

# North Atlantic Oscillation (NAO)

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# Outline

- What is the NAO?
- NAO characteristics and indices
- NAO impacts

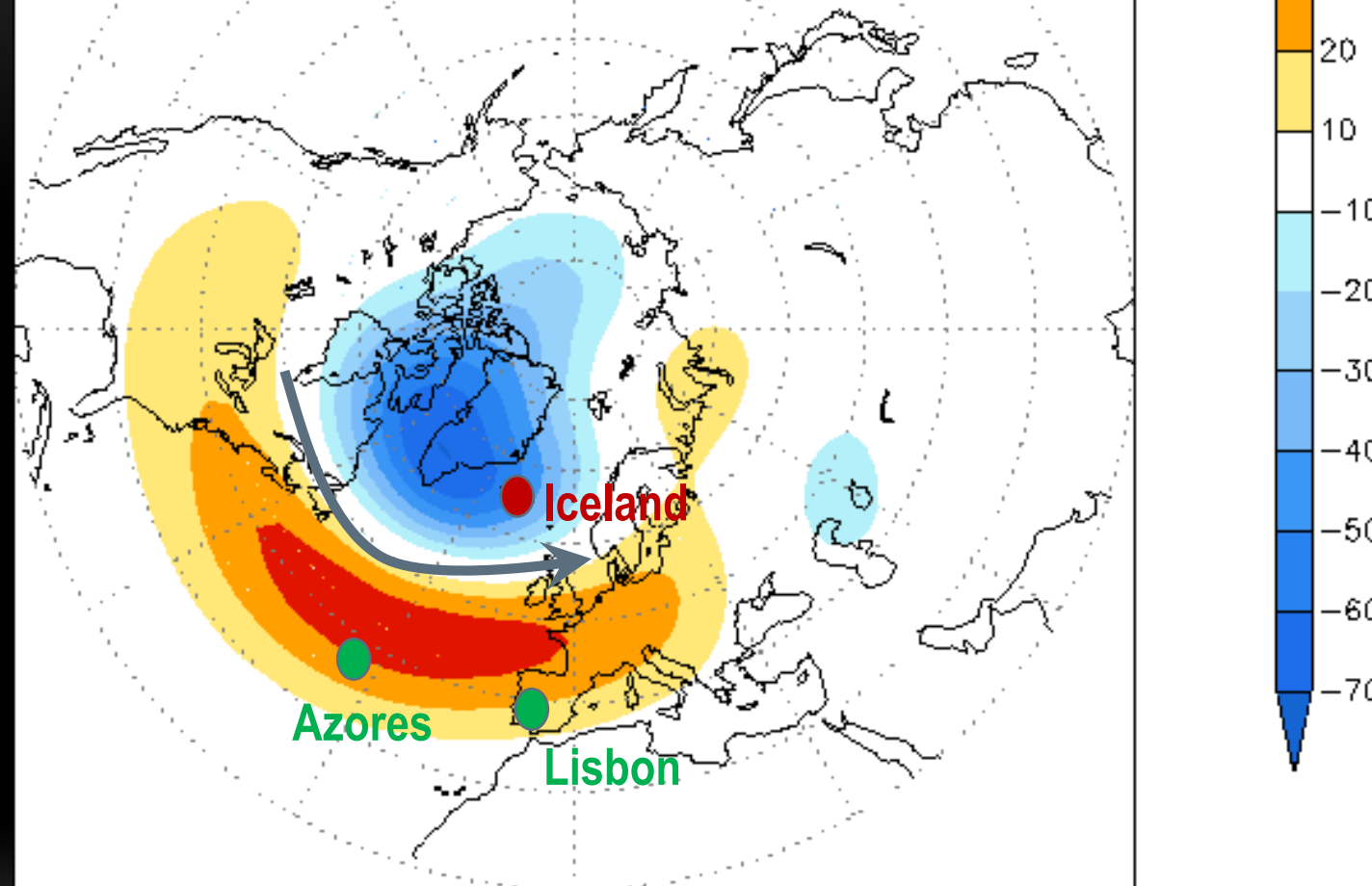
# What is the NAO?

- The North Atlantic Oscillation (NAO) is one of the most prominent teleconnection patterns in all seasons in the North Atlantic. The NAO consists of a north-south dipole of anomalies, with one center located near Greenland and the other center of the opposite sign spanning the North Atlantic between 35°N and 40°N.
- The positive phase of the NAO reflects below-normal heights and pressure across the high latitudes of the North Atlantic and above-normal heights and pressure over the central North Atlantic. The negative phase reflects an opposite pattern of height and pressure anomalies over these regions.
- The NAO is associated with basin-wide changes in the intensity and location of the North Atlantic jet stream and storm track (Walker and Bliss 1932, van Loon and Rogers 1978, Rogers and van Loon 1979).

# Positive Phase of the NAO: the Mean Large-scale Circ. in Boreal Winter

- High Pressure over the Azores
- Low Pressure over Iceland
- *How does the dipole pattern affect the westerly jet and storm track?*
  - Stronger jet stream
  - More extratropical cyclones or enhanced storm track

NAO+ pattern derived from REOF of H500 the NOAA CPC  
Adapted figure from  
[https://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/nao\\_loading.html](https://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/nao_loading.html)



- Azores high and Icelandic Low are the centers of action
- Tendency for Azores high and Icelandic low is **negatively correlated**
- Dipole pattern → north-south gradient of geopotential height → changes in the zonal flow (jet stream) → changes in the storm track

# NAO Indices

- An Index can be constructed to represent the NAO. A commonly used index is based on the **normalized** sea level pressure (SLP) difference between the Subtropical (Azores) high and the Subpolar (Iceland) low.

$$\text{NAO Index} = \text{SLP (Subtropical)} - \text{SLP (Subpolar)}$$

↓  
Lisbon/Azores

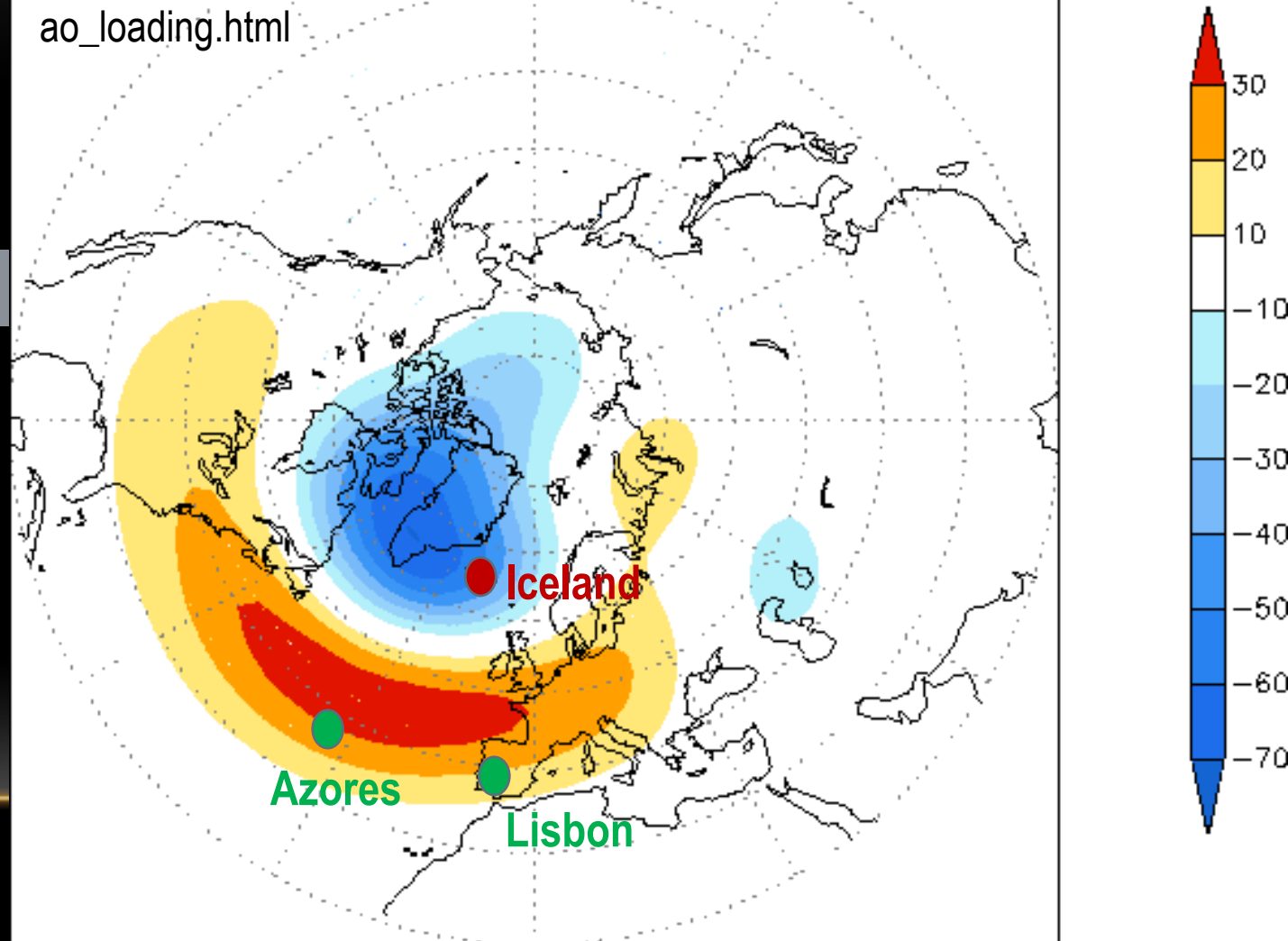
↓  
Iceland

- Specific locations used for the NAO index definition include Akureyri, **Iceland**, and Ponta Delgada, **Azores** (Rogers 1984) and Stykkisholmur, **Iceland**, and **Lisbon**, Portugal (Hurrell 1995).

REOF (10.2%) shown as  
regression map of 500mb height (m)

Adapted figure from the NOAA CPC

[https://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/nao\\_loading.html](https://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/nao_loading.html)



# More about the SLP based NAO Index

- KEY STRENGTHS:
  - **Simple** to construct and easy to understand
  - With availability of station SLP data, station-based indices can be **extended back** to the mid-19th century or earlier
- KEY LIMITATIONS:
  - Individual station pressure readings can be **noisy** due to small-scale and transient features unrelated to the NAO
  - The stations are **fixed in space**, and a station-based index thus can not track the movement of the NAO centers of action through the annual cycle (see the next slide)

- The NAO is most noticeable during the winter season (November - April) with maximum amplitude in the Atlantic sector.
- The centers of action shift northward and westward from winter to summer

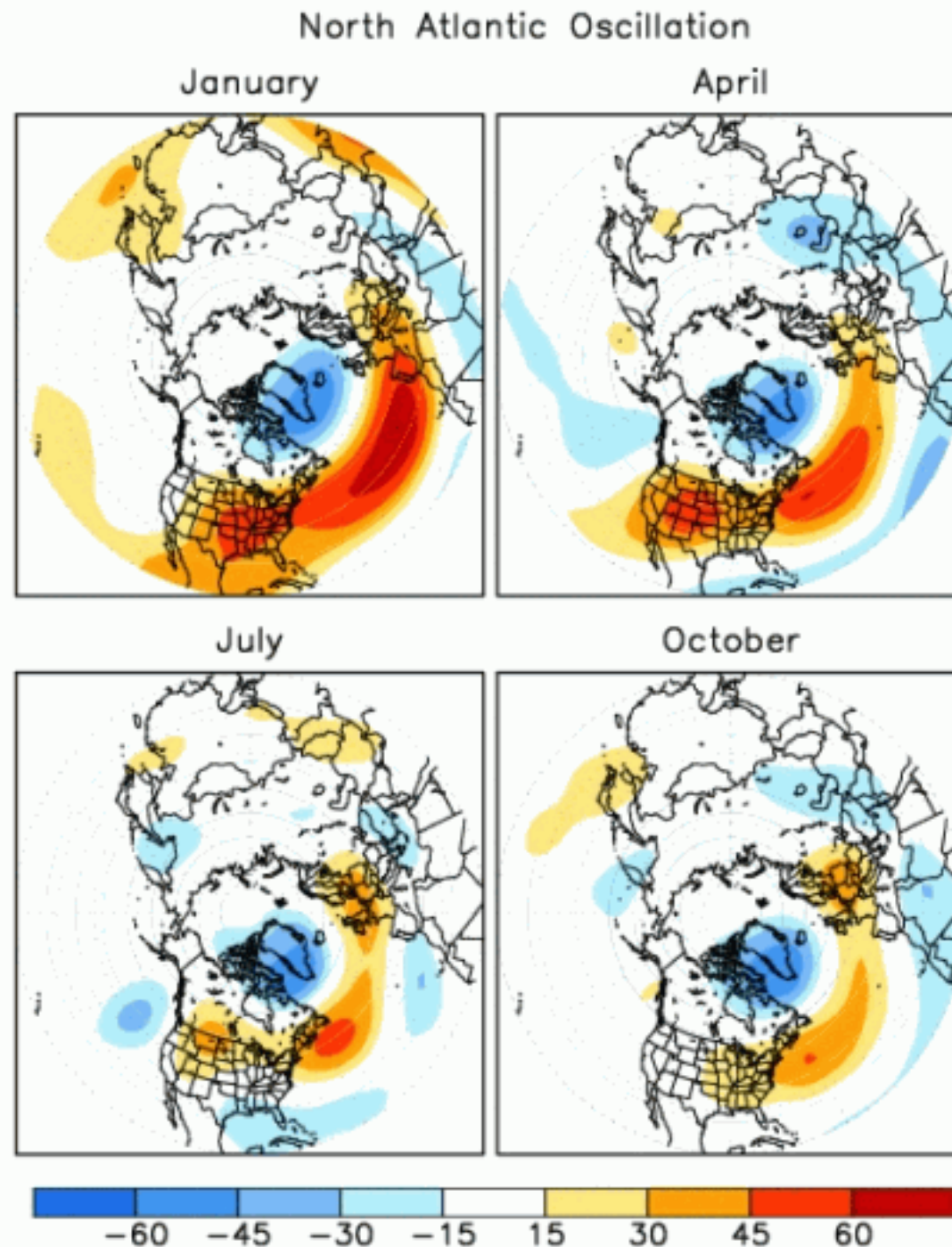


Figure from the CPC:  
<https://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/nao.loading.shtml>



# NAO Centers of Action

The monthly nodal locations of action centers (computed for 1948–99) are labeled by month number. Arrows indicate the annual march of the NAO index nodes. (Portis et al. 2001 © American Meteorological Society. Used with permission)

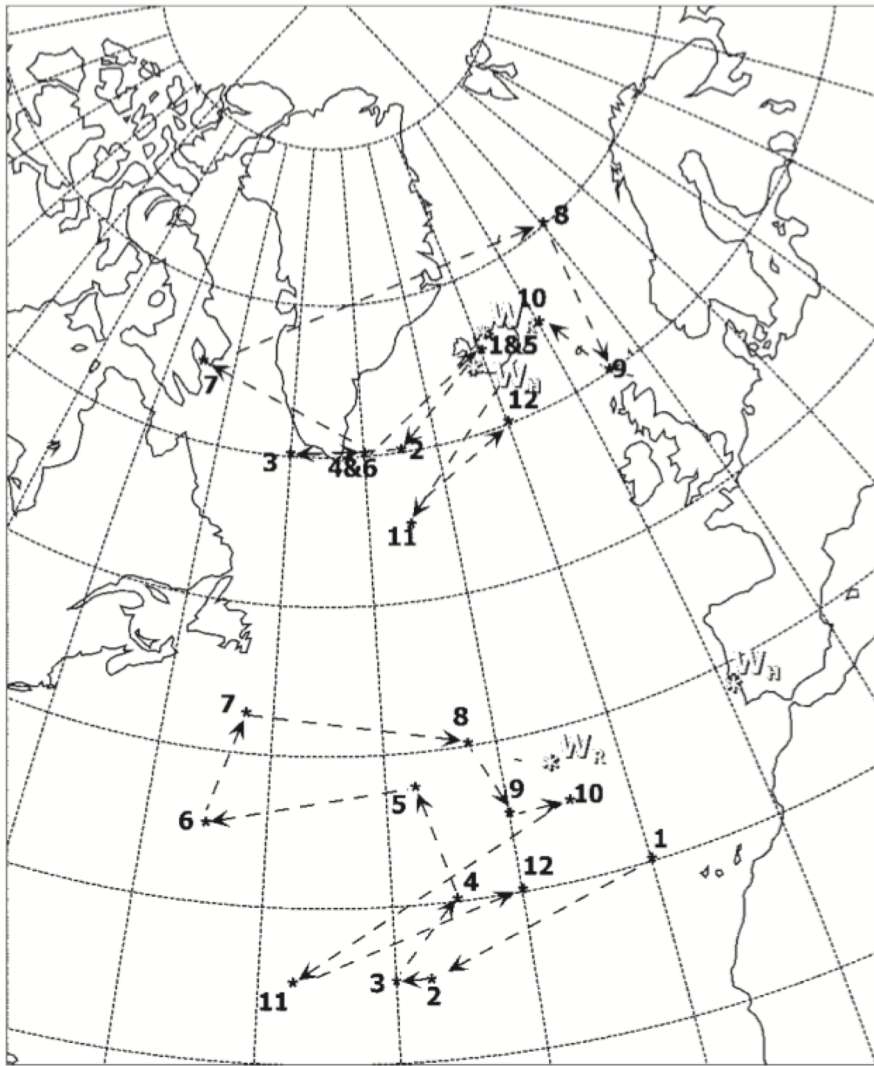


FIG. 1. Locations of nodes defining the three NAO indices considered—Mobile, Rogers, and Hurrell. The monthly nodal locations of the Mobile index (computed for 1948–99) are labeled by month number; the station-based nodes of the Rogers’s and Hurrell’s indexes are located by “ $W_R$ ” and “ $W_H$ ,” respectively. Arrows indicate the annual march of the mobile NAO index nodes.

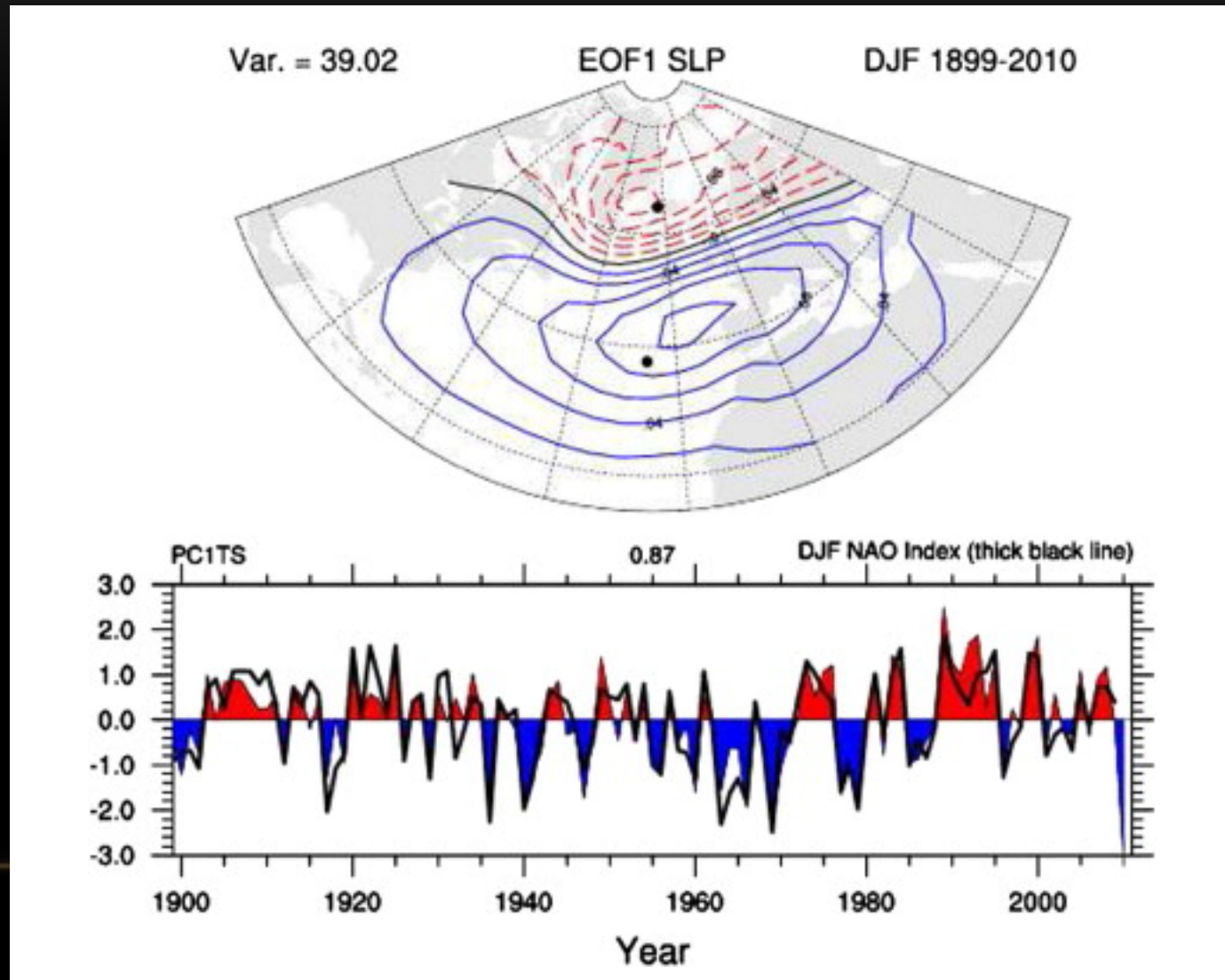


# Another Way to Define the NAO

Another way to define the NAO is to use the EOF analysis.

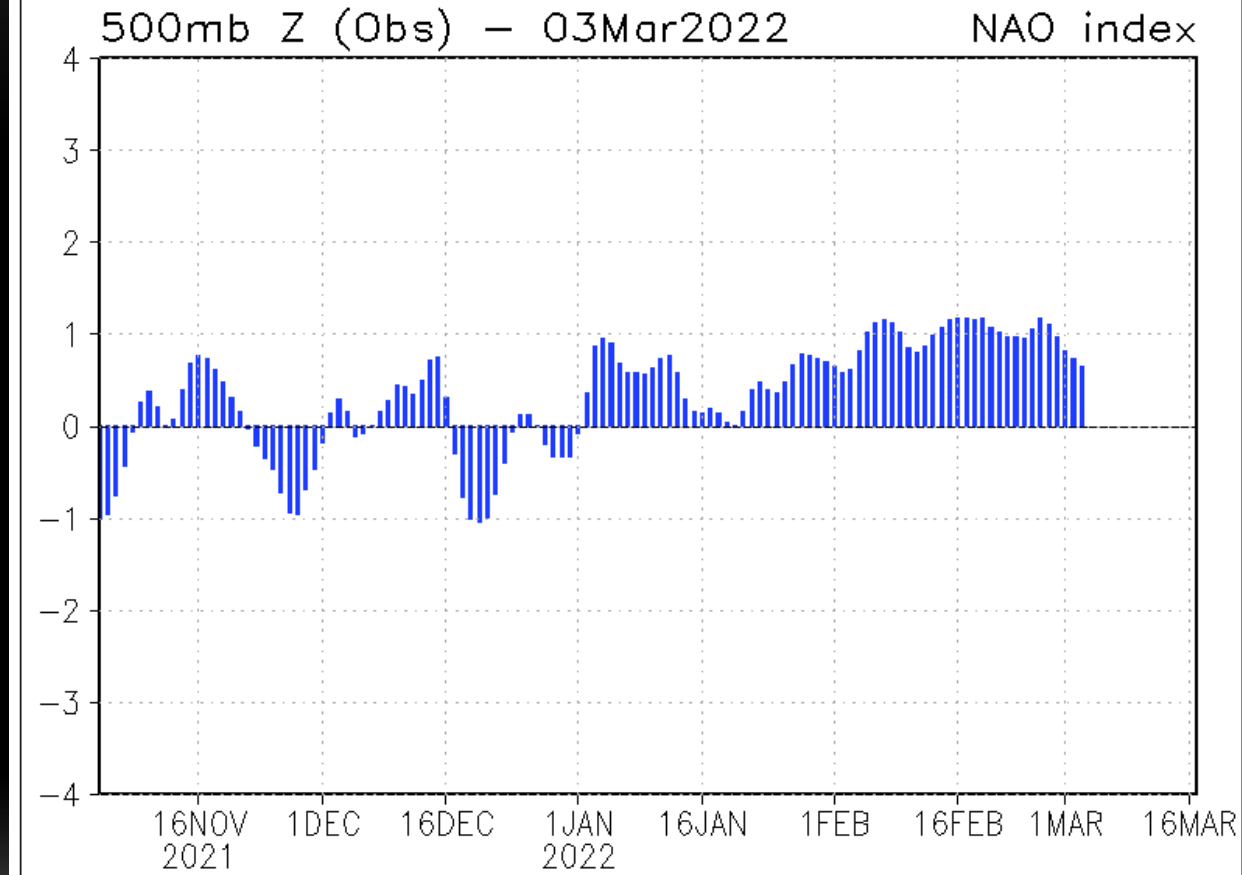
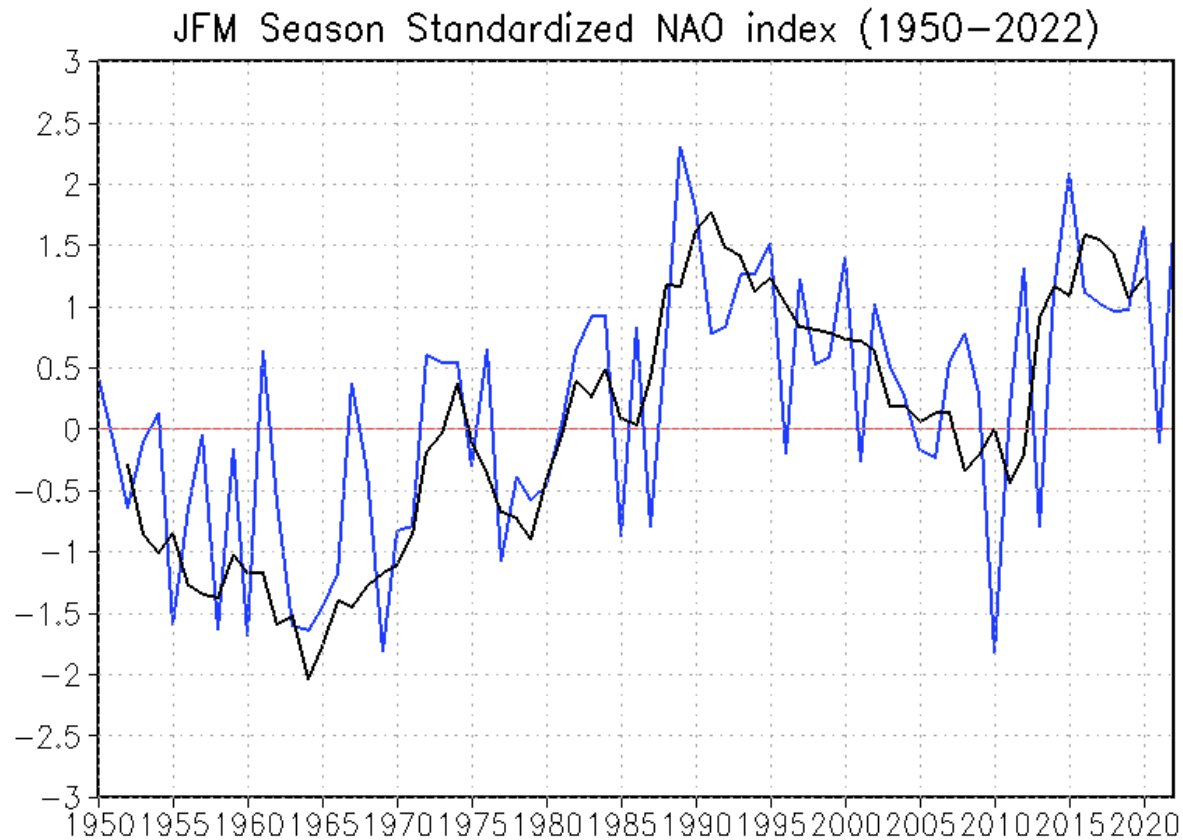
- The NAO is the **leading** (1<sup>st</sup>) EOF mode of the SLP over the North Atlantic in boreal winter.
- The principal component (**PC**) time series of the leading EOF of seasonal (December through March) SLP anomalies over the Atlantic sector (20-80N, 90W-40E) serves as an alternative index (Hurrell 1995).
- The NAO index can be defined for other seasons as well.

# EOF Based NAO Index (DIF)



- The EOF based NAO is in color; the station based index is the black line.
- The correlation between the station-based NAO index and the EOF based NAO index is high in winter but relatively low in summer.

# NAO Time Series



- The NAO has variability on intraseasonal to decadal time scale.

# References

- The CPC's page on the North Atlantic Oscillation :  
<https://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/nao.shtml>
- Barnston, A. G., and R. E. Livezey, 1987: Classification, seasonality and persistence of low-frequency atmospheric circulation patterns. *Mon. Wea. Rev.*, **115**, 1083-1126.
- Portis, D. H., Walsh, J. E., El Hamly, M., & Lamb, P. J. (2001). Seasonality of the North Atlantic Oscillation, *Journal of Climate*, *14*(9), 2069-2078.