**Centre for Environment Fisheries & Aquaculture Science**

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*World Class Science for the Marine and Freshwater Environment*

# UK marine ecosystem impacts under future warming pathways

# Climate projection summary

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# UK marine climate projections

Climate change models for UK seas are downscaled from global climate models using additional information about local processes. The most recent and detailed UK marine climate models tend to use the high emission scenario (RCP8.5), and to a lesser extent, the moderate mitigation emissions scenario (RCP4.5).

The climate model projections, or outcomes (i.e. projected sea temperature increase), that are available for UK seas vary depending on: the climate scenario behind the model; the global model simulation/s used; the local or downscaled models and simulations used; and the number of ensemble members. The differences between the climate model simulations that have been run provide an indication of uncertainty. Table 1 summarises the most recent downscaled climate models that we identified in our review, that are available for UK marine ecosystem studies. A more detailed description for each is available in Appendix 1.

Climate models include a wide range of physical and biogeochemical variables that can be used to project ecosystem impacts of climate change. The most commonly used variables are temperature, salinity, currents, phytoplankton and pH as these are available in some or many climate models. Other variables are captured in climate models and can be used as appropriate and on request, where climate modellers can provide these. Variable selection depends on the species or habitats under study and how much species variation is explained by the variable.

*Table 1. Summary details of recent and available climate models available for UK seas (see Appendix 1 for further details). SST – sea surface temperature; SSS – sea surface salinity; NBT – near bed temperature; DFT – difference in temperature between the surface and bed; PEA – potential Energy anomaly; MLD – Mixed Layer Depth; DOC – dissolved organic carbon; POC – particulate organic carbon; DIC – dissolved inorganic carbon.*

| Climate scenarios | Model name | Variables modelled | Are there any other variables in your model that may be of interest for species/ecosystem modellers. | Number of ensemble members | Baseline period for climate projection | Time period of projections and are they continuous | Spatial extent | Spatial scale | Vertical resolution |
|---|---|---|---|---|---|---|---|---|---|
| RCP8.5 | AMM7-ROAM-HADGEM RCP8.5 NEMO-ERSEM | 3D temperature, salinity, currents, phytoplankton, pH | Primary production, phytoplankton, zooplankton, bacteria, nutrients, oxygen, DIC | 1 member | 1980-2009 | 1980-2100, continuous | 20W-13E, 40N - 65N | 7km | 32 terrain-following levels |
| RCP 8.5 | AMM7-RECICLE-IPSL RCP8.5 | 3D temperature, salinity, currents, phytoplankton, pH | Primary production, Zooplankton, DOC, POC, benthic variables, nutrients | 1 member | 1990-2005 | 1990-2099, continuous | 20W-13E, 40N - 65N | ~ 7km | 51 terrain following s-levels |
| RCP 8.5 | AMM7-RECICLE-GFDL RCP8.5 | 3D temperature, salinity, currents, phytoplankton, pH | Primary production, Zooplankton, DOC, POC, benthic variables, nutrients | 1 member | 1990-2005 | 1990-2099, continuous | 20W-13E, 40N - 65N | ~7km | 51 terrain following s-levels |
| RCP4.5 and 8.5 | AMM7-C3S | 3D temperature, salinity, currents, phytoplankton, pH | Primary production, PEA, Zooplankton, DOC, POC, benthic variables, nutrients | 1 member per scenario | 1990-2005 | 1990-2050, continuous | 20W-13E, 40N - 65N | ~ 7km | 51 terrain following s-levels |
| RCP4.5 and 8.5 | POLCOMS-ERSEM-C3SP5 | 3D temperature, salinity, currents, phytoplankton, pH | Primary production, Zooplankton, DOC, POC, benthic variables, nutrients | 1 member per scenario | 1990-2005 | 1990-2099, continuous | 20E-35E, 15N - 65 N | ~11km | 43 terrain following s-levels |
| RCP4.5 and 8.5 | MPIOM-HAMOCC | 3D physics and biogeochemistry | Unknown | 3 | 1961-2005 | 2006-2100 | global | <10km on the shelf | 30 standard levels |
| RCP8.5 | AMM7 NWSPPE RCP8.5 | Temperature (SST, NBT, DFT), Salinity, Currents | Stratification (PEA), water column structure (MLD) | 12 member Perturbed Parameter Ensemble | 2000-2019 | (1980-)1990-2098, continuous | 20W-13E, 40N - 65N | 7km | 51 terrain following s-levels |
| RCP8.5 | FVCOM | Physics only (likely currents, temperature, salinity) | Unknown | Unknown | climatology for present day | climatology for period 2038-2062 | 13W-13E, 48N-63N | Variable from 500m to 20km | Unknown |
| RCP4.5 and 8.5 | RisesAM-NEA-clim | Wave height | Unknown | Unknown | 1970-2006 | 2005-2100 | 20W-13E, 40N - 65N | 12km | Spectral wave model |
| RCP8.5 | AMM7-NEMO | 3D temperature, salinity, currents, stratification | No | 11 members forced by 11 global models | 1983–2012 | 1983-2095, continuous | 20W-13E, 40N - 65N | 7km | 51 terrain-following s-levels |

# Appendix 1 - Description of the selected climate simulations

## AMM7-ROAM-HADGEM

## NEMO-ERSEM



**Domain: AMM7** (40N to 65N; 20W to 13E)

**Scenario: high emission scenario** (RCP8.5)

**Period: 1990-2099**

**CMIP model used: HadGEM2-ES**
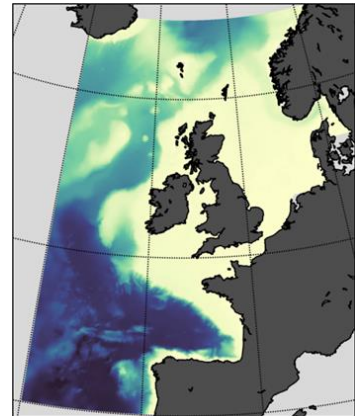
**Model: NEMO (3.2) – ERSEM (15.06)**

**Resolution: 7km**

**Ensemble: 1 member**

**Variables: 3D physics and biogeochemistry** (daily and monthly)

**Availability:** Data available on request from Plymouth Marine Laboratory published here: https://doi.org/10.1016/j.pocean.2020.102400

**Narrative:**

This model is driven by a CMIP model with a high sensitivity to greenhouse gas emissions, and therefore the impact of climate change is on the higher end of the variability for this scenario. The sea surface temperature is projected to increase by about 2-4 degrees by the end of the century and the surface salinity is projected to decrease between 1 and 2PSU, with much stronger freshening projected in the Norwegian Trench (up to -4PSU).

By the end of the century, the total net influx of North Atlantic water into the North Sea is projected to decrease by 100%.

# AMM7-RECICLE-IPSL RCP8.5



**Domain: AMM7** (40N to 65N; 20W to 13E)

**Scenario: high emission scenario** (RCP8.5)

**Period: 1990-2099**

**CMIP model used: IPSL-CM5A-MR**

**Model: NEMO (3.6) – ERSEM (20.09)**

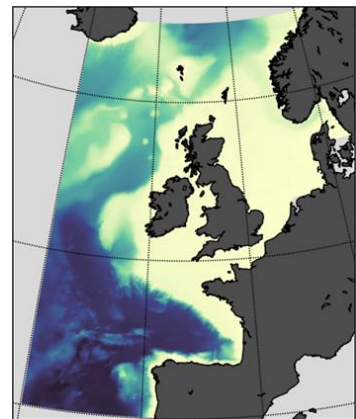**Resolution: 7km**

**Ensemble: 1 member**

**Variables: 3D physics and biogeochemistry** (daily and monthly)

**Availability:** Data available on request from Plymouth Marine Laboratory, published here: https://doi.org/10.5194/bg-21-2143-2024.

**Narrative:**

This model is driven by a CMIP model that is quite sensitive to GHG emissions, and therefore the impact of climate change is on the higher end of the variability for this scenario. The sea surface temperature is projected to increase by about 1-3 degrees by the end of the century and the surface salinity is projected to decrease by about 1PSU in most of the domain, with much stronger freshening projected in the Norwegian Trench (up to -4PSU).

By the end of the century, the influx of North Atlantic water into the North Sea is projected to decrease by 70%.

# AMM7-RECICLE-GFDL RCP8.5

**Domain: AMM7** (40N to 65N; 20W to 13E)

**Scenario: high emission scenario** (RCP8.5)

**Period: 1990-2099**

**CMIP model used: GFDL-ESM2G**

**Model: NEMO (3.6) – ERSEM (20.09)**
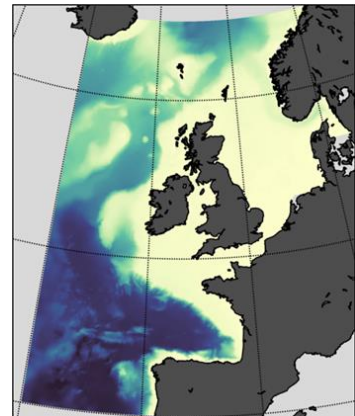
**Resolution: 7km**

**Ensemble: 1 member**

**Variables: 3D physics and biogeochemistry** (daily and monthly)

**Availability:** Data available on request from Plymouth Marine Laboratory, published here: https://doi.org/10.5194/bg-21-2143-2024.

**Narrative:**

This model is driven by a CMIP model with a low sensitivity to GHG emissions, and therefore the impact of climate change is on the lower end of the variability for this scenario. The sea surface temperature is projected to increase by about 1-2 degrees by the end of the century and the surface salinity is projected to decrease by less than 0.5PSU in most of the domain. No significant change in the influx from North Atlantic water into the North Sea is projected.
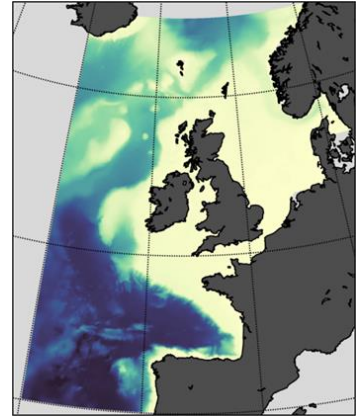
# AMM7-C3S RCP4.5 and 8.5

**Domain: AMM7** (40N to 65N; 20W to 13E)

**Scenario: high emissions scenario** (RCP8.5)

**mid-range mitigation scenario** (RCP4.5)

**Period: 1990-2049**

**CMIP model used: HadGEM2-ES** (downscaled atmosphere)

**Model: NEMO (3.6) – ERSEM (20.09)**

**Resolution: 7km**

**Ensemble: 1 member**

**Variables: 3D physics and biogeochemistry** (daily and monthly)

**Availability:** Data available on request from Plymouth Marine Laboratory

**Narrative:**

This model is driven by a CMIP model with a high sensitivity to GHG emissions, and therefore the impact of climate change is on the higher end of the variability for this scenario. The sea surface temperature is projected to increase between 0.5 and 1.5 degrees by 2050 with surface salinity decreases of less than 0.5 PSU.

# POLCOMS-ERSEM-C3S RCP4.5 and 8.5

**Domain: Pan European seas**

**Scenario: high emissions scenario** (RCP8.5)

**mid-range mitigation scenario** (RCP4.5)

**Period: 1990-2099**

**CMIP model used: MPI-ESM-LR** (downscaled atmosphere)

**Model: POLCOMS-ERSEM**

**Resolution: 7km**

**Ensemble: 1 member**

**Variables: surface and depth averaged physics and biogeochemistry** (daily and monthly)

**Availability**: Data available on request from Plymouth Marine Laboratory

**Narrative:**

This model is driven by a CMIP model with intermediate sensitivity to GHG emissions, and therefore the intensity of climate change can be considered close to the average for this scenario. The sea surface temperature is projected to increase between 1 and 4 degrees by the end of the century and a freshening of the Atlantic waters between 0.7PSU in open waters and 2-3PSU in Atlantic coastal waters. In contrast, the Mediterranean Sea is projected to increase its salinity up to 1PSU in its Eastern part.
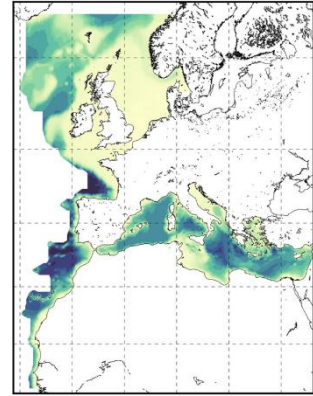
# MPIOM-HAMOCC RCP4.5 and 8.5

**Domain: global** (with focus on North-Western European Shelf)

**Scenario: high emission scenario** (RCP8.5)

**mid-range mitigation scenario** (RCP4.5)

**Period: 1920-2099**

**CMIP model used: MPI-ESM-LR**

**Model: MPIOM-HAMOCC**

**Resolution: variable,** 5-10 km on the shelf, 20 km in the North Atlantic
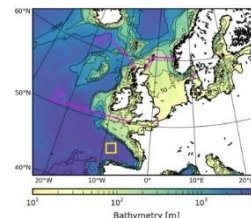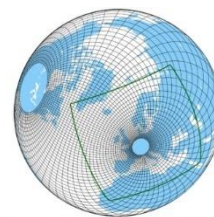
**Ensemble: 3 members** (of CMIP model)

**Variables: 3D physics and biogeochemistry** (monthly)

**Availability:** Data available here: https://www.wdc-climate.de/, published here: https://www.sciencedirect.com/science/article/abs/pii/S0924796318300198?via%3Dihub

**Narrative:**

This model is driven by a CMIP model with intermediate sensitivity to GHG emissions, and therefore the intensity of climate change can be considered close to the average for this scenario. The sea surface temperature in North-Western European Shelf is projected to increase by about 1.5-2.5 degrees by the end of the century and the surface salinity is projected to decrease by about 0.5 PSU, with a stronger freshening projected in the Norwegian Trench (up to -1.5PSU).

This simulation uses three different ensemble members of the original CMIP model, to explore how the uncertainty of the CMIP model translates in the finer resolution model.

# AMM7 NWSPPE RCP8.5

**Domain: AMM7** (40°N to 65°N; 20°W to 13°E)

**Scenario: high emission scenario** (RCP8.5)

**Period: 1990-2099**

**CMIP model used: HadGEM3 GC3.05**

**Model: NEMO (4.0.4)**

**Resolution: 7km**

**Ensemble: 12 members** (of the downscaling model)

**Variables: 3D physics** (daily and monthly)

**Availability:** Available from https://catalogue.ceda.ac.uk/uuid/7d6c30d625664d4d805e26b385e65964/ with higher frequency data available to collaborators on request from Met Office. Publication available here: OS - Twenty-first century marine climate projections for the NW European shelf seas based on a perturbed parameter ensemble

**Narrative:**

This model is driven by a CMIP model with a high sensitivity to GHG emissions, and therefore the impact of climate change is on the higher end of the variability for this scenario. The sea surface temperature is projected to increase between 2 and 5 degrees by the end of the century and the surface salinity is projected to decrease between 1 and 2 PSU.

This is a 12 members parameter perturbation ensemble, i.e. the driving CMIP model (HadGEM3 GC3.05) has been run 12 times with different values for some parameters to explore the uncertainty linked to the parameters of the model itself. Each of the 12 CMIP simulations as been downscaled with the downscaling model (NEMO 4.0.4) to show how this uncertainty is expressed within the seas around the UK.

These projections are consistent with the UKCP18 climate projections, allowing these marine climate projection data to be used with consistent projected changes in the atmosphere, and land surface.
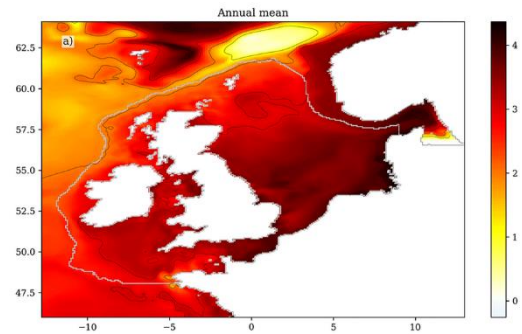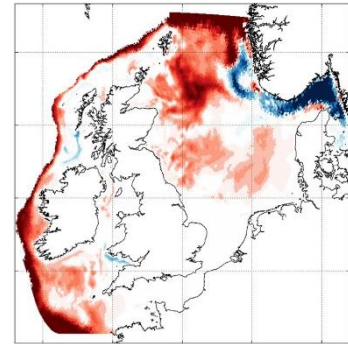
# FVCOM RCP8.5

**Domain: NW European Shelf**

**Scenario: high emissions scenario** (RCP8.5)

**Period: present day and 2050 climatologies**

**CMIP model used: HadGEM2-ES** (downscaled atmosphere)

**Model: FVCOM**

**Resolution: variable** (from 500m near the coast to 20 km)

**Ensemble: 1 member**

**Variables: 3D physics**

**Availability:** Published here: https://doi.org/10.1029/2018jc013832

**Narrative:**

This model is driven by a CMIP model with intermediate sensitivity to GHG emissions, and therefore the intensity of climate change can be considered close to the average for this scenario. The model projects a warming and freshening of the North Sea although this is not quantified.

# RisesAM-NEA-clim RCP4.5 and 8.5



**Domain: Pan European seas** (focus on NW European Shelf)

**Scenario: high emission scenario** (RCP 8.5)

**mid-range mitigation scenario** (RCP4.5)

**Period: present day to 2100**

**CMIP model used: EC-Earth** (downscaled)

**Model: Wave Watch III**

**Resolution: 12km**

**Ensemble: 1 member**

**Variables: significant wave height** and other wave related statistics

**Availability:** Published here:
https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018JC013866

**Narrative:**

This model is driven by a CMIP model with intermediate sensitivity to GHG emissions, and therefore the intensity of climate change can be considered close to the average for this scenario. The model projects that by the end of the century, the significant wave height will decrease by up to 0.2m, with significant spatial and temporal variability (e.g. winter significant wave height increasing, up to 0.1m, in the Celtic Sea, the English Channel and the southern coast of the North Sea). An increase in intensity of rare high wave is projected, although uncertain.
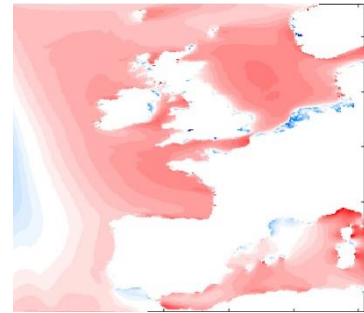
# About us

We are the Government's marine and freshwater science experts. We help keep our seas, oceans and rivers healthy and productive and our seafood safe and sustainable by providing data and advice to the UK Government and our overseas partners.

We are passionate about what we do because our work helps tackle the serious global problems of climate change, marine litter, over-fishing and pollution in support of the UK's commitments to a better future (for example the UN Sustainable Development Goals and Defra's 25 year Environment Plan).

We work in partnership with our colleagues in Defra and across UK government, and with international governments, business, maritime and fishing industry, non-governmental organisations, research institutes, universities, civil society and schools to collate and share knowledge.

Together we can understand and value our seas to secure a sustainable blue future for us all, and help create a greater place for living.

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In our laboratories in Lowestoft and Weymouth we:
• safeguard human and animal health
• enable food security
• support marine economies.

This is supported by monitoring risks and disease in water and seafood; using our data in advanced computer models to advise on how best to manage fish stocks and seafood farming; to reduce the environmental impact of man-made developments; and to respond to serious emergencies such as fish disease outbreaks, and to respond to oil or chemical spills, and radioactivity leaks.

Overseas, our scientists currently work in Commonwealth countries, United Kingdom Overseas Territories, South East Asia and the Middle East.

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