Development of an EnKF-based ocean data assimilation system

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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

In the last fiscal year, using an ensemble Kalman filter-based ocean data assimilation system, we produced the LETKF-based Ocean Research Analysis (LORA) datasets, an eddy-resolving ensemble ocean analysis product for the western North Pacific and Maritime Continent regions and released them on the JAXA-RIKEN Ocean Analysis website. To demonstrate the usefulness of this ensemble product, we conducted ensemble forecasts and compared their accuracy with conventional deterministic forecasts. The results showed that for the Kuroshio south of Japan, the predictability limit of the ensemble mean forecasts was 100-110 days, approximately one month longer than the 70-80-day limit of deterministic forecasts. A sensitivity experiment initialized in August 2017 demonstrated

that the ensemble mean forecast was closer to the analytical Kuroshio axis than the deterministic forecast (Fig. 1). These results have been submitted to an international journal (Ohishi et al., submitted).

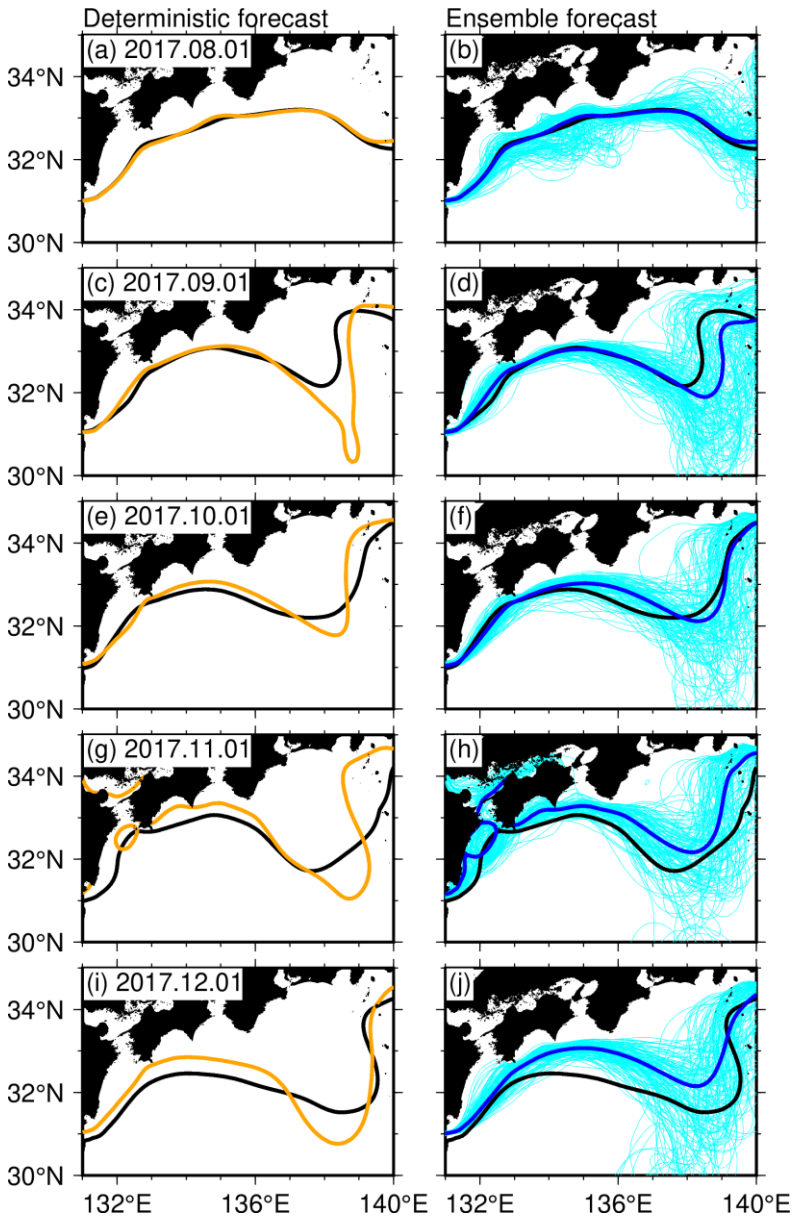

Fig. 1: The Kuroshio path positions for the (left) daily-mean deterministic forecasts (orange) and the (right) 128-member ensemble forecasts (light blue) and the ensemble mean forecasts (blue) initialized on 1st August 1 2017. The black line represents the represents the analysis Kuroshio path. The Kuroshio path is estimated from the sea surface height where thesurface current speed is maximum south of Japan.

Publications

- Peer-reviewed papers

- Arakawa, T., Yashiro, H., Sumimoto, S., and Nakajima, K., 2025: Large Scale Ensemble Coupling of Non-hydrostatic Atmospheric Model NICAM. In Proceedings of the International Conference on High Performance Computing in Asia-Pacific Region (HPCAsia '25). Association for Computing Machinery, New York, NY, USA, in press.

- Furukawa, K., H. Sakamoto, M. Ohhigashi, S. Shima, T. Sluka, and T. Miyoshi, 2024: Particle filter data assimilation for ubiquitous unstable trajectories of two-dimensional three-state cellular automata. Nonlinear Dyn., doi:10.1007/s11071-024-09803-5

- Li, L., J. Li, and T. Miyoshi, 2024: Chaos suppression through Chaos enhancement,E38 Nonlinear Dyn(2024)., doi:10.1007/s11071-024-10426-z

- Ohishi, Shun, Takemasa Miyoshi, and Misako Kachi, 2024: Impact of atmospheric forcing on SST in the LETKF-based ocean research analysis (LORA), Ocean Modelling, 189, 102357,
doi:10.1016/j.ocemod.2024.102357

- Ohishi, Shun, Takemasa Miyoshi, Takafusa Ando, Tomohiko Higashiuwatoko, Eri Yoshizawa, Hiroshi Murakami, and Misako Kachi, 2024, LETKF-based Ocean Research Analysis (LORA) version 1.0, Geoscience Data Journal, 11, 995-1006, doi:10.1002/gdj3.271

- Ohishi, Shun, Yuki Kobayashi, Takemasa Miyoshi, 2025, Including cross-correlation forecast and observation errors in an ensemble Kalman filter, Monthly Weather Review, in press

- Invited Presentations

2024/4/3 Takemasa Miyoshi, "Tokyo Olympics/Paralympics forecast experiment with phased array weather radar", Deepdive session at IMT Atlantique, Brest, France

2024/5/28 Takemasa Miyoshi, Every 30-second Phased Array Radar Data Assimilation Proven Effective for Short-range Convective Weather Forecast, The 8th WMO Workshop on the Impact of Various Observing Systems on Numerical Weather Prediction and Earth System Prediction, SMHI, Sweden (Keynote)

2024/6/18 Takemasa Miyoshi, "Big Data Assimilation: Real-time 30-Second-Refresh Heavy Rain Forecast Using Fugaku during Tokyo Olympics and Paralympics", Seminar, Central Weather Administration, Taiwan.

2024/6/19 Takemasa Miyoshi, "Toward next 100 years of data assimilation and numerical weather prediction", MSROC Centennial Celebration and Symposium, Central Weather Administration, Taiwan. Keynote.

2024/7/2 Takemasa Miyoshi, Big Data Assimilation Revolutionizing Numerical Weather Prediction Using Fugaku, 24th International Conference on Computational Science (ICCS2024), Malaga, Spain (Keynote)

2024/9/17 Takemasa Miyoshi, Toward next 100 years of data assimilation and numerical weather prediction, The CRC International Summer school 2024, Boltenhagen, Germany

2024/9/17 Takemasa Miyoshi, Toward efficient control of extreme weather events, The CRC International Summer school 2024, Boltenhagen, Germany

2025/1/29 Takemasa Miyoshi, Prediction Science: the fifth science integrating inductive and deductive sciences, ISDA Online

2025/3/6 Takemasa Miyoshi, Prediction Science: the fifth science integrating inductive and deductive sciences, ISEE Symposium Frontier of Space-Earth Environmental Research as Predictive Science, Nagoya University

2025/3/13 Takemasa Miyoshi, RIKEN's activities to integrate DA and AI/ML, DA Forum by University of

Melbourne, Bureau of Meteorology, Melbourne, Australia

- Oral Presentations

2024/04/16 Ohishi, Shun, Takemasa Miyoshi, and Misako Kachi, 'LETKF-based Ocean Research Analysis (LORA): A new ensemble ocean analysis dataset', EGU General Assembly 2024, Vienna, Austria

2024/5/30 Ohishi, Shun, Takemasa Miyoshi, and Misako Kachi, 'Deterministic and Ensemble forecasts of Kuroshio south of Japan', Japan Geoscience Union Meeting 2024, Chiba

2024/6/20 Ohishi, Shun, Takemasa Miyoshi, and Misako Kachi, 'LETKF-based Ocean Research Analysis (LORA): A new ensemble ocean analysis dataset', 14th International Workshop on Modeling the Ocean 2024, Sapporo

2024/6/27 Takemasa MIYOSHI, Yanina SKABAR, Shigenori OTSUKA, Arata AMEMIYA, Juan RUIZ, Tomoo USHIO, Hirofumi TOMITA, Tomoki USHIYAMA, Masaya KONISHI, Second Year Progress of PREVENIR: Japan-argentina Cooperation Project for Heavy Rain and Urban Flood Disaster Prevention, 2024 AOGS Annual Meeting, Alpensia Convention Centre, Pyeongchang, Korea

2024/7/18 Takemasa Miyoshi, Advances and applications of satellite data assimilation of clouds, precipitation, and the ocean, 11th workshop of International Precipitation Working Group(IPWG-11), Tokyo

2024/10/21 Takemasa Miyoshi, Kalnay Session, ISDA2024, Kobe

2024/10/22 Kobayashi, Yuki, Shun Ohishi, Takemasa Miyoshi, 'Including cross correlations between the forecast and observation errors in the ensemble Kalman filter', The 10th International Symposium on Data Assimilation, Kobe

2024/10/29 Ohishi, Shun, Takemasa Miyoshi, and Misako Kachi, 'LETKF-based Ocean Research Analysis (LORA) in 2015-2023', 6th WCRP International Conference on Reanalysis, Tokyo

2024/11/18 Ohishi, Shun, Takemasa Miyoshi, and Misako Kachi, 'Deterministic and Ensemble forecasts of Kuroshio south of Japan', OceanPredict Symposium 2024, Paris, France

2024/11/21 Ohishi, Shun, Takemasa Miyoshi, and Misako Kachi, 'LETKF-based Ocean Research Analysis (LORA): A new ocean analysis', The Joint PI Meeting of JAXA Earth Observation Missions FY2024, Tokyo

2024/12/12 Miyoshi, T., Skabar, Y. G., Otsuka, S., Amemiya, A., Ruiz, J., Ushio, T., Tomita, H., Ushiyama, T., and Konishi, M, Third Year Progress of PREVENIR: Japan-Argentina Cooperation Project for Heavy Rain and Urban Flood Disaster Prevention. American Geophysical Union Annual meeting, Washington, D.C., USA

2024/12/24 Takemasa Miyoshi, Prediction Science, U Toyama-RIKEN Joint Workshop on Prediction Science Toyama

2025/1/16 Miyoshi, T., Skabar, Y. G., Otsuka, S., Amemiya, A., Ruiz, J., Ushio, T., Tomita, H., Ushiyama, T., and Konishi, M, Third Year Progress of PREVENIR: Japan-Argentina Cooperation Project for Heavy Rain and Urban Flood Disaster Prevention Conference Title: 29th Conference on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS) Meeting Title: 105th AMS Annual Meeting, New Orleans, USA

2025/3/19 Takemasa Miyoshi, "Introduction of Earth data assimilation", Workshop for Venus modelling and observations 2025, Paris, France

- Poster Presentations

2024/4/15 Miyoshi, T., Skabar, Y. G., Otsuka, S., Amemiya, A., Ruiz, J., Ushio, T., Tomita, H., Ushiyama, T., and Konishi, M.: Second Year Progress of PREVENIR: Japan-Argentina Cooperation Project for Heavy Rain and Urban Flood Disaster Prevention, EGU General Assembly 2024, Vienna, Austria

2024/5/30 Hirose, Naoki, Shuichi Watanabe, Shoichiro Kido, Shun Ohishi, Nariaki Hirose, Takashi Sakamoto, and Teiji In, 'Intercomparison and ensemble project of coastal ocean prediction models in Japan', Japan Geoscience Union Meeting 2024, Chiba

2024/10/21 Ohishi, Shun, Takemasa Miyoshi, and Misako Kachi, 'LETKF-based Ocean Research Analysis (LORA): A new ensemble ocean analysis', The 10th International Symposium on Data Assimilation, Kobe

2024/10/25 Takemasa Miyoshi, Advances and applications of satellite data assimilation of clouds, precipitation, and the ocean, ISDA2024, Kobe

2024/11/18 Ohishi, Shun, Takemasa Miyoshi, and Misako Kachi, 'LETKF-based Ocean Research Analysis (LORA): A new ocean analysis', The Joint PI Meeting of JAXA Earth Observation Missions FY2024, Tokyo

2024/11/21 Takemasa Miyoshi, Advances and applications of satellite data assimilation of clouds, precipitation, and the ocean, JAXA PI meeting, Tokyo

2024/12/23 Ohishi, Shun, Takemasa Miyoshi, and Misako Kachi, 'Deterministic and Ensemble forecasts of Kuroshio south of Japan', U Toyama-RIKEN Joint Workshop on Prediction Science, Toyama

2025/1/23 Ohishi, Shun, Takemasa Miyoshi, and Misako Kachi, 'Deterministic and Ensemble forecasts of Kuroshio south of Japan', The 7th R-CCS International Symposium, Kobe

Usage of JSS

Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP
Number of Processes	4 - 384
Elapsed Time per Case	30 Minute(s)

- **JSS3 Resources Used**

Fraction of Usage in Total Resources[*1](%): 2.23

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	60,653,386.22	2.78
TOKI-ST	1,435.63	0.00
TOKI-GP	0.00	0.00
TOKI-XM	14.98	0.01
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	0.83
/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.