Coupling carbon allocation with leaf and root phenology accounts for tree-grass partitioning along a savanna rainfall gradient.

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Motivation

- Vegetation dynamics of global savanna systems , which exhibit enormous spatio-temporal variability in woody and herbaceous biomass, structure and plant functional forms are poorly understood (Lehmann 2009).
  - Accurate C-allocation and phenology for the main elements of savanna systems (trees and grasses) may be a key to understanding variations in tree/grass partitioning in time and space in the savanna biome worldwide.
- No existing vegetation model allows phenology to emerge as a result of allocation of assimilated carbon.
- New approach: links phenology and allocation, accounting for a temporal shift between assimilation and growth, mediated by plant carbohydrate storage

New Model: Key Elements

- Two-store dynamic water balance model (basis for AWAP) (Raupach et al. 2008)
- Vegetation model predicts dynamics of leaf and fine-root carbon in trees and grass
- NPP depends on limiting resource uptake by leaves and roots, and their respiration costs
- Growth (= NPP in the long-term) depends on soil moisture, current carbon pools and diagnosed C carrying-capacity.
- Dynamic Allocation: growth allocated to pool with highest marginal gain in NPP (Raupach 2005)
- Dynamic Storage: the resultant of NPP and growth

Dynamic Storage: the resultant of NPP and growth

- Change in Storage (zero in long term)

$$\int_{t-t_{av}}^{0} \frac{dC_{storage}}{dt} dt = \int_{t-t_{av}}^{0} F_{C,NPP}\, dt - \int_{t-t_{av}}^{0} F_{C,\mathrm{Growth}} dt$$

Long term change in Storage (non-structural carbohydrate)

Long term NPP

Long term growth

Logistic Growth

$$F_{C,Growth} = \underbrace{\beta_{growth}\left(\overline{F_{C,NPP}} + \Delta C_{storage}\right)}_{\text{Maximum Growth Rate}} \underbrace{w}_{\text{Relative Soil Moisture}} \underbrace{\left(1 - \frac{C_L + C_R}{C_{\max}}\right)}_{\text{Deviation From Carrying Capacity}}$$

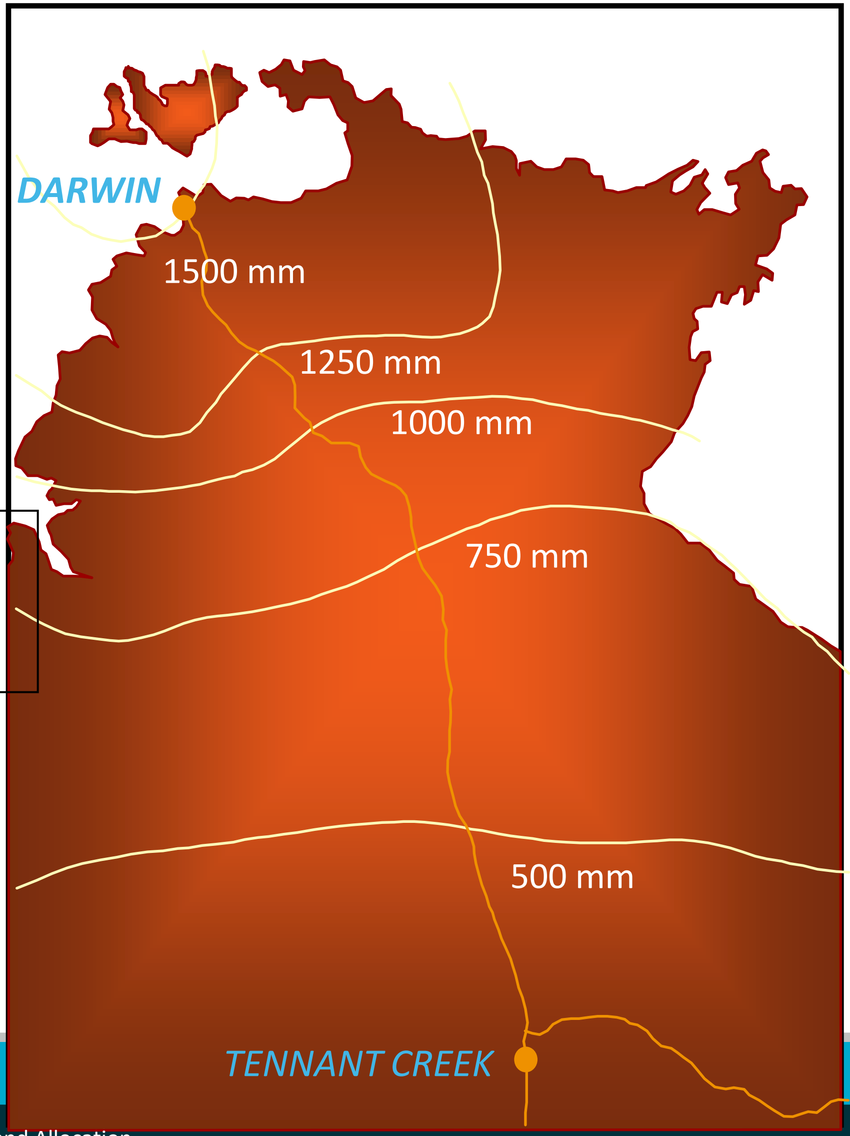
Dynamic Allocation: growth allocated to pool with highest marginal gain in NPP

- C dynamics controlled by allocation of growth , and first-order decay, e.g.

$$\frac{dC_L}{dt} = \alpha_L F_{C,Growth} - k_L C_L$$

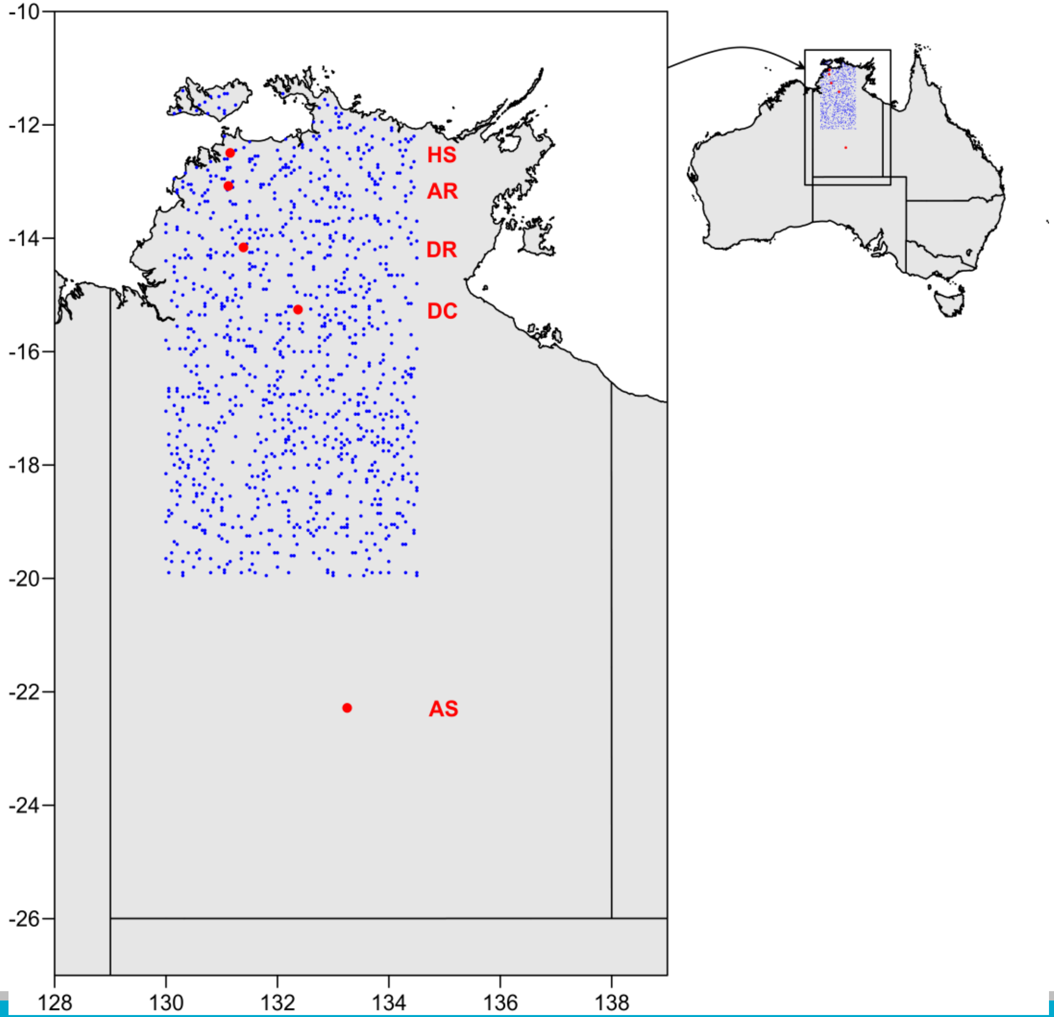
- Carbon allocation coefficients vary in time to maximise the total carbon gain, i.e. the long-term integral of $F_{C,NPP}$
- Allocation coefficients have "bang-bang" character
  - at each instant *t*, an allocation coefficient of one is assigned to the pool for which the marginal return on invested growth is largest while all the other pools receive zero allocation

Case Study: Northern Australian Tropical Transect

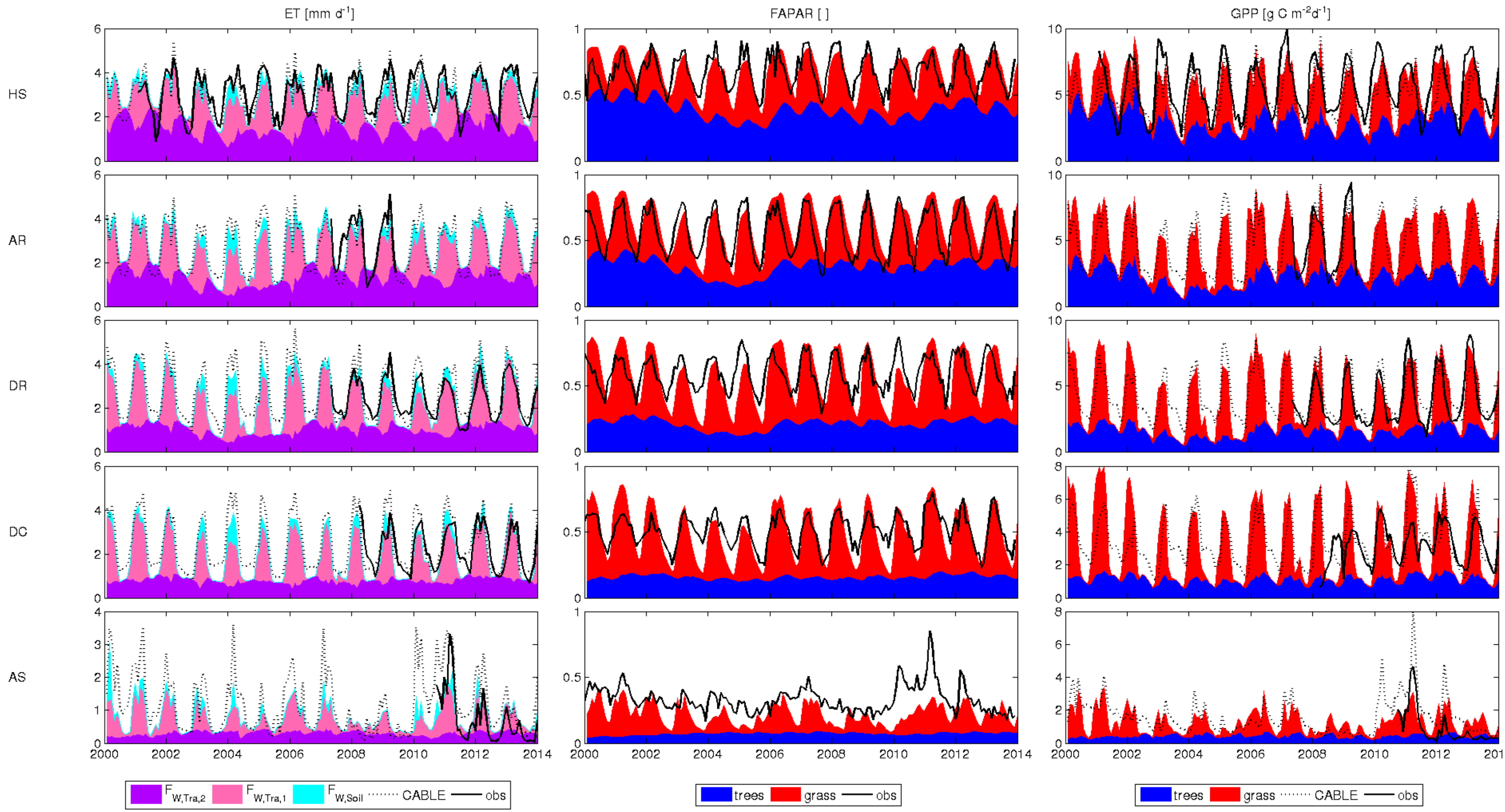


Photos: Adam Liedloff

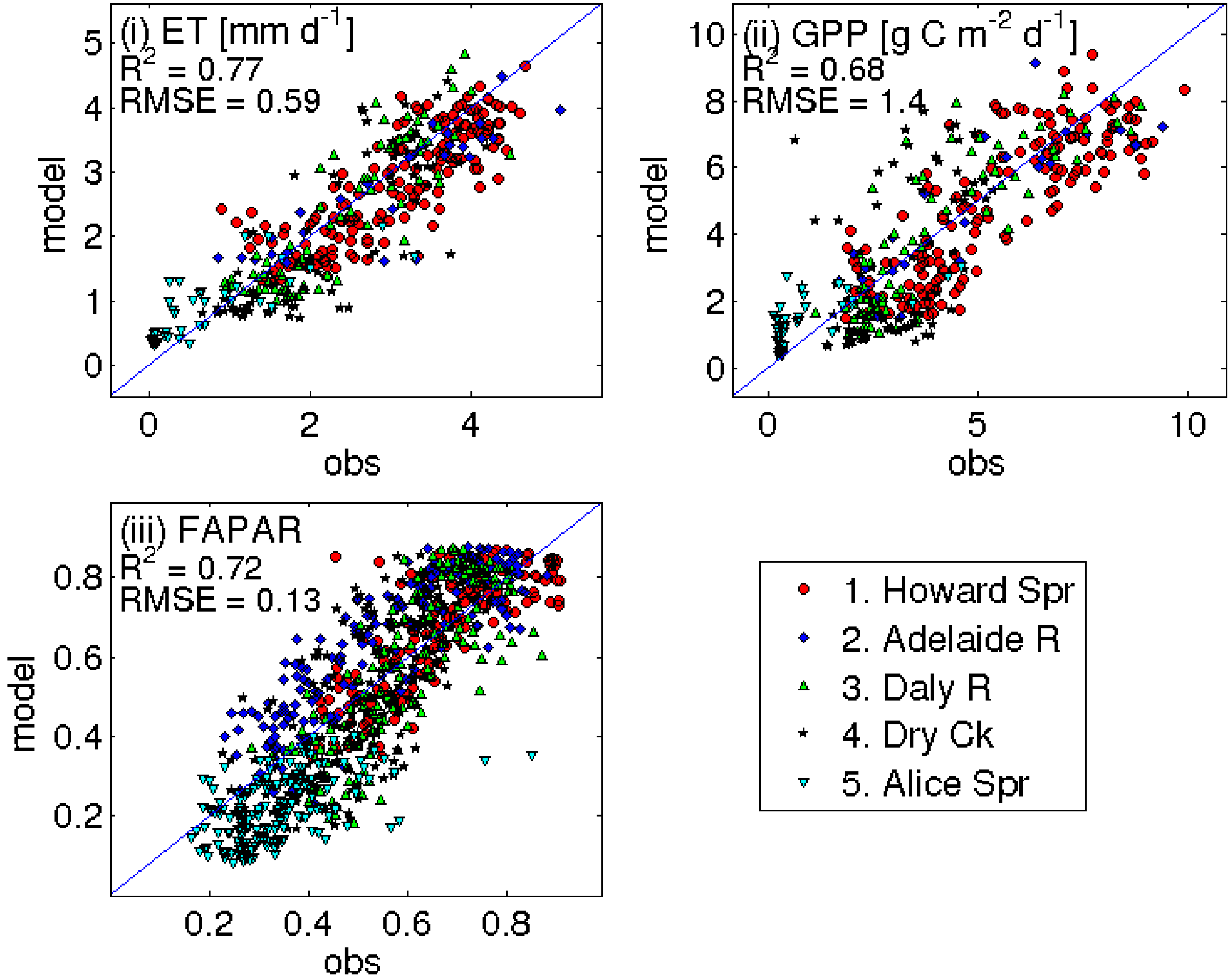
Sampling the Northern Australian Tropical Transect



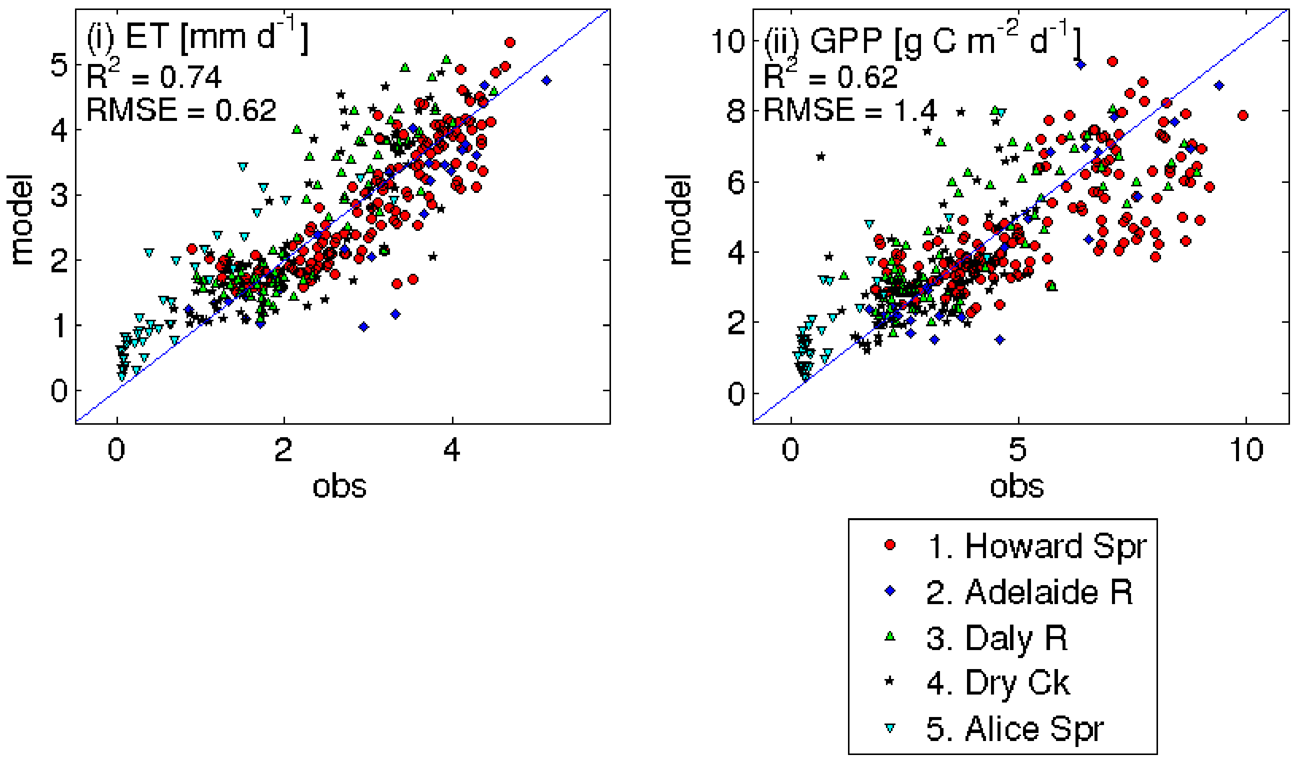
Model Validation: Flux Data and Remotely-Sensed Vegetation Cover



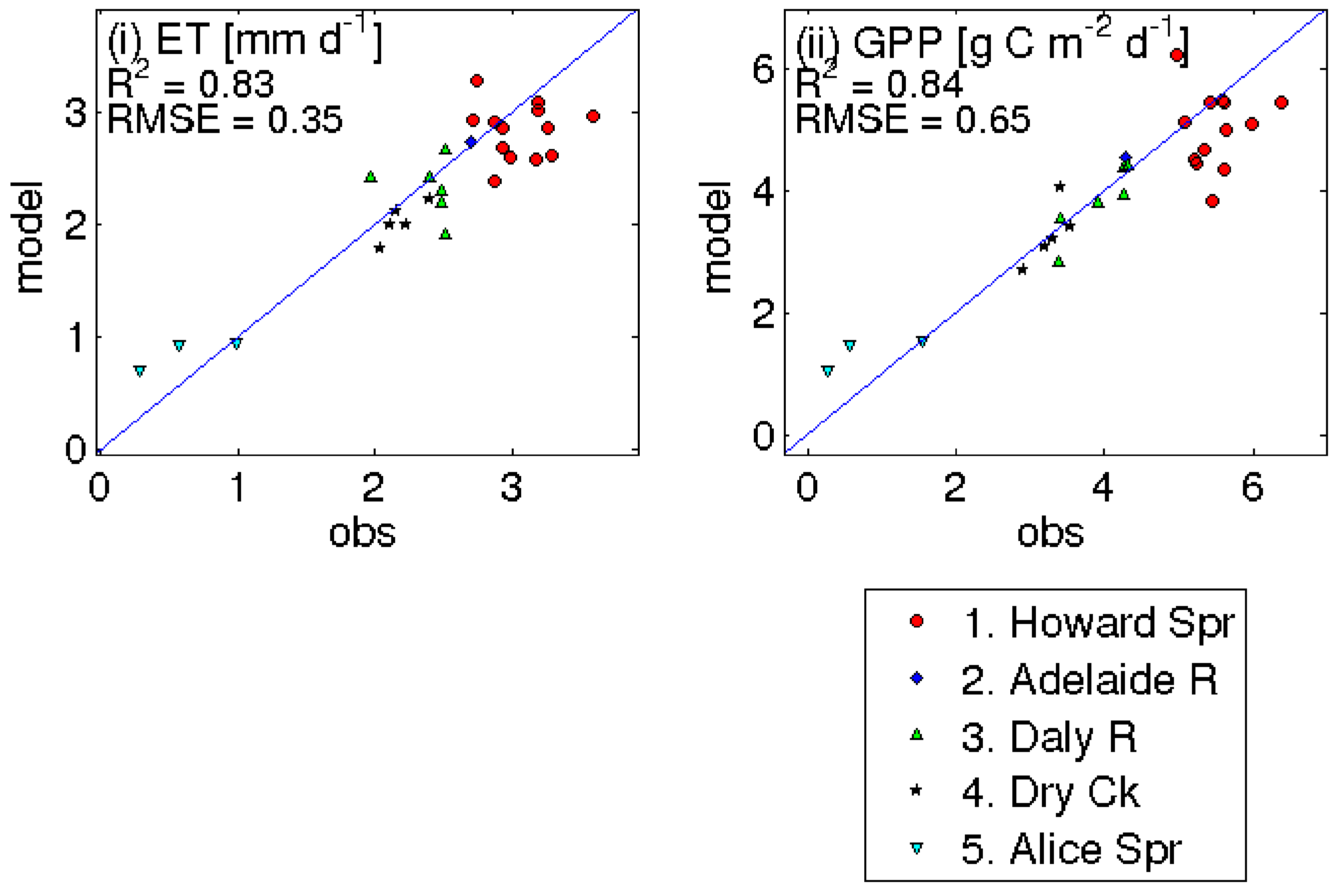
New Model Validation: Flux Data and Remotely-Sensed Vegetation Cover (monthly)



CABLE Model Validation: Flux Data (monthly)

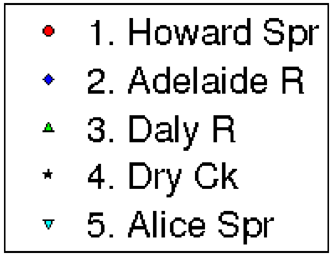


Model Validation: Flux Data (annual)



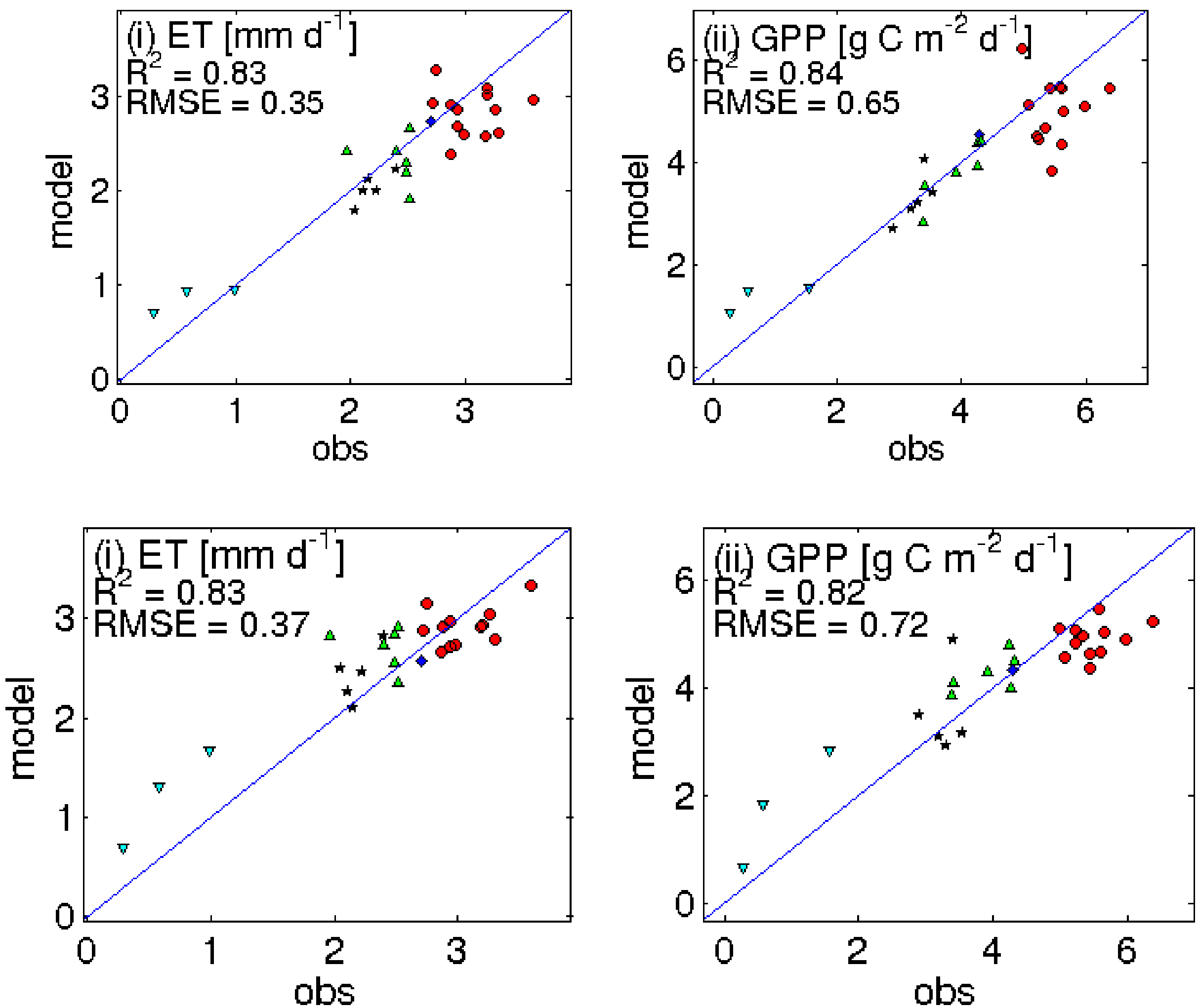
New Model

Model Validation: Flux Data (annual)

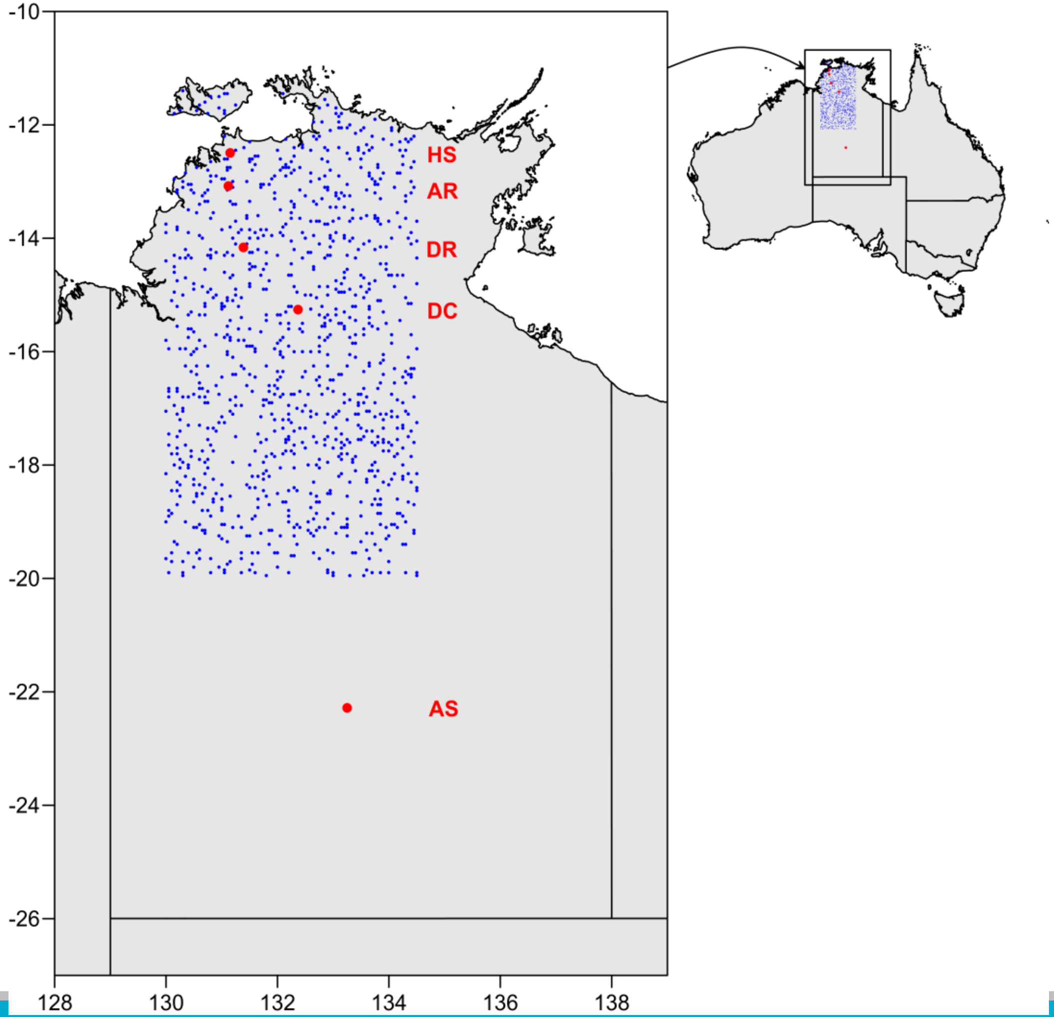


New Model

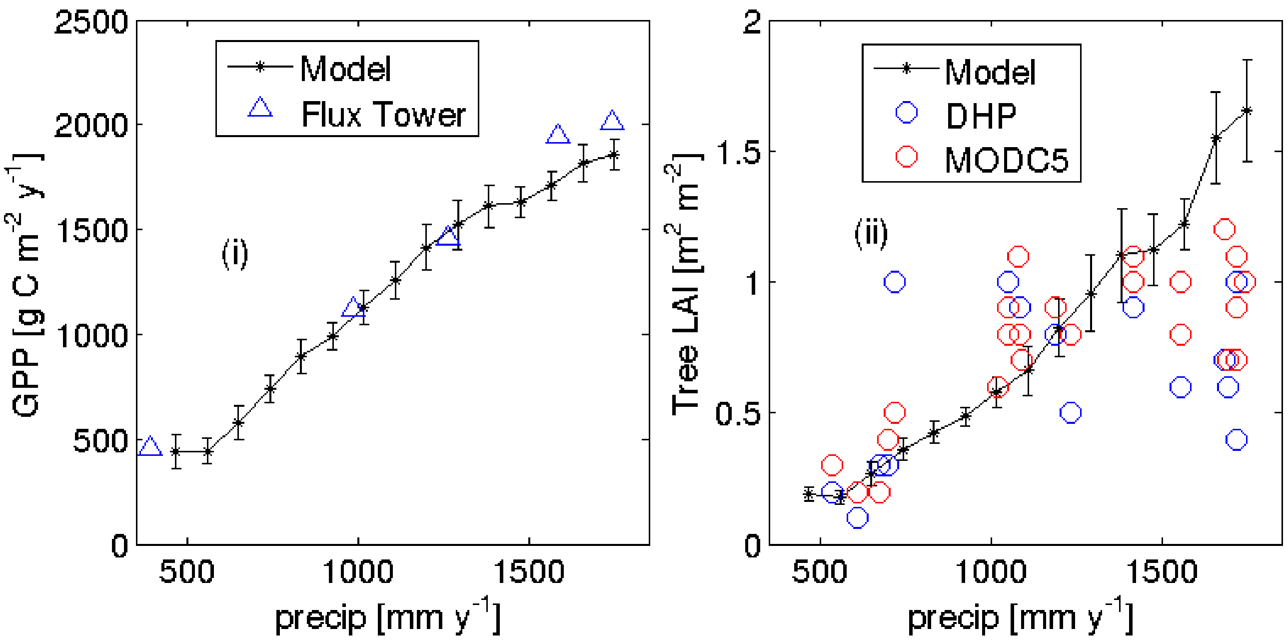
CABLE



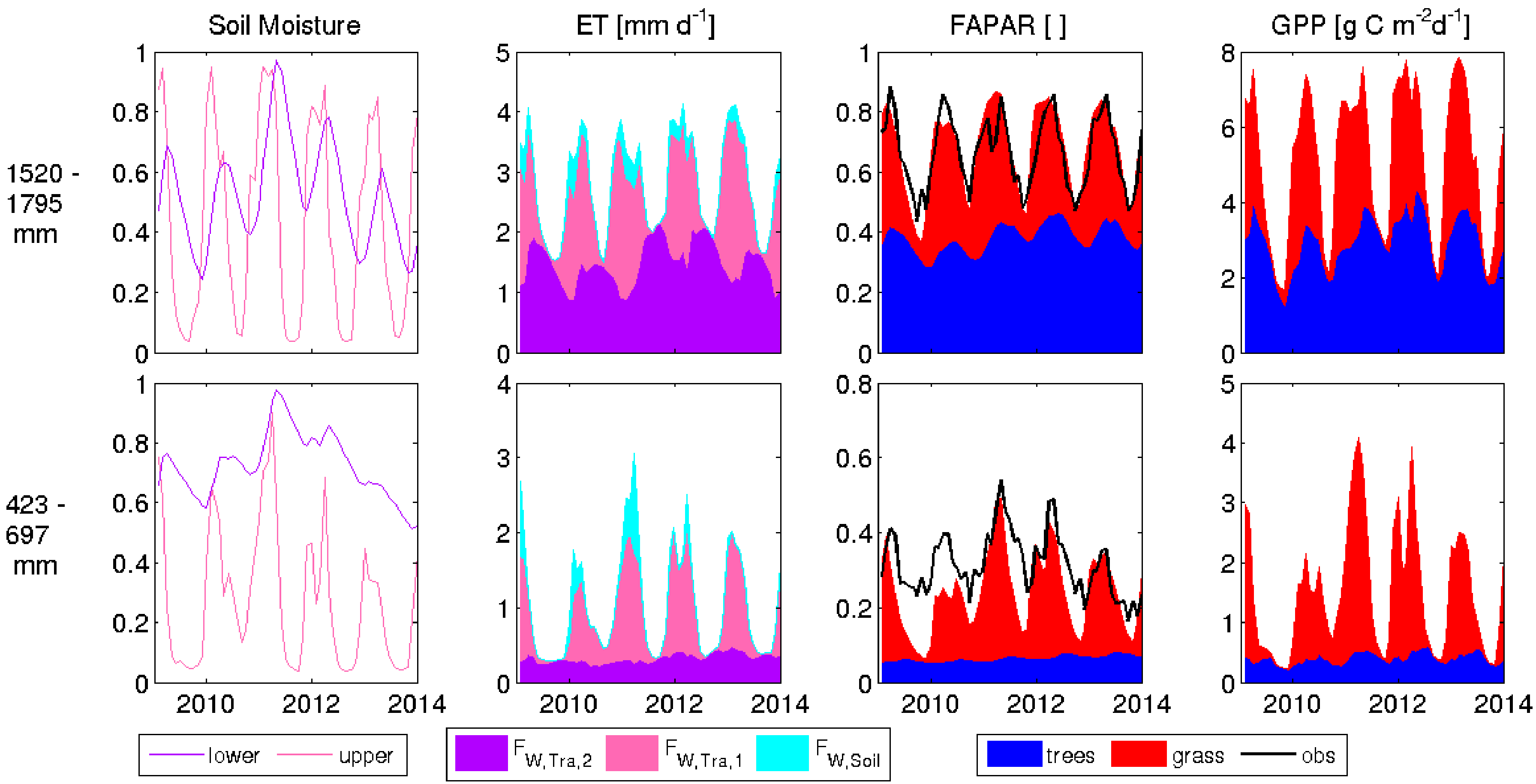
Sampling the Northern Australian Tropical Transect



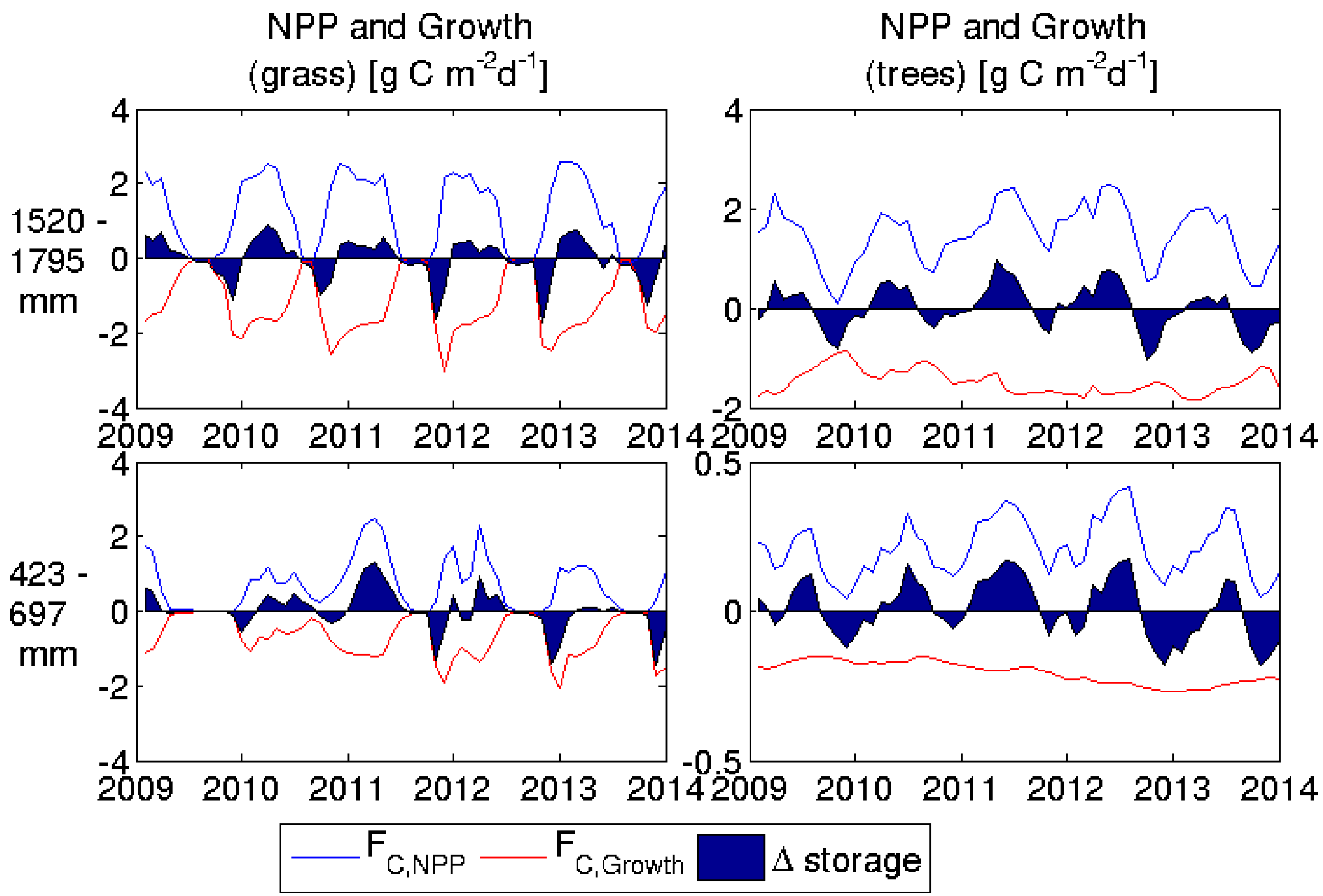
GPP and Tree LAI: Variation Along NATT



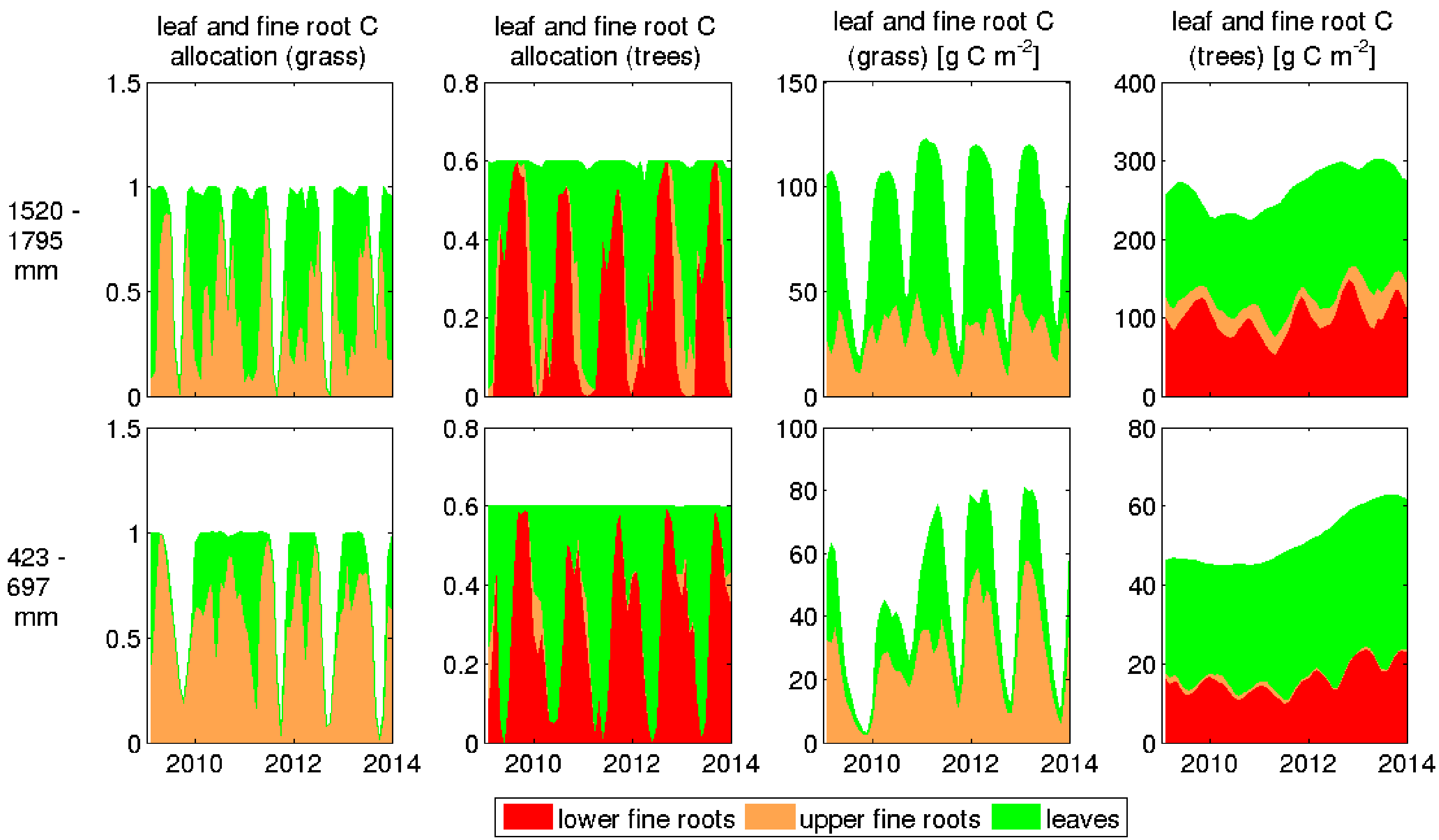
Model Dynamics: Soil Moisture, GPP, LAI



Model Dynamics: NPP, Growth and Storage



Model Dynamics: Allocation and C Pools



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Future Directions: Merging with POP

A stand-alone tree demography and landscape structure module for Earth system models

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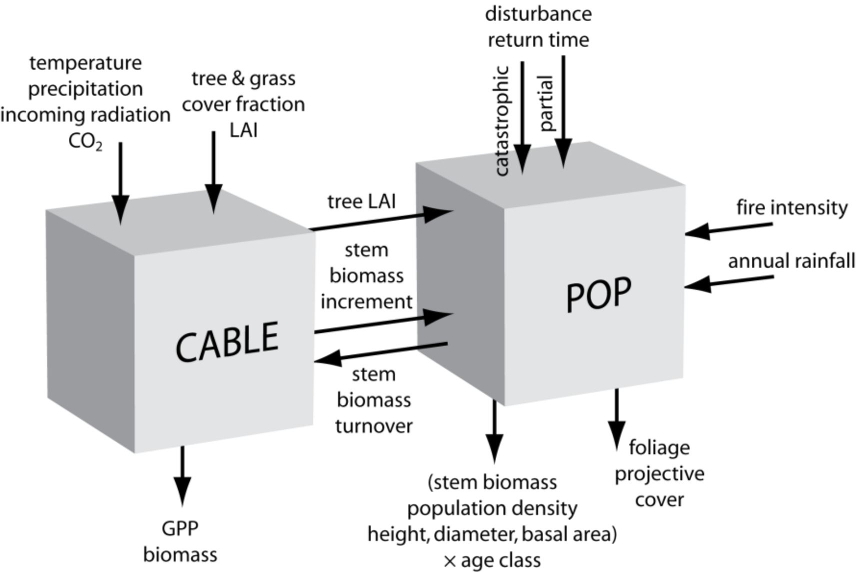
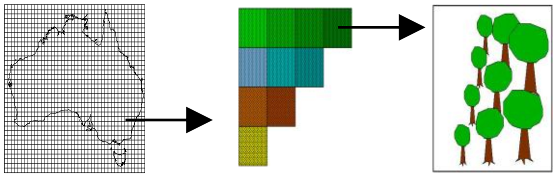
Received 12 July 2013; revised 17 September 2013; accepted 18 September 2013.





Grid-cell (tile) represented by patches distinguished by time since last disturbance

Recruitment, Growth, Mortality in each patch

Future Directions

- Coupling Phenology/Allocation model with POP -> POPOP
- Coupling POPOP with CABLE
- Integration with Fire Model
- Application of POPOP in CABLE to Australian and Global Savannas