Development of Four-Dimensional Variational Global Ocean Data Assimilation System for Coupled Predictions in Japan Meteorological Agency and Evaluation of the effects of Argo Data Quality Control in the System

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Introduction

- **Current Operational Global Ocean 4DVAR System in JMA**
  - JMA currently uses 4DVAR (outer: 0.25º×0.25º, inner: 1º×0.3-0.5º) in the global ocean data assimilation system for the initialization of the operational coupled prediction model.
- **OSEs for assessing the impacts of QC**
  - We conducted OSEs assimilating Argo data with different QC levels and confirmed that the QC activity by the Argo GDAC contributes to reliable ocean reanalysis.
- **Development for future update of the system**
  - We are testing a 4DVAR system with a 0.25º×0.25º-resolution inner model.

OSEs for assessing the impacts of QC

Background

- Argo GDAC provides observed Argo profiles with real-time and delayed-model QCs. The Argo data with the real-time QC are also distributed through GTS.
- Argo GDAC also provides the gray list in which the floats reporting doubtful observation data.
- About 15% of Argo floats deployed after 2015 have experienced abrupt large salinity drifts due to break down of the instrument. The bad floats are listed on the gray list and excluded by the delayed-mode QC. The real-time QC also excludes the bad floats after the problem was recognized.
- We conducts OSEs assimilating Argo data with different QC levels in order to assess the impacts of QC.

Configuration of OSEs

- Exp-CNTL: Assimilate Argo data on GTS.
- Exp-GLST: Same as Exp-CNTL but data listed on the gray list are excluded.
- Exp-DELAY: Assimilate the delayed-mode data in Argo GDAC.
- Exp-NOQC: Assimilate the raw observation data in Argo GDAC.
- Exp-FREE: Model free run started from the same initial condition at Jan 2015
- MOAA-GPV: Objective Analysis based on the delayed-mode Argo data by JAMSTEC

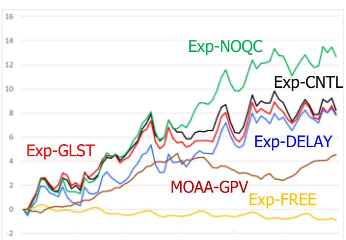

Fig. 6: Change of the global salt content between 0-2000m in each OSEs

- It is almost conserved in Exp-FREE but increasing in other OSEs.
- The real-time and delay-mode QCs effectively mitigate the increasing trend. The effect of the gray list is optional.
- The QC activity by the Argo GDAC contributes to reliable ocean reanalysis.

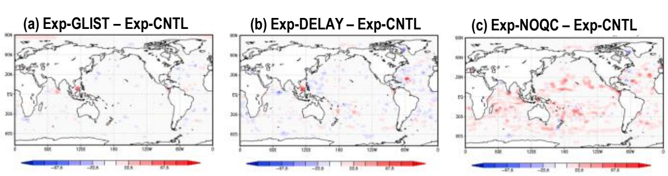

Fig. 7: Difference of vertically integrated salinity between 0-2000m averaged over 2019-2020 (psu x m) in (a) Exp-GLST, (b) Exp-DELAY, (c) Exp-NOQC from that in Exp-CNTL.

- ✓ The impact of the real-time QC (Fig. c) is relatively large in the Pacific and Atlantic subtropical regions and the Indian Ocean.
- ✓ The impact of the gray list (Fig. a) is relatively small.
- ✓ The impacts of the gray list (Fig. a) and the delayed mode QC (Fig. c) are relatively large in the Atlantic and relatively small in the eastern Pacific.

Development for future update of the system

The current operational 4DVAR system (G3A) cannot resolve meso-scale eddies in the western boundary current regions due to its low resolution. In order to resolve this problem, we are currently testing a 4DVAR system with a ¼˚-resolution inner model. In order to avoid increase of computational time, the assimilation window is shorten to 2 days (1-day IAU and 1-day observation windows). As shown below, the test system realistically represents the ocean current fields and meso-scale eddies.

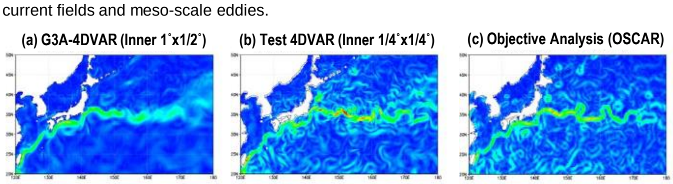

Fig. 8: Distribution of ocean current speed at 15m depth in the western North Pacific for G3A (4DVAR version), (b) test of the 4DVAR with a ¼˚-resolution inner model, and (c) objective analysis (OSCAR)

Current Operational Global Ocean 4DVAR System in JMA

System Specification

- **System: MOVE/MRI.COM-G3**
- Constituted of the analysis model G3A, and the forecast model G3F

- **Analysis Model (G3A)**
- Resolution: 1º×0.3-0.5º
- 4DVAR scheme for TS fields
  - ✓ Optimization periods (10 days) have 5-day overlapping.
  - ✓ Increments of IAU for the first 5 days are optimized.
  - ✓ 4DVAR optimization starts from 3DVAR results.
- Sea-Ice 3DVAR scheme
  - ✓ Separated from the 4DVAR
  - ✓ Surf. Air. Temp. is modified.

- **Forecast Model (G3F)**
- Resolution: 0.25º×0.25º
- TS fields are constrained to G3A analysis results via IAU.
- SIC fields are directly assimilated by the Sea-Ice 3DVAR.
- Provide oceanic initial condition for the coupled model.

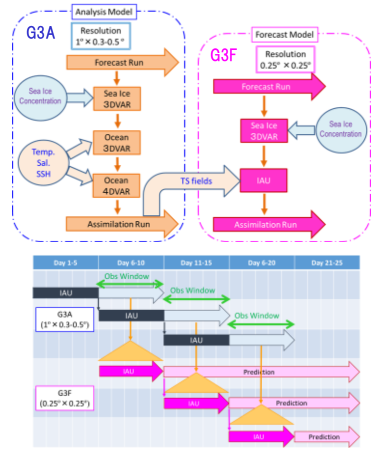

Fig. 1: Schematic figure (top) and the planed system flow (bottom) of MOVE/MRI.COM-G3

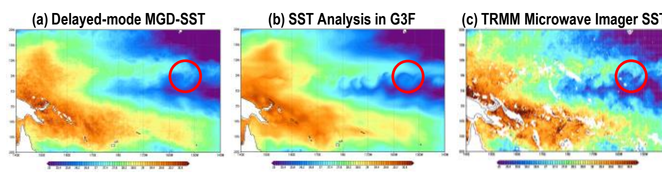

Fig. 2: Representation of Tropical Instability Waves (TIWs) in MOVE/MRI.COM-G3. Showing snapshots of SST fields at 01 Jan. 2012. a) Delayed-mode MGD-SST (observation-based SST analysis which are assimilated in the 4DVAR of G3A). b) SST Analysis field in G3F. c) SST fields observed by TRMM Microwave Imager. TIWs are not clear in the delayed-mode MGD-SST due to smoothing property of statistical interpolation. However, SST variation associated with TIWs (the streamer in the red circle for example) are reasonably represented in G3F due to dynamical interpolation using forward and adjoint models.

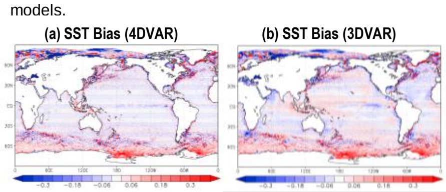

Fig. 3: SST bias of (a) 4DVAR and (b) 3DVAR version of G3A from the JMA's objective SST analysis, MGDSST, which are assimilated in G3A.

4DVAR effectively reduces the SST bias from the objective SST analysis witch are assimilated compared with 3DVAR.

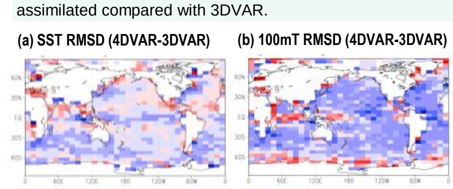

Fig. 4: Difference of (a) SST and (b) 100m temperature RMSDs from assimilated Argo data between 4DVAR and 3DVAR version of G3A (4DVAR - 3DVAR).

RMSDs from assimilated Argo data are also generally reduced by 4DVAR. Thus, 4DVAR more effectively reduces the data-misfits.

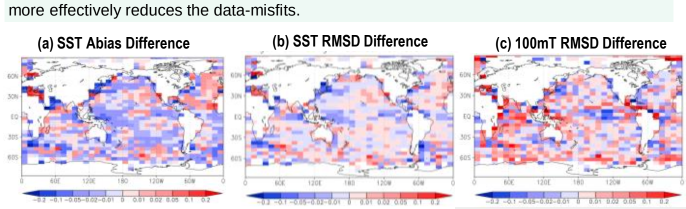

Fig. 5: Differences of (a) SST absolute bias, (b) SST RMSDs, and (c) 100m temperature RMSDs from independent Argo data which are not assimilated between 4DVAR and 3DVAR version of G3A (4DVAR - 3DVAR).

Although 4DVAR reduces the SST bias more effectively than 3DVAR, the impact of 4DVAR on RMSDs of SST and 100mT evaluated with independent data is not clear, probably because the model does not sufficiently represent the real physics due to the low resolution. However, 4DVAR represents large variability in the Equatorial Pacific and the Kuroshio Extension area better than 3DVAR.