6.7 Northern Hemisphere Warming: A Thickness Climatology

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1. Introduction

Climate change, specifically climate warming, has become a hotly contested scientific and political issue over the past several years. While there is still some question of attribution, (anthropological vs. inherent climate variability) evidence is mounting that the increasing trend in the global temperature record is both statistically significant and greater than what is expected due to natural variability (e.g., Hegerl et. al 1996, Fomby and Vogelsang 2002). Increases in population and urbanization are also insufficient to account for the warming exhibited (e.g., Jones et. al 1989). However, given that warming of the global climate is taking place, questions remain as to how this warming is differentially manifested over time and space. An additional issue of importance is to understand how these variations are related to changes in the dominant large scale atmospheric flow regimes. In an attempt to address some of these issues, an objective global climatology of the 1000-500 hPa thickness is constructed covering the period from 1953-1999.

2. Data and methodology

The climatology is performed using the National Center for Environmental Prediction (NCEP)/National Center for Atmospheric Research (NCAR) Reanalysis valid at 00 UTC and 1200 UTC on a 2.50^{o} lat-lon grid. The 1000-500 hPa layer is used because it is a commonly referenced thickness threshold and because it is a deep enough layer that anomalous values resulting from spurious surface readings or reductions to sea level are minimized. The Reanalysis is utilized due to its convenience and availability and because recent studies (e.g., Chelliah and Ropelewski 2000) have indicated that the tropospheric temperature representations in the Reanalysis are consistent with trends produced from independent remote sensing techniques. For the purpose of calculating aerial averages, the data were normalized based on the latitude of the grid box.

3. Results and Discussion.

The mean 1000-500 hPa thickness for January is shown in Fig. 1. On average, the coldest thickness is 498 dam, which stretches from Siberia, across the Arctic, to northern Canada. As expected, the thickness ridges are located in the oceanic basins and at the end of the Pacific and Atlantic storm tracks. The 540 dam thickness contour, representative of a 50-50 probability of rain versus snow for continental locations near sea level, lies across the southern Middle Atlantic portion of the US while the 570 dam thickness contour, indicative of tropical air, is generally confined to the 20-25^{o}N latitude band. By contrast, the minimum thickness reached during the period is 456 dam in northern Canada (Fig. 2). The presence of the Arctic Ocean is evident in the weak thickness ridge across the polar region. The southward penetration of the 498 dam thickness contour seen in the minimum thickness map (Fig. 2), in general, mimics the location of the 540 dam thickness contour in the January climatology (Fig 1.). A very tight gradient is found across the sub-tropical regions, with differences between climatology and the coldest thicknesses varying by only 6 dam.

An analysis of temporal variation of the coldest thickness found in the Northern Hemisphere is shown in Fig. 3. Depicted in this figure is the minimum thickness over the Northern Hemisphere computed twice daily and averaged over the winter months (DJF) for each year. The time series shows a decrease in the minimum thickness in the late 1950s and early 1960s, followed by a general increase in minimum thickness values from the mid 1960s until present day. A linear trend line shows an increase of approximately 2 dam, or 1^{o}C, over the past 30 year period. At the same time, the area encompassed by thickness values that are less than or equal to 498 dam has decreased by 0.3% of the surface area of the Northern Hemisphere (Fig. 4). These results indicate that the extremes of cold are reducing in intensity while concomitantly covering smaller area over the past 30 years.

The mean 1000-500 hPa thickness for July is shown in Fig. 5. Thickness troughs are located in the oceanic basins, while thickness ridges are generally located in the desert basins in the 30-35^{o}S latitude bands. In the mean, the warmest thickness is located over the Middle East across the Arabian Peninsula and southern Iran. The coolest thickness is located across the Arctic Ocean with a mean value of 540 dam. The pattern in Fig. 6 generally mimics that in Fig. 5 and shows the maximum thickness recorded from 1953-1999 is 597 dam over the Iranian desert regions. However, in contrast to the July mean, another local thickness maximum can be found over Siberia. The warmest thickness found in the Arctic is about 558 dam or about 18 dam (~9^{o}C) higher than the July mean.

A measure of the *continentality* of the Northern Hemisphere can be obtained by subtracting the January thickness field from the July thickness field and is presented in Fig. 7. The greatest variation in thickness is located over Siberia with a difference of over 69 dam (~33^{o}C). A secondary maximum is located northern Canada with a difference of about 52 dam (~25^{o}C). Differences at the end of the Pacific and Atlantic storm tracks are less than 10 dam (~5^{o}C). An expected signature of anthropogenic warming would be a general decrease in continentality as the polar regions would warm preferentially in the cool season. A rough measure of the change in continentality is obtained by dividing the climatological period in half (1953-1978 and 1979-1999), and subtracting the continentality maps for the two time periods. The results are shown in Fig.8. In this map, an increase in continentality is represented by negative values (dashed lines) and a decrease in continentality is indicated by positive values (solid lines). The greatest decrease in continentality is found over the Northwest Territories of Canada. Here, a change of almost 6 dam represents a decrease in summer-winter variation of about 3^{o}C. It can be noted that areas in Fig. 8 which exhibit the greatest decrease in continentality (e.g. northern Canada, Siberia) are areas that are associated with the largest continentality in Fig. 7. An additional point of interest is that increases in continentality are seen over the oceanic basins (Fig. 8). While reasons for this pattern are not speculated here, it is worthwhile to note that the change in the pattern of continentality is consistent with a change in the dominant mode of the North Atlantic Oscillation (e.g., Wallace and Gutzler 1981).

Acknowledgements

This research was supported by NSF grants ATM-9912075 and ATM-0000673.

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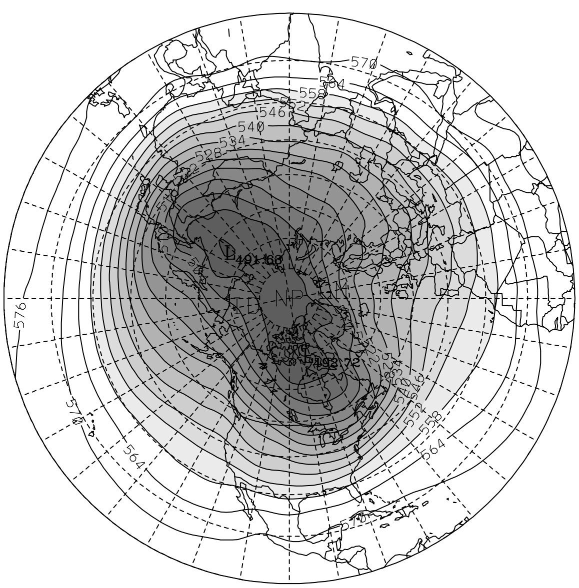

Fig. 1. Mean 1000-500 hPa thickness (dam) for January over the period 1953-1999.

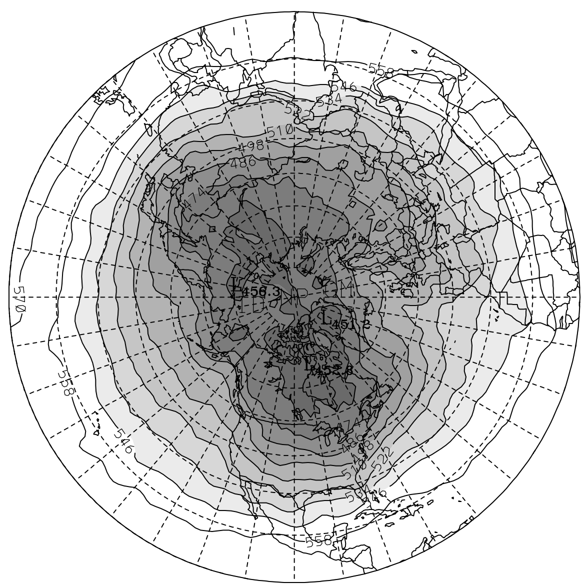

Fig. 2. Minimum1000-500 hPa thickness (dam) over the period 1953-1999.

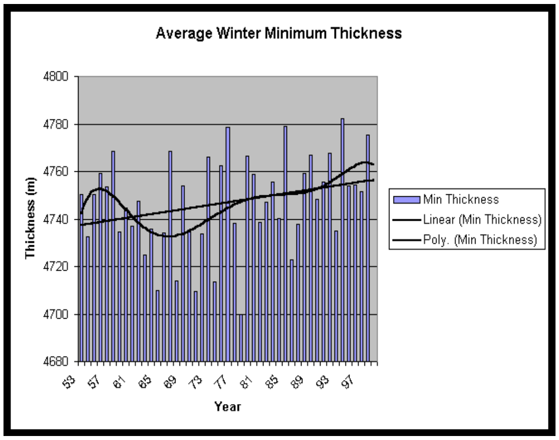

Fig. 3. Time series of average minimum Winter (DJF) 1000-500 hPa thickness (dam) over the period 1953-1999.

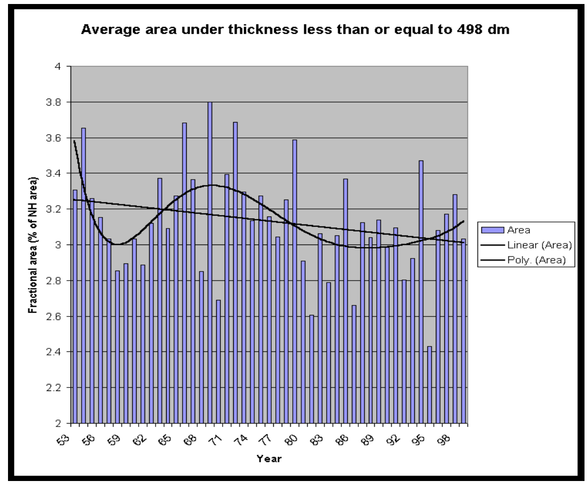

Fig. 4. Time series of average area (expressed as a fraction of the total area of the Northern Hemisphere) under 1000-500 hPa thickness less than or equal to 498 dam over the period 1953-1999.

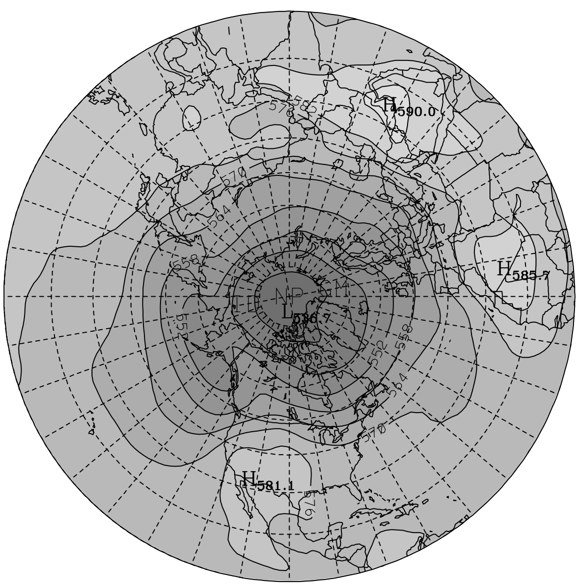

Fig. 5. Mean 1000-500 hPa thickness (dam) for January over the period 1953-1999.

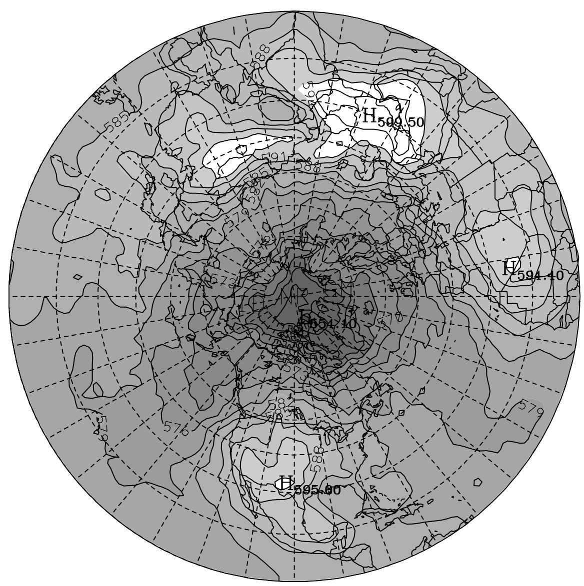

Fig. 6. Maximum1000-500 hPa thickness (dam) over the period 1953-1999.

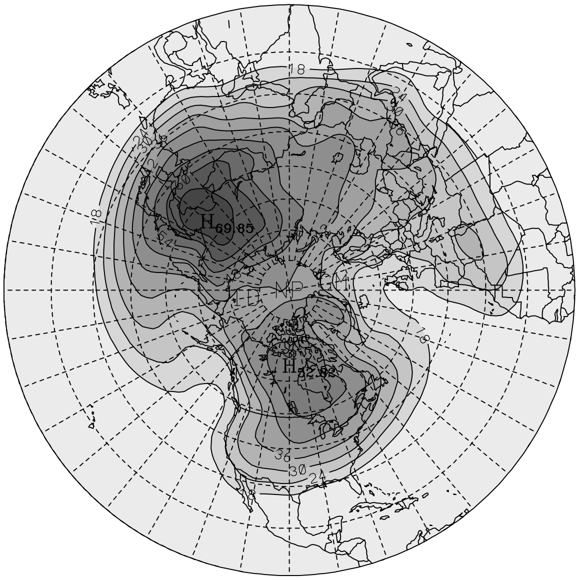

Fig. 7. Mean continentality (July - January 1000-500 hPa thickness) over the period 1953-1999. Units are dam.

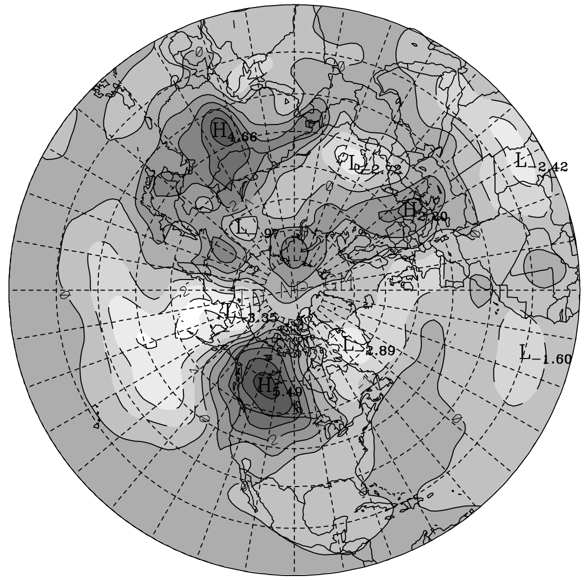

Fig. 8. Change in mean continentality (dam) between the periods 1953-1978 and 1979-1999. Negative (positive) values denote increase (decrease) in continentality.