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PRIMAVERA

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PRocess-based climate sIMulation: AdVances in high resolution modelling and European climate Risk Assessment

Deliverable D*6.2 version 2*

Stream 1 historical AMIP runs

Deliverable Title	*Model configurations for Stream1 integrations*	
Brief Description	*Report on model configurations for Stream 1 integrations agreed by all partners and published on project website*	
WP number	6	
Lead Beneficiary	*Rein Haarsma KNMI*	
Contributors	*Rein Haarsma* *Johann Jungclaus* *Katja Lohmann* *Jon Seddon* *Malcolm Roberts*	
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		PP - Restricted to other programme participants, including the Commission services
		RE - Restricted to a group specified by the consortium, including the Commission services
		CO - Confidential, only for members of the consortium, including the Commission services

Version	**Date**	**Modified by**	**Comments**
V1	01/11/2017	Rein Haarsma	
V2	05/07/2018	Rein Haarsma	This version represents a significant update to the results reported in Version 1

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1. Executive Summary

The stream 1 historical AMIP simulations have been completed, post processed and uploaded to JASMIN. These simulations are made according to the HighResMIP protocol *highresSST-present*, that is outlined in Haarsma et al. (2016). HighResMIP and its protocol were initiated and developed by PRIMAVERA. The output of the stream 1 AMIP simulations is CMORized according to the CMIP6 and HighResMIP requirements and stored on JASMIN. Quality control is performed and the data is now ready for analyses. First results are becoming available. Because the CMIP6 scenario forcings are not yet available, the *highresSST-future* could not be made yet. Therefore for a small annex will be provided once the scenario forcing datasets are available and the *highresSST-future* have also been completed.

The CMORized and quality-checked output from the coupled Stream1 simulations will be made publicly available on the Earth System Grid Federation (ESGF) data nodes as soon as possible, providing the basis for publications which will enter the IPCC AR6 report. Currently, the *highresSST-present* Stream1 simulations are available to all PRIMAVERA project members as well as selected individuals from the CLIVAR project working closely with PRIMAVERA scientists.

2. Project Objectives

With this deliverable, the project has contributed to the achievement of the following objectives (DOA, Part B Section 1.1) WP numbers are in brackets:

No.	Objective	Yes	No
A	To develop a new generation of global high-resolution climate models. *(3, 4, 6)*	Y	
B	To develop new strategies and tools for evaluating global high-resolution climate models at a process level, and for quantifying the uncertainties in the predictions of regional climate. *(1, 2, 5, 9, 10)*		N
C	To provide new high-resolution protocols and flagship simulations for the World Climate Research Programme (WCRP)'s Coupled Model Intercomparison Project (CMIP6) project, to inform the Intergovernmental Panel on Climate Change (IPCC) assessments and in support of emerging Climate Services. *(4, 6, 9)*	Y	
D	To explore the scientific and technological frontiers of capability in global climate modelling to provide guidance for the development of future generations of prediction systems, global climate and Earth System models (informing post-CMIP6 and beyond). *(3, 4)*		N
E	To advance understanding of past and future, natural and anthropogenic, drivers of variability and changes in European climate, including high impact events, by exploiting new capabilities in high-resolution global climate modelling. *(1, 2, 5)*		N
F	To produce new, more robust and trustworthy projections of European climate for the next few decades based on improved global models and advances in process understanding. *(2, 3, 5, 6, 10)*		N

G	To engage with targeted end-user groups in key European economic sectors to strengthen their competitiveness, growth, resilience and ability by exploiting new scientific progress. *(10, 11)*		N
H	To establish cooperation between science and policy actions at European and international level, to support the development of effective climate change policies, optimize public decision making and increase capability to manage climate risks. *(5, 8, 10)*		N

3. Detailed Report

3.1 Model simulations

The stream 1 AMIP simulations follow the *highresSST-present* protocol of HighResMIP (Haarsma et al. 2016). HighResMIP and its protocol were initiated and developed by PRIMAVERA. *highresSST-present* are the Tier 1 simulations of HighResMIP for the period 1950-2104. The SST sea-ice data set used in these AMIP type runs is HADISST2.0.0 (Kennedy et al., 2017), with a horizontal and temporal resolution of ¼ degree and one day respectively. Restricting the AMIP runs to the historical period also makes it possible for numerical weather prediction (NWP) centers to contribute to the multi-model ensemble. A schematic outline of the HighResMIP protocol and its different Tiers is given in Fig.1

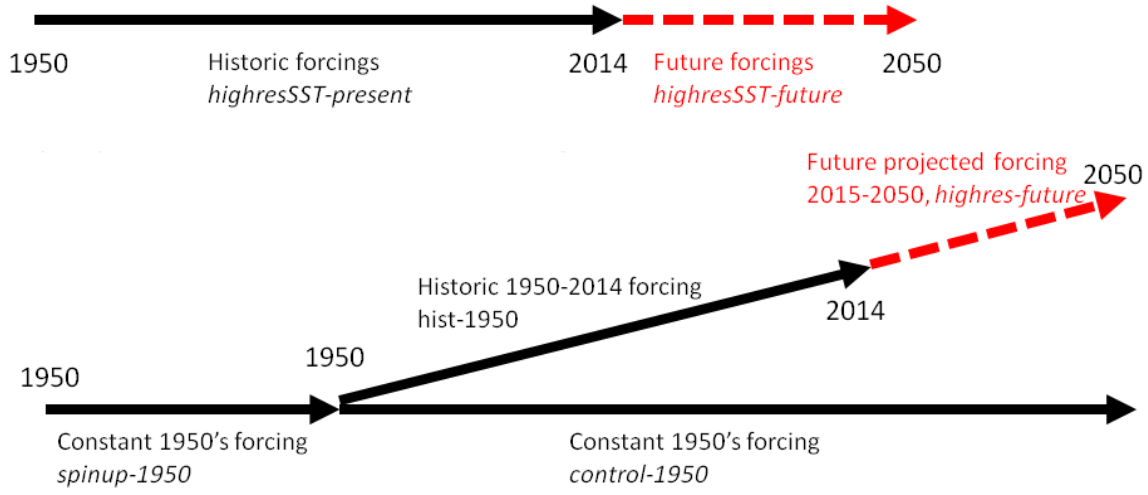

Figure 1. Schematic representation of the HighResMIP simulations. The stream 1 historical AMIP simulations have been made according the highSST-present protocol.

The simulations have been made by the high and standard resolution of each PRIMAVERA model to allow the investigation of the added value of enhanced horizontal resolution.

Table 1 shows the PRIMAVERA models that have completed the *highresSST-present* Tier 1 simulations.

Causes of delay

In the original PRIMAVERA Description of Action, completing the coupled Stream1 simulations was foreseen by April 2017. The substantial delay in completing these simulations is due to a combination of factors:

- *Delay in the development of the models*

The development of the new CMIP6 version of the models at the institutes took longer time than expected. This was partly due to the incorporation of new parameterizations such as the new aerosol scheme (EASY-AEROSOL). In particular for the high resolution version with a few simulated years per computing day, testing and tuning is a slow process.

- *Post-processing CMORization*

Because the PRIMAVERA simulations follow the HighResMIP protocol, post-processing, including the CMORization appeared to be time consuming. Because of the huge amount of data involved the work flow of the simulations had to be redesigned and tested for most models. Even after redesigning the whole chain of post-processing including uploading to JASMIN caused serious delays.

- *Delay in CMIP6 forcings*

All the necessary CMIP6 concentration fields for the scenarios (SSP) for the future climate are still yet not available. This why only the *highresSST-present* simulations could be made up to now. The *highresSST-future* simulations are still on hold. Therefore, this deliverable is submitted now and a small annex will be provided once the *highresSST-future* scenario simulations have been completed. There was also a delay in the delivery of the historical concentration fields, which contributed to the delay in the stream 1 simulations.

- *Adaption of the code to high resolution to ensure scale-ability*

The high resolution models where developed starting from the standard resolution. A 4x increase in horizontal resolution requires ~30X more computational capacity, however lack of scalability can amplify this substantially. This happened for some models and redesigning of the code was needed.

3.2 Data

The data request for the *highresSST-present* simulations is described in the CMIP6 and HighResMIP data requests outlined by the Working Group on Climate Models (WGCM)

https://earthsystemcog.org/projects/wip/CMIP6DataRequest.

The requested output data volume for HighResMIP Tier 1 is by far the largest (http://clipc-services.ceda.ac.uk/dreq/tab01_1_1.html) of all CMIP6 MIPs due to high spatial and temporal resolution of the data.

The PRIMAVERA data is uploaded to the JASMIN infrastructure of the Centre for Environmental Data Analysis (CEDA). It is hosted at the Science and Technology Facilities Council Rutherford Appleton Laboratory.

(http://www.ceda.ac.uk/projects/jasmin/).

Full details of JASMIN can be found at the JASMIN site http://www.jasmin.ac.uk/

The PRIMAVERA data available at JASMIN can be searched and queried using the Data Management Tool (DMT) https://prima-dm.ceda.ac.uk/, developed for PRIMAVERA. It is a graphic web based tool. The DMT's Variable Received Query can be used to search through the stream 1 AMIP data.

Because of the resolution and large size of the stream 1 simulations (378410 files and 179.9 TB) there is insufficient storage capacity at JASMIN to hold all of them on disk. Instead the files are stored on tape systems at JASMIN or the Met Office. The DMT allows users to restore data from tape to disk when it is required for analysis.

Because of the large amount of data the philosophy of PRIMAVERA for analyzing the data is to bring your script to the data instead bringing the data to your analysis. To facilitate this JASMIN has a set of scientific analysis servers and a batch processing cluster. For the PRIMAVERA partners the documentation of JASMIN, including training video's, is available from the PRIMAVERA wiki.

All PRIMAVERA data received at JASMIN is checked using the primavera-val tool (https://github.com/PRIMAVERA-H2020/primavera-val). This checks that the essential metadata is correct and that a random data point can be read, ensuring that the file has not been corrupted during transfer. Additionally, data that has been received since the CMIP6 PrePARE validation tool was released is also checked with PrePARE. PrePARE ensures that a file fully complies with the CMIP6 meta data standards. Files that were received before PrePARE was available will be checked with PrePARE before publication on the Earth System Grid Federation (ESGF). Software has been developed to correct any meta data issues that are identified by PrePARE before submission to the ESGF.

Ideally the CMIP6 data request and PrePARE validation tool would have been finalised before the stream 1 simulations began. The changing data request created additional work for every PRIMAVERA partner as they adapted their simulations to match the changes. Additional work has been required by work package 9 to update the meta data in some of the first results so that they can be published through the ESGF.

All of the PRIMAVERA partners providing stream 1 data have now developed and optimised their own systems to interface to their HPCs, CMORize the data and transfer it to JASMIN. These systems are unique to each partner's own IT systems, although best practice was shared with other partners during the development. The use of these optimised systems will allow stream 2 data to be easily generated and shared amongst partners.

The Stream 1 data is currently available to all PRIMAVERA project members. Additionally, selected individuals from the CLIVAR project are working closely with PRIMAVERA scientists and have been granted access to the data at JASMIN. A guidance note on data sharing has been developed. The note states that data will only be released to institutes who are actively collaborating with the analysis of PRIMAVERA data, all analysis work is performed at JASMIN and that the project will be acknowledged in results. Work package 10 is currently collaborating with some energy companies using this guidance note. This data sharing and the publication on the ESGF is consistent with the data policy in the PRIMAVERA project proposal.

3.3 First analyses

Although PRIMAVERA data will be analysed for a wide range of weather and climate phenomena, an obvious new research area that can investigated with the PRIMAVERA simulations are tropical cyclones. The horizontal resolution of CMIP5 models is too low for a reliable tropical cyclone analysis. For the first time tropical cyclones can be investigated in a global multi-model framework. Figure 2 and 3 show the composite tropical cyclones for the low and high resolution simulations respectively. They reveal that we can see many more of the higher intensity storms in the higher resolution models, with structures agreeing well with re-analyses.

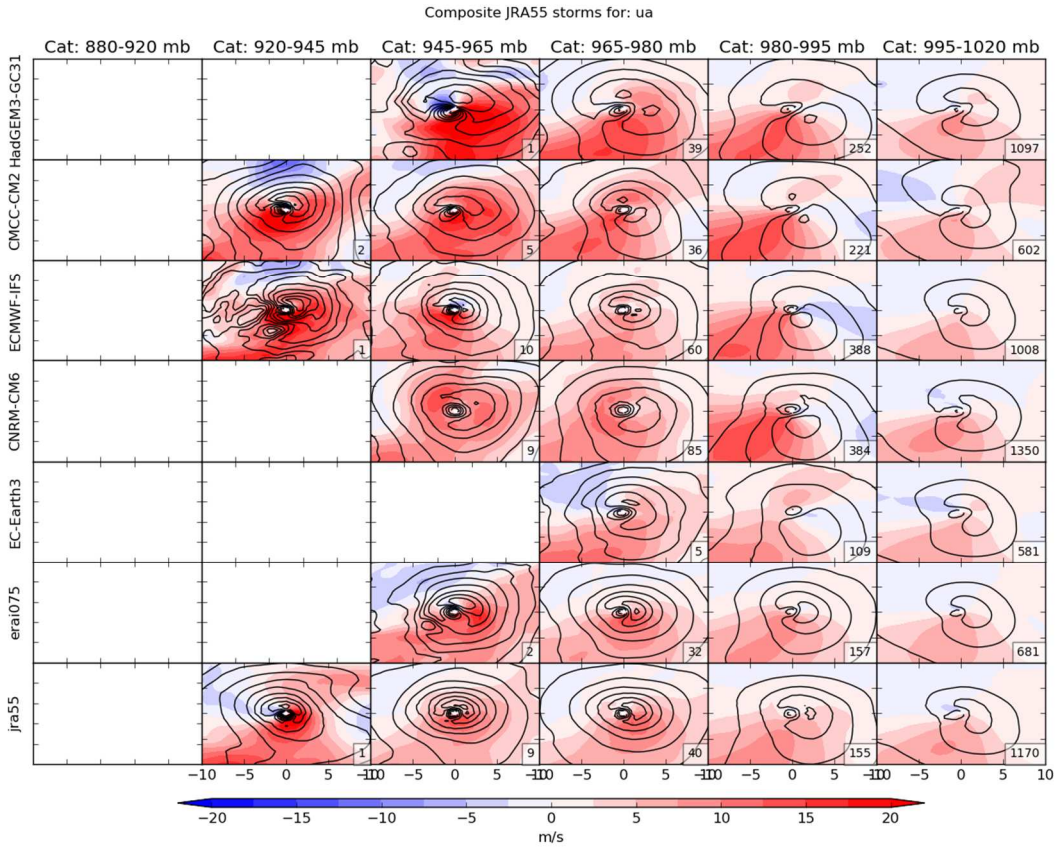

Figure 2. Composite storm structures from the low resolution models at 925 hPa, together with ERA-I and JRA55 re-analyses, stratified by minimum surface pressure at peak storm intensity (more intense storms to the left). Colour indicates the radial velocity away from the storm centre, and contours the tangential velocity around the storm. The numbers indicate the number of storms sampled over a 30 year period of the simulations

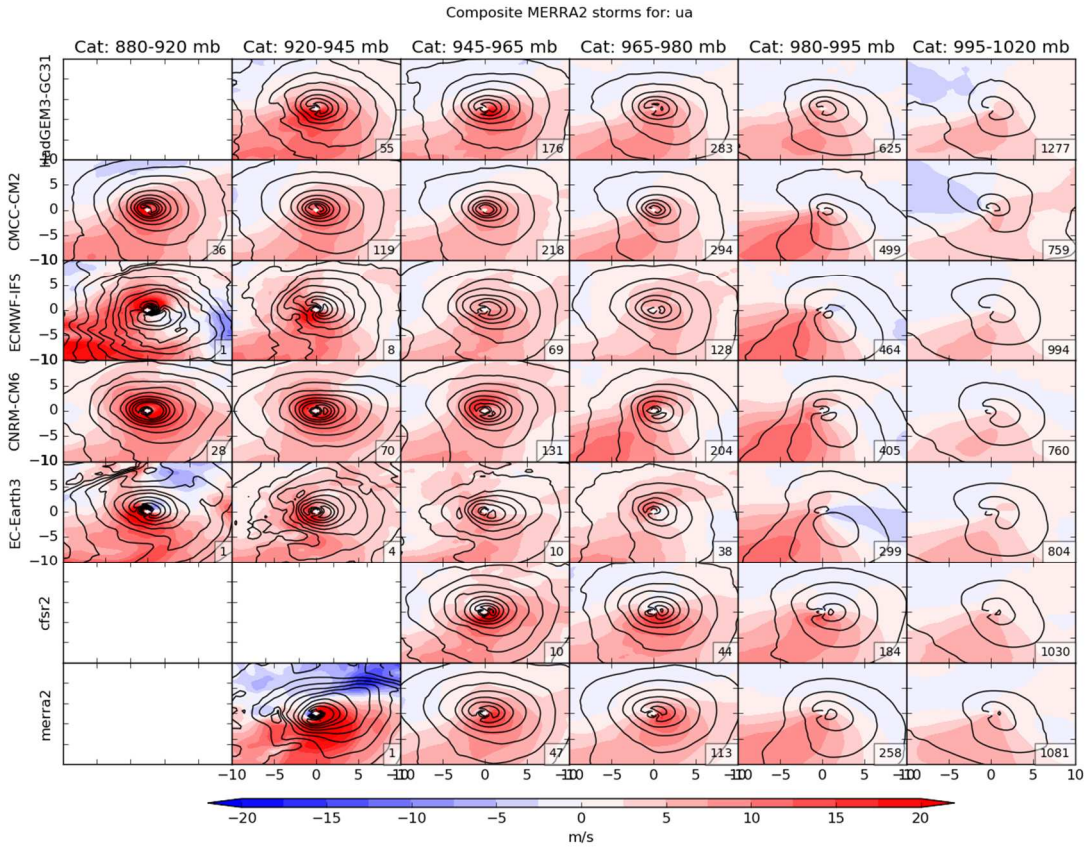

Figure 3. As Fig. 2, but now the higher resolution models and the CSFR2 and MERRA2 re-analyses.

Model	Institute	Country	Atmos
CMCC	CMCC	Italy	100 km 25 km
CNRM-CM6	CNRM-CERFACS	France	T127 (~ 100km) T359 (~35km)
EC-Earth3	KNMI/ BSC/ SMHI/ CNR	EU	T255 (~50km) T511 (~25km)
ECMWF-IFS	ECMWF	EU	Tco199 (~50km) Tco399(~25km)
ECHAM	MPI	Germany	T127 (~100km) T255 (~50km)
HadGEM-GC3.1	Met Office	UK	130km 60km 25km

Table 1. PRIMAVERA models and their resolutions (standard and high) that have performed the Tier 1, highresSST-present, simulations. The Met. Office. has performed those simulations for three resolutions (standard, medium and high).

4. Lessons Learnt

The substantial increase in horizontal resolution has been a major step forward in the computational design of climate models, post-processing of the data and the analysis of it. Although the NWP community is used to high horizontal resolutions, the climate modelling community has yet to made this step, because of the much longer time scales involved. During the PRIMAVERA project many issues with respect to high resolution modelling came across and solutions had to be found. The ambition of PRIMAVERA is partly also its pitfall. The delays of the stream 1 simulations are partly due to the fact that at the start of the project there was a lack of overview of the problems that could be encountered. A better investigation at the beginning might have localized some of upcoming issues. However, some of the delays, such as the delay in the CMIP6 forcings are outside the scope of PRIMAVERA

5. Links Built

The Stream1 simulations are the heart of PRIMAVERA, and are linked with almost all other work packages. In addition strong links have been built with the high resolution global modelling community outside Europa, in particular with modelling groups in Asia and the USA. PRIMAVERA has been the initiator of HighResMIP, which places Europe at the forefront of the high resolution global modelling community. Joint analysis of PRIMAVERA data on for instance tropical cyclones is being initiated. Further joint analysis on a wide range of topics is being organized through the participation of the CLIVAR Climate Dynamics panel.
Also the very high frequency output of atmospheric quantities such as near-surface air temperature and wind speed provides the basis for user engagement such as energy companies.

References

Haarsma RJ et al. (2016) High Resolution Model Intercomparison Project (HighResMIP v1.0) for CMIP6. Geoscientific Model Development, 9, 4185-4208, https://doi.org/10.5194/gmd-9-4185-2016

Kennedy, John; Titchner, Holly; Rayner, Nick; Roberts, Malcolm (2017). Input4mips.MOHC.sstsandseaice.highresmip.MOHC-hadisst-2-2-0-0-0.Earth System Grid Federation. Https://doi.org/10.22033/ESGF/input4mips.1221