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Arbeitspaket B1: – Datenbankmanagement und statistischer Modellierung

Extreme events down-regulate the grassland biomass response to elevated carbon dioxide

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Introduction

Projecting future warming trends has become important for future policy making and the development of adaptation strategies. It has been well recognized that the rising atmospheric CO_2 concentration ($[CO_2]$) is the main contributor, but the interactions between $[CO_2]$ and ecosystems make the projections challenging. Up to now, big uncertainties still exist when estimating the reactions (mitigation effects) of ecosystems to elevated $[CO_2]$, and which role extreme events play is not clear[1]. Since extreme events cause large disturbances in ecosystems, and they have been projected to happen more frequently in the future, it is of great importance to study the effects of extreme events on ecosystem responses.

Results and Outlook

- Extreme events (such as extreme cold/dry events, hard frost, heat wave, ect.) may decrease the CO_2 –fertilisation effect .
- As a result, the grassland biomass responses to eCO_2 were down-regulated in the years with extreme events.
- For summer Harvest (H2), the Killing Degree Days (KDDs)[2] was well correlated to the grass biomass response, which indicates a good index for a better projection of the ecosystem response.
- A higher frequency of extreme events in the future will down regulate the C-sink function and we may face a faster warming trend.

Year	Hard Frost in spring	Extremely Cold	Extremely Dry	Extreme eCO_2	EffectSize Grass
1998	–	–	–	–	→
1999	–	–	–	–	↓
2000	–	–	–	–	↑
2001	–	–	–	–	↑
2002	–	–	–	–	↑
2003	–	√	–	–	↓
2004	–	–	–	–	→
2005	√	√	–	–	↓
2006	–	–	–	–	↑
2007	–	–	√	–	↓
2008	–	–	–	–	↑
2009	–	–	–	–	↑
2010	√	–	–	–	↓
2011	–	–	–	–	↑
2012	–	–	–	LOW	↓
2013	√	√	–	LOW	↓

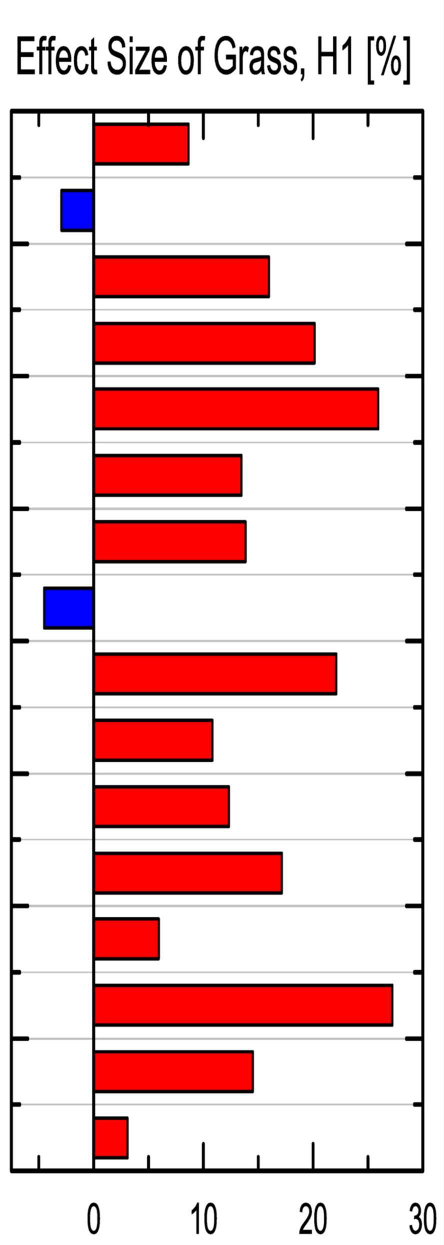

Figure 1: Relationship between extreme events and the effect size of grass biomass in the spring Harvest (H1). The left hand side table shows the extreme events that happened over the past 16 years (1998-2013); colored boxes with check marks indicate extreme events in the corresponding years). The right hand side figure shows effect sizes of grass biomass. The arrows in the middle represent how the effect size changed over time.

Year	Heat wave events	Extreme KDDs	Extremely Dry	Extreme eCO_2	EffectSize Grass
1998	–		–	–	→
1999	–		–	–	↑
2000	–		–	–	→
2001	–		–	–	→
2002	–		–	–	↑
2003	√	√	–	–	↓
2004	–		–	–	↑
2005	–		–	–	↑
2006	√	√	–	–	↓
2007	–		–	–	↑
2008	–		–	–	↑
2009	–		–	–	→
2010	√	√	–	–	↓
2011	–		–	–	→
2012	√		–	LOW	↓
2013	–	√	–	HIGH	↑

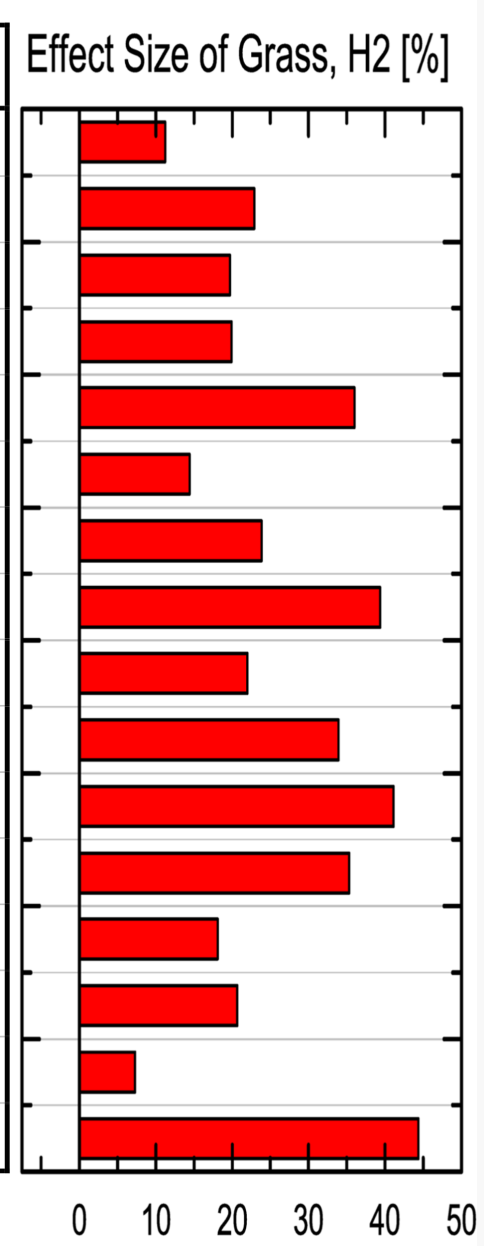

Figure 2: Relationship between extreme events and the effect size of grass biomass in the summer Harvest (H2), similar to Fig.1. Besides heat wave, extremely high Kill Degree Days (KDDs) are also marked. For the years with strong heat wave event, we use dark red. While for the years without strong heat wave event but very close to satisfying the conditions of being heat wave event, we use light red.

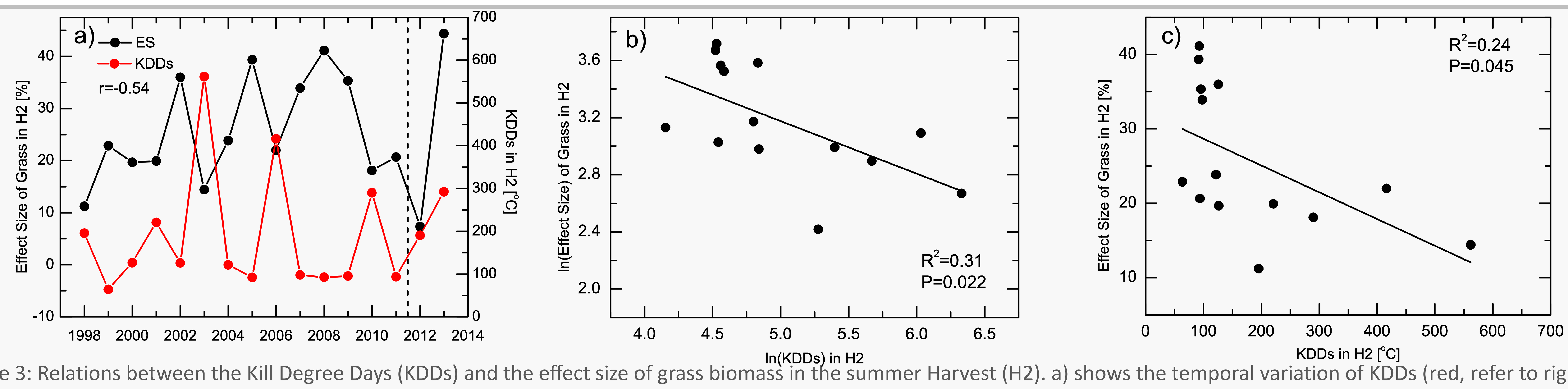

Figure 3: Relations between the Kill Degree Days (KDDs) and the effect size of grass biomass in the summer Harvest (H2). a) shows the temporal variation of KDDs (red, refer to right axis) and the effect size (black, refer to left axis). b) shows the results of a simple regression analysis. 31% variance of the natural logarithm effect size can be explained by the natural logarithm KDDs, which is significant with p=0.022. c) is similar to b), but without doing natural logarithmic transformation. 24% variance of the effect size can be explained with p=0.045.

Material & Method

- Grass biomass measured from both Harvests (1998-2013) are used for the calculation of effect size. Besides, soil moisture, air temperature, precipitation, as well as $[CO_2]$ records are used for the determination of extreme events.
- Effect size is defined as relative differences of grass biomass between the eCO_2 plots and the aCO_2 plots.
- Extreme events are determined according to the 2-fold of standard deviations; Hard frost is confirmed when the daily minimum temperature is below -10°C; Heat wave events are determined when the daily maximum temperature is higher than 30°C for five or more consecutive days.
- KDDs is the sum of maximum temperatures in excess of 30°C[2].

Future Prospects

- Extreme events may cause large damages on ecosystems, but due to the lack of data, few studies have addressed the issue of how extreme events may affect the ecosystem responses to elevated carbon dioxide.
- Gi-FACE is one of the longest FACE experiment, which allows a preliminary analysis on the effects of extreme events.
- Based on this study, we found negative effects of extreme events on the ecosystem responses. But the findings need to be confirmed either dynamically or via modelling.
- The continuation of the long time series will help to confirm the results when future extreme events can be included into the analysis.

Literature:
[1] Frank, D., et al., Effects of climate extremes on the terrestrial carbon cycle: concepts, processes and potential future impacts, *Global Change Biology*, 21, 2861-2880, (2015).
[2] Butler, E. E., and P. Huybers, Adaptation of US maize to temperature variations, *Nature Climate Change*, 3, 68-72, (2013).

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