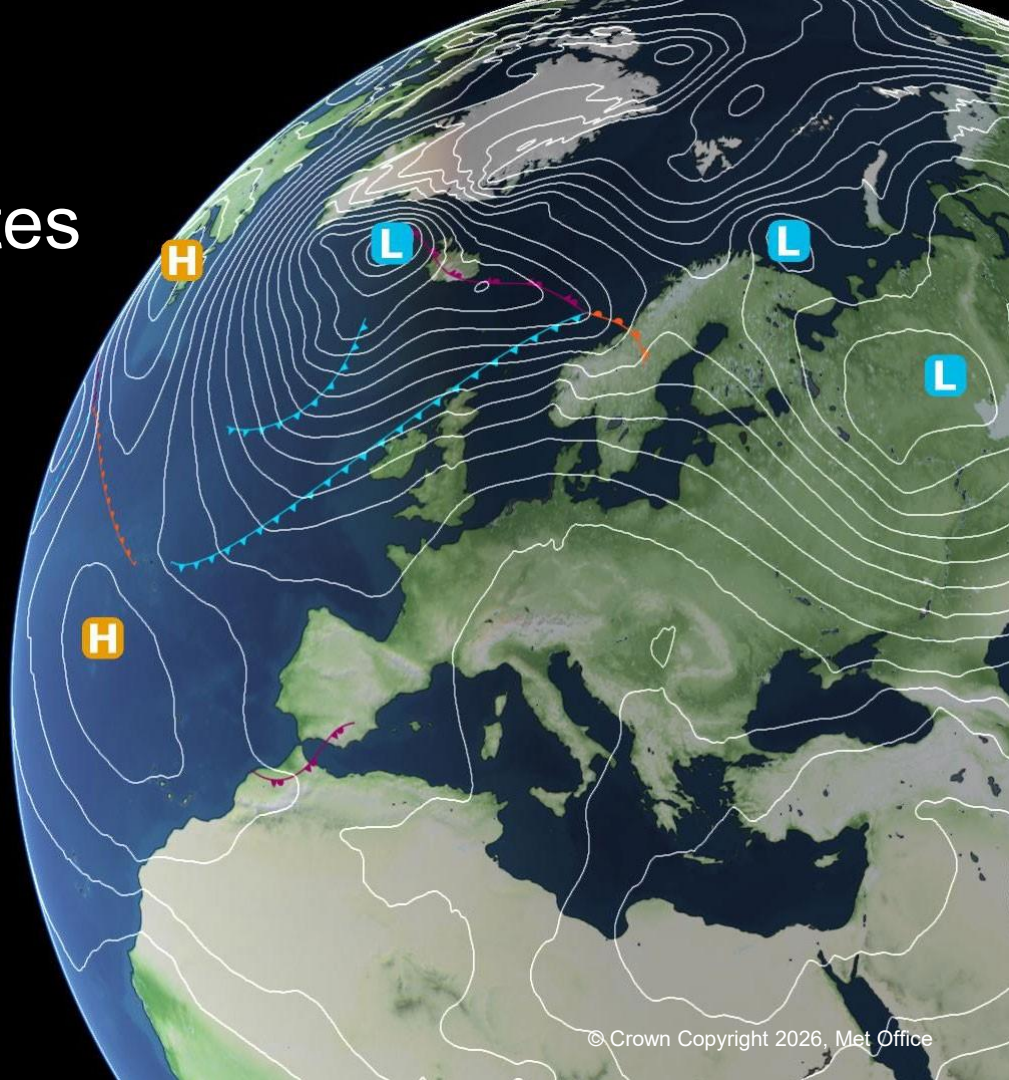


# Met Office systems updates

David Ford with thanks to colleagues in  
the Ocean Forecasting R&D team

Ocean Predict Science Team meeting,  
15<sup>th</sup> April 2026



- **Operational 3D ocean (FOAM)**

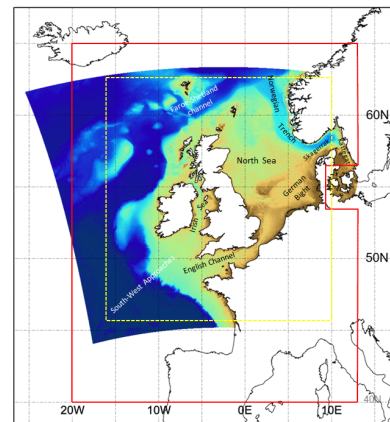
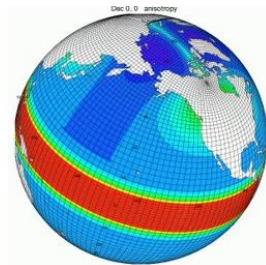
- Global ocean – atmosphere – land – sea ice ( $1/4^\circ$ )
- Global ocean – sea ice ( $1/12^\circ$ )
- Regional ocean – waves (1.5 km)
- Regional ocean – biogeochemistry (7 km)

- **Operational 2D ocean**

- Global and regional waves
- Regional storm surge
- Global SST and sea ice analysis (OSTIA)

- **R&D**

- Regional ocean – waves – biogeochemistry (1.5 km)
- Regional ocean – atmosphere – land – waves – biogeochemistry (1.5 km)
- Global ocean – sea ice – biogeochemistry ( $1/4^\circ$ )
- SPRAI: AI to emulate daily global SST forecasts out to 7 days
- And other projects



- **Operational 3D ocean (FOAM)**

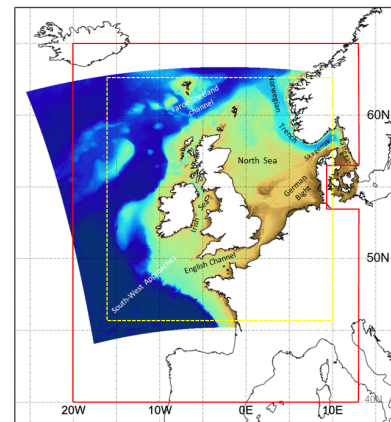
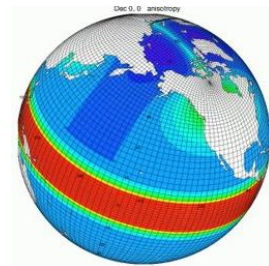
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# Global 3D Ocean

- Deterministic (~10 km atmosphere)
- 18-member ensemble (~20 km atmosphere)
- Both run 6-hourly with 1/4° ocean
- 7-day forecasts

## UM atmosphere

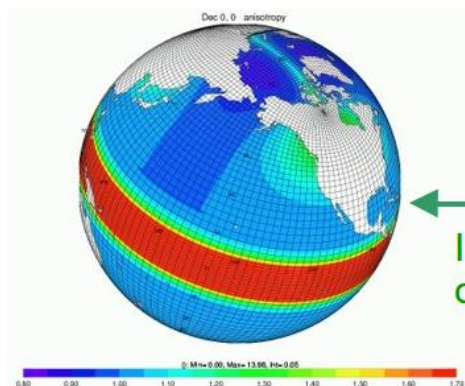


## JULES land surface



Internal  
communication

OASIS3-MCT  
coupler (every hour)



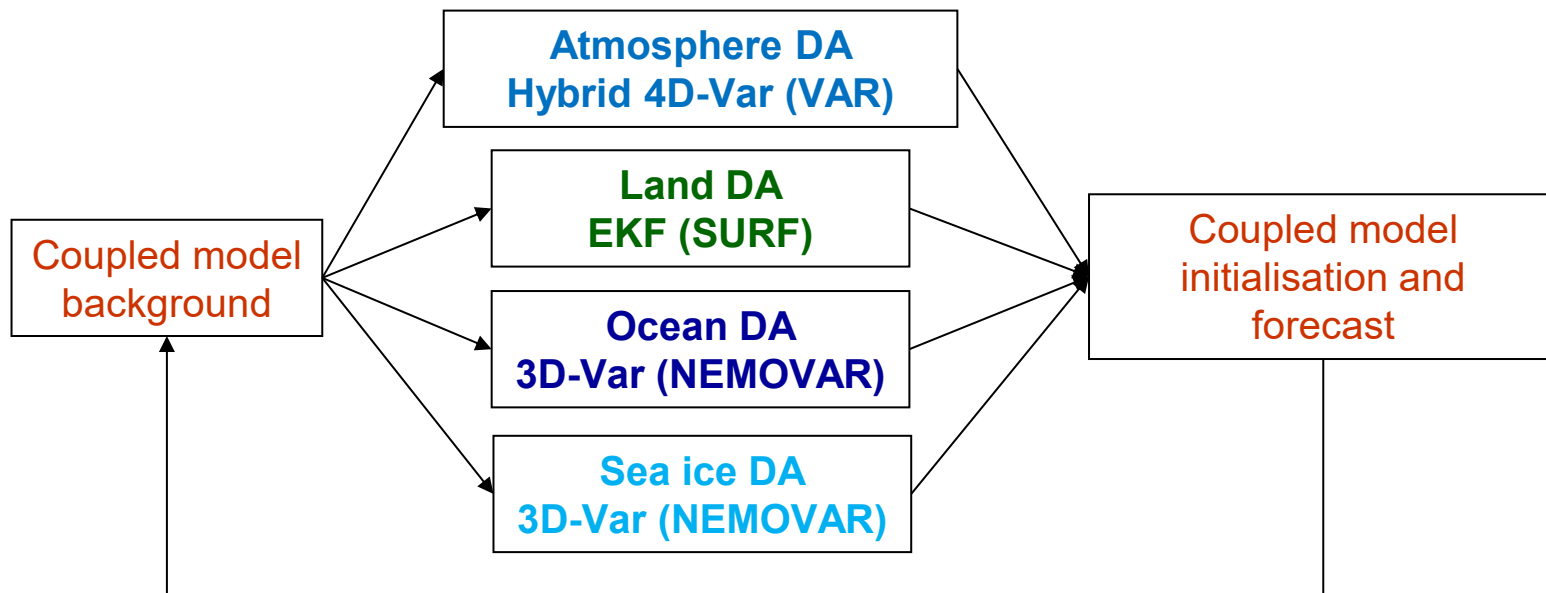
## NEMO ocean



Internal  
communication

## SI<sup>3</sup> sea ice

# Met Office Weakly coupled data assimilation

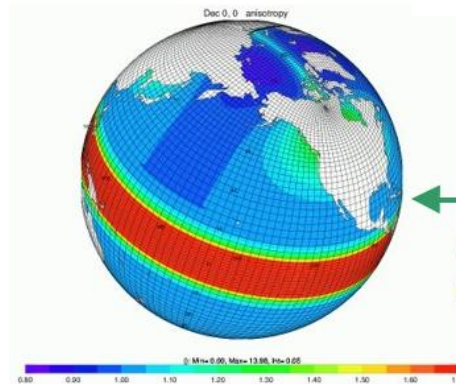


- Coupled model used in the forecast (and for DA background)
- Separate component DA with increments added to coupled model



- Deterministic
- Run daily at 1/12°
- 7-day forecasts

## UM atmosphere



## NEMO ocean

Internal  
communication



## SI<sup>3</sup> sea ice

# Met Office Recent ocean upgrades (Jan 2026)

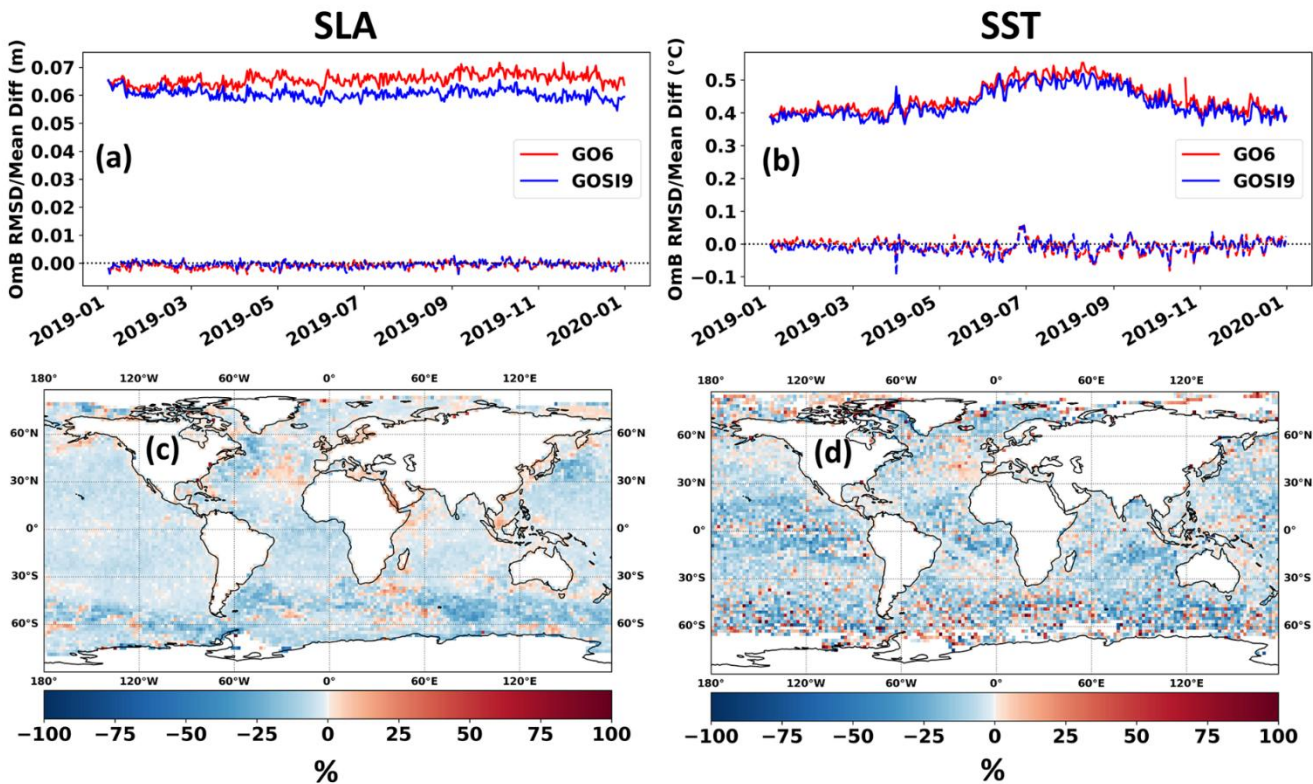
|                                               | FOAM GO6                                                                                                                             | FOAM GOSI9                                                                                                                                                                                            |
|-----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Ocean model                                   | NEMO 3.6                                                                                                                             | NEMO 4.0.4 with improved parameter settings in the Southern Ocean (Storkey et al., 2024), fourth-order tracer advection scheme, and space- and time-dependent version of Gent-McWilliams scheme       |
| Sea ice model                                 | CICE5                                                                                                                                | SI <sup>3</sup> 4.0.4                                                                                                                                                                                 |
| Equation of state                             | EOS80                                                                                                                                | TEOS10                                                                                                                                                                                                |
| SST and SLA observation errors                | Seasonally and spatially varying estimates produced using the Hollingsworth and Lönnberg method. This is treated as the total error. | Seasonally and spatially varying representation error due to unresolved scales in the model (Oke and Sakov, 2008) + observation-specific measurement error for SST and 4 cm measurement error for SLA |
| Background error correlation length scales    | Short and long length scales are used for both $T$ and $S$                                                                           | Long length scale is not applied for $T$ but is used for $S$                                                                                                                                          |
| Inner loop iterations (ocean DA)              | 40                                                                                                                                   | 120                                                                                                                                                                                                   |
| SSH balance                                   | Applied below but not in the mixed layer                                                                                             | Applied through the whole water column                                                                                                                                                                |
| Rejection of $T/S$ increments                 | None                                                                                                                                 | Rejection of $T/S$ increments based on water column instabilities diagnosed from Brunt–Väisälä buoyancy frequencies                                                                                   |
| Normalisation factors                         | Look-up table                                                                                                                        | Decomposed normalisation factors                                                                                                                                                                      |
| Multi-resolution for implicit diffusion model | Not implemented in NEMOVAR                                                                                                           | Implemented in NEMOVAR                                                                                                                                                                                |

JEDI-based (JOPA) observation processing – scientifically neutral





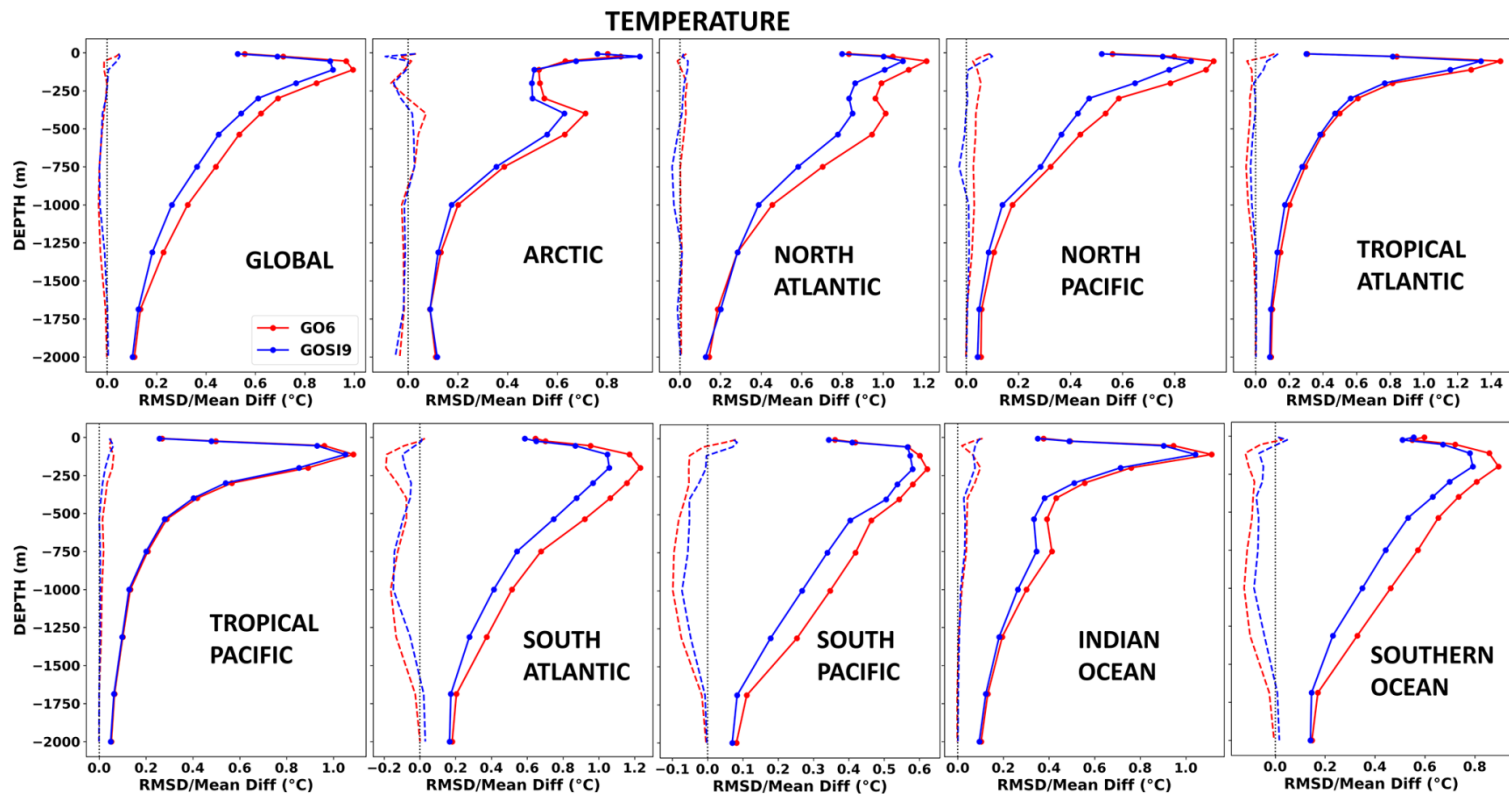
# Met Office Recent ocean upgrades



Change in RMSE, blue = improvement



# Met Office Recent ocean upgrades

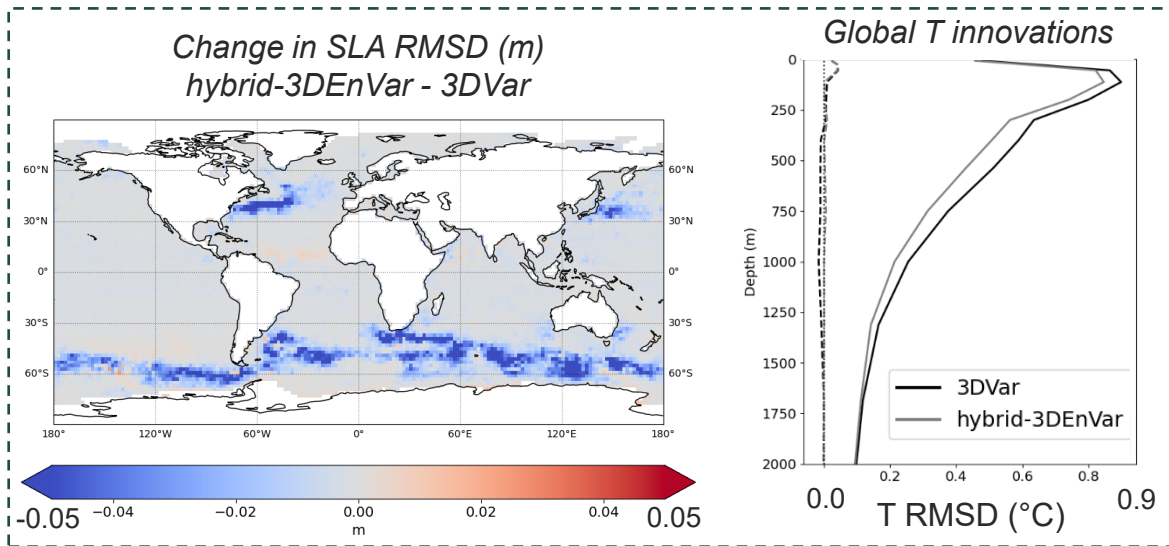


Temperature profile errors, blue = new system, red = old

# Met Office Planned upgrades

- Early 2027:
  - Atmosphere ensemble resolution increased to ~10 km
  - Forecasts out to 10 days
  - Sea ice thickness assimilation
- Early 2028 (TBC):
  - Brand new atmosphere model (LFRic)
  - JEDI-based atmosphere assimilation (JADA)
- Beyond:
  - HPC upgrade
  - 1/12° ocean in coupled system
  - 1/12° ensemble-var ocean data assimilation
  - Sea surface salinity and sea surface velocity assimilation

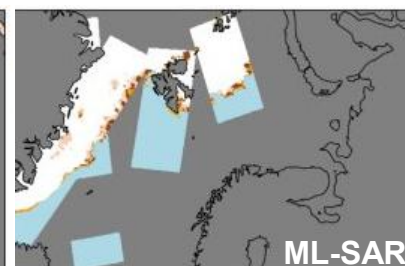
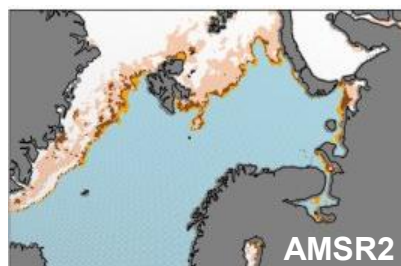
- **GOSI9 (NEMO4)** version of the FOAM system with updates to background and observation error covariances being implemented in coupled and ocean-only systems => improvements in accuracy and reanalysis behaviour.
- Now preparing **hybrid-3DEnVar ocean DA** in the uncoupled  $1/12^\circ$  GOSI9 system  
→ 36-member EDA (perturbed observations & model, ensemble surface forcing).
- Major improvements in accuracy to the unperturbed member with hybrid-3DEnVar compared with existing 3DVar.
- 15-20% reduction in global sea level anomaly (SLA) RMSD in an 11-month experiment at  $1/4^\circ$  resolution.
- Similar improvements in shorter trial at  $1/12^\circ$  resolution.



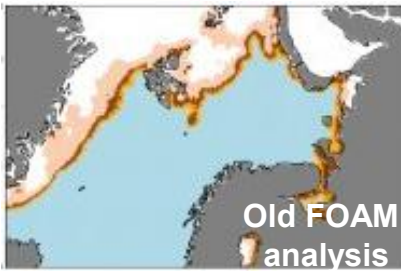
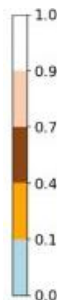
# Improving sea ice analysis

- Assimilation of winter **sea ice thickness** data is planned to be implemented early 2027.
- Now focussing on improving **sea ice concentration** (SIC) - operational system has **too-smooth sea ice edge**.
- New product from DMI (ML-SAR) gives better representation of SIC derived from Sentinel-1 SAR data using ML, trained on ice charts.

*Sea ice concentration  
on 13<sup>th</sup> Apr 2023*



- Assimilating ML-SAR & AMSR2 data gives **better agreement with the ice charts** and **increased gradients** near the ice edge.
- On-going work to develop **bias correction for AMSR2** data, particularly important over the summer in presence of melt ponds.



## Coupled DA:

- Existing operational system is a weakly coupled DA system (separate atmosphere/land and ocean/sea ice analyses).
- Research into the nature of [coupled background error covariances](#) was carried out using a version of the Met Office coupled NWP ensemble system [Lea et al., 2023; Wright et al., 2024].
- Research into [coupled observation operators](#) – PhD with Univ. of Reading.

⇒ Need to develop common software infrastructure to be able to implement more strongly coupled DA methods.

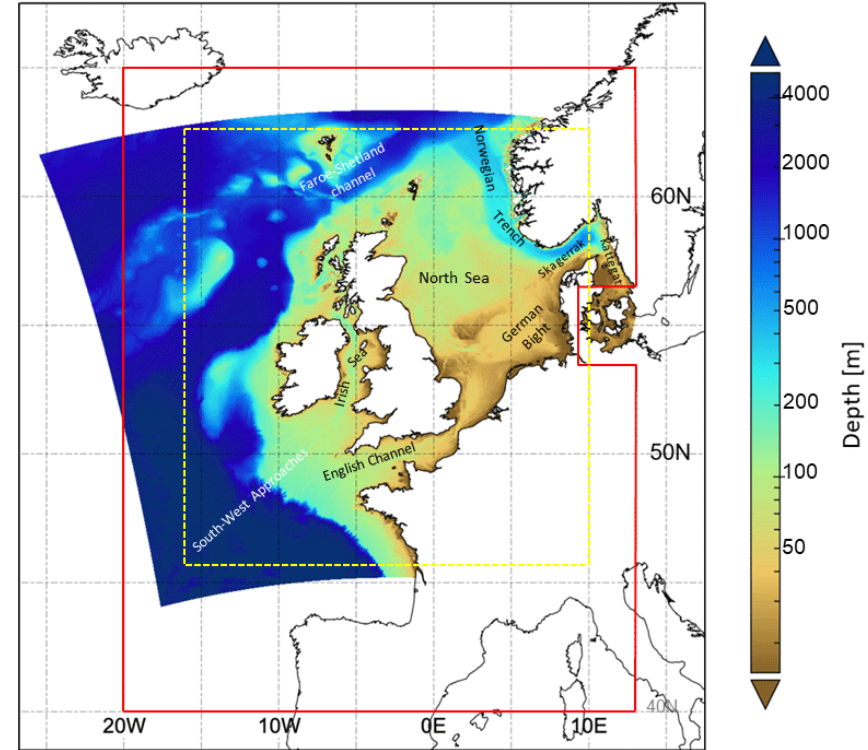
## JADA-Ocean:

- We have begun implementing JEDI for ocean and sea ice DA, making use of NEMOVAR components.
- Testing so far in simple, low-resolution configuration which will be expanded to replicate operational functionality.



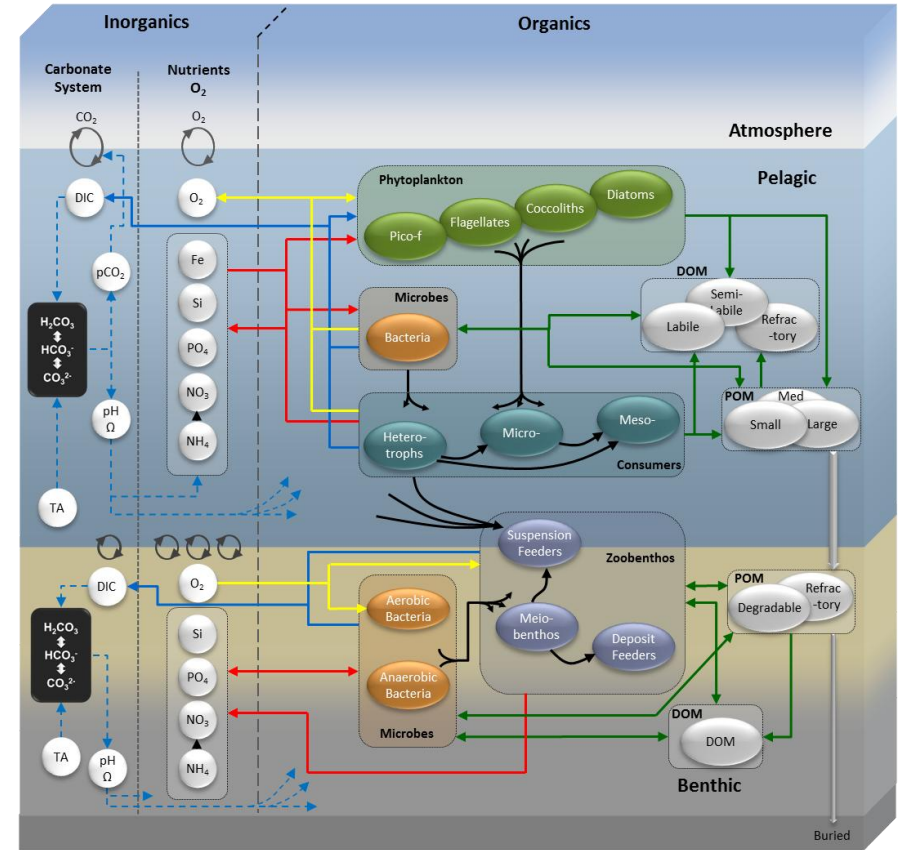
# Northwest European Shelf 3D ocean

- NEMO coupled with WaveWatch III
- 1.5 km resolution
- 3D-Var (NEMOVAR)
  - T, S, SST, SLA
- Ocean-only, but used as lower boundary condition for UK NWP
- Run daily, 7-day forecasts



Tonani et al., 2019, GMD

- NEMO coupled with ERSEM
- 7 km resolution
- 3D-Var (NEMOVAR)
  - T, S, SST, SLA
  - Ocean colour chlorophyll-a
- Ocean-only
- Run daily, 7-day forecasts



Butenschön et al., 2016, GMD

# Met Office Recent upgrades

- Forecasts available via Copernicus Marine Service
- Forcing updates:
  - Atmosphere from Met Office global NWP model
  - Lateral boundaries from Met Office 1/12° global ocean model
- Assimilation updates:
  - SLA assimilated on-shelf
  - New chlorophyll error covariances
- Improvements to biogeochemistry light inputs
- Newer version of ERSEM biogeochemistry model

# Met Office Planned upgrades

- Early 2027:
  - 1.5 km: NEMO v4.0.4, TEOS10, wetting and drying
  - 7 km: Dynamic alkalinity, improved BGC boundaries, ERSEM update (NECCTON)
  - Both: 10-day forecasts, JOPA
- Early 2028 (TBC):
  - 7 km: NEMO v4.0.4, TEOS10
  - 7 km: phytoplankton functional type chlorophyll and (maybe) BGC-Argo assimilation
  - 1.5 km: “Demonstration” ocean – wave – biogeochemistry system
- Beyond:
  - Ensembles and hybrid ensemble-var assimilation
  - Improved multivariate balancing for BGC assimilation
  - Sediment model and spectral light model

# Contribution to OP strategic objectives

# Met Office Strategic objectives

- Continue contributing to collaborations, intercomparisons, projects (e.g. SynObs), etc.
- Continue developing state-of-the-art forecasting systems
- All strategic objectives look relevant – happy to discuss!



# Questions?