SPECIAL PROJECT PROGRESS REPORT

All the following mandatory information needs to be provided. The length should *reflect the complexity and duration* of the project.

Reporting year	2022
Project Title:	Impacts of Atlantic Meridional Overturning Circulation (AMOC) decline on European climate
Computer Project Account:	spitbell
Principal Investigator(s):	Katinka Bellomo
Affiliation:	Department of Environment, Land and Infrastructure Engineering, Polytechnic University of Turin, Turin, Italy
Name of ECMWF scientist(s) collaborating to the project (if applicable)	N/A
Start date of the project:	01/01/2021
Expected end date:	31/12/2022

Computer resources allocated/used for the current year and the previous one

(if applicable)

Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	9,880,000	9,880,000	9,450,000	3
Data storage capacity	(Gbytes)	18,000	N/A	33,000	N/A

Summary of project objectives (10 lines max)

The objectives of this project are to investigate the nonlinear response of the AMOC to increasing concentrations of CO_2, and the associated weather impacts of an AMOC decline over the European climate. To address these objectives, we proposed to run ad-hoc climate model experiments using the EC-Earth3 coupled climate model with varying degrees of coupling between the atmosphere and the ocean, specifically using the model in fully-coupled mode (ocean and atmosphere fully coupled) and in atmospheric-only mode, in which the atmospheric model is forced by a 12-month climatology of sea surface temperature (SST) pattern computed from the fully-coupled simulations.

Summary of problems encountered (10 lines max)

We didn't encounter specific problems, however we approached the objectives in a slightly different manner. Instead of running simulations with increasing concentrations of CO_2, we started by performing experiments in which the AMOC is artificially weakened imposing a freshwater flux (often referred to as 'water hosing' experiment) in the North Atlantic and Arctic Oceans. We decided to opt for this different experimental design to better separate the role of AMOC from the effects of CO_2, which we will explore next. In this past year, we completed the simulations and the analysis of the climate impacts of a weaker AMOC and we have a draft that will be ready for submission by the end of the summer.

Summary of plans for the continuation of the project (10 lines max)

We plan to continue this project by running simulations in which in addition to the water hosing we will also increase the concentration of greenhouse gases, and one additional control simulation in which we only increase greenhouse gases but we don't modify the strength of the AMOC. With these new simulations we will be able to assess the relative roles of AMOC decline and increasing concentration of greenhouse gases on the European and global climate. We focused so far on mechanisms of precipitation change and we plan to further analyze changes in precipitation extremes and water availability.

List of publications/reports from the project with complete references

- (presentation) Jackson L.C., and Coauthors: "AMOC thresholds in CMIP6 models: NAHosMIP", *European Geophysical Union General Assembly*, May 23-27, 2022, Vienna, Austria

- (peer-reviewed paper) Bellomo K., Meccia V. L., D'Agostino R., Fabiano F., Larson S., von Hardenberg J., Corti S., in prep.: Climate impacts of a weaker AMOC over the Euro-Atlantic region in the EC-Earth3 climate model.

- (presentation) Bellomo K., V. Meccia, F. Fabiano, R. D'Agostino, J. v. Hardenberg and S. Corti: "The climate impacts of an abrupt AMOC weakening on the European winters*",* *European Geophysical Union General Assembly*, May 23-27, 2022, Vienna, Austria

- (presentation) "Global and regional impacts of an abrupt AMOC decline", *Potsdam Institute for Climate Impact Research*, December 15, 2021, online

- (peer-reviewed paper) Bellomo K., M. Angeloni, S. Corti, and J. von Hardenberg, 2021: Future climate change scenarios shaped by inter-model differences in Atlantic Meridional Overturning Circulation response. Nature Communications 12, 3659.

- (presentation) Bellomo K., V. Meccia, F. Fabiano, R. D'Agostino, P. Davini, J. v. Hardenberg and S. Corti. Weather impacts of an AMOC decline in the EC-Earth climate model: *TiPES General Assembly*, 7-11 June, 2021, online.

- (presentation) Jackson L.C., R.A. Wood, K. Bellomo, G. Danabasoglu, A. Hu, J. Jungclaus, V. Meccia, O. Saenko, D. Swingedouw: AMOC tipping points in GCMs. *TiPES General Assembly*, 7-11 June, 2021, online.

- (presentation) Bellomo K., M. Angeloni, S. Corti, J. von Hardenberg: "Future climate change scenarios shaped by inter-model differences in Atlantic Meridional Overturning Circulation response", *International workshop for mid-latitude air-sea interaction*, June 12-14, 2021, online.

- (presentation) Bellomo K., M. Angeloni, S. Corti, J. von Hardenberg: "Future climate change scenarios shaped by inter-model differences in Atlantic Meridional Overturning Circulation response", *European Geophysical Union General Assembly*, April 19-30, 2021, online.

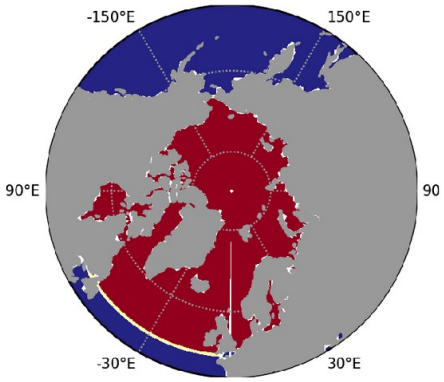
- (presentation) Bellomo K.: "Future climate change scenarios shaped by inter-model differences in Atlantic Meridional Overturning Circulation response", *TiPES monthly seminar*, February 3, 2021, online.

Summary of results

The results of the simulations run at ECMWF over the course of this special project have been prepared and are ready for submission to a peer-reviewed journal (Climate Dynamics) by the end of this summer. Here I will summarize a few notable results of this work.

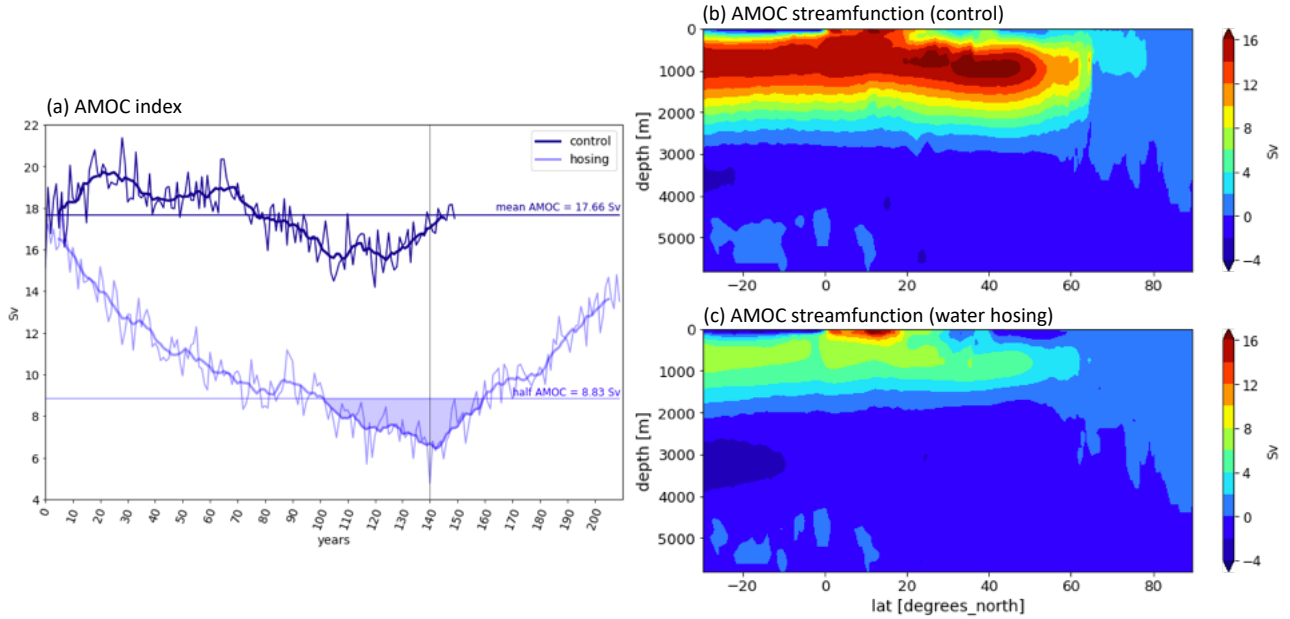
We ran EC-Earth3 in its standard resolution (T255L91, ORCA1L75) to run a control simulation with preindustrial forcing and a water hosing simulation obtained imposing a freshwater anomaly in the red region of fig. 1 and a compensating salinity flux globally. To obtain a stable simulation with acceptable results, we had to make several attempts. We also ran a few simulations with a smaller freshwater flux and our runs will be included in the NAHosMIP inter-model comparison.

Figure 1: The 0.3 Sv freshwater flux anomaly is applied in the red regions.



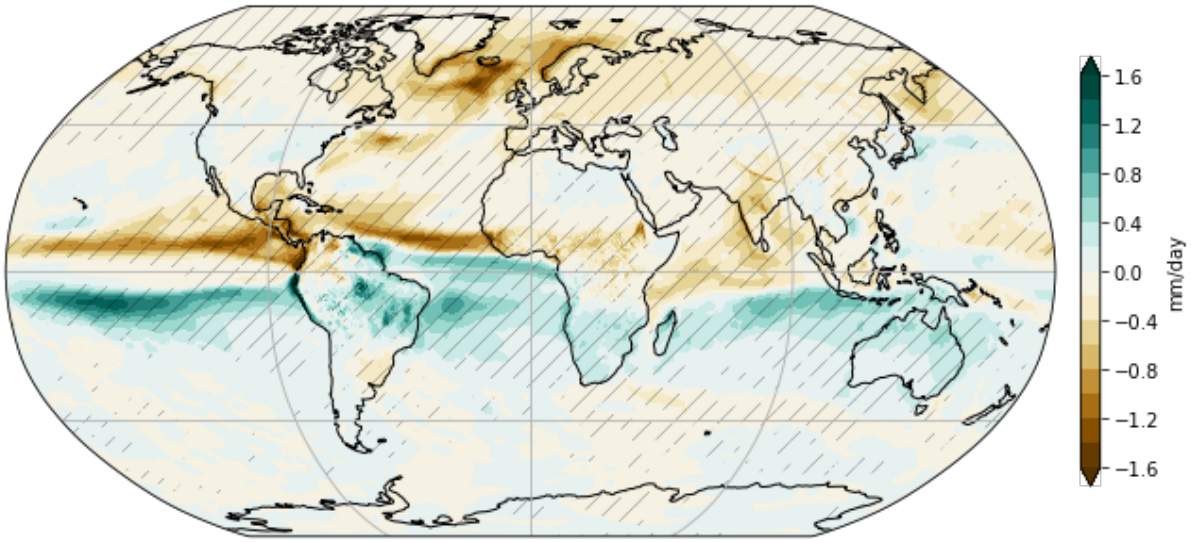
As a result of our attempts we were able to obtain a 200 years long simulation in which the AMOC declines for approximately 140 years, after which we stop the hosing and let the model to freely recover (fig. 2).

Figure 2: (a) AMOC index, (b) and (c) meridional overturning stream-function in the Atlantic Ocean.



We focused our analysis on mechanisms of precipitation change in the years were the AMOC is consistently weaker compared to the control climate (purple shading in fig. 2), finding that despite an overall drying in the northern hemisphere, there exist regions where precipitation is projected to increase (fig. 3).

Figure 3: Annual mean precipitation change.



We applied the atmospheric moisture budget to assess the relative roles of dynamic and thermodynamic processes in driving precipitation changes in the Euro-Atlantic sector. We found that thermodynamic processes alone are insufficient to explain the overall drying, while transient eddies containing both dynamic and thermodynamic processes are able to explain the overall pattern of precipitation change. We also applied a clustering algorithm to calculate changes in weather regimes, and we found a significant increase in NAO+ days, which we found consistent with wind circulation and precipitation changes.