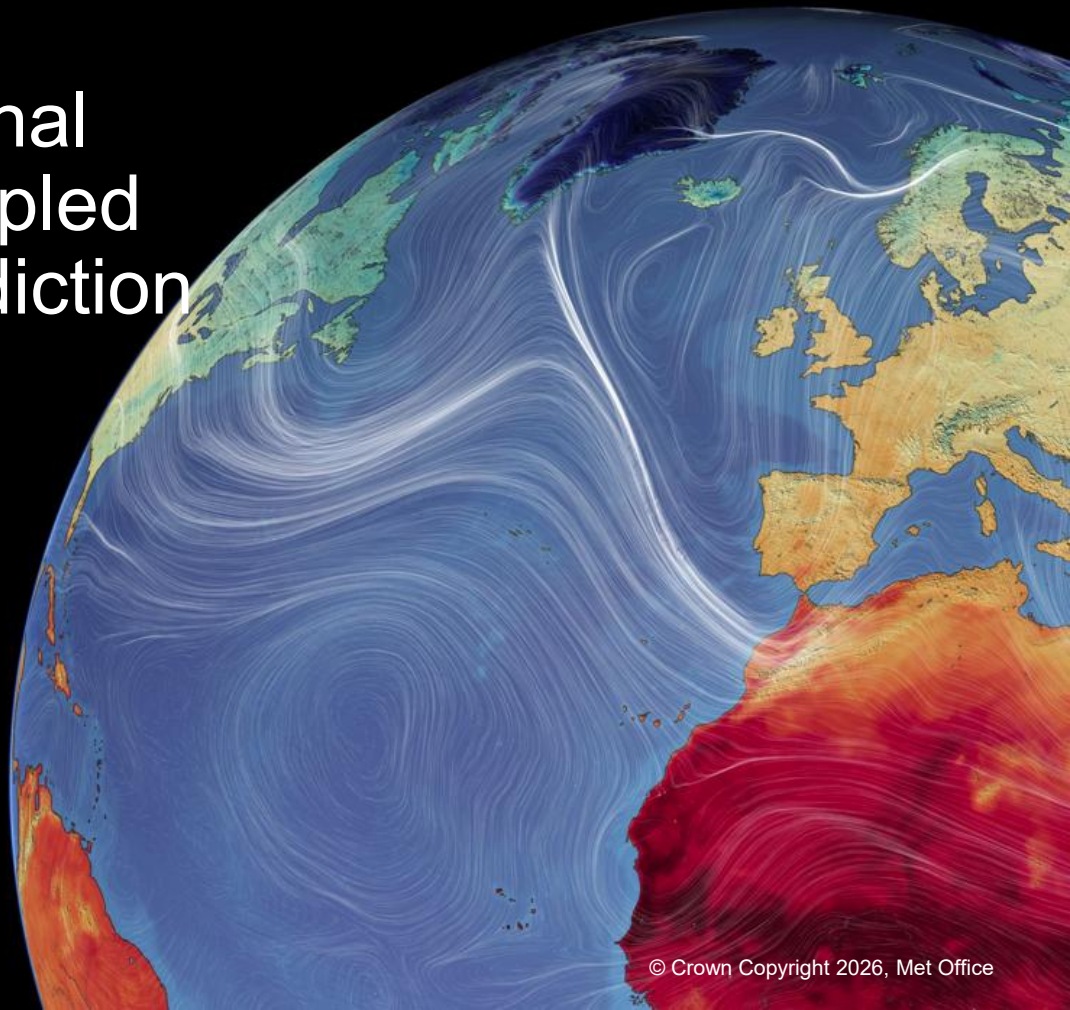
# UK Met Office operational ocean-atmosphere coupled numerical weather prediction system: current status and future outlook

Joint CP-TT/DA-TT Workshop 2026

26th Oct 2026



This content has been created by the author.

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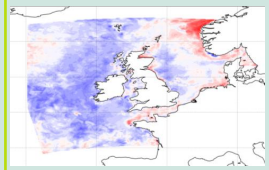
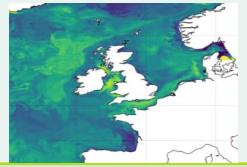
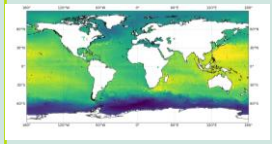
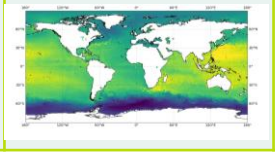
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# Purpose and content

- Ocean Forecasting at the Met Office
- Global O-A Coupled: high level view of the system
- Global O-A Coupled: Current status
- Global O-A Coupled: Future outlook
- Q&A

# Ocean forecasting at the Met Office

| System | Domain | Description | Coupled | Public task |
|---|---|---|---|---|
| NWS FOAM-AMM15 |  | ~1.5km, 50 level NEMO 3D ocean | NWS-wave model<br>SST for UK NWP | Regional ocean conditions for Marine Emergency Response and Met Office UK weather forecasts |
| NWS FOAM-AMM7 |  | ~7km, 50 level NEMO 3D ocean | Marine BGC model (1-way) | Marine in-water visibility forecasts |
| FOAM-GO ORCA12 |  | 1/12º, 75 level NEMO 3D ocean-SI$^3$ sea ice | Ocean-sea ice | Lateral boundary conditions for Met Office NWS regional systems |
| Global O-A Coupled |  | 1/4º, 75 level NEMO 3D ocean-SI$^3$ sea ice | Ocean-sea ice-land surface-atmosphere | Global ocean conditions for Met Office coupled weather and seasonal forecasts |

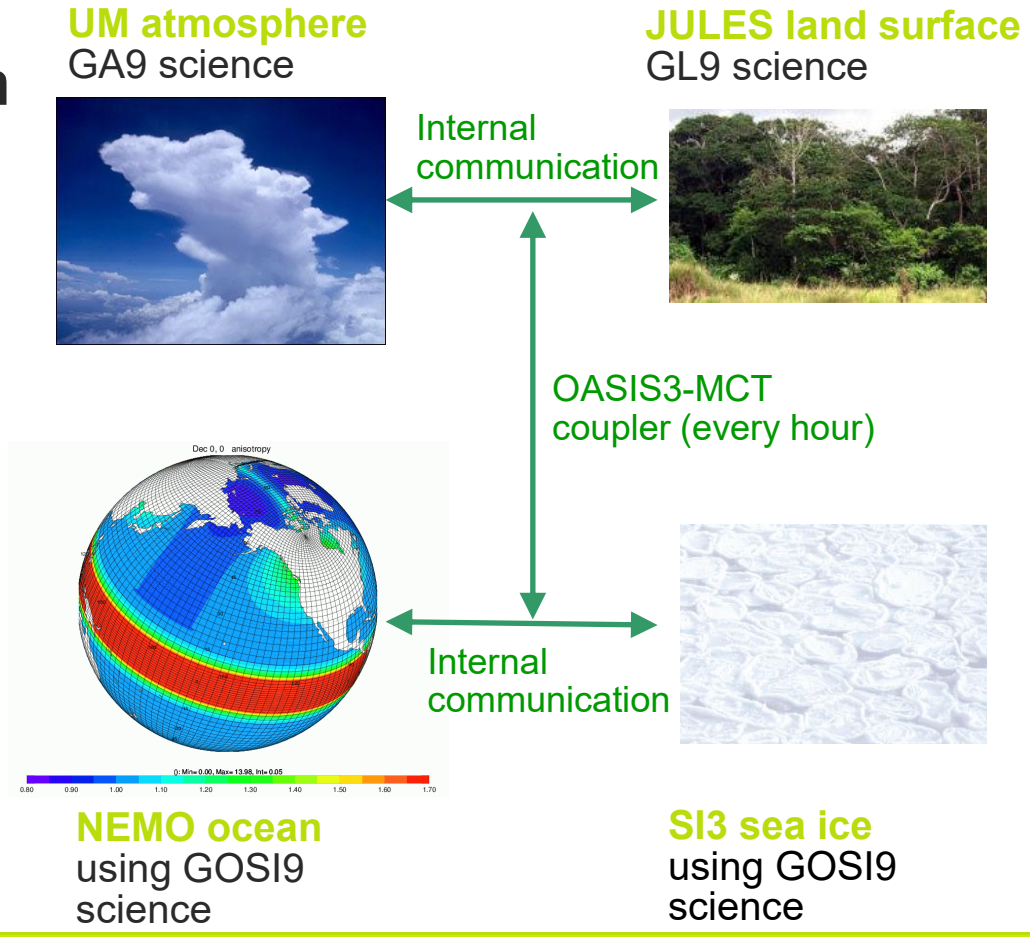
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# Global O-A Coupled system

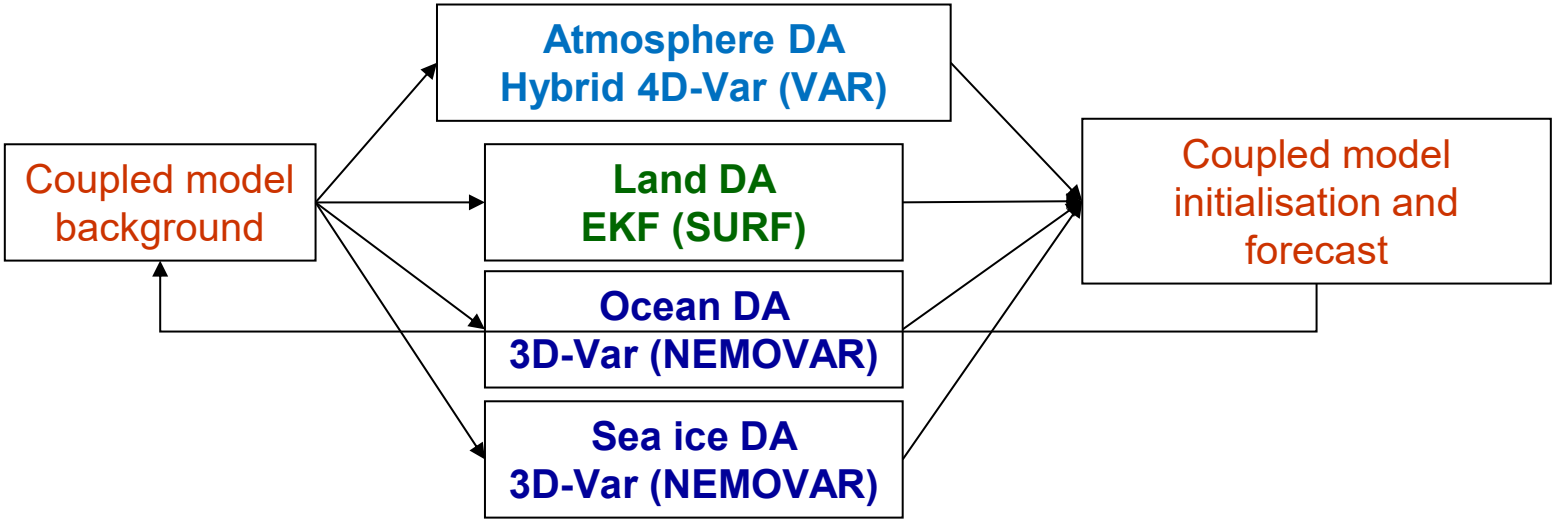
High level overview of the system

# Global O-A coupled system

- Global NWP system is coupled to an interactive ocean, went live in May 2022.
- Deterministic and ensemble system are coupled to a ¼° NEMO-SI$^3$ model.
- 44 member coupled ensemble is currently initialised from deterministic ocean with perturbed SST.
- Coupled system inherited the 6 hourly cycling of previous NWP systems.
- Evolution of the Coupled system that was providing products to the Copernicus Marine Service from 2016-2022



# Weakly coupled data assimilation




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

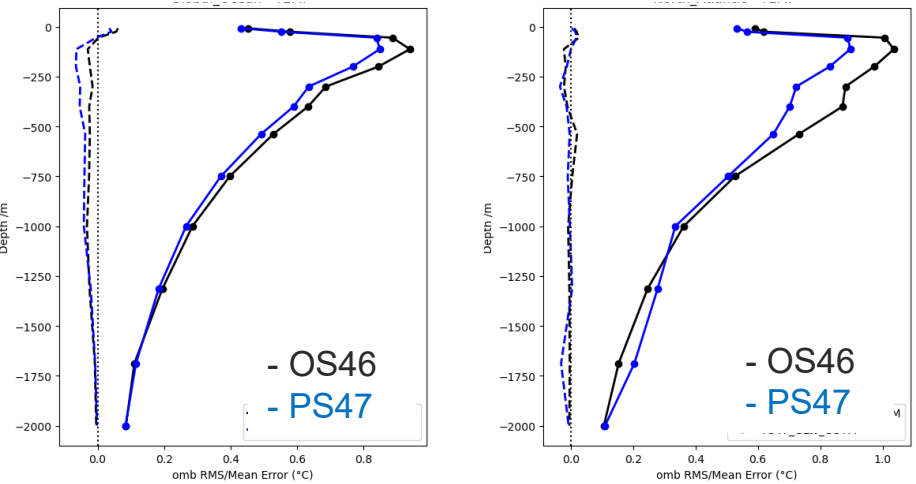
# Global Coupled: Current status

# Global Coupled: Current status

- In 2026 (OS47) the ocean component of global coupled system was significantly upgraded.
  - Ocean and sea ice model configuration was upgraded to GOSI9 (NEMO 4, $SI^3$ sea ice model, TEOS-10 eqn of state)
  - New ocean DA configuration (increased iterations, revised observation errors and T length scales)
- In 2027 (PS48) coupled system extend to 10-day fcsts, increase in the atmospheric ensemble resolution (to 10 km) and the nudging of 6/18 members to AIFS MLWP model.
- In 2027 a minor upgrade to the ocean component via DA configuration (revised S length scale).

# Temperature and Salinity profile performance

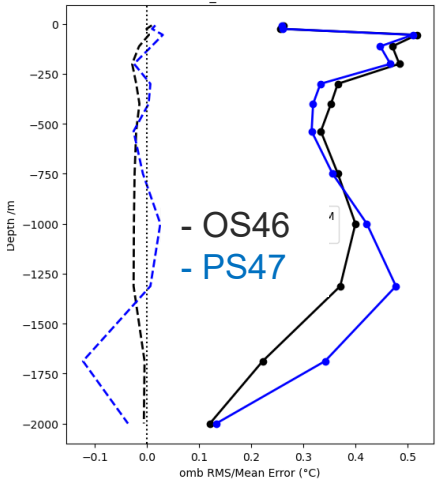
*Bias and RMSD for analysis temp vs Argo: 2026 change; left – Global, right – North Atlantic*

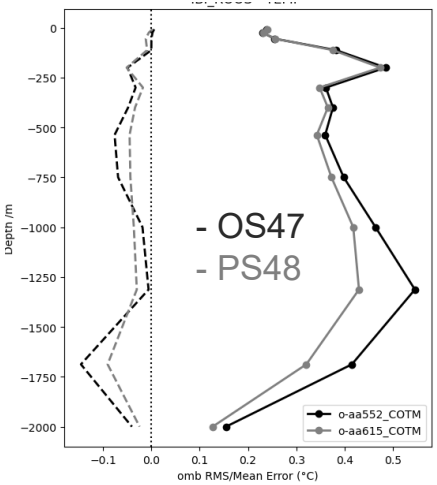






*Bias and RMSD for analysis temp vs Argo for Med Outflow; left – 2026 change, right – 2027 change*

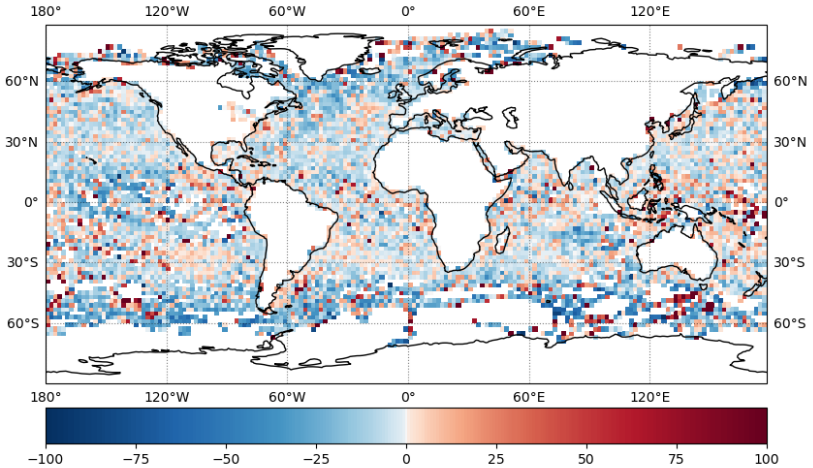


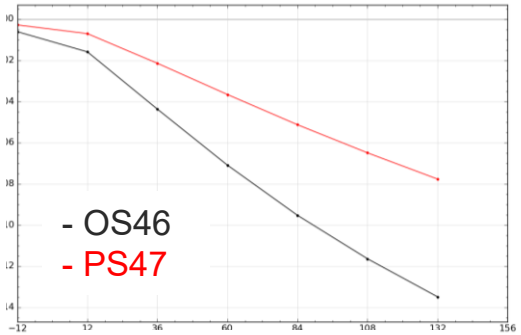

2026 package improves T-S profiles over majority of the globe, and global SLA (not shown)
2027 package addresses regional T degradations e.g. at >1000 m in Med outflow region
2027 package some regional S degradations persist

# SST and sea ice performance

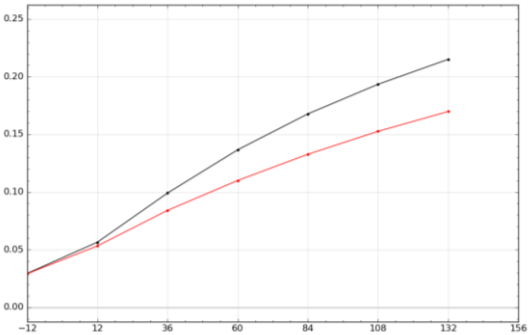
*% change in SST RMSD vs in-situ SST: 2026 change; blue shows improvement*




*Forecast leadtime vs sat SIC: 2026 change; left- mean diff, right- RMSD*




*Forecast leadtime*



*Forecast leadtime*

2026 package improves global SST
2026 package improved Arctic sea-ice concentration forecast (reduced over-melting) in summer
2026 Antarctic sea-ice concentrations are degraded

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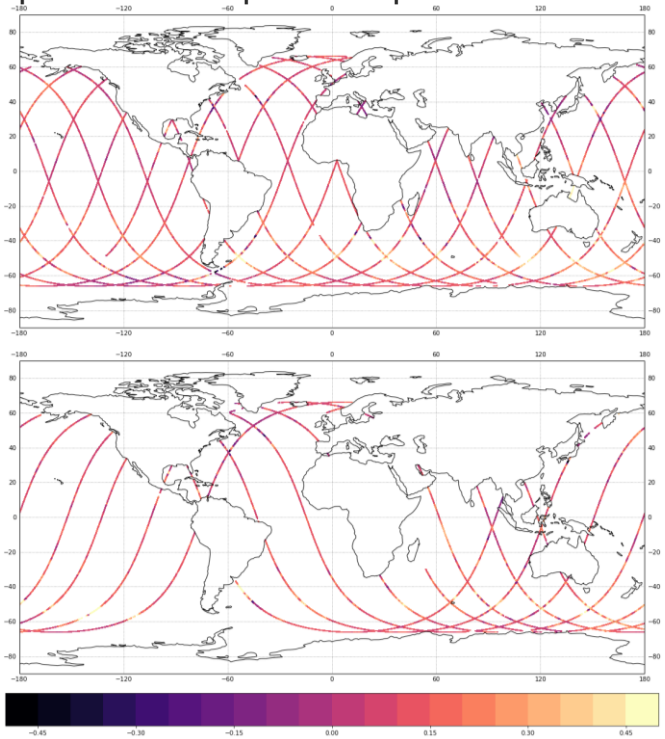
# Global Coupled: Future outlook

- NRT running and observation availability
- Coupled ocean ensemble initialisation
- Coupled DA
- Coupled eddy resolving ocean model
- AI for Global Coupled forecasting

# NRT running and observational availability issues.

- The coupled O-A system was designed to include catch-up analysis cycles to make use of late arriving ocean observations.
- These run more frequently and closer to near real-time (NRT) than the ocean-only systems run previously at the Met Office.
- For latest running cycle an observation needs to be available within ~12-18 hours to be assimilated.
- Sensitive to change in timeliness and frequency of delivery of observations e.g. CMEMS SLA product update in 2024. Now resolved ☺
- Issues using observations that require higher levels of processing (=> increased latency) e.g. SIT observations assimilated in ocean-only system in 2027 but not available for Global Coupled, SWOT WiSA.
- Explore options to make use of later arriving observations without significant redesign of system e.g. smoother

Sentinel-6A daily observation pre and post-CMEMS product update in 2024



# Towards coupled ocean ensemble system

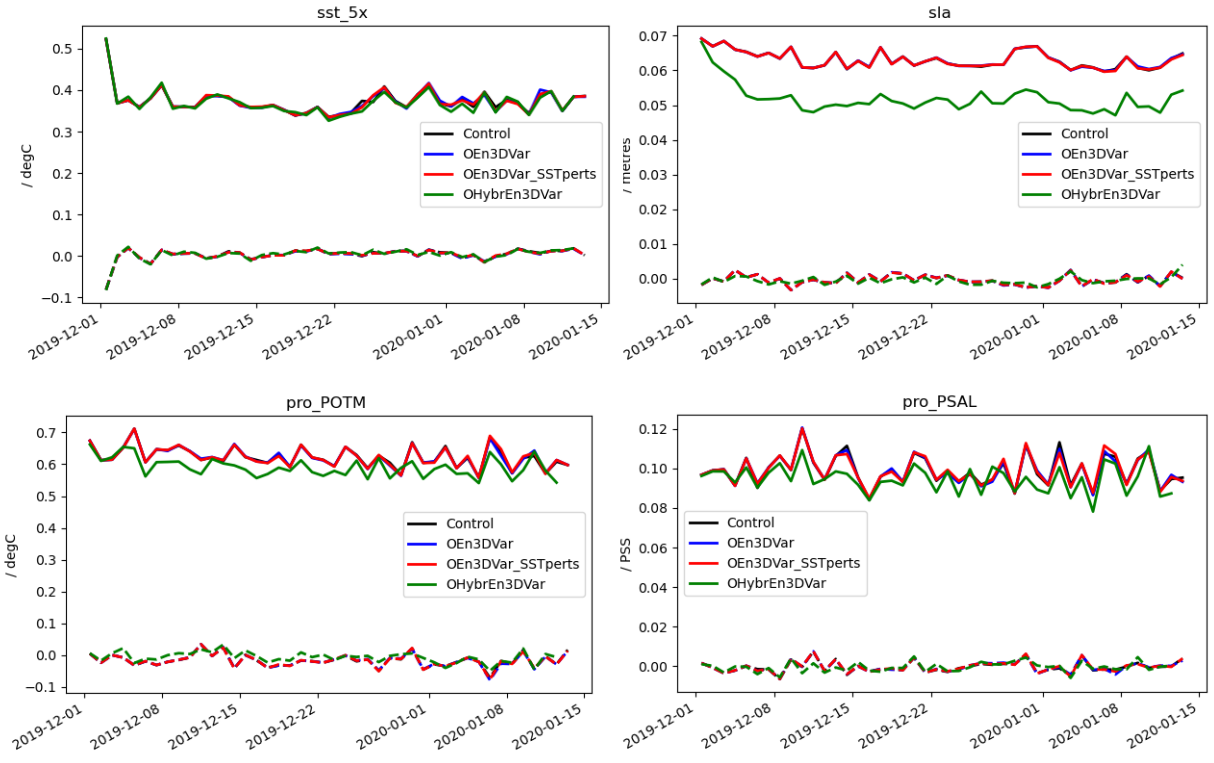
- In the Global O-A Coupled ensemble, the ocean component is currently initialised from a single deterministic analysis. The spread in the ocean ensemble is therefore very small. An artificial SST perturbation is applied to the atmosphere ensemble to account for this.
- Research carried out to implement a full ocean ensemble into the Global Coupled NWP system.
- Follows on from ocean-only ensemble system (developed within WCSSP India project) which includes observation and stochastic model perturbations. [Lea et al, 2022]

Dan Lea: Assessing the new Met Office high resolution global ocean ensemble hybrid-3DEnVar system (Thurs 11:50-12:10)

# Ocean ensemble performance

- The coupled ocean ensemble results are comparable to those for ocean-only ensemble system.
- The hybrid DA approach delivers improved sea surface height and profile statistics.

## Deterministic: SST, SSH, prof T, S innovations

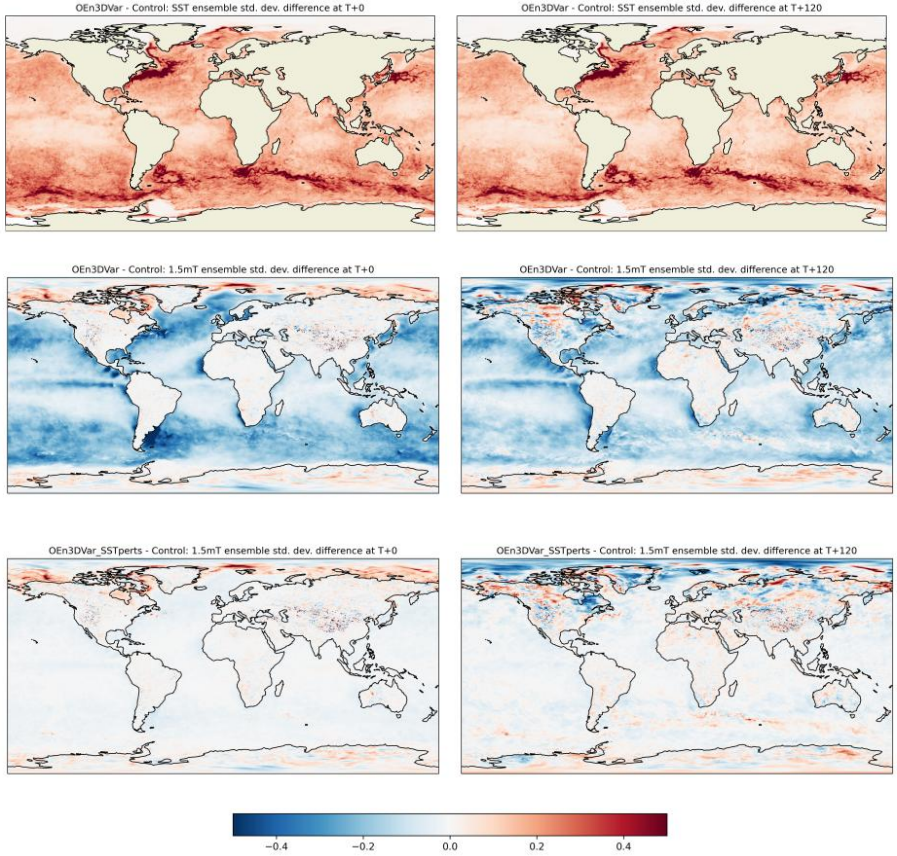


# SST and 1.5 m air T ensemble spread

Including the ocean ensemble allows a realistic ensemble spread to build up in SST

However reduced 1.5 m air T spread over the ocean using the ocean ensemble.

Regain the spread in 1.5 m T with SST perturbations added. **This need further investigation**

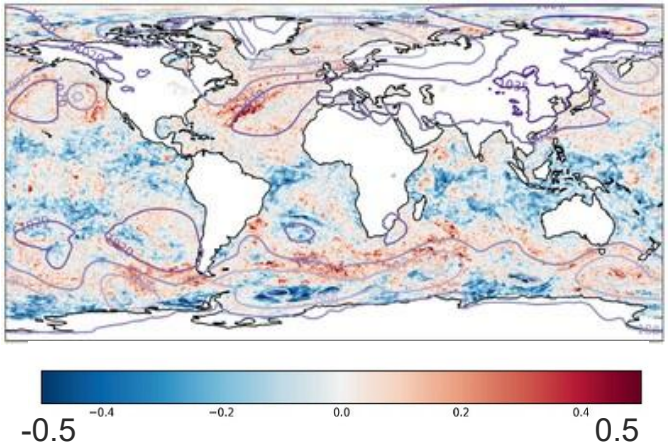



Daniel Lea

# Towards Coupled Data Assimilation

- Current 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 the Met Office global coupled ensemble system [Lea et al., 2023; Wright et al., 2024]
- Research into coupled observation operators – PhD with Univ. of Reading.

- R&D Pathway
  - Need to develop software infrastructure to be able to implement more strongly coupled DA methods.
  - JEDI is being implemented for atmospheric DA at the Met Office.
  - We are now 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.

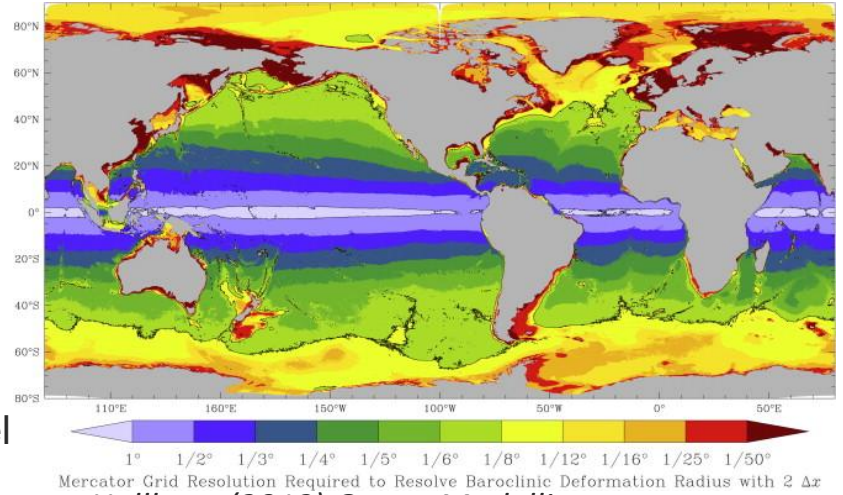



Cross-correlations between atmosphere wind-speed and SST 6-hr forecast errors on 5th Dec 2019.

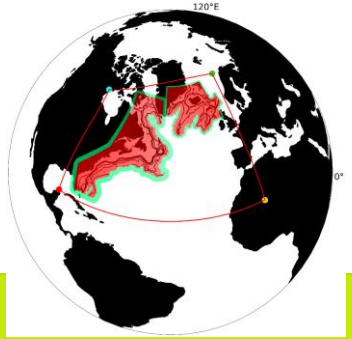
Sophia Moreton: Advancing ocean data assimilation towards a JEDI-based framework at the UK Met Office (Weds 12:25-12:45)

# Towards a coupled eddy resolving ocean model

- Eddy resolving systems improve energy budget from major currents and eddy rich regions.
- 1/12º resolution allows improved representation of coupled processes with comparable ocean and atmospheric resolutions.
- Over most of the global ocean 1/12º is sufficient but not on the shelf (eddy radius ~3km) or at high latitudes (require 1/25º or higher).
- Developing ORCA12+ ocean model: 1/12º parent model with 1/36º AGRIF zoom in North Atlantic. Use terrain following multi-envelope (ME) vertical coordinates in Nordic Seas OFV and Gulf Stream regions.
- GOSI10 model configuration will include ME vertical coordinates.
- Due to HPC availability/costs the year-on-year resolution increases in model resolutions will be difficult.

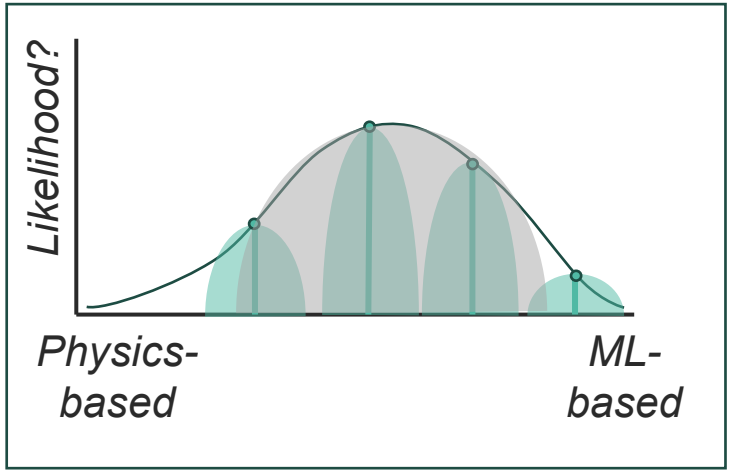


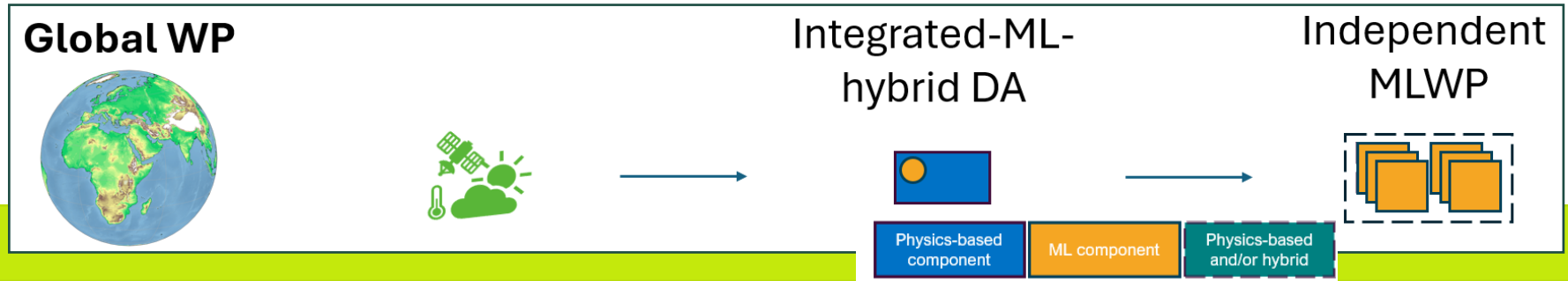

*Hallberg (2013) Ocean Modelling*
*https://doi.org/10.1016/j.ocemod.2013.08.007*



# AI for Global Coupled forecasting

- Met Office is taking a scenario-based approach to developing it MLWP capability.
- Systems highly likely to include ML elements so ocean components will need to adapt.
- One front-runner is a physical/hybrid Coupled DA analysis initialising a MLWP ensemble forecast.
- Currently also exploring emulation for ocean forecasting (initially SST via SprAI) and extend to 3D ocean



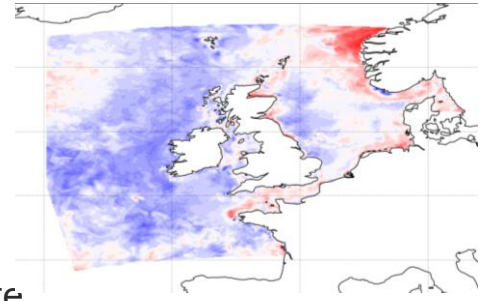



Met Office

# Questions

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# Northwest Shelf Ocean Forecast



**Our system**
NWS FOAM-AMM15 is a ~1.5km, 50 level NEMO 3D ocean model, assimilating satellite and in-situ temperature, salinity and sea level observations. **The model is two-way coupled with the NWS-Wave model.**
Provides lower boundary forcing for UK weather forecast
Daily forecasts are run to 7 days ahead.

**Published via:** Met Office Marine Data Service ftp, Copernicus Marine Service (forecasts from Nov 2025)

**Public task:** Regional ocean conditions for Marine Emergency Response and Met Office UK weather forecasts

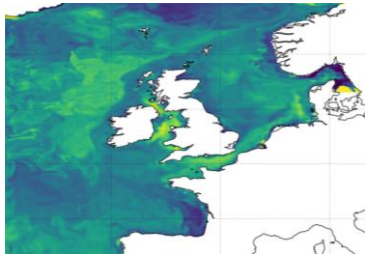
**Applications:** Assess and forecast regional seas currents and hydrography

## Additional use cases:

| System Output(s) | Motivation |
|---|---|
| Temperature | Sea-temperature forecasts for swimmers and beachgoers |
| Surface currents | Ship e-navigation, ECDIS charts |

# Northwest Shelf Marine Ecosystem Forecast

## Our system



NWS FOAM-AMM7 is a ~7km, 50 level NEMO 3D ocean model, which assimilates satellite and in-situ temperature, salinity, sea level and chlorophyll observations. **The model is one-way coupled with the ERSEM marine biogeochemistry model.**

Daily forecasts are run to 7 days ahead. Historical re-analysis in production.

**Published via:** Met Office Marine Data Service ftp, Copernicus Marine Service (forecasts from Nov 2025)

**Public task:** Marine in-water visibility forecasts

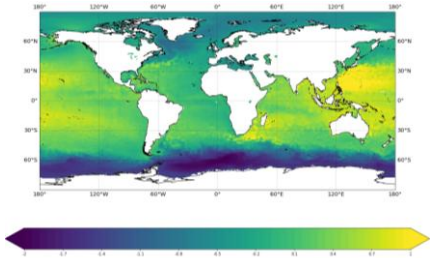
**Applications:** Assess and forecast regional seas marine stressors

## Additional use cases:

| System Output(s) | Motivation |
|---|---|
| Seabed Temperature | Managing flow for North Sea gas pipelines |
| Biogeochemistry | Site assessment for aquaculture |

# Global Ocean Forecast

## Our system



Global FOAM-ORCA12 is a 1/12 degree, 75 level NEMO 3D ocean and SI3 sea ice model, assimilating satellite and in-situ temperature, salinity, sea level and sea-ice observations.

Daily forecasts are run to 7 days ahead.

**Published via:** Not currently available

**Public task:** Lateral boundary conditions for Met Office NWS regional systems

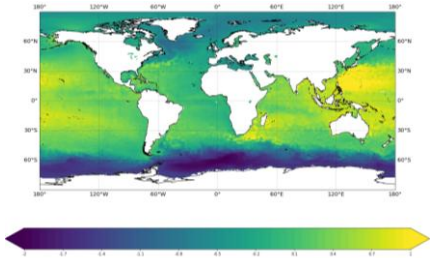
**Applications:** Assess and forecast open ocean/deep water currents, hydrography and sea-ice extent

## Additional use cases:

| System Output(s) | Motivation |
|---|---|
| Temperature, salinity profiles | Ocean sound speed for sub-surface navigation and sound channel identification |
| Surface currents | Ship routing |
| Surface currents | Search and Rescue |

# Global O-A Coupled Forecast

## Our system



Global FOAM-ORCA025 is a 0.25 degree, 75 level NEMO 3D ocean and SI3 sea ice model, assimilating satellite and in-situ temperature, salinity, sea level and sea-ice observations. **The model is two-way coupled with the Met Office global weather model.**

Twice-daily forecasts are run to 7 days ahead. Historical re-analysis in production.

**Published via:** Met Office Marine Data Service ftp, ASDI

**Public task:** Global ocean conditions for Met Office coupled weather and seasonal forecasts

**Applications:** Assess and forecast open ocean/deep water currents, hydrography and sea-ice extent

## Additional use cases:

| System Output(s) | Motivation |
|---|---|
| Temperature, salinity profiles | Ocean sound speed for sub-surface navigation and sound channel identification |
| Surface currents | Ship routing |
| Surface currents | Search and Rescue |