Predictabilities of Typhoon Yagi 2013

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In order to clarify the variation mechanisms of predictability of high-impact weather events in global numerical weather prediction, forecast experiments from multiple analyses and ensemble analysis were conducted. In the case study of Typhoon Yagi 2013, forecast tracks but intensities are found to be sensitive to the initial conditions. In order to determine the relative importance of the vortex and ambient flow, additional experiments from modified initial conditions were performed. It is found that the representation of the structure near the centre is important in reproducing the track of the most successful forecast. In addition to the case study, ensemble forecast experiments were conducted for 22 typhoons observed in 2013 and 2014. The track error tends to be large with weak storms in weak ambient flows.

Keywords: Tropical Cyclone, Typhoon, Atmospheric General Circulation Model, Data Assimilation, Ensemble Forecast

1. Introduction

Atmospheric predictability fluctuates day-to-day and its amplitudes vary among regions of the globe in season to season. Such variability of the forecast error can be demonstrated in the ensemble forecast experiments using Atmospheric General Circulation Model (AGCM) for the Earth Simulator (AFES) [1][2][3][4] initialized with ALERA2 (AFES–LETKF experimental ensemble reanalysis 2, where LETKF stands for the local ensemble transform Kalman filter [5][6]) [7][8][9]. The experiments were conducted from 12 UTC for each day in January, April, July and October 2010, representing the winter, spring, summer and autumn seasons and thus are referred to *as the four-seasons experiments*. The model resolution is T119L48, the truncation wave number of 119 using the triangular truncation or 1° in the horizontal and 48 levels in the vertical, which is the same as that of the forecast model used in ALERA2. Figure 1 displays the root-mean square error (RMSE) of the 48-h forecast of the geopotential height at 500 hPa (Z500) against ALERA2 (own analysis) in the global domain, in the Northern Hemisphere (NH, between 20°N and 90°N), in the Southern Hemisphere (SH, between 20°S and 90°S) and in the Tropics (TR, between 20°S and 20°N).

In addition to the daily fluctuations, the forecast error also varies in time scales in pentads or longer. In the Northern and Southern Hemispheres, the amplitudes are generally larger in cold months i.e. January (black) and July (red) in the Northern and Southern Hemispheres, respectively. The values in April (blue) and in October (orange) are larger in the Northern and Southern Hemispheres, respectively, although the differences are smaller. The global RMSE is dominated by that of the winter Hemisphere. The large peaks on 23 January and 10 October reflect the values in the Northern and Southern Hemispheres, respectively. The error is large in the Tropics on 10 October.

In the following sections we investigate the variation of predictability of typhoons. We present the preliminary results from forecast experiments of Typhoon Yagi in 2013 from multiple analyses and ensemble forecast experiments.

2. Forecast experiments of Typhoon Yagi 2013

The operational track forecasts of Typhoon Yagi (201303) from 1200 UTC 9 June 2013 are largely different between ECMWF and JMA. Although both of the forecasts cannot

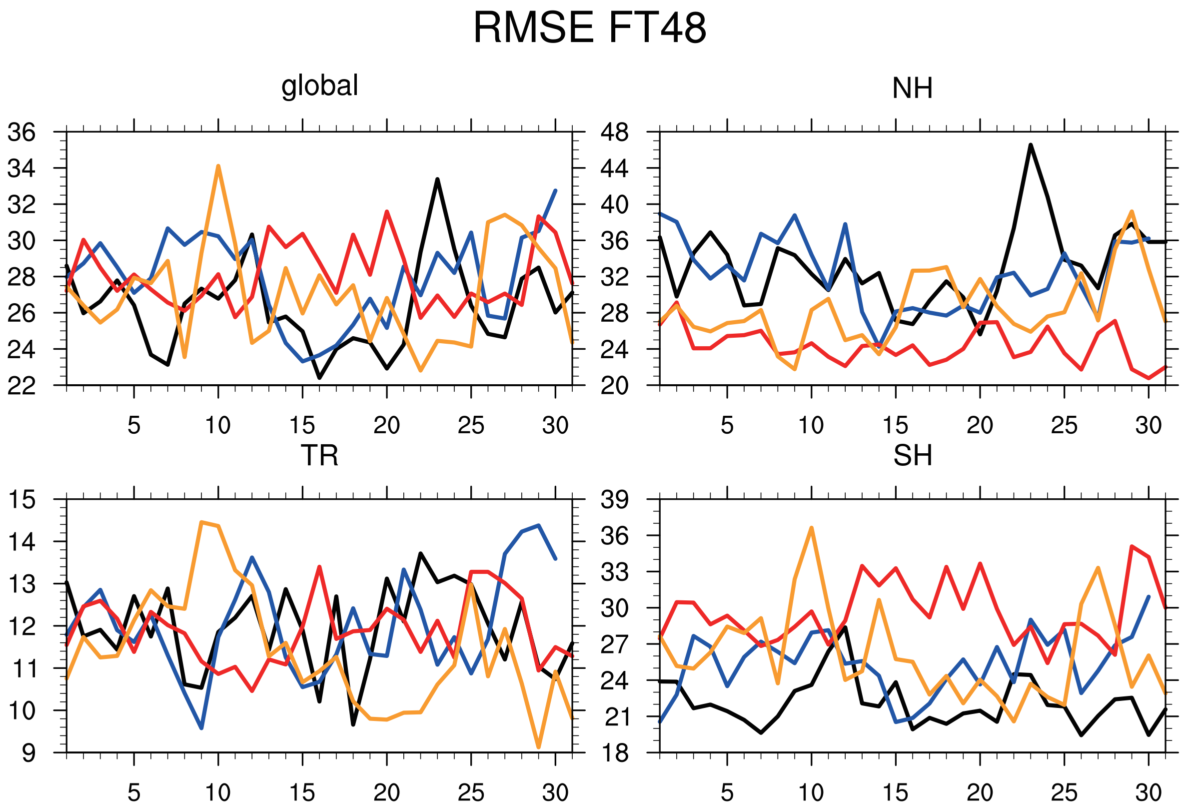

Fig. 1 The root-mean square error of the 48-h forecast of the geopotential height (gpm) at 500 hPa in the global domain (top left), in the Northern Hemisphere (top right), in the Tropics (bottom left) and in the Southern Hemisphere (bottom right) in the four-seasons experiment. The black, blue, red and orange curves represent the RMSE for January, April, July and October 2010, respectively. The horizontal axis indicates the initial dates.

predict the observed northeastward track, the northward track of ECWMF is closer to the observation than the northwestward track of JMA.

To clarify either initial value or model is important for the track prediction, sensitivity experiments were conducted using AFES with T239L48 (0.5° in the horizontal and 48 levels in the vertical) from ECMWF, JMA and JRA-55 [10] initial values (hereafter denoted as ECMWF, JMA JRA-55 runs, respectively). The ECMWF run predicts northward track similar to the operational ECMWF forecast, whereas the JMA run predicts northwestward track similar to the operational JMA forecast (Fig. 2). These tracks are consistent with the results of the sensitivity experiments with JMA-GSM computed at MRI and with NICAM conducted in other ES2 projects. These results indicate that the forecast of Yagi is sensitive to the initial conditions, but is insensitive to the model used. The JRA-55 run and the experiment with NCEP-GSM from the NCEP initial conditions computed at Kyoto University predict intermediate tracks between the ECMWF and JMA runs.

The predicted central sea-level pressure, however, does not depend on initial values, but depends on models. JMA-GSM and NICAM intensify the typhoon, whereas AFES and NCEP-GSM weakens the typhoon gradually at a similar rate with the best track (Fig. 3). The results reveal that track prediction is sensitive to initial values, but not related with intensity prediction in this case.

In order to clarify the relative importance of the vortex and the ambient flow, sensitivity experiments were conducted. In these experiments, the ECWMF initial value is used only the neighbourhood of the typhoon, given by the distance from the initial cyclone centre, whereas the JMA initial value is used the outer area. Three experiments were conduced with the distances

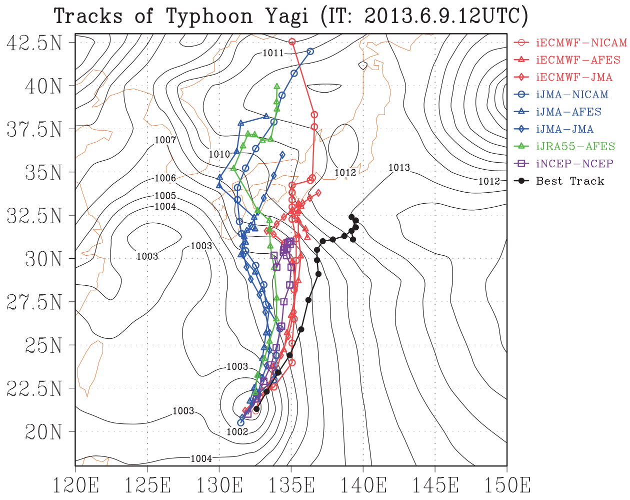

Fig. 2 Tracks of Typhoon Yagi from 1200 UTC 9 June 2013. Colours differentiate the dataset of the initial values (red: ECMWF, blue: JMA, green: JRA-55, purple: NCEP) and marks indicate 6-hourly typhoon positions classified by models (circle: NICAM, triangle: AFES, diamond: JMA-GSM, square: NCEP-GSM). The black curve repersents the best track.

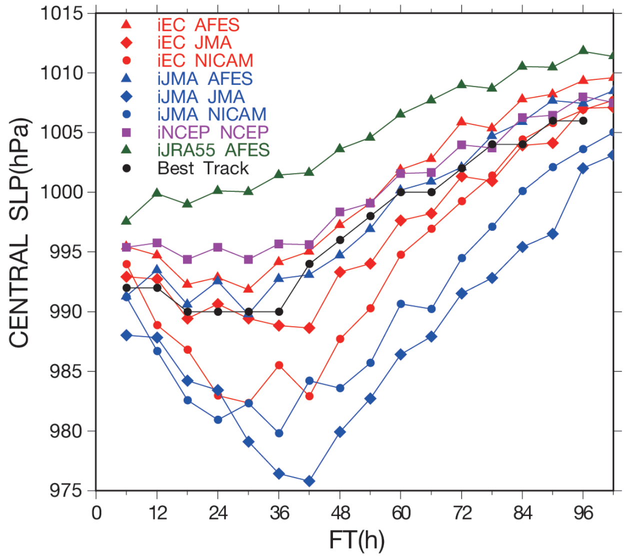

Fig. 3 Time series of the central sea-level pressures of the forecast and of the best track. Colours and marks are same as in Fig. 2.

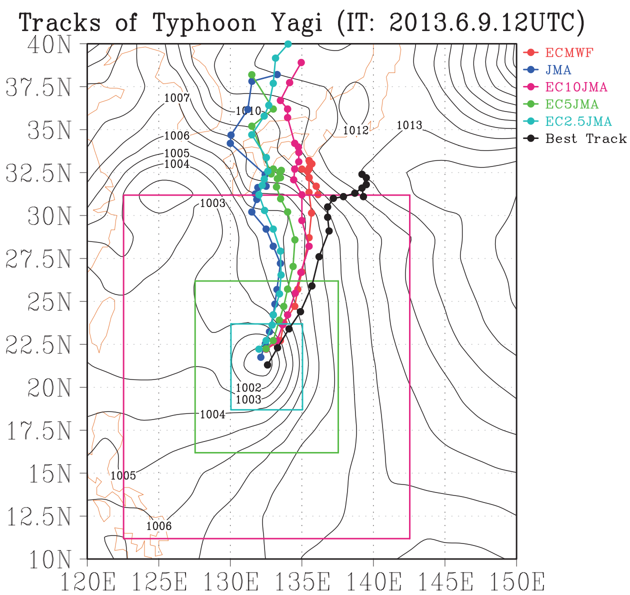

Fig. 4 Track of ECMWF run (red), JMA run (blue), EC10JMA (pink), EC5JMA (green) and EC2.5JMA (skyblue). The black curve represents the best track.

of 2.5 (EC2.5JMA), 5 (EC5JMA) and 10 degrees (EC10JMA). The ECMWF track prediction is reproduced in EC10JMA (Fig. 4). It appears that the all variables at the initial time around the typhoon centre are important in reproducing the track of the ECMWF run because it was not reproduced in additional experiments replacing the specific humidity or the variables other than the specific humidity (not shown).

3. Typhoon position errors in ALEPS2

To investigate the systematic errors of typhoon centre forecasts in ALEPS2 (ensemble AFES from ALERA2), 22 forecasts experiments for 13 typhoons in 2013 and 9 typhoons in 2014 were conducted. The 5-day forecasts were conducted starting from the dates when each typhoon became more than 16.2 m s^{-1} (class 3) at 12 UTC in the best track data of RSMC Tokyo-Typhoon Center of JMA. Here, we focus on only the position errors if typhoon centres in the ALEPS2 ensemble-mean fields from the best tracks at 48 h (FT48) and 120 h (FT120) from the initial time. Note that some of the typhoons became extratropical cyclones (class 6) at FT120.

Table 1 shows the position errors of the predicted typhoons. Here, we define the missed cases as those in which the centre errors of FT48 and FT120 were larger than 5 and 10 degrees in longitude or latitude, respectively. The number of the missed cases at FT48 was 6 and the number at FT120 was 6. The number of the cases missed both at FT48 and FT120 was 3, implying that the error of the typhoon centre in ALEPS2 does not always grow during the early stage of forecast (before FT48). In addition, we found from Table 1 some characteristics of the error cases in the physical properties of typhoons:

- weak central pressure,
- long time spent in relatively low latitude, or
- eastward recurvature before FT120.

Table 1 Errors of the centres at FT48 and FT120 from the best tracks for selected typhoons in 2013. Bold letters highlight the position errors more than 5° for FT48 and 15° for FT120, respectively.

Typhoon cases	Error of the centre	
	FT48	FT120
1311 (Utor)	(**+5.73**, –0.27)	(**–17.2**, +8.2)
1312 (Trami)	(+1.20, +1.53)	(–11.6, +6.1)
1313 (Pewa)	(–0.64, **–6.85**)	(**–33.9**, **–22.3**)
1318 (Man-yi)	(–0.80, –3.30)	(**–28.9**, **–30.2**)
1319 (Usagi)	(–0.74, +0.23)	(+3.6, –2.5)
1320 (Pabuk)	(–0.80, –0.67)	(–2.2, –2.7)
1323 (Fitow)	(+3.47, –0.93)	(+2.6, –3.5)
1325 (Nari)	(+3.12, +0.16)	(**+26.0**, +3.3)
1326 (Wipha)	(+1.82, –0.51)	(–3.7, –7.9)
1327 (Francisco)	(+2.10, –2.73)	(+1.4, –1.6)
1328 (Lekima)	(+0.20, +0.05)	(–6.0, –4.6)
1329 (Krosa)	(–1.30, –3.94)	(+7.0, –14.3)
1330 (Haiyan)	(**+7.62**, +1.49)	(**+19.5**, –4.1)

Table 2 As in Table 1 but for selected typhoons in 2014.

Typhoon cases	Error of the centre	
	FT48	FT120
1408 (Neoguri)	(+4.70, +0.55)	(+3.6, +2.7)
1409 (Rammasun)	(+2.60, +1.06)	(+6.8, –0.9)
1410 (Matmo)	(+3.80, +4.81)	(+5.0, –1.0)
1411 (Halong)	(+1.75, +2.66)	(+6.7, +5.7)
1412 (Nakri)	(+0.07, +1.39)	(+0.4, –6.1)
1415 (Kalmaegi)	(**+5.57**, –2.70)	(+9.11, –4.35)
1416 (Fung-wong)	(**+6.40**, +1.24)	(+14.2, +2.4)
1417 (Kammuri)	(–2.20, –1.86)	(**-15.9**, –10.0)
1418 (Phanfone)	(**+5.66**, +0.39)	(+7.2, –2.0)

We are planning further investigation to understand why the systematic errors occurred in ALEPS2 by exchanging the forecast models and/or initial (re)analysis fields.

4. Concluding remarks

In this report we showed the day-to-day variations of the error in the four-seasons experiments from ALERA2. Errors exhibit distinct seasonal variations as well as day-to-day fluctuations. Forecast experiments were conducted from multiple analyses in order to investigate the spread of the track of Typhoon Yagi 2013 in the operational forecast. The track but intensity of Yagi is found to be sensitive to the initial conditions. The experiments with modified initial conditions indicate that the representation of the field near the centre of the typhoon is of primary importance. Ensemble forecast experiments imply that the track error tend to be large with weak storms in a weak flow.

Our results imply the importance of the representations of the vortical structure. Because the diabatic processes are important to the tropical cyclones, the representation of convections would affect the tracks although the results using AFES and NICAM are consistent. It is of great interest to run models at higher resolution, permitting convections. We plan to run NICAM with the 14-km resolution and CReSS nested in AFES to address this question.

List of Acronyms

AFES
AGCM for the Earth Simulator
AGCM
Atmospheric General Circulation Model
ALEPS2
AFES–LETKF ensemble prediction system version 2
ALERA2
AFES–LETKF experimental ensemble reanalysis version 2
CReSS
Cloud Resolving Storm Simulator
ECMWF
European Centre for Medium-range Weather Forecasts
GrADS
Grid Analysis and Display System
GSM
Global Spectral Model
JMA
The Japan Meteorological Agency
JRA-55
The Japanese 55-year Reanalysis
LETKF
Local Ensemble Transform Kalman Filter
NCAR
National Center for Atmospheric Research
NCEP
National Centers for Environmental Prediction
NCL
NCAR Command Language
NICAM
Nonhydrostatic ICosahedral Atmospheric Model
RMSE
Root-mean square error
RSMC
The Regional Specialized Meteorological Center Tokyo

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2013 年台風第 3 号 Yagi の予測可能性

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顕著な気象の予測可能性変動のメカニズムを明らかにするため、複数の解析値やアンサンブル解析値から予報実験を行った。2013 年台風第 3 号（Yagi）の事例では、初期値依存性は、予報された経路に見られたが、強度には見られなかった。渦と環境風の相対的な重要性を明らかにするため、初期値に変更を加えた実験を追加して行った。その結果、台風中心付近の再現性が台風経路の予測には重要であることが明らかになった。この事例のほかに、アンサンブル予報実験を 2013 年と 2014 年に観測された 22 個の台風に対して行った。経路の誤差は、弱い環境風中の弱い台風の場合に大きくなる傾向が認められた。

キーワード : 熱帯低気圧 , 台風 , 大気大循環モデル , データ同化 , アンサンブル予報