Characteristics of Storm Tracks in JMA's Seasonal Forecast Model

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INTRODUCTION

Mid-latitude baroclinic eddies along storm tracks play an important role in the climate system by transporting heat, moisture and angular momentum. Seasonal changes of storm track activities and relation to the mean fields have been argued for the Northern Hemisphere (NH; e.g. Blackmon et al. 1977; Wallace et al. 1988; Nakamura 1992, hereafter N92; Nakamura et al. 2004). Over Pacific, the storm track activity has its peak of strength in late fall and early spring and a relative minimum in midwinter. This phenomenon is called "midwinter suppression" and argued in many previous studies (e.g. N92). In this study, characteristics of storm tracks are examined using Japanese 25-year Reanalysis (JRA-25; Onogi et al. 2007), and the performance of the Japan Meteorological Agency (JMA) seasonal forecast model are examined in the view of representation of seasonal change of storm tracks and its relation to the mean westerly wind fields.

DATASET AND ANALYSIS METHOD

JRA-25 and its real-time analysis JCDAS are used as an analysis data set with 6-hourly, 2.5 × 2.5 horizontal grids. JMA seasonal forecast model (hereafter, JMA-SFM) has TL95 as the horizontal resolution and 40 layers up to 0.4 hPa in the vertical. Retrospective ensemble experiments with 11 members have been performed for 210 days from 10th of every month from 1984 through 2005 (22 years). In this study, only results from the experiments of 10th of November of the initial dates. Initial conditions were from JRA-25 and JCDAS. JMA-SFM adopts a two-tier method. Prescribed sea surface temperatures (SSTs) are given to the model, which are calculated using a combination of persisted anomalies, climatology and prediction with the JMA El Niño prediction model (atmosphere-ocean coupled model). Centenial in-situ Observation Based Estimates of variability of SST and marine meteorological variables (COBE; Ishii et al. 2005) daily data are used to calculate SSTs given to the model. Model outputs are interpolated to the 2.5 × 2.5 horizontal grids for verification. In this study, 22 winters from 1984/1985 to 2005/2006 are mainly argued.

To extract the component associated with synoptic-scale baroclinic eddies, a digital filter with the half-power cut off period 8 days was used (highpass filter). Mean fields were evaluated with 8-day lowpass filtered fields. And to estimate the local, instantaneous amplitudes of eddies, an envelope function of geopotential height (*Ze*) is calculated as the square root of the squared time series of the 8-day highpass-filtered geopotential height smoothed using a low-pass filter, after multiplied by a factor of 2 (see Nakamura and Wallace (1990) for more detail). To verify the amplitudes of eddies like stream function, envelope functions are multiplied by the factor of [sin45˚/sin(lat)]. To all variables including envelope function, 31-day running mean is applied and climatological mean of each variable is defined as the 22-year mean of the 31-day running mean value for each calendar day. After 31-day running mean, only the data at 12Z are used for verification.

In this study, a storm track is defined daily at each meridian in the 31-day running mean field of 300-hPa *Ze* between 15˚N and 75 ˚N. The quantities of variables along with the axis are defined as 10 degree latitudinal band averages. Mean westerly wind speed (*U*) is calculated with the 8-day lowpass filter.

RESULTS

Figure 1(a) shows the climatological January distributions for the 300-hPa *Ze* and 300-hPa *U* for JRA-25.

Major storm tracks are seen over both the north Pacific and the north Atlantic, and they are located downstream and north of the two jet streams. These features are in agreement with previous studies using other analysis or observations (e.g. Blackmon et al. 1977). In JMA-SFM, roughly estimated, it can be seen that distributions of storm tracks and mean westerly wind fields at the upper troposphere are represented well (Figure 1b). However, there are some differences of storm tracks and mean westerly wind fields between analysis (JRA-25) and JMA-SFM. Mean westerly wind speed is larger in JMA-SFM than analysis over both the Pacific and the Atlantic. On the other hand, the amplitudes of storm tracks are smaller in JMA-SFM. And, both storm tracks and westerly wind fields in JMA-SFM look more sharply in meridian than analysis. In addition, at the entrance of Eurasia continent, though *Ze* is smaller than that over the Pacific and the Atlantic, a storm track branches out in analysis, however, it does not in JMA-SFM. Based on the evaluation of eddy propagation using horizontal components of extended Eliassen-Palm flux (Trenberth 1986), over Eurasia, the eddy propagation is mainly observed in high latitude in analysis, while it is in low latitude in JMA-SFM (not shown).

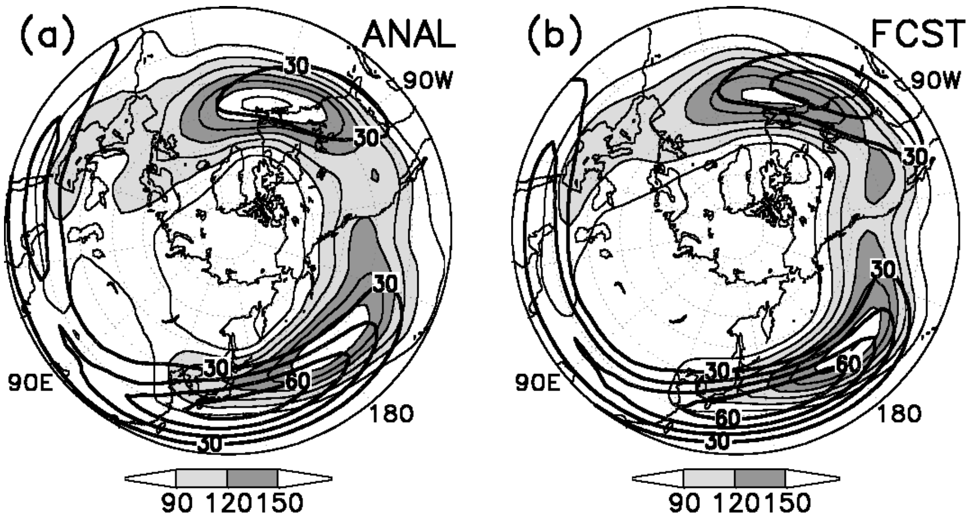

Figure 1 Climatological January distributions for the 300-hPa envelope function of geopotential height (Ze; unit: m every 15; light and heavy stippling for 90~120 and 120~150, respectively) and 300-hPa mean westerly wind speed (U; unit: m s-1; contoured for 30, 40, 50, and 60) over the Northern Hemisphere (20°N-90°N). (a) JRA-25 and (b) JMA seasonal forecast model (JMA-SFM).

Figure 2 shows seasonal changes of 300-hPa *Ze* and *U* at the storm track, and its position over the western Pacific (W-PAC; 120˚E-160˚E) and the Atlantic (ATL; 80˚W-40˚W). In W-PAC, the maximum of the 300-hPa *U* is seen in midwinter. On the other hand, the maxima of 300-hPa *Ze* are seen in both late fall (around November) and early spring (March to April), while relative minimum is seen in midwinter, called “midwinter suppression” of the storm track over the Pacific. Over ATL, the seasonal change of the 300-hPa *Ze* is similar to that of 300-hPa *U* at the storm track, which has a maximum in midwinter. The axes of storm tracks move southward during fall and the storm tracks stay southernmost in midwinter over W-PAC and late winter over ATL. The axis over W-PAC is located lower latitude than that over ATL during winter season in NH. Features of the seasonal change of storm tracks and mean westerly wind speed over the central Pacific are similar to those seen over W-PAC (not shown). These characteristics look similar to those examined in previous studies (e.g. N92)

Seasonal changes of 300-hPa *Ze* and U at the storm track and its position for JMA-SFM are also shown in Figure 2. Over W-PAC, *Ze* is smaller than analysis and its difference of climatological mean is about 20 m. Mean westerly wind speed at the storm track is a little bit larger in JMA-SFM than in analysis and the difference is largest in January. Axis of storm track in JMA-SFM shifts southward about 2 degrees from that in analysis. Similar tendencies are seen over ATL, but by the decrease of the 300-hPa *Ze* in JMA-SFM, seasonal change of 300-hPa *Ze* bocomes smaller than analysis. It is interesting that 300-hPa *U* at the storm track has almost same strength as analysis. Axis of storm track shifts southward compared to analysis like W-PAC, however, it shifts more over ATL than over W-PAC.

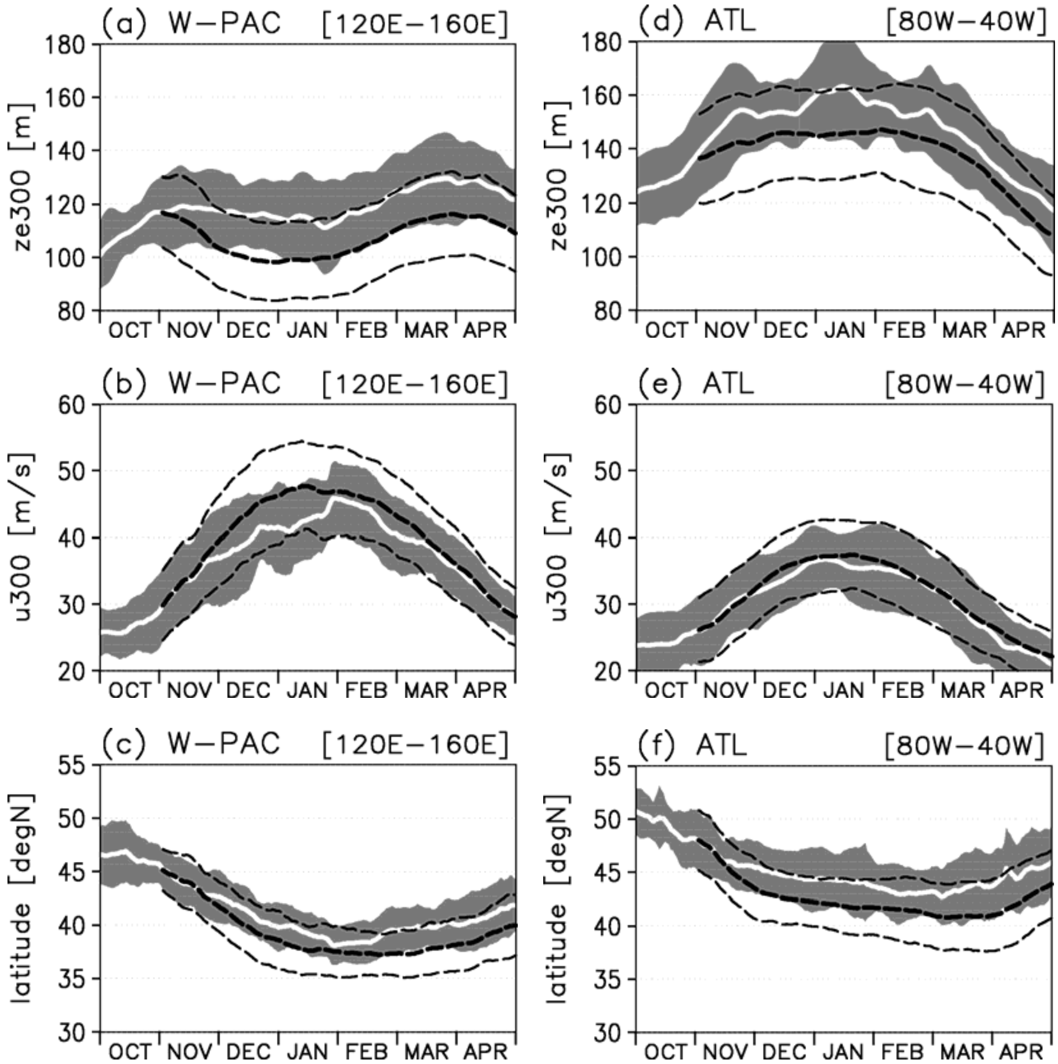

Figure 2 Seasonal change of (a) 300-hPa envelope function of geopotential height (*Ze*; unit: m), (b) 300-hPa westerly wind speed at the storm track (*U* ; unit: m s^{-1}), and (c) position of axis of the storm track (unit: degree N) averaged over the western Pacific (120°E-160°E) between October and April. (d)-(f) same as (a)-(c) but for the Atlantic (80°W-40°W). Thick white line shows the climatological mean for JRA-25 and stippling shows the range of interannual variability at each calendar day. Thick dashed line shows the climatological mean for JMA seasonal forecast model and thin dashed lines show the range of interannual variability.

Scatter diagrams between 300-hPa *Ze* and *U* over W-PAC and ATL for analysis and JMA-SFM are shown in Figure 3. From analysis, over W-PAC (Figure 3a), positive correlations are seen between 300-hPa *Ze* and *U* for $U < 35$ m s^{-1}, while negative for $U > 35$ m s^{-1}. This relationship between the amplitude of storm track and mean westerly wind speed is similar to that shown in N92, though the critical strength of mean westerly wind speed is 45 m s^{-1} at 250-hPa in N92. 300-hPa *Ze* is positively correlated with 300-hPa *U* over ATL for all range of

300-hPa *U* (Figure 3c). In JMA-SFM, it can be seen that the distributions of scatters shift lower value of 300-hPa *Ze* at each 300-hPa *U* over W-PAC (Figure 3b) with similar critical strength of mean westerly wind speed for midwinter suppression of 300-hPa *Ze* as analysis. Similar tendency is also seen for ATL (Figure 3d). It suggests that synoptic-scale baroclinic eddies might be difficult to grow in JMA-SFM.

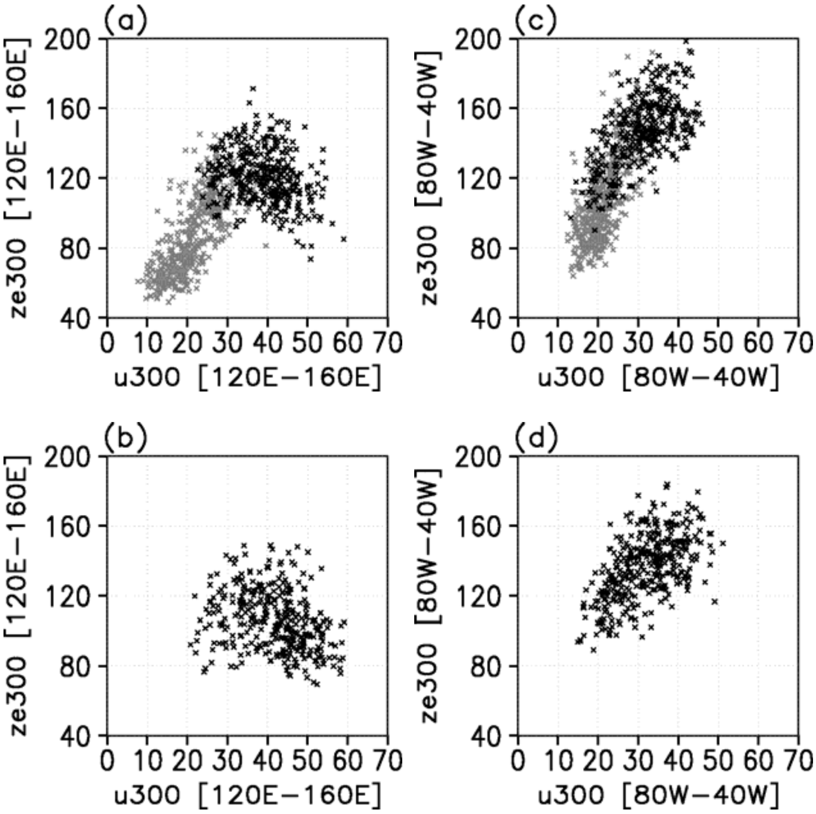

Figure 3 (a) Scatter diagram showing the relationship between the 300-hPa mean westerly wind speed (U; unit: m s^{-1}) and 300-hPa envelope function of geopotential height (*Ze*; unit: m) averaged over the western Pacific (120°E-160°E) for JRA-25. Based on sampling every 10 days. Black crosses are sampled from December through April and gray crosses are from May through November for 22 years (1984/1985 – 2005/2006). (b) same as (a) but for JMA-SFM. Only black crosses are shown because of its integration term. Only data of the control member are plotted. (c)(d) same as (a)(b) but for the Atlantic (80°W-40°W).

CONCLUDING REMARKS

Seasonal changes of storm tracks and relationship to mean westerly wind fields are investigated using JRA-25 analysis and forecasts by JMA-SFM. The characteristics of the seasonal change of storm tracks in JRA-25 are similar to previous studies using other analysis data sets. The midwinter suppression of storm tracks and its relation to the mean westerly wind speed over Pacific are seen in both time sequences of climatological means of 300-hPa *Ze* and scatter diagrams between 300-hPa *Ze* and *U*. For JMA-SFM, roughly estimated, seasonal change of storm tracks is in agreement with that in JRA-25. However, some differences are seen. Storm track amplitudes in JMA-SFM is smaller than those in JRA-25, and its axes shift southward. Nakamura et al. (2004) discussed relationships between storm tracks, jet streams and oceanic fronts. They suggested that a strong subtropical jet traps synoptic-scale eddies at upper troposphere and interaction between upper and lower eddies becomes weak. That is why the activity of eddies along storm tracks becomes weak. This might be an interpretation of the reason of smaller amplitudes of storm tracks.

However, more examinations are needed. In addition, predictability of storm track activity should be investigated, which could be helpful to examine the predictability of an individual cyclone activity.

Finally, it should be noted that JRA-25 and JCDAS, the real-time operational analysis using the same assimilation system as JRA-25, are used as a basis for validation of the JMA-SFM. JRA-25 should contribute to not only an improvement of JMA-SFM but also an understanding of the phenomena seen in real.

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