Development of an EnKF-based ocean data assimilation system

Report Number: R23ER2402
Subject Category: Space Technology
URL: https://www.jss.jaxa.jp/en/ar/e2023/23639/

Responsible Representative
Misako Kachi, Earth Observation Research Center

Contact Information
Misako Kachi(kachi.misako@jaxa.jp)

Members
Misako Kachi, Shun Ohishi

Abstract

With the recent enhancement of ocean observation networks by satellites and Argo profiling floats, spatiotemporally higher-resolution temperature, salinity, and sea surface height have been observed. However, for example, the satellites cannot observe under rainy conditions, and the number of Argo float observations is still not sufficient to capture spatiotemporally short-scale 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://www.eorc.jaxa.jp/ptree/LORA/index.html

Reasons and benefits of using JAXA Supercomputer System

The computation costs of high-resolution ensemble data assimilation using an ocean model and EnKF are expensive. Therefore, integration of an EnKF-based ocean data assimilation system becomes feasible with a high-performance computing infrastructure such as the JSS3.

Achievements of the Year

Through the previous fiscal year, we have demonstrated that the combination of Incremental Analysis Update (IAU; Bloom et al. 1996), Relaxation-To-Prior Perturbation (RTPP; Zhang et al. 2004), and Adaptive Observation Error Inflation (AOEI; Minamide and Zhang 2017) is necessary for an EnKF-based Ocean data assimilation system with frequent assimilation interval of 1 day (Ohishi et al. 2022a, b). We established a new high-resolution eddy-resolving system configured for the western North Pacific and Maritime Continent regions and created new ensemble ocean analysis datasets called LETKF-based Ocean Research Analysis (LORA). The validation results showed that the LORA has sufficient accuracy for geoscience research and various applications (Ohishi et al.

2023). However, substantial warm temperature biases are distributed around coastal regions. This year, we conducted sensitivity experiments to mitigate the biases by changing the atmospheric forcing dataset from an atmospheric reanalysis dataset JRA-55 to an ocean forcing dataset JRA55-do. The results showed that the nearshore warm SST biases are significantly improved if the JRA55-do is applied (Ohishi et al. in press). We have released the dataset called LORA version 1.0 through the "JAXA-RIKEN Ocean Analysis" website (https://www.eorc.jaxa.jp/ptree/LORA/index.html; Ohishi et al. submitted).

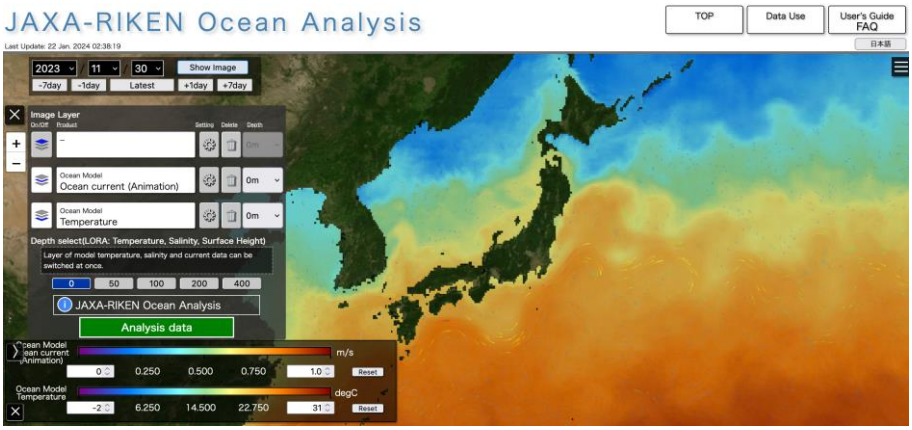

Fig. 1: Sea surface temperature (color) and velocity (vector) from the LORA version 1.0 at 30th Novmber 2023 on the JAXA-RIKEN Ocean Analysis website.

Publications

- Peer-reviewed papers

1. Oishi, K., and Kotsuki, S. (2023): Applying the Sinkhorn Algorithm for Resampling of Local Particle Filter. SOLA, 19, 185-193. doi: 10.2151/sola.2023-024

2. Ohishi, Shun, Takemasa Miyoshi, and Misako Kachi: Impact of atmospheric forcing on SST in the LETKF-based ocean research analysis (LORA), Ocean Modelling (accepted)

3. Terasaki, K., and T. Miyoshi, 2024: Including the horizontal observation error correlation in the ensemble Kalman filter: idealized experiments with NICAM-LETKF. Mon. Wea. Rev., 152, 277-293. doi:10.1175/MWR-D-23-0053.1

- Invited Presentations

2023/4/12 Takemasa Miyoshi, Big Data Assimilation Revolutionizing Numerical Weather Prediction Using Fugaku, Data Assimilation Forum at Centre for Climate Research Singapore (CCRC) Seminar, Online

2023/6/19 Takemasa Miyoshi, "Chaos implies effective controllability of extreme weather", The Third International Nonlinear Dynamics Conference (NODYCON 2023), Rome, Italy, Keynote.

2023/7/14 Takemasa Miyoshi, Big Data Assimilation Revolutionizing Numerical Weather Prediction Using Fugaku, The 28th IUGG General Assembly (IUGG2023), Berlin, Germany

2024/3/15 Takemasa Miyoshi, Advances and applications of satellite data assimilation of clouds, precipitation, and the ocean, DA Forum, University of Melbourne

- Oral Presentations

2023/4/24 Takemasa Miyoshi, Celeste Saulo, Shigenori Otsuka, Juan Ruiz, Yanina Skabar, Arata Amemiya,

Tomoo Ushio, Hirofumi Tomita, Tomoki Ushiyama, Masaya Konishi, PREVENIR: Japan-Argentina Cooperation Project for Heavy Rain and Urban Flood Disaster Prevention, EGU General Assembly 2023, Vienna, Austria

2023/5/22 Ohishi, Shun, Yuki Kobayashi, Takemasa Miyoshi: Including cross correlations between the forecast and observation errors in the ensemble Kalman filter, Japan Geoscience Union Meeting 2023, Chiba

2023/5/26 Takemasa Miyoshi, Advances and applications of satellite data assimilation of clouds, precipitation, and the ocean, Japan Geoscience Union Meeting 2023, Chiba

2023/7/13 Takemasa Miyoshi, Celeste Saulo, Shigenori Otsuka, Juan Ruiz, Yanina Skabar, Arata Amemiya, Tomoo Ushio, Hirofumi Tomita, Tomoki Ushiyama, Masaya Konishi, PREVENIR: Japan-Argentina Cooperation Project for Heavy Rain and Urban Flood Disaster Prevention, IUGG2023, Berlin, Germany

2023/7/13 Miyoshi, Takemasa, Sun, Qiwen, Terasaki, Koji, Maejima, Yasumitsu, From Predictability to Controllability: Control Simulation Experiment, The 28th IUGG General Assembly (IUGG2023), Berlin, Germany

2023/8/3 Takemasa Miyoshi, Celeste Saulo, Shigenori Otsuka, Juan Ruiz, Yanina Skabar, Arata Amemiya, Tomoo Ushio, Hirofumi Tomita, Tomoki Ushiyama, Masaya Konishi, PREVENIR: Japan-Argentina Cooperation Project for Heavy Rain and Urban Flood Disaster Prevention, Asia Oceania Geosciences Society (AOGS)2023, Singapore

2023/8/4 Takemasa MIYOSHI, Shun OHISHI, Jianyu LIANG, Rakesh Teja KONDURU, Shigenori OTSUKA, Shunji KOTSUKI, Koji TERASAKI, Atsushi OKAZAKI, Hirofumi TOMITA, Ying-Wen CHEN, Kaya KANEMARU, Masaki SATOH, Hisashi YASHIRO, Kozo OKAMOTO, Eugenia KALNAY, Takuji KUBOTA, Misako KACHI, Advances and Applications of Satellite Data Assimilation of Clouds, Precipitation, and the Ocean, AOGS2023, Singapore

2023/8/23 Takemasa Miyoshi, Qiwen Sun, Koji Terasaki, Yasumitsu Maejima, Chaos implies effective controllability of extreme weather, From Weather Predictability to Controllability: Control Simulation Experiment (CSE) , 10th International Congress on Industrial and Applied Mathematics (ICIAM2023), Tokyo

2023/8/29 Kobayashi, Yuki, Shun Ohishi, Takemasa Miyoshi: Including cross correlations between the forecast and observation errors in the ensemble Kalman filter, IMT-Atlantique & Kyoto University & RIKEN joint Data Assimilation workshop, Kobe

2023/8/29 Jianyu Liang, Koji Terasaki, Takemasa Miyoshi, A machine learning approach to the observation operator for satellite radiance data assimilation, IMT-Atlantique & Kyoto University & RIKEN joint Data Assimilation workshop 2023

2023/8/30 Ohishi, Shun, Takemasa Miyoshi, and Misako Kachi: LETKF-based Ocean Research Analysis (LORA): A new ensemble ocean analysis dataset, 14th Data Assimilation workshop, Kobe

2023/8/31 Takemasa Miyoshi, Celeste Saulo, Shigenori Otsuka, Juan Ruiz, Yanina Skabar, Arata Amemiya, Tomoo Ushio, Hirofumi Tomita, Tomoki Ushiyama, Masaya Konishi, PREVENIR: Japan-Argentina Cooperation Project for Heavy Rain and Urban Flood Disaster Prevention, The 6th International Workshop on Nonhydrostatic Models (NHM-WS 2023)(The 25th Workshop on Nonhydrostatic Models), Sapporo

2023/9/1 Takemasa MIYOSHI, Toward efficient control of extreme weather events, The 6th International Workshop on Nonhydrostatic Models (NHM-WS 2023) (The 25th Workshop on Nonhydrostatic Models), Sapporo

2023/10/17 Takemasa Miyoshi, RIKEN Center for Computational Science, Toward efficient control of extreme

weather events, ISDA2023, Bologna, Italy

2023/10/18 Jianyu Liang, Koji Terasaki, Takemasa Miyoshi, A Machine Learning Approach to the Observation Operator for Satellite Radiance Data Assimilation, 9th International Symposium on Data Assimilation, Kobe

2023/11/9 Takemasa Miyoshi, Advances and applications of satellite data assimilation of clouds, precipitation, and the ocean, The Joint PI Meeting of JAXA Earth Observation Missions FY2023, Tokyo

2023/11/15 Takemasa Miyoshi, Arata Amemiya, Shigenori Otsuka, Yasumitsu Maejima, James Taylor, Takumi Honda, Hirofumi Tomita, Seiya Nishizawa, Kenta Sueki, Tsuyoshi Yamaura, Yutaka Ishikawa, Shinsuke Satoh, Tomoo Ushio, Kana Koike, and Atsuya Uno, Big Data Assimilation: Real-time 30-second-refresh Heavy Rain Forecast Using Fugaku during Tokyo Olympics and Paralympics, SC23, Denver, US

2024/1/23 Kotsuki, S., Kawasaki, F. and Ohashi, M.: Quantum Data Assimilation: A New Approach to Solve Data Assimilation on Quantum Annealers, RIKEN Data Assimilation Seminar, Kobe

2024/1/29 Takemasa Miyoshi, Shun Ohishi, Jianyu Liang, Rakesh Konduru, Shigenori Otsuka, Shunji Kotsuki, Koji Terasaki, Atsushi Okazaki, Hirofumi Tomita, Kaya Kanemaru, Satoh Masaki, Hisashi Yashiro, Kozo Okamoto, Advances and Applications of Satellite Data Assimilation of Clouds, Precipitation, and the Ocean, 104th AMS Annual Meeting, Hilton Baltimore Inner Harbor, US

2024/2/20 Ohishi, Shun, Takemasa Miyoshi, and Misako Kachi: LETKF-based Ocean Research Analysis (LORA): A new ensemble ocean analysis dataset, Ocean Sciences Meeting 2024, New Orleans, US

2024/2/29 Ohishi, Shun, Takemasa Miyoshi, and Misako Kachi: LETKF-based Ocean Research Analysis (LORA): A new ensemble ocean analysis dataset, The First NCU-RIKEN Joint Workshop on Data Assimilation for Severe Weather Prediction, Taoyuan, Taiwan

2024/3/1 Ohishi, Shun, Yuki Kobayashi, and Takemasa Miyoshi: Including cross-correlation between forecast and observation errors in the ensemble Kalman filter, The First NCU-RIKEN Joint Workshop on Data Assimilation for Severe Weather Prediction, Taoyuan, Taiwan

2024/3/1 Jianyu Liang, Koji Terasak, Norihiko Sugimoto, Takemasa Miyoshi: Developing Observation Operator for Satellite Radiance Data Assimilation Using Machine Learning, The First NCU-RIKEN Joint Workshop on Data Assimilation for Severe Weather Prediction, Taoyuan, Taiwan

2024/3/1 Jianyu Liang, Koji Terasak, Norihiko Sugimoto, Takemasa Miyoshi: Analyzing the Instabilities in the Venus Atmosphere Using Bred Vectors, The First NCU-RIKEN Joint Workshop on Data Assimilation for Severe Weather Prediction, Taoyuan, Taiwan

- Poster Presentations

2023/5/22 Ohishi, Shun, Takemasa Miyoshi, and Misako Kachi: Impact of atmospheric forcing on SST biases in the LETKF-based Ocean Research Analysis (LORA), Japan Geoscience Union Meeting 2023, Chiba

2023/5/23 Takemasa Miyoshi, Celeste Saulo, Shigenori Otsuka, Juan Ruiz, Yanina Skabar, Arata Amemiya, Tomoo Ushio, Hirofumi Tomita, Tomoki Ushiyama, Masaya Konishi, PREVENIR: Japan-Argentina Cooperation Project for Heavy Rain and Urban Flood Disaster Prevention, Japan Geoscience Union Meeting 2023, Chiba

2023/5/25 Takemasa Miyoshi, Experimental platform for design and advance evaluation of frequent satellite observations toinnovate weather, ocean and land surface prediction, Japan Geoscience Union Meeting 2023, Chiba

2023/10/17 Takemasa Miyoshi, Celeste Saulo, Shigenori Otsuka, Juan Ruiz, Yanina Skabar, Arata Amemiya, Tomoo Ushio, Hirofumi Tomita, Tomoki Ushiyama, Masaya Konishi, PREVENIR: Japan-Argentina Cooperation

Project for Heavy Rain and Urban Flood Disaster Prevention, ISDA2023, Bologna, Italy

2023/12/13 Takemasa Miyoshi, Shun Ohishi, Jianyu Liang, Rakesh Konduru, Shigenori Otsuka, Shunji Kotsuki, Koji Terasaki, Atsushi Okazaki, Hirofumi Tomita, Kaya Kanemaru, Satoh Masaki, Hisashi Yashiro, Kozo Okamoto, Advances and Applications of Satellite Data Assimilation of Clouds, Precipitation, and the Ocean, AGU23, Moscone Center (San Fransisco), US

2023/12/13 Takemasa Miyoshi, Qiwen Sun, Serge Ricard, Yasumitsu Maejima, Lin Li, Koji Terasaki, control. Toward efficient control of extreme weather events, AGU23, Moscone Center (San Fransisco), US

2023/12/20 Ohishi, Shun, Takemasa Miyoshi, and Misako Kachi: A new ensemble ocean analysis dataset LORA (LETKF-based Ocean Research Analysis), OIST-RIKEN Joint Workshop on Prediction Science, Okinawa

2023/12/20 Jianyu Liang, Koji Terasaki, Takemasa Miyoshi, A Machine Learning Approach to the Observation Operator for Satellite Radiance Data Assimilation, OIST-RIKEN Joint Workshop on Predictive Sciences, Okinawa

2024/1/29 Ohishi, Shun, Takemasa Miyoshi, and Misako Kachi: Impact of atmospheric forcing on SST biases in the LETKF-based Ocean Research Analysis, The 6th R-CCS International Symposium, Kobe

2024/1/31 Takemasa Miyoshi, Qiwen Sun, Serge Richard, Yasumitsu Maejima, Lin Li, Koji Terasaki, Taking advantage of Chaos for efficient control of extreme weather, 104th AMS Annual Meeting, The Baltimore Convention Center, US

- Web

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

Usage of JSS

Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP
Number of Processes	128 - 256
Elapsed Time per Case	20 Minute(s)

- **JSS3 Resources Used**

Fraction of Usage in Total Resources[*1](%): 0.24

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	6,569,009.72	0.30
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	0.00	0.00
/data and /data2	174,080.00	1.07
/ssd	0.00	0.00

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.