LATE REQUEST FOR A SPECIAL PROJECT 2025–2027

MEMBER STATE:	Italy
Principal Investigator[1]:	Andrea Vito Vacca
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Project Title:	Simulating the 8.2ka event: a contribution to the TIPMIP-OCEAN project

Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	**2026**	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for project year:		**2025**	**2026**	**2027**
High Performance Computing Facility	[SBU]	0	22.500.000	0
Accumulated data storage (total archive volume)[2]	[GB]	0	25	0

EWC resources required for project year:		**2025**	**2026**	**2027**
Number of vCPUs	[#]			
Total memory	[GB]			
Storage	[GB]			
Number of vGPUs[3]	[#]			

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide annual progress reports of the project's activities, etc.
[2] These figures refer to data archived in ECFS and MARS. If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year etc.
[3]The number of vGPU is referred to the equivalent number of virtualized vGPUs with 8GB memory.

1. Extended abstract

Tipping points are critical thresholds in the Earth system beyond which small perturbations can trigger abrupt, non-linear transitions to qualitatively different states. Such transitions are often irreversible on human timescales and may entail profound socioeconomic consequences (Lenton et al., 2008). As a result, Earth system tipping points represent one of the key uncertainties in the evolution of ongoing anthropogenic climate change (Lenton et al., 2025).

The Tipping Point Modeling Intercomparison Project (TIPMIP) is a global collaborative initiative designed to reduce these uncertainties by systematically investigating tipping dynamics across major Earth system components, including the biosphere, ocean, ice sheets, and permafrost (Winkelmann et al., 2025). TIPMIP aims to achieve this through the intercomparison of standardized numerical experiments conducted with an ensemble of Earth System Models, enabling robust assessment of model agreement, process understanding, and uncertainty sources.

The proposed special project contributes to TIPMIP within the ocean domain (TIPMIP-OCEAN) and focuses specifically on the Atlantic Meridional Overturning Circulation (AMOC). The AMOC is widely recognized as one of the most critical tipping elements of the Earth system (Broecker 1997), as recent studies suggest that anthropogenic climate change may be pushing the AMOC closer to its critical threshold than previously assumed, with the potential for a complete shutdown of the circulation (Ditlevesen and Ditlevesen, 2023; van Westen et al. 2024),

Evidence from paleoclimate records further supports the existence of nonlinear AMOC dynamics. Past periods of abrupt climate change have been linked to AMOC instabilities, most notably during transitions between glacial and interglacial states (Rahmstorf, 2002). Even during the Holocene, the last geological epoch characterized by stable climatic conditions, proxy records document several abrupt cooling events associated with AMOC sensitivity to freshwater forcing (Wanner et al., 2011). The most prominent of these is the **8.2 ka event**, characterized by a rapid Northern Hemisphere cooling of approximately 1–3 °C (Lochte et al., 2019). This event was triggered by the sudden release of large volumes of freshwater from the remnants of the Laurentide Ice Sheet into the North Atlantic (Barber et al., 1999; Lochte et al., 2019). The resulting surface freshening reduced seawater density, weakened deep-water formation, and led to an abrupt slowdown of the AMOC. Altought the dynamics and the implications of the 8.2 kya event have been widely investigated, is still unknown how well Earth System Models are able to reproduce the response of the AMOC to such event (Gregoire and Morrill, 2021).

Therefore, following the TIPMIP-OCEAN protocol (experiment D), this special project aims to perform climate model experiments that simulate the AMOC response to an 8.2 ka–like event. This experiments will contribute to the understanding of the AMOC resilience in Earth System Models and the timescales of its return to a pre-perturbation state.

2. Proposed activity

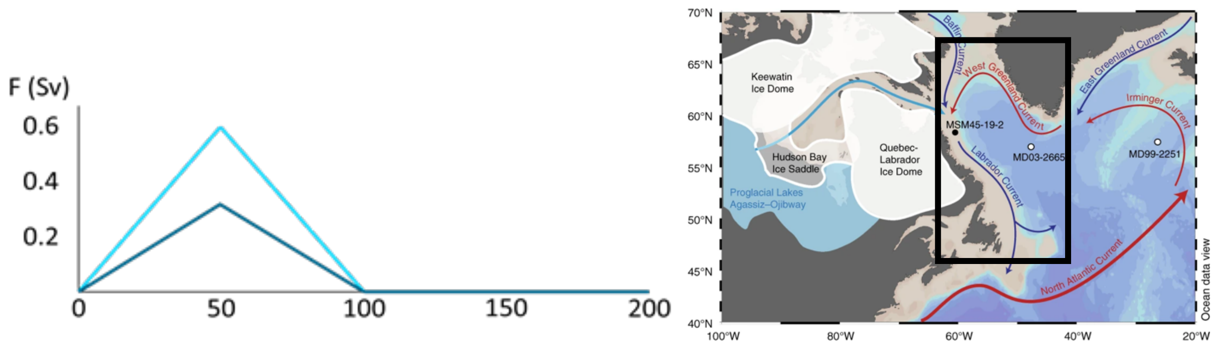
2.1 Climate model

We plan to conduct model experiments using EC-Earth3, a cutting-edge global climate model developed by the Earth System Model (ESM) consortium which partecipated in the CMIP6 (Coupled Model Intercomparison Project Phase 6) (Döscher et al., 2021). Compared to the version of the model used in the CMIP6, the last version of the model (v3.3) includes several improvemens and bug fixes.

The model consists of several components: the atmospheric model ECMWF IFS cy36r4, the ocean model NEMO3.6 with the LIM3 sea ice component, a dynamic vegetation model LPJ-GUESS, a dynamical Greenland Ice Sheet and a closed carbon cycle. We plan to run EC-Earth3 at its standard resolution, which utilizes a spectral truncation of TL255 with 91 vertical levels for the atmosphere, and an ORCA1 grid with 75 vertical levels for the ocean, corresponding to a horizontal resolution of approximately 80 km in the atmosphere and 100 km in the ocean, with a grid refinement to around 40 km in the tropical ocean. EC-Earth3 is already installed and used on the ATOS machine of ECMWF.

2.2 Climate experiments

We plan to run TIPMIP-OCEAN *experiment D*, following the latest available version of the experimental protocol (Jackson et al., 2025). The experiments consist in the application of a freshwater forcing that mimics the 8.2ka event. In particular, the experiments will start from a pre-industrial control integration and will include a ramp-up and ramp-down freshwater forcing in the Labrador Sea over a period of 100 years. Given the large uncertainty in the magnitude of freshwater injected during the 8.2ka event, the protocol prescribes two experiments with two different freshwater forcing rates (Jackson et al., 2025). The first experiment (D1) is such that a 0.3 Sverdrup (Sv) increase in freshwater is reached on a time span of 50 years, following the estimation of Lochte et al. (2019). The second experiment (D2) is such that a 0.6 Sverdrup (Sv) increase in freshwater is reached on a time span of 50 years, following Matero et al., (2017). Then both experiments include a stabilization for additional 100 years. The figure below shows a schematic of the time evolution of the freshwater forcings and the region where the forcing is applied. Additional details about the experimental protocol will be reported in a related paper to be published in 2026.



Left: Freshwater forcing over simulation years in D1 (dark blue) and D2 (light blue) experiments.

Right: The black shape over the map represents the region where the forcing will be applied. Adapted from Lochte et al., (2019).

3. Justification of computer resources requested

According to test performed by partners of the EC-Earth consortium on the ATOS machine, the optimal configuration for the experiment consists of 1173 cores on 10 computational nodes. With this configuration and at the standard model resolution the model runs with 45.000 SBU per year.

The required computational resources are summarized in Table 1. A total of 22.500.000 SBU is required, with a storage necessity of 25 TB (0.05 TB per year).

Model configuration	Experiments	Model years	Resources (SBU)	Storage (TB)
8.2ka event simulation	D.1	200	9.000.000	10
	D.2	200	9.000.000	10
	Extra (for testing/issues)	100	4.500.000	5
Total model years	500			
Total resources	22.500.000 SBU			
Total storage	25 TB			

References

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