18th Swiss Global Change Day
Bern, April 2017

Climate extreme effects on biogeochemical cycles – an observation driven exploration

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with contributions from

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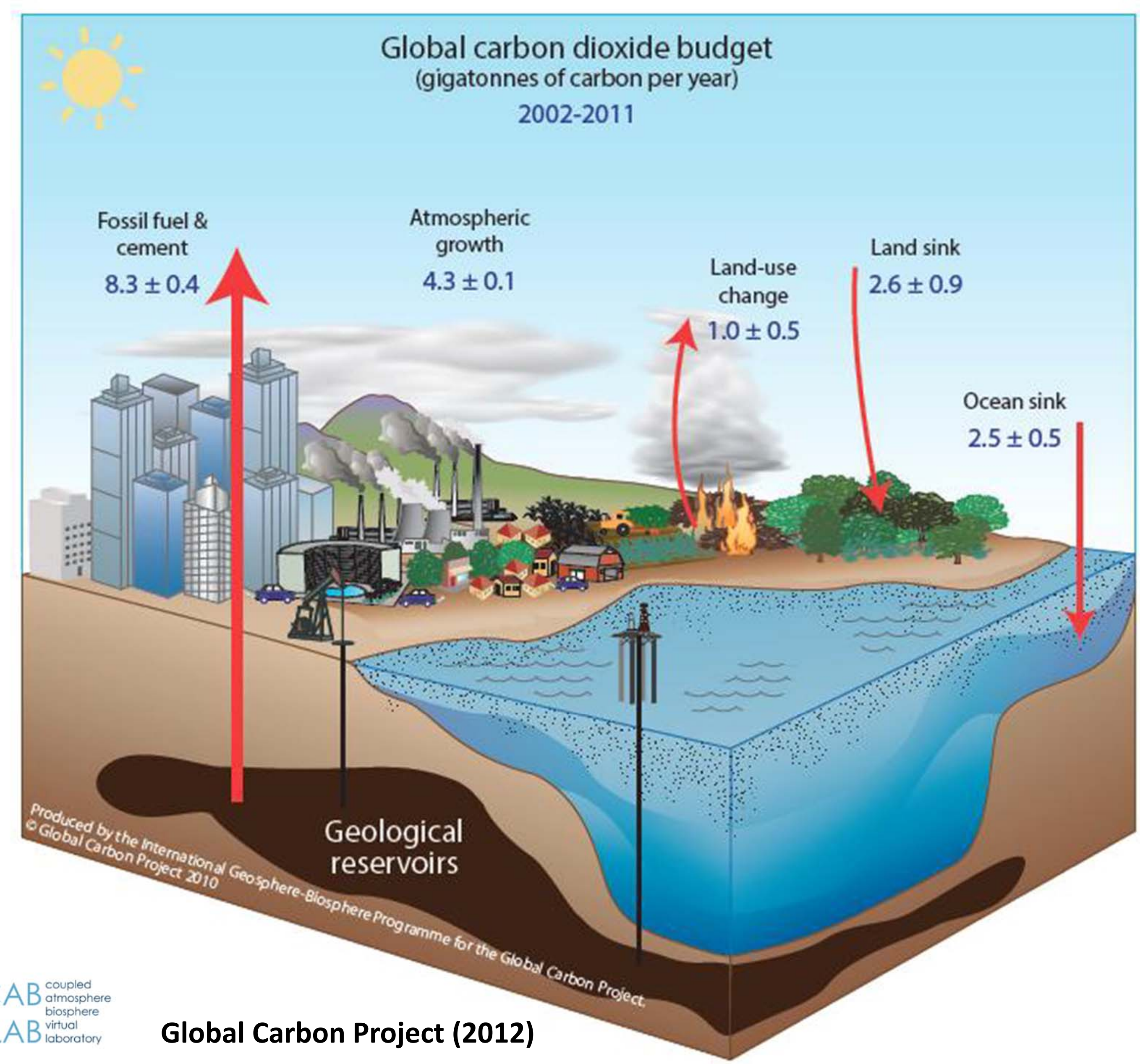
Global Change context: carbon cycle



Global Carbon Project (2012)

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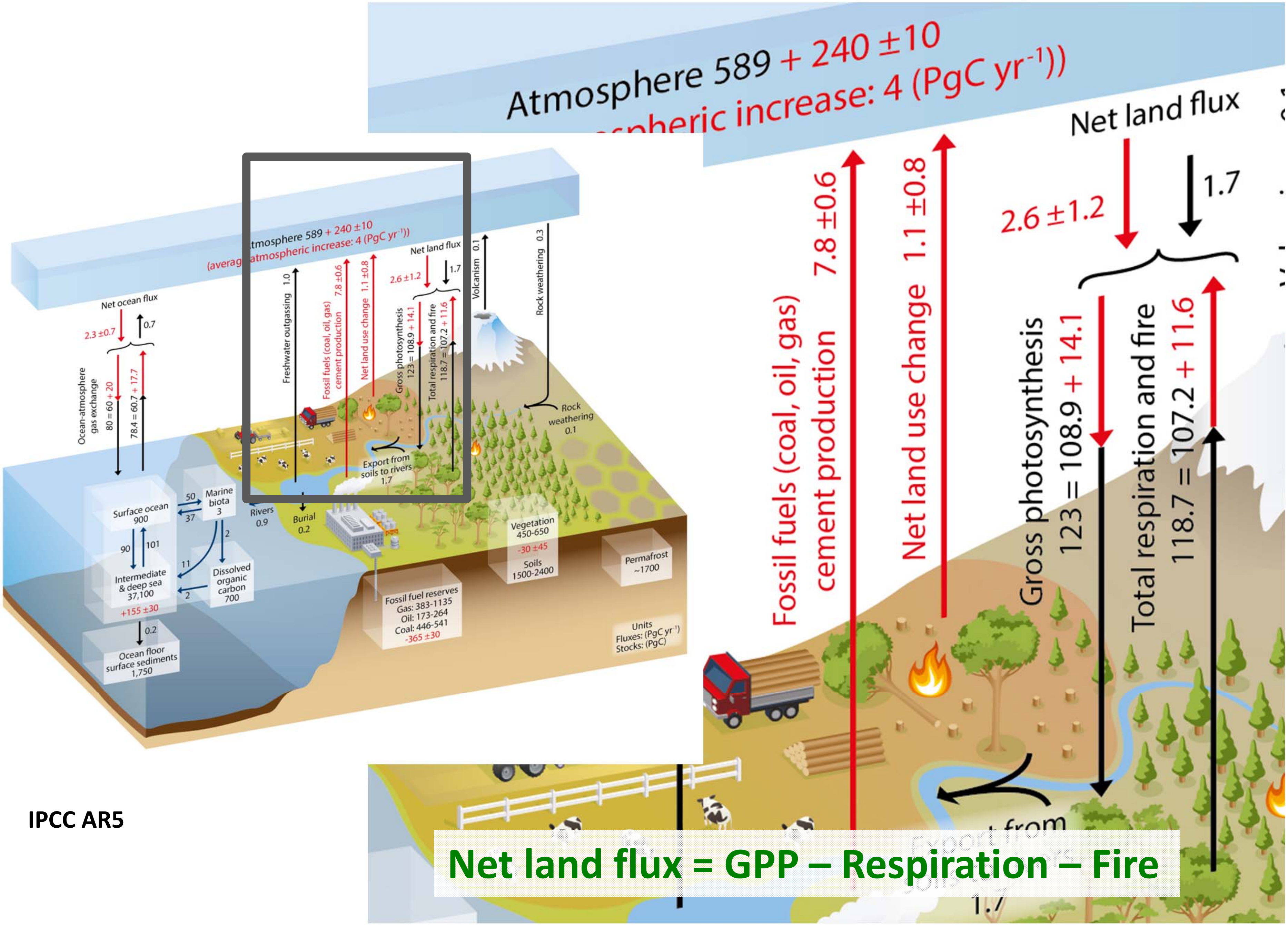
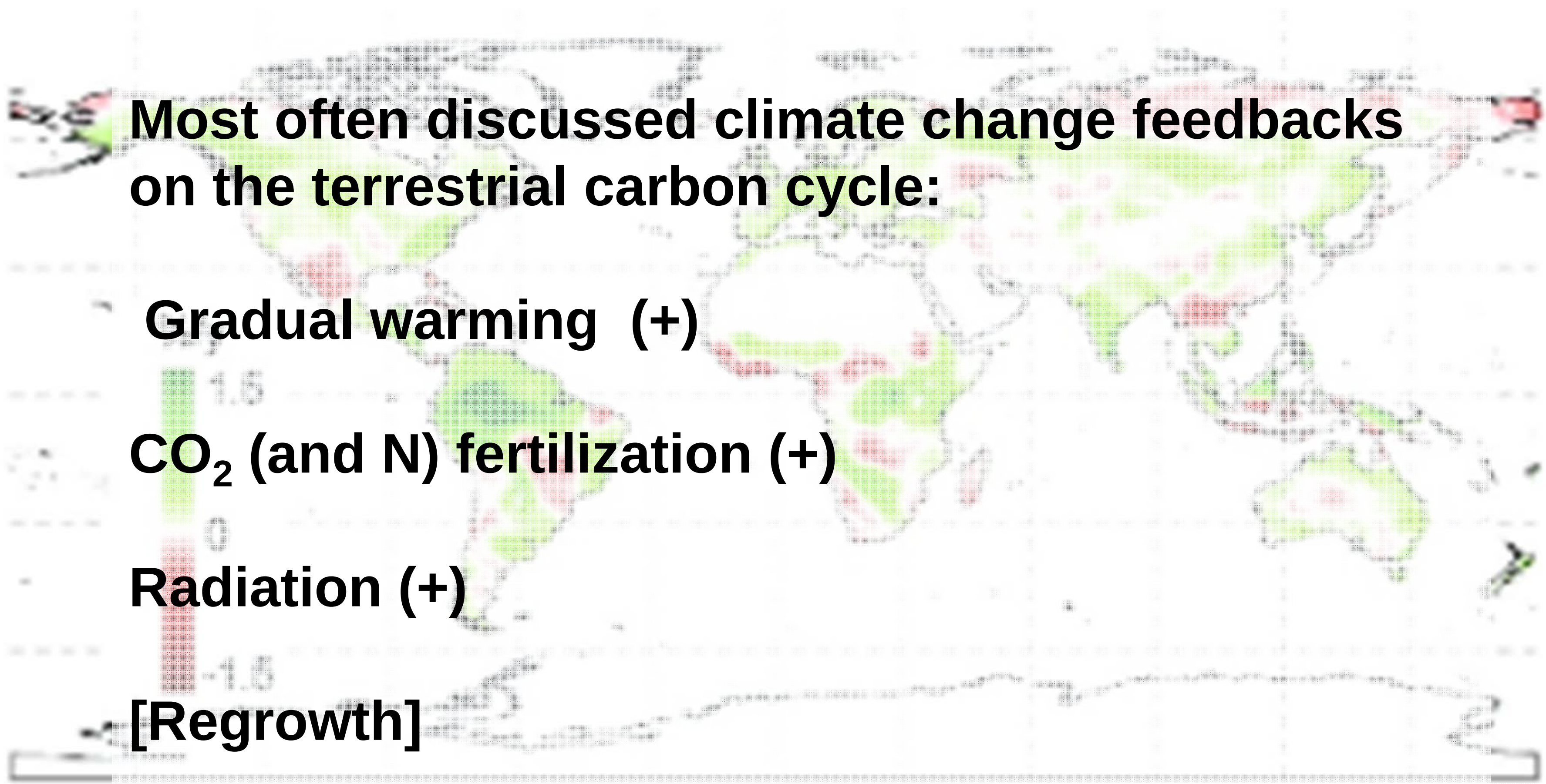


Net land flux = GPP – Respiration – Fire

IPCC AR5

Smooth trends for primary productivity over the last decades



Most often discussed climate change feedbacks on the terrestrial carbon cycle:

Gradual warming (+)

CO_2 (and N) fertilization (+)

Radiation (+)

[Regrowth]

e.g. Nemani et al., Science 2003

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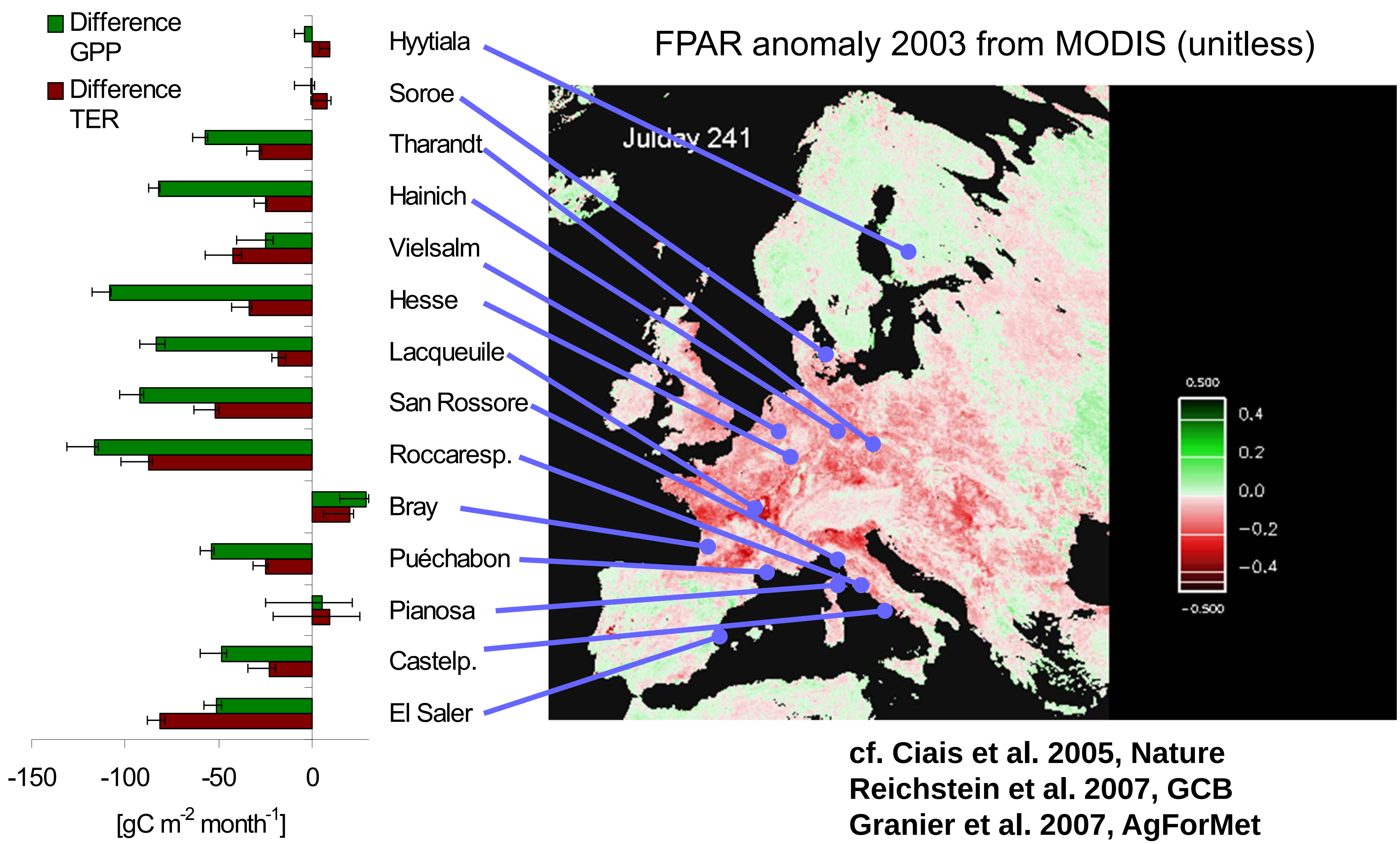
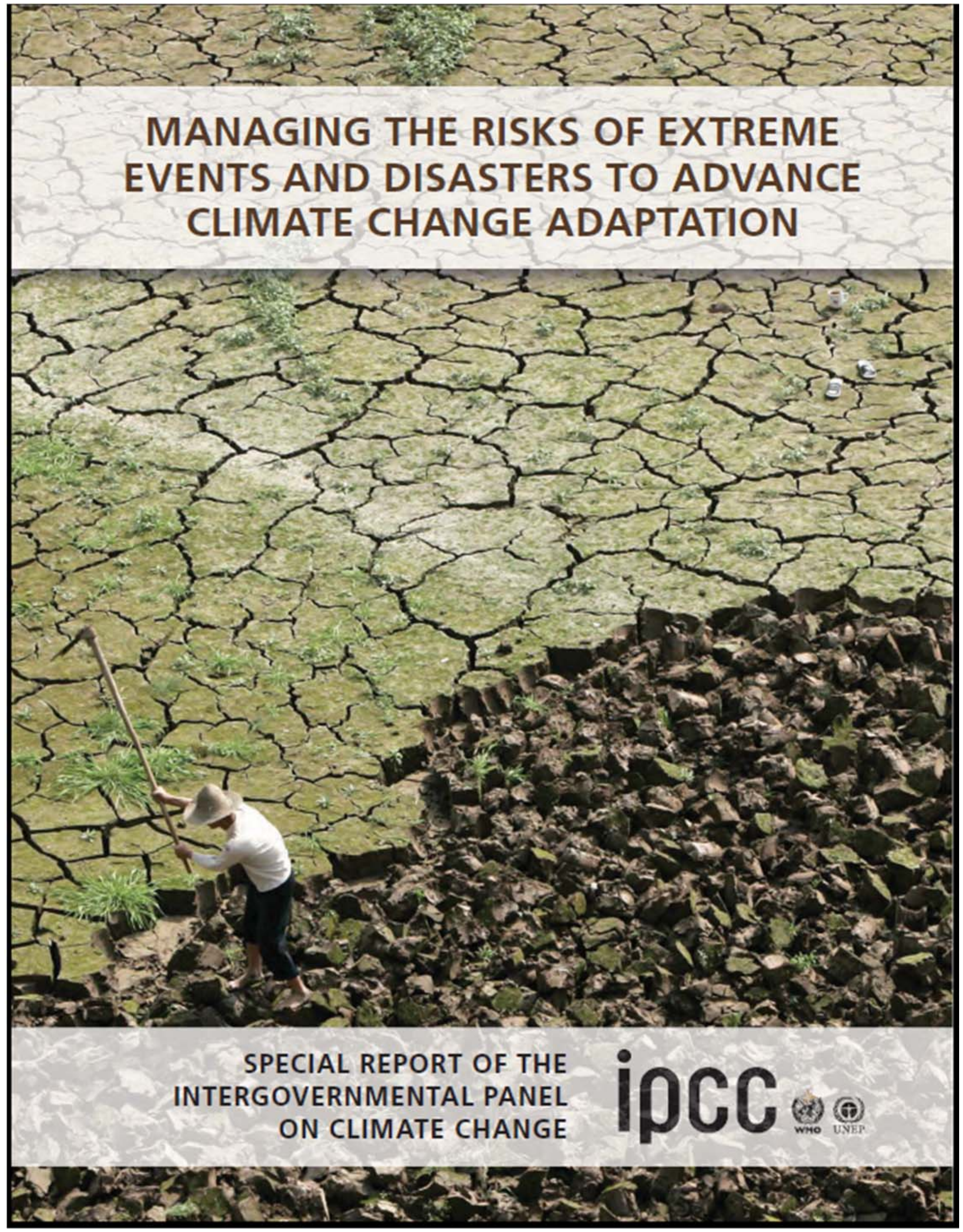
C-balance during European heatwave & drought

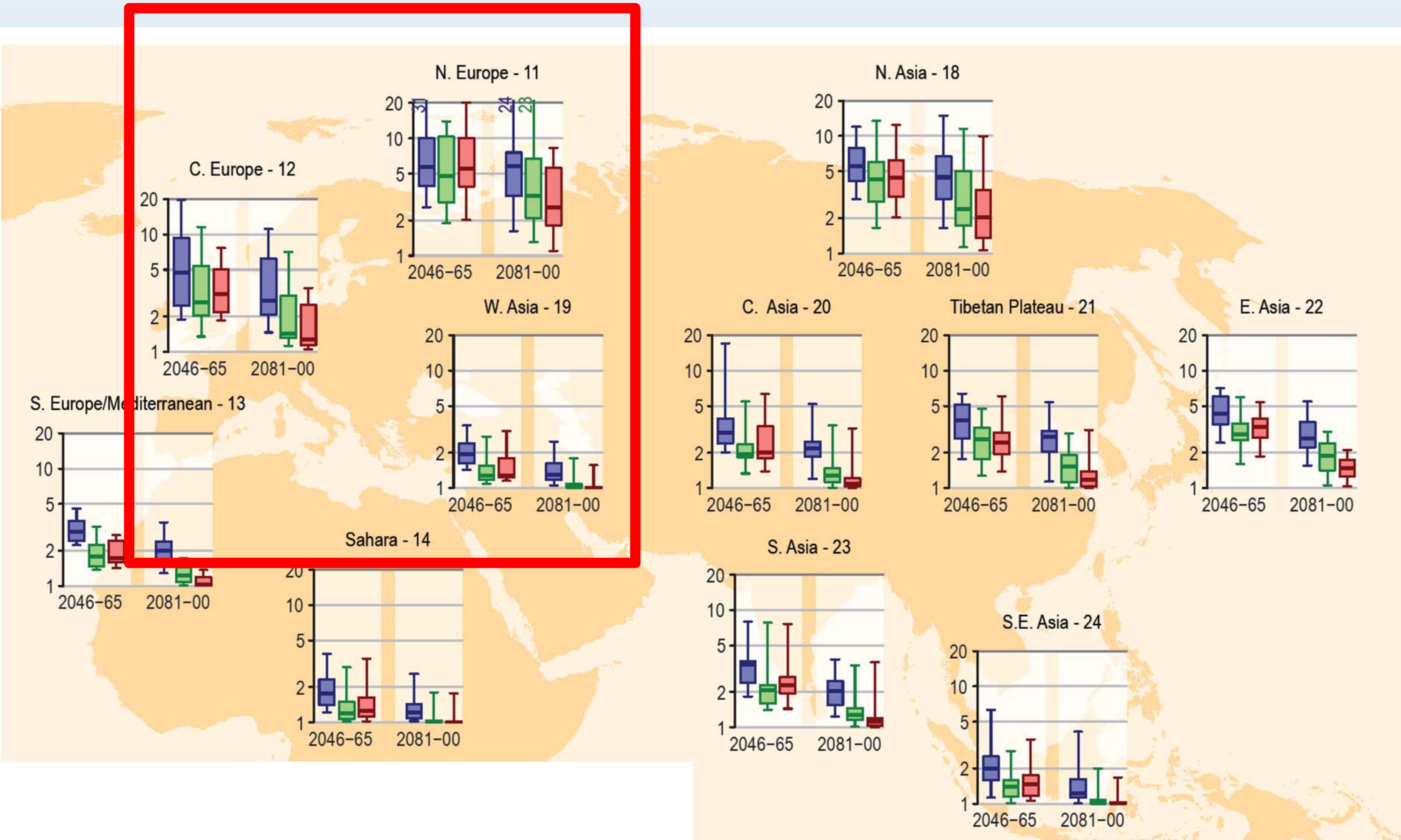


cf. Ciais et al. 2005, Nature
Reichstein et al. 2007, GCB
Granier et al. 2007, AgForMet

Chapter 3:
Seneviratne, S. I., N. Nicholls, D. Easterling, C. M. Goodess, S. Kanae, J. Kossin, Y. Luo, J. Marengo, K. McInnes, M. Rahimi, M. Reichstein, A. Sorteberg, C. Vera, and X. Zhang. 2012. Changes in climate extremes and their impacts on the natural physical environment. Pages 109-230 in C. B. Field, V. Barros, T. F. Stocker, D. Qin, D. J. Dokken, K. L. Ebi, M. D. Mastrandrea, K. J. Mach, G.-K. Plattner, S. K. Allen, M. Tignor, and P. M. Midgley, editors. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC SREX Report). Cambridge University Press, Cambridge (UK), New York (USA).



SREX Projections: Temperature extremes



A1B, A2: A (late 20th-century) 1-in-20 year hottest day is *likely* to become a **1-in-2 year** event by the end of the 21st century in most regions, except in the high latitudes of the Northern Hemisphere, where it is *likely* to become a **1-in-5 year** event

B1: *likely* to become a **1-in-5 year** event (**1-in-10** in NH high latitudes)

Seneviratne et al. (2012)

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INTERGOVERNMENTAL PANEL ON climate change

SREX Projections: Dryness assessments

Several types of measures can be used to quantify changes in dryness / drought:

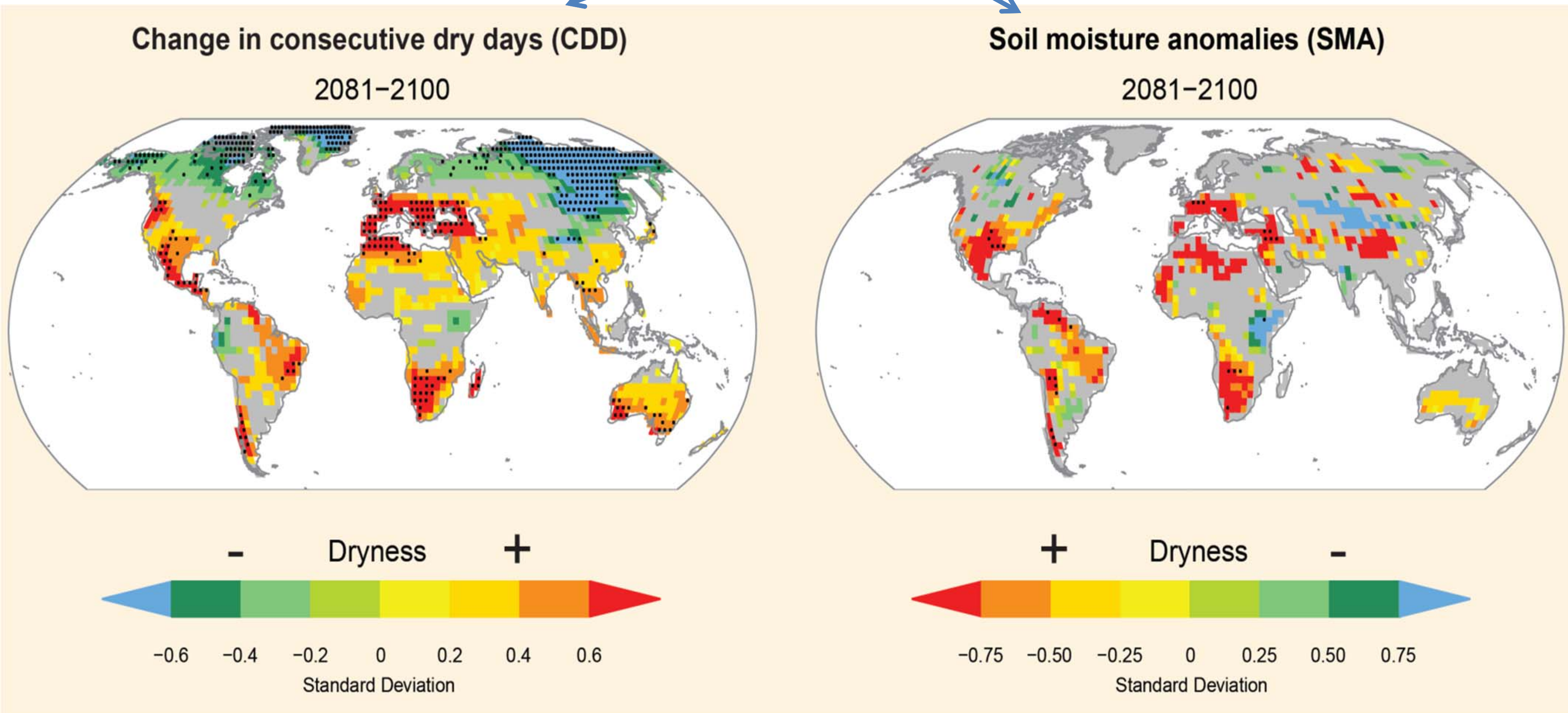
- Reflect different dimensions of dryness (soil moisture drought, meteorological drought, hydrological drought)

- Some examples:
    - **Consecutive Dry Days (AR4)**
    - **Soil moisture anomalies**
    - Standardized Precipitation Index
    - Palmer-drought severity index
    - …

Seneviratne et al. (2012)

SREX Projections: Dryness assessments

Two dryness indices



Gray shading: less than 66% model agreement on sign of change

Coloured shading: ≥ 66% model agreement on sign of change

Stippling: ≥ 90% model agreement on sign of change

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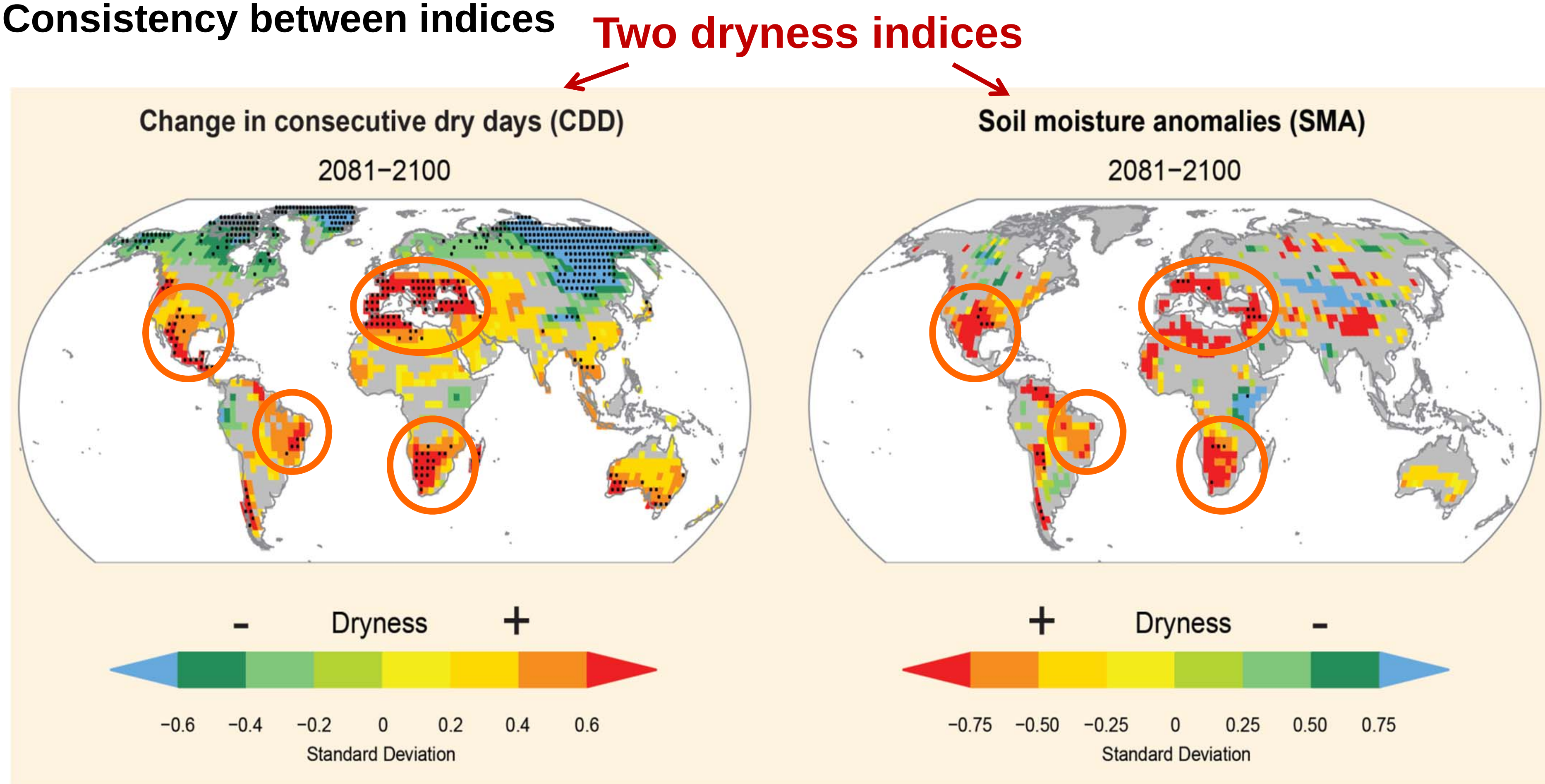
SREX Projections: Dryness assessments

Consistency between indices



Consistent projections of increased dryness for these (and other) indices in the Mediterranean region, central Europe, central North America, Central America and Mexico, northeast Brazil, and southern Africa

Seneviratne et al. (2012)

Impacts on biosphere and biogeochemical cycles

Journal of Ecology

Journal of Ecology 2011, **99**, 656–663 doi: 10.1111/j.1365-2745.2011.01798.x

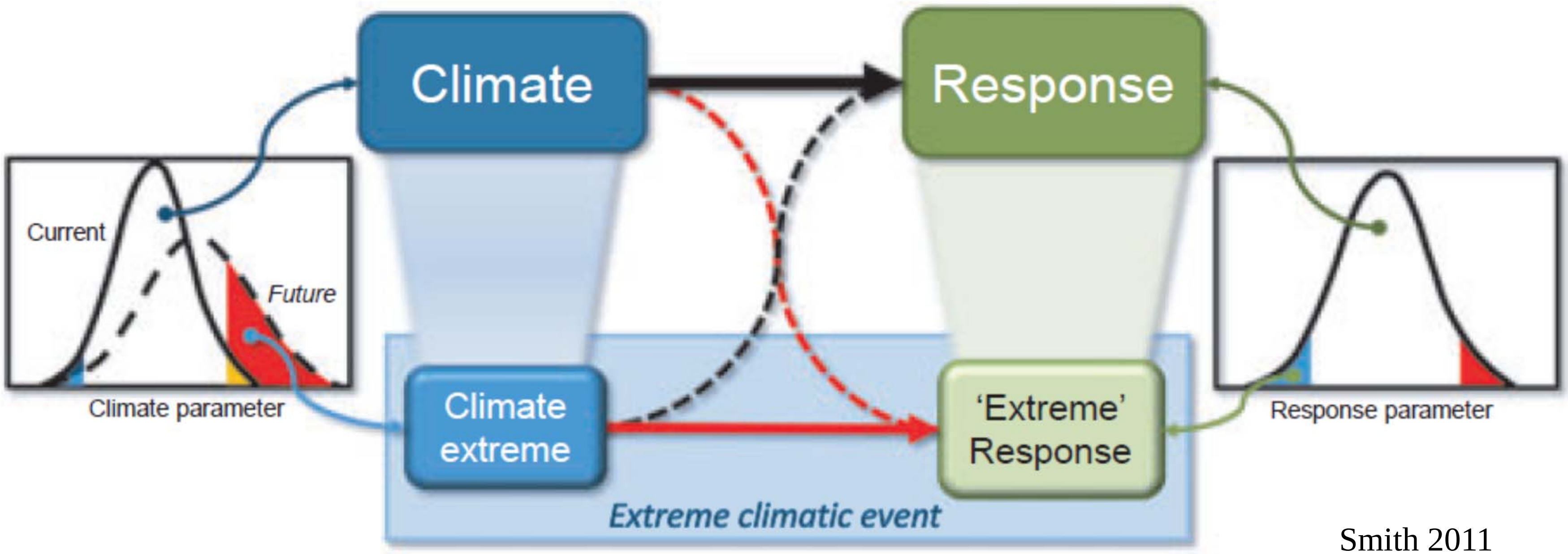
SPECIAL FEATURE – ESSAY REVIEW

ECOLOGICAL CONSEQUENCES OF CLIMATE EXTREMES

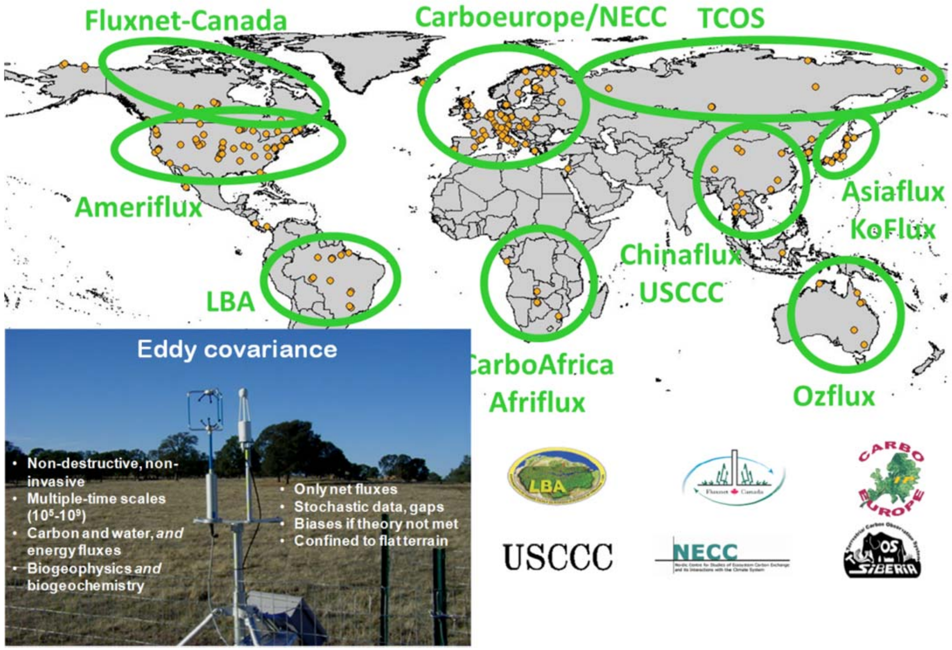
An ecological perspective on extreme climatic events: a synthetic definition and framework to guide future research

Melinda D. Smith*

Department of Ecology and Evolutionary Biology, Yale University, New Haven, CT 06520, USA



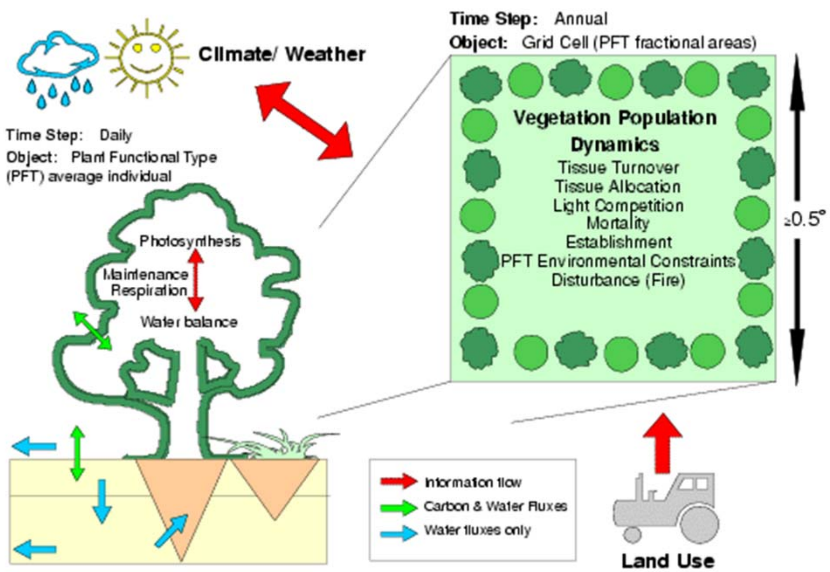
Smith 2011



4 different approaches

MTE: Upscaled Model Tree Ensemble [Jung et al., 2011] (fPAR, temp., precip.)

MOD17+: Light Use Efficiency model [Running et al., 2004, Beer et al. 2010] (fPAR, radiation, temp., air hum.)



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LPJmL: Terrestrial biosphere model [Sitch et al., 2003; Bondeau et al. 2007] (radiation, temp, precip, air hum)

OCN: Land-surface model based on ORCHIDEE [Zaehle and Friend, 2010] (radiation, temp, precip, air hum, wind speed)

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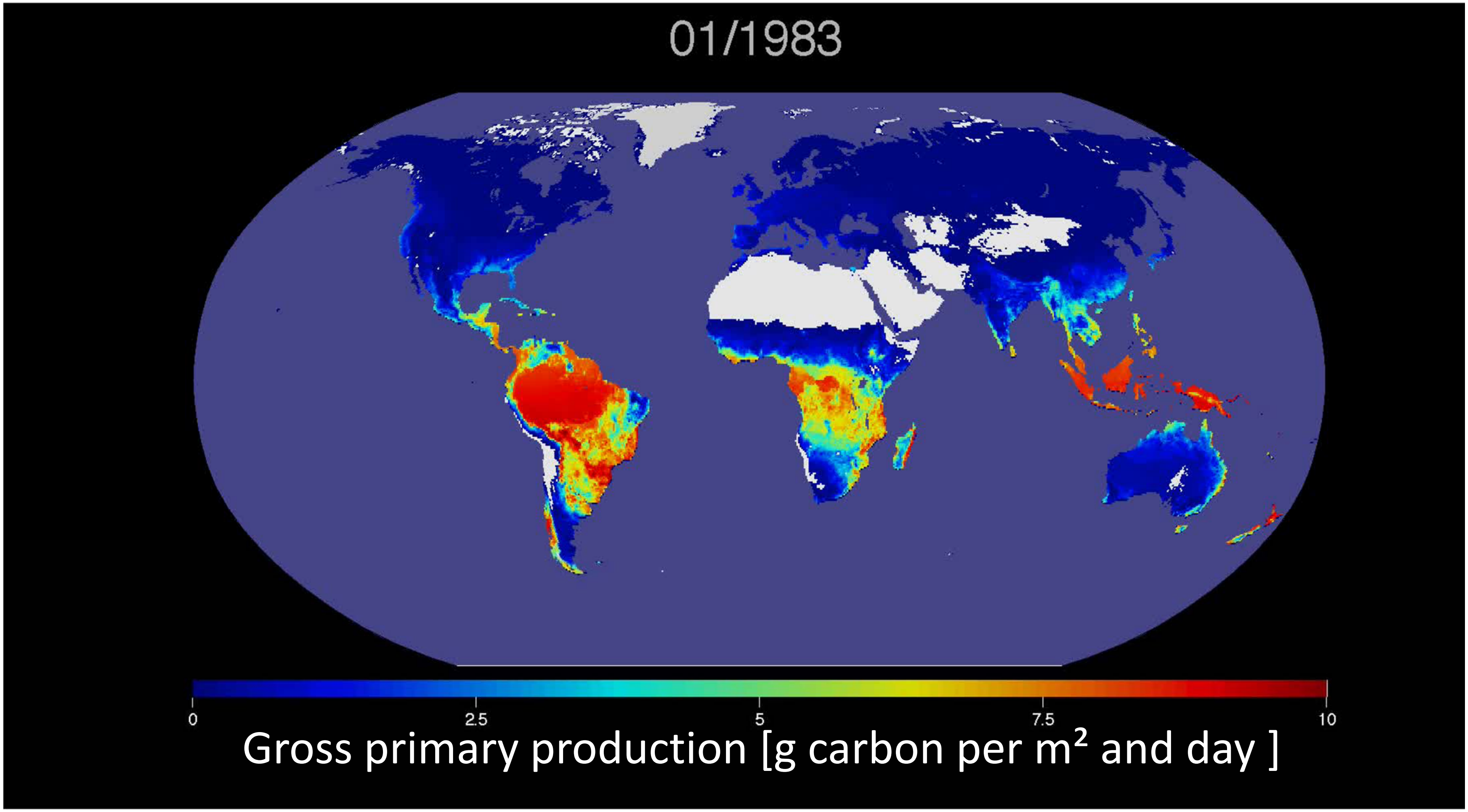
Decades of monthly global biosphere-atmopshere exchange @ 0.5°



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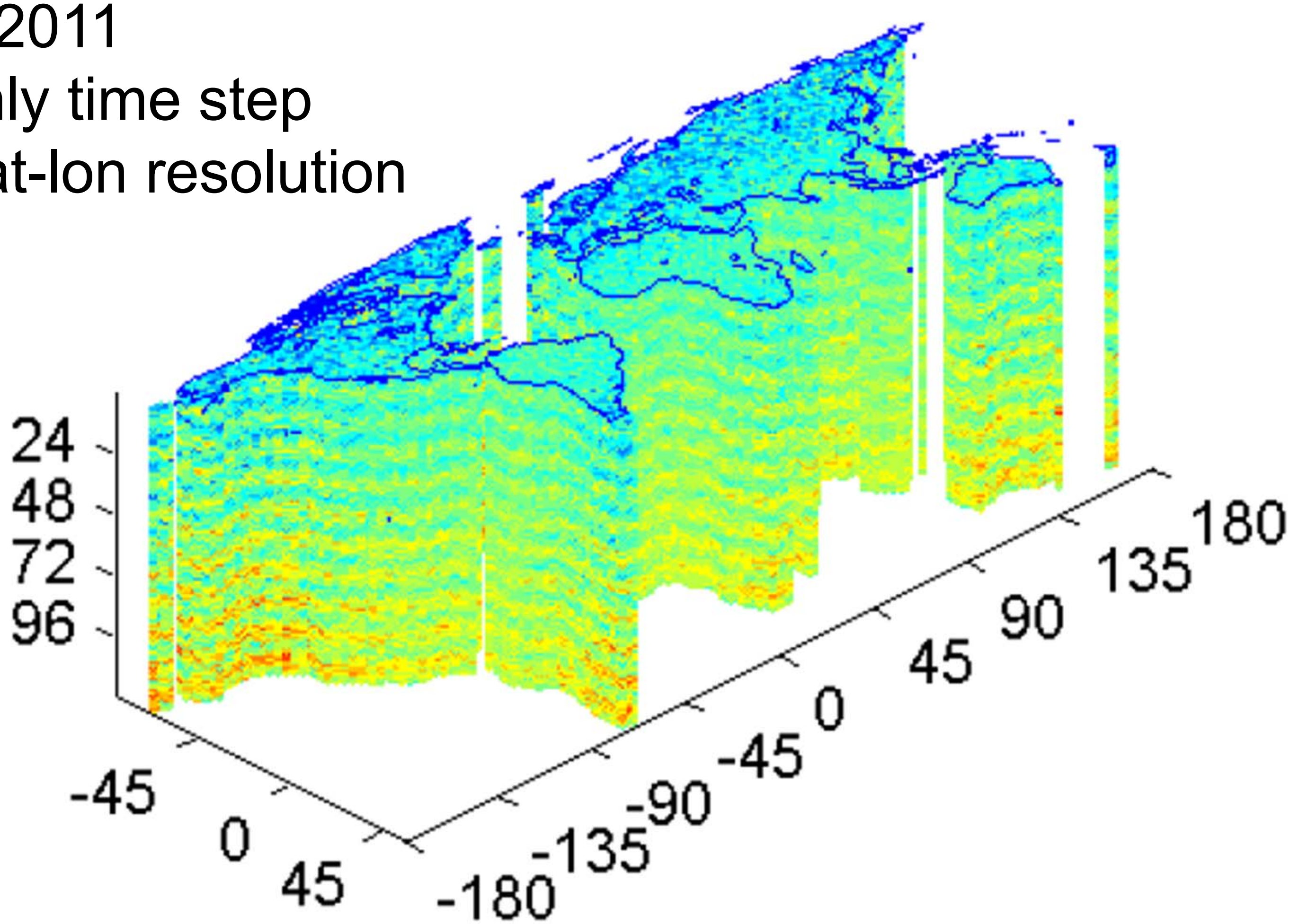
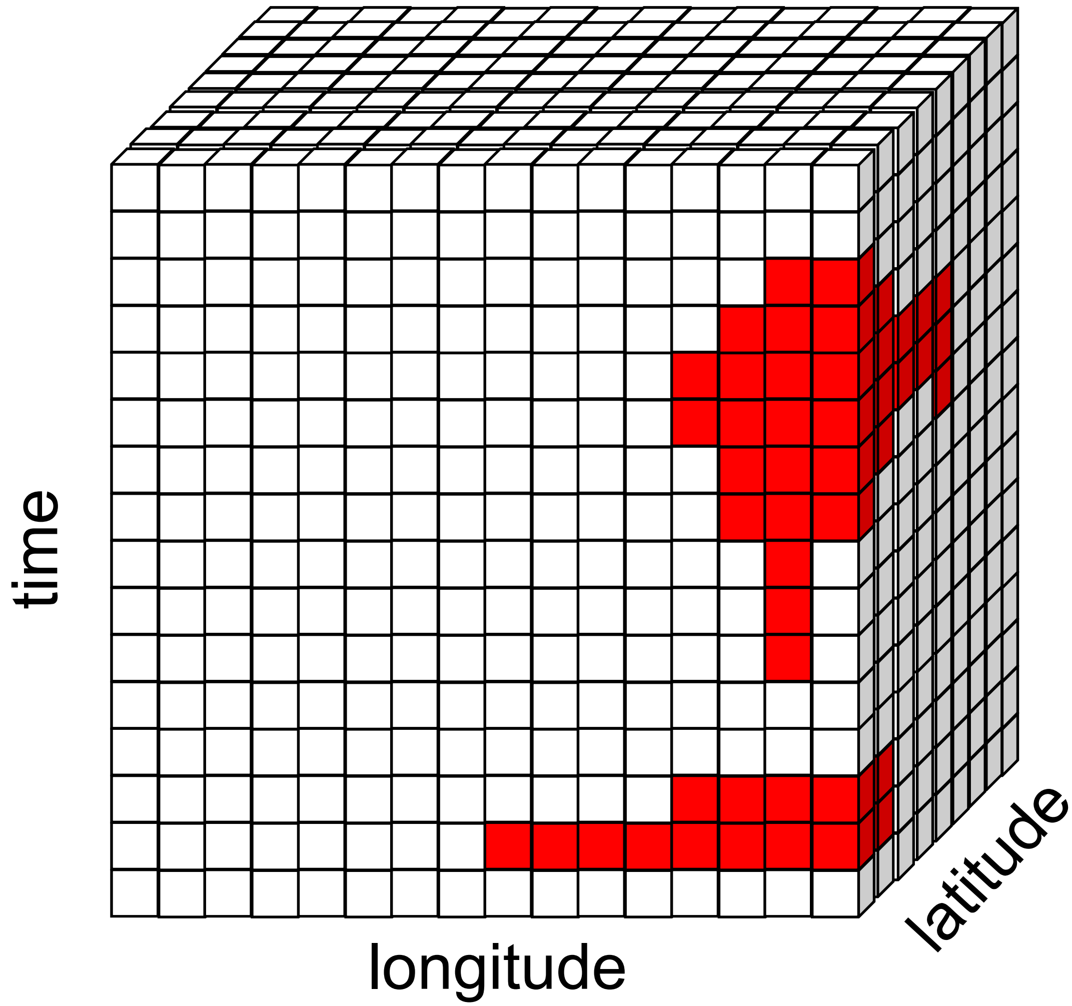
➔ 4 Global data sets of gross-primary production (GPP)

1982-2011
Monthly time step
0.5° lat-lon resolution



Extraction of spatio-temporal extreme <u>events</u>

1. Detrend and deseasonalize pixel by pixel
   - ➢ *Anomalies*
2. Tag voxels (lat, lon, time) with extreme anomaly
   - ➢ *Based on 1%, 5% or 10% percentile*
3. Find spatio-temporally connected voxels
   - ➢ ***"Extreme events"***
4. Characterize them
   - ➢ *Magnitude*
   - ➢ *Spatial extent*
   - ➢ *Duration*
   - ➢ *Total integral*
   - ➢ *…*



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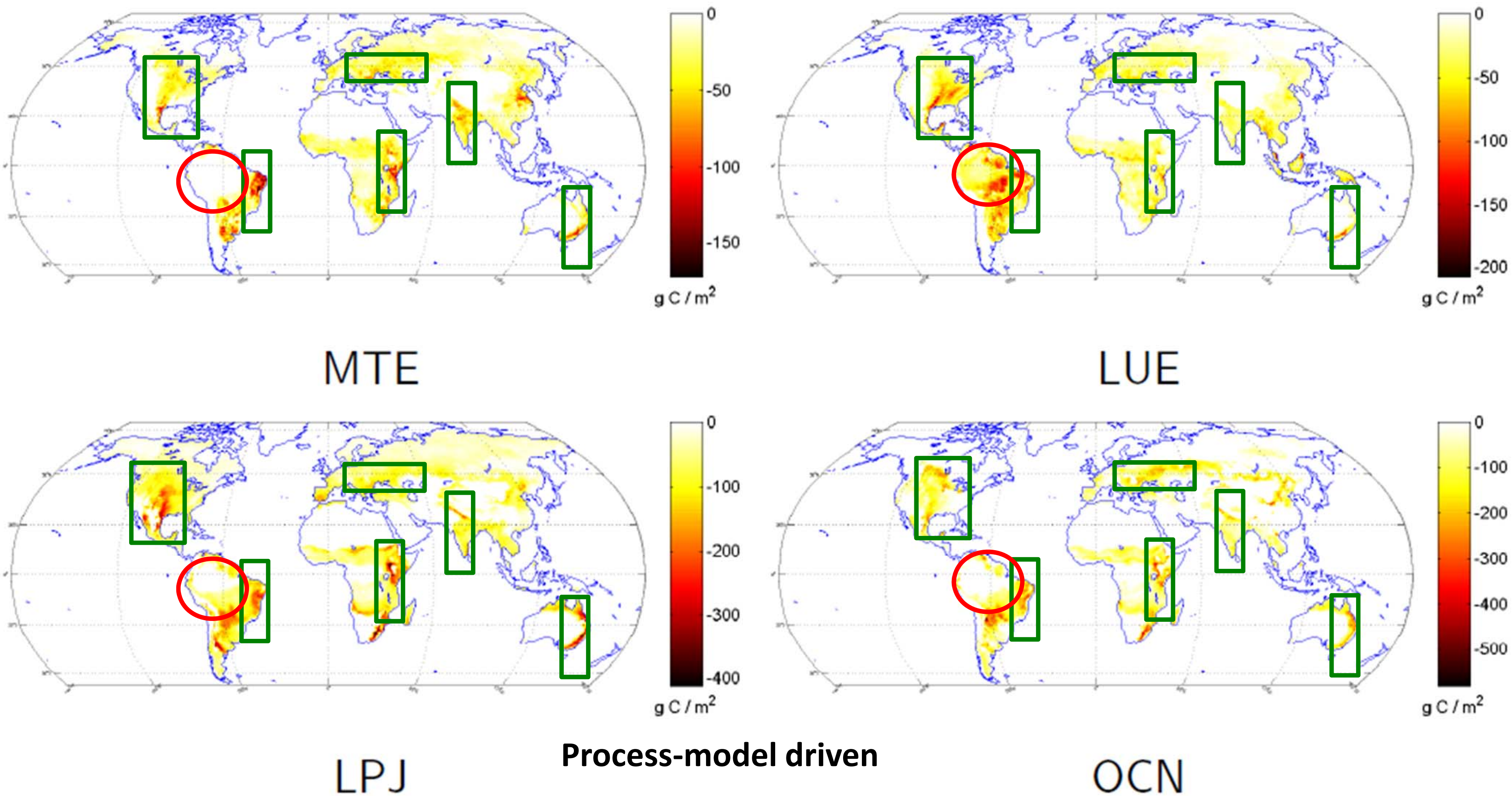
Spatial distribution of GPP extremes

Data-driven

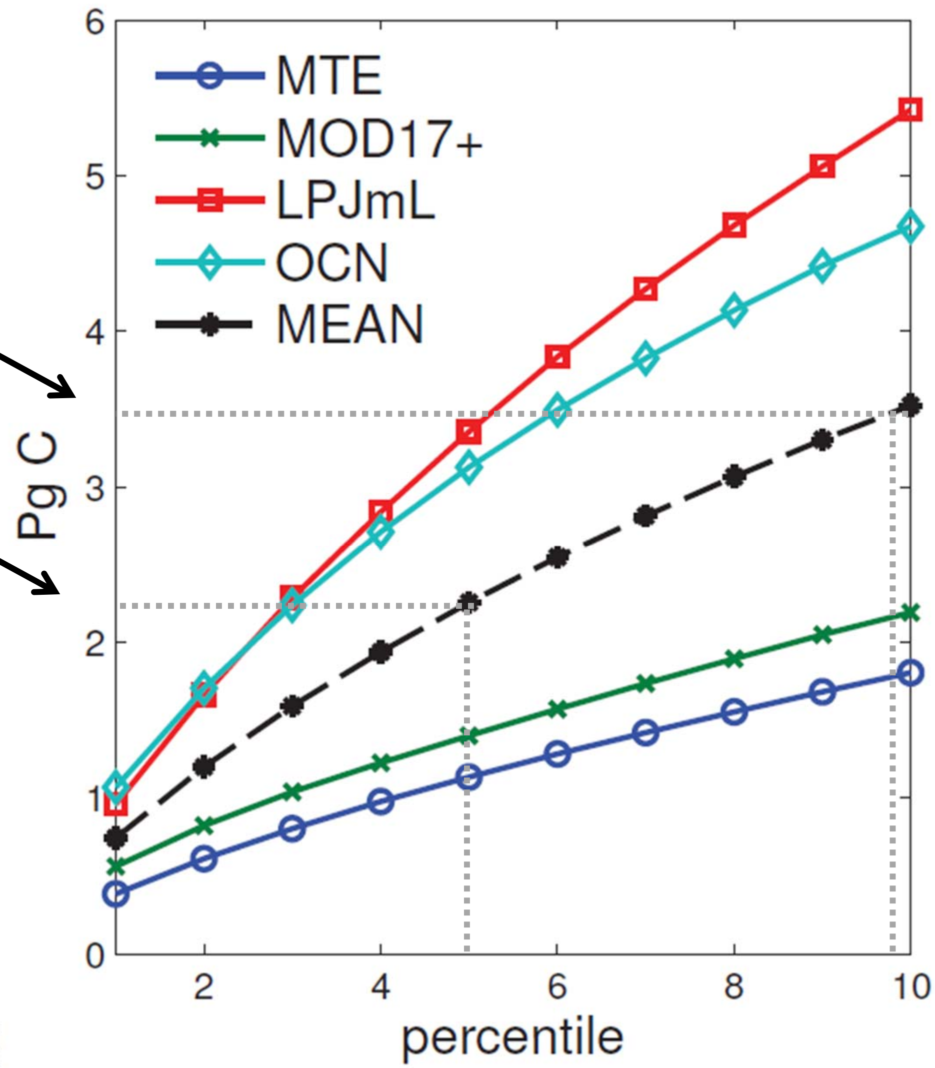


Zscheischler et al. (2014), ERL

Global sum of 1000 biggest negative GPP extremes

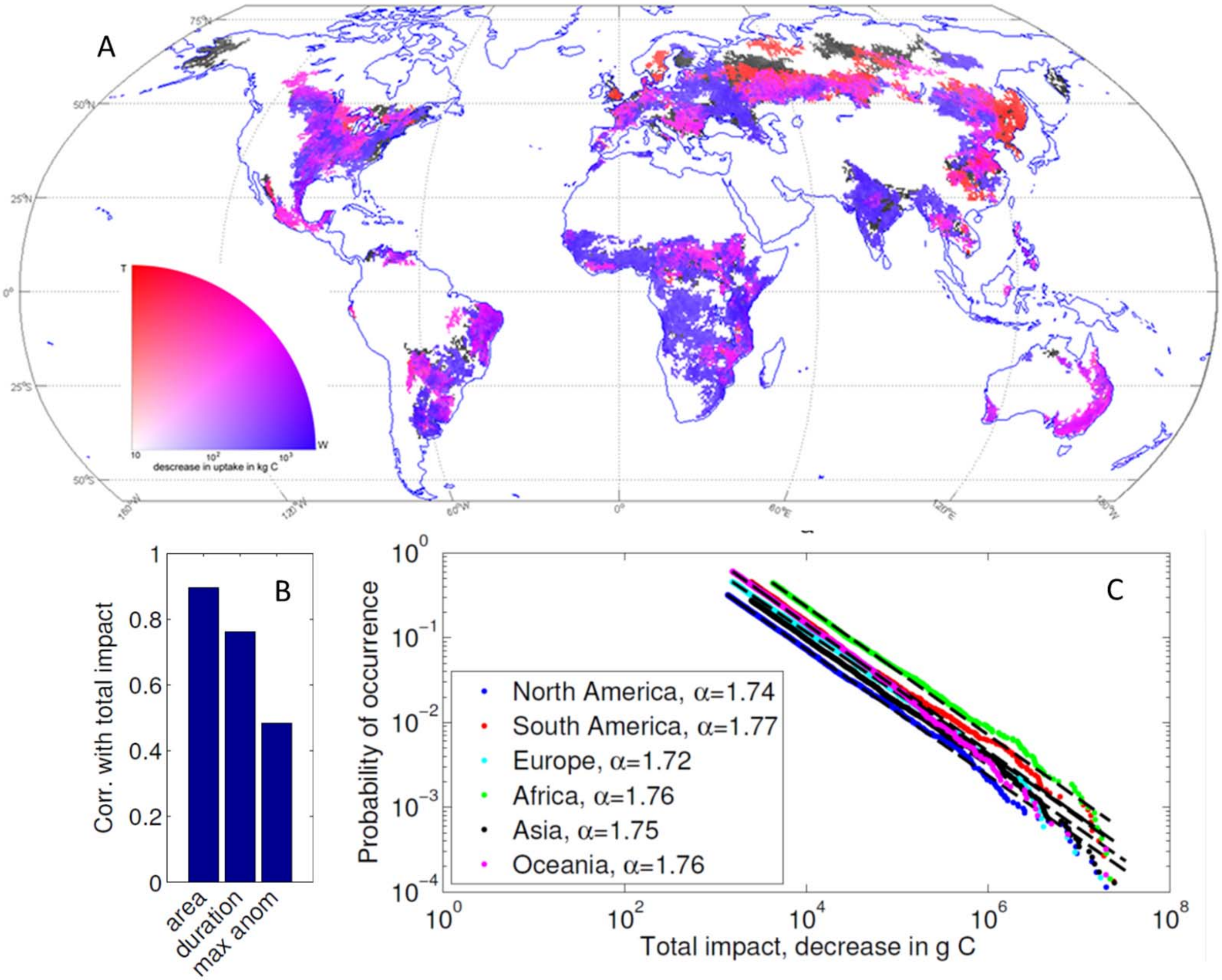
3.5 Pg

2.2 Pg



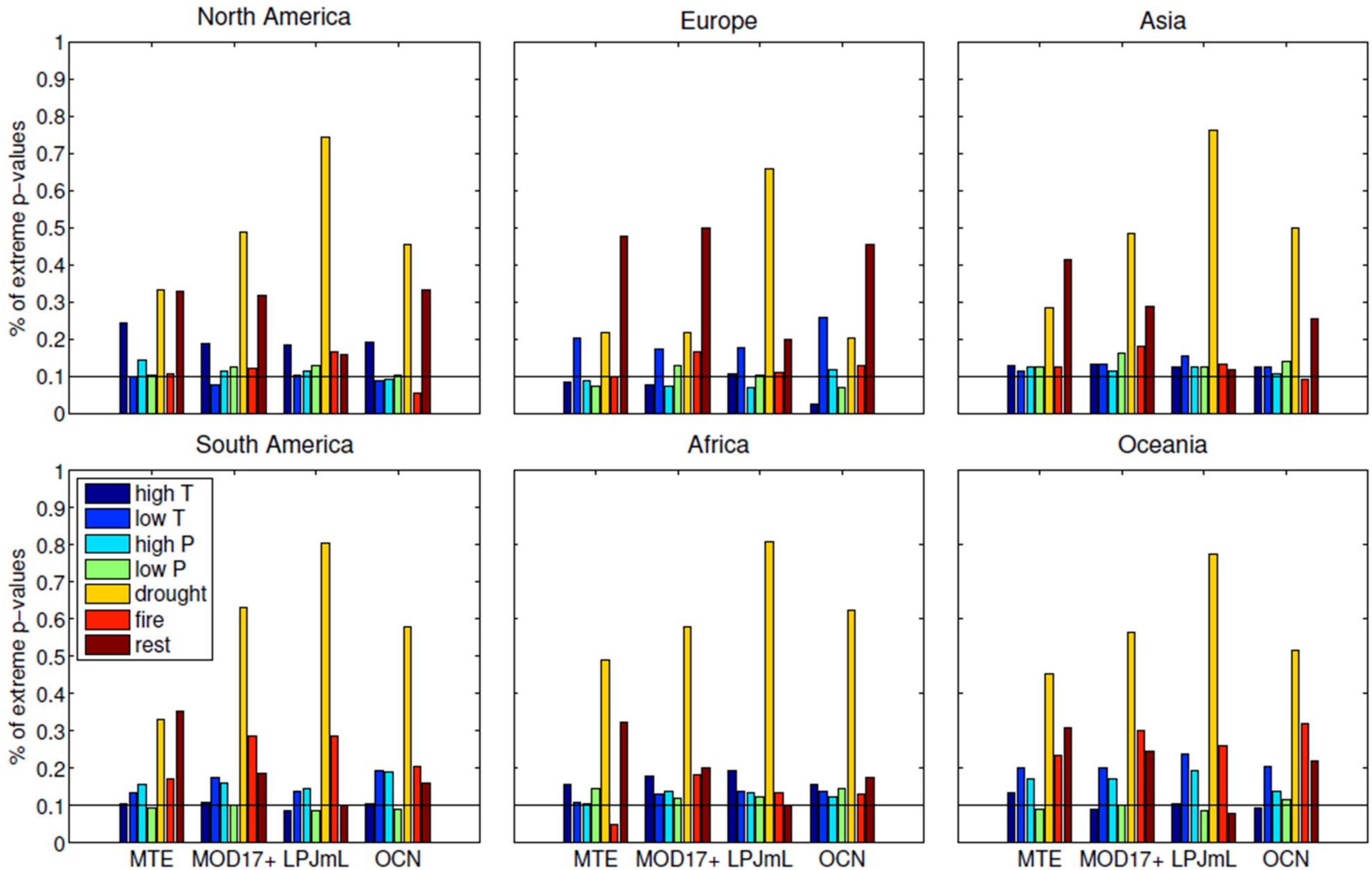
Zscheischler et al. (2014), ERL

C-cycle extremes often associated with drought



Reichstein et al. 2013, Nature

Association of C-cycle extremes by continent…



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Zscheischler et al. (2014), BG

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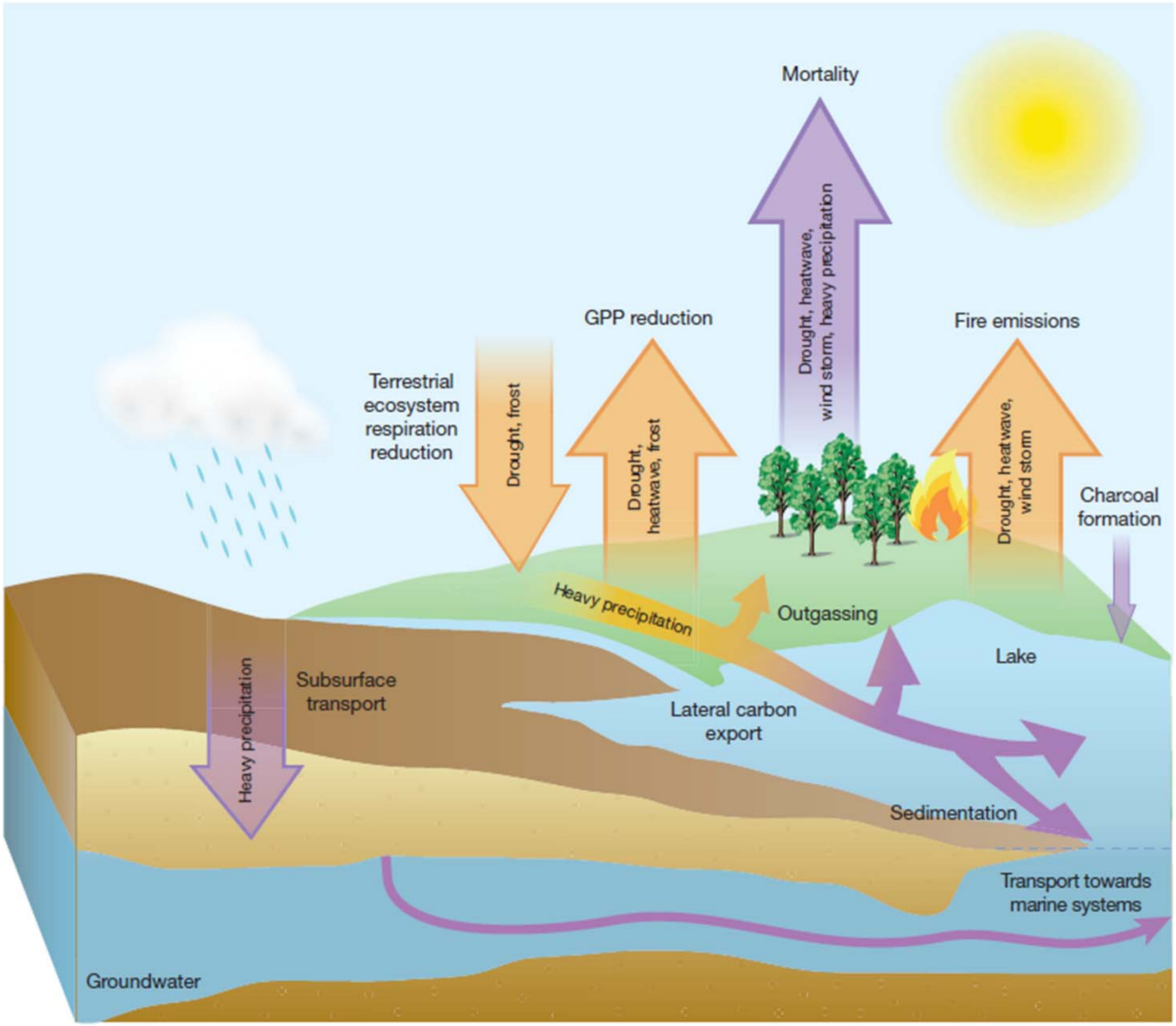
Limitations of our approach



Reichstein et al. (2013) Nature

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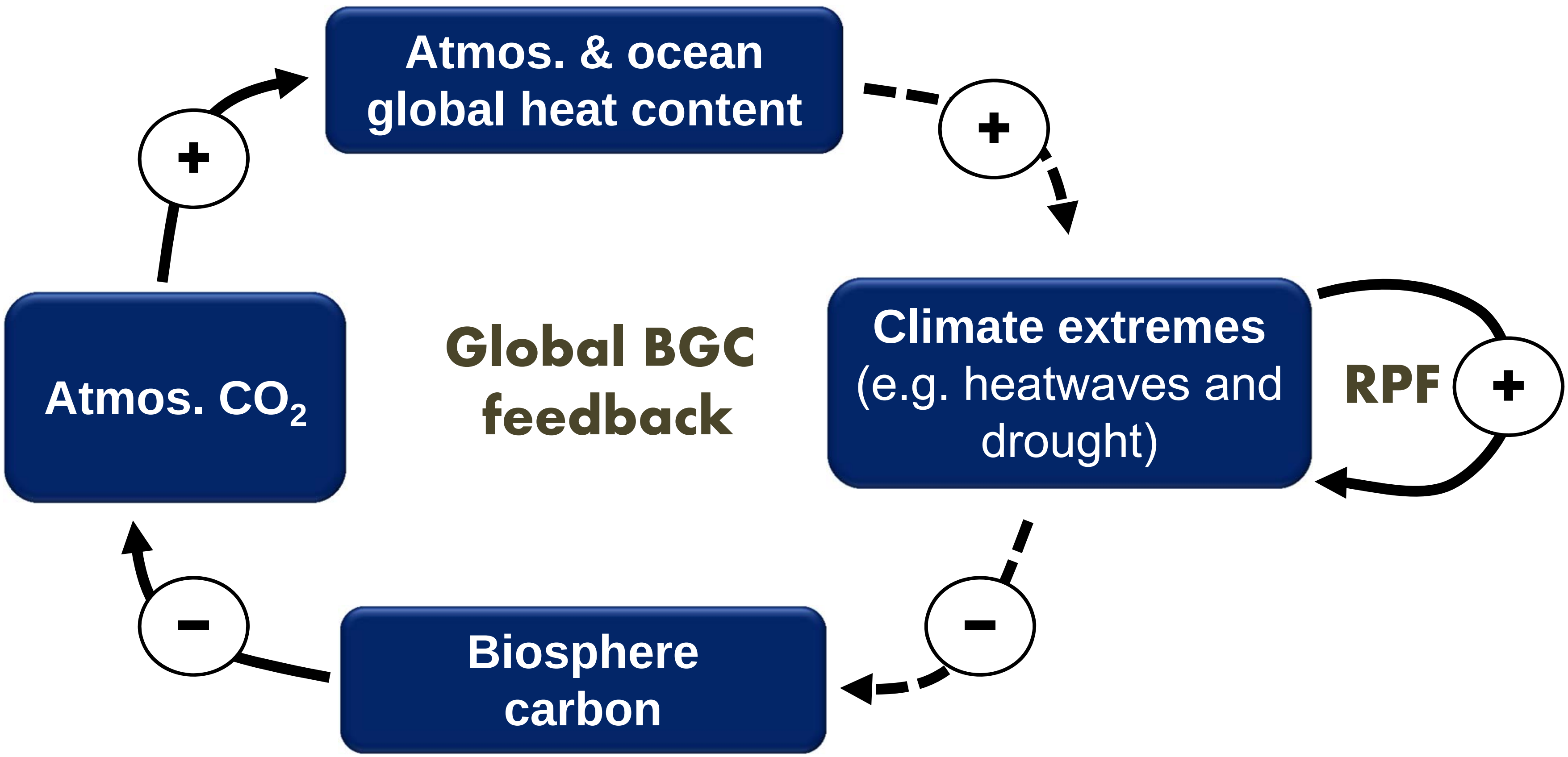
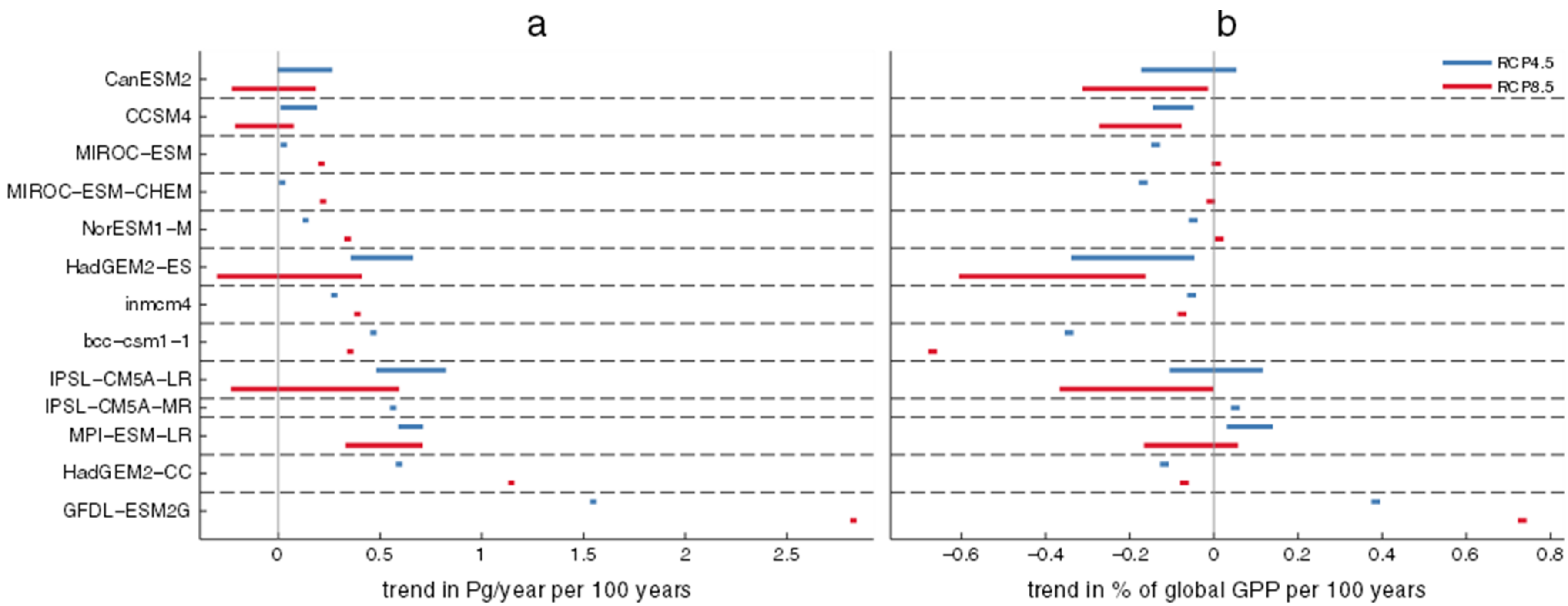
First conclusions

Very likely:

- **Climate extremes contribute to positive carbon cycle feedback**
- **Carbon-water cycle interactions (droughts) crucial**



CMIP5 C-cycle projections



Zscheischler et al. (2014) GRL

Ongoing research, open questions and beyond…

Multivariate extremes

"Winner and losers"

Societal impacts

For public viewers: Some slides had to be left out - please contact me for further info on this!

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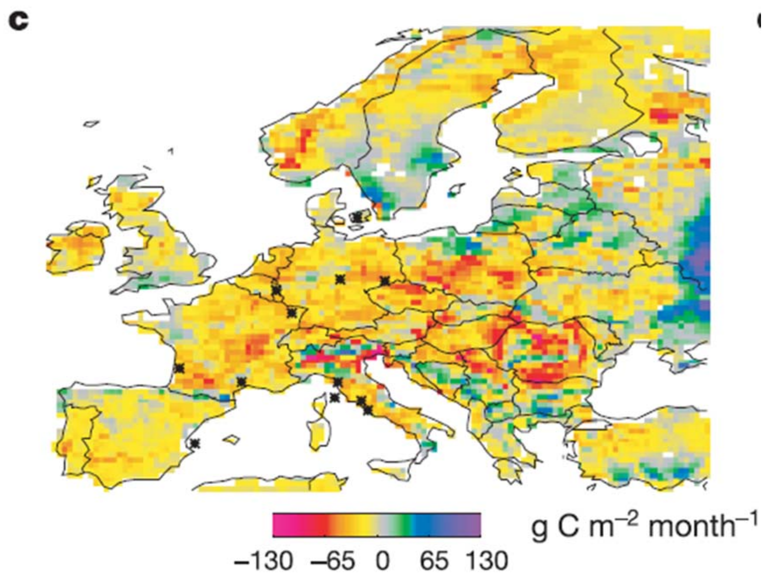
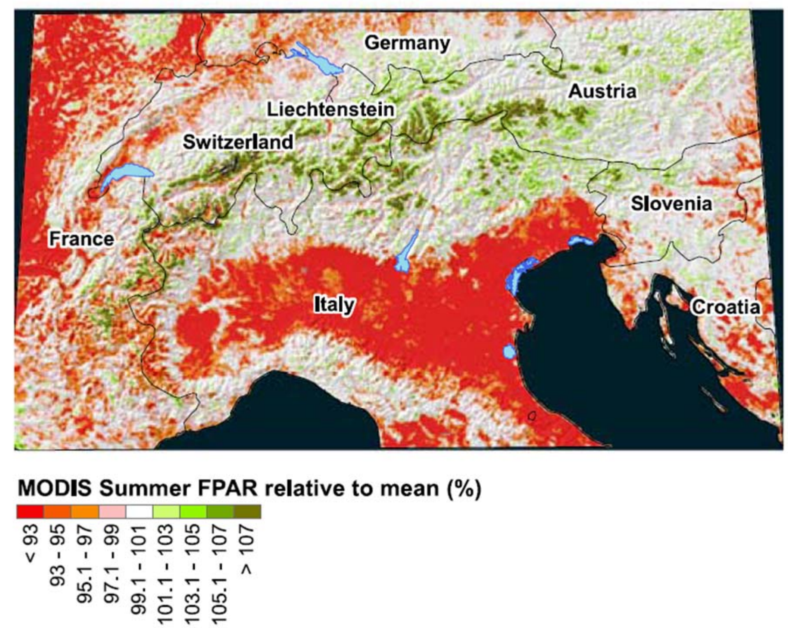
‘Negative’ / ‘positive’ responses of climate extremes





Ciais et al. (2005)

1948 citations

Jolly et al. (2005)

140

Reichstein et al. (2007)

315

futurearth
research for global sustainability

Extreme Events and Environments - from climate to Society ($E^3 S$) -

Which system properties yield resistance and resilience to extreme conditions?
What are meaningful indices of impact-relevant climate extremes? And to-be predicted variables?

How do social and natural systems interact at different time-scales (dir. reaction to adaptation)?
How does perception and moral valuation affect societal response to extreme events?

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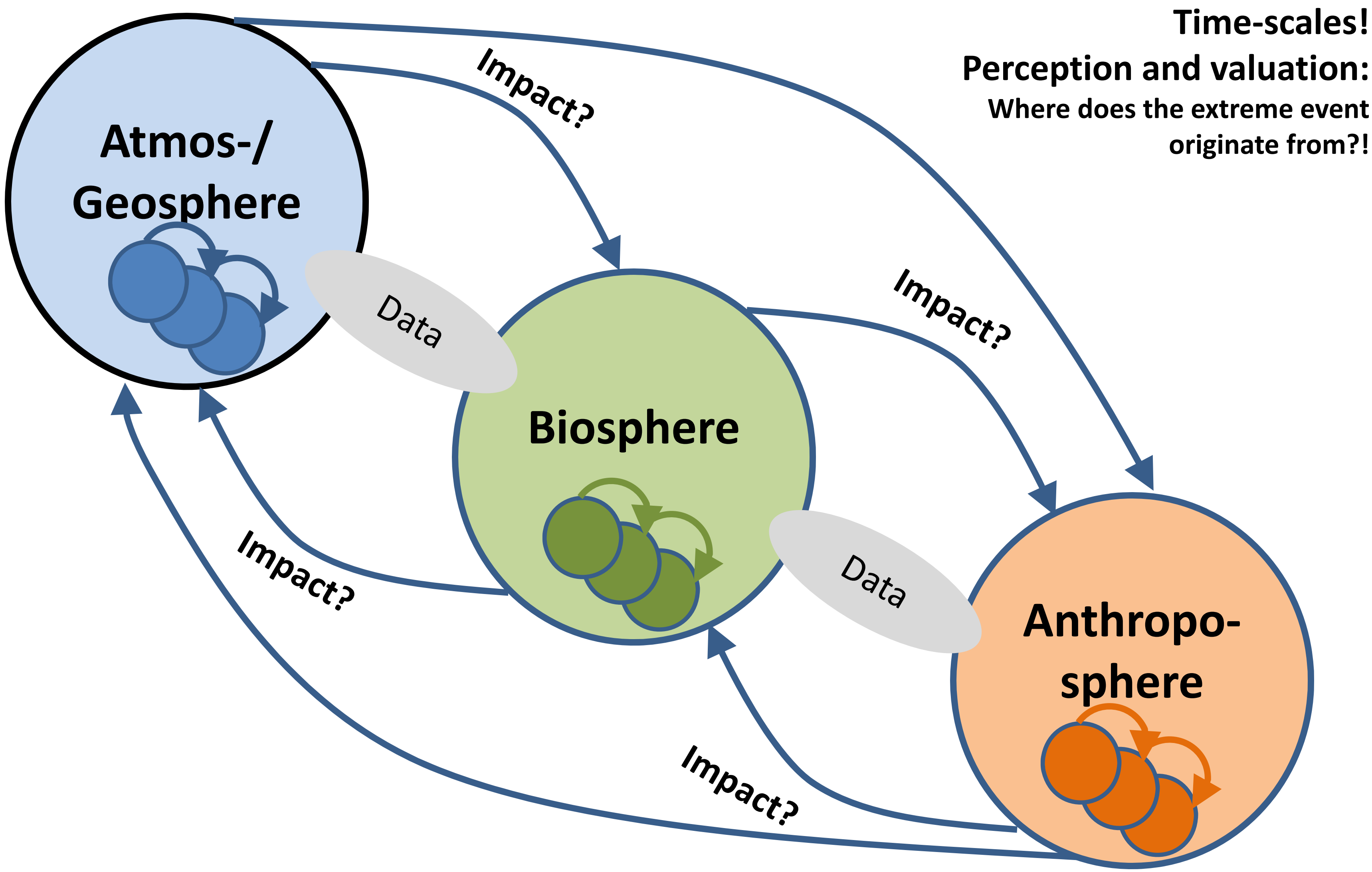
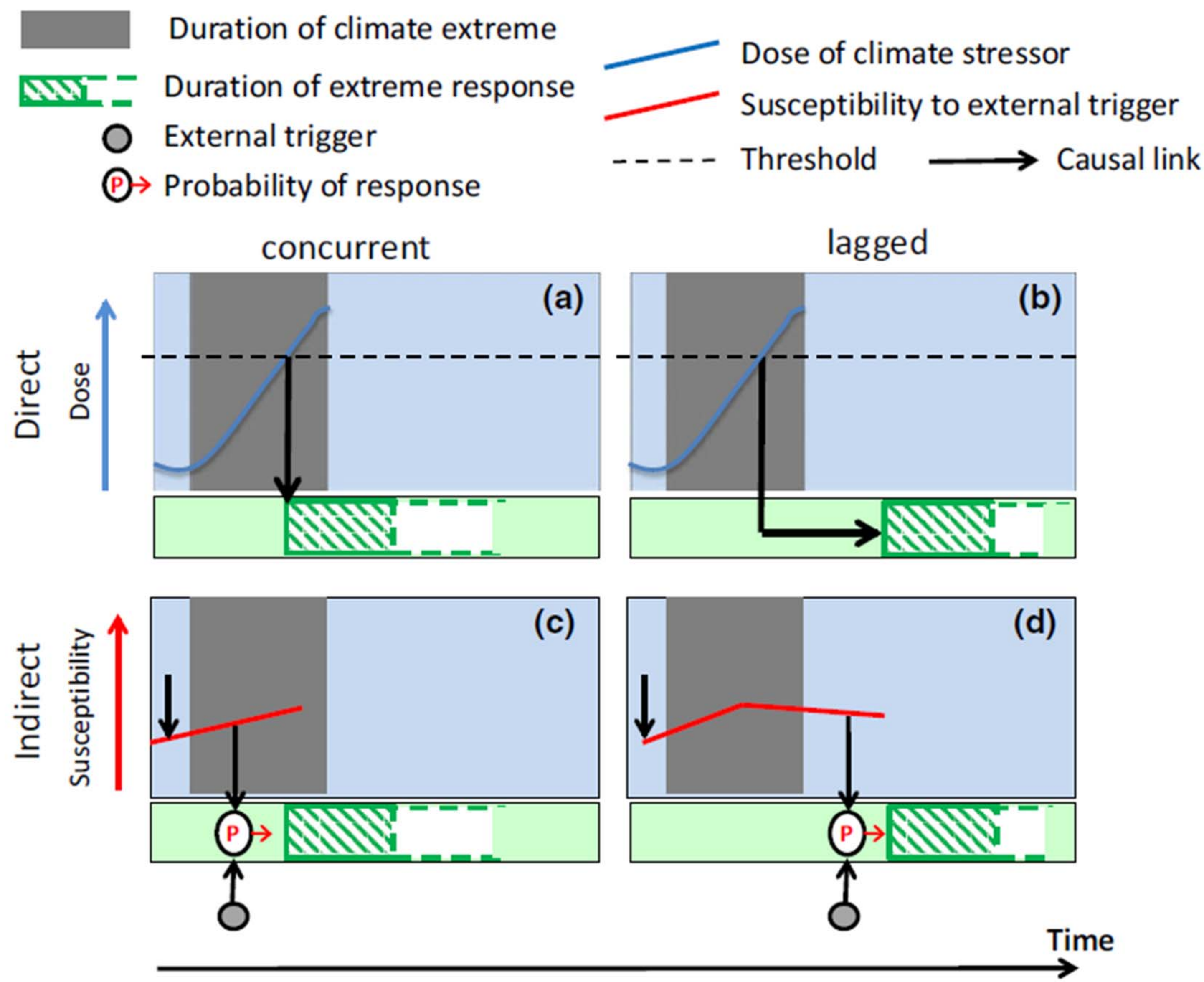
System-cascading effects of extreme events

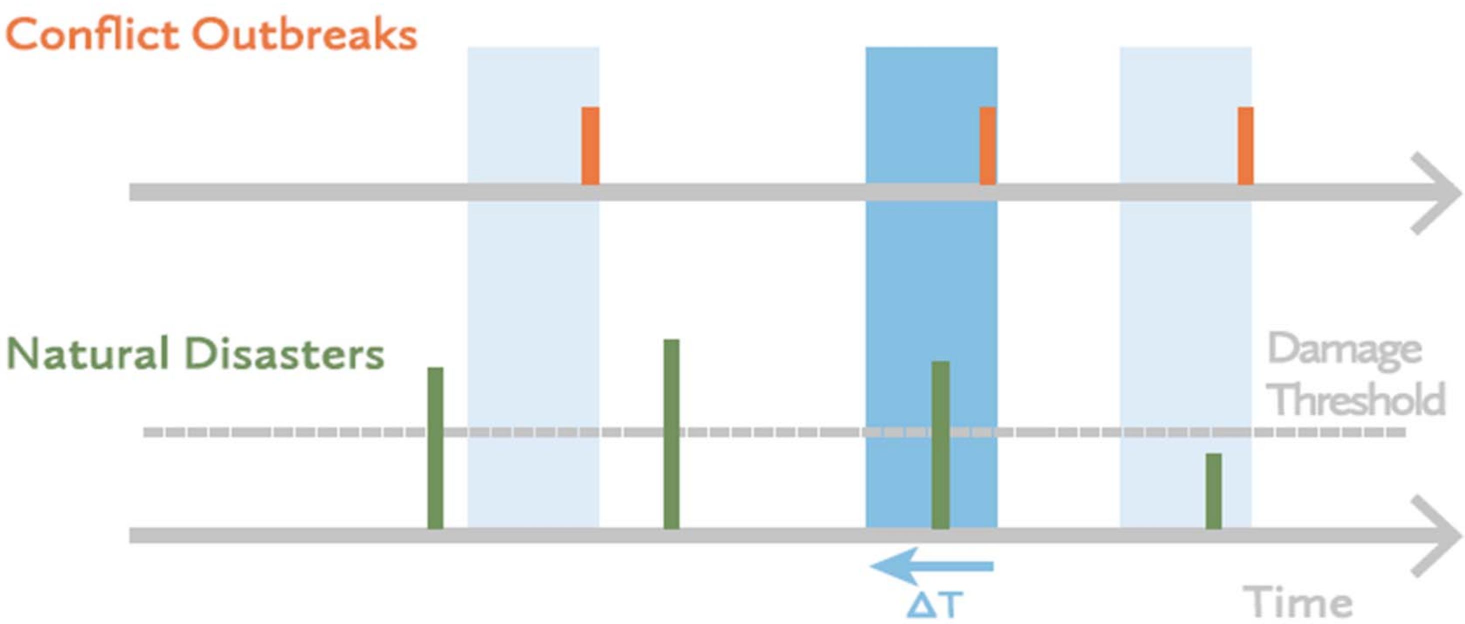


Classification of extreme events and their impacts



Frank et al. (2015)

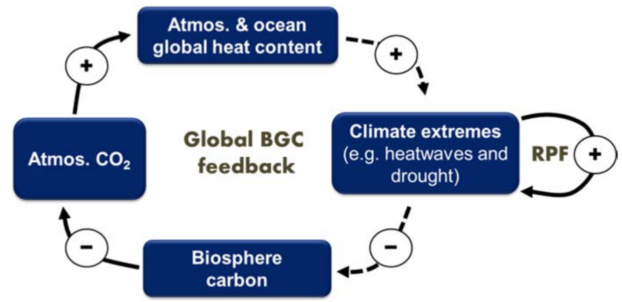
Similar concept used for link natural disasters with conflict outbreaks (coincidence analysis)

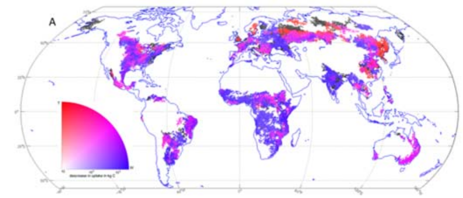


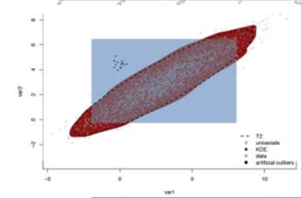
Schleussner et al. (2016) PNAS

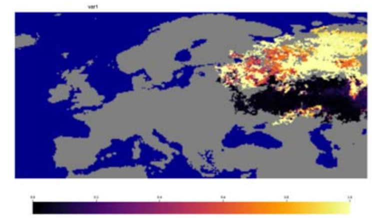
Summary

- <u>Very likely:</u>
  - Climate extremes contribute to positive carbon cycle feedback
  - Carbon-water cycle interactions (droughts) crucial
- Significance of multivariate and compound extremes?
- System response can be equivocal and unintuitive
- Event-based data-driven approach to link physical, biological and societal sub-systems

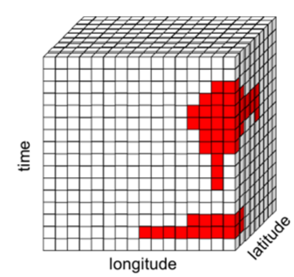


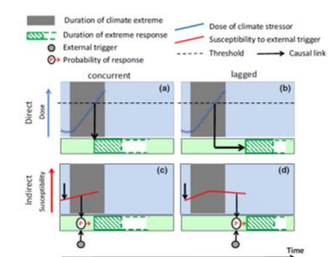






Biosphere: mean quantile of *GPP* (affected voxels 2010.3 -2010.7)





Thanks for your attention!

“Extremely nice day”, Beatenberg, Apr 9, 2017

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Some limitations

- Just looking at GPP and “fPAR-visibile” effects
  - NEE effect smaller, because of compensating respiration response (factor 2-3)
  - Other processes affected ➔ e.g. mortality
    - Tendency to underestimate
- Coarse resolution disfavours smaller, disconnected extremes (e.g. small scale windthrows)
  - Tendency to underestimate total effect
  - Tendency to overestimate relative effect of droughts