New operational high resolution regional mesoscale model at JMA

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Offenbach/Main, Germany
JMA’s New supercomputer system

• The supercomputer system at JMA was upgraded in June 2012, and now in operation.

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td><strong>HITACHI SR11000</strong></td>
<td></td>
<td><strong>HITACHI SR16000/M1</strong></td>
</tr>
<tr>
<td><strong>Total Peak Performance</strong></td>
<td><strong>27.584 TFlops</strong> (134.4 GFlops/1 node)</td>
<td><strong>847 TFlops</strong> (980.5 GFlops/1 node)</td>
</tr>
<tr>
<td><strong>Total number of nodes</strong></td>
<td><strong>210 nodes</strong> (16 CPU/1 node)</td>
<td><strong>864 nodes</strong> (32 CPU/1 node)</td>
</tr>
<tr>
<td><strong>Memory</strong></td>
<td><strong>64 GB/node</strong></td>
<td><strong>128 GB/node</strong></td>
</tr>
<tr>
<td><strong>Memory Bandwidth</strong></td>
<td><strong>134.4 GB/s/1 node</strong></td>
<td><strong>612 GB/s/1 node</strong></td>
</tr>
<tr>
<td><strong>Network Bandwidth</strong></td>
<td><strong>8 GB/s (one-way)</strong></td>
<td><strong>96 GB/s (one-way)</strong></td>
</tr>
<tr>
<td><strong>System configuration</strong></td>
<td><strong>80 nodes x 2 + 50 nodes x 1</strong></td>
<td><strong>432 nodes x 2</strong></td>
</tr>
</tbody>
</table>
Local NWP system

- Taking advantage of the powerful performance of the new supercomputer system, a high resolution convection-permitting regional NWP system (Local NWP system) has been operated since August 2012.

- The purpose is providing information on aviation weather and disaster prevention.

### NWP systems at NPD/JMA (deterministic)

<table>
<thead>
<tr>
<th></th>
<th>Global</th>
<th>Meso</th>
<th>Local (plan)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objectives</td>
<td>Short- and Medium-range forecast</td>
<td>Disaster reduction Short-range forecast</td>
<td>Aviation forecast Disaster prevention</td>
</tr>
<tr>
<td>NWP model</td>
<td>Global Spectral Model (GSM)</td>
<td>Meso-Scale Model (MSM)</td>
<td>Local Forecast Model (LFM)</td>
</tr>
<tr>
<td>Horizontal resolution</td>
<td>TL959 (0.1875 deg)</td>
<td>5 km (817x611)</td>
<td>2 km (1581x1301)</td>
</tr>
<tr>
<td>Vertical levels / Top</td>
<td>60 0.1 hPa</td>
<td>50 21.8 km</td>
<td>60 20.2 km</td>
</tr>
<tr>
<td>Forecast Hours (Initial time)</td>
<td>84 hours (00, 06, 18 UTC)</td>
<td>39 hours (every 3 hours)</td>
<td>9 hours (every hour)</td>
</tr>
<tr>
<td>Initial Condition</td>
<td>Global Analysis (4D-Var)</td>
<td>Meso-scale Analysis (4D-Var)</td>
<td>Local Analysis (3D-Var)</td>
</tr>
<tr>
<td>Forecast Domain</td>
<td>Global</td>
<td>Meso</td>
<td>Local</td>
</tr>
</tbody>
</table>
Domain of the Local NWP system

1581x1301 with 2km grids.

operational domain (plan)  
A region of the same size (for reference)

topography in the forecast model
Basic design of the Local NWP system

• The **Local NWP system** provides 9-hour period forecasts every hour.
• In the system design, high resolution to permit explicit convection and frequent updates of forecasts assimilating the latest observation are highly emphasized.

• The Local NWP system consists of two subsystems
  – **NWP model**: The **Local Forecast Model (LFM)** has a 2-km horizontal gridspacing and 60 vertical layers.
  – **Data assimilation system**: The **Local Analysis (LA)** employs an analysis cycle based on the three dimensional variational data assimilation (3D-Var) at a 5-km resolution.

Forecast: 1581x1301 (2km grids)
Analysis: 633x522 (5km grids)
Local Analysis:
The first guess and boundary

- Global Analysis (4D-Var) 00UTC
  - GSM forecast
  - Meso Analysis (4D-Var) 00UTC
    - MSM forecast
      - Local Analysis 03UTC
        - LFM
      - Local Analysis 04UTC
        - LFM
      - Local Analysis 05UTC
        - LFM
      - Local Analysis 06UTC
        - LFM
      - Local Analysis 07UTC
        - LFM
      - Local Analysis 08UTC
        - LFM
  - Meso Analysis (4D-Var) 03UTC
    - MSM forecast
      - Local Analysis 03UTC
        - LFM
      - Local Analysis 04UTC
        - LFM
      - Local Analysis 05UTC
        - LFM
      - Local Analysis 06UTC
        - LFM
      - Local Analysis 07UTC
        - LFM
      - Local Analysis 08UTC
        - LFM
  - Meso Analysis (4D-Var) 06UTC
    - MSM forecast
      - Local Analysis 03UTC
        - LFM
      - Local Analysis 04UTC
        - LFM
      - Local Analysis 05UTC
        - LFM
      - Local Analysis 06UTC
        - LFM
      - Local Analysis 07UTC
        - LFM
      - Local Analysis 08UTC
        - LFM
  - Global Analysis (4D-Var) 06UTC
    - GSM forecast
      - Meso Analysis (4D-Var) 00UTC
        - MSM forecast
          - Local Analysis 03UTC
            - LFM
          - Local Analysis 04UTC
            - LFM
          - Local Analysis 05UTC
            - LFM
          - Local Analysis 06UTC
            - LFM
          - Local Analysis 07UTC
            - LFM
          - Local Analysis 08UTC
            - LFM
• Firstly, **the first guess** of the 3D-VAR at FT=-3 (3 hours before the initial time) comes from forecasts of MSM (5km operational mesoscale model).

• After the analysis at FT=-3 is obtained by assimilating observations around FT=-3, **1-hour integration from the analysis is conducted to generate the first guess of the next 3D-VAR at FT=-2**.

• The cycle is repeated, then the final analysis is produced by the final 3D-VAR using the first guess obtained from 1-hour forecasts initialized at FT=-1 and observations around FT=0 (the initial time).
Local Analysis: Assimilated observations

### Observation types

<table>
<thead>
<tr>
<th>Observation types</th>
<th>Parameters used in the analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYNOP</td>
<td>pressure</td>
</tr>
<tr>
<td>TEMP</td>
<td>wind, temperature, pressure, humidity</td>
</tr>
<tr>
<td>Aircrafts</td>
<td>wind and temperature</td>
</tr>
<tr>
<td>Wind profilers</td>
<td>wind</td>
</tr>
<tr>
<td>Ground-based GNSS receivers</td>
<td>precipitable water vapor</td>
</tr>
<tr>
<td>Radars</td>
<td>radial velocity, Rh retrieved from reflectivity</td>
</tr>
<tr>
<td>Surface observational stations (not SYNOP,</td>
<td>1.5-m temperature</td>
</tr>
<tr>
<td>placed all over Japan)</td>
<td>10-m wind velocity</td>
</tr>
</tbody>
</table>

### Parameters

- **SYNOP**: pressure
- **TEMP**: wind, temperature, pressure, humidity
- **Aircrafts**: wind and temperature
- **Wind profilers**: wind
- **Ground-based GNSS receivers**: precipitable water vapor
- **Radars**: radial velocity, Rh retrieved from reflectivity
- **Surface observational stations (not SYNOP, placed all over Japan)**: 1.5-m temperature, 10-m wind velocity
Local Analysis:
Effects by assimilating observations near the surface

1.5m temperature observations  w/ assimilation  w/o assimilation

- Features of observed temperature are well represented by an analysis field for the LFM assimilating the surface observations.
- More realistic representations in the lower layer could give considerable impacts to forecast of severe phenomena because temperature and winds at the lower layer are important to generate unstably stratified layers and initiate convection.
Model specification of LFM

- LFM employs the JMA-NHM as its NWP model.
  - The same model package as 5-km operational mesoscale model (MSM).
- **No convective parameterizations**
  - It is expected to represent convective transport by the grid mean vertically velocity, avoiding uncertainty coming from the parameterization.
- Some modifications have been made in physical processes which depend on scales
  - Made a PDF to diagnose cloud fraction narrower because inhomogeneity is smaller as the grid-spacing is smaller.

<table>
<thead>
<tr>
<th></th>
<th>LFM (plan)</th>
<th>MSM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Horizontal Resolution/Forecast Domain</strong></td>
<td>2km (1581x1301)</td>
<td>5km (817x661)</td>
</tr>
<tr>
<td><strong>Vertical Layers</strong></td>
<td>60 Layers, up to 20km</td>
<td>50 Layers, up to 22km</td>
</tr>
<tr>
<td><strong>Integration Time Step</strong></td>
<td>8 seconds</td>
<td>20 seconds</td>
</tr>
<tr>
<td><strong>Initial Condition</strong></td>
<td>3D-Var analysis cycle</td>
<td>4D-Var</td>
</tr>
<tr>
<td><strong>Boundary Condition</strong></td>
<td>MSM</td>
<td>GSM</td>
</tr>
<tr>
<td><strong>Forecast hours</strong></td>
<td>9 hours</td>
<td>39 hours</td>
</tr>
<tr>
<td><strong>Cloud Physics</strong></td>
<td>Qc, Qr, Qi, Qs, Qg</td>
<td>Qc, Qr, Qi, Qs, Qg and Ni</td>
</tr>
<tr>
<td><strong>Cumulus convective parametrization</strong></td>
<td><strong>Not Used</strong></td>
<td>Kain-Fritsch scheme</td>
</tr>
</tbody>
</table>
Advantages of LFM
no need to rely on convective parametrization

• It is expected to represent convective transport explicitly by the grid-mean vertical velocity.
  – But it is not clear if all of transport can be resolved by the grid-mean values. Partly resolved? : related to Grey Zone.

• One of the origins of model uncertainty.
Advantages of LFM accurately predict peak amount of precipitation

1-hour accumulated precipitation amounts until 1700UTC on July 11 2012

- The **LFM** produced the line-shaped precipitation and the peak strength of the precipitation is well predicted.
- While the **MSM** predicted the position of the front correctly, the line-shaped precipitation area was not generated enough and the peak value of the precipitation is much smaller than the corresponding observation.
- As long as the boundary conditions (i.e. the MSM forecasts in the system), which considerably control synoptic fields in the LFM, give reliable fields, the **LFM** has considerable potential to reproduce peak values more precisely.
Advantages of LFM
frequent updates of forecasts

Time Series of Threat Score > 1mm/h, 10km verification grids

- The latest forecasts are better than older one (except 1 hour forecast), as we aimed at.
- Assimilating the latest observations gains the performance.
Advantages of LFM
frequent updates of forecasts

Time Series of Threat Score > 1mm/h, 10km verification grids

- Forecasts using the same MSM forecasts as the initial guess for the Local analysis behaves similarly each other.
- Considerable part of the LFM accuracy is determined by the MSM performance through the first guess and boundary conditions.
LFM forecasts whose first guess is predicted by the same MSM behaves similarly.
LFM Forecast for 7/11 18UTC by different initial time

FT=1  FT=2  FT=3
FT=4  FT=5  FT=6
FT=7  FT=8  FT=9

MSM forecast
Spin Up problem

- Clear underestimate of precipitation during the first 3-4 hours.
- It might be related to converting resolution when the model received the initial conditions from the analysis system.
- It needs further investigation to resolve the problem.
Spin Up problem

LFM forecasts started from different initial time

- Too small precipitation in first few hours. (especially in FT=1.)
• The underestimate of precipitation in the first 1 hour is common to small precipitation.
• Heavy precipitation is overestimated especially in the middle period. (This corresponds to grid point storm.)
• Smaller convection than 10km is not resolved even in 2km horizontal resolution.
• We should somehow deal with them.
Although the vertical transport is explicitly represented in the LFM, the entrainment/detrainment and the initiation of convection are not necessary resolved. We need to deal with them.
Summary

• The JMA launched the new operational NWP system (Local NWP system) at a convection-permitting resolution.
  • The latest observations are quickly assimilated and forecasts are updated frequently.
  • Some physical processes were modified from the coarser operational model considering their dependency on the resolutions.
  • The LFM shows its potential to predict peak values of precipitation more appropriately.

• There are some problems to resolve.
  • Spin up problem
    • Too small precipitation in the first few hours. (It comes from the difference of the resolution between analysis and forecast.)
  • Initiation of convection / Grid point storm
    • All of convective transport is not resolved.
    • Processes to initiate convection smaller than the resolution, and the entrainment/detrainment of the convection should be parameterized.