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 JSS2 is used for the NICAM-LETKF experiments to assimilate satellite observations and to conduct NWP model forecasts. The JSS2 is a necessary infrastructure for our study to conduct massive computations for the ensemble-based data assimilation and ensemble atmospheric simulations.

Achievements of the Year

(1) GPM / DPR direct assimilation experiment

In this fiscal year, model parameters related to the terminal velocity of snow were optimized by assimilating GPM / DPR observations. The temperature and water vapor fields from the lower to middle troposphere were improved by modifying the terminal velocity parameter of snow (Fig. 1). However, in the upper troposphere, the temperature field was degraded. Generally, a constant value is used for this parameter everywhere. However, data assimilation allows estimating different values for each altitude, and this may mitigate the degradation in temperature. In the next fiscal year, we plan to continue the research on parameter estimation for cloud microphysics schemes using GPM/DPR observations.

(2) NICAM-LETKF hydrological assimilation system

Continuing with RA8, NICAM-LETKF was used to develop a coupled data assimilation system for land-based observation data. In addition to atmospheric observation data assimilated by NICAM-LETKF, as the first step of assimilation of hydrological observation data, we performed a data assimilation experiment using soil water content provided by global land reanalysis GLDAS. All coupled data assimilation experiments showed good results with reduced errors in soil moisture for GLDAS compared to the control experiments. In the coupled data assimilation experiments, partially strongly-coupled data assimilation, which updates the atmospheric model variables by assimilating soil moisture observations but does not update the land surface model variables by assimilating atmospheric observations, provided the best result. The results suggest that the estimation of atmospheric states by assimilation of soil moisture observation be effective.

(3) Improvement of model radiation bias by model parameter estimation

A method for model parameter estimation was investigated. In climate predictions, it is important to maintain the radiation balance of the Earth system properly, and tuning of model parameters is required to reduce the radiation bias of the model. In the default model settings, cloud cover was an issue, and cloud reflections caused excessive upward shortwave radiation at the top of the atmosphere. The parameters of the large-scale condensation scheme were estimated using the cloud amount observed by the Advanced Microwave Scanning Radiometer 2 (AMSR2) onboard the GCOM-W (Global Change Observation Mission-Water) satellite. As a result, we obtained results that improved cloud cover and drastically reduced the radiation bias of the model.

(4) Development of NICAM-LETKF=GSMaP_RNC Seamless Forecasting System

The world's first global precipitation seamless forecast system was developed by combining precipitation forecasts from NICAM-LETKF and GSMaP_RNC. The prediction of precipitation is obtained as a locally-optimized weighted average of the forecasts from both NICAM-LETKF and GSMaP_RNC. The experiment was conducted with the training period for 1 year from September 2014 for finding the optimal weights at each location, and the verification period as the subsequent year. GSMaP_RNC outperformed NICAM in the forecast accuracy up to 7 hours ahead but reversed after that. The result that the prediction became more accurate at all forecast lead times by merging both.

(5) Accounting for the horizontal observation error correlation in data assimilation

In this fiscal year, we conducted data assimilation experiments to explore methods accounting for the horizontal observation error correlation of the Advanced Microwave Sounding Unit-A (AMSU-A) which has the most significant impact in the NICAM-LETKF numerical weather prediction. The horizontal observation error correlation of AMSU-A was estimated using the method proposed by Desroziers et al. (2005). By explicitly considering observation error correlations in data assimilation, geopotential fields in the lower troposphere tended to degrade. However, the accuracy of the analyses for temperature, zonal wind, and humidity improved by up to about 5% (Fig. 2). In addition, the accuracy of forecast was improved.

(6) Improving the base assimilation system of NEXRA

The performance of a new NICAM-LETKF system which is planned to be the base model of the next generation of NEXRA has been tested on JSS2. The new NICAM-LETKF system newly assimilates the microwave radiance observed by the Advanced Technology Microwave Sounder (ATMS) and the humidity profiles observed by

Microwave Humidity Sounder (MHS) in addition to PREPBUFR, AMSU-A and GSMaP_NRT. Results show that the atmospheric field obtained from the new NICAM-LETKF system shows a good agreement with reanalysis data JRA55 (Fig. 3).

(7) The development of high resolution of NEXRA

In this fiscal year, a new forecast system with 14-km resolution in horizontal is developed. The 14-km resolution in horizontal is also called as cloud system resolving resolution, which is able to resolve the life cycles of cloud systems. The initial data for this new forecast system are linearly interpolated from 112 km analysis data obtained from the current NICAM-LETKF system. Meanwhile, the large condensation scheme used in 112 km NEXRA is replaced to the cloud microphysics scheme (NSW6). We conducted a forecast experiment for the typhoon KROSA which hit Hiroshima prefecture of Japan in August 2019 by using this new forecast system. Results show that the forecasted typhoon path of KROSA has good agreements with observations (Fig.4). At the time before KROSA hit the Hiroshima prefecture, the structure of the large eye of the typhoon KROSA is also well captured in this high-resolution experiment.

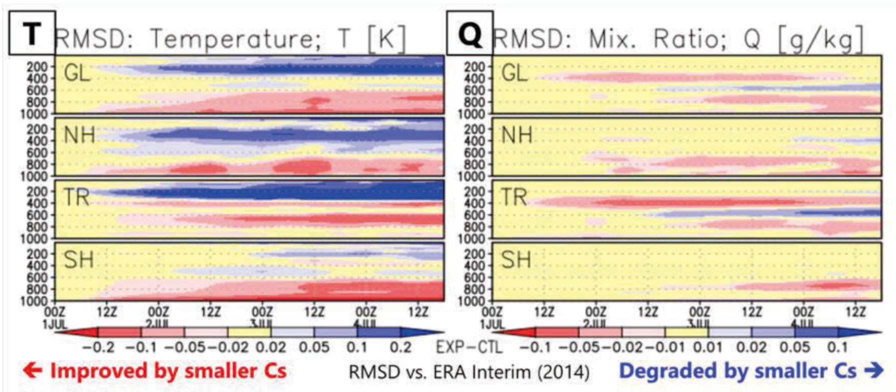

Fig. 1: Time-series of change in root mean square error against ERA-interim of (left) temperature (K) and (right) specific humidity (g/kg) by modifying terminal velocity of snow. Negative value indicates improvement. Four panels show the global (GL), Northern hemisphere (NH), Tropics (TR), and Southern hemisphere (SH), respectively.

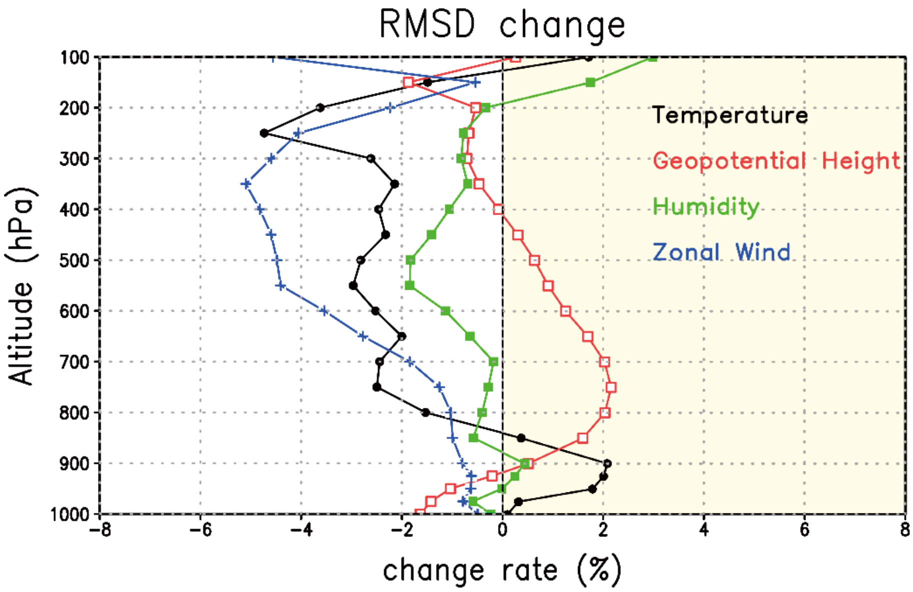

Fig. 2: Difference in analysis root mean square error with and without accounting for horizontal observation error correlation. The colored solid lines indicate (black) temperature, (red) geopotential height, (green) specific humidity, and (blue) zonal wind, respectively.

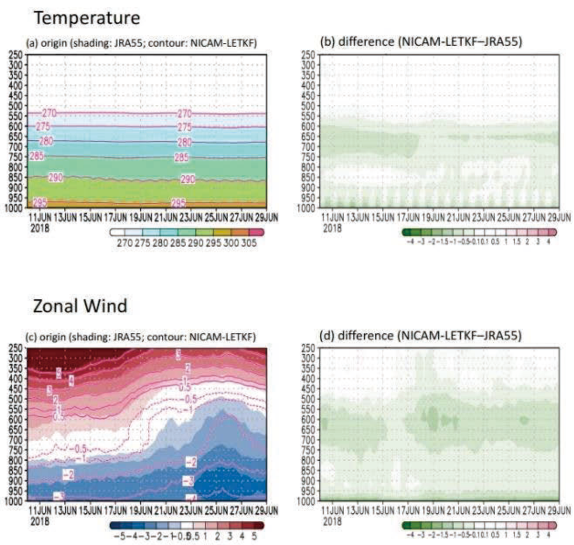

Fig. 3: Time-height sections for the temperature (the upper panel, unit K) and zonal wind (the lower panel, unit m/sec) fields. (a) shows the comparison between the temperature obtained from new-NICAM-LETKF (contours) and JRA55 (shadings) and (b) shows the difference. (c) shows the comparison between the zonal wind obtained from new-NICAM-LETKF (contours) and JRA55 (shadings) and (d) shows the difference. The unit of the vertical axis is hPa and the duration is from 00Z10JUN2018 to 18Z29JUN2018 (UTC).

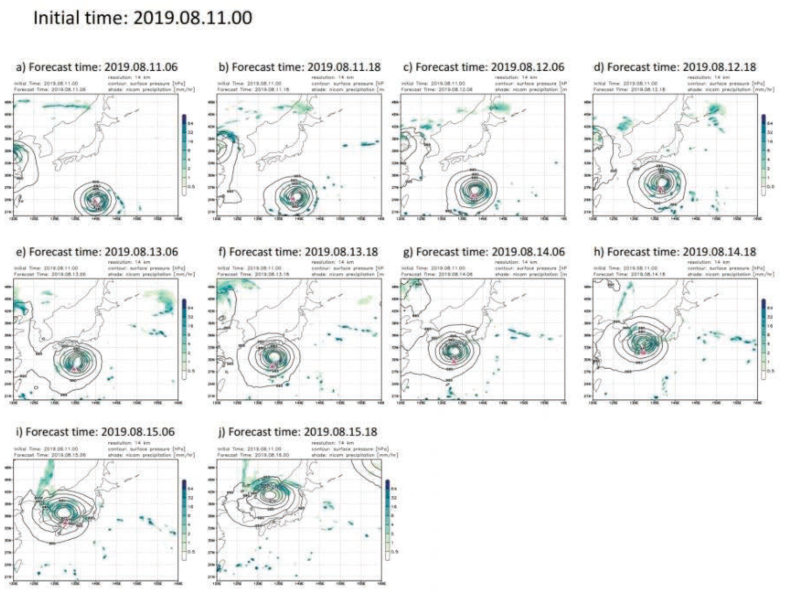

Fig. 4: The 12 hourly snap shots for the 14-km NEXRA forecast experiment for typhoon KROSA (2019) with the initial time at 00Z11AUG2019 (UTC). Contours and shadings denote the sea level pressure (unit: hPa) and hourly precipitation (mm/hr), respectively. The pink triangle in each snap shot shows the observed typhoon center.

Publications

- Peer-reviewed papers

1. Kotsuki, S., K. Kurosawa, S. Otsuka, K. Terasaki, and T. Miyoshi, 2019: Global Precipitation Forecasts by Merging Extrapolation-Based Nowcast and Numerical Weather Prediction with Locally Optimized Weights. Wea. Forecasting, 34, 701-714. https://doi.org/10.1175/WAF-D-18-0164.1
2. Kotsuki S., Kurosawa K., and Miyoshi T. (2019): On the Properties of Ensemble Forecast Sensitivity to Observations. Quarterly Journal of the Royal Meteorological Society, 145, 1897-1914. https://doi.org/10.1002/qj.3534
3. Kotsuki, S., Sato, Y., & Miyoshi, T. (2020). Data assimilation for climate research: Model parameter estimation of large‐scale condensation scheme. Journal of Geophysical Research: Atmospheres, 125, e2019JD031304. https://doi.org/10.1029/2019JD031304

- Invited Presentations

1. 2019/5/29 Kotsuki S., Sato Y., Terasaki K., Yashiro H., Tomita H., Satoh M. and Miyoshi T.: Model Parameter Estimation with Data Assimilation using NICAM-LETKF. JpGU Meeting 2019.
2. 2019/6/4 Takemasa Miyoshi, Big data assimilation: A new science for weather prediction and beyond, 14TH INTERNATIONAL EnKF WORKSHOP IN VOSS, PARK HOTEL VOSSEVANGEN, VOSS, NORWAY
3. 2019/6/13 Takemasa Miyoshi, Big Data Assimilation: A New Science for Weather Prediction and Beyond,

Seminar, DWD, Frankfurt, Germany

4. 2019/6/17 Takemasa Miyoshi, Big Data Assimilation: A New Science for Weather Prediction and Beyond, Seminar, LMU, Munich, Germany
5. 2019/7/10 Takemasa Miyoshi, HPC challenges in numerical climate simulation and weather prediction, INTERNATIONAL HPC SUMMER SCHOOL 2019, R-CCS, Kobe, Japan
6. 2019/7/17 Takemasa Miyoshi, Advancing data assimilation as a science hub: from weather forecasting and beyond, ICIAM2019, University of Valencia, Valencia, Spain
7. 2019/9/26 Takemasa Miyoshi, Invited talk, 6th CREST Big Data Application Camp for Researchers, Shonan Village Center, Kanagawa, Japan
8. 2019/11/12 Takemasa Miyoshi, Big Data Assimilation: 30-second-update Weather Forecasting and Perspectives toward DA-AI Integration, Big Data, Data Assimilation and Uncertainty Quantification, Institut Henri Poincare, Paris, France
9. 2019/11/27 Takemasa Miyoshi, Big Data Assimilation:A New Science for Weather Prediction and Beyond, seminar, ACADEMIA SINICA, Taipei, Taiwan
10. 2019/11/28 Takemasa Miyoshi, Big Data Assimilation:A New Science for Weather Prediction and Beyond, seminar, National Taiwan University, Taipei, Taiwan
11. 2019/11/29 Takemasa Miyoshi, Big Data Assimilation:A New Science for Weather Prediction and Beyond, seminar, National Central University, Taoyuan City, Taiwan
12. 2019/12/5 Otsuka, S. and T. Miyoshi: Overview of the rapid-update weather forecasting with the phased-array weather radar, 2019 6th KNU CARE Workshop on Phase array radar and Nowcasting, Daegu, Korea

- Oral Presentations

1. 2019/4/8 Takemasa Miyoshi, Shigenori Otsuka, Takumi Honda, Guo-Yuan Lien, Yasumitsu Maejima, Yoshito Yoshizaki, Hiromu Seko, Hirofumi Tomita, Shinsuke Satoh, Tomoo Ushio, Tatiana V. Martsinkevich, Balazs Gerofi, and Yutaka Ishikawa, Big Data Assimilation: Past 5 Years and Perspectives for the Future, EGU2019, Austria Center Vienna (ACV), Vienna, Austria
2. 2019/4/9 Takemasa Miyoshi, Shunji Kotsuki, Koji Terasaki, Kenta Kurosawa, Shigenori Otsuka, Kaya Kanemaru, Hisashi Yashiro, Masaki Satoh, Hirofumi Tomita, Kozo Okamoto, and Eugenia Kalnay, Enhancing Data Assimilation of GPM Observations: Past 6 Years and Future Plans, EGU2019, Austria Center Vienna (ACV), Vienna, Austria
3. 2019/4/14 Takemasa Miyoshi, Big Data Assimilation: A New Science for Weather Prediction and Beyond, Japan-Israel meeting, Collabo Shiga 21, Otsu, Japan
4. 2019/5/30 Kotsuki S., Terasaki K., and Miyoshi T.: Ensemble-Based Data Assimilation of GPM/DPR Reflectivity into the Nonhydrostatic Icosahedral Atmospheric Model NICAM. JpGU Meeting 2019, Chiba, Japan
5. 2019/7/30 Takemasa Miyoshi, Big Data Assimilation: Past 5 Years and Perspectives for the Future, AOGS, Suntec Singapore Convention & Exhibition Centre, Singapore
6. 2019/8/2 Takemasa Miyoshi, Enhancing Data Assimilation of GPM Observations: Past 6 Years and Future Plans, AOGS, Suntec Singapore Convention & Exhibition Centre, Singapore
7. 2019/8/26 Takemasa Miyoshi, Big Data Assimilation: A New Science for Weather Prediction and Beyond, Seminar, CIMA, Buenos Aires, Argentina

8. 2019/9/17 Takemasa Miyoshi, Shigenori Otsuka, Takumi Honda, Guo-Yuan Lien, Yasumitsu Maejima, Marimo Ohhigashi, Yoshito Yoshizaki, Hiromu Seko, Hirofumi Tomita, Shinsuke Satoh, Tomoo Ushio, Balazs Gerofi, Yutaka shikawa, Naonori Ueda, Kana Koike, Yasuhiko Nakada: Big Data Assimilation: Past 6 Years and Future Plans, 39th International Conference on Radar Meteorology, Nara Kasugano International Forum IRAKA, Nara, Japan
9. 2020/1/13 Takemasa Miyoshi, Big Data Assimilation: Real-Time Workflow for 30-Second-Update Forecasting and Perspectives Toward DA-AI Integration, AMS 100th Annual Meeting, Boston Convention and Exhibition Center, Boston, USA
10. 2020/1/24 Takemasa Miyoshi, Enhancing Precipitation Prediction Algorithm by Data Assimilation of GPM Observations, The Joint PI Meeting of JAXA Earth Obervation Missions FY2019, TKP Shinbashi Conference Cetre, Tokyo, Japan
11. 2020/2/10 Koji Terasaki and Takemasa Miyoshi, Accounting for the horizontal observation error correlation of satellite radiances in data assimilation, Brest, France
12. 2020/2/17 Takemasa Miyoshi, "Big Data Assimilation in Weather Prediction: From K to Fugaku", The 2nd R-CCS International Symposium, Nichii Gakkan Kobe Port Island Center, Kobe, Japan

- Poster Presentations

1. 2019/8/21 Ying-Wen Chen, Kaya Kanemaru, Masaki Satoh, Koji Terasaki, Shunji Kotsuki, Takemasa Miyoshi, and Takuji Kubota: The resent progress of NICAM-LETKF forecast system, The 2019 University Allied Workshop on Climate and Extreme Weather, Chiba, Japan

2.2019/9/16 Kotsuki S., Kurosawa K., Kanemaru K., Terasaki K. and Miyoshi T.: A New Evaluation Method for Cloud Microphysics Schemes Using GPM Dual-frequency Precipitation Radar. 39th International Conference on Radar Meteorology, Nara, Japan
3.2020/2/3 Kotsuki S., Terasaki K., Satoh M. and Miyoshi T.: Ensemble-Based Data Assimilation of GPM/DPR Reflectivity into the Nonhydrostatic Icosahedral Atmospheric Model NICAM. 4th workshop on assimilating satellite cloud and precipitation observations for NWP, Reading, UK
4.2020/2/17 Koji Terasaki and Takemasa Miyoshi, Towards big data assimilation in Fugaku by accounting for the horizontal observation error correlation of satellite observations, R-CCS international symposium, Kobe, Japan

Usage of JSS2

- **Computational Information**

Process Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP
Number of Processes	5 - 400
Elapsed Time per Case	12 Hour(s)

- **Resources Used**

Fraction of Usage in Total Resources*1(%): 4.32

Details

Computational Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage*2(%)
SORA-MA	37,398,934.21	4.55
SORA-PP	8.87	0.00
SORA-LM	0.00	0.00
SORA-TPP	0.00	0.00

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage*2(%)
/home	2,412.80	2.01
/data	767,040.60	13.13
/ltmp	15,625.01	1.33

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage*2(%)
J-SPACE	40.25	1.01

*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.