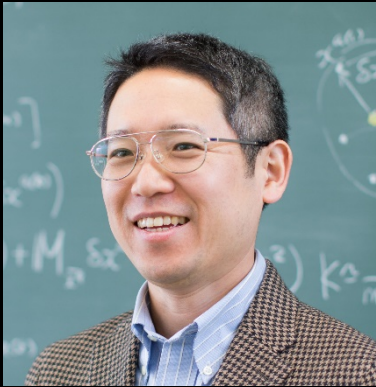


Big Data Assimilation



in Weather Prediction: From K to Fugaku



Takemasa Miyoshi

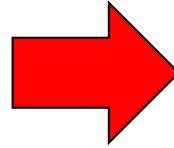
Ph.D. (Meteorology)
Data Assimilation Scientist

Data Assimilation Research Team

RIKEN



Only in 10 minutes!!

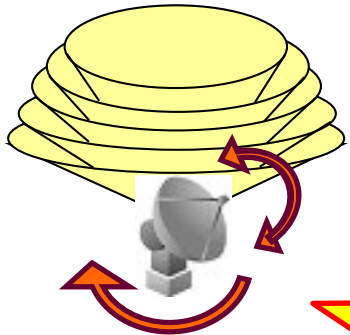
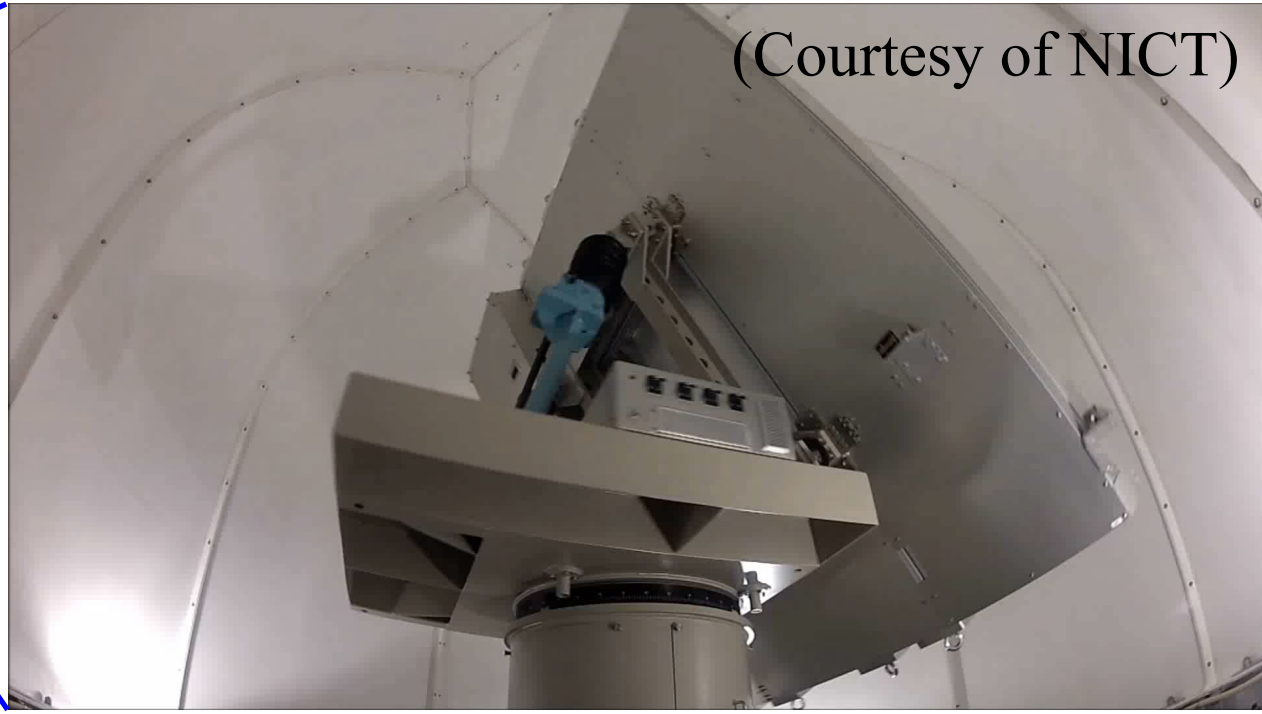


Kobe newspaper (<https://www.kobe-np.co.jp/news/kobe/201807/0011486822.shtml>)

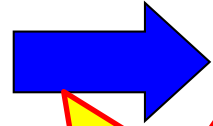
1.34 m ↗ in 10 minutes!!

5 people died in River Toga in Kobe
on July 28, 2008

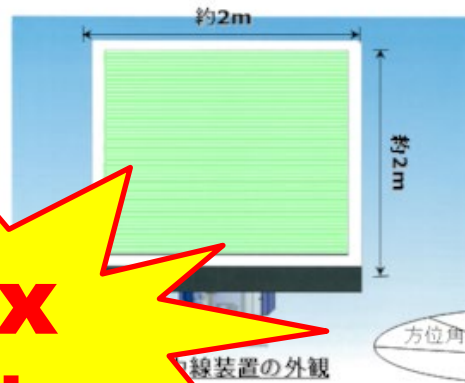
Phased Array Weather Radar (PAWR)



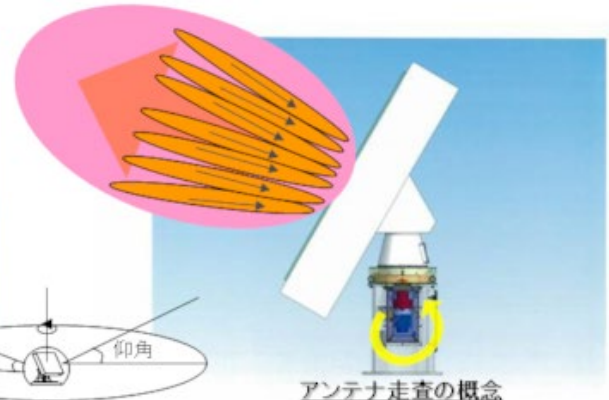
3-dim measurement using a parabolic antenna (150 m, 15 EL angles in 5 min)



100x data size



線装置の外観



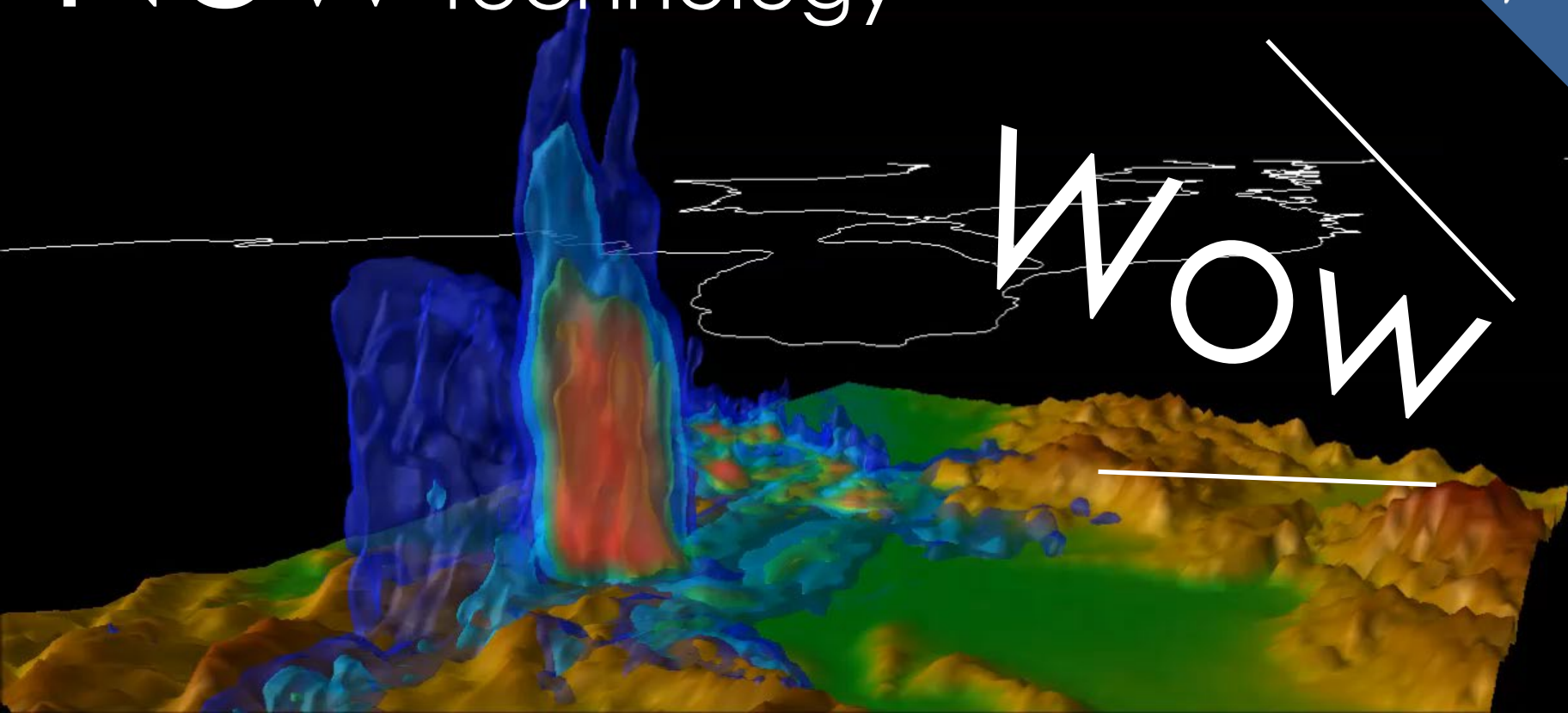
アンテナ走査の概念

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

New radar technology



WOW

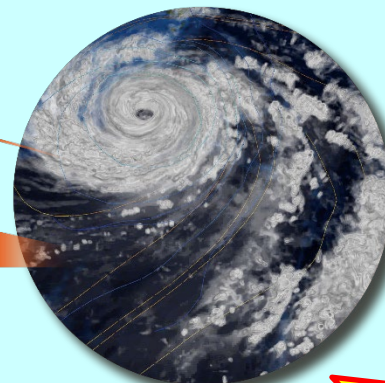


Big Data Assimilation

Observations



Simulations

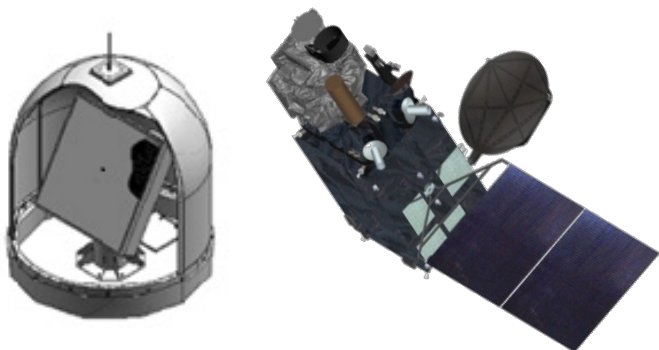


Data Assimilation

100x

Big Data

New sensors, IoT



100x

Big Data

Powerful supercomputer



Data Assimilation (DA)

Observations



Data Assimilation



Simulations



> 2

Data Assimilation (DA)

**Data-driven
Induction
Real world**

**Process-driven
Deduction
Cyber world**

Observations

Simulations

1

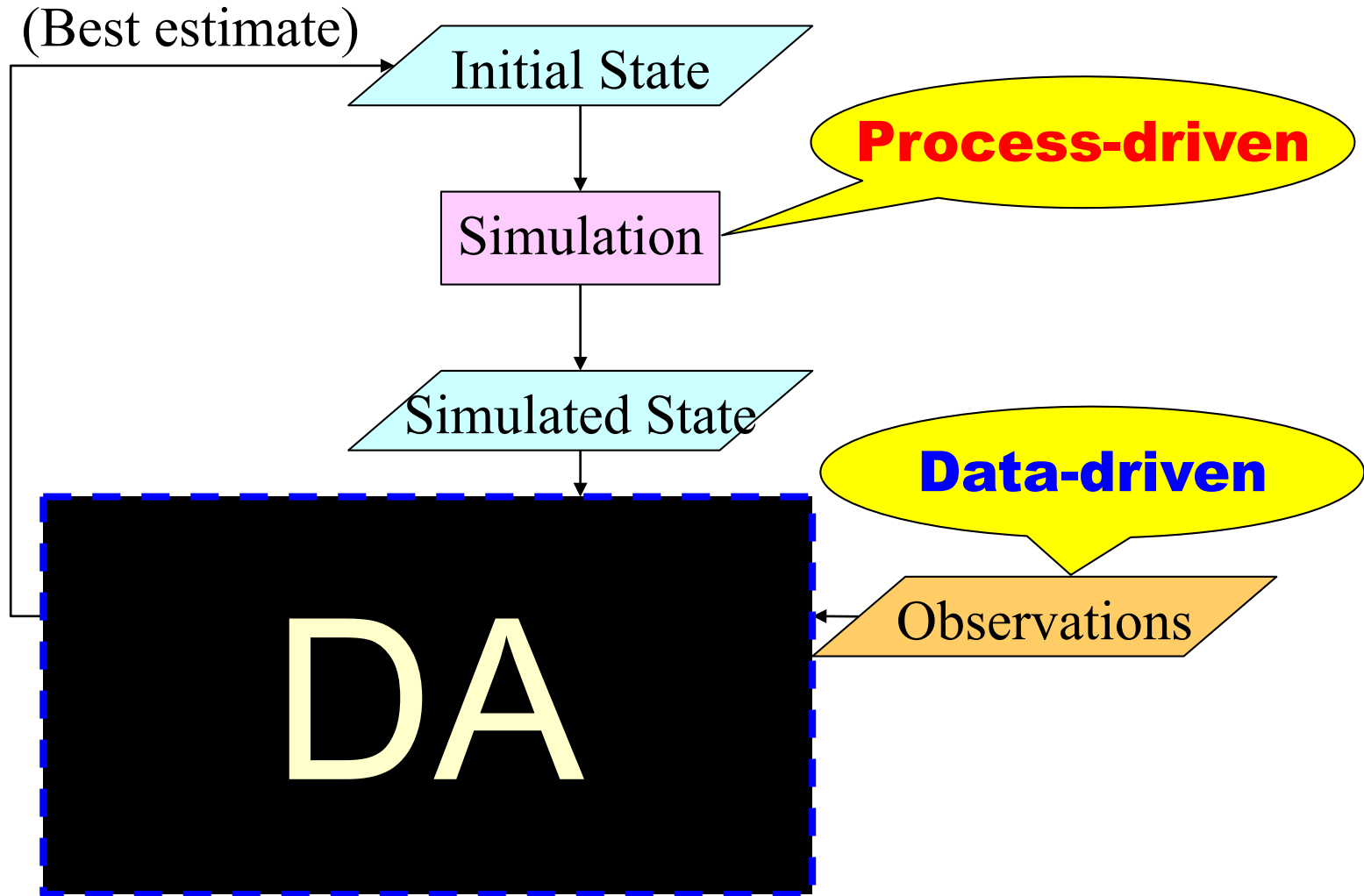
Data Assimilation

+

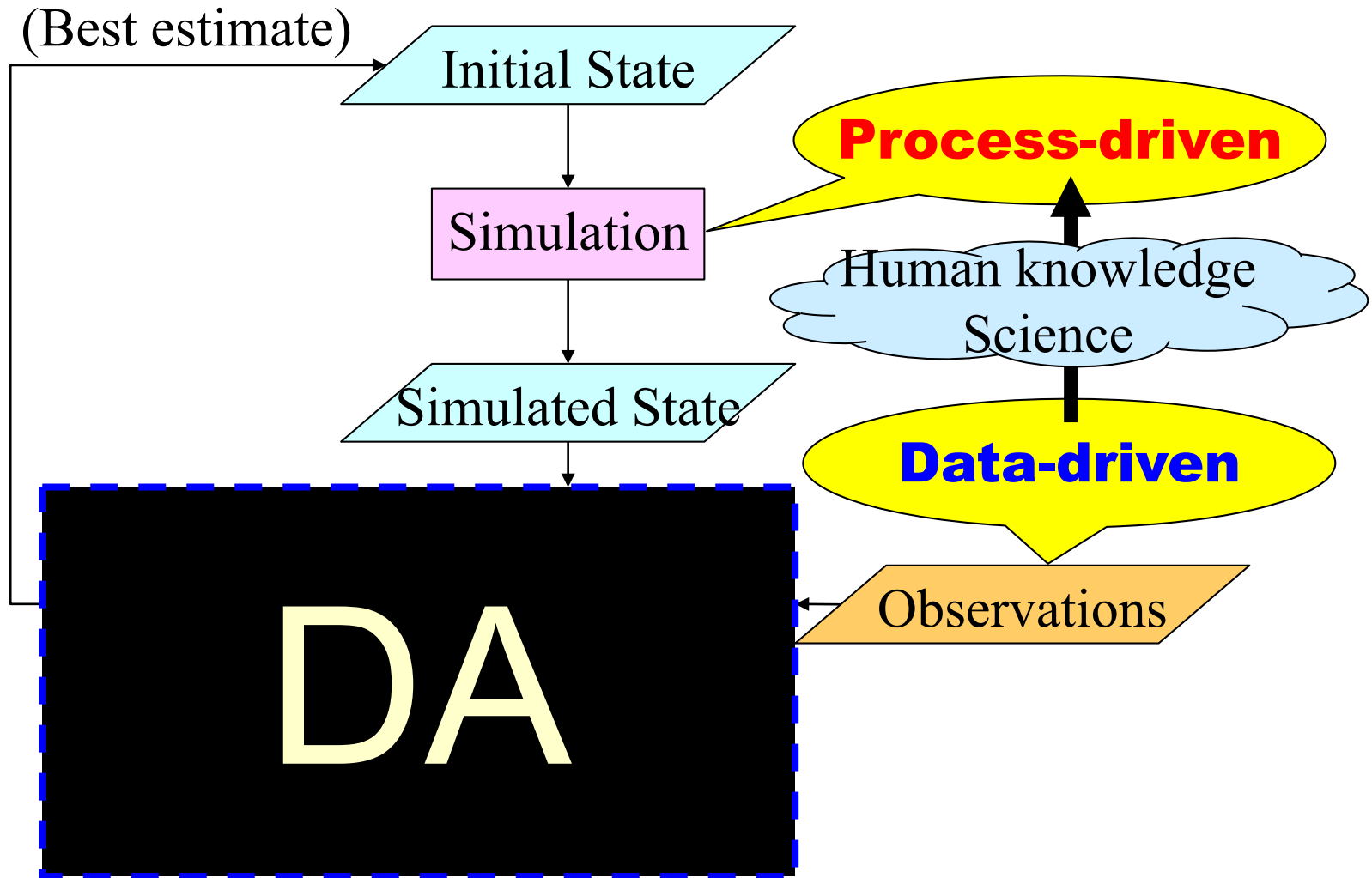
1

> 2

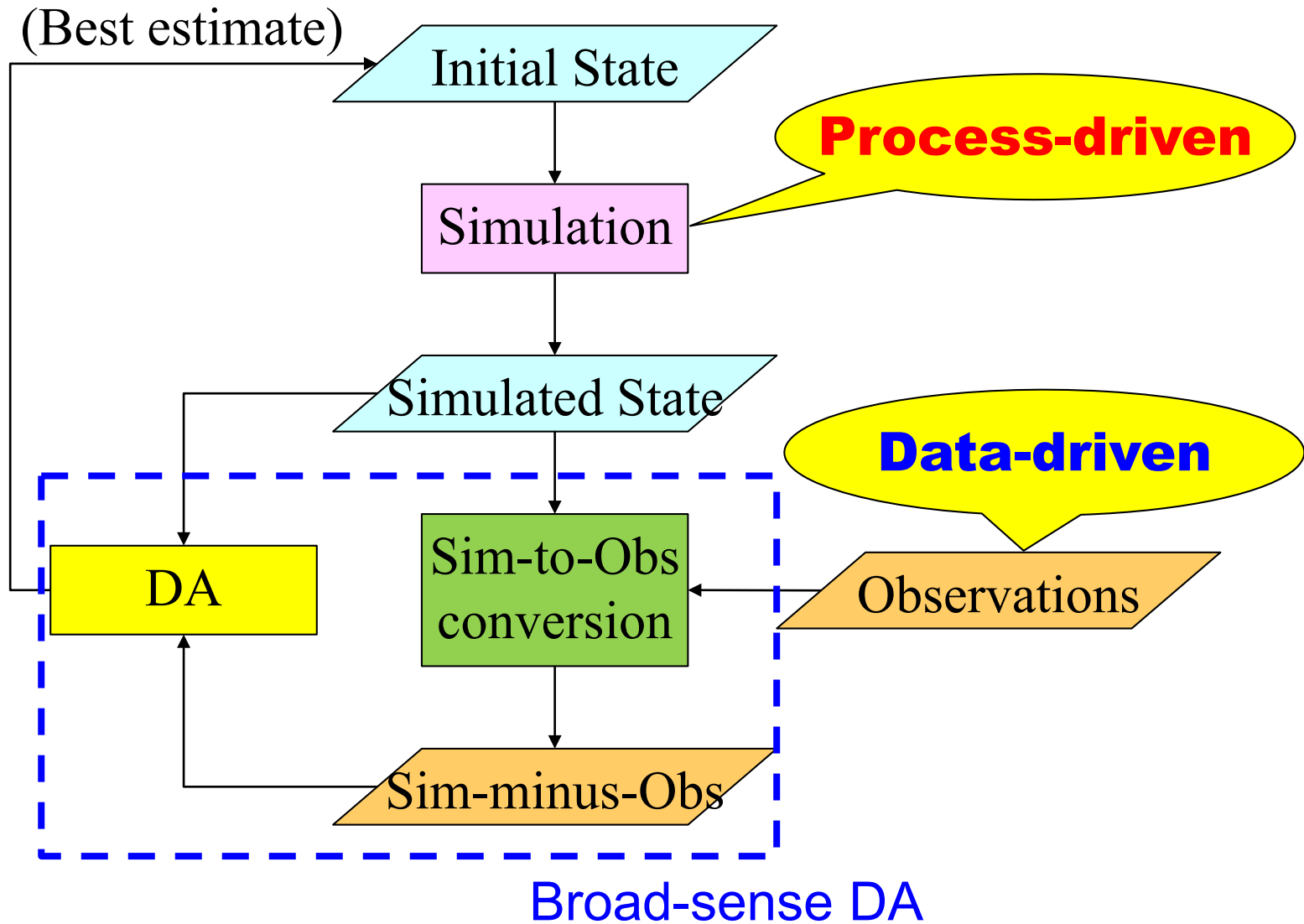
DA workflow



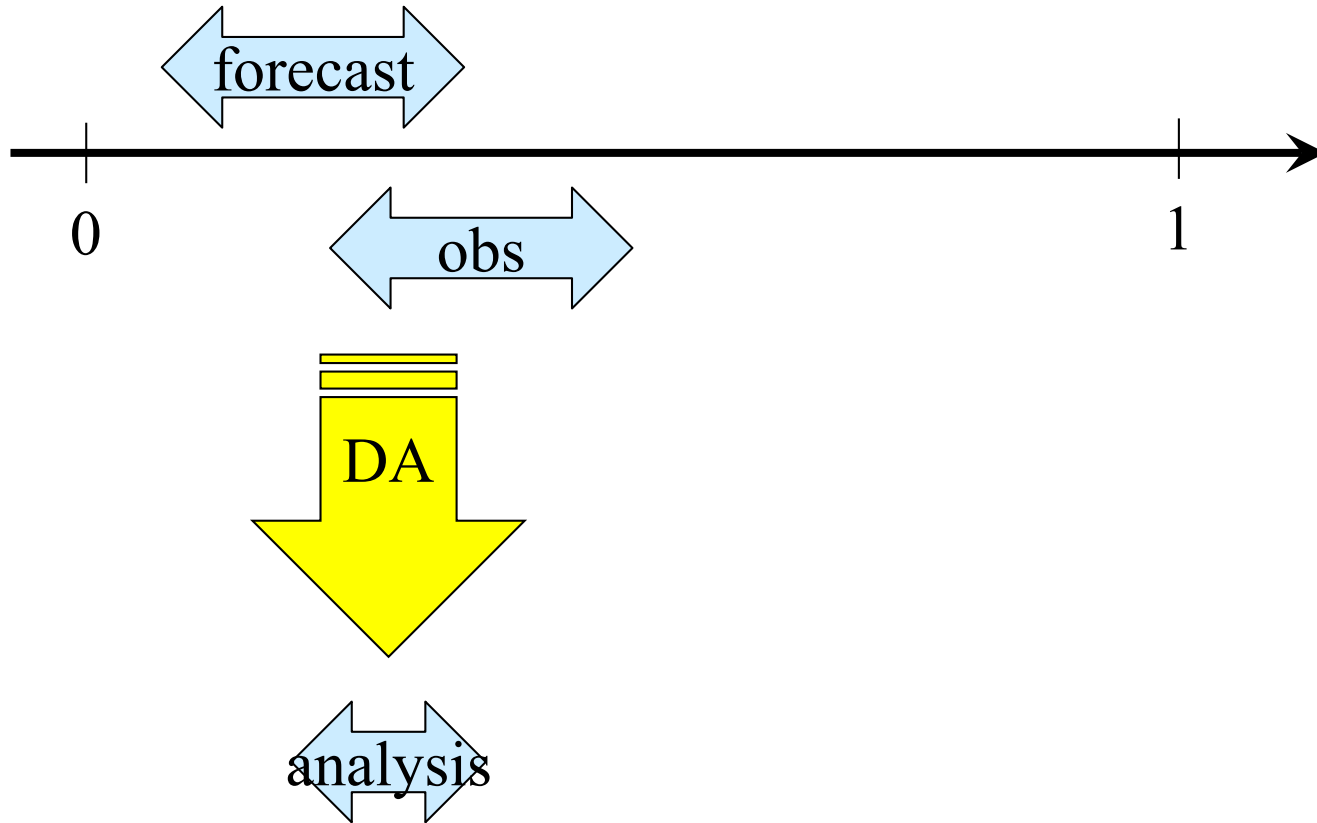
DA workflow



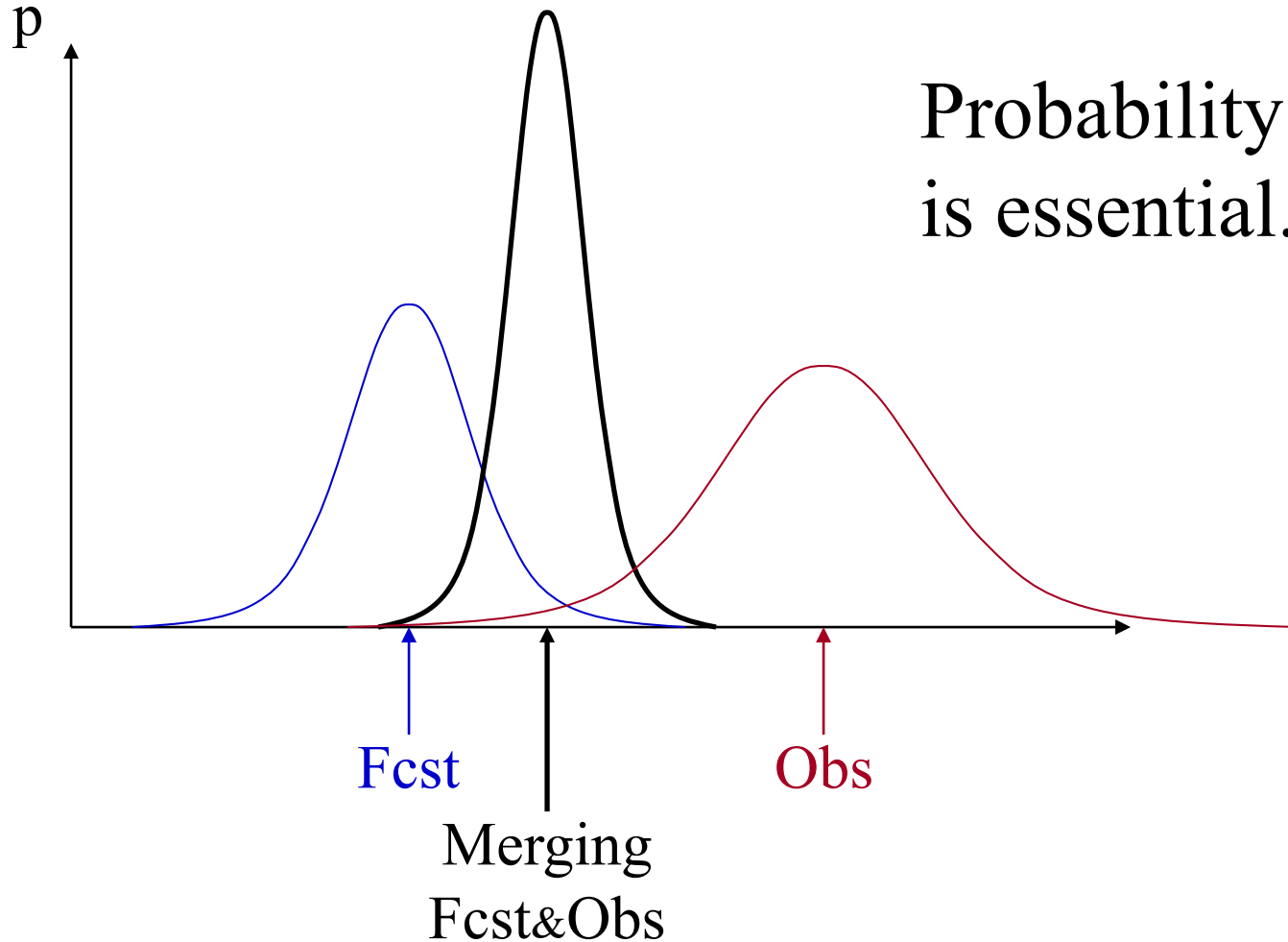
DA workflow



DA = math of errors



Merging 2 information (Bayesian estimation)

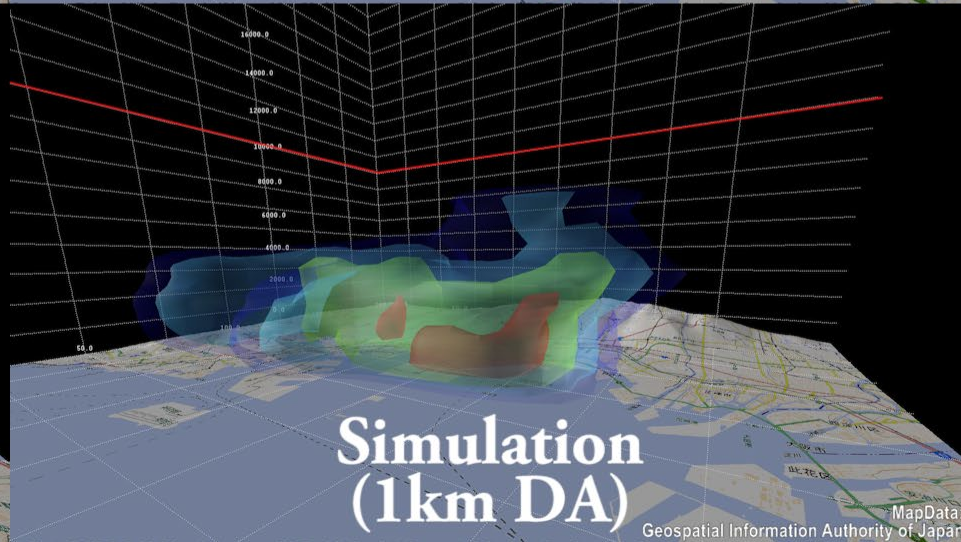
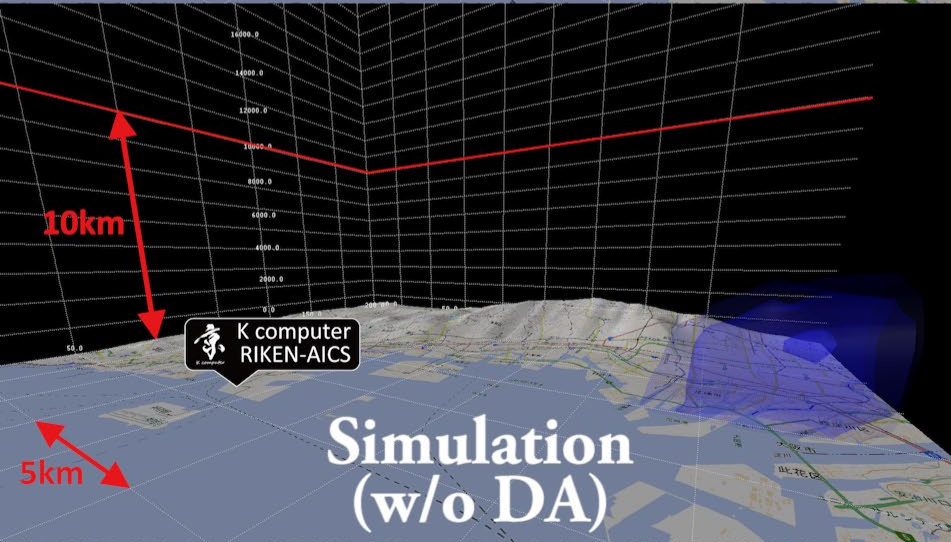
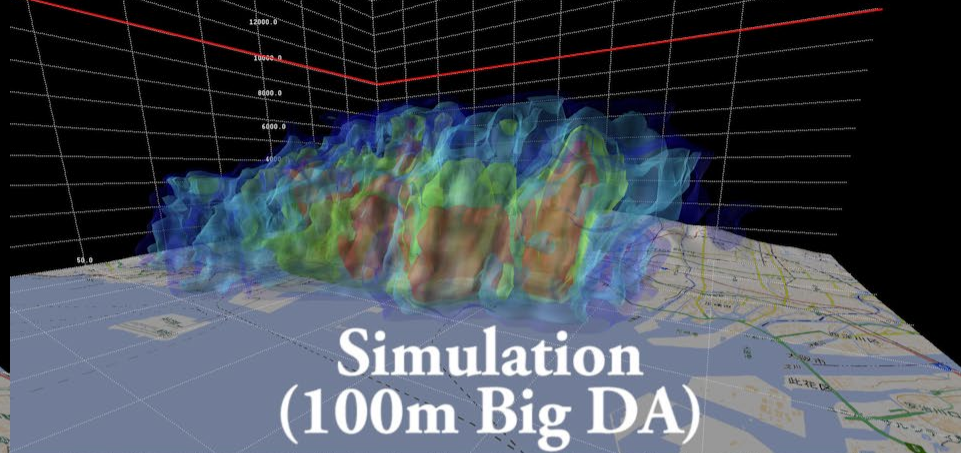
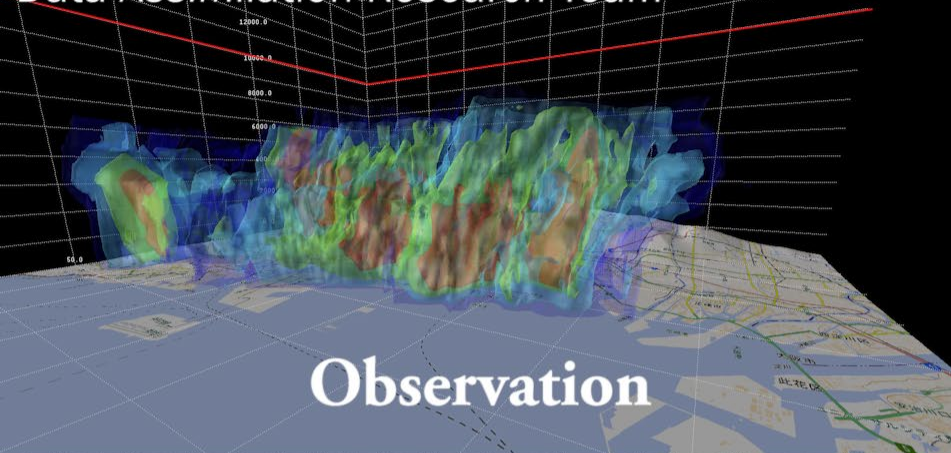


Probability distribution
is essential.

9/11/2014, sudden local rain

RIKEN Advanced Institute for Computational Science
Data Assimilation Research Team

2014.09.11 08:25:00



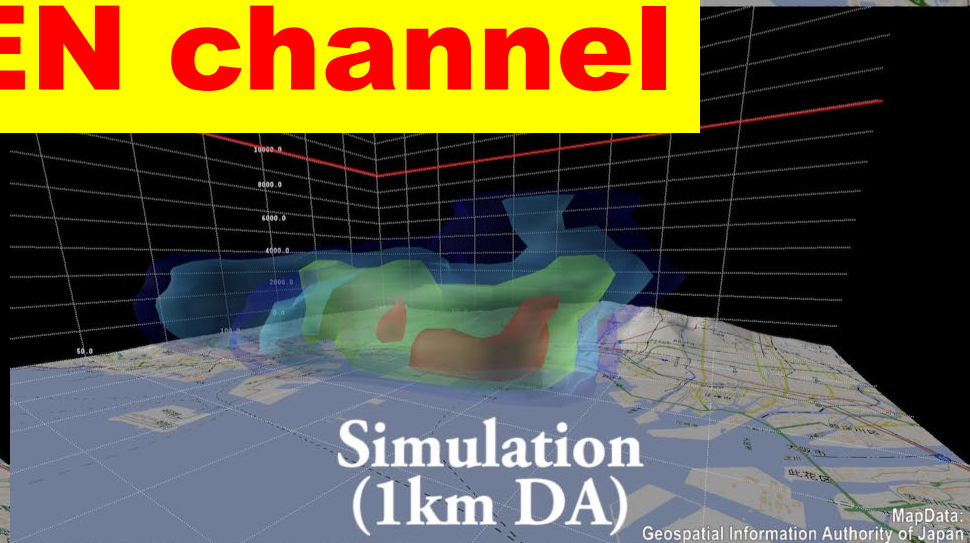
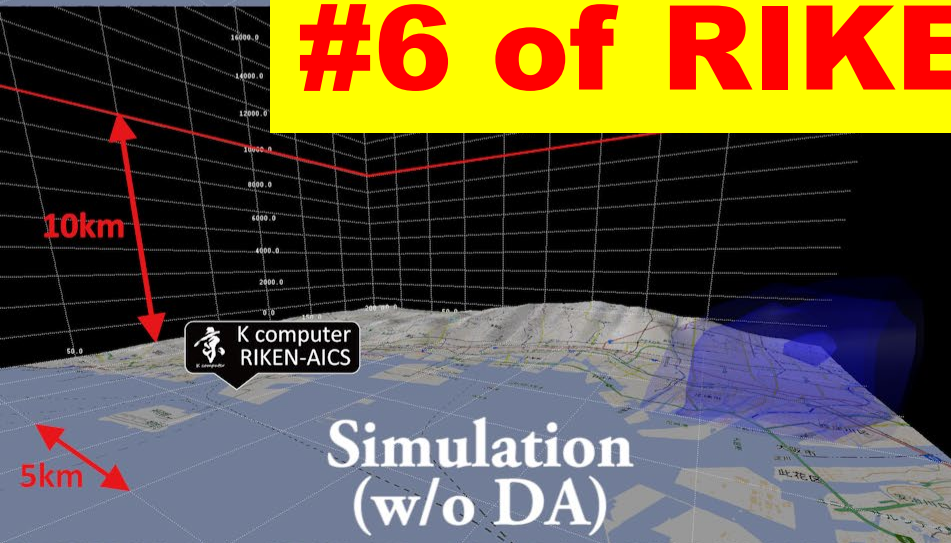
Youtube: <https://www.youtube.com/watch?v=42NZTGdp1Js>

9/11/2014, sudden local rain

RIKEN Advanced Institute for Computational Science
Data Assimilation Research Team

2014.09.11 08:25:00

>41,000 views
#6 of RIKEN channel

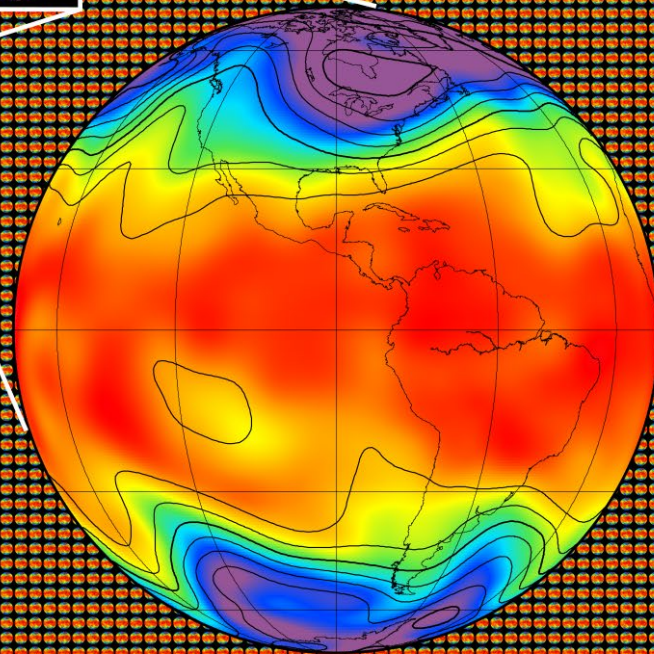
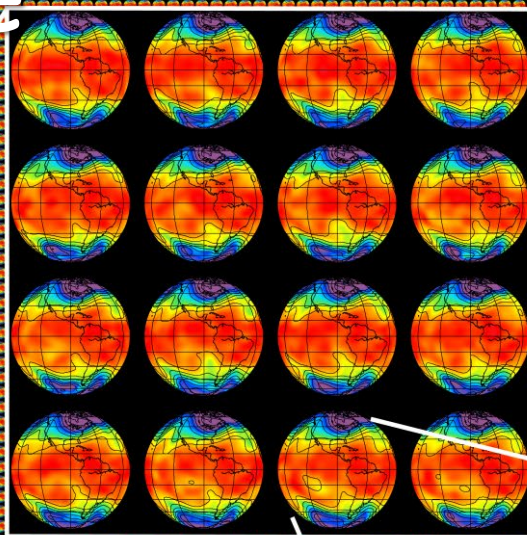


Youtube: <https://www.youtube.com/watch?v=42NZTGdp1Js>

Big Ensemble DA

10240 parallel earths

Miyoshi, Kondo, Terasaki
(2014, Computer)
[doi:10.1109/MC.2015.332](https://doi.org/10.1109/MC.2015.332)



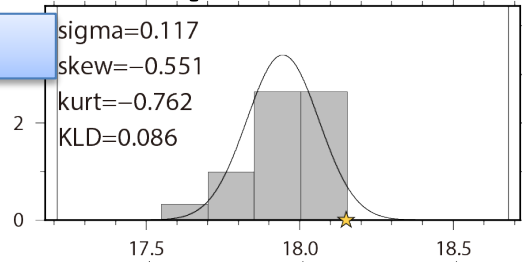
500 hPa Temperature [K]



Sample size = Resolution of probability

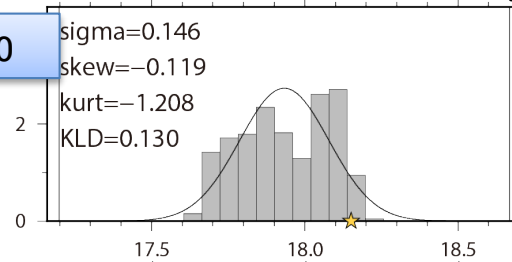
20

sigma=0.117
skew=-0.551
kurt=-0.762
KLD=0.086



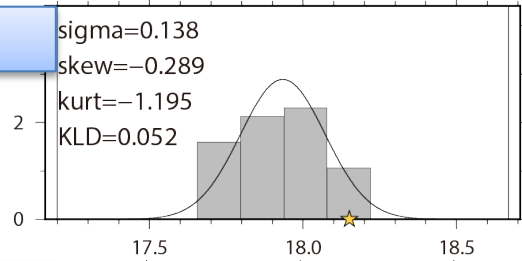
640

sigma=0.146
skew=-0.119
kurt=-1.208
KLD=0.130



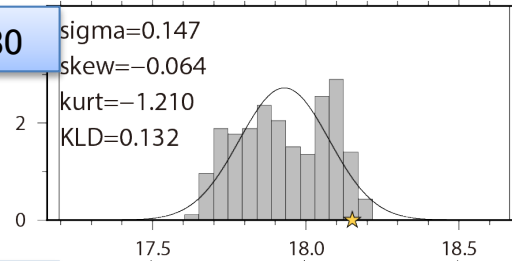
40

sigma=0.138
skew=-0.289
kurt=-1.195
KLD=0.052



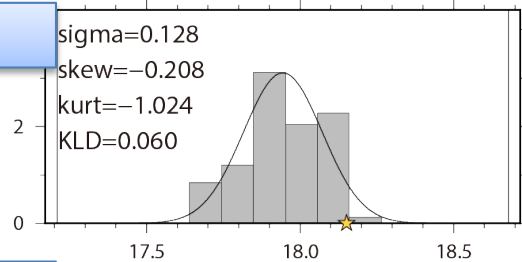
1280

sigma=0.147
skew=-0.064
kurt=-1.210
KLD=0.132



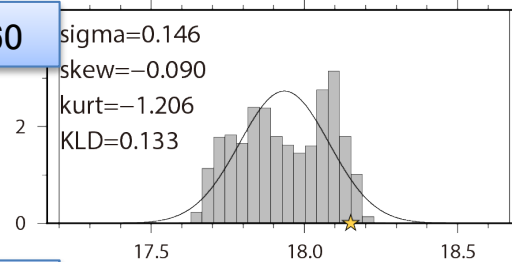
80

sigma=0.128
skew=-0.208
kurt=-1.024
KLD=0.060



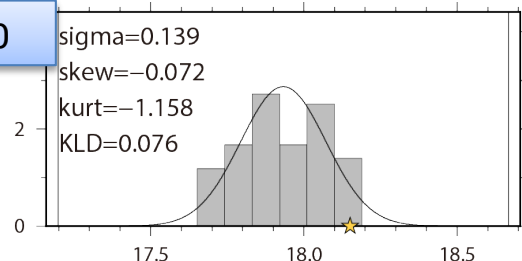
2560

sigma=0.146
skew=-0.090
kurt=-1.206
KLD=0.133



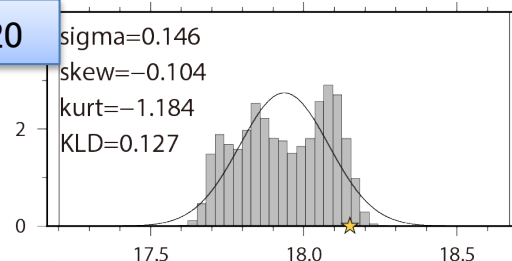
160

sigma=0.139
skew=-0.072
kurt=-1.158
KLD=0.076



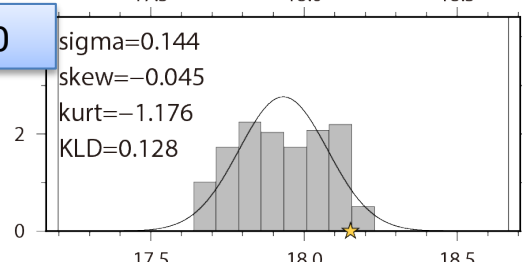
5120

sigma=0.146
skew=-0.104
kurt=-1.184
KLD=0.127



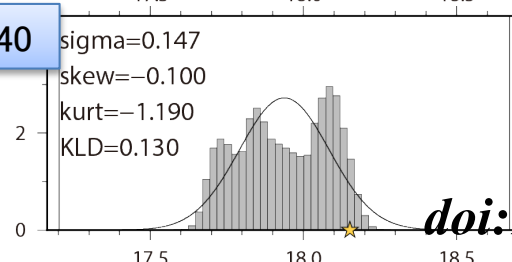
320

sigma=0.144
skew=-0.045
kurt=-1.176
KLD=0.128



10240

sigma=0.147
skew=-0.100
kurt=-1.190
KLD=0.130

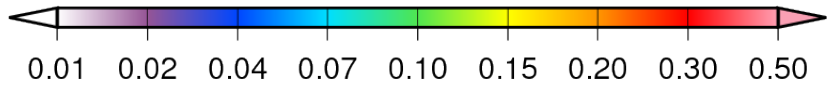
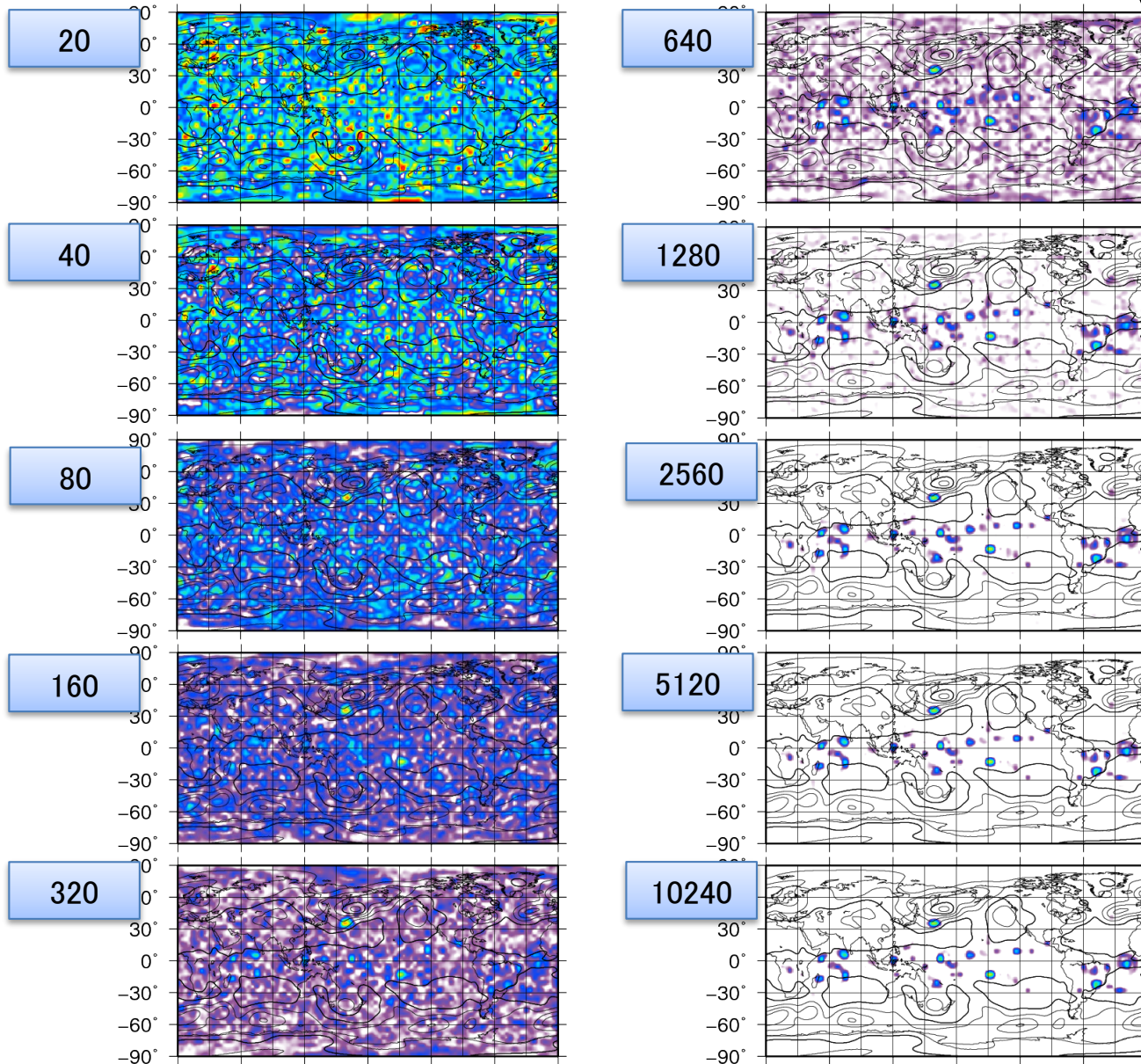


1.856N, 176.25E

*Kondo&Miyoshi
(2019, NPG)*

doi:10.5194/npg-26-211-2019

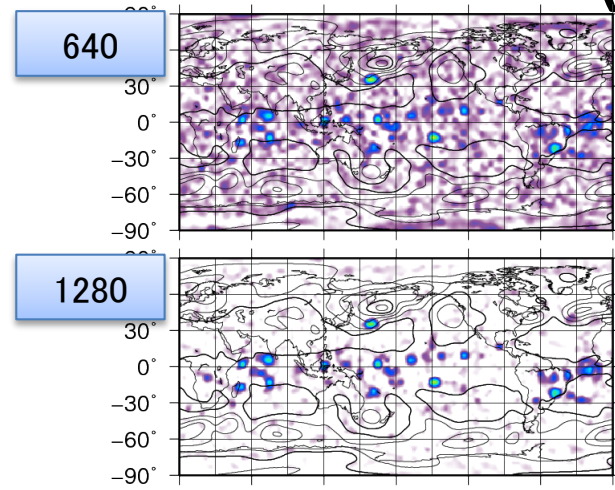
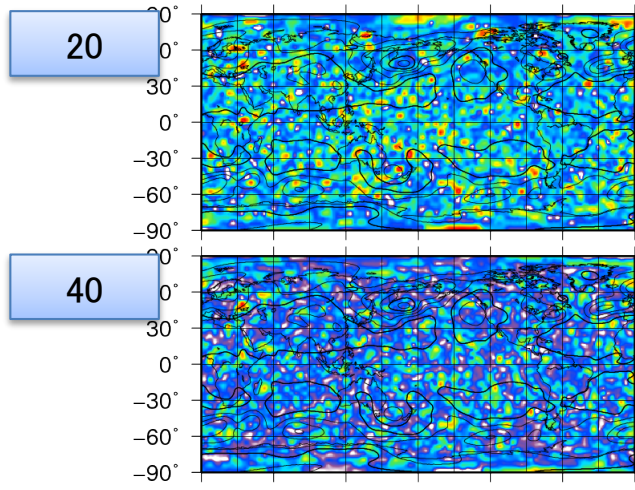
Non-Gaussian metric (KLD)



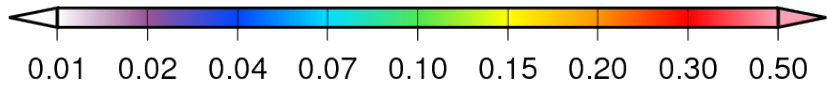
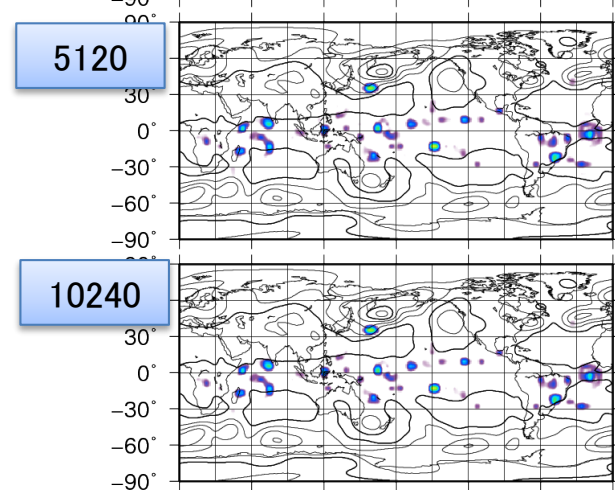
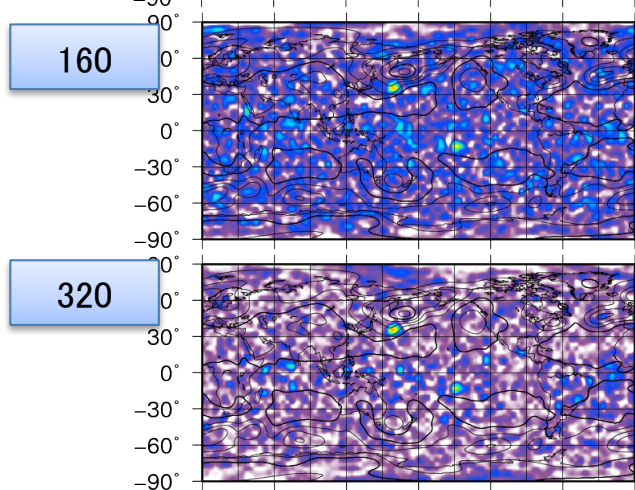
*Kondo & Miyoshi
(2019, NPG)*

doi:10.5194/npg-26-211-2019

Non-Gaussian metric (KLD)



Non-Gaussian PDF captured with >1000



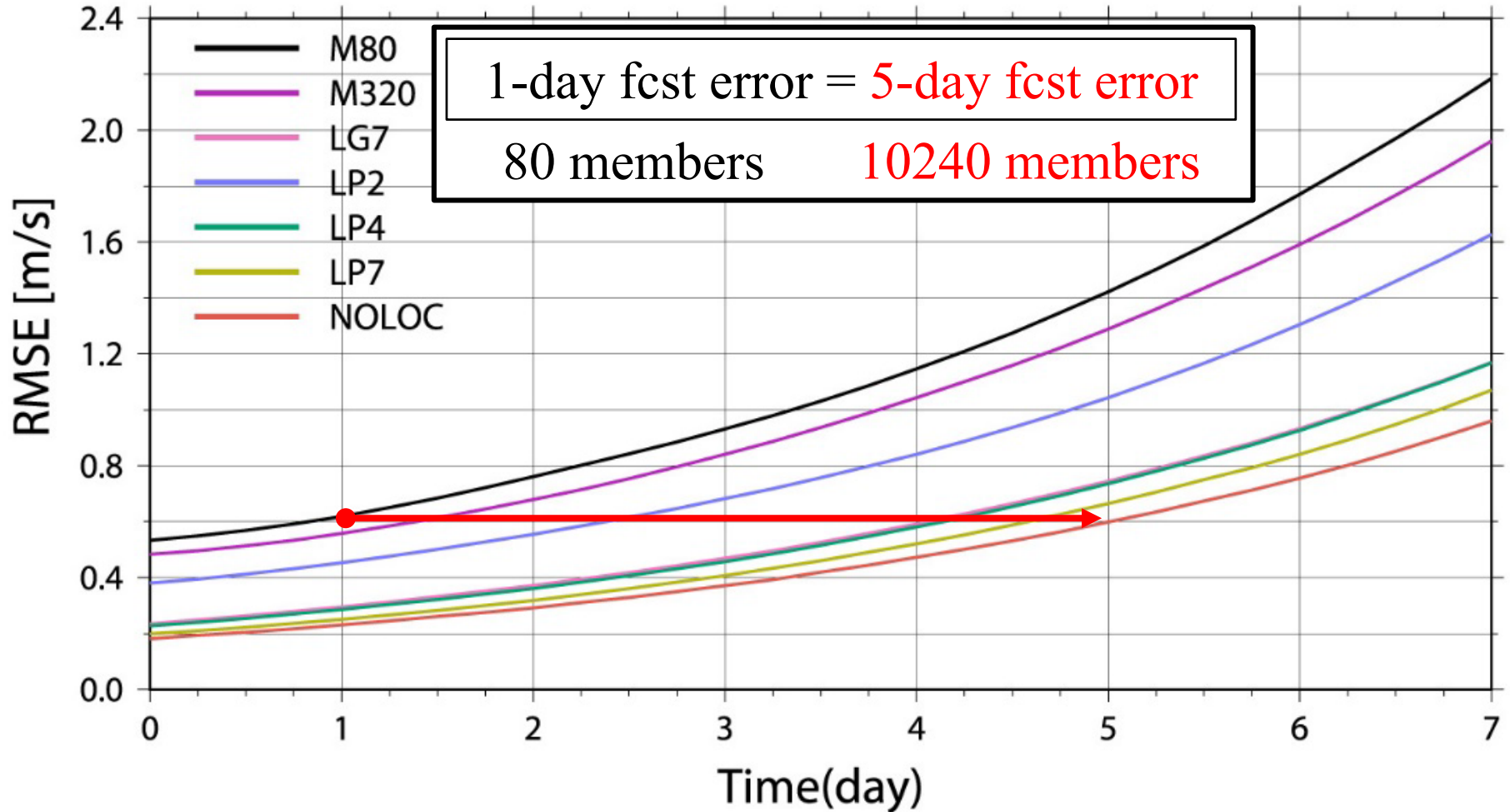
*Kondo & Miyoshi
(2019, NPG)*

doi:10.5194/npg-26-211-2019

Improving NWP

(a)

Forecast RMSEs (U, Lev = 4)



Kondo and Miyoshi (2016, MWR, doi:10.1175/MWR-D-15-0388.1)

Pushing the limits

Big Data × *Big Simulations*

Big ensemble (10240 ensemble members)

Rapid update (30-second update)

High resolution (100-m mesh)

→ Future Numerical Weather Prediction



Fugaku

**Global 3.5-km mesh
1000 samples**

K

**Global 112-km mesh
10240 samples**

Fugaku : K = 100 : 1

Mesh size: 32x
(Grid points: 1024x)

Sample size: 0.1x

Toward Weather-Ready Society 5.0 with

Cyberspace

synchronize
predict & control

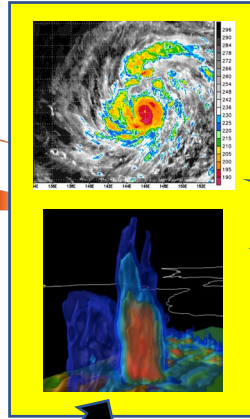
Real world

Simulation



Big Data Assimilation
Data Assimilation

Big Data



Sensing

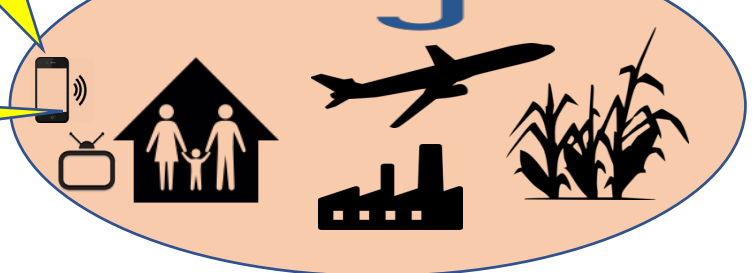


Nature



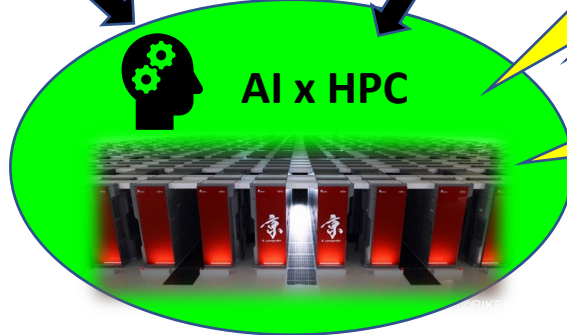
Prepared for weather

IoT



Human society and economy

AI x HPC



Toward Weather-Ready Society 5.0 with



Cyberspace

synchronize
predict & control

Real world

Simulation

Big Data

Sensing

Nature

Big Ensemble to Warn

- early & accurately
- without miss

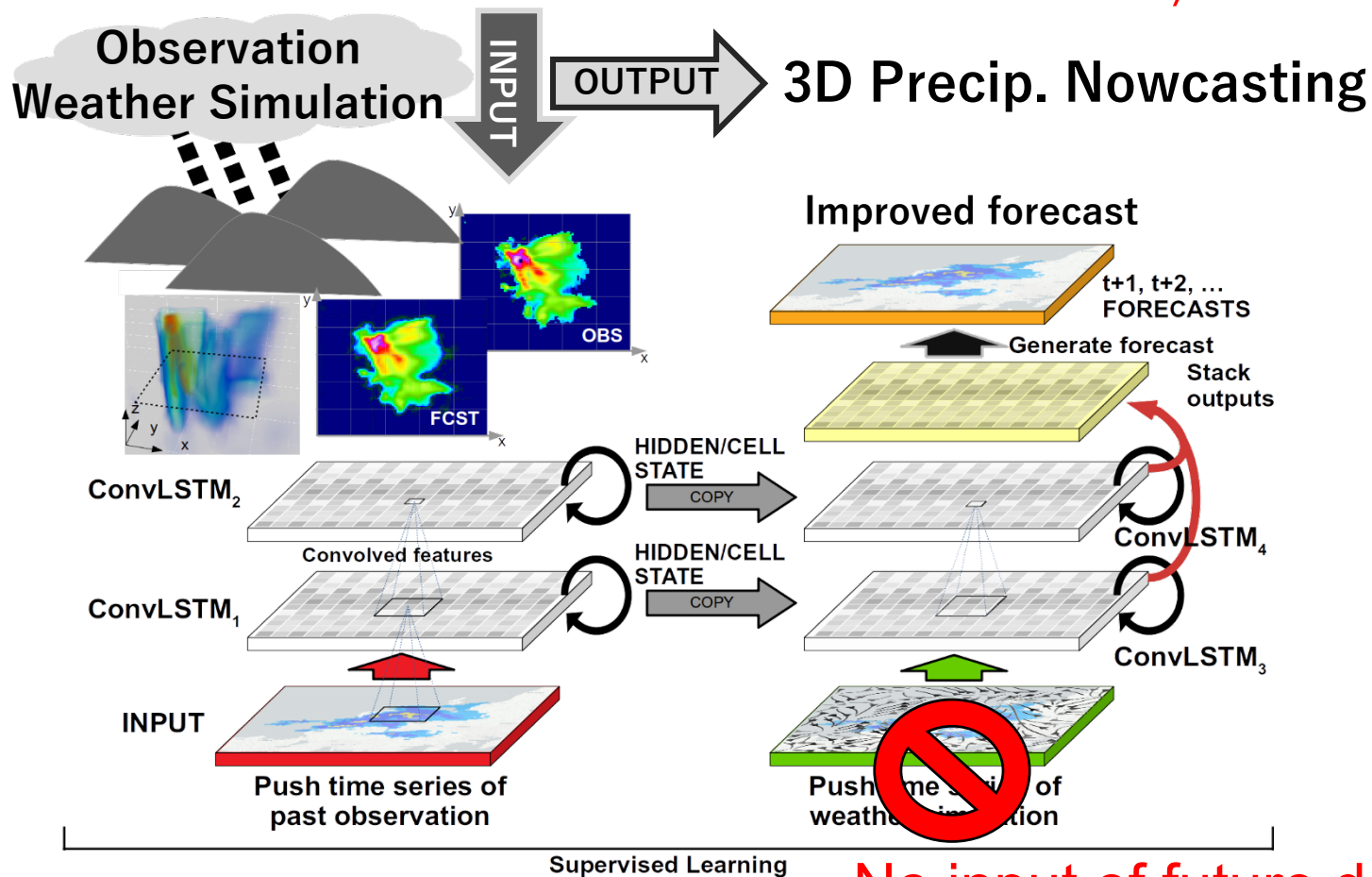
→ Effective disaster prevention



Human society and economy

PAWR 3D Nowcasting

Parallel test of real-time nowcasting w/ ConvLSTM since June 6, 2019!!



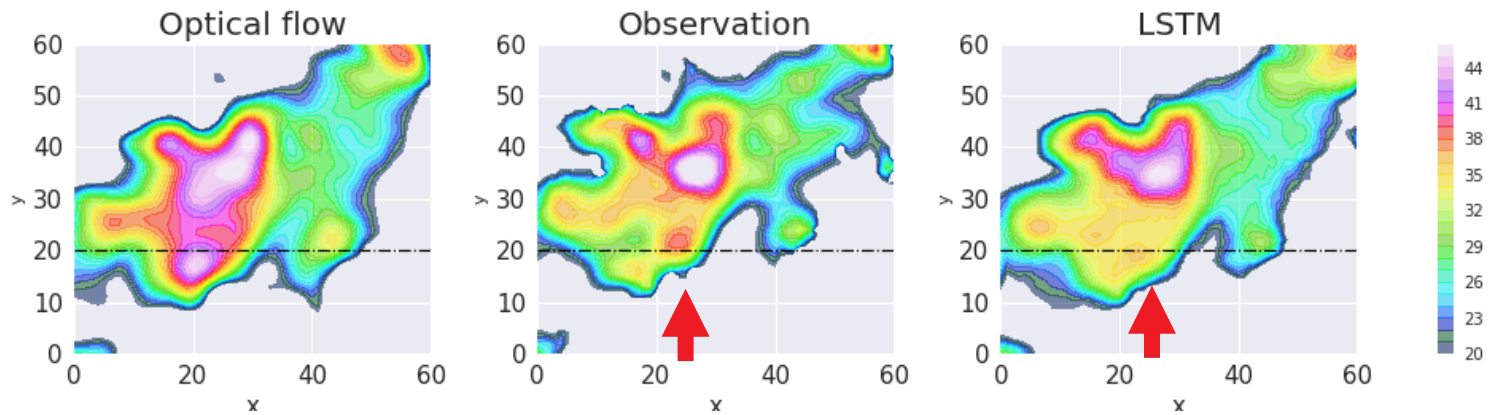
No input of future data at this moment

Conv-LSTM is effective.

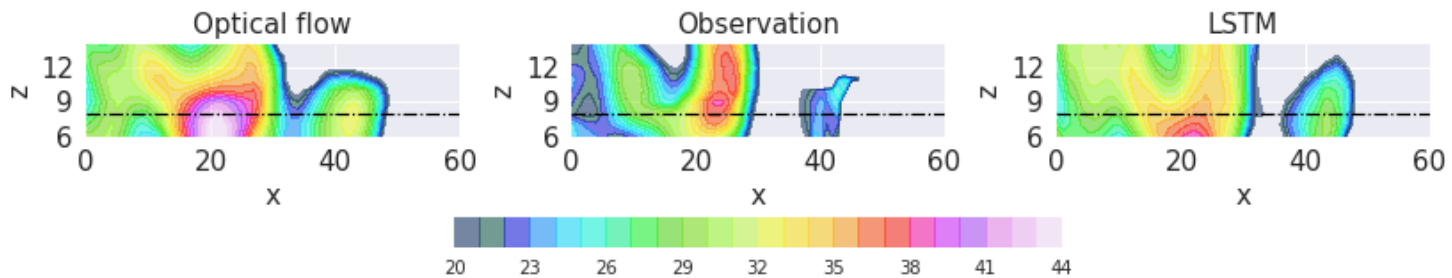
(Work with Mr. Viet Phi Huynh and Prof. Pierre Tandeo)

2.5-min prediction

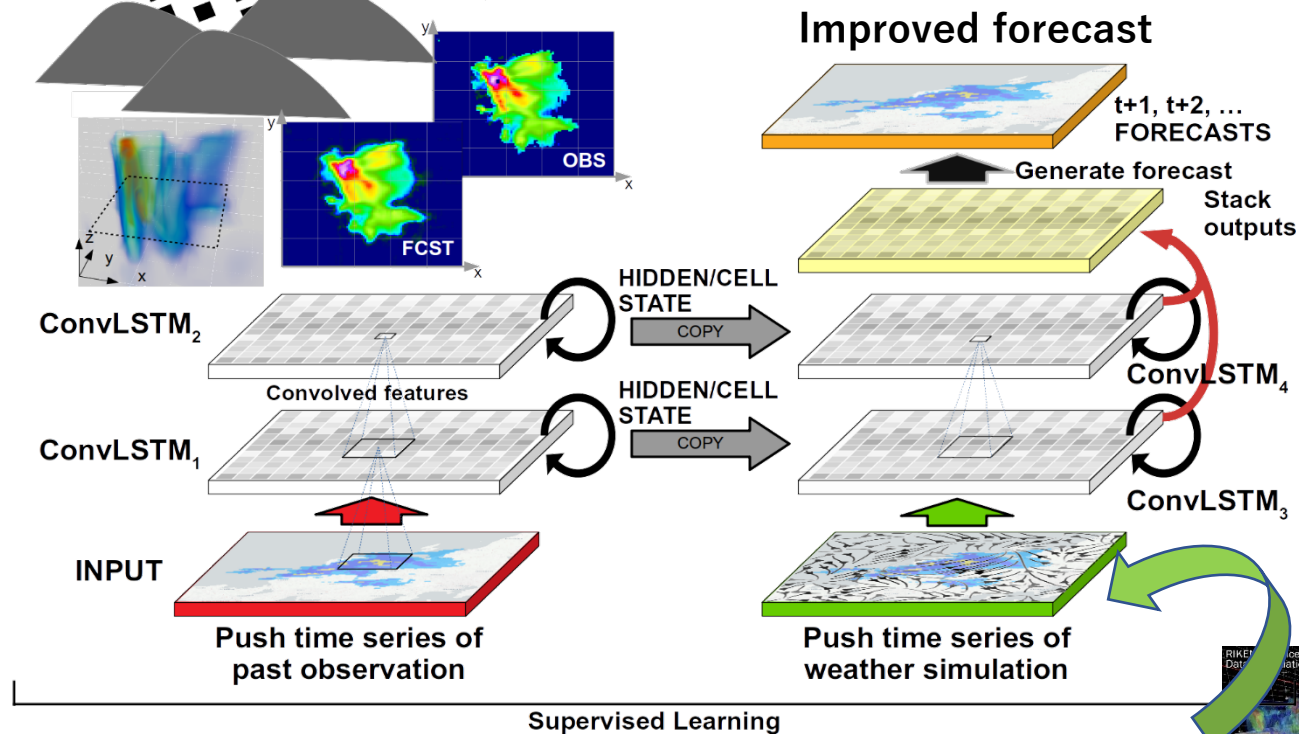
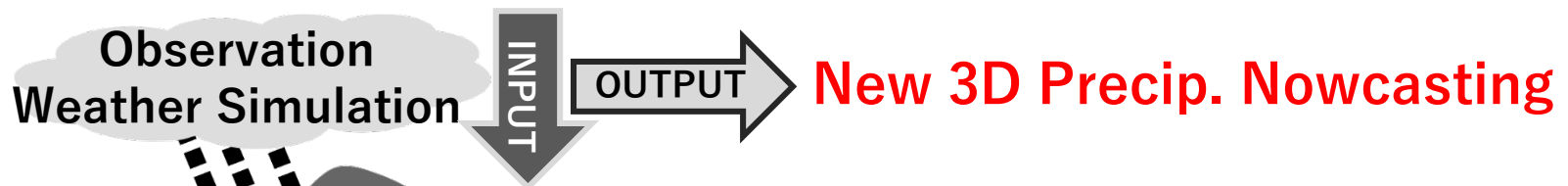
t = 2018-07-27 20:35:30 + 2.5 min



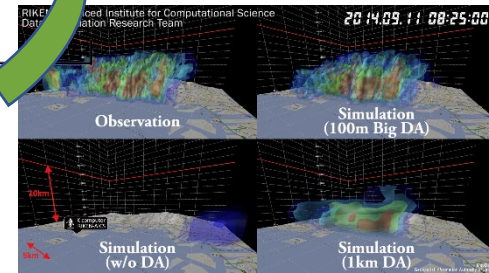
t = 2018-07-27 20:35:30 + 2.5 min



Future direction: **Fusing ML+DA+Simulation**



Input of future data from NWP!!



DA-AI fusion

(Best estimate)

Initial State

Simulation

Predict high-resolution from low-resolution model

Predict model error

Surrogate model

Need to learn big

DA algorithm

Integrating DA and AI
→ Pioneering new meteorology

DA

conversion

Observations

Sim-minus-Obs

Quality control

Broad-sense DA

