SPECIAL PROJECT PROGRESS REPORT

All the following mandatory information needs to be provided. The length should *reflect the complexity and duration* of the project.

Reporting year	……2024…………………………………………………
Project Title:	……Improving the ORAS5 Global Ocean Reanalysis using a Smoother Algorithm ………………………………………………………… …………………………………………………………
Computer Project Account:	………spgbdong……………………………………
Principal Investigator(s):	………Bo Dong, Keith Haines…………………… ………………………………………………………………
Affiliation:	………University of Reading
Name of ECMWF scientist(s) collaborating to the project (if applicable)	…… Hao Zuo ………………………………………………………………
Start date of the project:	………1/1/2023……………………………
Expected end date:	………31/12/2025………………

Computer resources allocated/used for the current year and the previous one

(if applicable)
Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	N/A	N/A	200,000	2,007
Data storage capacity	(Gbytes)	N/A	N/A	2.5T	2.5T

Summary of project objectives (10 lines max)

We have developed a reanalysis post-processing smoothing method (DHM smoother, Dong et al. 2021; 2023), which makes use of historically stored increment data to produce a more physically plausible time-evolving ocean state, with smoother temporal adjustments towards the available observations. We have tested this new method in the Lorenz 1963 model, as well as the Met Office FOAM ocean analysis. Both systems show that the errors have been reduced effectively against independent data (Dong et al. 2021). In the work proposed here we will explore how the smoother works when longer assimilation time windows are being used as in the ECMWF ORAS5 system. We also hope to gain from the improved treatment of bias that has been applied in ORAS5 which should allow the smoothing timescales in the subsurface ocean to be extended for longer periods than we have used before.

Summary of problems encountered (10 lines max)

None. We have run the smoother algorithm on temperature and salinity fields for the full year 2019 on the HPC.

Summary of plans for the continuation of the project (10 lines max)

For project year 3, we plan to run error diagnostics on smoothed temperature and salinity fields, and compare it's performance with the ORAS5 analysis fields and the new generation reanalysis ORAP6. We also plan to make closer comparisons with observational data set including altimeter data which have been given very little weight in the ORAS5 product, and also with independent datasets including drifter data eg from iQuam, https://www.star.nesdis.noaa.gov/socd/sst/iquam/?tab=0&dateinput_year=2024&dateinput_month=07&dayofmoninput_day=21&dateinput_hour=00&dayofmon=monthly&qcrefsst=_qcrey&qcrefsst=_qccmc&outlier=qced#qmap

List of publications/reports from the project with complete references

Dong, B., Bannister, R., Chen, Y., Fowler, A., and Haines, K. (2023): Simplified Kalman smoother and ensemble Kalman smoother for improving reanalyses, *Geoscientific Model Development*, https://doi.org/10.5194/gmd-16-4233-2023

Haines, K. B. Dong, Y. Chen, R. Bannister, A. Fowler (2023): Simplified Kalman smoother and ensemble Kalman smoother for improving Earth system reanalyses. *AGU fall meeting 2023*, NG31B-0754

Dong, B., K. Haines, Y. Chen, R. Bannister, A. Fowler (2024): Simplified Kalman smoother and ensemble Kalman smoother for improving Earth system reanalyses. *6th WCRP International conference on Reanalysis*

Summary of results

We applied the smoother algorithm on daily T and S fields, using a selection of different decay timescales - 10, 15, 30, 45 and 60 days. This represents the e-folding time over which future increments are projected into additional smoothing increments. Generally the longer the timescale, the larger the smoothing increments become as more data are incorporated. Figures 1 and 2 show side by side comparisons of 10-day decay smoother increments and 5-day analysis increments. We notice that the analysis increments are small in the ORAS5 reanalysis, relative to what we have seen before in FOAM, probably due to fairly low weighting being applied to the observations. The smoother increments are of a similar amplitude to the original analysis increments but are more widespread spatially as a result of back-propagation and accumulation of the future analysis increments. Longer decay timescale smoothing increments are presented in supplementary figures S1 and S2. Judging the best decay timescale for the smoother requires some external metrics and this will be examined in further work this year.

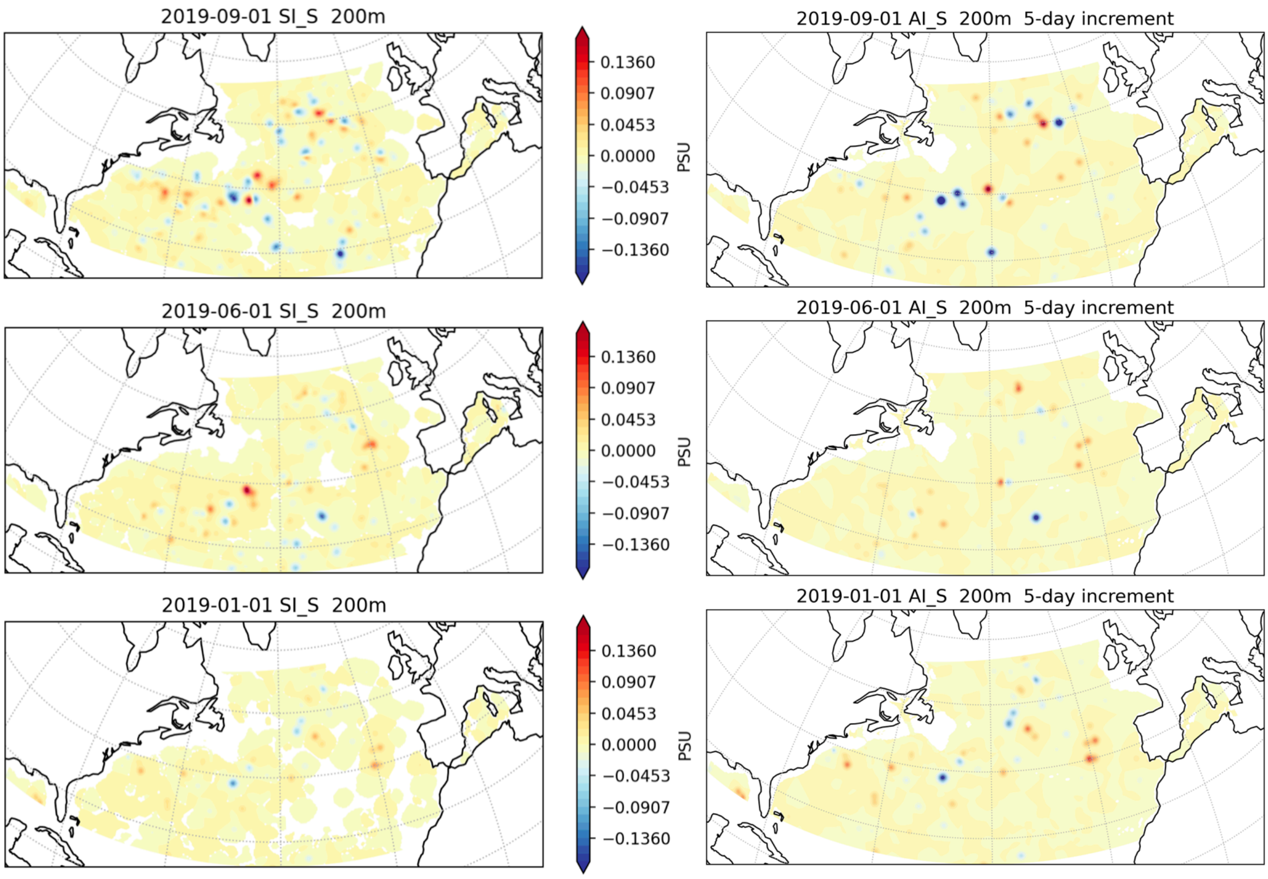

Fig. 1. Smoother increments (left) and analysis increments (right) in 200m salinity field for selected days in 2019. The smoother increments field is from the 10-day decay smoothing.

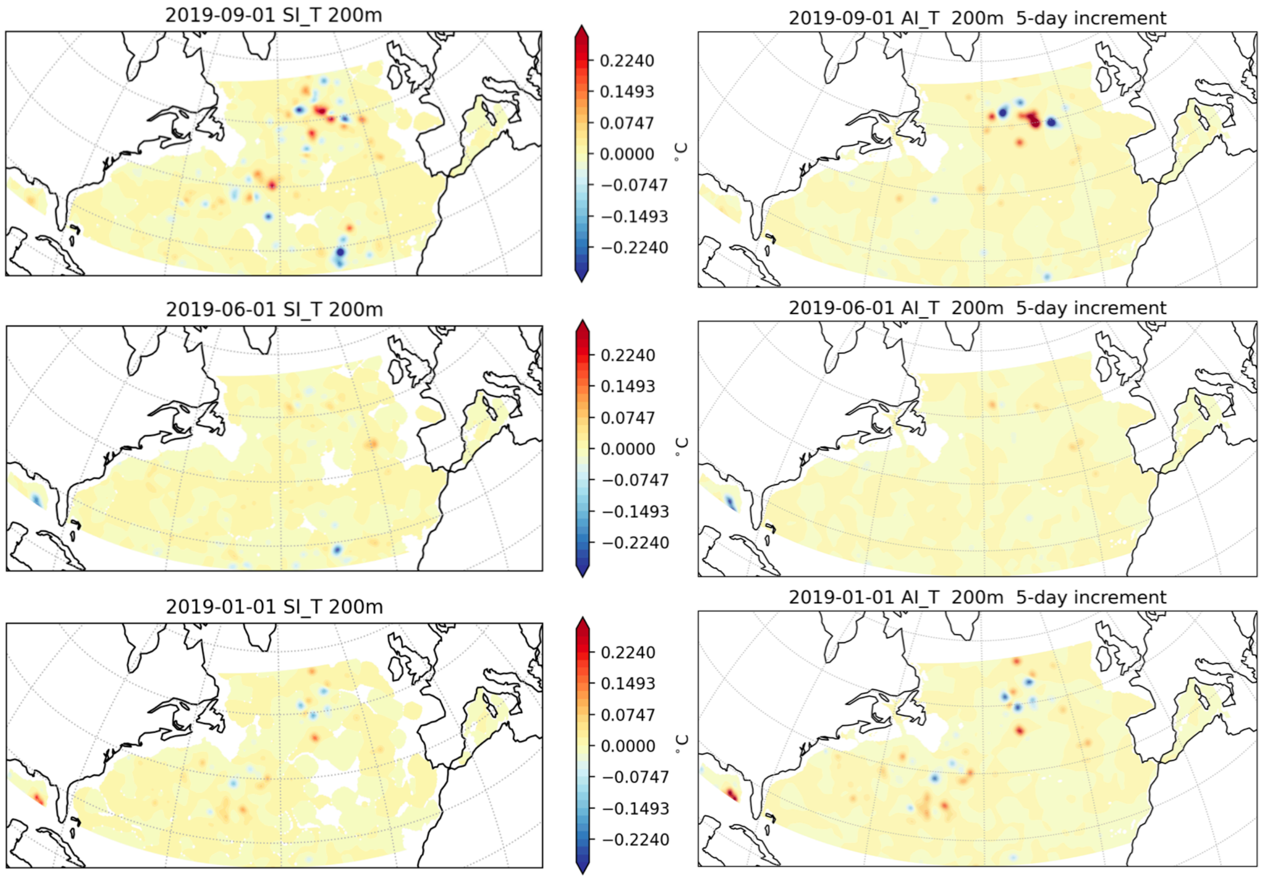

Fig. 2. Same as Fig.1 but for temperature field.

Similar to Dong et al. (2021), we examined the OHC and OSC temporal variability over selected regions in the North Atlantic, including a section of Gulf Stream off the US east coast, and a section of the overturning circulation in the northern central North Atlantic (Fig.3)

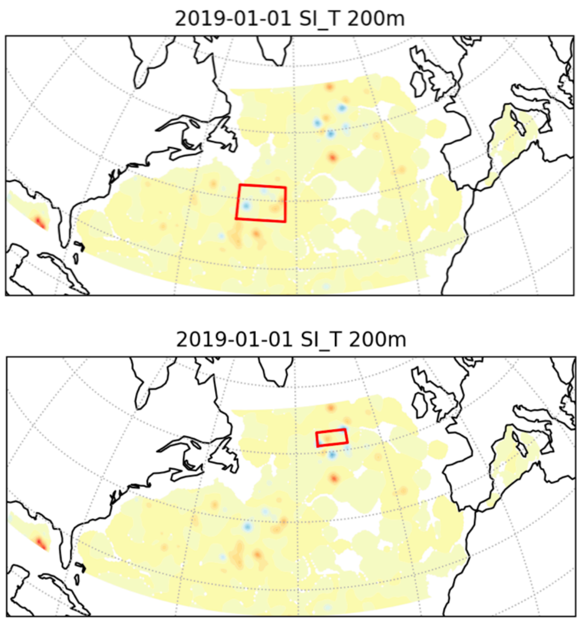

Fig. 3. Red box regions showing where OHC time series are calculated

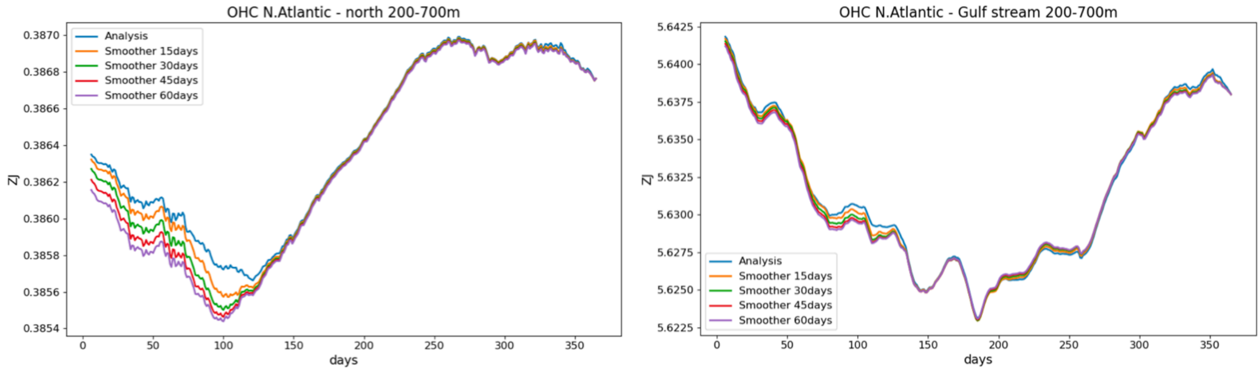

Fig. 4. 200-700m OHC for the year 2019 over regions indicated in Fig. 3.

In the smoother results, the high frequency variations in the analysis OHC (Fig. 4) are not effectively removed because these are the result of modelled variability coming from the forcing. The analysis increments in these regions (Fig. 5), and even accumulated smoother increments are too small compared to natural temporal variability range of the model. It seems that no high frequency changes are being introduced through DA as the weighting of the observations is very small, so that the DA makes only small adjustment to the model free run in the ORAS5 reanalysis.

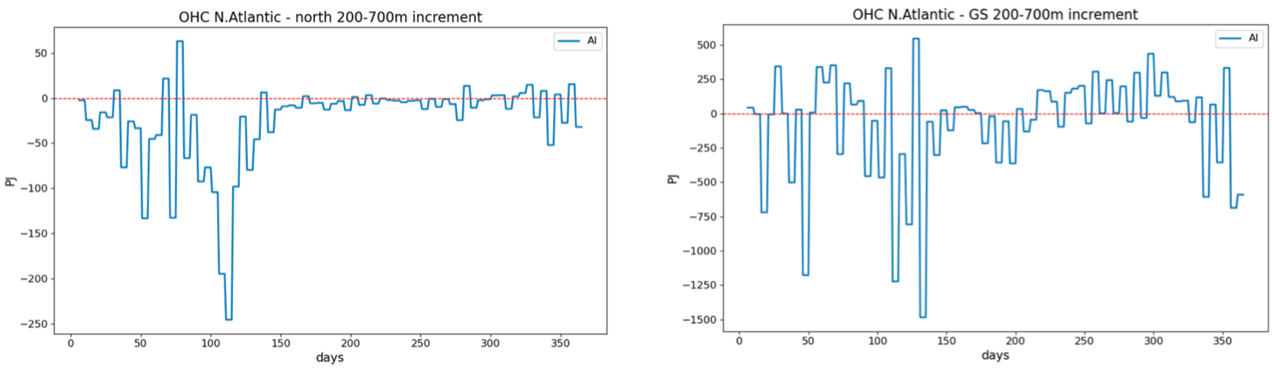

Fig. 5. Same as Fig. 4 but for OHC analysis increments.

We also noticed that the smoother OHC for the Gulf Stream regions shift to an earlier time. Taking the analysis increments (Fig. 5) into account, it clear that the early time shift is consistent with the persistent negative increments prior to ~day 200. It suggests that model is not reproducing enough winter cooling in the seasonal cycle at these depths probably because the mixed layer is too shallow. We plan to examine whether these adjustments lead to any improvements to the smoother reanalysis by running some error diagnostics in the next phase of the project.

References:

Dong, B., Haines, K., and Martin, M.: Improved high resolution ocean reanalyses using a simple smoother algorithm, Journal of Advances in Modeling Earth Systems, 13, e2021MS002 626, 2021.

Dong, B., Bannister, R., Chen, Y., Fowler, A., and Haines, K. (2023): Simplified Kalman smoother and ensemble Kalman smoother for improving reanalyses, *Geoscientific Model Development*, https://doi.org/10.5194/gmd-16-4233-2023

Haines, K. B. Dong, Y. Chen, R. Bannister, A. Fowler (2023): Simplified Kalman smoother and ensemble Kalman smoother for improving Earth system reanalyses. *AGU fall meeting 2023*, NG31B-0754

Dong, B., K. Haines, Y. Chen, R. Bannister, A. Fowler (2024): Simplified Kalman smoother and ensemble Kalman smoother for improving Earth system reanalyses. *6th WCRP International conference on Reanalysis*

Supplementary figures

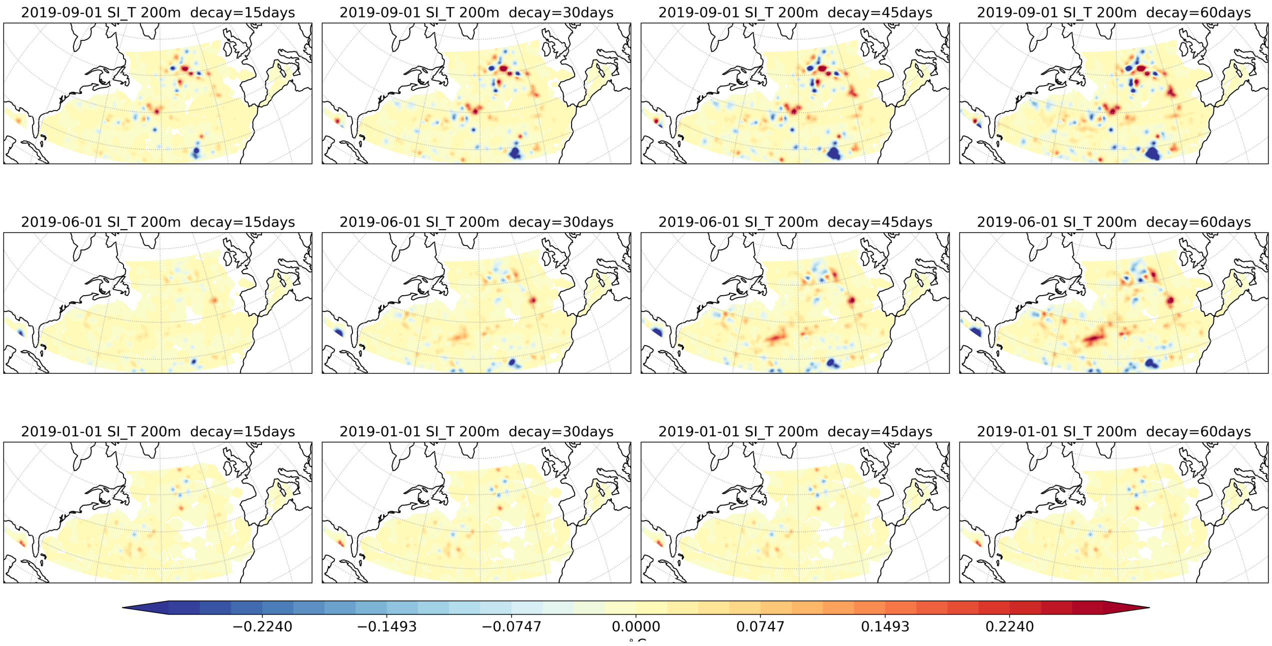

Fig S1. Smoother increments in 200m temperature field for selected days in 2019. Smoother fields are from 15, 30, 45 and 60 days smoothing.

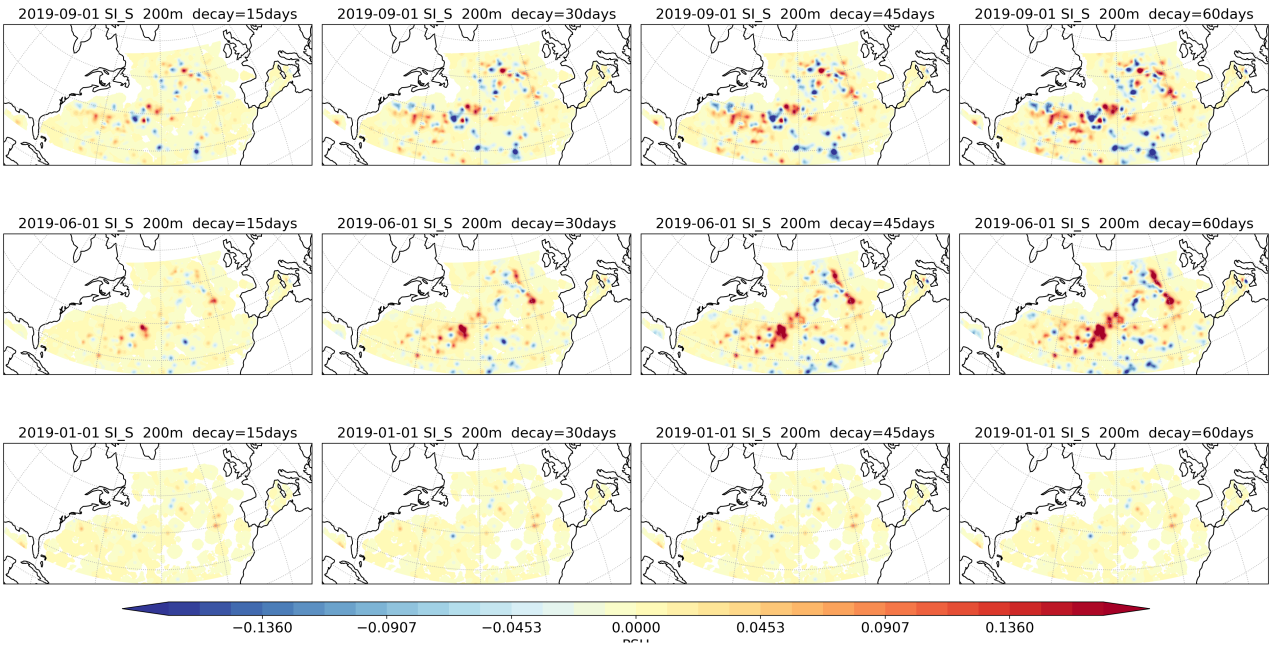

Fig. S2. Same as Fig. S1 but for salinity field.