Data Assimilation Experiments of Tornado occurring on 6th May 2012

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1. Introduction

Since numerical forecasts or analyses of local heavy rainfalls or tornadoes have errors, it is difficult to predict them accurately. Especially, generation points of thunderstorms in weak convergence areas are sensitive to initial conditions. To express the thunderstorms that cause local heavy rainfalls or tornadoes, probabilistic forecasts based on ensemble predictions are desired. The ensemble prediction is also expected to reduce the miss rate of forecasts because it provides many possible scenarios of severe phenomena. The convection cells that generate the severe phenomena and environments such as low-level convergence should be reproduced simultaneously. In this presentation, a tornado generated on 6th May 2012 in the Kanto Plain was reproduced by using a two-way nested-LETKF (Local Ensemble Transform Kalmar Filter) system with horizontal resolutions of 2 km and 15 km, which expressed convection cells and environments. Downscaling forecasts with the horizontal grid intervals of 350 m and 50 m that can create intense vortices were also performed. The factors for the generations of intense vortices that were investigated by the outputs of downscale experiments are shown.

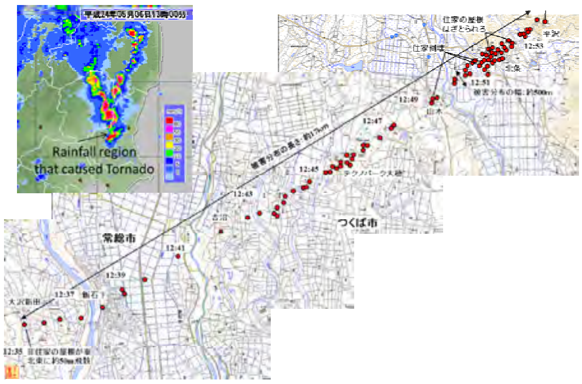

Fig. 1. Rainfall regions that were obtained by the JMA operational radar (upper left). The damage caused by the southernmost tornado. *http://www.jma.go.jp/jma/press/1205/11c/120511tsukuba_tornado.pdf.)*

2. Observed Futures of Tornadoes

On 6th May 2012, three tornadoes occurred in the Kanto plain. The southernmost tornado that was generated at the southern tip of the convection band (Fig. 1) was observed by the Meteorological Research Institute (MRI)'s Doppler radar, and high resolution deterministic forecasts were conducted by the MRI *(http://www.jma.go.jp/jma/press/1205/11c/120511tsukuba_tornado.pdf.)*. A vortex associated with the southernmost tornado, which was captured by the MRI's Doppler radar, was generated at the southern part of the filament-like rainfall region (Fig. 2). A deterministic forecast with the horizontal grid interval of 50 m indicated that a tornado was generated in a super-cell rainfall. A moist airflow with a water vapor mixing ratio of over 12 g/kg was supplied into the convection band, in which the tornado was generated.

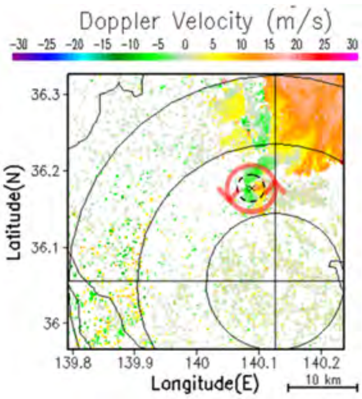

Fig. 2. Radial wind observed by the Doppler Radar of MRI. Red arrows indicate the vortex. *(http://www.jma.go.jp/jma/press/1205/11c/120511tsukuba_tornado.pdf.)*

3. Outline of experiments using the Nested LETKF system

To obtain the initial conditions of the Japan Meteorological Agency non-hydrostatic model (JMANHM) with the horizontal grid interval of 350 m (NHM-350) and 50 m (NHM-50), the nested-LETKF system, which was composed of two LETKFs (Miyoshi and Aranami, 2006), was used (Fig. 3). The outer LETKF with a grid interval of 15 km assimilates the convectional data of the Japan Meteorological Agency. The assimilation window was 6 hours. An inner

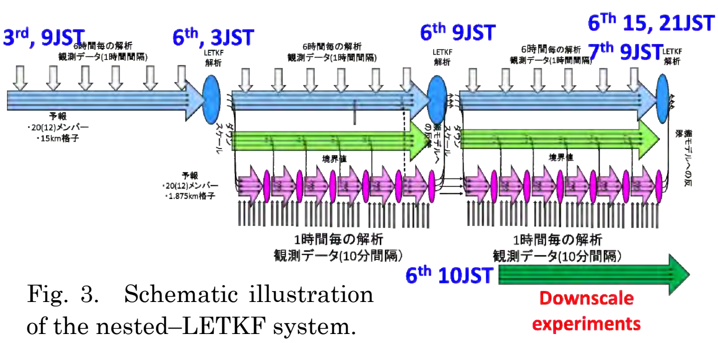

Fig. 3. Schematic illustration of the nested–LETKF system.

LETKF was deployed in the Kanto region in the outer LETKF. The grid interval of the inner LETKF is about 2 km. The assimilation window was 1 hour. Results of the inner LETKF were reflected in the outer LETKF every 6 hours. The Outer and Inner LETKFs were begun at 9 JST 3rd and 3 JST 6th, respectively. Also, downscale experiments using NHM-350 and NHM-50 were performed from 10:30 JST and 11:20 JST, respectively. The initial and boundary conditions of NHM-350 and NHM-50 were produced from the outputs of the Inner LETKF and NHM-350, respectively. In this study, the assimilation data that was used in the Japan Meteorological Agency was used in the Inner LETKF and high resolution data, such as Doppler radar data or GPS water vapor data, was not used in the assimilation of the Inner LETKF.

4. Results of ensemble forecasts

A rainfall region that extended northward and moved northeastward was reproduced in all ensemble members of NHM-350. Intense vortices in which the vertical vorticity exceeded 0.1 (1/s) were generated in 10 of 12 ensemble members. Namely, the occurrence probability of intense vortices in this case was 83 %. Positions and durations depend on the ensemble members. Tornadoes occurred in 3 areas (Fig. 4), which were the same as the observations though they were shifted northward by 10 km. A comparison of environments in NHM-350 forecasts around the vortices in their mature stages shows that the large vertical shear of the horizontal wind and low-level humid airflow made the duration of the vortices longer (Fig. 5). A comparison of initial conditions between the ensemble members, in which intense vortices were generated and not generated, indicated that a small moister region from the south extended their durations (not shown).

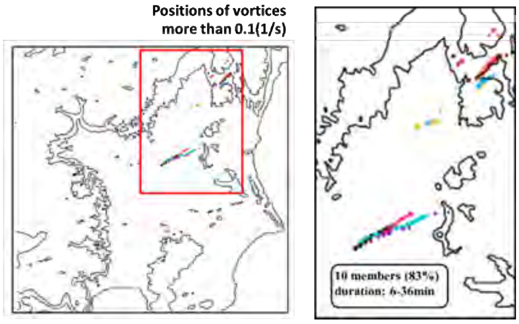

Fig. 4. Positions of vortices more than 0.1 (1/s) reproduced by NHM-350.

As for the ensemble forecast of NHM-50, which was calculated by the K-computer (Fig. 6), various structures of vortices, such as a vortex that had two minimum pressure points (not shown), were generated. These comparisons provide the generation mechanisms of tornadoes.

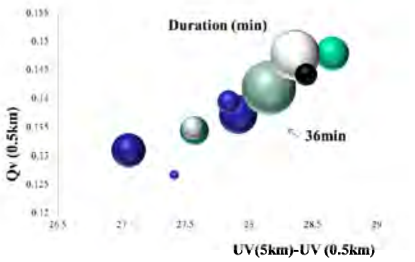

Fig. 5. Relationship between the duration of vortices, vertical wind shear, and low-level water vapor that was reproduced by NHN-350. Sizes of spheres indicate the durations of vortices.

5. Summary and future plan

The vortices of tornadoes occurring on 6th May 2012 were reproduced by the nested LETKF system, which is under development to reproduce the environments and convection cells. An ensemble forecast of 60 members is now being conducted by the K-computer. Results of ensemble forecasts are to be used to investigate the generation mechanisms of tornadoes. Doppler radar data and GPS water vapor data, which are expected to improve the forecasts of convection cells, will be used as assimilation data of the Inner LETKF.

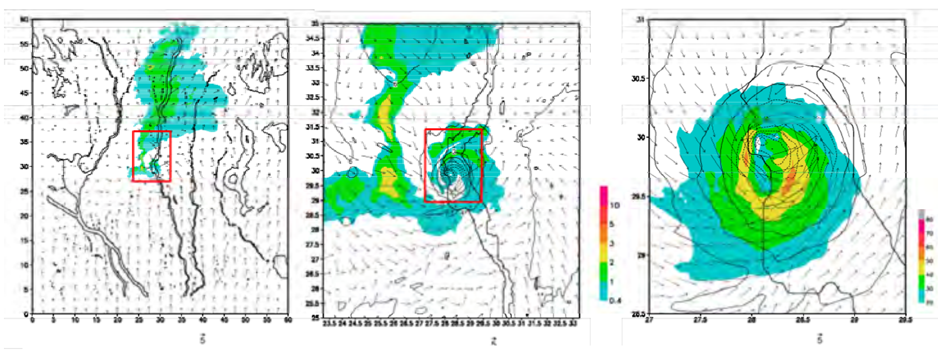

Fig. 6. (a) Rainfall regions (colored regions) and horizontal wind (vectors) near surface of ensemble member #004 that were reproduced by NHM-50. (b) and (c) Magnified figures of (a). Colored region in (c) indicates wind velocity.

Acknowledgements

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References

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