SYMPOSIUM OP'24 — ADVANCING OCEAN PREDICTION SCIENCE FOR SOCIETAL BENEFITS

Sea ice thickness assimilation impacts on the Met Office's coupled NWP short-range forecasts

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Introduction

In the face of substantial reductions in both Arctic sea ice extent and thickness in the past few decades, there is an increasing need for accurate sea ice predictions covering the time-scales of days, seasons and beyond. Therefore, we assess here the impacts on the short-range forecasts due to the additional assimilation of derived **Arctic sea-ice thickness** (SIT) from CryoSat-2 and SMOS satellites into the UK Met Office's ocean-sea ice-land-atmosphere coupled system.

Met Office fully coupled system

The coupled model combines the Met Office Unified Model atmosphere (MetUM) and the Joint U.K. Land Environment Simulator land surface model (JULES) coupled to the Nucleus for European Modelling of the Ocean Model (NEMO) and the Los Alamos sea ice model (CICE). These model components are coupled at hourly intervals. The initial conditions of the coupled model are corrected using a weakly coupled data assimilation (DA) system, which uses two separate 6-h window DA schemes: a 4DVAR system for the atmosphere and a 3DVAR-first-guess-at-appropriate-time system for the ocean and sea ice. Detailed information can be found in Lea et al. (2015).

Model	Horizontal resolution	Levels/Layers/Categories
MetUM	Approximately 17 km (operational deterministic resolution is ~10km)	85 vertical levels (50 levels below 18 km and 35 levels above it)
JULES		Four soil layers with each land point subdivided into five types of vegetation and four non-vegetated surface types
NEMO	ORCA tripolar grid approximately at 25 km	75 vertical levels with approximately 1-m resolution in the top 10 m of the ocean
CICE		Five ice thickness categories

Table 1: Configurations of the model components in the fully coupled system.

SIT assimilation and experiment setup

CryoSat-2 along-track SITs, which are converted from freeboard measurements, and a daily, gridded SMOS SIT product are used in the assimilation (see Fig. 1). CryoSat-2 mission was primarily designed to measure the thickness of perennial, thick ice, since the retrieval method can have large uncertainties over thin ice regions. SMOS provides measurements of brightness temperatures at microwave frequencies, which can be used to infer SITs over areas of thin ice with relatively low uncertainties. Detailed information about the SIT assimilation can be found in Mignac et al. (2022).

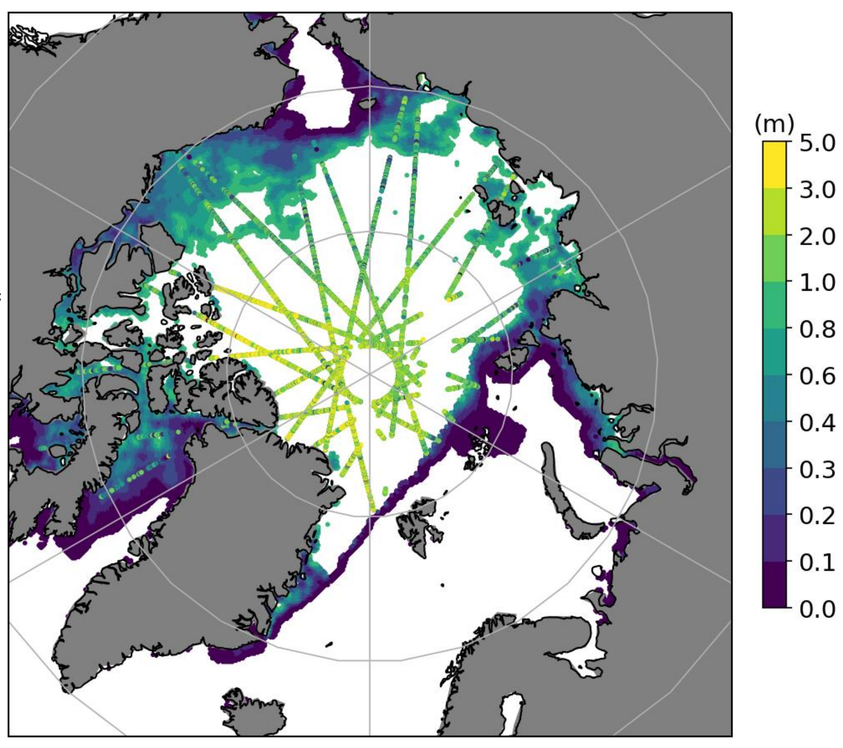

Figure 1: CryoSat-2 and SMOS SITs within a 24-h window.

Runs	Assimilation configuration	Initial condition	Period
CTL	**Ocean:** T/S profiles, in situ and satellite SLA & SST **Sea ice:** sea-ice concentration (SIC) **Atmosphere:** satellite and in situ temperature, wind, humidity, pressure and direct radiances	From operational system	Dec 2019 – Feb 2020
NOICE-DA	No SIC assimilation relative to CTL	From CTL	
SIT-DA	Additional SIT assimilation with respect to CTL		

Table 2: Experiments to test the impact of sea-ice DA on the fully coupled system.

Summary of results

- SIT-DA (NOICE-DA) consistently improves (degrades) the Arctic SIT and SIC (Figs. 3 & 4).
- SIT-DA (NOICE-DA) makes the ice thinner (thicker) near the ice edge (Fig. 2c), which results in an overall warming (cooling) of the Arctic (Fig. 2i), leading to a bias reduction (increase) in the air temperature forecasts of not only the Arctic, but (to a lesser extent) also the North Atlantic region (Fig. 5). There is a small overall improvement in North Atlantic SST RMSD (Fig. 4c).
- Although positive for air temperatures and SST, the additional SIT assimilation impact on the fully coupled system is restricted to near the surface and is less clear for other variables in the short-range atmospheric forecasts.

References

1. Lea et al. (2015) Assessing a new coupled data assimilation system based on the Met Office coupled atmosphere–land–ocean–sea ice model. *Monthly Weather Review*, 143, 4678–4694.
2. Mignac et al. (2022) Improving the Met Office's Forecast Ocean Assimilation Model (FOAM) with the assimilation of satellite-derived sea-ice thickness data from CryoSat-2 and SMOS in the Arctic. *Quarterly Journal of the Royal Meteorological Society*, 148(744), 1144–1167.
3. Ricker et al. (2017) A weekly Arctic sea-ice thickness data record from merged CryoSat-2 and SMOS satellite data. *Cryosphere*, 11, 1607–1623.

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General impacts

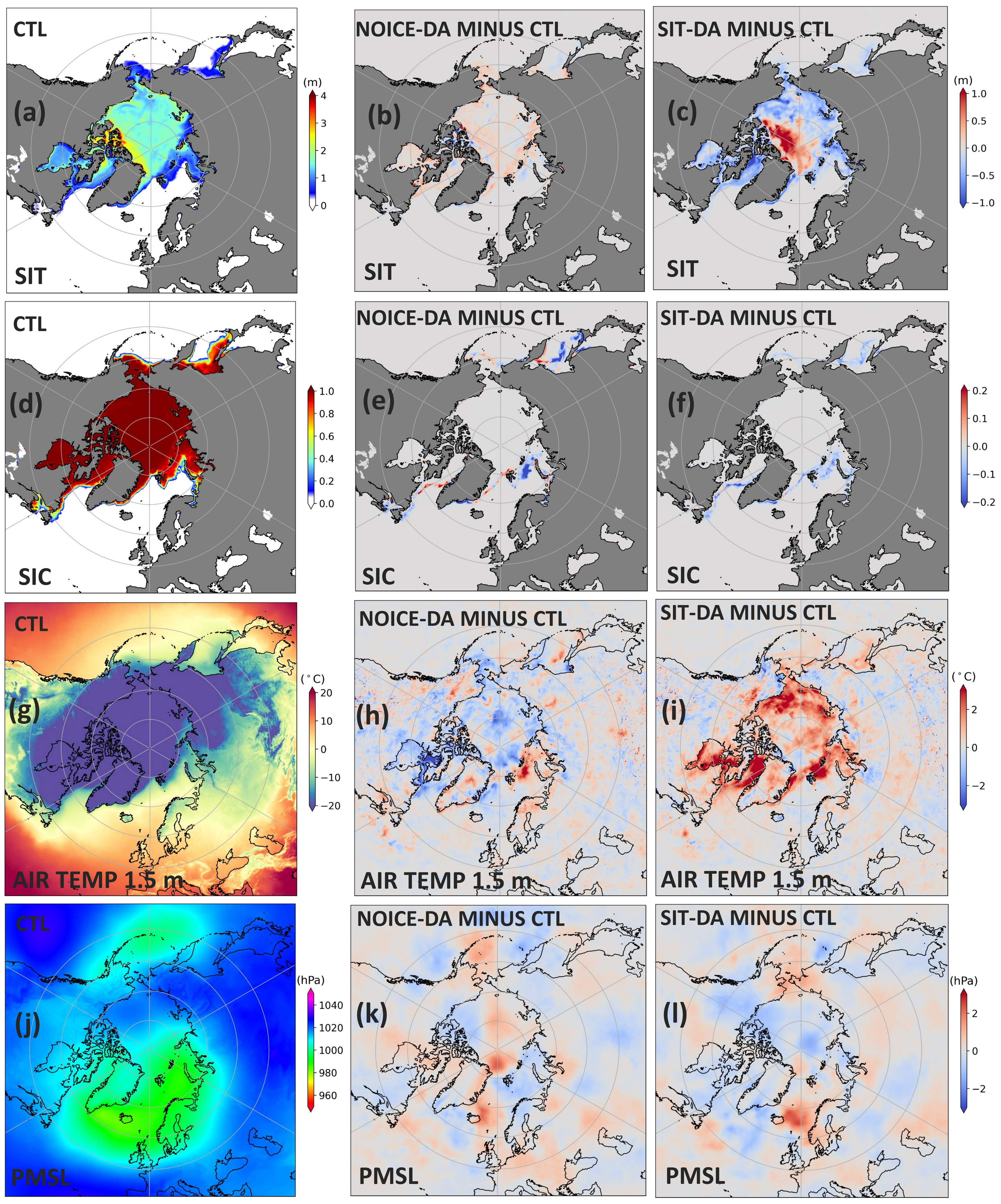


Figure 2: 5-day forecast CTL fields and 5-day forecast differences of NOICE-DA minus CTL and SIT-DA minus CTL for sea ice thickness (a, b, c), sea ice concentration (d, e, f), air temperature at 1.5 m (g, h, i) and pressure at mean sea level (j, k, l) for February 2020, respectively.

Sea-ice and ocean forecast improvements

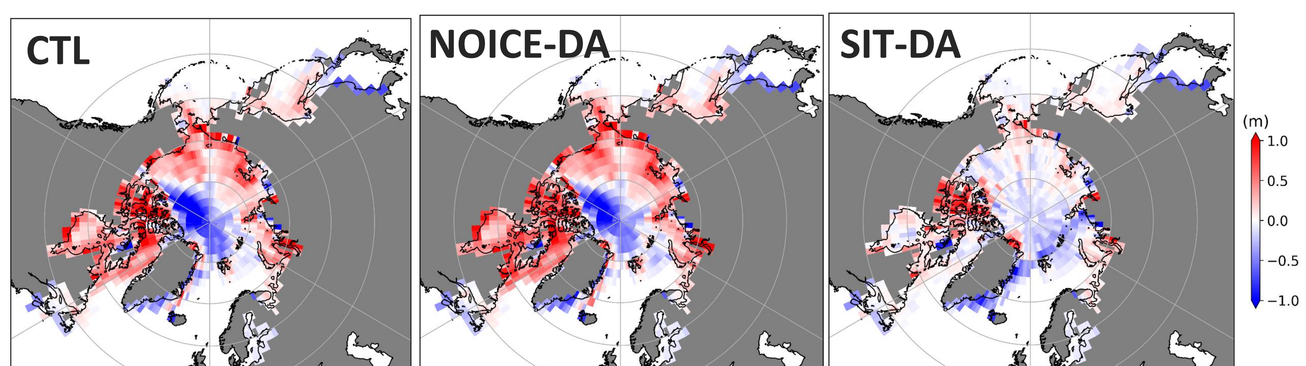


Figure 3: SIT mean difference of the 5-day forecasts minus the objective analysis from Ricker et al. (2017) for February 2020.

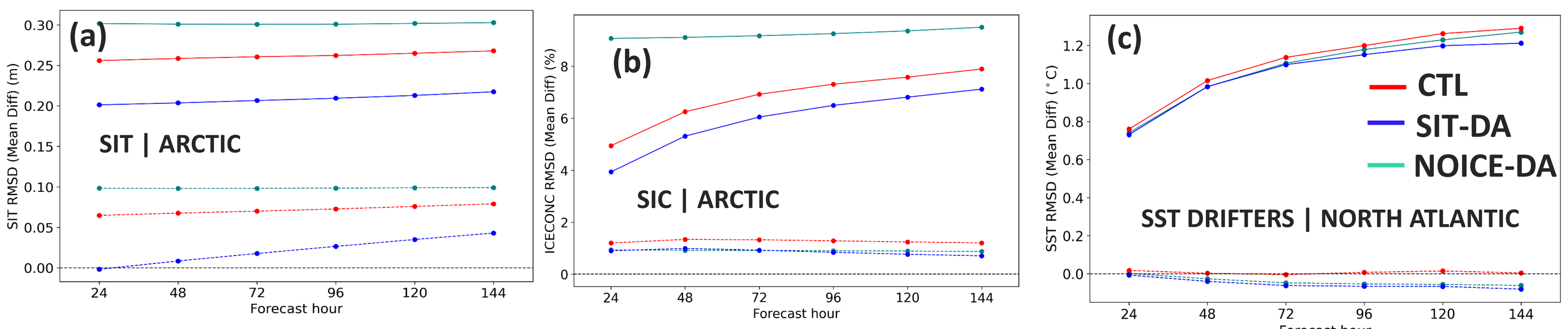
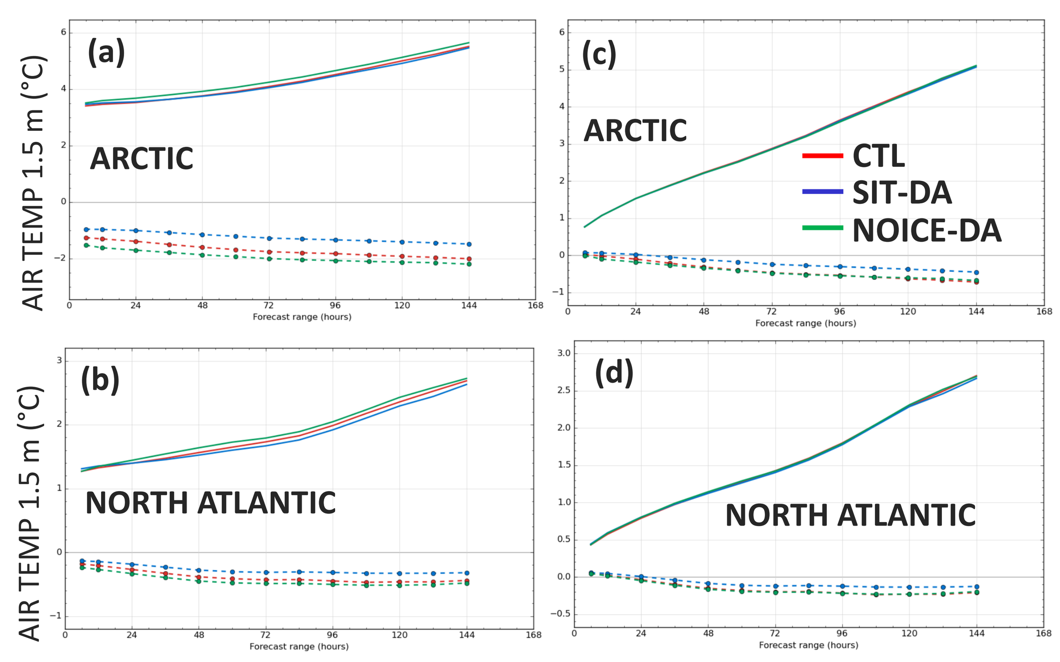


Figure 4: RMSD (solid) and mean difference (dashed) for each forecast lead time with respect to (a) the SIT analysis from Ricker et al. (2017), (b) OSISAF SIC and (c) SST drifters.

Atmospheric forecast improvements



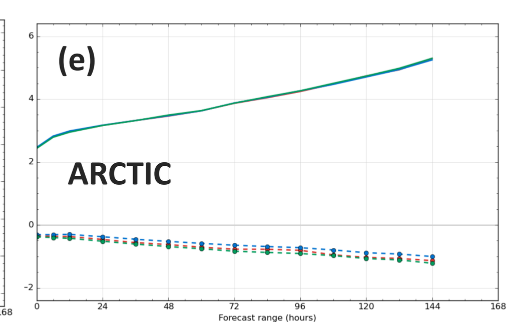


Figure 5: RMSD (solid) and mean difference (dashed) of air temperature at 1.5m for each forecast lead time with respect to (a, b) the ECMWF analysis, (c, d) the analysis of each experiment and (e) ground stations.