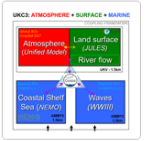
RCS-UKC4: Version four of the regional coupled system over Northwest Europe

Ségolène Berthou, Sana Mahmood, Vivian Fraser-Leonhardt, Juan Manuel Castillo, Claudio Sanchez, Alex Arnold, Huw Lewis, …

The UKC2 regional coupled environmental prediction system

Huw W. Lewis[1], Juan Manuel Castillo Sanchez[1], Jennifer Graham[1], Andrew Saulter[1], Jorge Bornemann[1], Alex Arnold[1], Joachim Fallmann[1], Chris Harris[1], David Pearson[1], Steven Ramsdale[1], Alberto Martínez-de la Torre[2], Lucy Bricheno[3], Eleanor Blyth[2], Victoria A. Bell[2], Helen Davies[2], Toby R. Marthews[2], Clare O'Neill[1], Heather Rumbold[1], Enda O'Dea[1], Ashley Brereton[3], Karen Guihou[3], Adrian Hines[1], Momme Butenschon[4], Simon J. Dadson[5], Tamzin Palmer[1], Jason Holt[3], Nick Reynard[2], Martin Best[1], John Edwards[1], and John Siddorn[1]

The UKC3 regional coupled environmental prediction system



Huw W. Lewis ✉, Juan Manuel Castillo Sanchez, Alex Arnold, Joachim Fallmann, Andrew Saulter, Jennifer Graham, Mike Bush, John Siddorn, Tamzin Palmer, Adrian Lock, John Edwards, Lucy Bricheno, Alberto Martínez-de la Torre, and James Clark

The Regional Coupled Suite (RCS-IND1): application of a flexible regional coupled modelling framework to the Indian region at kilometre scale

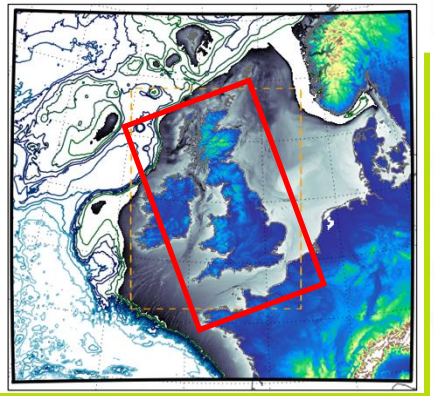
Juan Manuel Castillo ✉, Huw W. Lewis, Akhilesh Mishra, Ashis Mitra, Jeff Polton, Ashley Brereton, Andrew Saulter, Alex Arnold, Segolene Berthou, Douglas Clark, Julia Crook, Ananda Das, John Edwards, Xiangbo Feng, Ankur Gupta, Sudheer Joseph, Nicholas Klingaman, Imranali Momin, Christine Pequignet, Claudio Sanchez, Jennifer Saxby, and Maria Valdivieso da Costa

Regional Coupled Suite

Across Momentum and UK partners

Momentum®
The Unified Earth Environment Prediction Framework

RCS-UKC4

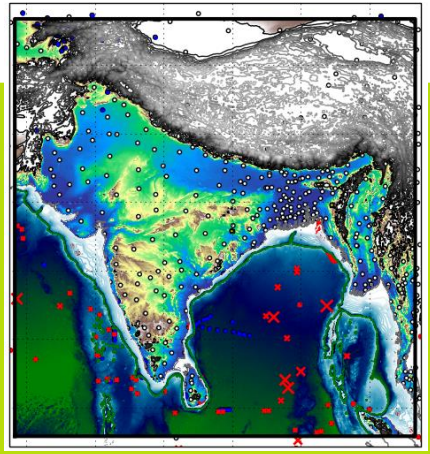


Met Office MONSooN

NOC – OW on Archer2 500m

Ocean, waves, Atmosphere, Biogeo-chemistry

RCS-Ind1



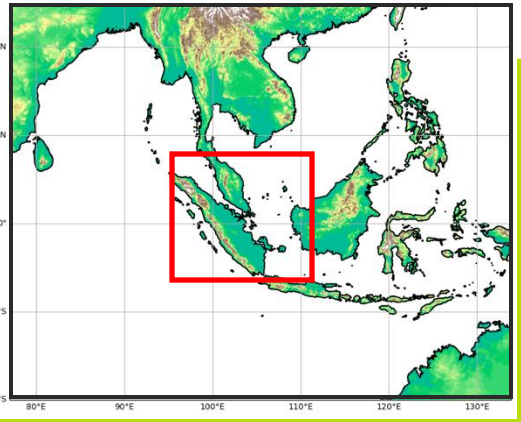
Met Office

MONSooN

NCMRWF

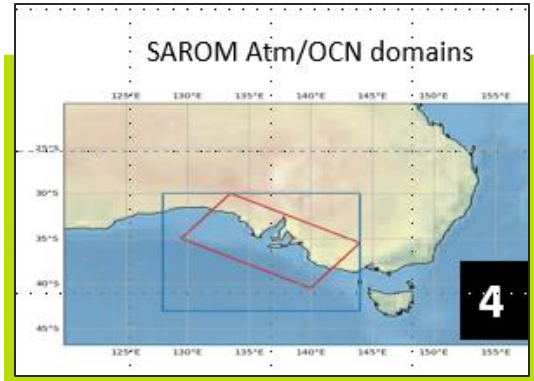
Ocean, waves, atmosphere +1D ocean (KPP)

RCS-EIWP
RCS-cSingv



Met Office (branch) ocean and atmosphere

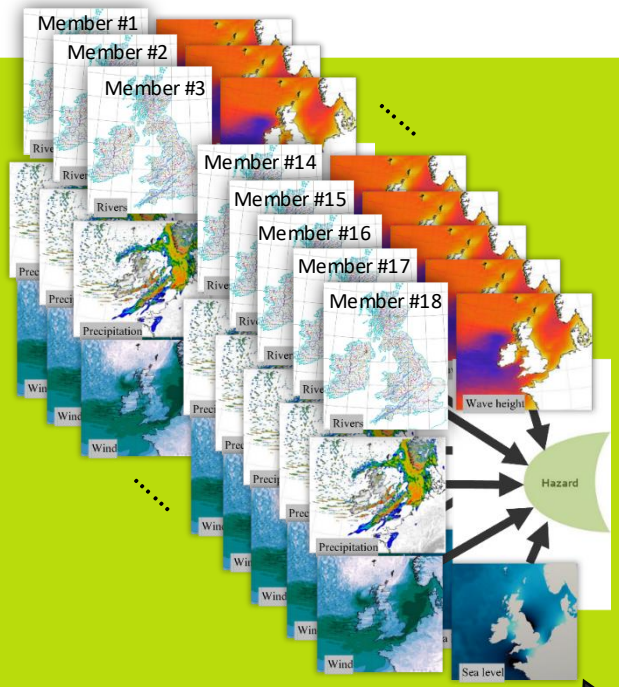
Singapore (cSingv) Ocean, waves, atmosphere



The Bureau of Meteorology ocean and atmosphere

What's new?

Near real time ensemble capability

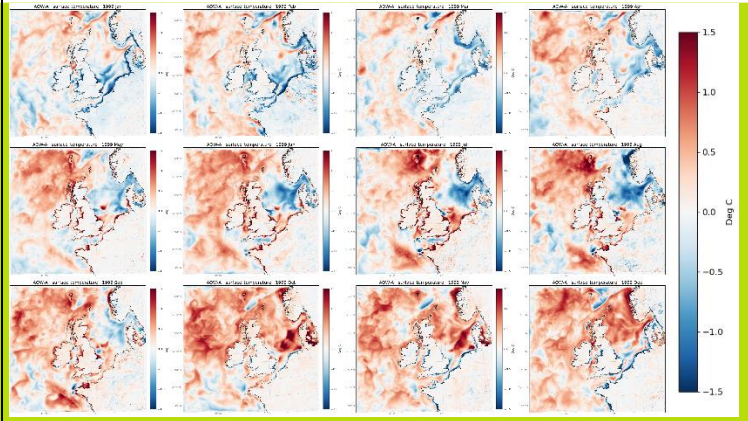


RCS-UKC4 configuration

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

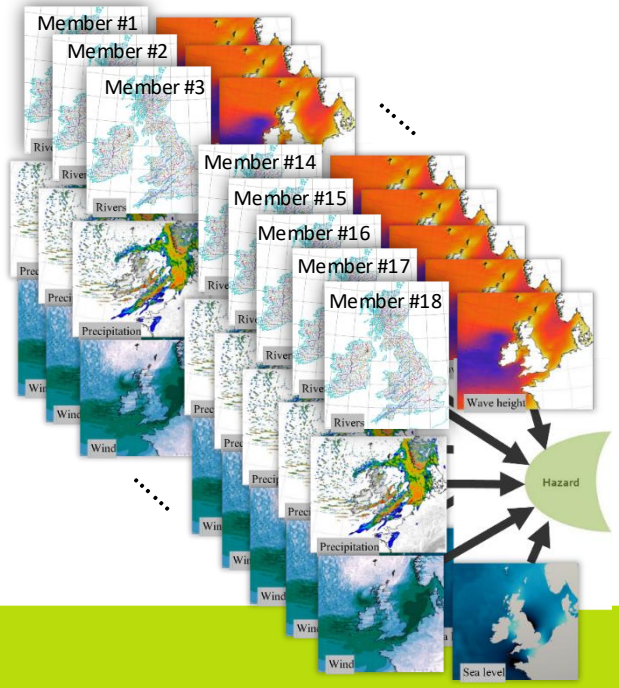


ERA-5 20-year hindcast started

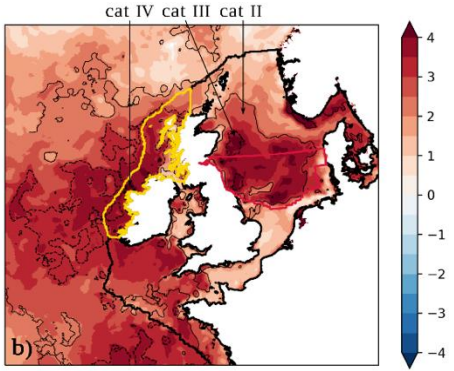
Use hindcast to calculate return levels in individual variables needed for NWP applications

Evaluation & optimisation strategy

Ensembles:
8 winter case studies (1 storm)
12 summer case studies (3 storms)
Wave, wind, SST evaluation
T2m ensemble spread

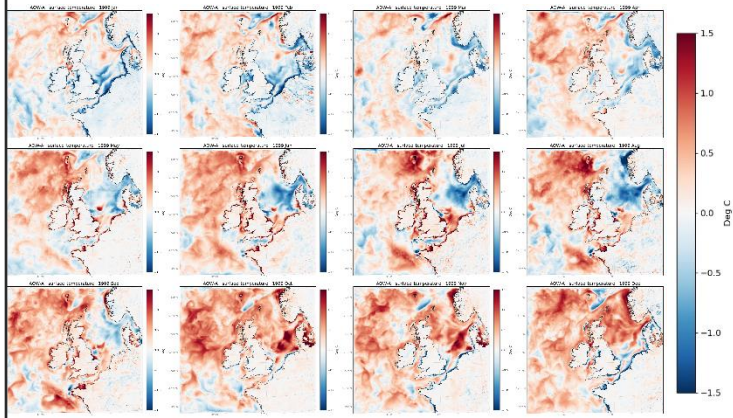


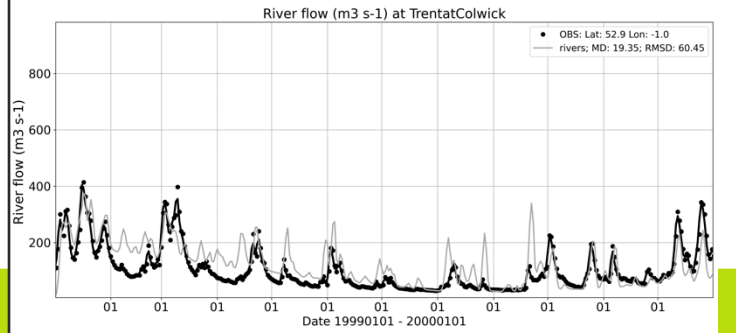
1-month recent hindcast
operational analysis
boundaries
flux & SST evaluation in
marine heatwave conditions



Berthou et al. (2024)

3-year hindcast (1999-2001),
ERA-5&glosea6 boundaries
river evaluation, SST bias

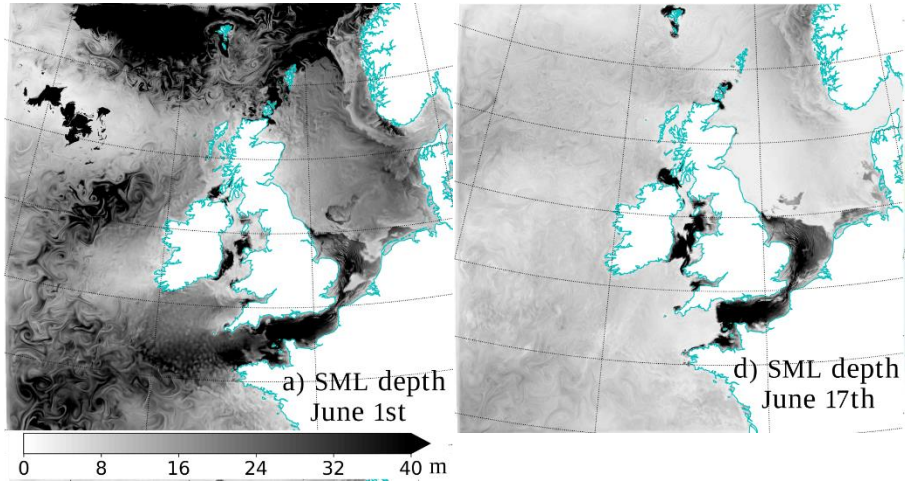




Met Office

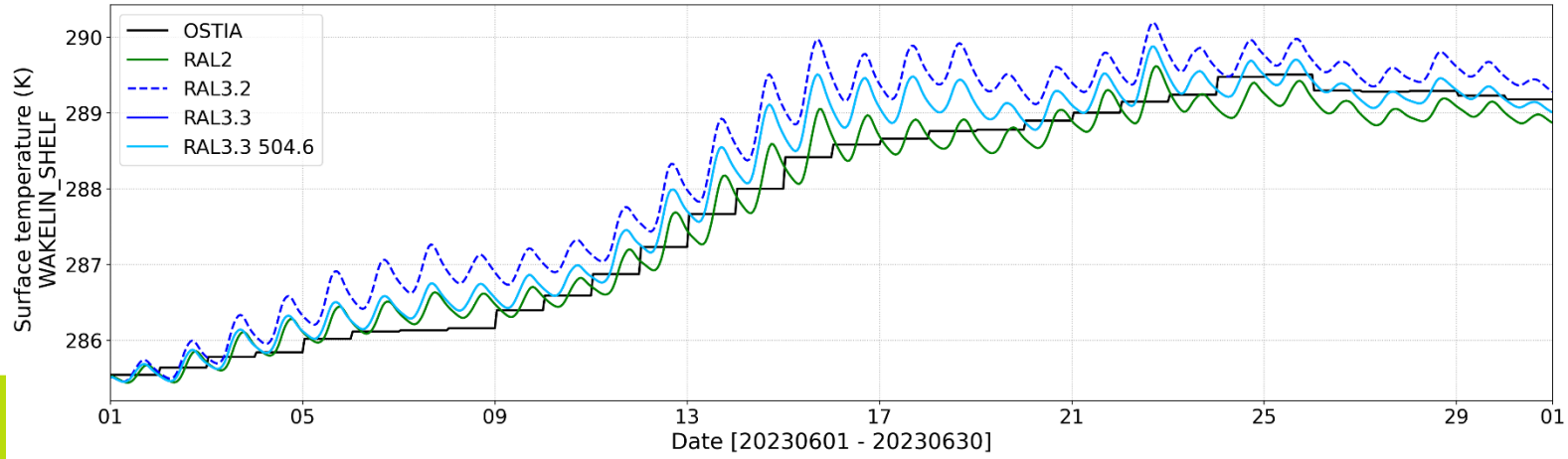
SST evaluation

1-month long hindcast during June 2023 marine heatwave



Marine heatwave conditions:
Extremely shallow mixed layer, very sensitive to correct balance in surface fluxes.

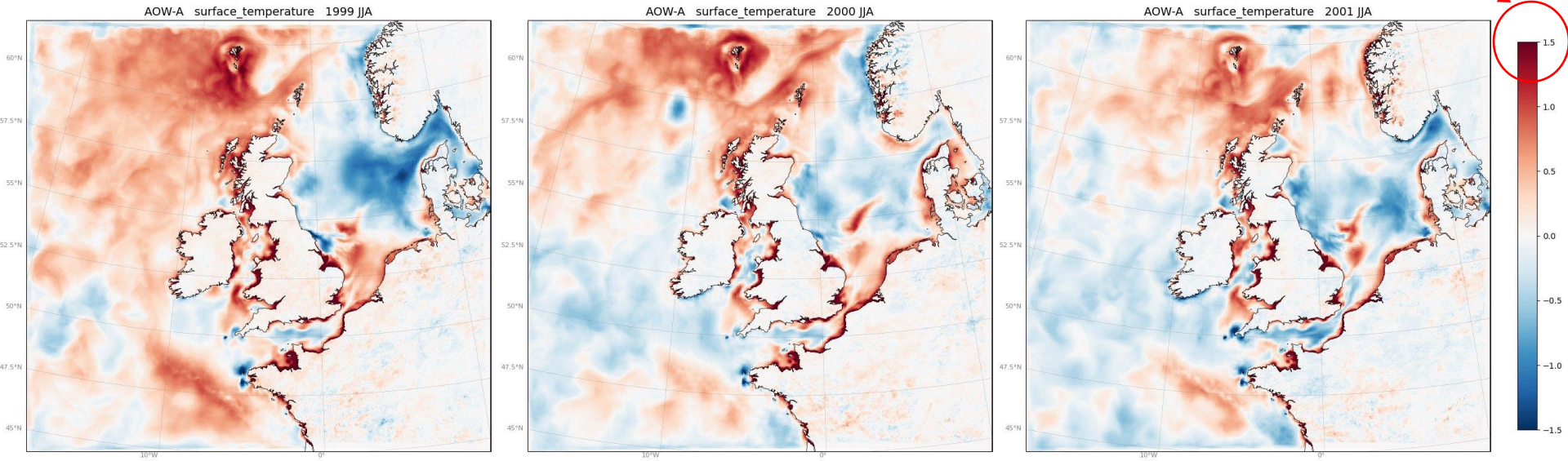
RAL3.2 not acceptable, RAL3.3 much better.



3-year long hindcast (1999-2001)

Summer SST bias against HadiSST (used in ERA-5)

Reasonable bias

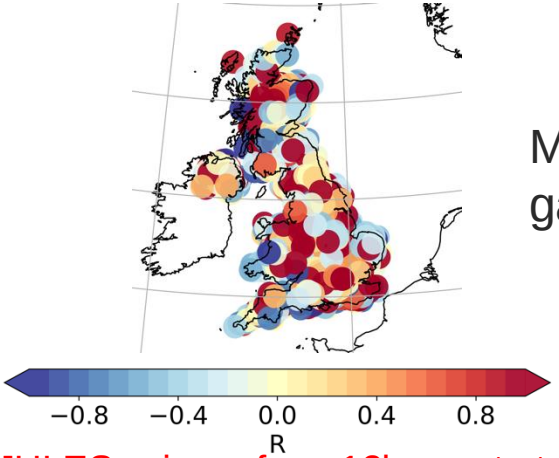


Alex Arnold

Met Office

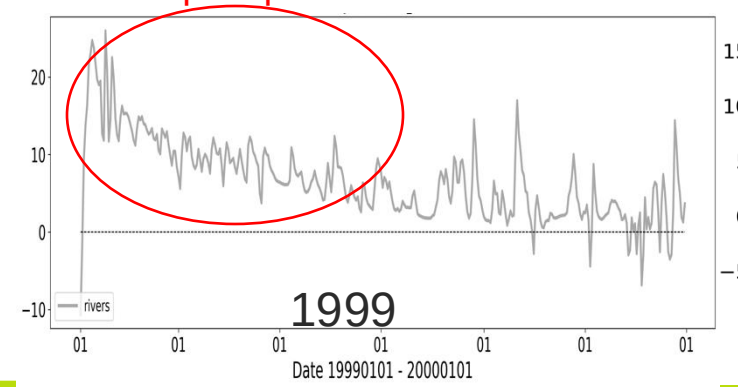
River evaluation

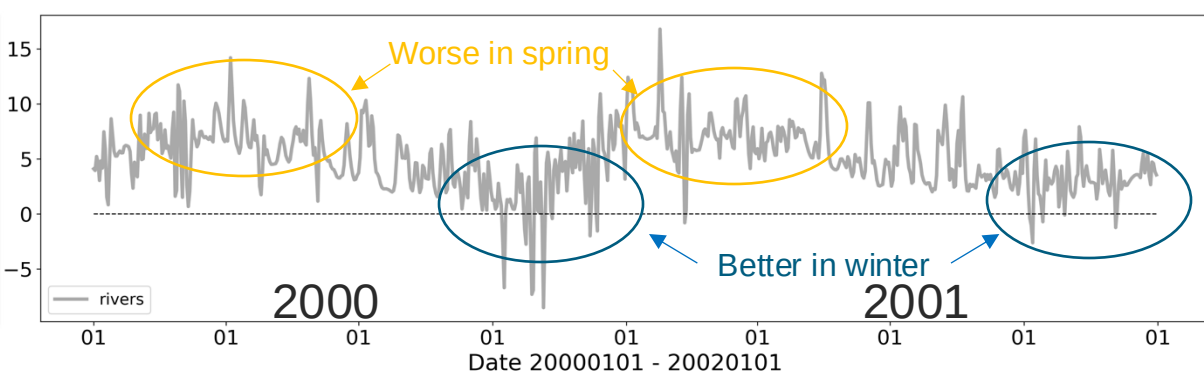
Mean river bias over the UK



Mean bias against NRFA gauges (2000-2001)

JULES spin-up from 12km restart: ~6-month





Ségolène Berthou

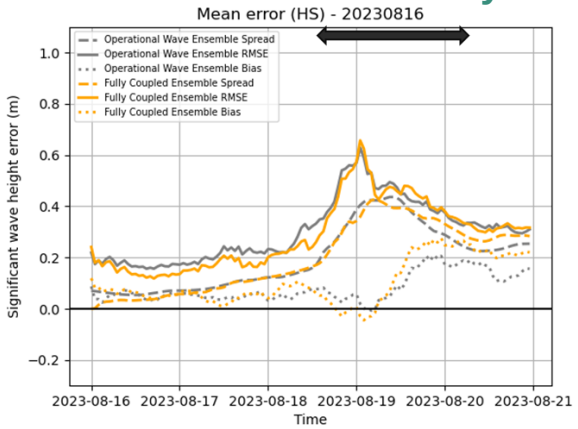
Met Office

Wave evaluation

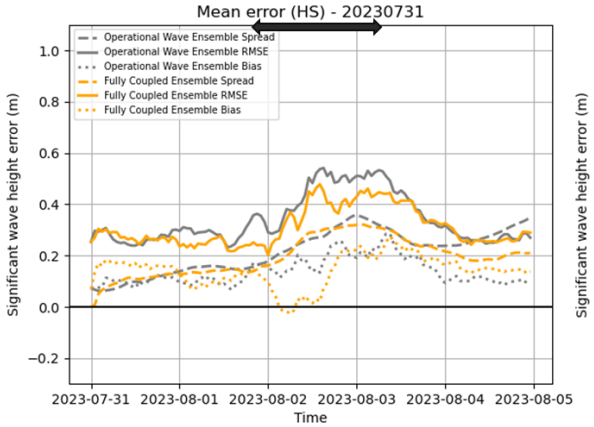
Ensemble skill in significant wave height

Operational / Coupled

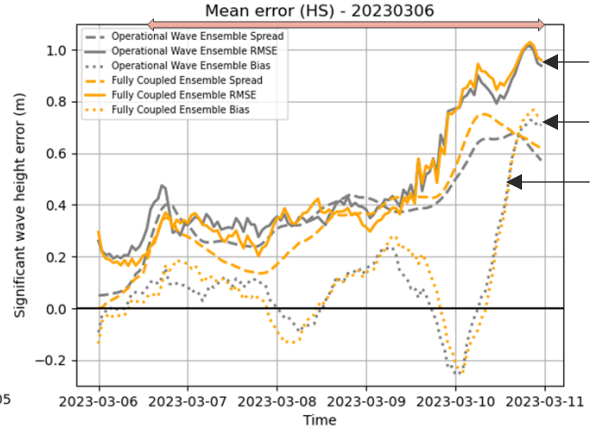
Storm Betty



Storm Patricia



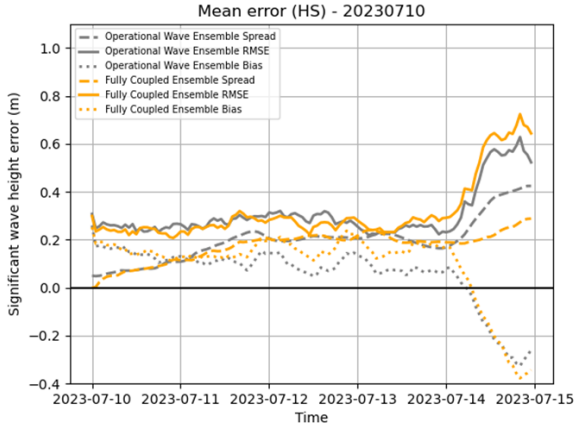
Storm Larisa

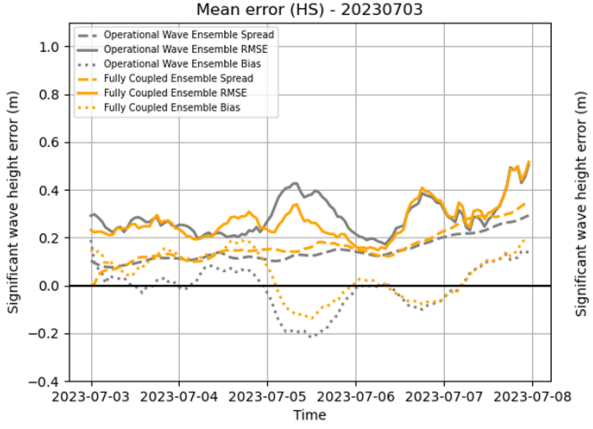


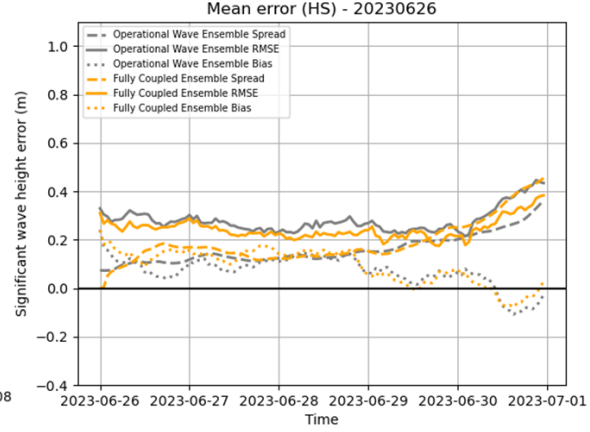
RMSE

spread

bias

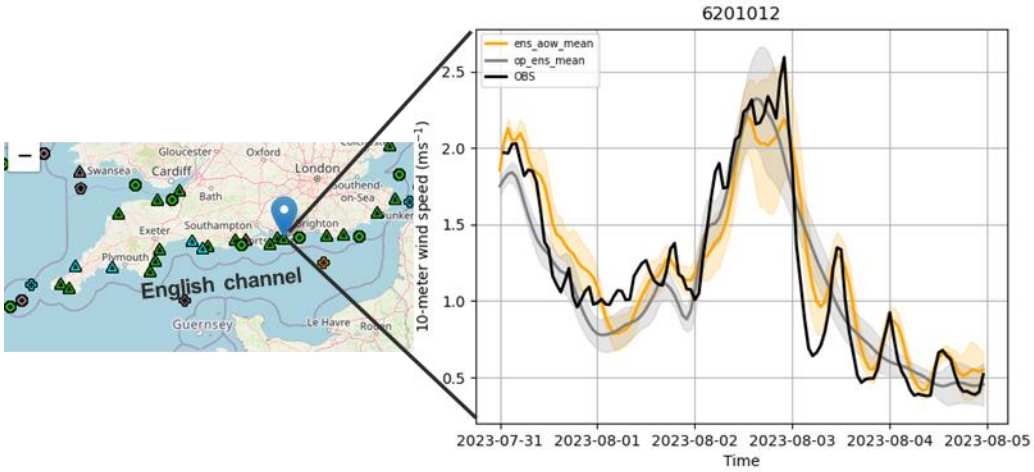






Vivian Fraser-Leonhardt

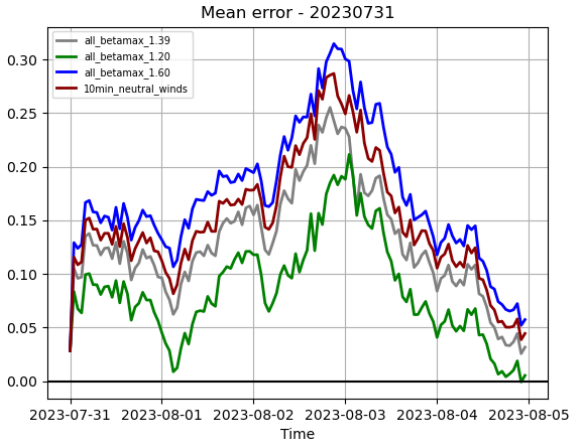
Reason for the improvement in wave RMSE



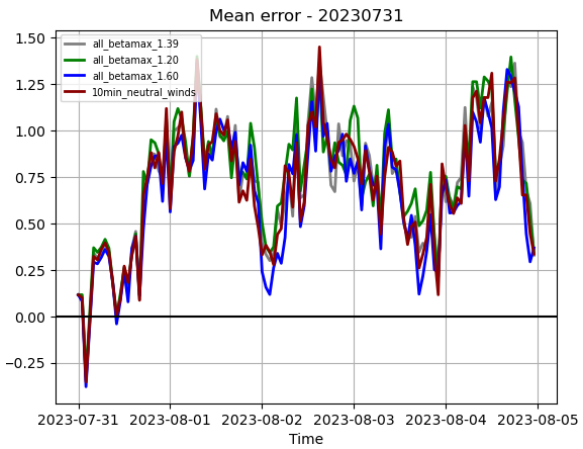
Wind and waves are modulated by tidal currents in the Channel, and this is well captured by the coupled system

Optimisation of the wave/wind coupling parameter Beta_max

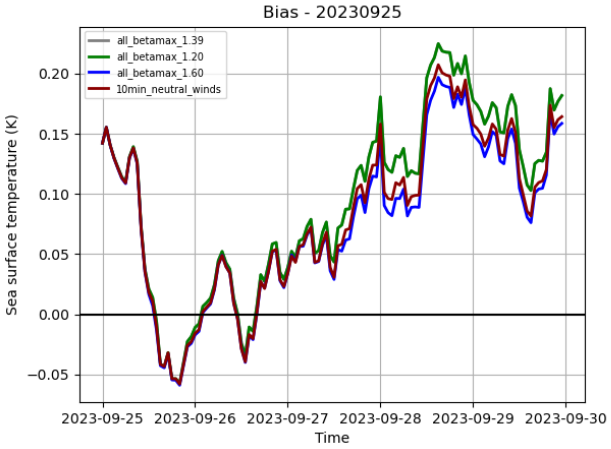
Wave biases



Wind biases



SST biases



Compromises in coupled model:

Reducing Beta_max improves waves, but deteriorates wind and SST

Betamax value kept to its initial value of 1.48

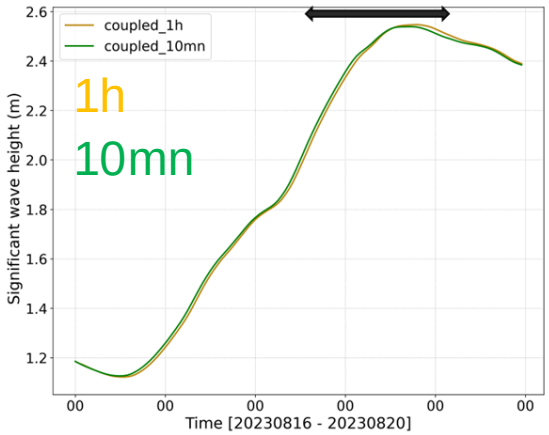
Vivian Fraser-Leonhardt

Met Office

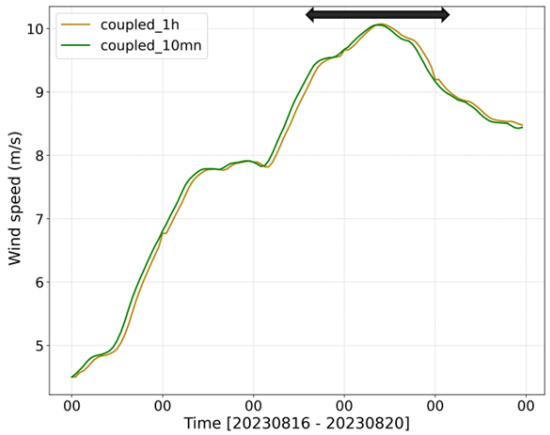
Coupling frequency: from 1h to 10mn

10mn coupling frequency

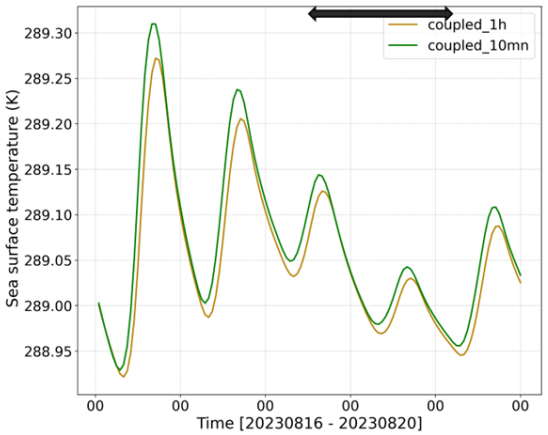
Earlier wind and wave build-up (slight deterioration) Improved SST diurnal cycle



waves



wind



SST

Domain-averaged plots over 5-day forecast for storm Betty

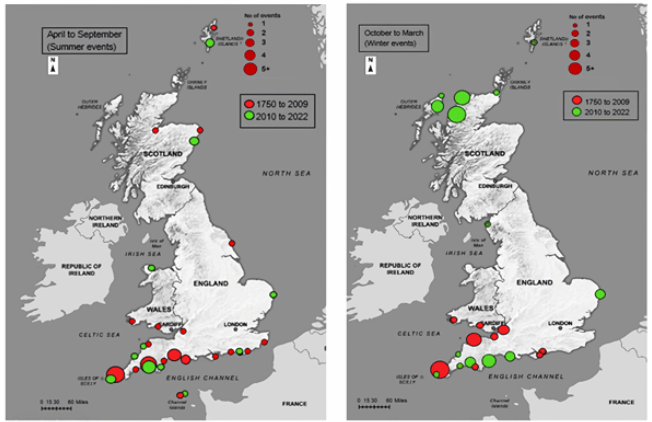
10mn coupling frequency

Aim: To improve forecasting high frequency events such as meteorological tsunamis.

Meteotsunamisin the UK:

- Is a rare seasonal hidden hazard
- Typically occur with precipitating convective weather systems

=> on-going research activity (Nefeli Makrygianni)



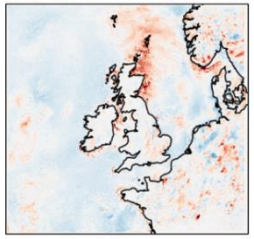
Met Office

Ensemble spread in air temperature

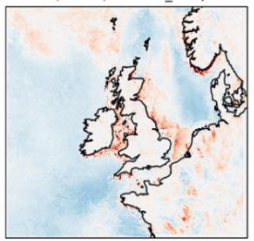
Met Office Ensemble spread in T2m after 5 days

Ratio of ensemble spread in coupled vs atmosphere/land after 5 days

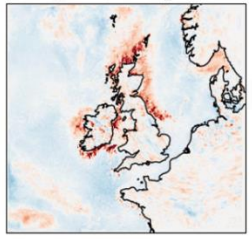
02/08/2023
d ratio (aow/a) surface_temperature



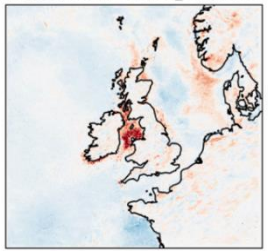
26/06/2023
td ratio (aow/a) surface_temperature



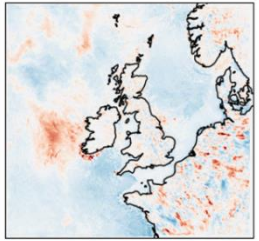
03/07/2023
std ratio (aow/a) surface_temperature



24/07/2023
std ratio (aow/a) surface_temperature



31/07/2023
std ratio (aow/a) surface_temperature



07/08/2023
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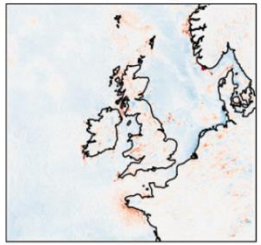

14/08/2023
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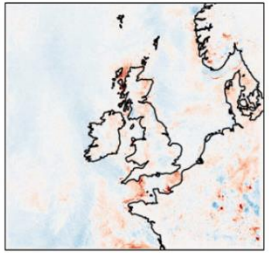
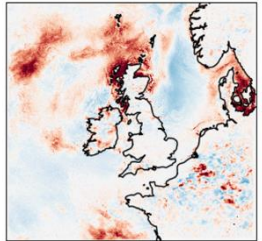
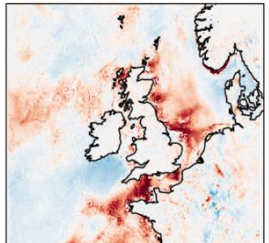


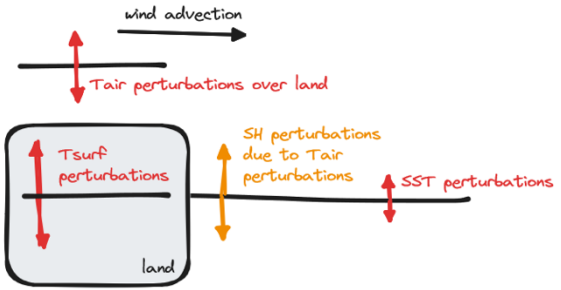
05/06/2023
std ratio (aow/a) surface_temperature



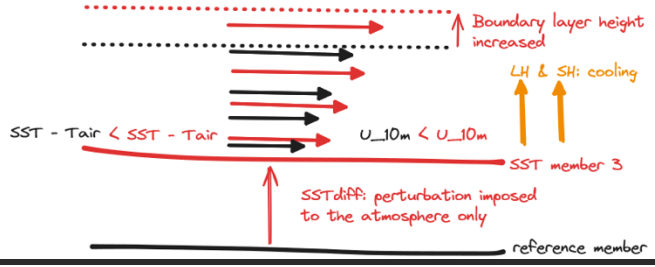
19/06/2023
std ratio (aow/a) surface_temperature



a) Illustration of impact from land perturbations in coastal areas



b) Illustration of negative turbulent flux/SST feedback



c) Spread in atmospheric cloud-cover generates large SST spread when mixed layer is shallow (marine heatwaves)

Sana Mahmood

Met Office

RCS-UKC4:

a learning journey of evaluation and optimisation across most of Met Office's modelling expertise: from ensembles to climate; from the atmosphere to the land through rivers and down to sea and waves

And a huge collaborative work

Next steps: use the system for science & prediction

- **Process-understanding of multi-hazard compound events**
- **Climate projections (ongoing!)**
- **Near-real time ensemble forecasts**
- **Plug rivers into ocean / better treatment of the coast (UKC5 / Ind2)**
- **… contributions welcome!**