SPECIAL PROJECT FINAL REPORT

All the following mandatory information needs to be provided.

Project Title:	EC-Earth high resolution simulations
Computer Project Account:	SPNLHAAR
Start Year - End Year:	2017 - 2020
Principal Investigator(s)	Dr. R. J. Haarsma, Dr. Ph. Le Sager
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The following should cover the entire project duration.

Summary of project objectives

In this special project we perform simulations with the high resolution versions of EC-Earth. Runs as outlined in the HighResMIP protocol will be performed with the T511/ORCA025 resolution. They will contribute to the HighResMIP simulations done within the European H2020 PRIMAVERA project. In addition we will perform simulations with the T1279/ORCA0125 resolution. At this resolution small scale atmospheric and oceanic phenomena, like tropical cyclones, air-sea interaction over SST fronts, and deepwater formation are expected to be significantly better simulated. This enables a better understanding of the physical mechanisms and will be beneficial for the quality of the climate simulations and seasonal to decadal forecasts. Analysis of the runs will be done in collaboration with the other partners of PRIMAVERA and EC Earth.

Summary of problems encountered

The simulations with the T1279/ORCA0125 appeared to be numerically unstable and the simulations crashed. This problem has not been resolved during the project. It was therefore decided to focus on the T511/ORCA025 resolution as this is the resolution that is used in the HighResMIP simulations for PRIMAVERA. Originally the plan was produce one member. However, preliminary analysis revealed that for many processes the natural variability prohibits to draw conclusions about the impact of enhancing the resolution from T255/ORCA1 to T511/ORCA025. It was therefore decided to use SPNLHAAR to increase, in collaboration of the other EC-Earth partners of PRIMAVERA, the ensemble size to three. This allowed for a better evaluation of the added value of enhancing resolution for simulating the climate.

Experience with the Special Project framework

The experience with the application, reporting and managing the allocated resources is very positive. It minimizes the administrative burden and still ensures to provide and overview of the progress of the project.

Summary of results

A new global high-resolution coupled climate model, EC-Earth3P-HR has been developed by the EC-Earth consortium, with a resolution of approximately 40 km for the atmosphere and 0.25 degree for the ocean, alongside with a standard resolution version of the model, EC-Earth3P (80 km atmosphere, 1.0 degree ocean). The model forcing and simulations follow the HighResMIP protocol. According to this protocol all simulations are made with both high and standard resolutions. The model has been optimized with respect to scalability, performance, data-storage and post-processing. In accordance with the HighResMIP protocol no specific tuning for the high resolution version has been applied. Increasing horizontal resolution does not result in a general reduction of biases and overall improvement of the variability, and deteriorating impacts can be detected for specific regions and phenomena such as some Euro-Atlantic weather regimes, whereas others such as El Niño-Southern Oscillation show a clear improvement in their spatial structure. The omission of specific tuning might be responsible for this. The shortness of the spin-up, as prescribed by the HighResMIP protocol, prevented the model to reach equilibrium. The trend in the control and historical simulations, however, appeared to be similar, resulting in a warming trend, obtained by subtracting the control from the historical simulation, close to the observational one.

A more extensive overview of the results is described in Haarsma et al. 2020. Apart from this paper the HighResMIP simulations of EC-Earth3P-HR are used in a large number of publications within the PRIMAVERA project. These papers focus on a range of topics, that include tropical cyclones and their extra-tropical transition, North Atlantic dynamics (e.g. blockings, jet streams, ocean-atmosphere interaction

along the Gulf stream) and Arctic processes. A full list of those papers can be found at
https://www.primavera-h2020.eu/output/scientific-papers/. Part of these results also serve as input for the
upcoming IPCC, WGI, AR6 report.

The HighResMIP simulations of EC-Earth3-HR within the PRIMAVERA project were distributed over the
EC-Earth partners. The simulations performed by KNMI using SPNLHAAR are indicated below

	highresSST-present	*highresSST-future*	*control-1950*	*hist-1950*	*highres-future*
EC-Earth3P-HR	3 members: r1i1p1f1 r2i1p1f1 r3i1p1f1	3 members: r1i1p1f1 r2i1p1f1 r3i1p1f1	4 members: r1i1p1f1 r1i1p2f1 r2i1p2f1 r3i1p2f1	4 members: r1i1p1f1 r1i1p2f1 r2i1p2f1 r3i1p2f1	4 members: r1i1p1f1 r1i1p2f1 r2i1p2f1 r3i1p2f1
EC-Earth3P	3 members: r1i1p1f1 r2i1p1f1 r3i1p1f1	3 members: r1i1p1f1 r2i1p1f1 r3i1p1f1	4 members: r1i1p1f1 r1i1p2f1 r2i1p2f1 r3i1p2f1	4 members: r1i1p1f1 r1i1p2f1 r2i1p2f1 r3i1p2f1	4 members: r1i1p1f1 r1i1p2f1 r2i1p2f1 r3i1p2f1

List of publications/reports from the project with complete references

Haarsma, R., Acosta, M., Bakhshi, R., Bretonnière, P.-A. B., Caron, L.-P., Castrillo, M., Corti, S., Davini, P.,
Exarchou, E., Fabiano, F., Fladrich, U., Fuentes Franco, R., García-Serrano, J., von Hardenberg, J., Koenigk,
T., Levine, X., Meccia, V., van Noije, T., van den Oord, G., Palmeiro, F. M., Rodrigo, M., Ruprich-Robert, Y.,
Le Sager, P., Tourigny, É., Wang, S., van Weele, M., and Wyser, K.: HighResMIP versions of EC-Earth: EC-
Earth3P and EC-Earth3P-HR. Description, model performance, data handling and validation, Geosci. Model
Dev. Discuss., https://doi.org/10.5194/gmd-2019-350, accepted, 2020.

PRIMAVERA publications that have used EC-Earth3P-HR data in their analyses. For a complete list see:
https://www.primavera-h2020.eu/output/scientific-papers/

Future plans
The future simulations of the PRIMAVERA version EC-Earth (EC-Earth3P-HR) with T511/ORCA025
resolution are according to the HighResMIP protocol from 2014-2050 using SSP85 scenario. The future
plans are to extend these simulation to 2100 with a full 3 member ensemble. This will be done in
collaboration with the other PRIMAVERA EC-Earth partners.