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OceanPredict
Advancing the science of ocean prediction

# IMPORTANCE OF OCEAN OBSERVATIONS IN ECCC'S GLOBAL OCEAN ANALYSIS SYSTEM (GIOPS): A CONTRIBUTION TO THE SYNOBS PROJECT


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# THE UN DECADE SYNOBS PROJECT

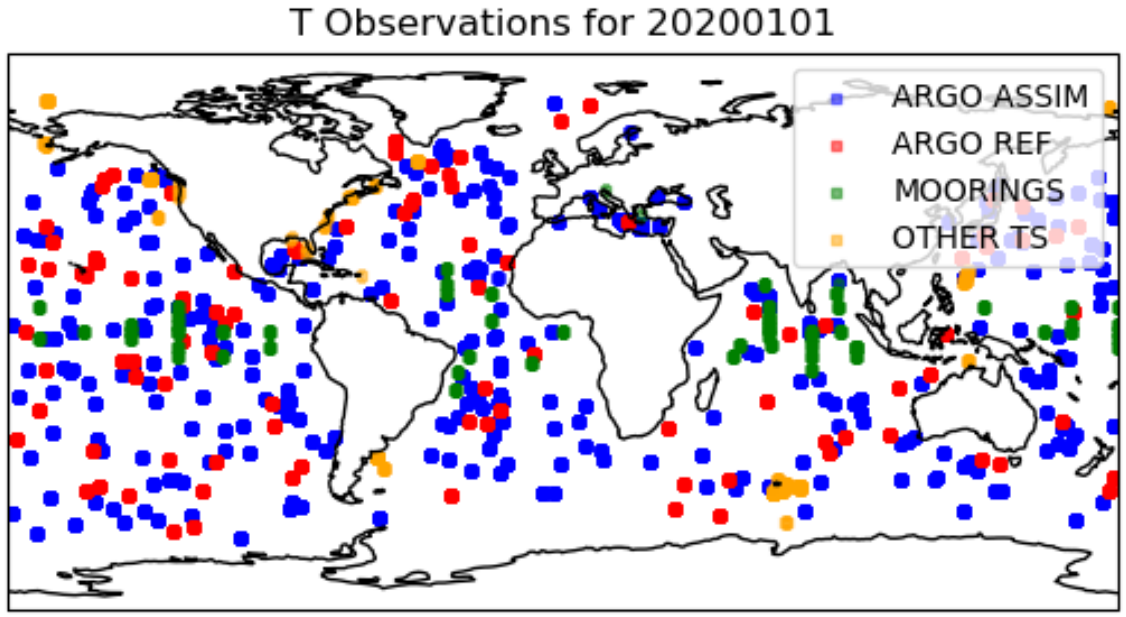
- The Synergistic Observing Network for Ocean Prediction (SynObs) project seeks to find synergies between ocean observations and ocean prediction through multi-system Observing System Experiments (OSEs).
  - https://oceanpredict.org/synobs

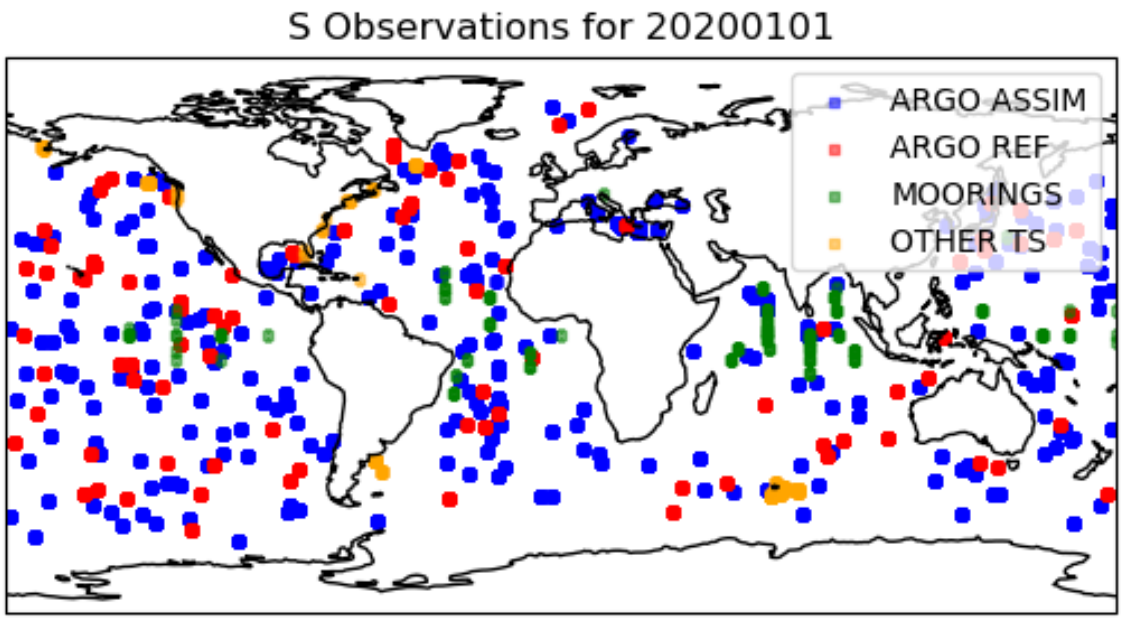
- SynObs was proposed and designed to test the impact of different observing systems including in-situ T/S profile (Argo) observations as well as satellite SST and altimeter observations.
- Here we assess the impact of Synobs OSEs on analysis error and the degradation in three user-relevant areas:
  - Shallow water ducts, representation of mesoscale eddies and surface drift

# SYNOBS OSE EXPERIMENT DESIGN

## Observing System Experiments

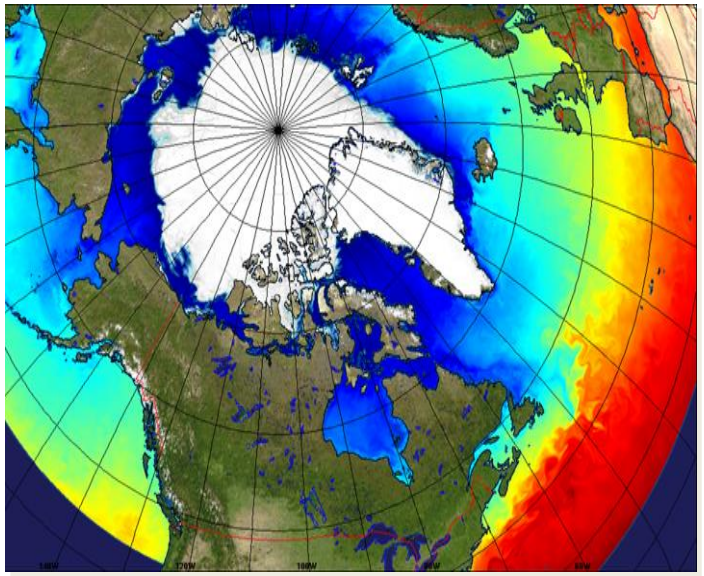
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **1** | CNTL | | SST | Argo 80% | Mooring | Other TS | Altimeter* |
| **2** | NoAlt | | SST | Argo 80% | Mooring | Other TS | |
| **3** | NoArgo | | SST | | Mooring | Other TS | Altimeter* |
| **4** | NoMoor | | SST | Argo 80% | | Other TS | Altimeter* |
| **5** | NoSST | | | Argo 80% | Mooring | Other TS | Altimeter* |
| **6** | NoInsitu | | SST | | | | Altimeter* |
| **7** | SSTonly | | SST | | | | |
| **8** | Free | | | | | | |
| **9** | HalfArgo | | SST | Argo 40% | Mooring | Other TS | Altimeter* |
| **10** | Oper | Oper. Setting | SST | Argo 100% | Mooring | Other TS | Altimeter |



# GLOBAL ICE OCEAN PREDICTION SYSTEM (GIOPS)

- Provides ECCC Global Ocean/Ice initial conditions
  - Ocean State Analysis for coupled 10d deterministic, 16/39d ensemble and seasonal forecasts
  - based on Mercator Assimilation System (SAM2v1)
  - Reduced-order extended Kalman filter
  - 3D-Var T/S bias correction term
  - 7-day assimilation window with 1-day IAU
- Observations assimilated:
  - T/S profile observations including Argo profiles
  - Along-track sea level anomaly (SLA).
  - CMC L4-SST analysis (satellite/in-situ data).
  - Blended with 3DVar sea ice analysis.
- For daily forecasts, 7x1d updates (SST/ice only) provide initial conditions



Canada

MERCATOR OCEAN INTERNATIONAL

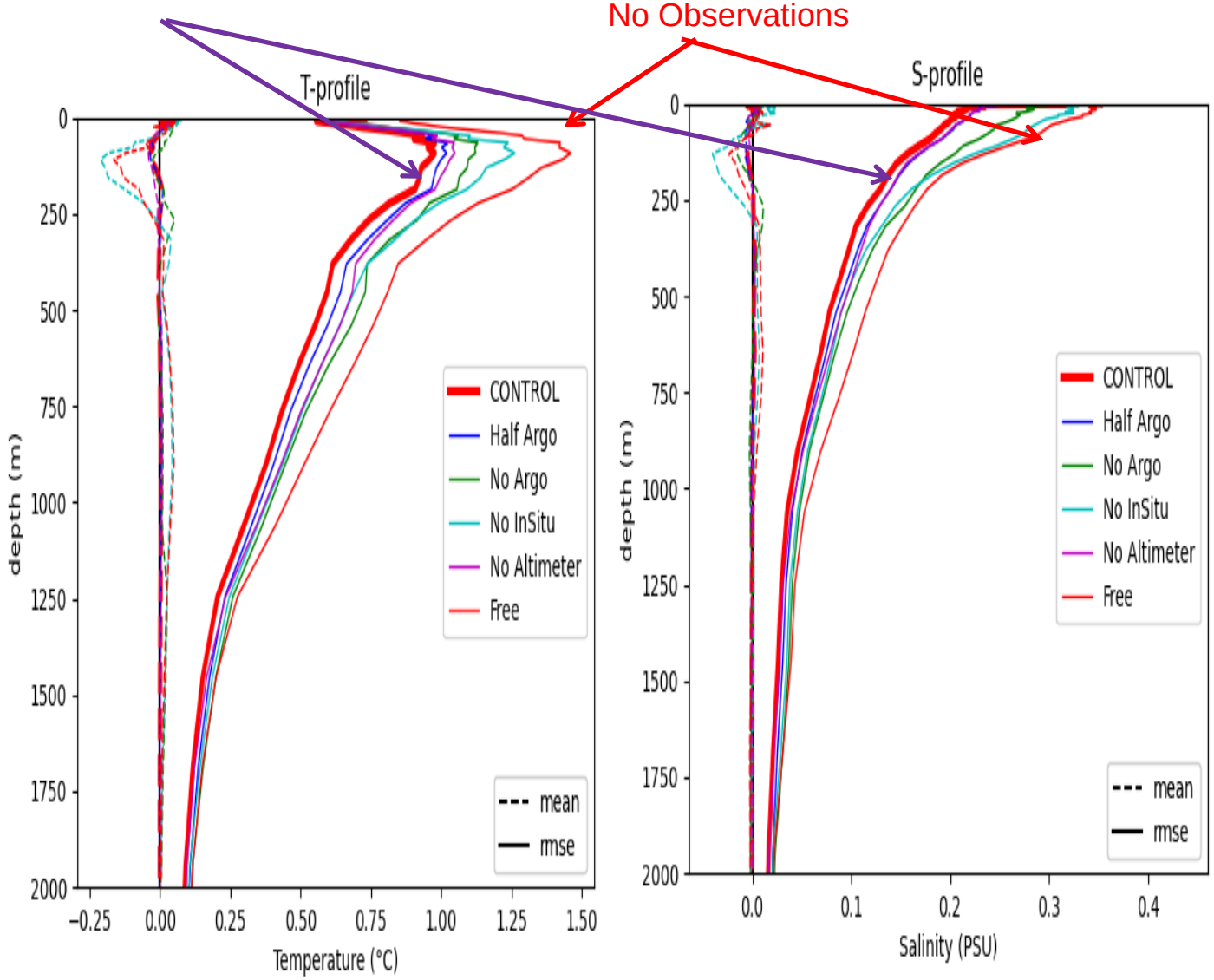
*Smith et al. (QJRMS2015, MWR2018, GMD2021)* CONCEPTS - Science.gc.ca

CONCEPTS

# IMPACT OF REMOVING ARGO

CNTL/80% ARGO

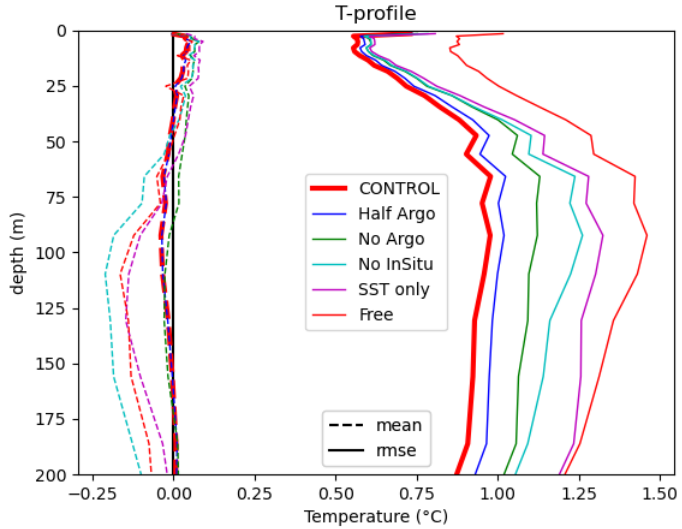
Free:
No Observations



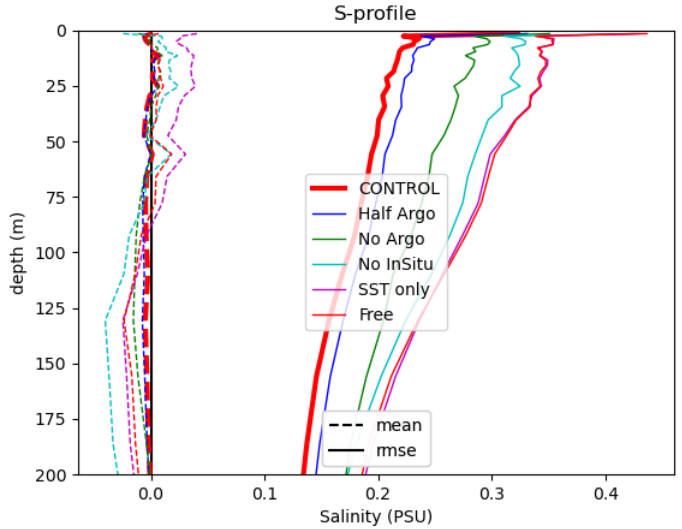

- CNTL (THICK) (80% Argo + all other observations)
- As **Argo** is taken away (HalfArgo --40% Argo; NoArgo – 0% Argo; NoInSitu) profile fits gets progressively worse and more like Free Run (thin).
- Except below 500m when NoInSitu better than NoArgo (more later).
- NoAlt is about as bad as NoArgo/NoInsitu below 500m
  - But profiles are important to get mix layer maximum error down.

# IMPACT OF REMOVING SATELLITE SST/ALT

## T 0-200m




## S 0-200m

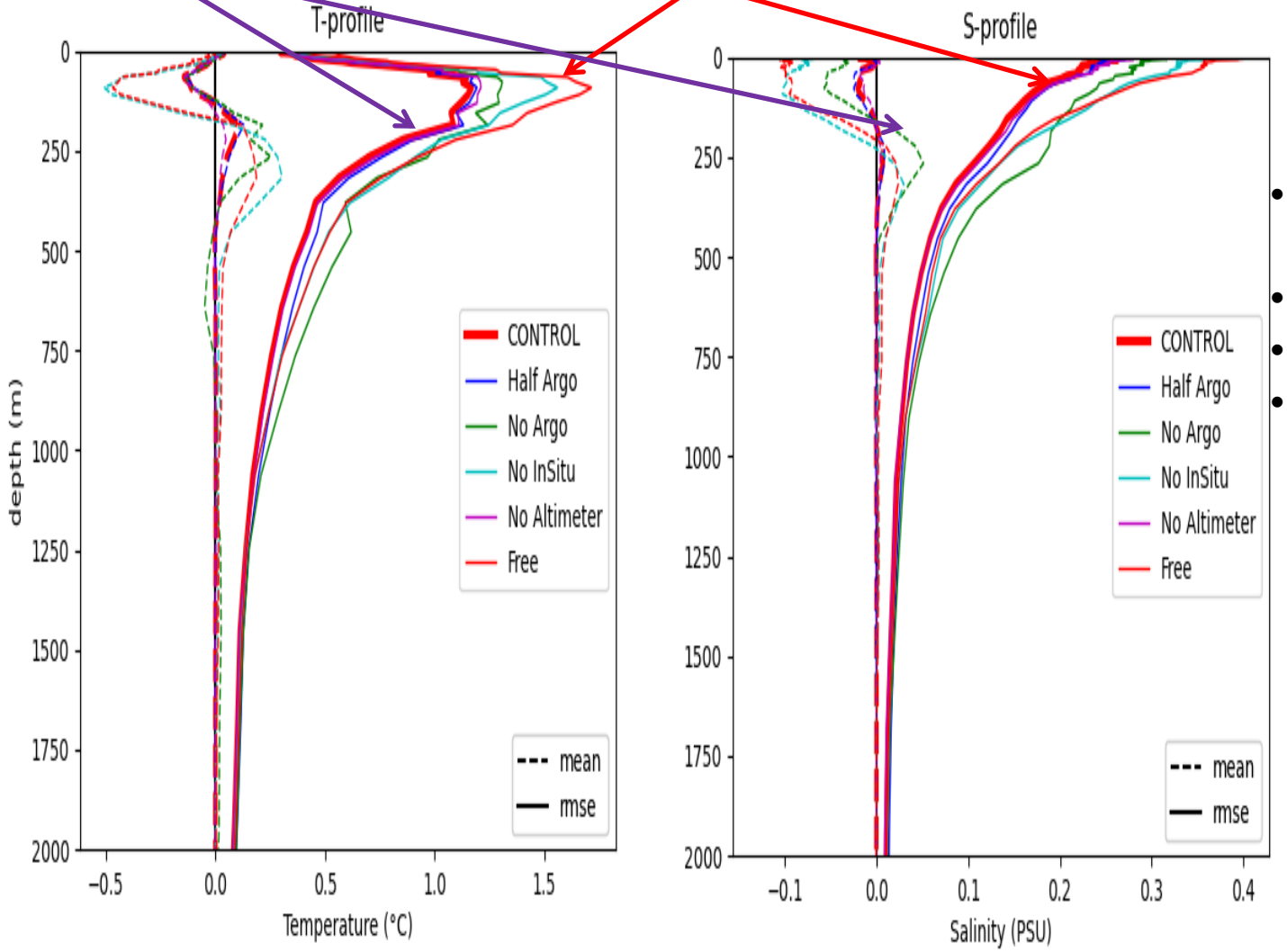



- Impact of SST (SST only / Free (thin) only in top 200m of T Profile
  - No influence on S Profile at all.
- NoInSitu (No T/S profiles but altimeter and SST obs)
  - 0-75m influence of SST (SST only)
  - > 100m influence of altimetry
  - NoInsitu maximum error ~100m shows importance of profiles to capture depth of mixed layer.

# IMPACT OF REMOVING ARGO IN TROPICS

CNTL/80% ARGO

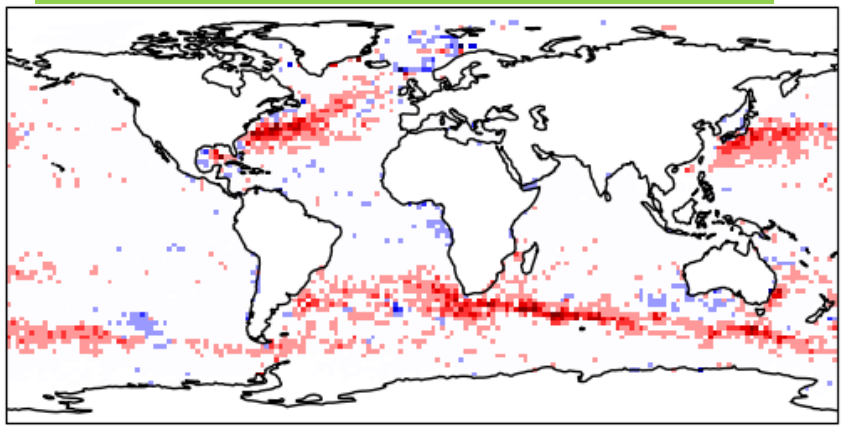
Free:
No Observations

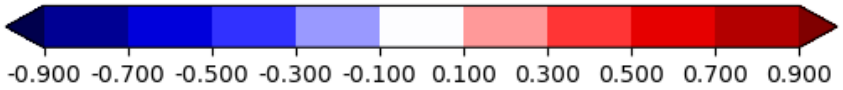



- In Tropics, have TAO/RAMA/PIRATA arrays – so ARGO should not matter as much.
- However, NoARGO gets as bad as free from 250m down.
- And worse than free below 500m
- Arrays only go down 500m!
- Below 250m NoInSitu == Free
  - Altimeter isn't helping much.

# IMPACT OF ARGO AND OTHER PROFILES ON DEEP WATER MASSES

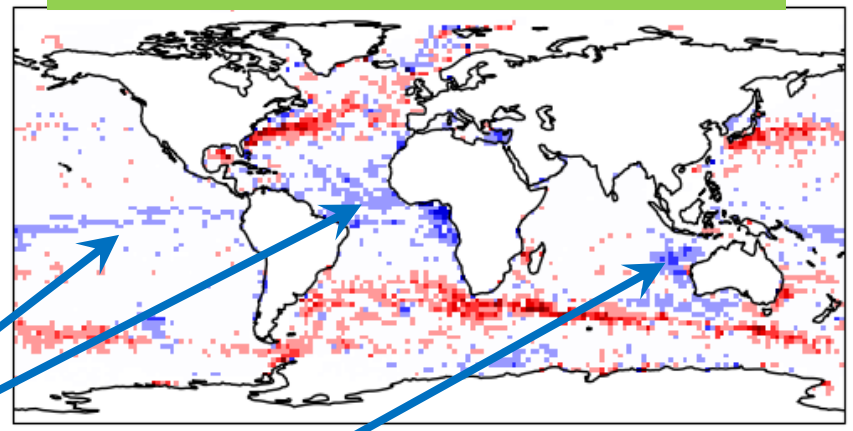
Add Altimeter and SST
Free - NoInsitu

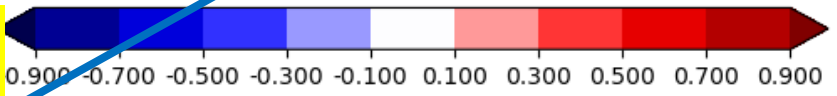





**Difference WRT Free RMSE**

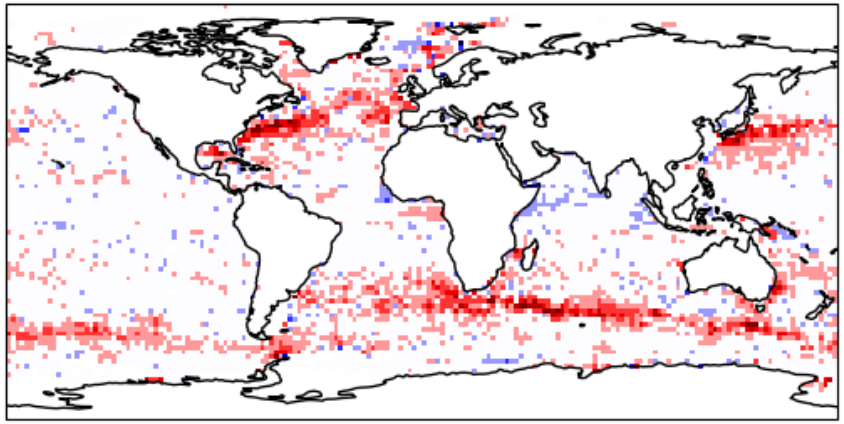
Further Add Non-Argo Profiles
Free - NoArgo






Only having observations (moorings) above 500m degrades solution below 500m

Further Add 40% Argo
Free - HalfArgo

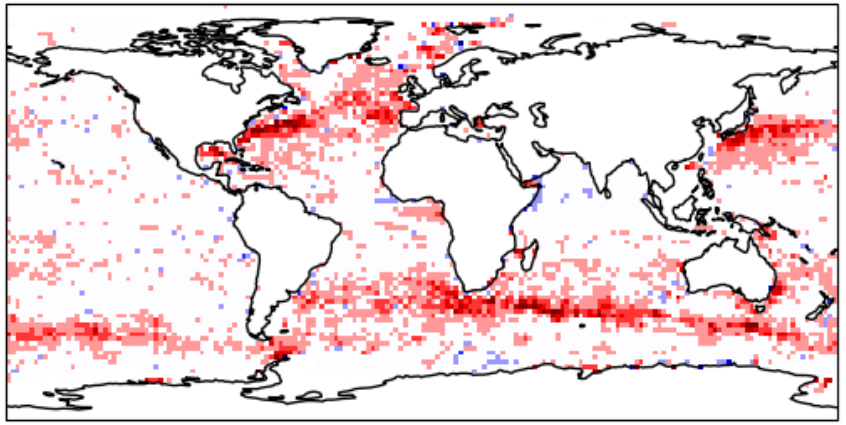


Upwelling also difficult

RED == Improvement (RMS SMALLER)

BLUE == Degradation (RMS Bigger)

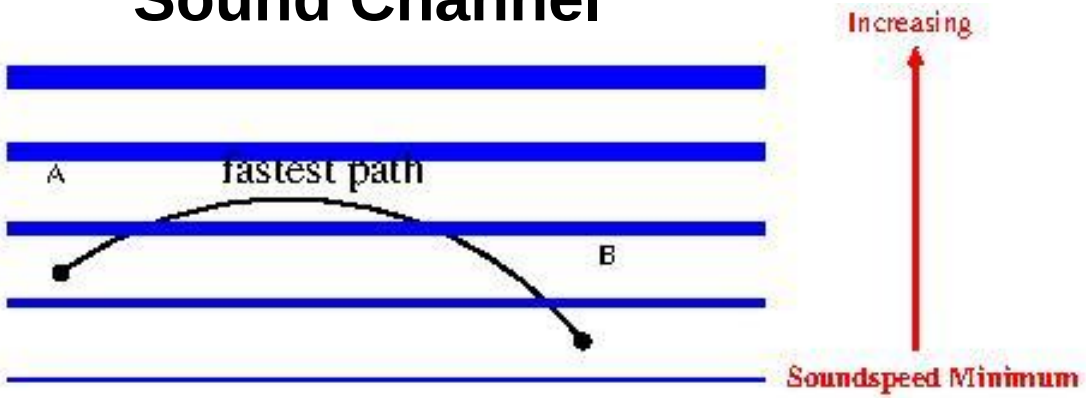
Further add full 80% Argo
Free - CNTL



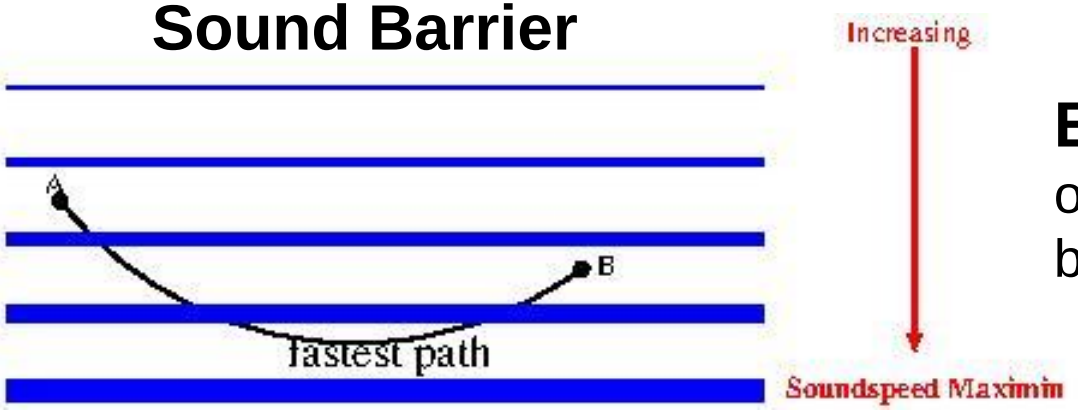
# SHALLOW WATER DUCTS

**Fermat's Principle:** Waves travel between two points along the path that requires the least time, as compared to other nearby paths

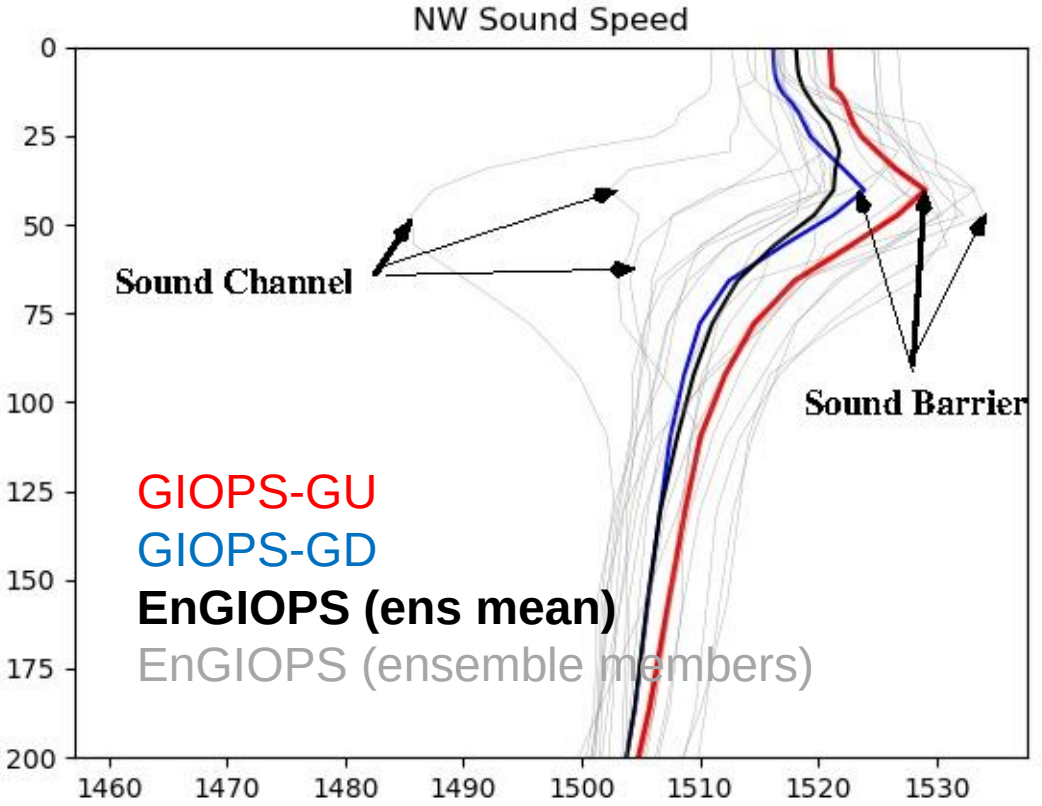
## Sound Channel




## Sound Barrier




*Typical* set of sound speed profiles for North Wall of Gulf Stream on 2020-10-09



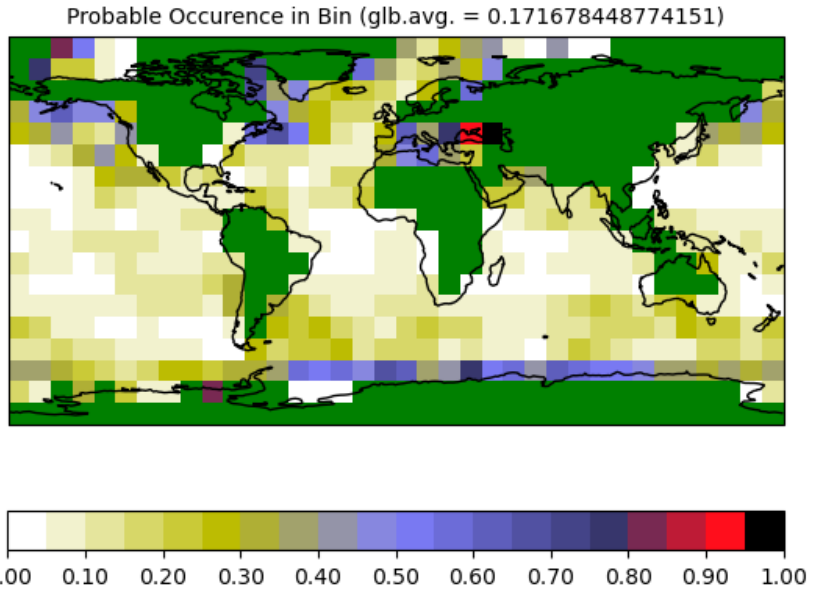

**Existence of Shallow Duct:** Determine if Model or Observation has local minimum in sound speed between 10-100m (using scipy.signal.find_peaks)

**Score**: Find Incorrect Forecasts: | M – O |

0 == Correct  1 == Incorrect

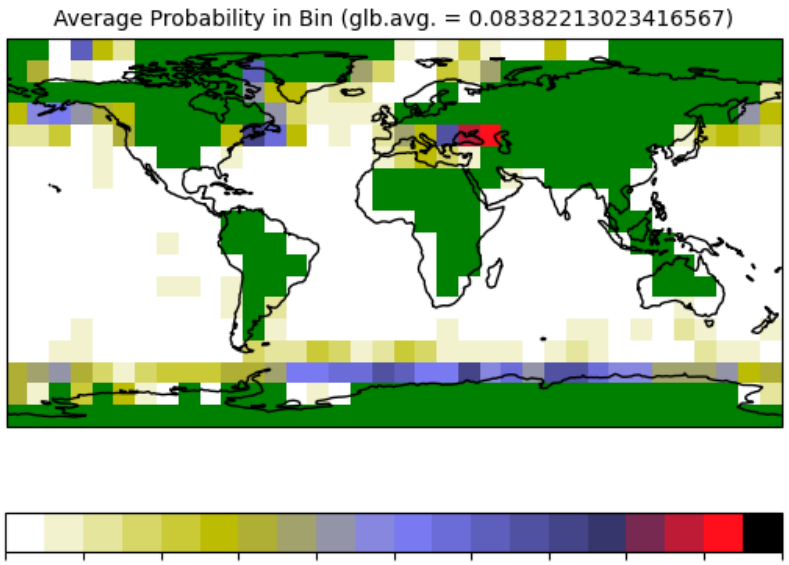
# SHALLOW WATER DUCTS

## Observed Frequency

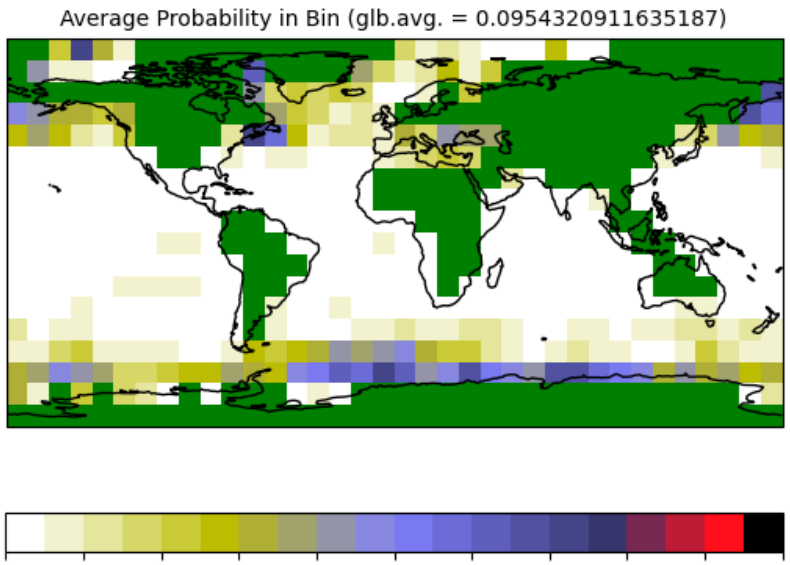



- See Tollefsen [2023]
  - https://cradpdf.drdc-rddc.gc.ca/PDFS/unc423/p816498A1b.pdf
- Measure of vertical gradients in T and S.
- Modelled Frequency of ducts roughly matches observed occurrence
  - At least in high latitudes / extra-tropics
- Missing something in tropics (surface salinity?)

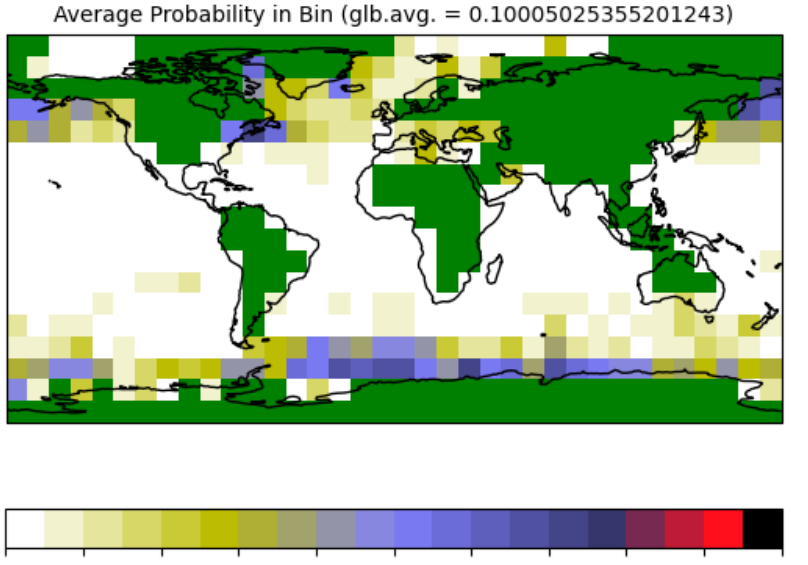
## Frequency in CNTL




## Frequency in NoArgo




## Frequency in Free

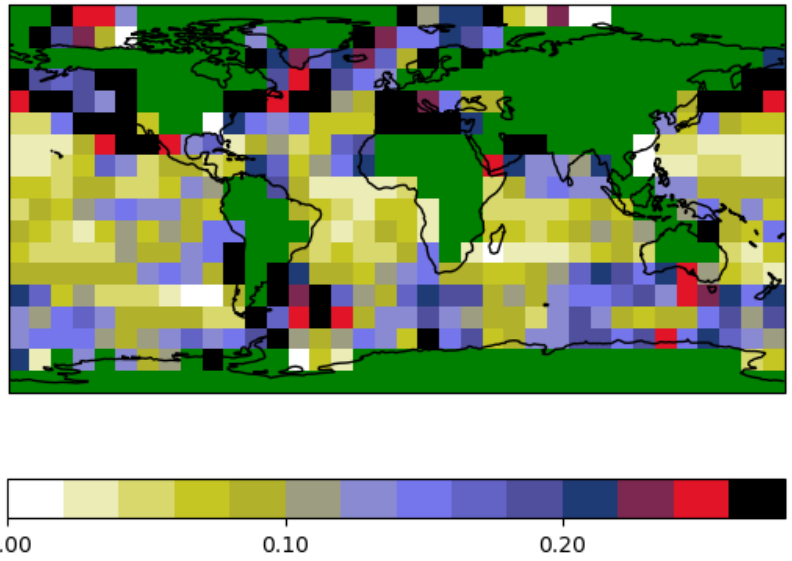


# SHALLOW WATER DUCTS

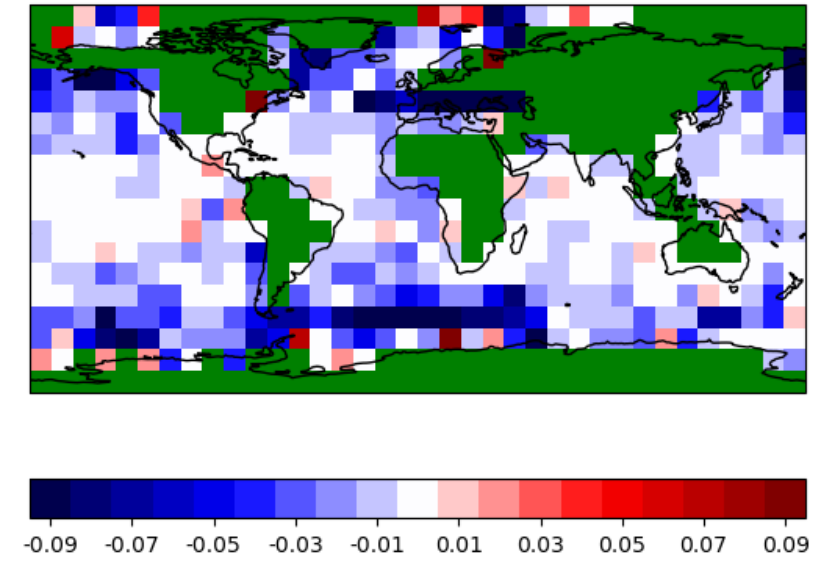
- Observations (CNTL vs Free) improve ability to detect sound channels.
- Profiles (NoArgo vs CNTL) and to lesser extent altimeter (NoAlt vs CNTL) provide information.
- Altimeter (NoAlt) provides about the same information as having half of ARGO array (HalfArgo)

| EXPT | global |
|---|---|
| | % missed |
| CNTL | 13.98 |
| NoSST | 14.08 |
| NoAlt | 14.39 |
| HalfArgo | 14.49 |
| NoArgo | 15.74 |
| Free | 16.29 |
| SSTOnly | 17.01 |

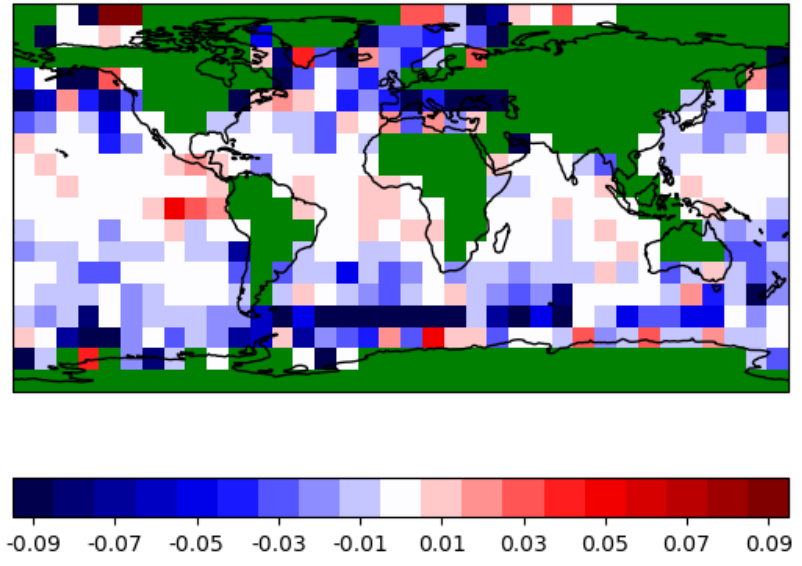
**fraction missed in CNTL expt**



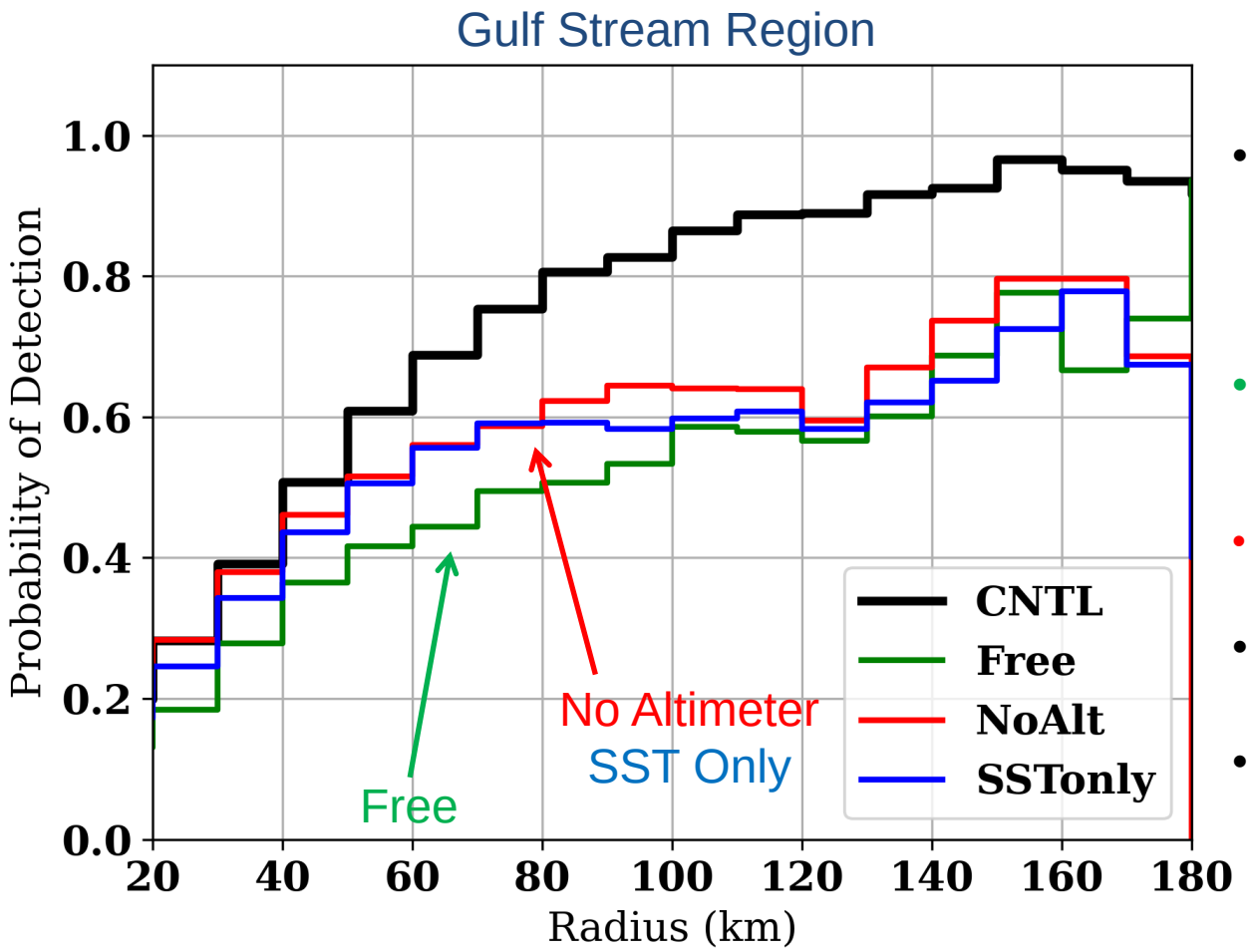

**fraction missed in CNTL - NoArgo**




**fraction missed in CNTL - Free**



# EDDY TRACKING




- Apply py-eddy tracker [Mason et al., 2014], a closed-contour approach over Northwest Atlantic
- Once eddies identified in obs (AVISO) find model matches using cost function based on amplitude, radius and distance.
- Free Run – should be random (but up to 80% detection).
  - **RANDOM BASELINE**
- Removing Altimeter (NoAlt vs CNTL) removes most of ability to detect eddies.
- But eddies < 100km are still detected (NoAlt vs Free)
- Position of small eddies are being given through the SST (SST only) observations.
  - NoAlt (SST+Insitu)
  - SSTonly (only SST)
- Profile data (NoAlt) may contribute to the detection of larger eddies (but the statistical significance is weak),.

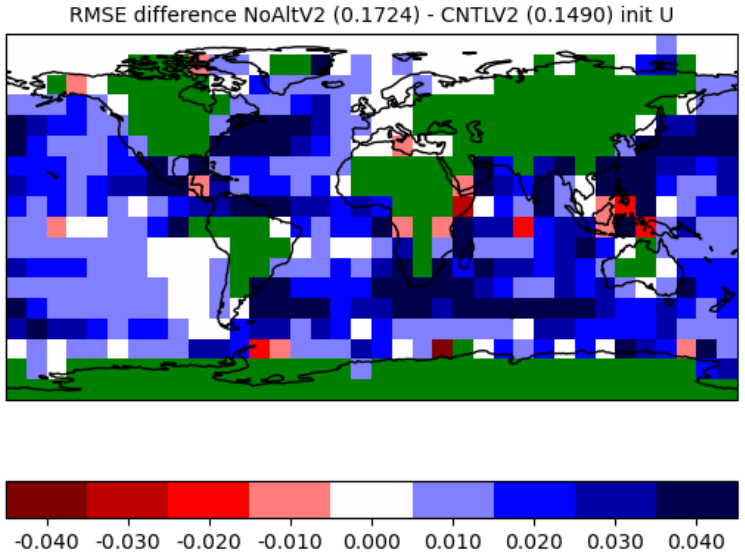
See Smith and Fortin [2022]
https://doi.org/10.1016/j.ocemod.2022.101982

# CURRENT VALIDATION

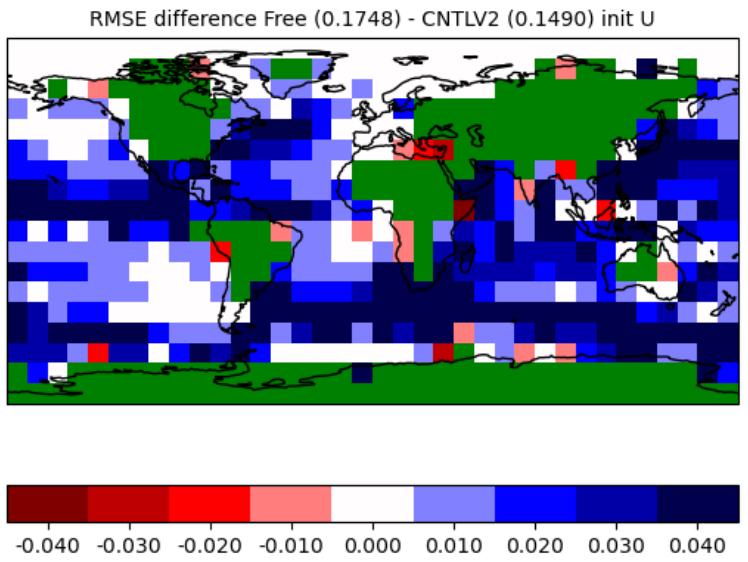
| EXPT | Speed | U | V |
|---|---|---|---|
| | rmse | rmse | rmse |
| | m/s | m/s | m/s |
| CNTL | 0.1472 | 0.1490 | 0.1413 |
| SSTonly | 0.1666 | 0.1693 | 0.1592 |
| NoAlt | 0.1611 | 0.1724 | 0.1647 |
| Free | 0.1734 | 0.1748 | 0.1655 |

- **Comparison against 15-m drogued drifters (as in Aijaz et al., 2023)**
- **Removing Altimeter** (both NoAlt and SSTonly; Note: NoAlt == SST+insitu T/S) substantially reduces ability to predict currents.

U RMSE difference NoAlt - CNTL




U RMSE difference Free - CNTL



# SUMMARY

- ECCC is participating in OceanPredict SynObs project to investigate importance of various observing systems to ocean analysis systems.
- We have finished all observing system (OSE) data withholding experiments using GIOPS system.
- Initial results show importance of each of the in-situ profile, altimeter and SST observations.
- Novel and independent validation techniques can show importance of observations beyond just testing fits against observations.
  - Eddy tracking and Current Verifications show importance of Altimeter with secondary importance of SST observations.
  - Ability to detect shallow water ducts – and therefore gradients in T/S profiles shows importance of assimilating profiles with secondary importance of altimeter observations.

CONCEPTS

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