Responses of carbon and water fluxes following drought events in combinations with warming and elevated CO2

Selsted, Merete Bang; Albert, Kristian Rost; Ambus, Per; Michelsen, A.; Ro-Poulsen, H.; Mikkelsen, Teis Nørgaard; Ibrom, Andreas

Published in:
Oral and Poster Presentations of the BIOGEOMON 2009 Conference (online)

Publication date:
2009

Document Version
Publisher's PDF, also known as Version of record

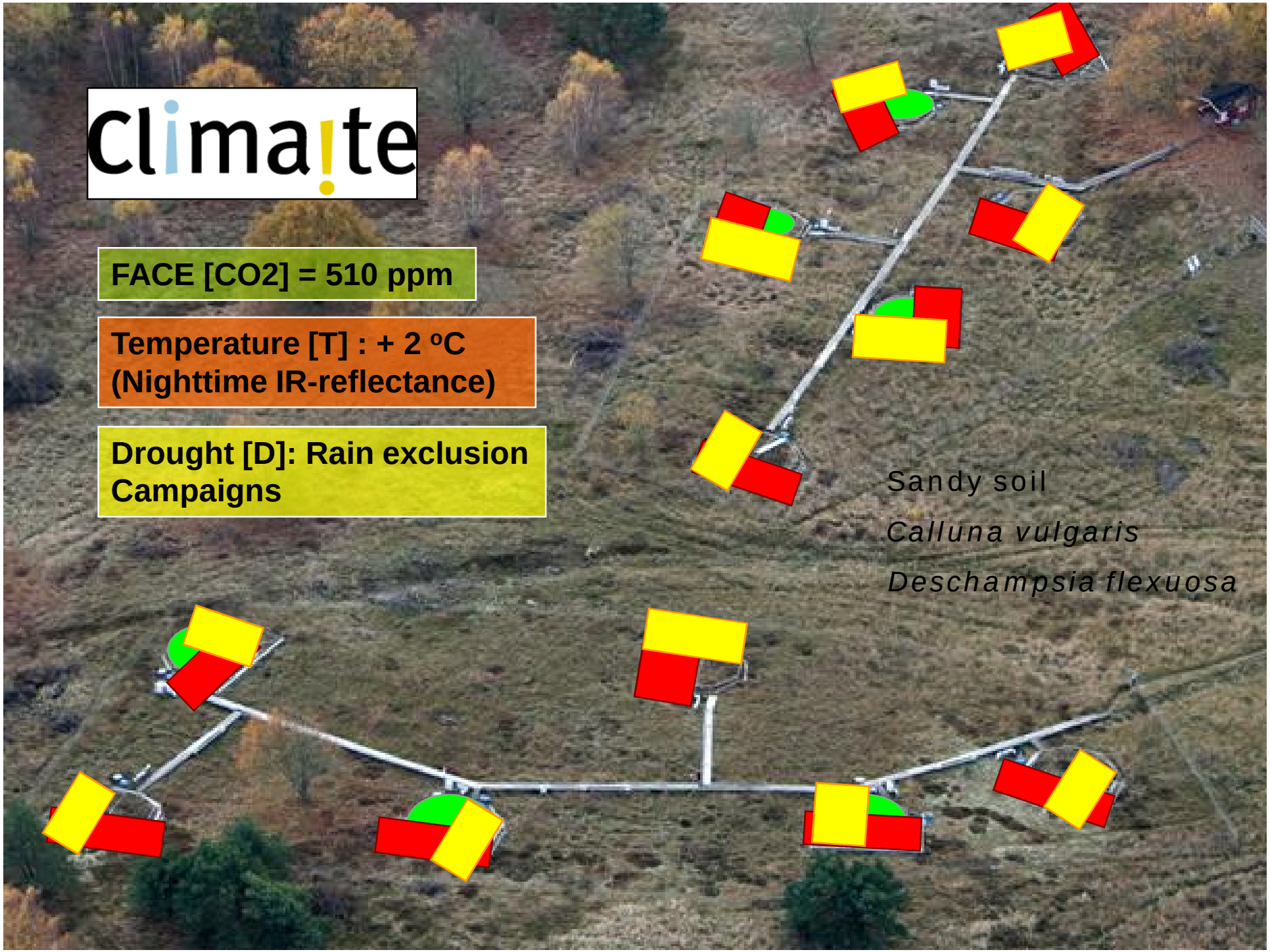
Responses of carbon and water fluxes following drought events in combinations with warming and elevated CO_2 in a semi-natural temperate heath ecosystem

Helge Ro-Poulsen[1], Kristian R. Albert[1], Teis N. Mikkelsen[2] and Anders Michelsen[1]

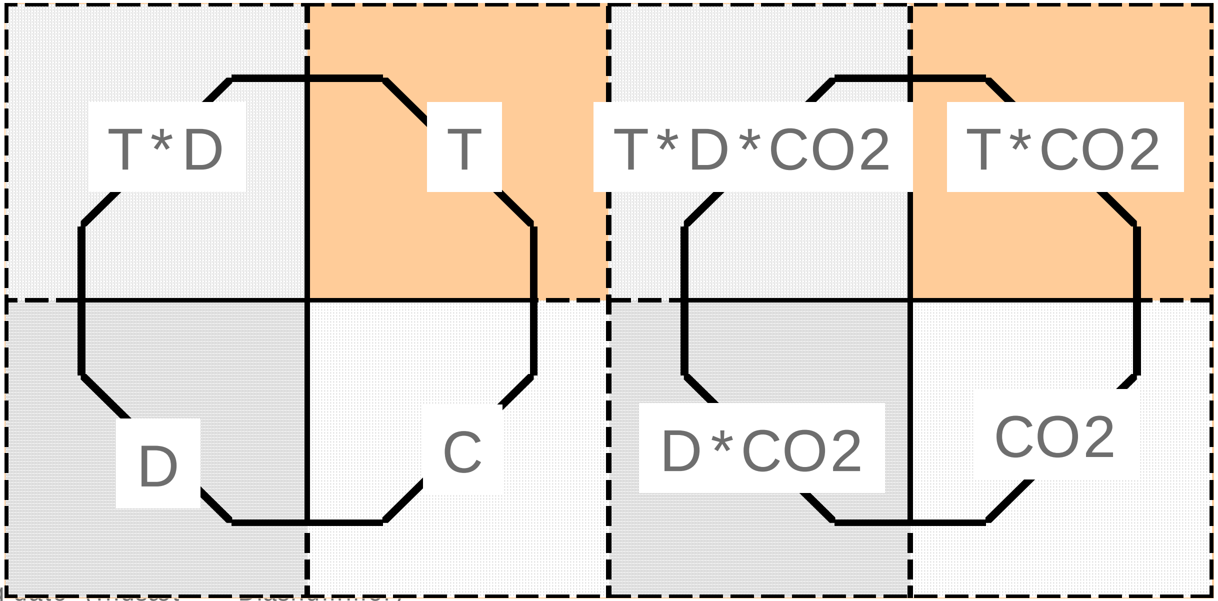
(1) Section of Terrestrial Ecology, Department of Biology, University of Copenhagen, Denmark

(2) Biosystems Department, Risø National Laboratory for Sustainable Energy, Technical University of Denmark


Climate


Climate
FACE [CO2] = 510 ppm
Temperature [T] : + 2 ºC
(Nighttime IR-reflectance)
Drought [D]: Rain exclusion
Campaigns
Sandy soil
Calluna vulgaris
Deschampsia flexuosa

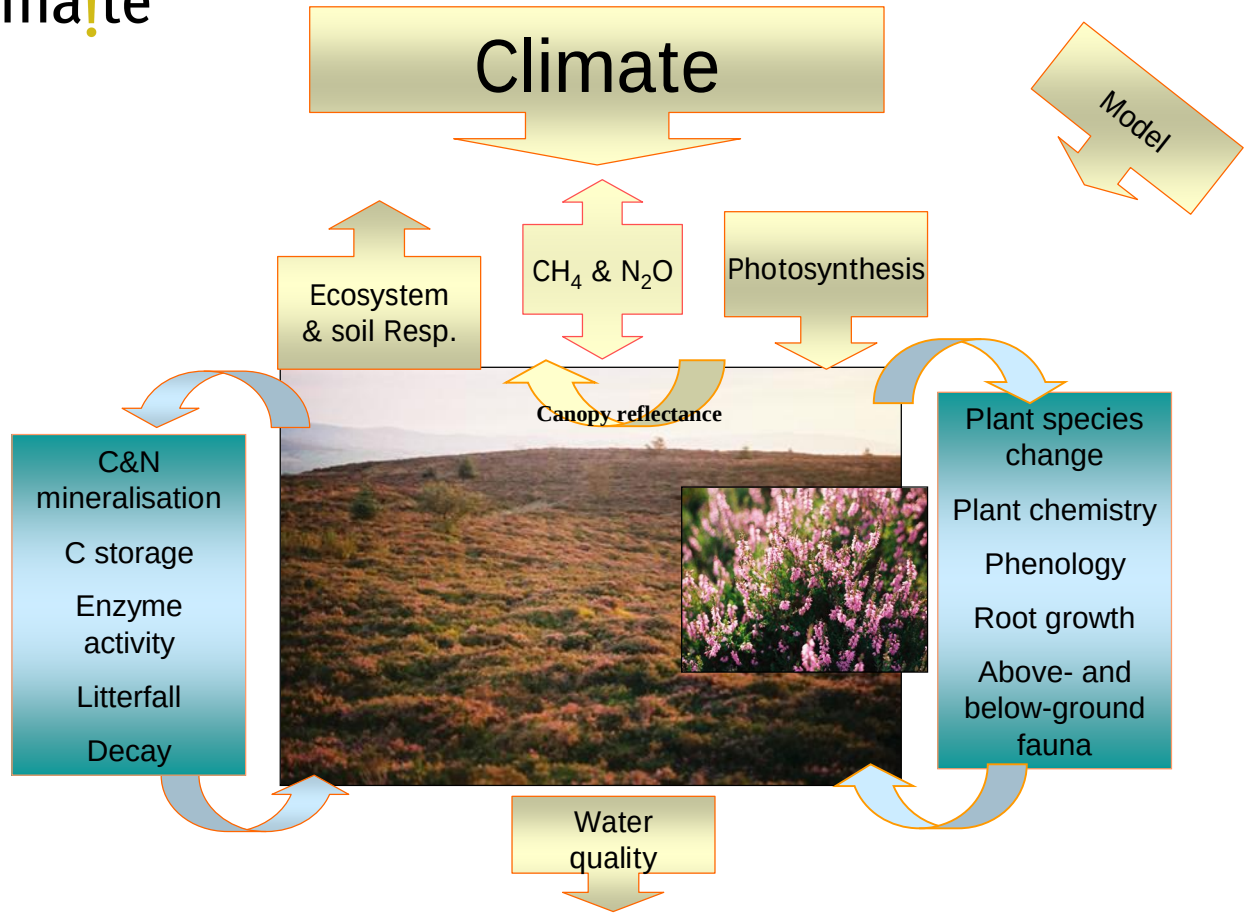
Experimental Setup



x 6

Studies of Ecosystem processes and the responses to climatic changes

Climaite



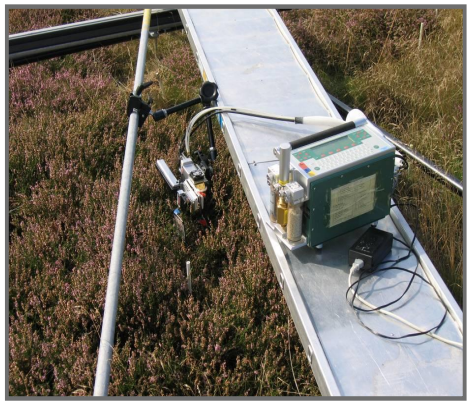
Plant Ecophysiology:

Photosynthetic Performance of *Calluna vulgaris* and *Deschampsia flexuosa*

Responses to treatments (short vs long term)

Seasonal variation

Photosynthesis Model



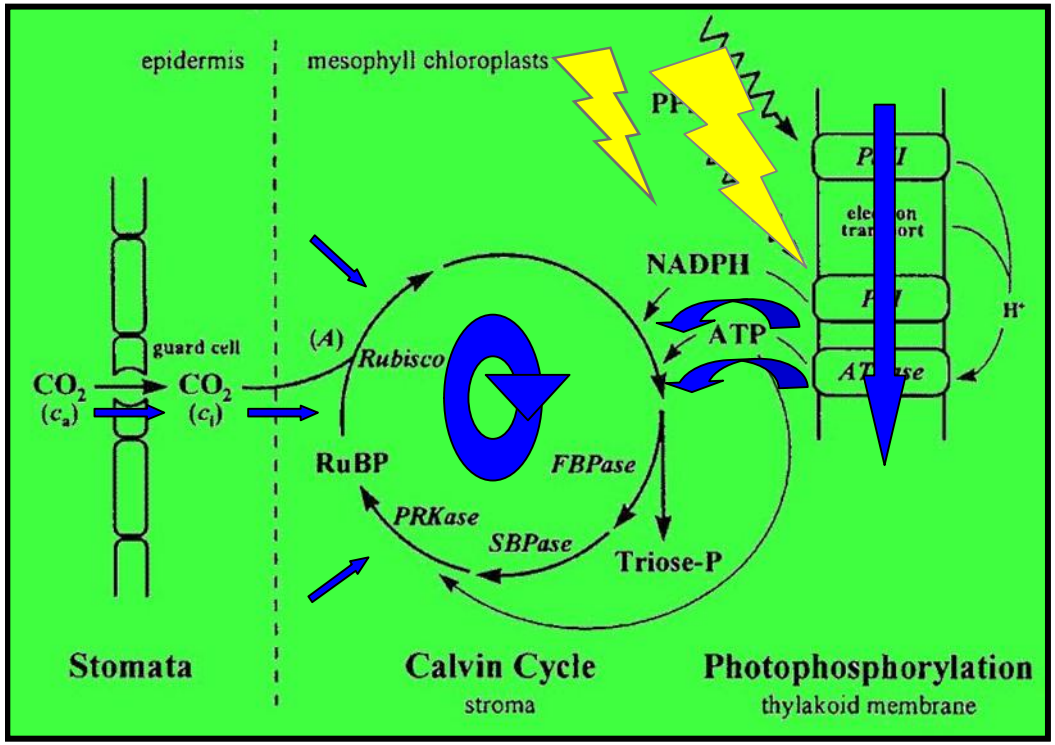
Measured and *modelled* photosynthetic parameters

Sink Side:

Net Photosynthesis
Respiration
Stomatal conductance
Mesophyll conductance
Transpiration
Vcmax, Jmax and Rd

Source Side:

PSII performance
Electron transport

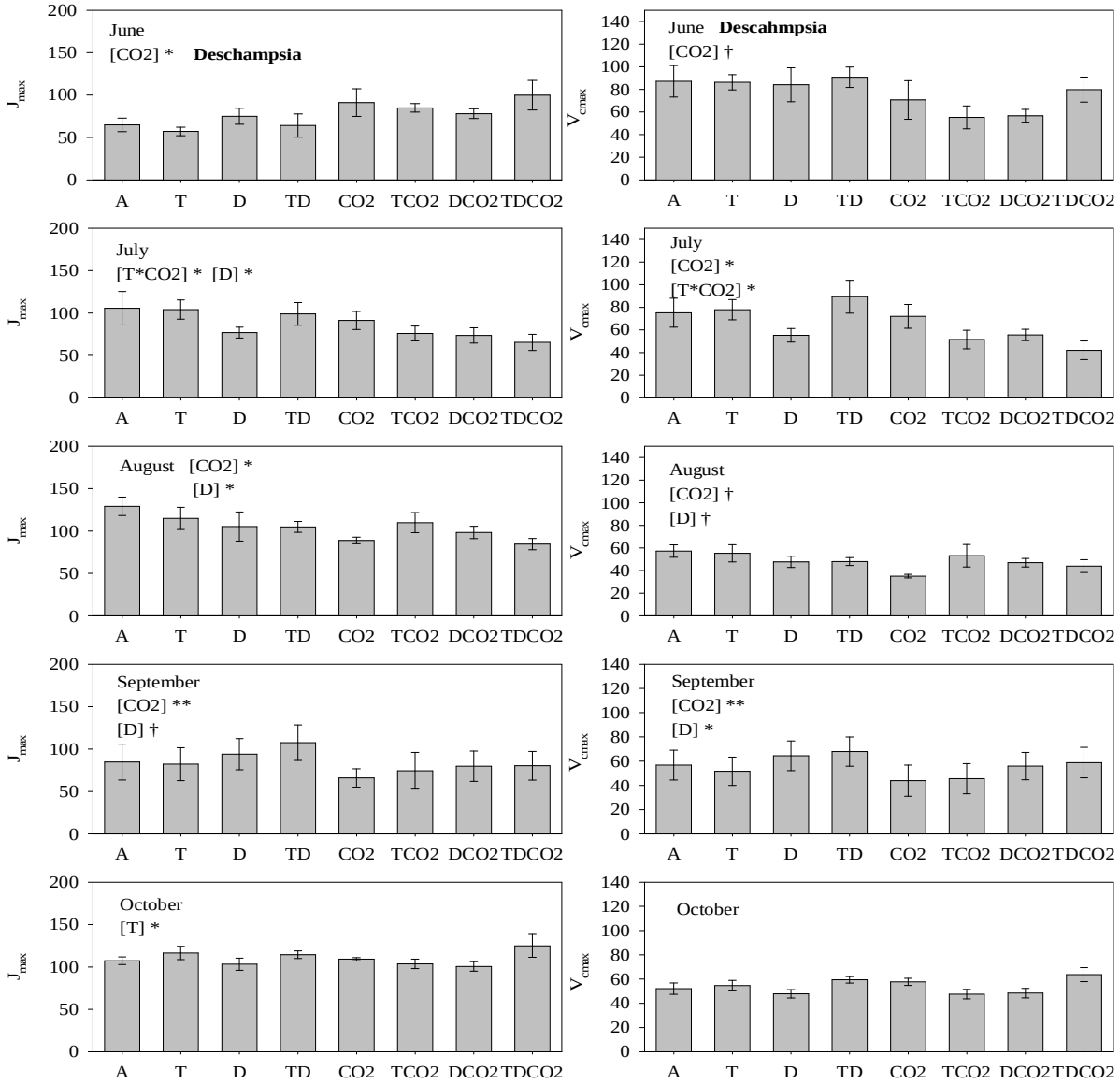


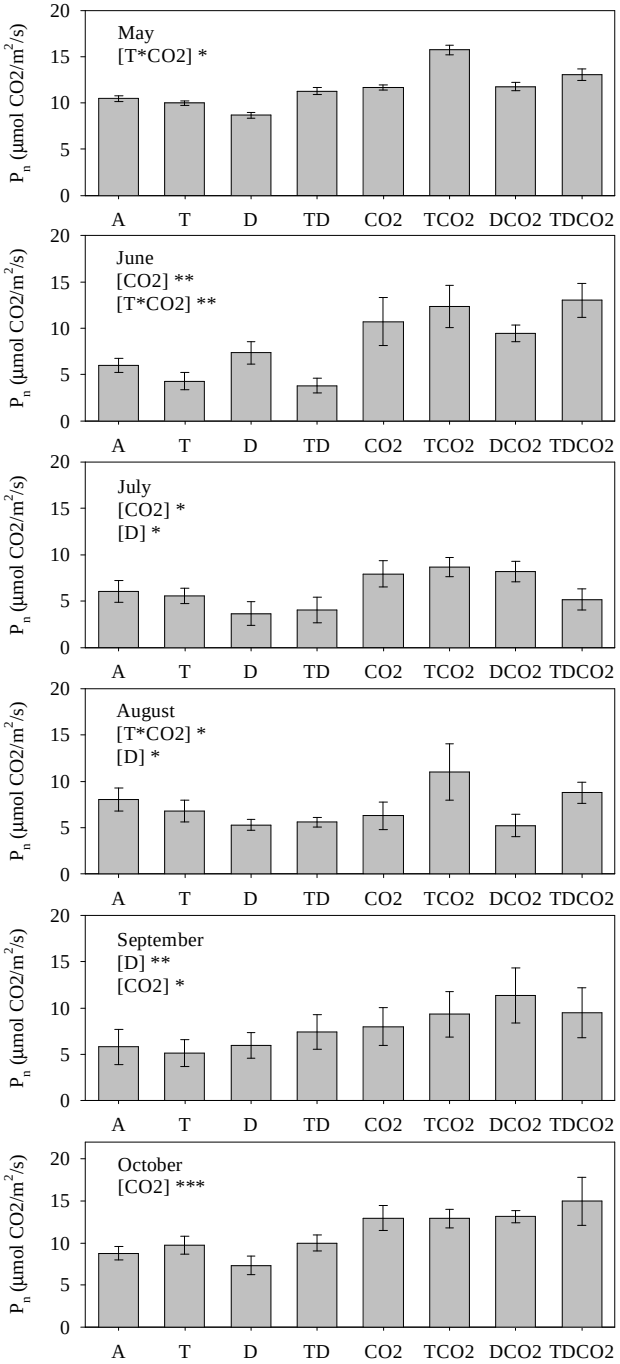
Deschampsia Jmax and Vcmax.

Pn →

Left panels are Maximal velocity of RuBP regeneration, Jmax.

Right panels are Maximal velocity of Rubisco carboxylation, Vcmax.





Working hypotheses

Passive night warming [T]

- Increased length of the growth season
- Shifts in phenological phases
- No direct impact on daytime plant performance
- Increased sesonal Carbon input and Water consumption

Summer drought [D]

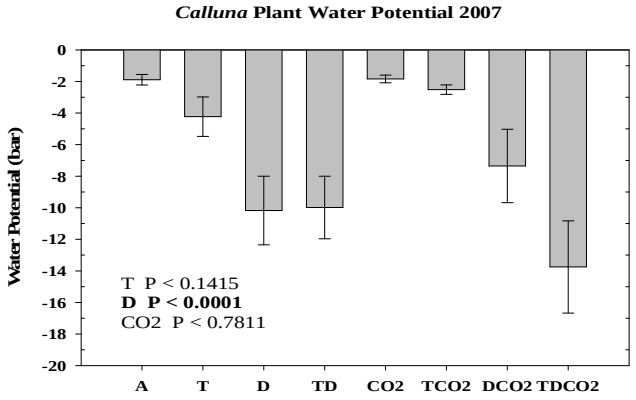
- Plant water potential
- Stomatal closure
- Reduced photosynthesis

Elevated CO_2 [CO2]

- Increased growth
- Shift C-N ratio
- Photosynthetic down regulation
- Increased Water Use Efficiency

Following slides: Data from summer 2007 late in the drought period

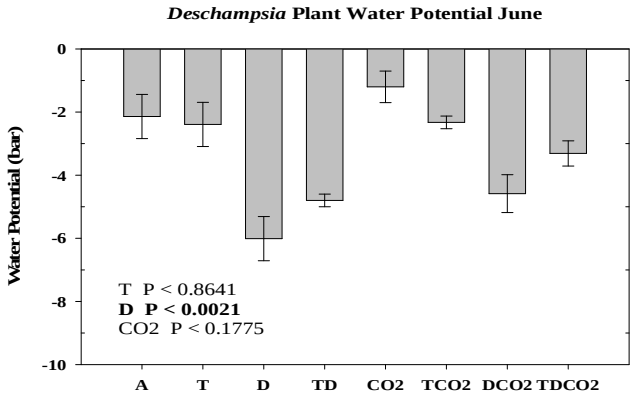
Plant water potential



- Site heterogenity and large varriation

Calluna (Ericorid dwarf scrub)

- Down to -39 bar (-3.9 MPa)
- Significantly affected by drought
- No effect of elevated CO_2 and T

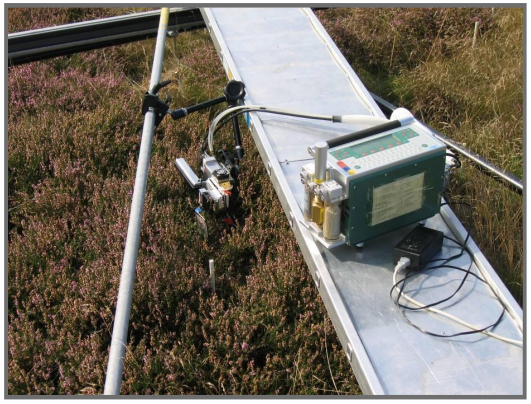


Deschampsia (grass)

- WP level about half of *Calluna*
- Significantly affected by drought
- No effect of elevated CO_2 and T

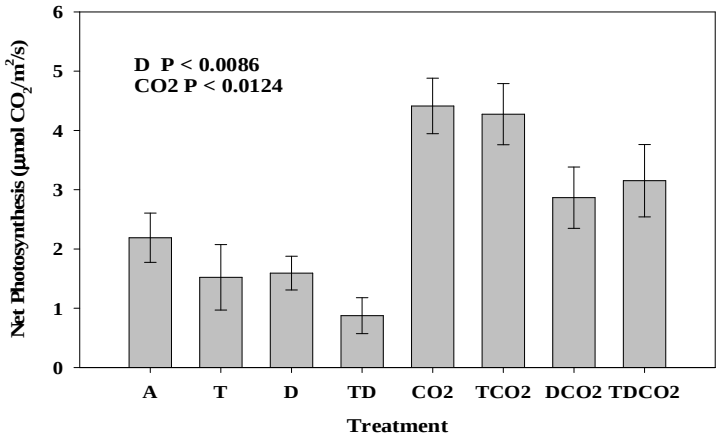
NDVI decreases during drought
Pronounced grass wilting
Very few Callunas with visual symptoms of drought

Climaite

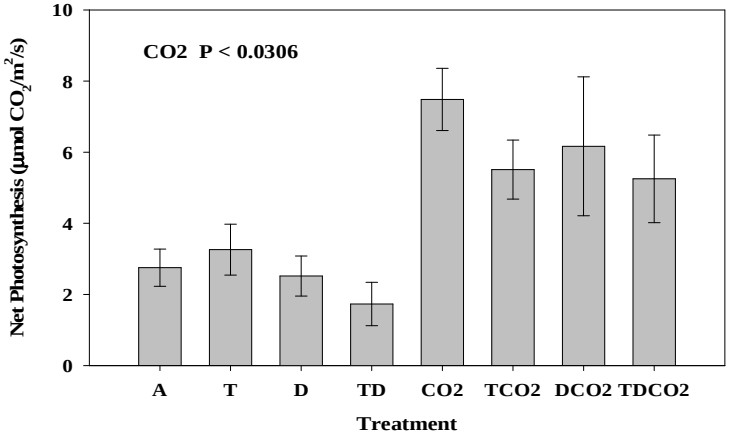


Net photosynthesis under field conditions

Net Photosynthesis at field conditions *Calluna vulgaris* august 2007



Net Photosynthesis at field conditions *Deschampsia flexuosa* august 2007



Data extracted from A/Ci- curves

Calluna

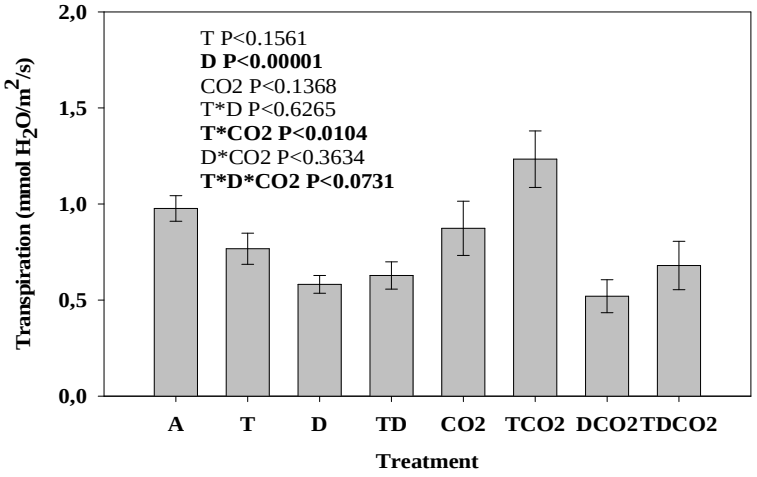
- CO_2 fertilization
- Negative impact of drought - also in interaction with CO_2

Deschampsia

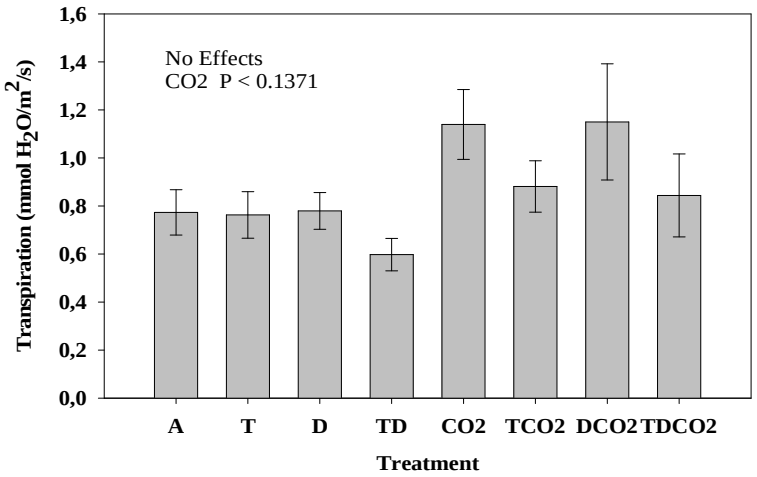
- Rate of photosynthesis higher than *Calluna* ś
- CO2 fertilization
- No drougth effect ('Filthy Few "?)

Transpiration at field conditions (Data extracted from A/Ci curves)

Transpiration at field conditions *Calluna vulgaris* august 2007



Transpiration at field conditions *Deschampsia flexuosa* august 2007



Larger varriation in FACE plots compared to non fumigated plots

About same level of water consumption in the two species

Calluna

- Negative impact of D
- Interaction of drivers T*CO2, T*D*CO2

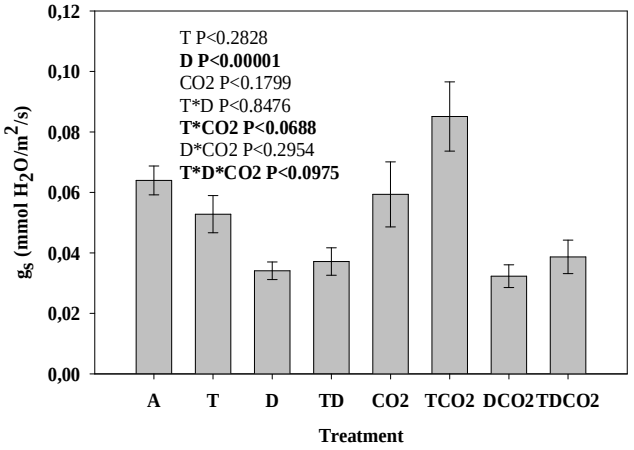
Deschampsia

- Increased water consumption in FACE plots ?

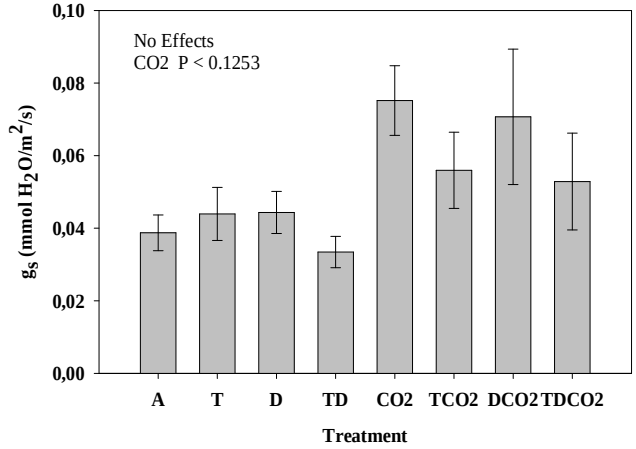
  (more water left ?)

Stomatal conductance at field conditions

Stomatal conductance at field conditions *Calluna vulgaris* august 2007



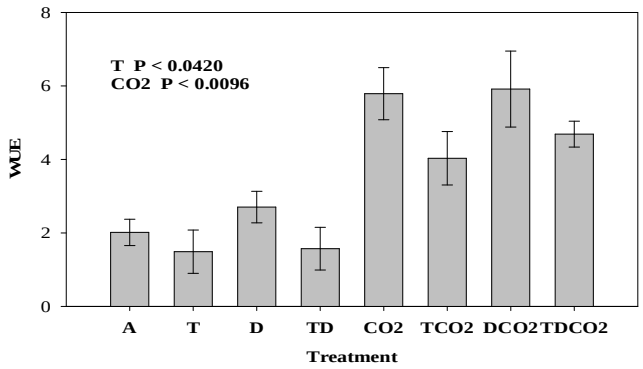
Stomatal Conductance at field conditions *Deschampsia flexuosa* august 2007



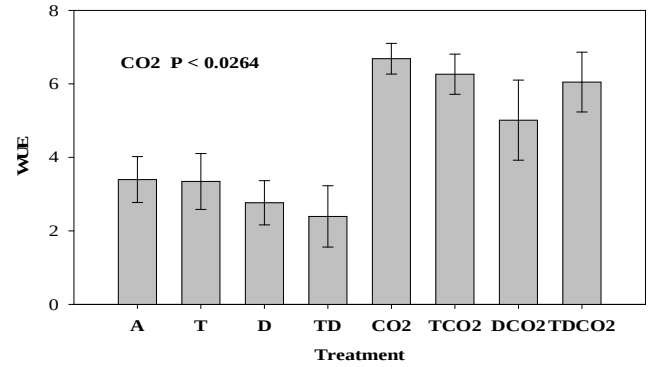
Parallel response in Stomatal conductance and transpiration

Water use efficiency at field conditions

WUE at field conditions *Calluna vulgaris* august 2007



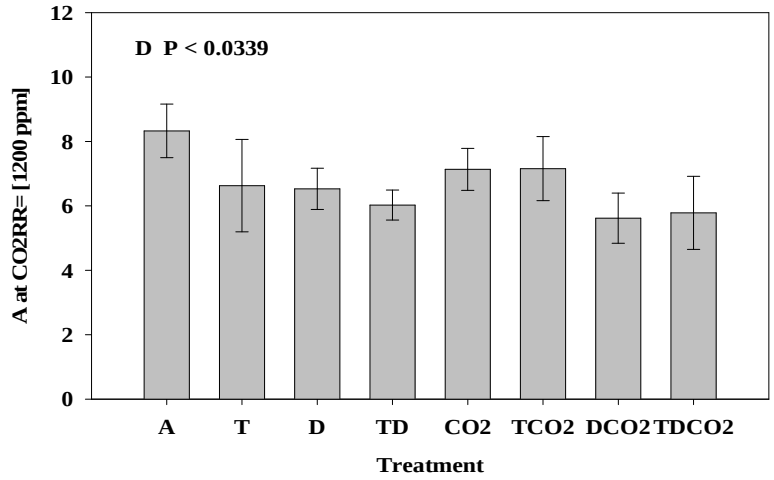
WUE at field conditions *Deschampsia flexuosa* august 2007



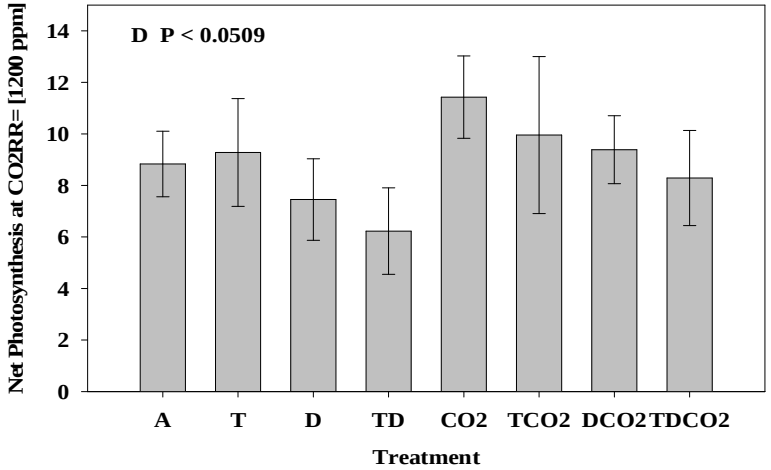
- [CO2] increases WUE – primarily via the increased CO_2 uptake
- *Deschampsia* had higher WUE in all treatments compared to *Calluna*
- [T] decreased WUE in *Calluna*
- No effect of [D]

Max Photosynthesis (saturating light and CO_2)

Max Net Photosynthesis *Calluna vulgaris* august 2007



Max Net Photosynthesis *Deschampsia flexuosa* august 2007

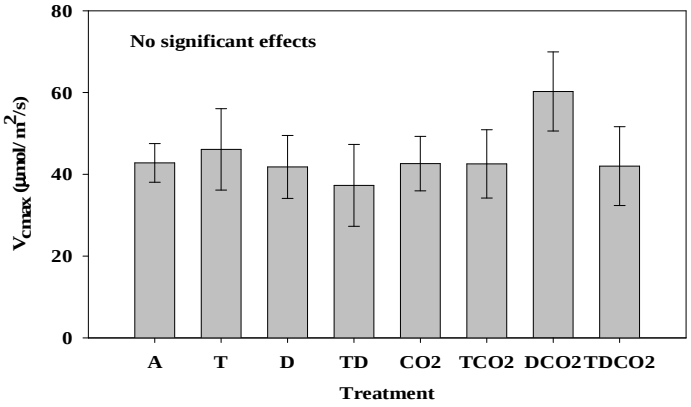


Drought is reducing the photosynthetic capacipy in both species.

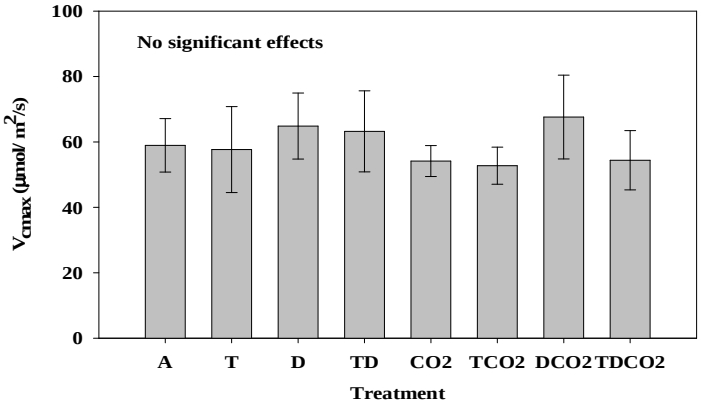
No CO_2 effect : Acclimation to 510 ppm does not change the photosynthetic capacity significantly.

Maximum velocity of Rubisco Carboxylation, V_{cmax}

Maximum rate of Rubisco carboxylation *Calluna vulgaris* august 2007



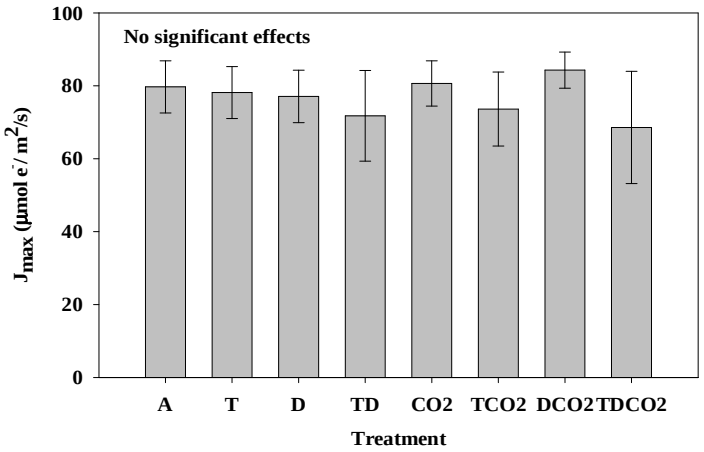
Maximum rate of Rubisco carboxylation *Deschampsia flexuosa* august 2007



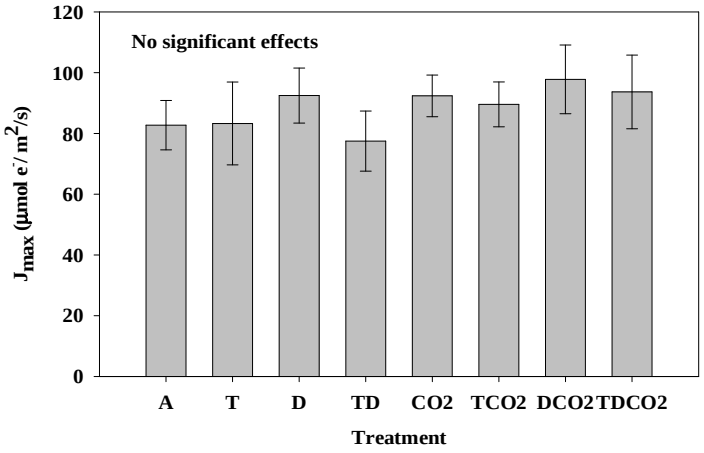
No effects

Maximum electron transport, J_{max}

Maximum rate of Electron transport for *Calluna vulgaris* august 2007



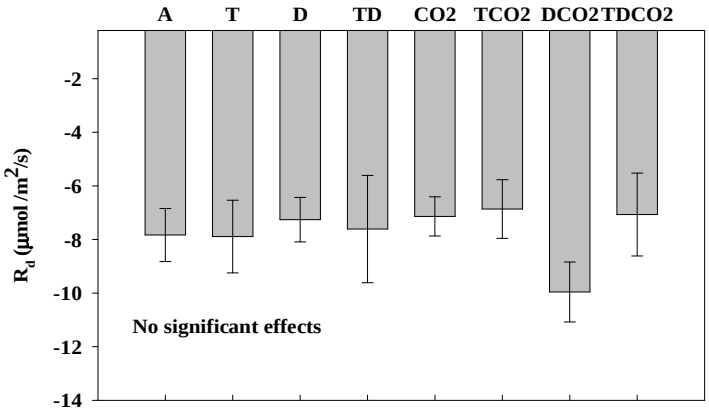
Maximum rate of Electron transport for *Deschampsia flexuosa* august 2007



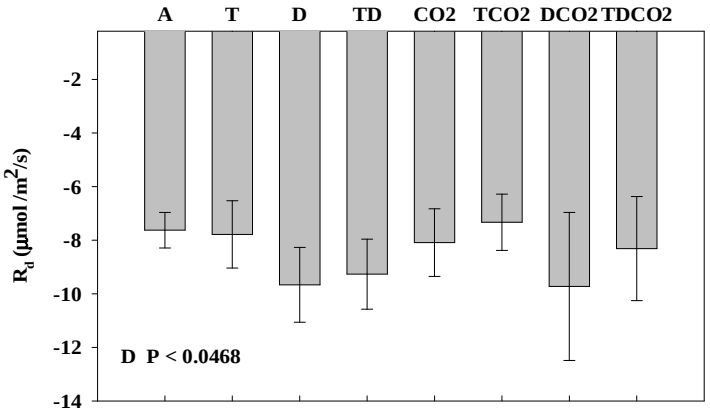
No effects

Non-Photorespiratory CO_2 evolution

Non-Photorespiratory CO2 evolution for *Calluna vulgaris* august 2007



Non-Photorespiratory CO2 evolution for *Deschampsia flexuosa* august 2007

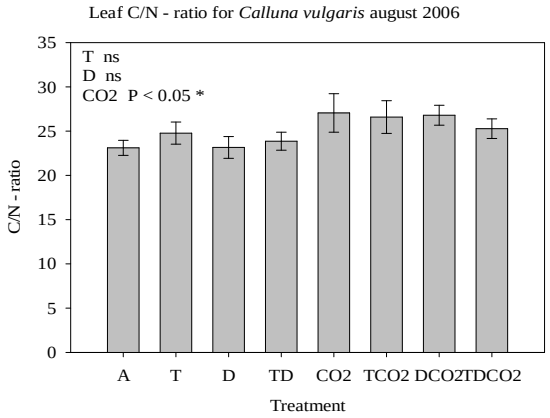


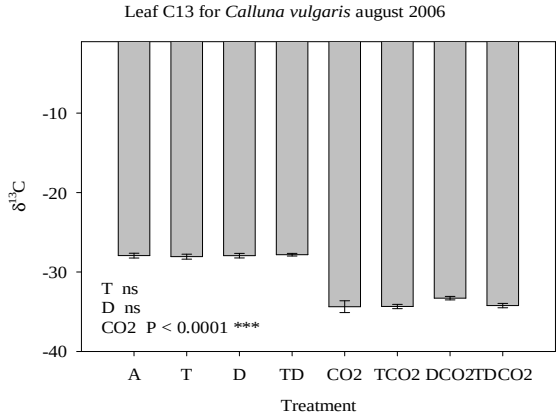
Drought increased respiration

Leaf C/N-ratio and $\delta^{13}C$

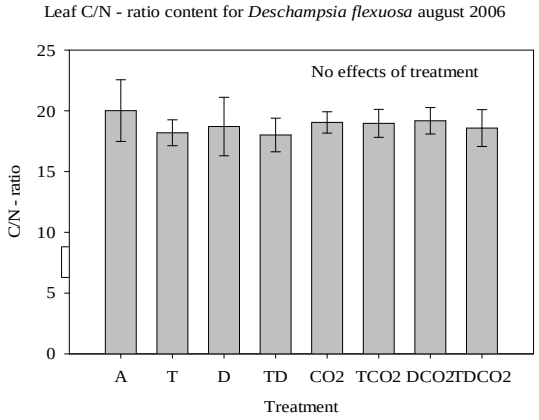
CO2 effect:

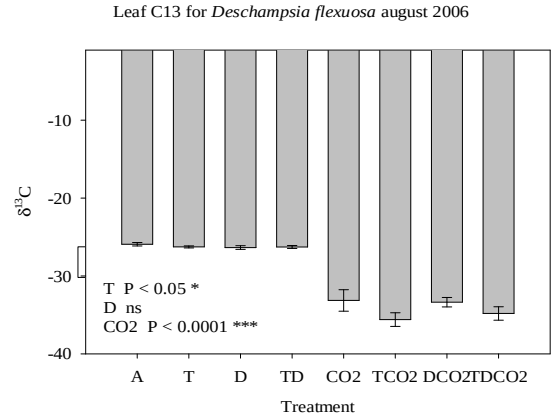
Small C% decrease, Larger N% decrease





Added CO_2 other signal than atmo-spheric CO_2





Small T-effect

Responses and the plant strategies

Both species increases CO_2 uptake in [CO_2] also in combinations with [D] and [T]

Characteristics

- *Calluna*
  - Xeromorphic dwarph scrub
  - Deep roots, almost evergreen, strong water conducting tissues, long lived (1-3 year) xeromorphic leaves,
  - Benefits in the extended growth season when water availability is sufficient
  - Stand the drought

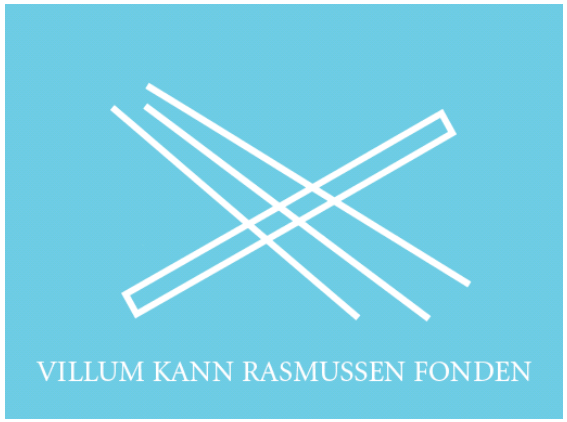
- *Deschampsia*
  - Perennial grass with several shoot generations
  - Low investment cost in leaves
  - Leaf wilting under stressfull conditions
  - Fast comeback after drought and benefits from the extended growth season
  - Probably more dependent of summer precipitation compared to *Calluna*

Conclusions

- No down regulation of photosynthetic capacity (in this phase of the growing season)
- Under field conditions
  - Increased CO_2 uptake and WUE in response to elevated CO_2 for both species.
  - Stomatal regulation of particular importance:
    - Decreased *Calluna* CO_2 uptake when drought: Lower g_s
    - No drought effect on *Deschampsia*: Unchanged g_s
  - *Calluna* drought tolerant, whereas *Deschampsia* wilt a large proportion of the leaves and regrow them when water availability gets better
  - Elevated CO_2 increased *Calluna* leaf C/N ratio.
  - Both species benefits from extended growth season and shifts in phenological phases may impact the photosynthetic response
  - Cross scale evaluation of responses will strengthen the synthesis at ecosystem level.
- Long term multifactor experiments important for understanding the effects of Global Change on primary productivity and water relations.

Thanks to all in the CLIMAITE consortium, especially project manager Claus Beier

Elsam, Air Liquide, Danfoss and main sponsor: Villum Kann Rasmussen Foundation




Thanks for Your attention !