Department for Environment Food & Rural Affairs

Department of Energy & Climate Change

Met Office Hadley Centre

Environment Agency

Is UKCP09 still an appropriate tool for adaptation planning?
Marine Projections

November 2016

Contents

Executive Summary

The purpose of this document is to review the relevant scientific advances that have taken place since the release of the UKCP09 Marine Projections and provide advice on what information to use for coastal or marine adaptation planning until the new projections are available from the UKCP18 project.

The summary of advice is as follows:

- There have been substantial changes in the science of time-mean sea level projections since UKCP09 was published, which was based on the science of the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4; IPCC, 2007). We advise users to avoid using this older information and to wait for the updated UKCP18 projections to become available if possible. If information is needed to inform a decision before then, we advise users to take information from the IPCC Fifth Assessment Report (AR5; IPCC, 2013) into account: http://www.climatechange2013.org/images/report/WG1AR5_Chapter13_FINAL.pdf

- Changes in climate projections of mid-latitude Atlantic storms are less different between AR4 and AR5 than the assessment of time-mean sea level. We recommend that users continue to use projections of storm surge changes reported in UKCP09 as a minimum estimate of the range, until new information becomes available from UKCP18.

- Wave projections will not be updated as part of UKCP18 and users should continue to make use of the projections provided as part of UKCP09. Global wave projections are available for RCP4.5 and RCP8.5 as part of the Coordinated Ocean Wave Climate Project (COWCLIP) from https://data.csiro.au/dap/landingpage?pid=csiro:13500

- Shelf sea projections of temperature, salinity and circulation will not be updated as part of UKCP18. UKCP09 provided a single projection for shelf sea water properties. More recently a similar modelling system has been used to generate an ensemble of projections under the MINERVA project (Tinker et al, 2016). We recommend that users make use of the full MINERVA data set (which includes the

UKCP09 projections) when considering potential changes in shelf water properties over the 21st Century. These data are available from http://catalogue.ceda.ac.uk/uuid/c92a088715184487a2eab79949dfe497

- New H++ scenarios for time-mean sea level over the 21st Century will be developed during the UKCP18 period in collaboration with the UK academic community. Users should continue to use the H++ scenarios developed for UKCP09 and also refer to the AR5 statement on potential additional sea level rise (above their "likely ranges") associated with possible collapse of the West Antarctic Ice Sheet. The relevant section of AR5 is available from: http://www.climatechange2013.org/images/report/WG1AR5_Chapter13_FINAL.pdf .

  We do note that the science relevant to H++ scenarios is evolving quickly with new information on ice sheets becoming available.

1. Summary of what is provided under UKCP09

There were several strands to the current Marine Projections presented by Lowe et al (2009) as part of UKCP09:

- projections of the regional time-mean sea level
- projections of storm surge activity
- projections of significant wave height
- changes in coastal water properties
- consideration of “H++” scenarios for time-mean sea level and storm surge.

UKCP09 was released following the publication of the IPCC AR4 and made use of climate model simulations performed under phase 3 of Coupled Model Intercomparison Project (CMIP3; Meehl et al, 2007). Additionally, UKCP09 used a perturbed physics ensemble (PPE) based on the HadCM3 climate model (Gordon et al, 2000).

Time-mean sea level projections for UKCP09 were based on the CMIP3 multi-model ensemble (MME), as published in the IPCC AR4. The HadCM3 PPE was used in conjunction with a 25 km resolution regional atmospheric model to provide suitable driving surface boundary conditions for the surge and wave projections based on 11 and 3 HadCM3 model variants, respectively. A single member of the PPE was used to provide projections of shelf water properties around the UK (Table 1).

UKCP09 Science Component	Models Used
Time-mean sea level projections	CMIP3 multi-model ensemble (11 members)
Surge projections	HadCM3 PPE downscaled using a 25km regional atmospheric model (11 members)
Wave projections	HadCM3 PPE downscaled using a 25km regional atmospheric model (3 members)
Shelf water properties projections	HadCM3 PPE (1 member)

Table 1: Summary of the modelling systems and number of ensemble members used in UKCP09 Marine Projections.

2. Changes in the science since the UKCP09 Marine Projections

Since the publication of UKCP09 there have been several scientific advancements in the field of climate science. Firstly, climate models have become more sophisticated. They now include a wider range of Earth System processes and are better able to reproduce observed climatic changes (Flato et al, 2013). Secondly, the climate change scenarios used to underpin the work of the IPCC has evolved. AR4 used the Special Report on Emissions Scenarios (SRES) but more flexible Representative Concentration Pathways (RCPs) are used as the basis of climate change projections in AR5 . Thirdly, there have been advances in our physical understanding of climate change and better agreement between process-based models and available observations.

In the following sections we describe in more detail the recent scientific progress in a range of topics relevant to the Marine Projections that will be delivered by UKCP18.

2.1 Changes in projections of time-mean sea level

Substantial advances in the science of sea level change have been made between the publication of AR4 and AR5. In particular, there is:

- greater confidence in projections of global mean sea level (GMSL) owing to improved understanding of the components of sea level,
- better agreement between processed-based models and observations, and
- ice-sheet dynamical changes have been included in process-based projections of global and regional sea level change.

For UKCP09, potential changes in ice sheet dynamics were only incorporated into the "H++" scenario for time-mean sea level. This scenario provided a plausible upper bound on potential future sea level change over the 21st Century. However, increased understanding and confidence in future ice sheet dynamic changes means that a "likely range" estimate for these terms was included in the AR5 estimates for global and regional sea level projections and therefore will form the basis of the updated UKCP18 projections. Minor differences were also introduced to AR5 by both the change from SRES (Special Report on Emissions Scenarios) to RCP (Representative Concentration Pathways) emission scenarios, and in the baseline period used to compute the climate change signals. AR4 used 2090-2099 minus 1980-1999 while AR5 used 2081-2100 minus 1986-2005. The inclusion of ice sheet dynamics in AR5 is the most important

change from AR4 and leads to a substantial increase in the projected sea level rise over the 21st Century (Figure 1).

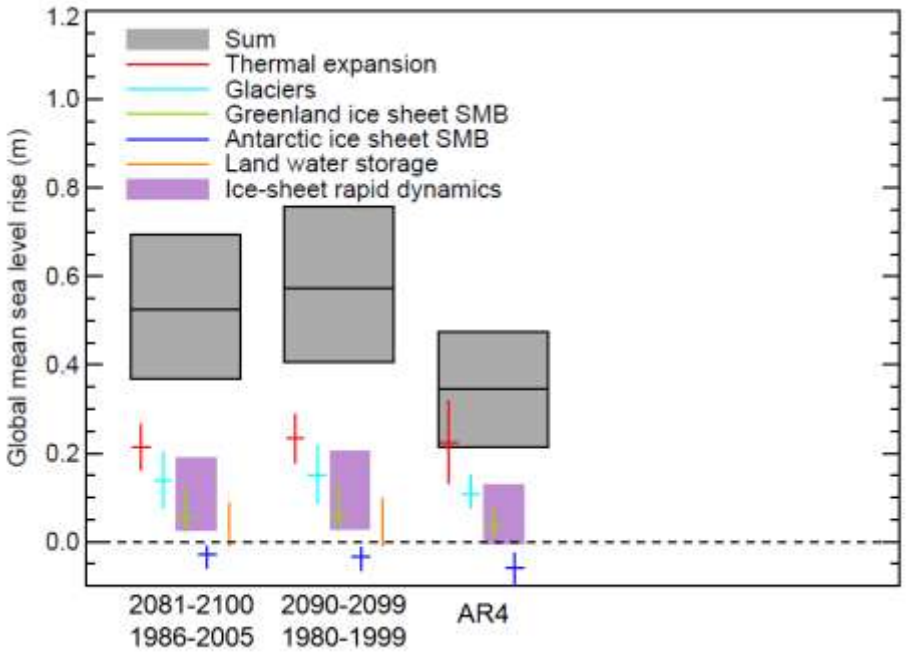

Figure 1: Global mean sea level projections for the SRES A1B scenario, showing the breakdown of contributions. The difference between the first and second columns shows the difference arising from different baseline periods for AR5 (2081-2100 and 1986-2005) and AR4 (2090-2099 and 1980-1999). The difference between the second and third columns shows the impact of including the ice sheet rapid dynamics terms in AR5, which was excluded from the main projections in AR4 (but the tentative estimate is shown here for comparison) The greatest difference between the left-hand and right-hand columns is the inclusion of the ice sheet dynamic terms. Figure provided by Jonathan Gregory.

There are regional effects that also need to be taken into account for the UK, including changes in the local oceanography under climate change and ongoing vertical land motion associated with the last deglaciation. In addition, the relative proximity of the UK to Greenland reduces the additional sea level rise from changes in the mass of this ice sheet. Preliminary work at the Met Office Hadley Centre suggests that the central estimates of regional sea level change over the 21st Century for UKCP18 will be around 20-30% larger than the values presented in UKCP09 for the highest emissions scenario.

If possible, users of UKCP09 time-mean sea level change information should wait for the release of the UKCP18 information. Until this becomes available, please refer to the AR5 chapter on sea level for further information if required: http://www.climatechange2013.org/images/report/WG1AR5_Chapter13_FINAL.pdf.

2.2 Changes in storm surge activity

UKCP09 assessed potential changes in storm surge activity using an 11-member perturbed physics ensemble of HadCM3 (PPE) to drive a regional storm surge model. The projections in surge activity showed very minor increases in 50 year return levels (< 0.9mm yr^{-1}) that could not be distinguished from natural climate variability in most locations.

UKCP18 will use the same storm surge model ("CS3") as that used in UKCP09, which remains the current basis of the Met Office operational storm surge forecast. However, the atmospheric driving data will come from the World Climate Research Programme's Coordinated Regional Climate Downscaling Experiment for the European domain (Euro-CORDEX). Euro-CORDEX (www.euro-cordex.net) provides atmosphere-only simulations with a horizontal resolution of approximately 10km, derived from state-of-the-art CMIP5 global climate model data (Taylor et al, 2012).

UKCP09 assessed projections of changes in European storm track characteristics from the HadCM3 PPE and the CMIP3 multi-model ensemble (MME) using band-pass-filtered mean sea level pressure to estimate changes in storm track position and intensity. While this is not a robust way of assessing potential changes in storm surge activity, since details of individual events may be crucial, it gives a useful first indication. UKCP09 found that the HadCM3 PPE spanned a narrower range of storm track changes than the CMIP3 MME, and therefore the expectation would be for CMIP3 models to show a larger range of projections for storm surge activity.

Figure 2 illustrates the projected changes in storm track location and intensity for the CMIP3 and CMIP5 models based on 2-6 day band-pass-filtered mean sea level pressure. There is no strong evidence for systematic differences between CMIP3 (used in AR4) and CMIP5 (used in AR5) models based upon this initial analysis. While the UKCP18 storm surge projections may show larger trends than reported in UKCP09 the changes in extreme water levels are most likely to be dominated by changes in time-mean sea level (as found in UKCP09).

Prior to the release of updated storm surge projections from UKCP18 users can continue to use UKCP09 estimates, but note that the range of outcomes should be regarded as a minimum range.

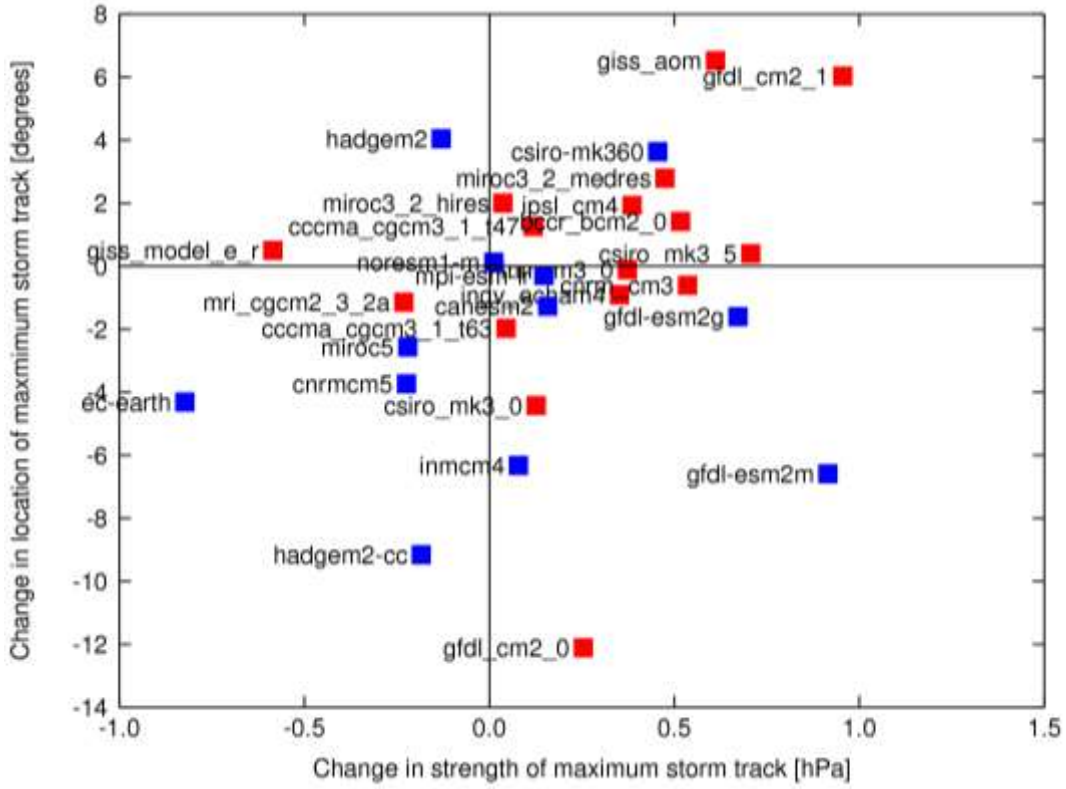

Figure 2: Climate change responses of the latitude and strength of the DJF storm track at 0E. Blue and red squares represent CMIP5 (RCP8.5) and CMIP3 (SRESA1B) models respectively and the climate change response is defined as the difference between late 21st century and late 20th century values. The measure of the storm track is the 2-6 day bandpass-filtered mean sea level pressure. Figure provided by Ben Harvey.

2.3 Changes in wave activity

Probably the most significant advance in projections of global and regional wave climate since UKCP09 is the development of the Coordinated Ocean Wave Climate Project (COWCLIP). The first results of a coordinated effort to explore global wave climate conditions were published by Hemer et al (2013).

Changes in wave activity will not be assessed under UKCP18, which will focus instead on projections of storm surges as this is the primary mechanism affecting UK coastal extreme water levels. Users should continue to use UKCP09 projections of UK wave climate and may wish to supplement this information with the results reported under the EU RISES-AM project (http://www.risesam.eu/) and COWCLIP (http://www.jcomm.info/COWCLIP). COWCLIP global wave projections for RCP4.5 and RCP8.5 are currently available from the following webpage under a Creative Commons data license: https://data.csiro.au/dap/landingpage?pid=csiro:13500.

2.4 Changes in coastal water properties

As part of UKCP09 a single member of the HadCM3 PPE was used to provide projections of shelf water properties (temperature, salinity and currents). This initial demonstration of concept has been taken forward under the DEFRA MINERVA* project that carried out projections using the entire 11-member ensemble of the HadCM3 PPE (Tinker et al, 2016). Figure 3 shows the comparison of the UKCP09 member (highlighted in red, inset panels) in the context of the MINERVA ensemble, illustrating that this member is relatively close to the ensemble mean response.

The shelf projections will not be updated for UKCP18 and we recommend that users continue to make use of the UKCP09 projections and draw on the MINERVA simulations to gain further information on the uncertainties. The MINERVA simulations are available from the Centre for Environmental Data Analysis here: http://catalogue.ceda.ac.uk/uuid/c92a088715184487a2eab79949dfe497

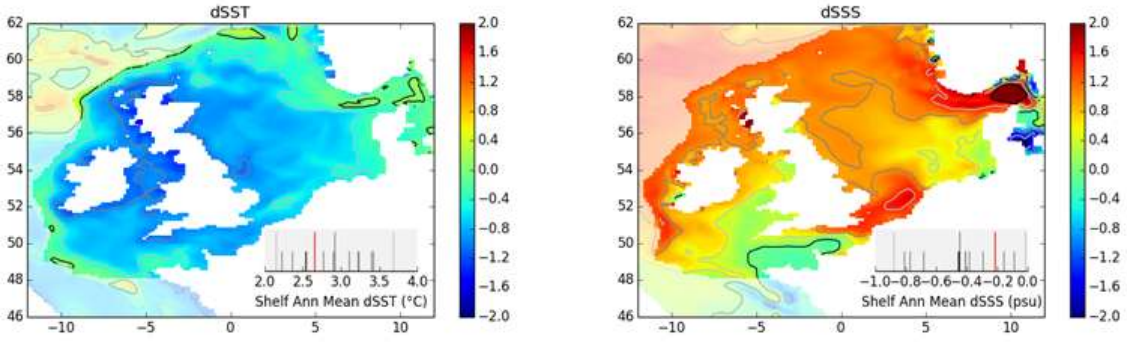

Figure 3: Maps show the difference between the UKCP09 shelf projections and the 11-member MINERVA ensemble average, expressed in terms of the ensemble standard deviation. Plots show sea surface temperature (SST, left), and sea surface salinity (SSS, right). Inset panels show area mean values for each ensemble member with the UKCP09 projection highlighted in red. Figure adapted from Tinker et al (2016).

2.5 Change in "H++" scenarios

The main sea level rise and storm surge projections presented in UKCP09 did not account for all uncertainties in potential future changes on these phenomena. For this reason, so-called High-plus-plus ("H++") scenarios were developed for the 21st Century for both time-mean sea level and storm surge changes. The H++ scenarios can be thought of as a plausible high end scenario – i.e. the top end of the H++ range is currently believed to be very unlikely, but cannot be ruled out.

Updated H++ scenarios for time-mean sea level will be developed during the UKCP18 period in collaboration with the wider UK academic community that reflects the current and rapidly evolving literature and scientific understanding. Users should continue to use the UKCP09 H++ scenario in the meantime if needed. The IPCC AR5 “likely ranges” include a global mean sea level rise of up to 0.98m under the most severe greenhouse gas scenario. In addition to this, the collapse of the marine-based sectors of the Antarctic ice sheet could bring about a further sea level rise of “several tenths of a metre” during the 21st Century (Church et al, 2013). This should also be considered when choosing to use the H++ scenario.

References

Church, J.A., P.U. Clark, A. Cazenave, J.M. Gregory, S. Jevrejeva, A. Levermann, M.A. Merrifield, G.A. Milne, R.S. Nerem, P.D. Nunn, A.J. Payne, W.T. Pfeffer, D. Stammer and A.S. Unnikrishnan, 2013: Sea Level Change. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Flato, G., J. Marotzke, B. Abiodun, P. Braconnot, S.C. Chou, W. Collins, P. Cox, F. Driouech, S. Emori, V. Eyring, C. Forest, P. Gleckler, E. Guilyardi, C. Jakob, V. Kattsov, C. Reason and M. Rummukainen, 2013: Evaluation of Climate Models. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Gordon, C., C. Cooper, C. A. Senior, H. Banks, J. M. Gregory, T. C. Johns, J. F. B. Mitchell, and R. A. Wood, 2000: The simulation of SST, sea ice extents and ocean heat transports in a version of the Hadley Centre coupled model without flux adjustments, Climate Dynamics, vol 16, p147-168. (doi:10.1007/s003820050010)

Lowe, J. A., Howard, T. P., Pardaens, A., Tinker, J., Holt, J., Wakelin, S., Milne, G., Leake, J., Wolf, J., Horsburgh, K., Reeder, T., Jenkins, G., Ridley, J., Dye, S., Bradley, S, 2009: UK Climate Projections science report: Marine and coastal projections. Met Office Hadley Centre, Exeter, UK.

Meehl, G. A., C. Covey, K. E. Taylor, T. Delworth, R. J. Stouffer, M. Latif, B. McAvaney, and J. F. B. Mitchell, 2007: THE WCRP CMIP3 Multimodel Dataset: A New Era in Climate Change Research, Bulletin of the American Meteorological Society, 88:9, 1383-1394.

IPCC, 2007: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp

IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

Tamisiea, M.E., and J.X. Mitrovica, 2011: The moving boundaries of sea level change: Understanding the origins of geographic variability. Oceanography 24(2):24–39, doi:10.5670/oceanog.2011.25.

Taylor, K.E., R.J. Stouffer, G.A. Meehl: An Overview of CMIP5 and the experiment design. Bull. Amer. Meteor. Soc., 93, 485-498, doi:10.1175/BAMS-D-11-00094.1, 2012.

Tinker J., J. Lowe, A. Pardaens, J. Holt and R. Barciela, 2016: Uncertainty in climate projections for the 21st century northwest European shelf seas, Progress in Oceanography, http://dx.doi.org/10.1016/j.pocean.2016.09.003.

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