Impact of fire on the carbon cycle of Australian savannas

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TROPICAL SAVANNAS CRC

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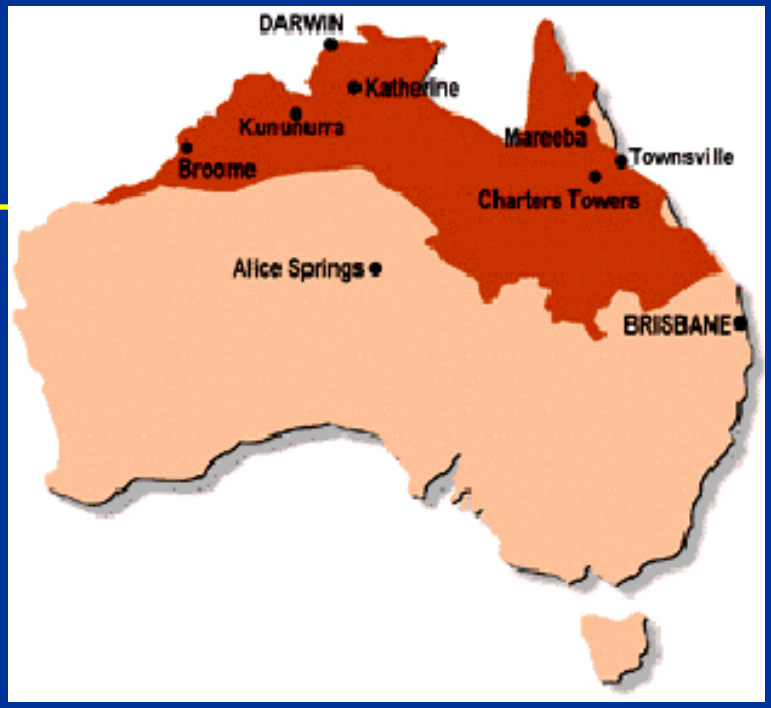
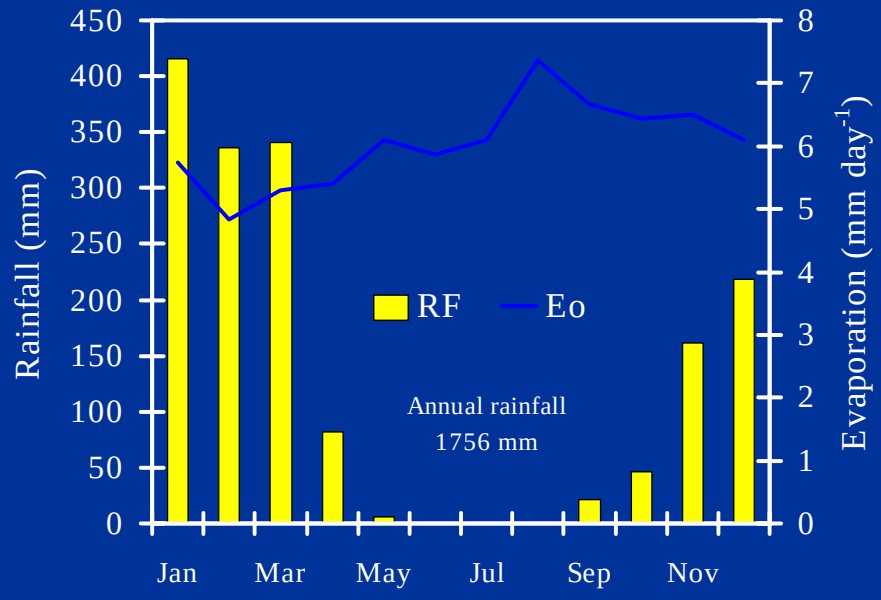
Overview

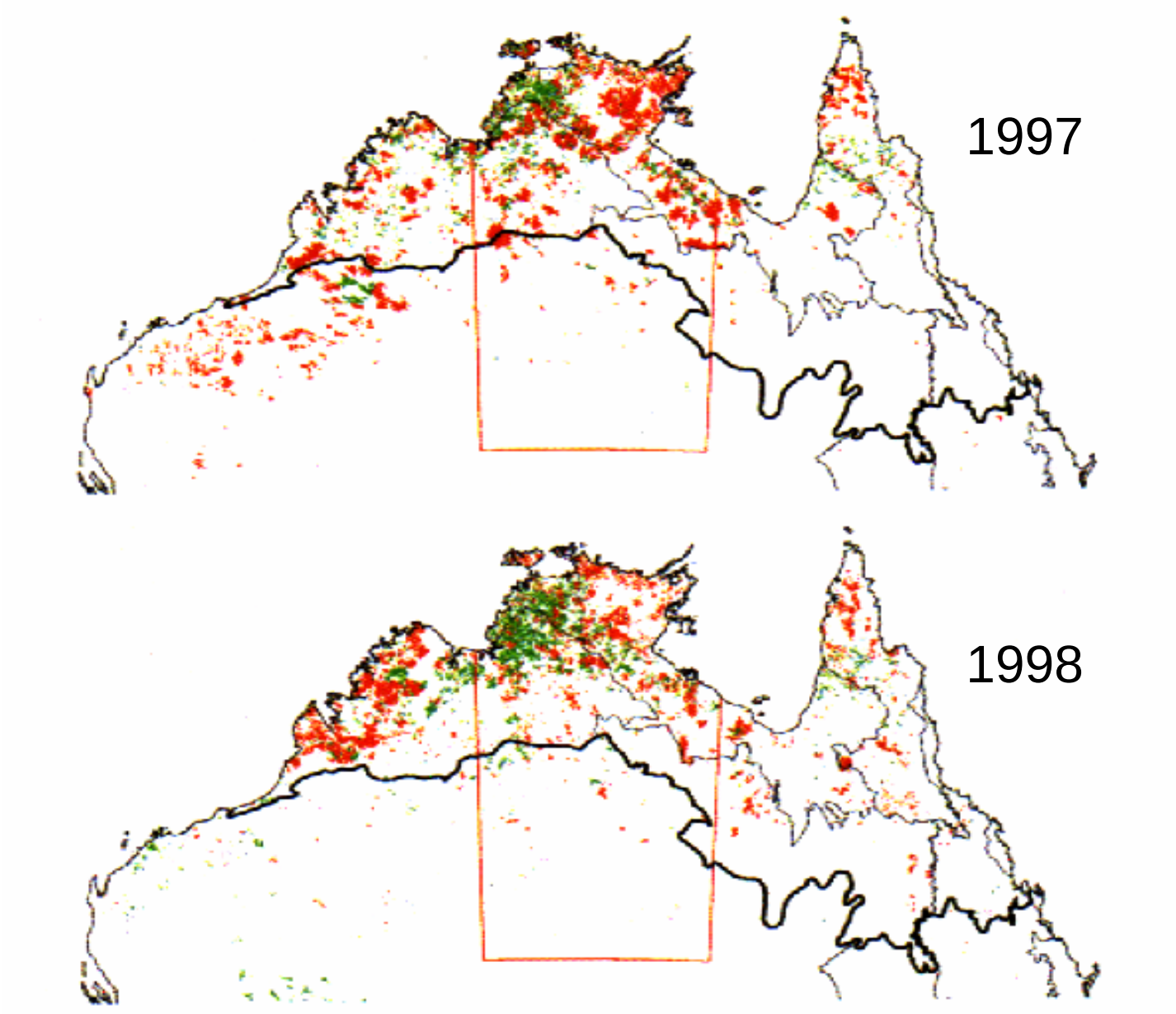
- North Australian Savannas
- Research questions
- Howard Springs field site
- Results
  - Biophysical impact and surface energy and moisture fluxes
  - Burning and ecosystem productivity
- Conclusions

Australian tropical savannas



- Savanna - trees (C3) and grass (C4)
- Open-forest/woodland savanna 25% of Australia, ~2 million km^2
- Mining, Tourism, Pastoralism, Culturally
- Cyclones, grazing and FIRE are disturbances
- Highly seasonal climate in the wet-dry tropics





Early dry season **Late dry season**

(Russell-Smith *et al*. 2000)

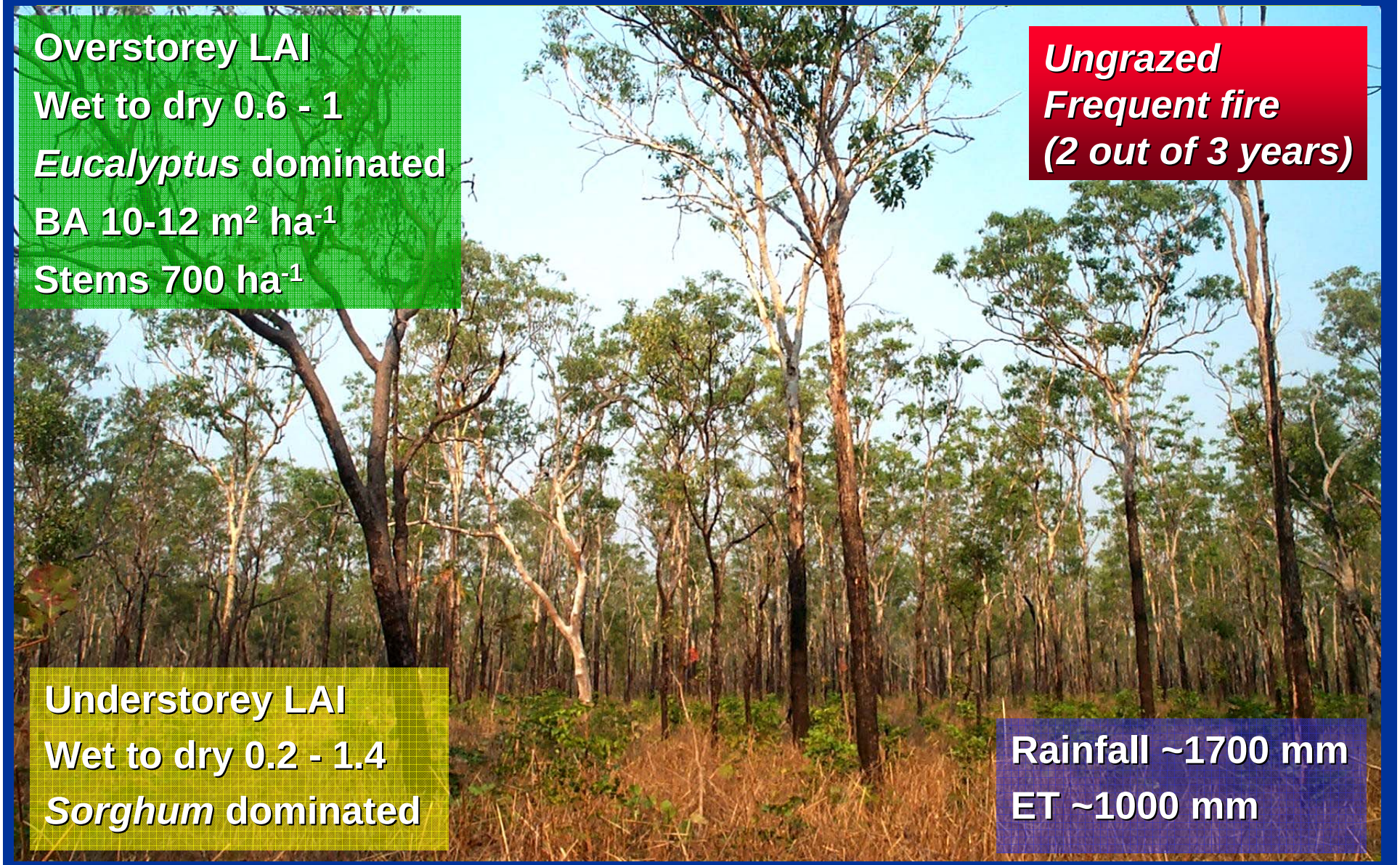
Research questions

What is the impact of fire on:

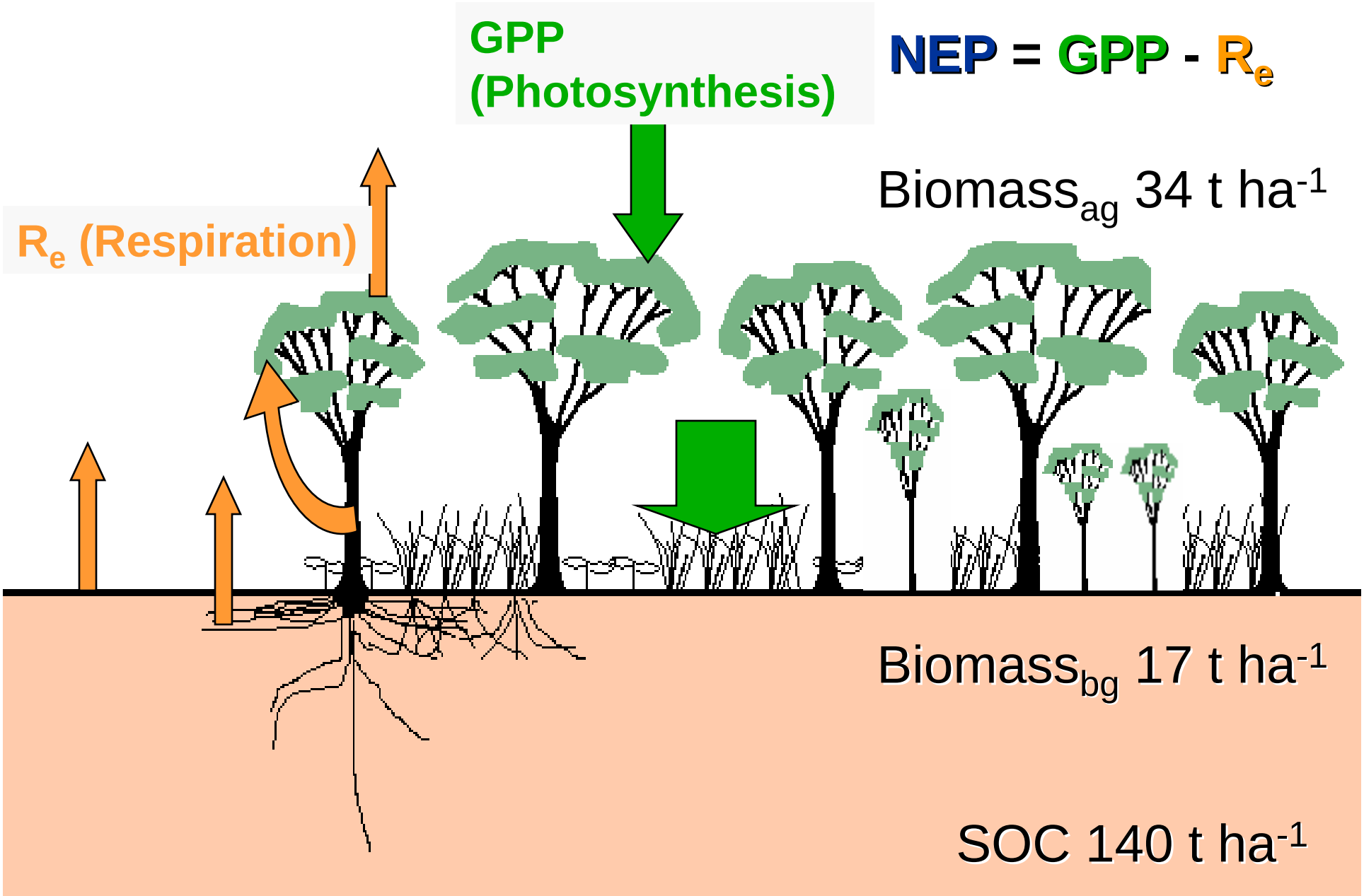
- carbon fluxes (including emissions) and ecosystem productivity?
- surface properties and canopy ?
- the surface energy balance?
- feedbacks to local and regional climate?

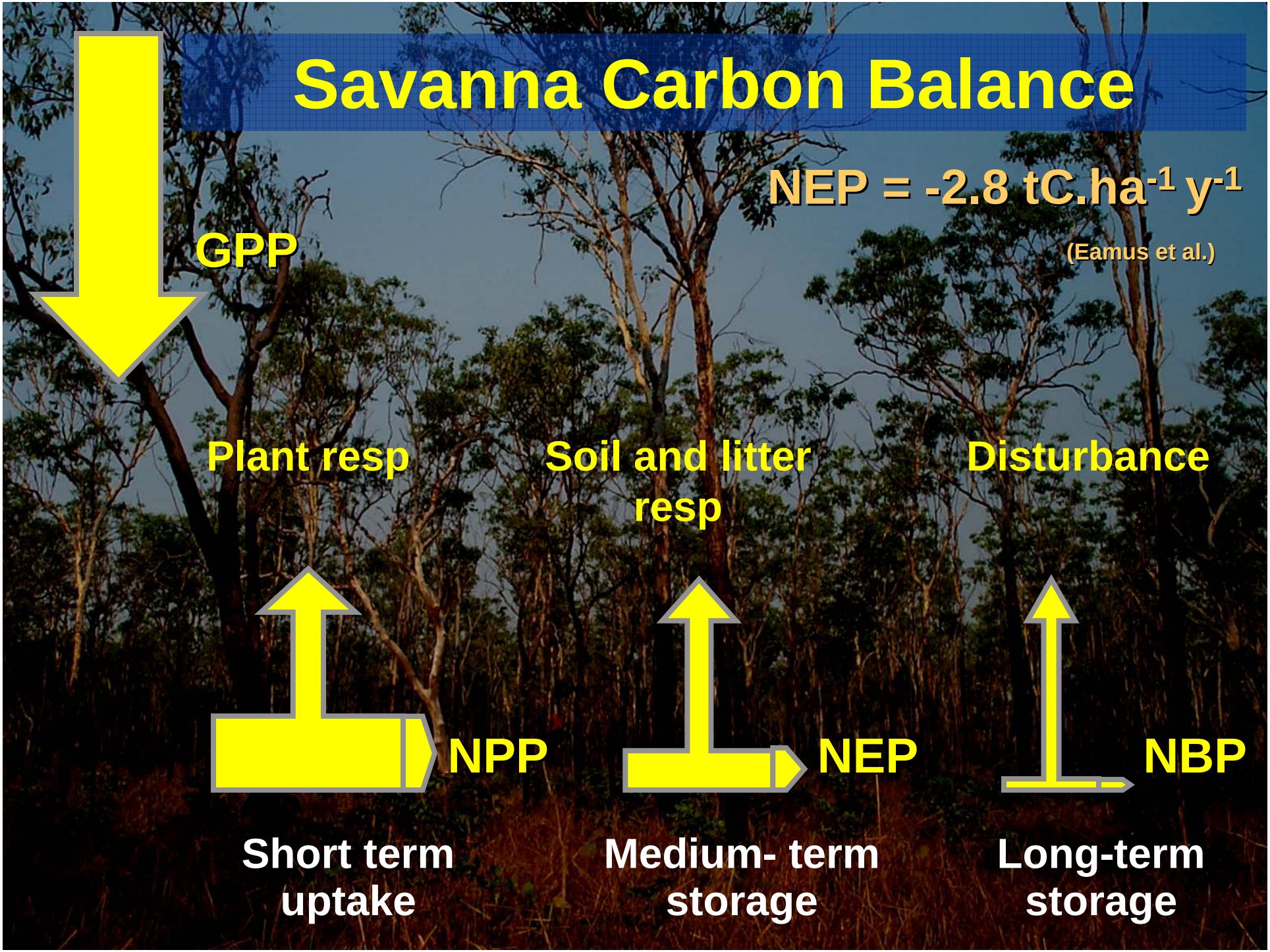
Research site at Howard springs

- Open-forest savanna



Savanna carbon fluxes and pools



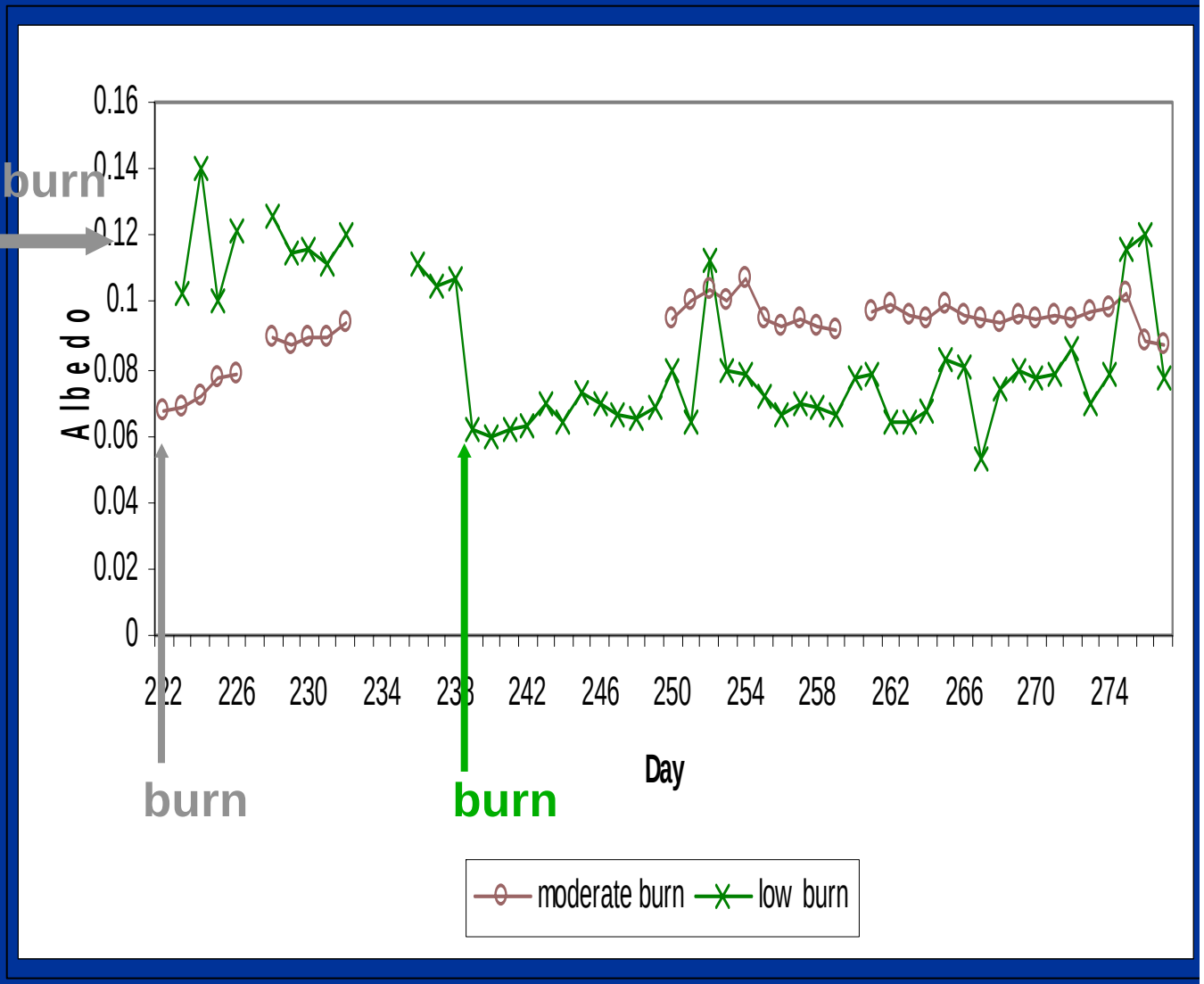

Savanna Carbon Balance
NEP = -2.8 tC.ha-1 y-1
(Eamus et al.)
GPP
Plant resp
Soil and litter resp
Disturbance
NPP
NEP
NBP
Short term uptake
Medium- term storage
Long-term storage

Flux measurements

- Use eddy Covariance technique to quantify net carbon, water and energy fluxes from the ecosystem
- Measure turbulent fluctuations CO_2, water vapour and heat (temperature) from burned and unburned savanna ecosystems.
- Nighttime corrected and gap filled data over 2 years
- Use long term flux measurements to determine carbon balance and Net Biome Productivity

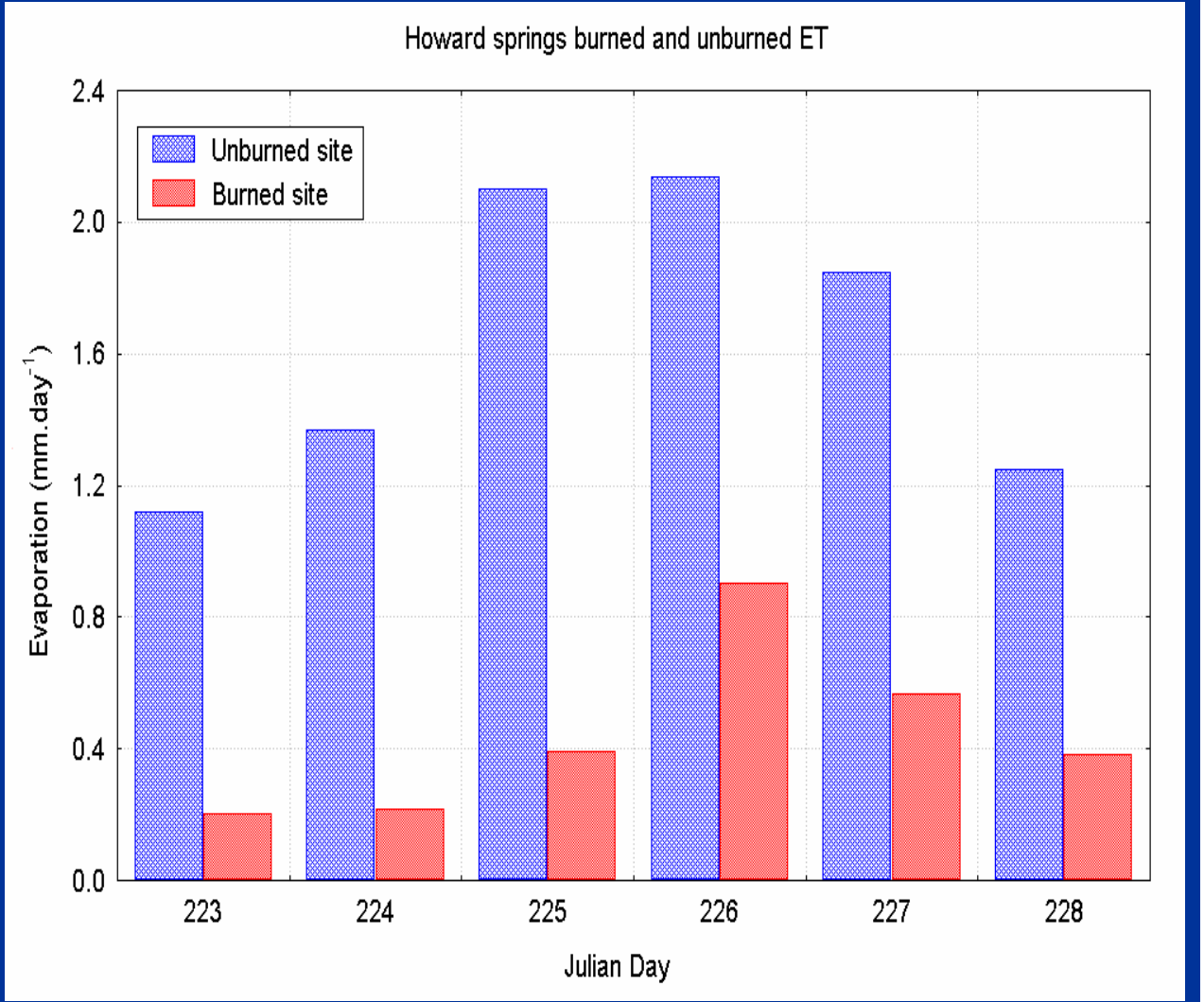
Biophysical ecosystem changes - Albedo

- Albedo halved
- Increase in absorbed radiation
- Moderate increase in R_n



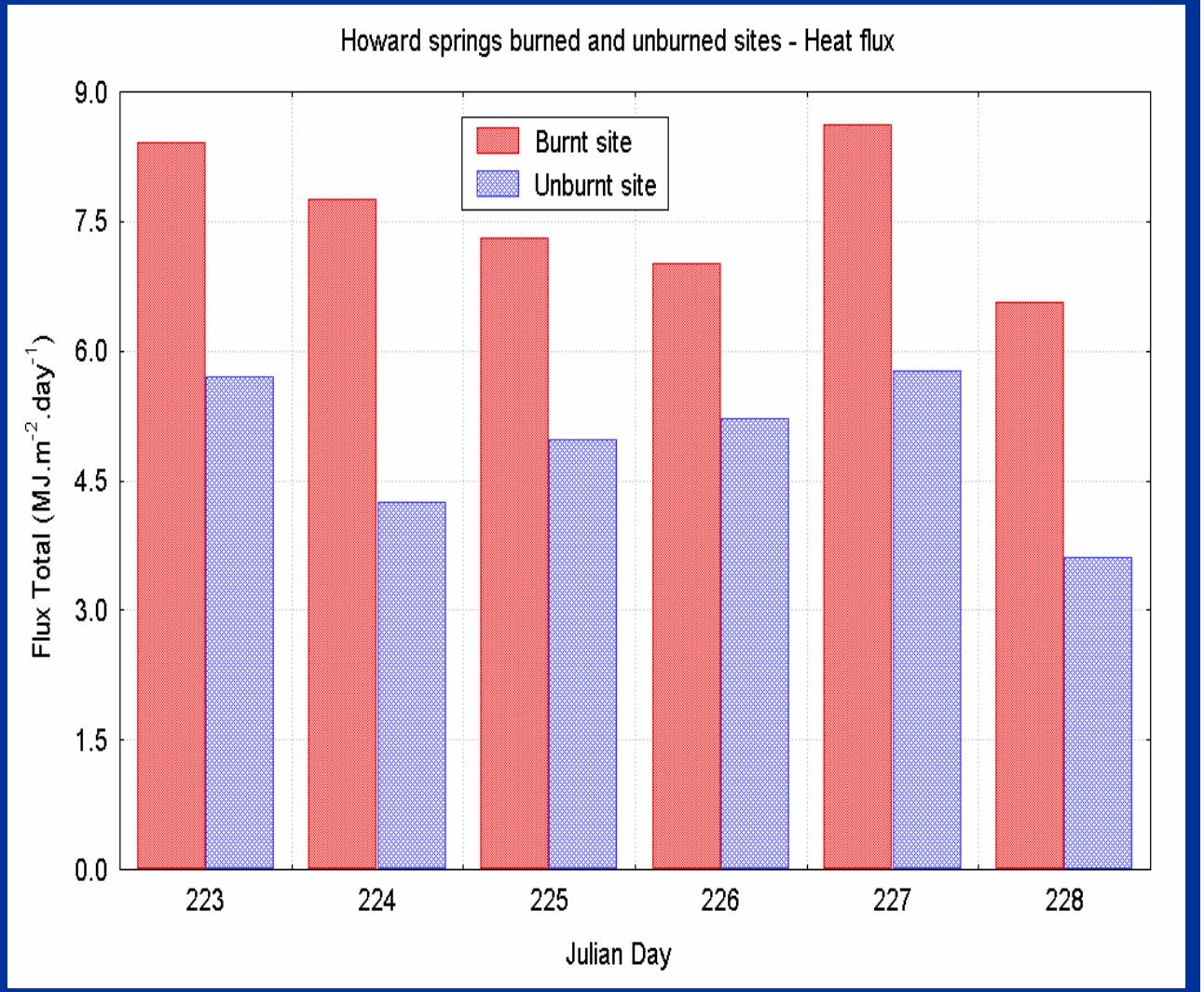
Biophysical ecosystem changes - ET

- Simultaneous measurements at burned and unburned sites
- Leaves are scorched and shutdown
- Transpiration reduced
- ET reduced by ~75%



Biophysical ecosystem changes – Sensible heat flux

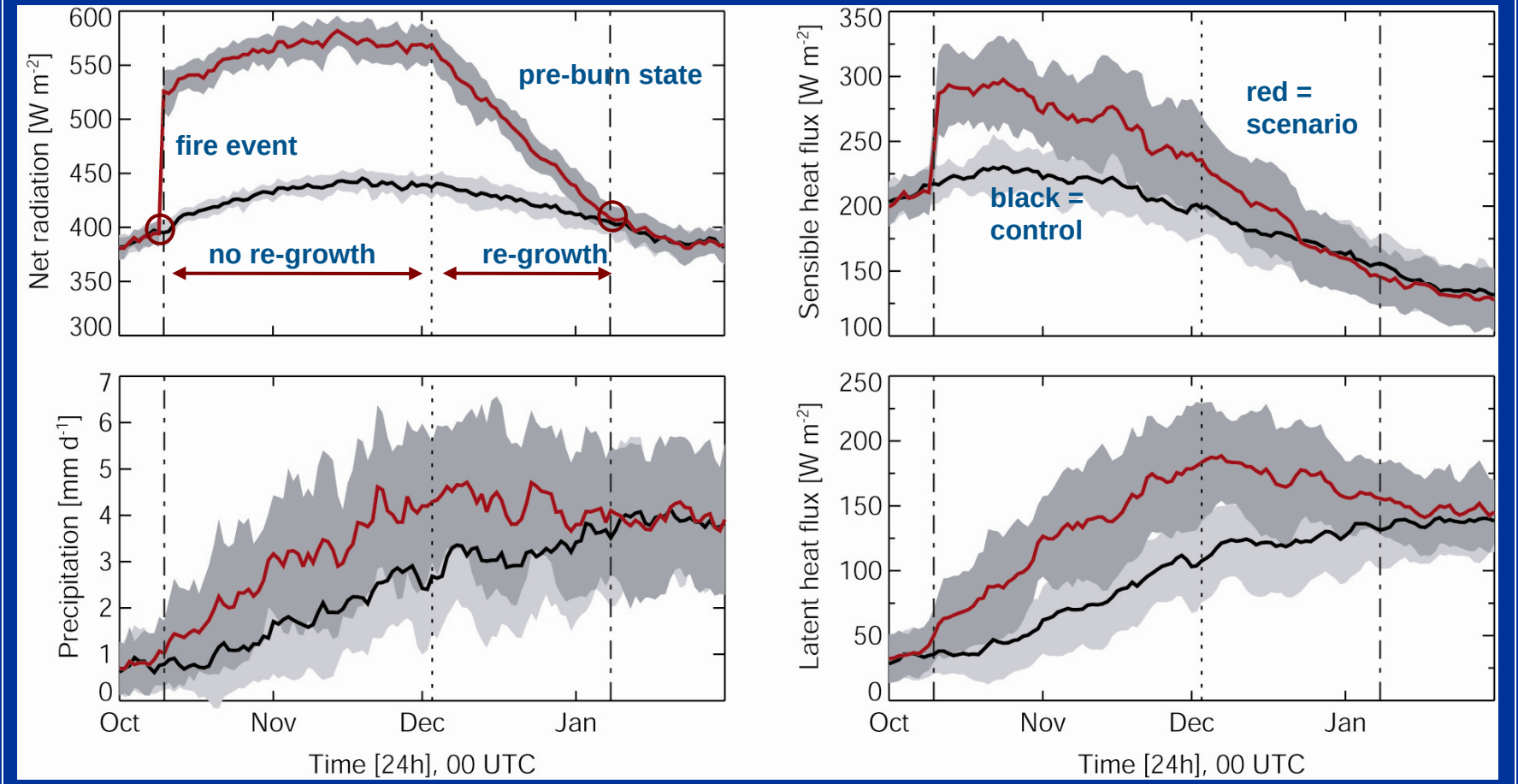
- Reduced ET results in increased partitioning into sensible heating
- Increased by ~40%
- Impact on overlying atmosphere?



Climatological Impacts Single Scenario, Regional Impacts

Longterm (1979 to 1999) means, averaged over fire-affected area

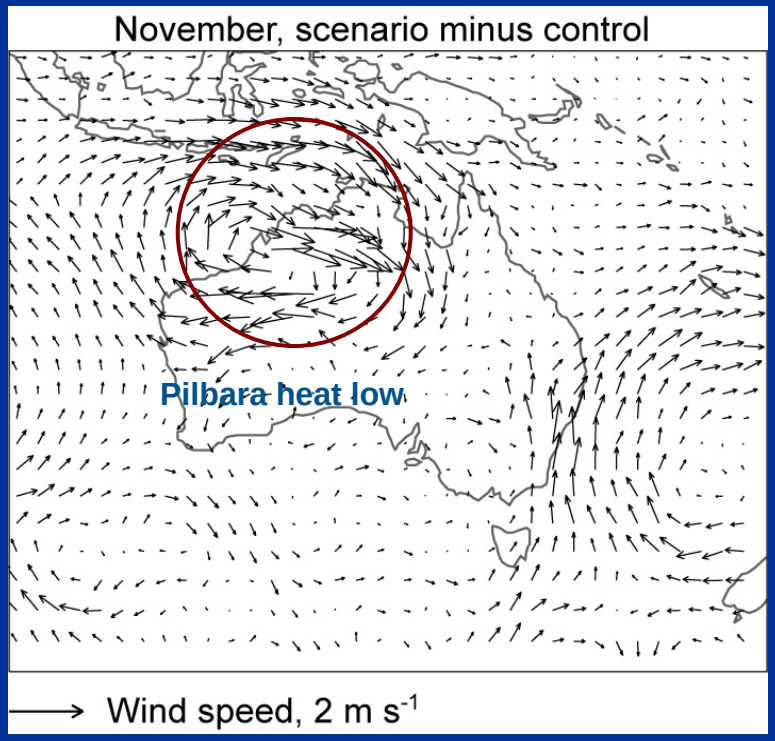
Scenario: intensity=80%, area=80%, timing=10 October, re-growth length=90 d



(Görgen et al. 2006)

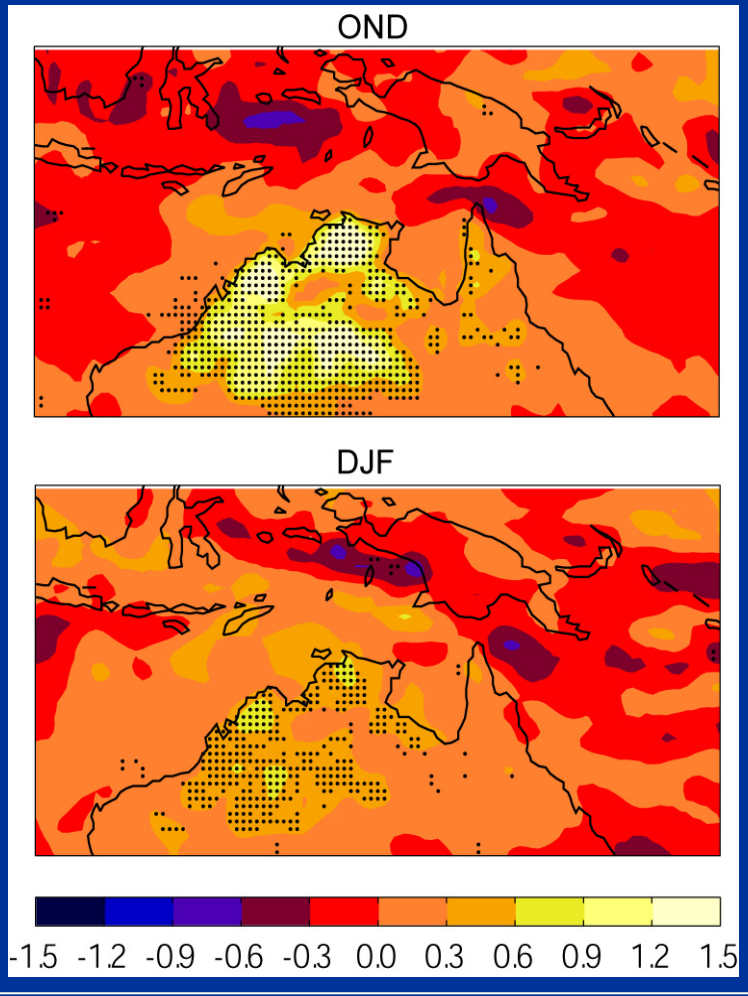
Continent-Wide Impacts

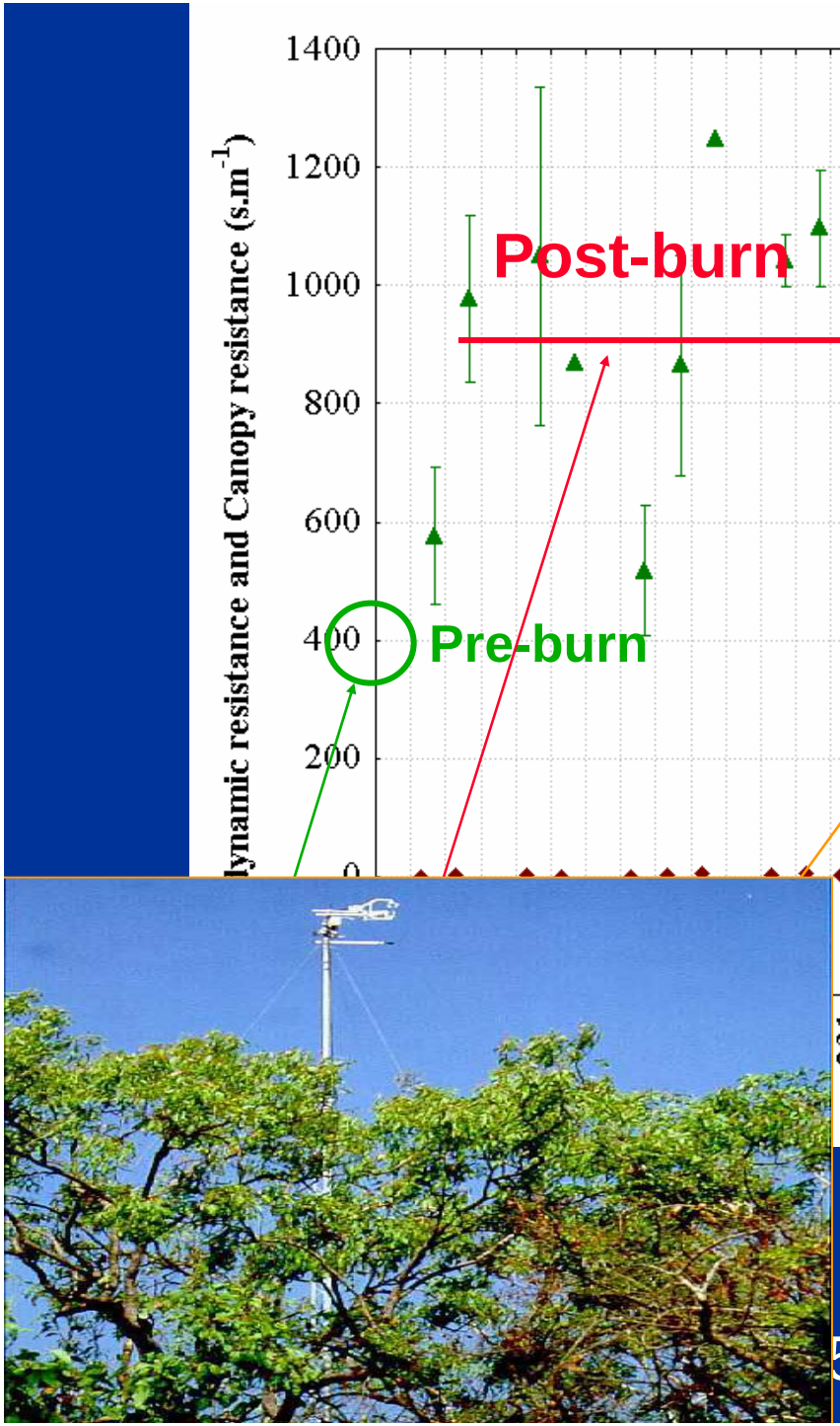
Scenario minus control, longterm
850 hPa wind fields



- Intensification of heat low
- Significant precip. increase

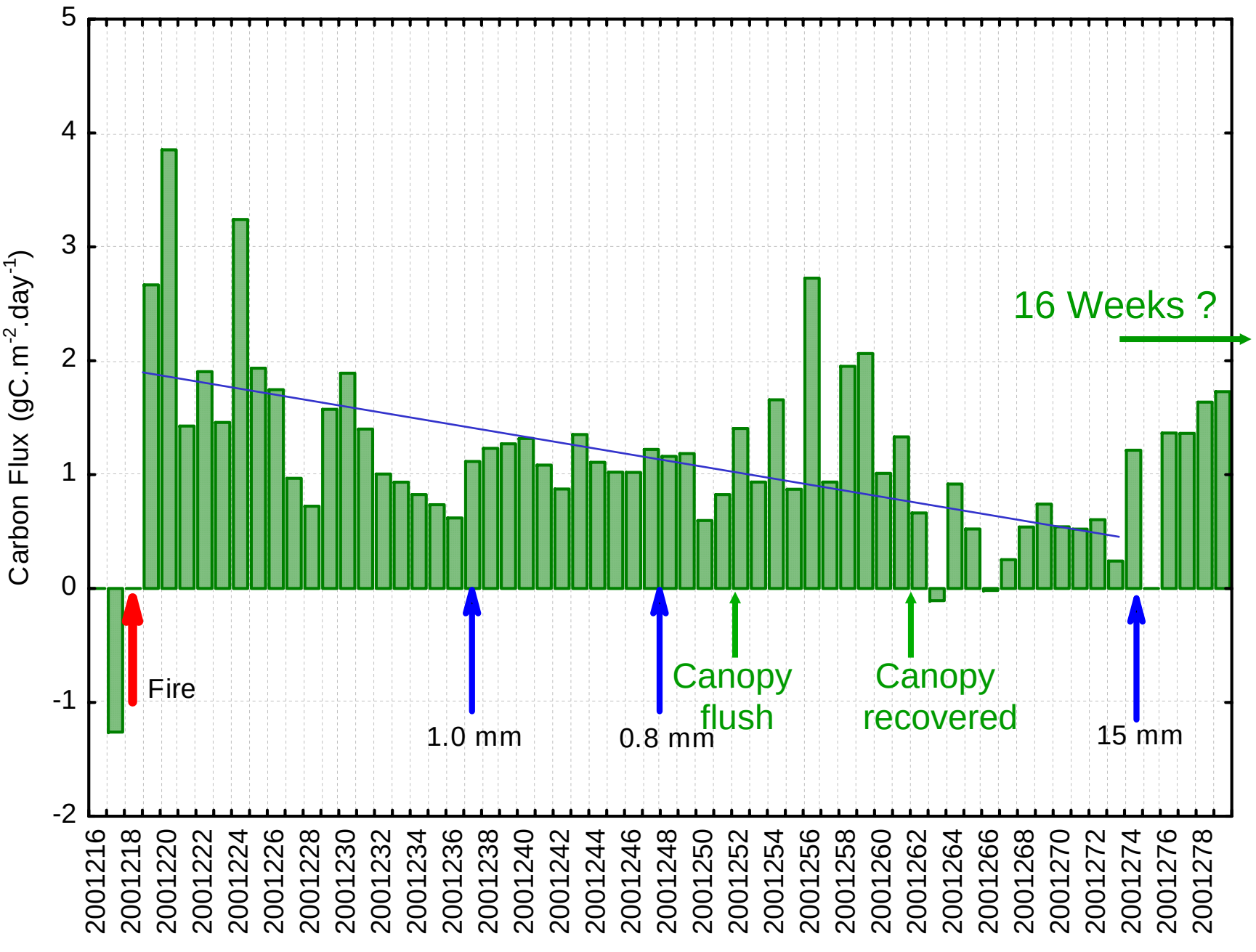
Scenario minus control, longterm
mean precipitation [mm d^{-1}]

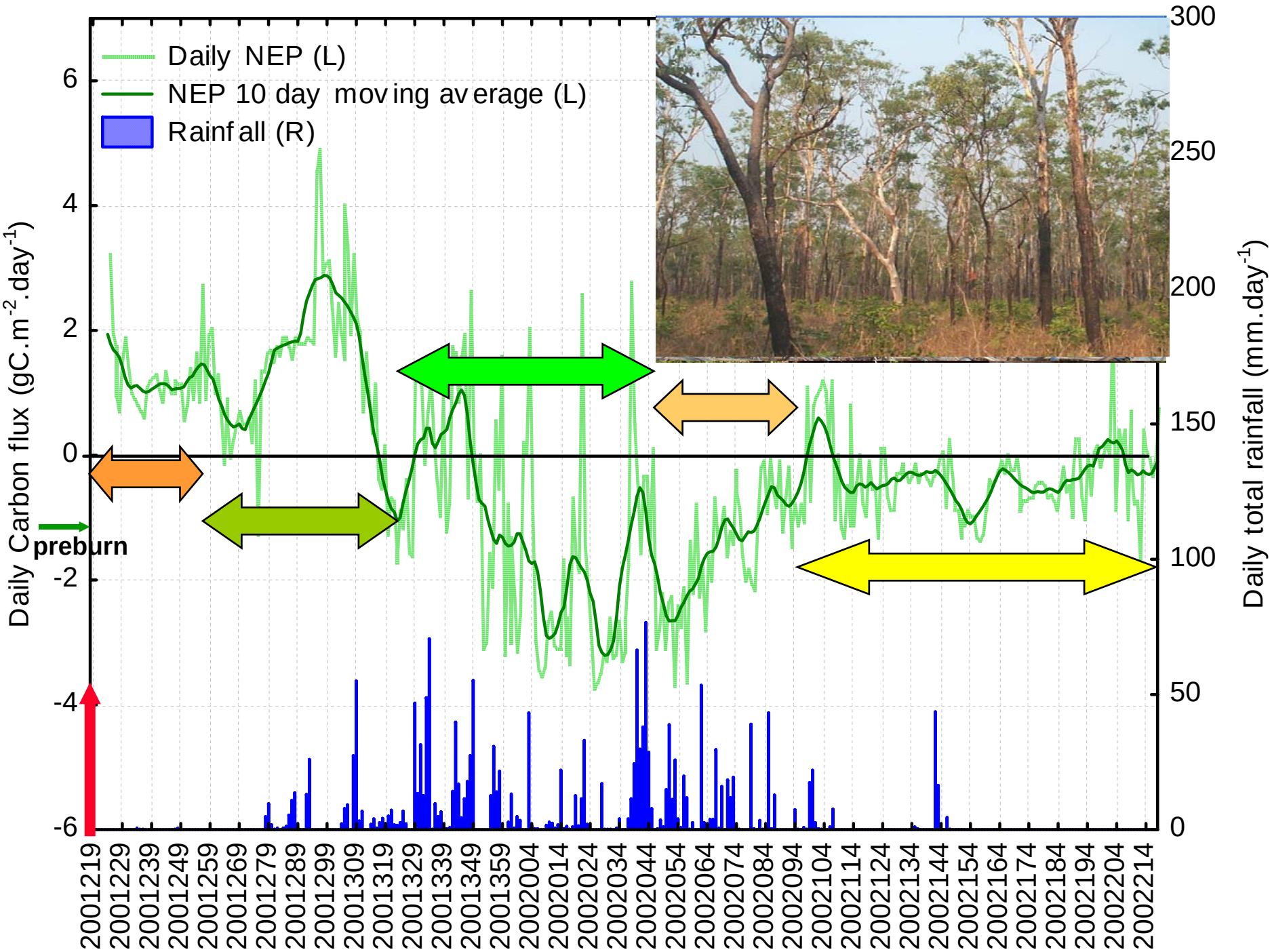


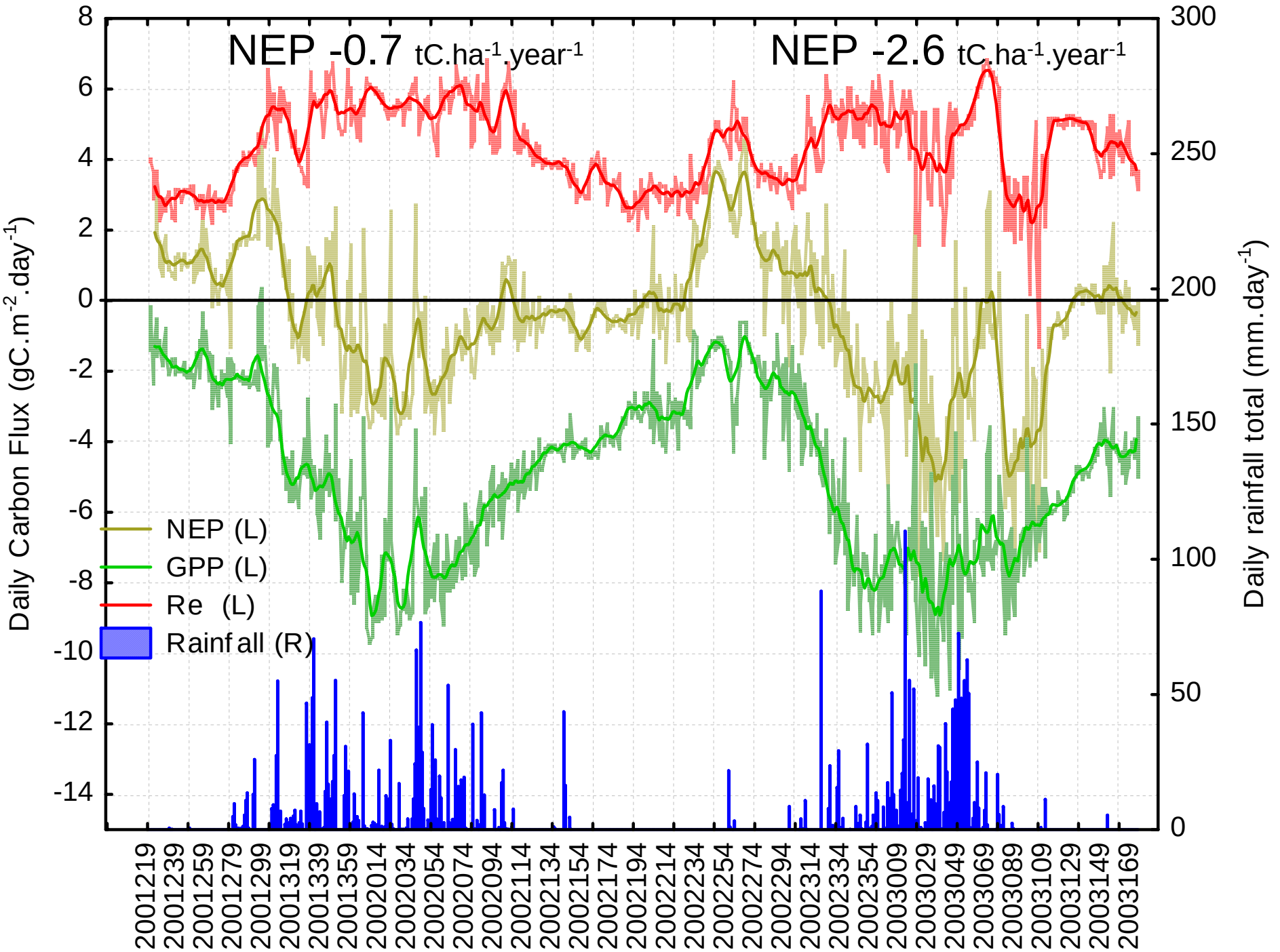


5 weeks. Recovery 6-7 weeks

•Carbon recovery not the same!




Daily NEP (L)
NEP 10 day moving average (L)
Rainfall (R)
preburn
Daily Carbon flux (gC.m-2.day-1)
Daily total rainfall (mm.day-1)
6
4
2
0
-2
-4
-6
300
250
200
150
100
50
0
2001219
2001229
2001239
2001249
2001259
2001269
2001279
2001289
2001299
2001309
2001319
2001329
2001339
2001349
2001359
2002004
2002014
2002024
2002034
2002044
2002054
2002064
2002074
2002084
2002094
2002104
2002114
2002124
2002134
2002144
2002154
2002164
2002174
2002184
2002194
2002204
2002214


NEP -0.7 tC.ha-1.year-1
NEP -2.6 tC.ha-1.year-1
Daily Carbon Flux (gC.m-2.day-1)
Daily rainfall total (mm.day-1)
NEP (L)
GPP (L)
Re (L)
Rainfall (R)
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
300
250
200
150
100
50
0
2001219
2001239
2001259
2001279
2001299
2001319
2001339
2001359
2002014
2002034
2002054
2002074
2002094
2002114
2002134
2002154
2002174
2002194
2002214
2002234
2002254
2002274
2002294
2002314
2002334
2002354
2003009
2003029
2003049
2003069
2003089
2003109
2003129
2003149
2003169

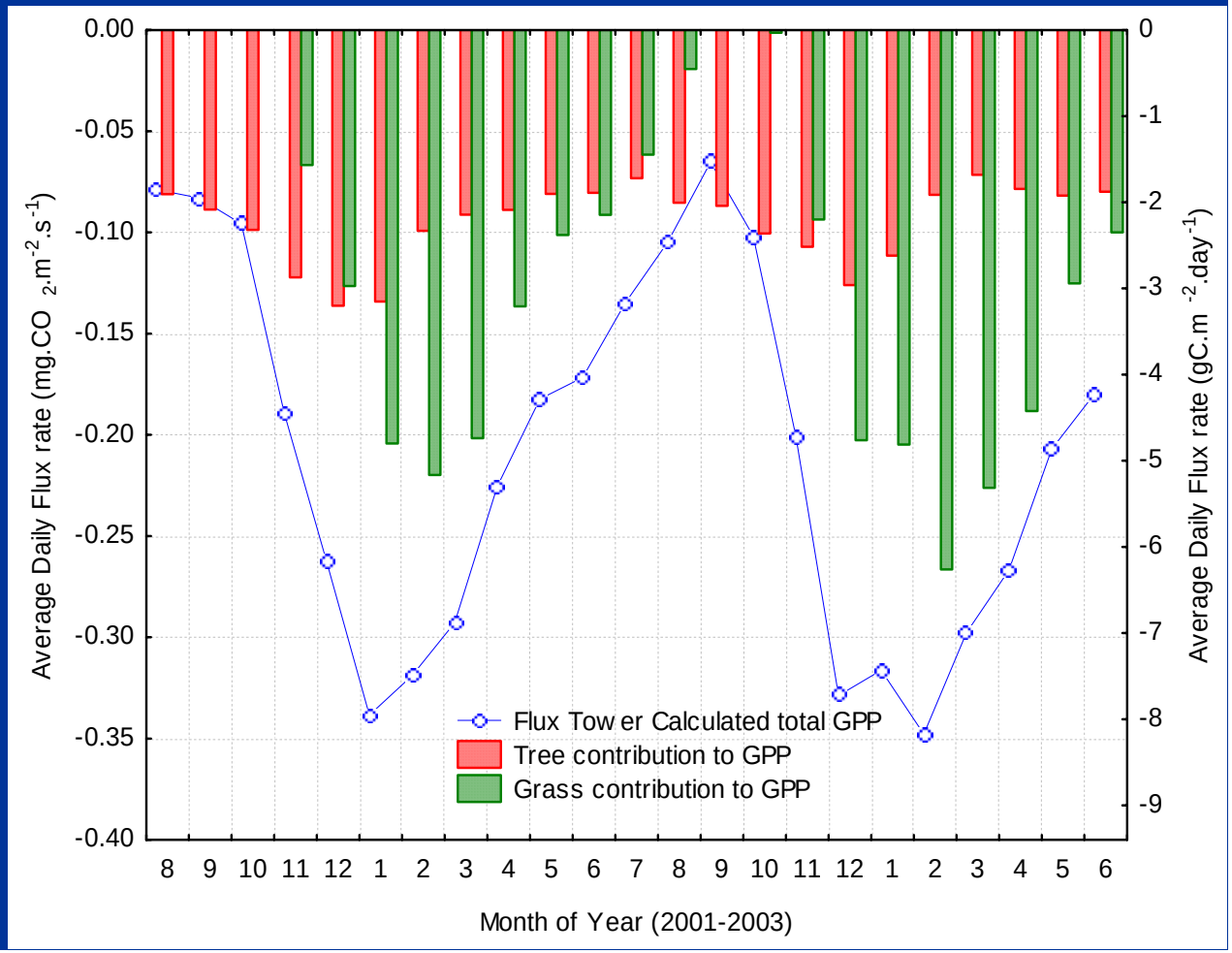
Components of Annual GPP

•Measurements indicate NEP -0.7 and -2.6 tC.ha^{-1}.yr^{-1} for each annual period.

YEAR	TREES (tC.ha^{-1}.yr^{-1})	GRASS (tC.ha^{-1}.yr^{-1})
2001-2002	-8.6	-8.5
2002-2003	-8.5	-10.2

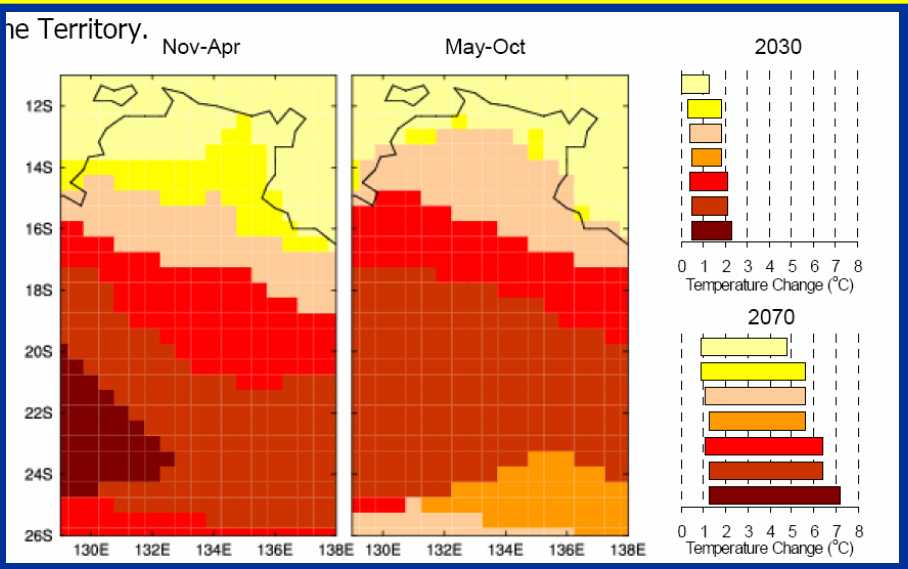
- Why much higher NEP in 2002-3?

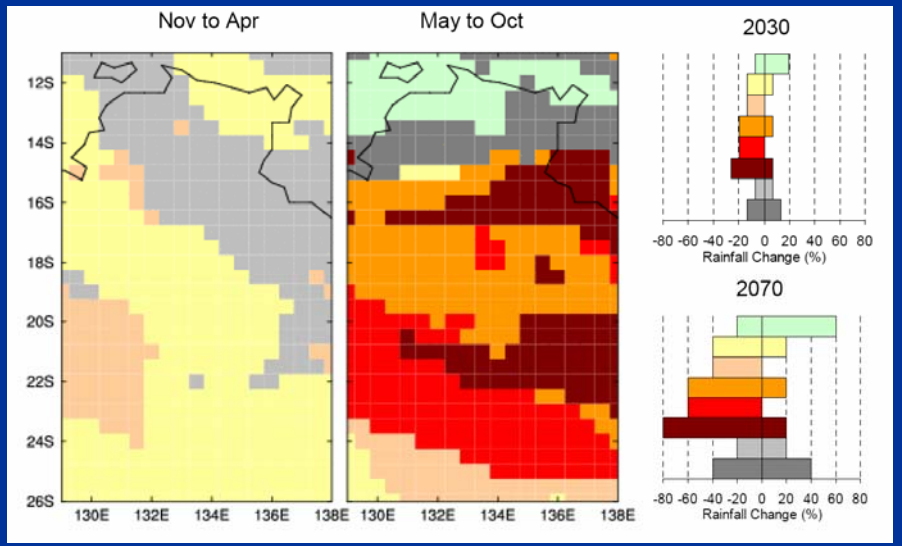
- Mostly higher GPP (from where?)
- NN analysis used to model tree GPP through the year with LAI adjustment.
- Grass GPP calculated as residual of measured and modelled.
- Increased GPP mainly from Grass



Impact of climate change on productivity

- Build a NN model using 4 years flux data
- Single sensitivities of carbon and water budgets to changes in Temperature and Precipitation (soil water content).
- Multiple sensitivities following 2070 projections





Hennessey, *et al.* (2004) Climate Change in the Northern Territory

Impact of climate change on productivity

- Moisture is major driver
- Temperature response unexpected
- Response to multiple drivers not just additive.
- Simulations for 2070 show large decreases on NEP and hence reduce carbon sink

Climate Change Scenario		Ecosystem Response (% Change)			
T (°C)	Soil Water	ET	GPP	Re	NEP
+1.2	-	+3.0	-0.3	-0.1	-0.5
+4.9	-	+17.2	+1.8	-6.4	+18.4
-	+10%	+4.0	+5.1	+1.0	+14.0
-	-10%	-5.1	-5.2	-2.3	-11.2
-	+20%	+7.2	+9.4	+1.5	+25.2
-	-20%	-10.5	-9.5	-5.5	-17.6
+4.9	+20%	+19.4	+1.1	-2.3	-17.6
+4.9	-20%	-7.2	-23.0	-14.7	-39.2

Net Biome Productivity

	2001-2002	2002-2003	Inventory	Eamus et al.
Re	+16.1	+15.6	+17	
GPP	-16.8	-18.0	-20.8	
NEP	-0.7 *	-2.6 *	-3.8	-2.8
Fire losses	+0.52	+0.96	~+1.5	
NEP-fire	-0.18	-1.64	-2.3	
NBP				-1.54

* Includes impacts of a fire event in that year excluding emissions

Conclusions

- Step change in albedo, energy and carbon fluxes after fire
- Burning on large scale may influence regional climate
- Relatively rapid recovery of water but not carbon exchanges driven by canopy flush
- Savanna remained a source of carbon for a long period following fire
- Fire is an important disturbance factor that will reduce NEP through initial burning emissions and recovery. Gives Net Biome Productivity (NBP)
- NEP-Fire was +0.8 (2001-2002) & +0.3 (2002-2003) and **NBP ~ -1.5 tC ha^{-1} y^{-1}**
- Possibilities for carbon sequestration.