Phenology, Climate, Fire, and Remote Sensing

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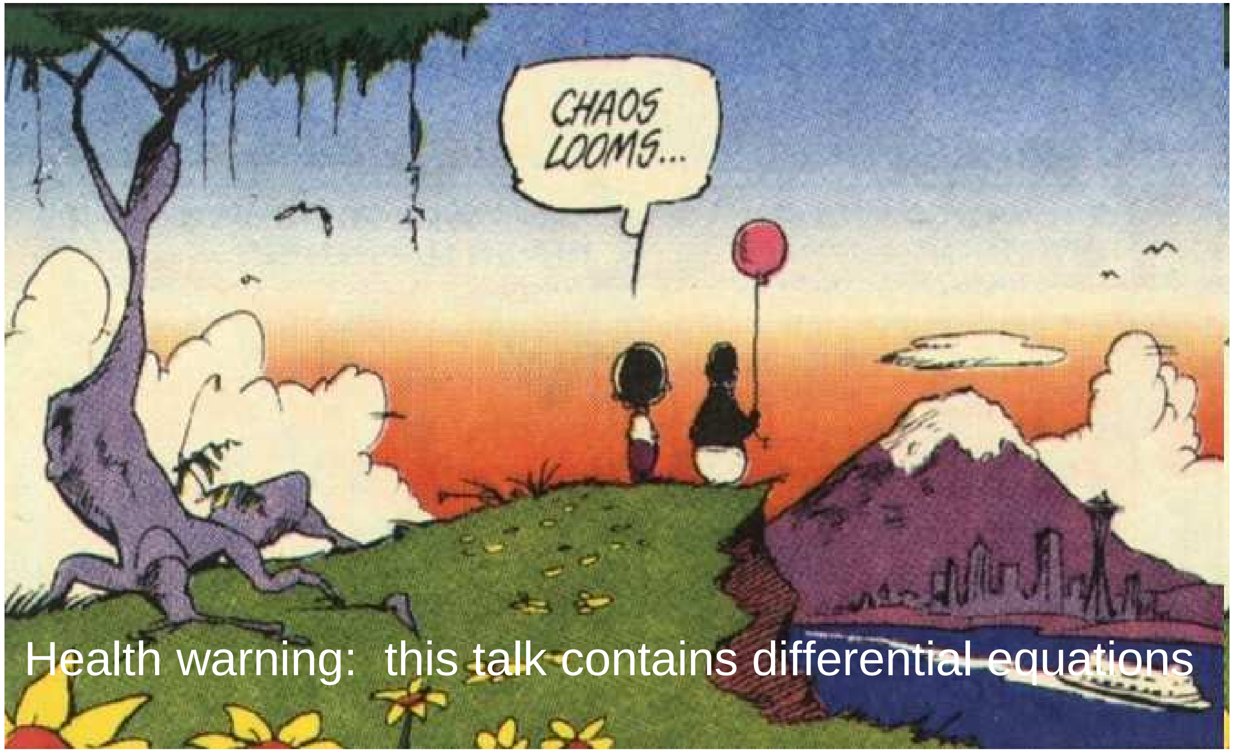
Ozflux Course, Creswick

5 February 2010



Health warning: this talk contains differential equations

My flux tower history

- Started work with WLEF Tower data (Nov 1996)[1]
- Installed micromet and soil moisture/temp data
- Bear (Bigfoot?) knocks down solar panel (Feb 1998)
- Power out (March 1998)
- Squirrels cut TDR cables (Pete's Hot Sauce doesn't work)
- Helped set up Willow Creek site (Park Falls, WI, May 1998)[2]
- Large gap in data at WLEF, post-doc on holiday (Jul-Aug 1998)
- Dennis Baldocchi asks me a question at Ag & For Met Conf. (Nov 1998)
- Bill Clinton impeached (Dec 1998)
- Skukuza (Kruger National Park, SA)[3] LAI measurements (Jan 2003)
- Tumbarumba biometric measurements (2009)[4]
- Helped install Sturt Plains NDVI sensor (Nov 2009)[5]

Knowledge is power --- Francis Bacon

The only true wisdom is knowing you know nothing --- Socrates

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Outline

- Introduction
- An exercise in fire and remote sensing
- Vegetation structure, climate, and phenology
- Fire and phenology
- Decoupling tree and grass components
- Mitchell grasslands and ecohydrological modeling
- An exercise in GPP: finding the flux tower game
- Summary comments

What is phenology?

Phenology is the study of periodic plant and animal life cycle events and how these are influenced by seasonal and interannual variations in climate. (*Wikipedia)*

Examples:

Kyoto, Japan cherry tree record of flowering times from the 9th Century

My grandma's record of spring 'leaf out' dates (1936-83)

Quantitative phenology

- Most phenological studies have been descriptive and have focused on N. America or Europe
- Few studies have taken an LAI or quantitative viewpoint
- Few studies have been done on tropical, water-limited systems

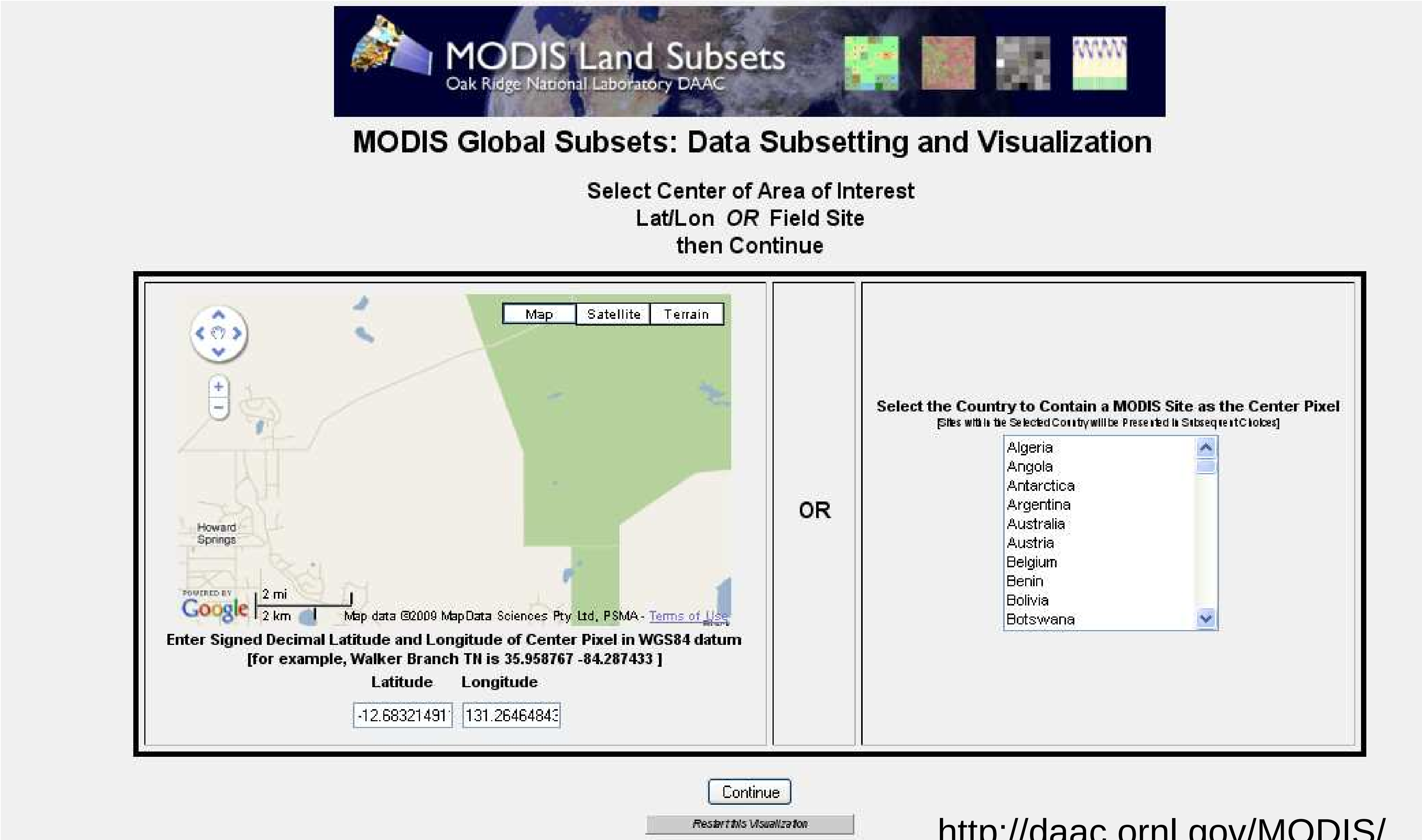
Two main approaches to phenology

- Diagnostic studies
  - mostly at the global scale using remote sensing
  - curve fitting of phenological responses
  - statistical models to identify the main drivers of vegetation response

- Process-oriented models
  - mostly at the local scale using data from highly instrumented sites
  - ecohydrological modelling coupling soil water content dynamics and plant growth

- A combination of empiricism and quantitative ecosystem modelling in most LSM-GCM

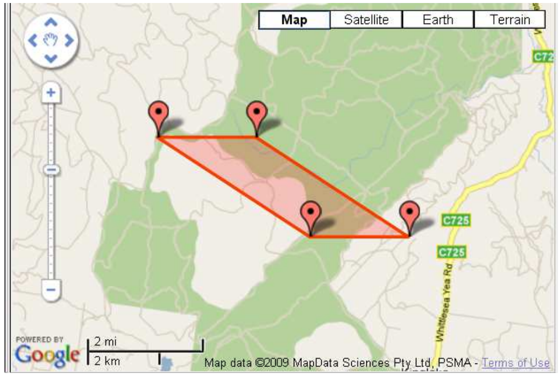
Exercise 1: MODIS subsetting tool



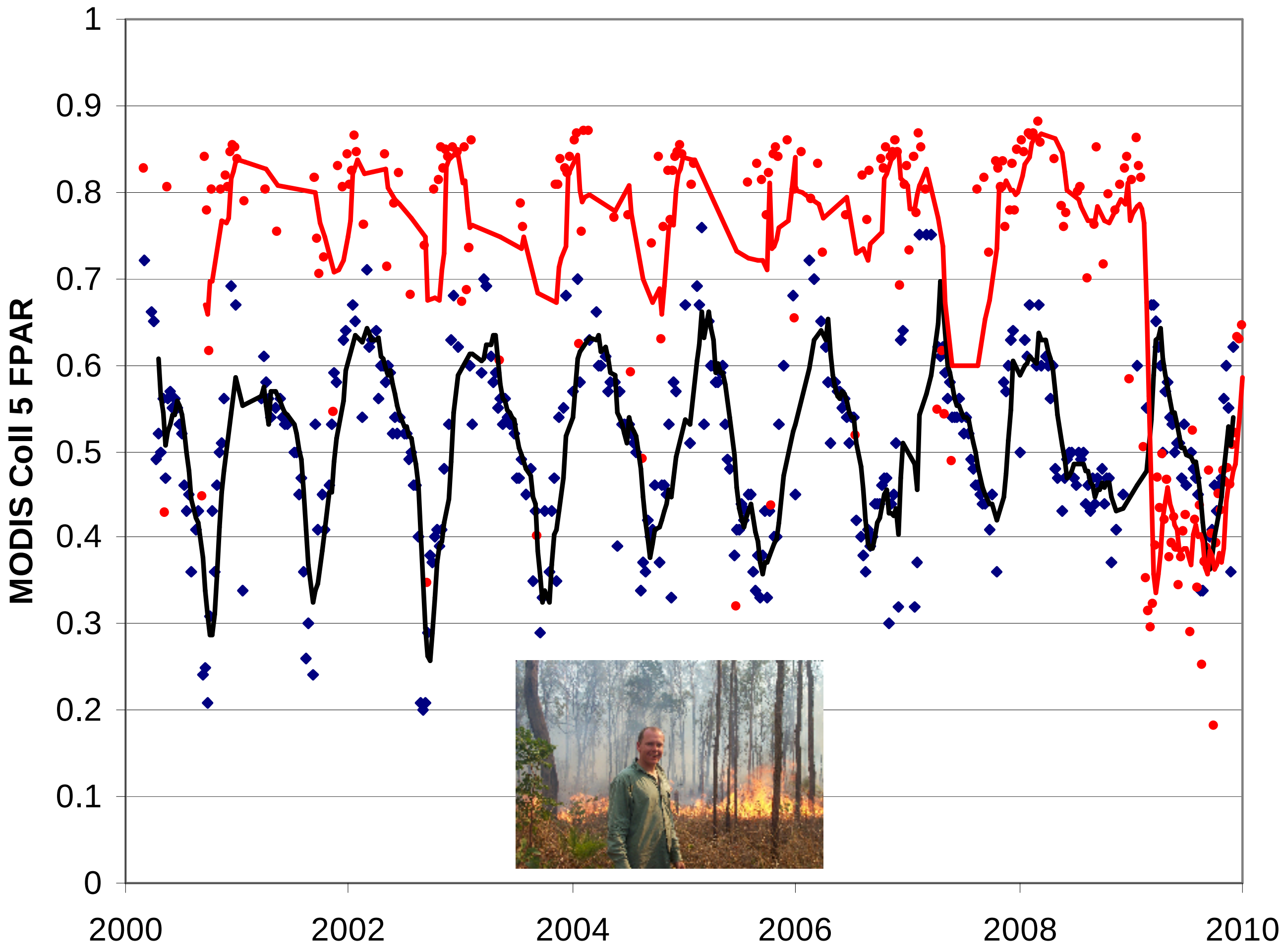
http://daac.ornl.gov/MODIS/

Howard Springs, Northern Territory

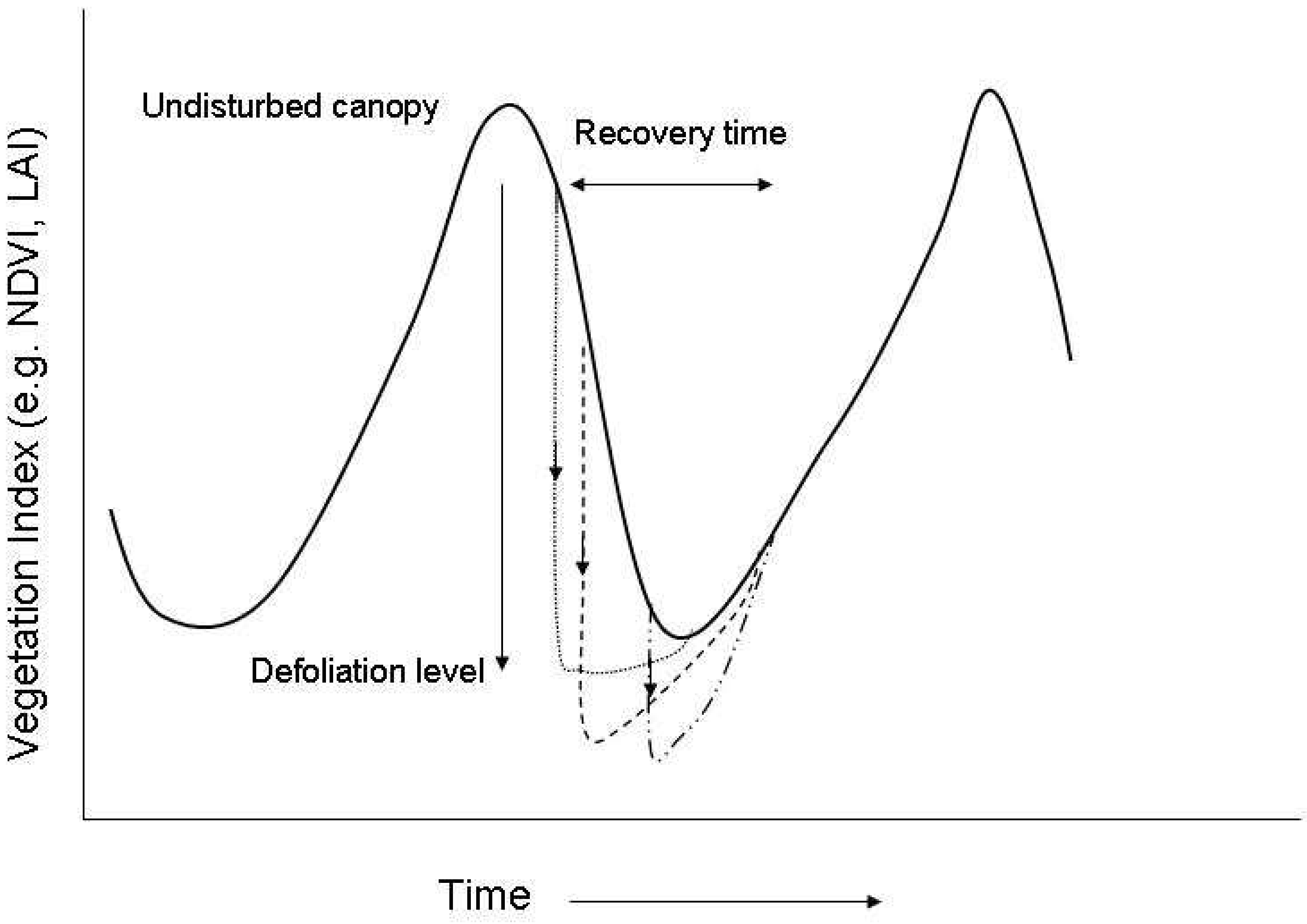
Kinglake, Victoria (Ozflux site subject to fire 2009)



MODIS phenology



Conceptual Model



Using remote sensing at larger scales

Vegetation phenology

Phenology data comes from MODIS Collection 5.0 FPAR/LAI composite data (2000-2009).

Vegetation structure

Vegetation structure data comes from the Australian Major Vegetation Group map. Eight classes studied for mixed tree-grass systems.

Fire

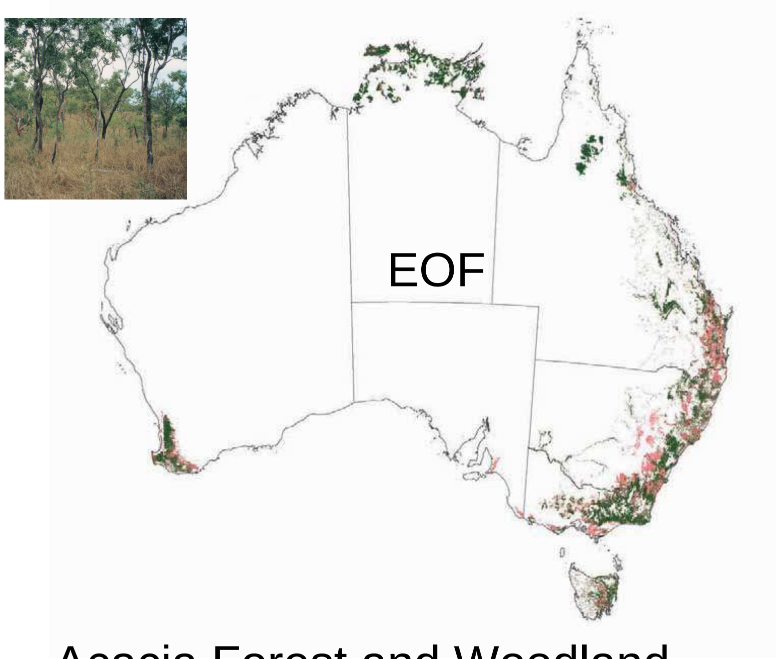
Fire record from WA DOLA dataset derived from AVHRR fire scars. Each polygon is painstakingly verified manually (1997-2008).

Climate data

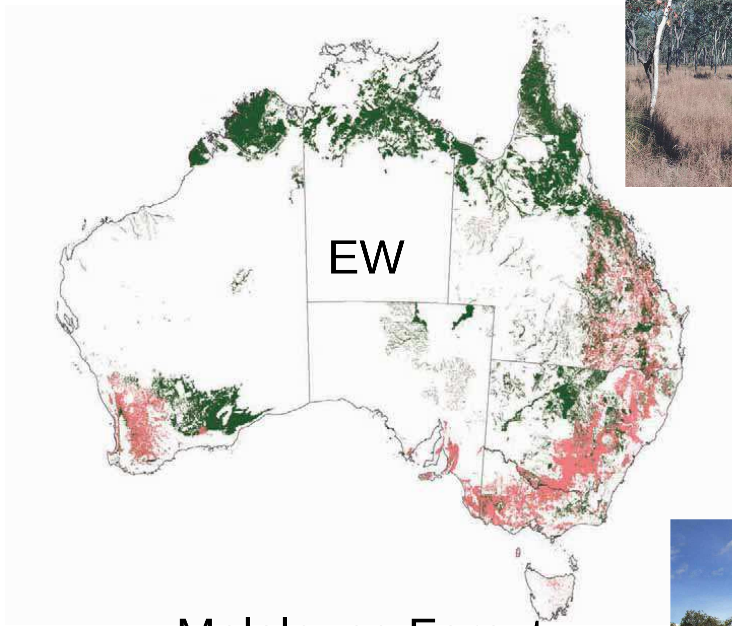
Precipitation data comes from QLD gov’t SILO-grid project (2000-2008).

All data is aggregated to ~ 5 x 5 km

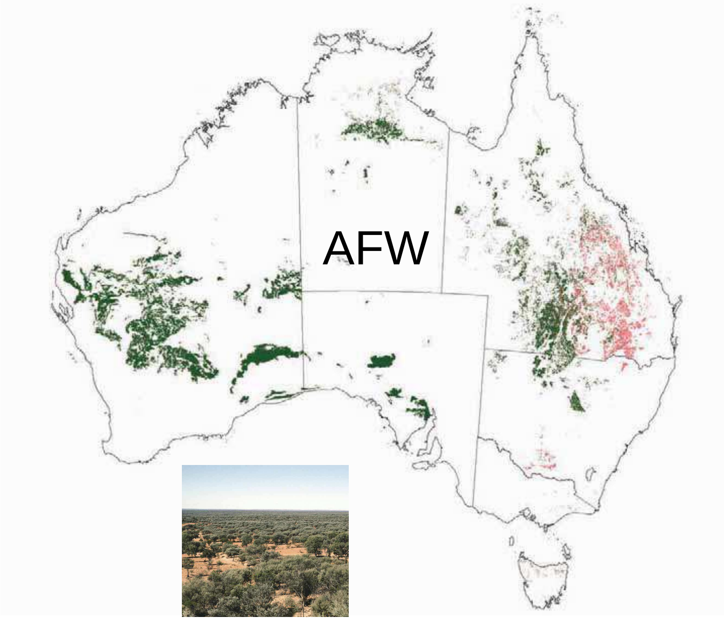
Eucalypt Open Forest



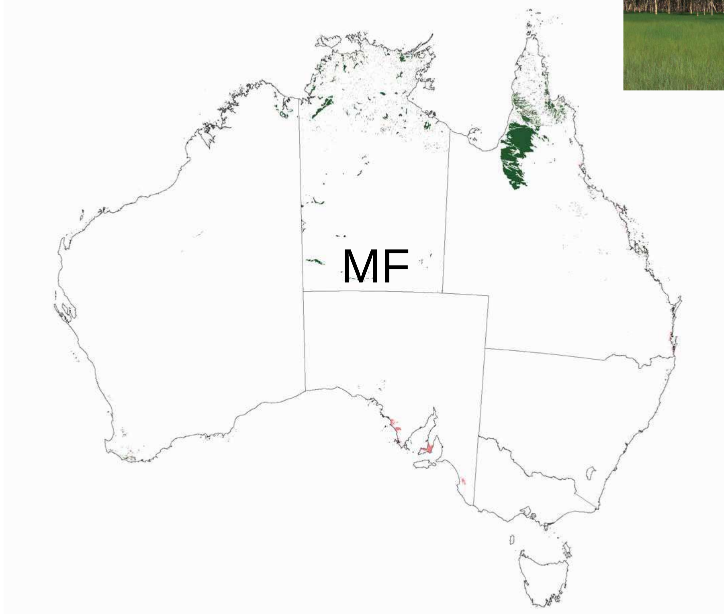
Eucalypt Woodland



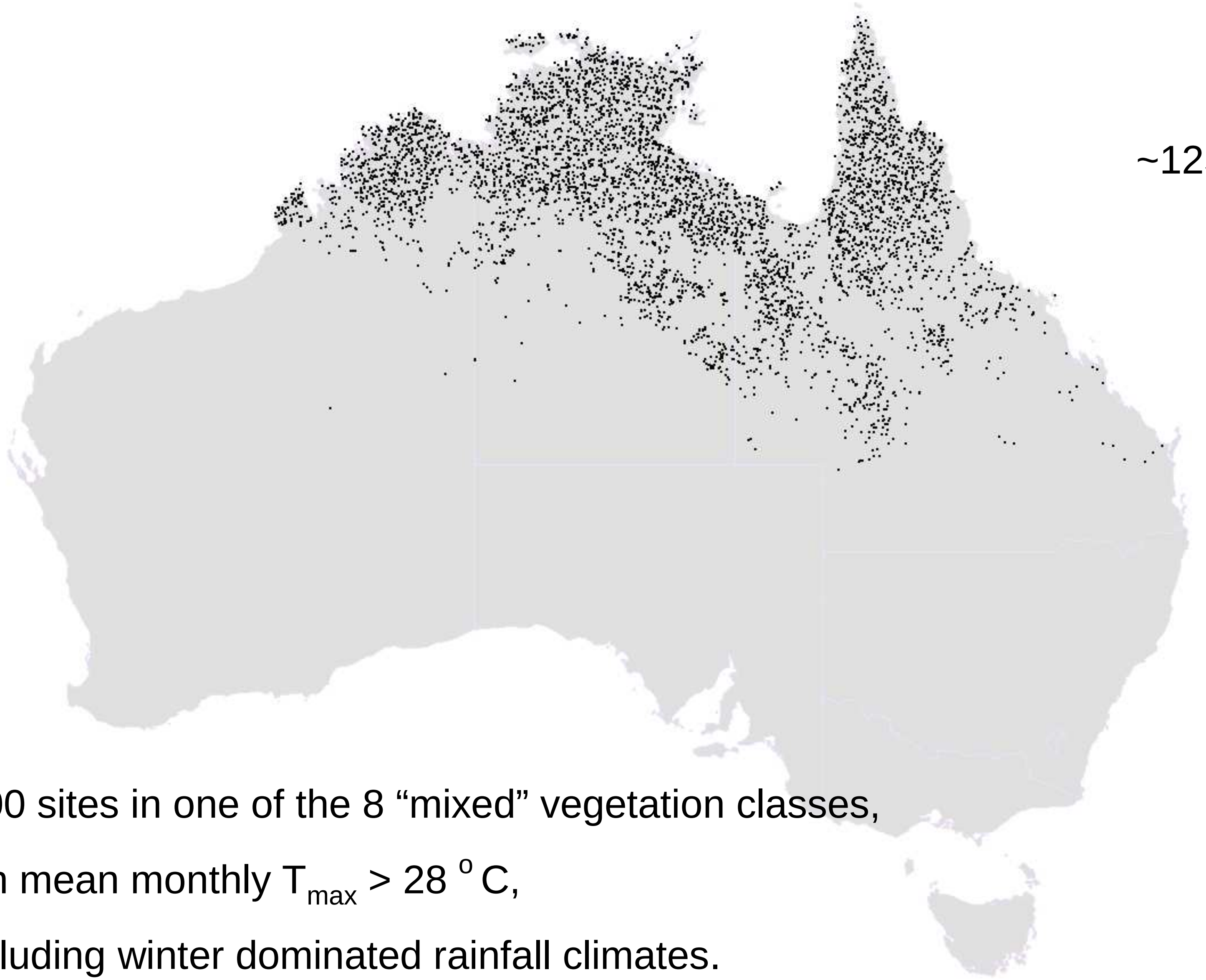
Acacia Forest and Woodland



Melaleuca Forest



Randomized sampling in northern Australia

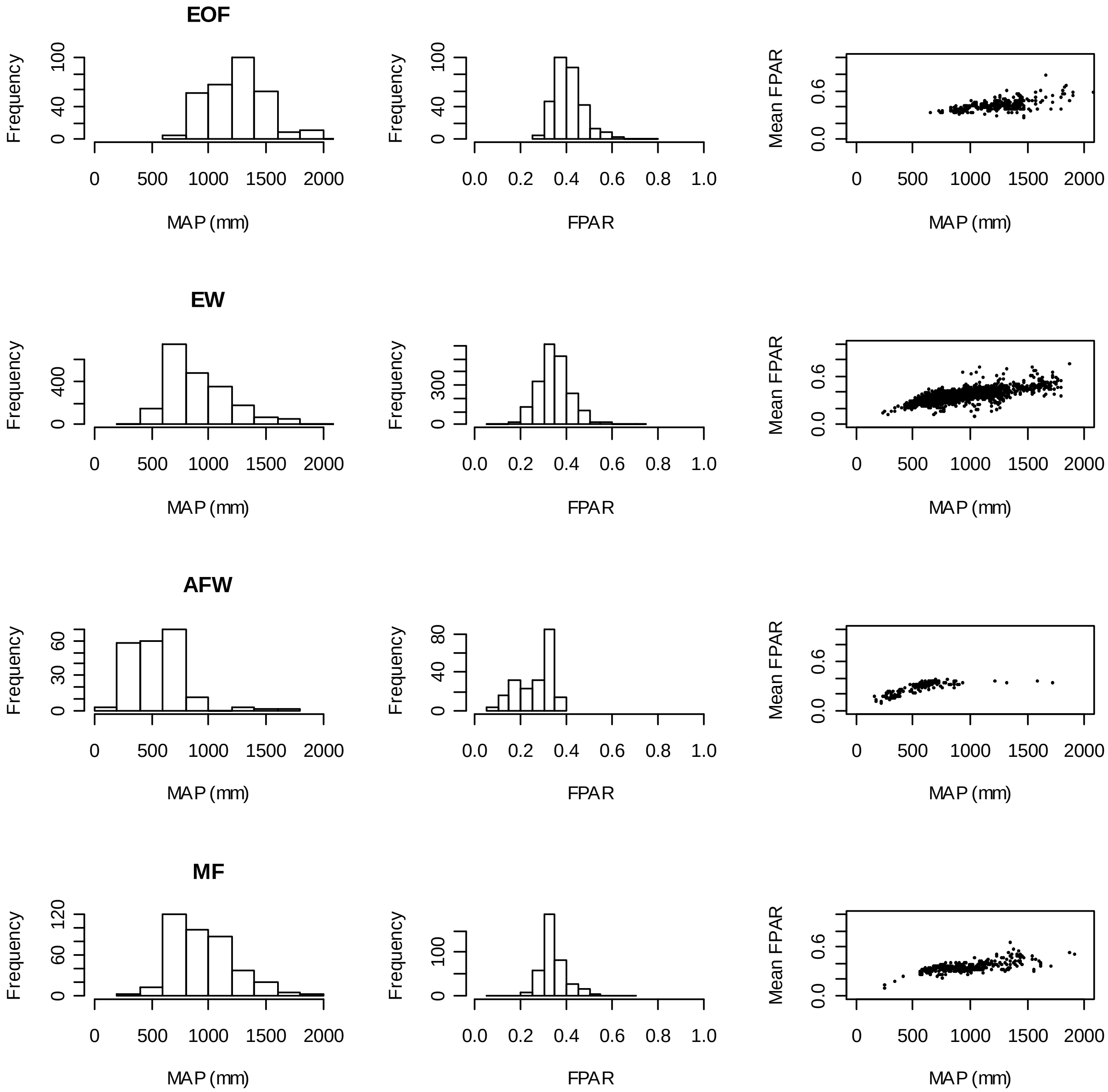


~125,000 km^2

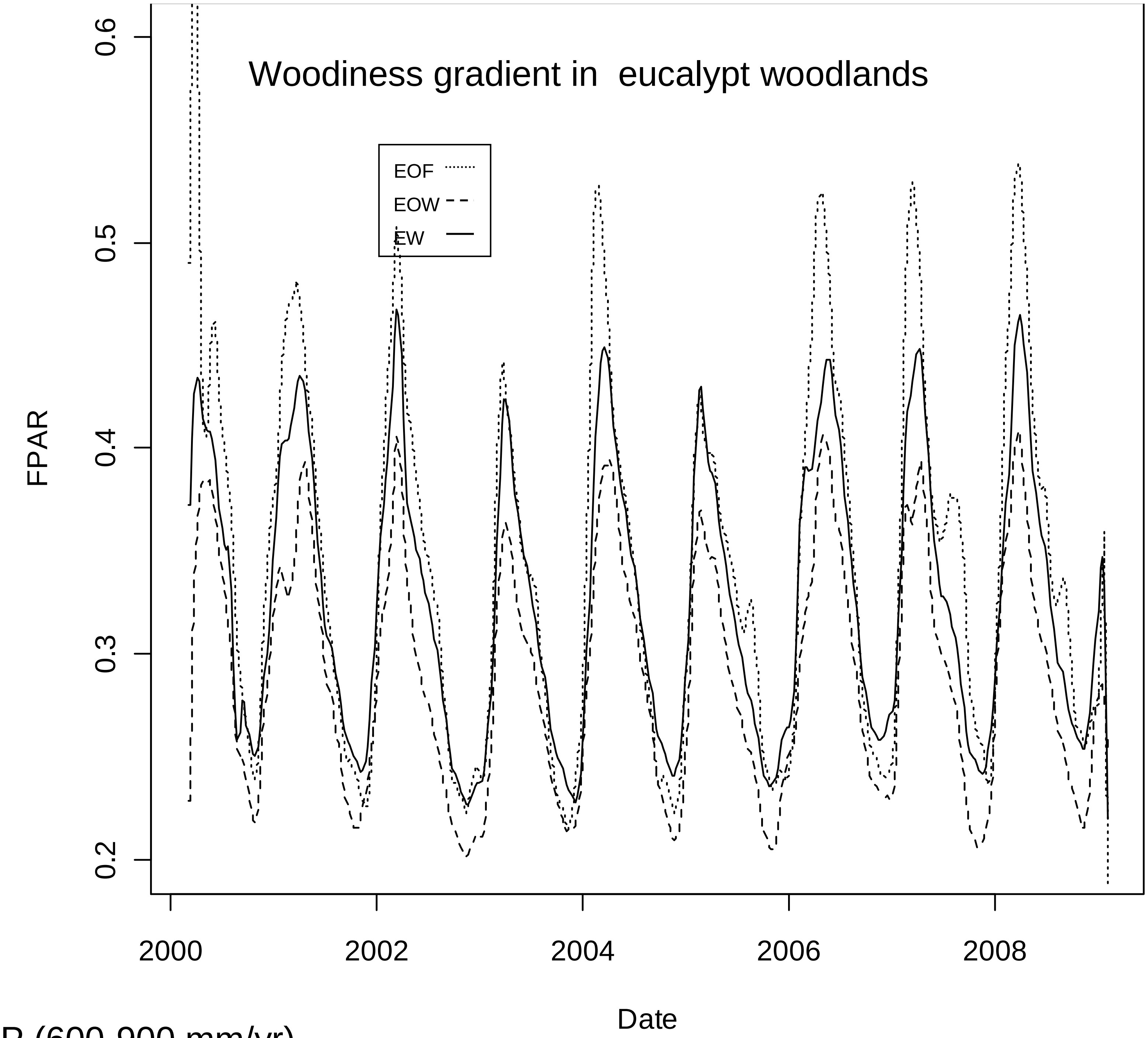
5000 sites in one of the 8 “mixed” vegetation classes,

with mean monthly T_{max} > 28 ^{o}C,

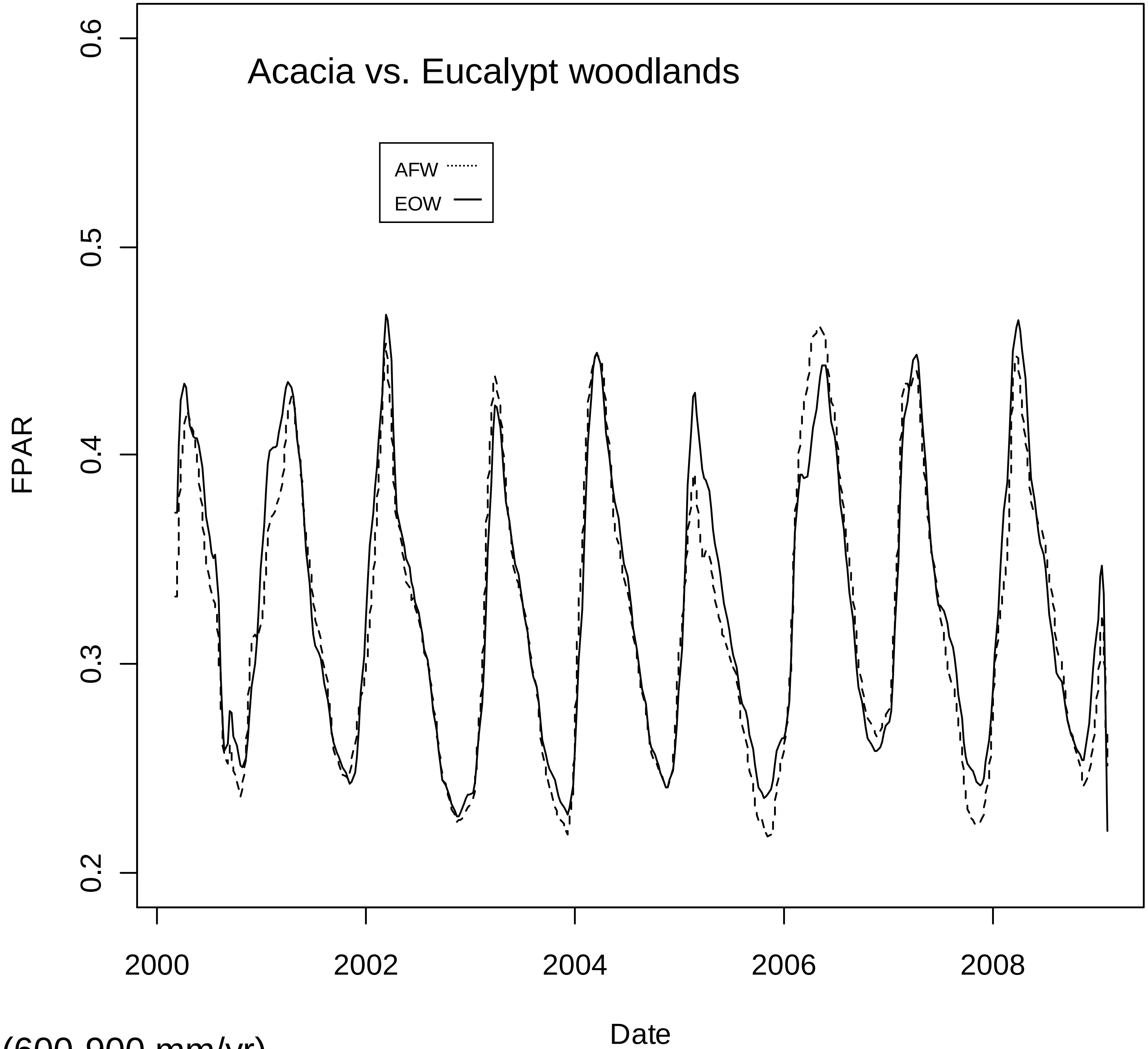
excluding winter dominated rainfall climates.



EOF
EW
AFW
MF
Frequency
MAP (mm)
FPAR
Mean FPAR
0 500 1000 1500 2000
0.0 0.2 0.4 0.6 0.8 1.0
0 40 100
0 400
0 300
0 30 60
0 40 80
0 60 120
0 100
0.0 0.6

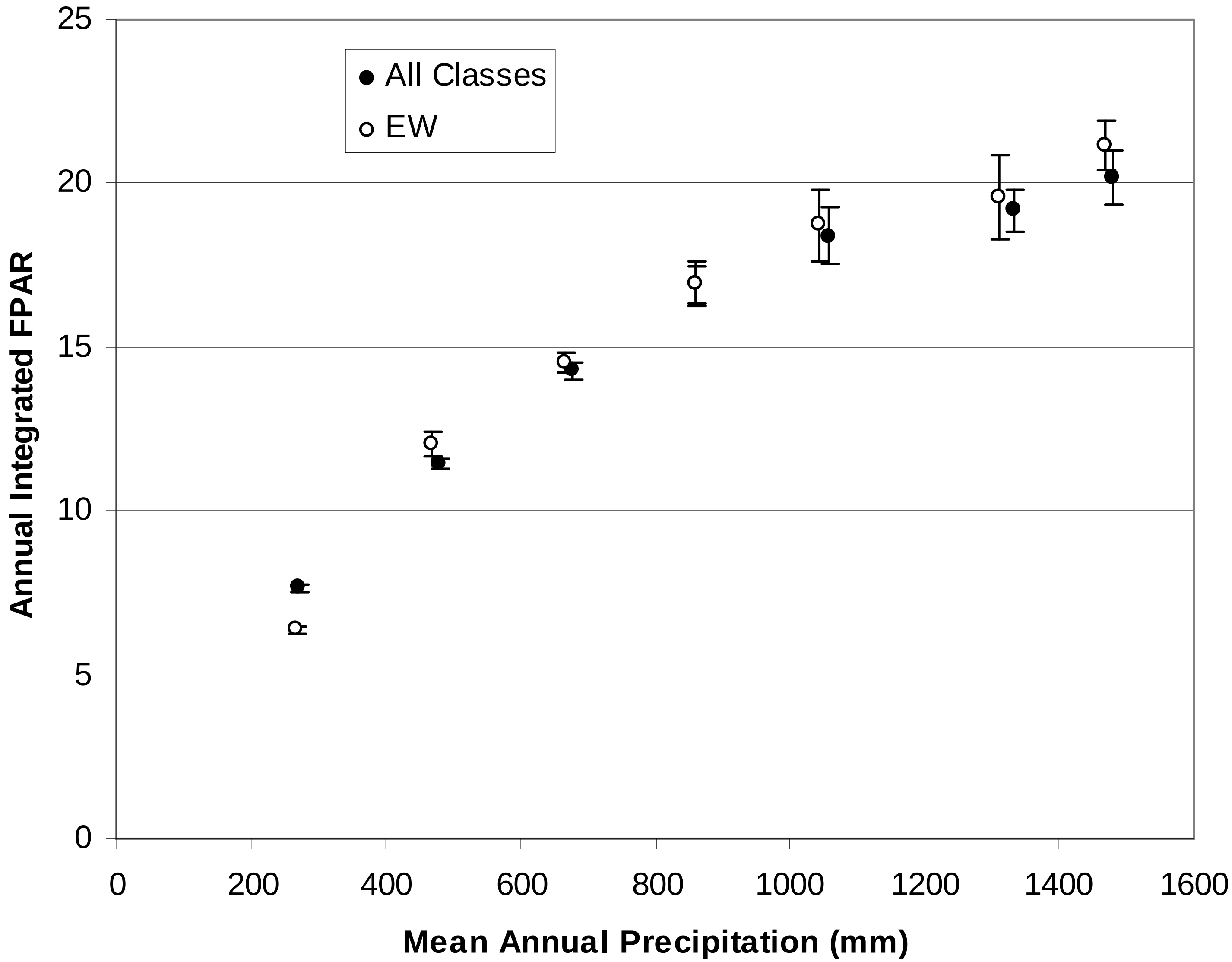


MAP (600-900 mm/yr)

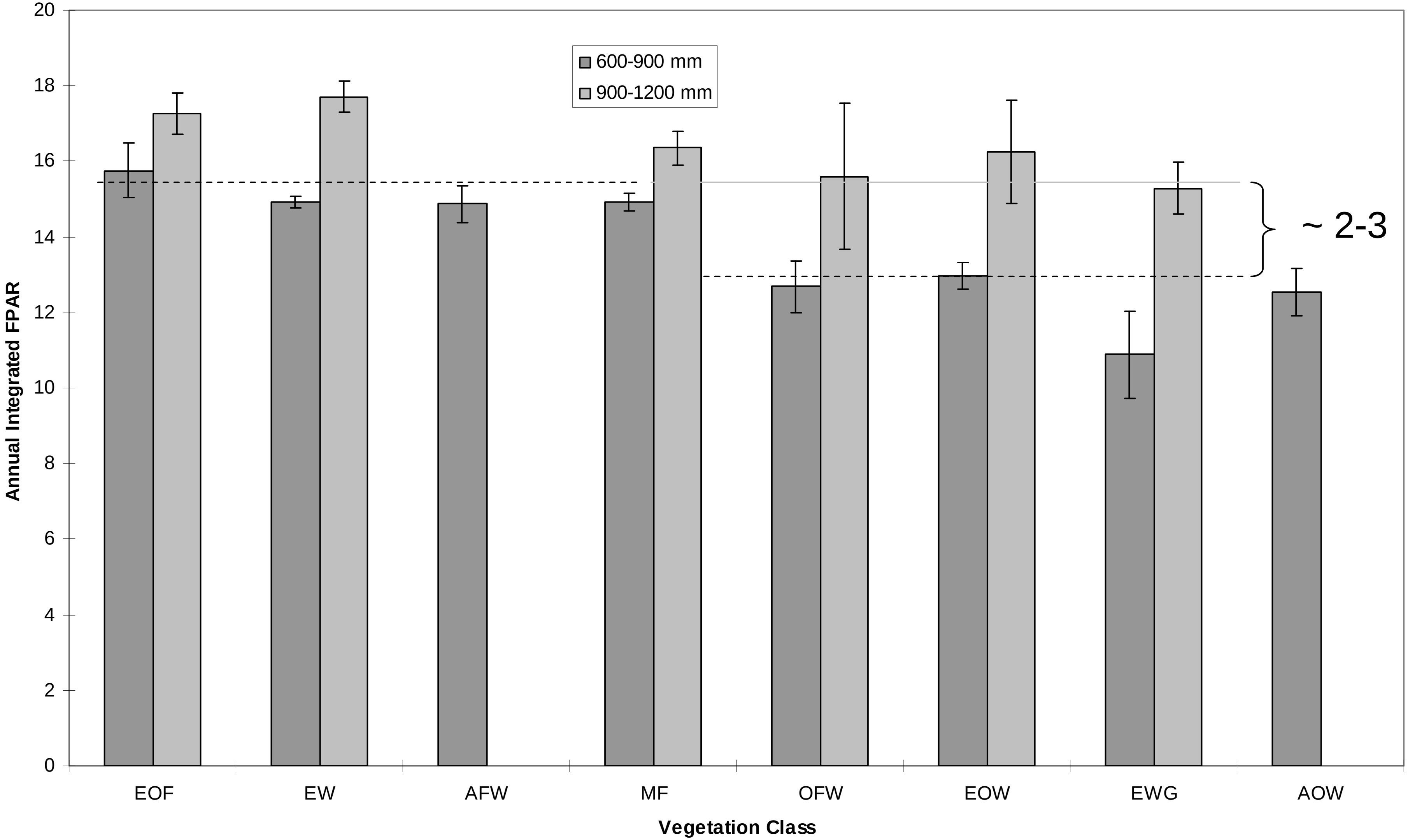


MAP (600-900 mm/yr)

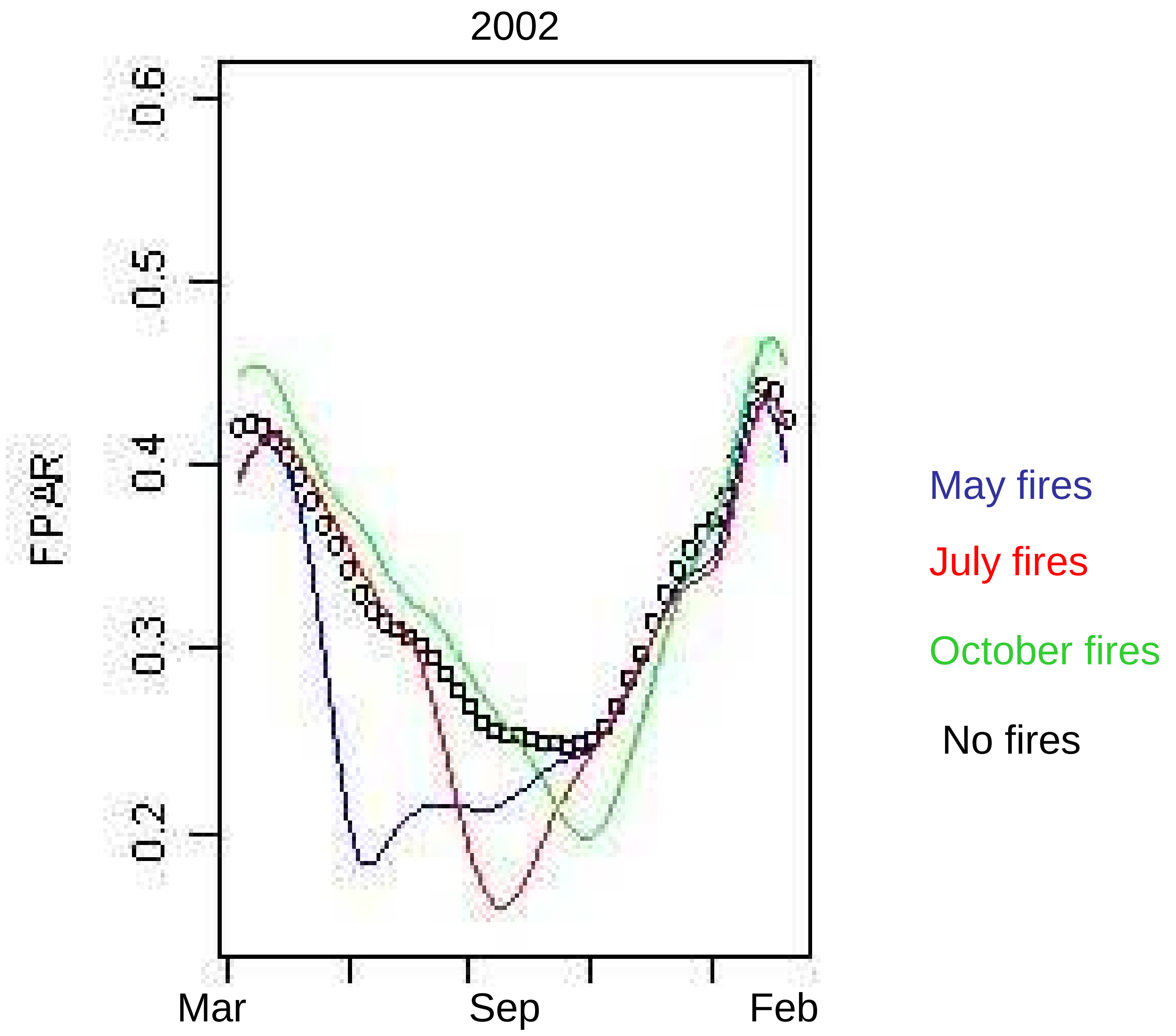
‘Production’ along a climate gradient



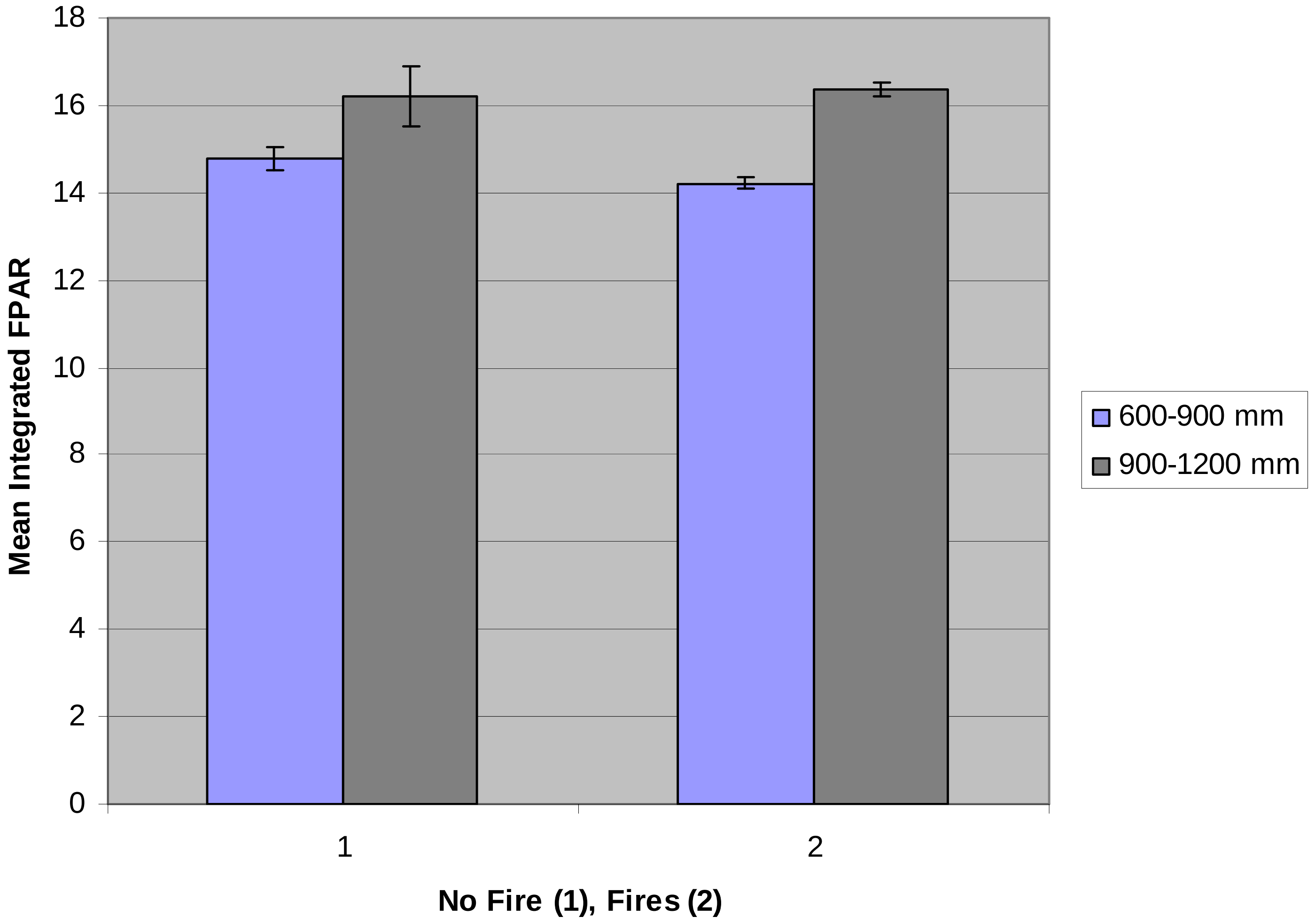
Putting it together



Inclusion of fire: ensemble averages



For the entire time series (2000-2009)



Fires refers to sites with > 1 in 3 year fire return

Decomposition into Tree and Grass Components

Donahue, McVicar, and Roderick GCB (2008)

$$F_{p1}(t) = \min[F_t(t-3), \ldots, F_t(t), \ldots, F_t(t+3)], \quad (1)$$

$$F_{p2}(t) = \frac{1}{9}[F_{p1}(t-4) + \cdots + F_{p1}(t) + \cdots + F_{p1}(t+4)]. \quad (2)$$

$$F_{r1}(t) = F_t(t) - F_{p2}(t). \quad (3)$$

Where an F_{r1} value was negative, its absolute value was subtracted from F_{p2} to yield the final estimate of F_p:

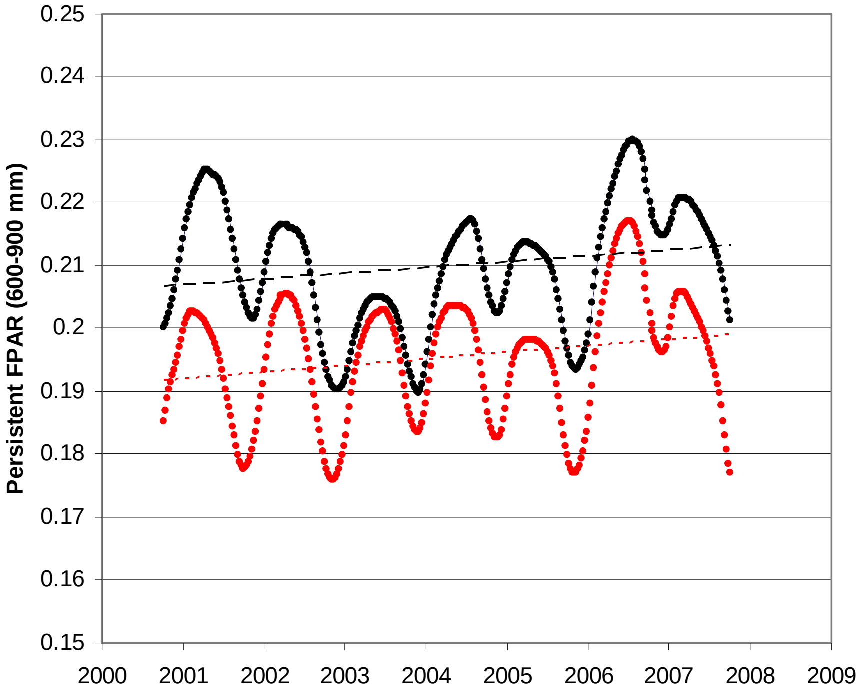
$$F_p(t) = F_{p2}(t) - |F_{r1}(t)|, \quad \text{where } F_{r1}(t) < 0 \quad (4a)$$

$$F_p(t) = F_{p2}(t), \quad \text{where } F_{r1}(t) \geq 0. \quad (4b)$$

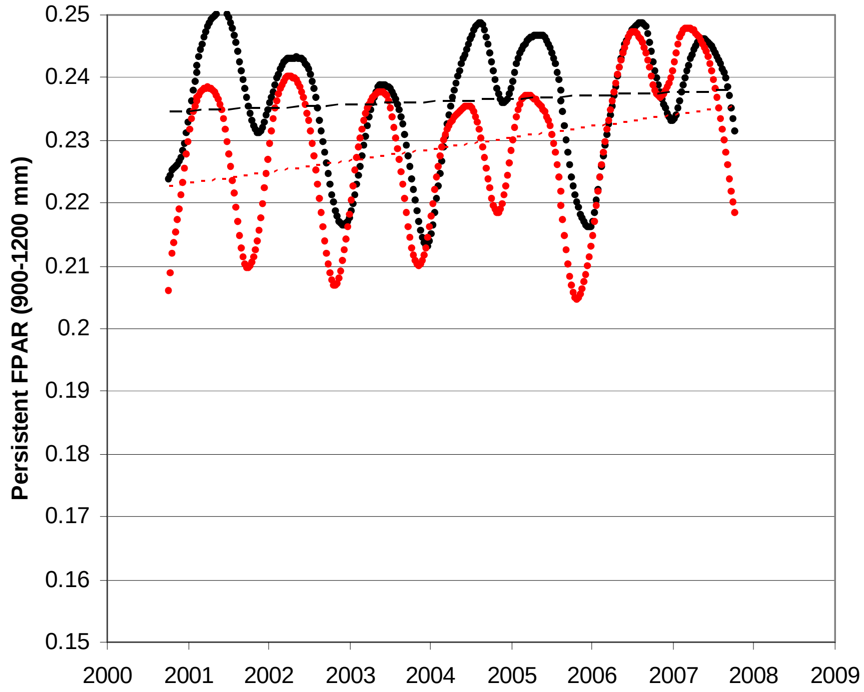
Lastly, F_r was calculated as

$$F_r(t) = F_t(t) - F_p(t). \quad (5)$$

Trends in persistent FPAR in northern Australia: fire vs. no fire



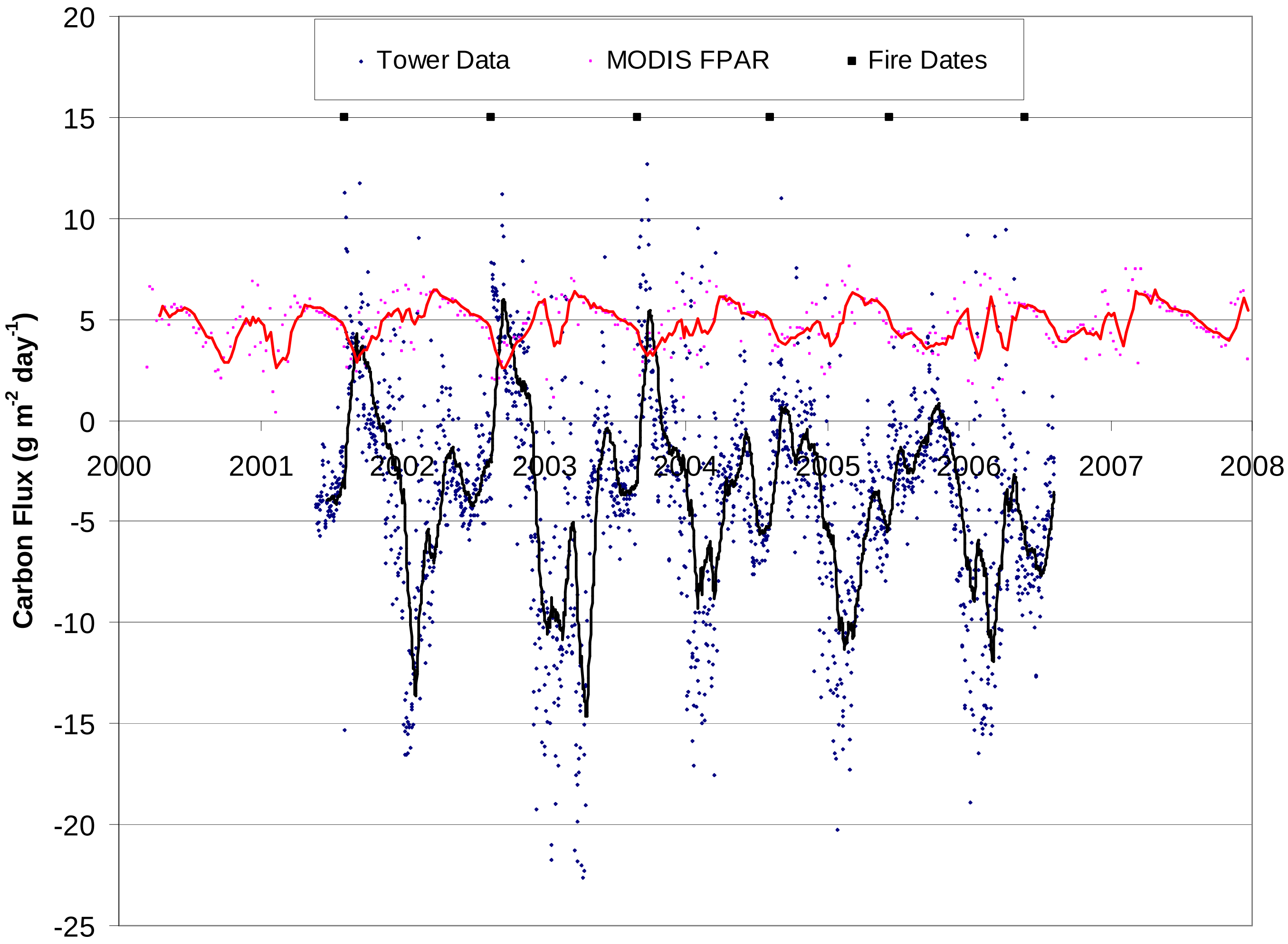
MAP (600-900 mm)



MAP (900-1200 mm)

Thought Question

Can we scale changes in absorbed FPAR with changes in carbon exchange at flux towers?

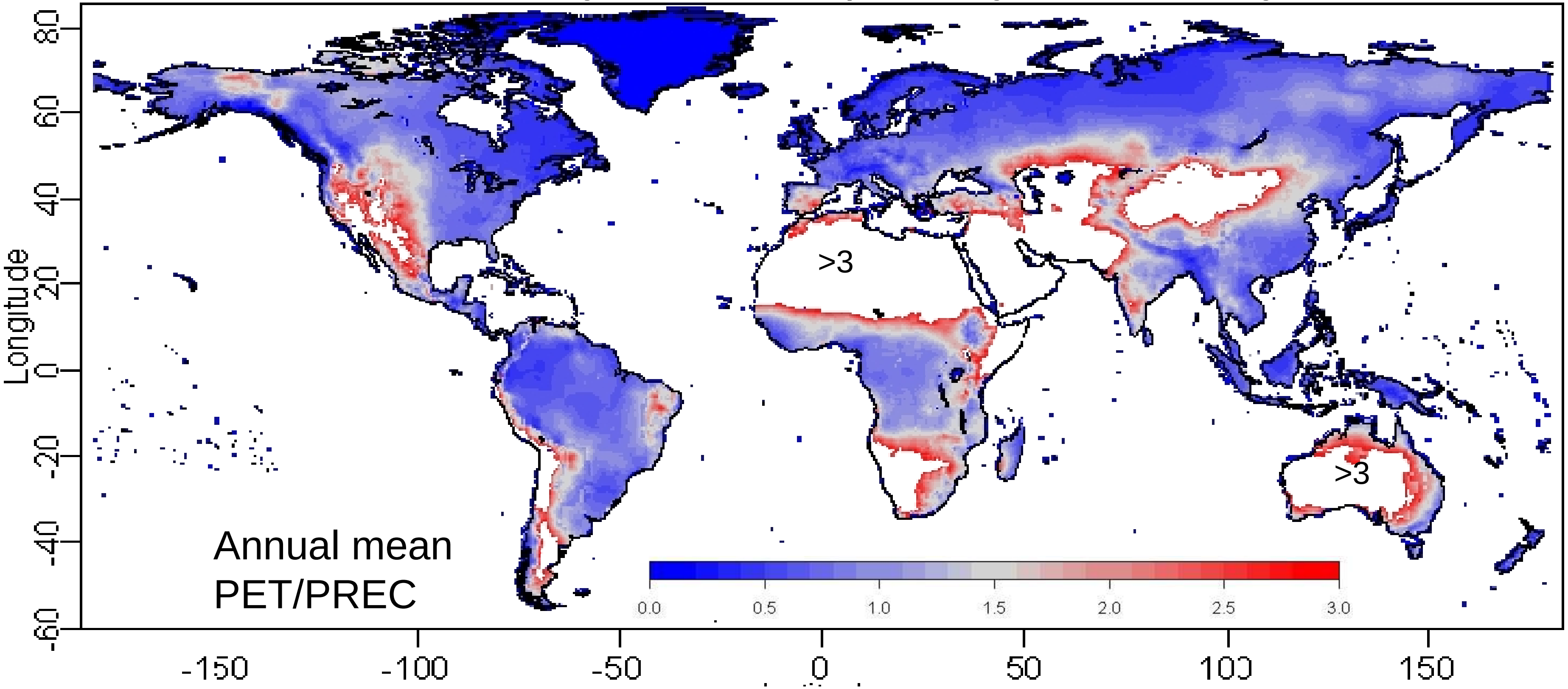


Ecohydrological Modeling

Water-controlled ecosystems

- Specific problems in water-controlled ecosystems include
  - spatial and temporal variability of the main driver (precipitation)
  - difficulties to model soil water balance
  - feedback between plant growth and soil water content

- 50% of terrestrial ecosystems NPP primarily controlled by water

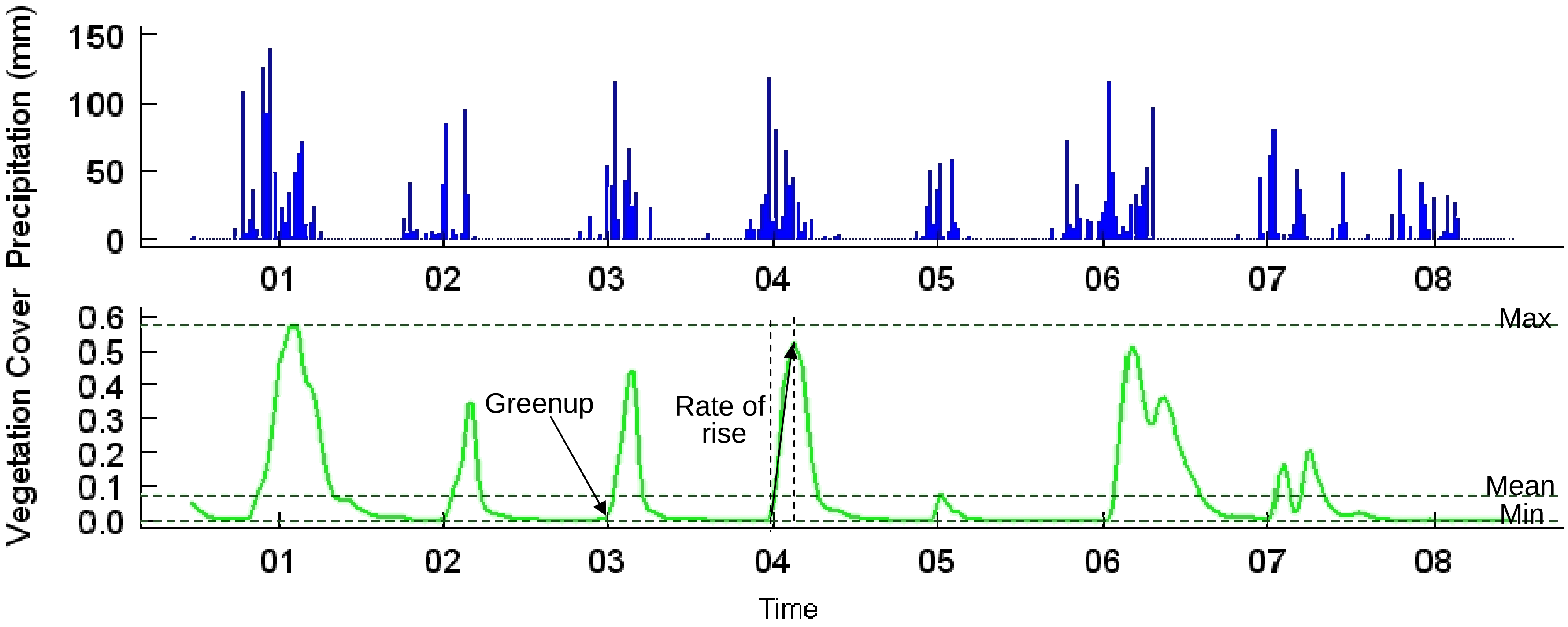


Semi-arid perennial grasslands

- Perennial grasslands dominated by tussock forming species (*Astrebla*, *Dichanthium*...). Mostly Mitchell grass dominated grasslands.

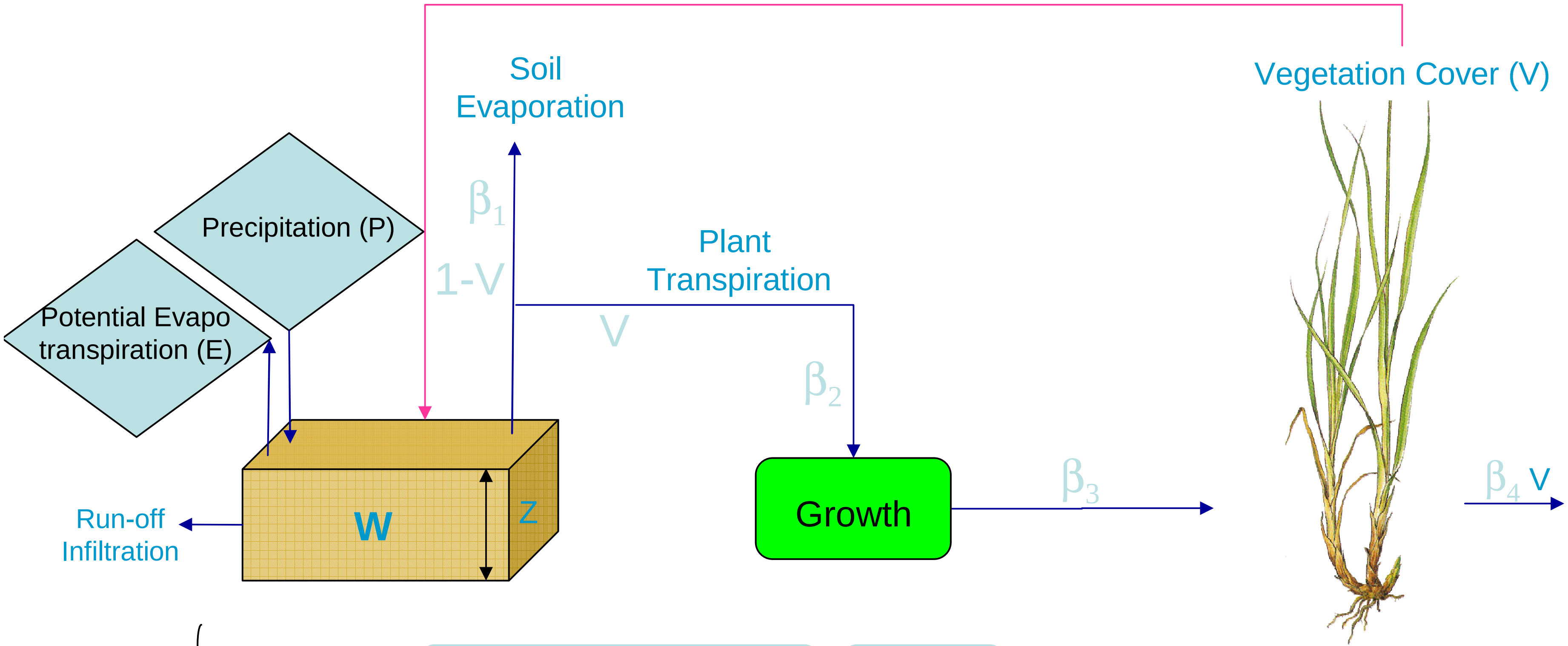
- Mainly found on cracking clay soils
- Support an extensive pastoral industry
  - one sheep/ha, one cow/10ha
  - $ 500 million AUD (2001) from sheep and cattle products

A diagnostic study



Nonlinear ecohydrological modelling

Choler & al. ***Biogeosciences*** **(in revision)**



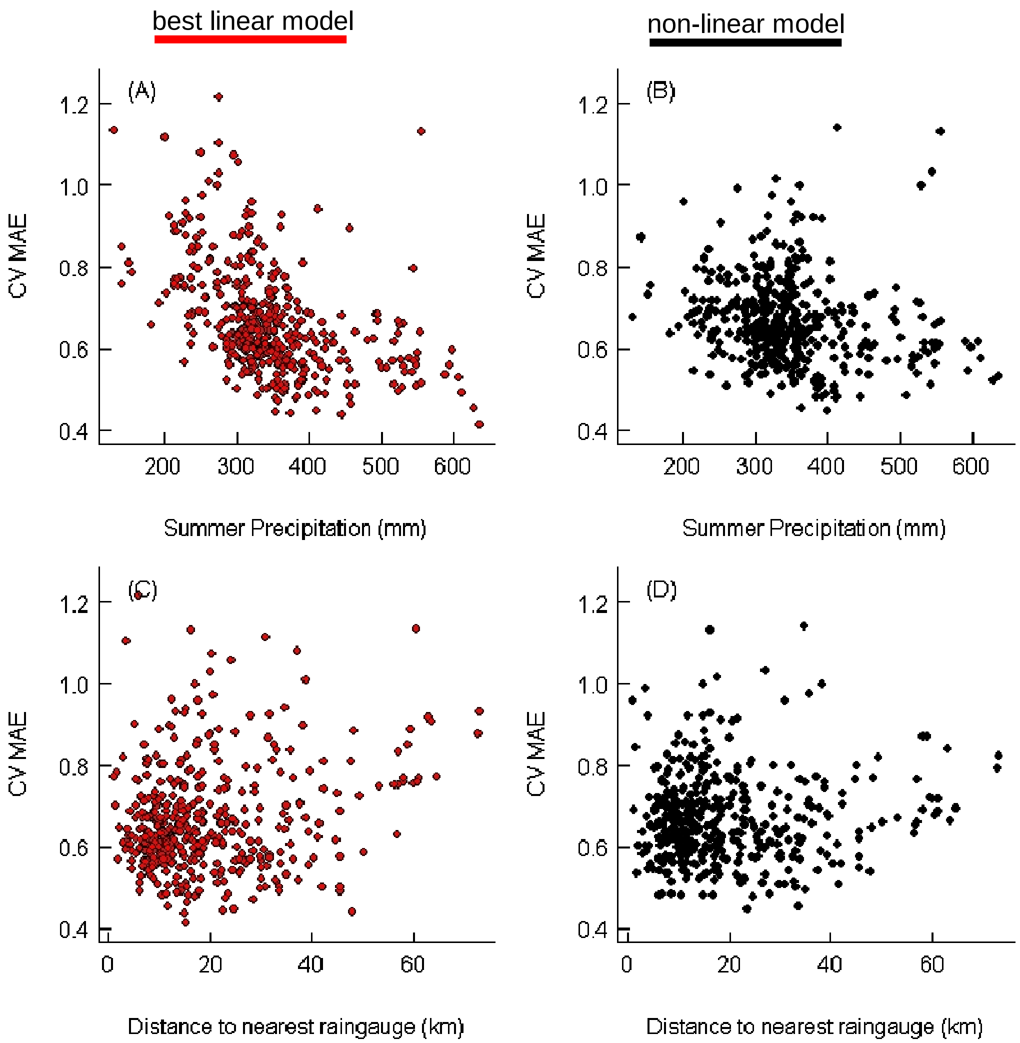
$$\frac{dW}{dt} = P - \beta_1 (1-V)(W/W_{cap})\,E - \beta_2\, V\, W \qquad \text{with } W \in [0, W_{cap}]$$

Soil Evap. — Plant Transp.

$$\frac{dV}{dt} = \beta_3 (W/W_{cap})\, V\, (1 - V / V_{max}) - \beta_4\, V \qquad \text{with } V \in [0, V_{max}]$$

Logistic Growth — Leaf Mortality

Analysis of model residuals

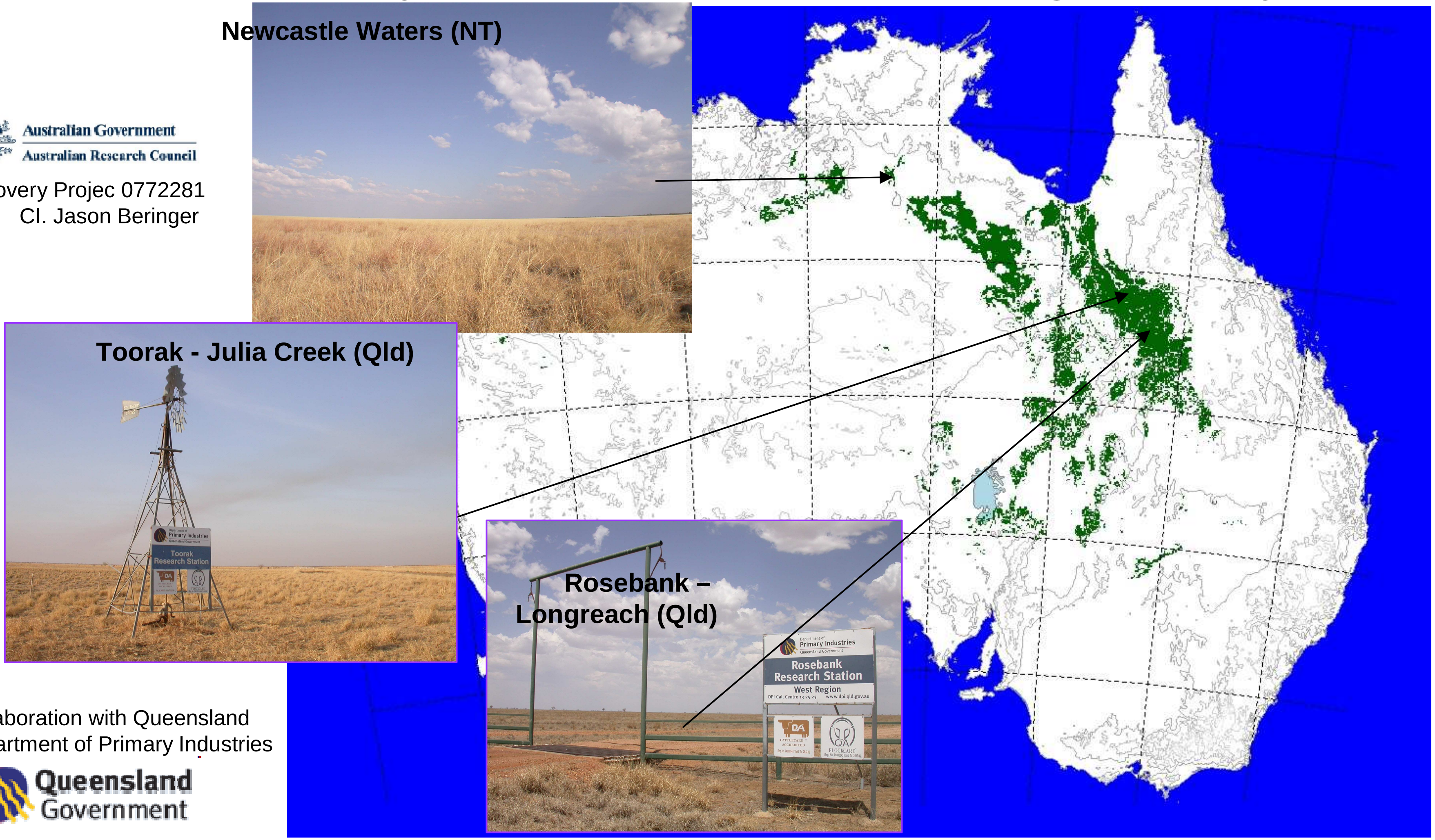


- Residual analysis shows
  - performance of nonlinear models is more consistent across the precipitation gradient
  - no significant effect of the uncertainty in rainfalls (distance to raingauge)
  - no significant effect of distance to watering point (proxy of grazing pressure) (not shown)

Choler & al. *Biogeosciences* (in revision)

Downscaling

Currently three instrumented sites in Mitchell grass country



Australian Government
Australian Research Council

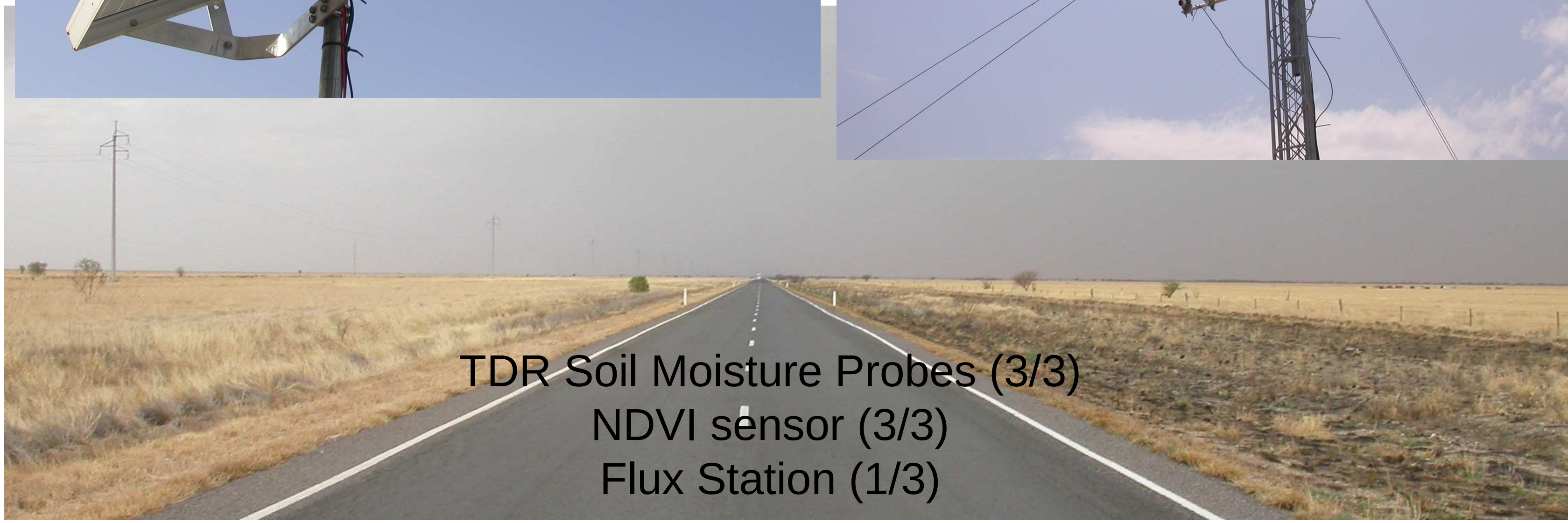
Discovery Projec 0772281
CI. Jason Beringer

Collaboration with Queensland
Department of Primary Industries

Queensland
Government

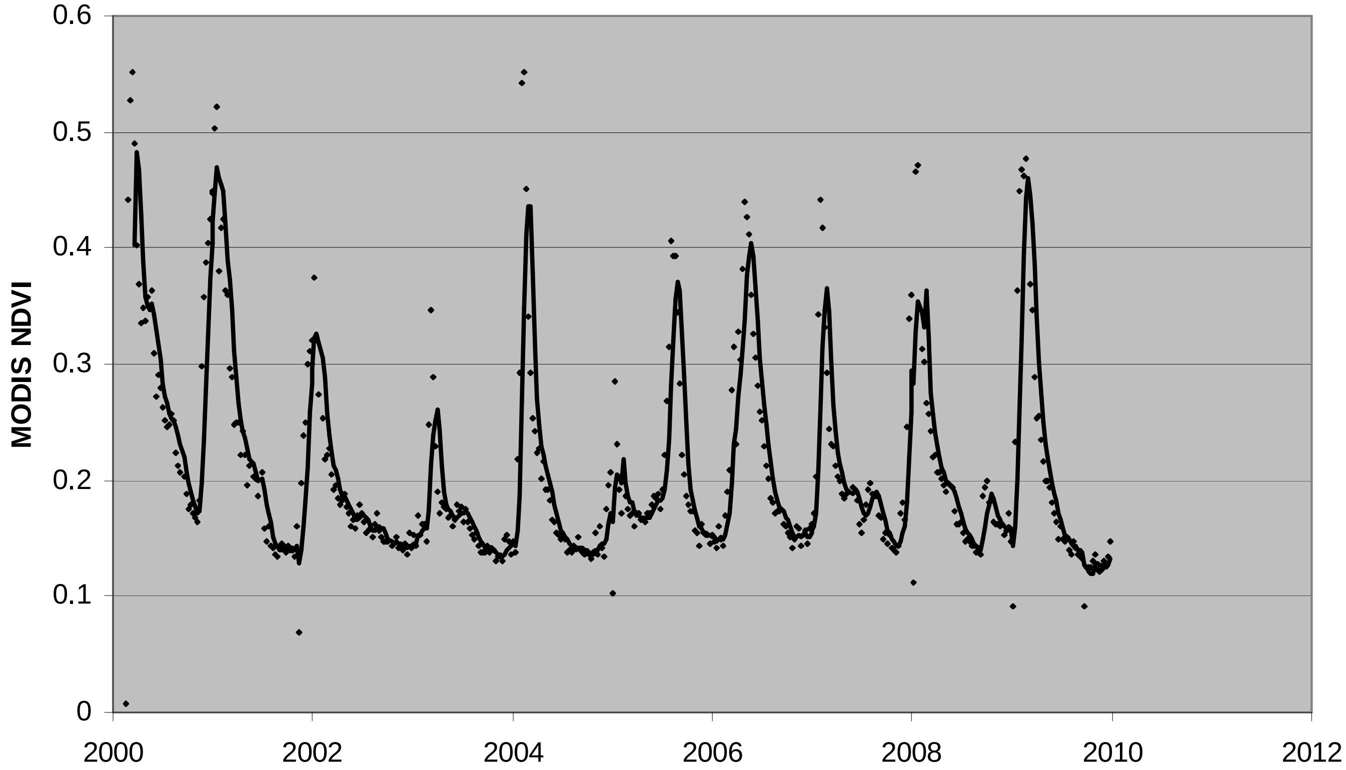
On ground measurements

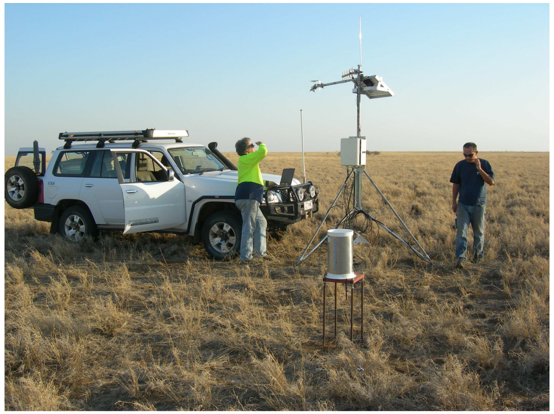
$$NDVI = \frac{NIR - RED}{NIR + RED}$$



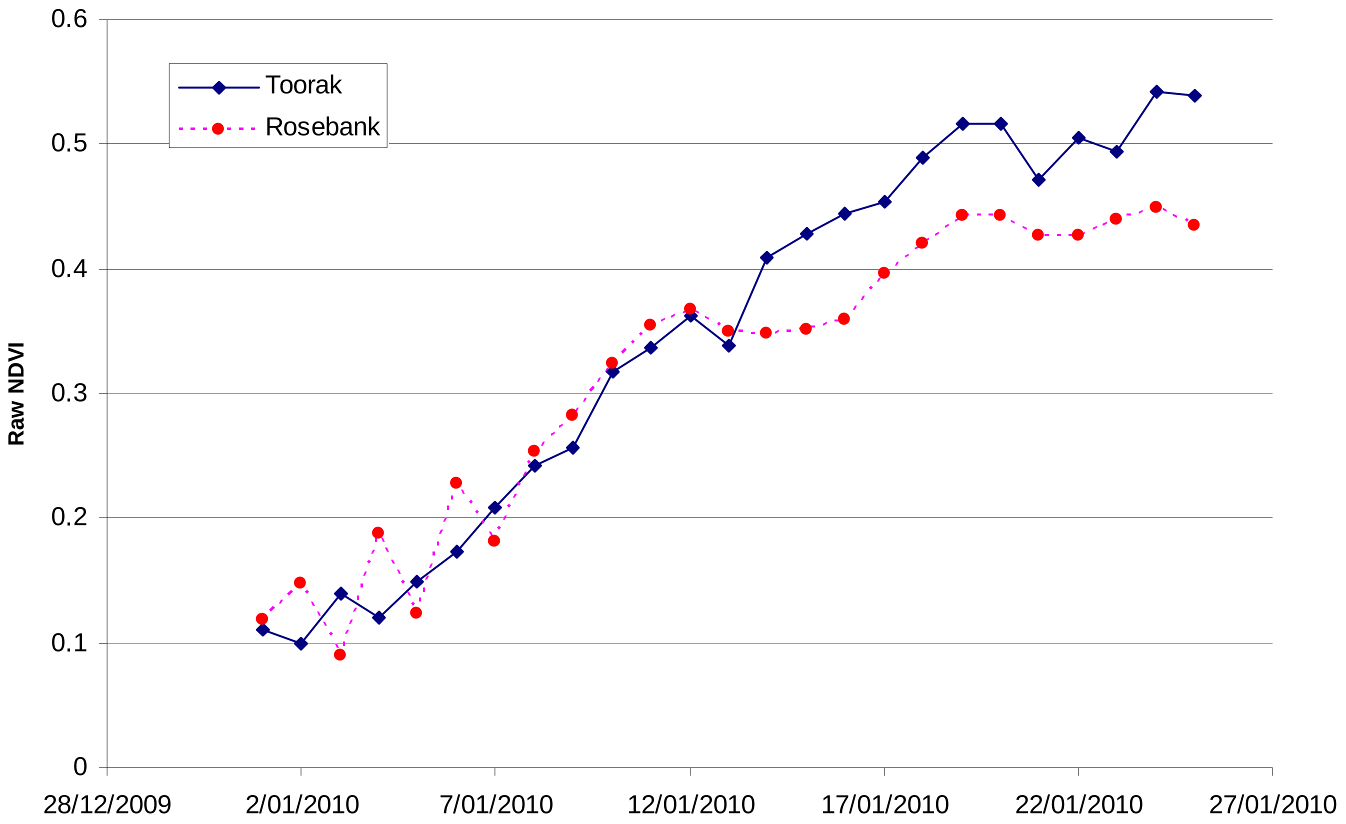
TDR Soil Moisture Probes (3/3)
NDVI sensor (3/3)
Flux Station (1/3)

MODIS phenology at Rosebank



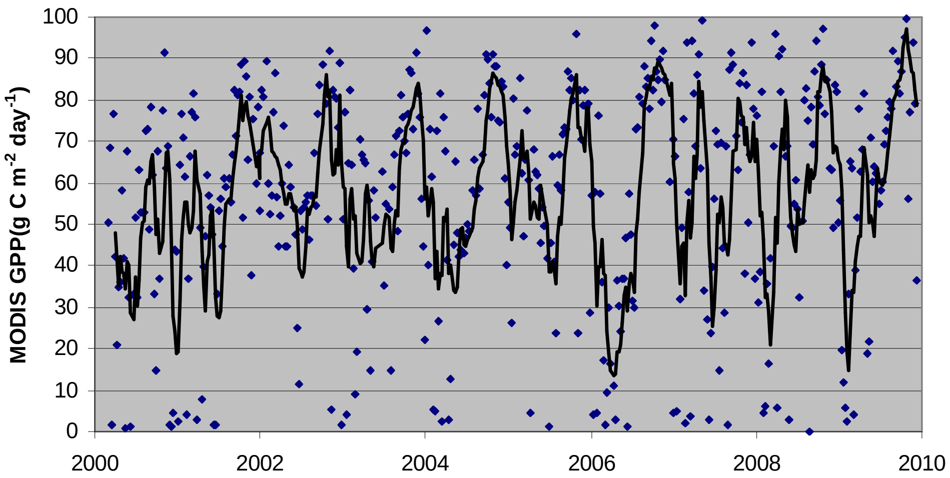


How is it doing?

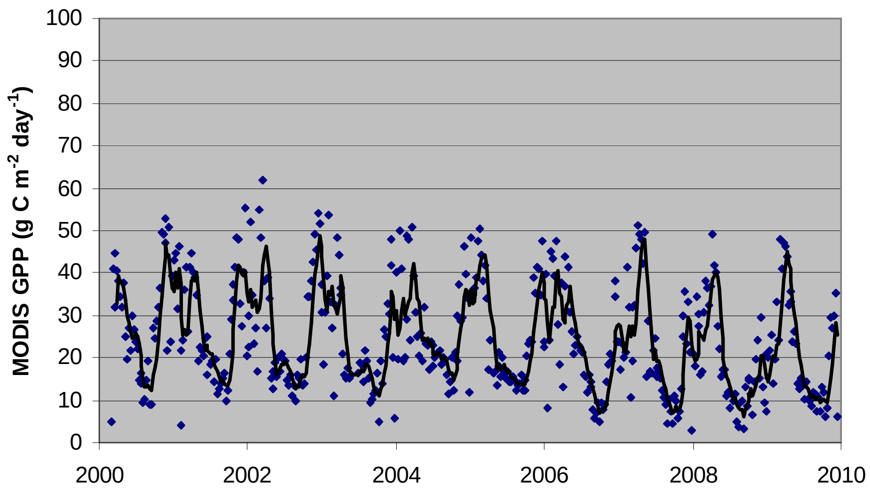


Exercise 2: GPP, finding the flux tower?

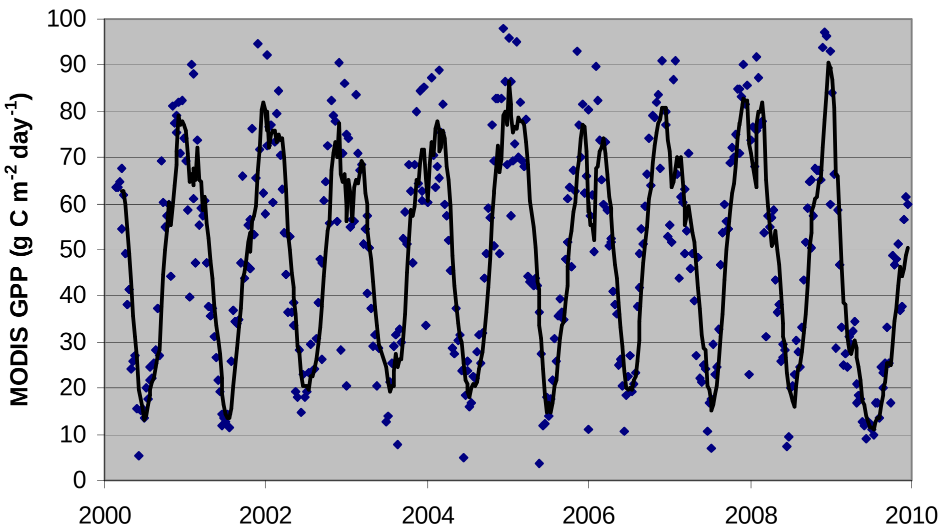
A 21.0 tons C ha^{-1} yr^{-1}



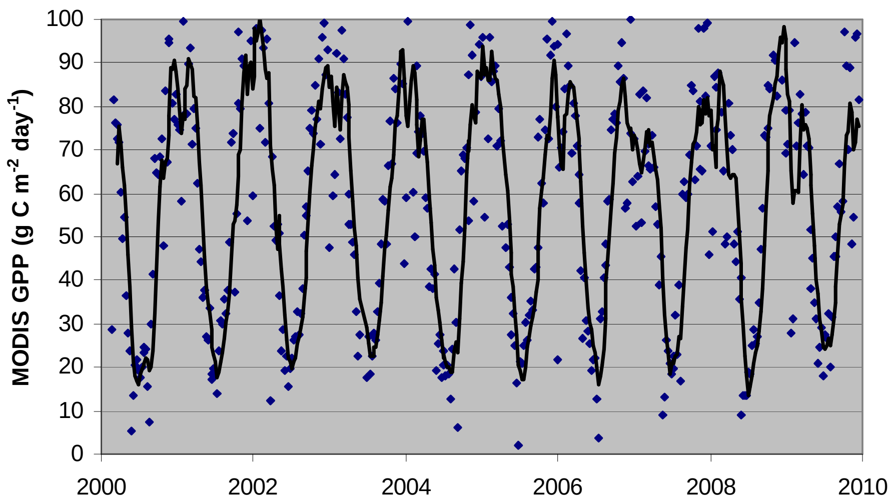
B 10.0 tons C ha^{-1} yr^{-1}



C 18.6 tons C ha^{-1} yr^{-1}



D 21.4 tons C ha^{-1} yr^{-1}



Summary

- Remote sensing products are “tailored-made” for phenology studies.
- Additional datasets such as gridded climatology and fire scars allow us to study the drivers of phenology.
- Remote sensing allows to potentially scale up from our flux tower measure to the larger scales.
- Simple ecohydrology models are elegant alternatives to more complex model, and when fairly compared, may do a better job.