# Atmospheric constraints on plant water use efficiency in JULES

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UNIVERSITY OF EXETER

Met Office

# Water Use Efficiency?

* **Agriculture** - Conference in London: "More Crop Per Drop - Raising Water Use Efficiency"

* Why **$CO_2$ is good**: "Rising $CO_2$ Boosts Plant Water Use Efficiency" (http://www.plantsneedco2.org)

# Water Use Efficiency?

* WUE controls the relationship between the ecosystem water and carbon balance

* Improving understanding of vegetation responses to climate variations, responses of carbon and hydrological cycle

* When the WUE is known, GPP can be calculated from hydrological cycle variables

# Hypothesis

* Ecosystem WUE$_{eco}$ derived from fluxes is equal to atmospheric WUE$_{atm}$ derived from meteorological variables at the leaf level

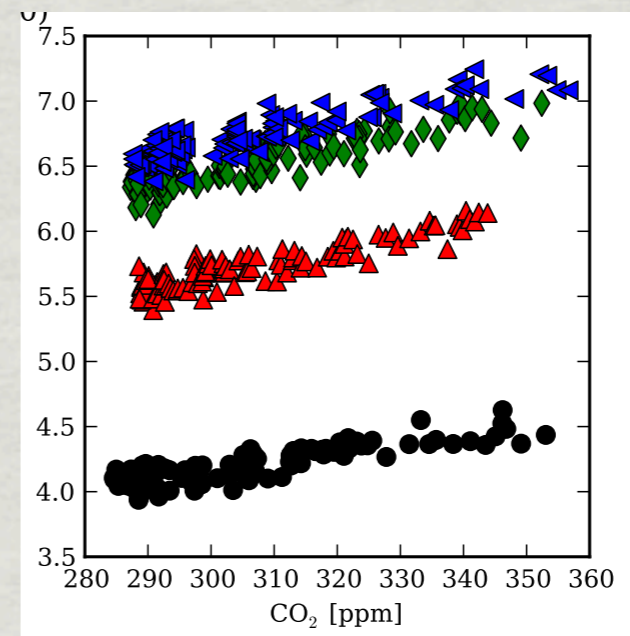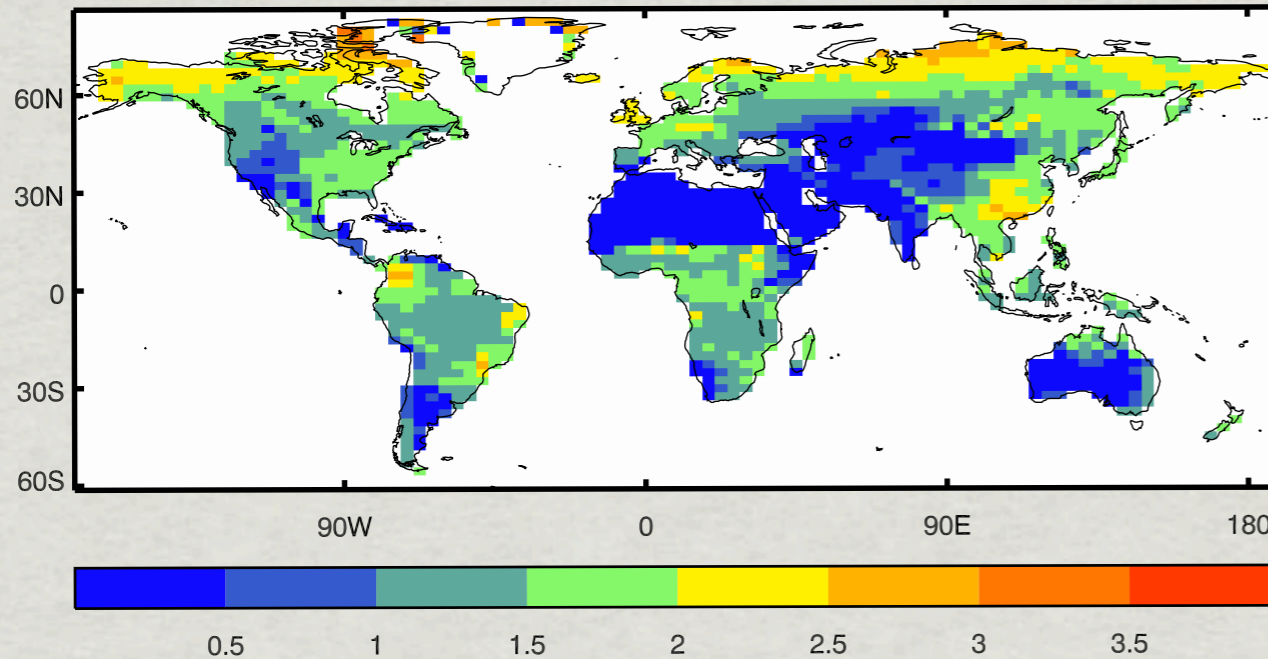* This is valid on larger scales as well

$$WUE_{eco} = \frac{GPP}{ET}$$

$$WUE_{atm} = \frac{C_a - C_i}{1.6D} = \frac{C_a(1 - f)}{1.6q_{sat}(1 - RH)}$$

$f = 1 - f_0$
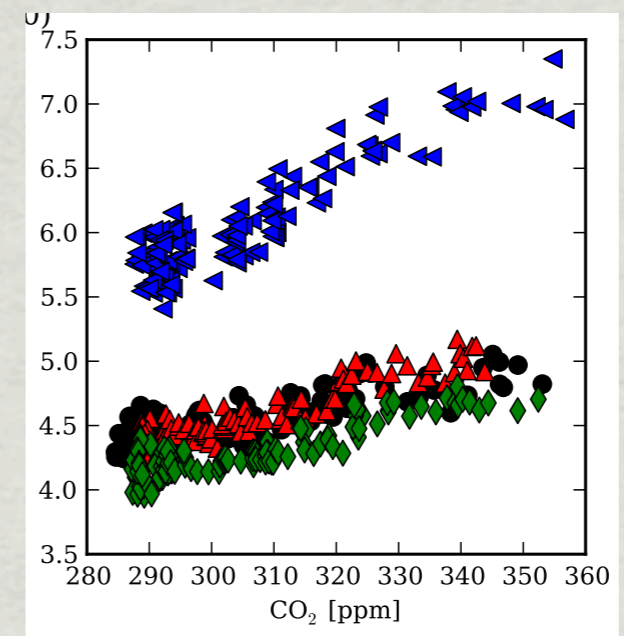$f_0$ : stomatal resistance ($C_i/C_a$)

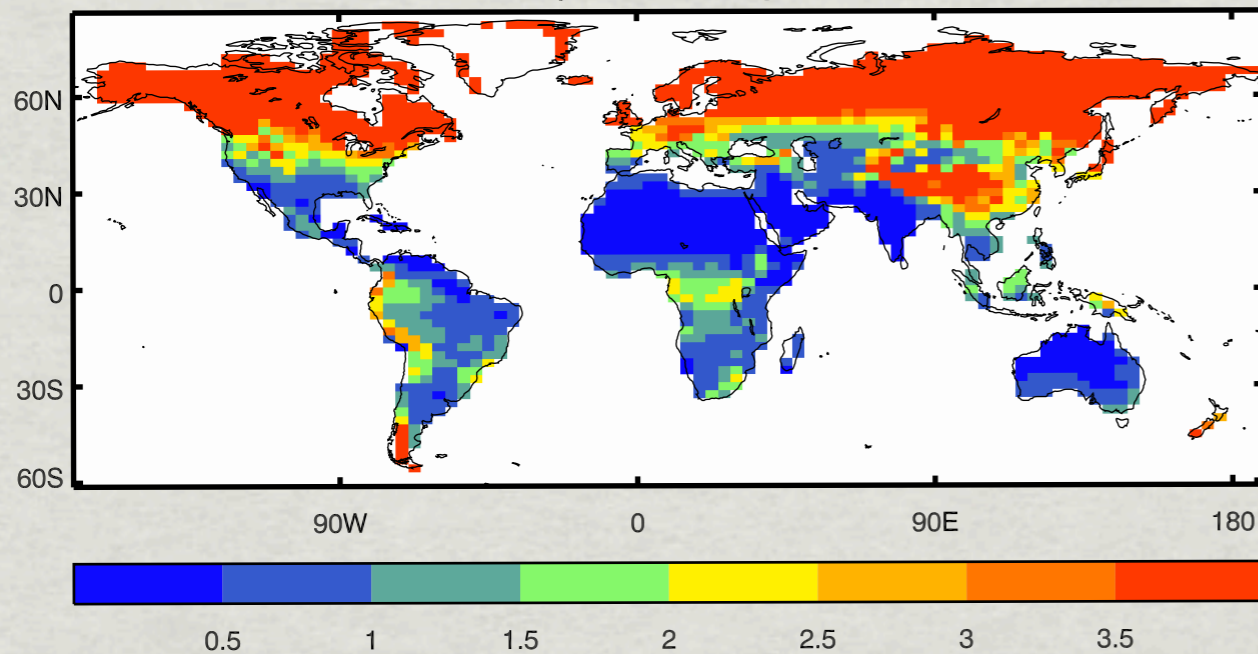# Global Water Use Efficiency


Annual vegetation WUE [g CO2/kg H20]


Ecosystem WUE
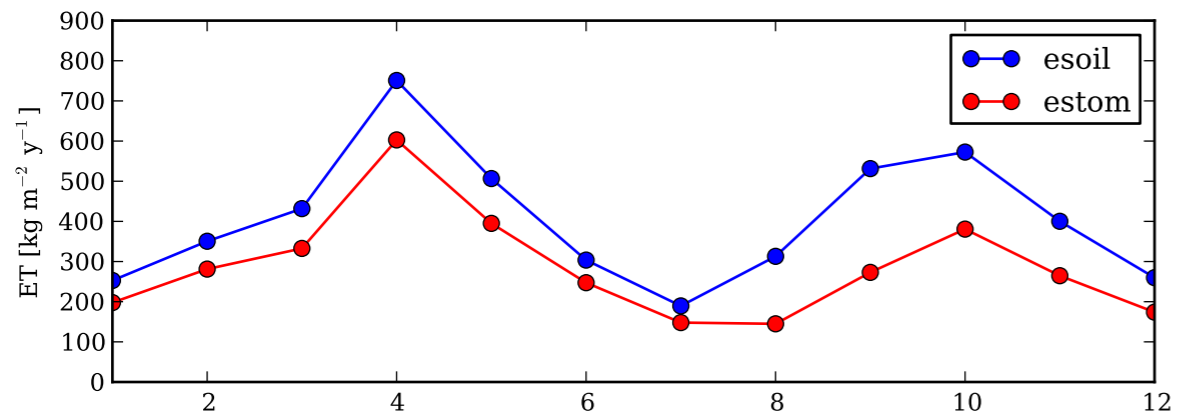

Annual atmospheric WUE [g CO2/kg H20]


Atmospheric WUE

aknac
aknbl
aknco
akndj

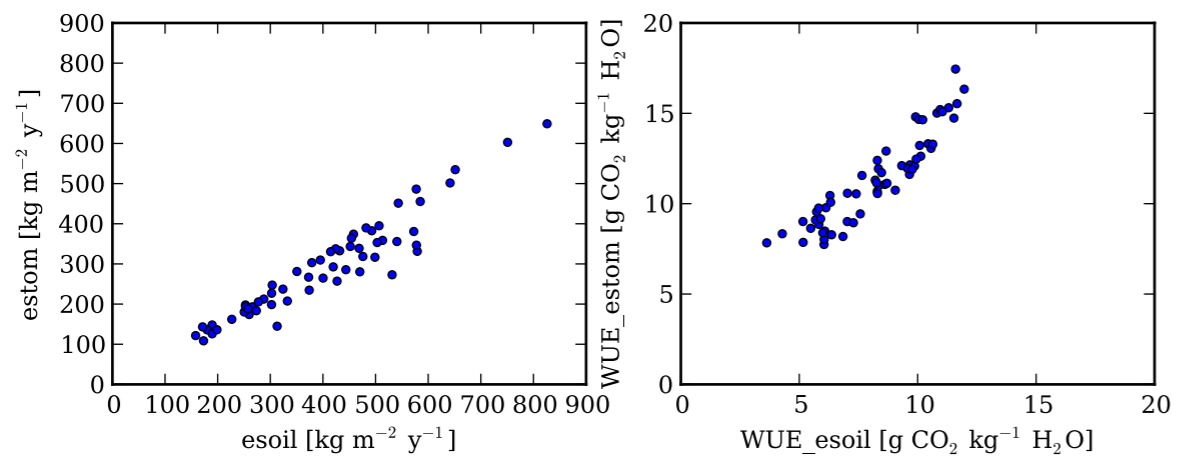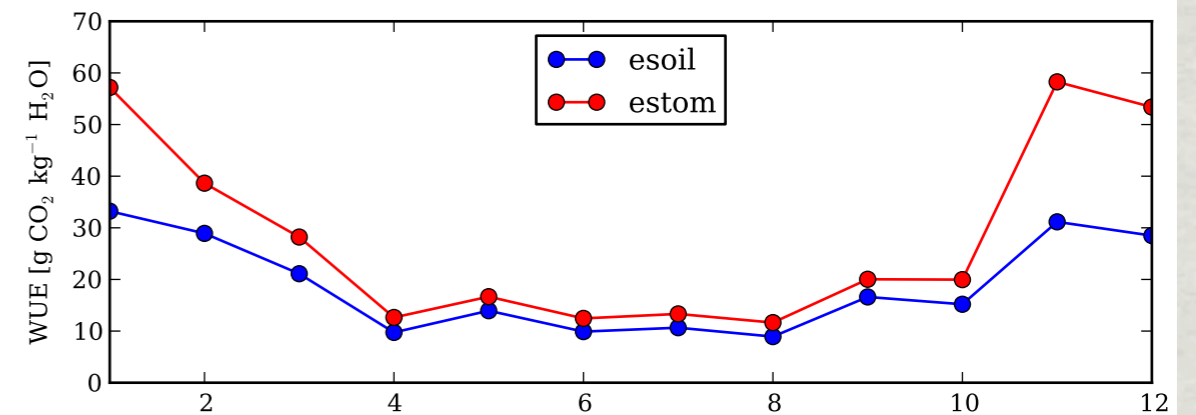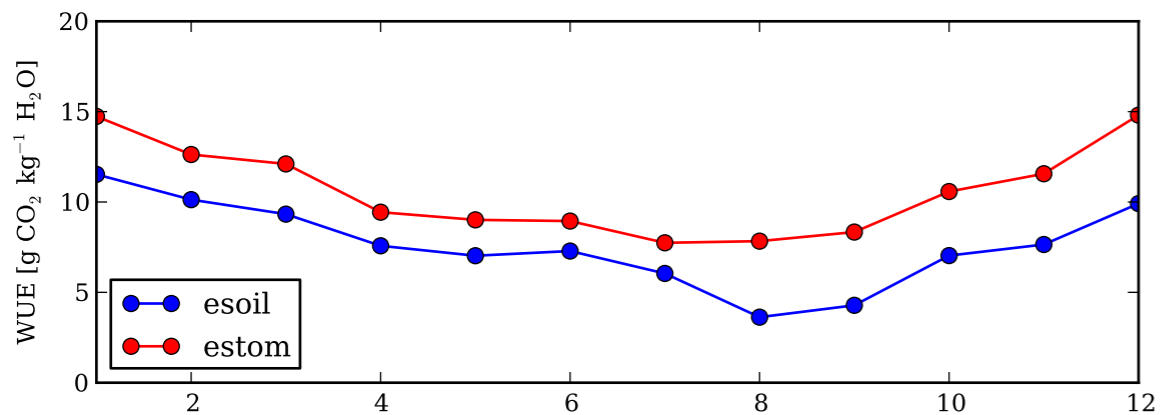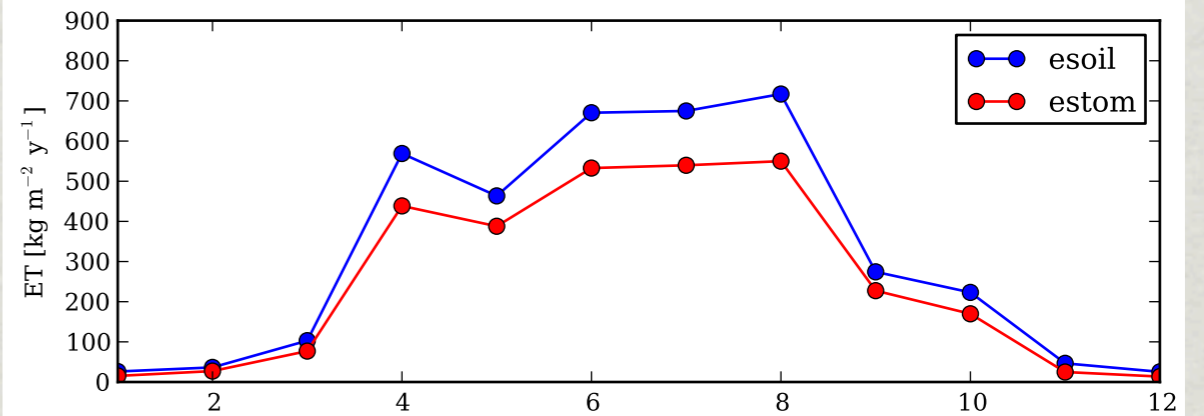Examples from HadCM3 QUMP ensemble

$$WUE_{eco} = \frac{GPP}{ET}$$

# Which fluxes to use?


Monthly JULES output for El_Saler
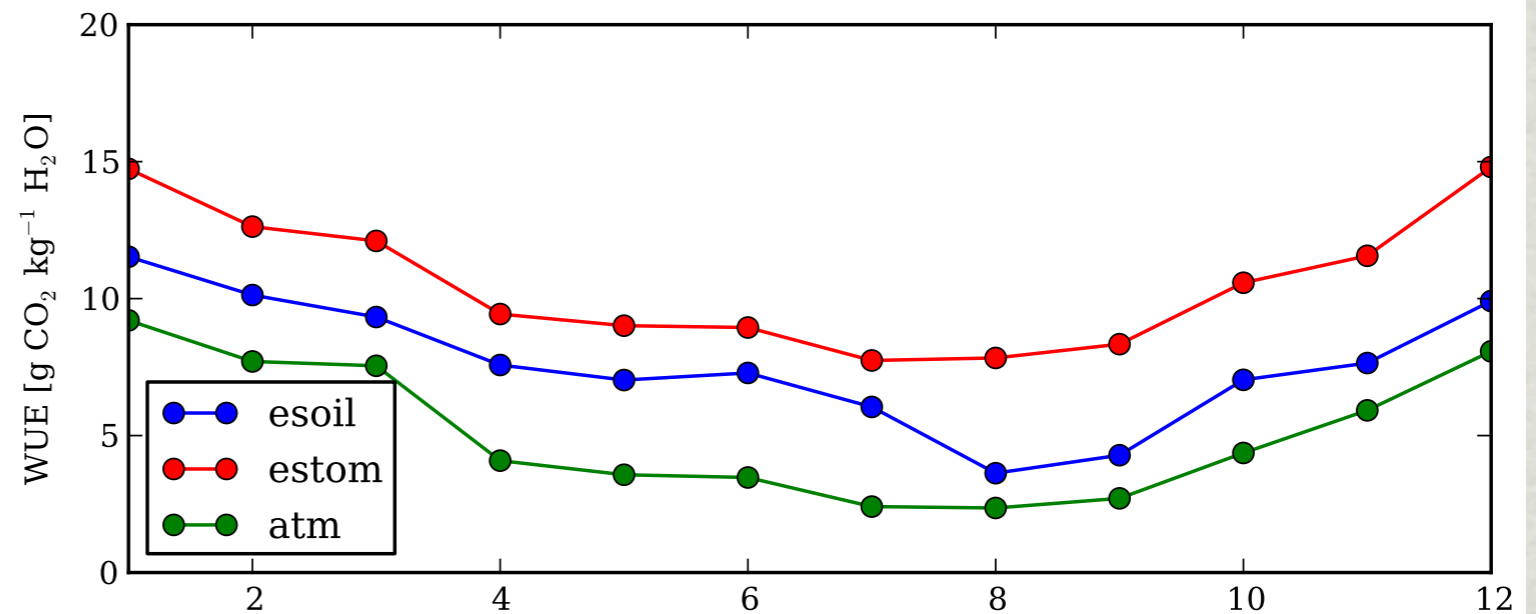

Monthly JULES output for Tharandt
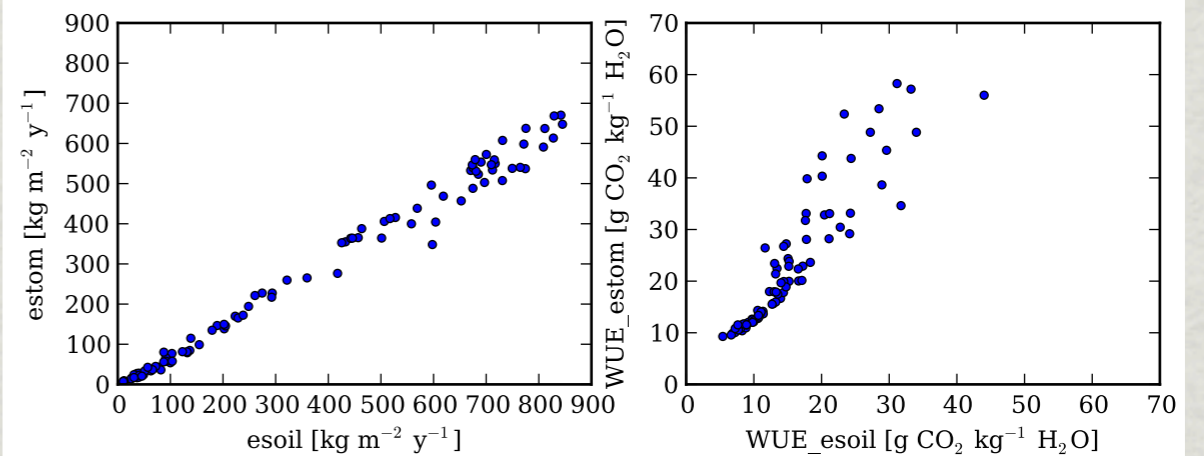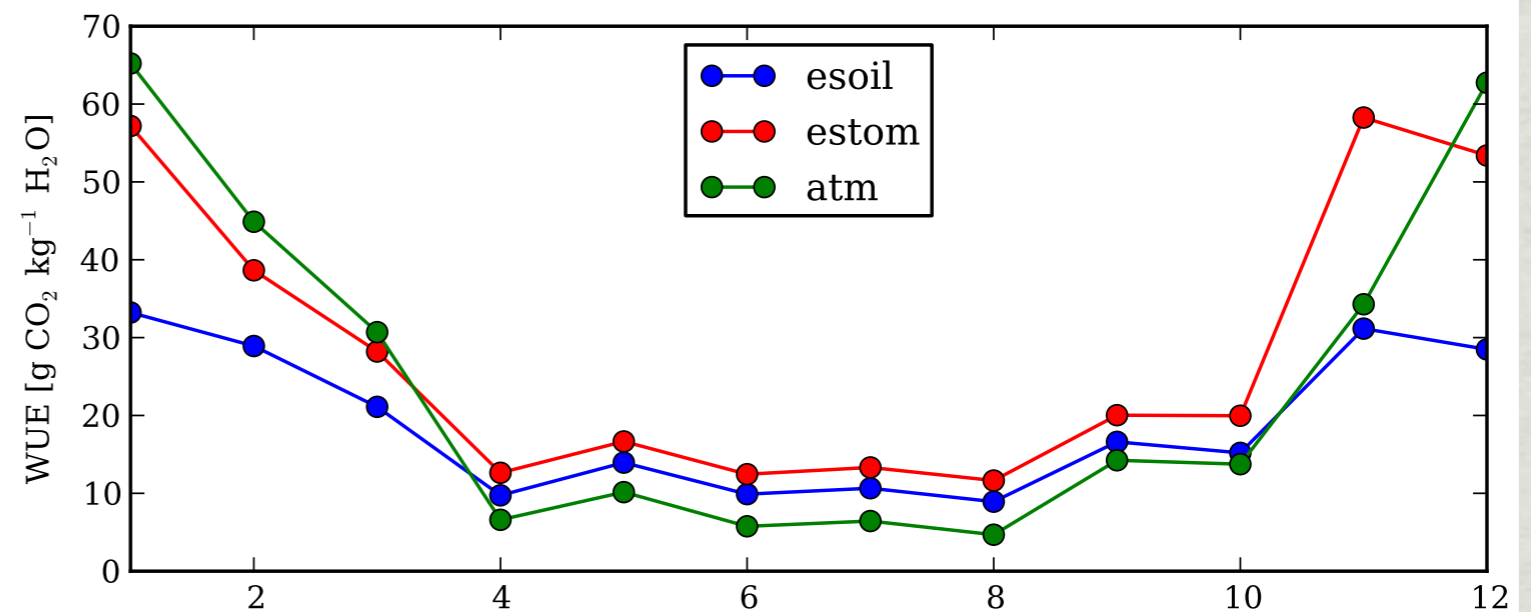
# The same?

$$WUE_{eco} = \frac{GPP}{ET}$$

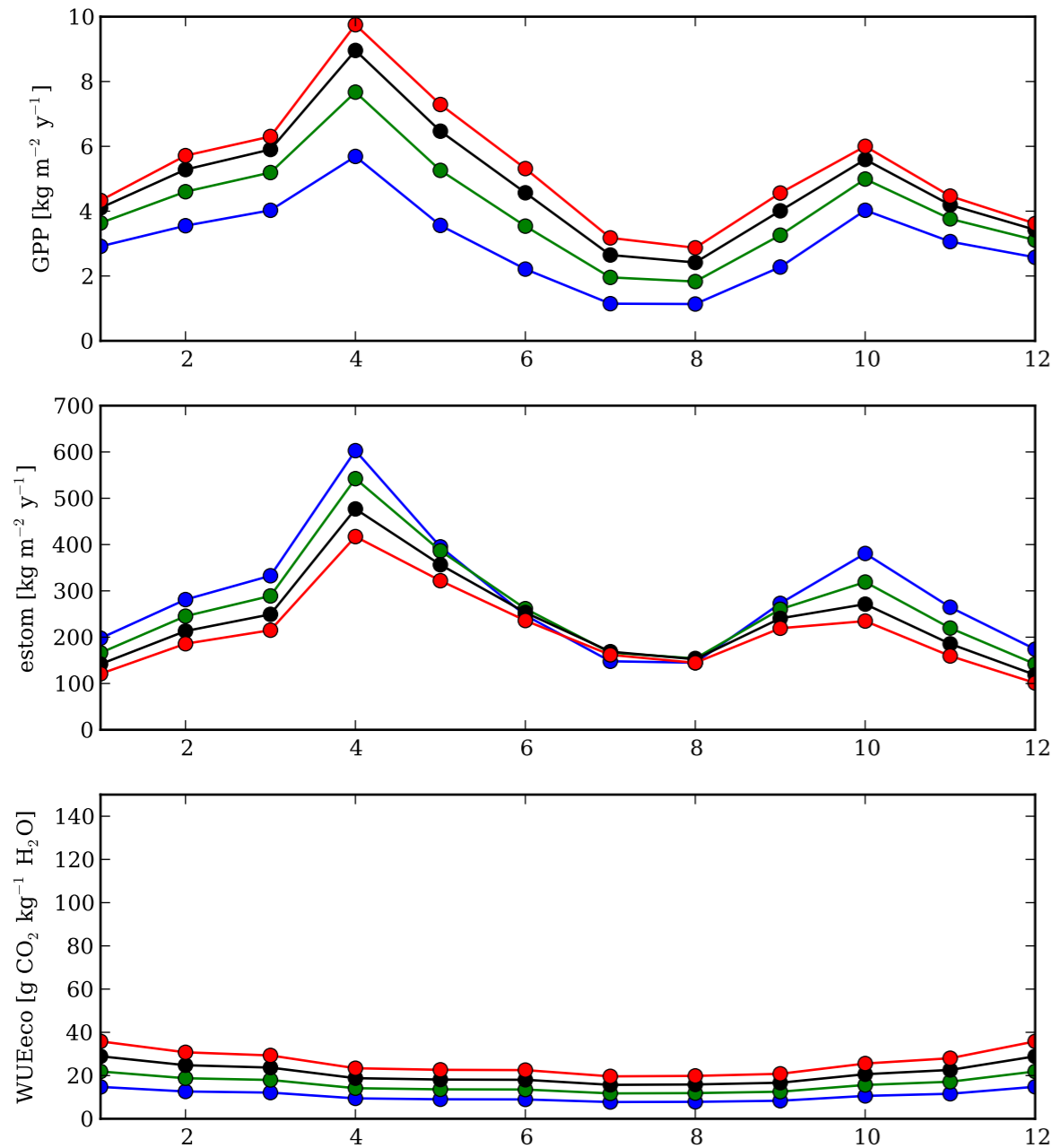$$WUE_{atm} = \frac{C_a - C_i}{1.6D}$$



Monthly JULES output for El_Saler



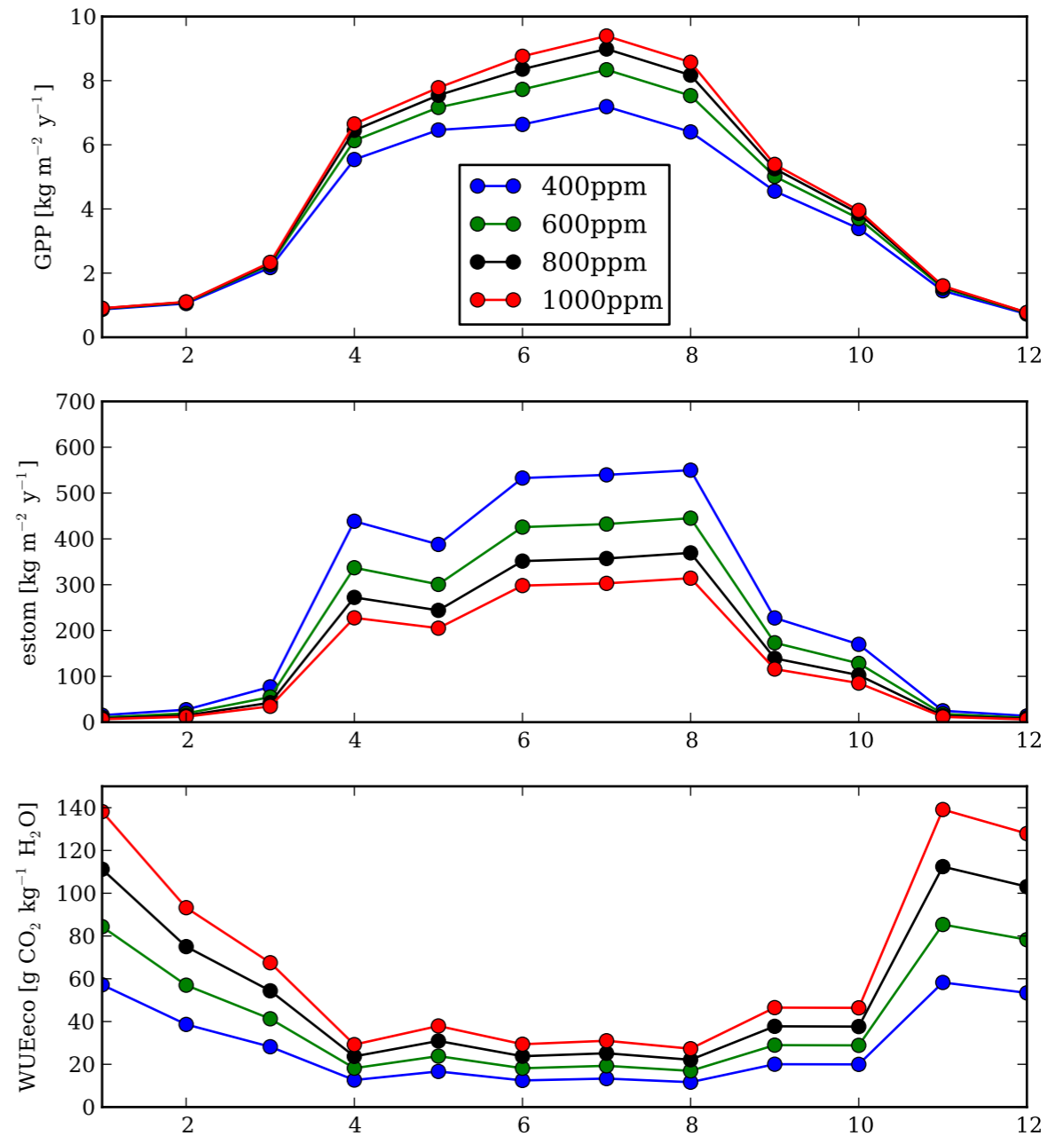Monthly JULES output for Tharandt

# Increasing CO$_2$



Monthly JULES output for El_Saler

Monthly JULES output for Tharandt

$$WUE_{eco} = \frac{GPP}{ET}$$

Legend:
- 400ppm (blue)
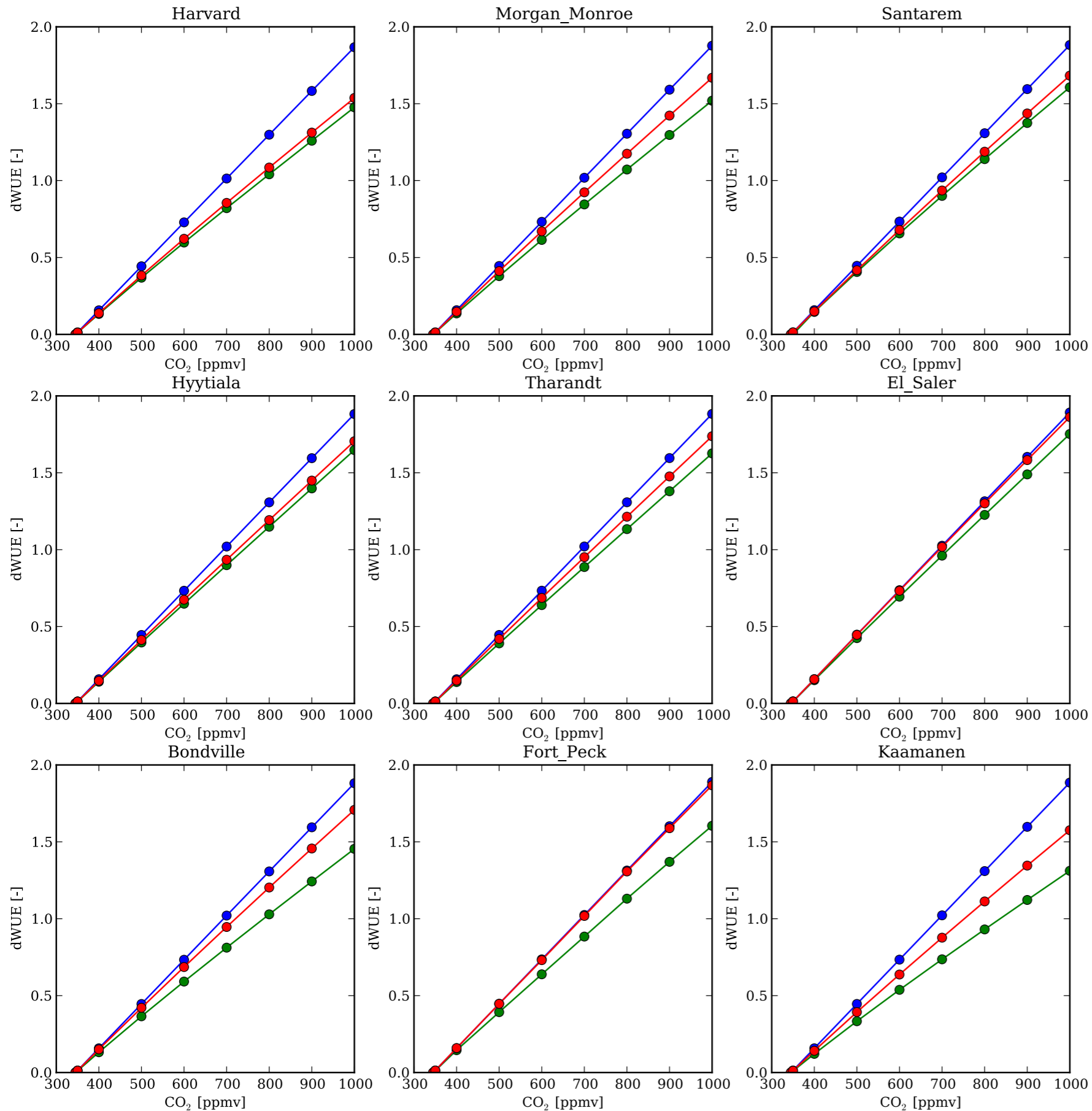- 600ppm (green)
- 800ppm (black)
- 1000ppm (red)
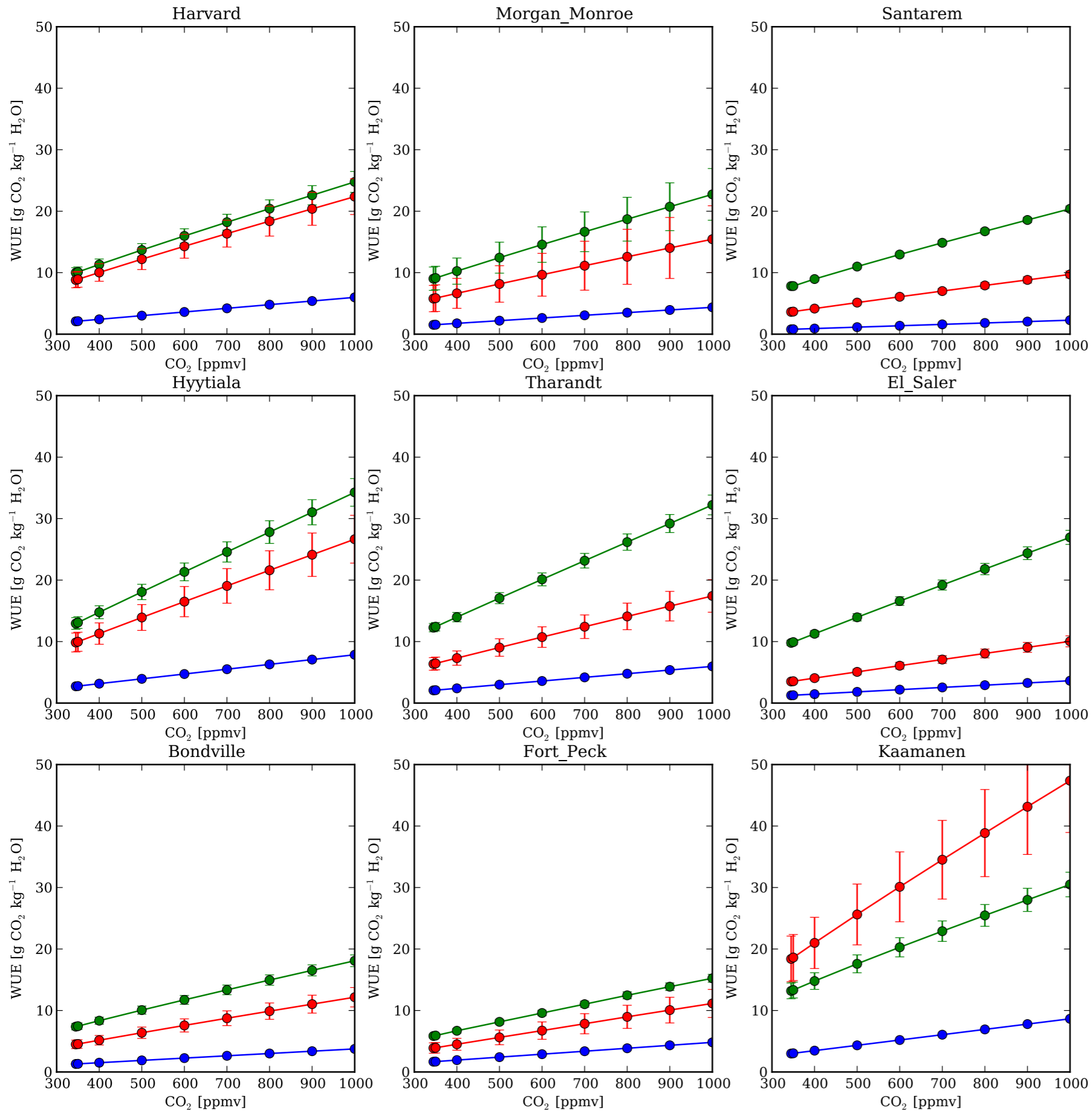
Increasing CO₂

Average annual WUE for 9 sites

Ecosystem
Air temperature
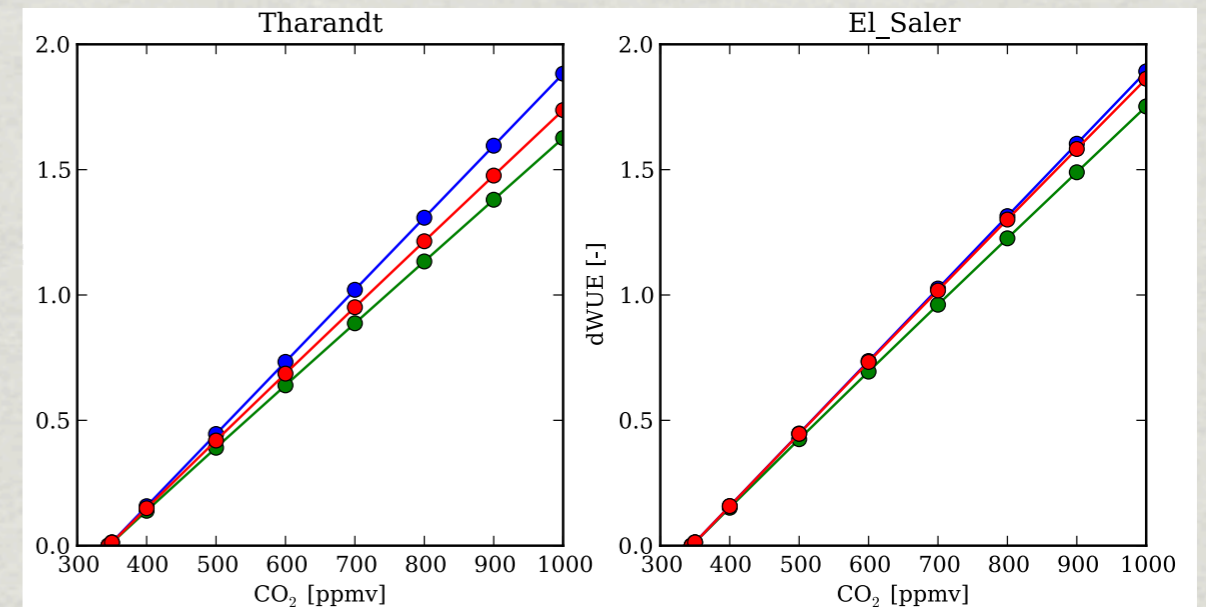Surface temperature

Increasing $CO_2$

Relative change of WUE for 9 sites

Ecosystem
Air temperature
Surface temperature

$$WUE_{eco} = \frac{GPP}{ET}$$

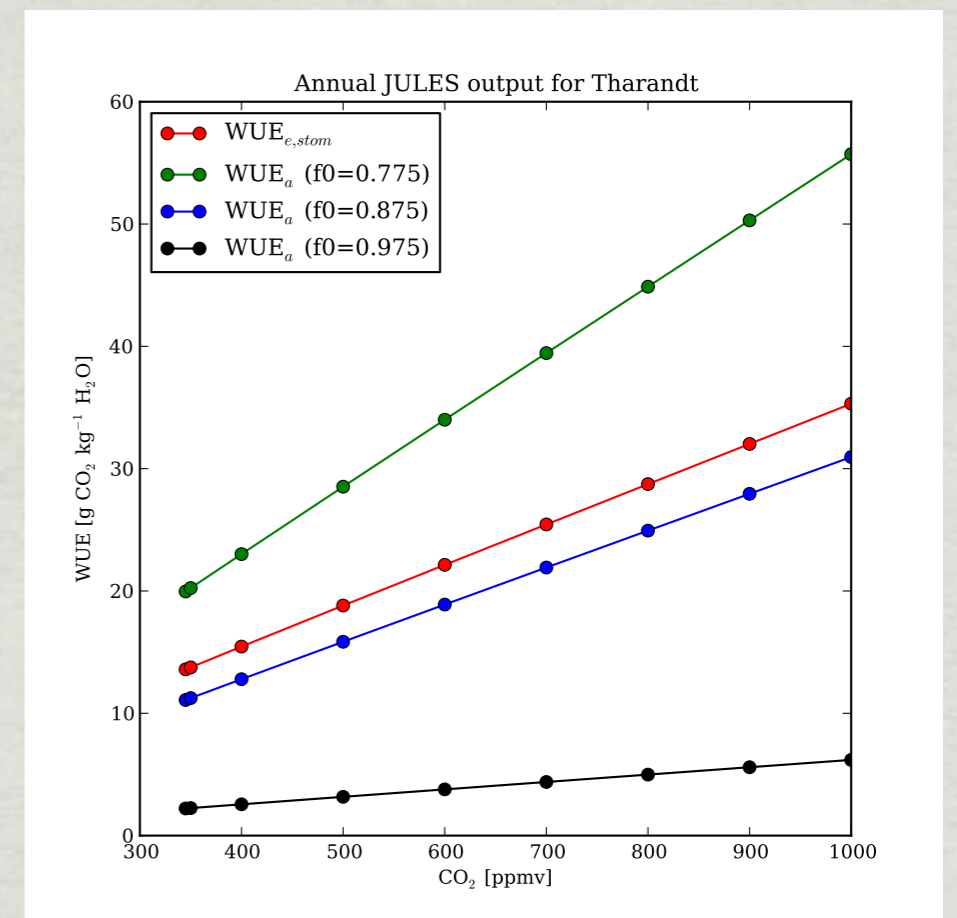$$WUE_{atm} = \frac{C_a - C_i}{1.6D} = \frac{C_a(1-f)}{1.6q_{sat}(1-RH)}$$



✳ Why are there still differences?

✳ Soil moisture limitation?
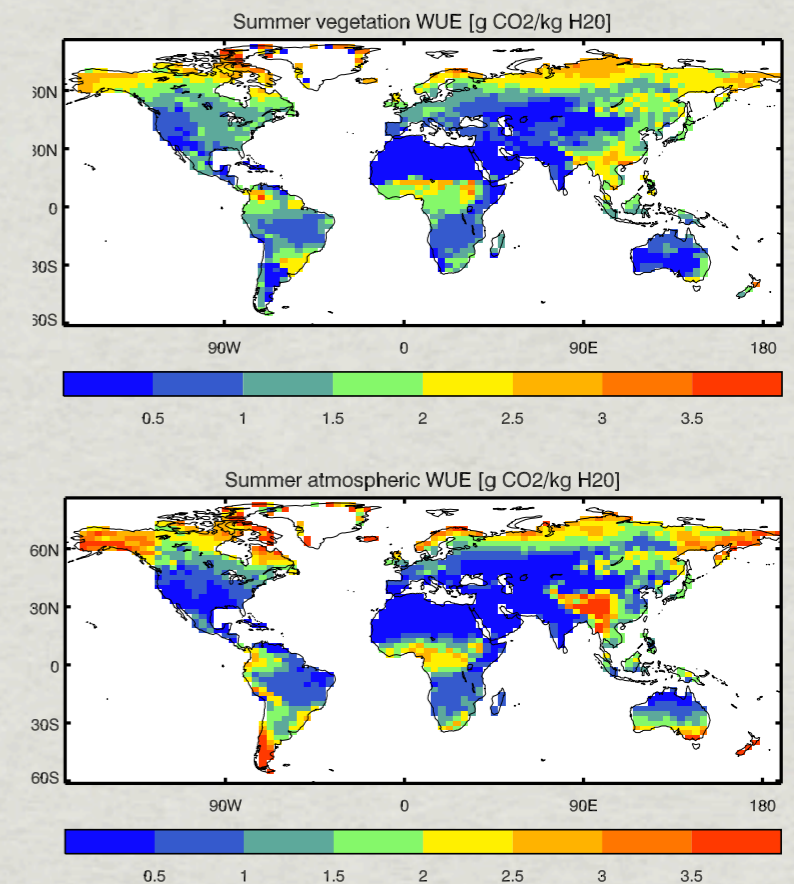
✳ *VPD* sensitivity of *f₀*?

✳ Dark respiration?

✳ Averaging?

# Global WUE


WORK IN PROGRESS

* **BIG QUESTION** reproducible with observations over last century?

  * Only growing season?

  * Validation: Fluxnet and …

  * What is best observational data?

    * (Surface) Temperature

    * Humidity

    * $CO_2$


Summer vegetation WUE [g CO2/kg H20]


Summer atmospheric WUE [g CO2/kg H20]

# NEW perturbing land surface in a large ensemble

✳ MOSES2 coupled to HadAM3P

✳ climateprediction.net

✳ Perturbations:

✳ **Model parameters**

✳ Land use maps from different datasets

✳ Soil type maps

WORK IN PROGRESS