Chapter 3

Climatological Analysis of the Mackenzie River Basin Anticyclones: Structure, Evolution and Interannual Variability

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Abstract A compilation of a climatology of anticyclones allows identification of the structural and dynamic features that characterize anticyclonic development in the Mackenzie River Basin (MRB) during the winter period. A sophisticated tracking algorithm is applied to the analysis of the ERA-40 dataset that spans the 1957-2002 period. The MRB anticyclones are monitored at consecutive times to obtain statistical estimates of their characteristics and density distributions. The results indicate that the MRB anticyclones are deep, warm-core structures whose development is caused by the amplification of the climatological semi-permanent ridge that dominates over western North America in winter. The warm anomalies that lead to the ridge amplification are, at low levels, generated locally in response to the orographic effect of the Rockies and, at upper levels, advected from other high latitude regions. Sensitivity to the interannual variations of the Pacific-North-American and the Arctic Oscillation was identified. This is mainly manifested in the weaker or stronger meridional/zonal orientation of the anticyclonic activity for opposite phases. The transformation of the MRB anticyclones to cold core structures as they move away from the Basin toward the eastern Provinces of Canada and the remote origin of the upper tropospheric warm anomalies that sustain them point to strong dynamical links with atmospheric developments over other Canadian regions.

1 Introduction

This study was motivated by earlier reports (Harman 1987; Zishka and Smith 1980) that western North America, including the Mackenzie River Basin (MRB) is among the preferred regions of winter anticyclonic activity in the Northern Hemisphere. The region is also noted for events of rapid anticyclogenesis (Alberta et al. 1991). The predominance of anticyclonic conditions affects precipitation and the regional hydrologic cycle, the sublimation and redistribution of accumulated snow by blowing snow events (Déry and Yau 1999, 2007) and the regional radiation budget. The
latter is associated with an increase in outgoing longwave radiation under clear sky conditions induced by anticyclones.

The geographical position of the MRB in the lee of the Rockies subjects it to several orography related effects. The westerly flow impinging on the mountain range leads to the formation of a semi-permanent ridge over the broader region of western North America in winter. The orography also affects the thermal characteristics of the air masses as the air warms adiabatically upon its descent down the mountain barrier (Szeto 2007). In addition, there is the influence of the Alaskan region to the west and the western Arctic Ocean to the north both of which are known to be regions of anticyclonic activity (Serreze and Barry 1988). The Alaskan anticyclones have received particular attention in the literature because of their intensity and persistence (Tan and Curry 1993).

There has been limited success by operational models in accurately predicting the occurrence of anticyclones in the MRB. The implication is that the MRB anticyclones may differ from the neighboring anticyclones of Alaska and the Arctic and that the factors underlying their development may not be fully understood. In view of their complex character and their importance to the water and radiative budgets a detailed study of anticyclones over the MRB is warranted. Thus the first objective of this study was to compile a climatology of the activity of the winter time anticyclones over the MRB, focusing on the structural and dynamic features that characterize their generation and evolution. A second objective was to investigate their interannual variability, especially in relation to the Pacific-North American pattern (PNA) and the Arctic Oscillation (AO), two of the most prominent patterns of low frequency variability in the extratropics of the Northern Hemisphere.

2 Data and Method

Two datasets were used in our climatological analysis, the ERA-15 and the ERA-40. The former covers the 1979–94 period, and the latter spans from 1957 to 2002. The ERA-40 is the most up-to-date atmospheric reanalysis dataset because (a) a three dimensional variational technique for data assimilation was employed and (b) measurements from satellites and past field experiments were incorporated. The assimilation of satellite observations began in 1973 with radiance measurements, and progressed in 1979 to include more advanced observations such as altimeter wave heights, cloud track winds, ozone profile data, scatterometer winds, and TOVS measurements. Fifty three atmospheric fields are available but in our