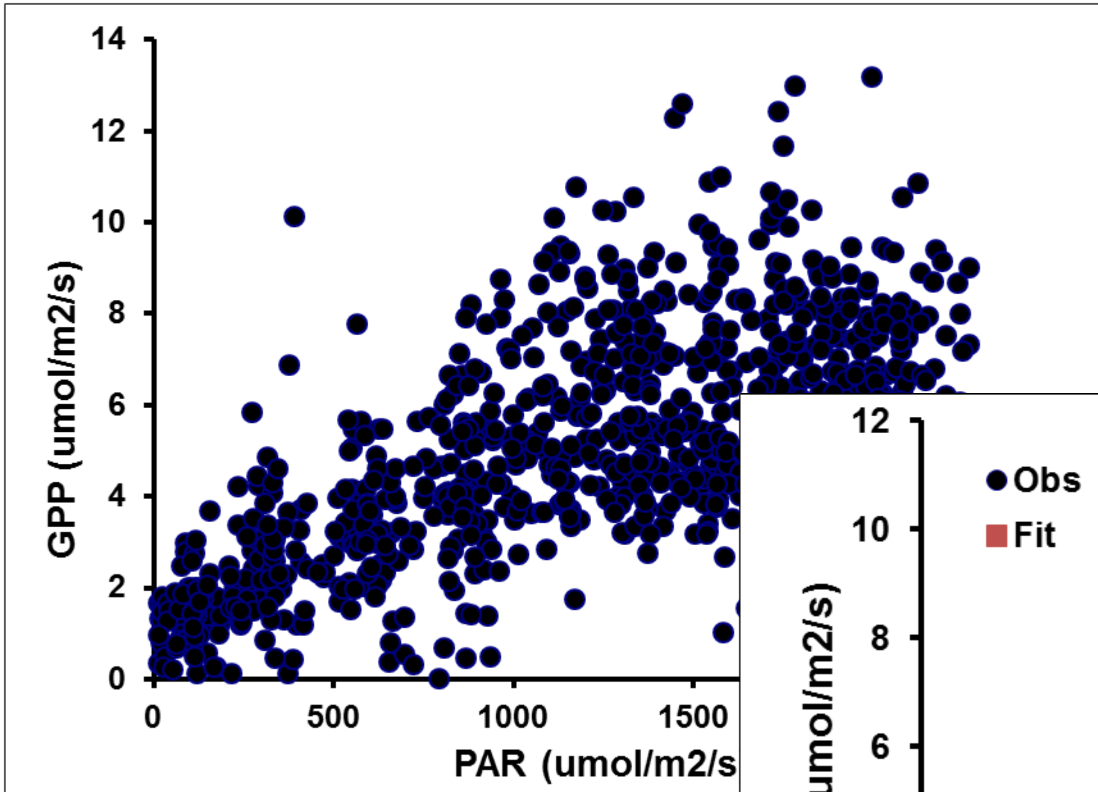
$$GPP = \frac{\phi A\,PAR}{\phi PAR + A}$$

$$A = A_{max}, D \le D_0$$

$$= \frac{A_{max}}{\left(1 + \left(D - D_0\right)/D_0\right)}, D > D_0$$

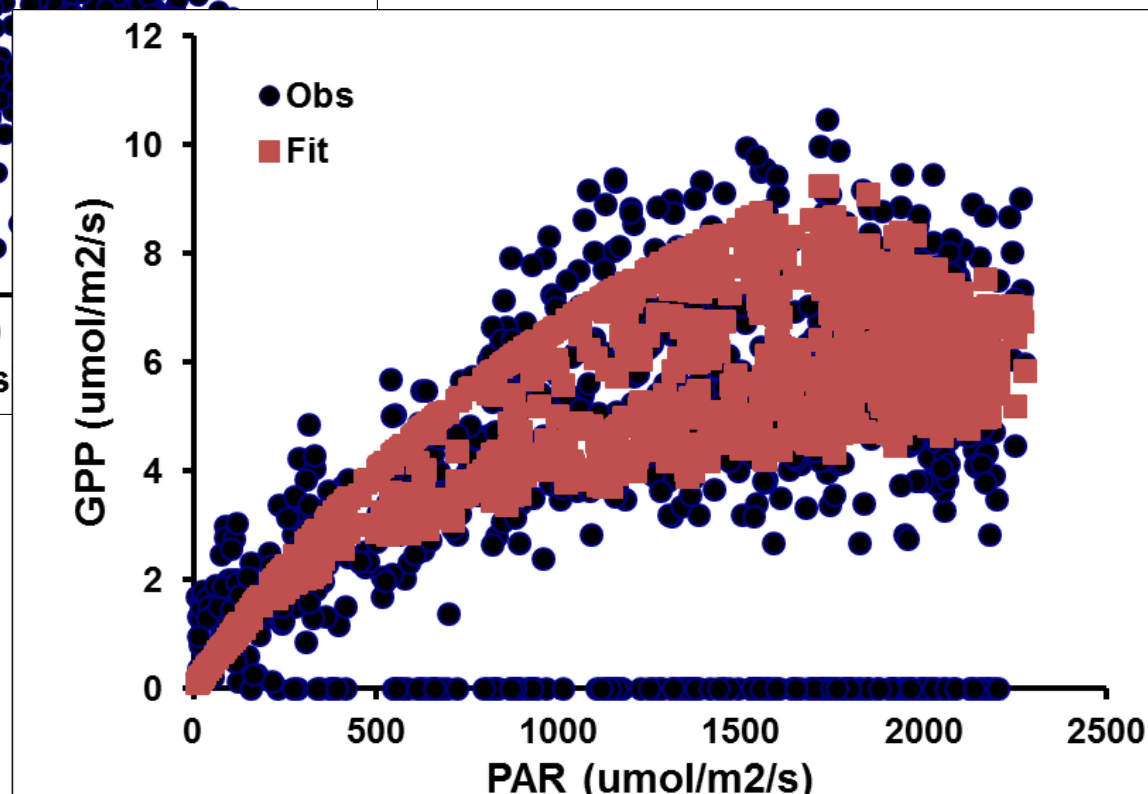


A Better Fitting Method



Robust non-linear regression

- IRLS
- Huber weight function



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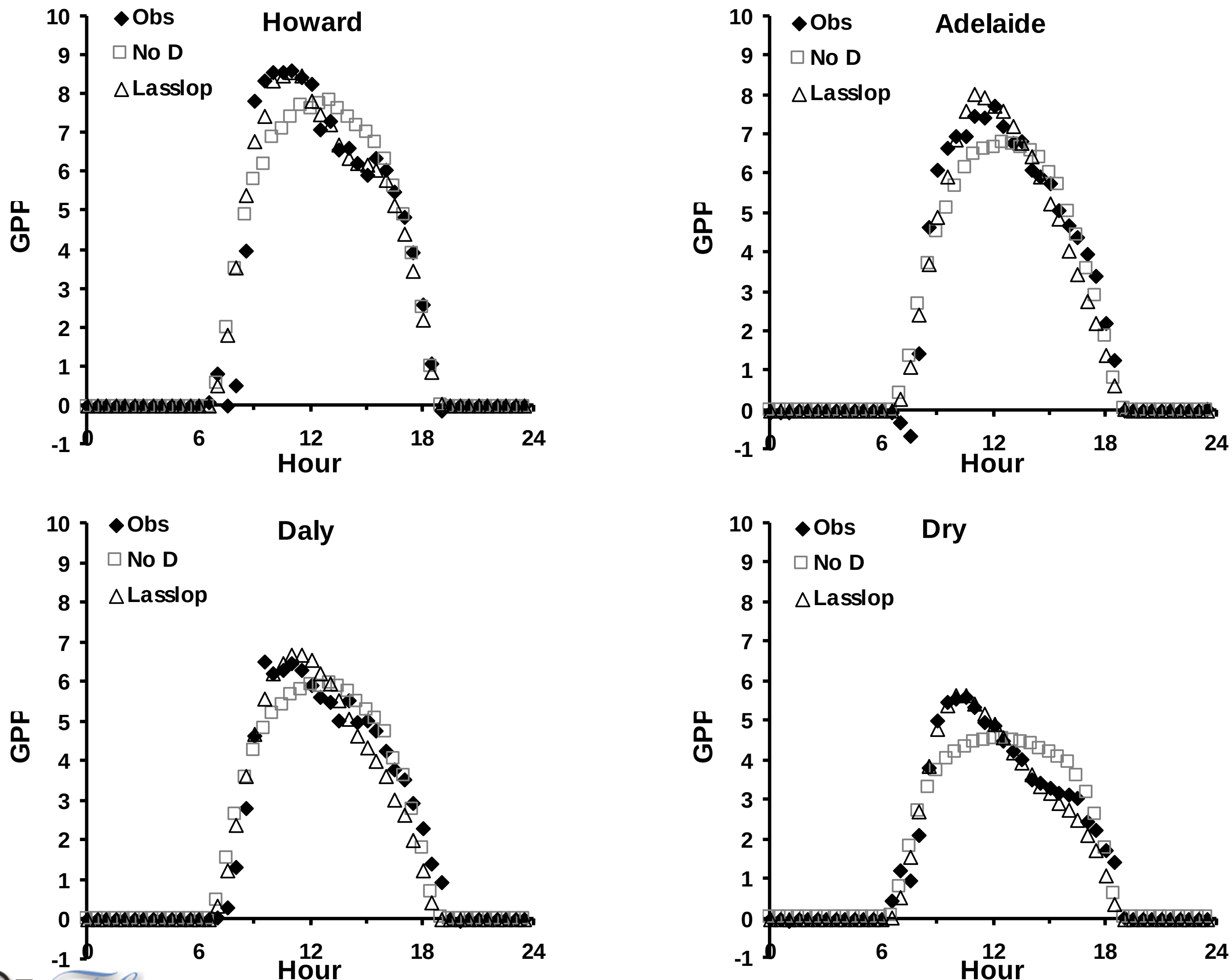
Diurnal Variation in GPP



Canopy Conductance and Latent Heat

We can do a similar thing with latent heat flux via a simple model for canopy conductance:

- Originally from Kelliher et al (1995), modified by Isaac et al (2004), used by Leuning et al (2008).

$$G_c = \frac{g_{sx}}{c_Q} \ln\left(\frac{S + S_{50}}{S \exp\left(-c_Q L_{ai}\right) + S_{50}} \right) f\left(D\right)$$

$$f\left(D\right) = 1, D \le D_0$$

$$= \left(\frac{1}{1 + \left(D - D_0\right)/D_0} \right), D > D_0$$

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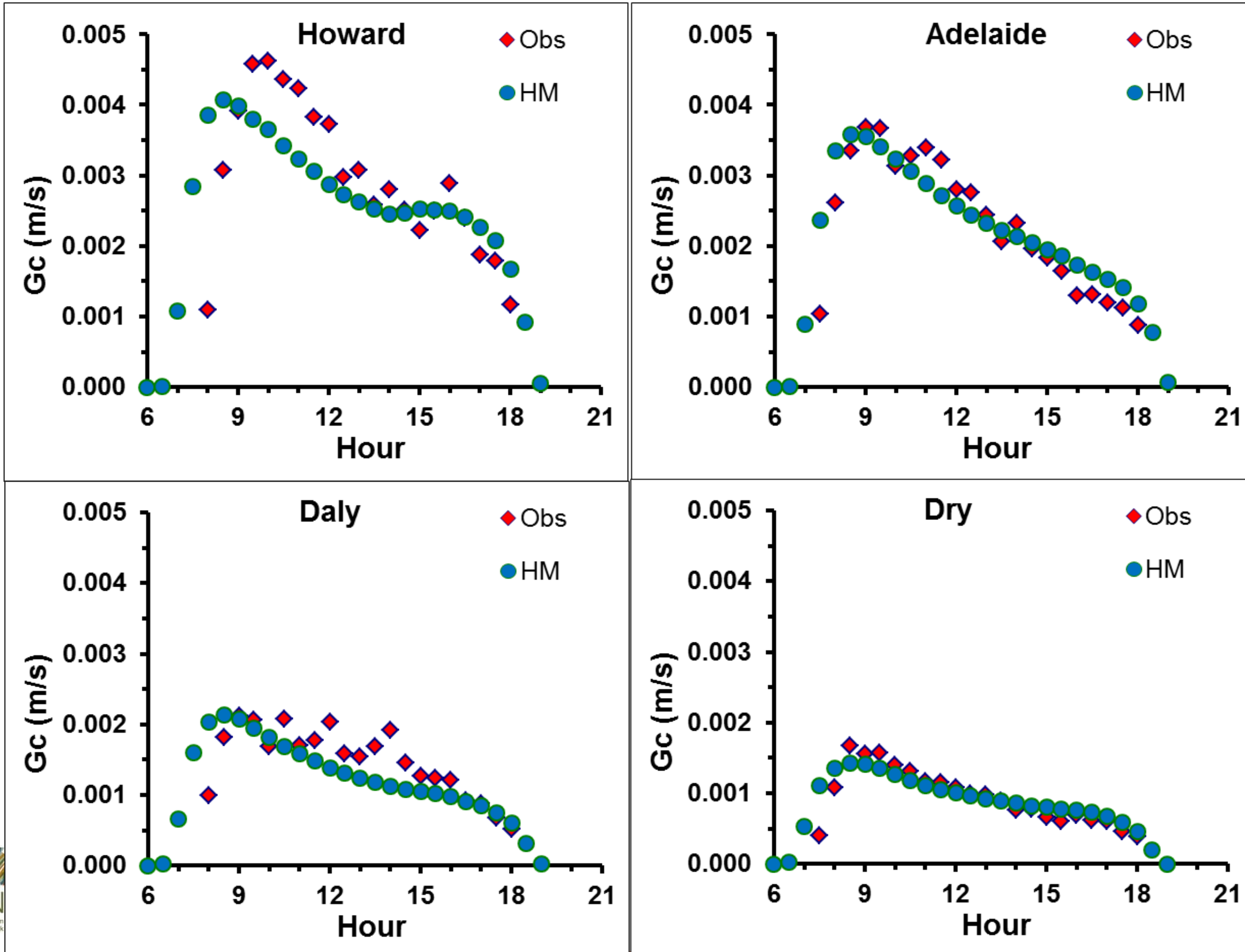
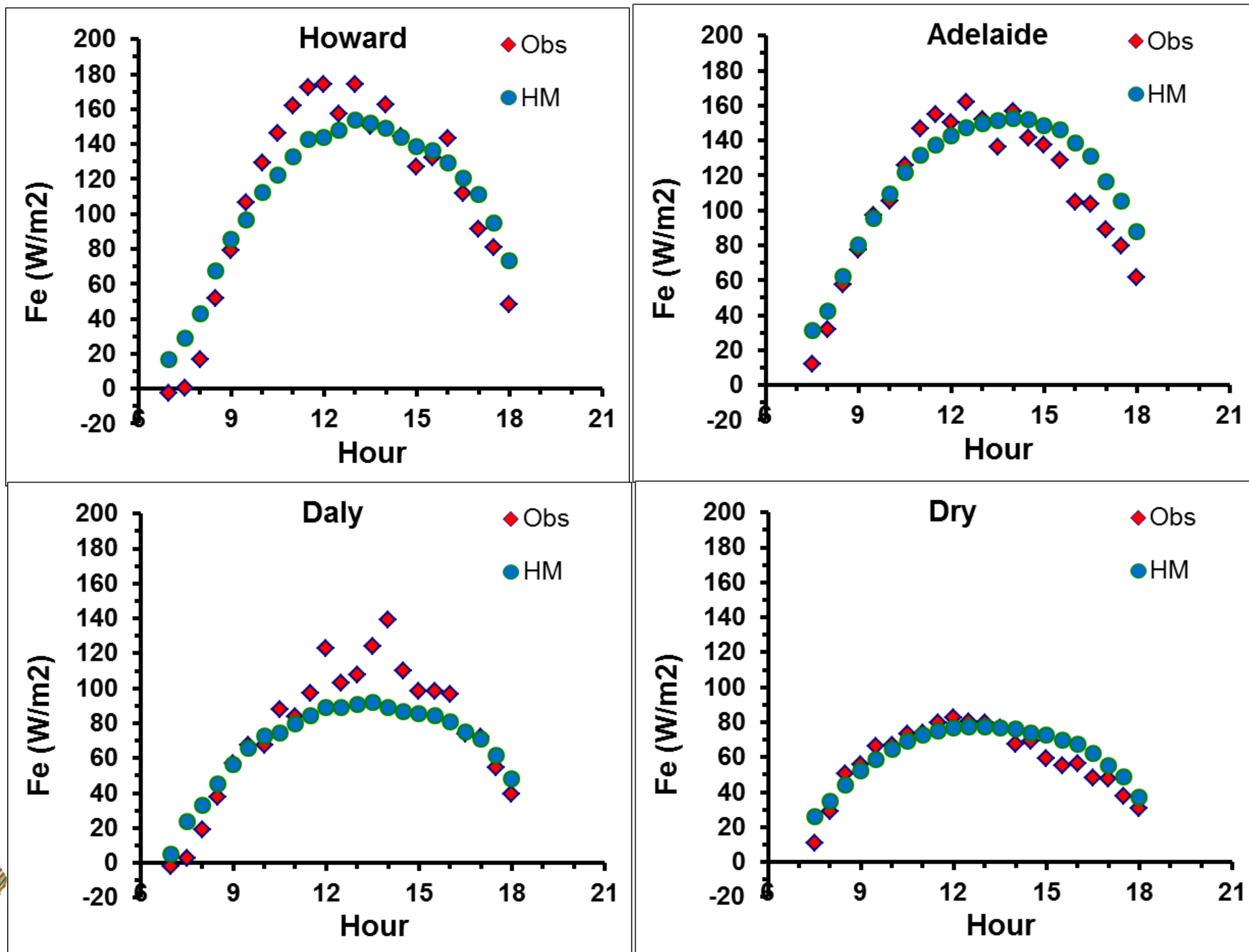
Diurnal Variation in Canopy Conductance



Diurnal Variation in Latent Heat



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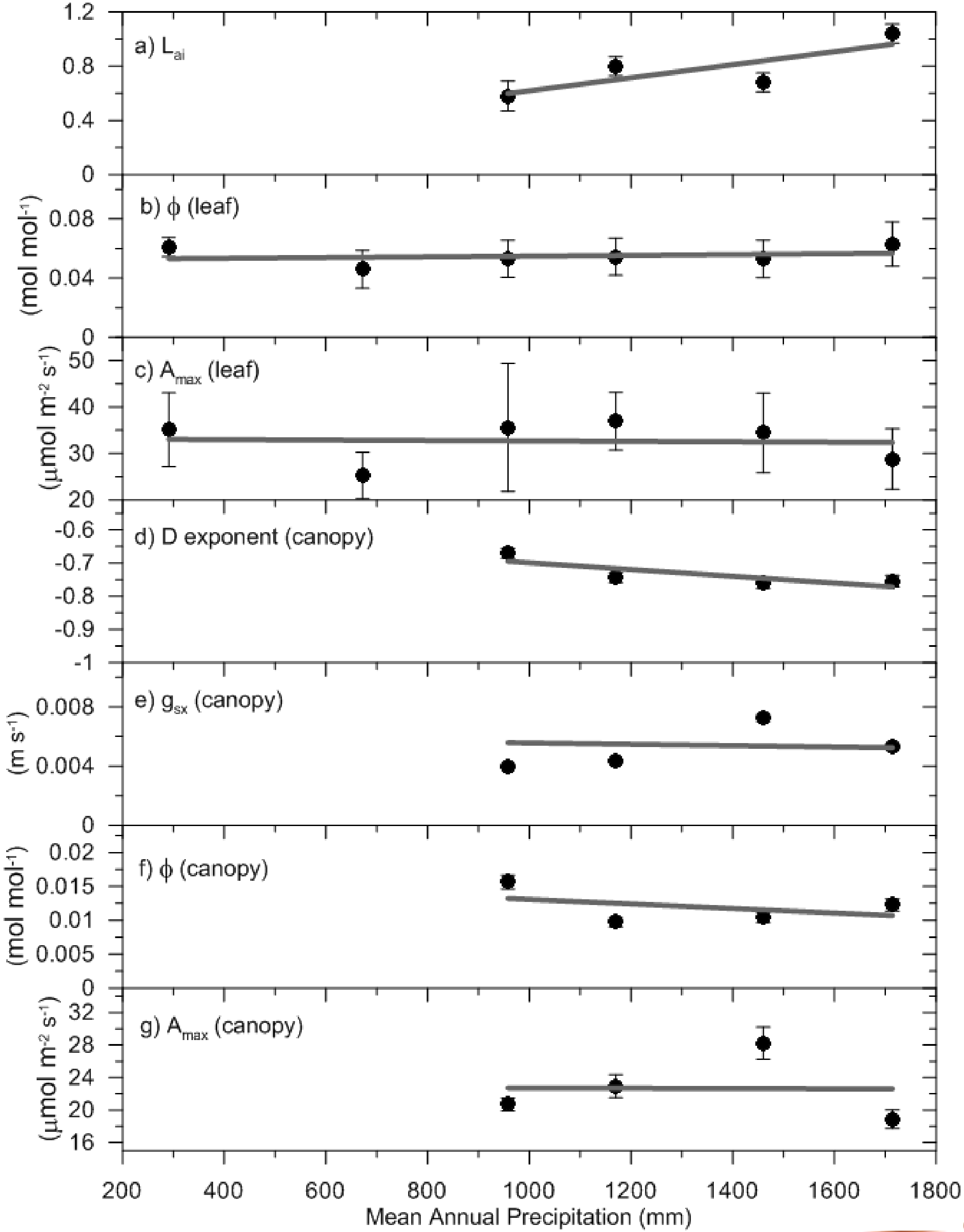

$$m = \left(2.3\times10^{-4}, 7.3\times10^{-4}\right)$$

$$m = \left(-3.2\times10^{-6}, 8.3\times10^{-6}\right)$$

$$m = \left(-4.9\times10^{-3}, 3.9\times10^{-3}\right)$$

$$m = \left(-1.5\times10^{-4}, -4.9\times10^{-5}\right)$$

$$m = \left(-3.8\times10^{-6}, 3.0\times10^{-6}\right)$$

$$m = \left(-8.5\times10^{-6}, 1.8\times10^{-6}\right)$$

$$m = \left(-8.8\times10^{-3}, 8.5\times10^{-3}\right)$$

Conclusions

Land use is the major driver of spatial heterogeneity over Tropical Savanna in the late dry season.

Leaf-area index is second for woody savanna:

- Photosynthetic properties don’t vary with MAP for this data period.
- Response to D along transect uncertain.

We only need 1 leaf to describe the spatial variability of fluxes over Tropical Savanna in the late dry season.

Surface properties at the canopy scale may be constrained by knowledge of leaf-level properties.

Thanks

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