

# HISTORY OF METEOROLOGICAL MONITORING IN VARAŽDIN

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**Abstract:** Meteorological observations include visual monitoring of weather phenomena and instrumental data collection. Ivan Krstitelj Lalangue, a physician by profession, was the first to collect meteorological data in Varaždin in 1785. Organized meteorological monitoring began worldwide in the 18th century and in Croatia in the 19th century. The first network of meteorological stations in Croatia was proposed in 1849, with measurements in Varaždin starting in 1859. Disruptions in observations and measurements occurred during World War I and World War II, leading to the restoration of the main meteorological station (GMP) in Varaždin in 1947. The modernization of meteorological monitoring continued in the 1990s with the introduction of electronic instruments and automated remote data transmission. As part of the MetMonic project, the national meteorological network was modernized, enabling the Croatian Meteorological and Hydrological Service (DHMZ) to invest in the advancement of meteorological research in the Republic of Croatia.

**Keywords:** Drava River, hidrological station, water gauge, hidrological parameters, Varaždin.

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## 1. INTRODUCTION

Meteorological observations include two main categories of data: visual observations of weather phenomena such as clouds, wind, precipitation, atmospheric optical and acoustic phenomena, and storms, as well as instrumental data, which encompass measurements of meteorological variables such as temperature, humidity, and air pressure, wind direction and speed, precipitation amount, sunshine duration, and more. These complex observations began globally at the end of the 18th century, while in Croatia, they started in the first quarter of the 19th century.

According to the legal provision of June 7, 1784, city, district, and county physicians, i.e., public doctors, were required to include their meteorological observations in annual health reports. This practice continued until the end of the 19th century, resulting in a wealth of collected data from more than twenty locations in Croatia (Čačić et al. 2014). Most meteorological stations were established thanks to individual intellectuals who, upon requesting and receiving instruments from meteorological centers, became part of the official observation network.

Regulations and agreements regarding the placement of instruments, their types, observation times, units for various meteorological elements, as well as the names and definitions of atmospheric phenomena, developed gradually. It was not until 1870 that Celsius degrees were standardized for temperature, and millimeters for air pressure and precipitation amounts. That same year, nearly all stations began conducting observations at 7 AM, 2 PM, and 9 PM, whereas earlier, morning observations were conducted at 6, 7, or 8 AM, and evening ones at 8, 9, and most often 10 PM (Čačić et al. 2014).

After Andrija Mohorovičić's persistent efforts, the Territorial Government for Croatia and Slavonia decided on January 15, 1901, to place all meteorological stations within the jurisdiction of the Ban's Administration under the supervision of the Meteorological Observatory Zagreb - Grič, which was led by Mohorovičić. At that time, he issued observation guidelines with the recommendation:

"Whoever takes on this moral duty of recording data should do so correctly or not record at all. It is better to have nothing than to have incorrect data.

## 2. BEGINNINGS OF METEOROLOGICAL MONITORING IN VARAŽDIN

Among the physicians who recorded weather conditions, the Varaždin doctor Ivan Krstitelj Lalangue stands out, as he documented weather conditions in 1785 (Čačić et al. 2014). Lalangue was born on April 27, 1743, in Matton, Luxembourg, Belgium, and passed away on May 20, 1799, in Varaždin. He completed his medical studies in 1770 in Vienna. Encouraged by the Austrian healthcare reformer Gerard van Swieten, Lalangue came to Croatia in 1772 to reorganize the healthcare system and was appointed county physician in Varaždin.

His work encompassed hygiene and preventive medicine, the improvement of economic and social conditions for the population, and the systematic training of midwives. He was a key figure in Enlightenment-era healthcare,

a pioneer of professional medical literature in the Croatian language, and the author of the first public health education books for the general public: "Vračta ladanjska" (1776) and "Kratek navuk od meštrije pupkorezne" (1777) (Hrvatska enciklopedija 2024).

The first known initiative for establishing a network of meteorological stations in Croatia can be attributed to Daniel pl. Stanisavljević, a financial advisor from Zagreb (Katušin 2009). On December 4, 1849, Stanisavljević submitted a proposal to the Austrian Academy of Sciences in Vienna for the establishment of meteorological stations in Karlovac, Mali Alan, Maljevac, Rijeka, Varaždin, Zavalje, and Zagreb. The reason for choosing these locations was that Stanisavljević had found individuals willing to take responsibility for meteorological observations in these places.

Thus, the first official meteorological station in Croatia was established in 1851 in Dubrovnik as part of the meteorological station network of the Austro-Hungarian Monarchy. In 1859, three more stations were established: in Osijek, Split, and Varaždin. The Osijek station was located in the garden of the military hospital within the Osijek Fortress, with military officer Ulmann as the first observer. In Split, the first observer was Ivan de Bortoli, who was transferred from Dubrovnik, while in Varaždin, observations were conducted by Professor Franz Folprecht (Čačić et al. 2014).

During the first half of the 19th century, meteorological measurements were increasingly linked to vegetation in specific areas, particularly in the context of tourism development, especially spa tourism. Phenological observations, which include monitoring plant growth, budding, flowering, and fruit ripening, were organized in schools throughout continental Croatia, including those in Varaždin (Čačić et al. 2014).

The meteorological pillar in Varaždin, shown in **Figure 1**, was installed in 1909 along Alojzija Stepinca Street near Šetalište Vatroslava Jagića. It is placed on an octagonal (concrete) pedestal with three steps. The city administration provided funding for the construction of the pillar and the purchase of the most modern instruments available at the time. The pillar was equipped with a large clock, which was maintained by the city's watchmakers. Even today, the people of Varaždin can check meteorological data such as air pressure, humidity, temperature, and other meteorological elements on the meteorological pillar at any time of the day (TZVŽ 2024).



**Figure 1** Meteorological pillar in Varaždin

The First World War (1914–1918) caused the closure of many meteorological stations, resulting in the loss of instruments and data. The recovery of the meteorological station network was difficult and slow. During the Second World War, meteorological observations were conducted at several dozen stations within the territory of the Independent State of Croatia at the time. The meteorological station in Varaždin was built in 1947, with the first measurements beginning in 1949 (Čačić et al. 2014).

Over time, meteorological observations were conducted at several different locations in Varaždin. One such location was from January 1936 to December 1950 at the Vinkovščak auxiliary airfield, northwest of the city. From 1950 to December 31, 1971, the station was located near the Varteks factory, in the Brezje area. From January 1, 1972, the meteorological station was relocated to an airport east of the city. Finally, on April 16, 2009, Varaždin established a new main meteorological station in Brezje, near the radar center, where it remains today (**Figure 3**) (Žibrat Z 2009).

Meteorological observations are recorded in the Main Meteorological Station Logbook immediately after observation, with additional data from processed tapes being entered later—a practice implemented in Varaždin since December 1997. Since 1990, in addition to mechanical anemographs—instruments that continuously record

wind speed and direction on paper strips (anemograms)—electronic anemographs (Type  $\mu$ m, Croatia) have been gradually introduced at main meteorological stations (GMP) (Hrvatska enciklopedija 2024). At GMP Varaždin, an electronic anemograph has been in operation since 1999, and by 2012, 33 such devices were functioning within the network of main meteorological stations (Čačić et al. 2014).

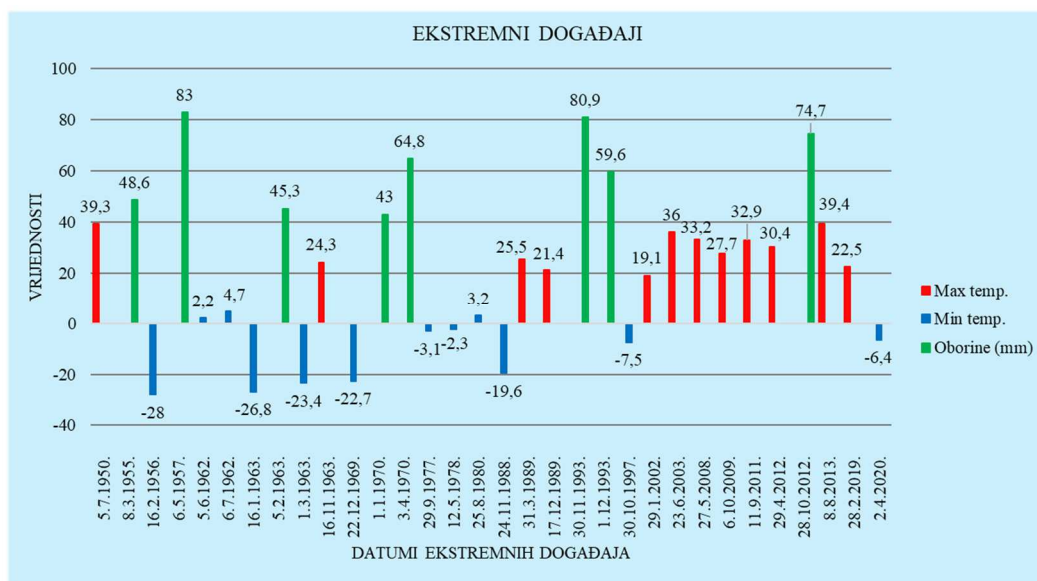
One of the primary tasks in maintaining the observation system is to preserve and ensure the representativeness of the observation site, which includes maintaining the station grounds as well as constructing and maintaining meteorological station facilities.

All these responsibilities—observations, measurements, and maintenance—have been part of the regular activities of meteorological observers. Over time, many observers, through their dedication and contributions have ensured a valuable archive of meteorological data (Žibrat 2009). Based on these data, the first comprehensive meteorological study for spatial planning was developed for Varaždin County in 1995.

The graphical representation in **Figure 2** illustrates the extreme values of cumulative daily precipitation (mm/24h) and extreme daily temperatures for Varaždin during the period 1949–2020.

The data were obtained from the Croatian Meteorological and Hydrological Service (DHMZ) ([https://meteo.hr/klima.php?section=klima\\_podaci&param=k1&Grad=varazdin](https://meteo.hr/klima.php?section=klima_podaci&param=k1&Grad=varazdin)).

The graph shows that the maximum daily cumulative precipitation of 83 mm was recorded in Varaždin on May 6, 1957. Since 1949, the lowest recorded daily temperature in Varaždin was  $-28.0^{\circ}\text{C}$ , measured on February 16, 1956, while the highest recorded temperature of  $39.4^{\circ}\text{C}$  was measured on August 8, 2013.



**Figure 2** Graphical representation of extreme events in Varaždin



**Figure 3** New meteorological station in Varaždin, Brezje (Regionalni tjednik 2019)

The reduction in the number of regular meteorological stations began in 1983 and dropped significantly in 1991 due to the Homeland War. Many main meteorological stations were damaged by direct hits to buildings, meteorological enclosures, or their immediate surroundings (**Figure 4**) (Čačić et al. 2014).



**Figure 4** GMP Varaždin damaged during the Homeland War in 1991 (Čačić et al. 2014)

### 3. MODERN METEOROLOGICAL MONITORING IN VARAŽDIN

The advancement of science has enabled the development of technology, including the use of advanced meteorological observation devices, such as remote and automatic monitoring systems and satellite observations beyond Earth's atmosphere.

The Croatian Meteorological and Hydrological Service (DHMZ), as a scientific research institution in the field of natural sciences, serves as the national center of excellence and expertise in meteorology and climatology and is responsible for the establishment and maintenance of the national meteorological network.

An analysis of the current state of the meteorological network has highlighted the need to increase data availability and quality for various economic sectors and public services. Through the MetMonic project (2017–2024), efforts have been made to establish a modern system of automatic meteorological stations, oceanographic buoys, and remote sensing systems for the atmosphere, including meteorological radars, at more than 400 locations in Croatia.

As part of this project, the focus at GMP Varaždin has been on data quality and availability, ensuring that data is automatically updated every 10 minutes. Within the project, new instruments with sensors were procured and installed at GMP Varaždin for measuring the following meteorological variables (DHMZ 2024).

- Wind speed and direction at 10 m height (Vaisala WMT702)
- Temperature and relative humidity at 2 m height in a meteorological shelter (Rotronic HC2A S3)
- Air pressure (Vaisala PTB330)
- Precipitation amount (OTT Pluvio2L)
- Snow height (Lufft SHM31) (**Figure 5**)
- Weather conditions and visibility (Biral VPF 750) (**Figure 6**)
- Precipitation detector (Eigenbrodt RS 85) (**Figure 7**)
- Air temperature at 5 cm above ground (Eigenbrodt LTS2000) for minimum temperature and frost
- Evaporation, Class A evaporimeter (evaporation pan), water temperature in the evaporimeter (Microstep MIS PT100)
- Wind run at 2 m height (ThiesClima First Class – cup anemometer)

- Water level in the evaporimeter (Microstep TSP.0250)
- Soil temperature at multiple levels (Microstep TPP probe)
- Soil moisture (IMKO Trime Pico 64) (**Figure 8**)
- Snow density\*\* (SOMMER SPA-2) (**Figure 9**)
- Cloud base height (Lufft CHM 15k Ceilometer) (**Figure 10**)



**Figure 5** Snow height measurement device, Lufft SHM31 (Lufft an OTT HydroMet brand 2024)



**Figure 6** Device for determining weather conditions and visibility, Biral VPF 750 (Biral 2024)



**Figure 7** Precipitation detector, Eigenbrodt RS 85 (Eigenbrodt 2024)



**Figure 8** Soil Moisture Measurement Device, IMKO Trime Pico 64 (Surechem 2024)



**Figure 9** Snow density measurement device, SOMMER SPA-2 (AAXIS NANO TECHNOLOGIES PVT. LTD. 2024)



**Figure 10** Cloud base height measurement device, Lufft CHM 15k Ceilometer (ResearchGate 2024)

An additional meteorological parameter introduced is the new measurement of soil moisture (**Figure 8**), which will be highly beneficial for assessing soil conditions and drought evaluation in agriculture. Furthermore, for the GMP Varaždin location, instruments for determining weather conditions, visibility, and cloud base height (**Figures 6 and 10**) have been procured. However, these serve only as a partial replacement for direct observations. This type of measurement is particularly useful for forecasting extreme sudden summer storms and convective precipitation, which are difficult to predict without real-time measured data.

## 5. CONCLUSION

Since the establishment of the meteorological station in Varaždin, 165 years have passed. As described in this study, until 1999, when the first electronic anemometer was installed, measurement results relied entirely on human factors—specifically, the responsibility and dedication of individual meteorological observers and the accuracy of measurements taken at specific observation times. These dedicated individuals ensured a high-quality

archive of meteorological data, which can be considered part of Varaždin's cultural and scientific heritage. Through the analysis of historical meteorological data, we can now evaluate changes in climate patterns in the city and its surroundings.

Over time, significant progress has been made in the number of meteorological variables available in real time, which is crucial for timely warnings about extreme weather events. The modernization of meteorological monitoring aims to enhance adaptation to climate change and enable rapid response to natural disasters, ultimately contributing to safety, the protection of human lives, and the preservation of property.

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