Dynamics and Statistics of Cyclones over the Arctic Ocean Compared with Extra-tropical Cyclones

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1 INTRODUCTION

The Arctic has undergone drastic warming in recent years. During 2007, the summer minimum ice extent, observed in September, reached to 4.3 million km^2. This marked a new record minimum, with a dramatic reduction in the area of coverage relative to the previous record of 5.6 million km^2; marked just 2 years ago in 2005. At the end of the 2007 melt season, the sea ice coverage was 23% smaller than the area was in 2005 and 39% below the long-term average from 1979-2000. In 2007, the ocean surface circulation regime in the Beaufort Sea was strongly anticyclonic in winter and summer. In the summer, sea ice from the Canada Basin was transported out quickly by strong winds.

One of the key factors contributing to the drastic loss of sea ice is the unusually persistent high-surface pressure over the Beaufort Sea from June through to August, which is coupled with a persistent cyclone over the Barents Sea.

The loss of sea ice on the Pacific side of the Arctic in 2007 resulted from an unusually persistent high-surface-pressure/southerly wind pattern from June through to August that transported heat and altered the cloud distribution. The southerly winds also advected sea ice across the central Arctic towards the Atlantic sector (Gascard et al., 2008).

Shimada et al. (2006) referred to the impacts on sea ice circulation, in which sea ice concentration near the coast decreased; causing an enhancement of sea ice velocity and changing oceanic heat transport. This increased the fluidity of the Arctic Ocean, preventing the creation of sea ice.

The open-water areas reduced both the regional albedo and fostered the enhancement of heat fluxes to the atmosphere in autumn. A strongly developed cyclone pattern also spread the existing ice over a larger area, contributing to the high variability in Arctic ice extent, supporting the overall downward trend (Ogi and Wallace, 2007).

Serreze and Barrett (2008) indicated that cyclones made by baroclinity concentrate in the central Arctic Ocean, residing in the same region for a long time period. Due to the pressure field created by the cyclones, the sea ice is stirred around the central Arctic Ocean, gradually decreasing its composition.

In this study, the dynamics and statistical analysis of the cyclones over the Arctic Ocean are examined using the JRA-25/JCDAS reanalysis data. We investigate the frequency of the cyclone tracks, the vertical structure of the vortex tube and the characteristic features of the life cycle of the cyclones in comparison with the extra-tropical cyclones excited by baroclinic instability.

2 DATA AND METHOD

In this study, the Sea Level Pressure (SLP) and vorticity data of the JRA-25 reanalysis data/JCDAS was used for latitudes above 50°N during the summer period (JJA) from 2007-2008.

Firstly, the position of the cyclones and anticyclones were detected by lower level pressure field maps (Pressure Reduced to Mean Sea Level, PRMSL) and the polar vortex was detected by upper level pressure field maps (500hPa height) . Next, vorticity distribution for each elevated height; Sea Level Pressure (SLP), 850, 500 and 200 hPa height were examined. Here, vorticity ζ is represented by.

$$\zeta = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}. \quad (1)$$

The vorticity data used in the analysis had originally been included in the JRA-25/JCDAS dataset. For eliminating the influence of atmospheric density ρ the below equation was used.

$$\zeta_{dc} = \frac{\zeta}{\sqrt{\rho}} \times 10^5 = \zeta \times \sqrt{\frac{p_s}{p}} \times 10^5. \quad (2)$$

Vorticity (with density correction applied) is represented by ζ_{dc}. Here, p represents pressure and p_s represents standard pressure (1000 hPa). The reason which equation (2) is multiplied by 10^5 is because the value for vorticity is too small to utilize within the analysis. This study applies ζ_{dc} as vorticity. Monthly SLP data was applied in order to perform the cyclone tracking. The study's algorithm was applied to a 6-hourly SLP field on a 1.25° × 1.25°latitude/longitude version of the National Center for Geographic Information and Analysis (NCGIA) north polar Equal-Area Scalable Earth (EASE) grid. This algorithm detects cyclones with a diameter of over 500 km^2. A cyclone is defined when duple closed isobars are identified. Cyclone tracking employs a nearest-neighbour analysis approach, which compares the positions of the cyclones for a given 6-h chart with those of the next 6-h chart.

3 RESULTS

3.1 Cases of target cyclones

The summer period (JJA) of 2007-2008 was examined, analyzing the cases for each year. Case 1 shows the cyclogenesis in 2007; on 12Z on July 31st 2007 at 76.76°N / 129.75°E. The life time for this cyclone (from cyclogenesis to cyclolysis) lasted for 10.75-days. Case 2 represents the cyclogenesis in 2008; on 18Z June 22nd 2008 at 79.12°N / 141.38°E. The life time for this cyclone lasted for 17 days.

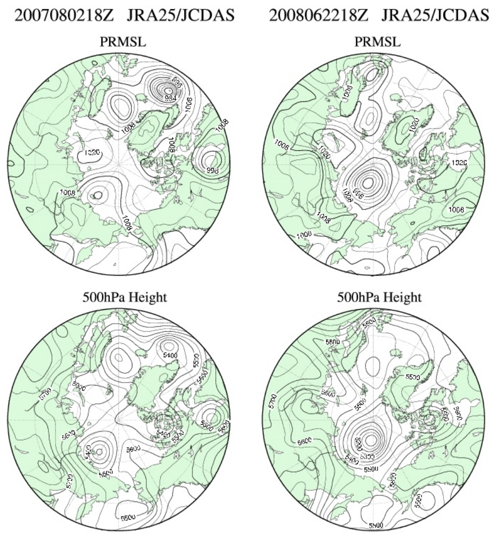

Figure 1: Pressure Fields for Case 1 and Case 2 of PRMSL (hPa, top row) and 500 hPa height (bottom row) for Case 1 (left hand column) and Case 2 (right hand column).

3.2 PRMSL and 500 hPa height

Figure 1 shows Case 1 and Case 2 of the Pressure Reduced to Mean Sea Level (PRMSL) and 500 hPa height field. The PRMSL field in Case 1 show the cyclones near the East Siberian Sea. The 500 hPa height field for Case 1 shows the polar vortex in the same position. In Case 1, there were some polar vortices and cyclone in same position.

In Case 1 (2007), several polar vortices were observed at the 500 hpa height field in the regions surrounding the East Siberian Sea. Simultaneously, cyclones were observed directly below the polar vortices at the 500 hPa height field.

Case 2 concurrently showed a well-developed cyclone near the East Siberian Sea. The pressure field at the PRMSL for Case 2 also showed an underlying cyclone beneath the polar vortices at the 500 hPa height field.

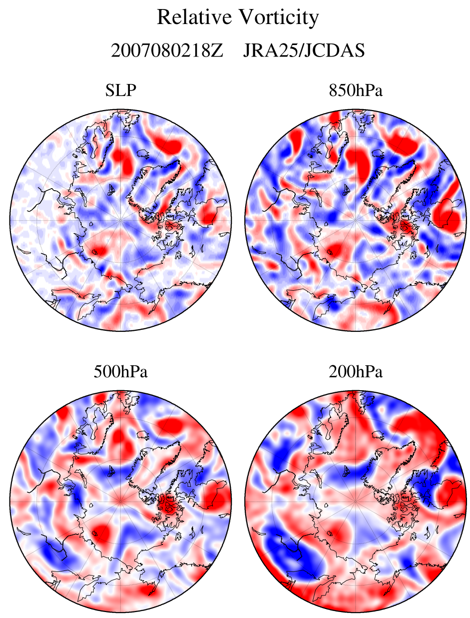

Figure 2: Relative vorticity for Case 1 of SLP (top left diagram) and 850 hPa height (top right diagram) and 500 hPa height (bottom left diagram) and 200 hPa height (bottom right diagram). The red color shows positive vorticity or cyclonic circulation. The blue color shows negative vorticity or anticyclonic circulation.

3.3 Relative vorticity for each level

Figure 2 shows the relative vorticity for each level (sea level pressure, 850 hPa height, 500 hPa height, 200 hPa height) for Case 1. Positive vorticity was observed at the positions that the cyclones were seen in the East Siberian Sea as shown in Fig. 1 for each level.

Figure 3 shows the same results (as Fig. 2) as for Case 2. Similar to Case 1, positive vorticity at each level was observed at the same position as the cyclone.

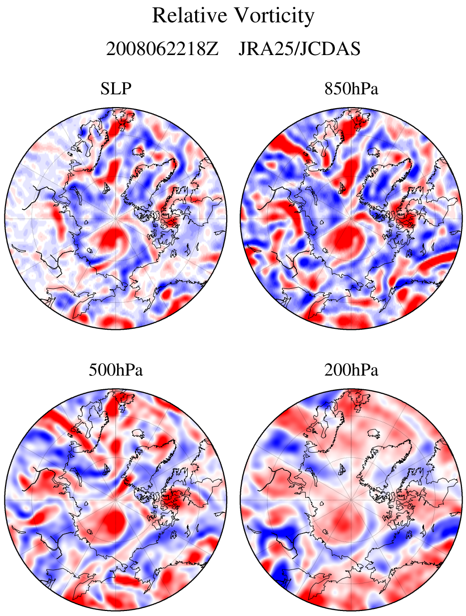

Figure 3: Same as Fig. 2, but for Case 2.

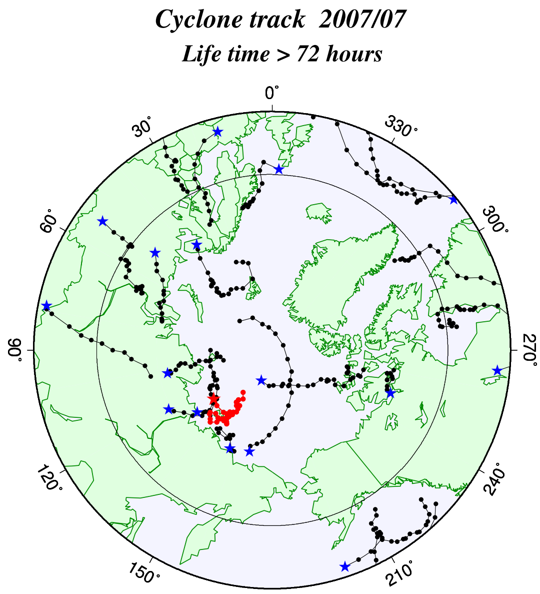

Figure 4: Cyclone track for Case 1 in July 2007. Only cyclones with a life time longer than 72-h were marked. The cyclones were observed every 6-h and the cyclogenesis points were marked with a star. The red line shows the cyclone track for Case 1.

3.4 Cyclone tracks

The majority of the cyclones moved eastward due to the influence of the polar jet. However, there were cases when the cyclones did not move eastward, residing above the Arctic Ocean.

Figure 4 shows the cyclone tracks for July 2007 (Case 1). The cyclone position was marked every 6-h. Each cyclogenesis is indicated with a star mark. The cyclone track for Case 1 is shown by a red line. As shown in the diagram, the cyclone track did not move to a far extent. Furthermore, the direction of movement of the cyclone was uncertain.

Figure 5 displays the same results as Fig. 4 but for the cyclone track in June 2008 (Case 2). The cyclone track for Case 2 is indicated by a red line. Similar to Case 1, the cyclone track for Case 2 displayed a very random direction of movement. However in this case, the extent of movement was much broader.

To summarize, the cyclone for Case 1 and 2 resided in the same region for a long time period. Moreover, the life time of these cyclones were relatively long; 10.75-d for Case 1 and 17.00-d for Case 2.

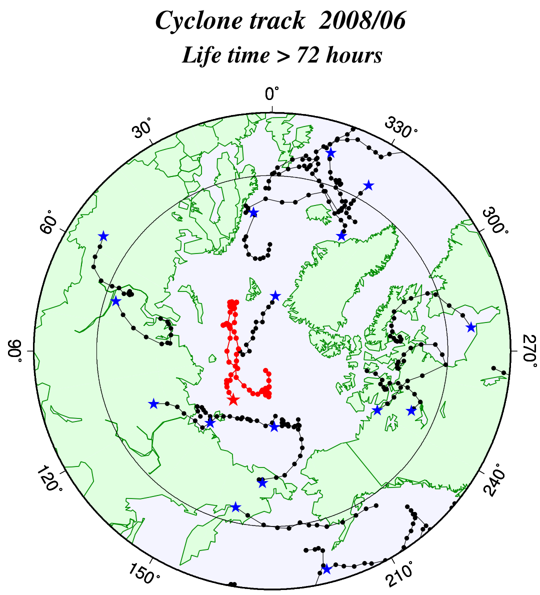

Figure 5: Same as Fig. 4, but the cyclone track for case 2 in July 2008. The red line shows the cyclone track for Case 2.

3.5 Vertical structure of the vortex tube

Figure 6 shows the vertical structure of the vortex tube for Case 1. The cyclone for Case 1 was located at 150°E. This showed that the cyclone for Case 1 had a barotropic structure. Another cyclone located at 270°E also had a barotropic structure. An anticyclone was observed at 210°E around the Beaufort Sea (The

Beaufort High). Figure 7 shows the vertical structure of the vortex tube for Case 2. The Cyclone for Case 2 is located at 140°E. This clearly showed that the cyclone for Case 2 has a barotropic structure.

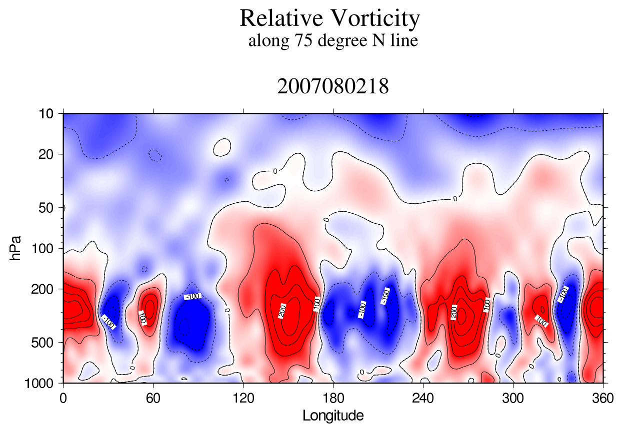

Figure 6: Longitude by pressure cross section of the relative vorticity. Vertical structure of the vortex tube for Case 1 at longitude of 150°E. The red color shows positive vorticity, showing a cyclonic circulation and the blue color shows negative vorticity, identifying an anticyclonic circulation.

4 DISCUSSIONS

In this study, the cyclones of the Arctic Ocean were analyzed and two different cases were referred. The summer period (JJA) of 2007-2008 was examined and the cyclones resembling these two cases were indicated. The cyclones identified in these two cases had several interesting characteristics; the life times were longer than a week (maximum:17-d), the cyclone tracks did not move to a far extent and the direction of movement of the cyclones were uncertain. Furthermore, the cyclones exhibited a barotropic structure and were observed directly below the polar vortices at the 500 hPa height field. The cyclones are assumed to be created due to the influence of the vorticity of the polar vortices propagating down to the SLP field. However, exceptions found within these cyclones were a change in the baroclinic structure (as the extra-tropical cyclones) to a more barotropic structure, once they had moved below the polar vortices.

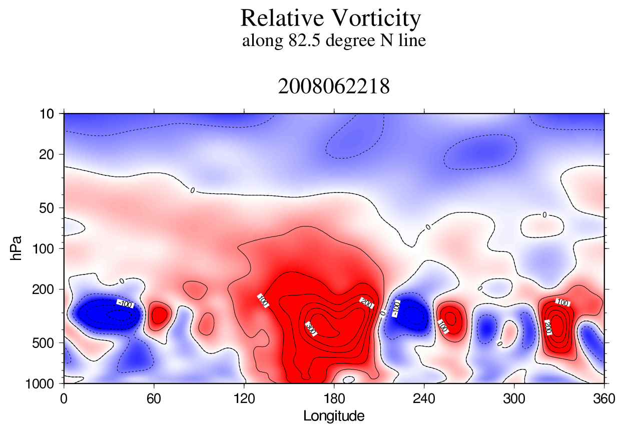

Figure 7: Same as Fig. 6, but for Case 2. The longitude of cyclone center (Case 2) is 140°E.

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