"Big Data Assimilation"

Revolutionizing Weather Prediction

Data Assimilation Team

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RIKEN K computer

RIKEN Advanced Institute for Computational Science

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BDA BIG DATA ASSIMILATION CREST JST 独立行政法人 科学技術振興機構 Japan Science and Technology Agency

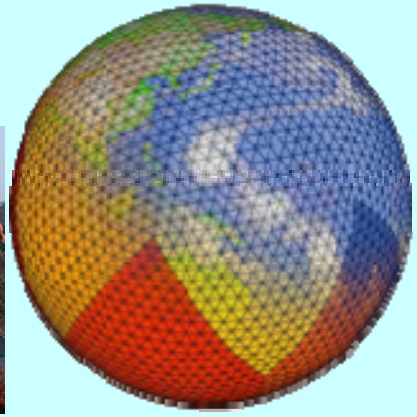
S. Satoh, T. Ushio, H. Tomita, Y. Ishikawa, K. Bessho, H. Seko

Data Assimilation (DA)

Observations

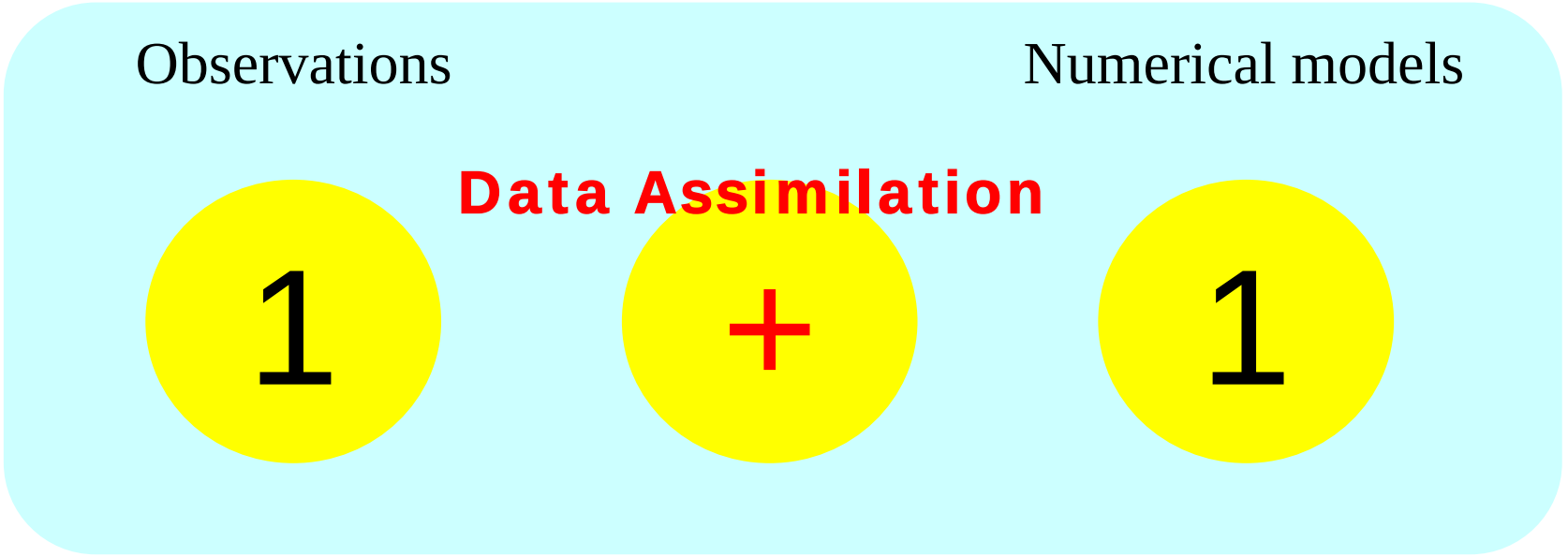
Data Assimilation

Numerical models



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

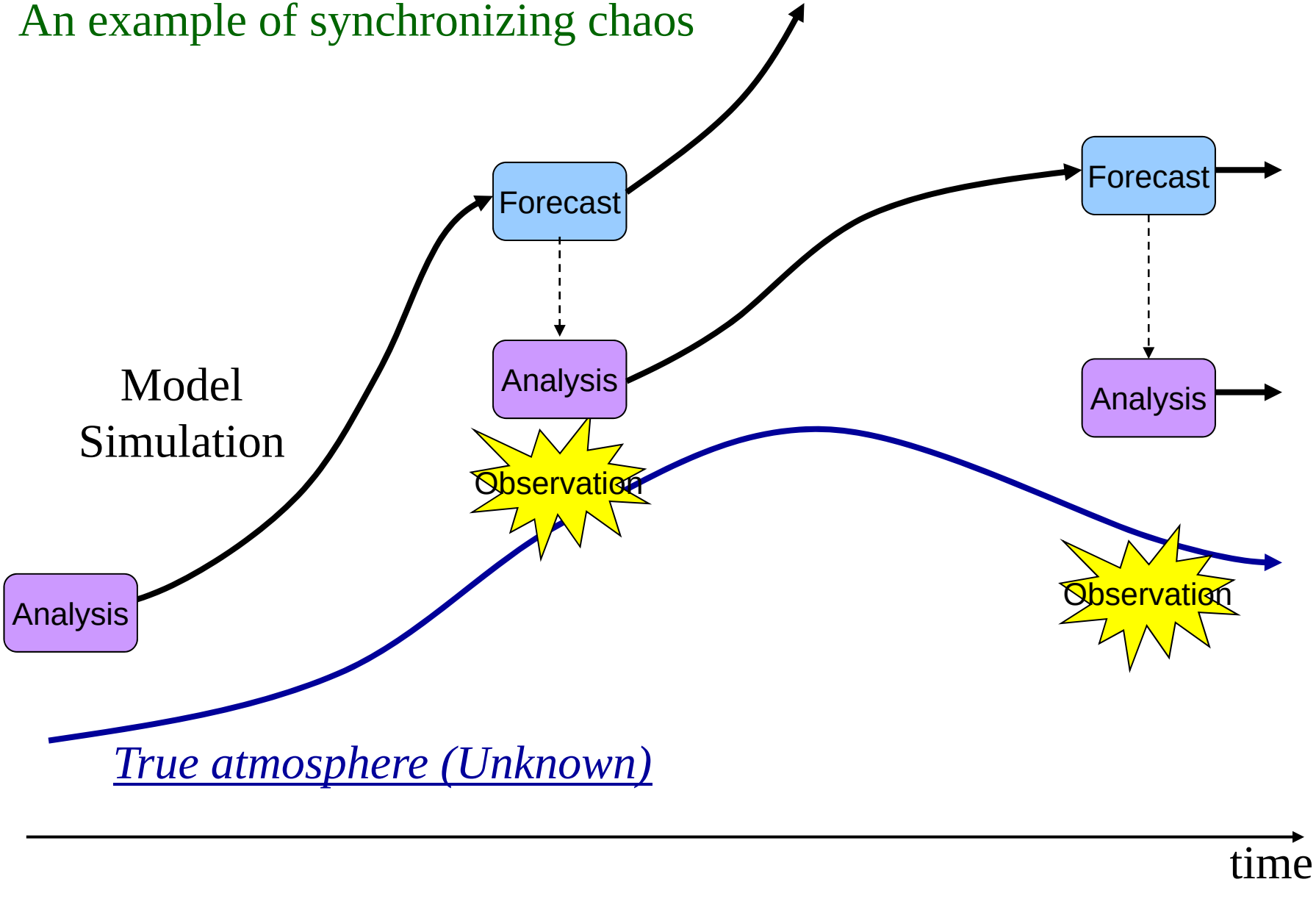
Data Assimilation (DA)



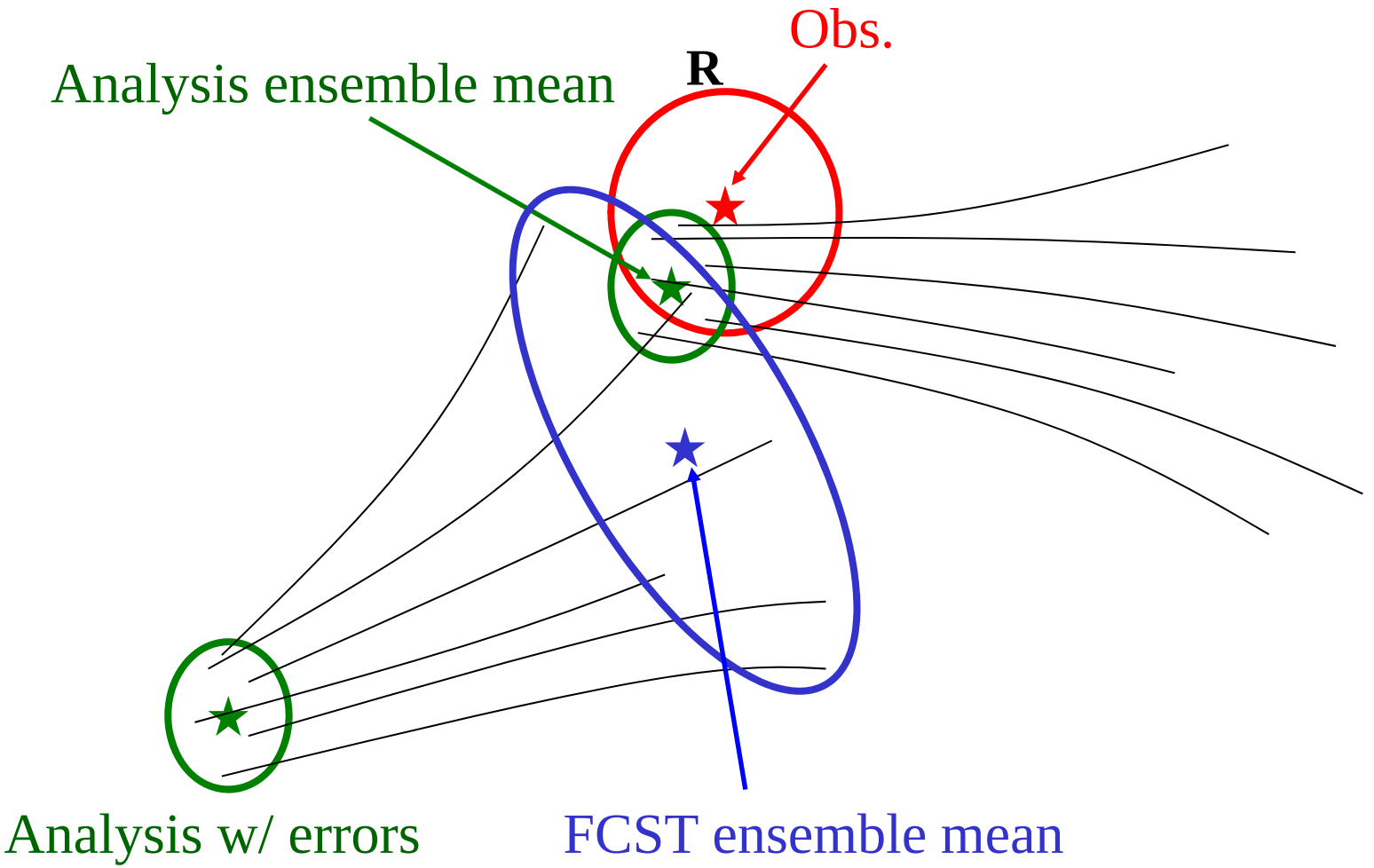
> 2

Numerical Weather Prediction

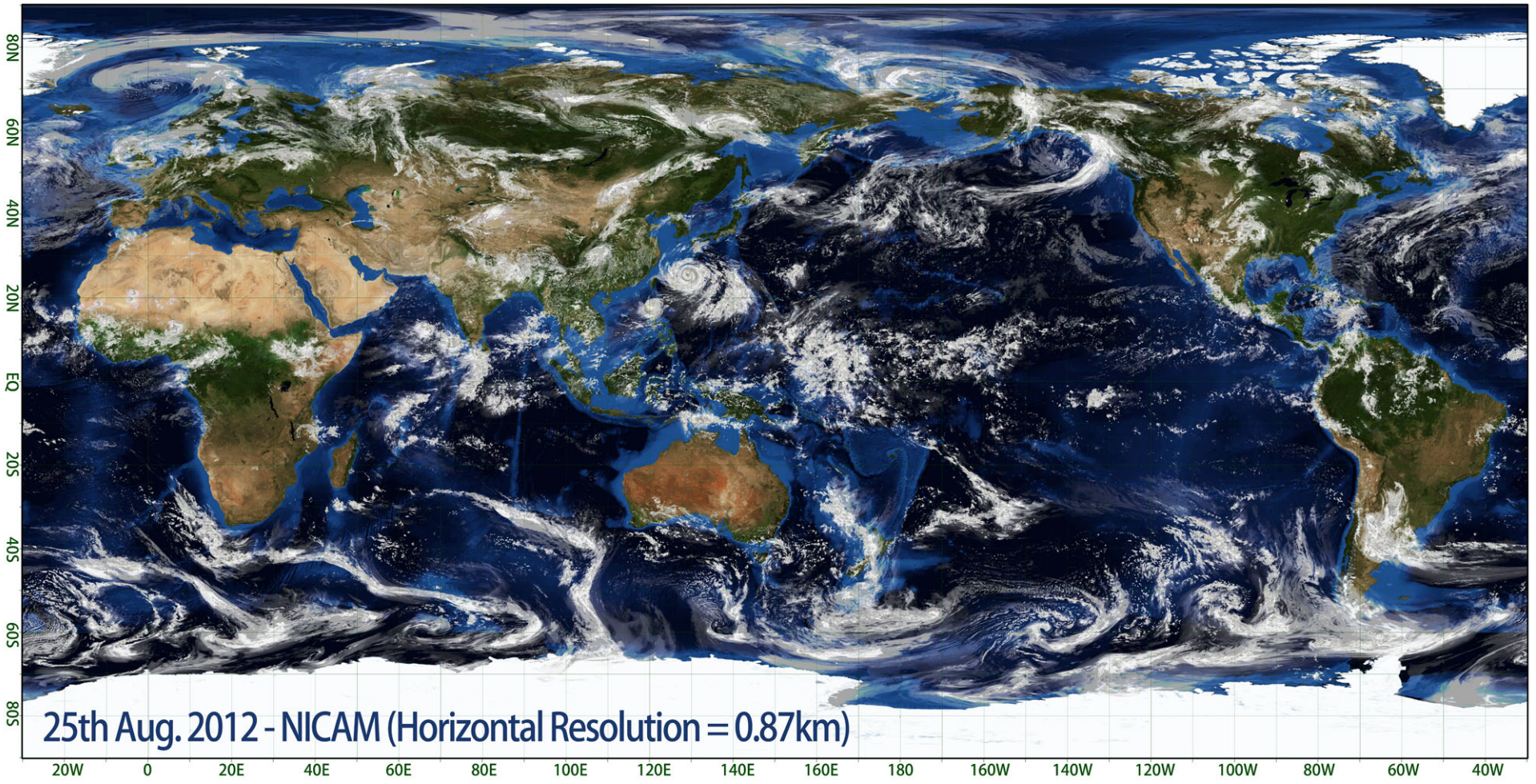
An example of synchronizing chaos



We consider the evolution of PDF



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



Visualized by Ryuji Yoshida

Computers getting more powerful…

- With the “post-K” supercomputer (~2020), we can afford 100 members of global 870-m simulation.
- Or a larger ensemble at a lower resolution?

The Japanese 10-Peta-Flops K computer ©RIKEN

Press Release

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July 23, 2014

K computer runs largest ever ensemble simulation of global weather

Ensemble forecasting is a key part of weather forecasting today. Computers typically run multiple simulations, called ensembles, using slightly different initial conditions or assumptions, and then analyze them together to try to improve forecasts. Now, in research published in *Geophysical Research Letters*, using Japan's flagship 10-petaFLOPS K computer, researchers from the RIKEN Advanced Institute for Computational Science (AICS) have succeeded in running 10,240 parallel simulations of global weather, the largest number ever performed, using data assimilation to reduce the range of uncertainties.

The assimilation of the 10,240 ensemble data sets was made possible by a cross-disciplinary collaboration of data assimilation experts and eigenvalue solver scientists at RIKEN AICS. The "Local Ensemble Transform Kalman Filter" (LETKF), an already efficient system, was further improved by a factor of eight using the "EigenExa" high-performance eigenvalue solver software, making possible a three-week computation of data from the 10,240 ensembles for simulated global weather. By analyzing the 10,240 equally probable estimates of atmospheric states, the team discovered that faraway observations, even going beyond 10,000 kilometers in distance, may have an immediate impact on eventual state of the estimation. This finding suggests the need for further research on advanced methods that can make better use of faraway observations, as this could potentially lead to an improvement of weather forecasts.

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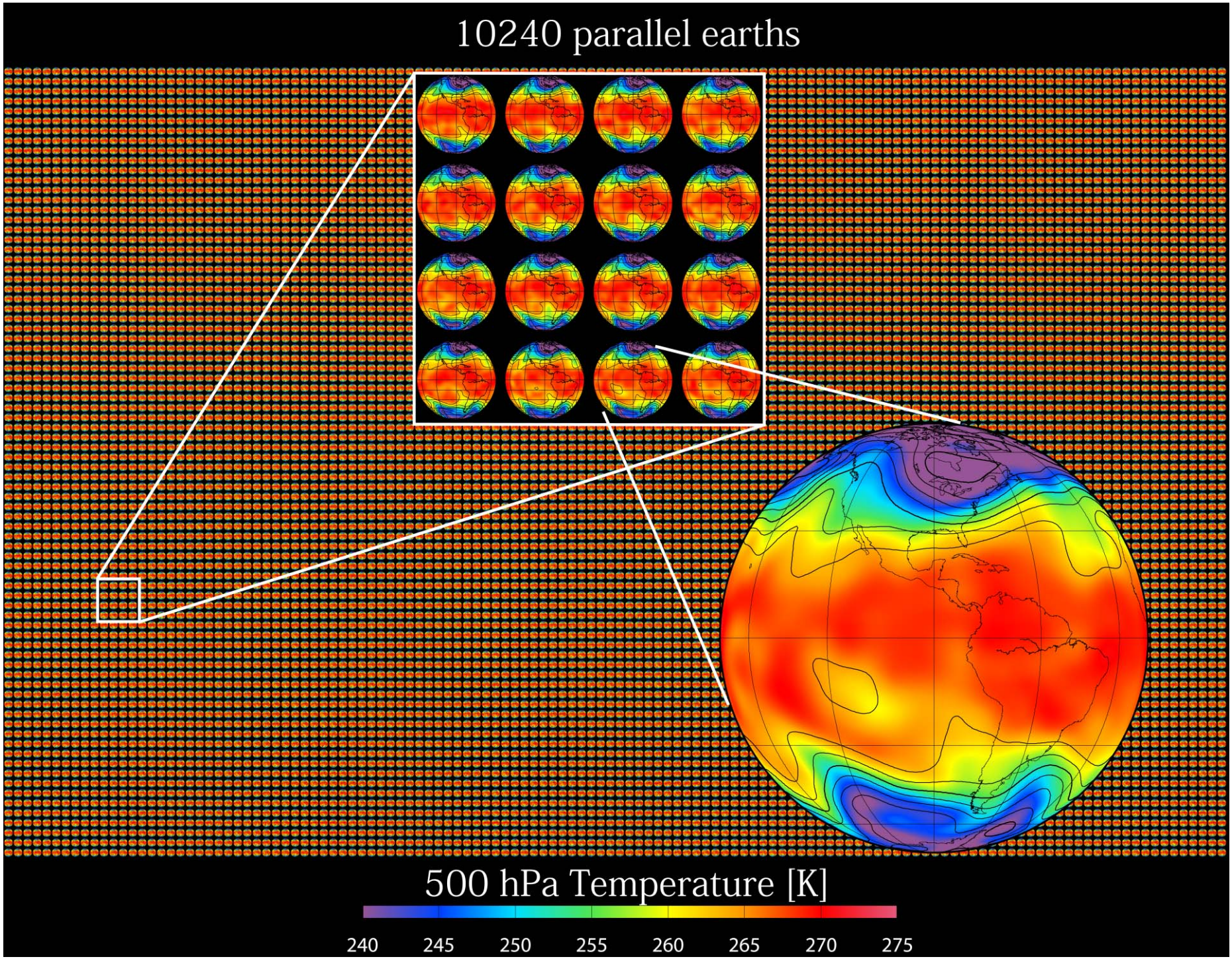
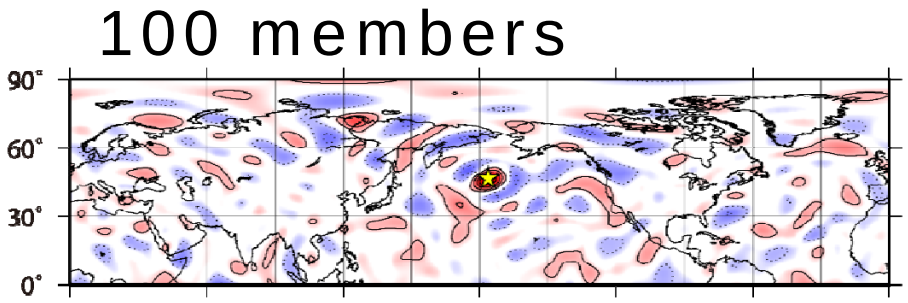
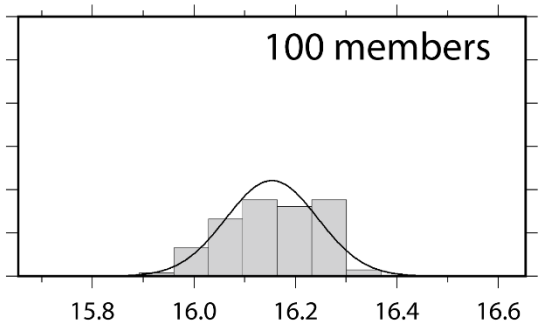
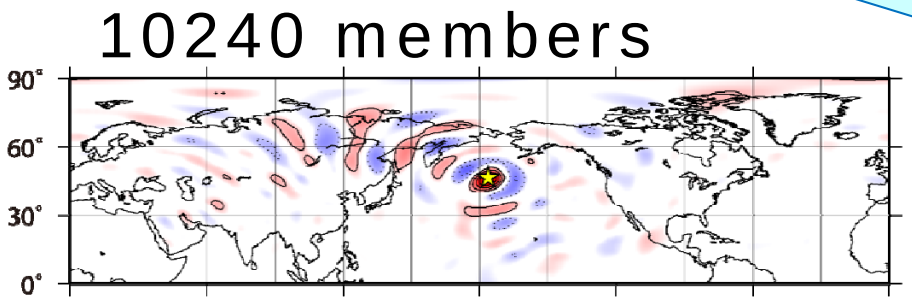

10240 parallel earths
500 hPa Temperature [K]
240
245
250
255
260
265
270
275

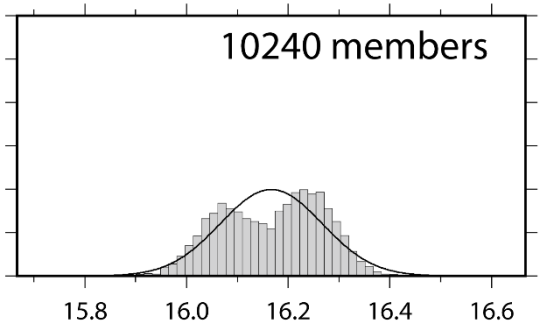
Advantage of large ensemble

(Miyoshi, Kondo, Imamura 2014)









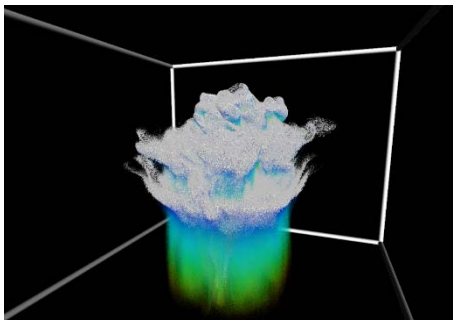
Sampling noise reduced

High-precision probabilistic representation

Cf. P-26 Kondo, Tue

Toward next 20 years of DA

"Big Data Assimilation" Era



Courtesy of S. Shima

Exploding data

Enabling effective use

Big Data

Big Data

High-resolution simulation

High-resolution obs

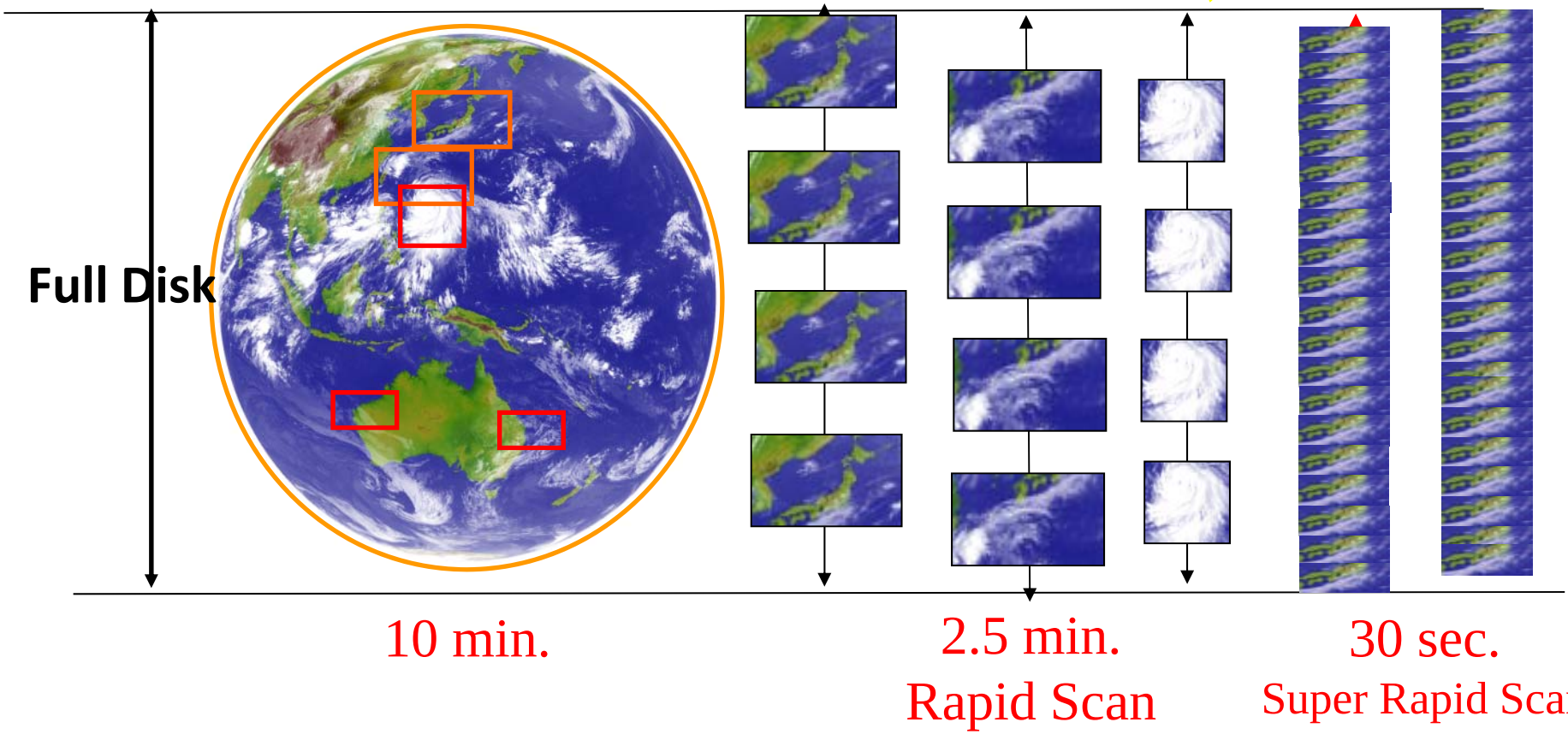
More computational power

Advanced obs technology

Next-generation geostationary satellite

Himawari-8 was launched successfully on 7 October 2014.
Himawari-9 will be launched in 2016.

Super Rapid Scan
every 30 seconds

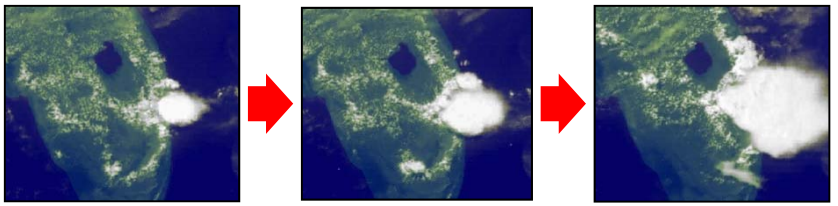


(Courtesy of JMA)

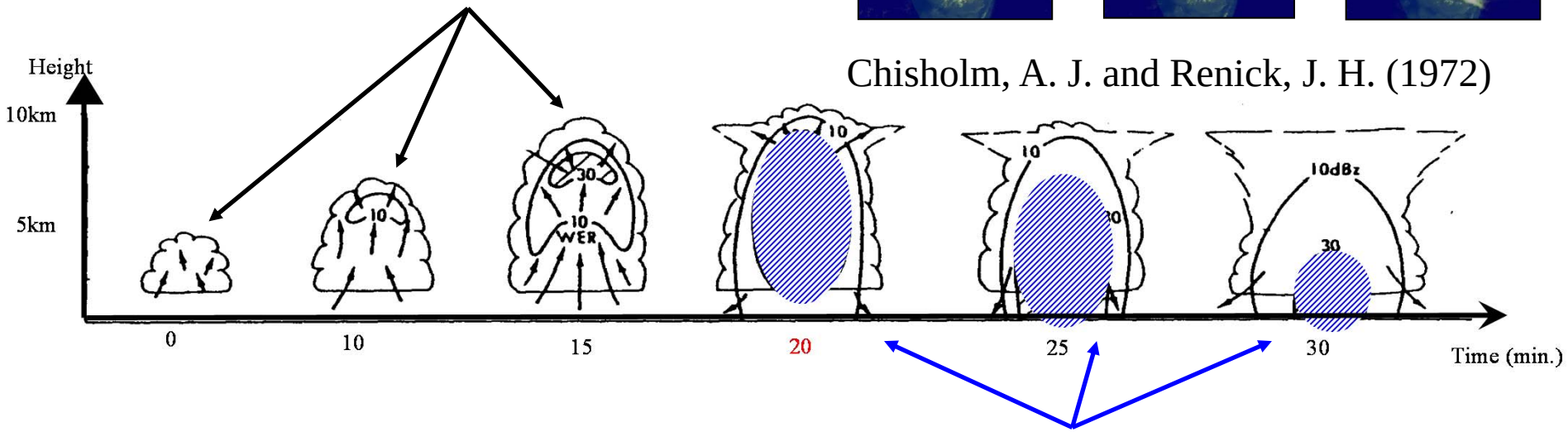
Rapid scan effective for convections

Typical lifetime of a convective system ~30 min.

Satellite imagery captures developing convections.

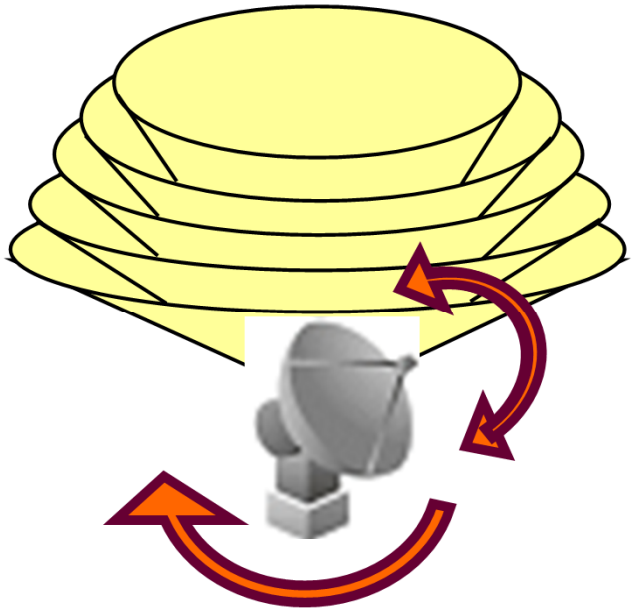


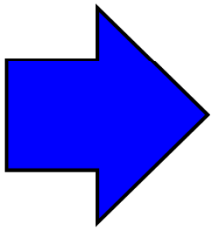
Chisholm, A. J. and Renick, J. H. (1972)



Radar captures rain particles after the developing stage. (may be too late…)

Phased Array Radar





(courtesy of NICT)

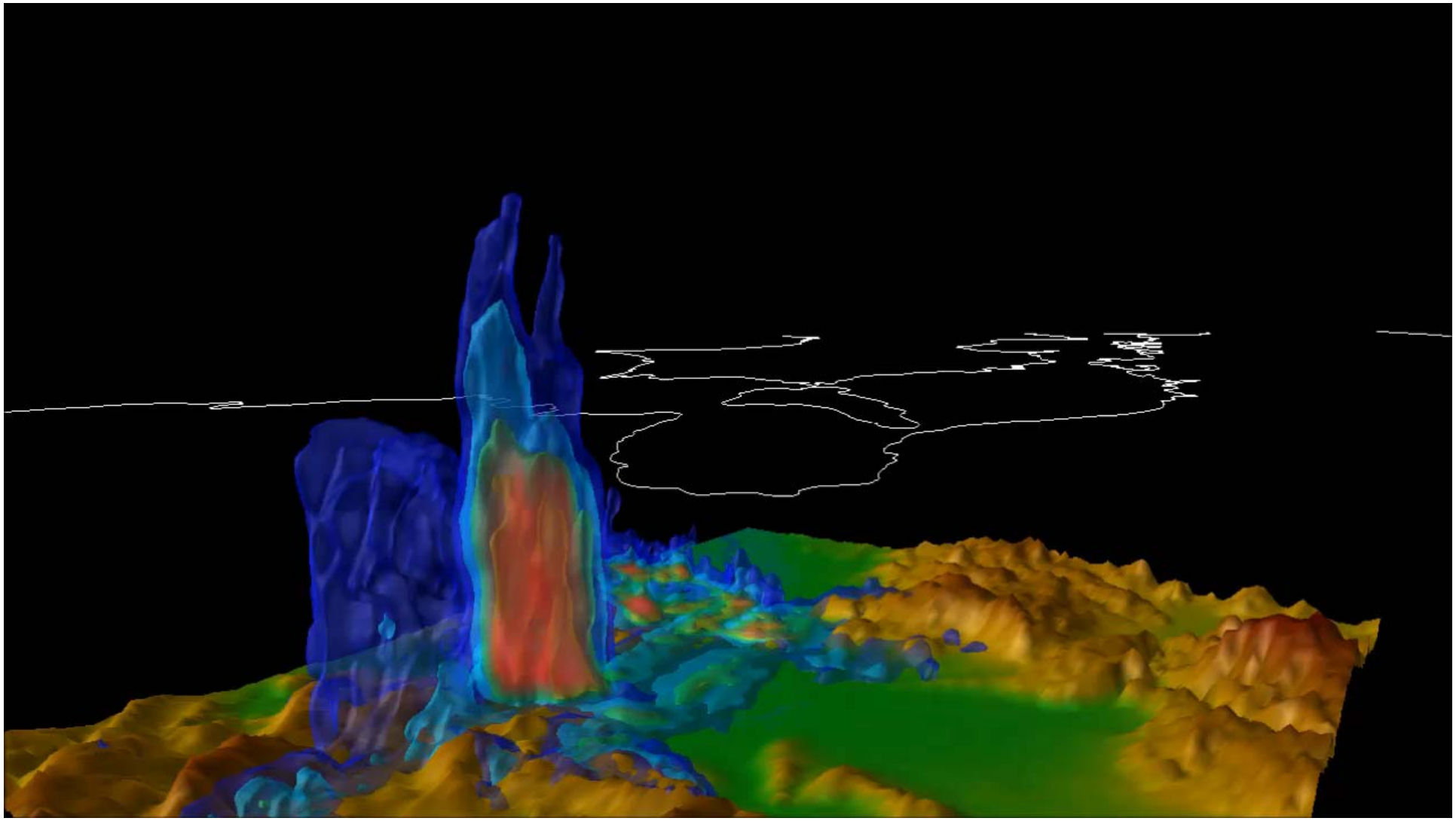
Conventional Radar

~15 scan angles
Every 5-10 minutes

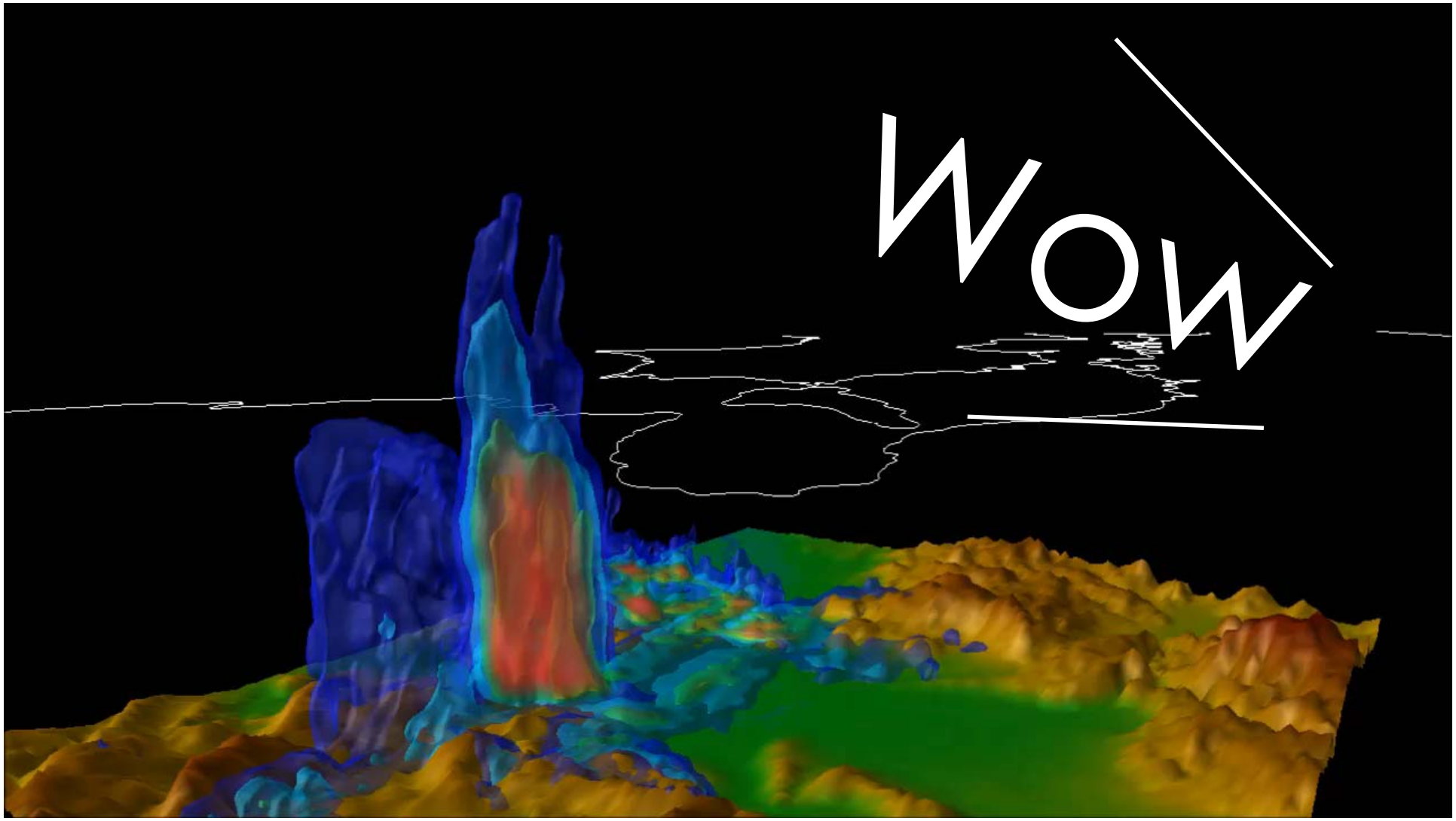
Phased Array Radar

~100 scan angles
Every 10-30 seconds

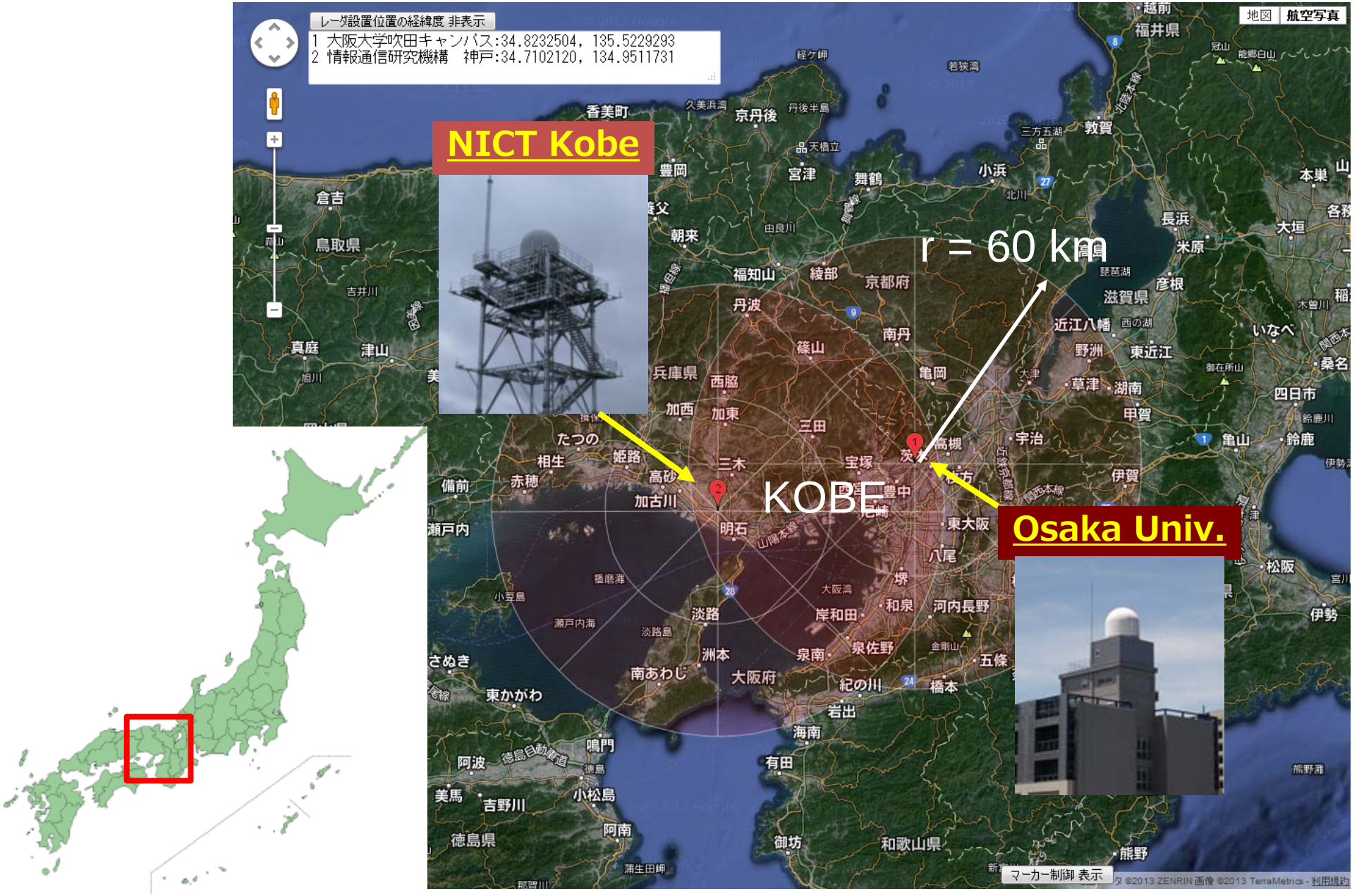
Conventional Radar (every 5 min.)



Phased Array Radar (every 30 sec.)



Two PAR in Kobe area

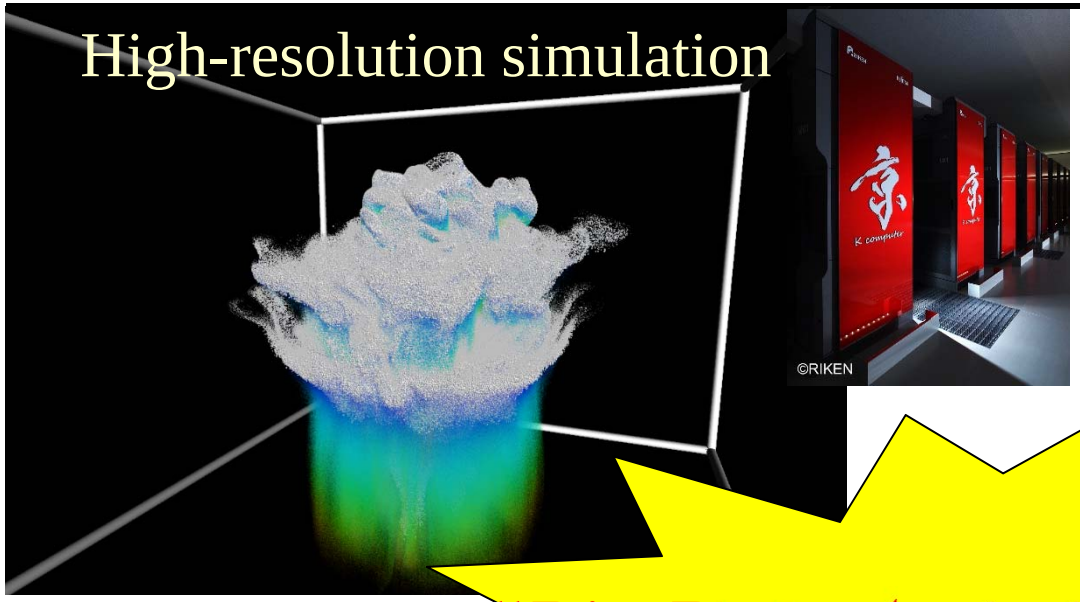


Exploring new data: live-camera images?

1. Reduced/extracted information (e.g., weather type, visibility)
   (challenge) Automated image processing

2. Simulating images from model outputs
   (challenge) precise 3-dimensional radiation model

Towards “Big Data Assimilation”



Combination of
next-generation technologies

“Big Data Assimilation”

Improving simulations

Storm forecasting with Big Data Assimilation

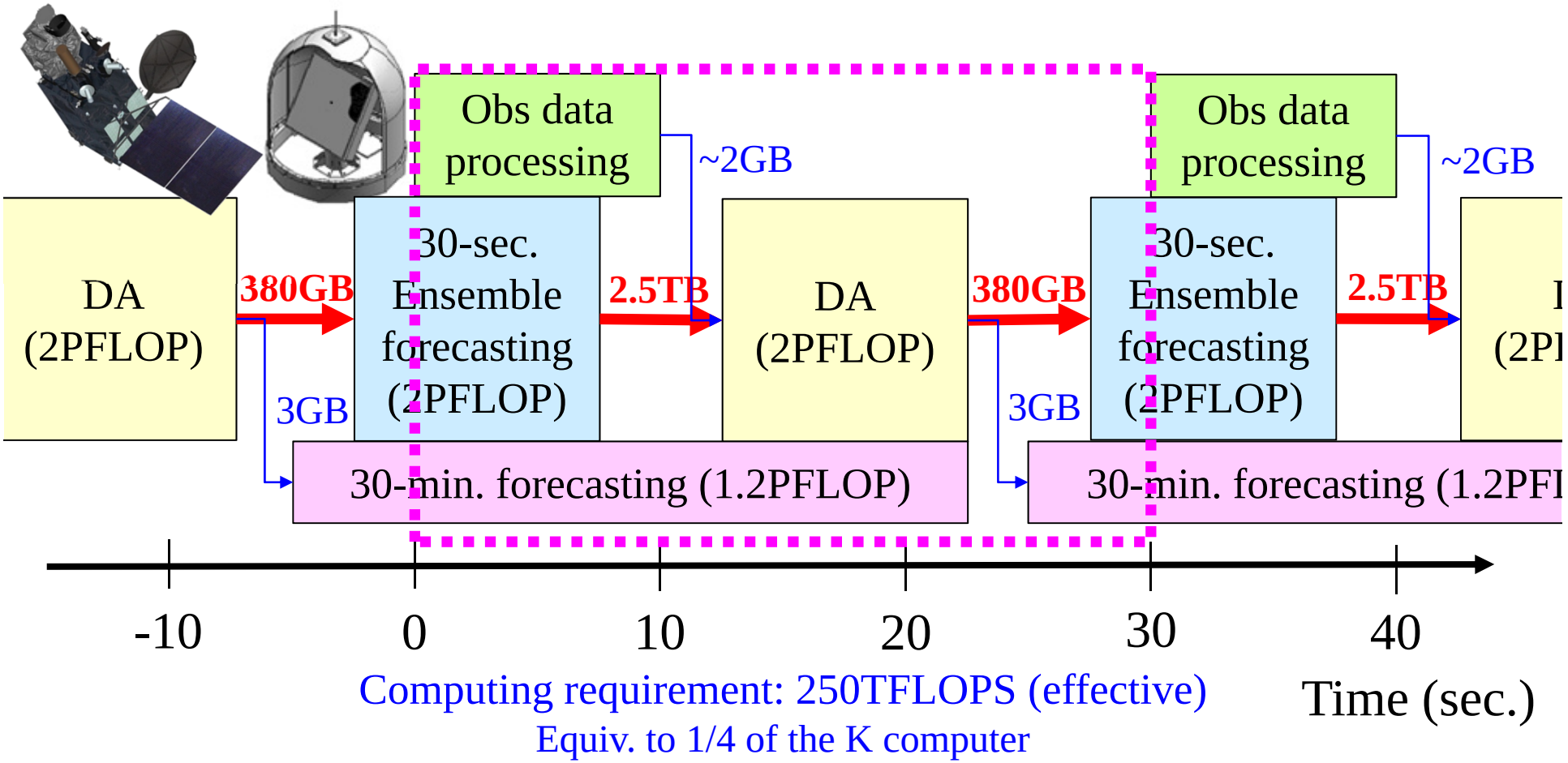
水位は 10分間で約1m30cm も上昇

5 people died in Kobe on July 28, 2008, due to local heavy rainfall

気象庁
Japan Meteorological Agency

Goal: 30-min forecasting of local severe weather through Big Data Assimilation innovations.

Revolutionary super-rapid 30-sec. cycle



Computing requirement: 250TFLOPS (effective)

Equiv. to 1/4 of the K computer

120 times more rapid than the hourly "Rapid Refresh"

A case selected for the first offline study

讀賣新聞

2013年(平成25年)
7月14日日曜日

猛暑のち局地的豪雨

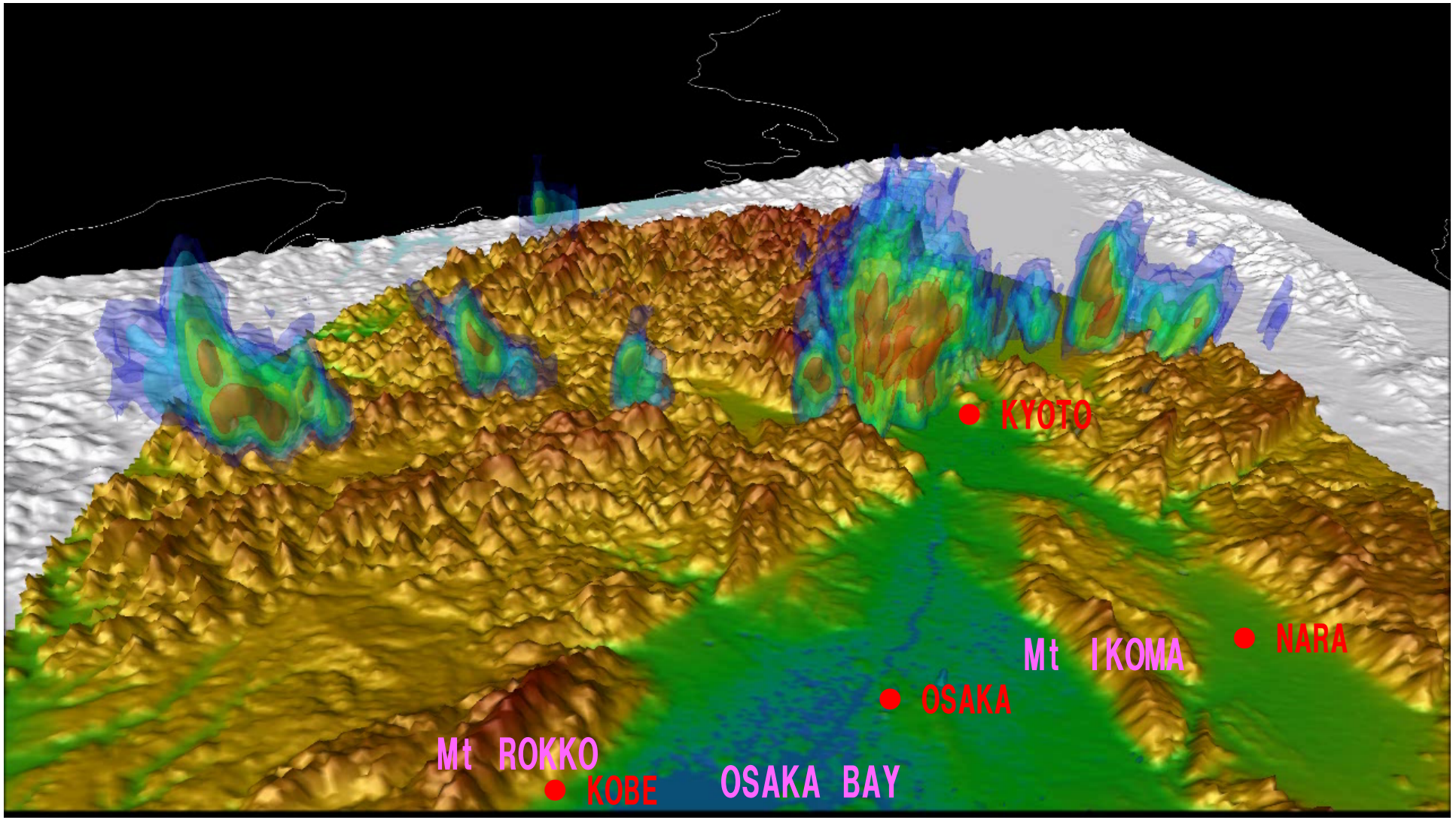
日本列島は13日、西日本を中心に引き続き猛暑となったが、午後には上空の寒気の影響で大気の状態が不安定になり、近畿や中国では局地的に落雷や激しい雨に見舞われた。

大阪管区気象台によると、1時間の降水量では、京都府京田辺市で56・5ミリ（午後4時27分まで）、広島県北広島町で50・5ミリ（午後5時半まで）を記録した。京都府宇治、城陽両市で床上浸水1軒、床下浸水22軒の被害が出たほか、京都市内で一時、約3300軒が停電した。

祇園祭の山鉾が並ぶ同市中心部では、午後2時過ぎから雷を伴う強い雨が降った。観光客らはアーケードの下で雨宿りするなか、芸舞妓が足元を気遣いながら道を急いでいた＝写真＝。（宇那木健一撮影）

The top page of Yomiuri newspaper
on 14 July, 2013

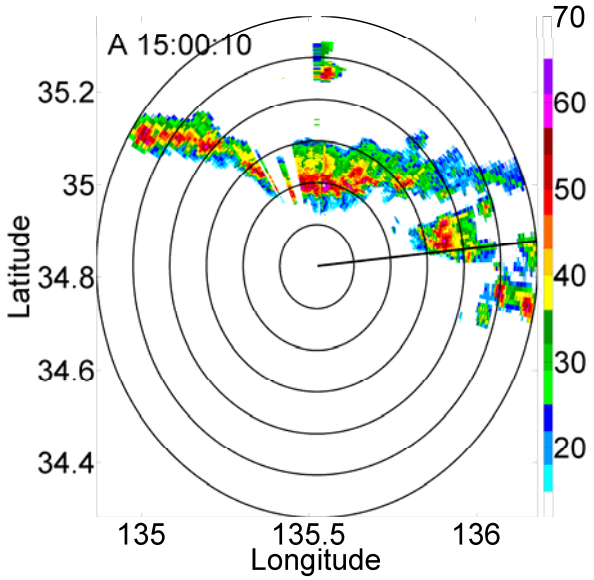
Phased Array Radar (2013/7/13, 14:00~16:20)

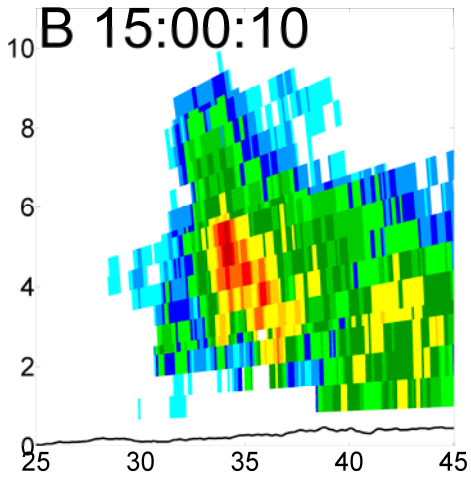


10fps → 300x

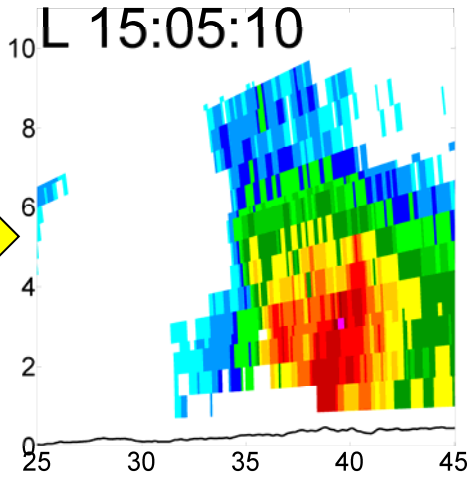
30-sec. and 5-min. evolutions

(Miyoshi et al. 2015)



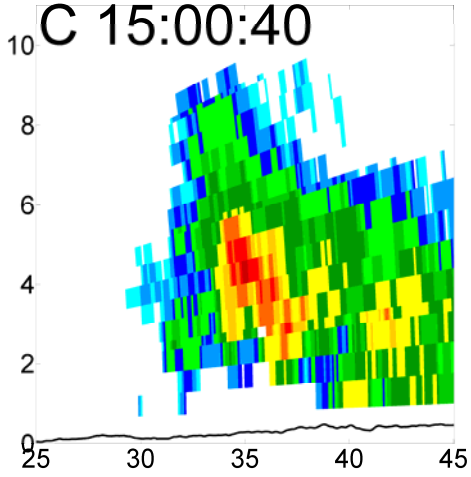


5 min



nonlinear evolution

30 sec

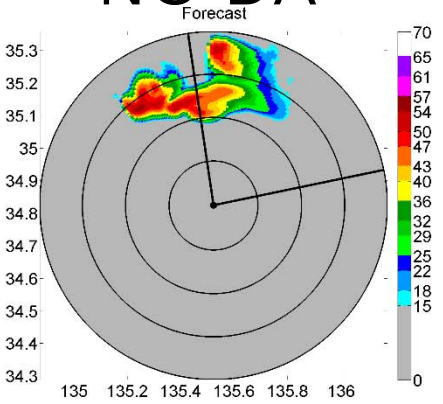


linear evolution

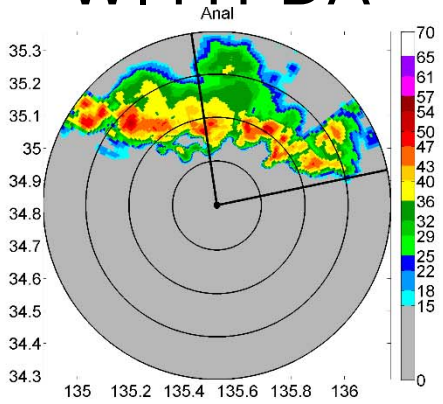
Impact of “Big Data Assimilation”

15:00:30 JST after the first assimilation

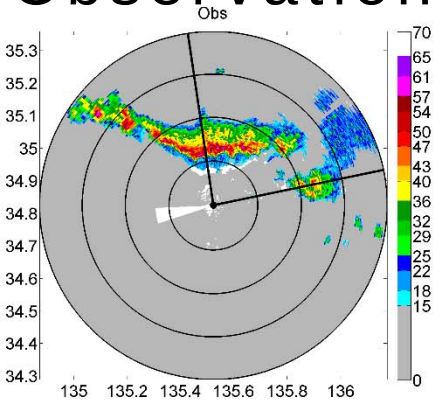
NO DA



WITH DA

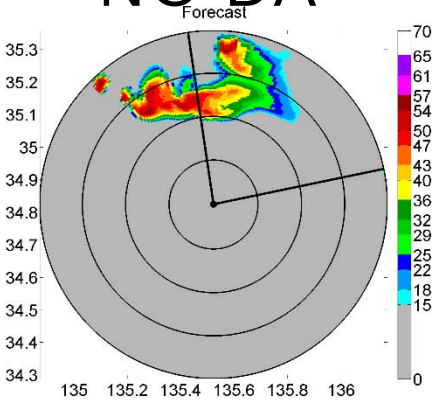


Observation

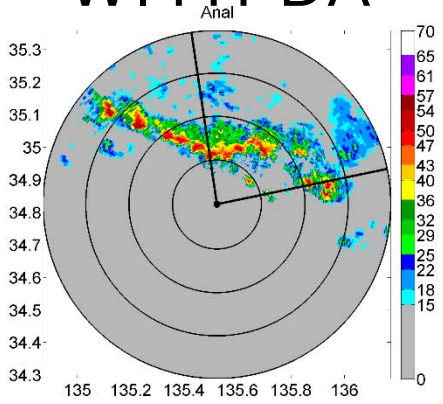


15:06:00 JST after the 12th assimilation

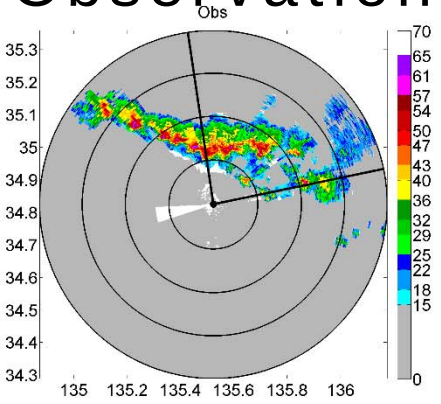
NO DA



WITH DA



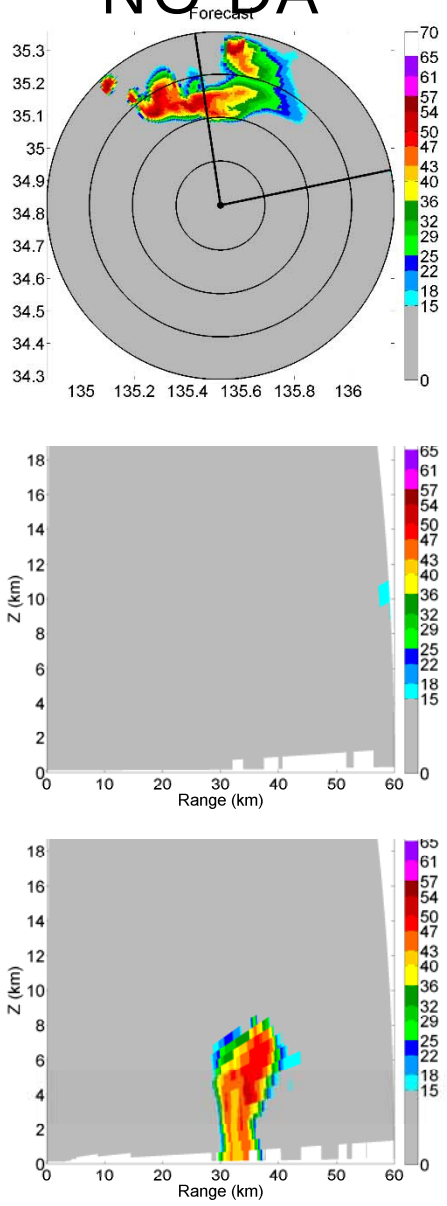
Observation



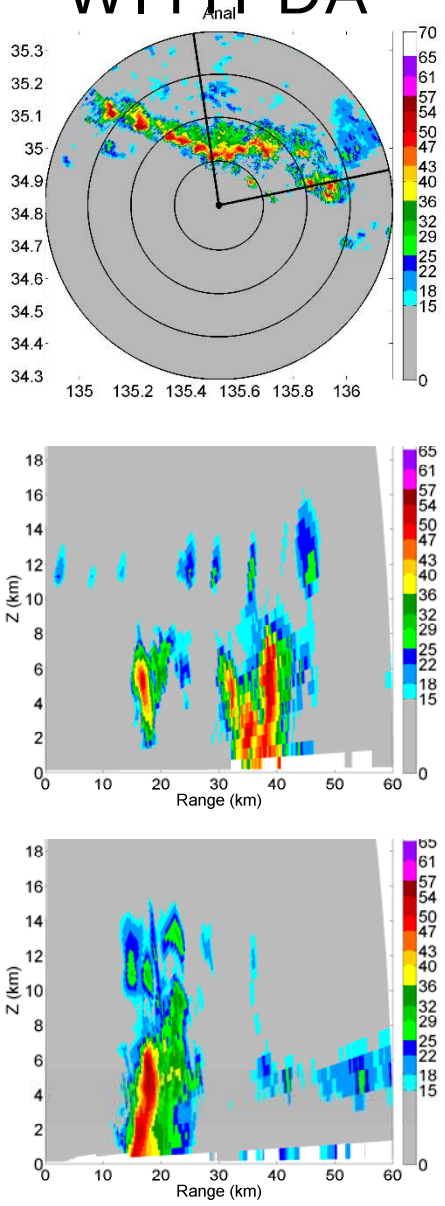
Vertical section

15:06:00 JST

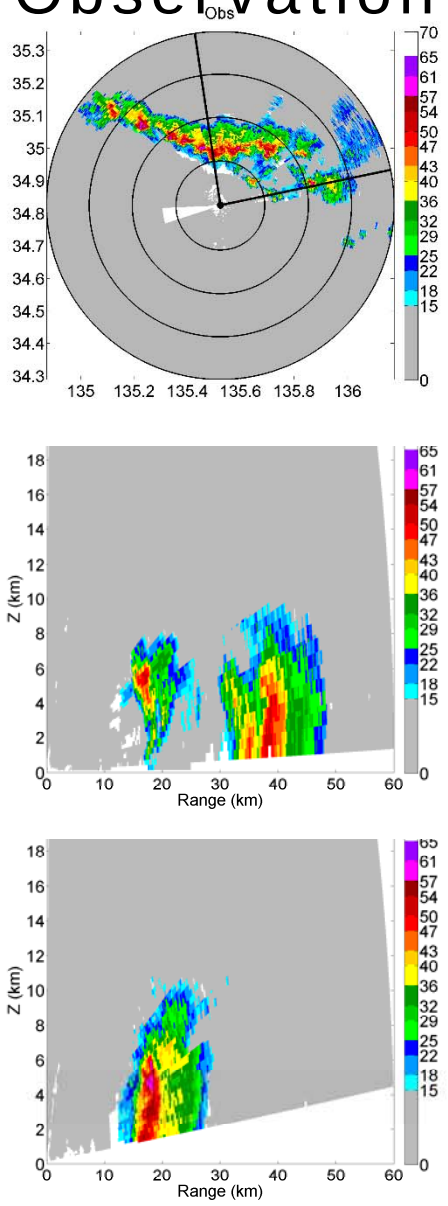
NO DA



WITH DA

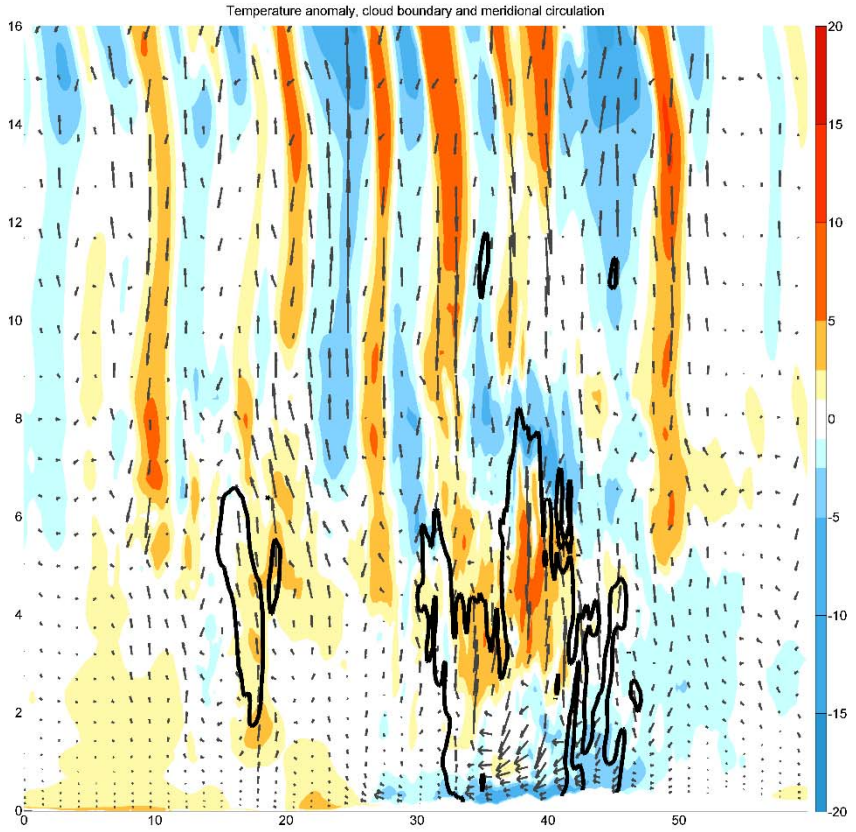


Observation



Thermodynamic structure

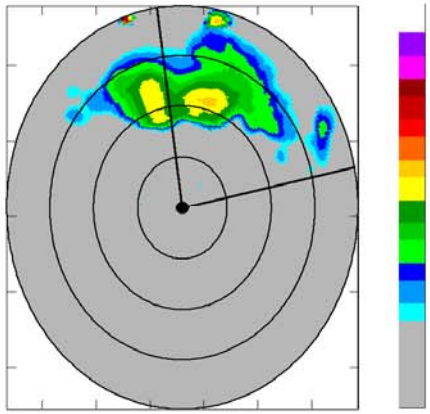
15:06:00 JST



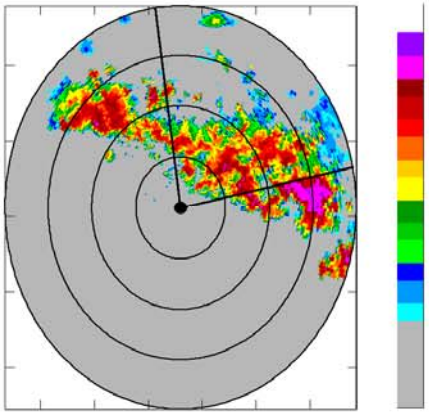
Forecasts

10-min. 15:06:00 JST → 15:16:00 JST

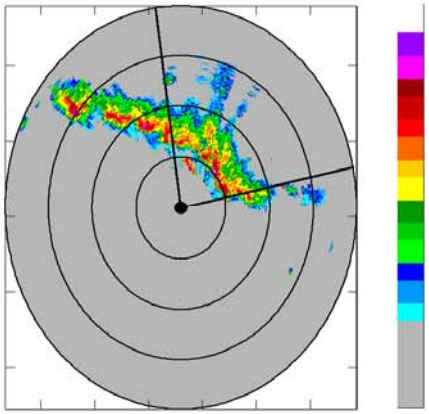
NO DA



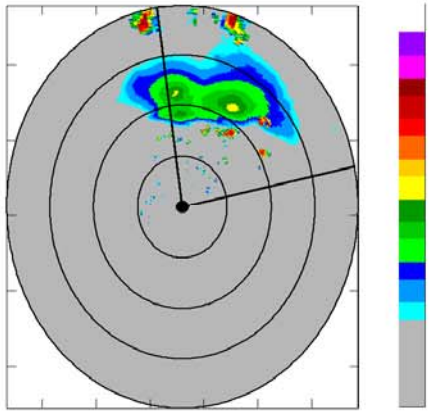
WITH DA

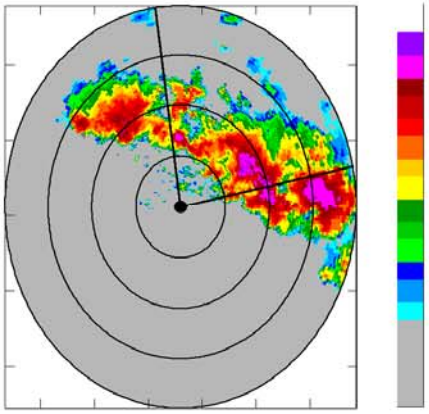


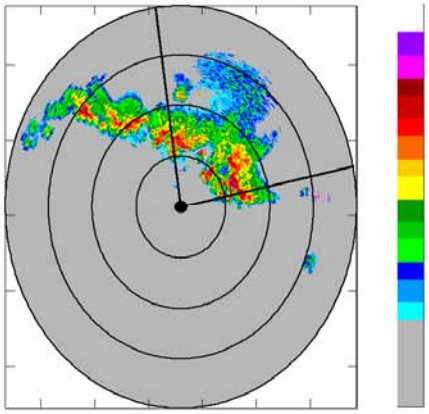
Observation



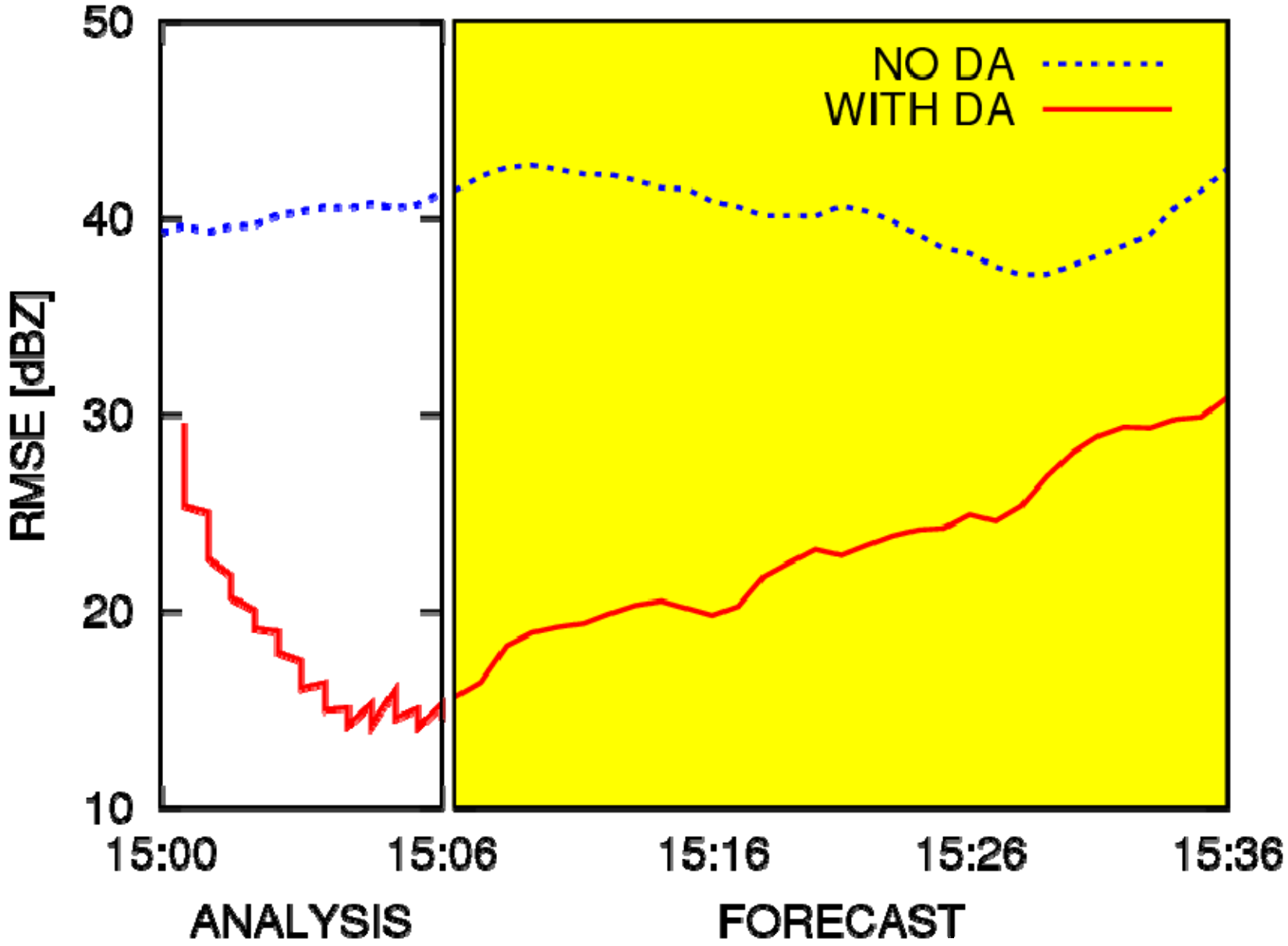
20-min. 15:06:00 JST → 15:26:00 JST



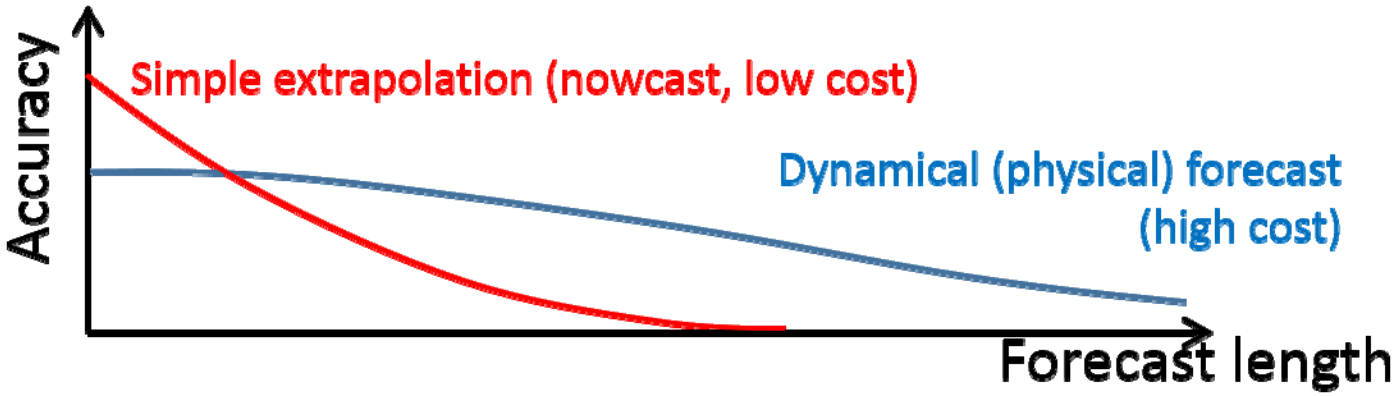


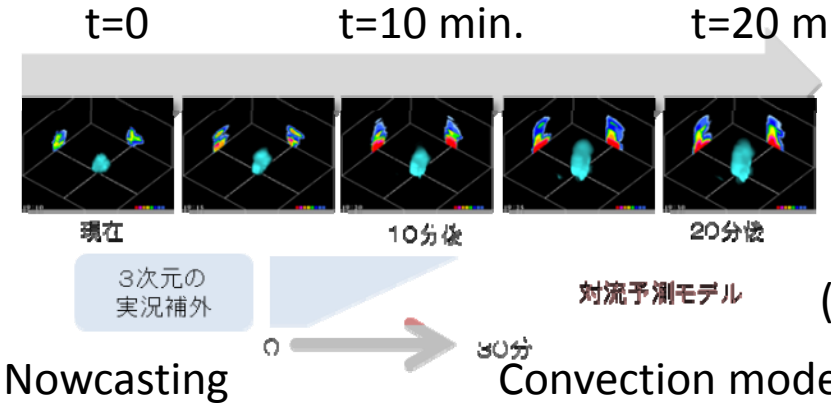


RMS Errors


50
40
30
20
10
RMSE [dBZ]
NO DA
WITH DA
15:00
15:06
15:16
15:26
15:36
ANALYSIS
FORECAST

Toward seamless prediction





(adopted from JMA webpage)

Nowcasting Convection model

A nowcasting system taking advantage of the dense/frequent PAWR data is explored.

Making sense of Big Data for local severe storms: Real-time processing of three-dimensional 30-second-update radar data -AICS HPC Internship program-

S. Otsuka, G. Tuerhong, J. Ruiz, and T. Miyoshi

Data Assimilation Research Team

Intern students:
R. Kikuchi (Tohoku Univ.),
Y. Kitano (Hokkaido Univ.),
and Y. Taniguchi (Univ. of Hyogo)

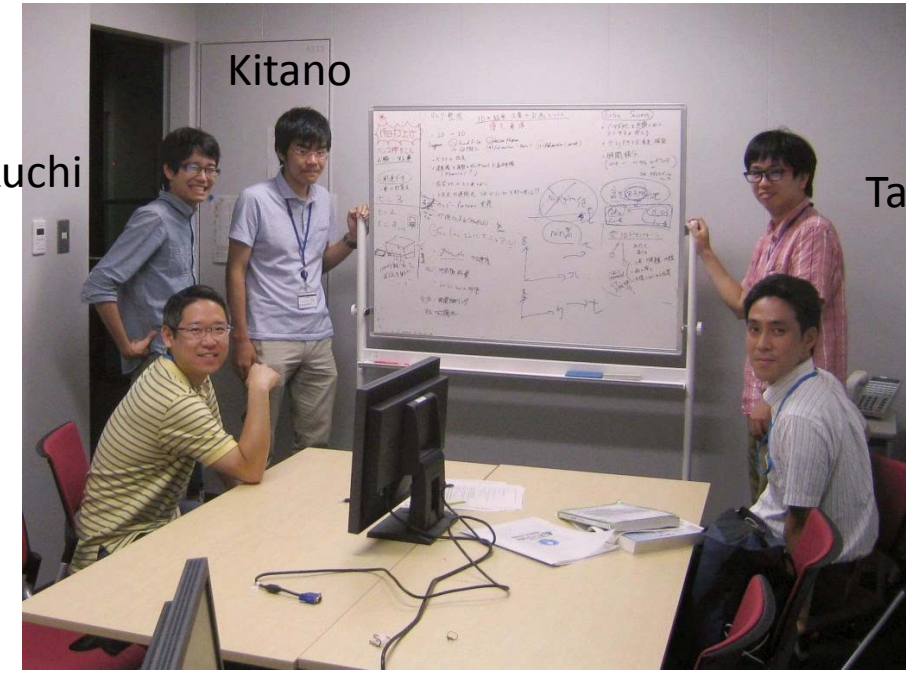
CREST Big Data Assimilation project:
H. Tomita, H. Seko, K. Bessho,
S. Satoh, T. Ushio, and Y. Ishikawa

Data Assimilation Team

BDA BIG DATA ASSIMILATION

AICS HPC Internship program 2014

- Three intern students from 8/29 to 9/19
  - R. Kikuchi (Tohoku Univ.)
  - Y. Kitano (Hokkaido Univ.)
  - Y. Taniguchi (Univ. of Hyogo)

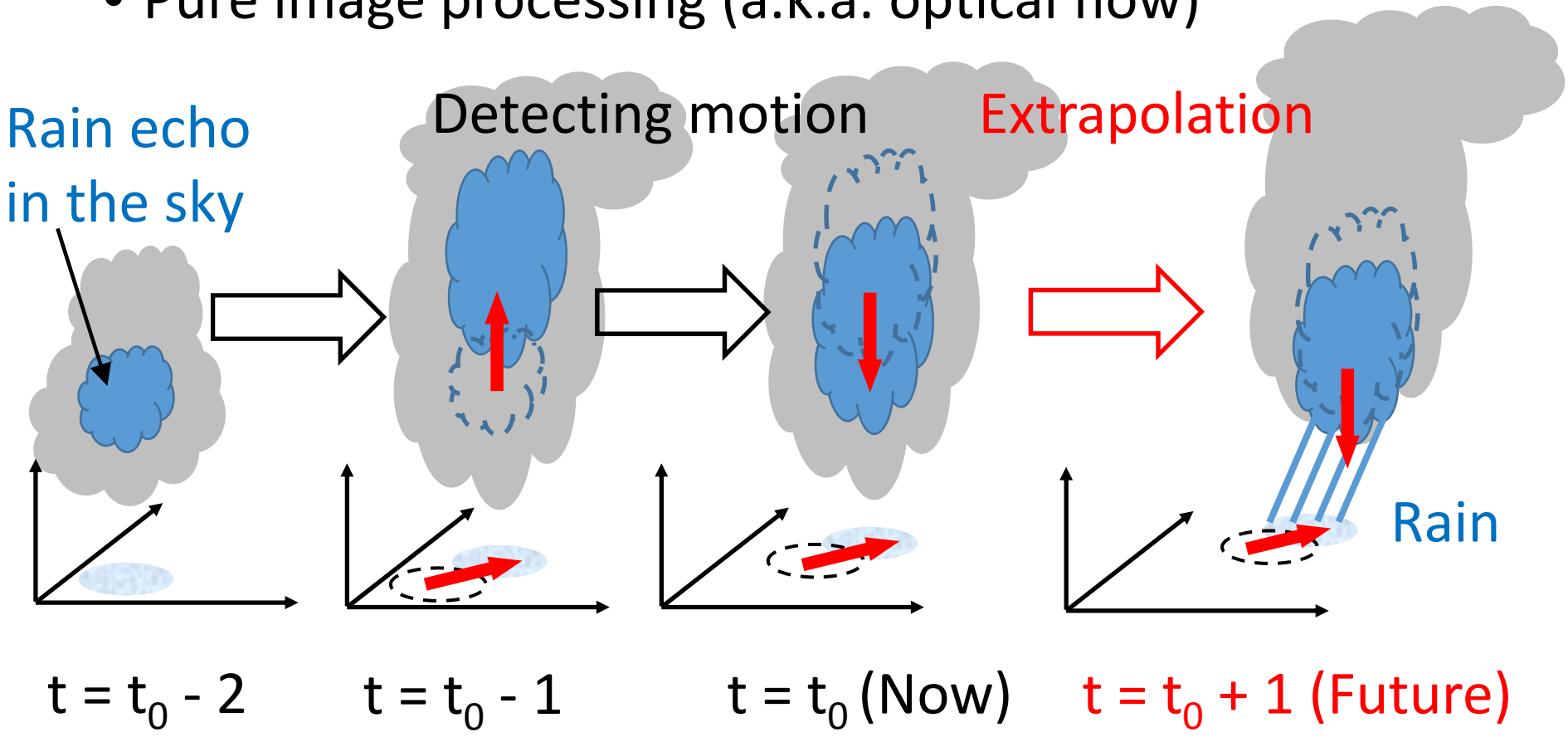


A nowcasting system using PAWR

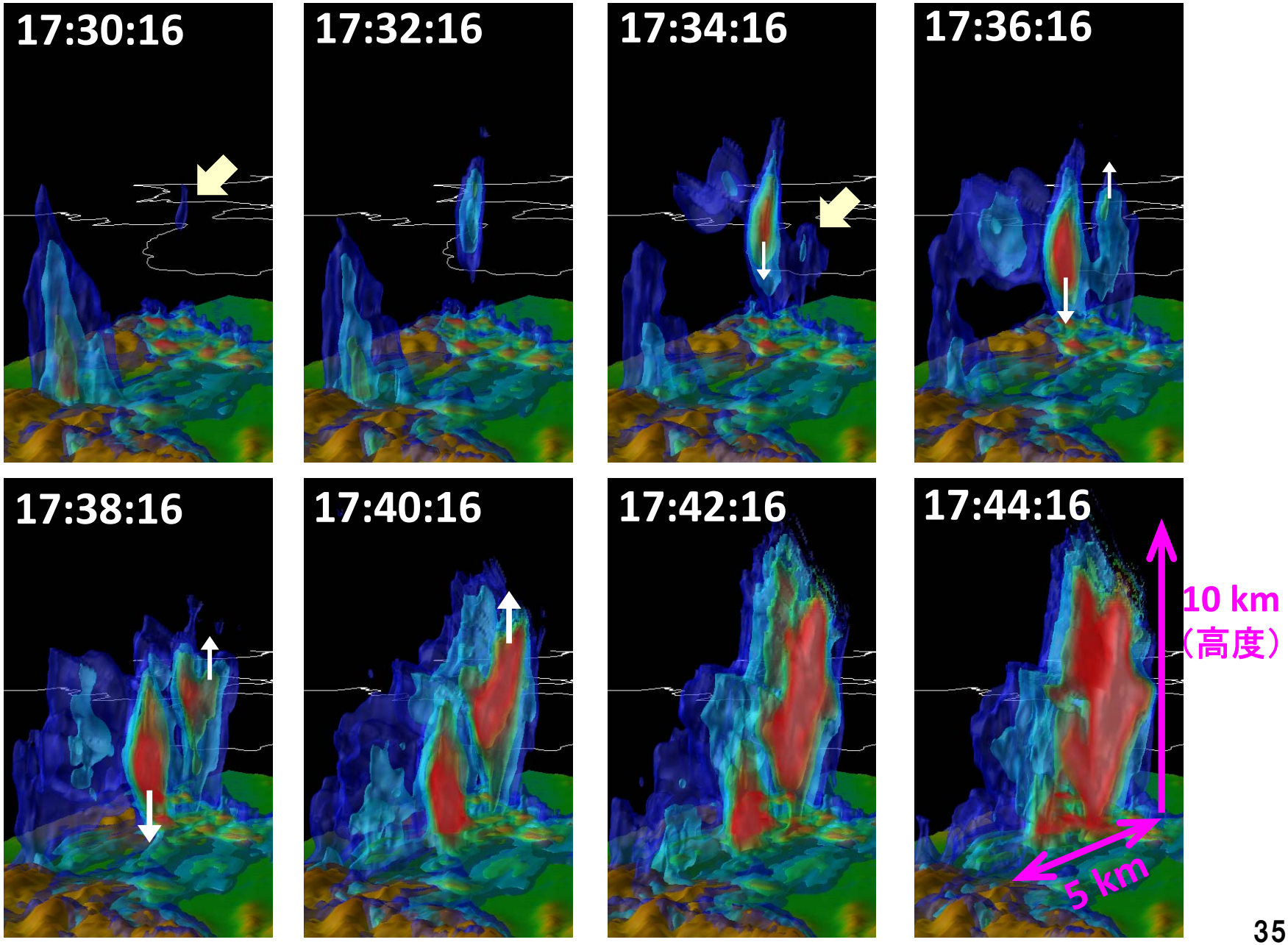
- Fully utilize the new vertically-dense and super-rapid PAWR
  - 100-m horizontal, 100-level vertical resolutions
  - 30-second time resolution
  - PAWR can capture high-precision 3D rain motion
- High-precision forecasts with a few minute lead
  - Purely based on PAWR data

2D vs. 3D

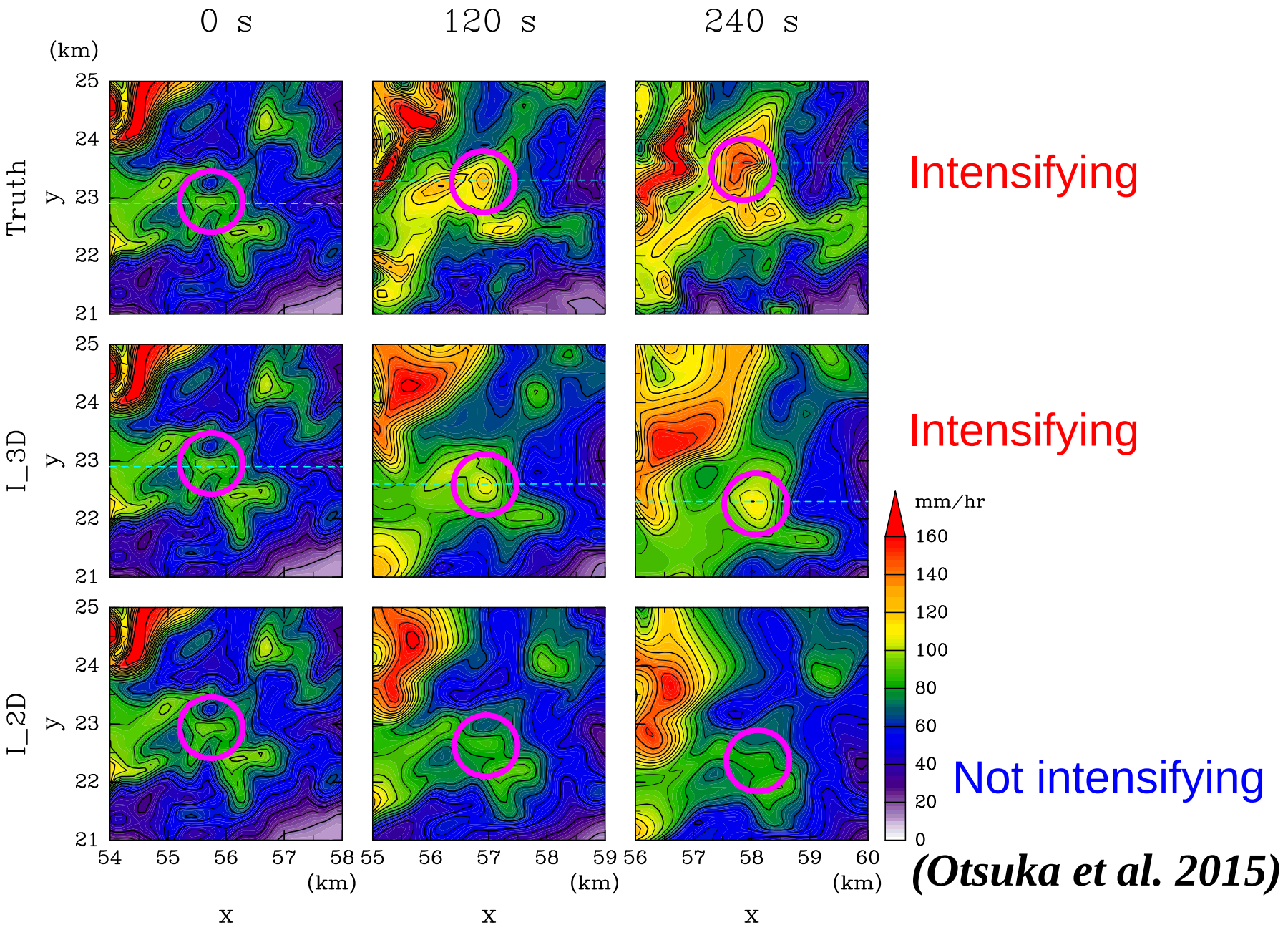
- 3D motion extrapolation
- Pure image processing (a.k.a. optical flow)



A real case: sky to the ground in 10 min.

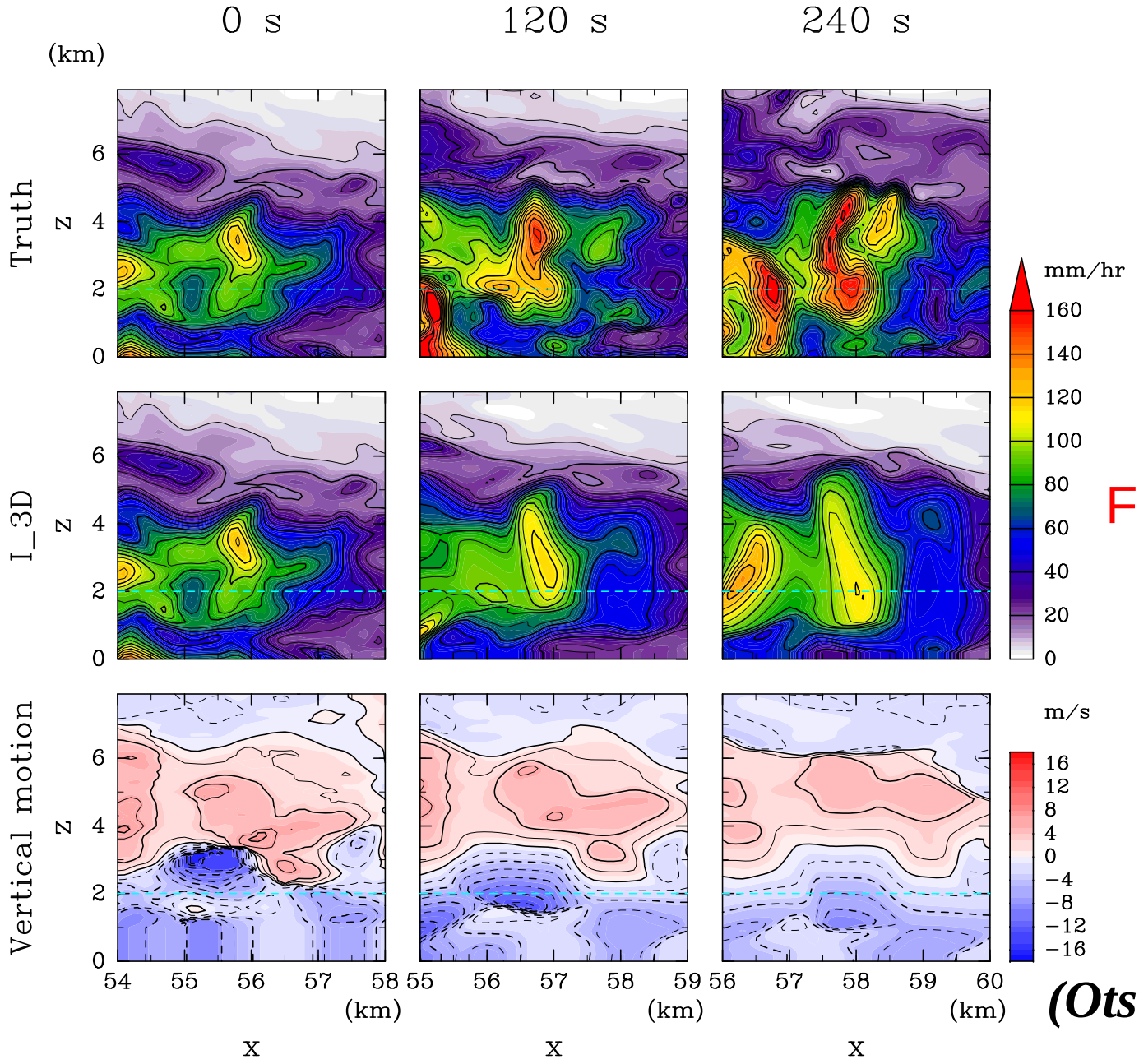


An idealized case: simulated rain



(Otsuka et al. 2015)

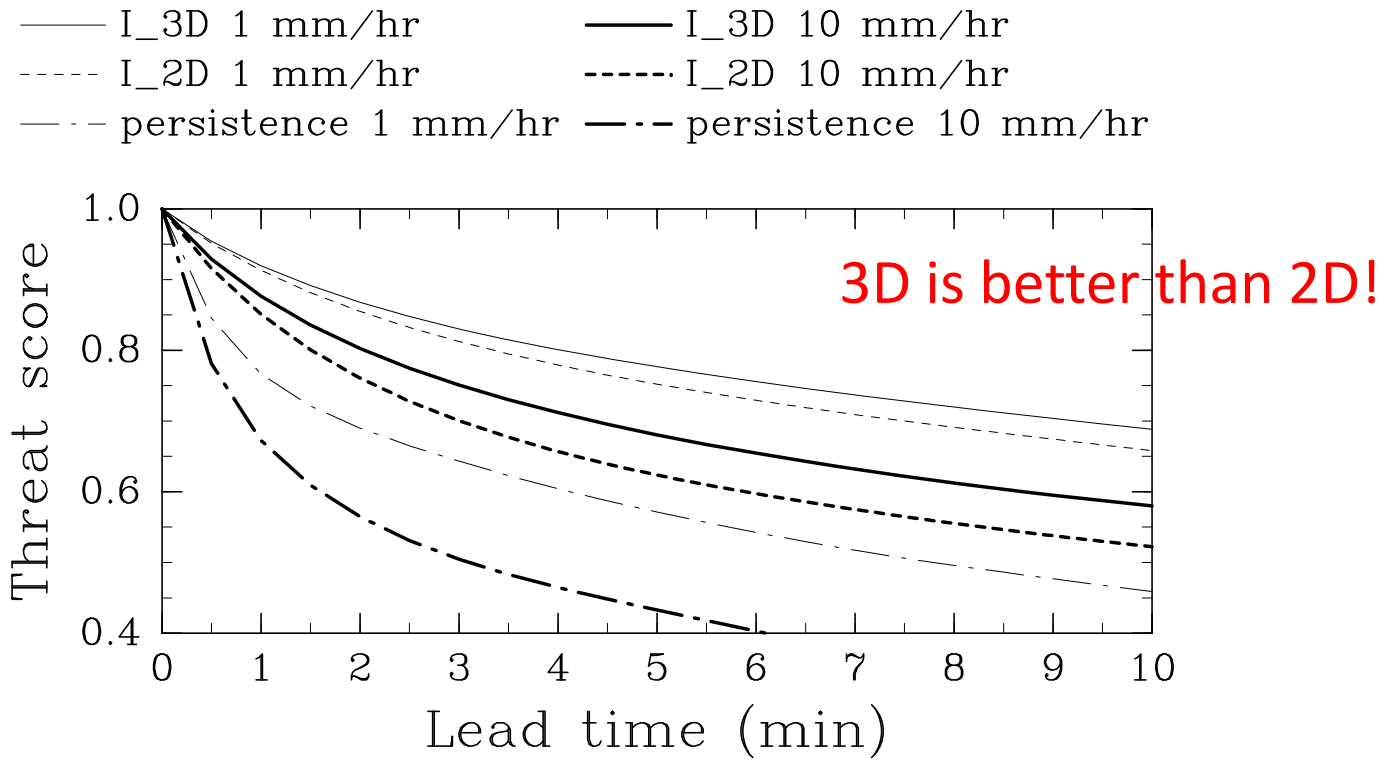
Vertical cross sections



Falling from sky

(Otsuka et al. 2015)

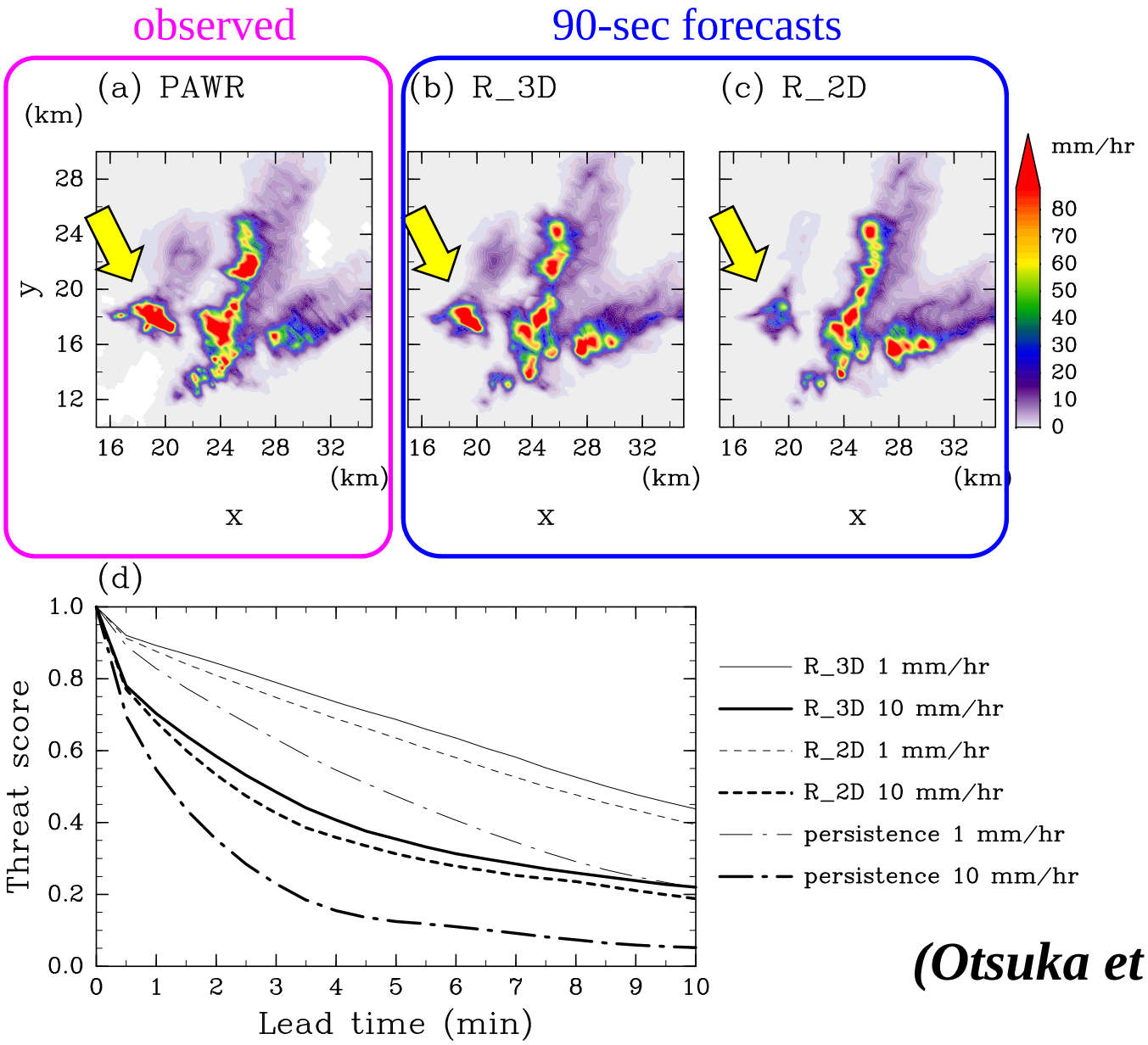
Threat scores



3D is better than 2D!

(Otsuka et al. 2015)

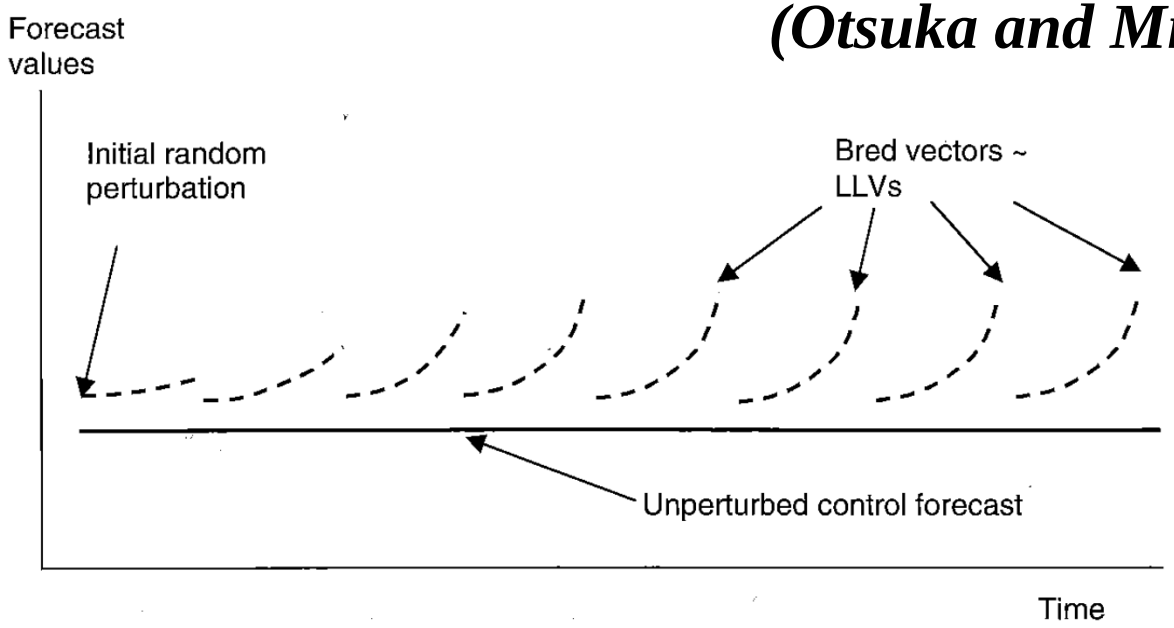
With the real Phased Array Radar



(Otsuka et al. 2015)

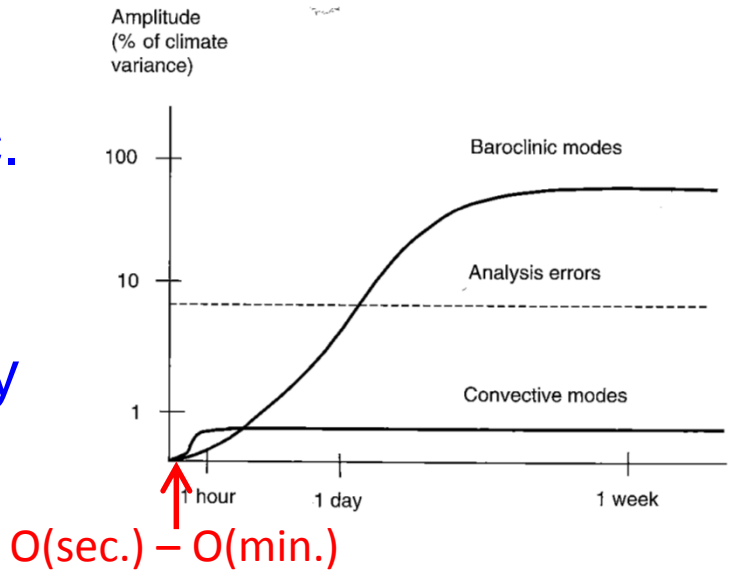
Predictability explored with Bred Vectors

(Otsuka and Miyoshi 2015)



To understand the 30-sec. updates meteorologically

→ Insights in meteorology



(Kalnay, 2003)

BV norm evolution (θ [K], z = 5 km)

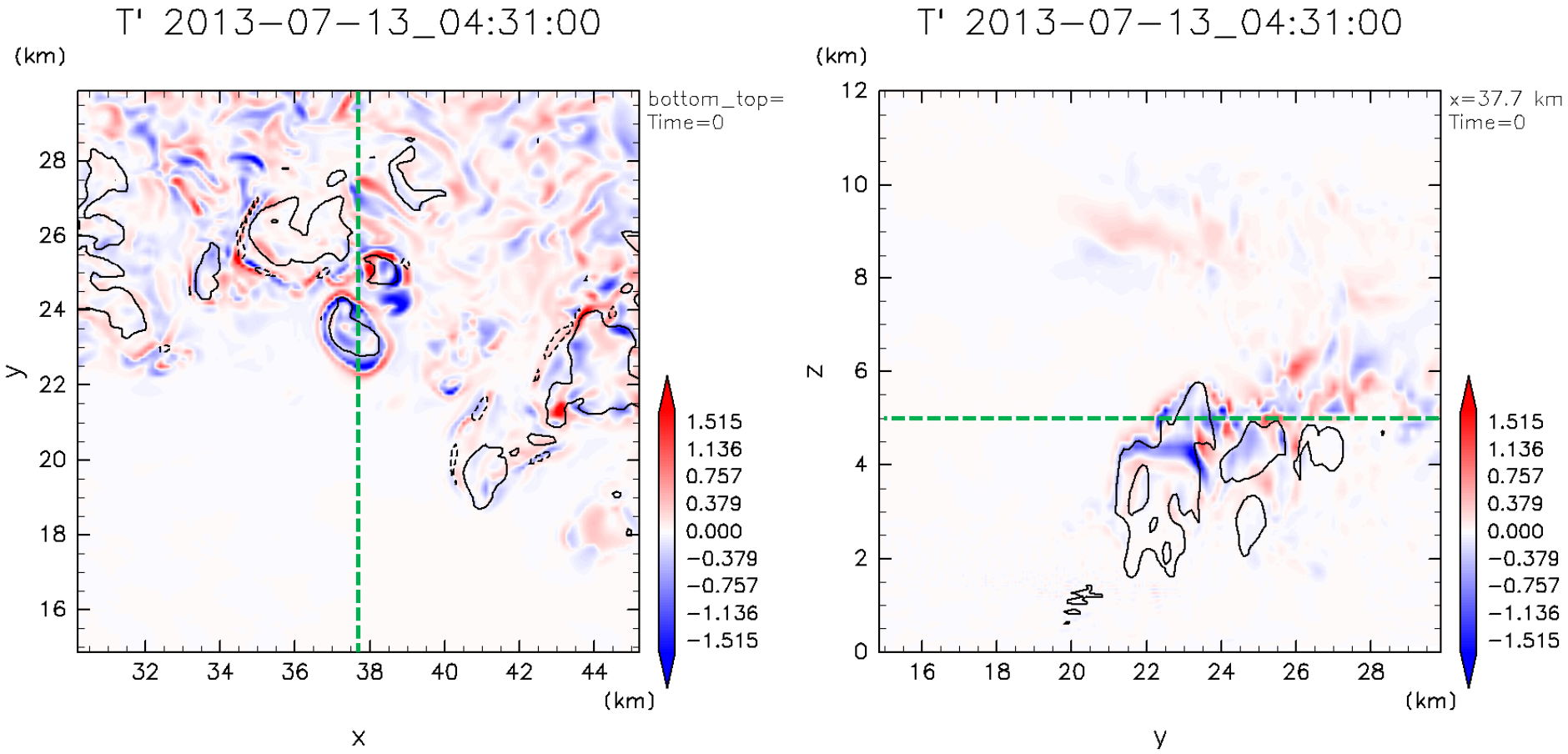
(Otsuka and Miyoshi 2015)

0 min 30 min 60 min

Vertical structure of BV (θ)

(Otsuka and Miyoshi 2015)

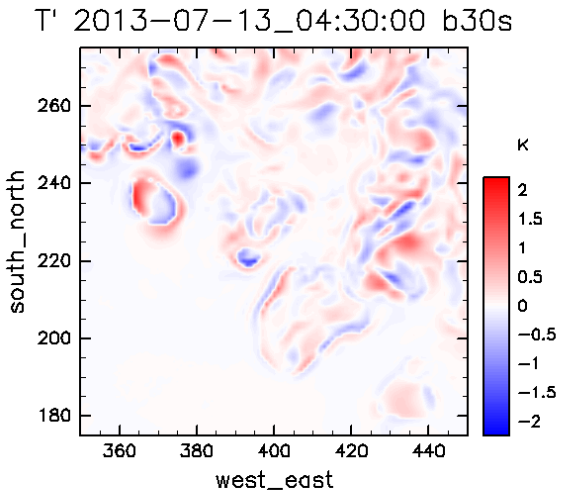
- 30-second breeding cycle

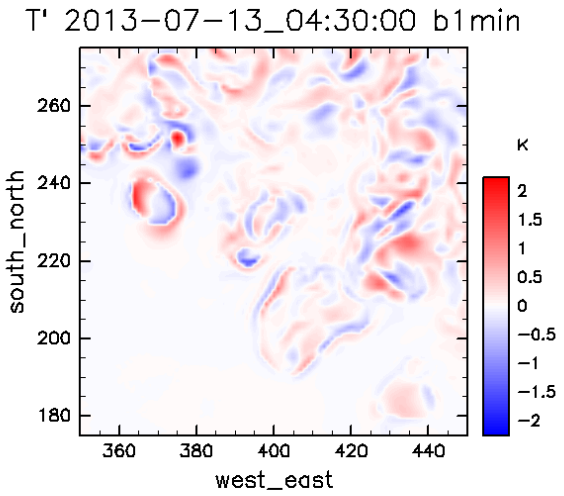


Different breeding intervals

(Otsuka and Miyoshi 2015)

30 seconds

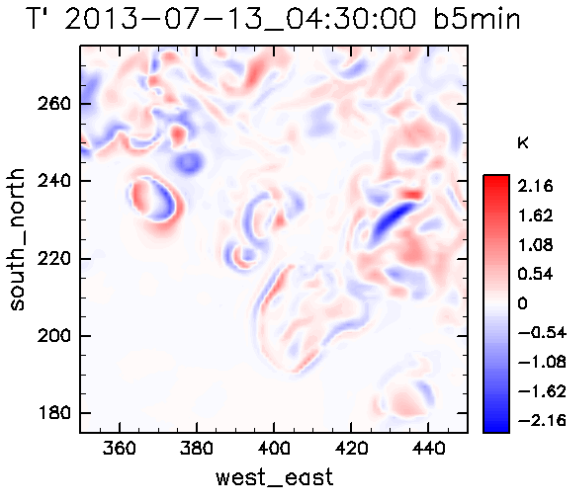


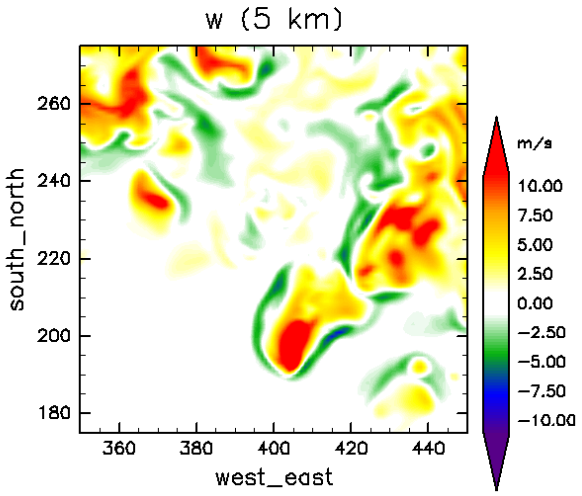


1 minute

Temp. bred vectors at 5 km

5 minutes

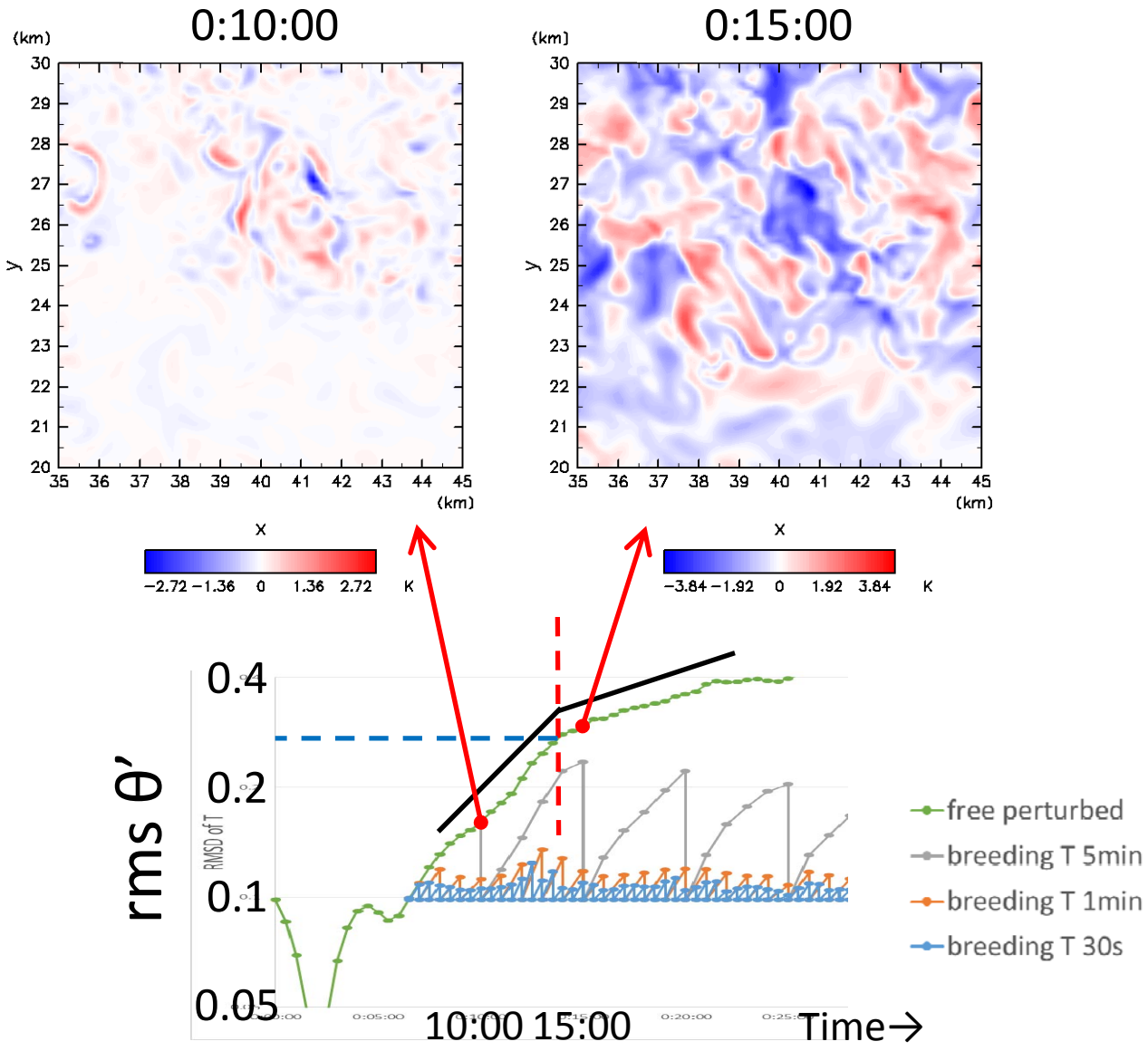




Vertical winds

Perturbations in the free run

(Otsuka and Miyoshi 2015)

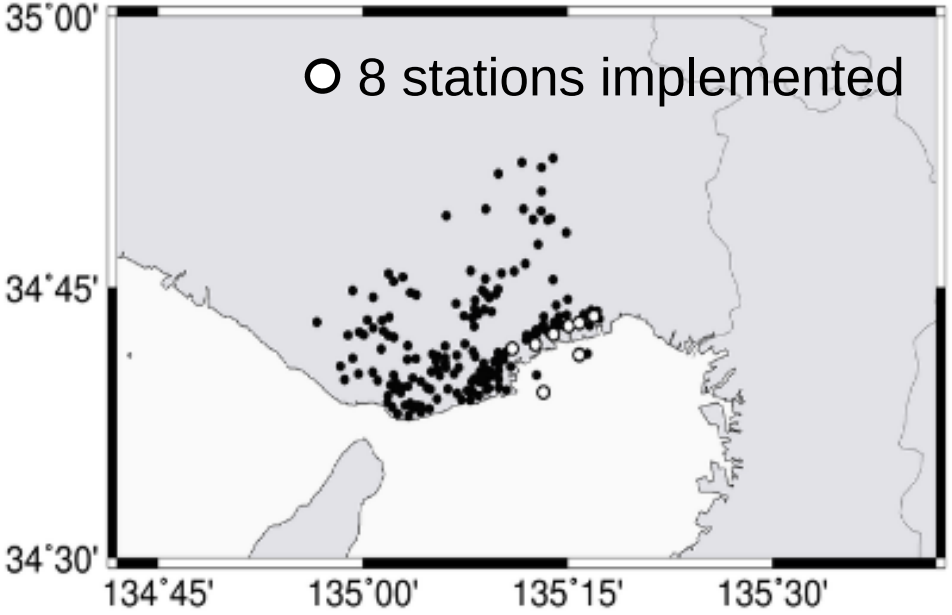


Exploring dense surface observations

(Maejima et al. 2015)

POTEKA Ⅱ by Meisei Electric
(on the roof of RIKEN AICS)

Kobe city elementary schools

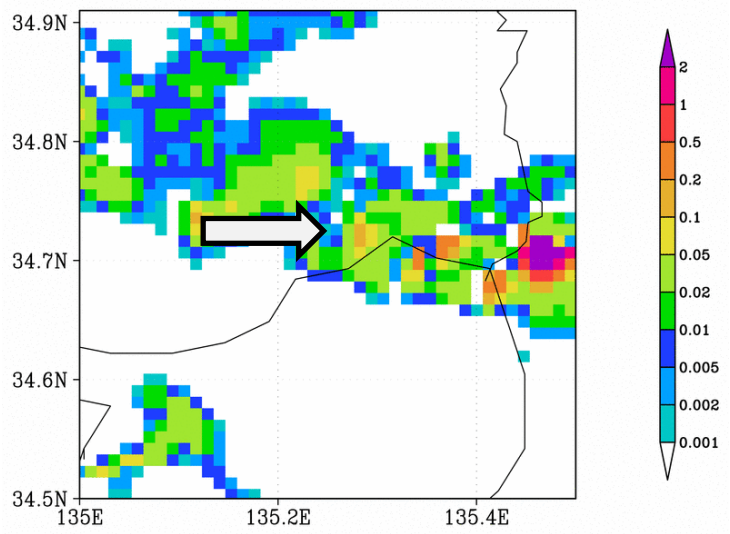


OSSE performed

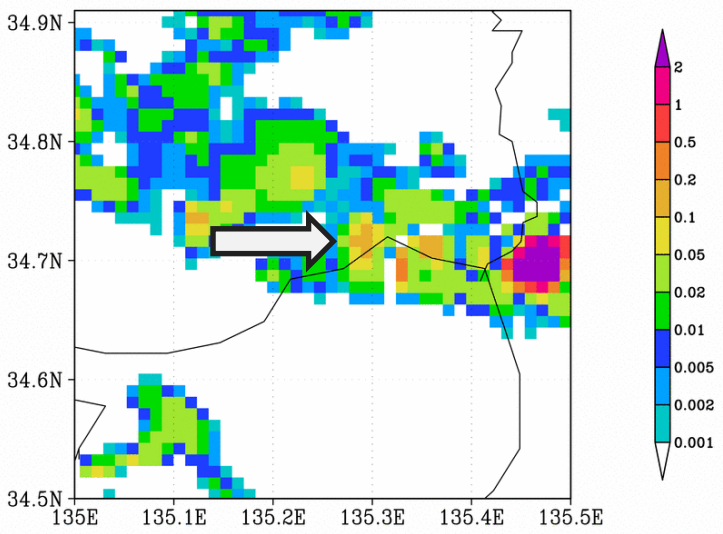
(Maejima et al. 2015)

1-km resolution, 1 min cycle. Rain analysis after 50 cycles.

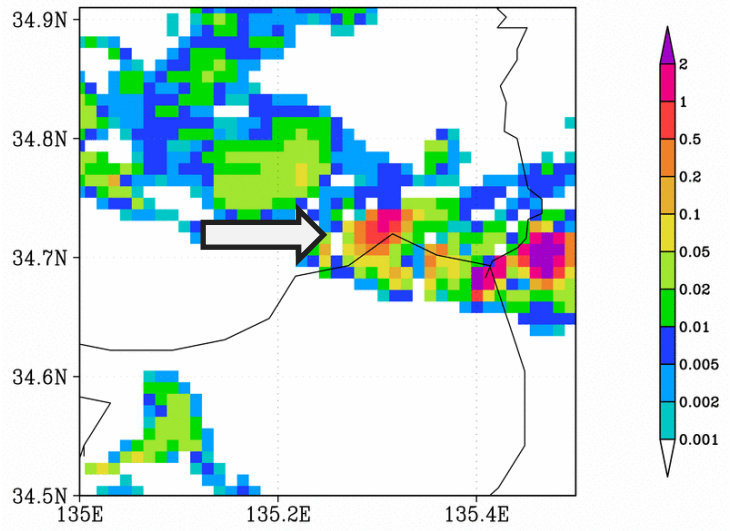
(a) PAWR only



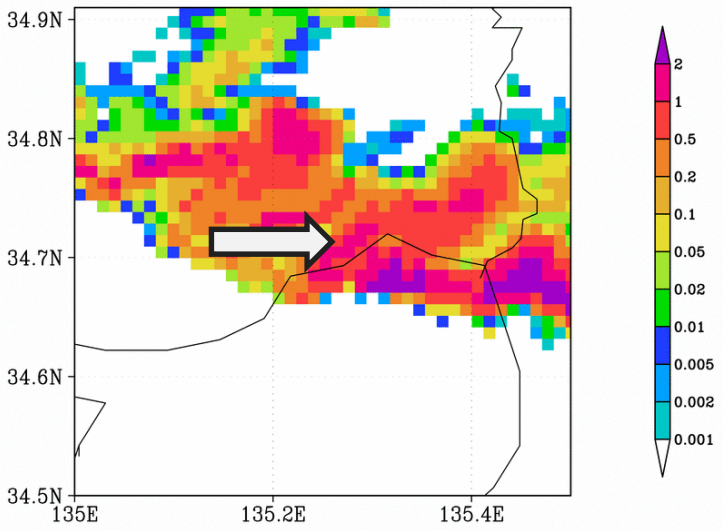
(b) 8points of ground data



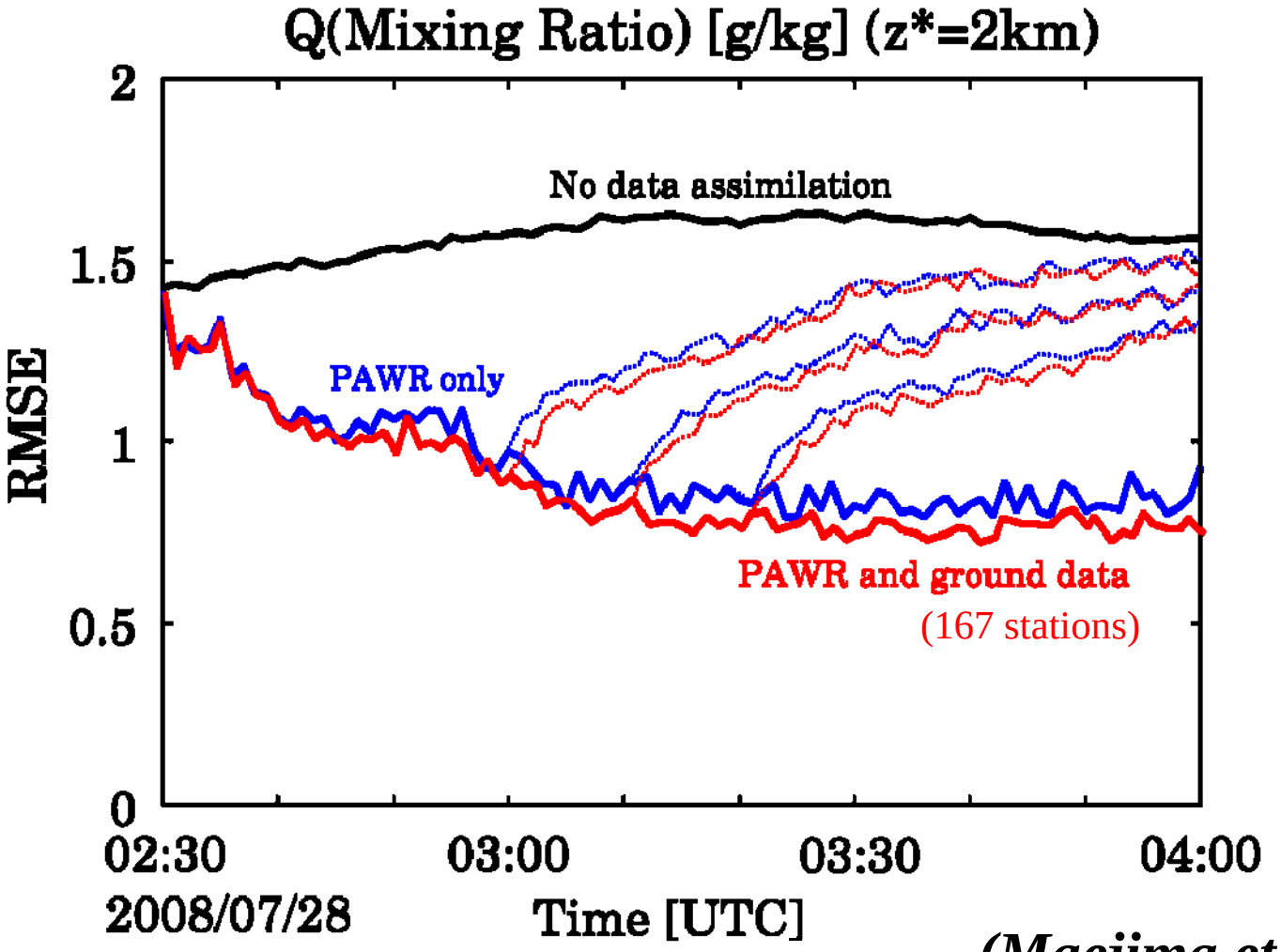
(c) 167points of ground data



(d) Nature run



Dense/frequent ground data impact



(Maejima et al. 2015)

Future perspectives

- Explore a 30-sec. super-rapid DA cycle thorough innovating the "*Big Data Assimilation*" technology.
  - Funded by CREST JST 独立行政法人 科学技術振興機構 Japan Science and Technology Agency
- Japanese "post-K" supercomputer planned in 2020
  - May "Tokyo 2020" be a good place to demonstrate?