Observing system evaluation and feedback from the OceanPredict centers

Elisabeth Rémy, Yosuke Fujii, Peter Oke and the OceanPredict community

Meteorological Research Institute
Japan Meteorological Agency

MERCATOR OCEAN INTERNATIONAL

OceanPredict - advancing the science for OceanPrediction

OceanPredict
Advancing the science of ocean prediction

Ocean Predict is an international research and development network focussed on Ocean Prediction, and has a 20+ year origin

Ocean Forecasting Centers, Government, and University Research Groups: UKMet, CMEMS, Mercator-Ocean, CONCEPTS (ECCC…), BlueLink, INCOIS, KHOA, JMA, REMO (Brazil), NOAA, US NAVY, HYCOM Consortium, ECCO, US universities, NERSC, NMEFC …

Meteorological Agencies play a strong role in Ocean Forecasting.

Ocean Observing system agencies and science groups: ESA, EUMETSAT, CNES, NASA, GOOS, OOPC, CGOS, **Argo**, OSTST, GHRSST, etc.

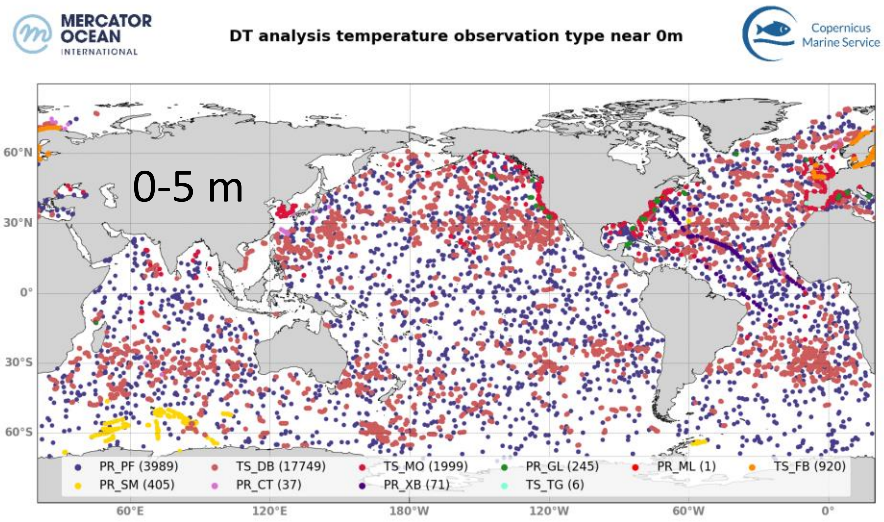
A dedicated **Task Team to Observing System Evaluation**

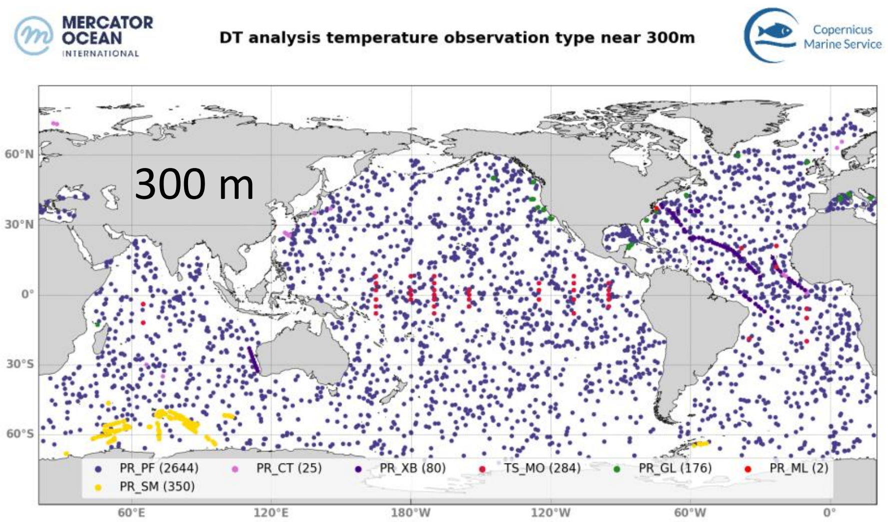
https://oceanpredict.org

Use of observations in ocean forecasting systems

Ocean physical and BGC observations are used:

- To assess evolutions of the model and the data assimilation system
- To optimize model parameters
- To constrain the model forecast circulation with assimilation
- To evaluate the produced forecast and analysis quality.





In situ data assimilated for a week, in color the different type of platforms. In dark blue, Argo observations.

Use of observations by OP

Table on the different useage of physical and BGC Argo observations by OceanPredict operational systems (regularly updated)

Levels	Description
Level 0	Not used at all
Level 1	Used for validation (The system is constructed independently from the data)
Level 2	Not assimilated but used for input data (The system depends on the data), or assir
Level 3	Assimilated on the research basis
Level 4	Assimilated indirectly in operation (as the ingredient of objective analysis or forcin
Level 5	Assimilated directly in operation (The data are assimilated without combining with

https://oceanpredict.org/observations-use/#section-argo-profiling-floats

Center/ Institute	System Name	Trajectory	Temp.	Salinity	Oxygen	Chlorophyl
BoM (CSIRO)	OceanMAPS	Level 1	Level 5	Level 5		
CHM-REMO	RODAS		Level 5	Level 5		
ECCC	GIOPS (global 1/4°)		Level 5	Level 5		
	RIOPS (Pac-Arctic-NAtl 1/12°)		Level 5	Level 5		
	CIOPS (East&West Coast, 1/36°)		Level 4	Level 4		
	WAVEWATCH III					
ECMWF	OCEAN5 Global 1/4	Level 1	Level 5	Level 5		
	ECWAM					
INCOIS	RAIN (1/12 degree)		Level 5	Level 5	Level 1	Level 1
	INCOIS-GODAS (1/2X1/4 global)		Level 5	Level 5		
	HYCOM (1/12 degree)		Level 5	Level 5		
	SWAN					
	WAVEWATCH III (1 degree)					
JMA	MOVE (Global)	Level 1	Level 5	Level 5		
	MOVE (Regional)	Level 1	Level 5	Level 5		
	Wave DA Systems					
Mercator Ocean	GLO12 (Global 1/12°) + BIO4	Level 1	Level 5	Level 5	Level 1	Level 1
	IBI36 (Regional 1/36°)	Level 1	Level 5	Level 5	Level 1	Level 1
MET Norway	TOPAZ4 (Pan-Arctic)		Level 5	Level 5	Level 3	Level 3

Questionnaire send to OceanPredict on Argo requirements

Affiliation of the people who answered the questionnaire

- *Environment and Climate Change Canada (ECCC), Canada*
- *European Centre of Medium-Range Forecasts (ECMWF), UK*
- *Japan Meteorological Agency (JMA), Japan*
- *Mercator Ocean International, France*
- *Met Office, UK*
- *Nansen Environment and Remote Sensing Center (NERSC), Norway*
- *NASA Global Modeling and Assimilation Office (GMAO), US*
- *NASA Jet Propulsion Laboratory (JPL), US*
- *NOAA Environment Modeling Center (EMC), US*

Global and regional ocean only systems and ocean/atmosphere coupled systems are represented

◆ ***What timeliness (or latency) is needed for real-time delivery of Argo data?***

A latency of 1 day is reasonable for majority of the current operational systems. However, shorter latencies, such as less than 6 hours, will be required when Argo data get to use in numerical weather predictions (probably via. coupled data assimilation systems) in the future.

Questionnaire send to OceanPredict on Argo requirements

◆ ***Do you expect Argo floats to sample at a depth of about 1 or 2 meters near the sea surface?***

Since near surface observation is important for air-sea interaction, calibration of satellite data etc., many people expect Argo floats to observe up to 1-meter depth. On the other hand drifter buoys form a good network for observing SST. Therefore, If it require a huge cost for Argo floats to observe near the surface, it is reasonable to use that cost for other part of the ocean observing network.

◆ ***What do you think about the OneArgo design, including the tropical and western boundary current enhancements?***

Most people supported the OneArgo design as the tropical and western boundary current regions have high uncertainty but important for predictions by operational centers. But some people mentioned that other platform may be more suitable for a high-resolution observations. And other people indicated that floats should be increased in the regions where observations are sparse, such as polar regions and shelf seas.

◆ ***Other comments***

- Near surface observations by Argo is necessary for the calibration of satellite SST and SSS data (NASA satellite needs working group).
- The possibility of applying a higher sampling frequency (e.g., 5 days) should be discussed.

What timeliness (or latency) is needed for real-time delivery of Argo data?

- current system 12 hr; future system 6 hr
- 6 h
- Ideally within a few hours (< 6 hours) of their validity time. This requirement comes from assimilation into a coupled data assimilation to initialise coupled global weather forecasts at the Met Office. The closer to real time we get the data the better.
- 1 day
- We are fine with a latency of 1-3 days. Any longer and it would impact our production S2S products
- For forecasts starting at t0, we use Argo data that are t0-36 to t0-12 windows. I.e. latency is 36 to 12 hours.
- 24 hours is ideal although we handle profile data up to 5 days late using FGAT
- About a month.
- 24 hours is ideal for the current operational system. In the future, we may start to use a coupled data assimilation (DA) system in the numerical weather prediction. In that case, we will need to have ocean data.

Do you expect Argo floats to sample at a depth of about 1 or 2 meters near the sea surface?

- Yes. This is very important for Argo to sample at depth of 1 m. Many satellite-based SST analysis product (e.g. OSTIA/CCI2/OISST) uses Argo for verification/calibration.
- Yes. Near surface ARGO is required for independent checks on satellite generated SST analysis.
- Our model has a top level which represents the top 1 m of the ocean. Argo observations at this depth would be useful to constrain the model, and as a reference unbiased dataset to correct the satellite SST and SSS data.
- Yes, To complement surface drifters.
- The closer to the surface the better. There are very few observations closer to the surface than the standard parking depth of Argo at 5m. 1-2m observations are very valuable because model thicknesses are now fine enough to resolve 1-2m and assimilation into these depths would improve our fundamental understanding of near-surface processes, mixing, water mass, etc.. In addition, abundant near-surface observations would continue to help validate satellite observations. These observations would be especially useful to help observe near-surface vertical salinity and density gradients.
- This would be helpful
- top level of model is 1 m so shallow sampling is used but not required. best to avoid pumping near the surface to prevent bio-fouling in order to extend float lifetimes.
- At the moment, the ECCO project is more concerned what happens below 2 km than above 1-2 m.
- It is ideal to observe up to 1m depth. On the other hand drifter buoys form a good network to calibrate satellite data and validate data assimilation system. If it require a high cost for Argo floats to observe near the surface, it is reasonable to use the cost for improving another part of the ocean observing network.

Part of the OneArgo design is the tropical and western boundary current enhancements. What do you think about those needs?

- Also quite important for NWP centres. Better representation of WBCs (e.g. GS) and tropical temperature gradient (e.g. in tropical Pacific Ocean) in initial conditions are critical for European weather forecasts (medium-range) and global ENSO forecasts (seasonal), respectively.
- Additional profile data in western boundary currents is required to make best usage of altimeter data in WBC regions.
- More data in the tropics and western boundary current regions would be very useful as was shown in the AtlantOS project.
- Requires a fine cost benefit analysis. Other platforms may be more adequate for higher resolution
- Since the study of ENSO has large socioeconomic impacts, I would give primary emphasis to enhancing the tropical Argo data coverage. However, the enhanced Western Boundary currents Argo coverage may have significant positive impact on mid-latitude prediction.
- This may improve the forecasts of these boundary currents. However there are other regions of the World Ocean that are not covered by Argo's (e.g. Arctic Ocean, shelf regions). It would be beneficial to find technical solutions to enhance observations in these regions.
- if floats (with Iridium) can be maintained along the equator and in boundary currents then that would be advantageous. glider deployments are probably the best choice to supplement Argo in those areas.
- Increasing sampling where there is most uncertainty and/or most variability is helpful.
- I think we need to increase the float density in mid and high latitude regions.

Synergistic Observing Network for Ocean Prediction

A **UN Ocean Decade Project** Under the **ForeSea program**

Objective

SynObs will seek the way to extract maximum benefits from the combination among various observation platforms, typically between satellite and in situ observation data, in ocean predictions.

Strategy

SynObs aims to identify the optimal combination of different ocean observation platforms through observing system design/evaluation, and to develop assimilation methods with which we can draw synergistic effects.

Partner Institutions / systems:

- JMA/MRI (contact point, Japan), MOi (FR), Met Office (UK), NOAA QOSAP and GOMO (US), ECMWF, CNR ISMAT (Italy), NERSC (Norway), Ocean DataNetwork (Denmark) CNRS (FR), UFBA (Brazil), NASA/GMAO and JPL (US), ECCC (Canada), Met Service (NZ), UCSC (US), Pukyong Uni (S.Korea)
- OceanPredict, GOOS (**Ocean Observing Co-Design**), TPOS, S2S project, Argo

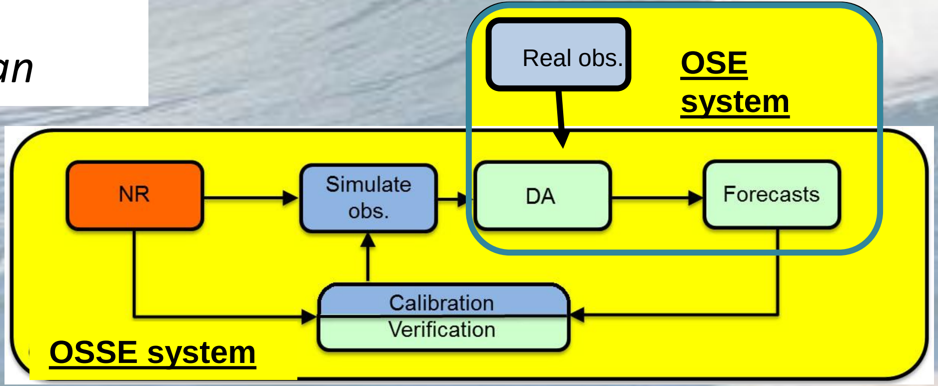
https://oceanpredict.org/un-decade-of-ocean-science/synobs-2/

★ Observation system evaluation and design experiment

- **Improve/develop the capacity** of monitoring and forecasting systems **to benefit from current or future observations**.
- **Evaluate** the impact of existing or future networks, from an integrated system perspective,
- ➢ **Provide feedback on observing system impact** from ocean monitoring and forecasting centers perspective.
- ➢ Help **defining suitable observation products** for operational oceanography.

OSSE: Observing System Simulation Experiment
OSE: Observing System Experiment
NR = Nature Run simulating the true ocean

https://www.aoml.noaa.gov/qosap/osse-checklist/



★ Planned multi-system OSEs

CNTL	Ocean Model		SST	Argo 80%	Mooring	Other TS	Alt. (optional)
NoAlt	Ocean Model		SST	Argo 80%	Mooring	Other TS	
NoArgo	Ocean Model		SST		Mooring	Other TS	Alt. (optional)
NoMoor	Ocean Model		SST	Argo 80%		Other TS	Alt. (optional)
NoSST	Ocean Model			Argo 80%	Mooring	Other TS	Alt. (optional)
NoInsitu	Ocean Model		SST				Alt. (optional)
SSTonly	Ocean Model		SST				
Free	Ocean Model						
HalfArgo	Ocean Model		SST	Argo 40%	Mooring	Other TS	Alt. (optional)
Oper	Ocean Model	Oper. Setting	SST	Argo 100%	Mooring	Other TS	Nadir Altimeter

OP 1-year OSEs: 01 Jan. 2020 - 31 Dec. 2020 (possibly extended to 31 Dec. 2022)

S2S 10-year OSEs: 2003-2022

SWOT	Ocean Model		SST	Argo	Moor	Other TS		SWOT
FullAlti	Ocean Model		SST	Argo	Moor	Other TS	Nadir Alti.	SWOT

For the 2nd phase (2024-…) of the project

OSSEs are also planned in a later phase of the project.

SynObs_FlagshipOSE_Guideline_Ver1.pdf (oceanpredict.org)

☆ Plan of SynObs Flagship OSEs/OSSEs

- SynObs is currently conducting OSEs/OSSEs using various ocean and S2S prediction systems with a common setting, and named it as SynObs flagship OSE.
  - More than 10 systems are participating in the flagship OSE/OSSE project

◆ OP (Ocean Prediction) OSEs

- Use higher-resolution ocean DA and prediction systems.
- Assimilation run **for 2020-2022** (at least for 2020)
- **10-day predictions**: Started from every pentad

◆ S2S (Subseasonal-to-seasonal) OSEs

- Use coupled prediction systems including lower-resolution ocean DA for initialization
- **Reanalysis run for 2003-2022** (2023?)
- **Subseasonal (1-month) predictions**: Once a month
- **Seasonal (4-month) predictions**: from May and Nov.

◆ OP (Ocean Prediction) OSSEs

- Planned for evaluating **SWOT, glider observations in coastal and shelf seas, satellite ocean velocity**. etc.
- 1-year assimilation run and 10-day predictions from every pentad

Systems participating in the OP OSEs

Center	System	Area	Res. (Deg.)
UK MetOffice	FOAM	Global	1/12
NOAA/NCEP	RTOFS-DA	Global	0.08
ECMWF	ORAS5/6	Global	1/4
NASA/GMAO	GEO-S2S V3	Global	1/4
JMA/MRI	MOVE-G3F	Global	1/4
ECCC	GIOPS	Global	1/4
NOAA/NCEP	GLORe	Global	1
NOAA/QUOSAP	MOM6	Global	?
JAMSTEC-APL	JCOPE-FGO	Semi-glob.	0.1
JMA/MRI	MOVE-NP	N Pac.	1/10x1/11
Pukyong Uni.	KOOS-OPEM	N. Pac	1/24
REMO-UFBA	HYCOM-RODAS	S. Atl.	1/12
MetService, NZ	MetService, NZ	S. Pac.	1/24

★ Collaborative Analysis of the flagship OSEs

<u>Global scale analysis – Argo related diagnostics</u>

- Impact of Argo on Heat budget and surface flux imbalances for OP OSE: *Greg Smith, ECCC, Canada*
- Impact of Argo on Sound Speed Profiles (Shallow water ducts/local minimums, depth of deep sound channel/absolute sound speed minimum): *Andrew Peterson, ECCC, Canada*
- Tropical Cyclone related quantities of interest (0-50mT, Z20, Z26, TCHP, MLD): *Matthieu Le Henaff, UM/CIMAS - NOAA/AOML, and TC ObsCoDe Exemplar*
- Innovation (model-observations) statistics, class 4 assessment for OP OSEs: *Jennifer Water/G. Smith in collaboration with OceanPredict IV-TT*
- Ocean heat budget analysis and marine heatwaves: *Eric de Boisseson, ECMWF, UK*

A public data archive center will be established in JAMSTEC to store the OSE data and make them accessible to participants.

★ Collaborative Analysis of the flagship OSE

<u>Regional scale analysis</u>

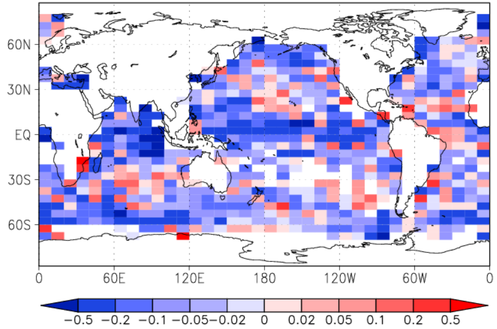
- Tropical Regions
- Eastern Equatorial and South Pacific: *Boris Dewitte, CEZA, Chile*
- Western Equatorial and South Atlantic: *Clemente Tanajura, UFBA-REMO, Brazil*
- Western South Indian Ocean: *Tamaryn Morris, South African Water Service, South Africa*
- Western North Pacific: *Yosuke Fujii, JMA/MRI, Japan*
- Arctic and subarctic regions: *Dimitry Dukhovskoy, NOAA NWS EMC, USA*
- North Atlantic ?
- Western South Pacific (around New Zealand)?

Volunteers to analyze the observation impacts from the OSE results are welcome!

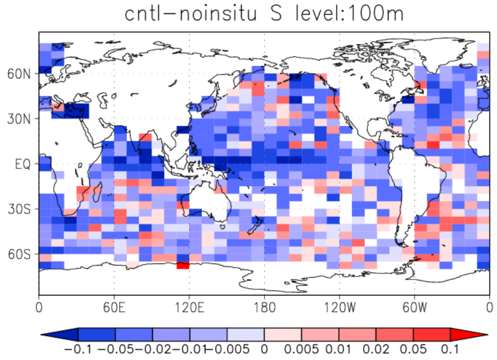
☆ Differences of RMSE wrt. Independent Argo between JMA/MRI (2003-2010)

RMSE(CNTL) – RMSE(NoInSitu)

100m T

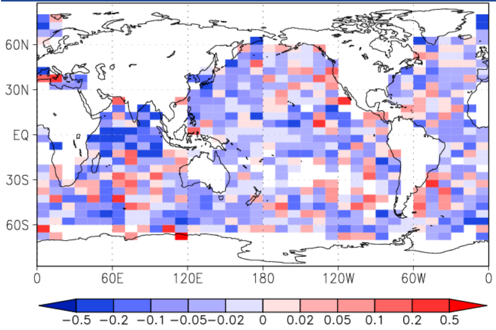


100m S

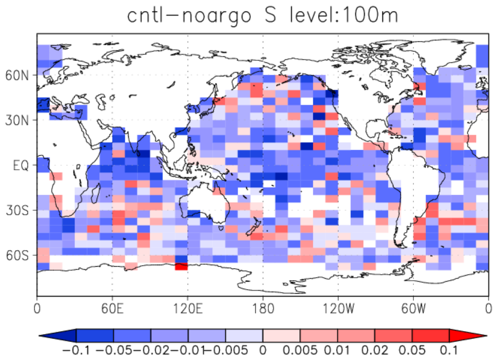


RMSE(CNTL) – RMSE(NoArgo)

100m T

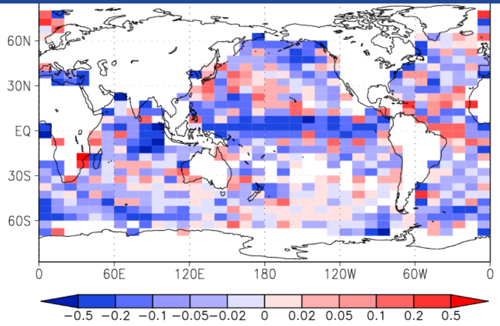


100m S

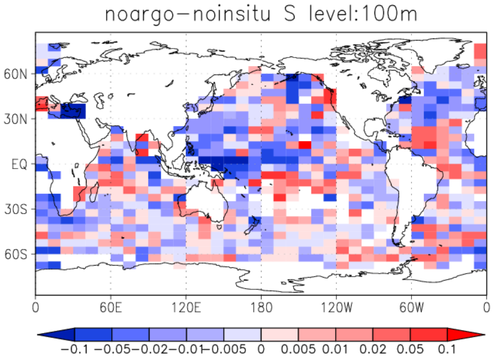


RMSE(NoArgo) – RMSE(NoInSitu)

100m T



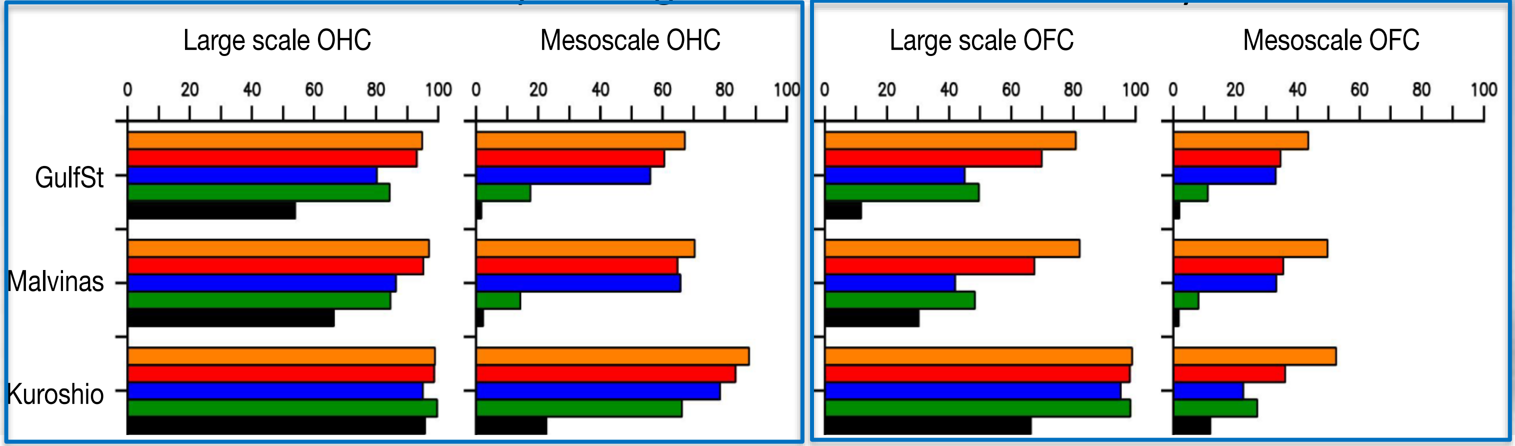
100m S



- In situ observation impact is significant in a large part of the global ocean.
- Argo impact is spread over the entire global ocean.
- The large negative values in the tropical Pacific and Tropical Indian Ocean implies substantial impacts of the tropical moorings.

☆ OSSEs with the Mercator Ocean global ¼° physical system

Complementarity of the in situ and altimetry observations in constraining the large and meso scale variability of the global ¼° Mercator ocean analysis



% of represented variance of the Nature Run for 0-700 m ***Ocean Heat (OHC)*** *and* ***Freshwater Contents (OFC)*** *of the* ***FREE*** *(black),* ***NOMINAL*** *(red),* ***ONLYSAT*** *(blue),* ***ONLYSITU*** *(green) and* ***ENHANCED_ARGO*** *(orange) experiments.*

- In western boundary current, in situ T and S observations well constrain the large scale Ocean Heat Content and Fresh Water Content as satellite observations (SST and SLA) are constraining the meso-scale variability.
- OHC is better constrain that FWC in global ocean analysis.
- Argo extensions will improve the OHC and FWC estimates, at meso-scale in WBC.

F. Gasparin et al., 2023

SynObs/OS-Eval Co-Chairs:

Yosuke Fujii (JMA/MRI), Elisabeth Remy (MOi) *(formerly Peter Oke as OSEval co-chair)*

E-Mail: synobs@mri-jma.go.jp

SynObs Webpage:

https://oceanpredict.org/un-decade-of-ocean-science/synobs-2/

A **Frontiers special issue** is in preparation on «**Demonstrating observation impacts for ocean and coupled prediction**», submission of final papers in June 2024

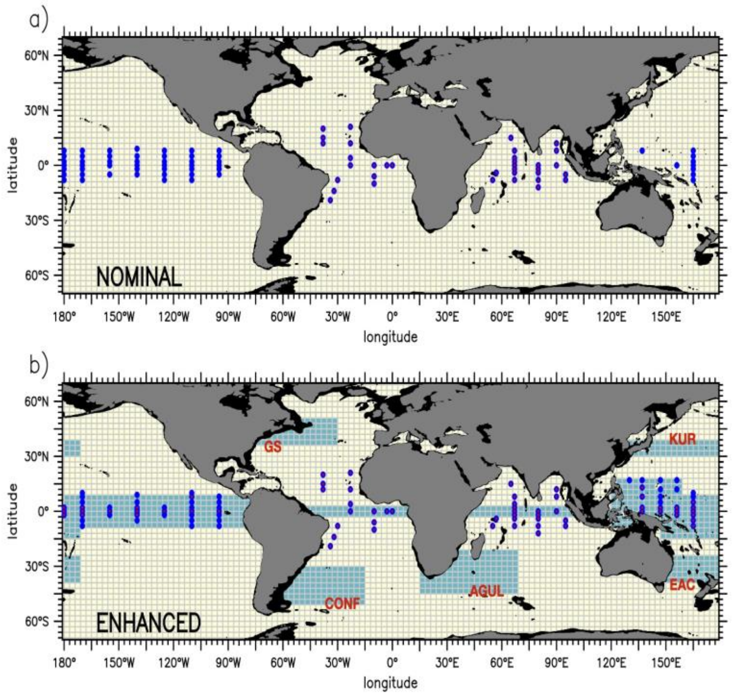
Extra slides

MERCATOR OCEAN INTERNATIONAL

OSSEs with the Mercator Ocean global ¼° physical system

EuroSea

Today physical Argo and tropical mooring networks and planned extensions tested in the OSSEs



OSSE experiments	In situ assimilated observations	Satellite assimilated observations
FREE	No	No
ONLYSAT	No	Altimetry, SST
ONLYINSITU	Argo, Tropical moorings	No
NOMINAL	Argo, Tropical moorings	Altimetry, SST
ENHANCED_AR	Argo enhanced, Tropical moorings	Altimetry, SST
ENHANCED_MO	Argo, Tropical moorings enhanced	Altimetry, SST
ENHANCED_AR MO	Argo and Tropical moorings enhanced	Altimetry, SST
DEEP	Argo + deep Argo, Tropical moorings	Altimetry, SST

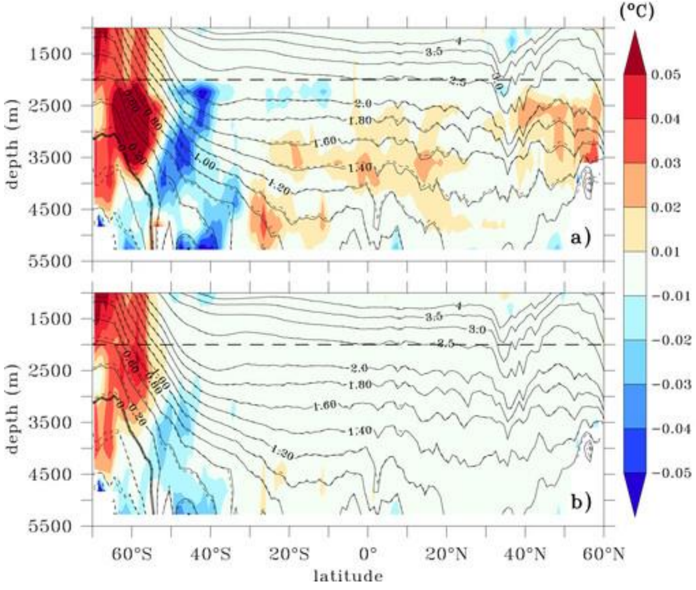
Constraining the deep ocean in ocean reanalysis

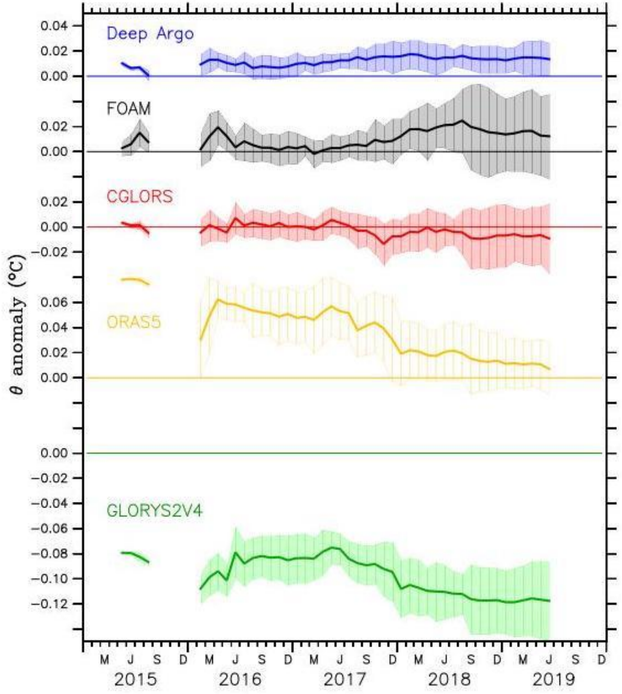
The deep ocean is underconstrained in reanalysis; prediction centers are using different strategy to limit deep ocean unrealistic trends (often larger than the observed trends).

➢ Deep Argo observations can significantly help to reduce analysis and forecast errors in the deep ocean when assimilated (OSSEs).

Zonally average 2009 – 2013 mean temperature for the OSSEs ARGO_2000 m and ARGO_6000 m.

Gasparin et al., J. Climate, 2019





Different time-evolution of the 5000-m θ anomaly (ref. to WOA18) in Copernicus Marine GREP reanalysis

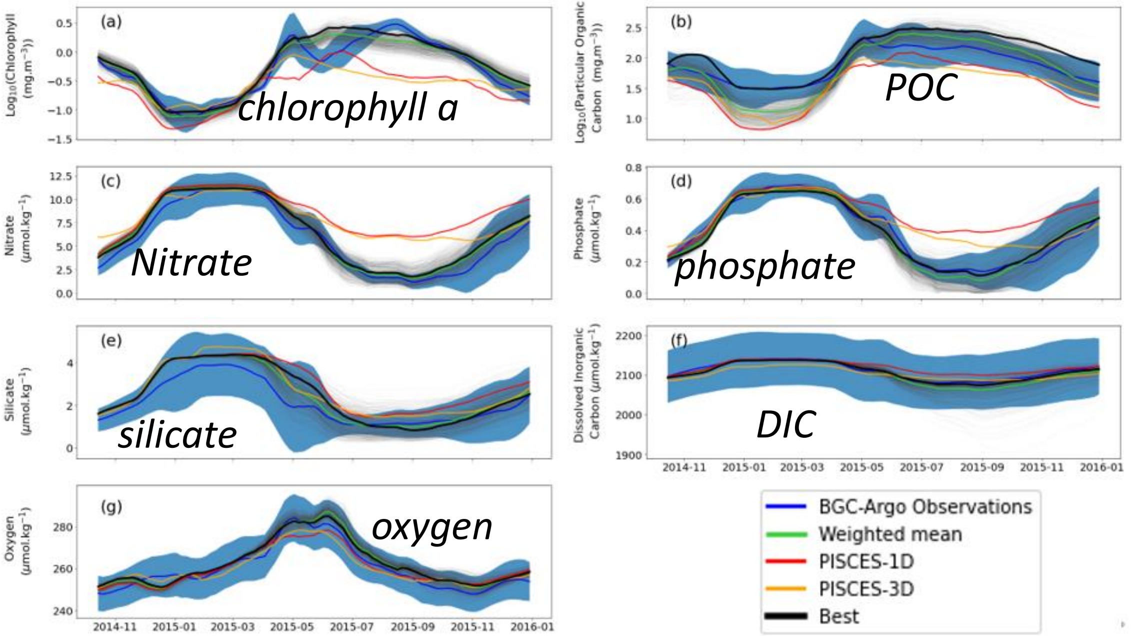
F. Gasparin et al., 2020

Biogeochemical model optimization using BGC-Argo float data

Optimization of PISCES 1D parameters using a particle filter algorithm:

- It greatly improves the model's ability to reproduce the North Atlantic bloom.
- The optimized model is able to reproduce different BGC variables more accurately than PISCES 3D and PISCES 1D.

Time series of BGC variables averaged in the mixed layer along the float trajectory from: the BGC-Argo floats observations (blue), PISCES-1D (red) , from PISCES-3D (orange), and the best member of PISCES 1-D (black) and ensemble mean (green). The blue shading indicates the observational errors.



➢ The method will be applied to derive a spatially variable map of optimized parameters for PISCES "3D" BGC forecast model.