Accident to the BOEING - 737 - 800 - 8JP registered SE-RPE on 25 July 2021 en route to Nice

Time	18:36[1]
Operator	Norwegian Air Sweden
Type of flight	Passenger commercial air transport
Persons on board	Captain (PF[2]), co-pilot (PM[3]), 4 cabin crew members, 180 passengers
Consequences and damage	One cabin crew member severely injured, one cabin crew member injured
This is a courtesy translation by the BEA of the Final Report on the Safety Investigation. As accurate as the translation may be, the original text in French is the work of reference.	

Turbulence en route, severe injury to a cabin crew member, emergency landing at destination

Note: a glossary is available in the appendix to the report.

1 HISTORY OF THE FLIGHT

Note: the following information is principally based on CVR and FDR recordings, statements, radio communication recordings, as well as radar data provided by Météo-France.

On 25 July 2021, the Boeing 737-800, registered SE-RPE, took off from Copenhagen-Kastrup airport (Denmark) to carry out the passenger commercial air transport flight NAX 3646, bound for Nice-Côte d'Azur airport.

At 18:14:47, the crew contacted the Milan Area Control Centre (Milan ACC) and reported that they were on heading 195° in order to avoid storm cells (see Figure 1, point 0). The aircraft was then at Flight Level 370 (FL 370).

The Milan ACC controller asked the crew to report when they were able to proceed directly to BORDI waypoint.

The crew replied that they would call back but that there were Cumulonimbus (CB) ahead, over a distance of 80 NM. The controller asked them to call back when able to.

[1] Except where otherwise indicated, the times in this report are in Coordinated Universal Time (UTC). Two hours should be added to obtain the legal time applicable in Metropolitan France on the day of the accident.
[2] Pilot Flying.
[3] Pilot Monitoring.

At 18:16, the crew requested approval to carry out an avoidance manoeuvre by deviating 20° to the right (see Figure 1, point 1). The controller authorised the manoeuvre.
Around five minutes later, the flight was transferred to another Milan ACC control sector.
At this moment, the crew were discussing the large storm cells to their left.

Upon first contact with the new sector at 18:21:32 (shortly before point 2), the crew informed the controller that they were on avoidance heading 215. The controller asked the crew to call back when they were ready to head left towards BORDI (see Figure 1). The crew replied that they would be able to call back in approximately 40 NM.

At 18:24:33, the controller asked the crew if they were able to start the descent now. The crew replied in the affirmative and were transferred to another Milan ACC control sector. Upon first contact at 18:24:55, the crew reported that they were at FL 370, on avoidance heading 215°. They received approval to descend to FL 340. The crew read this back then stated that they were able to turn left to BORDI. The controller authorised this turn at 18:25:19 (see Figure 1, point 3), then the flight was transferred to another Milan ACC control sector.
Upon first contact with this sector at 18:26:09, the crew received approval to descend to FL 310 then to FL 270 and lastly to FL 170 with the controller requesting that they reach this level before BORDI (see Figure 1, point 4).

Between 18:31:48 and 18:33:33, the crew discussed the avoidance strategy to be adopted with regards to the cloud mass located ahead, and the extent of the route deviation to be cleared with the Air Traffic Control (ATC).

At 18:33:34, the crew requested "*20° to the right to avoid*" from the Milan ACC (see Figure 1, point 5). The controller approved the manoeuvre and asked the crew to stop their descent at FL 210.

At 18:34:21, the controller asked the crew over what distance they wanted to maintain this heading[4] (see Figure 2, point 6)[5]. The crew said that they needed to maintain it for a further 10 NM.

At 18:35:37, the captain saw a new "*area coming up*" and signalled this to the co-pilot. The co-pilot asked him if he should notify the control centre that they were able to head towards BORDI waypoint. The captain did not answer the question and told the co-pilot that there was lightning.

At 18:35:58, the crew notified the controller that they were able to head towards BORDI waypoint (see Figure 2, point 7). The controller authorised the manoeuvre and asked the crew to descend to FL 170 in order to be at this level on reaching BORDI waypoint. The crew read this back.

At 18:36:23, the captain notified the co-pilot of the appearance of a new storm cell and said, "*This one will make a bang.*" He told the co-pilot that he had selected the "*Fasten seat belt*" sign, stating "*I have turned on the sign*", then the crew mentioned the lightning they could see nearby.

[4] Controllers are unable to see the meteorological situations on their screens.
[5] The playback of the CVR recording showed that numerous flights were avoiding thunderstorm zones in this region.

The indicated airspeed decreased from 250 kt[6] to 228 kt in 14 s, this last speed being reached at 18:36:37. It then increased up to 272 kt 13 s later.
At the same time, the PF announced, "*Engine anti-ice on*". One second later, there was a change in background noise (see Figure 2, point 8), as if there was heavy precipitation pelting down on the cockpit windshields.

At 18:36:46 (see Figure 2, point 9) the recorded vertical acceleration[7] reached + 1.79 g, decreased to 0.38 g in the following second, and then rose to + 1.52 g in the next two seconds.

At 18:36:50, the roll angle reached a maximum of 35.5°. The "BANK ANGLE" synthetic voice message was activated. The PF disconnected the autopilot (see Figure 2, point 10). The vertical acceleration decreased to 0.27 g, then increased again to 1.67 g in the following two seconds. During this two-second phase, the speed decreased from 272 kt to 250 kt.

At 18:36:53, the noise on the windshields stopped. The captain said to the co-pilot, "*And now we are out.*"

At 18:36:59, the turbulence stopped (see Figure 2, point 11).

At 18:37:18, the controller asked the crew to contact the Nice approach controller (see Figure 1, point 12).

At 18:37:29, exchanges took place between the purser located at the front of the cabin and the cabin crew members located in the aft galley. These exchanges mentioned two injured cabin crew members.

A few seconds later, the purser confirmed to the captain that a cabin crew member at the rear of the aeroplane had a broken leg. The captain acknowledged receipt of the message.

The crew contacted the Nice approach controller while flying through FL 208 in descent to FL 170 and requested a left-hand RNP Z4 approach.

At 18:38:28, the crew asked the purser for more information and agreed the need for an ambulance to be waiting for them at Nice.

The flight crew then discussed the occurrence. They agreed that the meteorological situation had been complex as although the radar display had not shown an ominous situation, it had been quite difficult to anticipate when choosing route changes.

During the approach, the crew announced to the controller that a cabin crew member had a suspected broken leg and that an ambulance was required upon arrival. The controller read this back and continued to vector the flight, announcing that they had been granted priority.

The aeroplane landed without further incident at 18:57:51.

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[6] Speed selected by the PF several minutes earlier in preparation for possible turbulence ahead.
[7] The sampling intervals of the recording meant that the extreme values reached could not be determined.

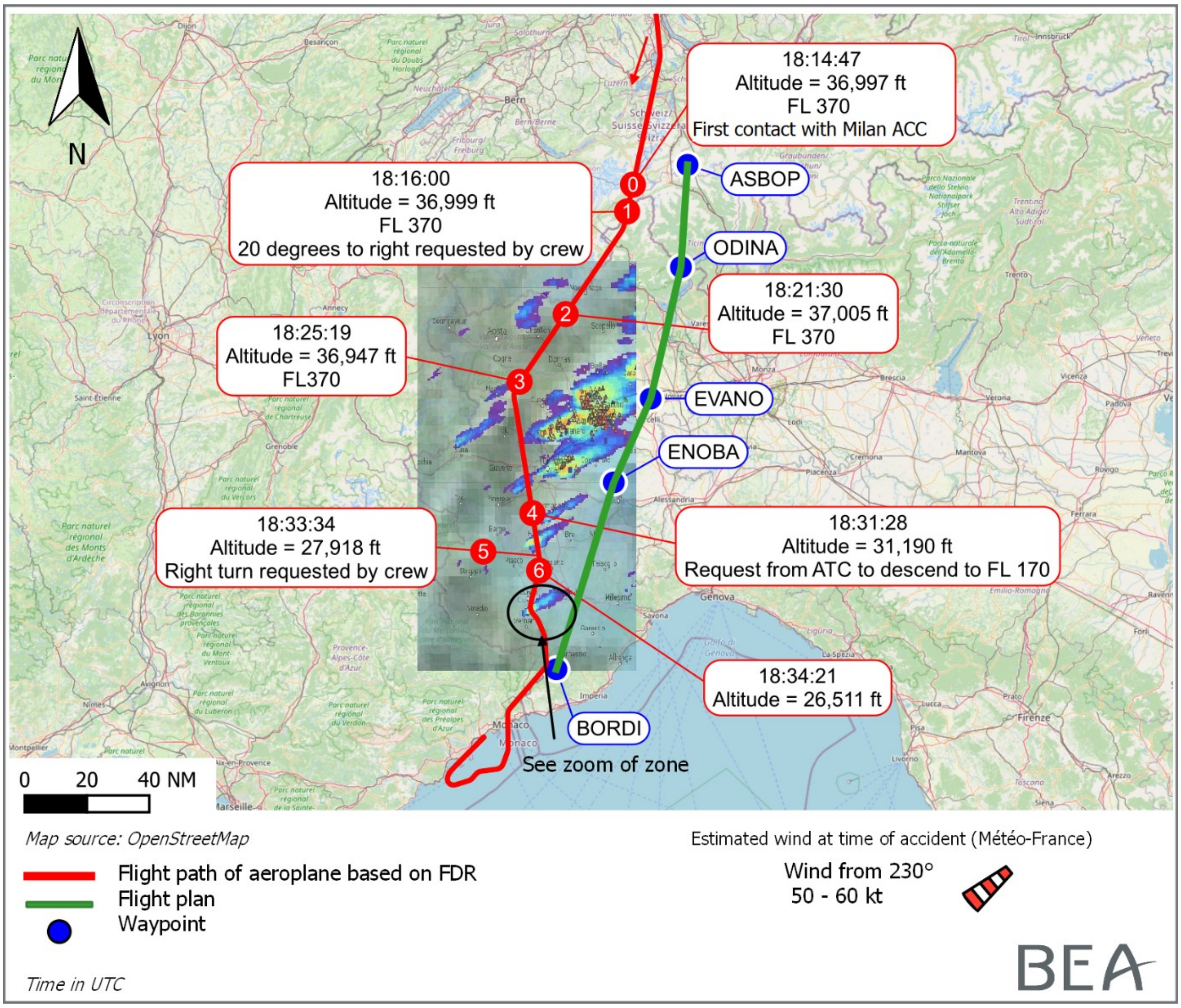

Figure 1: path of the aircraft superimposed over the Météo-France radar image at 18:40[8]

[8] A layer of cirrus (refer to para. 2.2) meant that the satellite images could not be used. Radar images from the Italian ground radar at Turin were used. This radar belongs to the European radar network named OPERA. The signal transmitted by the radar is reflected (backscattered) by liquid or solid hydrometeors. The signal received is then processed so as to display it in the form of reflectivity images. The radar images are recorded every 10 minutes.

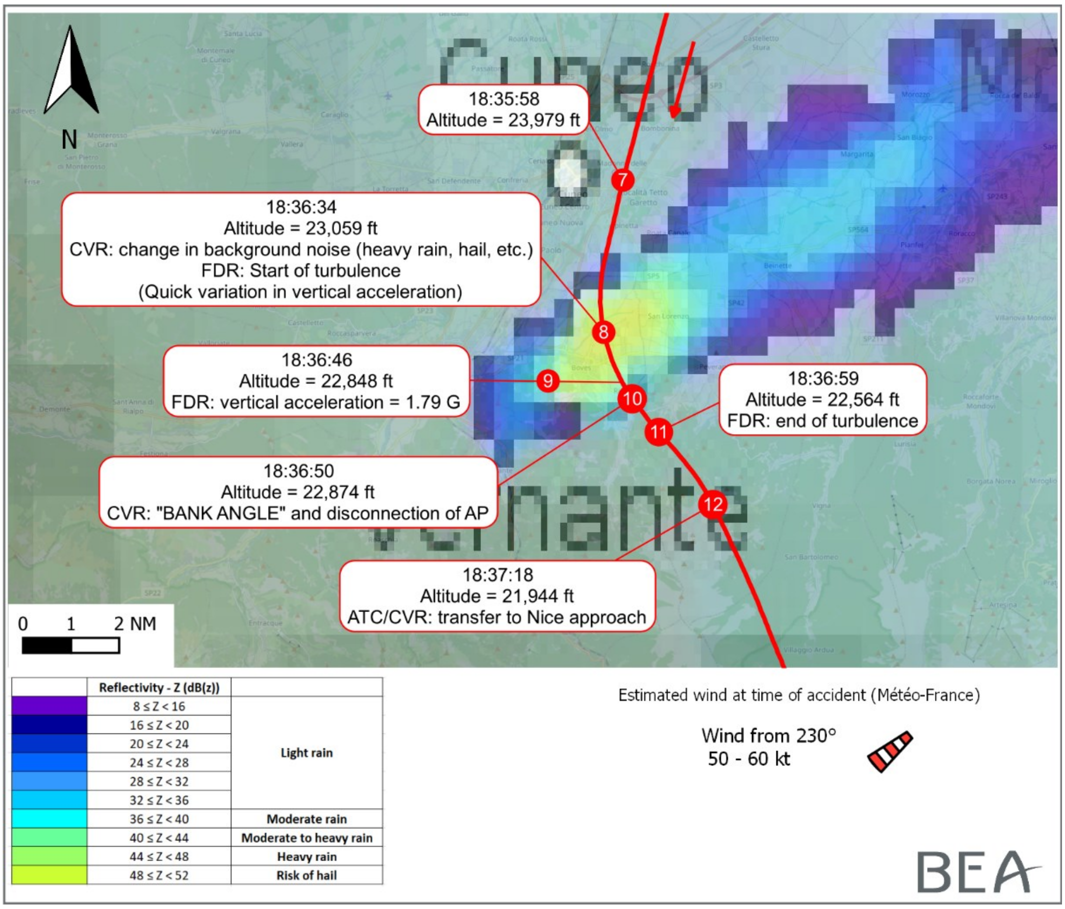

Figure 2: zoom in on the path at the time of the accident

2 ADDITIONAL INFORMATION

2.1 Statements

2.1.1 Flight crew's statement

The captain stated that he had observed squall line returns on the onboard weather radar whilst flying over the Italian-Swiss Alps. He asked the controller for approval to deviate to the west in order to circumnavigate this area. After circumnavigating by sight the last cumulonimbus detected on the radar, he received approval to re-join his route to BORDI waypoint and to descend.
The crew then informed the passengers of possible turbulence on approach and notified the cabin crew that it was 20 minutes to landing.
The descent was uneventful until a new radar echo was picked up. The return was green with a yellow centre, and the decision to circumnavigate was once again made. The co-pilot stated that at no time were there red indications on the radar. Once they had circumnavigated this area, the crew asked the controller once again for approval to head towards BORDI waypoint. The crew then saw developing storm clouds embedded in the cloud layers, immediately behind the cell they had just circumnavigated. Realising that it was too late to avoid the build-up ahead, they immediately turned on the SEAT BELT SIGN.
Expecting some turbulence, the crew held the speed at 250 kt. Around 30 s later, the crew noted that the speed had dropped to 230 kt accompanied by pitch attitude variations and hail on the windshield. A violent roll movement of more than 30° triggered the "BANK ANGLE" synthetic voice message, and the captain decided to disconnect the AutoPilot (AP) and the Auto-THRottle (A/THR). A final jolt was felt before the aircraft emerged from the cloud and the weather cleared up

completely. The turbulence felt in the cockpit had not been as violent as expected, however the pitch variations along with the twisting motions incited the crew to ask the cabin crew members if all was well. The co-pilot specified that there had not been much vertical turbulence but unusually, a lot of lateral turbulence.

The captain estimated that it had taken less than ten seconds to pass through the cloud cell. The purser announced that a cabin crew member had most likely broken his leg.

Having been transferred to the Nice approach controller, the crew requested an ambulance and priority for landing. They landed ten minutes later. The injured cabin crew member remained lying on the floor in the aft galley. The passengers were asked to remain seated until the medical personnel was able to board the aircraft. The passengers then disembarked and both aft galley crew members were taken to hospital.

2.1.2 Cabin crew's statement

Cabin crew member 3, who had been working in the aft galley of the aircraft with cabin crew member 2, stated that when the "*Fasten seat belt*" sign came on, cabin crew member 2 had just taken the waste trolley out and was about to collect waste before landing. The "*Fasten seat belt*" sign and chime warned them of the imminent occurrence of turbulence.

Cabin crew member 2 stated that he was checking that all of the equipment was latched when a first jolt made him quickly take his seat. Before he even had time to secure the waste trolley, severe turbulence threw him from one side of the aft galley to the other. He was lifted off the floor before landing heavily. His right foot caught under an escape slide housing and a second jolt threw him upwards. He then heard his ankle crack and suspected that he had broken his leg. He stated that this had all happened very quickly, in a period of five to ten seconds.

Although cabin crew member 3 had also injured her ankle, she was able to assist him and asked the other cabin crew members for help. She was able to attend to cabin crew member 2 who remained on the floor until the aircraft landed. He was evacuated via the rear exit of the aircraft on a stretcher carried by medical personnel from the Nice Rescue and Fire Fighting service. Cabin crew members 2 and 3 were taken to hospital.

Examinations revealed two fractures and a dislocated ankle for cabin crew member 2 and bruising to the ankle for cabin crew member 3.

2.2 Weather conditions

2.2.1 General situation in northern Italy between 18:00 and 19:00 according to Météo-France

The air mass was unstable at medium altitude, with the formation of convective clouds of towering cumulus (TCU) and isolated cumulonimbus (CB). These clouds extended to a high altitude up to the top of the layer of cirrus at around FL 380.

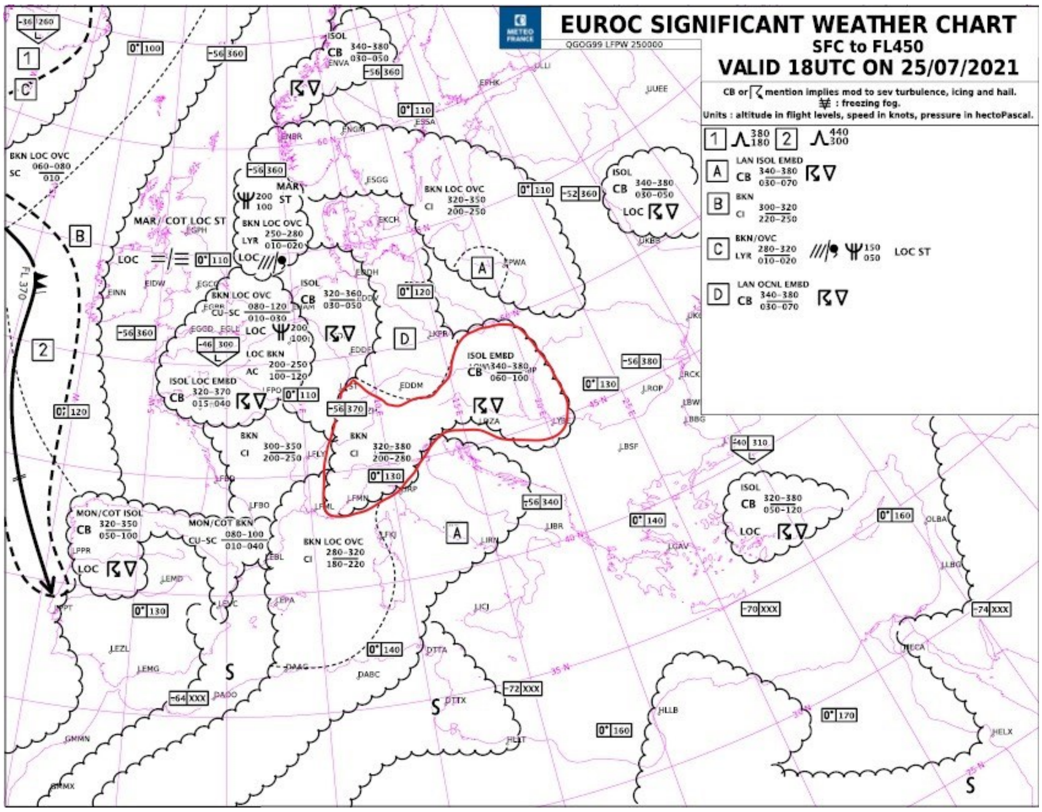

Figure 3: SIGWX chart valid at 18:00 (source: Météo-France)

The area circled in red on the SIGWX chart incorporates the accident site, and indicates:

- isolated CB, base FL 060 - FL 100, top FL 340 - FL 380;
- broken cirrus clouds, base FL 200 - FL 280, top FL 320 - FL 380;
- a 0° isotherm at FL 130.

2.2.2 Situation estimated by Météo-France, based on radar images at and in the vicinity of the accident site between 18:20 and 18:40

An isolated convective cloud formed between 18:15 and 18:20 less than 10 km to the south of Cuneo (Italy), in the vicinity of the position indicated as the occurrence site. This almost-stationary convective cloud extended rapidly between 18:20 and 18:40, generating heavy showers with no thunderstorm activity, which made it difficult to decide whether it was a TCU with a long vertical extension or a CB; it dispersed as quickly as it had formed between 18:50 and 19:00.

The strong updrafts that occur as TCU or CB convective clouds form provoke severe local turbulence.

The strong southwesterly wind combined with these convective updrafts may have generated windshear leading to severe and sudden turbulence.

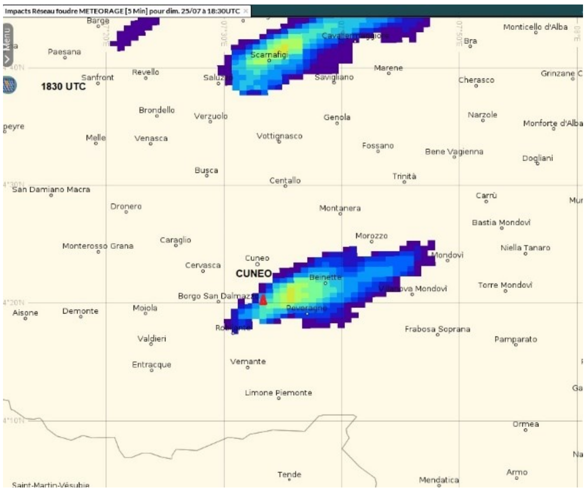

Figure 4: situation at 18:30 (Source: Météo-France)

The red triangle shows the position of the accident (each square measures 40 km x 40 km)

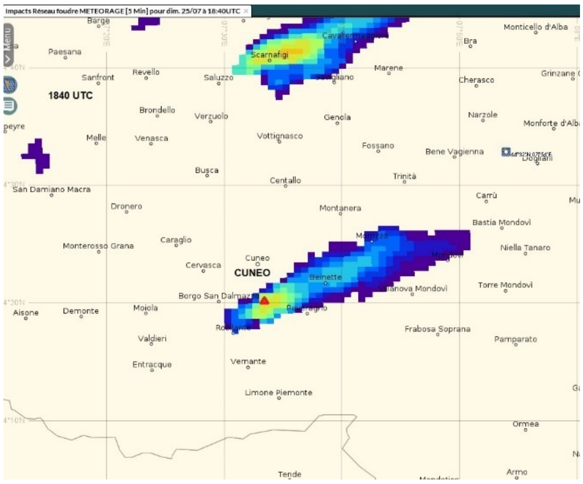

Figure 5: situation at 18:40 (Source: Météo-France)

The red triangle shows the position of the accident (each square measures 40 km x 40 km)

The area of strong convection slightly moved to the west, in the opposite direction to the southwesterly wind, and was located just below the accident site. The showers were moderate to heavy. No lightning strike was detected but this situation usually causes windshear and severe turbulence.

2.2.3 Milan FIR SIGMET aeronautical messages

The SIGMET messages from the Milan FIR concerned a storm area stretching over part of Italy north of the 45th parallel. The accident site, which was slightly further to the south, was not included:

- LIMM SIGMET 5 VALID 251630/251830 LIIP- LIMM MILANO FIR EMBD TS OBS WI N4628 E00822 - N4545 E00752 - N4529 E00840 - N4529 E00950 -N4652 E01034 - N4631 E00957 - N4631 E00913 - N4558 E00855 - N4628 E00822 TOP ABV FL 390 STNR NC=

- LIMM SIGMET 6 VALID 251830/252030 LIIP- LIMM MILANO FIR EMBD TS OBS WI N4548 E00856 - N4601 E01010 - N4555 E01116 - N4509 E01100 -N4507E00831 - N4548 E00856 TOP ABV FL 390 STNR NC=

2.3 Characterisation of the turbulence

From 18:36:34 onwards, the load factor values recorded presented major variations for 25 s. In the middle of this period, the variations in the vertical load factor reached high amplitudes for a duration of around seven seconds[9]. The load factors experienced at the cabin crew seat at the rear of the aircraft were estimated. These values are given in the table below (the extreme values reached may have been higher):

Time	Estimated vertical load factor (g)	Estimated horizontal load factor (g)	Roll angle (°)
18:36:46	1.79	0.15	-29.7
18:36:47	0.38	-0.13	-29.2
18:36:48	01.19	-0.04	-25.1
18:36:49	01.52	0.04	-33.2
18:36:50 ("Bank angle" voice announcement)	0.66	0	-35.5
18:36:51	0.27	0.07	-30.8
18:36:52	1.67	-0.01	-8.6

Figure 6: estimation of load factors and roll angles

Note: the AP was engaged during this phase, until it was disconnected by the PF when the "BANK ANGLE" voice announcement triggered.

[9] The manufacturer's FCOM considers a variation in acceleration greater than 0.3 g as synonymous with severe turbulence.

BEA

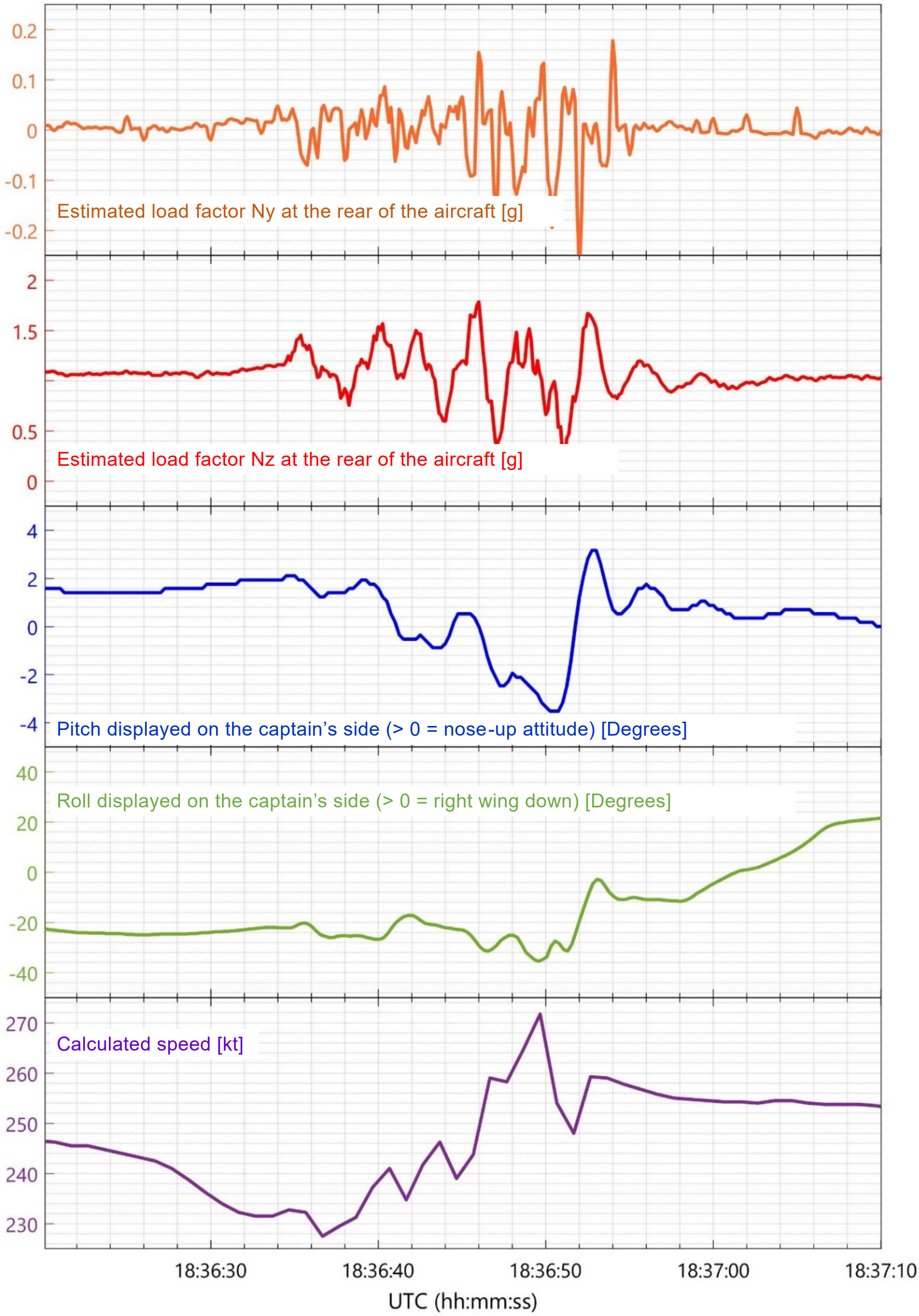

Figure 7: graphs showing parameters recorded as the aircraft flew through the area of turbulence (source: BEA)

2.4 Onboard weather radar (WXR)

The radar image obtained is based on three parameters: the gain, the tilt (angle between the horizontal line and the middle of the radar beam) and the scale selected by the pilot on his Navigation Display (ND). The radar beam opening angle is 3°.
The weather radar is designed to detect water in liquid form (rain or wet hail) by measuring precipitation levels. According to the levels detected and the gain selected, echoes appear on the ND in different colours. The weather radar barely detects water in solid form, such as ice crystals or dry snow.

The tilt adjustment determines the area passed through by the radar beam and, consequently, the echoes that are detected and displayed on the ND. The gain adjustment can then be adapted to the reflectivity of the precipitation encountered. It should be noted that clouds located ahead of the aircraft, which the beam does not pass through, will not be seen on the radar.

Moreover, the structure of cumulonimbus clouds requires an adjustment of the tilt and of the scale as the aircraft gets closer to a convective cell. Indeed, the reflectivity of precipitation inside a cumulonimbus depends on the temperature. The most reflective zones (liquid precipitation) are located under the 0°C isotherm. The reflectivity is high in these zones. Between the 0°C isotherm and the 40°C isotherm (known as the "radar top"), medium reflectivity is observed, based on the liquid water/ice crystal ratio. When the temperature is below -40°C, the reflectivity is very low (ice crystals).
The radar can operate in manual or automatic mode. The gain and the tilt can be adjusted separately. The operator, Norwegian Air Sweden recommends activating "WX + T" mode (detection of cloud layers and turbulence) in automatic mode. The T mode consists in an analysis of the doppler signal of the radar echo, which is used to estimate the movements of water droplets or ice particles detected, and variations in their movements, thus enabling detection of turbulence.
The radar does not detect cells hidden by other cells, and new cells can appear depending on changes to the aircraft's path. In addition, these cells can be difficult to detect due to an insufficient amount of water.
Weather radar adjustments are not saved in the FDR parameters, so it was not possible to determine its configuration during the flight.

2.5 Transfer conditions from Milan ACC to Nice approach

The transfer conditions from Milan ACC to Nice approach are governed by a letter of agreement between the two units.

This letter of agreement notably stipulates that, if the aircraft is flying on the filed route and flight level (in this case, not exceeding FL 170 at BORDI waypoint), automatic exchanges of flight plan data by the organisation in charge of the transfer is sufficient for the tacit transfer of the flight, i.e. without prior coordination.
It is specified that when the Milan ACC is unable to ensure transfer to Nice on the filed route, in the event of a storm for example, a verbal coordination must take place.

2.6 Meteorological information available to Italian controllers

The Milan ACC controllers are provided with two screens.

- One screen is used to display the Milan FIR METAR reports, which contain the QNH values required to manage transition levels and transition altitudes.
- The other screen is used to display the control sector limits, as well as the frequencies of neighbouring centres or standard arrival (STAR) routes in force at the time.

SIGMET messages can be displayed on either one of the two screens instead of the information previously displayed.

The controllers are unable to see meteorological situations on their screens. There are currently no plans to change this.

2.7 Meteorological information available on aircraft

In addition to the meteorological information provided by the onboard radars, some operators send meteorological images to the Electronic Flight Bag (EFB). However, this meteorological information cannot be displayed on the ND due to the processing time.

In general aviation, some manufacturers have chosen to install equipment which retrieves and displays this meteorological information in the form of an image on one of the main onboard avionic screens.
One example is the meteorological information displayed on the Multi-Function Display (MFD) on board TBM type aircraft. An iPAD is connected to the avionic system to upload the meteorological information on the ground. The image is then refreshed during the flight, at intervals of less than 15 minutes. This system combined with the weather radar, the lightning radar and the cloud turbulence forecasting system, improves the crew’s situational awareness.

2.8 Statistics on accidents associated with convective turbulence

The occurrences recorded in the BEA’s database include those which gave rise to a BEA investigation and those for which the BEA received notifications from foreign investigation organisations, as the representative of the State of design, State of manufacture, State of registry or State of the operator, in compliance with the provisions of Annex 13 to the Convention on International Civil Aviation.

Over the last ten years (2012-2021), the BEA recorded 65 accidents[10] in the “TURB: turbulence encounter” category according to the international taxonomy, resulting in a total of 86 serious injuries. This number is subject to the variability that may exist worldwide concerning the assessment of what constitutes a serious injury and the reporting system in general.

For 18 of these accidents, the small amount of information available, in particular the absence of a report, meant that the nature of the turbulence encountered (convective turbulence, wake turbulence, or clear-air turbulence) could not be determined.

[10] Accidents involving aircraft weighing more than 5.7 t or engaged in commercial air transport.

However, of the remaining 47 cases, 25 were related to turbulence associated with a convective phenomenon.

- Thirty-seven people were severely injured during these 25 accidents. In 80 % of cases, at least one cabin crew member was injured.
- In 18 of the 25 cases, the risk of turbulence had not been identified by the crew (6 cases), or was identified late (12 cases), prior to the occurrence.

It is important to remain cautious with regards to the lessons that can be learned based on this small sample. Nevertheless, it is possible to note that:

- The majority of these accidents occurred during the descent and approach (14 of the 25 cases). A high proportion of these accidents occurred when the risk of turbulence had been identified, with the cabin crew instructed to take their seat (10 of the 14 cases). The injuries occurred when the cabin crew members were finishing their tasks and completing the customer service in preparation for landing.
- Seven cases occurred en route caused by various factors (no activation of the weather radar, rapid convective development, turbulence detected but no vocal instructions given to the cabin crew, cabin crew taking their seats late).
- Accidents were rarer on departure paths and in climb, probably because the instruction to stay seated, in particular for cabin crew members, is easier to enforce.

3 CONCLUSIONS

The conclusions are solely based on the information which came to the knowledge of the BEA during the investigation. They are not intended to apportion blame or liability.

Scenario

When the crew contacted the Milan ACC, 20 min before the occurrence, they were already engaged in storm cell avoidance manoeuvres. Other crews were also avoiding storm zones. This weather situation had been forecast. The meteorological file contained information about it.

The Milan ACC controllers regularly asked the crew to call back when they were able to head to BORDI waypoint, which is the point of tacit transfer between the Milan ACC and Nice approach.
The controllers were not able to see the meteorological information on their screens. They could not see the exact location of the storm zones that prevented the crew from heading to the requested waypoint for over 20 minutes.

After circumnavigating what they thought to be the last storm cell, the crew stated that they were able to head to BORDI waypoint. Approval was granted by the air traffic controller. On turning, they suddenly saw on the weather radar and had in sight, storm cloud developments embedded in the cloud mass, immediately behind the cell they had just circumnavigated.
It is possible that these storm clouds may have been hidden by the previous storm cell and that the onboard weather radar was unable to detect them earlier. It is also possible that they could not be detected by the onboard radar when the cell was in the radar's detection beam. Lastly, it is possible that they may have been developing and appeared only shortly before on the aircraft's path.

The crew were unable to avoid this cell and expected turbulence. They alerted the passengers. The aircraft passed through a zone of strong windshear and turbulence due to the presence of convective uplifts in a predominantly very strong southwesterly air flow.
Flight through this zone was short but very turbulent. Strong vertical and horizontal accelerations associated with windshear and variations in speed followed in succession in the space of around

seven seconds.

It is very probable that it was at the beginning of this phase that a cabin crew member, who was busy securing equipment in the aft galley, was thrown to the ground. His foot then became trapped under an escape slide housing and his ankle broke during the vertical accelerations that followed.

4 RECOMMENDATIONS

Note: in accordance with the provisions of Article 17.3 of Regulation No 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation, a safety recommendation shall in no case create a presumption of blame or liability for an accident, serious incident or incident. The recipients of the safety recommendations shall report to the safety investigation authority which issued them on the measures taken or being studied for their implementation, as provided for in Article 18 of the aforementioned regulation.

4.1 Presentation of meteorological information on air control screens

Recommendations already issued

In 2008, the BEA published a study on Turbulence in Air Transport. This study looked at accidents and incidents in commercial air transport that occurred en route, where the turbulence encountered was caused by atmospheric conditions. The study therefore excluded events where an input on the controls was the main cause of the accelerations encountered and those caused by wake turbulence. In this scope, the BEA recorded 48 occurrences between 1995 and 2007 in France or abroad to aircraft operated, registered or manufactured in France.
Nineteen of these occurrences for which the file was particularly comprehensive, were used to identify the contributing factors in this type of event.
In particular, this study concluded that approach controllers and en-route controllers were not systematically provided with a display of the storm zones superimposed on the air traffic image, which might be detrimental to pilot/controller synergy. This study concluded that, generally speaking, the sharing of information held by the various stakeholders could offer a consistent level of knowledge of the situation conducive to the development of strategies by crews and controllers.

Consequently, the BEA recommended that:

- *EASA[11] and Eurocontrol work to implement data link systems for the communication of meteorological information, enabling this information to be consolidated and distributed to cockpits and control positions;*
- *within the framework of the application of the aforementioned recommendation, the DGAC[12] introduce tools, and define associated work methods, enabling en-route and approach controllers to display storm zones and turbulence zones on their control screens.*

Following this recommendation, Eurocontrol indicated that it considered the display of meteorological information on the radar screens of air traffic controllers to be the responsibility of European air navigation service providers, their national authorities and EASA.
EASA replied that it would look into the technical possibilities of redistributing meteorological information to cockpits in real time. The redistribution of this information to air traffic control

[11] European Aviation Safety Agency
[12] French civil aviation authority

screens was not on the agenda at the date of publication of this report.

The DGAC's response implied that there was no short-term plan for displaying meteorological information on controller radar screens.

In 2015, following the serious incident to the Airbus 320 registered F-HBNI operated by Air France on 2 August 2013 near Bordeaux, the BEA recommended that:

- The DGAC ensure that the meteorological information made available to controllers enables them to give the most comprehensive and relevant flight information possible and enhance the crew's situational awareness, in particular in cases of hailstorms.

The French Air Navigation Service provider (DSNA) replied that it was planning to gradually integrate meteorological information into controller display tools. In the framework of the SYSAT project, the need to integrate the display of storm zones directly onto the radar screen was incorporated in the specifications. Its effective implementation could not however be guaranteed at this stage, as it depended on the integration possibilities provided by the equipment that was to be selected from the different manufacturers.

With respect to the 4FLIGHT programme, the DSNA informed the BEA that the integration of this function on the radar screen had also been taken into account but that the lead time could not be specified at this stage. The BEA regretted that the definition and lead time for deploying these developments remained uncertain.
At the date of publication of this report, the BEA has no knowledge of the addition of this functionality in the 4FLIGHT system being deployed in Metropolitan France.

New recommendation
The serious incident on 25 July 2021, the subject of this report, occurred in Italian airspace. As in France concerning the display of meteorological information on air traffic control screens, storm phenomena are not displayed on the radar screens of Italian air traffic controllers.

Consequently, the BEA recommends that:

- ***whereas the display of meteorological phenomena on air traffic control radar screens is likely to enable air traffic controllers to anticipate possible crew requests to modify flight paths and to implement, if needed, transfer strategies outside of the standard route;***
- ***whereas this situation can be extrapolated to different air navigation service providers in Europe;***
- ***whereas the recommendations already issued on the topic have not come to fruition;***

EASA, in coordination with Eurocontrol:

1. ***conduct a global review of existing systems and those being developed that display near-real-time weather images on the radar screens of air traffic controllers, and their use by air navigation service providers as part of the flight information service, with the aim of facilitating meteorological avoidance strategies developed by flight crews,***
2. ***on the basis of the above review and other available data, identify the system specifications, tools and working methods that would be most suitable for use by the European air navigation service providers in order to facilitate weather avoidance strategies developed by flight crews,***

3. ***promote the implementation and use of such systems, tools and working methods by the European air navigation service providers in order to facilitate meteorological avoidance strategies developed by flight crews.***

[Recommendation FRAN 2022-014]

4.2 Improvement of meteorological information provided on board aircraft

Many different generations of weather radar exist today. The oldest systems offer limited performance and/or require specific training to ensure they are used correctly (e.g. manual selection of tilt and gain). In addition, the weather radar can only detect precipitation and some hazards associated with precipitation. The effectiveness of the detection depends on the size, composition, phase (liquid/solid) and the concentration of droplets (water) or particles (ice). Moreover, pilots must be familiar with the techniques for using the different radars (adjustment, parameters and analysis of the display) and know the limitations of the system used.
Heavy precipitation can, in addition, hide the meteorological situation behind a cell shown on the radar screen (mitigation phenomenon), and radar returns do not always provide a comprehensive image of the situation behind the strongest cells.

Consequently, the BEA recommends that:

- ***whereas the effectiveness of the detection capability of onboard weather radars is variable;***
- ***whereas weather radars do not always provide the flight crew with the information required to safely navigate through large areas of convective activity;***
- ***whereas the provision of observed and forecast high-resolution meteorological information, such as images derived from satellites and ground weather radars, is likely to improve the crew's situational awareness;***

EASA promote systems and equipment providing advanced meteorological information on board aircraft that is updated in near real-time.
[Recommendation FRAN 2020-015]

APPENDIX 1: GLOSSARY

Acronyms	English version	French version
A/THR	Auto THRust	
ACC	Area Control Centre	
AP	AutoPilot	
ATC	Air Traffic Control	
CB	Cumulonimbus	
CVR	Cockpit Voice recorder	
DGAC	French civil aviation authority	Direction Générale de l'Aviation Civile
DSNA	French air navigation service provider	Direction des Services de la Navigation Aérienne
EASA	European Aviation Safety Agency	
EFB	Electronic Flight Bag	
FCOM	Flight Crew Operating Manual	
FDR	Flight Data Recorder	
FIR	Flight Information Region	
FL	Flight Level	
ICAO	International Civil Aviation Organization	
METAR	Aerodrome routine meteorological report	
MFD	MultiFunction Display	
ND	Navigation Display	
NM	Nautical Mile	
OPERA	Operational Programme for the Exchange of weather RAdar data	
PF	Pilot Flying	
PM	Pilot Monitoring	
SIGMET	SIGnificant METeorological phenomena	
SIGWX	Significant weather	
TCU	Towering Cumulus	
UTC	Universal Time Coordinated	

The BEA investigations are conducted with the sole objective of improving aviation safety and are not intended to apportion blame or liabilities.