EGU25 OSPP

My website

Connecting complex and simplified models of tipping elements: an emulator of the AMOC

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EGU 25 Poster Presentation

VRIJE UNIVERSITEIT BRUSSEL

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Paper under review

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This presentation participates in OSPP

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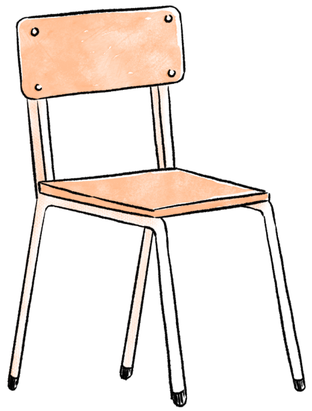
Outstanding Student & PhD candidate Presentation contest

Rationale - What is a Tipping Point?



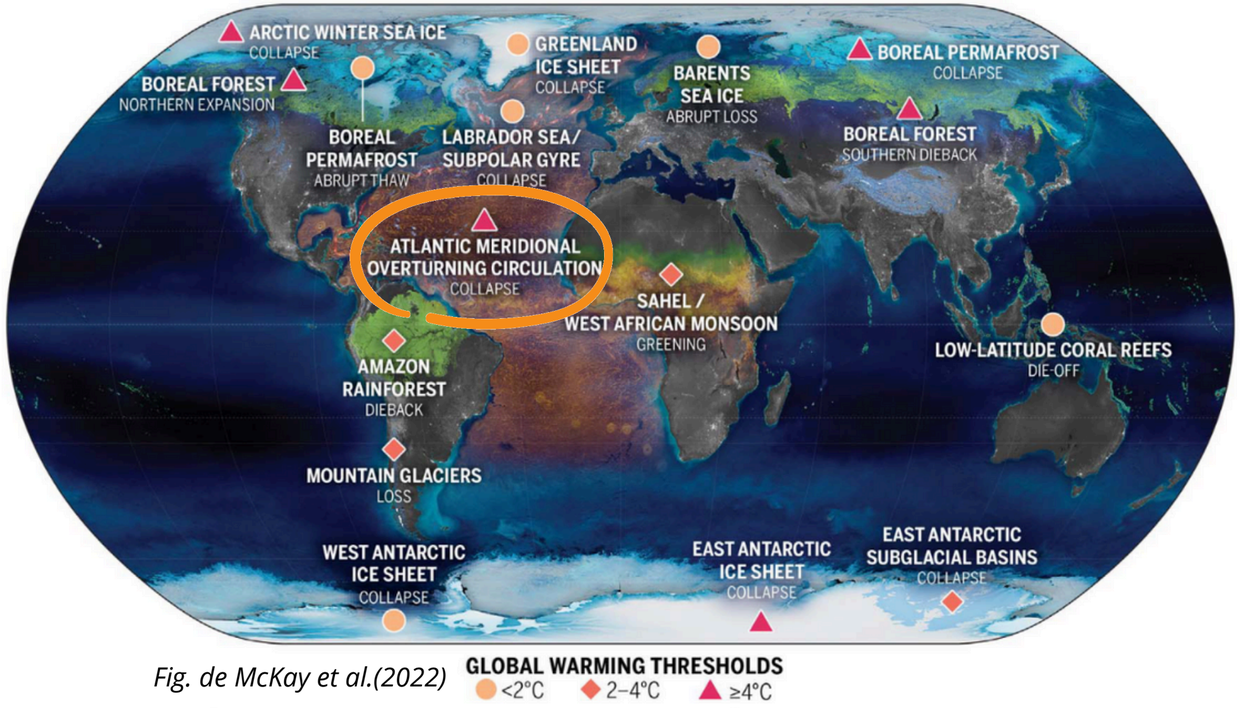


Fig. de McKay et al.(2022)

IPCC Definition

Tipping point : A **critical threshold beyond** which a **system reorganizes**, often **abruptly** and/or **irreversibly**.

A ***Tipping Element*** is a **large-scale component** of the **climate system** that **can reach** a **tipping point**

Paper under review

RESEARCH ARTICLE

Connecting complex and simplified models of tipping elements: a nonlinear two-forcing emulator for the Atlantic meridional overturning circulation

[version 1; peer review: awaiting peer review]

Amaury Laridon, Victor Couplet, Justin Gérard, Michel Crucifix, Wim Thiery

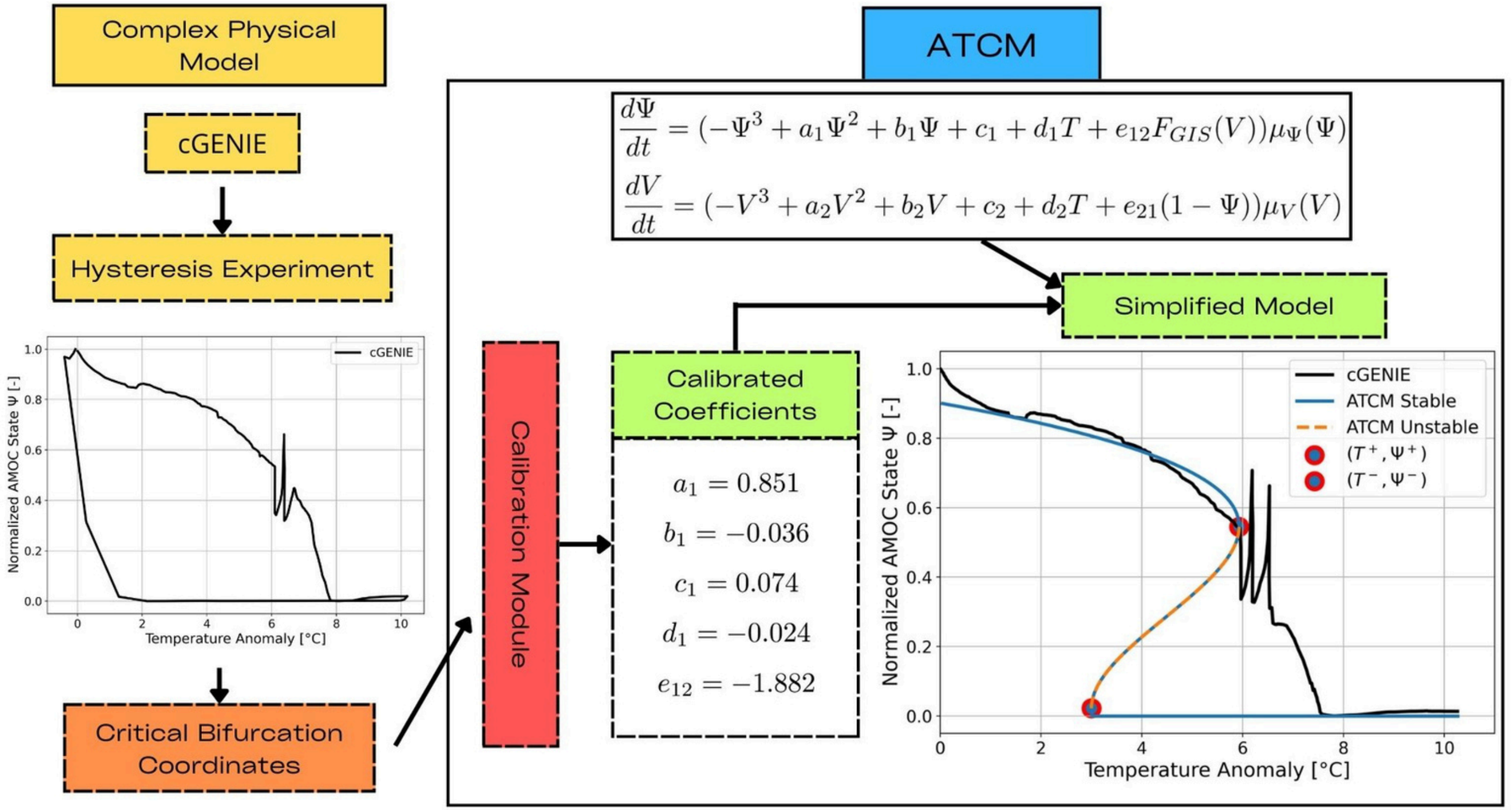
Research Question

"**How can we develop** an **AMOC emulator** with **two forcing parameters** — temperature and freshwater flux — that can be calibrated against sensitivity experiments from complex models and integrated into a climate model ?"

Rationale

- **Uncertainty** regarding the **location** of **tipping points and** the **dynamics** of tipping elements such as the **AMOC.**
- **Complex models** with spatial resolution, such as ESMs and EMICs, **have computational constraints** that do **not allow** for rapid **sampling** of **various realistic future scenarios.**
- **Reduced-complexity models** have been developed to **capture** the **behavior** of **tipping elements** in the system. These models are then calibrated against complex models to act as **emulators**.
- **Current AMOC emulators only consider one forcing** (temperature anomaly), whereas we know that freshwater flux can also have a decisive impact.

Method – The AMOC Tipping Calibration Module (ATCM)

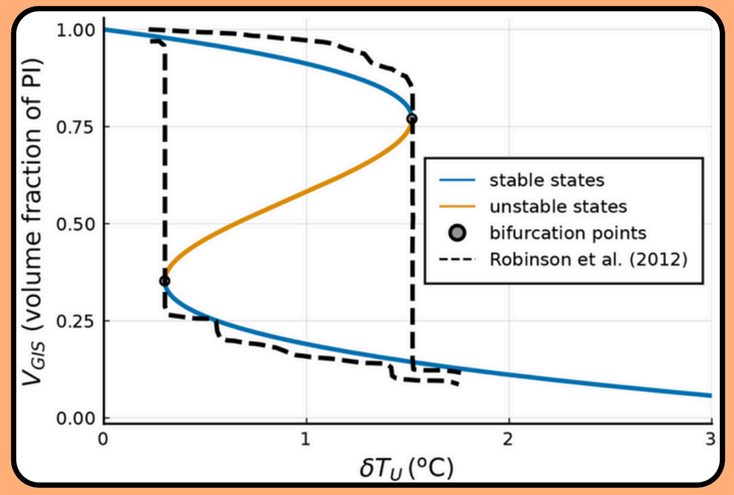


Laridon et al. (2025) *in review*

Method - The Calibration Module

The **1-forcing tipping element** calibration **module** of **Martinez Monteiro et al.(2022)**

$$\frac{dV}{dt} =\equiv f^{Mont}(V) = \mu(V)(-V^3 + aV^2 + bV + cT + d)$$



$$a = \frac{3(V_- + V_+)}{2}$$

$$b = -3V_-V_+$$

$$c = -\frac{(V_+ - V_-)^3}{2(T_+ - T_-)}$$

$$d = \frac{T_+V_-^2(V_- - 3V_+) - T_-V_+^2(V_+ - 3V_-)}{2(T_- - T_+)}$$

Idea for the 2-forcing tipping element calibration module

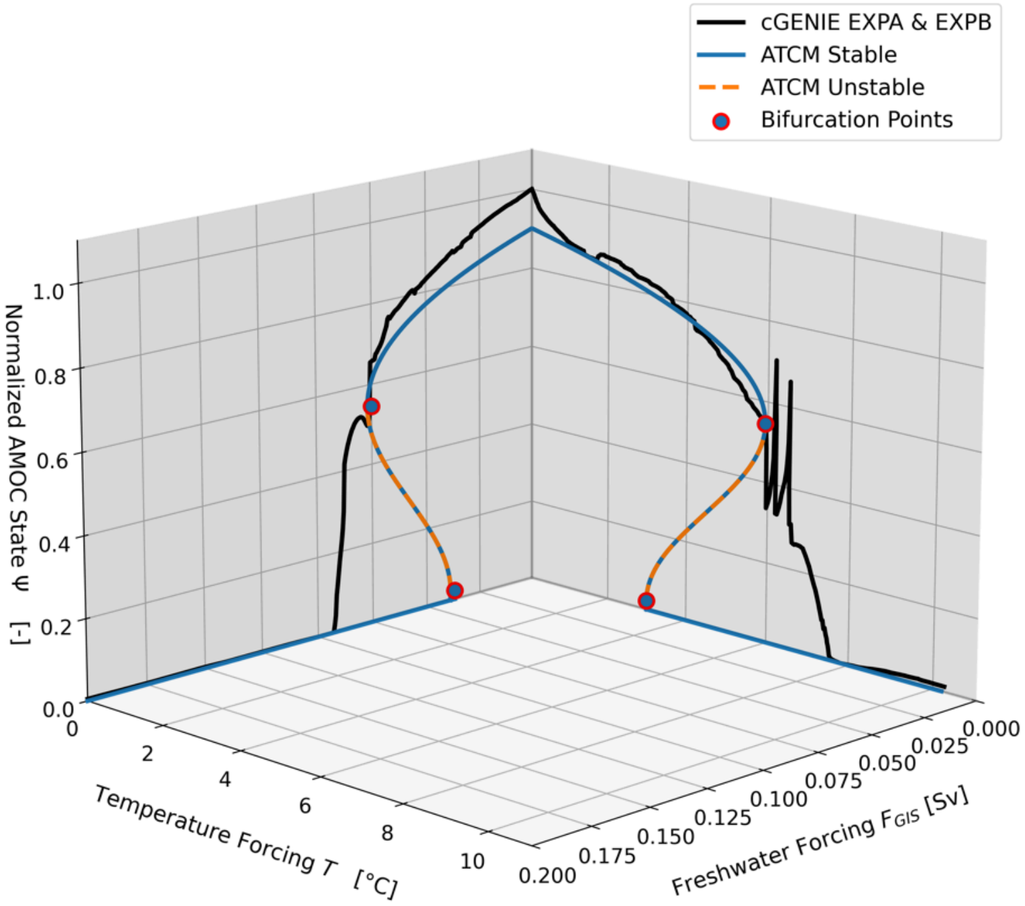
Hypothesize that **independent calibration experiments can be conducted using** the **complex model** to retrieve two 1-forcing calibration experiments

Martinez Monteiro et al. (2022) *in Geosci. Mod. Dev.*

Results – Good calibration of the simplified dynamics

AMOC Dynamics in ATCM

$$\frac{d\Psi}{dt} = (-\Psi^3 + a_1\Psi^2 + b_1\Psi + c_1 + d_1 T + e_{12} F_{GIS}(V))\mu_\Psi(\Psi)$$



Laridon et al. (2025) *in review*

Results - Good calibration of the simplified dynamics

AMOC Dynamics in ATCM

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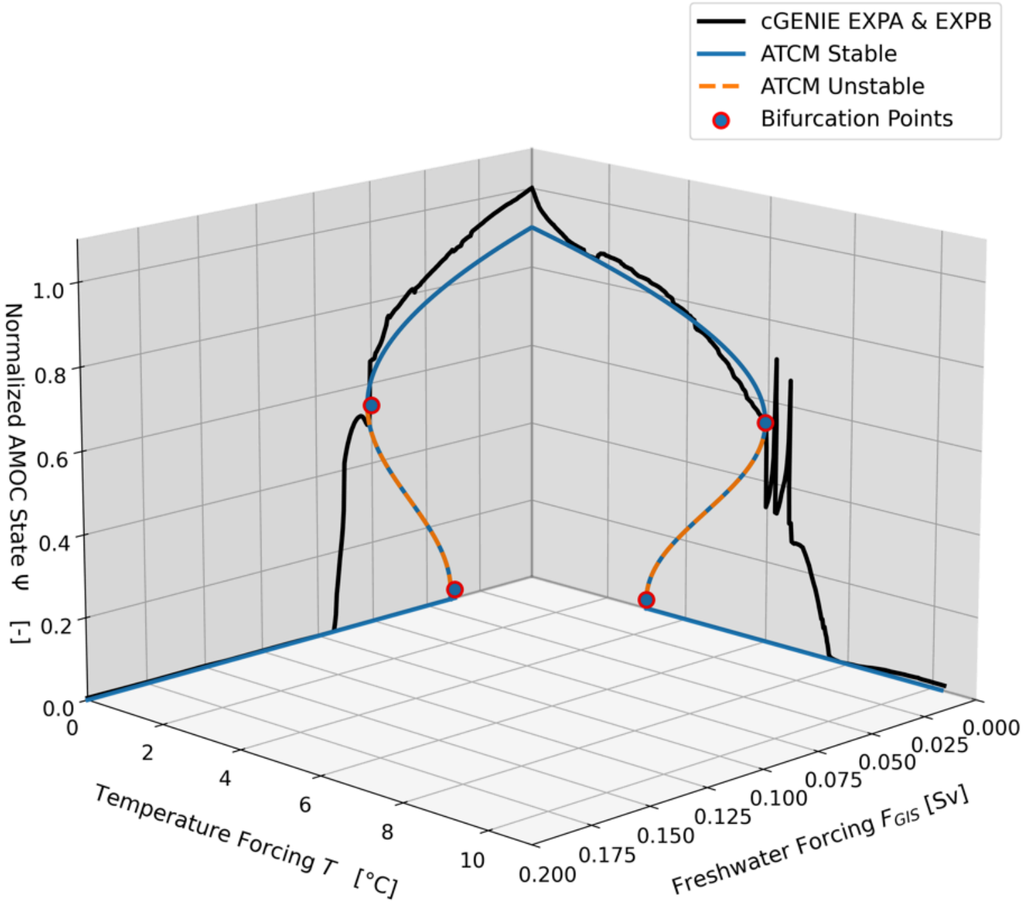
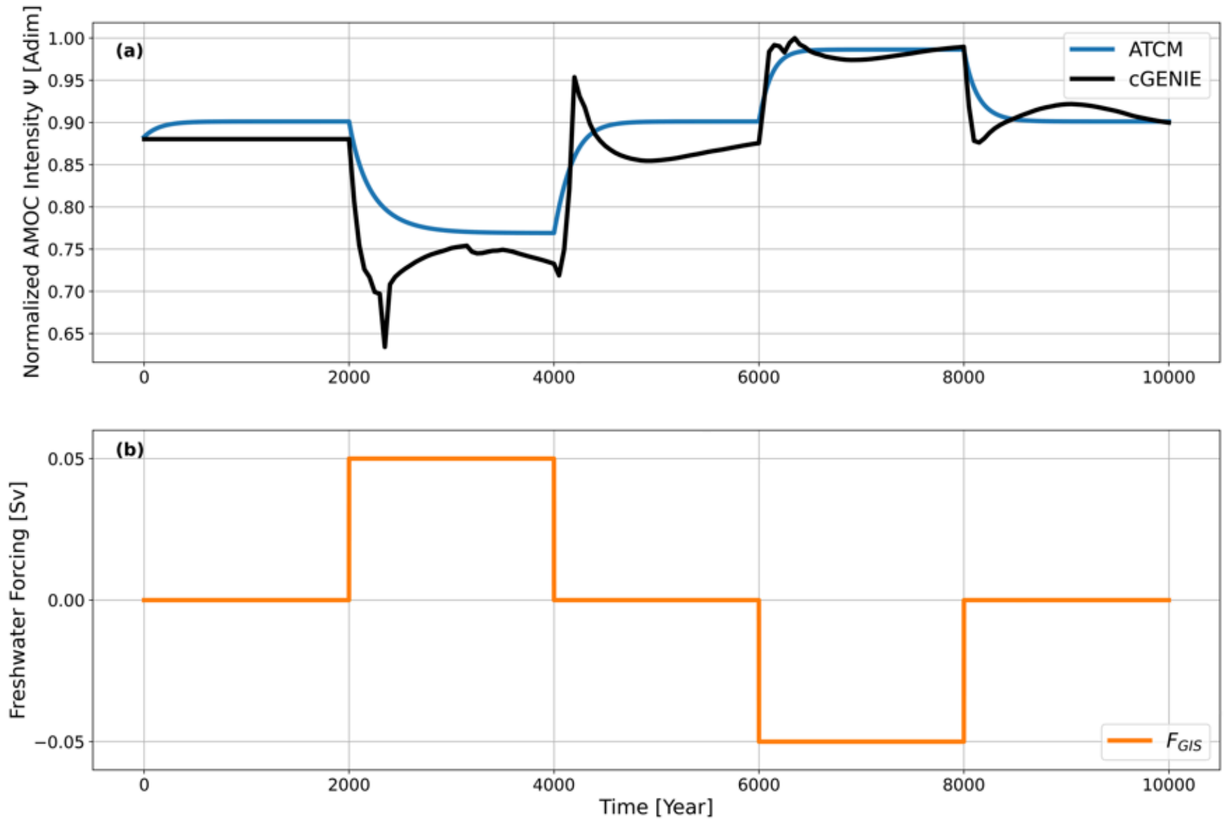
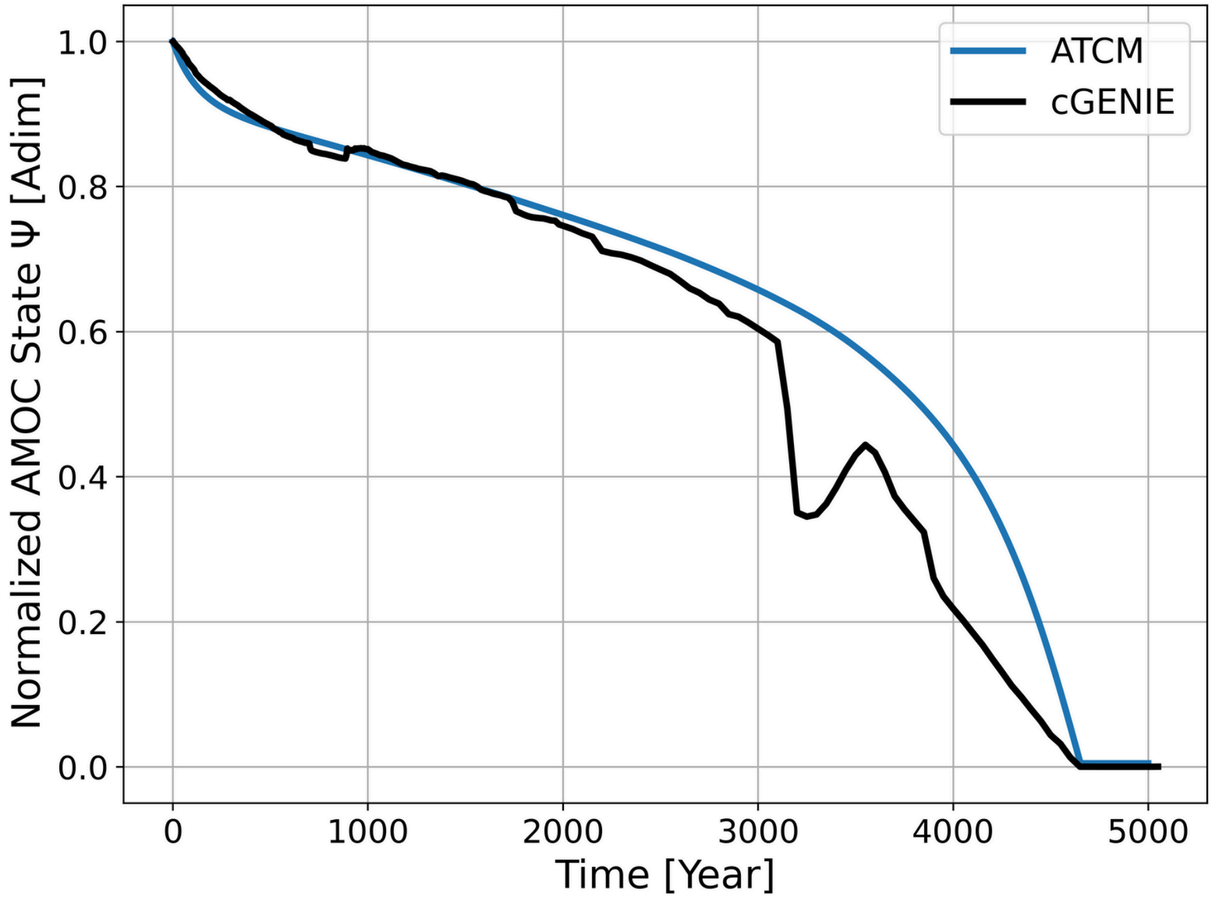




Laridon et al. (2025) *in review*

Results - Successful Validation Test

AMOC Trajectory in *val_exp_1*



Up to a **26% difference** in the projected **AMOC intensity**.

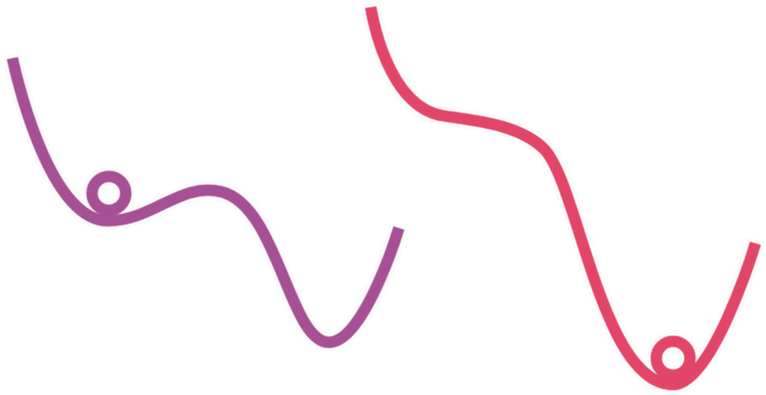
A **difference** of **less than 5 years** in the **projected timing** of total **collapse**.

Laridon et al. (2025) *in review*

Results – A Framework to assess the Critical Manifold

AMOC Dynamics in ATCM

$$\frac{d\Psi}{dt} = (-\Psi^3 + a_1\Psi^2 + b_1\Psi + c_1 + d_1 T + e_{12} F_{GIS}(V))\mu_\Psi(\Psi)$$

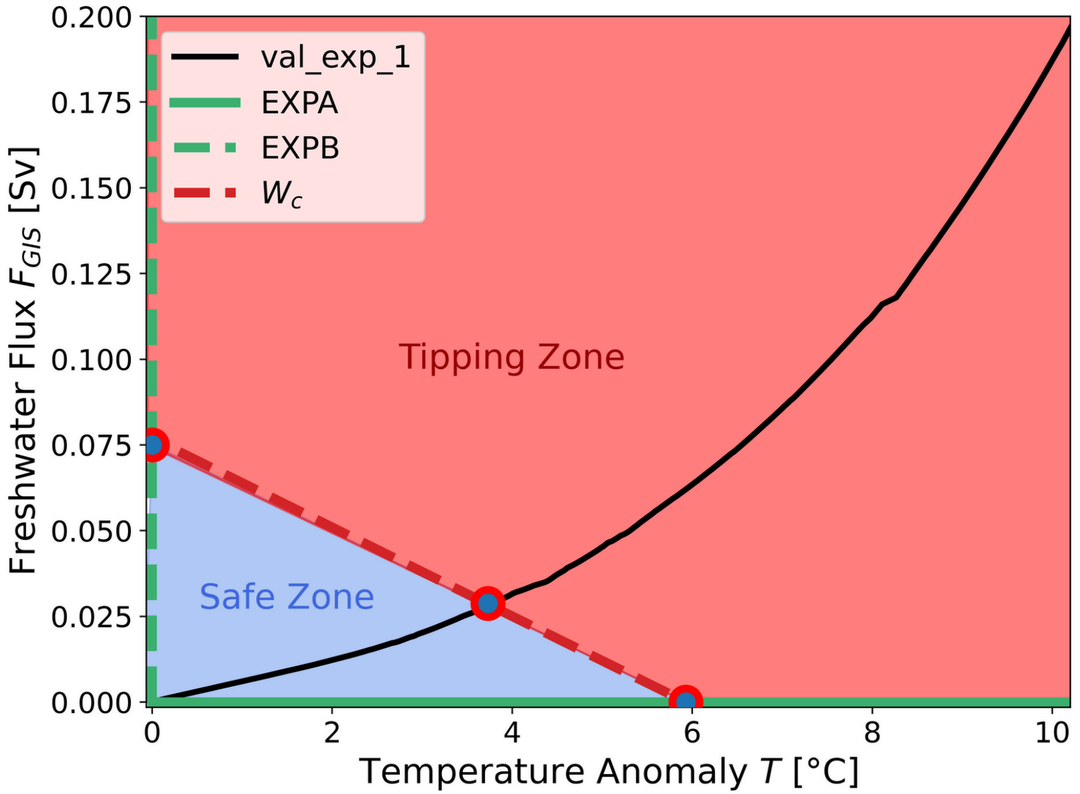


Critical Manifold

$$W_c(T) = \frac{d_1}{e_{12}}(T^+ - T).$$

Fig. from Lenton et al. (2024)

Forcing Space of the AMOC in ATCM

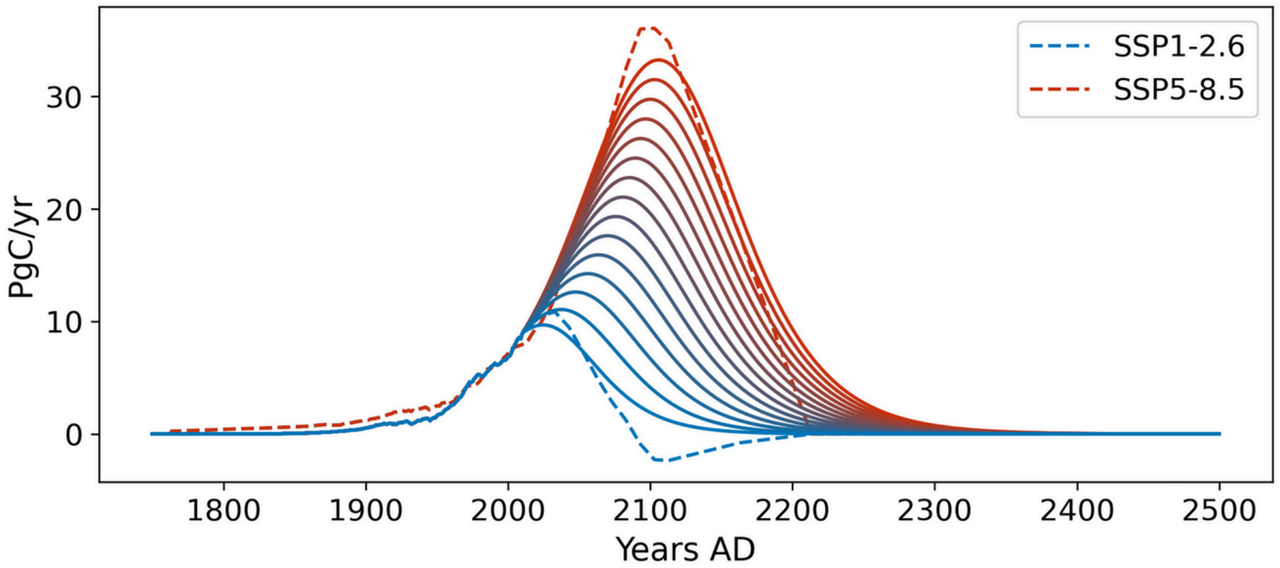


Laridon et al. (2025) *in review*

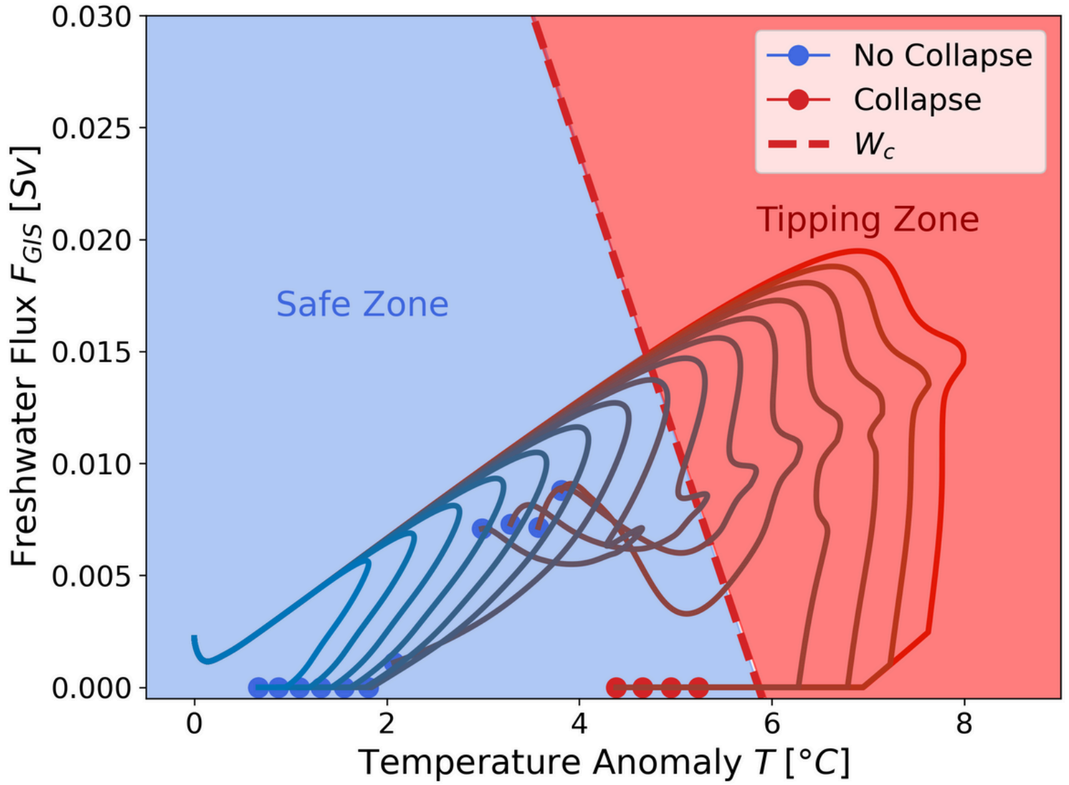
Results – Integration of ATCM in SURFER for sampling the forcing space

SURFER is a **reduced complexity climate model**

15 Emission Scenario used in SURFER



AMOC Trajectory in Forcing Space

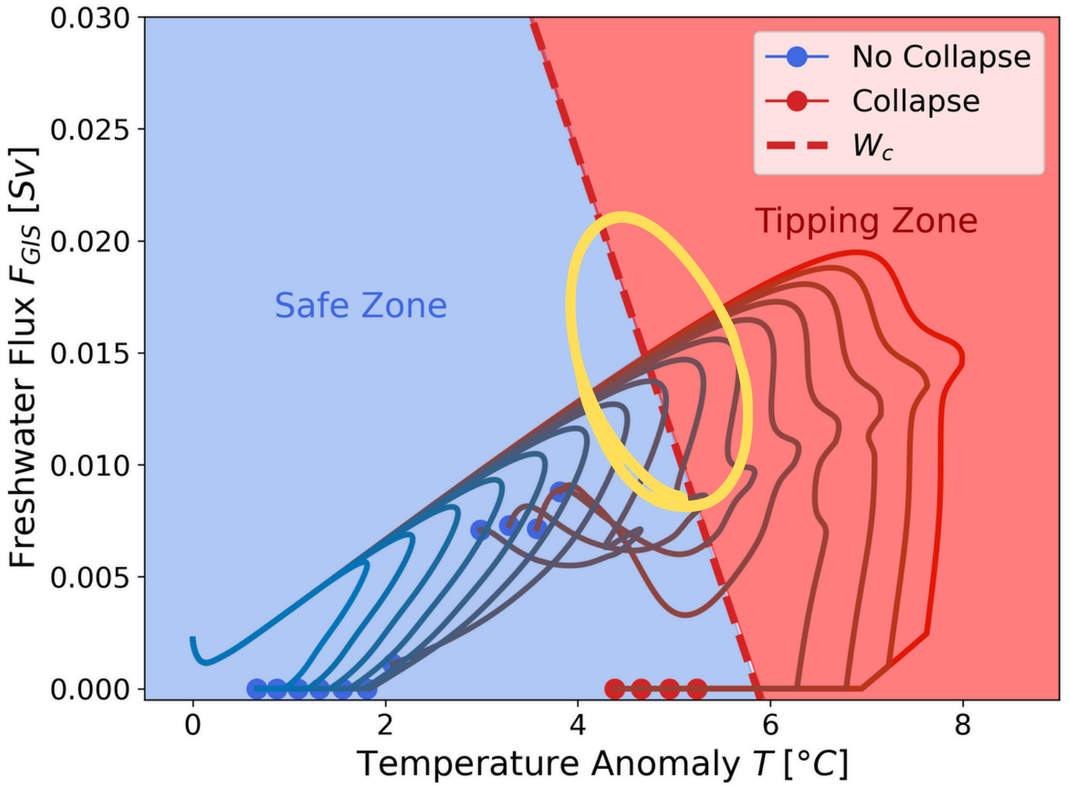


Laridon et al. (2025) *in review*

Results – A Tool to Sample the Forcing Space

- The **bifurcation threshold** is **exceeded** for the **8 highest emission scenarios**

AMOC Trajectory its Forcing Space



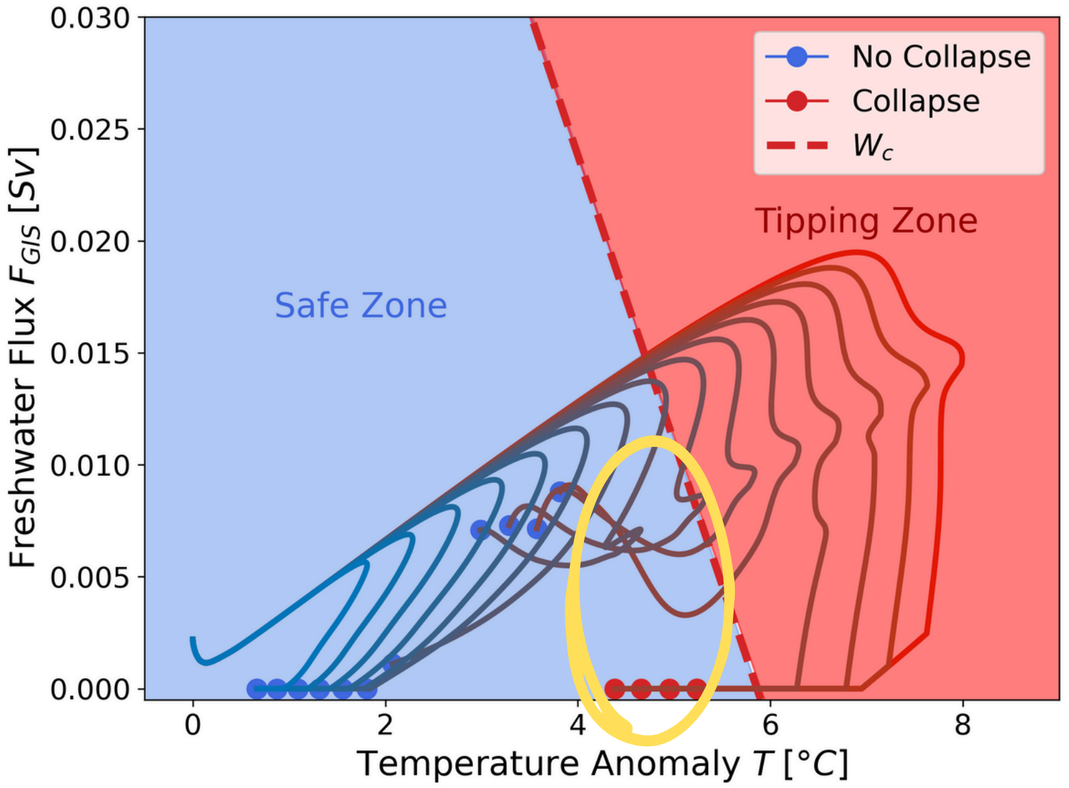
Laridon et al. (2025) *in review*

Results – A Tool to Sample the Forcing Space

- The **bifurcation threshold** is **exceeded** for the **8 highest emission scenarios**

- **Hysteresis** phenomena

AMOC Trajectory its Forcing Space

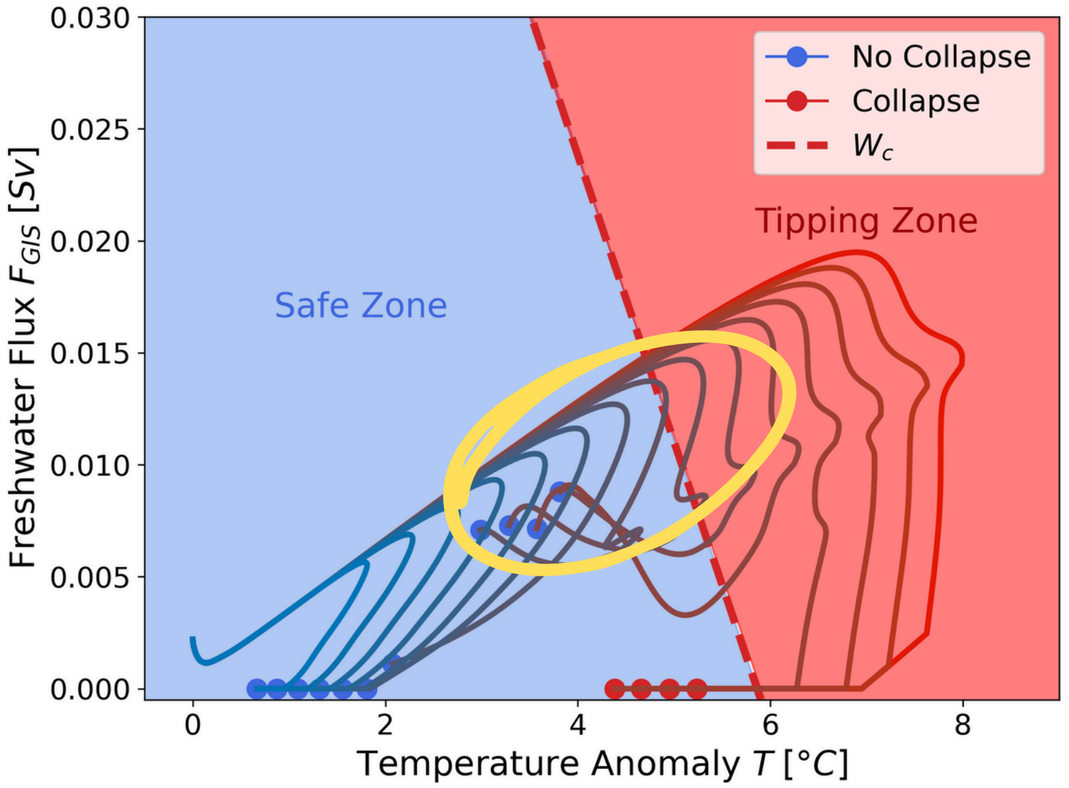


Laridon et al. (2025) *in review*

Results – A Tool to Sample the Forcing Space

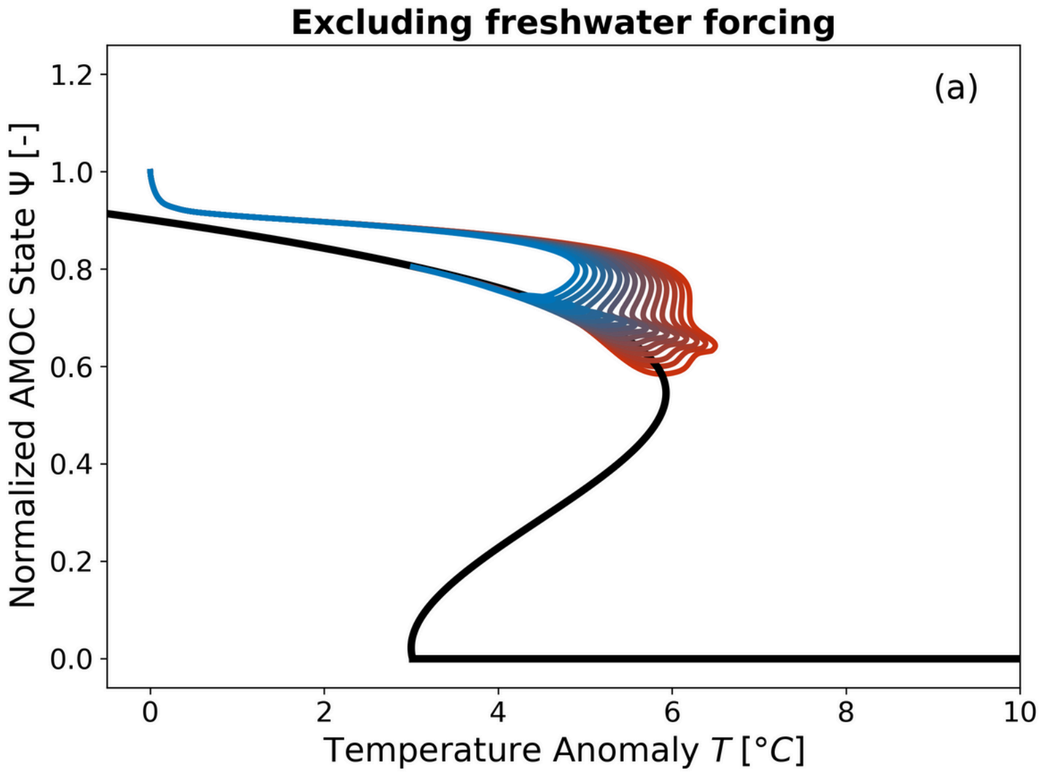
- The **bifurcation threshold** is **exceeded** for the **8 highest emission scenarios**
- **Hysteresis** phenomena
- **4 trajectories** exhibit an **overshoot without tipping**

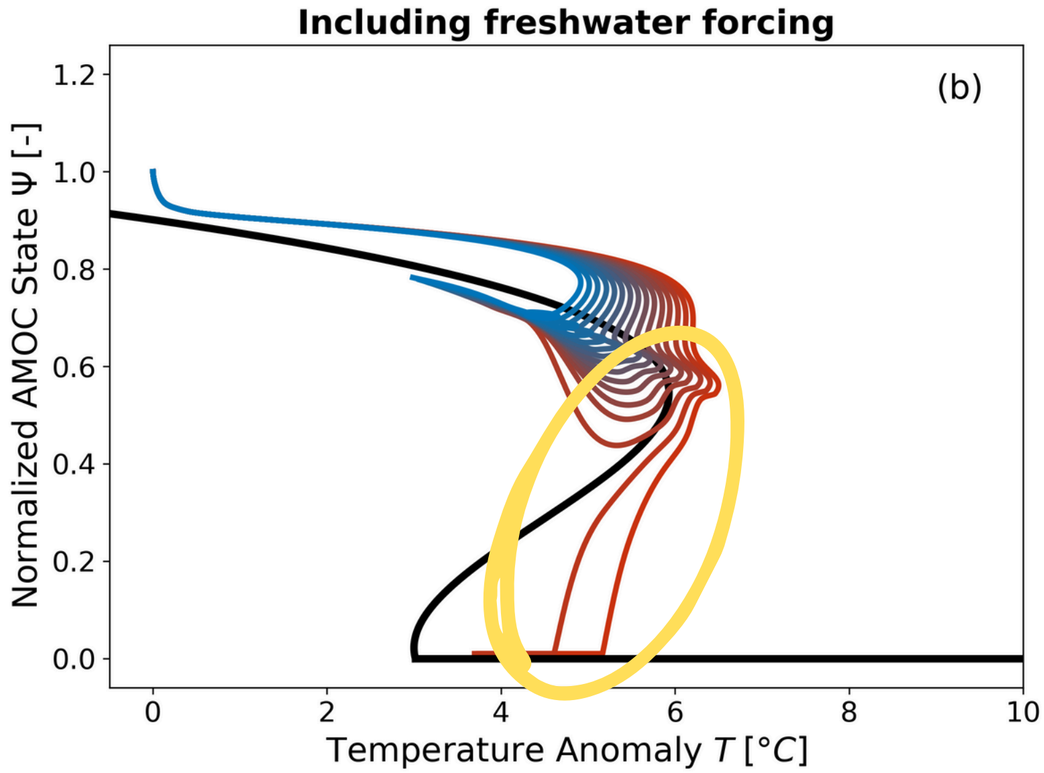
AMOC Trajectory its Forcing Space



Laridon et al. (2025) *in review*

Results - New Collapse Trajectories Captured with a 2 Forcing Emulator





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Key Message

Open Research Europe

Connecting complex and simplified models of tipping elements: a nonlinear two-forcing emulator for the Atlantic meridional overturning circulation

Amaury Laridon[1, 2], Victor Couplet[2], Justin Gérard[2], Wim Thiery[1], Michel Crucifix[2]

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→ **First two-forcing AMOC tipping element emulator** that reasonably reproduces the behaviour of the complex model it emulates.

→ **Emulator captures two new AMOC collapse** trajectories and **one overshoot without tipping**, under **emission scenarios ranging** from **SSP3-7.0** to **SSP5-8.5**.

→ **Tool** to **map** the **forcing configurations** that **lead** to the **collapse** of the **tipping element** in the complex model.

→ **Method** is **easily generalizable** to other tipping elements and applicable to other reduced-complexity climate models.