Development of a global ocean data assimilation system for weak coupling to the KIAPS system

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1 Background

- The Korean Integrated Model (KIM) - a non-hydrostatic model based on a cubed-sphere grid - was developed for the global atmosphere/land NWP system that was made operational at KMA in April 2020.
- The global data assimilation (DA) system is based on a hybrid-4DEnVar system, consisting of KVAR (KIM VARiational data assimilation) and an LETKF (Local Ensemble Transform Kalman Filter).
- For extended-range forecasting (up to ~30 days), KIAPS is developing a coupled model that considers interactions between Earth system components (Ocean: NEMO, Sea-ice: SI3, Wave: WW3, Land: Noah-MP & CLM).
- If the components are initialized with independent data assimilation (DA) systems, coupled forecasts can be affected by initial shocks as the components adjust to each other.

➔ To reduce this initial shock, we are developing a **"weakly" coupled DA system** based on the KIAPS atmosphere-ocean model

2 Development Plan

- **Step 1**: Establish baseline ocean DA system
  - Import, analyse, and simplify an existing ocean-only DA system "GODAPS", which uses NEMOVAR (3DVar-FGAT).
- **Step 2**: Develop ocean DA system for the KIM system
  - ✓ **Step 2A.** Change surface forcing system (KMA implementation of Met Office Unified Model (KMA-UM) ➔ KIM)
    - Develop a surface forcing production system using KIM, optimized for an ocean DA system based on Rose/Cylc
    - Create REMAP matrices to reflect various domain configurations (KIM-NEMO)
    - Diagnose NEMOVAR system impact at the observation locations
  - ✓ **Step 2B.** Match the atmospheric DA cycle
    - Set-up 6-hour cycles and DA windows + forcing with KMA UM, Background time 0 to 6 (Results not shown)
    - Set-up 6-hour cycles and DA windows + forcing with KIM , Background time -3 to 3.
    - Consider observation cut-off times, such as using the atmospheric LATE cut-off time.
- **Step 3**: Create a weakly-coupled DA cycling system by merging with the KIM-KVAR DA system.

3 Step 1 - GODAPS

- For ocean DA, our baseline system is KMA's "GODAPS" (Global Ocean Data Assimilation and Prediction System).
- GODAPS uses the NEMOVAR DA system developed and optimized for the NEMO model, with 3-hourly surface forcing provided by the KMA-UM system (Table 1).
- These analyses use the 3DVAR-FGAT (First Guess at Appropriate Time) method with a 24 hr DA window.
- The system acquires various observation data (Fig. 1) from all over the world and performs quality control (QC).

Table 1. Configuration of GODAPS system.

GODAPS		
Model	Ocean	NEMO v3.6
	Sea Ice	CICE v5.1.2
Resolution (Spatial/Temporal)	Tri-polar coordinates extORCA025 (~25km)	
	75 levels (z-coordinate)	
	7 days forecast	
Bathymetry	based on ETOPO 1 (GEBCO in the coast)	
DA method	3DVar-FGAT (NEMOVAR)	
DA window	2 days hindcast (-48~-24 hr / -24~0 hr)	

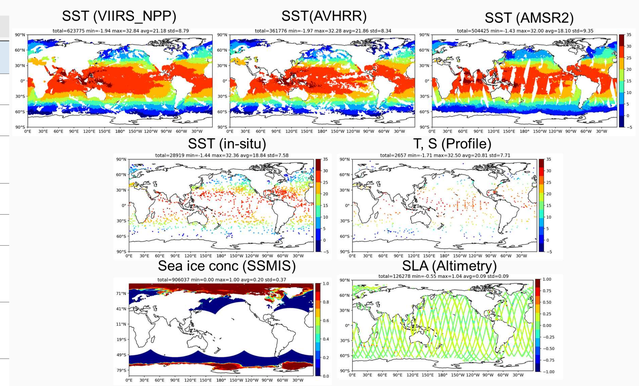


Fig. 1. Spatial distribution of the assimilated ocean observations in the GODAPS over 24 hr.

4 Step 2A – Results

Change of surface forcing

- We analysed the ocean response to the change from KMA-UM to KIM surface forcing (Table 2).
- With the assimilated observations, we obtained the distributions of the O-B (innovation), O-A (analysis error), and A-B (increment) in observation space, and compared the analysis RMSEs to the background RMSEs (Fig. 2-4).
  ➔ Ocean DA (NEMOVAR) is doing its role well ☺
  ➔ KIM surface forcing gives similar results to KMA-UM surface forcing.

Table 2. Experiment configurations for the surface forcing change.

Experiment name	Surface forcing	Time interval	DA window
UM	KMA UM N1280 (~10km)	3 hr (1hr wind speed)	24 hr (2day hind-cast)
KIM	KIM ne360np3 (~12km)	3 hr	
Period : 2022/05/20 - 2022/06/21 (Spin-up in May) in KIM case, use UM analysis for restart on 2022/05/19			

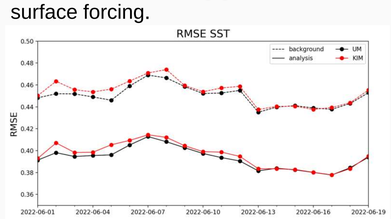


Fig 2. Time-series of RMSE for SST of the satellite and in-situ. The dashed line and solid lines denote background error and analysis error. The black, and red lines denote UM and KIM forcing experiment, respectively.

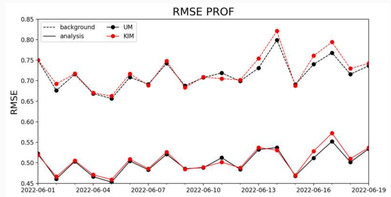


Fig 3. Same as in Fig. 2, but for the temperature of profile data about the total depth.

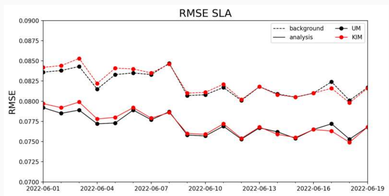


Fig 4. Same as in Fig. 2, but for the sea level anomaly of altimetry.

5 Step 2B – In progress & Discussion

Obs. for DA cycle & window

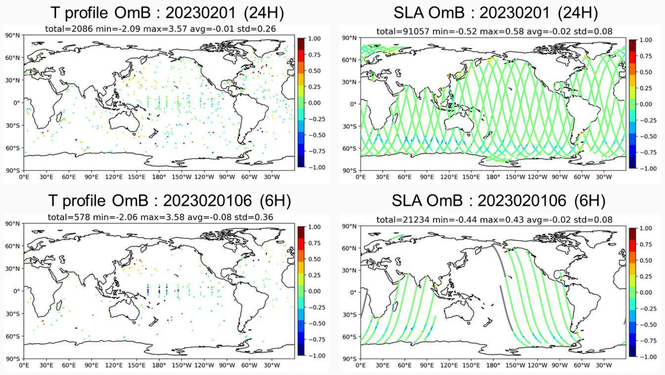
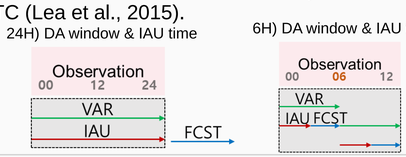


Fig 5. Spatial distribution of O-B according to cycle and window difference. The upper and lower panels are 24 hr and 6 hr experiment results. The left and right panels are temperature profile and sea level anomaly variables. The gray color denotes a fill value.

- We reduced the original 24 hr DA cycle and DA window length to 6 hr - the same as those of the atmosphere.
- 24H target background : 20230201 **00 – 23UTC**
  6H : 20230201 **03 – 09UTC**
- Although we have only checked the background ingest process for one time, the number of observations was significantly decreased (~25%), with no ice concentration at all (Fig.5).
- The cut-off time was not considered in this experiment.
  ➔ If the actual obs. arrival time was taken into consideration, the number of obs. would decrease.
- For the 6H experiment, the IAU insertion time will be reduced to 3 or 6 hr to meet the anlaysis center time of 06 UTC (Lea et al., 2015).



6 Conclusion and Plan

- We confirmed that changing the surface forcing from KMA-UM to KIM forecasts had little impact.
  - Analysis and background errors were similar in both systems.
- When the development of the 6H ocean DA system is completed, we plan to compare the 24H and 6H analyses.
- In the future, it is necessary to investigate the use of "catch-up" cycles with later cut-off times, to increase the number of ocean observations available for assimilation.
- We will develop a weakly coupled DA method that can also be used with our KVAR system.

Acknowledgments
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