Decadal trends in the East Atlantic West Russia pattern and the Mediterranean precipitation

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Keywords: wind, correlation, precipitation, teleconnection, East Atlantic Western Russia

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International Journal of Climatology

Submitted: September 2003

Revised: August 2004

Abstract

Investigation of the role of the East Atlantic / Western Russia (EA/WR) teleconnection pattern in the monthly mean Mediterranean area precipitation is performed. Space correlations between the mean monthly precipitation and the EA/WR index during 1950 – 2000 have been calculated. The EA/WR-precipitation correlations are statistically significant over the eastern Atlantic and southeastern Mediterranean regions. Two pares of the characterized by low and high EA/WR regimes ten-year periods have been selected. The EA/WR-precipitation correlation patterns have been calculated for each of the periods. Common features that characterize the periods with the two EA/WR regimes are determined. One of the zones with the notable differences between the correlation patterns is found located over the EM region. To determine the mechanisms responsible for the differences we analyze the low and high EA/WR low-troposphere circulations which characterize the periods with the EM precipitation (CEMP). The differences in the correlation patterns are explained by the variations in the air mass transport to the EM area during the wet DJF months during the two EA/WR regimes. Namely, during the low EA/WR years the CEMP is characterized by the mean atmospheric flow transporting the air-masses from Atlantics to the EM. On the contrary, typical for the high EA/WR DJFs the CEMP is characterized by advection to the EM of the air-masses from central Europe to the Mediterranean region. The finding allows explanation of the observed precipitation decline over the EM during the last several decades of the past century by the positive trend of the EA/WR.

1. Introduction

Two prominent European teleconnection patterns, - North Atlantic Oscillation (NAO) and East Atlantic/West Russia (EA/WR) have been detected (Barnston and Livezey 1987). The NAO pattern is associated with the meridional oscillation in the Sea Level Pressure (SLP) with the centers of action located in proximity to the Iceland Low and Azores High during winters. Periods with the positive values of the NAO index are characterized by enhanced westerly flow across North Atlantic and west Europe. This leads to the warmer and wetter weather conditions over northwest Europe and drier conditions in the western and northern Mediterranean regions. The opposite situation takes place during the periods with the low NAO index values, when wetter air masses are transported to the western and northern Mediterranean regions (Hurrell 1995). A significant positive trend of the NAO pattern has been noted during about four last decades of the past century (Hurrell 1995). The role of the NAO trend in the weather conditions over Europe has been widely investigated (Hurrell 1995; Ben-Gai et al. 2001; Krichak et al. 2002; Kushnir et al 2001; Paeth et al. 1999; Trigo et al. 2002; Ulbrich and Cristoph, 1999).

Much less attention has been paid to the role of the EA/WR pattern in the European weather. The pattern is zonally oriented. In winter, two main anomaly centers, located over the Caspian Sea and Western Europe, comprise the EA/WR. The EA/WR teleconnection pattern is also active during winters. During the negative (positive) EA/WR phases, wetter (drier) than normal weather conditions are observed over a large part of the Mediterranean region (Barnston and Livezey 1987). Positive phases of the pattern are characterized by the negative pressure/height anomalies throughout western and the southwestern Russia, and positive pressure/height anomalies over north-western Europe. Over the eastern Mediterranean region the positive EA/WR winter periods are associated with more intense northern air flows. On the contrary, negative EA/WR phases are associated with the positive pressure/height anomalies over the Caspian Sea and Western Russia and the negative pressure/height anomalies over north-western Europe. A positive EA/WR trend during the last several decades of the previous century has been noted (Krichak et al. 2002).

A negative eastern Mediterranean (EM) precipitation trend has been detected during the same period (Ben-Gai et al. 1993, 2001). Extreme wet (dry) winter EM months were characterized by the anomaly patterns, that have much in common with those of the positive (negative) EA/WR phases (Krichak et al. 2000; 2002). Benaroch (2000) and Kutiel and Benaroch (2002) and Kutiel et al. (2002) also demonstrated a dependency of the EM precipitation on the characteristics of a dipole pattern with the centers located over the east Atlantic and the Caspian Sea areas. The results allow assuming a role of the EA/WR trend in the variations of the EM precipitation during the period.

The aim of the current study was to investigate the possible dependency of the monthly mean precipitation over the Mediterranean area on the EA/WR. With this aim correlations between the monthly mean precipitation amounts and the EA/WR index are calculated. Analysis of the correlation dependencies allows an understanding of the role of the recent EA/WR trend in controlling the precipitation over the Mediterranean area. Additionally the lower troposphere atmospheric circulation patterns typical for the wet high and low WA/WR periods over the EM are determined and analyzed.

2. Data

Gridded data on the time variation of the EA/WR index are adapted in the study. The index values are taken from the NOAA Climate Prediction Center (CPC) website http://www.cpc.ncep.noaa.gov/data/teledoc/nao.html . The EA/WR patterns here are determined according to the diagnostic procedure for the identification of teleconnection patterns using the Rotated Principal Component Analysis RPCA (Barnston and Livezey 1987) approach. The procedure isolates the primary teleconnection patterns for all months and allows for time series of the amplitudes of the patterns to be constructed. The RPCA technique is being applied at the CPC to monthly mean 700-mb height anomalies. The analysis accounts for variability in the structure and amplitude of the teleconnection patterns associated with the annual cycle of the extratropical atmospheric circulation. It also allows for better continuity of the time series from one month to the next, than if the patterns were calculated based on the data for each month independently. The RPCA procedure is superior to grid-point-based analyses, typically determined from one-point correlation maps, in that the teleconnection pattern is identified based on the entire flow field, and not just from height anomalies at a few select locations.

The data on the u- and v wind components at 850 hPa isobaric surface are also used here. They are from the gridded National Center for Environment Prediction / National Center for Atmospheric Research (NCEP/NCAR) Reanalysis Project (Kalnay et al. 1996; Kistler et al. 2001). The NNRP data are derived through a consistent assimilation and forecast model procedure allowing incorporation of all available observation data. Usefulness of the data for the climate analyses over the European region has been widely proven (e.g. Trigo et al. 2002). The NNRP data assimilation system includes the T62/28-level global spectral model with horizontal resolution of about 210 km. The reanalysis data are available with 2.5º lat x lon horizontal spacing. The data are globally determined for the time period from 1948-current. Data for the area 20ºN - 50ºN; 30ºW - 40ºE were used. The NNRP data are derived through a consistent assimilation and forecast model procedure allowing incorporation of all available observation data. Usefulness of the data for the climatological analyses over the European region however has been proven (e.g. Trigo et al. 2002).

Gridded (0.5º lat-long) monthly precipitation data over land are also adapted. The data are available from the Climatic Research Unit (CRU) University of East Anglia (New et al. 1999, 2000) for the period from 1901 to 1998. The precipitation data in the CRU archive have been directly interpolated from terrestrial station observations. The data archive is considered as the most advanced among those currently existing datasets for climate applications.

Due to the seasonal character of the EA/WR behavior the analysis is restricted to the December-February (DJF) season.

3. EA/WR index – precipitation spatial correlation

Time variation of the running 3-year mean EA/WR index from the NOAA CPC during the DJF period of 1950-2000 is presented in Figure 1. The positive tend of the index (Krichak et al. 2002) is notable. According to Figure 1 the time periods from 1953 to 1962 and from 1974 to 1983 were characterized by the low EA/WR winters. Time periods from 1964 to 1973 and from 1984 to 1993 were characterized by the high EA/WR values. The periods may be used to distinguish the processes typical for the high and low EA/WR circulation regimes. The index-precipitation space correlations are calculated in the study. The obtained space correlations between the EA/WR index and the gridded monthly mean CRU data on the DJF precipitation for 1952-2000 are presented in Figure 2. Results of analogous calculations for the two pares of low/high EA/WR DJF's (1974-1983/1984-1993) and (1953-1962/1964-1973) are presented in Figures 3a,b and 4 a,b respectively. Shaded areas in Figures 2–4 indicate the zones with the high (> 0.95) level of statistical significance of the obtained correlations. On the pattern for 1950-2000 one of the two such zones is centered over the eastern Atlantic to the NW of Pyrenean Peninsula where one (high) of the two EA/WR dipole centers is usually located (Figure 2). The second area with statistically significant (positive) correlations is found over the eastern part of the N. Africa and southeastern Mediterranean region. Results of the calculations for each of the EA/WR phases are presented in Figures 3a, 4a for (low) and Figures 3b, and 4b (high). Only minor differences may be found in the patterns for each of the two EA/WR regimes. The fact proves reliability of the obtained dependencies. The use of only one of the two earlier selected pares of the ten-year periods appears sufficient. The patterns for the low and high EA/WR regimes differ however. Namely, a zone over the EM with the relatively high (~.5-.6) correlations between the two parameters characterizes the low EA/WR winters (Figures 3a and 4a) whereas a weaker, though also positive (~0.3) index-precipitation correlation dependency characterizes the area during the high EA/WR winters (Figures 3b, 4b).

4. Circulation patterns typical for the EM precipitation

The detected changes in the correlation patterns may be attributed to the EA/WR trend. To evaluate the suggestion a determination of the EA/WR role in controlling the low-troposphere circulation is performed. In accordance with the strategy of the research the circulations have been separately determined for the both 1974-1983/1984-1993 and 1953-1962/1964-1973 ten-year pares of the low and high EA/WR ten-year periods.

The following evident considerations have been adapted in the study. Total amount of precipitation over an area during DJF periods over the eastern Mediterranean depends on the frequency of occurrence of the rainy periods as well as on their intensity. No notable decrease in the frequency of occurrence of the periods with the EM precipitation has been reported. A decrease in the precipitation intensity has been noted (Alpert et al. 2002). The current analysis is focused on investigation of the role of the EA/WR trend in this process. Wet DJF periods over the EM are usually characterized by a specific lower tropospheric circulation (e.g. Zangvil et al. 2003). Due to the possible contribution of the surface friction effects this circulation may be better represented by the typical for high and low EA/WR atmospheric motions at the 850 hPa isobaric surface.

The following approach has been adapted for the determination of the typical circulation regimes. Representing the EM target area (35ºE-40ºE; 30ºN-35ºN) has been selected and a normalized index of the precipitation over the target area has been calculated. Time variation of the index is given in Figure 5. One-dimensional (Press et al., 1997) correlations between the squared (to allow a better fit to the Gaussian distribution) precipitation indices with the u and v wind field components at 850 hPa isobaric surface have been computed. The correlations were calculated on detrended time series. The fit of the data to the Gaussian distribution was evaluated according to

Kolmogorov-Smirnov test (Press et al., 1997). Circulation patterns that characterize the low and high EA/WR wet EM periods were constructed based on the correlations computed. Results of the computations are presented in Figs. 6a,b and 7a,b for 1974-1983/1984-1993 and 1953-1962/1964-1973 respectively. The arrows in the figures represent the typical for the corresponding EA/WR periods wind directions. The wind vectors represent the magnitudes of the winds-precipitation correlations obtained. The isolines and shaded areas in the figures represent the correlations and statistical significances of the dependencies between relative vorticity at 850 hPa and precipitation. It is worth noting here that the directions of the typical atmospheric flows are reliable only over the areas with sufficiently high level of statistical significance. Over the other areas the figures provide only approximate information on the directions of the air-mass transport during the wet periods over the target area. The obtained circulation patterns are referenced in the following as the Circulation typical for the Eastern Mediterranean area Precipitation (CEMP).

Characterizing low EA/WR 1974-1983 and 1953-1962 phases CEMP patterns for 850 hPa surfaces are given in Figures 6a and 7a. The corresponding patterns for high EA/WR periods (1984-1993 and 1964-1973) are given in Figure 6b and 7b respectively.

Obtained circulation patterns for the low EA/WR regime during 1974-1983 (Figure 6a) differ significantly from that for the 1953-1962 (Figure 7a). During the both ten-year periods wet EM months were characterized by the circulation conditions with a northerly air flow in the lower troposphere. Orientation of the flow was different however during the two time periods. Similar differences between the two circulation patterns for the high EA/WR regime (Figures 6b and 7b) may also be noted. A common feature that characterizes the circulation during the two EA/WR regimes may be noted. During the both EA/WR regimes wet EM periods are associated with a relatively small scale counter-clockwise composite system over the region. The areas of origin of the air masses that arrive to the EM during the low and high EA/WR periods appear to be different however. Namely, during the low EA/WR years (Figures 6a, 7a), the DJF CEMP's are characterized by the atmospheric flows with the air-mass advection from Atlantics to the EM area. At the same time, typical CEMP's for the high EA/WR winters (Figures 6b, 7b) are characterized by advection of the air-masses from central Europe to the Mediterranean region Figure 6b).

5. Summary and discussion

Long-term variations of the monthly mean precipitation over large areas of Europe during the last several decades of the past century are often attributed to the positive trend of the NAO during the period (Hurrell 1995; Ben-Gai et al. 2001; Krichak et al. 2002; Kushnir et al 2001; Paeth et al. 1999; Trigo et al. 2002; Ulbrich and Cristoph, 1999). The NAO trend was not the only climatically important feature of the period however that could contribute to the weather variations. Also positive trend of another prominent European teleconnection pattern - EA/WR, (Krichak et al. 2002) could be playing a significant role in the process. Physical mechanisms responsible for the EA/WR trend are not fully understood. The trend could be caused by the positive trend of the NAO, as a consequence of the intensification of the southern NAO center of action (Paeth et al. 1999). Other explanations of the phenomena have been also suggested. The NAO and EA/WR trends could be a representation of more complex non-linear interactions (Feldstein 2000). An eastward shift of the southern NAO positive center (Ulbrich and Christoph 1999) could be playing a role in the process. A contribution of the ENSO effects may be assumed (Price et al. 1998; Van Oldenbrugh 2003). The trend could also be affected by a decline in intensity and eastward shift of the Siberian anticyclone (Panagiotopoulos et. al., 2003).

Independently on the physical nature of its origin the EA/WR trend was playing a role in the recent past European climate. The aim of the current study was to evaluate the role. With this aim space correlations between the mean monthly precipitation and the EA/WR index have been calculated. Existence of a significant relationship between the precipitation and the EA/WR index over large areas of Europe was demonstrated. The EA/WR-precipitation correlations are statistically significant over the eastern Atlantic and southeastern Mediterranean regions. It is also demonstrated that quite different space correlation patterns characterized the periods with the low and high EA/WR regimes. One of the zones with the notable differences between the correlation patterns is found located over the EM region. To understand the physical meaning of the differences we performed a determination of the typical circulations responsible for the EM precipitation. It is demonstrated that the changes in the correlation patterns were associated with significant variations in the orientation of the air mass transport to the area during the DJF months. Namely, during the low EA/WR years the CEMP was characterized by the mean atmospheric flow transporting the air-masses from Atlantics to the EM. On the contrary, typical for the high EA/WR DJFs CEMP was characterized by advection to the EM of the air-masses from central Europe to the Mediterranean region. The detected changes allow explanation of the observed precipitation decline over the EM during the last several decades of the past century by the effects associated with the positive trend of the EA/WR during the period.

It is not yet fully known if the trends in the NAO and EA/WR teleconnection patterns are subject to an increased greenhouse gas concentration induced climate changes. It is also not known if the future climate will be characterized by positive EA/WR regime. Presented results show however that a precipitation decline over the Mediterranean area will prevail in the case that the high EA/WR conditions will be characterizing the future climate over Europe.

Acknowledgments

The research was supported by German-Israeli research grant (GLOWA - Jordan River) from the Israeli Ministry of Science and Technology; and the German Bundesministerium fuer Bildung und Forschung (BMBF) and EU DETECT projects. The authors acknowledge the use of computer resources from the Inter University Computation Center (IUCC), Israel. Adapted in the study NAO teleconnection index values were taken from the NOAA climate Prediction Center(CPC) – website: http://www.cpc.ncep.noaa.gov/data/teledoc/nao.html. Used in the study data on the mean monthly winds for the 1950-2000 are from the NCEP NCAR Reanalysis archive with their website: http://www.cdc.noaa.gov/cdc/data.ncep.reanalysis.derived.html. High-resolution (0.5ºx0.5º) data on terrestrial precipitation from the Climate Prediction Center of the University New Anglia, UK are also adapted. One of the authors (SOK) greatly appreciates the help from G.J. van Oldenborgh in the work with the Climate Explorer system of the Royal Dutch Meteorological Institute (KNMI) http://climexp.knmi.nl as well as and the advices from V.N. Kryjov.

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Captions:

Figure 1. Time variation of running 3-year mean normalized winter (December-February) indices of EA/WR from 1950 to 2000 based on the CPC teleconnection pattern determination (confidence interval is indicated by the dashed lines).

Figure 2. Spatial correlation between the EA/WR index and DJF precipitation (1952-2000) over the Mediterranean area (contour interval 0.1) and its statistical significance (shaded).

Figure 3. Same as in Figure 2 but (a) for low EA/WR period from 1974 to 1983, (b) high EA/WR period from 1984 to 1993.

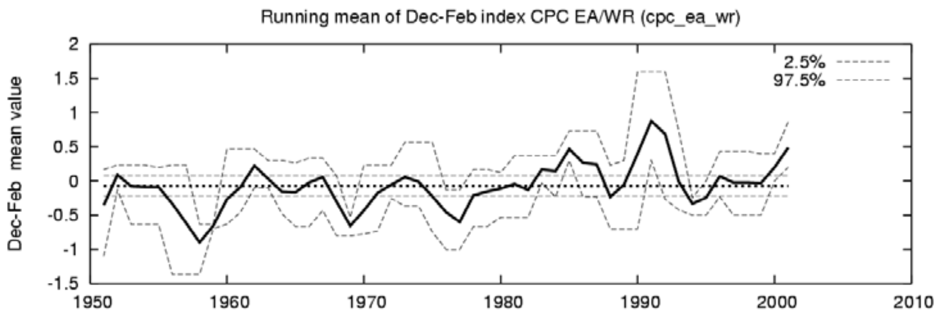
Figure 4. Same as in Figure 2 but (a) low EA/WR period from 1953 to 1962, (b) high EA/WR period from 1964 to 1973.

Figure 5. Time variation of running 3-y mean winter (December- February) normalized index of precipitation based on the CRU 0.5º x 0.5º archive over the EM target area.

Figure 6. Correlations between precipitation index over the EM target area, relative vorticity and the wind components at 850 hPa during DJF months. Shaded areas: statistical significance of the index-relative-vorticity relationships. Solid lines: magnitudes of the index-relative vorticity correlations. Arrows in the patterns represent wind directions most appropriate for the precipitation over the target area, while the vectors' lengths - the winds--precipitation correlation relationships varying

from 0 to 1: (a) for low EA/WR period from 1974 to 1983, (b) high EA/WR period from 1984 to 1993.

Figure 7. Same as in Figures 6, but for 1953-1962 and 1964-1973.



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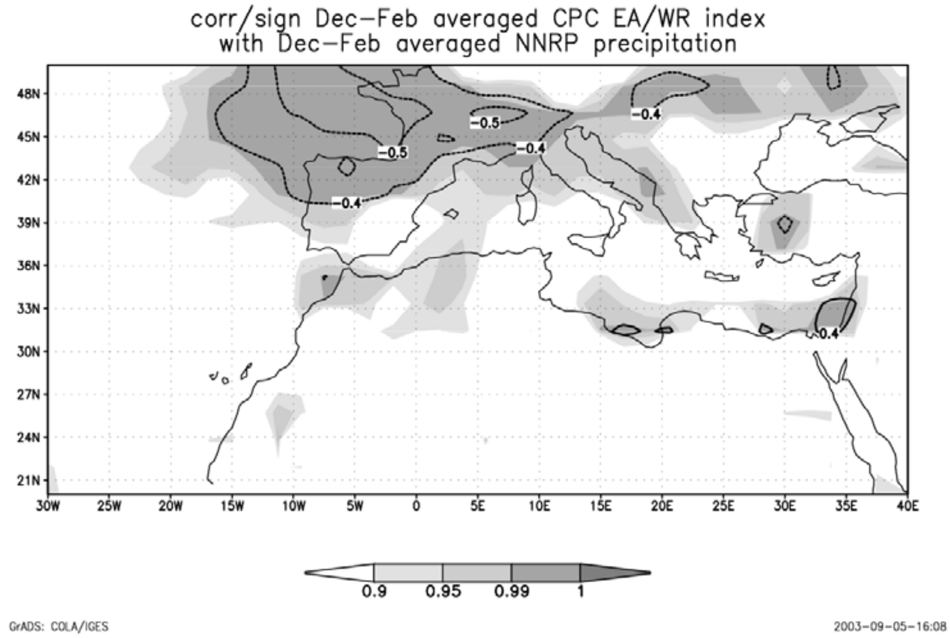

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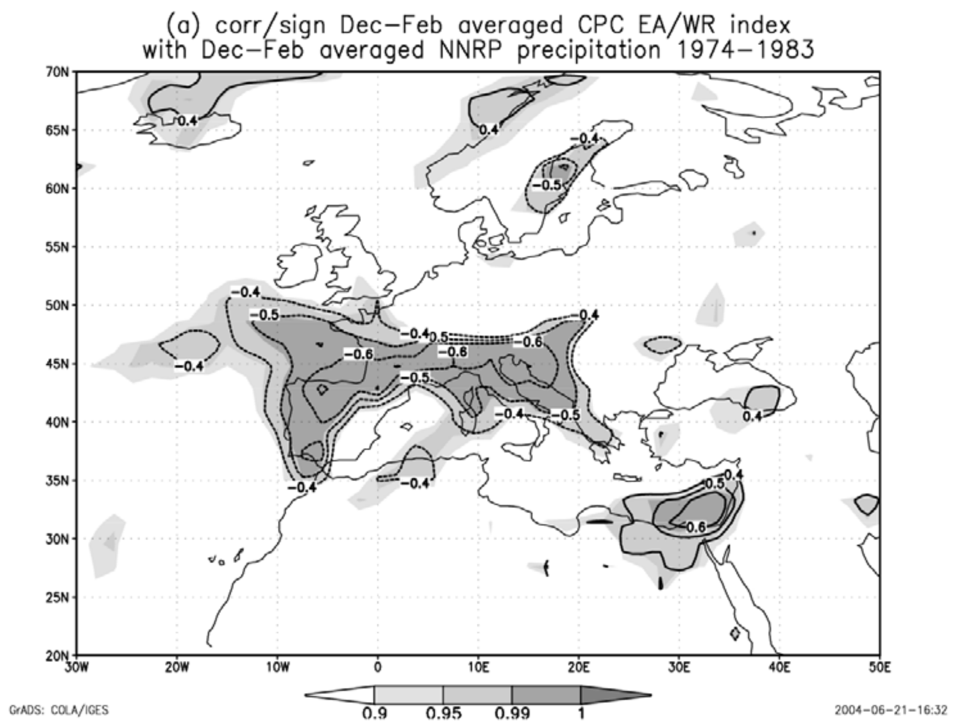

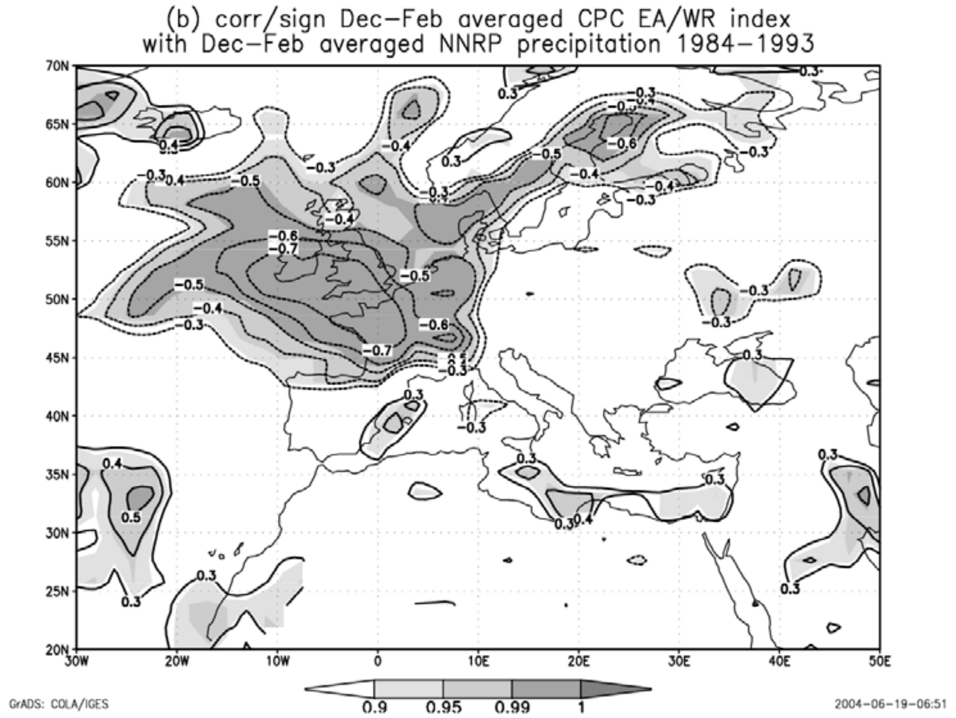

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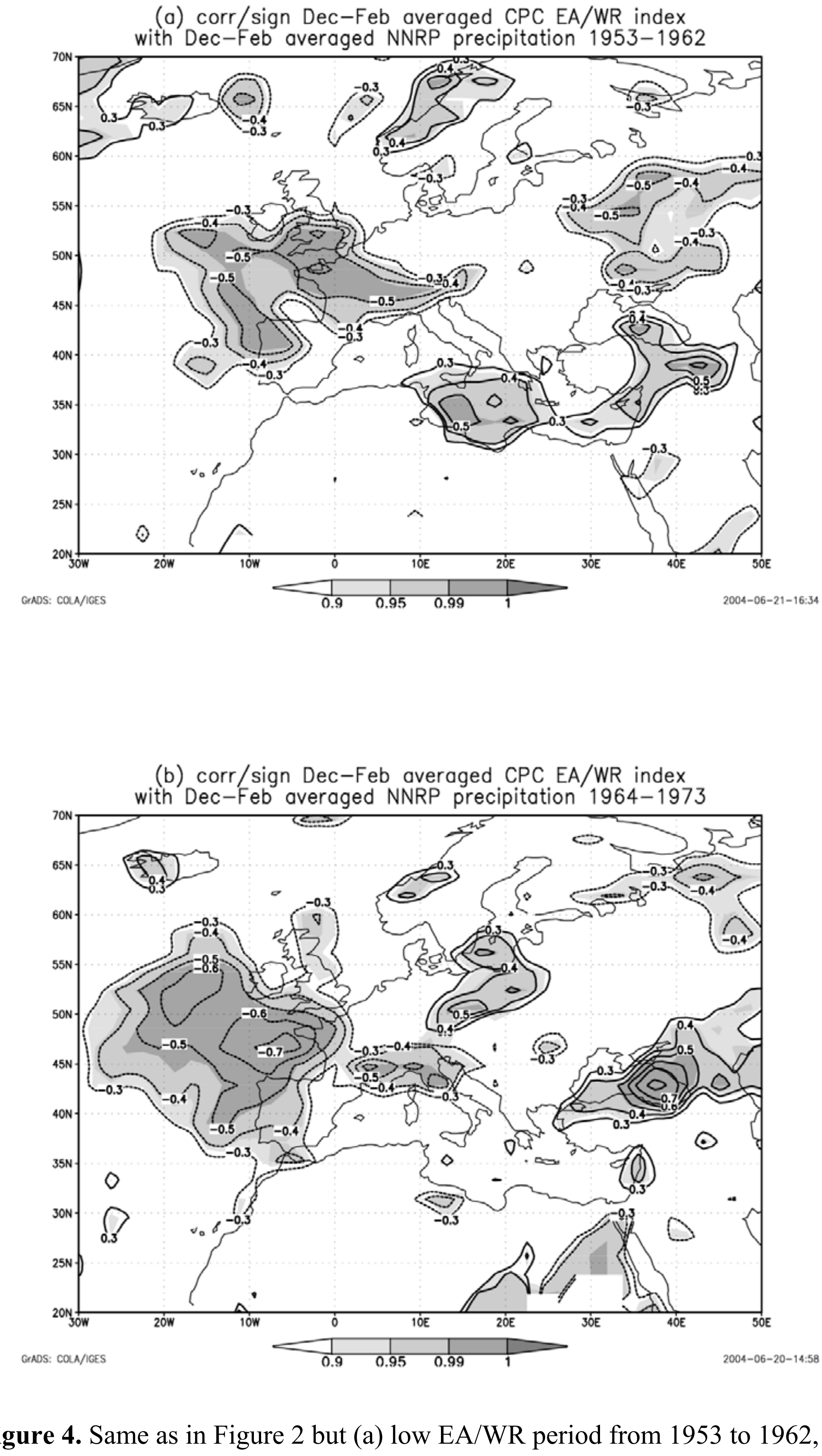

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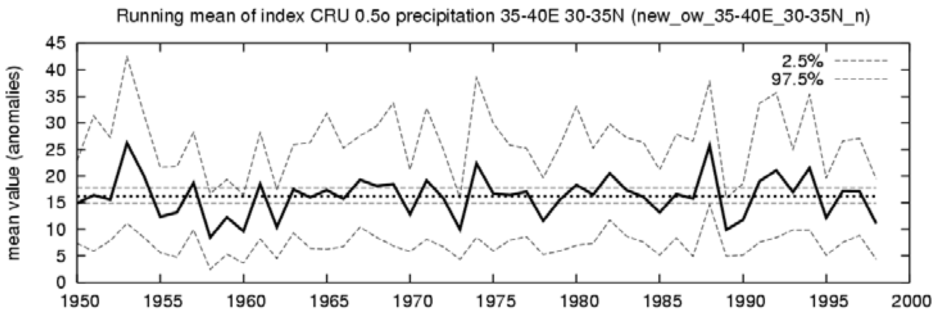

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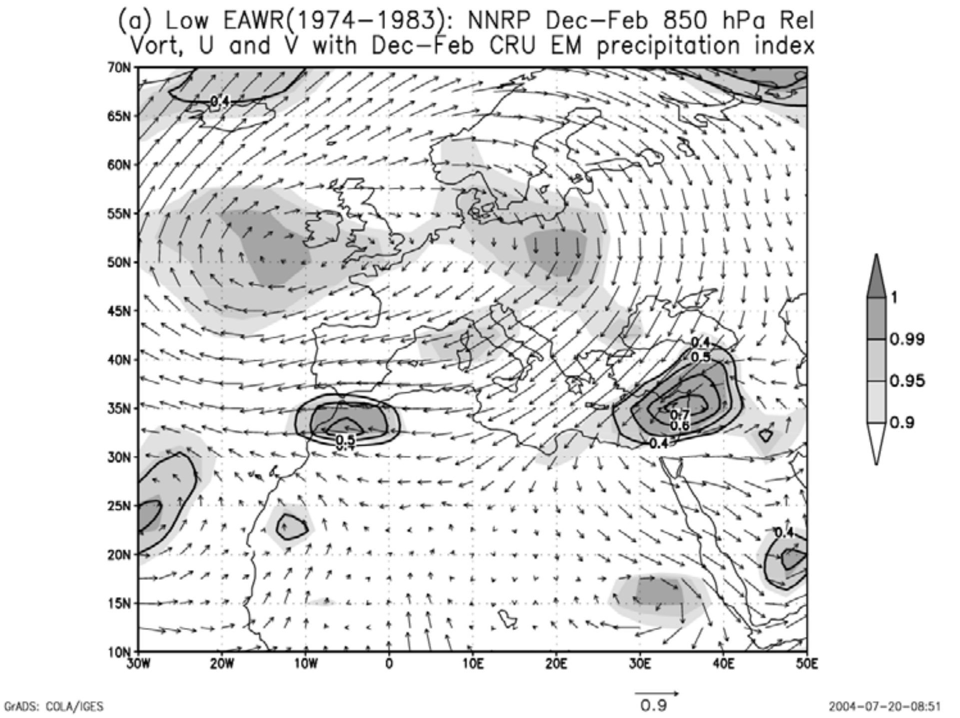

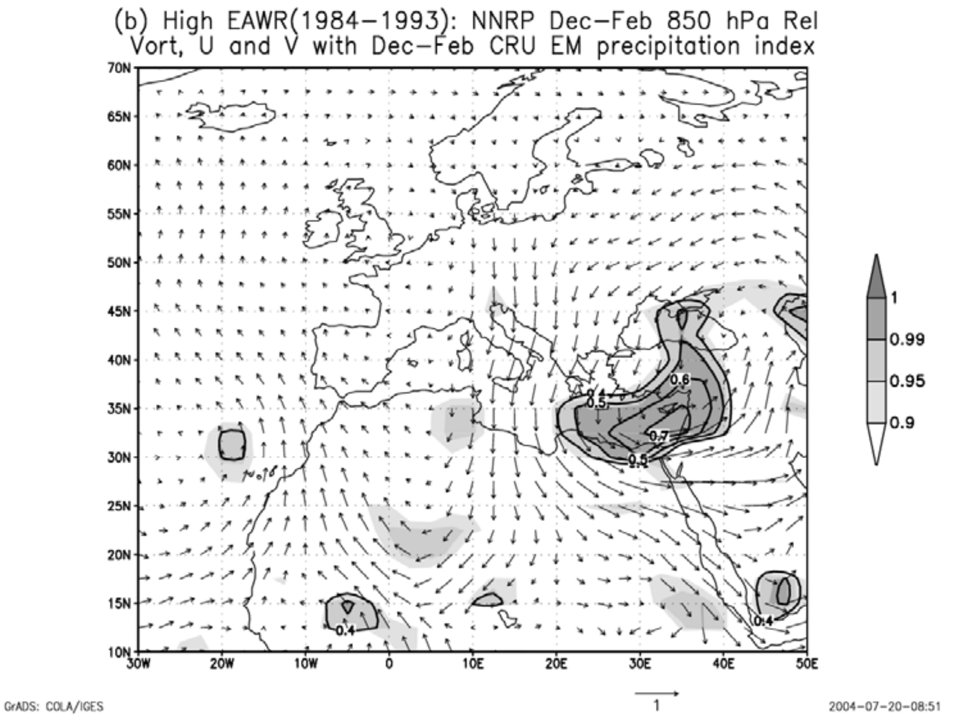

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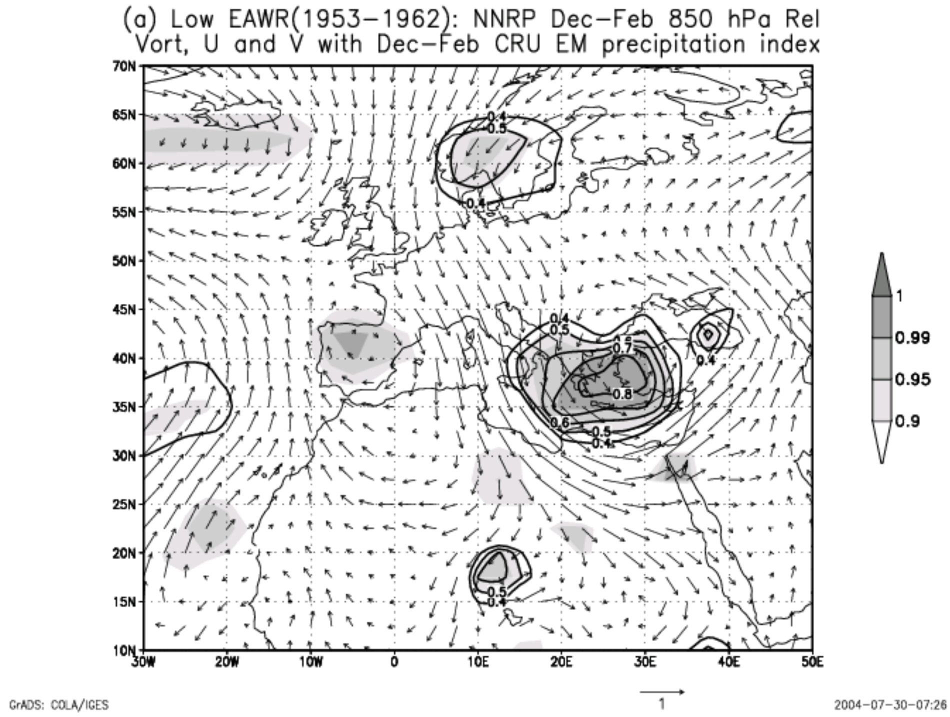

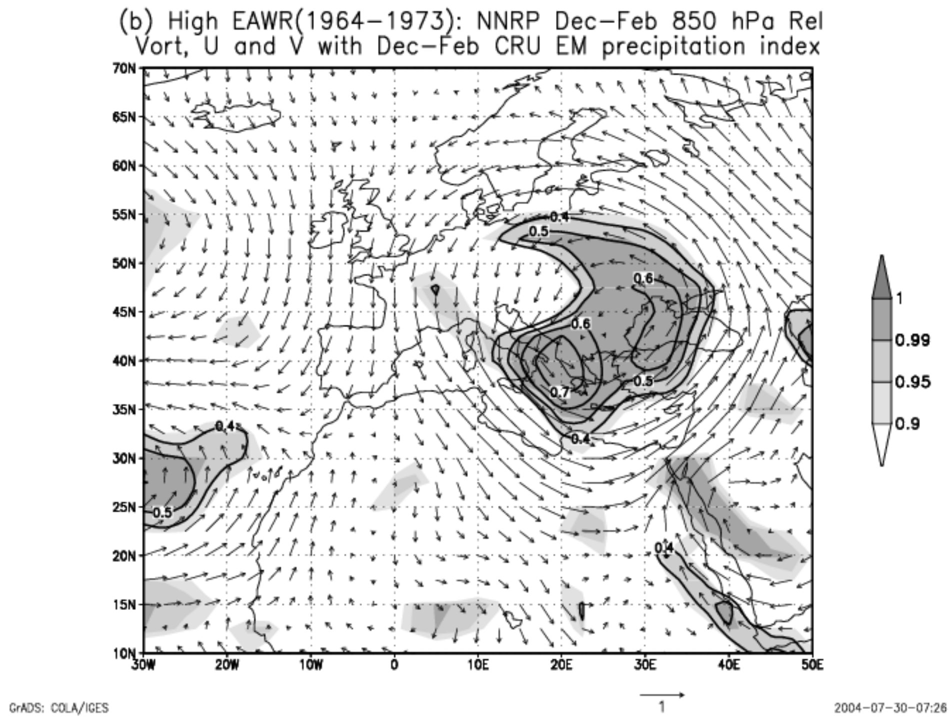

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