Project of Interest
"NextData"

Research project :

High Resolution Climate Information for Mountain Areas (HR-CIMA)

Coordination: Dr. Michele BRUNETTI

CNR- Istituto di Scienze dell'Atmosfera e del Clima (ISAC)

Work Pachage :
WP 2.1 ; WP 2.6

TITLE OF THE PROPOSED PROJECT:
High **R**esolution **C**limate **I**nformation for **M**ountain **A**reas (HR-CIMA).

Project duration: 2013-2015
start date (in the first semester 2013): 1st June 2013
end date (in the second semester 2015, no later than 30 September 2015): 30 Septemner 2015

Scientific coordinator of the proposed project:
Dr. BRUNETTI Michele

CNR Institute coordinating the proposed project:
Istituto di Scienze dell'Atmosfera e del Clima (ISAC)

Participating units:

Unit 1 (CNR coordinating Institute): ISAC – BRUNETTI Michele

1. GENERAL INFORMATION

Abstract of the proposed project

High spatial resolution (30-arc-second) 1961-1990 climatologies of monthly temperature and precipitation will be produced for the Italian alpine area, based on a dense, quality controlled observational data set. For some case study areas, the temporal series of the same variables will be reconstructed at the same spatial resolution. The target areas will be chosen on the basis of data availability, with particular attention to natural parks and protected areas, where the availability of high-quality data with the adequate spatial resolution is crucial to evaluate the impact of climate change and variability on ecosystems.
The approach that will be used integrates the information contained in meteorological records with that arising from digital elevation models; it allows recognizing the link between the meteorological and the physiographical variables, permitting the construction of climatologies on a regular grid with several orders of magnitude more nodes than the available records.

Main goals of the project

The main goal of the project is to improve the knowledge of the climate of the Italian Alpine areas. The project will focus first on data rescue, quality control and homogenisation activities, and then on the evaluation of methodologies to interpolate climate data at a very high spatial resolution in a complex terrain. The key issues of the project are i) the knowledge (at a high spatial resolution and monthly timescale) of the spatial distribution of thermal and pluviometric resources for the whole Italian Alpine area and ii) the construction of local virtual records on a regular grid to study climate variability and change for some target areas at a very high spatial resolution (30-arc-second).

Expected results of the project

The project database and the investigated methodologies will allow us to set up monthly temperature and precipitation 1961-1990 climatologies at 30-arc-second resolution for the Italian alpine region (h>1500 m asl). This result will fill an important gap as, at present time, monthly high-resolution temperature and precipitation climatologies are only partially available for the Italian Alpine area and they are often based on datasets which are plagued by rather discontinuous records as well as inhomogeneous spatial coverage.
Another important result of the project will be the construction of monthly temperature and precipitation data sets (temporal series) in absolute values for the past decades at 30-arc-second resolution for some target areas, with particular attention to natural parks and protected areas, to be defined on the base of data availability. Such local virtual records turn out to be a fundamental tool to evaluate

the impact of climate change and variability at the local scale in a region characterized by a very heterogeneous climate. Moreover they are very useful in order to downscale the climate projections for the future at the local scale.

Role of the different units

The present proposal is structured into one single unit that will develop the whole proposed activity. Instead of planning one additional unit, a limited part of the activity, concerning in particular the data rescue and validation for a sub-domain of the area under study (the Alpine area of the Lombardy Region), will be assigned as a Scientific Advice to the Department of Physics of the Milan University to exploit the agreement existing between ARPA-Lombardia (the data holder for that area) and the Physics Department itself. The contribution of the Department of Physics of Milan University will also concern the know-how transfer of their interpolation techniques and algorithms to be used as an intercomparison instrument to evaluate strengths and weaknesses of the approach here proposed (in principle the best performing for a complex terrain such as the Alpine region).

2. DETAILED PROJECT DESCRIPTION

State of the art and motivations

Datasets of monthly climatological normals of meteorological variables (or climatologies) at a high spatial resolution have proved to be of increasing importance in the recent past, and they are likely to become even more important in the near future. Indeed, they are crucial in a variety of models and decision supporting tools in a wide spectrum of fields such as agriculture, engineering, hydrology, ecology and natural resource conservation, just to mention a few. In order to provide sound estimations of monthly climatologies, even for areas with complex topography, a large, high-density dataset must be used together with interpolation techniques that allow the most realistic representation of the major factors driving spatial gradients.
At present time, monthly high-resolution temperature and precipitation climatologies are not available for Italy. At a national scale, only lower resolution products are available, such as the 30 km resolution temperature climatology delivered within the "Sistema Informativo Agricolo Nazionale", as well as collections of monthly station normals, such as those produced by the National Hydrographic Service in the 1960s, or more recently, those produced by the Italian National agency for new technologies, energy and sustainable economic development (ENEA), and those by the Italian National Air Force (http://clima.meteoam.it/atlanteClimatico.php).
A very important contribution toward a better knowledge of the spatial distribution of air temperature over Italy has been given in the last years by SCIA (see www.scia.sinanet.apat.it) a system for the elaboration, update and fast availability of climatological indicators set up by the "Istituto Superiore per la Protezione e la

Ricerca Ambientale" (ISPRA): SCIA is the basis for the yearly reports on Italian climate issued by ISPRA. ISPRA also produced monthly high-resolution temperature maps from 1961 to 2009, by means of regression-kriging with altitude and latitude as external variables (and also longitude for mean temperature); the underlying observational dataset, however, is plagued by rather discontinuous records (from about 200 stations in the 1960s to about 750 in 2008) as well as inhomogeneous spatial coverage.

Within this context there is need of 1961–1990 monthly temperature and precipitation climatologies at a high spatial resolution based on a dense, quality controlled observational dataset. These needs are even more evident in mountain regions where the availability of good data is particularly lacking.

Together with climate normals (spatial component), a detailed knowledge of the evolution of climate variables over the past decades (temporal component) at the adequate spatial resolution is crucial for climate change impact related studies.

It is therefore necessary to create methodologies that transfer the information of time series of meteorological data to the local scale. In practice, to create a valuable spatialization tool, it is necessary to construct virtual time series related to the points of a high-resolution grid, from the actual sparse station series.

At present time, the most promising approach to do this is based on the assumption that the spatio-temporal structure of meteorological variables over a given area can be described by the superimposition of two fields: the normal values related to a standard time period, i.e. the climatologies, and the deviations from them, i.e. the anomalies. In this sense, the availability of high-resolution climatologies, besides being important per se, is a pre-requisite for the construction of temporal series of a meteorological variable in absolute values at the adequate spatial resolution.

The projection of the anomalies onto a high-resolution grid is fully justified by the fact that the temporal fluctuations of meteorological variables, linked to the variability of climate, present a high spatial coherence. On the contrary, the climatologies are linked to the geographical characteristics of the territory: this causes very strong spatial gradients and, as a consequence, strengthens the need of a higher number of stations, though on a limited temporal interval.

Then, on the one hand, low-density data sets but with long enough temporal coverage and a high quality level in terms of homogeneity are necessary to construct the anomaly component. On the other hand, high-density data sets, even if available for a limited temporal period, are fundamental to capture the spatial gradients of meteorological variables.

Detailed description of the project, including the work plan, deliverables and milestones (explicitly indicating the activities of the different years) (max 8000 characters)

The goals of this project are, *i)* the realization of monthly temperature and precipitation 1961-1990 climatologies at 30-arc-second resolution for the Italian Alpine region and, *ii)* the construction of monthly temperature and precipitation data sets (time series) in absolute values for the past decades, at the same resolution, for some target areas. The latters will be defined on the basis of data availability, with particular attention to natural parks and protected areas.

TASK 1. *Data rescue.*

This task is aimed at setting up the bases of data to be used for the construction of the climatology and the anomaly fields (tasks 3 and 4 respectively).
An inventory of monthly temperature and precipitation data already available in digital form for the Alpine region will be compiled and accessible data rescued.
If necessary, additional data will be digitalized to fill spatial gaps. In addition to termo-pluviometric data, a set of pluviometric observations referred to very remote areas will be recovered by digitalizing some "nivo-pluviometric totalizer" data measured by the former National Hydrographic Service between 1920s and 1970s. These data, even if do not cover the 1961-1990 period, will be very important to fill a gap in precipitation observations at very high elevation. Moreover, nivo-pluviometric totalizer should be less biased by wind in snow and precipitation measurements.
Besides the data required for the climatology construction, particular attention will be given to the recovery of long temporal series that will be used for the construction of the temporal component. Based on the availability of long temporal series, some case study areas will be identified and a 30-arc-second spatial resolution data set of temporal series will be reconstructed for them. We will focus in particular on the National Park of Paneveggio and Pale di San Martino, where a good data coverage is potentially available; other areas will be selected in the western sector of the Alps between Lombardy, Piedmont and Valle d'Aosta, based on the data availability verified in the data inventory/rescue activity. Among others, potential interesting areas are the Stelvio and the Gran Paradiso National Parks.

Deliverable 1.1. Inventory (table list) of monthly temperature and precipitation data available in digital form for the Italian Alpine area and surroundings (Month 9).

TASK 2. *Quality control and homogenization.*

All the data will be subjected to quality checks and consistency as far as their geographical location is concerned. Such checks will be performed by comparing

each site's elevation with that of a 30-arc-second digital elevation model (DEM). All major discrepancies will be corrected by means of metadata or web mapping tools such as Google Earth. This detailed data verification, though extremely time consuming, is very important to enhance the reliability of the stations elevation, as incorrect elevation values can introduce significant errors in the estimation of the relation between the meteorological variable and elevation, which represents the key-point of the model for the construction of climatologies (see TASK 3). Finally, for all the available stations the 1961-1990 monthly normals will be extracted (the choice of the 1961-1990 period is suggested by the wider data availability in that 30-year time window for Italy). When the 1961–1990 period is not completely available (or not available at all), the normals will be calculated with the available data and the database of the Italian temperature and precipitation anomaly records presented by Brunetti et al. (2006) will be used to adjust them to the 1961–1990 period.
The longest series, useful for the reconstruction of the temporal component, will be subjected to additional quality controls to ensure their homogeneity and, if necessary, they will be homogenized by means of statistical methods (Brunetti et al., 2006).

Deliverable 2.1. Registry (table with data) of stations' monthly climate normals (referred to 1961-1990), geographical coordinates and associated geomorphological parameters (Month 12).

Deliverable 2.2. Metadata (coordinates and quality flags) of long series that will be involved in the reconstruction of the temporal component (Month 15).

TASK 3. *High resolution 1961-1990 climatologies of monthly temperature and precipitation at 30 arc-second resolution for the Italian Alpine region (h>1500 m asl).*

The climatological grid construction will be based on a model that evaluates the meteorological variable on each point of the USGS GTOPO30 DEM.
The methodology that will be adopted evaluates a "local" relationship between the meteorological variable vs elevation on each point of the DEM over the examined area.
In particular, the value of the meteorological variable for each point of the DEM, is estimated with a weighted linear fit of the meteorological variable vs elevation by choosing the neighbouring stations with geographical features similar to those of the DEM cell itself.
In this procedure the definition of the weights plays a key role. The weight assigned to the i-th station involved in the linear regression will be obtained as the product of the following weights: radial weight, elevation weight, slope weight, slope orientation weight, and sea distance weight.

Besides a good performance in terms of station errors, the proposed method has the additional advantage to permit the estimation of a prediction interval for any grid point of the considered domain.
If their spatial resolution will be sufficiently high, the outputs arising from the results of the activity of theme 4 of the present NextData call (high resolution non-hydrostatic simulations) will constitute a useful additional information to improve the precipitation reconstruction of the highest elevation areas of the domain.

Deliverable 3.1. 30 arc-second resolution 1961-1990 climatologies (the data will be provided) of monthly temperature and precipitation for the Italian Alpine region (h>1500m asl) (Month 21).

Deliverable 3.2. Monthly temperature and precipitation confidence interval associated to any grid point of the considered domain (Month 21).

TASK 4. *Realization of data sets (time series) of monthly temperature and precipitation series in absolute values for the past decades in some target areas.*

The approach that will be used assumes that the spatio-temporal structure of the meteorological variable over a given area can be described in terms of the superimposition of two fields: the normal values related to a standard time period (e.g. 1961-1990), i.e., climatologies, and the deviations from them, i.e., anomalies. The projection of the latters onto a high-resolution grid is fully justified by the fact that the temporal fluctuations of meteorological variables, linked to the variability of climate, present a high spatial coherence. On the contrary, the climatologies, linked to the geographical characteristics of the territory, present very strong spatial gradients and a higher number of stations is needed, though on a limited temporal interval.
The anomaly records at each point of the area will be calculated by means of an improved version of the method described in Brunetti et al. (2006), with the introduction, besides the radial weight, of an elevation and an angular weight. The latter takes into account the anisotropy in the spatial distribution of the stations.
Then, the information coming from the spatial distribution of the normal values (TASK 3) will be combined with those coming from the spatio-temporal behaviour of the anomalies, to obtain a high-resolution grid of temperature and precipitation series in absolute values for target areas. Absolute values will be simply obtained by summing/multiplying (precipitation anomalies are defined as ratios to the mean) the two fields (climatologies and anomalies).
The target areas will be identified in the frame of TASK 1, on the base of the data availability.

Deliverable 4.1. Data sets (time series) of monthly temperature and precipitation series in absolute values for the past decades in target areas (Month 28).

Milestone 1. Definition of a well performing methodology to produce high-resolution virtual temperature and precipitation records (Month 28).

Milestone 2. Monthly temperature and precipitation climatologies at 30-arc-second resolution for Italian Alpine area (h>1500 m asl) (Month 28).

Milestone 3. Monthly temperature and precipitation local virtual records for the past decades at 30-arc-second resolution for some target areas in the Alpine region (Month 28).

Note: Only gridded data and not stations' data will be made available to respect the data policies of the different data providers.

Time schedule:

MONTH	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
YEAR	2013							2014												2015								
TASK 1																												
TASK 2																												
TASK 3																												
TASK 4																												

Ref.: Brunetti et al. 2006. Int. J. Clim., 26, 345-381.