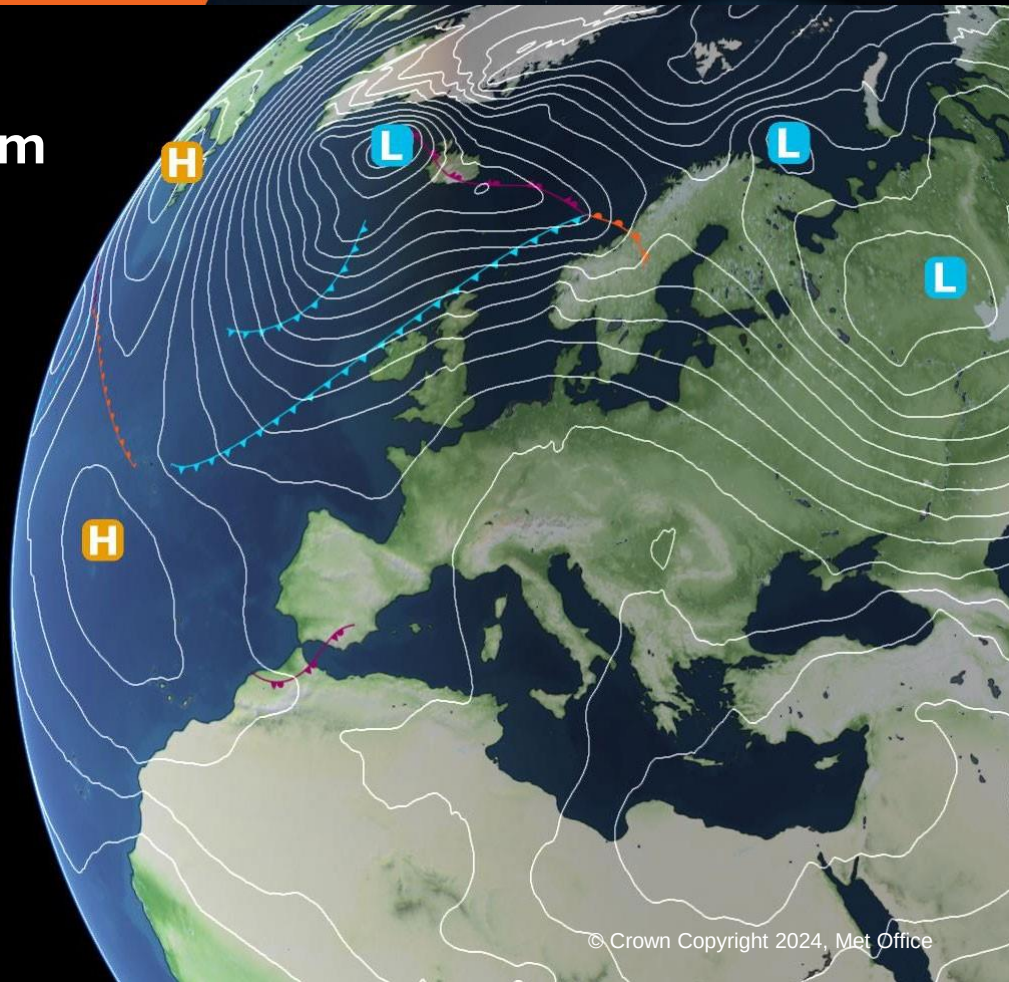
Ocean component of the operational coupled NWP system @ UK Met Office

Current status and future developments

Sophia Moreton, Jonah Roberts-Jones

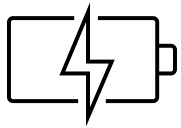
DA: Davi Carneiro, Dan Lea, Matthew Martin, Jennie Waters

OM: Diego Bruciaferri, Tim Graham

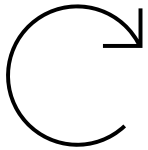


Coupled Global Ocean Forecasting @ UK Met Office

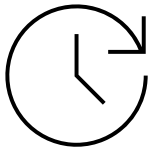
What does the **current** global coupled operational NWP system look like?



What are the latest updates to this system due live in **2025**?



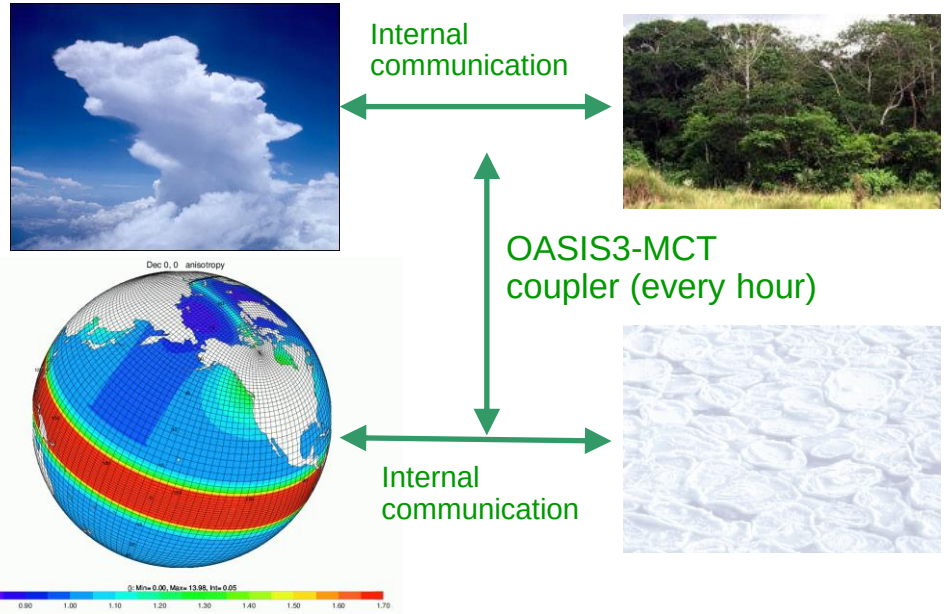
Current scientific research to inform our **future** operational systems



What does the **current** global coupled operational NWP system look like?

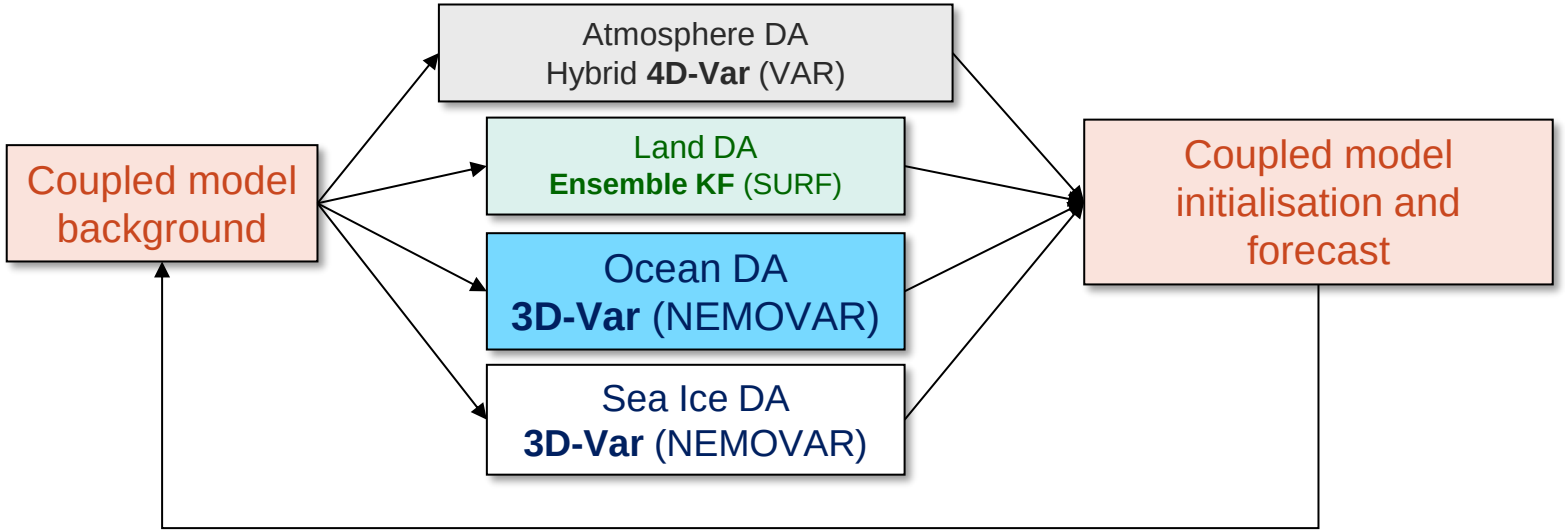
FOAM - Global Coupled (GC)

System	
What it does	Daily analysis and 7-day forecast of 3D physical atmosphere & ocean (coupled since May 2022), using 'weakly coupled' DA
Components	NEMO3.6, CICE & NEMOVAR
Observations	T & S Argo profiles, satellite and in-situ SST, sea ice concentration & satellite SLA
Resolution(s)	¼ degree (~25km) ORCA025 ocean coupled to ~10km deterministic and ~20km ensemble atmosphere
DA window length	6hrs (1 main & 3 update cycles)



What does the **current** global coupled operational NWP system look like?

Weakly coupled data assimilation



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

What does the **current** global coupled operational NWP system look like?

Pros/ Cons of 6hr DA window

- Atmospheric DA window must be short as it's a rapidly evolving system
- Ocean DA needs to fit into same cycles
- Smaller forecast errors

- Reduced SLA altimeter obs in past year by ~40% due to increase in obs processing time
- Noisier (oscillating) increments in 4x 6hr DA window c.t. 24hr window
- Often R&D updates are tested in ocean-only setting with 24hr DA window

What are the latest updates to this system due live in **2025**?

Short-term scientific and technical updates (due 2025)

Updates to:

NEMO ocean model

(3.6 → 4.0.4)

Sea-ice model

(CICE → SI^3)

- TEOS-10 variable change: practical salinity & potential temp. → absolute salinity & conservative temperature
- Higher order advection scheme
- Scale-aware Gent-McW parameterisation
- Partial slip lateral BCs .

More info in Guiavarch et al., 2024

Updates to **data assimilation**:

- **TEOS-10** variable changes
- Shorter **temperature length-scale** (based on Rossby radius) for increments
- Updated QC of T/S increments after IAU (based on physical **Brunt-Vaisala stability checks**) due to removal of long length scale for T
- ~3x increase in **no. iterations** (40 → 120) to minimise the cost function
- new estimates of **SST & SLA obs error variances** (obs specific)
- Separate horizontal and vertical **normalisation factors** (& use of transfer grid)
- Update to **MDT** for SLA assimilation:

CNES CLS13 ->CLS18

More info in Carneiro et al., 2024

Updates to horizontal and vertical **observation extraction & QC**:

'JOPA' based on JEDI: Joint Effect for Data Assimilation Integration

- Differences in observation thinning

What are the latest updates to this system due live in **2025**?

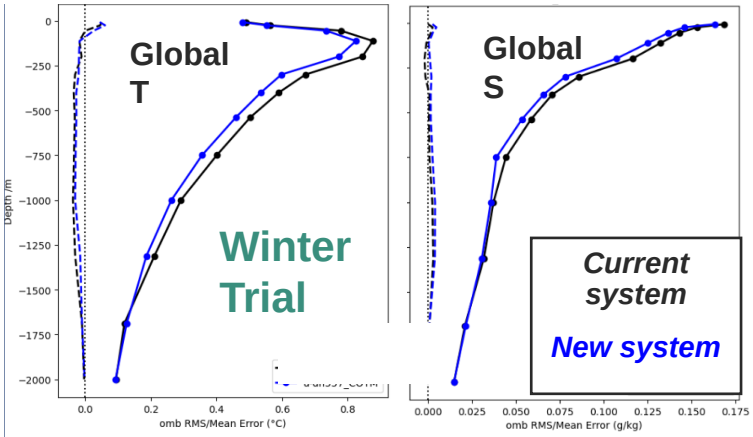
Impact on T & S Profiles in FOAM-GC

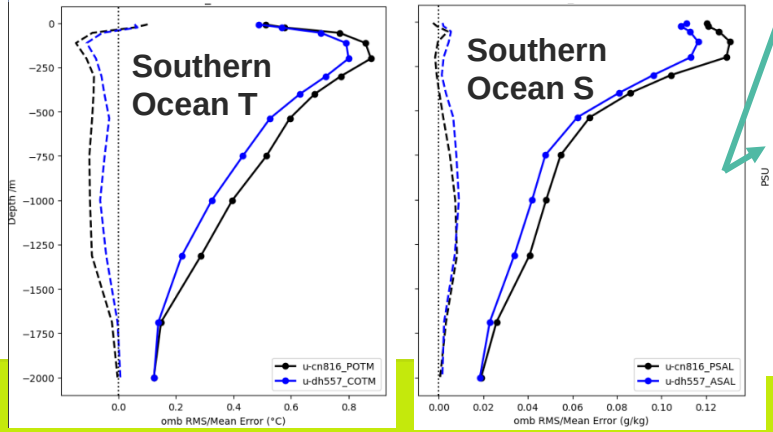
- Significant improvement in T-S profiles globally, mainly in SO.

As expected, due to **NEMO** reduction in T&S bias along Antarctic shelf from being excessively fresh. T&S improvement is associated with a stronger ACC.

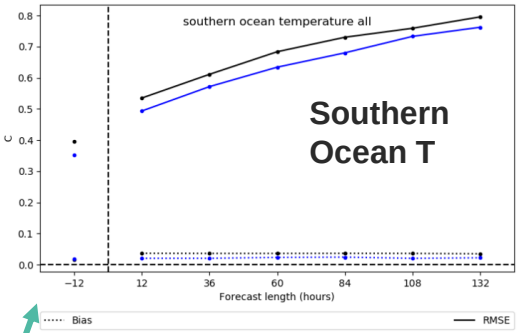
Main impact is from **DA**: removing T long length scale to limit the projection of the SLA signal onto large-scale temperature at depth (also from the new SLA obs errors, increased number of iterations & B-V stability checks).

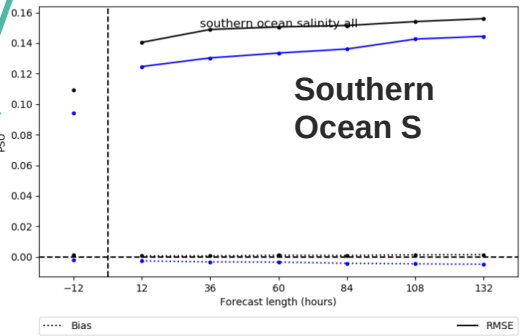
omb RMSE (solid) & bias (dotted)





Winter SO RMSE vs Lead time (class-4):



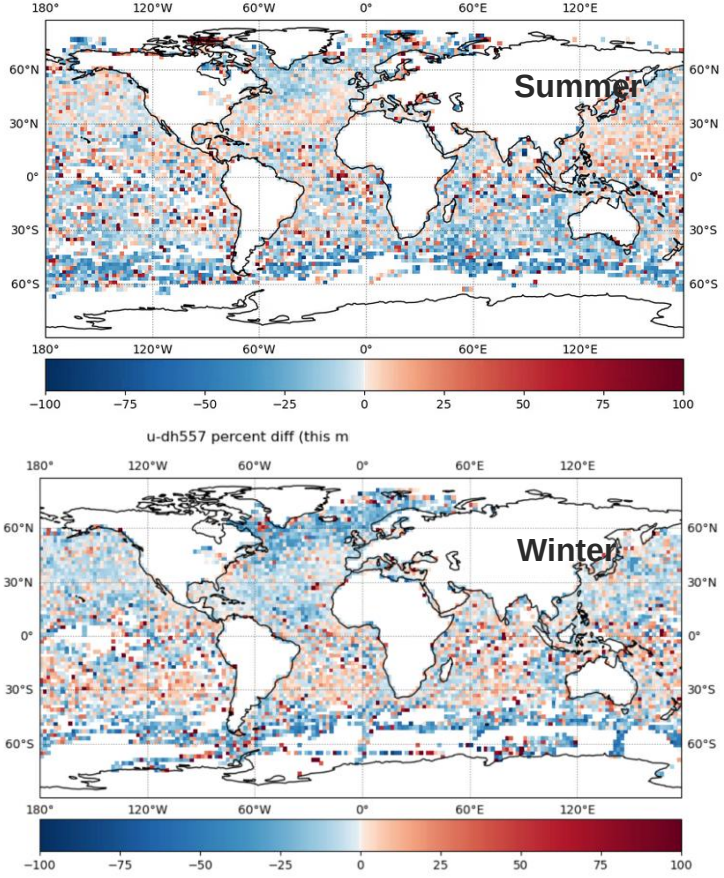


Impact on SST in FOAM-GC

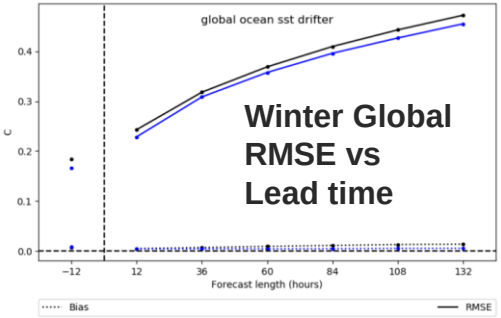
- Significant improvement in in-situ SST, especially in SO & Winter Arctic & NA subpolar gyre.
- Due to **DA** updates: removing T long length-scale and updated SST obs errors
- Slight hemispheric negative impact on in-situ SST in subtropical gyres due to shallowing of MXL in **NEMO**.

Improvement is blue, degradation is red.

SST: New–Current System omb RMSE (%)



What are the latest updates to this system due live in **2025**?



Current system

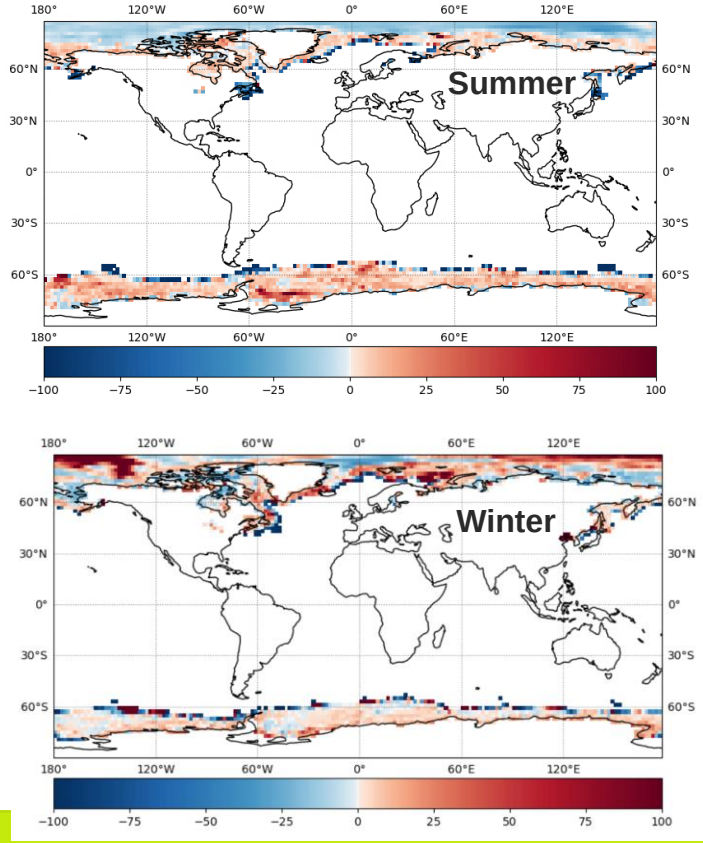
New system

Impact on sea ice concentration (SIC) in FOAM-GC

- In summer, overall improved SIC in Arctic summer due to improved melt pond scheme in model, which is reflected in forecast.
- Improvements seen at ice shelf globally.
- But degradation in SIC in Antarctica (both seasons) & Arctic winter.
- Due to **model** representation & **DA:** poor background errors for SIC & seasonal co-variances are too long (work in prog. → daily & on av. reducing obs error, **Davi Carneiro**)

Improvement is blue, degradation is red.

SIC: New–Current System omb RMSE (%)



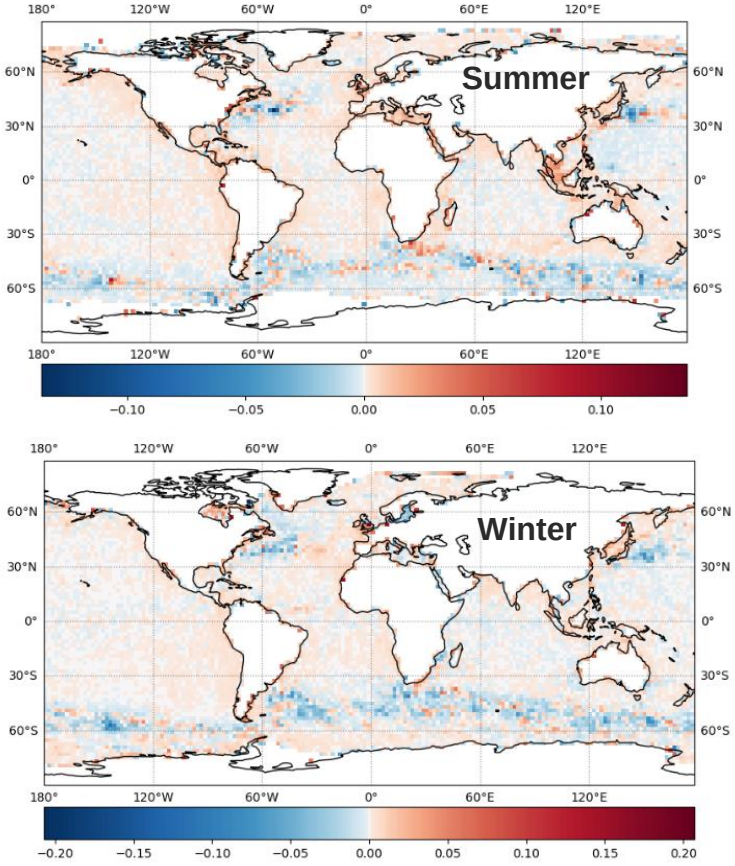
What are the latest updates to this system due live in **2025**?

Impact on SLA in FOAM-GC

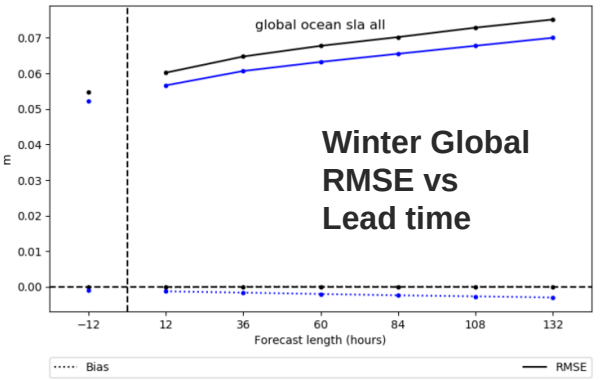
- Improved SLA from **DA** updates (T long length scale & SLA obs errors) in SO & WBCs
- But slight degradation elsewhere especially in Indonesia & Med. Degradation from updated **model** config with compensating improvements from **DA** update.

Improvement is blue, degradation is red.

SLA: New–Current System
omb RMSE (abs)



What are the latest updates to this system due live in **2025**?



Current system

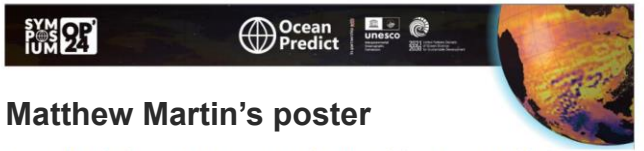
New system

Met Office

Current scientific research to inform our **future** operational systems

Future coupled system developments

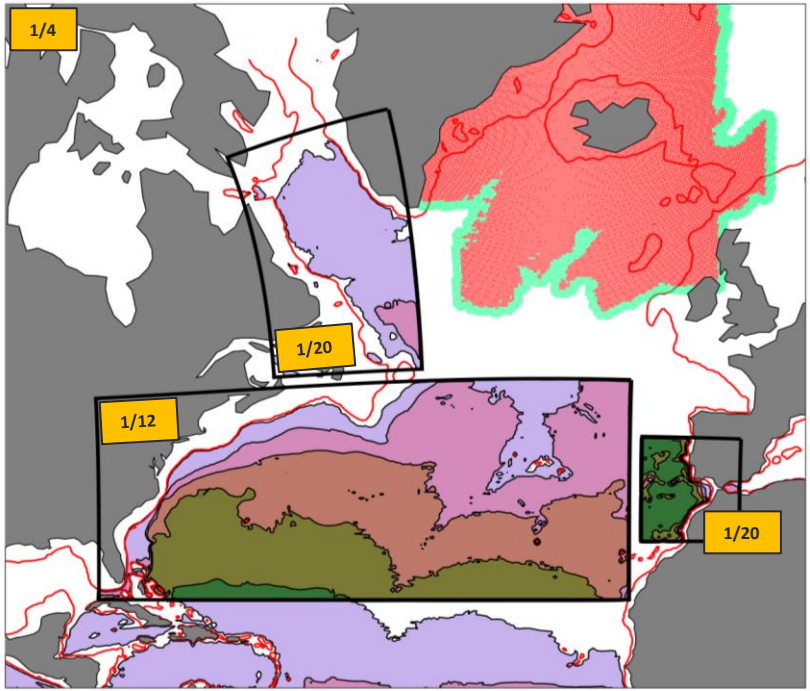
- ‘Trail blazer’ 5km-ORCA12 run alongside operational NWP with no DA (Tim Graham)
- A ‘go-anywhere’ global ocean forecasting capability e.g. AGRIF (Diego Bruciaferri) and/or coupled ORCA12
- Including ocean ensemble developments in coupled ensemble system (Dan Lea)
- New obs: SWOT Altimeter and Sea Ice Thickness
- Improving background error covariances in FOAM-GC (for 6hr window)
- Ocean prediction using AI?



Also in the atmosphere…

- Retirement of deterministic model & increased resolution of **atmospheric ensemble**
- New LFRic model
- Updated JEDI-based DA called JADA

AGRIF: Adaptive Grid Refinement In Fortran



R_H

2 3 4 5 6 7

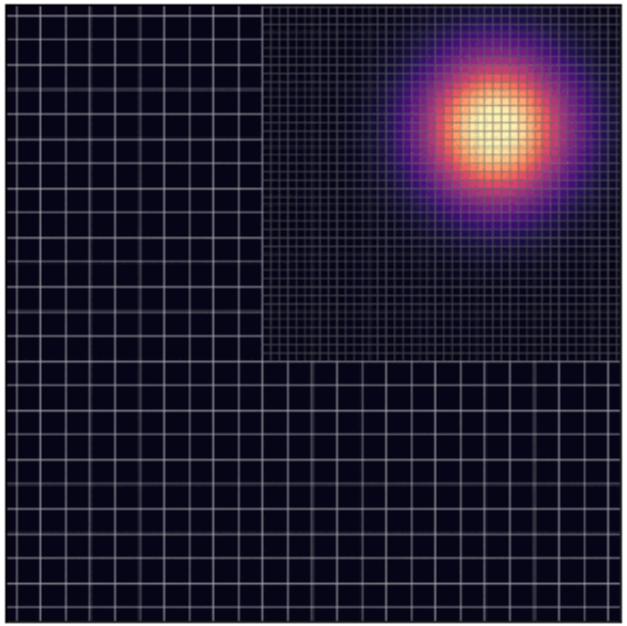
Not resolv. R_D | Number of grid points to resolve R_D

Proposed GOSI10na+ configuration

Current scientific research to inform our **future** operational systems

Full **two-way communication** between meshes.

The parent grid feeds the child grid open boundaries, while the child model updates the solution of the parent in the nesting area



The Spall and Holland (1991) baroclinic vortex test-case (SST) replicated with NEMO-AGRIF (the zoom uses a refinement factor of 3; from https://sites.nemo-ocean.io/user-guide/zooms.html).

Diego Bruciaferri et al., 2024, DOI: 10.1029/2023MS003893

More info on AGRIF: (paper is in prep.) 10. bruciaferri-diego-oceanmodel.pptx

Met Office

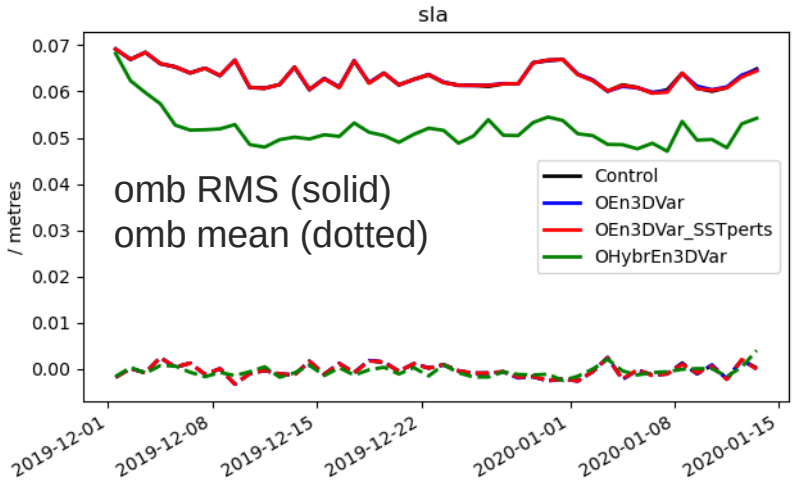
Current scientific research to inform our **future** operational systems

Coupled full ocean ensemble system

Currently, produce an O-A coupled ensemble: the ocean component is initialised from (a single) **deterministic** analysis.

The spread in the ocean ensemble is therefore very *small.* An artificial SST perturbation is applied to the atmosphere ensemble to account for this.

- Research is ongoing to implement a **full ocean ensemble** into coupled system using hybrid 3DEnVar.
- Follows on from ocean-only ensemble system, see Lea et al 2022 doi:10.1002/qj.4292 (coupled FOAM gave similar results)



- Control = 3DVar deterministic
- OEn3DVar = ensemble of independent 3DVars (but not ensemble information used in the DA).
- OHybrEn3DVar is the hybrid ensemble 3DVar. The hybrid ensemble weight = 0.8

Daniel Lea

Summary

Given overview of current status of coupled FOAM, including advantages/ disadvantages of 6hr cycling.

Going operational in 2025, improvements to the NEMO ocean and sea ice models and a range of data assimilation and observation processing updates will **significantly improve** our analysis and forecasting abilities.

Range of future ambitions for the ocean in the coupled system in the coming years, including higher resolution, multi-mesh zooms and ensembles.