STARDEX

STAtistical and Regional dynamical Downscaling of EXtremes for European regions

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Deliverable D13

Recommendations on the most reliable predictor variables and evaluation of inter-relationships.

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Introduction

The aim of the deliverables D13 is to evaluate the performance of the HadAm3p model (control run) to simulate the predictors used in the downscaling of extreme precipitation and temperature from Emilia-Romgna. The downscaling model developed by ARPA-SIM requires large scale patterns as: geopotential height at 500hPa, mean sea level pressure, temperature at 850 hPa. The present report is focus on the analysis of the above fields simulated by the HadAm3p model in three control run: *addfa*, *addfb* and *addfc*. The analysis has been done separately for each control run experiments.

Method and data

The Statistical Downscaling (hereafter SD) of extreme events in Emilia-Romagna has been performed using two methods: multi linear regression (MLR) and multivariate regressions based on Canonical Correlation Analysis (CCA). These two SD methodologies have been set-up using the NCEP reanalysis data set and the predictors used are the Principal Components (PCs) associated to the leading EOFs of the geopotential height at the level of 500 hPa (Z500), temperature at 850 hPa (T850) and sea level pressure (SLP). In order to apply these SD methods to the Climate Model output, it is necessary first to assess its capability to reproduce the predictors proposed. In particular, we have assessed the performance of the Climate Model HadAm3p and its skill to simulate the above predictors identified in the downscaling methods using the NCEP reanalyses.

We have been evaluated and compared, separately, the predictors provided by each control run experiment (hereafter: *addfa*, *addfb*, *addfc*) of HadAm3p-model with those provided by NECP reanalyses. The methods used is based on the empirical orthogonal function (EOF). Thus, we have been analysed the spatial variability of the above fields given by the first four empirical orthogonal function (EOFs) and the Principal Components associated to these EOF patterns. The analysis has been done using data averaged for the four seasons (DJF,MAM,JJA,SON) and for the period 1960-1990. The mainly characteristics analysed for these EOF patterns are:

- the variance explained by each EOF patterns;
- the spatial correlation between model and NCEP EOF patterns;
- the BIAS of each EOF patterns (HadAM3P/EOFs-NCEP/EOFs);
- Statistics (mean values, type of distribution, lower and upper quartile etc.) computed for each PC (model in NCEP data). The Kolmogorov -Smirnov test has been used to test the normality of the distribution.

The verification has been done in two different domains:

A) the whole model area (0°N-90°N; 90°W-90°E)
B) different smaller domains which have been identified to be optimum for our SD method:

- Z500 = lat (20°N- 90°N); long (90°W - 60°E)
- SLP = lat (30°N- 60°N); long (35°W - 35°E)
- T850 = lat (20°N- 80°N); long (60°W - 60°E)

The EOF patterns evaluated for each domain (A and B) area very similar, thus, in the following we described the results obtained only for B) area.

Results

VERIFICATION of Z500 EOFs

WINTER

The first four EOFs evaluated for winter season using HadAM3P data have been compared with those obtained from NCEP re-analysis data. The patterns simulated by all 3 experiments (addfa, *addfb*, addfc), explain a cumulative variance around 73% of the total variance, in each control run and are very close to those computed from NCEP data, which explain 74.1% of the total variance. The first EOF shows a dipolar structure in both model and NCEP reanalysis data and resembles the North Atlantic Oscillation in each control run. These could be observed in the Figure 1a, 2a, 3a, and 4a that display the first 4 EOFs of *addfa, addfb, addfc* and NCEP reanalysis. The EOF2 (figure 1b-4b) presents a structure with three centres in both data set, model and NCEP reanalysis. The third EOF resembles the European Blocking in NCEP data set and is well simulated by the model data. The EOF4 is not so well simulated by the control run in comparison with the first 3 EOFs.
The spatial correlation between *addfa* patterns and NCEP patterns are presented in Table 1, the significant values are in bold face.

	mod_eof1	mod_eof2	mod_eof3	mod_eof4
ncep_eof1	**0.88**	-0.45	-0.37	-0.19
ncep_eof2	-0.43	**0.91**	0.12	0.18
ncep_eof3	0.04	-0.46	**0.87**	-0.60
ncep_eof4	-0.39	0.08	0.02	**0.64**

Table 1 Spatial correlation between addfa and NCEP winter patterns

Also, a significant correlation (not shown) has been found when the first 4 EOFs of *addfb /addfc* has been correlated with NCEP EOFs. These *correlation vary is 0.9 and -0.8 for EOF1* of *addfb/addfc* and 0.87 and -0.44 for EOF2 of *addfb/addfc.*
The BIAS computed for each patterns has the values in the interval 0.08 (EOF1) and 0.39 (EOF2) for *addfa*, while for *addfb* this reach the value up to 0.1 for EOF1 and –0.1 for EOF2.Concerning the third experiment the BIAS is a little higher than in the other two.

The Principal Components associated to the above patterns tend to have in general a normal distribution well represented by the PC1. The difference between the mean of each pair of PCs, derived by the model and NCEP, is not significant from a statistical point of view. Figure 5 shows, as an example, the histogram of the first four PCs computed for *addfa* and NCEP data. The histogram put in evidence that for PC1 and PC2 the upper quartile of the model tends to have greater values than those of the NCEP data.

SPRING

The first four EOFs computed from model data and NCEP data explain around 67% of the total variance, except *addfb* experiment where the variance is 64.2%. The patterns well simulated by the model in all 3 control run are: EOF1, EOF2 and EOF3. EOF1 for HadAm3p and NCEP reanalysis. shows again a dipolar structure, with opposite sign of the centres. Figures 6 and 7 show an example of EOFs patterns during spring computed for *addfa* and NCEP data. Similar patterns (not shown) have been obtained for the other two control run.

The structure of EOF2 seems to be more closer to NCEP-EOF4 than to the NCEP-EOF2 in *addfa* (see figure 6b and 7b) *addfb* and *addfc* (not shown). EOF3 has a structure with three poles which are very well simulated by *addfa* and *addfc* and less by *addfb*. EOF4 is badly simulated by the model. The BIAS of the above patterns reach the value is in the interval (0.01;-2).

Table 2 present an example of spatial correlation between spring EOFs patterns of *addfa* and NCEP, the significant values are in bold face.

	mod_eof1	mod_eof2	mod_eof3	mod_eof4
ncep_eof1	**-0.89**	-0.01	-0.32	-0.31
ncep_eof2	0.04	**0.54**	0.10	-0.47
ncep_eof3	0.38	-0.24	**0.83**	-0.08
ncep_eof4	0.47	**0.66**	-0.48	0.36

Table 2 Spatial correlation between addfa and NCEP spring patterns

Concerning the correlation of the other two control run, the higher values has been obtained for EOF1 (0.8) and a smaller values for EOF4(0.4) .

The first 4PCs of model has the values of lower and upper quartile close to those of NCEP data, while the difference in the mean values of the PCs (model/NCEP) is not significant.

SUMMER

The first four EOFs computed from model data explain together 71.8% in *addfa* and around 68% in *addfb* and *addfc* while those computed from the NCEP data explain together 66.8% from the total variance. During summer season good concordance between patterns has been found for EOF1 in all three control run with a spatial correlation that vary between 0.69 (*addfa*) and 0.8 (*addfb*). BIAS for this pattern is 0.42 for EOF1 in *addfa*, 0.2 for *addfb* and -1.9 *addfc*. Concerning the other patterns, the model-EOF2 is more similar with the NCEP-EOF4 while the model-EOF3 with NCEP-EOF2. An example of patterns are represented in figure 8 and figure 9 for *addfa* and NCEP.

The analysis of PC1, associated with EOF1 (the best simulated patterns), put in evidence that the model PC1 has the *lower* and *upper* quartile close to the NCEP PC1.

AUTUMN

The first four EOFs computed from model data explain together around 70%, while those computed from the NCEP data explain together 68.2% from the total variance. EOF1 and EOF2 are well simulated by *addfa* and *addfc* when reach a correlation with NCEP up to 0.7 for *addfa* and 0.8 for *addfc*. Concerning the control run *addfb*, the EOF1 is swapped with EOF2, while the EOF3 and EOF4 are less simulated. An example of autumn Z500 patterns are represented in the figure 10 and 11 for *addfa* and NCEP.

The BIAS is up to 0.6 (EOF2) and 2.3 (EOF1). The analysis of PCs reveals that the *upper* quartile are in generally greater in model than in NCEP data, while the *lower* quartile is lower in model than in NCEP data.

The results presented above emphasis that the performance of the model to simulate the Z500 is good in winter, spring and autumn and less satisfactory in summer. The first two patterns are in generally well represented by all three control run in all season.

VERIFICATION of T850 EOFs

WINTER

The variance explained by the first four EOFs of the three control run data is close to those explained by the patterns derived from NCEP data ,around 68% in each control run and 69.2% for NCEP. During winter season the first 2 EOFs of *addfa* are very well simulated by the model. Figure 10 and 11 display the first 4EOFs of *addfa* and NCEP data set. The spatial correlation between the patterns in this case is presented in table 3.

	mod_eof1	mod_eof2	mod_eof3	Mod_eof4
Ncep_eof1	**-0.96**	0.06	-0.05	-0.14
Ncep_eof2	-0.13	**0.72**	0.46	-0.07
Ncep_eof3	-0.05	0.32	-0.24	**0.77**
Ncep_eof4	0.23	-0.39	**0.76**	0.26

Table3 Spatial correlation between ADDFA and NCEP winter patterns

Analysing the results presented in the above table it can be observed that EOF3 and EOF4 derived by model data are EOF4 and EOF3 in the NCEP data, the correlation is statistically significat. Concerning the other two experiments (*addfb* and *addfc*) a good concordance with NCEP patterns has been detected for all 4 EOFs, the spatial correlation vary between -0.9 (EOF1 - *addfb*) and 0.65 (EOF4 - *addfc*).
The BIAS computed for the EOF patterns has low values except for *addfc* control run, when reach the higher value = 0.3 (EOF1 and EOF4).
The analysis of the first 2 PCs shows a normal distribution with the value of lower model quartile similar to those of NCEP, while the upper quartiles of the model are smaller than NCEP re-analysis.

SPRING

During spring season EOF1 and EOF4 are well simulated by the *addfa* and *addfb* and explain together a cumulative variance around 36% in comparison with 30,5% explained by the NCEP patterns. The spatial correlation for these patterns is statistical significant. The analysis of the EOF2 and EOF3 of the model reveals a significant correlation with EOF3 and EOF2 of the NCEP re-analysis; like in the other cases, the pattern are inverted.
Concerning the *addfc* control run, all four patterns are well simulated on the contrary in the other two experiments.

The figure12 and 13, respectively, show the first 4EOFs of *addfa* and NCEP reanalysis data set. The BIAS computed for each patterns is in generally insignificant and vary between –0.04(EOF3) and –0.14 (EOF1). The analysis of the PCs associated with the above patterns reveals that the model tends to have smaller values of the extreme quartiles respect to the NCEP data.

SUMMER

The analysis of the summer EOFs patterns displayed in the figure 14 (*addfa*) and figure 15 (NCEP) emphasis that the pattern best reproduced in this case is the EOF1 that explains a variance around 23% in the model and 19% in the NCEP data. The model EOF2 corresponds to the EOF3 of the NCEP, while the spatial structures of the EOF3 and EOF4 is less capture by the model. The variance explained by the last 3 EOFs is around 35% for model and 32% for NCEP.
Concerning the other two control runs, the pattern best simulated is EOF1 with a spatial correlation of 0.8 for *addfb* and 0.7 for *addfc*. The EOF2 is less simulated while the configurations of EOF3 and EOF4 are inverted. The BIAS of the mainly pattern (EOF1) is lower especially in *addfb* and *addfc* ,while the analysis of PC1 reveals that the lower and upper quartile are similar values in both situation.

AUTUMN

During autumn season, T850 is well simulated by all three control runs, with a cumulative variance very close to those explained by NCEP reanalysis (53%) in *addfc* and a little higher in the other two experiments (around 67%). The spatial correlation computed for each pairs of EOF (model/NCEP) is situated in the interval 0.89 (EOF1) and 0.4 (EOF4).Figure 16 shows an example of configurations for *addfa* while the NCEP patterns are presented in figure 17
The BIAS is very small in *addfa* and *addfb* and higher in *addfc* where reach the value 0.27.
The analysis of the first 4 PCs put in evidence that the extreme quartiles are not very different (model/NCEP), especially for the first 2 EOFs .

Taking into account the above results, we could say that the mode simulate the T850 with a good performance especially during autumn and winter, while in the other seasons the mainly pattern simulated is EOF1 in summer and EOF1 respectively EOF4 in spring.

VERIFICATION of SLP EOFs

WINTER

The variance explained by the first four EOFs of the model data is close to those explained by the patterns derived from NCEP data (around 93%). An example of EOFs configurations for *addfa* are presented in figure 18 while NCEP configurations are presented in figure 19.The EOFs of the other two control run (not shown) are close to *addfa* control run. The spatial correlation computed for each EOF pairs (model-NCEP) reveals that the first 4 EOFs are well simulated by the model, the values are statistically significant in all three control run, higher in *addfa* and a little smaller (but significant) in *addfc*. Table 4 presents, as an example, the correlation between *addfa* patterns and NCEP patterns.

	mod_eof1	mod_eof2	mod_eof3	mod_eof4
ncep_eof1	**-0.71**	-0.16	0.59	-0.17
ncep_eof2	0.63	**0.85**	0.47	-0.05
ncep_eof3	-0.27	-0.38	**0.84**	-0.36
ncep_eof4	0.49	-0.31	0.08	**-0.94**

Table4 Spatial correlation between addfa and NCEP winter patterns

The analysis of the PCs shows that for PC1, PC2 and PC4 the model tends to have the lower and upper quartile greater than of the those corresponding to the NCEP data. On the contrary, the model PC3 has the values of quartile smaller than NCEP PC3.

SPRING

During spring season, the first 4 EOFs of the model explain together 92% of the total variance in *addfa* while those computed from NCEP data explain 86% .The variance explained by the first 4 EOFs in the others two control run are more closer to NCEP. The analysis of the structure of the patterns (figure 22 for *addfa* and figure 23 for NCEP data) reveals that, all the first 4EOFs are well reproduced by *addfa* control run. This result is confirmed by the values of the spatial correlation presented in Table 5.

	mod_eof1	mod_eof2	mod_eof3	mod_eof4
ncep_eof1	**0.87**	0.02	0.56	-0.12
ncep_eof2	0.02	**0.97**	0.09	-0.14
ncep_eof3	-0.29	0.08	**-0.90**	-0.11
ncep_eof4	-0.07	0.14	0.30	**0.94**

Table5 Spatial correlation between ADDFA and NCEP spring patterns

A good performance in the pattern simulation has been found in the other two control run but not so significant as in *addfa*. The BIAS has the values in the interval 0.06 (found for EOF4) and 0.2 (found for EOF2).
The analysis of the PCs histograms shows in generally that the lower quartile for PC1 and PC3 has value greater in model than in NCEP data; on the contrary for PC2 and PC4 the values are smaller. Concerning the upper quartile the values are greater in the model for PC1, PC2, and PC4 and smaller for PC3.

SUMMER

During summer the model has good skill in the simulation of the first 2 EOFs that explain together a variance of 64% (65%in the NCEP). The model EOF3 and EOF4 are less simulated, the model EOF3 is in generally *inverted* with EOF4 of NCEP data. An example of patterns are displayed in figure 24 (*addfa*) and figure 25 (NCEP). The analysis of upper quartile reveals in generally smaller values in model for all PCs except for PC2.

AUTUMN

During autumn season the variance explained by the first 4 EOFs from the model is close with those explained by the NCEP data, around 90%. All the patterns are well simulated especially in the *addfa* and *addfc* control run, while in *addfb* the EOF1 and EOF4 are best simulated. Figure 26 shows the *addfa* EOFs while the figure 27 presents the NCEP patterns. The quartile analysis of the model are in generally greater (except for PC2) than those of NCEP data.

The analysis presented above reveals that the SLP is well simulated by the model in winter, spring and autumn, while during summer season good performance are found only for the first two EOFs.

CONCLUSION

The results presented in this study emphasis that the HadAM3P model (three control run) reproduce quite well the characteristics of the EOFs pattern of Z500, T850 and SLP. The seasons with best skill are winter, spring and autumn for Z500 and SLP, and autumn and winter for T850.
These results seem to be quite good (at least in winter and autumn) and allow us to be optimistic as regard the application of our SD methodology using as predictors the HadAm3p model outputs.

Figure 1: addfa EOFs (WINTER)

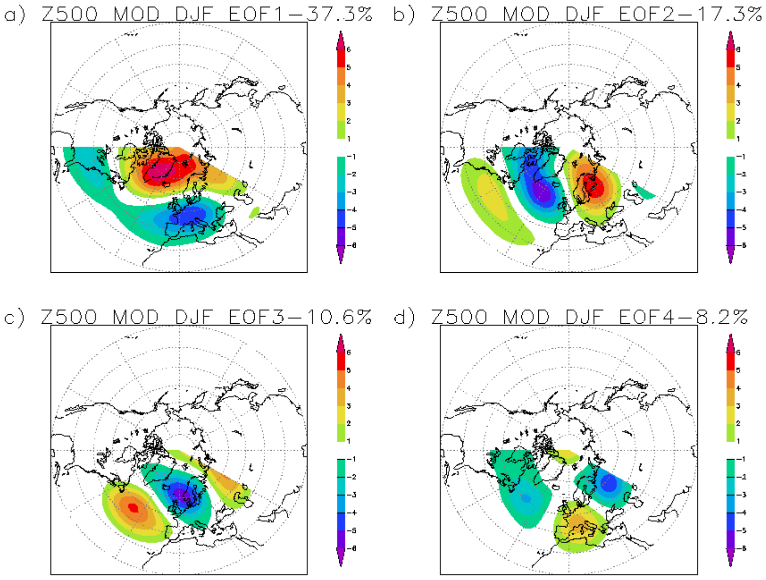

Figure 2: addfb EOFs (WINTER)

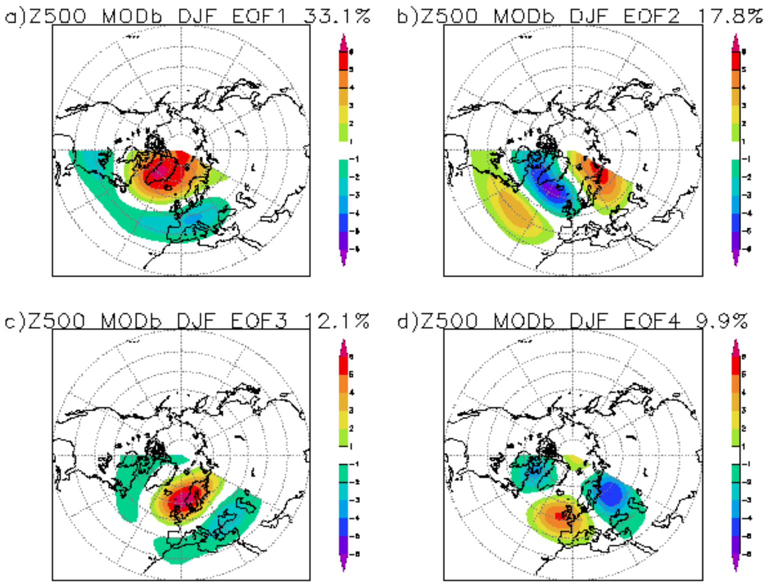

Figure 3: addfc EOFs (WINTER)

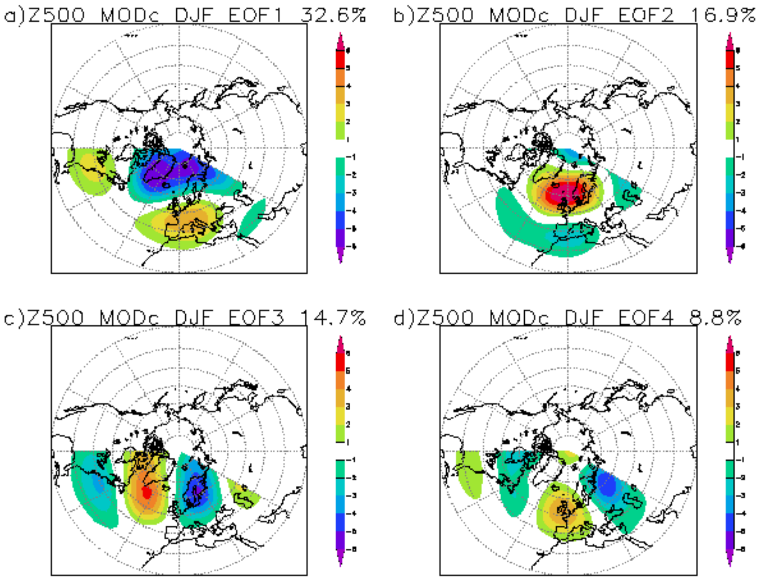

Figure4: NCEP EOFs (WINTER)

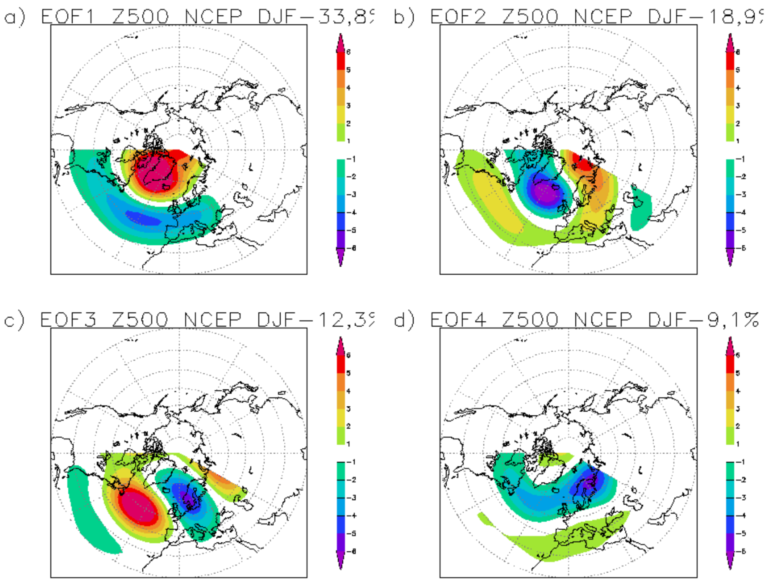

Figure 5 Histograms of the first 4 PCs-Z500 (addfa and NCEP data)

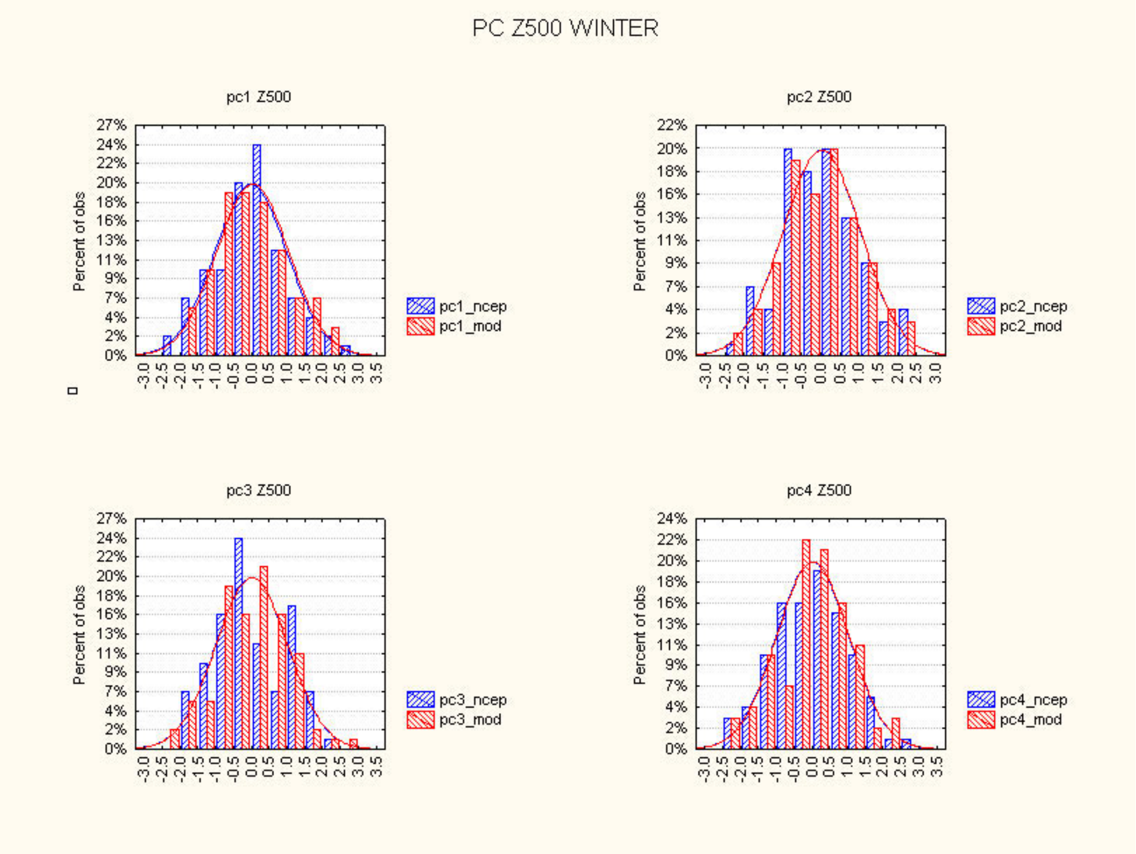

Figure 6: addfa EOFs (SPRING)

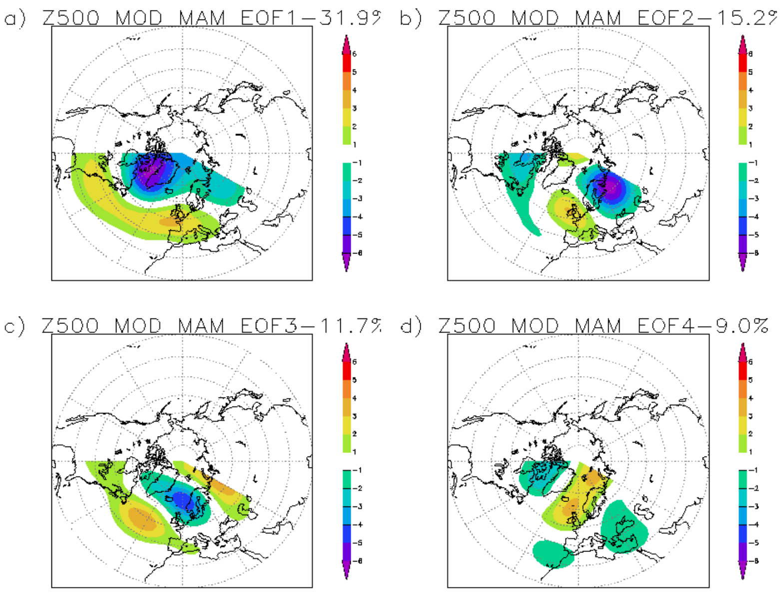

Figure 7: NCEP EOFs (SPRING)

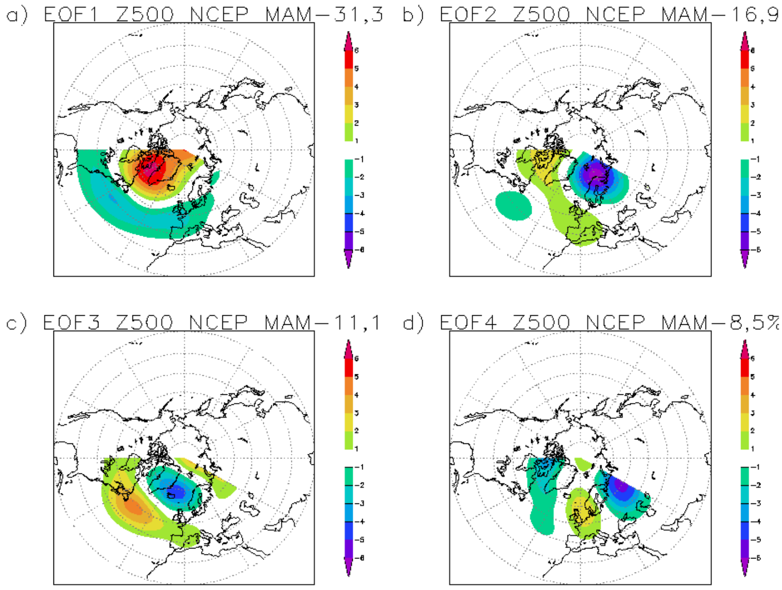

Figure 8: addfa EOFs (SUMMER)

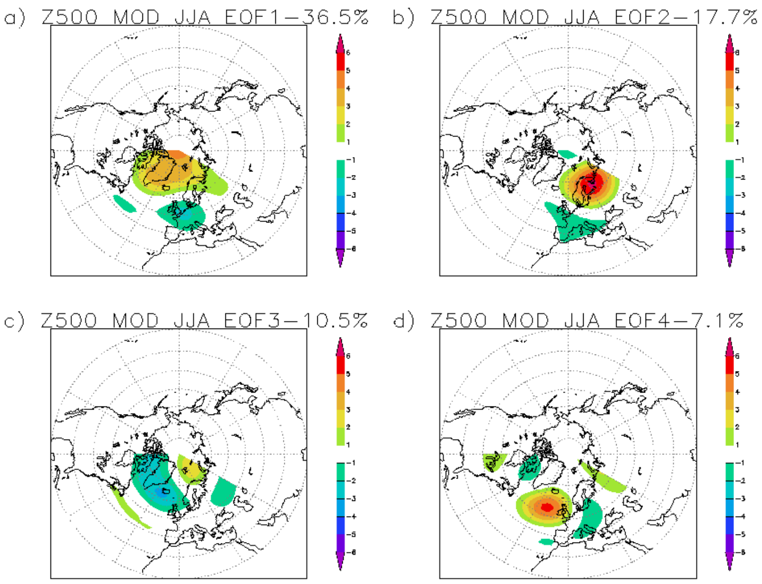

Figure 9: NCEP EOFs (SUMMER)

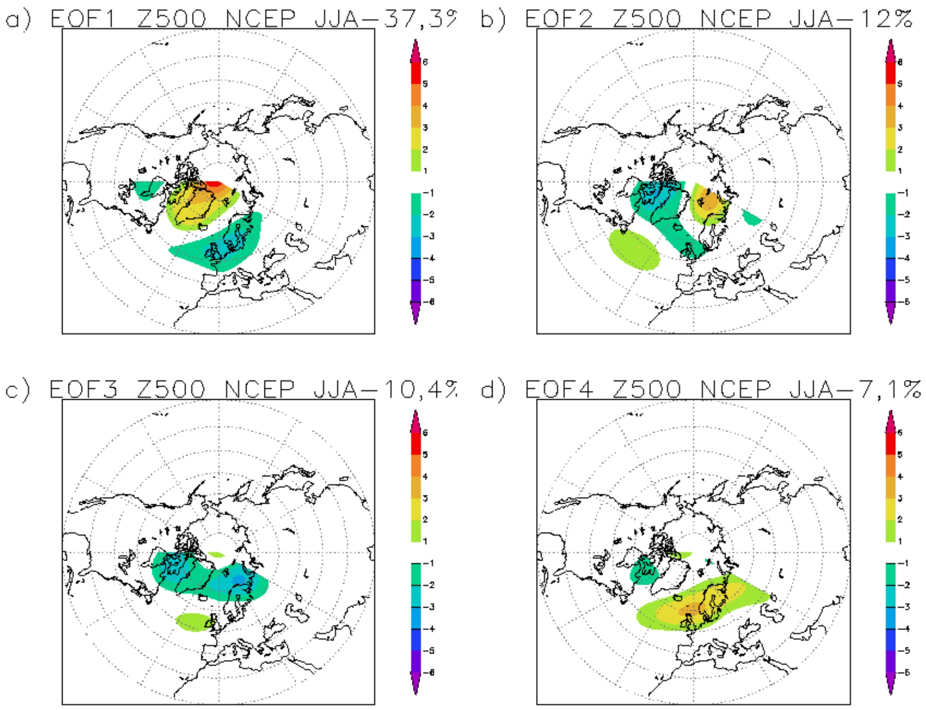

Figure 10: addfa EOFs (AUTUMN)

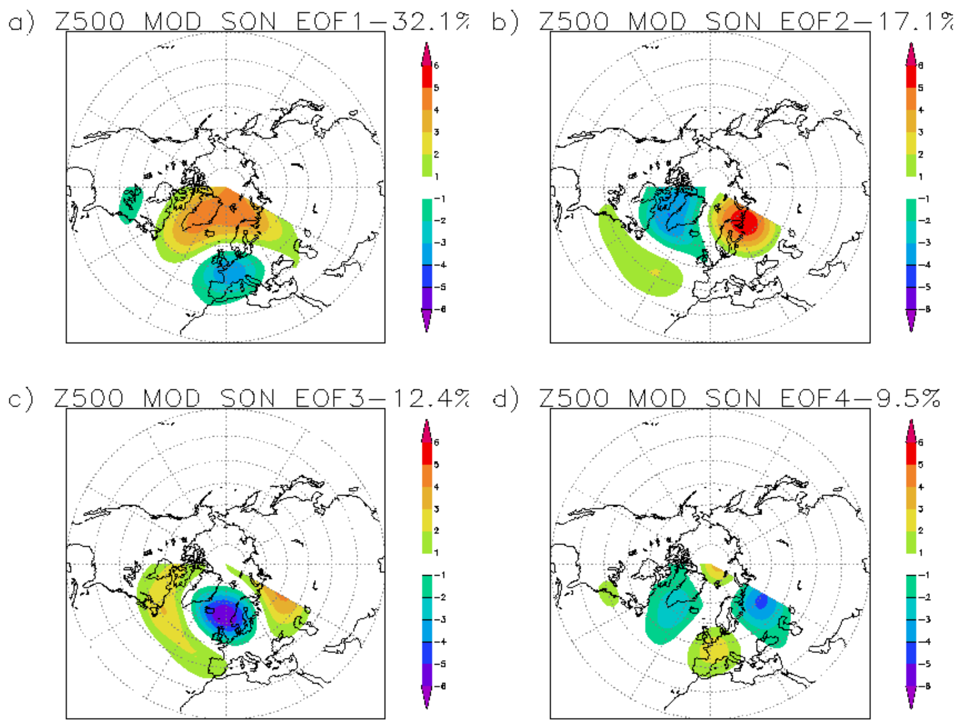

Figure 11: NCEP EOFs (AUTUMN)

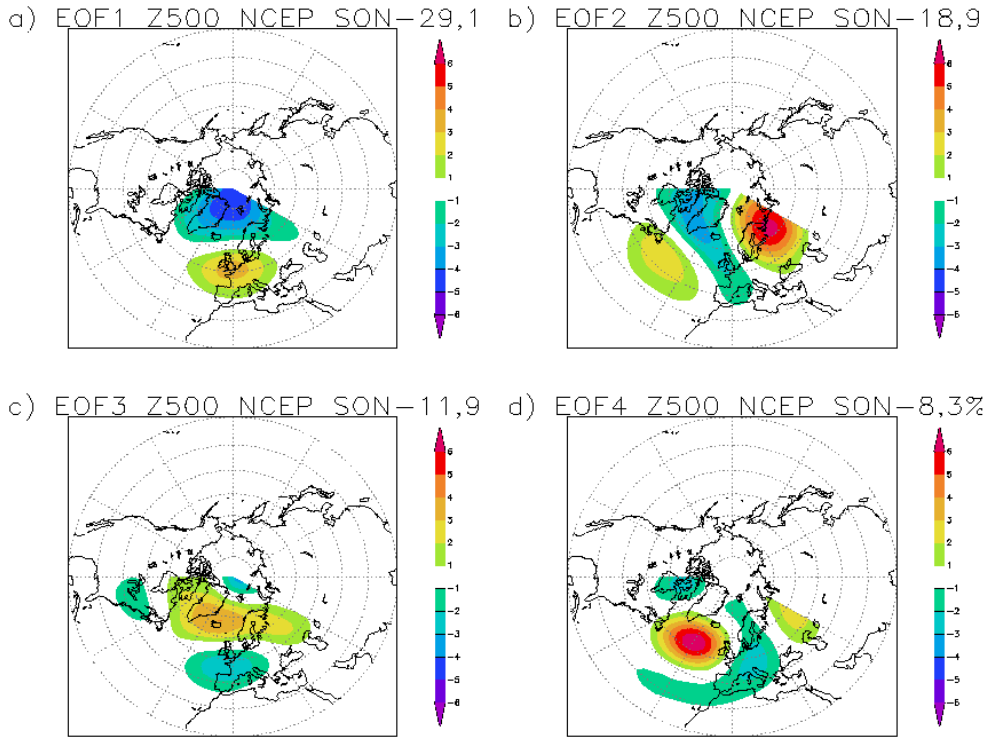

Figure 12: addfa EOFs (WINTER)

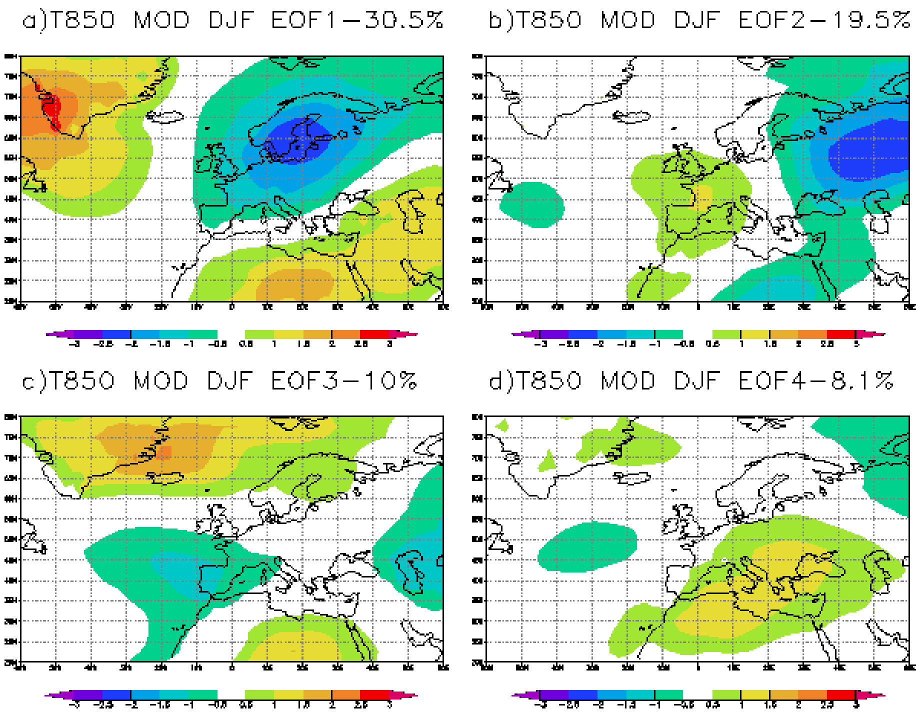

Figure 13 NCEP EOFs (WINTER)

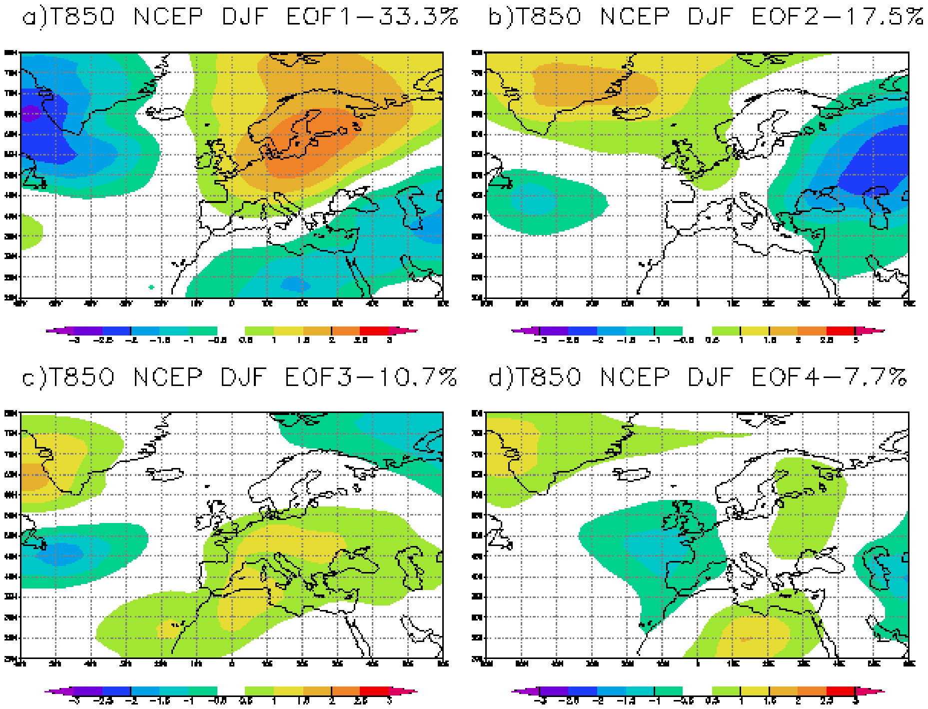

Figure14 addfa EOFs (SPRING)

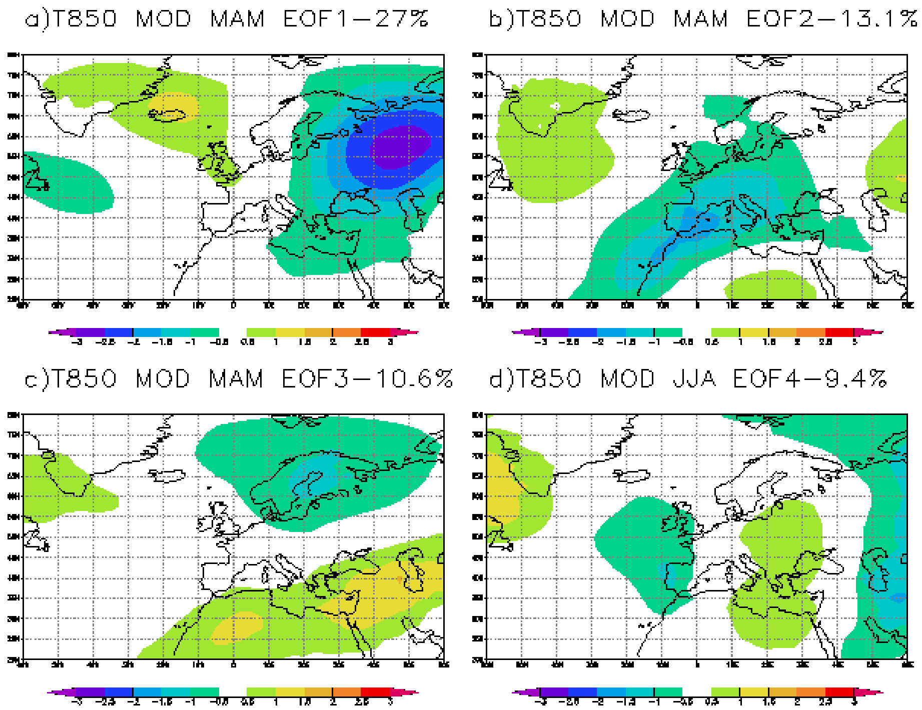

Figure 15 NCEP EOFs(SPRING)

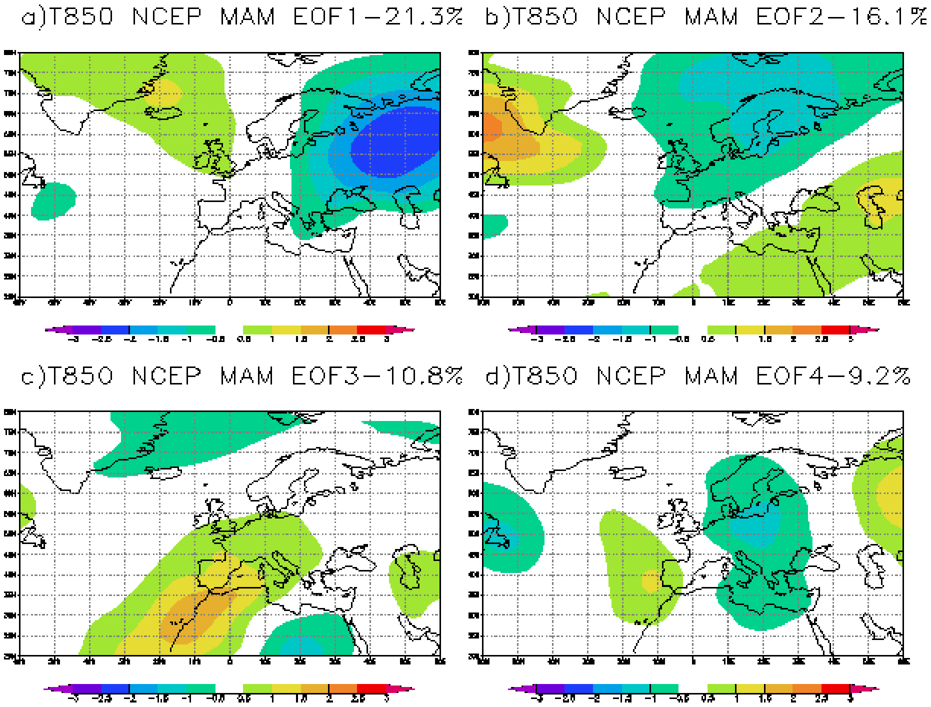

Figure 16 addfa EOFs (SUMMER)

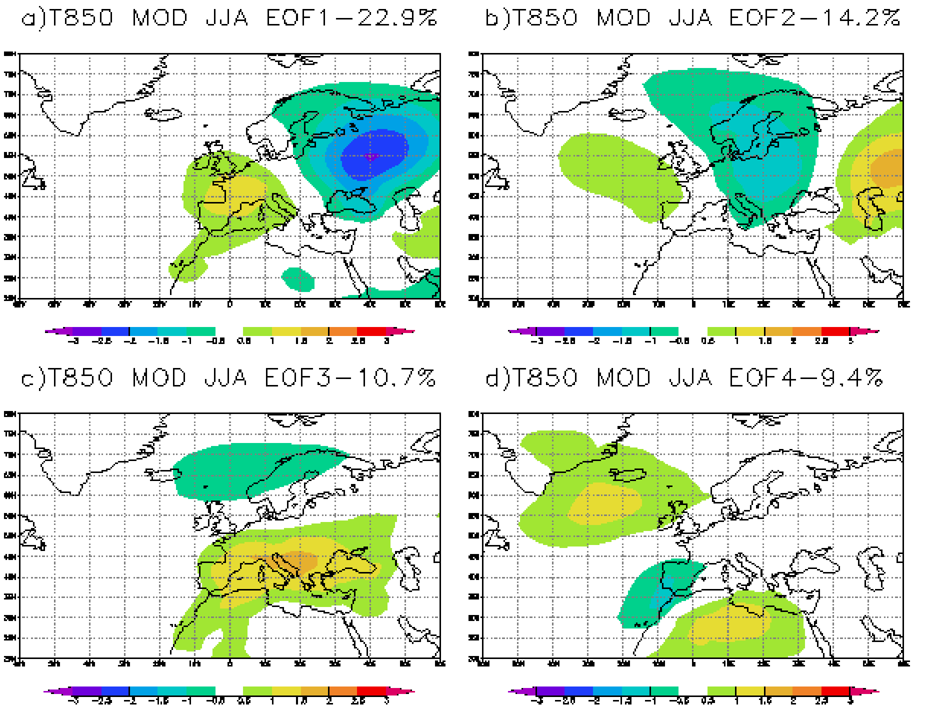

Figure 17 NCEP EOFs (SUMMER)

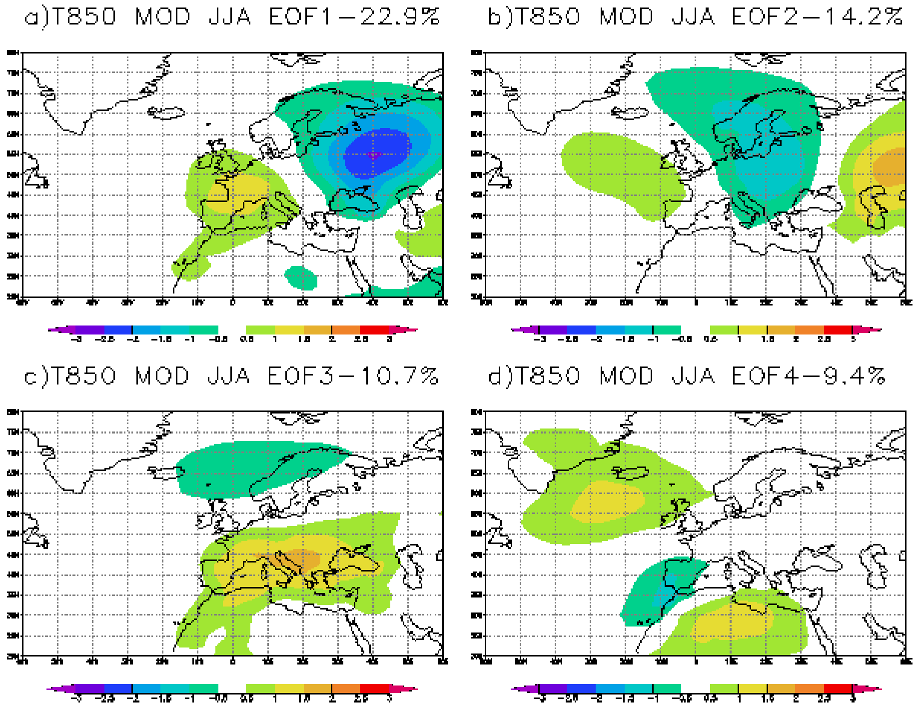

Figure 18 addfa EOFs (AUTUMN)

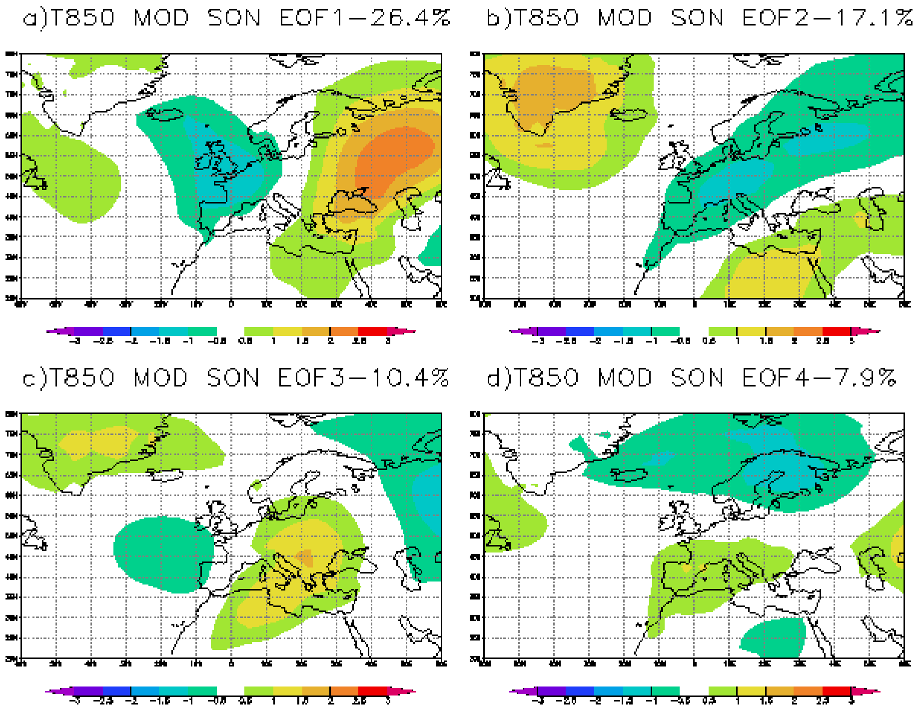

Figure 19 NCEP EOFs (AUTUMN)

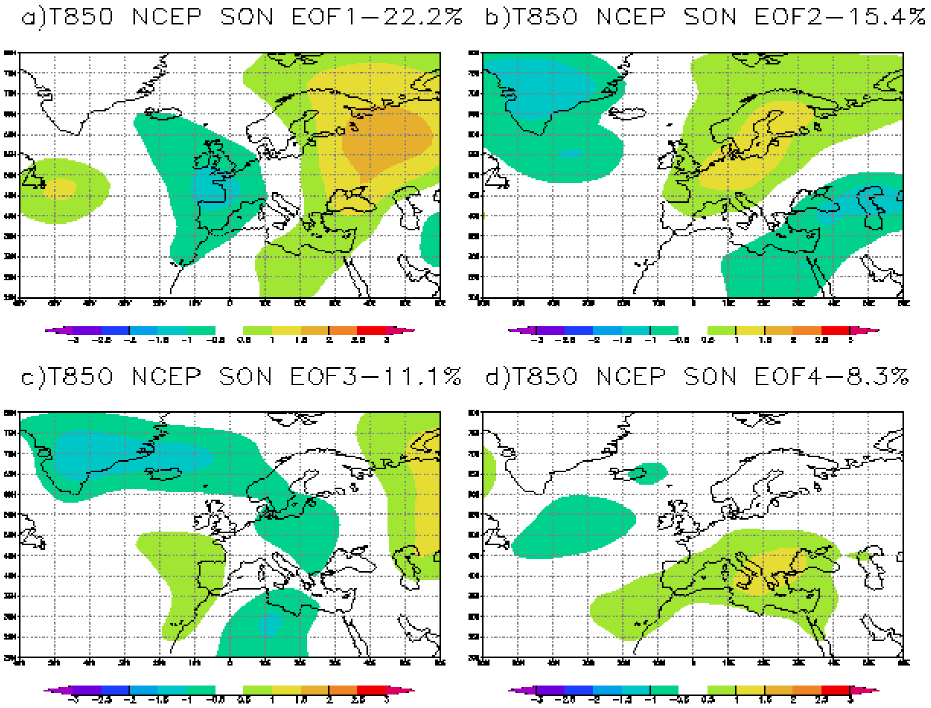

Figure 20 addfa EOFs (Winter)

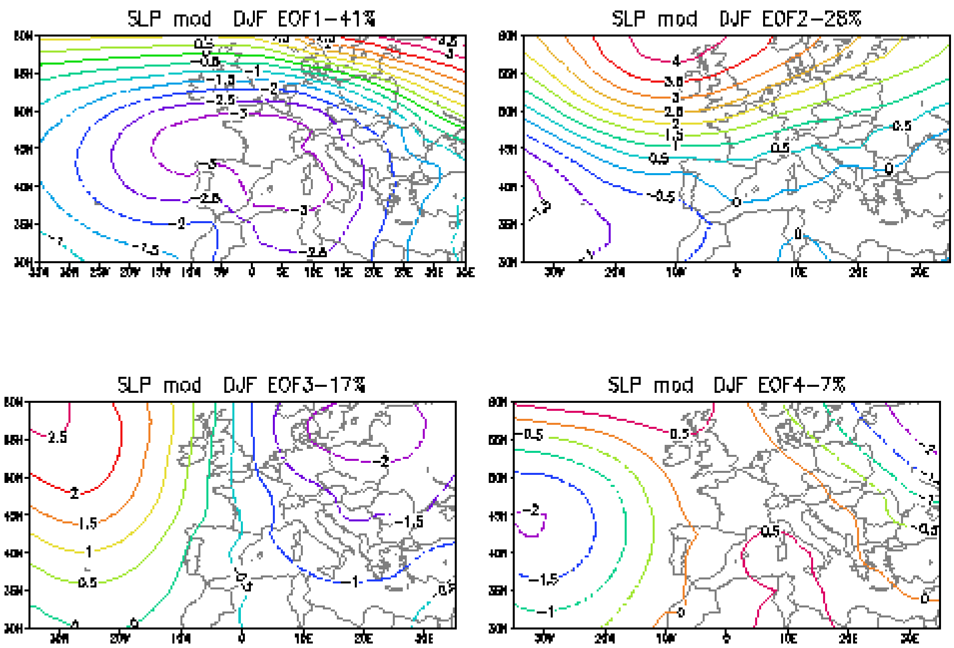

Figure 21 NCEP EOFs (Winter)

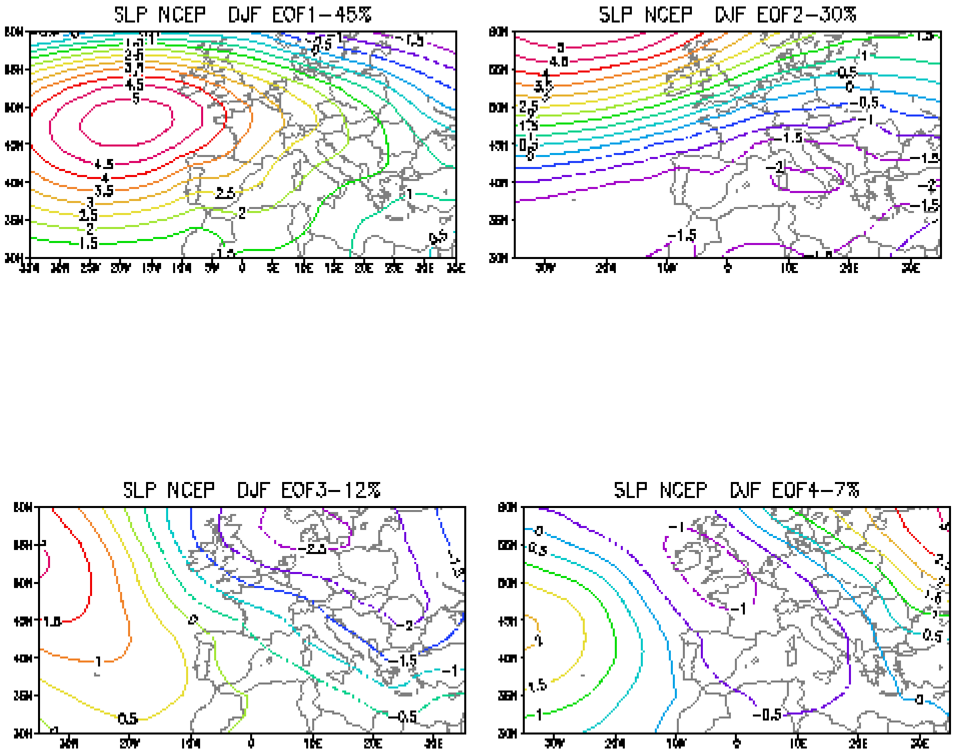

Figure 22 addfa EOFs (SPRING)

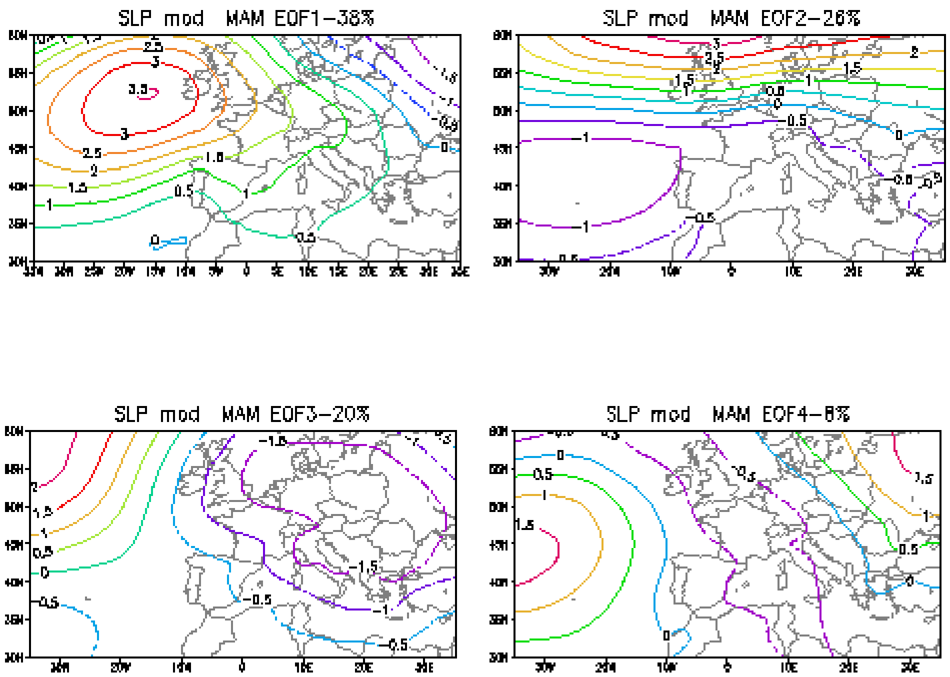

Figure 23 NCEP EOFs (SPRING)

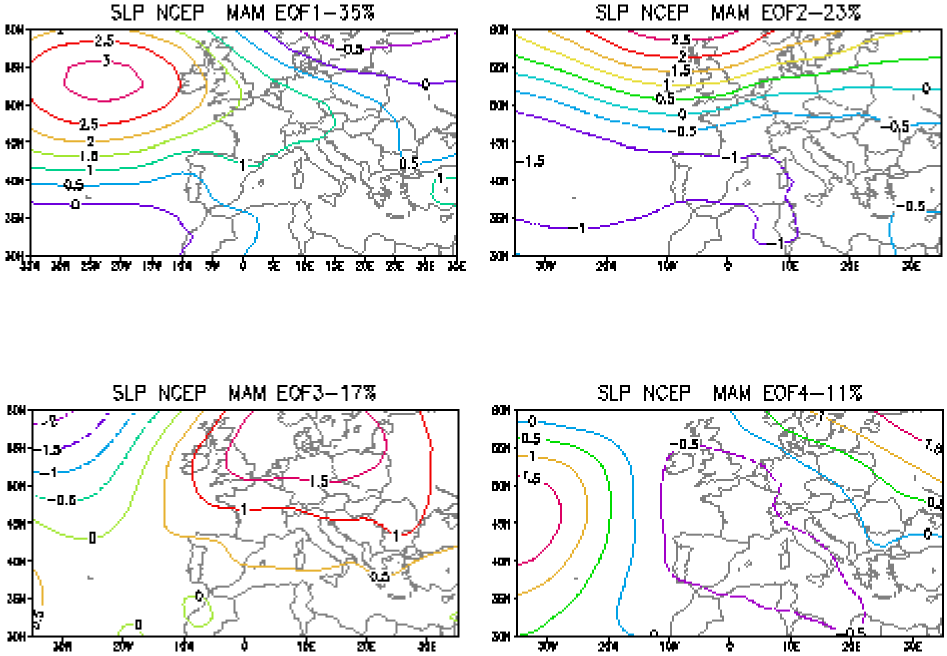

Figure 24 addfa EOFs (SUMMER)

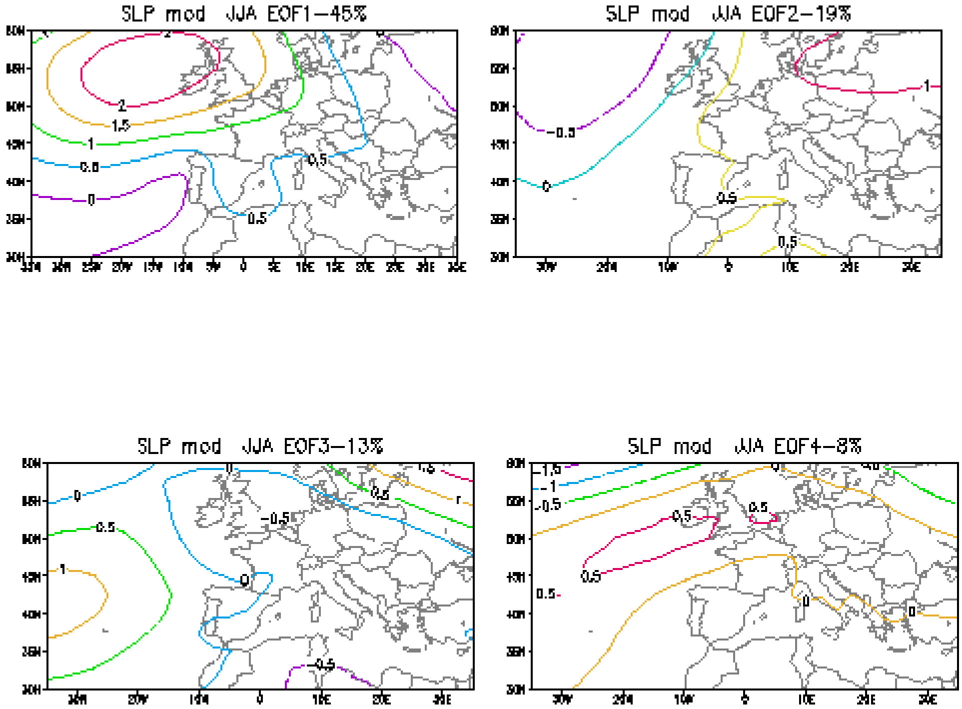

Figure 25 NCEP EOFs (SUMMER)

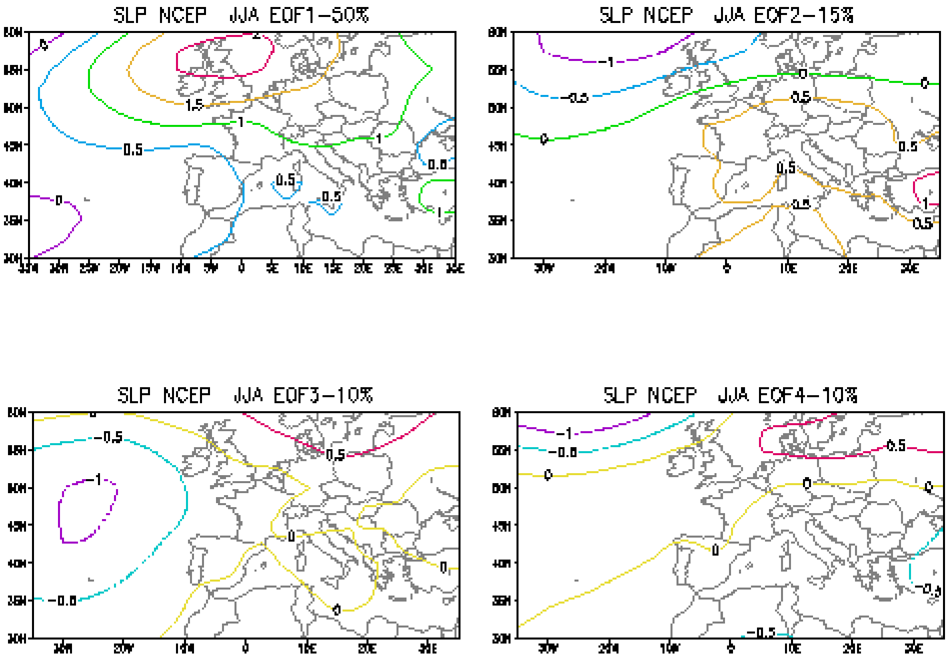

Figure 26 addfa EOFs (AUTUMN)

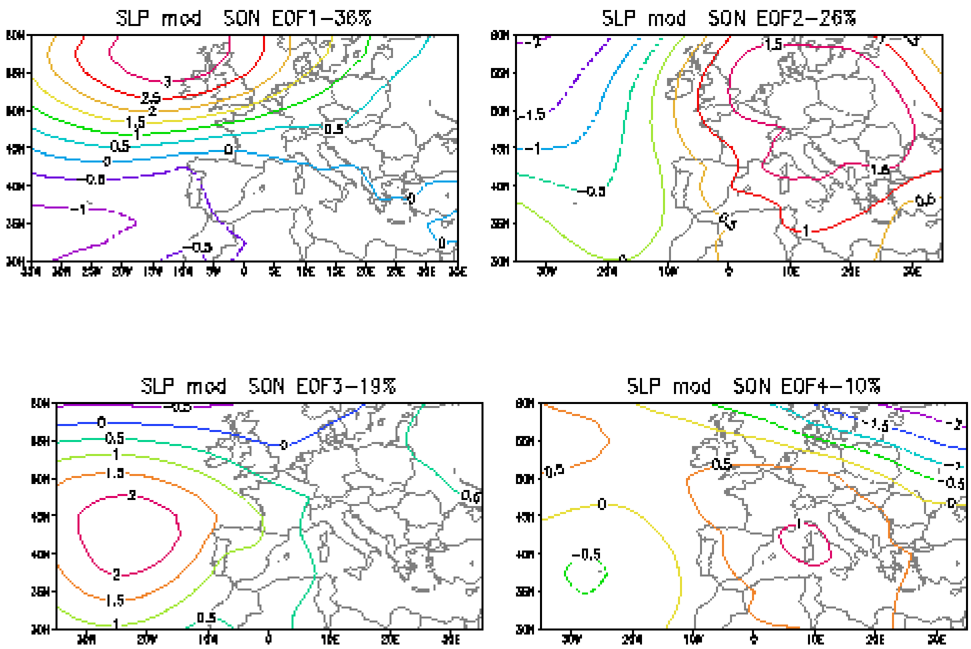

Figure 27 NCEP EOFs (AUTUMN)