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Long-term Analysis of Extratropical Cyclone Activity by Tracking and Clustering Methods

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There is growing interest in knowing the impact of climate change on extratropical northern hemisphere cyclone activity. In a warming global climate, properties of extratropical storms such as intensity, frequency, and distribution of genesis regions are expected to differ from nowadays climate.

To analyze long-term change of these properties, mean sea level pressure fields (MSLP) of a quasi-millennial (1000-1990) global climate simulation are applied to track storm events using a previously developed tracking algorithm (Hodges 1996). In our study the global climate model ECHO-G was used, which has been found skillful in simulating the seasonal mean climatology and inter-annual variability of MSLP. For validation reasons tracks gained from ECHO-G simulations are compared to those from NCEP/NCAR reanalysis data. The numbers of tracks from the ECHO-G simulation data are on a similar level as those derived from the NCEP/NCAR reanalysis data.

Densities for genesis regions representing the origins of storm tracks are also compared. Both data deliver the known genesis maxima for Pacific storms located over Mongolia, Northeast of China, around southeast China, east of Japan and in the central Pacific. This result is consistent with the studies by Adachi and Kimura (2007) and Inatsu (2009). Genesis maxima of Atlantic storms are located over continental American in the lee of the northern Rockies, along the coast of the United States and around Iceland, in accordance to the study of Hoskins and Hodges (2002) based on vorticity data. However the genesis maxima in the lee of the northern Rockies are much stronger in the NCEP/NCAR reanalysis data than in the ECHO-G simulation data. Further genesis regions are found over the Norwegian Sea, over the western Mediterranean and over the Caspian Sea.

By using a clustering analysis that sorts the tracks into different categories, temporal changes in different regional storms activities are examined. Track types are identified and frequency, density, and lifespan of these types are individually studied for temporal changes from simulation year1000 to 1990. Before clustering, each track path is fitted as a second-order polynomial function of the lifetime of this storm. Storm tracks are clustered as several groups using the K_mean clustering method. For each group, the zero-order parameter provides the mean genesis location of this type; the first-order parameter describes the direction of this type; the second-order parameter determines the recursive shape of this type. Climatological changes of extratropical cyclones including frequency, density and lifespan are analyzed for each group.