The impact of elevated CO_2 on the water balance: modelling and predictions

Lei Cheng, Lu Zhang: *CSIRO Water for a Healthy Country Flagship*

Yingping Wang: *CSIRO Marine and Atmospheric Research*

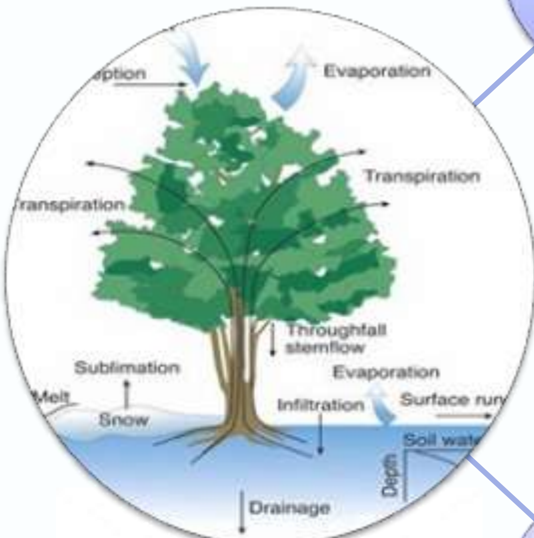
Qiang Yu, Derek Eamus: *University of Technology Sydney*

Motivation and issues

Modelling at FACE experimental sites

Predicting the impact of elevated CO_2 (eCO_2) on the water balance of different ecosystems in Australia

Motivations and issues



ET

- g_s ↓
- → ET ↓
- → Soil water ↑
- → *Q* ↑ → growth ↑

GPP

- C assimilation ↑
- → LAI ↑
- → ET ↑
- → *Q* ↓

ROOT

- Root turnover ↑
- → GPP ↑
- → ET ↑
- → *Q* ↓

Q ↑ + *Q* ↓ + *Q* ↓ → *Q* ?

Physiological → Hydrological

Motivations and issues

Will eCO_2 increase water availability and by how much?

global | **regional** | **points**

- Modelling of experiments (OTC, FACE): Wullschleger *et al*., 2002; Schafer *et al*., 2002; Dijkstra *et al*., 2007; Leuzinger and Korner, 2010; Katul *et al*., 2010; Drewry, *et al*., 2010a, b; Warren *et al*., 2011; *etc*.
- primarily focus on the physiological responses (*leaf scale*);
- incorporated latest experiment responses;
- robust in physiology and too empirical in hydrology
- difficult to extrapolate to larger spatial and longer time scales

Motivations and issues

Constraint modelling with experiments

Model:	Prediction:
✓impact CO_2 is explicitly parameterized in the processes; ✓water-carbon dynamically coupled ✓ balanced complexity and accuracy between hydrological and physiological processes ✓has the potential to be applied at larger spatial (regional) and long time (decades) scales	✓ model can capture the observed physiological responses in experiments (FACE and OTC) ✓under future ambient CO_2 (eCO_2) ✓under future changing climate condition

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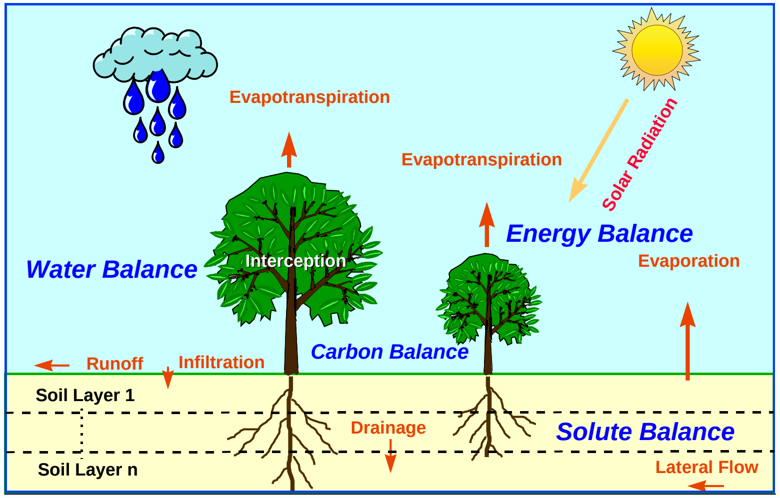
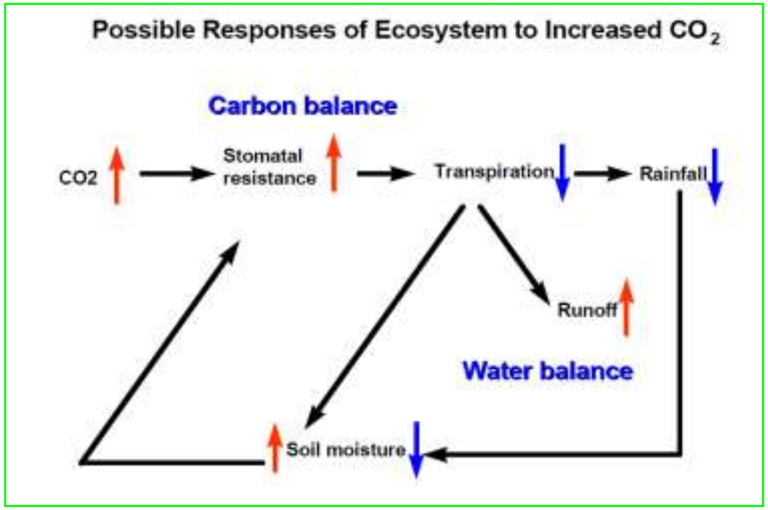
Modelling at the FACE experimental sites

Why WAVES

- It can dynamically simulate the responses and feedbacks of the growth of vegetation to water, light, temperature, and nutrient availabilities;
- It is robust in modelling catchment water balance;
- Coupled water-carbon relationship, and balanced complexity between physiological and hydrological processes;
- Well-tested in a number of experiments.

Water Vegetation Energy and Solute Modelling (WAVES)

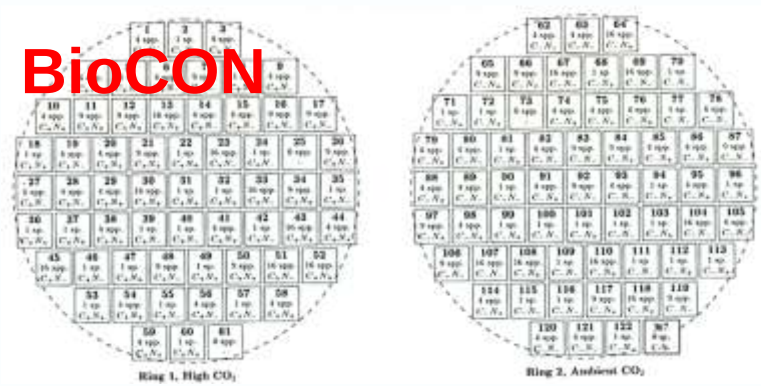




Modelling at the FACE experimental sites

Close canopy forest FACE

- 2 aCO_2 + 2 eCO_2 rings
- Daily modelling, 1999-2008
- Canopy transpiration (Ec)
- Soil water content (SWC)



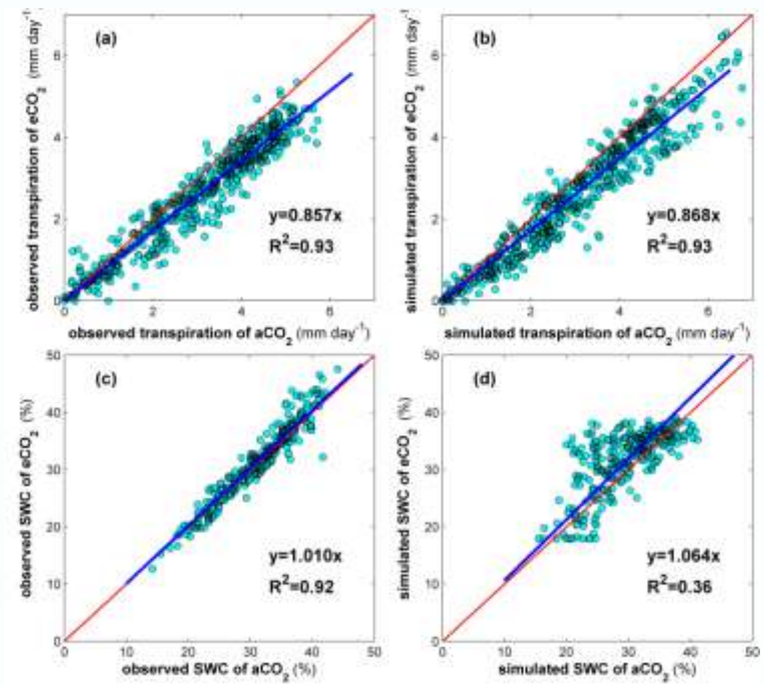
Grass FACE

- Monoculture C3 grass (*Poa pratensis*)
- CO_2 treatments only (2 aCO_2 + 2 eCO_2)
- Daily modelling, 1998-2006
- Leaf area index (LAI)
- Soil water content (SWC)

Modelling at the FACE experimental sites

Results of modelling ORNL FACE

Transpiration: observed : 14.3% ↓
simulated: 13.2% ↓

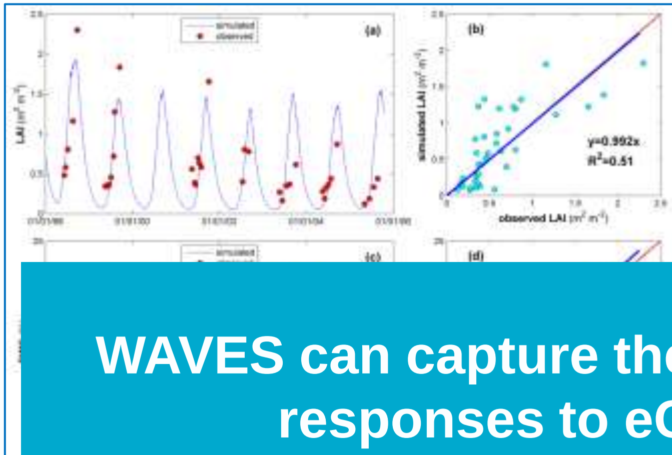


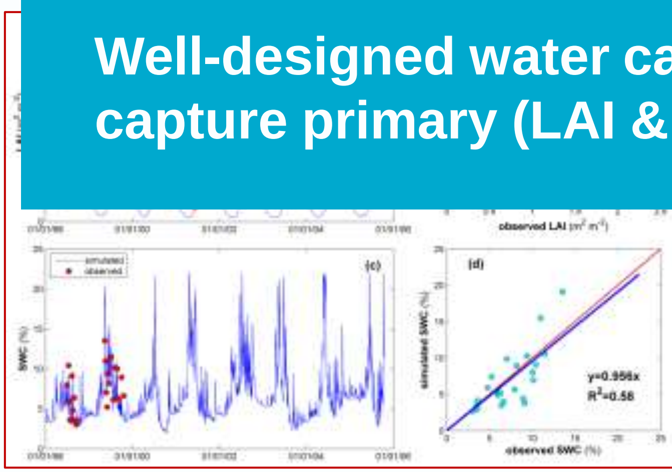
SWC: observed : 1.0% ↑
simulated : 6.4% ↑

- **aCO_2 plots modelling**
  - ET: bias = -0.3%; R^2=0.71
  - SWC: B=-7%; R^2=0.37
- **eCO_2 plots modelling**
  - ET: bias=-0.9%; R^2=0.83
  - SWC: bias=-0.8%; R^2=0.6

Modelling at the FACE experimental sites

Results of modelling BioCON FACE





Calibration under aCO_2 plots

LAI: B=-0.8%; R^2=0.51	**SWC:** B=5.3%;R^2=0.62

WAVES can capture the daily physiological and hydrological responses to eCO_2 at two different FACE sites

Well-designed water carbon coupling models can potentially capture primary (LAI & g_s) impacts of eCO_2 on water balance

Prediction for eCO_2 plots

LAI: B = -0.1%; R^2= 0.4	**SWC:** B=-4.4%; R^2 = 0.58

Motivation and issues

Modelling at FACE experimental sites

Predicting the impact of eCO_2 on the water balance of different ecosystems in Australia

eCO_2~Water in Australia
Four different ecosystems

	energy-limited (wet)	water-limited (dry)
forest	Bellinger River in NSW (150km^2) T = 12.5°C; P = 1300mm/yr ETp/P = 0.7; Forested: >90%	West Brook in NSW (72.9km^2) T = 17.8°C; P = 802mm/yr ETp/P = 1.7; eucalypt open forest: >90%
grass	Fisher River in TAS (37.5km^2) T = 5.9°C; P = 2000mm/yr ETp/P = 0.25; Native grass: >60% (sparse shrub:~30%)	Fletcher River in WA (68.2km^2) T = 26.8°C; P = 928mm/yr ETp/P = 2.16; Hummock grass : 100%

eCO_2~Water in Australia

Data & modelling

- Vegetation data: NVIS
- Soil data: ASRIS
- Streamflow data: measured
- Observed climate data: SILO

- Future climate:
  - 2050s; eCO_2 = ~550ppm
  - Downscaled A2 of 12GCMs (IPCC AR4)
  - Three global warming scenarios
    - Low: 0.84 °C
    - Median: 1.4 °C
    - High: 2.24 °C

No.	Climate	CO_2	descriptions
1	CC	aCO_2	model calibration
2	CC	eCO_2	similar with FACE
3	FC	eCO_2	"real" future
4	FC	aCO_2	Impact of changing climate
		(3)-(4)	Impact of eCO_2

CC: Current Climate
FC: Future Climate (GCM)

aCO_2: ~370ppm
eCO_2: 550ppm

eCO_2~Water in Australia

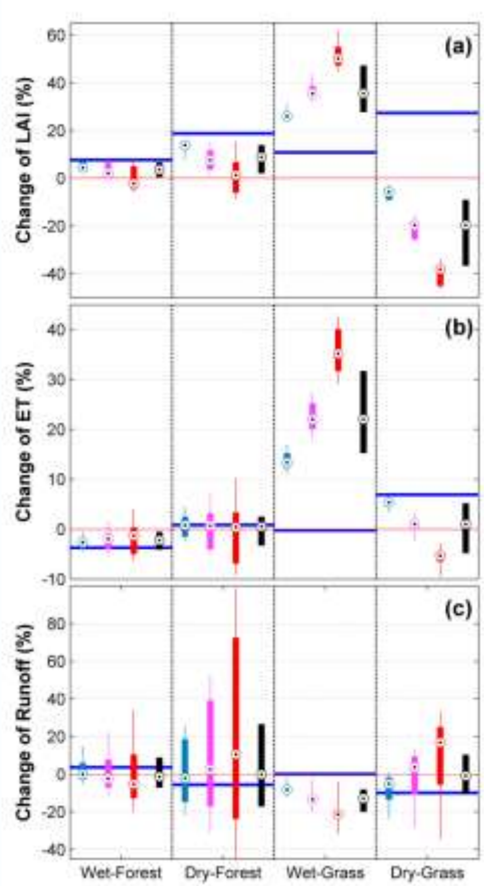
Impacts of eCO_2

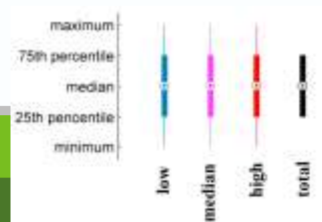
eCO_2 effect under current climate

LAI	wet	dry
Forest	7.7%↑	18.8%↑
Grass	10.8%↑	27.4%↑

ET	wet	dry
Forest	3.7%↓	0.9%↑
Grass	0.2%↓	6.9%↑

runoff	wet	dry
Forest	3.7%↑	5.5%↓
Grass	0.1%↑	9.9%↓





eCO_2 effect under future climate

LAI	wet	dry
Forest	3.6%↑	8.9%↑
Grass	35.6%↑	19.6%↓

ET	wet	dry
Forest	2.2%↓	0.5%↑
Grass	22.0%↑	1.0%↑

runoff	wet	dry
Forest	1.3%↓	0.1%↓
Grass	12.8%↓	0.8%↓

eCO_2~Water in Australia

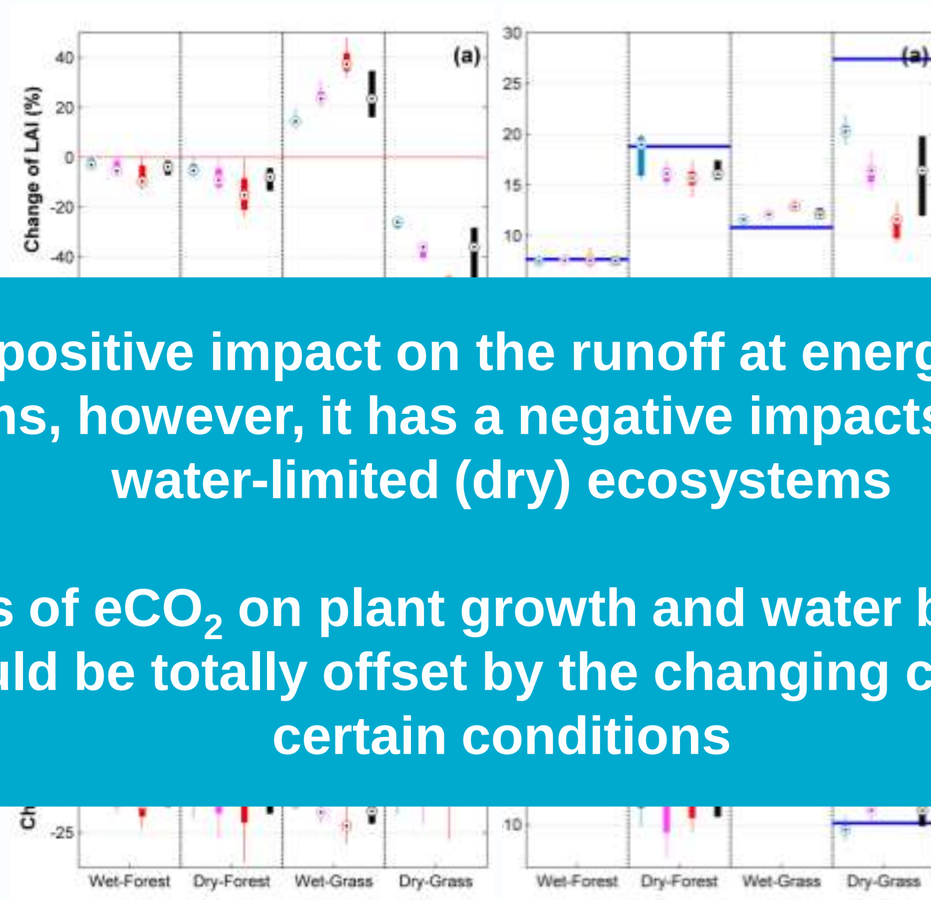
Impact of changing climate and eCO_2 on water

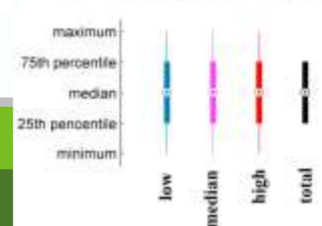
future climate impact only

LAI	wet	dry
Forest	3.9%↓	8.0%↓
Grass	[illegible]	[illegible]

ET	[illegible]	[illegible]
Forest	[illegible]	[illegible]
Grass	[illegible]	[illegible]

runoff	[illegible]	[illegible]
Forest	5.1%↓	7.9%↑
Grass	13%↓	8.8%↑





future eCO_2 impact only

LAI	wet	dry
Forest	7.5%↑	16%↑
Grass	[illegible]	[illegible]%↑

[illegible]	[illegible]	[illegible]ry
[illegible]	[illegible]	[illegible]%↑
[illegible]	[illegible]	[illegible]%↑

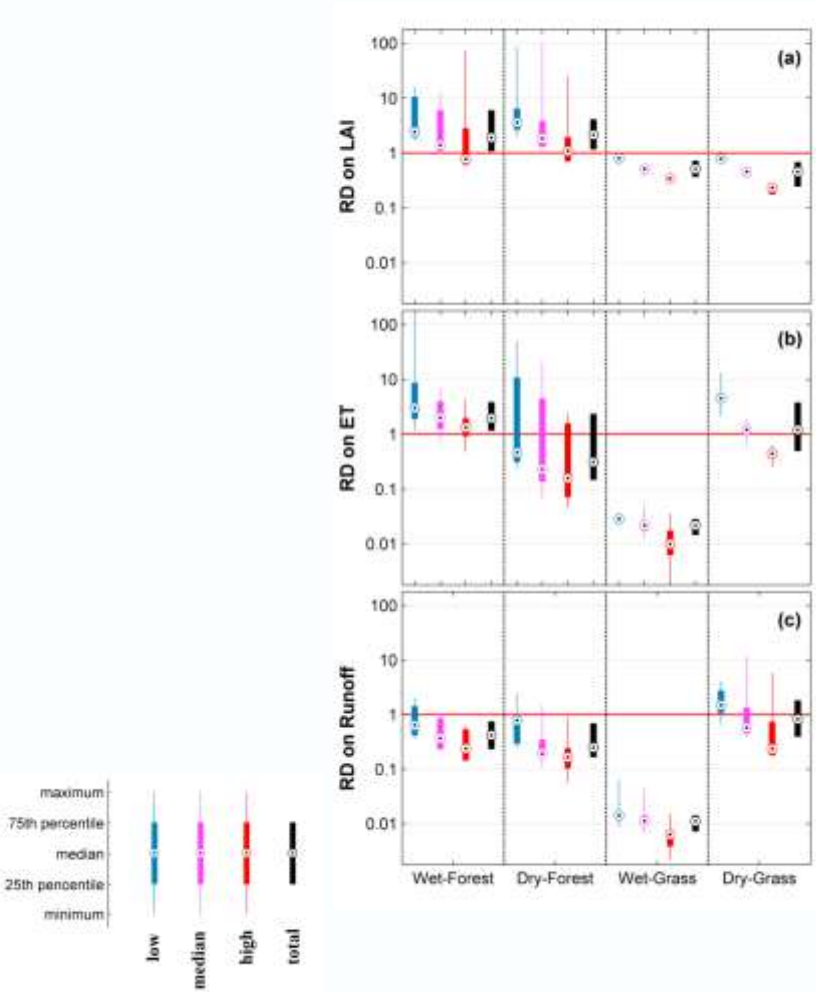
[illegible]	[illegible]	[illegible]ry
Forest	3.8%↑	7.1%↓
Grass	0.1%↑	9.0%↓

eCO_2 has a positive impact on the runoff at energy-limited (wet) ecosystems, however, it has a negative impacts on runoff at water-limited (dry) ecosystems

The effects of eCO_2 on plant growth and water balance in the future could be totally offset by the changing climate under certain conditions

eCO_2~Water in Australia

Relative dominance of eCO_2 & changing climate



$$RD = \frac{impact\ of\ eCO_2}{impact\ of\ future\ climate}$$

LAI	wet	dry
Forest	eCO_2	eCO_2
Grass	climate	climate

runoff	wet	dry
Forest	climate	climate
Grass	climate	climate

Thank you!

LEI.CHENG@CSIRO.AU
www.csiro.au