Geo Factsheet

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North Atlantic Oscillation: El Niño's Atlantic Partner

Introduction

The media often attributes unusual weather patterns to El Niño - Southern Oscillation (ENSO). Yet there is another large-scale climate pattern that has been overlooked. It's El Niño's fickle Atlantic sister, the North Atlantic Oscillation. First noticed by Norse seafarers many centuries ago, it is the most significant driver of climate variability in the middle and high latitudes of the Northern Hemisphere. It regularly stirs up trouble in Europe, Canada, and the eastern United States yet when did you last hear about it? Have you ever heard about it?

So what is the NAO?

The acronym NAO (North Atlantic Oscillation) is used to describe the fluctuations in the strength of air pressure between two key locations over the North Atlantic Ocean, a low pressure system that forms around Iceland and a high pressure in a region called the Azores (to the west of Portugal). These two weather systems appear to have a controlling influence on the strength and track of depressions as they form in the North Atlantic and head towards Europe. They also play a crucial role in determining temperature and precipitation across northern and southern Europe, the United States and beyond.

How does it work?

Table. 1 shows the two opposing states of the NAO, referred to as positive and negative. In each state pressure changes influence the movement of the jet stream and associated weather.

Table 1 Positive and negative NAO.

Positive NAO	Negative NAO
Azores High increases	Azores High weakens
Icelandic Low deepens	Icelandic Low shallows
Increased pressure difference	Decreased pressure difference
Higher wind speeds	Lower wind speeds
More depressions	Less depressions
Jet Stream tracks North	Jet Stream tracks South

Positive NAO

In diagram 1 air turns counter-clockwise around the low-pressure centre over Iceland and, moves clockwise around the Azores high. These two systems work like giant wheels spinning over the Atlantic, in a figure-8 formation. The flow around these two systems meets at about 45° north and the jet stream that naturally flows west to east in the gets channelled straight through the meeting point by these spinning wheels.

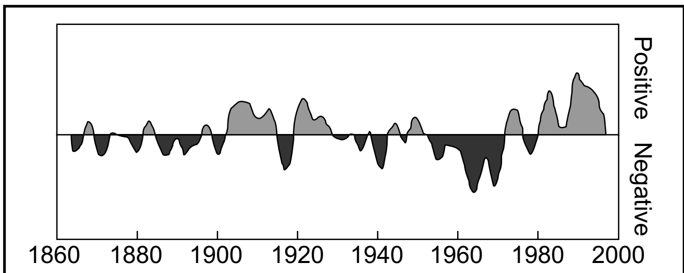
In a positive NAO phase, the high and low are particularly strong speeding up the passage of the jet stream and associated depressions on a brisk north-eastern path. The depressions pick up warmth and moisture from the Atlantic Ocean and carry it over Northern Europe, dropping as much as 3.6mm per day of extra rainfall and warming the area as much as 3°C.

The remainder of the air swirling around the low and the high create more weather changes. The northwest edge of the Icelandic low throws dry, cold air from the Arctic to the south, cooling Northern Canada and Greenland. Meanwhile, warm air from the Caribbean gets cycled around the Azores high, to the US east coast warming its winter.

Negative NAO

In a negative NAO phase *(Fig. 1)*, the low and high weaken. The wheels slow down, weakening the drive of the jet stream. This slow down allows the jet stream to meander and depressions to drift toward Southern Europe, releasing the rain and warm weather there instead. The North-westerly Arctic air is also less directed, and descends further into the northeast US and Northern Europe, bringing with it cold weather and windy winters. Northern Canadian and Greenlandic winters becoming relatively mild.

Fig. 1 NAO Index.



Why does this occur?

At the moment there is no clear scientific agreement on the precise cause of NAO fluctuations but a number of observations have lead to two principle theories being forwarded:

1. The event is initiated as a result of upper air Rossby Wave fluctuations. Some studies suggest that changes in NAO occur when the amplitude of Rossby waves gets too large, distorting the shape and collapsing into a turbulent flow. When this happens over the Atlantic, the turbulence disturbs the jet stream within the wave and pushes it to the north or south and it is the path of the jet stream that influences the passage of weather systems to different parts of Europe.

2. Another theory is based on the observation that Sea Surface Temperatures (SSTs) and the strength of the NAO are related. During a positive year the ocean warms just off the East coast of America and cools in the sub polar region between the UK, Newfoundland and Iceland. The Gulf Stream transports those temperature anomalies downstream towards Europe. Some scientists have suggested that the storage and movement of SSTs anomalies by the ocean gives an important feedback to atmospheric heating and cooling and is responsible for the pressure systems which move the position of the jet stream.

How often does NAO occur and can we predict it?

Unlike the El Niño Southern Oscillation (ENSO), the NAO varies on a daily basis. Weather stations in Iceland, the Azores and Lisbon take two surface air pressure readings every day throughout the winter period (November – March) when the NAO is most noticeable.. These readings are then averaged to construct an NAO index which shows the direction and strength of the major variations from year to year.

Early records during the 19th century show a relatively regular fluctuation between the two states, however, sometimes the NAO index stays in one state for many years in a row- even for decades, as in the early part of the 20th century. The same can be said of the current trend of positive NAO which began in 1972 and continues to this day with more peak positive years, including the highest on record in1989. Some climatologists link this trend with the enhanced greenhouse effect while others believe that records do not go back far enough to rule out a natural fluctuation in the index over longer timescales. However, all scientists believe that an effective prediction system would be very beneficial for businesses, governments, and individuals. Growing seasons and crop yields could be anticipated, ecosystems could be protected, water and energy resources could be managed and financed better.

Met Office forecasters are still in the early days of being able to provide accurate forecasts of the next years NAO leanings and strength, and are forecasting correctly around two thirds of the time. The current forecasting system is based on the collection of SSTs in May in order to predict the following years NAO and general seasonal forecast.

The idea is that by the spring of each year the NAO has led to alterations in the Atlantic's temperature at depth. These temperature readings are 'preserved' by a thin layer of surface water heated by the sun during the summer which acts like a duvet. When the winter comes the warm layer is removed revealing the SSTs from the previous spring- these in turn affect the air pressure and influence the next NAO.

What are the Impacts of the NAO?

Linking events to NAO cycles is not an exact science. and There has been much criticism over the lack of holistic thinking between NAO, ENSO and Climate change. There is some new research coming to the fore that suggests that not only are ENSO and NAO linked in some way but also that the last few decades of positive NAO may be due to climatic forcing, caused by CO_2 omissions and climate changes. *Table 2* outlines some of the major impacts linked to NAO changes in the key areas around the North Atlantic. Other evidence suggests there are wider teleconnections of the more positive shift even linking it with warmer winters in cities across the Northern Hemisphere, including Seattle, Dallas, Paris, and Tokyo.

Effects of Positive NAO trend since the 1970's

As we have seen from the NAO index there has been a strong positive trend over the last 30 years. This trend has had a significant and cumulative effect on some countries around the Atlantic. The two case studies below illustrate how this trend is affecting both Northern and Southern Europe in different ways, favouring one country and significantly impacting another.

Table 2 An overview of NAO Impacts.

Location	Positive NAO	Negative NAO
N. Europe	Drier and sunnier conditions across the French Riviera boost tourism income. Warmer conditions in Sweden increase the length of the growing season by 20 days.	Cold and dry conditions across Austria improve the skiing conditions and boost winter tourism. Very low temperatures in Denmark lead to downed power lines and increased accident rate.
S Europe	Decreased precipitation and flow of Tigris-Euphrates river systems by up to 50% leading to droughts and conflict between bordering countries.	Warm and wet conditions across Greece, Portugal, Spain lead to increased Olive and Grape production.
USA	Eastern states (Washington-New York) experience milder winter temperatures reducing the amount of snow fall. Central states receive increase rainfall and river runoff leading to floods such as the Mississippi floods 1993.	Increase in the number and strength of North Atlantic Hurricanes. Scallop fisheries on eastern Long Island coasts devastated by harmful algal blooms which starve scallops by paralysing their feeding mechanisms.
Atlantic Ocean	Increase in storms from positive phases has boosted wave heights by more than 10% in the North Atlantic over the last 30 years. To protect from these more likely events, oil companies are strengthening and raising the decks of new rigs, pushing up the cost of oil. Arctic Sea Ice can be up to 50cm thinner and break up earlier in positive phase. This is leading to a reduction in the extent of sea ice over the last 30 years. Atlantic cod landings have been slumping for decades. Repeated positive NAO phases have been offered as a cause, driving colder waters into the Labrador Sea slowing cod growth and reproduction rates.	Arctic ice shelves are slow to break up

Case Study 1: Norway's Energy Consumption

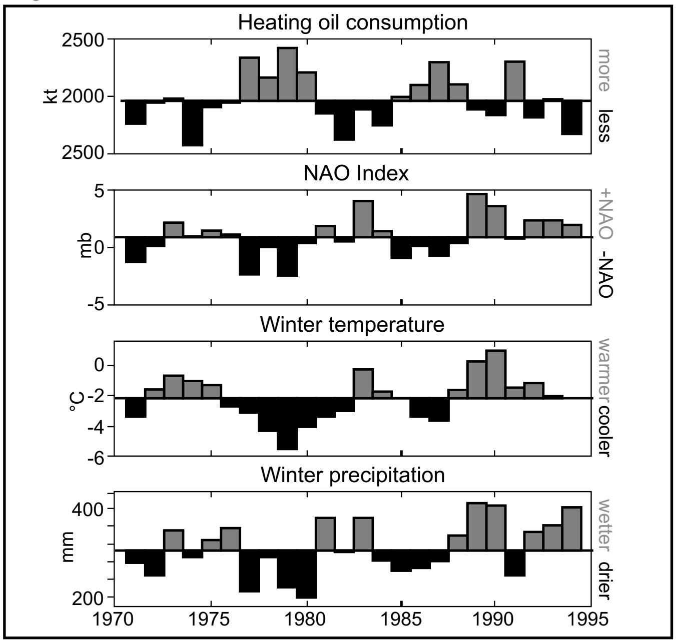
Norway is a country which is significantly affected by the NAO in both temperature and precipitation which impacts heavily on the country's energy consumption.

There is a strong positive correlation between the NAO index and winter temperatures. A negative index can cause temperatures to be up to 5.5°C lower than during a winter with a positive index. As a result the consumption of oil for heating systems also varies significantly with up to a 30% increase during a negative year.

Winter precipitation in Norway also mirrors the NAO pattern with quantities varying by as much as 100mm between the extremes. In a positive index year this additional water makes a significant difference to Norway's hydroelectric systems and results in a surplus of energy which can be exported to neighbouring Scandinavian counties.

The positive trend over the last thirty years has subsequently boosted Norway's export of energy by over 130 TWh since 1974 adding to the fact that Norway's per-capita income is one of the highest in the world.

Fig. 2



Case Study 2: Turkey's Water Supply & Agriculture

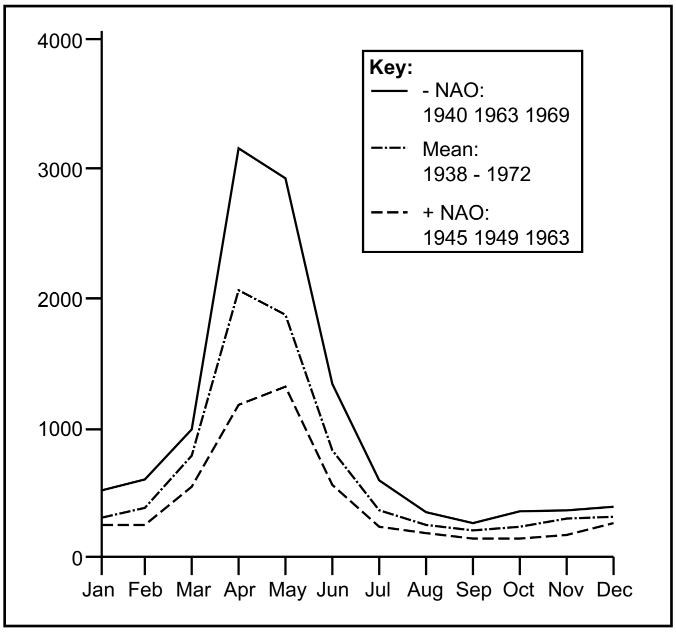
The precipitation patterns in Turkey are well correlated with the phases of the NAO index. The Euphrates' stream flow in Spring varies by about half with the NAO index, staying low during a positive year. Unfortunately since the persistence of a more positive phase in the 1970s precipitation totals have been falling year on year.

Tuz Gölü, a large salt lake in central Turkey has lost half of its water volume in the last three decades. The surrounding Konya Basin, which holds a third of Turkey's groundwater reserves, has seen a water table drop of 1-2 meters over the same time period.

In 2007 the combination of the increased aridity and summer temperatures of 460c impacted heavily on agriculture with 30% lower yields in cotton, corn and tobacco, 15% less wheat and 50% less figs costing over $3.9 billion.

Drought also affected the capital, Ankara with serious water rationing (two days on, two days off) and car washing and lawn watering were outlawed. With the burst of the main water pipe feeding the metropolis, the whole city was left without running water for an entire week. Hospitals were issued groundwater in tankers, and the government delayed school openings until mid-October to contain the potential spread of disease.

Fig. 3



Conclusion

Although still a relatively new field of research NAO science has obvious repercussions for the counties around the Atlantic. It plays a clear role in the supply and demand of energy in counties such as Norway, currently favouring their economy. Southern Europe's water supply and demand is of increasing concern as is the agriculture and tourism which depend upon it.

Over the next decade it is likely that research will show an even larger impact generated by the NAO and that it will find its way into the media alongside El Niño and global climate change. It is also possible that our understanding of the process will increase and allow for a more accurate prediction system which could have many positive consequences. However, if the trend of the last few decades continues it is also likely that the consequences of NAO will also become much more widely felt as part of our ever changing climate. Therefore, do not blame all extreme weather on global warming.

Useful websites

- North Atlantic Oscillation: www.ldeo.columbia.edu/res/pi/NAO/
- MET Office has a useful article on NAO prediction: www.metoffice.gov.uk/research/seasonal/regional/nao/index.html

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