

Climate monitoring in Italy: design and analysis of ISTAT hydro-meteorological database

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Abstract: This paper illustrates the GIS-based information system developed by Istat and aimed at monitoring climate conditions in Italy since 1951 at a detailed spatial scale. This project evaluates the possible data integration from different meteorological sources by considering more than 500 potential monitoring networks (Italian air force meteorological service, ministry of agriculture, regional agencies for environmental protection, as well as several local networks) which cover up to nearly sixty years (1951-2007). Data were collected through a statistical survey in 2007-2008 by using software tools and data capturing. Metadata from each considered station were collected through CATI interviews with the holders of each network. The number of collected stations is actually increasing and it is expected to reach more than 6.100 gauging stations at the end of 2009. Statistical analyses, as well as geo-statistical and cartographic procedures, will be developed to produce estimates of meteorological variables at a fine spatial scale.

Keywords: climate, data-warehouse, Italy.

1. Introduction

The increasing interest on climate and its impact on natural and agricultural ecosystems in the framework of climate change is demonstrated by the consistent growth of research activities in such field (Salvati *et al.*, 2005). Several databases and statistics are actually available at different spatial scales (global, sovra-national, national, regional, local). Several indexes were proposed as well in order to describe climate characteristics. Indexes suggest that large (historical) data sets are necessary to identify relationships between the different variables involved in climate events. The development of efficient tools to analyse information from large databases represents a crucial issue in meteorological statistics (e.g. Perini *et al.*, 2007). The aim of this paper is to illustrate the project carried out by National Institute of Statistics (Istat) aimed at developing a geo-database from a large number of gauging stations in order to provide, through a GIS-based scheme, estimations of several climatic, meteorological and hydrological statistics and indicators.

2. The Istat project on meteorological statistics

In Italy, the meteorological observations were carried out in the past mainly by the Italian Air Force Meteorological Service, the Central Office for Crop Ecology of the Ministry of Agricultural and Forestry Policies, as well as by the Central Hydrographical

Service. With their large networks, the three institutions guaranteed a complete country coverage and a good data quality (ISTAT, 2006). The reform of the national technical services, carried out at the end of 1990s, shifted the central hydrological network to the twenty administrative regions (i.e. at the NUTS-2 level). In addition, several agro-meteorological services started their activity at the regional level since early 1980s. Finally, a lot of meteorological networks with a smaller number of gauging stations started (or continued) to operate in that period throughout Italy, especially in the northern regions. Although the monitoring potential of these networks is good due to the generally high-quality data, the complete national coverage and the quite satisfactory spatial resolution of the gauging networks, the heterogeneity of the information collected is high.

Since 1926, Istat disseminates meteorological data collected from gauging stations located over Italy (ISTAT, 2005). In 2007 Istat carried out a research project entitled "Meteo-climatic and hydrologic indicators". The aim of this project, which is included in the National Statistical Program (2008-2010), is to implement a geographical data-warehouse with meteorological, agro-meteorological, and hydrological daily values measured since 1951 from some thousand gauging stations provided by several national, regional, and local institutions. The project is conducted within the partnership of the Central Office for Crop Ecology (Cra-Cma) and the Italian Air Force Meteorological Service.

The project has the following objectives: (i) to provide a complete survey of the Italian institutions collecting meteorological data through their own network of gauging stations, (ii) to collect the meteorological data available from these services into a geographical data-warehouse, (iii) to study possible procedures for data integration, and (iv) to develop procedures for climate monitoring through statistical indexes and maps.

3. The National Institute of Statistics survey on meteorological networks in Italy

The survey of meteorological networks was conducted on all the national services, regional services (e.g. rural development agencies) and several local institutions (e.g. research institutes, universities, technical schools) operating in the environmental field and potentially holding at least one gauging station actually at work (see Table 1 for a review). The respondent's list was compiled by dedicated searches on the web, by collecting information through the national meteorological services, and by interviews with experts working at both the regional and local levels. Data were collected through a statistical survey in 2009 by using software tools and data capturing. Metadata from each considered station were gathered through CATI interviews with holders of each network.

Provisional results of the survey, to be finished at the end of 2009, were reported in Table 1. More than 6.100 gauging stations were individuated throughout Italy. Nearly 5.000 stations were managed by the regional meteorological services. The remaining stations were managed by the national services (nearly 400 stations) and by several local institutions (nearly 700 stations). Quite all the stations measured rainfall at the daily or hour basis, while 50% of the surveyed stations measured minimum and maximum temperature. Other meteorological variables, measured by a very limited number of the surveyed stations, included wind, air humidity, and solar radiation.

Concerning the length of available time series, with special regard to daily rainfall and temperature, long time series (more than 50 consecutive years) were collected by both national and regional services. Interestingly, several time series with more than 30 consecutive years are managed by various research institutions (CRA, CNR) and local networks (especially those of geo-physical observatories, faculties of Sciences and Agriculture, and some technical schools).

Table 1: *The survey of meteorological networks in Italy.*

Service/institution name (type)	Number of respondents	Estimated number of stations working	Average length of time series (years)	Institution type
Italian Air Force Meteorological Service	1	100	50	National
Italian Company for Air Navigation Services	1	30	30	National
Central Office for Crop Ecology	1	200	50	National
Corpo Forestale dello Stato	1	100	10	National
Regional hydrological services	21	4.000	50	Regional
Regional Agro-meteorological Services	19	1.000	20	Regional
National Research Council (CNR)	20	50	30	Local
Council for Agricultural Research (CRA)	41	100	30	Local
Agro-meteorological services of provinces	10	200	15	Provincial
Agricultural consortia	350	250	10	Sub-regional
Climatological and geophysical observatories	15	50	40	Local
Universities, agricultural schools, and other institutions	25	50	20	Local
Total	505	6.110	-	-

Source: provisional survey figures.

4. The Istat hydro-meteorological database

A geo-database was developed in Oracle/ArcGis environment in order to properly store collected time series data of all the measured variables. The number of collected data from gauging stations was rapidly increasing and it is expected to reach a size of about 6.100 stations in a few months. The number of stations actually available in the hydro-meteorological database is reported in Table 2 by geographical area.

Table 2: *Number of gauging stations actually available in the hydro-meteorological database by geographical area.*

Geographical area	Meteorological gauging stations (temperature and/or precipitation)	Hydrological gauging stations
North	2.074	264
Centre	1.599	176
South	1.632	294
Italy	5.305	734

Source: provisional survey figures.

5. Discussion and further development

After data collecting, checking and imputation of lacking values, the data-warehouse will allow to estimate the main climate variables at high spatial resolution. One of the main problems in this phase will be the possible data integration among different meteorological networks. Collected metadata will be useful to individuate comparable time series. In a first phase, only stations managed through international standards will be considered. In a second phase, homogeneity tests will be performed on the remaining time series for possible integration.

A third phase will include the elaboration of a set of indicators describing the interaction of climate with biological, agronomic, pedological, and hydrological themes. Indicators will be estimated, through geo-statistical and regression approaches, and down-scaled at various administrative spatial scales (e.g. municipalities, local labour systems, agricultural homogeneous regions) in order to achieve integration with other statistical (e.g. socio-economic) variables obtained at those scales.

6. Conclusion

As there has been recently a tendency to evaluate climate characteristics by using several indices or variables simultaneously (APAT, 2007), the framework presented here will allow to produce long time series thematic indicators across the whole national territory at an adequate spatial scale. In fact, complex evaluation of climatic events needs to develop a comprehensive framework in which several aspects should be combined, including (i) climatic (hydro-meteorological) data and indices, (ii) soil quality and topography, (iii) crop cover (vegetation) conditions, and (iv) other human factors, like land use, population growth, and others. The next step of the present work will be the full integration of the geo-database, developed through a GIS environment, with other geographical database developed by Istat at the municipality scale and concerning important socio-economic issues with potential link with climate.

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