Validation of a regional agro-meteorological network in Central Italy using ECMWF ERA5 reanalysis

Paolina Bongioannini Cerlini[1] and Lorenzo Silvestri[1]

[1]CIRIAF-CRC (University of Perugia)

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Abstract

During the analysis - funded by The European Agricultural Fund for Rural Development (EAFRD) that has financed the EU's contribution to rural development program in Umbria (Italy) – of meteorological data from automatic weather stations following the WMO requirements [1], it has become evident the need of using the newest global climatic data (ERA5, ECMWF [2]) to compute indices to perform an extended quality control over data and to give climate information to the end users. The peculiar regional environment with strong orographic modulation of the Umbria region and the consequent impact over the precipitation field together with the signal of a seasonal and intra-seasonal change of the temperature distribution, show a complex impact of the climate change over the Umbria region and broadly over Central Italy. This work is trying to show how to account for the impact of climate change over the phenology of vineyards using different indices as SPI , SPEI, and Winkler starting from the new reanalysis dataset with enhanced resolution in time and space. Moreover, within this project agronomists and plant pathologists are cooperating with meteorological scientists to analyze and relate weather epidemic development in order to reduce the economic impact and environmental effects of airborne plant disease epidemics and ultimately to make the end-users timely decisions about the effective and economical application of fungicides and about other tactics to manage plant diseases. [1] WMO. Guide to agricultural meteorological practices (WMO-no. 134). World Meteorological Organization: Geneva, Switzerland, 2010. [2] https://www.ecmwf.int/en/forecasts/datasets/archive-datasets/reanalysis-datasets/era5

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P. Bongioannini Cerlini[1], L. Silvestri[1], A. Onofri[2], M.Farneselli[2]

[1] CIRIAF-CRC, University of Perugia, Italy (paolina.cerlini@unipg.it)

[2] Department of Agricultural, Food and Environmental Sciences, University of Perugia, Italy

Introduction

"Validation is a process used to determine whether data are inaccurate, incomplete, inconsistent or unreasonable" [1].
This project is part of the rural development program in Umbria (the small region in Central Italy shown in figure 1) founded by the European Agricultural Fund for Rural Development (EAFRD). The main objectives are:

- Collection of agro-meteorological fundamental variables [2] and climatic data on the regional territory;
- Implementation of quality control procedures following the WMO standard requirements [1];
- Interpolation of validated meteorological data;
- Data correction by means of gap-filling and data-cleaning procedures in order to obtain complete and reliable time series.

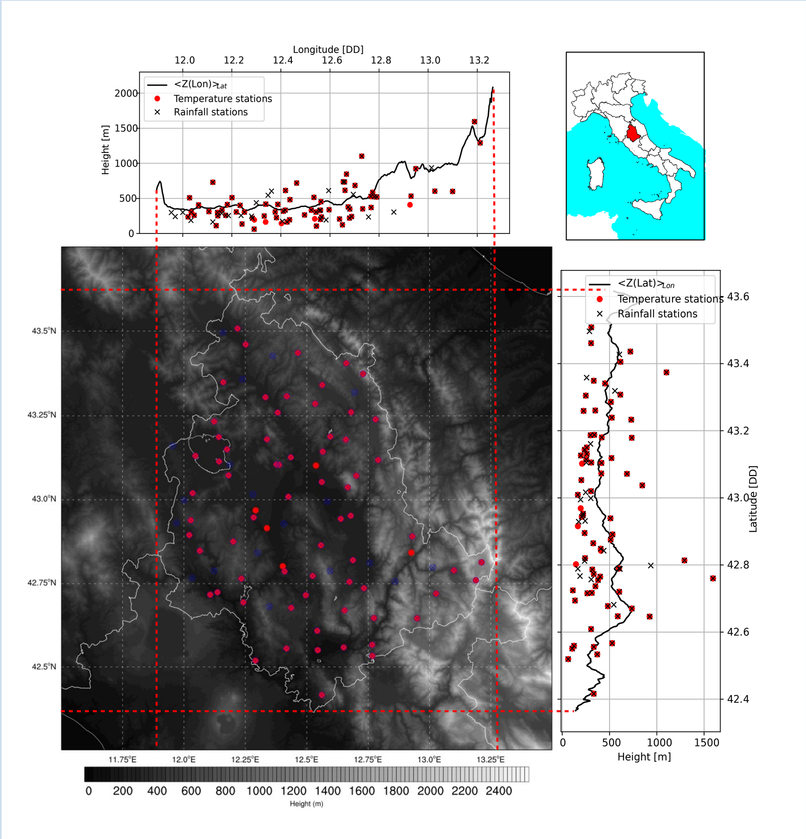

Figure 1: Topography of the Umbria region: (on the center) the topography height of the region as derived by the SRTM DEM (with spatial resolution of about 90 meters) together with the rainfall (blue cross) and temperature (red dots) stations used in this study; (on the upper right corner) the location of Umbria with respect to the Italian country; (on the top) the latitudinal average of DEM cell height contained inside the regional limits together with the discrete altitude distributions of the regional network; (on the right side) the longitudinal average of DEM cell height. The surface extension is about 8464 km^2, while the Utilised Agricultural Area (UAA) is 3262 km^2, about the 40% of the total area. The grid spacing in this figure is about 31 km.

Data

Four different data have been used during this analysis:

1. **Regional automatic weather stations (AWS)**: about 92 stations are located on the region, 67 of which measuring both rainfall and temperature. The available temporal extension of these data is from 2010 to March 2018. Other important variables like solar radiation, relative humidity and wind are actually available only in few, unreliable and recently implemented stations and therefore disregarded in this analysis;
2. **ERA 5**: the new reanalysis of the ECMWF with hourly time resolution and with 30 km grid resolution available from 1979 to within 3 months of real time [3];
3. **E-OBS**:the new ensemble version of the European daily high-resolution gridded dataset of surface temperature and precipitation [4];
4. **ArCIS**: the high resolution gridded climatological dataset over North-Central Italy ([5]). Until now only daily precipitation is available from 1961 to 2015. The spatial resolution is about 5 km.

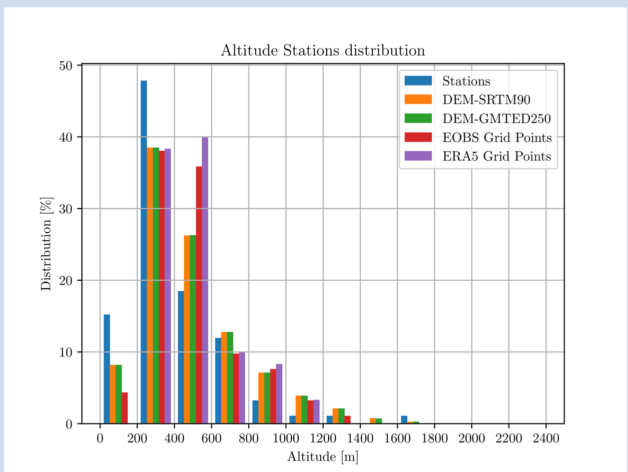

Figure 2: Percentage altitude distribution of the grid cells or the station points of the different data listed in this box, with respect to the digital elevation model resolution. Stations distribution is actually representative of the different altitude ranges except between 800-1400 meters of altitude. ERA5 grid points are not present below 200 meters, while E-OBS grid points are covering all the altitude ranges except those above 1400 meters.

Validation procedure

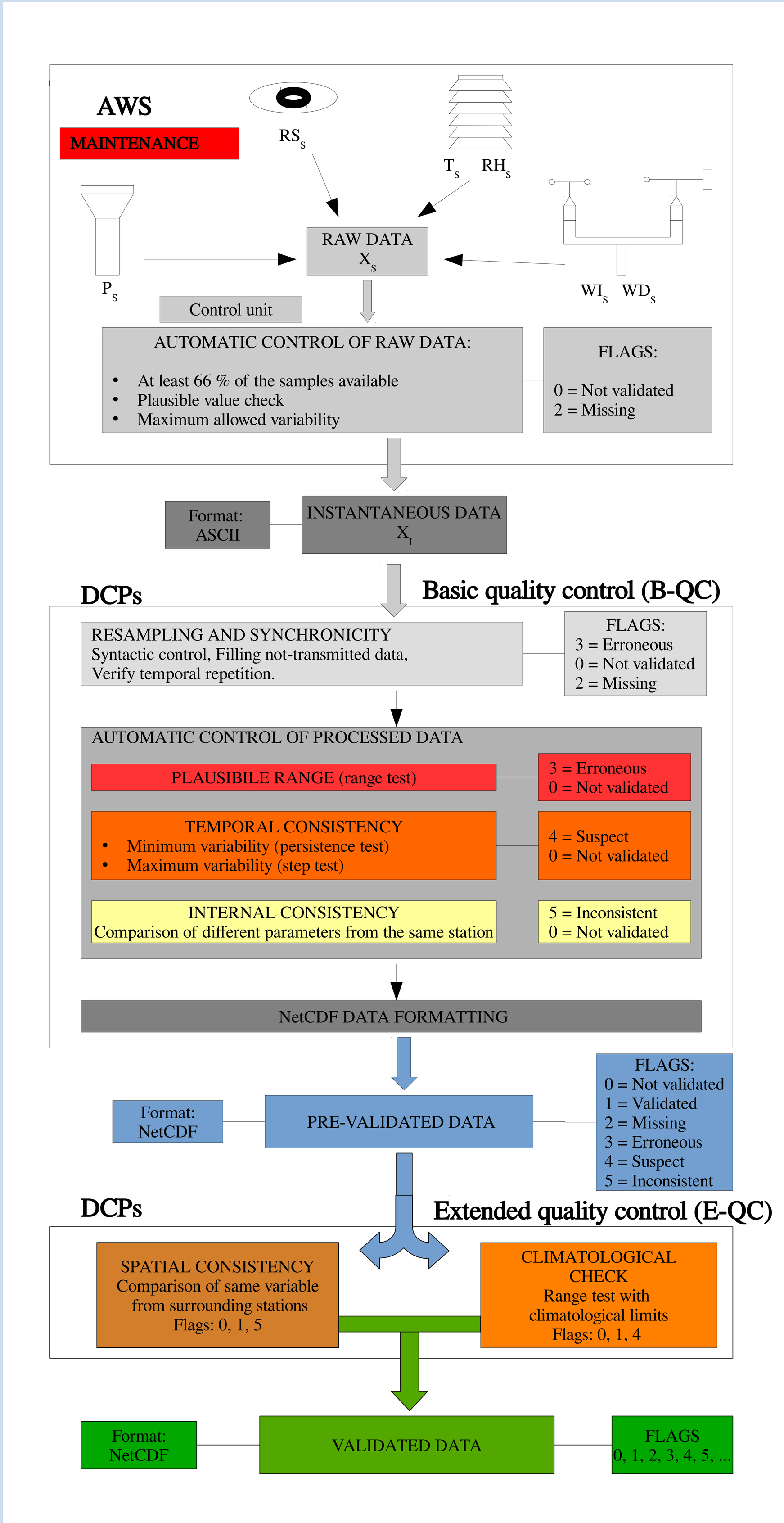

Figure 3: Flow diagram of the validation procedure. Each test should produce its own flag (bitmask) in order to detect which type of failure occurs during the procedure. It should be notice that not all the tests are common to all variables. For example the spatial consistency test is not applied to precipitation.

The validation procedure is made by three step (figure 3):

1.**Automatic quality control of raw data**: it is assumed that automatic weather stations (AWS) fulfill basic requirements in transforming raw data into processed data and that maintenance is made at least one time per year.

2.**Basic quality control of processed data**: range, temporal consistency and internal consistency tests follow common international guidelines [1], except for precipitation temporal consistency that is evaluated following national guidelines [6].

3.**Extended quality control of processed data**: the spatial consistency test is carried out by spatial regression technique, while the climatological check has to be implemented by using ERA5 reanalysis data since its high quality temporal and spatial resolution.

Var		*Miss*	*Range*	*Pers*	*Step*	*Spat*	*Valid*
T	Mean	4.73	0.001	2.42	2.46	3.08	89
	Std	12.66	0.008	9.09	2.18	6.47	17.29
	Max	32.44	0.068	48.12	11.9	40.1	98.1
		Miss	*Range*	*Att*	*MissPre*	*Isol*	*Valid*
P	Mean	6.69	0.031	0.016	0.014	0.85	92.42
	Std	10.59	0.05	0.02	0.001	0.2	10.48
	Max	73.67	0.33	0.09	0.01	1.49	94.81

Table 1: Mean, standard deviation and maximum Percentage of network data flagged by each test

Interpolation

The interpolation of station data is carried out by using the Barnes algorithm (a convergent Gaussian weighted average interpolation technique). Hourly data are interpolated on the DEM grid with a spatial resolution of 250 meters. The temperature field is firstly detrended by its topographical component using a double lapse rate analysis [5]. This spatial interpolation represents both a spatialization of station data and a gap filling technique.

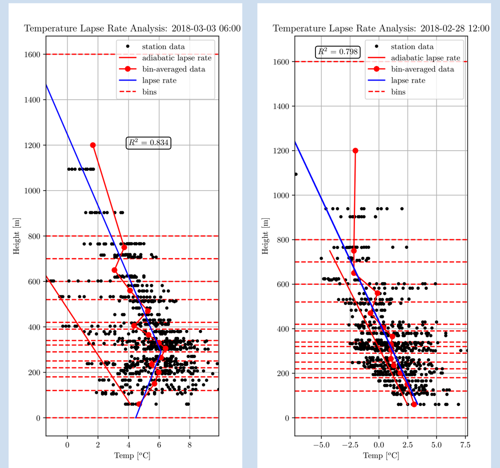

Figure 4: Double lapse rate analysis. On the left side: example of detection of temperature inversion, a phenomenon frequently observed in Umbria. On the right side: single lapse rate example used to produce the map in figure 5.The squared correlation coefficient R^2 is used as a measure of the goodness of the linear piecewise regression.

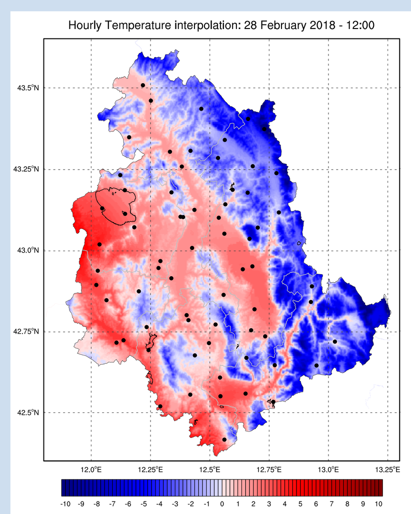

Figure 5: Interpolation of the Temperature field. An example of the gridded temperature field obtained from the superposition of the mean topographic component and the residual component of station data (represented by black dots)

Climatic indexes

Climatic indexes are fundamental both for studying the impact of climate change over the crops' phenology and validating the collected data. Climatic trends, seasonal and intra-seasonal changes of variables distribution founded in other data should be reflected also by the regional network data.

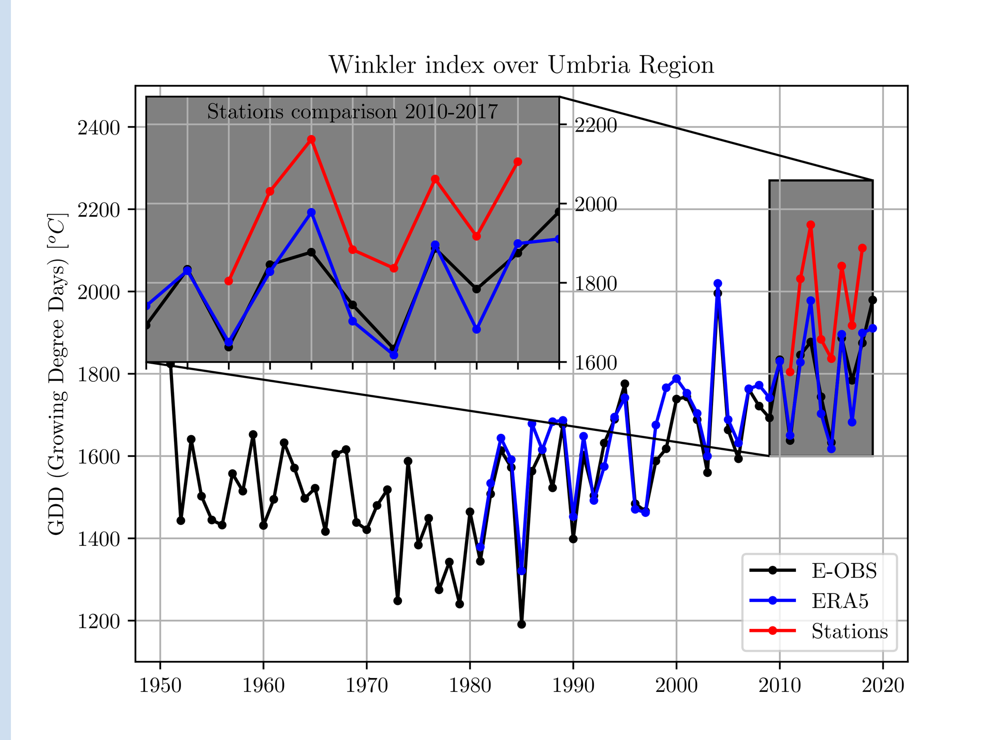

Figure 6: Winkler index areal average time evolution. The Winkler index (or GDD, Growing Degree Days) is the summation of all the daily average temperatures above a base temperature (10 ^oC) during the crop growing season (April-October for grapevines in Northern Emisphere). This figure highlights the positive trend (very similar between ERA5 and E-OBS data) of this index over all the region. The same trend, together with the annual variability, is found also on the station data. However a significant BIAS is present between stations and the ERA5 reanalysis. This could be due to many different components, among which the non-uniform altitude distribution of stations location, as shown in figure 2.

Conclusion and further developments

A first procedure has been implemented in Umbria region for the validation and interpolation of hourly temperature and precipitation data coming from the regional network. Further improvements will focus on:

- Collecting other fundamental agro-meteorological variables like relative humidity, wind and solar radiation for a longer time interval;
- Implementing other extended quality control procedures like homogeneity test and climatological checks against external data;
- Modifying the gap-filling, data-cleaning and interpolation techniques by using either advanced statistical methods (optimal interpolation and EOFs) to relate stations data both in the temporal and spatial dimensions or by debiasing ERA5 reanalysis data.
- Calculating other important indexes as PET, SPI and correlate them to phenological data in order to support decisions of end-users and disseminating regional climatic information.

Acknowledgements

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