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IMPACT OF CLOUDS ON THE AVIATION

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Abstract

The aim of the paper is to study concepts and types of cloud coverage and clouds itself. It also brings the different types of clouds and its effect on aviation closer to the reader. In the first part paper focuses on general concepts. Then it describes types of clouds and talks about them in detail. Next theme are radars and maps used in aviation to worn and tell us about the cloud coverage as its possible threats. In the last part, the paper shows us some maps and tells us about possible threats caused by clouds or vice versa its positive effects on the flights.

Keywords

Clouds, Cloud coverage, Meteorological reports, Cloud base.

1. INTRODUCTION

In this paper we study basic concepts as clouds and cloud coverage. We also devide clouds into diferent groups and we allocate types of clouds that belongs to the groups. We mostly focused on types of clouds which are the most important in aviation, weather for pilots and meteorologists. Then we talked about negative effect that accompany cloud coverage. Next topic to discuss are satelites, radars that we use to detect clouds. Maps and reports are used to plan the flight, from the deprature to landing, with minimum meteorological threts during the flight. During this teoretical part we collect informations. This informations are later used in more practical part of the paper. In the practical part of the paper we collect maps and we talk about clouds and the threts that can accompany them. In this part we use maps that are accessible on the Internet.

2. CLOUDS AND CLOUD COVERAGE

Clouds are visible sets of small particles of water or ice in the atmosphere. But they can also contain parts of dust or smoke. Fog is also considered a type of cloud. I tis cloud touching the Earth's surface. Clouds differ by the height which they are located, shape, by their composition, etc. [1,2].

There is several reasons why the air that contains water vapour begins to go up to the sky. This is mostly conected to the air temperature. Air with the higher temperature is extruded by cooler air. Wind output can also take place along atmospheric frontal surfaces but also along terrain obstacles. With rising height atmospherich pressure decreases and temperature of the air is also decreasing. In this height, when temperature and preassure are lower, water particles are frozing and becoming ice [1,2].

The part of the sky that is covered in clouds is called cloud coverage. It is one of the most important meteorological elements, not only for aviation but also for our Earth. Informations about clouds are provided by Air Weather Service and then they are forwarded to air traffic control and pilots. To identify clouds and cloud coverage we use satellite images and our own eyes [1,2].

In aviation is important to know how many eights of sky is covered by clouds. With cloud coverage reduces visibility. That impacts VFR flights the most. On the other hand IFR flights aren't so limited. IFR flights are instrument flights so visibility is not a problem, but aircraft needs to be equpped with instruments for flying in the clouds. In higher hights with temperatures below zero, aircraft must have defrosting equippment due to possible icing. Biggest problem with cloud coverage is during landing and take – off. When the visibility is low flight can be canceled or delayed. With landing there is a bigger problem, becouse when ther is very low visibility aircraft can't land at a designated airport but it must find alternate airport. With cloud coverage there is several negative effect, not just on flight, but also for crew, there are higher operating costs [1,6,10].

Table 1: Cloud coverage.

Meaning	Sky cover	Abbreviation
Clear or Few	≤1/8	SKC or FEW
Few	2/8	FEW
Scattered	3/8 – 4/8	SCT
Broken	5/8 – 7/8	BKN
Overcast	8/8	OVC

3. CLASSIFICATION

Clouds are divided into different groups. Clouds are classified according to their height above and appearance from the ground, how they form, types of clouds [4].

Cloud classification according to the mechanism of their formation:

- Convective clouds,
- Frontal clouds,
- Turbulent clouds,
- Orografical clouds,
- Ect

Cloud classification according to their heigh appearance from the ground:

- Low clouds – 0 ft to 6 500 ft,
- Middle clouds – 6 500 ft to 23 000 ft,
- High clouds – 16 500 ft to 45 000 ft,
- Clouds with vertical development – clouds which belong to more floors.

We also classify clouds according different types, which belong to each floor. We know clouds as Cirrus, Stratocumulus, Nimbostratus, etc. [1,4].

3.1. Low clouds

Low clouds are the most important clouds for aviation. Low clouds have most negative effect on flights. They can affect take – off, landing and flight itself. Best conditions for the creation of low clouds is in warm sectors of cyclone. Width of this clouds can be up to 400 km and its length can be up to 2 000 km [5].

In this group of clouds we include clouds as Sc – Stratocumulus, St – Stratus, Ns – Nimbostratus [1].

Low cloud base should be in the height of dew point. In reality i tis different. Low clouds base is higher than dew point. Cloud base has multiple layers [5].

Low visibility during landing can be biggest problem during flight. Landing visibility can be divided into oblique visibility and horizontal visibility. As it was told earlier, cloud coverage doesn't affect only landing, but also flight itself and take – off. Thanks to advanced technology we don't need to have good visibility to fly. Pilots can also fly safe thanks to instruments on the board. That helps pilots to monitor inclination and height of the aircraft during flight. Low clouds can also influence cargo flights, construction helicopters, when the cloud base is near the construction area [5].

3.2. Middle clouds

Middle clouds consists of both water droplets and ice crystals. They are forming vertically instead horizontally, that is why they look like heaps. Width of this clouds can be between 200 m to 700 m [4].

In this group of clouds we include clouds as Ac – Altocumulus, As – Altostratus [1].

3.3. High clouds

High clouds are made up of ice crystals. This category of clouds can be higher than tropopause, but mostly they have base 1 km to 2 km under the base of tropopause. High clouds arise in warm fronts. Sun, moon, stars can be visible through the high clouds [4,6].

In this group of clouds we include clouds as Ci – Cirrus, Cc – Cirrocumulus, Cs – Cirrostratus [1].

3.4. Convective clouds

Convection clouds belong to the group of clouds with vertical development. Flowing air with vertical air currents as a result of warming is called convection. This convection usually take place in summer, during the day when the sun is shining. Best conditions for formation of convectional clouds is in atmospheric fronts. Convectional clouds can reach up to the level of tropopause, as a result of strong warming. Convectional currents are makers of copious clouds called Cumulus. They can also make storm cloud called Cumulonimbus [4,5].

We can await low visibility and turbulence around clouds as Cumulus. Icing shouldn't be the problem around them because they are result of warm fronts. But there are exceptions between seasons, when clouds can reach up to the heights with minus temperatures. And there is also exception in more developed clouds, as Cumulus congestus, where we can have problems with strong icing during flight, turbulences and low visibility. Worst conditions are in cloud called Cumulonimbus. Cumulonimbus is storm cloud where the visibility can be only up to 20 m. Vertical development of Cumulonimbus may cause overloading of the aircraft, change in angle of attack, tilt of the aircraft, frontal air repulsion. There is also a chance of being struck by lightning and strong icing. Flying in this clouds is prohibited [5].

3.5. Wave clouds

This clouds, like other clouds, they arise under certain conditions. They are formed from air inversions. Wave clouds consist of ice crystals, water droplets or as combination of both. They are usually formed in temperatures below zero. In very low temperatures wave clouds are considered unstable. This means that we can await rain, snow or ice. In this clouds we can normally have problems with icing or lower visibility or some different phenomena relevant to aviation [5].

Among wave clouds we can find low clouds as Stratocumulus and Stratus, middle clouds as Altocumulus and high clouds as Cirrus and some Cirrocumulus clouds. As it was said earlier, in aviation are low clouds the most important. They are St and Sc from this category. Flight in this conditions is quite hard if we plan VFR flight [5].

3.6. Copious clouds

They are usually formed on warm atmospheric fronts. We can find here clouds from every single category. From low clouds we have St, Sc and Ns, middle cloud are As and high clouds are Cs. They are vertically long, up to 2 km. On the other hand we also have small copious clouds which are formed in Anticyclones under the inversions. They have horizontal length up to 100 km [5,9].

3.7. Frontal clouds

Atmospheric front is the area separating air masses. We know three main atmospheric fronts: warm front, cold front and occluded front. Every front has it own clouds. Frontal clouds can make flight very difficult. Clouds which are in this group are horizontally and vertically very large. We can await here turbulence, fogs, icing or maybe storms. They are 1 500 km to 2 500 km long. Impact of aviation are similar to groups earlier, we can await turbulence, icing, rain, low visibility and in summer we can await also storms [4,5].

Warm front clouds are formed under and above the frontal area. With warm air are clouds above frontal area formed and vice versa with cold air are clouds under frontal area formed. Clouds under the frontal area are produced by turbulent air mixing. In this group we include clouds as St a Fs. Clouds above the frontal area are clouds vertically very large. In this group clouds as As, Ns, Ci and Cs are included [5,6].

Cold fronts are divided into two groups. Cold front type one and cold front type two. Cold front type one has mostly clouds above frontal area. Impacts are similar to warm front clouds. Only difference is in temperature and in icing. In summer moths we can count on the occurance of storms. Clouds which belong to this group are storm clouds Cb. Cold front type two is characteristic by faster movements of air. In this type we know clouds as Ci, Cc, As and Ac. This type is associated with colder months of the year. This clouds produce zones of rain. This zones have width up to several tens of thousands of km and length up to several thousands km.

Occluded front formed by catching up warm front by cold one. We know Occluded warm front and occluded cold front. It is for the best for flight to avoid this types of clouds, especially in summer. The reason is emergence of storm clouds Cb [6].

4. RADARS, MAPS, REPORTS

Weather reports are one of the key ingredients for flight planning. It is important to report rain, icing, turbulence, etc. With rain reports we can say if the visibility is going to be positive, in the icing on the ground or on the aircrafts won't be strong, To forecast such phenomena we use reports as METAR, SPECI, etc. For METAR making we use maps and photos from satellites and radars. On the other hand we can use our own eyes to observe clouds [10].

4.1. Meteorological cosmic systems – Satellites

Satellites were designed in the early twenties by Arthur C. Clark. In 1945 he wanted to put satellites on the geostationary path of the Earth. First European satellite were used in 1977 and it was Meteostat-1. Now we use Meteostat-MSG. To analyse weather we need only one photography. One photography can provide so many useful information for meteorologist so he can make a report. With satellites we can classify clouds into other different groups: clouds of small size, clouds od subsynoptic size, clouds of synoptic size and cloud of planetary size [9, 10].

4.2. Radars, radar images of cloud coverage

Without satellites we can't imagine life in modern meteorology and this also applies to radars. During Word War 2 were more practical use for radars found. They started to use radars to track aircrafts. But it wasn't that easy as they wanted, because there were smudges all around the images. It was found out later that this smudges were clouds. That is why now we use radars to identify clouds and weather. They gave us clear image of zones of rain, zones of clouds and so on. Radar images are freely available on the internet. In Slovakia we can find them on the SHMÚ website [10].

On the airports it is important that weather reports are up-to-date. Meteorological maps are very important for flight planning. Reports are published every 30 min or 60 min, it is up to the airport. We also know reports as TAF, SIGMET, GAMET, AIRMET and more [10].

4.3. Meteorological maps

Meteorological maps are mandatory equipment for pilots and meteorologist. They easily and aptly displays every crucial information about weather during flight. Meteorological maps are also important for flight planning. Some maps are specially adapted by meteorologists to facilitate planning. For pilot and meteorologist are important surface pressure maps same as heightmap [10].

4.4. SYNOP

By observations at the Earth's surface and aerological observations of various mountains or levels are a synoptic maps made. On this map is easy to mark information from large areas as Europe and whole Atlantic. This map contains current information about weather in UTC. It contains compared information from more weather stations. Information are sent to this stations in numeric form and then they are transformed into the map using symbols. This symbols are used worldwide for easy reading. There are two types of synoptic maps – first one is analyzed and the second is unanalyzed. Unanalyzed map contains only symbols of weather. On the other hand analyzed map contains also symbols of weather, atmospheric fronts, surface pressure fields, etc [10].

4.5. Significant weather

SW maps are maps that shows us important changes or information about weather. This maps are designated for airliners. It describes weather on flight level FL100 and FL450. They show us important meteorological phenomena which can have impact on our flight. Such as JetStream, turbulence, icing, storms, occurrence of Cb clouds, zones with vulcanic ash, and so on. In the past there were also atmospheric fronts shown, but is was many information in one place. They are published four times a day: 0000 UTC, 0600 UTC, 1200 UTC and 1800 UTC. Maps are freely available on the internet. The current SW map is mandatory aircraft equipment [10].

4.6. METAR and SPECI

METAR is a report about current weather. METAR is published by Air Weather Service every 30 min or every 60 min. It is written in codes according to the standards of ICAO. In this reports are informations about airport, time and date, speed of the wind, temperature, dew point, cloud coverage, meteorological phenomenons and so on. We can find informations about visibility on the position 5 or 6. Code CAVOK or 9999 means that visibility is more than 10 km, but on the other hand code as 0800

means that visibility is only 800 m. Between informations about clouds and visibility are often informations about meteorological phenomenons as rain RA, sand SA, Storm TS, etc. Before the abbreviation is + as strong intensity or – as minimum intensity used. Next group are codes used to identify cloud coverage in eights, as it was written earlier. We can find here abbreviation as SKC, FEW, SCT, BKN, OVS, then height of cloud base in ft and type od clouds. If the wind values, cloud coverage values, or else, suddenly changes, a SPECI report is published. SPECI is published immediately after worsening weather conditions, but it is published after 10 min after improving weather conditions [10].

4.7. SIGMET

SIGMT is report drowing attention to a certain meteorological phenomena. I tis one of the most important reports in aviation. It is published exclusively by met office. Name of this report is from the phrase „Significant Meteorological Phenomenon". SIGMENT is send to the flying aircrafts, because it contains informations which are important now. But we can also use it during the flight planning. Report is send by VOLMET. And i tis written similar to METAR or every single meteorological report. But in this report is possible to use whole words. SIGMET is actual only for 4 hours, but it can be published to less than 4 hours. Exception is SIGMET for vulcanic ash, it is published for 6 hours [10].

We divide SIGMETs into three categories:

- SW SIGMET – significant weather SIGMET,
- WV SIGMET – vulcanic ash SIGMET,
- TC SIGMET – Tropical cyclones SIGMET [10].

Every SIGMET report has introduction as place of phenomena, met office, expiration time. Next part is meteorological, which describes concrete phenomenon, for example SEV TURB – Severe turbulence, OBSC TS – Obscured thunderstorm, and more. Next is time when the phenomenon was spotted and place where it was spotted, height maybe displacement of the phenomenon and the last one is intensity. Intensity is written if the phenomenon is intensifying – INTSF, No change – NC or if it is weakening – WKN. In reports is mostly marked intensifying of phenomenon [10].

5. OBSERVATION

In this part of paper we are going to use informations what we get earlier in the theoretical part. We are going to read maps and try to report weather and it impact of flight.

5.1. SYNOP

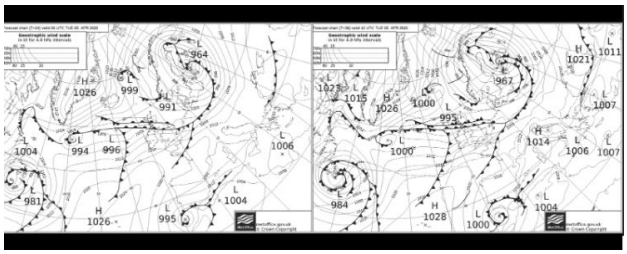

Figure 1: Weather & Aviation Page - Weather Forecast Europe UKMO mslp and thickness (skystef.be).

MSL pressure map, main sea level pressure map, is calculated by ISA (1 013,2 hPa) and atmospheric fronts. We can describe possible incoming frontal clouds and then characterize its possible impact on flight.

On the left map we can see that it was published on the April the 5th at 0600 UTC. Cyclones dominate above the Europe. Informations on the maps are analyzed. We can see atmospheric fronts – above the west Europe and Benelux we can see cold and also warm atmospheric front.

The right map is also published on the April 5th but at 1200 UTC. On this map we can see that in six hours are some changes around South Europe. Now we observe that there is mostly anticyclone around this part. For atmospheric fronts it is almost the same. Occluded fronts are visible. But in the southwest we can see the warm front.

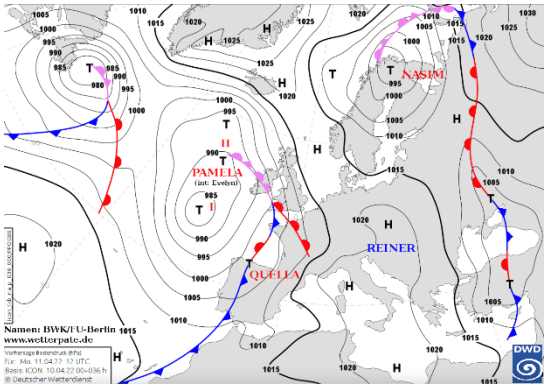

Figure 2: Weather & Aviation Page - Weather Forecast Europe DWD mslp (skystef.be).

Next used map is map of surface pressure and with atmospheric fronts. It is possible to see that the middle Europe is located in zone of anticyclone and west Europe is lightly in the zone of cyclone. In the southwest we can see cold atmospheric front, in the west we see warm atmospheric front and above the Great Britain is occluded front.

5.1.1. Warm front

With warm fronts are clouds like St, Fs, As, Ns, Ci and Cs formed. Conditions for flight in warm fronts depend on the flight level [5,10].

Ci – Cirrus is on the level of 10 km. It consists of ice crystals, because of the minus temperatures on his hight level. There is no icing associated with this type of cloud, but as a result of bumping and melting ice crystals on an aircraft there is possibility of icing [8].

Cs – Cirrostratus also consists of ice crystals and is formed 10 km above ground. If sky is fully covered with this clouds, then we can await tropical temperatures. Only large cargo airplanes fly through this clouds and there is not so many negative impact on flight. Just aggravated visibility [7,9].

As – Altostratus is a cloud at a height of 2 km to 5 km above the Earth's surface. They are grey and they usually cover whole sky.

Rainfall is usual with this type of clouds and with it there is also low visibility and possibility of icing [7,8].

Ns – Nimbostratus is rain style cloud. They can be made by ice crystals or water droplets or as combination of both. There are many negative impact on flight associated with Nimbostratus. One of them is icing, then rain, snow. Sometimes flight in this conditions is impossible [7,8].

St – Stratus not so different from fog. Sometimes drizzle may fall out of these clouds. There is also low visibility in this clouds [7].

5.1.2. Cold front

In this type of front are clouds like Cb, Ci, Cc, As, Ac, Sc and Cu formed.

Cc – Cirrocumulus is very rare. It looks like little sheeps on the sky and is made from ice crystals. There are no negative impacts on flight associated with clouds like Cirrocumulus [7,8].

Ac – Altocumulus is a cloud at a height 2 km to 4 km above the ground surface. Altocumulus is made from water droplets or as a mix of water and ice. Precipitation from these clouds falls, but they do not reach the Earth's surface, as they gradually evaporate during the fall [8].

Sc – Stratocumulus looks like duvet. Rainfall may fall out of Sc clouds [7].

Cu – Cumulus looks like hills or towers. They are formed during the day only. They are made from water droplets primary, but on his tips we can find ice crystals too. Rain tend to fall out of Cumulus. They are phase before the storm clouds. They can have large proportions, but they can be small too [7].

5.1.3. Occluded front

Cb – Cumulonimbus is only cloud formed with occluded fronts. Cb is storm cloud and it don't belong to any level of troposphere. He can be from 2,5 km to 15 km high. Cloud base is 2,5 km above the ground and it's going bigger with raining. Rain turns into hail. Cb are already ranked as dangerous in aviation on their own, that's why we can't fly through this type of clouds. In these clouds, vertical speeds cause very strong turbulence, which can even damage the plane. Furthermore, due to the cooling of the wind in the clouds, strong icing on the plane may occur [7,8].

5.2. Significant Weather charts

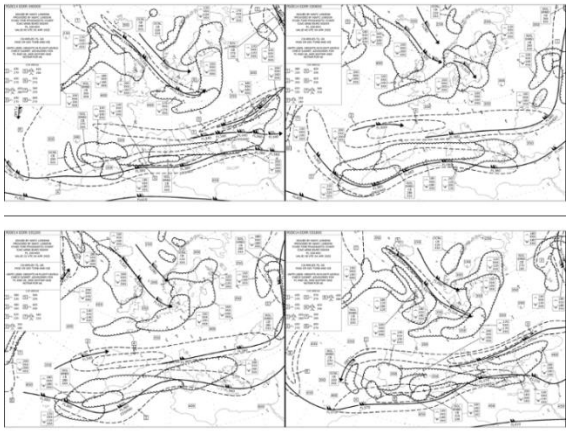

Figure 3: Weather & Aviation Page - Aviation Weather (skystef.be).

Significant weather maps are published four times a day. First map, upper left, is published at 0000 UTC. On the left are inormations about the map, used symbols for meteorological phenomenon, that we can await during the flight.

First map is published on April 5th at 0000 UTC. On this map, we can observe the occurrence of cumulonimbus storm clouds over the whole of northern Europe and also over the southern part of Europe. Next information that we can see, is information about turbulence around the clouds and JetStream is also visible.

On the second map, also from April the 5th, but at 0600 UTC are no significant changes. Clouds are still over the northern part of Europe. On the other hand, over the southern Europe clouds reduced.

On the third map from April the 5th, at 1200 UTC, we can't see any significant changes. But on the south side there is turbulence and icing only on the eastern and western parts of the clouds. On the north side are turbulences mainly on the north – east parts of the clouds.

On the last, forth map, published at 1800 UTC there is almost no cloud coverage above the southern part on the Europe. Cloud cover over the northern part of Europe is still shifting slightly towards the middle of the Europe. In these clouds we still see weak turbulence and mild icing, almost on the entire area.

According to the maps of the significant weather on April the 5th 2022, we can say that the best track for flying over Europe in terms of cloud cover is through its center. Cloud cover appears throughout the day in the south as well as in the north. Throughout the day there is no flyover through the cloud cover completely without negative impacts.

6. CONCLUSION

By observing the meteorological maps available on the Internet, we have brought to our attention the phenomena associated with cloud cover, which can significantly affect our flight. Using maps, we've zoomed in on the types of clouds that may occur above those territories. For observation, we used maps of significant weather, commonly available on the Internet. This maps give us closer informations about already given phenomena that may affect our flight at certain hours. Next, we used synoptic maps that show us pressure fields on the sea level and on the Earth's surface, and incoming atmospheric fronts associated with pressure fields. According to the incoming atmospheric fronts, we have better defined the clouds that might be above the territories and what adverse conditions they might cause for our flight.

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