11: North Atlantic Oscillation

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What is the NAO and how does it affect climate?

The North Atlantic Oscillation (NAO) is a large-scale mode (i.e., pattern) of natural climate variability that has important impacts on the weather and climate of the North Atlantic region and surrounding continents, especially Europe. Although the NAO occurs in all seasons, it is during winter that it is particularly dominant, and therefore the focus of this information sheet is on the December to March period.

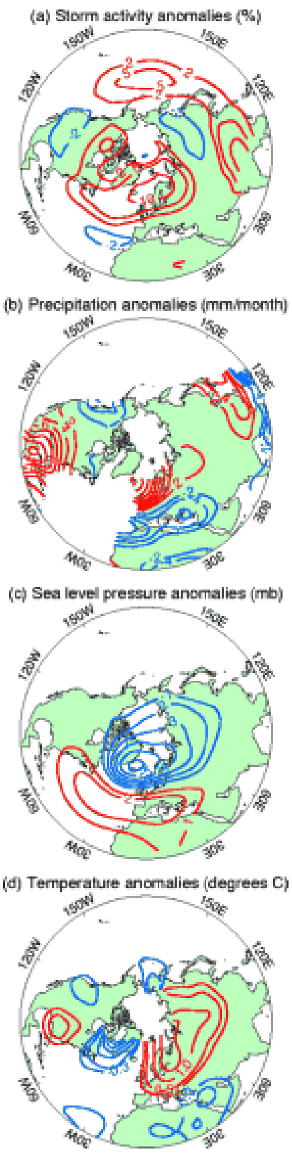

Figure 1: Average anomalous conditions during high NAO winters
(Postscript version)

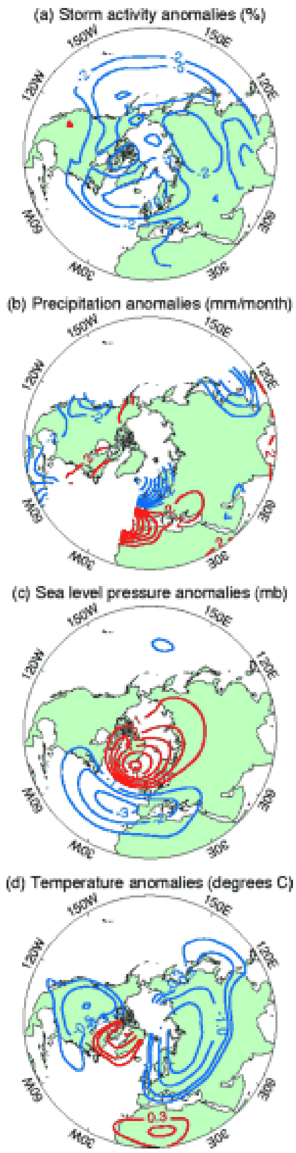

Figure 2: Average anomalous conditions during low NAO winters
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The NAO is a north-south shift (or vice versa) in the track of storms and depressions across the North Atlantic Ocean and into Europe. The storm track exhibits variations from winter to winter in its strength (i.e., number of depressions) and position (i.e., the median route taken by that winter's storms), but a particularly recurrent variation is for the storm track to be either strong with a north-eastward orientation taking depressions into NW Europe (a *high* NAO winter, Figure 1a) or weaker with an east-west orientation taking depressions into Mediterranean Europe (a *low* NAO winter, Figure 2a). Since the Atlantic storms that travel into Europe control our rainfall, there is a strong influence on European precipitation patterns (with a wet northern Europe and a dry Mediterranean Europe during a high NAO winter, Figure 1b, and the opposite during a low NAO winter).

The year-to-year variability in storm tracks is associated with a change in the mean atmospheric circulation averaged over the winter season. This is evident in the anomalous sea level pressure (SLP) patterns associated with high or low NAO winters (Figures 1c and 2c). When the Iceland Low pressure centre is deeper than usual, the Azores High is stronger than usual, and vice versa. The change in the mean atmospheric circulation drives patterns of warming and cooling over much of the northern hemisphere (Figures 1d and 2d). For example, when the NAO is high, the SLP gradient between Iceland and the Azores/Iberia is enhanced (Figure 1c), driving stronger westerly and southwesterly flow that carries warm maritime air over the cold winter Eurasian land mass, bringing anomalously warm winter temperatures (Figure 1d).

How do we measure the NAO and how has it varied?

The sea level pressure averaged over the winter is easier to measure (and we have longer records) than the storms themselves, so the variability of the NAO can be measured by the difference between the mean winter SLP at Gibraltar and the mean winter SLP over Iceland. Some people use Lisbon or the Azores instead of Gibraltar, but it makes little difference. Figure 3 shows the variation in this index of the NAO from the early 1800s to the winter of 1999/2000. This figure, and the underlying data, are regularly updated on the CRU website. Note the high year-to-year variability in the NAO, but also the upward trend from the 1960s to the early 1990s whose possible cause has not yet been identified.

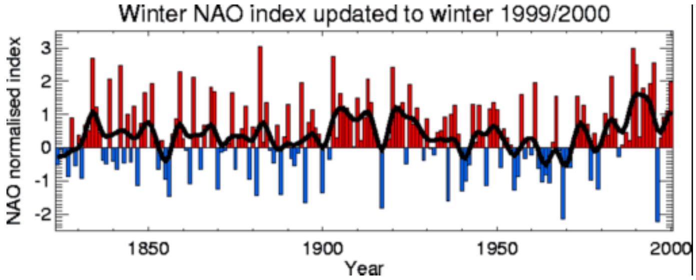

Figure 3
(Postscript version)

How well can we forecast the NAO?

Because the influence of the NAO is so strong on the winter climate of Europe, if the state of the NAO (i.e., the value of the NAO index) could be forecast in advance (say 6 months ahead) then extremely valuable seasonal climate forecasts could be made for Europe. Unfortunately, the NAO is a noisy mid-latitude phenomenon and even the best predictions to date have not be able to capture more than 10% of its year-to-year variance. David Stephenson outlines the potential for forecasting the NAO on his website (http://www.secam.ex.ac.uk/cat).

Looking further ahead, there is the possibility that climate change may induce a change in the state or behaviour of the NAO. Unfortunately, the global climate models that are used to study anthropogenic climate change do not yet give unequivocal predictions for the future of the NAO, linked to the fact that the NAO is related to the tracks of Atlantic storms, and predictions of storminess changes are also currently uncertain.

Acknowledgements

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