## Natural Climate Variability & Ocean Ecosystems



#### **Spatial-scales**

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# Mean Sea Level Pressure North Atlantic





**Azores High** 

### NAO Index = SLP(Azores High) - SLP(Iceland Low)

#### measured November through March





measured December through March



Sometimes the NAO index stays in one phase for several years in a row. This decadal variability was quite strong in the second half of the 20th century.





- ✓ 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 warm and wet winters in Northern Europe and in cold and dry winters in Mediterranean region.
- ✓ The eastern US experiences mild and wet winter conditions.



- ✓ The negative NAO index phase shows a weak subtropical high and weak Icelandic low.
- ✓ The reduced pressure gradient results in fewer and weaker winter storms crossing on a more westeast pathway.
- ✓ They bring moist air into the Mediterranean and cold weather to northern Europe.
- ✓ The US east cost experiences more cold air outbreaks and hence snowy winter conditions.



IMPACTS ASSOCIATED WITH A POSITIVE NAO YEAR.



NORTHEASTERN US Increased temperature results in decreased number of snow days



NORTH SEA Increased wave height affects safety of oil rigs and their operators



NORWAY Surplus water in hydroelectric reservoirs provides potential for selling surplus electricity



SCANDINAVIA Length of the plant growth season is lengthened by 20 days



CENTRAL US Increased precipitation and river ranoff

This figure shows surface temperature response and some well-documented racis-accountic inpacts associated with a strong NAO index year.

Temperature response is a measure of the degree to which whiter sea surface? You at the search of durings in the KAO index. Rel bightights those regions which are some at times when the northsouth pressure gradient over the Alfsteith Beain is greater than sureal. Bhar marker regions which are acader, Sao author

over the Atlantic Basin is greater than usual. Blue marks explose which are cooler. Sea surface temperatures are taken from a reconstruction of historical data while the

colored points are landbased weather stations. In the late 16th century, the missionary Hans Egede Saabye, after several years of travelling back and forth between Scandinavia and Greenland, recorded in his journal: "In Greenland, all winters are severe, yet

they are not alike. The Danes have noticed that when the winter in Denmark was severe, as we perceive it, the winter in Greenland in its manner was mild, and conversely."

> As we now know, this east-west temperature see-saw was due to changes in the north-south contrast in sea level pressure over the North Atlantic Ocean, with low pressure in the north near Iceland and high pressure in the south near the Azores. The pressure contrast drives surface winds and wintertime storms from west to east across the North Atlantic. Variations in the pressure gradient affect the winds and storm tracks, thereby altering sea surface temperature, air temperature and precipitation. The impacts of this climate phenomenon reach as far eastward as central Siberia

> > and the eastern Mediterranean, southward to West Africa, westward to North America and extend throughout the entire Arctic region. These changes in atmospheric pressure and its associated impacts are known as the North Atlantic Oscillation (NAO).

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IMPACTS ASSOCIATED WITH A NEGATIVE NA0 YEAR.



TROPICAL ATLANTIC/ GULF COAST Warmer sea surface temperatures cause increases in number and strength of hurricanes



ATLANTIC Increased growth and recruitment of Northern Cod



EASTERN LONG ISLAND Decreased "brown tide" events increase scallop harvests



PORTUGAL & SPAIN Increased grape and olive harvests



Increased precipitation and streamflow in the Tigris-Euphrates River Basin





Increased temperature results in decreased number of snew down







Surplus water in hydroelectric reservoirs provides potential for selling surplus electricity



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increased precipitation and river runoff



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## **Negative Phase**

✓ Less winter outberaks --> **Reduced snow cover** 

✓ Warmer temperature --> **Red Tides** 

✓ Colder SST --> reduced Hurricanes

✓ Colder SST --> less Cod reproduction (Grand Banks)

## **Positive Phase**

- Mild Winter N Europe --> reduced hydroelectric power
- ✓ Less rain SE Europe --> reduced drinking water & reduced stream flow in Middle East
- Increased length of growing season
- Impact on harvest of grapes and olives





# The Sensitivity of Significant Wave Height in the Wintertime (DJFM) to the NAO

## NAO and fish catch in the North Atlantic

#### **Topliss**, **BIO**, **Canada**

Each time series shows a comparison between [coloured lines] historic fish catch records and [plack lines] MONACLE, with its zero axis [horizontal black line] indicating positive and negatives feedback in all regions. The autocorrelation, time was 7 or 9 years, season start months are those as in world map and season length swere 3 months except 2 months for the Norway subplot.



## **Ecological effects of the North Atlantic Oscillation**

Geir Ottersen, Benjamin Planque, Andrea Belgrano, Eric Post, Philip C. Reid, Nils C. Stenseth

Posted on class website (12 pages)

# ...more than 100 documented correlation between NAO and marine ecosystems.

How to make sense?

## **Ecological effects of the North Atlantic Oscillation**

The response to NAO is classififed into 3 type:

**DIRECT -** A direct ecological response to one of the environmental parameters synchronised with the NAO.

**INDIRECT** - The indirect effects of the NAO are non-trivial mechanisms that either involve several physical or biological intermediary steps between the NAO and the ecological trait and/or have no direct impact on the biology of the population.

**INTEGRATED** - The integrated effects of the NAO involve simple ecological responses that can occur during and after the year of an NAO extreme. This is the case when a population has to be repeatedly affected by a particular environmental situation before the ecological change can be perceived (biological inertia). or when the environmental parameter affecting the population is itself modulated over a number of years (physical inertia)

# Ecological effects of the North Atlantic Oscillation Direct Effects

## **Temperature Mediated Response**

Length of active growing season, Individual growth (size), growth rate, eggs variability, timing of reproduction, spawning, time of food availability, larval growth and mortality,

# **Indirect Effects**

## Physically induced by changes in oceanic transport

Changes in spatial distribution of phytoplankton and larvae, alteration in competition between different levels of the trophic chain and alteration in food web

## **Effects on Predator-Prey**

Through changes/alteration in the food



Fig 4.1 shows a schematic diagram of the impact of the North Atlantic Oscillation (+) on ungulant populations in northern Europe. The Thick green line beneath the circles is a rough graph of ungulate abaundance over time, with time along the x axis, and abundance along the y axis.

## **NAO and Copepods (***Calanus Finmarchicus***)**

Difficult to identify causes of observed relationships

#### Hypotheses:

1) Changes in food availability

2) Alteration of competition balance

3) Variations in transport of individuals from North Atlantic

#### Calanus Finmarchicus distribution



#### Calanus Helgolandicus distribution



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- ★ It has also been suggested that tropical ocean temperatures can influence the phase of the NAO.