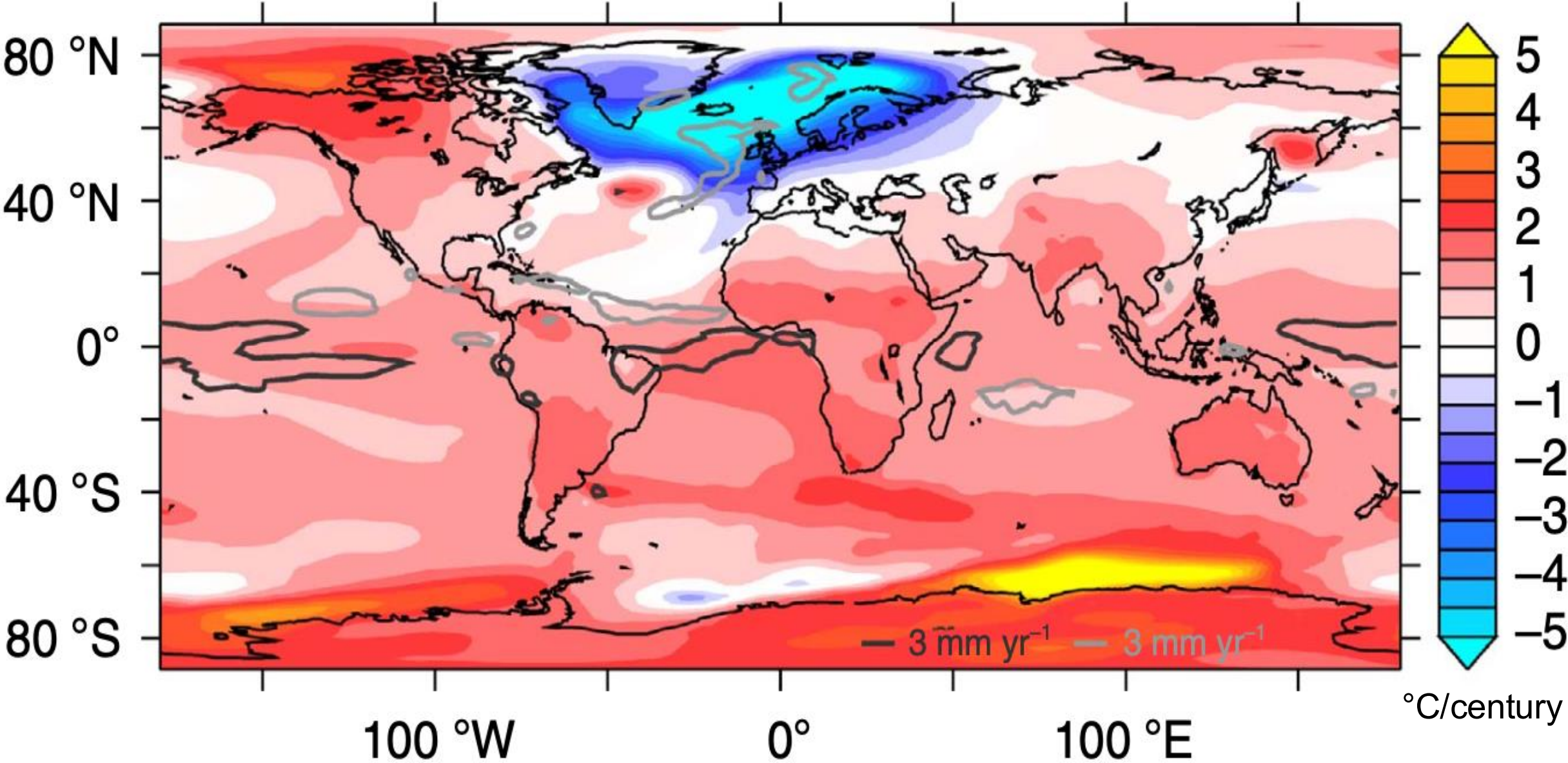


Future changes in the AMOC: what can we learn from combining models and observations?

AMOC disruption in 2100








Sgubin et al. (Nat. Com. 2017)








Impact of a substantial (>50%) AMOC weakening



Physical system

-  Droughts
-  Sea level rise
-  Sea ice and snow
-  Storminess
-  Temperature trend
-  Cyclones frequency
-  Precipitation and flooding

Biological system

-  Vegetation
-  Marine ecosystems
-  Wetland methane
-  Oxygenation
-  Oceanic carbon and acidification

Human and managed systems

-  Agriculture and food production
-  Migration pressure due to degradation in livelihoods

Direction of the change

-  Increase
-  Decrease

Confidence in process understanding

-  High
-  Medium
-  Low

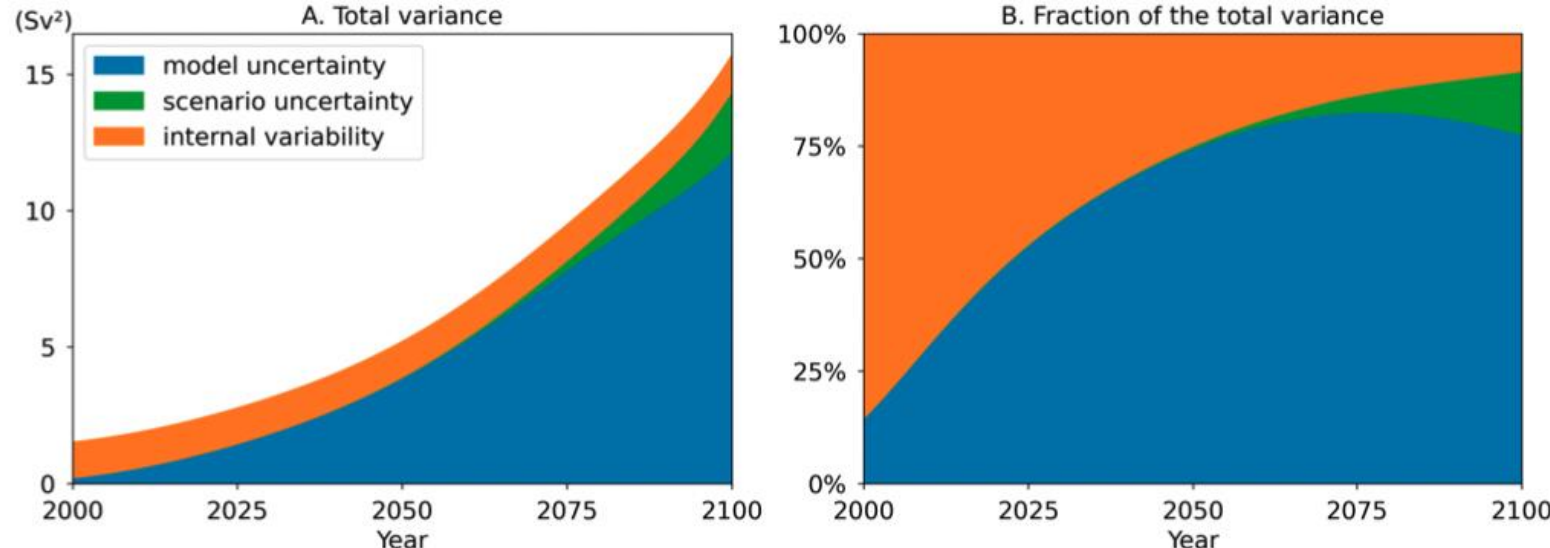
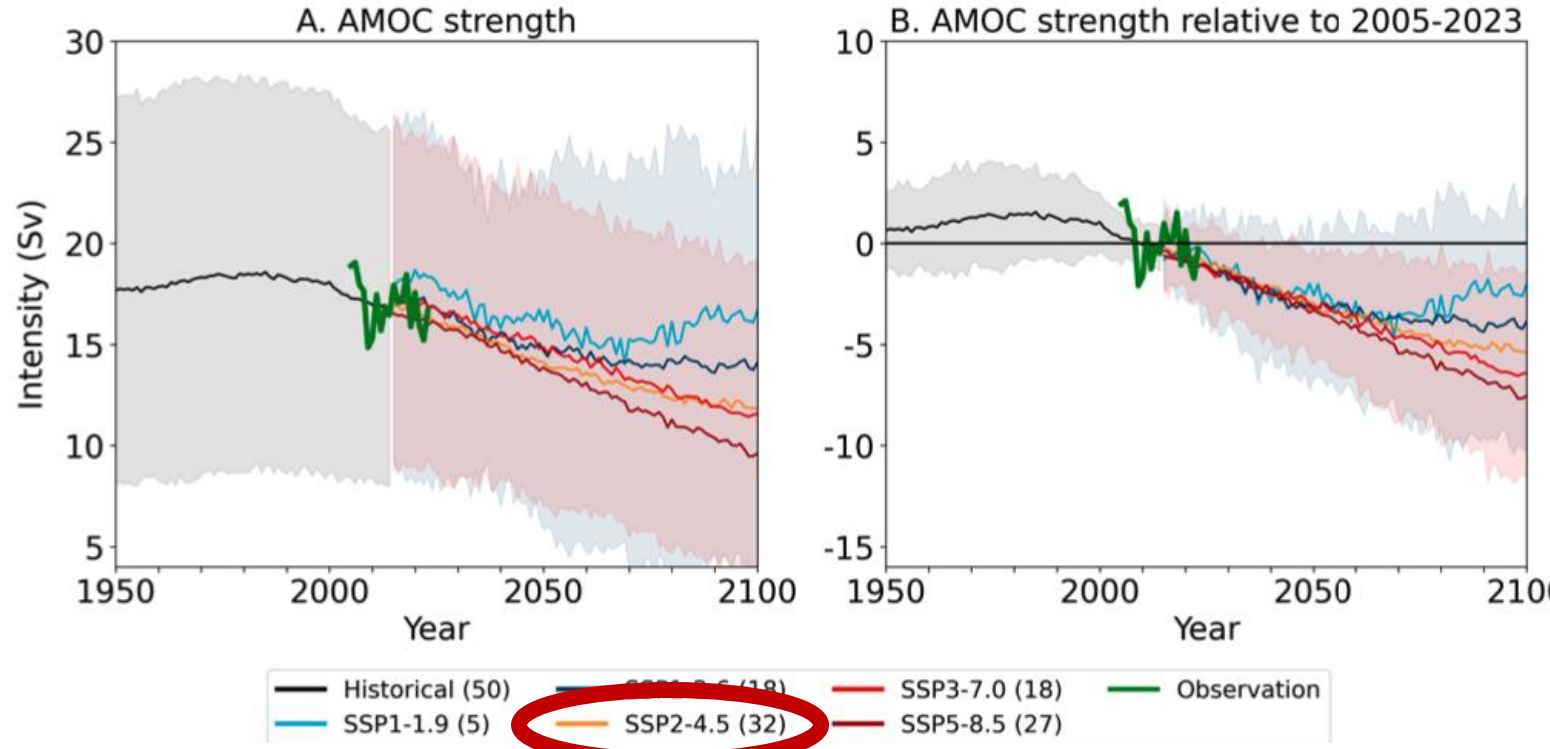
Fig. 6.10 from IPCC SROCC report 2019



AMOC Projections

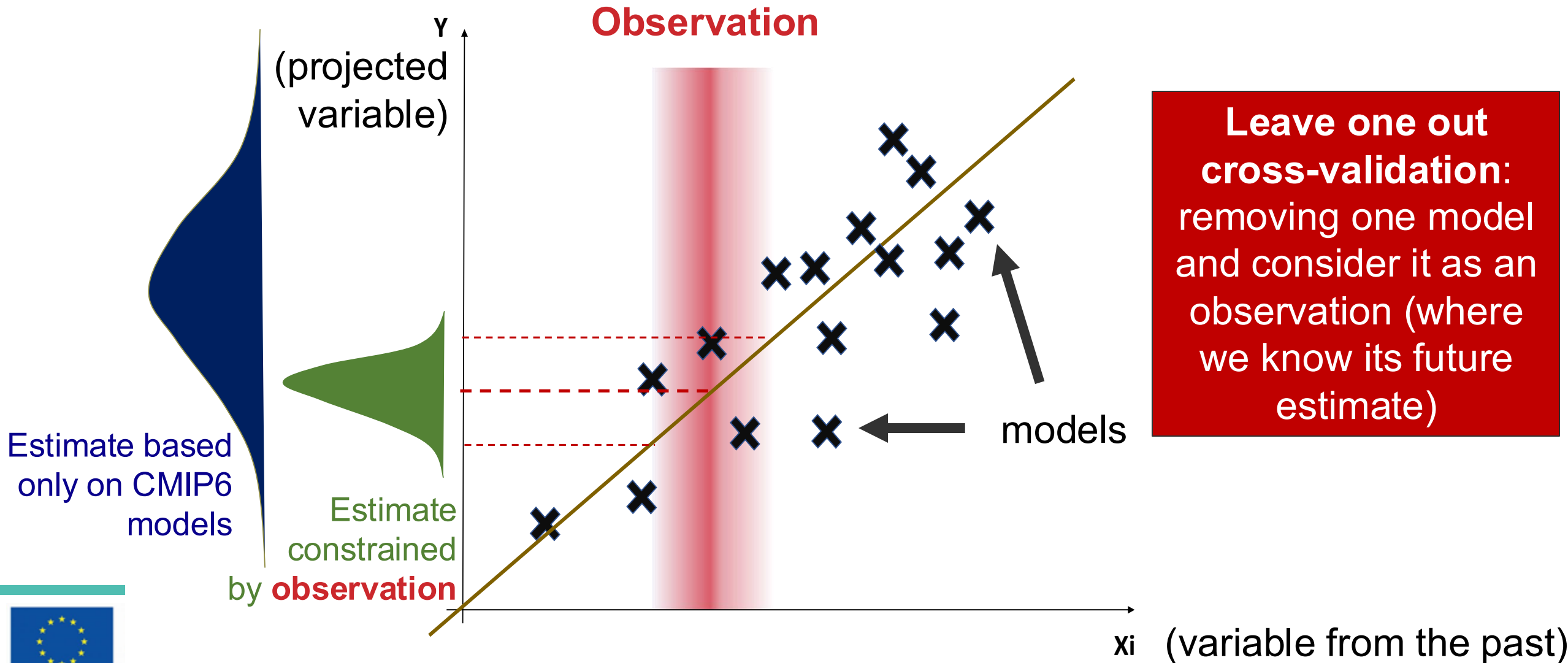
- CMIP6 models suggest a **32 ± 37% (90% probability)** reduction in AMOC strength by 2100 (SSP2-4.5 scenario, **3 to 72%** depending on the model!)

- This large uncertainty is dominated by **model uncertainty** for the end of the century



**Since *AMOC model uncertainty* is huge,
can we go beyond multi-model ensemble mean?**

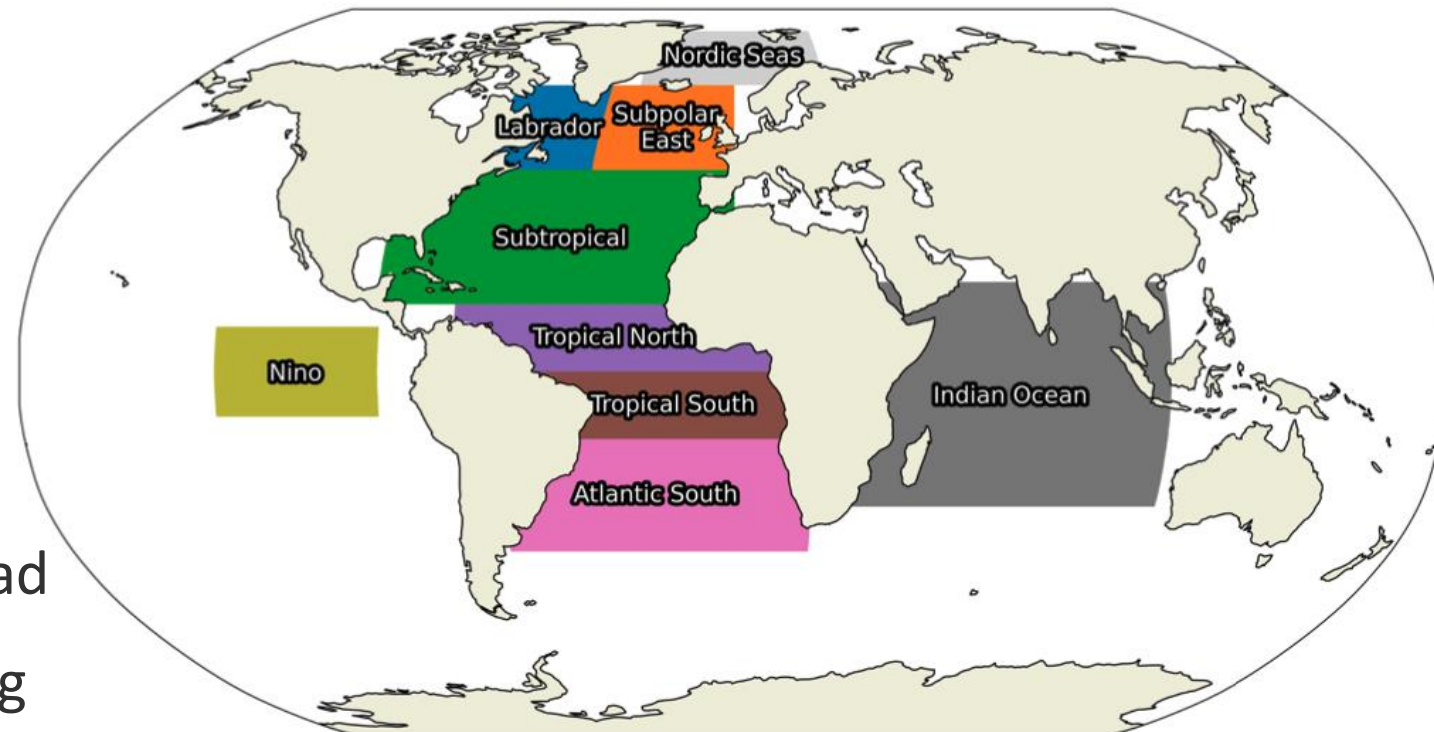
Observational constraint approach



Observational constraints

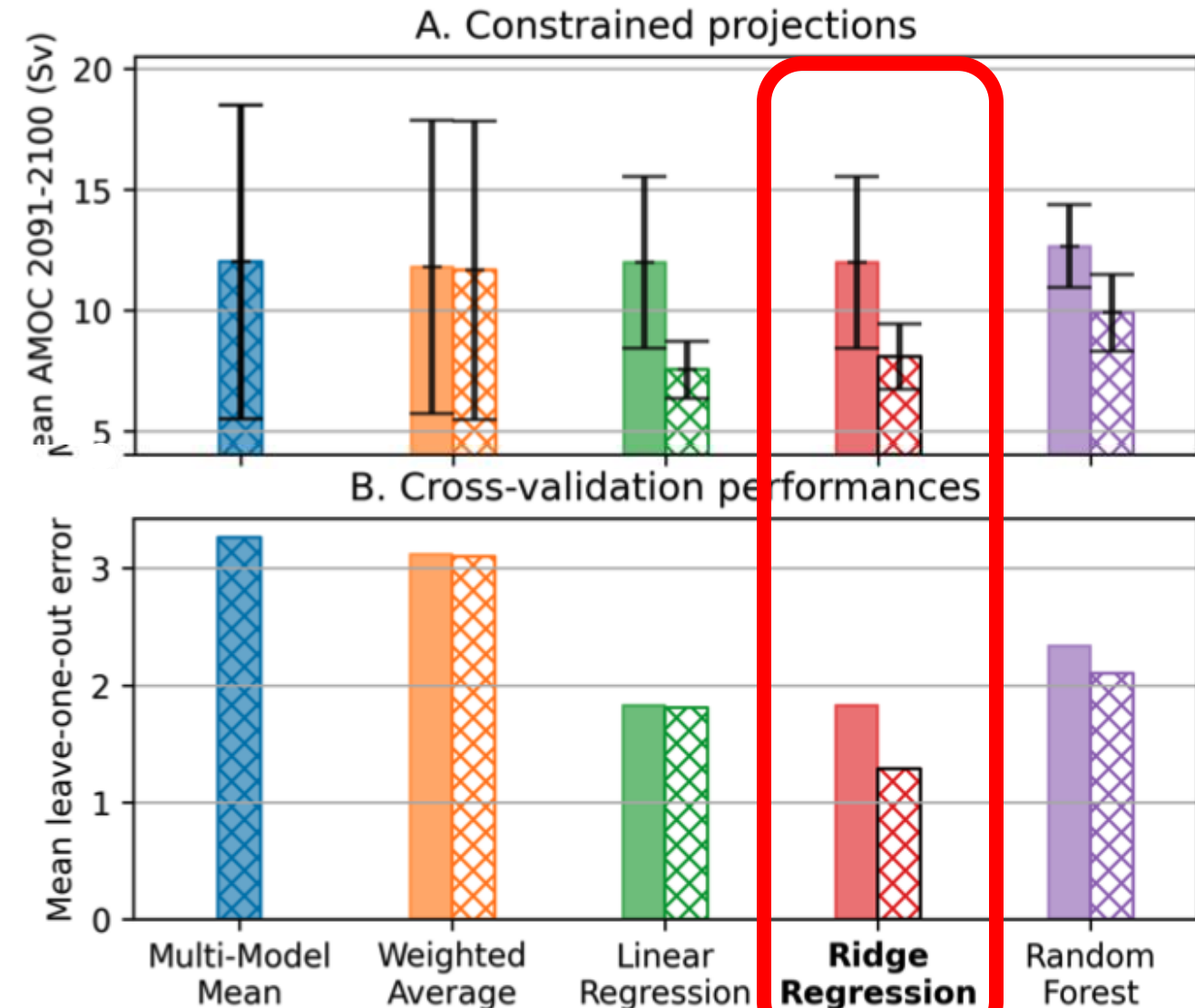
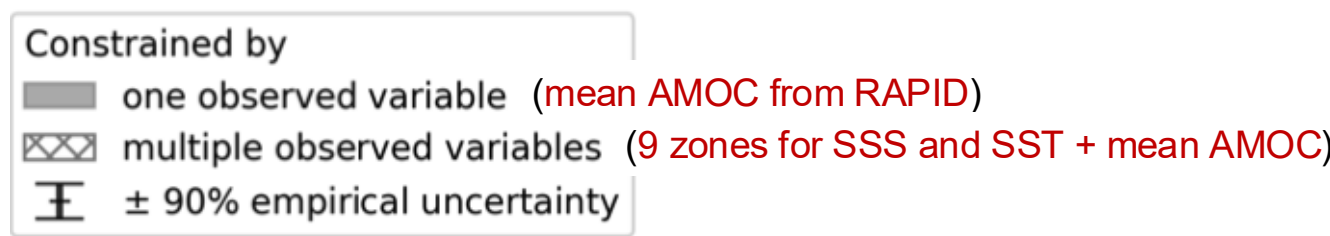
- Use of 4 methods of observational constraint approaches:
 - Weighted average
 - Random forest
 - Linear regression
 - Ridge regression
- Use of one variable (mean AMOC) or **multiple variables** to explain the spread
- Check robustness of the methods using leave-one-out method

Chosen regions for SSS and SST as predictors of the AMOC spread



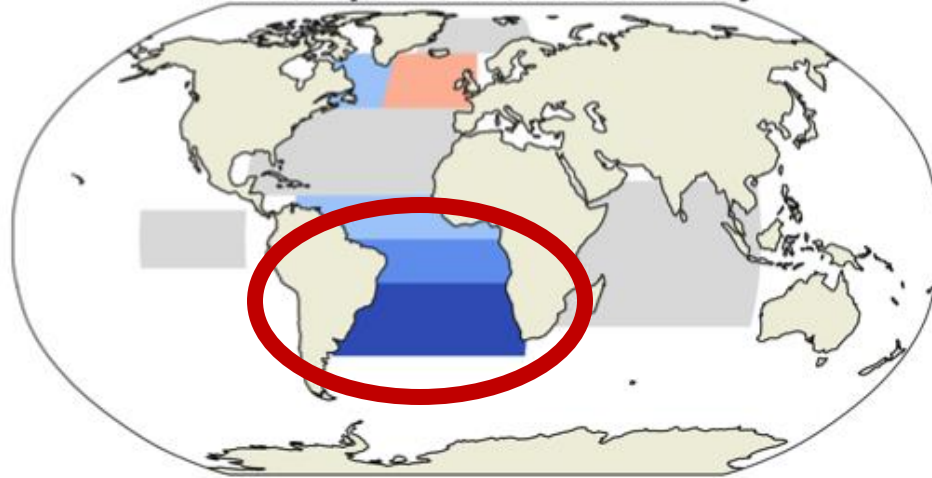
AMOC constrained projections

- Constraining by multiple variables is leading to weaker future AMOC
- The best method in terms of leave-one out is **the ridge regression with multiple predictor variables**
- It provides a guess of the AMOC slowdown of **$54 \pm 8\%$** (90% probability) i.e. a **70% stronger weakening** than the multi-model mean

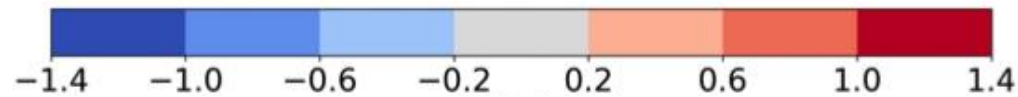
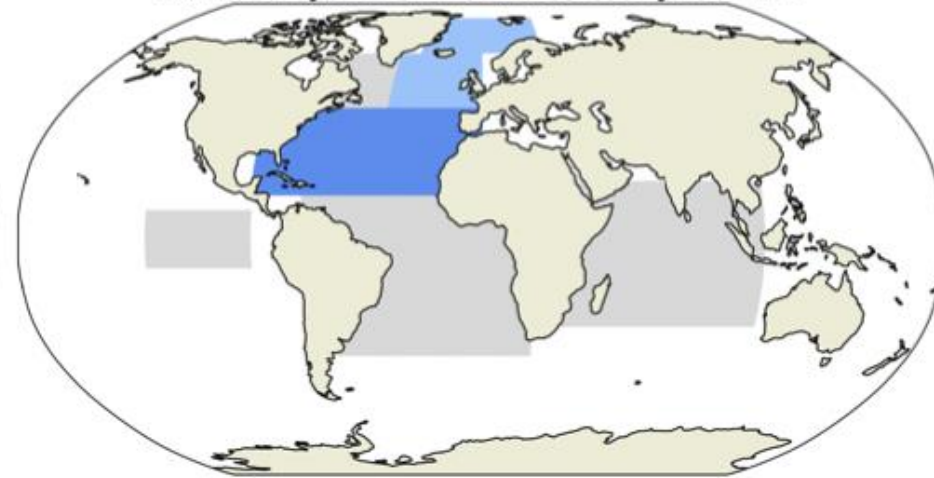


Main factors explaining the change in the future mean of the AMOC

A. Correction on future AMOC (Sv) induced by the sea surface **salinity**



B. Correction on future AMOC (Sv) induced by the sea surface **temperature**



$$\hat{f}(x_0) = \hat{\mu}_Y - \hat{\beta}^T (\hat{\mu}_X - x_0)$$

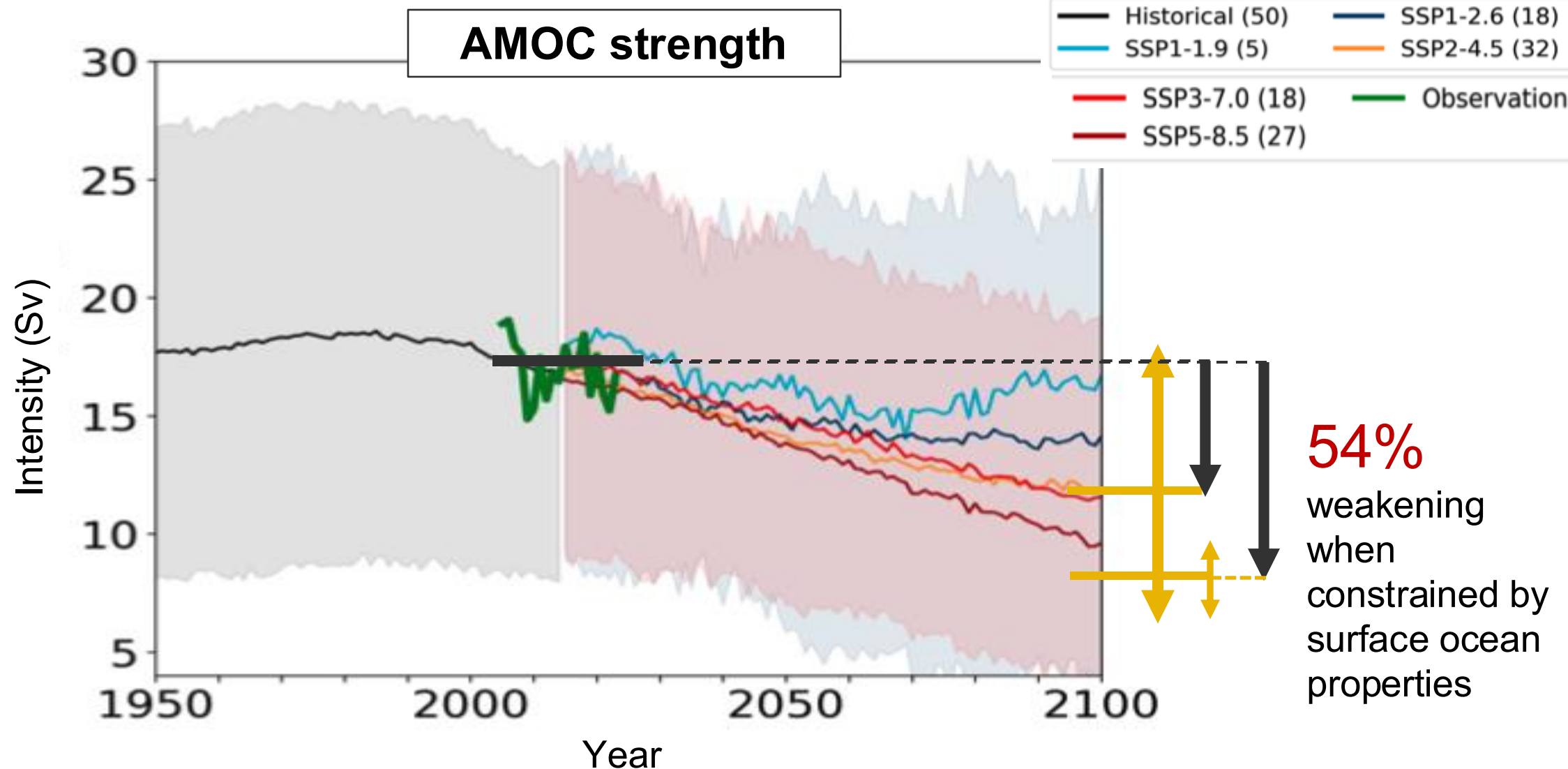
Observation-constrained estimate

Multi-Model Mean

Regression coefficient

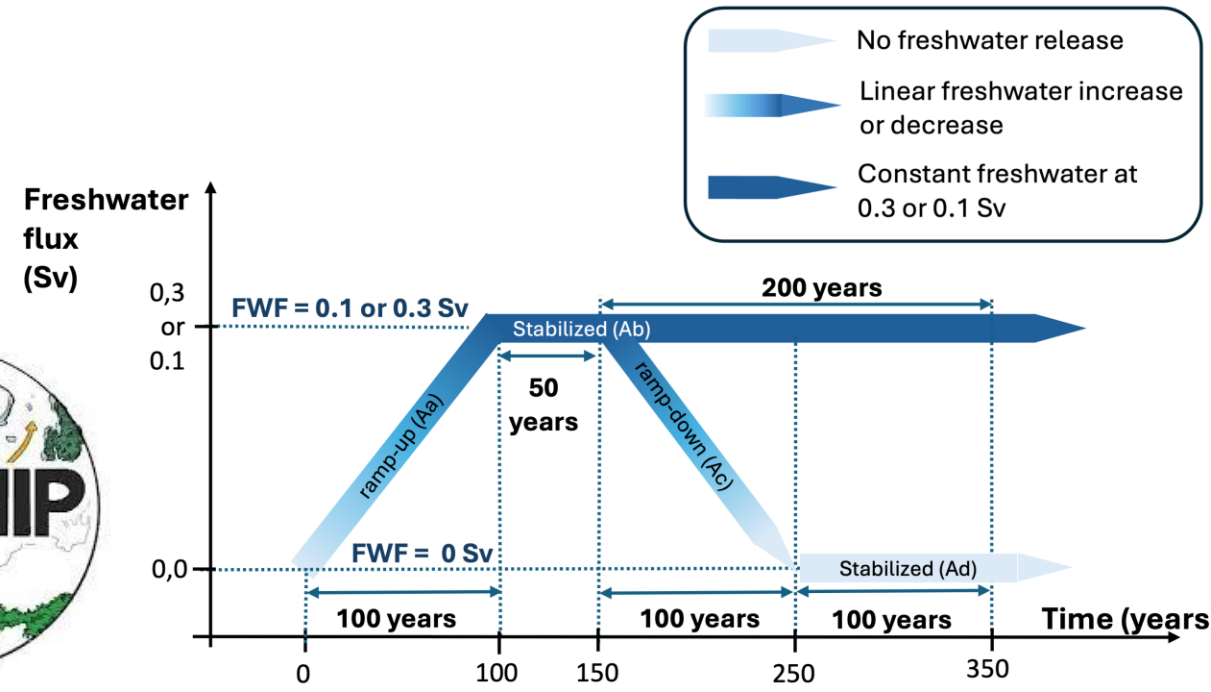
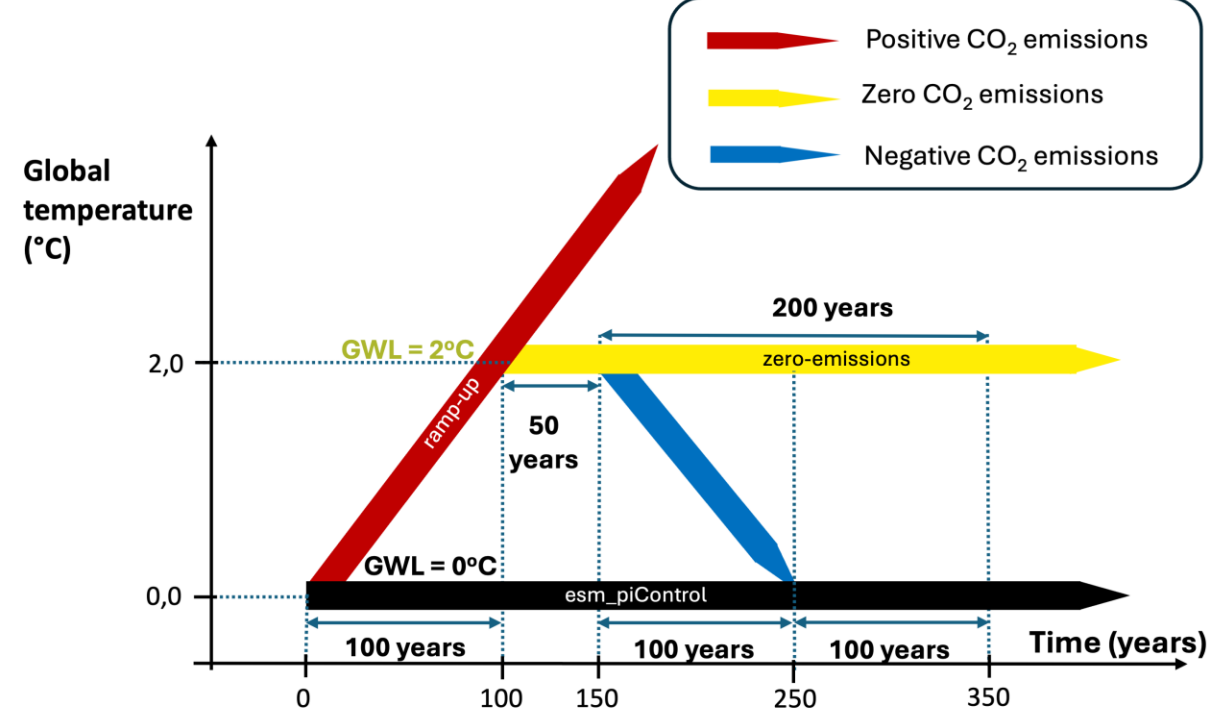
(mean bias)

Changes in the distribution of the AMOC projections



Changes in the AMOC on multi-centennial scale

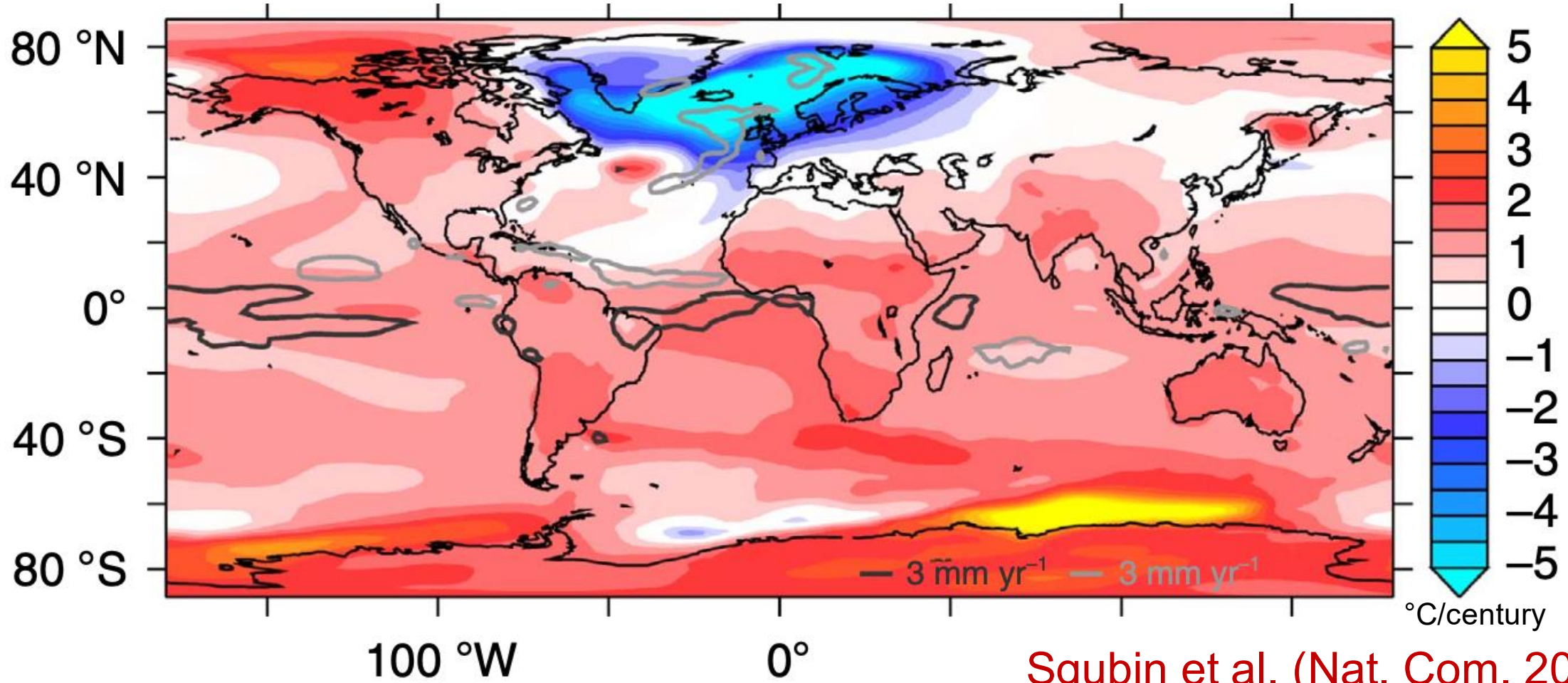
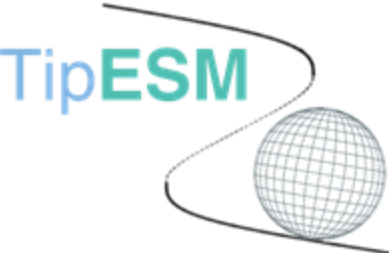
- Knowing when we can say that the AMOC might have crossed its tipping point is still an open question
- TIPMIP, a new model-intercomparison project at the international scale will notably aim to tackle this question and evaluate potential irreversibility of the AMOC using CMIP6-7 models



Conclusions

- Multi-variate observational constraints suggest a potentially **larger AMOC weakening (70% more) in 2100** than suggested by simple ensemble mean of CMIP6 models
- This might be mainly related to **large SSS bias in the South Atlantic**, possibly related with a biased salt advection positive feedback at 34°S in models making **some models too stable** to perturbation
- Based on existing literature, there are now a number of evidences highlighting that projected AMOC weakening seen as a multi-model mean is not large enough

Thank you



Sgubin et al. (Nat. Com. 2017)

