

Theme 2: Development and validation of regional cloud-resolving ensemble forecast system

Meteorological Research Institute,
Japan Agency for Marine-Earth Science and Technology,
Japan Meteorological Agency,
Tohoku University,
Kobe University,
Disaster Prevention Research Institute,
Kyoto University, etc.

Theme 2: Development and validation of regional cloud-resolving ensemble forecast system



- Forecasts with the probability are desired because it is difficult to predict severe events such as local heavy rainfalls.
- Ensemble prediction is also expected to reduce the miss rate of their forecasts because they provide many scenarios of severe phenomena.

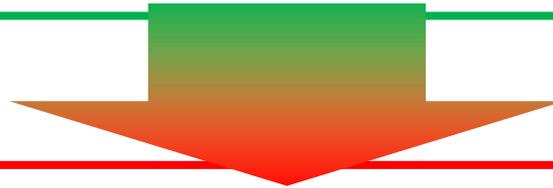


- The ensemble forecast system is under development using the K-computer (high resolution, large ensemble member).
- The outputs of ensemble forecasts have been used as the input data of the inflow predictions of Dams in this project.

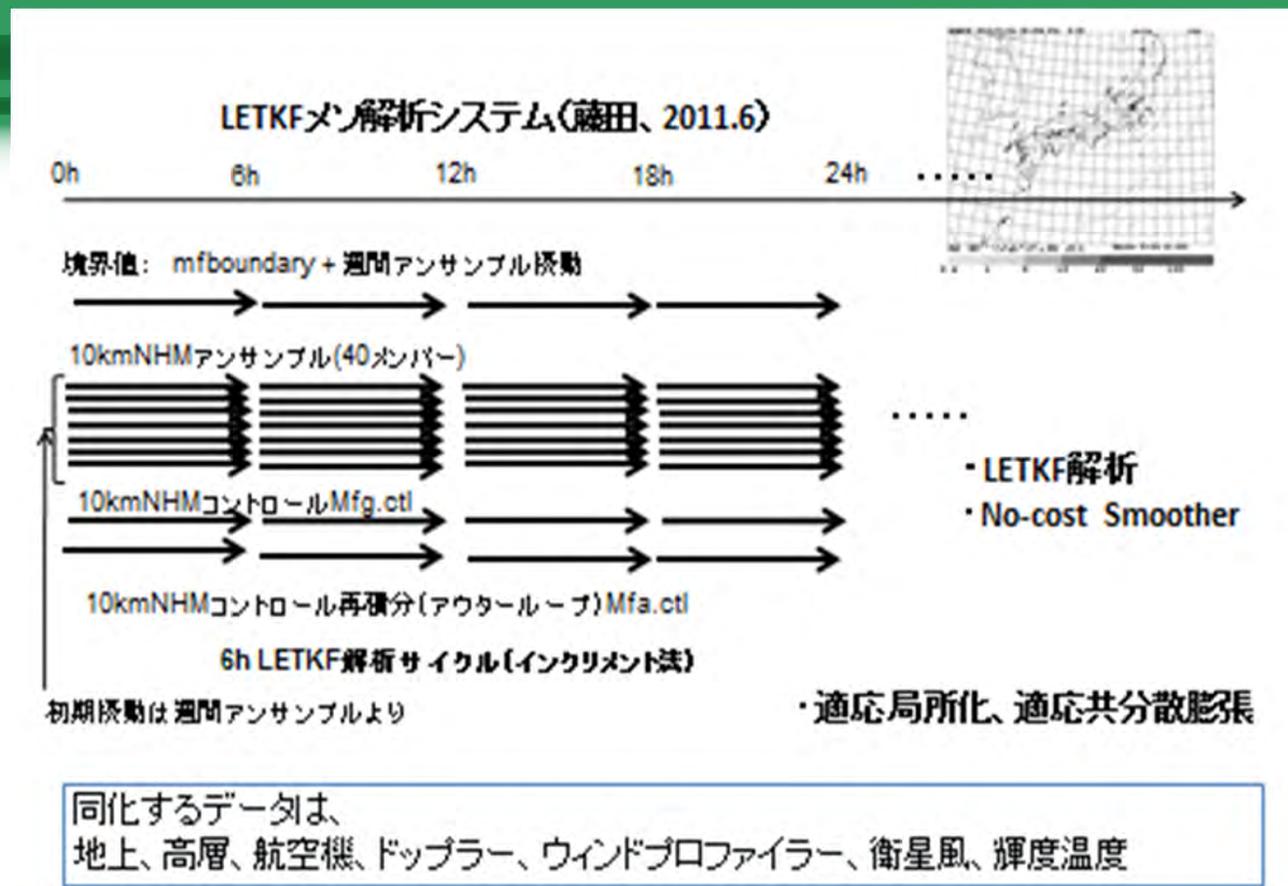
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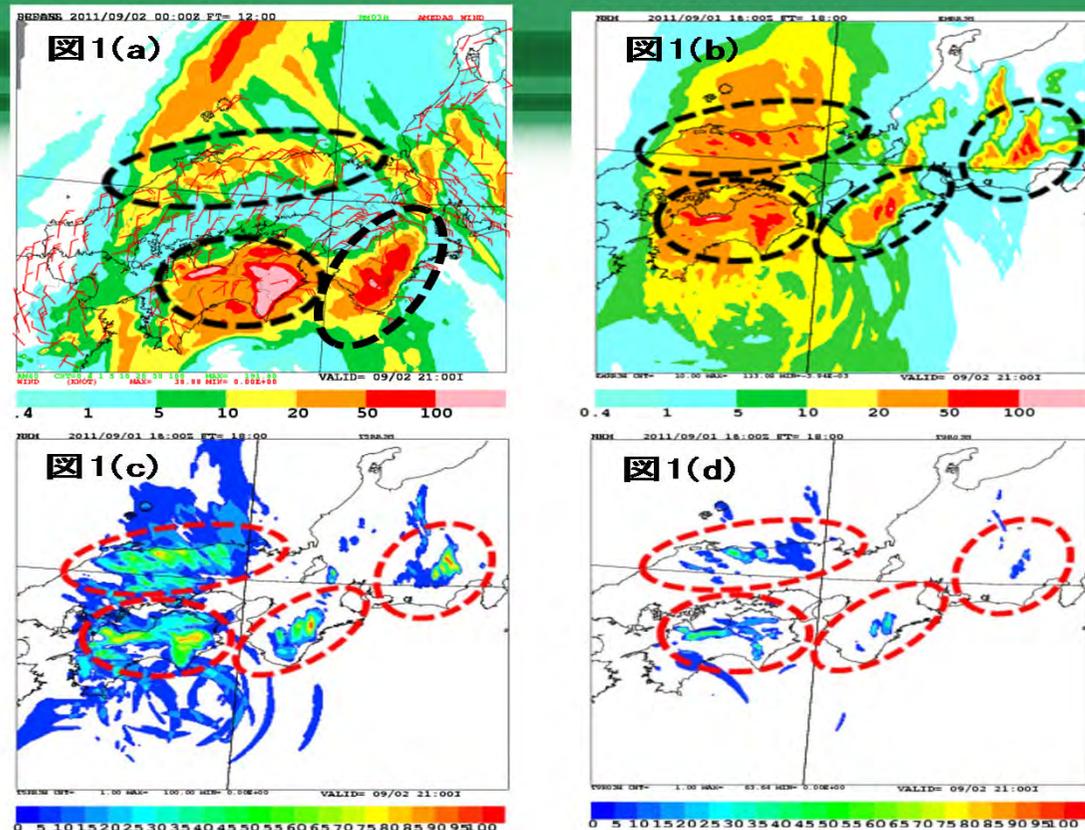


Results of the ensemble forecast systems and the applications using the outputs of ensemble forecasts, such as the inflow prediction of Dams, will be shown briefly.



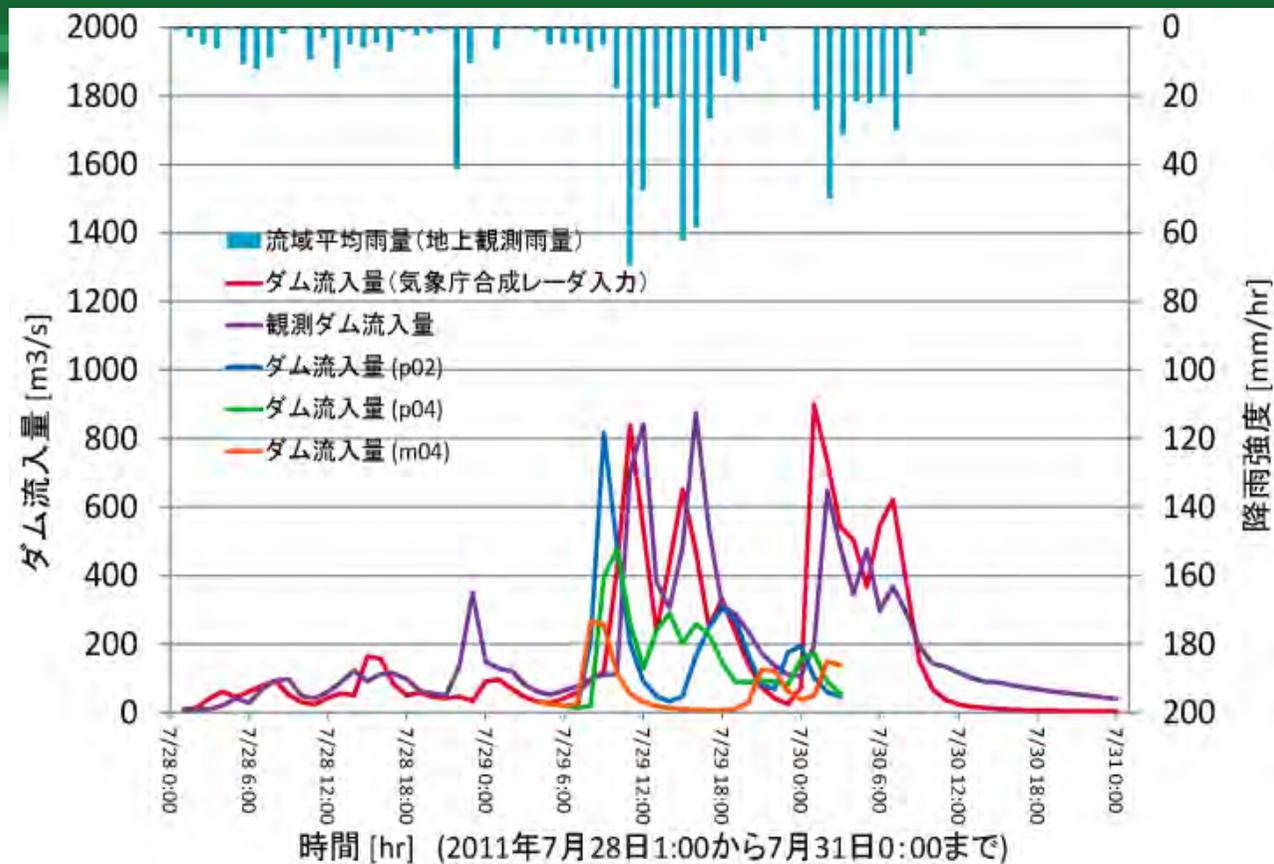
Schematic illustration of a full-version of LETKF system, which was moved to the K-computer system

Mesoscale LETKF system has been moved to the K-computer by JAMSTEC and JMA. Almost all of processes have been verified (JAMSTEC, JMA).



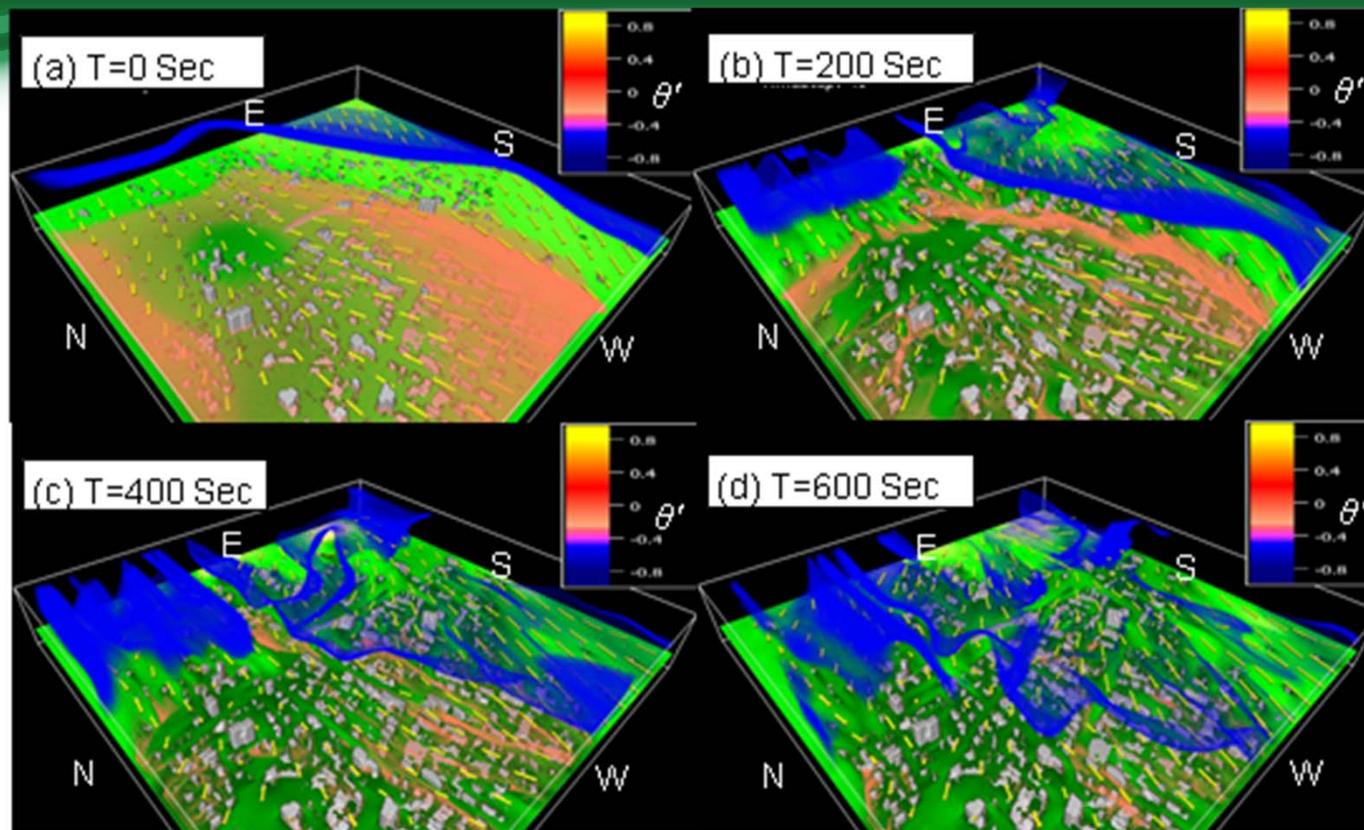
(a) Analyzed rainfall region, (b) predicted 3-hour rainfall ensemble mean, (c) probability distribution of rainfall that exceeds 50 mm/3h, (d) Same as (c) but 100 mm/3h.

Results of Typhoon 12 of 2011, which caused severe damage over the Iki Peninsula, were analyzed by MRI and sent to Kyoto Univ (MRI).



Inflow into the Kasahori Dam obtained from the ensemble forecast analysis.

The accuracy of the Kasahori Dam inflow forecast was verified by Kyoto Univ. by using the results of the ensemble forecast (Kobe Univ., DPRI, Kyoto Univ.).



Sea breeze distributions reproduced by DS³.

Tohoku university developed a forecast system with the grid interval of 10m that expresses sea breezes (DS³). This system is now being moved to the K-computer (Tohoku Univ.).

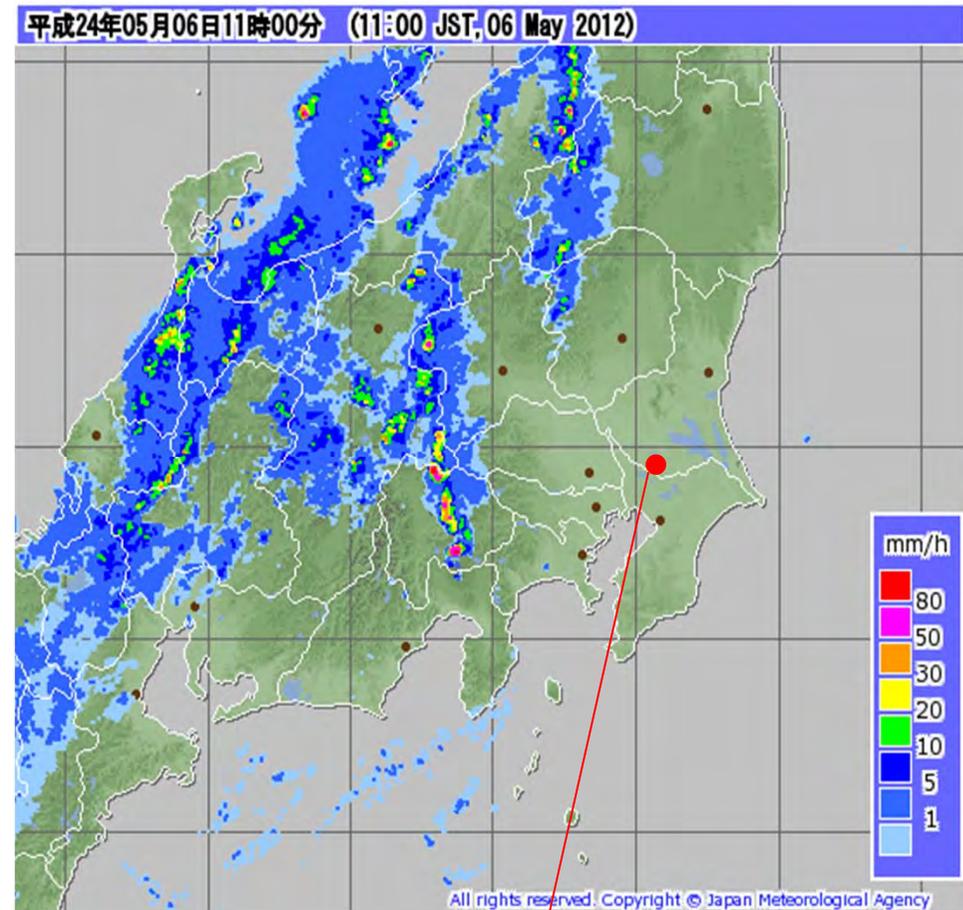
Data Assimilation Experiments of Tornado occurring on 6th May 2012

Hiromu Seko, Kazuo Saito (MRI/JAMSTEC),
Tadashi Tsuyuki, Masaru Kunii (MRI),
Takemasa Miyoshi (RIKEN)

Tornadoes Occurred on 6th May 2012



<http://mainichi.jp>



MRI/JMA

Tornadoes Occurred on 6th May 2012



本資料配布先：気象庁記者クラブ
(参考配布) 筑波研究学園都市記者会

報道発表資料
平成 24 年 5 月 11 日
気 象 研 究 所

平成 24 年 5 月 6 日に茨城県つくば市付近で発生した竜巻について

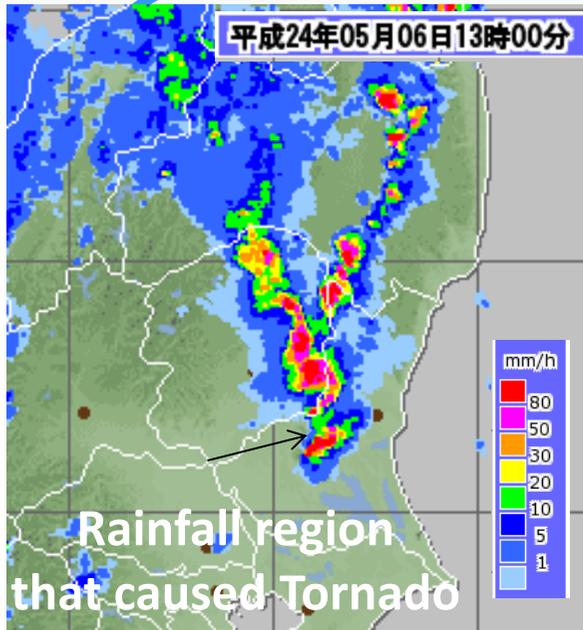
～気象研究所ドップラーレーダー及び気象環境場の解析・高解像度モデルでの再現実験結果～

5月6日につくば市北条付近を中心に大きな被害をもたらした竜巻について、直ちにその現象の調査を行うと同時に、気象研究所にあるドップラーレーダーの観測結果を解析し、また気象場の解析と高解像度モデルでの再現実験を行いました。

その結果、レーダーが竜巻に伴う大気下層の渦をとらえていたこと、竜巻は常総市からつくば市にかけての約 17 キロを 18 分ほどかけて通過(時速約 60km)していたことがわかりました。また、当日は、竜巻を起こすような発達した積乱雲を発生させやすい気象条件であったことが確認できました。

A tornado was observed by the MRI Doppler radar and deterministic forecasts were conducted by MRI/JMA.

Tornadoes Occurred on 6th May 2012



12:35 非住家の屋根が東北東に約50m飛散

常総市

新石下

大沢新田

12:37

12:39

12:41

12:43

12:45

12:47

12:49

12:51

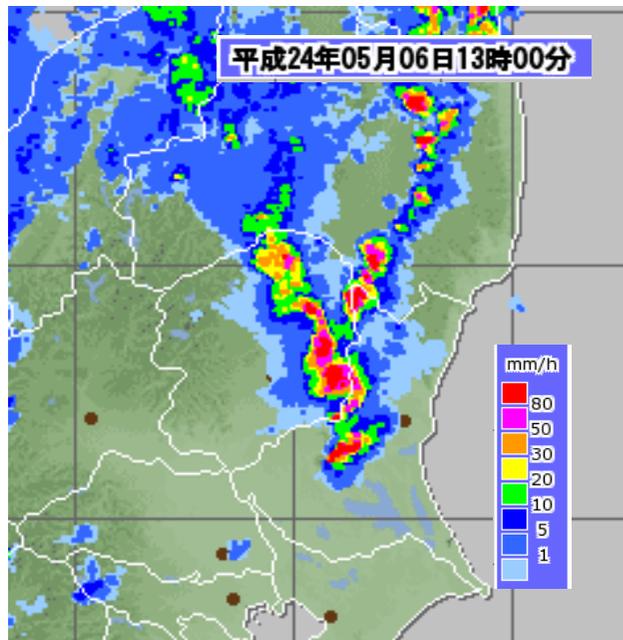
12:53

http://www.jma.go.jp/jma/press/1205/11c/120511tsukuba_tornado.pdf

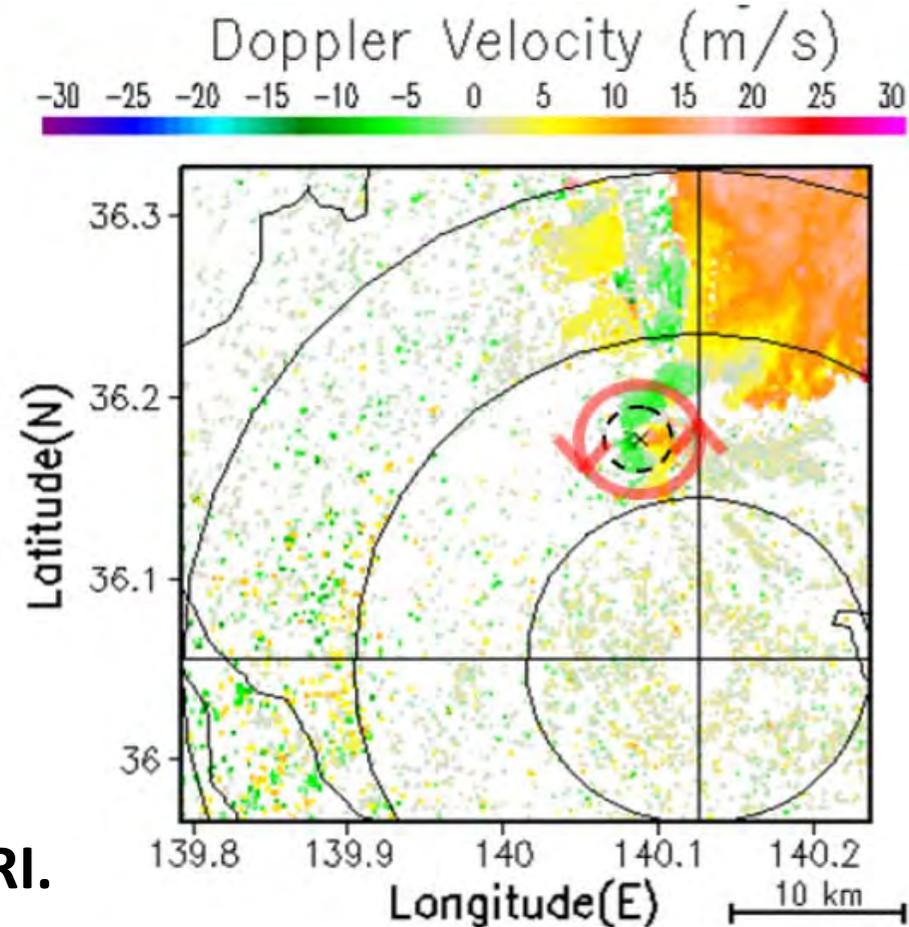
<http://mainichi.jp>



Tornadoes Occurred on 6th May 2012



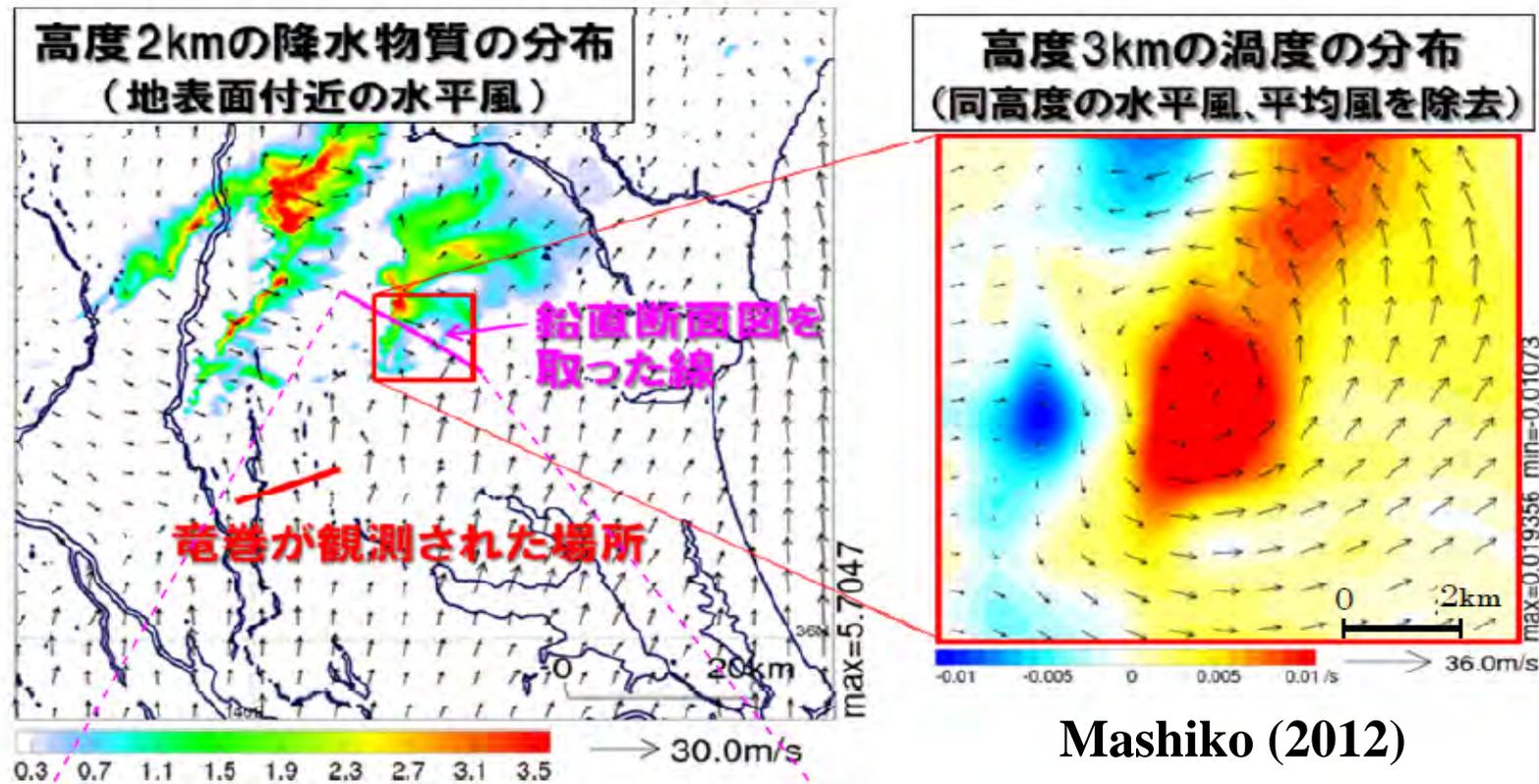
- A vortex was captured by Doppler radar of MRI.
- A vortex was located at the southern tip of the rainfall band.



Yamauchi and Shoji (2012)

http://www.jma.go.jp/jma/press/1205/11c/120511tsukuba_tornado.pdf

Tornadoes Occurred on 6th May 2012

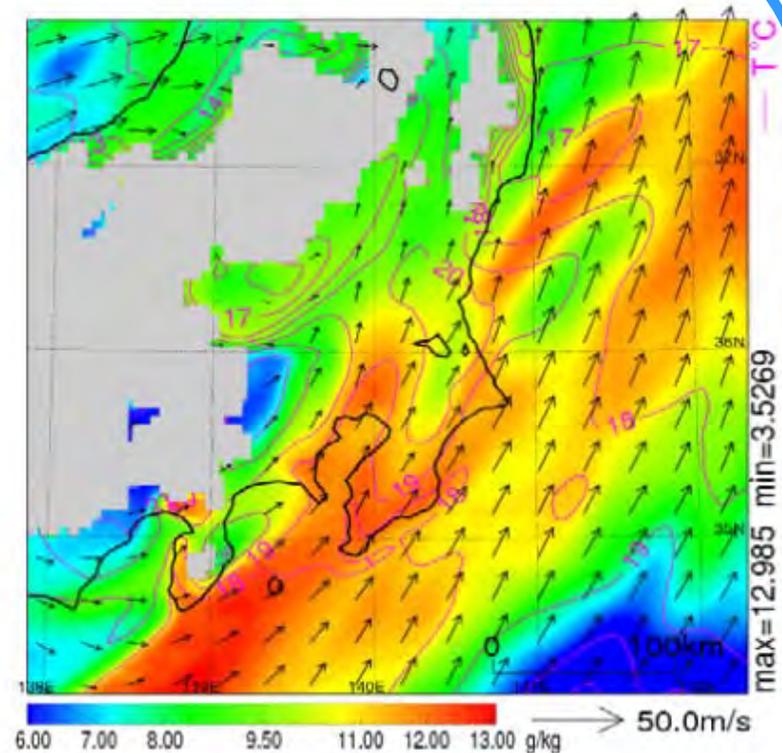
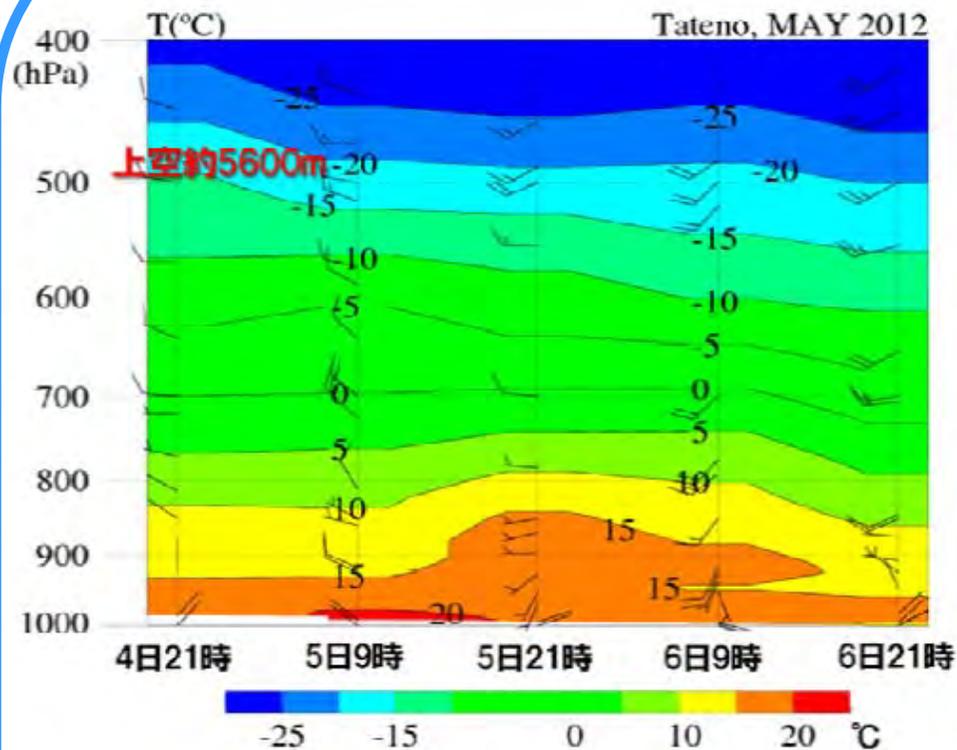


Mashiko (2012)

http://www.jma.go.jp/jma/press/1205/11c/120511tsukuba_tornado.pdf

Super-cell rainfall system that generated a tornado was reproduced by a deterministic forecast with $\Delta x=50\text{m}$.

Tornadoes Occurred on 6th May 2012



http://www.jma.go.jp/jma/press/1205/11c/120511tsukuba_tornado.pdf

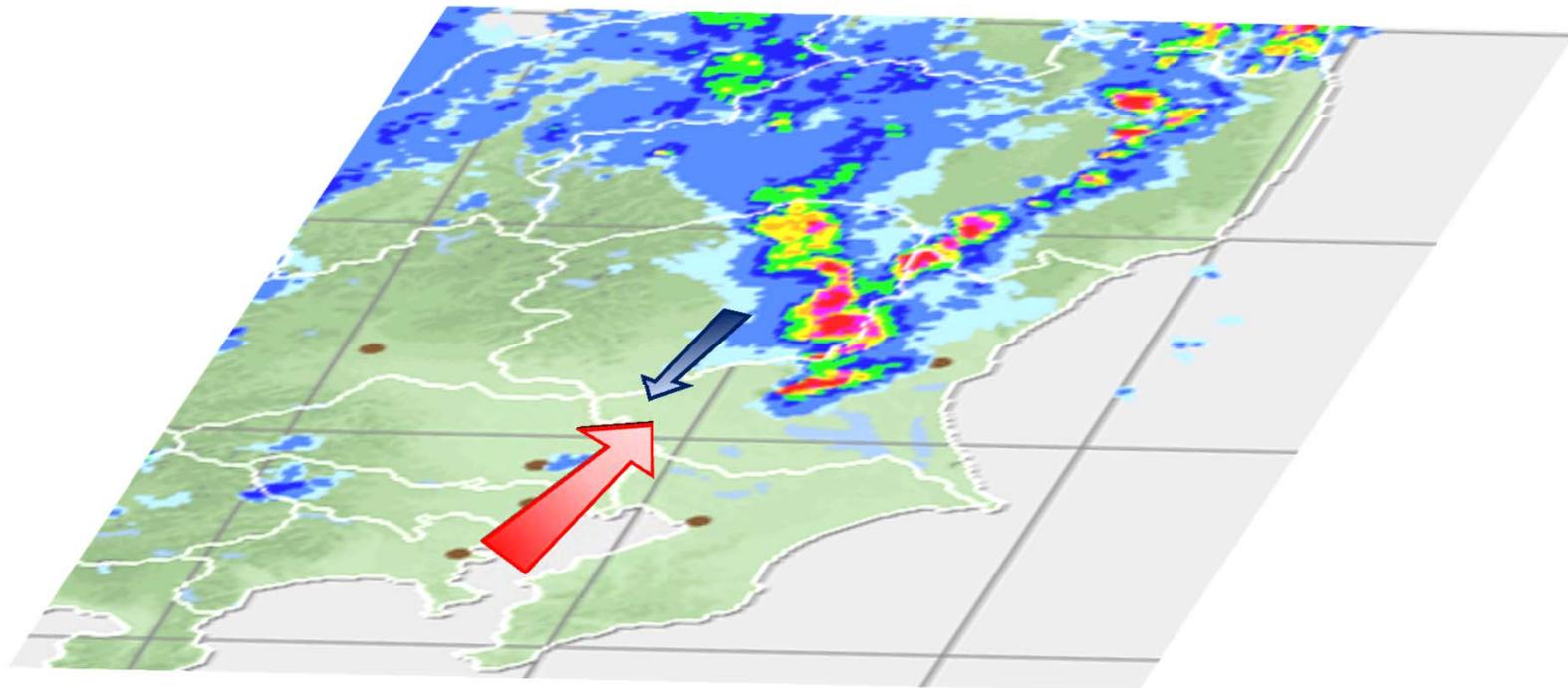
Kato (2012)

- The inflow that was supplied into the rainfall region was very humid (12g/kg).

Necessity of a nested assimilation system



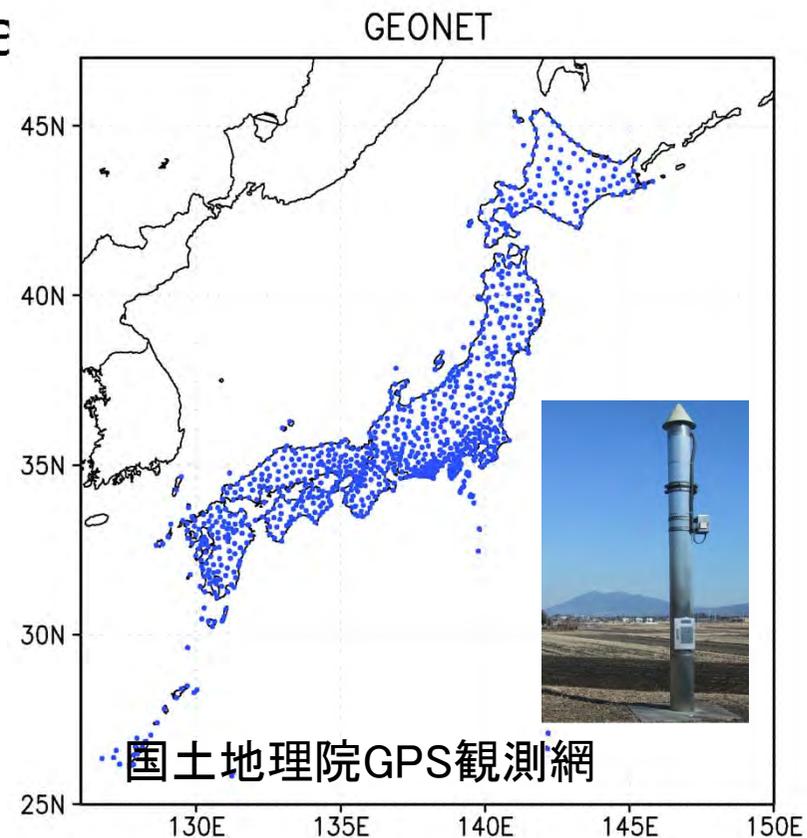
- Tornadoes were generated by the intense convection cells.
- To reproduce tornadoes, **mesoscale environment and convection cells should be reproduced simultaneously** by numerical models with large and small grid intervals.



Necessity of a nested assimilation system



- Tornadoes were generated by the intense convection cells.
- To reproduce tornadoes, mesoscale environment and convection cells should be reproduced simultaneously by numerical models with large
- **An X-band radar network and a GPS network have been established in Japan. This data can be used as assimilation data to improve the forecast of convection cells.**

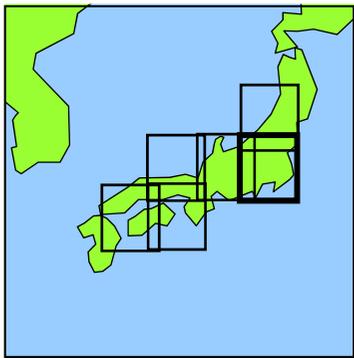
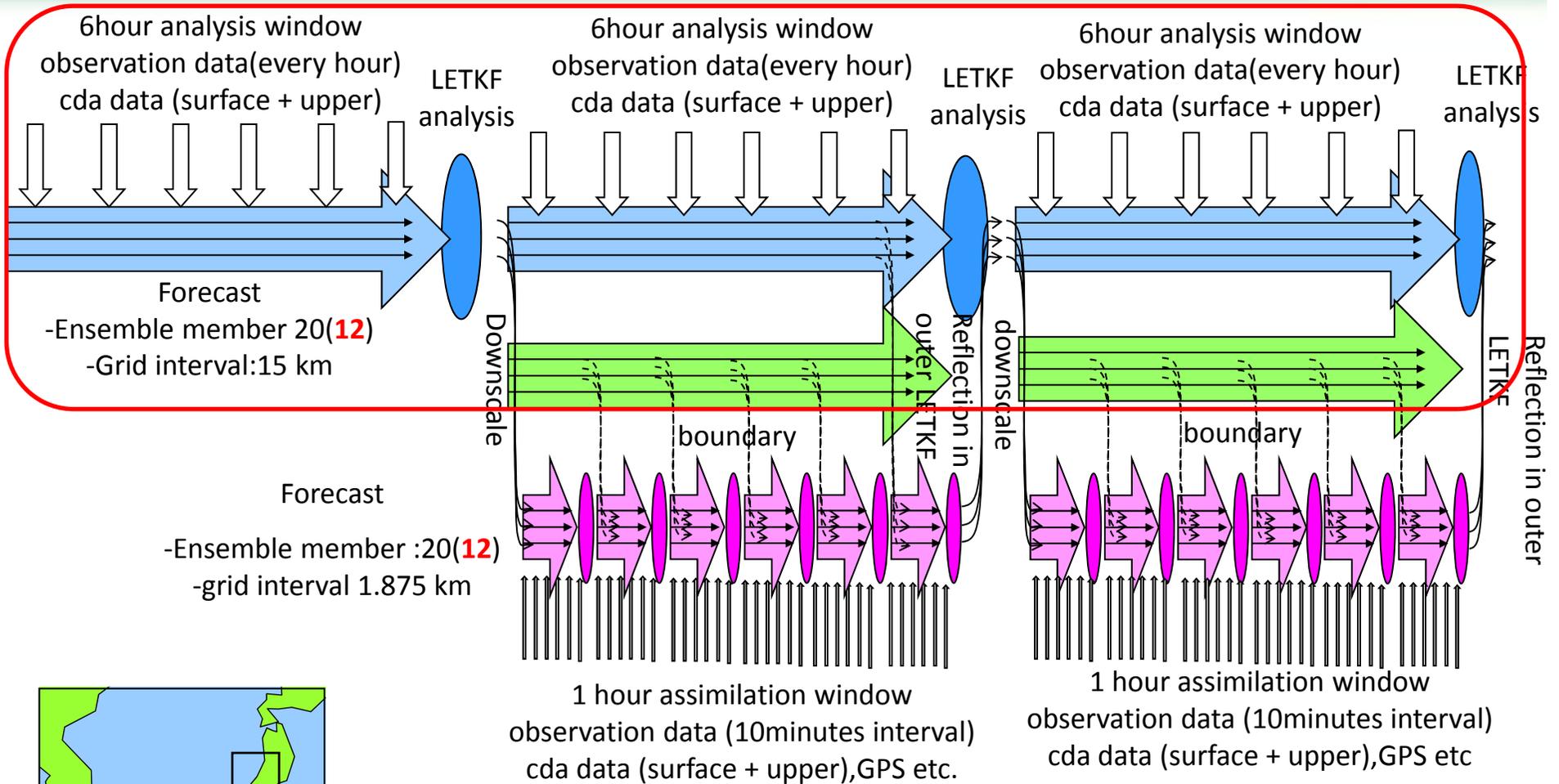


Necessity of a nested assimilation system



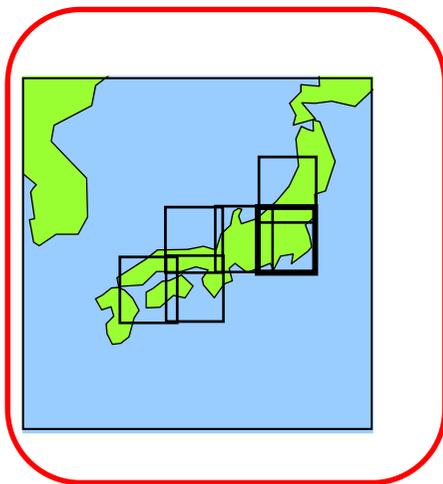
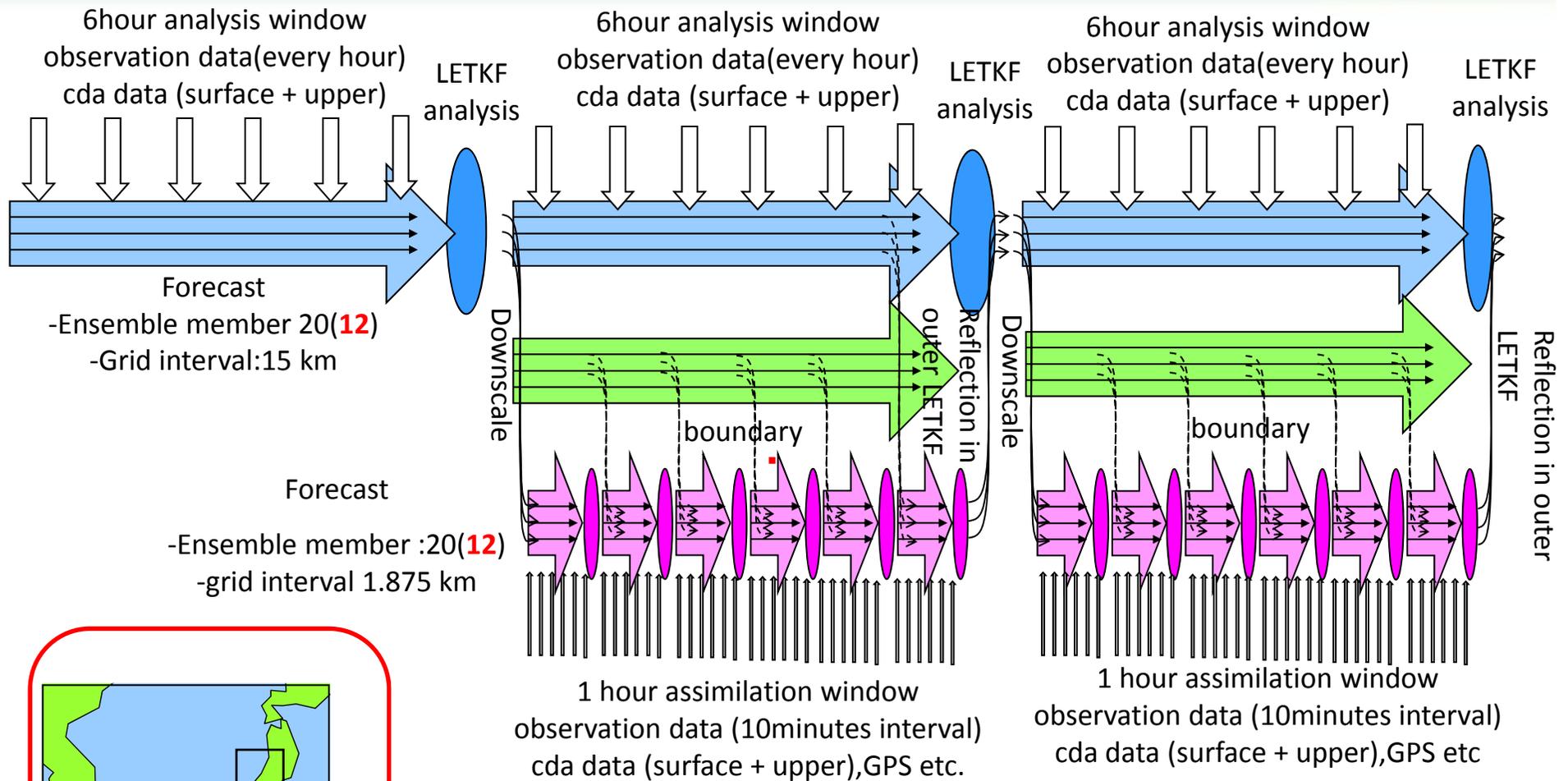
- Tornadoes were generated by the intense convection cells.
- To reproduce tornadoes, mesoscale environment and convection cells should be reproduced simultaneously by numerical models with large and small grid intervals.
- An X-band radar network and a GPS network have been established in Japan. This data can be used as assimilation data to improve the forecast of convection cells.
- **LETKF** (Local Ensemble Transform Kalman Filter; Miyoshi and Aranami, 2006) was used in this study.

Schematic of the Nested LETKF System



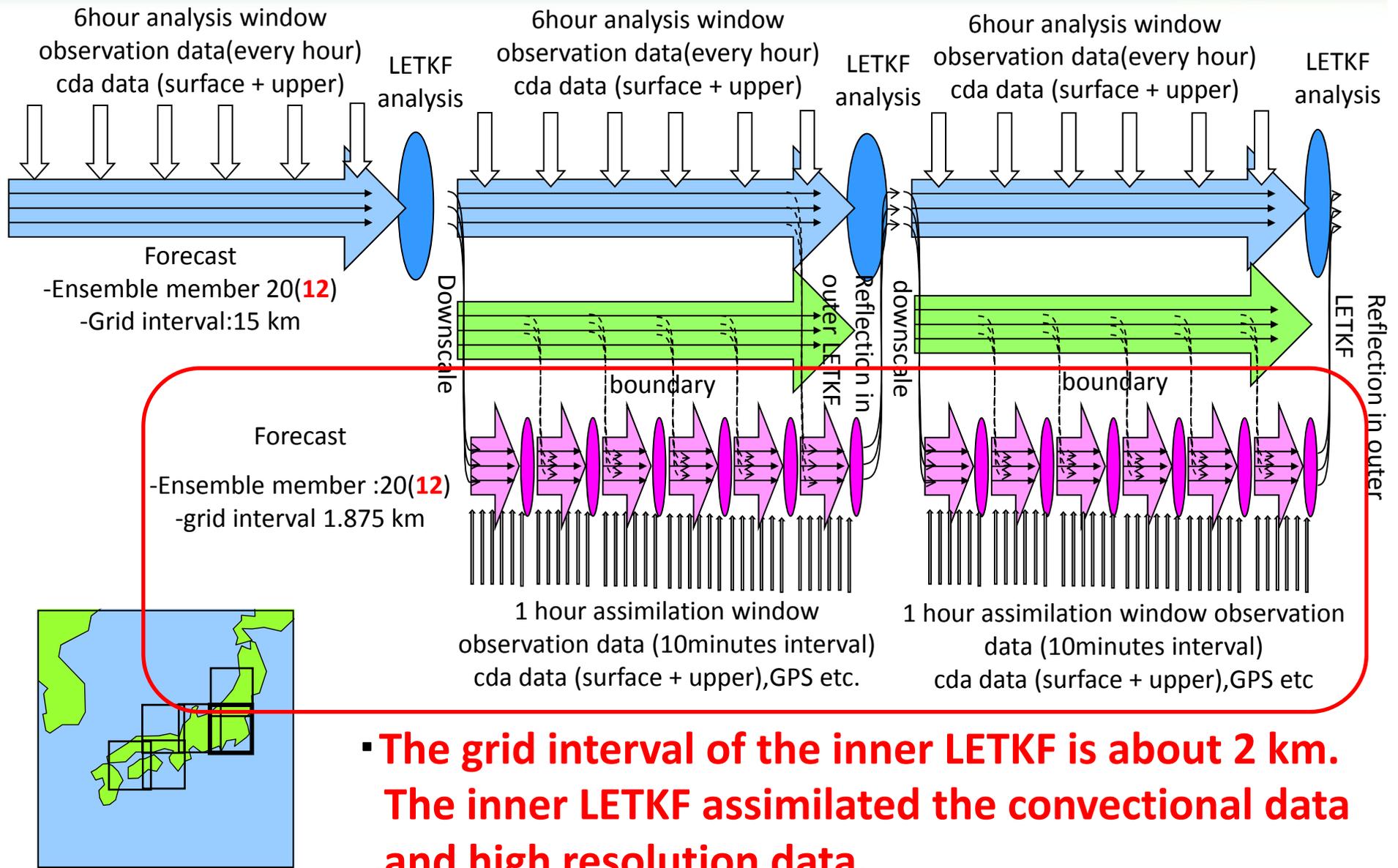
- **The outer LETKF with a grid interval of 15 km assimilates the convective data of Japan Meteorological Agency.**
- **Assimilation window was 6 hours.**

Schematic of the Nested LETKF System



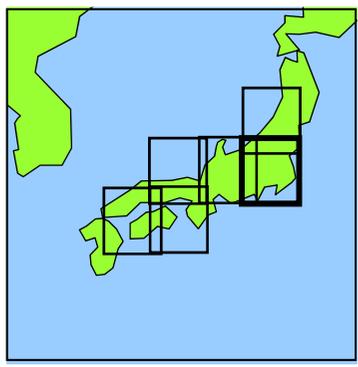
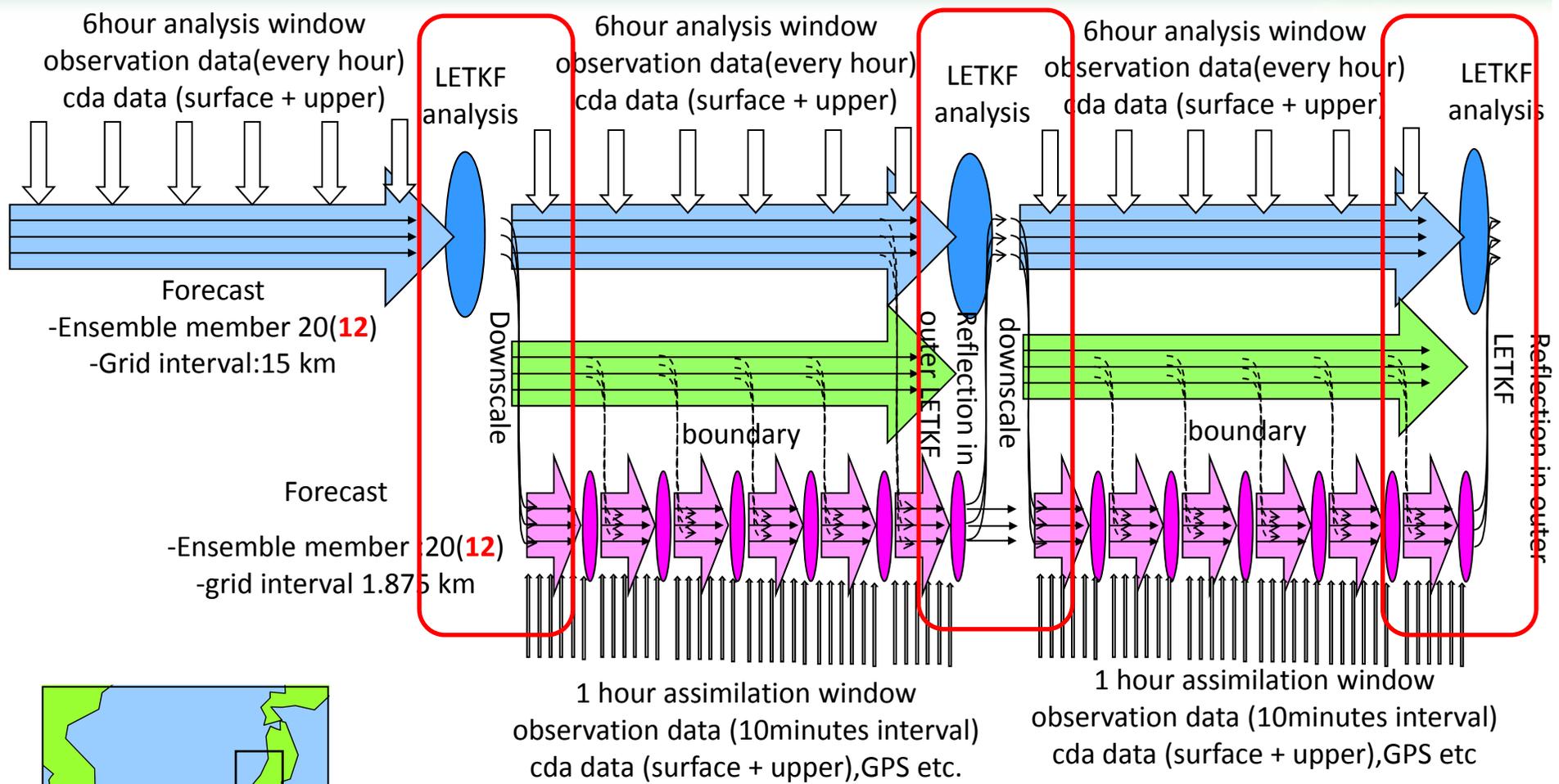
Inner LETKFs were deployed in the domain of the outer LETKF.

Schematic of the Nested LETKF System



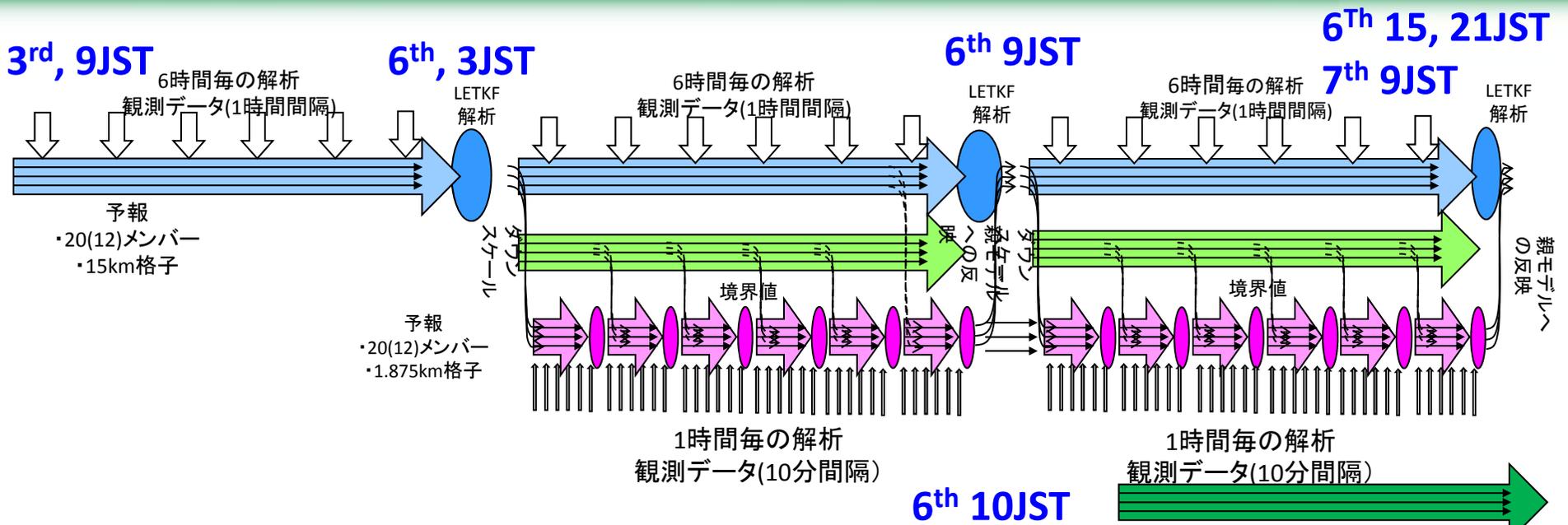
- **The grid interval of the inner LETKF is about 2 km. The inner LETKF assimilated the convectonal data and high resolution data.**
- **Assimilation window was 1 hour.**

Schematic of the Nested LETKF System



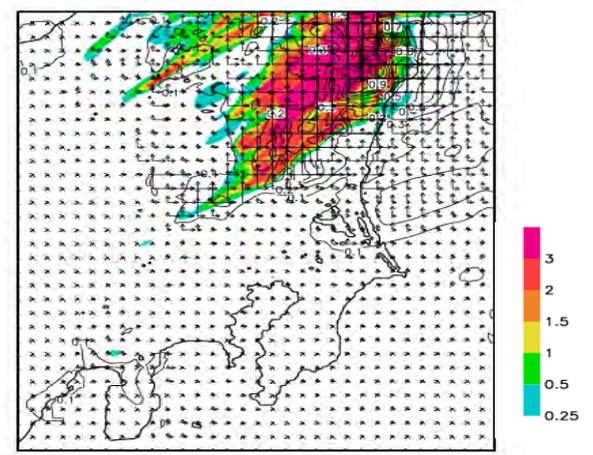
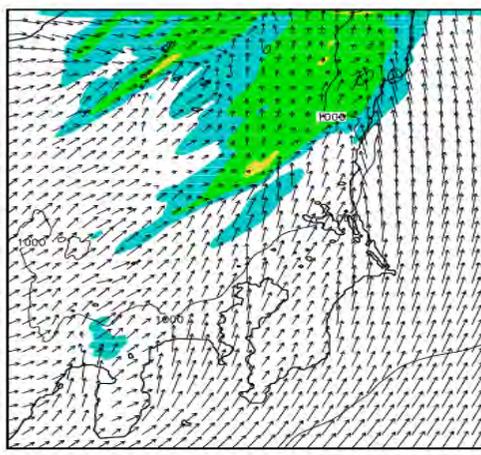
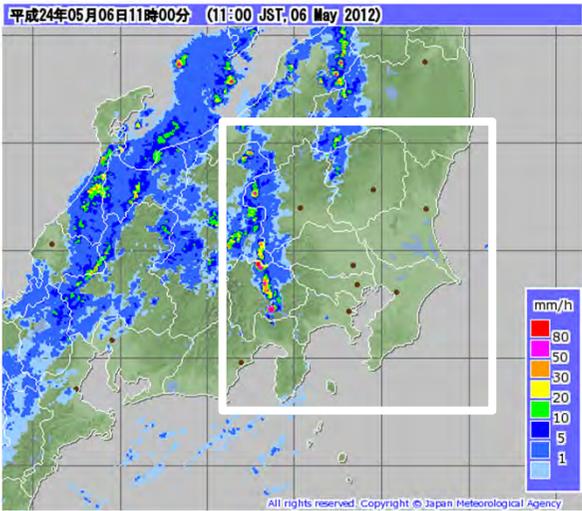
- Initial seeds and boundaries of the inner LETKFs were produced from forecasts of the outer LETKF.
- Results of the inner LETKFs were reflected in the outer LETKF every 6 hours.

Tornadoes Occurred on 6th May 2012



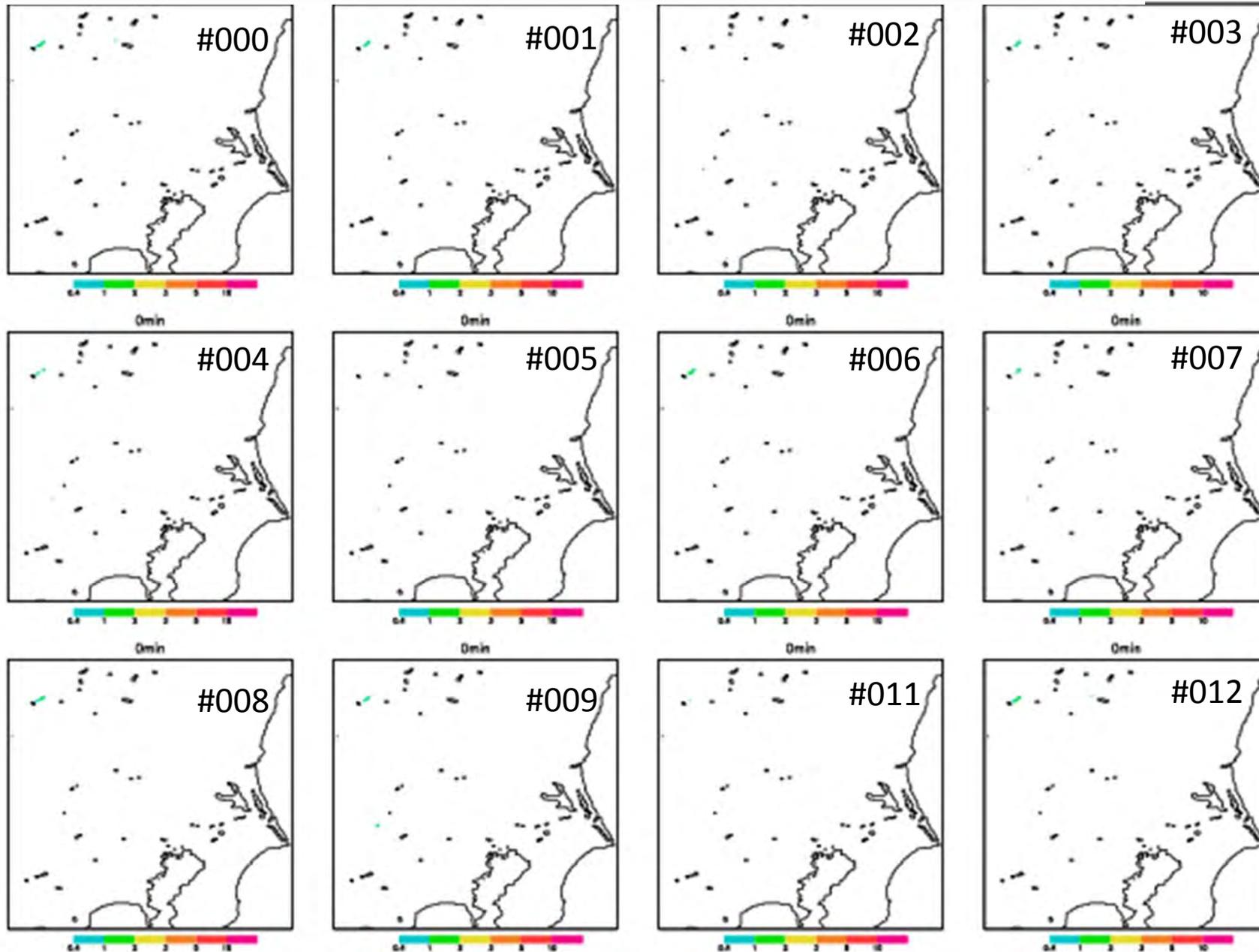
Ensemble mean
of Inner LETKF at 12JST
1 hour rainfall

Downscale experiments
Spread at 12JST
1 hour rainfall



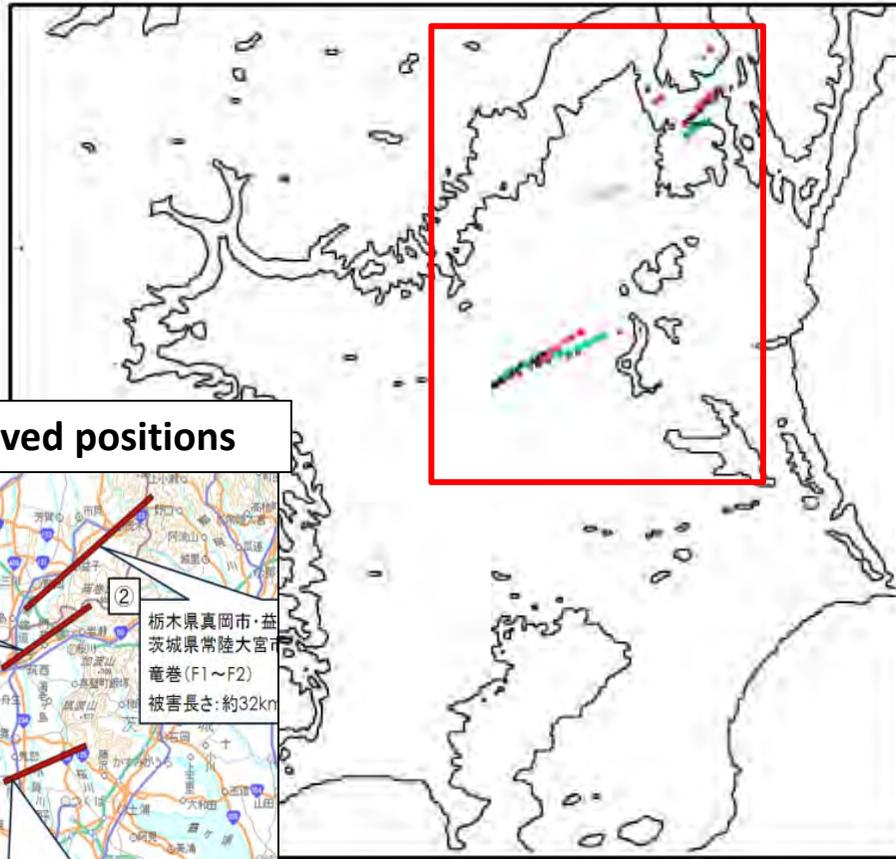
Rainfall distribution $\Delta x=350\text{ m}$

From 1130JST
to 1430JST

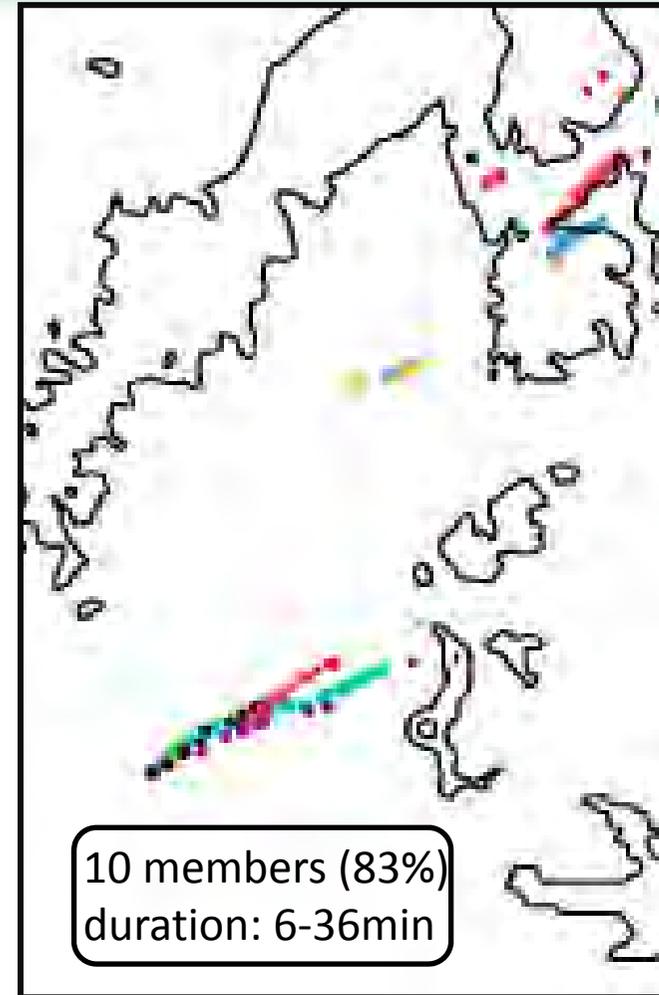


Downscale Experiments with $\Delta x=350m$

Positions of vortices
more than 0.1(1/s)



Observed positions



- Positions and durations differed among the ensemble members.
- Tornadoes occurred in three areas, which were the same as the observations though they were shifted northward by 10 km.

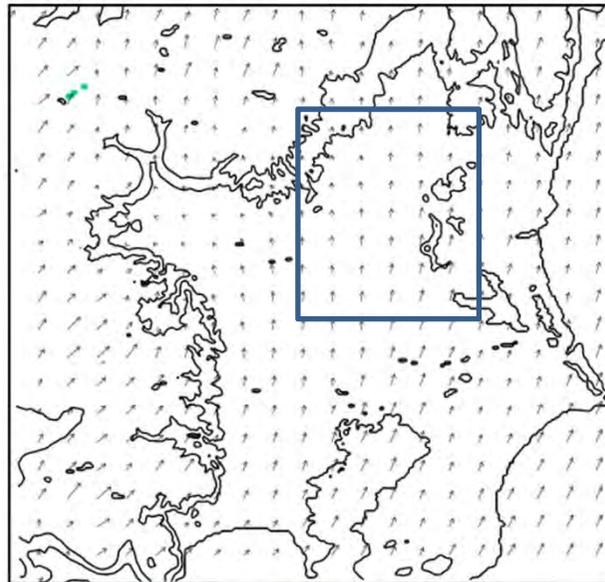
Downscale Experiments with $\Delta x=350m$

From 1130JST to 1430JST

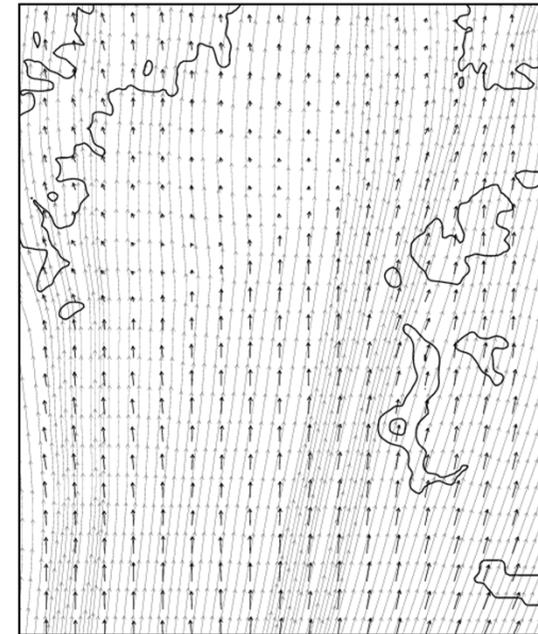
#004:
Intense vortex is maintained.

#007:
Intense vortex isn't generated.

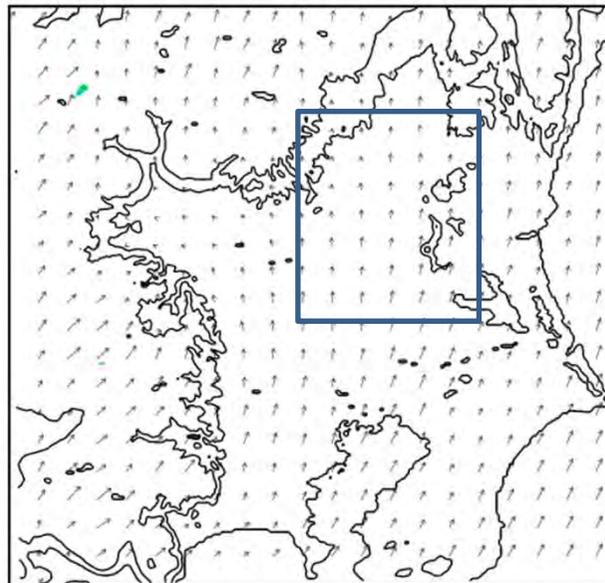
350 m #004 0min



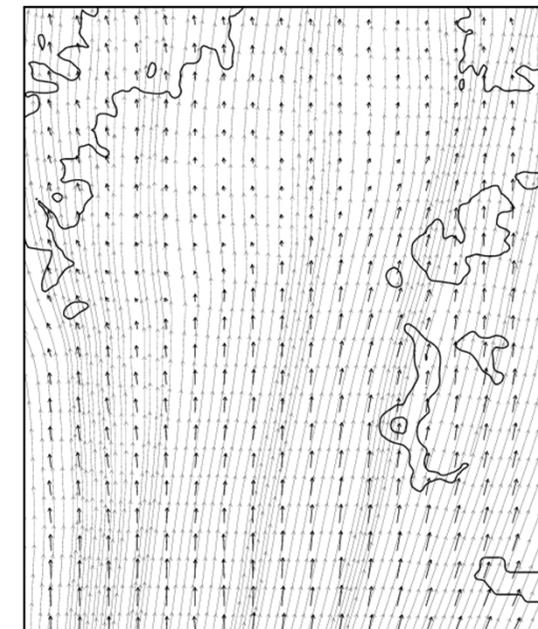
350 m #004 0min



350 m #007 0min

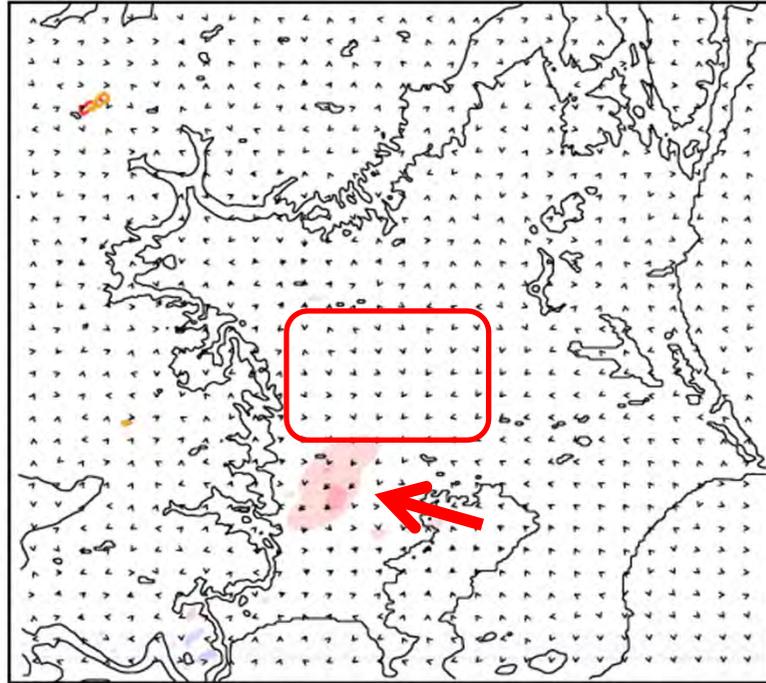


350 m #007 0min

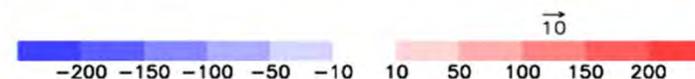
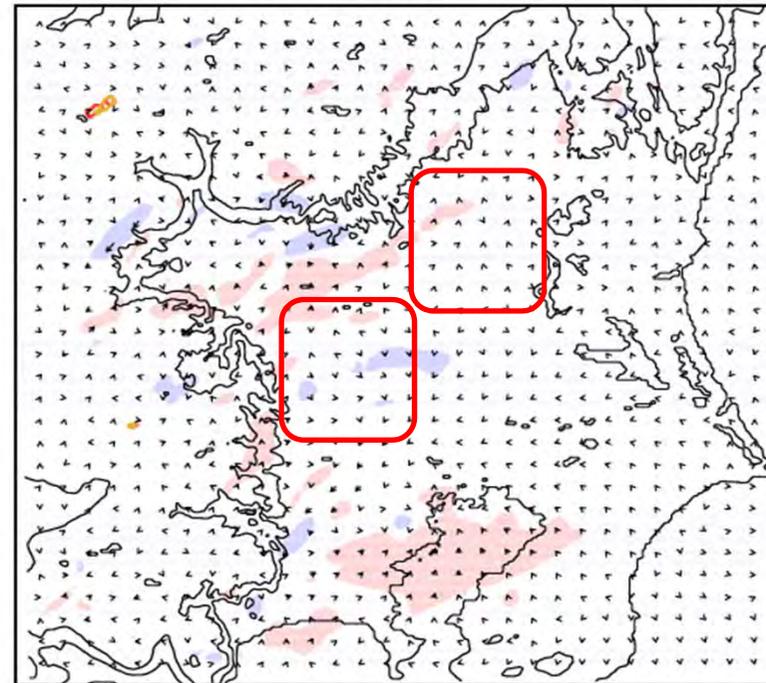


Difference of water vapor and flux distribution

QV #004-007 Q_{min} 11:30-14:30



Flux #004-007 Q_{min} 11:30-14:30



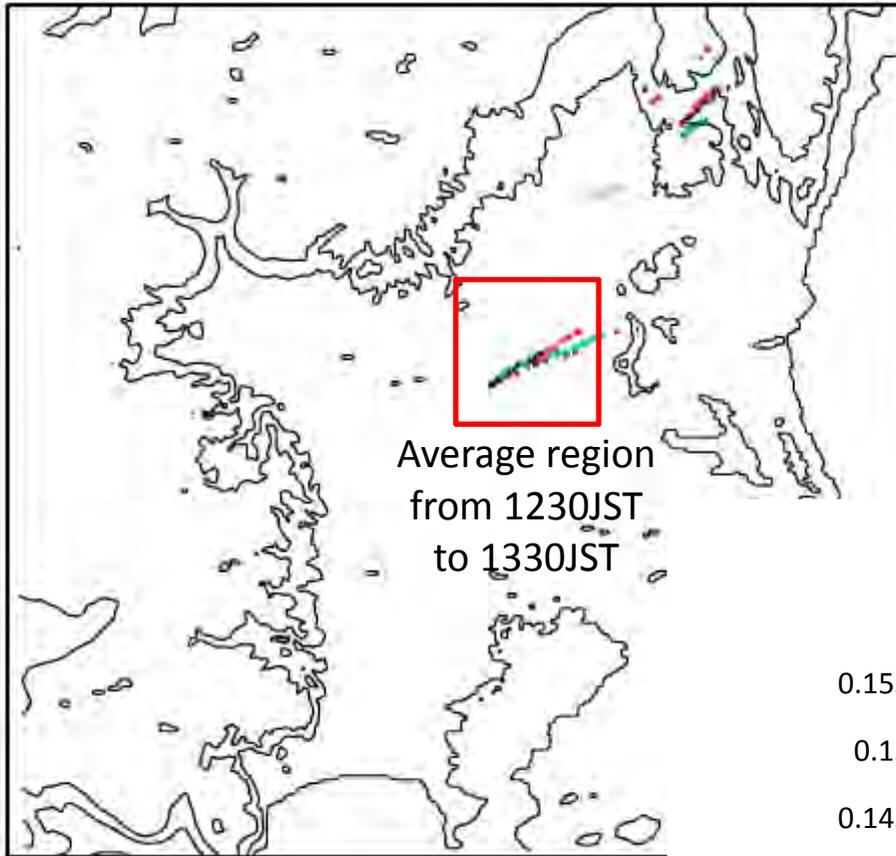
#004-#007:

Left: horizontal wind $\cdot Q_v$ at $z=600m$

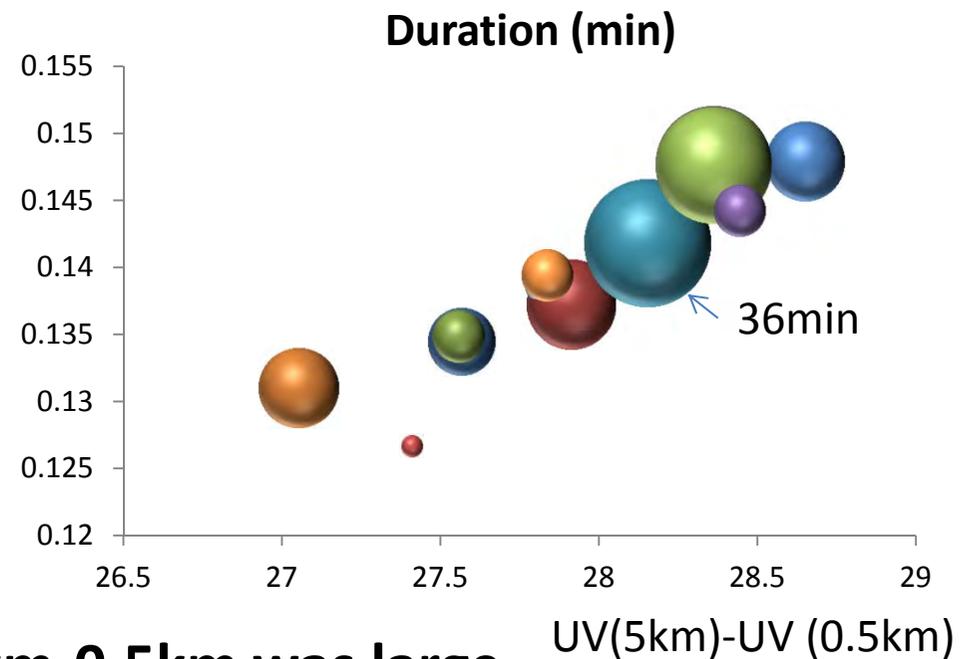
Right: Horizontal wind $\cdot v\rho Q_v$ at $z=600m$

- In #004, in which tornadoes were generated, more humid air was supplied into the rainfall region.

Downscale Experiments with $\Delta x=350m$



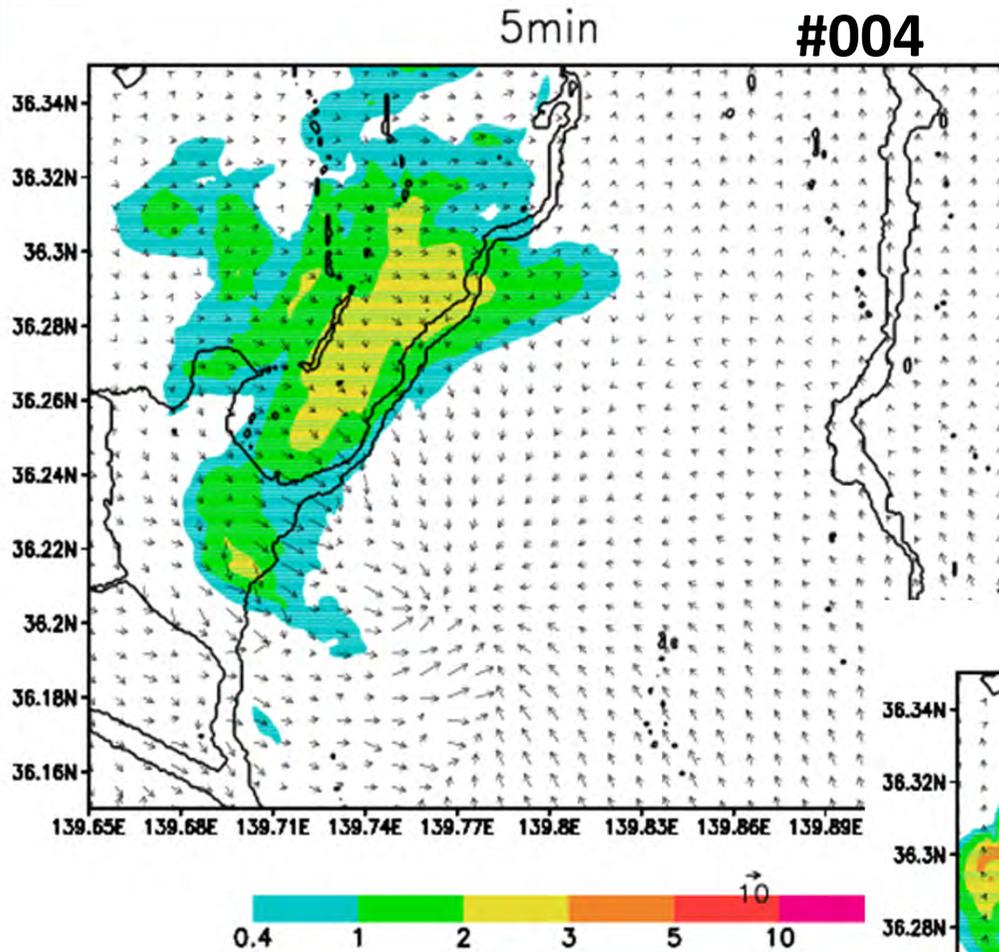
- Circles indicate Q_v (0.5km) the duration of tornados.
- Duration is long when water vapor at 500m height is large and vertical shear between 5km-0.5km was large.



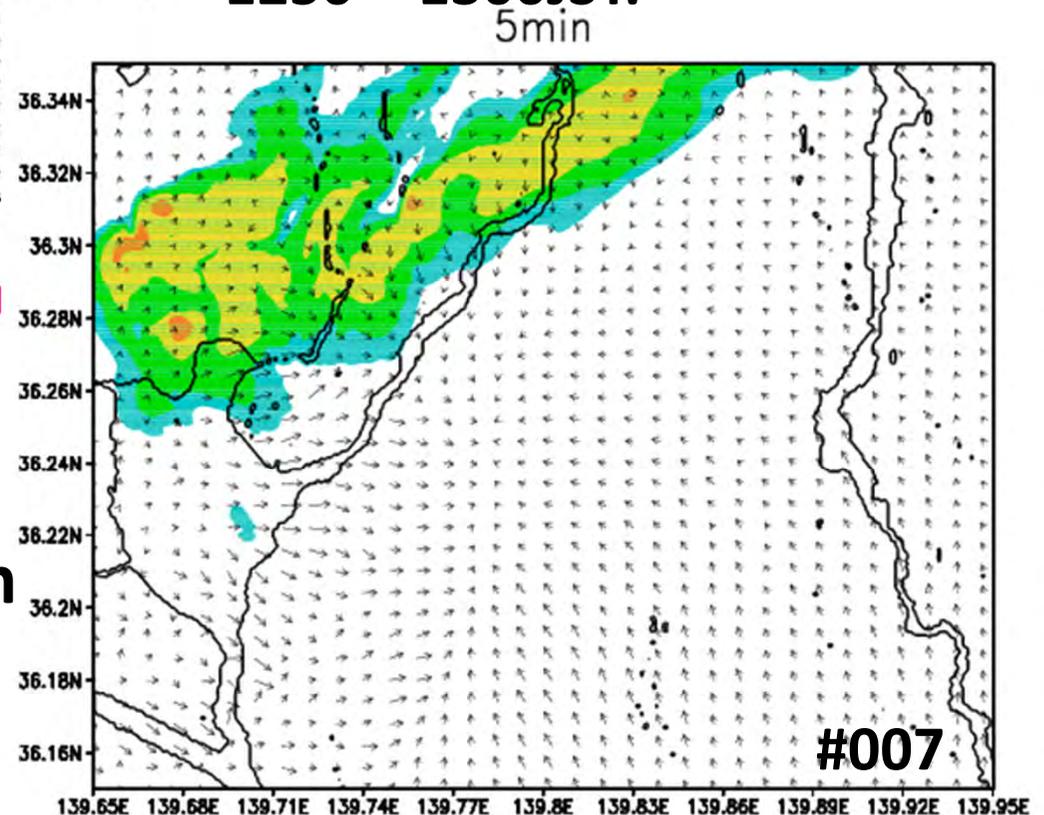
Downscale

Experiments with $\Delta x=50m$

- From 1240JST to 1320JST
- Shifted northward.
- Vortex was intensified at 1250~1300JST.

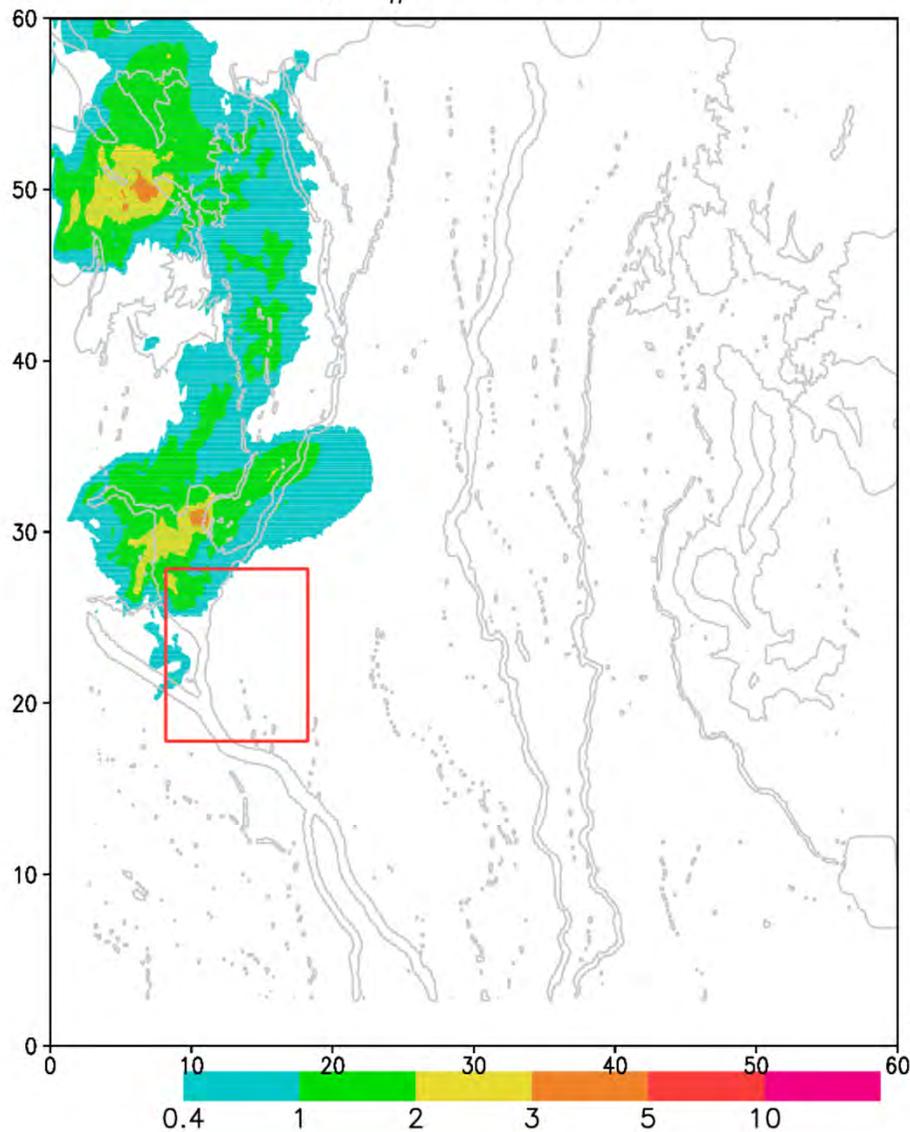


- Red points indicate vortices > 0.4 (1/s)
- Horizontal wind at 600 m height
- Rain at 20 m height.

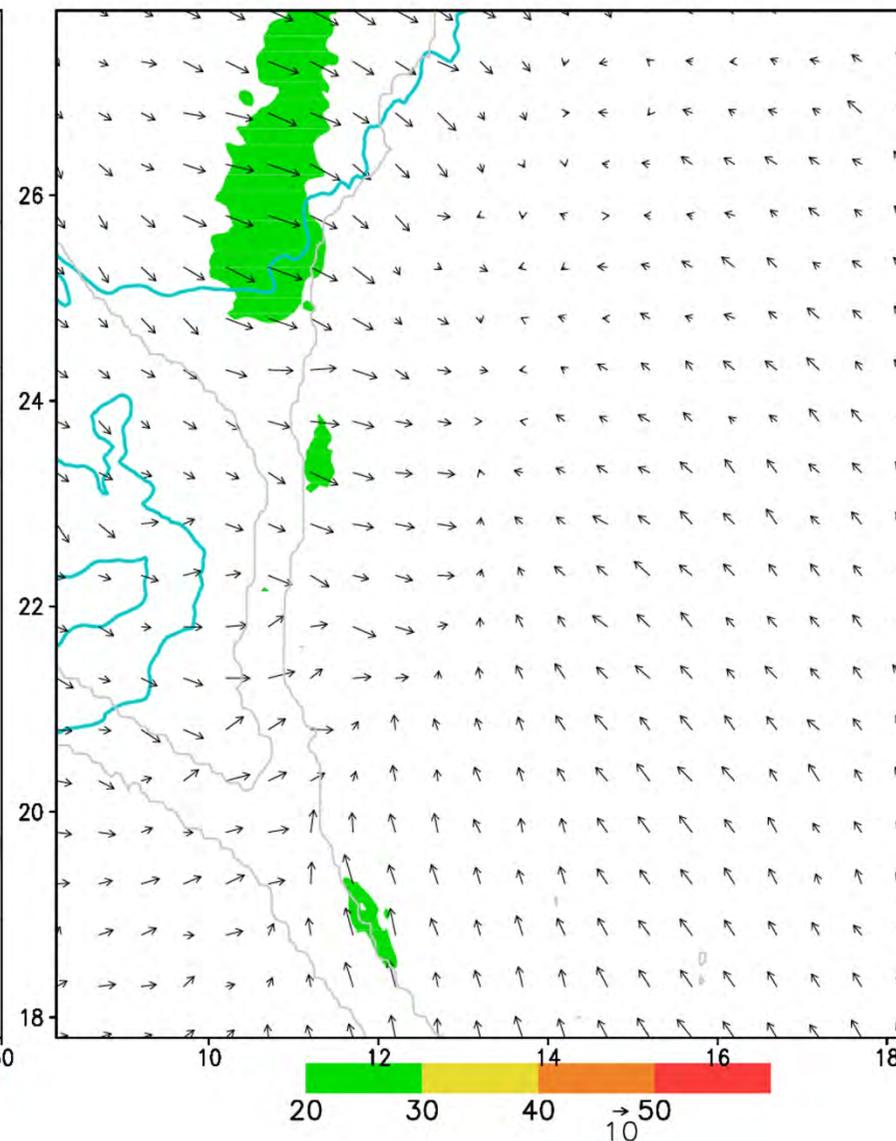


Downscale Experiments with $\Delta x=50m$

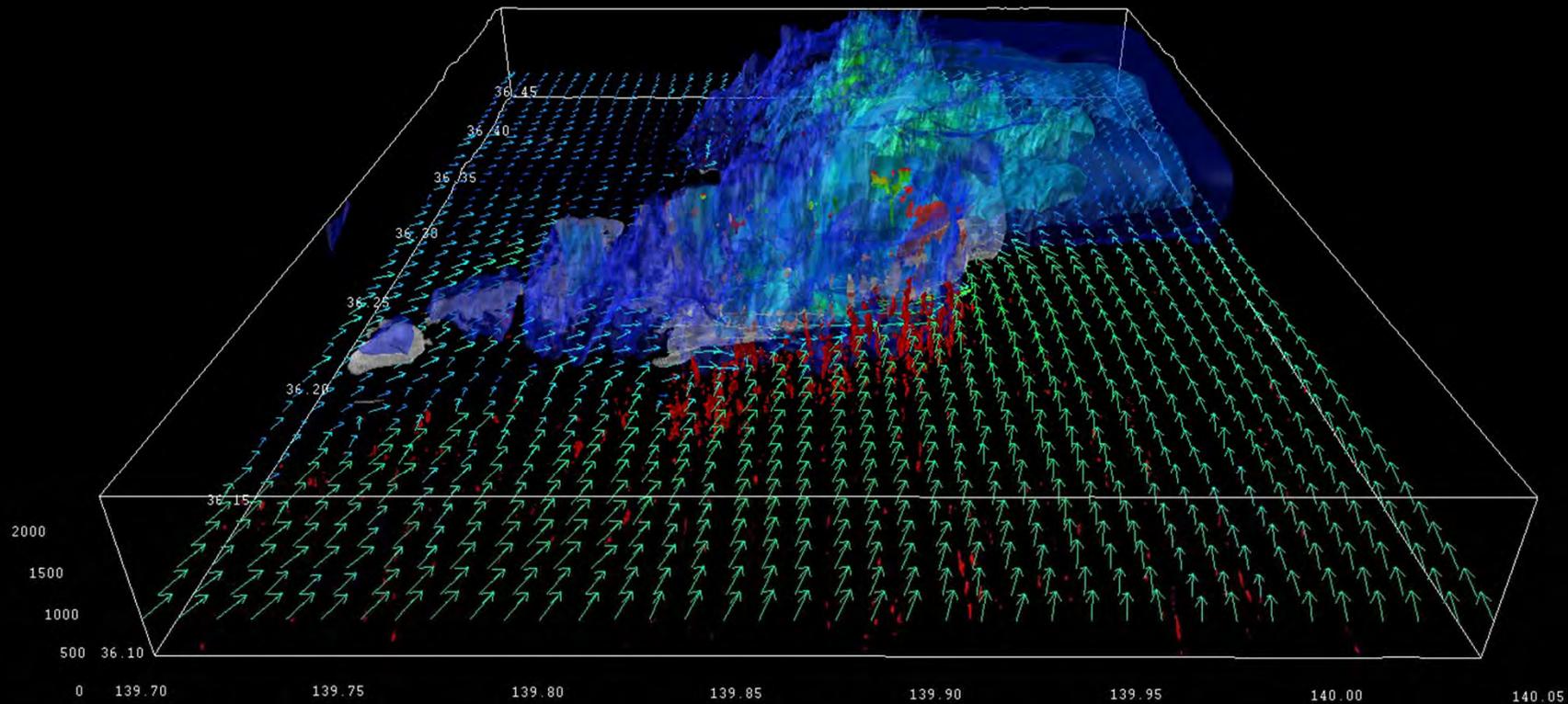
Qr #004 0min



Vel #004 0min



Downscale Experiments with $\Delta x=50m$



(Produced by Mr. Nishi of Tsukuba Univ.)

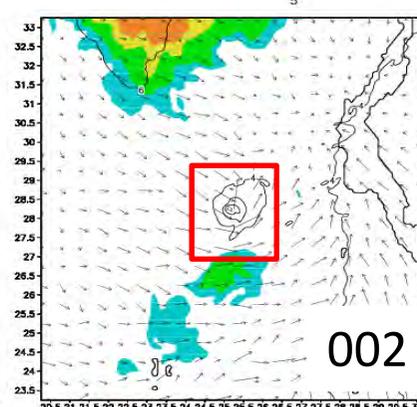
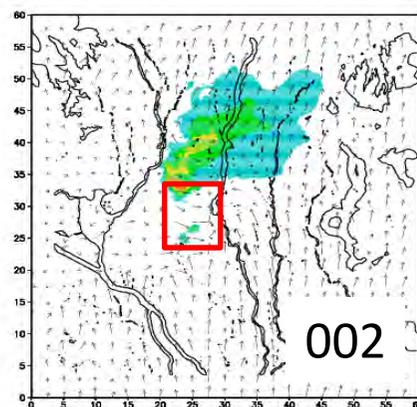
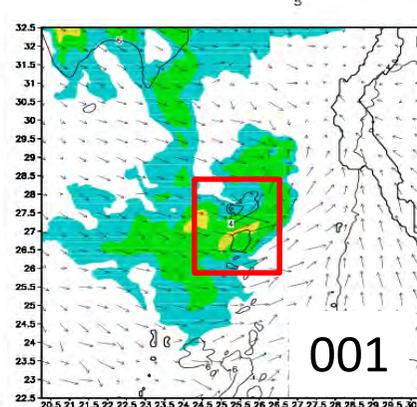
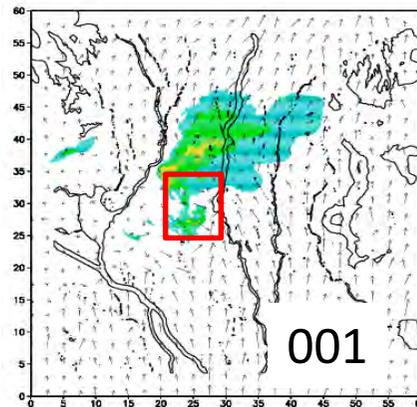
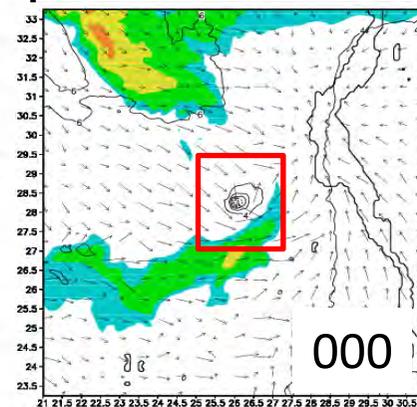
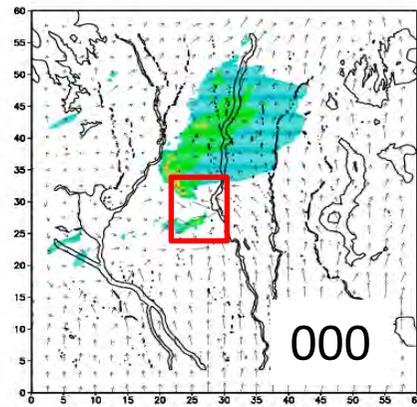
Downscale experiment with $\Delta x=50m$

With K-computer

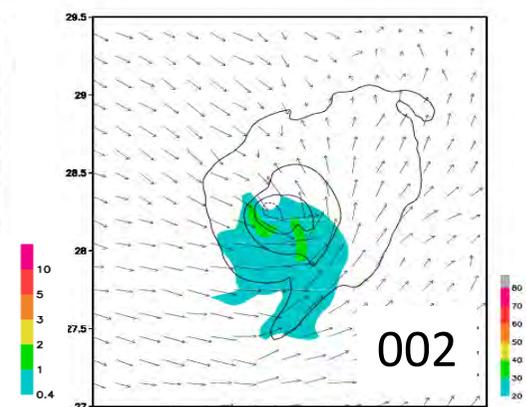
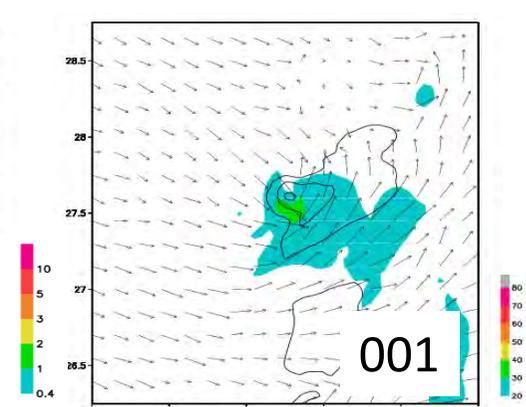
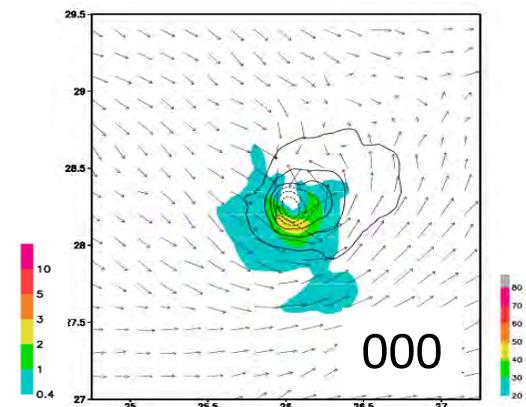


1200x1200
x50
Initial time:
12:10
Valid time:
13:00

Rain +Horizontal wind, Surface pressure



Wind velocity Pressure



*Downscale
experiment
with $\Delta x=50m$*

With K-
computer



1200x1200
x50

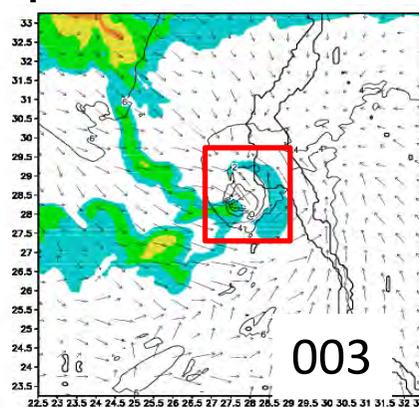
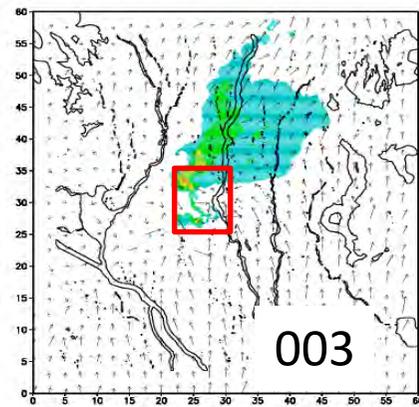
Initial time:

12:10

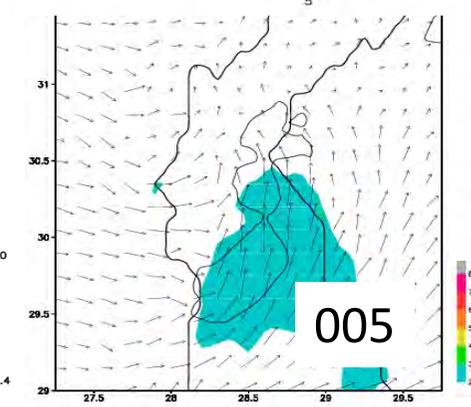
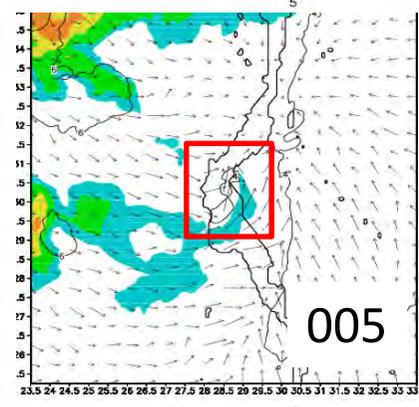
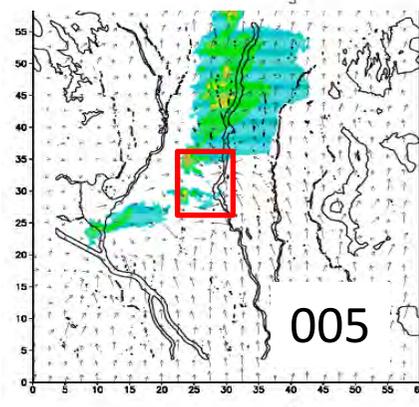
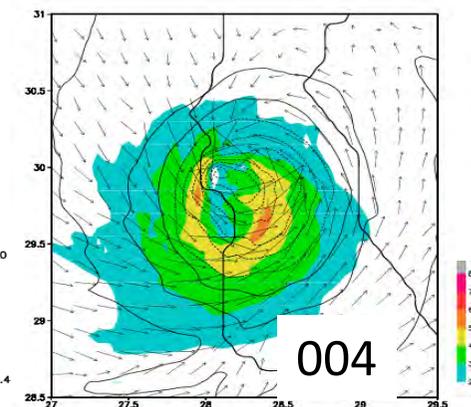
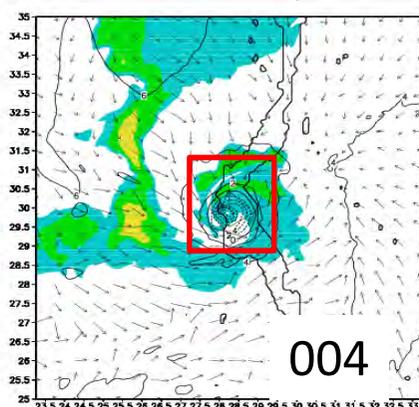
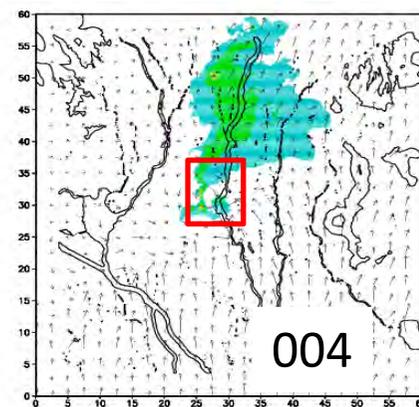
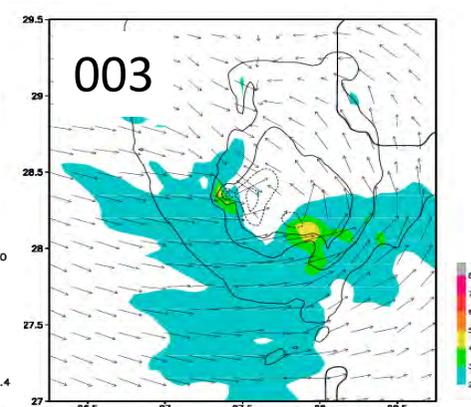
Valid time:

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Rain +Horizontal wind,
Surface pressure



Wind velocity
Pressure



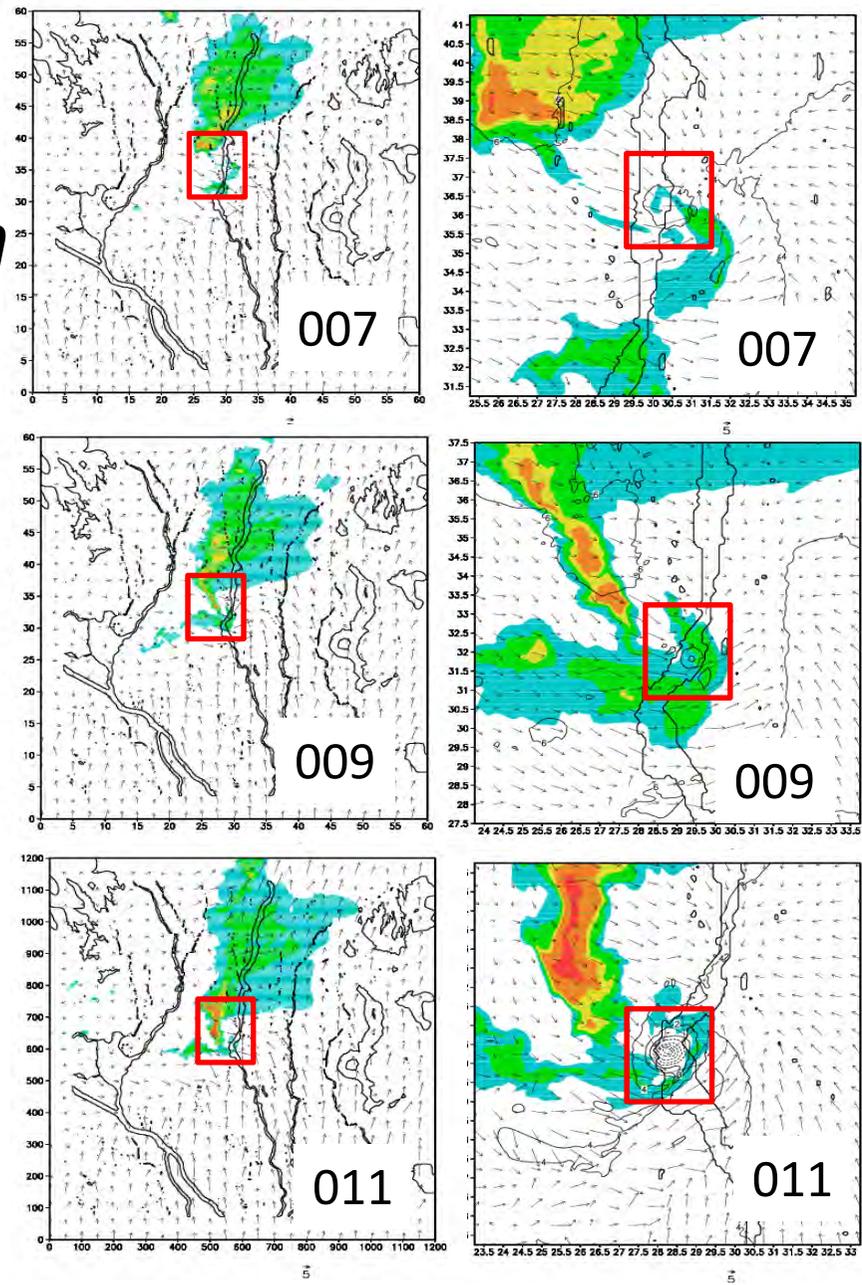
*Downscale
experiment
with $\Delta x=50m$*

With K-
computer

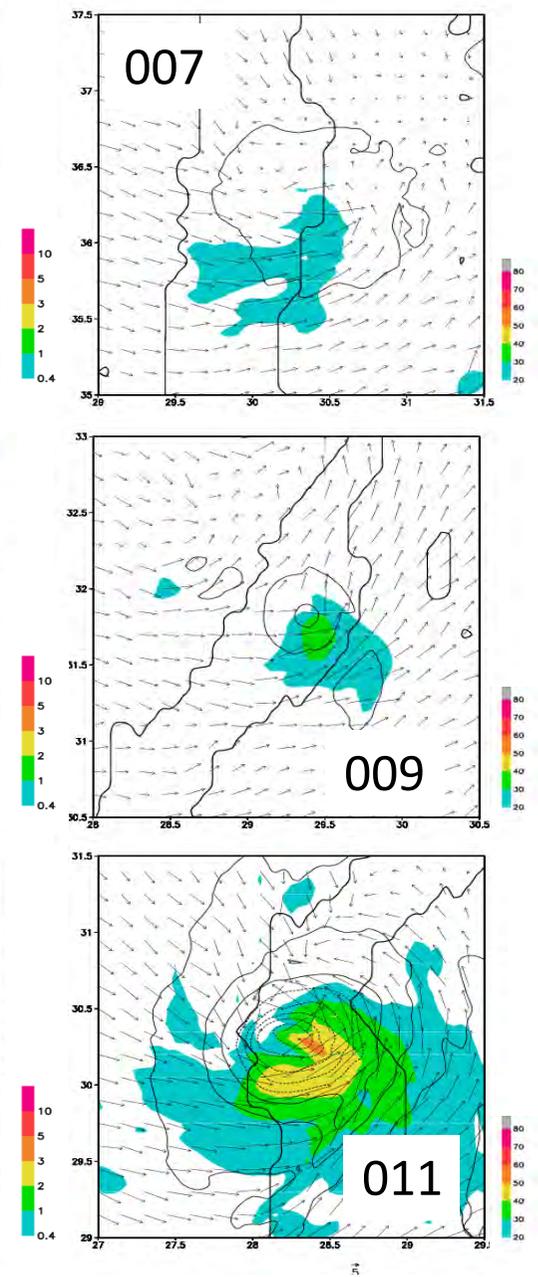


1200x1200
x50
Initial time:
12:10
Valid time:
13:00

Rain +Horizontal wind,
Surface pressure



Wind velocity
Pressure



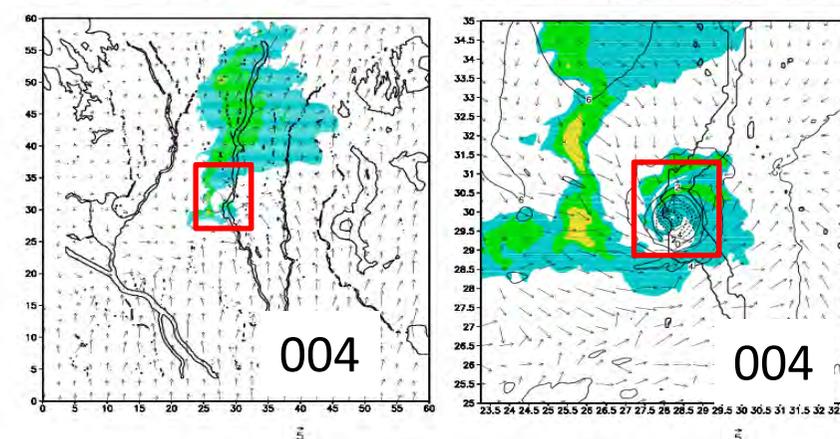
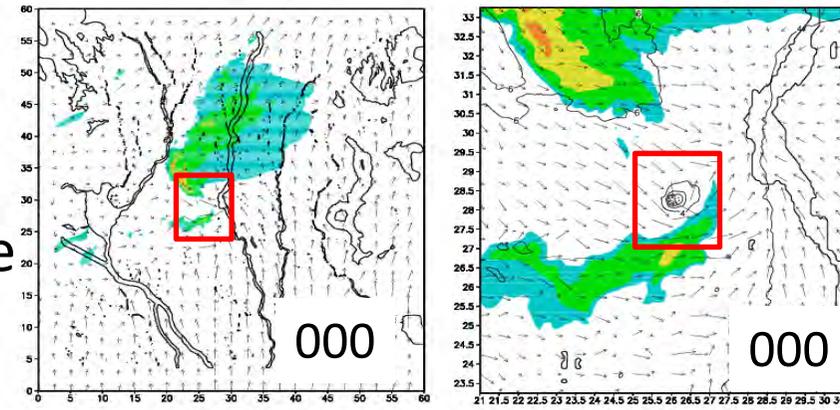
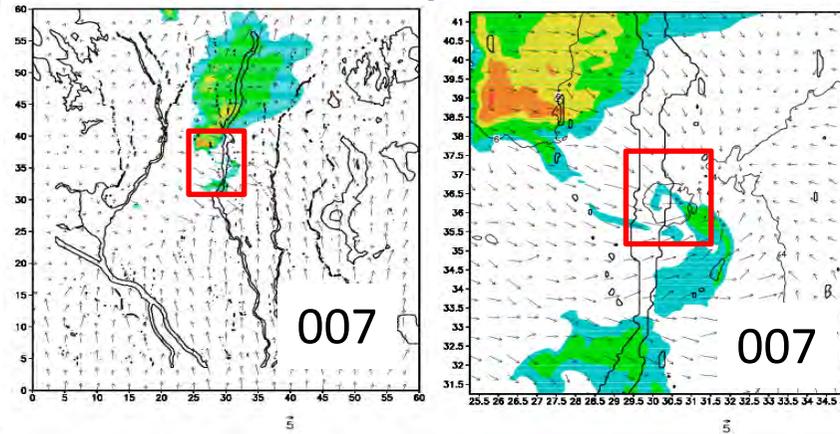
*Downscale
experiment
with $\Delta x=50m$*

13:00JST

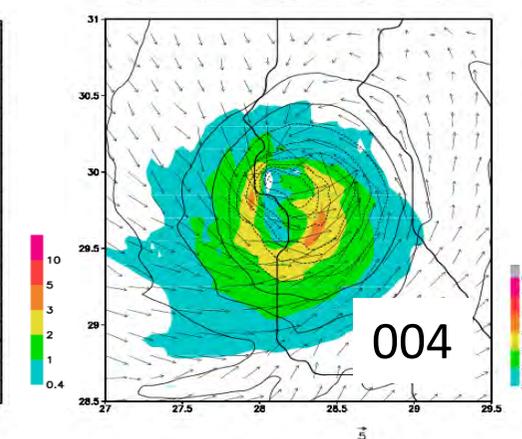
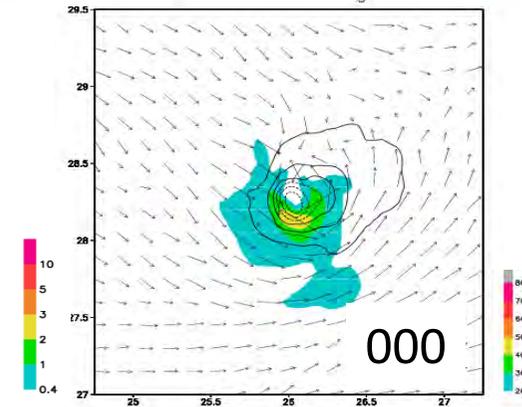
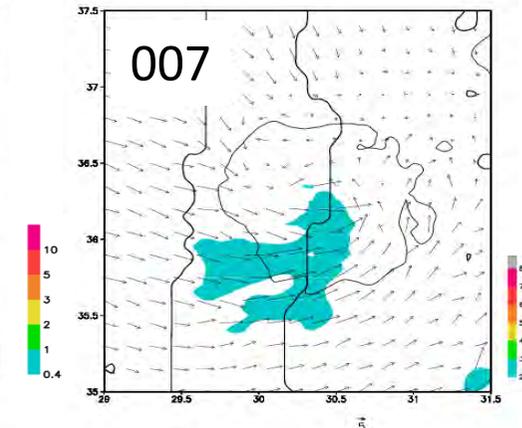
Positions of the
thunderstorm were
similar among
the members.

Various sizes and
intensities of
tornadoes were
generated.

Rain +Horizontal wind,
Surface pressure



Wind velocity
Pressure



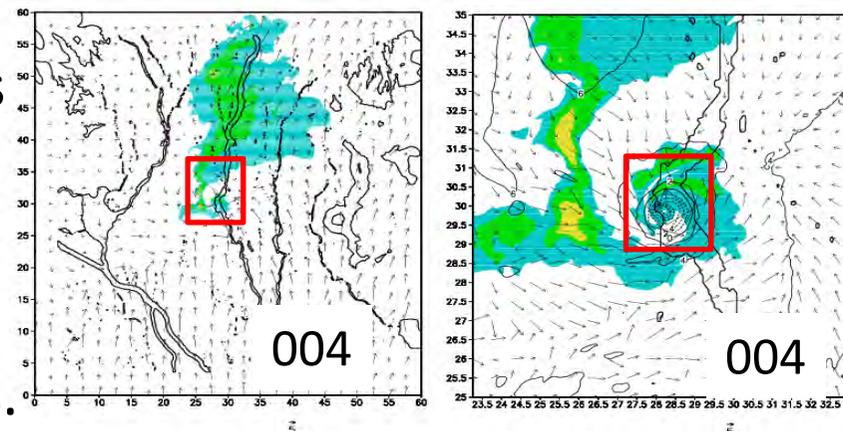
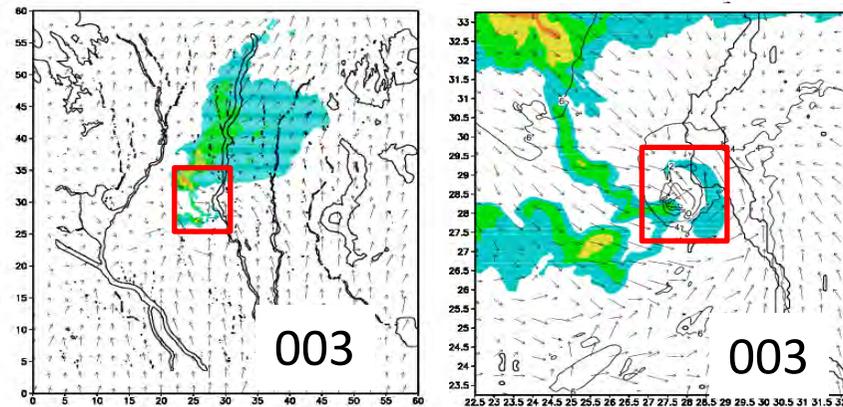
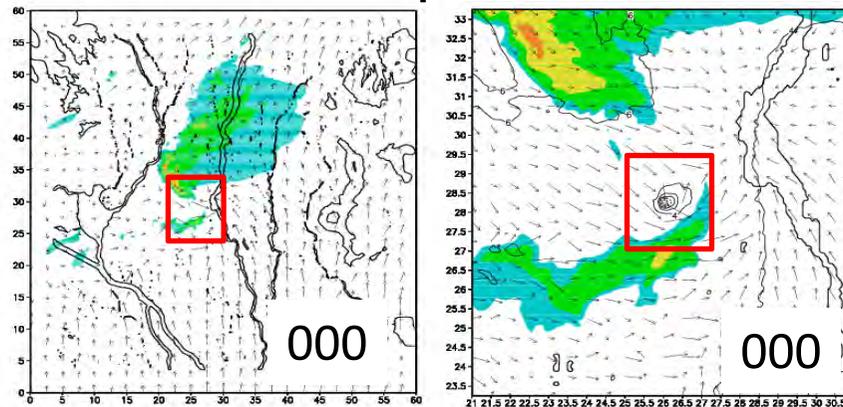
*Downscale
experiment
with $\Delta x=50m$*

13:00JST

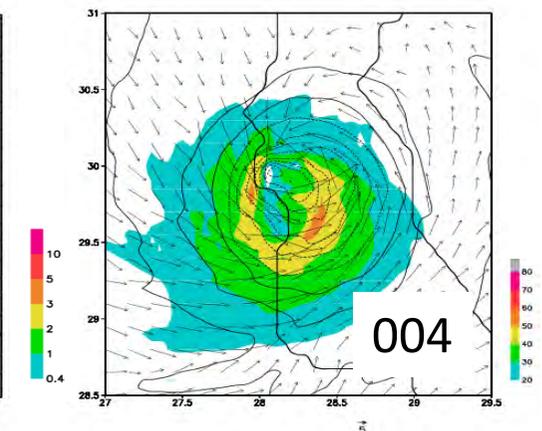
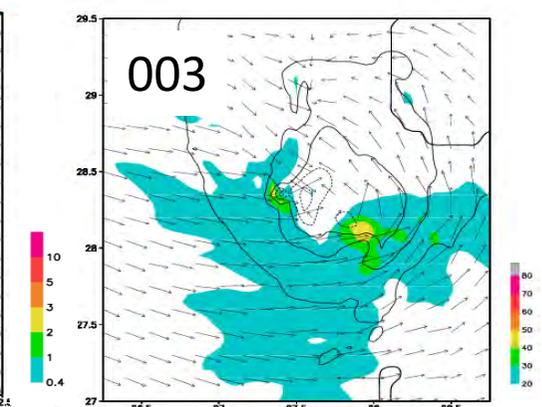
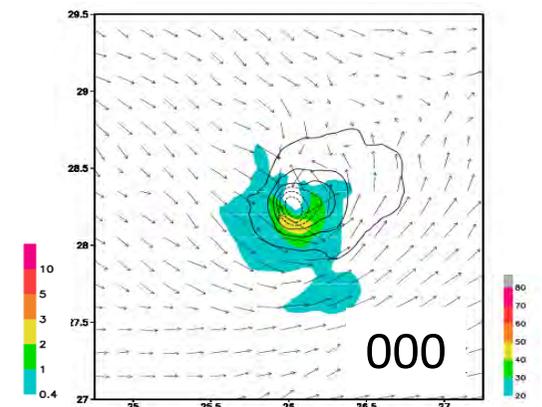
Various sizes and
intensities of
tornadoes were
generated.

Ensemble forecasts
are to be used to
investigate the
factors that
generate tornadoes.

Rain +Horizontal wind,
Surface pressure

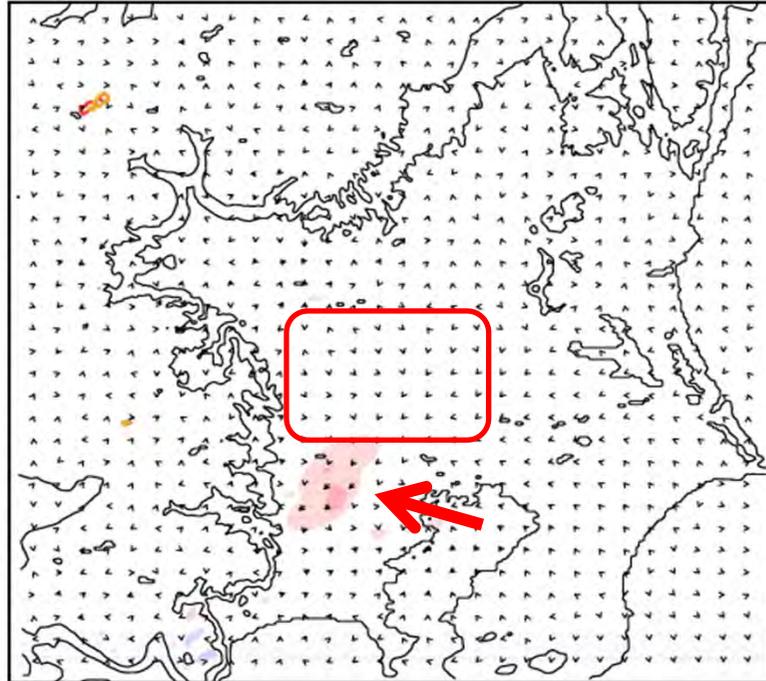


Wind velocity
Pressure

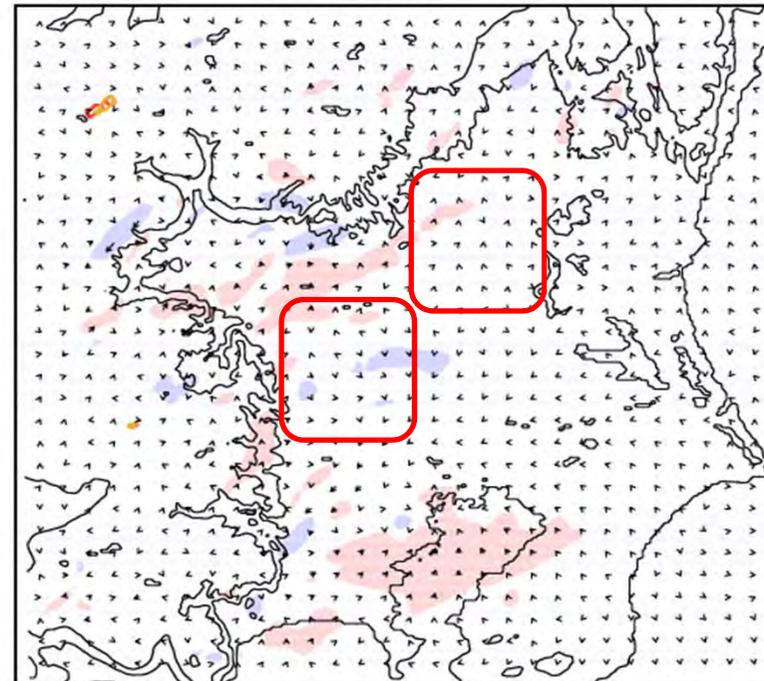


Difference of water vapor and flux distribution

QV #004-007 Q_{min} 11:30-14:30



Flux #004-007 Q_{min} 11:30-14:30



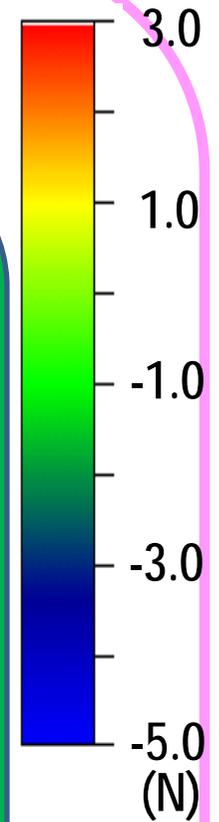
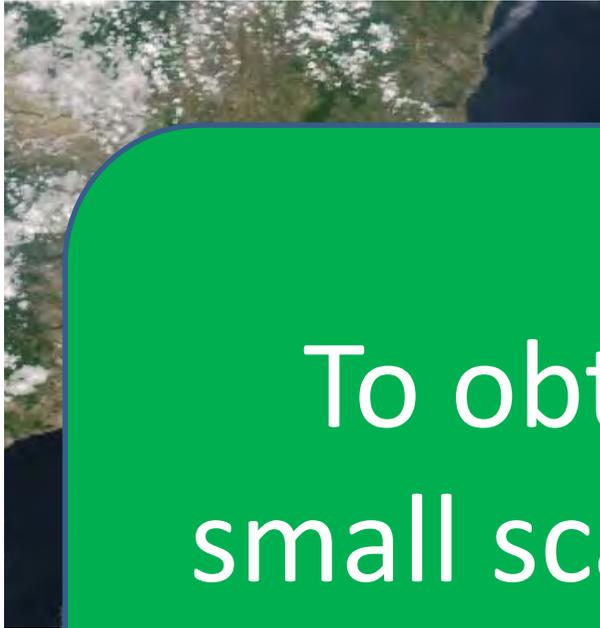
#004-#007:

Left: horizontal wind $\cdot Q_v$ at $z=600m$

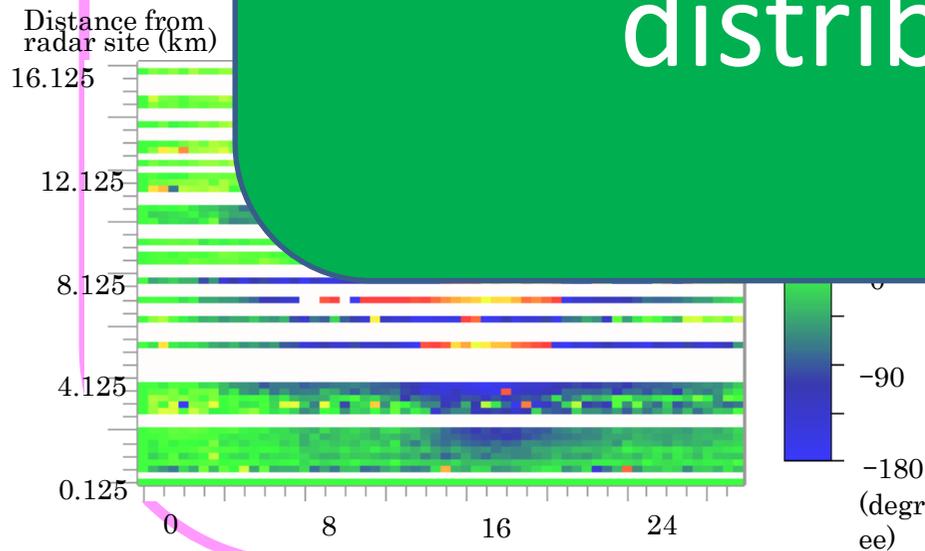
Right: Horizontal wind $\cdot v\rho Q_v$ at $z=600m$

- In #004, in which tornadoes were generated, more humid air was supplied into the rainfall region.

Incrementation of refractivity at 1455JST

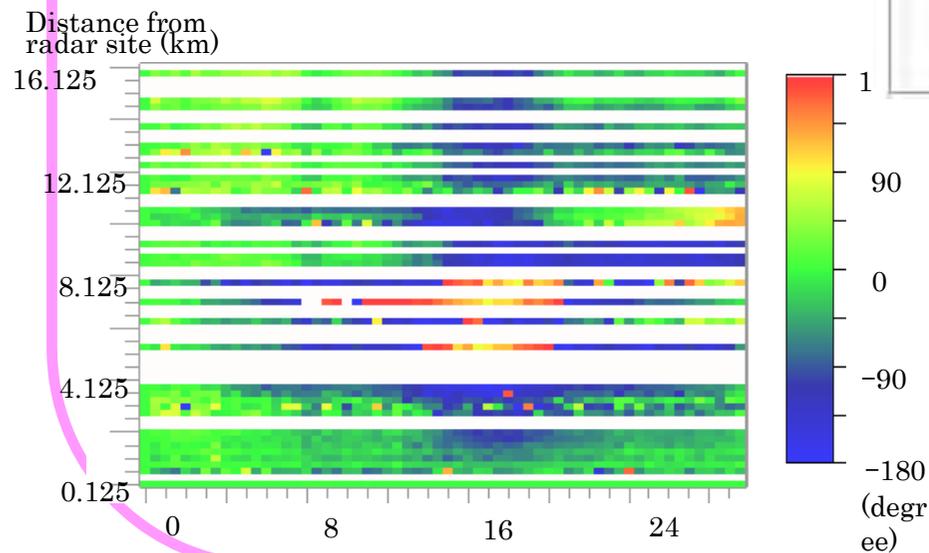
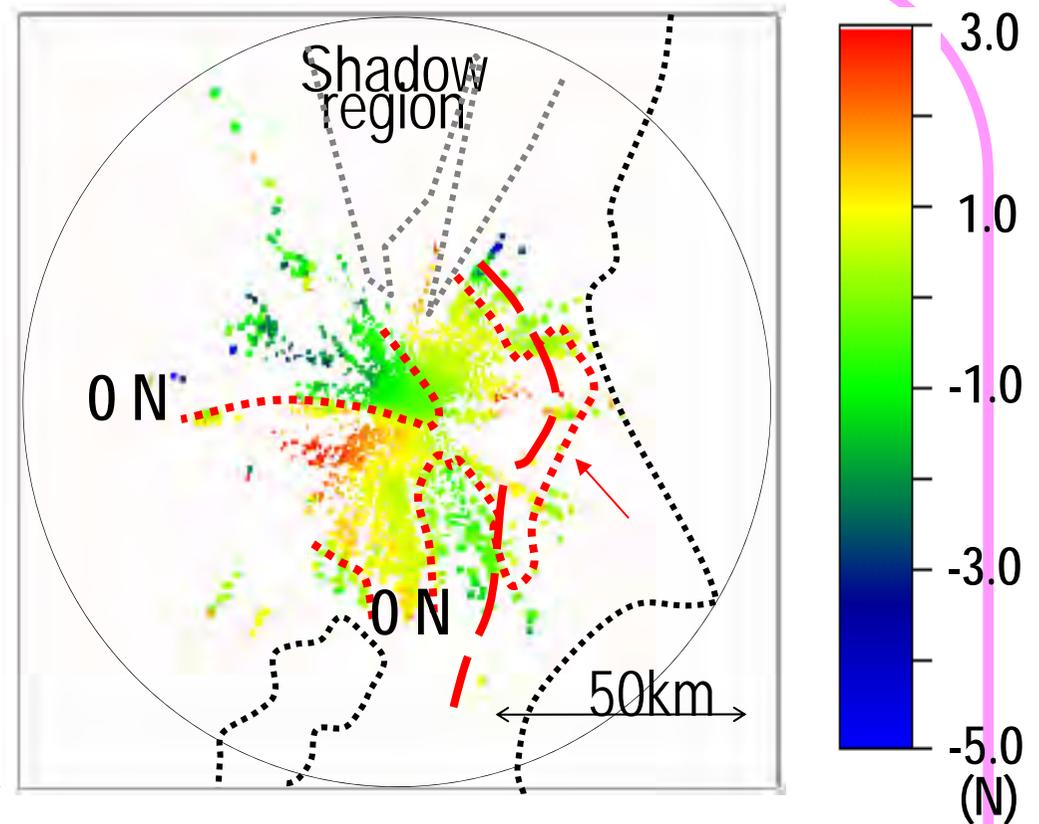


To obtain real-time small scale water vapor distribution...



near the cloud band was increased.

Incrementation of refractivity at 1455JST



- The refractive index near the cloud band was increased.

Summary and Future Plan



1. The nested LETKF system is under development to reproduce the environments and convection cells.
2. Vortices of tornadoes occurring on 6th May 2012 are reproduced by a nested-LETKF system.
3. Ensemble forecasts are to be used to investigate the factors that generate tornadoes.
4. Doppler radar and GPS water vapor data will be used as assimilation data.
(Further improvements of forecasts is expected).
5. Obtaining water vapor data from Doppler radar refractivity is being investigated.

Thank you for your attention



Acknowledgements

- Figures from the preceding studies on the Web:
http://www.jma.go.jp/jma/press/1205/11c/120511tsukuba_tornado.pdf were used.
- K-computer was used to simulate the tornadoes by JMANHM with a 50 m.