1.23 CYCLONE ACTIVITY AROUND THE GREENLAND ICE SHEET FOR LAST 50 YEARS

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1. INTRODUCTION

The Greenland ice sheet has significant impacts on the climate of the North Atlantic Ocean. The ice sheet accumulation is related to the regional precipitation, synoptic-scale circulation and downslope katabatic winds. Studies (Bromwich et al 1999) show that the North Atlantic Oscillation (NAO) is highly correlated with the cyclone activity near Greenland, and hence affects the precipitation pattern. When the NAO is positive, the precipitation is less than normal, particularly over southern Greenland, and vice versa.

This presentation discusses the relationship between cyclone activity around Greenland and the NAO. Further study will cover the cyclone activity over Greenland ice sheet and the changing precipitation pattern will be explored.

2. DATA AND METHODS

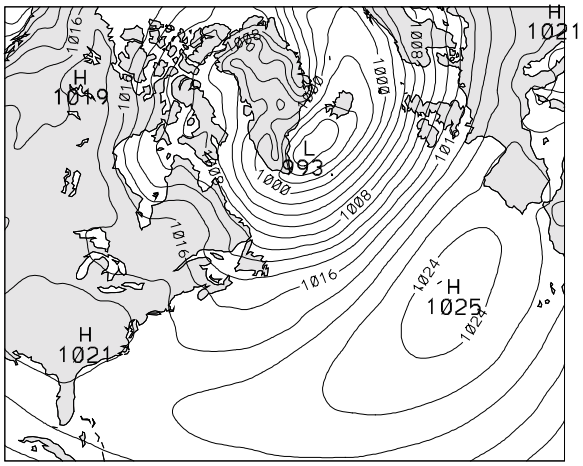
Fifty years of NCEP/NCAR (National Centers for Environmental Prediction and National Center for Atmospheric Research) datasets from 1950 to present are used to track cyclones around and over Greenland. ECMWF Reanalysis (ERA-15) data are used for the same purpose over their availability period of 1979-1993. Both datasets overlap for this period. These 6 hourly sea level pressure fields are analyzed by the Serreze (1995) tracking algorithm which has been optimized. These optimizations include the replacement of objective analysis by a bi-linear method in the data interpolation from latitude-longitude grids to equal area grids and replacing the low center searching strategy. The judgment of cyclone movement and generation is the same as in the original version. After optimization, the tracking algorithm reduces the calculation time greatly and can be applied to any variable.

Because of the high elevation of the Greenland ice sheet, analyses based on mean sea level pressure are distorted due to the pressure reduction to sea level. The modified tracking algorithm then is applied to the equivalent geopotential in sigma coordinates which accurately accounts for the impact of elevated terrain on atmospheric analyses (Chen and Bromwich 1999). The results from both variables (SLP and equivalent geopotential) will be compared to display the cyclone activity variation around and over the ice sheet during the last 50 years.

3. PRELIMINARY RESULTS

At this early stage, ERA-15 winter season (November, December, January, February and March)

(a)



(b)

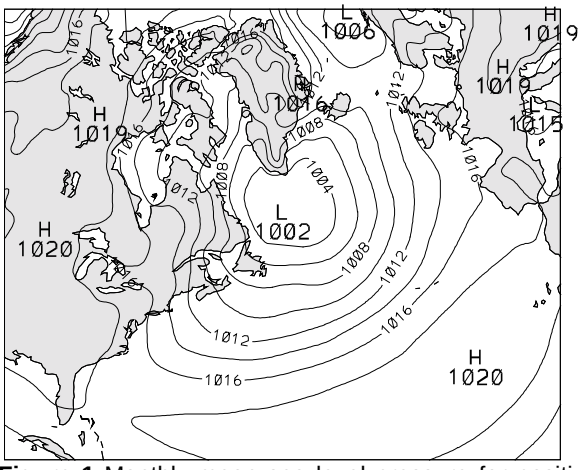


Figure 1 Monthly mean sea level pressure for positive (a) and negative (b) NAO months. Contour interval is 2hPa

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mean sea level pressure fields are used to analyze the relationship between the cyclone activity and NAO over a domain covering Greenland, most of North America, the North Atlantic, most of the Arctic region, and western Europe. NAO indices used are due to Rogers (1984); see http://www-bprc.mps.ohio-state.edu/NAO for up-to-date values. Figure 1 shows that monthly mean sea level pressure field for positive NAO and negative NAO months over the 15 winter seasons. It can be seen that during positive NAO months, the central pressure of the Icelandic low at 993hPa is lower than that during negative NAO months (1002hPa). The mean low center for negative NAO months is located to the south of Greenland rather than between the southern tip of Greenland and Iceland for positive NAO months.

TABLE 1 The number of cyclones entering Denmark Strait (including cyclogenesis in the same region) for winter season from 1979 to 1993. The shaded number indicates that monthly NAO index is negative. –NAO/+NAO is the total number of cyclones for negative/positive NAO months, respectively. The average cyclone number is total number of cyclones divided by the total number of negative/positive NAO months.

	Jan	Feb	Mar	Nov	Dec
79	10	6	8	10	12
80	4	5	10	5	7
81	12	7	3	7	5
82	5	9	10	8	11
83	12	7	10	6	9
84	9	13	8	7	9
85	3	10	5	7	3
86	6	4	10	7	9
87	8	4	12	10	8
88	4	4	5	5	11
89	15	11	9	6	7
90	11	12	11	3	10
91	11	10	4	9	11
92	10	12	9	11	10
93	10	10	11	11	9

-NAO: 168 Average: -NAO: 6.2
+NAO: 454 +NAO: 9.5
Total: 622

Two regions are selected to study the cyclonic activity associated with extremes of the NAO index. One is Denmark Strait between the southern tip of Greenland and Iceland, and the other is along the west coast of Greenland. These two regions are the places most cyclones move through. Cyclones from the west coast of Greenland may cross the southern part of Greenland to enter the Denmark Strait. Sometimes cyclones from the south will steer into either west coast region or Denmark Strait, or split into both directions due to the blocking of the southern tip of Greenland. Table 1-4 show the number of cyclones passing or forming in both regions for 15-years of winter months. The results show that the number of cyclones passing over (including cyclogenesis) Denmark Strait is larger than that over west coast region during all winter seasons. It also shows that in positive NAO months, the monthly mean number of cyclones passing Denmark Strait (9.5) is more than that in negative NAO months (6.2). For cyclogenesis over Denmark Strait, there are more cyclones (4.0) generated during positive NAO months than in negative NAO months (2.7).

TABLE 2 Same as Table 1 but for cyclones passing through Davis Strait (including cyclogenesis in the same region).

	Jan	Feb	Mar	Nov	Dec
79	10	5	9	10	8
80	8	6	7	6	5
81	6	10	12	6	7
82	9	5	7	16	7
83	5	7	5	3	8
84	10	5	11	5	6
85	8	3	8	10	8
86	10	8	10	8	8
87	7	5	8	11	4
88	8	9	8	8	8
89	6	4	7	7	5
90	6	4	9	7	6
91	6	9	9	5	11
92	10	8	8	9	7
93	6	9	6	12	8

-NAO: 203 Average: -NAO: 7.5
+NAO: 362 +NAO: 7.5
Total: 565

TABLE 3 Same as Table 1 but for cyclogenesis only.

	Jan	Feb	Mar	Nov	Dec
79	6	2	6	4	7
80	2	2	5	3	2
81	5	3	1	3	2
82	2	4	3	3	6
83	6	2	6	3	4
84	4	6	6	5	2
85	1	5	0	4	3
86	3	0	4	1	4
87	2	1	6	5	1
88	2	2	2	1	6
89	7	5	4	4	2
90	3	5	4	0	4
91	5	4	2	3	2
92	5	2	3	6	5
93	7	6	5	3	3

-NAO: 74 Average: -NAO: 2.7
+NAO: 193 +NAO: 4.0
Total: 267

For the west coast region of Greenland, the monthly averaged numbers of cyclone are the same (7.5) for both positive and negative NAO months. However, the mean numbers (4.4) of cyclogenesis events for positive NAO month is slightly larger than that (3.9) in negative NAO months. For Davis Strait, west of Greenland, the variation in cyclogenesis/formation with NAO is minimal.

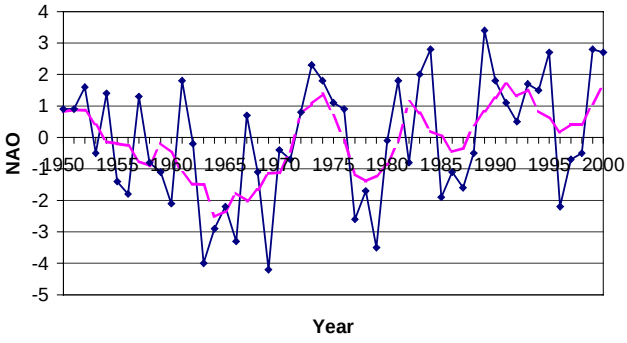
TABLE 4 Same as Table 2 but for cyclogenesis only.

	Jan	Feb	Mar	Nov	Dec
79	4	2	7	5	6
80	4	2	4	2	4
81	5	3	6	4	3
82	6	5	5	10	4
83	3	5	1	2	7
84	8	3	3	3	3
85	6	1	3	4	6
86	6	6	3	6	6
87	2	3	5	6	2
88	2	3	6	3	5
89	3	2	3	6	4
90	5	3	5	4	1
91	4	5	1	1	5
92	4	5	5	7	5
93	5	6	2	7	3

-NAO: 103 Average: -NAO: 3.9
+NAO: 209 +NAO: 4.4
Total: 314

Figure 2 shows the Rogers NAO index (Rogers 1984) for winter season from 1950 to 2000. The dashed line is the five-year running mean value. NAO index oscillates between negative and positive frequently. However, the upward trend to much more positive values is obvious since the late 1960s. This suggests that there is enhanced cyclonic activity around

Figure 2 Rogers NAO index for Winter Season (DJF)



Greenland in recent decades. For the ERA-15 time period, the pattern of cyclone activity in Denmark Strait is quite similar with that of NAO index (Fig. 3 and Fig. 4). The upward trend toward more cyclone activity can be easily noticed (Fig. 5). While along the west coast of Greenland, the opposite pattern can be found before 1989, and the upward trend is not so obvious (Fig. 4). One notable thing about the cyclone activity patterns is that after 1989, the cyclone activity pattern along the west coast seems to be positively corrected with that in Denmark Strait (Fig. 4). The dashed lines indicate the

Figure 3 Same as Figure 2 but for the period of 1979 - 1993

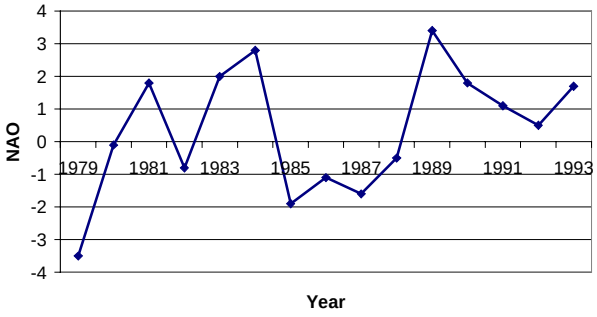


Figure 4 Cyclone Activity for Denmark Strait and West Coast of Greenland

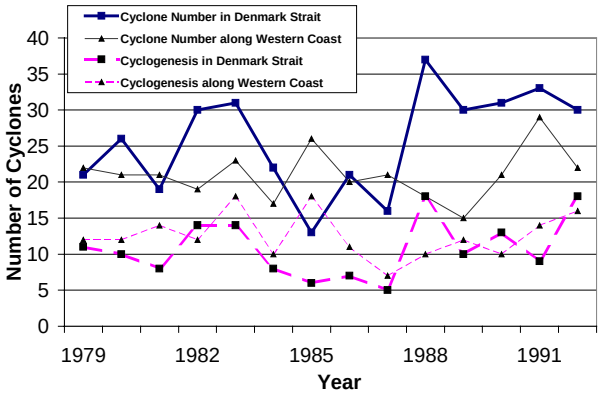
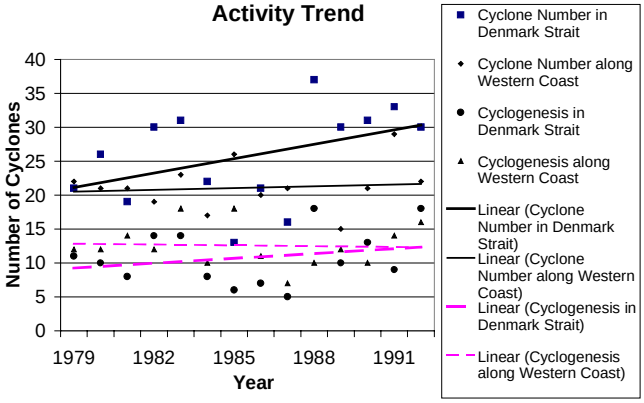


Figure 5 Same as Figure 4 but for Cyclone Activity Trend



numbers of cyclogenesis events in Denmark Strait and along the west coast. The upward trend still can be noticed (Fig. 5). At present stage, since the tracking period is not long enough, it is too early to conclude that somewhat dramatic regional climate change in the northern Atlantic has occurred.

4. REMARKS FOR FUTURE STUDY

ERA-15 winter season mean sea level pressure fields have been analyzed to reveal the relationship between the cyclone activity and NAO. Future research work will cover the last 50 years using NCEP/NCAR Reanalysis datasets. Since the tracking algorithm has been optimized such that it can apply to any variable, the equivalent geopotential in sigma coordinates which eliminates the terrain effect will also be used. The precipitation pattern over Greenland Ice Sheet has been found to be undergoing change; by applying the tracking algorithm to equivalent geopotential, the precipitation changing pattern can be explained.

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5. REFFERENCES

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