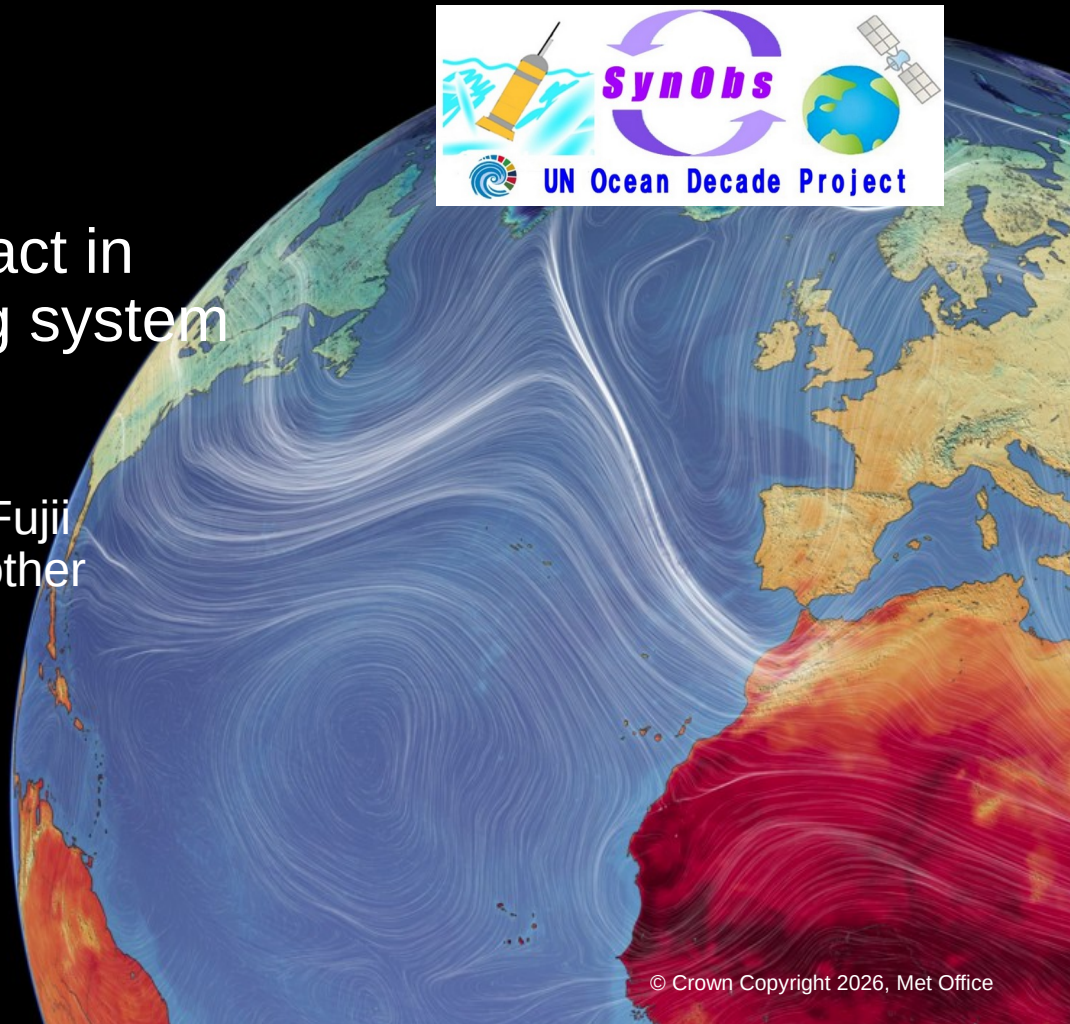
Assessing Observation impact in our global ocean forecasting system through the SynObs project

Jennie Waters, Matt Martin, Yosuke Fujii (JMA), Drew Peterson (ECCC) and other SynObs members



This content has been created by the author.
AI [M365 Copilot] has also been applied to refine the document.

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1. Introduce SynObs Flagship OSEs
2. Assessment of SynObs OSEs from the Met Office’s FOAM system
3. Assessment of the SynObs multi-system 15m velocities

SynObs OSEs

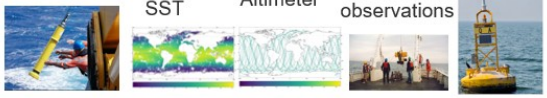
SynObs Flagship OSEs are a **coordinated** set of observation withholding experiments using different ocean forecasting systems (Fujii et al; 2024).

- Evaluate impact and synergy
- Identify deficiencies in our systems and use of obs
- Robust evaluation

Participating institutes and systems

1. ECCC (GIOPS)
2. ECMWF (ORAS6)
3. JAMSTEC (JCOPE_FGO)
4. JMA (MOVE_G3, MOVE-NPR)
5. NOAA-CPC (GLORe)
6. Pukyon National University (OPEM-MOM5)
7. Met Office (FOAM)

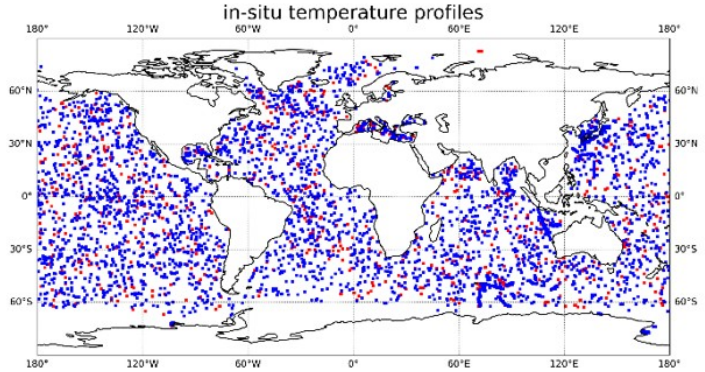
OSE settings



Control (CNTL)	80%	✓	✓	✓	✓
Without Argo (NoArgo)	✗	✓	✓	✓	✓
Without Altimeter (NoAlt)	80%	✓	✗	✓	✓
Without Mooring (NoMoor)	80%	✓	✓	✓	✗
Without Satellite SST (NoSST)	80%	✗	✓	✓	✓
Satellite only (NoInsitu)	✗	✓	✓	✗	✗
Satellite SST only (SSTOnly)	✗	✓	✗	✗	✗
Half Argo (HalfArgo)	40%	✓	✓	✓	✓
Model Only (Free)	✗	✗	✗	✗	✗

20% of Argo (those with IDs ending in 8 or 9) were withheld from all OSEs to be used as independent reference data

Experiments covered **2020**, 2021, 2022 (with a 3 month spin up in 2019)



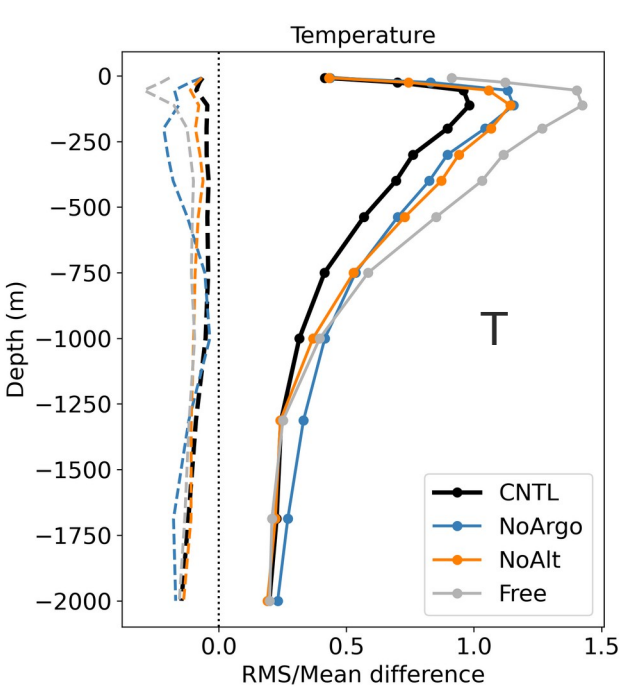
Met Office Results

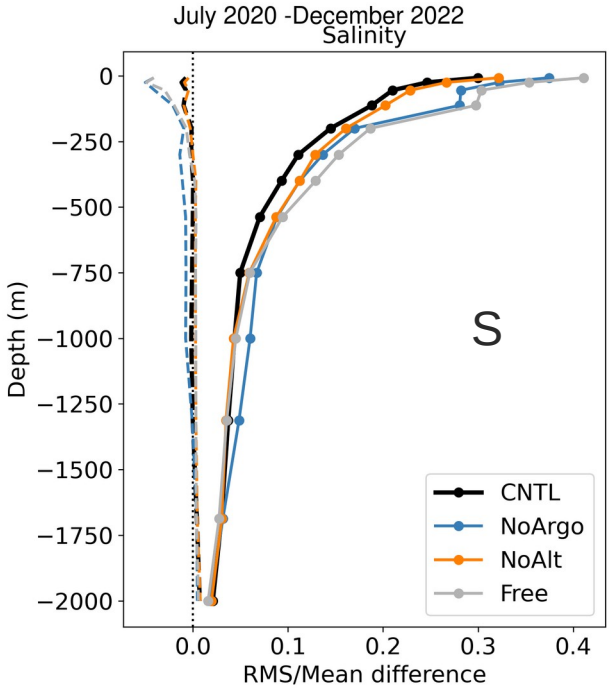
Results focus on the impact of withholding obs on the analysis in the forced FOAM global 1/12th degree system

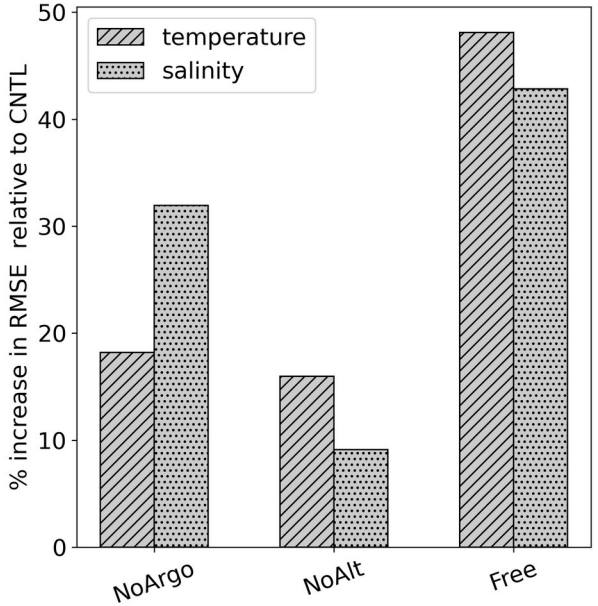
3DVAR (NEMOVAR)

Assessing CNTL, NoArgo, NoAlt and Free.

RMSD/ mean difference of analysis against Reference Argo







T: NoArgo +18% NoAlt +18%
+10%

Altimeter assimilation reduces the global temperature and salinity RMSD, but we do see some increases in RMSD in the deep ocean and some increased biases.

Comparisons of analysis T and S against Reference Argo

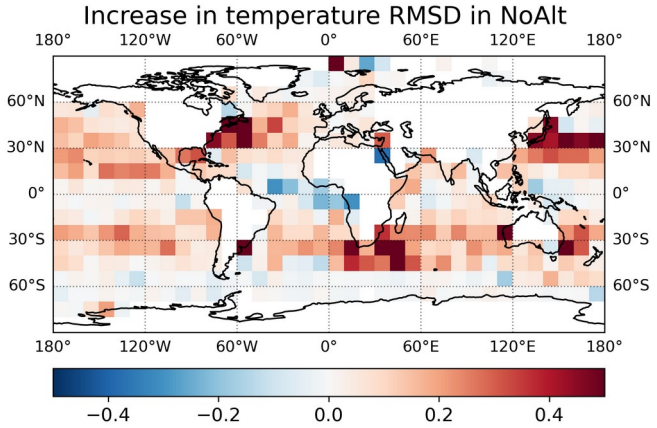
Plots show the change in the RMSD between the OSEs and CNTL

RMSD calculated in 10x10 bins over all depths down to 2000m.

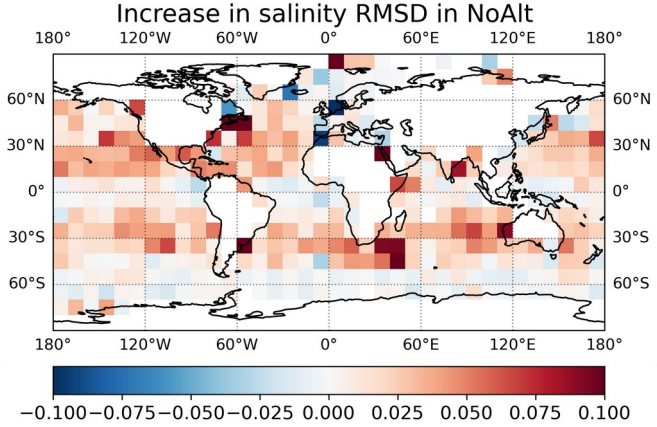
Red indicates RMSD is increased in the OSE

NoAlt

T

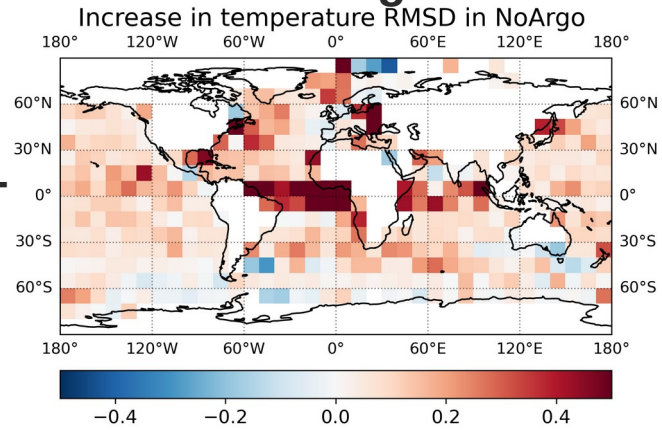


S

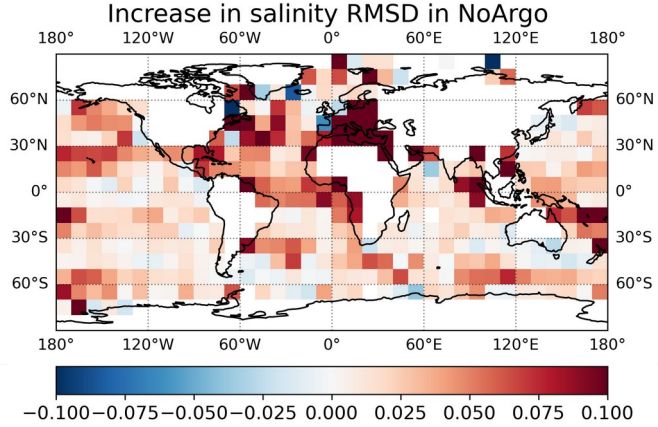


NoArgo

T



S

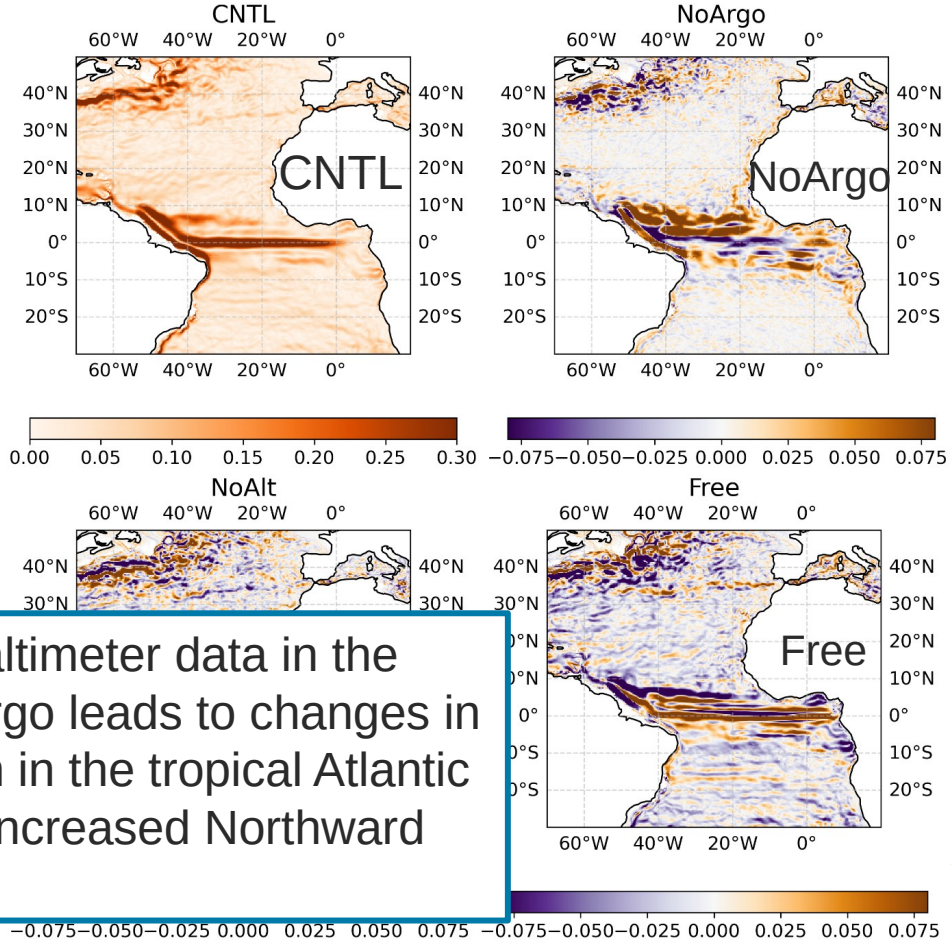


OSE AMOC results compared to RAPID

Experiment	Mean Difference	RMSD	Correlation coefficient
CNTL	0.88	2.35	0.77
NoArgo	-1.70	3.38	0.67
NoAlt	2.15	3.25	0.75
Free	3.60	3.91	0.85

Stats calculated for July 2020 to December 2022

80m current speeds (m/s) averaged over 2 years



Assimilating altimeter data in the absence of Argo leads to changes in the circulation in the tropical Atlantic and leads to increased Northward transports.

Top left plot shows the mean 80m current speed for CNTL

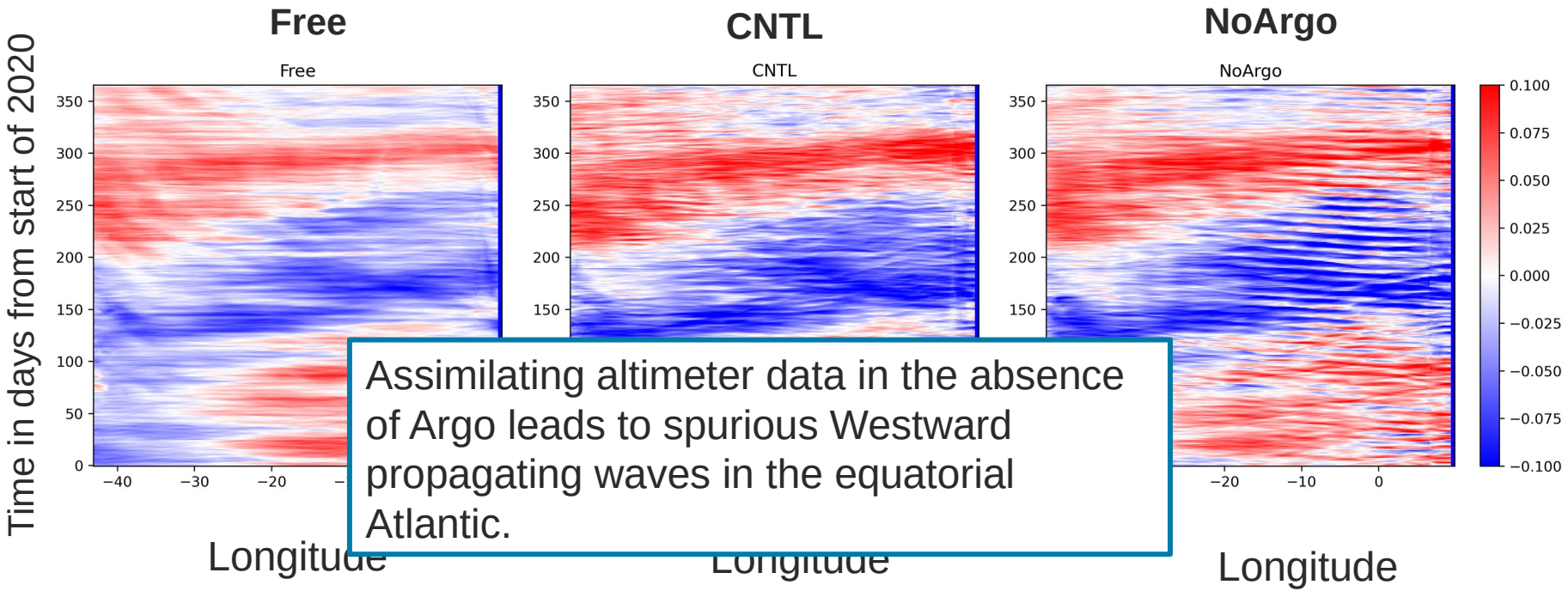
Three remaining plots show the change in the mean 80m speeds between the OSEs and CNTL

Orange indicates mean speed is increased in the OSE

In NoArgo the North Brazil current and NECC are increased.

Met Office

SSH during 2020 normalised by it's local temporal mean – at the equator



Assimilating altimeter data in the absence of Argo leads to spurious Westward propagating waves in the equatorial Atlantic.

In NoArgo, Westward propagating waves are visible. Note there is an island near the location where they propagate from.

Summary

- Altimeter assimilation improves T and S RMSD in the top 1000m and in the midlatitudes and WBC; assimilating Argo improves RMSD throughout the top 2000m and in most regions.

- RMSD and Mean Difference of FOAM AMOC against RAPID is smallest when both altimeter and Argo are assimilated.

- Results have highlighted issues with assimilating altimeter in the absence of Argo

    - Poor circulation in the Tropical Atlantic and spurious westward propagating waves

    - Development of subsurface temperature and salinity biases

- Potential mitigation
    - Reduce weight of altimeter assimilation in the tropics, particularly near the coast
    - Tuning of the SSH balance
        - In the future we could use the ensemble to determine the balance
        - ML approaches to improve balance

Synobs multi-system 15m velocity Assessment

Results focus on the impact of withholding obs on the analysis

Met Office

- Assessing the 15m currents in the SynObs OSES
  - Comparisons against drifters (Drew Peterson ECCC)
  - Comparisons against Globcurrent (me)

- Looking at 2021, outputs from 4 systems available: FOAM, GIOPS, ORAS6, MOVE-G3F

- Comparing CNTL, NoAlt and NoArgo

$\mathbf{V_1} = (u¿¿1, v_1)¿$ Globcurrent 15m velocity

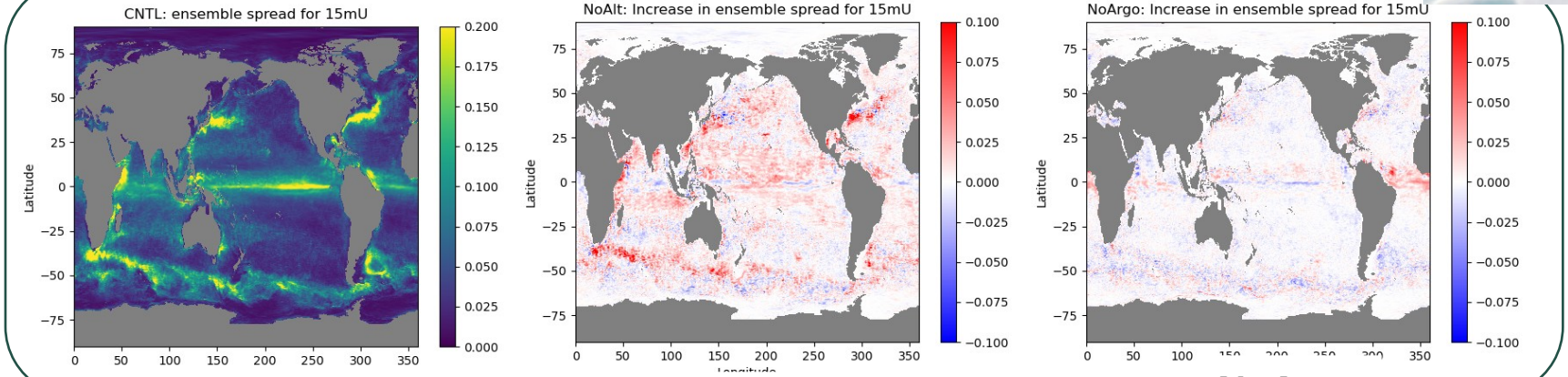
$\mathbf{V_2} = (u¿¿2, v_2)¿$ OSE 15m velocity

$$15\,m\,speed\,RMSD = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\overline{\mathbf{V_1}} - \overline{\mathbf{V}_2}\right)^2}$$

$$15\,m\,direction\,RMSD = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\cos^{-1}\left(\frac{(u_1u_2 + v_1v_2)}{\overline{\mathbf{V_1}}\,\overline{\mathbf{V}_2}}\right)\right)^2}$$

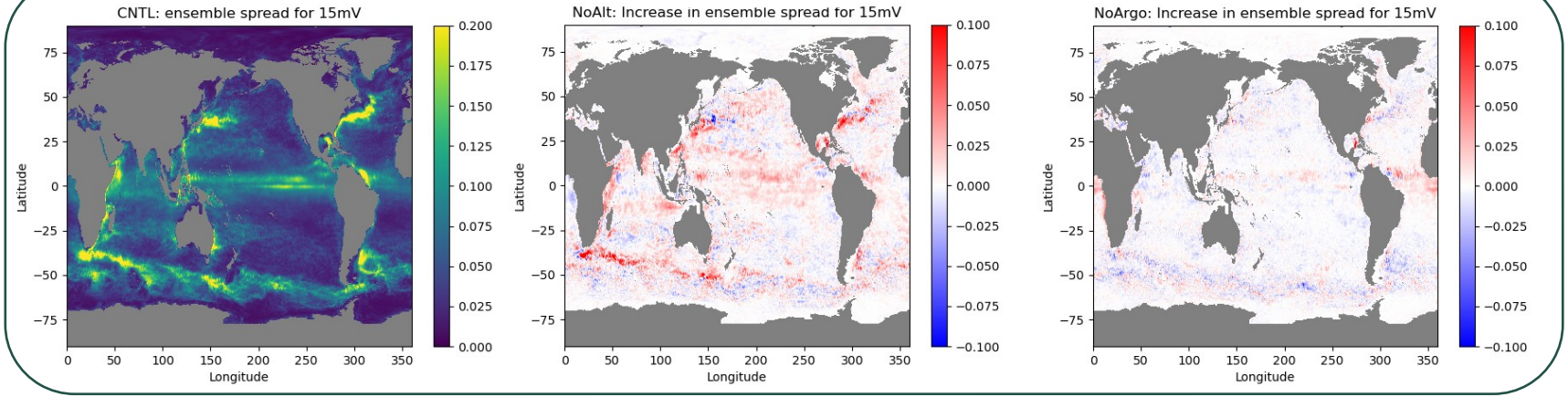
Impact on 15m velocity multi-system ensemble spread

$$Spread = \frac{1}{365}\sum_{t=1}^{365}\sqrt{\sum_{i=1}^{4}\frac{\left(\left(A_i(t)-\overline{A(t)}\right)\right)^2}{4}}$$



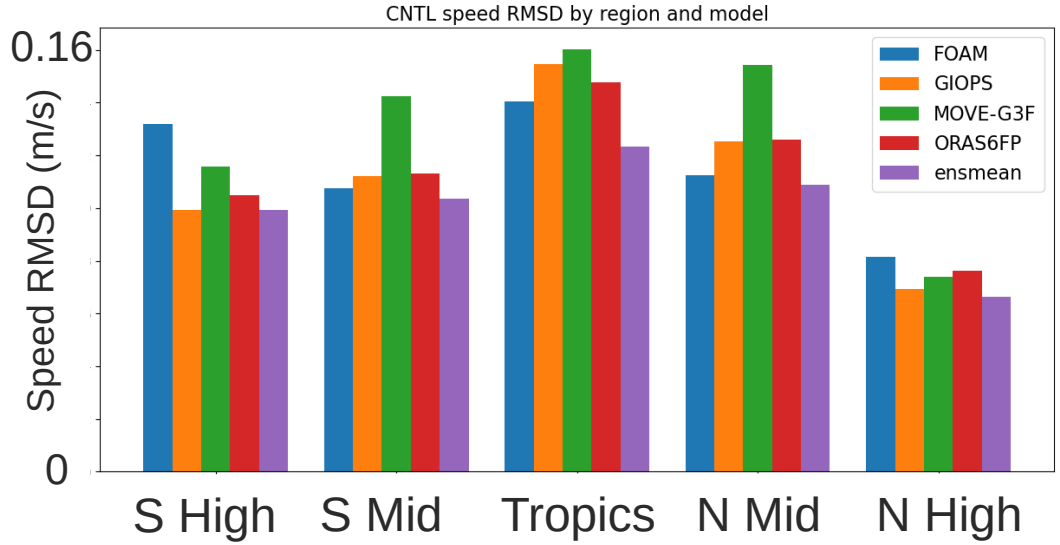
U

CNTL NoAlt NoArgo

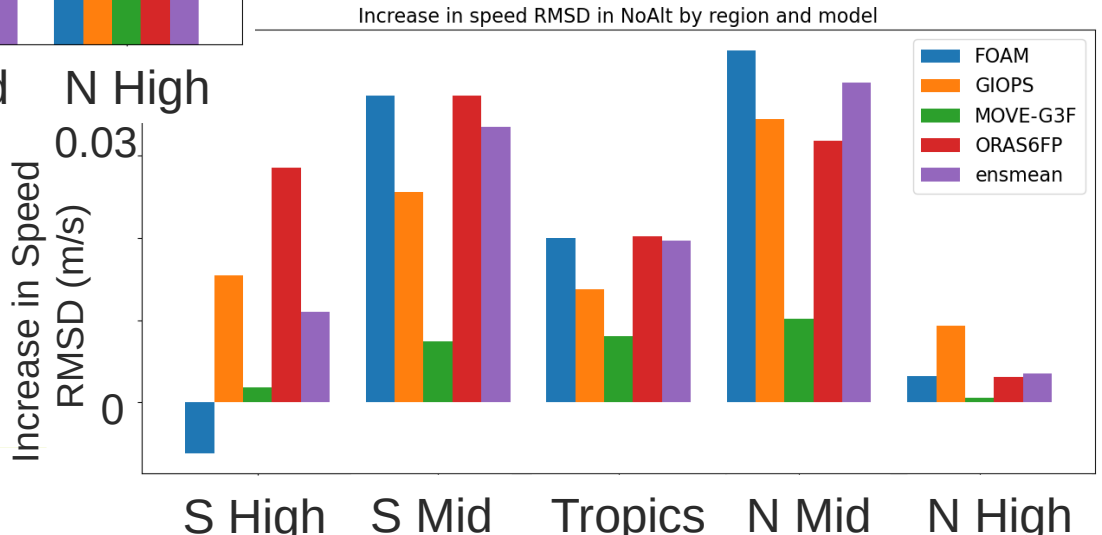


V

15m Speed RMSD relative to Globcurrent

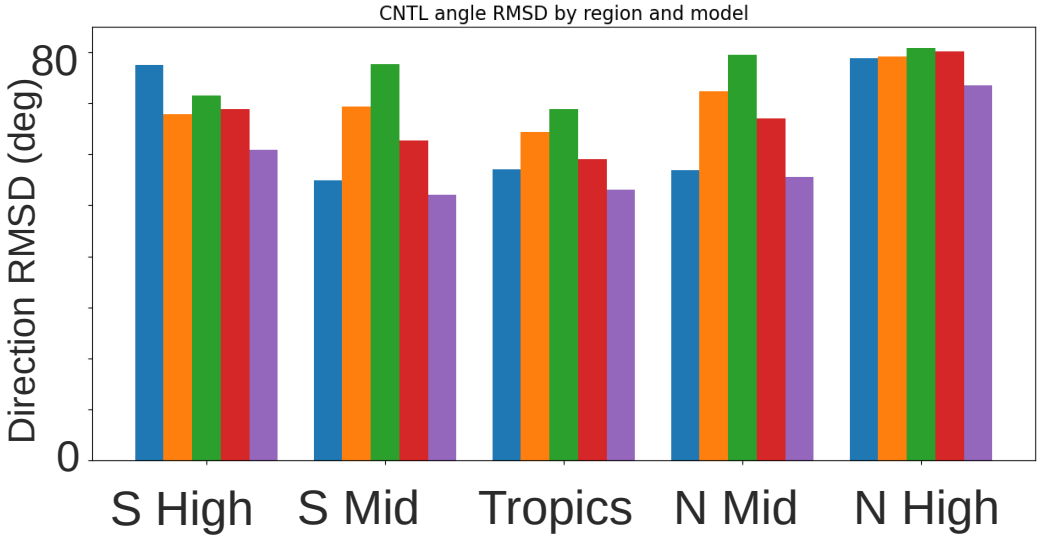


Change is 15m speed RMSD when altimeter withheld

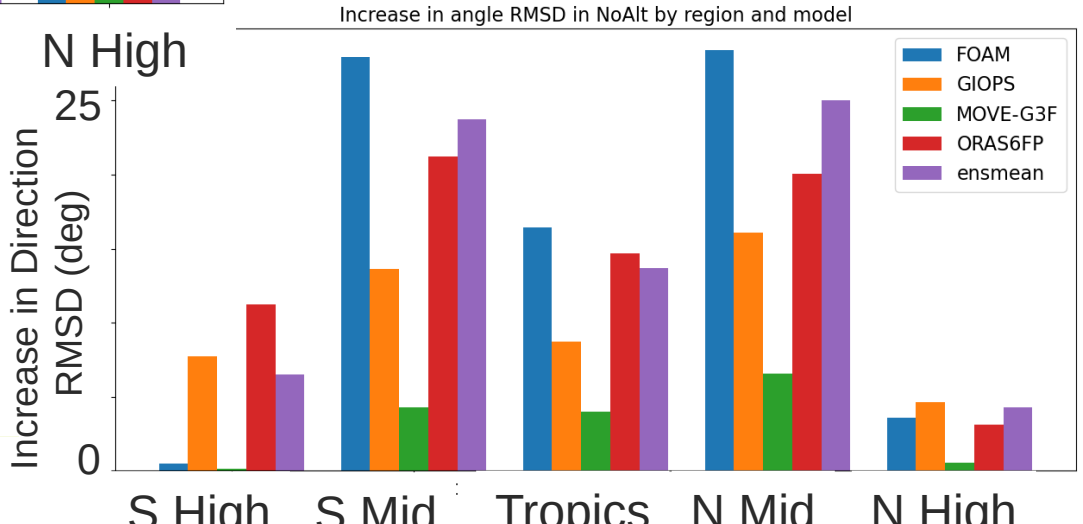


N High Lat: >50N
N Mid Lat: 23N – 50N
Tropics: 23S – 23N
S Mid Lat: 50S – 23S
S High Lat: <50S

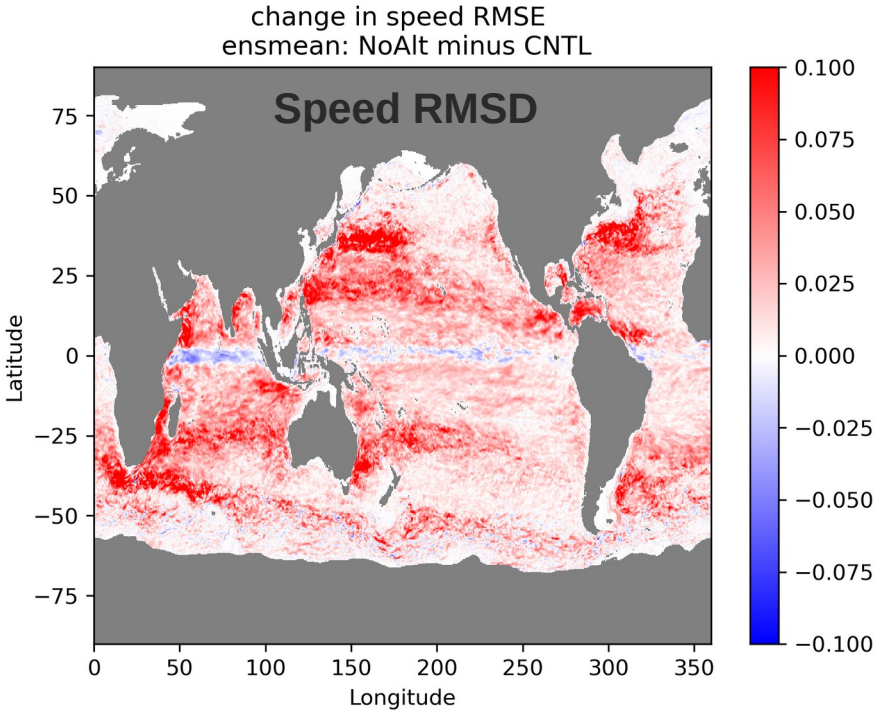
15m Direction RMSD relative to Globcurrent

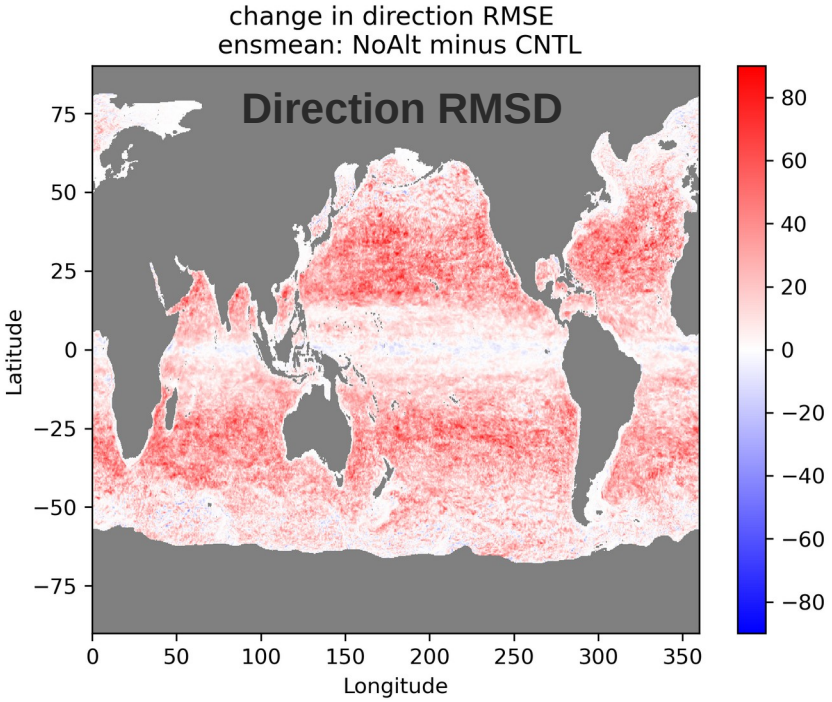


Change is 15m direction RMSE when altimeter withheld



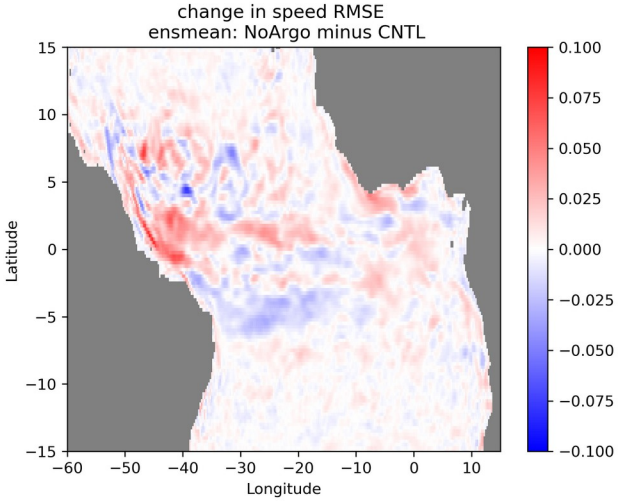
15m speed and direction RMSD of the NoAlt multi-system ensemble mean relative to Globcurrent



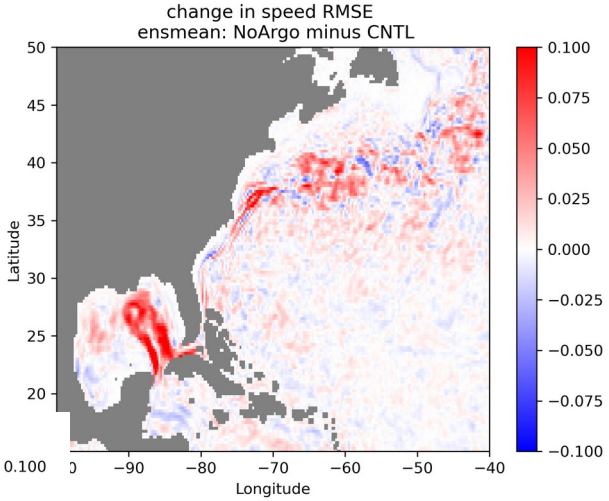


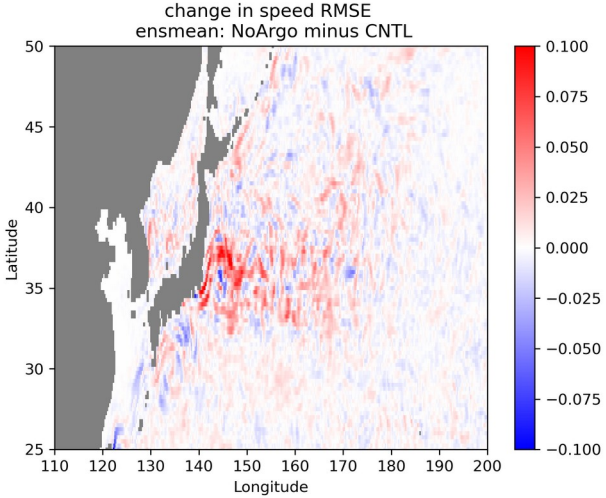
Red indicates altimeter assimilation reduces RMSD in ensemble mean

15m Speed RMSD of the NoArgo multi-system ensemble mean relative to Globcurrent



Red indicates Argo assimilation reduces RMSD in ensemble mean





Withholding Argo has a small impact globally on the 15m current speeds, but some larger regional impacts

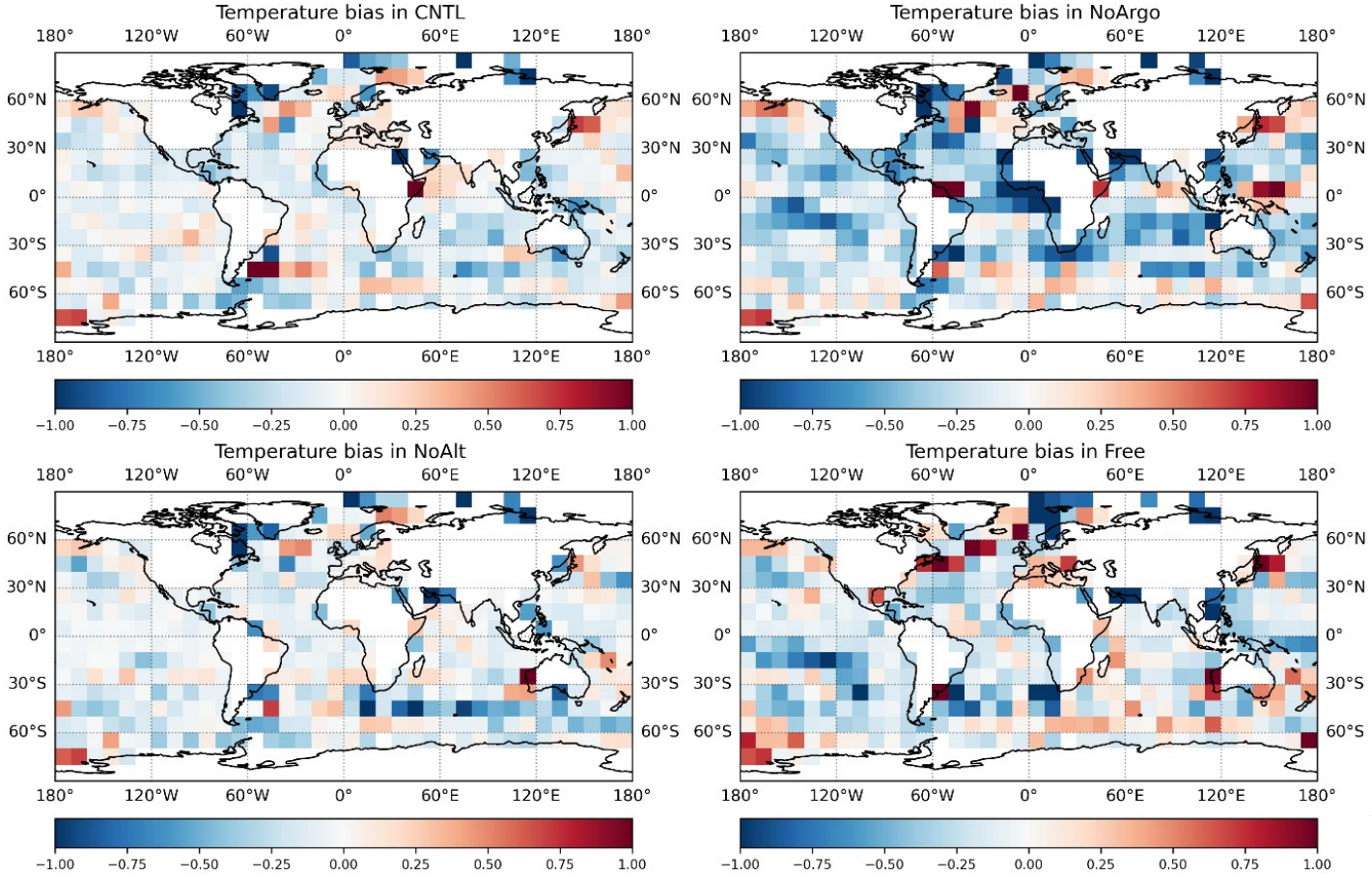
Conclusion

- Presented some preliminary analysis of the 15m velocities in the SynObs multi-system OSEs
- Assessed against Globcurrent
- Diversity of the quality of the CNTL 15m currents over different regions for different systems, and diversity of impacts from altimeter assimilation
- Ensemble mean suggests largest impacts of altimeter assimilation on 15 m velocities are in the mid-latitudes and tropics
- Argo assimilation has small impact globally but is important in some regions.
- Southern Ocean a target region for DA improvements in FOAM (possibly improved in the ensemble hybrid-3DEnVar system).

SynObs results on a common grid can be freely downloads from a public database:
https://synobs-database.pages.dev/

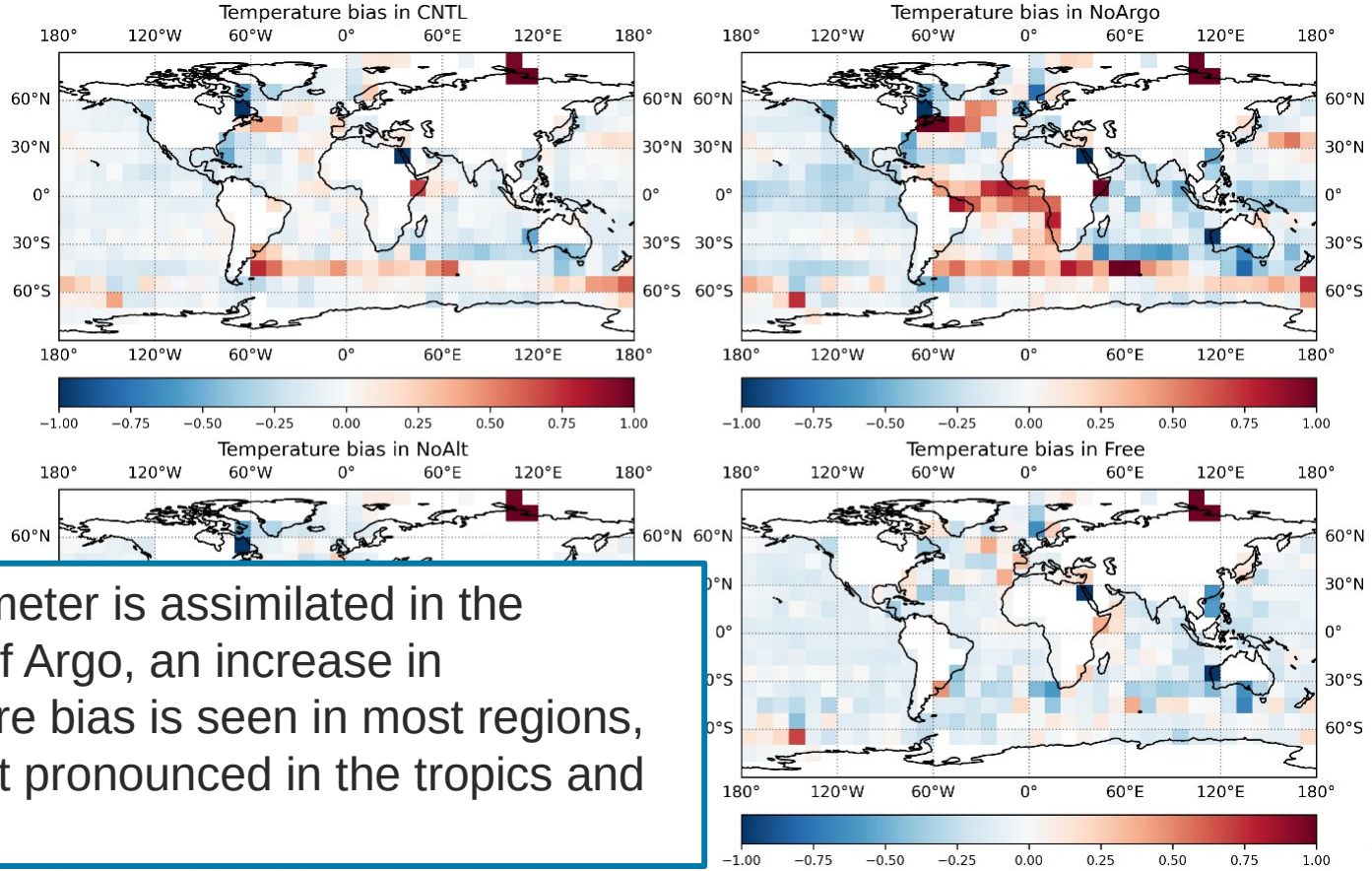
Extra slides

Temperature bias between 200-300m



Temperature bias between 750-800m

750-850m



When altimeter is assimilated in the absence of Argo, an increase in temperature bias is seen in most regions, but is most pronounced in the tropics and Atlantic

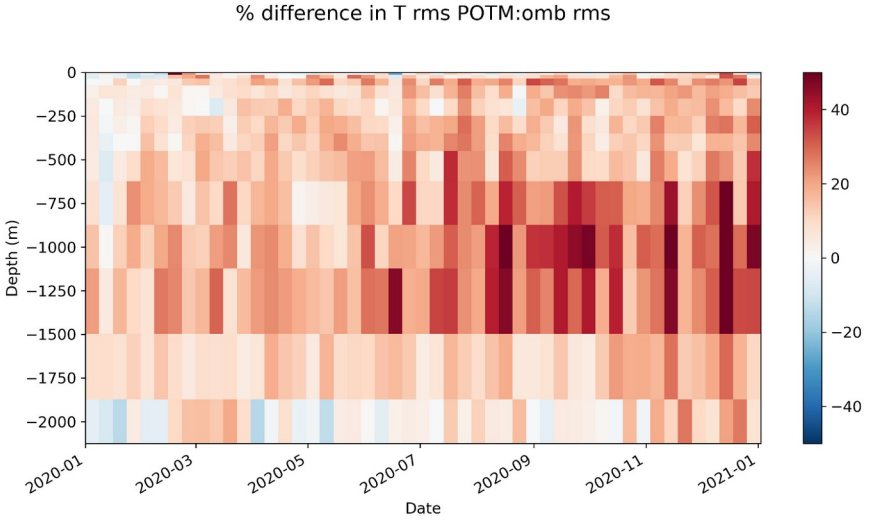
Met Office

System name (prediction centers)			
FOAM (UKMO)	GIOPS (ECCC)	MOVE-G3 (JMA)	JCOPE-FGO (JAMSTEC)
Modeling system			
NEMO 4.0.4 and SI3	NEMO 3.6 and CICE6	MRI.COM Ver 4	JCOPE-T
Model domains (horizontal resolution)			
Global ocean (1/12° × 1/12°)	Global ocean (1/4° × 1/4°)	Global ocean (1/4° × 1/4°)	75°S to 75° (1/10° × 1/10°)
Vertical coordinate system			
75 z coordinate levels with partial bottom steps	50 z coordinate levels with partial bottom steps	Rescaled height coordinate system, 60 levels	44 sigma layers
Atmospheric forcing			
Met Office NWP	ECCC GDPS	JRA-3Q	NCEP CFS
Data assimilation method (analysis frequency)			
NEMOVAR—3DVAR (1/4° × 1/4°) with FGAT (1 day)	Reduced order extended Kalman filter (7 days)	4DVAR (0.3°–0.5° × 1°) and IAU downscaling (5 days)	3DVAR and IAU (7 days)

SynObs OSEs: Met Office

- All experiments start from a run which assimilated all standard obs types from the 1st of September 2019.
- Using the 1/12th degree FOAM system
- NEMOVAR for DA: 3DVAR FGAT

	Experiment description
Free	No assimilation
CNTL	All standard observations assimilated
NoArgo	Same as the control but all Argo withheld
NoAlt	Same as the control but all altimeter withheld



“Toward Codesigning Sustainable and Fit-for-purpose Ocean Observing”
SynObs & Ocean Observing Codesign International Workshop 2026

- Held on August 24-30 in Mutsu, Japan
- 103 participants (68 on-site participants)
- From Australia, Canada, China, Fiji, France, India, Italy, Indonesia, Japan, Norway, Rep. Korea, South Africa, Spain, Taiwan, UK, USA

OceanPredict
Advancing the science of ocean prediction

SynObs
UN Ocean Decade Project

GOOS Ocean Observing Co-Design
by The Global Ocean Observing System
- Tropica Cyclone Exemplar
- Marine Heatwave Exemplar
- Boundary Current Exemplar







Slide courtesy of Yosuke Fujii



- **Shared the achievements** on evaluation and designing the ocean observing systems among the associated communities and stakeholders
- **Enhanced the collaboration** between SynObs and Ocean Observing Co-design
- Discussed on contributions to **OceanObs’29**

Comparisons of analysis 15m current speed against Globcurrent

Top left plot shows the 15m current speed RMSD of CNTL relative to GlobCurrent

Three remaining plots show the change in the RMSD between the OSEs and CNTL

Red indicates RMSD is

