An Assessment of 2010 North American Temperatures

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A Persistent Pattern of 2010 North American Temperature Anomalies

Surface air temperatures were very warm across Canada during 2010, a feature that prevailed during all seasons and dominated the pattern of North American temperatures throughout the year (Fig. 1, left panels). The noteworthy features over the contiguous United States were the much below normal temperatures over the southern and eastern states in the first and latter portions of 2010 which book-ended record high temperatures in those same regions during the warm half of the year.

January-March 2010 conditions (Fig. 1, top left) were especially noteworthy for the widespread greater than +3°C departures that consumed all Canadian provinces from the Pacific to the Atlantic coast; statistics compiled by Environment Canada indicated that winter 2010 was the warmest in Canada since records began in 1948. The contrast with cold winter conditions over the United States was especially striking, with up to -3°C departures over the Gulf Coast regions. The following seasons showed a remarkable reversal in U.S. surface temperature conditions even while Canada remained consistently warm; April-September 2010 was very warm across the eastern U.S. and cold across the

West. As a further testament to intense seasonal temperature variability over the U.S., Fall 2010 saw a sharp turn to cold conditions in the East and Gulf Coast (Fig, 1, bottom left panel), while Canada remained unusually mild yet again   In many ways, the pattern of Fall 2010 North American temperatures reprised the prior winter pattern.

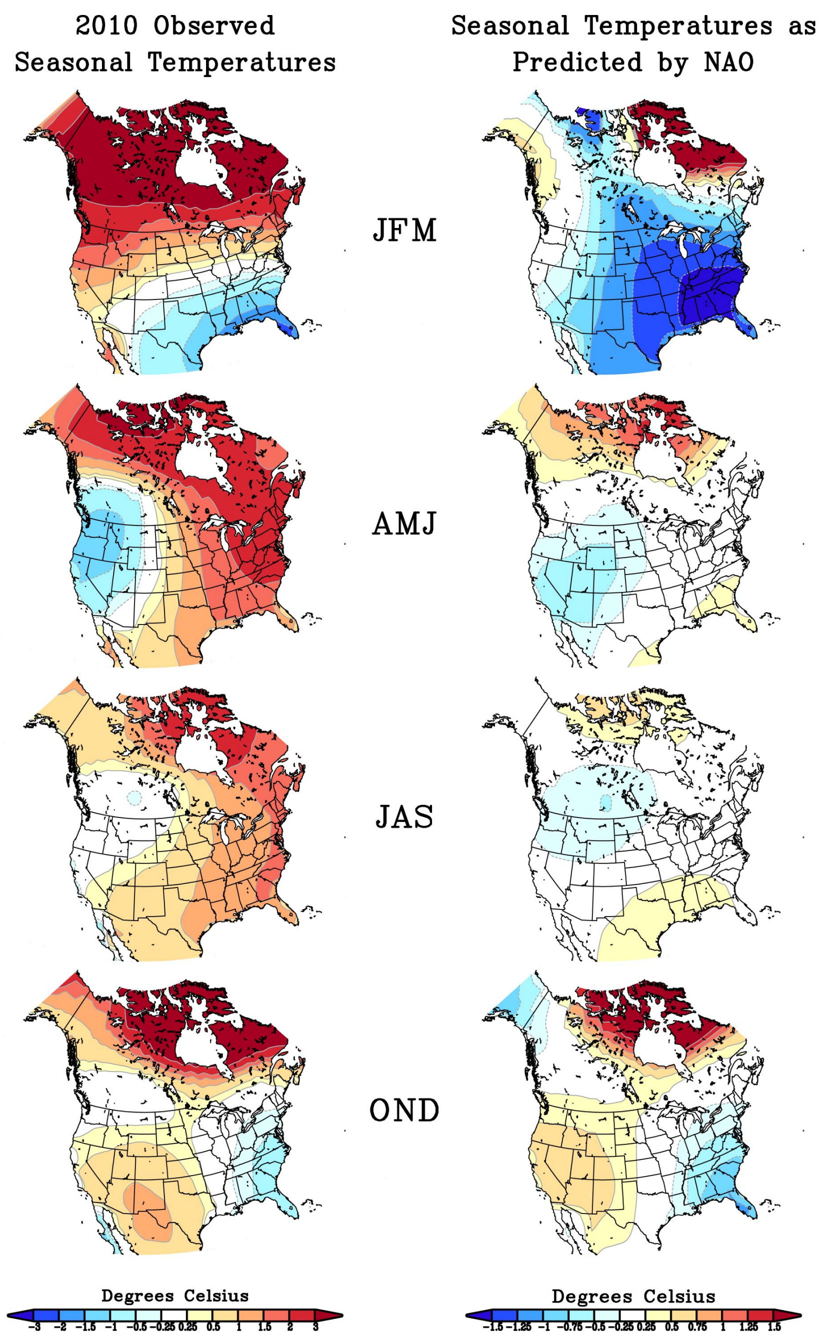

Figure 1. **(left)** *North American surface air temperature departures (°C) during 2010 for Winter (January-March), Spring (April-June), Summer (July-September), and Fall (October-December). The seasonal anomalies are based on the NOAA gridded analysis and departures are calculated relative to a 1961-1990 reference.* **(right)** *The 2010 signal of North American seasonal temperature anomalies (°C) attributable to the state of the 2010 North Atlantic Oscillation. The NAO signal is calculated by regressing the monthly surface temperatures upon the Climate Prediction Center's NAO index time series for 1950-2009, and the 2010 anomalies are derived by multiplying the regression pattern by the observed 2010 standardized NAO index for each season.*

A Persistent Phase of the North Atlantic Oscillation during 2010

A notable extreme climate event during 2010 was the intense negative phase of the North Atlantic Oscillation (NAO). An annual mean index of the NAO, based on the Jones' analysis of the difference between normalized sea level pressure over Gibraltar and the normalized sea level pressure over Southwest Iceland, ranked as the most negative in the historical record that began in 1823. As indicated in Table 1, the 2010 NAO index was nearly twice as extreme as the prior most negative index year. The marquis feature of atmospheric circulation in the middle troposphere associated with the negative phase of the NAO is an anomalous anticyclone located over the Arctic that typically has maximum intensity between Hudson Bay and Iceland. Though such a feature is usually best developed during the cold months, the high latitude blocking and associated negative NAO index was a persistent feature during all months of 2010.

Table 1. *Ten most negative annual values of the Jones' NAO index, which covers the period 1823-2010.*

Rank	Year	NAO-index value
1	2010	-2.05
2	1996	-1.01
3	1878	-0.92
4	1828	-0.88
5	1915	-0.87
6	1872	-0.80
7	1853	-0.79
8	1855	-0.78
9	2008	-0.73
9	1941	-0.73

Here we assess whether the observed North American temperature conditions of 2010 (Fig. 1, left) could be reconciled with the extreme blocked behavior of the NAO. The right panels of Figure 1 show the seasonal surface temperature signals attributable to the seasonal NAO index of 2010. The results are based on a linear regression between an NAO index and observed surface temperatures during the period 1950-2009, with the resulting regression pattern scaled by the actual NAO for the four individual seasons during 2010. The best agreement between observations and the NAO signal occurs over eastern North America. In particular, the Canadian warmth juxtaposed with southeast U.S. cold during winter and fall seasons can be largely reconciled with a meridional dipole pattern of NAO-related temperature anomalies; of particular note is that the cold eastern U.S. and very warm northeast Canadian regime were very likely features linked with the persistent blocked NAO. For North America as a whole, the spatial correlation of the observed anomalies and the NAO signals is 0.6, 0.8, 0.7, and 0.9 for the winter, spring, summer, and fall 2010 seasons, respectively.

A Sharp Reversal in ENSO During 2010

Strong El Niño conditions prevailed over the tropical Pacific during January-March 2010. A swift transition commenced during spring, however, with a moderate to strong La Niña event established by early summer 2010 and continuing into Fall. In light of ENSO's known impact on North American climate conditions, it is reasonable to inquire whether the strong seasonality in contiguous U.S. temperatures especially may have been linked to this abrupt swing of the ENSO cycle. The seasonal surface temperature signals attributable to the seasonal ENSO index of 2010 were computed based on the linear regression between a Nino3.4 SST index and observed surface temperatures during the period 1950-2009. We have combined that signal with our prior calculation of the NAO signal during 2010, the result of which is shown in Fig. 2. We note that the spatial correlation of this combined signal is slightly better than when using the NAO signal alone, especially for the summer pattern. What emerges clearly from this diagnosis is the dominant effect of the persistent NAO in generating cold eastern US conditions in early and late 2010, with some indication that the reversal to warm summer conditions in the eastern U.S. was partly due to the region's sensitivity to La Niña conditions which had emerged with considerable vigor by July 2010.

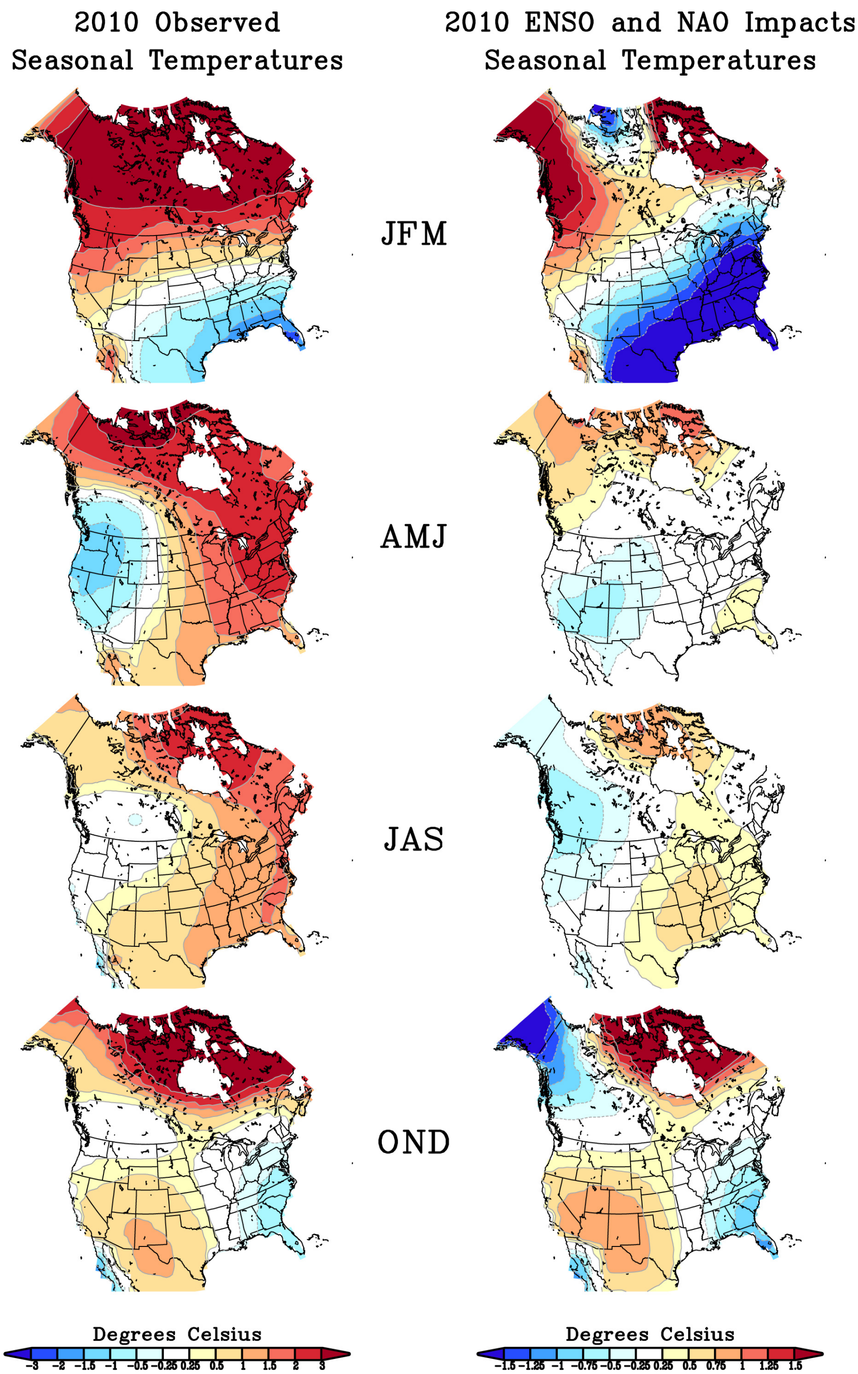

Figure 2. **(left)** *North American surface air temperature departures (°C) during 2010 for Winter (January-March), Spring (April-June), Summer (July-September), and Fall (October-December) as in Fig. 1 The seasonal anomalies are based on the NOAA gridded analysis and departures are calculated relative to a 1961-1990 reference.* **(right)** *The 2010 signal of North American seasonal temperature anomalies (°C) attributable to the combined effects of the state of the NAO and the state of ENSO. The NAO signal is computed as in Fig, 1. The ENSO signal is calculated by regressing the monthly surface temperatures upon a Nino 3.4 SST index time series for 1950-2009, and then scaling by the observed 2010 index values of Nino 3.4 SSTs. The combined 2010 anomalies are derived by adding the separate NAO and ENSO signals.*

By no means are all the seasonal features of 2010 North American temperatures interpretable as a signal of NAO variability. In particular, the spatial scale and intensity of the observed Canadian warmth was considerably greater than one would have expected from NAO relationships. Indeed, the record setting Canadian warmth of winter appears not to be consistent with the region's sensitivity to a negative phase of the NAO, the strong NAO warming of eastern Canada notwithstanding. An important research task is to ascertain the effect of boundary forcings on the North American conditions of 2010, including the state of global SSTs, sea ice, and anthropogenic GHG forcing.