Development of an EnKF-based ocean data assimilation system

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Abstract

With the recent enhancement of observation networks such as satellites and Argo profiling floats, temperature, salinity, and sea surface height have been observed at relatively high spatiotemporal resolution. However, for example, the satellites cannot observe rainy regions and the number of Argo float observations is still not sufficient to capture the spatiotemporal variations over the global ocean. Data assimilation reproduces an accurate three-dimensional ocean analysis field without missing values by combining simulation and observations. In this study, using the JAXA Supercomputer System Generation 3 (JSS3), we aim to develop an ensemble Kalman filter (EnKF)-based ocean data assimilation system that assimilates satellite and in-situ observations at a daily interval and to create ocean analysis datasets.

Ref. URL: https://earth.jaxa.jp/en/research/fields/ocean/index.html
https://www.eorc.jaxa.jp/ptree/LORA/index_j.html

Reasons and benefits of using JAXA Supercomputer System

The computation costs of high-resolution ensemble simulation using an ocean model and data assimilation using the EnKF are very high. Therefore, a high-performance computing infrastructure such as the JSS3 enables us to integrate an EnKF-based ocean data assimilation system.

Achievements of the Year

Our previous studies demonstrated that the combination of incremental analysis updates (IAU; Bloom et al. 1996), relaxation-to-prior perturbation (RTPP; Zhang et al. 2004), adaptive observation error inflation (AOEI; Minamide and Zhang 2017) is necessary to increase the analysis accuracy in an ensemble Kalman filter-based ocean data assimilation system (Ohishi et al. 2022a, b). In this fiscal year, we aim to create ensemble ocean analysis products in the western North Pacific and Maritime Continent regions by updating a system with horizontal resolution of 0.25 degrees (i.e., eddy-permitting resolution) used in the previous year to that with horizontal resolution of 0.1 degrees (i.e., eddy-resolving resolution).

We compared the validation results from the created dataset referred to as LETKF-based Ocean Research Analysis (LORA) with the existing reanalysis dataset JCOPE2M (Miyazawa et al. 2017) and observational dataset AVISO (Ducet et al. 2000). The results show that the surface horizontal velocities in LORA are more accurate than JCOPE2M (AVISO) in the mid-latitude region, especially around the Kuroshio and Kuroshio Extension regions (around the equatorial region). The accuracy of sea surface temperatures (SSTs) in LORA is higher than JCOPE2M over the almost whole western North Pacific domain. However, the nearshore SST accuracy in LORA is lower than JCOPE2M because of higher SST biases in boreal winter.

This study shows that the LORA has sufficient accuracy to utilize for geoscience research and other applications. The results in this study are published by an international journal, Ocean Dynamics (Ohishi et al. 2023). In the next fiscal year, we plan to conduct sensitivity experiments on atmospheric forcing to alleviate the nearshore high SST biases.

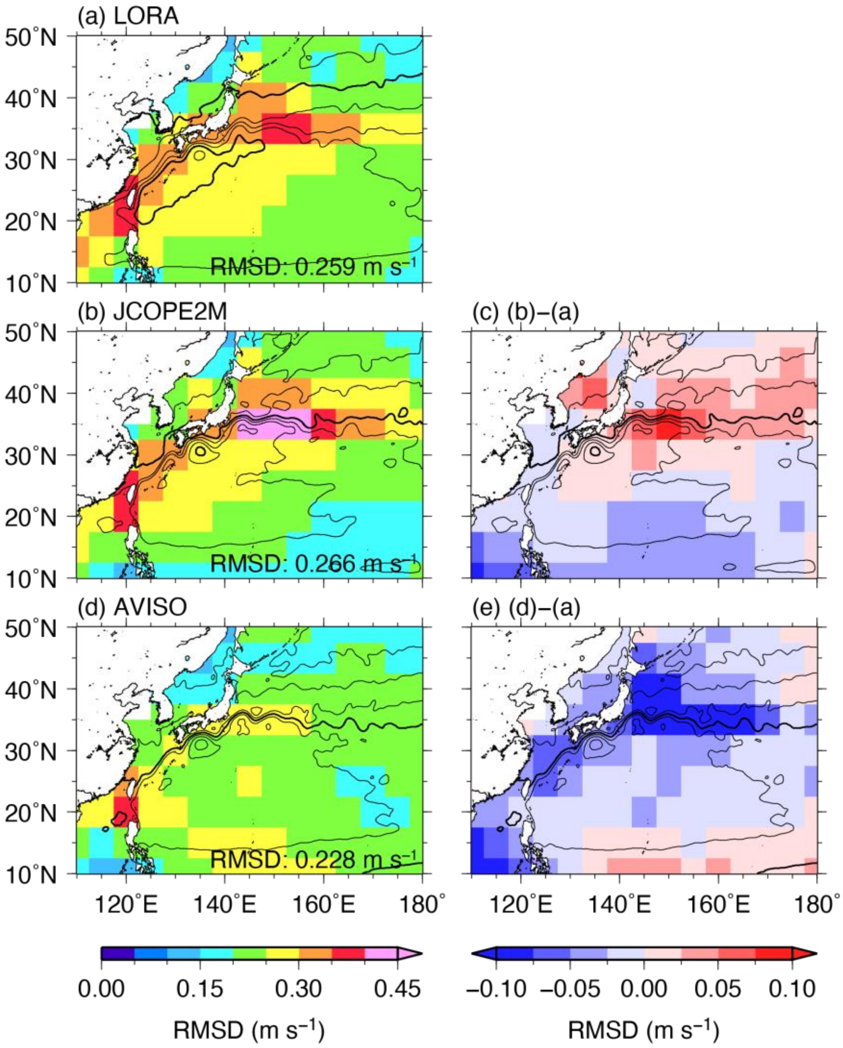

Fig. 1: Root mean square deviations (RMSDs) of the surface zonal velocities from (a) LORA, (b) JCOPE2M, and (d) AVISO relative to the drifter buoys in 5 degree lontitude x 5 degree latitude bins averaged over 2016-18. RMSD differences between the (c) JCOPE2M [(e) AVISO] and LORA. Contours indicate SSH averaged over 2016-18 from the LORA in a, JCOPE2M in b and c, and AVISO in d and e. Thin (Thick) contour intervals are 0.25 (1) m. RMSDs averaged over the whole analysis period and domain are shown at the bottom right corner in the left panels.

Publications

- Peer-reviewed papers

1. Ohishi, Shun, Tsutomu Hihara, Hidenori Aiki, Joji Ishizaka, Yasumasa Miyazawa, Misako Kachi, and Takemasa Miyoshi, 2022: An ensemble Kalman filter system with the Stony Brook Parallel Ocean Model v1.0, Geosci. Model Dev., 15, 8395-8410, doi: 10.5194/gmd-15-8395-2022

2. Ohishi, Shun, Takemasa Miyoshi, and Misako Kachi, 2022: An ensemble Kalman filter-based ocean data assimilation system improved by adaptive observation error inflation (AOEI), Geosci. Model Dev., 15, 9057-9073, doi: 10.5194/gmd-15-9057-2022

3. Ohishi, Shun, Takemasa Miyoshi, and Misako Kachi, 2023: LORA: a local ensemble transform Kalman filter-based ocean research analysis, Ocn. Dyn., doi: 10.1007/s10236-023-01541-3

- Oral Presentations

1. Ohishi, Shun, Takemasa Miyoshi, and Misako Kachi 'LETKF-based Ocean Research Analysis (LORA) in the Western North Pacific region', JpGU Meeting 2022, Chiba, May 2022

2. Miyoshi, Takemasa, Ting-Chi Wu, Koji Terasaki, Jlanyu Liang, Shun Ohishi, Shigenori Otsuka, Shunji Kotsuki, Atsushi Okazaki, Hirofumi Tomita, Ying-Wen Chen, Kaya Kanemaru, Masaki Satoh, Hisashi Yashiro, Kozo Okamoto, Eugenia Kalnay, Takuji Kubota, and Misako Kachi, 'Advances and applications of satellite assimilation of clouds, precipitation, and the ocean', JpGU Meeting 2022, Chiba, May 2022

3. Ohishi, Shun, Takemasa Miyoshi, and Misako Kachi 'LETKF-based Ocean Research Analysis (LORA) in the Western North Pacific region', AOGS 2022, Online, Aug. 2022

4. Ohishi, Shun, Takemasa Miyoshi, and Misako Kachi 'LETKF-based Ocean Research Analysis (LORA) in the Western North Pacific region', ISDA-online, Online, Oct. 2022

5. Ohishi, Shun, Takemasa Miyoshi, and Misako Kachi 'LETKF-based Ocean Research Analysis (LORA) in the Western North Pacific and Maritime Continent regions', The Joint PI Meeting of JAXA Earth Observation Missions FY2022, Tokyo, Nov. 2022

6. Miyoshi, Takemasa, Shun Ohishi, Sigenori Otsuka, Jlanyu Liang, Rakesh Teja Konduru, Hirofumi Tomita, Ying-Wen Chen, Shunji Kotsuki, Atsushi Okazaki, Kaya Kanemaru, Hisashi Yashiro, Kozo Okamoto, Koji Terasaki, and Eugenia Kalnay, 'Advanced and applications of satellite data assimilation of clouds, precipitation, and the ocean', The Joint PI Meeting of JAXA Earth Observation Missions FY2022, Online, Nov. 2022

- Poster Presentations

1. Ohishi, Shun, Takemasa Miyoshi, and Misako Kachi 'LETKF-based Ocean Research Analysis (LORA): Assimilating high-frequency satellite observations', Joint Workshop of the OS-Eval TT and CP-TT and SynObs Kick-Off, Tsukuba, Nov. 2022

2. Ohishi, Shun, Takemasa Miyoshi, and Misako Kachi 'LETKF-based Ocean Research Analysis (LORA)', The 5th R-CCS International Symposium, Kobe, Feb. 2023

- Web

https://earth.jaxa.jp/ja/earthview/2022/10/21/7342/index.html

https://www.eorc.jaxa.jp/ptree/LORA/index.html

Usage of JSS

- **Computational Information**

Process Parallelization Methods	MPI
Thread Parallelization Methods	Automatic Parallelization
Number of Processes	48 - 512
Elapsed Time per Case	20 Minute(s)

- **JSS3 Resources Used**

Fraction of Usage in Total Resources[*1](%): 0.56

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	15,377,459.05	0.67
TOKI-ST	0.00	0.00
TOKI-GP	0.00	0.00
TOKI-XM	0.00	0.00
TOKI-LM	0.00	0.00
TOKI-TST	0.00	0.00
TOKI-TGP	0.00	0.00
TOKI-TLM	0.00	0.00

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage[*2] (%)
/home	12.50	0.01
/data and /data2	174,205.00	1.34
/ssd	125.00	0.02

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage[*2] (%)
J-SPACE	0.00	0.00

[*1]: Fraction of Usage in Total Resources: Weighted average of three resource types (Computing, File System, and Archiver).

[*2]: Fraction of Usage：Percentage of usage relative to each resource used in one year.

- **ISV Software Licenses Used**

ISV Software Licenses Resources		
	ISV Software Licenses Used (Hours)	Fraction of Usage[*2] (%)
ISV Software Licenses (Total)	0.00	0.00

[*2]: Fraction of Usage：Percentage of usage relative to each resource used in one year.