Generating ocean initial condition for coupled forecasts through nudged NEMO experiments


European Centre for Medium-Range Weather Forecasts
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Outline and stakes

- **ECMWF operational systems:**
  - currently use **coupled ocean** (NEMO3.4, ¼°) - **sea ice** (LIM2) - **atmosphere** (IFS 9, 18, 36km) models, with initial conditions relying on **data assimilation**.
  - have undergone substantial research effort carried to move towards **NEMO4.0 with SI3 sea-ice model**;
  - including adapting the **ocean data assimilation** to the new model versions.

*Top: desired procedure for generating ocean initial conditions.*
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  – have undergone substantial research effort carried to move towards **NEMO v4.0 with SI3 sea-ice model**;
  
  – Including adapting the **ocean data assimilation** procedure to the new model versions.

• **Destination Earth initiative** aims at investigating the benefits of pushing all model components to higher resolutions.
  
  – The ocean’s influence on **weather prediction** mostly lies in its **initial conditions**.
  
  – Need for an affordable, fast method for **high-resolution ocean initialisation**.

*Top: desired procedure for generating ocean initial conditions.*
Nudging yields consistent results across model versions

- **Sanity check** on transposing to NEMO4-SI3 at same resolution (1/4°).

- Performance looks *roughly similar* in both experiments, still displaying features.
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Mean temp. bias (0-300m, 2000-2020)

- **Sanity check** on transposing to NEMO4-SI3 at same resolution (1/4°).
- Performance looks **roughly similar** in both experiments, still displaying features.
- Significantly lower **sea-ice volume** SI3 (better in winter, degraded in summer/fall).

Above: average 2012 – 2020 November sea-ice volume biases in free NEMO3.4 (top) and NEMO4.0 (bottom).
Sea-ice data assimilation deals with concentration only and performs well.

In SI3, each grid box contains five-fold sea-ice thermodynamical information.

The thickness is not fully orthogonal to the concentration’s anymore.
Hybrid sea-ice concentration assimilation, including thickness nudging

- Arctic sea-ice thickness nudging performed **on top of sea-ice concentration**.

- **CS2SMOS** (AWI’s merged Cryosat-SMOS product) used in prototypes.

- **Gridbox sea-ice concentration** information unaltered by nudging procedure, but **subgrid-scale distribution** skewed towards more realistic state.
Impact of hybrid sea-ice initialisation method on coupled forecasts: seasonal case

• As expected, memory from different initial conditions slowly decreases.
• But still visible throughout the integration length (6 months).
Perspectives

- **Proof of concept for obtaining realistic ocean initial conditions** at reasonable costs.

- Adaptation of sea-ice nudging to the **multicategory framework** now possible.

- Significant memory of sea-ice initial conditions **still at seasonal timescales**.

- Workflow now adapted to eORCA12 (1/12º) for **Extreme Digital Twin** ocean initial conditions within DestinE.

- **Trade-off** to be established between eddy-rich small scales vs. fitting observation-informed, potentially coarser products.

*Right: sea-surface current speeds in the Gulf Stream area in free (left) and nudged (right) experiments at both 1/4º (top) and 1/12º (bottom).*
Impact of hybrid sea-ice initialisation method on seasonal coupled forecasts

- Less (but still) biased initial conditions **spatial patterns persist up to several months**.
- Less **lead-time dependence** with new ice initialisation.
- Occasional impact (threshold effect) on **sea-ice concentrations**, including in summer.
- Other ocean signals (mid-latitude temp. and salinity, transport…) **marginally affected**.

Left: seasonal forecasts verifying in November 2015 initialized with old and new ice initial conditions (top and bottom rows) from different initialisation times (June to September, columns).