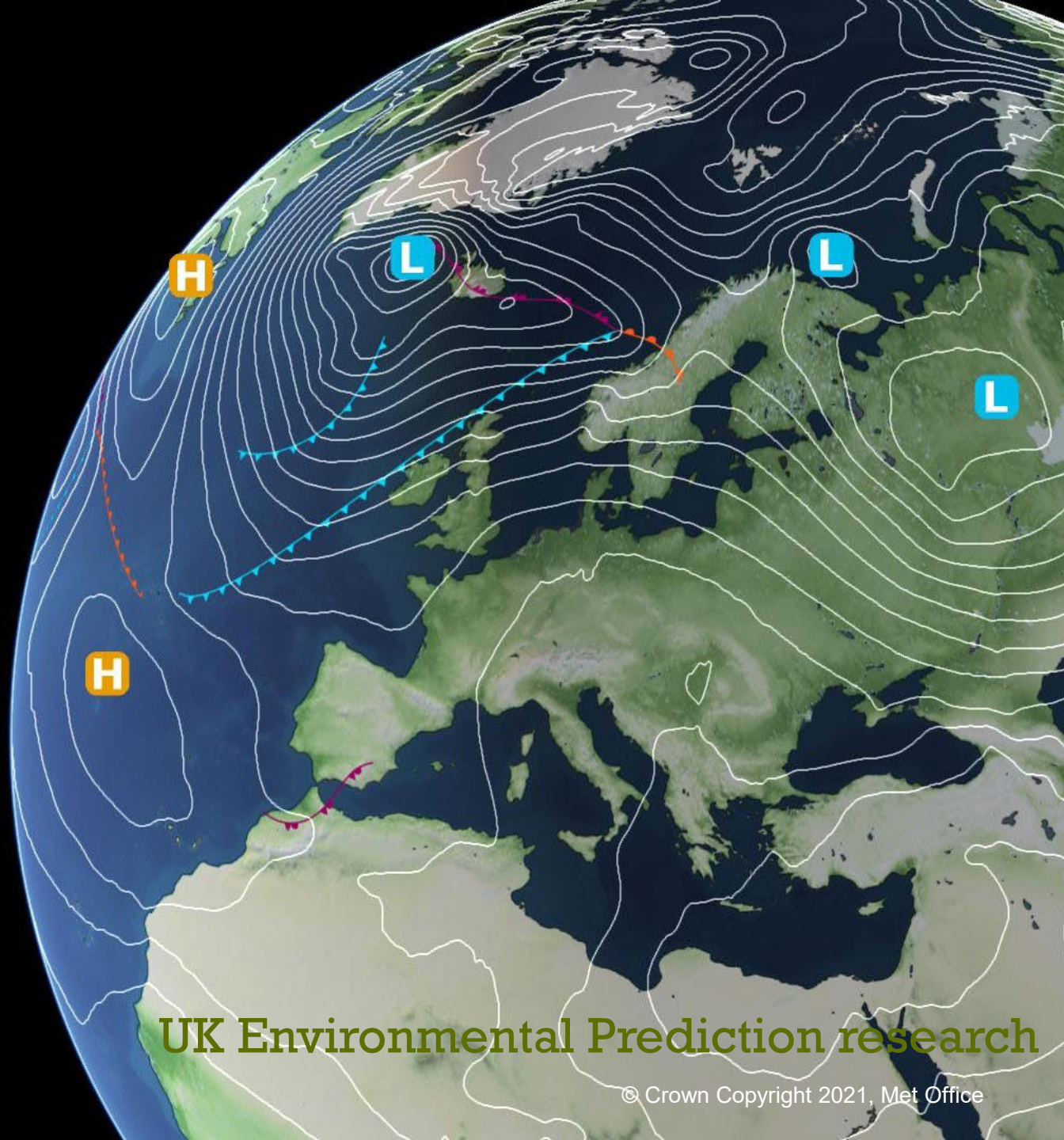
Met Office

Regional coupled modelling at km-scale over the UK: the RCS-UKC4 configuration



Ségolène Berthou
Alex Arnold, JuanMa Castillo, Vivian Fraser-Leonhardt, Huw Lewis, Sana Mahmood, Nefeli Makrygianni, Claudio Sanchez,
& regional ocean / wave / atmosphere/ land modellers in Met Office and NERC centres

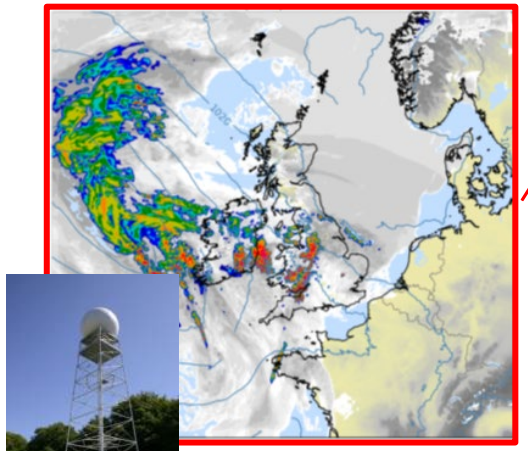
Met Office | UK Centre for Ecology & Hydrology | National Oceanography Centre | PML Plymouth Marine Laboratory

www.metoffice.gov.uk

UK Environmental Prediction research

Regional coupled suite

ATMOSPHERE: UM



Neutral Wind

Charnock coefficient

OASIS coupler

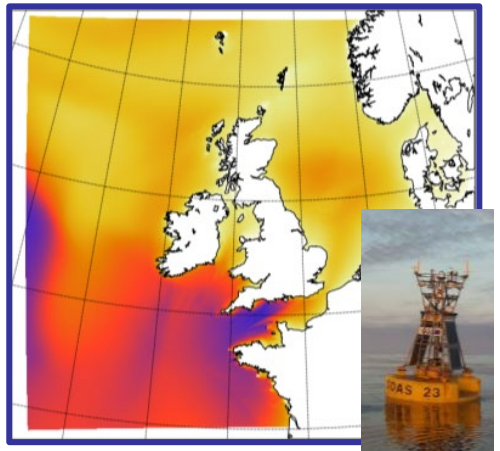
Wind, Pressure, Temperature, Radiation, Surface fluxes

SST, Currents

Wave height, Sfc stress

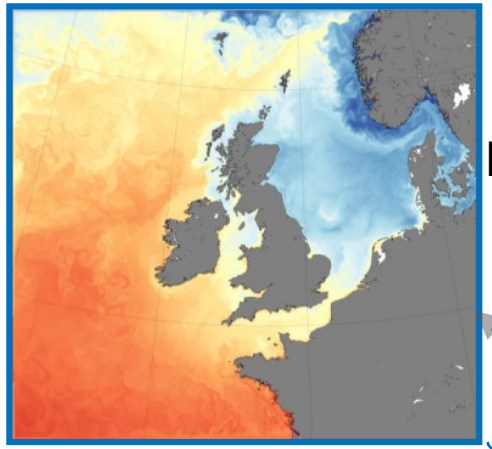
Currents, Depth

WAVES: WaveWatch III



Surface fluxes

Radiation, Temp, Precip, Evap

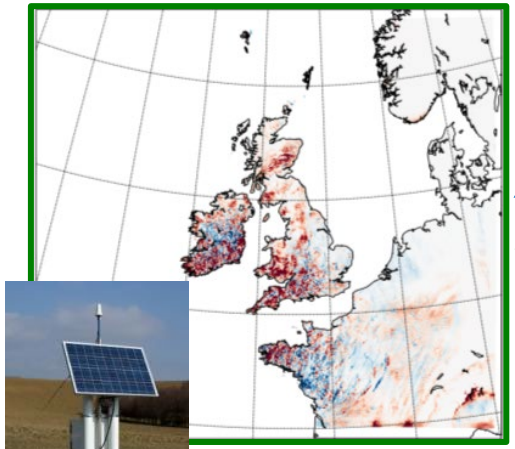


OCEAN: NEMO

FABM cpl

Water Colour

3D Currents, 3D T, S

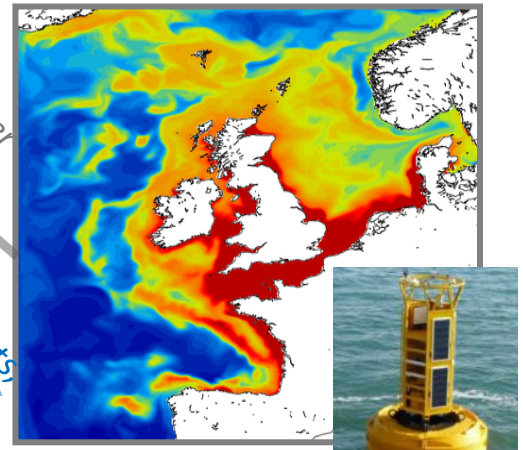


Inundation

Freshwater

River Nutrients, Temperature

LAND SURFACE: JULES

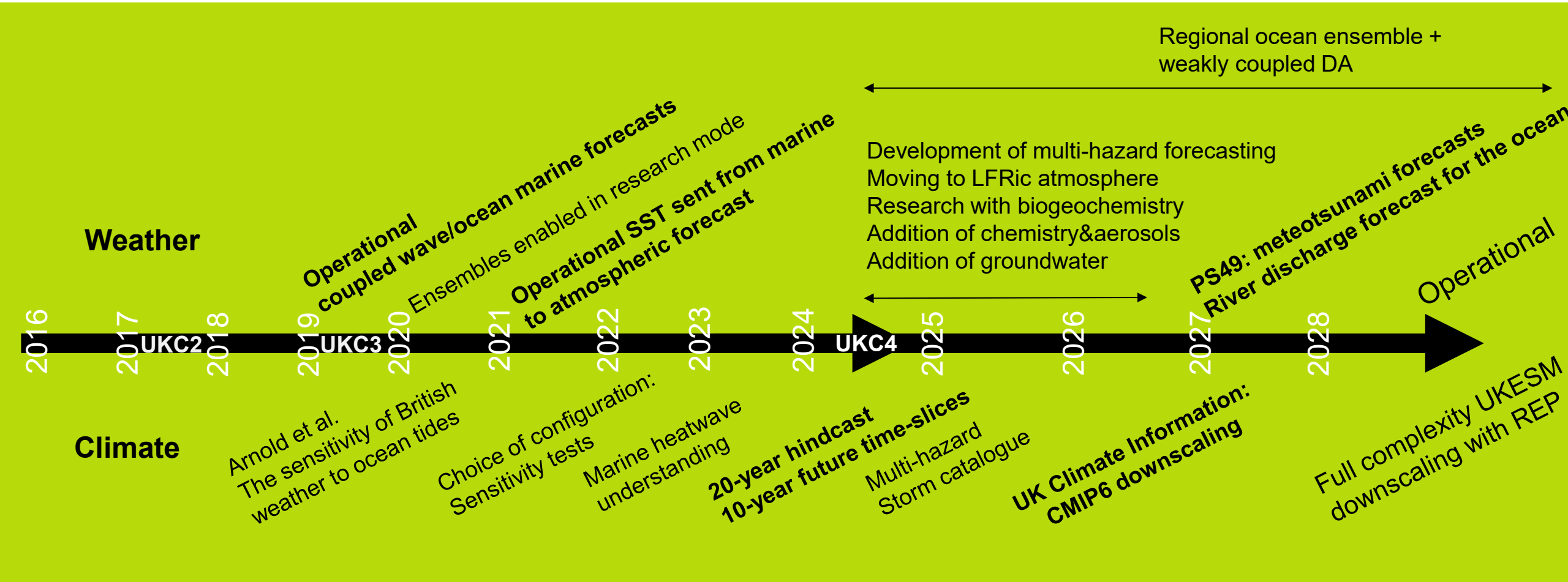


BIOGEOCHEMISTRY: ERSEM

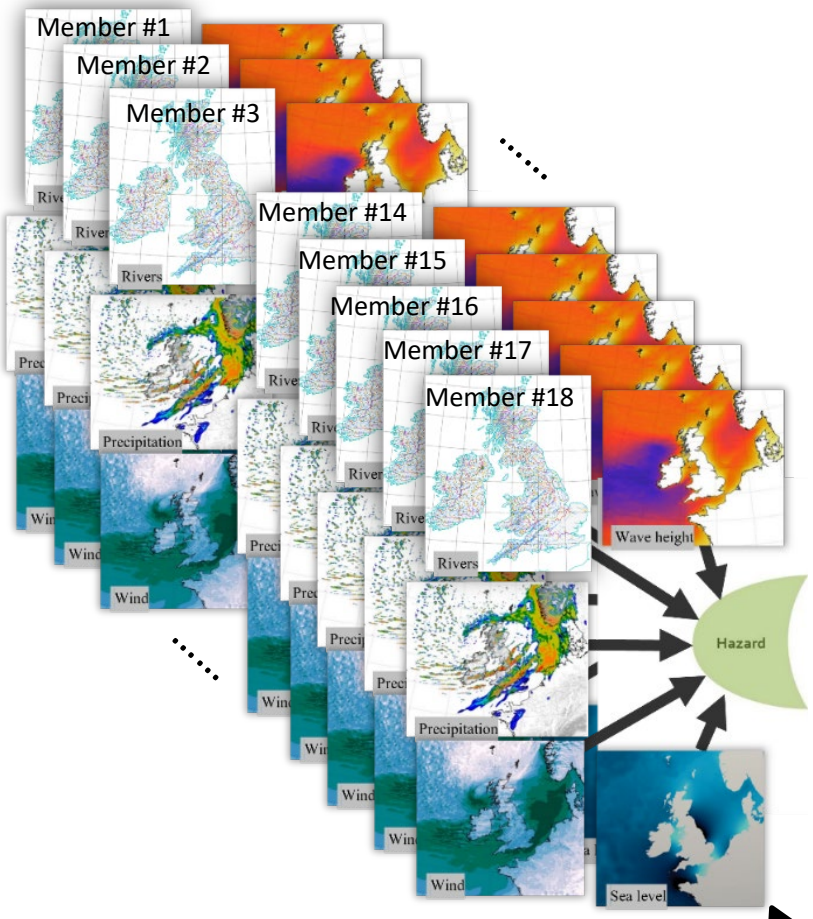
Coupling term in UKC4

Future coupling term

Regional Environmental Prediction



Near real time ensemble capability

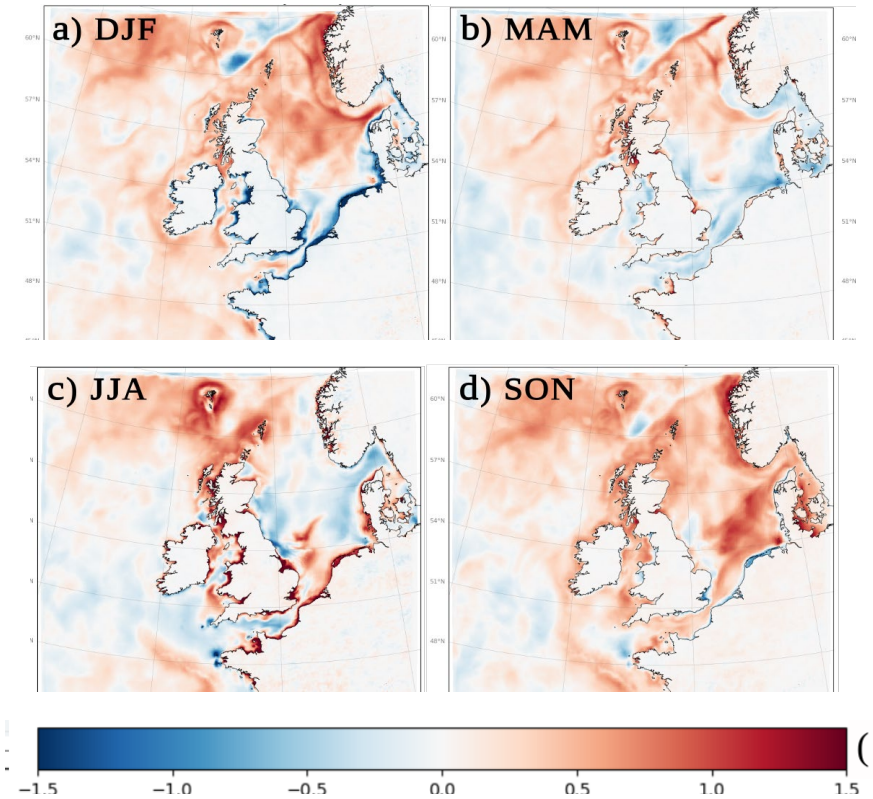


RCS-UKC4 configuration

Model and configuration upgrades:

- UM 13.0 – Regional Atmosphere & Land RAL3.3 + #504.6
- JULES 7.0 + **RFM (Rivers)**
- NEMO 4.0.4 – CO8 config
- WAVEWATCH III 7.12
- **ERSEM (biogeochemistry)**
- Neutral wind exchange with waves
- **10mn coupling (instead of 1h)**

Climate capability



ERA-5 driven 20-year hindcast
UKCP18 future 10-year timeslices

Use hindcast to calculate return levels in individual variables needed for NWP applications

Berthou et al. (in prep) Km-scale regional coupled system in the Northwest European shelf for weather and climate applications: RCS-UKC4 *GMD*

Met Office

STATE OF THE PLANET

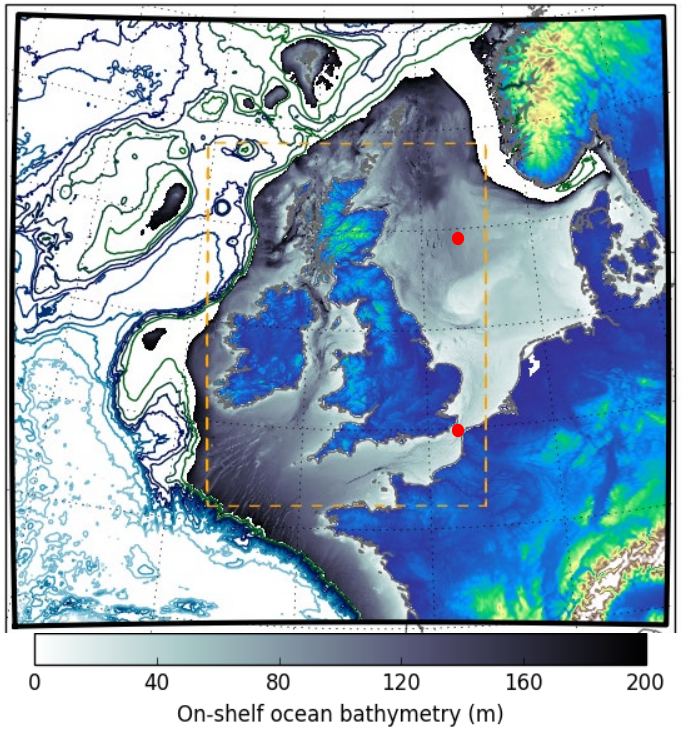
Why coupling at km-scale around the UK?

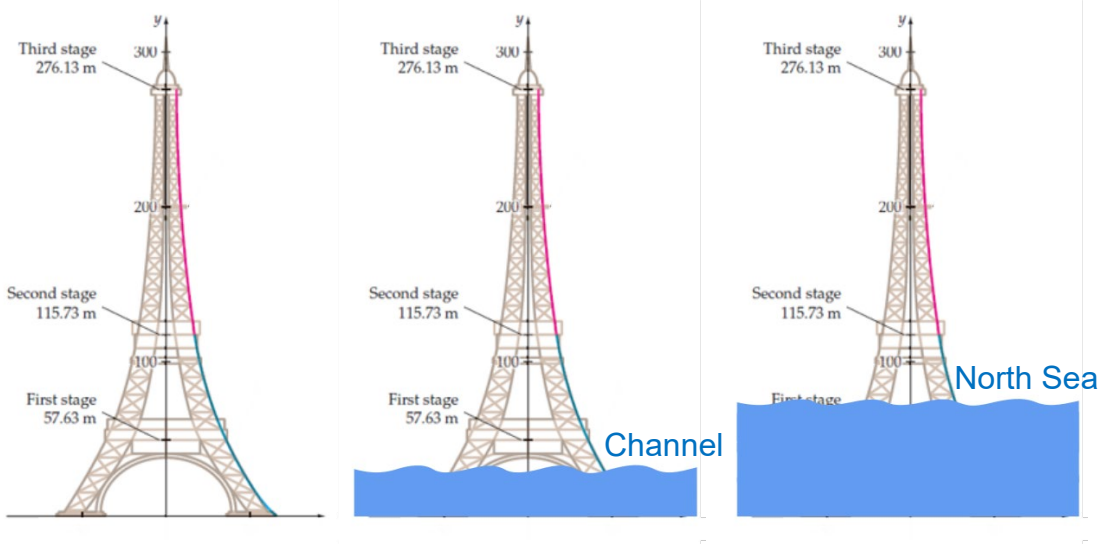
Towards Earth system modelling: coupled ocean forecasting

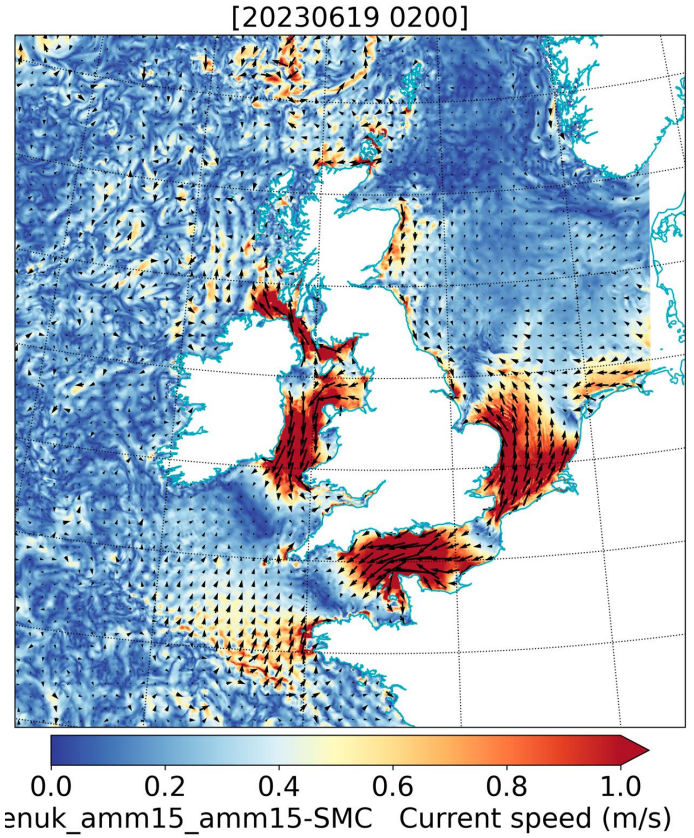
Ségolène Berthou[1], John Siddorn[2], Vivian Fraser-Leonhardt[1], Pierre-Yves Le Traon[3], and Ibrahim Hoteit[4]

[1]Met Office, Exeter, UK
[2]Data, Science and Technology, National Oceanography Centre, Southampton, UK
[3]Mercator Ocean International, Toulouse, France
[4]Physical Science and Engineering Division, King Abdullah University of Science and Technology (KAUST), Thuwal, Saudi Arabia

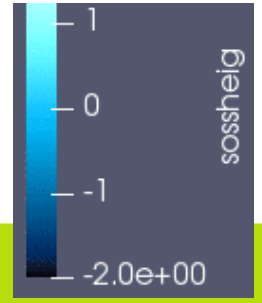
Explicit tides and terrain-following coordinates in regional ocean for the Northwest European shelf





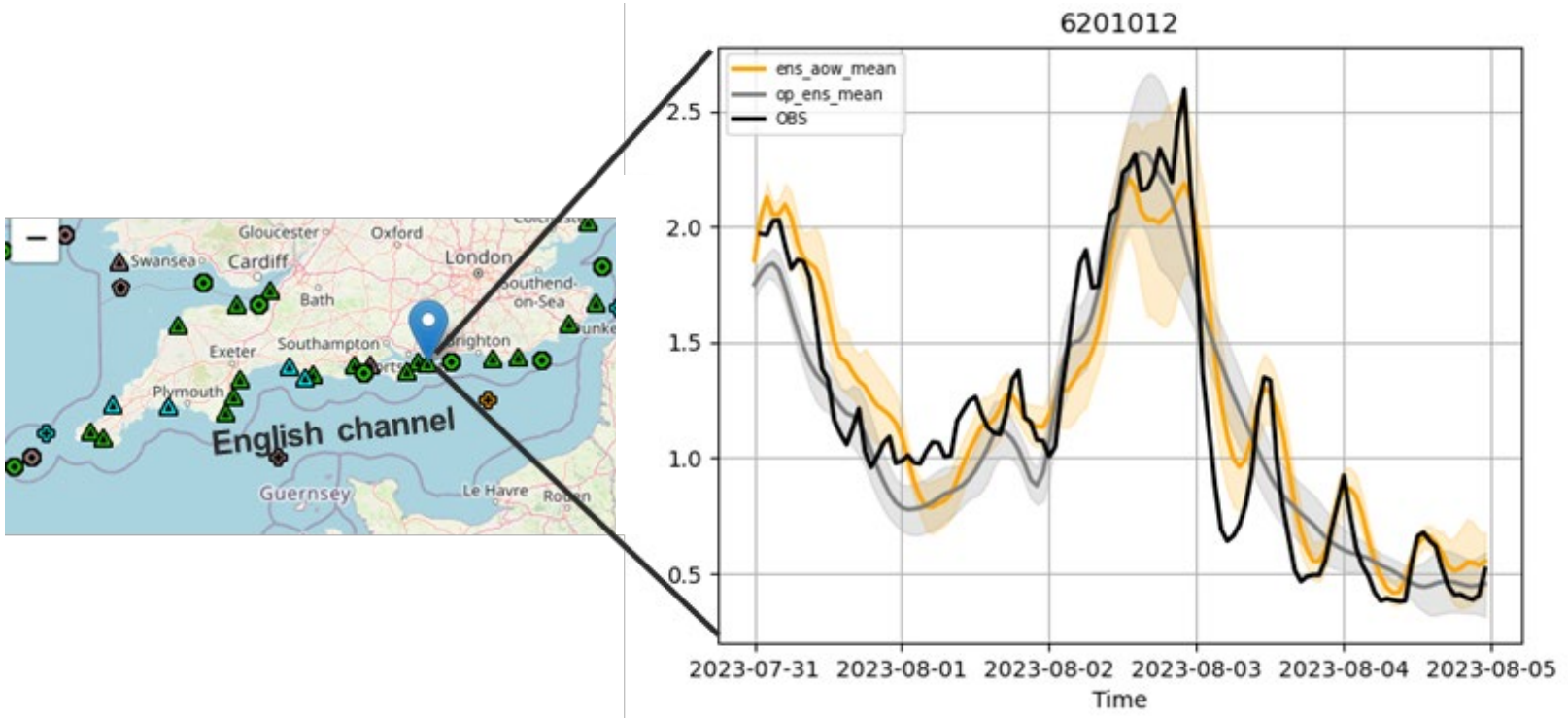


The Northwest continental shelf is a shallow oceanic region.
Tides play a major role in vertical mixing on the shelf.
The Channel is permanently mixed by tidal currents.



Capturing local feedbacks

Significant wave height during storm Antony



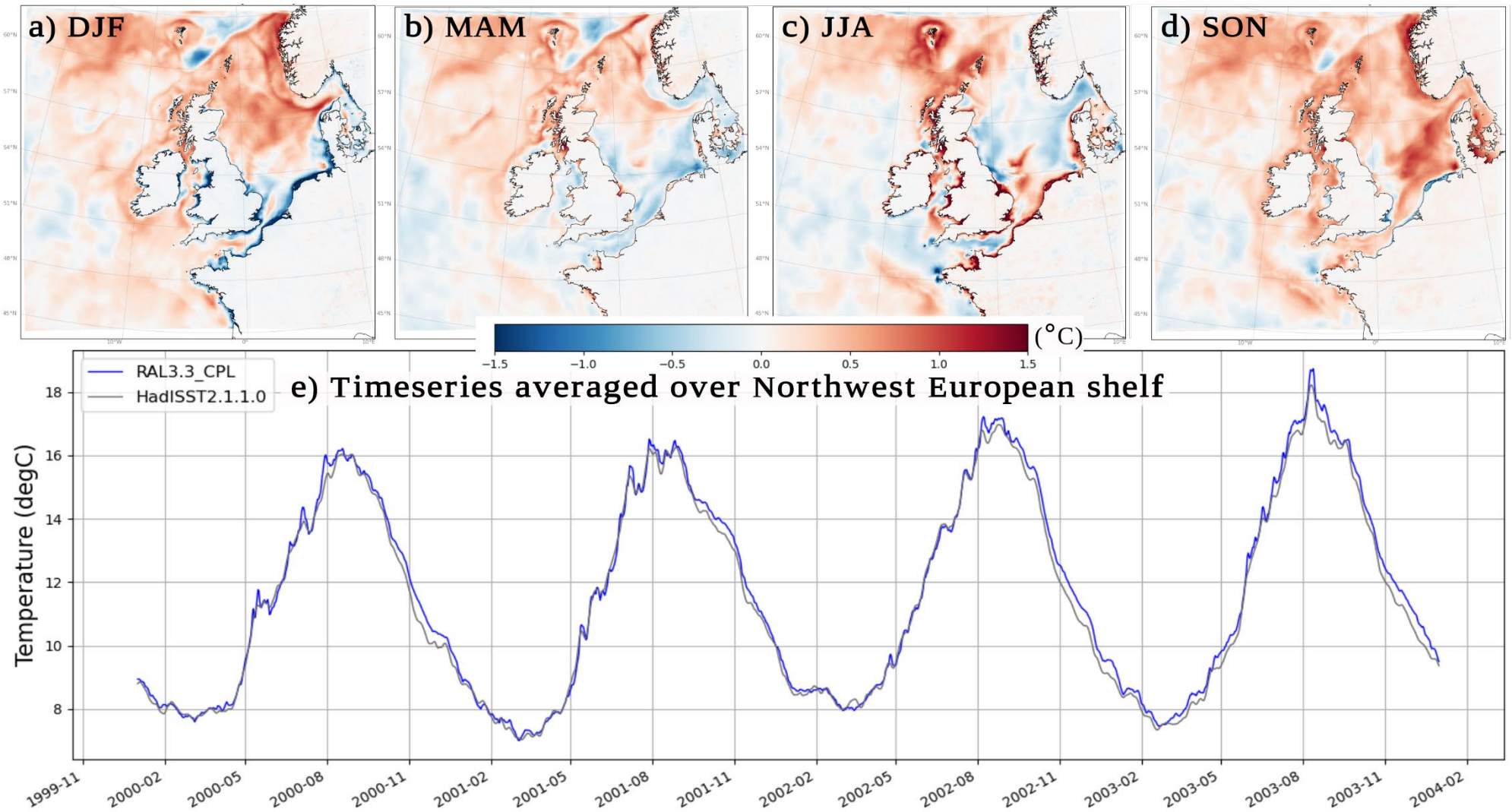
Impact of wave modulation by tidal currents in the English Channel.

The operational wave ensemble in grey forced by global winds doesn't get the modulation of the wave height by tidal currents. The regional coupled system captures this much better.
Tides modulate both waves and wind (Renault et al. 2022).

Vivian Fraser-Leonhardt

Berthou et al. (in prep): km-scale regional coupled system in the Northwest European shelf for weather and climate applications, RCS-UKC4

Ensuring Regional Atmosphere has good surface fluxes over the ocean



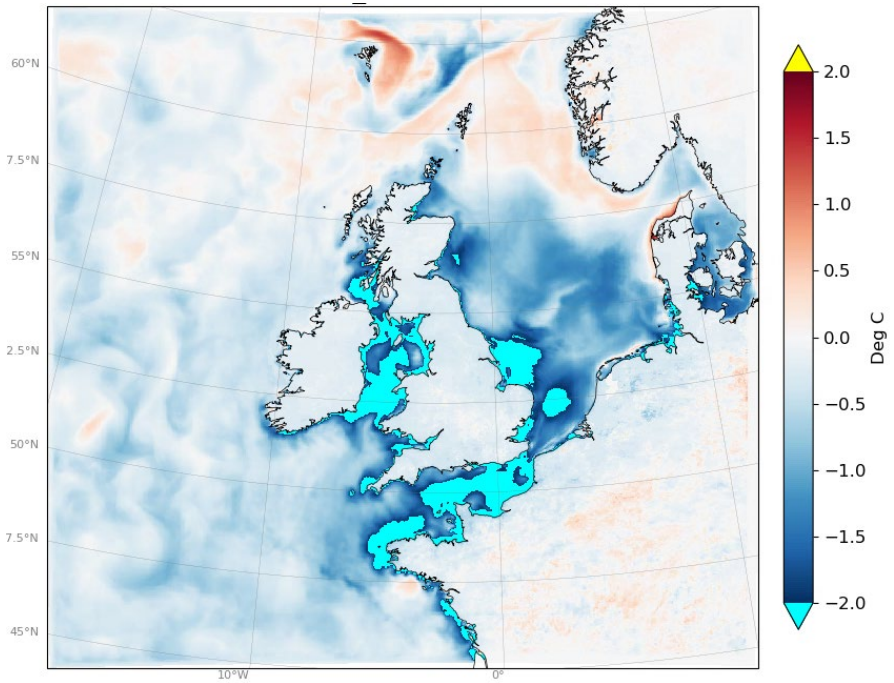
Bush et al. (2015) The third Met Office Unified Model-JULES Regional Atmosphere and Land Configuration, RAL3 *GMD*

Met Office

What is the impact of coupling a shelf-enabled ocean to UKCP-local projections?

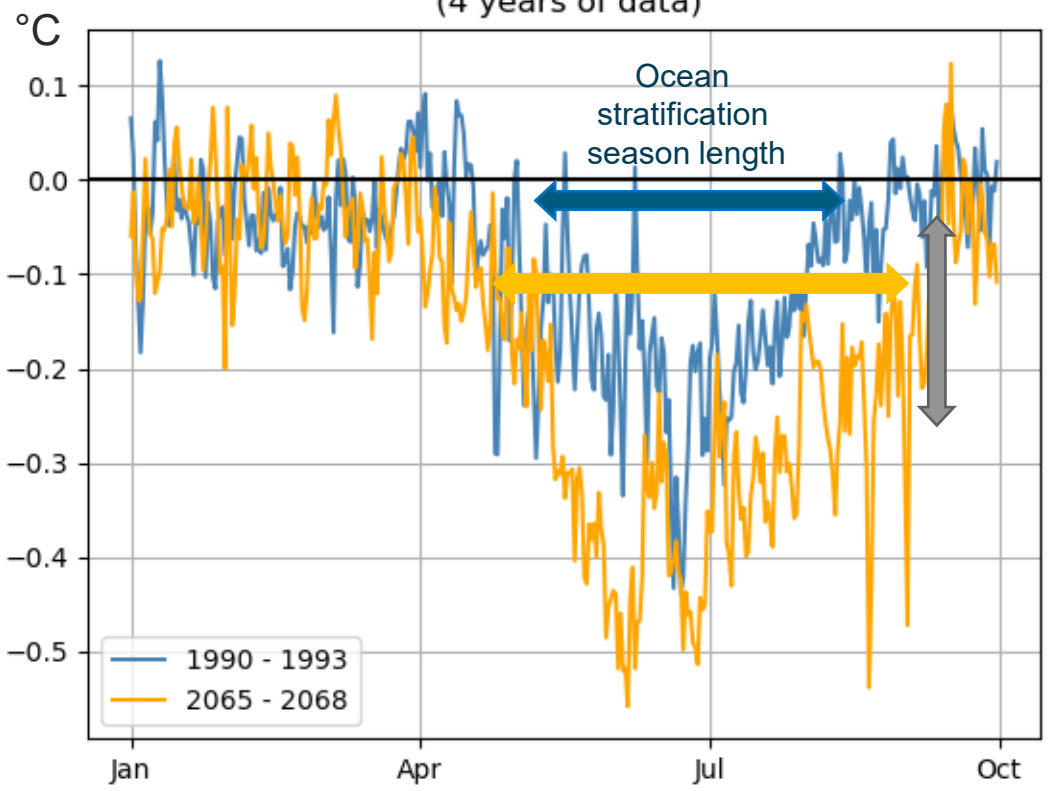
New science emerging from Regional Environmental Prediction

Surface temperature modulation
by the regional coupled system in summer 1990
Difference dominated by the effects of explicit tidal mixing
in the regional ocean



- In summer, shallow regions are stratified, tidal mixing reduces stratification => cools down the SST

GB land air temperature modulation by the regional coupled system
(4 years of data)



Ocean stratification season extends into autumn in the future

Stronger stratification in the future means tidal mixing has larger cooling in the future

Dampening of the climate change signal by the coupled system over land from July to October.

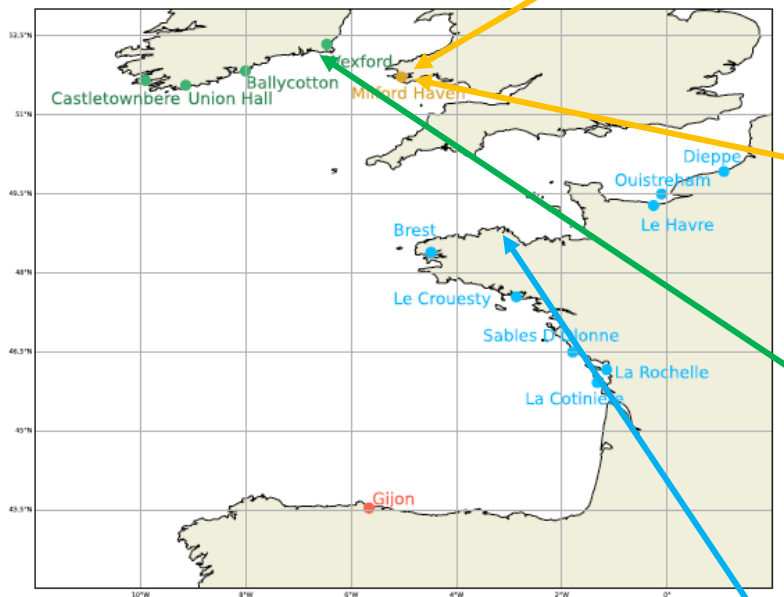
Alex Arnold

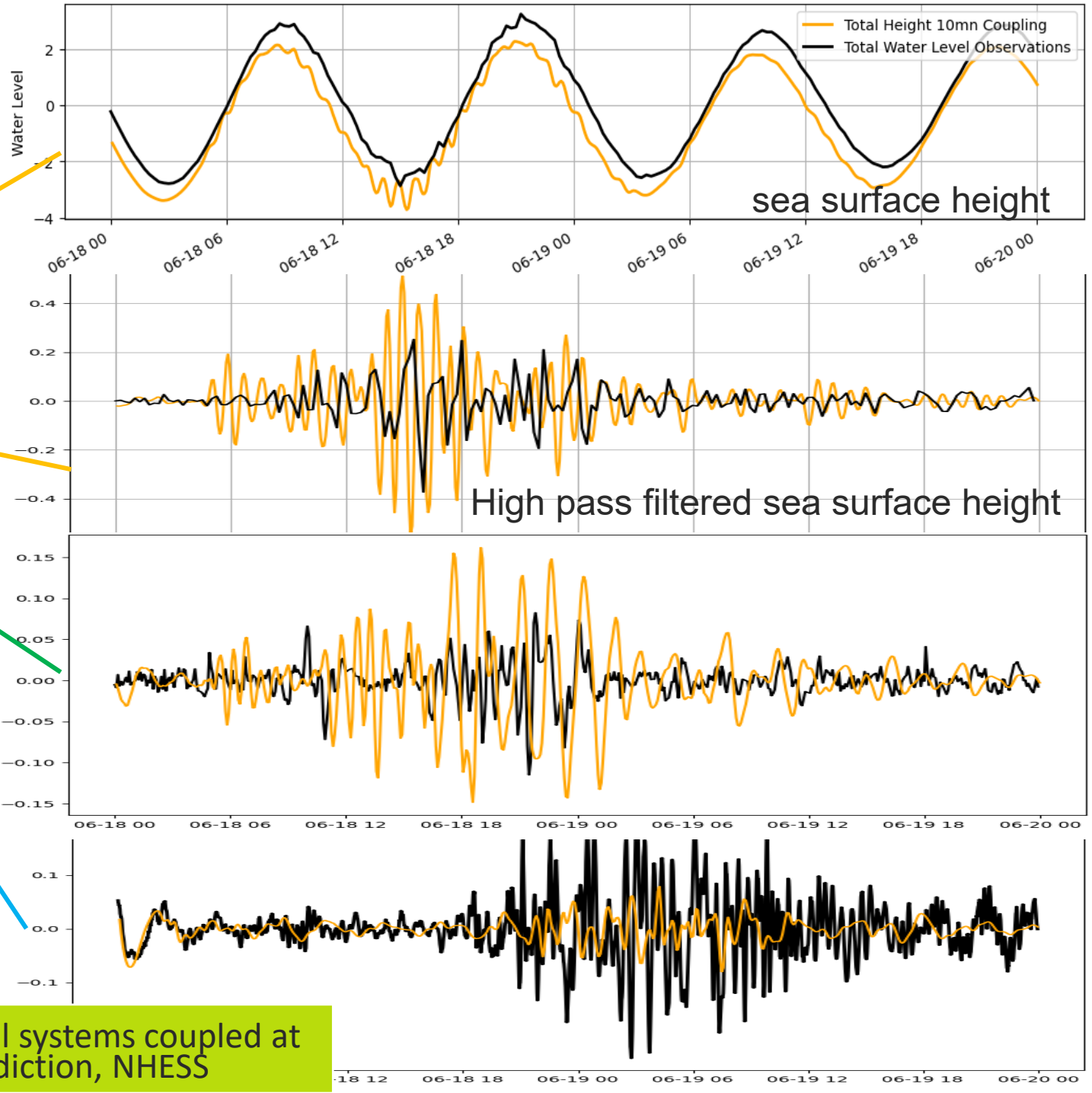
What is the current coastal risks associated with meteotsunamis?

Met Office, Uni. Northumbria, Uni. Reading

Met Office

18-19 June 2022 case study: High-frequency sea surface disturbances linked with small-scale pressure disturbances





Please see Nefeli Makrygianni's poster today

Makrygianni et al. (in prep) Km-scale regional systems coupled at high frequency for meteotsunamis prediction, NHESS

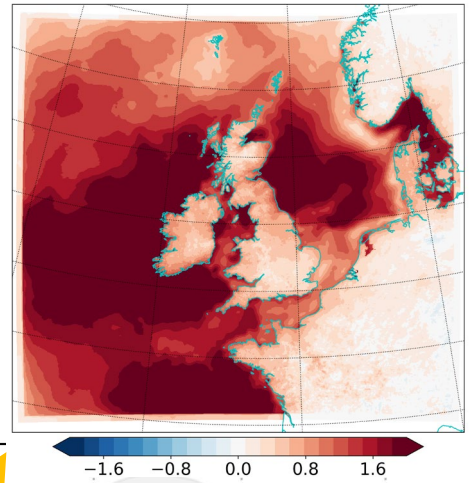
How do marine heatwaves feedback on British weather?

Berthou et al. (2024), Exceptional atmospheric conditions in June 2023 generated a Northwest European marine heatwave which contributed to breaking land temperature records.” *Communications Earth & Environment*

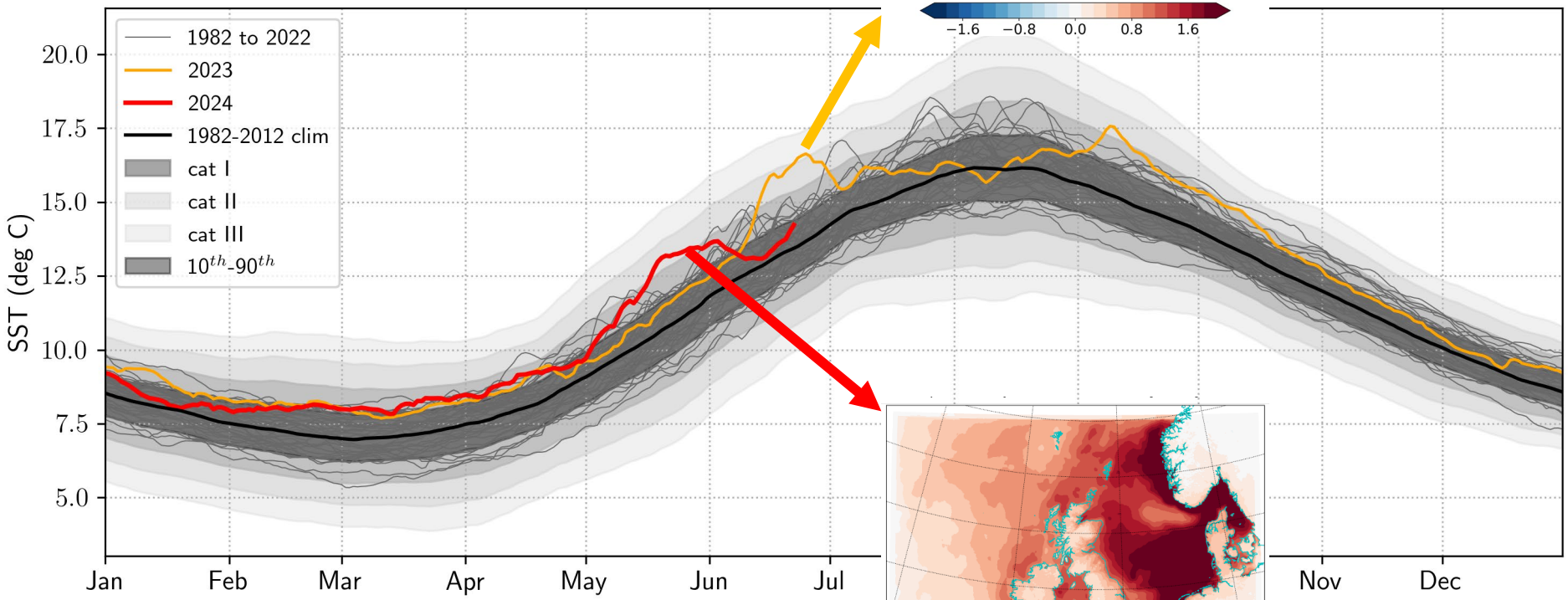
Mahmood, Goswami et al. (in prep) Storm multi-hazards amplified by the marine heatwave it terminates

Met Office

REP & Regional marine heatwaves (MHW)

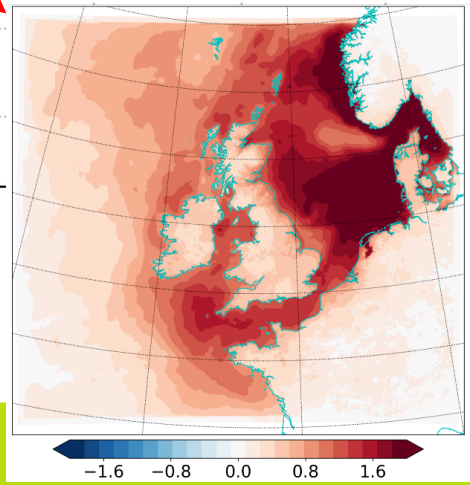


June 2023:
UK monthly mean temperature
broken by 0.9°C
Marine heatwave contributed to 0.6°C



Local marine heatwaves amplify margin by which land record are broken

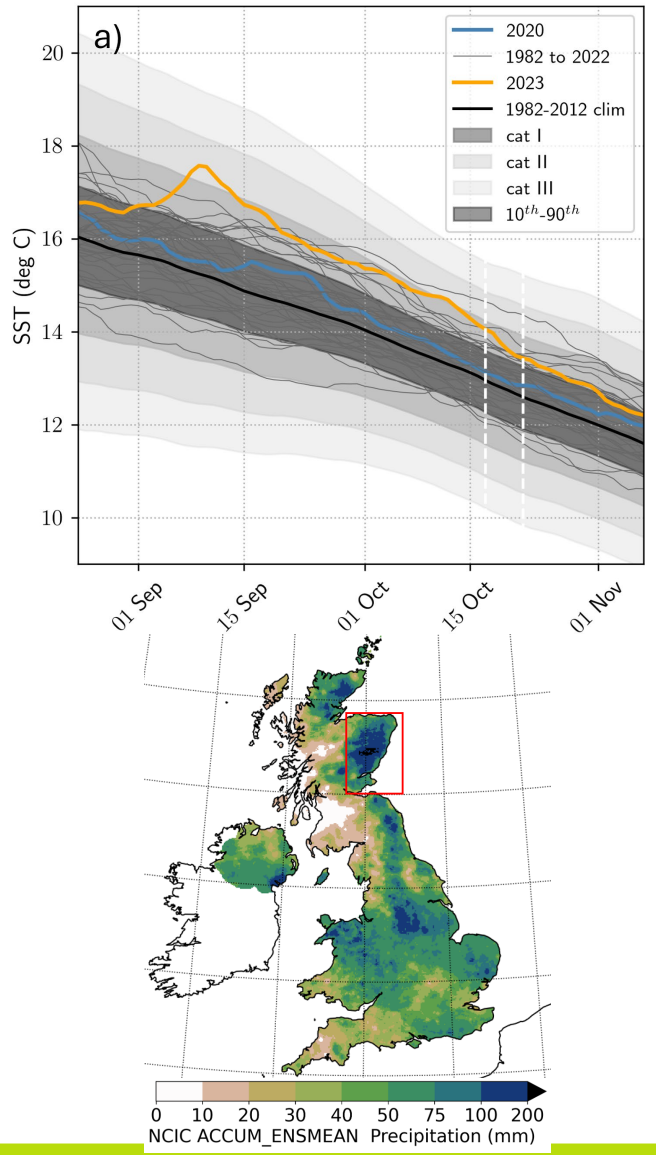
The May 2024 MHW was less intense, but impacted land temperatures similarly: models indicate marine heatwave impact on land depends on boundary layer height ratio between land and sea: a sunny land is less impacted by a MHW than cloudy land

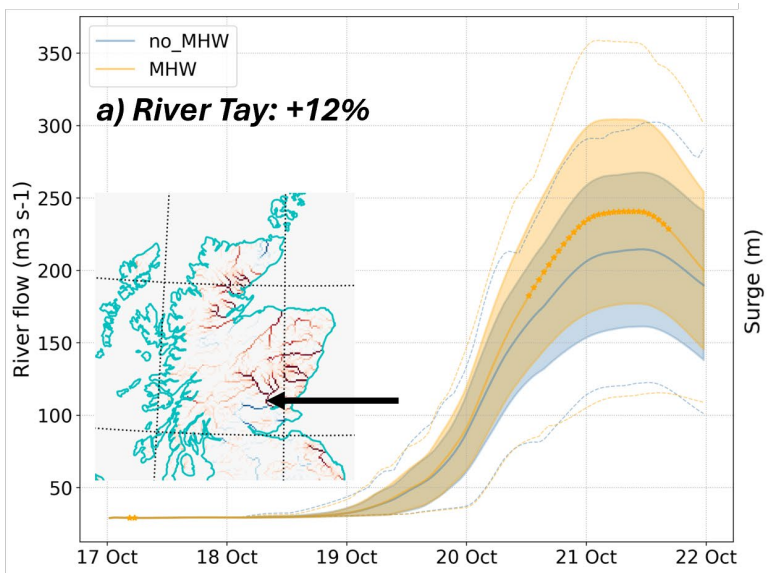


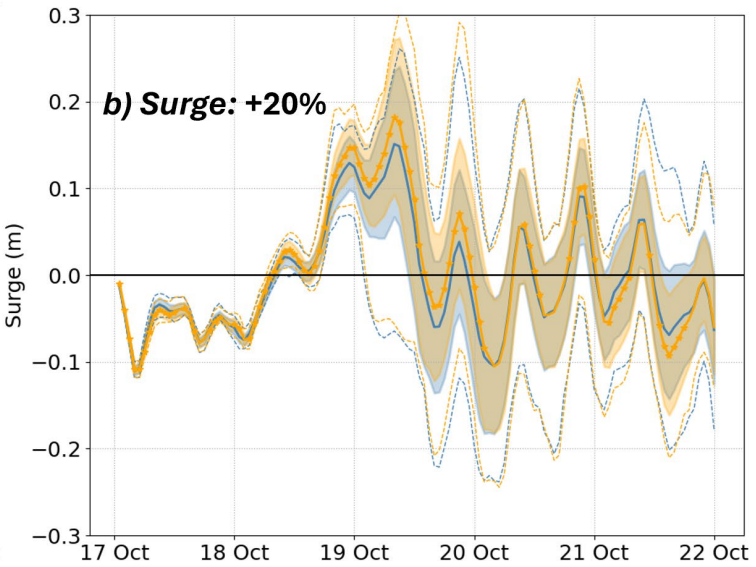
May 2024:
UK monthly mean temperature
broken by 1.0°C
Marine heatwave contributed to 0.5°C

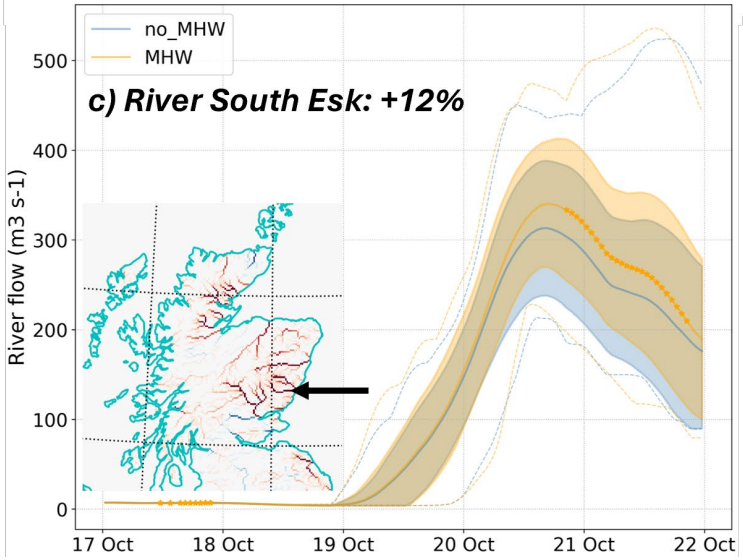
Berthou et al. (2024)
Berthou & extremes team report on May 2024

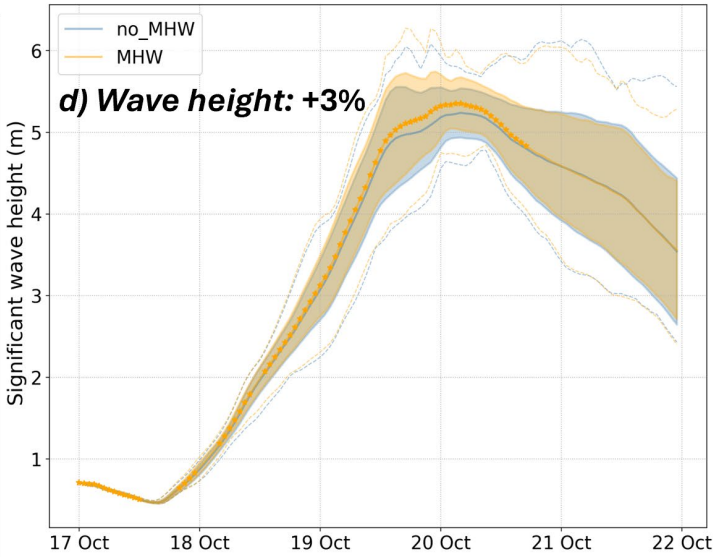
Storm Babet's coastal hazards exacerbated by marine heatwave











Regional coupled ensemble shows increased river flow, surge and wave height on the eastern coast of Scotland with the marine heatwave.

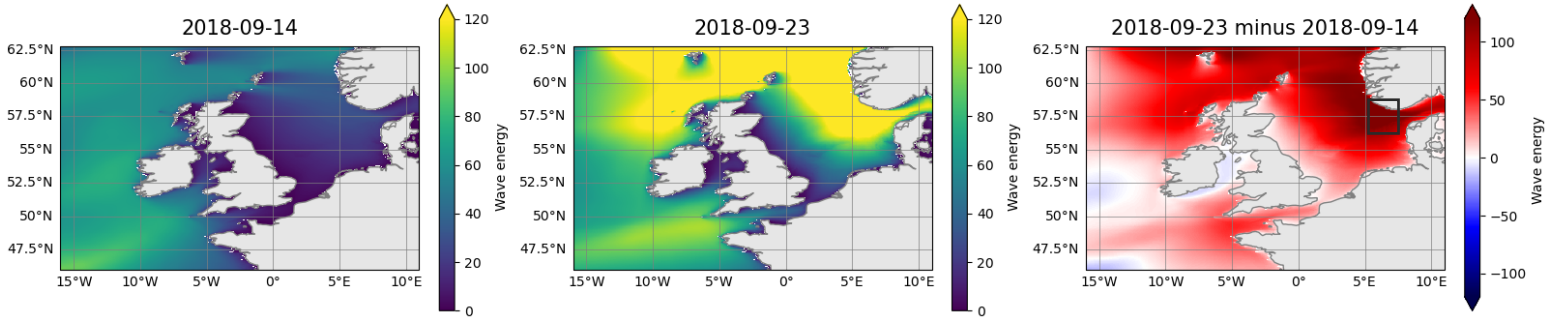
Met Office

How does wave activity impact phytoplankton blooms?

PML, Met Office, NOC

Partridge et al. (in prep) Impacts of waves on phytoplankton activity in the northwest European shelf: insights from a km-scale coupled model

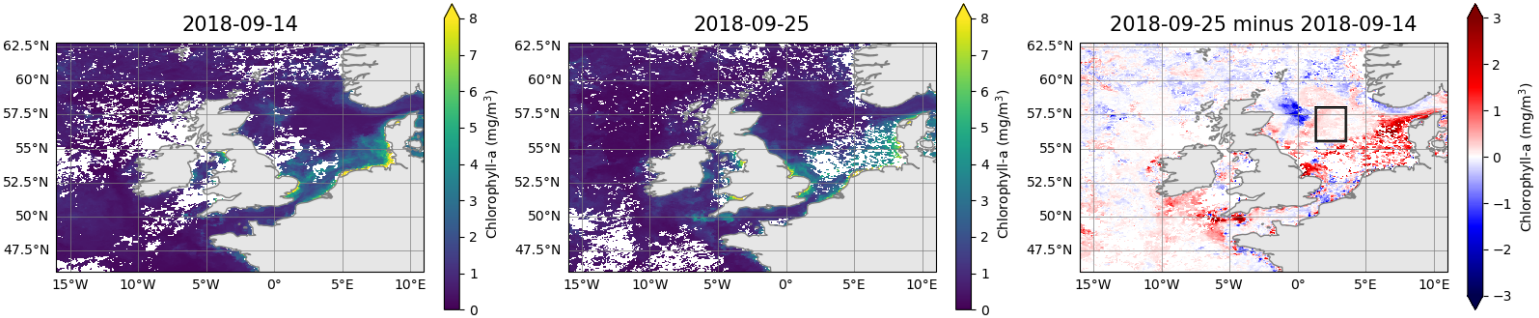
Wave activity impact on phytoplankton activity



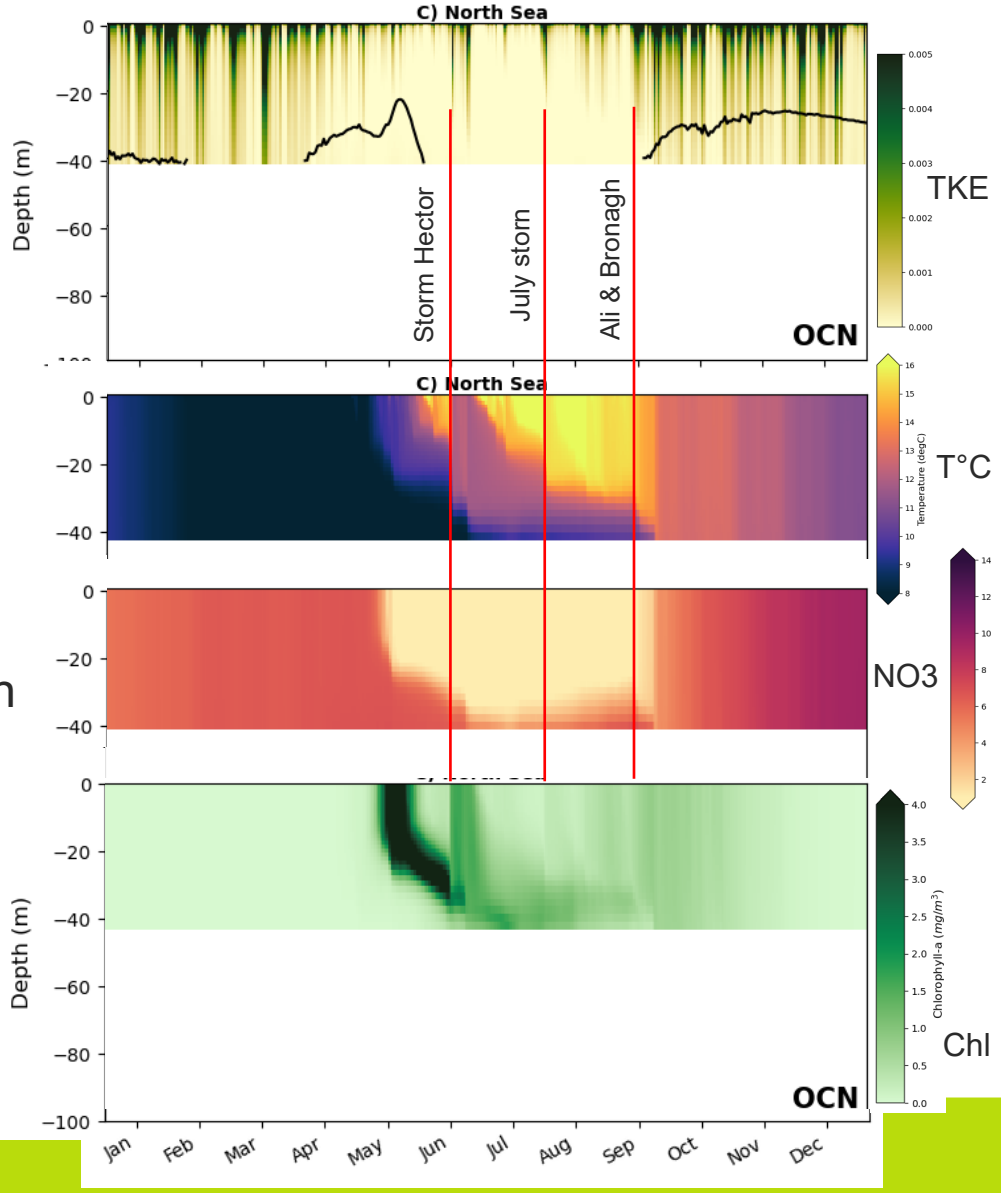
Wave energy (**reanalysis**) before and during storms Ali & Bronagh

Late summer wave activity favours late phytoplankton blooms on shelf

Chlorophyll satellite **observations** before and after storms Ali & Bronagh



North Sea depth/time Hovmuller of **coupled model**



Partridge et al. (in prep)

Regional Environmental Prediction

Process understanding

- Can afforestation help mitigate climate change impacts in the UK? (Buechel et al. 2024)
- Marine heatwaves around the UK and how they feedback on the weather (Berthou et al. 2024, …)
- What is the impact of coupling a shelf-enabled ocean to UKCP-local projections?
- What is the current coastal risks associated with meteotsunamis?
- What would be the impact of large-scale roll out of offshore wind farms on the environment?
- What kind of carbon dioxide removal options are most efficient at the national scale?
- What is the likelihood of multi-hazard coastal events in the UK?
- What is the impact of extreme atmospheric events on marine ecosystems?
- What is the impact of climate change on air quality?

Coupled system developments

- UKC4 paper (Berthou et al, in prep)
- New atmosphere (LFRic)
- More domains (add sea ice)
- More coupling terms
- River improvements / more land complexity
- Wind farms
- Moving coastline
- Switch carbon cycle on (add UKCA)
- Coupled data assimilation

Weather

- River flow & nutrient forecasts for ocean input (2026)
- Meteotsunami forecasts (2026)
- Ensemble forecasting with physical coupled system (2030)

Event-based attribution

Climate

- UKCP physical coupled system timeslices (now)
- storm catalogue or CMIP6 downscaling
- Regional coupled reanalysis (?)
- UKESM downscaling (?)