SCIA: a system for a better knowledge of the Italian climate

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ABSTRACT The objectives of SCIA (Sistema nazionale per la raccolta, elaborazione e diffusione di dati Climatologici di Interesse Ambientale) are the elaboration, update and fast availability of climatological indicators derived from the meteorological time series that come from the main networks operating in Italian territory. The need for such a system derives from the fact that meteorological data are sparse among several national and regional organizations and that climate indicators need to be calculated using quality-checked data and homogenous statistical procedures. The indicators and the representation of their trend and spatial distribution, are available through a dedicated web site. It is possible to get, quickly and easily, synthetic information on the Italian climate and its tendencies, as normal values, on thirty-year reference climatological periods and yearly estimated anomalies of the main variables, like temperature and precipitation. The climate indicators available through SCIA may be useful for research and environmental institutions and for the public. As an example of the use of the indicators, an estimate of the mean temperature trend in Italy, in the last 45 years, is presented.

1. Introduction

The availability of coherent data on the Italian climate is a fundamental requirement for the comprehension, the evaluation and the design of effective control strategies of climate change and atmospheric pollution impacts. The knowledge of the climate and its tendencies, at the different space and time scales given by the responses to environmental pressures, depends on the availability of reliable data and indicators. They must be complete and geographically well distributed, in order to be representative of the variety and complexity of the Italian environment and territory. In Italy, there is a large number of historical meteorological data series useful to know about the climate, but there is also a fragmentation of this information, spread between several national and regional institutions that, for different institutional reasons, operated and operate in the field of climate monitoring and manage their own archives of meteorological data series. The need for harmonisation and standardisation of the methods for calculating the climate indicators, and for a fast and reliable system for accessing and continuous updating of these informations avose from this situation.

In order to fulfill these needs, the national agency for environmental protection (APAT: agenzia nazionale per la protezione dell'ambiente e per i servizi tecnici) developed the SCIA system (Sistema nazionale per la raccolta, elaborazione e diffusione di dati Climatologici di Interesse Ambientale). The system is generated by the meteorological time series of the national air force weather service (AM), the "Ufficio Centrale di Ecologia Agraria" (UCEA) of the Agricultual Ministry, and, at present, by ten regional environmental protection agencies (ARPA), located mainly in northern Italy. The input data may be different in terms of the frequency and average time of the observations, but

in principle they all satisfy the World Meteorological Organization requirements for station instruments. In any case, a complete set of meta-information documents the location and the characteristics of the stations of the different networks.

2. Climate indicators

SCIA calculates and provides the significant statistical values (average, extremes and date of occurrence, standard deviation when appropriate) of the meteorological variables, over each ten day, monthly and yearly period. This calculation is performed through a computerized standard procedure, which is applied once to historical data sets and periodically (typically once a year) for the update of climate indicators.

The main variables treated by the SCIA system are: temperature, potential temperature, equivalent potential temperature, precipitation, relative humidity, wind, water balance, bioclimatic indices, evapotranspiration, degree days, fog and visibility, cloud cover, atmospheric pressure, global radiation. For each variable, different kinds of indicators are calculated. For temperature: mean temperature based on all (hourly or three-hourly) daily observations and on minimum and maximum daily temperatures; minimum and maximum daily temperatures: mean, extremes, date of extremes, number of days with values within specified intervals of 5 °C; daily temperature range: mean, maximum, date of maximum; number of frozen days. For precipitation: cumulated precipitation; hourly, 6-hourly, 12-hourly and daily precipitation: maximum value, date of occurrence of maximum and distribution of precipitation values within specified ranges; number of days with snow; number of days with thunderstorms; number of thunderstorm events.

Based on ten-day, monthly and yearly indicators, the normal climatological values over standard periods (for example, the thirty-year period 1961-1990) and annual anomalies, are calculated.

Up to now, all the indicators derived from the historical series of observations of the AM, the UCEA, and ten regional environmental protection agencies (ARPA), have been uploaded on the SCIA database. In addition, precipitation data coming from about four thousand stations of the formerly networks of the Servizio Idrografico e Mareografico Nazionale (SIMN), now managed by the Italian Regions, have been uploaded. The recent involvement of regional agencies in SCIA has been very important for the completeness and the updating of the information on the Italian climate and its tendencies. Several regional services detain very interesting meteorological data series which are useful for climate evaluations, due to their duration, continuity and quality. An effort, in the near future, will be directed to improve and homogenize the capabilities of meteorological monitoring at a regional level, and to involve other regional agencies from central and southern Italy in the SCIA system.

3. Validity controls

All the indicators calculated through SCIA undergo the same set of validity controls agreed upon with the data owners. This allows the integration and the comparison of indicators obtained from different data sources. The procedure for calculating the climatic indicators consists of a set of computer programs that reconstruct the series of ten daily, monthly and yearly indicators, based on raw meteorological data. The general criteria adopted for the calculation of the

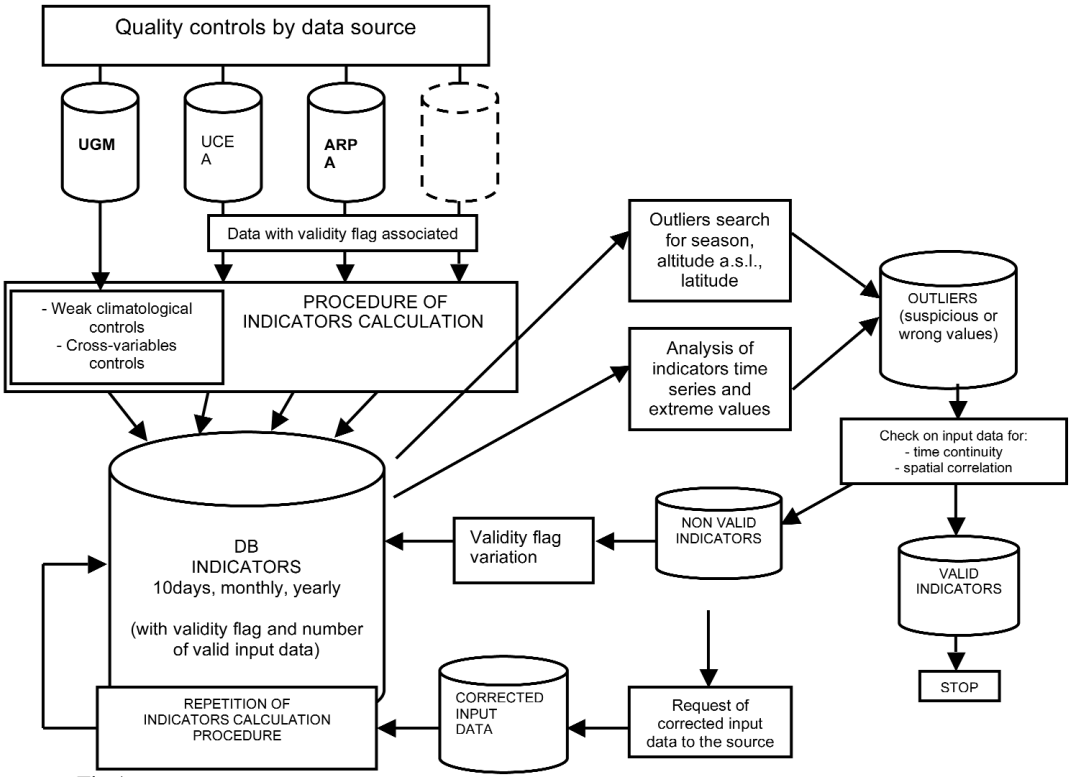

Fig. 1 - Scheme of the validity control procedure on climatic indicators processed by the SCIA system.

indicators are defined by the World Meteorological Organisation (WMO, 1990).

The input data may be different both in content and format, depending on the source. The content varies as a function of the station type (automatic or manual), of the instrumentation and of the modality of data acquisition and archiving. In particular, the frequency of the observations and the averaging or sampling time may be different. As an example, for AM stations the input series contain three-hourly synoptic observations and daily SYREP compilations, while for UCEA there are one or three observations per day from the "historical" network and hourly measurements from the automatic stations of the National Agrometeorological Network (RAN).

The main problems in the elaboration of the climatic indicators concern the treatment of missing values and the validity controls of both input data and indicators. In general, the validity of input data is under the responsibility of the source. However, two classes of formal controls are applied to input data before they are used to calculate the climatic indicators. In the first (weak climatological control), each data must fall within a range delimited by a minimum and a maximum threshold, representing the limits for physically acceptable data. In the second (internal consistency control), the values of different variables at the same time are controlled in order to check eventual inconsistencies between them; as an example, air temperature and dew point temperature are checked in order to verify that the seconds in not greater than the first.

Together with the value of each indicator, the number of valid raw data that generates the indicator is memorized, and a validity flag is assigned to the indicator. In general, an indicator is considered valid if it is generated by at least 75% of raw, valid input data. Considering the irregular distribution of missing or non valid data in the input series, this criterion represents a compromise between the need for saving as much valid data as possible, and the need to maintain a good representativity of the indicators in relation to their reference time interval. For cumulated variables like precipitation, the threshold for the validity of the indicators is raised to 90% of input data.

A very important aspect is the control of the indicators that may have been generated by one or more wrong input data. The entity and the evidence of the error depend on the entity of the error of the original data and on the type of indicator. In general, a wrong data may be hidden in an annual average indicator, while it can be evident in the analysis of extreme values. Non valid indicators are found by looking for outliers, i.e. indicators with suspicious or evidently wrong values. The threshold values for the outliers depend on the variable, the season and the climatic characteristics of the station (Baffo *et al.*, 2005). Once that group of outliers is found, the input values that generated the outliers are verified, by analysing the continuity of the time series and/or the spatial correlation with nearby stations. If it is confirmed that input data are wrong, the corresponding indicators are invalidated and do not contribute to the elaboration of the normals, the anomalies, and the spatial interpolation needed to produce the climatic maps (Fig. 1).

4. The web site

The indicators of the Italian climate produced by SCIA are accessible through a dedicated web site within the national environmental information system of APAT, at the address www.scia.sinanet.apat.it. The main climatic indicators, the normal climatological values and the anomalies calculated and stored by the system, can be displayed in the form of tables, diagrams and maps, and downloaded as text files,. Each function of the web site is equipped with a help function available also in the English language.

A first function, STATIONS, is dedicated to the data sources which pinpoints, on a map of Italy, the meteorological stations of the different networks, whose data are used to derive the climatic indicators. Some metadata, such as geographical coordinates and the altitude above mean sea level of the stations, and the list of variables measured by each station, may be downloaded on a text file.

The SCIA indicators may be retrieved looking at the time series of a station, or at the spatial distribution of indicators of the same reference time. In the first case (TIME SERIES function), one can display the trend of a variable by choosing the time interval and the time step (ten days, one month or one year), and the corresponding values may be downloaded. As an alternative, (FREQUENCIES function), one can display the statistical distribution of the indicators on an histogram; if available, the position of the current or most recent year with respect to the distribution is highlighted. For the wind, the frequencies of speed and direction classes are represented by wind roses.

The MAPS function allows one to visualize the spatial distribution of an indicator (for example, the average temperature of a certain year and month) by contour lines. The data

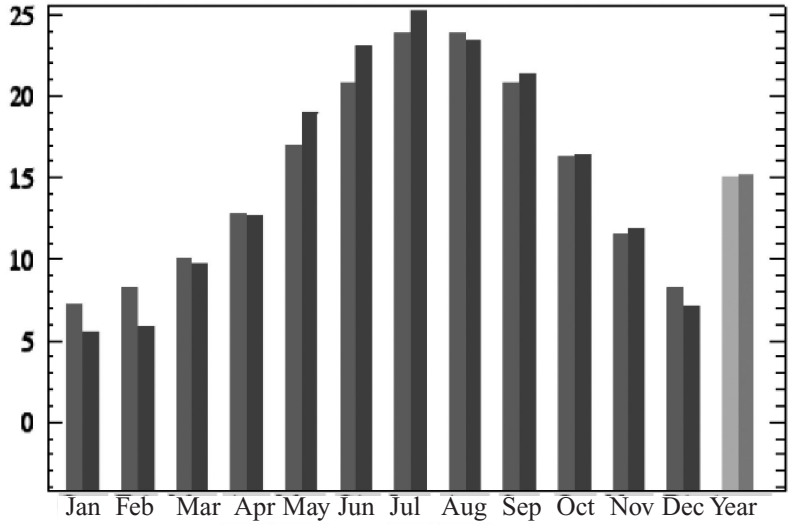

Fig. 2 - 2005 mean temperature (right bars) compared with 1961-1990 normal mean temperature (left bars). Synoptic station Roma Ciampino.

interpolation on a regular grid is carried out through a kriging algorithm (see for example Wackernagel, 2003). The parameters of the variogram are empirically optimised on the base of the physical meaning of the variable and on the average density of measurement points. Due to the wide variability of the density and the distribution of the stations, and to the complexity of the Italian topography, the accuracy of the maps may be rather limited in some cases. Thus, contourlines may give a general idea of the spatial variability of climate over Italy, but should not be used to get the exact value of an indicator over a specific location. In any case, it is possible to download both the data on the station points and the data interpolated on the grid points, in order to allow a successive data processing by the user, with geostatistical techniques that are more appropriate case by case.

Another section of the web site (CLIMATE NORMALS) is dedicated to the normal values over climatological reference periods, in particular the thirty years 1961-1990. Finally, the values of annual ANOMALIES may be represented, i.e. the differences between the values of an indicator in a certain year and its normal value (see an example in Fig. 2).

5. Temperature trend estimate

One of the main institutional tasks of environmental agencies is to report on the state of the environment and its trends. The SCIA system offers an opportunity to, periodically, report on the state of the climate over Italy. In 2005, on the occasion of a workshop dedicated to present the SCIA system to national and regional environmental organizations, a first report was presented, that contained, in the form of tables, diagrams and maps, a set of normal climatological values (1961-1990) of temperature, precipitation, relative humidity, cloud cover and wind, and of average anomalies of temperature, humidity and cloud cover from 1961 to 2004 (Desiato *et al*., 2005).

Studies and evaluations on the impact of climate change focus, first of all, on the mean

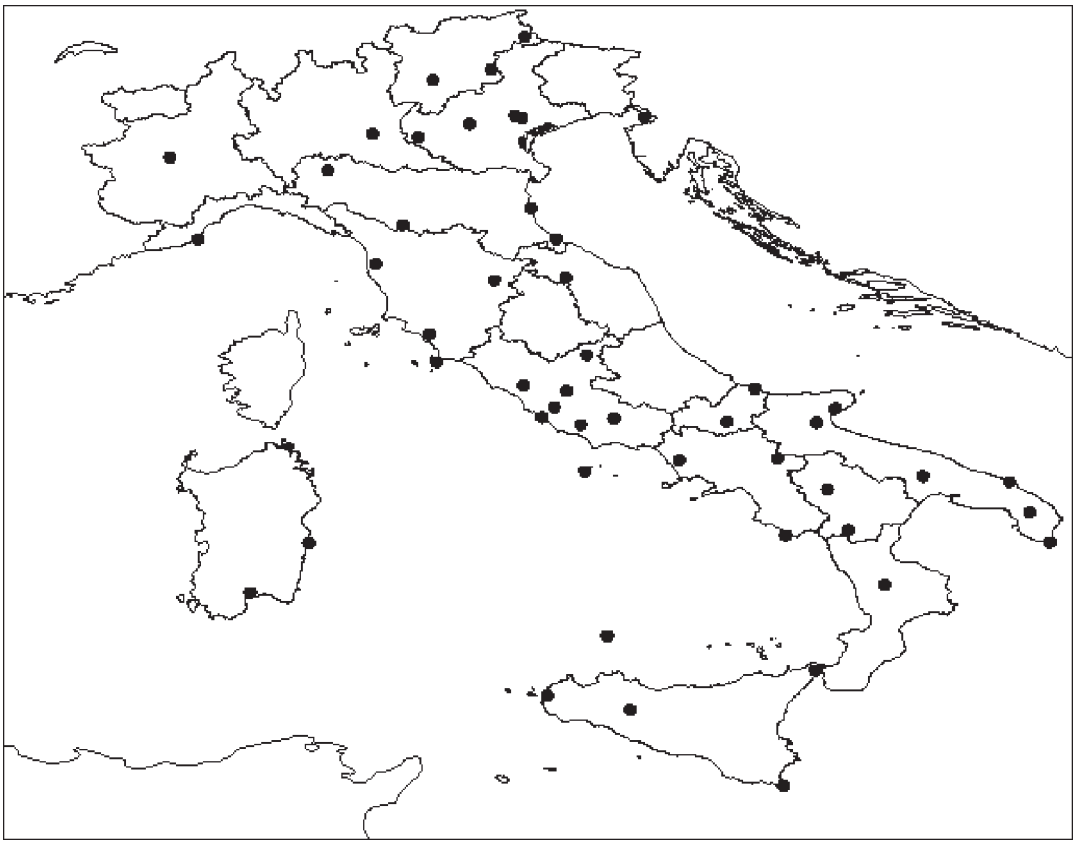

Fig. 3 - Map of the 49 synoptic stations used for the mean temperature trend estimation over Italy.

temperature trend. At a global scale, there is, by now, a sound estimate of an average heating of 0.6 - 0.7 °C, in the last century. The temperature increase has been faster in the last 25 years, for which a variation of 0.15 – 0.18 °C/year is estimated (IPCC, 2001). The warmest years were, in the following order, 1998, 2002, 2003 and 2004.

As far as Italy is concerned, we made an estimate of the mean temperature trend by processing a group of temperature indicators made available through SCIA. They are based on minimum and maximum daily temperature data of 49 synoptic stations, whose time series satisfy some requirements of completeness and homogeneity (Fig. 3). In fact, prior to the trend analysis, time series must undergo homogeneity tests in order to detect and eventually eliminate possible data alteration due to external, non-climatic signals, such as the relocation of a station or the change of instruments (Alexandersson and Moberg, 1997; Suatoni and Toreti, 2005). In our case, annual mean temperature anomaly series were homogenized and used for trend recognition and evaluation through appropriate statistical models. In particular, with the application of a "sloped-steps" model (Fig. 4) a decrease of the mean temperature over Italy of 0.6 °C from 1961 to 1980, followed by an increase of 1.6 °C until 2004 (Toreti and Desiato, 2006) was estimated. This result indicates an average warming over Italy consistently more intense than the global mean in the last 25 years.

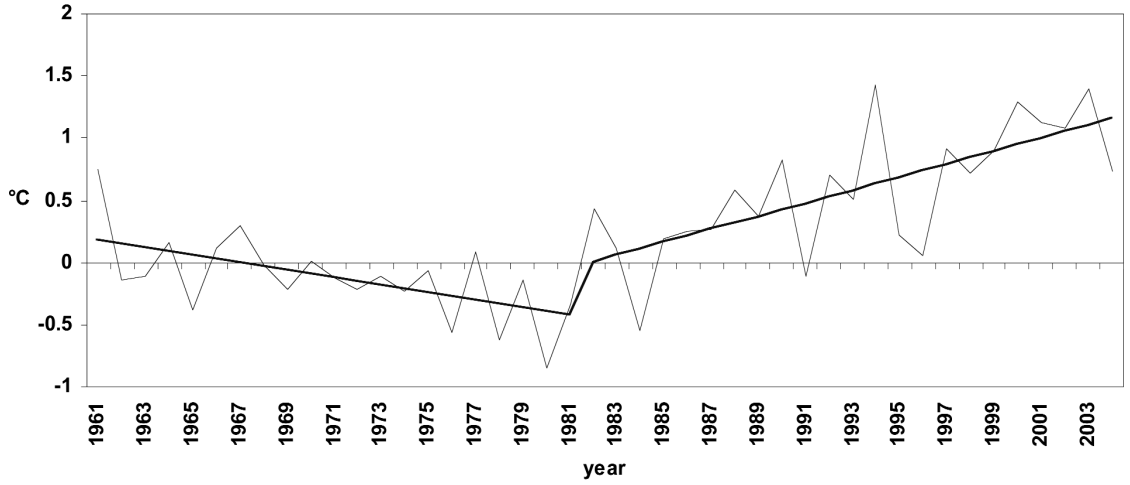

Fig. 4 - Average temperature anomaly over Italy and trend estimated with the "sloped steps" model (thick line). A mean temperature increase of 1.6 °C from 1981 to 2004, following a decrease of 0.6 °C from 1961 to 1981, are estimated.

6. Conclusions

The SCIA system represents a reference tool for the standardized processing of, and the access to, climatic indicators derived from meteorological data available from several national and regional sources in Italy. At present, the developments of the system are oriented towords the inclusion of other data sources, and to the improvement of the quality and control of the information. The quality-checked indicators provided by SCIA may be useful for studies and evaluations aiming at a better knowledge of the Italian climate and its trend. As a first result, an estimate of the mean temperature trend over Italy in the last 45 years was obtained from homogenized annual mean temperature series of 49 synoptic stations, indicating an average warming of 1.6 °C from 1981 till 2004, significantly more intense than the corresponding rate at the global level.

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