SPECIAL PROJECT PROGRESS REPORT

Progress Reports should be 2 to 10 pages in length, depending on importance of the project. All the following mandatory information needs to be provided.

Reporting year

2018

Project Title:

EC-Earth high resolution simulations

Computer Project Account:

SPNLHAAR

Principal Investigator(s):

Dr. R. J. Haarsma, Dr. Ph. Le Sager, Dr. G. van den Oord

Affiliation:

Royal Netherlands Meteorological Institute (KNMI)

Name of ECMWF scientist(s) collaborating to the project
(if applicable)

Start date of the project:

January 1th 2017

Expected end date:

January 1th 2020

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)	50,000,000	50,000,00 (100%)	50,000,000	230844.15 (0%)
Data storage capacity	(Gbytes)	190,000	166,000	240,000	0

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

Due to the delay of the CMIP6 future scenario forcings the scenario simulations have not started yet.

Summary of results of the current year

With the PRIMAVERA high resolution version of EC-Earth (EC-Earth3P-HR) (T511/ORCA0.25) the simulations according to the HighResMIP protocol (Haarsma et al., 2016) have been performed. This has been done in collaboration with the PRIMAVERA partners.

Outline of HighResMIP protocol

The protocol of the HighResMIP simulations consists of Tiers 1, 2, 3, and a spin-up procedure. Below we give a short summary of the protocol. Further information can also be found at the HighResMIP website (http://collab.knmi.nl/project/highresmip/).

Tier 1: Forced-atmosphere runs 1950-2014; highresSST-present

The Tier 1 experiments will be historical forced atmosphere (ForcedAtmos) runs for the period 1950-2014. The SST sea-ice data set used in these AMIP type runs is HADISST2.0.0 (References), with a horizontal and temporal resolution of ¼ degree and daily respectively. Restricting the ForcedAtmos runs to the historical period also makes it possible for numerical weather prediction (NWP) centers to contribute to the multi-model ensemble. The experiment name is *highresSST-present.*

Tier 2: Coupled runs 1950-2050

The period of the coupled simulations is restricted to 100 years because of the computational burden due to the high model resolution and limited computer resources. The period 1950-2050 covers historic multi-decadal variability and near term climate change. The coupled simulations consist of a control, historic and future simulation.

- *Control; control-1950*

This is is the HighResMIP equivalent of the pre-industrial control, here being a 1950's control using fixed 1950s forcing. The forcing consists of GHG gases, including O3 and aerosol loading for a 1950s (~10 year mean) climatology. The initial state is obtained from the spin-up. The experiment name is *control-1950.*

- *Historic; hist-1950*

These are coupled historic runs for the period 1950-2014, using the same initial state from the spin-up as the control run. The experiment name is *hist-1950.*

- *Future; highres-future*

These are the coupled scenario simulations 2015-2050, effectively a continuation of the hist-1950 experiment into the future. For the future period the forcing fields will be based on CMIP6 scenario's (SSPx). The experiment name is *highres-future*.

Tier 3: Forced-atmosphere 2015-2050 (2100); highresSST-future

The Tier 3 simulations are an extension of the Tier 1 atmosphere-only simulations to 2050, with an option to continue to 2100. To allow comparison with the coupled integrations the same scenario forcing as for Tier 2 (SSPx) will be used. The experiment name is *highresSST-future*.

Spin-up; spinup-1950

Due to the large computer resources needed, a long spin-up to (near) complete equilibrium is not possible at high resolution. Therefore as an alternative approach the EN4 analyzed ocean state representative of 1950 is used as the initial condition for temperature and salinity. To reduce the large initial drift a spin-up of ~50 years is made using constant 1950s forcing. Output from the initial 50 years spin-up is saved to enable analysis of multi-model drift and bias, something that was not possible in previous CMIP exercises, with the potential to better understand the processes causing drift in different models. The experiment name is *spinup-1950.*

A schematic representation of the HighResMIP simulations is given in Figure 1.

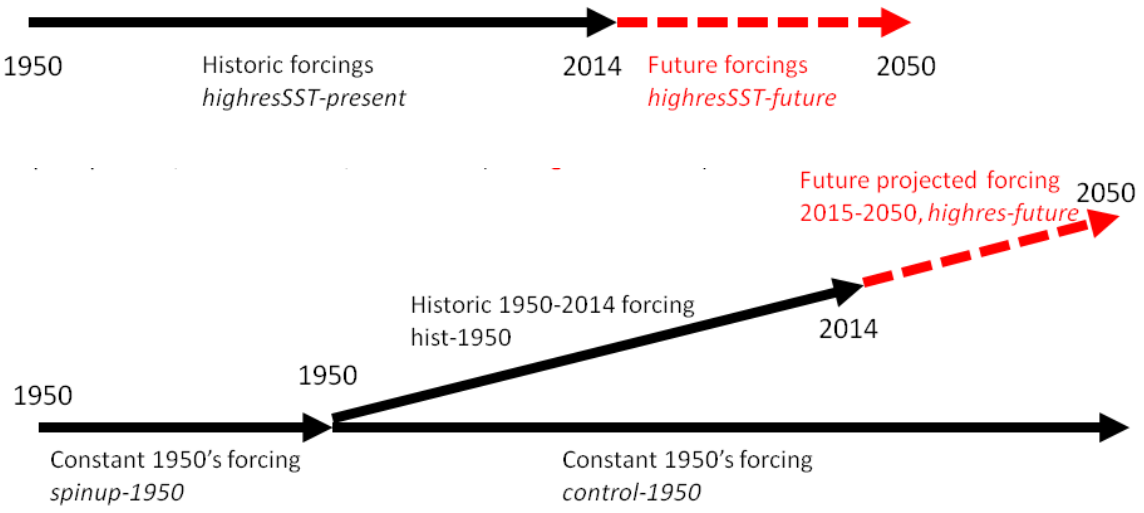

Figure 1. Schematic representation of the HighResMIP simulations.

Progress of PRIMAVERA simulations and contribution of KNMI

For the historical period KNMI has done the SST-forced simulations and the spin-up of the coupled simulations and the Barcelona Supercomputing Centre (BSC) the control and transient runs of the coupled simulations. These SST-forced simulations have been post-processed, CMORized and uploaded to JASMIN at CEDA in the UK. A special CMORizing tool has been developed to cope with the large data volumes involved with the high resolution. The CMORized data is in accordance with the CMIP6 HighResMIP data request. Analyses of these runs has started. The coupled simulations will be completed during this summer. A summary of the progress can be seen at the PRIMAVERA website (https://www.primavera-h2020.eu/) The simulations for the future are on hold because the CMIP6 forcings are not available yet. They will be available probably by the end of June. To compare the impact enhanced resolution the simulations have been repeated with the standard version EC-Earth3P

At BSC the very high resolution version EC-Earth3P-VHR (T1279/ORCA0125) has been developed. This is the follow-up of the successful coupled simulation that was discussed in the progress report of 2017. The new EC-Earth3P-VHR has apart from enhanced resolution the same configuration as EC-Earth3P-HR. We will use this version and coordinate our experimental efforts with them. One option will be to do in collaboration with BSC the HighResMIP simulations with EC-Earth3P-VHR. Another option is to perform an ensemble of simulations of Ophelia in a warmer climate. The decision on the exact set-up of the experiments will be made later this year based on the feasibility in terms of computer resources and experimental design. Presently we are performing test simulations with EC-Earth3P-VHR.

Forced-atmosphere runs 1950-2014; highresSST-present

The *highresSST-present* simulation of EC-Earth3P-HR is compared with ERA-Interim (1979-2014), except for precipitation where GPCP V2.3 (1979-2014) data is used. The resolution of ERA-Interim is T255 and the EC-Earth data is regridded to this resolution before comparison. Also the GPCP data is regridded to this resolution. Seasonal means (DJF and JJA) are analyzed. A short summary of the results is presented in Figs. 2-5

Due to the prescribed SST the largest biases are over the continents. The most negative biases are over the Sahara in DJF and Greenland in summer. The largest positive biases are over Antarctica in JJA and north eastern Siberia in DJF. Over most areas EC-Earth is slightly too cool. Over most of the tropics the MSLP is underestimated, whereas the Antartica has a strong positive bias. Further noteworthy is the positive bias south of Greenland during DJF. This is an observed blocking region, suggesting an overestimation by EC-Earth. The largest precipitation errors are seen in the tropics over the warm pool regions in the Pacific and the Atlantic with too much precipitation. The planetary wave structure of Z500 during DJF is well represented with the exception of the region south of Greenland, which was already observed in the MSLP bias.

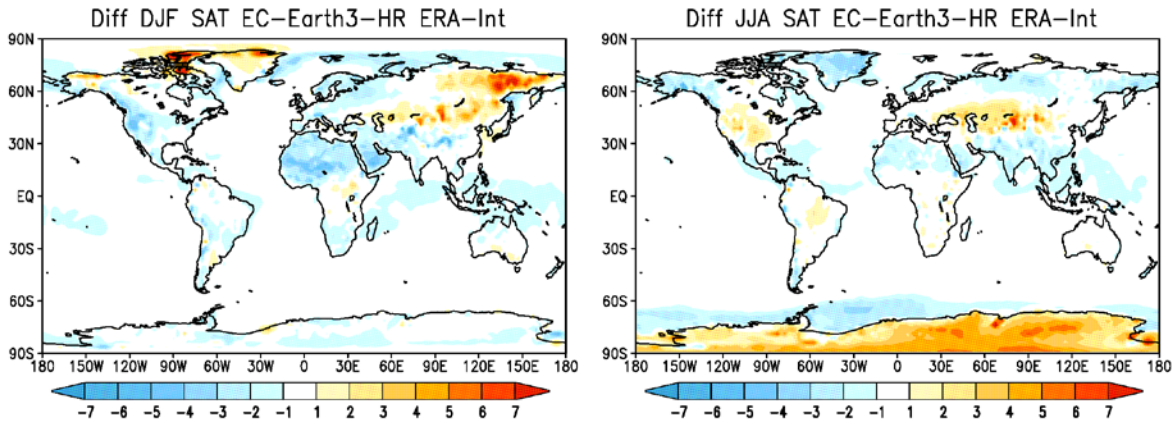

Figure 2. SAT: Bias [ºC] with respect to ERA-interim for the period 1979-2014. left panel DJF, right panel JJA.

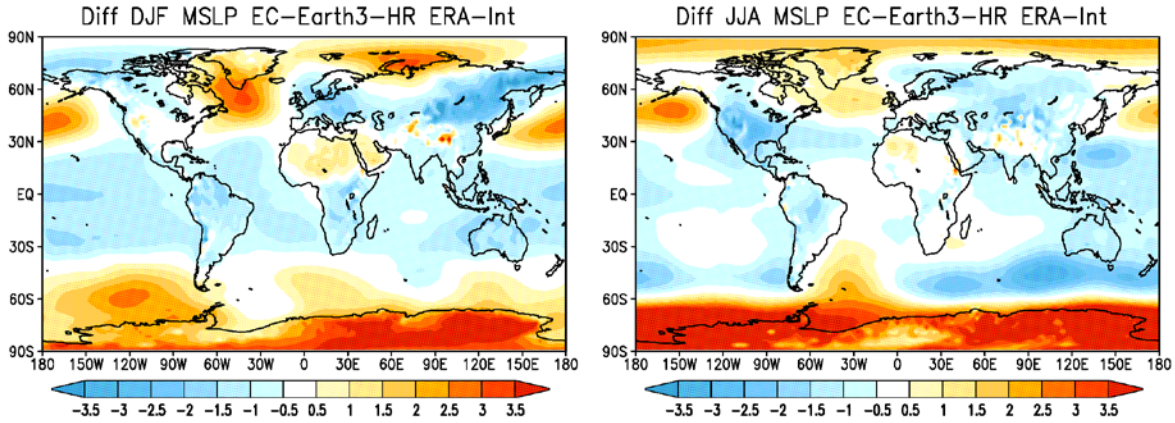

Figure 3. MSLP: Bias [hPa] with respect to ERA-interim for the period 1979-2014. left panel DJF, right panel JJA.

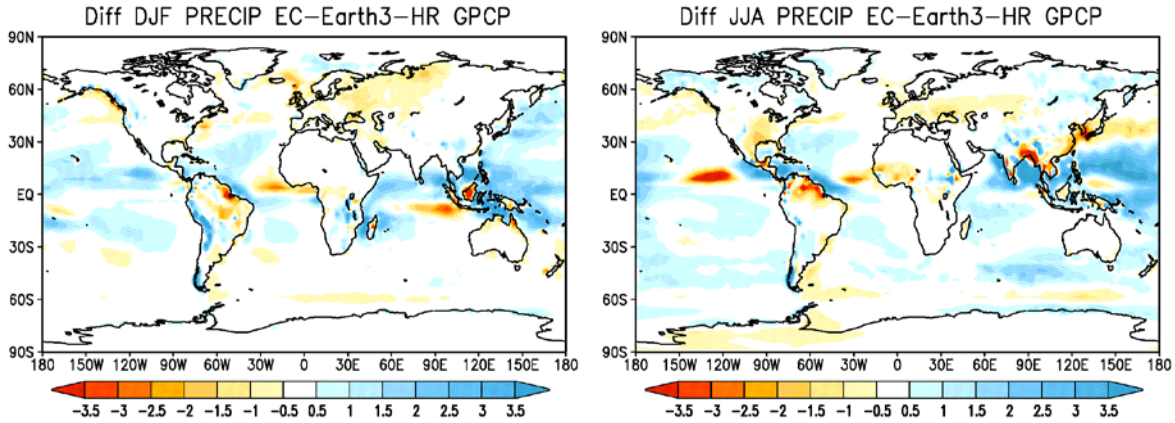

Figure 4. Precipitation: Bias[mm/day] with respect to GPCP for the period 1979-2014. left panel DJF, right panel JJA.

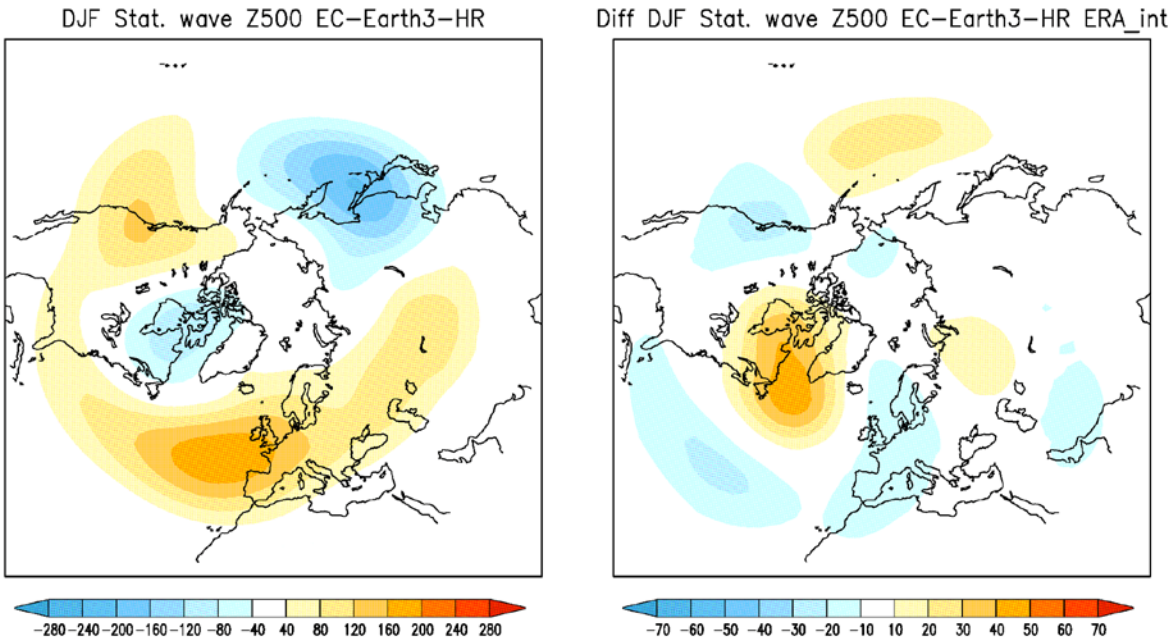

Figure 5: Left: Stationary eddy component (departure from zonal mean) of the 500-hPa geopotential height (m) in boreal winter; Right: the difference with ERA-Interim. Note the difference in colour scale between the two panels.

Spin-up and control simulations spinup-1950 control-1950

As discussed in the outline of the HighResMIP protocol, the spin-up was started from an initial state that is based on observations for 1950. For the ocean this is EN4 and for the atmosphere ERA20C.

The drift during the *spinup-1950* experiment the global mean SST shows a sharp drop of about 0.5 degree in the first year with a slow recovery in the following 40 years (not shown). A similar behavior is seen for the mixed layer temperatures. A continuing warming between 100 and 500 m is seen due to an adjustment of the thermocline structure with warmer surface waters entraining into deeper layers. For the deep ocean 50 years is too short to have a notable impact.

The control run consists of a continuation for 100 year after the spin-up. After 30 year the SST reaches a semi-equilibrium at around 18 ºC (Fig. 6). At around 500 m there is still continuous warming. The Atlantic Meridional Overturning Circulation (AMOC) stabilizes at about 14 Sv with notable interannual and decadal variability (Fig. 6).

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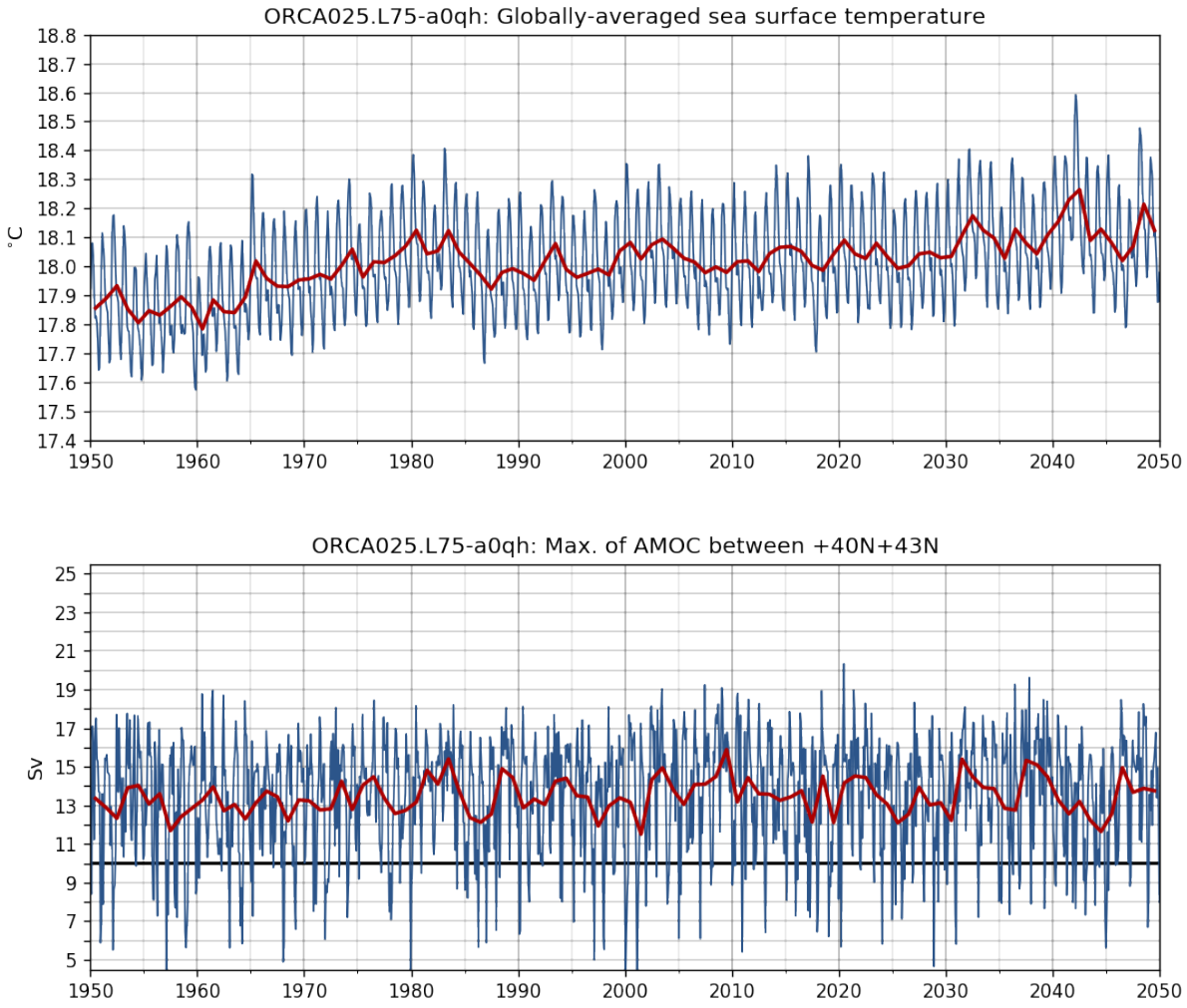

Figure 6. Global mean SST (upper panel) and AMOC (lower panel) of the control run (control-1950)

KNMI analyses of PRIMAVERA simulations

At the KNMI the focus is on 3 topics: post tropical cyclones, ocean-atmosphere interaction along the Gulfstream and the spectral energy budget. Below we will give a short summery of the first analyses with respect to these topics.

- *post tropical-cyclones*

The post tropical cyclone tracks have been computed (Fig. 7) and the statistics analysed. In collaboration with the university of Reading they are being compared with observed and re-analyses data sets. A joint publication is in preparation.

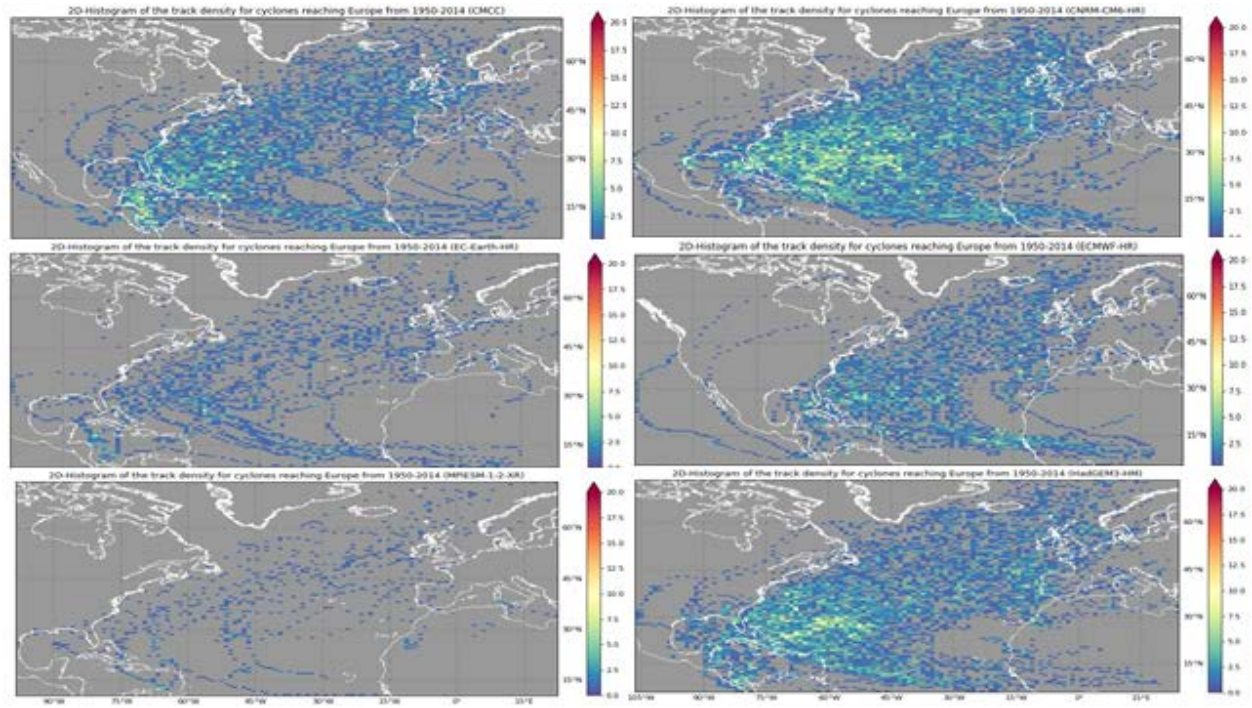

Figure 7:Tracks of tropical cyclones that reach Europe for the different PRIMAVERA models in the historic SST-forced simulations.

- *Air sea-interaction along the Gulf stream*

Analyses of heat fluxes, divergence and precipitation along the Gulf stream region of the coupled control simulations has started.

- *Spectral energy budget*

The effective resolution based on the spectral energy budget has been computed (Fig. 8). The effective resolution appears to be about 3 times the nominal resolution for all PRIMAVERA models except for the ECMWF model for which effective resolution is only 2 times the nominal resolution. The different behaviour of the ECMWF model is probably due to the use of the octahedral grid. A paper is in preparation.

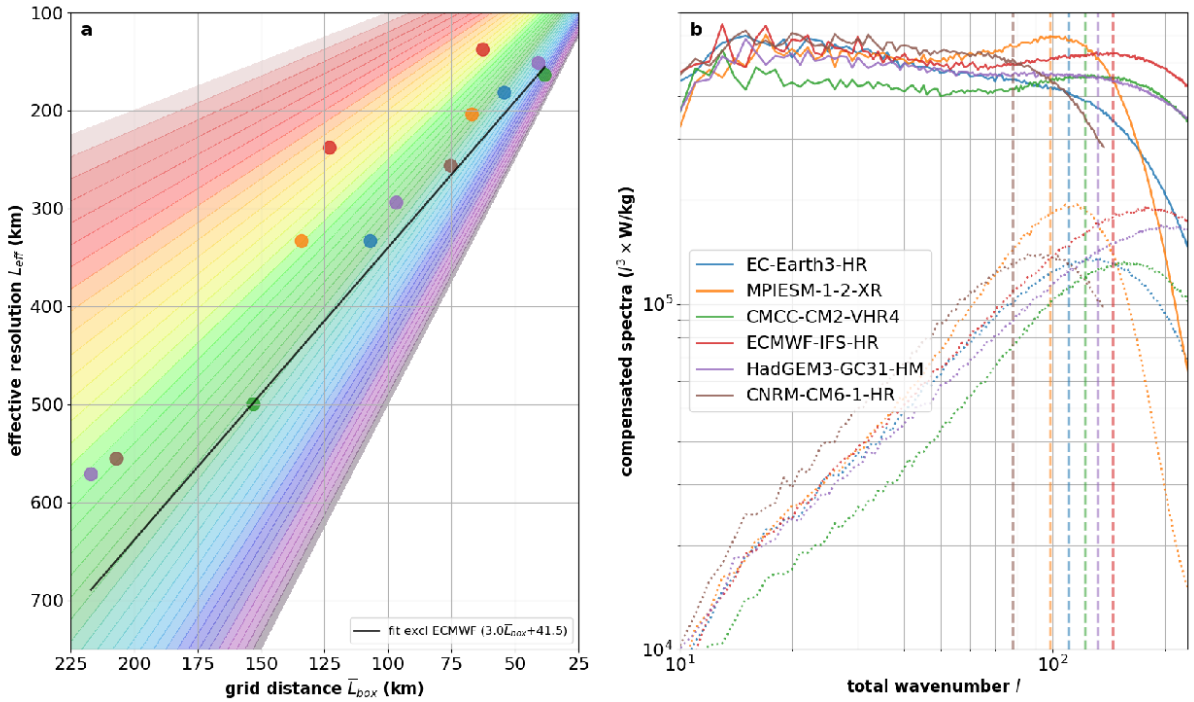

Figure 8. left: Scatter plot of the effective resolution versus mean grid distance of the models native grids. right: Compensated spectra. Total kinetic spectra in solid lines. Kinetic spectral derived from only divergent wind in dotted lines.

As was mentioned in the progress report of 2017 apart from the required computer resources, data storage is a serious issue at these high resolutions. In collaboration with BSC XIOS is being developed that will be implemented in open IFS. A first version is expected next year.

References

Haarsma, R. J., Roberts, M. J., Vidale, P. L., Senior, C. A., Bellucci, A., Bao, Q., Chang, P., Corti, S., Fučkar, N. S., Guemas, V., von Hardenberg, J., Hazeleger, W., Kodama, C., Koenigk, T., Leung, L. R., Lu, J., Luo, J.-J., Mao, J., Mizielinski, M. S., Mizuta, R., Nobre, P., Satoh, M., Scoccimarro, E., Semmler, T., Small, J., and von Storch, J.-S.: High Resolution Model Intercomparison Project (HighResMIP v1.0) for CMIP6, Geosci. Model Dev., 9, 4185-4208, doi:10.5194/gmd-9-4185-2016, 2016

List of publications/reports from the project with complete references

{DATE \@"MMMM\ yyyy"**}**

No publications or reports yet. The following publications are in preparation:

Haarsma et al. *Impact of enhanced horizontal resolution in EC-Earth*

Klaver et al. *Effective resolution in high resolution global atmospheric models for climate studies*

Baker et al. *Extra-tropical transition in high resolution global climate models*

Summary of plans for the continuation of the project

Finalizing the historical simulations of the PRIMAVERA stream I EC-Earth3p-HR runs during the summer of 2018. Starting the CMIP6 scenario PRIMAVERA stream EC-Earth3P-HR runs when the CMIP6 scenario forcings are available. Continuation of the initial simulations with EC-Earth3P-VHR. Design of the experiments to be done with EC-Earth3P-VHR in collaboration with BSC.

Continuation of the analyses of the PRIMAVERA stream I simulations with respect to post tropical cyclones, ocean-atmosphere interaction along the Gulf stream and the spectral energy budget.