IMPACT OF WEATHER CONDITIONS ON FLIGHTS AND AIRCRAFT

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Abstract: *Examine the effects of three phases of flight—takeoff and climb, enroute, descent, and landing and five different forms of unfavorable weather—fog, wind shear, thunderstorm, icing, and snow on aircraft operations and accidents. Methods: collect statistically up-to-date data and compare the data to estimate the impact of the various meteorological conditions on flights and the dangers of flight incidents. Use EJM to establish expert systems to report the impact of various weather conditions on flights. Results: evaluate the impact of weather events on flights and the necessity of prevention systems. Discussion: define the need of advanced numerical modeling techniques of time in Air Traffic Management systems.*

Keywords: *accident; adverse weather conditions; expert judgement method; machine learning; stages of flight*

1. INTRODUCTION

Aircraft operations can be greatly impacted by a variety of weather factors, from the routine consideration of wind speed and direction to the more unusual difficulties posed by snow or dense fog. Low cloud, fog and rain may reduce visibility at or around an airport while thunderstorms and lightning can cause serious disruption to flight schedules [1]. Operations may be significantly impacted by fog, which can reduce surface visibility to less than 1 km. Snowfall and wind-blown snow can have a significant impact on aircraft when they are in the air, as well as during ascent and descent. Due to its influence on the aircraft's control, wind shear has a substantial impact during takeoff and landing and has been a primary or contributory factor in numerous aviation accidents. In-flight icing is one of the main dangers of flying in cold weather because it messes with airflow and impairs control and performance. Thunderstorms are among the most dangerous weather events you can experience, making them one of the worst risks to aircraft.

The derived estimations in this article could be used in airplane operations to evaluate the impact caused by weather and to implement the new technology and new ‘ways’ of displaying meteorological information in a way that is consistent with safe and efficient practices [2].

The reliability of a human operator and his prompt professional judgements are the primary factors that determine the efficacy of aviation systems and the supply of flight safety. The Human Factor still has a significant impact on flight safety – nearly 80% of aviation events are due to the fault of people [6].

2. IMPACT OF WEATHER CONDITIONS

Atmosphere and weather conditions.

There is no upper limit to the atmosphere, which surrounds and revolves around the globe. The earth and its atmosphere move together. It mostly consists of nitrogen (78%), oxygen (21%), and a mixture of other gases (1%), including carbon dioxide, hydrogen, and argon. Air created by these gases behaves almost identically like liquid.

Commercial aircraft fly in the bottom two layers of the atmosphere, the troposphere, which is closest to the surface, and the stratosphere, which is immediately above it. The atmosphere is divided into five primary layers.

The air pressure, temperature, and air density all drop as you ascend into the troposphere. You will experience a 35°F drop in air temperature for every 1,000 feet you ascend. The Tropopause, the boundary layer before entering the Stratosphere, is encountered after ascending for around 36,000 feet. At this point, the temperature no longer drops with height and instead stabilizes.

The temperature of the air below the tropopause has an impact on it. The Tropopause rises with increasing air temperature. It thus tends to be higher at the equator (about 55,000 feet) and lower over the poles (about 25,000 feet).Because it effectively serves as a lid to keep the majority of the weather below it, the tropopause is significant.

Turbulence

Most of the time, turbulence only causes passengers discomfort, but it can occasionally be highly dangerous when it is strong.

The brief and chaotic movement of air particles is known as turbulence. The airplane may shake occasionally for no apparent reason, but if it is particularly severe or dangerous, it may also crash, mostly affecting small and light aircraft. Turbulence appears in clouds and their vicinity, especially in thunderclouds.[3]

Although less dangerous, clear air turbulence is annoying because it is hard to spot. We experience it as buffeting and it can catch passengers and pilots off guard.

Aircraft Icing

FIG. 1 Aircraft icing Source: http://aviationtroubleshooting.blogspot.com/2011/01/future-of-deicing-technology-and.html

A quiet killer might be aircraft ice. An airplane's wings may unexpectedly develop ice, greatly impairing their aerodynamic capabilities and causing the aircraft, which is unable to fly, to rapidly drop.

Because water can exist in the atmosphere in the form of water droplets even at temperatures below 0°C, icing results from the physical characteristics of the atmosphere. However, as soon as they touch a solid, such droplets abruptly freeze.

An aircraft, including its wings and other surfaces, as well as the aircraft engine, might be the solid. In that situation, aircraft icing can be extremely dangerous. Despite having ice protection systems, modern aircraft are still susceptible to icing, especially light aircraft. Today, meteorologists predict icing zones and share this information with their users.

Strong Wind

Strong surface wind while landing is especially risky if it is a crosswind, or wind that is perpendicular to the direction of the airplane. Pilots frequently have to attempt a second landing since it is so difficult to line the aircraft with the runway in such circumstances.

If the wind is so strong that it also causes strong turbulence, an additional problem arises, making it quite difficult to stabilize the aircraft to land safely. That sometimes happens at Dubrovnik and Rijeka airports during the bora As a result, meteorologists pay close attention to such circumstances, forecast them, and alert users.

High-altitude wind is also common and is connected to jet streams. Strong wind can be problematic if it is a headwind since it slows down the aircraft, depending on where the jet stream is and what direction it is moving in. But it can also be advantageous because a jet stream causes the plane to accelerate.

Modern airlines use wind forecasts into their route planning since doing so can considerably shorten travel times and cut expenses. On February 12, 2020, a British Airways plane broke the previous record for the quickest trip between New York and London for subsonic aircraft. In a jet stream, the Boeing 747 reached a speed of 1327 km/h and landed in 4 hours, 56 minutes—80 minutes earlier than expected.

Wind Shear

When landing, wind shear is also particularly risky because it can result in an abrupt drop of the aircraft.

It occurs when winds of different speed or direction blow at different points which can be near each other. Wind shear can be horizontal or, more often, vertical. When that happens, the aerodynamic flight parameters are suddenly altered, causing the aircraft to rise or stall out of control. If it is close to the ground when landing, this can be fatal.

Today, wind shear is forecasted and also detected by onboard or ground-based devices. The majority of current heavy aircraft have wind shear detection equipment to alert pilots of this phenomena, which poses a serious risk to their safety.

Mountain Waves

Mountain waves are a type of meteorological phenomenon that can both help and hurt aviation.

When air moves over a barrier, like a mountain, mountain or lee waves are created. They emerge from behind the mountain as updrafts and downdrafts. Light aircraft, balloons, ultralight aircraft, hang gliders, and paragliders are all at risk from them.

For instance, they most frequently occur in Croatia on the lee side of the Dinaric Alps because to a strong southwest breeze. They can happen during the bora over the Adriatic.

A cloud on a mountain's lee side can also be seen visually in conjunction with the mountain wave phenomena. Mountain waves are dangerous because the downdrafts that occur in them can make steering the aircraft difficult, but they can also be useful because the updrafts can be used for flying and gaining altitude (gliders).

Reduced Visibility

Flying in clouds and fog is the technical term for conditions with low visibility. In fact, it frequently involves flying blind while using navigational aids. In terms of safety, technology has mostly solved the issue of flying in low visibility situations. It refers to using a variety of radio navigation aids during all flight phases so that the aircraft can be operated even in low visibility situations with less than 50 meters of vision.

Of course, for such aircraft operations, all safety standards must be satisfied. There must be enough ground- and air-based radio navigation and other equipment, and the flight crew must be properly educated.

Fog, on the other hand, is the main problem at airports. It is routinely predicted by meteorologists, who use this information to alert travelers to potential issues. Flight operations may be halted due to fog if all safety criteria are not met. However, even if the safety requirements are met, fog can still be a problem. For safety reasons, separation requirements between aircraft are raised under low visibility circumstances, which reduces capacity. Due to flight delays, this can be extremely problematic in congested skies or at busy airports.

Thunderstorm

A thunderstorm is regarded as the most hazardous meteorological occurrence for aircraft due to the massive energy it produces and the following meteorological phenomena.

The thundercloud itself, as well as those above, below, beside, and inside of it, are put at risk. It is dangerous for airplanes not only when they are in the horizontal flight phase but also when they are taking off or landing.

It can be brought on by a single cloud or a cumulonimbus cloud, a group of clouds. Pilots typically steer clear of them since they tend to build overland during the summer and can reach heights of up to 15 km. This makes flying challenging and risky.

A thunderstorm is often accompanied by a number of other dangerous meteorological phenomena, including turbulence, strong wind, wind shear, strong updrafts and downdrafts, ice, electrical discharge, heavy precipitation (rain, snow, or hail), microbursts, gust fronts, and funnel clouds.

The Aeronautical Meteorology Service pays particular attention to thunderstorms due to their importance for flight safety by anticipating their formation and disappearance and offering a variety of information for users.

Variations in air pressure are what cause the sustained horizontal movement of air we refer to as "wind". When you view the weather report on TV, the wind speed is stated in mph. In aviation, it is calculated in knots (kt), where 1kt is equivalent to 1.15mph.Most likely, you've seen a chart similar to the one below that displays areas of high and low pressure. Similar to how water will flow down a slope and fill in a lower lying area, air will naturally move from locations of high pressure to areas of low pressure**.**

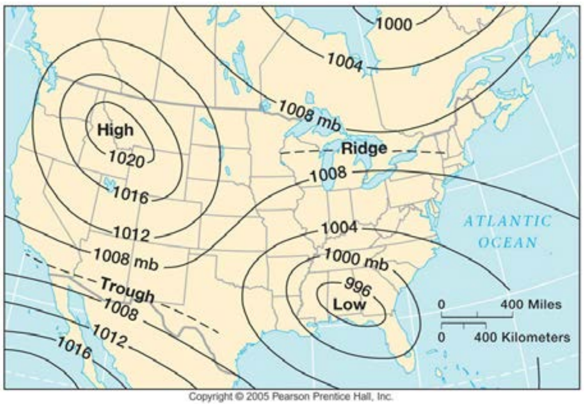

FIG. 2 Charts like this show pilots areas of high and low pressure. (Image courtesy web.gccaz.edu), http://thepointsguy.com/news/how-weather-affects-flight/

The rings on the chart are called isobars and they indicate areas of equal pressure. The closer the isobars are together, the greater the pressure change for a given distance, and therefore the stronger the wind. We also know that air circulates around areas of low pressure and high pressure in the northern hemisphere in opposite directions. In the southern hemisphere, the situation is the opposite.

As a result, you can determine the direction and strength of the wind by looking at a chart like the one above. One of the most crucial things that pilots need to know for their trip is what the wind is doing.Why is that important for pilots? First up, let us dispel a common myth. Contrary to popular belief, an aircraft's wings, not its engines, are what cause it to fly. The engines merely provide forward acceleration.

That's because a wing works by air flowing over its surface. The wing begins to provide lift as soon as the airflow reaches a particular speed. The airplane ascends into the air when the lift produced exceeds the weight. The driving power behind the airflow across the wing is provided by the engines. Because of this, the wind's strength and direction (velocity) are crucial to aircraft at all times throughout flight, but especially during takeoff and landing.

Latest research

Data of the National Transportation Safety Board (NTSB) shows, that during the last 10 years 21, 3% aviation accidents happened due to weather conditions, of which 39,1% – in bad weather conditions. The major cause of aviation accidents in bad weather conditions (68%) considered improper and untimely DM by crew of the aircraft [5]. According to the IATA Safety Report for 2016, inclement weather was a contributing factor in 49 percent of incidents, making it the most significant environmental issue.

The proper communication between the pilot and ATC is essential for both the safety of air travelers and those on the ground.

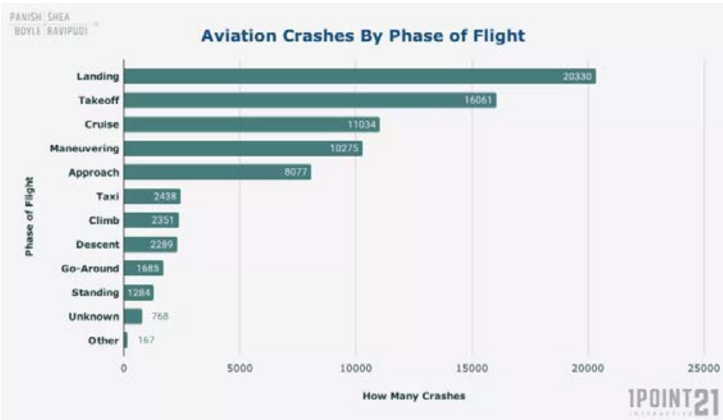

FIG. 3 Aviation crashes by phase of flight
https://www.psbr.law/aviation_accident_statistics.html

ATC interference with the flight crew, language barriers, communication issues, incorrect ATC instructions or commands, etc. caused about 2 000 fatal aviation accidents in the second half of the 20th century, according to statistics from the Aviation Safety Network (ASN).

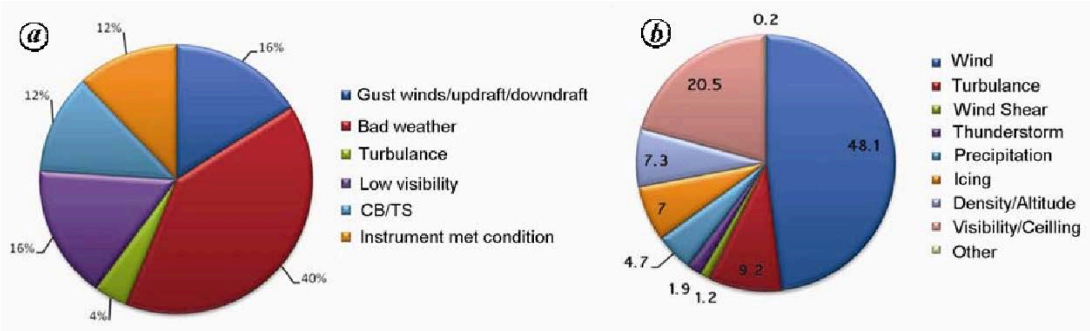

FIG. 4 Proportional occurrences of various accidents by further classifying all weather-related aircraft accidents into various categories of fog, winds (squalls, gusty, updraft, downdraft), low visibility, CB/TS and turbulence for (a) India and (b) USA. [7]

Thus, the Aviation Safety Network safety database presents the following accident statistics with weather as a contributing factor:

1) 224 incidents resulting from icing (including 133 loss of control, 15 forced landings away from the airport, and 11 total engine power loss);

2) 132 incidents resulting from low visibility (including 55 CFITs - Ground, 26 CFITs - Mountain, and 9 loss of control);

3) 116 incidents resulting from windshear or downdraft (including 36 loss of control, 18 runway mishaps, and 9 heavy landing

According to research done by the (Aviation Accident and Incident Database) and Plane Crash Information, the percentage of aeronautical accidents caused by weather conditions decreased from 31% in the 1990s to 24% between 2003 and 2007. Approximately 17% of aviation accidents today are weather-related. Aerial accidents and incidents that occur during the descent phase, first and final approach, landing, beginning and final ascent, and takeoff phases are also mostly caused by unfavorable weather conditions. Even though the percentages of incidents and accidents caused by weather are declining year after year, meteorology still has a significant impact on aeronautical activities, both in terms of aviation safety and the economy.

Expert System is one of the type of the Artificial Intelligence (AI) systems. Besides AI technologies can be clustered in the following capabilities, such as Machine Learning (ML); Natural Language Processing (NLP); vision; speech; planning; robotics, decision support system, etc. In AI, an expert system is a computer system that simulates the decision-making ability of a human [4].

Expert systems are made to reason through knowledge bases that are expressed as if-then rules rather than procedural code in order to tackle complex problems..

The first stage in creating an expert system is to analyze a complex system.

Second is to break complex systems down into smaller units:

a. Define subsystems for expert estimation of their significance and describe their characteristics;

b. Define estimation criteria (3-5 criteria) and describe their features;

c. Estimate subsystems using the Expert Judgment Method (EJM) by criterion No. 1 and calculate the weight coefficients of subsystem significance by criterion No. 1;

d. Analogously calculate the next criterion.

In three stages of flight, the impact of five different types of bad weather—fog, wind shear, thunderstorm, icing, and snow was estimated using the expert judgement method:

- Takeoff and climb
- Enroute
- Descend and landing.

Using the results of calculations, a general histogram of weight coefficients for three different stages of flight was built that illustrates that the biggest influence: Using the expert judgement method, the impact of five different types of bad weather conditions (fog, wind shear, thunderstorm, icing, and snow) on the aircraft operations was estimated during three stages of flight:

- On takeoff and climb has Fog
- On enroute has Thunderstorm
- On descend and landing has Wind shear.

And for all three stages of flight the most influential is wind shear.

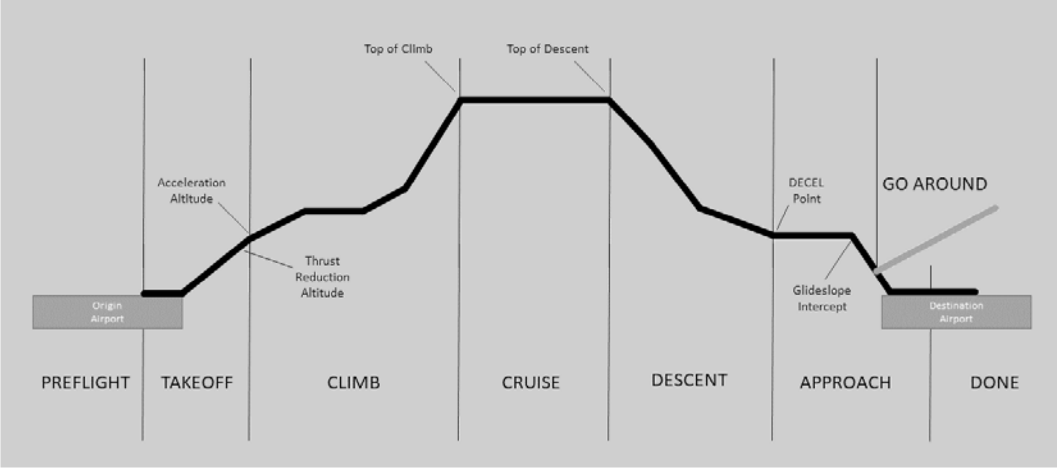

FIG. 5 Stages of flight,
https://docs.flybywiresim.com/pilots-corner/advanced-guides/flight-phases/

3. CONCLUSIONS

The methodology described in this article assesses how weather occurrences affect the flight. In order to make the aviation system less susceptible to weather events, these estimates could be used to further enhance situational awareness and decision-making in pilots through the application of current technologies and the development and deployment of new artificial intelligence technologies.

When it comes to ATM operations, issues including sudden changes in wind direction and speed, the presence of wind shear, instances of low visibility, and other unfavorable weather conditions need to be taken into account. Information is therefore crucial for the organization and security of air operations, both in airports and on flight routes. As a result, it is essential to supply ATMs with forecasted meteorological data utilizing current state-of-the-art numerical modeling techniques.

It is crucial for ATM systems to be able to have correct knowledge of meteorological conditions both at a synoptic scale and at smaller sizes due to the varying spatial resolutions with which they operate.

Implementation of the modern and developed Expert systems as a type of the Artificial Intelligence (AI) systems will lead to management and aviation security improvements.

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