Recent Developments of JMA Operational NWP Systems and WGNE Intercomparison of Tropical Cyclone Track Forecast

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Numerical Prediction Division
Japan Meteorological Agency
CURRENT STATUS AND RECENT DEVELOPMENTS OF JMA NWP SYSTEM
Numerical Weather Prediction

Meteorology
- Mechanism, Observation

Fluid dynamic
- Governing equation

Computational science
- Mathematics, Numerical method, Computer

Supercomputer

Weather forecast

Climate Prediction
History of NWP at JMA
# Current NWP models of NPD/JMA

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<th>Objectives</th>
<th>Global Spectral Model GSM</th>
<th>Meso-Scale Model MSM</th>
<th>Local Forecast Model LFM</th>
<th>One-week Ensemble WEPS</th>
<th>Typhoon Ensemble TEPS</th>
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<td>Japan and its surroundings (4080km x 3300km)</td>
<td>Japan and its surroundings (3160km x 2600km)</td>
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<td>Horizontal resolution</td>
<td>$T_{L,959}(0.1875 \text{ deg})$</td>
<td>5km</td>
<td>2km</td>
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<td>$T_{L,319}(0.5625 \text{ deg})$</td>
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<td>Vertical levels / Top</td>
<td>60 0.1 hPa</td>
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<td>60 20.2km</td>
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<td>Forecast Hours (Initial time)</td>
<td>84 hours (00, 06, 18 UTC) 264 hours (12 UTC)</td>
<td>39 hours (00, 03, 06, 09, 12, 15, 18, 21 UTC)</td>
<td>9 hours (00-23 UTC hourly)</td>
<td>264 hours (12 UTC) 51 members</td>
<td>132 hours (00, 06, 12, 18 UTC) 11 members</td>
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<td>Initial Condition</td>
<td>Global Analysis (4D-Var)</td>
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<td>Global Analysis with ensemble perturbations (SV)</td>
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Verification score of global model

1-day forecast | 2-day forecast | 3-hour forecast

RMSE of 500 hPa geopotential height in Northern Hemisphere (20-90N)

The accuracy of 3-day forecast in 2013 compares with that of 1-day forecast in 1980’s.
Example of Typhoon Forecast by 20km-GSM

- Accuracy of current NWP is generally good.
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Enhancement of GSM (Mar 2014)

- JMA also plans to upgrade its operational GSM.
  - The number of vertical levels in GSM will be enhanced from 60 to 100
  - The top level of the model will be raised from 0.1 hPa to 0.01 hPa.
- The physical processes will be revised.
  - Non-orographic gravity wave scheme will be newly introduced.
## Plans to upgrade JMA’s global EPSs (Mar 2014)

### Specifications of JMA’s medium-range EPSs (red: upgrade plan)

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Strategy

Upgrade Supercomputer system

2011 | 2012 | 2013 | 2014 | 2015 | 2016 -

60km

1-week Global Ensemble

Typhoon Global Ensemble

TL319L60M51

TL319L60M11

40km

Global Model

TL959L60 11days forecast

20km

Global Ensemble

Twice per day

TL479L60M27

Twice per day

TL479L100M27

9hours forecast

Every 3 hours

10km

Meso-scale Ensemble

10km

TL479L60M25

TL479L100M25

TL479L100M27

5km

Meso-Scale Model

39hours forecast

Local Forecast Model

2kmL60

Every 3 hours, 9hours forecast

Eastern Japan region

Whole Japan region

Upgrade Supercomputer system
WGNE TC VERIFICATION
WGNE

• Numerical Weather Prediction (CAS) and Climate (WCRP)
  – Working interface between operational forecasting and climate modelling communities

• WGNE fosters the open exchange of information in a competitive NWP environment

• WGNE theme: atmospheric models, their evaluation and improvement
WGNE Activities

• Meeting
• Related Workshop
• Intercomparison, Verification
  – Tropical Cyclone
  – Precipitation
  – Surface drag
  – Impact of aerosol
WGNE intercomparison of Tropical Cyclone Track forecast, 2011

Chiashi Muroi, colleagues at JMA, and WGNE-Friends
5-9 Nov. 2012, Toulouse
WGNE-28
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* except for South Pacific and north Indian-Ocean

**Data from July 2011 to October 2011 are almost missing.
2. Verification Method

- **Position Error [km]**
  The distance between the best-track (analyzed) position and the forecast position.

- **Along Track – Cross Track bias**
  AT(along-track)-bias : The bias in the direction of TC movement
  CT(cross-track)-bias : The bias in the rectangular direction of TC movement

- **Detection Rate [%]**
  Detection Rate (t) = A(t) / B(t)

  A(t) : The number of forecast events in which a TC is analyzed at forecast time t on the condition that a NWP model continuously expresses the TC until the forecast time t.
  B(t) : The number of forecast events in which a TC is analyzed at forecast time t.
TC Verification

TC tracks on 2011 season

- Northern-Hemisphere [2011/01/01 to 2011/12/31]
- Southern-Hemisphere [2010/09/01 to 2011/08/31]

Number of TCs, [best-track data provider]

- **21** western North-Pacific [RSMC Tokyo]
- **11** eastern North-Pacific (including Central-Pacific) [RSMC Miami, Honolulu]
- **19** North Atlantic [RSMC Miami]
- **2** north Indian-Ocean [RSMC New-Delhi]
- **3** south Indian-Ocean [RSMC La-Reunion]...

...the lowest number of tropical cyclones for 50 years

- **15** around Australia [RSMC Nadi and 4 TCWCs]

(Except for Errol and Bune 13 typhoons was actually verified)
(a) western North-Pacific (WNP) domain Position Error

21 TCs in 2011

Japan Meteorological Agency
(a) WNP domain  Detection Rate

Detection Rate – Position Error map (FT 72)

better
Scatter diagram of TC positions at 72 hour forecast.

- **Red**: Before recurvature
- **Green**: During recurvature
- **Blue**: After recurvature

Y-axis represents position errors in Along Track (AT) direction
and X-axis does that in Cross Track (CT) direction.

Unit: km
(a) WNP domain Central Pressure scatter diagram (FT +72)

Y-axis represents central pressure of forecast and X-axis does that of analysis. Unit: hPa
visualization with “pie-chart”

- BOM
- CMA
- CMC
- DWD
- ECMWF
- Meteo France
- JMA
- KMA
- NCEP
- NRL
- UKMO

Western North-Pacific
Eastern North-Pacific
North-Atlantic
Around Australia
Southern Indian Ocean
Detection rate

- : 100 %
- : 0 %
transition of FT+72 position error over decade(s)
(a) western North-Pacific (WNP) domain
Position Error for 2012
SUMMARY
Summary

• JMA began to operate NWP in 1959 and the models will be upgraded.
• WGNE encourages numerical model development for both NWP and climate.
• TC verification of WGNE shows remarkable improvement of operational Global NWP models in all centers.
  – Enhancement of resolution, physical process and data assimilation are key points.
Data assimilation systems of NPD/JMA

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<td><strong>Data cut-off time</strong></td>
<td>2 hours 20 minutes [Early Analysis]</td>
<td>50 minutes</td>
<td>30 minutes</td>
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<tr>
<td></td>
<td>11 hours 50 minutes (00, 12 UTC)</td>
<td></td>
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<tr>
<td></td>
<td>7 hours 50 minutes (06, 18 UTC) [Cycle Analysis]</td>
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<td><strong>Assimilation window</strong></td>
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# Plans to upgrade JMA’s global EPSs (Mar 2014)

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  – 4th WGNE workshop on systematic errors in weather and climate models, Exeter, UK, 15-19 April 2013
• Publication
  – Blue Book: Research Activities in Atmospheric and Ocean Modelling
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TCs to be verified

TCs which intensity reached tropical storm (TS) with the maximum sustained wind of 34 knots or stronger are set as targets for this verification. The tropical depression (TD) stage of the targeted TCs is also included in this verification. However, the TCs which stayed at TD level all through their life are excluded.

1. Tracking Method

   local pressure minimum;
   a) First position (FT +0hr) : search from the best track position
   b) Second position (FT +12hr) : search from the first position
   c) Third and after (FT +24hr~) : search from estimated position from the latest two positions

   (all position searched within 500km radius)
2. Verification Method

- **Position Error [km]**
  The distance between the best-track (analyzed) position and the forecast position.

- **Along Track – Cross Track bias**
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(a) western North-Pacific (WNP) domain Position Error

21 TCs in 2011
Scatter diagram of TC positions at 72 hour forecast.

- **Red**: Before recurvature
- **Green**: During recurvature
- **Blue**: After recurvature

Y-axis represents position errors in Along Track (AT) direction and X-axis does that in Cross Track (CT) direction.

Unit: km
Scatter diagram of central pressure at 72 hour forecast.

Y-axis represents central pressure of forecast and X-axis does that of analysis.
Unit: hPa
visualization with “pie-chart”
transition of FT+72 position error over decade(s)

Western North Pacific

Eastern North Pacific

North Atlantic

Southern Indian Ocean

around Australia

North Indian Ocean

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• TC verification of WGNE shows remarkable improvement of operational Global NWP models in all centers.
  – Enhancement of resolution, physical process and data assimilation are key points.

• Verification of TC intensity, genesis and EPS will be issues.