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TAKING THE PULSE OF OUR PLANET FROM SPACE

EUMETSAT ECMWF EUSPA

Ocean circulation tipping elements

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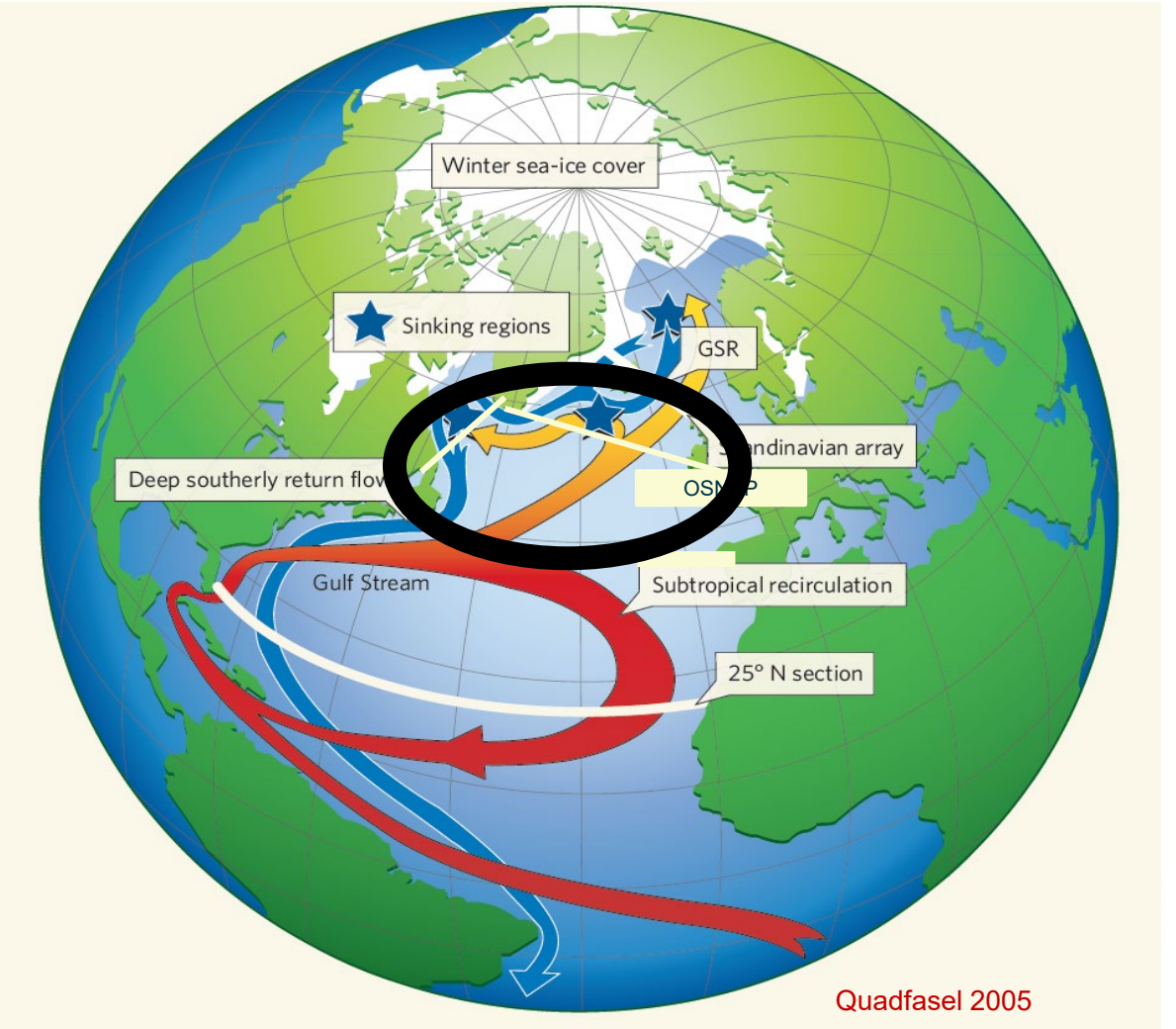
Tipping elements – Agora session, 25th of May 2022

Ocean circulation tipping elements

- There is an observed cooling and freshening of the subpolar gyre (SPG) over the last century (IPCC SROCC 2019)
- This could be a fingerprint of an on-going weakening of the Atlantic Meridional Overturning Circulation (AMOC, by about 15% Caesar et al. 2018)
- Lessons from the past both in glacial and interglacial periods and climate models highlight that abrupt changes/tipping points are possible
- Such rapid changes can be due to a **collapse** of the AMOC (**century**), or just of the SPG subsystem (**decade**)



Quadfasel 2005

Impacts of a substantial weakening in the AMOC

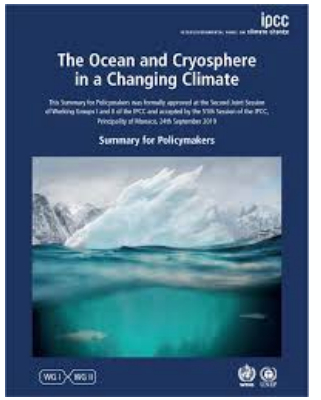
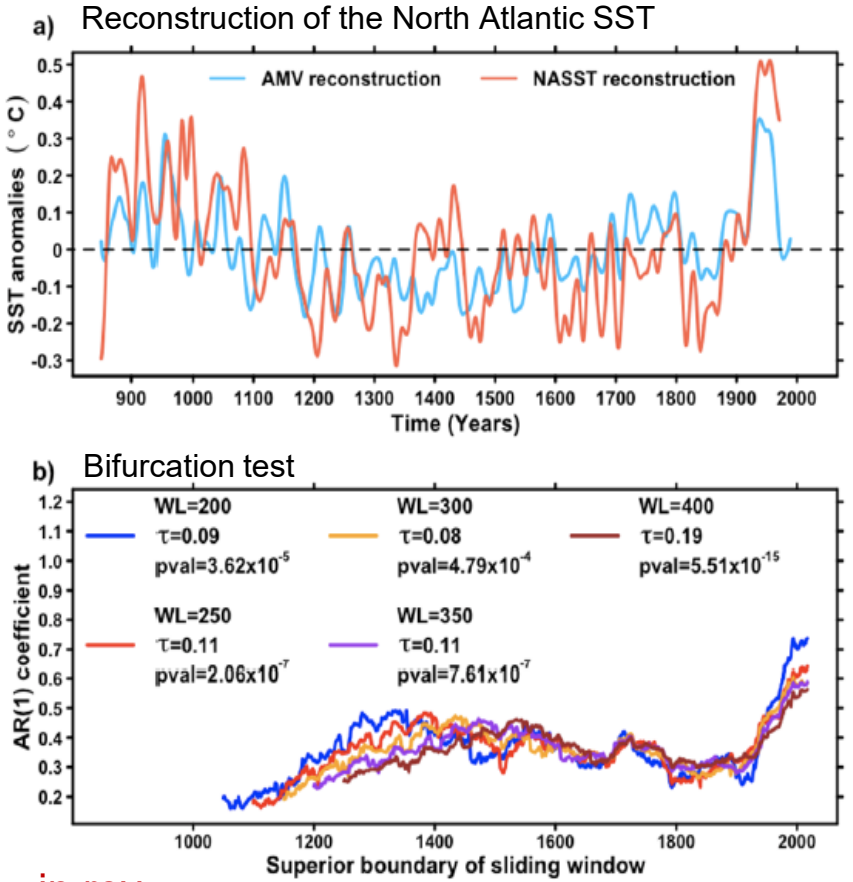


Fig. 6.10 from IPCC SROCC report, 2019

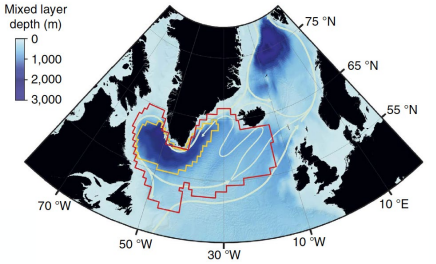
Proximity to an AMOC or SPG collapse?

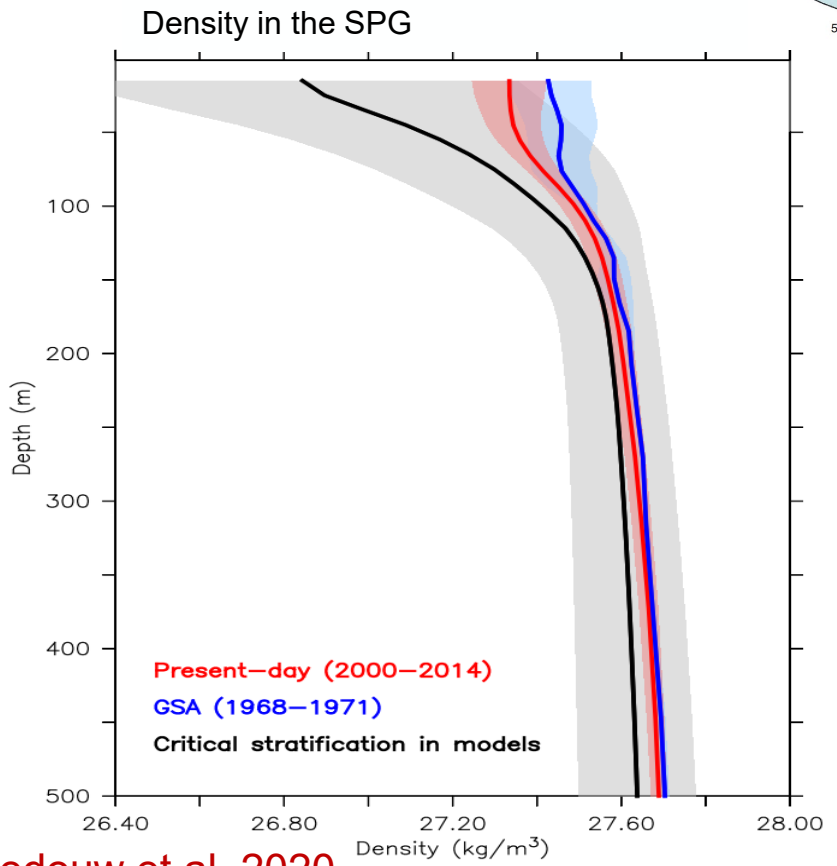
North Atlantic reconstruction as a proxy of an AMOC early warning

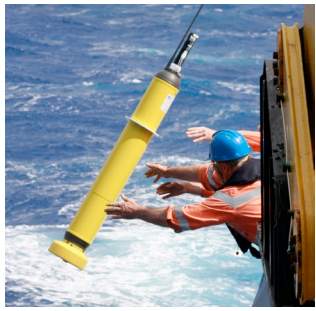


Michel et al., in rev.

Critical stratification in the SPG







Swingedouw et al. 2020

Decadal predictions to provide early warnings

Initial conditions

External forcing

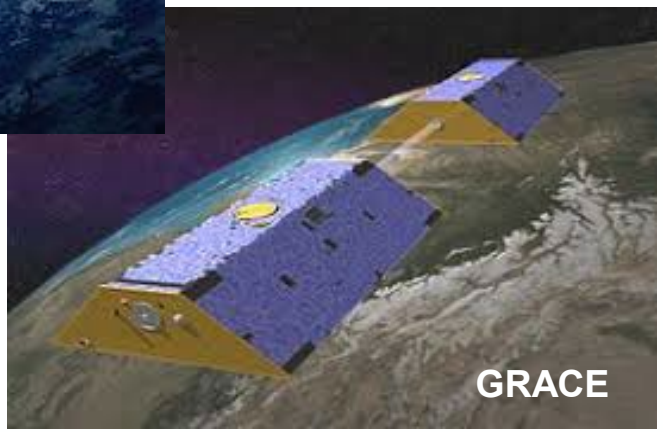
Weather forecast | **Seasonal prediction** | **Decadal prediction** | **Centennial projections** | **Glacial cycles**

day — week — month — year — decade — century — millennium

Timescales

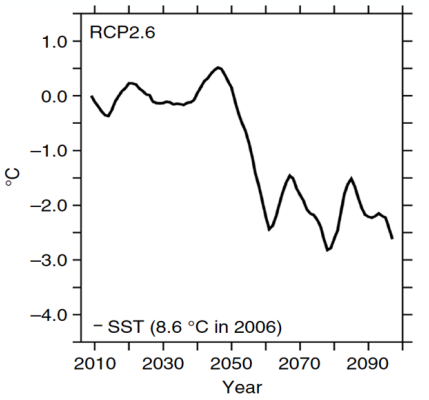
Necessity of Earth Observations

- 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)



Key take-home messages

Possibility of Abrupt Changes in the North-Atlantic ocean circulation system both in paleo-reconstruction and in IPCC-type climate models



They have global impacts (Atlantic marine life, Sahelian precipitations, European heat waves, storms, agriculture, Asian monsoon shift…)

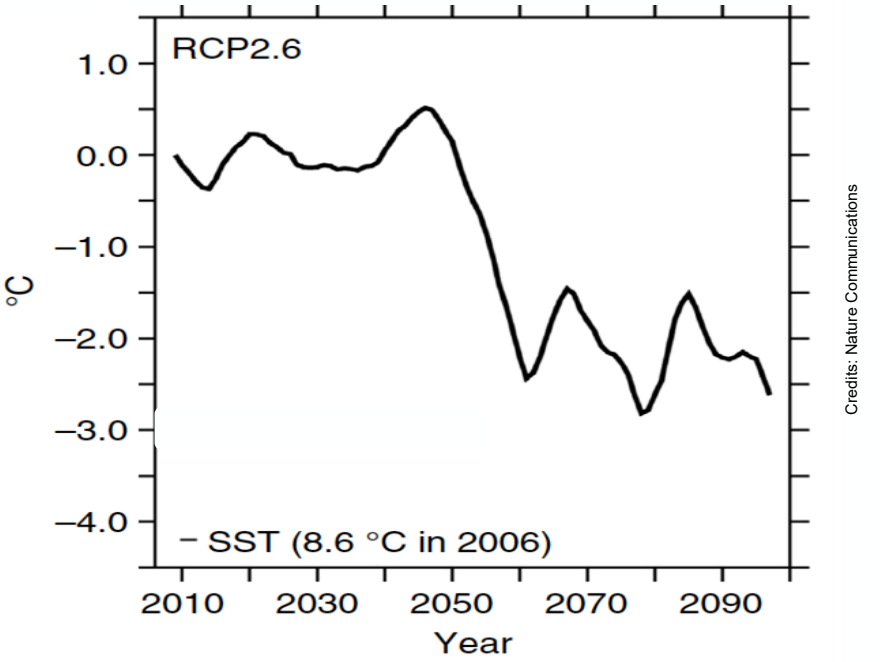
Decadal prediction systems need to be further developed to better include EO and provide early warnings of such potential abrupt changes

Thank you!

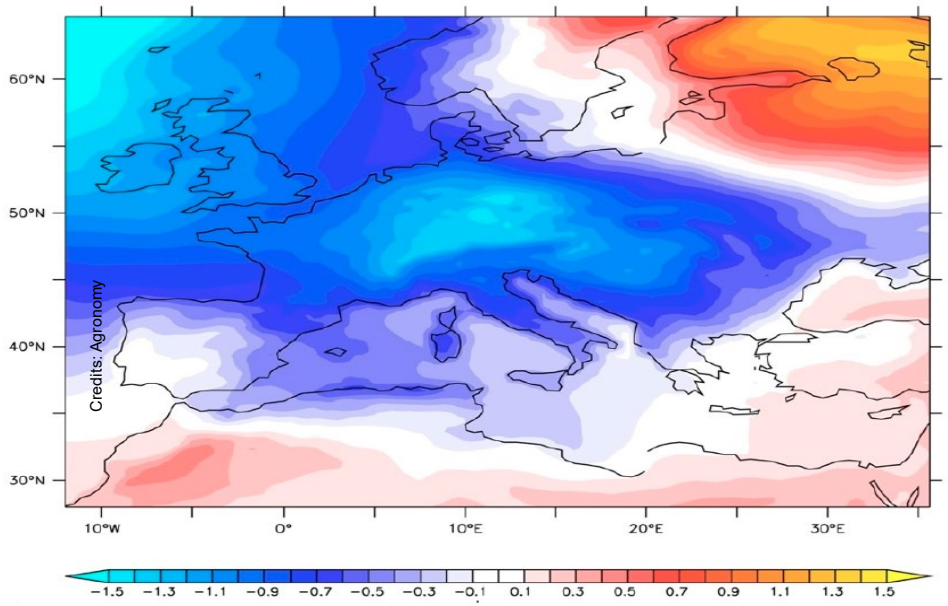
Possibility of an Abrupt Change in the North Atlantic in climate models

- Some models do show abrupt (<10 years) cooling in the subpolar gyre (SPG)
- The risk for such changes can be estimated between about 20 to 45% (Sgubin et al. 2017)

Changes of surface temperature in the subpolar gyre in a model projection



Difference of temperature after and before the shift

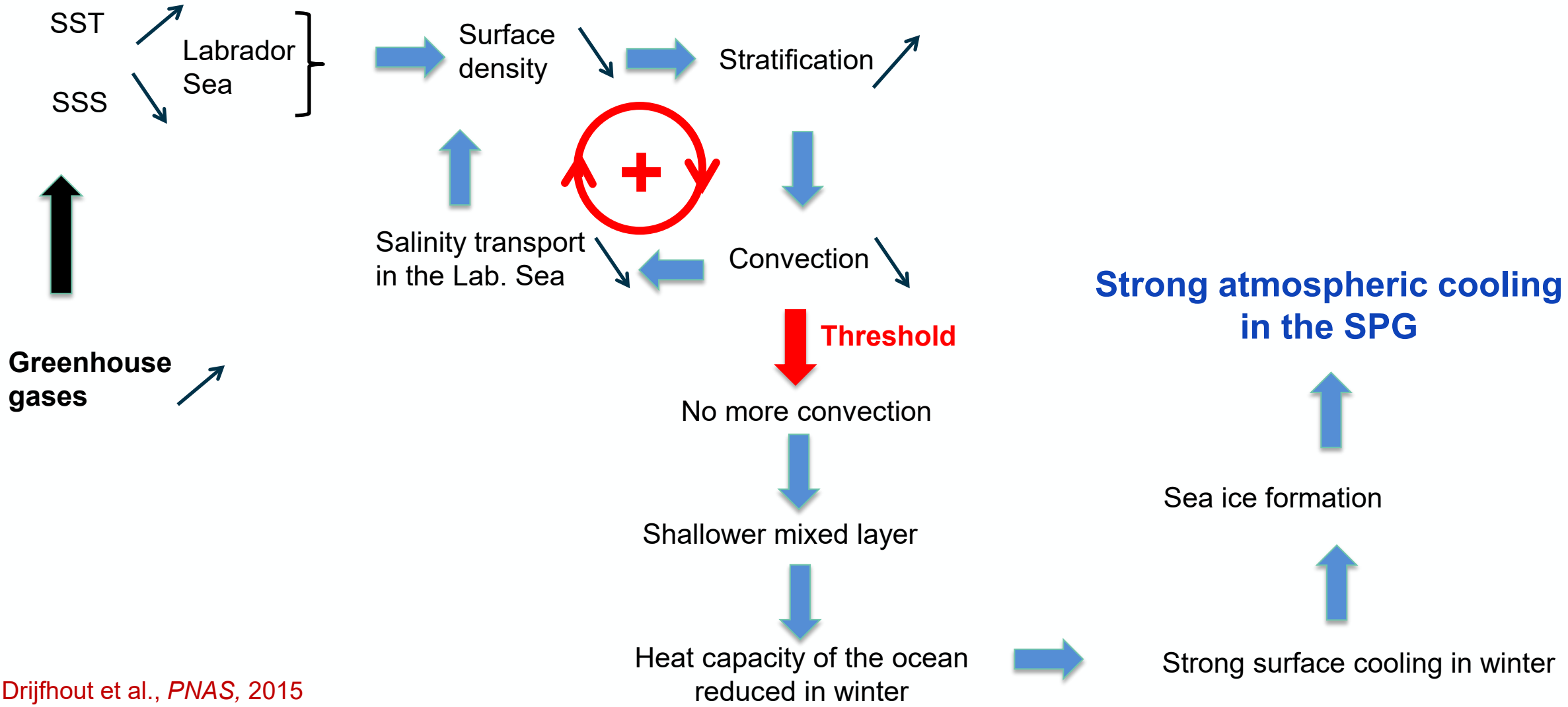


Sgubin et al. 2017

- The impact of the decade after the abrupt change, as compared to the former one, can be huge over Europe
- This might put some adaptation measures in agriculture at risk (e.g. viticulture) on a decadal time scale

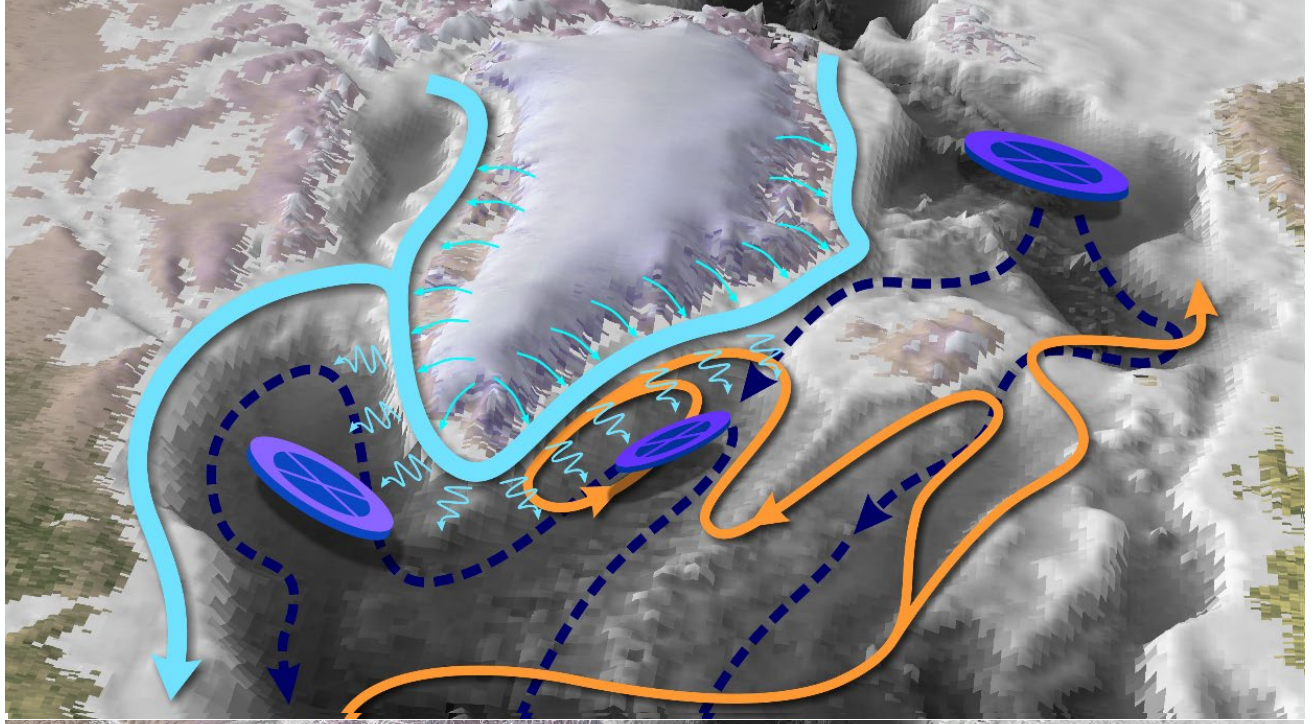
Sgubin et al. 2019

Mechanism of the subpolar gyre collapse



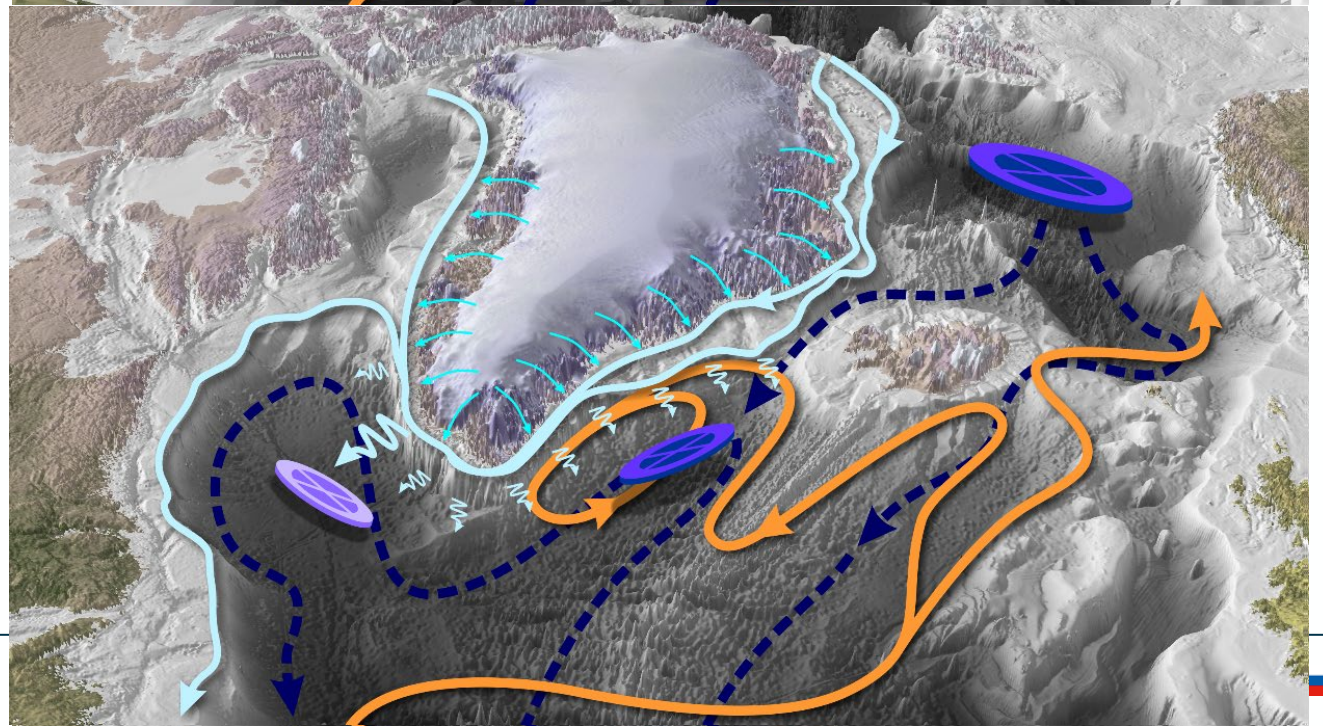
Drijfhout et al., *PNAS*, 2015

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