Preliminary comparison study of two independent precipitation network in Piedmont

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Abstract

Long historical climate records typically contain inhomogeneities. Parallel measurements are ideal to study such non-climatic changes. In this study we will analyze the transition from conventional precipitation observations to automatic weather stations. The dataset comes from two independent climate networks in the region of Piedmont, Italy. From this dataset we could identify 20 pairs of stations with up to 17 years of overlap. This is a valuable dataset because it allows us to study an ensemble of independently managed pairs of standard-quality stations. The main systematic differences was found in the number of weak rainy events The automatic weather stations report more events. On average they report 7 events more per year. While for the heavy and extreme precipitation, in some cases, we have identified great differences between the two series that can falsify the behavior of the variables.

Keywords: daily precipitation, parallel measurement, inhomogeneity

1. Introduction

Climate change is one of the great environmental concerns facing mankind in the twenty first century. The major changes are likely to occur in the global hydrological and energy balance. The greatest threat to humans will be manifested locally via changes in regional extreme weather and climate events. The society is particularly vulnerable to change in frequency and intensity of extreme events such as heavy precipitation, droughts and heat waves [11, 12].

Long term climate datasets are essential to study climate change. More specifically, long series of rainfall are essential for various hydrological applications related to water resource planning, power production, irrigation, flood control, forecasting and validation of remotely sensed data from space platforms. However, these applications require high quality long series. The observations need to be recorded, transmitted, digitized, quality controlled and then examined by an expert familiar with the instruments and the climatology [13].

Italy has a leading role in the development of meteorological observations. This interest in meteorology over the last three centuries has produced a wealth of observational data of enormous value.

This long legacy, however, also means that the Italian networks have experienced many technological, economical and organizational changes, which may affect the homogeneity of the record [4,15]. Consequently, studies on non-climatic changes are necessary to be able to reliably interpret the climatic changes [14]. For precipitation gauge measurements inhomogeneities can be cause by changes in the instruments, in the position or changes in the surrounding environmental [2,5].

It is necessary to apply a homogenization procedure to detect and correct non-climatic changes. [18].

These homogenization corrections allow the quantification of the climatic changes in the mean value of precipitation and in some indices of rain [7, 10, 12]. These studies found significant increasing trends in the mean annual precipitation and in the average precipitation intensity, in particular in winter. The extreme weather and climate events that have a deep impact on society are studied less because they require high-quality daily series. The most direct way to study non-climatic biases in daily data relies on parallel measurements with multiple measurement set-ups.

In this study we have analyzed the recent transition to automatic precipitation measurements in Piedmont, Italy.

An important feature of our study is that it is based on 20 pairs of nearby high-quality stations. This enables us to study the variability of the inhomogeneity from station to station and in particularly to understand as the discontinuities occur on the precipitation events classified as weak, moderate or extreme.

2. Methodology

In this study we have analyzed the difference between the precipitation events recorded by two independent networks present in the Piedmont region, North-Western Italy, during 17 years, from 1986 to 2003 [1]. Then we have evaluated the effects of the differences on the climate analysis.

The first network considered is the Hydrographic Mareographic Italian Service (SIMN) which was founded in 1913. In the closing year, 2002, the SIMN in Piedmont handled only 142 meteorological stations in total.

Most of the rainfall stations of SIMN have used a tipping bucket rain gauge with a calibrated mouth (1000 cm^2). The height of the mouth was typically 2 m. The stations of SIMN require the presence of an operator for collecting the measurements. The registration of the rain gauge was done on a paper roll, which needed to be collected weekly and read for the manual transcription of the values [Fig. 1].

A new meteorological network managed by Agency for Environmental Protection Piedmont (ARPA) was build up in Piedmont starting 1986. In the first year ARPA had 42 stations. Now it is extended to 400 automatic stations with a density of 1 rain gauge per 70 km^2 [8].

The instrument used by ARPA is a rain gauge with a calibrated mouth (1000 cm^2) and a tipping bucket. The height of the mouth is 1.5 m. The data are subjected to an immediate quality control, during which a flag is attached to every value and the data is directly transmitted to the database [Fig. 1].

Fig. 1: (left) Photos of rain gauge used by SIMN to measurement the rain; (right) Photo of rain gauge utilizing by ARPA Piedmont.

In 2002, a national law has forced the unification of the meteorological networks owned by the SIMN with those of the ARPA. Because the ARPA network was more modern, ARPA has decided to discontinue the SIMN stations after unification for reasons of technological innovation and cost-effectiveness.

In Piedmont there are therefore rain series from two different meteorological networks; the SIMN network, with data collected from 01/01/1913 to 31/12/2002 and the ARPA network of automatic stations, that providing information since 1986. This gives us an overlapping period of up to 17 years to study the influence of this transition in detail.

We have selected locations with pairs of stations according to several criteria. First of all, they need to have an overlapping period greater than 5 years [19].

A further selection criterions are the difference in elevation and the distance between two stations. This selection has been based on the results of the work already done [9, 6], in which a spatial consistency check, depending on the elevation difference, less than 200 m, and distance below 20 km, is estimated.

We have selected only 20 pairs of meteorological stations with a long overlap period and a good continuity in the recorded of daily precipitation data [Tab. 1].

Successively we have analyzed if these pairs of stations have recorded the same precipitation events or an instrument overestimates or underestimates a particular rain event. An accurate statistical analysis to identify if the two series have the same statistical characteristics, same distribution, same mean, median, variance and so on, have been conducted [5, 6, 7].

Location	***SIMN elevation***	***ARPA elevation***	***Difference elevation***	***Distance***	***Period***
Ala di Stura	1006	1006	0	70	1993–2003
Bardonecchia	1250	1353	103	800	1991-2003
Boves	590	575	15	1240	1988–2003
Bra	290	285	5	15	1993–2003
Carcoforo	1150	1290	140	2500	1997–2003
Casale M.to	113	118	5	20	1988–2000
Ceresole Reale	2260	2304	44	920	1996–2003
Cumiana	289	327	38	2800	1988–2003
Lanzo T.se	540	580	40	2200	1989–1999
Locana - L.Valsoera	2410	2365	45	250	1987-2003
Luserna S. Giovanni	478	475	3	760	1988–2003
Mondovi	440	422	18	390	1993–2003
Oropa	1180	1186	6	5	1991–2002
Piedicavallo	1050	1040	10	180	1996–2003
Salbeltrand	1031	1010	21	1250	1991–2002
Susa	510	520	10	820	1991–2003
Torino	270	240	30	850	1990–2003
Valprato Soana	1550	1555	5	465	1993–1999
Varallo Sesia	453	470	17	2040	1989–2003
Vercelli	135	132	3	1360	1994–2003

Tab. 1 The 20 selected locations for the compared the SIMN precipitation series and ARPA precipitation series: elevation [m a.s.l.], difference of elevation [m], distance [m] and period of overlap.

We have calculated for every month and for every location the precipitation class using the percentiles calculated for each station on the reference period, from 1961 to 1990. We have divided the rain event in five principles class (weak, moderate, heavy, very heavy and extreme) [Tab. 2]. The heavy and extreme precipitation class were calculated exactly as the RClimdex software created by the Expert Team (ET) on Climate Change Detection and Indices (ETCCDI). RClimdex is one of the more utilized package by the scientific community to calculate the climate indices [3, 13].

For each one, we have calculated the number of events and the amount of rain and then we have compared the results between the pairs of the meteorological stations.

For every year and for each class we have calculated the difference of the number of events and the ratio of cumulate rain.

Class	Range
weak rain (w_r)	R < 50th
mean rain (m_r)	50th ≤ R < 80th
heavy rain (h_r)	80th ≤ R ≤ 95th

very heavy rain (R95p)	R95p = Rclimdex; R>95p
extremely rain (R99p)	R99p =Rclimdex; R>99p

Tab 2: Five precipitation class and their range

3 Results

The first result of the comparison study on precipitation class highlight two difference behavior for precipitation events classified as weak and moderate and events catalogued as heavy, very heavy and extreme. For the weak or moderate precipitation the major difference is estimated in the number of events. Averagely the automatic stations (ARPA) report 7 events more per year for the weak rains and more 3 events per year for the mean rains [Tab. 3]. For the cumulate precipitation these two class does not highlight great difference. The ratio is near to 1 and averagely the ARPA stations record more 3% of annual rain of weak events and more 4% for mean rain events [Tab. 3 and Fig. 2].

Class	Difference number of events	ST_DEV diff	Ratio cumulate precipitation	ST_DEV ratio
w_r	7	23	1.01	0.06
m_r	3	18	1.01	0.08
h_r	-6	13	0.97	0.06
R95p	-4	13	0.92	0.19
R99p	-2	2	0.86	0.14

Tab. 3: The mean annual values of difference of number of events and the mean annual ratio and their standard deviation between the pairs of stations calculated for every precipitation class. The difference is calculated as ARPA events - SIMN events while for the ratio ARPA amount /SIMN amount.

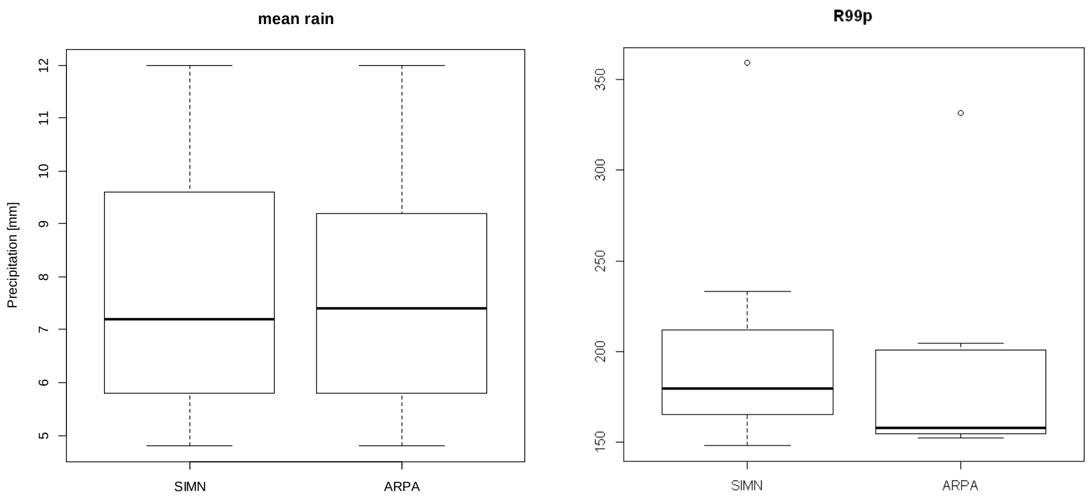

Fig. 2: left box plot of the mean rain recorded by the two meteorological stations of Torino from 1990 to 2002; right box plot of the extremely rain recorded by the two meteorological stations of Oropa from 1990 to 2002.

For the heavy, very heavy and extreme class of precipitation the SIMN stations record a greater number of events and a greater amount of rains respect to ARPA stations [Tab 3]. For the number of events the major differences are highlighted in the heavy rains with averagely more 6 events per year in the SIMN stations while for the ratio in the extreme rains. For the extreme class the SIMN station record averagely more 24% of amount precipitation per year [Fig 1 and Fig 3].

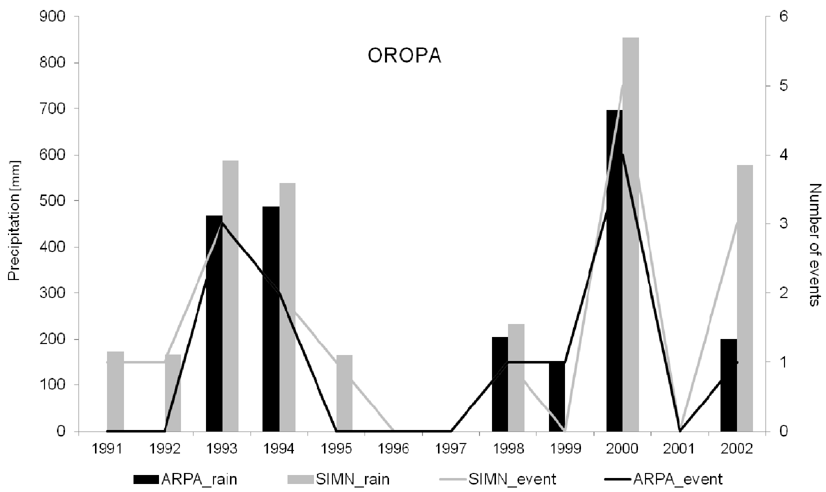

Fig. 3: Amount of extreme precipitation and number of extreme events recorded in the ARPA station, black, and in the SIMN station, grey, for Oropa.

4 Conclusions

We have studied an important non-climatic change in the precipitation record of the Piedmont region. This region has many long daily precipitation series. The meteorological observations have been recorded continuously since 1913.

In 2002 the observational network was replaced by a new automatic network. In 20 locations the transition from the old to the new network has allowed for a period of overlapping measurements for up to 17 years. The overlapping period provides a unique dataset with independently measured parallel observations.

The two networks, SIMN and ARPA, have shown important differences in the measurements of the precipitation.

For the weak and mean precipitation the major difference is estimated in the number of events. The ARPA stations record a greater number of these rainy events and this divergence can alter the real behaviour of some climate indices for example the dry or wet periods.

For the heavy, very heavy and extreme precipitation we have identified great differences between the two series. The SIMN stations record a greater number of events and a consequently a greater amount of rain. These divergences can falsify the behavior of the variables.

The present study has clearly highlighted the importance of analyzing parallel measurements for the study of non climatic changes in the climate record to identify the real variation of the meteorological variable.

Finally, further analyses will be conducted on other manual and automatic stations, in order to quantify the inhomogeneities at regional scale. This is especially important in case of precipitation, where statistical relative homogenization is hampered by low cross-correlations between stations. The differences were found to vary highly from location to location, emphasizing the importance of studying ensembles of parallel measurements over studying single pairs of observations.

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