Research for data assimilation of satellite global rainfall map

Report Number: R23ER0201
Subject Category: Space Technology
URL: https://www.jss.jaxa.jp/en/ar/e2023/23633/

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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

The next version of NEXRA (version 3.0) was developed. The setup of the previous year was modified from a setup using only the cloud microphysics scheme to a setup using both the cloud microphysics scheme and cumulus parameterization. Figure 1 summarizes the changes from the current NEXRA 2.0. The main changes in NEXRA3.0 from NEXRA2.0 are an increase in the horizontal and vertical resolution and a change of cloud microphysics scheme that includes precipitating particles.

Sensitivity experiments showed that cumulus parameterization remains necessary in this NEXRA update. Although it is possible to create a realistic temperature and moisture field using only a cloud microphysics scheme without cumulus parameterization. However, the precipitation distribution deviates from observations (Figure 2). This difference affects the NEXRA system, which assimilates GSMaP.

Figure 3 compares NEXRA2.0 and NEXRA3.0 analysis with JRA-55, and shows that NEXRA3.0 improves the temperature, especially in the troposphere. The calculation is currently being performed to catch up with the real-time in the NEXRA 3.0 settings.

NEXRA data were also used to analyze the impact of high SSTs in the Japan Sea on Typhoon No. 7 in 2023. Two sets of atmospheric simulations were conducted: one with high SSTs in the Japan Sea and the other with climatology SST in the Japan Sea. Figure 4 shows a comparison of the two simulations, revealing that high SSTs in the Japan Sea affected typhoon intensity and vapor transport, resulting in more precipitation, especially over the Japan Seaside.

LETKF	NEXRA 2.0	NEXRA 3.0
NICAM version	16.2 (bug on land surface precipitation)	21.3(bug fix, Optimized A64fx)
Horizontal res.	112km(gl06)	56 km(gl07)
Vertical layer	38	78
Cloud microphysics	LSC	NSW6-Roh
Cumulus parameterization	PAS	CHIKIRA
Member	128	128
Analysis(Forecast)	U, V, W, T, Qv, (Qc)	U, V, W, T, Qv, (Qc, Qr, Qi, Qs, Qg)
Observation	Prepbufr, Amsu-A, GSMaP, mhs, atms	Same as left

Fig. 1: Model setup in NEXRA 2.0 and NEXRA 3.0

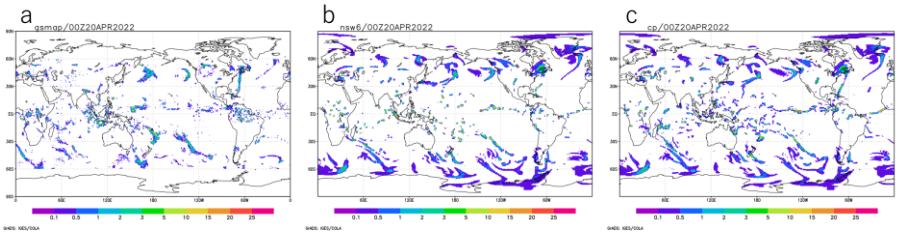

Fig. 2: Hourly rain at 00 UTC 19 APR 2022 in GSMaP (a), cloud microphysics only (b), and cloud microphysics and cumulus parameterization simulation by NICAM.

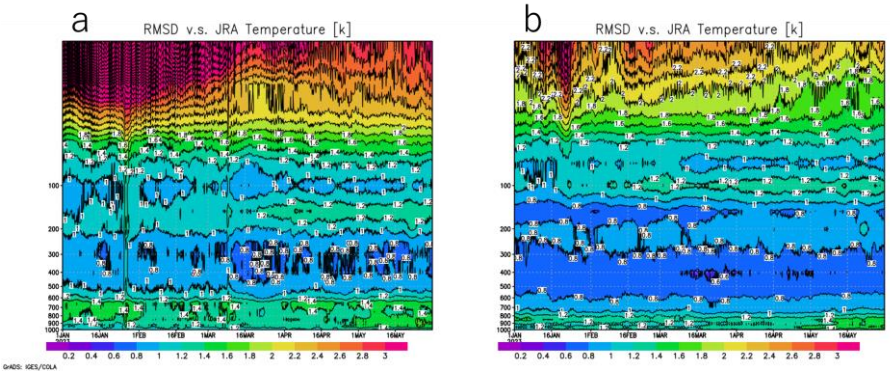

Fig. 3: Time series of the global averaged root mean square difference for temperature (K) relative to the JAR-55 for (a) the NEXRA 2.0 and (b) NEXRA 3.0.

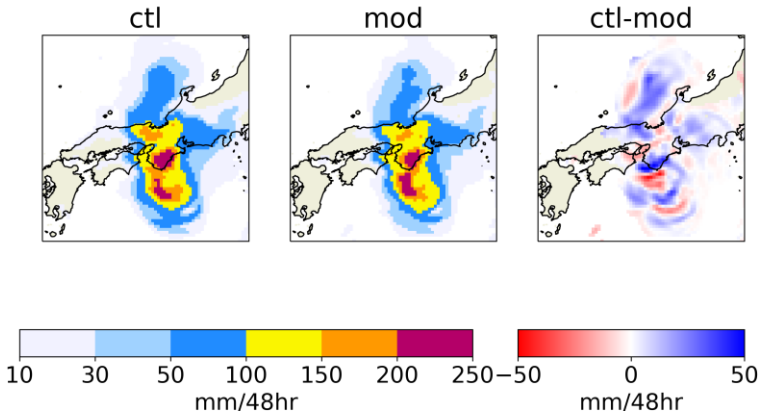

Fig. 4: 48-hour total precipitation [mm] for August 14-15, 2023. The left panel shows the experiment when the sea surface temperature in the Japan Sea is high (CTL experiment) and the center panel shows the experiment when the sea surface temperature is normal (MOD experiment). The right figure shows the difference between CTL and MOD.

Publications

- Peer-reviewed papers

1. Kurosawa, K., Kotsuki, S., and Miyoshi, T. (2023): Comparative Study of Strongly and Weakly Coupled Data Assimilation with a Global Land-Atmosphere Coupled Model. Nonlin. Processes Geophys., 30, 457-479. doi: 10.5194/npg-30-457-2023

2. Muto, Y., Kanemaru, K., and Kotsuki, S. (2023): Correcting GSMaP through histogram matching against satellite-borne radar-based precipitation. SOLA, Vol19 217-224, doi:10.2151/sola.2023-028

3. 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

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

5. 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.

2023/6/27 Otsuka, S. and T. Miyoshi, Development of precipitation nowcasting systems at RIKEN and Japan-Argentina cooperation project. Bi-annual meeting of the Nowcasting and Mesoscale Research Working Group,

Seoul, Korea

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

2023/8/31 Otsuka, S. and T. Miyoshi, Toward 3D precipitation nowcasting by fusing NWP-DA-AI: application of adversarial training. The 6th international 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

2024/2/29 Michael R Goodliff, Takemasa Miyoshi, NCU-RIKEN Workship, 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(1,2,3) , 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 Miyoshi1, Qiwen Sun1.2, Serge Ricard2, Yasumitsu Maejima1, Lin Li1, Koji Terasaki3, 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 Otsuka, S. and T. Miyoshi, Toward 3D precipitation nowcasting by fusing NWP DA AI: application of adversarial training. The 6th R-CCS International Symposium, Kobe

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

2024/1/29 Presentation: Michael R Goodliff, Takemasa Miyoshi, 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	4 - 1024
Elapsed Time per Case	30 Minute(s)

JSS3 Resources Used

Fraction of Usage in Total Resources[*1](%): 1.87

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	56,003,210.95	2.53
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	3,074.00	2.55
/data and /data2	649,530.00	4.01
/ssd	66,860.00	6.32

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage*2 (%)
J-SPACE	31.16	0.11

*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.