"Big Data Assimilation"

Revolutionizing Weather Prediction

Data Assimilation Team

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S. Satoh, T. Ushio, H. Tomita, Y. Ishikawa

RIKEN K computer

*RIKEN Center for Computational Science

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

Y. Yoshizaki, H. Seko

Who am I?

B.S. from Kyoto U
↓
JMA administration (2y)
↓
JMA NWP (1.25y)
↓
UMD (2y, M.S. and Ph.D.)
↓
JMA NWP (3.5y)
↓
UMD (4y)
↓
RIKEN (5.5y+)

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

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

Takemasa Miyoshi, Ph.D.
Team Leader
Data Assimilation Research Team
RIKEN Center for Computational Science

Deputy Director
RIKEN interdisciplinary Theoretical and Mathematical Sciences (iTHEMS) Program

Chief Scientist
Prediction Science Laboratory
RIKEN Cluster for Pioneering Research

Visiting Professor
University of Maryland, College Park

Affiliate Professor
Graduate School of Science, Kyoto University

Visiting Principal Scientist
Application Laboratory, JAMSTEC

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

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

Data Assimilation Research Team

Data Assimilation Research Team

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. On April 1, 2018, RIKEN AICS was renamed RIKEN Center for Computational Science (R-CCS). R-CCS is operating the world's leading K computer, and also has a strong Research Division. R-CCS 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. R-CCS 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 methodsand their 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 a include 1) research on parallel-efficient algorithms for data assimilation with the super-parallel K computer, 2) research on data assimilation metho and applications by taking advantage of the world-leading K computer, and 3) development of most advanced data assimilation software optimized the K computer.

February 21, 2018 at R-CCS

RIKEN R-CCS

Data Assimilation Team

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

Team Leader	Research Scientist	Research Scientist	Research Scientist (Excellent Young Researcher)
			
Takemasa Miyoshi	Koji Terasaki	Shigenori Otsuka	Shunji Kotsuki

Postdoctoral Researcher	Postdoctoral Researcher	Special Postdoctoral Researcher	Postdoctoral Researcher	Postdoctoral Researcher	Research Associate
					
Guo-Yuan Lien	Takumi Honda	Atsushi Okazaki	Kohei Takatama	James Taylor	Yasumitsu Maejima

Technical Staff	Technical Staff	Technical Staff	Technical Staff	Technical Staff
				
Hazuki Arakida	Taeka Awazu	Hideyuki Sakamoto	Marimo Ohhigashi	Kenta Kurosawa

Press Release

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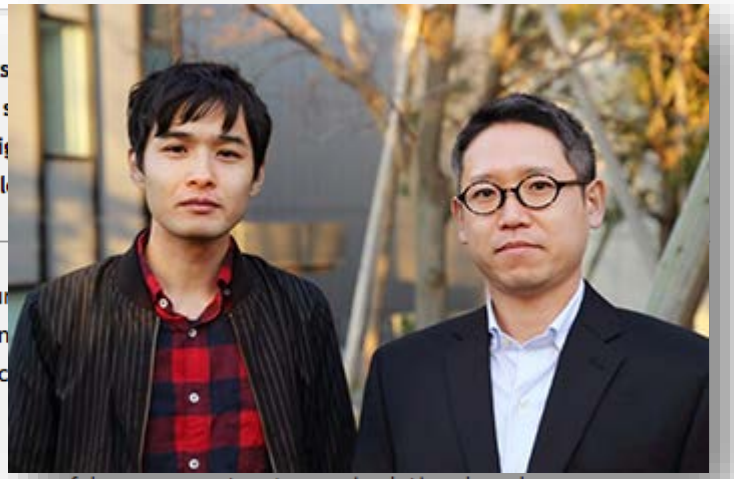
January 18, 2018

Himawari-8 data assimilated simulation enables 10-minute updates of rain and flood predictions

Using the power of Japan's K computer, scientists and collaborators have shown that incorporating s this study—into weather prediction models can sig allow more precise predictions of the rapid devel



Weather prediction models attempt to predict futur taken from various sources of data. However, the in precision and timeliness of the data, makes it diffic systems such as sudden precipitation.

As a means to improve models, scientists are using powerful supercomputers to run simulations based on more frequently updated and accurate data. The team led by Takemasa Miyoshi of AICS decided to work with data from Himawari-8, a geostationary satellite that began operating in 2015. Its instruments can scan the entire area it covers every ten minutes in both visible and infrared light, at a resolution of up to 500 meters, and the data is provided to meteorological agencies. Infrared measurements are useful for indirectly gauging rainfall, as they make it possible to see where clouds are located and at what altitude.

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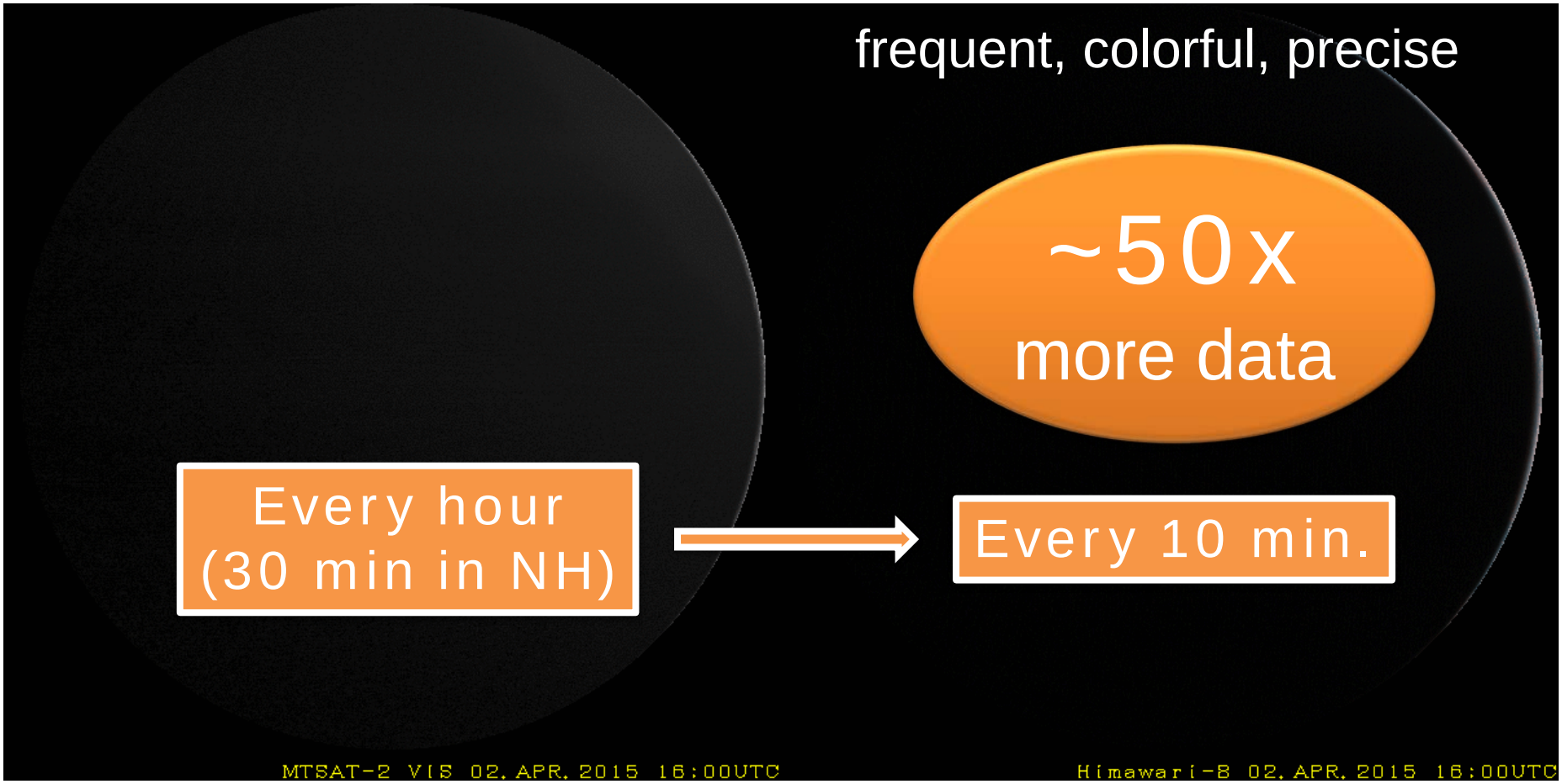
Himawari-8: a new generation geostationary meteorological satellite



16UTC 2 to 13UTC 3 April 2015
MTSAT-2 (VIS)
Every 1 hour

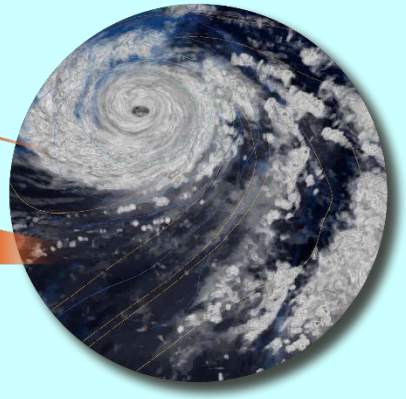
16UTC 2 to 13UTC 3 April 2015
Himawari-8 (True Color)
Every 10 minutes

(Courtesy of JMA)

Big Data Assimilation

Observations

Simulations



Data Assimilation

Big Data

New sensors, IoT

Big Data

Powerful supercomputer

Data Assimilation (DA)

Data-driven
Induction
Real world

Process-driven
Deduction
Cyber world

Observations

Simulations

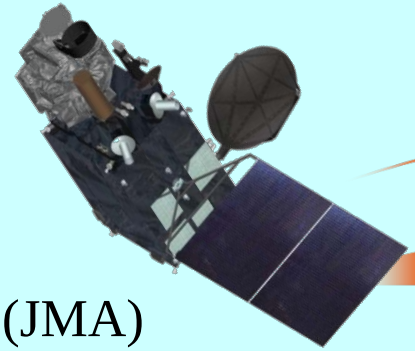
Data Assimilation

1 + 1

> 2

SCALE-LETKF system

Himawari-8

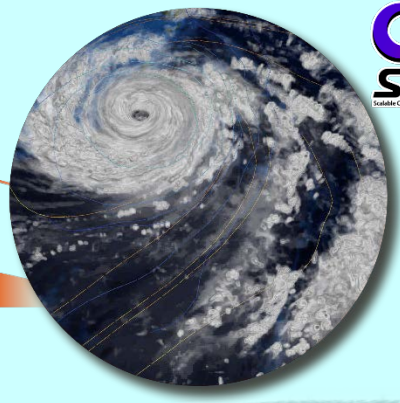


(JMA)

LETKF

Data Assimilation

Regional weather model



Local Ensemble Transform Kalman Filter
(Hunt et al. 2007)

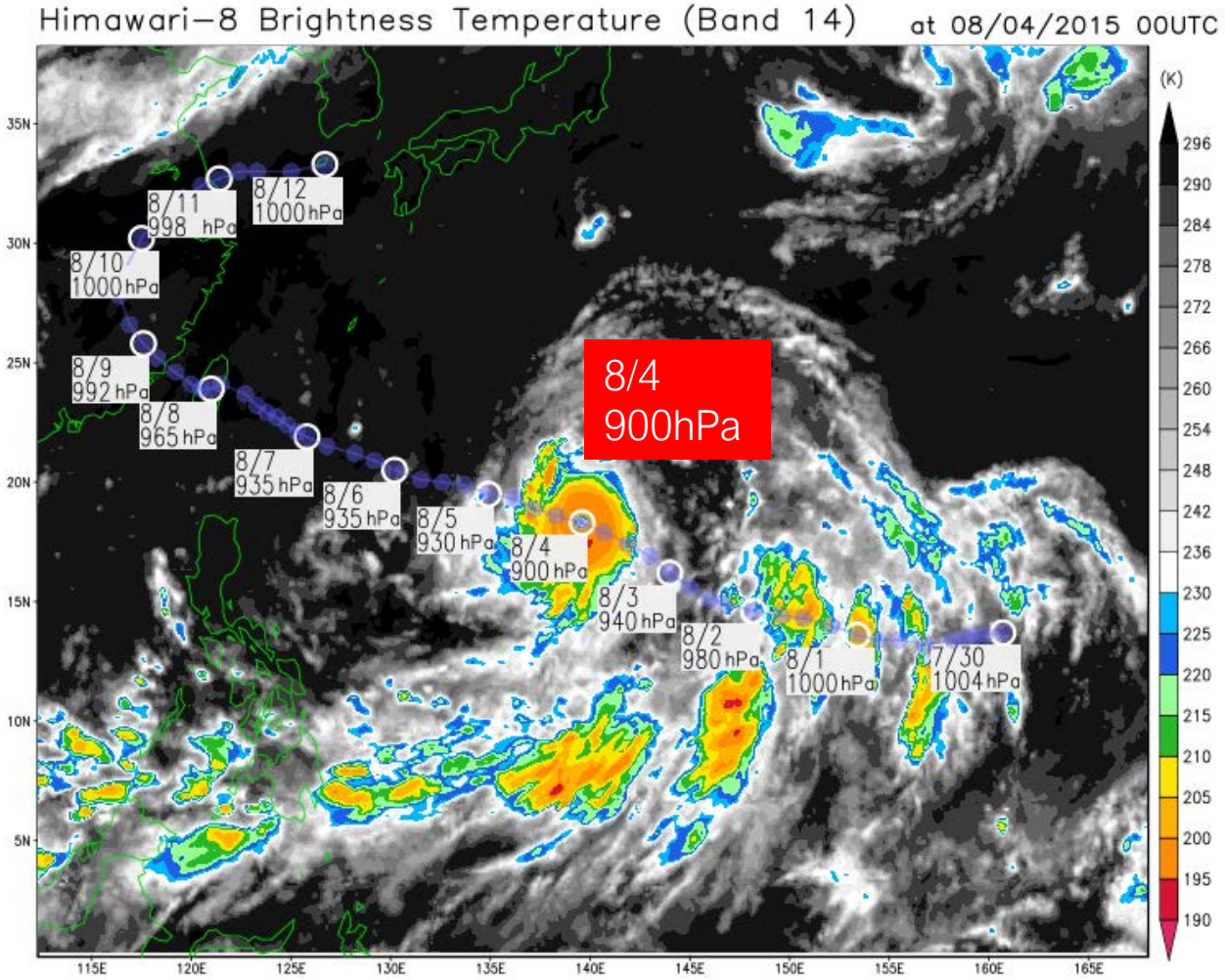
SCALE-LETKF

A Regional Numerical Weather Prediction System developed at RIKEN

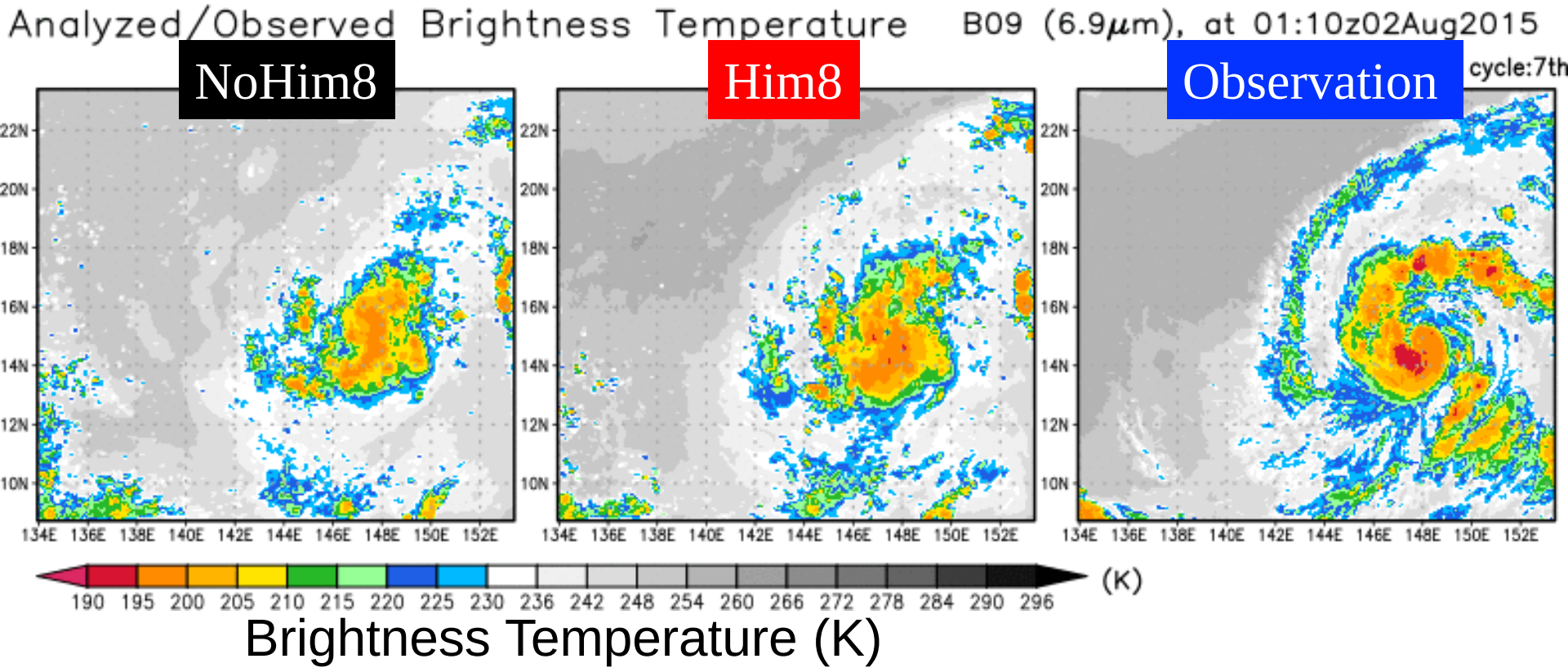
(Lien et al. 2017, DOI:10.2151/sola.2017-001)

Typhoon Soudelor (2015)

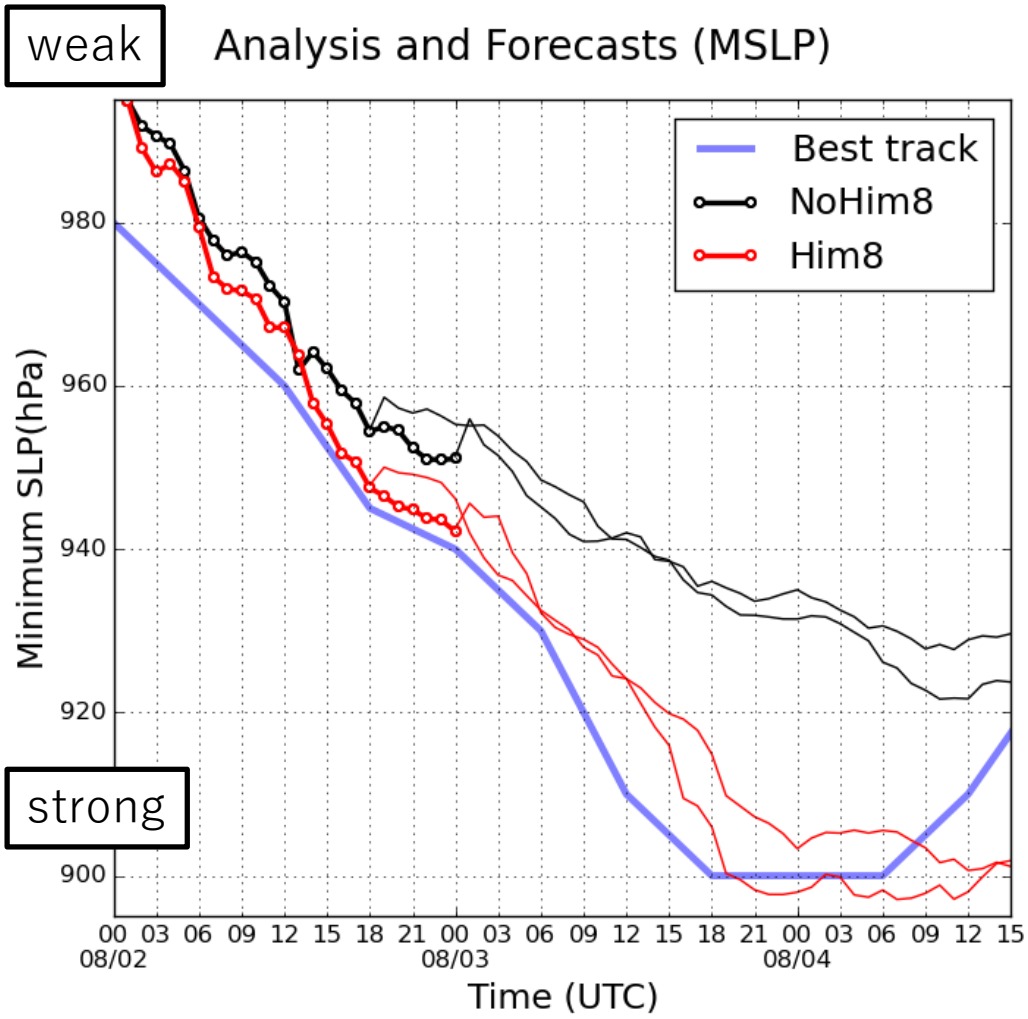
- The strongest western north Pacific typhoon in 2015 captured well by Himawari-8



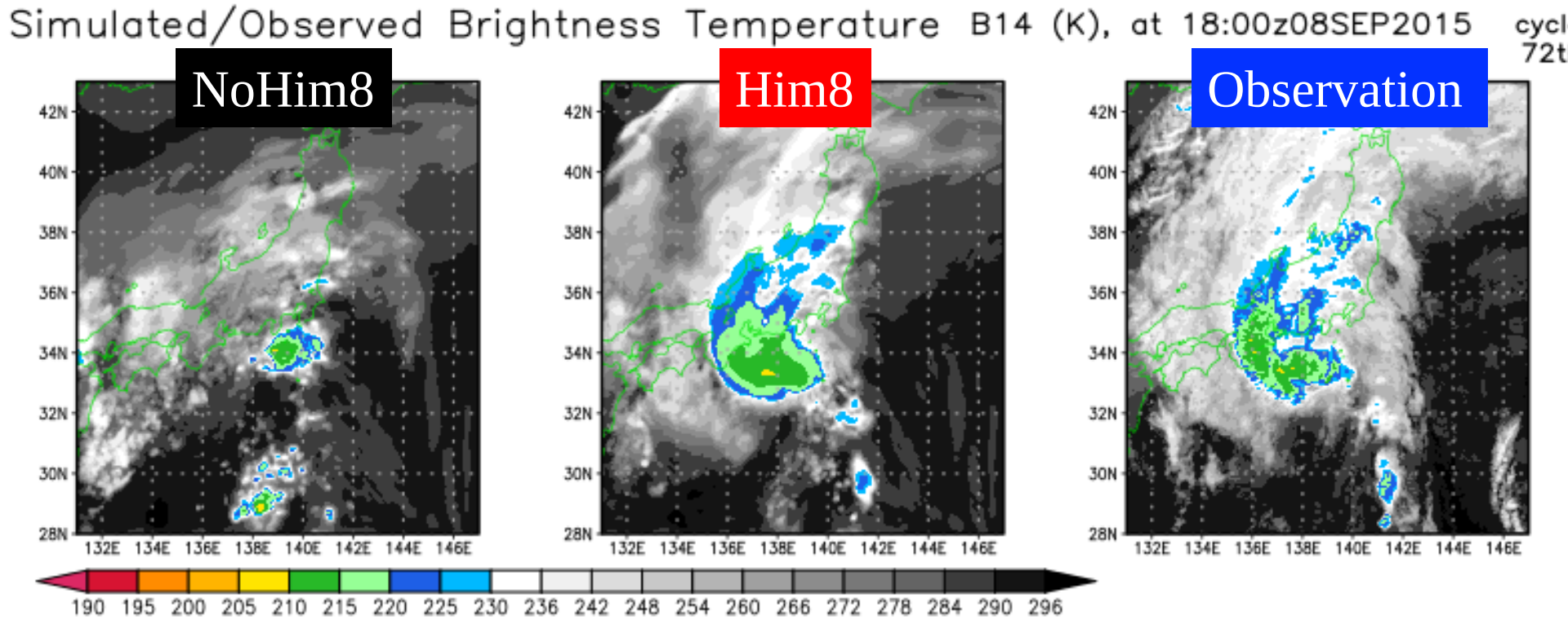
Himawari-8 impact



Himawari-8 impact on intensity fcst



Himawari-8 impact

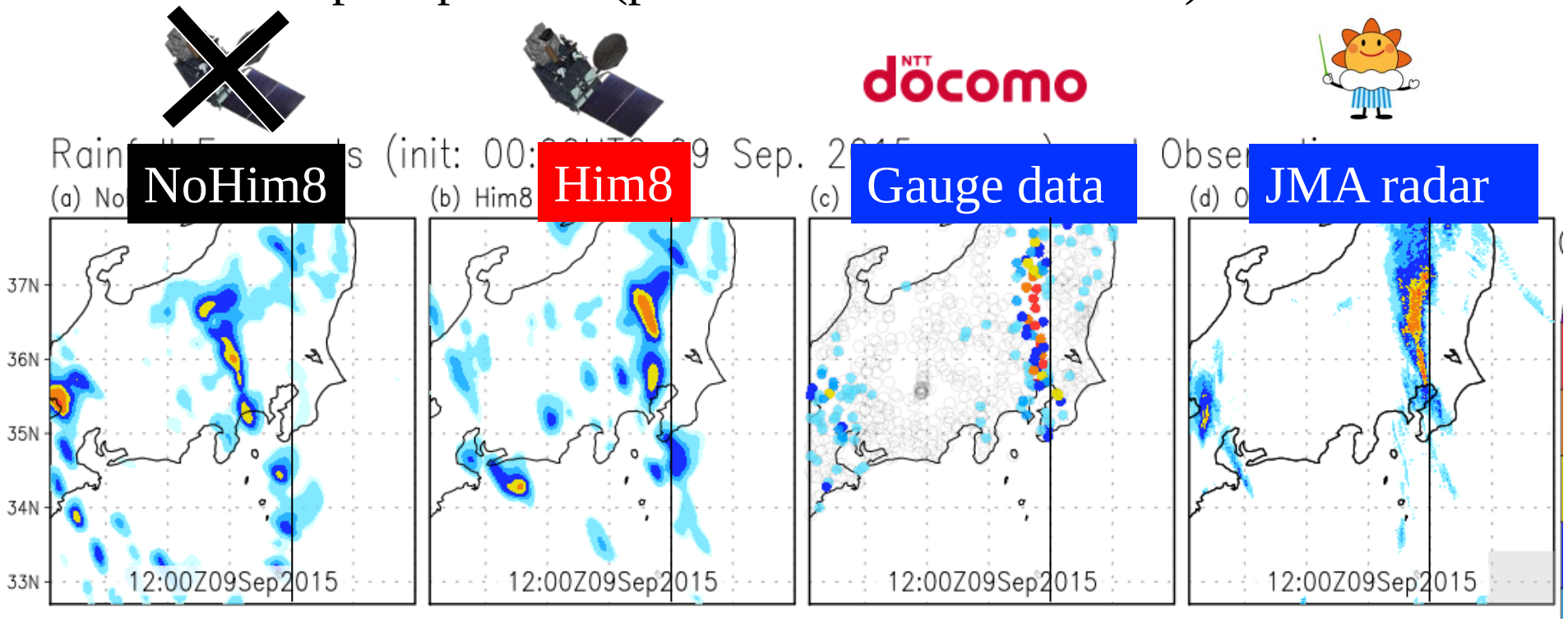


High clouds

Low clouds/clear sky

Himawari-8 impact

12-h forecast precipitation (previous 1 h accumulation)

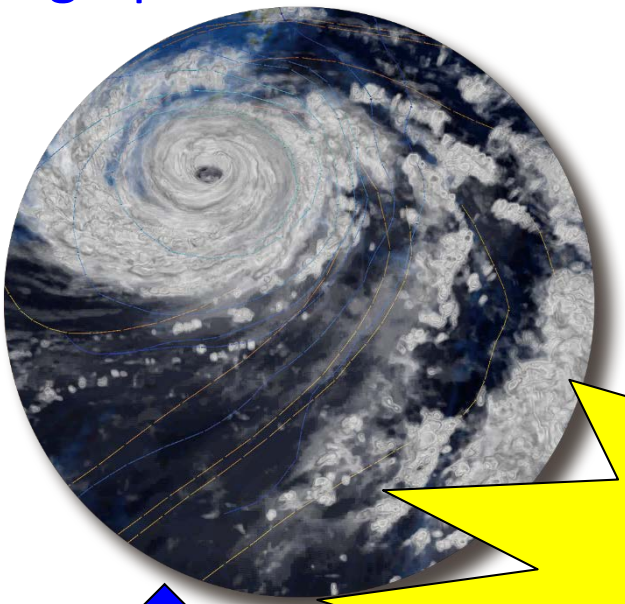


(Honda et al. 2017)

12-h forecast rain location much improved

Pioneering “Big Data Assimilation” Era

High-precision Simulations

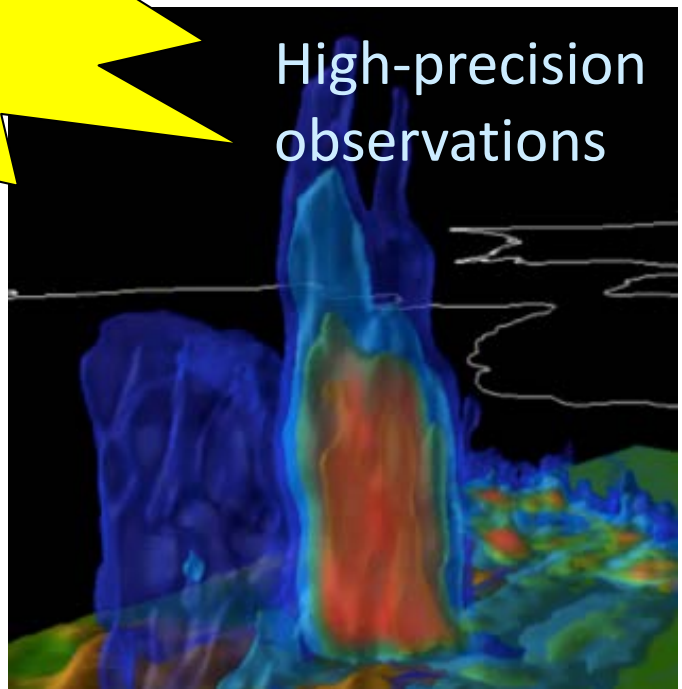


国立研究開発法人 科学技術振興機構 Japan Science and Technology Agency CREST

Future-generation technologies available 10 years in advance

BDA BIG DATA ASSIMILATION

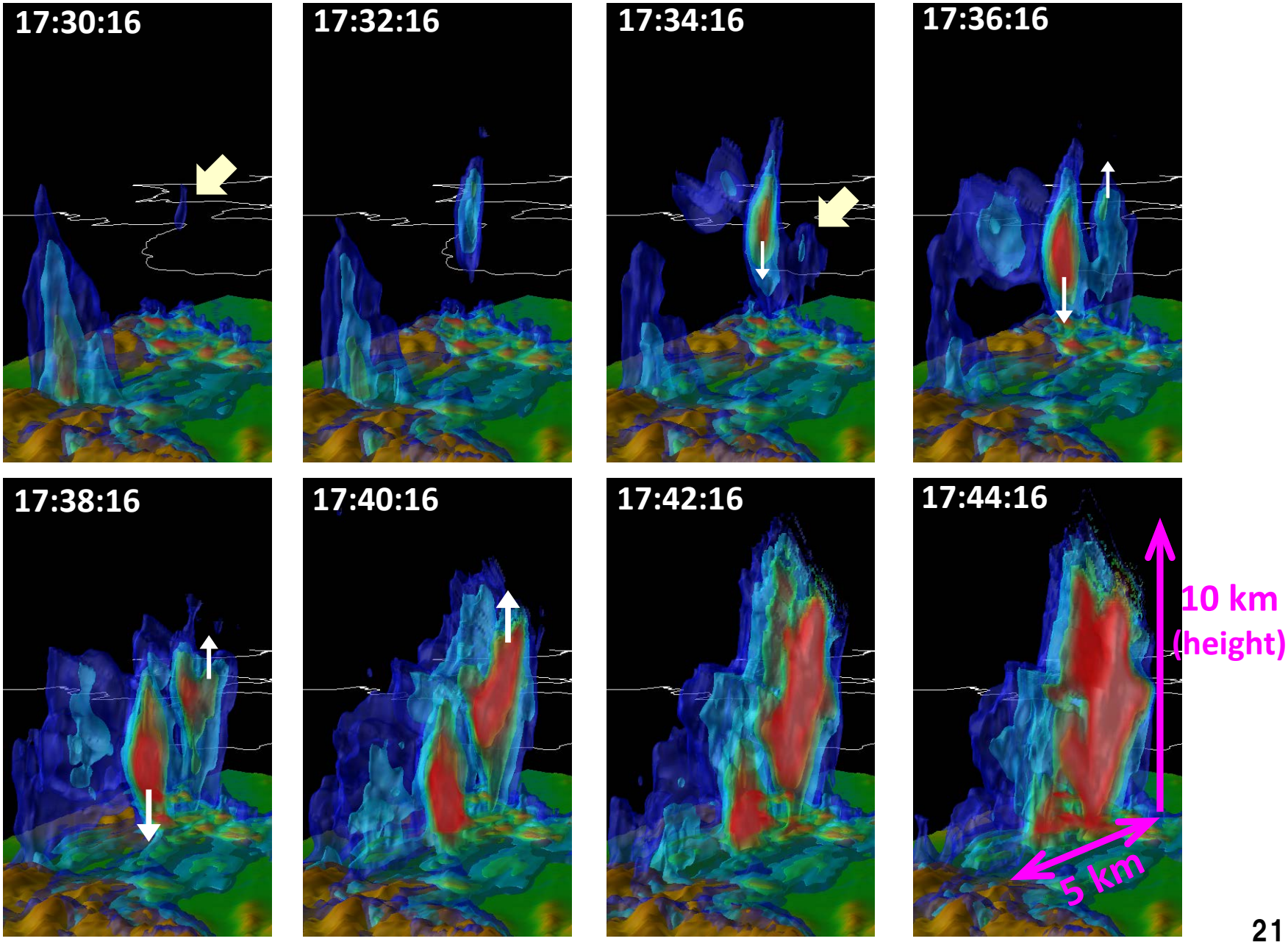
High-precision observations



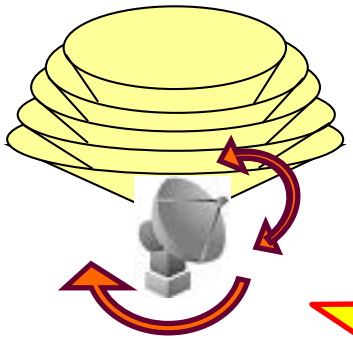
Mutual feedback

Only in 10 minutes!!

(Courtesy of NICT)

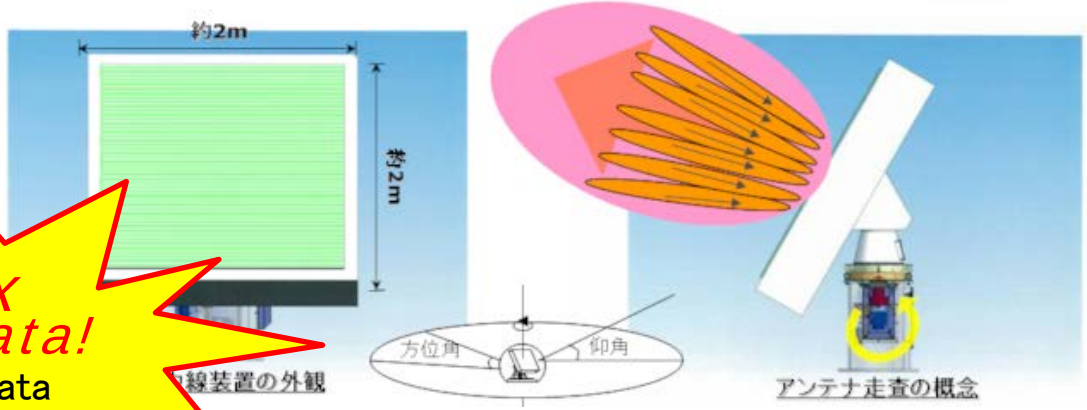


Phased Array Weather Radar (PAWR)



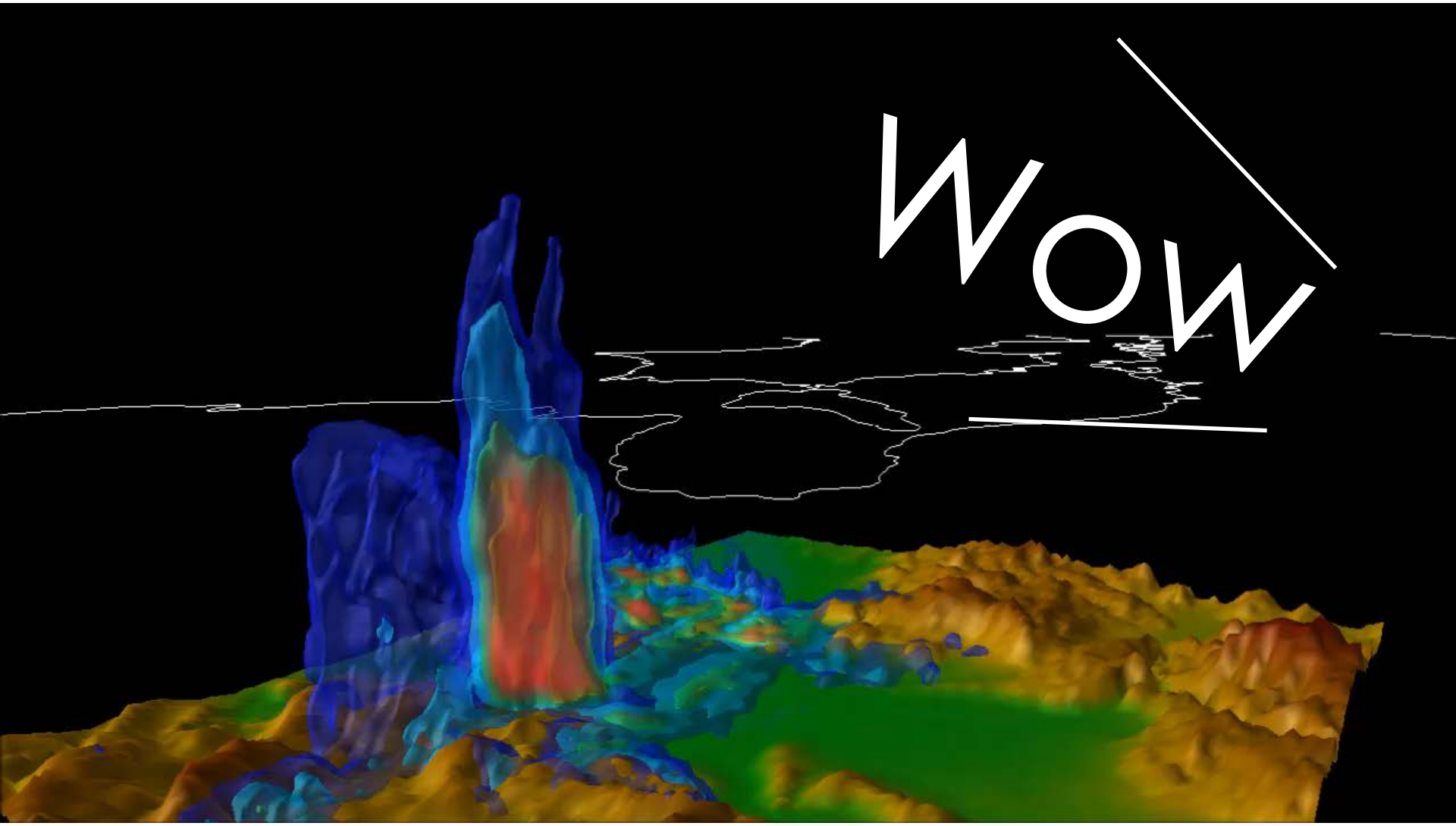
3-dim measurement using
a parabolic antenna (150 m,
15 EL angles in 5 min)

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

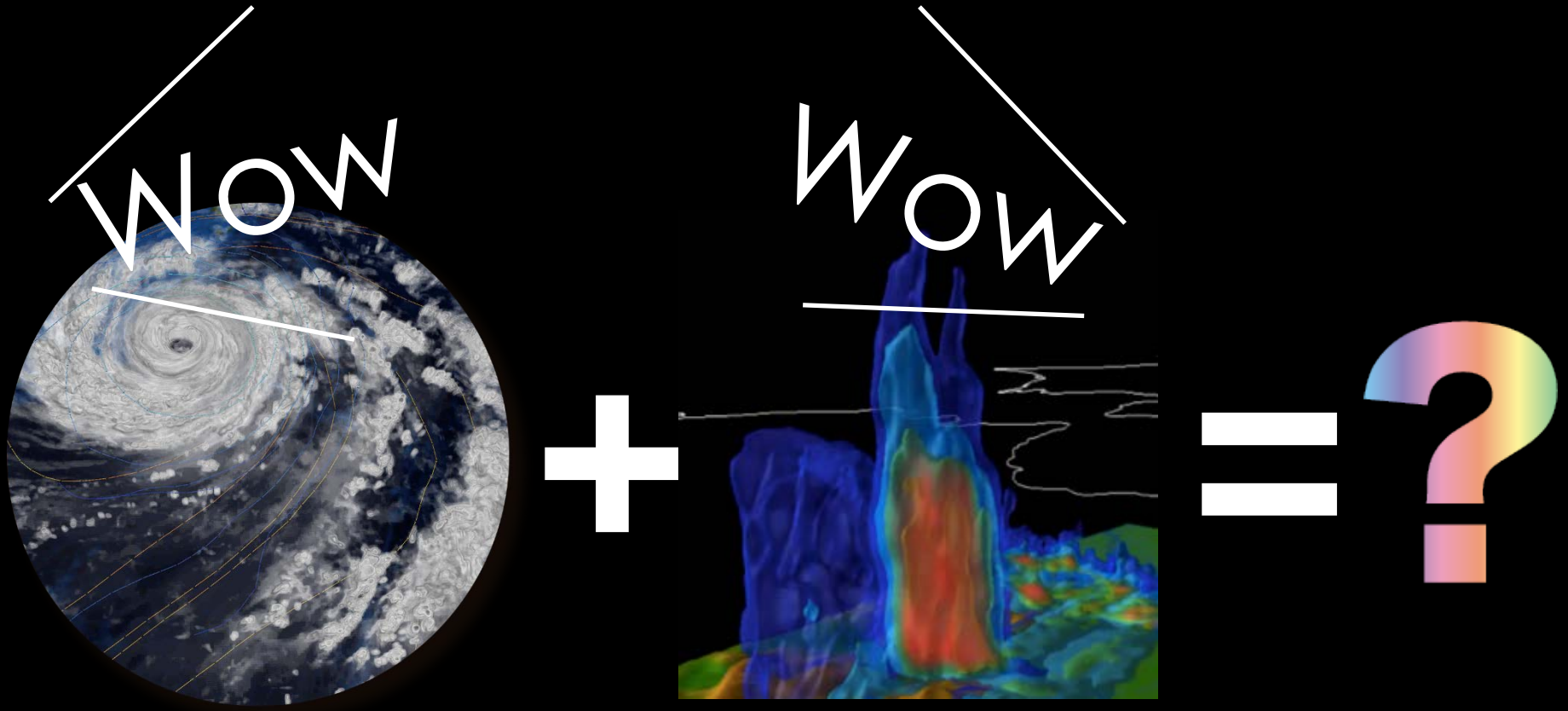


3-dim measurement using a phased array antenna
(100 m, 100 EL angles in 30 sec)

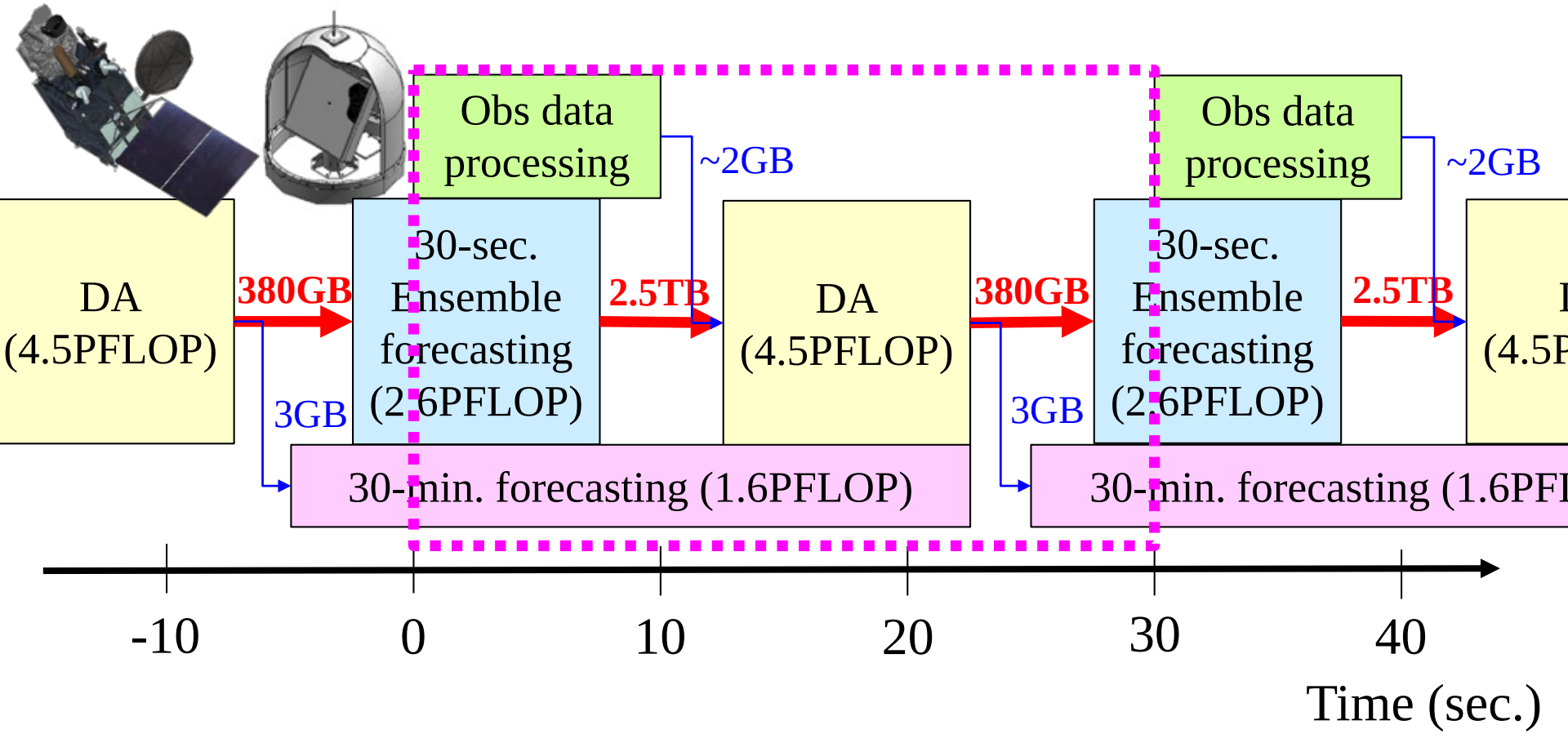
Phased Array Radar (every 30 sec.)



(Courtesy of NICT)

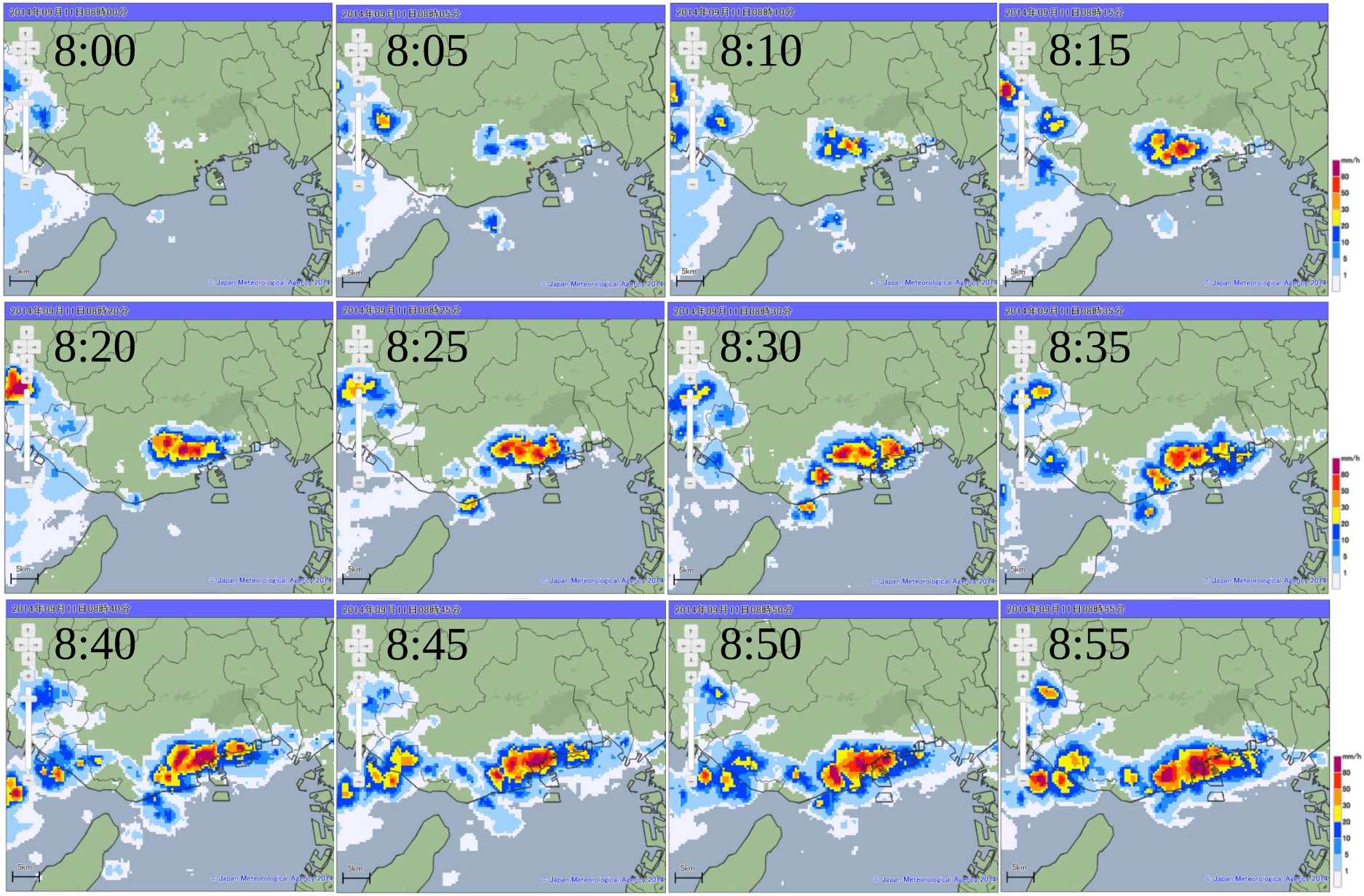

Wow
Wow
+
=
?

Revolutionary super-rapid 30-sec. cycle

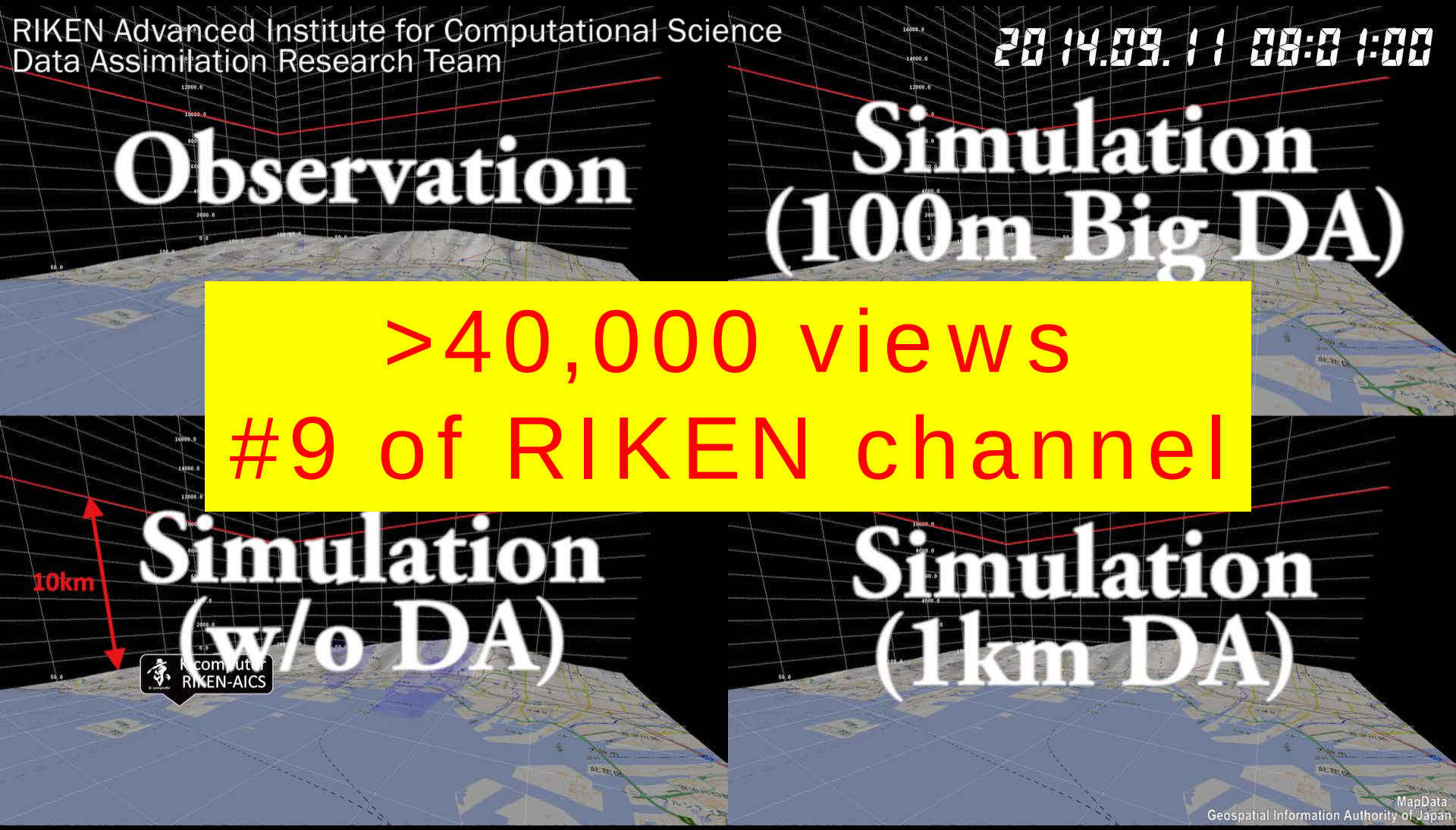


120 times more rapid than hourly update cycles

9/11/2014 morning, sudden rain



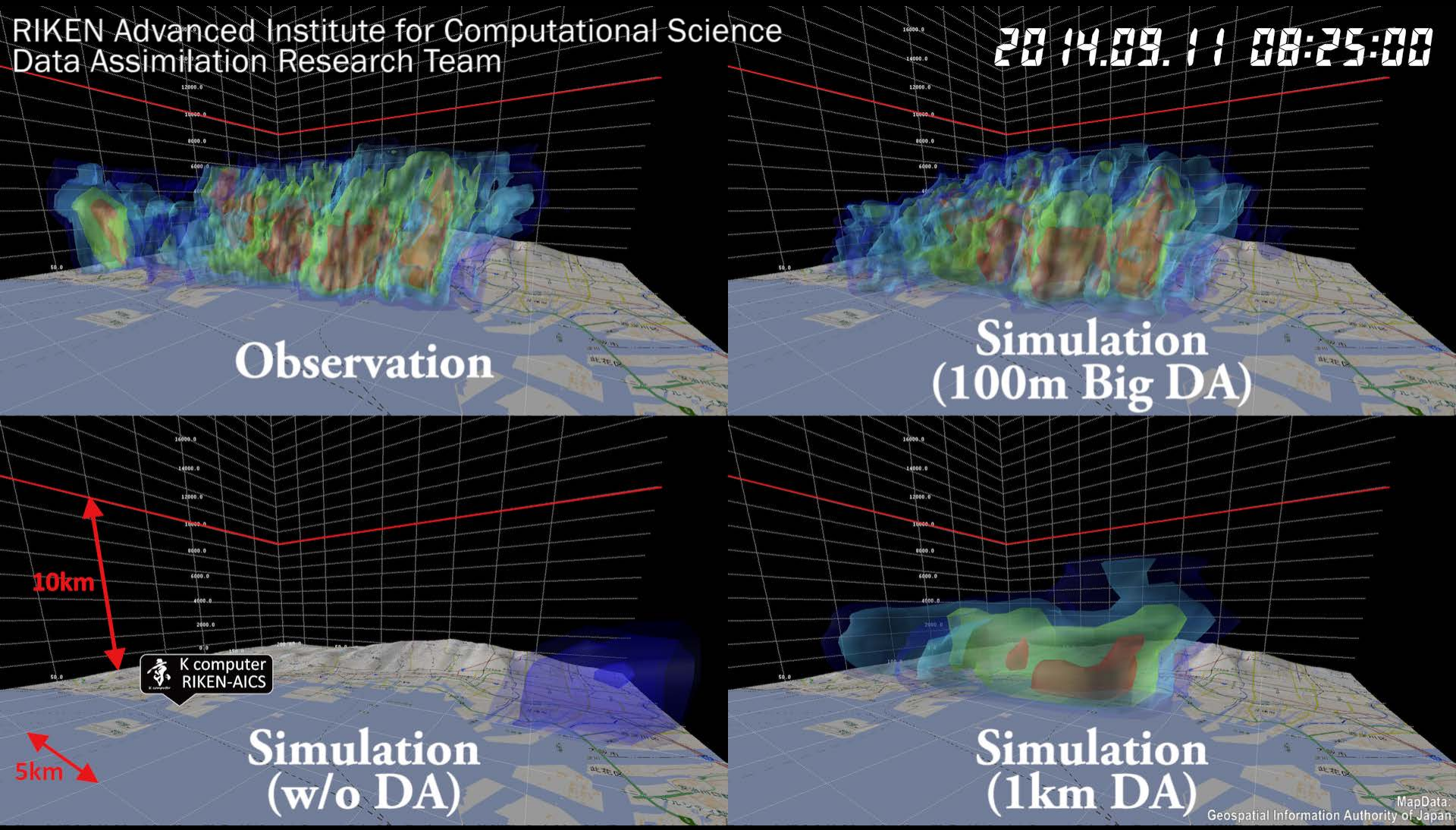
9/11/2014, sudden local rain



>40,000 views

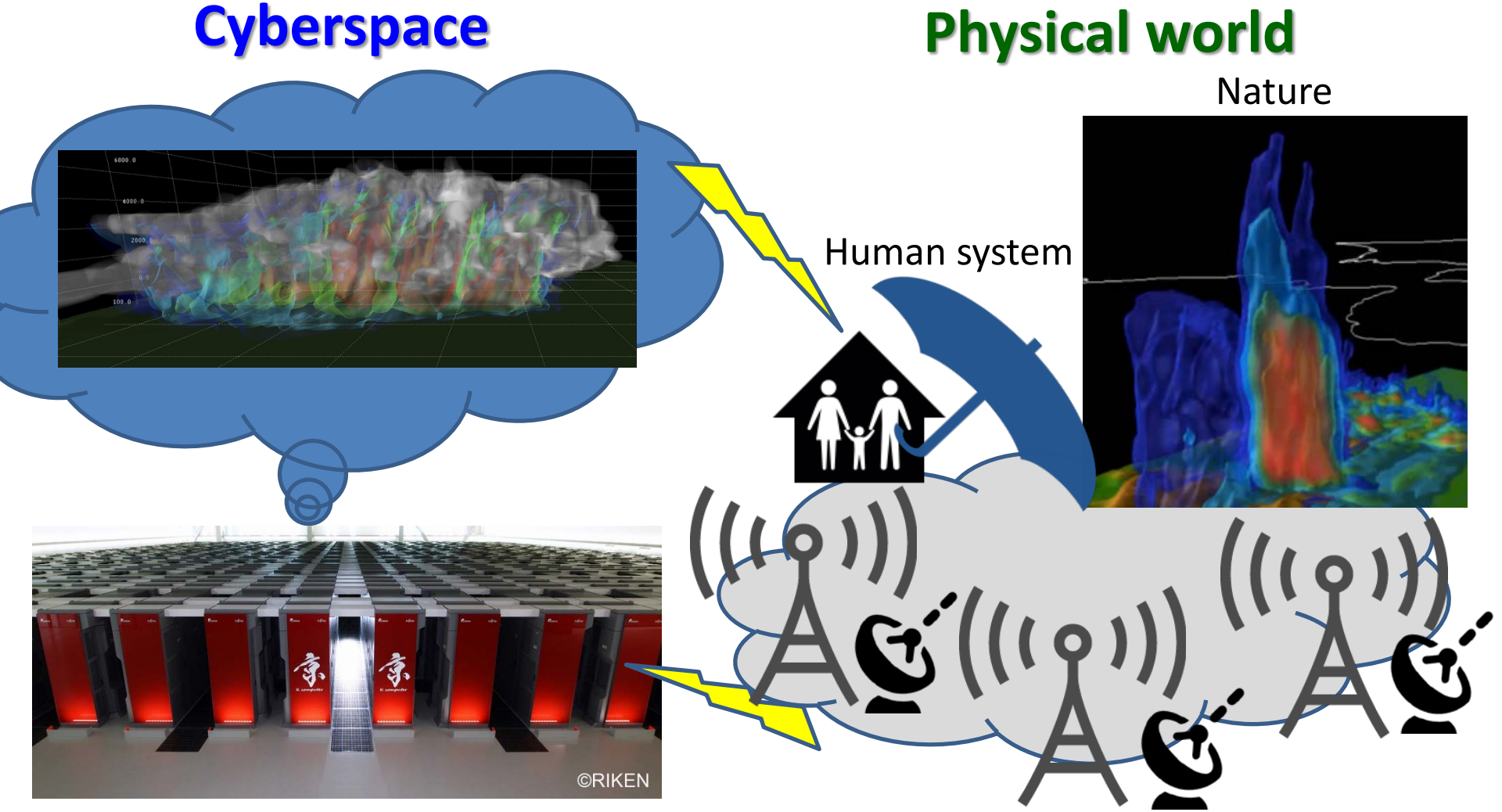
#9 of RIKEN channel

9/11/2014, sudden local rain



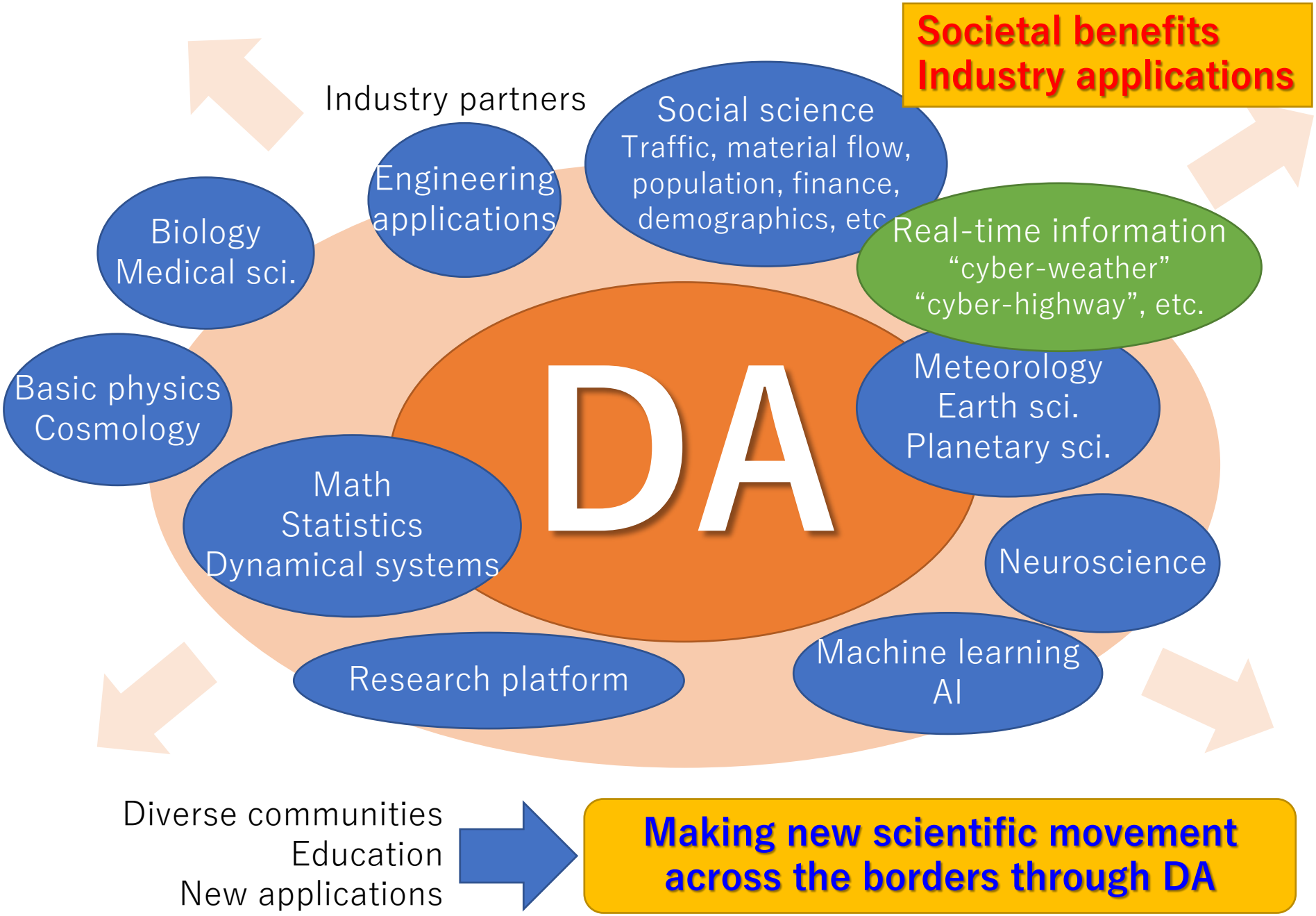
Cyber-Physical fusion for weather prediction

Data Assimilation is the key



Data Assimilation (DA)

Data assimilation best combines real-world data and a model, and brings synergy.

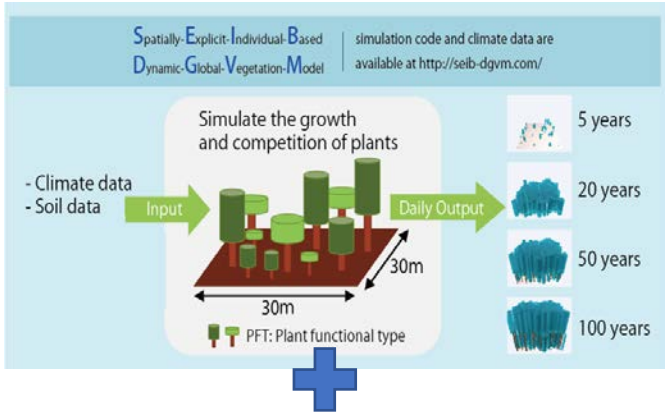

Societal benefits
Industry applications
Industry partners
Social science
Traffic, material flow,
population, finance,
demographics, etc.
Engineering
applications
Biology
Medical sci.
Real-time information
“cyber-weather”
“cyber-highway”, etc.
Basic physics
Cosmology
DA
Meteorology
Earth sci.
Planetary sci.
Math
Statistics
Dynamical systems
Neuroscience
Research platform
Machine learning
AI
Diverse communities
Education
New applications
Making new scientific movement
across the borders through DA

Data Assimilation as a tool for vegetation management

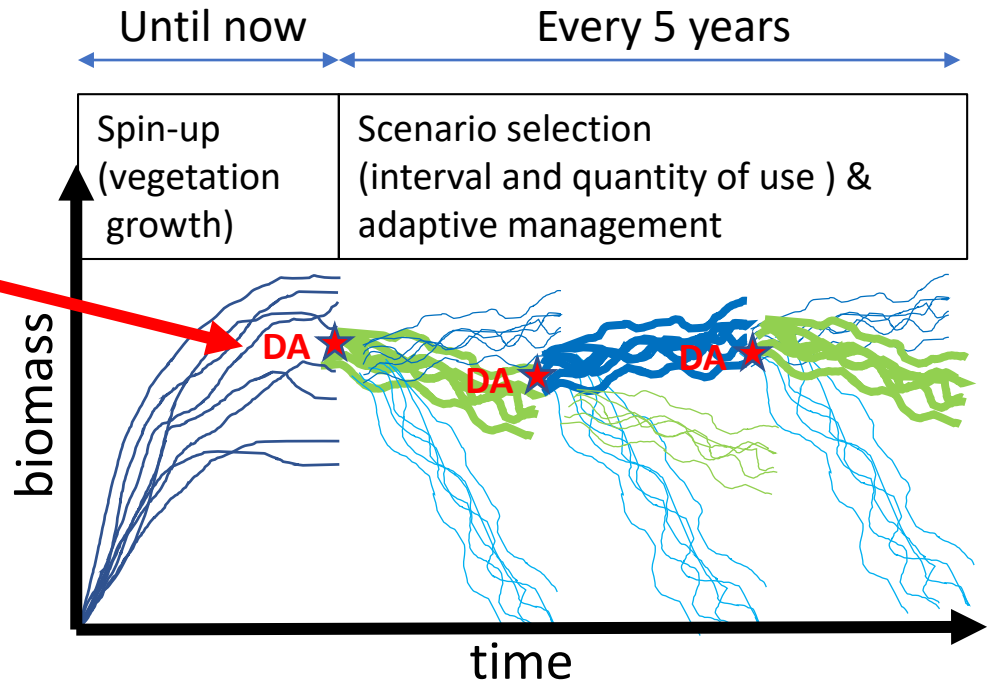
Arakida, H., S. Otsuka, S. Kotsuki, T. Miyoshi (RIKEN AICS), S. Moriya (RIKEN CSRS),
N. Kobayashi (RIKEN ACCC), J. Aikawa (RIKEN Chief Scientist Laboratories)

Optimizing an individual-based vegetation model for better prediction of forest evolution.

Vegetation model



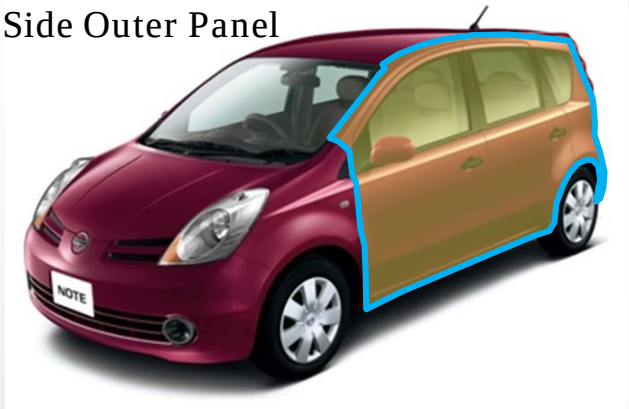
Field observations

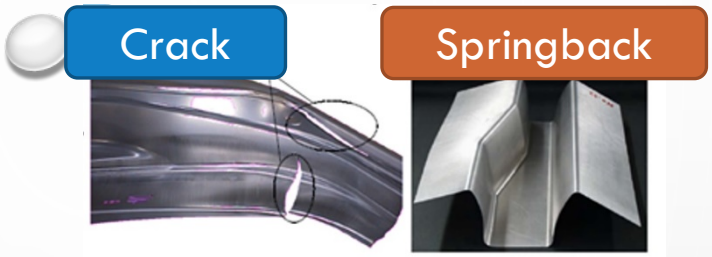


Data assimilation: Application for press forming simulation

Hideyuki Sakamoto, Takemasa Miyoshi (RIKEN AICS)
Masato Takamura (RIKEN Center for Advanced Photonics)

Body Side Outer Panel

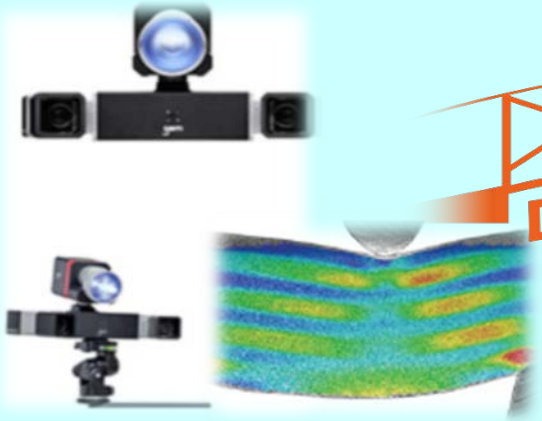




Optimizing press forming conditions by predicting strain to suppress cracks, crumpled, and springback

Data Assimilation aims to improve a press forming simulation using measurements of surface strain !

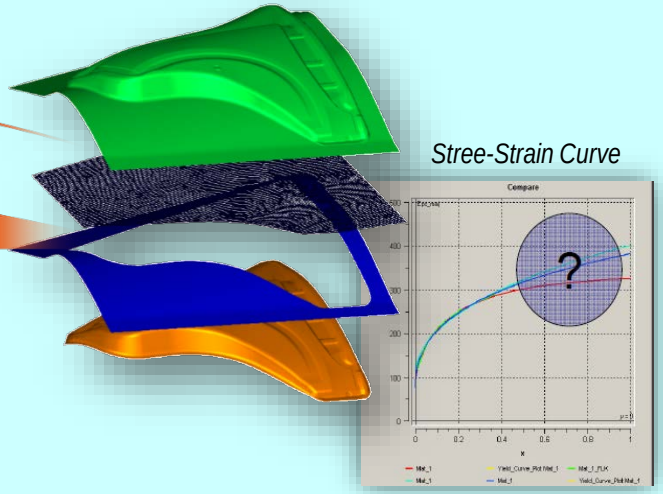
Observations



Surface strain measured by ARAMIS

Data Assimilation

Simulations



Industry applications

Toward smart hydroelectric dam operations

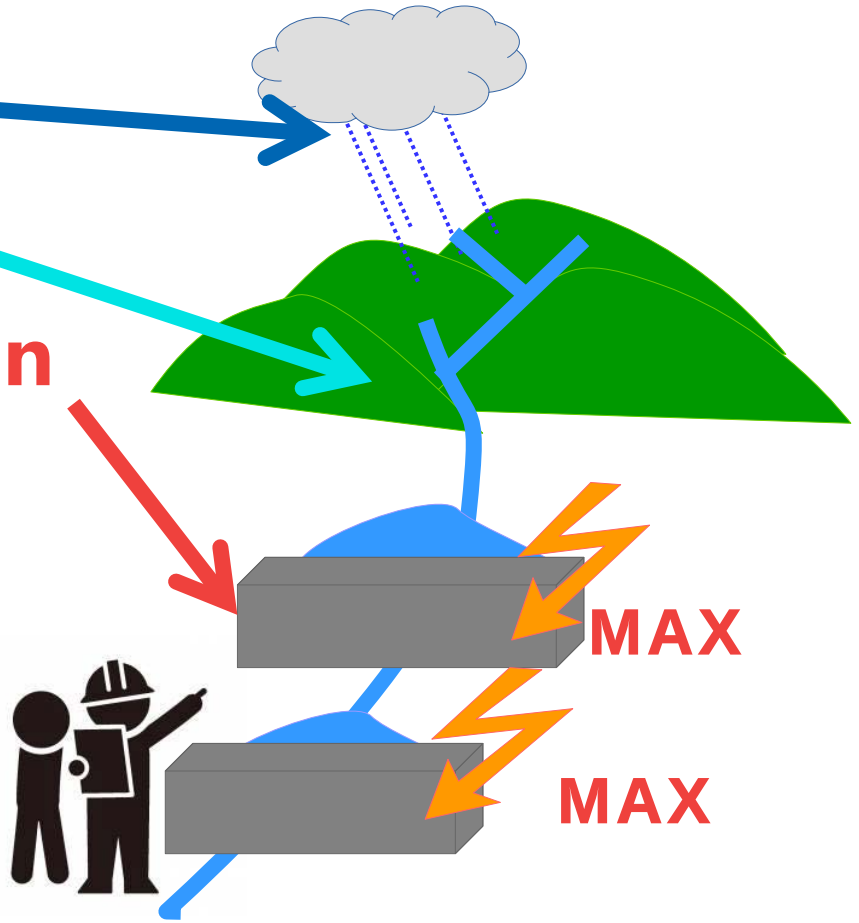
with TEPCO Tokyo Electric Power Company

Japanese leading power company

Rain prediction

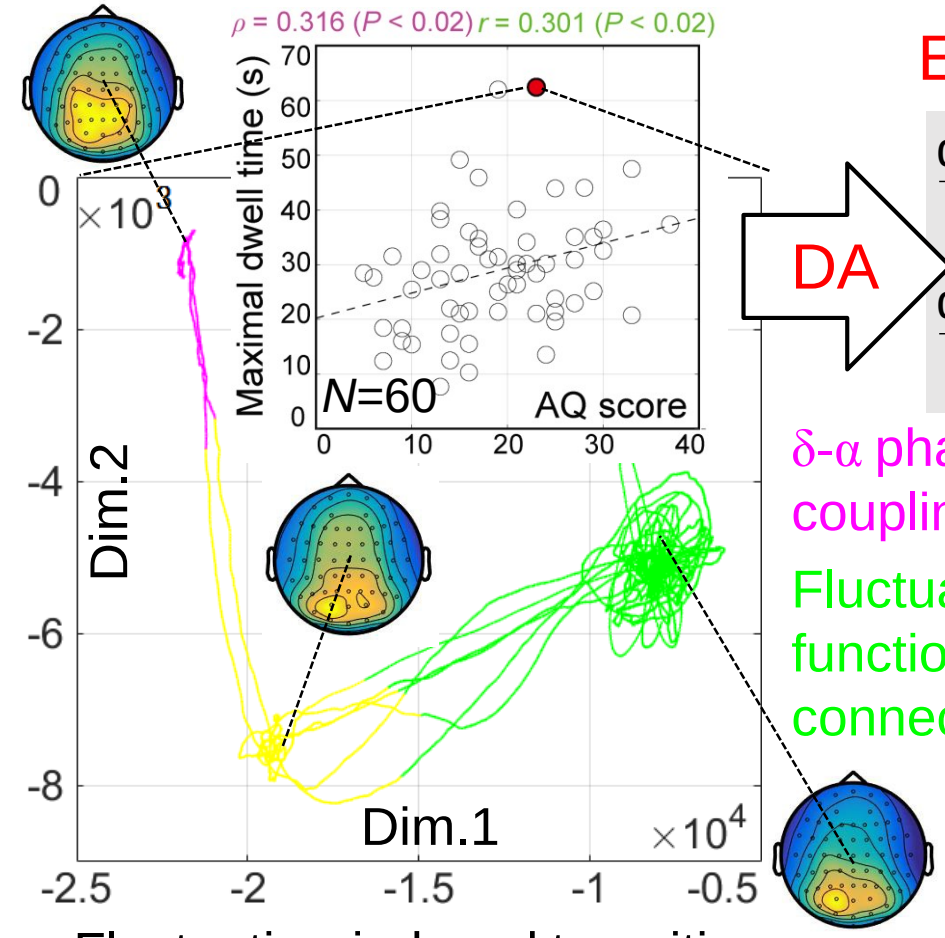
River flow prediction

Optimize dam operation



Modelling rhythms of the brain individually by a data assimilation approach

Takumi Sase & Keiichi Kitajo (RIKEN BSI)



DA

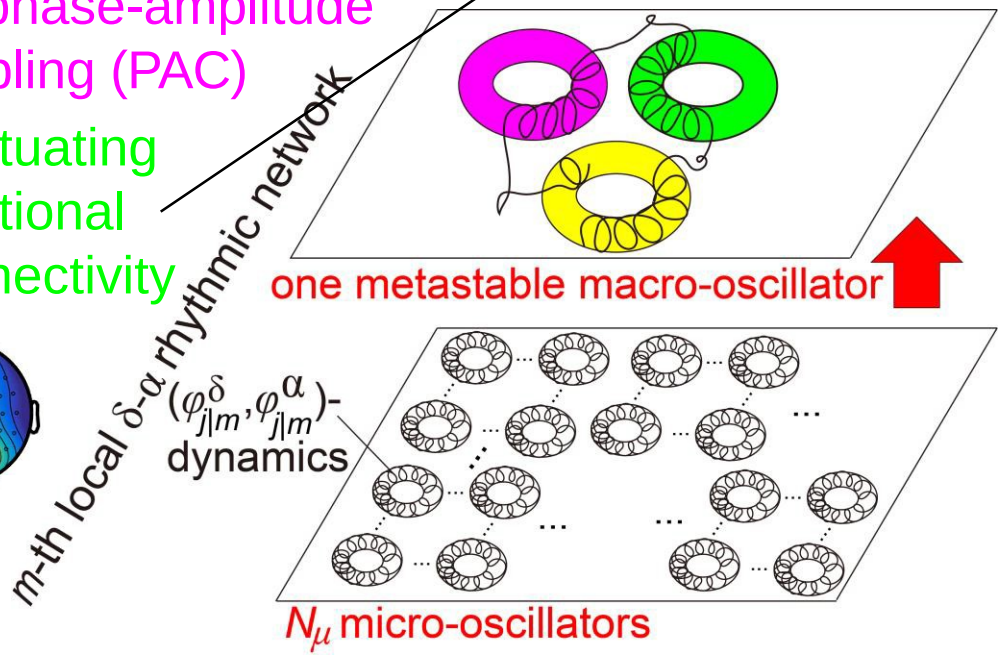
Estimating connectivity individually

$$\frac{d\varphi^{\alpha}_{j|m}}{dt} = \omega^{\alpha}_{m} - \sum_{n=1}^{N_s}\sum_{k=1}^{N_\mu} J^{\alpha\alpha}_{(j,k)|(m,n)} \left(\varphi^{\delta}_{k|n}\right) \sin\left(\varphi^{\alpha}_{j|m} - \varphi^{\alpha}_{k|n}\right)$$

$$\frac{d\varphi^{\delta}_{j|m}}{dt} = \omega^{\delta}_{m} - \sum_{n=1}^{N_s}\sum_{k=1}^{N_\mu} J^{\delta\delta}_{(j,k)|(m,n)} \left(\eta^{\delta\delta}_{k|n}\right) \sin\left(\varphi^{\delta}_{j|m} - \varphi^{\delta}_{k|n}\right)$$

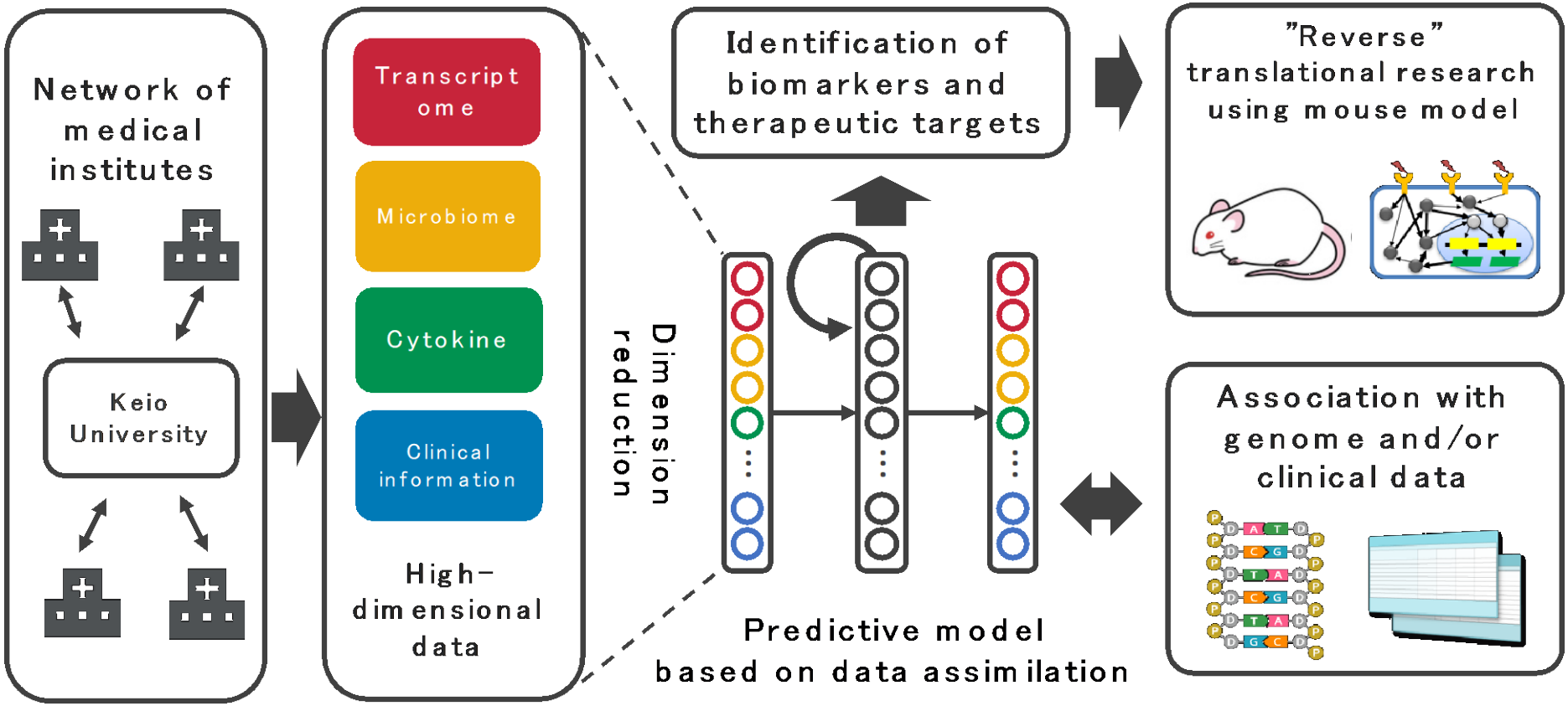
δ-α phase-amplitude coupling (PAC)

Fluctuating functional connectivity



Data assimilation in medicine and biology: towards preventive and personalized medicine

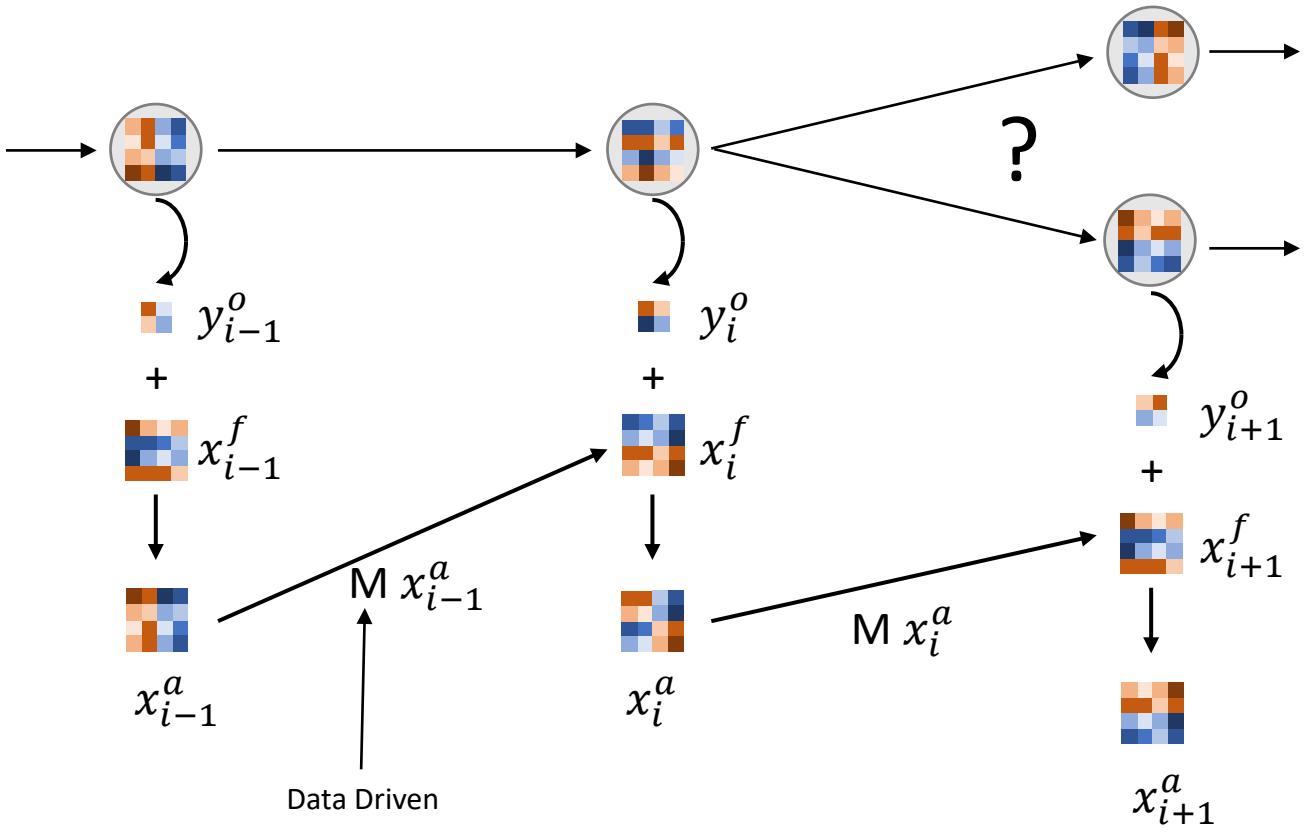
Eiryo Kawakami
Medical Sciences Innovation Hub Program, RIKEN



Forecast Cell Fate by Data Assimilation of Gene Expression Profile

Jun Seita, M.D., Ph.D.

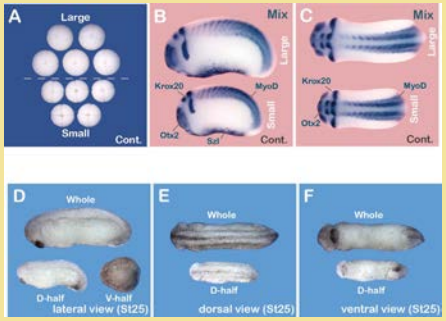
RIKEN MIH / IMS / AIP, Stanford University



Development of mathematical model in biology with Approximate Bayesian Computation (ABC)

Tatsuo Shibata (RIKEN Quantitative Biology Center, QBiC)

Embryonic patterning is so robust.



Inomata, H., Shibata, T., Haraguchi, T., & Sasai, Y. (2013). Cell, 153(6), 1296–1311.

Scaling !

Scaled patterning with proportionality

Mathematical model of DV pattern formation

$$\frac{\partial C}{\partial t} = V_C \frac{K_F^{h_F}}{K_C^{h_C} + (A+B)^{h_C}} - \lambda_C \frac{C}{1+S/K_t+(C+BC+AC)/K_m} - k_{chdbmp} C \cdot B - kC \cdot A + D_{chd} \Delta C$$

$$\frac{\partial B}{\partial t} = V_B \frac{(A+B)^{h_A}}{K_B^{h_B} + (A+B)^{h_B}} - \lambda_B B + \lambda_C \frac{BC}{1+S/K_t+(C+BC+AC)/K_m} - k_{chdbmp} C \cdot B + D_{bmp} \Delta B$$

$$\frac{\partial A}{\partial t} = V_A \frac{K_A^{h_A}}{K_A^{h_A} + (A+B)^{h_A}} - \lambda_B A + \lambda_C \frac{AC}{1+S/K_t+(C+BC+AC)/K_m} - k_{chdadmp} C \cdot A + D_{admp} \Delta A$$

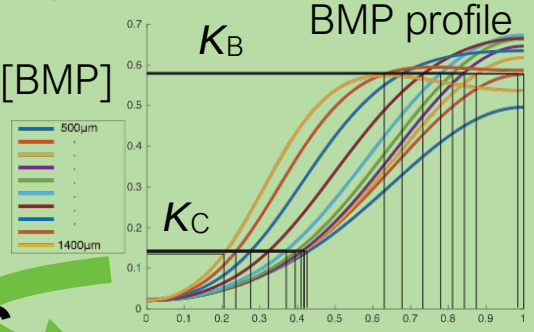
$$\frac{\partial S}{\partial t} = V_S \frac{(A+B)^{h_S}}{K_S^{h_S} + (A+B)^{h_S}} - \lambda_S S + D_{sol} \Delta S$$

$$\frac{\partial BC}{\partial t} = -\lambda_C \frac{BC}{1+S/K_t+(C+BC+AC)/K_m} + k_{chdbmp} C \cdot B + D_{chdbmp} \Delta BC$$

$$\frac{\partial AC}{\partial t} = -\lambda_C \frac{AC}{1+S/K_t+(C+BC+AC)/K_m} + k_{chdadmp} C \cdot A + D_{chdadmp} \Delta AC$$

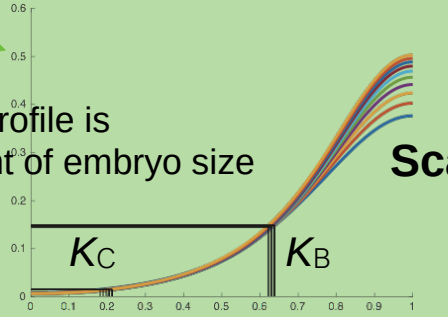
Inomata, H., Shibata, T., Haraguchi, T., & Sasai, Y. (2013). Cell, 153(6), 1296–1311.

Bayesian inference from data



ABC

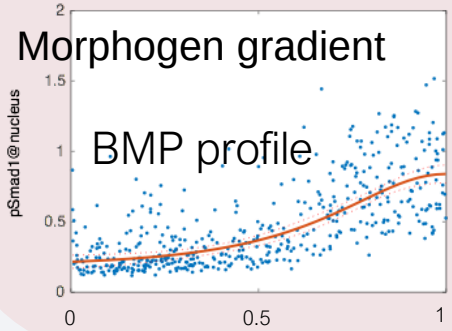
The BMP profile is independent of embryo size



Scaling !

Question?

What is the mechanism that underlies the scaling behavior for different size of embryo?



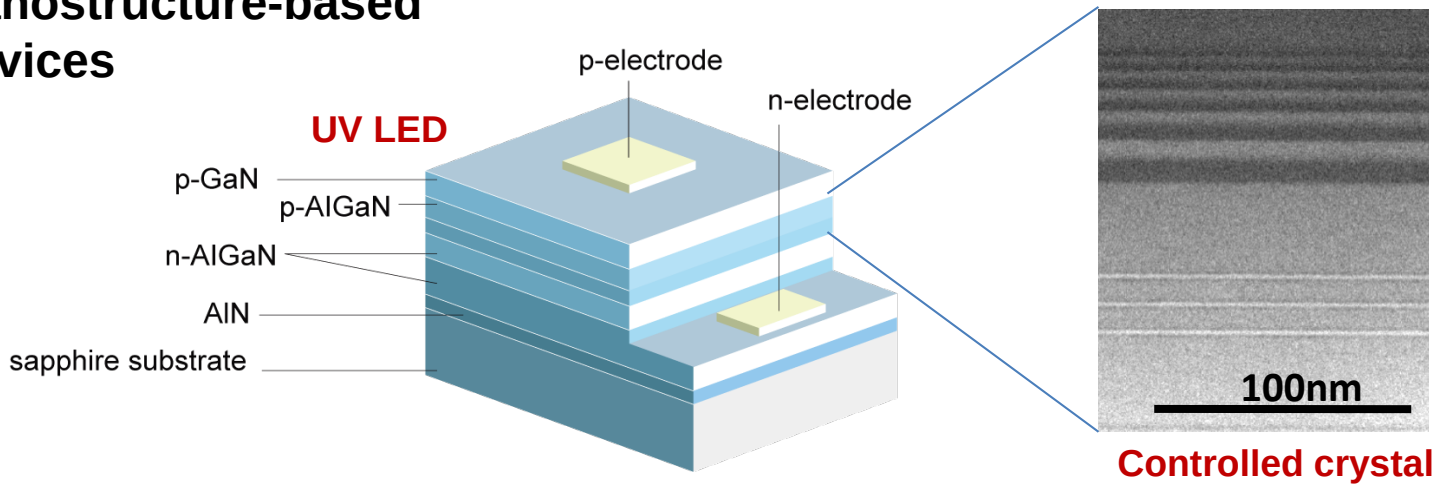
=> What is the mechanism that make the BMP profile independent of embryo size?

Crystal growth with data assimilation

Quantum Optodevice Lab., RIKEN
M. Jo

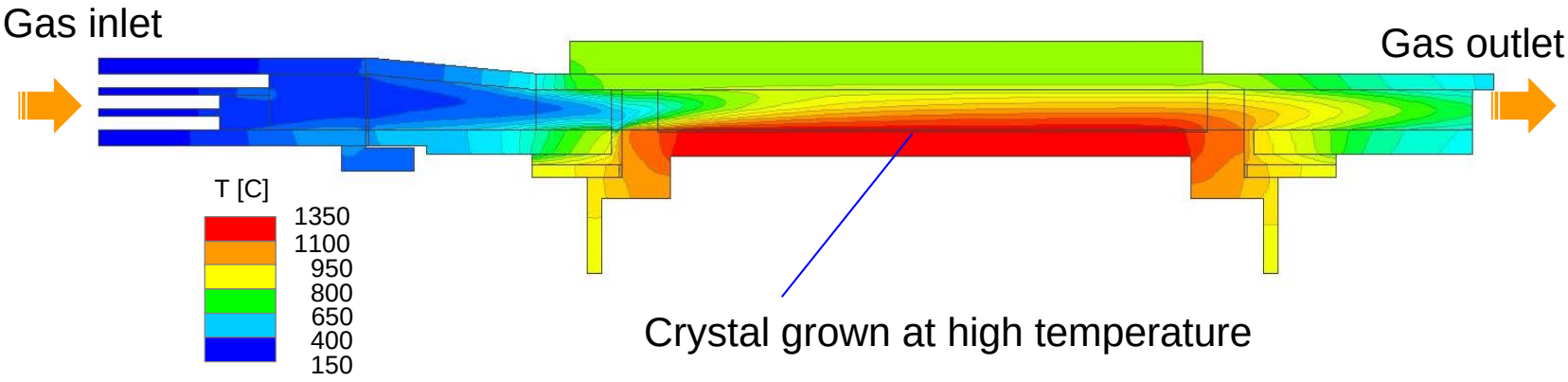
Producing the desired structures based on the growth history data

Nanostructure-based devices



Controlled crystal structures

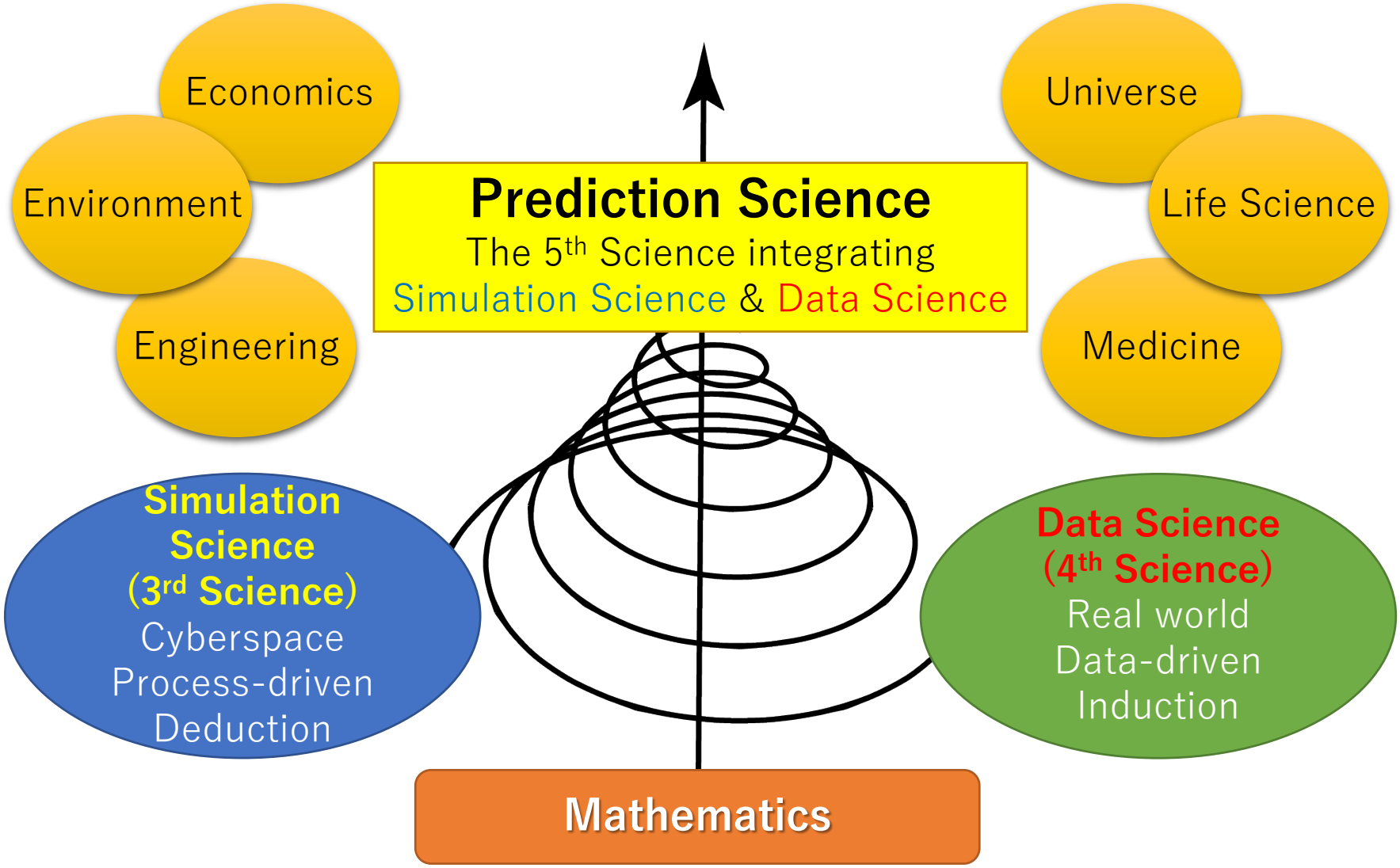
Simulation model of crystal growth



Invited Speakers

- Youssef Marzouk (MIT)
- Omar Knio (KAUST)
- Loic Giraldi (KAUST)
- Olivier Le Maitre (LIMSI-CNRS)
- Pierre Tandeo (IMT-Atlantique)
- Mohamed Iskandarani (University of Miami)
- Serge Guillas (University College London)

7 lecturers + 32 participants from 6 countries


Economics
Environment
Engineering
Universe
Life Science
Medicine
Prediction Science
The 5th Science integrating
Simulation Science & Data Science
Simulation Science (3rd Science)
Cyberspace
Process-driven
Deduction
Data Science (4th Science)
Real world
Data-driven
Induction
Mathematics