UK ocean modelling activities 2008-9
Summarised by Malcolm Roberts (MOHC)

Met Office Hadley Centre (MOHC)
The ocean/sea-ice components of HadGEM2-ES (Earth System) model, our model for IPCC AR5, are broadly similar to HadGEM1 (IPCC AR4). Main ocean differences are parameter values for vertical tracer diffusivity (changed vertical profile near surface to reduce mixing), and reducing horizontal viscosity near the equator.

Our new HadGEM3 coupled climate model, which incorporates the NEMO ocean and CICE sea-ice models (on a tri-polar, nominally 1x1° grid with enhancement to 1/3 degree meridionally at the equator) coupled to the atmosphere via OASIS3, is currently being developed, as one of a hierarchy of coupled models at different resolutions. This model is now being used for the operational seasonal forecast, but will not be used for IPCC AR5. The initial version gave a rather cold SST climatology, so sensitivity studies looking into parameters in the TKE vertical mixing scheme are ongoing.
Contribution to NEMO system developments, including improved Gent-McWilliams implementation (with NOCS).

Met Office Ocean Forecasting (John Siddorn)
The Ocean Forecasting R&D group has been focusing on transitioning their modelling systems from the Unified Model FOAM, for non-tidal modelling applications, and the POLCOMS system, for tidal applications, to use NEMO in all Met Office short-term forecasting systems. At the same time as transitioning to NEMO the opportunity was taken to increase both the horizontal and vertical resolution of our open ocean systems and rationalise the configurations used. This has resulted in a reduction from 10 to 4 operational open ocean configurations. The focus to date has been on validating these systems to give an understanding of the product quality, the results of which have been extremely encouraging. Progress for the tidal applications using has been slower, and the focus has been on updating the NEMO code to ensure suitability of tidal work. It is envisaged that by the end of 2009 a NEMO-Shelf system will be running that will form the basis for future operational runs.

NCAS-Climate, University of Reading, and UKMO
The HiGEM coupled model (incorporating a 1/3 degree ocean model and based on HadGEM1), developed as part of the UK-HiGEM and UK-Japan Climate Collaboration projects, is being used for seasonal-to-decadal integrations which will be submitted to AR5. An enhanced resolution version of the HadGEM3 model, using the 1/4° NEMO model, is also being developed jointly between MOHC and NCAS-Climate, and may be used as part of a seasonal-to-decadal contribution to AR5 if it is ready in time.

National Oceanography Centre, Southampton (NOCS) (Adrian New)
A number of ORCA025 integrations performed using DFS3/4 forcings (DRAKKAR forcing set) as part of DRAKKAR group. Global 1/12 model planned, and short 1/36 model integrations to study internal tides.
NEMO system developments, including on-the-fly interpolation of forcing fields.
Work on CHIME – HadCM3 model but with hybrid coordinates in the ocean (z at surface, isopycnal beneath mixed layer) – to increase model model diversity – used for freshwater hosing and warming experiments.
Work on AGRIF nesting to enable use in sea-ice covered regions.
NOCS and MOHC have signed an agreement to work together more closely on ocean and sea-ice model development.

Imperial College Ocean Model (ICOM) – unstructured, adaptive mesh **(Matthew Piggott)**
Progress on the development of ICOM is currently focusing strongly on three-dimensional, large-scale, high aspect ratio baroclinic problems. The associated highly-demanding

computational issues that result include the accurate representation of balanced dynamics, very ill-conditioned elliptic pressure equations, maintaining sharp interfaces as well as subtle stratification in tracer fields, and high computational cost because of large degree-of-freedom counts and long simulation times. We are addressing these through the following: implementation of a new finite element discretisation type (discontinuous linear representation of velocity and tracer fields, and a continuous quadratic representation of pressure) which allows for accurate and stable representation of balanced dynamics, as well as excellent treatment of advection dominated fields; new algebraic multi-grid (AMG) solvers that have been demonstrated to perform better than off-the-shelf AMG libraries for the uniquely challenging ocean problem; parallelisation of new developments and benchmarking on a number of platforms including a Cray XT4 where preliminary results have shown excellent scaling up to 1024 cores.

Additional developments include a new fully functioning conservative and bounded mesh-to-mesh interpolation method for use with adaptivity; in addition to full 3D adaptivity, the new capability to use 2D adaptivity in the horizontal, and 1D adaptivity in the vertical so that columns can be preserved in certain regions if required; upper mixed layer models implemented via the flexible generic length scale method and validated against lab and real world data; a new NPZD biology module; improved mesh movement algorithms.

Reading ESSC (Keith Haines)
Working on global ocean reanalysis with the NEMO 1 degree and 1/4 degree models forced with ECMWF meteorology. Currently available reanalysis products assimilate all available hydrography for 1960-2007@ 1degree and 1987-2007@1/4 degree. Diagnostics of interest include water mass changes, circulation changes in the Arctic, and thermohaline circulation changes, including the AMOC.
Results show DFS4 performs better than DFS3 (fresh water fluxes more in balance with assimilated salinity data, hence reducing sea level trends in assimilated run). Future work will focus on altimeter assimilation and also the use of assimilation to initialise coupled models for AMOC and climate prediction studies in Rapid-Watch.