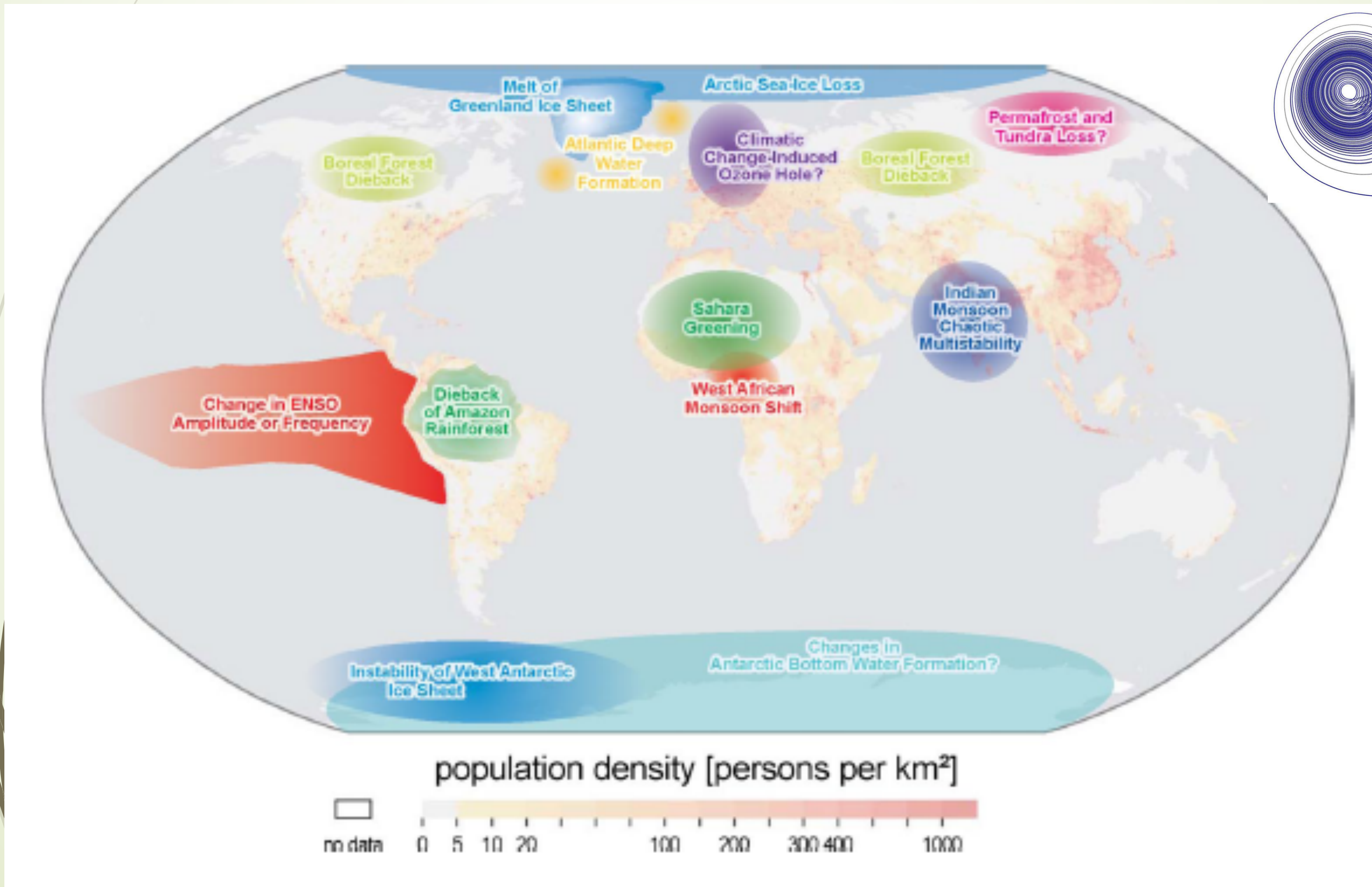
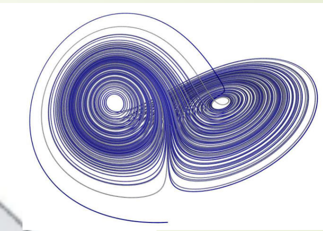
Tipping elements of the climate system

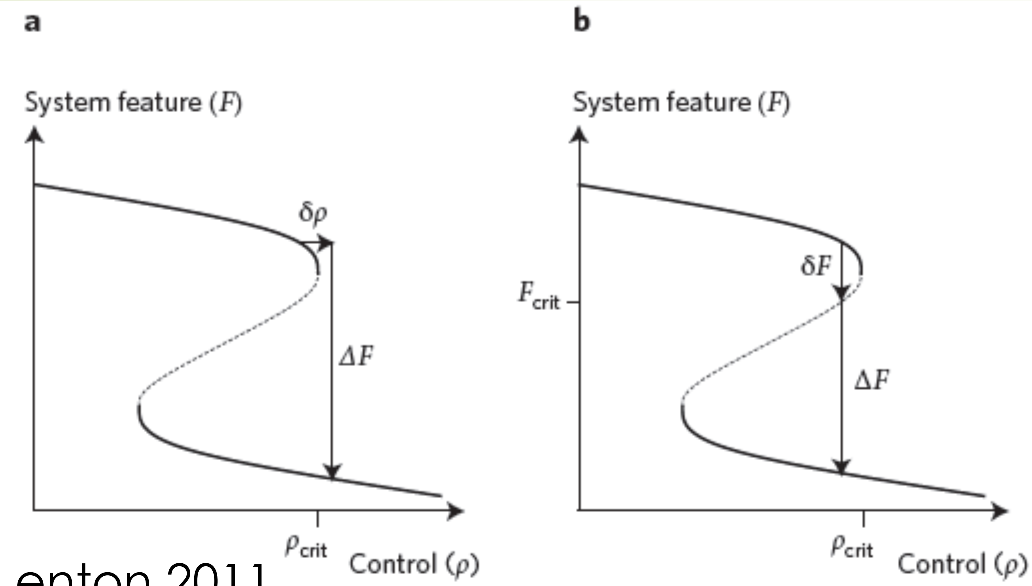
Didier Swingedouw
CNRS-EPOC / University of Bordeaux

Definition from Lenton et al. (2008): The term ‘‘tipping point’’ commonly refers to a critical threshold at which a tiny perturbation can qualitatively alter the state or development of a system. Here we introduce the term ‘‘tipping element’’ to describe large-scale components of the Earth system that may pass a tipping point.

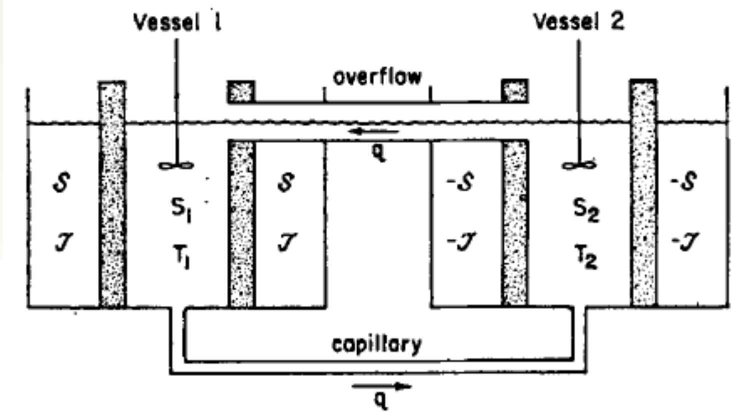




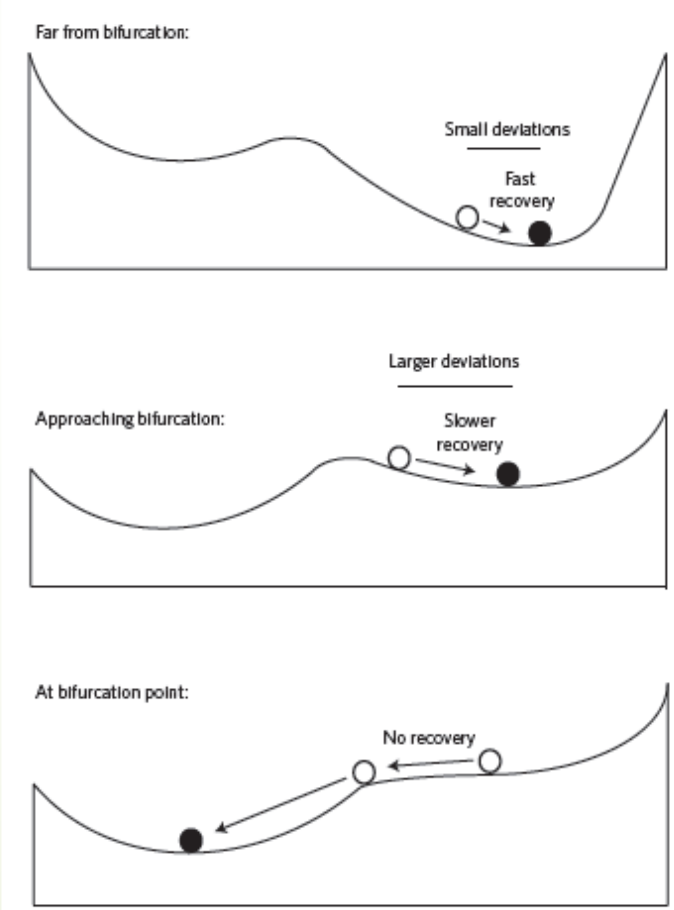
Tipping points



Lenton 2011



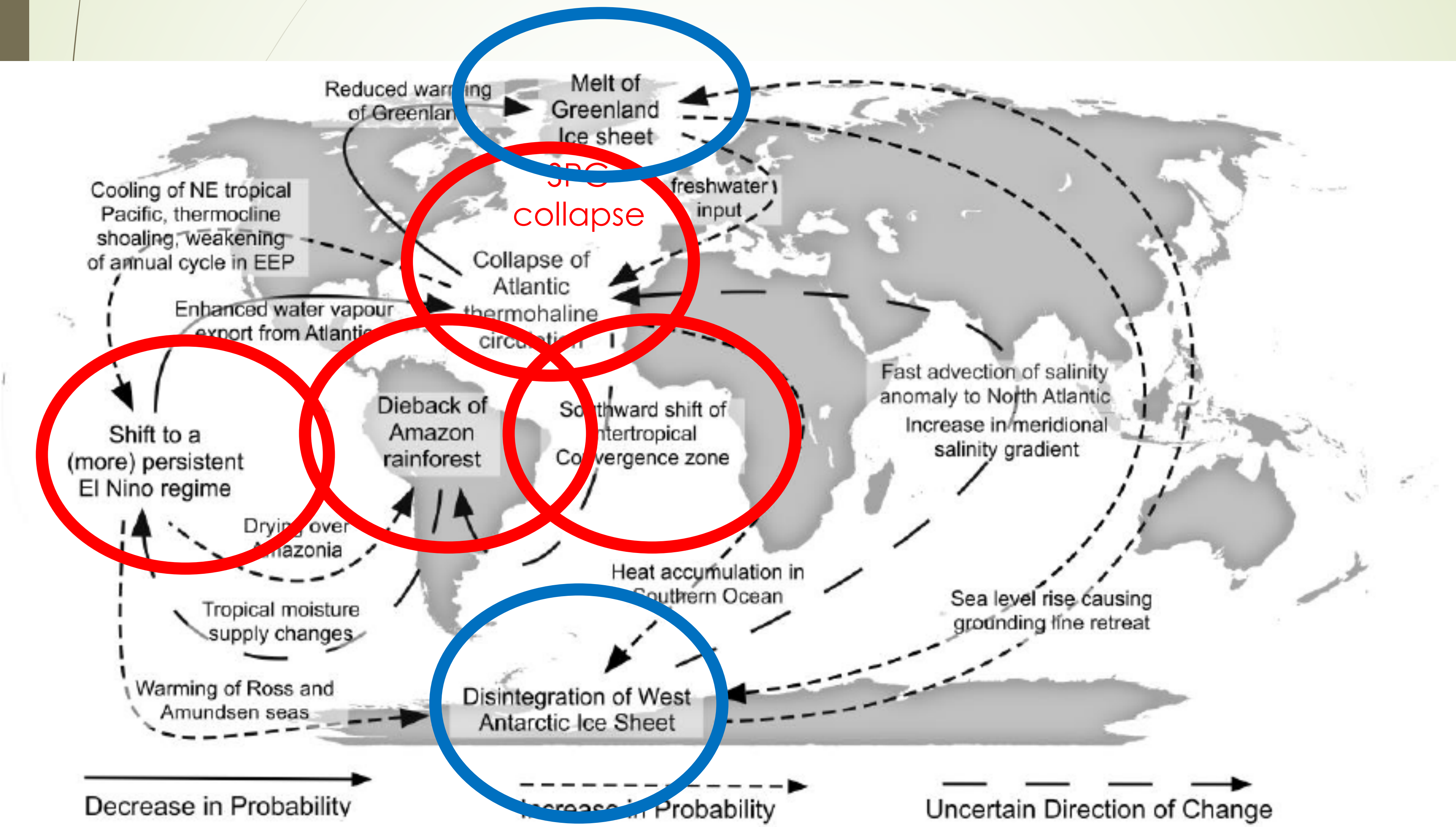
Stommel (1961)



Implications:

- Within an ensemble of simulations, some members can cross the threshold, other not: stochasticity matters
- Potential of early warning from analysis of changes in statisical properties in time windows (variance, AR1 model...)

Interactions between tipping elements (Cai et al. NCC 2017)

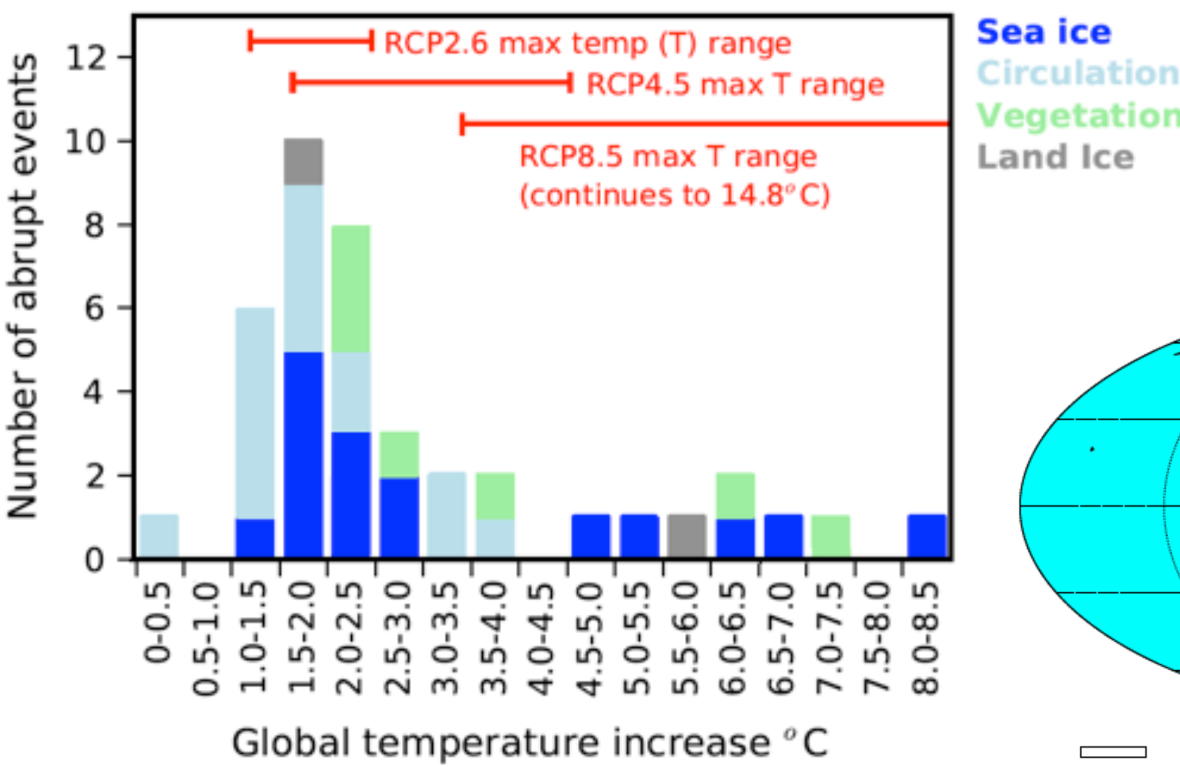


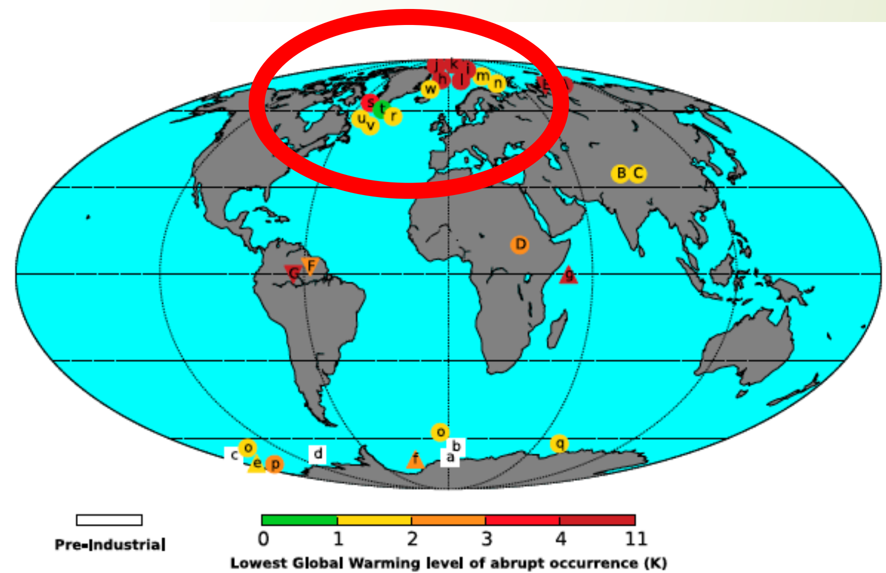
Catalogue of abrupt shifts in Intergovernmental Panel on Climate Change climate models

Sybren Drijfhout[a,b,1], Sebastian Bathiany[c,d], Claudie Beaulieu[b], Victor Brovkin[d], Martin Claussen[d,e], Chris Huntingford[f], Marten Scheffer[c], Giovanni Sgubin[g], and Didier Swingedouw[h]

Are the model showing abrupt changes in the subpolar gyre trustworthy?

39 abrupt events (in 36% of the realizations)

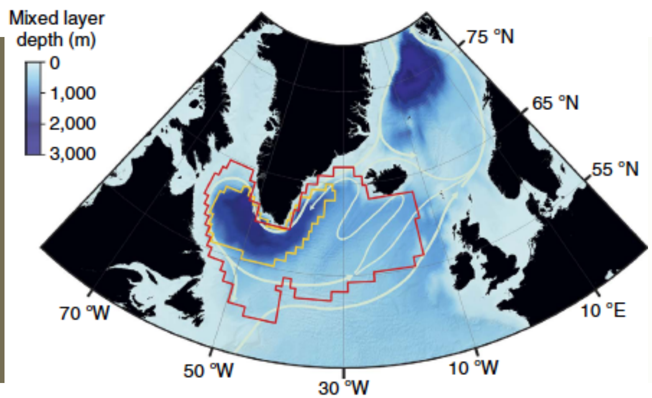


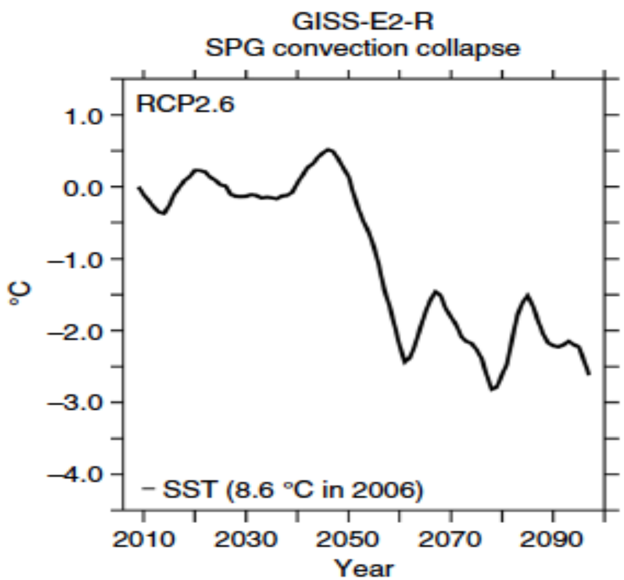


nature COMMUNICATIONS

Abrupt cooling over the North Atlantic in modern climate models

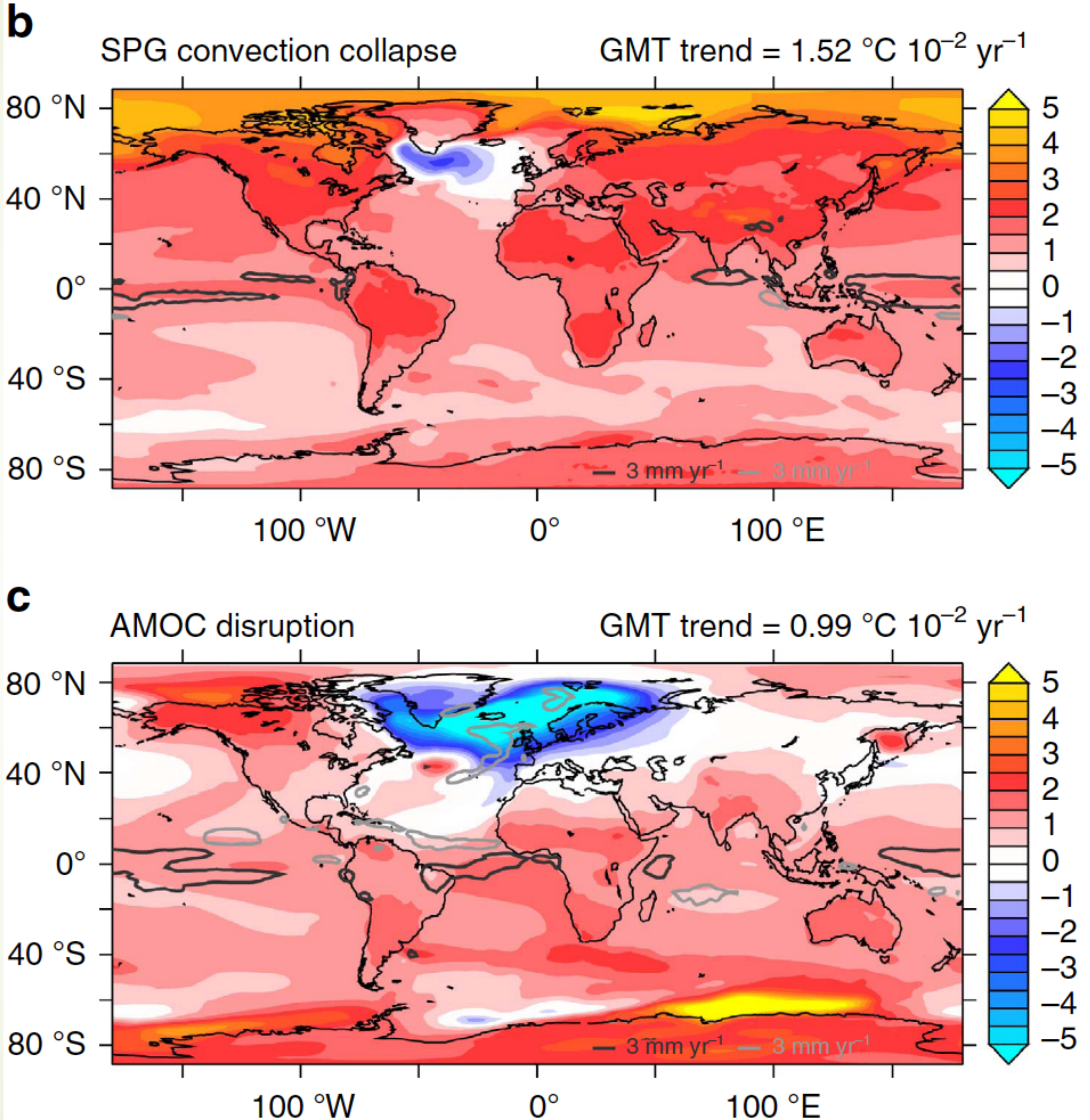
Giovanni Sgubin[1,2], Didier Swingedouw[2], Sybren Drijfhout[3,4], Yannick Mary[2] & Amine Bennabi[5]





Stratification skill score

- Potentially large climatic impact
- **When** can it occurs?

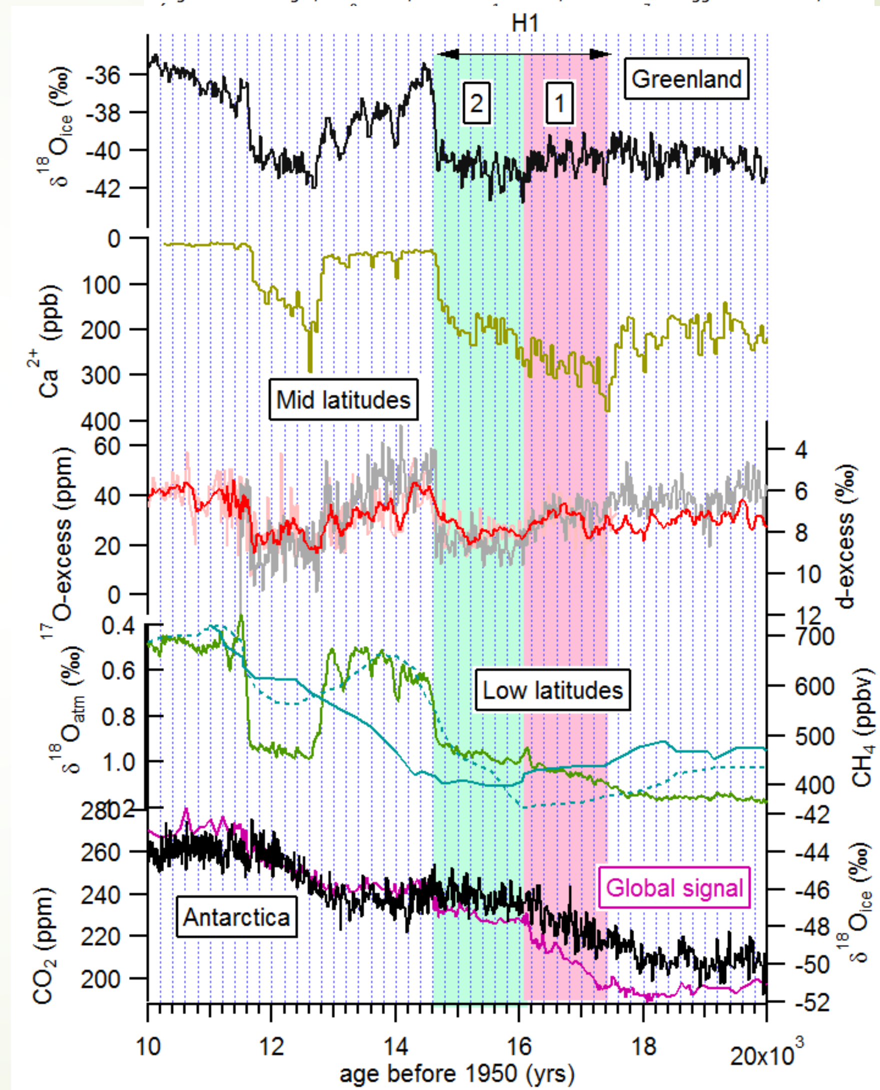


Lessons from the

High-Resolution Greenland Ice Core Data Show Abrupt Climate Change Happens in Few Years

Jørgen Peder Steffensen,[1*] Katrine K. Andersen,[1] Matthias Bigler,[1,2] Henrik B. Clausen,[1] Dorthe Dahl-Jensen,[1] Hubertus Fischer,[2,3] Kumiko Goto-Azuma,[4] Margareta Hansson,[5] Sigfús J. Johnsen,[1] Jean Jouzel,[6] Valérie Masson-Delmotte,[6] Trevor Popp,[7] Sune O. Rasmussen,[1] Regine Röthlisberger,[2,8] Urs Ruth,[3] Bernhard Stauffer,[2] Marie-Louise Siggaard-Andersen,[1]

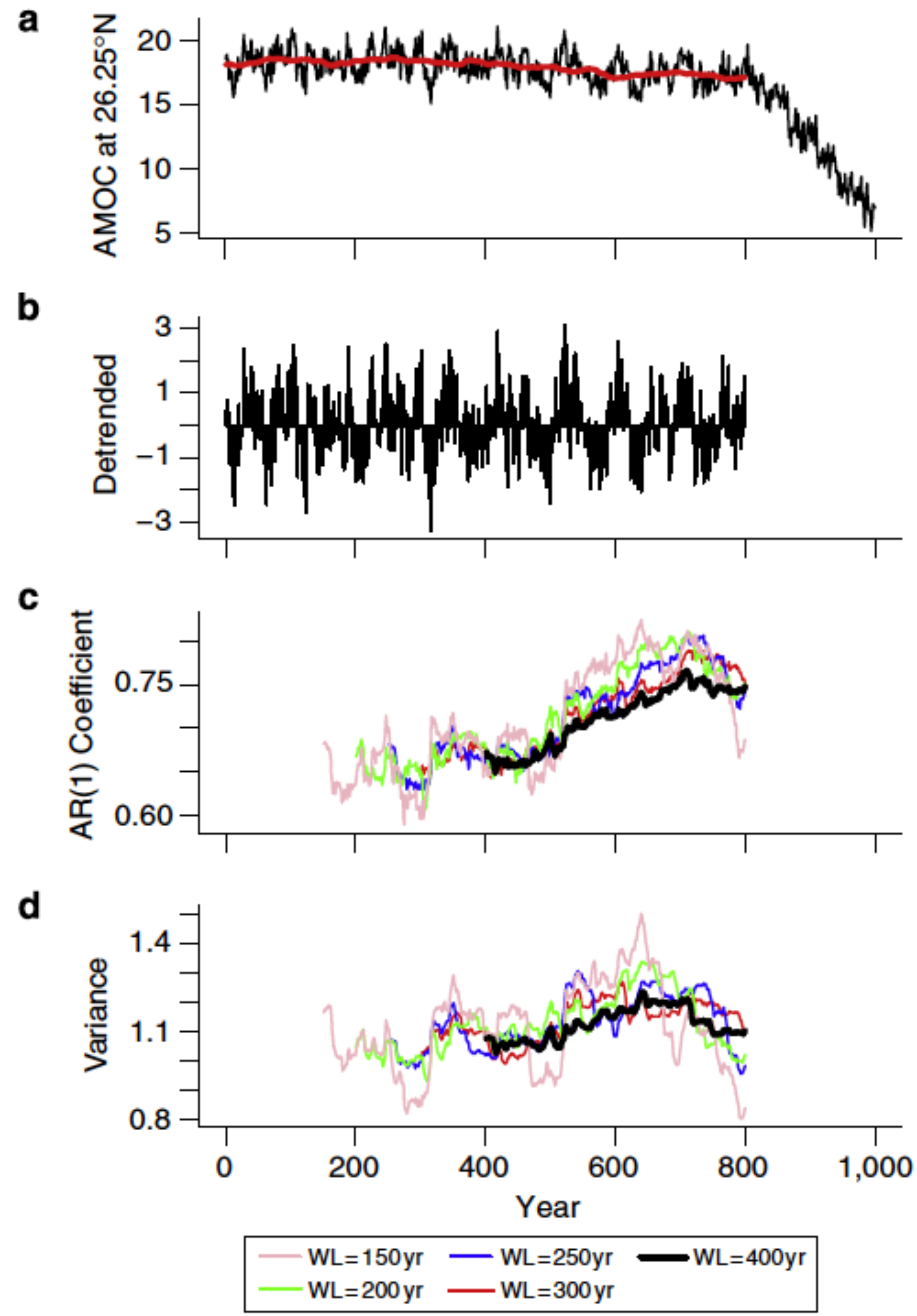
- Abrupt changes of the SPG as a driver of Little ice age (Miller et al. 2012, Moreno-Chamarro et al. 2017)
- High resolution proxies for Dansgaard-Oeschger (DO) timeline (Landais et al. in prep.
- Holocene period to enlarge potential of analysis of abrupt variations
- Emerging constraints from PMIP4 simulations as compared to reconstruction (Green Sahara from 6K, 9K…)



Landais et al. in prep.

Early Warning

- Boulton et al. (2014): Early warning up to 250 years in advance if at least 500 years of AMOC monitoring
- Need for long enough reconstruction of AMOC variations
- What can be found with only 15 years of monitoring?



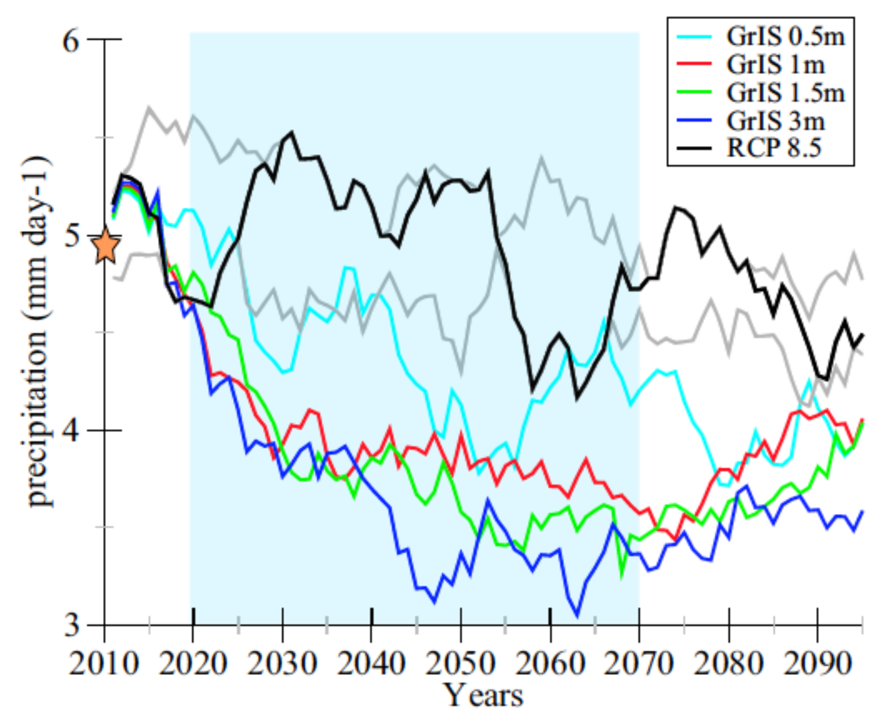
Impact

Consequences of rapid ice sheet melting on the Sahelian population vulnerability

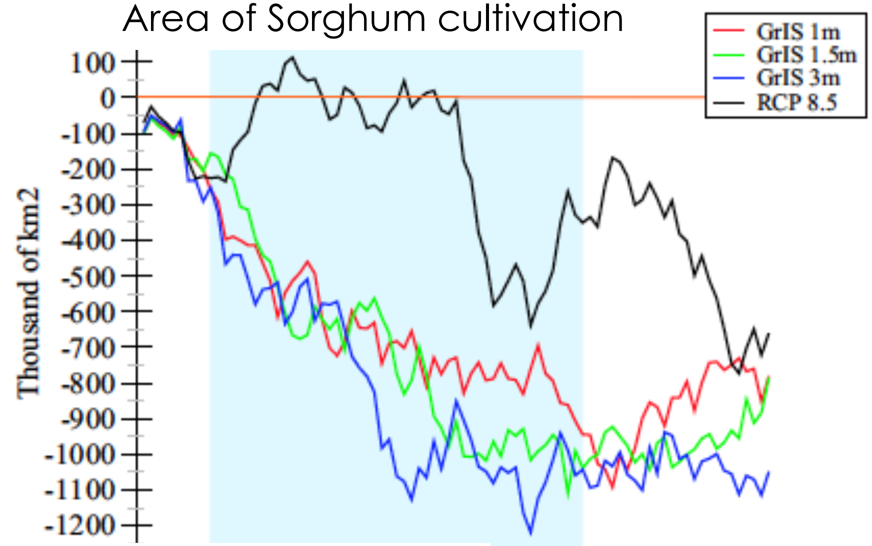
Dimitri Defrance[a,b,1], Gilles Ramstein[a], Sylvie Charbit[a], Mat
Didier Swingedouw[d], Christophe Dumas[a], François Gemen

Adding GrIS freshwater in the North Atlantic…

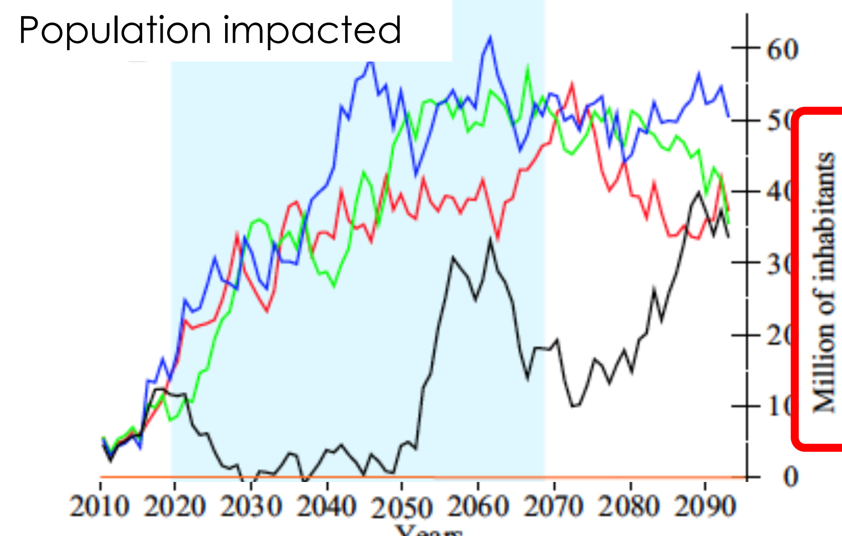
Precipitation changes in Sahel region



Area of Sorghum cultivation



Population impacted

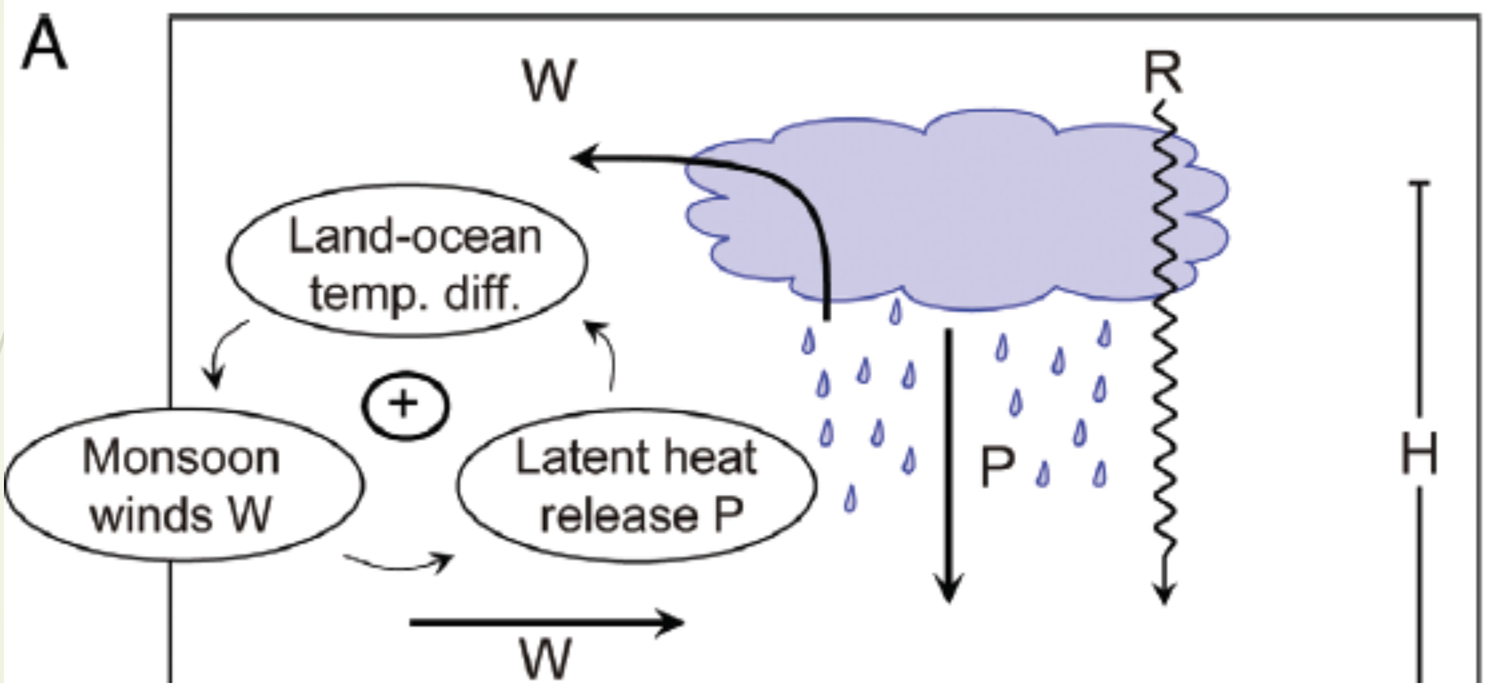


Basic mechanism for abrupt monsoon transitions

Anders Levermann[a,b,1], Jacob Schewe[a,b], Vladimir Petoukhov[a], and Hermann Held[a]

[a]Earth System Analysis, Potsdam Institute for Climate Impact Research, 14473 Potsdam, Germany; and [b]Institute of Physics, Potsdam University, 14473 Potsdam, Germany

Edited by Hans Joachim Schellnhuber, Potsdam Institute for Climate Impact Research, Potsdam, Germany and approved August 18, 2009 (received for review February 11, 2009)



Near-linear response of mean monsoon strength to a broad range of radiative forcings

William R. Boos[a,1] and Trude Storelvmo[a]

[a]Department of Geology and Geophysics, Yale University, New Haven, CT 06520

Edited by Robert E. Dickinson, The University of Texas at Austin, Austin, TX, and approved December 9, 2015 (received for review August 27, 2015)

Special Report on the Ocean and the Cryosphere in a Changing Climate

Chapter 6: Extremes, Abrupt Changes and Managing Risks

- Risks of abrupt change in ocean circulation and cryosphere and potential consequences
- Extreme ENSO events and other modes of variability and their implications
- Marine heat waves and implications
- Changes in tracks, intensity, and frequency of tropical and extra-tropical storms and associated wave height
- Cascading risks (e.g., storm surge and sea level rise), irreversibility, and tipping points
- Monitoring systems for extremes, early warning and forecasting systems in the context of climate change
- Governance and policy options, risk management, including disaster risk reduction and enhancing resilience

What is worth achieving

- Making a clear focus on **process analysis in complex models**, since this is usually missing for tipping elements analysis, with an in depth analysis of physical and biogechemical processes at play (this is a necessary step to « *result in better understanding of abrupt climate change* »
- **North Atlantic** as a key tipping element, but interesting in evaluating **other elements** as well and cross expertise in a project.
- Include monitoring systems and paleo to have **real data in our scientific approach** and not only models => reaching **multiple line of evidences**

Potential key activities/ideas and novelty

- **CMIP6** analysis for abrupt changes
- Abrupt changes in **large ensembles** of simulations
- **Emerging constraints** in **decadal prediction systems and projections, using PMIP4 simulation as well**
- **Early warning signals for *in situ* oceanographic** observations
- AMOC reconstruction (**data assimilation**) over the last millennium
- Lessons from Holocene and DO syntheses
- **Interactions** between tipping point (monsoon, Amazon dieback…)
- Impact of abrupt changes on human and mitigation
- Threshold in the Nordic Seas, critical stratification in the SPG