HISTORICAL ANALYSIS OF NIVOMETEO DATA OVER 100 YEARS OF RECORDINGS BY THE OROPA SEISMIC WEATHER OBSERVATORY

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ABSTRACT: The seismic weather observatory of Oropa is located within the Marian religious complex "Santuario di Oropa". Geographically, it is located in the north-western part of Italy, specifically in the Piedmont region. Its position, on the slopes of the 'Southern Pennine Alps' mountain complex at an altitude of 1180 m asl (lat. 45°37' long. 07°58') allows it to record nivo-weather data characteristic for the underlying mountainous sectorof Oropa". The observatory was founded in 1874 by Barnabite Father Francesco Denza of Naples, an illustrious scientist and founder of the 'Regio Osservatorio Carlo Alberto' in Moncalieri. However, the real scientific activity began in 1920, the year in which, thanks to the work of the Redemptorist Fathers Rizzi, Balladinelli and Balzerani, the observatory went from being a thermo-pluviometric station to a meteo-seismic observatory, and daily manual recordings of weather conditions, temperatures and precipitation amounts (rain or snow) began systematically. Manual recordings continued until 2003, when automatic weather stations were adopted for continuous recording of weather data. In the 1980s, the observatory became part of the Piedmont regional weather network, the regional seismic network, and the national one.

KEYWORDS: Climate change, weather data analysis

1. INTRODUCTION

This work, starting from the historical series of nivo- metereological data collected in about 100 years of activity of the Seismic Weather Observatory of Oropa and from the evolution of the acquisition systems, analyses the local trend of temperatures and quantities of snowfall recorded at an altitude of 1180 m above sea level from 1920 until today.

2. LOCATION OF THE MONITORING STATION

The Oropa Seismic Weather Observatory is situated in the mountainous area under the territorial jurisdiction of the Province of Biella located south of the Western Alps, in correspondence with part of the mountainous sector known as the Southern Pennine Alps. The mountainous area of Biella extends from west to east from longitude E 7°90' to E 8°17' over approximately 30 km and from south to north from latitude N 45°60' to N 45°75' over a distance of about 12 km.

Altimetrically, the Biellese mountain area, includes mountainous elevations between 1500 m asl and 2600 m asl.

The area of land occupied by the Biellese mountain sector covers approximately 360 km^2 (Figure 1).

Figure 1: general view of the portion of the Southern Pennine Alps falling under the territorial jurisdiction of the Province of Biella.

The Biella Mountain area is an important tourist-recreational attraction, characterized by various mountain road infrastructures at municipal and provincial level, mountain settlements and two managed ski areas, as well as numerous ski mountaineering and winter mountaineering trails.

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3. DETECTION SYSTEMS AND AVAILABLE DATA

The Oropa Seismic Weather observatory is located NW of the city of Biella, in the Oropa area. Its position, at the base of the Oropa basin, makes it possible to assess the thermal characteristics and rainfall extent of the upper sector of the Oropa valley as well as the hydrographic characteristics of the upper portion of the Oropa stream basin. The following table shows the geographical and altimetrical references of the location of the Oropa Seismic Weather Observatory, while figure 2 shows its position in the context of the Biellese mountainous sector.

Seismic weather observatory of Oropa			
location	*position*[3]		
	est	*north*	*altitude*
Santuario di Oropa	420668	5053282	1186

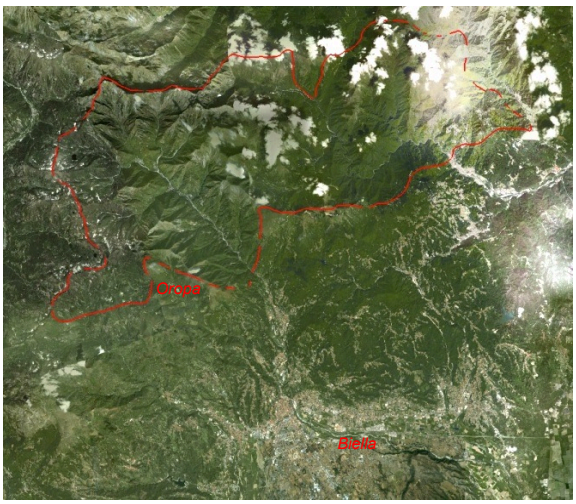

Figure 2: General view of the spatial position of the Oropa survey station.

From the historical yearbooks of the Seismic Weather Observatory of Oropa, the data referring to manual[4] measurements, for the period 1920-2003, and automatic[5] measurements, for the period 2004-2024, were extrapolated and altogether cover a period of more than 100 years for the altimetrical altitude of about 1200 m asl.

[3] cartographic coordinates expressed in meters and referred to the ED50 system, with UTM projection of fuse 32 and elevation expressed in meters above mean sea level

[4] manual recording - data recorded manually by an operator daily, the data available are the minimum and maximum value for temperature and the maximum value for snowfall

[5] automatic recording - data recorded automatically on an hourly basis, data available are minimum, maximum and average value

4. NIVO-WEATHER DATA ANALYSIS

The analysis of the data collected by the Oropa Seismic Weather Observatory was carried out in two ways: the first, by evaluating, according to a "100- year historical series", the variation in the amount of snowfall and temperatures over 104 years of manual and automatic recordings; the second, by analyzing the data collected automatically, evaluates, according to a "20-year historical series", the variation in the amount of snowfall and recent temperatures. The two types of analysis, as reported below, have made it possible to assess how the extent of snowfall and the temperature regime in the Oropa basin area have changed in both the "long term" and "short term".

4.1 Data Analysis – 100- year series

The analysis of the 100-year series, and in particular the data related to temperature, ground snow depth and snowmelt equivalent, made it possible to assess the change in precipitation amount and temperature regime over the period from 1920 to 2024.

Figure 3 shows the graphs of the snow depth trends (monthly and annual Hs) and figure 4, the graphs of the temperature trends (Tmin and Tmax).

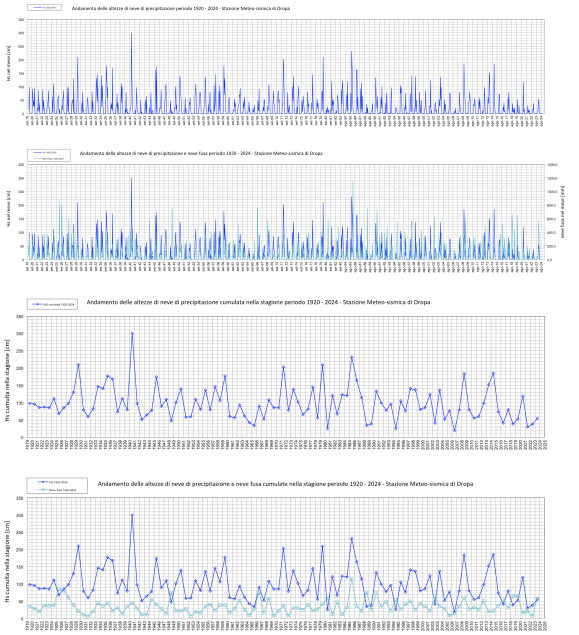

Figure 3: trend of monthly and annual maximum values of Hs and snowmelt equivalent.

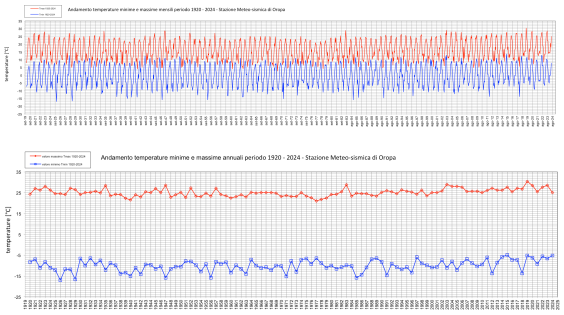

Figure 4: Trend of monthly and annual maxima of Tmin and Tmax.

4.2 Data analysis – 20-year series

The analysis of the 20-year series, and in particular the data related to temperature, ground snow depth and snowmelt equivalent, made it possible to assess the change in precipitation amount and temperature regime over the period 2004-2024.

Figure 5 shows the graphs of the snow depth trends (monthly and annual Hs) and Figure 6 the graphs of the temperature trends (Tmin and Tmax).

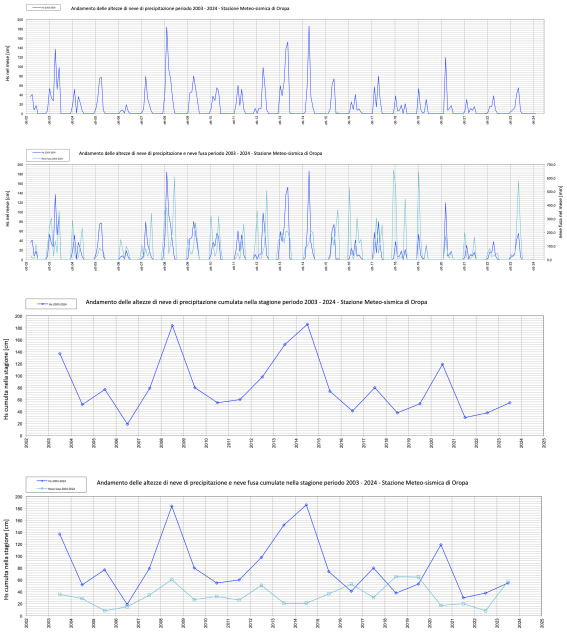

Figure 5: trend of monthly and annual maximum values of Hs and snowmelt equivalent.

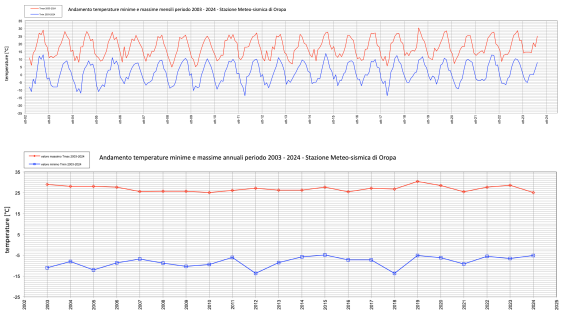

Figure 6: trend of monthly and annual maxima of Tmin and Tmax.

5. ANALYSIS RESULTS

5.1 Data analysis results – 100-year series

The analysis of the snowfall data referring to the 100- year series made it possible to extrapolate the following limit values for snow present on the ground at an altitude of 1186 m asl for the period 1920-2024:

Hs max → 300 cm season 1940-1941
Hs min → 19 cm season 2006-2007
Hs med → 98,1 cm period 1920-2024

Using the mean value (Hs med) of the period 1920- 2024 as the threshold for snow depths on the ground, it is possible to estimate the number of annual maximum snow depths exceeding the mean value in 41 cases and equaling it in 3 cases.

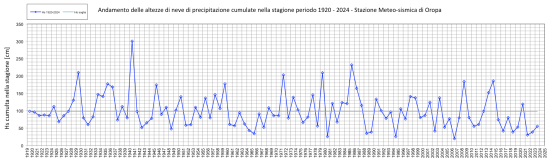

Figure 7: trend of annual Hsmax and calculated mean value over the period 1920-2024.

It can be deduced from Figure 7 that most of the values exceeding the mean value (number 32) are concentrated with a greater numerical density in the time periods 1925-1961 and 1968-1988, while in the period 1998-2024 the cases exceeding the limit value are numerically lower (number 9).

The analysis of the temperature data referring to the 100-year series, has allowed us to extrapolate for the period 1920-2024, the following limit values relating to the magnitude of the minimum and maximum temperature recorded at an altitude of 1186 m asl:

T max → +30,4°C season 2019-2020
T max med → +25,1°C cm period 1920-2024
T min → -17,0°C season 1926-1927
T min med → -10,1°C cm period 1920-2024

Using the mean value of the maximum and minimum temperature for the period 1920-2024 as the threshold temperature, it is possible to estimate the number of temperatures in 46 cases maximum temperatures exceeding the threshold and in 56 cases the minimum temperature values.

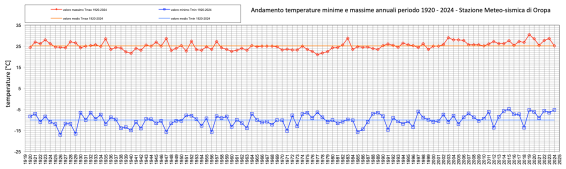

Figure 8: trends of annual Tmax and Tmin and the mean value of Tmax and Tmin calculated over the period 1920-2024.

From Figure 8, it can be deduced that most of the Tmax values that exceed the mean value of maximum temperatures (number 25) are concentrated with a greater numerical density in the period 1981-2024, while for Tmin, there is no specific period in which there is a greater density of exceedances than the mean value of minimum temperatures. For the period 2000-2024, all annual maximum and minimum temperature values (Tmax and Tmin) continuously exceed the average maximum / minimum value for the period 1920-2024.

Approximating the minimum and maximum temperature data with a linear function, as shown in Figure 9, a positive upward trend of the temperatures Tmin and Tmax in relation to the mean value of the period can be appreciated from the end of the 1960s onwards, which, according to the interpolation method adopted, leads to a temperature increase of approximately +1,7°C for minimum temperatures and approximately +1,0°C for maximum temperatures.

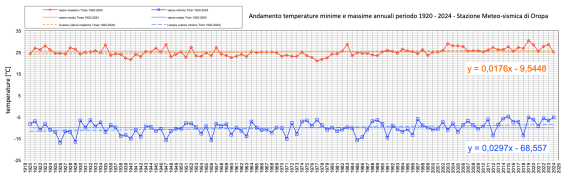

Figure 9: trends of annual Tmax and Tmin and regression lines.

5.2 Data analysis results – 20-year series

By analyzing the snowfall data referring to the 20-year series, it was possible to extrapolate for the period 2004-2024, the following limit values for snowfall at an altitude of 1186 m asl:
Hs max → 186,0 cm season 2014-2015
Hs min → 19 cm season 2006-2007
Hs med → 81,3 cm period 2004-2024

Using the average value (Hs med) of the period 2004-2024 as the threshold for snow depths on the ground, it is possible to assess in 6 cases, the number of annual maximum snow depths that exceed the average value and in 2 cases those that equal it.

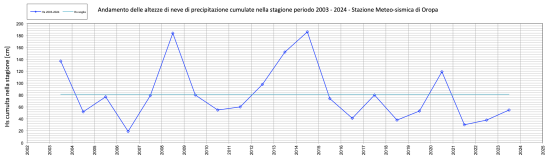

Figure 10: Trend of annual Hsmax and calculated mean value over the period 2004-2024.

Figure 10 shows that in only 6 out of 21 cases did the value of the snow depth on the ground exceed the average value, while in 15 cases the value of the snow depth on the ground remained below the average value over the period 2003-2024.

The analysis of the temperature data referring to the 20-year series made it possible to extrapolate for the period 2004-2024, the following limit values for the magnitude of the minimum and maximum temperature recorded at an altitude of 1186 m asl:
T max → +30,4°C season 2018-2019
T max med → +27,0°C period 2004-2024
T min → -13,7°C season 2011-2012
T min med → -8,2°C period 2004-2024

Using the mean value of the maximum and minimum temperature for the period 2004-2024 as the threshold temperature, it is possible to assess the number of maximum temperatures exceeding the threshold in 11 cases and the minimum temperature values in 12 cases.

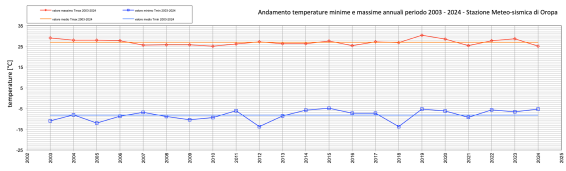

Figure 11: trends of annual Tmax and Tmin and the average value of Tmax and Tmin calculated over the period 2004-2024.

It can be deduced from Figure 11 that most of the Tmax and Tmin values exceeding the respective mean value are concentrated with a higher number density in the period 2013-2024.

Approximating the minimum and maximum temperature data with a linear function, as shown in Figure 12, one can appreciate the coincidence of the Tmax with the mean value and, starting in 2013, a positive upward trend of the Tmin temperatures with respect to the mean value of the period, which, according to the interpolation method adopted, leads to a temperature increase of approximately +1,9°C in the minimum temperatures.

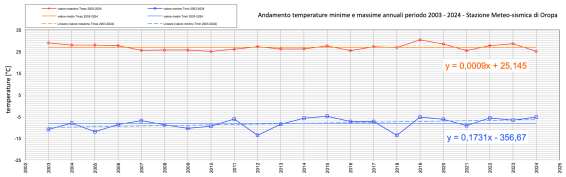

Figure 12: trend of annual Tmax and Tmin and regression lines.

6. CONCLUSION

The processing of nivo-weather data recorded manually and automatically by the Oropa Seismic Weather Observatory made it possible to assess the extreme and average values of the nivo-weather conditions that have characterized the Oropa basin area over the last 100 years. Synthesizing the results of the above-mentioned elaborations, the following summary considerations can be made:

- snowfall, over the last 100 seasons, compared to the average value of the period, there is a decrease in the number of events exceeding the average value, a reduction observed in the recent period and from the end of the 20th century to the present. Analyzing the maximum value of snow on the ground recorded in the period 1920-2024 and the similar value recorded in the period 2003-2024, a drastic reduction in the maximum height of snow on the ground can be seen, which passes from $Hs^{1920-2024}$ = 300 cm to $Hs^{2003-2024}$ = 186 cm, a reduction that entails a negative change in the maximum thickness of snow on the ground of approximately 38%;
- temperatures, over the last 100 seasons, there is an increase in the number of annual minimum and maximum temperatures that exceed the average value for the period. This occurs particularly in the period 1981-2024 and in the period 2000-2024 where the exceeding of the mean value is continuous;
- temperatures, analyzing the trend of the regression lines that approximate the data of the last 100 seasons, it is possible to assess a positive trend of increase in both maximum and minimum temperatures, which, depending on the interpolation method adopted, entails an increase of +1,0°C and 1,7°C respectively, a trend that assumes a value of approximately 1,9°C if we analyze the linear function that approximates the minimum temperature data of the last 20 seasons.

CONFLICT OF INTEREST

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