Discussion:

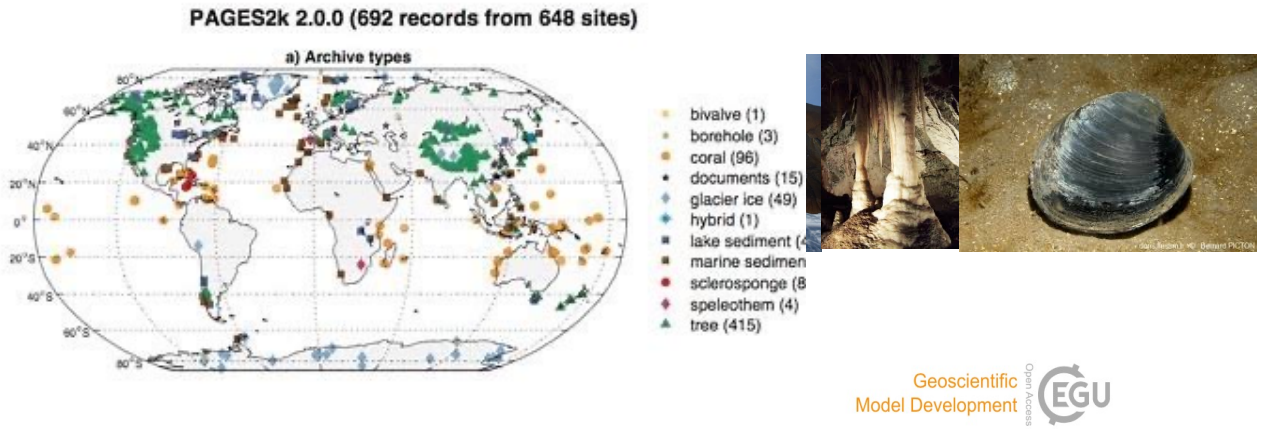
remote sensing for model-based prediction

(e.g. decadal forecasting):

identifying opportunities/gaps

animated by Didier Swingedouw

Proximity to an AMOC tipping point? The use of Early warning signal



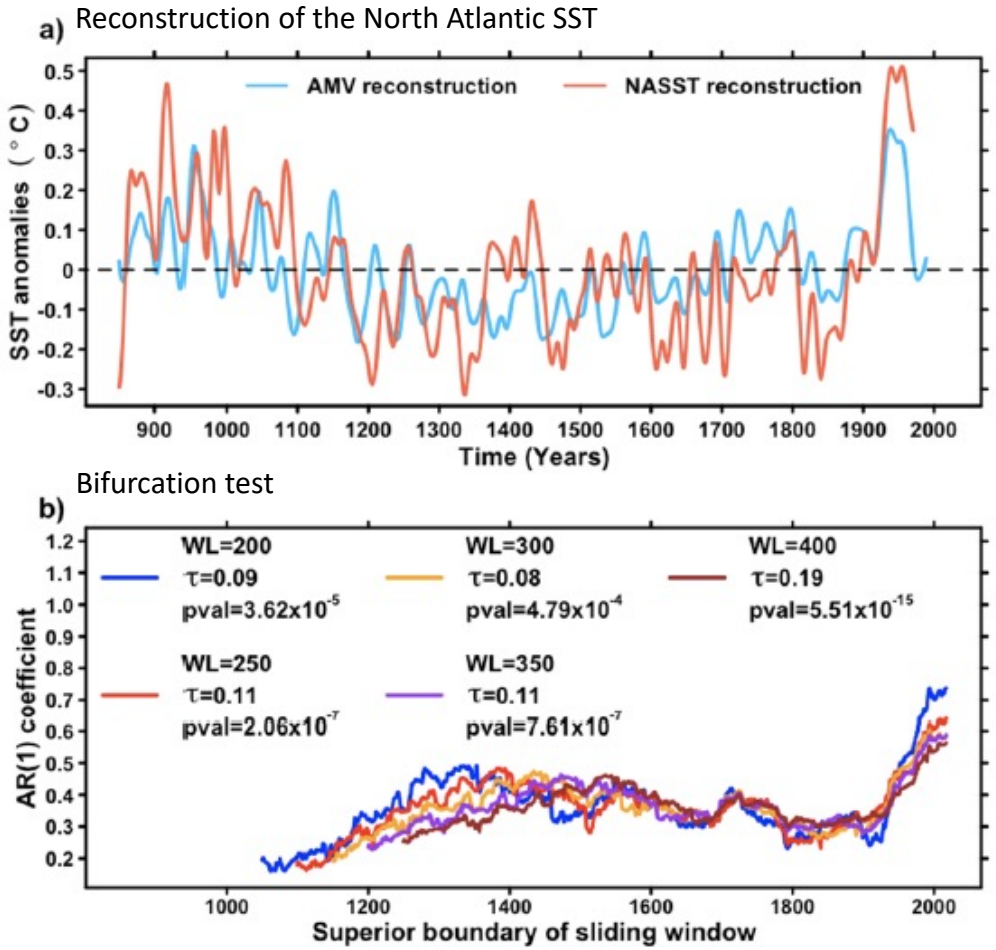
Geoscientific Model Development
Open Access
EGU

Reconstructing climatic modes of variability from proxy records using ClimIndRec version 1.0

Simon Michel[1], Didier Swingedouw[1], Marie Chavent[2], Pablo Ortega[3], Juliette Mignot[4], and Myriam Khodri[4]

When will it occur?
Is it compatible with our latest knowledge of AMOC dynamics and response to GHG?

North Atlantic SST reconstruction as a proxy of AMOC internal variability



Michel et al., Nat. Com. 2022

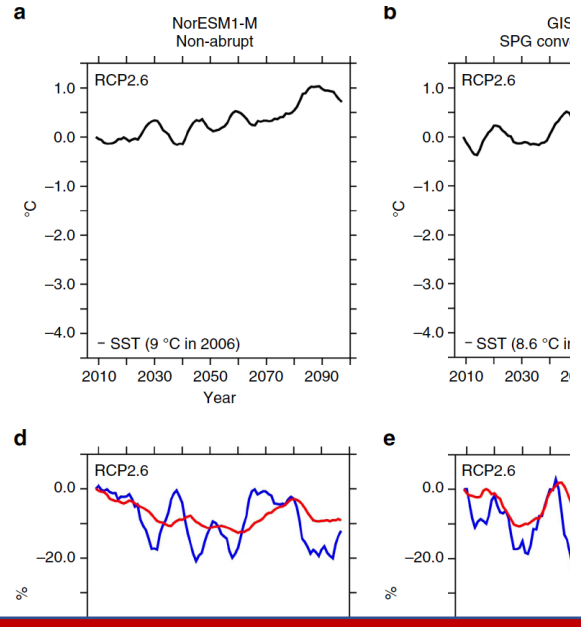
Possibility of Abrupt Changes in the North Atlantic in models

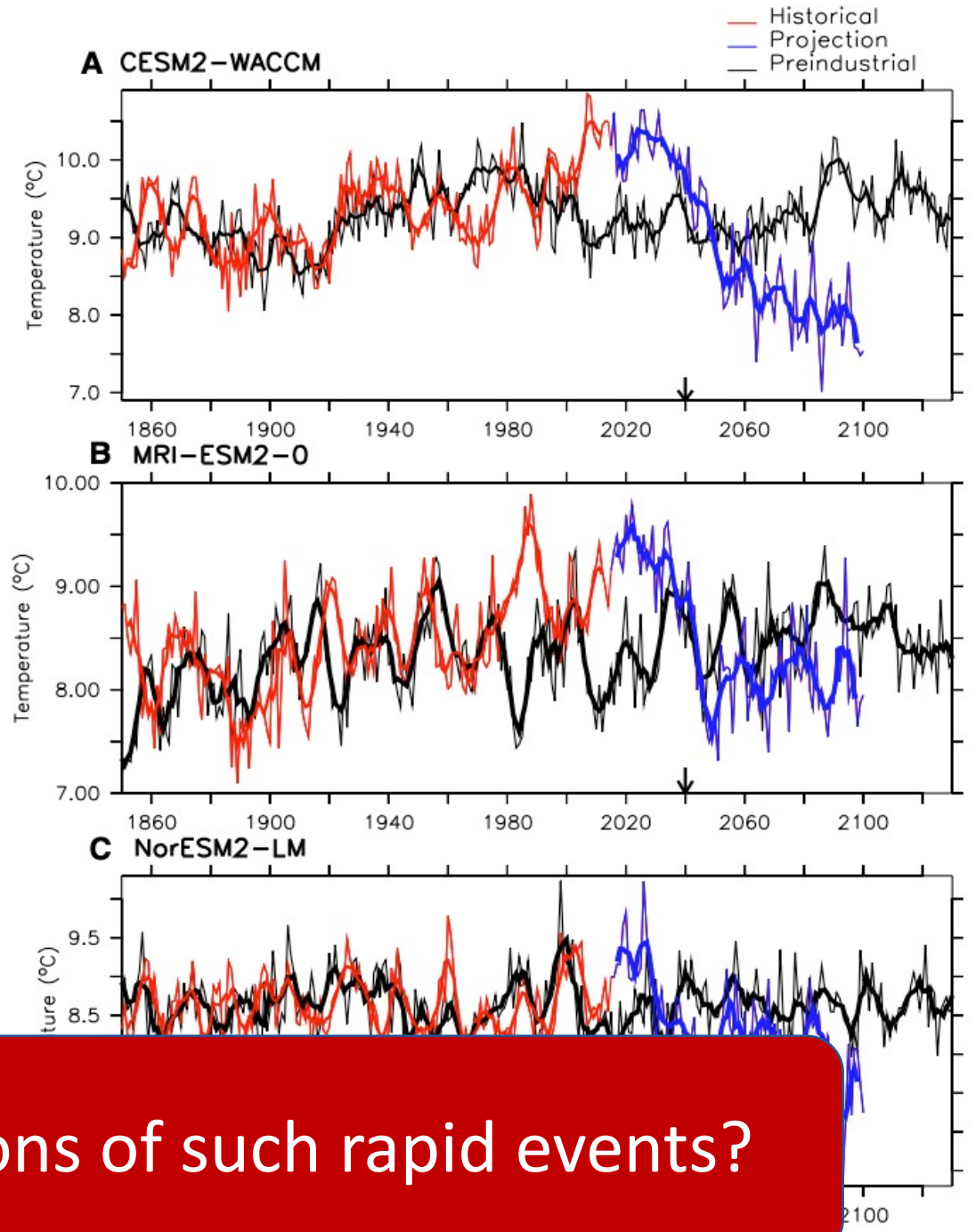
- Some CMIP models do show abrupt (<10 years) cooling in the subpolar gyre (SPG)

- Two different processes
  - Disruption of the AMOC (strong decrease of convection both in the Labrador and Nordic Seas)
  - Collapse of convection in the Labrador Sea : can occur in only one decade => **the SPG as a new tipping element**

- This was true in CMIP5 (Sgubin et al. 2017) and is still the case in CMIP6 for SPG collapse

Changes in the subpolar gyre



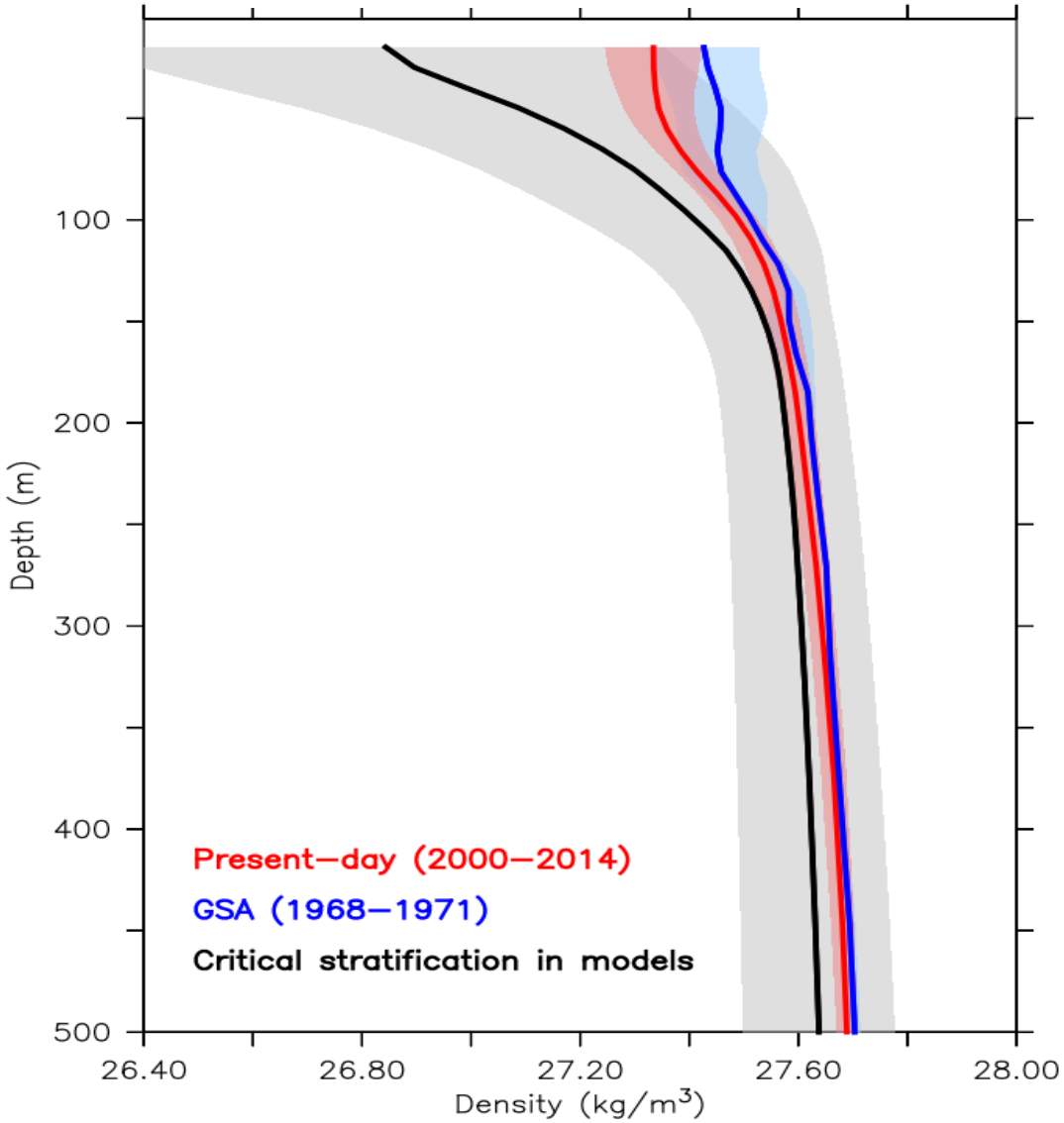


How to have early warnings/predictions of such rapid events?

Proximity to a SPG tipping point?

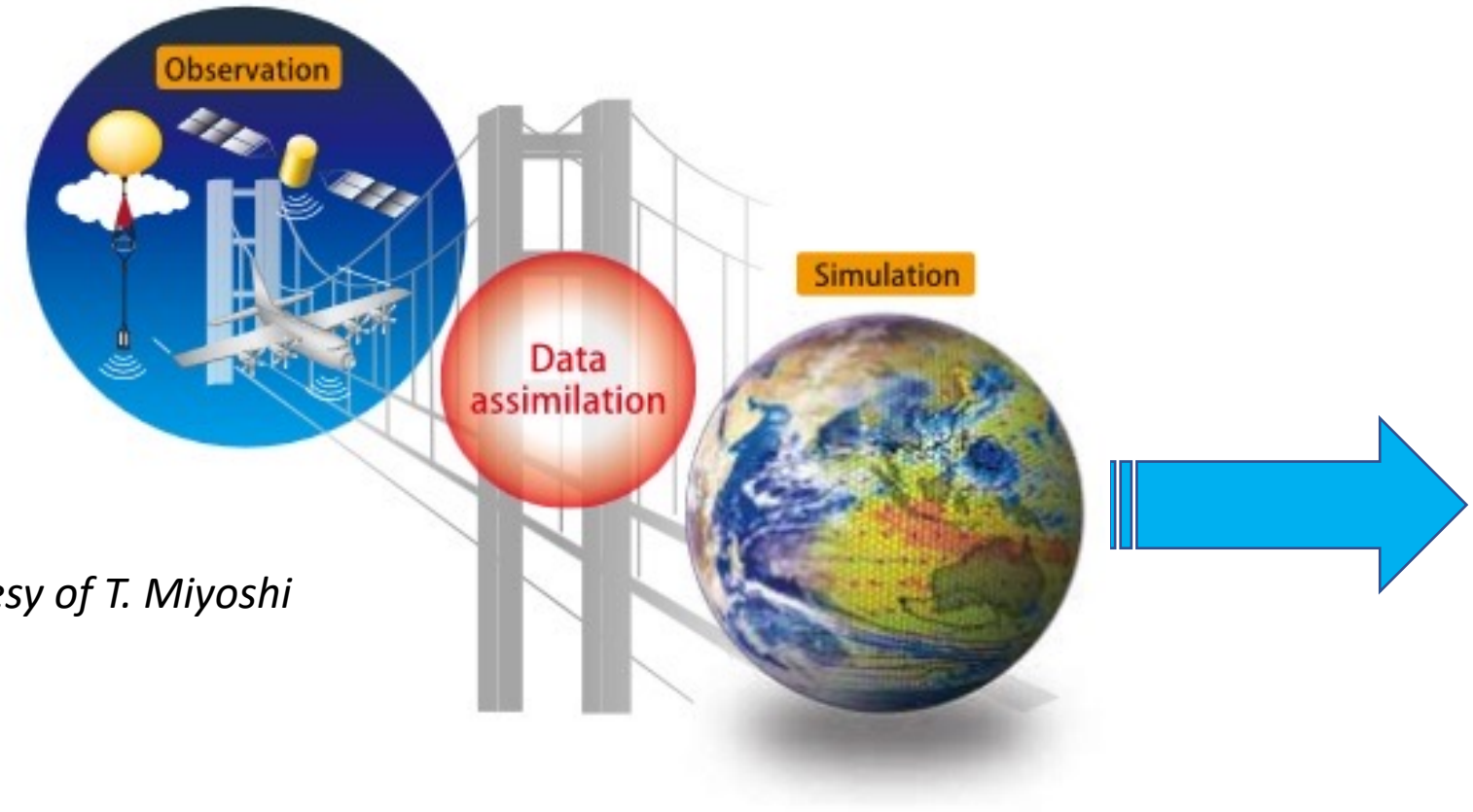
- To analyse the proximity to tipping points, models can be useful as well, on top classical early warning statistical approach.
- For instance, since SPG stratification is a crucial element of ocean convection, it is interesting to define a **critical stratification** just before the large drop in SST
- When estimated in CMIP5 models, present-day observations are in the envelop (66%) of the models just before theit abrupt cooling…
- EO of SSS and SST might be key to estimate this (if the density at depth remains relatively constant)

Stratification in the SPG



Swingedouw et al., *Surv. Geoph.*, 2020

Bringing EO and models together



Courtesy of T. Miyoshi

Data assimilation **corrects the initial condition (position, shape, strength …)** in order to provide more accurate predictions

Decadal predictions to gain insights on early warnings of abrupt changes

Data assimilation

Initial conditions

External forcing

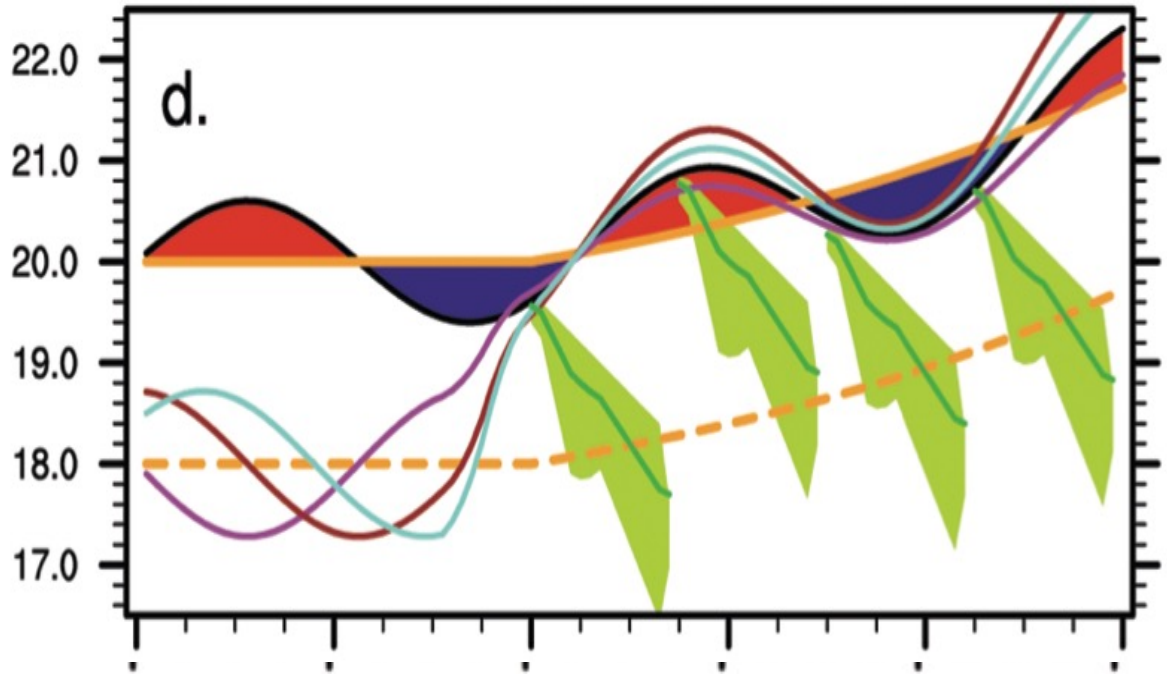
Weather forecast | **Seasonal prediction** | **Decadal prediction** | **Centennial projections** | **Glacial cycles**

day | week | month | year | decade | century | millennium

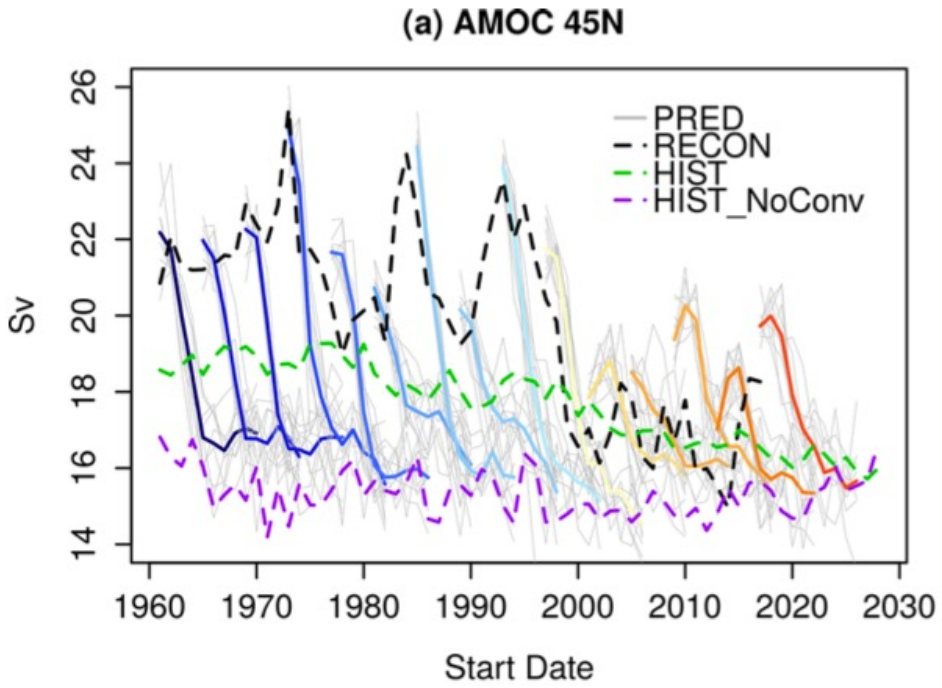
Time scale

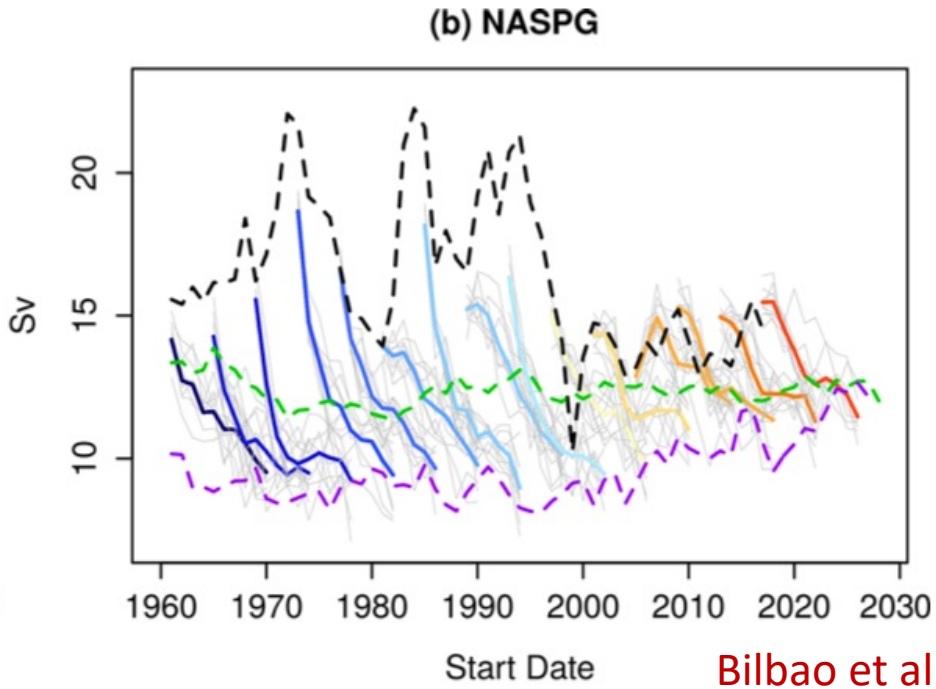
Limitations

- Biases in the mean state => drift in the hindcasts!
- Need of very high resolution (2-3 km) to solve key processes like the spread of Greenland melting by eddies in the Labrador Sea (Swingedouw et al. 2022)



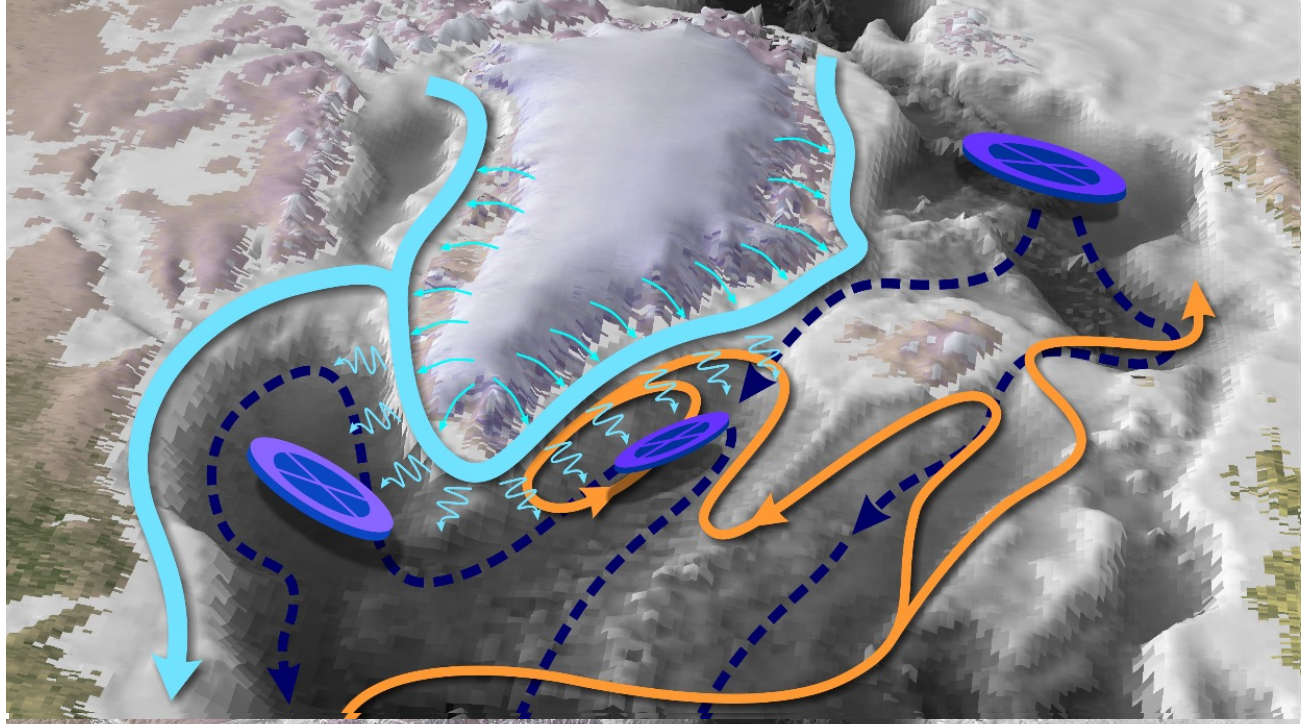
Cassou & Mignot. 2013





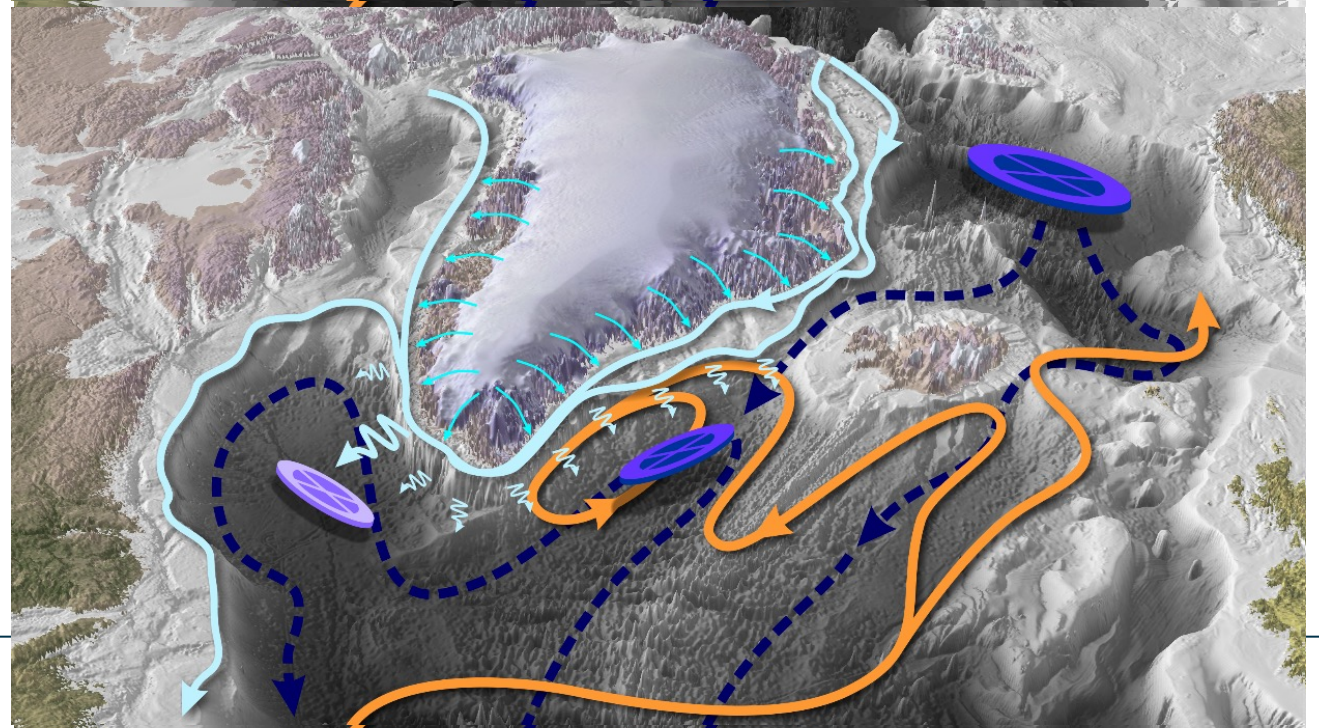
Bilbao et al. 2021

Low Resolution



Swingedouw et al.,
Frontiers in Cilmate,
2022

High Resolution



A crucial role for ocean fine-scale processes and Greenland melting?

Figures from Vincent Hanquiez

Potential avenues

- **Towards higher resolution models?**
  - Might not solve all biases issues
  - We might need to go beyond 1 km resolution to solve crucial processes

- **Shifting observations towards models' mean state**:
  - Use of mathematical "projections" to move the real observed dynamics towards the simulation one.
  - First try from Polkova et al. (2019) using simple EOF analysis is promising
  - More development can be thought (use of more advanced "projection tools" from machine learning for instance)
  - Towards Data Mearning approaches (mixing DA and ML)

How to combine numerical models and EO?

- Numerical models bring process-based understanding!
- But limitations in their capabilities might necessitate to account for alternative approaches as well
- Lessons from ENSO prediction : both numerical and statistical models can work hand in hand
- Statistical approach of EWS: The potential of “space for time approach”=> use ”perfect model” approach to validate its potential (+ link TipMIP)
- Developping model using artificial intelligence based on EO observation! A difficult but promising new field of research

What else can we do to bring numerical models and EO observations together towards improved EWS systems?

Thank you!

Necessity of Earth Observations

- To bring Earth System Models close to the real ocean circulation state, data assimilation of **Earth Observations** in **coupled ocean-atmosphere** models is necessary (using e.g. new Machine Learning techniques to allow this)
- Altimetry gives access to barotropic ocean circulation (e.g. SPG, Koul et al. 2020)
- SMOS/Aquarius gives access to surface salinity, a key variable for critical stratification threshold (Reul et al. 2020)
- Even GRACE can provide information on deep ocean pressure, a key element of the AMOC (Landerer et al. 2015)