A cyclone statistics for the Arctic based on European Centre re-analysis data

B. Brümmer, S. Thiemann, and A. Kirchgäßner

With 14 Figures

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Summary

Based on the six-hourly re-analysis sea-level pressure data of the European Centre for Medium-Range Weather Forecast (ECMWF) a cyclone statistics for the Arctic region north of 60° N is elaborated for the period 1 November 1986 to 31 October 1991. For each low pressure center on a weather map its location, central pressure and horizontal pressure gradients in E, W, N, and S direction are determined. Furthermore, cyclone centers are followed with time to calculate trajectories, pressure tendencies, and lifetimes.

A horizontal grid of 300 km × 300 km is used as unit area for the statistical computations. A unit area experiences about 20 cyclone passages per year (range 5–40). On the average, six cyclones occur simultaneously in the Arctic region. Lifetimes vary from 6 h to 15 days.

The annual cyclone activity over the 5-year period is nearly the same. Cyclones are more frequent in summer (about 94 per month) than in winter (77 per month). In general summer cyclones are weaker than winter cyclones. On the average, the minimum central pressure during the lifetime of a cyclone is about 1000 hPa (typical range 980–1020) in summer and about 988 hPa (typical range 940–1030) in winter.

In winter, a zone of high cyclone frequency extends from the region near Iceland over the Greenland Sea, Barents Sea, and Kara Sea to the Laptev Sea while the interior of the Arctic shows little cyclone frequency. In summer, the region near Iceland and the interior of the Arctic are separate centers of high cyclone frequency. Both in winter and summer very high cyclone frequencies are observed over the northern Baffin Bay. The regional distribution of mean central pressures and maximum pressure gradients roughly follows the distribution of cyclone frequencies except for the Baffin Bay cyclones which are generally weak. Cyclolysis dominates cyclogenesis over largest parts of the Arctic. Regions of high cyclone frequency are also regions of frequent cyclogenesis and frequent cyclolysis. One third of all cyclones is generated in a region with an already existing cyclonic circulation.

Cyclones in the Fram Strait are studied in more detail because of their special impact on the ice export from the Arctic Ocean to the Atlantic Ocean. On the average, there are 5 cyclones per month. The cyclone frequency in the Fram Strait is higher during the winter period than during the summer period. This is in contrast to the overall Arctic frequency which is higher in summer than in winter. Cyclogenesis predominates in winter and cyclolysis in summer in the Fram Strait. The most frequent direction of motion is from SW to NE.

1. Introduction

Cyclones in the Arctic are of particular interest primarily because of their influence on the sea ice, on the sea-air and ice-air turbulent heat fluxes and radiation fluxes, and on the atmospheric heat budget. Cyclones are the strongest synoptic-scale weather events in the Arctic region. If cyclones approach from the Atlantic sector, the Greenland Sea or Barents Sea, they transport warm and moist air from the open water to the Arctic ice shield. Cyclones are connected with a high degree of
cloudiness and thus they influence the radiation and energy budget of the Arctic (e.g., Curry et al., 1996).

In addition cyclones affect the sea ice cover. The inhomogeneous, transient wind stress causes deformation, divergence and rotation of the ice field and openings in the ice deck. With increasing cyclone frequency the sea ice cover decreases (Maslanik et al., 1996) because they break off the ice.

Statistics of cyclone activity in the Arctic have been elaborated since the middle of the 20th century and have been based on different data bases. Petterssen (1950), Keegan (1958), and Read and Kunkel (1960) use daily routinely hand-analyzed weather maps. Serreze and Barry (1988), and Serreze et al. (1993) use daily sea-level pressure (SLP) data prepared by the US National Meteorological Centre (NMC) on an octagonal grid with a mesh size of 300 to 400 km in the Arctic region north of 60° N. In recent papers by Serreze (1995), and Serreze et al. (1997) twice-daily sea-level pressure data are used again from the NMC and on the same grid. In all these studies cyclones are specified by position and central pressure and are identified manually or automatically on subsequent weather maps in order to calculate cyclone trajectories, propagation velocities, or pressure tendencies. In the paper by Serreze et al. (1997) in addition the local Laplacian, \( \nabla^2 p \), which is proportional to the geostrophic relative vorticity, is calculated as a measure of cyclone intensity.

In this paper, we use for the first time the six-hourly re-analysis data of the European Center for Medium-Range Weather Forecast (ECMWF) with a horizontal grid resolution of 1.125° in a latitude–longitude grid. Analyses are available six-hourly at 00, 06, 12 and 18 UTC.


2. Data

As mentioned above the data source for this study are the SLP data for the ECMWF re-analysis project. ECMWF has reanalyzed 15 years (1978–1994) of data using the same version of the operational data assimilation system and the same model version during the whole period, in order to minimize errors and inhomogeneties in the data due to model changes.

The re-analysis data include the full model resolution (spectral resolution T106) with a horizontal grid resolution of about 1° in a latitude–longitude grid. Analyses are available six-hourly at 00, 06, 12 and 18 UTC.

The study presented here covers a period of 60 months with 7304 individual analyses from 1 November 1986 to 31 October 1991. The investigation is limited to the Arctic region north of 60° N (Fig. 1). The number of grid points in the investigation area is 8320 (26 in latitudinal direction and 320 in longitudinal direction). Thus the horizontal grid resolution is different; it is everywhere 125 km in north-south direction, but due to the meridional convergence the resolution is increasing in east-west direction from 55.5 km at 60° N to 2.2 km at 88.875° N. The regular grid of squares with 300 km side length in Fig. 1 is