Decadal Variability of the NAO –
Introducing An Augmented NAO index

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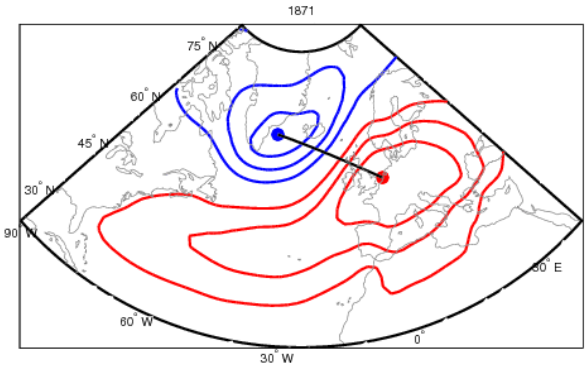
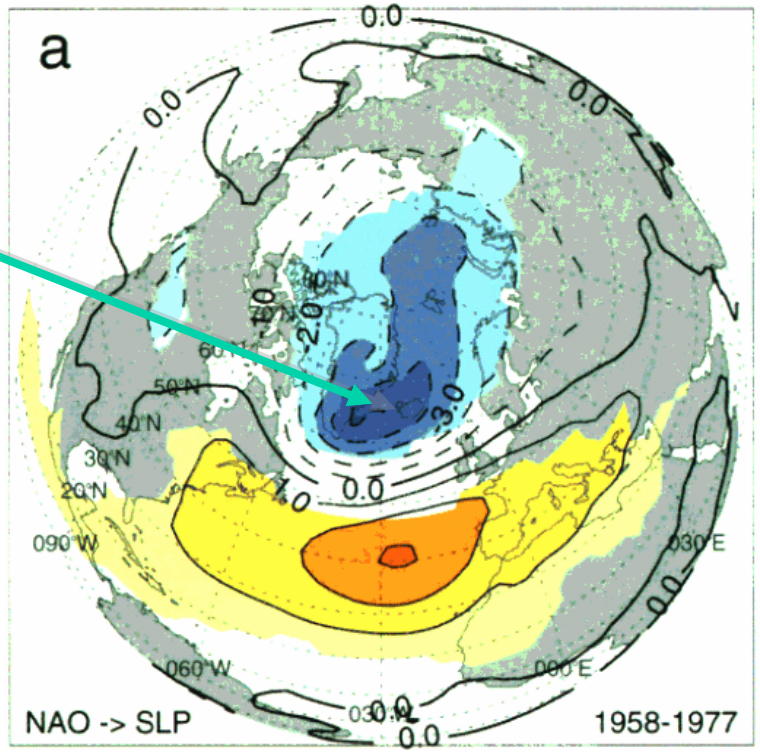
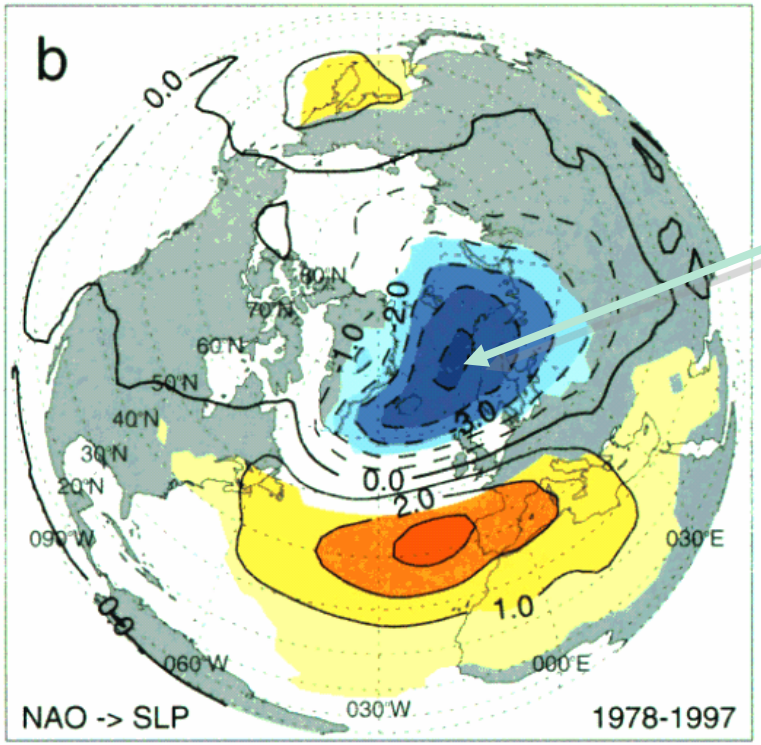


Spatial shift

1958-1977



1978-1997



Hilmer and Jung (2000)

What about earlier in the century?

The NAO index refers to a fixed spatial pattern

Another index to account for spatial variability of the NAO?

Data & Methods

Data:

Dec – Mar, 1871-2008 (137 yrs), Twentieth Century Reanalysis.
SLP, wind and temperature close to surface (sigma=0.995)

Methods:

20-yr running window moved by 1 yr (118 twenty-yr periods).
De-seasonalize in each period.

The NAO is defined as the first EOF of SLP in each period.

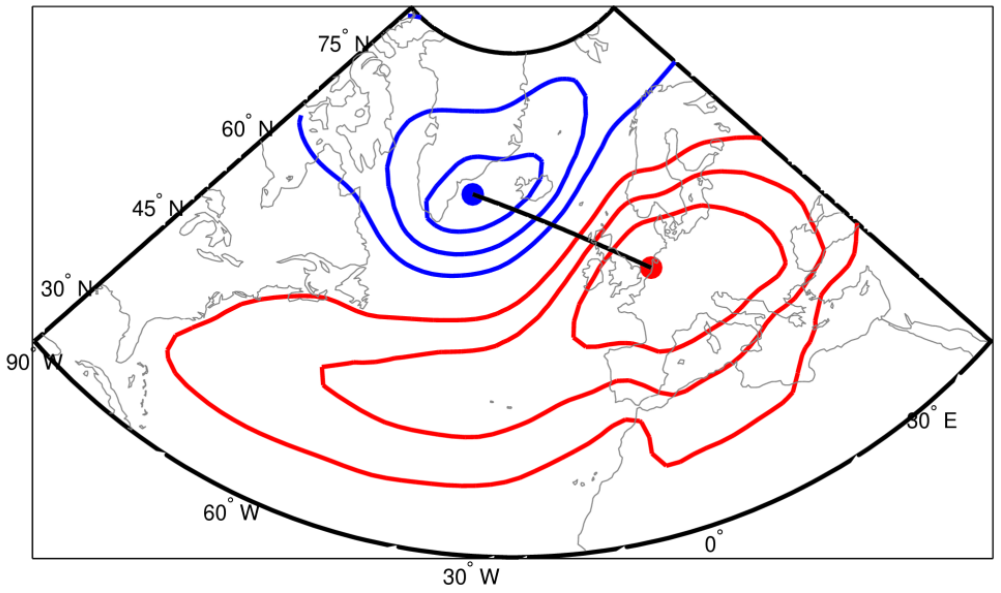
Introduce:

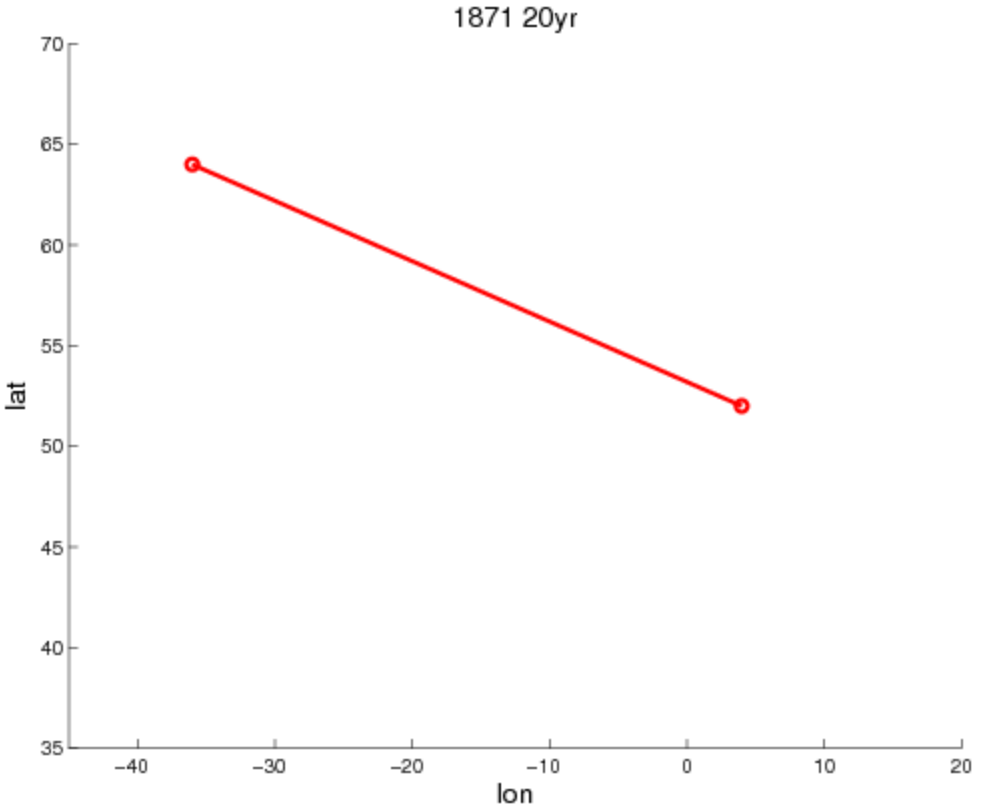
the **angle index**: variability of the NAO spatial structure.

the **smooth NAO index**: variability in NAO polarity.

Decadal variability of the NAO

1871 Dec – 1891 Mar





Decadal variability of the NAO

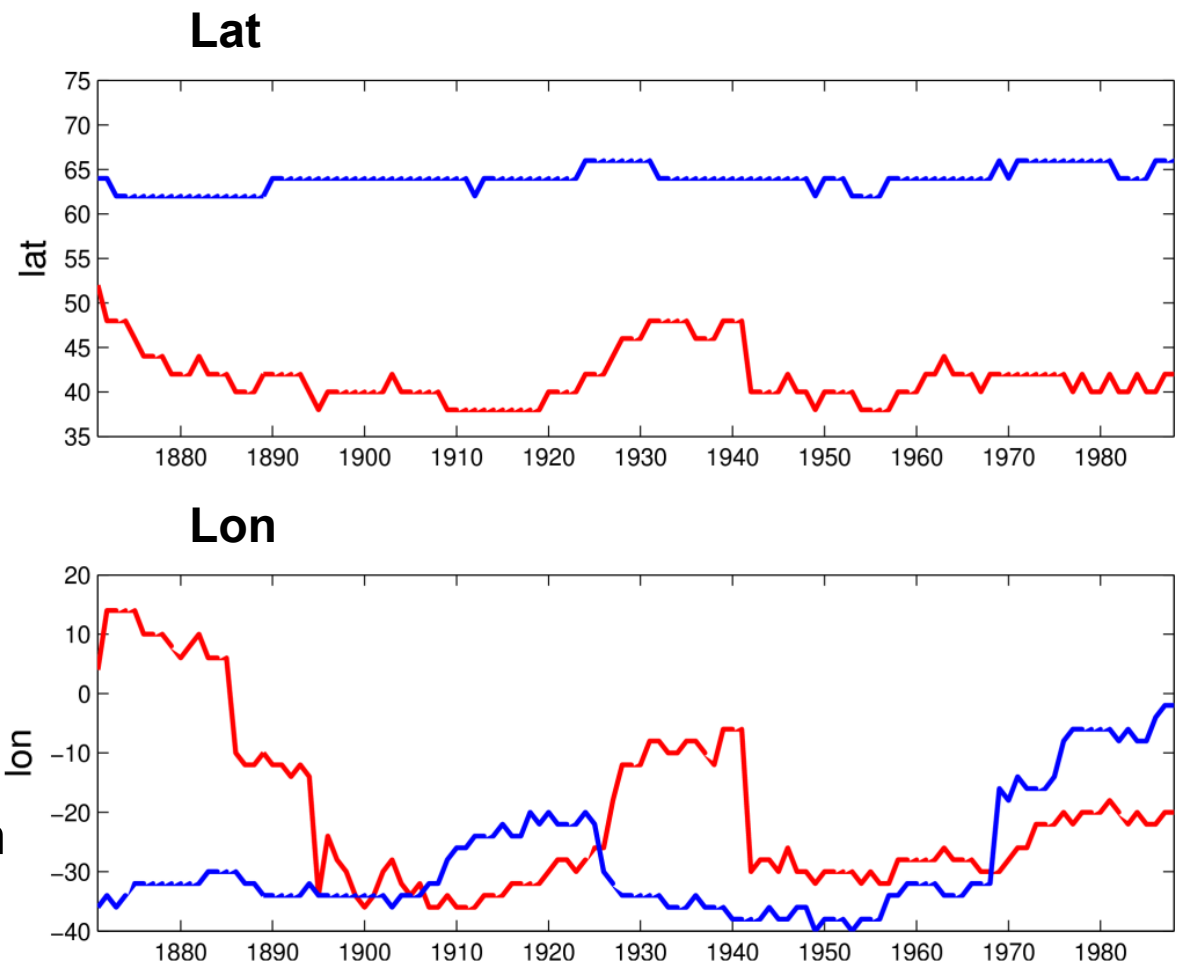
Northern node: blue

Southern node: red

Primarily zonal shifts, especially in the northern node.

Primarily eastward shift in the northern node over the most recent period (from ~1970).

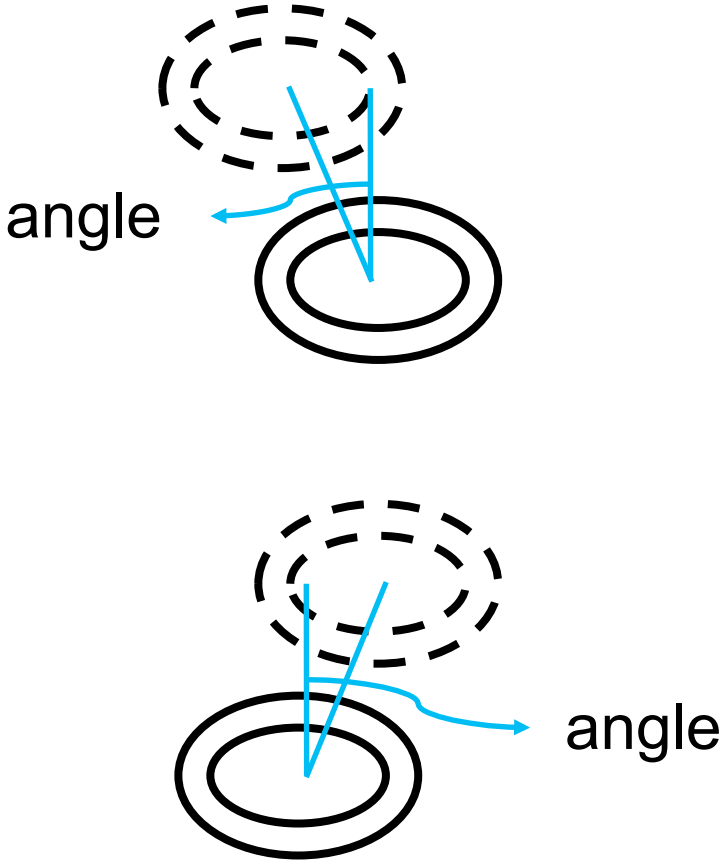
Stronger variations in location of the southern node especially in the late 1800s, but also close to mid-century.



X-axis: starting year of a period,
e.g. 1880 for Dec 1880 to 1900 Mar

The angle index – a new index

Angle between the line connecting the nodes and the meridian through the southern node.

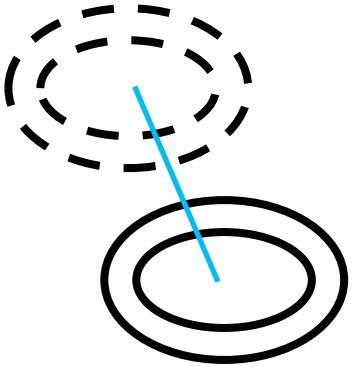


The angle index – a new index

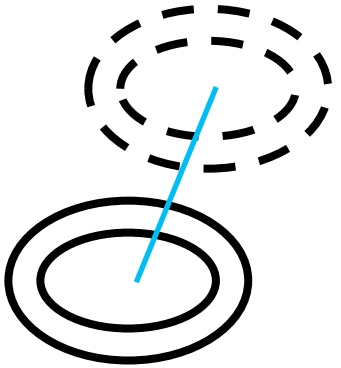
Angle between the line connecting the nodes and the meridian through the southern node.

Negative: The tilt is southeast to northwest

Positive: The tilt is southwest to northeast.



- angle



+ angle

The angle index – a new index

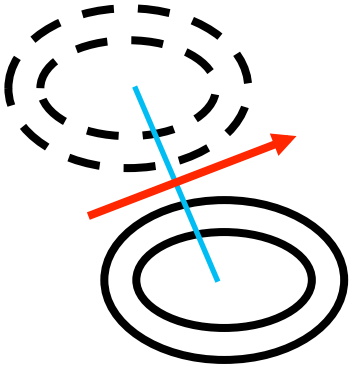
Angle between the line connecting the nodes and the meridian through the southern node.

Negative: The tilt is southeast to northwest

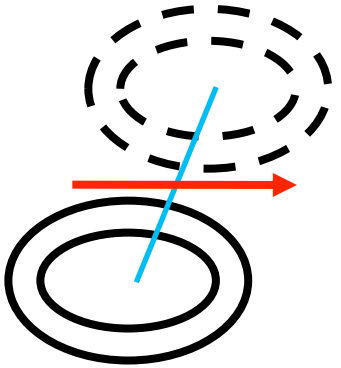
Positive: The tilt is southwest to northeast.

Related to the direction of winds.

Negative: more southerly component
Positive: more westerly component



- angle



+ angle

Two indices

The smooth NAO index

Assume a fixed spatial structure for the NAO throughout the entire time series.

Project 137-yr SLP anomaly onto the NAO for an annual NAO index.

Describe the polarity of the NAO per 20 yrs. By taking a 20-yr running mean on overlapping windows.

The angle index

Angle between the line connecting the two nodes and the meridian through the southern node.

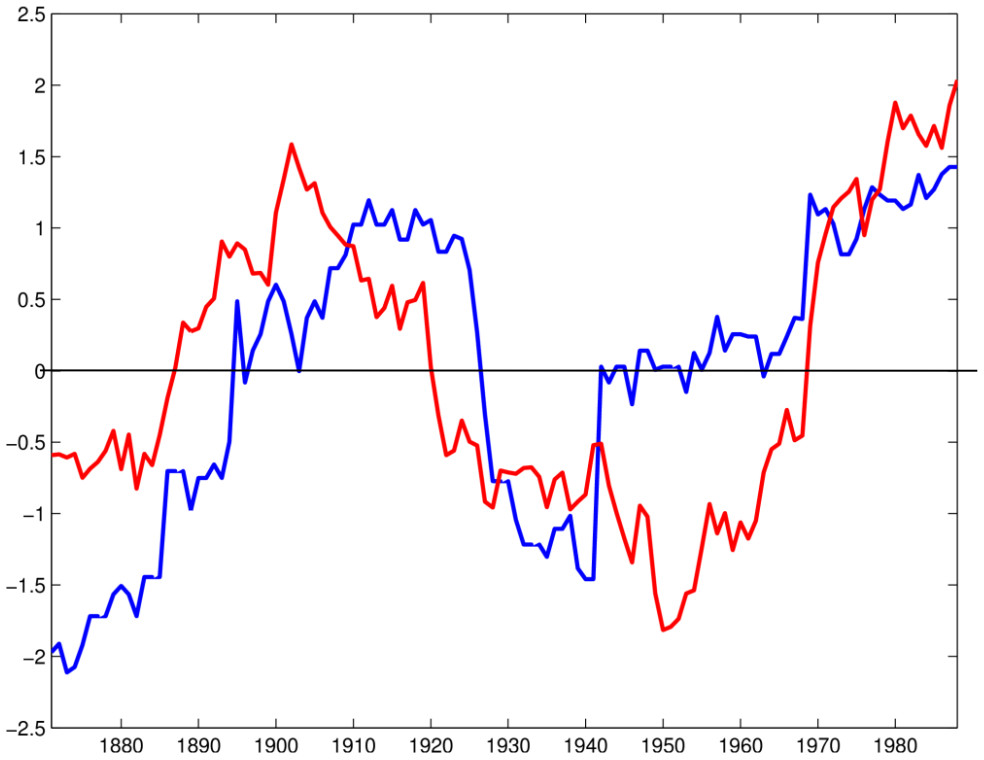
Describes the relative position of the two nodes.

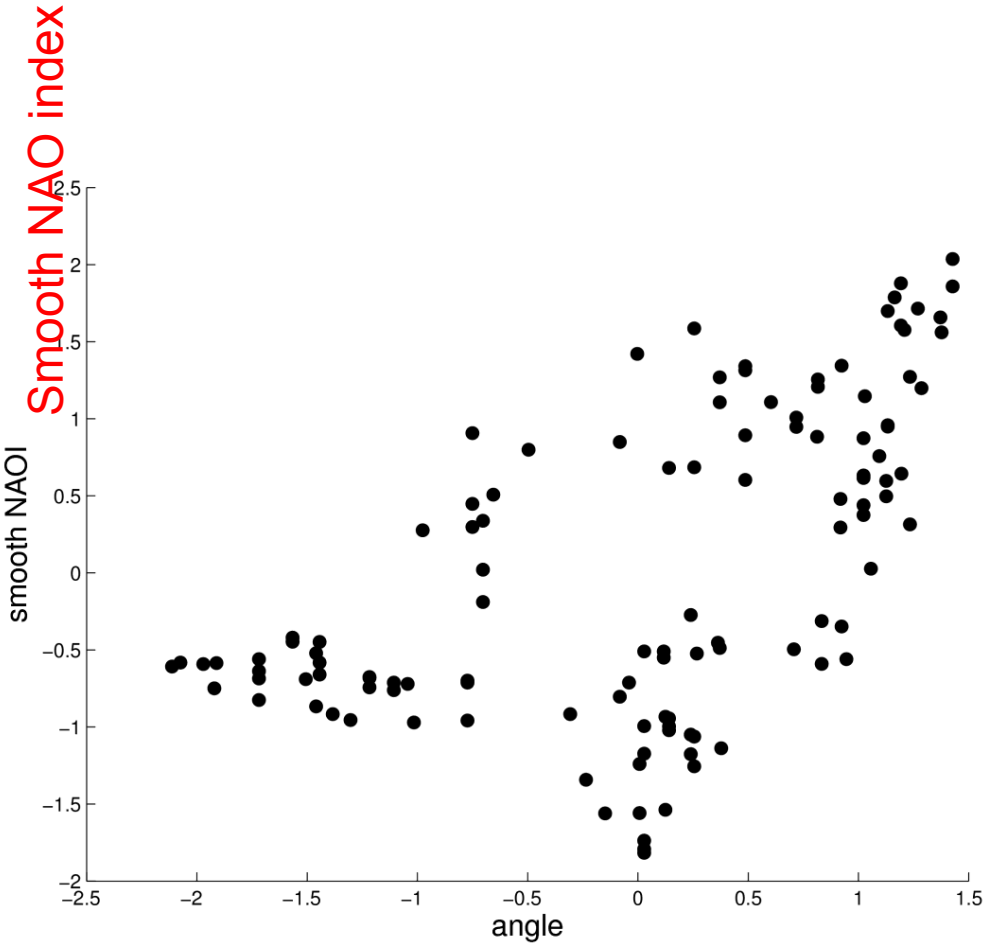
Negative: two nodes tilt southeast-northwest;
positive: two nodes tilt southwest-northeast.

Relationship between the smooth NAO index and the angle index

Correlation coefficient: 0.57.
The relationship is not perfectly linear.

Blue: normalized angle;
Red: normalized smooth NAO





Multiple linear regression models

Model the **20-yr running mean** climate variable Y (stands for u,v and T at 0.995 sigma level and SST) point by point:

$$Y' = b_0 + b_1*(\text{smooth NAO index}) + b_2*(\text{angle index})$$

Y': prediction of a climate variable

b_0, b_1 and b_2: coefficients estimated by least-squares fit.

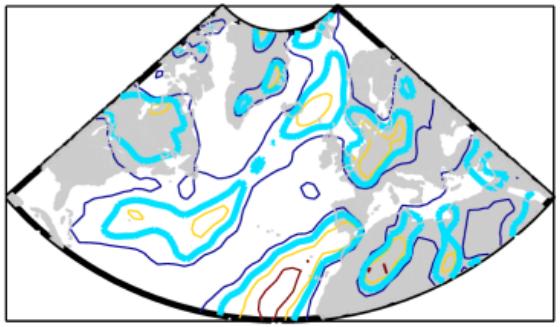
Compare R^2 in the following regression models:

1. Only smooth NAO index: (angle index is neglected)
2. Only angle index: (smooth NAO index is neglected)
3. Smooth NAO index & angle index are both included

R^2 in regression models

Low-level meridional wind

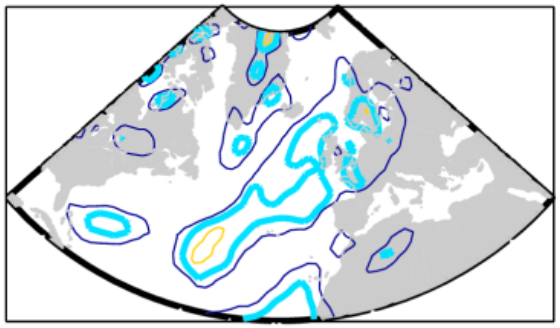
(a) V: NAOI



Contour interval 0.2

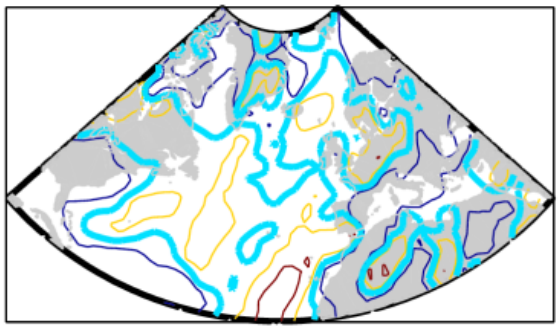
The smooth NAO index is the only predictor

(b) V: angle



The angle index is the only predictor

(c) V: NAOI & angle

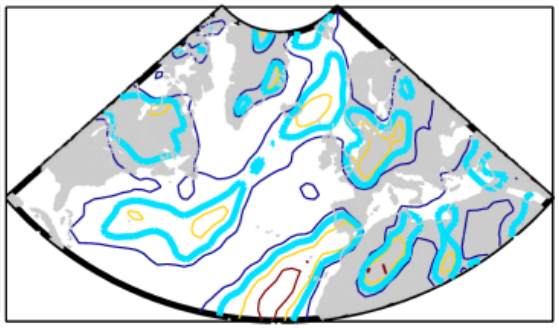


Both the smooth NAO index and the angle index are predictors

R^2 in regression models

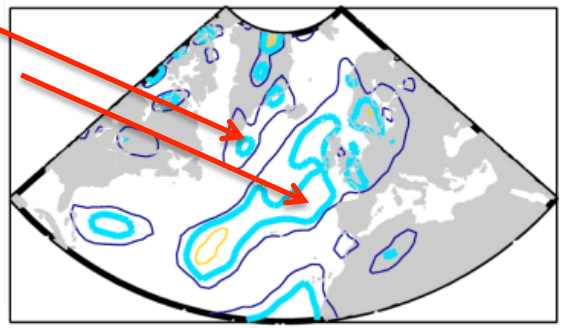
Low-level meridional wind

(a) V: NAOI



Contour interval 0.2

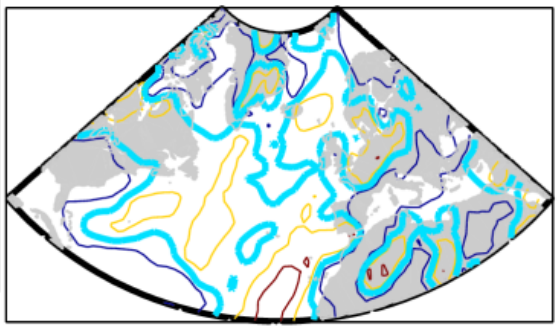
(b) V: angle



The smooth NAO index captures the primary variation in 20-yr mean v (and other variables)

The angle index adds information to improve the prediction such as in the areas highlighted.

(c) V: NAOI & angle



Conclusions

Progressive movement of the NAO in 20-yr running windows back to 1871.

- More movement in location of the southern node.
- The northern node moves primarily zonally; the southern node moves zonally and meridionally.

Angle index: the relative position of the NAO per 20 yrs.
Smooth NAO index: polarity of the NAO per 20 yrs.

Unclear linear relationship between indices when the angle index is negative.

The smooth NAO index is more important in capturing the 20-yr running mean of climate variables.

The augmented angle index can improve upon prediction of the climate variables especially in the areas corresponding to the shift in the NAO.