Safety & Defense 9(2) (2023)
DOI: https://doi.org/10.37105/sd.205

Sources of information on weather conditions in connection with air accidents

Mirosław JEMIELNIAK
miroslaw.jemielniak@polsl.pl (Corresponding author)
https://orcid.org/0000-0001-8908-2281
Silesian University of Technology, Katowice, Poland

Robert KONIECZKA
robert.konieczka@polsl.pl
https://orcid.org/0000-0003-1095-2973
Silesian University of Technology, Katowice, Poland

Received: 27 July 2023 | Revised: 07 November 2023
Accepted: 07 November 2023 | Available online: 22 November 2023

Abstract

This article is an attempt to comprehensively identify the sources of weather condition information in relation to the occurrence of aviation accidents. This issue, according to the authors, should be considered in the following main areas: the actual weather condition at the scene of the accident and its impact on the course of the accident, the information obtained by the flight crew about the weather condition before the flight, the correctness of the crew's decision on how to carry out the flight on the basis of the information obtained about the weather condition.
This publication first discusses the legal basis and requirements for meteorological protection of aviation activities and the resulting consequences. This is followed by a discussion of the meteorological data available for use in the investigation of aviation incidents. This is realized in relation to various weather conditions. All messages and forecasts are characterized, and the possibilities for their use in conducting air accident investigations are discussed. In doing so, a selection of the main meteorological phenomena that may directly or indirectly impact flight safety is discussed.
Sources of weather information for accident investigators and their importance for the investigation are identified. Methods of cross-checking actual weather conditions at the accident scene are indicated.

Keywords: investigation of aviation incidents, meteorological phenomena, weather

1. Introduction

The occurrence of aircraft accidents can be strongly influenced by meteorological conditions. Therefore, this factor that can shape the course of events cannot be ignored during the investigations. It must be taken into account in the following main areas:

- the actual weather conditions at the accident scene and its influence on the course of the accident,
- the information the flight crew obtained about the weather conditions before the flight,
- the correctness of the crew's decision on how to conduct the flight on the basis of the information obtained about the weather conditions.

Hence, at least a basic knowledge of these issues seems necessary for investigating accidents (Konieczka, 2017). This applies to the members of the air accident investigation committee and to the officers of other bodies involved in the activities related to the occurrence of an air accident, such as the police or prosecutors.

Safety & Defense 9(2) (2023)
DOI: https://doi.org/10.37105/sd.205

In the process of investigating an air accident, elements of flight safety theories may be used to determine the causes and to categorize the event into a specific causal group. These theories are based on concepts and methods that seek to establish a causal chain of events, such as James Reason's theory, according to which an event occurs as a result of failures, e.g., in the management of the aviation organization or because of insufficient preparation for the flight in terms of predicted meteorological conditions. At the same time, the "SHELL" theory of F. H. Hawkins presents the relationship between people and the environment, procedures, aircraft or workplace (Milkiewicz, 2001). In the use of this theory, a commission or other body will investigate the relationship of the human being (the so-called operator) with the environment understood as the external environment. This case will assess the state of the atmospheric conditions and the crew's preparation to fly in the given atmospheric conditions.

Regardless of the methods and techniques used, in an event related to atmospheric conditions the analysis should include:

- the weather forecast for the flight (if obtained),
- the rate of change in the atmosphere,
- circulation of information about occurring and changing meteorological phenomena,
- actual weather conditions at the time and place of the event,
- cloud cover (lower and upper limit, type, visibility in clouds, icing, turbulence),
- visibility,
- humidity,
- wind direction and speed,
- wind gusts,
- atmospheric pressure,
- lighting conditions (dawn, dusk, night, day).

Establishing these parameters seems to be crucial for investigating the circumstances of the air accident.

2. Legal basis and requirements for meteorological protection of aviation activities

Knowledge of weather-related issues is an indispensable part of flight preparation and execution. Deficiencies in this area can be either a contributing factor or the cause of an aircraft incident. The need for systemic measures in the areas of meteorological protection and flight operations is reflected in numerous normative documents at the level of international and national aviation organizations, regulating the principles of organization and execution of flights and the operation of flights. The International Civil Aviation Organization (ICAO) is one of the leading international organizations. The ICAO, in its Annex 3, *Meteorological service for International Air Navigation* (ICAO, 2010), which contains international standards and recommended practices for meteorological service for international air navigation, recommends that contracting States use in their national regulations, as far as possible, the precise definitions of the ICAO standards having the character of regulations, as well as indications of deviations from the standards, including any additional national regulations that are important for the safety or regularity of air navigation (EU Regulation 373/2017).

These recommendations concern, inter alia:

1. the organization of a meteorological service for aviation;
2. making of observations and preparing meteorological messages;
3. observations from aircraft and messages from the air;
4. meteorological forecasts;
5. meteorological warnings;
6. climatological information and studies for aviation;
7. services provided to air operators and flight crew members and to air traffic and aeronautical information services;
8. communication and telecommunication requirements for the distribution and exchange of meteorological data.

The Commission Implementing Regulation lays down common requirements for providers of air traffic management/air navigation services and other air traffic management network functions and their oversight, repealing Regulation (EC) No 482/2008. Implementing Regulations (EU) No 1034/2011 (EU) No 1035/2011 and (EU) 2016/1377 and amending Regulation (EU) No 677/2011 provides that the provision of air navigation services (including meteorological services) within the Community will be subject to certification by Member States and sets out the requirements that entities must meet to obtain and maintain a certificate in accordance with Executive Regulation (EU) No 2017/373 (EU Regulation 373/2017). Annex V of this Regulation sets out specific requirements for meteorological service providers, are in line with the standards and recommended practices in ICAO Annex 3 (ICAO, 2010).

Safety & Defense 9(2) (2023)
DOI: https://doi.org/10.37105/sd.205

At the Polish national level, it is necessary to note the Regulation of the Minister of Infrastructure of May 8, 2020 on meteorological cover for civil aviation (Ministry of Infrastructure Poland, 2020). This regulation sets out the detailed conditions and method of providing meteorological cover for civil aviation, the provision of meteorological data to airspace users, and specifies the obligations of the airport operator with regard to access to meteorological data and information to airspace users.

3. Meteorological data usable in the investigation of aviation incidents

Meteorological services ensure safety by providing airspace users and flight safety services with the relevant meteorological information needed to perform an aviation task. The conditions under which the task will be performed is essential. These conditions are defined as:

a) VMC (visual meteorological conditions) – a term used to denote meteorological conditions defined by visibility, distance from clouds and ceiling equal to or above-specified minima. The rules of the International Civil Aviation Organization (ICAO) and the Standardized European Rules of the Air (SERA) detail the conditions under which VMC flights may be conducted, depending, among other things, on flight altitude, class of airspace, visibility and distance from clouds.

b) IMC (Instrument Meteorological Conditions) – a term for meteorological conditions in instrument flight. These conditions are expressed as visibility, distance from clouds and ceiling - less than the minima specified for flight under VMC. ICAO regulations define in detail the minima for IMC flights.

It is important to note the basic difference between flying under VFR and IFR regulations. IFR flight is conducted under regulations using information read from the aircraft's instruments. In VFR flight, the pilot is responsible for avoiding terrain obstacles and other aircraft. It should also be noted that an IFR flight can be flown under both VMC and IMC conditions, while a VFR flight can only be flown under VMC conditions.

For a flight under these conditions, the crew should be equipped with up-to-date aeronautical and meteorological documents, which provide the basis for knowledge of the current weather.

Annex 3 of the Chicago Convention defines meteorological documentation or flight documentation as "[w]ritten or printed documents, including charts or forms, containing meteorological information for a flight" (ICAO, 2010, p. I-3). The fact that this documentation is in the possession of the crew is the first and primary element verified by the investigation team. At the same time, the content of this documentation will be the basis of knowledge for the incident investigation committee on the forecast conditions along the route and in the flight area.

The indicated documentation includes:

- GAMET (General Aviation Meteorological Information) – an area forecast, which is prepared using applicable abbreviations. It is intended for low-altitude flights and refers to the relevant flight information region or parts of it. This forecast contains information on: the area for which it is prepared, the hours during which it is valid, and the height of the atmosphere it reaches in the area. In addition, it consists of two parts:
  - SECN I contains information on weather phenomena dangerous for low-level flight operations.
  - SECN II contains information required for low-level flight operations.
- METAR (Meteorological Aerodrome Reports) – a dispatch used to provide routine, up-to-date meteorological observations for a given aerodrome, drawn up every hour or half-hour. It contains information on:
  - wind speed and direction,
  - visibility,
  - runway visibility range (RVR),
  - current weather conditions,
  - previous weather conditions,
  - cloud cover,
  - air temperature and dew point,
  - pressure.
- TAF (Terminal Aerodrome Forecast) – a dispatch containing weather forecast information for a specific airport. This message is issued for a period of not less than nine hours and not more than 24 hours. The general form of this message is very similar to the METAR message in structure and reading.
- TREND – weather forecast for landing, which contains a description of the expected significant changes to the meteorological conditions at the aerodrome. This message is attached to the METAR or SPECI message and is valid for two hours from the time of issue.
- SPECI – a dispatch providing special meteorological information for aviation. The format of this message is the same as that of the METAR message, and it is issued 10 minutes after an improvement in conditions is observed and immediately in case of a deterioration.

Safety & Defense 9(2) (2023)
DOI: https://doi.org/10.37105/sd.205

- SIGMET (Significant Meteorological Information) and AIRMET (Airman's Meteorological Information) – information issued by the Meteorological Surveillance Office relating to phenomena which have occurred or are forecast and have a significant impact on flight operations. SIGMET applies to all flight levels, whereas AIRMET is issued below FL100. These messages are issued for a period of four hours and are an essential element in meteorological preparation for flight.
- SIGNIFICANT - maps of relevant weather factors prepared for different altitude ranges. These maps contain information presented in graphical and textual form and text, these include:
  - lines of atmospheric fronts with information on their direction and speed of movement,
  - areas of cloud cover with information on the type of clouds,
  - significant weather phenomena,
  - areas of restricted visibility,
  - tropopause heights,
  - icing areas and levels,
  - areas and levels of turbulence,
  - height of jet currents and their speed,
  - altitude of 0° isotherms.
- GAFOR (General Aviation Forecast) - an area forecast presented in graphical form using a color scale, which is intended for low-altitude flights and includes information on visibility, cloud base and specific meteorological phenomena. This message is issued with a six-hour validity period. The GAFOR forecasts the minimum conditions a pilot may encounter while performing a flight in a given area (Janiszewski, 2010).

The meteorological assessment performed by the crew in preparation for the flight and the survey team should also include an analysis of:

- wind map,
- temperature map
- synoptic map,
- radar map,
- icing,
- turbulence.

It should be noted that not only having the documentation, but also the ability to read it and interpretation of it is important for the safe execution of an aerial task. Therefore, in the event of an aircraft incident, the investigation team should assess the feasibility of performing a proper analysis of the weather by the flight crew. The investigation should also include an assessment of the availability of the weather forecast and its appropriate use.

The values given in the messages by the crew should be understood as the most probable. During the course of the task, weather bureaus may issue another message with a change in the forecast. In extreme cases, these messages may contain data with values that make it impossible to continue the task. In such cases, it will be the responsibility of the incident investigation committee to check the crew's ability to plan the task correctly in case of deteriorating meteorological conditions, communication with the flight services and correct decisions made by the crew.

4. Characteristics of a selection of the main meteorological phenomena with a direct or indirect impact on flight safety.

There are many phenomena that can have a direct and indirect impact on flight safety. In view of their multiplicity, for the purposes of this study, the main phenomena can be identified, which include:

Aircraft icing where the ice structure on its components can significantly alter the aerodynamic characteristics of the structure and cause a reduction or loss of engine function and, in extreme cases, damage to the power units. Airframe icing can cause a significant loss of aircraft performance and controllability. The strongest, most violent and unpredictable icing can occur in the cloud layer between 0°C and -20°C, where over-cooled rain with snow can be observed, significantly compromising the safety of flight operations. Ice can form on sensitive parts of the aircraft while it is still on the ground before flight and needs to be removed. Efficient aircraft de-icing and anti-icing systems must ensure the protection of the aircraft during the departure procedure and mission execution.

Turbulence is caused by the resultant horizontal and vertical air movements, which are converted into disordered wave motion. This movement during the flight of an aircraft creates unwanted drag, and violates the stability of the flight. During flight in turbulent air, depending on the type of aircraft, the type of turbulence, the weight of the load and the speed of the flight, there may be a reduction in airspeed, difficulty in piloting and, in extreme cases, even loss of control of the aircraft.

Safety & Defense 9(2) (2023)
DOI: https://doi.org/10.37105/sd.205

Fog is a suspension of condensation products at the atmosphere's ground level. This phenomenon reduces visibility below 1 km. In heavy fog, visibility can be reduced by up to several meters. Such a large reduction in visibility can make safe flight difficult or impossible, even with the help of modern navigational aids (instrument landing system (ILS), weather radar, synthetic vision systems, etc.).

Windshear, where this term is understood to mean changes in wind direction and speed occurring suddenly, which can cause rapid changes in the amount of lift and airspeed. In the phenomenon of wind uplift, a descending current can be observed occurring in parallel with the vortex or rainfall phenomenon. When the descending current reaches the Earth's surface, it causes the air to spread out and produce horizontal vortices. Due to the suddenness of the phenomenon, it is currently practically impossible to accurately predict or forecast it and thus effectively counteract or avoid it.

Precipitation such as rain, hail and snow affect aircraft aerodynamics and visibility, especially during the landing phase.

Lightning strikes can significantly disrupt the crew, cause negative emotions in passengers. Damage to aircraft leading to significant destruction is very rare. Of greater concern is the effect of lightning on avionics, particularly the navigation system and engine operation. In the case of rear-mounted jet engines, there is the potential for transient airflow disturbances associated with lightning strikes to cause engine shutdown for both Full Authority Digital Engine Control (FADEC) and non-FADEC engines.

Meteorological conditions can affect not only the aircraft directly but also operational safety such as:

Runway Excursion - the indirect effect of weather on runway surface condition and the non-indirect effect of the crosswind component on runway direction control.

Controlled Flight into Terrain -- Weather-related incidents occur when an aircraft is in cloud cover or reduced visibility with impaired crew situational awareness related to weather conditions or loss of control of the aircraft in the event of unintentional entry into a bad weather zone (SSHSZ, 2011).

The State Aviation Accident Investigation Commission may be required to examine the aviation organization's strategy for maintaining safe flight in certain types of weather.

5. Sources for obtaining information on the weather condition by the accident investigators

Independently of obtaining information about the weather condition at the scene of the accident, it is reasonable to verify this data with witness statements. This is particularly important when data for the weather report are obtained from distant measurement points in the absence of such data at the scene. In these circumstances, these data may be the only reliable ones to be obtained. In addition, changes in weather conditions must be taken into account, including local conditions resulting from the terrain (mountains) or, for example, the influence of large bodies of water (sea, lakes).

In such circumstances, the following information should be obtained from the witnesses of the incident or other persons present at that place and time when interviewing them:

- perceived temperature,
- horizontal visibility,
- lower cloud base,
- amount of cloud (sky cover) and its color and shape,
- wind strength and direction,
- precipitation (intensity).

As non-professionals carry out this assessment, the answers obtained can be verified in the field using the visibility of both altitude points and other points located at a known distance from the observer (Figure 1). This will avoid confabulation on the part of the witnesses and assist in obtaining a reliable account.

It may be that an aircraft accident has occurred at a location where there is no so-called meteorological cover. The use of weather measuring points from a location far away from the accident site should be considered unreliable. It particularly loses credibility if there is a strong influence of local conditions on the weather pattern. Hence, if possible, data should be obtained from another less distant location, even if the weather condition information is dedicated to a different purpose.

Safety & Defense 9(2) (2023)
DOI: https://doi.org/10.37105/sd.205

Figure 1. Eyewitness account of the accident at the scene allows verification of various details including existing weather conditions at the scene
Source: Frątczak & Konieczka, 2018.

Measurement points of the General Directorate for Roads and Motorways can serve as an example here. They are located on roads and junctions at the disposal of this authority. The measuring points collect, among other things, the following data:

- air temperature,
- pavement temperature,
- temperature under the carriageway,
- dew point temperature,
- humidity,
- pavement condition (including the presence of chemicals),
- wind speed and direction,
- precipitation (type and intensity of precipitation).

An important part of this data can be used to assess the real conditions in the area of the incident. It is worth noting that the meteorological data from these stations are transmitted at intervals of approximately 10 minutes, which allows the conditions to be accurately determined over time.

A valuable source of information on weather conditions is the various kinds of monitoring cameras at the disposal of state and local government bodies, organizations and individuals. They make it possible to obtain weather data, particularly on visibility, type and base of clouds and other phenomena in real time. An excellent example of this is the recording of monitoring on a national road in the area where the crash of the Mi-2 Plus helicopter of the Polish Air Rescue took place on February 17, 2009 (the Jarostowo region of the Lower Silesian Voivodeship). The images of weather conditions on the road presented in Fig. 2 in an interval of 20 minutes, show how suddenly visibility deteriorated, becoming the main cause of the accident.

Safety & Defense 9(2) (2023)
DOI: https://doi.org/10.37105/sd.205

Figure 2. Camera images from Budziszów on February 17, 2009, left at 7.10 a.m., right at 7.30 a.m., respectively
Source: PKBWL, 2009.

Facilities or managers of small local airports or airstrips can also be equally important sources of information on weather conditions. They are not obliged to make such observations of weather conditions. However, it is evident from common practice that it is carried out. This is realized using technical recording means or traditional records.

6. Summary

As can be seen from the analysis carried out, obtaining information on the weather conditions is an extremely important element when investigating the circumstances of an accident. It must not be abandoned, which is due to the necessity of taking into account in the investigation all factors that could have influenced the occurrence of the accident. In view of the multitude of sources of information on weather conditions, it is difficult to agree that it is impossible to make assessments. Moreover, it is possible to peer review the forecasts obtained and take into account relevant local conditions. The network of available resources also not dedicated to aviation allows this.

From the point of view of the investigation, determining what information they had at their disposal and whether, on the basis of that information, they reached the right decision as to how to perform the flight is important for making an objective assessment of the actions taken by the flight crew. This may also be an important indication of the cause of the accident or, at the very least, a contributory factor.

Declaration of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

References

1. EU Regulation 373/2017. (2017). *Commission Implementing Regulation laying down common requirements for providers of air traffic management/air navigation services and other air traffic management network functions and their oversight, repealing Regulation (EC). No 482/2008. Implementing Regulations (EU). No 1034/2011. (EU) No 1035/2011 and (EU) 2016/1377 and amending Regulation (EU) No 677/2011*. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32017R0373
2. Frątczak, D., & Konieczka, R. (2018). Interviewing witnesses in proceedings related to an aircraft accident. *Problemy Kryminalistyki, 300*(2), 67–75.
3. ICAO [International Civil Aviation Organization]. (2010). *Annex 3 to the Convention on International Civil Aviation: Meteorological Service for International Air Navigation* (7th ed.). https://www.icao.int/airnavigation/IMP/Documents/Annex%203%20-%2075.pdf
4. Janiszewski, J. (2010). *Podstawy meteorologii lotniczej*. Centrum kształcenia Kadr Lotnictwa Cywilnego Europy Środkowo-Wschodniej.

Safety & Defense 9(2) (2023)
DOI: https://doi.org/10.37105/sd.205

5. Konieczka, R. (2017). General methodology of the activities undertaken by the authorities investigating aviation occurrences. *Proceedings of the International Conference SimSchool 2017: Application of simulators in aviation specialists training* (pp. 102–109). Let's Fly s.r.o. Ostrava.
6. Milkiewicz, A. (Ed.). (2001). *Podstawy organizacji i metodyki badania wypadków lotniczych w lotnictwa cywilnym RP*. GILC.
7. Ministry of Infrastructure Poland. (2020). *Rozporządzenie ministra infrastruktury z dnia 8 maja 2020 r. w sprawie osłony meteorologicznej lotnictwa cywilnego*. http://g.ekspert.infor.pl/p/_dane/akty_pdf/DZU/2020/106/881.pdf
8. PKBWL [Państwowa Komisja Badania Wypadków Lotniczych]. (2009). *Raport końcowy: Zdarzenie nr: 80/09*. https://www.gov.pl/documents/905843/1047987/200980RKPKBWL.pdf
9. SSHSZ [Szefostwo Służby Hydrometeorologicznej Sił Zbrojnych RP]. (2011). *Meteorologia dla pilotów: Poradnik*.