

Seasonal Forecast of the North Atlantic Oscillation in GEM and GCM3

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with contributions from:

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Juan S. Fontecilla and Normand Gagnon

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Outline

- Ø Review of the North Atlantic Oscillation
- Ø Tropical Pacific connection of the NAO
- Ø Seasonal forecast of the NAO in GEM and GCM3

What is the NAO?



The North Atlantic Oscillation is a large-scale seesaw in atmospheric mass between the subtropical high-pressure system over the Azores Islands and the subpolar low-pressure system over Iceland.

What is the NAO?

ØThe NAO is the most important mode of atmospheric variability in the northern hemisphere

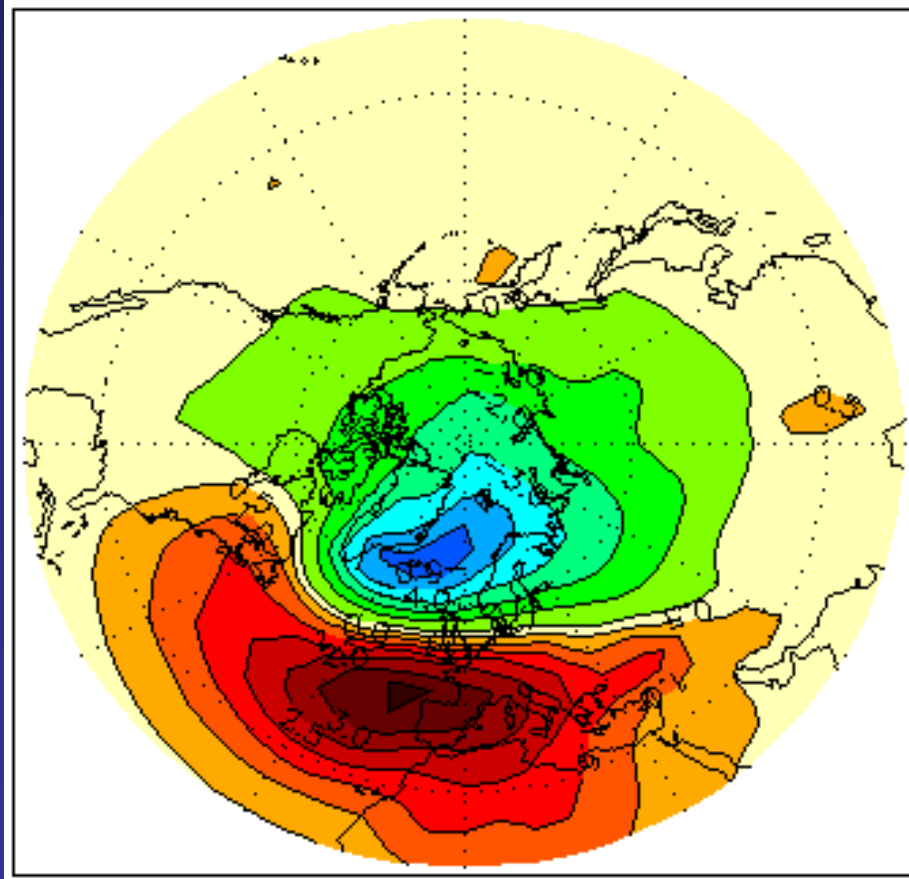
ØThe NAO accounts for 31% of the variance in winter surface air temperature north of 20°N (Hurrell, 1995)

To identify the dominant modes

- Ø Empirical Orthogonal Function (EOF) analysis
- Ø One-point correlation (Wallace and Gutzler, 1981)

EOF1 of DJF SLP

37%

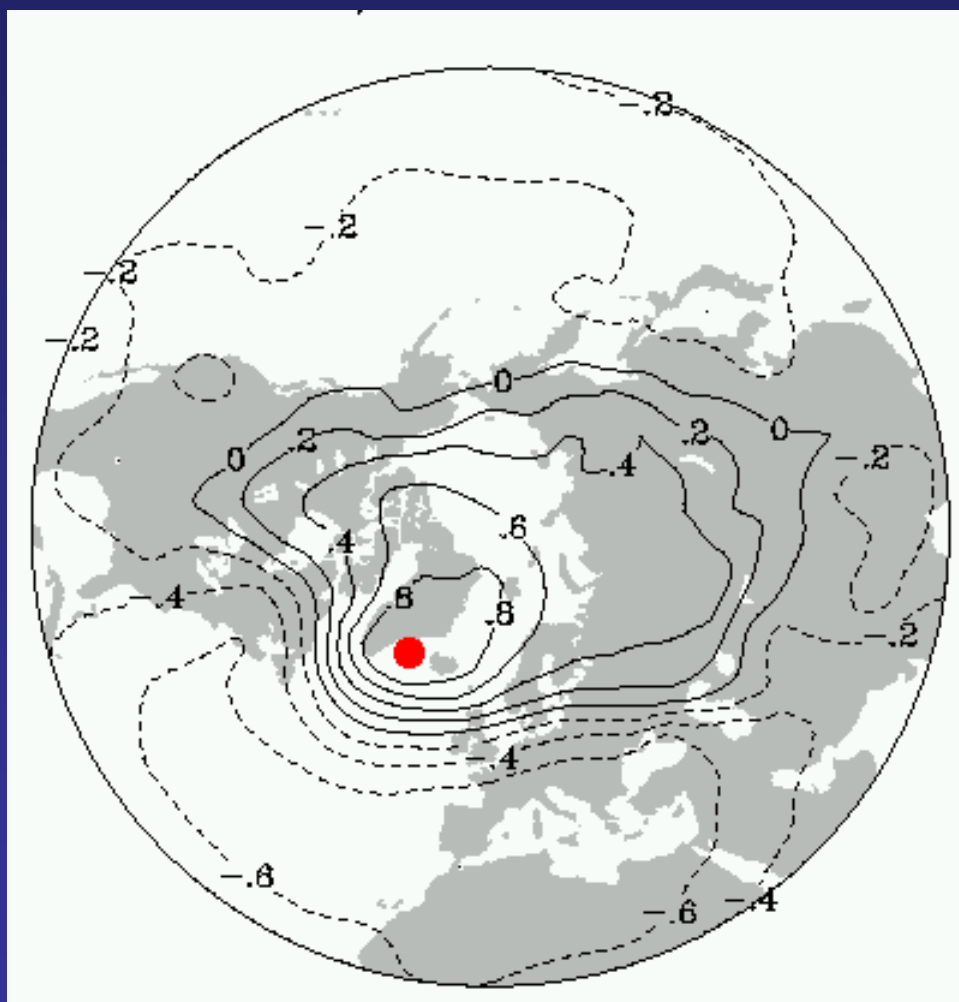


NCEP data 1948-1999

90W-40E, 20-80N

One-point correlation

65N,30W



DJF SLP
1948-1999

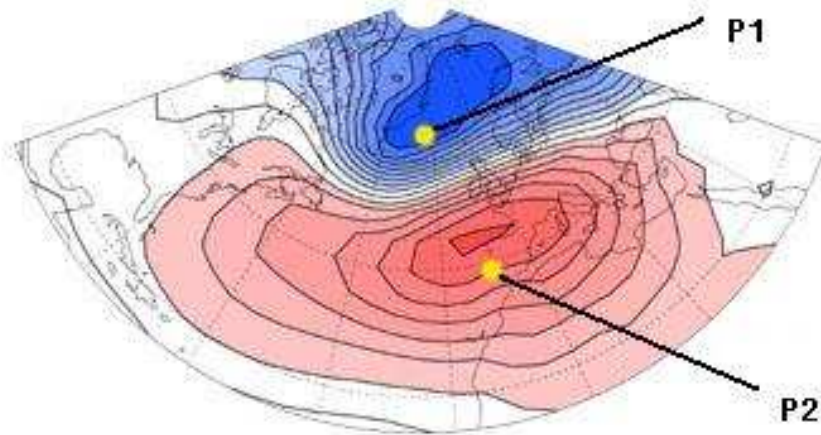
The NAO index

— a measure of phase and amplitude

Ø Two-point index: difference between normalized mean winter SLP anomalies at Lisbon, Portugal and Stykkisholmur, Iceland

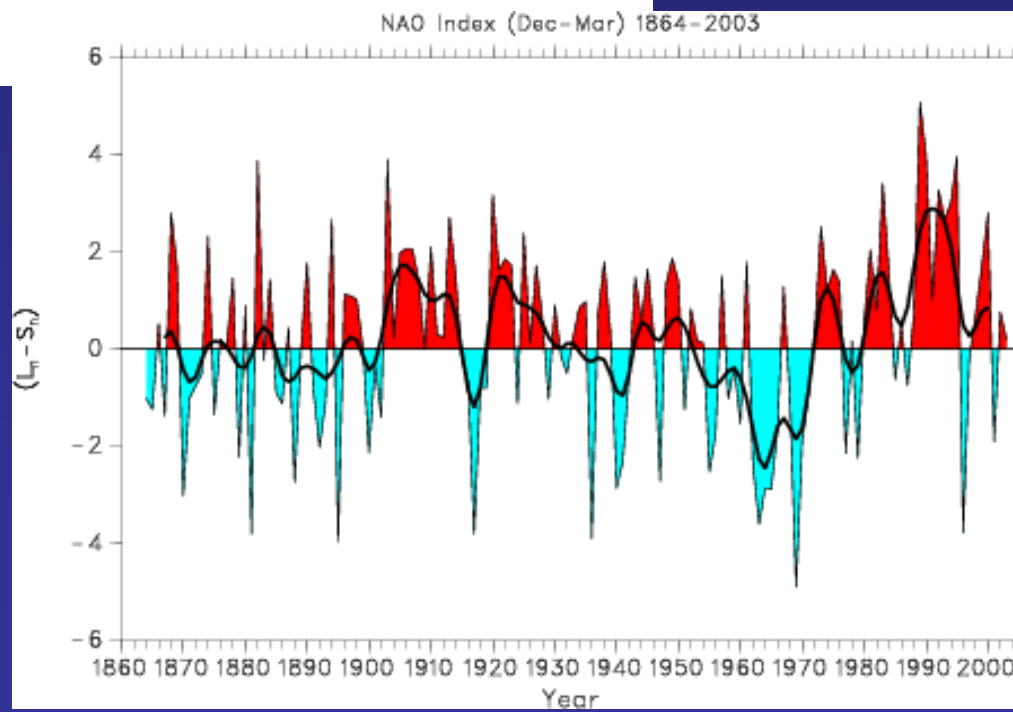
Ø Principal component (PC) based

Station Based Indices



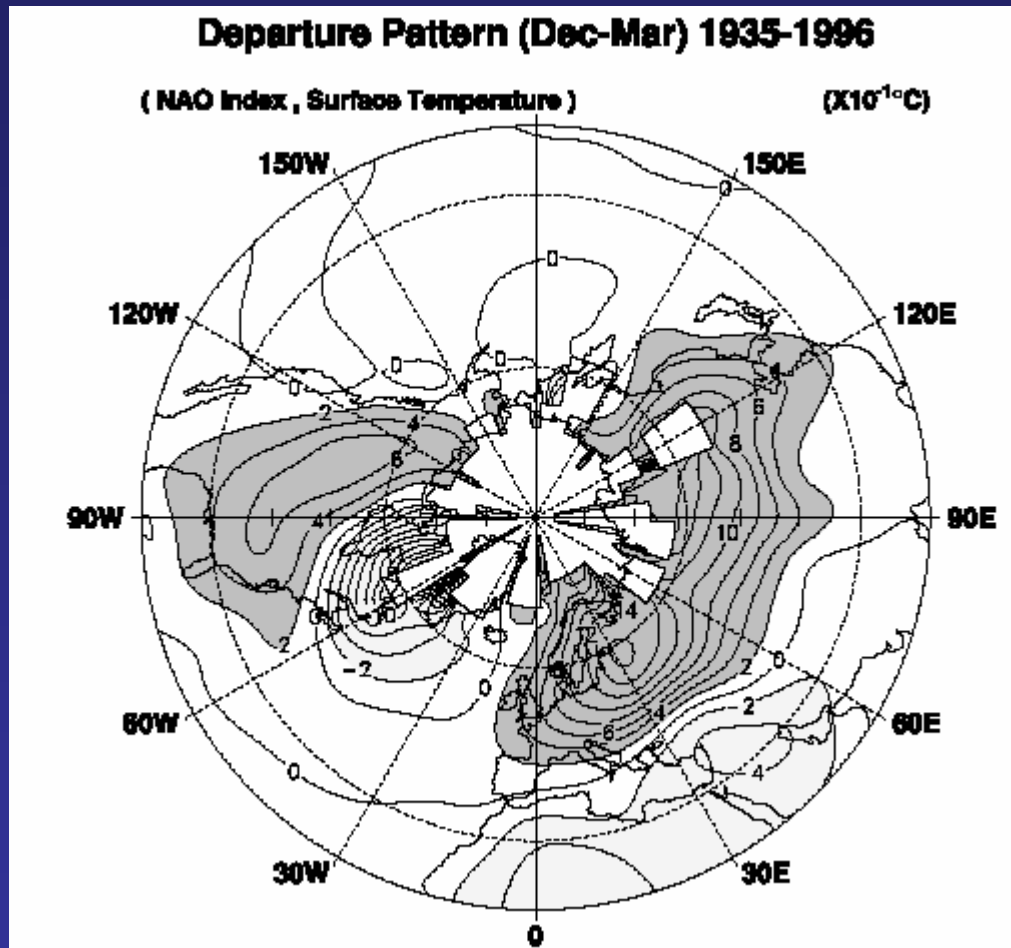
$$s = P2^* - P1^*$$

(Hurrell, 1996)



Impact of the NAO

Surface temperature

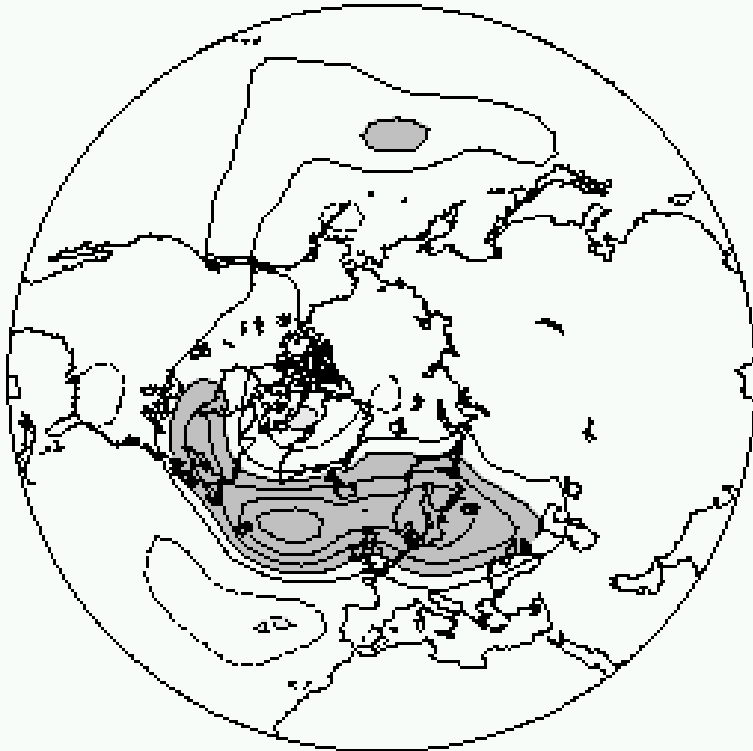


Surface temperature change associated with one standard deviation (positive) of the NAO index. Hurrell(1996),

(Hurrell, 1996)

Storm activity

Regression onto NAO Index (gpm)



**Regression onto the
NAO index for:**

**300 hPa root mean
square transient
geopotential height
(gpm) bandpassed to
include 2-8 day period
fluctuations.**

(Hurrell et al., 2003)

Mechanisms of the NAO variability?

Ø Atmospheric internal dynamics; AGCM with climate SST; transient forcing → difficult to predict

Ø SST anomaly in the North Atlantic : on interannual time scale the SST anomaly is a response to the NAO

Ø Stratosphere-troposphere coupling → that may help to predict the NAO on the time scale of 10 days

NAO forecasts

∅ The best possible linear predictions are not able to explain more than about 10% of the total variance of wintertime means (Wunsch 1999).

∅ Rodwell et al. (1999) obtained a correlation of $r=0.41$ for the ensemble mean NAO simulated by an ensemble of 6 atmosphere-only runs over the period 1947-97. (not a useful forecast, Bretherton and Battisti, 2000)

à Forecast the unpredictable

Demeter II

Projection onto NAO

Model: DEMETER II

Start dates: November

Avg. over 2-4 months FC (DJF)

Ratio of total st-dev: model/ERA-40 = 0.99

Signal/Noise ratio [Conf.-Level] = 0.31 [0.00]

RMSE = 0.15

Correlation [Conf.-Level] = -0.03 [0.00]

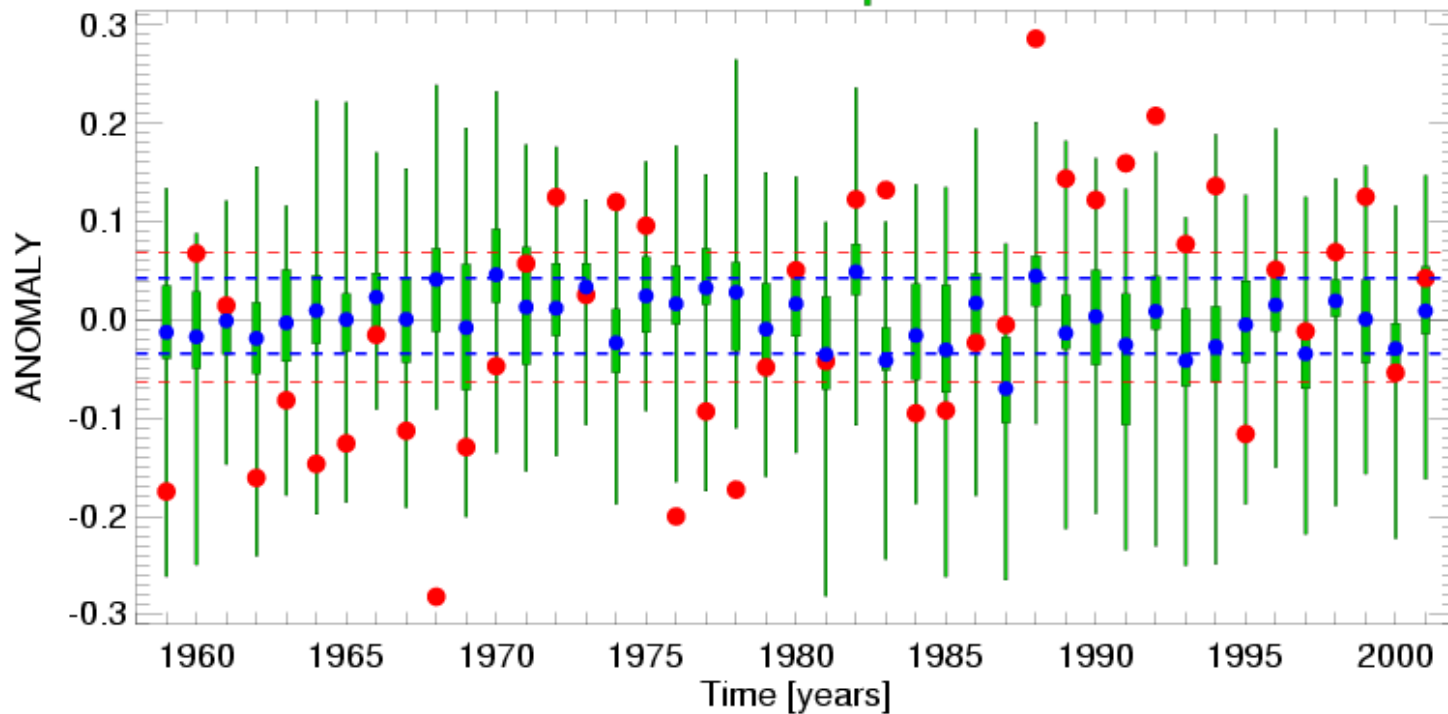
RPSS [Conf.-Level] = -0.05 [0.00]

dashed lines: tercile boundaries for whole dataset of ERA-40 and hindcasts

● ERA-40

● Ensemble-mean

■ Ensemble Spread / Tercile



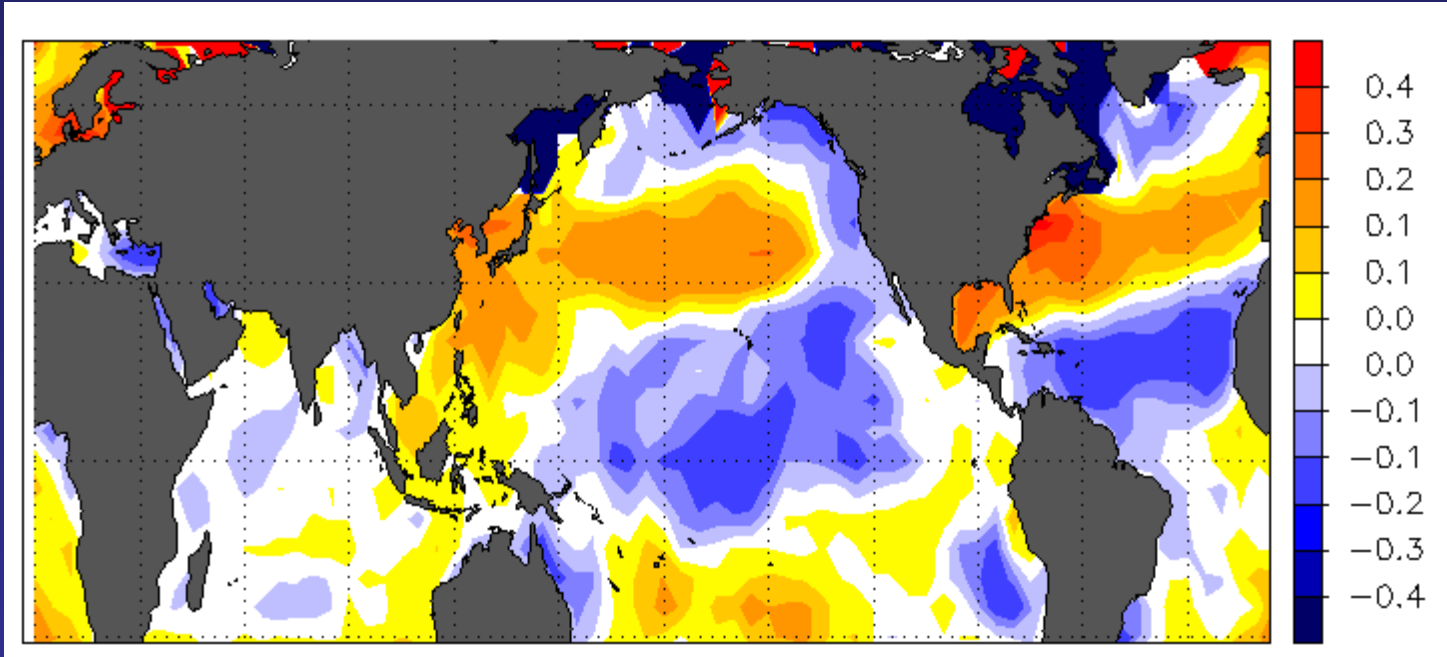
Tropical Pacific connection of the NAO

Ø Observational evidence

Ø Model support

Regression of SST to NAO index: 50 winter detrended

NAO



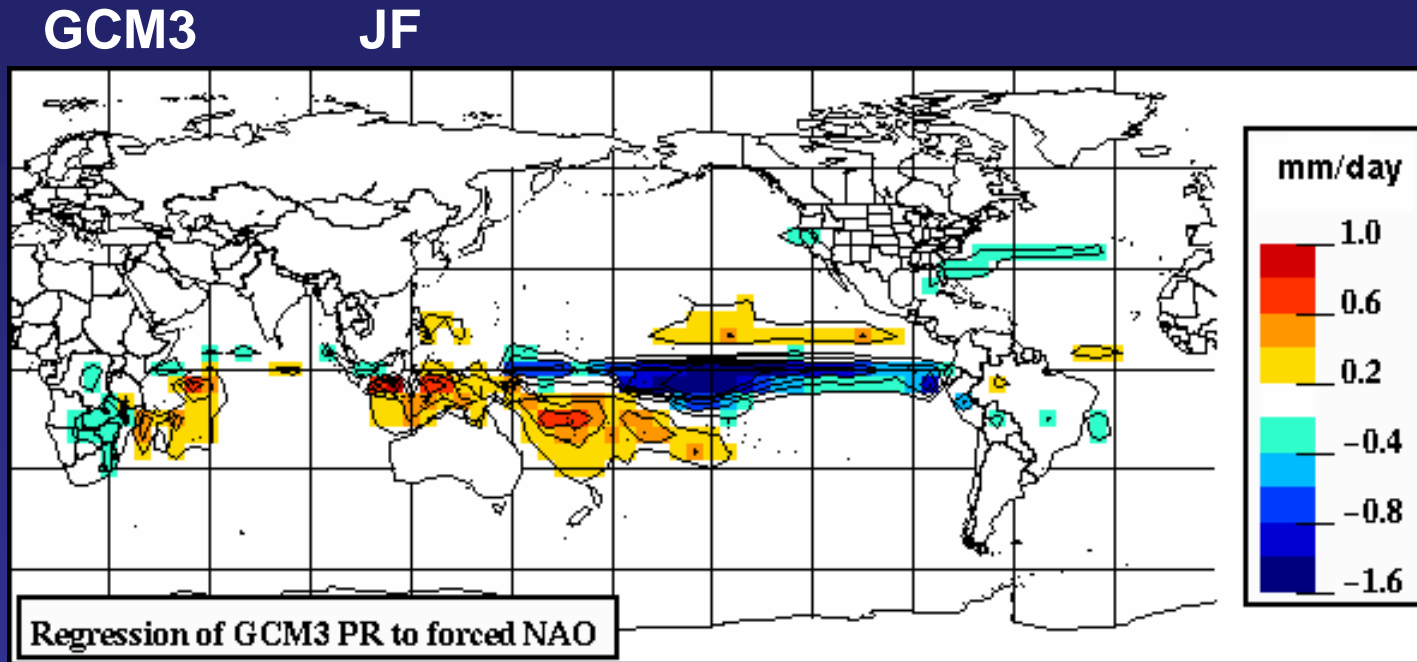
GISST data

More evidence of tropical Pacific link of the NAO

Ø Positive NAO β \rightarrow reduced tropical Pacific convection: Lin and Derome (2004); Lin et al. (2005)

Ø Some NAO skill in NEPSO years: Derome et al. (2005)

Regression of model precipitation to ensemble mean (forced) NAO



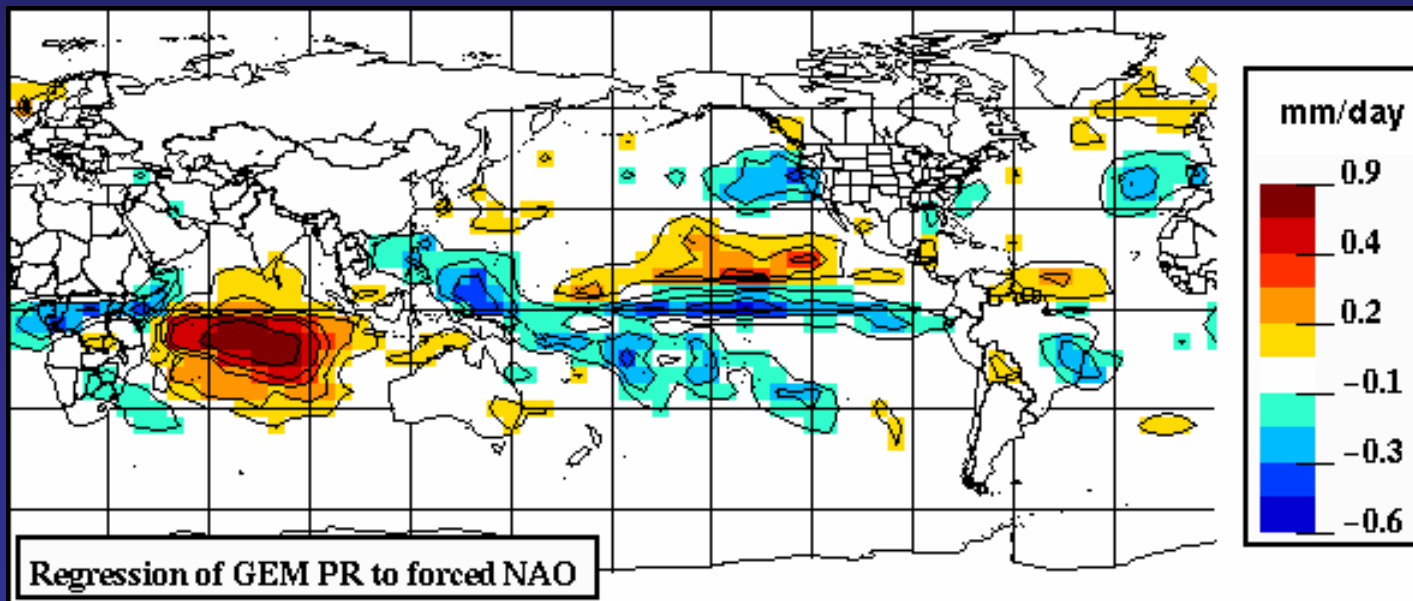
Proxy for diabatic heating anomaly for positive NAO

HFP2 output: 10 member djfm forecasts

Regression of model precipitation onto ensemble mean (forced) NAO

GEM

JF



Proxy for diabatic heating anomaly for positive NAO

HFP2 output: 10 member djfm forecasts

Seasonal forecast by GEM and GCM3

- ∅ As part of the Historical Forecasting Project (HFP2)
- ∅ 10 integrations were conducted starting from the beginning of each month.
- ∅ Each integration lasts 4 months
- ∅ The forecasts are conducted for the 31 years from 1969 to 1999.
- ∅ SST anomaly from previous month is added to the climate of the forecast period.
- ∅ In this study, we analyze the winter forecast djfm. JF is verified.

Models

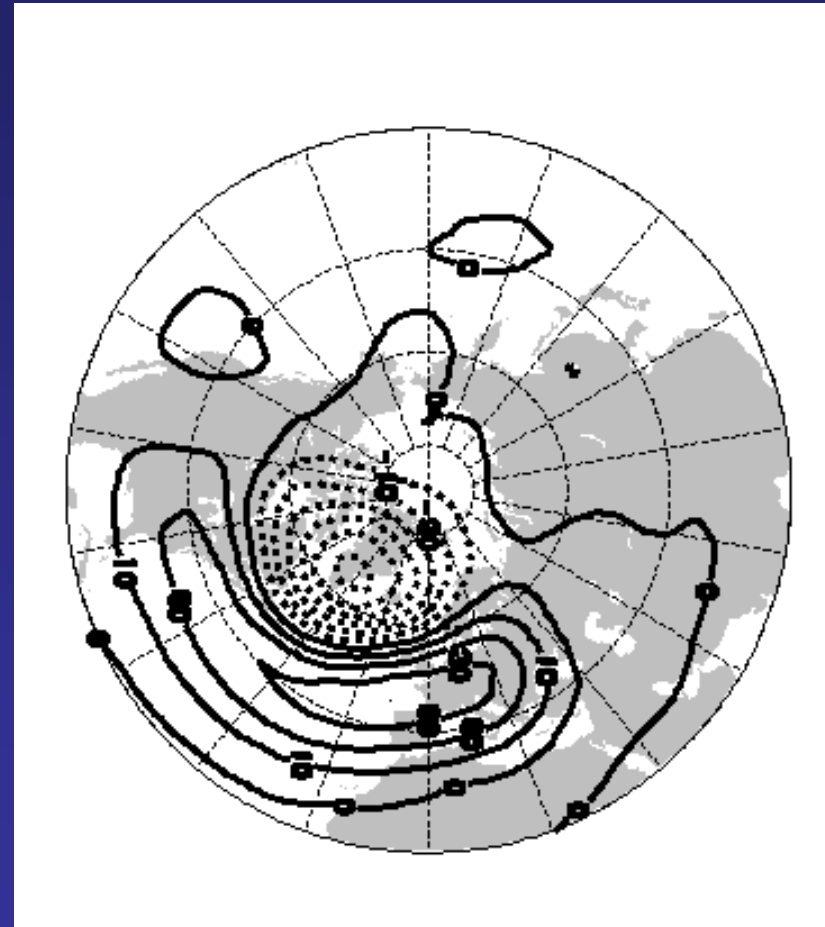
- GEM
- 192x96 global uniform grid (1.875x1.875)
- 50 levels

- GCM3 (CCCma)
- Triangular 63 (T63)
- 32 levels

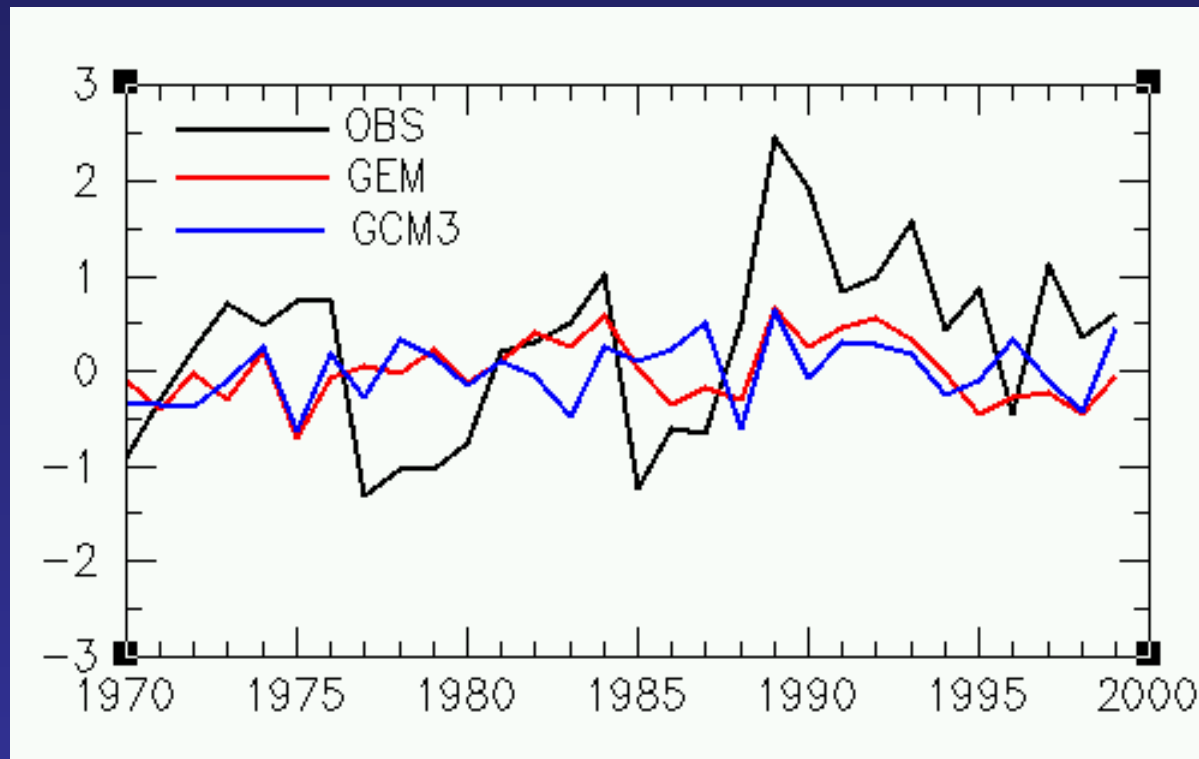
Forecast of NAO index

ØThe NAO is defined as the second REOF mode of DJF Z500 in the Northern Hemisphere

ØEnsemble forecasts of JF 500 hPa heights are projected to the NAO pattern to get the forecasts of the NAO index



Skill of ensemble NAO forecast



JF

Correlation skill: GEM: 0.34

GCM3: 0.12

(NOT pass 95% level)

Correction of ensemble forecast

Ø Because of model deficiencies, the atmospheric response to SST forcing is biased and model dependent. → errors in the seasonal forecast

Model's forced signal

SVD analysis:

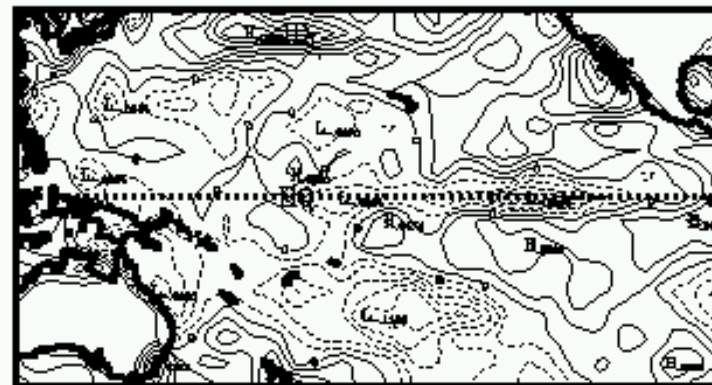
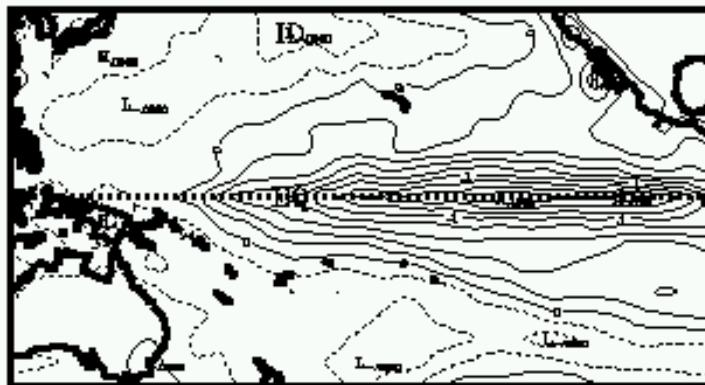
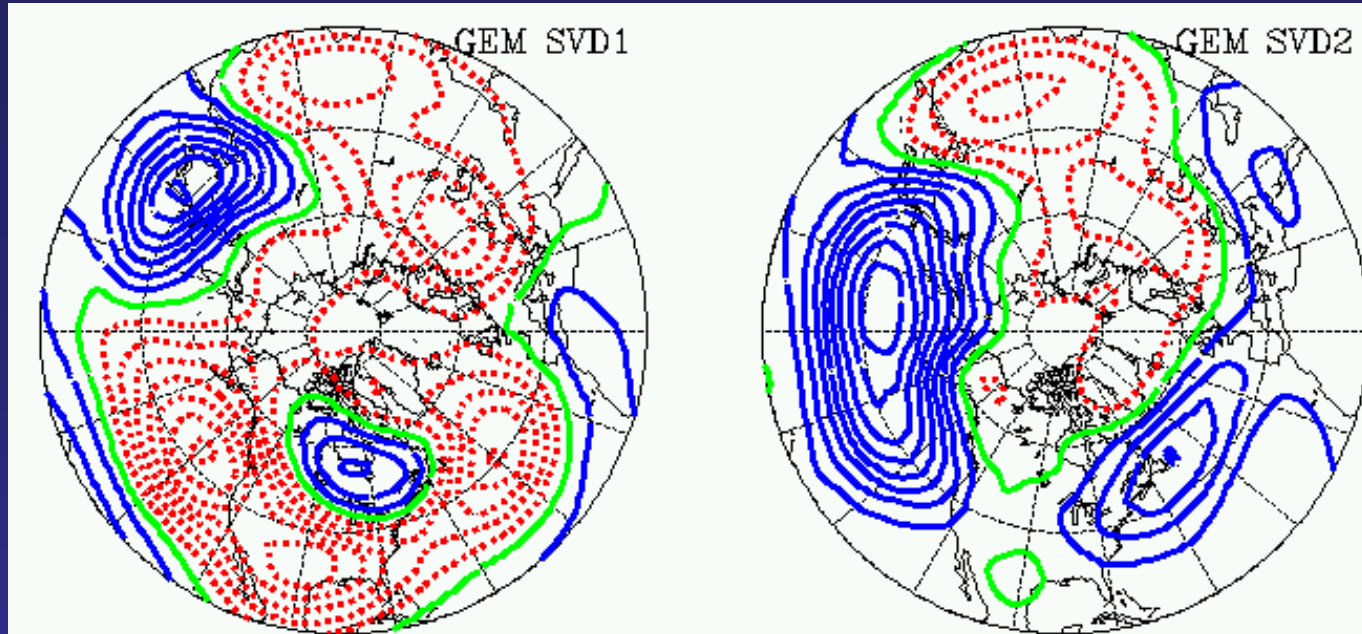
Tropical Pacific (40N-40S, 120E-90W) SST in November

→

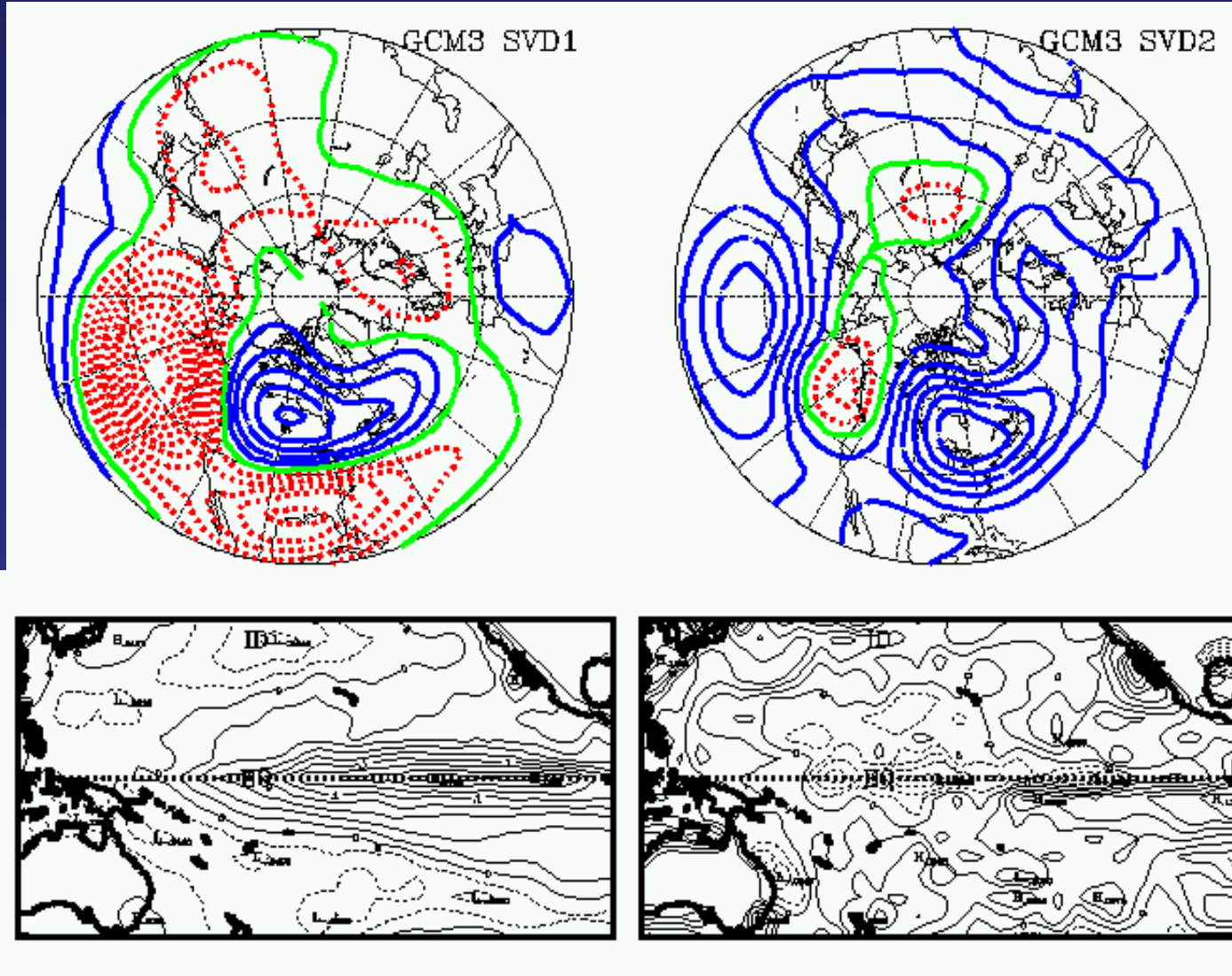
forced (ensemble mean) Northern Hemispheric Z500 in JF

→ dominant forced Z500 patterns associated with the SST forcing in the tropical Pacific, we also have their time evolution (PCs)

GEM SVD



GCM3 SVD



Correction of ensemble forecast

Ø Original forecast: (SVD definition) for year t_1

$$Z_f(x,y,t_1) = E_1(x,y) \alpha(t_1) + E_2(x,y) \beta(t_1) + E_3(x,y) \gamma(t_1) + \dots$$

Ø Find new patterns that matches the observations with variations of the PCs by a linear regression model:

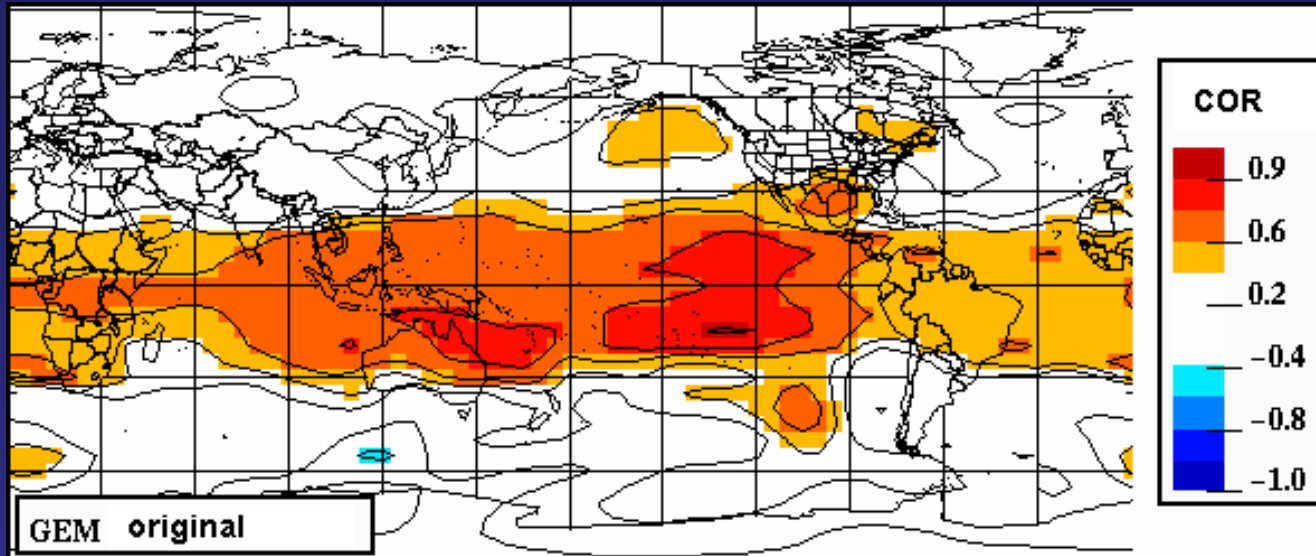
$$Z_o(x,y,t) = D_1(x,y) \alpha(t) + D_2(x,y) \beta(t) + D_3(x,y) \gamma(t)$$

for $t \neq t_1$ (cross-validation)

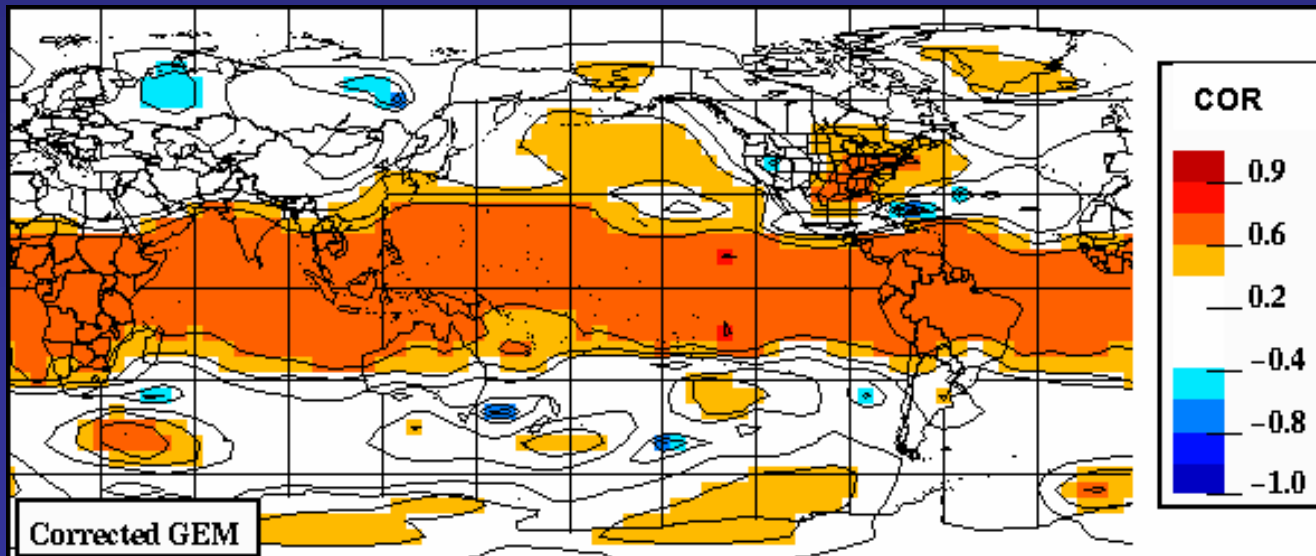
Ø Corrected forecast for year t_1 :

$$Z_c(x,y,t_1) = D_1(x,y) \alpha(t_1) + D_2(x,y) \beta(t_1) + D_3(x,y) \gamma(t_1)$$

Skill of ensemble forecast

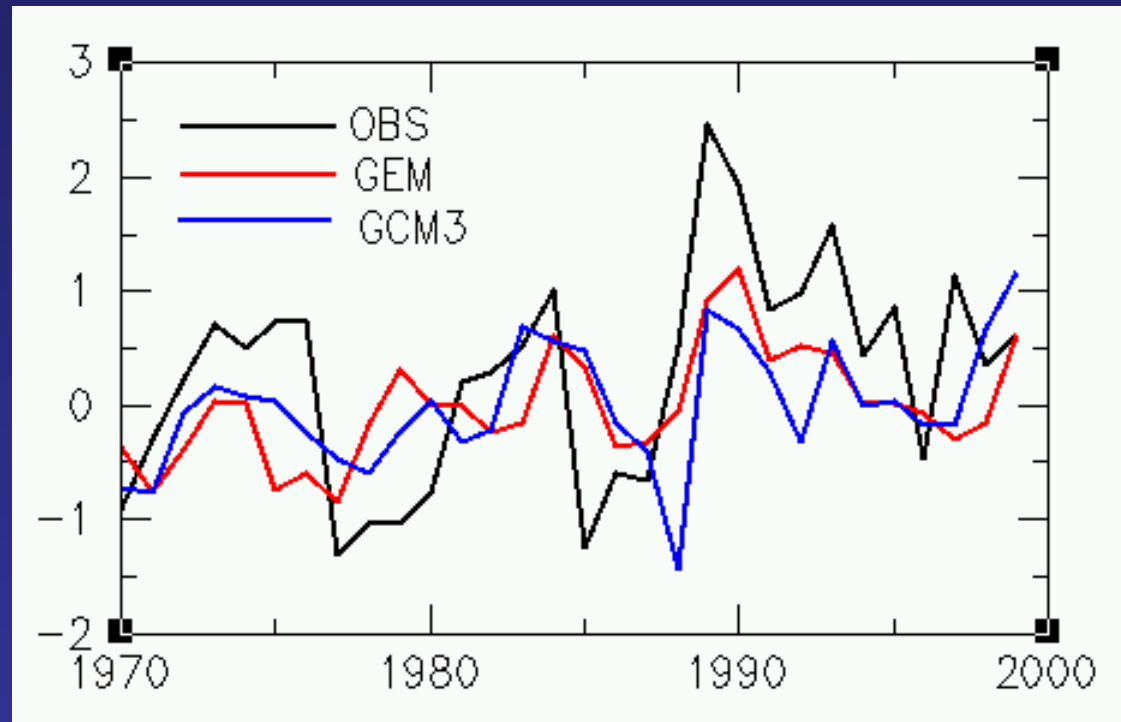


GEM
Before correction



GEM
After correction

Skill of the corrected NAO forecast



JF

Correlation skill: GEM: 0.54

pass 99% significance level

GCM3: 0.48

pass 99% significance level

NAO skill of ensemble forecast

	Before correction	After correction
GEM	0.34	0.54 (0.4%)
GCM3	0.12	0.48 (1.2%)
GEM+GCM3	0.26	0.57 (0.2%)

How many SVDs?

Corrected NAO skill

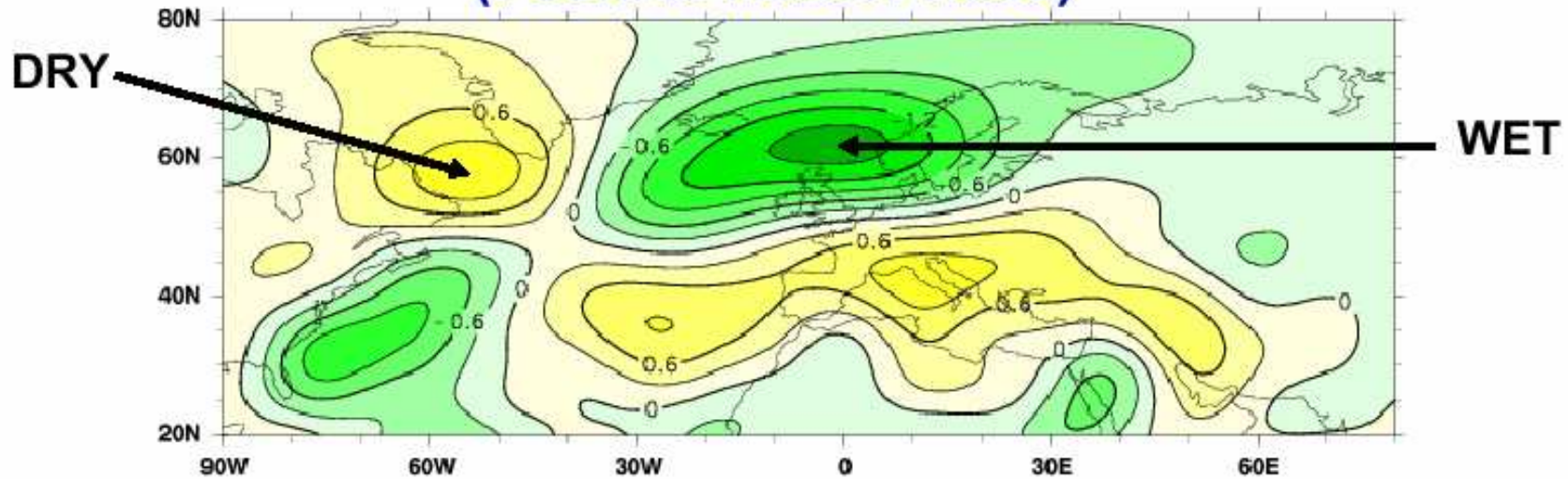
SVDs	GEM	GCM3
1	0.18	0.14
1+2	0.56	0.46
1+2+3	0.54	0.48

Conclusions

- Significant seasonal forecast skill for the NAO is possible
- The interannual variability of the NAO is associated with the SST anomaly in the tropical Pacific. A positive phase of the NAO is associated with a cold anomaly in the equatorial Pacific
- The GEM and GCM3 have some NAO signal but it is not in the right place (or right structure)
- A correction scheme based on 3 SVDs works effectively to improve the NAO skill

Merci!

NAO Influence on Winter Precipitation **(Positive Index Phase)**



Evaporation minus precipitation computed from the atmospheric moisture budget for high minus normal or low NAO index winters is shown. The contour interval in (C) is 0.5 mm/day