Developing the next-generation operational seasonal forecast system at JMA

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1. Introduction

- Since the first implementation of ENSO forecast system in late 1990s, continuous effort has been made to improve its accuracy and reliability at JMA.
- For the next version to be released in 2021-2022, we plan to introduce ocean four-dimensional variational data assimilation method (4DVAR) in search for reducing large forecast bust as such happened for 2014-2015 El Nino.
- MOVE-G3, next candidate version of ocean data assimilation system, is briefly described and experimental ENSO forecast using JMA:'s latest generation AOGCM is presented.

2. Ocean 4DVAR system

- MOVE-G3 4DVAR has two suites of job in one analysis cycle (**Fig.1**).
- In the Analysis suite, a coarse (1.0° for lon. x 0.3-0.5° for lat.) global ocean model is used throughout. Sea ice concentration, as well as Temperature, salinity and sea surface height (SSH) observations are assimilated first with 3DVAR. 4DVAR then starts from the 3DVARed field. In the IAU suite, an eddy-permitting (0.25°x 0.25°) ocean is integrated over the same time window whilst adding misfit to the 4DVAR.
- Preliminary tests suggest that this incremental 4DVAR improves the analysis quality in regions with dynamically active current; e.g. Eastern tropical Pacific and western boundary currents(**Fig.2**). The compromise to a lower model resolution in the Analysis suite seems reasonable.
- MOVE-G3 4DVAR has been ported lately to Cray XC50 in Kiyose, Tokyo. A very recent benchmark test shows that the system takes two days on 48 nodes for the Analysis suite and a half day on 24 nodes for the IAU suite to complete one analysis year.
- For details, refer to **Yosuke Fujii**'s companion poster on **Thursday, Sep. 20** at Center Green, entitled "Development of a global ocean and coupled data assimilation system for subseasonal to seasonal forecasts in Japan Meteorological Agency". (**P-A6-03**)

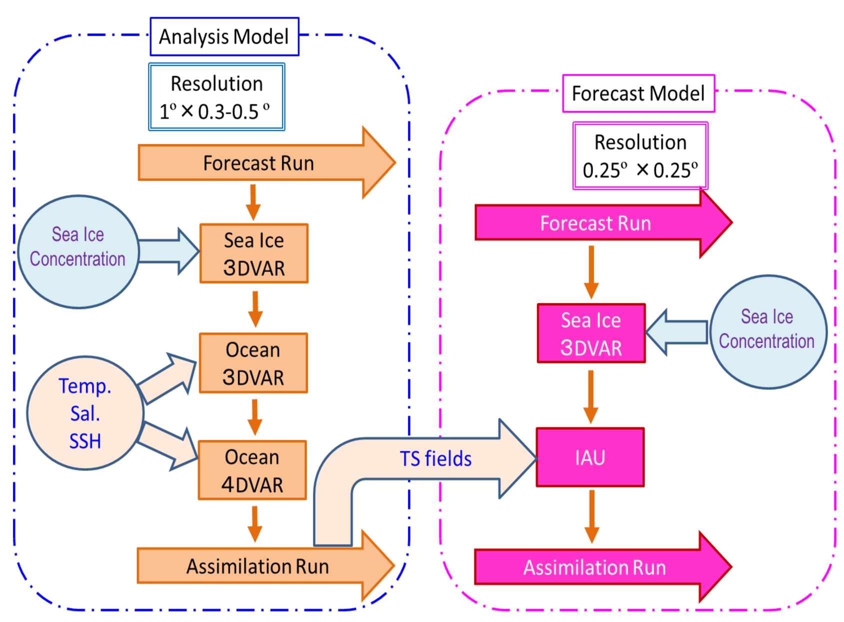

Fig.1 MOVE-G3 assimilation suite.
Data assimilation widows is set to 10 days in this study.

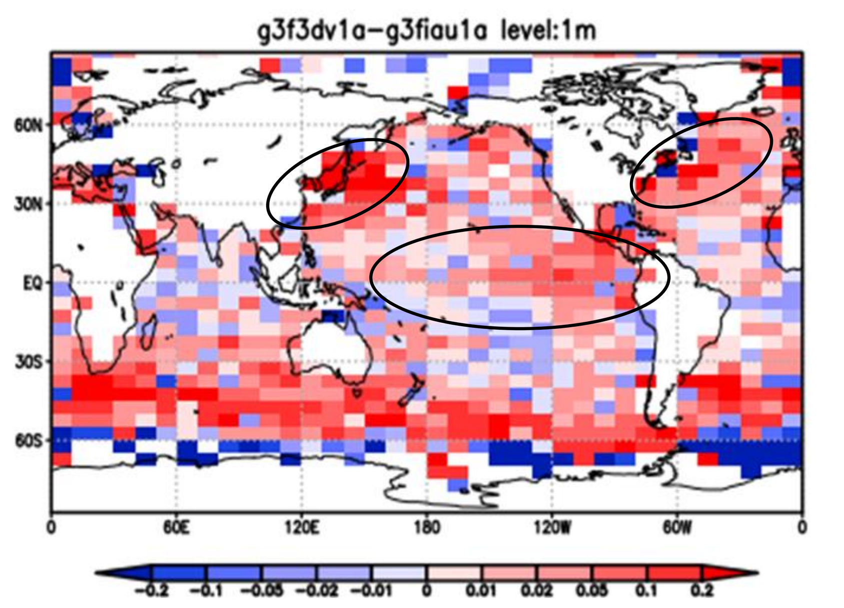

Fig.2 Root Mean Square Error difference (3DVAR-4DVAR) of potential temperature [K] at 1m depth. Red (Blue) shades indicate that 4DVAR is closer than 3DVAR to reference (independent) ARGO buoys in 2010-2015.

	JMA/MRI-CPS2	JMA/MRI-CPS3
Operation period	June 2015-	Dec. 2021- (TBD)
Atmospheric model	◻ GSM 1103 ◻ TL159L60 (~110km, 60 vertical levels up to 0.1hPa) ◻ Climatological Land/Sea aerosol profile (WMO 1986) ◻ Ozon climatology	◻ **GSM1705 or a later version** ◻ **TL319L100** (~55km, 100 vertical levels up to 0.01hPa) ◻ **Improved representation of cumulus, gravity waves and land processes** ◻ **3-D Multi-Species Aerosol climatology** ◻ **Improved ozone climatology**
Ocean model	◻ MRI.COM ver 3 ◻ Coarse resolution 1.0°(lon) x 0.3-0.5°(lat) L52+BBL	◻ MRI.COM ver 4 (Tsujino et al 2010) ◻ **Eddy-permitting resolution** 0.25°(lon) x 0.25°(lat) L60
Initial Condition	Atm.: JRA-55 (TL319L60) Land: JRA-55 Ocean: MOVE-G2 3DVAR Ice: no data assimilated	Atm: **JRA-3Q** (TL479L100) Land: **JRA-3Q** Ocean: **MOVE-G3 4DVAR+IAU** Ice: **3D-Var**

Table1 System configuration for the current(left) and next(right) seasonal forecast system at JMA
Orange : **done**, Black: **yet done**

Acknowledgements

➤ TMI data were produced by Remote Sensing Systems and sponsored by the NASA Earth Sciences Program. Data are available at www.remss.com/missions/tmi.

3. Ocean 4DVAR as initial condition for seasonal forecast

- An experimental set of 4DVAR reanalysis is produced for 2010-2015. JRA-55do (Tsujino et al. *Ocean Modelling*, 2018) is used for atmospheric forcing. This is then compared in a seasonal forecasting context to similarly produced 3DVAR using a prototype version of JMA/MRI-CPS3 (**Table 1**). These forecast experiments are denoted as EXP4DVAR and EXP3DVAR hereafter. Only ocean initial condition differs between the experiments.
- The atmosphere in the prototype CPS3 has good enough climate reproducibility for ENSO forecasting, with annual mean net radiation imbalance at the model top by +0.4W/m^2 against CERES (not shown).
- Forecasts are initialized at every four month (Jan., Apr., Jul., Oct.) and integrated for seven months. Two member ensemble is generated with Lagged Average Forecast (LAF) method with initial dates 15days apart. Note that only two members each month may result in poor ENSO statistics.

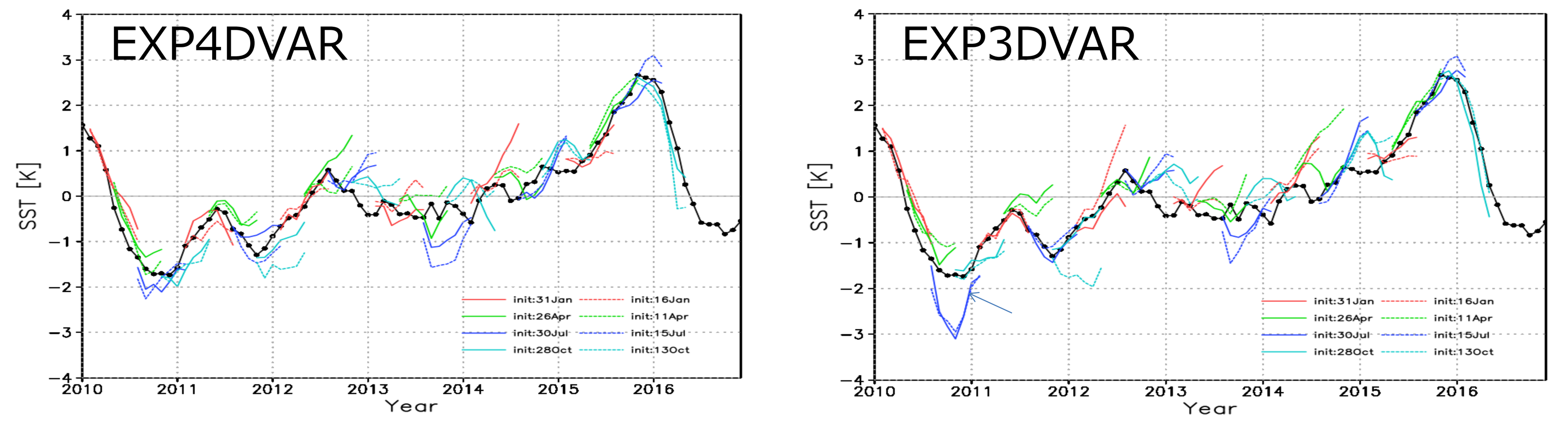

Fig.3 NINO3.4 SST anomalies with respect to COBE-SST Climatology(1991-2009). COBE-SST(Black), January initial (Red), April initial (Green), July initial (Blue), October initial (Cyan). **No posteriori model bias correction applied.**

- Regarding NINO3.4 forecast, we find roughly equal performance for EXP3DVAR and EXP4DVAR in a sense that both well predicts the strong La Nina event in 2010-2011 and El Nino event in 2014-2015 from April initials (**Fig.3**).
- A closer look indicates that 4DVAR may help reduce chances for forecast bust.
- Fake signals for strong 2014-2015 El Nino remain, suggesting that it cannot be improved by ocean initial condition alone..

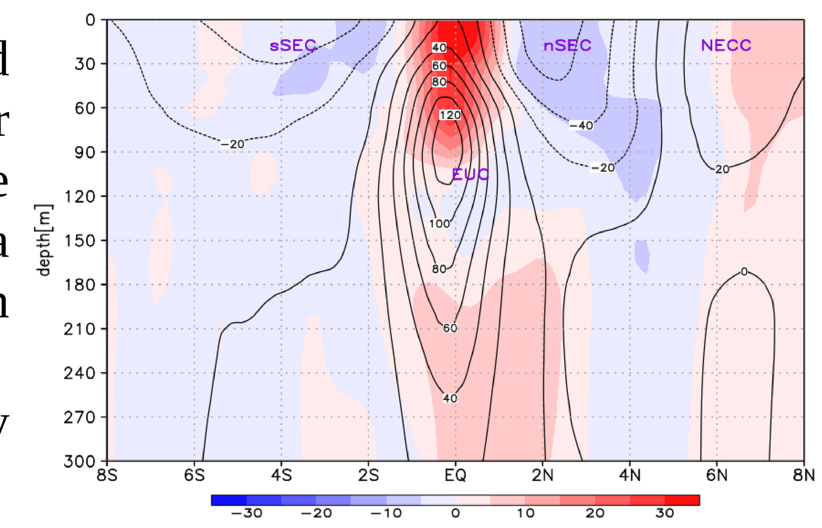

Fig.4 Zonal Mean (180-90W) Zonal Velocity [cm/s] profile at Forecast Day 1.
Contour: 4DVAR initial zonal mean U
Shade: (4DVAR initial) – (3DVAR initial)

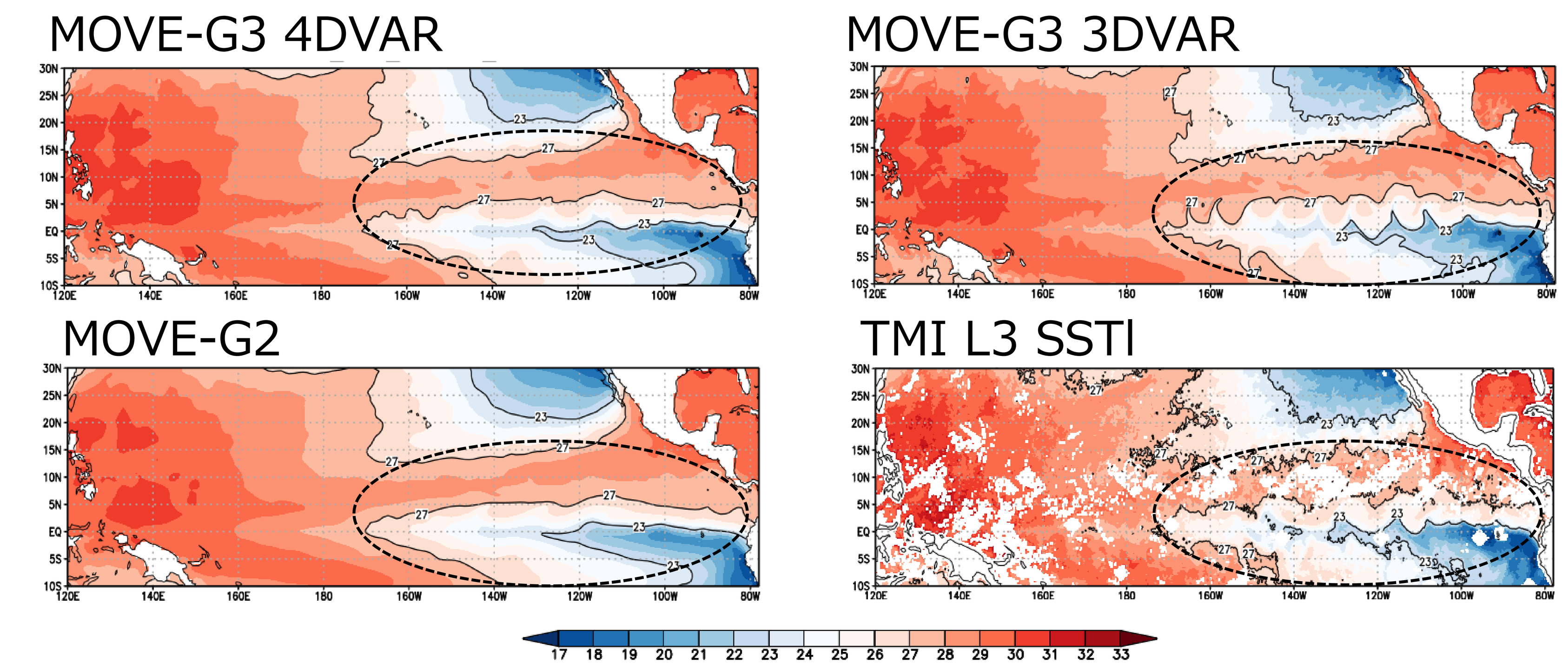

Fig.5 Initial SST in degrees Celsius at 30th July, 2010. For a reference, the bottom right panel shows 29Jul-31Jul average TRMM Microwave Imager (TMI) SST, which is not assimilated in any of the MOVEs.

- To highlight differences, we focus on 2010 La Nina forecast case (**Fig.3**).
- In July 2010, a big La Nina was quickly developing. Tropical Instability Waves(TIWs) were clearly observed at the Eastern tropical Pacific. The 4DVAR provides visibly different initial condition from 3DVAR on 30th July 2010 (**Fig.5**).
- At the time 4DVAR represents stronger zonal current gradient between Equatorial Under Current (EUC) and northern South Equatorial Current (nSEC) (**Fig.4**). Consistently zonally elongated waves appear in the SST field whilst smaller eddies are dominant in 3DVAR. Comparison to TMI SST suggests that, although weak in amplitude, 4DVAR better reproduces observed position of ridges and troughs of TIWs. Initial advective warm-up/cool-down above 100m depth might have triggered different air-sea interaction later on.
- Detailed analysis with more forecast cases is under progress.

4. Future developments

- Answering to "Does the computational cost for 4DVAR really pay in seasonal forecast?" requires more forecast cases before reaching a solid conclusion. Preliminary results seem encouraging. Ocean reanalysis and hindcast will be extended back to 1991-.