Proceedings of the Resilient Cities 2014 congress

Session B3: Adaptation on the ground in Bologna, Italy

Observed climate profile at local level – BLUEAP Bologna case study

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Abstract:

A detailed framework of present and future climate changes at local level represents an important tool in the study of impacts as well as in the construction of adaptation and mitigation strategies. One objective of **2011 Life+ project BLUE AP** for the adaptation plan of the city of Bologna, is to produce information about observed and future climate changes, risks and vulnerability in the city and to define local measures in order to make it more resilient. The present work is focused on the construction of observed local climate profile for Bologna, derived from the analysis of the observed climate variability of the main climatological fields. To this aim, daily minimum, maximum temperature, and precipitation registered by the historical station of Bologna over the period 1951-2011 have been used. Trends and changes in seasonal minimum, maximum temperature, total amount of precipitation, heat wave duration index, frost days and consecutive number of dry days have been analyzed over the observed period.

The observed climate profile reveals significant positive trends in seasonal minimum and maximum temperature and a slightly decrease in precipitation. As regards extreme events it has been detected: an increase in heat wave and consecutive dry days, more intense during summer, and a decrease in winter frost and ice days.

Keywords:

Local climate profile, Temperature, Precipitation, Extreme events

1. Introduction

The last IPCC report (IPCC,WG1-2013) underlined that "the warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia". This hypothesis is sustained by the results derived from the analysis of the climatological fields (for example temperature, precipitation) from different areas and over different periods of time. The results contribute to the understanding of the past and present climate variability and also to the construction of future climate change scenarios using different tools. The climate analysis requires in generally long time series, in order to estimate the significance of signal, and also large area in order to capture better the spatial variability (basin, region, continent) needed for the assessment of the impacts of climate variability and change in a given area, and necessary for planning adaptation and strategies.

This connect to the idea that in order to design adaptation strategies over a region, first step is to investigate the "present and future climatic stimuli", that means detailed study of present and future climate variability over the region is required. Of course, thinking at the definition of the climate system, the work concerning the climate profile at local scale has to be integrated with the results obtained over a larger area.

A complete framework of climate variability requires analysis focused not only on mean values, but also on extreme values. During the last century the frequency of extreme events in Europe has significantly changed. For example: an increase in the frequency of extreme events associated to higher temperature and a decrease of the frequency of events associated with lower temperature have been observed. As concerns precipitation, an increase of intense precipitation and of dry events have been registered. Similar signal of changes have been obtained at smaller scale, for example over Italian peninsula (Toreti et al.,2010), Northern Italy. Positive trend of temperature has been detected in Emilia –Romagna over the period 1961-2011, more intense in maximum (0.5°C/decade) than in the minimum (0.3°C/decade) temperature. The analysis of extreme temperature revealed also an increase in 10th and 90th percentile associated with a decrease in winter frost days and an increase in summer heat waves, over the period 1958-2000 (Tomozeiu et al., 2006). As concerns precipitation from Emilia-Romagna, seasonally, a slightly negative trend had been recorded in winter, spring and summer precipitation, while a positive trend had been obtained during autumn. Pavan et al.,(2008) founded negative trends in the number of wet days during winter and spring and positive trend for the number of days with intense precipitation during summer season.

2. Data and methods

Bologna is located in Emilia Romagna, region situated in the Northern Italy. The meteorological station used in this study was initially placed in via della Zecca, then has been moved to Piazza VIII Agosto (height 51m., latitude 44°29'36'' and longitude 01°06'25''). Daily minimum, maximum temperature, and precipitation registered by the historical station of Bologna over the period 1951-2011 has been take into account. The data has been checked from the quality and homogeneity point of view in the framework of ERACLITO project (Marletto et al.,2010). The following climatic indices had been selected, computed and analyzed at seasonal and annual level, in order to construct present climate profile for Bologna city:

- seasonal and annual minimum (Tmin) and maximum temperature (Tmax);
- the 90th percentile of maximum temperature (Txq90);
- the 10th percentile of minimum temperature (Tnq10);
- the number of frost days, defined as the number of days when the minimum temperature is under 0°C (Fd)
- the number of ice days, defined as the number of days when the minimum and maximum temperature are under 0°C (Txice)
- heat wave duration (HWD), defined as the maximum number of consecutive days with maximum temperature greater than daily 90th percentile. This index has been computed for each season and particular attention has been paid on summer season;
- seasonal and annual amount of precipitation (prec);
- the number of days with precipitation greater than 90th percentile;
- the number of consecutive dry days, defined as the maximum number of consecutive days without precipitation (pxcdd).

The above indices were selected such as to describe the intensity and the frequency of extreme events. Trend analysis have been performed for each seasonal index, with focus on extreme indices, and the significance of trends has been tested through statistical test (Kendall-Tau test).

3. Results

3.1 The observed variability of minimum and maximum temperature

The analysis of annual minimum and maximum temperature registered at Bologna emphasis a positive and significant trend over the period 1951-2011(up to 0.3°C/decades). The signal of warming became more intense after 1990, when peak of 2.5°C of anomaly had been registered for both minimum and maximum temperature. The positive trend of temperature has been detected also at seasonal level, more intense especially after 1990, when peaks of anomalies up to 4°C had been registered, for example during summer (Figure 1).

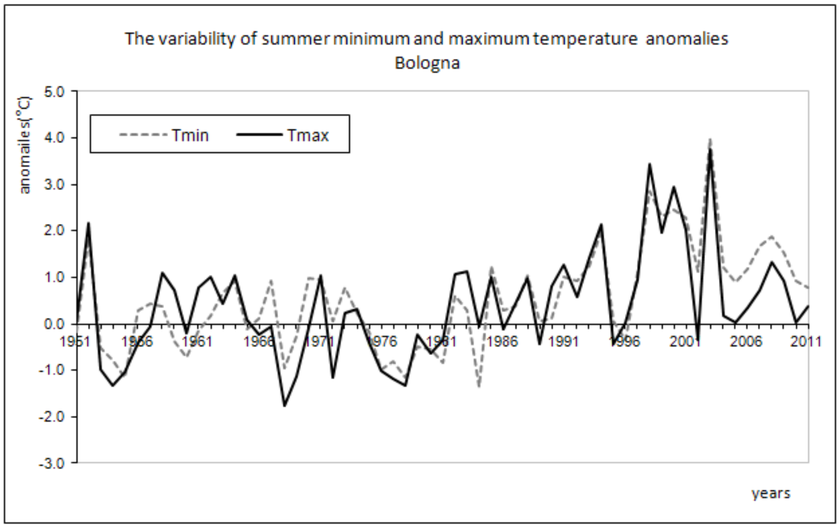


Fig. 1 The temporal variability of summer minimum and maximum temperature anomalies – Bologna

A similar tendency of increases has been detected analyzing the extreme temperature computed starting from daily data. For example, 10th percentile of minimum and 90th percentile of maximum temperature exhibits positive and significant trends for each season and at annual level, more intense in the 10th percentile of Tmin and especially during winter (0.6°C/decade) and spring (0.4°C/decade). Table 1 reports the coefficient of trends for 10th of Tmin (Tnq10), number of frost days(Fd), number of ice days (Txice), 90th percentile of Tmax (Txq90).

Season	Trend (°C/decade) Tnq10	Trend (days/dec.) Fd	Trend (°C/dec.) Txice	Trend (°C/dec.) Txq90
Winter (DJF)	0.6*	-4*	-1*	0.3*
Spring (MAM)	0.4*	-4*	n.s.	0.2*
Summer(JJA)	0.3*	-	-	0.3*
Autumn(SON)	0.3*	n.s	n.s.	n.s

Tab1. Seasonal values of trend coefficient of extreme temperature over the period 1951-2011, Bologna. The values significant at 95% are marked by stars, while the values that are not significant are marked by n.s.

As could be noted from table 1, the increase in the 10th percentile of minimum temperature connect to a decrease in the number of frost days, significant during winter and spring seasons (4 days/decade). As regards the trend of seasonal ice days, only winter season shows significant decrease in the index. An important signal has been detected also in extreme of maximum temperature, especially in the heat wave duration index. The heat wave duration is defined as the maximum number of consecutive days with maximum temperature greater than daily 90th percentile computed over the climate period (1961-1990). Figure 2 presents the evolution of the summer heat wave duration (continuous line) and the climatic value of the index (dashed line) at Bologna. The climate value of the index is around 3 days (dashed line), but after 1990 the index registered high value, up to 12 consecutive days. This shift point founded in the extreme of temperature is in agreement with those detected in the mean of minimum and maximum temperature.

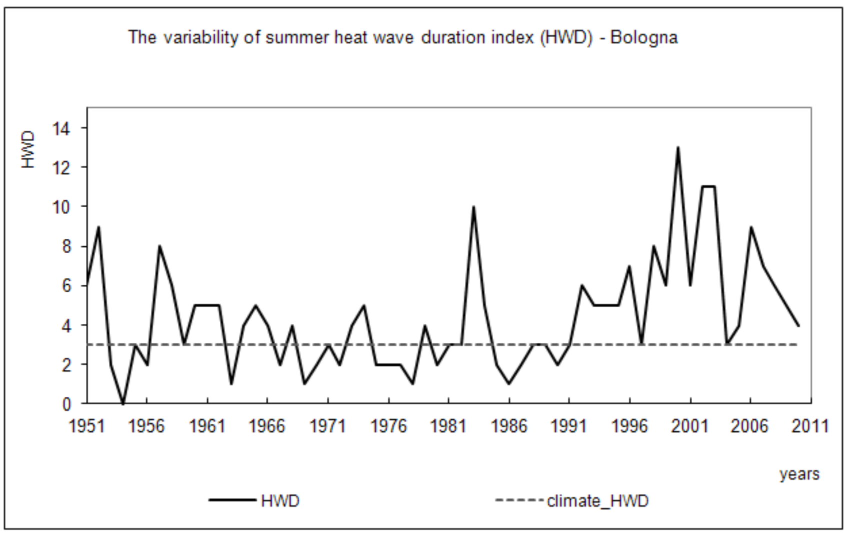
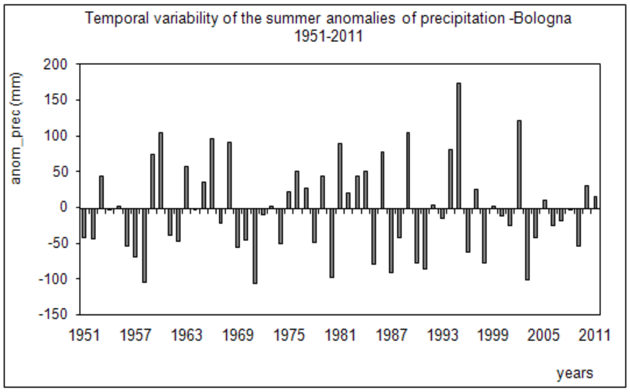


Fig.2 The evolution of the time series of heat wave duration (continuous line) and the climatic value of the index (dashed line)

3.2 The observed variability of precipitation

The quantity of precipitation registered at Bologna shows a slightly negative trend during winter, spring, and summer and a positive trend during autumn, over the period 1951-2011. Figure 3a presents like an example the variability of summer anomalies of precipitation. As could be noted there are years with intense positive/negative anomalies, but during the last decade negative anomalies have been frequently registered. This pattern of precipitation, especially of the last decades influenced also the distribution of extreme of precipitations. For example, it has been noted that the dry days index presents a positive trend over 1951-2011 period, more intense during summer. Figure 3b presents the temporal variability of maximum number of consecutive dry days during summer with an increase of the values of index especially during the last decade. As it could be noted, the index presents a climatic value (1961-1990) around 15 days, the last decade registered high value (up to 50 days consecutive without precipitation).

a)



b)

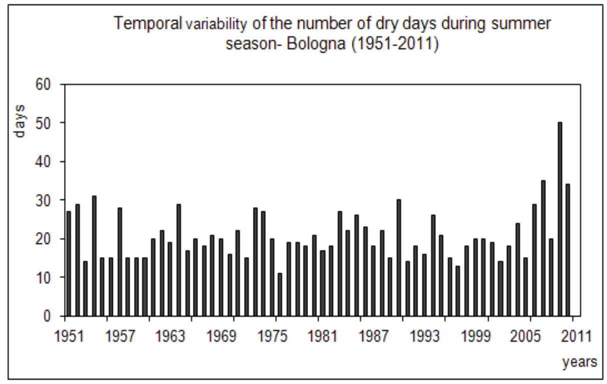


Fig. 3 The variability of the anomalies of precipitation(a) and consecutive dry days(b) – Bologna

A slightly positive trend has been detected also in the frequency of days with intense precipitation in all season, except on spring when a slightly negative trend has been observed (figure not shown).

The results of the observed profile constructed for Bologna city are in agreement with those described over Emilia-Romagna region (Tomozeiu et al.,2006; Pavan et al.,2008), and represent the baseline in the construction of the future climate profile at Bologna. To this aim, a statistical downscaling scheme (Tomozeiu et al.,2013) had been developed in the project, starting from observed local profile and large scale data. The statistical model have been applied to global climate models (6GCMs) that run in the Ensemble project (van der Linden,2009). Climate change scenarios of seasonal minimum and maximum temperature obtained through statistical downscaling technique applied to GCMs experiments, estimate a possible increasing in both minimum and maximum temperature at Bologna, in all seasons and over both periods: 2021-2050 and 22071-2099 with respect to 1961-1990. The peak of increasing appear during summer when the projected changes is around 2.5 °C over the period 2021-2050, and around 5.5°C over 2071-2099(http://www.blueap.eu/site/now-on-line-pubblicato-il-profilo-climatico-locale-del-comune-di-bologna/). As regards precipitation, a reduction of the amount has been projected during all seasons, more intense to the end of century and especially during summer season (reduction around 30%).

4. Conclusions

The results of present climate variability at Bologna could be summarized as follows:

- positive and significant trends of seasonal minimum and maximum temperature over the period 1951-2011 (around 0.3°C/decade) have been detected. During the analyzed period, an increase in the heat wave duration , especially during summer, and a decrease in winter frost and ice days has been founded. These signals became more intense after 1990, when strong and positive anomalies in temperature have been recorded (for example summer 2003, winter 2007-2008);
- as concerns observed precipitation, the signal of trend is different from season to season. A slightly decrease have been observed during winter, spring and summer, while a slightly increase has been noted during autumn. The observed consecutive dry days shows an increase during summer season, when it was noted also an increase in the frequency of the number of intense precipitation.

The results presented above underlined that important changes have been noted in the past climate of Bologna, with relevant impacts in different sector. The analysis emphasizes the main vulnerability factors of the city, namely: drought /water scarcity, heat wave, extreme events and hydrometerological risks.

Acknowledgements:

The ENSEMBLES data used in this work was funded by the EU FP6 IP Ensembles (Contract nr 505539) whose support is gratefully acknowledged. The results have been obtained in the framework of BLUE AP Life+ project (http://www.blueap.eu/).

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Rodica Tomozeiu works in the climate field since 1995. She is graduated in Physics at the University of Bucharest, Romania (1991) and holds a PhD in Physics/Physics of the atmosphere at the University of Bucharest (2001). Starting with 1999 up to present she has developed her activity at ARPA-SIMC (Italy). The main topic of her research covers: past and present climate variability, statistical downscaling techniques, climate change projections, validation of the global climate models, evaluation of the uncertainties in the statistical models.

Lucio Botarelli is graduated in agronomy (1982), attended the Interregional qualification course in agricultural meteorology (1986) and specialized in the WMO 2nd International post graduate course in agrometeorology (1989). In 1986 he joined the Regional Meteorological Service in ERSA first, then in Emilia-Romagna Regional Administration and eventually in ARPA, the Regional environmental agency. Since 2005 he has been head of the agrometeorology unit, later including the climate activities and studies.