Concerted global high resolution coupled modelling - PRIMAVERA

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PRIMAVERA overview

PRIMAVERA is an EU funded Horizon 2020 project running from November 2015 to July 2020 comprising 19 climate research institutes in Europe. For the first time, we want to use "weather-resolving" models for coordinated climate studies. This will allow us to examine the impact of model horizontal resolution (including eddy-rich regimes **[1]**) on the simulation of climate variability and change, with a focus on the European region.

Using multiple models at different resolutions will enable us to find robust results, and examine the physical processes. The results will provide an exciting new component in the next Intergovernmental Panel on Climate Change (IPCC) report AR6.

SST biases at end of spinup-1950

The HighResMIP coupled model spinup period needs to be short to make higher resolution model simulations possible. Fig. 1 shows the SST bias at the end of the spinup period, compared to the EN4 1950-54 mean, as well as the difference between higher and lower resolution models at this point.

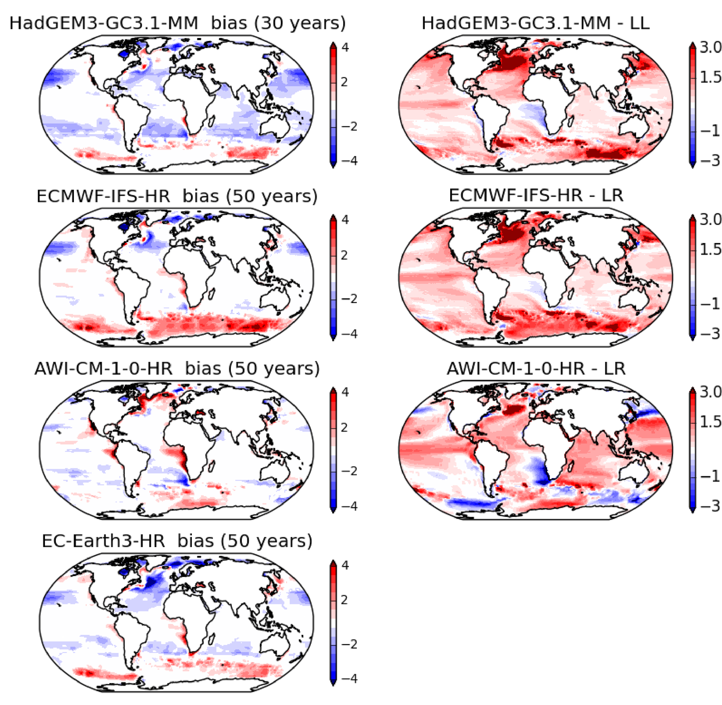


Fig. 1: (left) SST bias vs EN4 1950-54 mean over last 10 years of spinup-1950. (right) Difference in bias between higher and lower resolution models

Air-sea coupling strength

An important metric of coupled models is the coupling strength between atmosphere and ocean. So far this analysis has only been done using one model. The correlation of spatially filtered, monthly mean SST and surface windstress **[5]** are shown in Fig. 2 for the same resolution atmosphere, and ocean resolutions at 1˚, ¼˚ and 1/12˚.

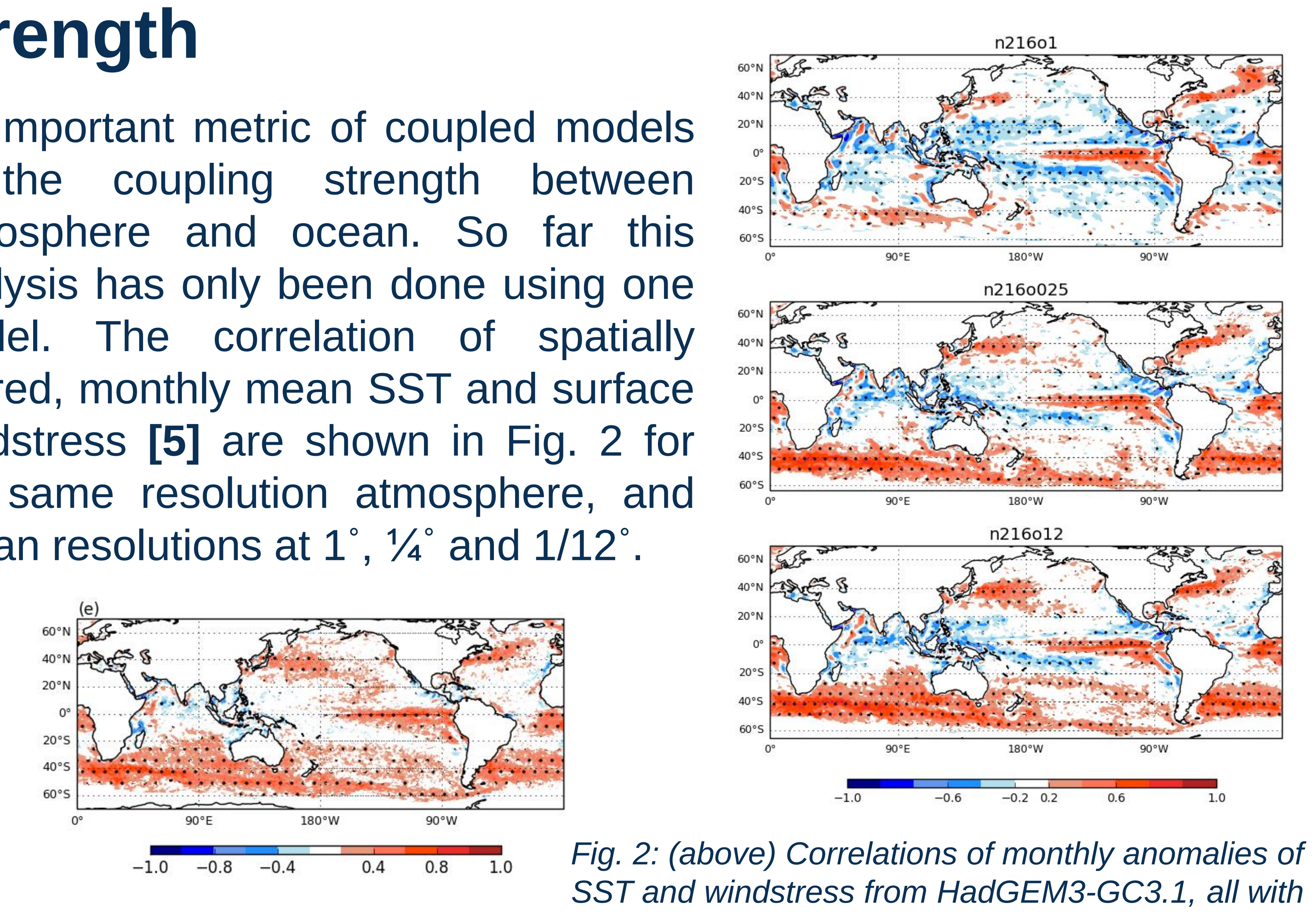


Fig. 2: (above) Correlations of monthly anomalies of SST and windstress from HadGEM3-GC3.1, all with ~60km atmos. model, and 1˚, ¼˚ and 1/12˚ ocean; (left) observed correlation of same using ESA-CCI SSTs and QuikScat winds

PRIMAVERA models

The table shows some details of all the models contributing to the PRIMAVERA project and following the CMIP6 HighResMIP protocol **[2]**.

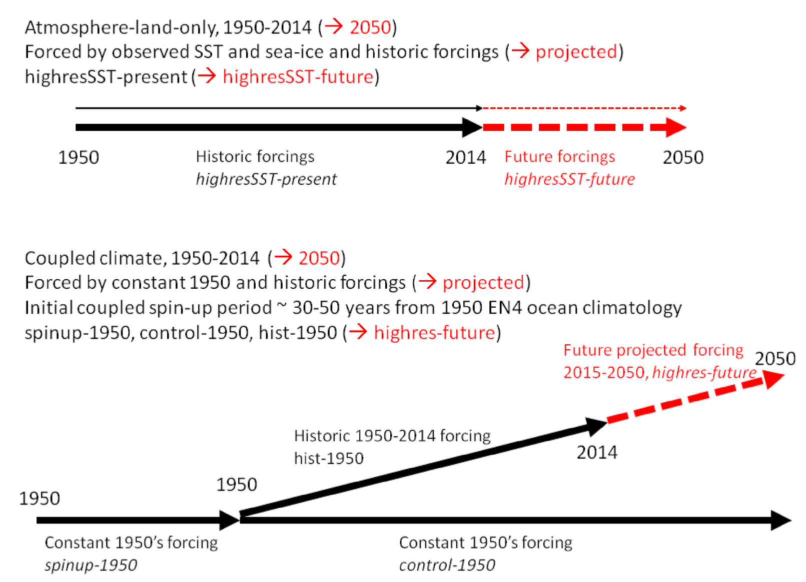
Institution	MOHC, UREAD, NERC	EC-Earth KNMI,SHMI, BSC, CNR	CERFACS	MPI-M	AWI	CMCC	ECMWF
Model name	HadGEM3 GC3.1	EC-Earth3	CNRM-CM6	MPIESM-1-2	AWI-CM 1.0	CMCC-CM2	ECMWF-IFS
Model components	UM NEMO3.6 CICE5.1	IFS cyc36r4 NEMO3.6 LIM3	ARPEGE6.3 NEMO3.6 GELATO6.1	ECHAM6.3 MPIOM1.63 MPIOM1.63	ECHAM6.3 FESOM1.4 FESIM1.4	CAM4 NEMO3.6 CICE4	IFS cyc43r1 NEMO3.4 LIM2
Atmos dynamical scheme (grid)	Grid point (SISL, lat-long)	Spectral (linear, reduced Gaussian)	Spectral (linear, reduced Gaussian)	Spectral (triangular, Gaussian)	Spectral (triangular, Gaussian)	Grid point (finite volume, lat-long)	Spectral (cubic octohedral, reduced Gaussian)
Atmos grid name	N96 , N216, N512	Tl255, Tl511	Tl127, Tl359	T127, T255	T63, T127	1x1, 0.25x0.25	Tco199, Tco399
Atmos mesh spacing 0N	208, 93, 39	78, 39	156, 55	104, 52	200, 100	100, 28	50, 25
Atmos mesh spacing 50N	135, 60, 25	71, 36	142, 50	67, 34	129, 64	64, 18	50, 25
Atmos nominal res (CMIP6)	250, 100, 50	100, 50	250, 50	100, 50	250, 100	100, 25	50, 25
Atmos model levels (top)	85 (85km)	91 (0.01 hPa)	91 (78.4 km)	95 (0.01 hPa)	95 (0.01 hPa)	26 (2 hPa)	91 (0.01 hPa)
Ocean grid name	ORCA	ORCA	ORCA	TP	FESOM (unstructured)	ORCA	ORCA
Ocean nominal res (km)	100, 25, 8	100, 25	100, 25	40, 40	50, 25	25, 25	100, 25
Ocean levels	75	75	75	40	47	50	75

Details of PRIMAVERA models and their configurations running the HighResMIP coupled protocol. Several groups will also run with eddy-resolving ocean models.

CMIP6 HighResMIP protocol

Our core simulations follow the CMIP6 HighResMIP protocol, using both a standard resolution (typical of CMIP6) and a higher resolution model. Key aspects of this include:

- a simplified representation of aerosol (specifying optical properties) using MACv2-SP **[3]**;
- a short spin-up (~30-50 years) for the coupled models, starting from EN4 1950 initial conditions **[4]**.



Model development

An important component of the project is to investigate model science developments suitable for higher resolution models. These include:

- Improved upper ocean mixing schemes – OSMOSIS-OBL (**[6]**, being implemented into NEMO ocean model) and internal gravity wave-induced mixing (**[7]**, being implemented in the MPI-M ocean model).
- Sea-ice developments such as different rheology schemes, and improvements in thermodynamcs (such as multi-layer ice) are being investigated.
- A new microphysics package called CASIM **[8]** is being tested in the HadGEM3-GC3.1 model – currently it does not work with a convection parameterisation, so it is being tested in a 10km global resolution model with explicit convection.
- Several enhancements to land-surface representation, such as river networks and soil properties, are being developed and tested.

References

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[3] Stevens et al, 2017,doi:10.5194/gmd-10-433-2017
[4] Good et al, 2013,doi:10.1002/2013JC009067
[5] Roberts et al, 2015,doi:10.1002/2016GL070559
[6] Belcher et al, 2012,doi:10.1029/2012GL052932
[7] Eden et al, 2014,doi:10.1175/JPO-D-13-0260.1
[8] McCoy et al, 2017,doi:10.5194/acp-2017-649
[9] RapidMoc – Roberts, C.D., 2017, doi:10.5281/zenodo.1036387

AMOC time evolution

One of the problems with a short spinup period is continuing model drift and the implications for understanding. As an example, the AMOC timeseries from the HadGEM3-GC3.1 model with different ocean and atmosphere resolutions is shown in Fig. 3. It is clear 30 years was not enough for the AMOC to reach a settled value for several model resolutions. Understanding such issues may help improve future protocols.

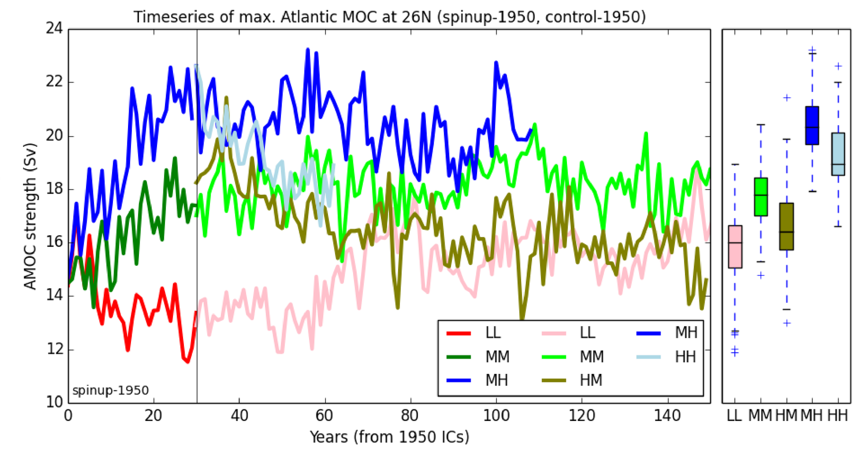

Fig. 3: Timeseries of various different resolution simulations of the HadGEM3-GC3.1 model, both during the 30 year spinup-1950 (left) and then the control-1950 simulations.

AO is AtmosphereOcean resolution:

L=130km; L=1˚ocean; M=60km; M=1/4˚ocean; H=25km; H=1/12˚ocean

AMOC and ocean heat transport

To try and understand the models in the same framework as observations, packages such as RapidMoc **[9]** are being used. Figure 4 shows the AMOC vertical structure at 26˚N for the ECMWF climate model compared to the RAPID-MOCHA array, and the breakdown of MOC and heat transport into components (total, overturning and gyre).

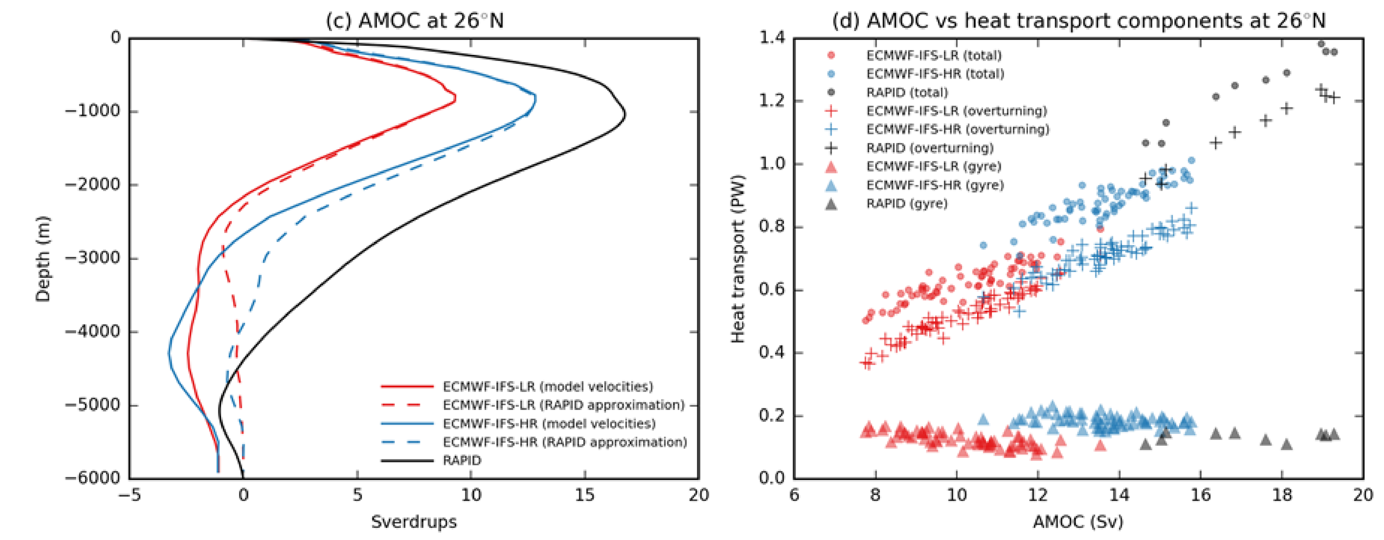

Fig. 4: (left) Vertical structure of AMOC in ECMWF models and observations; (right) Scatter plot of AMOC strength vs northward heat transport, for total, gyre and overturning contributions.

Coordinated analysis and data access

Data volumes are a big challenge for the project, and we currently have ~500TB of data available from our simulations. PRIMAVERA partners are using a common platform (CEDA-JASMIN) for all our data and analysis tools, together with standard data formats (CMIP-CMOR3) and open software (e.g. python). We are engaging with other communities (such as various CLIVAR panels, the tropical cyclone community) to enable access to our data and coordinated analysis – see **collab.knmi.nl/highresmip**. The output will be published to ESGF as soon as possible.

Please contact us if you have ideas for novel analysis and want to access our data.

PRIMAVERA
www.primavera-h2020.eu

PRIMAVERA is a collaboration between 19 leading European research and technology organisations with complementary expertise in climate science, climate change modelling, and high-performance computing. The project is led by the Met Office and the University of Reading.

Discover more about PRIMAVERA

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