Dynamic Meteorology

(WAPE: General Circulation of the Atmosphere and Variability)

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4) Midlatitudes tropospheric variability

a) Asymmetric circulations, synoptic eddies, and low-frequency variability in the NH

Level 0 statistics (time mean and variances, high-pass and low pass)

b) Dominant patterns of low-frequency variability

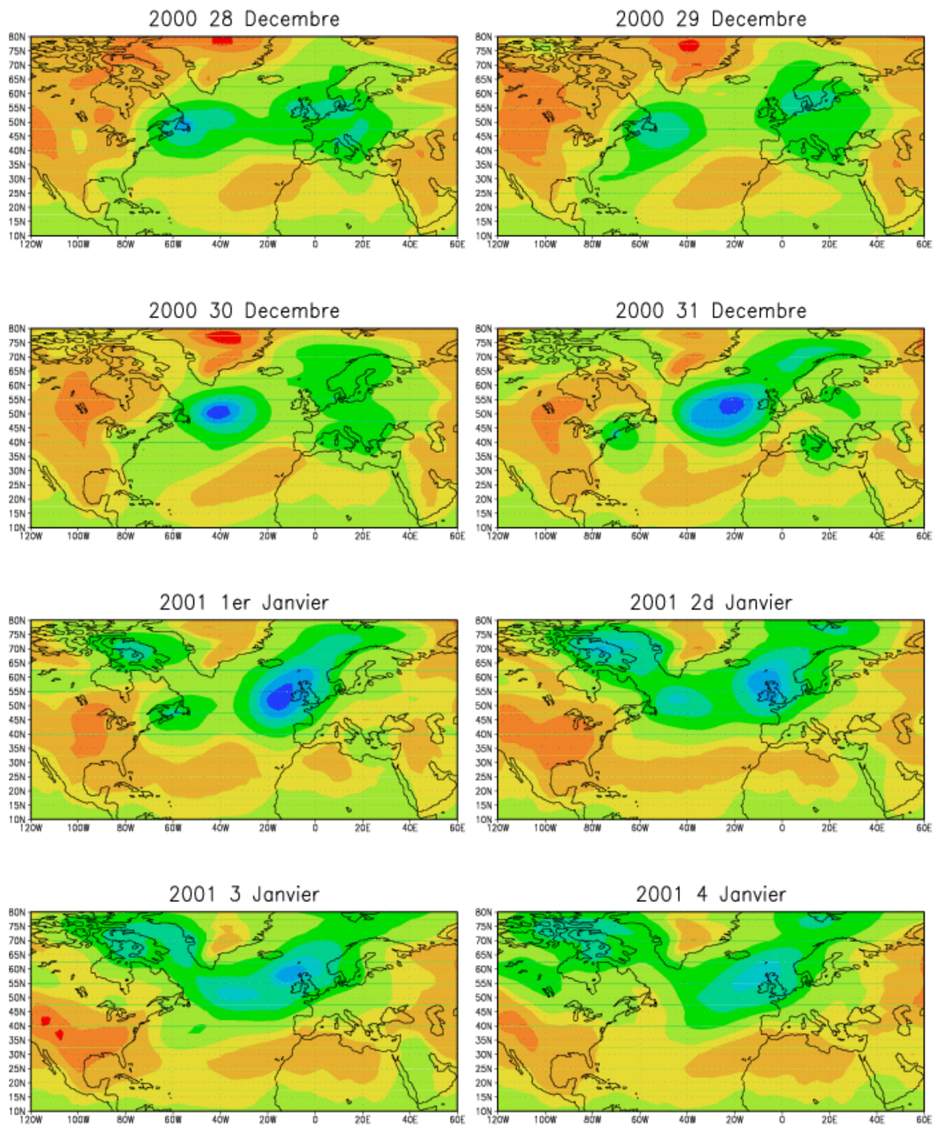
Teleconnections and EOFs

Annex: Minimum about EOFs

a) Asymmetric circulations, synoptic eddies, and low-frequency variability in the NH

Usual trajectory of a weather system developping in winter across the Atlantic

Sea-level pressure, NCEP data



Low level pressure systems usually form over the North-East atlantic near Newfound Land island (Terre-neuve)

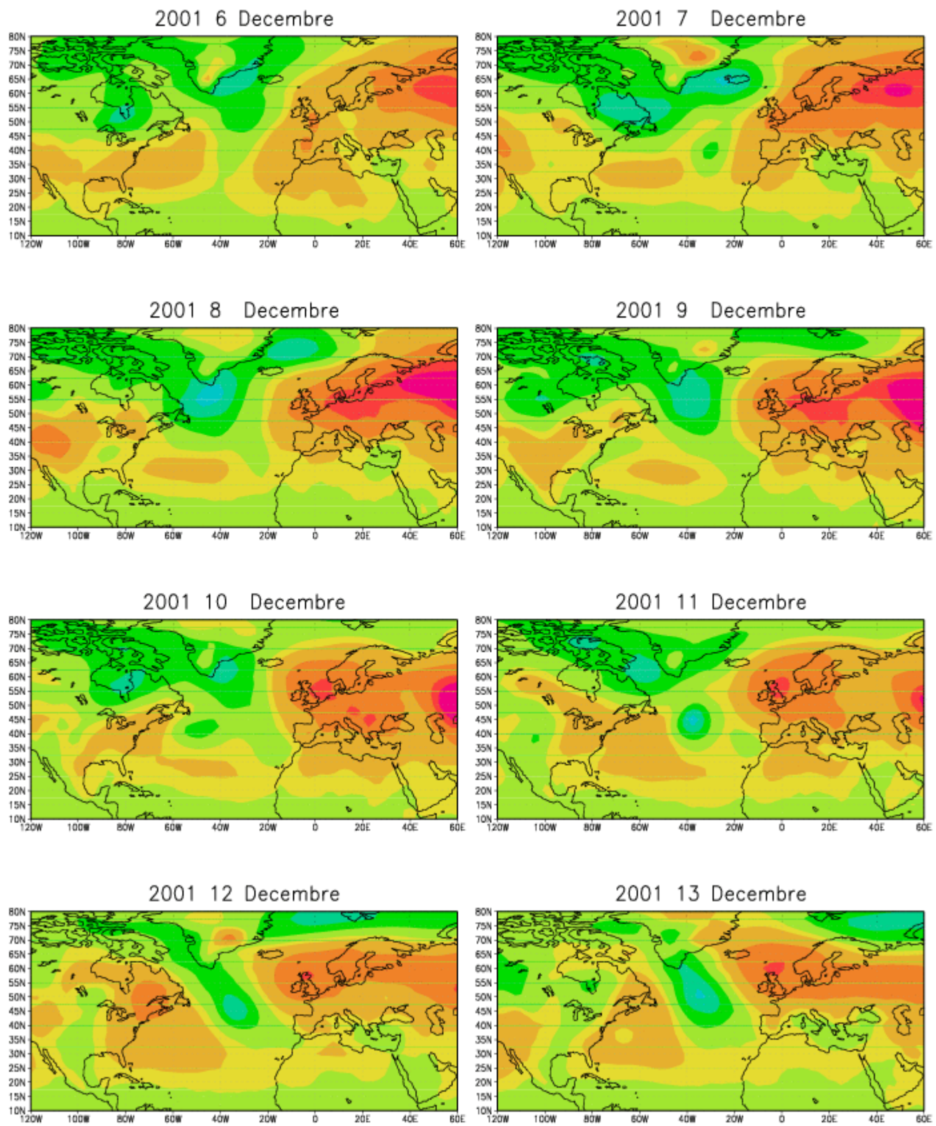
They depens as they cross the Atlantic within 3-5 days

Reach a « mature » quasi-steady stage over northern west europe before decaying (days 4-5-6-7 here)

a) Asymmetric circulations, synoptic eddies, and low-frequency variability in the NH

Modified trajectory of a weather system developing in winter across the Atlantic

Sea-level pressure, NCEP data



Low level pressure systems usually form over the North-East Atlantic near the newfound land Island (Terre-neuve)

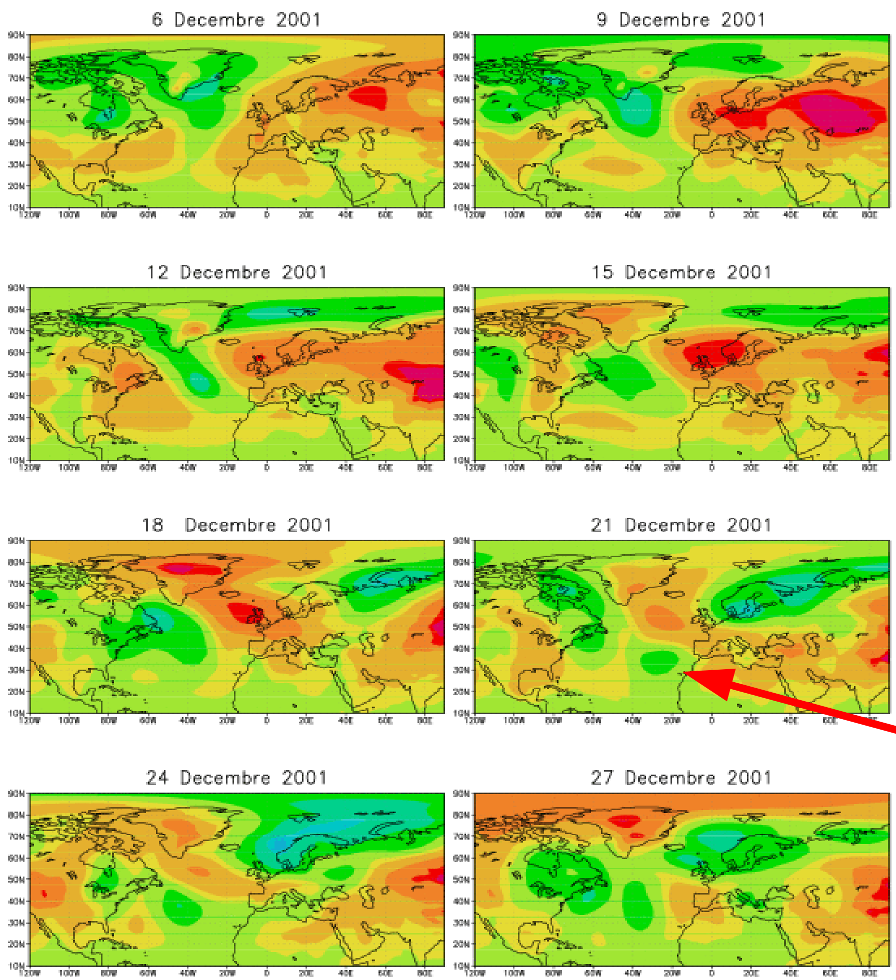
They depens but stay here « blocked » over central Atlantic by an anticyclone that develops over Europe

The low pressure system eventually travel much to the north, or to the south, bringing rain In the subtropical Africa

a) Asymmetric circulations, synoptic eddies, and low-frequency variability in the NH

Extension of the Siberian anti-cyclone over western-Europe and North Atlantic

Sea-level pressure, NCEP data



<u>1 Map every 3 days:</u>

To illustrate that the antyclone develops Slowly, we show 1 map every 3 days, and over a much larger domain than before (including all Europe and Atlantic)

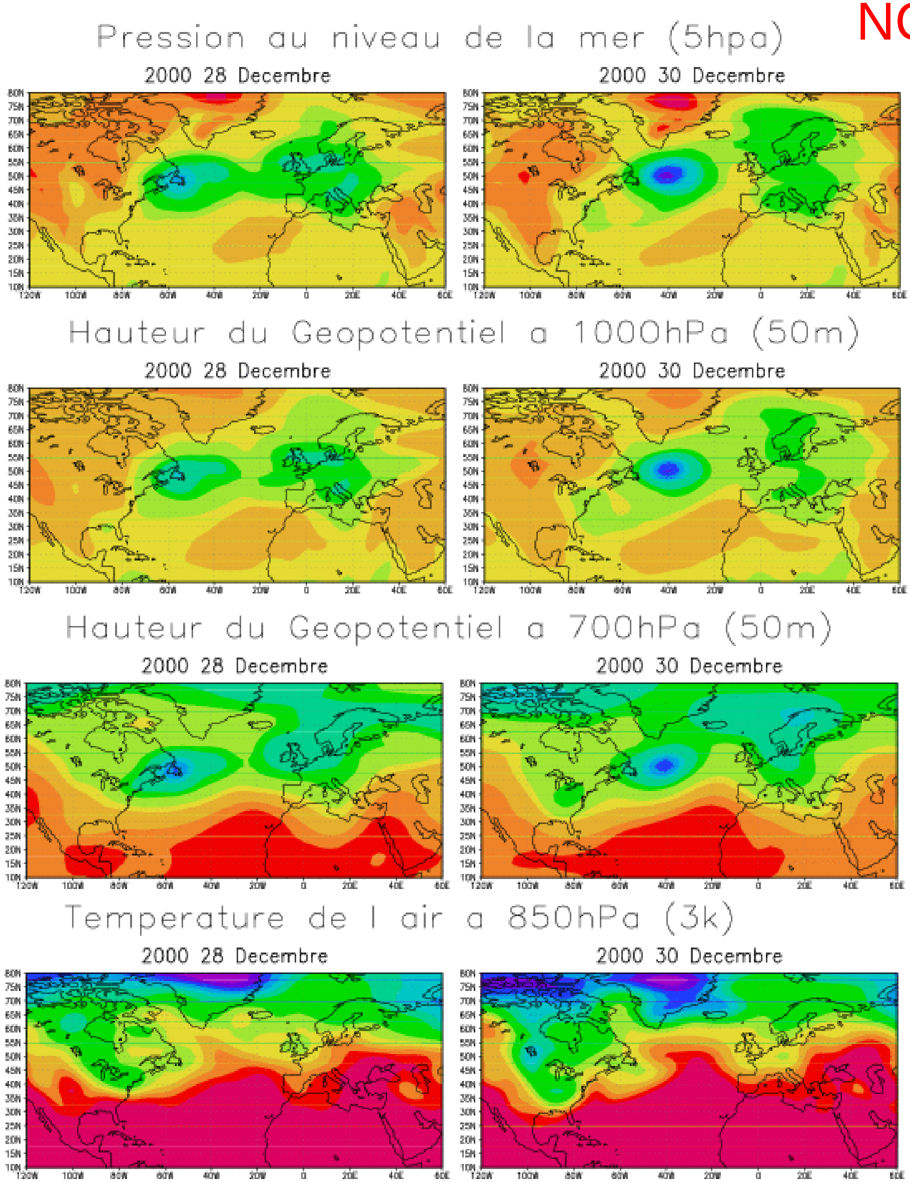
Note the slow development of the anticyclone, as well as its persistence

This meteorological situation is characteristic of the winter blockings over Europe, and when the low pressure systems pass to the south

a) Asymmetric circulations, synoptic eddies, and low-frequency variability in the NH

Low pressure systems impact on other conventionnal fields: 850hPa geopotential and Temperature

NCEP data



The sea-level pressure is often an interpolated quantity, we prefer to characterize the impact of the synoptic scales on meteorological fields at upper levels, for instance near above the boundary layer

For instance the geopotential height at 1000hPa, and 700hPa, contains almost the same as the SLP maps.

The T at 825hPa is warm ahaead the low pressure system, the warm and humid air is advected northward to bring moisture

This is the base mechanism explaining the development of the synoptic scale weather systems, and which is at the base of the Eady waves dynamics (Course 5)

a) Asymmetric circulations, synoptic eddies, and low-frequency variability in the NH

Statistics of the 700hPa, winter monthes (DJF) 1958-2010, NCEP data

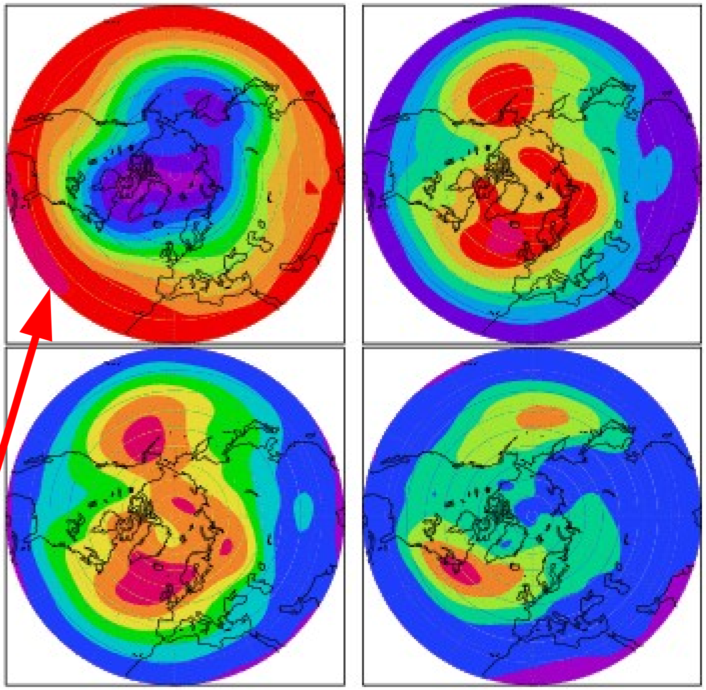
<u>Mean:</u>

Note the intensification of the westerly jet at the East of the continents (storm tracks)

And its enlargement to the East of the ocean, related to the different routes the low pressure systems can follow

<u>Low-frequency standard deviation</u>

It represent the largest fraction of the total standard deviation



<u>Standard deviation:</u>

The maxima in variability are over the North-eastern ocean. It is more due to the changes in trajectory of the mature weather systems, than two their initial birth and development

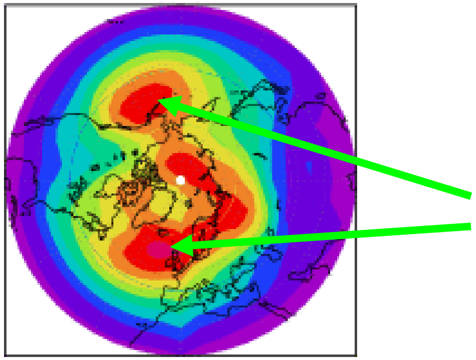
<u>High-frequency standard deviation:</u>

It directly translates where the low pressure systems form and travel during the few days after their birth

<u>Important: the stationnary Rossby waves forced by mountains build-up the planetary scale stationnary planetary wave</u>

b) Dominant patterns of low-frequency variability

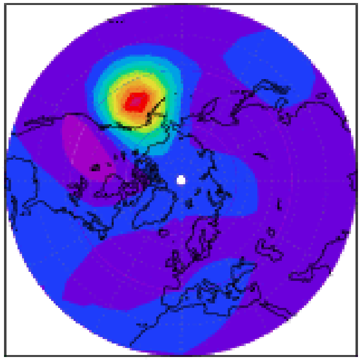
Statistics of the 700hPa, winter monthes (DJF) 1958-2010,
NCEP data



Low frequency standard deviation:

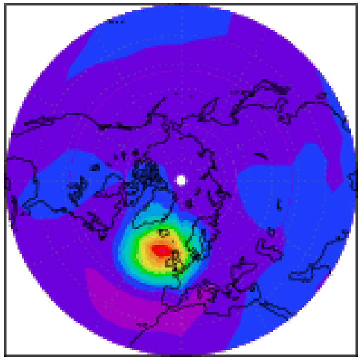
It represents most of the total standard deviation

It points two maxima, or centres of action in the NH, over the north-east Pacific and the Atlantic Nord-Est



Low frequency correlation with the Pacific center of action:

Note the extent and the anti-correlation over the american continent



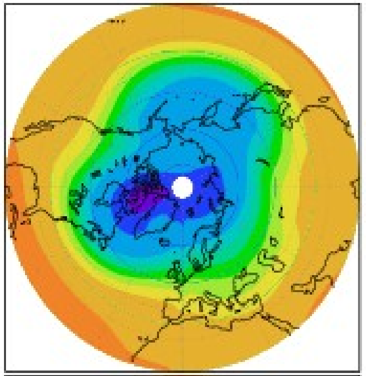
Low frequency correlation with the Atlantic center of action:

Note the extent and the anti-correlation with the subtropical regions

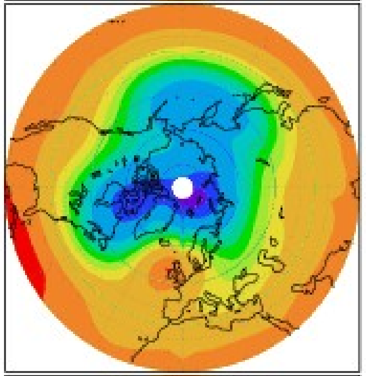
b) Dominant patterns of low-frequency variability

Mean and composite keyed to the geopotential height values in the middle of the Atlantic center of action (15°W, 58°N)

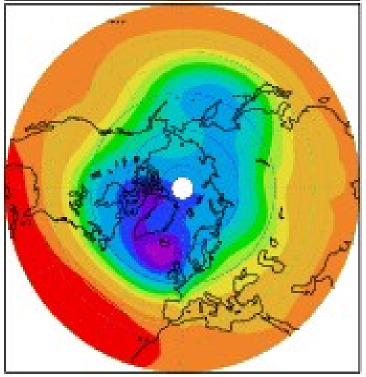
Winter month (DJF) 1958-2010, NCEP Data



Winter mean (the stationnary planetary wave)



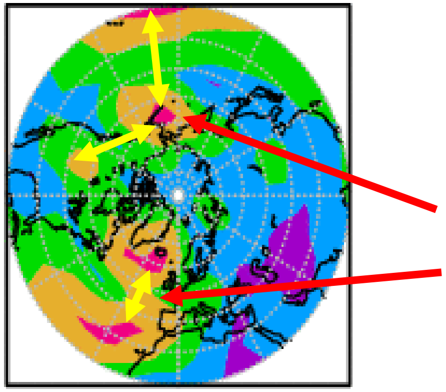
Composite keyed on positive values:
European blockings



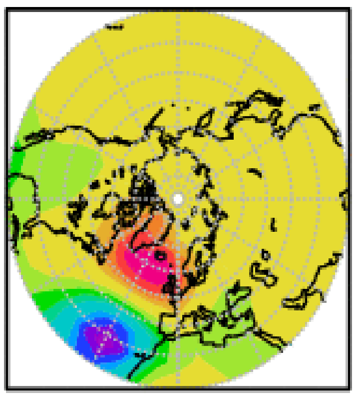
Composite keyed on negative values:
Zonal situation, favourable to storms over western europe

b) Dominant patterns of low-frequency variability

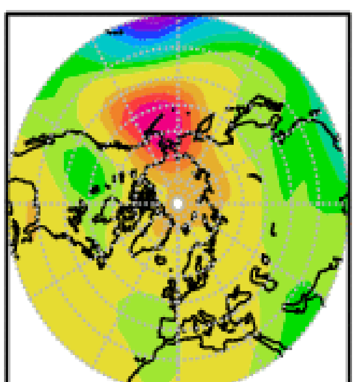
<u>Teleconnections:</u> maxima of anticorrelation between distant points
700hPa Geopotential (DJF) 1958-2010, NCEP



Maxima of anti-anticorrelations:
North Pacific, America, and subtropical Pacific: PNA
North Atlantic, and subtropical Atlantic: NAO



Regression with NAO center located near Iceland
(North Atlantic Oscillation):

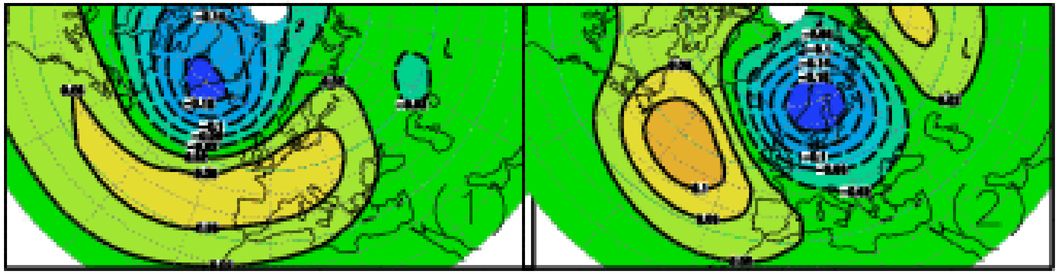


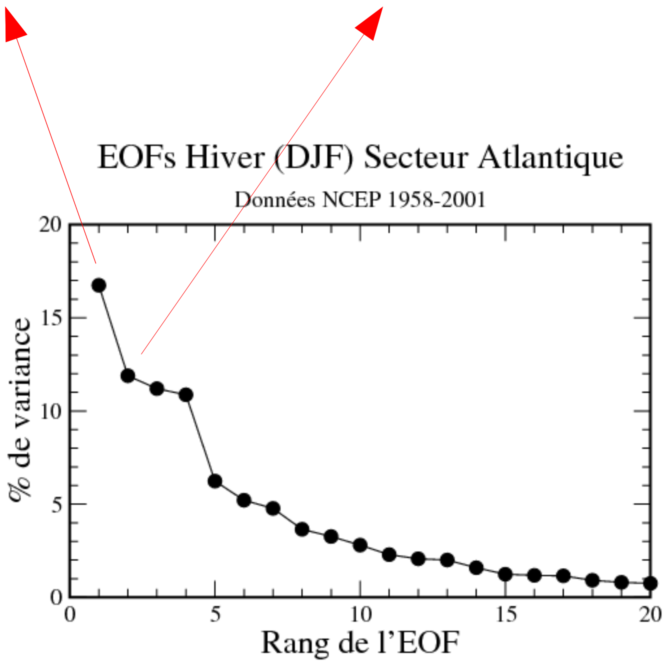
Regression with PNA center of action located near Alaska
(Pacific North-American Pattern):

b) Dominant patterns of low-frequency variability

Atlantic EOFs (DJF 1958-2001, NCEP data)
Sector: 90°W-90°E, 30°N-90°N

EOF1 EOF2





The first EOF describe fluctuations in position and intensity of the low level mid-latitude jet

It looks like the Arctic Oscillation and Represent 17% of the Atlantic variance

Its fluctuations describe climate varaitions over north-west europe

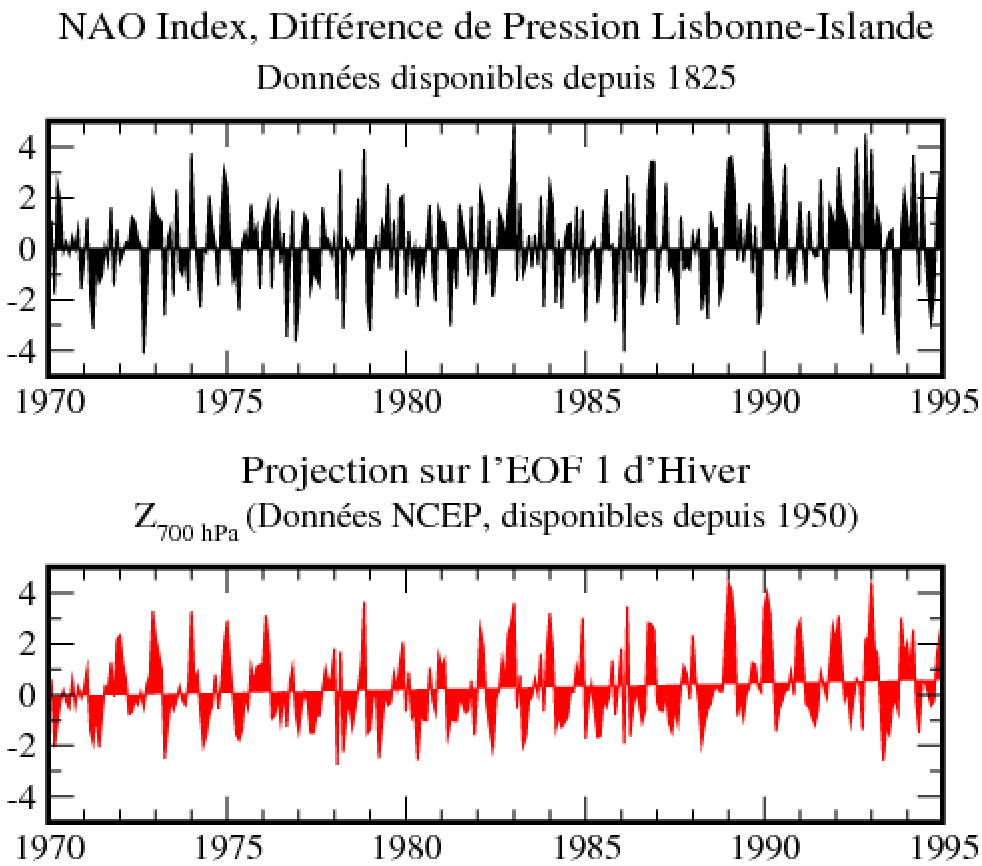
The second EOF is reminiscent of the European blocks

b) Dominant patterns of low-frequency variability

Characteristic scales of the North Atlantic Oscillation

1958-1997, NCEP data

1925-today, surface pressure difference between Reikjavit and Lisbon

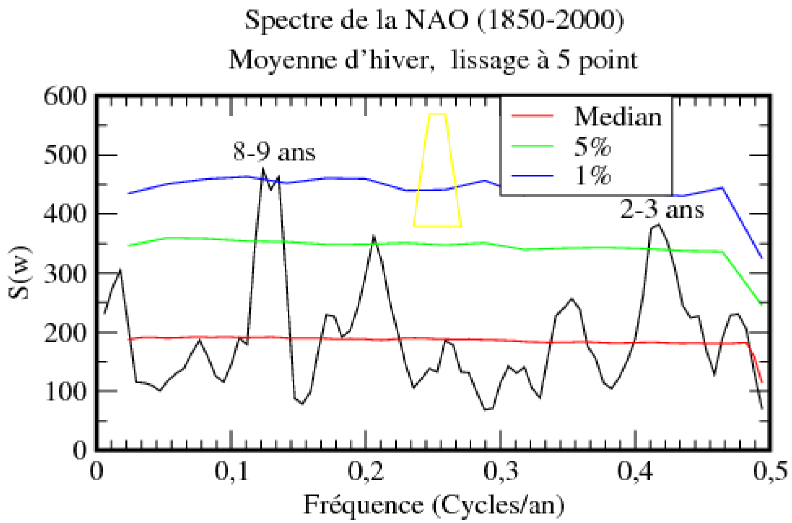


We see on this two sets that the pressure difference follows well the PC1:
It can be used as a proxy of the NAO

We can therefore extent in the past and analyse the interannual low frequency variability

b) Dominant patterns of low-frequency variability

Characteristic time scales of the North Atlantic Oscillation
1958-1997, NCEP data
1925-today, surface pressure difference between Iceland and Portugal



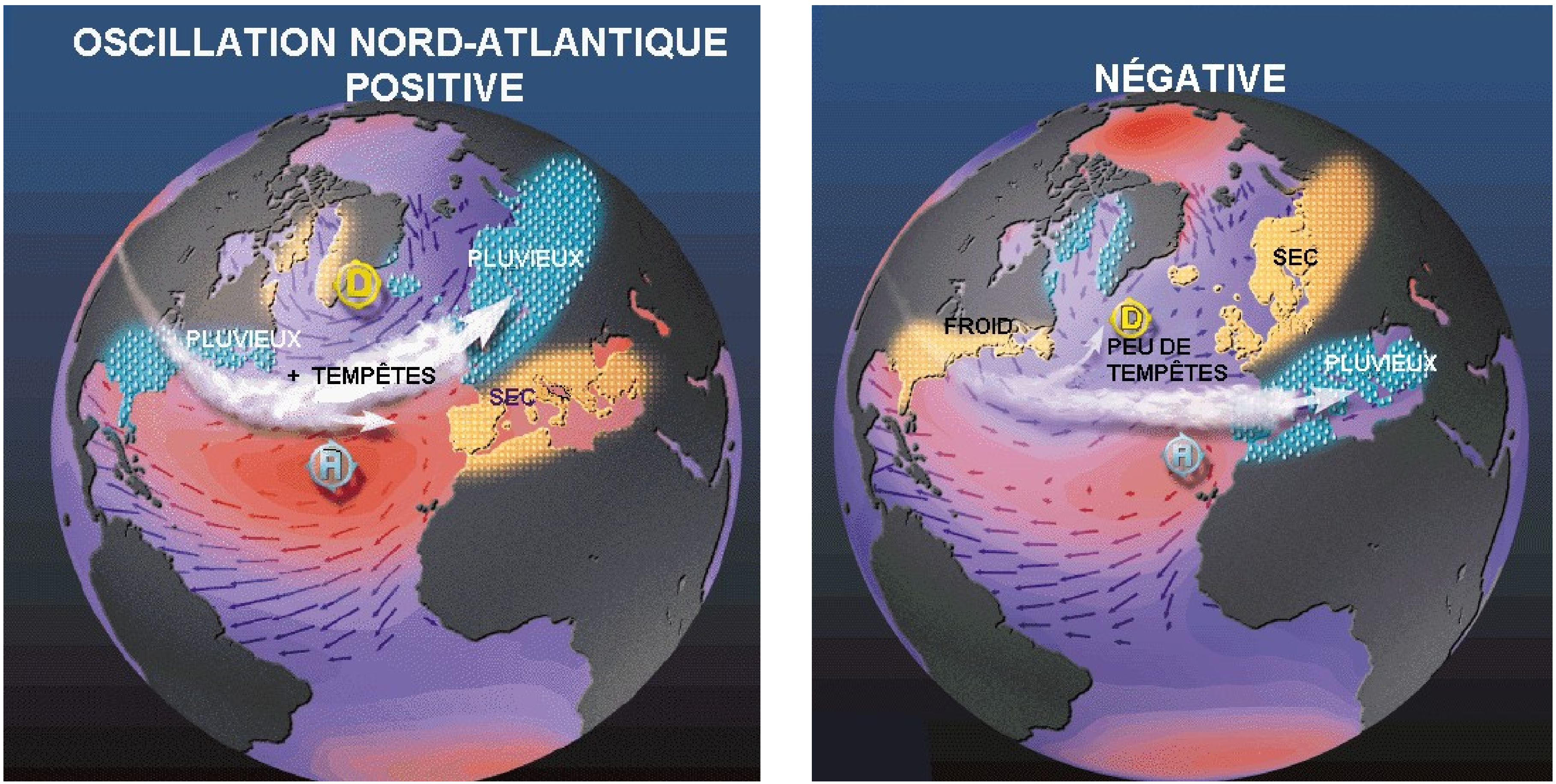
The series are not much different from a white Noise:
quite energetic at slow time scales but not « predictible »:

A 10-year peak, weakly energetic, is present around 10yrs,
Suggesting the presence of a decadal oscillation?

b) Dominant patterns of low-frequency variability

The North-Atlantic Oscillation

(Original authors: M. Visbeck and Heidi Cullen)

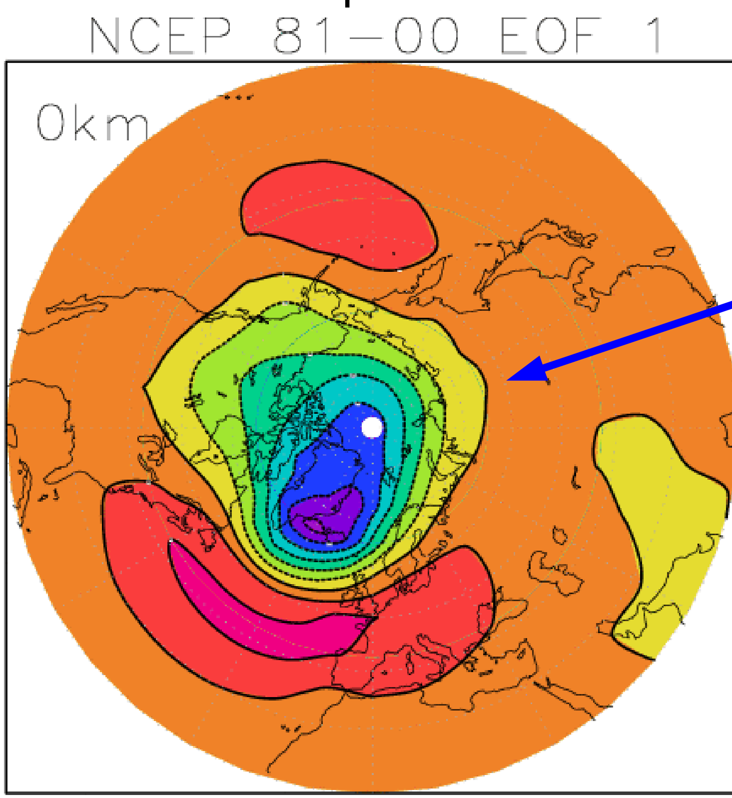


b) Dominant patterns of low-frequency variability

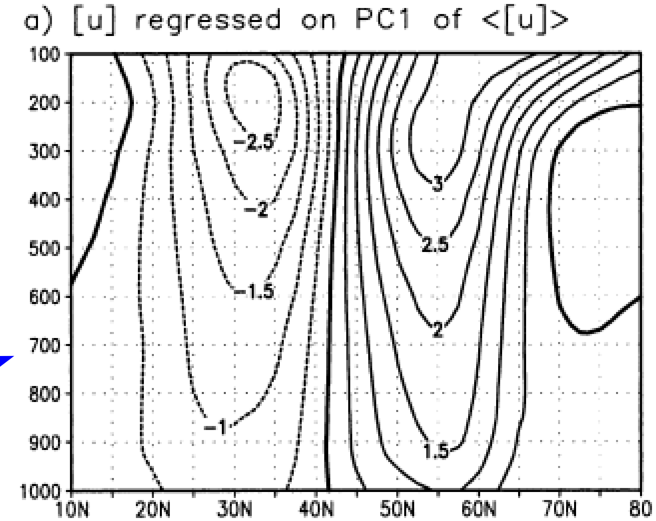
The Arctic Oscillation :

first mode of
Hemispheric variability in the NH

Surface pressure



Zonal mean zonal wind
regressed on PC1

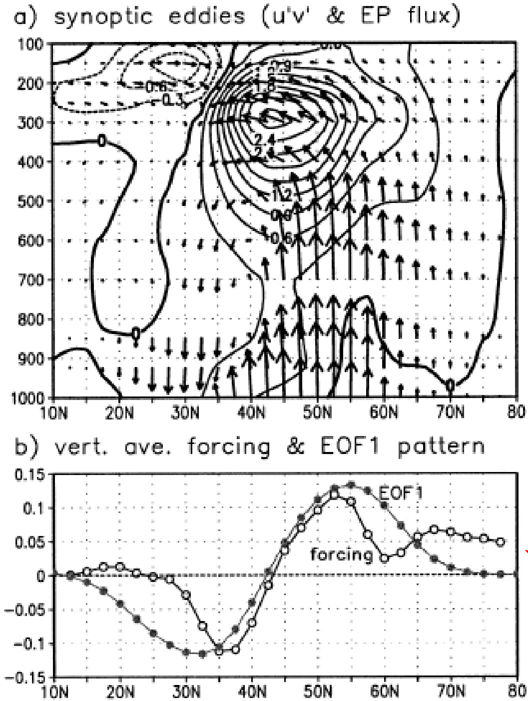


Quite « barotropic structure»

Larger zonal wind north of 40°N

b) Dominant patterns of low-frequency variability

$\cos\phi\,\overline{u'v'}$ and $\vec{\overline{F}}$



Eddy forcing ($\cos\varphi\ \overline{u'v'}$, contours)
8 to 30 days after a max in PC1

The EP flux indicate strong Eady activity (baroclinic instability)

This shows that the Eddies maintain « feedback » the AO

The vertical average of the forcing
(8 to 30 days after)

Matches the vertical average of the zonal wind associated with EOF1
(e.g. the Arctic Oscillation)

The Arctic Oscillation is maintained by the Eddies
Lorenz and Hartmann (2003)

Annex: Minimum to be known about Empirical Orthogonal functions:

Maps over a sector are designed by a vector :

$$\underline{Z}(t)=\left(Z(\lambda_{1,}\phi_1,t),Z(\lambda_{2,}\phi_2,t),....,Z(\lambda_M,\phi_M,t)\right)$$

λ_i, ϕ_i, and a_i : longitude, latitude and area

$\lambda_{1,}\phi_1$ a_1	$\lambda_{2,}\phi_2$ a_2	...		
				λ_M,ϕ_M a_M

Time mean and disturbances

(disturbances denoted by primes are not disturbances to the zonal mean) :

$$\underline{Z}(t)=\langle\underline{Z}\rangle+\underline{Z}'(t) \qquad \langle\underline{Z}\rangle=\frac{1}{N}\sum_{n=1}^{N}\underline{Z}(t_n)$$

Low frequency: $\underline{\tilde{Z}}(t)=\left(\underline{Z}'(t-1)+\underline{Z}'(t)+\underline{Z}'(t+1)\right)/3.$

Scalar product between two maps

$$\underline{\tilde{Z}}\cdot\underline{E}=\frac{1}{a}\sum_{m=1}^{M}a_m\tilde{Z}_m E_m \qquad \text{Total area:} \quad a=\sum_{m=1}^{M}a_m$$

Total low pass variance averaged over the sector: $\langle\underline{\tilde{Z}}\cdot\underline{\tilde{Z}}\rangle$

Projection onto a normalised pattern $(\underline{E}\cdot\underline{E}=1)$: $\quad(\underline{E}\cdot\underline{\tilde{Z}})\,\underline{E}$

Variance associated with a projected pattern :

$$\langle(\underline{E}\cdot\underline{\tilde{Z}})^2\rangle=\sum_{m=1}^{M}\sum_{k=1}^{M}E_m\underbrace{\langle\tilde{Z}_m\tilde{Z}_k\rangle}_{C_{mk}}E_k=\underline{E}\cdot\left(\underline{\underline{C}}\cdot\underline{E}\right)$$

The eddy covariance matrix is symmetric definite positive :

It admits orthogonal eigenvectors $\underline{E}_m$ (the EOFS) with eigenvalues α_m $\qquad \alpha_1>\alpha_2>....>\alpha_M$

They represent the percentage of total variance associated with the EOF:

Principal Component : $\quad \underline{\tilde{Z}}(t)=\sum_{m=1}^{M}\underbrace{\left(\underline{E}_m\cdot\underline{\tilde{Z}}(t)\right)}_{Pc_m(t)}\underline{E}_m$

percentage of total variance $\quad \langle\underline{\tilde{Z}}\cdot\underline{\tilde{Z}}\rangle=\sum_{m=1}^{M}\langle\left(\underline{E}_m\cdot\underline{\tilde{Z}}\right)^2\rangle=\sum_{m=1}^{M}\alpha_m$