Research for data assimilation of satellite global rainfall map

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Abstract

This study explores an effective use of satellite data including GSMaP and GPM/DPR through an advanced ensemble data assimilation method for improving numerical weather prediction (NWP) and pioneering a new precipitation product based on an NWP model and satellite observations, named as NICAM-LETKF JAXA Research Analysis (NEXRA).

Ref. URL: https://www.eorc.jaxa.jp/theme/NEXRA/index_e.htm

Reasons and benefits of using JAXA Supercomputer System

In this study, the JSS3 is used for the NICAM-LETKF experiments to assimilate satellite observations and to conduct NWP model forecasts. The JSS3 is an essential infrastructure for our study to conduct massive computations for the ensemble-based data assimilation and ensemble atmospheric simulations.

Achievements of the Year

NEXRA3.0 has been developed. Continuing from last year, the spin-up process was carried out, and in May 2024, the system caught up with real time and began real-time operations. On July 1, 2024, the NEXRA website (https://www.eorc.jaxa.jp/theme/NEXRA/index_j.htm) was also updated accordingly.

Figure 1 shows the precipitation distribution from NEXRA3. Compared to the rainfall distribution from NEXRA2 shown in Figure 2, the precipitation area has expanded, particularly in the tropics. The distribution of weak rainfall has also become wider. We are currently preparing a paper comparing the results of NEXRA2 and NEXRA3.

Additionally, we have obtained a DOI (10.57746/EO.01jac0dzq2azqzpm56mxyrn048) for the previously operated NEXRA2.0 dataset, which is now publicly available. The list of available datasets is shown in Figure 3. The data can be accessed via the FTP site upon user registration. A paper describing this dataset is submitted.

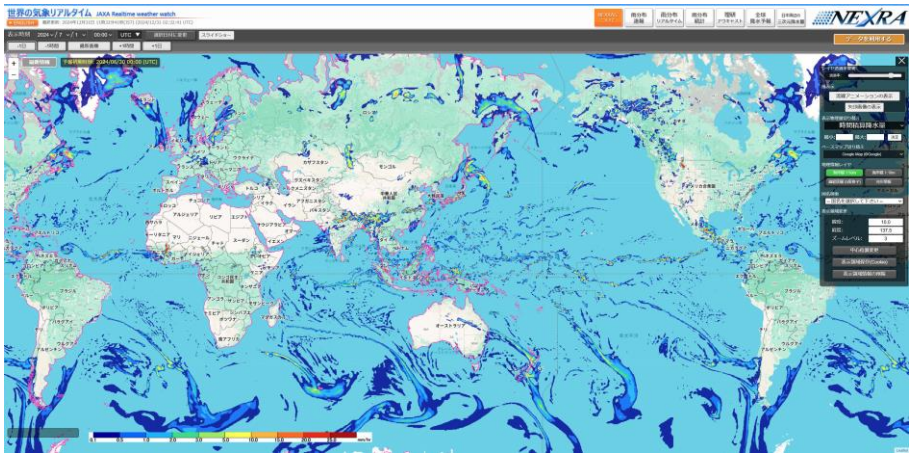

Fig. 1: Hourly rain at 00 UTC on 1st July 2024 in NEXRA3

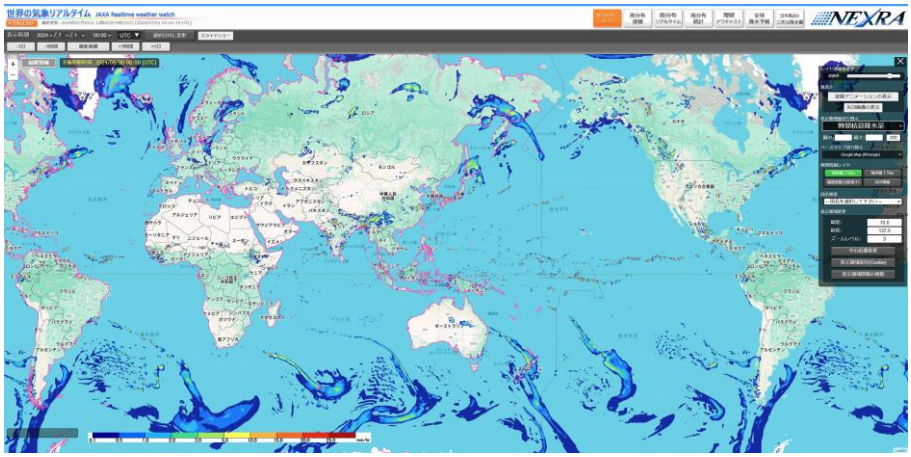

Fig. 2: Hourly rain at 00 UTC on 1st July 2024 in NEXRA2

アンサンブル平均・スプレッド

Variable name	Dimension	Units	Description
z	time, lev, lat, lon	meter	Geopotential height
t	time, lev, lat, lon	K	Temperature
u	time, lev, lat, lon	m s^{-1}	Zonal wind
v	time, lev, lat, lon	m s^{-1}	Meridional wind
w	time, lev, lat, lon	m s^{-1}	Vertical wind
qv	time, lev, lat, lon	kg kg^{-1}	Specific humidity
qc	time, lev, lat, lon	kg kg^{-1}	Cloud water
slp	time, lat, lon	Pa	Pressure
tppn	time, lat, lon	mm/s	6 hour mean precipitation intensity

128メンバー地表面データ

Variable name	Dimension	Units	Description
sa_lwd_sfc	time, lat, lon	W m^{-2}	surface longwave radiation (downward)
sa_swd_sfc	time, lat, lon	W m^{-2}	surface shortwave radiation (downward)
sa_tppn	time, lat, lon	kg m^{-2} s^{-1}	Precipitation intensity
ss_ps	time, lat, lon	Pa	Surface pressure
ss_q2m	time, lat, lon	kg kg^{-1}	2m specific humidity
ss_t2m	time, lat, lon	K	2m temperature
ss_u10m	time, lat, lon	m s^{-1}	10m zonal wind
ss_v10m	time, lat, lon	m s^{-1}	10m meridional wind

Fig. 3: Publicly Available Data on NEXRA2

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

- Guannan H., S. L. Dance, A. Fowler, D. Simanin, J. Waller, T. Auligne, S. Healy, D. Hotta, U. Lohnen, T. Miyoshi, N. C. Prive, O. Stiller, X. Wang, and M. Weissmann, 2024: On methods for assessment of the influence and impact of observations in convection-permitting numerical weather prediction. QJRMS., in press

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

- Muto, Y. and Kotsuki, S., 2024: Estimating global precipitation fields by interpolating rain gauge observations using the local ensemble transform Kalman filter and reanalysis precipitation. Hydrol. Earth Syst. Sci., 28, 24,

5401-5417, doi:10.5194/hess-28-5401-2024

- 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, and Takemasa Miyoshi, 2025: Including cross-correlation forecast and observation errors in an ensemble Kalman filter. Monthly Weather Review, in press

- Okamoto, K., T. Ishibashi, I. Okabe, and H. Shimizu, 2024: Extension of all-sky radiance assimilation to hyperspectral infrared sounders. Quarterly Journal of the Royal Meteorological Society, 150(765), 5472-5497, https://doi.org/10.1002/qj.4883

- 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

2025/3/12 Otsuka, S., T. Miyoshi, J. Liang, M. Goodliff, G. Saliou, S. Ouala, and P. Tandeo, Toward integration of ML/NWP/DA. Super Computing Asia 2025, Singapore

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

2024/5/22 Yashiro H., Feasibility study for the next flagship supercomputer development and high-resolution

climate modeling efforts in Japan. 8th ENES HPC workshop on "High-resolution climate and weather modelling", Lecce, Italy

2024/5/26 Konduru, R.T., Liang, J., Otsuka, S., and Miyoshi, T., Enhancing Small-Scale Global Weather Forecasting by High-Frequency Satellite Data Assimilation: A Horizontal Localization Aspect. JpGU, Chiba

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

2024/5/27-30 Okamoto, K., T. Ishibashi, I. Okabe, 2024: All-sky infrared radiance assimilation in the operational global system, 8th WMO workshop of the impact of various observation system on NWP and earth system prediction, Norrkoping, Sweden

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

2024/7/11 Yashiro H., Niwa Y., Goto D., Someya Y., Saeki T., Matsunaga T., Development of a short-term prediction system for greenhouse gases and SLCFs in conjunction with GOSAT-GW and TANSO-3 observations. The 1st NIES-IAP Young Scientists Symposium on Atmospheric Environment and Climate Change, Tsukuba

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

2024/8/5 Otsuka, S., Application of quantitative precipitation estimates to nowcasting. PREVENIR short course on "Quantitative precipitation estimation with satellites and its applications to nowcasting", Buenos Aires, Argentina

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

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

2024/10/24 Otsuka, S. and T. Miyoshi, Global precipitation nowcasting using a ConvLSTM with adversarial training, ISDA2024, Kobe

2024/10/21-25 Okamoto, K., T. Ishibashi, I. Okabe, 2024, Global assimilation of all-sky radiance from infrared imagers and sounders, The 10th International Symposium on Data Assimilation (ISDA), Kobe, Japan

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

2024/11/14 Otsuka, S. and T. Miyoshi, Global precipitation nowcasting with GSMaP, World Meteorological Center Beijing workshop on new technology and products, Guangzhou (hybrid)

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, 29th Conference on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS), 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

2024/5/29 Yashiro, H., Sugita, T., Saeki, T., Someya, Y., Fujinawa, T., Yoshida, Y., Kikuchi, S., Kawazoe, F., Kamei, A., Kajihara, T., Kanagawa, M., Gognadze, N., Tanimoto, H., Matsunaga, T., Preparation status of the data processing system for GOSAT-GW/TANSO-3 in NIES, 20th International Workshop on Greenhouse Gas Measurements from Space (IWGGMS-20), Boulder, USA

2024/5/30 Hirose, N., 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

2024/10/24 Terasaki, K., Y. Ikuta, and T. Kawabata, Development of LETKF system based on the JMA operational ASUCA-Var, ISDA2024, Kobe, Japan

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

2025/1/23 Otsuka, S. and T. Miyoshi, Global precipitation nowcasting using a ConvLSTM with adversarial training, The 7th R-CCS International Symposium, Kobe

Usage of JSS

Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP
Number of Processes	4 - 1024
Elapsed Time per Case	30 Minute(s)

JSS3 Resources Used

Fraction of Usage in Total Resources[*1](%): 2.59

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	21,475,623.03	0.98
TOKI-ST	4,017.82	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	2,336.00	1.58
/data and /data2	649,530.00	3.11
/ssd	66,860.00	3.58

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage*2 (%)
J-SPACE	43.22	0.14

*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.