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# *The international multi-system OSEs/OSSEs by the UN Ocean Decade Project SynObs and its early results in JMA/MRI*

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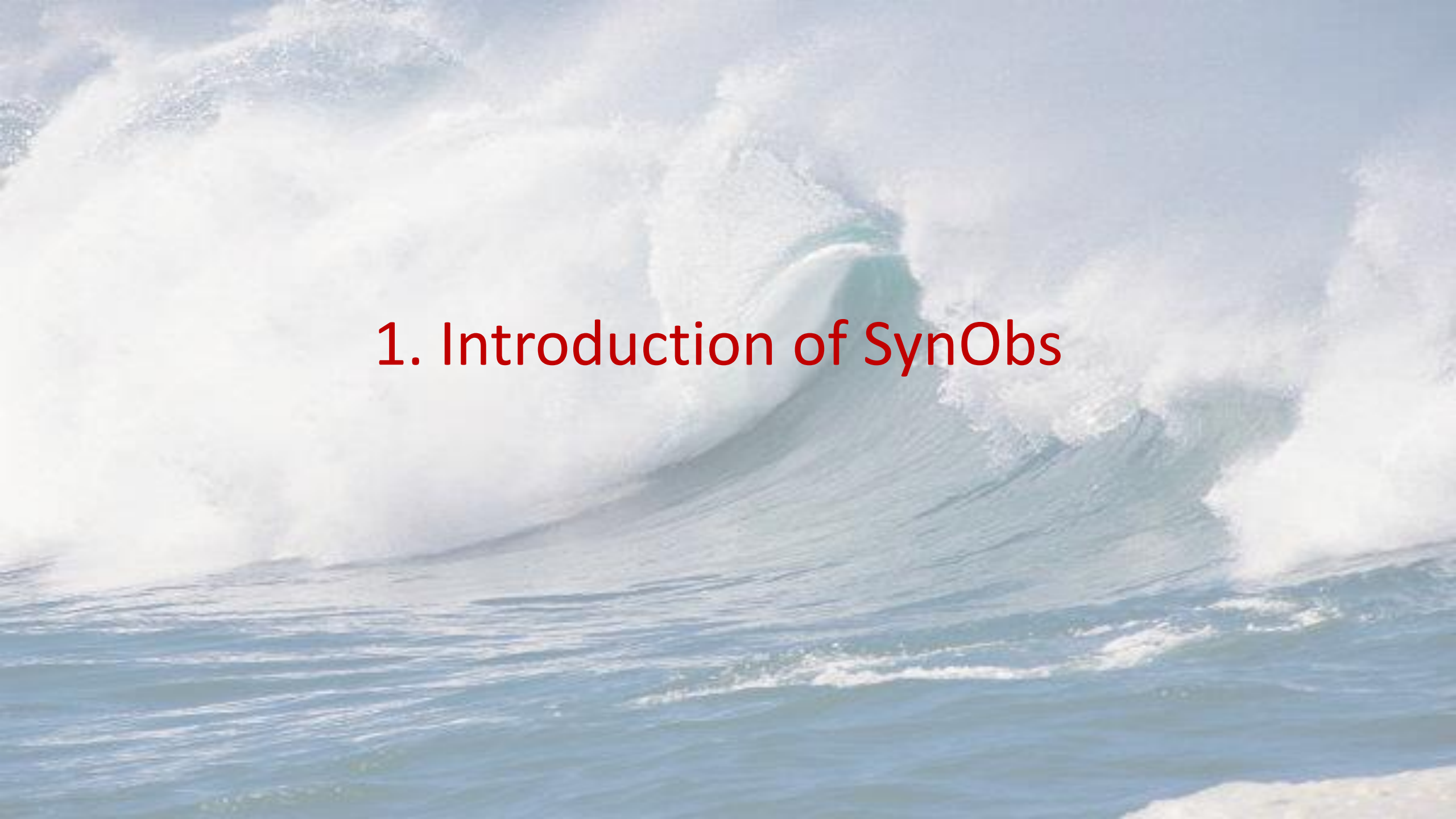

# 1. Introduction of SynObs

# Synergistic Observing Network for Ocean Prediction

***Led by OceanPedict OS-Eval TT***

- 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.

SynObs Contact

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# ☆ Outline of SynObs Activity Plan

## 1. Collaboration for evaluation and design

- Collaboration on a Multi-System OSE and OSSE (SynObs flagship OSEs/OSSEs)
- Establish the best practice based on the collaboration above.

## 2. Supporting DA scheme development

- Share the information on the development of DA schemes
- Planning of observation campaigns for DA scheme development If necessary

## 3. Framework to provide information from ocean prediction systems in real time

- Explore the methods to evaluate observing system status in real-time

## 4. OS-Eval showcase and reporting

- Introduce OS-Eval examples to demonstrate its potential (E.g., Frontiers in Marine Science Special collection is on-going!)
- Contributing to WMO Observation Impact workshop and Rolling Review of Requirement (RRR)

# 2. SynObs Flagship OSEs

# ☆ Request of OSEs and past achievements by ocean prediction community

## ◆Request of OSEs for the new observing system designs

- ➢ The TPOS2020 report recommended to perform the new TPOS evaluation with S2S forecasting systems.
- ➢ The Argo community expects to evaluate the impacts of doubling Argo floats, and the new Argo array design.

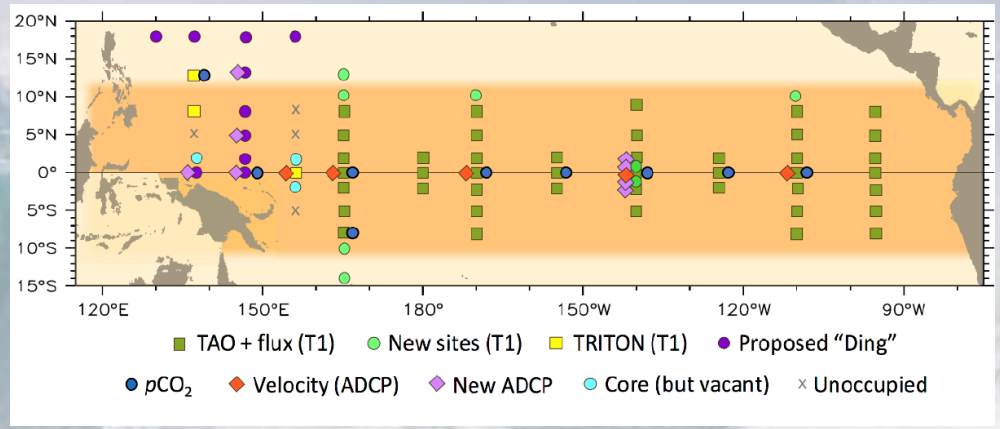
## ◆Achievements of OceanPredict OS Evaluation Task Team

- ➢ Fujii et al. (2019). Front. Mar. Sci. (OceanObs'19 Community White Paper)
- ➢ Oke et al. (2015a,b). J. of Oper. Oceanogr. (In the GODAE OceanView Special Issue.)

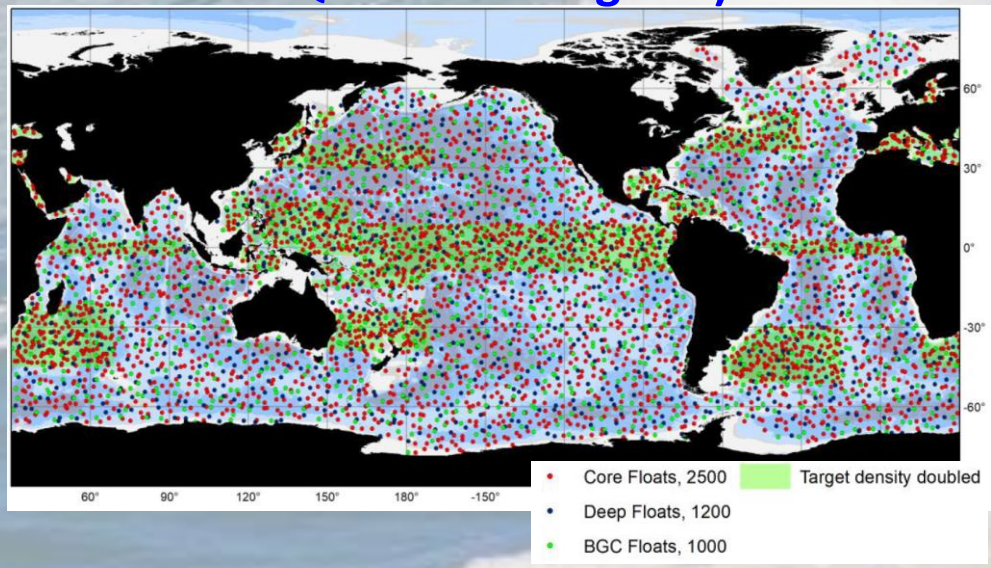
## ◆ Lessons Learnt from past activities

- ➢ Obs has various purposes (OSEs/OSSEs cannot evaluate all obs values)
- ➢ Data for calibration and validation are also important.
- ➢ Near-real-time evaluations are necessary.
- ➢ System dependency must be considered.

**The new tropical Pacific buoy array design (from TPOS2020 2nd Report Fig. 7.4b)**




**Argo 2020 Design (doubling floats in EQ and WBC regions)**

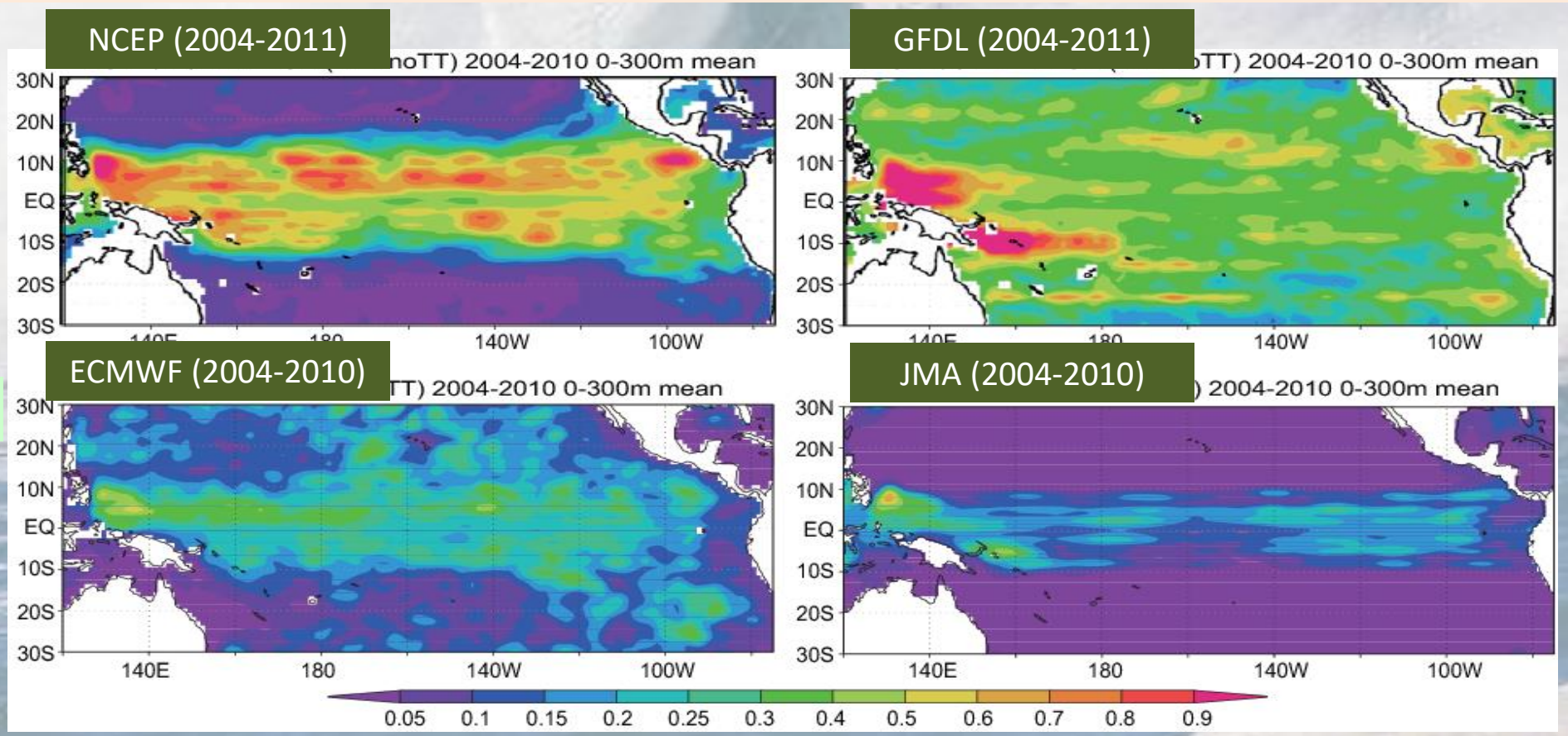


# ☆ System Dependency of Observation Impacts

- ◆ Evaluation results inevitably depends on the prediction system.
  - ✓ Systematic errors often hide impacts of ocean observation data.
  - ✓ The dependency is significant in the S2S predictions, but it cannot be ignored in ocean reanalysis and predictions.
- ◆ Therefore, multi-system efforts are indispensable to remove the system dependency and to make a robust and reliable evaluation

0-300m averaged RMSD of temperature (˚C) between the regular ODA runs and OSE without assimilating tropical mooring buoys

From Fujii et al., 2015 QJRMS



# ☆ 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

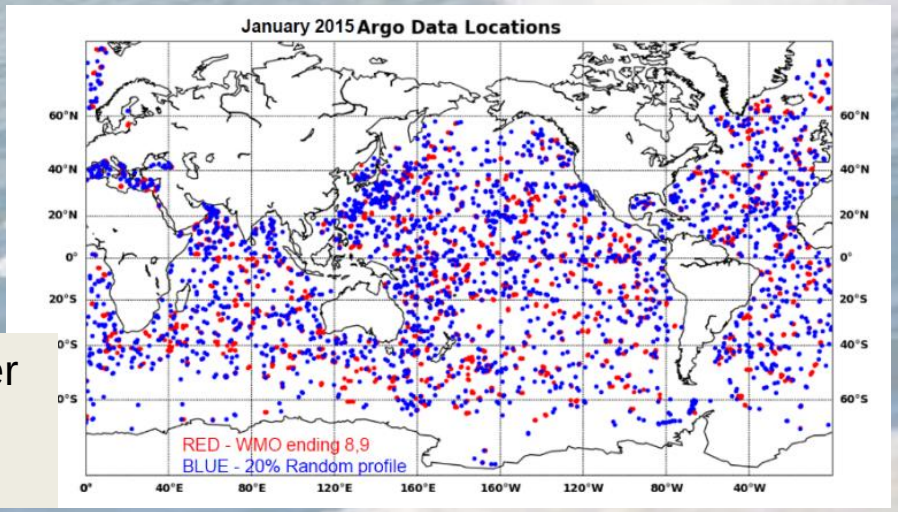
| Center | System | Area | Res. (Deg.) |
|---|---|---|---|
| UK MetOffice | FOAM | Global | 1/12 |
| NOAA/NCEP | RTOFS-DA | Global | 0.08 |
| ECMWF | ORAS5/6 | Global | 1/4 |
| NASA/GMAO | GEO-S2S V3 | Global | 1/4 |
| JMA/MRI | MOVE-G3F | Global | 1/4 |
| ECCC | GIOPS | Global | 1/4 |
| NOAA/NCEP | 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 |

# ☆ SynObs flagship OSEs (OSE settings and the schedule)

- OSE Settings for OP and S2S OSEs
  - Control Run (CNTL)
    - Basically, regular observation data are assimilated
    - 20% of Argo data are withhold and used as reference.
    - Other observation data regularly assimilated in each system will be assimilated.
  - OSEs
    - Data of a targeted observation type are excluded (e.g., NoArgo, NoMoor, NoAlt etc.)
- OP OSSE setting is now being discussed.
- Analysis
  - **SynObs asked some volunteer groups to analyze the OSE/OSSE results generally in their own way.**
  - Results are planned to be **stored as netCDF files in a public database on a JAMSTEC-APL server** and shared with the analysis groups.

Suggested OSE Settings

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




Distributions of Argo floats whose last digits of WMO number is 8 or 9 (red) and 20% random profiles (blue). Example for January 2015 (Thanks to Li Ren, NASA/GMAO.)

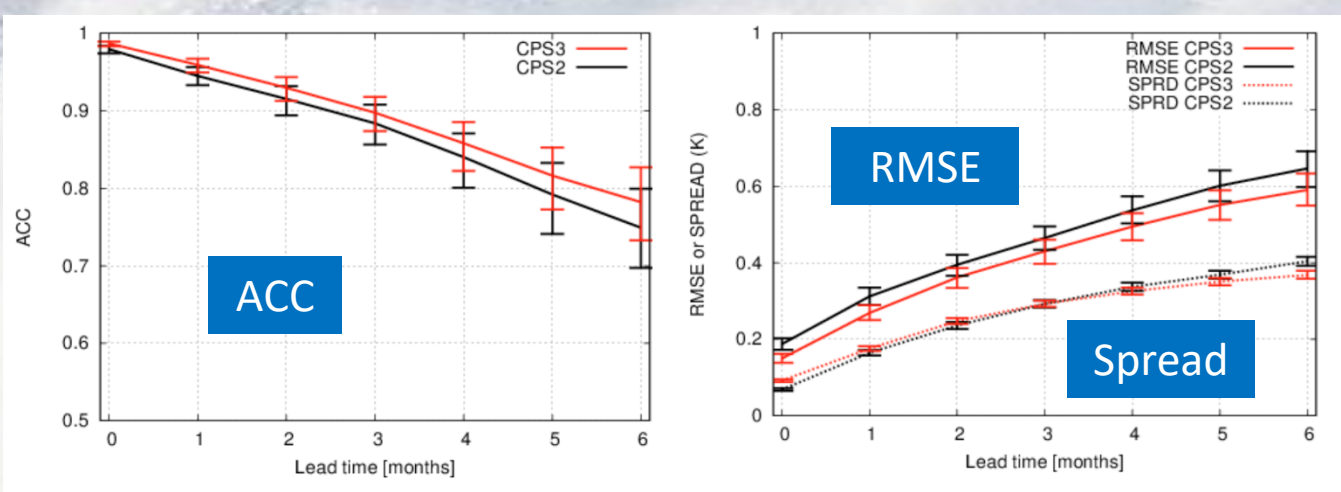
# 3. OSEs conducted in JMA/MRI for the SynObs flagship OSE activity

# Specifications of Coupled Prediction System (CPS) in JMA

| | | CPS2 (June 2015) | CPS3 (February 2022) |
|---|---|---|---|
| **Atmospheric model** | Model version | GSM1011C | GSM2003C |
| | Horiz. resolution | TL159 (~110 km) | TL319 (~55 km) |
| | Vertical levels | 60 levels | 100 levels |
| **Ocean model** | Model version | MRI.COM v3.2 | MRI.COM v4.6 |
| | Horiz. resolution | 1° (longitude) × 0.3-0.5° (latitude) | 0.25° |
| | Vertical levels | 52 levels with a bottom boundary layer | 60 levels |
| **Initial conditions** | Atmosphere | JRA-55 | Global Analysis (GA) |
| | Ocean/Sea ice | MOVE-G2 (3D-Var) | MOVE-G3 (0.5°x1°, 4D-Var) |
| **Ensemble generation** | Size and Frequency | 13 members per 5 days | 5 members per day |
| | Perturbation | Stochastic physics in the atmosphere<br>Breeding for the atmosphere | Stochastic physics in the atmosphere<br>Breeding for the atmosphere<br>New ocean perturbations |

MRI.COM: Meteorological Research Institute Community Ocean Model.

# ☆ Improvement of S2S forecasts skills by introducing CPS3




← Anomaly correlation, RMSE, and Spread of NINO 3.4 SST for different lead time. Based on 360 instances from hindcast (1991-2020).

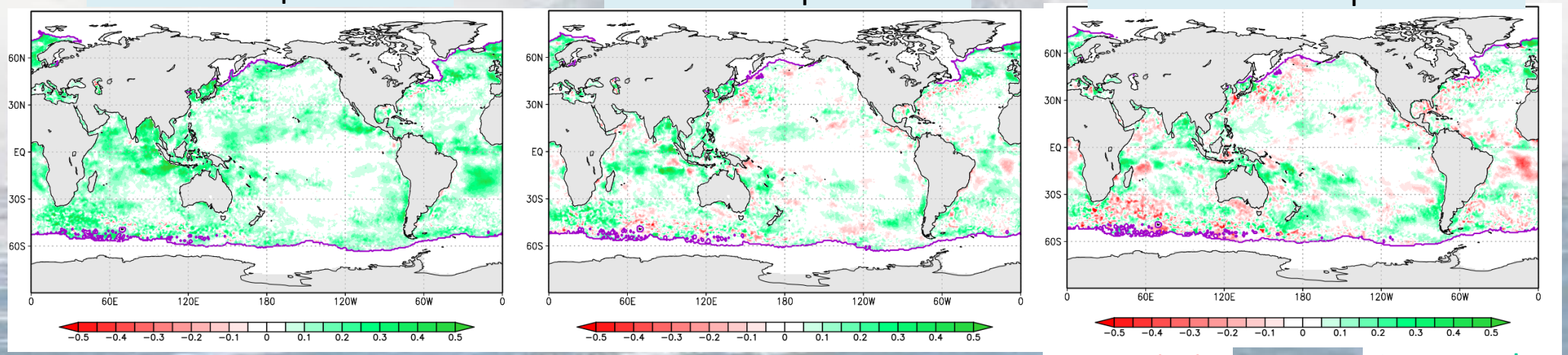
Black: CPS2 Red: CPS3

ACC difference of forecasted SST between CPS3 – CPS2 in the subseasonal range.

1st week of prediction

2nd week of prediction

3rd-4th weeks of prediction



Degraded Improved

✓ This improved SST is used in the monthly uncoupled atmospheric forecasting system (i.e., 2-tiered SST) from the 6th day in the tropics.

# ★ Setting of the S2S Analysis OSEs for the flagship OSEs in JMA/MRI

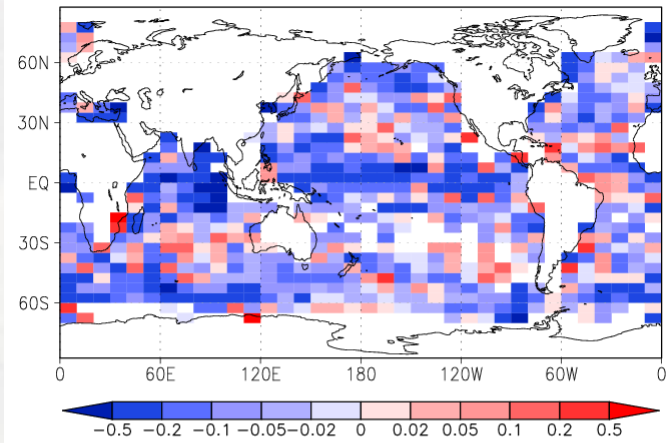
MOVE-G3 Ocean RA for the calibration of operational Seasonal Forecasts


- ✓ All RA runs except for CNTL and NoInsitu are still on-going.
- ✓ Forecast runs have not started yet.
- ✓ RA and Forecast runs for OP OSEs using higher resolution model are also planed.
- ✓ Only RA runs of these 3 OSEs are shown today.

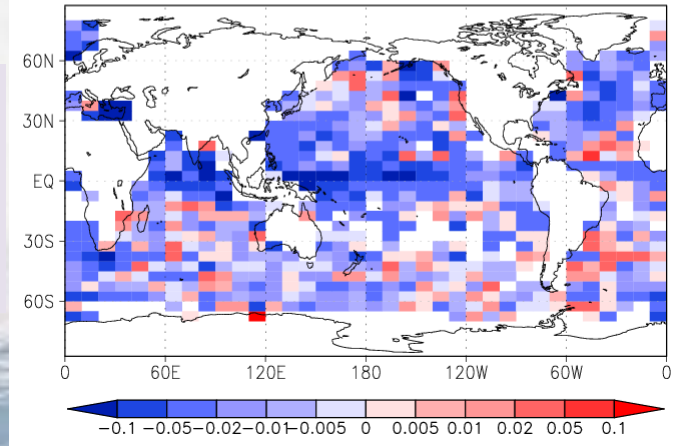
# ☆ Differences of RMSE wrt. Independent Argo between OSEs (2003-2010)

## RMSE(CNTL) – RMSE(NoInSitu)

100m T

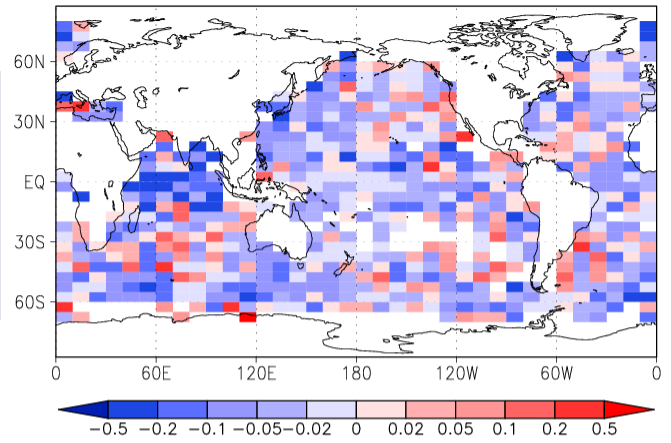



100m S

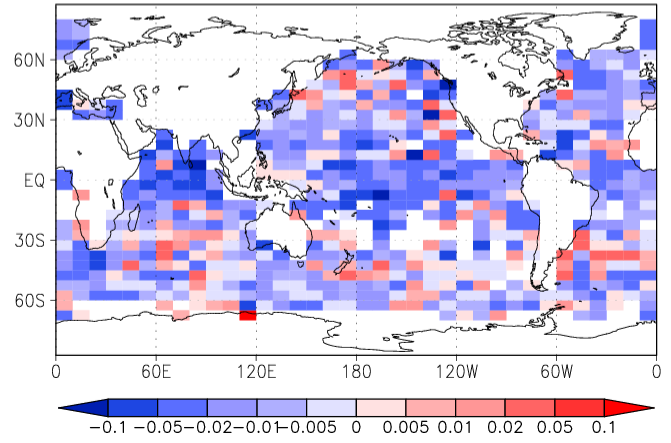



## RMSE(CNTL) – RMSE(NoArgo)

100m T

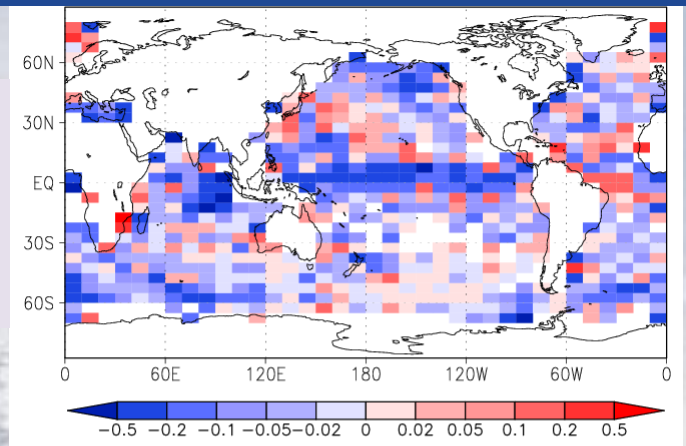



100m S

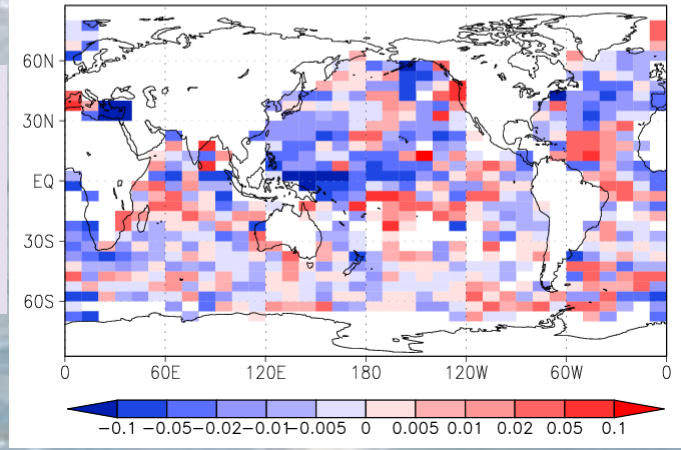



## RMSE(NoArgo) – RMSE(NoInSitu)

100m T



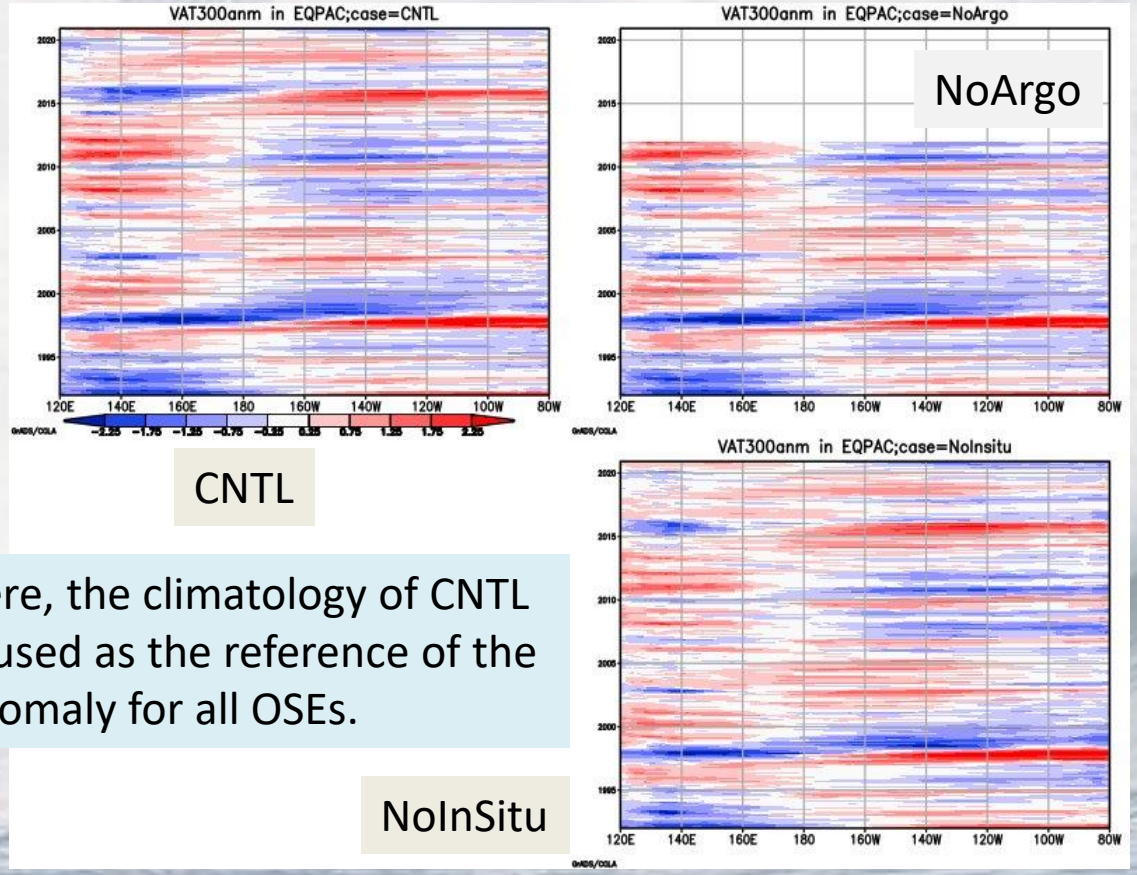

100m S




- 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.

# ☆ Lon-Time plots of 0-300m TS anomaly at the equator in the Pacific

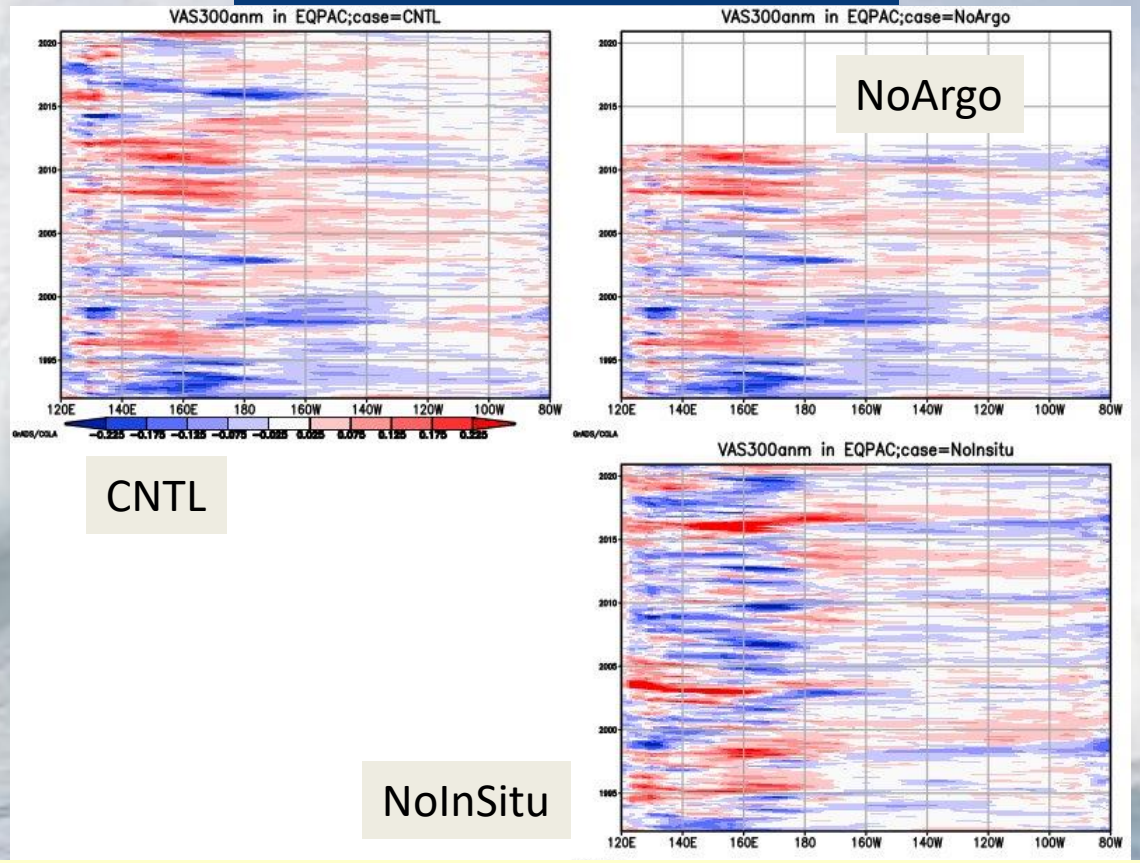
## 0-300m averaged Temperature



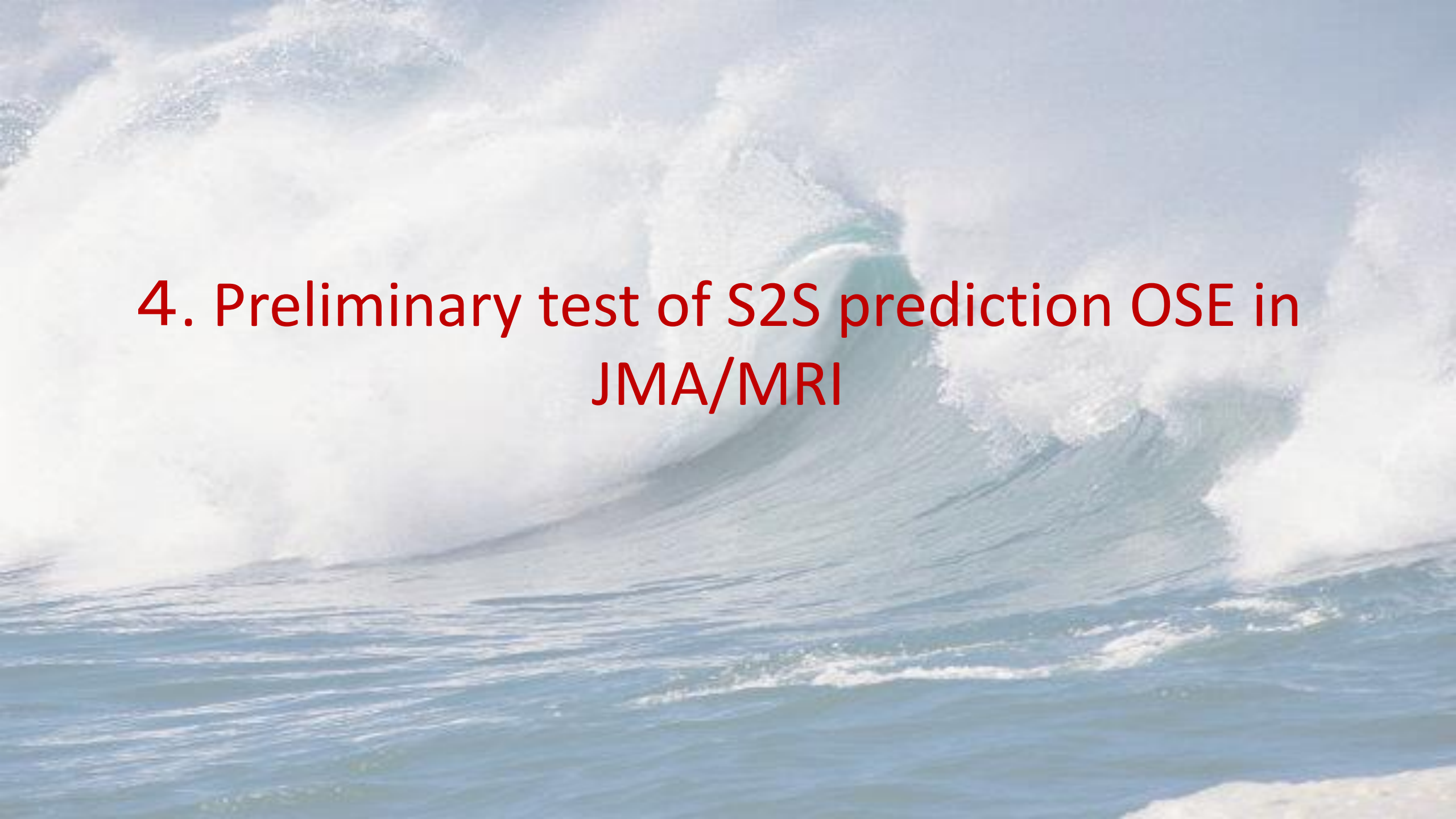

Here, the climatology of CNTL is used as the reference of the anomaly for all OSEs.

- The T plots of NoArgo and NoInSitu are very similar to the plot for CNTL. Satellite altimetry data, together with wind stress information are effective enough to capture the temperature variation in the equatorial Pacific.

## 0-300m averaged Salinity




- S plot of NoInsitu significantly differs from the plots of other OSEs. It indicates the necessity of the tropical mooring for reproducing the salinity variation.
- Similarity of the plot between CNTL and NoArgo shows the effectiveness of tropical moorings for reproducing salinity variations.



# 4. Preliminary test of S2S prediction OSE in JMA/MRI

# ☆ Setting of the preliminary test

CPS3:TL159+G100

1989 — Forced by the atmospheric reanalysis, JRA-3Q — 2016

Ocean RA of MOVE-G3A for the calibration of operational Seasonal Forecasts

- MOVE-G3 (**3D-Var** Version) (SSTonly)
- MOVE-G3 (**3D-Var** Version) (CNTL)
- MOVE-G3 (No Assimilation) (FREE)

1991

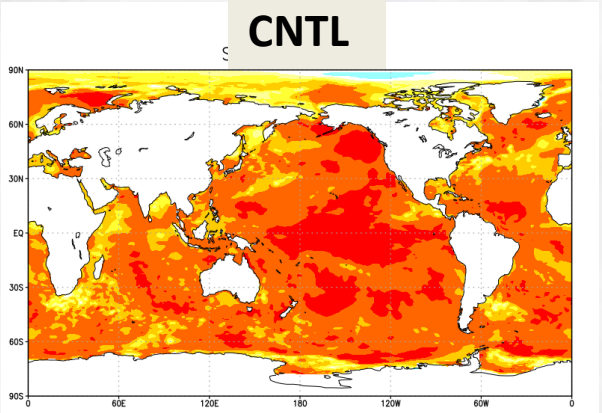
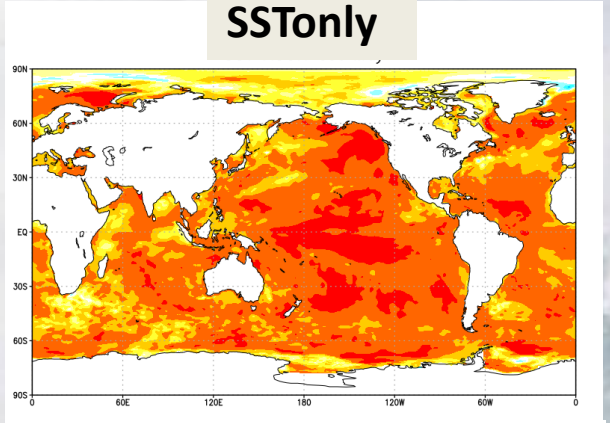
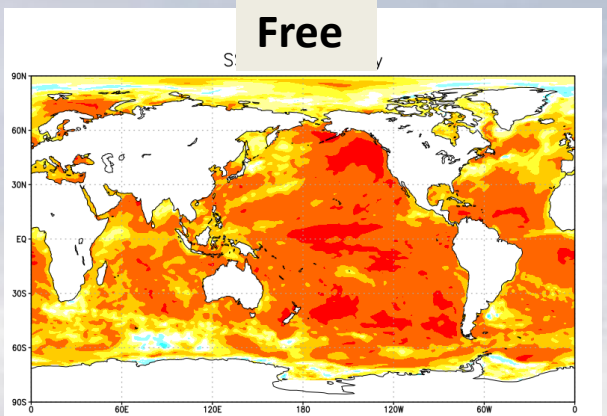
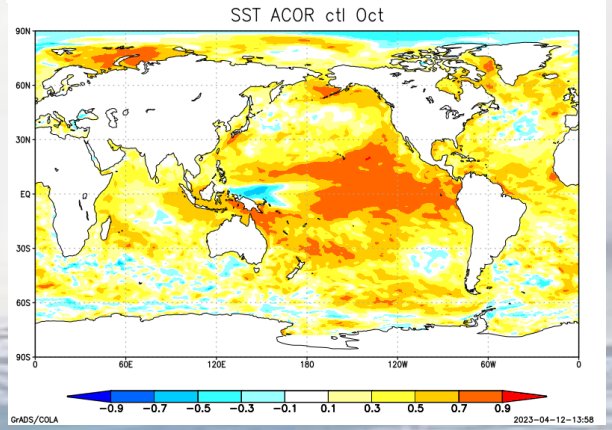
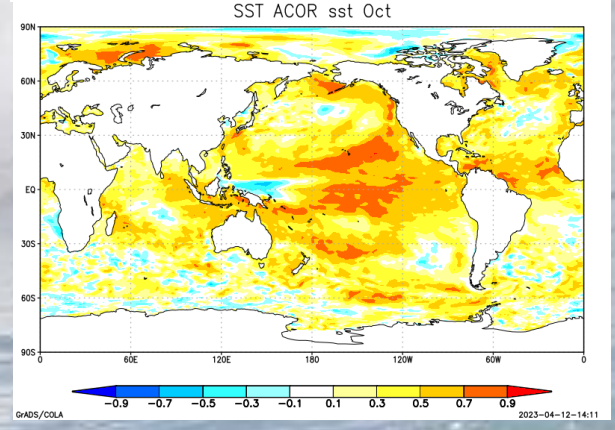
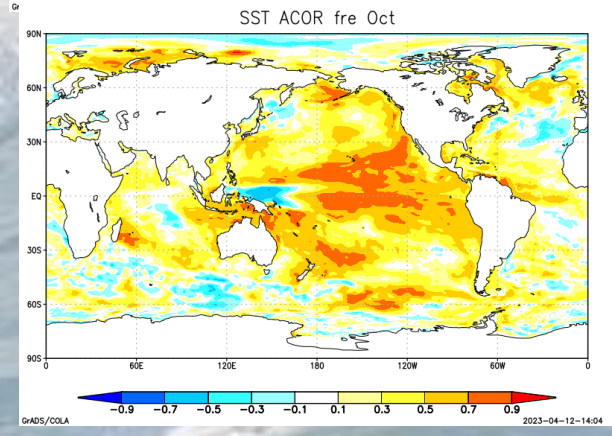
- CPS3LL, 5-month forecasts (for each OSE)

CPS3LL:**Lower-resolution version of CPS3** (Atmos: TL159, Ocean: 0.3-0.5˚x1˚)

◆ Forecasts are started from Apr. 26th of every year
◆ Atmospheric Initial Condition: JRA-3Q

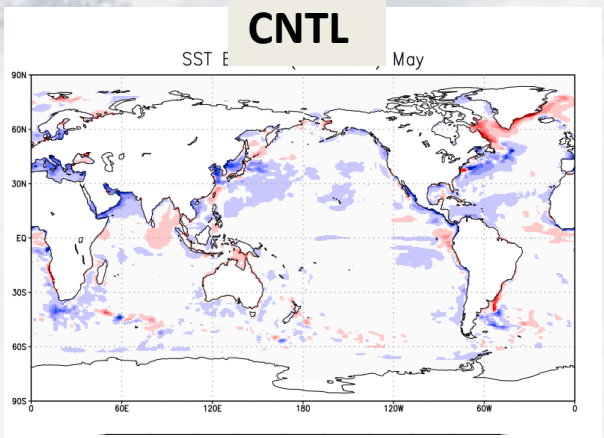
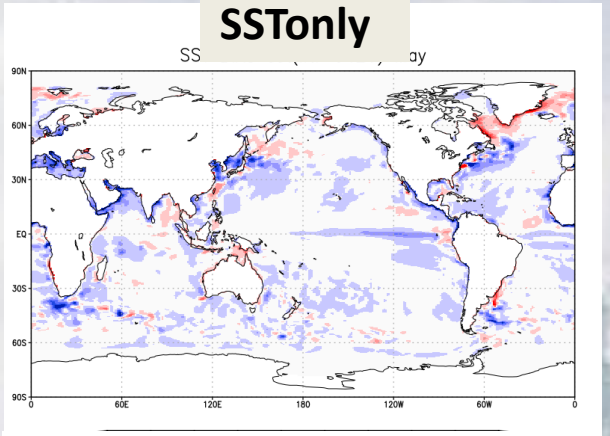
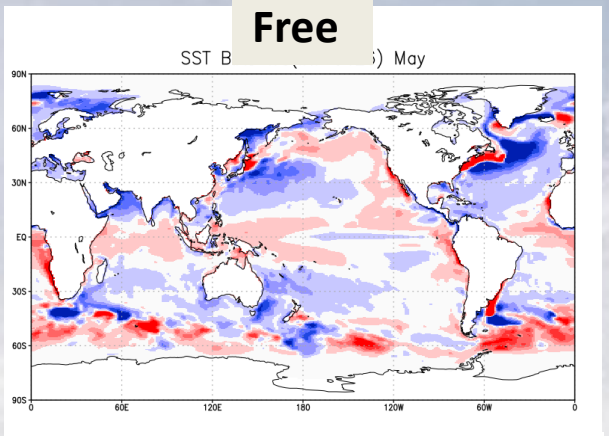
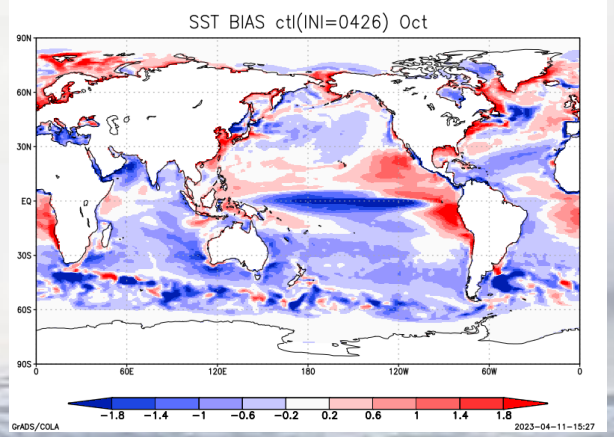
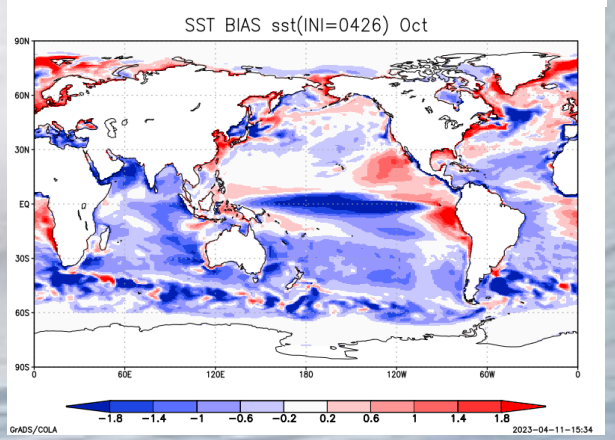
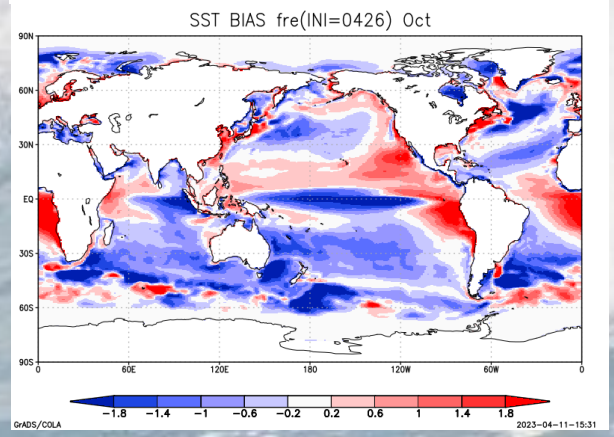
# ☆ ACC of forecasted SST for the 1st and 6th Month

ACC: Anomaly Correlation Coefficient

| | CNTL | SSTonly | Free |
|---|---|---|---|
| May (1st Mon) |  |  |  |
| October (6th Mon) |   |   |   |

- In the 1st month, the difference is clear for the areas in which ACC is more than 0.8 in the tropical Pacific.
- In the 6th month, the improved ACC score in CNTL is significant. But, the difference between SSTonly and Free is not clear.

# ☆ Bias of forecasted SST for the 1st and 6th Month

| | CNTL | SSTonly | Free |
|---|---|---|---|
| May (1st Mon) |  |  |  |
| October (6th Mon) |  |  |  |



- The cold bias in the equatorial Pacific and the south hemisphere in SSTonly in the 1st month is reduced by assimilating in-situ and satellite altimetry data in CNTL.
- Although the ACC difference is small between SSTonly and Free in the 6th month, the SST bias is clearly reduced in the North Pacific in the range in SSTonly.

# 5. Summary

# ☆ Summary and Concluding Remarks

- UN Ocean Decade Project SynObs is now implementing a multi-system OSE/OSSE collaborations, named the flagship OSEs/OSSEs.
- In the flagship OSEs/OSSEs, we try to remove system dependency by averaging OSE results of various systems and try to make fair evaluation and design.
- SynObs will share the OSE/OSSE results through a public web database prepared by JAMSTEC-APL.
- The flagship OSE/OSSE results will be analyzed several analysis groups.
- The results of OSEs in JMA/MRI demonstrate impacts of Argo floats, tropical moorings, other in situ observations, and satellite altimetry data on the ocean reanalysis.
- **Please mail to SynObs (synobs@mri-jma.go.jp) to join the SynObs activities.** (We share the information on the activity through the SynObs mailing list and the SynObs web meetings.)

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

Thank you!!