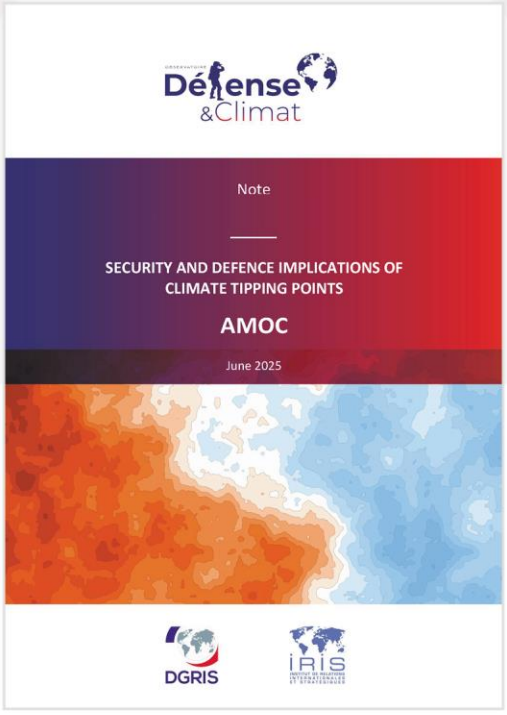
SUMMARY

SECURITY AND DEFENCE IMPLICATIONS OF CLIMATE TIPPING POINTS: AMOC

June 2025



The Defence and Climate Observatory, launched in December 2016, aims to study climate-related security and defence issues.

It is coordinated by IRIS as part of the contract carried out on behalf of the French Ministry of Armed Forces's Directorate General for International Relations and Strategy (DGRIS). The Observatory's multi-disciplinary team includes researchers specializing in international relations, security, defence, migration, energy, economics, climatology and health. It is directed by Mathilde Jourde and François Gemenne.

The Observatory has initiated numerous collaborations with European partners (Netherlands, Luxembourg) and international partners (Australia, United States, India), international NGOs and national and international public bodies. These initiatives have strengthened cooperation on climate issues and their security implications.

The Climate and Defence Observatory produces reports and notes, organises restricted seminars and conferences open to the public, and hosts the podcast "On the climate front".

www.defenseclimat.fr/en

The Ministry of Armed Forces regularly calls upon private research institutes for outsourced studies, using a geographical or sectoral approach to complement its external expertise. These contractual relationships are part of the development of the defence foresight approach, which, as emphasised in the White Paper on Defence and National Security, *"must be able to draw on independent, multidisciplinary and original strategic thinking, integrating university research as well as specialised institutes*".

Many of these studies are made public and available on the Ministry of Armed Forces website. In the case of a study published in part, the Directorate General for International Relations and Strategy may be contacted for further information.

DISCLAIMER: The Directorate General for International Relations and Strategy or the organisation leading the study cannot be held responsible for the statements made in the studies and observatories, nor do they reflect an official position of the Ministry of Armed Forces.

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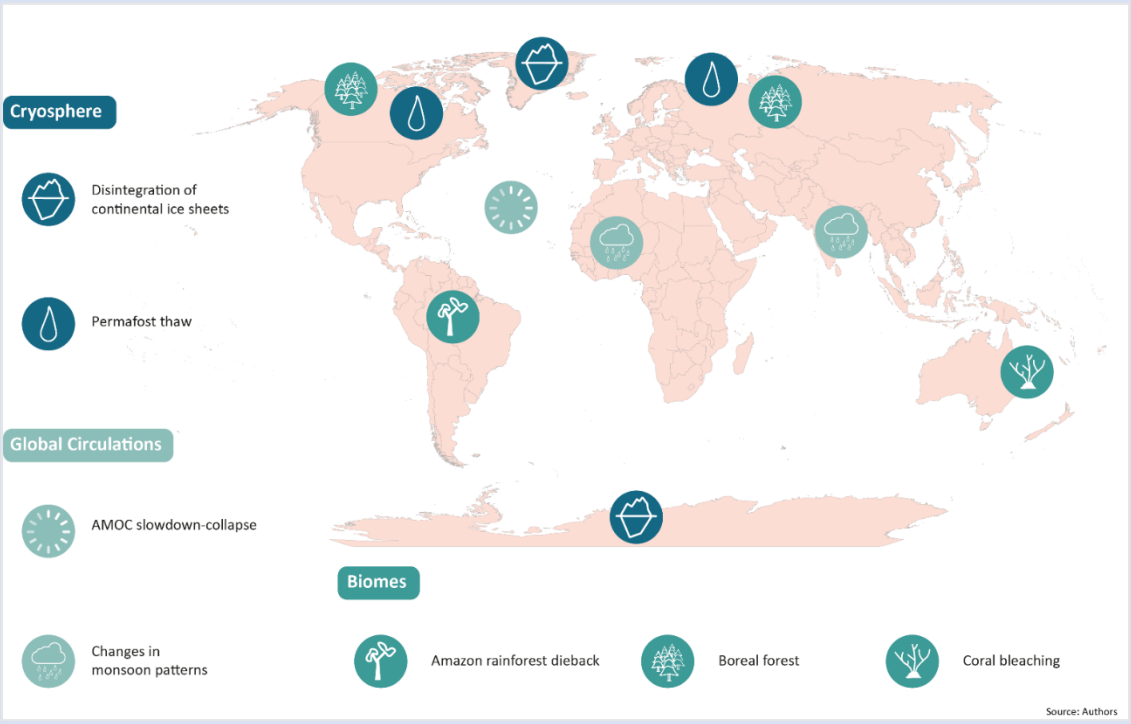
This note is part of a forthcoming series, focusing on the **security and defence implications of climate tipping points. This initial note studies the Atlantic Meridional Overturning Circulation (AMOC)**. The first part of this note aims to explain **the main mechanisms of this circulation**, as well as the security implications of its slowdown or potential collapse. The second part offers avenues for reflection on how **to incorporate such implications and weak signals of the AMOC tipping into defence strategies**.

Climate Tipping Points

A tipping point is conceived as **a level of change in the properties of a given system beyond which it reorganises itself, often in a nonlinear manner** (IPCC, 2019).

When referring to the climate system, the term is defined by a **critical threshold beyond which global or regional climate change from a stable state to another stable state**.

Figure 1 – Map displaying main climate tipping points



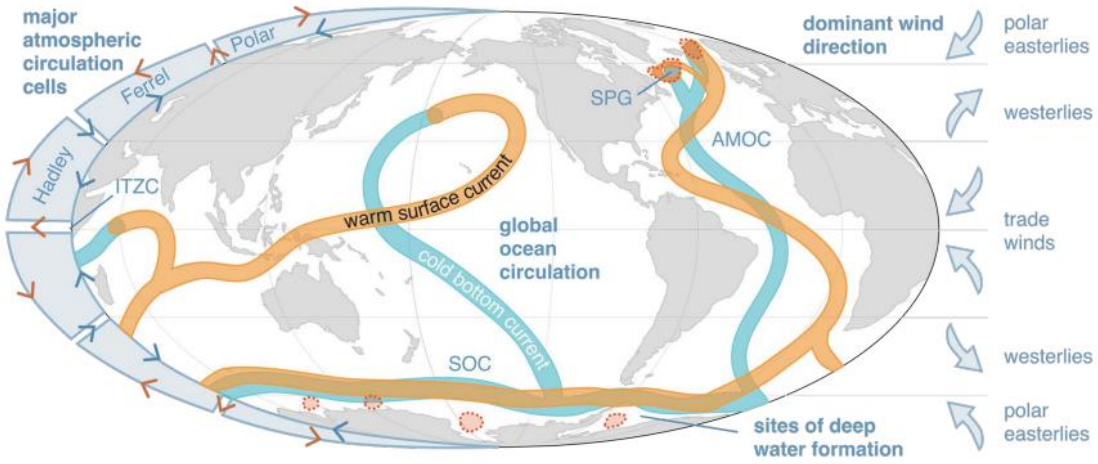
The **uncertainties surrounding tipping points should not undermine the relevance of integrating climatic tipping points into security and defence policies. Excluding from a strategic radar an event with a low probability of occurrence but potentially devastating consequences would be a risky choice**.

I. UNDERSTAND THE AMOC AND ITS SECURITY IMPLICATIONS

The AMOC is **one of the branches of the global ocean circulation**. It is characterised by the **transport of warm, salty water at the surface from South Africa to the Northern Atlantic**, and cold water at depth from the north to the south of the Atlantic. This heat transfer enables Europe to experience a more temperate climate than North America at similar latitudes. As the water moves towards higher latitudes, part of the ocean heat is transferred to the atmosphere, causing **the surface waters to become colder and denser, eventually leading them to "sink".**

Figure 1 – Global ocean circulations, deep water formation zones and major atmospheric circulation cells

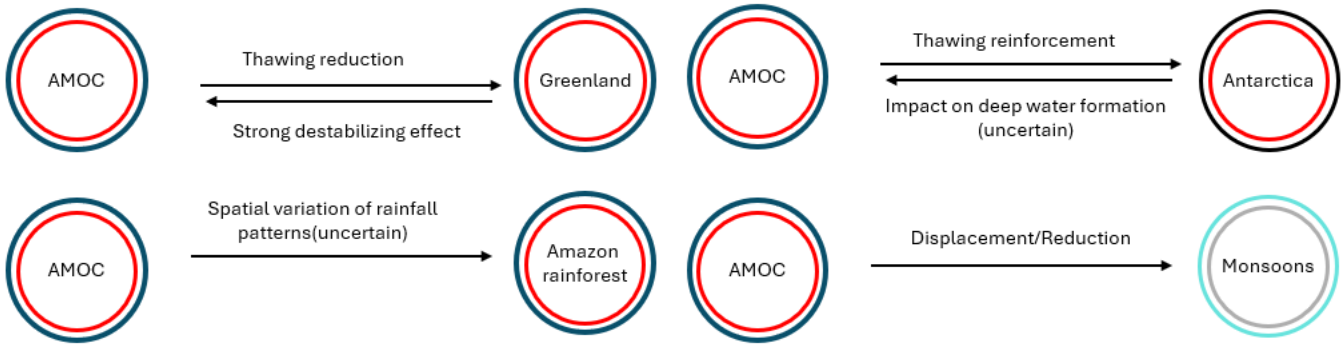
***ITZC** : Inter-Tropical Convergence Zone ; **SOC** : Southern Ocean Circulation ; **SPG** : Sub-Polar Gyre (see Part 2. 1.1)*



Source: Lenton *et al.*, 2023

The state of the AMOC is therefore **a key element in the stability of the climate system**. However, the consequences of climate change could lead to its **slowdown or even complete shutdown**, profoundly disrupting the climate. This is why the AMOC is considered a **tipping point** which, due to its global scale, could strongly interact with other tipping points.

Figure 2 – Interactions between the AMOC and other climate tipping points



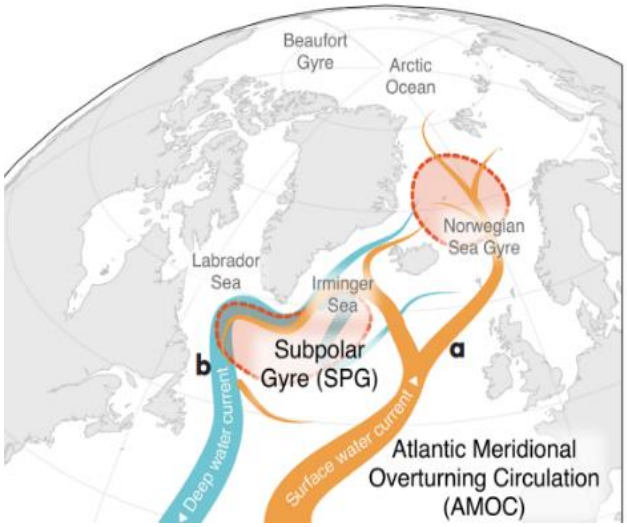
Sources: Lenton *et al.,* 2023; Ben Yami *et al.,* 2024

The first-order impacts of the AMOC (temperatures and precipitation collapse in Europe, changes in monsoon patterns, increase in extreme weather events and ocean stratification, etc.) **would trigger cascading effects with major consequences for European security** (decline in agricultural yields and energy production, **degradation of submarine and anti-submarine warfare capabilities**, etc.).

II. INTEGRATE THE AMOC TIPPING INTO DEFENCE STRATEGIES

Studying climate tipping points for defence foresight purposes involves preparing systems for the occurrence of such an event. This preparation requires: **I) the ability to detect the destabilisation** of the climate system, and **II) the anticipation of necessary adaptations to infrastructure, equipment, and practices** in response to the resulting deterioration of living and operating conditions. These two objectives call for close monitoring of scientific research focused on **key early warning signals**. Better understanding of the AMOC should make it possible to better understand the **transition interval.** The aim is to assess how long it would take for a massive cooling of European climates to occur. Some publications **suggest a transition period of 15 to 300 years**, whereas others point to an interval of **just a few decades, or even a few years**. However, **even an AMOC slowdown alone could generate significant climate changes.** In this second part of the note, the authors recommend **monitoring scientific developments related to the subpolar gyre, which remains one of the most promising potential early warning signal of major AMOC destabilisation.**

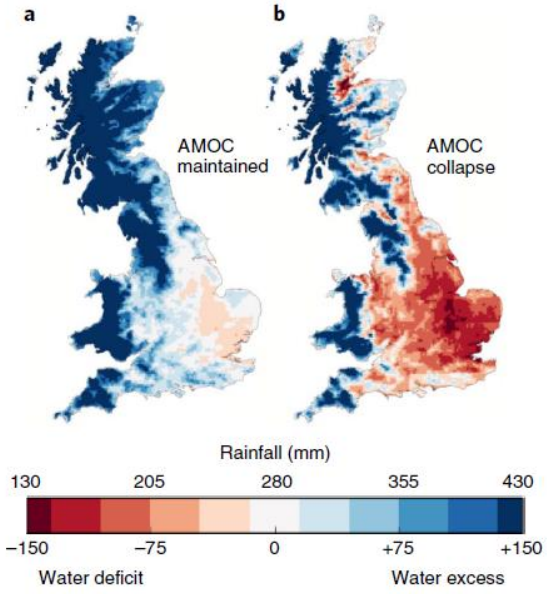
Figure 3 – Schematic representation of the subpolar gyre, located at the core of AMOC's deep water formation process



Source: Lenton *et al.*, 2023

Given the rapidly evolving body of knowledge on this topic, it is useful to identify **the main actors working on the security implications of the AMOC**. The United States (US), the United Kingdom (UK), and more recently the European Union (EU) host the most advanced projects on these issues. **The UK agency ARIA,** modelled on DARPA, **invested £81 million at the beginning of 2025** in a project aimed at identifying early warning signals of tipping points. Several other studies have also been published by British researchers or institutions. In addition, a **letter signed by 43 scientists** was sent to the Nordic Council of Ministers**, highlighting the major risk posed by the crossing of climate tipping points**, and the AMOC in particular.

Figure 4 – British water balance in 2080 during the growing season, with irrigation available, under climate scenarios for which the AMOC is either maintained or collapsed.



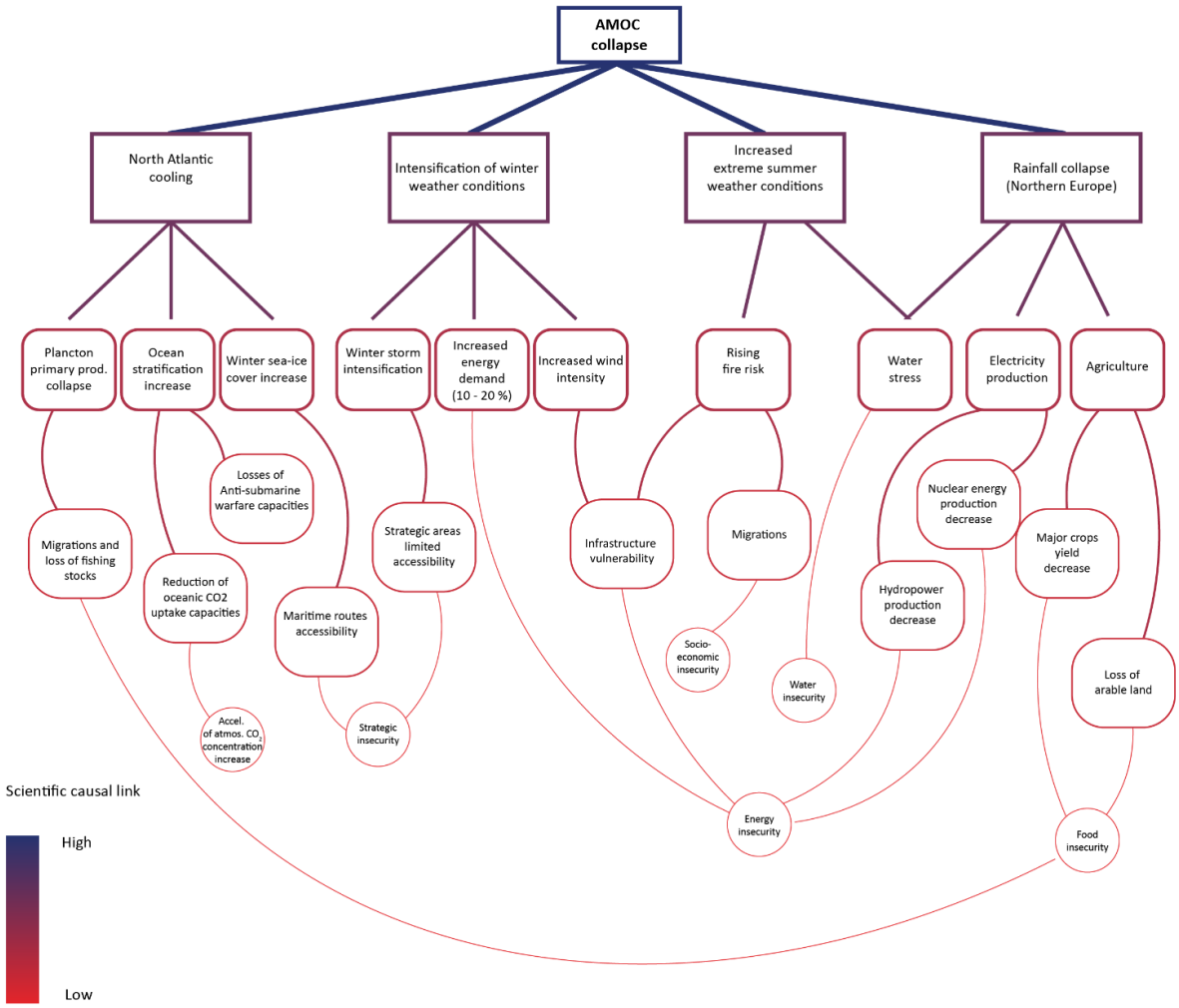
Water deficit (<280mm) during the growing season (April to September) where irrigation occurs (in red), and areas with excess of water (>280mm) (in blue) during the growing season. **On the map (a) AMOC is maintained**, whereas it is **collapsed on the map (b).**

Source : Ritchie *et al.,* 2020

The nature of the work being carried out is also a key factor: the review conducted for this note highlights the importance, beyond scientific studies, of **using foresight to overcome data collection limitations and inform strategic thinking**. As early as the 2000s, the US Department of Defense commissioned a foresight study on the collapse of the AMOC. The *Global Tipping Points Report* (2023), a scientific review of key work on climate tipping points, includes a scenario involving the collapse of the AMOC, which would lead to a **rapid decline in habitability conditions in Europe and a growing sense of resentment among European populations**. This body of work demonstrates that **an AMOC collapse could destabilise the security of Northern and Western Europe**. It is therefore essential to establish mechanisms for **monitoring scientific findings** on this issue to improve preparedness, and to develop parallel response and crisis management scenarios.

Appendix 1. Diagrams

Figure 10 – Schematic representation of the main cascading impacts of the AMOC slowing or collapse and representation of associated scientific causality level of confidence

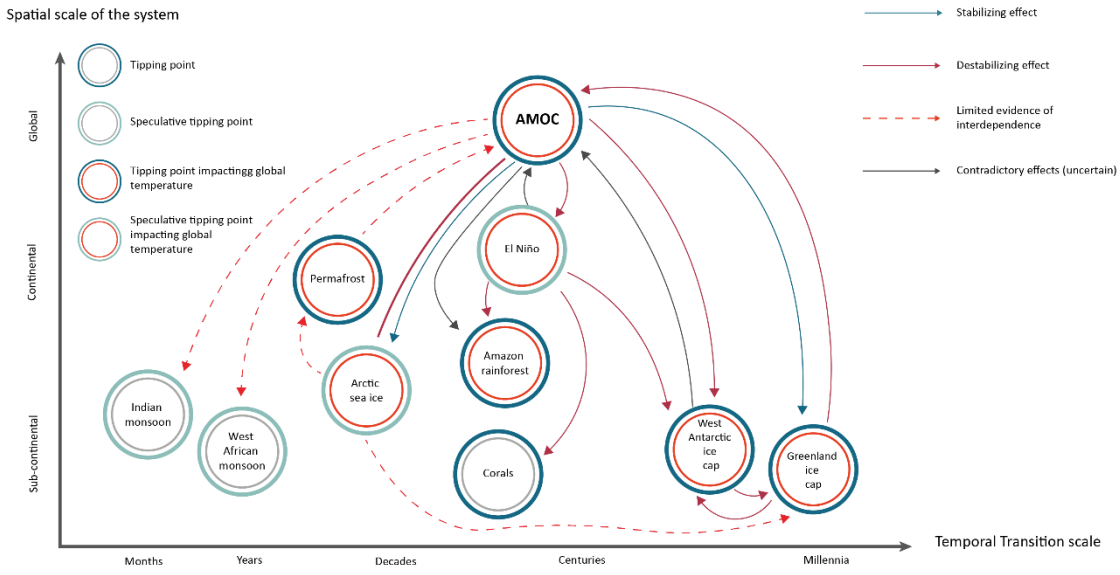


Source: authors

Figure 5 – Main feedback loops between tipping points

Some systems remain speculative about their ability to exhibit multiple stability states.

Adapted from Lenton *et al.*, 2022



Appendix 2 – Ongoing research projects aiming at enhancing the understanding of AMOC system and consequences of a potential collapse

Funder	Name	Duration	Budget	Coordination	Objectives
France	**LOCEAN** *Laboratoire d'Océanographie et du Climat : Expérimentations et Approches Numériques*	2005 -	2,7 M €/an	Sorbonne Université	LOCEAN conducts numerous research projects related to the AMOC, through oceanographic, climatological, and paleoclimatic studies. For more information.
	MARCARA *(MArine radioCArbon Reservoir Age)*	2021-2025	526 K € (ANR)	Université d'Aix en Provence	Observe and model the evolution in time of surface waters and their implications for paleoceanography, paleoclimatology, and geochronology. For more information.
European Union	**EPOC** (*Explaining and Predicting the Ocean Conveyor*)	2022-2027	4,8 M €	Hamburg University (Germany)	Develop models to understand the consequences of an AMOC slowdown on weather and climate (several days to years). For more information.
	ROVER (*Resilient Northern Overturning in a Warming Climate*)	2024-2028	3 M€	Bergen University (Norway)	Understand whether icecap retreat could impact AMOC's behavior, particularly by strengthening it (counter to expectations). For more information.
	TipESM (*Exploring Tipping Points and Their Impacts Using Earth System Models*)	2024-2027	4,8 M€	13 consortiums and institutions	Understand tipping points, particularly early warning signals and emission trajectories limiting the risk of tipping. For more information.
	Joint Action on AMOC	2024-2026	/	JPI Climate and JPI Ocean	Produce a report updating AMOC scientific knowledge since IPCC's 6th Assessment Report, as well as its potential impacts over populations.
	Medley (*MixED Layer hEterogeneitY*)	2020-2024	/	LOPS – CNRS	Improve the understanding of the spatial heterogeneity of surface waters and its impacts on energy, heat, and gas exchanges. For more information.
United Kingdom	**Forecasting Tipping Points**	2025-2030	81 M£	27 Teams	Identify tipping points' early warning signals. For more information.
Germany	**TIPMIP** *(tipping point modelling intercomparison project)*			Earth Commission, Max Planck, Postdam Institute	Identify early warning signals and study the risks associated with simultaneous tipping of several climate sub-systems. For more information.
United States	**Quantifying Global and Regional Impacts of the AMOC Slowdown in the 21st century**	2021-2026	324K€	Yale University (United States)	Understand local and global impacts of an AMOC slowdown, particularly the cooling of the North Atlantic Warming Hole. For more information
	EXPLANATIONS *(Exploring AMOC controls on the North Atlantic carbon sink using novel inverse and data-constrained models)*	2024-2027	440K€	MIT (United States)	Refine the estimation of carbon dioxide uptake, transport, and storage capacities in the North Atlantic, as well as the role of AMOC in the variability of these capacities. For more information.

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