Weather More

Unit 2

More about the major wind systems,the Southern Oscillation Index and the North Atlantic Oscillation

The different warming of our planet depending on the latitude and the allocation of water and land is the driving engine of the wind systems of our planet Earth. Monsoons and trade winds are examples of two such systems.

Many of the traditional names of the wind zones have their roots from the time when sailing ships were used in the middle ages, when calms and storms could often decide about life and death. The El Niño phenomena, which is based on pressure variances, in this case over the mid Pacific, has a strong influence on temperature and precipitation on several continents. The weather in Europe and in the Mediterranean region, however, depends more on the North Atlantic Oscillation. You will learn more about these systems in the following sections of this unit.

1. Sailing ship: The Grand Turk
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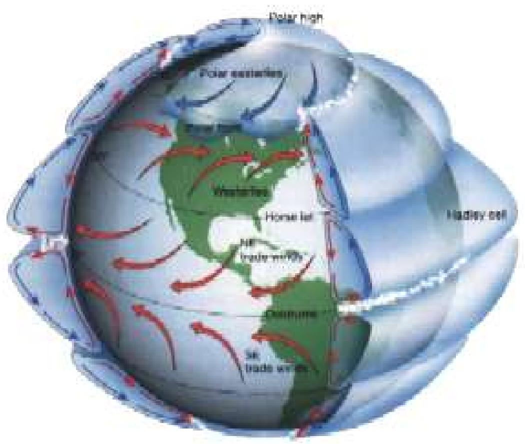
Part 1: Major wind systems

Major wind systems, the trade winds, monsoons

Major wind systems
The incident solar radiation, the distribution of the continents and the oceans, the rotation of the Earth and the land elevation all affect the climate. Most of the solar radiation falls in the Equatorial region. Just slightly to the north of the equator is a region of low winds known as the doldrums. These occur between two windy regions where the trade winds blow.



1. Rotating Earth - Global Circulation

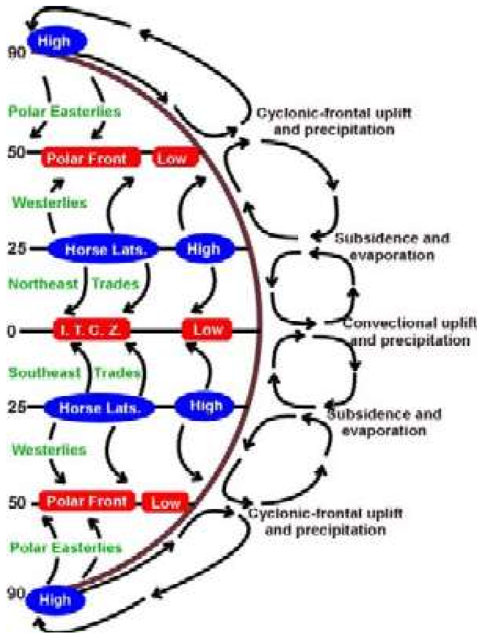
Source: website of University of Michigan-Ann Arbor, Department of Geological Sciences

The large amount of solar radiation that arrives at the Earths surface around the Equator causes intense heating of the land and the ocean. This heating causes warm moist air to rise into the atmosphere leaving an area of low pressure underneath. The region is also characterised by cloudiness, high humidity, light and variable winds and various forms of severe weather including thunderstorms and hurricanes. The doldrums are also noted for calms, these are periods when the winds fall, trapping sailing boats for days.

The air that rises around the Equator cools and descends over the so called horse latitudes. These are two belts of latitude where the winds are light and the weather is hot and dry. They are located mostly over the oceans, at about 30° latitude in each hemisphere. They have a north-south range of about 5° as they follow the seasonal migration of the Sun.
Once the descending air reaches the surface of the Earth, it spreads out towards the Equator as part of the prevailing **trade winds** or towards the poles as part of the **westerlies**. This region in the northern hemisphere is sometimes called the 'calms of Cancer' and called the 'calms of Capricorn' in the southern hemisphere. The horse latitudes supposedly get their name from the days when Spanish sailing vessels transported horses to the West Indies. Ships would often become becalmed in mid-ocean at this latitude, thus severely prolonging the voyage. The resulting water shortages would make it necessary for crews to throw their horses overboard.

Trade winds

The air at doldrums rises high over the Earth, recirculates poleward, and sinks back toward the Earth's surface at the horse latitudes. Surface air from the horse latitudes that moves back towards the equator is deflected by the Coriolis Force. This causes the winds to blow from the north-east in the northern hemisphere and from the south-east in the southern hemispehre. These winds are known as the **trade winds**. In both hemispheres, therefore, these winds tend to blow from the east to the west and towards the equator. Sometimes the trade winds are just called "easterlies" to avoid having to specify the hemisphere. These steady winds are called the trade winds because they provided trade ships with an ocean route to the New World.



2. Global Circulation

source: San Francisco State University (SFSU) website

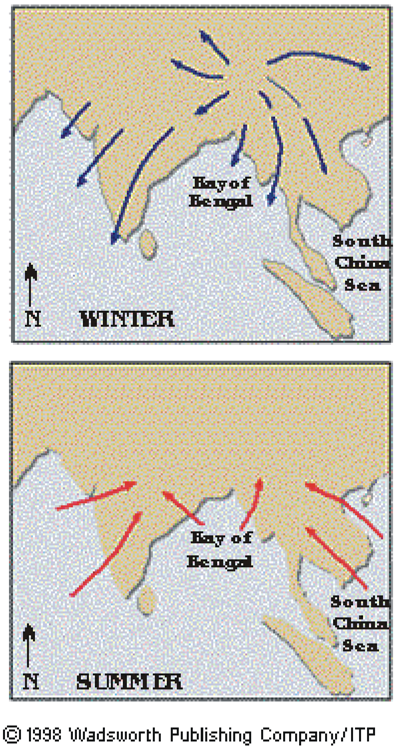
3. Effect in the Indian sub-continent - Monsoon

Photo by Chip Hires

Monsoons

A **monsoon** circulation is determined by the different heat capacity characteristics of continents and oceans. They are similar to sea and land breezes but occur over much larger areas. In summer, the winds usually flow from the water to the land, causing heavy rains inland. In winter, the winds usually reverse and the wind flows from the land to the sea resulting in dry conditions.
The word "monsoon" is derived from the Arabic word "mausim" which means season. Ancient traders sailing in the Indian Ocean and adjoining Arabian Sea used it to describe a system of alternating winds, which blow persistently from the northeast during the northern winter and from the opposite direction, the southwest, during the northern summer. Thus the term monsoon actually refers solely to a seasonal wind shift and not to precipitation.

Even though the term monsoon was originally defined for the Indian subcontinent, monsoon circulations exist in other locations of the world as well, such as in Europe, Africa, Australia, and the west coasts of Chile and the United States. Approximately 65 % of the world's population lives within monsoon regions. The most famous monsoon circulation occurs over India and southeast Asia. During the summer, the air over the continent becomes much warmer than the water surface, so the surface air moves from the water to the land. The humid air from the water converges with dry air from over the continent and produces precipitation over the region. Additional lifting from hills and mountains causes copious amounts of precipitation to occur, over 400 inches at some locations! During the winter the flow reverses and the dominant surface flow moves from the land to the water.



4. Monsoon Circulation

source: Homepage of the Cooperative Institute for Mesoscale Meteorological Studies

The Indian summer monsoon typically lasts from June through September. During this period large areas of western and central India receive more than 90% of their total annual rainfall, while southern and northwestern India receive 50%-75% of their total annual rainfall. Overall, monthly rainfall totals average 200-300 mm, with the largest values observed during the heart of the monsoon season in July and August. Rainfall across southeastern Asia is also monsoonal in nature, with the largest totals typically observed during May-September. Area-average totals normally reach 200 mm in each of these months, with seasonal totals of 1000 mm commonly observed.

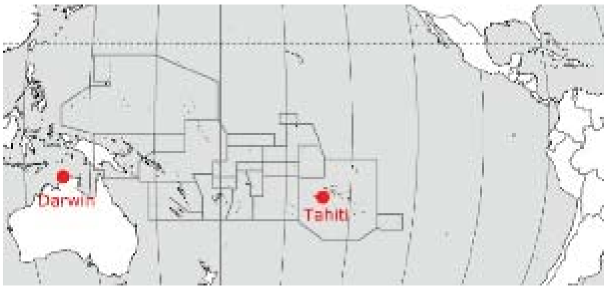
Part 2: El Niño and SOI

The Southern Oscillation and El Niño

Southern Oscillation

The fluctuations in ocean temperatures during El Niño and La Niña events are linked to even larger-scale fluctuations in air pressure between the western and eastern tropical Pacific known as the Southern Oscillation.

The Southern Oscillation is a change in air pressure measured in the Pacific Ocean between Tahiti in the east and Darwin, Australia in the west. When the pressure is high at Darwin, it is low at Tahiti and vice versa.



1. Map of the South Pacific, showing Darwin in Australia and Tahiti, one of the Pacific Islands

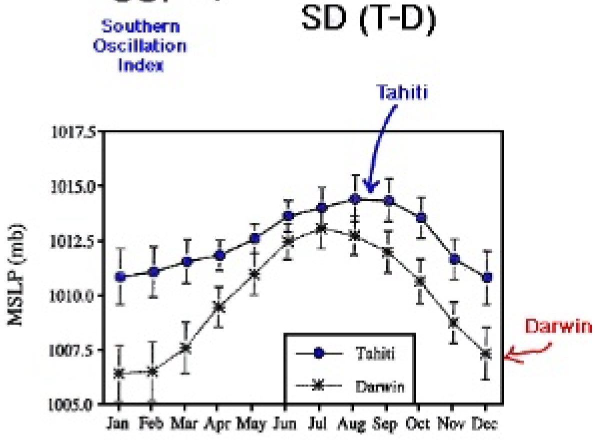
El Niño, and its sister event "La Niña" represent the opposite extreme phases of the Southern Oscillation. During El Niño events higher than average air pressure covers Indonesia and the western tropical Pacific and below average air pressure covers the eastern tropical Pacific.
These pressure departures are reversed during La Niña, which features below-average air pressure over Indonesia and the western tropical Pacific and above-average air pressure over the eastern tropical Pacific.

To sum up:

- El Niño refers to the oceanic component of the El Niño/Southern Oscillation (ENSO) system
- The Southern Oscillation refers to the atmospheric component
- ENSO is the coupled ocean-atmosphere system

ENSO has 3 phases: a warm phase known as El Niño, a cold phase called La Niña and neutral phase when neither El Niño or La Niña conditions occur.

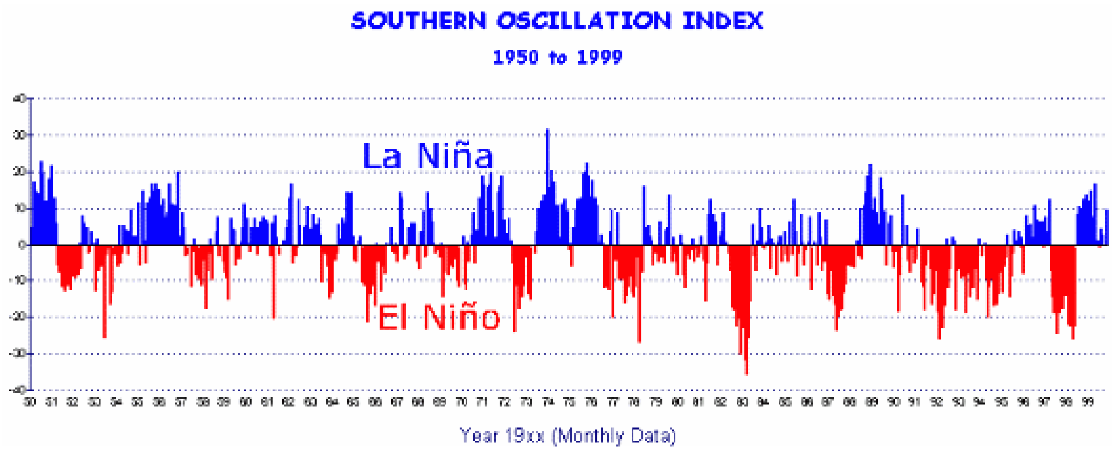
$$\text{SOI} \propto \frac{(\text{Tahiti} - \text{Darwin})}{\text{SD (T-D)}}$$



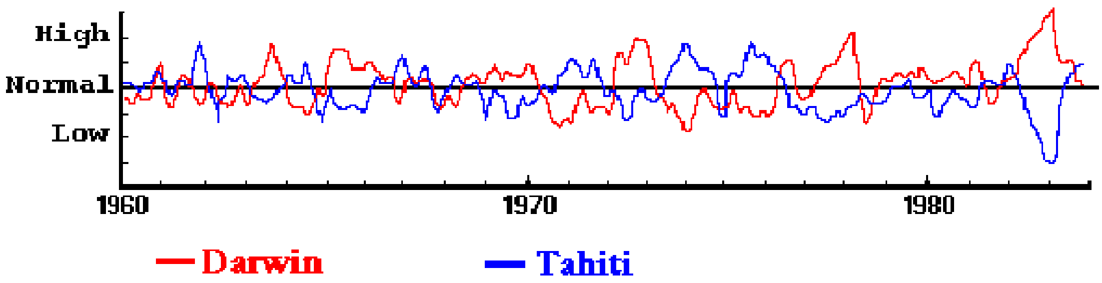
2. The normal mean sea level pressure (MSPL) at Tahiti is higher than at Darwin. If the pressure at Darwin rises relative to Tahiti the SOI becomes negative and we have an El Niño event.
source: Climate System Lectures, Univ. of Columbia, NY

Southern Oscillation Index (SOI)

The Southern Oscillation Index (SOI) is a measure of the strength and phase of the Southern Oscillation. During El Niño episodes the SOI has a large negative value due to lower-than-average air pressure at Tahiti and higher-than-average air pressure at Darwin.
During La Niña episodes, the SOI has a positive value due to higher-than-average air pressure at Tahiti and lower-than-average air pressure at Darwin.
El Niño episodes occur in every 2-7 years.



3. The southern oscillation index SOI. Strong negative red values stand for El Niño events, strong positive blue values stand for La Niña conditions.
Source: Long Paddock website, Gov. of Queensland



4. Sea Level Pressure 1960-1984
source: U. S. Army Topographic Engineering Center

Historical review on El Niño events

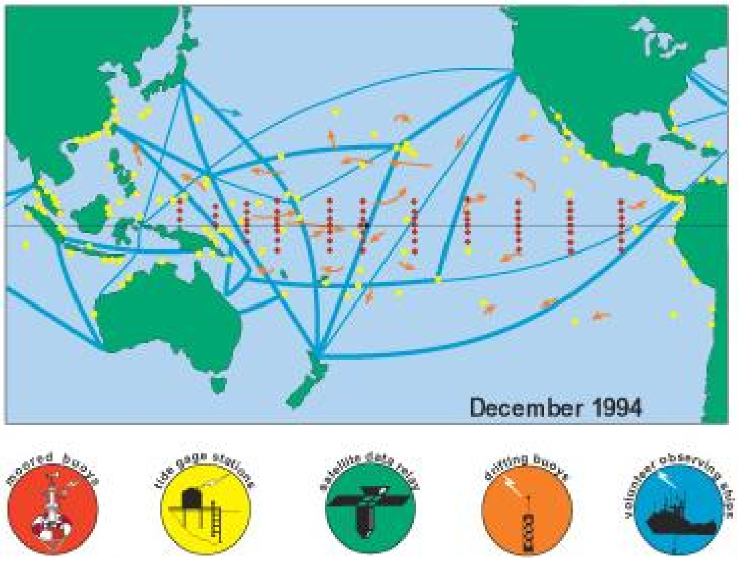
El Niño is not a new phenomenon, it has been around for thousands of years. Chemical signatures of warmer sea surface temperatures and increased rainfall caused by El Niño appear in coral specimens at least 4000 years old, but some researchers claim to have found coral records that hold evidence of El Niño cycles more than a 100,000 years ago!

Records of El Niño events date back as far as the 1500's. At that time fisherman off the coast of Peru started noticing that periodic warm waters resulted in low anchovy catches. However, Peruvian farmers also noted that the warm waters lead to increased rainfall, transforming normally barren areas into fertile farmland.

Between 1700 and 1900 European sailors made sporadic attempts at documenting the phenomenon and scientists became interested in identifying the cause.

5. Fishermen off the coast of Peru. Warm waters during El Niño events reduce the number of fish along the Peruvian coast causing reduced fish catches.
© downtheroad.org - Peru

It wasn't until the middle of the 20th century that the scientific causes of ENSO were worked out. Interest increased in the late 1960's and early 1970's and, using new observations including satellite data, climatologists and oceanographers recognised that El Niño events were much more than just a local feature of climate variability.

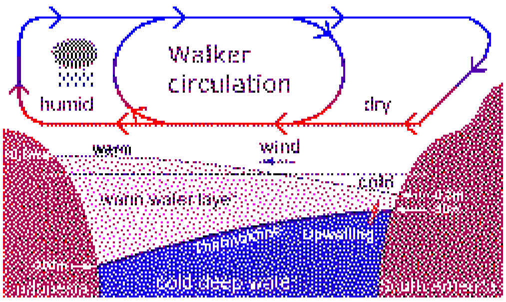


7. Atlas buoy
source: NOAA/PMEL

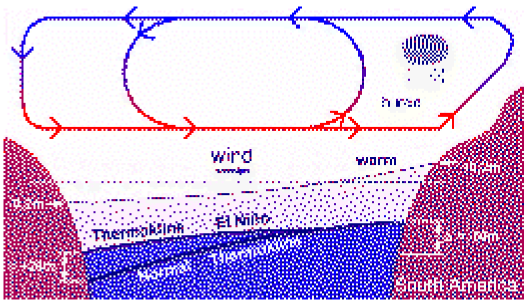
6. Nowadays we record conditions in the Pacific Ocean using fixed Atlas buoys which measure lots of different parameters, both at the surface and at depth. We also use drifting buoys, research ships, coastal tide gauge stations and make measurements of sea surface temperature from space using satellites. All this data forms an El Niño early warning system which helps people prepare for the next El Niño event.

In 1923, a British Scientist, Sir Gilbert Walker discovered that when air pressure is high in the Pacific, it is low in the Indian Ocean from Africa to Australia, and vice versa. His findings, which he named the Southern Oscillation, were the first indication that weather conditions in distant parts of the tropical Pacific region are connected.

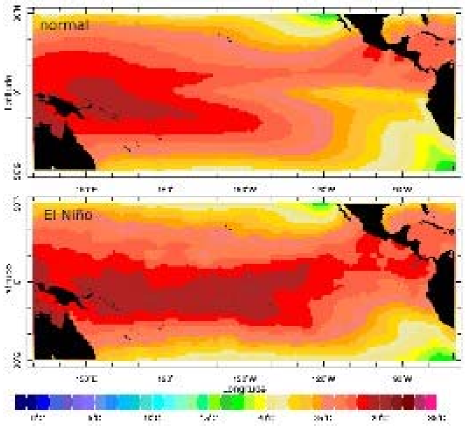
Fifty years later, in the late 1960's, Jacob Bjerknes a Norwegian meteorologist and Professor of the University of California at Los Angeles came up with the first detailed description of how El Niño works. He made the connection between Walker's Southern Oscillation and El Niño and this is now officially known as the El Niño/Southern Oscillation or ENSO for short.



8. a) the Walker circulation over the Pacific. The image shows the circulation for neutral conditions.



8. b) this is what changes during El Niño conditions.



9. Comparison of the absolute sea surface temperature for normal conditions and the El Niño event in 1982.
source: Climate science lecture, Univ. of Columbia, NY

El Niño events and consequences

Between 1982 and 1983, a very strong El Niño caused havoc around the world. Associated floods, droughts & wildfires killed about 2,000 people worldwide. The damage caused was estimated at US$13 billion.

An even stronger El Niño event developed in the Pacific between 1997 and 1998. Warnings were issued in mid 1997 and emergency preparedness conferences were convened. By March 1998, El Niño-related events globally caused US$34 billion of direct losses and killed 24,000 people. 111 million people were affected in some way and the related events left 6 million displaced people behind them.

Floods and fires are often a consequence of El Niño events. Smaller bush fires are normal in shifting cultivation areas, such as Indonesia. But sometimes it is also industrial burning, i.e. burning forest areas to enlarge plantations. Normally the heavy rain in December extinguishes all fires. But under El Niño conditions there is no rain.
Look at the following pictures what severe drought conditions mean.

10. Bush fires in Borneo, 1997 (Centre for Remote Imaging, Sensing and Processing The National University of Singapore.All images are acquired by the SPOT satellites. Copyright of images CNES.)

11. Bush fires over Sumatra and Kalimantan, Sept. 1997 (image: NOAA/NESDIS) author: Bildungszentrum Marktdorf, Project group ENSO
Source: http://www.enso.info/globaus.html

La Niña, on the other hand, can mean lots of rain in the following areas: South Asia (during monsoon times), North and North East Australia, South Africa, Northern South America, Central America, Hawaii.

Part 3: NAO

North Atlantic Oscillation (NAO)
Climate variability comprises three primary, but interrelated phenomena in the North Atlantic region:

- **the Tropical Atlantic Variability**
- **the North Atlantic Oscillation**
- **the Atlantic Meridional Overturning Circulation.**

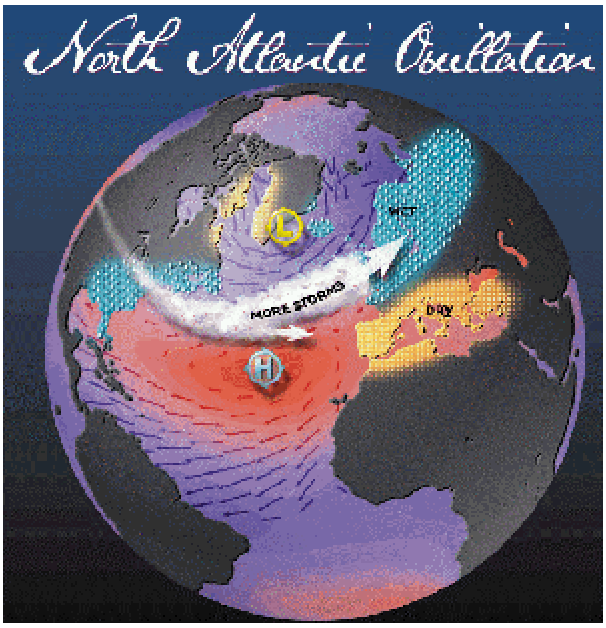
The NAO is a fluctuation in a sea level pressure difference between Iceland and the Azores. The name was first cited by Gilbert Walker in 1924.

The history of the NAO

The NAO has a long history. The missionary Hans Egede Saabye made observations in his diary as far back as 1770 to 1778: "When the winter in Denmark was severe, as we perceive it, the winter in Greenland in its manner was mild, and conversely". Simultaneously, coherent fluctuations in temperatures, rainfall and sea level pressure were documented, reaching eastwards to central Europe, southwards to subtropical West Africa and westward to North America.
The fluctuations of NAO influence climate from North America to Siberia and from the Arctic Ocean to the equator.

NAO index

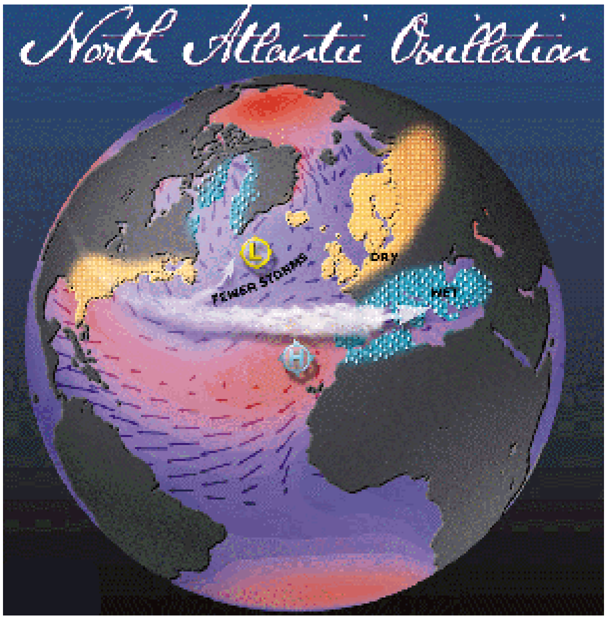
The strength of the NAO is described by the NAO index. The NAO index is the difference of sea-level pressure between two stations situated close to the centres of the Icelandic Low and the Azores High. Stykkisholmur (Iceland) is used as the northern station, and either Ponta Delgada (Azores), Lisbon (Portugal) or Gibraltar are used as the southern station.
This simple index clearly does not take into account the possibility that the centres of the actual pattern may not overlap with these locations, nor can it accurately capture the seasonal variations in the NAO. However, there is a key advantage to the use of such an index, existing weather records allow it to be extended back in time to at least 1864. When the index is correlated or regressed with gridded surface pressure data, the resulting north-south dipole pattern defines the spatial pattern of the NAO.



1. source: http://www.ldeo.columbia.edu/res/pi/NAO/

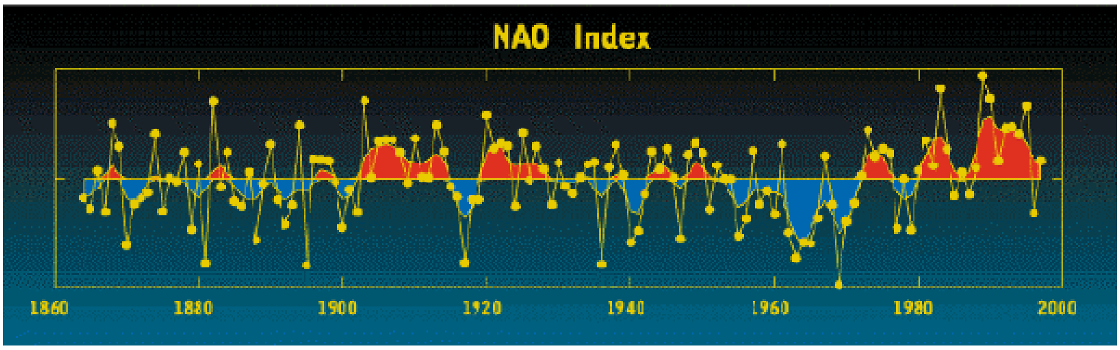
The positive NAO index phase shows a stronger than usual subtropical high pressure center and a deeper than normal Icelandic low. The increased pressure difference results in more and stronger winter storms crossing the Atlantic Ocean on a more northerly track. This results in a warm and wet winters in Europe and in cold and dry winters in northern Canada and Greenland. In this case, the eastern US experiences mild and wet winter conditions. For example, the high index winter/springs of 1989, 1990, and 1995, were caused by a net displacement of air from over the Artic and Icelandic regions towards the subtropic belt near the Azores and the Iberian peninsula, and had strengthened westerlies over the North Atlantic Ocean. Stronger westerlies bring more warm moist air over the European continent and gives rise to milder maritime winters.

The negative NAO index phase shows a weak subtropical high and a weak Icelandic low. The reduced pressure gradient results in fewer and weaker storms crossing on a more west-east pathway. They bring moist air into the Mediterranean and cold air outbreaks and hence snowy weather conditions. Greenland, however, has milder winter temperatures. The low index winter/springs of 1917, 1936, 1963, and 1969 had weaker mean westerlies over the North Atlantic Ocean with corresponding colder than normal European winters.



2. source: http://www.ldeo.columbia.edu/res/pi/NAO/

Strengthened or weakened westerlies over the North Atlantic both have major impacts on oceanic and some continental ecosystems. They have a large impact on North Atlantic fish stocks.



3. source: http://www.ldeo.columbia.edu/res/pi/NAO/

The winter NAO index is defined as the anomalous difference between the polar low and the subtropical high during the winter season (December through March).

NAO index has exhibited considerable variability over the past 100 years. From the turn of the century until about 1930 (with exception of the 1916-1919 winters), the NAO was high and so stronger-than-usual winds carried the moderating influence of the ocean over Europe contributing to the higher-than-normal European temperatures during this period. From early 1940's until the early 1970's, the NAO index exhibited a downward trend corresponding to a period when European wintertime temperatures were frequently lower than normal. A sharp increase in the NAO has occurred over the past 25 years. Since 1980, the NAO has remained in a strongly positive phase and displayed an upward trend. Since the turn of the 20th century, winters have exhibited the most pronounced positive indices ever recorded (except 1996). This situation has contributed much to the observed warming seen in northern hemisphere surface temperatures over the past two decades.