Effect of drought and disturbance on the carbon budget of a temperate forest

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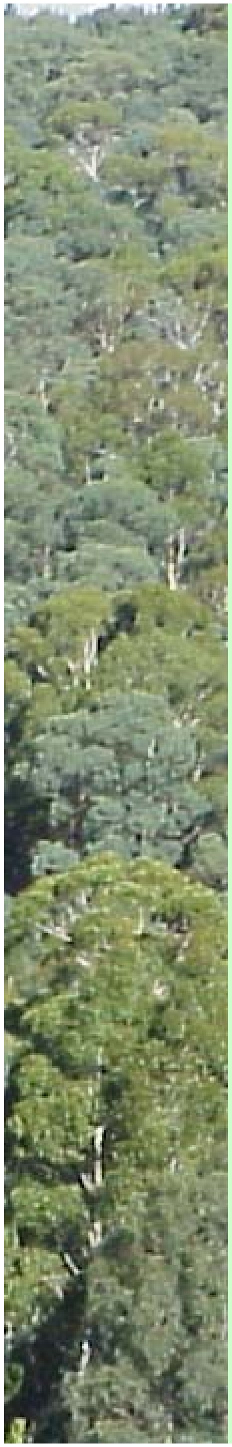
Are forest carbon sinks vulnerable ?

- **Temperate forests are an important carbon pool and carbon sink**

- **What will be the effect of changing climate and climate variability?**
  - **Carbon gains/losses are affected by climate and climate-induced disturbances e.g. fire, insects**
  - **Positive feedbacks between climate and net carbon emissions**
  - **Feedbacks between carbon and water cycles**
  - **Crossing thresholds**



1. Tumbarumba Flux Tower site
2. Climate and Drought
3. Response of Carbon Cycle
4. Forest Growth Dynamics
5. Implications and Concluding Comments

1. Tumbarumba Flux Tower

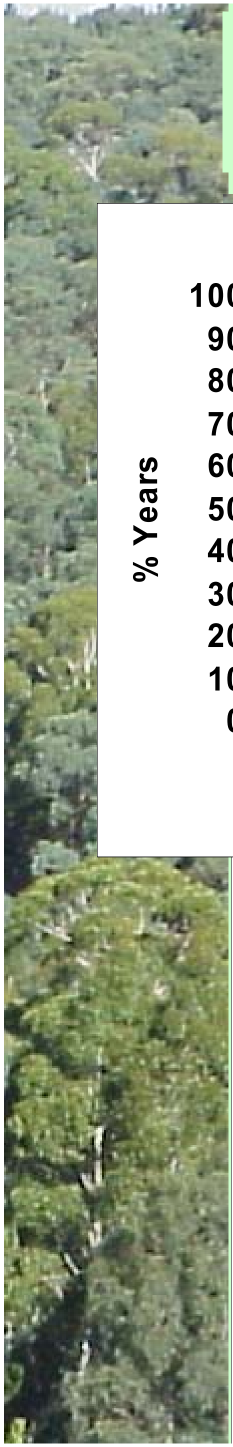
In Bago State Forest, NSW

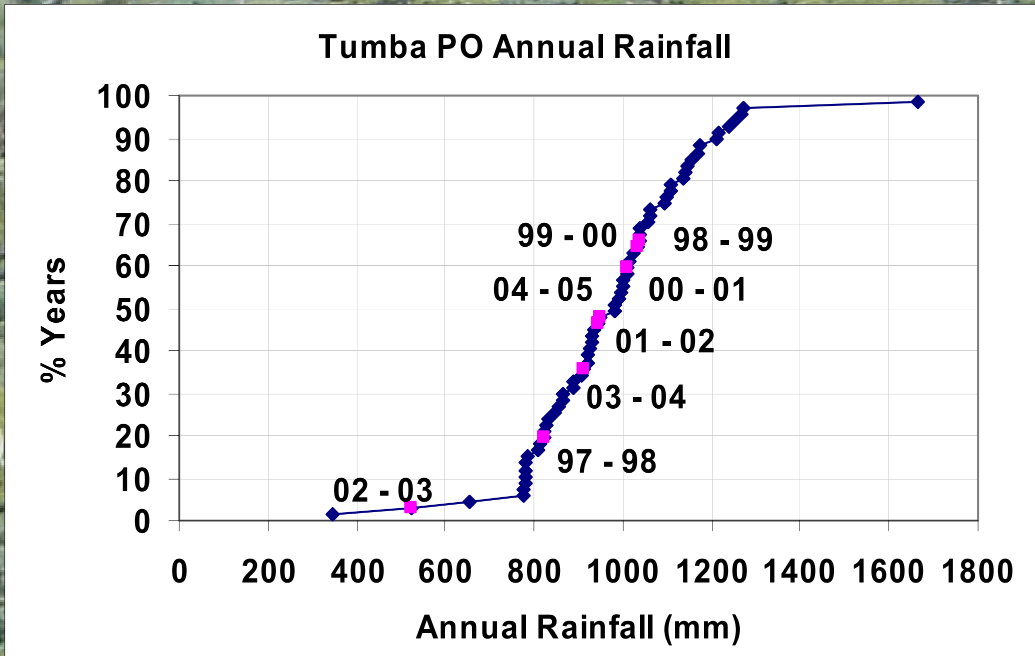
- Annual precipitation is ~ 1000 mm
- Elevation: 1200 m
- 40 m tall, broad-leaf, evergreen forest: *Eucalyptus delegatensis, E. dalrympleana*
- LAI: trees ~ 1.4; total ~ 3

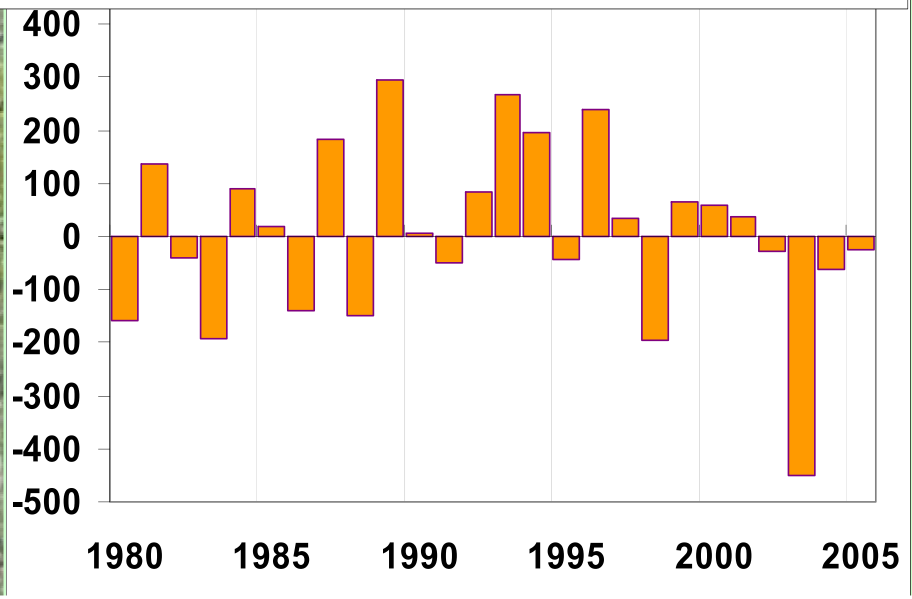
Measurements:

- Radiation fluxes and meteorology
- Turbulent CO_2, water, heat, momentum fluxes
- CO_2, temperature and wind profiles
- Terrestrial C-budget:
  - Pools: soil, litter, canopy, roots, biomass
  - Fluxes: respiration, litterfall

2. Climate and Drought
Rainfall distribution and deficits







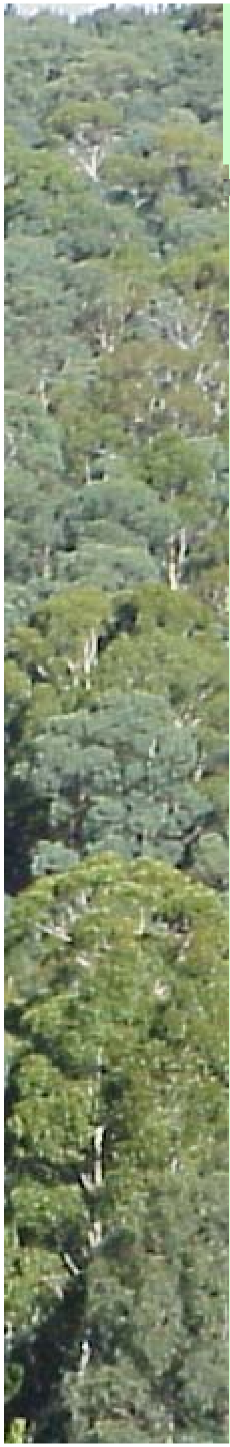
Long-term (65 y) rainfall distribution:

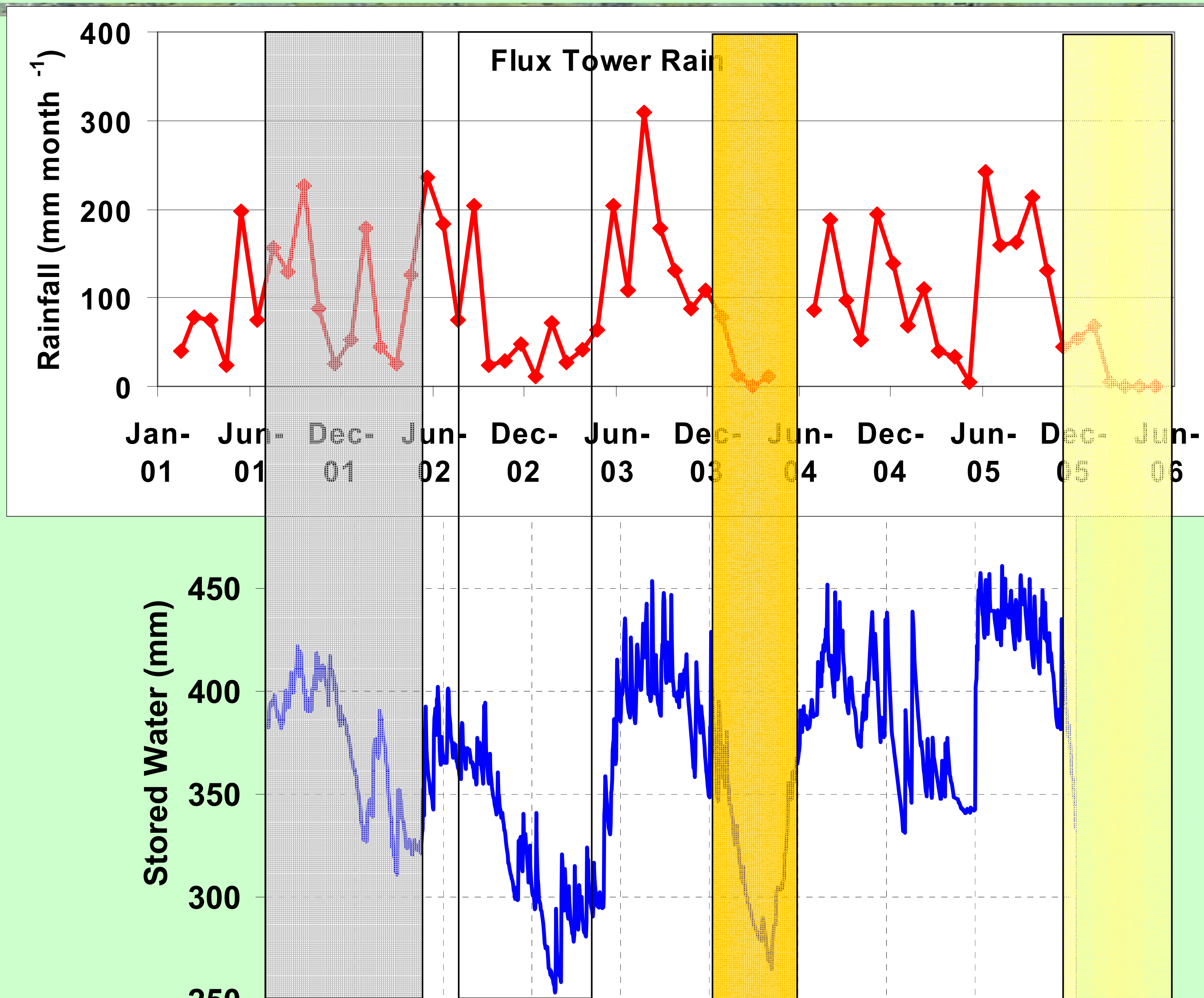
2002 – 2003 rainfall in the lowest 5th percentile

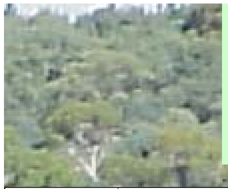
2000 – 2006 spans 5th – 70th percentiles

Departure of annual rainfall from long-term mean shows that much of the last decade has been in a dry phase

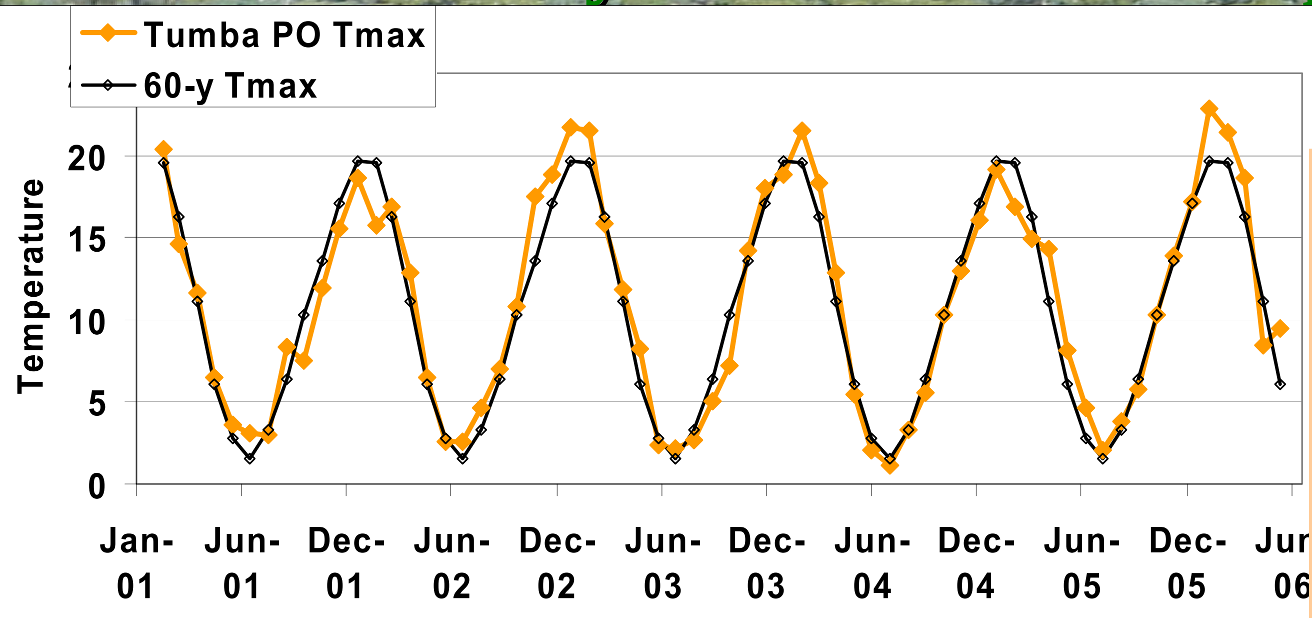
2. Climate and drought
Rainfall and soil moisture

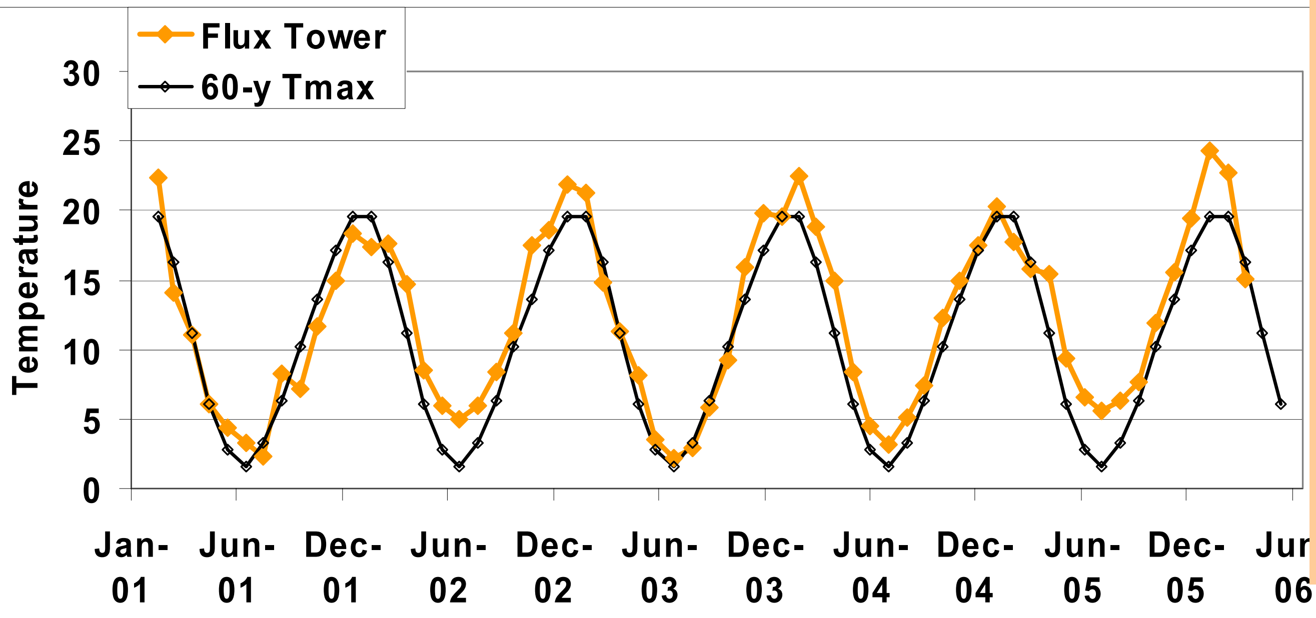






2. Climate and drought
Daily maximum air temperature





Jan 01 – Jun 02:
slightly cooler, average rainfall

Jun 02 – 04:
warmer and much drier

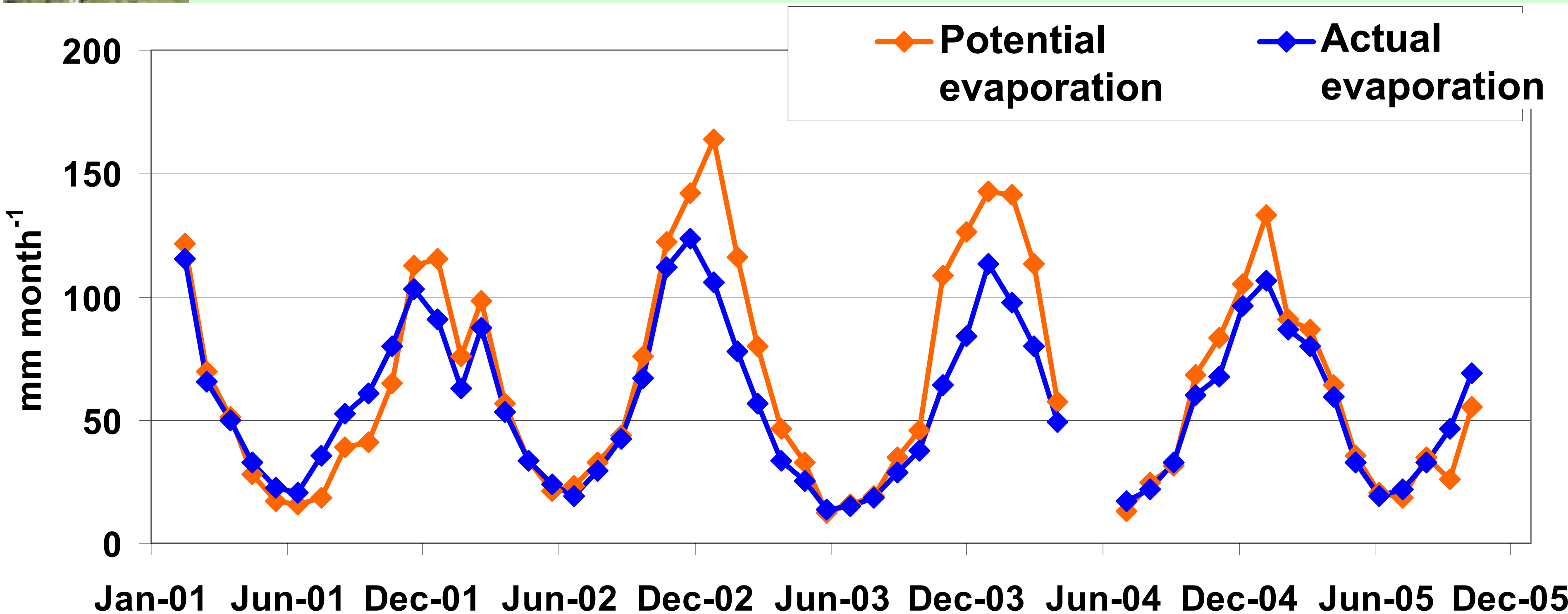
Jun 2005 – 06:
slightly drier, much warmer

than long term mean

2. Climate and Drought
Evaporation

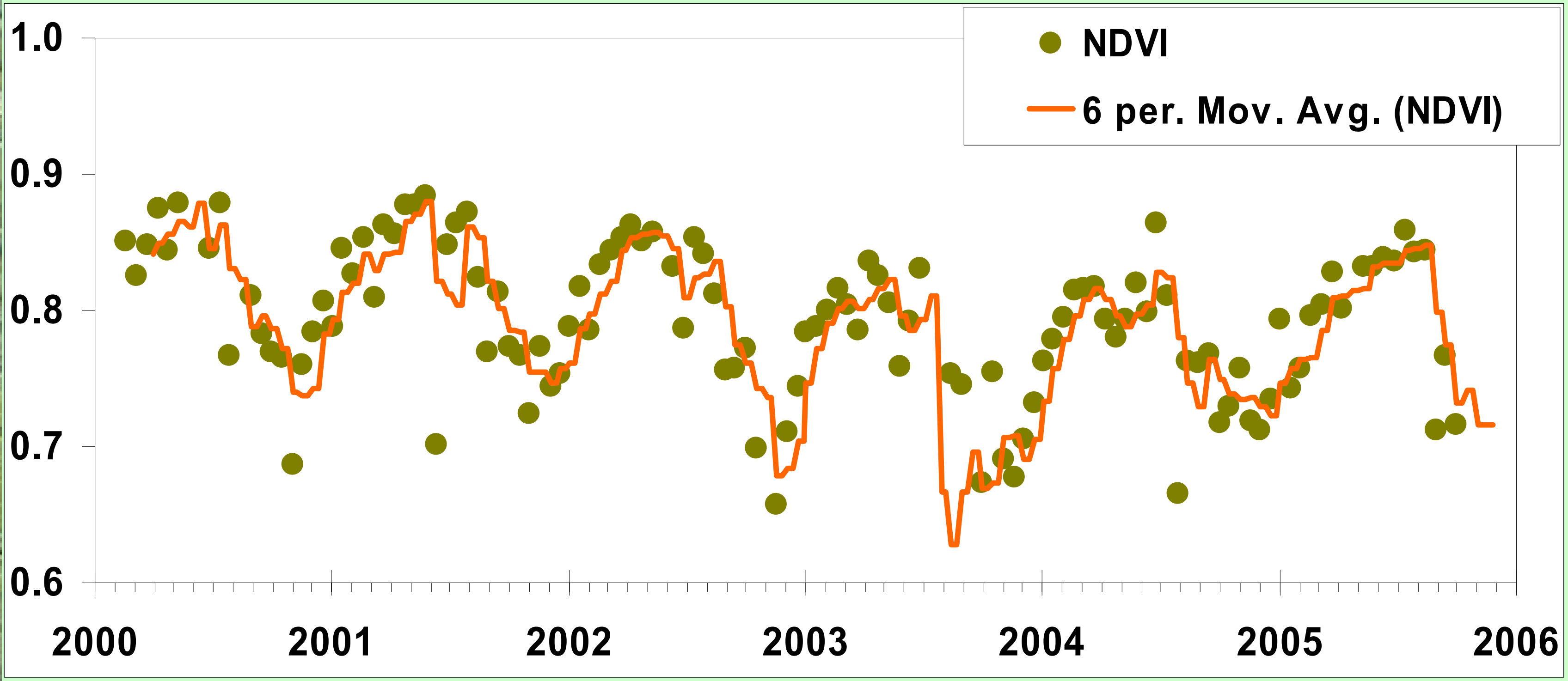
Potential evaporation combines all meteorological drivers (radiation, temperature, humidity deficit)

Difference between actual and potential evaporation illustrates combined effects of meteorology and soil water deficit



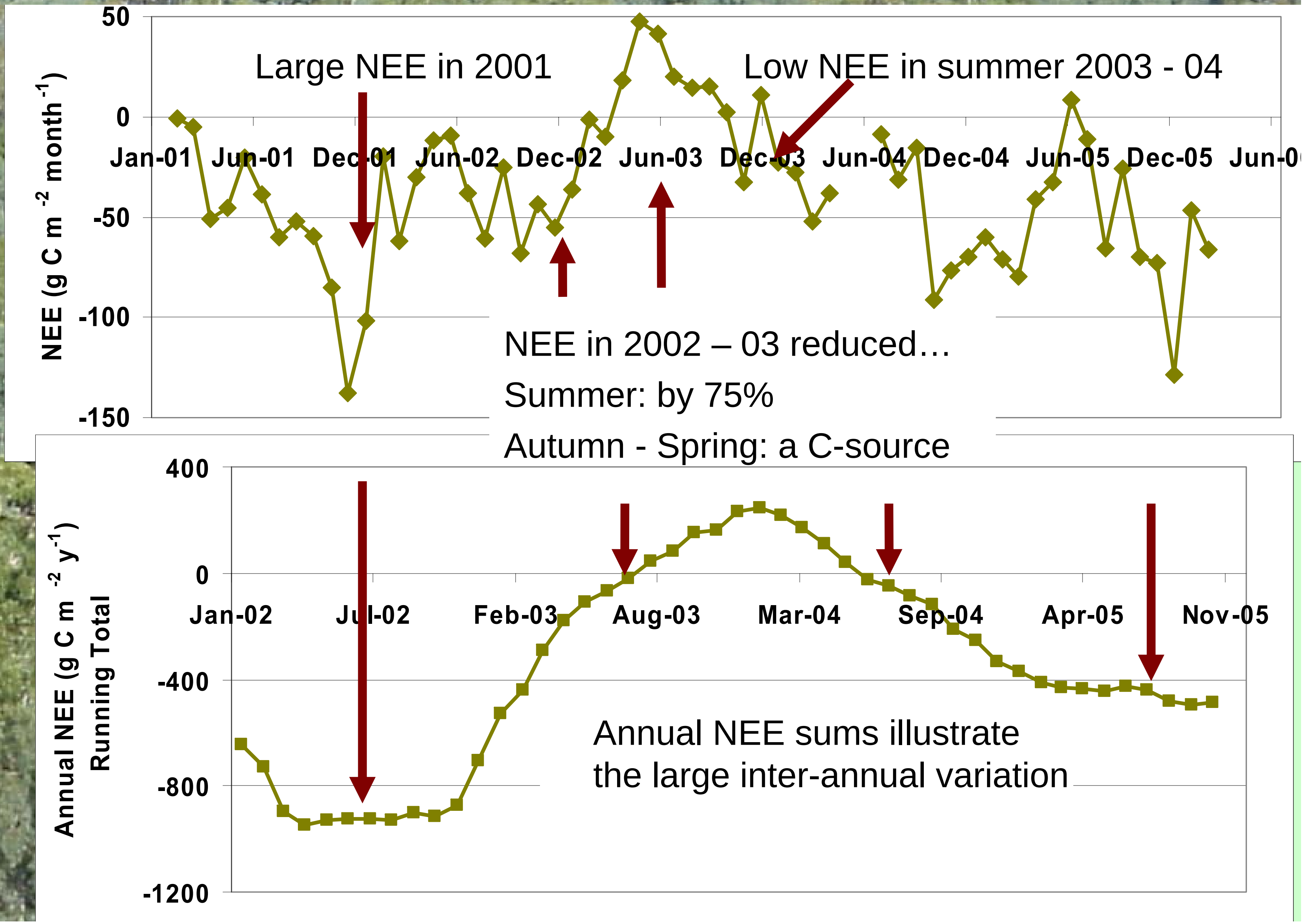
2. Climate and Drought
NDVI

MODIS NDVI indicates a vegetation response, similar to the regional NDVI anomalies of Briggs et al

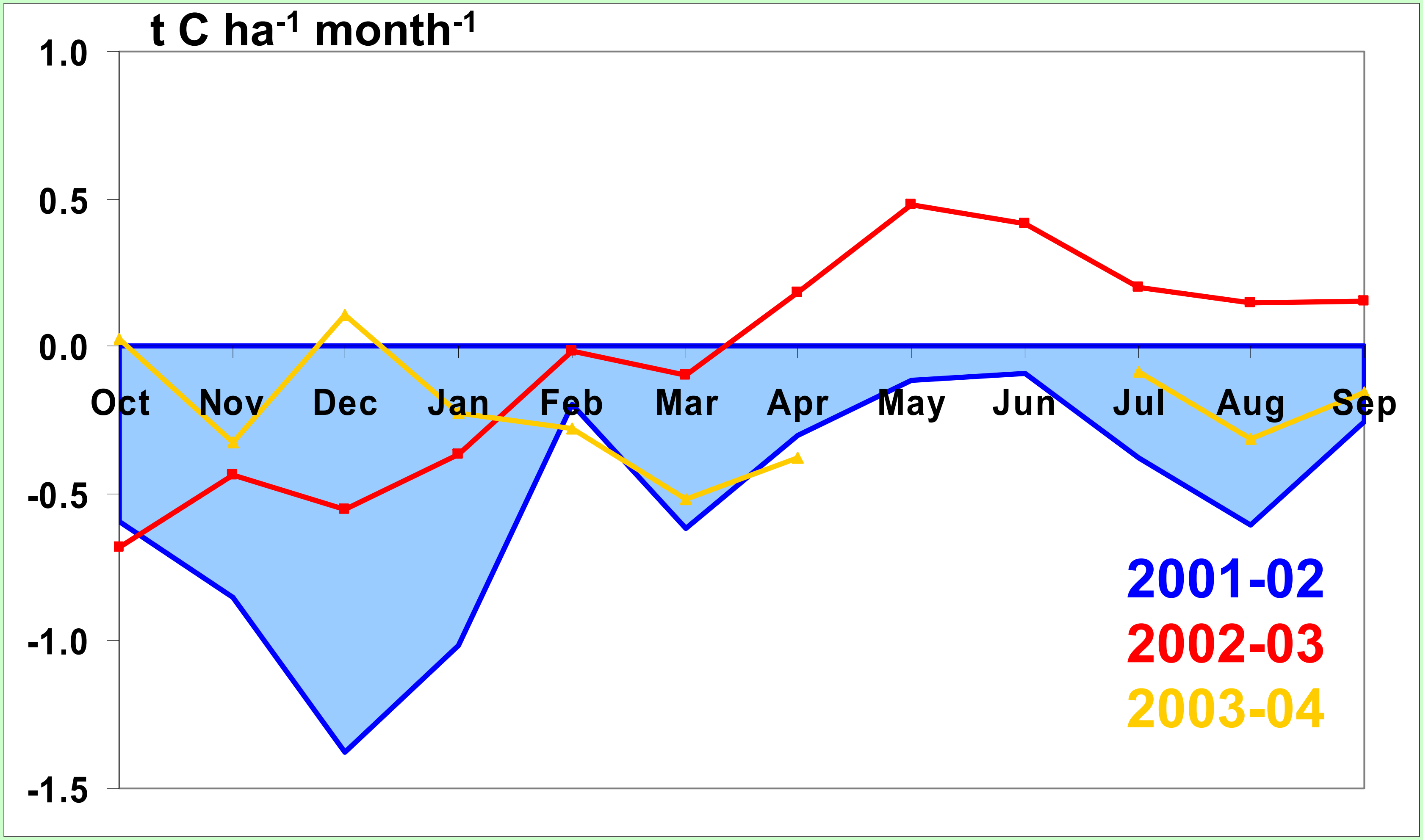


7 km x 7 km cutout surrounding flux tower

3. Response of carbon cycle: NEE



3. NEE from flux tower



C sink during normal conditions

C source for periods during drought and disturbance

3. Components of NEE

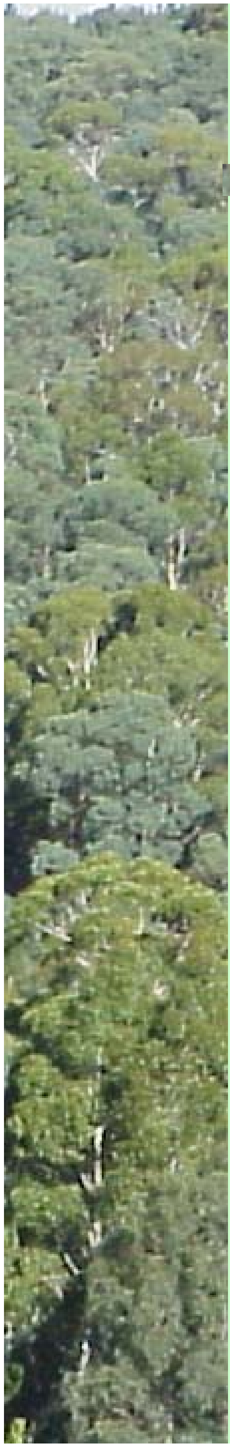
NEE can be calculated as:

1. Eddy flux: $-Fc$

2. Difference between fluxes: $GPP - (R_a + R_h)$

3. Change in pools: $\Delta B + \Delta S + \Delta L$

Aim is to link ground and tower measurements to estimate NEE

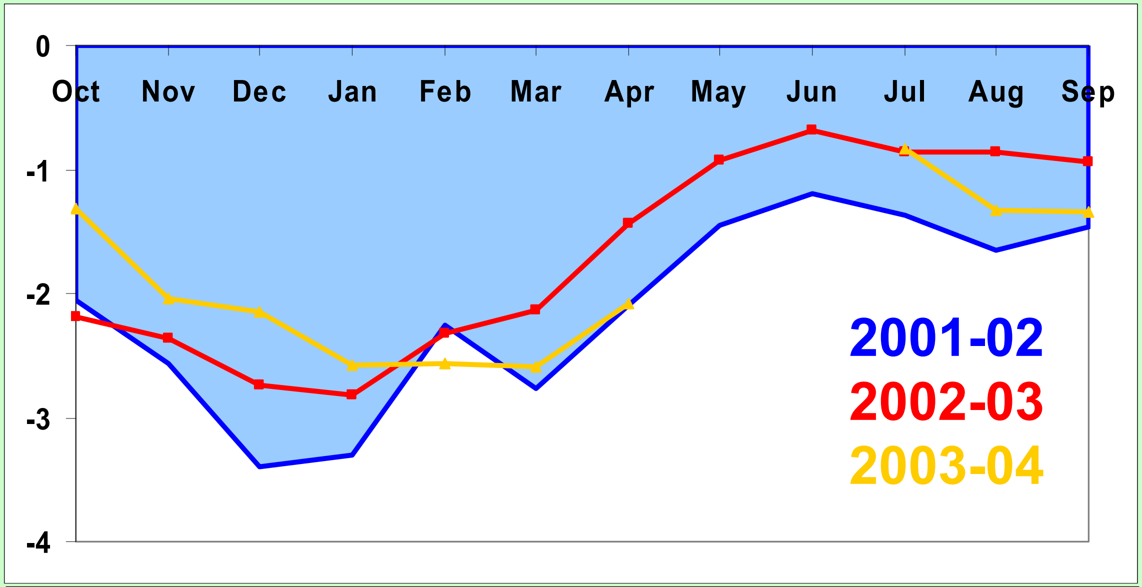


GPP and Respiration

t C ha^{-1} month^{-1}

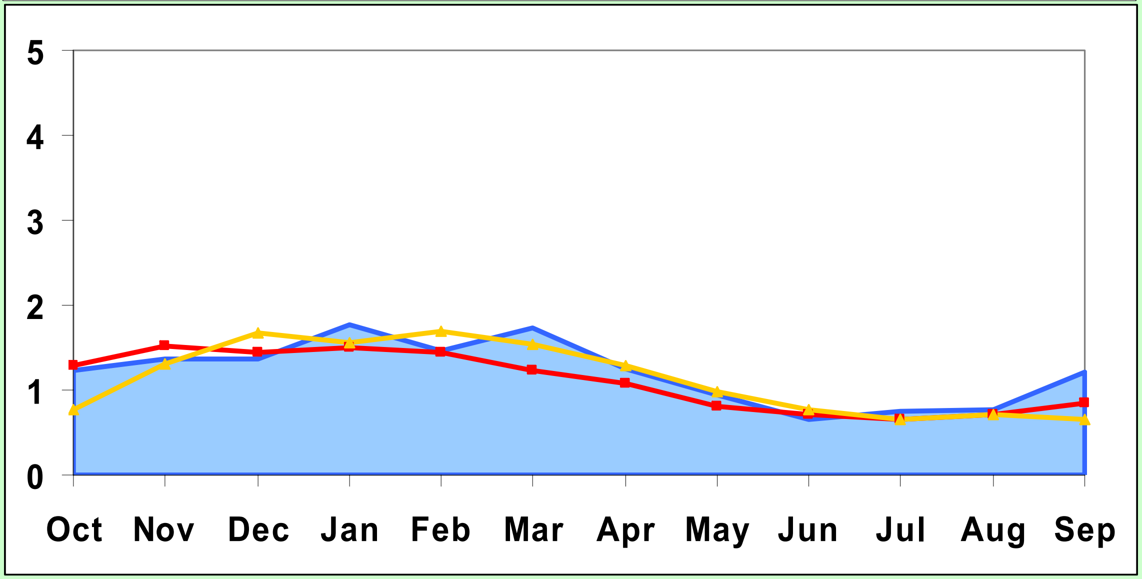
C gain
GPP

derived from eddy flux



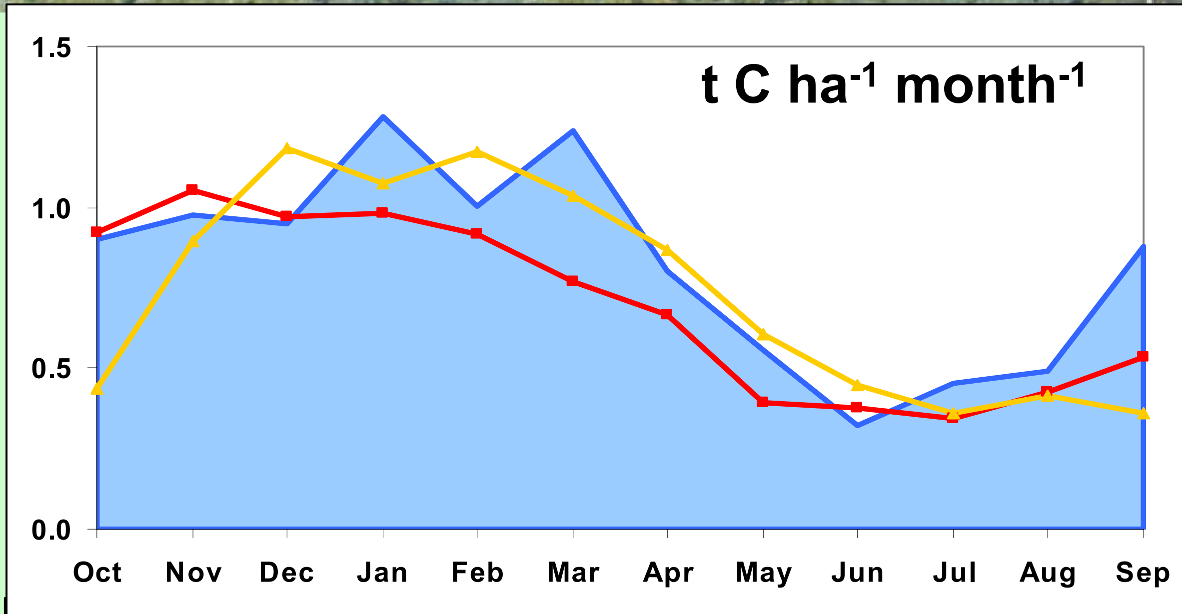
C loss
Respiration

derived from chambers

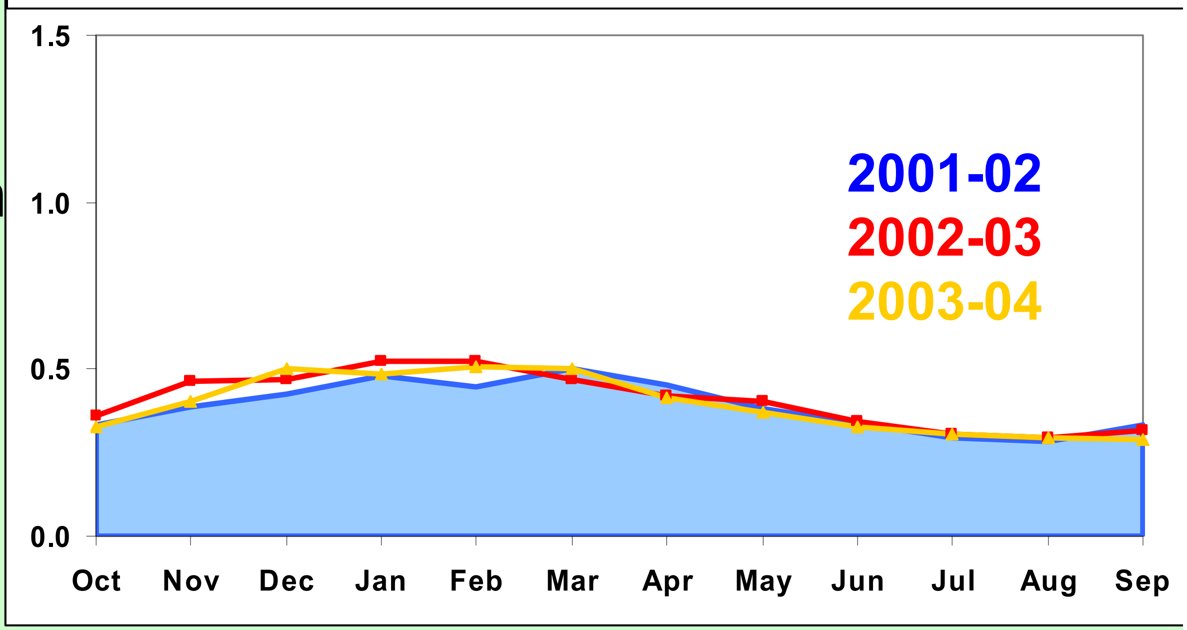


Respiration rates

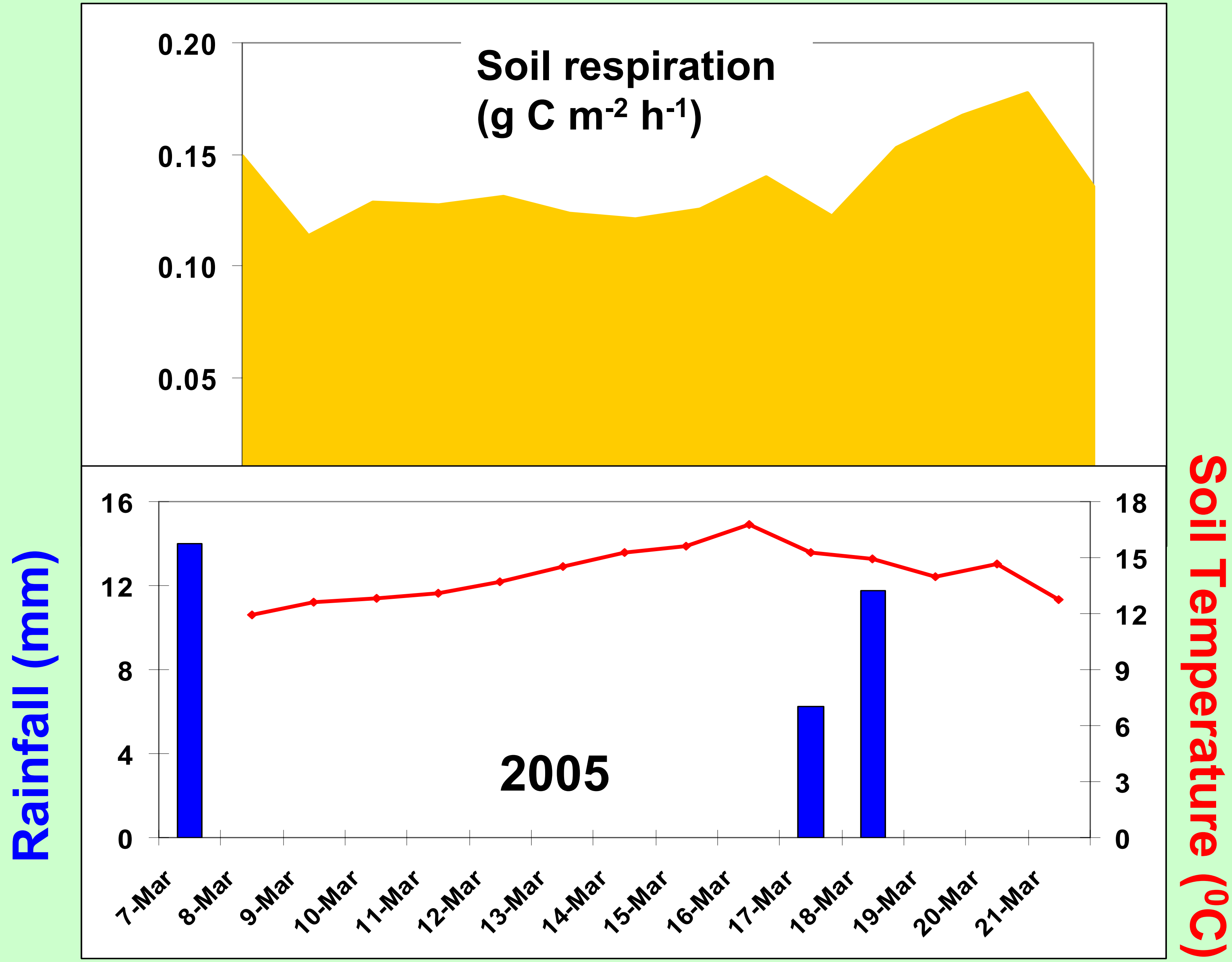
Soil respiration
- **Heterotrophic**
- **Autotrophic fine roots**



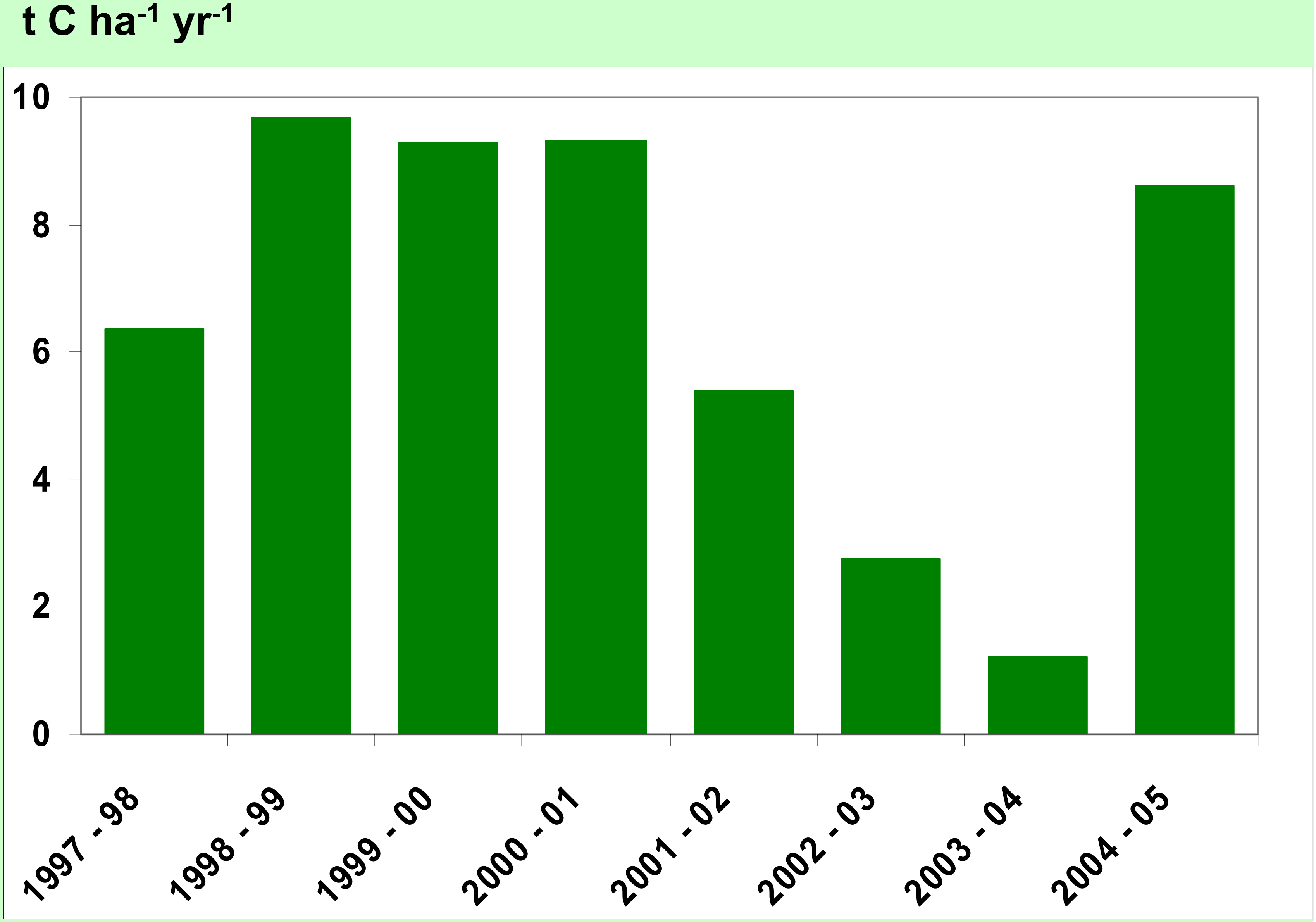
Plant respiration
- **Leaves**
- **Wood**
- **Coarse roots**



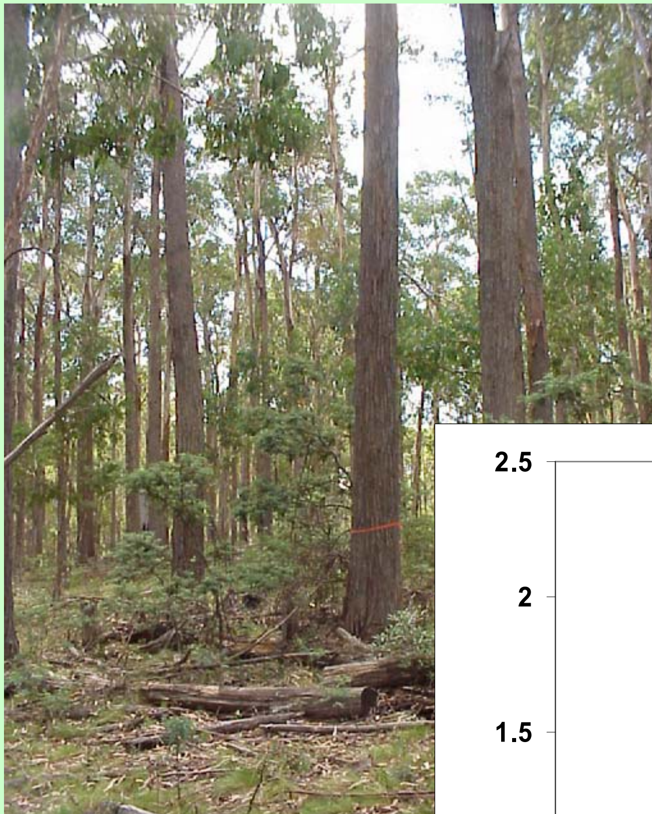
Soil respiration rates: temperature and moisture interactions



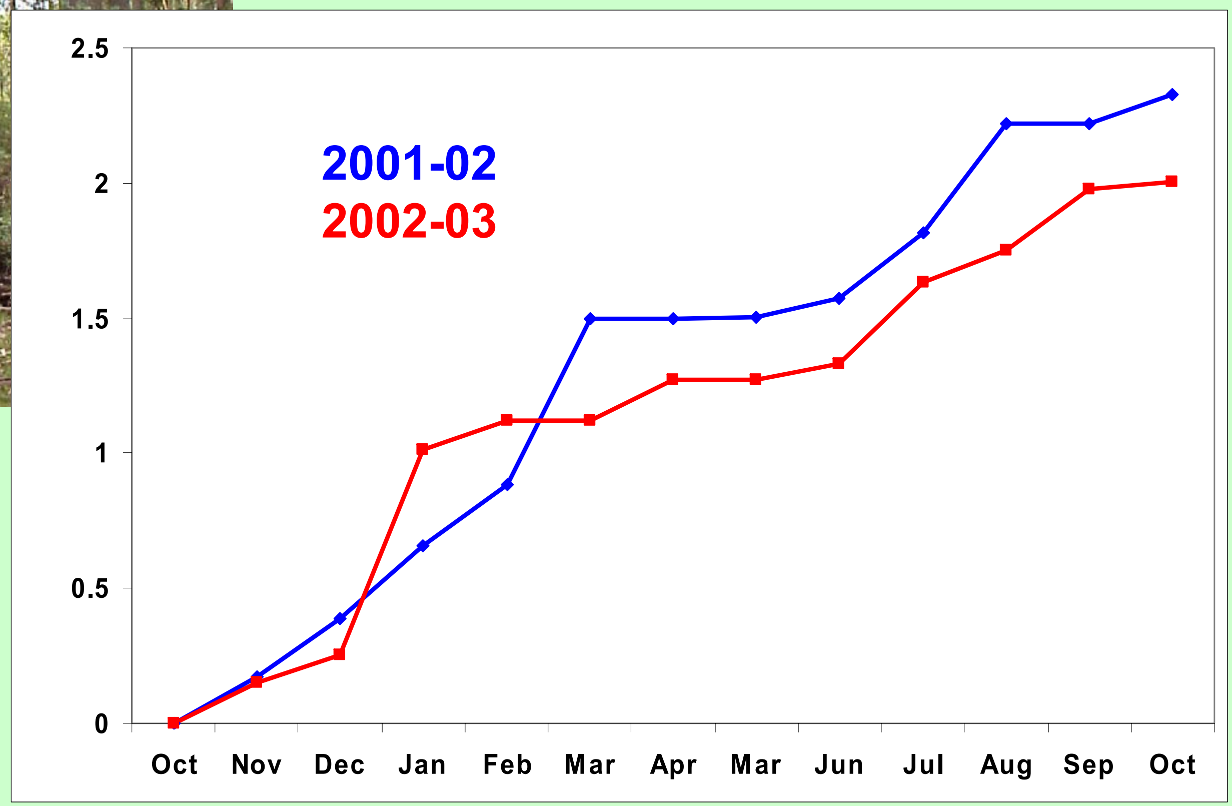
Annual increment in biomass carbon



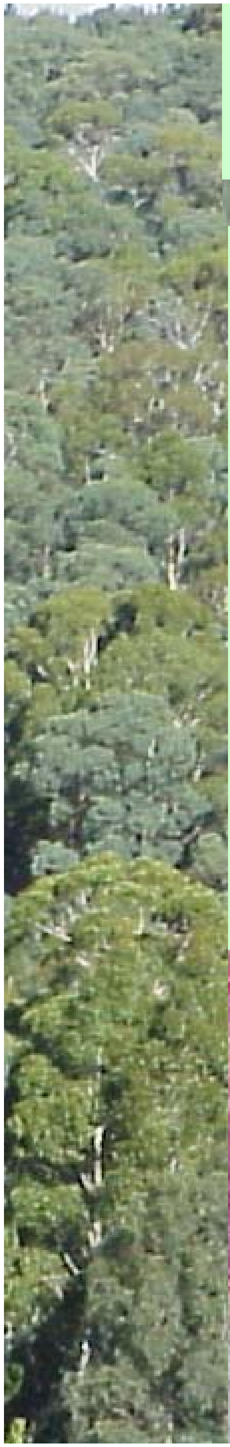
Seasonal patterns of growth



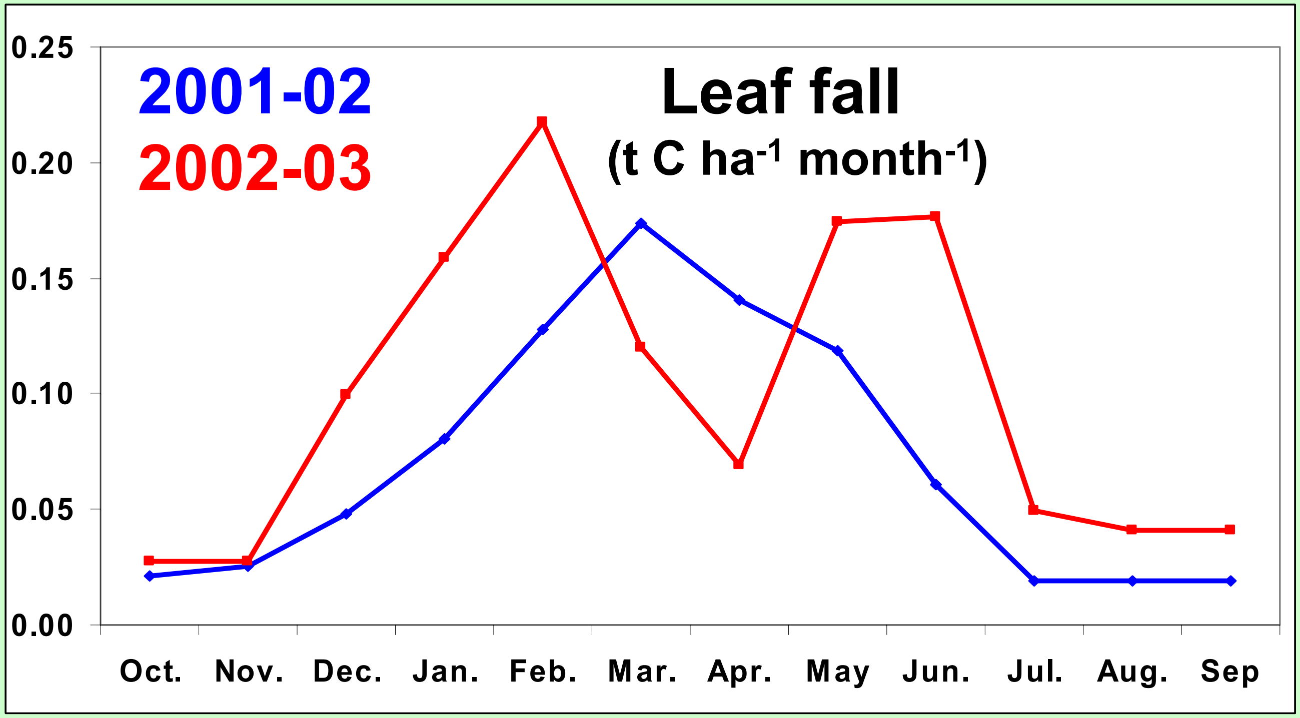
Basal area increment
(cm^2 $tree^{-1}$)



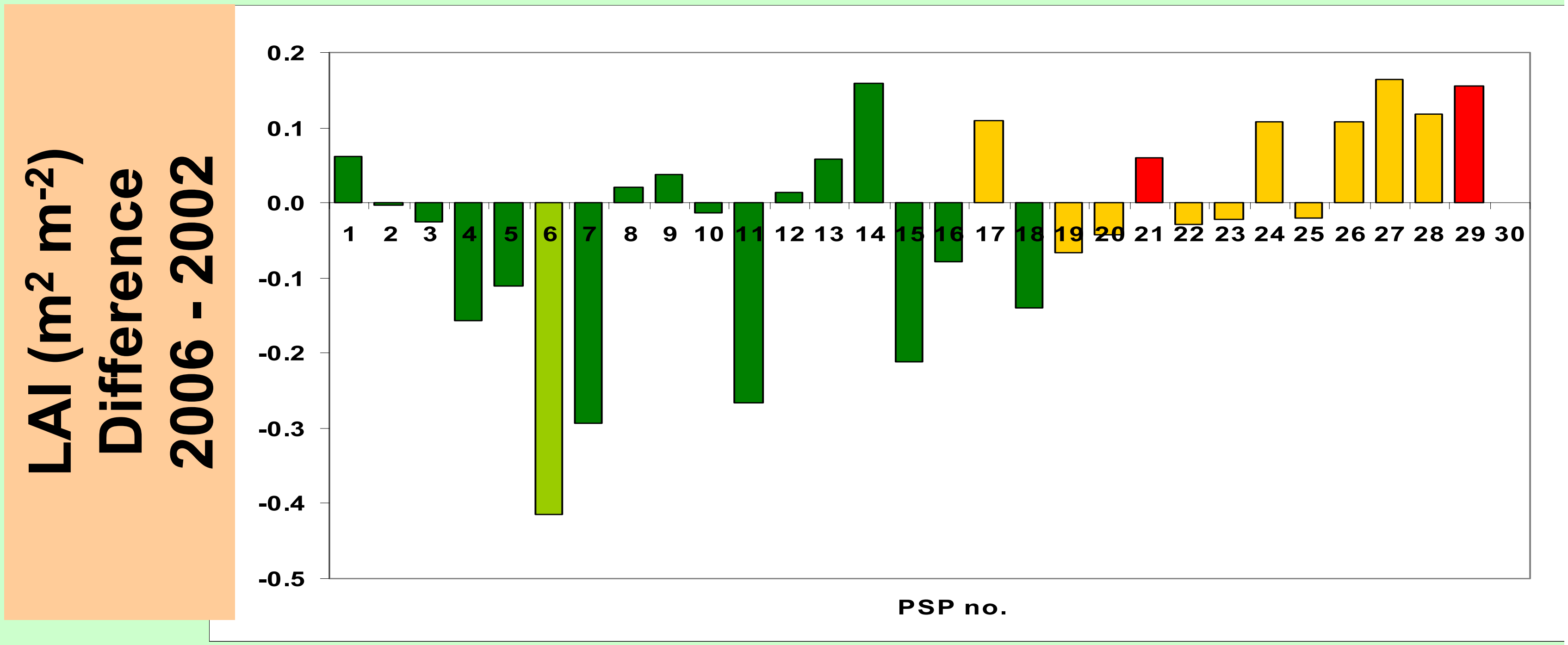
Disturbance by insect damage



Additional leaf fall: 27% of annual total



Change in LAI: 2006 - 2002



4. Forest Growth Dynamics

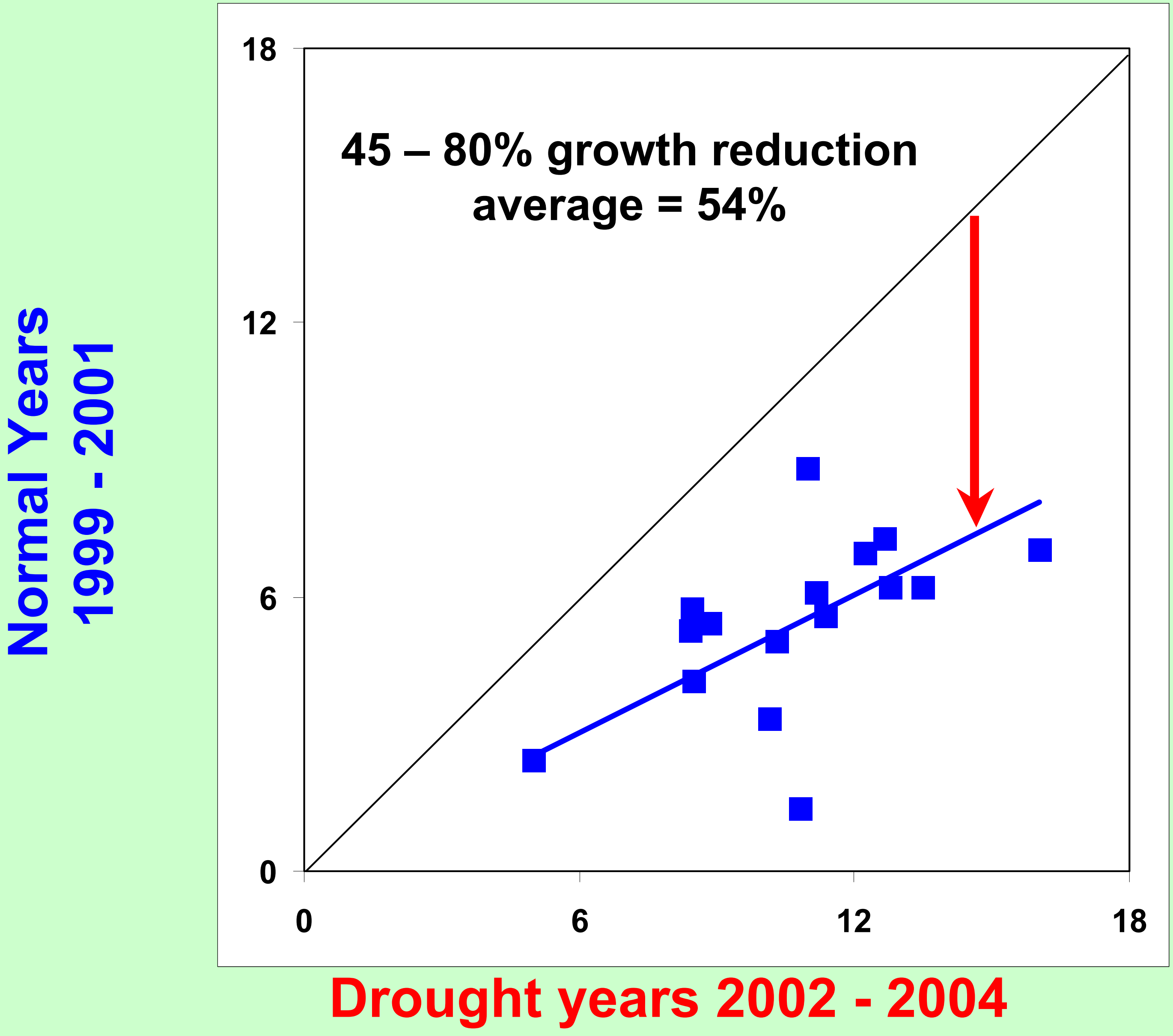
- **Current productivity:**
  - Increment of live trees
  - Mortality

  ⇒ Consequences for annual variability in C sinks

- **Future productivity:**
  - Stand structure
  - Recruitment

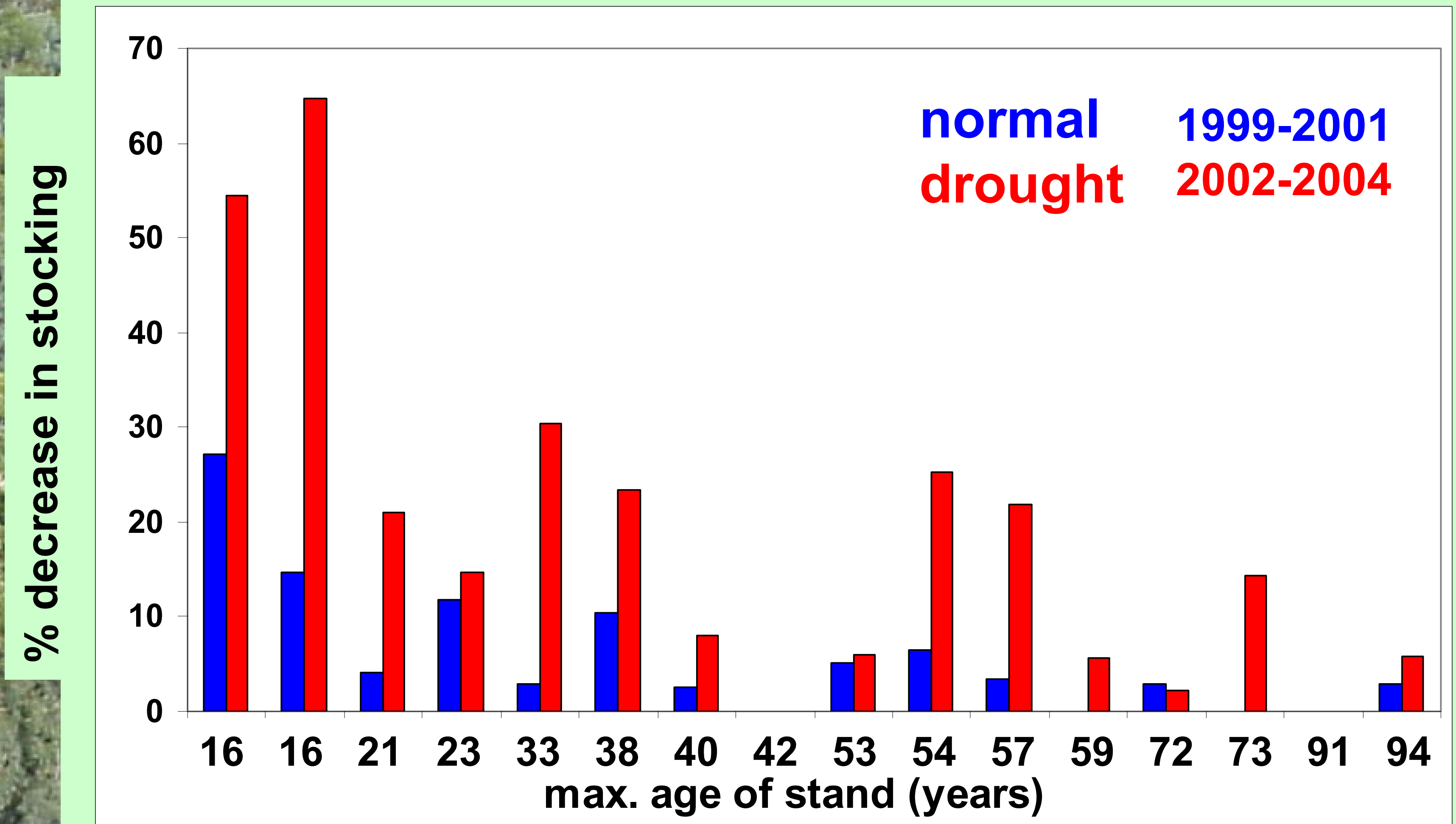
  ⇒ Consequences for continuity of timber production and trends in C sinks

Forest growth dynamics: Biomass C Increment (t C 3 y^{-1})

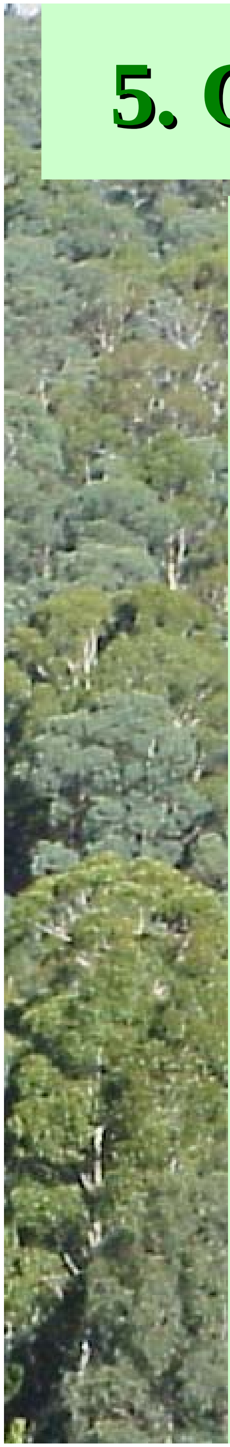


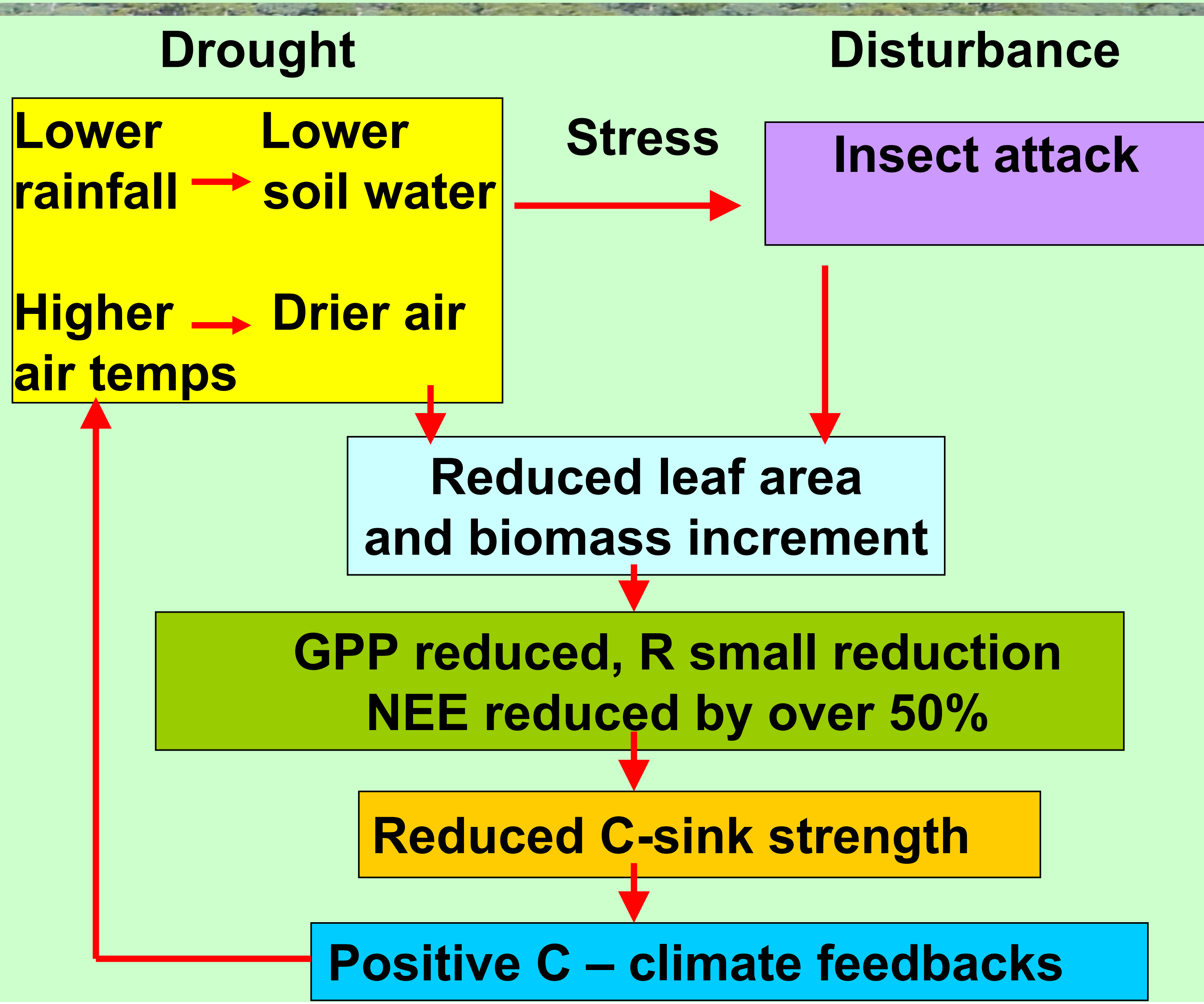
Forest growth dynamics: Mortality

Higher mortality during drought in most age classes, not just self-thinning of young stands.



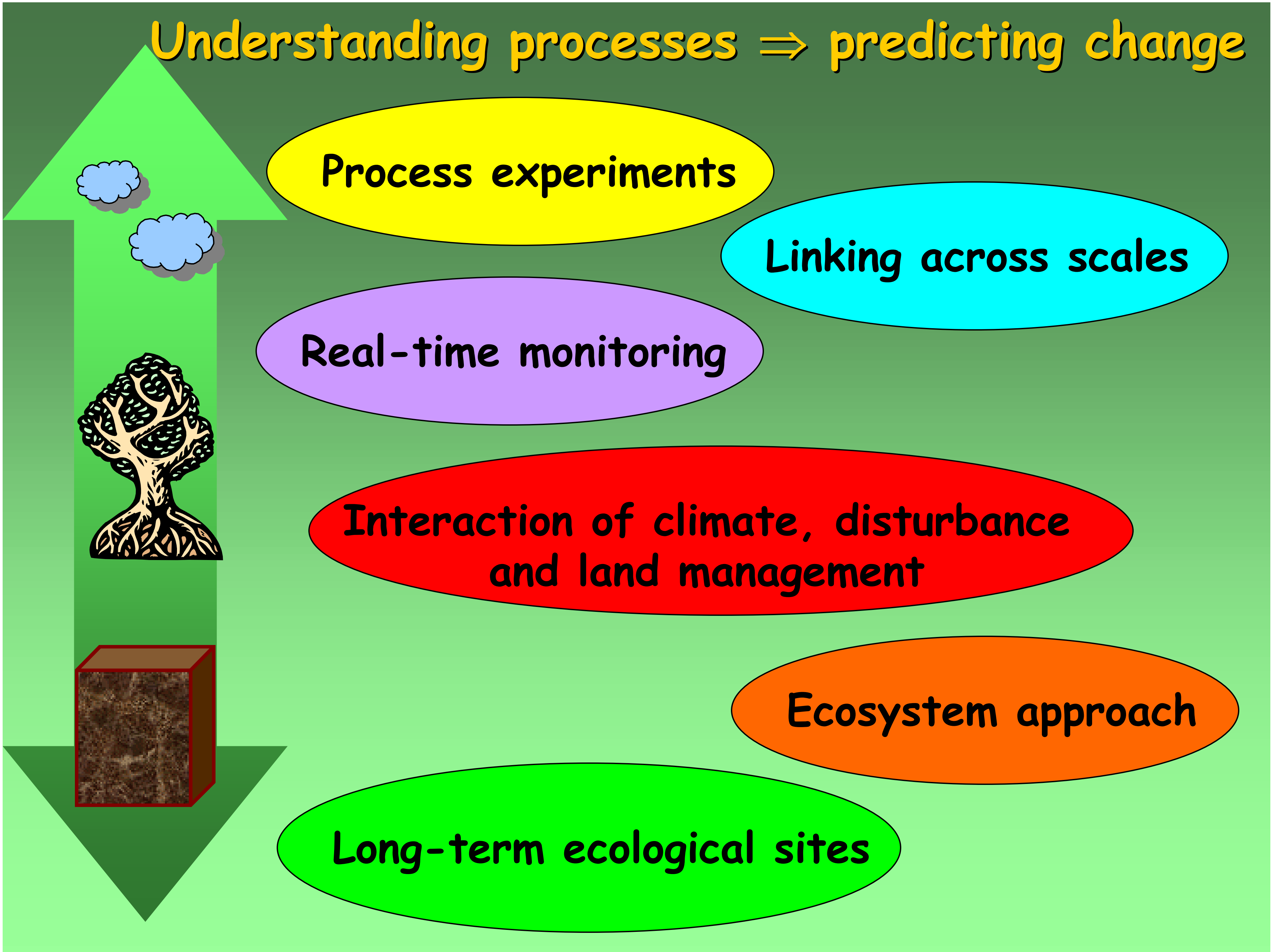
5. Carbon – drought – disturbance feedbacks



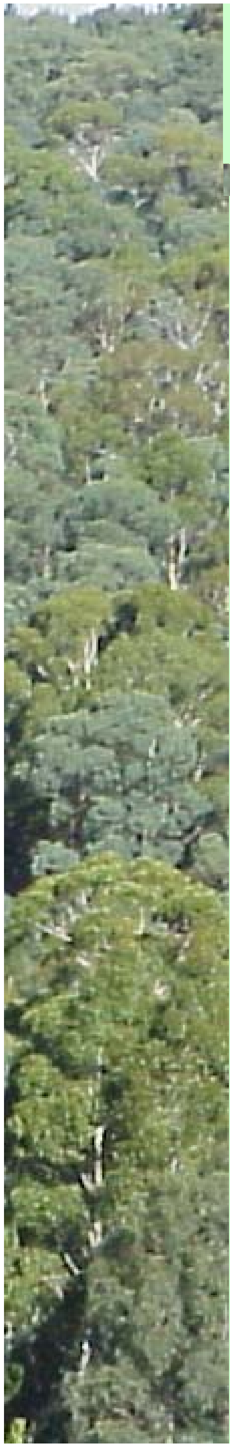


5. Implications for vulnerability of C sinks

- Tree damage and mortality
  – long-term consequences for **forest structure**
- Confounding stress factors
  – greater **susceptibility to insect attack**
- Reduced carbohydrate storage in trees
  – reduced **resilience to disturbance**
- Increased litterfall due to insect damage
  – changes in **soil organic matter decomposition**
- Changes in **soil C pools:**
  – loss of labile or recalcitrant components?
  – C – nutrient interactions?
- Moisture / temperature interaction driving **soil respiration**
  – how will this change with climate?
- **Inter-annual variability in forest C exchange**
  – increase with climate variability



Understanding processes ⇒ predicting change
Process experiments
Linking across scales
Real-time monitoring
Interaction of climate, disturbance and land management
Ecosystem approach
Long-term ecological sites



Ecosystem Carbon Balance

t C ha^{-1} yr^{-1}

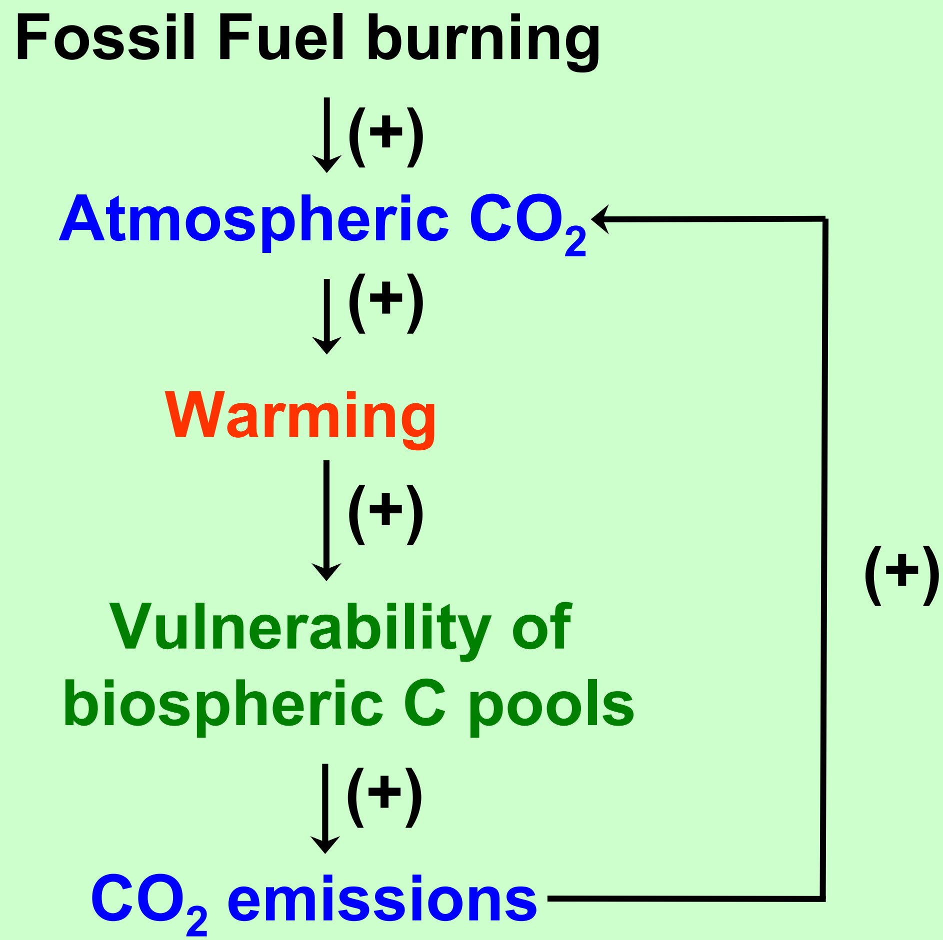
	2001-02		2002-03	2003-04
GPP (Maestra, eddy flux)	-20.9	-29.6	-19.6	-18.2
Respiration (chamber)	14.2		13.3	13.4
Biomass Increment (tree measurements)	4.5		2.3	1.0
NEE (difference, eddy flux)	-6.7	-9.0	0.8	-1.0
ΔC unknown (NEE - biomass inc.)	-2.2	-4.5	3.1	0

Year July – June	NEE t C ha^{-1} y^{-1}
2001 - 2002	-9.2
2002 - 2003	-0.18
2003 - 2004	-0.84
2004 - 2005	-4.38

Vulnerability of terrestrial carbon sinks

Vulnerability:

The risk of accelerated carbon release from a pool as climate change occurs because of a positive feedback



Source: Field and Raupach, 2004