Flux-anomaly-forced model intercomparison experiment (FAFMIP)

Steering committee

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Goals and overview of experiments

FAFMIP is proposed in support of the WCRP Grand Challenge on sea level rise and regional impacts. Projections of regional sea level change by CMIP5 AOGCMs, like earlier AOGCM generations, show a substantial spread due to the different models' differing simulations of regional ocean density and circulation changes, especially in high latitudes and the North Atlantic (Yin, 2012, 10.1029/2012GL052947; Bouttes et al., 2012, 10.1029/2012GL054207; IPCC AR5 WG1 chapter 13, Church et al., 2013; Slangen et al, 2014, 10.1007/s10584-014-1080-9). By applying flux perturbations from a range of CMIP5 models to the same AOGCM, previous analyses have shown that a substantial fraction, but not all, of the diversity of sea level projections arises from the spread in AOGCM projections of changes in surface fluxes of momentum (windstress), heat and freshwater (Bouttes et al., 2012, cited above; Bouttes et al., 2014, 10.1007/s00382-013-1973-8; Bouttes and Gregory, 2014, 10.1088/1748-9326/9/3/034004).

In the FAFMIP experiments, a prescribed set of surface flux perturbations will be applied to the ocean. These perturbations will be obtained from the ensemble-mean changes simulated at time time of doubled CO_2 by CMIP5 AOGCMs under the 1pctCO2 scenario, so they are representative of projected anthropogenic climate change. The aims of the experiments are:

- to quantify the difference in the geographical patterns of sea level change due to ocean density and circulation change simulated by the models, when given common surface flux perturbations.
- to provide information about the efficiency and interior distribution of ocean heat uptake in response to climate change; the AOGCM spread in these phenomena contributes to their spread in transient climate response and global mean sea level rise due to thermal expansion.
- to provide information about the sensitivity of the Atlantic meridional overturning circulation (AMOC) to prescribed buoyancy forcing of the character expected for CO_2 forcing, rather than idealised freshwater forcing such as has been used in previous AMOC intercomparisons; change in the AMOC is of relevance to both regional and global sea level rise, as well as to regional climate change.

The FAFMIP experiments are aimed at increased physical understanding. They are not themselves policy-relevant scenarios, but obviously the uncertainties in projection of global and regional sea level and AMOC change are of great policy relevance.

The steering committee undertakes to ensure that a paper on the FAFMIP design will be prepared, and all participants will be encouraged to collaborate in producing a paper on the results. At the time of writing (20 May 2015) there are ten groups who plan to run FAFMIP experiments (ACCESS, CanESM, CNRM/CERFACS, GFDL, GISS, IPSL, MIROC6, MPI, MRI, UKESM).

Design of experiments (see http://www.met.reading.ac.uk/~jonathan/FAFMIP)

All the experiments will add anomalies to the surface fluxes computed by the AOGCM (like a flux adjustment). The fluxes themselves will not be replaced because this would typically cause a very large climate drift and possible instability, and is technically more complicated than adding an anomalous flux. The surface flux anomalies are a function of (longitude, latitude, time of year) and constant throughout the experiments, which are proposed to be 70 years long (but shorter experiments would still be useful if 70 years cannot be afforded). The experiments will branch from and be analysed by comparison with the standard CMIP DECK pre-industrial control. All the experiments have pre-industrial atmospheric conditions.

There are three tier-1 experiments, most important first. The **bold** word is the name of the experiment.

stressFAF: Impose a perturbation in surface zonal and meridional windstress. We propose this experiment first because the windstress change appears to have the largest effect on sea level in CMIP5 scenario experiments. In addition to its relevance to sea level, this experiment will also be of interest regarding the phenomenon of eddy saturation (relative insensitivity of the circumpolar circulation to windstress change), especially in eddy-resolving models, and to study the influence of windstress change on advecting circumpolar deep water towards the Antarctic continental shelf, where it could affect ice-shelf melting and hence sea-level rise through the effect on ice-sheet dynamics (a different aspect of the Grand Challenge). The perturbation is made to windstress, rather than to wind speed in the atmosphere, because windstress is the flux experienced by the ocean. AOGCMs typically use other diagnostics of wind speed to supply turbulent mixing energy to the ocean in addition to windstress. Perturbing these quantities is not included in the proposed design at present.

heatFAF: Impose a perturbation in surface heat flux, which is second in importance in its influence on patterns of sea level change. It has also been found in a previous analyses to be the main influence on AMOC change. In an AOGCM, imposing a heat flux perturbation is not straightforward, because it alters the SST, which affects the surface heat flux calculated by the atmosphere model and tends to cancel out the perturbation. In this experiment and in the **allFAF** experiment, we propose to use a passive tracer to avoid this feedback (see documents on website). The design allows us to distinguish the effects of added heat and redistribution of the control heat content.

waterFAF: Impose a perturbation in the surface freshwater flux (including the contribution from runoff change). This is the least influential surface flux.

There are two tier-2 experiments.

passiveheat: Add a surface flux of passive tracer at the same rate as the surface heat flux perturbation in the **heatFAF** experiment. This flux will be added to the top layer of a passive temperature tracer. Comparison of this experiment with the **heatFAF** experiment will allow the effect of ocean advection on surface heat flux feedback to be assessed (cf. Winton et al., 2013, 10.1175/JCLI-D-12-00296.1).

allFAF: In the **allFAF** experiment, the anomalous fluxes of windstress, heat and water are simultaneously applied, using the passive-tracer method for heat as in the **heatFAF** experiment.

Diagnostics

No changes to the standard CMIP set of diagnostics or CF, CMOR or ESG are required. The analysis of sea level change will mainly use zos, zostoga, thetao and so. Analyses of ocean heat uptake efficiency will use thetao. Analyses of the AMOC will use msftmyz, msftyyz, uo and vo. It is strongly recommended that 3D ocean diagnostics should be implemented for monthly-mean temperature and salinity tendencies ($\partial T/\partial t$ and $\partial S/\partial t$) due to the various physical processes which modify the state (advection, diffusion, etc.). These diagnostics have been included in Table 2.9 of the recommendations from the CLIVAR Ocean Model Development Panel committee on CMIP6 ocean model output for use in all CMIP6 experiments, including DECK for instance, but their usefulness for FAFMIP is particularly noted there. If the $\partial/\partial t$ diagnostics are not submitted for all experiments, for FAFMIP they are particularly requested for the portion of the DECK piControl which is parallel to the FAFMIP experiments, and for the DECK idealised climate change experiments abrupt4xCO2 and 1pctCO2.

Proposed timing

The input fields will be prepared by the end of June 2015 and experiments can be done thereafter by any interested groups. Interim versions are currently being tested by three groups.