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APPLICATION OF SOFTWARE, REPRESENTING CUMULONIMBUS CLOUDS, IN AIR TRAFFIC CONTROL

Giedrius DERENČIUS, Ugnius RAGAUSKAS*

Vilnius Gediminas Technical University, Vilnius, Lithuania

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Abstract. In this paper we attempt to answer the question of whether the display of cumulonimbus clouds on air traffic controller radar screens has a significant impact on air traffic control. The developed cumulonimbus cloud mapping simulator allowed the study to be performed by performing simulations with a flight control simulator. This allowed an assessment of how the air traffic controller makes decisions when cumulonimbus is displayed and when it is not. The benefits of cumulonimbus imaging for aircraft trajectories and flight time were also assessed. The research was conducted in the space of Vilnius terminal manoeuvring area.

Keywords: cumulonimbus, weather radar, air traffic control, on board radar, cumulonimbus mapping.

Introduction

In the twenty-first century, air travel became available to almost anyone who wanted to travel on it. Falling ticket prices are leading to an increasing number of aircraft in the airspace each year. Smooth and safe air traffic is ensured by air traffic controllers working in air traffic control centers. Their main responsibilities are to control the movement of aircraft on the ground, i.e. at airports and in the air, and to ensure their safe movement in order to avoid collisions or other accidents. The main tasks of approach air traffic controllers are to ensure a consistent line-up of aircraft approaching the airport, to maintain safe distances between them and to control the traffic of aircraft that have already taken off. The smooth and safe air traffic is greatly affected by meteorological conditions. Certain meteorological phenomena can be dangerous to the aircraft in the air. One of them is cumulonimbus clouds. Meteorological information shall be provided to the air traffic controller from the meteorological services or from the airplanes themselves, which are equipped with special equipment to record meteorological phenomena, such as cumulonimbus clouds, in front of the aircraft. However, air traffic controllers themselves do not directly have the ability to see cumulonimbus clouds on their screens in controlled traffic based on pilot reports (Ohneiser et al., 2019). In the event of heavy air traffic, it may be difficult to organize the flow of aircraft smoothly, as they will be required to obtain a permit if they are asked to change their trajectory due to the cloud, and this may disrupt the original organization of air traffic. As many as 22% of air traffic delays are due to adverse weather conditions (Pagé, 2011). Clouds invisible on the radar can change the flight directions of other aircraft, and it is not clear when and how aircraft can be sequentially lined up for onward flight. The aim of this work is to analyze the flow of meteorological information received by pilots and air traffic controllers, to review its advantages and disadvantages, and to develop software that displays cumulonimbus clouds to air traffic controllers, allowing them to better understand and see the weather conditions in real time. Also, test this equipment using a flight control simulator to see if seeing cumulonimbus clouds for air traffic controllers has a significant impact on air traffic control. Coordinated operation of ground systems and aircraft is essential for proper air traffic planning and aircraft vectorization. On this basis, Sesar, the European Union's coordinator for research and development in the field of air traffic control, writes that planning, monitoring and implementing these factors can provide a better understanding of the conditions underlying the current changes in air routes. Proper monitoring and the compatibility of ground-based systems with aircraft allow for more accurate trajectories, which can lead

*Corresponding author. E-mail: *ugnius.ragauskas@vilniustech.lt*

to increased traffic predictability, leading to benefits such as increased capacity, efficiency and reduced environmental impact (SESAR Joint Undertaking, 2019).

1. Cumulonimbus clouds

Convection air, a meteorological phenomenon that mostly causes thunderstorms along with heavy rains, hail, and strong gusts of wind and can pose a serious problem in aviation safety (Yang, 2018). It is mainly caused by atmospheric instability and is characterized by a dense protruding vertical cloud, which is a storm cloud and is called a Cumulonimbus cloud or Cb. Cumulonimbus clouds pose a serious threat to aviation as they can cause dangerous phenomena such as turbulence, icing, thunderstorms, wind shear, hail, and intense precipitation (Tuomola, 2021). These high air hazards associated with cumulonimbus clouds increase the annual cost to the aviation industry due to extended time and lost fuel, as some flights may be delayed, canceled or diverted. Because Cumulonimbus clouds can be accompanied by heavy rains and turbulence, pilots should always try to avoid flight information and meteorological information (Forster & Tafferner, 2012). For all of the above reasons, it is important to forecast, detect, and monitor cumulonimbus clouds as much as possible. Cumulonimbus clouds can be isolated, occurring in groups, or along fronts. As clouds form along the cold front, the speed and direction of the winds, at their location and toward the locations they move, can vary. In the northern hemisphere, cold and occlusion fronts tend to move southeast and east. The wind direction changes clockwise: south and southeast winds usually blow before the front passes, and behind the front line the wind becomes southwest, west, or even northwest. The average speed of the cold front is about 35 km / h (Rimkus, 2011). The lifespan of a single cloud is typically about 30 minutes to 2 hours, and the diameter can range from 500 meters to 20 kilometers (Tuomola, 2021). The formation of these clouds usually goes through three stages: the developmental stage, the mature cloud stage, and dispersal. However, no matter what stage it is at, a typical horizontal cumulonimbus cloud shape can be depicted as a circle or ellipse that can extend up to several hundred kilometers, although this is usually the prevailing and unstable air instability around it. These clouds can form one at a time, in groups, or at the cold front line pushing warm air, and fissures form in the area.

The apex of the cumulonimbus is usually flat and can rise up to 23,000 m and is described as an elliptical cylinder from a three-dimensional perspective. Thus, convection meteorological forecasts for aviation safety focus on the variable characteristics of the cumulonimbus cloud: central position horizontally, mean, level of atmospheric instability, maximum peak height, direction of movement, and associated merging or splitting with adjacent clouds. Thus, aircraft are vectorized by pilot-in-command to prevent them from flying into these clouds and to ensure aviation safety. After analyzing the METAR reports for

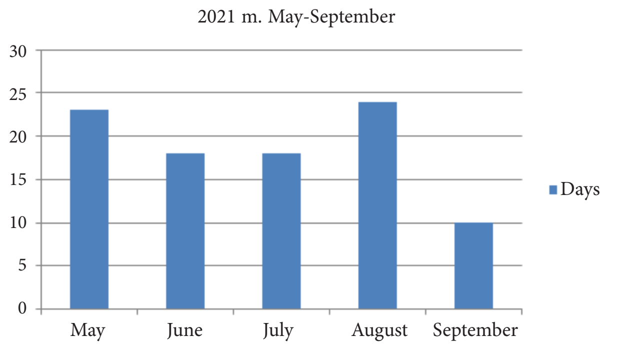

Figure 1. Number of cumulonimbus cloud capture days in Vilnius region (compiled by the author, 2022)

Vilnius Airport issued in May-September 2021, 93 days out of 153 days, cumulonimbus clouds were recorded in the Vilnius region, the data were compiled using the website www.ogimet.com (Figure 1).

Based on the analysis, it can be concluded that the formation of cumulonimbus clouds, the summer period in the Vilnius region is a common phenomenon, which may lead to frequent deviations of aircraft from the planned route.

2. Meteorological observations for aviation

Weather observations are needed to determine and monitor the meteorological parameters required for the safe and efficient operation of aviation. The information is necessary in the terminal maneuvering or TMA and cruising levels of the main airports, as well as in the surrounding areas, to enable a variety of operational activities at smaller aerodromes and other remote locations. Observations are important because some parameters can be inaccurately predicted by computer systems and the information is not provided in the structure required by the aviation sector (Gultepe et al., 2019).

Most disasters related to meteorological phenomena are caused by phenomena such as storms, heavy rain, thunderstorms, hurricanes, wind shifts, and so on. Meteorological radar observations play an important role in understanding the details of these phenomena and in making detailed weather forecasts (Houze et al., 1993).

Meteorological radar is an electronic system that generates electromagnetic waves, emits them into space through a transmitter, and receives from the object from which the electromagnetic waves reflected the return scattered signal and measures its position, movement, and so on. Typically, the same antenna is used to both transmit and receive returning electromagnetic waves (Fukao & Hamazu, 2014). The exact position is obtained from the direction from which the reflected signal returns and from the distance calculated from the time taken for the electromagnetic waves to travel from the radar to the object and back. Not only meteorological radars but also any other surveillance radars work on this principle.

Meteorological radars on aircraft are installed to detect certain weather conditions in the atmosphere, such as the location of rainfall or to calculate their movement, to assess in-flight weather situations such as rain, snow, hail storm clouds, and more (Graf & Werth, 2014). Most weather radars installed in aircraft today can detect the movement of water droplets and the level of rainfall. The principle of radar operation is based on the principle of transmitting radio waves and obtaining their reflection. Aircraft meteorological radars can typically capture meteorological phenomena up to 80 nautical miles in front of them, i.e., about 150 kilometers. The radar has the ability to be moved vertically from 15 degrees above the horizon to 15 degrees below the horizon. It cannot be rotated horizontally.

The peak of the Cumuloninbus cloud is usually higher than the cruising flight levels of aircraft, which means that aircraft can only fly these clouds by changing the horizontal direction, it is not possible to fly over it. Unplanned re-routing of an aircraft can lead to unbalancing the trajectories of other aircraft (Yang, 2018).

3. Metodology

After discussing the shortcomings of providing meteorological information so that air traffic controllers cannot see the location of the formed cumulonimbus clouds in real time, it was decided to investigate how they could be represented and what the benefits would be. To implement this, it was chosen to create a computer program – a simulator, which would allow to display cumulonimbus clouds and calculate its possible trajectory. The Cumulonimbus Cloud Deployment program is designed to evaluate the ability of an air traffic controller to plan aircraft approach routes in advance by knowing the locations and trajectories of Cumulonimbus clouds in advance.

Seeing clouds in advance by air traffic controllers can avoid such consequences as unplanned deviations from aircraft trajectories, and that is the main goal of the investigation. The flight control procedure using the developed software that analyzes meteorological phenomena will be tested using the flight control simulator "Nita expert ATC".

The test requires 2 people to use the software to perform tests with a flight simulator. The test is a simulation of air traffic control using equipment designed for it, simulating air traffic control using computer programs designed for this purpose and equipment prepared for that purpose. One person will perform air traffic control procedures and the other will perform aircraft piloting procedures. The piloting is performed by performing theoretical actions with a computer, according to the instructions of the air traffic controller. The image that is simulated on the air traffic controller screen remains similar to a real air traffic control radar. Using the simulator, 4 tests will be performed. 2 tests will be performed using the developed software and 2 tests without using. It is possible to specify that an identical test will be performed with or without the use of software. This is done in order to be able to compare the results obtained. Each test will take place in the Vilnius access area, simulating departing planes towards Vilnius Airport, and each test will simulate a cloud intersecting with specific aircraft routes. Using the software, the air traffic controller and the pilot operator will have one additional computer device each. The test is based on pilot reports, so the first simulated aircraft to notice a meteorological obstacle will ask the air traffic controller to circle the cloud, while describing it to the air traffic controller and marking it in the software. In this way, the cloud will also appear on the screen of the flight guide, according to which it will already be able to navigate other approaching aircraft.

The tests will first be performed using runway 19. A cloud will be simulated whose trajectory intersects the runway straight line, thus preventing the aircraft from approaching. Using a stopwatch, the flight time of each aircraft from its starting point to the landing at Vilnius Airport will be measured. The flight distance of the aircraft will also be measured using the distance measurement function of the Nita expert ATC simulator. This will be done in each test and will compare how aircraft routes and flight times change when the cumulonimbus cloud is visible to the air traffic controller and when it is not. What will be done during the test, when runway 01 will be used.

The research software will be used as an aid. This means that separate computer devices will be required to use it. The program will first present a geographical map of Vilnius surroundings, which is used from the Google maps map platform. It marks the indicative boundaries of the Vilnius TMA, including entry and exit points, different height restriction zones and the location of Vilnius Airport. These landmarks are designed to make it easier for the air traffic controller to link the information provided by the software to the information provided by the radar on the air traffic control screen. The drawing is done by marking specific points on the map, thus forming a closed shape. This will simulate a cloud that will be drawn manually. This option is implemented to allow the study to be performed in any simulated weather conditions, in this case, anywhere by selecting a cumulonimbus cloud. After marking the points represented by coordinates and creating a closed shape that is represented as a cloud, the program opens a table where you can enter additional data such as wind speed in knots (kt), wind directions, and cloud height in feet (ft). These are all sizes that are relevant to the study. The units for measuring distance and speed are those used in aviation. If neither wind speed nor direction is selected, the program automatically sets these values according to the current situation. This means that the wind speed selected in the selected cloud location and its direction will be the same as the minute the cloud was drawn. To make this possible, the online meteorological information platform Open Weather Map is used. The principle of its operation and integration is described in the section "Software development methodology".

For the practicality and usefulness of the application, the clouds marked on the map may change their position over time. This allows you to check the approximate location of the cloud based on the wind speed and direction entered manually or the current weather conditions at a specific location where the cloud is marked. The time shift is chosen up to 30 minutes, taking into account that the tests for the study will last up to half an hour. The program calculates the displacement of the marked cloud automatically, using several mathematical formulas. In particular, in order to know the displacement of an object, it is calculated what distance will be traveled after a certain unit of time, based on the set or current real wind speed. Knowing the distance traveled after a specific selected time interval, the formulas used to calculate the new longitudes and latitudes:

$$\lambda_2 = \lambda_1 + a\tan^2\left(\sin\theta \cdot \sin\left(d/R\right) \cdot \cos\varphi_1 \cdot \cos\left(d/R\right) - \sin\varphi_1 \cdot \sin\varphi_2\right), \quad (1)$$

where: λ_2 – the calculated longitude; λ_1 – the initial longitude; d – distance m; R – the diameter of the ground m; d – the distance traveled m.

$$\varphi_2 = a\sin\left(\sin\varphi_1 \cdot \cos\left(d/R\right) + \cos\varphi_1 \cdot \sin\left(d/R\right) \cdot \cos\theta\right), \quad (2)$$

where: φ_2 – the calculated latitude; φ_1 – initial latitude; d – distance m; R – the diameter of the ground; θ – direction in degrees.

With the cloud marked and the data entered, the program calculates the cloud trajectory according to Equation (1) and Equation (2), where the cloud will slide after a certain period of time. This air traffic controller can not only circumnavigate aircraft around the cloud, but also plan the routes of later arriving aircraft, making decisions earlier.

The program automatically calculates and displays the location of the object after the selected time period. With a highlighted object, in this case, clicking on the cloud provides relevant information that the air traffic controller can view, such as the direction of the cloud's movement. Checking the possible location of the cloud after a specific, selectable period of time increases the transparency of the object, thus showing that the displayed image is not visible at the current time, but after a specific time. Once the cloud is gone, you can delete it from the app. This can be done by informing the pilot that the cloud is no longer available.

In summary, the whole data transfer process and program integration will work on a simple principle. The pilot of the aircraft flying towards Vilnius captures the Cumulonimbus cloud on the TMA radar screen. It informs the air traffic controller, stating the distance from Cumulonimbus and its preliminary extent, based on meteorological radar information. This is how the pilot asks the pilot to circle it and an image of the cloud appears on the flight manual screen. A circle of irregular shape is drawn. Data on the meteorological conditions surrounding the cloud are also recorded, i.e. wind direction and speed in the cloud position. Although the Program has the ability to itself take data on wind speed and direction at a specific location where the cloud is marked, it does not meet the meteorological conditions in real Cumulonimbus circumstances.

4. Application of software analyzing software analysis in Vilnius TMA flight control

When testing a software, it is necessary to pay attention to several important factors, the emphasis of which is necessary in order to tailor the program and get the most out of it.

First of all, it's a runway selection. There are 2 runways at Vilnius Airport, 01 (facing north) and 19 (facing south). Typically, aircraft take off and land in the direction of the wind, due to the maximum carrying capacity, unless the wind speed does not exceed 5 knots, then the wind does not have a significant effect on the aircraft. However, if the runway used is selected according to the wind direction, it can be changed during operation while maintaining safety requirements. In this case, if the approach to the glide path is blocked by a cumulonimbus cloud, the aircraft may be diverted to another runway. It is worth noting that if the approach of aircraft to both runways is blocked, the aircraft will not be able to land at the airport and will be redirected to waiting areas or alternative airports that are scheduled in advance before the aircraft starts to travel. Therefore, the software test is not performed in a situation where the airport is inaccessible due to the cumulonimbus cloud above it, because in such a situation, the software will not be useful, the aircraft will not take off and land at the airport, and the results of the study will not be obtained.

Also, it should be noted that there are 7 waiting areas in the Vilnius access area. 4 of which are assigned to aircraft approaching runway 19 and 3 of which are assigned to aircraft approaching runway 01. Waiting areas are used in the event of unforeseen circumstances, such as unobstructed runway traffic or when it is not possible or safe to line up sequentially. aircraft to land. In this case, in the presence of cumulonimbus clouds, airspace may be blocked and incoming aircraft have less room to maneuver. This means that in heavy traffic, waiting areas are used to ensure safe traffic in a software test.

All aircraft entering the access airspace are automatically detected in the simulator to fly through certain points and specific STAR arrival routes are determined, as in real air traffic, which were described in the section "Methodology for Development and Research of Software Analyzing Meteorological Phenomena". In the event of unforeseen circumstances, in this case cumulonimbus clouds, the air traffic controller may, using software that maps these clouds on a map, make a decision to re-orient the aircraft before they enter the access airspace, provided that such control allows more effective control of air traffic around the cloud. The air traffic controller may do so in agreement with the air traffic controllers of other airspace or, if they delegate the aircraft, access to the air traffic controller. The study found that most aircraft had changed direction earlier than the pilots themselves would have asked for a change of direction due to the cloud. Therefore, in most situations, aircraft flew at non-entry and exit points.

The software developed is ancillary in nature to help assess whether the real-time vision of the cumulonimbus clouds has a significant impact on air traffic control, allowing the air traffic controller to see the formed cumulonimbus clouds and calculate their trajectory. Its operation has no direct interface with the flight simulator used for the test. The program displays certain reference markers, such as the boundaries of the Vilnius TMA, entry and exit points, so that the air traffic controller can see on both screens, that is, the simulator radar of the flight simulator and a computer device that displays the created software on the screens, being able to see exactly where in the space the cloud is.

5. Software application testing and process

For the study, 4 tests were developed using the flight control simulator "Nita expert ATC", which has already been described in the methodology section. The tests were prepared to simulate the arriving aircraft at Vilnius Airport, all of them flying through the Vilnius TMA area. Considering that the departing aircraft is less affected by the cumulonimbus cloud, as the aircraft can wait at the airport if necessary, the departing aircraft were not simulated in the test. The created 4 tests will be described and compared in the appropriate order:

1) Test 1 – Control of incoming aircraft without the use of software, runway 19.
2) Test 2 – Control of incoming aircraft with the use of software, runway 19.
3) Test 3 – Control of incoming aircraft without the use of software, runway 01.
4) Test 4 – Control of incoming aircraft with the use of software, runway 01.

It can be seen that in this case, the results of the first test will be compared with the results of the second test, and the results of the third test will be compared with the results of the fourth test. In other words, aircraft flight times and distances will be compared when the air traffic controller controls the aircraft based only on pilots' reports of cumulonimbus clouds and when the cumulonimbus cloud is marked at the appropriate location in software that can calculate the cumulonimbus cloud position over time.

There are six arriving aircraft in all tests with the same starting position. Each aircraft is assigned an appropriate standard arrival procedure STAR. They are the same in the first and second tests and in the third and fourth tests. This means that when testing with a different runway, the standard approach paths are changed without changing the initial position of the aircraft. During the teste, all aircraft do not arrive at the same time, i. they appear on the radar screen at different times, which means that if the aircraft appears on the radar at 00 min 00 s, it will appear at the same time in the second test. In the third and fourth tests, the sequence of occurrence of the aircraft is different from the first and second tests, without changing their initial positions. This will be described in more detail later, with a detailed description of each test.

In each test, choose one location where the cumulonimbus clouds will be simulated. Their initial location in the first and second test is the same. In the third and fourth tests, the starting point of the cloud is also the same, but different from the first and second. The location and direction of the clouds were chosen so that over time the cloud would slide on both the runway 01 and runway 19. The first and second tests were performed using runway 01, so the position of the cloud was chosen northwest of runway 01. glide The third and fourth tests are performed using runway 19. The position of the cloud is chosen in the southwest with respect to runway 19. Its direction of movement is towards runway 19 glide. The wind speed and direction at the cumulonimbus cloud position were also determined. The average speed of the torrential clouds together with the cold front is 35 km / h, a slightly higher speed than the average of 40 km / h was chosen, and the largest possible change in the position of the cloud, expressed in knots, yielded 22 kt. The direction of cloud movement is set at 150°. These parameters are needed to estimate the position of the cloud over time. The wind speed and direction in the airport area may differ from the speed and direction of cloud movement, so the wind speed and direction in the aerodrome area were ignored during the study.

The cloud position calculated and displayed by the software, whether or not the air traffic controller has used the software, remains the same. Aircraft pilots see these clouds in any case, given that the aircraft is equipped with meteorological radars to see the type of precipitation and the distance to it. During the test, when these clouds appear on the pilots' path, the pilots ask them to fly around. In tests using software that displays a cumulonimbus cloud, the first pilot of the aircraft who sees the cumulonimbus cloud notifies the air traffic controller, and the cloud is marked in the software. The air traffic controller, when controlling other aircraft, then decides on the position of the cloud according to the software and controls the other aircraft in advance by tilting them in a direction that prevents the aircraft from encountering the cumulonimbus cloud.

6. Results

The study shows that the flight time of the aircraft was reduced during the tests that used the software. Comparing the first and second tests, which initially used runway 19 and later changed to runway 01, aircraft flight time was reduced by an average of 17.5% during the second test using software (Figure 2).

It is worth noting that only one aircraft with the call sign CSA42F had a shorter flight time during the first test than during the second test. During the second test, the flight time of the aircraft was 14.15% longer than during the first test. It can be concluded that this is due to the fact that this aircraft was the first to report the cloud, which

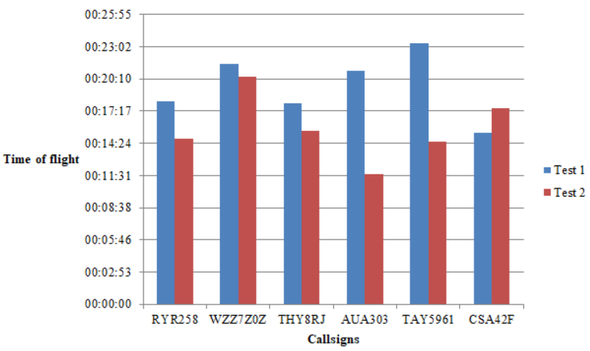

Figure 2. Comparison of aircraft flight time during the first and second tests (compiled by the author, 2022)

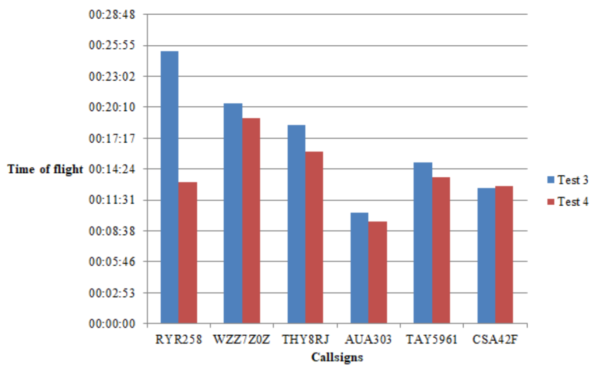

Figure 3. Comparison of aircraft flight time during the third and fourth tests (compiled by the author, 2022)

means that during the second test he had to provide more information to the air traffic controller in order to define the torrential cloud as precisely as possible. The flight time of the remaining aircraft decreased: RYR258 – 18.36%, WZZ70Z0 – 5.44%, THY8RJ – 13.88%, AUA303 – 44.02%, TAY5961 – 37.84%. The reduction in flight time was due to previous decisions made by the air traffic controller. This resulted in a more straightforward launch of the aircraft on the runway straight line with fewer maneuvers.

Comparing the third and fourth tests, which initially used runway 01 and later changed to runway 19, aircraft flight time was reduced by an average of 13.95% during the fourth test using software (Figure 3).

As with the first and second test, only one aircraft with the call sign CSA42F had a shorter flight time during the third test than during the fourth test. During the fourth test, the flight time of the aircraft was 1.34% longer than during the third test. It was the aircraft that first reported the torrential cloud, it had to provide the air traffic controller with more detailed information about it. However, compared to the first and second tests, the aircraft required less time and the flight time in the third and fourth years of the tests remained almost unchanged. The flight time of the remaining aircraft decreased: RYR258 – 48.04%, WZZ70Z0 – 6.53%, THY8RJ – 13.51%, AUA303 – 8.03%, TAY5961 – 8.93%. During the fourth test, the air traffic controller also made decisions earlier, seeing the torrential cloud and its possible trajectory, which led to more direct control of the aircraft towards the runway, which affected the amount of aircraft maneuvers.

Conclusions

1. Cumulonimbus clouds are a serious obstacle for flying aircraft. Aircraft that fly into them can experience severe turbulence, lightning, or heavy icing, making it dangerous to fly into them. Cumulonimbus clouds can be detected by meteorological radars, satellites or visually. However, they remain invisible on the radar screens of air traffic controllers and this causes unforeseen changes in the routes of the aircraft. Aircraft pilots themselves avoid spherical torrential clouds using integrated meteorological radars. The development of meteorological prevention systems is also reviewed.
2. Software has been developed to map spherical torrential clouds and calculate their possible trajectory according to wind speed and direction. The method of transmitting information about cumulonimbus clouds used in the study is also presented.
3. The study found that the mapping of spherical torrential clouds to air traffic controllers has a significant impact on air traffic control. During the simulations performed, the flight time using the developed software was reduced by an average of 15.7%. The main factor behind this is the decisions previously taken by the air traffic controller to change the trajectories of the aircraft. This means that the implementation of cumulonimbus cloud mapping capabilities can further avoid unforeseen deviations in aircraft trajectories.
4. After analyzing the obtained results and based on the performed literature analysis, it is recommended to conduct a study for further work on the possible application of in-flight meteorological radar for cumulonimbus cloud monitoring and direct submission of the obtained information to air traffic control centers.

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PROGRAMINĖS ĮRANGOS, ATVAIZDUOJANČIOS KAMUOLINIUS LIŪTINIUS DEBESIS, PRITAIKYMAS SKRYDŽIAMS VALDYTI

G. Derenčius, U. Ragauskas

Santrauka

Šiame darbe bandoma atsakyti į klausimą, ar kamuolinių debesų rodymas skrydžių vadovų radarų ekranuose turi reikšmingą įtaką skrydžių valdymui. Sukurtas kumuolinių debesų žemėlapių sudarymo simuliatorius leido atlikti tyrimą vykdant simuliacijas su skrydžio valdymo treniruokliu. Buvo įvertinta, kaip skrydžių vadovas priima sprendimus, kai rodomi kamuoliniai debesys ir kai ne. Taip pat aptarta kamuolinių debesų vaizdo gavimo nauda orlaivių trajektorijoms ir skrydžio laikui. Tyrimas atliktas Vilniaus terminalo manevravimo zonos erdvėje.

Reikšminiai žodžiai: kamuoliniai liūtiniai debesys, orų radaras, skrydžių valdymo zona, orlaivio radaras, kamuolinių debesų atvaizdavimas.