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	2019
Project Title:	Sensitivity experiments on decadal prediction
Computer Project Account:	SPITMECC
Principal Investigator(s):	Virna Loana Meccia
Affiliation:	Institute of Atmospheric Sciences and Climate, National Research Council (ISAC-CNR), Italy.
Name of ECMWF scientist(s) collaborating to the project (if applicable)	-
Start date of the project:	01-01-2019
Expected end date:	31-12-2021

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)	-	-	9,500,000	4,806,336.71
Data storage capacity	(Gbytes)	-	-	15,000	5,150

Summary of project objectives (10 lines max)

The original special project has the aim of exploring the role of the ocean decadal variability on global climate. Of particular interest is how the North Atlantic and North Pacific sea surface temperature modulate the global surface temperature trends and the regional climate variability in Europe. The original plan was to apply EC-Earth version v3.2.2. to a series of experiments designed following the Decadal Climate Prediction Project.

Summary of problems encountered (10 lines max)

We have recently analysed some coupled EC-Earth existing simulations. They were run in the context of the Climate SPHINX project and consist of coupled simulations in which three ensemble members constitute the control runs (*base*) and three ensemble members include stochastic physics (*stoc*) in the atmospheric component of EC-Earth. The period of simulation spans from 1850 to 2100 and the RCP8.5 scenario is used for the future forcing. By analysing those runs we have found that in the very end of the simulation, each of the *base* ensemble members seems to simulate the beginning of an abrupt collapse of the winter sea-ice extent in the Arctic. This feature is not present in the *stoc* runs. We have considered of utmost importance to extend those simulations to quantify the timing of the "probably" winter free of sea-ice in the NH. Therefore, we have deviated from the original plan and we have used the special project's computing time to extend for 60 years each of the above-mentioned simulations.

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

Depending on the results from the extension of the SPHINX simulations, we plan to use the rest of the resources for this year either to:
a) further extend the SPHINX simulations;
b) run a *base* and a *stoc* experiment in a regressive way. That is from 2160 to 1850;
c) start with the original project.

List of publications/reports from the project with complete references

Some preliminary results of the extended period have been presented in international meetings:

- Meccia V., Fabiano F., Corti S. and Davini P. Arctic sea-ice evolution in EC-Earth 3.1 simulations: sensitivity to Stochastic Physics. *EC-Earth Meeting*, 21-23 May 2019, ECMWF, Reading, UK.
- Meccia V., Fabiano F. and Corti S. Impact of stochastic physics on climate simulations with EC-Earth: looking at the ocean. Oral presentation. Geophysical research abstracts Copernicus GmbH, Vol. 21, EGU2019-18332, 1 pp. Electronic ISSN: 1607-7962; Printed ISSN: 1029-7006. *European Geosciences Union.*
- Meccia V., Fabiano F. and Corti S. Impact of stochastic physics on climate simulations with EC-Earth: looking at the ocean. Poster. *CMIP6 Model Analysis Workshop*, 25-28 March 2019, Barcelona.
- Fabiano F., Meccia V. and Corti S. Impact of stochastic physics on climate simulations with EC-Earth: looking at the atmosphere. Poster. *CMIP6 Model Analysis Workshop*, 25-28 March 2019, Barcelona.

A peer-reviewed paper is in preparation.

Summary of results

If submitted **during the first project year**, please summarise the results achieved during the period from the project start to June of the current year. A few paragraphs might be sufficient. If submitted **during the**

second project year, this summary should be more detailed and cover the period from the project start. The length, at most 8 pages, should reflect the complexity of the project. Alternatively, it could be replaced by a short summary plus an existing scientific report on the project attached to this document. If submitted **during the third project year**, please summarise the results achieved during the period from July of the previous year to June of the current year. A few paragraphs might be sufficient.

We analyze the potential effects of including stochastic physics schemes in the atmospheric component of the EC-Earth model on the evolution of the sea-ice extent in the Arctic during long-term simulations covering the historical and future periods.

The simulated Arctic sea-ice extent in September and March (Fig. 1) displays an overall decrease. The sea-ice loss is faster in the *base* experiments than in the *stoc* ones. An Arctic free of sea ice (less than 1×10^6 km^2 of sea-ice extent for at least 5 consecutive years) in September occurs around 2075 (2083) for the *base* (*stoc*) experiments (Fig. 1a; Table 1). The model simulates an abrupt sea-ice loss in March (Fig. 1b) in all the experiments. It takes place about 10 years earlier in the *base* experiments than in the *stoc* ones (Fig. 1b; Table 1). An Arctic free of sea ice in March occurs around 2151 (2153) in the *base* (*stoc*) runs.

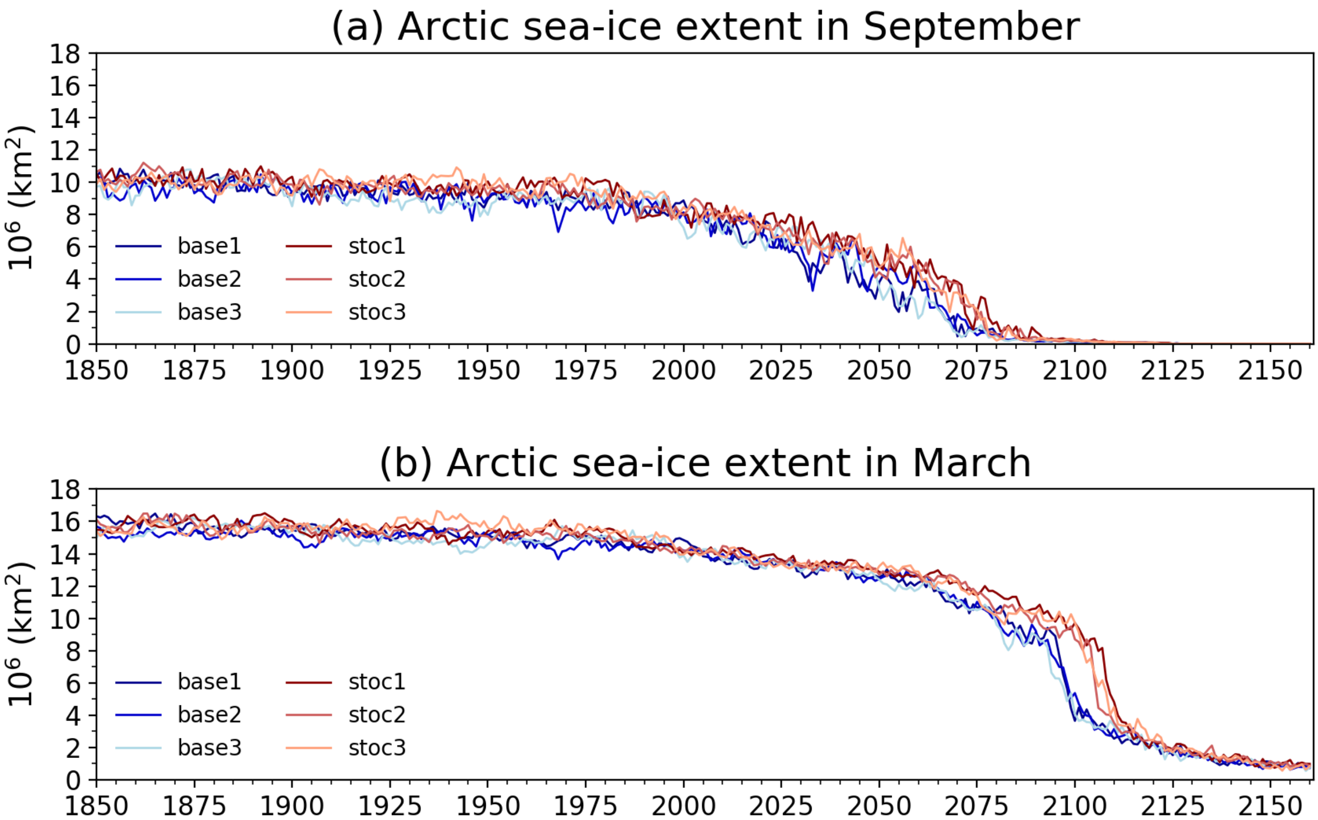

Figure 1: Time series of northern hemisphere sea-ice extent in (a) September and (b) March. All three ensemble members for the base (stoc) experiments are plotted in blue (red).

Table 1: Summary of the differences between the base and stoc experiments in simulating the evolution of Arctic sea ice.

	Base ensemble mean	*Stoc ensemble mean*
Arctic free of sea ice in September (yr)	~ 2075	~ 2083
Abrupt loss of sea ice in March (yr)	~ 2093	~ 2104
Arctic free of sea ice in March (yr)	~ 2151	~ 2153

The evolution of the global annual mean surface air temperature (Fig. 2a) is similar among the ensemble members but differs if the stochastic physics is on or off. Curves start separating by the second half of the 20th century; the difference results maximum in 2100 and curves become almost indistinguishable between both sets of experiments around 2110. This result is confirmed by Fig. 1b which shows the difference of temperature with respect to the *base* ensemble mean. The largest difference between the *base* and *stoc* runs is around 2100.

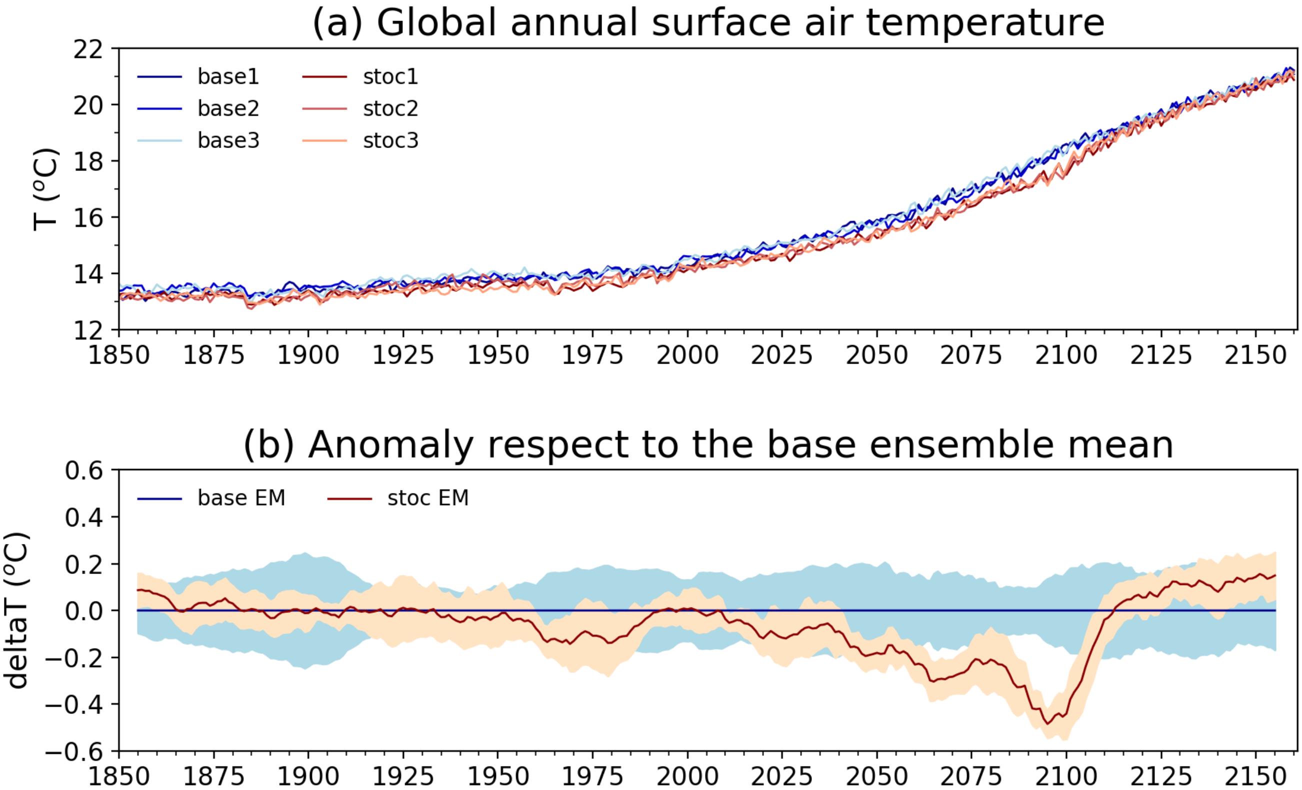

Figure 2: Time series of (a) mean global annual surface air temperature (ºC) and (b) anomalies with respect to the base ensemble mean. 10-yrs moving averaged ensemble means and standard deviations are plotted in (b).

Our results suggest that, probably due to the albedo and cloud feedbacks, the climate sensitivity is lower when the stochastic physics is on than when it is off during the 21st century. Consequently, also the timing of the abrupt collapse of winter sea ice is different. However, when the Arctic is free of sea ice along the year, the *base* and *stoc* experiments become almost indistinguishable, at least regarding the surface temperature. We believe that changes in the mean state of the climate might also change its climate sensitivity. This is a work in progress and we are investigating the physical mechanisms behind this behaviour.