An experimental study on the interactive effects of heat waves and droughts

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Why study extreme events?

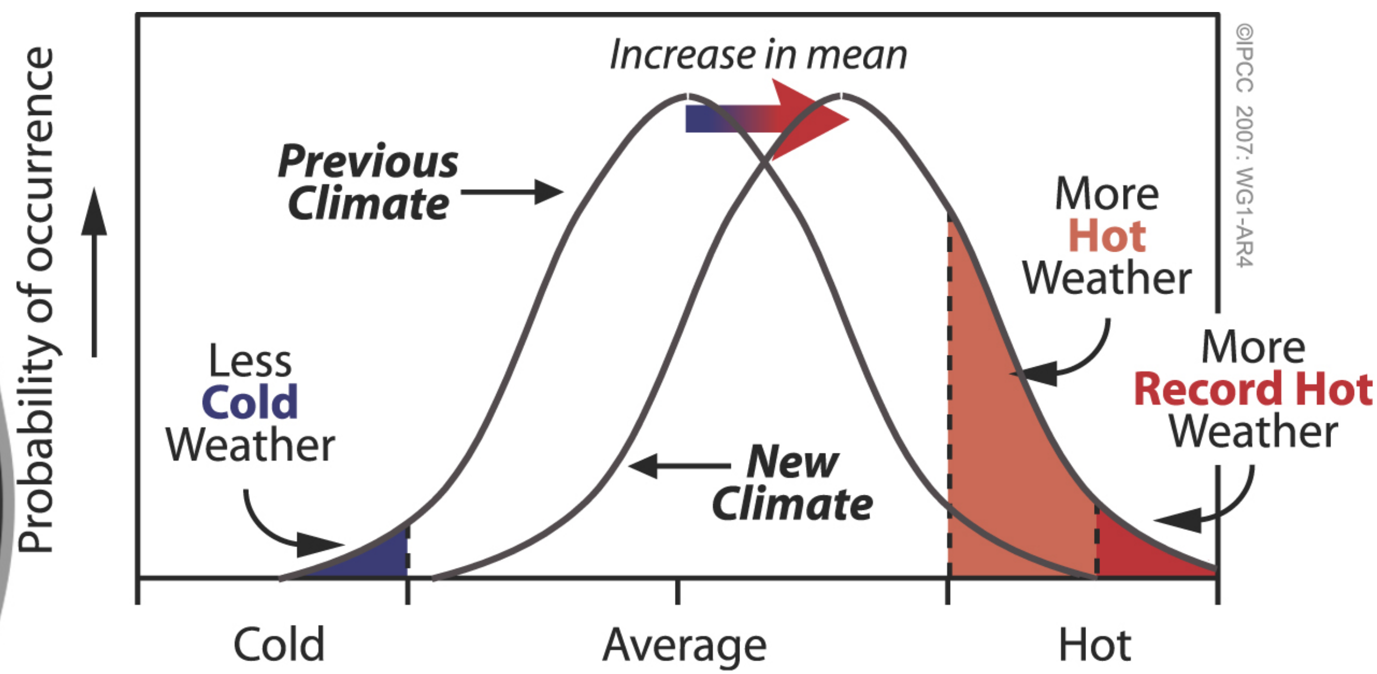
1. Biological reasons:

- organisms are more sensitive to abrupt than to gradual change
- extreme events (EE) drive evolution

Why study extreme events?

2. Statistical reasons

- climate change: frequency and intensity of EE will increase sharply



Why study extreme events?

3. Pragmatic reasons

- relatively « new » field of research
- spectacular results
- extreme events draw much public attention

Our experiment

EE we imposed: heat waves & droughts

- 2008: impact on short-lived species
- 2009: seasonal effects
- 2010: repeated extremes

Why heat waves and droughts?

- simulating a heat wave with (near) optimal water supply = unrealistic

→ in Western Europe: 78% less precipitation during heat waves*

- heat waves and droughts share climatic characteristics: sunny, dry, and high VPD

*De Boeck et al. (2010) Global Change Biology

Why heat waves and droughts?

	data (years)	HW count (numbers)	av HW length (days)	max HW length (days)	ΔT_{max} (°C)	ΔT_{min} (°C)	Δ sunshine (%)	Δ precipitation (%)	Δ RH (%)	ΔVPD (%)
Basel	105	58	9.14	17	8.61	3.10	70.7	-73.2	-13.2	93.8
De Bilt	109	50	8.98	16	8.03	3.55	77.9	-77.4	-17.2	127.9
Eelde	103	49	8.96	15	7.24	3.21	67.0	-66.1	-17.2	108.6
Genève	105	45	9.73	32	7.27	3.56	39.0	-83.0	-10.0	74.5
Hannover	70	43	8.74	15	7.87	2.99	77.3	-65.8	-16.4	105.7
Maastricht	103	51	8.57	17	8.71	3.94	86.8	-90.4	-21.3	131.3
Orléans	36	28	8.79	18	7.78	3.14	61.7	-86.6	-17.6	105.5
Reims	35	21	9.14	17	7.56	2.34	61.6	-77.3	-15.2	102.9
Saarbrücken	53	18	8.50	15	8.92	5.02	79.1	-83.8	-25.1	151.8
	719	363	8.95	18	8.00	3.43	69.0	-78.2	-17.0	111.3

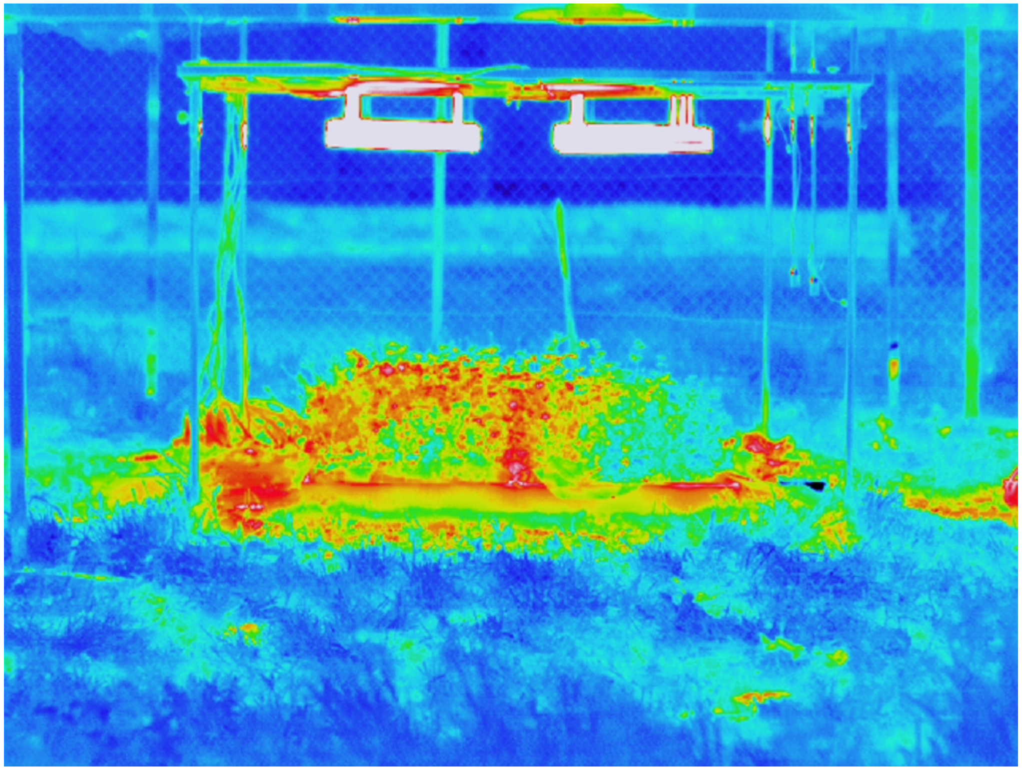
De Boeck et al. (2010) Global Change Biology

Simulation of heat and drought

heat waves created by means of infrared lamps

Simulation of heat and drought

heat waves created by means of infrared lamps



Simulation of heat and drought

- rainout shelters prevent precipitation
- plant communities in water-tight boxes

Simulation of heat and drought

- water supply by controlled water table
- drought = water table removal

Simulation of heat and drought

288 identical plant communities, 9 treatments

2009

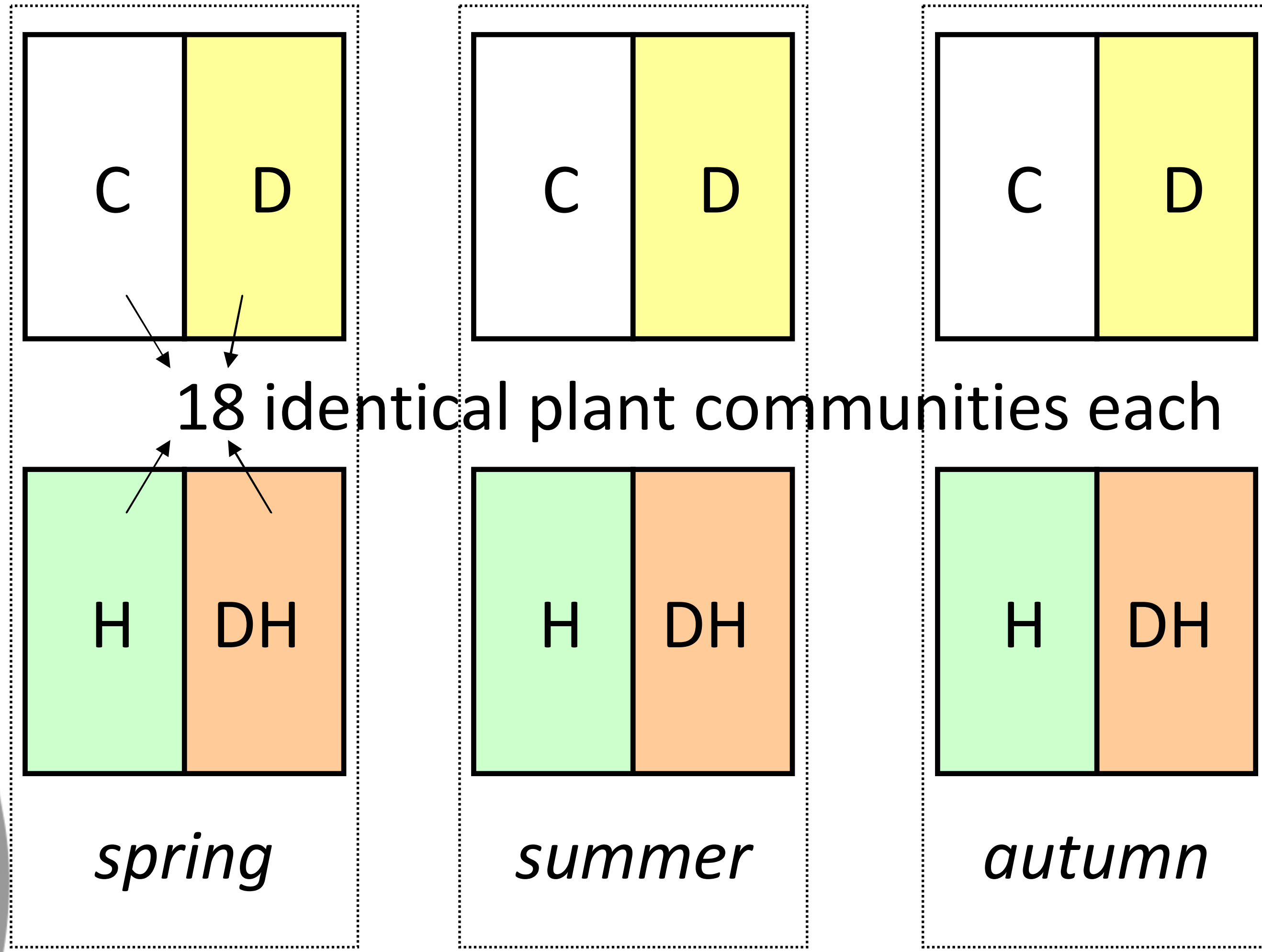
Simulation of heat and drought

9 treatments = full-factorial design: D – H – D+H

AND application in 3 seasons

(spring, summer, autumn)

Simulation of heat and drought



Simulation of heat and drought

Target: single-factor EE with 50y return time

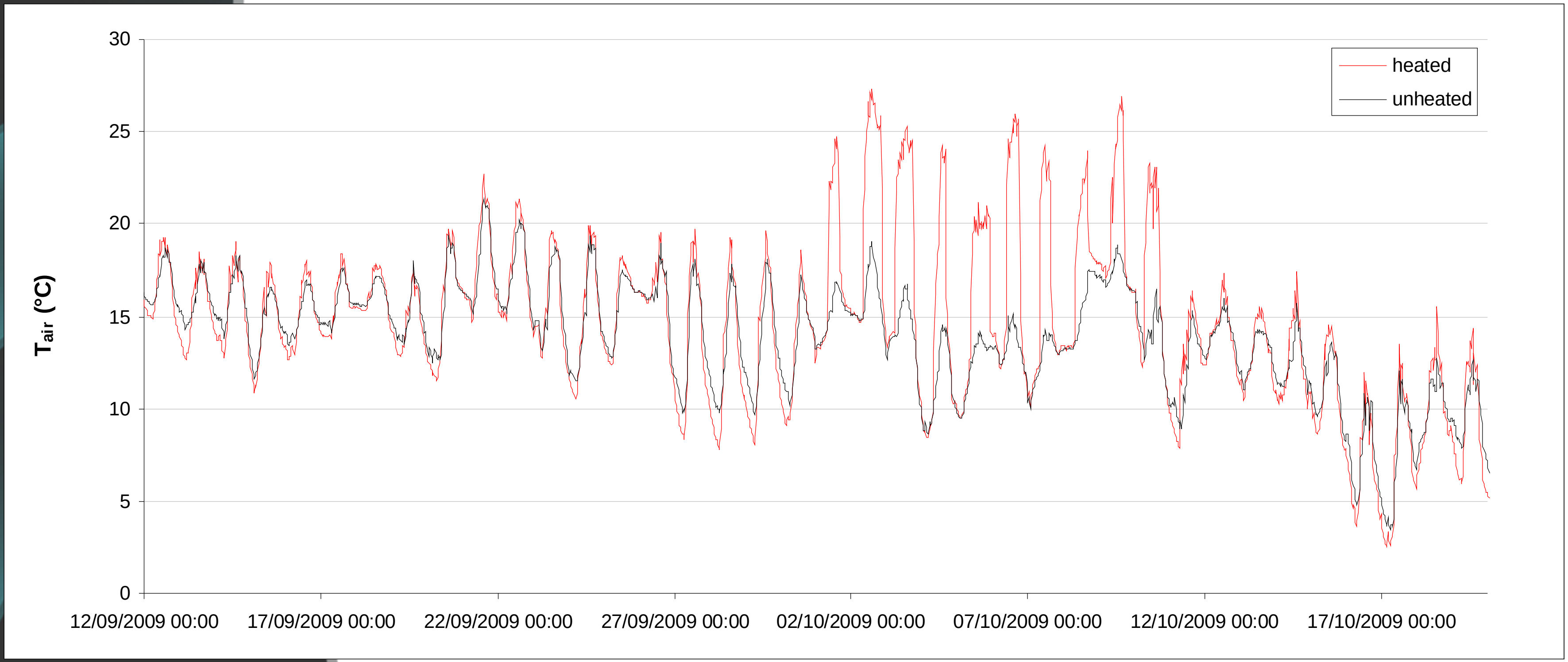
→ droughts = nr of days without precipitation

→ heat wave = fixed nr of days (10), target T_{max}

- spring (Apr-May): 26 day drought, T_{max} = 25.5 °C
- summer (July): 25 day drought, T_{max} = 30 °C
- autumn (Sep-Oct): 31 day drought, T_{max} = 22 °C

2009

Course of air temperatures



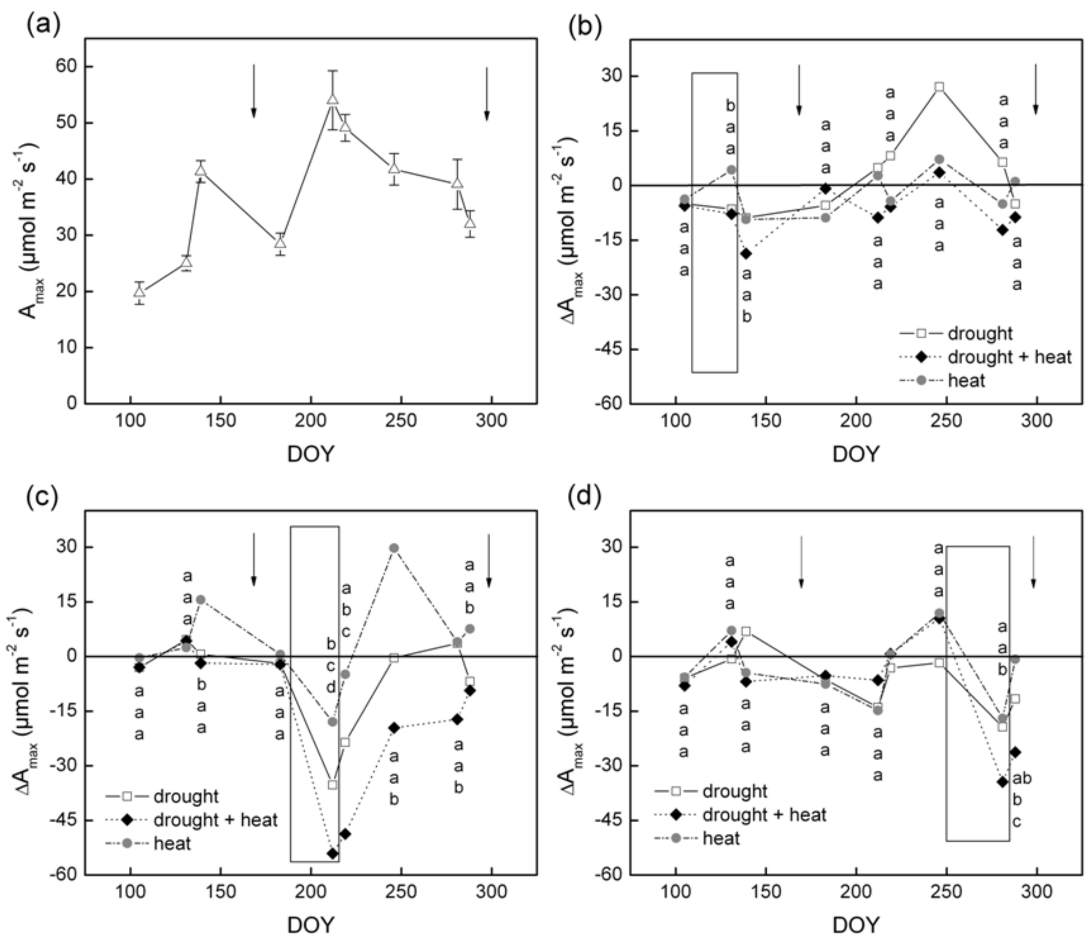
Whole system CO_2 fluxes

Cuvette measurements enable us to derive NEE, TER and gross photosynthesis

→ measure of immediate response of communities to the imposed treatments

2009

Whole system CO_2 fluxes



Whole system CO_2 fluxes

- heat wave: positive but transient in spring, negative but transient in summer
- drought: no effect in spring, negative but transient in summer (& autumn)
- heat wave + drought: negative effect in all seasons, but transient in spring

De Boeck et al., New Phytologist, in press

Biomass production

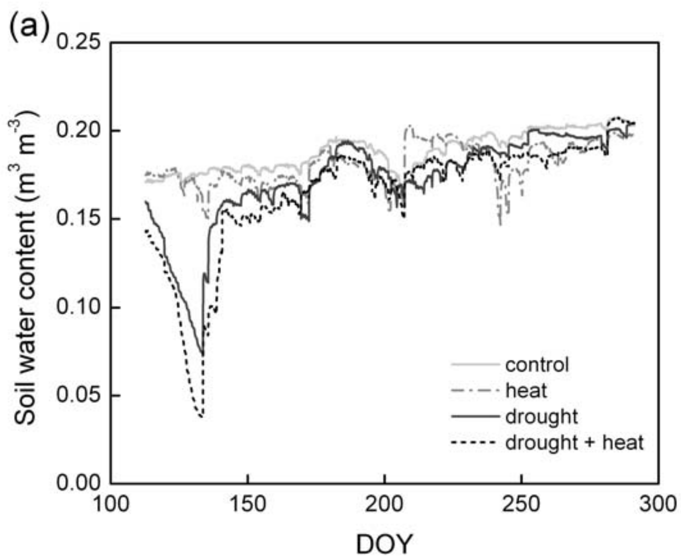
- spring: D = ns, H = ns, D+H = -48% in June harvest but ns in October harvest
- summer: D = -23%, H = ns, D+H = -66%
- autumn: D = -30%, H = ns, D+H = -65%

→ note that recovery time differed (!)

De Boeck et al., New Phytologist, in press

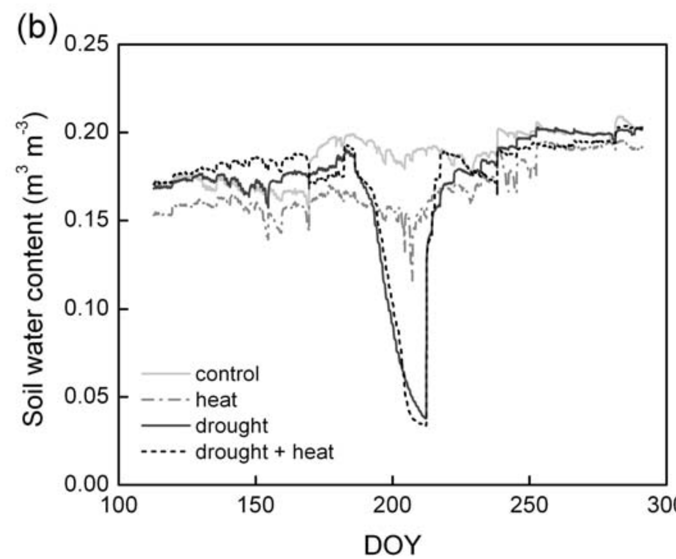
2009

Cause 1: drought stress



spring

wilting point at 3.7% SWC



summer

De Boeck et al., New Phytologist, in press

Cause 1: drought stress

- soil water status has substantial explanatory power in our experiment BUT their is an impact of season on the relationship

(note: our sensors cover the entire soil profile)

- a heat wave speeds up soil drying

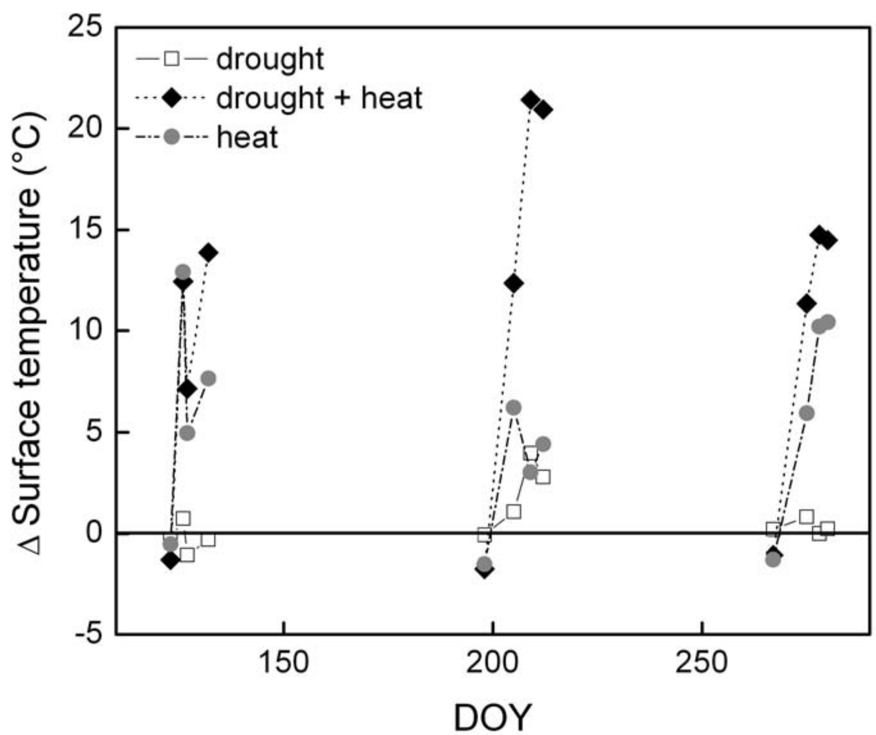
→ drought stress occurs faster and is more intense

De Boeck et al., New Phytologist, in press

2009

Cause 2: heat stress

canopy temperatures measured with infrared camera



De Boeck et al., New Phytologist, in press

2009

Cause 2: heat stress

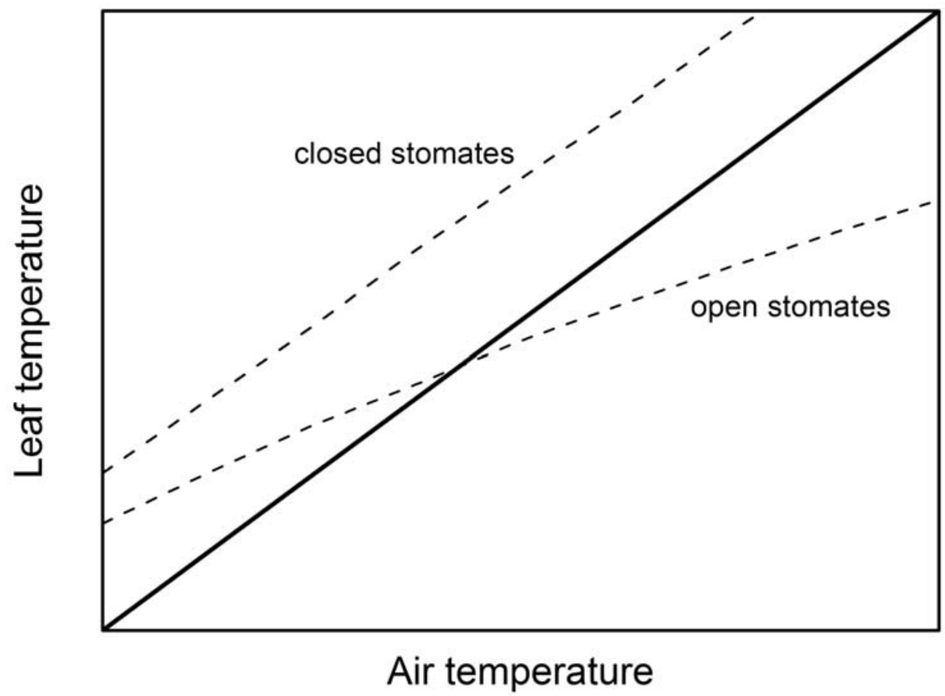
- canopy temperatures are an indication of drought stress
- ∆T between H and D+H canopies can be >15°C (!)

→ heat stress occurs only if there is drought

De Boeck et al., New Phytologist, in press

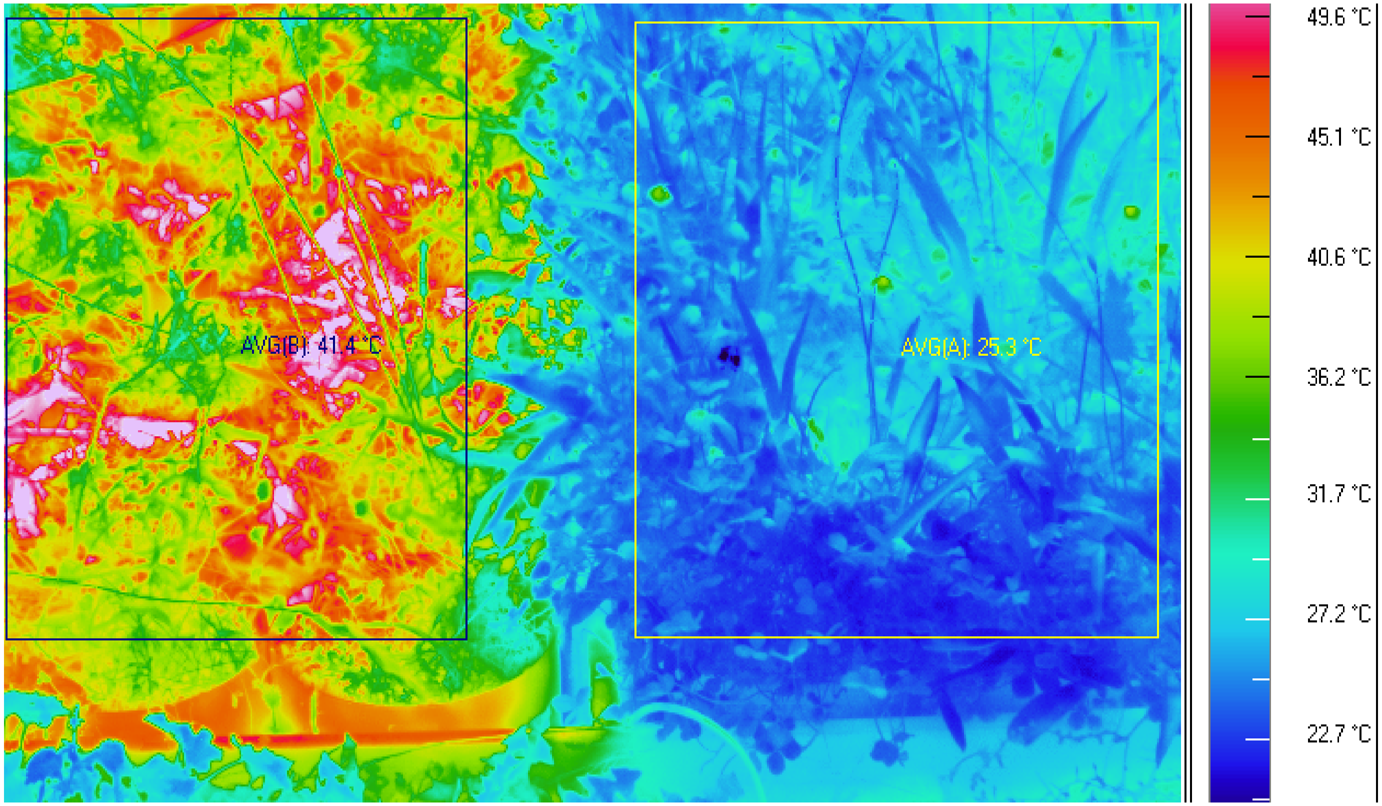
Cause 2: heat stress

explanation: environmental physics



2009

Cause 2: heat stress



Conclusions

- impacts of heat waves alone are limited and transient
- drought effects are negative if significant, but are exacerbated and last longer in combination with a heat wave
- drought stress is facilitated through heat, heat stress is dependent on drought

De Boeck et al., New Phytologist, in press

Unanswered issues

- longer-term after-effects?
- larger-scale effects (e.g. pest outbreaks, vegetation shifts, pollinator impact, etc.)
- the importance of species composition

Longer-term after-effects?

1. colonisation: new species

   *Controls: +5.2

   *Drought: +5 (spring), +4.8 (summer), +4.7 (autumn)

   *Heat wave: +5.2 (spring), +5.2 (summer), +4.7 (autumn)

   *Heat+drought: +6.5 (spring), +6 (summer), +7.4 (autumn)

Longer-term after-effects?

2. biomass production:

*Drought: -27% (spring), +26% (summer), +43% (autumn)

*Heat wave: -18% (spring), -16% (summer), -35% (autumn)

*Heat + drought: -27% (spring), -77% (summer), -17% (autumn)

The importance of species composition

- 2010 experiment: repeated extremes (summer)
- same drought length, heat length, T_{max}

→ identical extreme events as in 2009

- only difference: 1 species (Bellis perennis instead of Trifolium repens)

The importance of species composition

preliminary results (biomass):

- drought: -9%
- heat wave: +16%
- heat + drought: +30.5%

→ Trifolium is productive, uses much water, and is a N-fixer; Bellis is the opposite

The importance of species composition

preliminary results:

- drought: -9%
- heat wave: +16%
- heat + drought: +30.5%

→ water no longer most limiting factor, but nutrients, and heat releases more nutrients

Take home messages

1. Extreme events are cool

2. You can experimentally impose them

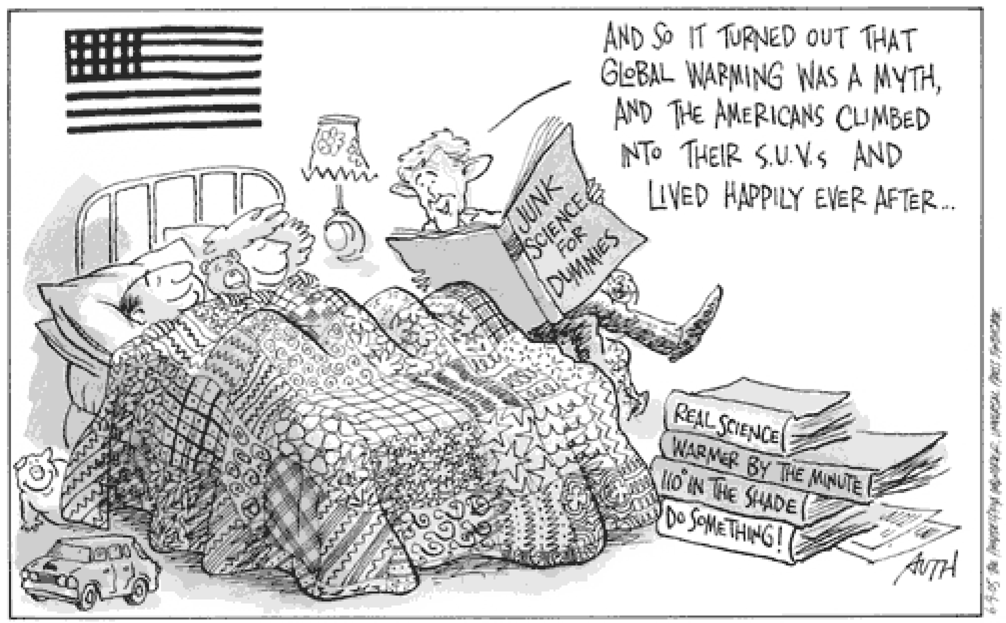
3. What stresses are really playing?

→ drought may not imply drought stress, a heat wave may not cause heat stress

4. A lot of things left to uncover

5. Using a curved left-margin graphical item in powerpoint can be awkward

Thank you



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