

# ON THE CONTINUITY AND CLIMATIC VARIABILITY OF THE METEOROLOGICAL STATIONS IN TORINO, ASTI, VERCELLI AND OROPA (PIEDMONT, ITALY)



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The study of the temperature and precipitation deserves great attention because being part of a recent past, they allow us to analyze in detail the variations which have occurred and their causes.

In this report, we have studied the daily thermo-pluviometric of four Piedmont towns: Torino, Asti, Vercelli and Oropa.



Figure 1: Geographic location of the meteorological stations.



Figure 2: Towns of Asti, Oropa, Torino and Vercelli.

STATION	E (m)	LAT N	LONG E	PERIOD	DISTANCE (m)
Torino SIMN	269	45°04'18"	7°47'2,7"	1951-2003	830
Torino ARPA	240	45°04'49"	7°40'25"	1989-2005	
Asti SIMN	158	44°54'34"	8°15'19"	1951-2003	2350
Asti ARPA	117	44°53'09"	8°12'48"	1998-2005	
Vercelli SIMN	135	45°19'50"	8°21'40"	1951-2003	1360
Vercelli ARPA	132	45°19'32"	8°23'26"	1993-2005	
Oropa SIMN	1180	45°37'40"	7°58'57"	1951-2002	5
Oropa ARPA	1186	45°37'40"	7°58'56"	1990-2005	

Table 1: Meteorological stations analyzed: E elevation (m. a.s.l.), LAT and LONG geographic location, period of operation of the instruments and distance (m).

For each site, we have analyzed and compared the series. The stations belong to two different institutions: the ARPA Piedmont (Regional Agency for Environmental Protection) and the SIMN (Hydrographic and Mareographic National Service). The series have different length but there are periods in which the data are measured contemporarily. From the comparison, we have highlighted both continuity and discontinuity among the series, in order to get information which will let us study in a more detailed way the homogeneity of the long duration series.

$$T_{\text{difference\_MAX}} = T_{\text{max\_SIMN}} - T_{\text{max\_ARPA}}$$

For each year we have computed the monthly, seasonally and annual coefficient of correlation during the period of overlapping of the measurements. In order to estimate whether the compared series admit the same distribution we have applied the Kolmogorov-Smirnov test both to the series of maximum and minimum daily temperatures and to the series concerning amount of monthly precipitation.

For the direct comparison between the daily series, we have used the following method: for the maximum and minimum temperatures, we have calculated the series of daily differences among the two stations; for the monthly precipitation, we have computed the series of the ratios between the two station values, according to the formulations here reported:

$$T_{\text{difference\_MIN}} = T_{\text{min\_SIMN}} - T_{\text{min\_ARPA}}$$

$$R = \frac{P_{\text{rain\_SIMN}}}{P_{\text{rain\_ARPA}}}$$

For each new series, a statistical analysis has been carried out. Data exceeding the distribution range of 0.02 and 0.98 quantiles have been neglected. Thus, the average, the standard deviations, the frequency of the ratios and of the differences have been calculated. The Kolmogorov-Smirnov test has been applied to examine whether the data have a normal distributions. The Student test has been applied to assess the obtained results. For both test, an  $\alpha = 5\%$  significance level has been assumed.

	MEAN MONTHLY PRECIPITATION RATIO			
	TORINO	ASTI	VERCELLI	OROPA
N-DATA	147	33	101	140
AVERAGE	0.96	0.98	1.08	1.20
SD	0.15	0.30	0.25	0.21
Q1	0.87	0.83	0.95	1.08
MEDIAN	0.94	0.97	1.08	1.15
Q3	1.02	1.07	1.20	1.26
K-S TEST	0.86	0.99	0.99	0.79
$\rho$	0.98	0.95	0.96	0.99

Table 2: Summary of statistical parameters evaluated for the monthly precipitation series. N-DATA = number of data used, average, SD = standard deviation, Q1 = first moment, median, Q3 = third moment, K-S test = p\_value of Kolmogorov-Smirnov test and  $\rho$  = correlation coefficient.

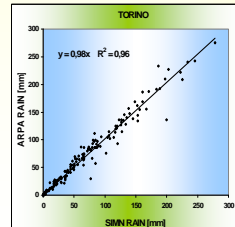


Figure 3: Torino, correlation between the precipitation in the two stations.

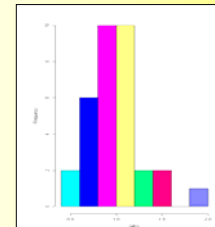


Figure 4: Asti monthly frequency of relations between SIMN/ARPA.

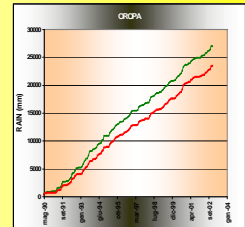


Figure 5: Oropa, cumulate curves of precipitation: red ARPA, green SIMN.

	MAXIMUM TEMPERATURES DIFFERENCE				MINIMUM TEMPERATURES DIFFERENCE			
	TORINO	ASTI	VERCELLI	OROPA	TORINO	ASTI	VERCELLI	OROPA
N-DATA	4635	1855	2677	3539	4665	1879	2618	3564
AVERAGE	-0.65	-0.45	-1.04	-0.57	0.91	0.36	0.48	0.58
SD	0.91	1.00	0.74	1.35	1.09	0.77	0.97	0.81
Q1	-1.30	-1.10	-1.50	-1.40	0.10	-0.10	-0.20	0.00
MEDIAN	-0.70	-0.40	-1.00	-0.50	0.90	0.40	0.40	0.40
Q3	0.00	0.20	-0.60	0.30	1.70	0.90	1.10	1.00
T-TEST	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
K-S TEST	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
$\rho$	0.99	0.99	0.99	0.96	0.98	0.99	0.99	0.99

Table 3: Summary of statistical parameters evaluated for the daily maximum and minimum temperatures series. N-DATA = number of data used, average, SD = standard deviation, Q1 = first moment, median, Q3 = third moment, T test = p\_value of Student test, K-S test = p\_value of Kolmogorov-Smirnov test and  $\rho$  = correlation coefficient.

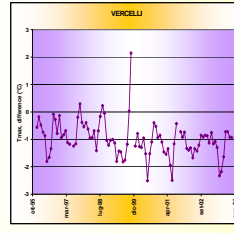


Figure 6: Vercelli series of the monthly mean difference among maximum temperatures.



Figure 7: Cartography of meteorological stations in Vercelli. Right ARPA station and left SIMN station.

The results obtained from the direct comparison between the thermo-pluviometric series of the four station pairs analyzed allow us to highlight that the measurements of the meteorological variables, even if recorded in the same town and at a small distance from each other, can result different, and only in few exceptions (precipitation series of Torino and Vercelli) it is possible to conclude that the two sensors recorded the same values.

The SNHT test has been applied to each 53-year series of the maximum and minimum temperatures measured by the meteorological stations of the ex-SIMN (from 1951 to 2003), to the 55-year precipitation series of Torino and Vercelli (from 1951 to 2005) and to the 53-year precipitation series of Asti and Oropa (from 1951 to 2003). For the maximum and minimum temperatures and precipitation series, several inhomogeneities in the data have been found.

After homogenizing the series, the annual time trends for each variable and series have been evaluated.

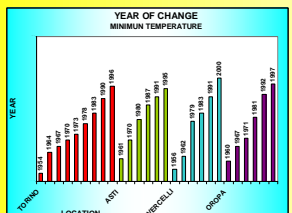


Figure 8: Discontinuity year of the minimum temperatures (left) and precipitation series (right) founded by applying the SNHT.

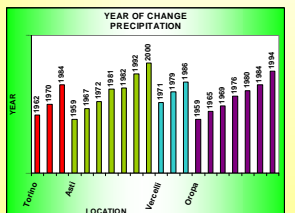


Figure 9: Year of change in precipitation series for Torino, Asti, Vercelli, and Oropa.

STATIONS	(°C/yr)	P value	(°C/yr)	P value	Prec (mm/yr)	P value
TORINO	0.020 ± 0.006	0.002	0.032 ± 0.005	<0.0001	-1 ± 2	0.52
ASTI	0.025 ± 0.007	0.0002	0.003 ± 0.006	0.40	-2 ± 2	0.22
VERCELLI	0.033 ± 0.007	0.0002	0.035 ± 0.005	<0.0001	-3 ± 2	0.26
OROPA	0.036 ± 0.005	<0.0001	0.025 ± 0.004	<0.0001	11 ± 5	0.01

Table 4: Maximum and minimum annual temperatures trends and annual precipitation trends computed in the different locations; P shows the significance of the Mann-Kendall test.

The trends of the maximum and minimum temperatures series mark a raise in temperatures. In the stations of Turin and Vercelli, the higher raise has been recorded for minimum temperatures, while in Oropa and Asti the higher raise has been recorded for maximum temperatures. Concerning the precipitation series, the trends have shown a generalized decrease of the annual cumulated rainfall in the plain stations (Torino, Asti and Vercelli) and an increase for the Oropa station, located in the Alps, at the foot of the mountains.

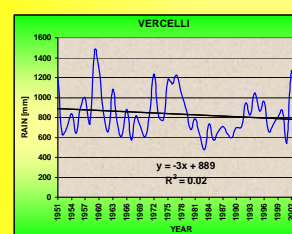


Figure 9: Annual precipitation trend computed in Vercelli.

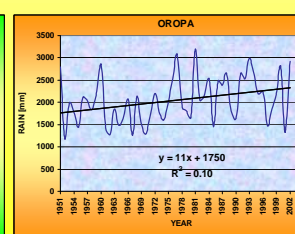


Figure 10: Annual precipitation trend computed in Oropa.

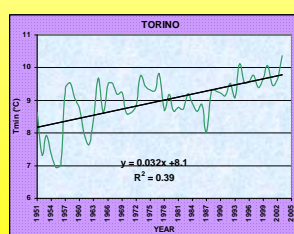


Figure 11: Minimum annual temperatures trend computed in Torino.

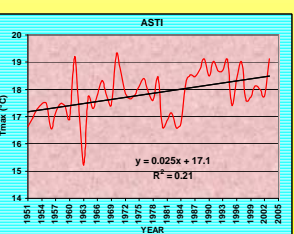


Figure 12: Maximum annual temperatures trend computed in Asti.

The results obtained from this study suggests to extend the work and analyze also other locations in which there are a couple of meteorological stations located close to each other and that have simultaneous observations. Future work could also include the historical research, the reconstruction of monthly and daily data and the evaluations of their impacts on the series. So that homogeneous climate data sets will increase.