IL NUOVO CIMENTO Vol. 26 C, N. 5 Settembre-Ottobre 2003
DOI 10.1393/ncc/i2003-10006-8

The precipitation field over Calabria: Large-scale correlations

S. Federico(1), L. Casella(2), C. Bellecci(1)(2) and M. Colacino(3)

(1) *CRATI Scrl, c/o Università della Calabria - 87036 Rende (CS), Italy*
(2) *INFM, Dipartimento di Scienze e Tecnologie Fisiche ed Energetiche Università degli Studi di Roma "Tor Vergata" - 00133 Roma, Italy*
(3) *ISAC-CNR - Via del Fosso del Cavaliere 100, 00133 Roma, Italy*

(ricevuto il 23 Luglio 2003; approvato il 19 Novembre 2003)

Summary. — In this paper we analyze the variability of the precipitation field over Calabria for the period 1948-1990 and its correlation with large-scale flow. Precipitation data are from "Istituto Mareografico ed Idrografico" database, have a monthly basis and cover the period 1921-1990. It is shown that precipitation is concentrated in the cold semester, from October to April, and that there is a large annual-to-annual variability. After studying correlation between precipitation and North Atlantic Oscillation (NAO), rainfall variability is further discussed by relating the precipitation standardized anomaly index to surface pressure, 500 hPa geopotential height and sea surface temperature. These dataset are derived from NCAR reanalysis project, and cover the 1948-2002 period. Due to temporal coverage of our databases the analysis is limited to 1948-1990. While a weaker correlation with NAO emerges, compared to other areas of the Mediterranean basin, precipitation over Calabria shows an interesting correlation with another dipolar structure located further East. This correlation is mainly related to the strength of Azores anticyclone over the Mediterranean area in the cold season and to the oscillation of Siberian high.

PACS 92.60.Jq – Water in the atmosphere (humidity, clouds, evaporation, precipitation).
PACS 92.60.Ry – Climatology.

1. – Introduction

Precipitation is one of the most important meteoclimatic parameters, because of its strong impact on natural ecosystems and humans activity. It is also a field that has a high spatial and temporal variability. Spatial variability is also determined by the interaction of large-scale systems with local orography, that plays a major role in flow modification and subsequent rainfall, in addition to orographic ascent [1].

The aim of this paper is to relate precipitation field over Calabria, the southernmost tip of Italian peninsula, to large-scale, low-frequency patterns, in order to connect rainfall to large-scale structures. This problem is of important concern not only from a scientific point of view, but also for water management and exploitation due to climatic characteristic of the country. Indeed there is a large year-to-year rainfall variability that produces periods of water abundance that alternate with periods of water shortage and drought. The economy of the region has a large base on agriculture and water is the basic resource also for region economy, then the possibility to develop a system that is able to relate rainfall to large-scale patterns, that rely on the individuation of large-scale structures that influence local climate, should be a valuable instrument for the humans activity planning. We start to assess this problem in this paper considering the correlation of rainfall over Calabria with three fields: sea level pressure (SLP), 500 hPa geopotential height (HGT) and sea surface temperature. Nowadays, the study of the connection between local weather and large-scale atmospheric flow is also assessed with Global Circulation Models (GCM) [2]. These models supply useful information for large scale but their output cannot be used at the resolution investigated in this study [3].

Rain data are available from "Istituto Mareografico ed Idrografico" and refer to the period 1921-1990. The aim of this institute is to collect rainfall for each river catchments, so stations density is high. In particular, for different years, we never found a number of available stations less than one hundred. Data refers to monthly collected values.

While our analysis would be more meaningful considering years up to 2000, data from 1991 are not available to us; nevertheless we think that the analysis presented in this paper is worth of note because it shows some clear signals.

Sea level pressure and geopotential height used in this study are derived from NCEP/ NCAR reanalysis project [4]. Datasets are available on a 2.5×2.5 degree latitude-longitude grid and cover the period 1948 January – 2002 February. This dataset is used, in this work, on a monthly basis, too. Considering both datasets, the superposition of data occurs for the period 1948-1990. In the following paragraphs we will limit our considerations to this superposition period, if not explicitly indicated.

To better present results obtained in this paper, we give a brief introduction of Calabria main features, that influence local climate.

Calabria (fig. 1) ranges between $38°12'$ and $40°$ latitude North and between $16°30'$ and $17°15'$ longitude East. The west coast of the region is bounded by the Tyrrhenian Sea and the east and south coasts by the Ionian Sea. Apennines run north to south along the peninsula and are characterized by five main topographical features reaching 1.5–2.0 km elevations: Pollino, Catena Costiera, Sila, Serre, Aspromonte. The average width of the region is about 50 km in the west-east direction and 300 km in north-south direction. Three main valleys locate by the sea and most of agricultural and industrial sites are in those valleys. Calabria is bounded by the warm central Mediterranean Sea that reaches its temperature maximum in September. These peculiar features, *i.e.* the presence of high mountains and the sea, affect local circulations and the climate of the region [5-7].

The paper is organized as follows: in the following section the monthly distribution and time variability of precipitation over Calabria and its correlation with NAO are shown. NAO is characterized by a north-south sea level pressure dipolar pattern, with one of the poles over Iceland and the other one above, approximately, Azores. In sect. **3**, a wider correlation with sea level pressure, 500 hPa geopotential height and sea surface temperature is studied and discussed. Section **3** also presents a discussion of results obtained using wet days, rather than rainfall. Conclusions are reported in sect. **4**.

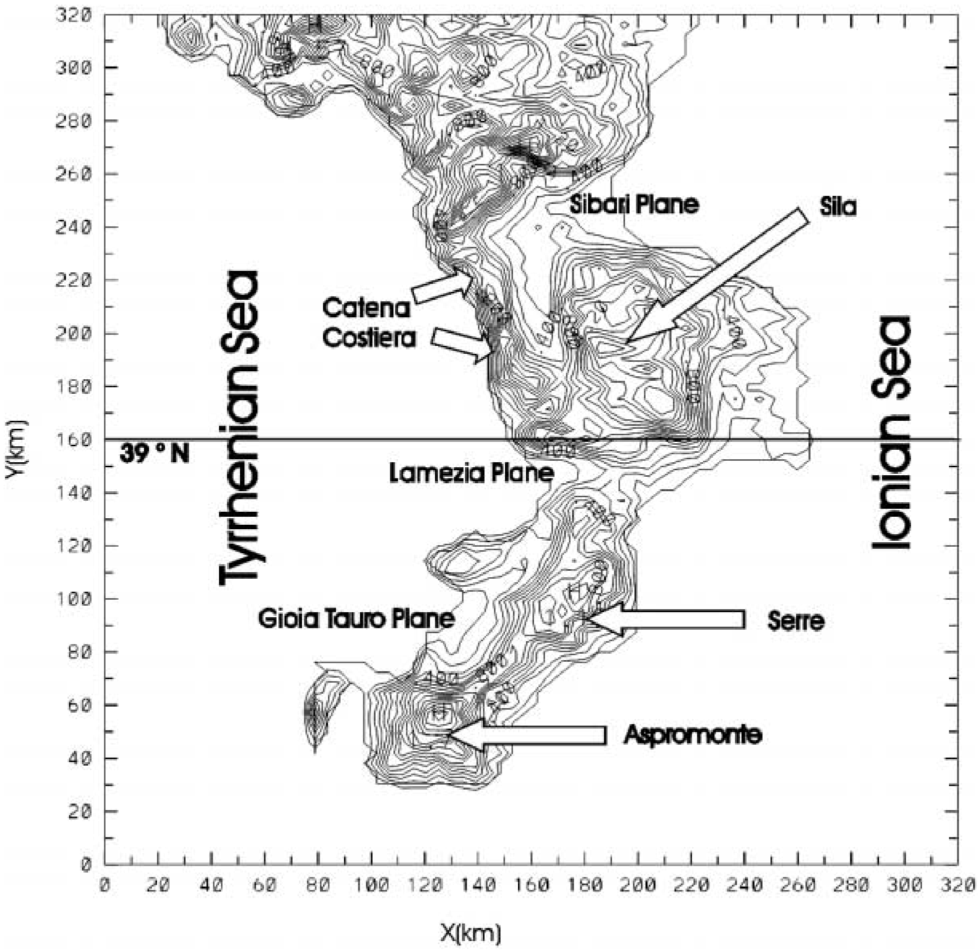

Fig. 1. – Calabria orography averaged over 10 km^2. Main orographic features are also reported.

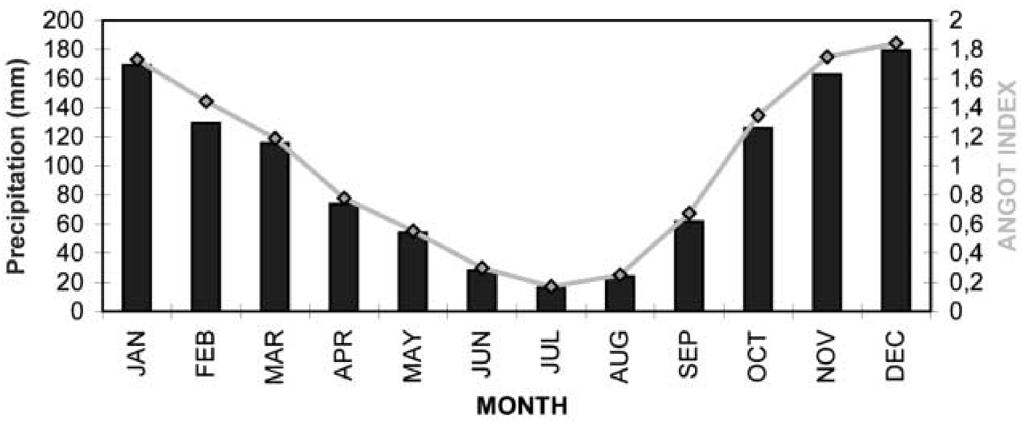

Fig. 2. – Monthly precipitation (left axis) and Angot index (right axis) averaged over 1921-1990.

2. – Precipitation over Calabria and its correlation with NAO

Figure 2 shows monthly precipitation over Calabria and the Angot Index averaged over the 1921-1990 period. With respect to the considerations made in this section, results are very similar if we limit this analysis to the superposition period (1948-1990) so, in this section, we will use the full rain dataset. Precipitation over Calabria is concentrated in the cold semester (from October to April) that accounts for about 83% of annual rainfall. The behaviour of fig. 2 shows a typical characteristic of the Mediterranean climate: precipitation is concentrated in winter, from December to February, while summer precipitation is scarce. This is partially related to the strength of Azores anticyclone during warm season in the Mediterranean area [5]. One of the earlier definitions of Mediterranean climate was given by Koppen [8], who defines mediterranean a region having a winter rainfall amount three times its summer total. This is verified for Calabria; comparing fig. 2 with those obtained for other areas of Italy [5,9] there is more evidence of mediterranean characteristics in Calabrian climate than in other regions, according to the previous definition.

To examine the precipitation field over Calabria, we consider its Standardized Anomaly Index [10, 11]. This index is defined as

$$\mathrm{SAI}_t = \frac{1}{N_t}\sum_{j=1}^{N_t}\frac{(P_{jt}-\mu_j)}{\sigma_j}\,, \tag{2.1}$$

where SAI_t is the SAI for the time t (usually a month or a year), P_{jt} is the precipitation recorded at station j for period t, μ_j and σ_j are the average and standard deviation at the station j and N_t is the number of station available for the period t. Hereafter we will refer to this index as SAI. Another interesting index is (2.1) computed for rainy days and, in this case, the parameter P_{jt} is the wet days number for the station j and for time t, while μ_j and σ_j are the average and standard deviation of wet days number. Hereafter we will refer to this parameter as DSAI.

Figure 3 shows the rainfall SAI index, along with its five-year running mean, averaged for the cold semester in Calabria, that is obtained considering all available stations for each year of the period 1921-1990. If one considers the five-year running mean, there are two large periods that can be identified: the first one is a wet period from about 1930 to 1960, the second is a dry period starting from 1970 up to 1990. The end of this drought period is not identifiable by our dataset. There is a decreasing trend for SAI considering the last period, nevertheless this trend is not assessed in this paper because of the lack of data between 1991 and 2000, that are the most important with respect to this subject. A large negative deviation of SAI is recorded for 1988-1989 and these years represent one of the worst drought periods for Calabria.

Linear correlations between the two SAI indices introduced above and NAO are shown in figs. 4a and b. The former shows the linear fit between the SAI index and NAO, the second shows the linear fit between DSAI and NAO. In these figures NAO is obtained by considering pressure values of dipole centres (Lisbon (35° N, 10° W) and Reykjavik (61.1° N, 22.5° W)) from October to March during 1921-1990. These values are available from the Climatic Research Unit of the University of West Anglia (`http://www.cru.uea.ac.uk`) and there are three different sets of the NAO index values that can be obtained using Ponta Delgada, Gibraltar or Lisbon, respectively as southern center of the dipole pattern. In fig. 4 the NAO index is computed using Lisbon as a southern dipole because,

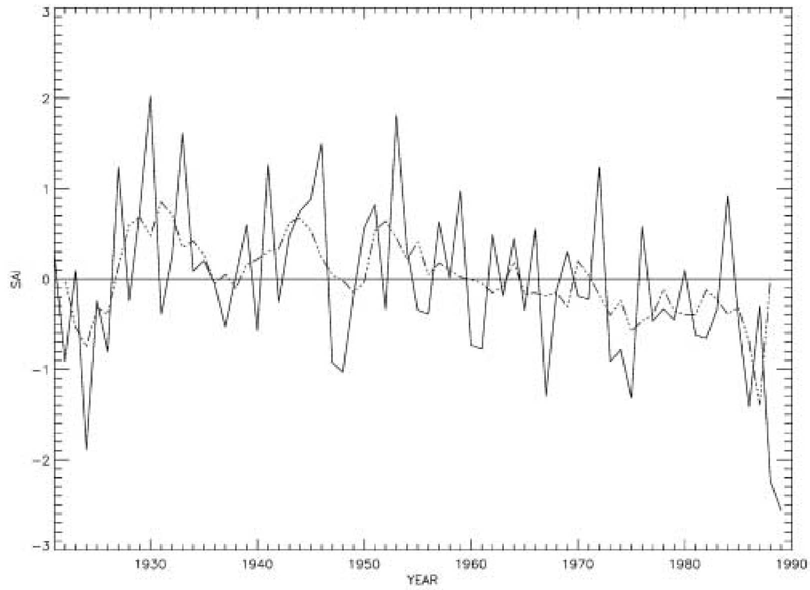

Fig. 3. – SAI index, averaged for all available stations, between 1921 and 1990. The five-years running mean is also reported.

as suggested by Hurrel [12], this index measures the northwest-southeast orientation of the dipole more closely. In addition, for this representation of NAO, we found the best correlation. The correlation coefficient is -0.32 ($p < 5\%$) for SAI and -0.50 ($p < 0.5\%$) for DSAI. The explained variance (r^2) is 12% in the former case and 27% in the latter.

The previous values refer to NAO computed from pressure measured at ground stations in Iceland and Portugal. However, it is interesting to compute the same index starting from reanalysis dataset. So we selected the two grid points nearest to Reykjavik and Lisbon in the reanalysis dataset, respectively, and computed correlations between SAI, DSAI and NAO indices obtained from NCAR data. Results are similar to those in figs. 4a and b. In particular, for the SAI index the correlation coefficient is -0.34 (explained variance 14%), while correlation coefficient for DSAI is -0.56 (explained variance 34%).

This correlation analysis confirms that a positive NAO phase is associated with the drought period in Calabria, nevertheless more general correlations would be a valuable tool in seasonal forecast. Perhaps because of its geographical position and also due to the lack of our rain data from 1991, correlations found for other Mediterranean areas are more stringent than that found for Calabria [13-15], even though databases extensions are different.

3. – Correlation with large-scale structures

In order to examine the correlation between Calabrian precipitation SAI index and large-scale patterns, we use the Pearson and Spearman correlation coefficients.

Pierson correlation coefficient is defined as the ratio of the sample covariance of two

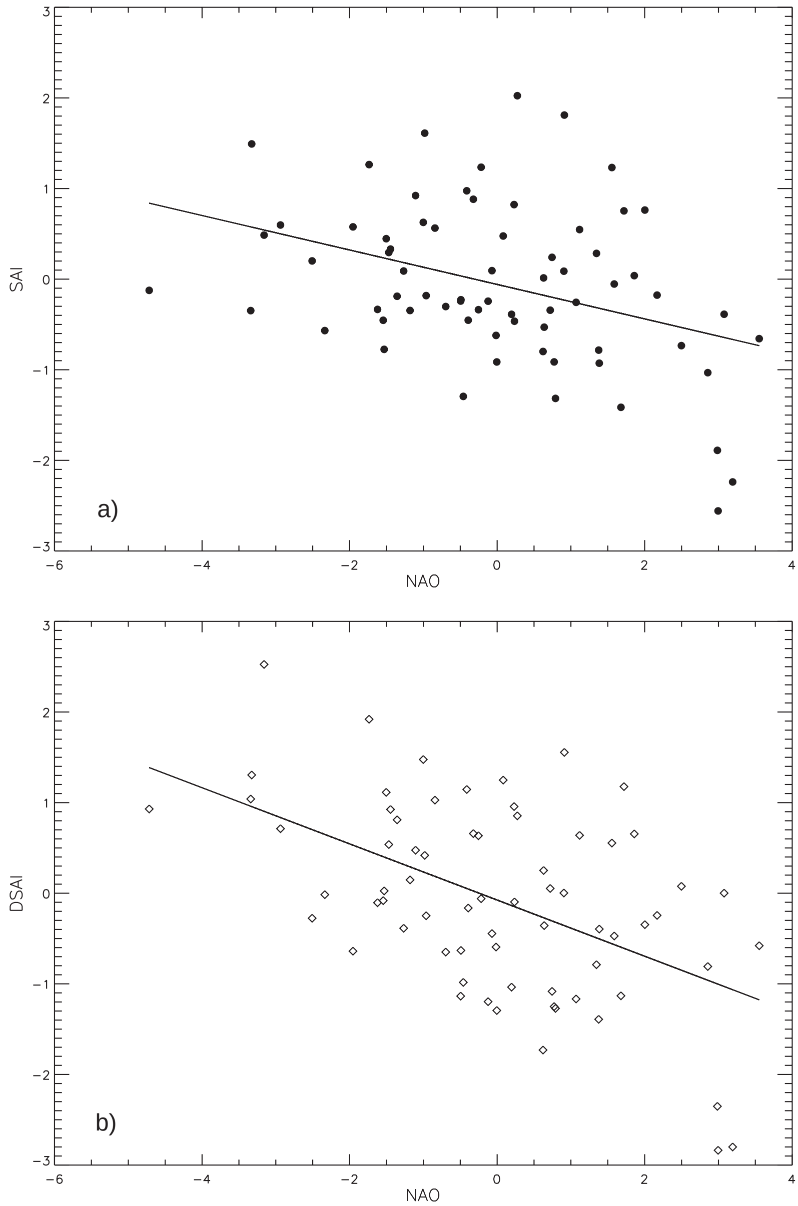

Fig. 4. – a) Linear regression of the NAO and SAI indices for the period 1921-1990. b) As in a) but for DSAI.

variables to the variables standard deviations:

$$r_{\mathrm{Pie}} = \frac{\mathrm{cov}(x,y)}{s_x s_y} = \frac{\sum\limits_{i=1}^{N} (x_i - \overline{x})(y_i - \overline{y})}{\left[\sum\limits_{i=1}^{N} (x_i - \overline{x})^2\right]^{1/2} \left[\sum\limits_{i=1}^{N} (y_i - \overline{y})^2\right]^{1/2}} . \tag{3.1}$$

This coefficient is neither robust nor resistant, so we also use the Spearman correlation coefficient that is computed using the rank of the values rather than values themselves [10]. It is computed by

$$r_{\mathrm{Spe}} = 1 - \frac{6\sum_{i=1}^{N} D_i^2}{N(N^2-1)}, \tag{3.2}$$

where D_i is the difference between the ranks of the i-th pair of data and N is the population size.

The significance of correlations is assessed by two different methods. Firstly we did a Monte Carlo test [10] permuting 1000 times the precipitation SAI index using a Monte Carlo routine and computing how many times the correlation coefficient of random selections is larger than the real one. The ratio of this number to the permutations number (*i.e.* 1000) gives the probability to obtain a larger correlation coefficient by chance.

The second method is applied by selecting values below the 10th percentile (driest cold seasons) and values above the 90th percentile (wettest cold seasons) and applying for these years a t-Student test against the null hypothesis that they were the same. Three fields are examined: sea level pressure, 500 hPa geopotential height and sea surface temperature.

3˙1. *Sea level pressure*. – Figure 5a shows the Pierson correlation coefficient between the SAI index in the cold semester and the sea level pressure, averaged for the years 1948-1990. The thick dot-dot-dashed line defines the area at the 5% level according to the Monte Carlo test.

Figure 5b is as fig. 5a but for the Spearman correlation coefficient. Also in this case Monte Carlo test has a rejection level of 5%.

It is important to note that, despite the different statistics used, results compare well in terms of area and correlation pattern. Correlations show two dipole patterns. The first one is over Europe and Asia, the second over Central-North America. The first dipole has its positive center over Scandinavia and North-Russia and its negative center over the Mediterranean Sea. The second dipole has its positive correlation center over North America and its negative correlation center over Central America.

The correlation coefficient is less that -0.6 in the central Mediterranean and its negative value indicates that lower-than-normal precipitations over Calabria (negative SAI) are related to greater-than-normal pressure values in that area and vice versa. The northern pole of the dipole pattern suggests a preference for higher-than-normal sea level pressure in this area during rainy years in Calabria and vice versa. Northern pole variability is due to the oscillation of Siberian high between wet and dry seasons in Calabria. Indeed, our analysis shows that during wet years in Calabria, Siberian high expands toward Europe determining a high pressure over Scandinavia and North-Russia.

Compared to other studies over the Mediterranean area, the dipole centers are shifted to the east of the classical NAO dipolar pattern (see for example [13] and [15]). This is confirmed by figs. 6a and b that show the sea level pressure anomaly for precipitation years under the 10th percentile and precipitation years above the 90th percentile, respectively. Thick dot-dot dashed lines enclose the area of a t-Student test at 5% significance level. Despite the different statistics used, also in this case the significance level

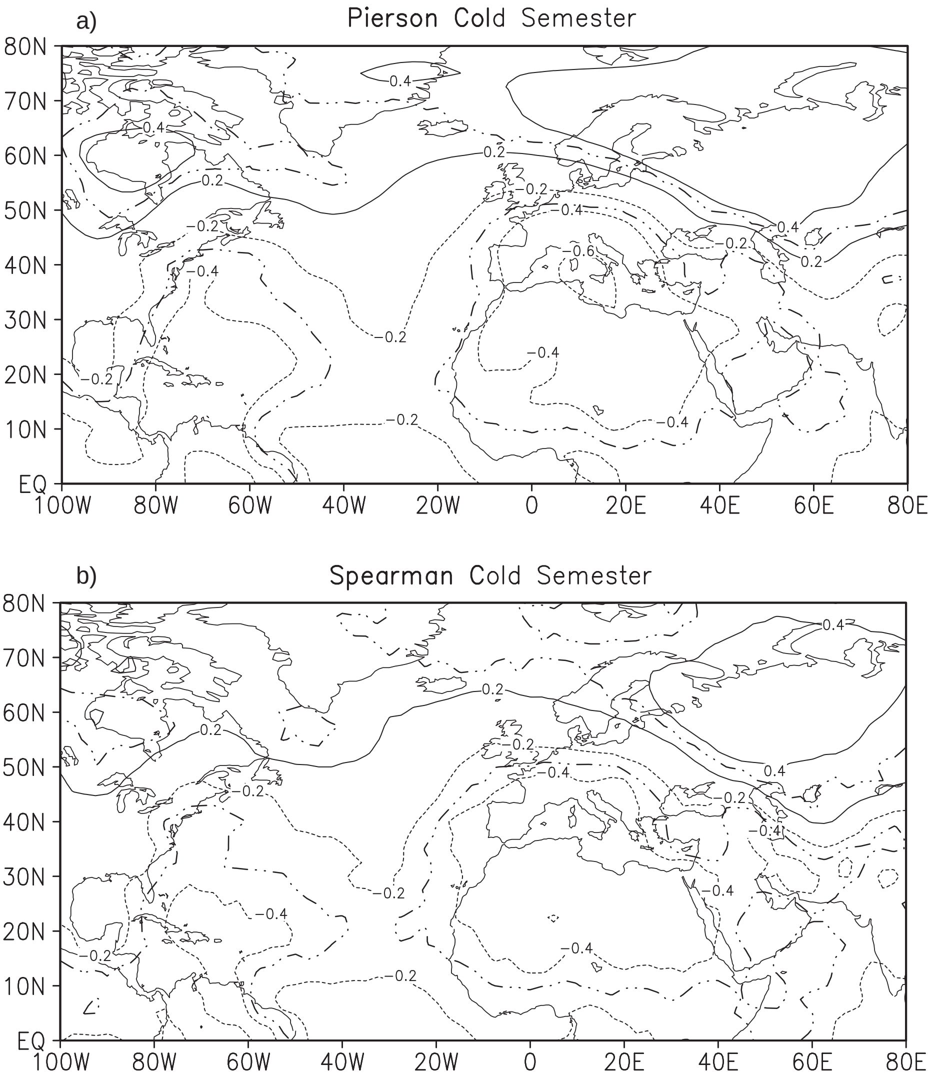

Fig. 5. – a) The Pierson correlation coefficients between SAI and sea level pressure for the cold semester, averaged over 1948-1990. The thick dot-dot-dashed lines enclose areas at the 5% level, assessed by a Monte Carlo test. Absolute contours values from 0.2 to 0.6. The contour interval is 0.2. b) As in a) but for the Spearman correlation coefficient.

encloses two wide areas. The first one over Central-North America and the second over the Mediterranean area.

For the driest years there is a large positive-anomaly area over central northern Africa, that extends over the Mediterranean area. Here is also the maximum anomaly contour 1.2. Negative anomaly over the North Atlantic suggests that during dry years, the cyclones route is deflected by this wide positive-anomaly area. However, due to the temporal resolution of our dataset, we cannot assess cyclones routes in different precipitation regimes over Calabria and this subject requires further investigation.

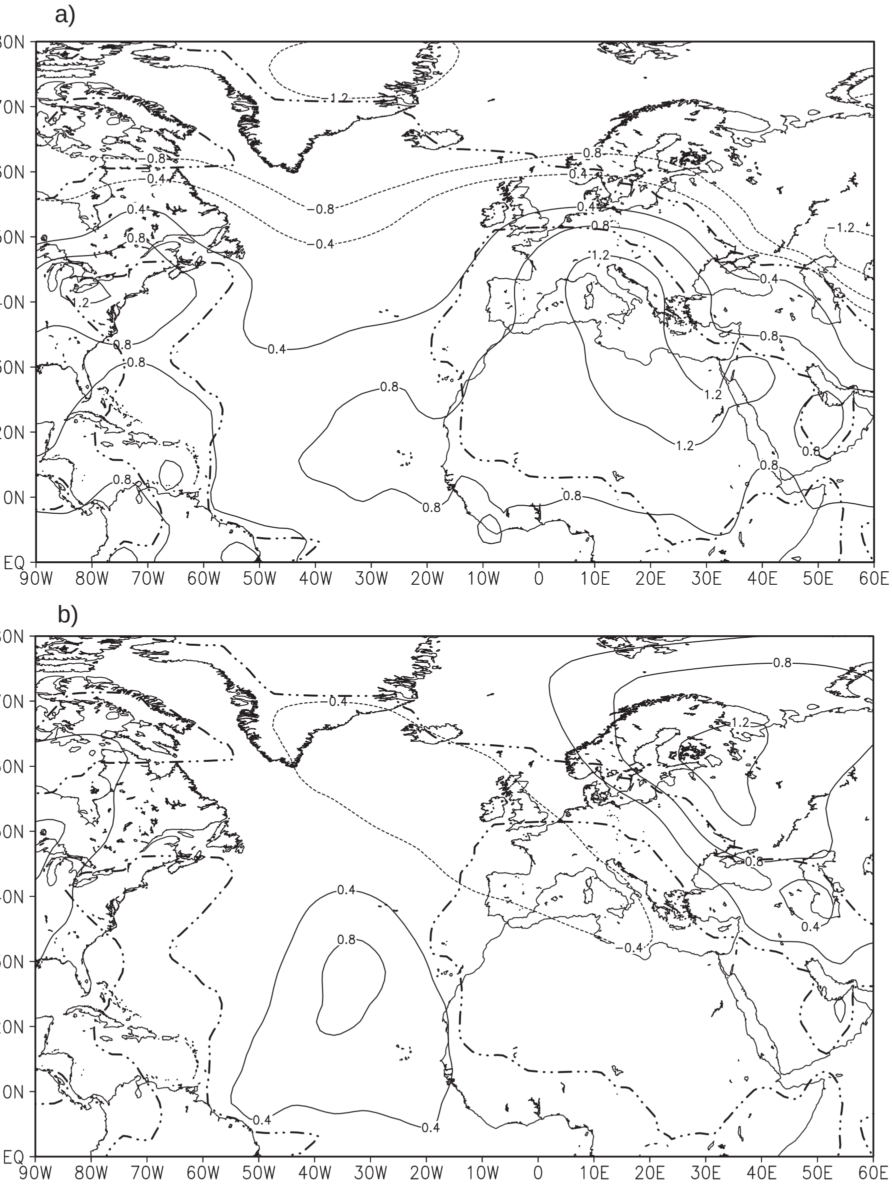

Fig. 6. – a) Sea level pressure anomaly averaged for the years with precipitation in the cold semester below the 10th percentile. Thick dot-dot-dashed lines enclose areas at the 5% level, assessed by a t-Student test. Absolute contour values from 0.4 to 1.2. The contour interval is 0.4. b) As in a) but averaged for the years above the 90th percentile.

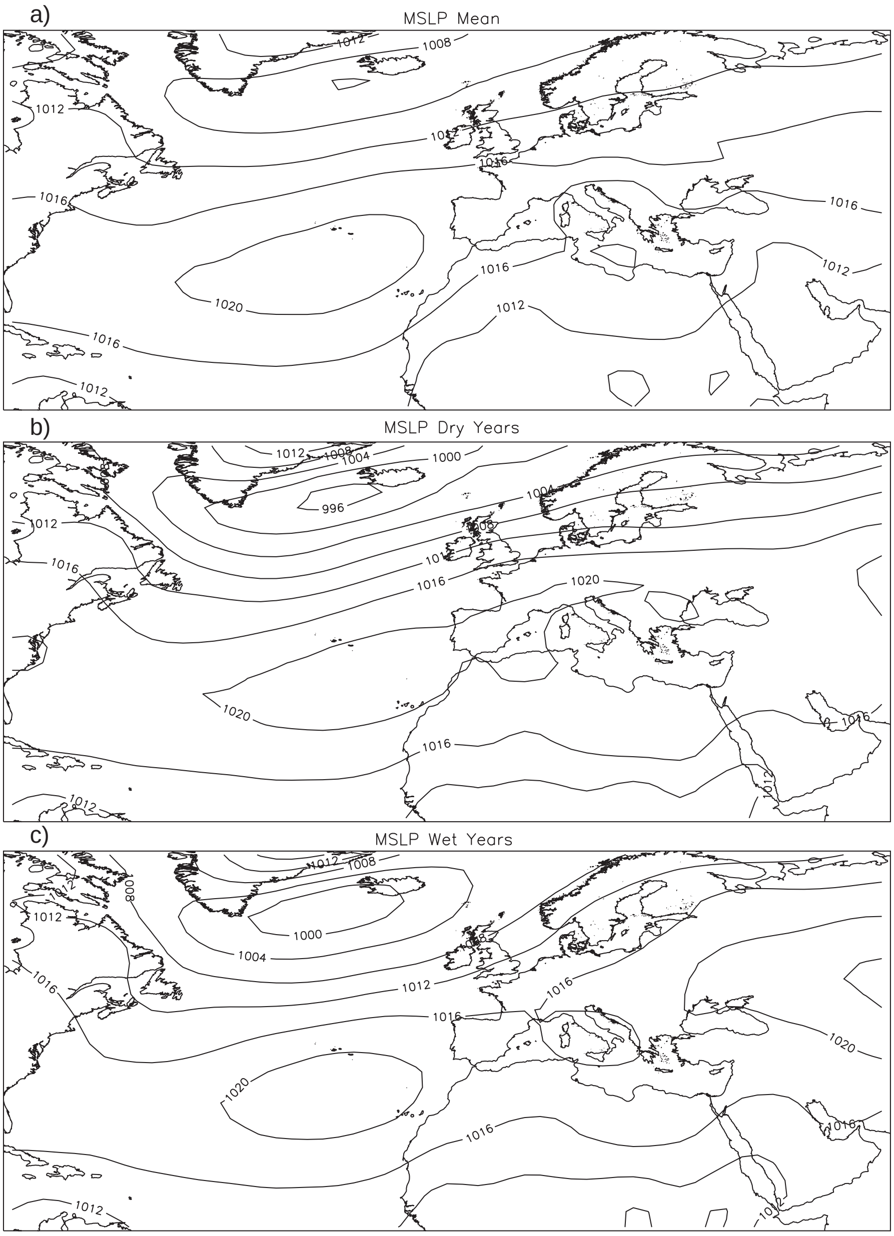

Fig. 7. – a) Mean sea level pressure averaged, for cold semesters, over 1948-1990. b) As in a) but for cold semesters below the 10th percentile (driest cold semesters). c) As in a) but for cold semesters above the 90th percentile (wettest cold semesters).

For the wettest years, positive anomalies are found in the central Atlantic Sea, North-Eastern Europe and North Asia, negative anomalies are found for a wide strip extending from Greenland to Calabria. This suggests that during wet years, the cyclones route is shifted toward the central Mediterranean Sea.

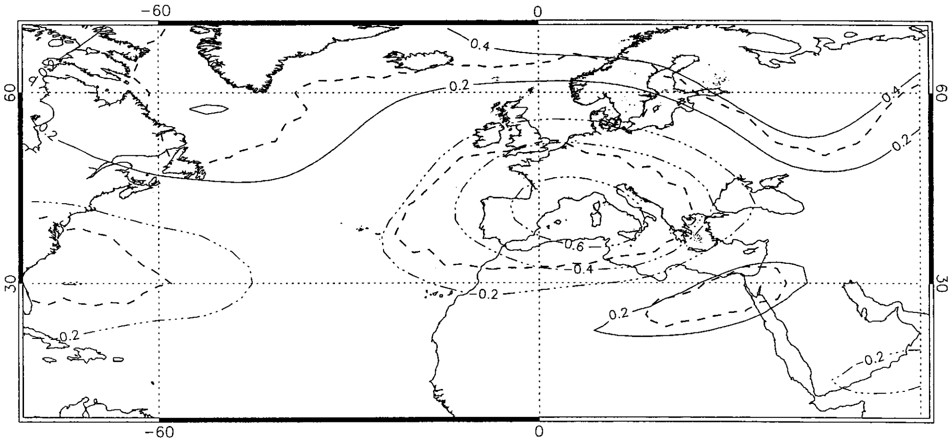

Fig. 8. – Pierson correlation coefficient between the precipitation SAI index and the 500 hPa geopotential height for the cold semester, averaged over the period 1948-1990. The thick dashed lines enclose areas at the 5% level, assessed by a Monte Carlo test.

To complete our discussion between precipitation over Calabria and pressure patterns, we show in figs. 7a, b, c, respectively, mean sea level pressure, sea level pressure averaged for years with precipitation under the 10th percentile and sea level pressure averaged for years with precipitation above the 90th percentile. Comparing dry years with average pressure field there is an extension of the Azores anticyclone over the Mediterranean area. This constitutes a barrier for cyclones coming from the Atlantic and reduces precipitation over Calabria. This situation is reversed for wet years in which the Azores anticyclone retracts leaving favourable conditions for Atlantic storms to enter the Mediterranean area.

3˙2. *Geopotential field.* – Figure 8 shows the Pierson correlation coefficient, averaged for the cold semester, between the Calabrian rainfall and 500 hPa geopotential height. The solid thin contours are positive correlations, the dashed lines are negative correlations. The thick dashed line encloses areas at 5% level assessed using the Monte Carlo routine. The Spearman correlation coefficient analysis lead to similar results and it is not further discussed.

There is an area of negative correlation in central America and over the Mediterranean area and two positive areas over Scandinavia and North-East America. This field is in good agreement with fig. 5a and shows a similar dipolar pattern between North Europe and the Mediterranean area. Nevertheless, at the same significance level, the area enclosed by the Monte Carlo test is reduced. This is probably related to the lack of measurements of geopotential height compared to sea level pressure. However, the absolute correlation coefficient for the Mediterranean area is larger than 0.6.

Figure 9a and b show, respectively, the anomaly of 500 hPa geopotential height for the cold semester rainfall under the 10th percentile (driest cold semesters) and above the 90th percentile (wettest cold semesters). Thick dot-dashed lines enclose areas at a level of 10%, according to a *t*-Student test. For the driest years there are negative areas in North America and Scandinavia with absolute values larger than 0.8. The strongest anomalies are found in the Mediterranean area (anomalies > 1.2).

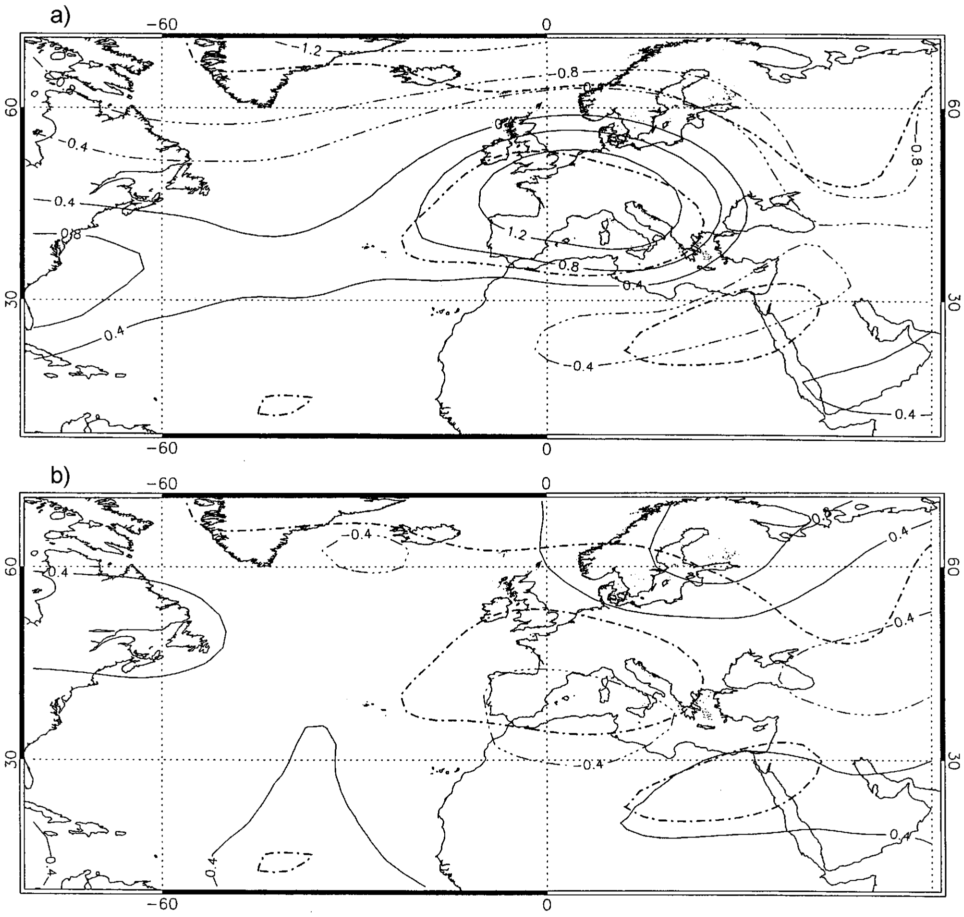

Fig. 9. – a) As in fig. 5a but for 500 hPa height. The thick dot-dashed lines enclose areas at the 10% level, assessed by a t-Student test. b) As in fig. 5b but for 500 hPa height.

For the wettest years, the patterns are similar to pressure maps, but absolute values are lower and enclose areas with less extensions. In addition the t-Student test has a higher level (10%). As said before, this can be related to the lack of measurements compared to sea surface pressure.

3·3. *Analysis of wet days.* – The same analysis shown in the previous two subsections was conducted using DSAI instead of precipitation. Figure 10 shows the correlation coefficient between Calabrian wet days in the cold semester and the sea pressure pattern, averaged for the period 1948-1990. This figure correspond to fig. 5b, because it refers to the Spearman correlation coefficient. The thick dashed lines enclose areas at a significance level of 99%, according to the Monte Carlo routine.

Comparing fig. 10 and fig. 5b the higher correlations values in the case of wet days compared to precipitation data are evident. This is clearly shown by the -0.6 correlation contour in the Mediterranean area and North Africa that is not present in fig. 5b.

With respect to large-scale structures, there is a general agreement between figs. 5b

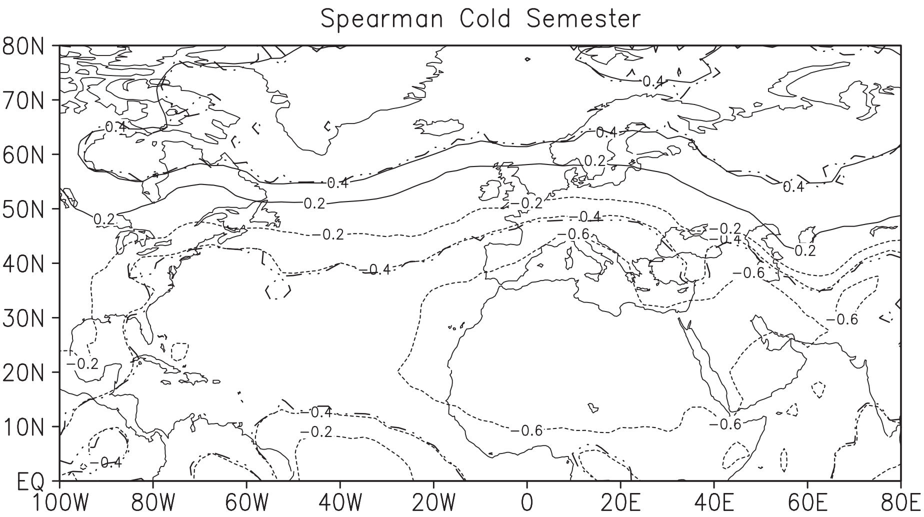

Fig. 10. – Correlation between Calabrian DSAI, in the cold semester, and the sea surface pressure, averaged over the period 1948-1990. The thick dot-dot-dashed lines enclose areas at a rejection level of 1%, assessed by a Monte Carlo test. Contours as in fig. 5a.

and 10 with large negative areas over the Mediterranean basin, the Atlantic Ocean and North-West Europe and with large positive areas over East Europe, North Asia and over the high-latitudes belt.

Larger correlation and higher values are shown by all maps relating wet days in Calabria and sea level pressure or 500 hPa geopotential height. In particular, the geopotential height Monte Carlo test attains the same levels of the sea level pressure (99%) and the areas that satisfy the test are larger than those in fig. 8. Also in this case patterns are similar.

In a recent paper on atmospheric circulation and precipitation in Italy for the last 50 years, Brunetti *et al.* [14] used daily rainfall from 75 Italian stations to relate precipitation over Italy to large-scale pressure variations. They found that correlations were higher using wet days instead of precipitation data. This is confirmed by our analysis both in correlation fields and in correlation with NAO (fig. 3). This is probably due to the fact that the wet-days number is a better indicator of the persistence of a cyclone than precipitation itself. This is particularly evident for Calabria, where, sometimes, single rainfall events can produce a large fraction of seasonal precipitation [5].

3˙4. *Correlation with sea surface temperature.* – Figure 11 shows the Pierson correlation coefficient between Calabrian precipitation and sea surface temperature (SST). Over land, correlation is between precipitation and skin surface temperature. The thick dashed lines enclose areas at a significance level of 10% according to the Monte Carlo test. Correlation rarely reaches this significance level over the sea and its absolute value is never greater than 0.4. No significant correlation is found for Pacific and North Atlantic Oceans, while two wide areas of correlation are evident in the Indian Ocean and in the South Atlantic. These correlations need further investigation. For the Spearman correlation coefficients, results are similar.

It is also important to note that no correlation is found for the Mediterranean basin.

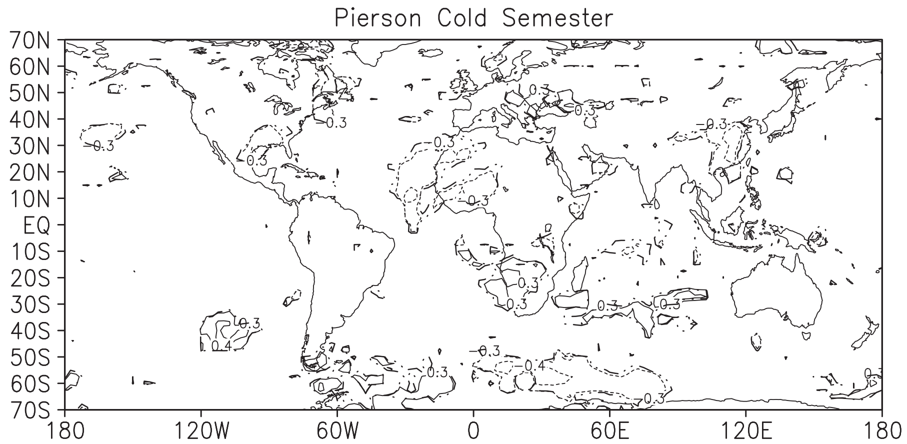

Fig. 11. – Correlation between precipitation over Calabria, during the cold semester, and SST, averaged over the period 1948-1990. The thick dashed lines enclose areas at the 10% level. The contour is 0.3.

This is surprising if we consider that precipitations over the Mediterranean basin can be strongly affected by SST due to water vapour exchange between the sea surface and the cyclone [16]. In addition, for Calabria, a preliminary study suggests the importance of SST in determining precipitation over the country [17]. Nevertheless, resolutions, both spatial and temporal, of our datasets are poor to investigate this kind of phenomena and additional work must be done with respect to SST.

Also for SST we have done the analysis using wet days rather than precipitation amounts. In this case, significance patterns are similar, even if they are a bit enlarged, and correlation values are a bit higher but still never greater than 0.4. In summary, no additional insight is given by this analysis.

4. – Conclusions

In this paper we analyzed the correlations between large-scale patterns and the Calabrian precipitation. This study is done using NCEP-NCAR reanalysis and data from "Istituto Mareografico ed Idrografico". Superposition of the two datasets is attained for the period 1948-1990. Conclusions can be summarized as follows.

1) Precipitation over Calabria shows a large year-to-year variability and the seasonal forecast for water availability should be a valuable instrument for human activity planning.

2) Correlation with NAO is less stringent than for other areas of the Mediterranean basin, nevertheless a second interesting dipolar structure, located east of NAO is evident from our analysis.

3) Correlation analysis using wet days instead of precipitation data shows similar structures obtained for precipitation, but correlation coefficients and levels of significance are higher.

4) There is no evidence of a correlation with SST. Nevertheless, the spatial and temporal resolutions of our datasets are not enough to assess the importance of this

parameter in Calabria. Indeed, for this country, the Mediterranean surface temperature should play a relevant role in determining precipitation associated with cyclones.

5) While more reliability will be obtained adding the years between 1991 and 2000 to our analysis, the results presented in this paper are valuable in the assessment of the correlations between Calabrian climate and large-scale structures.

* * *

We are grateful to the "Istituto Mareografico ed Idrografico" for making precipitation data available. This work was partially funded by "Ministero dell'Università e della Ricerca Scientifica" in the framework of the project "Sviluppo di Distretti Industriali per le Osservazioni della Terra".

REFERENCES

[1] Houze R. A., *Cloud Dynamics* (Academic Press, N.Y.) 1993.

[2] Giorgi F. and Mearns L. O., *Approaches to the simulation of regional climate change. A review*, *Rev. Geophys.*, **29** (1991) 191.

[3] Busuioc A., Von Storch H. and Schnur R., *Verification of GCM-generated regional seasonal percipitation for current climate and of statistical downscaling estimates under changing climate conditions*, *J. Climate*, **12** (1999) 258.

[4] Kalnay E. and Cohauthors, *The NCEP/NCAR 40 year reanalysis project*, *Bull. Am. Meteorol. Soc.*, **77** (1996) 437.

[5] Colacino M., Conte M. and Piervitali E., *Elementi di climatologia della Calabria*, IFA-CNR, 1997, pp. 218.

[6] Federico S., Dalu G. A., Bellecci C., Casella L. and Colacino M., *Atmospheric convergence diabatically generated in the CBL over a mountainous peninsula*, *Nuovo Cimento C*, **24** (2001) 223.

[7] Federico S., Dalu G. A., Bellecci C. and Colacino M., *Mesoscale energetics and flows induced by the sea-land and mountain-valley contrast*, *Ann. Geophys.*, **18** (2000) 235.

[8] Koppen W., *Das geographische system der klimate. In Handbuch der klimatologie*, (Gebruder Borntraeger Verlin) 1936.

[9] Mennella C., *Il clima d'Italia* (Fratelli Conte Editori, Napoli) 1967.

[10] Wilks D. S., *Statistial Methods in Atmospheric Sciences* (Academic Press, N.Y.) 1995.

[11] Nicholson S. E., *Subsaharian rainfall and the years 1976-1980: evidence of continued drought*, *Mon. Weather Rev.*, **111** (1993) 1646.

[12] Hurrel J. W., *Influence of variations in extratropical wintertime teleconnections on Northern Hemisphere temperature*, *Geophys. Res. Lett.*, **23** (1996) 665.

[13] Munoz-Diaz D. and Rodrigo S., *Effects of North Atlantic Oscillation on the probability for climatic categories of local monthly rainfall in southern Spain*, *Int. J. Climatol.*, **23** (2003) 381.

[14] Brunetti M., Maugeri M. and Nanni T., *Atmospheric circulation and precipitation in Italy for the last 50 years*, *Int. J. Climatol.*, **22** (2002) 1455.

[15] Delitala A. M. S., Cesari D., Chessa P. A. and Ward N., *Precipitation over Sardinia during the 1946-1993 rainy seasons and associated large-scale climate variations*, *Int. J. Climatol.*, **20** (2000) 519.

[16] Buzzi A., Tartaglione N. and Malguzzi P., *Numerical Simulations of the 1994 Piedimont flood: role of Orography and moist precesses*, *Mon. Weather Rev.*, **126** (1998) 2369.

[17] Federico S., Bellecci C. and Colacino M., *Quantitative precipitation of Soverato flood: the role of topography and surface fluxes*, *Nuovo Cimento C*, **26** (2003) 7.