The SST Variability Investigation In Northern Atlantic And The Assessment Of Related Changes In European Climate

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Abstract— Remote sensing data provided the major contribution to the sea surface temperature (SST) field analysis during last several decades. Climate variability of the SST in Northern Atlantic is investigated by using an empirical orthogonal function (EOF) and fuzzy classification techniques. The leading EOF of the wintertime sea-level pressure (SLP) field is more strongly coupled to the surface atmosphere temperature (SAT) fluctuations over Europe than the NAO. Non-linear trend estimation technique was developed to detect an inter-annual variability of the SST, the SLP and the SAT. The SST had a tendency to dropping in interval from late forties to early seventies of last century. This tendency was changed to increasing in the middle of seventies and continued to the end of last century. It is in a good coherence with the SAT climate series in Europe.

Keywords: Climate change; SST remote sensing; SST variability; non-linear trends

1. INTRODUCTION

The warming event in the first part of the twentieth century, considered at the time by some as the first sign of climate warming caused by increasing CO^2, had its largest amplitude in the higher latitudes of the Northern Hemisphere. The largest warming occurred in the Arctic (60^o–90^o N) (Johannessen et al. 2004) averaged for the 1940s with some 1.78C (2.28Cfor the winter half of the year) relative to the 1910s.It was a long-lasting event commencing in the early 1920s and reaching its maximum some 20 years later. The decades after were much colder, although not as cold as in the early years of the last century. It is interesting to note that the ongoing present warming has just reached the peak value of the 1940s, and this has underpinned some views that even the present Arctic warming is dominated by factors other than increasing greenhouse gases (Polyakov and Johnson 2000). However, other authors (e.g., Johannessen et al. 2004) concluded that the present warming in the Arctic is dominated by anthropogenic greenhouse gas forcing. Four possible mechanisms, individually or in combination, could have contributed to the early twentieth-century warming: anthropogenic effects, increased solar irradiation, reduced volcanic activity, and internal variability of the climate system. The radiation forcing by CO^2, for example, is largest in the Tropics but the largest surface warming occurs at higher latitudes (Bengtsson et al, 1999). The same is true for solar forcing. Characteristic for all of the models used in a Coupled Model Intercomparison Project (CMIP) study (Raisanen 2002) was a maximum warming in the Arctic, a modest warming in the Tropics, and a minimum warming at the higher latitudes of the Southern Hemisphere. Here we will provide in a semi-quantitative way using SST and SAT observations and time series non-linear trend analysis a possible explanation of the medium and high-latitude warming in 1950–2000. Moreover, an issue to be addressed in this paper is a possible ocean climate mechanism that can contribute toward long-lasting climate anomalies in the Arctic and medium-latitude areas.

2. METHOD

Along with linear tend computations we carried out alternative studies of time series (quadratic, cubic and non-liner approximations). All mentioned approaches with the exception of non-linear trend technique are known and widely used. Therefore, we consider a non-linear technique (Pokrovsky, et al, 2004). Let us assume that $x_1,..., x_n$ is an input time series. Our task is to recover it from short-term disturbances and to reveal non-linear long-term components. We transform input data $x_i\,(i = 1,..., n)$ to smooth values $\bar{x}_i\,(i = 1,..., n)$ in accordance to formula: $\bar{x}_i = \sum_{k=1}^{n} \rho_{ik} x_k$. The set of the weight coefficients $\rho_{ik}\,(i, k = 1,..., n)$ should be determined from following relationships:

$$\sum_{k=1}^{n} \rho_{ik} = 1, (i = 1,..k);$$

$$\sum_{k=1; k\neq i}^{n} \rho_{ik} = \alpha\rho_{ii}, (i = 1,..k), (0 \le \alpha \le 1);$$

$$\rho_{ik} = 1/(i-k)^2 (i, k = 1,..., n; i \ne k).$$

Thus smoothing estimate $\bar{x}_i\,(i = 1,..., n)$ is obtained from all input data, but with different weights. Smoothing coefficient α regulate smoothing rate. When α=0, smoothing is absent. Smoothing rate is maximal when α =1. Above procedure is an iterative and it assumes to be terminated when consecutive approximations differ less than assigned threshold.

3. RESULTS

Sorensen (1979) showed that the World Ocean contribution in atmosphere heat balance is comparable to those of the Sun radiation. Therefore, it is desirable to investigate ocean temperature long-term trends in various parts of World Ocean. We started this study from analysis of SST for Northern Atlantic. The fifty years (1948-1998) monthly SST, SAT and SLP data acquired from NCEP-

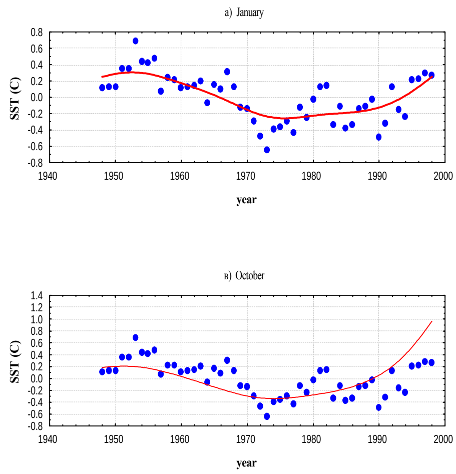

Figure 1. SST non-linear trends for various months

NCAR re-analysis archive was used in this study. Previous studies (e.g. Hurrell, 1995) came to the conclusion that short-term (from 6 months to 4 years) climate variability in SAT may be generated by SST disturbances of similar time scales. Having in disposal a new tool to investigate climate series, we explored simultaneous SST, SAT and SLP monthly magnitudes derived for 50 years of last century. We investigated SST spatial fields in rectangular 30°-60° N and 5°-75 ° W and anomalies of spatially mean magnitudes. Figure 1 demonstrates SST non-linear trends related to different seasons. January SST decreases till 1973 and than commence to increase until the end of last century (fig. 1a). As the Ocean surface is the main source of heat during this time, it is reasonable to assume that Ocean itself starts warming just after 1973. Moreover, positive SST anomaly achieved the magnitudes similar to those for beginning of fifties. It is known that SAT in nineties exceeds SAT magnitudes for fifties. This fact is another augment in support of assumption that it is the Ocean drives the Atmosphere changes in last quarter of twenties century. After intensive warming of Ocean in summertime related SST anomalies should better follow to SAT behavior. And it is the case (see fig.1b). In fact, positive SST anomaly in the end of nineties exceeds corresponding magnitudes observed in the beginning of fifties. Let us consider structures of first empirical orthogonal functions (EOF) in order to investigate spatial anomalies of North Atlantic SST. A set of 10 EOF explains about 90% of variability in the case of SLP field and 70% - in the case of SST field in North Atlantic. First EOF related to SST field has the only anomaly in the western region of North Atlantic located to south of Greenland (fig. 2a). This area corresponds to a maximum of SST variability. Second SST EOF describes a dipole in middle of Atlantic with a minimum at 35° N and a maximum located to south of Iceland and Greenland at 60° N (fig.2b). Third EOF has a picture, which is similar to NAO related to Azores SLP maximum and Iceland minimum SLP. At next stage we investigated temporal dependence of EOF expansion coefficients. Coefficient responded to first EOF attains negative values in fifties and sixties, but in mid seventies it change sign on positive and keeps positive magnitudes till the end of last century. Therefore, first coefficient describe long-term SST trend. If take into account fig.2a one can comes to the conclusion that cooling period in

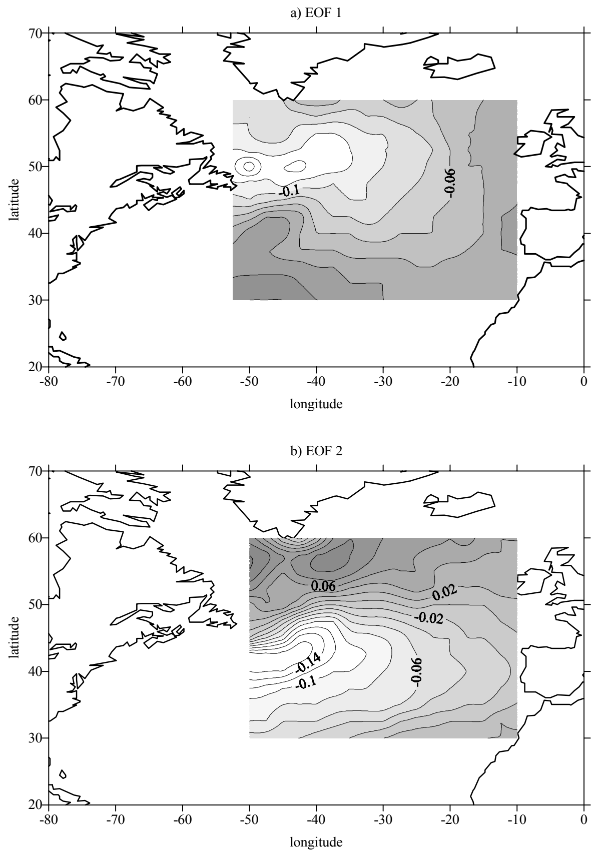

Figure 2. SST spatial EOF

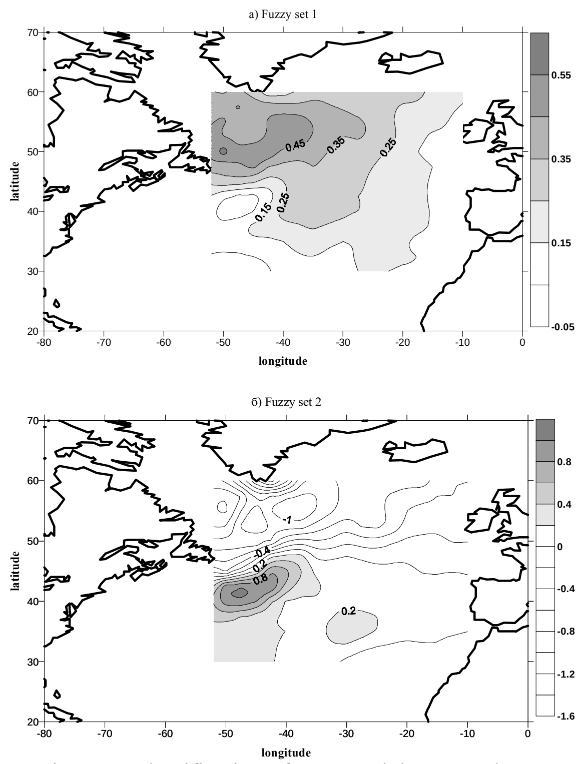

Figure 3. Classification of SST spatial patterns by fuzzy analysis

SST corresponds to surface water warming in Northwest region of North Atlantic, where EOF 1 achieves its maximum. In contrast, surface water became colder in period of global warming commencing in the middle of seventies. Coefficient responded to second EOF attains positive values in period of sixties and seventies, when a transition from decreasing to increasing in SST was occurred. Hence, there is evident linkage between mean SST trends and SST anomalies in Northwestern and Western regions of Atlantic. To extend our knowledge on spatial structure of SST fields and its variability we applied new classification method based on fuzzy analysis (Pokrovsky et al, 2002). Mean filed derived from first class (fig.3a) demonstrate an area of high SST variability located to south of Iceland and Greenland. Second class (fig.3b) reflects dipole component in SST spatial variance. This dipole is oriented in south-north direction. Physically it might be explained by instantaneous temperature contrast between warm water in Golf Stream and cold waters in Labrador currents.

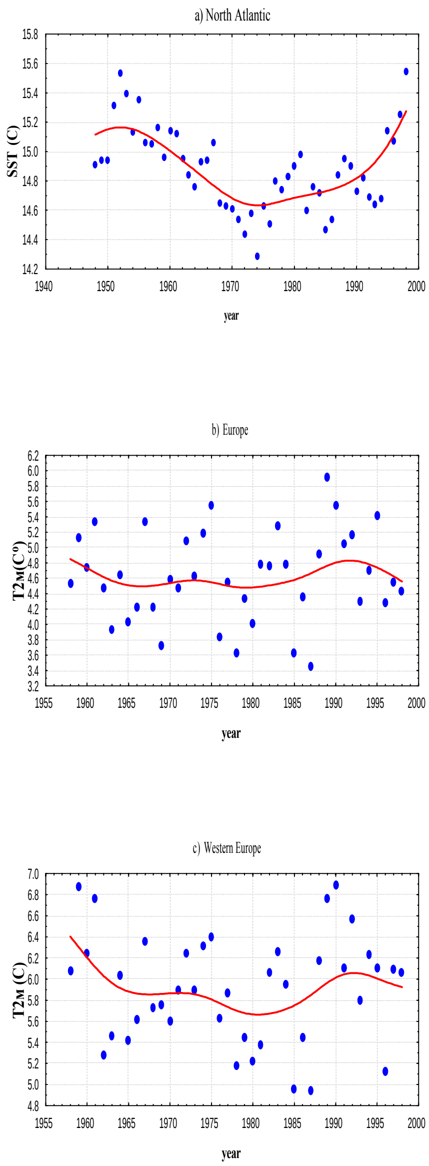

Figure 4. Annual mean SST series

Let us come to analysis of corresponding SAT time series in various parts of Europe. We selected its continental part restricted by rectangular area: 45° -70° N and 5° -50° E. When compare mean SST (fig.4a) and SAT (fig.4b) series, one can find joint features: similar trends. In the case of Western Europe SAT series (fig.4c) is even more close to SST series.

4. CONCLUSION

Obtained results shows that there are very close relationships between SST and SAT trends. Most coherence is observed in cold time of year when Ocean heating effect is maximal. It is known that equilibrium between ocean surface and atmosphere is established in 1-2 months. On other had it was found that SST trend differ quantitatively from those for SAT. SST attains close magnitudes in early fifties and in late nineties. But SAT nineties values exceed fifties magnitudes. Hence, it is possible to assume that there is very slow oscillation in ocean temperature, which might be partly observed in SST. Moreover, this slow oscillation generate corresponding very long-term trend in SAT, which is known as global warming.

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