Early warning indicators and the risk for cascades of TPs in the climate and ecosystem

Event: TipESM Kick-off Meeting (Copenhagen/Online)
Speaker: : Didier Swingedouw (CNRS-EPOC), Bo Christiansen (DMI), Robin Smith (UREAD), Torben Koenigk (SMHI)
Date: 23 January 2024

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Early warnings of tipping point

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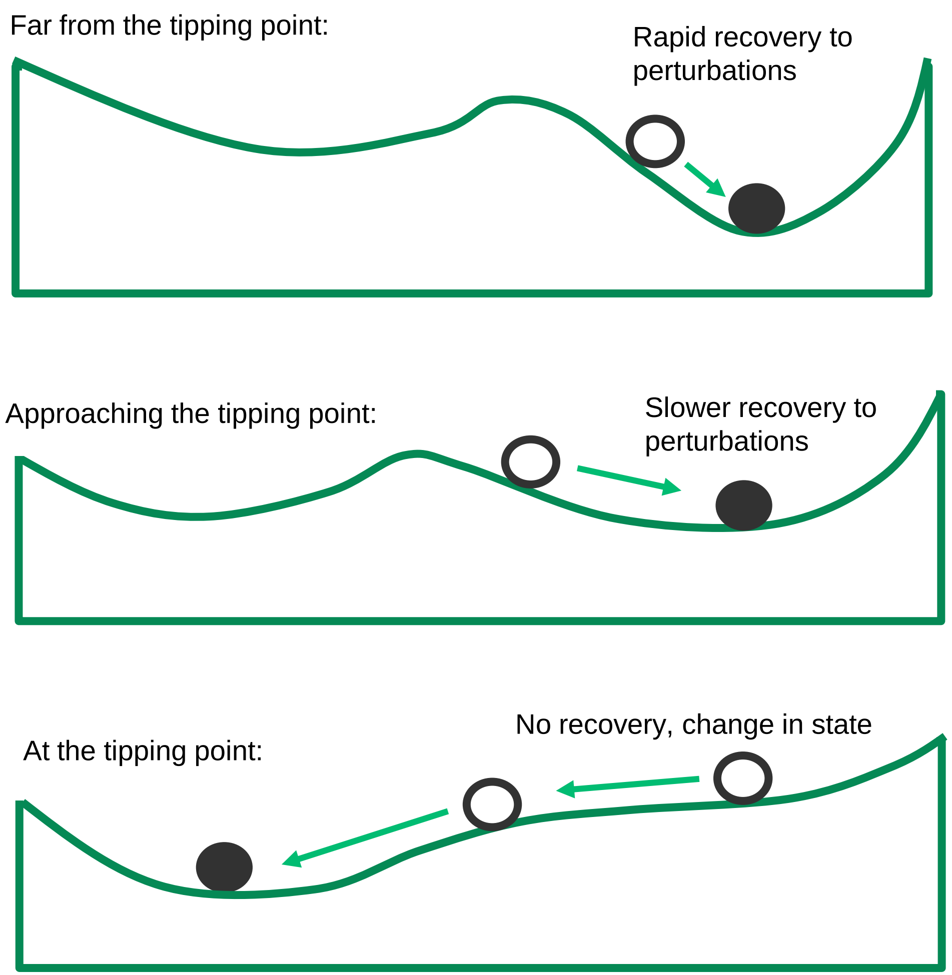
Change of temporal variability
when approaching a tipping point



- ❖ Theory from dynamical system teaches us that approaching a tipping point, the system variability tends to increase
- ❖ Change in **variance** or **autocorrelation** can be used to quantify such changes (also related to resilience loss)
- ❖ But **real system is far more complex** than theoretical models from dynamical system theory

⇒ use of **comprehensive ESM** to test them:

- ❖ Are those indicators "working" in models?
- ❖ How long the time series need to be?

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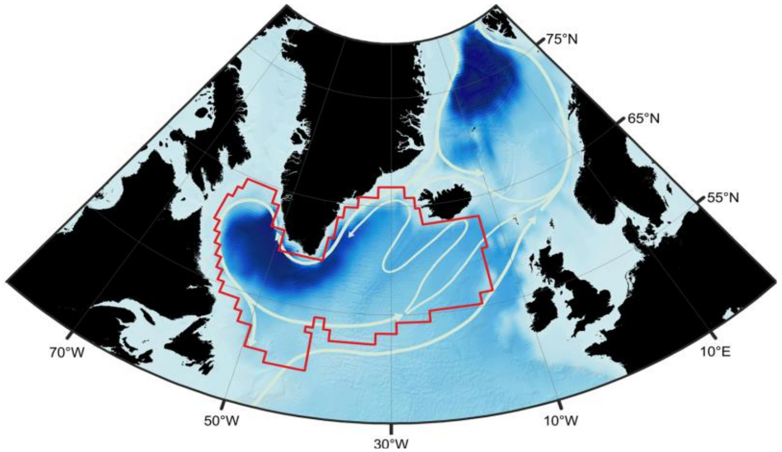
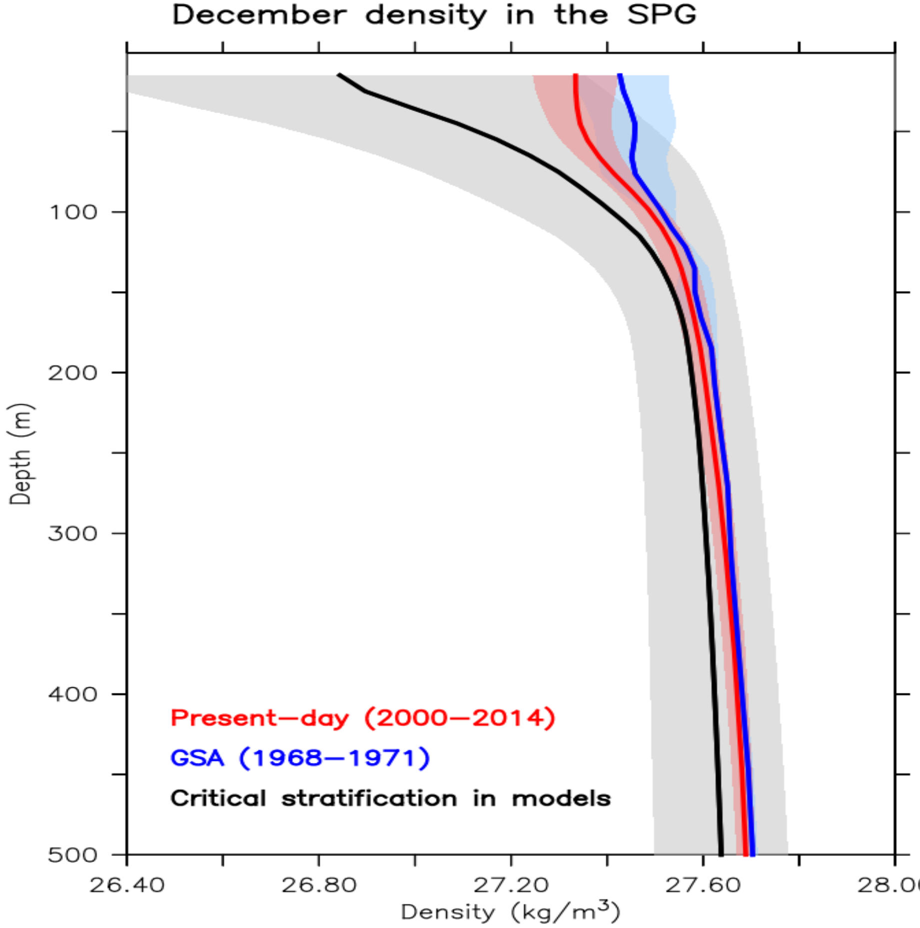
Adapted from: Lenton (2011)

Going beyond statistical EWI

- Using comprehensive climate models to test statistical indicators e.g. Boulton et al. (2014): we need **at least 250 years** to apply them to the AMOC, while Bowers (2021) uses **only the last 150 years**
- Using paleodata can solve this type of issues (Michel et al. 2021)
- Alternatively, we can also use space for time, taking advantage of e.g. HR remote sensing (e.g. Lenton et al. 2024)
- Nevertheless, what is missing in this type of indicators is a precise physical understanding related to the real complex system
- **Paragim shift**: **physical/process** understanding, definition of physical **threshold** in the precursors

⇒ example of stratification in the subpolar gyre





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WP4: Early warning indicators for TPs in the Earth system

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Objectives:

- Develop early warning indicators (EWI) for climate TPs identified in WP2-3.
- Test the robustness, associated time scale before the TPs and risk for false positives using ESMs and paleo-data.
- Apply the robust EWIs to observations to get reliable predictions for TPs.

Tasks:

- Task 4.1: Finding EWI and precursors
- D4.1: Register of EWIs for 4 climate/ecological TPs and guidance EPOC for future observation networks (*CNRS-EPOC*, M30)
- Task 4.2: Robustness and reliability of EWIs
- D4.2: Report on precursors, EWIs, their 4 robustness for specific TPs and their predictability (DMI, M42)

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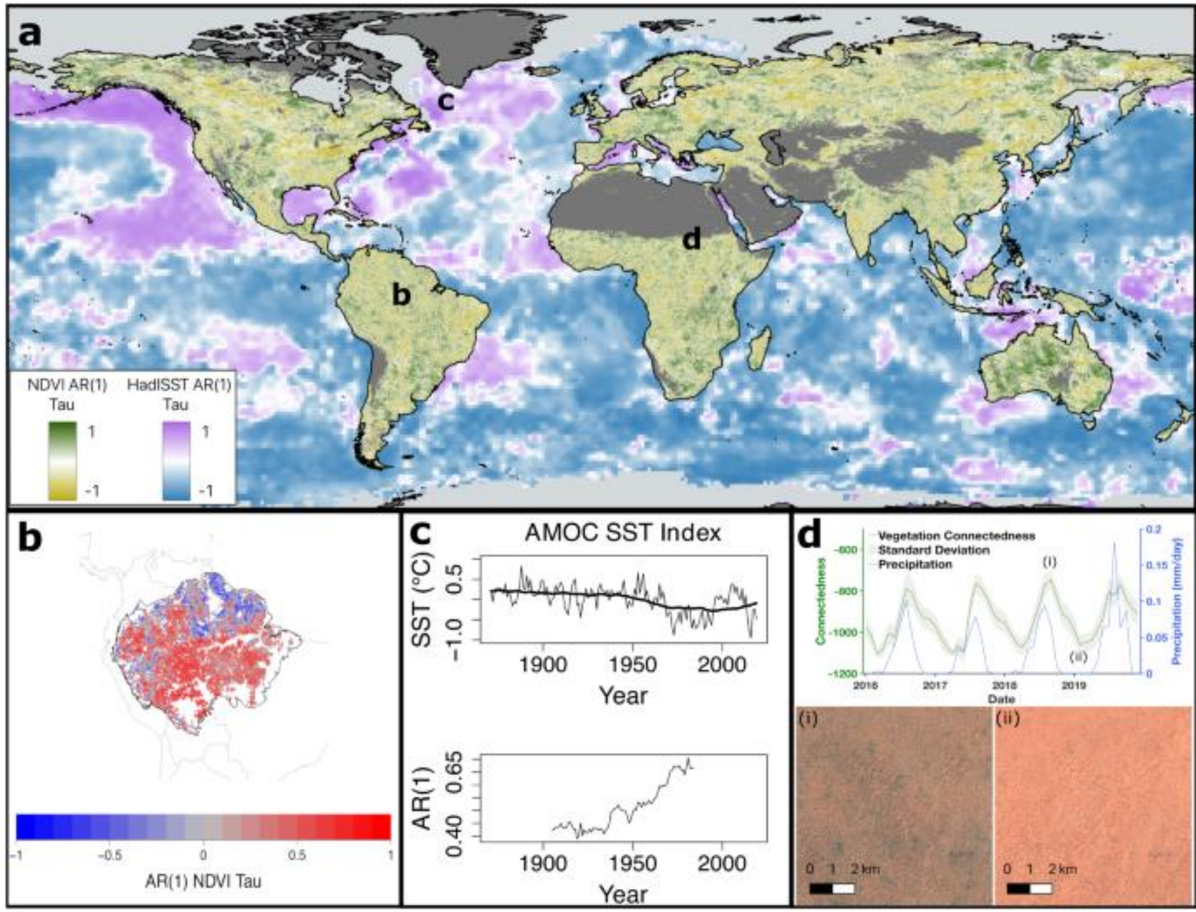
Task 4.1: Finding EWI and precursors

Lead: Didier Swingedouw

- Compile a set of classical EWIs derived from existing literature
- Application of them to precursors identified of relevant system from WP2 and 3 in models to check whether this EWI works well (perfect model approach)
- Develop new EWI
  - using time-dependent coefficients (tdARMA)
  - space for time using Earth Observation and models (e.g.: is there a specific, sea surface temperature, salinity or height before an SPG collapse?)



Lenton et al. *Nature Com.*, 2024

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Task 4.2 Robustness and reliability of EWIs

Lead: Bo Christiansen

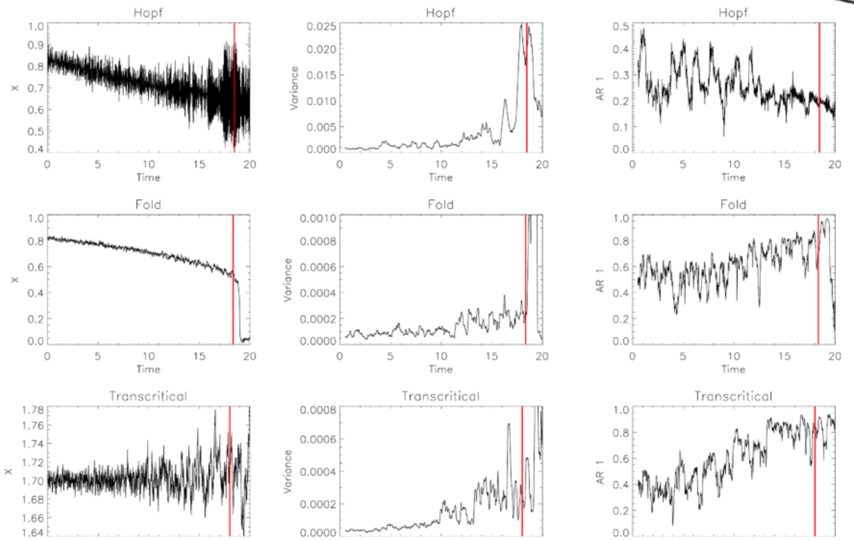
- Do different EWIs agree on predictions of TPs?
- Risk of false alarms: When an EWI show a significant change, how often will this actually be followed by a TP?
- How well can EWI distinguish between low-frequency variability and TPs?
- How far in advance can TPs be predicted?

We will test different classical EWIs and new ones developed in Task 4.1.

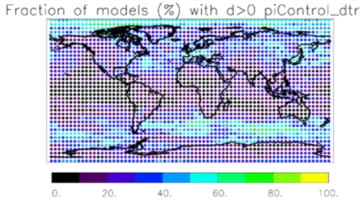
We will use both simple systems and ESM experiments where the truth is known.

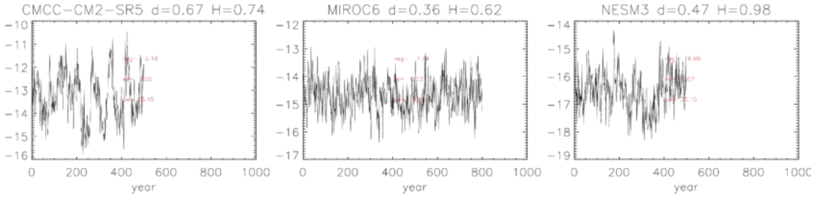
- Combine methods to provide new more reliable composite EWIs for specific TPs.
- Apply the most robust and well-tested EWIs to available observation (AMOC ..).

Repeating Bury et al. 2021



ESMs have complicated dynamics





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WP5: Risk for TPs cascades in the Earth system and the role of extremes for TPs

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WP leaders: T. Koenigk (SMHI), R. Smith (UREAD)

Objectives

- Improve the understanding of potential remote interactions in time and space between Earth system TPs.
- Understand the risk that rare extreme events can trigger Earth system TPs under different levels of global warming.

Task 5.1 Interactions between TPs (M13-48)

- **D5.1** Report on the potential interactions between TPs and the likelihood for occurrence of TP cascades (M40, UREAD)

Task 5.2 Extremes as trigger for TPs (M13-48)

- Report on the role of rare extremes for triggering TPs (M44, SMHI)

Methods: OptimESM and TipESM runs at different GWL and forced tipping experiments

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Cascades of tipping points

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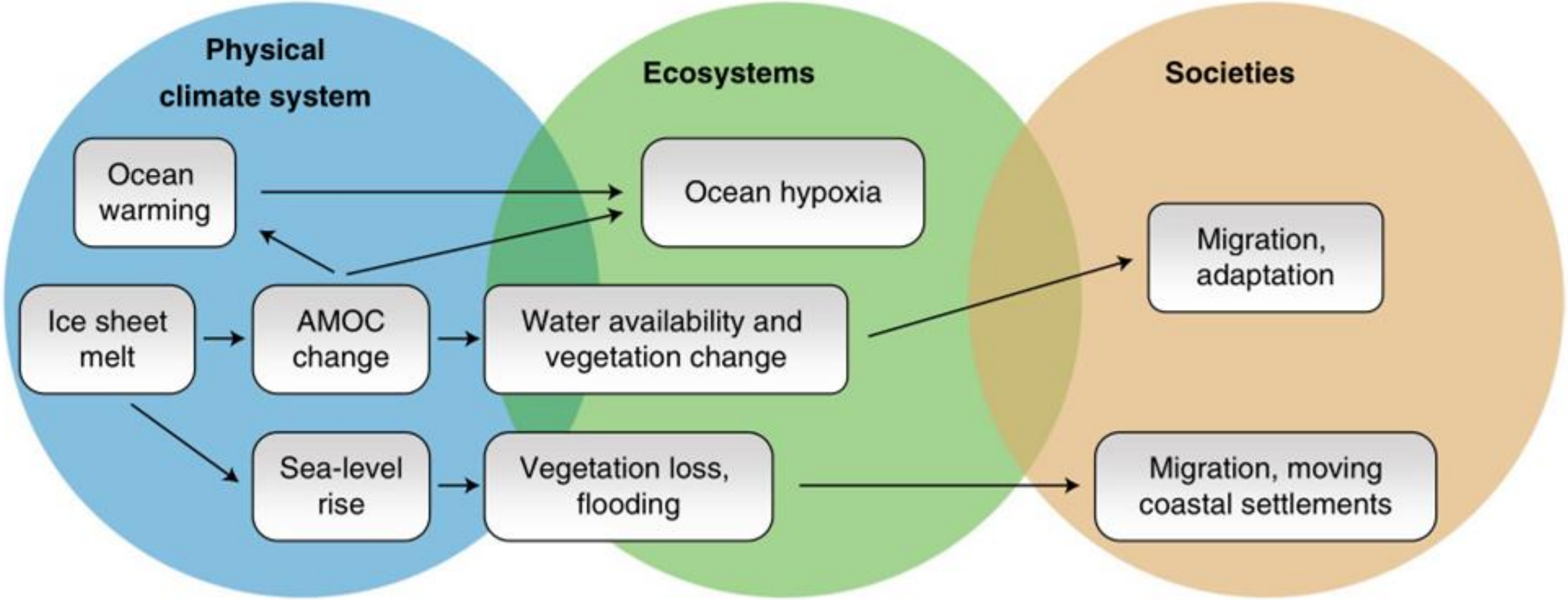
Proxies from past periods show that abrupt changes cascaded through the whole Earth system, e.g. in the deglaciation 14.7-12.8 ka,



Brovkin et al. 2021, Fig. 1a

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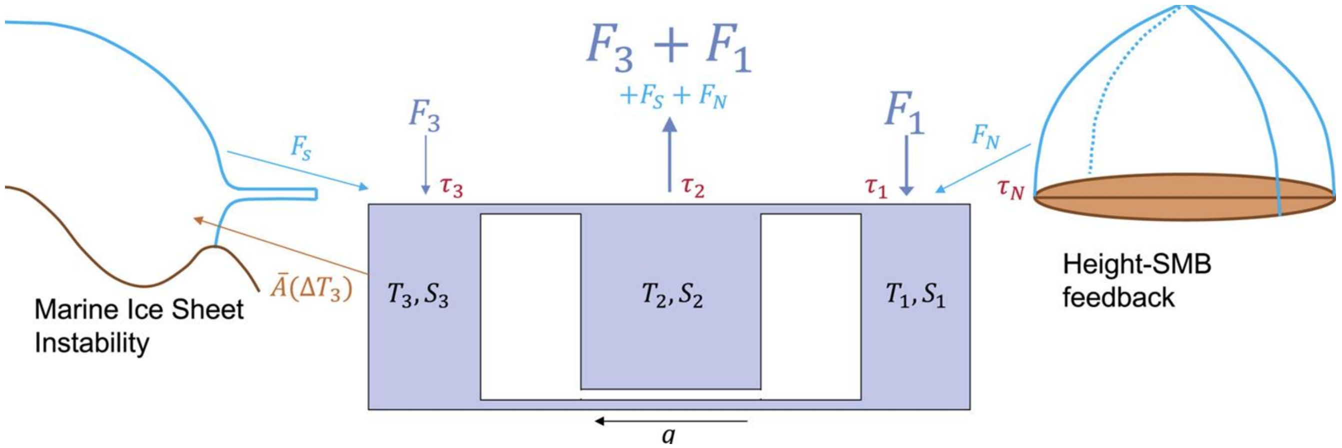
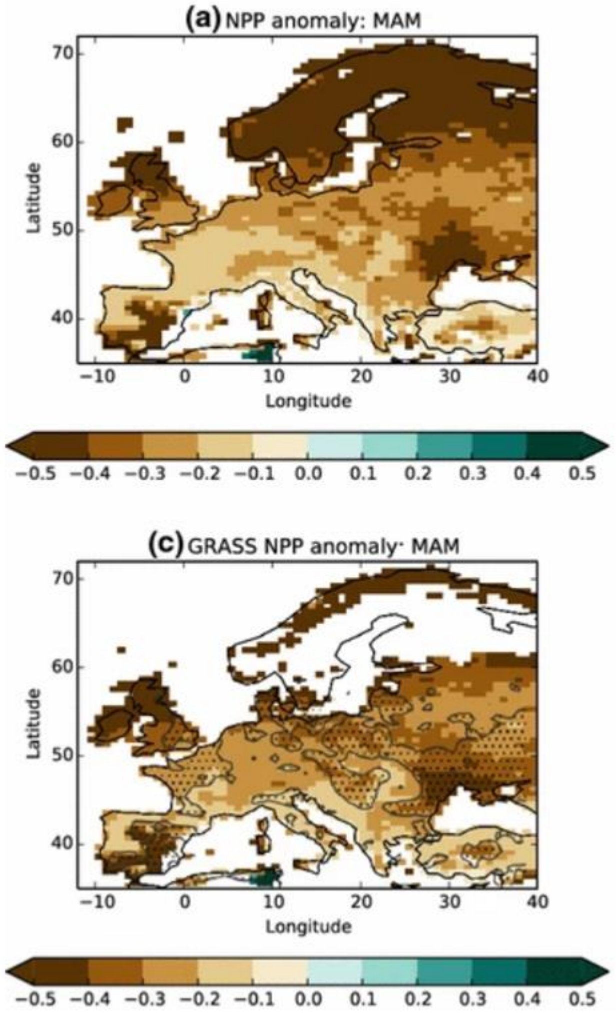
Cascades of tipping points



Sinet et al. 2023, Fig. 1

Often only modelled with conceptual or highly simplified tools



Jackson et al. 2015, Fig. 13

Additional process complexity also need to link up to societal impact

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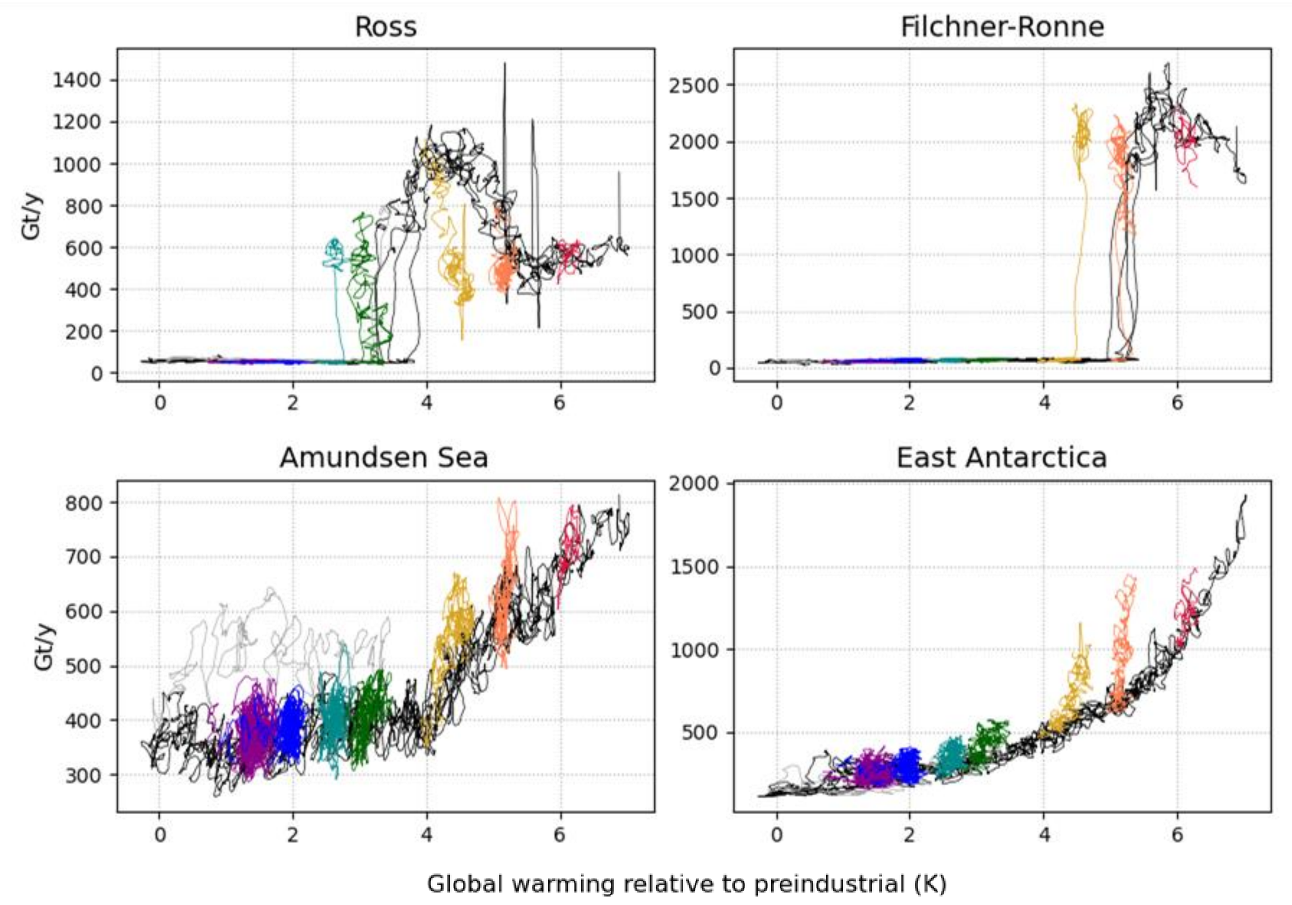
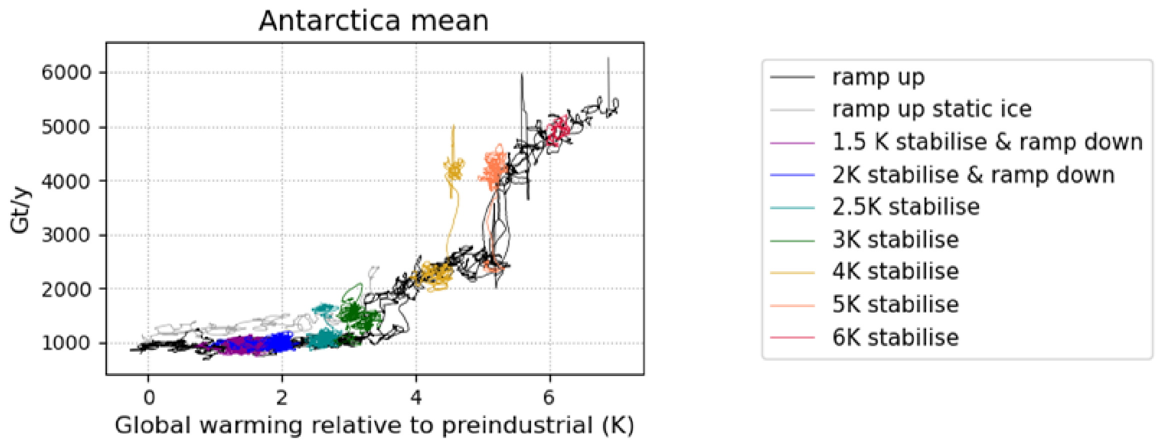
Cascades of tipping points





Early results from UKESM *TIPESM_core* show threshold behaviour for ocean under WAIS shelves – does this change AIS dynamical regime?

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Can extremes cause tipping?

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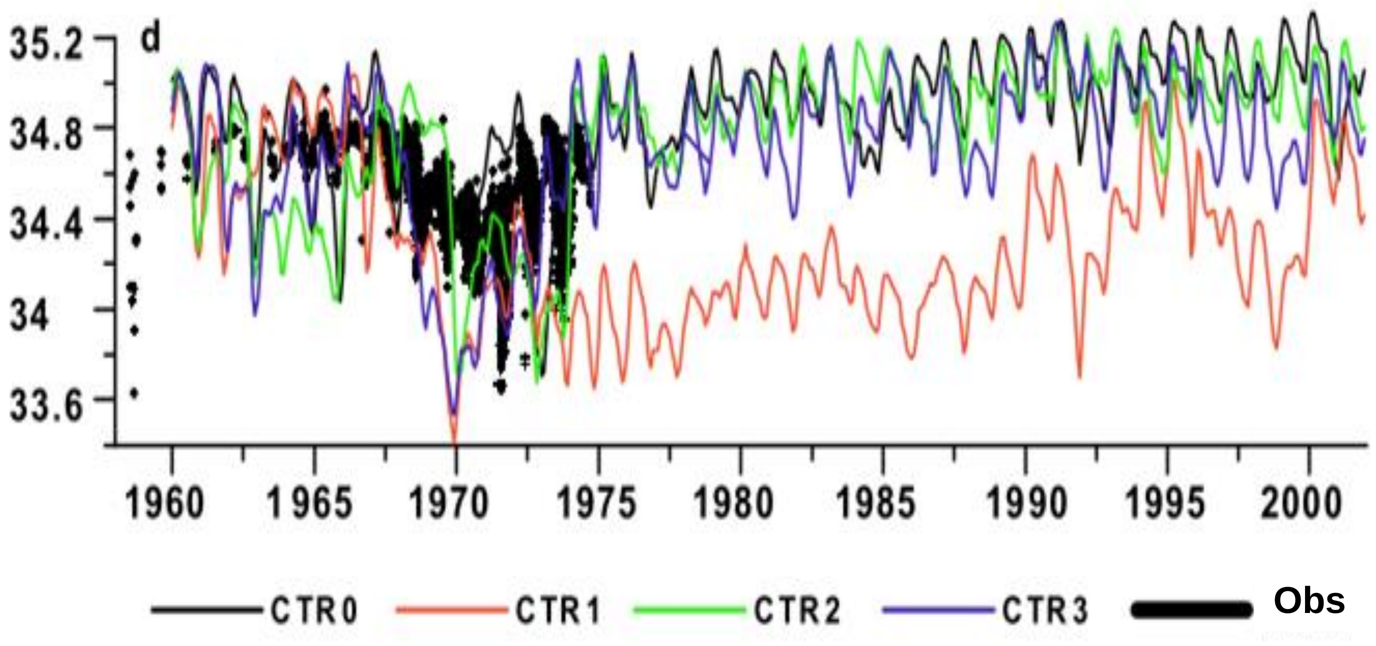
Great salinity anomaly in the Labrador Sea



After extreme Fram Strait sea ice export in 1966/67, Labrador Sea convection is shut down for several decades in 1 out of the 4 ensemble members.

Surface salinity in the Labrador Sea in 4 ensemble members of a coupled regional ocean-atmosphere model (Mikolajewicz et al. 2005)

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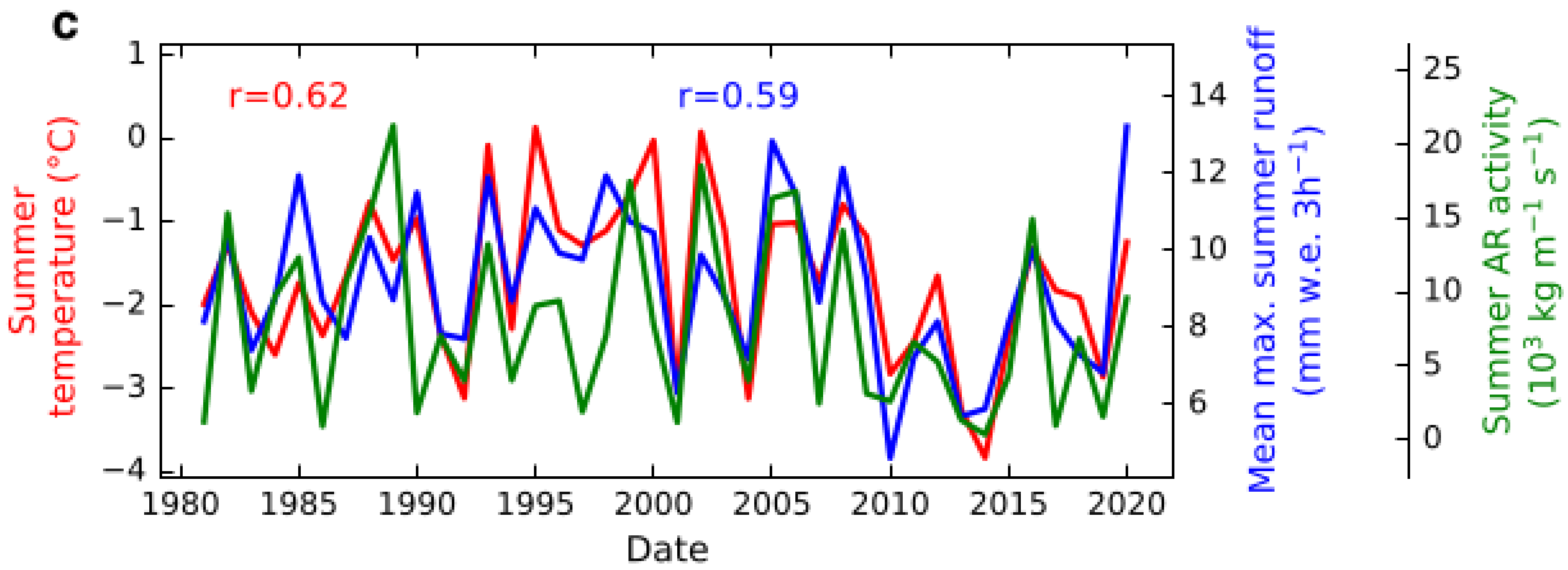
Can extremes cause to tipping?



Wille et al. 2022, Fig.6c

Atmospheric rivers (ARs), summer temperature and runoff at the Antarctic Peninsula.

Strong ARs were precursors for more than 60% of the major calving events of the Larsen A and Larsen B ice shelves since 2000 and precluded their main collapses.

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Thank you!

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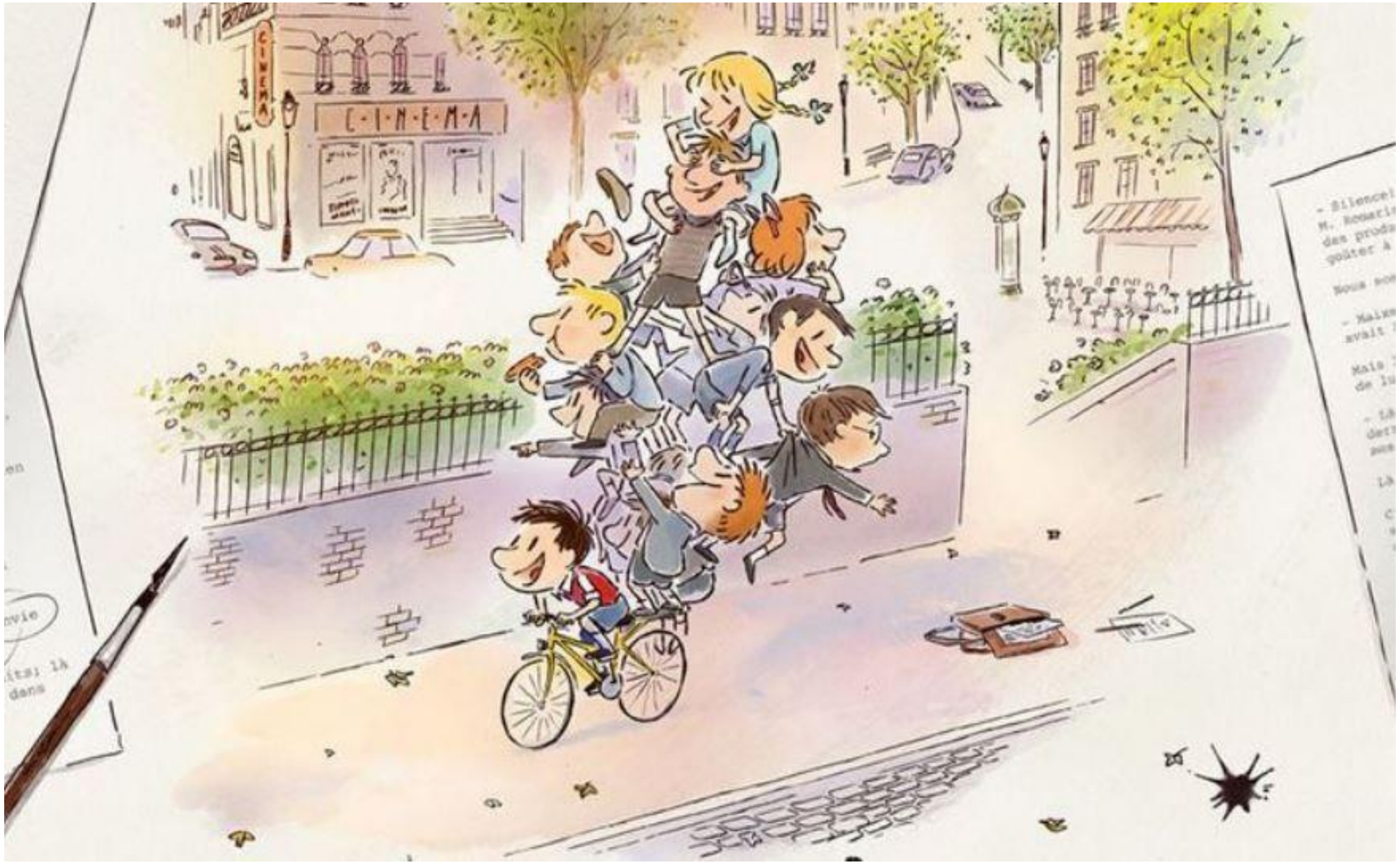

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