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IMPACT OF OCEAN SUB-SURFACE OBSERVATIONS ON COUPLED ATMOSPHERE-OCEAN 15 DAY PREDICTIONS

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Environment and Climate Change Canada

Special Thanks:

Yosuke Fujii (SynObs Project Lead)

Japan Meteorological Agency

OceanPredict

Advancing the science of ocean prediction

SynObs Project

SynObs & Ocean Observing Co-Design Workshop

24 August, 2026, 13:55-14:10 JST

Mutsu, Japan 24-28 August 2026

Canada

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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 Ocean International system
  - Reduced order extended Kalman 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\
    - Bogus T/S observations added under ice / in river runoff / Tropics :: Also Bogus U/V
  - Along track sea level anomaly (SLA) satellite observations (AVISO).
  - Gridded SST analysis (satellite/in-situ data).
    - Also used by atmosphere.
  - A sea ice analysis is blended in during the IAU.
- For daily forecasts, 7-1d updates (SST only) provide initial conditions

SMITH et al, 2016



Smith et al, 2016, QJRMS

Sea ice forecast verification in the Canadian Global Ice Ocean Prediction System

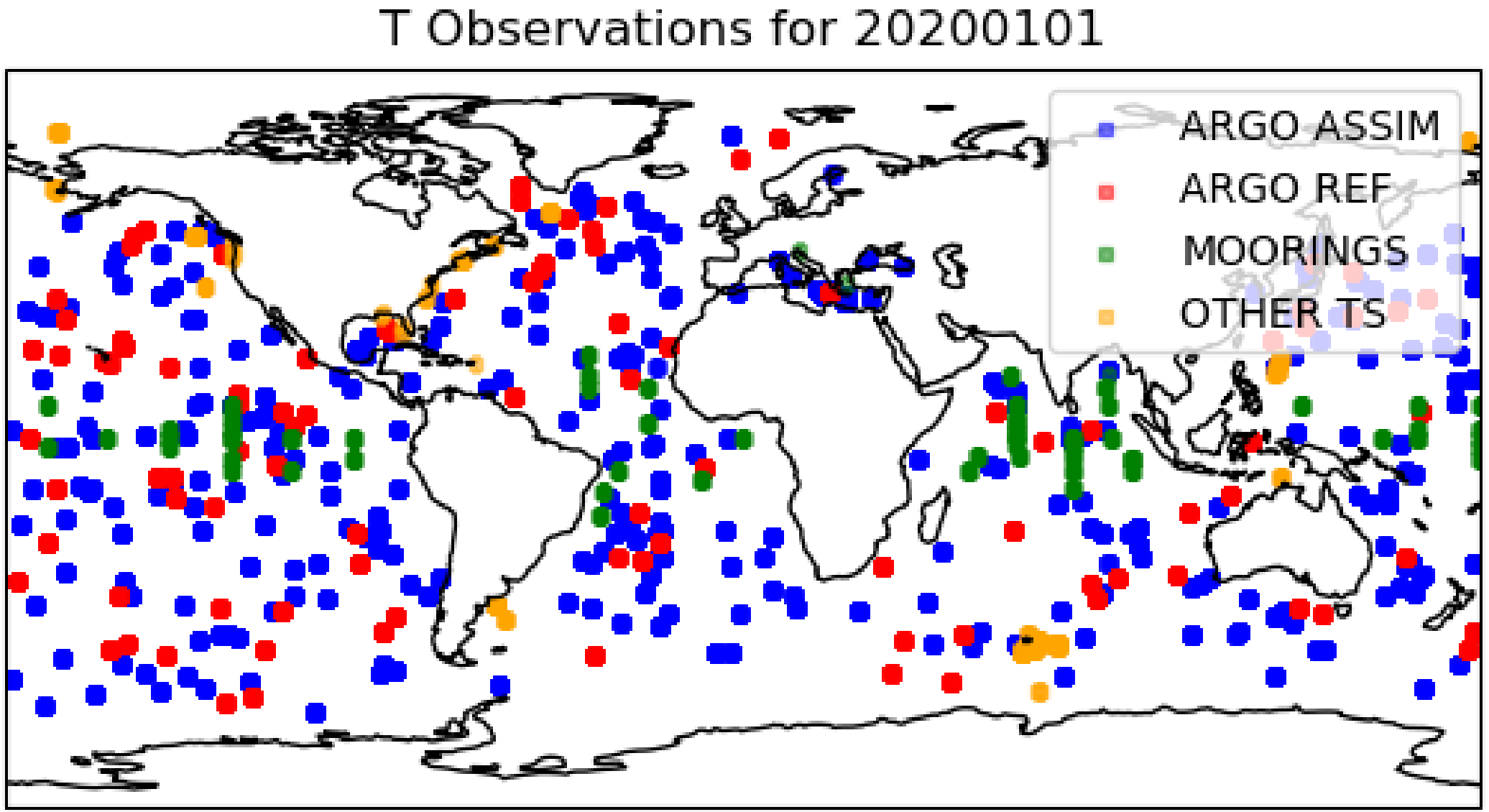
SYNOBS EXPERIMENTS

Configuration of 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

- https://oceanpredict.org/synobs
- The Synergistic Observing Network for Ocean Prediction (SynObs) project seeks to find synergies between ocean observations and ocean prediction through multi-system OSEs.
- OSE: Observing System Experiments: An ocean analysis -- or any data assimilation system -- is run using different observing networks to see how this changes the analysis.
  - Usually the observing system is changed by removing or adding some or all of a particular set of observations.
  - 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

T PROFILE OBSERVATIONS – 2020-01-01



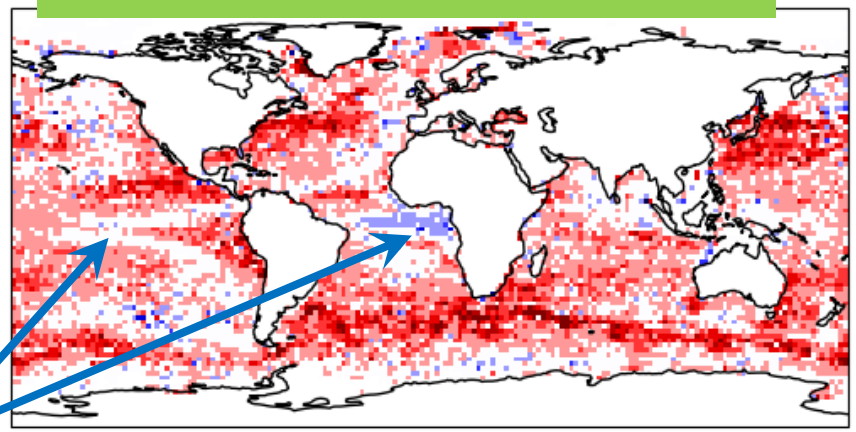
ARGO MOORINGS OTHER

IMPACT OF ARGO AND OTHER PROFILES ON NEAR SURFACE

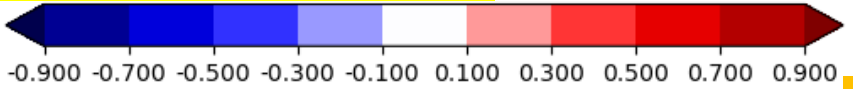
0-200m

Difference WRT Free RMSE

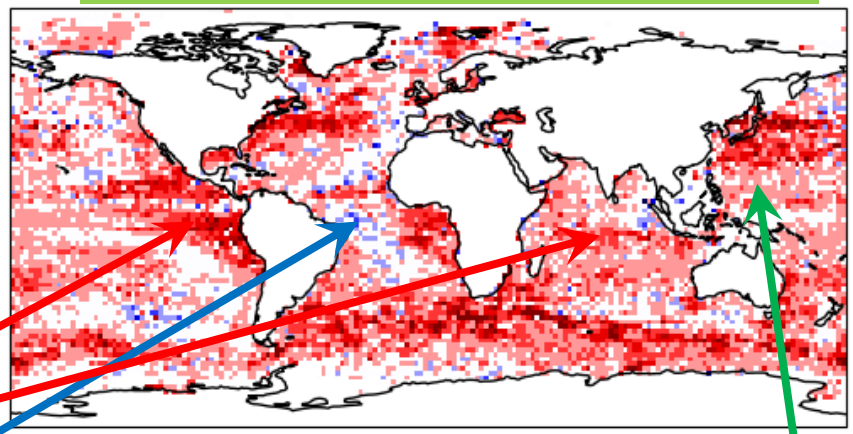
Add Altimeter and SST
Free - NoInsitu



f = 0 (Altimeter does not help!)



Add Non-Argo Profiles/Moorings
Free - NoArgo



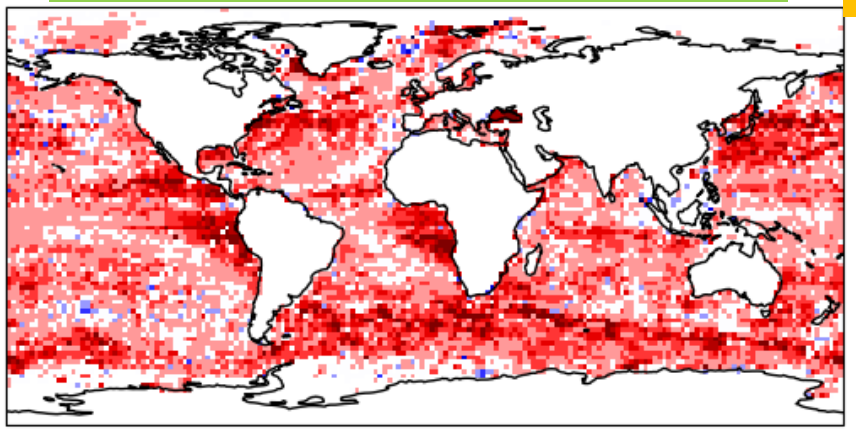
Moorings Help



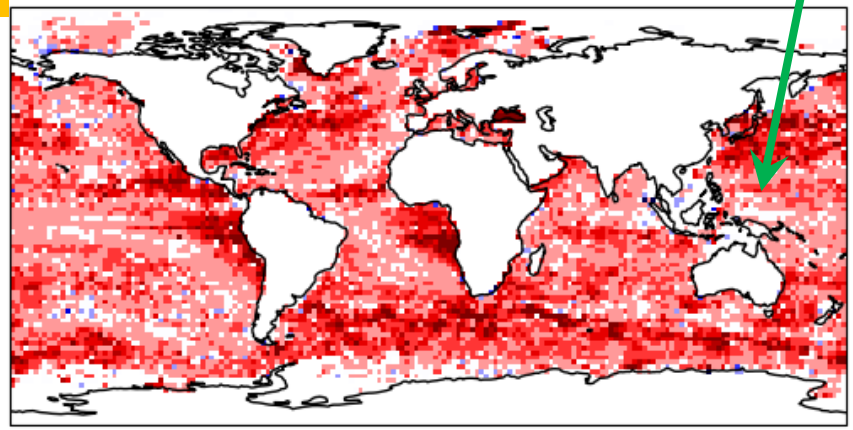
Pacific Warm Pool Improved

Atlantic (PIRATA) moorings not equatorially concentrated (hurricane)

Further Add 40% Argo
Free - HalfArgo



Further add full 80% Argo
Free - CNTL



RED == Improvement (RMS SMALLER)
BLUE == Degradation (RMS Bigger)

For SubSurface see hidden slides (pdf)

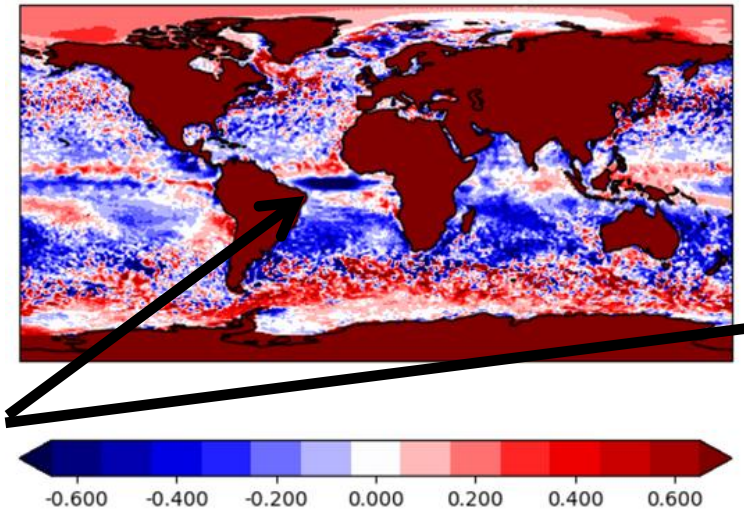
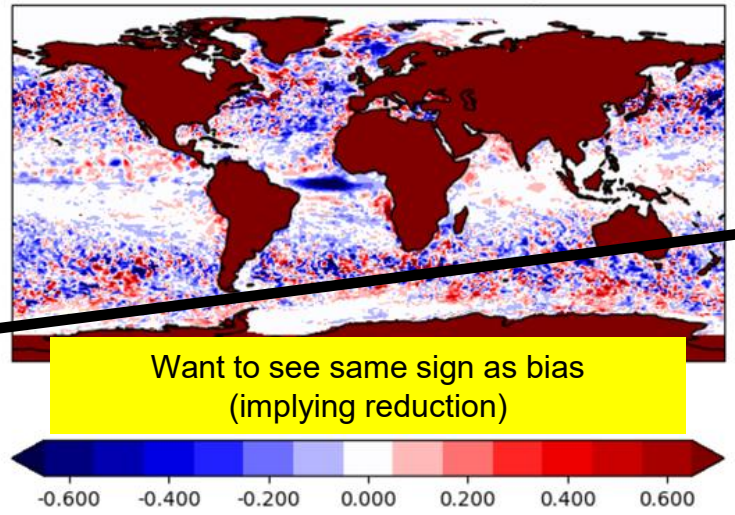
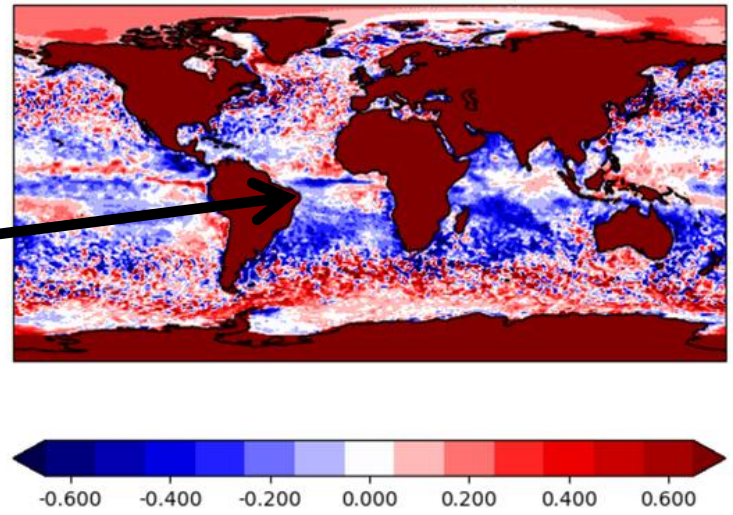
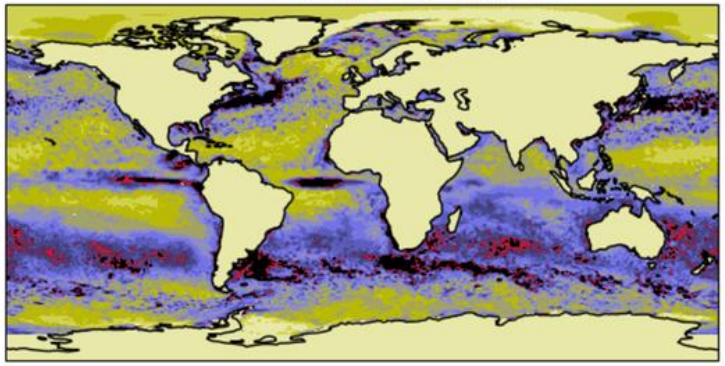
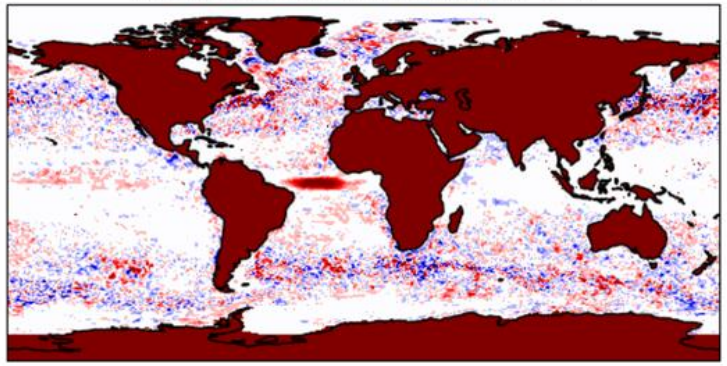
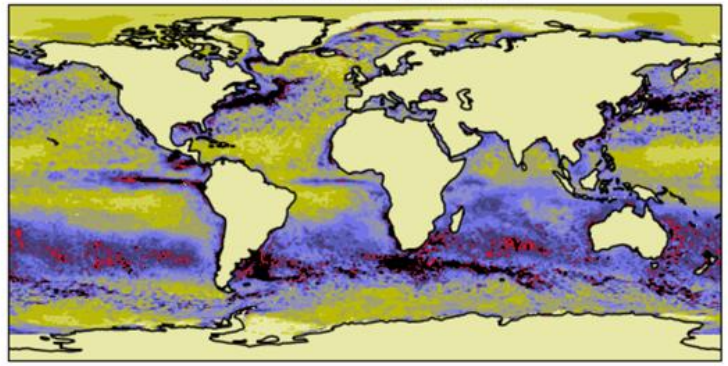
COUPLED FORECASTS

- Performed Coupled forecasts for
  - CNTL (80% Argo)
  - No Argo (0% Argo, but other T/S)
  - No Altimeter
- Use 21 member, 15 d forecasts of GEPS coupled system
  - Peterson et al 2022, QJRMS, **doi: 10.1002/qj.4340**
- Ensemble validation of
  - Nighttime SST against initialized CMC-SST (CRPS/RMSE/BIAS)
  - RMSE vs spread verification against ERA5 surface pressure
  - atmospheric radiosonde observations (GZ/T) on pressure levels (CRPS)
- Analysis over ~Nov/Dec/Jan/Feb (14/10/2021 – 1/3/2022)
- Also have forecasts over MAM /JJAS
  - 1/3/2022 – 5/31/2022 & 1/6/2022 – 30/9/2022 -- Tropical Cyclone Analysis?

Peterson
QJRMS 2022

SST ERRORS FOR NO ARGO @ 15D

20211014 – 20220228 (NDJF)

	No Argo	No Argo - Control	Control
BIAS	Mean Error for HNoArgo -- Lead Day 15	Mean Error for Lead 15d Difference HNoArgo - CNTL	Mean Error for HCNTL -- Lead Day 15
			
	-0.600 -0.400 -0.200 0.000 0.200 0.400 0.600	-0.600 -0.400 -0.200 0.000 0.200 0.400 0.600	-0.600 -0.400 -0.200 0.000 0.200 0.400 0.600
RMSE	RMSE for HNoArgo -- Lead Day 15	RMSE for Lead 15d Difference HNoArgo - CNTL	RMSE for HCNTL -- Lead Day 15
			
	0.000 0.100 0.200 0.300 0.400 0.500 0.600 0.700 0.800 0.900 1.000	-0.600 -0.400 -0.200 0.000 0.200 0.400 0.600	0.000 0.100 0.200 0.300 0.400 0.500 0.600 0.700 0.800 0.900 1.000

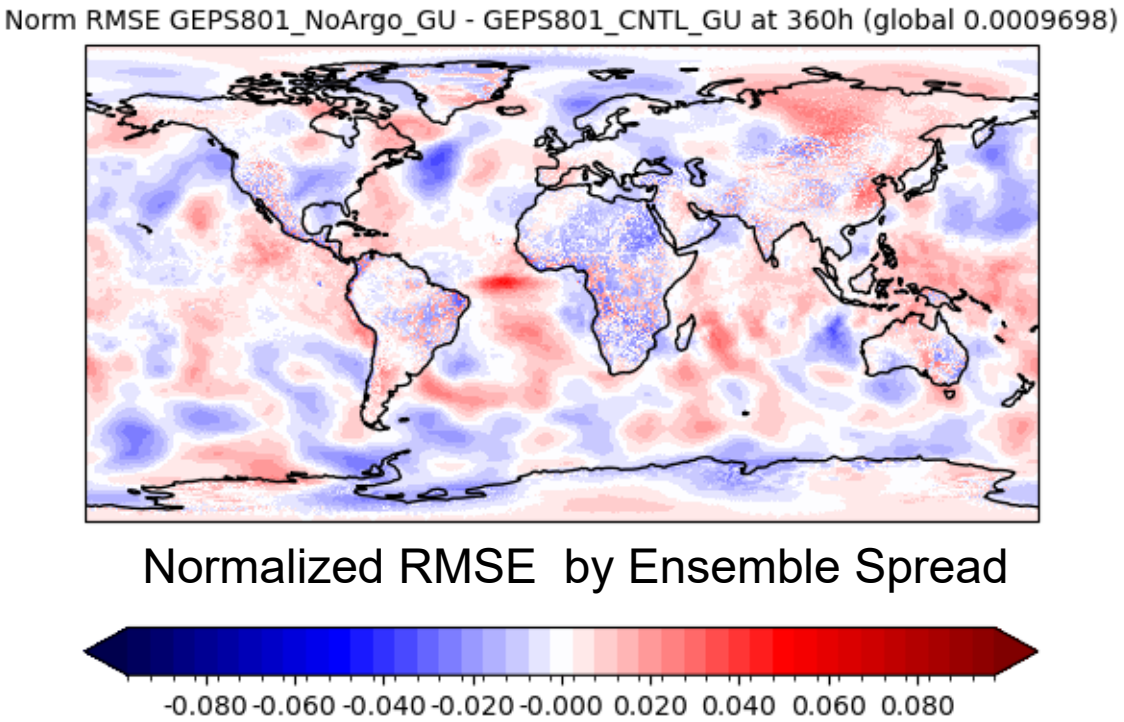
Substantial, 0.5°C, bias in tropics and summer hemisphere

Made worse in NoArgo

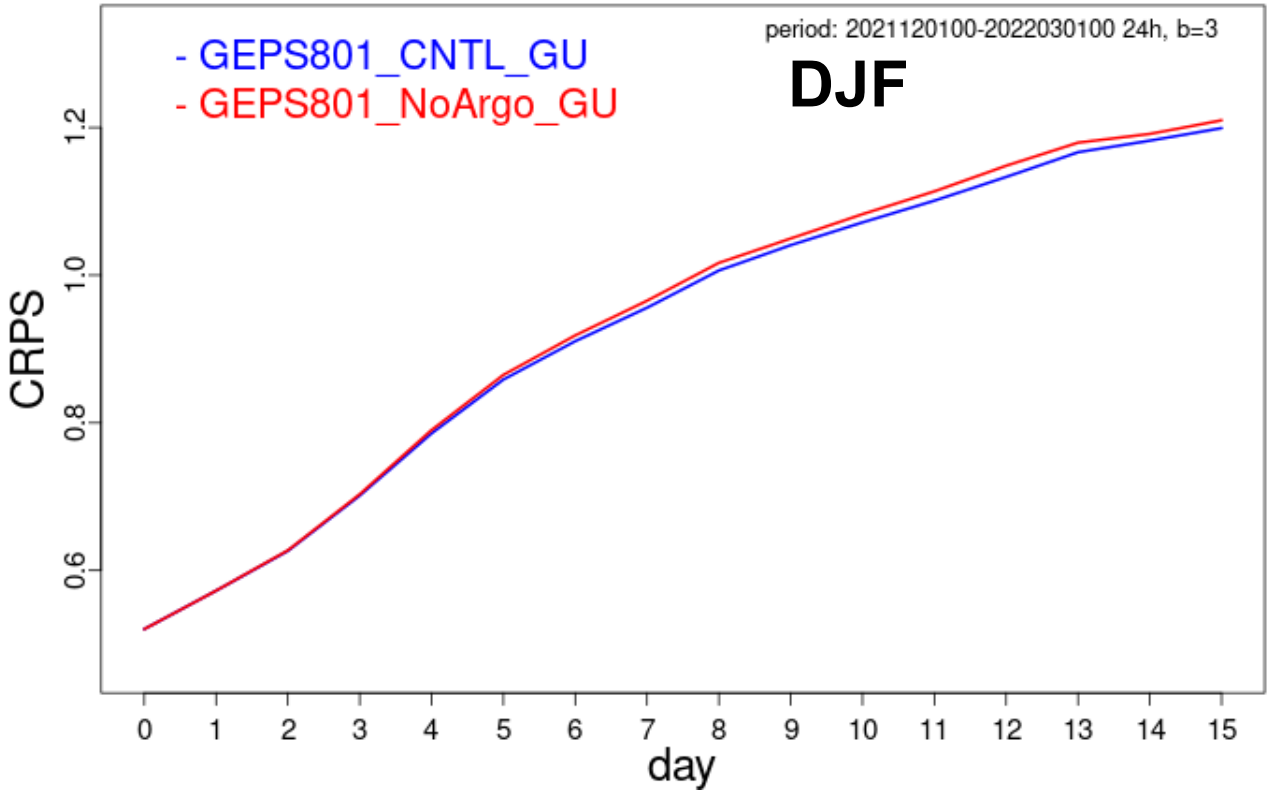
Want to see same sign as bias (implying reduction)

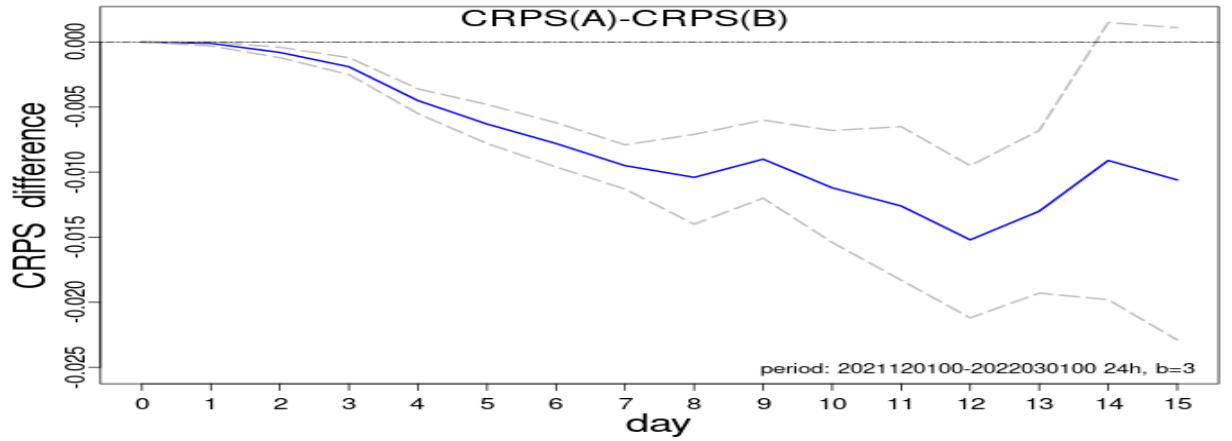
RED: Better Assimilating Argo

ATMOSPHERIC EFFECTS – NO ARGO



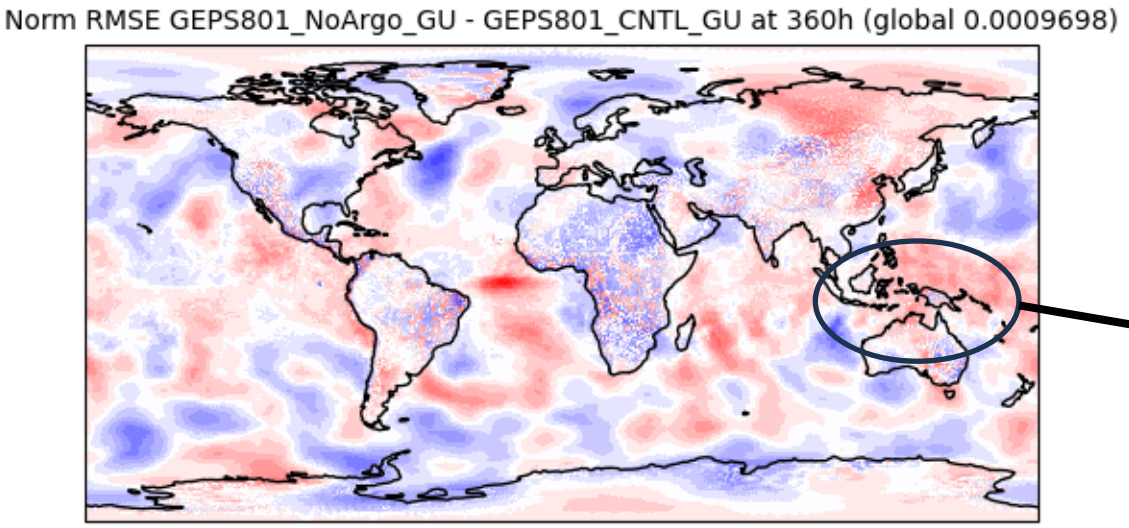
Normalized RMSE by Ensemble Spread

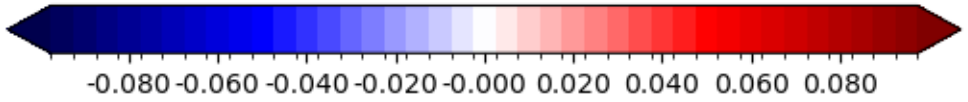


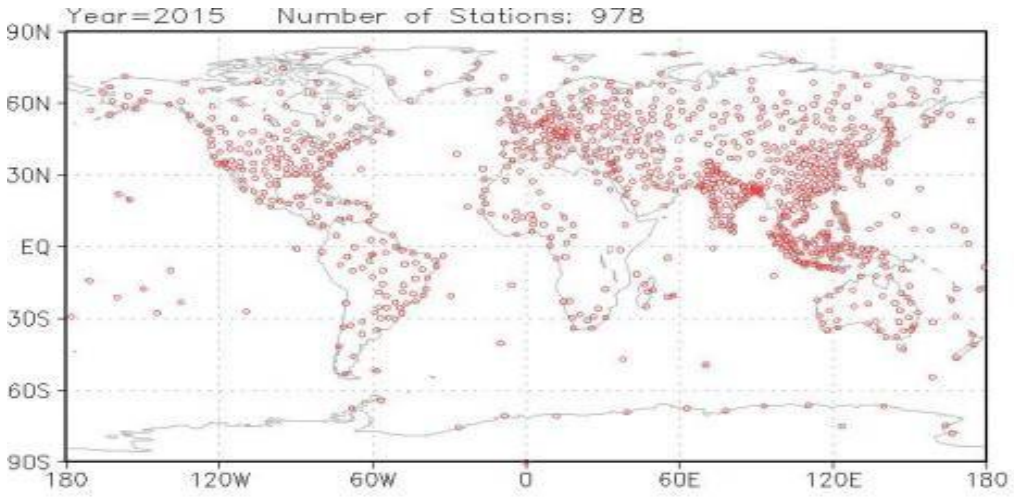


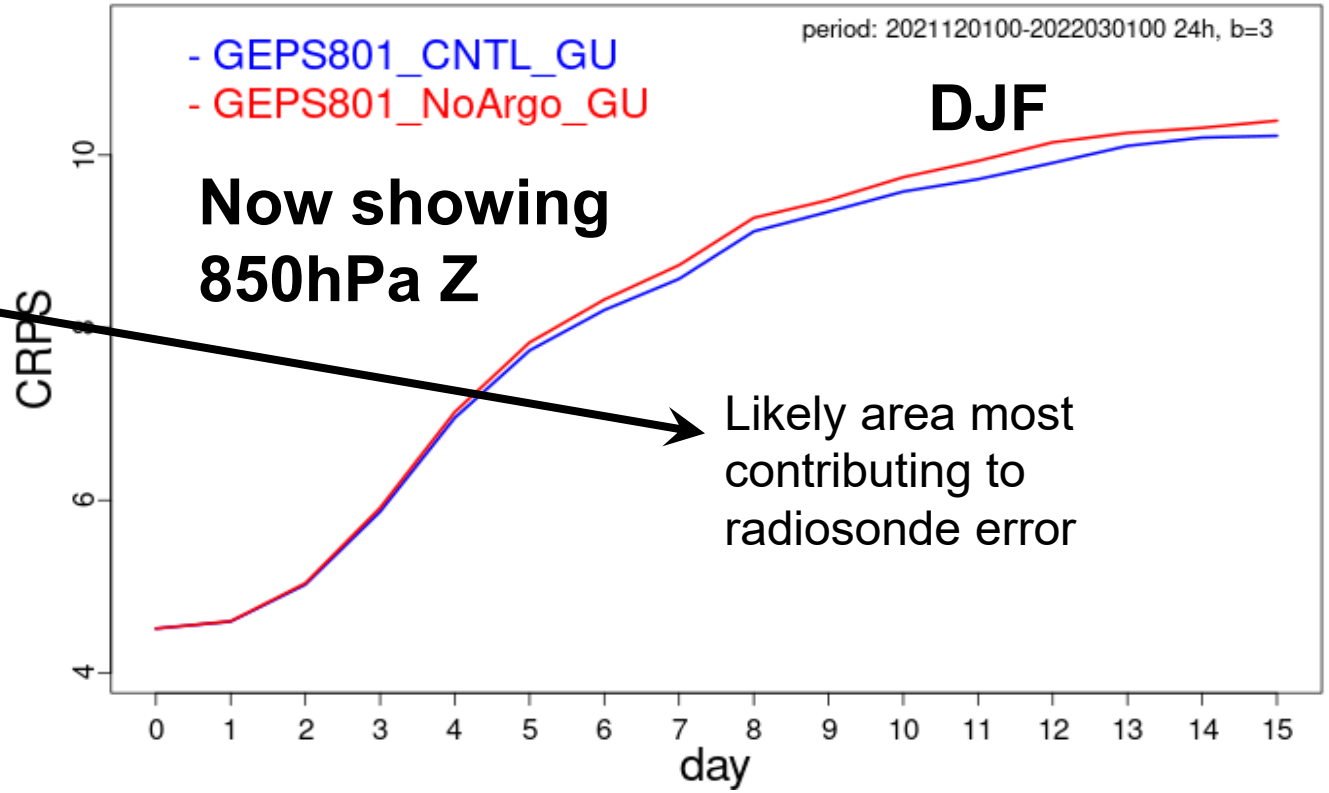
- LEFT: Normalizing RMSE with respect Ensemble Spread highlights significant error
- RIGHT: CRPS (smaller better) of MSLP(Pa) geopotential height
  - In tropics 20°S – 20°N
  - Bottom plot shows significance of difference.
  - RMSE show similar improvement
  - From radiosonde observations (see flip slide).

ATMOSPHERIC EFFECTS – NO ARGO

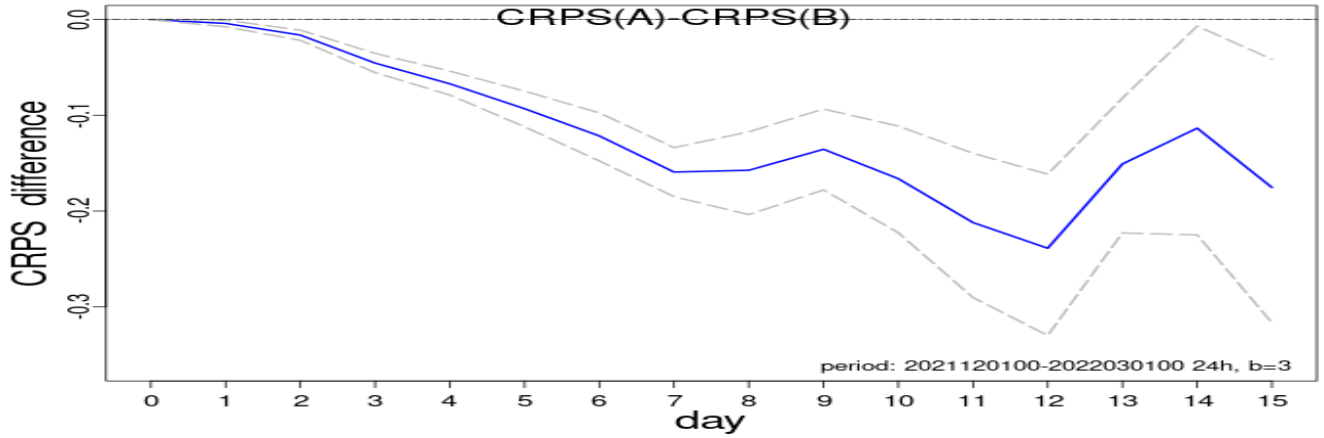




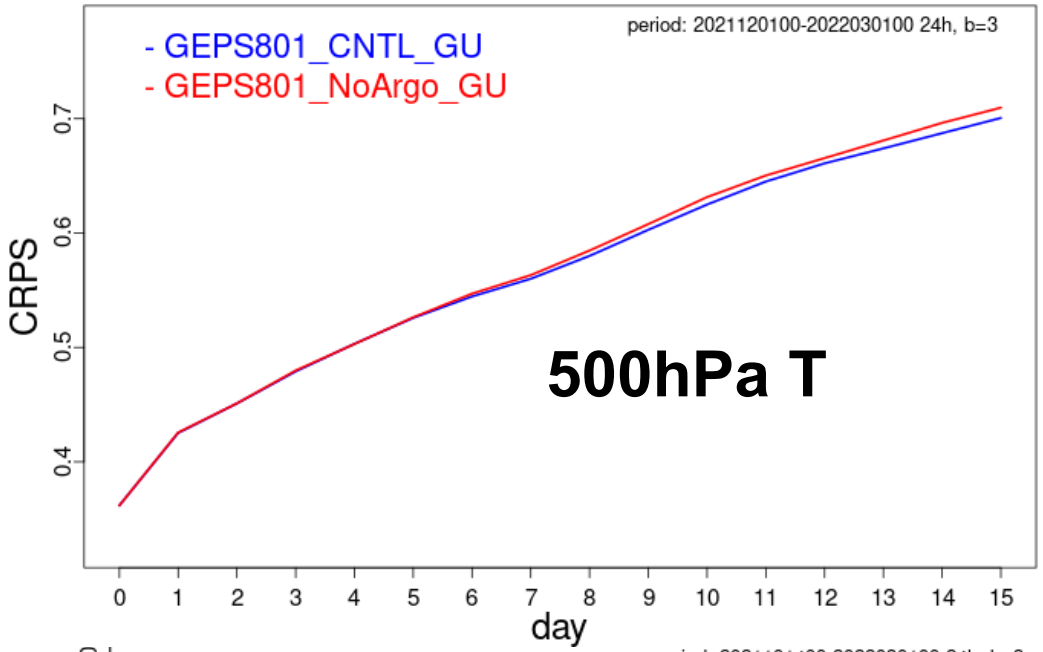


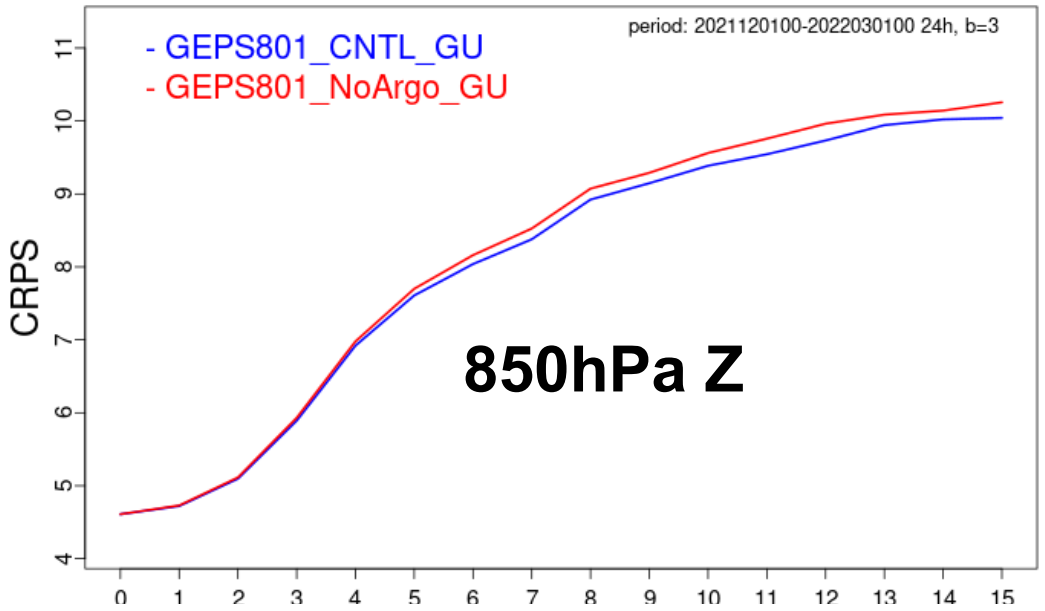


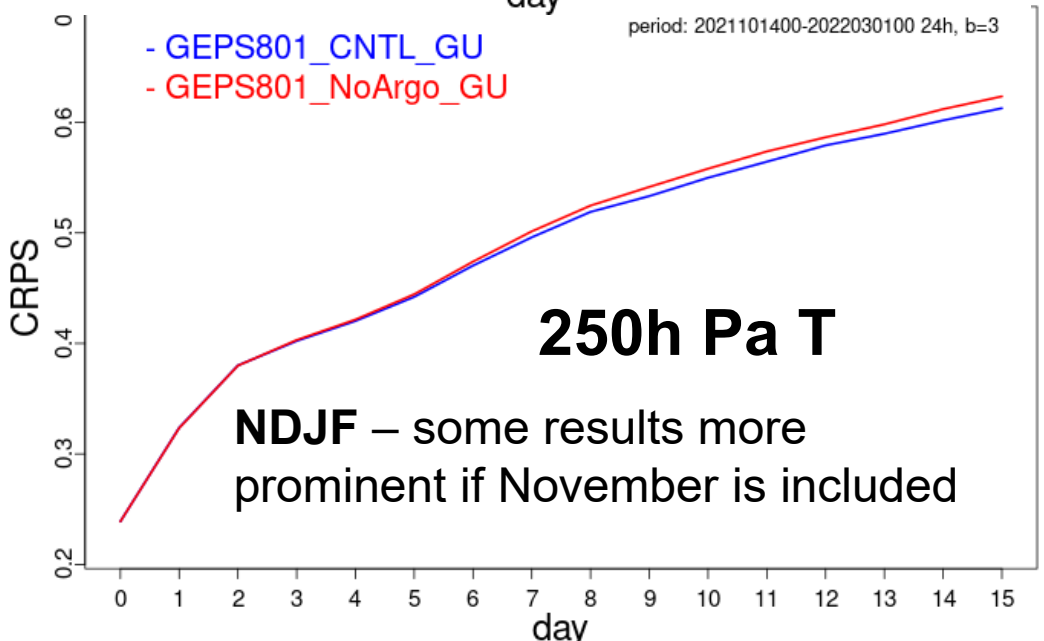
Likely area most contributing to radiosonde error



ATMOSPHERIC EFFECTS – NO ARGO -- DJF

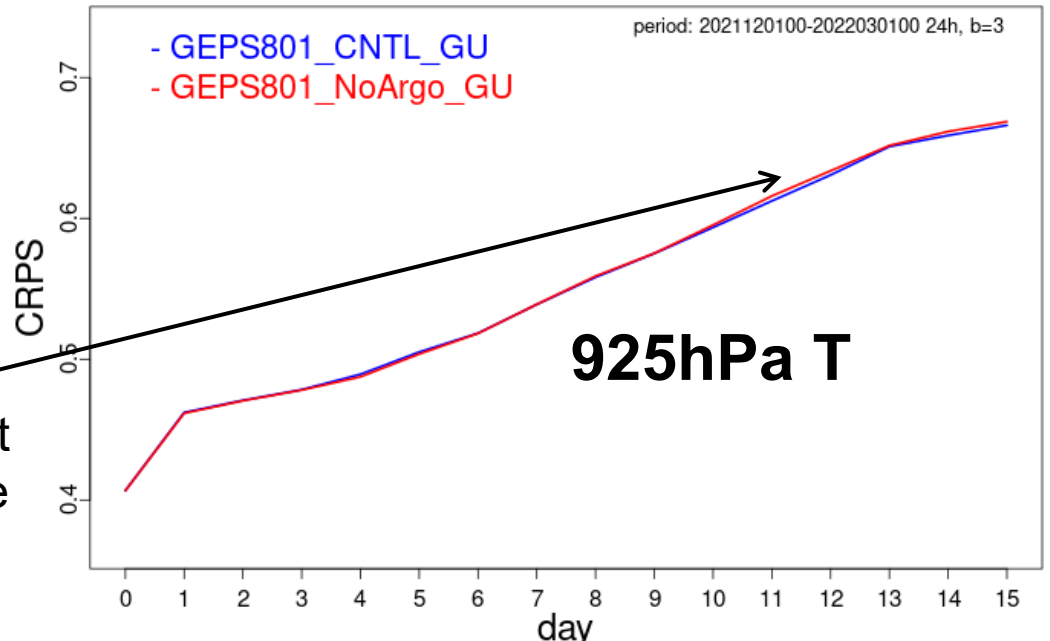






NDJF – some results more prominent if November is included

Continues Up Higher into Atmosphere



Significant Difference

SST ERRORS FOR NO ARGO @ 15D

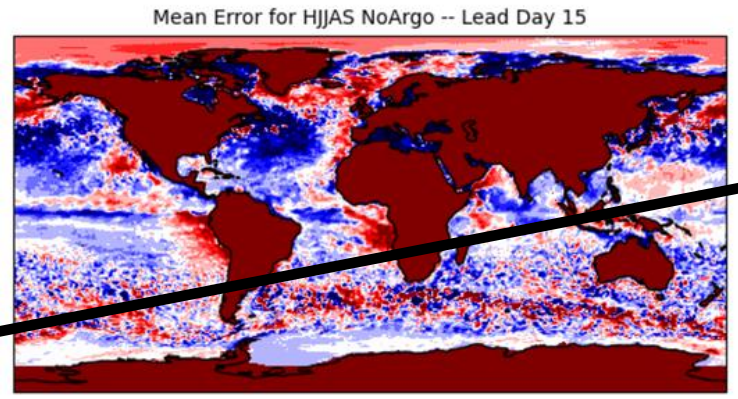
20220601 – 20220930 (JJAS)

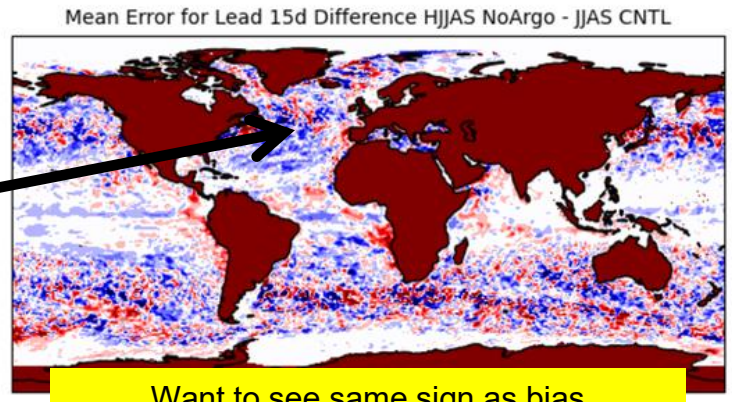
No Argo

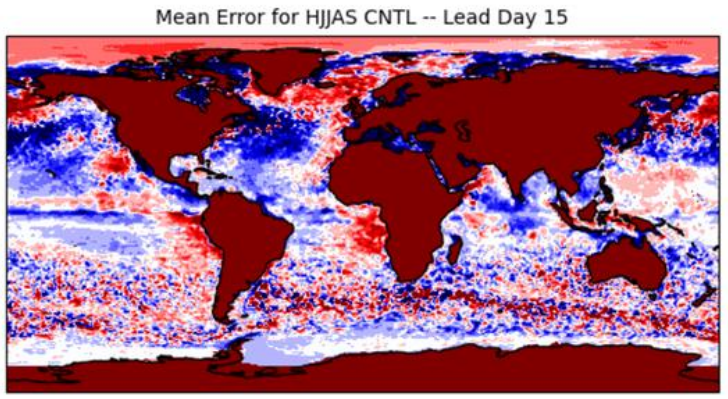
No Argo - Control

Control

BIAS

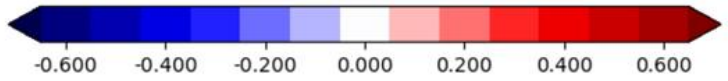


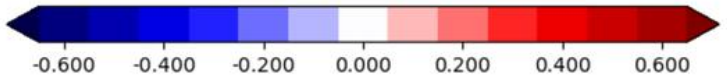


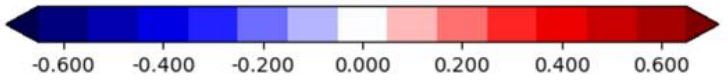


Reduction of bias/rmse in North Atlantic with **Argo**

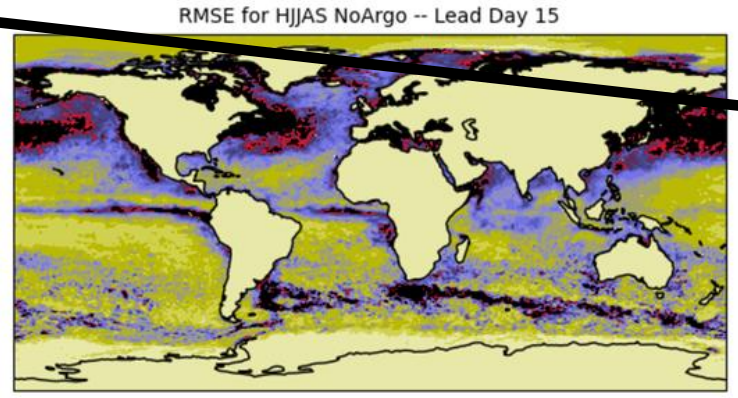
Want to see same sign as bias (implying reduction)

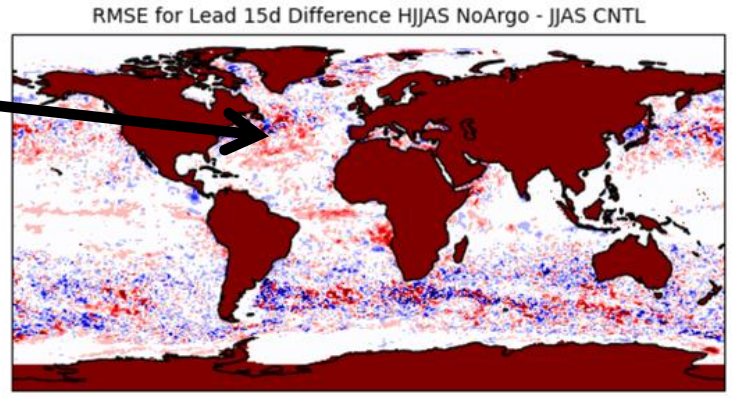


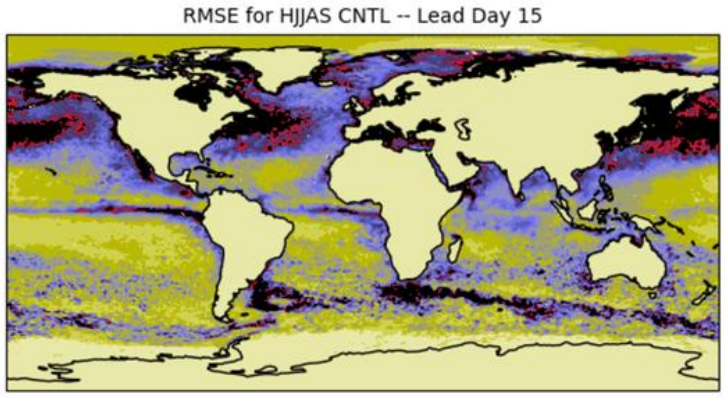




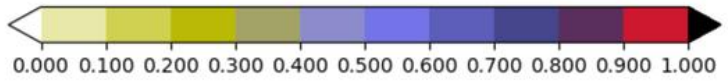
RMSE

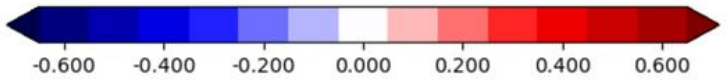


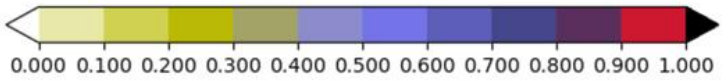




RED: Better Assimilating Argo



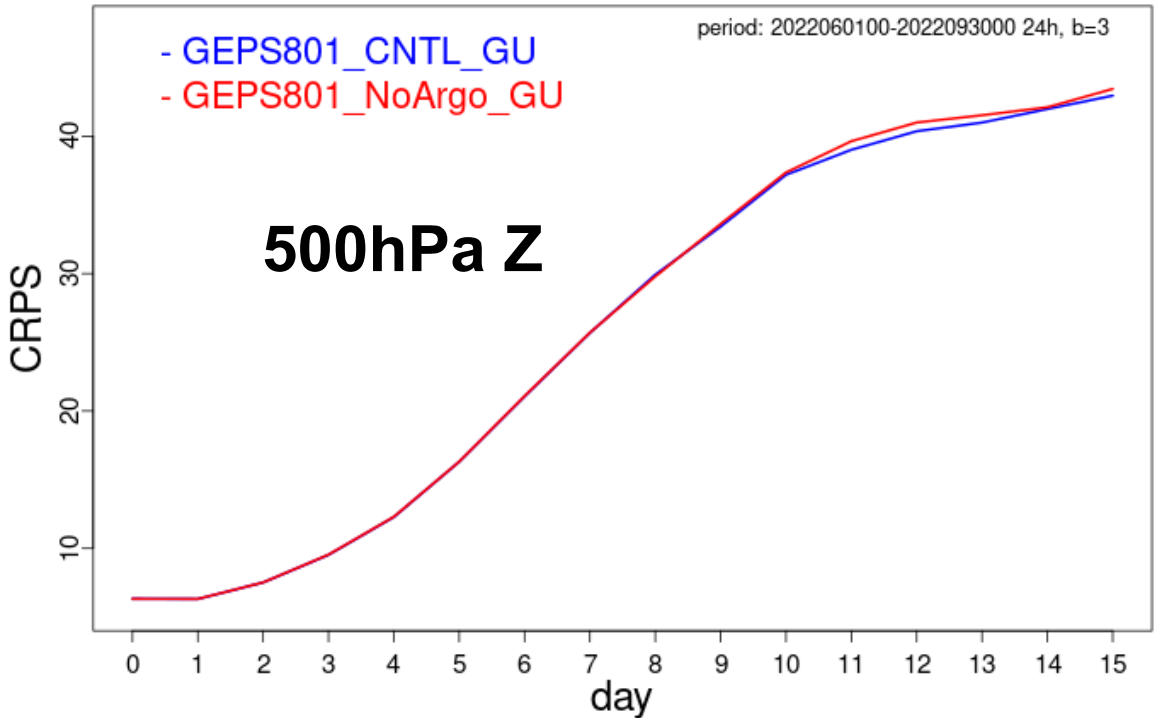


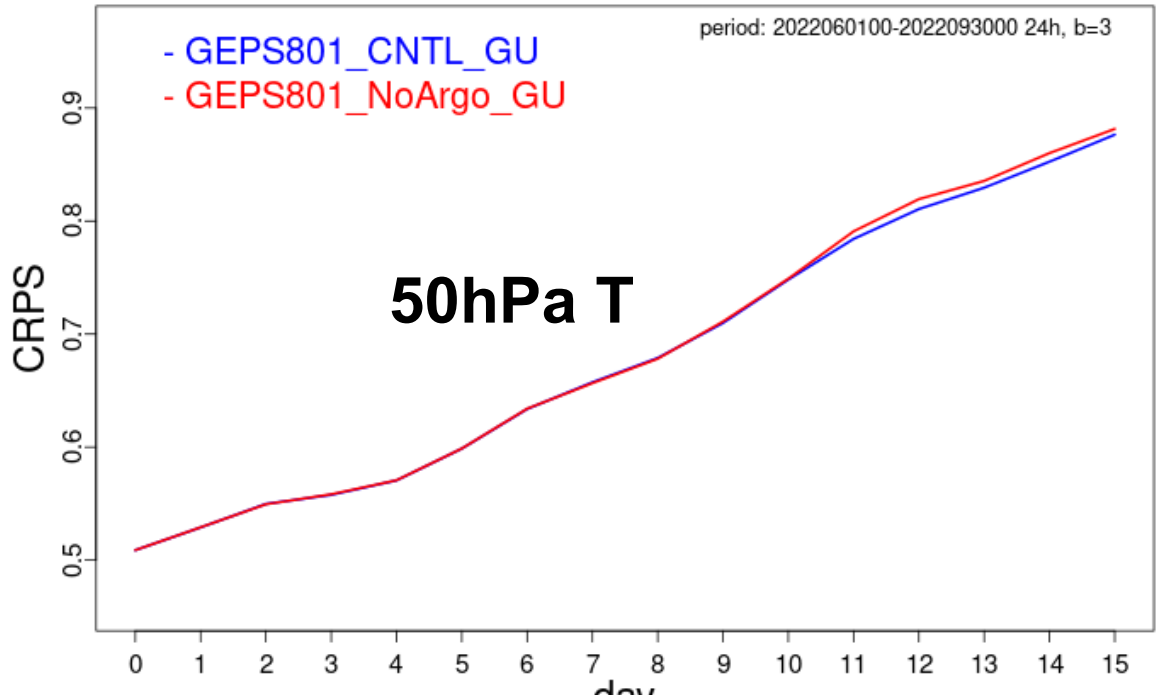


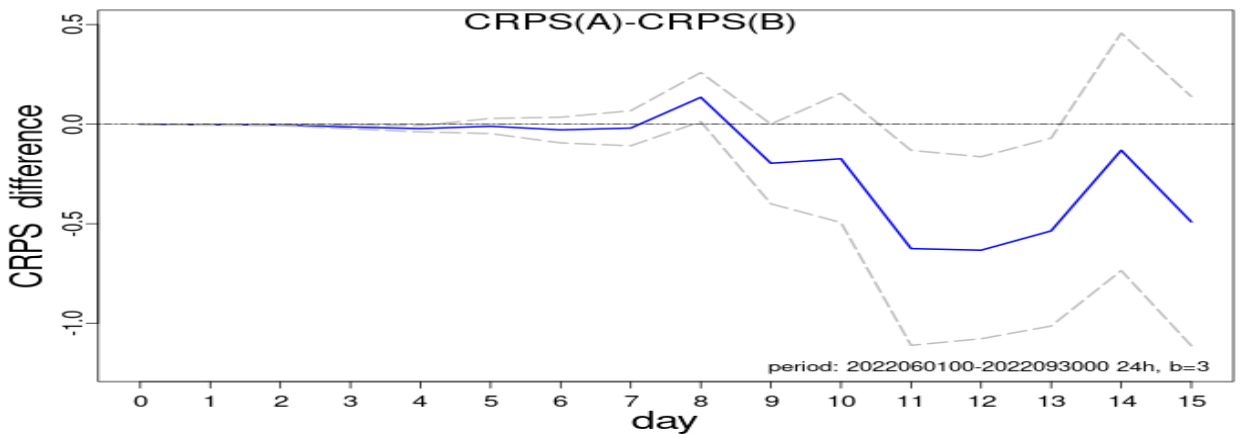
ATMOSPHERIC EFFECTS – NO ARGO -- JJAS

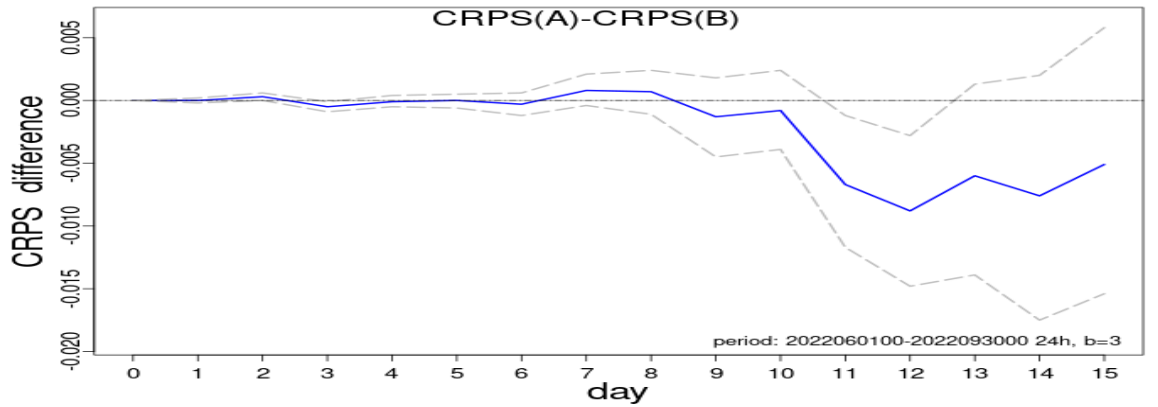
Oceanic SST improvement in Atlantic

⇒Atmospheric Improvement over Europe









SUMMARY

- ECCC participated in OceanPredict SynObs project to investigate importance of various observing systems to ocean analysis systems.
- Initial results show importance of each of the in-situ profile, altimeter and SST observations.
- Used Ensemble Coupled Prediction System (GEPS) to investigate impact on 15d predictions.
- Concentrated on DJF 2021/22 results
  - Improvement in Tropics not seen for JJAS, but some intriguing full column improvement over Europe perhaps linked to Atlantic SST improvements?
  - MAM (extra slides) shows improvement in tropical GZ, but does not propagate into meteorological relevant variables.
  - Some extra slides show effect of altimeter observations – but they are largely in the extratropics and hard to sort out from atmospheric chaos.
- Assimilation of Argo reduces SST bias in forecast, particularly in Tropics (and summer hemisphere)
  - Downstream effects on MSLP, Temperature and geopotential height throughout the atmosphere – but most improved between 500 and 250 hPa.
  - Improves fit to radiosonde – despite these being largely over land masses.
    - Still likely maritime regions where improvements are to be found.
    - Does altimeter improve results along North American eastern seaboard? Needs further investigation (1st extra slide)
  - Would still like to undertake (ensemble) tropical cyclone analysis (but never find time!)
    - Most of relevant data taken off spinning disk in recent computer upgrade (i.e. have to retrieve from tape archive)

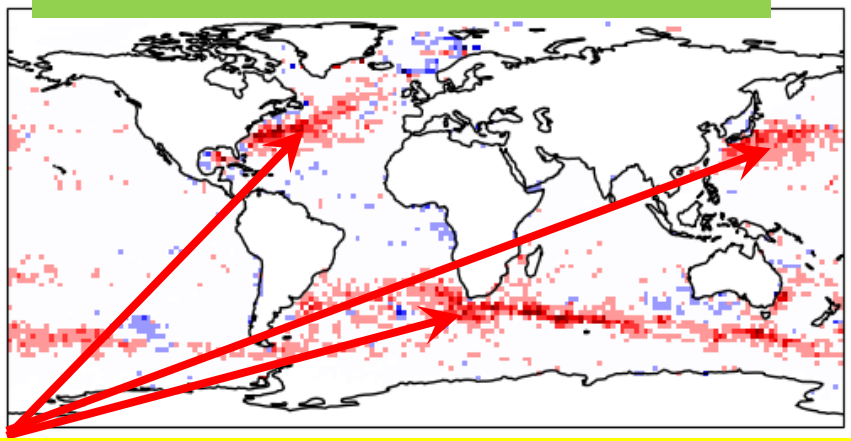
EXTRA SLIDES

IMPACT OF ARGO AND OTHER PROFILES ON DEEP WATER

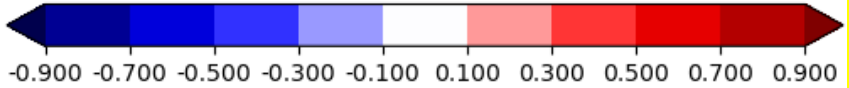
500-2000m

Difference WRT Free RMSE

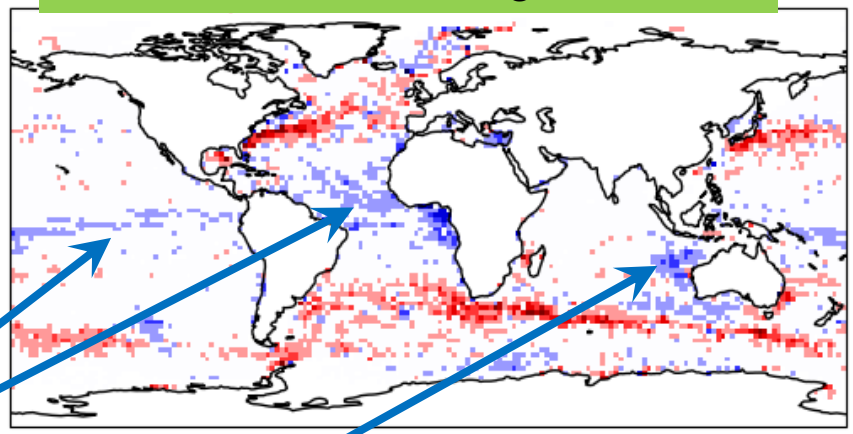
Add Altimeter and SST
Free - NoInsitu

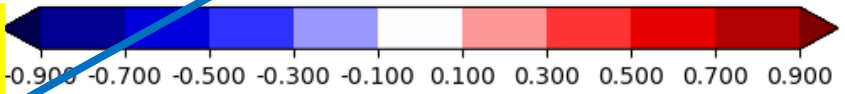


Altimeters can improve throughout water column



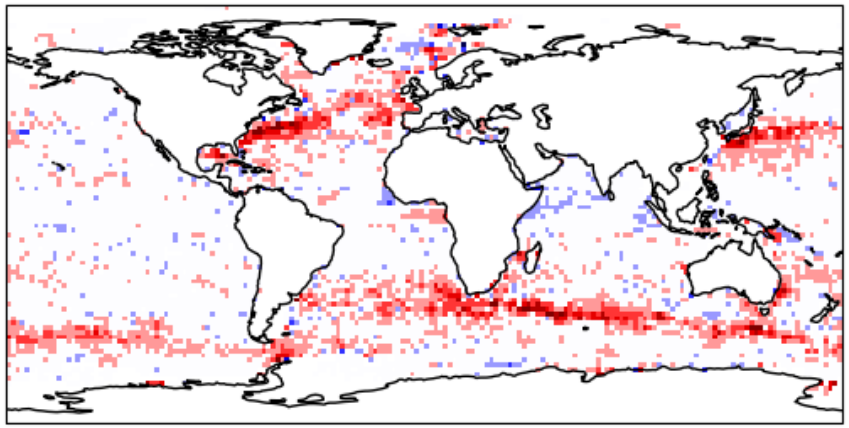
Further Add Non-Argo Profiles
Free - NoArgo





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

Further Add 40% Argo
Free - HalfArgo

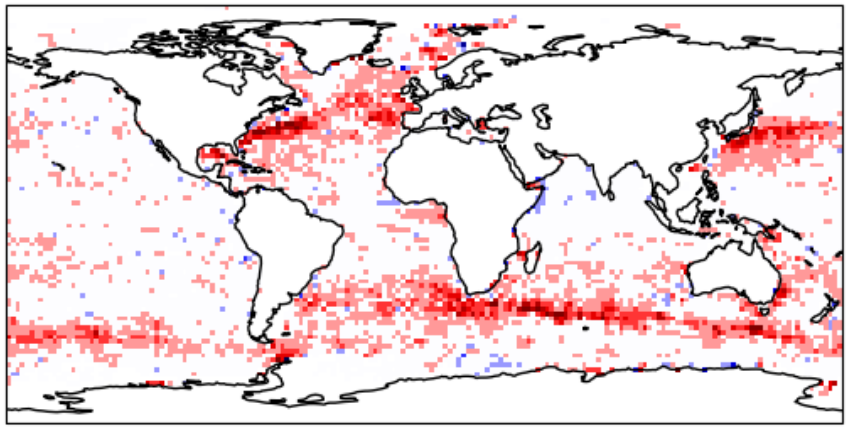


Upwelling also difficult

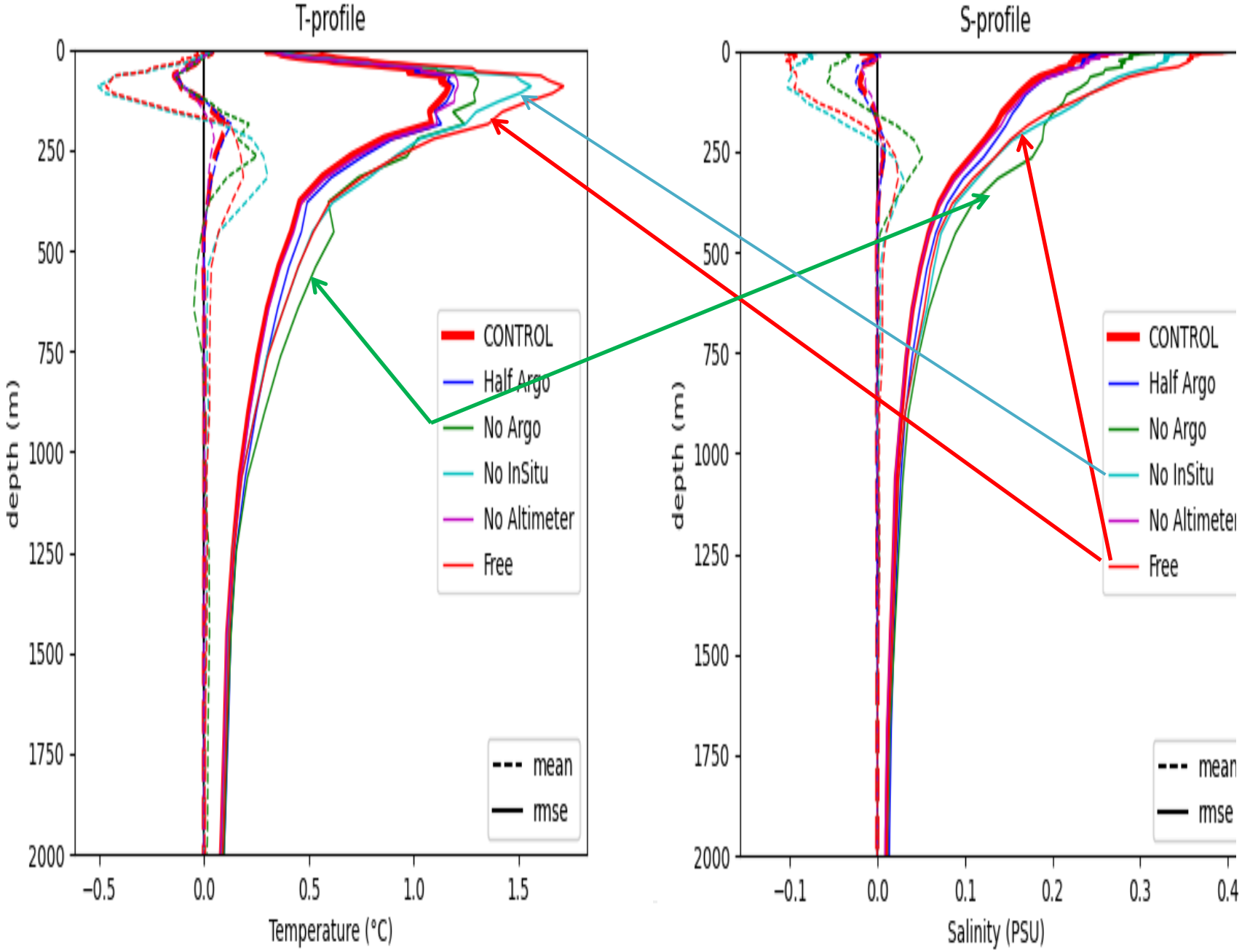
RED == Improvement (RMS SMALLER)

BLUE == Degradation (RMS Bigger)

Further add full 80% Argo
Free - CNTL



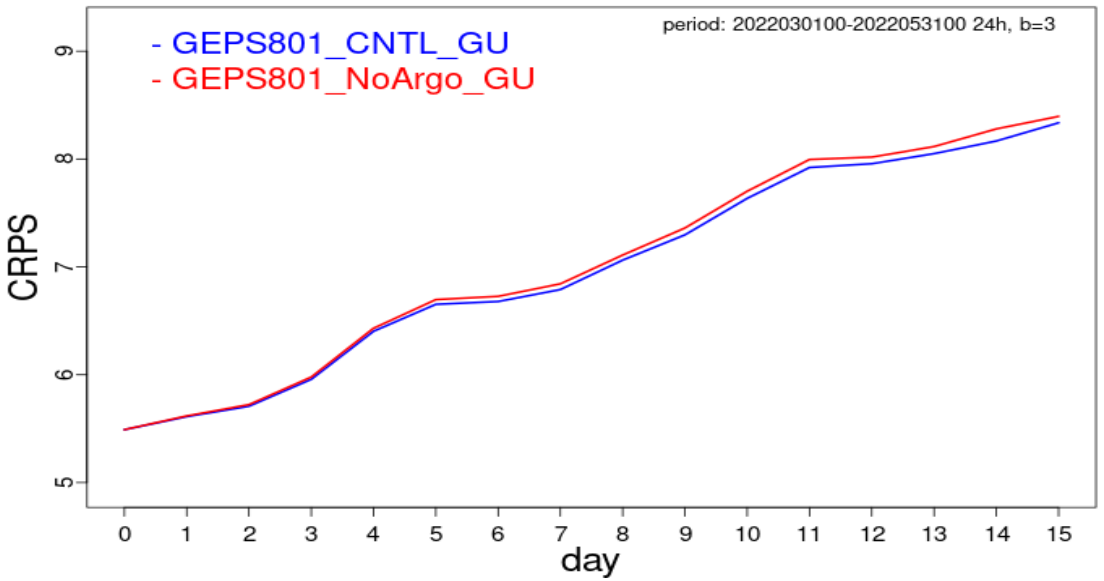
PROFILES: REMOVING ARGO IN TROPICS (20°S – 20°N)



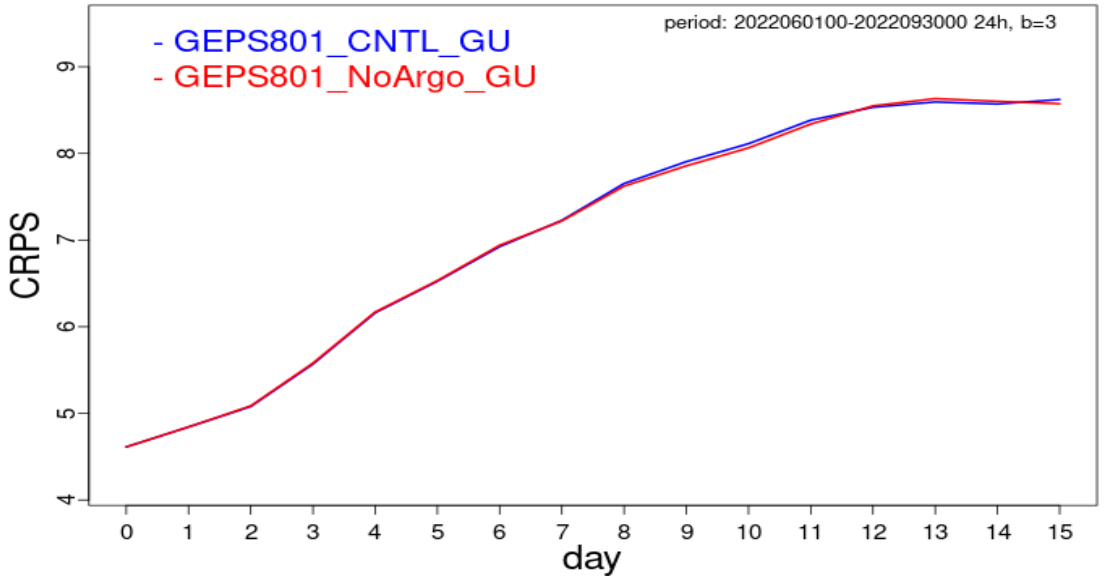
- In Tropics, have TAO/RAMA/PIRATA arrays – so ARGO should not matter as much.
- However, NoARGO gets as bad as free from 250m down.
- worse than free below 500m
- Arrays only go down 500m!
- Below 250m NoInSitu == Free
  - Altimeter isn't helping much.

- GIOPS system was designed for ARGO era
  - Further work required to assimilate shallower profiles if all that is available

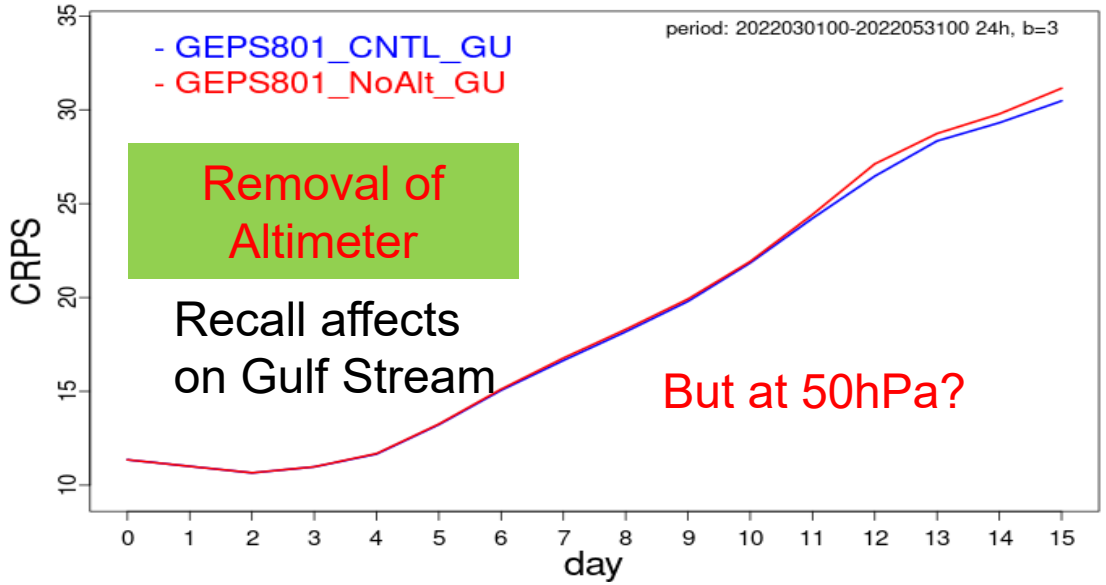
850 HPa GZ TROPICS – MAM (improves)



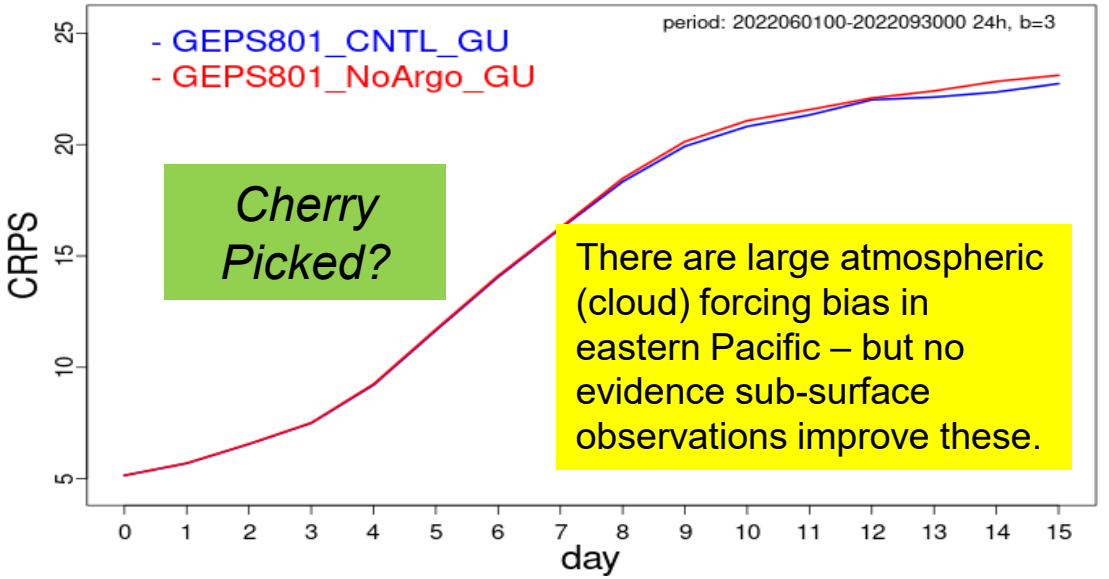
850 Hpa GZ TROPICS – JJAS (neutral/degrade)



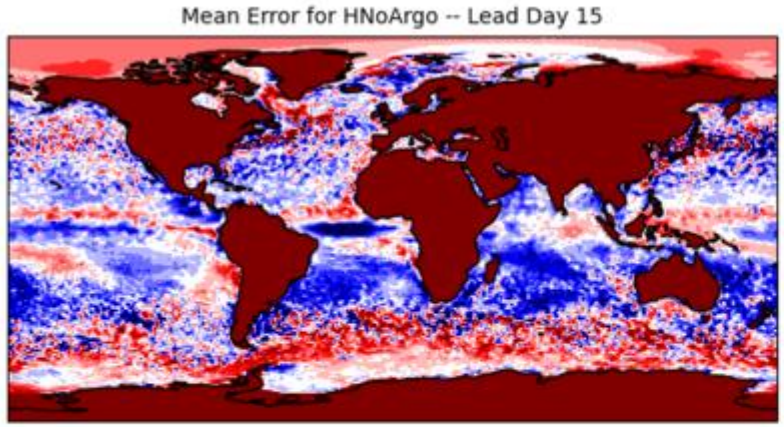
50 HPa GZ North Am. East – MAM (improves?)

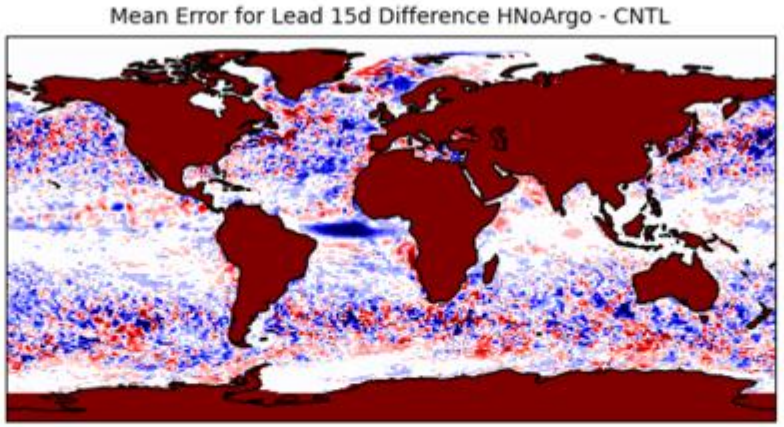


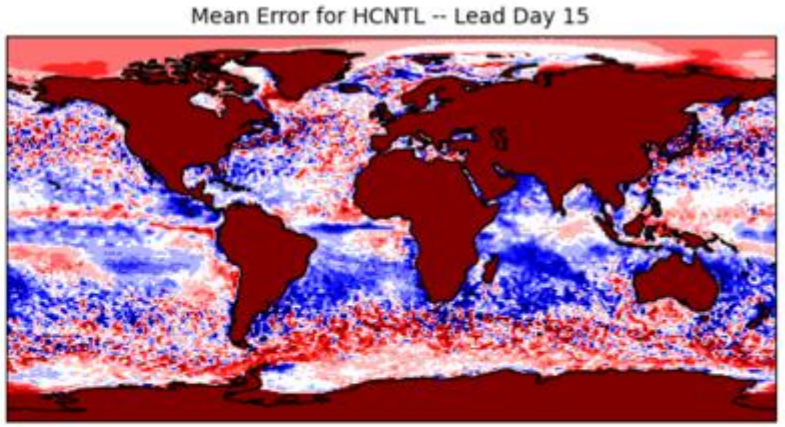
850 HPa GZ North Am. West – JJAS (improves?)

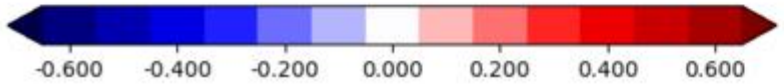


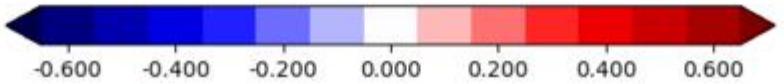
BIAS WITH LEAD TIME

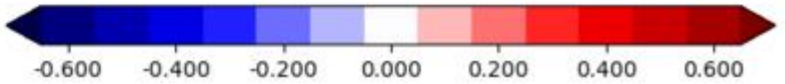




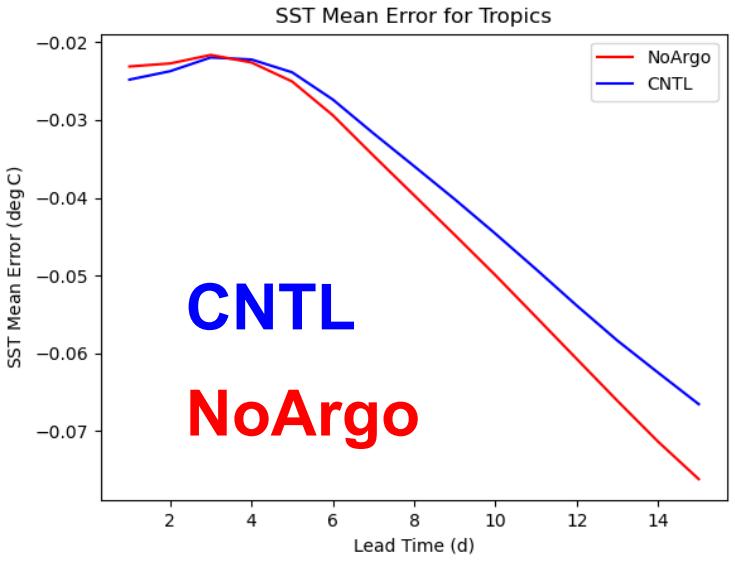




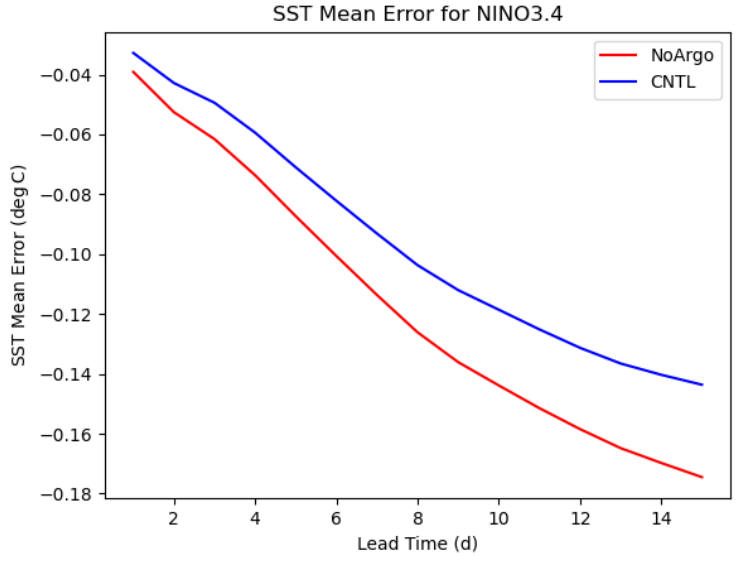




20°S – 20°N



NINO3.4 (170°W – 120°W, 5°S – 5°N)



40°S – 20°S

