The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

1968-55

Conference on Teleconnections in the Atmosphere and Oceans

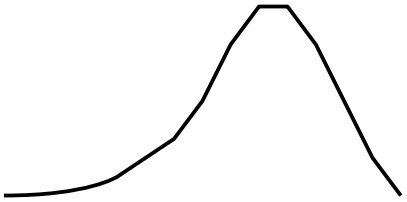
17 - 20 November 2008

On the skewness of the annular mode.

SELTEN Franciscus Maria and PASMANTER Ruben
Koninklijk Nederlands Meteorologisch Instituut K.N.M.I.
Wilhelminalaan, 10
P. O. Box 201
3730 AE de Bilt
NETHERLANDS

Skewness of the extra-tropical winter circulation: role of the Arctic Oscillation and sensitivity to greenhouse warming

Frank Selten and Ruben Pasmanter
KNMI Netherlands



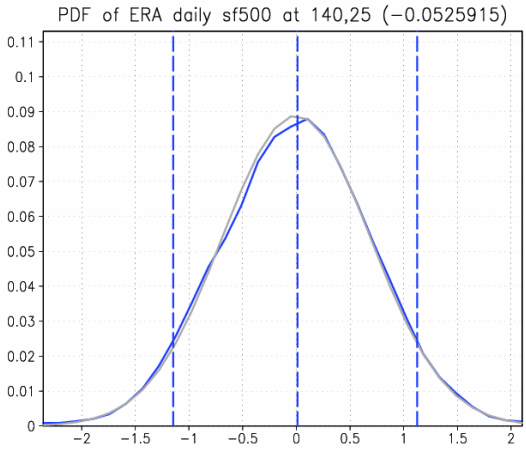
Not all things are normal .....

What is skewness ?

Skewness is a measure of the asymmetry of a distribution
Skewness = $\langle (x-\langle x \rangle)^3 \rangle^{1/3} / sd$ with $sd = \langle (x-\langle x \rangle)^2 \rangle^{1/2}$
Often climate variables are symmetrically distributed

normal PDF
PDF at 140E-25N
5-50-95 percentiles

Skewness = 0.

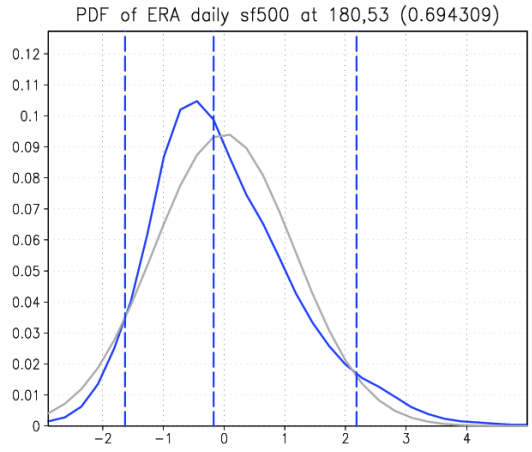


Positive skewness

Sometimes large positive anomalies occur more often
The distribution in that case has positive skewness

normal PDF
PDF at 180E-53N
5-50-95 percentiles

Skewness = 0.7

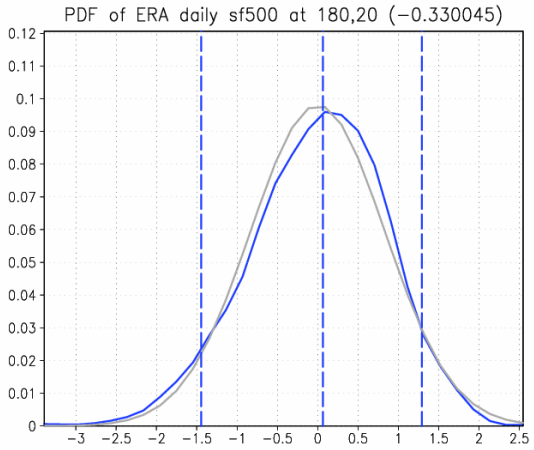


Negative skewness

Sometimes large negative anomalies occur more often
The distribution in that case has negative skewness
For example: daily DJF 500 hPa streamfunction anomalies

normal PDF
PDF at 180E-20N
5-50-95 percentiles

Skewness= - 0.3



Why study skewness ?

- Interesting in itself
- Is sensitive to the extreme values
- Indication of non-linearity: sign of the anomaly matters
- Teleconnection studies neglect skewness as it is based on linear correlations
- Might find non-trivial response to a forcing
- ...

Quasi-geostrophic atmosphere

Franco Molteni model

$$\frac{\partial q}{\partial t} = -J(\Psi, q) - D(\Psi) + S \qquad (1)$$

3 levels, 200, 500 and 800 hPa

Spectral model on sphere, truncated at T21 (1470 variables)

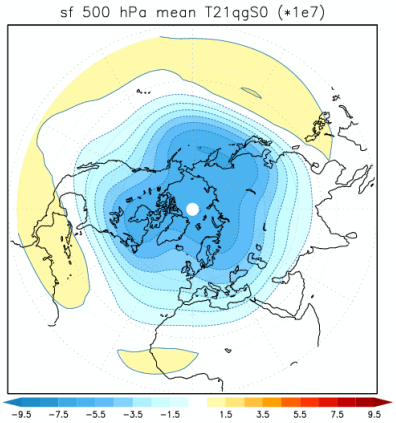
Damping *D:* Ekman and hyper-viscosity, Newtonian cooling

Forcing S calculated from NH winter daily analyses:

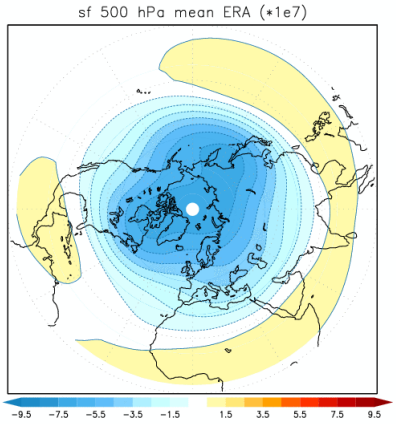
$$\overline{S} = \overline{J(q_{obs}, \Psi_{obs})} + D(\overline{\Psi_{obs}}) \qquad (2)$$

DJF streamfunction at 500 hPa

T21QG



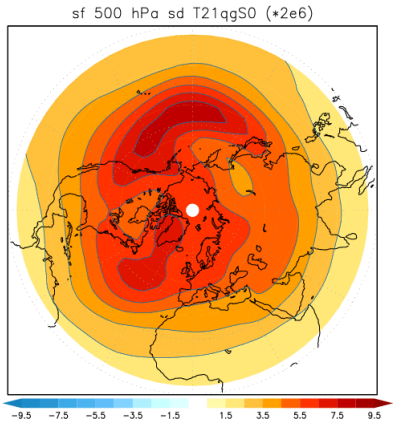
ERA



mean

DJF streamfunction at 500 hPa

T21QG



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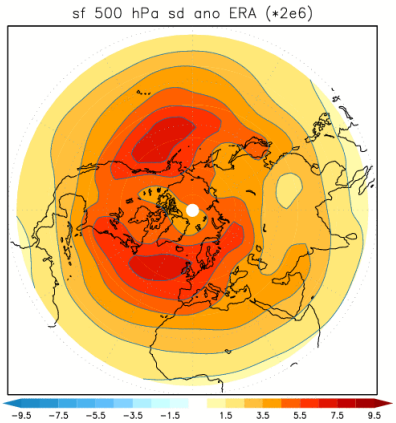


standard deviation of 1-90 days time scales

PDF of 1st EOF at 500 hPa in T21qg: sensitive to ΔS

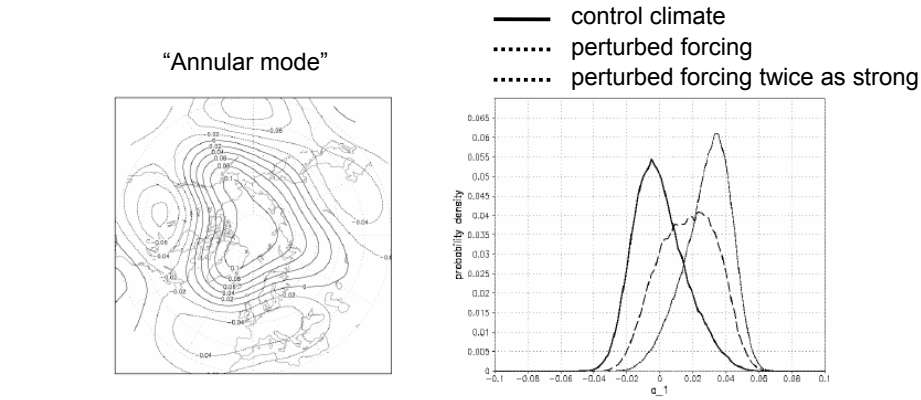
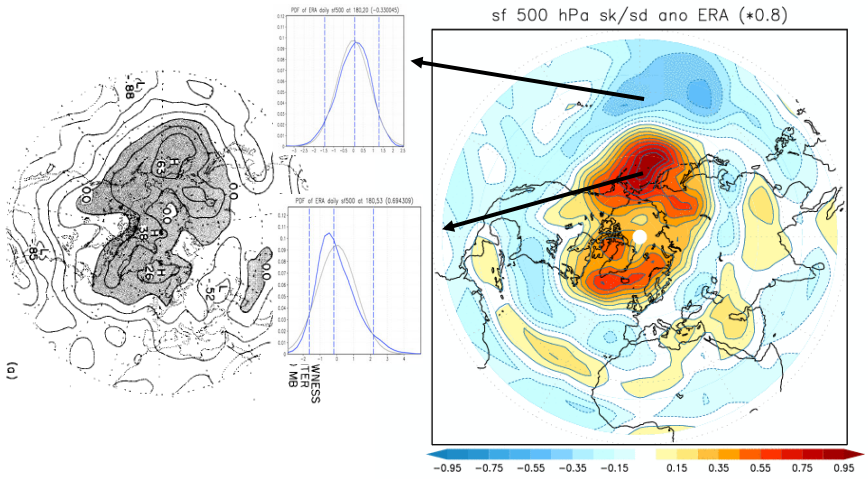


Figure 1: (Left) Dominant EOF of daily streamfunction variations of T21QG. (Right) Probability Density Function of this EOF for the unperturbed forcing case (solid), with 5% perturbation of the forcing with a spatial pattern of this EOF (dashed) and the same forcing perturbation but twice the amplitude (dotted).

Research questions

- What causes the skewness ?
- What makes the skewness change sign ?
- Why is the EOF with the largest skewness the most sensitive ?
- Do these results carry over to more realistic models ?
- Does greenhouse forcing change the skewness ?
- What about skewness in nature ?
- Is it sensitive to external perturbations ?

DJF skewness of daily values

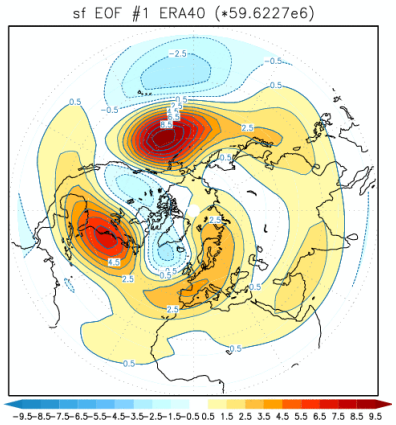


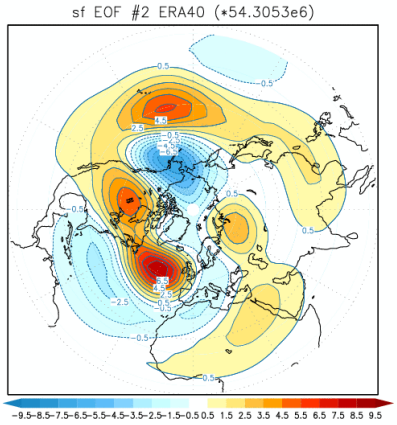
Geopotential height 500 hPa
White (1980) data from 1965-1976

Streamfunction 500 hPa ERA40
Data from 1958-2001: 3960 maps

Which patterns contribute to the local skewness ?

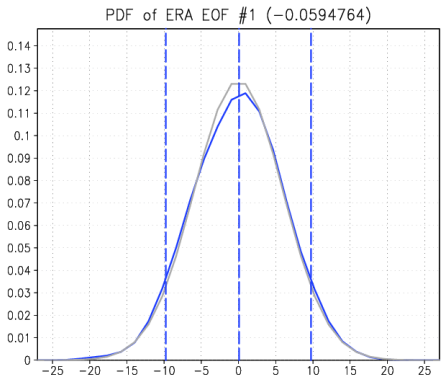
First EOFs 500 hPa DJF streamfunction

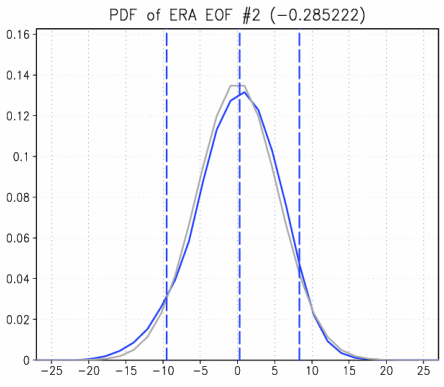




Mixture between PNA and (N)AO

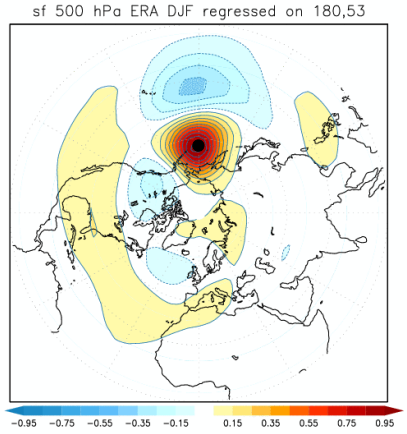
PDF of ERA EOFs

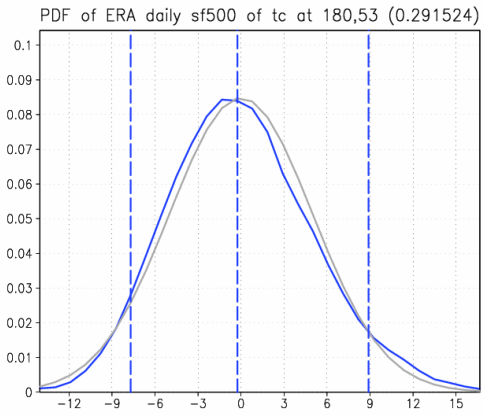




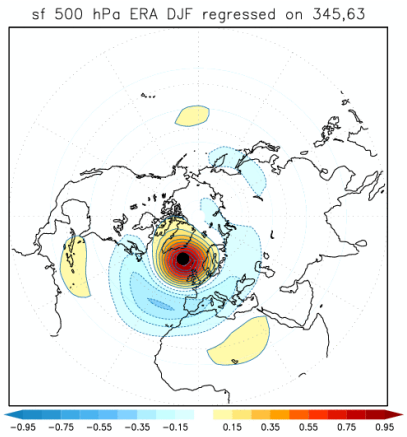
Negative skewness

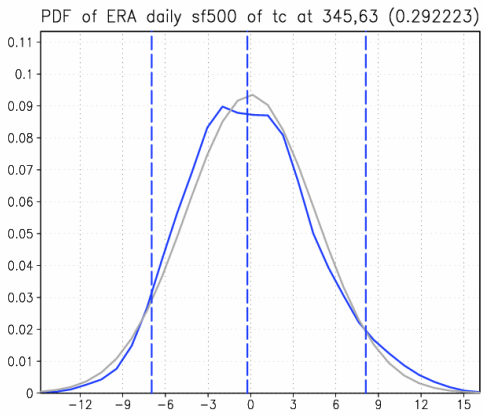
Teleconnection maps in maximum skewness locations





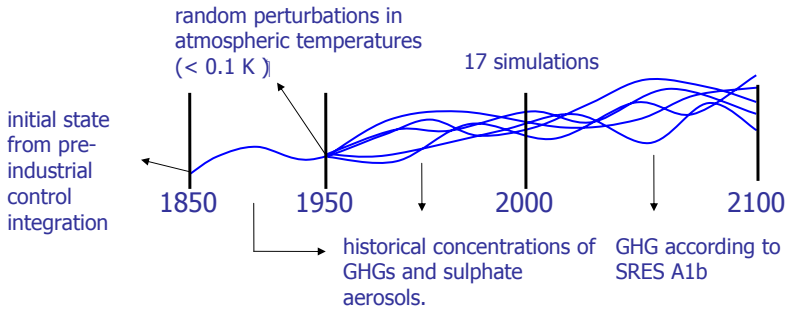
Teleconnection maps in maximum skewness locations





Evaluate AO and skewness in Essence

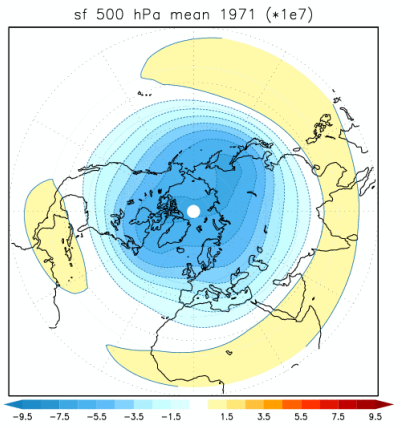
"ESSENCE project: a 17 member ensemble of climate SRES A1b scenario simulations from perturbed initial conditions using the ECHAM5-MPI-OM model"



http://www.knmi.nl/~sterl/Essence

DJF streamfunction at 500 hPa

Essence



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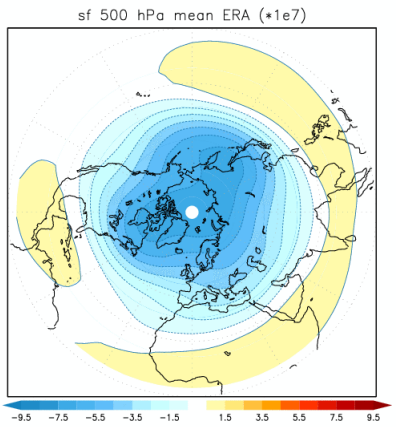
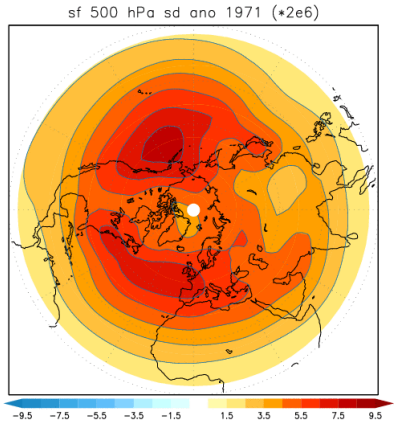


mean

DJF streamfunction at 500 hPa

Essence



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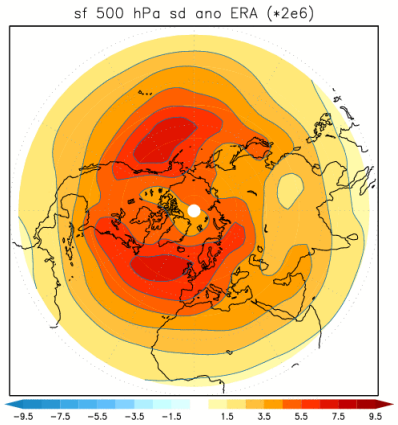
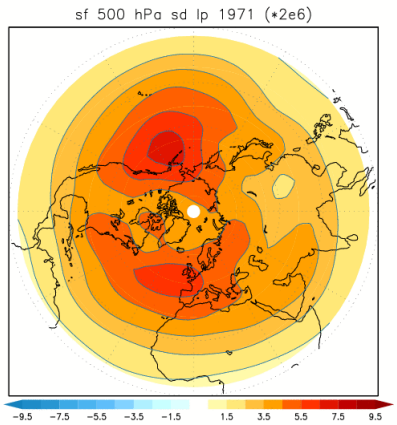


standard deviation of 1-90 days time scales

DJF streamfunction at 500 hPa

Essence



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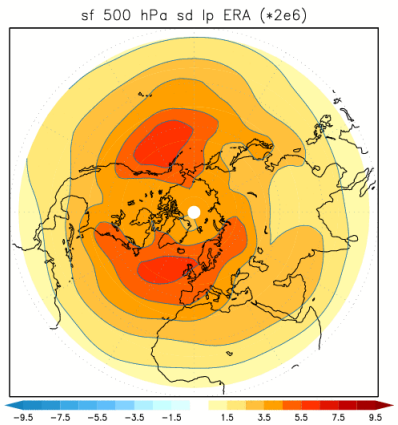
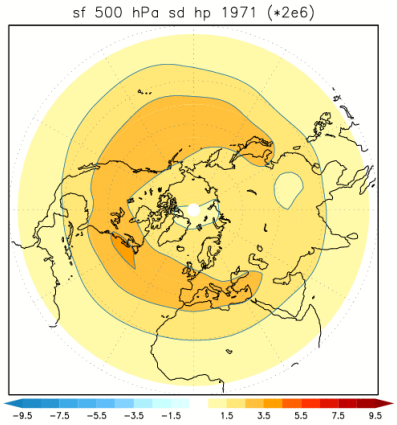


standard deviation of 5-90 days time scales

DJF streamfunction at 500 hPa

Essence



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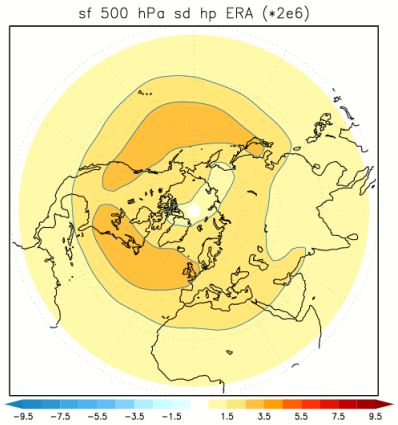
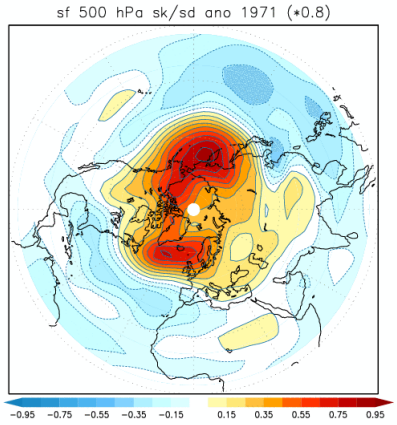


standard deviation of 1-5 days time scales

DJF streamfunction at 500 hPa

Essence



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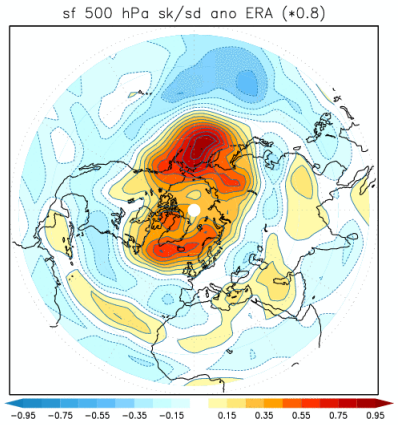
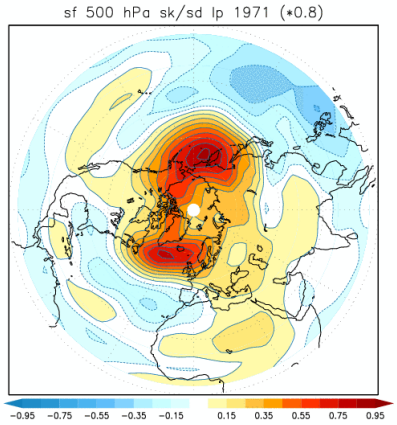


Skewness of 1-90 day timescales normalised to one sd

DJF streamfunction at 500 hPa

Essence



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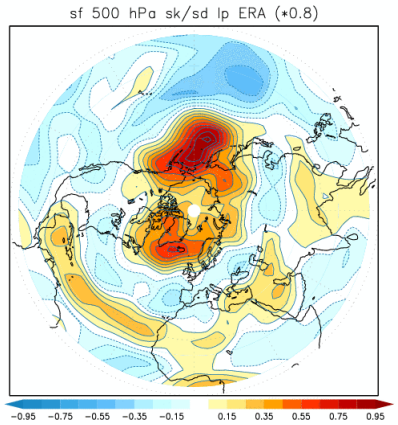
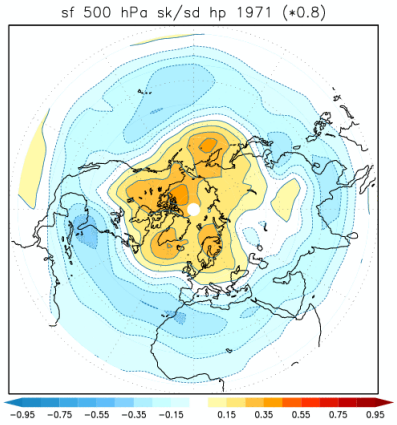


Skewness of 5-90 day timescales normalised to one sd

DJF streamfunction at 500 hPa

Essence



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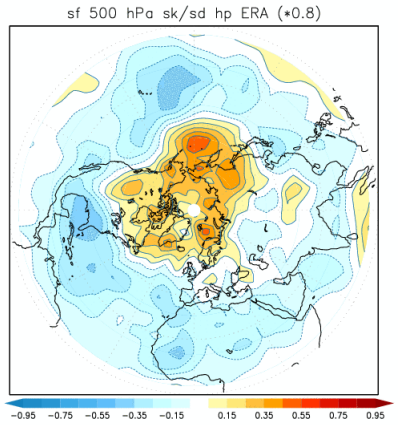
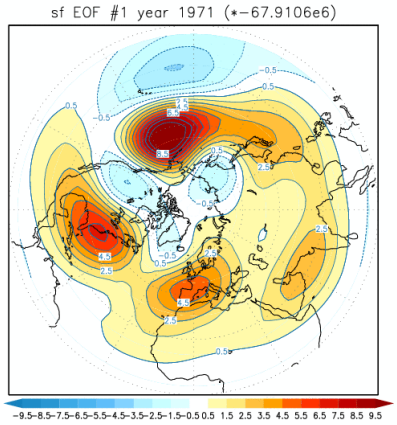


Skewness of 1-5 day timescales normalised to one sd

DJF streamfunction at 500 hPa

Essence



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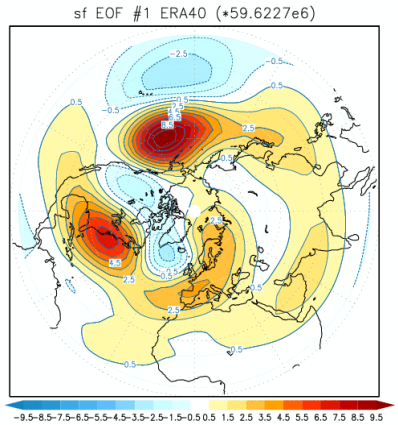
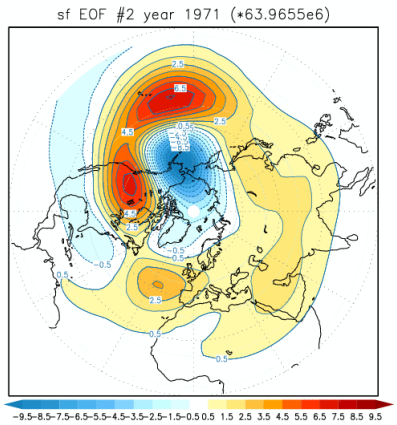


EOF #1

DJF streamfunction at 500 hPa

Essence



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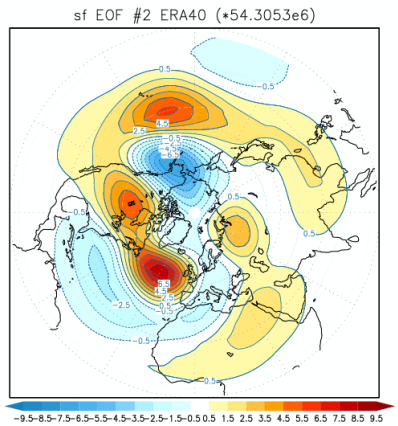

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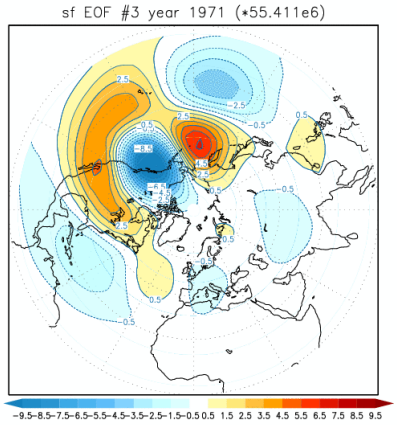
DJF streamfunction at 500 hPa

Essence



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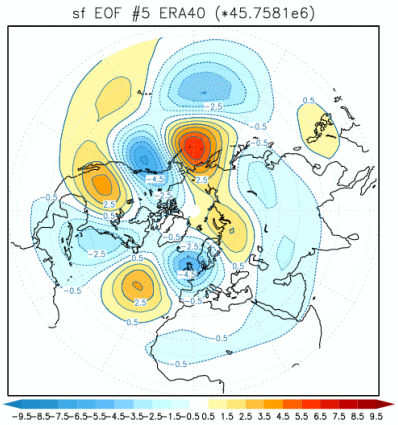

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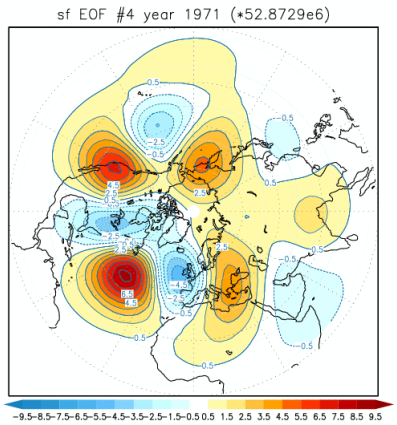
DJF streamfunction at 500 hPa

Essence



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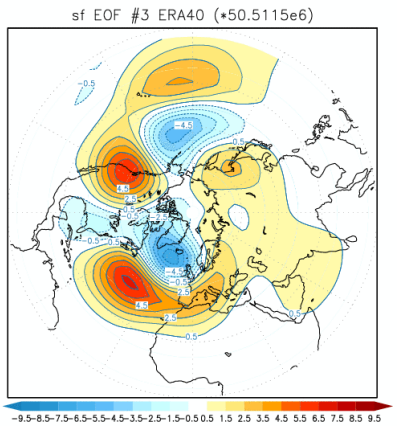

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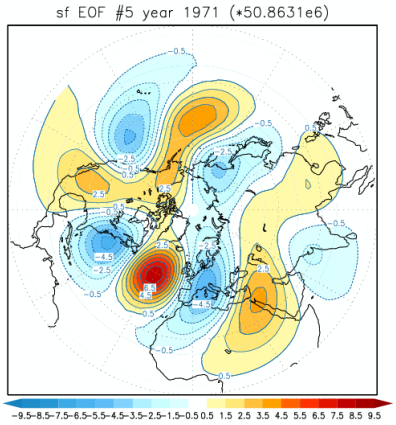
DJF streamfunction at 500 hPa

Essence



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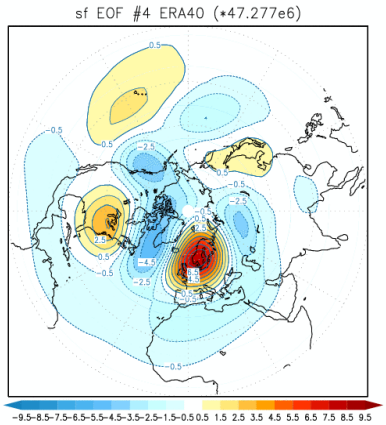

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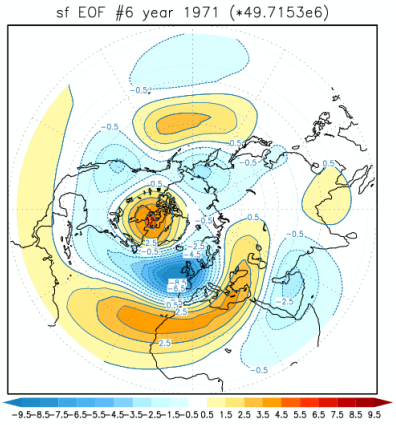
DJF streamfunction at 500 hPa

Essence



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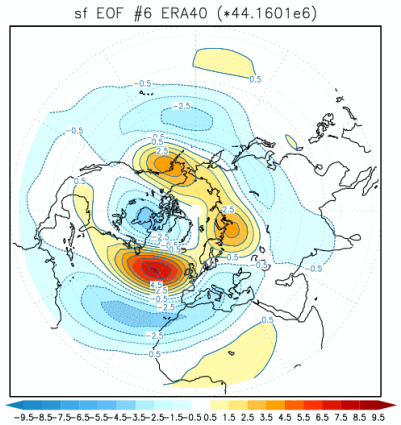

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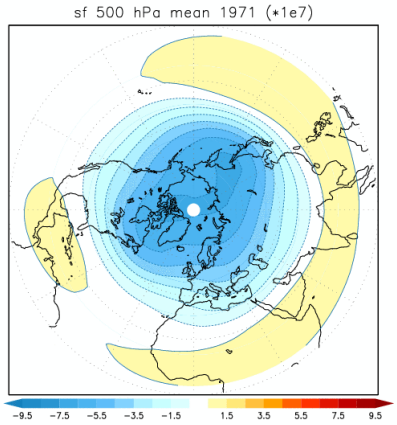
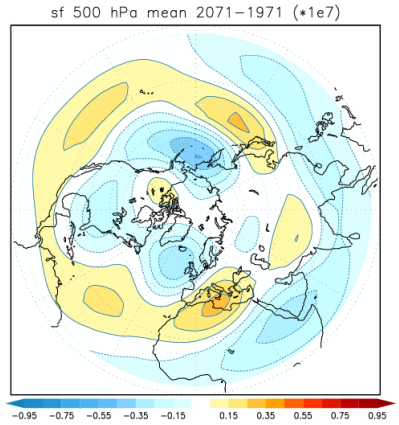
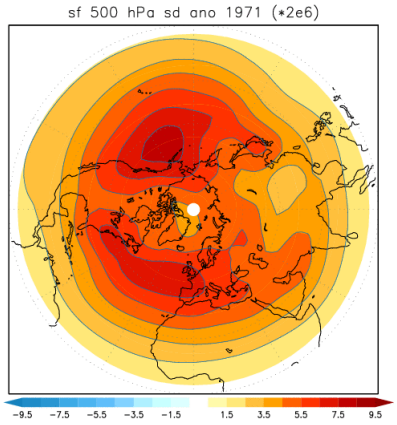
Essence DJF streamfunction 500 hPa climate change

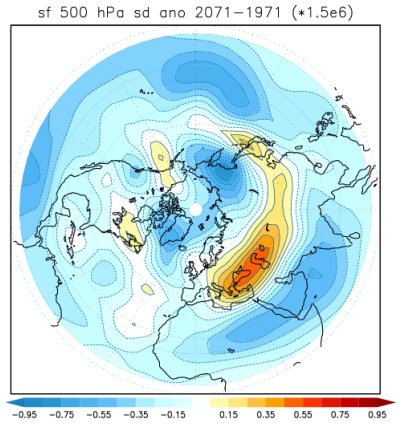




mean

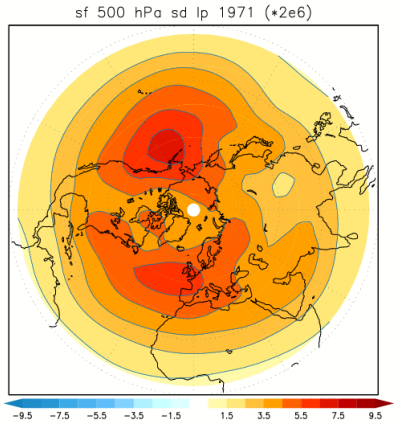
Essence DJF streamfunction 500 hPa climate change

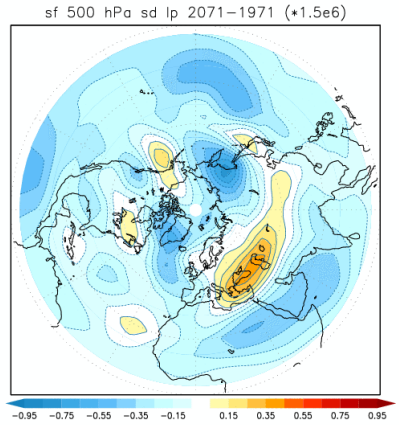




standard deviation of 1-90 day timescales

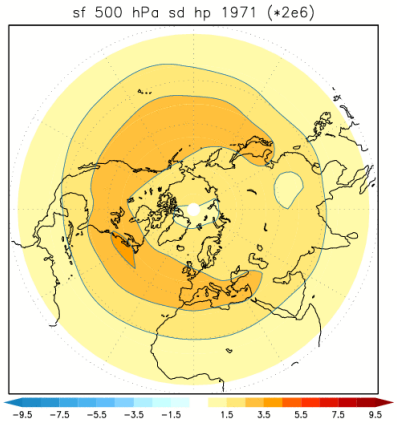
Essence DJF streamfunction 500 hPa climate change

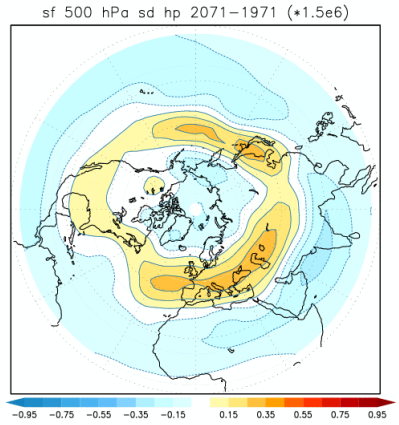




standard deviation of 5-90 day timescales

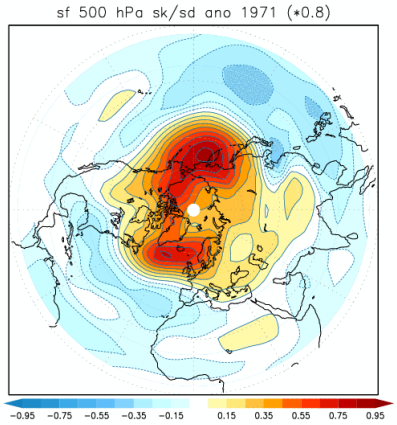
Essence DJF streamfunction 500 hPa climate change

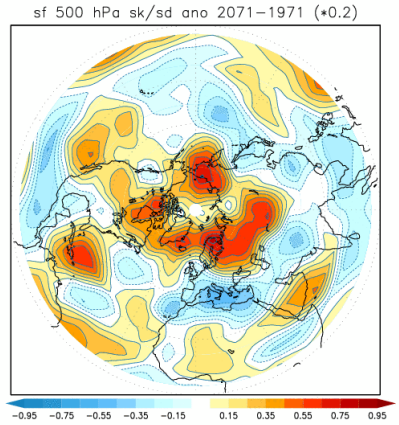




standard deviation of 1-5 day timescales

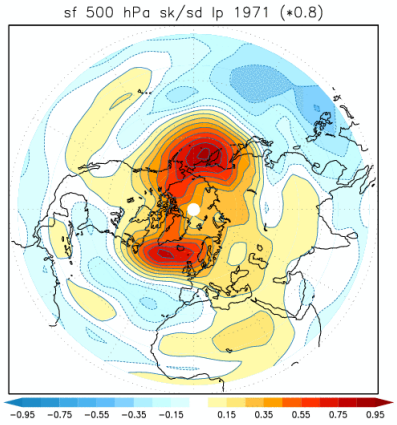
Essence DJF streamfunction 500 hPa climate change

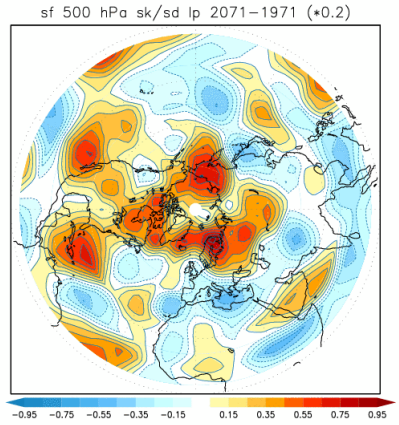




Skewness of 1-90 day timescales normalised to one sd

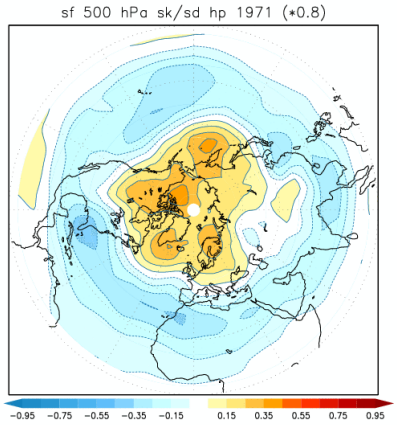
Essence DJF streamfunction 500 hPa climate change

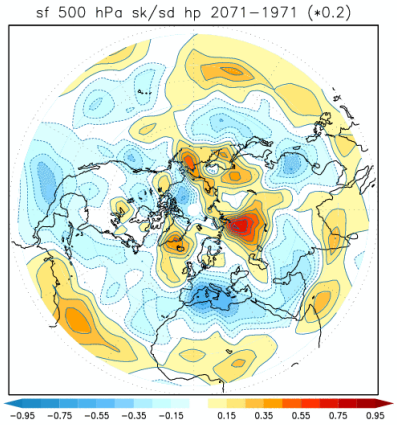




Skewness of 5-90 day timescales normalised to one sd

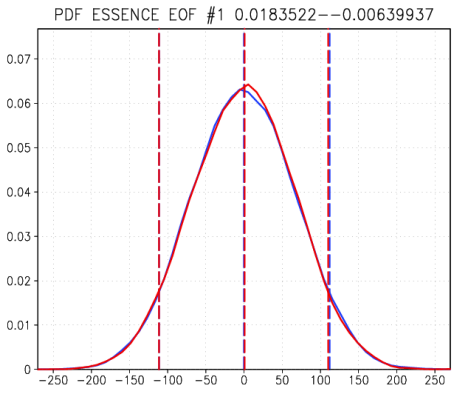
Essence DJF streamfunction 500 hPa climate change

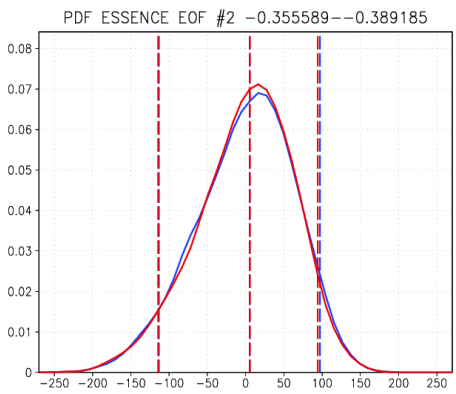




Skewness of 1-5 day timescales normalised to one sd

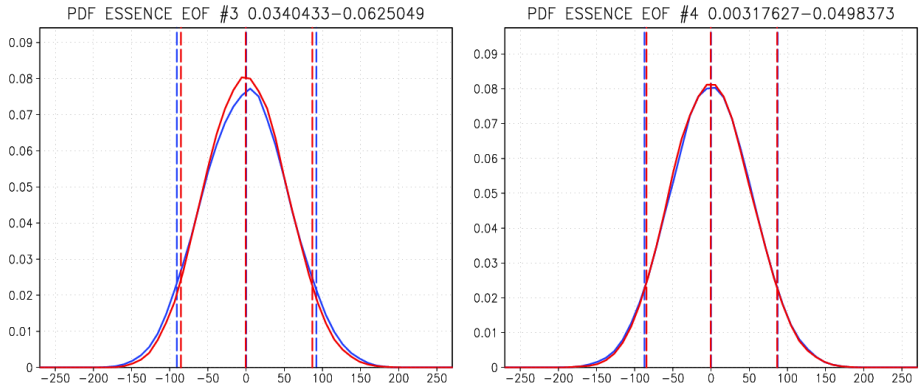
Essence DJF daily streamfunction 500 hPa EOF PDFs 1971-2071





Hardly any change in the PDF of the first two EOFs

Essence DJF daily streamfunction 500 hPa EOF PDFs 1971-2071



Use T21QG as a tool to understand climate change in Essence

Check that T21QG can reproduce ESSENCE skewness

Check that T21QG can reproduce ESSENCE skewness climate change

Decomposition of S in different terms

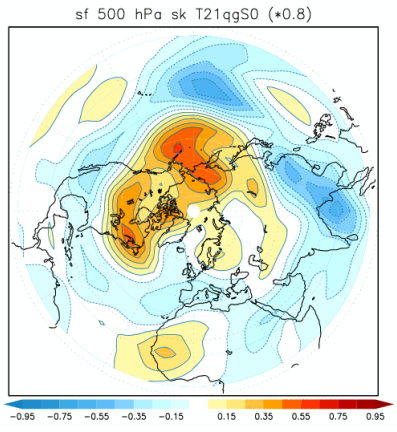
$$(1) \qquad \frac{\partial q}{\partial t} = -J(\Psi, q) - D(\Psi) + S$$

S(t) =

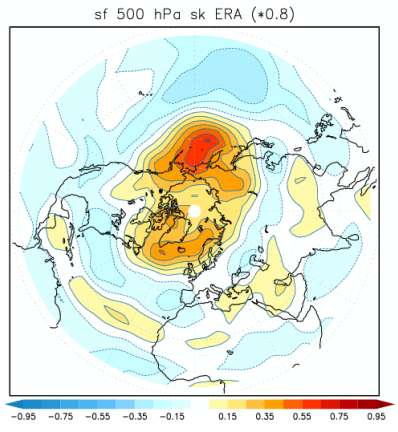
$S_o + S_{day}(t) + S_{year}(t) + (t\text{-}to)\Delta S_{trend} + S_{enso}(t) + R(t)$

DJF streamfunction at 500 hPa

T21QG



ERA



skewness

Summary

- Extra-tropical circulation is skewed
- Idealised QG simulations indicate that the skewness in the AO might be sensitive to small forcings
- ESSENCE simulates nature in DJF NH quite well; similar EOFs and skewness
- ESSENCE indicates 20 % change in future skewness
- Skewness is not concentrated in dominant EOFs
- More work needed to identify patterns that produce the skewness in ESSENCE and nature