# THUNDERSTORM PHENOMENA AT SLOVAK AIRPORTS

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https://doi.org/10.37904/clc.2022.4569

**Abstract**

The weather can easily affect human activities. Therefore, it is very important to plan our activities so that the weather does not affect the safety of them. Transport is one of those human activities where information on current and predicted weather conditions is very important. All modes of transport are dependent on information of current and predicted weather especially in the period of transportation process. Precise weather information is of vital importance for air transport. This paper deals with dangerous weather phenomena that affect air transportation in a very negative way and could also lead to termination of air transport services. More specifically, the paper deals with thunderstorm phenomena that often occur at Slovak airports in the summer season and compares their occurrence with the Climatic atlas of Slovakia.

**Keywords:** Weather, aviation, thunderstorm phenomena, slovak airports, summer season

## 1. WEATHER AND AVIATION

Many human activities are dependent on weather conditions. Therefore, the weather becomes a limiting factor in our efforts and plans. In particular, all modes of transport are very sensitive to weather-related phenomena. Air transport is very sensitive to adverse weather, where even a small change in weather conditions can cause operational problems with even fatal consequences. For example, weather caused a tragic accident of Aeromexico Embraer 190 aircraft, flying from Durango to Mexico City in July 31$^{st}$ ,2018. Shortly after becoming airborne, the plane encountered sudden wind shear caused by a microburst and the aircraft skidded off about 300 m beyond the runway of General Guadalupe Victoria International Airport. Although there were no fatalities (all 103 passengers survived the accident), three-quarters of them were injured and almost half of the passengers were taken to the hospital. One of the pilots had burns. The accident was caused by a strong storm at the airport. During the storm, the aircraft, which was just after take-off, was hardly hit by a strong gust of wind, causing the aircraft to lose speed. Consequently, the aircraft hit the ground with its left wing and slid off the runway. [1]

It is possible to ask the question whether similar phenomena can and to what extent affect the aviation safety in Slovakia, where climatic and meteorological conditions are significantly different.

There are numerous storms in Slovakia during summer season. Number of days with a storm counts for 15-30 in Slovakia [2]. There is greater number of storms in some specific areas of the country, such as: the eastern part of the Danubian Lowland, the Tatras, the Zvolen Basin, Spiš region, the Little Carpathians, the southern part of the East Slovakian lowlands. [2]

When it comes to frequency of storms, the storms are most frequent in July (28 %), May (24 %) and June (22 %). On the other hand, the storms are least common in January and February (less than 1 % of cases). [2] During the summer season, storms most often occur in the afternoon (around 2-3 pm), when there are best conditions for convection and the air temperature reaches its daily maximums. [3] The very development of clouds, which foreshadows the possible occurrence of a storm, is observed in the morning.

Storms are associated with dangerous phenomena such as low or limited visibility, rapid wind changes, gusts, heavy precipitation, mechanical and termical turbulence and also electrical activity in the atmosphere. The

occurrence of a storm at the airport, or in its close proximity can cause potential problems with flight safety and fluency of the flow of air traffic. That is why this paper deals with thunderstorm phenomena at Slovak international airports and it covers period from 2011 to 2018.

## 2. WHAT IS A THUNDERSTORM?

From a meteorological point of view, a thunderstorm is a set of optical, acoustic and electrical phenomena occurring between Cumulonimbus (Cb) type clouds and between this type of clouds and the earth [4]. In our latitudes, the storm is being accompanied by the cloud with the largest vertical extent [5]

The Cb cloud extend from its low base to a height of about 8 to 13 km, depending on the time of year in which the cloud occurs. In winter, the Cb reaches up to 7-8 km of height, in summer it could be even higher and it can reache up to 11-13 km of height. The cloud is known for its flat top, the so-called an anvil. This is due to the fact that, during the development phase, the cloud has already grown to the height where the tropopause is located. If the climate is warm enough, there are significant vertical processes present in this cloud. They could break through the tropopause and form the so-called overshooting top [5,6]

Many dangerous weather phenomena such as wind gusts, heavy rainfall, turbulence, but also the so-called micro and downburst are associated with the occurrence of Cb cloud. [6] If close to the airport, presence of the phenomena could cause an aircraft to crash. That is why airports do their best to provide quality meteorological information for flight crews so they make their plans with up to date weather information [7]

In summer, Cb develops during intense convection in the atmosphere. The development phase can last for about few minutes up to several tens of minutes, depending on the thermal conditions in the atmosphere. **Figure 1** depicts structure of a thunderstorm. **Figure 1** also shows a protruding peak of the cloud - the overshooting top. When the atmosphere becomes unstable enough to form large, powerful updrafts and downdrafts (as indicated by the red and blue arrows), a towering thundercloud is built up. At times the updrafts are strong enough to extend the top of the cloud into the tropopause, the boundary between the troposphere (or lowest layer of the atmosphere) and the stratosphere) [8]. Vertical movements in the cloud are very fast, often reaching more than 40 m/s [3,6]. Hail can occur frequently in this type of cloud.

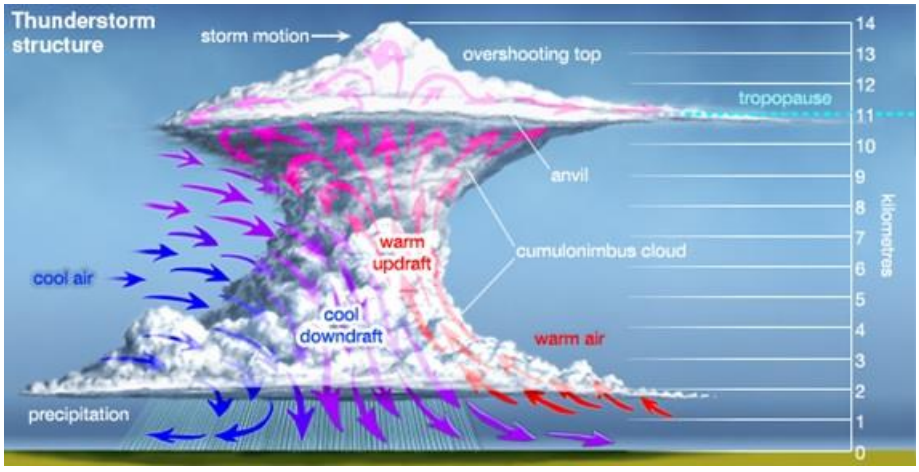


**Figure 1** Thunderstorm structure [8]

For larger areas, meteorologists are capable of predicting storms well in advance (24 hours in advance). However, they are not able to predict occurrence and exact timing of a thunderstorm for specific (small) location. Meteorological radar detection and a lightning detection network can help with the prediction e.g. near an airport. With the help of these devices, the vertical forming and movement of a potential storm can be captured. The development of the storm is very fast. Cumulonimbus cloud is able to be formed within 15 min. [4,6]. It must not be forgotten that, in reality, the storm is usually formed by one single storm core, one cloud

with a massive vertical development. The storm usually consists of groups of clouds, each of which has an individual stage of development [3,6].

A storm is a very dangerous phenomenon. One of the reasons is lightning that can occur several tens of kilometres away from the storm cloud and literally from the clear sky.

Reflecting dynamic processes in the atmosphere, storms can be divided into:

- frontal storms - related to the advancing frontal interface in specific territory (i.e. Slovak republic). The most common storms are those happening on the cold front, where the occurrence of storms can be observed in the area of 300 km in front of the front line. Storms happening on the warm and occlusion front are very rare [3]. In the cold front storm, the weather is very intense and it covers large area.

- storms inside the air mass - these storms often occur in the warm period of the year. Sufficient amount of warm and humid air is needed for this storm to be formed. These storms bring less intense weather and they spread over a small area [3,5].

This paper deals with the above mentioned types of storms and it does not take into account the origin of the storm when evaluating occurrence of storms.

### 2.1. Aviation information on the occurrence of storms

Because of the fact that storms are dangerous weather phenomena for aviation, it is important to be informed about its occurrence and the probability of its occurrence well in advance. METAR (meteorological terminal air report) weather reports are used in aviation to inform about current weather. The reports may also include the TREND landing forecast. The forecast contains a brief description of the expected changes in meteorological conditions at the airport. TREND is forecast for weather over a two-hour period, and is based on an actual weather report, such as a METAR or SPECI and appended to the end of it. [9]

The METAR report is mainly used by aircraft pilots, who draw pre-flight weather information from it, and by meteorologists, who use the METAR report to compile weather forecasts. Measurements and observations are carried out at airports 24 hours a day, with a METAR report issued every half hour. The basic format of the report is the most popular format in the world for sending and receiving weather data. It is highly standardized through ICAO, which allows it to be understood in most of the world.

Forecasts of prevailing meteorological conditions at airports are compiled in the form of a TAF (terminal aerodrome forecast) code, which is more or less identical to the METAR message code. The validity of TAF forecasts shall not be less than 6 hours and not more than 30 hours. TAF aerodrome forecasts are issued independently of METAR messages and do not relate to any extraordinary reports. Also, the preparation of TAF forecasts and their corrections, if necessary, depends on the content of the METAR or SPECI messages received. The TAF forecasts contain a full description of the expected meteorological conditions at and around the aerodrome during the entire forecast period, including any changes significant to air traffic. [9]

Because of the fact that weather observations are being made continuously, information about potential occurrence of a storm is available to all flight crews immediately.

## 3. AIRPORTS IN SLOVAKIA

Slovakia currently has six international airports, located in different parts of the country: M. R. Štefánik airport, Košice airport, Piešťany airport, Poprad-Tatry airport, Sliač airport and Žilina airport. Some of these airports, according to [2], are located in reigions with high probability of formation of thunderstorms. All six airports provide regular local meteorological information based on on-site measurements and observations. The service provision is in line with the airport meteorological system (AWOS) capable of providing measured meteorological data and MET REPORTS including SPECIAL messages.

The amount and type of clouds (only for Cumulonimbus and Towering Cumulus) are observed visually from the meteorological station area. The weather reports shall indicate only the clouds that affect traffic at and

around the airport. In this case, meteorological reports shall also indicate other clouds or cloud layers whose base height does not exceed 10 000 ft (3 000 m). If no such clouds are observed at or near an aerodrome, the abbreviations CAVOK or NSC shall be used in meteorological reports.

Horizontal visibility and cloud base height are measured at all six airports in Slovakia by a combination of an automated sensor and/or manual measurement or observation, where these manually measured or observed data are included in meteorological reports only during the operating time of the meteorological station.

Runway Visual Range (RVR) is measured by an automated sensor at all airports and the weather condition is measured or observed manually at all airports except of Piešťany Airport. In Piešťany, the observer puts the measured/observed data to the meteorological report manually in line with World Meteorological Observation (WMO) methodological guideline

## 4. METHODOLOGY OF WORK

Data on storm phenomena were extracted from METAR aeronautical meteorological reports, which were provided by the Slovak Hydrometeorological Institute. The reports cover period from 1 January 2012 (00:00) to 31 December 2018, when the last METAR report was issued at 11.30 pm.

We have extracted information on storm (indication TS) from every single METAR report app. 700,000 totally records were analysed.

Storms that occurred several times a day had to be spaced apart in the encrypted parts of messages. This means that the weather condition that occurred between the two storms during one day could not be defined as a storm. A standard arithmetic mean was used to obtain basic information on the number of storms, their occurrence by months, years and time of day.

### 4.1. Analysis of achieved results.

The analysis shows that, during the period from 2012 to 2018, storms were usually observed at Slovak airports in the warmer months as could you see at **Figure 2**.

Most frequently, the storms occurred in May, June and July. By the contrary, the smallest number of storms was recorded in January, February, November and December. During this period, there were almost no storms at Slovak airports. In March and October, the annual occurrence of storm was one on average.

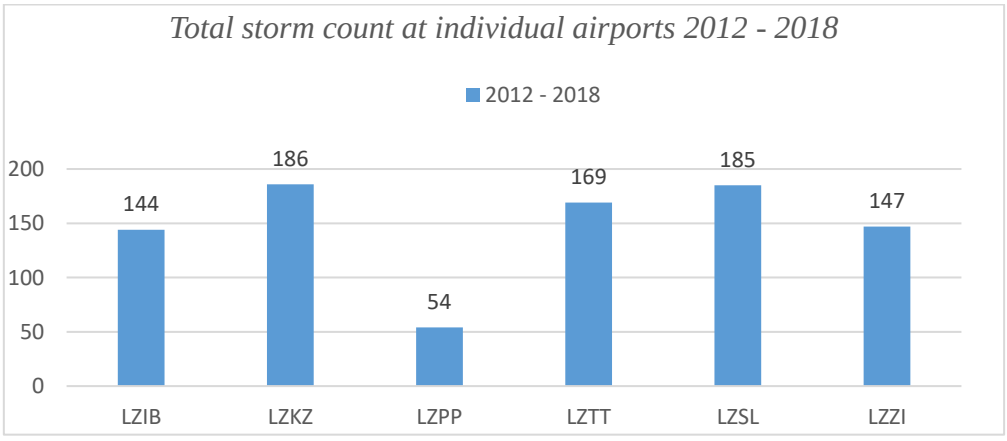


**Figure 2** Total storm count in individual months of the period 2012 - 2018 by author

ICAO (The International Civil Aviation Organization) international airports code:

LZIB Bratislava
LZKZ Košice

LZPP Poprad
LZTT Piešťany
LZSL Sliač
LZZI Žilina

The number represents the exact number of storms that occurred at airports during each month, and the storm could have occurred several times a day. We take into account the multiple occurrences during the day, provided that the storm that occurred over the airport disappeared after a certain time and then reappeared. The weather observed during the period between these two storms must not be of a stormy nature.

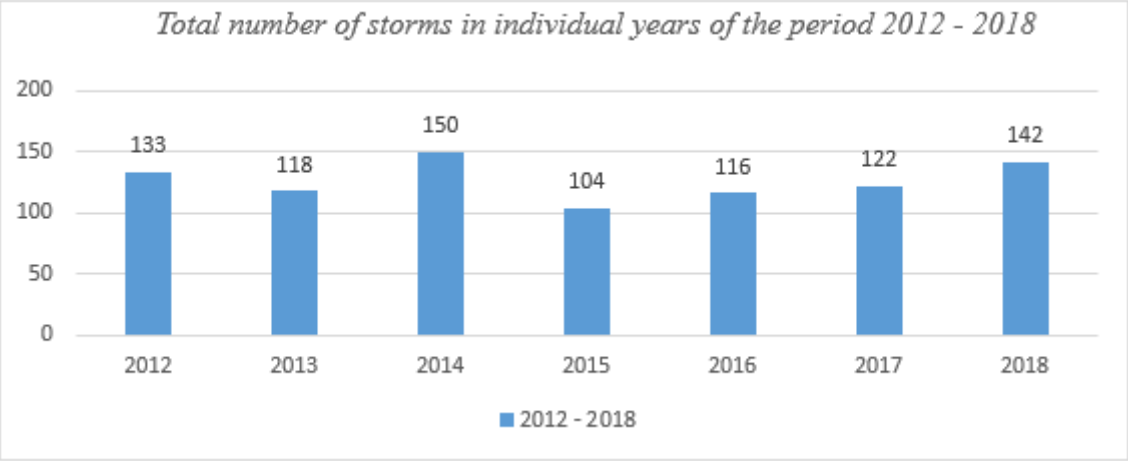


**Figure 3** Total storm count at individual airports 2012 - 2018 by author

Taking into account the situation at individual airports, the highest number of storms was registered at Košice and Sliač Airport (**Figure 3**) Third airport where storms occurred most frequently is Poprad-Tatry. On the contrary, the lowest number of storms (over the period) was recorded at Piešťany airport (with the yearly minimum of just 3 storms in 2015).

Taking into account individual years of the period 2012 - 2018, storms occurred most frequently in the years 2014 and 2018. On the contrary, the year in which the lowest number of storms was recorded is the year 2015. **Figure 4** shows the total number of storm phenomena in individual years of the period 2012 - 2018.

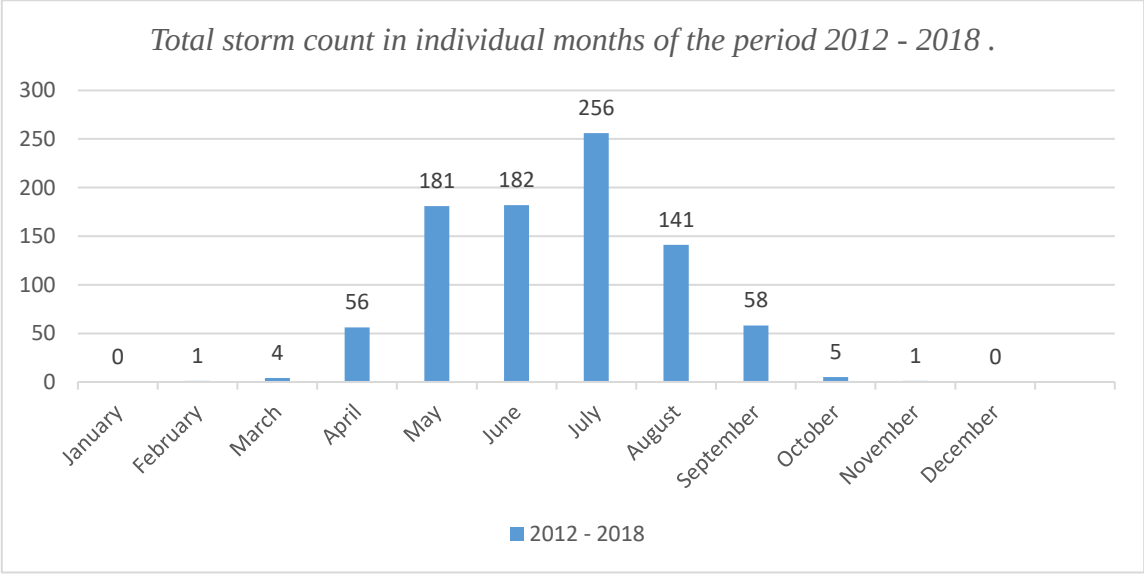


**Figure 4** Total number of storms in individual years of the period 2012 - 2018, by author

**Figure 5** depicts occurrence of storms according to the time of day. It shows that the storm (manifestation of intense convection) evolves when the atmosphere allows for formation and occurrence of intense convective movements of the air at the airport. It is the period around noon when the maximum of solar energy falling on the earth's surface is observed. Most often, storms form from 10:00 to 16:00, less often in the early evening, around 18:00, especially when convection is also caused by the progress of the frontal interface. Some storms are observed even during the night. These may be the storms that persist under suitable conditions until night, or, conversely, storms associated with the advancing frontal interface to the airport area.

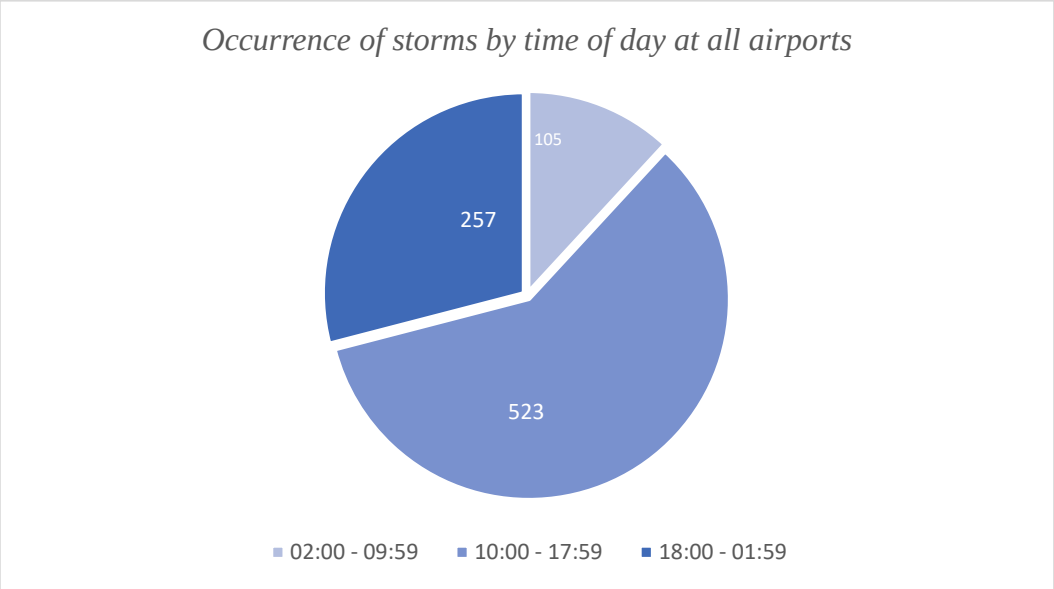


**Figure 5** Occurrence of storms by time of day at all airports by author

## 5. CONCLUSION

The paper deals with a dangerous weather phenomenon at the airport - storm. This phenomenon contains several dangerous weather phenomena, which can have fatal consequences and cause great damage to aircraft and fatalities.

We can predict a storm as a meteorological phenomenon, but we can only capture its beginning and subsequent development with the help of meteorological instruments. Experienced aerial observer or meteorologist can predict the possible occurrence of a storm at the airport based on the changes in the sky and his/her experience gained at particular airport. Therefore, it is necessary to train meteorological personnel constantly so that they are able to detect the storm just in time and alert pilots or people for whom the storm phenomenon could be potentially risky. Strategy of modern airports is to have technical and personnel capabilities to provide sophisticated and precise meteorological service. [10]

Taking into account the airports in Slovakia, the period from April to September recorded the most intense occurrence of storms with an average of 145 storms that occurred at all airports in the period 2012-2018. It means occurrence of one storm in almost 6 consecutive months of the year. If we take into account the total number of storms for the observed period, the storm occurs approximately 126 times a year on average. It averages to occurrence of over 10 storms per airport per month.

Taking into account individual years of the period 2012-2018, storms occurred most frequently in the years 2014 and 2018. On the contrary, the year in which the lowest number of storms was recorded is the year 2015. The storms occurred the most at Košice Airport and Poprad-Tatry Airport, which confirms the rule that storms are more attracted by highlands. Significantly lower number of storms was recorded at Piešťany Airport, located in the lowlands.

## REFERENCES

[1] VILLEGAS, P., CHAN, S. *'God, Come to Our Aid': Survivors Describe Mexico Plane Crash.* [online]. 2018. [viewed: 2020-03-24]. Available from: https://www.nytimes.com/2018/08/01/world/americas/mexico-aeromexico-plane-crash.html

[2] BOCHNÍČEK, O. et al. *Klimatický atlas Slovenska*. Bratislava: Slovenský hydrometeorologický ústav, 2015.

[3] ZVEREV, A.S. *Synoptická meteorológia*. Bratislava: Alfa, 1986.

[4] SOBÍŠEK, B et al. *Meteorologický slovník výkladový terminologický*. Praha: Academia, 1993.

[5] NEDELKA, M. *Letecká meteorológia II*. Bratislava: Alfa, 1979.

[6] DVOŘÁK, P. *Letecká meteorologie*. Cheb: Svět křídel, 2017.

[7] BADANÍK, B. Airlines' point of view as a new approach to measuring quality of service at airports. In: *26th Congress of International Council of the Aeronautical Sciences.* Anchorage: ICAS Secretariat, 2008, pp. 1767-1772.

[8] KRIDER, E. P. *"thunderstorm". Encyclopedia Britannica..* [online]. 2020. [viewed: 2020-03-24]. Available from: https://www.britannica.com/science/thunderstorm

[9] AN 3. Annex 3 to the Convention on International Civil Aviation - Meteorological Service for International Air Navigation. Québec, Canada: INTERNATIONAL CIVIL AVIATION ORGANIZATION (ICAO), 2010.

[10] LAPLACE, I., KAZDA, A., TOMOVA, A., BADANIK, B., LENOIR, N., MALAVOLTI, E. FAST: Future airport strategies. In: *8th Innovative Research Workshop and Exhibition*. Proceedings, 2009, pp. 19-28.