Data Assimilation Research Team

1. Team members

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Shigenori Otsuka (Postdoctoral Researcher)
Koji Terasaki (Postdoctoral Researcher)
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Shunji Kotsuki (Postdoctoral Researcher)
Guo-Yuan Lien (Postdoctoral Researcher)
Yasumitsu Maejima (Research Associate)
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Hazuki Arakida (Technical Staff)
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Juan J. Ruiz (Visiting Scientist)
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Masahiro Sawada (Visiting Scientist)
Shu-Chih Yang (Visiting Scientist)
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Masaru Kunii (Visiting Scientist)
Kozo Okamoto (Visiting Scientist)
Michiko Otsuka (Visiting Scientist)
Marimo Ohhigashi (Research Assistant)
Yukie Komori (Assistant)
Rie Deguchi (Assistant)

2. Research Activities

Data Assimilation Research Team (DA Team) was launched in October 2012 and is composed of 19 research and technical staff including 8 visiting members as of March 2015. Data assimilation is a cross-disciplinary science to synergize computer simulations and real-world data, using statistical methods and applied mathematics. As computers become more powerful and enable more precise simulations, it will become more important to compare the simulations with actual observations. DA Team performs cutting-edge research and development on advanced data assimilation methods and their wide applications, aiming to integrate computer simulations and real-world data in the wisest way. Particularly, DA Team tackles challenging problems of developing efficient and accurate data assimilation systems for "big simulations" with real-world "big data" from various sources including advanced sensors. The specific foci include 1) theoretical and algorithmic developments for efficient and accurate data assimilation, 2) data assimilation methods and applications by taking advantage of the world-leading K computer and "big data" from new advanced sensors, and 3) exploratory new applications of data assimilation in wider simulation fields. These advanced data assimilation studies will enhance simulation capabilities and lead to a better use of the K computer.

In FY2014, we continued on the ongoing data assimilation research in the following aspects: 1) theoretical research on challenging problems, 2) leading research on meteorological applications, 3) optimization of computational algorithms, and 4) exploratory research on wider applications. We also explored close collaborations with several research teams within the AICS Research Division. We have made substantial progress on the following research items:

[Theoretical research]

1. A discrete Bayesian optimization approach to find optimal ensemble sizes in a multi-model ensemble Kalman filter (EnKF) was investigated (1 paper accepted).
2. The role of observation error correlations in data assimilation was investigated with the Lorenz-96 system (1 paper published).
3. Potential impact of assimilation order of observations in serial EnKF was investigated (1 paper under review).
4. Particle filter methods to treat non-Gaussian PDF were further explored.

[Leading research on meteorological applications]

5. Local Ensemble Transform Kalman Filter (LETKF) experiments with a large ensemble up to 10240 members were performed with both simulated and real cases, in collaboration with Large-scale Parallel Numerical Computing Technology Research Team (1 paper published, press release on July 23, 2014).
6. The LETKF system with the global Nonhydrostatic ICosahedral Atmospheric Model (NICAM) was improved and tested with the real conventional and satellite observations, in collaboration with Computational Climate Science Research Team (1 paper published).
7. Satellite-based global precipitation data were considered for assimilation with NICAM-LETKF (1 paper published).
8. "Big Data Assimilation" experiments for a selected case of local severe rainstorms in Kyoto on July 13, 2013, were performed to take advantage of Big Data from both high-resolution simulations and phased array weather radar data.
9. A new quality control algorithm for the Osaka phased array weather radar was developed (1 paper accepted).
10. The development of the LETKF system with the SCALE model was started in collaboration with Computational Climate Science Research Team.
11. Convective predictability was investigated by performing breeding experiments.
12. A precipitation nowcasting system was developed to take advantage of the dense and frequent

phased array weather radar data. The system was first explored by the three intern students, Ryota Kikuchi of Tohoku University, Yoshikazu Kitano of Hokkaido University, and Yusuke Taniguchi of University of Hyogo, supported by the AICS internship program.

13. Impact of dense and frequent ground observation data on local severe weather forecasting was investigated.

[Computational optimization]

14. The inter-node communication of the LETKF core module was enhanced for acceleration.

[Wider applications]

15. A particle filter was applied to a dynamical vegetation model known as the SEIB-DGVM (Spatially-Explicit, Individual-Based Dynamic Global Vegetation Model).

Three achievements are selected and highlighted in the next section.

3. Research Results and Achievements

3.1. 10240-member LETKF with the SPEEDY model (Miyoshi et al. 2014)

Data assimilation combines simulations and real-world data based on statistical mathematics, in which probability density function (PDF) plays an essential role. For example, the error correlations of the simulated state determine how the information of observations spreads in space and among different variables. Ensemble-based data assimilation employs usually up to 100 samples or ensemble simulations to represent the errors of the simulated state. However, it is known that small ensemble sizes cause a significant sampling error, so that the signal to noise ratio becomes problematic. Therefore, a number of techniques such as error covariance localization and inflation have been explored extensively in the field of ensemble-based data assimilation. Here, we take advantage of the world's leading K computer and performed a series of LETKF experiments with large ensembles up to 10240, largest ever for the global atmospheric circulation.

10240 is two orders of magnitude greater than the typical choices of up to 100, requiring 10^6 more computations for the eigenvalue decompositions in the LETKF. To accelerate the eigenvalue computations, we collaborated closely with Large-scale Parallel Numerical Computing Technology Research Team and implemented their EigenExa into our LETKF system. This successfully accelerated the computations by a factor of 8, and enabled 3-week computations of LETKF data assimilation cycles assimilating global conventional observations every 6 hours (i.e., 84 LETKF cycles). We performed simulated experiments using an atmospheric general circulation model (AGCM) with intermediate complexity, known as the SPEEDY model, which has a low resolution (30 horizontal wave numbers and 7 vertical levels) and simple physics schemes. We also started performing real-world experiments using the NICAM-LETKF system. Here, we focus the former (cf. RIKEN press release on July 23, 2014, http://www.riken.jp/en/pr/press/2014/20140723_2/).

Figure 1 illustrates 10240 simulated atmospheric states in a single picture to quickly glance at what were computed. Here, we performed the LETKF data assimilation with simulated radiosonde (weather balloon) data. The 10240 atmospheric states are equally probable, and we find more similarities in the NH and differences in the SH, generally corresponding to the observing density. Radiosonde observations are made mainly over populated locations.

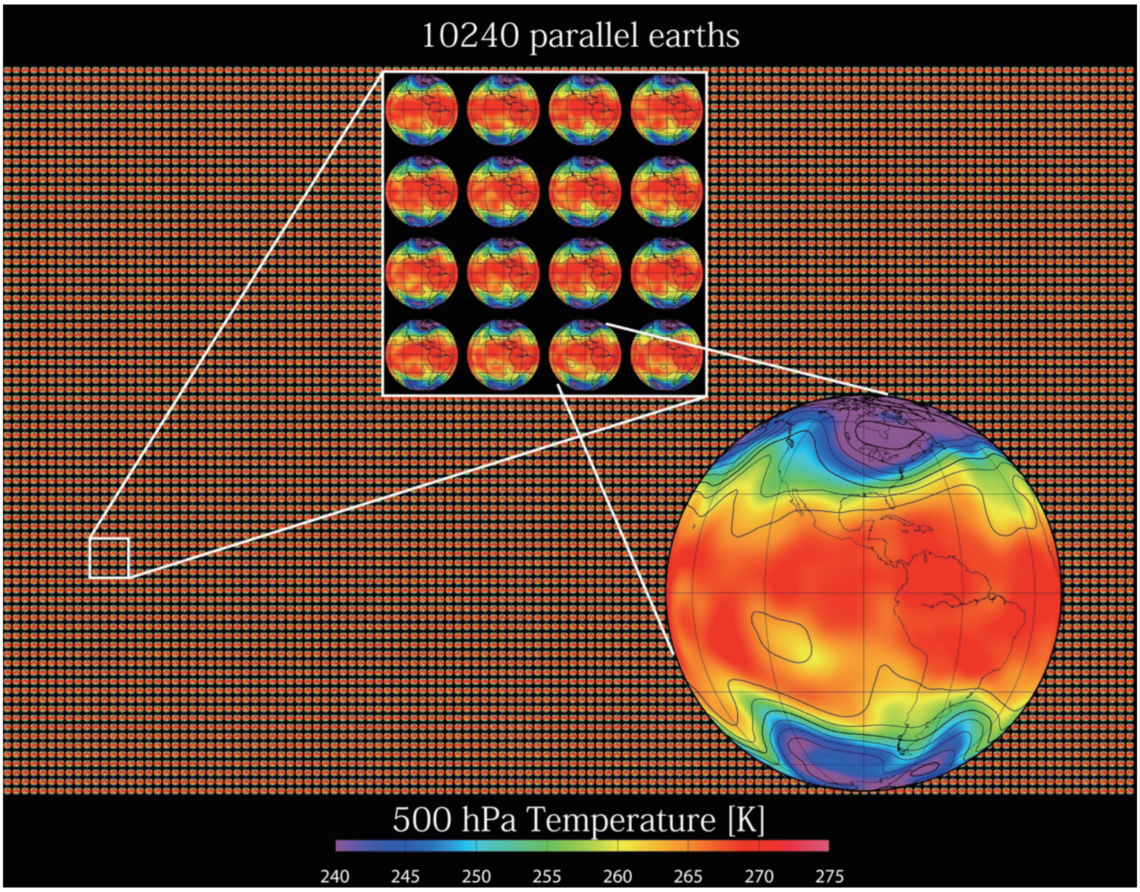

Figure 1. 10240 equally-probable global atmospheric states (temperature at the 500-hPa level).

Figure 2 left shows the spatial patterns of the error correlations for humidity from the yellow star point in the northern Pacific. We clearly find that the sampling errors are reduced significantly by increasing the ensemble size to 10240 from 100. Surprisingly, we find significant long-range error correlations extending in the planetary scales, so that the observation in the middle of Pacific may have significant impact in Siberia and even Eastern Europe. A possible future direction is to develop an efficient localization method that can capture such long-range correlations, and we may improve numerical weather prediction.

Figure 2 right shows the histogram of 100 and 10240 ensemble states of humidity at a single location. With 10240 samples or ensemble members, we find a clear bimodal structure, which is hardly captured by only 100 samples. We found that such strong non-Gaussianity occurred only occasionally. We could think about future developments of more advanced data assimilation that considers non-Gaussianity adaptively only when and where necessary. The LETKF and most other data assimilation methods for large-scale problems are usually based on the Gaussian assumption.

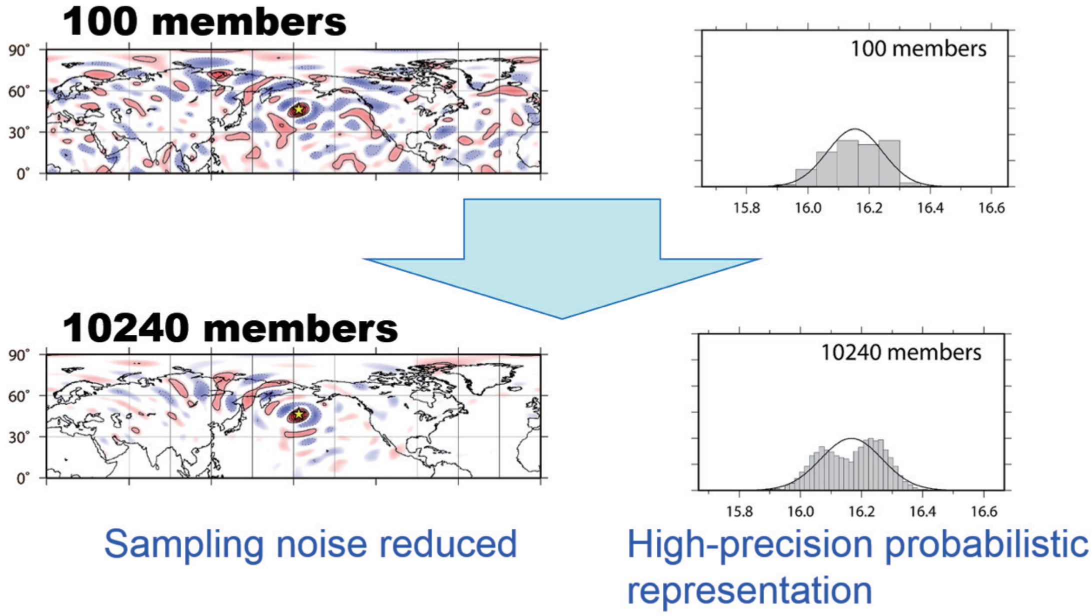

Figure 2. (Left) Spatial patterns of the error correlations for humidity from the yellow star point. This illustrates how the humidity observation at the star point makes the corrections in space. (Right) histograms of humidity (g kg^{-1}) at a single grid point.

3.2. Big Data Assimilation

With generous support by CREST, Japan Science and Technology Agency (JST), we have been working on the project titled "Innovating "Big Data Assimilation" technology for revolutionizing very-short-range severe weather prediction" (PI: Takemasa Miyoshi), or simply "Big Data Assimilation" (BDA) project, since October 2013. This project is a collaboration among RIKEN, Meteorological Research Institute, Meteorological Satellite Center, NICT (National Institute of Information and Communications Technology), and Osaka University, and almost 40 scientists are involved. DA Team plays a central role in this BDA project.

The main goal is to develop the BDA system that updates a 30-minute forecast at a 100-m resolution every 30 seconds by taking "big data" from new-generation sensors phased array weather radar (PAWR) and geostationary satellite Himawari-8 that produce orders of magnitude more data than the present counterparts. This way, we aim to resolve and capture precisely individual convective cells at a typical O(1)-km scale. The world's most advanced operational weather prediction systems update forecasts typically at an O(1)-km resolution every hour for convective-scale weather forecasting. The BDA system is two orders of magnitude more rapid and an order of magnitude more precise.

A prototype system based on the JMA nonhydrostatic mesoscale model (NHM) was developed and tested in a single heavy rainfall case on July 13, 2013, when a series of severe convective rainstorms caused a disaster in Kyoto. Figure 3 shows the actual observations from the Osaka PAWR, showing that the convective cell does not change much in 30 seconds, but it changes significantly in 5 minutes. The conventional radar with a parabolic antenna needs to be rotated repeatedly at different elevation angles; it usually takes 5 minutes to scan 15 vertical scan angles. Figure 3 suggests that the data taken every 5 minutes may produce significant nonlinearity in the convective systems. By contrast, every-30-second data from PAWR seem to be frequent enough to make the linear and Gaussian assumptions that the current approaches of data assimilation in numerical weather prediction assume.

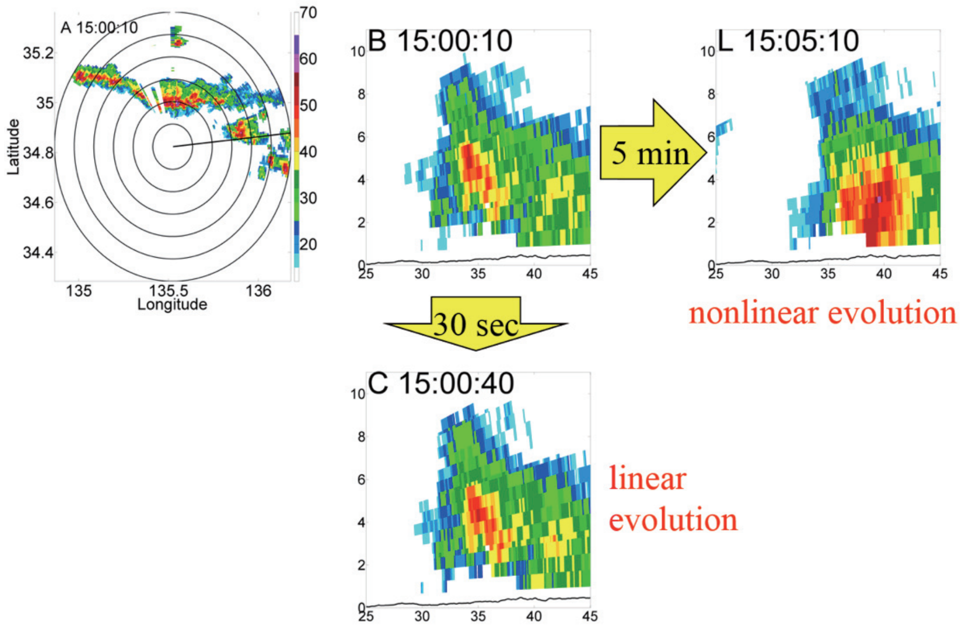

Figure 3. PAWR reflectivity (dBZ) on July 13, 2013. (Left) horizontal image at 15:00:10 JST, (Middle and Right) vertical cross sections along the line shown in the left panel at 15:00:10, 15:00:30, and 15:05:10 JST.

Our first trial of the case study was very promising. As shown in Fig. 4, the RMS errors dropped quickly in the first 4 minutes (8 data assimilation cycles), and the forecast was more accurate than the case without data assimilation for the entire 30-minute forecast period. We find that the individual convective cells matched the observations almost exactly due to “Big Data Assimilation” (Fig. 5).

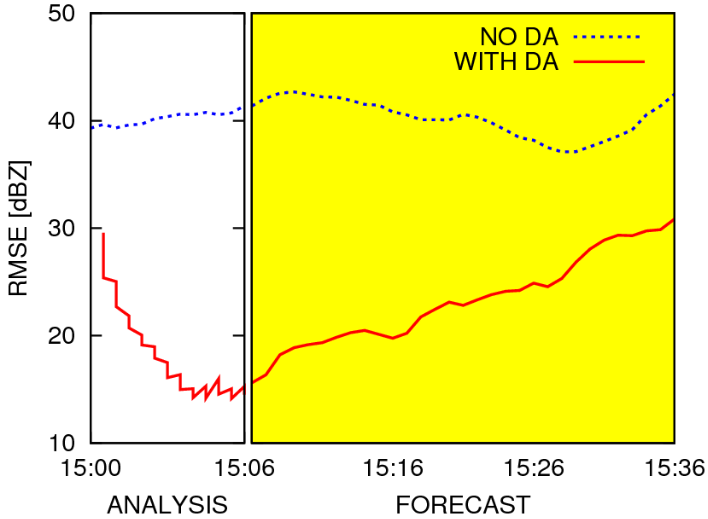

Figure 4. Time series of the rms errors relative to the observed reflectivity (dBZ). The observations were assimilated in the first 6 minutes (white background), and a 30-minute forecast was initialized at 15:06:00 JST (yellow background).

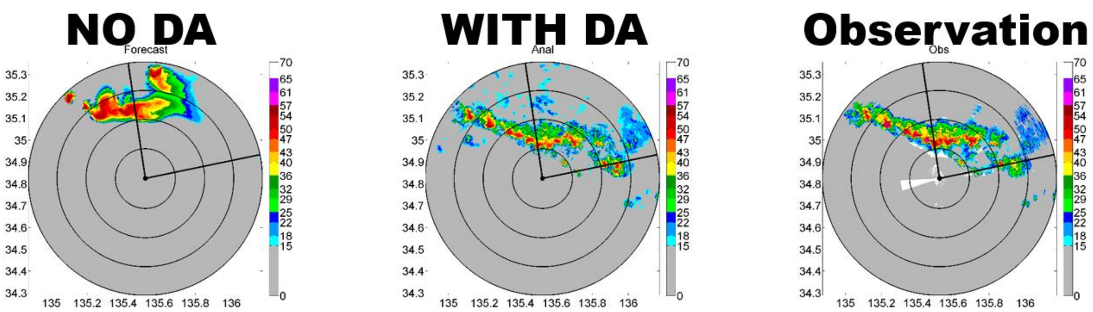

Figure 5. Horizontal maps of reflectivity (dBZ) at 15:06:00 JST.

3.3. New application to the dynamical vegetation model SEIB-DGVM

As one of the main foci of DA Team, we explore new applications of data assimilation. Since November 2013, we have been exploring data assimilation studies with the dynamical vegetation model SEIB-DGVM (Spatially-Explicit, Individual-Based Dynamic Global Vegetation Model). SEIB-DGVM simulates explicit individual plants (Fig. 6), so that the number of state variables, or the dimension of phase space, changes time to time as plants grow and die. It is not straightforward to perform Kalman-filter-based data assimilation in this type of dynamical system, so we decided to use a particle filter.

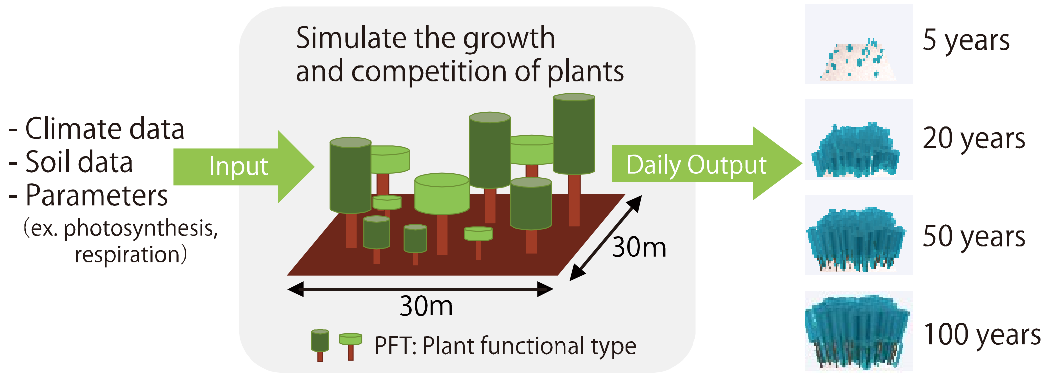

Figure 6. Schematic of vegetation simulation with SEIB-DGVM.

Figure 7 shows a schematic of the sequential importance resampling (SIR) particle filter. Particle filters consist of parallel simulations, a.k.a. particles, and each simulation or particle has probability. The probability is updated by taking observations. Observations have a likelihood function, and we use Bayes' theorem to update the probability: namely, the prior probability and likelihood function is multiplied and normalized to obtain the posterior probability for each particle. If we simply update the probability, some particles may have very small probability and add little value. To avoid performing useless simulations of little probability and to make the most use of limited computational resources, we omit the useless simulations and resample the states with larger probability. This way, the SIR filter normalizes the probability after resampling, so that every particle has equal probability. When resampling, we simply duplicate the high probability simulations, but with randomly perturbed to avoid exact duplication.

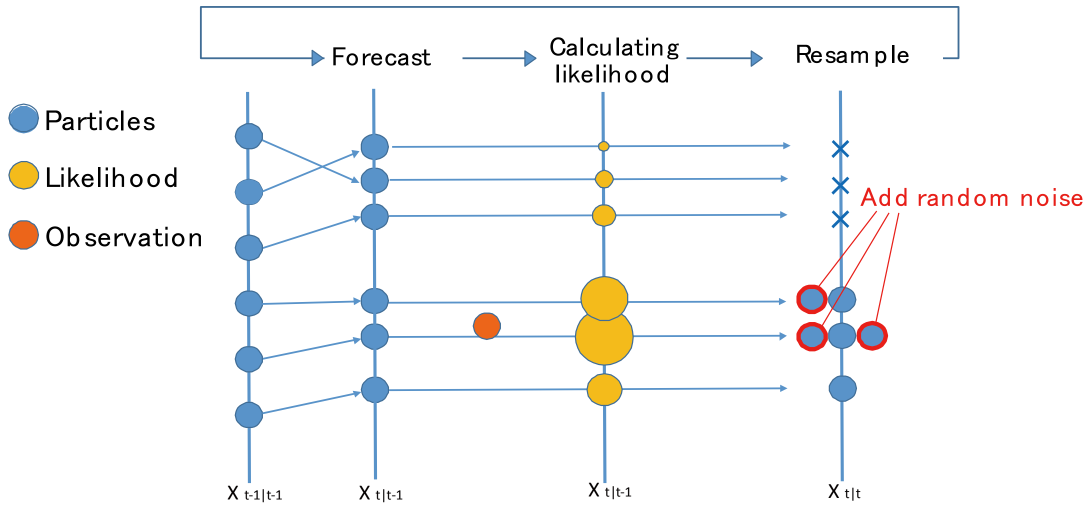

Figure 7. Schematic showing a sequential importance sampling (SIR) particle filter.

The SIR particle filter was applied to the SEIB-DGVM, and observing system simulation experiments were performed. Here, we assumed LAI (leaf area index) observations from satellites. The LAI observations were simulated from the free nature run of the SEIB-DGVM. The nature run was generated by setting the three parameters of the SEIB-DGVM, maximum photosynthesis rate, foliate date, and dormant date, to be 36 μmolCO2 m^{-2} s^{-1}, 110th day of year, 210th day of year, respectively. The nature run was assumed to be the true states, and the true LAI values were perturbed randomly to simulate the satellite-based LAI observations. This way, we test if the SIR particle filter can estimate the state variables and model parameters by assimilating the LAI observations.

First, without data assimilation, we generated 800 parallel simulations or particles, the median and percentiles shown in Fig. 8 left. Figure 8 right panel shows 800 particles with data assimilation. We find that the SIR particle filter works very well with the SEIB-DGVM, so that the 800 particles become closer to the true states.

Figure 9 shows the parameter estimation results. These parameters were not observed directly, but estimated through data assimilation. The results indicate that the true parameter values are reasonably estimated by the SIR particle filter.

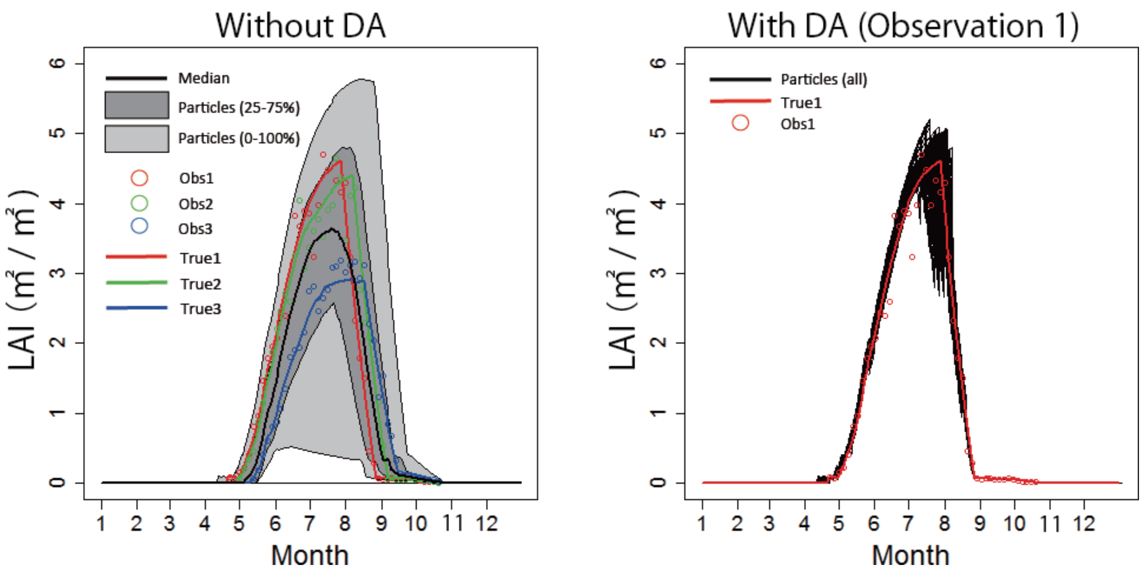

Figure 8. Time series of LAI, the observed variable. (Left) The true evolution is shown by red curve, and the observations are shown by red open circles. Ignore green and blue colors here. The black curve is the median of 800 particles without data assimilation, and grey shaded areas show the corresponding percentiles as shown in legend. (Right) Red curve and open circles are the same as the left panel, showing the nature run and observations, respectively. 800 particles with data assimilation are explicitly drawn.

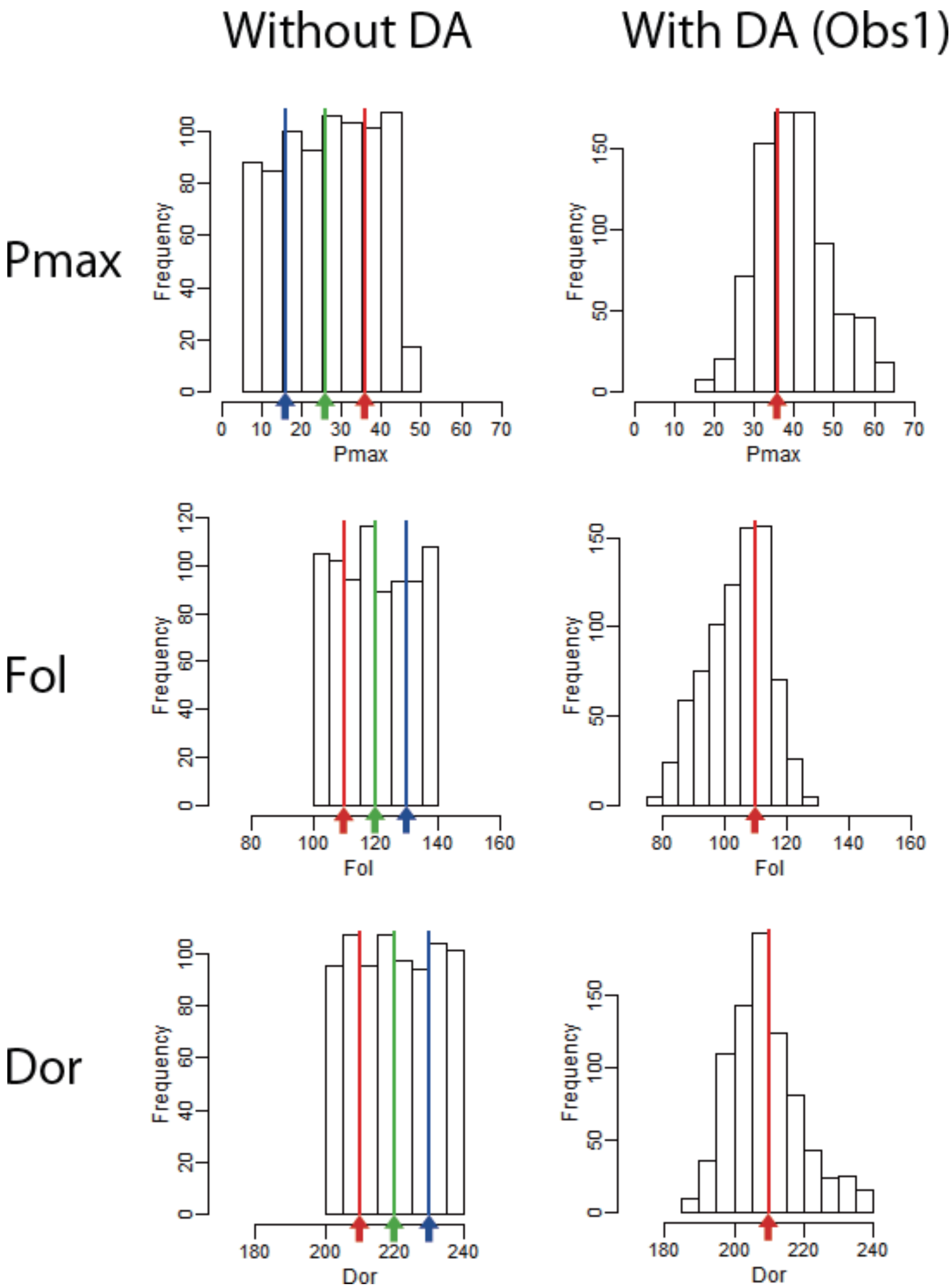

Figure 9. Parameter estimation results. Pmax, Fol, and Dor represent maximum photosynthesis rate (μmolCO2 m^{-2} s^{-1}), foliate date (day of year), and dormant date (day of year), respectively. Red bars indicate the true parameter values. White boxes indicate histograms of 800 particles: (Left) without data assimilation, (Right) with data assimilation.

4. Schedule and Future Plan

In FY2014, DA Team had four additional full-time research and technical staff and accepted more visiting researchers, leading to a continuing substantial growth. We continued our ongoing efforts on a wide range of data assimilation research on theoretical explorations, leading meteorological applications, algorithmic optimization, and wider applications. Our active research efforts have been making substantial impact on the scientific communities, and we are in a good shape in making progress on the research items of the AICS road-map. On February 23-26, we organized the fourth International Symposium on Data Assimilation (ISDA) 2015 at AICS. This event was received very well and attracted total 116 participants (42 from overseas and 16 from RIKEN), implying the successful development of DA research at AICS.

In FY2015, we will further extend and strengthen what we have achieved so far, and also will keep seeking new challenges. We will keep updating ourselves with the most recent movements and trends in the scientific community and society, while making substantial progress on traditional research. Team is still young and spinning up, but will keep the consistent and competitive level of productivity, aiming to be one of the world's leaders in the field of data assimilation.

5. Publication, Presentation and Deliverables

(1) Journal Papers

1. 牛山朋來，佐山敬洋，岩見洋一，**三好建正**，2014：2011 年台風 12 号・15 号を対象としたアンサンブル降雨流出予測実験．河川技術論文集, 20, 455-460.
2. Cecelski, S. F., D.-L. Zhang, and **T. Miyoshi**, 2014: Genesis of Hurricane Julia (2010) within an African Easterly Wave: Developing and Non-Developing Members from WRF-LETKF Ensemble Forecasts. J. Atmos. Sci., 71, 2763-2781. doi:10.1175/JAS-D-13-0187.1
3. Tsai, C.-C., **S.-C. Yang**, and Y.-C. Liou, 2014: Improving Short-Term QPFs with a WRF-LETKF Radar Data assimilation system: OSSEs on Typhoon Morakot (2009). Tellus A, 66, 21804. doi:10.3402/tellusa.v66.21804
4. Huang, Z.-K., Z. Peng, H.-N. Liu, M.-G. Zhang, X.-G. Ma, **S.-C. Yang**, S.-D. Lee, and S.-Y. Kim, 2014: Development of CMAQ for East Asia CO2 data assimilation under an EnKF framework: a first result. Chinese Science Bulletin. doi:10.1007/s11434-014-0348-9.
5. Yoden, S., K. Ishioka, D. Durran, T. Enomoto, Y. Hayashi, **T. Miyoshi**, and M. Yamada, 2014: Theoretical Aspects of Variability and Predictability in Weather and Climate Systems. Bull. Amer. Meteor. Soc., 95, 1101-1104. doi:10.1175/BAMS-D-14-00009.1
6. Matsuoka, S., H. Sato, O. Tatebe, F. Takatsu, M. A. Jabri, M. Koibuchi, I. Fujiwara, S. Suzuki, M. Kakuta, T. Ishida, Y. Akiyama, T. Suzumura, K. Ueno, H. Kanezashi, and **T. Miyoshi**, 2014: Extreme Big Data (EBD): Next Generation Big Data Infrastructure

Technologies Towards Yottabyte/Year. Supercomputing Frontiers and Innovations, 1, No.2, 89-107. doi:10.14529/jsfi140206

7. Yoshimura, K., **T. Miyoshi**, and M. Kanamitsu, 2014: Observation System Simulation Experiments Using Water Vapor Isotope Information. J. Geophys. Res., 119. doi:10.1002/2014JD021662.
8. **Miyoshi, T.**, **K. Kondo**, and T. Imamura, 2014: The 10240-member ensemble Kalman filtering with an intermediate AGCM. Geophys. Res. Lett., 41. doi:10.1002/2014GL060863.
9. **Otsuka, S.**, M. Takeshita, and S. Yoden, 2014: A numerical experiment on the formation of the tropopause inversion layer associated with an explosive cyclogenesis: Possible role of gravity waves. Progress in Earth and Planetary Science, 1, 19. doi:10.1186/s40645-014-0019-0
10. Satoh, M., H. Tomita, H. Yashiro, H. Miura, C. Kodama, T. Seiki, A. Noda, Y. Yamada, D. Goto, M. Sawada, **T. Miyoshi**, Y. Niwa, M. Hara, T. Ohno, S. Iga, T. Arakawa, T. Inoue, H. Kubokawa, 2014: The non-hydrostatic icosahedral atmospheric model: description and development. Progress in Earth and Planetary Science, 1:18. doi:10.1186/s40645-014-0018-1.
11. **Kotsuki, S.**, **K. Terasaki**, and **T. Miyoshi**, 2014: GPM/DPR Precipitation Compared with a 3.5-km-resolution NICAM Simulation. SOLA, Vol: 10, pp.204-209. doi:10.2151/sola.2014-043
12. **Terasaki, K.**, and **T. Miyoshi**, 2014: Data Assimilation with Error-Correlated and Non-Orthogonal Observations: Experiments with the Lorenz-96 Model, SOLA, 10, 210-213. doi:10.2151/sola.2014-044.
13. **Yang, S.-C.**, S.-Y. Chen, S.-H. Chen, C.-Y. Huang and C.-S. Chen, 2013: Evaluating the impact of the COSMIC-RO bending angle data on predicting the heavy precipitation episode on 16 June 2008 during SoWMEX-IOP8. Mon. Wea. Rev., 142, 4139–4163. doi:10.1175/MWR-D-13-00275.1
14. **Terasaki, K.**, M. Sawada, and **T. Miyoshi**, 2015: Local Ensemble Transform Kalman Filter Experiments with the Nonhydrostatic Icosahedral Atmospheric Model NICAM. SOLA, 11, 23-26. doi:10.2151/sola.2015-006
15. Chang, C.-C., **S.-C. Yang** and C. Keppenne, 2014: Applications of the mean re-recentering scheme to improve typhoon track prediction: A case study of typhoon Nanmadol (2011), JMSJ Ser. II Vol. 92 (2014) No. 6 p. 559-584. doi:10.2151/jmsj.2014-604
16. Sawada, M., T. Sakai, T. Iwasaki, H. Seko, K. Saito and **T. Miyoshi**, 2015: Assimilating high-resolution winds from a Doppler lidar using an ensemble Kalman filter with lateral boundary adjustment. Tellus, 67A, 23473. doi:10.3402/tellusa.v67.23473

(2) Conference Papers

1. 島伸一郎，“雲の物理学入門”，物性研究 3, 033210 (2014). http://bussei-kenkyu.jp/pdf/03/3/9999-033210.pdf
2. 荒木田葉月, 立澤史郎, 2014: 北極環境研究の長期構想 6 章「生物多様性を中心とする環境変化を解き明かす」:テーマ 8「陸域生態系と生物多様性への影響」- Q3「北極陸域生態系の変化が動物や気候に与える影響はどうなるか？」. 北極環境研究コンソーシアム(JCAR), p95-96.
   http://www.jcar.org/documents/longterm20140918_06_01.pdf
3. 立澤史郎, 荒木田葉月, 2014: 北極環境研究の長期構想 5 章「現在進行中の地球温暖化に伴う北極の急激な環境変化を解き明かす」: テーマ 7「北極環境変化の社会への影響」- Q2「地球温暖化に起因する陸域環境の変化による影響は？」- b. 植生変化・野生動物・家畜 」. 北極環境研究コンソーシアム(JCAR), p83.
   http://www.jcar.org/documents/longterm20140918_05_07.pdf

(3) Invited Talks

1. **Shima**, S., “Preliminary numerical study on the cumulus-stratus transition induced by the increase of formation rate of aerosols”, Workshop on Space Climate, Solar Terrestrial Environment Laboratory, Nagoya University, Japan, 3rd April 2014
2. **Terasaki, K**. and **T. Miyoshi**, “Data assimilations with correlated observation errors and non-orthogonal observation operator”, ESA-DA workshop on correlated errors in data assimilation, University of Reading, Reading, UK, 24th April 2014.
3. **Miyoshi, T.**, “Recent activities on 'Big Data Assimilation' in Japan”, The 6th EnKF Workshop, Buffalo, NY, USA, 21st May 2014.
4. **Miyoshi, T**., "Numerical Weather Prediction and 'Big Data Assimilation'", International HPC Summer School 2014, Budapest, Hungary, 3rd June 2014.
5. 三好建正, 別所康太郎, 瀬古弘, 富田浩文, 佐藤晋介, 牛尾知雄, 石川裕, “「ビッグデータ同化」によるゲリラ豪雨予測に向けて”, 画像電子学会年次大会, 東京, 2014年6月30日
6. **Miyoshi, T.**, “‘Big Data Assimilation’ for Revolutionizing Weather Prediction”, the 53rd IDC HPC User Forum, Kobe, Japan, 16th July 2014.
7. 三好建正, “DPR 降水量プロダクトと NICAM3.5km シミュレーションの比較”, DPR Quick Evaluation Team(QET)会合, 東京, 2014年7月24日
8. **Miyoshi, T.**, **M. Kunii**, **J. Ruiz**, H. Seko, S. Satoh, T. Ushio, Y. Ishikawa, H. Tomita, K. Bessho, Session SCI-PS137, “Recent activities on “Big Data Assimilation” in Japan”, WWOSC 2014, Montreal, Canada, 17th August 2014.
9. 三好建正, “ビッグデータ同化”, 東京大学大気海洋研究所　国際沿岸海洋研究セン

ター　共同利用研究集会　中緯度気象・気候研究の現状と展望, 大槌,　岩手, 2014 年 8 月 27 日.

10. 三好建正, “ビッグデータ時代のデータ同化”, グリッド協議会神戸セミナー, 神戸, 2014 年 9 月 12 日.
11. 島伸一郎, “次世代エクサ級スパコンによるゲリラ豪雨予測に向けた気象モデルの開発”, 兵庫県立大学知の交流シンポジウム 2014, 2014 年 9 月 24 日
12. **Miyoshi, T.**, “Big Data Assimilation” revolutionizing severe weather forecasting, Joint Workshop of 6th International Workshop on Global Cloud Resolving Modeling and 3rd International Workshop on Nonhydrostatic Numerical Models, Kobe, Japan, 25th September 2014.
13. **Miyoshi, T.**, “‘Big Data Assimilation’ revolutionizing severe weather forecasting”, Workshop on perspectives in computational climate science and 7th OFES International Workshop, Aizu-wakamatsu, Japan, 2nd October 2014.
14. **Miyoshi, T.**, “‘Big Data Assimilation’ Revolutionizing Weather Prediction”, 13th Japan Science and Technology Agency (JST) Advisory Committee Meeting, Kyoto, Japan, 3rd October 2014.
15. 三好建正, “「ビッグデータ同化」でゲリラ豪雨に挑む”, パターン認識・メディア理解（PRMU）研究会, 幕張, 2014 年 10 月 9 日.
16. 三好建正, “データ同化の今後の展望”, 日本気象学会 地球観測衛星研究連絡会, 福岡, Japan, 2014 年 10 月 23 日.
17. 三好建正, “「ビッグデータ同化」でゲリラ豪雨に挑む”, 第 37 回情報化学討論会, 豊橋, 2014 年 11 月 28 日.
18. 三好建正, “ビッグデータ時代のデータ同化”, 第 14 回 PC クラスタシンポジウム, 2014 年 12 月 12 日
19. **Miyoshi, T.**, “‘Big Data Assimilation’ Revolutionizing Severe Weather Forecasting”, the 95th AMS Annual Meeting, American Meteorological Society, 19th Conference on Integrated Observing and Assimilation Systems for Atmosphere, Oceans, and Land Surface (IOAS-AOLS), Phoenix, AZ, USA, 5th January 2015.
20. 三好建正, “Ensemble-based Data Assimilation of TRMM/GPM Precipitation Measurements”, PMM PI ワークショップ, 東京, 2015 年 1 月 15 日
21. 三好建正, “データ同化の応用に向けた展望”, 第 7 回 EFD/CFD 融合ワークショップ, 東京, 2015 年 1 月 26 日
22. **Miyoshi, T.**, “‘Big Data Assimilation’ Revolutionizing Severe Weather Forecasting”, the 4th International Symposium on Data Assimilation, Kobe, 23rd February 2015.
23. 三好建正, 小槻峻司, 寺崎康児、Guo-Yuan Lien, 富田浩文, 佐藤正樹, Eugenia Kalnay, “衛星降水観測データの全球大気モデル NICAM への同化に向け

て", GSMaP 及び衛星シミュレータ研究集会, 名古屋, 2015 年 3 月 2 日.

24. **島伸一郎**, "動的植生モデル SEIB-DGVM を用いたデータ同化実験, 他", 香川非線形研究会, 香川大学, 2015 年 3 月 3-4 日.
25. **Shima**, S., "Numerical study on the cumulus-stratus transition using the super-droplet method", International Workshop on Cloud Turbulence, Nagoya Institute of Technology, Nagoya, Japan, 4th-6th March 2015.

(4) Posters and presentations

1. **Kunii, M.**, "Data assimilation experiments for TCs with the LETKF", Japan Geoscience Union Meeting 2014, Yokohama, 29th April 2014.
2. 渡邊歩佳, 今村 剛, **前島康光**, "火星における対流励起重力波と熱圏への影響", 日本地球惑星科学連合 2014 年大会, 横浜, 2014 年 5 月 1 日
3. **Kotsuki, S.**, **T. Miyoshi**, and S. Greybush, "Does the assimilation order matter in the serial ensemble Kalman filter? A study with the Lorenz-96 model", the 6th EnKF Workshop, Buffalo, NY, USA, 19th May 2014.
4. **Kondo, K.** and **T. Miyoshi**, "The dual-localization approach and large ensemble data assimilation in the SPEEDY-LETKF", the 6th EnKF Workshop, Buffalo, New York, 19th May 2014.
5. **Otsuka, S.** and **T. Miyoshi**, "A Bayesian optimization approach to multi-model ensemble Kalman filter", the 6th EnKF Workshop, Buffalo, NY, USA, 19th May 2014.
6. **Terasaki, K.**, M. Sawada and **T. Miyoshi**, "Developing the Local Ensemble Transform Kalman Filter with the Japanese Icosahedral Global Model NICAM", the 6th EnKF Workshop, Buffalo, NY, USA, 21th May 2014.
7. **前島康光**, 橋本明弘, 村上正隆, 池田明弘, 伊東克郎, 水野克彦, 松尾崇宏, Richard D. Farley, "小河内ダム集水域におけるシーディングシミュレーション(その２)", 日本気象学会 2014 年度春季大会, 横浜, 2014 年 5 月 23 日
8. 渡邊歩佳, 今村 剛, **前島康光**, "火星における対流励起重力波と熱圏への影響", 気象学会 2014 年度春季大会, 横浜, 2014 年 5 月 23 日
9. 今村 剛, 樋口武人, **前島康光**, 高木征弘, 杉本憲彦, 池田恒平, 安藤紘基, "金星雲層における日射による対流の抑制", 気象学会 2014 年度春季大会, 横浜, 2014 年 5 月 24 日
10. **Kunii, M.**, "Data assimilation experiments of TC position and intensity with an ensemble Kalman filter", 2014 Meteorological Society of Japan Spring Meeting, Yokohama, 24th May 2014.
11. **小槻峻司**, "画像の類似性判定、統計的仮説検定、on-off インターミッテンシー", 第 3 回 理研・京大合同データ同化研究会, 神戸, 2014 年 7 月 28 日

12. 近藤圭一, 三好建正, “10240 メンバーSPEEDY-LETKF を用いた PDF 解析”, 第 3 回 理研・京大合同データ同化研究会, 神戸, 2014 年 7 月 28 日
13. **Lien, G.-Y.**, E. Kalnay, and **T. Miyoshi**, “Ensemble assimilation of global large-scale precipitation”, AOGS 11th Annual Meeting, Sapporo, Japan, 28th Jul-1st Aug 2014.
14. **Otsuka, S.**, M. Takeshita, and S. Yoden, “Diagnosis on gravity waves and their role in extratropical tropopause inversion layers simulated by a regional model”, AOGS2014, Sapporo, 30th July 2014.
15. Alicia, P. K. Tanaka K, **S. Kotsuki**, and S. Tanaka, “Reproduction of Past Surface Parameters and its Application to Regional Climate Change Study in Paraguay”, AOGS2014, Sapporo, 31th July, 2014.
16. **Otsuka, S.** and **T. Miyoshi**, “A Bayesian Optimization of the Ensemble Sizes in Multi-model Ensemble Kalman Filter”, AOGS2014, Sapporo, 31st July 2014.
17. Pierre Tandeo, Pierre Ailliot, Ronan Fablet, **Juan Ruiz**, François Rousseau and Bertrand Chapron, “The Analog Ensemble Kalman Filter and Smoother”, the 4th international Workshop on Climate Informatics, 25th-26th September 2014.
18. Felix Carrasco, **Juan Ruiz**, Celeste Saulo, Axel Osses, “Experimenting with the LETKF in a dispersion model coupled with the Lorenz 96 model”, WWOSC2014, Montreal, 16th-21st August 2014.
19. María Eugenia Dillon, Yanina García Skabar, **Juan Ruiz**, Eugenia Kalnay, Estela A. Collini, Pablo Echevarría, Marcos Saucedo and Takemasa Miyoshi, “Application of the WRF-LETKF system over Southern South America: Sensitivity to model physics”, WWOSC2014, Montreal, 16th-21st August 2014.
20. **Juan Ruiz**, **Takemasa Miyoshi** and **Masaru Kunii**, “How do model error and localization approaches affect model parameter estimation in the LETKF?”, WWOSC2014, Montreal, 16th-21st August 2014.
21. Marcos Saucedo, **Juan Ruiz** and Celeste Saulo, “Sensitivity experiments to design a regional assimilation system combining the LETKF and the WRF model”, WWOSC2014, Montreal, 16-21 August 2014.
22. Tanaka K. and **S. Kotsuki**, “Projection of Future Change in Aridity Index and Evaporation Ratio in the Arid and Semi-Arid Region”, the Second International Conference on Arid Land Studies, Samarkand, Uzbekistan, 9th September 2014.
23. **Shima, S.**, “Preliminary numerical study on the cumulus-stratus transition induced by the increase of formation rate of aerosol”, the 6th GCRM and 3rd NHM WS, Kobe, Japan, 24th-26th September 2014.
24. **Otsuka, S.** and **T. Miyoshi**, “Convective-scale predictability in WRF simulations at a 100-m resolution”, the 6th GCRM and 3rd NHM WS, Kobe, Japan, 24th-26th September

2014.

25. **小槻峻司**，田中賢治，樋口篤志，本間香貴，篠田太郎，相馬一義，竹中栄晶，可知美佐子，久保田拓志，梶原康司:, “環太平洋域を対象とした陸面再解析・速報解析システムの開発: －日本域における高解像度陸面再解析－”, 水文・水資源学会 2014年研究発表会, 宮崎, 2014年9月25日

26. 田中賢治, 峠嘉哉, 浅野倫矢, **小槻峻司**, “陸域水循環解析における気象強制力データの問題点”, 水文・水資源学会 2014年研究発表会, 宮崎, 2014年9月27日

27. **Kotsuki, S.**, **K. Terasaki** and **T. Miyoshi**, “Comparative study of GPM-derived precipitation with the 3.5-km-resolution NICAM simulations”, the 6th GCRM and 3rd NHM WS, Kobe, Japan, 24th-26th September 2014.

28. **Terasaki, K.**, “Developing the Local Ensemble Transform Kalman Filter with the Japanese Icosahedral Global Model NICAM”, the 6th GCRM and 3rd NHM WS, Kobe, Japan, 24th-26th September 2014.

29. **Maejima, Y.**, **M. Kunii**, H. Seko, K. Sato, R. Maeda and **T. Miyoshi**, “Impacts of dense and frequent surface observations on severe rainstorm forecasts”, the 6th GCRM and 3rd NHM WS, Kobe, Japan, 24th-26th September 2014.

30. **Kunii, M.**, **T. Miyoshi**, **J. Ruiz,** T. Ushio, S. Satoh, K. Bessho and H. Seko, “30-second-update ensemble Kalman filter experiments using JMA-NHM at a 100-m resolution”, the 6th GCRM and 3rd NHM WS, Kobe, Japan, 24th-26th September 2014.

31. Alicia, P., K. Tanaka, **S. Kotsuki**, and S. Tanaka, “Reproduction of Long-term Surface Parameters and its Application to Regional Climate Change Study in Paraguay”, 水文・水資源学会 2014年研究発表会, 宮崎, 2014年9月27日

32. **寺崎康児**, “NICAM-LETKFの開発状況”, NICAM開発者会議, JAMSTEC東京事務所, 2014年10月14日

33. **国井勝**, **Juan Ruiz**, **Guo-Yuan Lien**, **三好建正**, 牛尾知雄, 佐藤晋介, 瀬古弘, 別所康太郎, “水平解像度100mのNHMを用いた30秒サイクルデータ同化実験”, 日本気象学会2014年度秋季大会, 福岡, 2014年10月21日.

34. **大塚成徳**, **三好建正**, “100m 解像度の領域モデルによる積雲対流のブリーディング実験”, 日本気象学会2014年度秋季大会, 福岡, 2014年10月21日.

35. **前島康光**, **國井勝**, 瀬古弘, 前田亮太, 佐藤香絵, **三好建正**, “2008年7月28日に神戸市付近で発生した局地的大雨の 観測システムシミュレーション実験”, 日本気象学会2014年度秋季大会, 福岡, 2014年10月21日.

36. **近藤圭一**, **三好建正**, “10240 メンバーによるアンサンブルデータ同化実験”, 日本気象学会2014年度秋季大会, 福岡, 2014年10月22日

37. **大塚道子**, **国井勝**, 瀬古弘, 下地和希, 林昌弘, 今井崇人, “MTSAT-1Rによるラピッドスキャンデータのメソスケールデータ同化への利用”, 気象学会 2014 年度秋季

大会, 福岡, 2014 年 10 月 22 日.

38. **寺崎康児**, 沢田雅洋, **三好建正**, "全球非静力学モデル NICAM を使った 局所アンサンブルカルマンフィルタ LETKF", 日本気象学会 2014 年度秋季大会, 福岡, 2014 年 10 月 22 日.
39. **小槻峻司**, **寺崎康児**, **三好建正**, "GPM/DPR 地上降水量データの初期検証：3.5km NICAM との比較", 気象学会 2014 年度秋季大会, 福岡, 2014 年 10 月 23 日.
40. Higuchi, A., H. Takenaka, H. Hirose, M.K. Yamamoto, **S. Kotsuki**, H. Irie, K. Tanaka and M. Hayasaki, "CEReS archived satellites related datasets and these applications", the 22nd CEReS International Symposium, Yogyakarta, Indonesia, 29th October 2014.
41. **島伸一郎**, "不変多様体を使った連結階層シミュレーションの試み", 第 1 回計算科学連携センター学術会議, 兵庫県立大学, 2014 年 11 月 5 日.
42. **前島康光**, **國井勝**, 瀬古弘, 前田亮太, 佐藤香絵, **三好建正**, "2008 年 7 月 28 日に神戸市付近で発生した局地的大雨の 観測システムシミュレーション実験", 急発達する低気圧の実態・予測・災害軽減に関する研究集会, 京都, 2014 年 11 月 17 日
43. **大塚成徳**, **三好建正**, "100m解像度の領域モデルによる積雲対流のブリーディング実験", 急発達する低気圧の実態・予測・災害軽減に関する研究集会, 宇治, 2014 年 11 月 17 日.
44. **寺崎康児**, 沢田 雅洋, **三好建正**, "NICAM-LETKF システムの開発と現状", 急発達する低気圧の実態・予測・災害軽減に関する研究集会, 宇治, 2014 年 11 月 17 日
45. **近藤圭一**, **三好建正**, "10240 メンバーを用いたアンサンブルデータ同化実験", 急発達する低気圧の実態・予測・災害軽減に関する研究集会, 宇治, 2014 年 11 月 17 日
46. **Kotsuki, S.**, **K. Terasaki** and **T. Miyoshi**, "Comparative study of GPM-derived precipitation with the 3.5-km-resolution NICAM simulations", 7th IPWG Workshop on Precipitation Measurements, Tsukuba, Japan, 17th-21st November 2014.
47. **Shima**, S., "Data assimilation experiments of the dynamic global vegetation model SEIB-DGVM with simulated GPP observations", Data Assimilation Seminar, RIKEN-AICS, 26th November 2014.
48. **Kotsuki, S.**, **K. Terasaki** and **T. Miyoshi**, "Comparative study of GPM-derived precipitation with the 3.5-km-resolution NICAM simulations", the 5th AICS International Symposium, Kobe, Japan, 8th-9th December 2014.
49. **Kunii, M.**, **J. Ruiz**, **G. Lien**, T. Ushio, S. Satoh, K. Bessho, H. Seko and **T. Miyoshi**, "30-second-update ensemble Kalman filter experiments using JMA-NHM at a 100-m resolution", the 5th AICS International Symposium, Kobe, Japan, 8th-9th December 2014.
50. **Terasaki, T.**, M., Sawada, and **T., Miyoshi**, "Local Ensemble Transform Kalman Filter

Experiments with the Nonhydrostatic Icosahedral Atmospheric Model NICAM", the 5th AICS International Symposium, Kobe, Japan, 8th-10th December 2014.

51. **Lien, G.-Y.**, **T. Miyoshi**, S. Nishizawa, H. Yashiro, R. Yoshida, and H. Tomita, "Ensemble data assimilation for a large parallel numerical weather prediction model: Development of the SCALE-LETKF system", the 5th AICS International Symposium, Kobe, Japan, 8th-9th December 2014.
52. **G. Tuerhong**, **S. Otsuka**, **J. Ruiz**, R. Kikuchi, Y. Kitano, Y. Taniguchi, and **T. Miyoshi**, "Short term forecasting for precipitation by utilizing a new three-dimensional super-rapid phased array weather radar data", the 5th AICS International Symposium, Kobe, Japan, 8th-9th December 2014.
53. **Maejima, Y.**, **M. Kunii**, H. Seko, K. Sato, R. Maeda and **T. Miyoshi**, "Toward investigating the impacts of dense and frequent surface observations on severe rainstorm forecasts", the 5th AICS International Symposium, Kobe, 8th-9th December 2014.
54. **Otsuka, S.** and **T. Miyoshi**, "Convective-scale predictability in numerical weather prediction at a 100-m resolution", the 5th AICS International Symposium, Kobe, 8th-9th December 2014.
55. **Kondo, K.**, and **T., Miyoshi**, "The 10,240-member ensemble Kalman filtering with an intermediate AGCM without localization", the 5th AICS International Symposium, Kobe, Japan, 8th-9th, December 2014.
56. **Arakida, H.**, **T. Miyoshi**, T. Ise, **S. Shima**, "Data assimilation experiments with simulated LAI observations and the dynamic global vegetation model SEIB-DGVM", the 5th AICS International Symposium, Kobe, 8th-9th December 2014.
57. **Kotsuki, S.**, **K. Terasaki** and **T. Miyoshi**, "Comparative study of GPM-derived precipitation with the 3.5-km-resolution NICAM simulations", AGU Fall Meeting, San Francisco, USA, 15th-19th December 2014.
58. **Miyoshi, T.**, **S. Kotsuki**, **K. Terasaki**, **G. Y. Lien**, and E. Kalnay, "Toward Assimilation of GPM-derived Precipitation Data with NICAM-LETKF", Eugenia Kalnay Symposium, AMS Annual Meeting, Phoenix, AZ, USA, 6th January 2015.
59. **Miyoshi, T.**, **K. Terasaki**, M. Sawada, and **S. Kotsuki**, "Local Ensemble Transform Kalman Filter with Nonhydrostatic Icosahedral Atmospheric Model NICAM", IOAS-AOLS, AMS Annual Meeting, Phoenix, AZ, USA, 6th January 2015.
60. **Kondo, K.**, and **T., Miyoshi**, "The 10,240-member ensemble Kalman filtering with an intermediate AGCM without localization", 95th AMS annual meeting, Phoenix, USA, 4th-8th January 2015.
61. **Lien, G.-Y.**, E. Kalnay, D. Hotta, and **T. Miyoshi**, "Ensemble forecast sensitivity to the observations (EFSO) applied to precipitation data assimilation", the 4th International

Symposium on Data Assimilation, Kobe, Japan, 23rd-26th February 2015.

62. **S. Otsuka** and **T. Miyoshi**, "Convective-scale predictability in numerical weather prediction at a 100-m resolution", the 4th International Symposium on Data Assimilation, Kobe, Japan, 23rd-26th February 2015.
63. **S. Otsuka**, **G. Tuerhong**, **J. Ruiz**, R. Kikuchi, Y. Kitano, Y. Taniguchi, and **T. Miyoshi**, "Precipitation nowcasting with a new three-dimensional super-rapid phased array weather radar", the 4th International Symposium on Data Assimilation, Kobe, Japan, 23rd-26th February 2015.
64. **Kotsuki, S.**, **K., Terasaki**, and **T., Miyoshi**, "GPM/DPR precipitation compared with a 3.5-km-resolution NICAM simulation", the 4th International Symposium on Data Assimilation, Kobe, Japan, 23rd-26th February 2015.
65. **Arakida, H.**, **T. Miyoshi**, T. Ise, **S. Shima**, "Data assimilation experiments with simulated LAI observations and the dynamic global vegetation model SEIB-DGVM", the 4th International Symposium on Data Assimilation, Kobe, Japan, 23rd-26th February 2015.
66. **Lien, G.-Y.**, **T. Miyoshi**, S. Nishizawa, H. Yashiro, R. Yoshida, and H. Tomita, "Development of the SCALE-LETKF system for radar data assimilation", the 4th International Symposium on Data Assimilation, Kobe, Japan, 23rd-26th February 2015.
67. **Maejima, Y.**, **M. Kunii**, H. Seko, K. Sato, R. Maeda and **T. Miyoshi**, "Toward investigating the impacts of dense and frequent surface observations on severe rainstorm forecasts", the 4th International Symposium on Data Assimilation, Kobe, Japan, 23rd-26th February 2015.
68. **Kondo, K.**, and **T., Miyoshi**, "The 10,240-member ensemble Kalman filtering with an intermediate AGCM without localization", the 4th International Symposium on Data Assimilation, Kobe, Japan, 23rd-26th February 2015.
69. **Kotsuki, S.**, **K., Terasaki**, **G.-Y., Lien**, **T., Miyoshi**, and E., Kalnay, "Ensemble Data Assimilation of GSMaP precipitation into the nonhydrostatic global atmospheric model NICAM", the 4th International Symposium on Data Assimilation, Kobe, Japan, 23rd-26th February 2015.
70. **Terasaki, T.**, and **T., Miyoshi**, "Applying the four-dimensional Local Ensemble Transform Kalman Filter to the Nonhydrostatic Icosahedral Atmospheric Model NICAM", the 4th International Symposium on Data Assimilation, Kobe, Japan, 23rd-26th February 2015.
71. **Perianez, A.**, J. A. Otkin, A. Schomburg, R. Faulwetter, H. Reich, C. Schraff, R. Potthast, K. Okamoto, K. Bessyo, H. Seko and T. Miyoshi, "Cloud-affected Infrared Brightness Temperature Assimilation using a Local Ensemble Transform Kalman Filter", the 4th International Symposium on Data Assimilation, Kobe, Japan, 23rd-26th February 2015.
72. **Otsuka, M.**, **M. Kunii**, H. Seko, K. Shimoji, M. Hayashi, T. Imai, "Assimilation

experiments of MTSAT rapid scan data", the 4th International Symposium on Data Assimilation, Kobe, Japan, 23rd-26th February 2015.

73. **Masaru Kunii**, **Juan J. Ruiz**, **Guo-Yuan Lien**, Tomoo Ushio, Shinsuke Satoh, Kotaro Bessho, Hiromu Seko and **Takemasa Miyoshi**, "30-second-update ensemble Kalman filter experiments using JMA-NHM at a 100-m resolution", the 4th International Symposium on Data Assimilation, Kobe, Japan, 23rd-26th February 2015.
74. **Kotsuki, S.**, **K., Terasaki**, **G.-Y., Lien**, **T., Miyoshi**, and E., Kalnay, "Assimilating TRMM/GPM-derived Precipitation with NICAM-LETKF", the 5th DAWS, Kobe, Japan, 27th February 2015.
75. **Terasaki, T.**, and **T., Miyoshi**, "Applying the four-dimensional Local Ensemble Transform Kalman Filter to the Nonhydrostatic Icosahedral Atmospheric Model NICAM", the 5th DAWS, Kobe, Japan, 27th February 2015.
76. **小槻峻司**, **荒木田葉月**, **三好建正**, 田中賢治, "水資源・作物結合モデルの開発とデータ同化への展望", 日本農業気象学会　2015 年全国大会, つくば, 2015 年 3 月 16-19 日.
77. **Arakida, H.**, **T. Miyoshi**, T. Ise, S. Shima, "Data assimilation experiments with simulated LAI observations and the dynamic global vegetation model SEIB-DGVM", Annual Meetings of Ecological Society of Japan, Kagoshima, 18th-22th March 2015.

(5) Patents and Deliverables

The LETKF code is updated as needed and available at https://code.google.com/p/miyoshi/.

(6) Awards

1. 三好建正：科学技術分野の文部科学大臣表彰　若手科学者賞、2014 年 4 月 15 日「地球環境シミュレーションにおけるデータ同化の研究」（The Young Scientists' Prize, The Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology）
2. 芳村圭，三好建正，金光正郎：土木学会水工学委員会　水工学論文賞、2014 年 3 月 4 日「アンサンブルカルマンフィルタを用いた水同位体比データ同化に向けた理想化実験」（Hydraulic Engineering Paper Award, Committee on Hydroscience and Hydraulic Engineering, Japan Society of Civil Engineers）