12/20/2017 JST・NSF国際連携シンポジウム, 品川

“Big Data Assimilation”

Revolutionizing Weather Prediction

「ビッグデータ同化」による天気予報革命

Takemasa Miyoshi
三好　建正

Ph.D. (Meteorology)
Data Assimilation Scientist

Data Assimilation Research Team

RIKEN Advanced Institute for Computational Science

理化学研究所　計算科学研究機構　データ同化研究チーム

Who am I?

http://data-assimilation.riken.jp/~miyoshi/

Takemasa Miyoshi, Ph.D.
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RIKEN Advanced Institute for Computational Science

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University of Maryland, College Park

Visiting Principal Scientist
Application Laboratory, JAMSTEC

Research Counselor
Servicio Meteorológico Nacional (National Meteorological Service), Argentina

B.S. from Kyoto U
↓ 京都大学理学部卒
JMA administration (2y)
気象庁　企画課 ↓
JMA NWP (1y+3mo)
数値予報課 ↓
UMD (2y, M.S. and Ph.D.)
メリーランド大学 ↓
JMA NWP (3y+6mo)
↓
UMD (4y)
↓
RIKEN (5y)
理化学研究所

Education

- **2005** Ph.D. in Meteorology, University of Maryland, College Park, Maryland, USA (Dissertation PDF)
- **2004** M.S. in Meteorology, University of Maryland, College Park, Maryland, USA (Scholarly Paper PDF)
- **2000** B.S. in Physics, Faculty of Science, Kyoto University, Kyoto, Japan

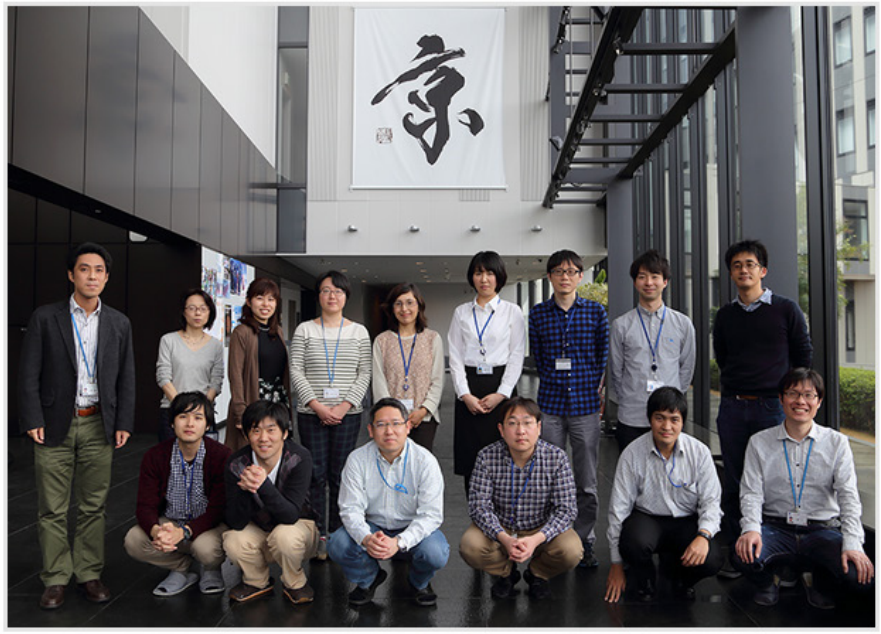
http://tedxsannomiya.com/en/speakers/takemasa-miyoshi/

Data Assimilation Research Team　データ同化研究チーム

Data Assimilation Research Team was launched in October, 2012, in RIKEN Advanced Institute for Computational Science (AICS), conveniently located in the beautiful and historic city of Kobe. RIKEN is known as the flagship research institution in Japan. AICS is operating the world's leading K computer, and also has a strong Research Division. AICS takes the lead in advancing the computational science and aims to be an international center of excellence for computational science in collaboration with a wide range of research organizations. AICS integrates the computer science and computational science to conduct most advanced research and development of a wide range of applied scientific computation, as well as of high performance computing technologies.

Data assimilation is a cross-disciplinary science to synergize numerical simulations and observational 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 simulation with actual observations.

Data Assimilation Research Team ("DA team") performs cutting-edge research and development on advanced data assimilation methods and their wide applications, aiming at integrating computer simulations and observational data in the wisest way. Particularly, the DA team will tackle challenging problems of developing efficient and accurate data assimilation systems for high-dimensional simulations with large amount of data. The specific areas include 1) research on parallel-efficient algorithms for data assimilation with the super-parallel K computer, 2) research on data assimilation methods and applications by taking advantage of the world-leading K computer, and 3) development of most advanced data assimilation software optimized for the K computer.



April 1, 2016 at AICS, RIKEN

RIKEN AICS

Data Assimilation Team

http://www.data-assimilation.riken.jp/

チームリーダー	研究員	研究員	特別研究員	特別研究員
				
三好建正 （みよしたけまさ）	寺崎康児 （てらさきこうじ）	大塚成徳 （おおつかしげのり）	近藤圭一 （こんどうけいいち）	小槻峻司 （こつきしゅんじ）

特別研究員	特別研究員	特別研究員	特別研究員	特別研究員
				
Guo-Yuan Lien （グオユエンリエン）	本田匠 （ほんだたくみ）	岡崎淳史 （おかざきあつし）	寺村俊紀 （てらむらとしき）	高玉孝平 （たかたまこうへい）

リサーチアソシエイト	テクニカルスタッフ	テクニカルスタッフ	テクニカルスタッフ	テクニカルスタッフ
				
前島康光 （まえじまやすみつ）	荒木田葉月 （あらきだはづき）	粟津妙華 （あわづたえか）	坂本英之 （さかもとひでゆき）	大東真利茂 （おおひがしまりも）

Data Assimilation (DA) データ同化

Data assimilation best combines observations and a model, and brings synergy.

データ同化は、シミュレーションと現実世界を結び、相乗効果を生む

Data Assimilation (DA) データ同化

観測
Observations

シミュレーション
Simulations

Data Assimilation

1 + 1

>2

Data Assimilation (DA) データ同化

Data-driven

Process-driven

Observations

Simulations

Data Assimilation

1 **+** **1**

>2

RIKEN Advanced Institute for Computational Science (AICS)
理化学研究所　計算科学研究機構（AICS）

Japan's flagship institute for computational science

Missions:

1) Development & operation of the Japanese flagship supercomputer
わが国のフラッグシップスーパーコンピュータの開発と運用

2) Center of Excellence for research on computational science
わが国の計算科学研究のフラッグシップ拠点

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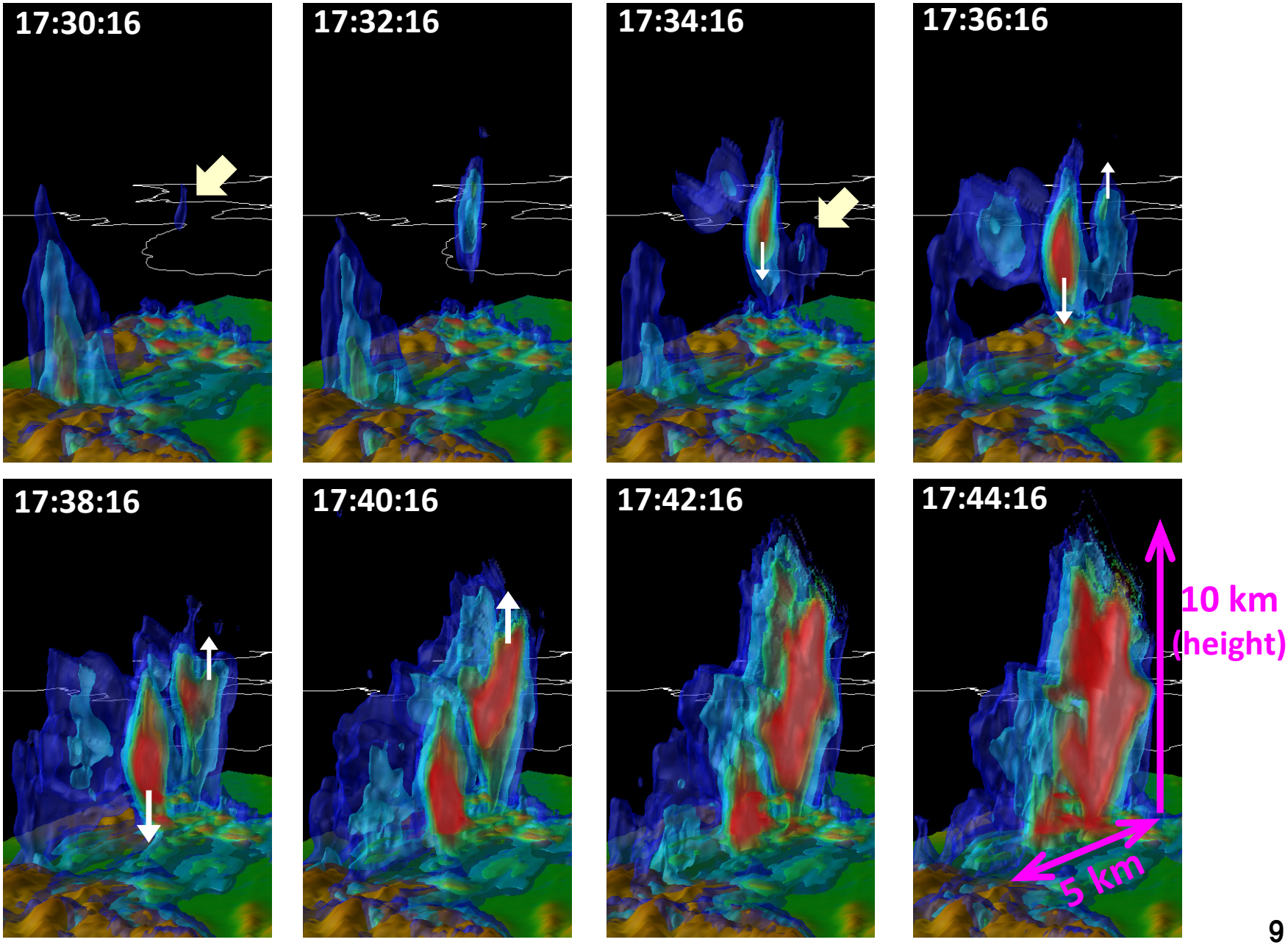
わが国の計算科学研究のフラッグシップ拠点

"Post-K" is planned on 2021
"FLAGSHIP2020 project"

Only in 10 minutes!!

(Courtesy of NICT)



“Big Data Assimilation” Revolutionizing Severe Weather Prediction

by

Takemasa Miyoshi, M. Kunii, J. Ruiz, G.-Y. Lien, S. Satoh,
T. Ushio, K. Bessho, H. Seko, H. Tomita, and Y. Ishikawa

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国立研究開発法人
科学技術振興機構
Japan Science and Technology Agency
CREST

"Big Data Assimilation" Revolutionizing Severe Weather Prediction

BY TAKEMASA MIYOSHI, MASARU KUNII, JUAN RUIZ, GUO-YUAN LIEN, SHINSUKE SATOH, TOMOO USHIO, KOTARO BESSHO, HIROMU SEKO, HIROFUMI TOMITA, AND YUTAKA ISHIKAWA

Data assimilation (DA) integrates computer simulations and real-world observations based on statistical mathematics and dynamical systems theory, and plays a central role in numerical weather prediction (NWP). As computing and sensing technologies advance, DA will deal with "big simulations" and "big data." Here we focus on rapidly changing convective weather and explore a future direction of two orders of magnitude more rapid weather forecasting by innovating what we call "big data assimilation" (BDA) technology. Tremendous efforts have been devoted to convective-scale NWP and radar DA, including the U.S. effort on the "Warn-on-Forecast" project (Stensrud et al. 2009; 2013), which has been pioneering rapidly updated NWP to be used for warnings about convective-scale hazards. Sun et al. (2014) provided a comprehensive review on this subject with a rich body of literature. Extending a wealth of previous studies, this article presents the concept of BDA research and the first proof-of-concept results of a real high-impact weather case, exploring 30-min forecasts at 100-m grid spacing refreshed every 30 s—120 times more rapidly than hourly updated systems. This revolutionary NWP is only possible by taking advantage of the fortunate combination of Japan's most advanced technological developments: the 10-petaflops (floating-point operations per second) "K computer" and Phased Array Weather Radar (PAWR; Ushio et al. 2014; Yoshikawa et al. 2013). The science and analytics of big data, typically characterized by four "big V's" (volume, variety, velocity, and veracity), are growing rapidly, and BDA is one of the first two projects awarded by the Japanese government strategic funding program started in 2013 on general big data applications.[1]

In contemporary weather forecasting, radar observations and NWP play an essential role in real-time monitoring and short-term prediction of severe weather. The widely used parabolic-antenna radar observes rain intensity along a curvilinear beam track. The radar is rotated, and changes the azimuth and elevation angles to capture the whole sky typically in 5 min for 15 elevation angles. Also, typical convective-scale NWP updates forecasts every hour for the next $O(10)$ hours at $O(1)$-km grid spacing. However, convective weather systems evolve quickly in 5 min and undertake a nonlinear evolution. The current NWP systems that could possibly use all 5-min radar data at the highest frequency may still be far from sufficient to precisely represent individual convective activities.

Here we explore what the highest-end, next-generation supercomputing and sensing technologies can do at their full capacity, pioneering the future of weather forecasting for the next 10 years. The cutting-edge PAWR implemented in Osaka, Japan, in

[1] The other project is on pharmaceutical science, focusing on drug discovery and production.

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Miyoshi et al. (2016)
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The flagship journal of the American Meteorological Society

「京」と最新鋭気象レーダを生かしたゲリラ豪雨予測
ー「ビッグデータ同化」を実現、天気予報革命へー

Press Release

Previous Index Next

August 9, 2016

K computer and high-tech weather radar come together to predict sudden torrential rains

Today, supercomputer-based weather predictions are typically done with simulations that use grids spaced at least one kilometer apart, and incorporate new observational data every hour. However, due to the roughness of the calculations, these simulations cannot accurately predict the threat of torrential rains, which can develop within minutes when cumulonimbus clouds suddenly develop. Now, an international team led by Takemasa Miyoshi of the RIKEN Advanced Center for Computational Science (AICS) has used the powerful K computer and advanced radar observational data to accurately predict the occurrence of torrential rains in localized areas.

The key to the current work, to be published later this month in the August issue of the *Bulletin of the American Meteorological Society*, is "big data assimilation" using computational power to synchronize data between large-scale computer simulations and observational data.

Using the K computer, the researchers carried out 100 parallel simulations of a convective weather system, using the nonhydrostatic mesoscale model used by the Japan Meteorological Agency, but with 100-meter grid spacing rather than the typical 2-kilometer or 5-kilometer spacing, and assimilated data from a next-generation phased array

News & Media
Press Center
Press Releases
2016
2015
2014
2013
2012
2011
2010
2009
2008
2007
2006
2005
News
Events & Symposiums

Proceedings of the IEEE *(Miyoshi et al., 2016)*

November 2016

"Big Data Assimilation" Toward Post-Petascale Severe Weather Prediction: An Overview and Progress

This article summarizes the activities and progress of the big data assimilation project for severe weather prediction and concludes with perspectives toward the post-petascale supercomputing era.

By Takemasa Miyoshi, Guo-Yuan Lien, Shinsuke Satoh, Tomoo Ushio, Kotaro Bessho, Hirofumi Tomita, Seiya Nishizawa, Ryuji Yoshida, Sachiho A. Adachi, Jianwei Liao, Balazs Gerofi, Yutaka Ishikawa, Masaru Kunii, Juan Ruiz, Yasumitsu Maejima, Shigenori Otsuka, Michiko Otsuka, Kozo Okamoto, and Hiromu Seko

ABSTRACT | Following the invention of the telegraph, electronic computer, and remote sensing, "big data" is bringing another revolution to weather prediction. As sensor and computer technologies advance, orders of magnitude bigger data are produced by new sensors and high-precision computer simulation or "big simulation." Data assimilation (DA) is a key to numerical weather prediction (NWP) by integrating the real-world sensor data into simulation. However, the current DA and NWP systems are not designed to handle the "big data" from next-generation sensors and big simulation. Therefore, we propose "big data assimilation" (BDA) innovation to fully utilize the big data. Since October 2013, the Japan's BDA project has been exploring revolutionary NWP at 100-m mesh refreshed every 30 s, orders of magnitude finer and faster than the current typical NWP systems, by taking advantage of the fortunate combination of next-generation technologies: the 10-petaflops K computer, phased array weather radar, and geostationary satellite Himawari-8. So far, a BDA prototype system was developed and tested with real-world retrospective local rainstorm cases. This paper summarizes the activities and progress of the BDA project, and concludes with perspectives toward the post-petascale supercomputing era.

KEYWORDS | Atmospheric measurements; computer applications; Kalman filtering; optimal control; phased array radar; remote sensing; simulation; supercomputers; weather forecasting

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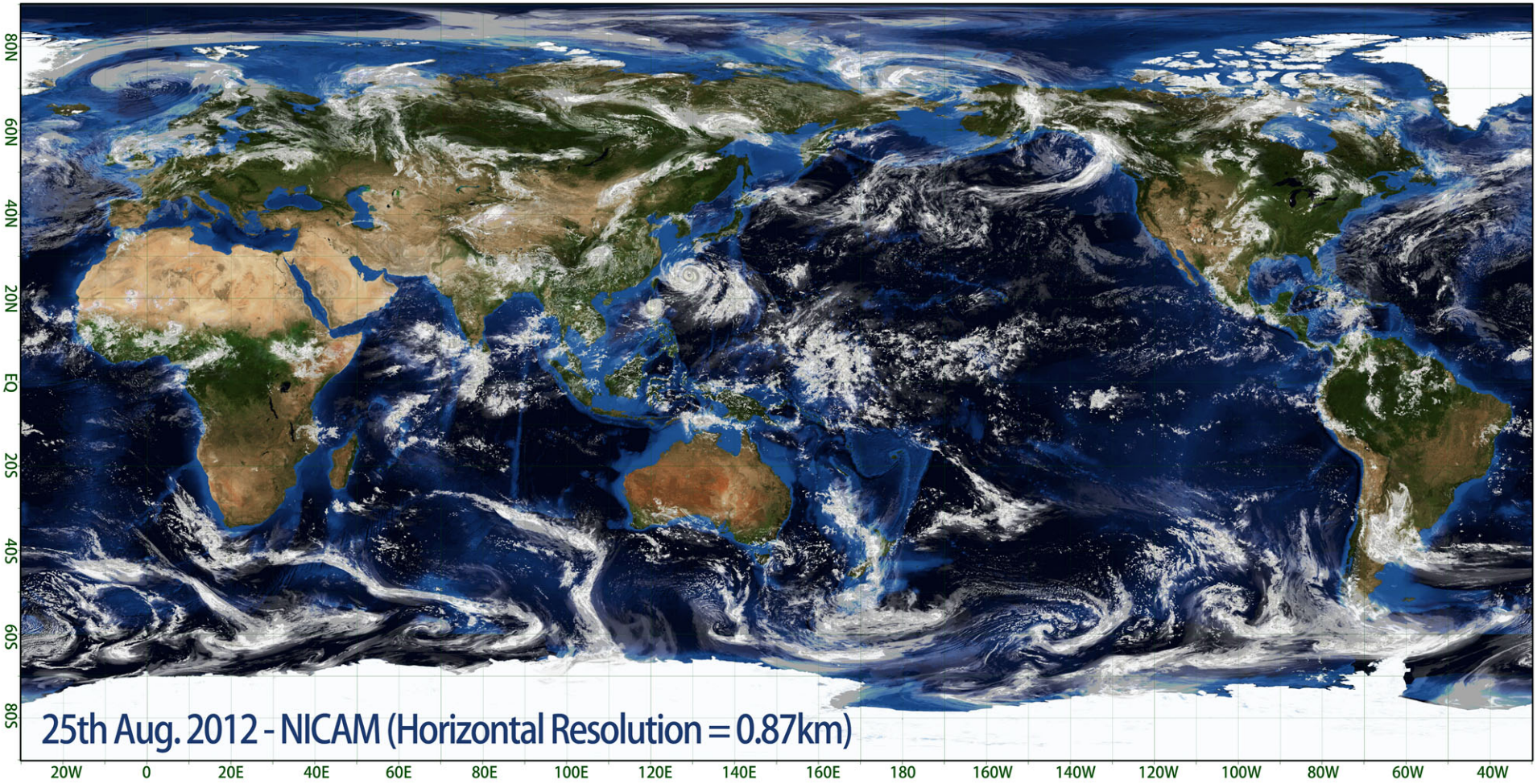
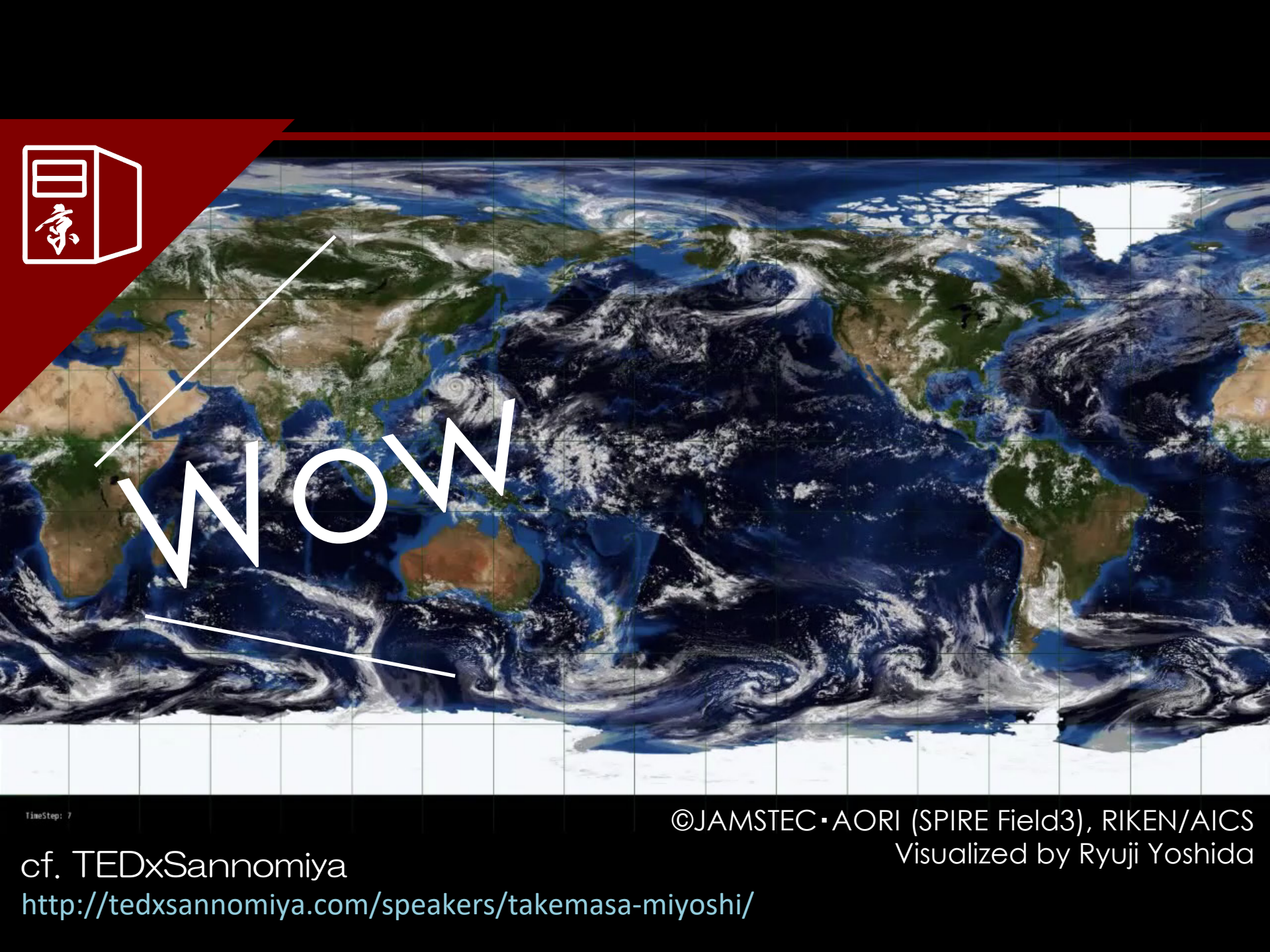
Global 870-m simulation (*Miyamoto et al. 2013*)



Visualized by Ryuji Yoshida



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cf. TEDxSannomiya
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京
K computer
京
K computer
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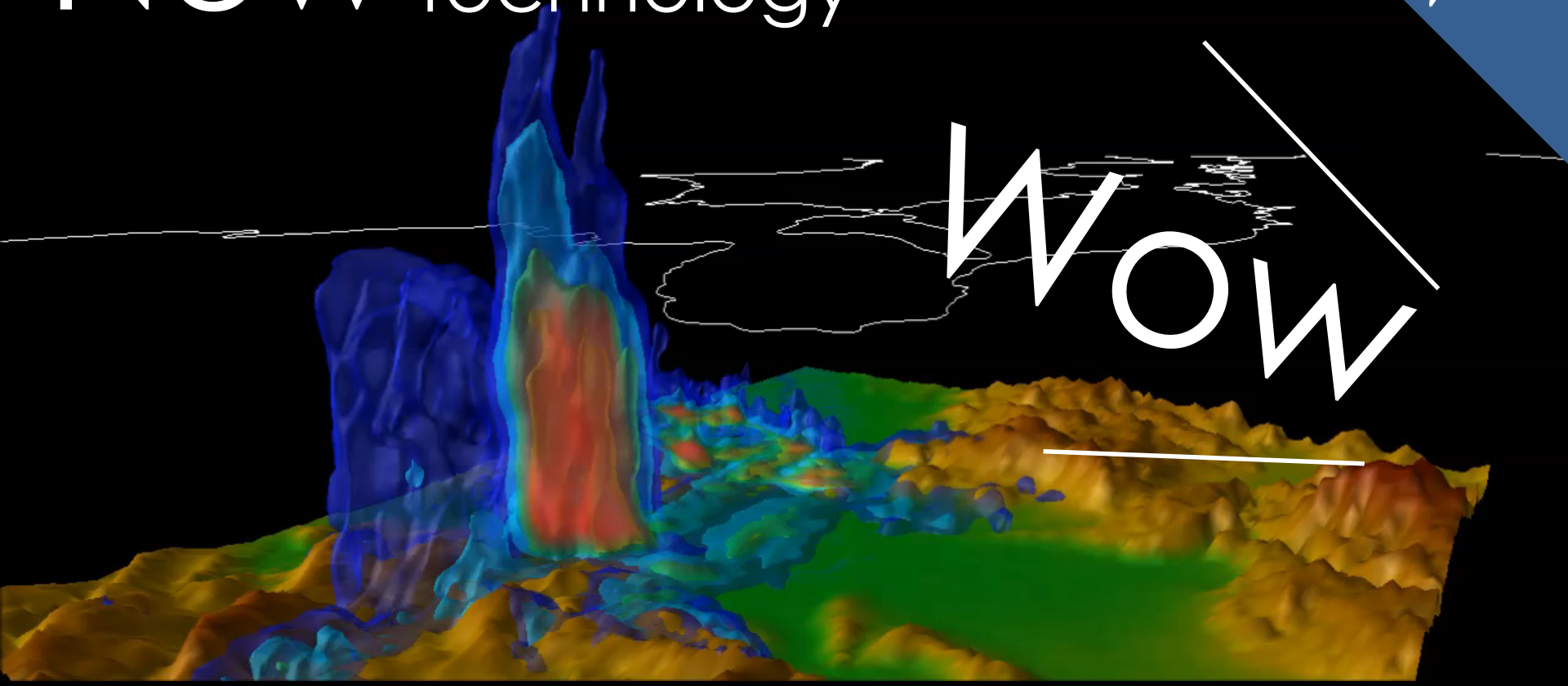
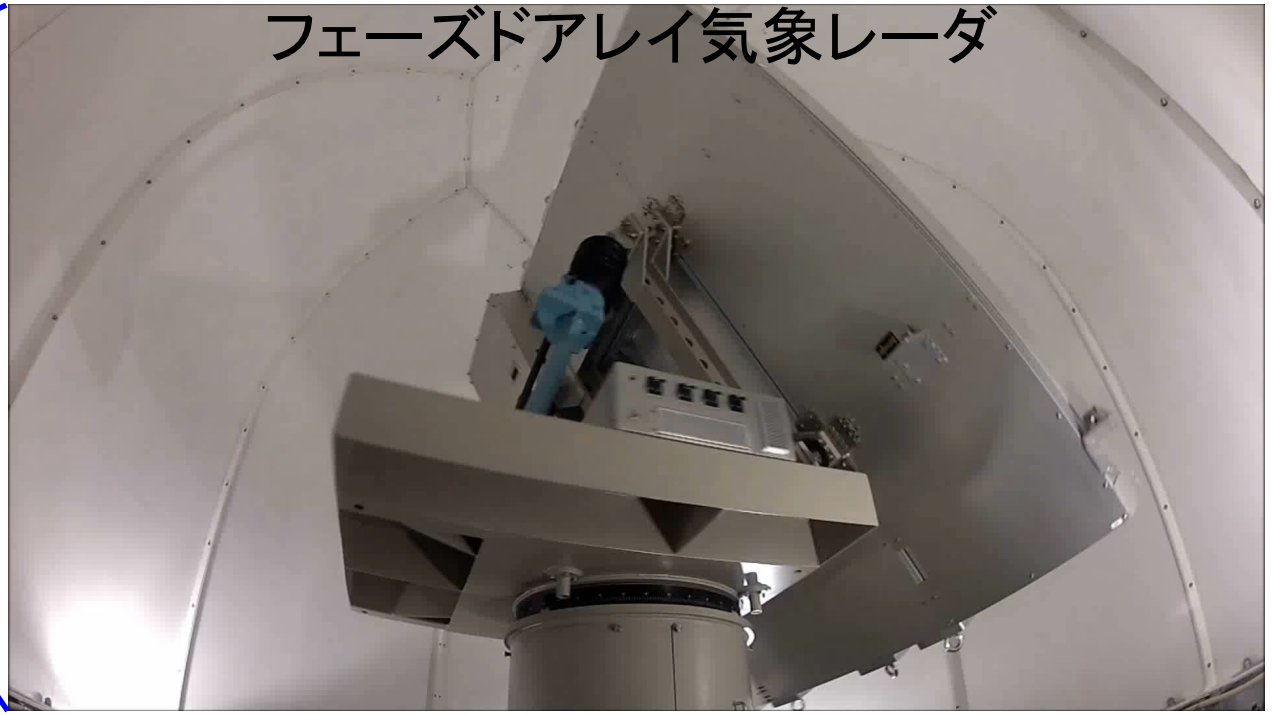
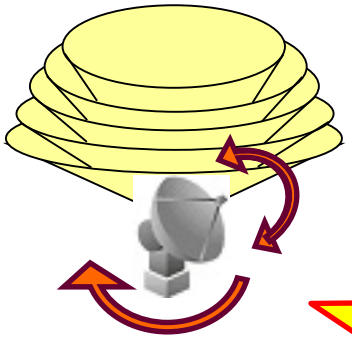
New radar technology



Wow

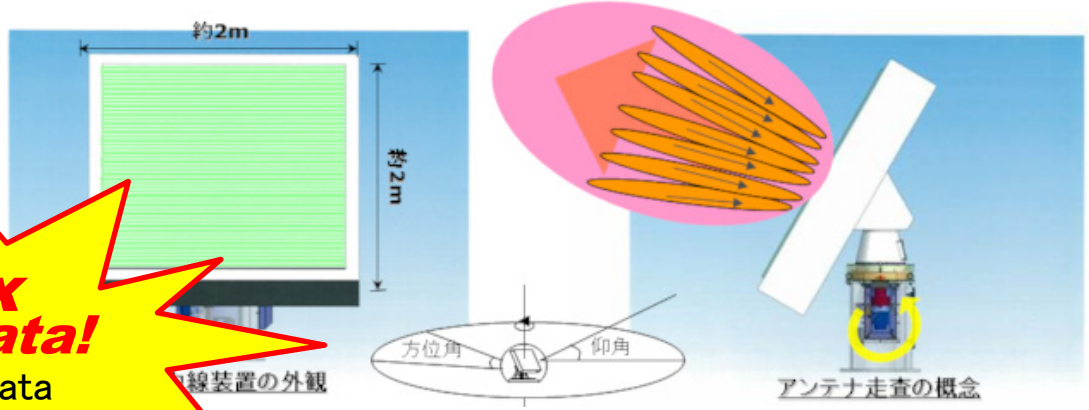
Phased Array Weather Radar (PAWR)





3-dim measurement using
a parabolic antenna (150 m,
15 EL angles in 5 min)

100x more data!
10x more data
in a 1/10 period

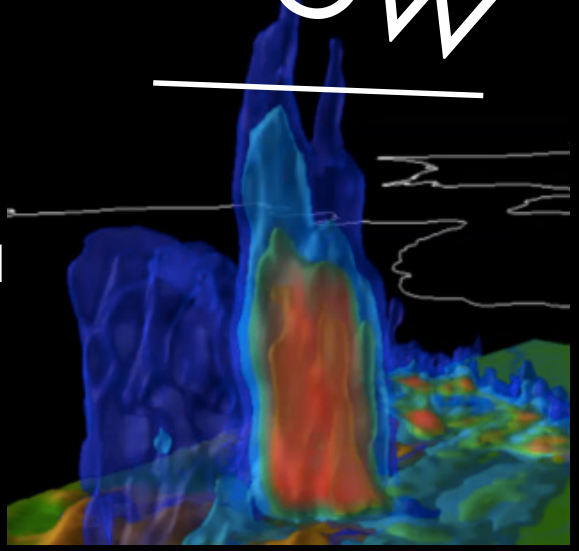


3-dim measurement using a phased array antenna
(100 m, 100 EL angles in 30 sec)

Wow

+

Wow



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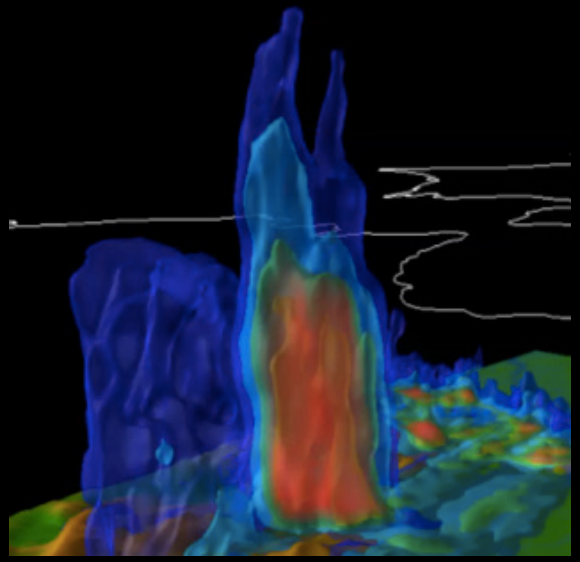


= ~~Sudden~~ heavy rain

~~ゲリラ~~豪雨

Sources of Big Data

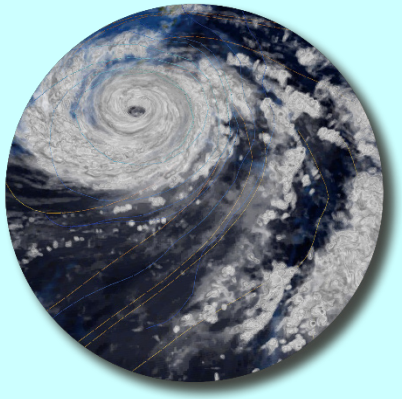
ビッグデータの源

観測
Observations

Big Data

Advanced obs technology

シミュレーション
Simulations



Big Data

Powerful supercomputer

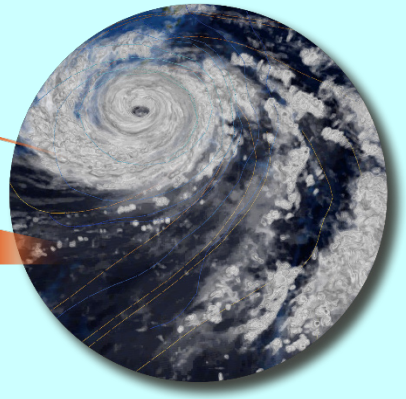
Big Data Assimilation

ビッグデータ同化

観測
Observations

シミュレーション
Simulations

Data Assimilation



Big Data

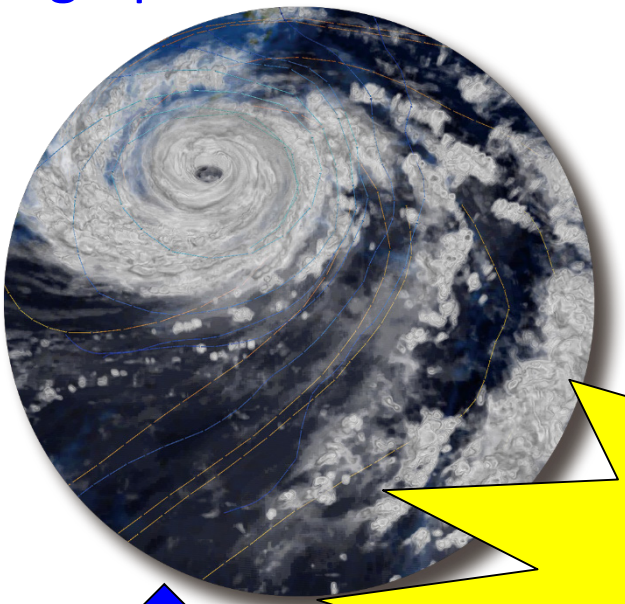
Advanced obs technology

Big Data

Powerful supercomputer

Pioneering “Big Data Assimilation” Era

High-precision Simulations

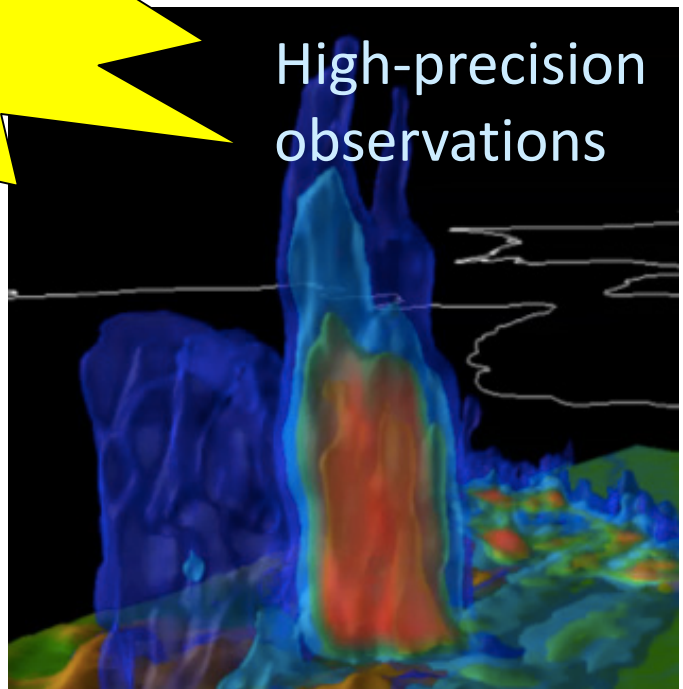


国立研究開発法人 科学技術振興機構 Japan Science and Technology Agency CREST

Future-generation technologies available 10 years in advance

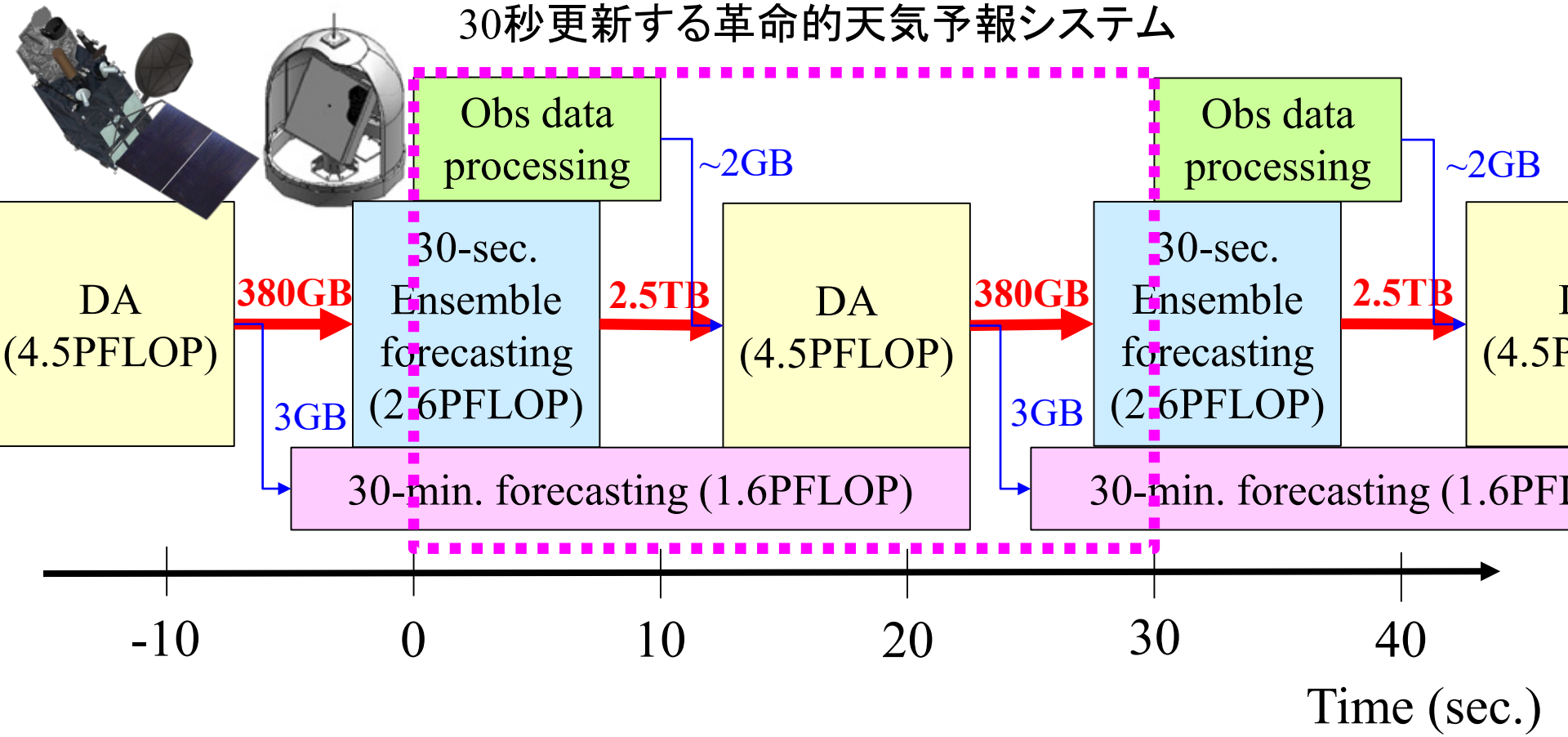
BDA BIG DATA ASSIMILATION

High-precision observations



Mutual feedback

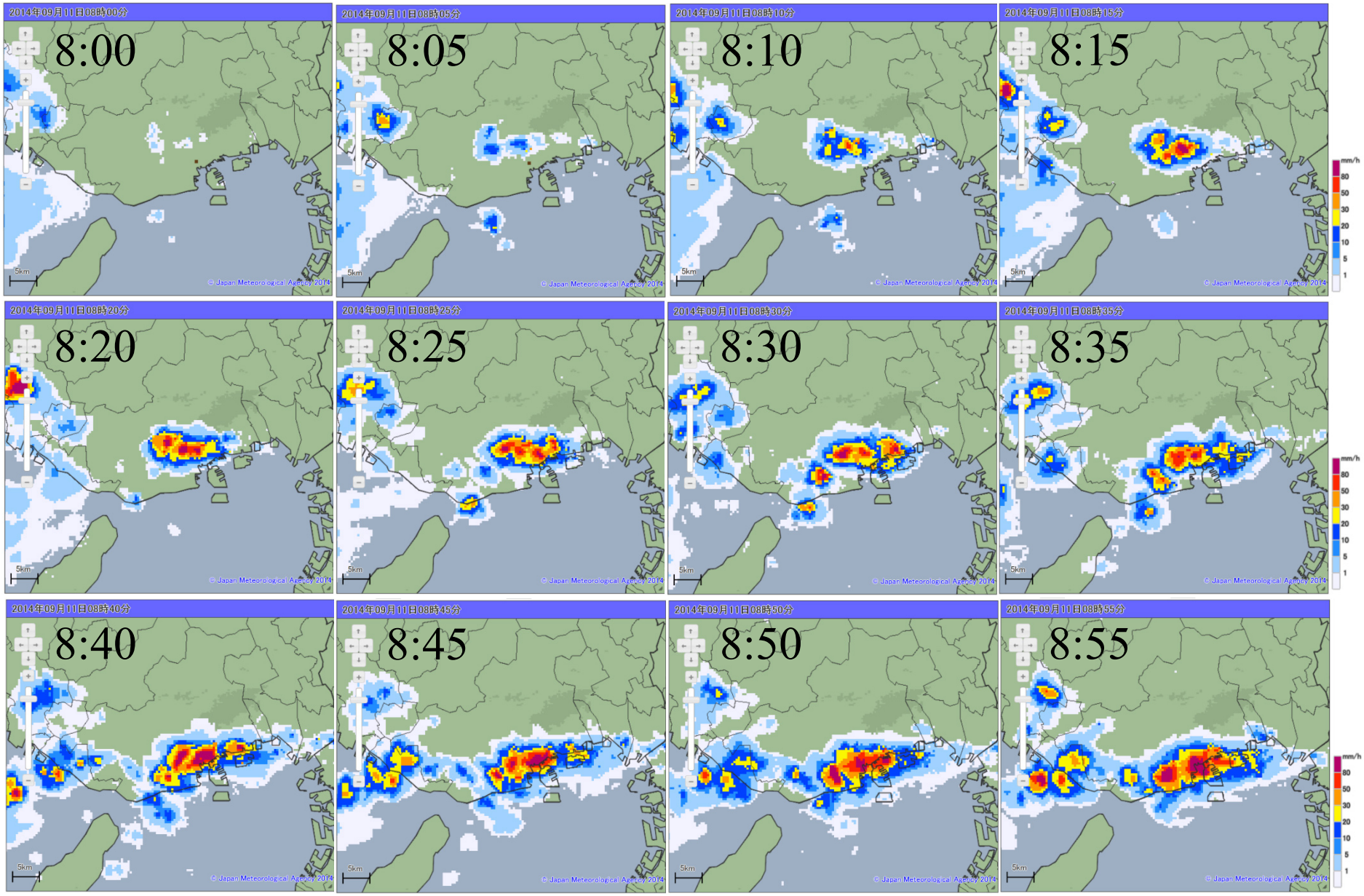
Revolutionary super-rapid 30-sec. cycle



120 times more rapid than hourly update cycles

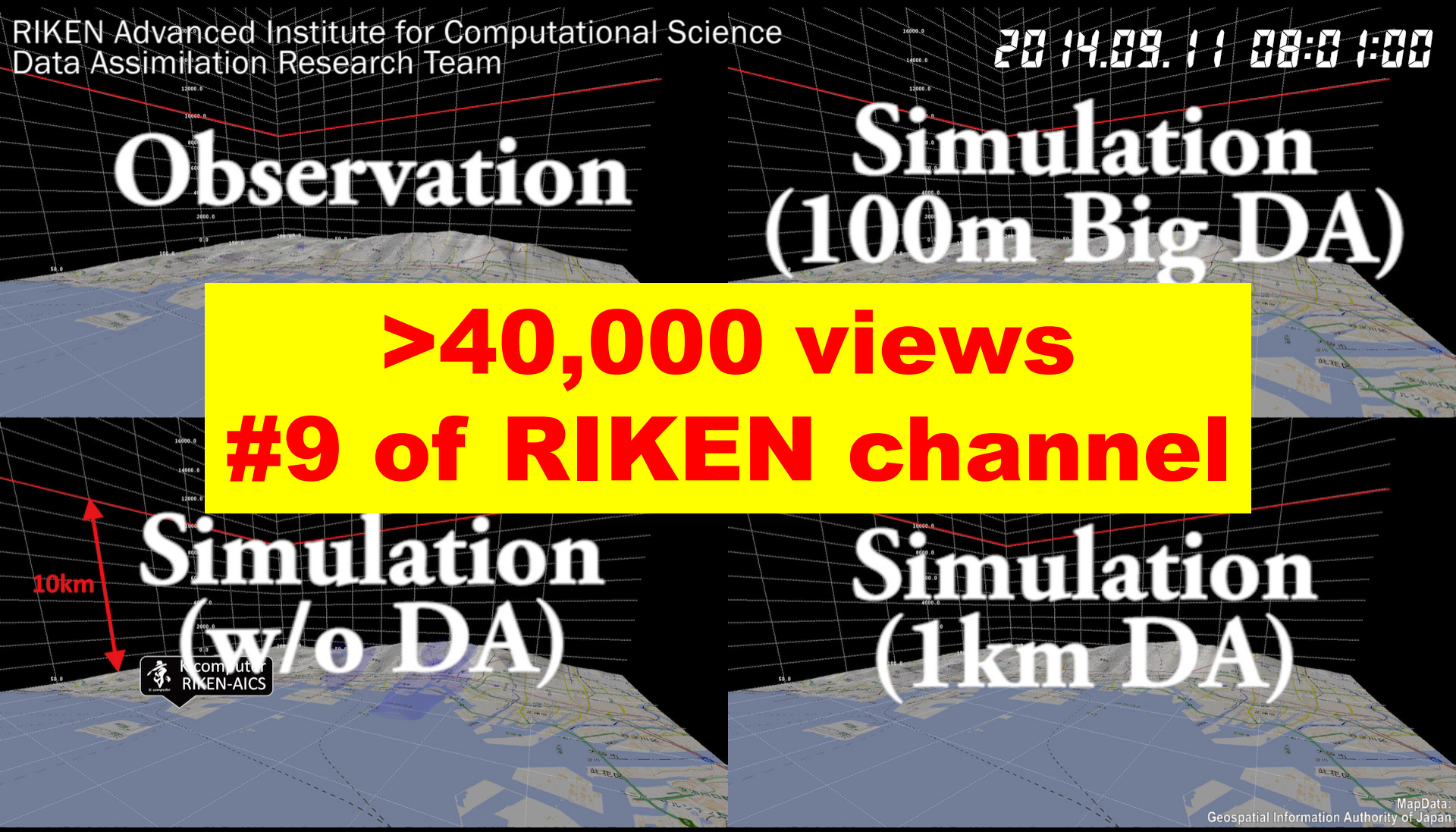
毎時更新より120倍高速

9/11/2014 morning, sudden rain

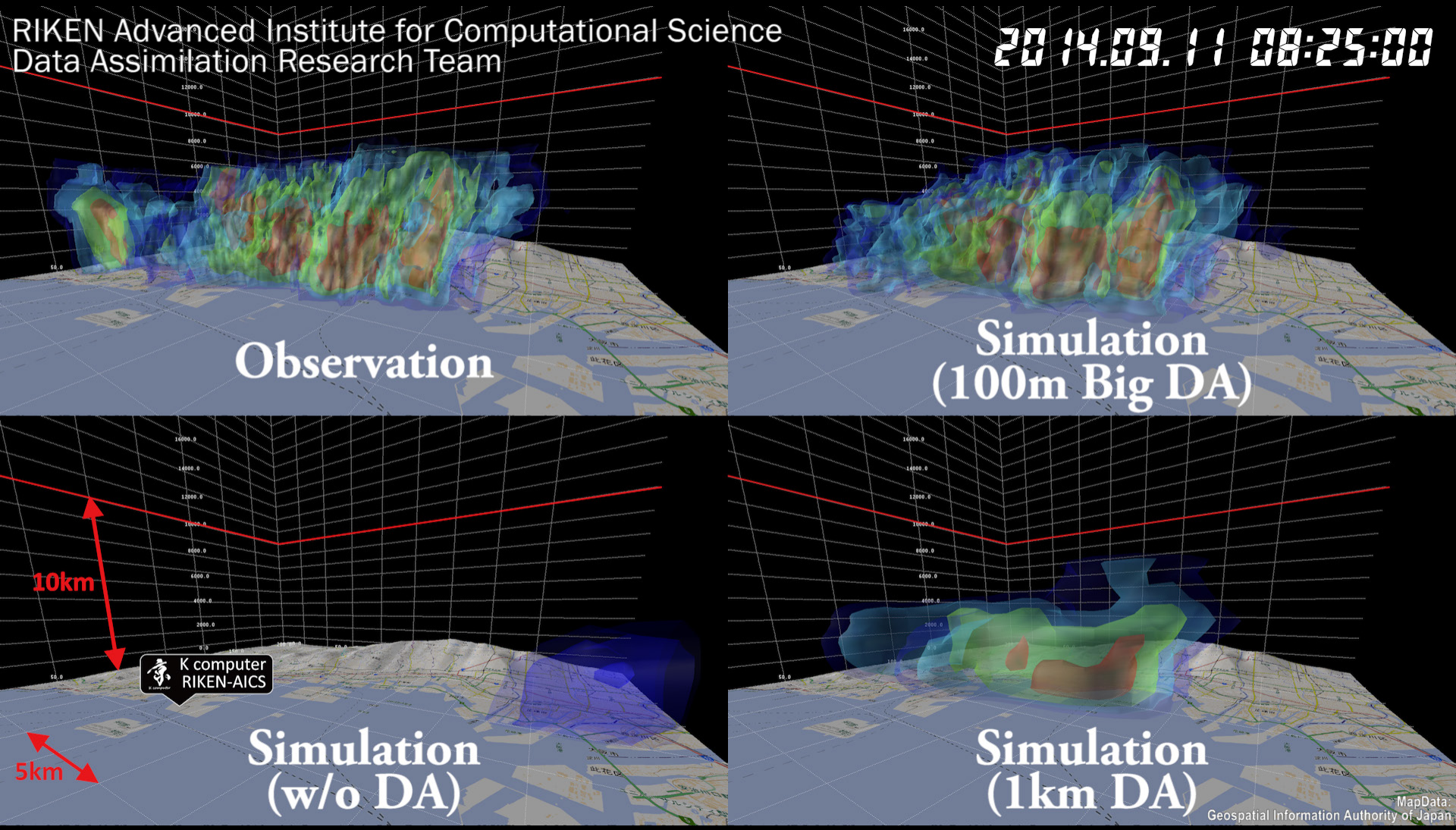


9/11/2014, sudden local rain

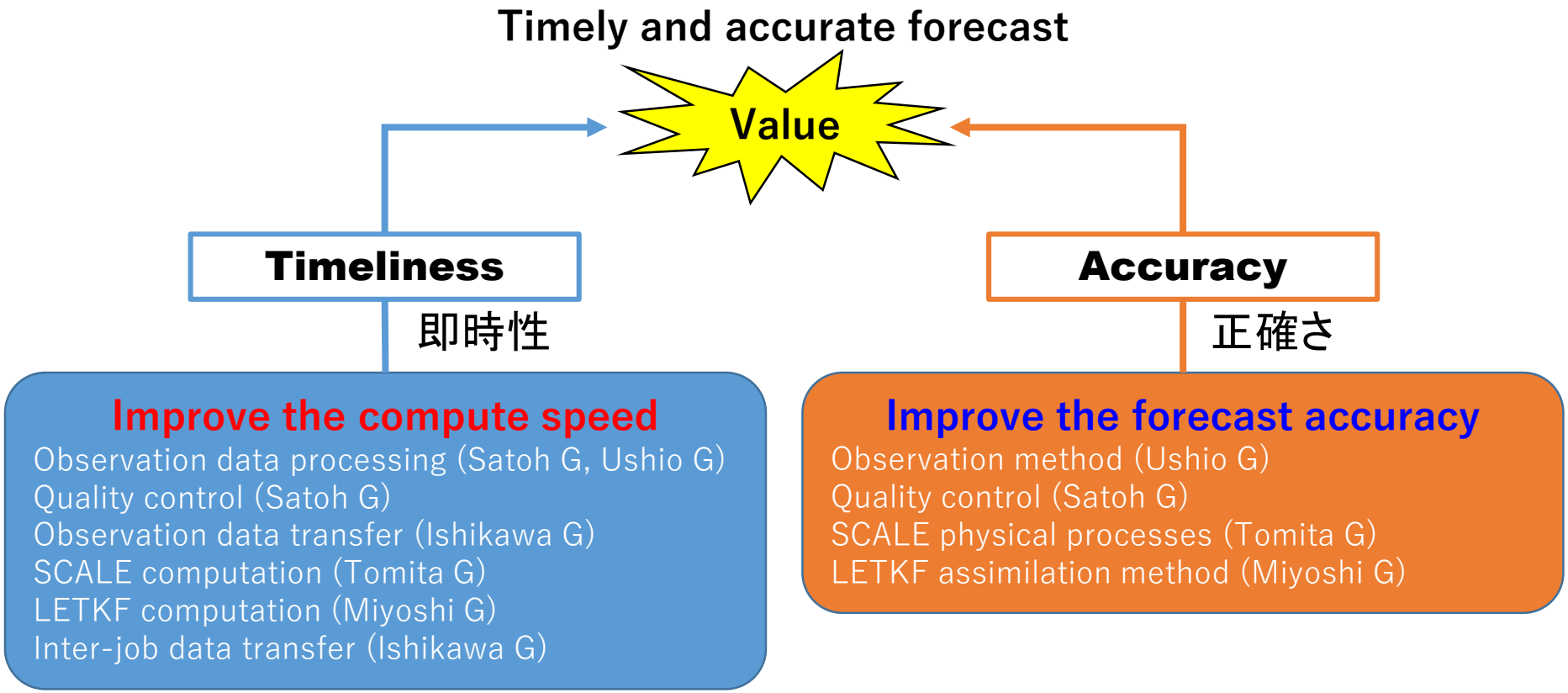
9/11/2014, sudden local rain



9/11/2014, sudden local rain



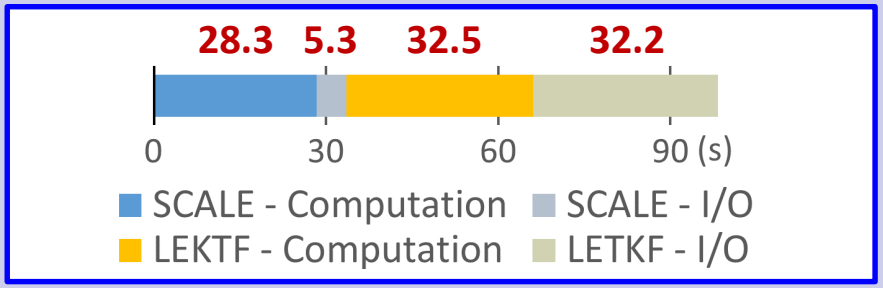
Future directions



Compute time (73440 nodes of K computer)

ensemble forecasts + data assimilation

Original proposal: 100-m mesh, 100 ensemble members, every 30 seconds



measured

total 98.3 sec. (without init+final)

~4x acceleration needed!

現状として98.3秒かかる。4倍程度の高速化が必要

will keep working on acceleration

REAL-TIME 30-second-update nowcasting

リアルタイムで動く30秒更新のナウキャスト

~1min.

Quality control

JIT-DT 61MB

Quality control

JIT-DT 61MB

conv. & tion ctor

10-min. nowcasting

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Data conv. & Motion vector

10-min. nowcasting

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210MB

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Time (sec.)

Working continuously in

REAL-TIME

REAL-TIME 30-second-update nowcasting

リアルタイムで動く30秒更新のナウキャスト

~1min.

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Quality control

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Quality control

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Visualization & Dissemination

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-10 0 10 20 30 40

Time (sec.)

Working continuously in

REAL-TIME

30秒更新10分後までの超高速降水予報を開始
－最新鋭気象レーダを活用したリアルタイム実証－

Press Release

Previous Index Next

July 4, 2017

New system promises more rapid and accurate prediction of rainfall

Using a powerful technique known as "3D nowcasting," an international team including scientists from the RIKEN Advanced Institute for Computational Science (AICS) has begun to provide, on an experimental basis, forecasts that predict the likelihood of precipitation in a given location ten minutes in advance. The group will use the system to determine if the experimental forecasts, based on data that is updated every 30 seconds, could be used to prevent damage from torrential rains. The work, conducted by a team including researchers from AICS as well as the National Institute of Information and Communications Technology (NICT), Tokyo Metropolitan University, and Osaka University, uses a combination of phased-array radar and computer algorithms that make predictions based on data from the radars.

Today, nowcasting—a term that refers to short-term weather forecasts made in real-time—is generally done using parabolic radar antennas, which take five to ten minutes to scan about 15 layers of the entire sky. Typically, it is done by looking at a single layer of the sky, detecting the rain there, and then extrapolating from weather conditions where the rain will be falling at a later time. However, though nowcasting requires much less computing power than weather simulations, it is not able to accurately predict rainfall from rapidly developing thunderclouds, where there are rapid vertical movements in the rain patterns.

Recently, however, a novel type of system, called a phased-array radar, was installed on the Suita Campus of Osaka

News & Media
Press Center
Press Releases
2017
2016
2015
2014
2013
2012
2011
2010
2009
2008
2007
2006
2005
News
Events & Symposiums

RIKEN real-time weather forecast

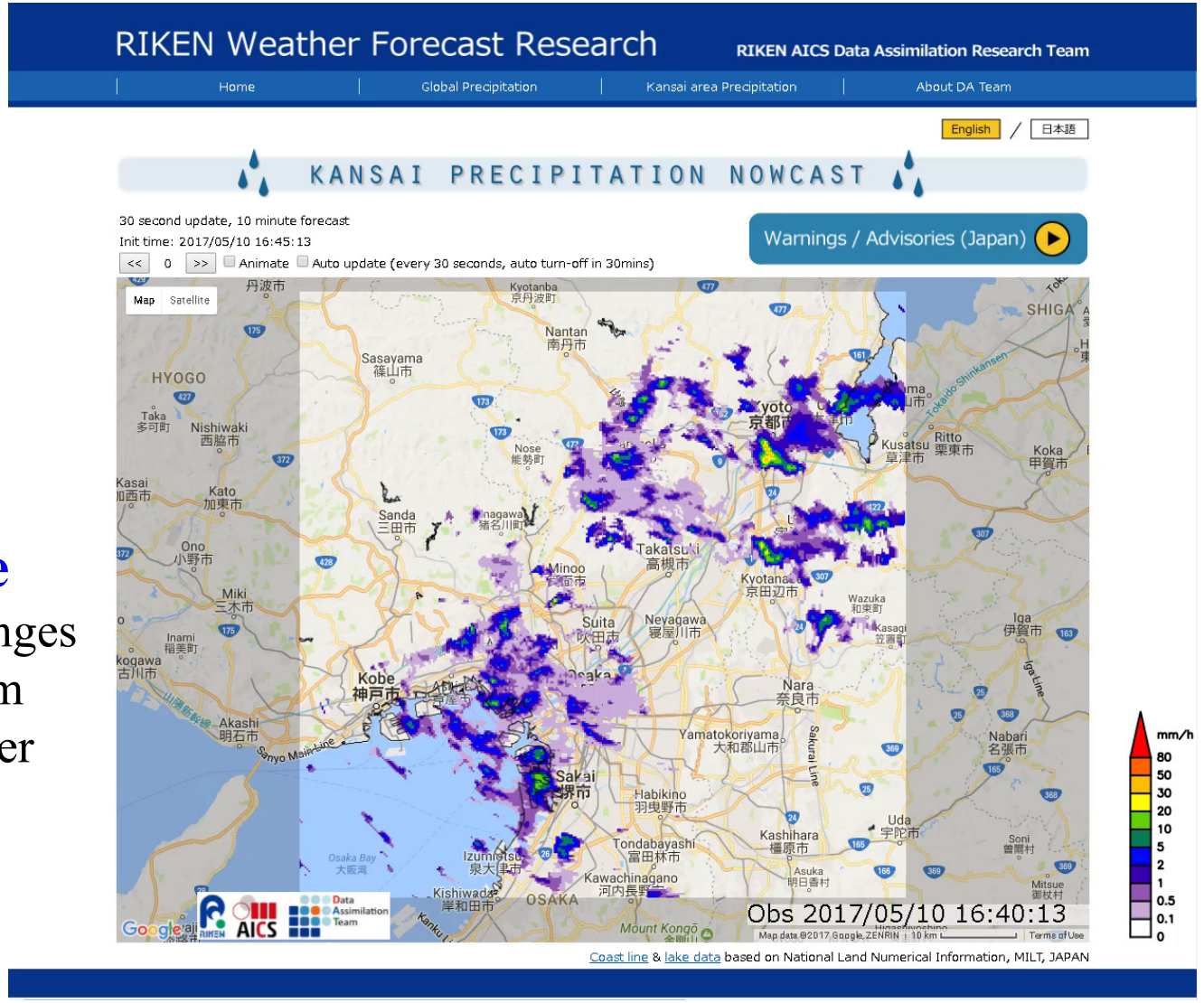
➔**http://weather.riken.jp**

30-second update nowcasting for 10 minutes started on July 3, 2017.

- JMA forecast license was issued.

Science → Service

- Engineering challenges
- Prediction algorithm
- Best use of computer



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プレスリリース・ニュースリリース配信サービスのPR TIMES

ゲリラ豪雨検知アプリ『3D雨雲ウォッチ』実証実験を関東エリアへ拡大！

～隅田川花火大会の公認アプリとして、当日の天気や安全な大会運営をサポート～

株式会社エムティーアイ

2017年7月27日 12時11分

4 いいね！ シェア | ツイート | B! 0 はてな | 画像DL | ・・・ その他

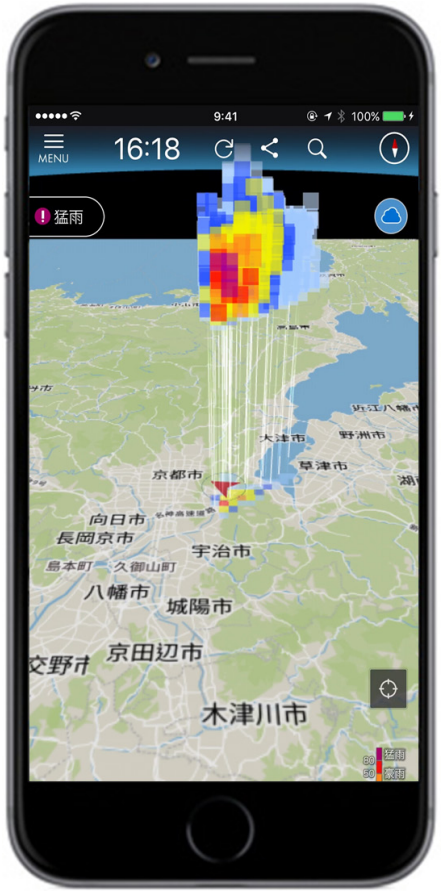
（株）エムティーアイが運営する天気総合情報サイト『ライフレンジャー』は昨年に続き、国立研究開発法人情報通信研究機構との共同研究により開発した、ゲリラ豪雨検知アプリ 『3D雨雲ウォッチ～フェーズドアレイレーダ～』の実証実験を、7月27日（木）より開始します。

今年で3年目となる実証実験では、3月より行っている国立研究開発法人理化学研究所（以下、理研）との共同研究で得られた予測データを用いて、ゲリラ豪雨のお知らせから避難までの時間を伸ばす試みを行います。さらに日本無線（株）からのデータ提供により、対象地域を関東にも拡大しアプリの利用人数を増やすことで、より多くの意見やデータを収集しサービスの有用性の検証と質の向上を図ります。

また今回アプリを活用した新たな取り組みとして、「第40回 隅田川花火大会」の公認アプリとして当日の天気や運営のサポートを行います。

◆理研との共同研究による予測データを用いてゲリラ豪雨の発生を10分前に通知！

本アプリは、最先端の気象レーダ「フェーズドアレイレーダ」のデータを用いてゲリラ豪雨の発生をリアルタイムでお知らせするサービスです。今まで察知が難しかったゲリラ豪雨が発生する可能性を、瞬時にスマートフォンのプッシュ通知で受け取れます。



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～隅田川花火大会の[illegible]アプリとして、当日[illegible]安全な[illegible]ポート～

株式会社エムティーアイ [illegible]時11分

4 いいね！ シェア ツイート はてな

>100,000 downloads!

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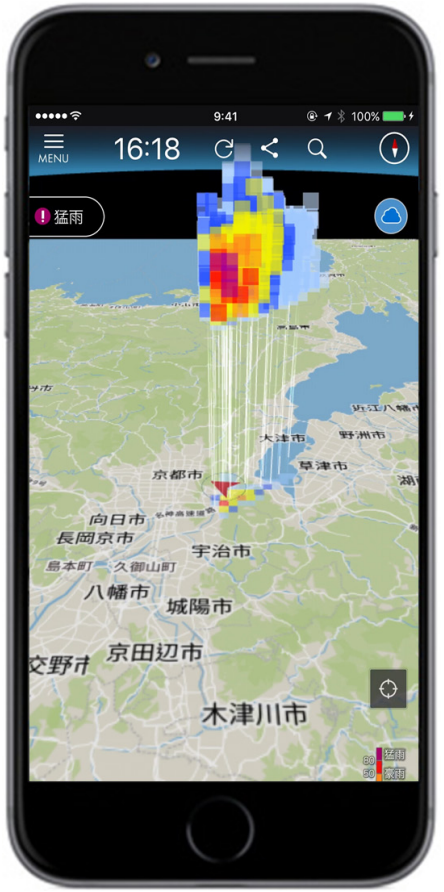
また今回[illegible]を[illegible]サポートを行います。

Making societal impact



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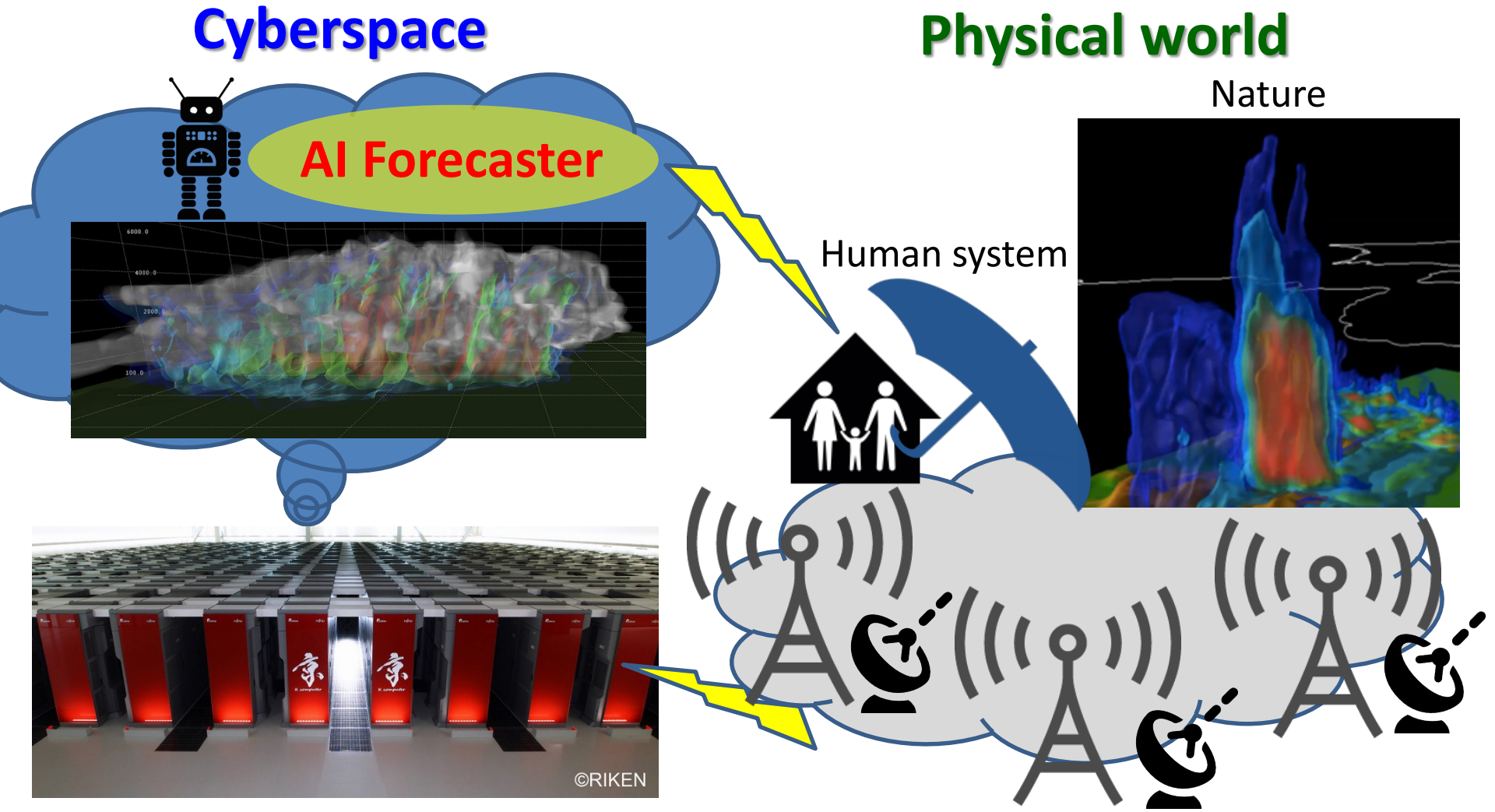
Cyber-Physical fusion for weather prediction

サイバーフィジカル融合

Data Assimilation is the key

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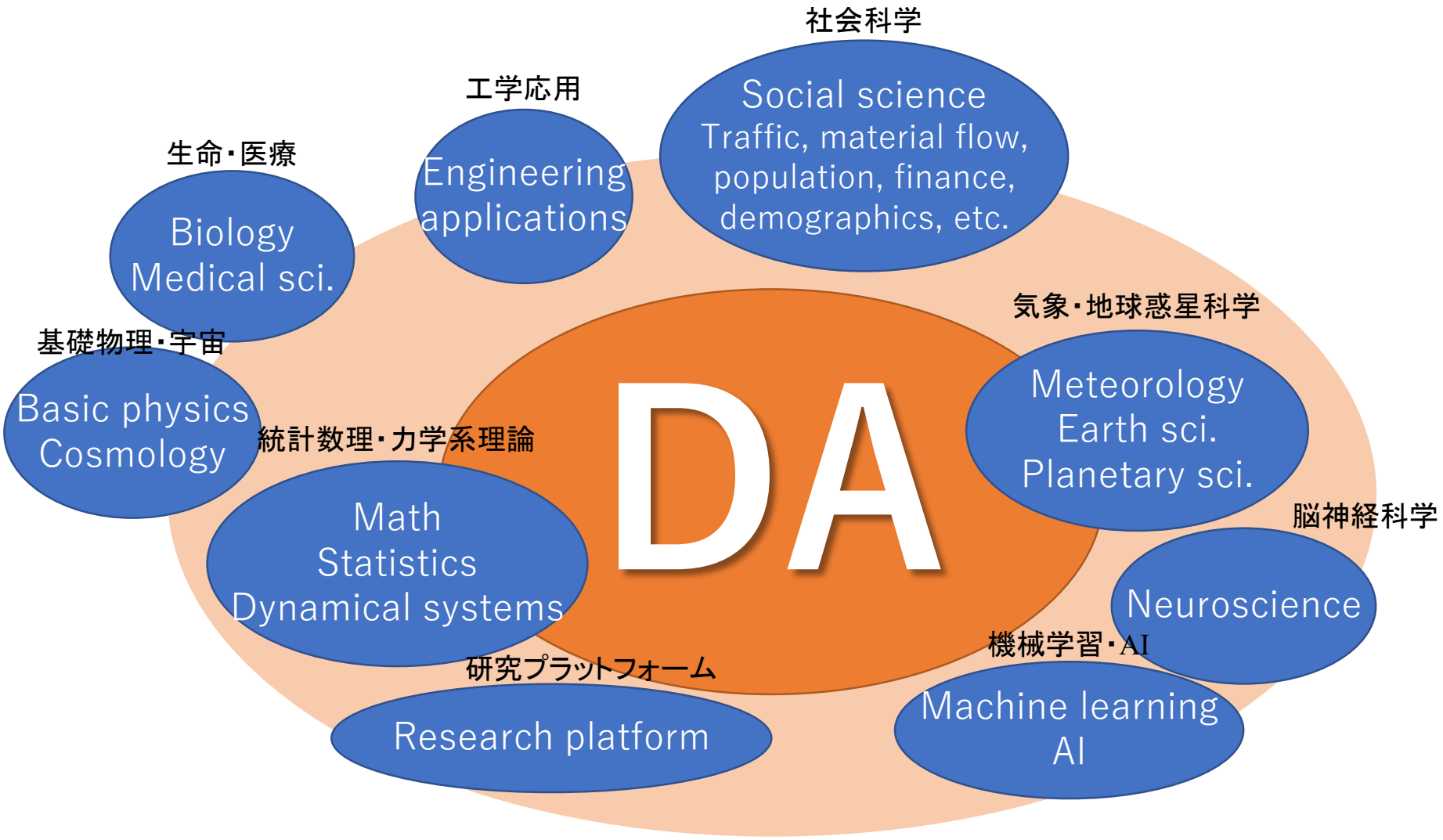
Meteorology
Earth sci.
Planetary sci.
DA
統計数理・力学系理論
Math
Statistics
Dynamical systems


社会科学
Social science
Traffic, material flow,
population, finance,
demographics, etc.
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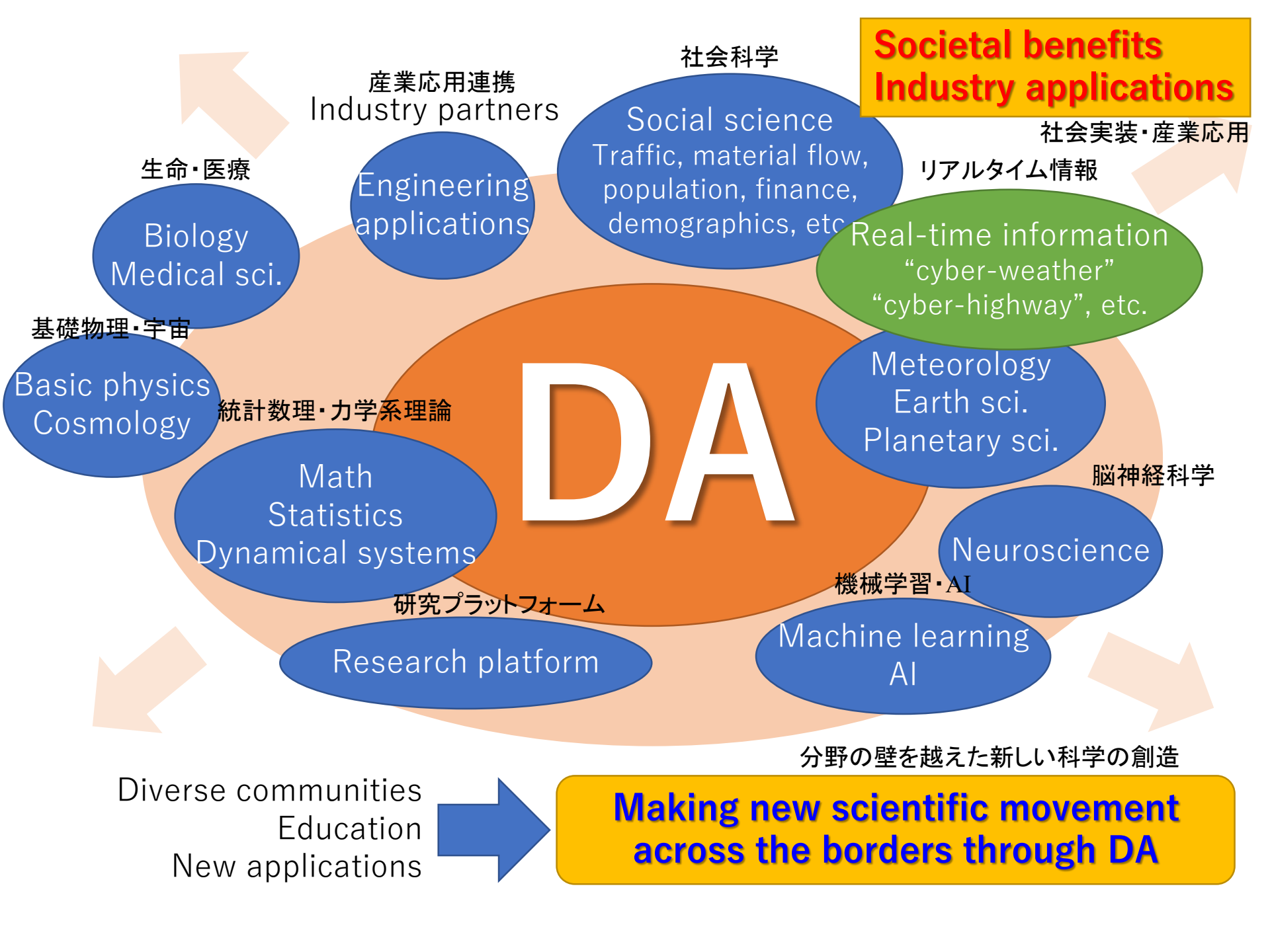
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“cyber-highway”, etc.
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Machine learning
AI
分野の壁を越えた新しい科学の創造
Diverse communities
Education
New applications
Making new scientific movement
across the borders through DA

Summary and a perspective

"*Big Data*" ⇔ "*Big Simulation*"

Compute SPEED and Forecast ACCURACY

For the next decade: Exa-scale computing

Processing orders of magnitude *Bigger Data*
in both space and time

➔ Revolutionize Weather Prediction

空間的・時間的に桁違いな「ビッグデータ同化」を実現
→天気予報を革命