P1.4 3D CLASSIFICATION OF WINTER NORTH ATLANTIC GEOPOTENTIAL FIELD VARIABILITY WITH THE HELP OF KOHONEN MAPS (SOM)

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1. INTRODUCTION

Different techniques, both linear and non-linear, have been used for analysis of variability of North Atlantic geopotential fields. Among the linear ones, PCA (Principal Component Analysis, both unrotated and rotated) is the most widely used. But PCA, if applied to nonlinear system, suffers from its linearity and for this reason its results may be ambiguous and their interpretation may be difficult. Lately, some nonlinear techniques (e.g. nonlinear PCA with the help of autoassociative neural network) have been developed and used to overcome this constraint (Hsieh, 2001a). It was clearly shown that these techniques may provide a new and more realistic insight into climatological fields variability (Hsieh, 2001b, Monahan, 2001, Metelka, 2003).

2. METHODOLOGY

Our study is focused on application of Kohonen Self Organizing Maps (SOM) for classification of observed winter geopotential fields in North Atlantic region. Kohonen SOM is a 2-layered neural network with radial units in typically (but not necessarily) 2-dimensional output layer (topological map). Kohonen networks use the unsupervised learning algorithm which attempts to locate clusters in the input data. Starting with an initially-random set of radial centers, the algorithm gradually adjusts them to reflect the clustering of the training data. The iterative training procedure also arranges the network so that units representing centers close together in the input space are also situated close together on the topological map. The basic iterative Kohonen algorithm simply runs through a number of epochs, on each epoch executing each training case and applying the following algorithm:

- Select the winning neuron (the one who's center is nearest to the input case)
- Adjust the winning neuron to be more like the input case

In the Kohonen algorithm, the adjustment of neurons is actually applied not just to the winning neuron, but to all the members of the current neighborhood. The neighborhood typically decays over time. Often, training of Kohonen network is conducted in two distinct phases: a relatively short phase with high learning rates and neighborhood (crude topological ordering of the topological map), and a long phase with low learning rate and zero or near-zero neighborhood (fine-tuning of individual neurons within the topological map).

3. DATA

We used the NCEP/NCAR reanalyses (monthly means) of geopotential fields at 1000, 850, 700, 500 and 300 hPa in Euro-Atlantic region (90W-50E, 10N-80N) from 1950 to 2003. As the zonal distances between neighboring grid points decrease poleward in the geographical grid, the data were transformed to most “regular” grid with each grid point representing similar area (see Metelka, 2003). Then winter seasonal means were calculated for 3 overlapping seasons within each winter (NDJ, DJF and JFM) and their anomalies (with respect to 1961-1990 period) were calculated. These anomalies were then clustered with the help of Kohonen SOM with 4x3 topological map. Clustering was not made separately, level-by-level, but for all levels at once so that the information about vertical structure of geopotential field was retained in results. Typical cluster centers were then found as the codebook vectors of individual neurons in the trained topological map.

4. RESULTS

Hereafter, the numbers of SOM nodes of interest, will be used as follows:

1	2	3	4
5	6	7	8
9	10	11	12

Cluster centers represent 12 types of observed geopotential anomaly fields. Moreover, they are arranged in the topological map so that similar anomaly fields are mapped close together while diverse anomaly fields are far-distant on the topological map (fig.1 = 1000 hPa, fig.2 = 700 hPa, fig.3 = 300 hPa, 850 hPa and 500 hPa not shown). As the main mode of North Atlantic geopotential variability is connected with NAO, the NAO+ and NAO- fields are situated in the most distant parts of the topological map (NAO+ corresponds to nodes 1 and 5, NAO- to nodes 8 and 12). Fields, corresponding to the neurons on the periphery of the topological map, describe possible ways of transition between positive and negative NAO phases (weakening of both NAO centers is followed by clockwise/anticlockwise “rotational exchange” of the weak centers and then both centers strengthen again but with opposite signs). Some phases of transition are connected with the occurrence of positive geopotential anomalies over Scandinavia (nodes 9, 10 and partly 11,

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especially in the middle and upper troposphere) which may indicate possible link between NAO and Scandinavian oscillation. Two "central" neurons of the topological map (nodes 6 and 7) are connected with plain anomaly fields.

The relation between SOM categories and "classical" NAO-indices (both PCA-based and station-based) is shown in fig.4 and fig.5. (NAO Index Data were provided by the Climate Analysis Section, NCAR, Boulder, USA). Despite the fact that the definition of SOM categories is totally different from the definitions of NAO indices, there is clear link between them. Definitions of NAO indices lead to continuous values of those indices while the application of Kohonen SOM leads to categorial classification. On the contrary, PCA-based NAO index maps some features of North Atlantic pressure field variability onto 1-dimensional space while Kohonen SOM maps it onto 2-dimensional space. Therefore it may be more applicable in some cases as it should be able to distinguish between different fields with similar PC-based NAO index.

As the information about vertical structure of geopotential field was retained in results, anomalies of relative topography RT 1000/500 hPa were calculated. They indicate possible links between geopotential anomalies and anomalies of mean temperature of the lower troposphere (fig.6). The comparison of fig.6 with fig. 1-3 shows that some geopotential anomaly fields are connected with low-tropospheric temperature anomalies, especially in European region (nodes 1 and 8) and in Labrador – Southern Greenland region (nodes 1, 2, 4, 8, 9, 11 and 12).

Moreover, it seems that the occurrence frequency of some categories of geopotential anomalies varied within the period of interest. These variations are shown in fig.7. It involves especially nodes 1, 2 and maybe 5 (increasing occurrence frequency) and 3, 4 and maybe 9 (decreasing occurrence frequency). It may indicate some systematical changes of the occurrence frequency of individual circular patterns but the number of data available is still too low to make clear final conclusions about that.

5. CONCLUSIONS

- As the classification with the help of Kohonen SOM does not suffer from the premise of linearity (which is the case of e.g. PCA), this method is able to reproduce well the nonlinear features of geopotential variability, including possible "rotational" exchange of the NAO centers and slightly different position of the centers in positive and negative NAO phases.
- Some categories of geopotential anomaly fields indicate possible link between NAO and Scandinavian oscillation.
- Some categories of geopotential anomaly fields are connected with anomalies of mean temperatures in lower troposphere.
- There is clear link between SOM categories and NAO indices (both station-based and PC-based).
- Categorization of anomaly fields with the help of Kohonen SOM methodologically differs from "classical" PC-based NAO index definition. The main difference is that PC-based NAO index maps the anomaly fields onto continuous 1-dimensional space while Kohonen SOM maps them onto discrete (categorial) 2-dimensional space (nodes of the "topological map").
- There is indication about the variability of occurrence frequency of some categories of geopotential anomaly fields but the number of data available is too low to make clear conclusions about it.
- These early results are very promising with respect to the future planned studies of possible links between North Atlantic pressure field and monthly (or seasonal) temperature anomalies in central Europe as well as the studies of temporal evolution of North Atlantic pressure fields.

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1000 hPa

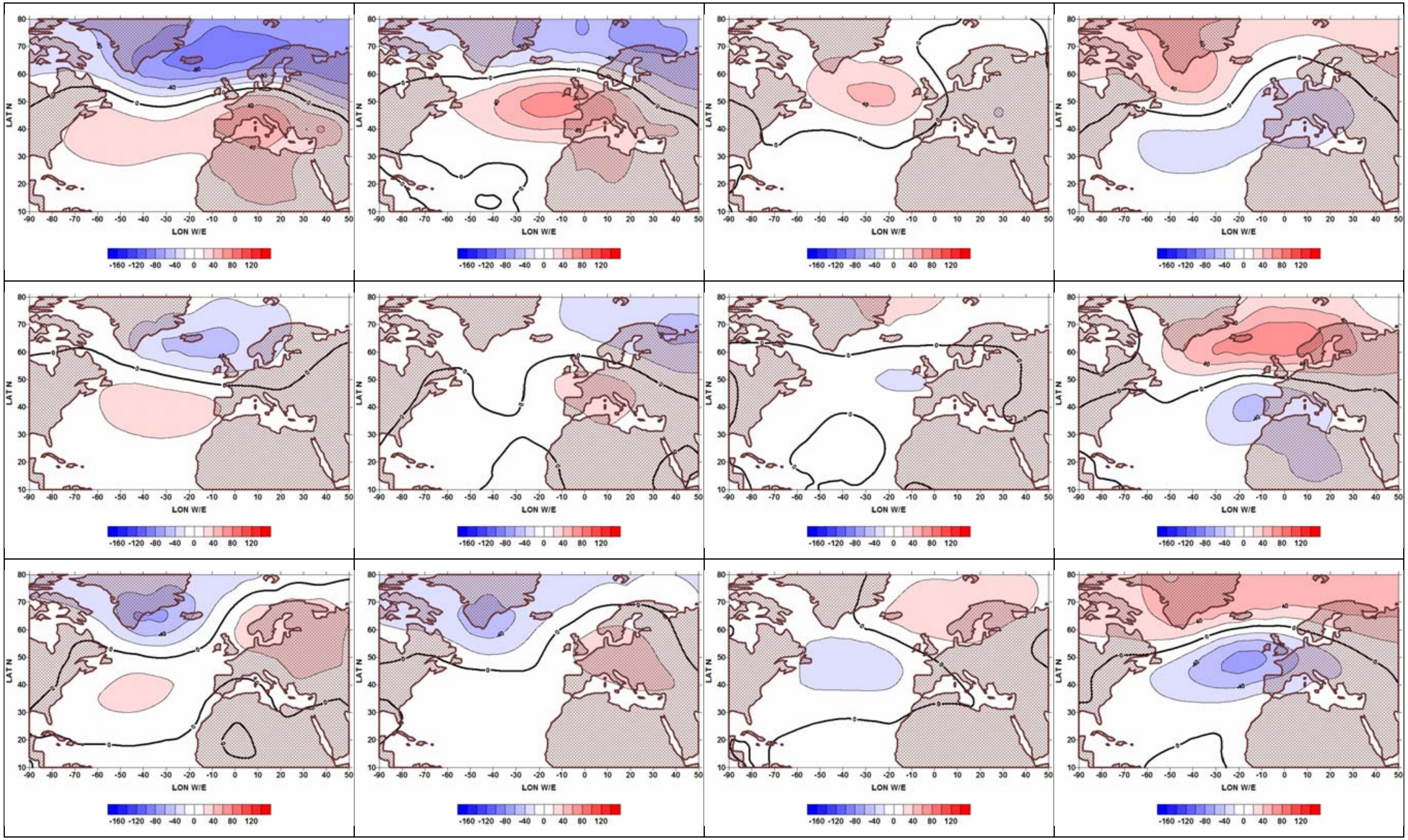

Fig.1: Codebook maps of Kohonen SOM results - 1000 hPa level

700 hPa

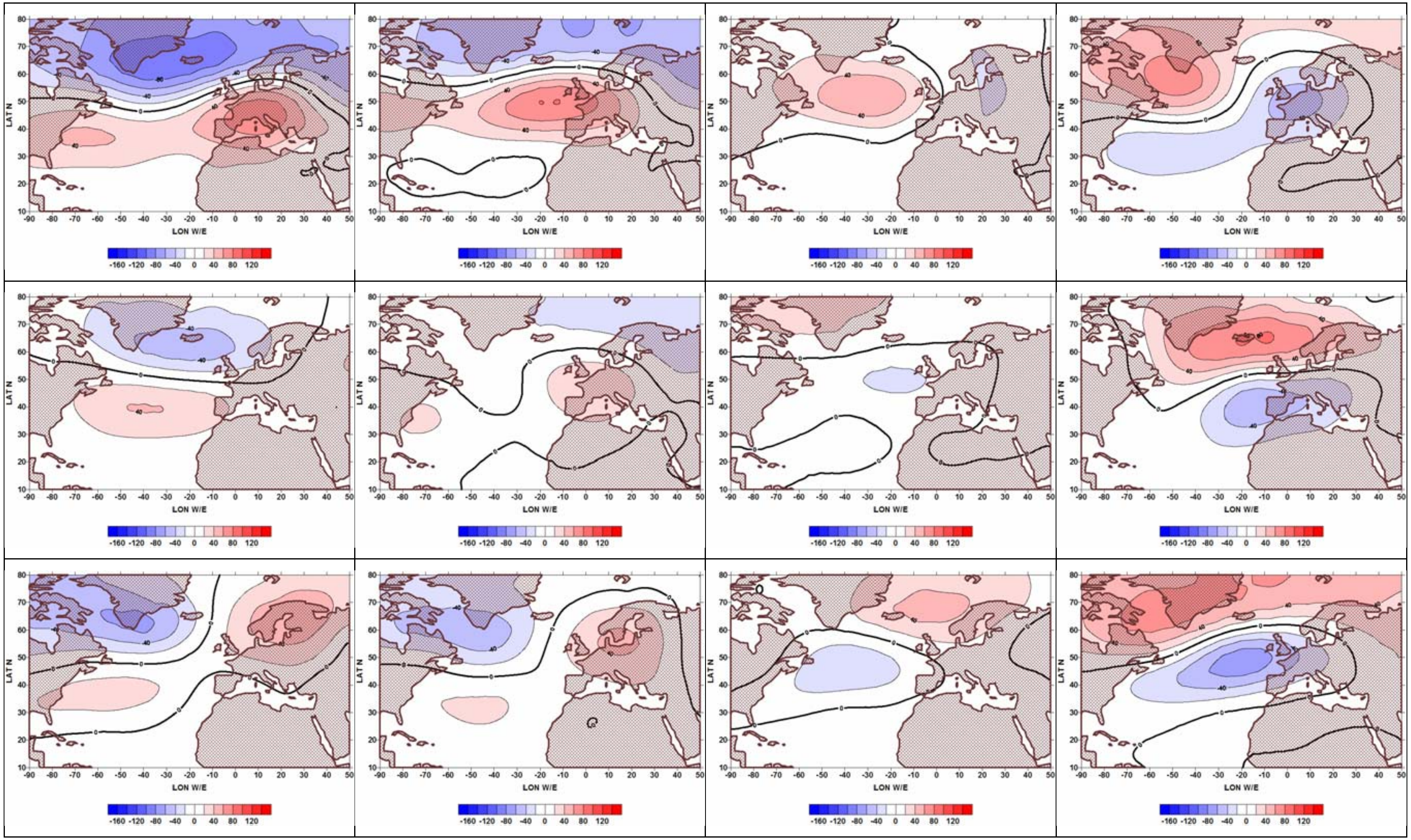

Fig.2: Codebook maps of Kohonen SOM results - 700 hPa level

300 hPa

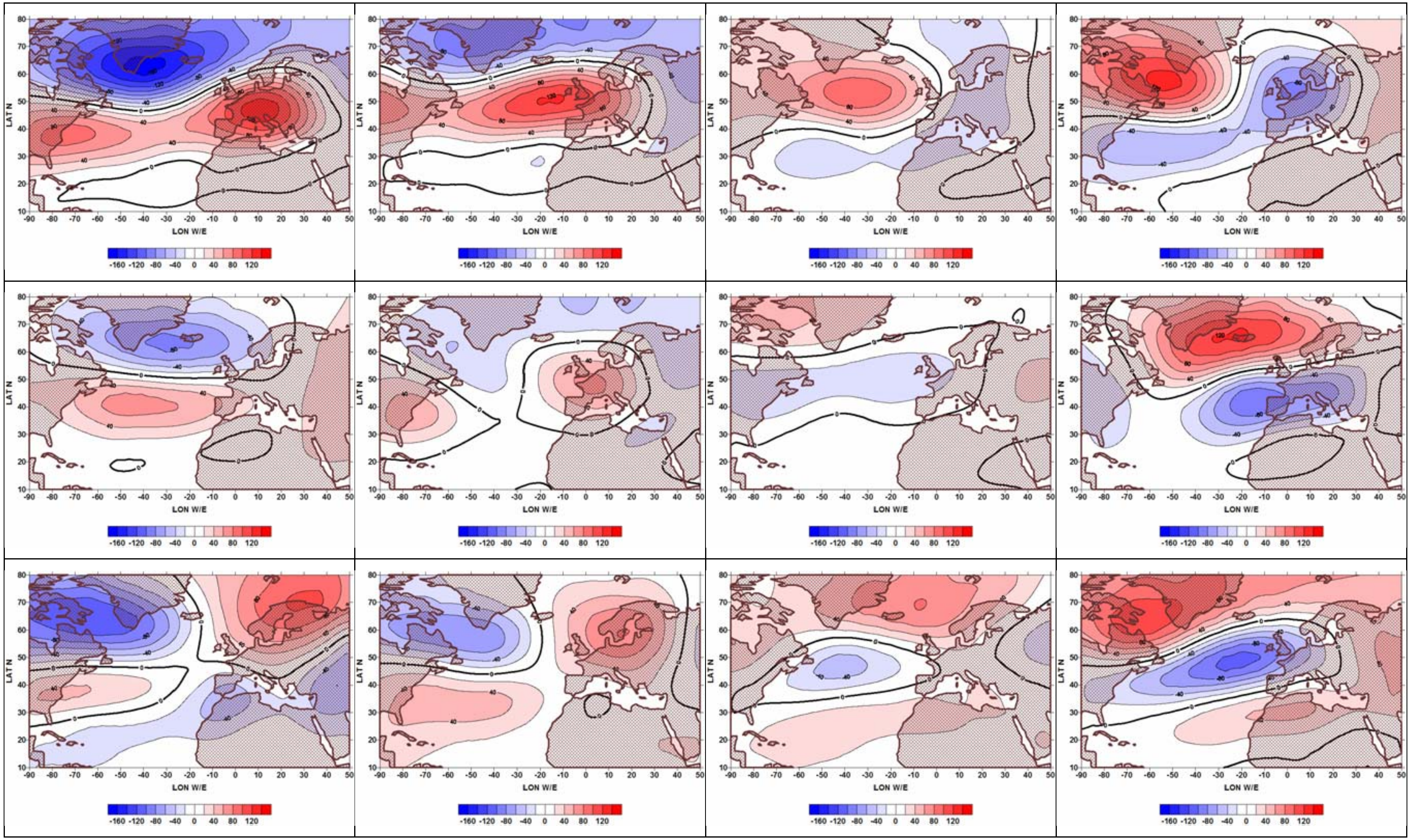

Fig.3: Codebook maps of Kohonen SOM results - 300 hPa level

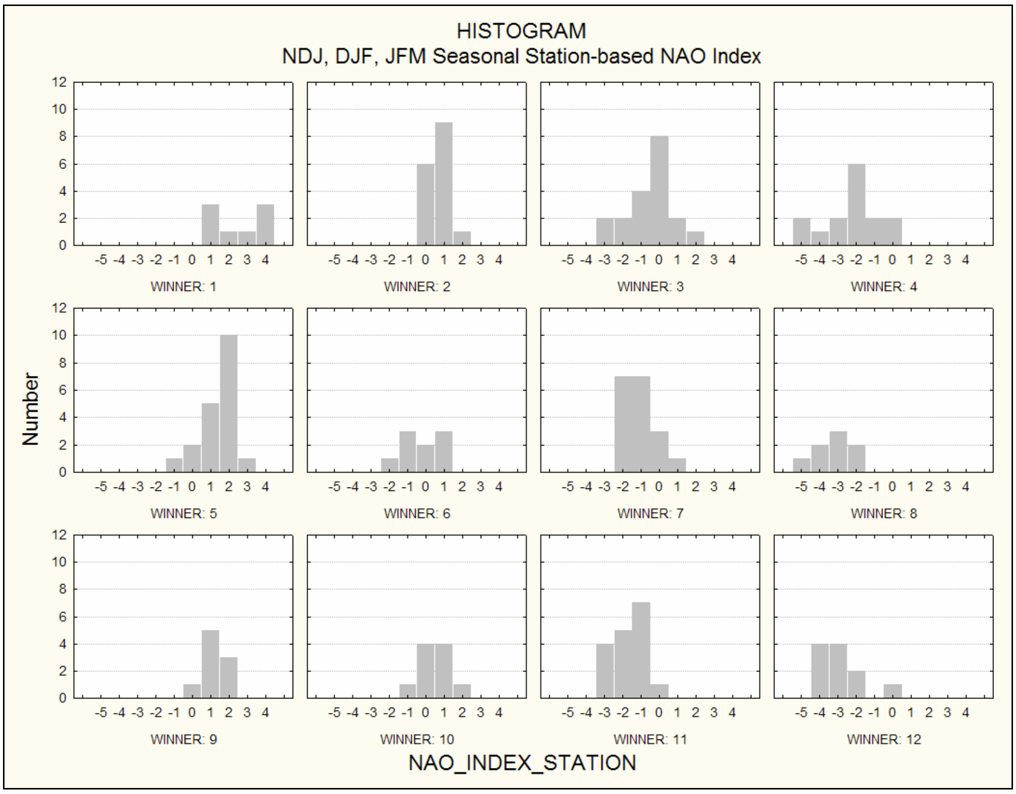

Fig.4: Histogram of the dependency between winter seasonal station-.based NAO index and the classification of the pressure field with the help of Kohonen SOM

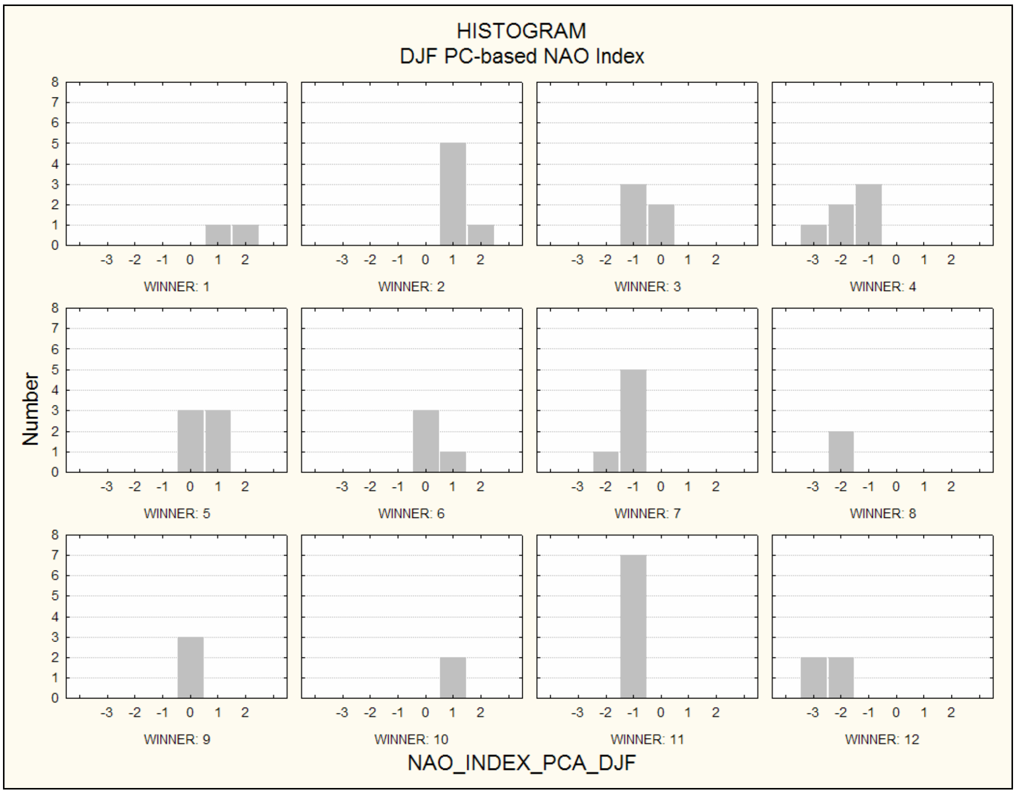

Fig.5: : Histogram of the dependency between DJF seasonal PC-based NAO index and the classification of the pressure field with the help of Kohonen SOM

RT 1000/500 hPa

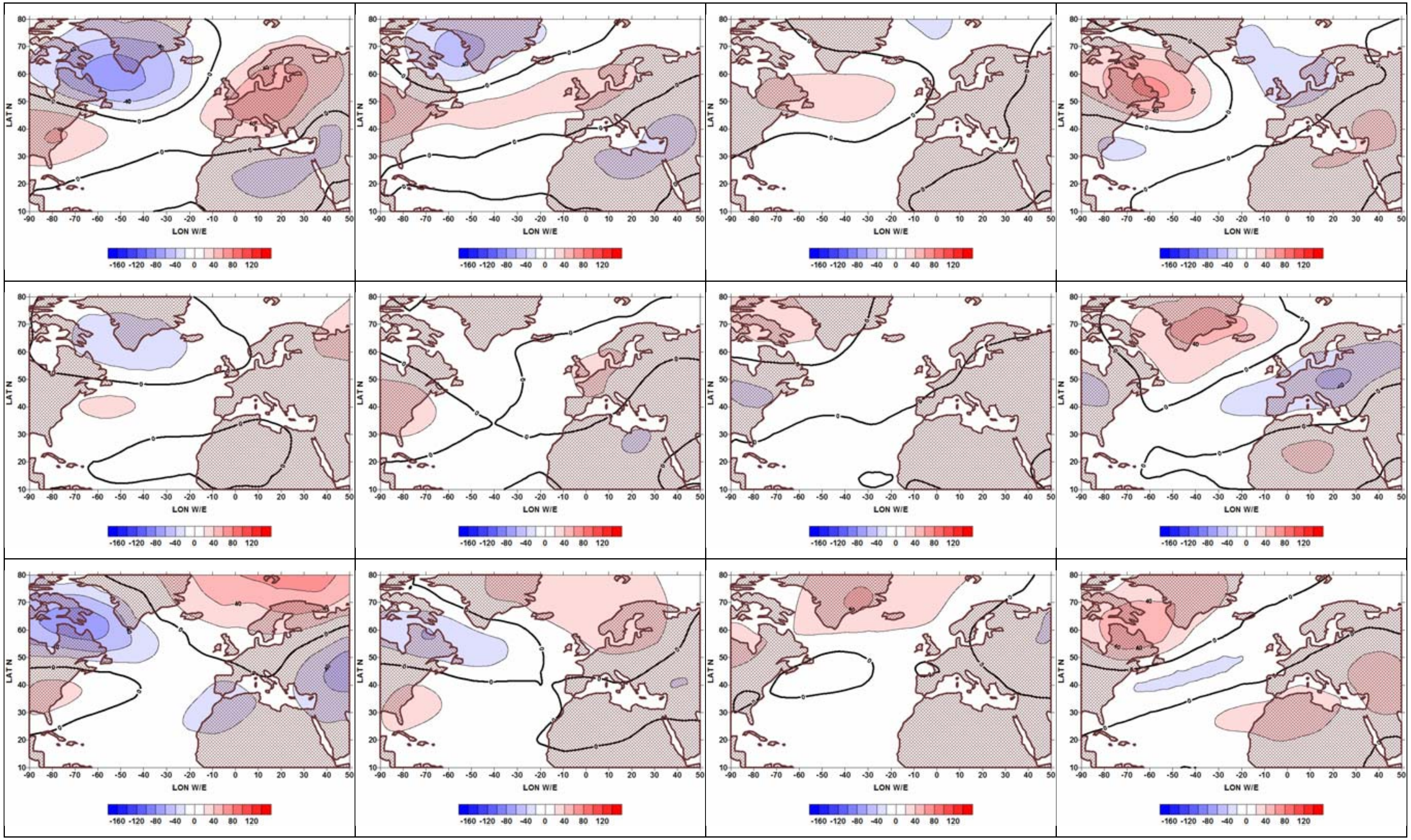

Fig.6: Relative topography 1000/500 hPa codebook maps calculated as the difference between codebook maps of Kohonen SOM results (500 hPa - 1000 hPa)

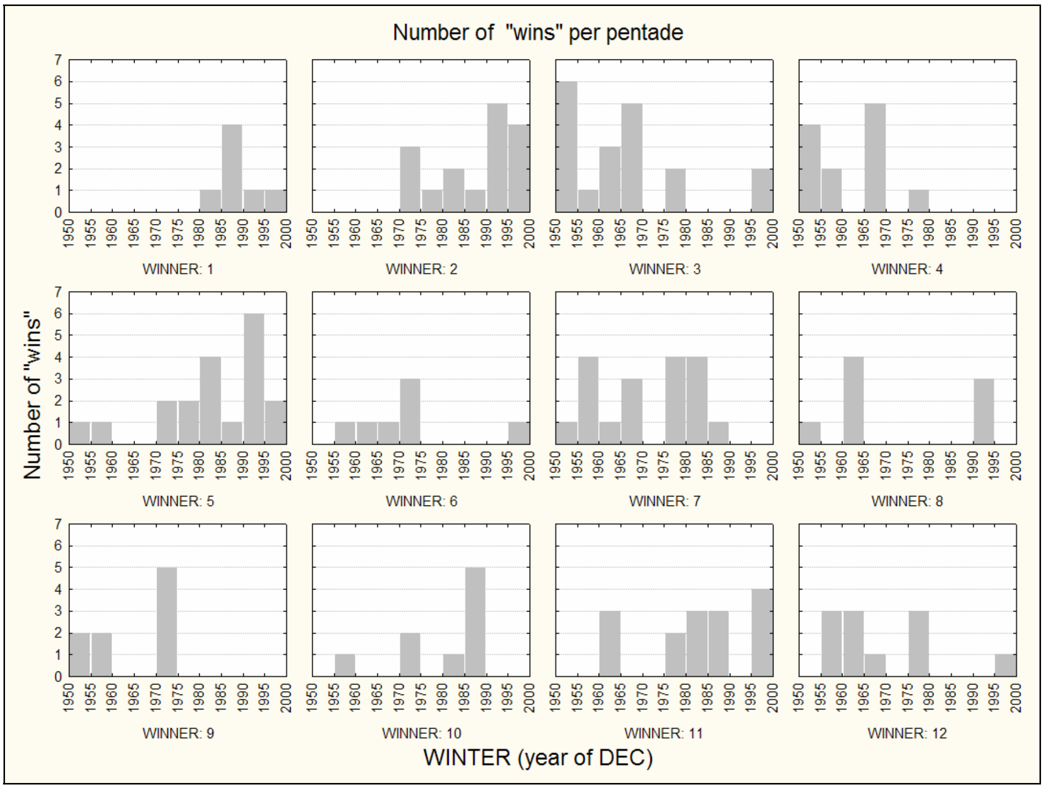

Fig.7: Time evolution of the pentadal number of "wins" for individual SOM nodes