# Impacts of winter-NAO on March cooling trends over subtropical Eurasia continent in the recent half century

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[1] At odds with global warming trends, surface air temperature over large subtropical Eurasia continent in spring March exhibits unique strong cooling over the last half century. The cause for this cooling is shown to be related to Winter (DJF) North Atlantic Oscillation (W-NAO). Positive values of W-NAO provoke cooling signals in northern Africa continent simultaneously from surface to tropopause. The W-NAO generated signals barotropically extend eastward over most of subtropical Eurasia and reaches eastern China in March. *INDEX TERMS:* 1620 Global Change: Climate dynamics (3309); 1610 Global Change: Atmosphere (0315, 0325); 0325 Atmospheric Composition and Structure: Evolution of the atmosphere. **Citation:** Yu, R. C., and T. J. Zhou (2004), Impacts of winter-NAO on March cooling trends over subtropical Eurasia continent in the recent half century, *Geophys. Res. Lett.*, *31*, L12204, doi:10.1029/2004GL019814.

## 1. Introduction

[2] As reviewed by *Marshall et al.* [2001], the North Atlantic Oscillation (NAO) exerts a dominant influence on temperatures, precipitation and ecosystems over most of the northern hemisphere. The most profound remote influence is that NAO is significantly correlated with the wintertime surface air temperature in wide regions across the North Atlantic basin eastward to most of Eurasia and northern Africa. For Eurasia area, many attentions are paid to the positive correlation between the NAO signal and the surface air temperature over most of northern Eurasia [*Hurrell*, 1995, 1996; *Hurrell et al.*, 2001; *Marshall et al.*, 2001; *Cohen*, 2003]. Recently the NAO indices have been related with the variations of Asian summer monsoon [*Chang et al.*, 2001; *Gong and Ho*, 2003]. But the cause of the far remote connection is not clear. Here evidence is presented to show that positive NAO will provides a eastward extended cooling signal over northern Africa and the significant cooling signal will reach India in February and reach eastern China in spring March, which passingly explain the negative correlation between winter western European surface air temperature and spring Indian surface air temperature in *Chang et al.* [2001]. The recent upward NAO provided cooling signals induce the unique March cooling against other months warming over subtropical Eurasia continent.

## 2. The Unique Cooling Trends in March Over Subtropical Eurasia Continent

[3] Based on the Land Surface Air Temperature (LSAT) data at grids of 0.5° by 0.5° [*Willmott and Robeson*, 1995], the changes (1975–1999 minus 1950–1974) in the LSAT are examined for each of 12 months. It is found that unique coherent LSAT cooling occurs in March subtropical Eurasia continent as shown in Figure 1a. The area averaged variation of March LSAT over sum of regions (35°E–80°E, 25°N–35°N) and (103°E–118°E, 27°N–32°N) is shown in Figure 1b. The annual cycle of the area averaged changes (1975–1999 minus 1950–1974) in the LSAT are shown in Figure 1c. It is only in March that strong cooling change appears over subtropical Eurasia continent. There are moderate cooling trends in February at western part and in April at eastern part of selected areas (not shown). Against the cooling trends, strong warming trends over the Tibetan Plateau broke the coherent cooling region into two parts.

[4] Previous work reported a significant trend in the NAO and the Eurasian surface temperature [*Hurrell*, 1995]. Further analysis indicates that the unique coherent LSAT cooling shown in Figure 1a is mainly resulted from this trend. Shown in Figure 1d is the linear trend in Eurasian surface temperature expressed in terms of 25 years accumulation, it strongly resembles Figure 1a in spatial pattern. The temperature data in grids of 0.5° by 0.5° used above is resulted from the spatial-based interpolation of station data. For comparison, we re-drew Figure 1a and 1c by using the Jones' data in grids of 5° by 5° [*Jones and Moberg*, 2003], which is mainly derived from the observation within each box. The strong cooling change still dominates the subtropical Eurasia continent and remains to be strongest in March (figures omitted). These two datasets agree well in general features, and the unique March cooling trends over subtropical Eurasia continent are believable.

## 3. Winter NAO Signal in the March Cooling Trends

[5] The time series of Hurrell's winter (DJF) NAO (W-NAO) index (http://www.cgd.ucar.edu/~jhurrell/nao.stat.other.html) [*Hurrell*, 1995] are used to compute teleconnections between the NAO signal and the LSAT. A 10-years running mean of the W-NAO index is shown in Figure 1b. Figure 2 shows correlation coefficients between the W-NAO indices and the LSATs in January (Figure 2a), February (Figure 2b), March (Figure 2c) and April (Figure 2d). During wintertime, the positive W-NAO provokes significant cooling signal in the northern Africa, the signal then propagates eastward quickly. In January, the cooling signal occupies almost all of the northern Africa and eastward across the Arabian Sea. From January to March, the cooling signal propagates eastward with slight diminishing of intensity. The cooling signal extends across the Indian Peninsula, Bengal and Burma in


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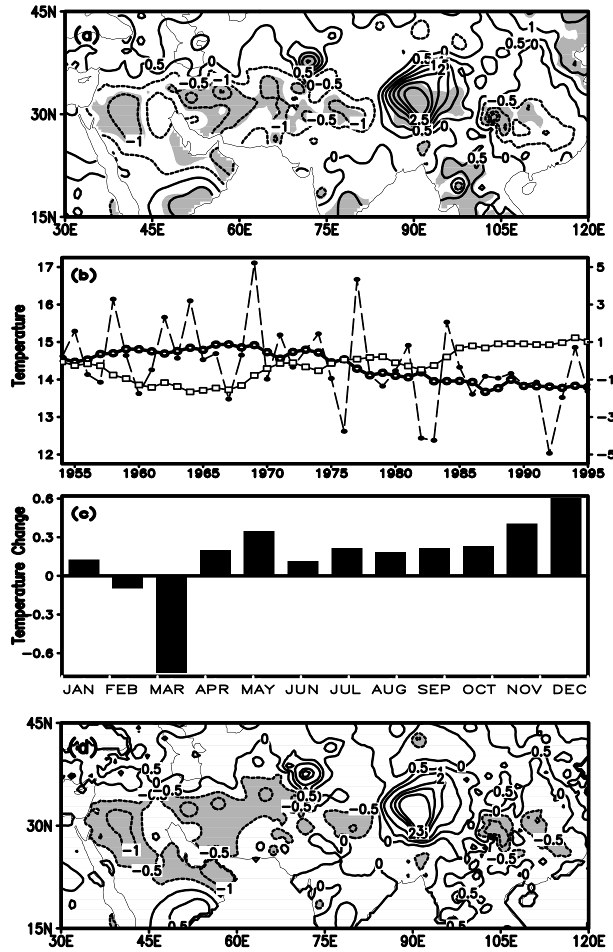


**Figure 1.** (a) Climatic mean changes (1975–1999 minus 1950–1974) in March land surface air temperatures (LSATs) in units of °C. Shaded regions are of 95% confidence significant by using a student-t test. Contour intervals are 0.5°C for changes below 0.5°C and 1°C for changes above 1°C respectively. (b) 1954–1995 time series of March LSAT averaged over sum of regions (35°E–80°E, 25°N–35°N) and (103°E–118°E, 27°N–32°N). The dashed line with filled circle represents yearly variations and the solid line with open circle represents the 10-years running mean. The solid line with open square shows 10-years running mean winter (DJF) NAO indices for comparison. (c) The area averaged monthly mean LSAT change bars (1975–1999 minus 1950–1974) for each of 12 months. (d) The linear trend in the past 50 years in unit of °C/25 years. The global LSAT data come from Willmott and the winter NAO indices come from Hurrell.

February and reaches the upper Yangtze River valley of China in March. When the NAO index and grid surface temperature are linearly detrended before the calculation, the time-lag correlation pattern is still similar (figures omitted). The well-matched negative correlation in Figure 2c versus cooling change in Figure 1a indicates that the recent upward trend in NAO index plays an important role in the March cooling over subtropical Eurasia continent. The cooling signal almost totally disappears in April as shown in Figure 2d. It is consistent with the monthly climatic surface air temperature changes in Figure 1c. From March to April, the temperature changes reverse rapidly from strong cooling to moderate warming. In addition, given the facts that NAO is still strong in March, and that the anomalous winter-NAO can persist into March (the DJF NAO index has a correlation coefficient of 0.24 with the following March NAO index), the simultaneous correlation between NAO index and surface temperature in March (figure omitted) resembles Figure 2c.

## 4. "Barotropic Structure" of the W-NAO Generated Signals

[6] As pronounced "equivalent barotropic" structure of NAO [*Kushnir and Wallace*, 1989], accompanying the March surface cooling signals due to positive W-NAO indices, full of vertical tropospheric atmosphere exhibits a similar eastward extended cooling feature as shown in

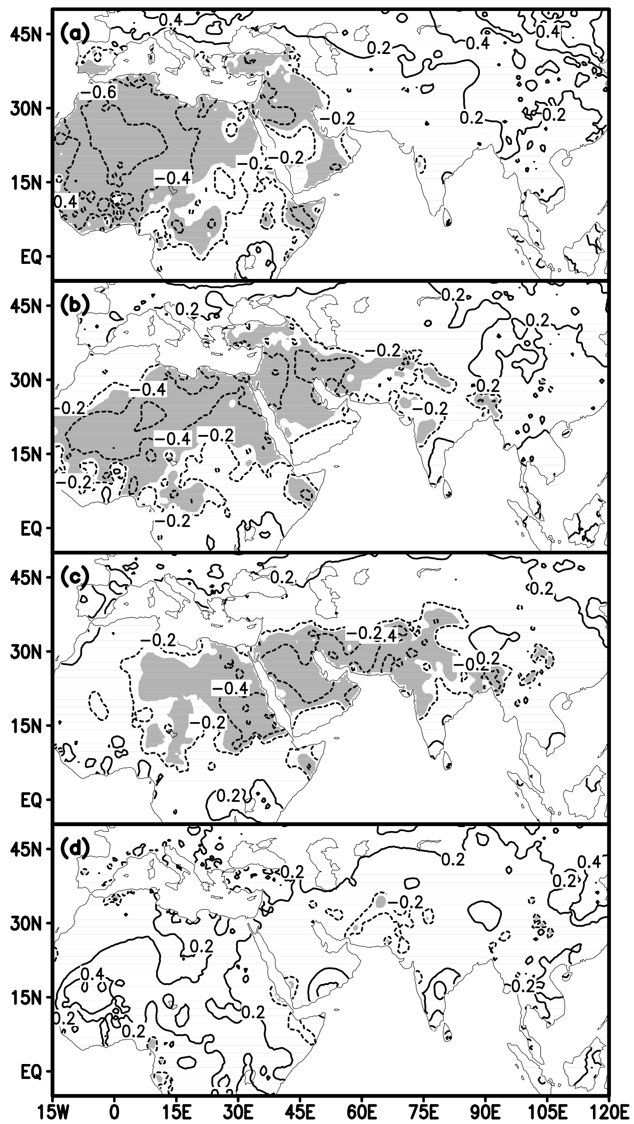


**Figure 2.** Distribution of correlations (contour interval 0.1) between the winter NAO index and Willmott's LSATs in January (a), February (b), March (c) and April (d), from 1950 to 1999. Correlations significant at 5% and above are shaded.

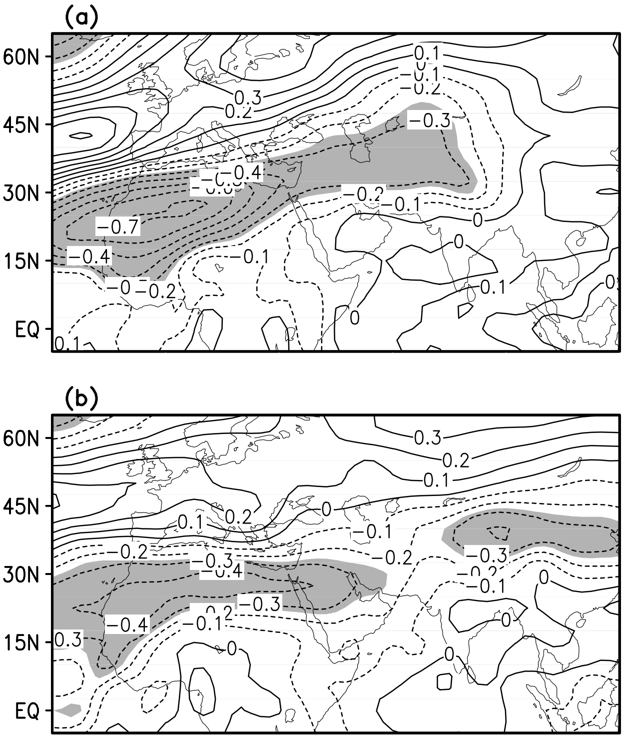


**Figure 3.** Distribution of correlations (contour interval 0.1) between Hurrell's winter NAO index and air temperature at 500 hPa in February (a) and March (b) from 1948 to 2002. Correlations significant at 5% and above are shaded. The air temperature data come from NCEP/NCAR reanalysis.

Figure 3 and Figure 4. The atmospheric data are derived from the National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) reanalysis data [*Kalnay et al.*, 1996] at a horizontal resolution of 2.5° by 2.5°and a vertical resolution of 17 pressure levels. Figure 3a and 3b show correlation coefficients between the W-NAO indices and 500 hPa air temperatures in February and March respectively. The significant negative correlation shifts northward in the upper troposphere in Figure 3b and southward in the surface in Figure 2c after meeting the Tibetan Plateau. To exhibit the full tropospheric structure, Figure 4 presents the zonal-height cross-sections of the correlation coefficients between the W-NAO and temperature in January (Figure 4a), February (Figure 4b), March (Figure 4c) and April (Figure 4d). The negative correlations, indicating cooling signal of positive W-NAO, in the tropospheric atmosphere presents a barotropic eastward extending feature (Figure 4a–4c) and the significant correlations almost disappear in April to the west of the Tibetan Plateau (Figure 4d), similar as that in surface cooling, but the cooling signal to the east of the Tibetan Plateau is robust in the upper troposphere after March.

## 5. Concluding Discussions

[7] Above results present the unique March cooling trends over the subtropical Eurasia continent and the March surface air temperatures are significantly correlated with the W-NAO indices. The positive values of W-NAO provide significant cooling signals simultaneously over almost all of the northern Africa from surface to tropopause. The cooling signals exhibit quick barotropically eastward extending to all subtropical Eurasia continents in about two months and result in the unique March cooling trends over the subtropical Eurasia continent. However, following questions are waiting for further study.

[8] (1) What is the mechanism involved in the teleconnected signals extending? Former studies suggest that snow cover and sea surface temperature might be partially forcing the atmosphere on inter-annual to decadal time scales [*Czaja and Frankignoul*, 1999; *Saito and Cohen*, 2003; *Bojarium and Gimeno*, 2003].

[9] (2) What is the role of the Tibetan Plateau forcing? Why is the plateau surface warming against around cooling in March and why are cooling signals more persistent over upper troposphere of northern China?

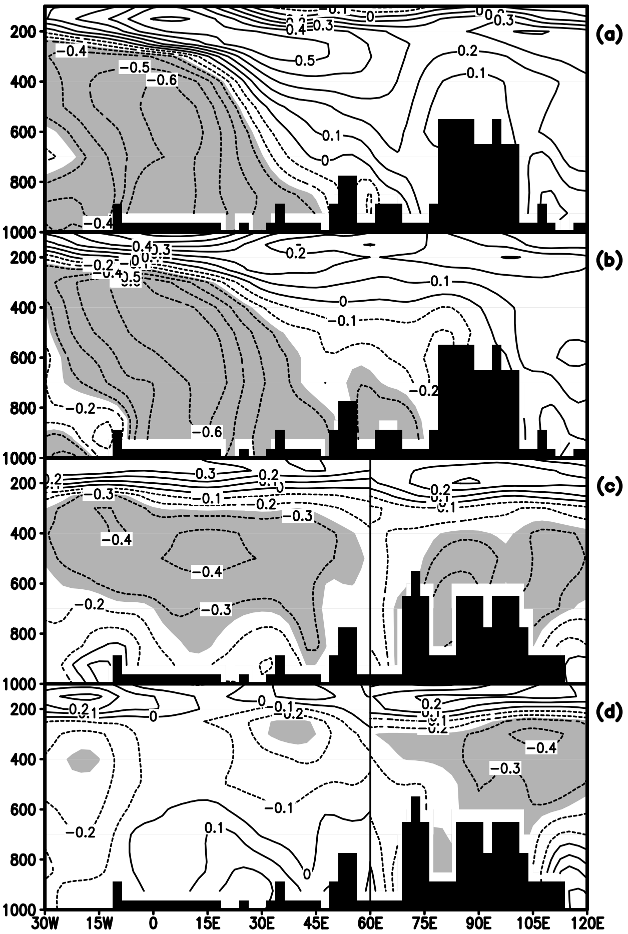


**Figure 4.** Zonal-height cross sections of correlation between Hurrell's winter NAO index and air temperature in January (a), February (b), March (c) and April (d), from 30°W to 120°E zonally and from 1000 hPa to 100 hPa in vertical. The correlation coefficients are computed by using data from 1948 to 2002. The longitude average of cross section is taken from 27°N to 32°N except in (c) and (d) from 60°E to 120°E where averaging from 34°N to 39°N referring to Figure 3b. Correlations significant at 5% and above are shaded. The air temperature data come from NCEP/NCAR reanalysis.

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