The North Atlantic Oscillation: Impact on Snowfall Conditions in the Northeastern United States

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ABSTRACT

This study examines the relationship between the NAO and winter (November – March) snowfall totals in northeastern U.S. between 1961 and 2010. The analysis revealed an inverse relationship between NAO phase and seasonal snowfall, with positive (negative) NAO index years associated with lower (higher) average snowfall and snowfall days. Significantly greater snowfall during the NAO negative phase was mainly located along the East Coast as well as the interior southern half of the study region. A composite analysis of various tropospheric variables (e.g., 500-hPa heights) showed NAO negative years produced greater snowfall due to more extreme weather conditions affecting the Northeast, such as below normal sea level pressure, a deepened mid-tropospheric trough and weaker upper-level westerlies that permitted more frequent polar outbreaks. Stations indicating no relationship between NAO and snowfall were mainly located in western and central New York, northern Vermont, and Maine. These regions of the Northeast correspond to those that receive snowfall in either NAO phase, as exhibited in the case studies, due to the effects of nearby lakes and higher terrain related to the storm tracks through these areas.

INTRODUCTION

What is the NAO?

- A teleconnection pattern characterized by sea level pressure differences between the Icelandic Low and the Azores High

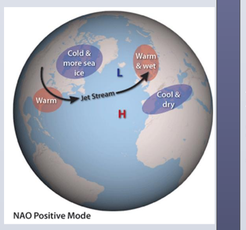
How does the NAO influence eastern U.S. winters?

Phase (+): Strong N. Atlantic pressure gradient and increased westerlies

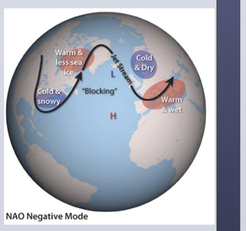
- Northeastward storm track shift
- Mild, wet, and less snowy winters

Phase (-): Weak N. Atlantic pressure gradient and reduced westerlies

- Subtropical High moves poleward
- Blocking pattern over the North Atlantic more likely w/ mean trough axis over eastern US
- More polar outbreaks and snowy conditions



NAO Positive Mode



NAO Negative Mode

OBJECTIVES

- Provide a 50-year climatology of NAO-related snowfall trends in the northeastern U.S. with a focus on the past decade
- Discuss how both NAO phases can generate extreme snowfall in some sub-regions using two case studies

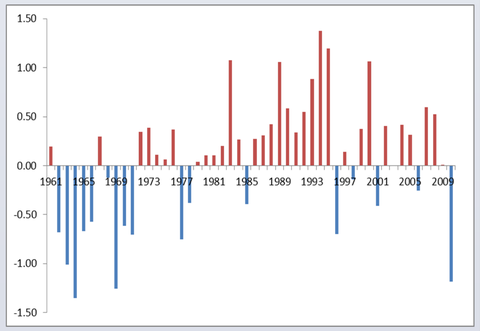
DATA & METHODOLOGY

DATA

November – March (NDJFM) Winters: 1961-2010

- Daily snowfall totals (n = 82) (USHCN)
  - Seasonal mean
  - Total days w/ light, moderate, and heavy snow
- Monthly mean NAO index (CPC)
- NCEP/NCAR Reanalysis: Surface and upper-level circulation

Winter (NDJFM) NAO Index: 1961-2010



METHODS

Statistical Analysis: Nonparametric

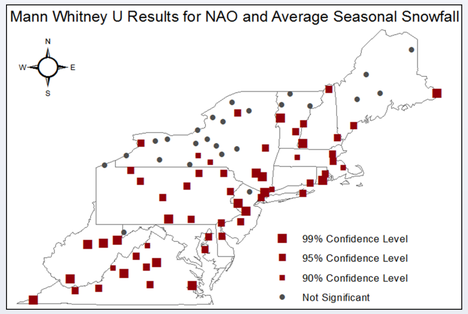
- Spearman's Rank Correlation Coefficient
  - Relationship: NAO index and seasonal snowfall total
- Mann-Whitney U Test
  - Snowfall differences between NAO phases

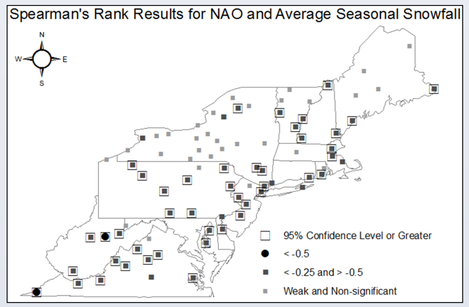
Composite Analysis: Circulation anomalies by NAO phase

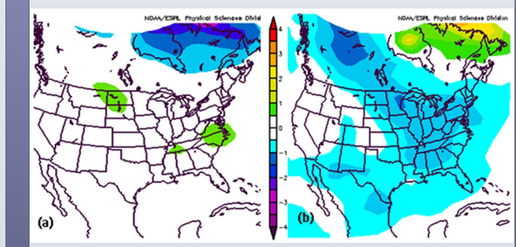
Case Studies: February 25-27, 2010 and February 24-26, 2011

- Analyzed two snow events in opposite NAO phase
- Explanation for statistical and composite analysis results

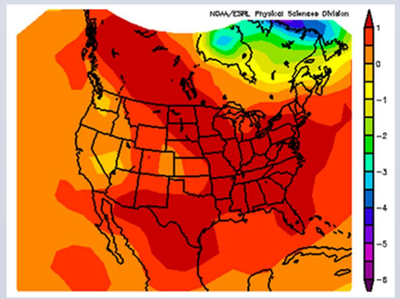
RESULTS







Composite analysis of seasonal surface air temperature (°C) anomalies expressed as departures from the 1981-2001 means during (a) NAO positive years and (b) NAO negative years from 1961-2010 (Data: Kalnay et al. 1996)

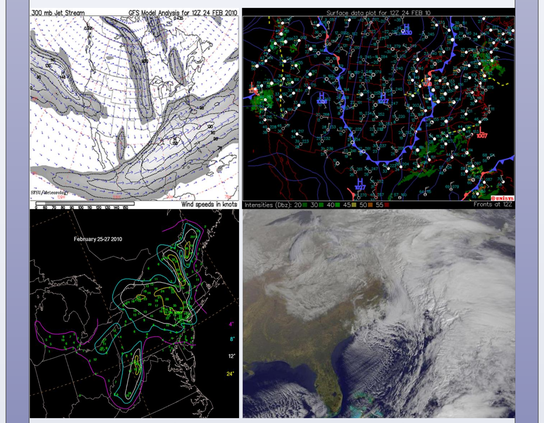


Composite analysis of seasonal mean surface air temperature (°C) of NAO positive years minus NAO negative years from 1961-2010 (Data: Kalnay et al. 1996)

CASE STUDIES

NAO (-): FEBRUARY 25-27, 2010

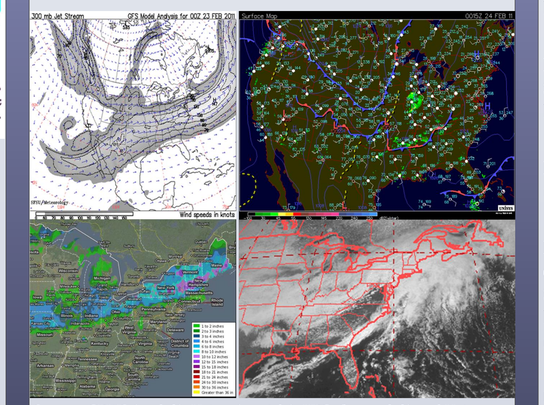
- Cape Hatteras Low merged with occluded low from the Midwest and generated a Nor'easter



Sources: CRWS (top left), Unisys (top right), HPC (bottom left), and NASA (bottom left)

NAO (+): FEBRUARY 24-26, 2011

- Southern Great Plains low progressed to the Northeast via the Ohio River Valley



Sources: CRWS (top left), Unisys (top right), HPC (bottom left), and Unisys (bottom left)

CONCLUSIONS & FUTURE WORK

SUMMARY

- Northeast overall showed greater snowfall during NAO (-)
  - East Coast and mid-Atlantic/southern Appalachians
- Some areas receive snowfall in either extreme NAO phase
  - Western/central New York, northern Vermont, and Maine
  - Local influences: lake-effect and orographic uplift
- NAO (+) trend from 1961 to 2010
  - Yet intermittent strong NAO (-) years produced higher frequency of snowfall days and amounts
  - High NAO phase variability since 2000
- The spatial distributions of snowfall in each case study corresponded well with the statistical and composite analyses

FUTURE WORK

- Currently conducting statistical analysis with de-trended NAO index using a DJF winter season

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