A Study of Quasi-millennial Extratropical Cyclone Activity Using Tracking and Clustering Methods

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1. Overview

Northern Hemispheric extratropical storm tracks are determined in mean sea level pressure fields (MSLP) of a quasi-millennial (1001-1990) global climate simulation by ECHO_G using a previously developed tracking algorithm (Hodges 1999). The ECHO-G simulation was shown skillful in simulating the seasonal mean climatology and inter-annual variability of MSLP (Gouirand et al. 2007). The numbers of tracks from the ECHO-G simulation data are on a similar level as those derived from the NCEP/NCAR reanalysis data. Winter storm tracks of the northern hemisphere (NH) are clustered in ten groups using the k-means clustering method. Climatological changes of extratropical cyclones in winter including frequency, density and lifespan are analyzed for each group.

2. Results

The cyclones are detected and tracked by the tracking algorithm of Hodges (1999). It detects the minima on the MSLP fields and connects the minima to form tracks. Minimum lifetimes of tracks are set to 2 days. Fig.1 shows the cyclone numbers for each winter season (DJF) from 1001 to 1990. Average cyclone numbers in each century are shown in Fig. 2. The fewest average cyclone number (201 counts) is in the twentieth century (1900-1990). The next minima of average cyclone numbers (202 counts) are in the thirteenth (1201-1300) and fourteenth (1301-1400) century. Afterward cyclone numbers increase slowly and reach the highest values (206 counts) in the sixteenth (1501-1600) century.

Cyclone tracks are clustered into ten groups by the k-means method. Before clustering, each track path is fitted as a second-order polynomial function of the lifetime of this storm (Chu et al. 2010). Fig. 3 shows the ten track groups. Red tracks denote the centroid track for each group. Histograms for different clusters show that more than 60% of cyclones in the Atlantic and Pacific last 2 to 6 days (Fig. 4a, c). Note that most long-lived (more than 10 days) cyclones are primarily over the western Atlantic (see cluster 9) with over 8% of all cyclones (Fig. 4 a). The climatological histogram of cyclone maximum deepening rates is shown in Fig. 4 b and d. Oceanic cyclones deepen rapidly compared to other cyclones. Cyclones over the Pacific are characterized by greater maximum deepening than in the Atlantic (Fig. 4 b and d). Cyclones of cluster 6 present the highest percentage (34%) on rapid deepening (larger than 10 hPa per 12 h) (Fig. 4 d).

3. Conclusion

The numbers of extratropical storms in winter have strong year to year variations but an obvious trend is not present during the quasi-millennial period (1001-1990). The minimum of average cyclone numbers is in the twentieth century (1901-1990). Cyclones are also less in the thirteenth (1201-1300) and fourteenth (1301-1400) century. Cyclone tracks are clustered into ten groups by the k-means method. Oceanic cyclones characterize the feature of rapid deepening and long lifetime. That also indicates the objective clustering method separates cyclone tracks into groups in a reasonable way.

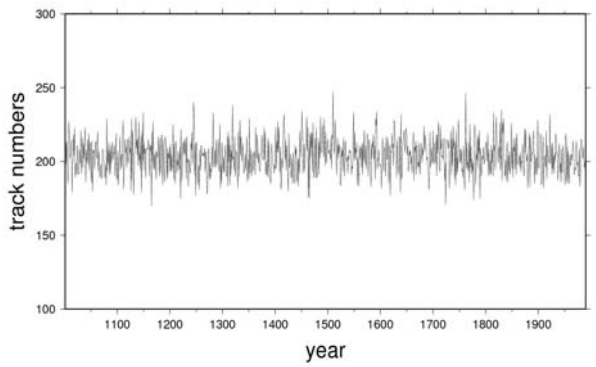

Fig. 1 time series (1001-1990) of annual winter cyclone counts

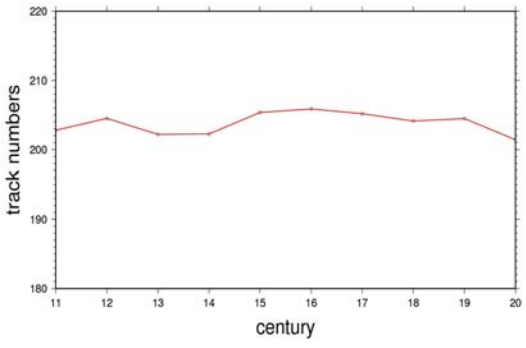

Fig. 2 average cyclone counts in each century

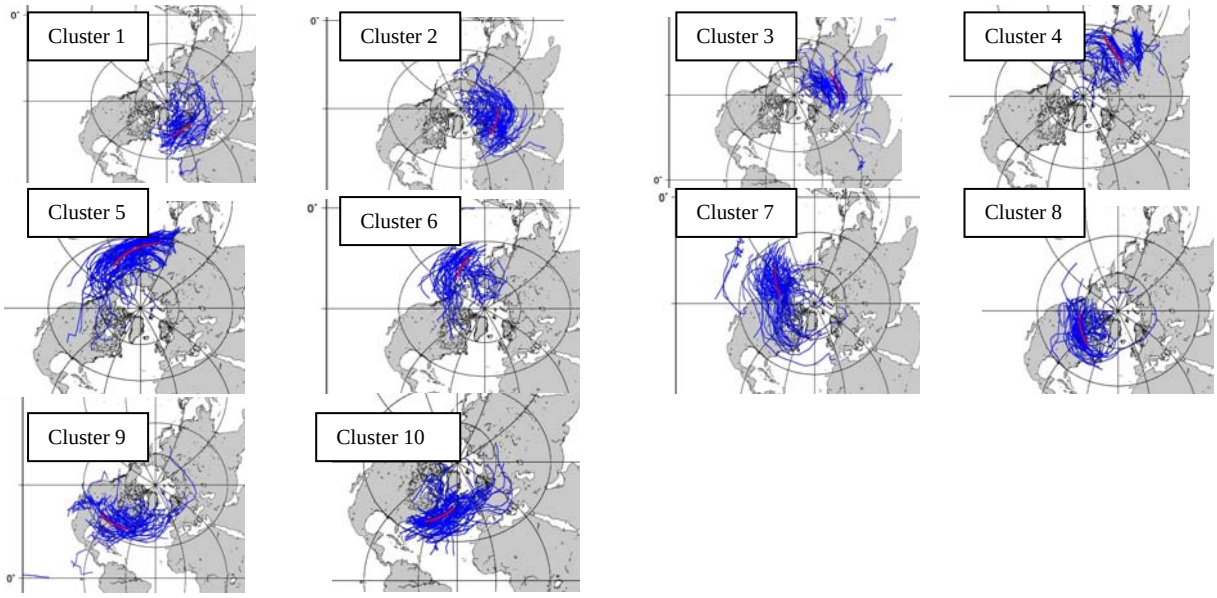

Fig. 3 Northern Hemispherical cyclone tracks clustered by K-mean: members (blue) and centroid (red) of ten clusters

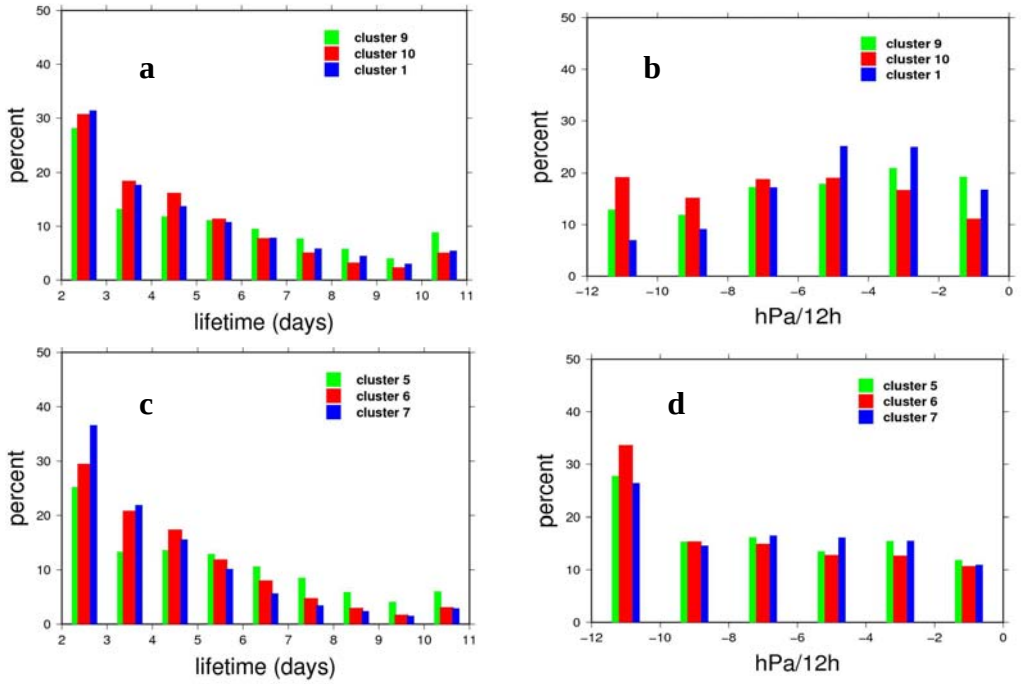

Fig. 4 winter histograms of cyclone lifetime (a and c), and maximum deepening rates (b and d) for cyclones over the Atlantic (a and b) and the Pacific (c and d)

Reference

Chu P., X. Zhao and J. Kim, 2010: Regional typhoon activity as revealed by track patterns and climate change. Hurricanes and Climate Change, 2, 137-148.

Gouirand I., V. Moron and E. Zorita, 2007: Teleconnections between ENSO and North Atlantic in an ECHO-G simulation of the 1000-1990 period. Geophysical research letters, 34, L06705.

Hodges K. I., 1999: Adaptive constraints for feature tracking. Monthly Weather Review, 127, 1362-1373.