A statistical evaluation of typhoon structures simulated by JMA nonhydrostatic model

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1. Introduction

Significant progress has been made in track forecast of tropical cyclone (TC) mainly through the global numerical systems. However, intensity forecasting is still severely limited and one of the most challenging problems in TC forecast because inner-core processes of a few or tens of km horizontal dimension are essential for intensity change. To tackle this issue, a statistical evaluation of simulated typhoon structures, especially inner-core structures, was conducted using the regional nonhydrostatic model with high resolution.

2. Model description

The numerical model used in this study is the Japan Meteorological Agency Nonhydrostatic Model (JMA-NHM; Saito et al. 2006), which is operationally used in JMA. It is based on fully compressible equations with a map factor. While the physical parameterizations for precipitation, turbulence, microphysics, and radiation were unchanged from the JMA's operational run, the numerical diffusion and targeted moisture diffusion were slightly altered to reduce artificial mixing.

The model contains 955 x 757 grid points horizontally with grid spacing of 5 km, which covers a domain of 4770 x 3780 km. The model contains 58 levels with variable grid intervals from 40 m near the surface to 1048 m at the top. The initial and boundary conditions are provided from an operational global analysis of JMA that adopted a four-dimensional variational data assimilation system.

3. Experimental design

The experiments cover 13 significant typhoons which had less than 950 hPa of minimum sea-level pressure (MSLP) since 2008: 3 from the 2008 season, 8 from 2009, and 2 from 2010. The initial time is 12 UTC during the period from the genesis to mature stage, which contains 73 cases in total. The integration time is 120 hours. The model domain is optimally located using JMA best track data for each case.

4. Results

a. Track and intensity

At first, standard measures of the accuracy of the TC simulation, such as track and MSLP are described. While the model shows a good performance for typhoon track (Fig. 1a), large positive bias of MSLP exists especially at initial time (Fig. 1b). This is due to the initial condition provided by coarse-resolution global analysis. Large value of MSLP root mean square (~ 20 hPa) is found throughout the 120 h integration in spite of decreasing bias value. Figure 2a shows the comparison of MSLP between the simulation and the best track. The model cannot reproduce the MSLP of less than 920 hPa and tends to underpredict TC intensity. Rapid intensification such as less than – 1.75 hPa/hour of the MSLP tendency cannot also be reproduced.

b. Structures

The simulated MSLP against radius of maximum wind (RMW) is shown in Fig. 3a. The RMW of significant TCs with less than 940 hPa MSLP, which has generally axisymmetric inner-core structure, ranges from 40 to 80 km. It is quite large compared to the estimation from satellite microwave imagery. Figure 3b illustrates the secondary circulation of major Typhoon LUPIT (2009) with MSLP of 930 hPa. Radial inflow layer is about 1.8 km depth peaking near the surface, and outflow is significant around at a height of 16 km. They are higher than the general structure of TCs. Further investigations as to resolution dependence and physical parameterizations will be needed to evaluate the performance of JMANHM and improve the TC intensity forecast.

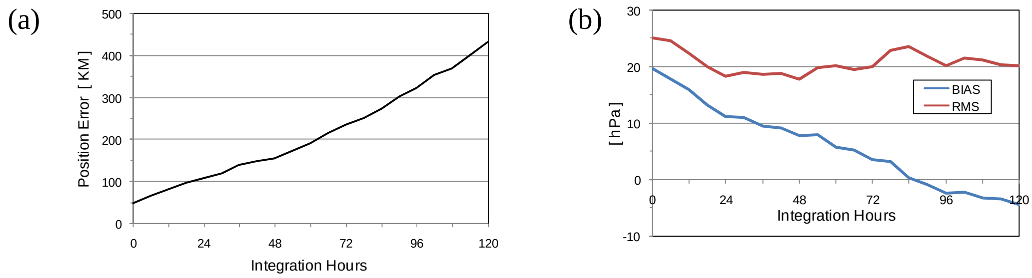

Fig. 1. (a) Average position error and (b) intensity error of bias (blue line) and root mean square (red line) for JAMNHM.

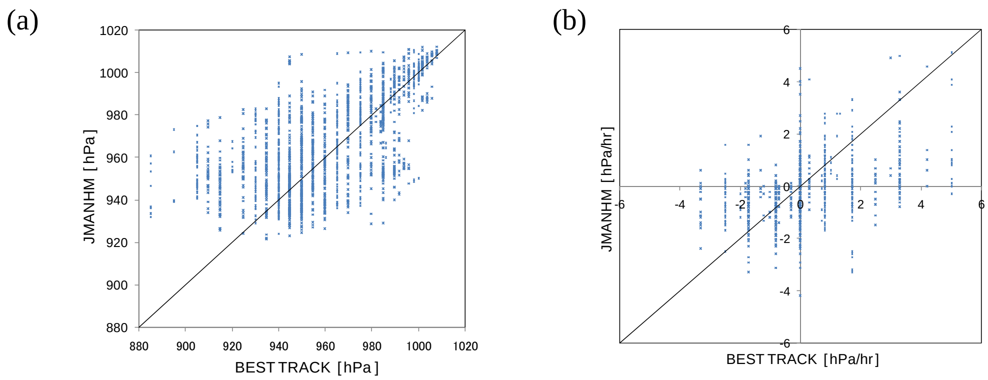

Fig. 2. Comparison of (a) minimum sea-level pressure (MSLP) and (b) its tendency between JMANHM and best track data.

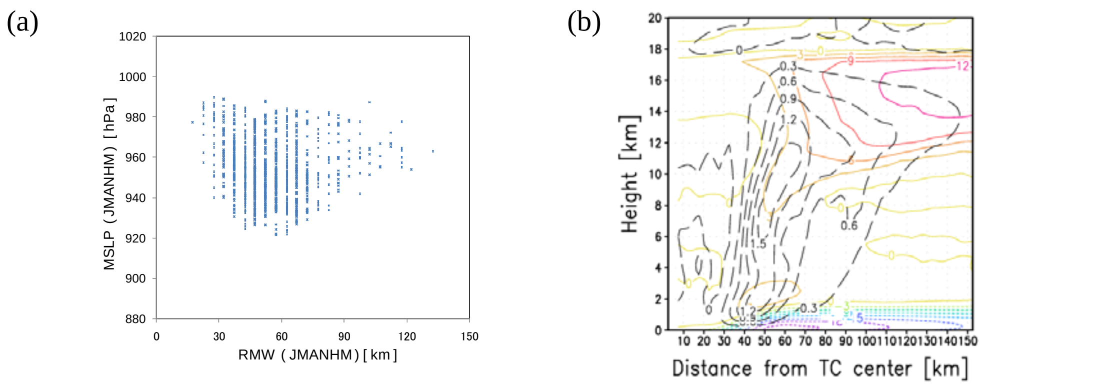

Fig. 3. (a) Minimum sea-level pressure (MSLP) against radius of maximum wind (RMW) simulated by JMANHM. (b) Radius-height plot of azimuthally averaged vertical motion (black broken lines) and radial wind (color contours) for Typhoon LUPIT (2009).

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