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CONCEPTS

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Importance of Ocean Observations to the ECCC Global Ocean Analysis System, GIOPS

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Abstract

The Synergistic Observing Network for Ocean Prediction (SynObs) project (https:// oceanpredict. org/ synobs) seeks to find synergies between ocean observations and ocean prediction through multi-system Observing System Experiments (OSEs). Skillful estimates of sub-surface T/S profiles, which in turn can determine local minimum in sound speed profiles (sound ducts) are important for ocean applications. Skillful estimates of the location and strength of ocean eddies and surface currents are also important. Ocean observations play a critical role through data assimilation in providing skillful estimates of these oceanic quantities, but the exact value of the observations, and in particular, which observations are most crucial for a given quantity are unknown. Within the SynObs context, Environment and Climate Change Canada's (ECCC's) system the Global Ice Ocean Prediction System (GIOPS) has performed several observation withholding experiments. We show the results here for global profile statistics, existence of near surface sound ducts, detection of eddies in the North Atlantic, and near surface 15m currents.

Global Ice Ocean Prediction System (GIOPS)

- Provides ECCC Global Ocean/Ice initial conditions [Smith et al., 2016]
  - Ocean State Analysis for coupled 10d deterministic, 16/39d ensemble and seasonal forecasts
  - based on Mercator Ocean International system [Lellouche et al., 2013]
  - Singular evolutive extended Kalman (SEEK) filter, plus 3D-Var T/S bias correction term
- 7 day window for trial run with 1 day incremental analysis update (IAU).
  - Assimilates T/S profile observations including ARGO profiles
  - + Along track sea level anomaly (SLA) satellite observations (AVISO).
  - + Gridded SST analysis (satellite/in-situ data) [Brasnett and Colan, 2016]. Also used by atmosphere.
  - + A sea ice analysis is blended in during the IAU [Buehner et al., 2013].
- For daily forecasts, 7-1d updates (SST only) providing initial conditions

SynObs Experiments

Configuration of OSEs

1	CNTL		SST	ARGO 80%	Moorings	Other TS	Altimeter
2	NoAlt		SST	ARGO 80%	Moorings	Other TS	
3	NoArgo		SST		Moorings	Other TS	Altimeter
4	NoMoor		SST	ARGO 80%		Other TS	Altimeter
5	NoSST			ARGO 80%	Moorings	Other TS	Altimeter
6	NoInsitu		SST				Altimeter
7	SSTonly		SST				
8	Free						
9	HalfArgo		SST	ARGO 40%	Moorings	Other TS	Altimeter
10	Oper	Operational Settings	SST	ARGO 100%	Mooring	Other TS	Altimeter

Fit to Profiles

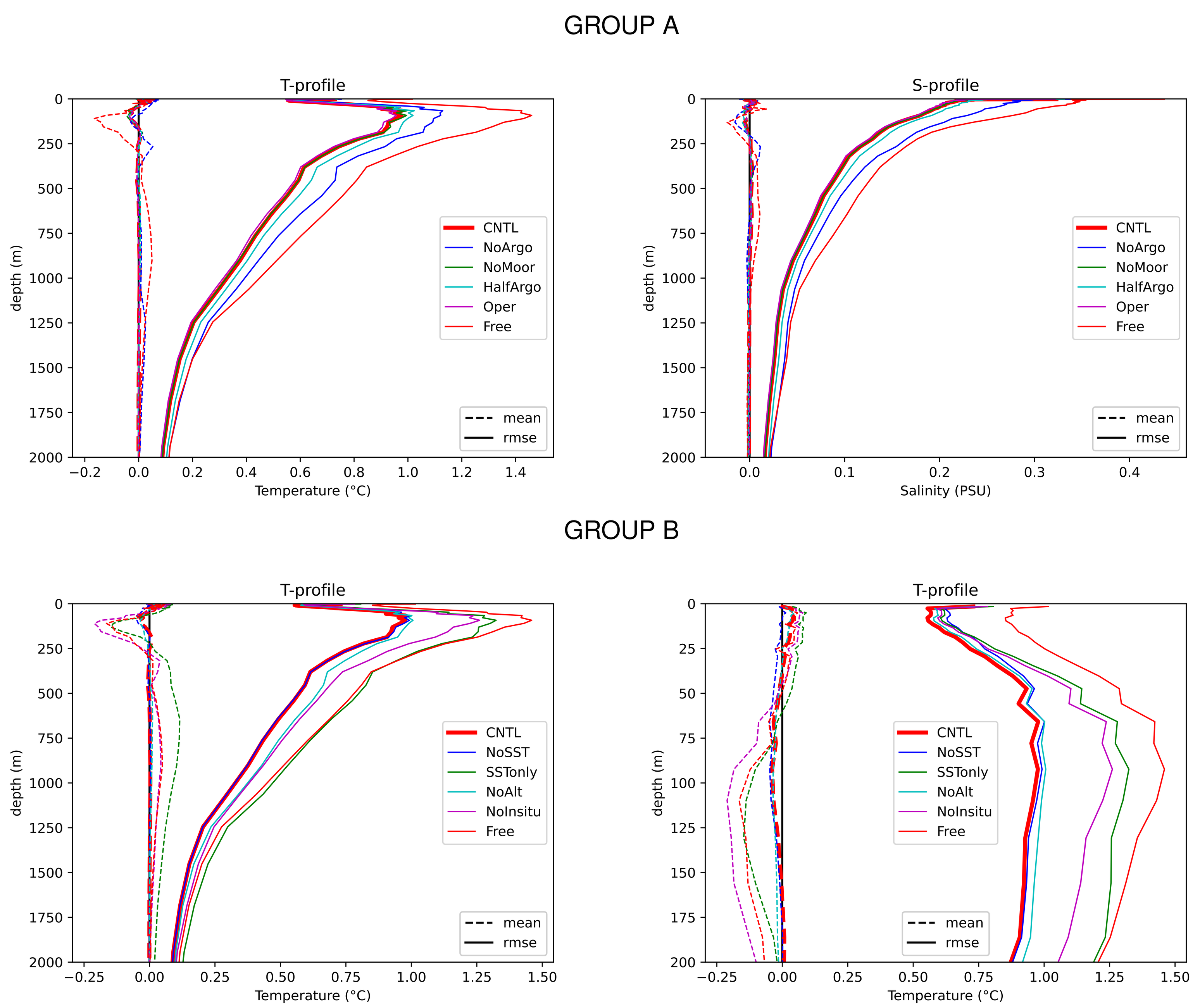

Figure 1: *Root Mean Square (Solid) and Mean (Dashed) Error with respect to subsurface temperature observations (°C) and salinity observations (PSU; Group A right plot). Group B right side plot is temperature misfit profile for top 200m.*

- Group A shows importance of profile observations CNTL (thick line)::NoArgo::NoMoor::HalfArgo::Oper::free
  - Clear separation between 0 (NoArgo), 40% (HalfArgo) and 80% (CNTL; thick line) of ARGO observations.
  - There is minimal separation between 80% (CNTL; thick) and 100% (Oper) experiments
  - Virtually no separation between (CNTL; thick) and removing moorings (NoMoor) – larger effect in Tropics.
- Group B shows merits of other observations CNTL (thick line)::NoSST::SSTonly::NoAlt::NoInsitu::free
  - Removing altimeter (NoAlt) degrades the fit to the profiles below 100m
    - ∗ and below 500m to same extent as removing profile obs (NoInsitu)
  - but removing SST (NoSST) only degrades slightly from surface to 125m
  - Having both altimeter and SST gives good fit in top 25m (NoInsitu), and continues to improve on free (thin line) for all depths.
    - ∗ But only having SST (SSTonly) only improves to depth of 200m – through depth of mixed layer

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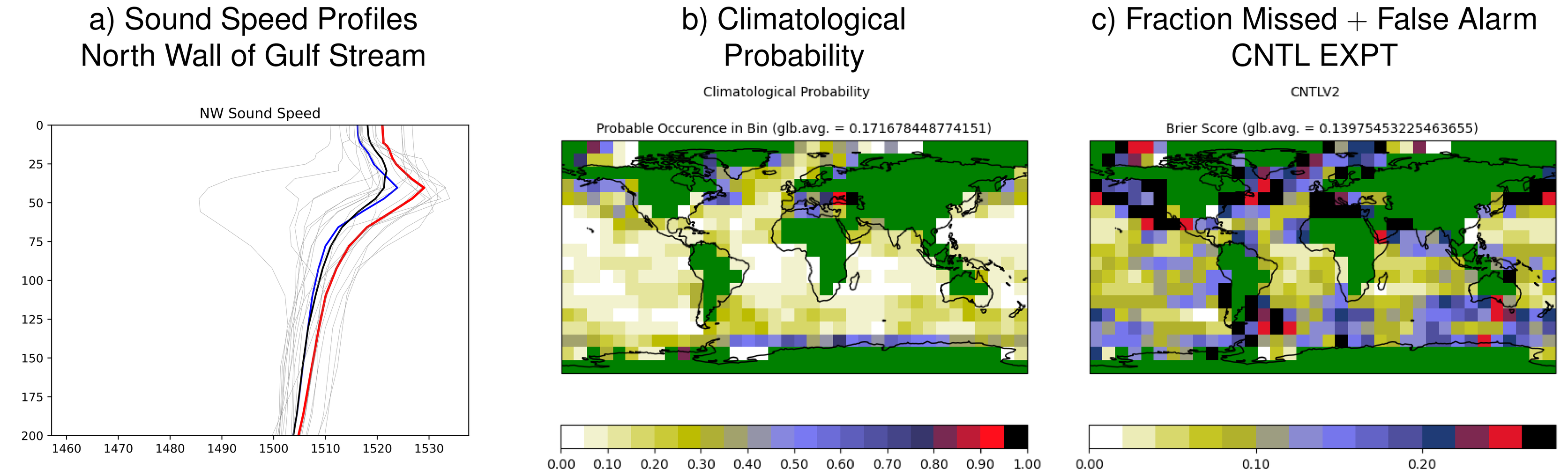
Shallow Water Sound Ducts



EXPT	Global % missed
CNTL	0.1398
NoMoor	0.1402
NoAlt	0.1439
HalfArgo	0.1449
NoArgo	0.1574
Free	0.1629

Figure 2: *a) A typical ensemble of sound speed profiles for North Wall of Gulf Stream. Only a subset display a local minimum in sound speed in upper 10-100m (a sound duct). b) Probability of observing a local minimum in sound speed in 10-100m from profile observations (EN4) over $10° \times 10°$ bins. c) Fraction of missed + false alarm sound duct occurences in CNTL run (smaller is better).*

- Table: Global fraction incorrect (Fraction Missed + Fraction False Alarms) for various OSE experiments.
  - Note: Smaller is better. Observation per bin weighted average of Figure 2c.
- Increasing % missed shows importance of profiles observations as they are removed.
  - Loss of altimeter observations almost as bad as losing half ARGO.
- See Tollefsen [2023] (https://cradpdf.drdc-rddc.gc.ca/PDFS/unc423/p816498_A1b.pdf)

Eddy Tracking

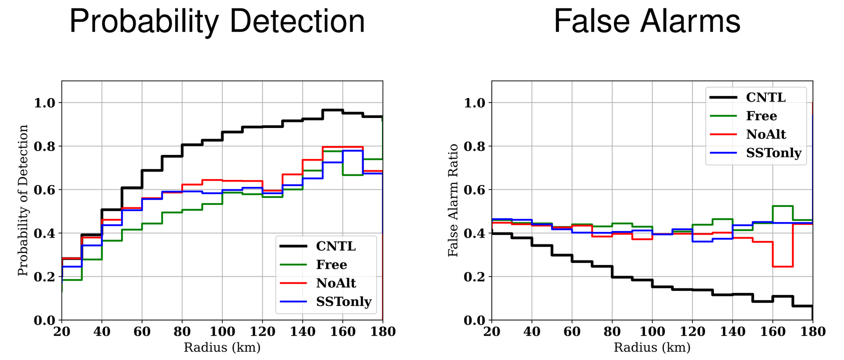
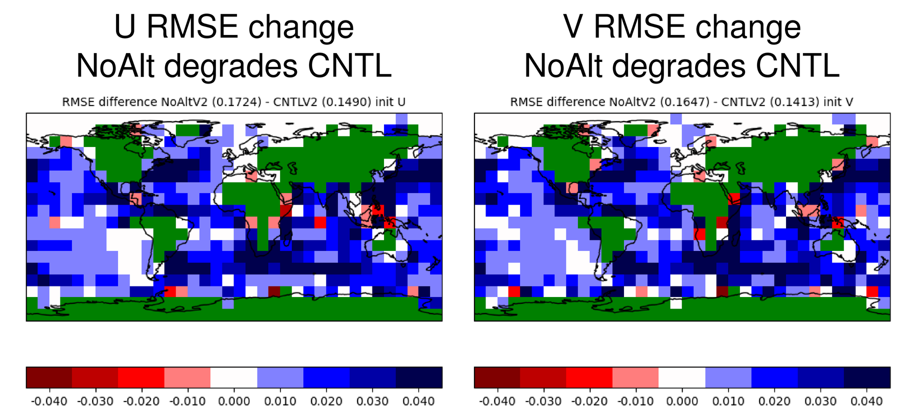


Figure 3: *a) Probability of matching an observed eddy through cost function based on amplitude, radius and distance. b) Ratio of false alarms. Higher probability of detection, and fewer false alarms implies increased skill.*

- Apply py-eddy-tracker, a closed-contour approach [Mason et al., 2014] over Northwest Atlantic (∼30-60 °N, 80-30°W)
- Once eddies have been identified in observations(AVISO), they are matched in model using a cost function based on amplitude, radius and distance.
- NoAlt is very similar to Free Run. Altimeter observations provide observed eddies.
- However, even without altimeter, NoAlt shows enhanced probability of detection over Free run for eddies less than 100km.
  - SSTonly provides observed eddies less than 100km – SST obs give eddy info.
  - Adding profile observations slightly degrades this by adding false alarms (not shown)
  - See Smith and Fortin [2022]
    - ∗ (https://doi.org/10.1016/j.ocemod.2022.101982)

Ocean Currents



EXPT	Speed rmse (m/s)	U rmse (m/s)	V rmse (m/s)
CNTL	0.1472	0.1490	0.1413
SSTonly	0.1666	0.1693	0.1592
NoAlt	0.1611	0.1724	0.1647
Free	0.1734	0.1748	0.1655

- No altimeter significantly degrades fit to observations.
  - Both NoAlt and SSTonly.
  - SST improves shape of isobars
    - ∗ SSTonly improves components
  - but not isobar gradient
    - ∗ SSTonly degrades speed

Figure 4: *Difference between NoAlt and CNTL of RMSE (m/s) between analysis and observed currents from drifting buoys. East U and North V velocities. Blue shows increased RMSE.*

- See Aijaz et al. [2023] (https://doi.org/10.1016/j.ocemod.2023.102241)

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