Evaluating the respective impact of Radiative Forcing and Fertilization of Vegetation to CO$_2$ Enriched Atmosphere During Heatwave in Western Europe

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Nature Climate Change (Submitted)

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Motivation (1/3)

Motivation

Atmosphere enriched in CO2: 2 contradictory feedbacks

increased radiation (+) vs fertilization of the vegetation (-)

After De Arellano et al (2012)
Increase in forest water-use efficiency as atmospheric carbon dioxide concentrations rise

Trevor F. Keenan¹, David Y. Hollinger², Gil Bohrer³, Danilo Dragoni⁴, J. William Munger⁵, Hans Peter Schmid⁶ & Andrew D. Richardson⁷

FLUXNET data shows increased water use efficiency (WUE) for Summer months of Northern Hemisphere forests under higher $[\text{CO}_2]_{\text{atm}}$
Motivation

France heatwaves in 2003

Consequences

France:
- 15,000 deaths
- Mortality increased by 55% over the 1st three weeks of Aug

Similar stories all over Western Europe

And... such extreme events are believed to occur more often with climate change!
1. Objectives and design of the study
2. Result Highlights
3. Main conclusions
Objectives and design of the experiment

- **Questions** investigated:
  - How the 2003 heatwave event would be different under 2100 \([\text{CO}_2]\)?
  - **radiative forcing vs. fertilization**?

- **2003 heatwave**
- **Regional scale**: 10x15deg domain centered on France

- **Coupling** of atmospheric model (WRF) with a surface model (ORCHIDEE)
- 4 runs

<table>
<thead>
<tr>
<th>CO2 (in ppm)</th>
<th>WRF</th>
<th>ORCHIDEE</th>
<th>Effect investigated</th>
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<tr>
<td>CTL</td>
<td>373</td>
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<td>RAD</td>
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<td>FUT</td>
<td>1370</td>
<td>935</td>
<td>Interactions between both effects</td>
</tr>
</tbody>
</table>
Longwave Heat Flux (1500 UTC)

June 2003

August 2003

Δ: Run - CTL

Radiation

Fertilization

Radiation + Fertilization

Unit: W/m²

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Max Temperature ($T_{\text{max}}$)

Results (2/5)

June 2003

- CTL

August 2003

- CTL

\[ \Delta: \text{Run} - \text{CTL} \]

- RAD-CTL

- PHOT-CTL

- FUT-CTL

Unit: K

Control Run

Radiation

Fertilization

Radiation + Fertilization
Results (3/5)

Water & energy cycles altered: latent heat flux (1500 UTC)

June 2003

August 2003

Δ: Run - CTL

Control Run

Radiation

Fertilization

Unit: W/m²

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Results (4/5)

Water & energy cycles altered: the soil moisture acts as a buffer

Control Run

Latent Heat Δ
\( \Delta LH_{\text{Run}} - \Delta LH_{\text{CTL}} \)

Soil Moisture Δ
\( \Delta s_{\text{Run}} - \Delta s_{\text{CTL}} \)

Radiation

No SM feedback on LH

Soil drying begins 4 days before actual heatwave

Fertilization

PHOT-CTL

+ Fertilization

RAD-CTL

Soil Moisture (kg/m²)

Radiation

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Results (5/5)

Every type of vegetation reacts differently

WUE = GPP / Transpiration

WUE ratio: \( wue_{\text{Run}} / wue_{\text{CTL}} \)

Soil Moisture Δ: \( S_{\text{Run}} - S_{\text{CTL}} \)

Trees mobilize lower water

Daily data from May 30 to August 31 2003

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Every type of vegetation reacts differently

WUE = \( \frac{\text{GPP}}{\text{Transpiration}} \)

WUE ratio: \( \frac{\text{wue}_{\text{Run}}}{\text{wue}_{\text{CTL}}} \)

Soil Moisture Δ: \( S_{\text{Run}} - S_{\text{CTL}} \)

Mitigation

Results (5/5)

Daily data from May 30 to August 31 2003

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Results (5/5)

Every type of vegetation reacts differently

\[ \text{WUE} = \frac{\text{GPP}}{\text{Transpiration}} \]

Crop

\[ \text{WUE ratio: } \frac{\text{wue}_{\text{Run}}}{\text{wue}_{\text{CTL}}} \]

Broad-Leaf Summergreen

\[ \Delta s = s_{\text{Run}} - s_{\text{CTL}} \]

Almost similar evolution

Daily data from May 30 to August 31 2003
Main conclusions

• Energy and water cycle are highly affected by fertilization

• Fertilization response seems to overtake the Radiative forcing effect

• “Water management” of the vegetation to buffer the heat waves

• Crop & trees have different behaviors:
  - trees: lower savings of water during the pre-Summer periods
  - but able to mobilize lower soil water
  - trees can sustain a higher GPP and WUE throughout the Summer

• But similar relative evolution of WUE simulated under higher [CO2] atm
Works cited


Thank You, really!

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Acknowledgement
Study enabled by an Alliance Doctoral Mobility Grant

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