5.10 RELATIONSHIP BETWEEN ARCTIC CLOUDS AND SYNOPTIC-SCALE VARIABILITY

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1. Introduction

Arctic clouds play an important role in the Arctic climate system. During summer, fall and spring, cloud fractions are typically in excess of 70% over the pack ice and near the Alaskan coast (Curry et al., 1996; Intrieri et al., 1999). Cloud cover over the sea-ice typically maximizes in summer, whereas coastal Alaskan cloudiness typically maximizes in October (Dissing and Wendler, 1998). This large spatial and temporal cloud coverage has a huge impact on the radiative budget of the Arctic system (Curry et al., 1996; Harrington and Olson, 2001) with clouds having a cooling effect in the summer and a warming effect in winter. Because of this strong cloud dependence, surface radiative fluxes are quite sensitive to changes in cloud cover. Alterations in cloud properties could affect the state of the sea-ice due to the underlying sea-ice sensitiveness to changes in surface fluxes.

Although cloudiness is an important issue with regard to Arctic climate, and though much good work has been accomplished in this area, we still lack knowledge regarding the physical processes responsible for the large cloud fractions over the Arctic terrestrial and oceanic regions. Curry and Herman (1985) found that during the summer synoptic-scale activity, while affecting low cloud cover over the Arctic ocean, appears to act in a secondary role with its effects superimposed on the first-order effects of air mass modification. However, it remains an open question as to whether this is true over coastal and terrestrial arctic regions and whether this is true during the transitional and cold seasons. In this study we compare the synoptic-scale variability over oceanic, coastal and terrestrial arctic regions as the first step in our attempt to answer this question.

2. Methods

NCEP Reanalysis data for the period of 1992 to 2001 and NWS soundings collected from 1989 to 2001 at Barrow, Alaska, were used in this study. The Reanalysis data were provided by the NOAA-CIRES Climate Diagnostics Center, Boulder, Colorado, from their Web site at http://www.cdc.noaa.gov .

The sites used in the analysis are shown on Fig. 1. Site (1) – “ocean” (77.5^{o}N 157.5^{o}W) is chosen to be representative for ocean/sea-ice regions.

Site (2) – “coastal” (72.5^{o}N 157.5^{o}W) is close to Barrow, Alaska at which is located the ARM North Slope of Alaska observation site. Site (3) - “terrestrial” (67.5^{o}N 157.5^{o}W) is assumed to be representative of the terrestrial regions.

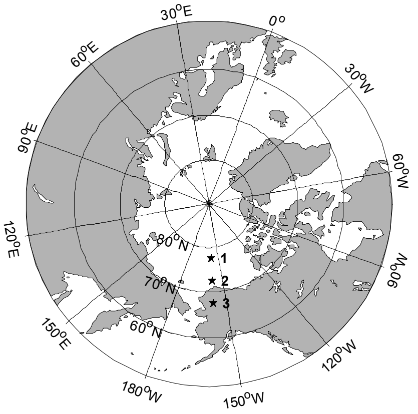

Fig. 1 Location of the sites selected for the analysis

To characterize the weather conditions at each of the chosen locations, the following variables from NCEP Reanalysis were selected at twelve levels between the ground and the isobaric surface p = 100 mb:

- geopotential height **Φ** [m] or surface pressure $\mathbf{p_s}$ [Pa]
- air temperature **T** [^{o}C]
- dew point temperature **Td** [^{o}C]
- wind speed |**V**| [m/s]

Dew point temperature data were available at the first 8 levels only (up to 300 mb); however, this is not a limitation as the Arctic tropopause is typically low.

Principal Component Analysis (PCA) is then used to reduce the initial set of inter-correlated variables to a smaller set of orthogonal principal components (PCs).

The PCs are the eigenvectors extracted from either a covariance, correlation or cross-products input matrix of the size ***n*** x ***n***, where ***n*** is the number of variables (Yarnal, 1993). Because the data used in this study are measured in different units - mb, meters, degrees Celsius, etc, we use the correlation matrix approach. Each of the resulting PCs defines a new variable that is a linear combination of the original variables. The first PC explains the largest amount of variance of the

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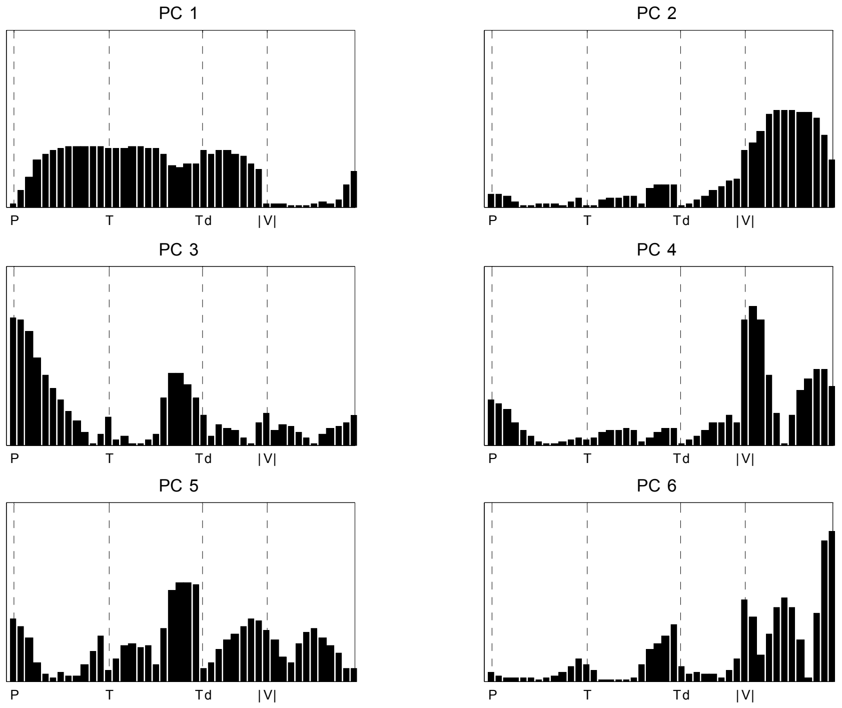

Fig. 2 The first six PCs at location (1) - "ocean".
Absolute values of elements are shown.

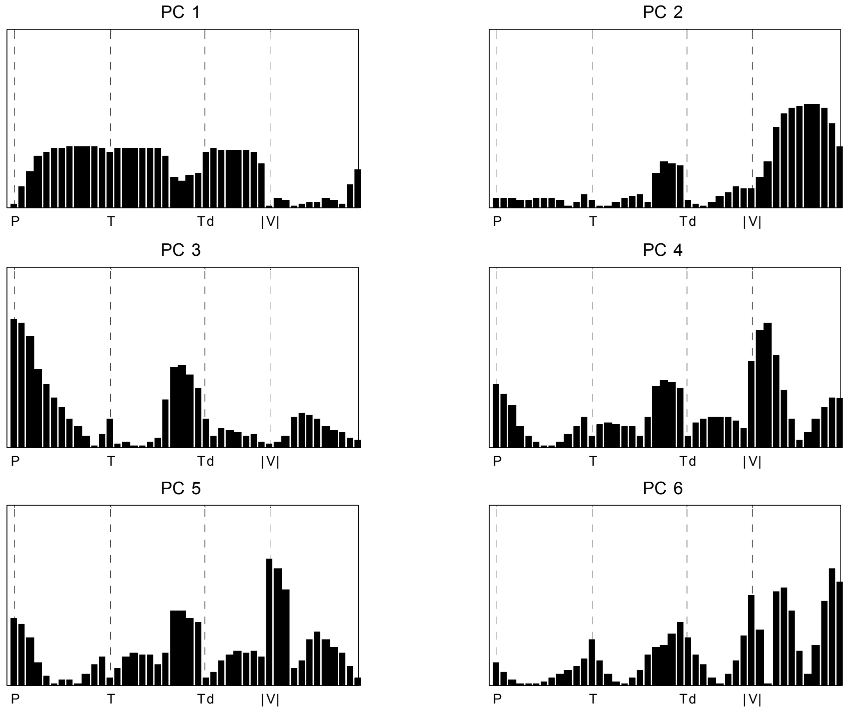

Fig. 3 The first six PCs at location (2) - "coastal".
Absolute values of elements are shown.

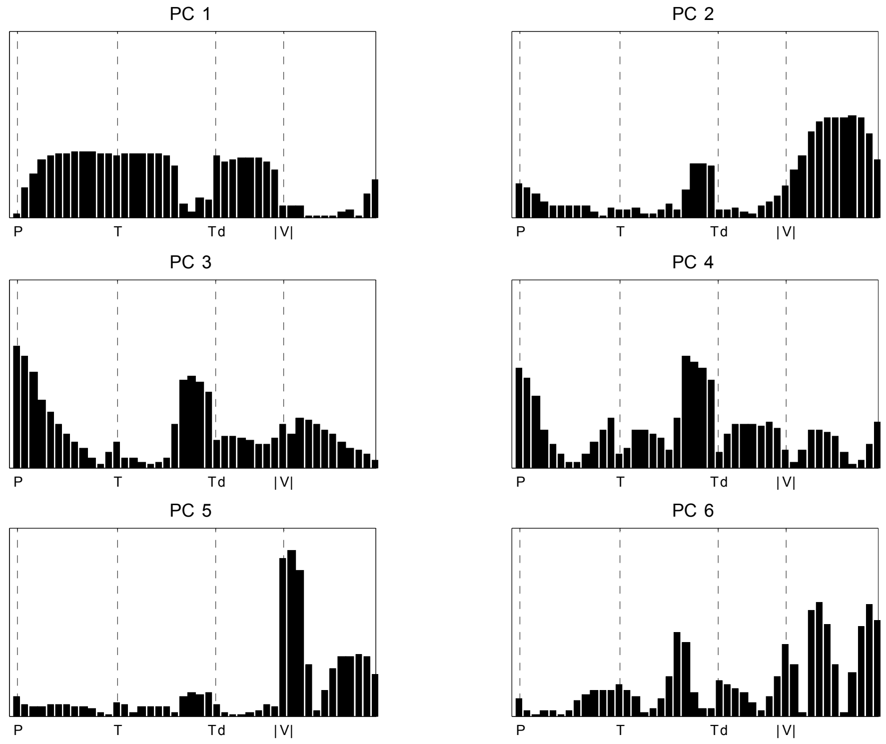

Fig. 4 The first six PCs at location (3) - “terrestrial”. Absolute values of elements are shown.

original variables and each of the subsequent PCs accounts for lesser amount. Because of the orthogonality of the PCs, one can extract only a number of components ***m*** (***m*** < ***n)*** explaining predetermined part of the original variance. Thus, in addition to eliminating the inter-variable collineraity, PCA also reduces the size of the original dataset.

3. Results

The data were arranged in a matrix of dimension 3653 x 44 such that each column was one of the parameters:

p_s, Φ_1, … Φ_{11}, T_s, T_1, … T_{11}, Td_s, Td_1, …Td_7, $|V_s|$, $|V_1|$, … $|V_{11}|$

and each row represents 1 day. The correlation matrix was calculated from the input matrix. Then 44 eigenvalue-eigenvector pairs are extracted from the correlation matrix. The number of PCs that should be retained was determined using the Scree test (Cattel, 1966) and N rule (Preisendorfer, 1988), both suggesting a five or six component solution. The choice of six PCs is also in accordance with the other often used criteria– a component is retained if Its associated eigenvalue≥ 1. This procedure was applied for each of the 3 locations and the results are shown on Figs. 2 – 4.

Comparing the first PC for the 3 locations the only difference is in the upper level temperature loading. The pressure loading onto the second PC shows difference between “terrestrial” from one side and “coastal” and “ocean” sites from the other. The “terrestrial” site is again different from the other two in terms in terms of the humidity and the wind speed loading onto the third PC. The fourth PC is almost the same for the all three sites, while the fifth PC shows similar pattern for the “coastal” and “ocean” site in respect to the pressure, temperature and humidity loadings. In contrast, the wind speed loading onto fifth and sixth PC shows some similarity between the “coastal” and “terrestrial” site.

In conclusion, the similarities between the “coastline” site and the “ocean” site are more pronounced than the similarities between the “terrestrial” site and the “coastal” site.

This results are somewhat unexpected since both Olsson et al. (2001) and Serreze et al. (2001) conclude that processes over coastal Alaska differ substantially from those that occur over oceanic regions. In particular, Sereze et al. (2001) show that the Brooks Range and north Alaskan coastline are regions of high frontal activity in summer. During winter, synoptic activity tends to diminish over the North Slope of Alaska, with fall and spring being periods of transition between winter and

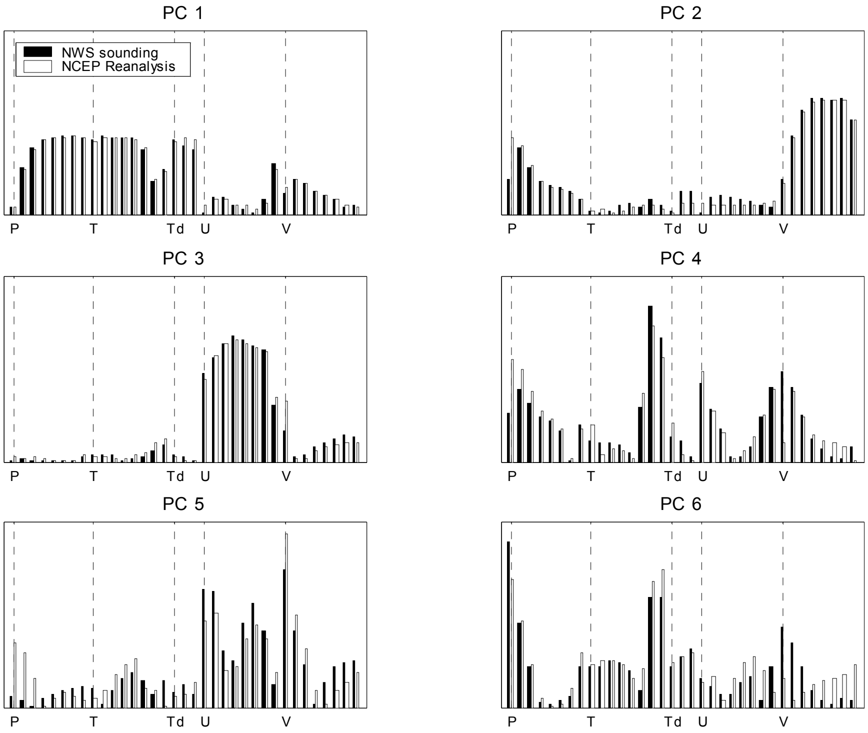

Fig. 5 The first six PCs from the PCA of NCEP Reanalysis data and NWS soundings

summer synoptic activity.

However, this discrepancy can be explained by the fact that we use year round data in contrast to the summertime observations reported by Olsson et al. (2001) and Serreze et al. (2001). Our results fit well into above picture, taking into account that the winter is the dominant season in Arctica.

To check that location (2) is representative of the coastal Arctic, we compare the PCs extracted from NCEP Reanalysis with those extracted from the NWS soundings made in Barrow. The input data in this case consist of daily mean values of surface pressure $\mathbf{p_s}$ or geopotential height **Φ**, air temperature **T**, dew point temperature **Td**, and **u** and **v** wind components at eight levels between the ground and the isobaric surface p = 100 mb. The results are shown in Fig. 5 where the NCEP Reanalysis data are plotted by open symbols and the sounding data are marked by full symbols. One can see that the variability of the reanalysis data resemble extremely well the variability of the real data. These findings confirm once again the validity of the NCEP Reanalysis.

4. Acknowledgements

We thank Chad Bahrmann for his assistance in retrieving NWS data. We would like to show our appreciation to the Atmospheric Radiation Measurement Program of Department of Energy under Battelle Memorial Institute contract number 3092.

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