Generating ocean initial condition for coupled forecasts through nudged NEMO experiments

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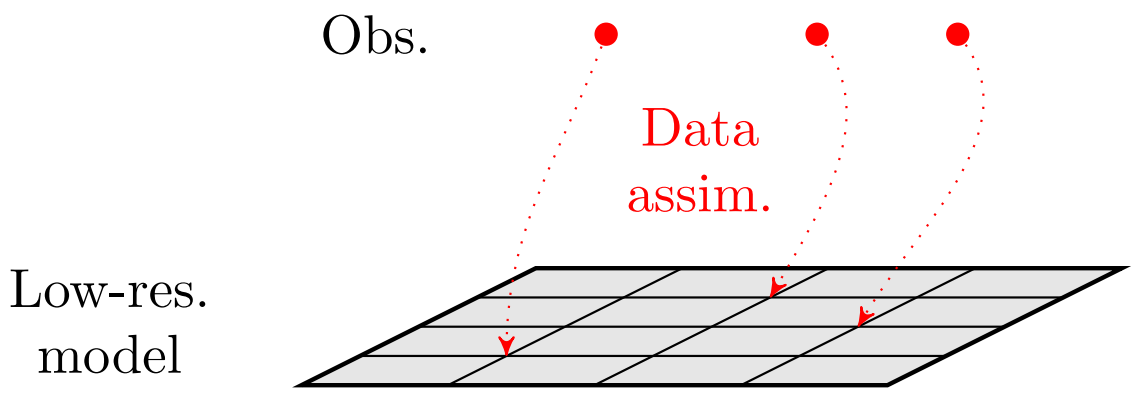
ECMWF

Outline and stakes



- ECMWF **operational systems**:
  - currently use **coupled ocean** (NEMO3.4, ¼º) – **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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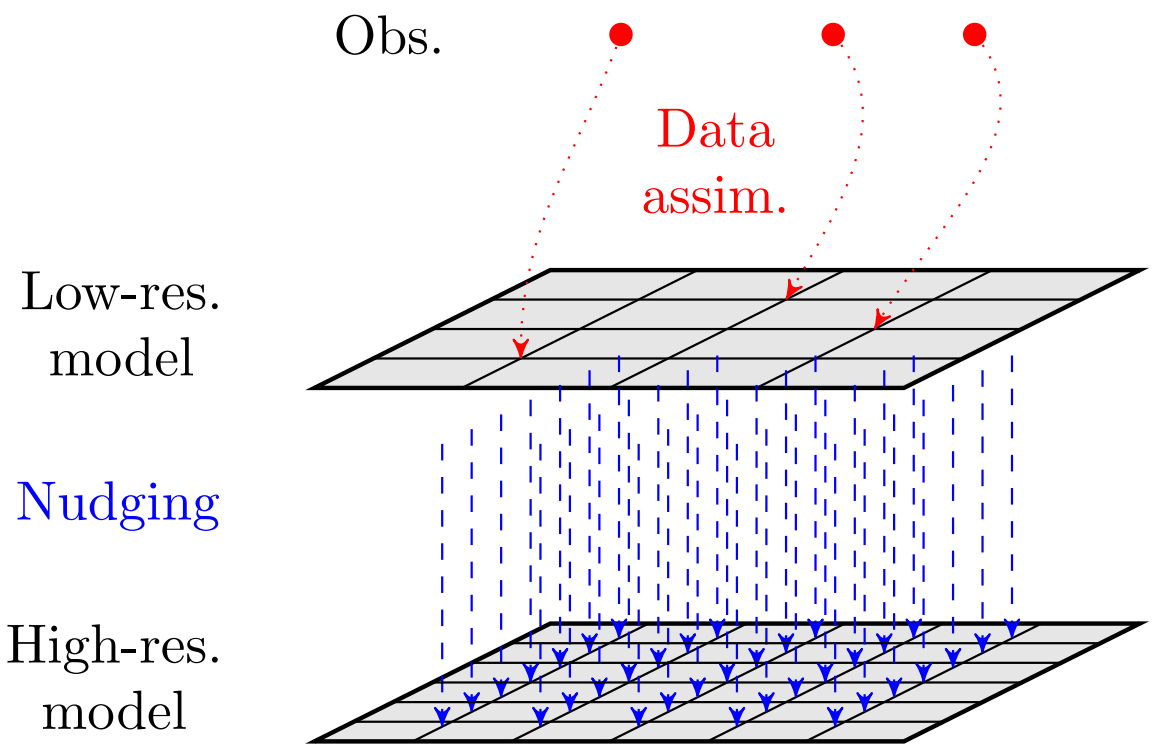

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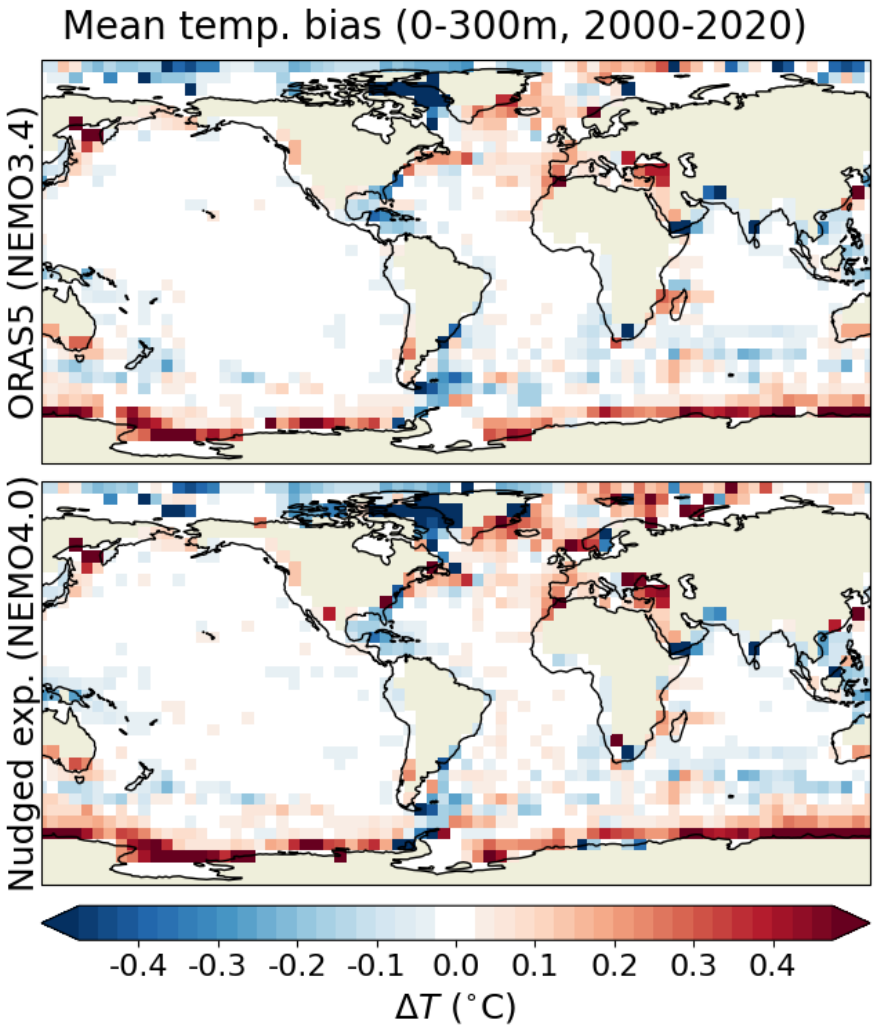
  - have undergone substantial research effort carried to move towards **NEMO v4.0 with SI3 sea-ice model;**
  - Including adapting the **ocean data assimilation** procedure to the new model versions.
- **Destination Earth initiative** aims at investigating the benefits of pushing all model components 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**.

Nudging yields consistent results across model versions



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

- Performance looks ***roughly*** **similar** in both experiments, still displaying features.

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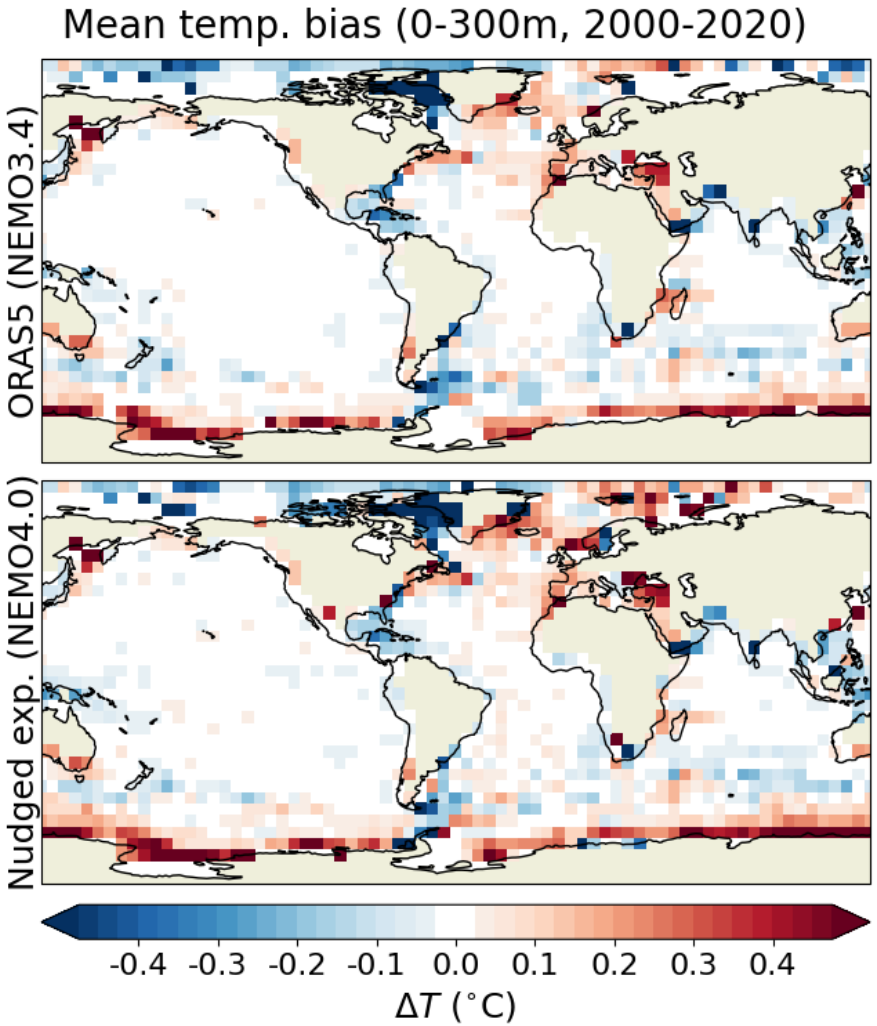
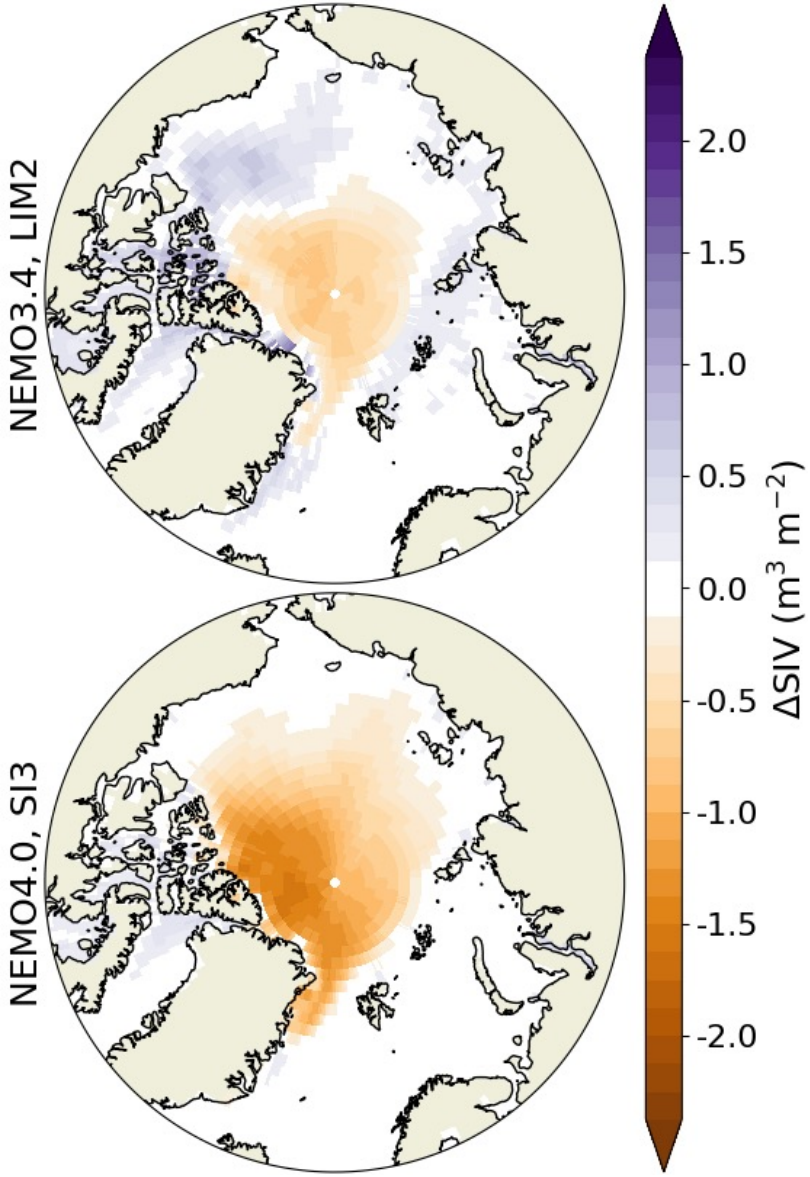
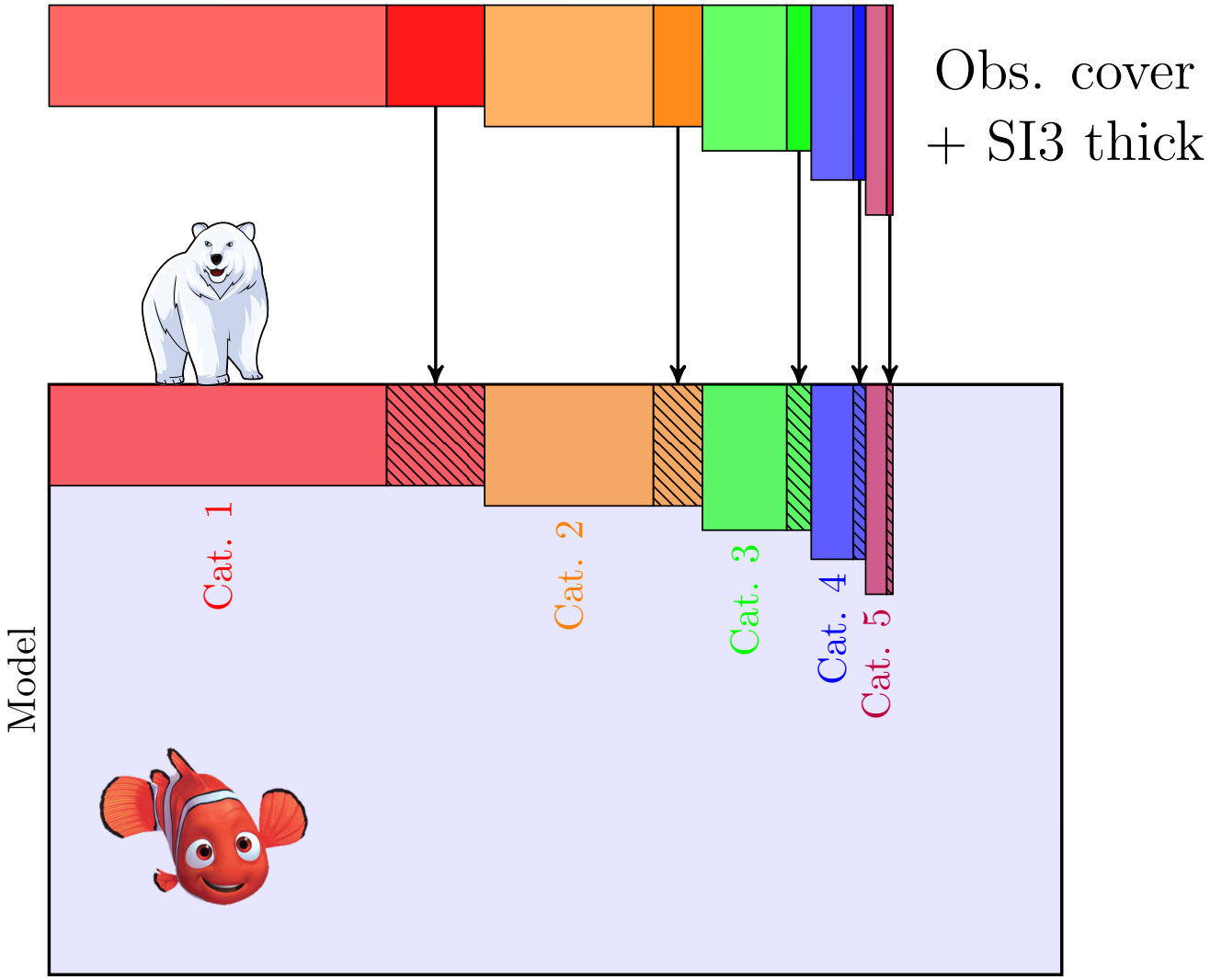


- **Sanity check** on transposing to NEMO4-SI3 at same resolution (1/4º).
- Performance looks ***roughly* similar** in both experiments, still displaying features.
- Significantly lower **sea-ice volume** SI3 (better in winter, degraded in summer/fall).



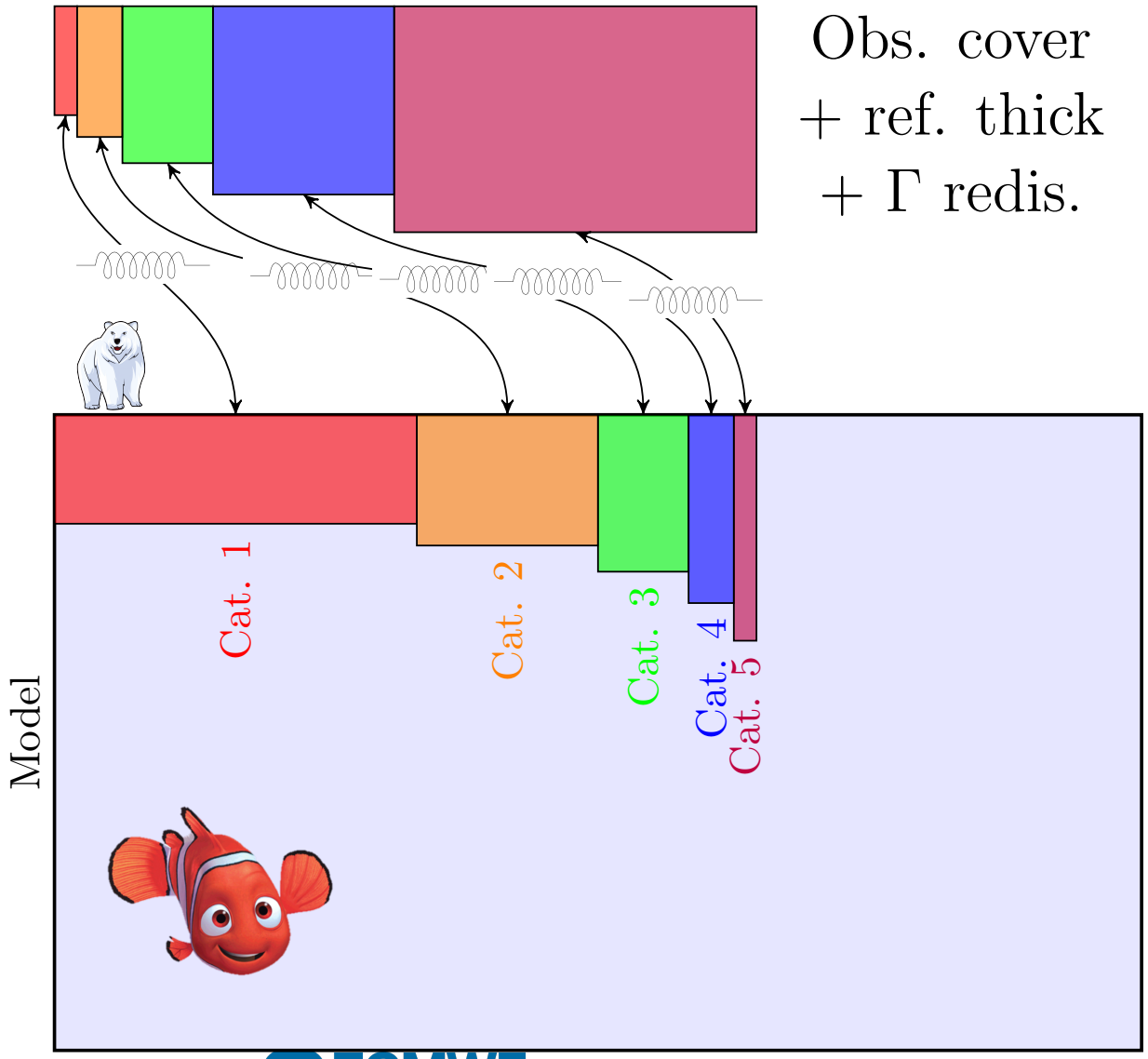
Above: average 2012 – 2020 November sea-ice volume biases in free NEMO3.4 (top) and NEMO4.0 (bottom).

Sea-ice assimilation in the multicategory SI3 model



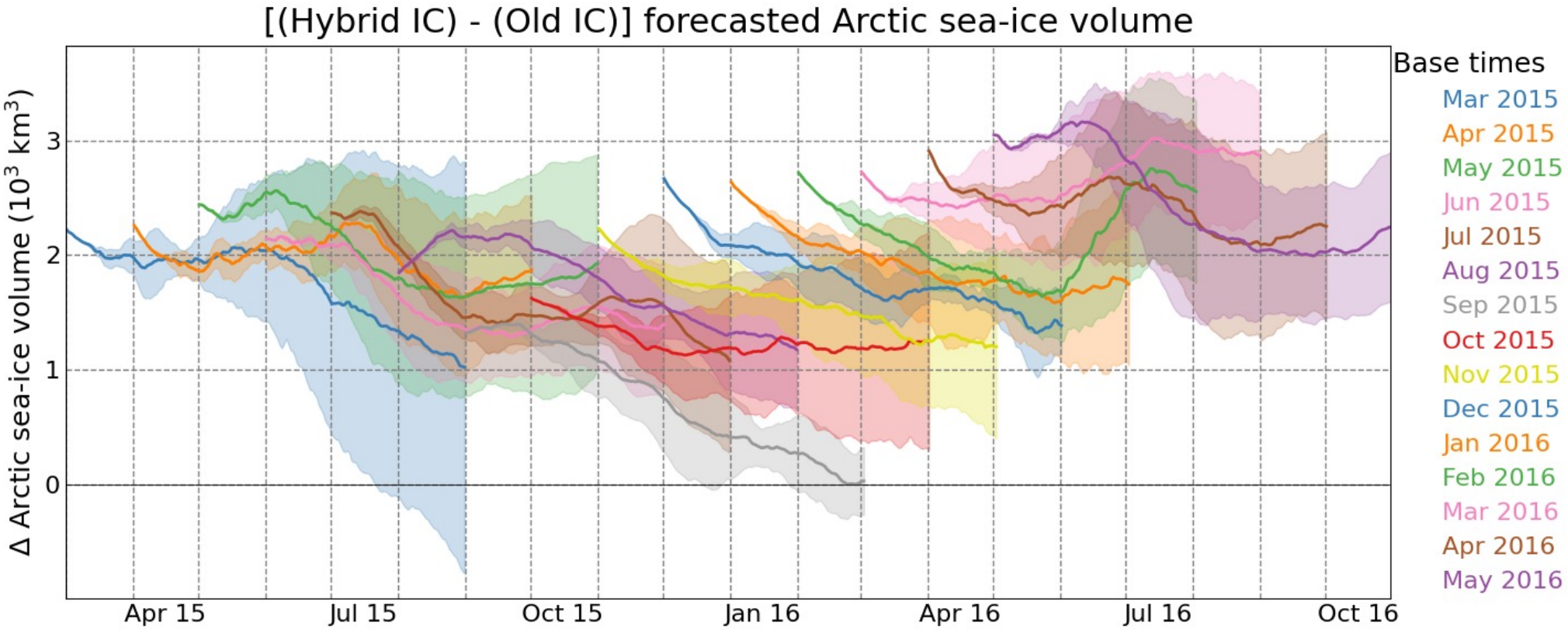
- Sea-ice data assimilation deals with **concentration only** and performs well.
- In SI3, each grid box contains **five-fold** sea-ice thermodynamical information.
- The thickness is not *fully* **orthogonal** to the concentration's anymore.

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

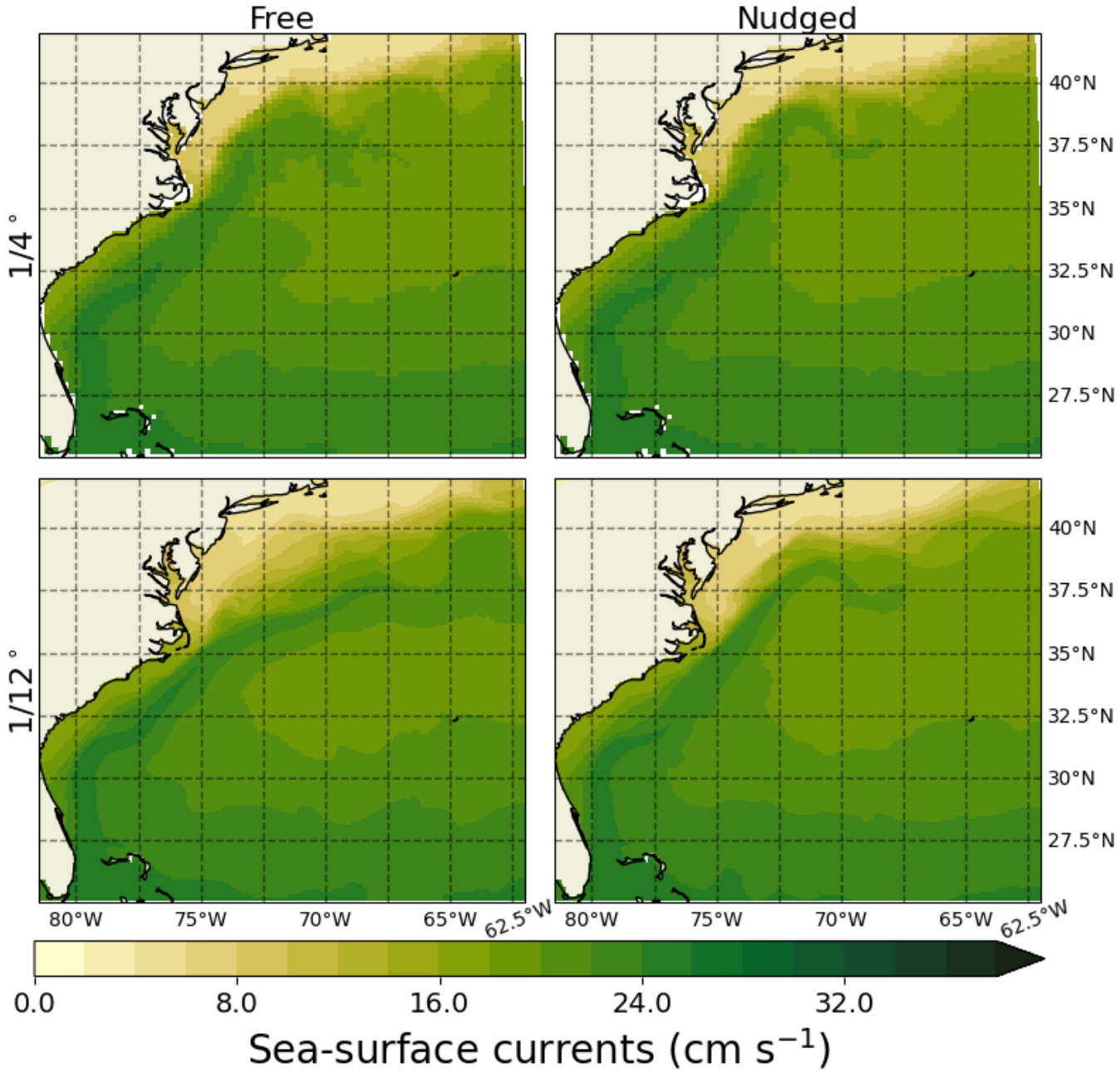


Left: Differences in total Arctic sea-ice volume in coupled six-month seasonal forecasts initialised with hybrid or old sea-ice initial conditions (hybrid-old shown) at different base times (5-member ensemble means and std shown).

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

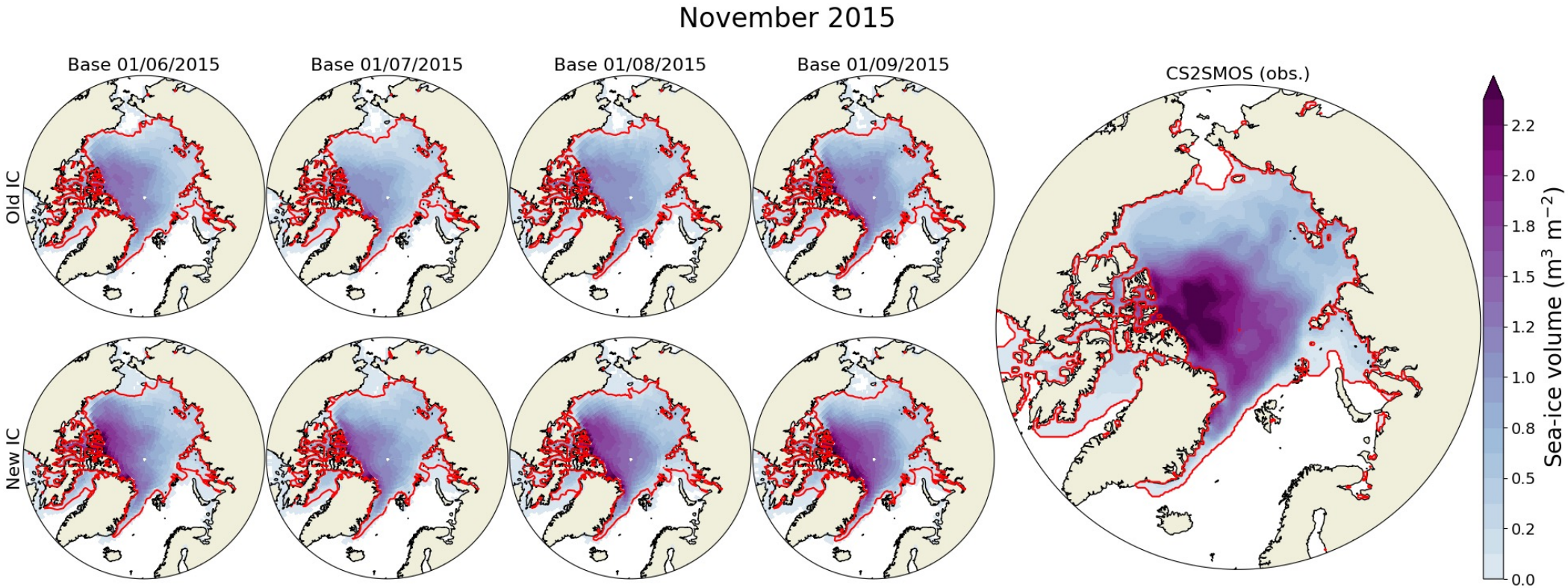
Perspectives

- 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



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)

- 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**.