*EMS/ECAM2011, Freie Universität, Berlin, 15 September 2011*

# Studies at MRI toward cloud resolving ensemble NWP -Next generation supercomputer project and the Tokyo metropolitan area deep convection field campaign-

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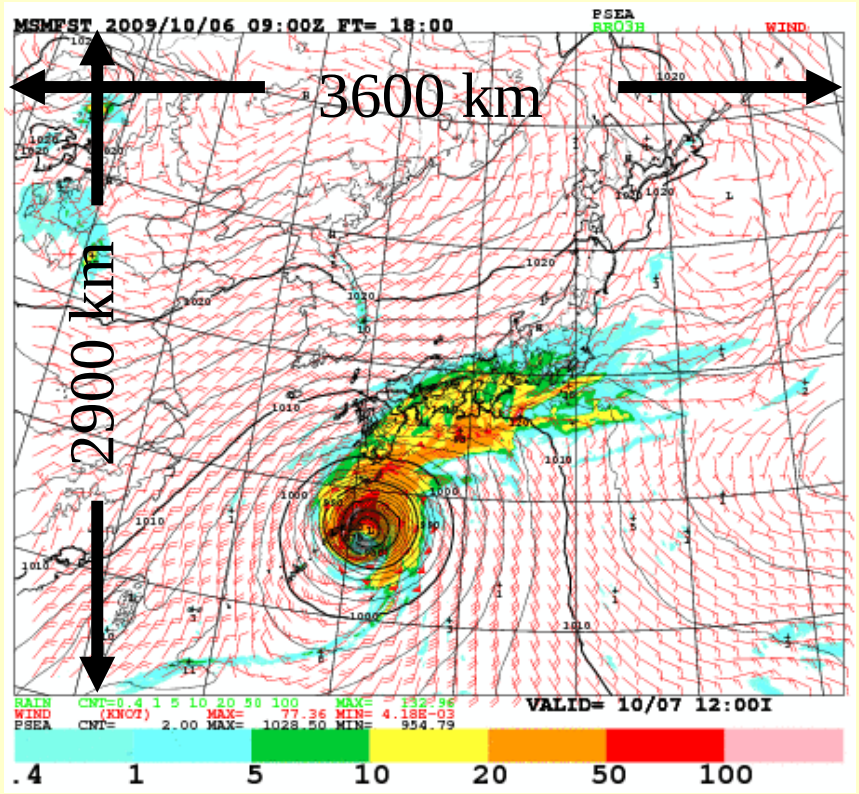
[3]*Numericak Prediction Division/JMA*

1. Background
2. The K-computer
3. Tokyo Metropolitan Area Convection Study (TOMACS)

# 1. Background

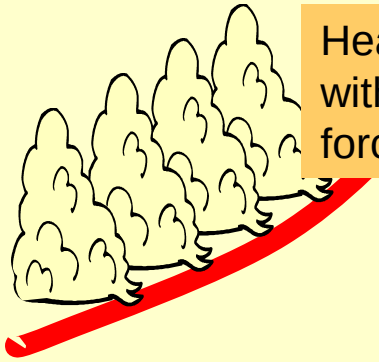
MSM: operational mesoscale model at JMA




- JMA nonhydrostatic model with 5km L50, 3hourly
- Initial condition: Nonhydrostatic 4DVAR (JNoVA)
- Boundary condition: High resolution GSM (TL959L60) forecasts

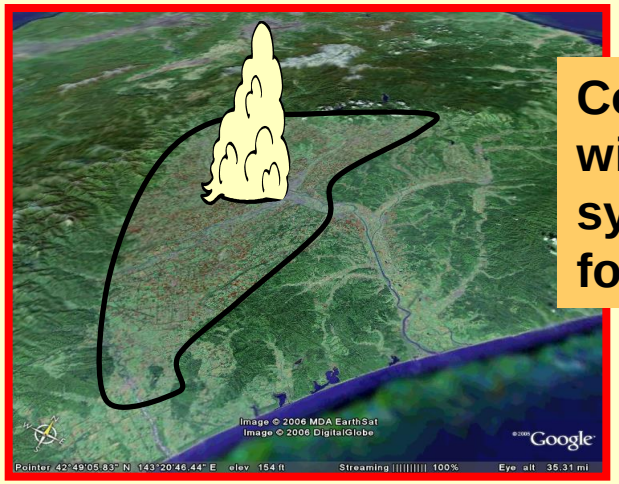
# Predictability of heavy rainfalls

Heavy rains with orographic forcing



Heavy rains with synoptic forcing

・・relatively predictable in the current mesoscale NWP up to a point

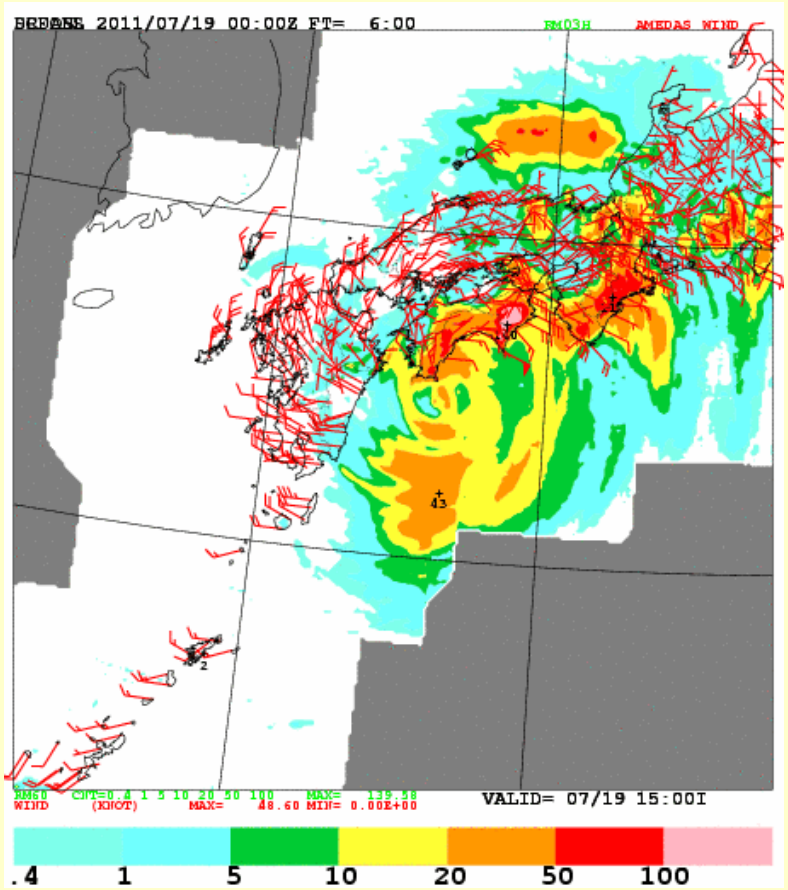



**Convective rains without strong synoptic/orographic forcing**

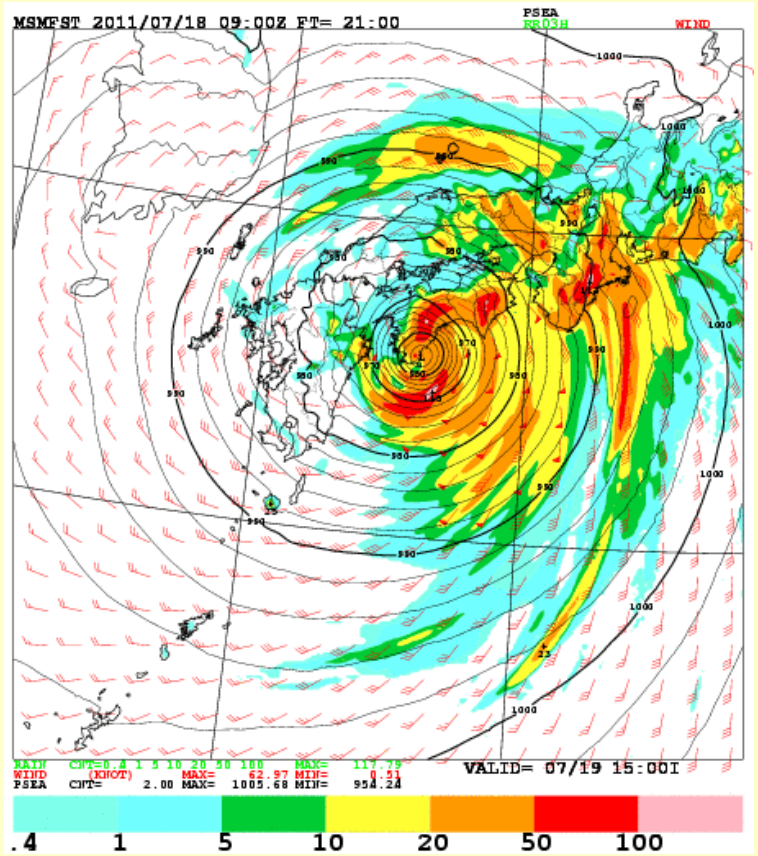
・・difficult to predict due to

- small spatial/temporal scales
- sensitive to small perturbations in initial conditions

# Example of orographic heavy rainfall



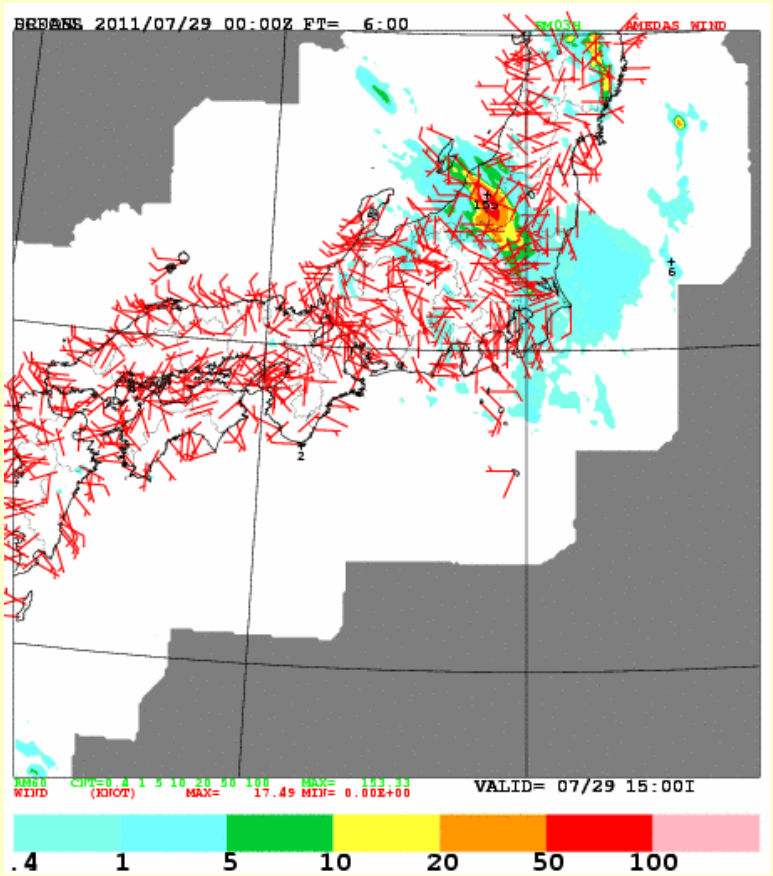

Radar-AMeDAS Observed rainfall
03-06 UTC, 19July 2011



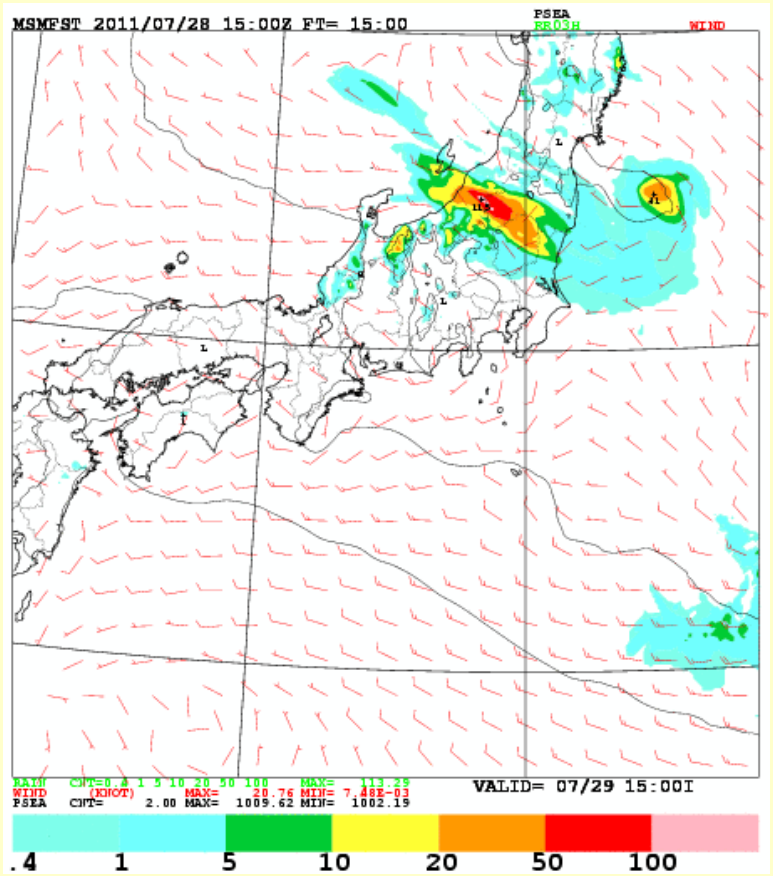

MSM prediction FT=21
03-06 UTC, 19July 2011

A strong typhoon (T201106 Ma-on) hit western Japan and record breaking 851mm rainfall was observed in one day (19 July 2001). MSM model accurately predicted the orographically forced rainfall.

# Example of frontal local heavy rainfall



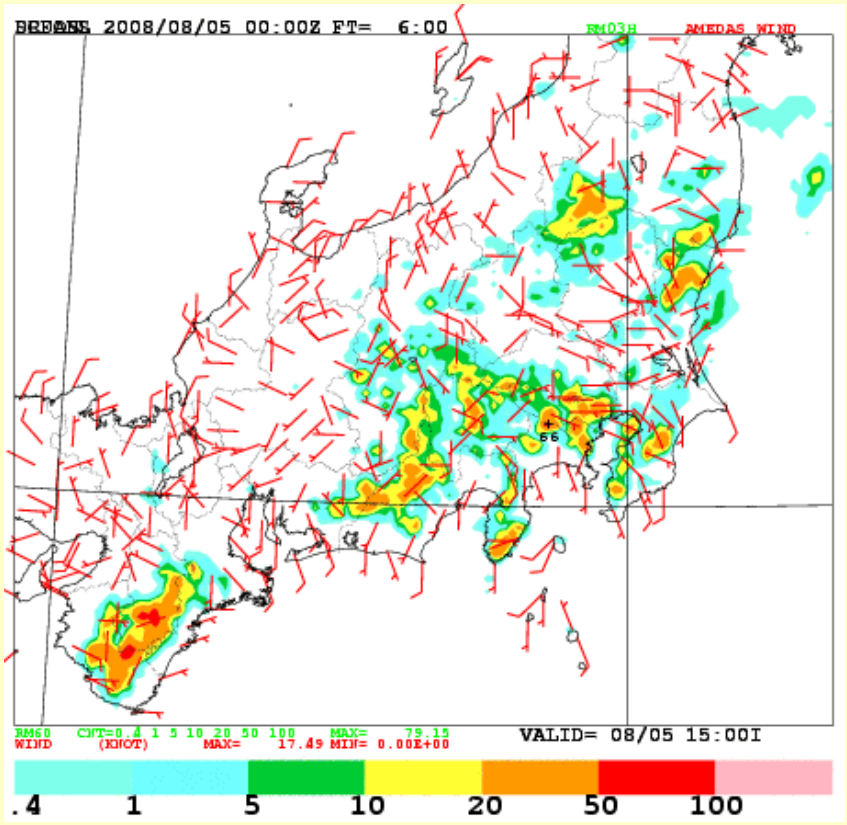

Radar-AMeDAS Observed rainfall
03-06 UTC, 29July 2011



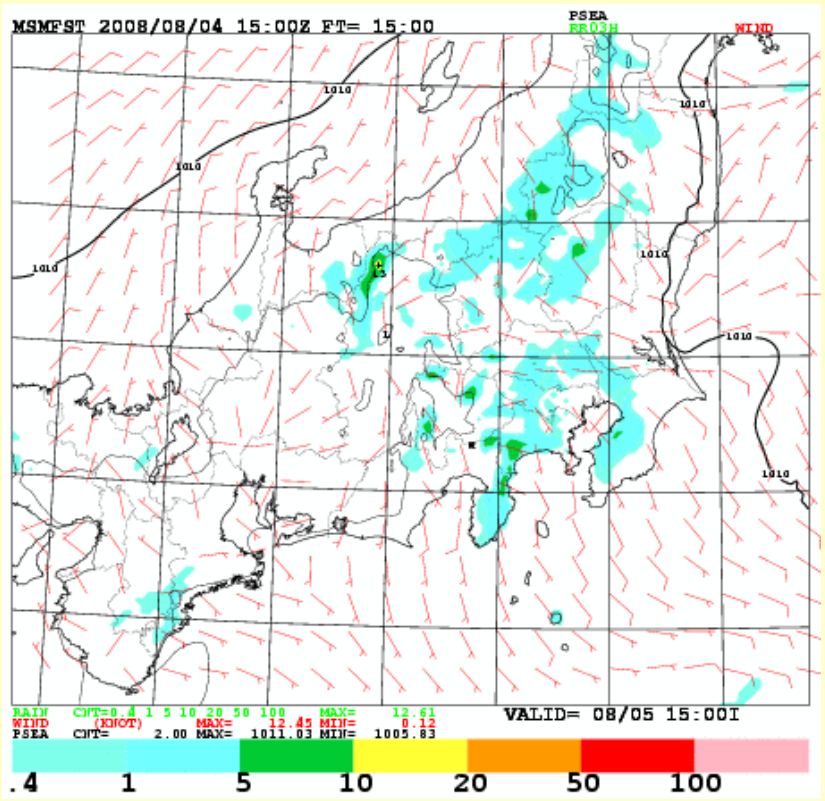

MSM prediction FT=15
03-06 UTC, 29July 2011

A stationary front brought 527 mm heavy rainfall in one day. MSM forecasts were accurate for this event.

# Example of unforced local heavy rainfall



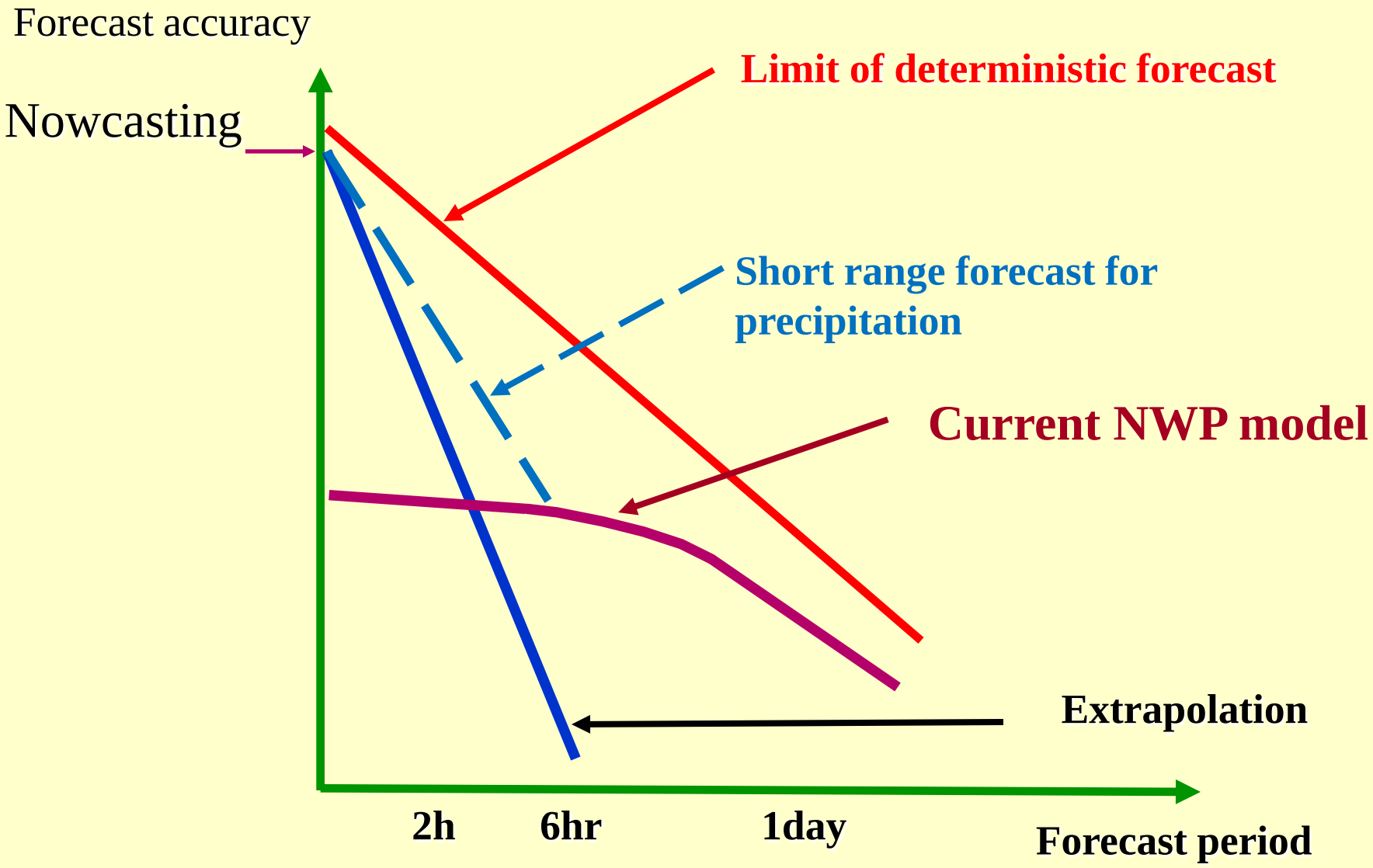

Radar-AMeDAS Observed rainfall
03-06 UTC, 5 August 2008



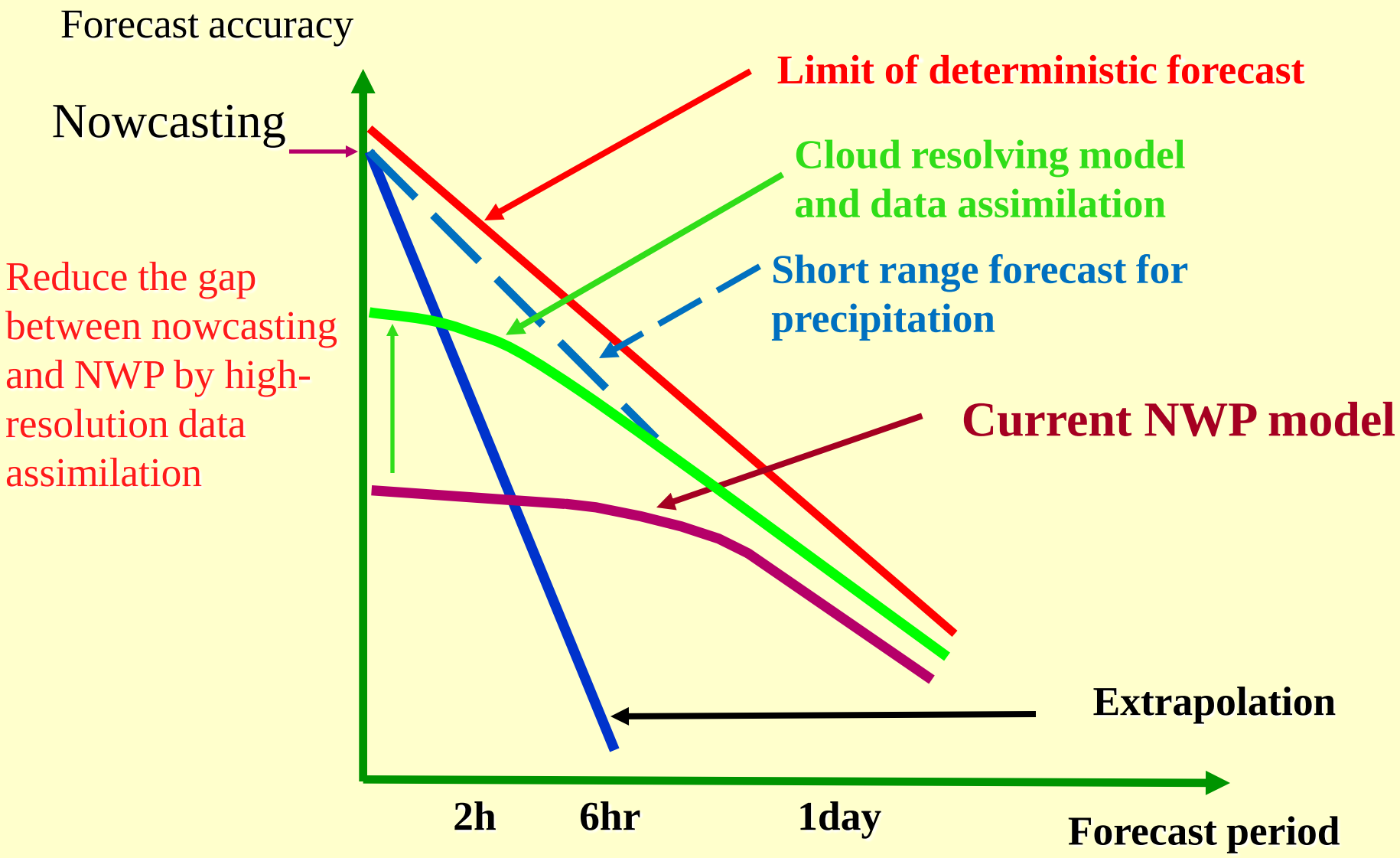

MSM prediction FT=15
03-06 UTC, 5 August 2008

Several convective cells yielded 50 mm per hour local heavy rainfalls at several locations. Five drainage workers were claimed.
Convection parameterized MSM failed to predict these local heavy rainfalls.

# Approaches to predict local heavy rain

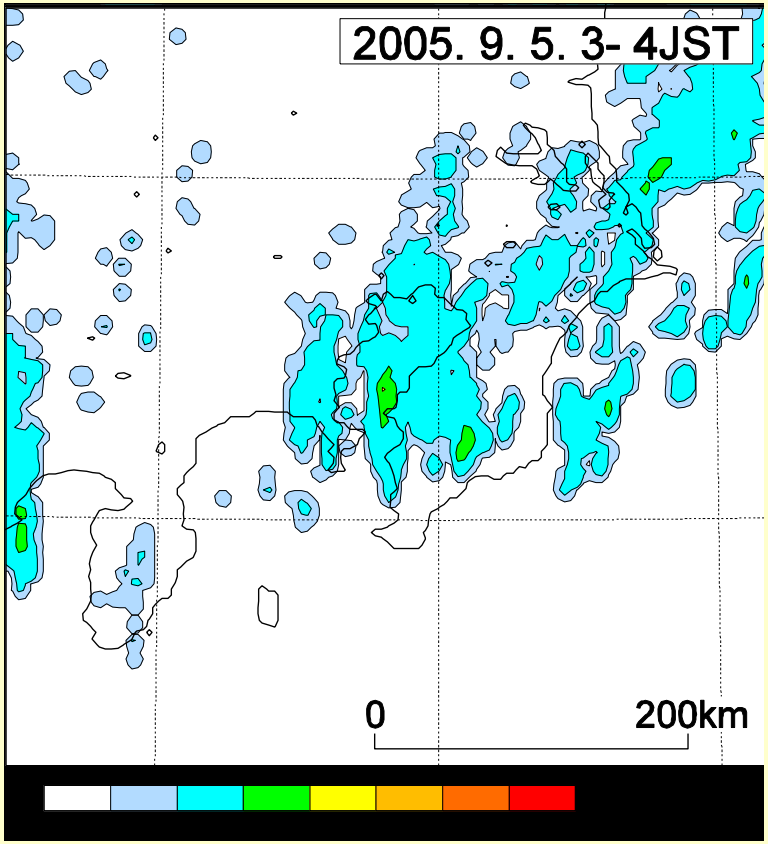


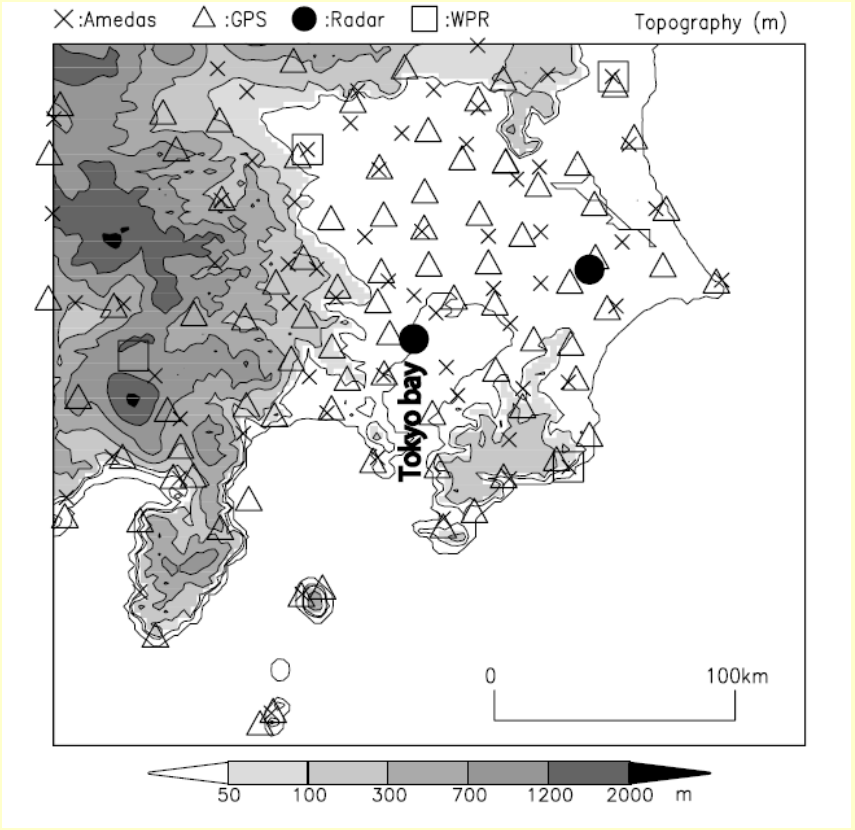
# 1) High resolution DA



# Cloud resolving 4DVAR

(Kawabata et al., 2011; *Mon. Wea. Rev.)*




Heavy rainfall event on 4-5 September 2005 at Tokyo

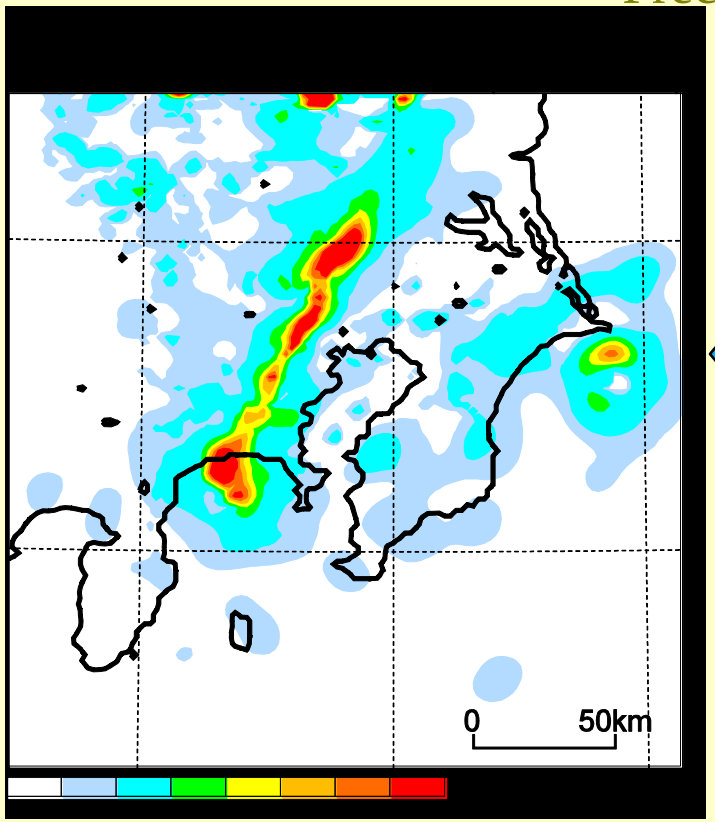
4DVAR assimilation of

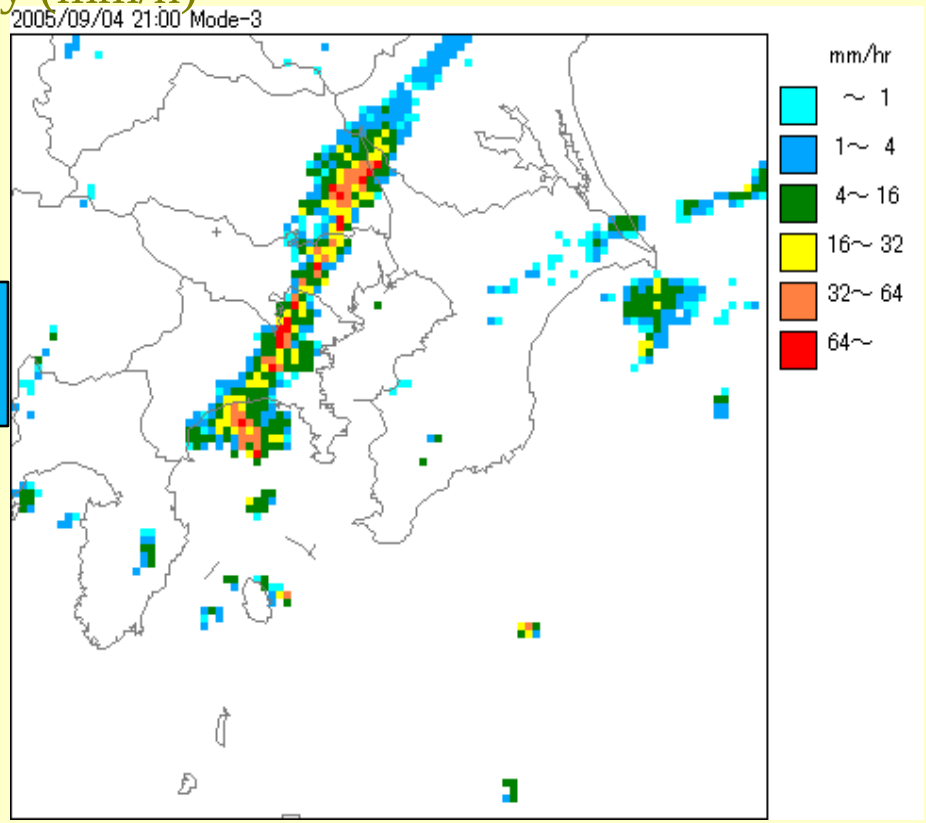
- Doppler Radar's Radial Winds
- Radar Reflectivity
- GPS precipitable water vapor
- Surface observations (wind, temperature)

4DVAR analysis

Precip. intensity (mm/h)

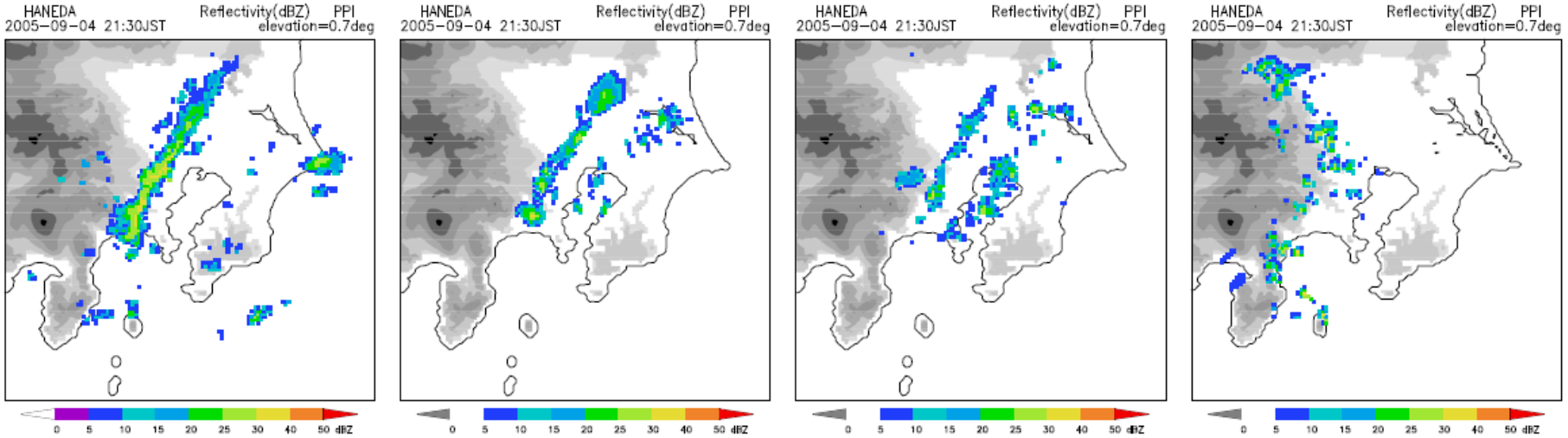
Observation




(Kawabata et al., 2011; *Mon. Wea. Rev.)*

Assimilation of radar reflectivity 2030-2100JST




2130 JST Obs

4DVAR with assimilation of radar reflectivity

4DVAR without radar reflectivity

1st guess

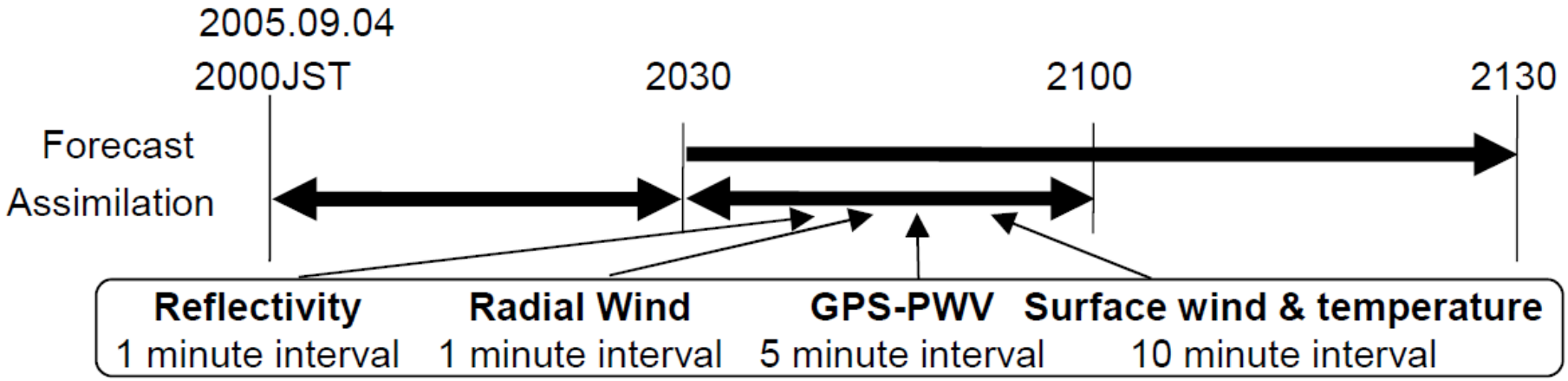
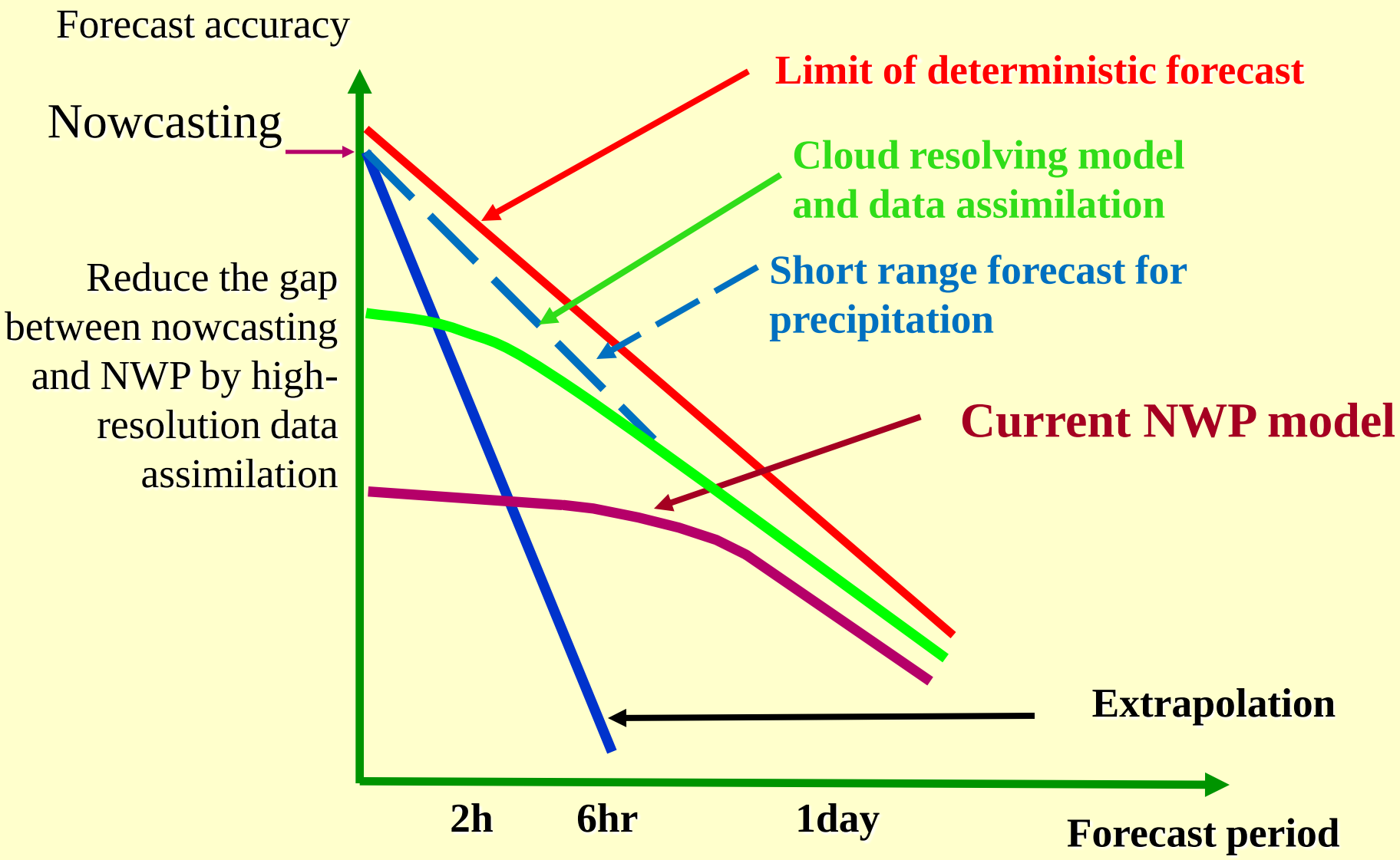


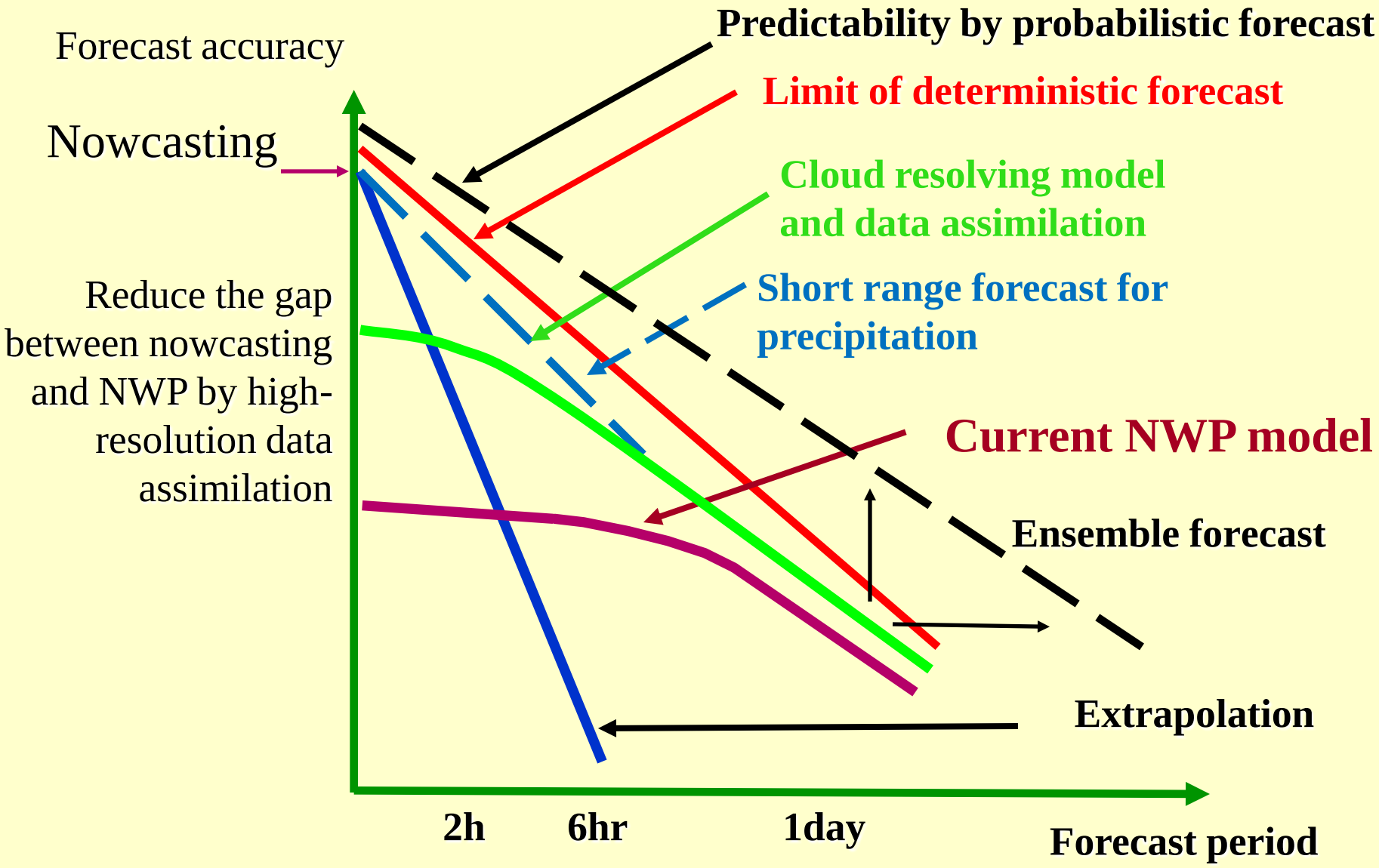

FIG. 9. Schematic diagram of assimilation experiment.

Kawabata et al. (2011; *Mon. Wea. Rev.*)

# Approaches to predict local heavy rain



# 2) Ensemble Prediction



# WWRP Beijing 2008 Olympics RDP Project

Intercomparison of the mesoscale (15 km) ensemble prediction.

NCEP, MSC, ZAMG&Meteo Fr., MRI/JMA, NMC/CMA, CAMS/CMA participated in RDP.

Project overview :Duan et al. (2011; *BAMS*)

MRI's contributions
Kunii et al. (2010; *SOLA*, 2011; *Tellus*)
Saito et al. (2011a, 2011b; *Tellus*)

Value of mesoscale EPS for moderate rain and surface conditions were obvious, but Not sufficient for intense rains.

お気に入り(S) D:¥Dynabook¥国際協力¥B08RDP¥From The Times.doc

News Site of the Year | The 2008 Newspaper Awards

TIMESONLINE

From The Times

May 12, 2008

## Toughest event at Beijing Olympics - getting weather forecast right

A storm rages over the Great Wall of China. Experts from seven countires are competing to predict the weather in Beijing

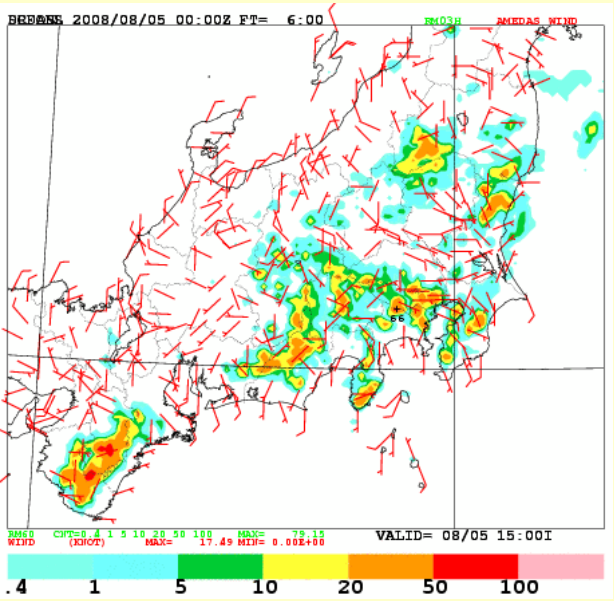
Ashling O'Connor, Olympics Correspondent

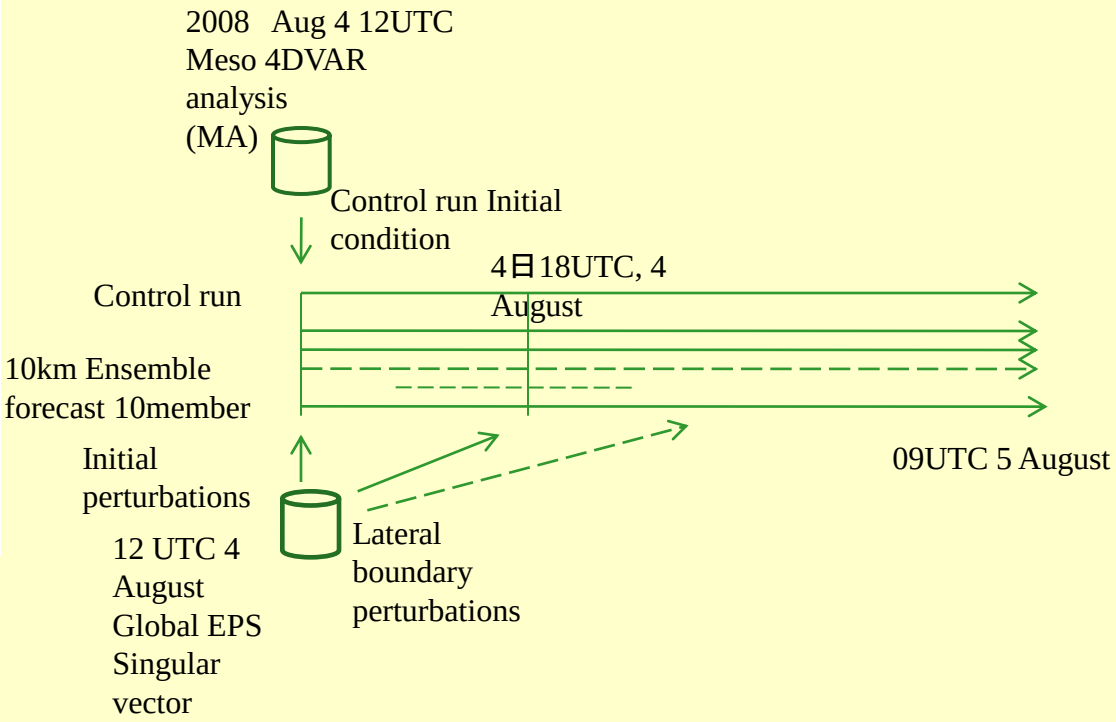
It might be all about higher, faster and stronger on the track – but hotter, wetter, smoggier, will be the motto for an unofficial event at the Beijing Games: weather forecasting.

Teams of experts from seven countries will be competing to be the Olympic forecasting champion. Every three hours scientists from Japan, the US, Australia, Canada, Austria, France and China will be analysing observational data and atmospheric pressure to predict the temperature, humidity and precipitation for the Beijing area for up to 36 hours ahead. Their forecasts will be submitted to the China Meteorological Administration, which will judge them against the weather.

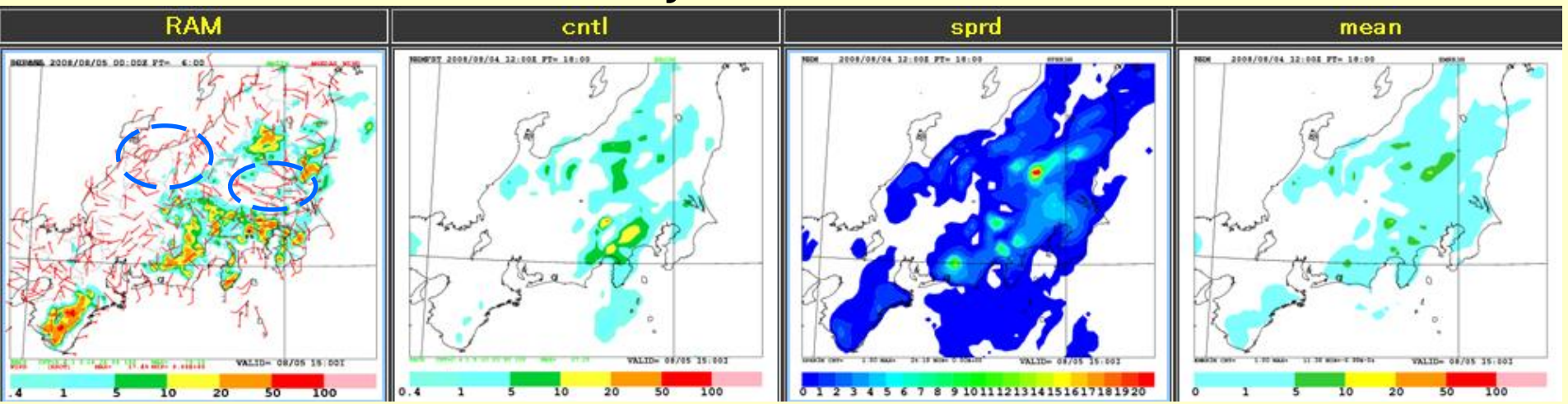
The Weather Demonstration Project is part of a global research programme started in 1999 by the World Meteorological Organisation, the United Nations' official "voice" on the weather. The project, which featured at the Sydney Games in 2000, is designed to showcase the latest technology used

# Application of mesoscale ensemble forecast to the August 2008 unforced convective rains



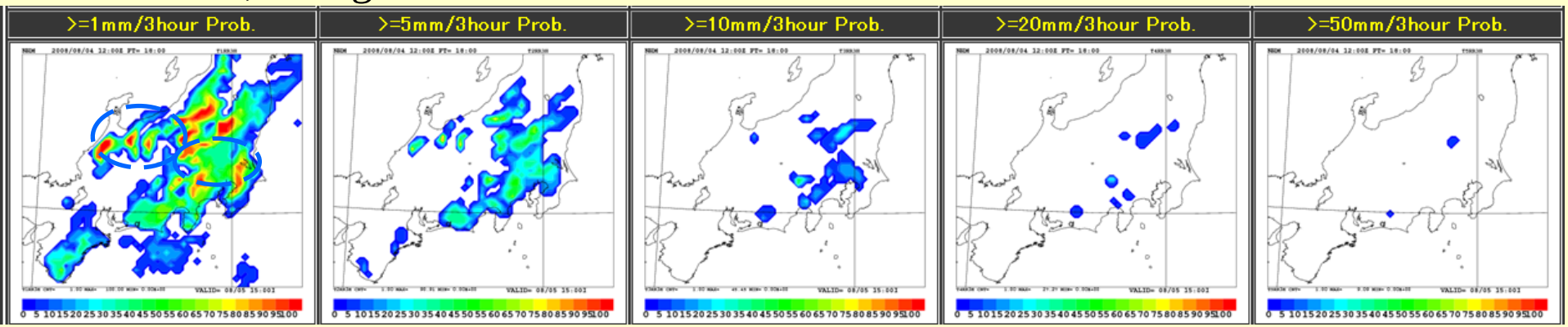



# 10 km ensemble prediction from hydrostatic 4D-VAR analysis FT=18




Observation　　Control run　　Ensemble spread　　Ensemble mean

03-06 UTC, 5 August 2008

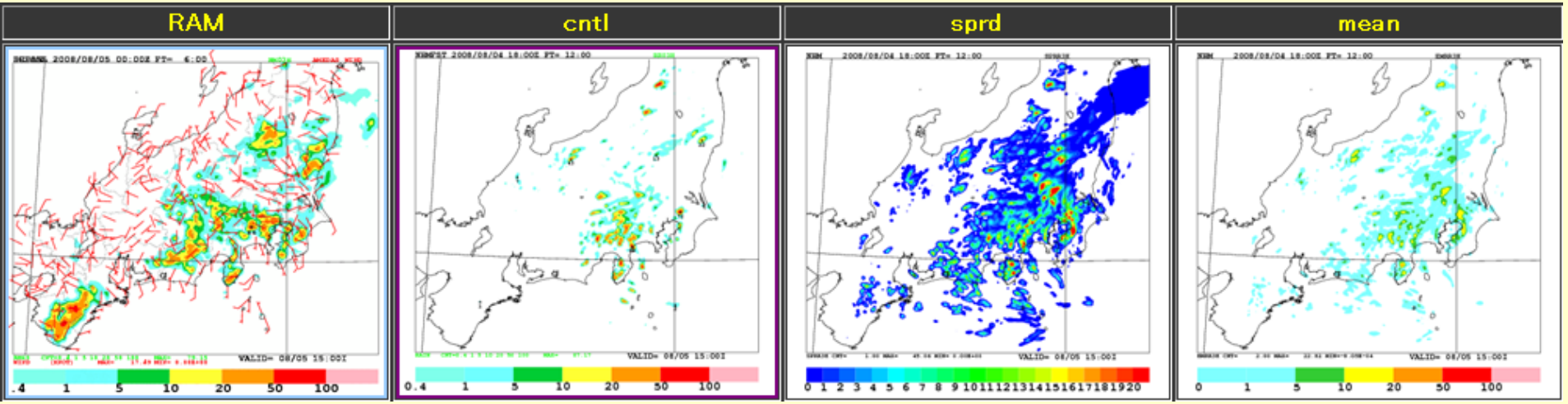



1mm/3h　　5mm/3h　　10mm/3h　　20mm/3h　　50mm/3h

Probability of precipitation

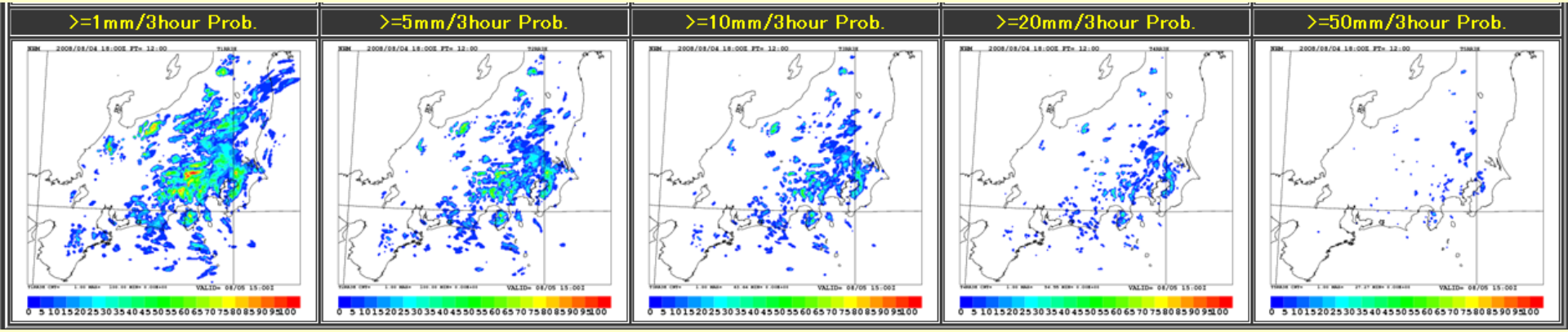
Intense rains are not detected.

# 2 km ensemble prediction from hydrostatic 4D-VAR analysis FT=18




Observation　　Control run　　Ensemble spread　　Ensemble mean

03-06 UTC, 5 August 2008

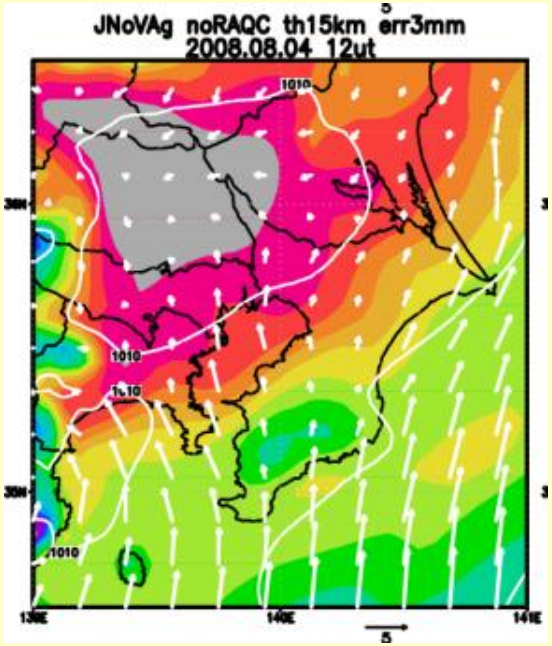


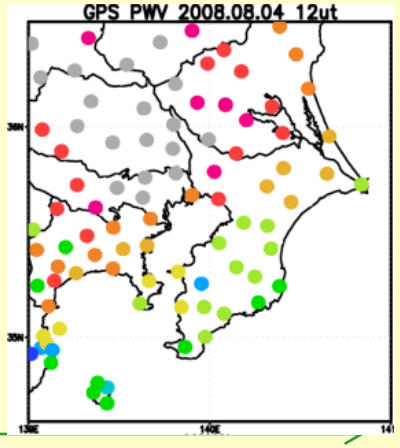

1mm/3h　　5mm/3h　　10mm/3h　　20mm/3h　　50mm/3h

Probability of precipitation

Intense rains appear, but still not enough.

# Assimilation of GPS TPW with nonhydrostatic 4DVAR and cloud resolving ensemble forecast for unforced convective rains




2008 Aug 1
21UTC
Meso
4DVAR
analysis
(MA)

00UTC, 2 August

12UTC, 4 August

3 hour
forecast

JNoVA DA cycle
with GPS TPW

Control run Initial
condition

4日18UTC, 4
August

Control run

10km Ensemble
forecast 10member

Initial
perturbations

12 UTC 4
August
Global EPS
Singular
vector

Lateral
boundary
perturbations

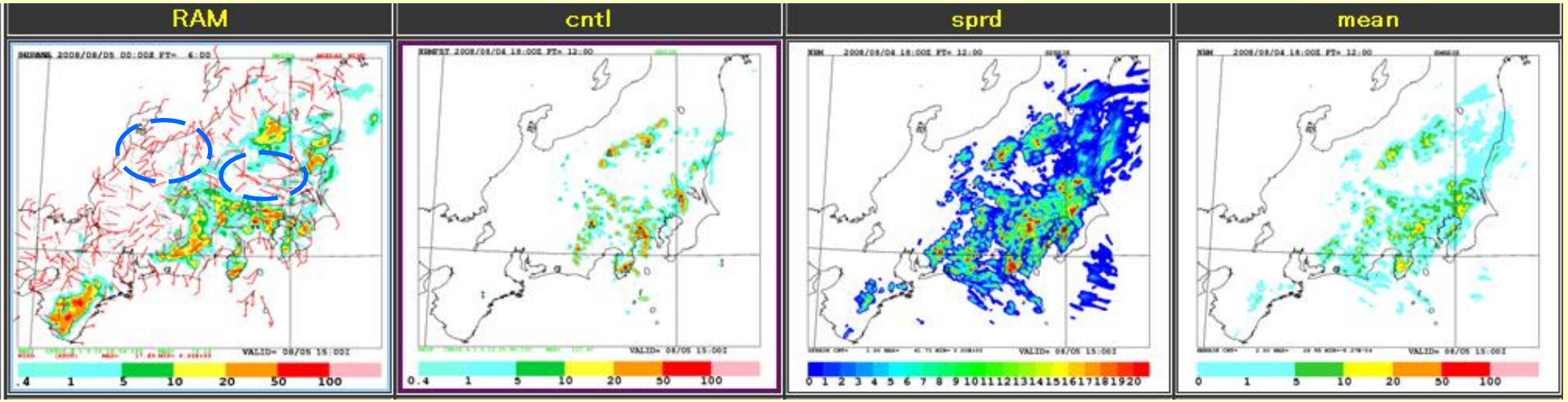
Initial and lateral boundary
perturbations

2km Ensemble forecast
11members

09UTC 5 August

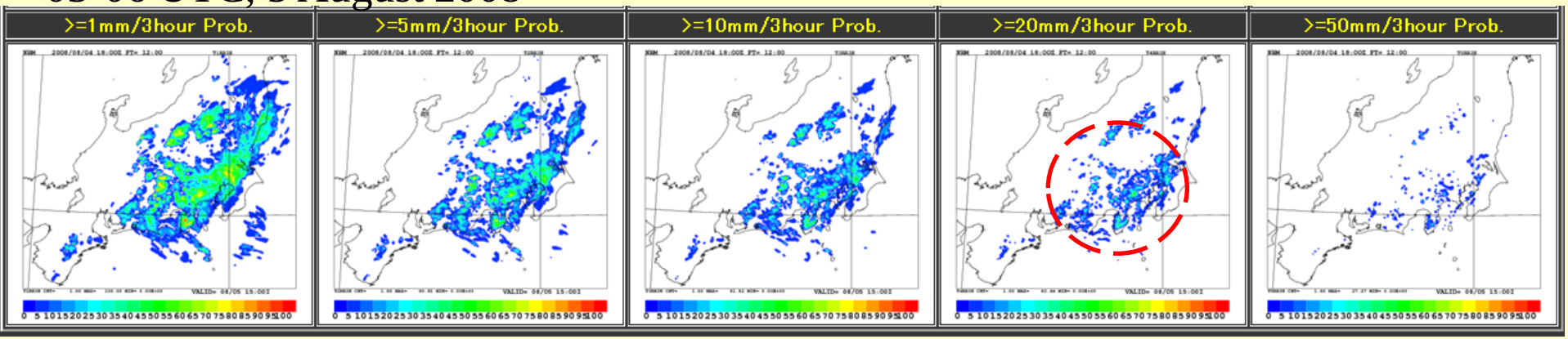
Saito et al (2011)

# Cloud resolving ensemble prediction for unforced convective rains from JNoVA analysis




Observation Control run Ensemble spread Ensemble mean

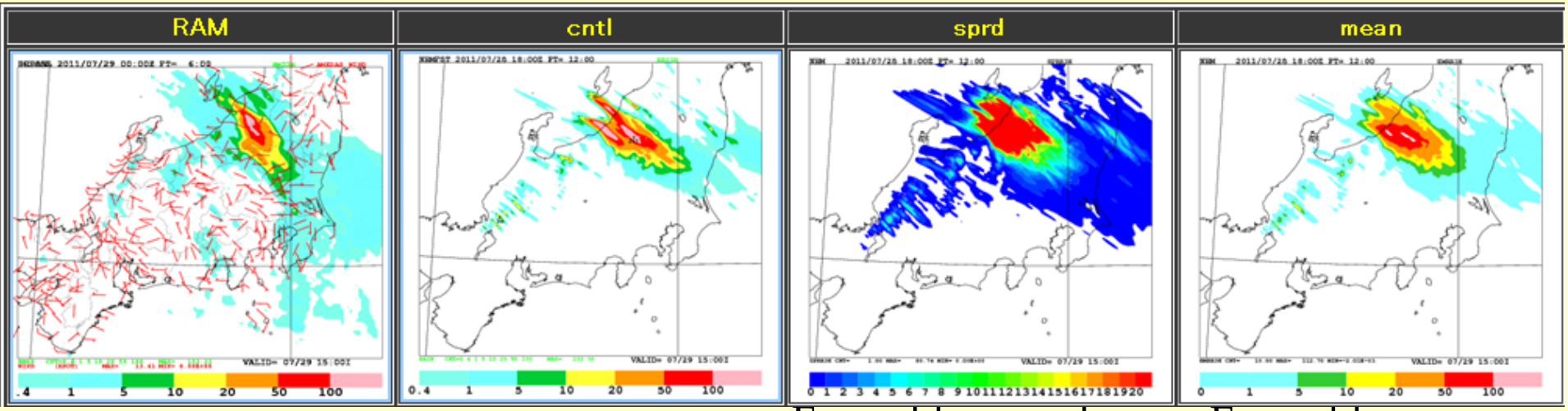
03-06 UTC, 5 August 2008




1mm/3h 5mm/3h 10mm/3h 20mm/3h 50mm/3h

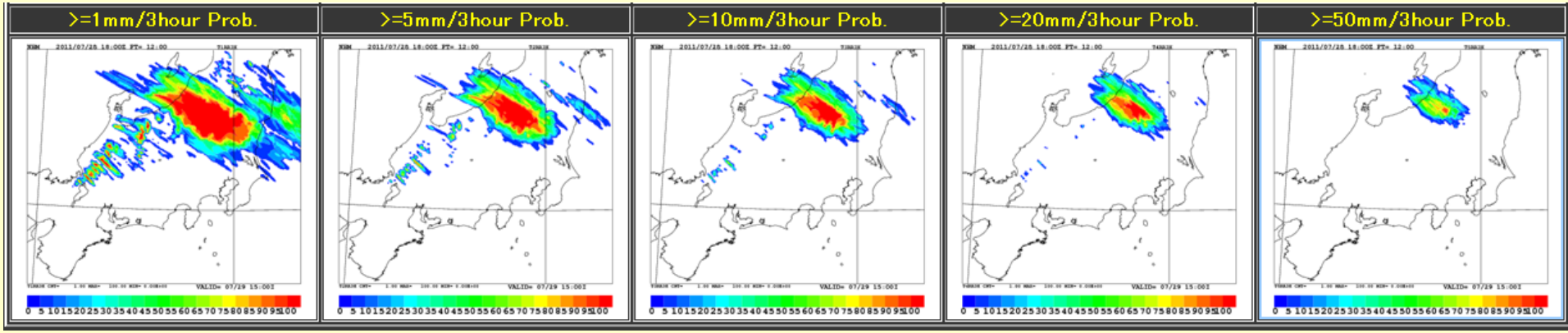
Probability of precipitation. A certain probability for 20mmm/3h .
IC by nonhydrostatic 4DVAR assimilation of GPS TPW was essential.

# 2km ensemble prediction from JMA nonhydrostatic 4D-VAR (JNoVA) analysis with GPS TPW assimilation




Observation | Control run | Ensemble spread | Ensemble mean

03-06 UTC, 29 July 2011




1mm/3h | 5mm/3h | 10mm/3h | 20mm/3h | 50mm/3h

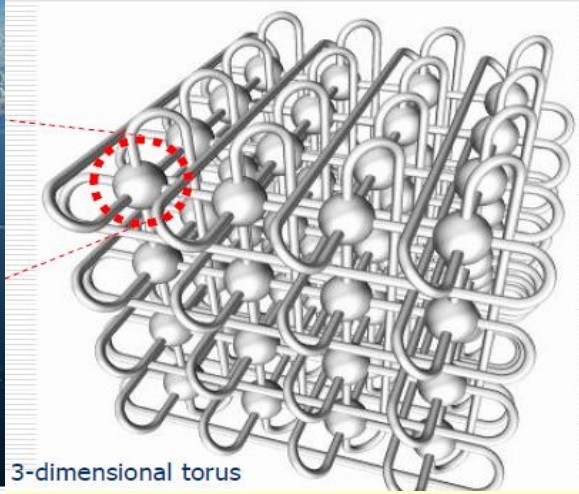
Probability of precipitation at FT=18

Solid probability even for 50mmm/3h !

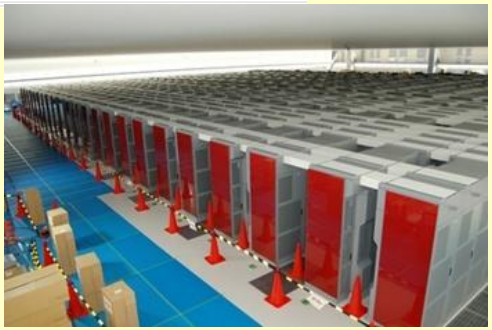
# 2. The K-computer

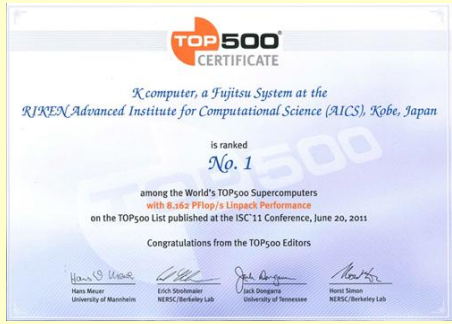

450km (280miles)
west from Tokyo


- Logical 3-dimensional torus network
- Peak bandwidth: 5GB/s x 2 for each direction of logical 3-dimensional torus network
- bi-section bandwidth: > 30TB/s



3-dimensional torus





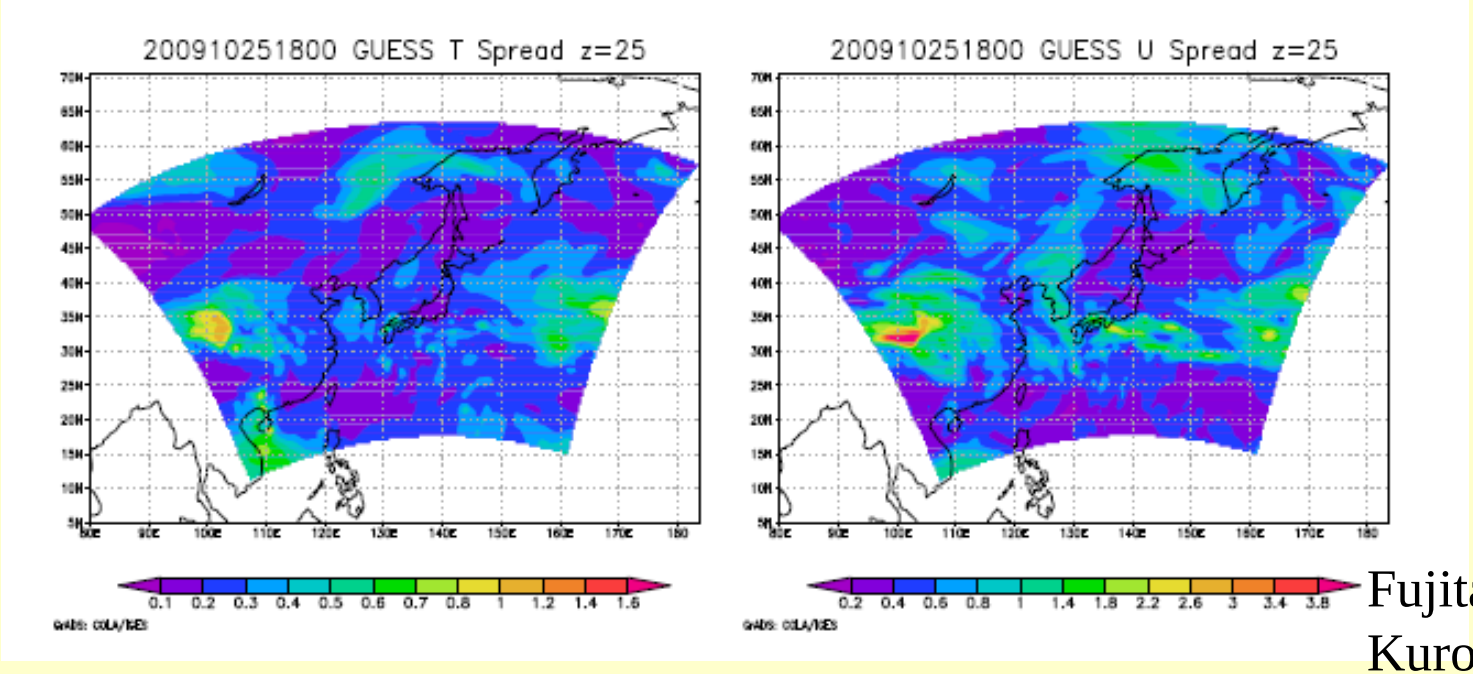

The K-computer has been constructed in Kobe. Whole system is complete in 2012.

http://www.nsc.riken.jp/index-eng.html

Fujitsu SPARC64™ VIIIfx, 8 cores, 128 Gflops x 80,000

8.162 Pflops in the LIMPACK benchmark in June 2011 with a computing efficiency ratio of 93.0%.

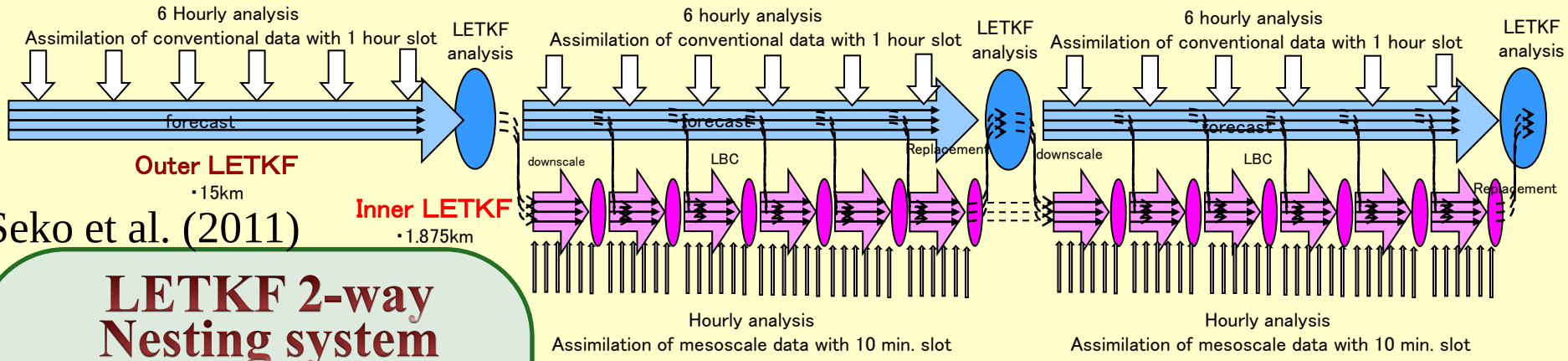
# Development of a full-scale incremental LETKF analysis and prediction system




Fujita et al. (2011)
Kuroda et al. (2011)

- Observation operators are shared with the JMA operational 4DVAR
- Adaptive inflation $\left\langle \mathbf{d}\mathbf{d}^{\top} \right\rangle = (1+\delta)\mathbf{H}\mathbf{P}^{f}\mathbf{H}^{\top} + \mathbf{R}$
- Adaptive localization (Bishop and Hodyss, 2007)
- Use of a no-cost smoother for the inner loop model to supply assimilation increment to the outer loop model, mimicking JNoVA

A maximum likelihood ensemble filter using neighbor ensemble (Aonashi and Eito, 2011) and a particle filter based on JMA-NHM are also under development



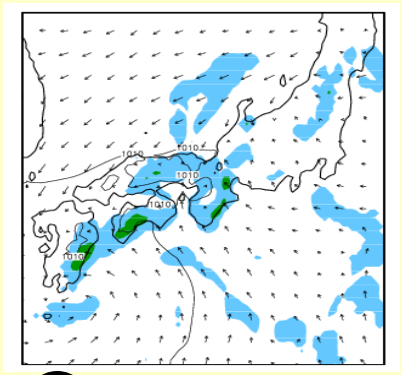

Seko et al. (2011)

# LETKF 2-way Nesting system

① Modifies the large scale convergence by LETKF no-cost smoother

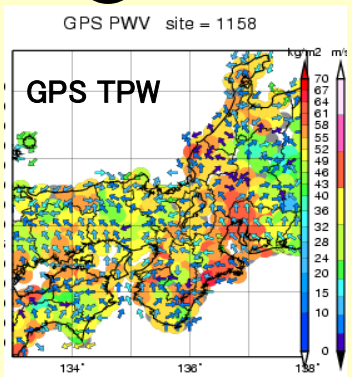
② Predicts convective rains by assimilating storm scale data with 10 min. slot

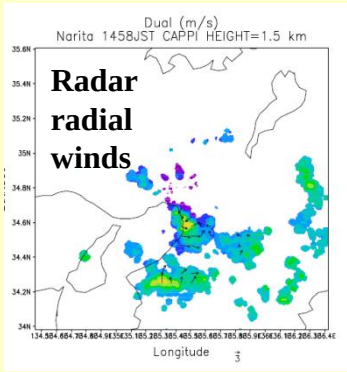
③ First guess of father EPS is modified by CR LETKF.

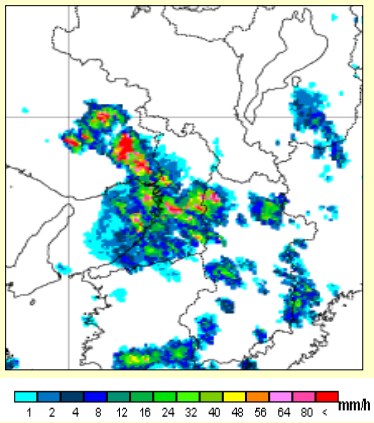


① Ensemble mean of outer LETKF

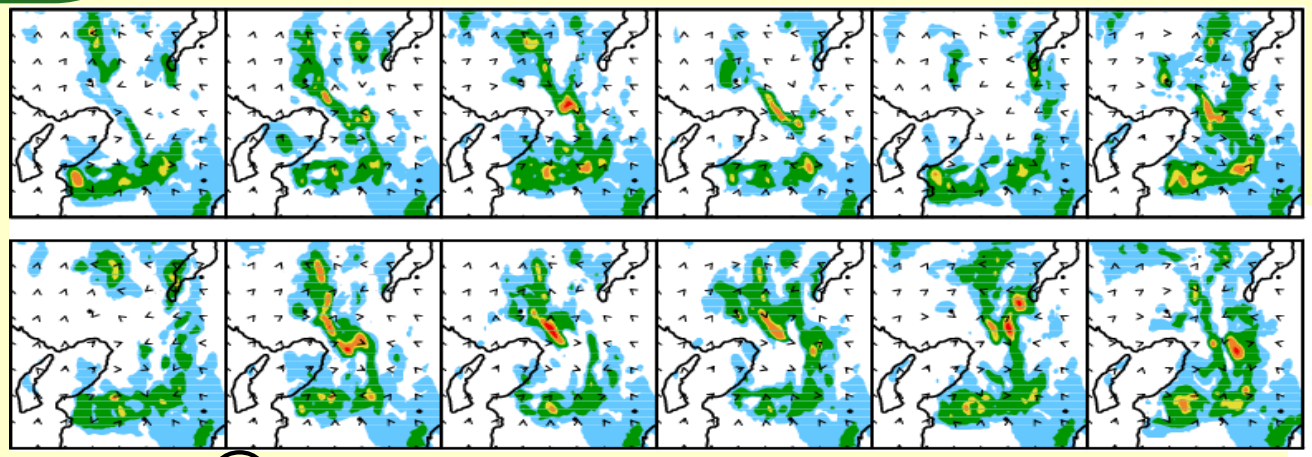
## ③ mesoscale observation data



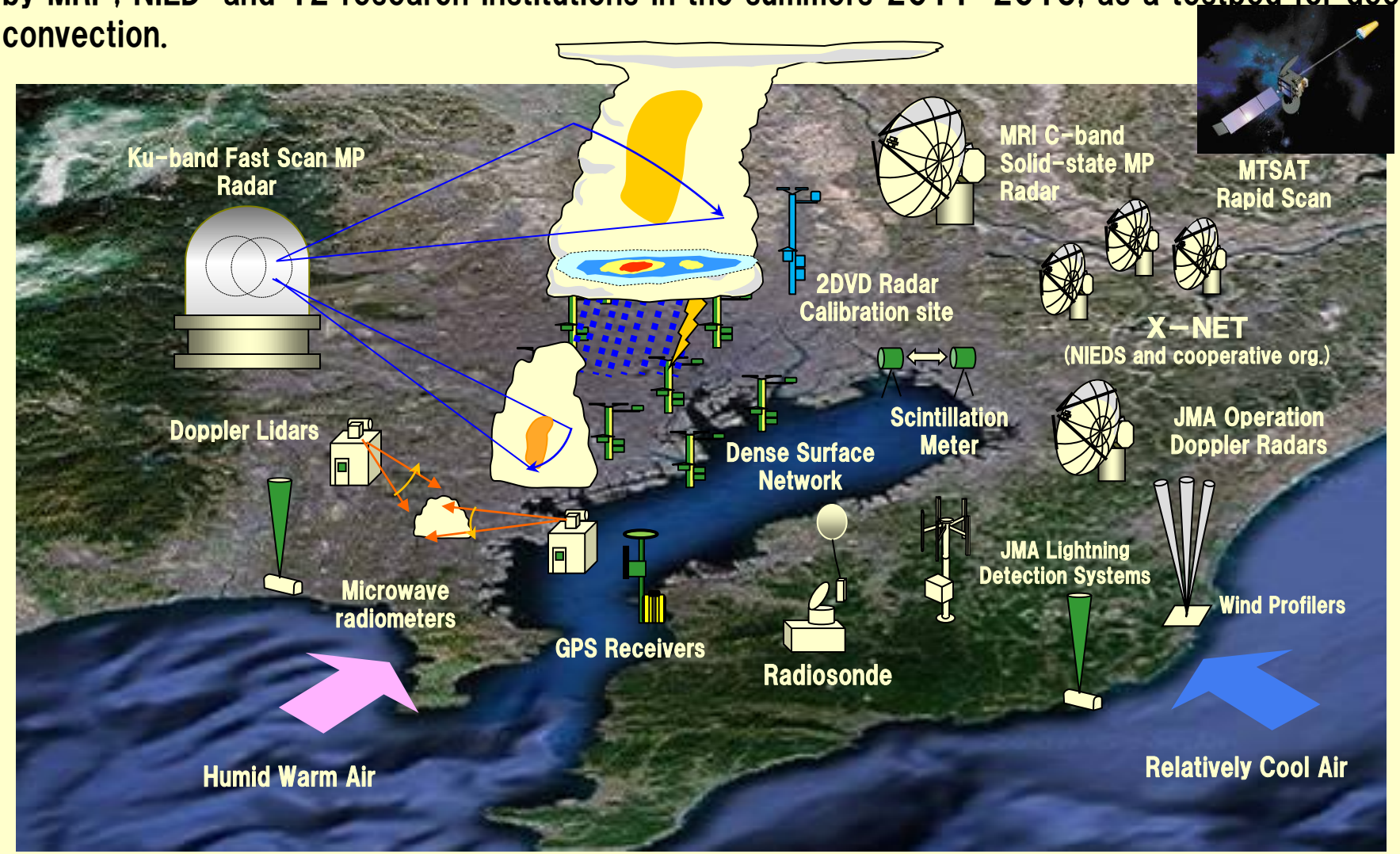

④ Observed precipitation




② Forecast of precipitation by inner LETKF

# 3. Tokyo Metropolitan Area Convection Study (TOMACS; 2011-2013)

**A field campaign in the Tokyo metropolitan area with a dense observation network is conducted by MRI[1], NIED[2] and 12 research institutions in the summers 2011-2013, as a testbed for deep convection.**

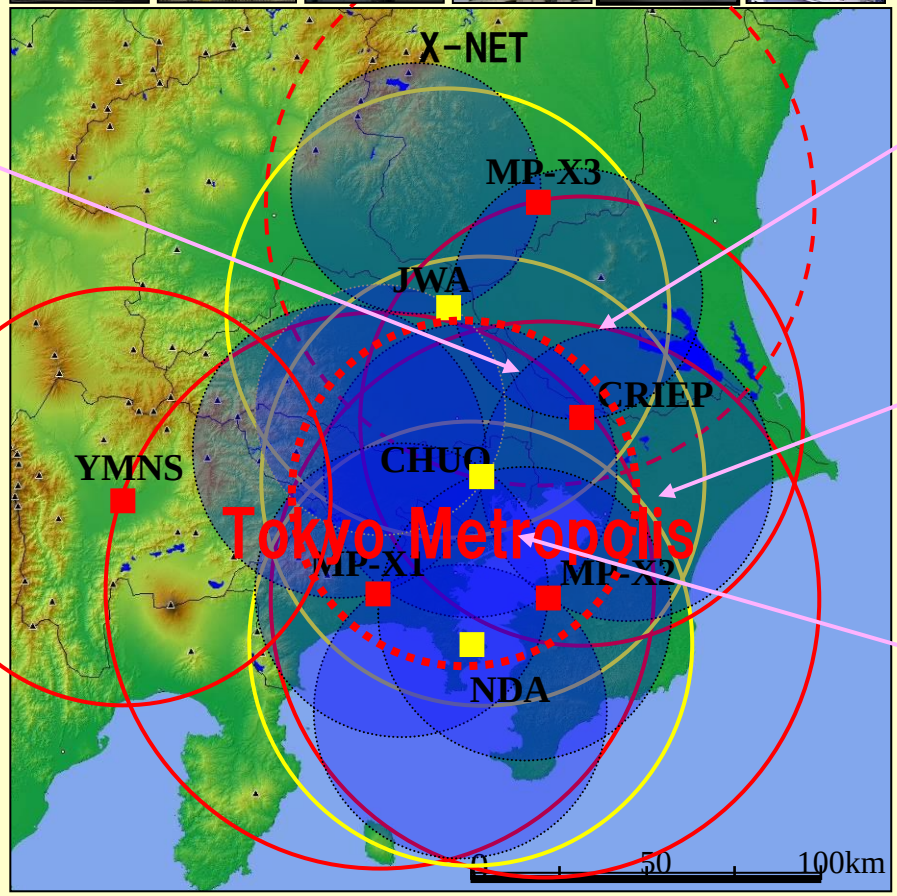



[1]Meteorological Research Institute, [2]National Research Institute for Earth Science and Disaster Prevention

# 14 Doppler Radars

Research/operation weather radars concentrate in the Tokyo Metropolitan Area: X-NET (5 X-band MP radars and 3 Doppler radars), two X-band MP radars of River Bureau, MRI C-band MP radar and 3 JMA C-band operational Doppler radars.

JMA Kashiwa C-band Doppler radar



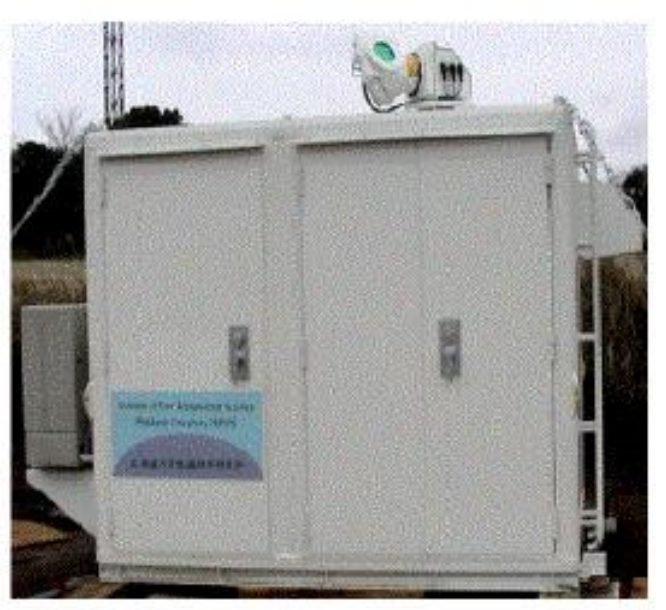

M. Maki of NIED and X-NET Group


JMA Narita Airport C-band Doppler radar

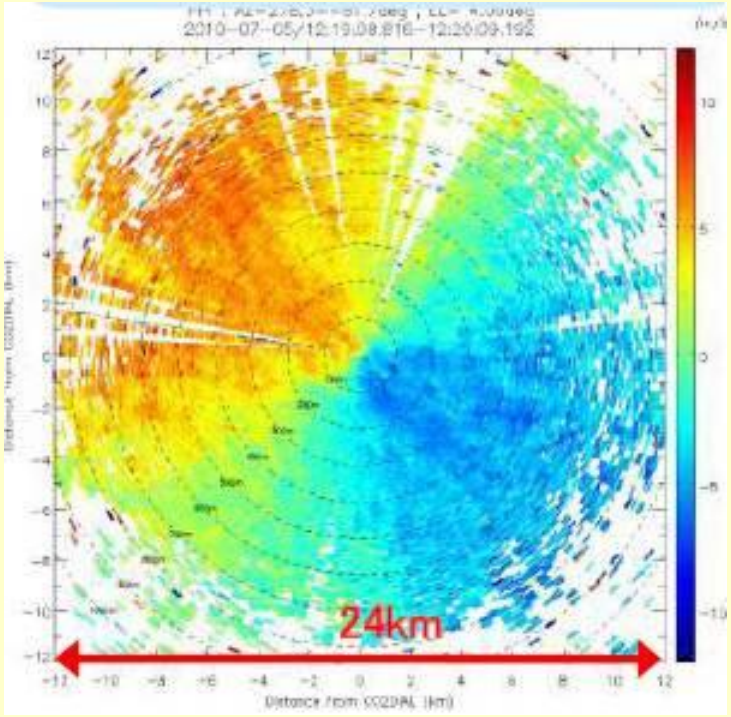
JMA Haneda Airport C-band Doppler radar

# 6 Doppler Lidars and a microwave radiometer

**Two research Doppler lidars are operated in the experiment in addition to four JMA operational Doppler lidars in the Haneda and Narita airports, to observe the initiation of convection and behaviors of sea breeze fronts.**



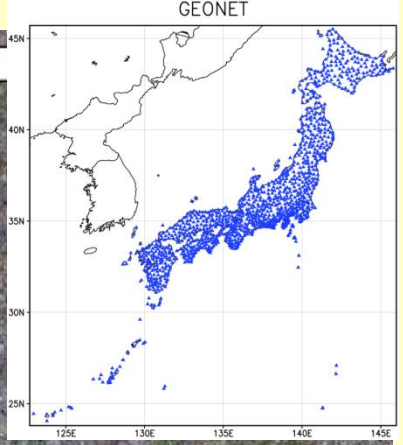
Lidar of Hokkaido University (Y. Fujiyoshi and M. Kawashima )
1.54μm eye-safe laser
20km of maximum range
25m resolution




PPI of the Lidar of National Institute of Information and Communications Technologies (NICT) on 5 July 2010, just before initiation of thunderstorms

NICT Team

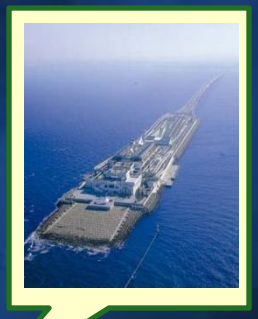
# TOMACS: GPS Observation
# For monitoring of water vapor variation




**KNAN:**
Tokyo Univ. of Marine Science and Technology

**URYS:**
Urayasu City Clean Center

**KHJM:**
Oota Incineration Plant



**KWSK:**
Kawasaki Harbor Joint Government Building

**UMHT:**
Umi-hotaru PA

- Five new GPS sites are installed in addition to GEONET.
- Online data acquisition at four stations except for UMHT.
- Solar –powered energy supply at UMHT.

: TOMACS
: GEONET by GSI
: Other organizations

# Summary

- Orographically/syonoptically forced heavy rainfalls are becoming predictable in the state-of-the-art mesoscale NWP system.
- Prediction of unforced convective local rains is still challenging, but recent progress of the advanced studies is promising.
- Quality of initial condition is critical in higher resolution cases, even in the ensemble prediction.
- The K-computer will reduce compromise of resolutions and members in ensemble NWP.
- TOMACS, unprecedented dense field campaign, is conducted in the summers 2011-2013 as a deep convection testbed.

# Thank you

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