The operational convection-permitting regional model at JMA

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1 Introduction

In June 2012, the Japan Meteorological Agency (JMA) began operation of a new supercomputer system for numerical weather prediction (NWP). Leveraging its high performance specifications, a high resolution convection-permitting NWP system has been operated since August 2012 to provide information for aviation operation and disaster prevention. This report briefly introduces the design of the NWP system, which consists of analysis and forecast parts, and outlines some typical results.

2 Basic design of the Local NWP System

The high resolution operational NWP system (called "Local NWP system") currently covers the eastern part of Japan, and provides 9-hour forecasts every 3 hours. In the system design, high resolution to permit explicit convection and frequent updates of forecasts assimilating latest observation are highly emphasized. The NWP model (called the Local Forecast Model; LFM), which is one of two subsystems in the Local NWP system, has 2-km horizontal gridspacing and 60 vertical layers. Both of these specifications are superior to those of the Meso-Scale Model (MSM), which was the finest resolution model in JMA's operational NWP system before the Local NWP system was launched. Local Analysis (LA; the other subsystem) employs an analysis cycle based on three dimensional variational data assimilation (3D-Var) at a 5-km resolution (detailed in Section 3). The assimilation system requiring fewer computational resources than more advanced systems such as 4D-Var allows to rapidly assimilate the latest observations and to frequently update forecasts.

3 Local Analysis

The analysis cycle (with 5-km gridspacing) combines the 3D-VAR and 1-hour forecasts produced by the numerical model (Figure 1). First, the first guess of 3D-VAR at FT=-3 (3 hours before the initial time) comes from the MSM forecast. After analysis at FT=-3 is conducted by assimilating observations around FT=-3, 1-hour integration from the results is conducted to generate the first guess of the next 3D-VAR at FT=-2. The cycle is repeated, and the final analysis is produced from the last 3D-VAR using the first guess obtained from the 1-hour forecast initialized at FT= -1 and observations around FT= 0 (the initial time).

Currently, observations assimilated in LA come from aircrafts (wind and temperature), wind profilers (wind), ground-based GNSS receivers (precipitable water vapor), Doppler radars (radial velocity), radars (reflectivity), land surface observatory stations (pressure) and radiosondes (wind, temperature, pressure and humidity). In addition, as high resolution enables assimilation for observations locality of which is strong such as temperatures and wind velocity near the surface, the 3D-VAR in the analysis cycle assimilates 1.5-m temperature and 10-m wind velocity data obtained from the automated surface observation network (the nationwide AMeDAS system), while Meso-scale Analysis (MA; the assimilation system used to produce initial conditions for the MSM) does not.

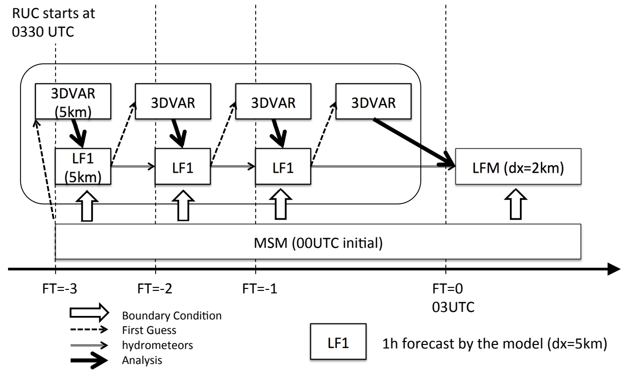

Fig. 1: Schematic diagram of the rapid update cycle (generating analysis at 0300UTC in this case). The cycle repeats assimilation with 3D-VAR and 1-hour forecasts (LF1).

4 Configurations of physical processes in the Local Forecast Model

One of the advantages of higher resolution models is that, needless to say, they can represent smaller scale phenomena. As a result of increasing resolution, parameterizations representing subgrid scale vertical transport can be removed if the grid mean vertical velocity fully represents the vertical transport of momentum, heat and masses including water. In particular, with 2-km horizontal gridspacing, it is considered highly feasible to resolve a significant part of convective transport using the grid mean vertical velocity. In this way, the dependency of physical processes on resolutions comes from partly (or fully) resolved transport, which is parameterized in coarser models. Inhomogeneity within each grid is also a source of the dependency.

Considering the dependency on resolutions, while the LFM and the MSM currently employ the identical non-hydrostatic numerical model package (JMA-NHM), some physical processes employed in the MSM were modified to give higher suitability for the LFM.

For example, no convective parameterizations are adopted in the LFM. As such convective parameterizations could be the origin of significant uncertainty in models, it is preferable not to employ them. Modification has also been introduced to the scheme for diagnosing the width of the probability distribution function (PDF) describing fluctuations of total water amount from grid means, which is used to diagnose cloud fractions. As a result, the width in the LFM can be smaller than that in the MSM because higher resolutions equate to less fluctuation. It has been confirmed that the LFM produces overly large cloud fractions when the PDF width is diagnosed with the same

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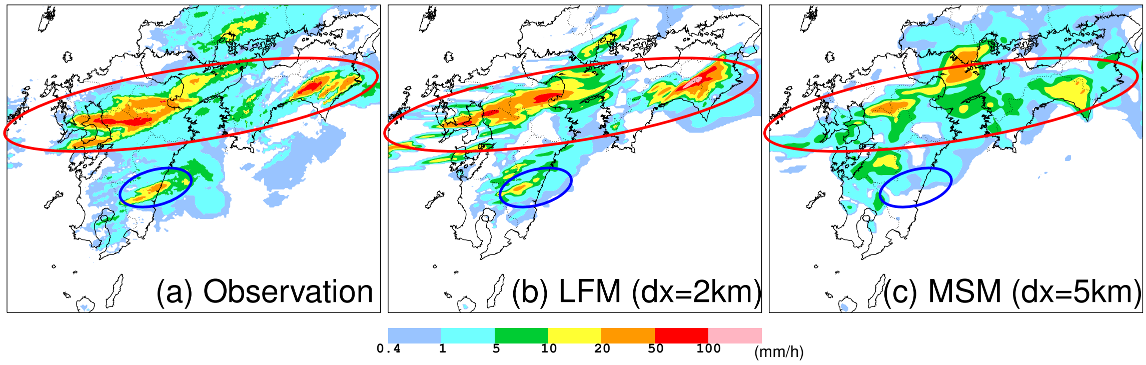

Fig. 2: Examples of forecasts provided by the LFM. All figures show 1-hour accumulated precipitation amounts observed or predicted until 1700UTC on July 11, 2012. (a) Observation, (b) 2-hour forecast by the LFM initialized at 1500UTC on the same day, (c) 5-hour forecast by the MSM initialized at 1200UTC on the same day.

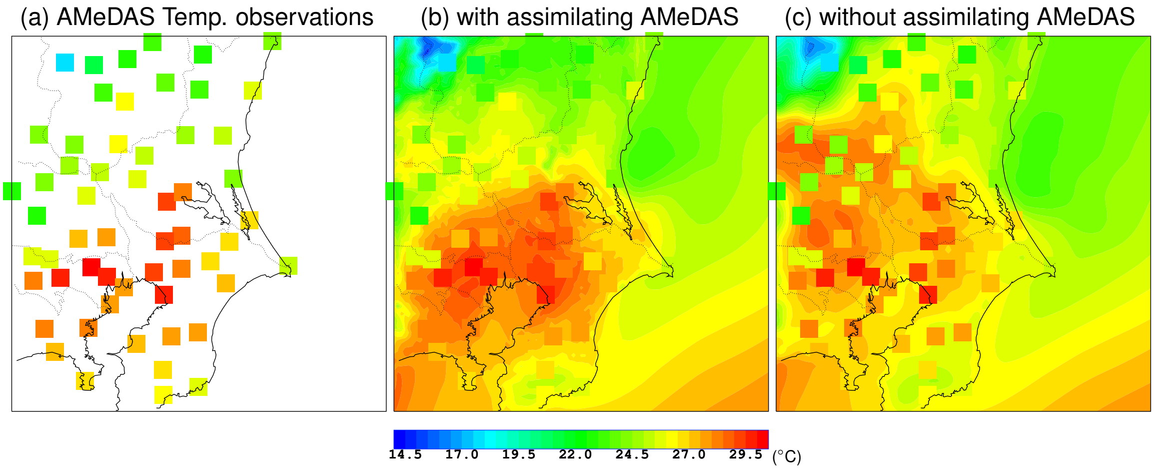

Fig. 3: Examples of analysis to show the effect of assimilating observations near the surface. (a): observation of 1.5-m temperature, (b) and (c) : analysis of 1.5-m temperature (shading) with/without assimilating observations near the surface (obtained from the AMeDAS network) and the corresponding observations (rectangles) with the same color tones as those in the analysis. The results shown in (b) and (c) were produced by the data assimilation systems used in the LFM and the MSM, respectively.

scheme as the MSM, leading to lower daytime surface temperatures and less convection activation.

5 Examples of forecasting and analysis with the Local NWP system

Figure 2 shows the ability of the LFM to accurately predict peak amounts of precipitation contributed by small scale phenomena. In a heavy rainfall event that hit the northern part of Japan's Kyushu Island in July 2012, a stationary front observed around the area over an extended period brought over 500mm of precipitation in a single day. While the MSM predicted the position of the front correctly, the line-shaped precipitation area was not sufficiently generated and the peak value of the predicted precipitation was much lower than the actual amount observed. Meanwhile, the LFM produced the line-shaped precipitation and predicted the peak value of precipitation well, although the positions of the peaks differed slightly from the observed ones. As long as the boundary conditions (i.e. the MSM forecasts in the system), which significantly control synoptic fields in the LFM, give reliable fields, the LFM has considerable potential to reproduce peak values more precisely.

Figure 3 shows the impacts of assimilating observations near the surface. Comparison of the observed temperatures with the analysis field shown in tones of the same color indicates that (b), on which analysis produced by the LA assimilating surface observations are drawn, shows more coincidences between observations and analysis than (c), which indicates analysis generated by the MA without reference to surface observations. More realistic representation in the lower layer can significantly affect forecasting of severe phenomena because temperatures and winds in the lower layer are important in the generation of unstably stratified layers and the initiation of convection.

6 Conclusion

JMA launched a new operational NWP system at a convection-permitting resolution, in which the latest observations are quickly assimilated and forecasts are updated frequently. Some physical processes were modified from those of the coarser operational model in consideration of their dependency on resolutions. As examples, no convective parameterization is employed and the smaller PDF width of the fluctuation of the total water amount is adopted. LFM's potential to predict peak values of precipitation more appropriately was demonstrated.

The current Local NWP system produces forecasts only for the eastern part of Japan and its update frequency is limited to every 3 hours. In 2013, the domain will be expanded to cover the whole of Japan and its surrounding area and hourly operation will begin.