DATA SUMMARY

LOCATION

Date and time	**Thursday, 8 July 2004; 17:19 h UTC**
Site	**P. of Girona, en route from Girona to Paris Beauvois**

AIRCRAFT

Registration	**EI-DAR**
Type and model	**BOEING B-737-800**
Operator	**Ryanair**

Engines

Type and model	**CFM56-7**
Number	**2**

CREW

	Pilot in command	Copilot
Age	**47 years**	**30 years**
Licence	**ATPL**	**ATPL**
Total flight hours	**11,850 hours**	**1,747 hours**
Flight hours on the type	**7,500 hours**	**1,500 hours**

INJURIES

	Fatal	Serious	Minor/None
Crew		**1**	**5**
Passengers			**158**
Third persons			

DAMAGES

Aircraft	**Minor**
Third parties	**None**

FLIGHT DATA

Operation	**Cial. air transport – Scheduled intern. passengers**
Phase of flight	**En route – Climb to cruising level**

1. FACTUAL INFORMATION

1.1. History of the flight

On 8 July 2004, approximately at 17:12 h[1], the aircraft took off from runway 02 of Girona Airport (GRO) in a non-scheduled flight to Paris Beauvois (BVA) with 2 pilots, 4 flight attendants and 158 passengers on board. The autothrottle was engaged and, when the aircraft was at approximately 4,000 ft, autopilot was also engaged.

The weather radar was on and the flight crew visually noticed some clouds around. They headed for Bagur VOR (BGR) as a normal leg of the BGR 1Z standard departure, instead of routing north, for weather avoidance purposes. The ATC cleared them to climb to flight level 180 at 17:14:34 h. The pilot in command stated that he decided to «manage the flight on heading to avoid weather». They were on heading 060° and then the ATC Barcelona instructed them to fly direct to KANIG at 17:16:20 h.

The captain also stated that to fly direct to KANIG they needed to make a 90° turn to the left and to head towards a big cloud, although nothing was noticed on the weather radar (the display appeared in green colour).

Therefore, the captain decided to continue with a heading of 60° «on blue sky» and when he estimated to be around 1,000 or 1,500 ft over the top of the cloud and 10 NM away from it, they turned left towards KANIG while still climbing towards the cleared FL180. This aircraft trajectory kept them away from the cloud but, when flying overhead the cloud (described by the captain to be a towering cumulus or TCU), it expanded very quickly and the crew did not have time to make a 180° turn to avoid it. Then the aircraft went through the active top of the cloud and, when it was at approximately FL170 and 230 kt at 17:18 h, it suffered severe turbulence for around 10 sec.

The cabin crew were standing on the cabin because they had been released by the Captain and were preparing for in-flight service. No passenger was standing because the seat belt was still on. According to the statements gathered, there were two flight attendants working at the back of the cabin setting up the drink trolley to start the service when light turbulence started. Within seconds the turbulence became stronger and the plane started shaking very badly. The flight attendants had managed to re-stow the trolley quickly when suddenly one of them (cabin attendant n° 3) was hitting the ceiling, and then the door and the door handle with her head. Eventually she could reach her jump seat and fastened the seat belt. After turbulence finished, she noticed she could not move because of her injuries. The other flight attendant located at the rear part was also thrown up and down violently, before having time to sit and fasten her

[1] All the times are UTC times unless otherwise noted. It is needed to add 2 h to obtain local time.

seat belt. She suffered contusions and bruises, and later noticed that her colleague was seriously injured and called the supervisor.

At 17:19:28 h the aircraft was transferred to Marseille ATC centre, and the flight crew acknowledged without reporting any problem. The aircraft was cleared to climb to FL280 and, when approaching that level, the flight crew were advised by the cabin crew that cabin attendant n° 3 was seriously injured, and the captain decided to return to Girona. He requested in French and English languages whether there was a doctor or nurse on board, but there was none. The aircraft started a left turn from 315° at approximately 17:28 h.

At 17:30:04 h Marseille ATC centre called Barcelona ATC to state that flight RYR910C was going back to Girona «because he has a passenger ill». At 17:35:34 h the flight contacted again Barcelona ATC when they were passing through FL210. They were directed to runway 02 of GRO. During the descent, the flight crew requested the ATC to have medical assistance prepared on ground.

They landed back at Girona Airport at 17:52 h. Medical assistance was ready when they went to the apron.

The seriously injured flight attendant was taken to hospital, with two fractures in the ankle and other injuries that needed stitches. The other flight attendant suffered several bruises caused by an undetermined part of the aircraft in the rear galley area, although she was not taken to hospital. No further injuries were reported.

The aircraft departed again towards BVA at 19:41 h without several passengers that decided not to travel.

1.2. Personnel information

1.2.1. *Pilot in command*

The captain was a 47 years old French national. He had a French National airline transport pilot license. The total flying experience was 11,850 h. He had approximately 7,500 h on type.

1.2.2. First officer

The first officer was a 30 years old Dutch national with a Dutch JAR ATPL. His total flying experience was 1,747 h and he had approximately 1,500 h on type.

1.3. Flight recorders

The aircraft was equipped with a cockpit voice recorder (CVR) and a digital flight data recorder (DFDR). When the incident was notified, the recorders were requested to be downloaded, but the CVR had already been over recorded. The operator provided a transcript of the DFDR. From the analysis of those data, it seems the strongest turbulence happened at the magnetic coordinates 42.098° N / 3.125° E (province of Girona) and it was determined that the aircraft suffered a maximum vertical acceleration of 2.096 g and a minimum vertical acceleration of –0.255 g when the altitude was around 17,000 ft. See a graph of the vertical acceleration on Figure 1. From an initial value of 230 kt of airspeed, it varied between 250 kt and 220 kt during the turbulence encounter. The horizontal and lateral accelerations also varied during the event (see Figure 2). The autopilot and autothrottle were engaged and remained engaged during the turbulence encounter and afterwards. There were large excursions of pitch and roll during the moments of maximum acceleration. The altitude did not suffer important changes, i.e. the aircraft continued its climb approximately with the rate of climb as before the encounter.

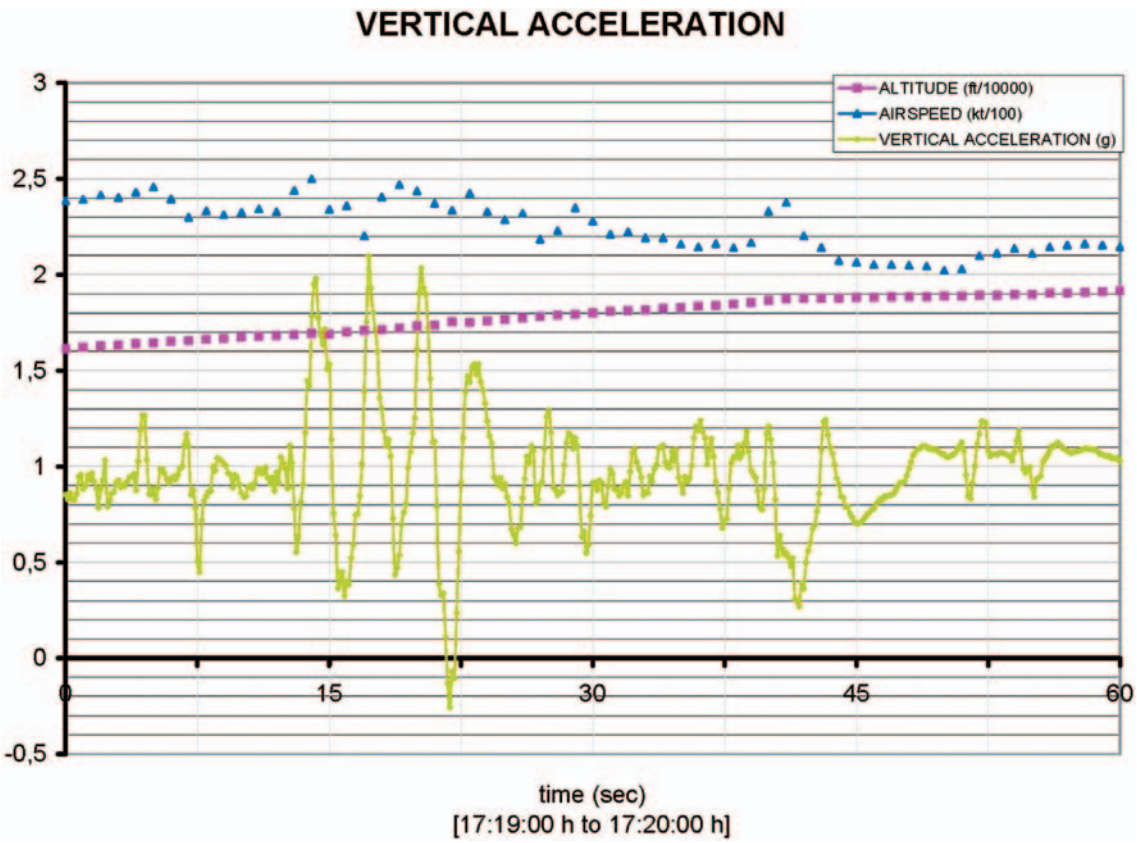

Figure 1

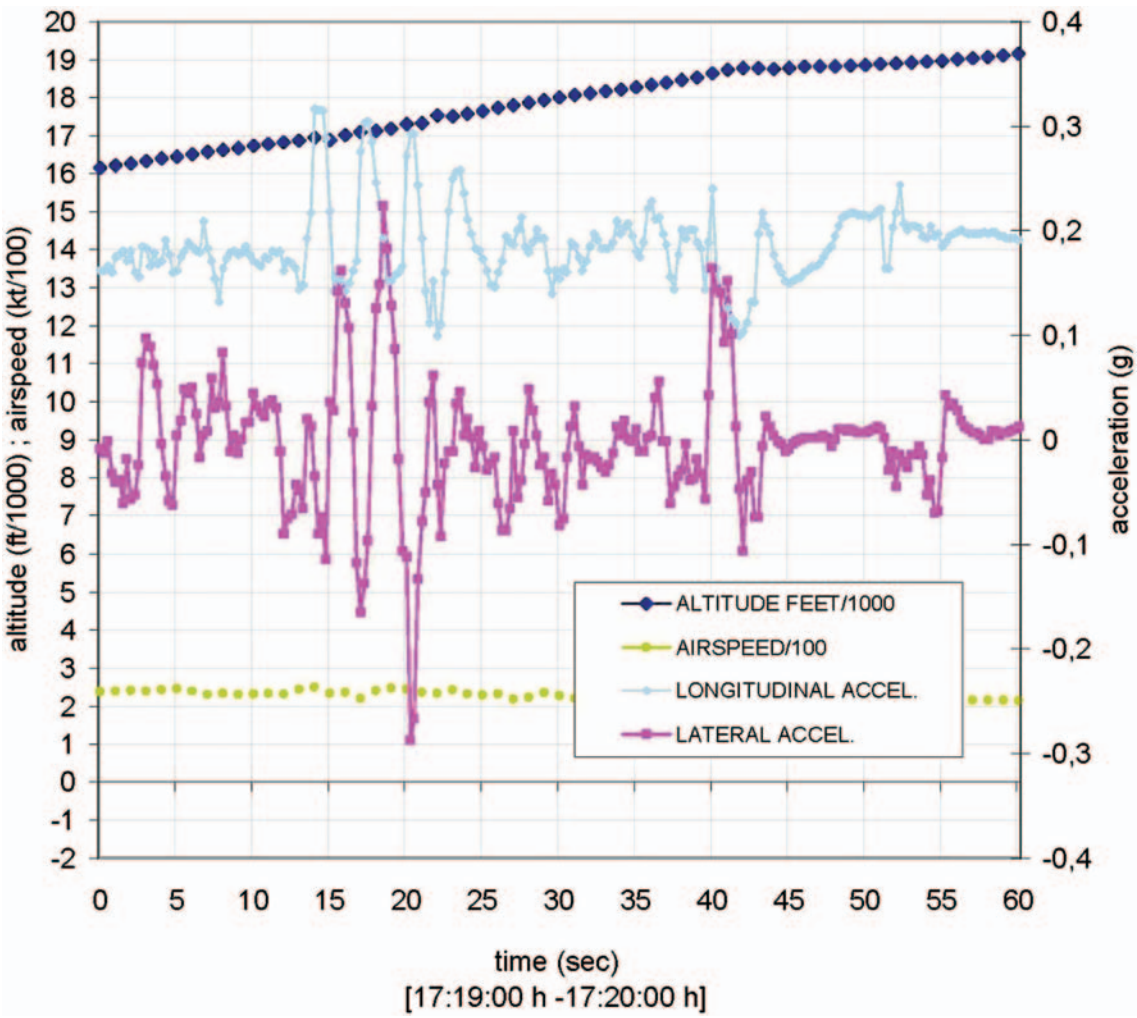

Figure 2

1.4. Meteorological information

The operator informed that the captain and first officer of the aircraft had received all relevant weather reports from their Operations Department at Girona.

The accident happened at the coordinates 42.098º N and 3.125º E

The meteorological office of Girona Airport informed that the day of the accident they provided the following information to the operator personnel at 16:06 h:

a) METAR and TAF of LFPO (Paris-Orly), LFPB (Paris-Le Bourget), LFQR (Lille-Losquin), and LFPG (Paris-Charles de Gaulle).

b) Tables of wind-temperature at levels FL180 and FL240.
c) Significant weather map from level FL100 to FL450.

The meteorological data for Girona Airport were the following:

METAR 17:00 UTC

— Wind: 050/9KT with gusts of 20 kt. Wind direction varying between 010° and 080°.
— Visibility: more than 10 km.
— Clouds: 3 to 4 octas of TCU (towering cumulus).
— Temperature: 24 °C. Dew point: 13 °C.
— QNH: 1,016.

Tables of forecast wind-temperature over Girona at 18:00 h UTC

Flight level	Wind direction/ Intensity (°/kt)	Temperature (°C)
FL050	NW/20	10
FL100	W/25	0
FL180	SW/60	–15
FL300	SW/100	–39

There had been some lightning activity close to the zone where the turbulence was encountered in the previous two hours (see attached map in Figure 3).

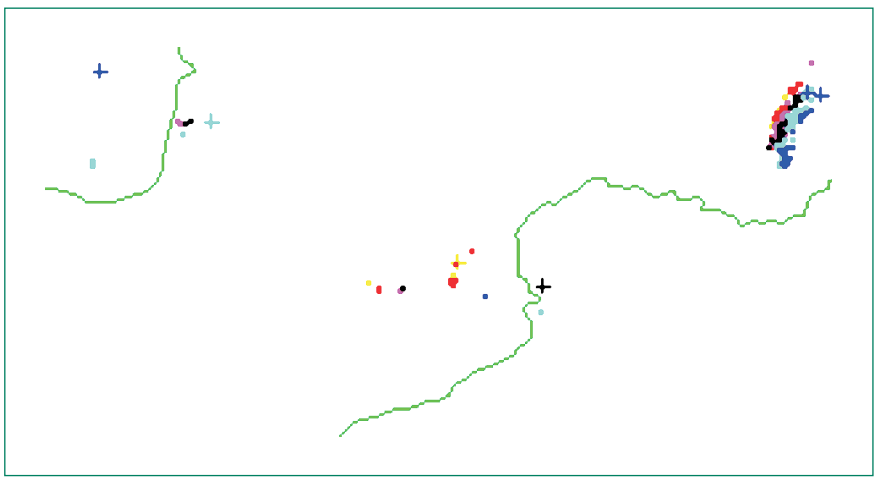

Figure 3. Map of lightning activity from 16:00 h to 18:00 h

The significant weather map at levels FL100 to FL450 at 18:00 h UTC showed a stream crossing the east of Catalonia with a SSW-NNE direction, with maximum winds SSW of 110 kt at FL330. When the airstream entered France it was oriented in an S-N direction.

Wind probing at Nimes on 8 July 2004 at 12:00 h UTC:

Altitude (m)	Wind direction/ Intensity (°/kt)	Temperatura (°C)
777	240/14	17.6
1,202	225/18	13.6
1,494	215/20	12.0
1,907	203/24	9.8
2,021	200/25	9.2
2,094	200/26	8.8
2,285	201/28	9.6
2,880	204/35	4.8
3,098	205/38	3.0
3,297	206/40	1.2
3,415	206/42	0.2
3,583	207/44	–1.1
4,661	211/57	–5.9
4,867	212/60	–7.3
4,661	211/57	–5.9
4,867	212/60	–7.3
5,236	213/65	–9.7
5,544	214/69	–11.9

With all the meteorological data, it was determined that during the climb to cruise altitude, the aircraft probably encountered wind currents that were changing their direction and increasing their intensity, from NW 20 kt at FL050 to SW 52 kt at FL150 and SW 60 kt at FL180. At higher altitude the wind was even stronger up to 100 kt at FL300, although with no important changes in its direction.

This turn of the wind at low and medium levels and the increasing of wind speed from low levels up to FL300 would produce moderate to strong turbulence, especially from FL100 to FL300.

Figure 4 with the meteorological map at 17:20 h shows some cloud presence close to the Pyrenees Range (more reflectivity means more precipitation activity).

As it can be seen on Figure 5, the place of the accident was close to an area of some precipitation activity.

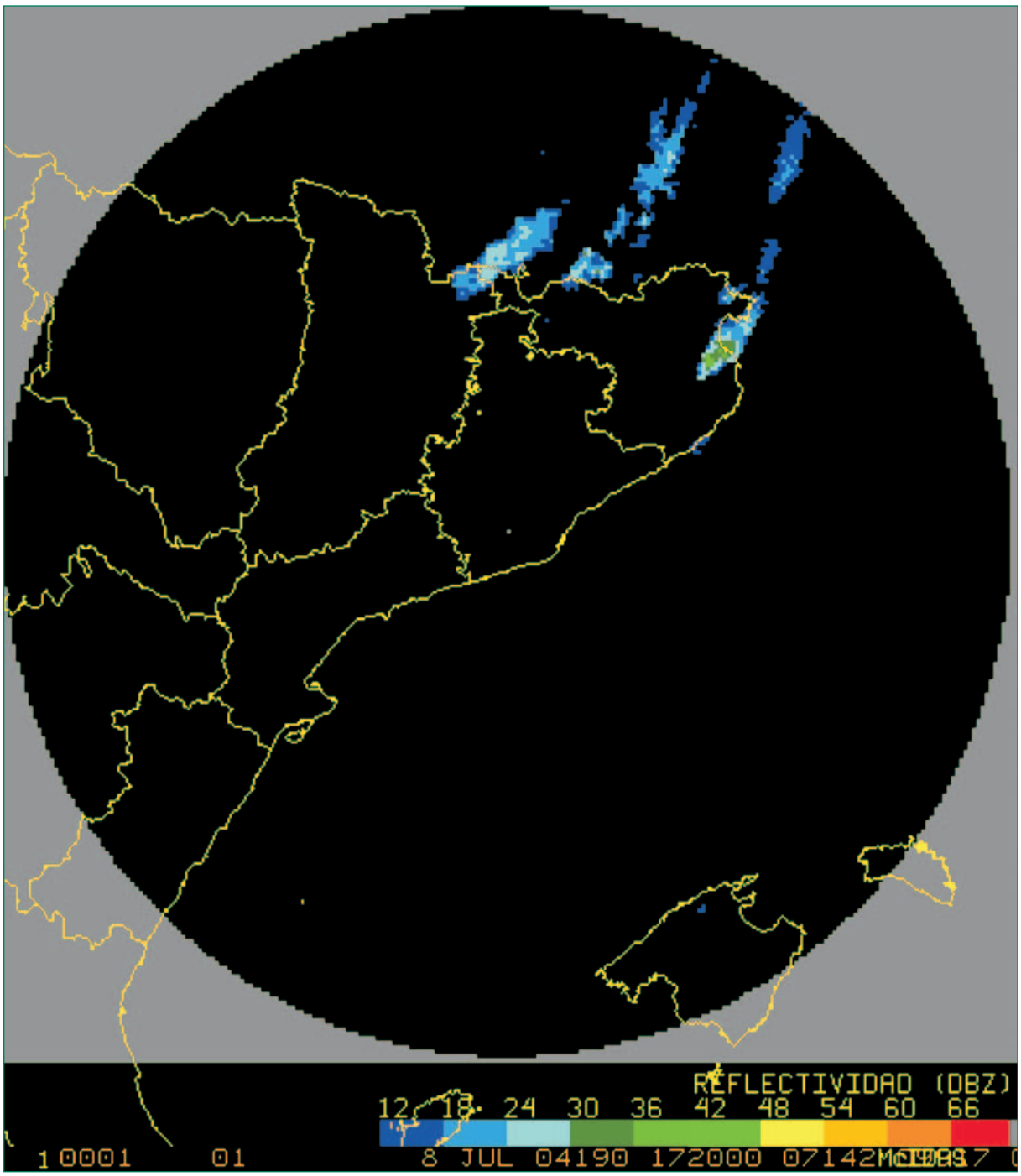

Figure 4. Weather radar map of the northeast of Spain on 8 July 2004, at 17:20 h

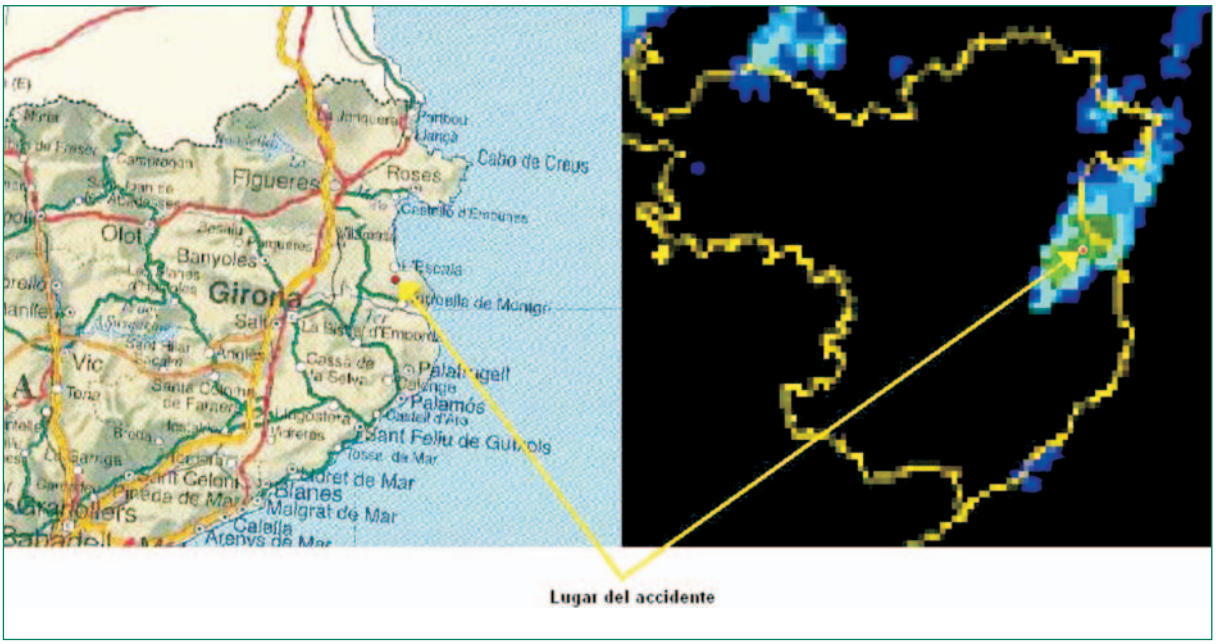

Figure 5. Place of the accident and detail of the weather radar map

1.5. Operational procedures

The Operator's operations manual (Chapter 8, 8.3.8, Issue 1, 1-12-1998) provided a quite complete guidance regarding characteristics of and means to avoid the weather turbulence, as well as of other adverse weather as ice, hail, windshear, microburst, etc. Only some of those important instructions are summarized below.

The policy of the operator was not to attempt flight through any area which is more than three quarters covered by thunderstorms.

The potential hazard of turbulence, which is found within the storm, underneath the base of the storm cloud, ahead of the storm at the gust front, and often around the edges and above the tops of the storm, was described in the operations manual, including the increase of intensity from the initial formation of the cumulus clouds with the development of shear between the updrafts and downdrafts, and precipitation.

It was stated that outside the cloud, shear turbulence had been encountered several thousand feet above and 20 miles laterally from a severe storm. It was also described that gust fronts often move far ahead (up to 15 miles) of associated precipitation. The manual showed in other paragraph that though lightning intensity and frequency have no simple relationship to other storm parameters, severe storms as a rule, have a high frequency of lightning.

To cope with the turbulence, the manual stated that «The speed of the aircraft determines the rate of turbulence encountered and stresses are least if the aircraft is held in

a constant attitude and allowed to "ride the waves"» instead of trying to keep a constant altitude, which maybe almost impossible.

Regarding the use of the weather radar, the manual highlighted the fact that «weather radar is provided for avoidance of thunderstorms and not for penetration of areas of storm activity» and that it detects only droplets of precipitation size (in the form of rain or hail) and not turbulence itself.

Detailed instructions for use of the radar were given to the crews, including the need to use the TILT and to switch to «WEATHER MODE» in conditions where cumulo-nimbus cloud or thunderstorm activity could possibly be expected. There was also reference to the aircraft operations manual for additional information.

The operational procedures provided guidance regarding distances to circumnavigate thunderstorms, which should be over flown at least with 5,000 ft of vertical separation and 5 to 10 miles of lateral separation between 0 and 20,000 ft of flight altitude depending on the intensity of the echoes in the weather radar.

Several general instructions for turbulence penetration (when avoidance could not be achieved) were also provided. In particular, the cabin attendants should be instructed to secure the passenger cabin and the autopilot should remain engaged (with the height hold mode disengaged) with a turbulence penetration indicated speed of 280 kt up to FL280 avoiding large control inputs. A constant thrust set should be established to hold this speed.

Additionally, the procedure of the operator for in-flight service was that above 3,000 ft in smooth flying conditions the Captain will signal that it is safe for the cabin crew to leave their seats. According to the information provided by the operator, in this occasion the Captain did not release the cabin crew until passing 10,000 ft when he was of the opinion that he was clear of any potential problems.

1.6. Aircraft information

The Flight Crew Operations Manual of Boeing had a supplement titled «Supplementary Procedures - Adverse Weather» dated April 26, 2004, which included a paragraph called «Turbulence». This supplement provided instructions for the cases of light to moderate turbulence and of severe turbulence.

> «*Turbulence*
>
> During flight in light to moderate turbulence, the autopilot and/or autothrottle may remain engaged unless performance is objectionable. Increased thrust lever activity

can be expected when encountering wind, temperature changes and large pressure changes. Short–time airspeed excursions of 10 to 15 knots can be expected.

Passenger signs ..... ON

Advise passengers to fasten seat belts prior to entering areas of reported or anticipated turbulence. Instruct flight attendants to check that all passengers' seat belts are fastened.

Severe turbulence

Autothrottle ..... DISENGAGE
AUTOPILOT (A/P) ..... CWS

A/P status annunciators display CWS («control wheel steering») for pitch and roll.

Note: If sustained trimming occurs, disengage the autopilot.

ENGINE START switches ..... FLT
Thrust ..... Set

Set thrust as required for the phase of flight. Change thrust setting only if required to modify an unacceptable speed trend.»

This speed was 280 kt or 0.76 Mach for the climb phase.

1.7. Additional information

1.7.1. *Standard Instrument Departures (SID) at Girona Airport*

The aircraft was using the SID Bagur 1Z. Other possibility was to use ALBER 2G (see Figure 6) that provided a more direct path to the north. The operator informed that this routing was chosen for weather avoidance. However, the crew probably did not have the information of the weather map (see Figure 4) because that map shows that some clouding was active in the area of the Gulf of Rosas and to the nort of BAGUR VOR at 17:20 h (the take off happened at around 17:12 h and the accident at around 17:19 h), although the precipitation level was probably light or moderate at the most. On the contrary, the trajectory of ALBER 2G SID seemed to have less clouds present.

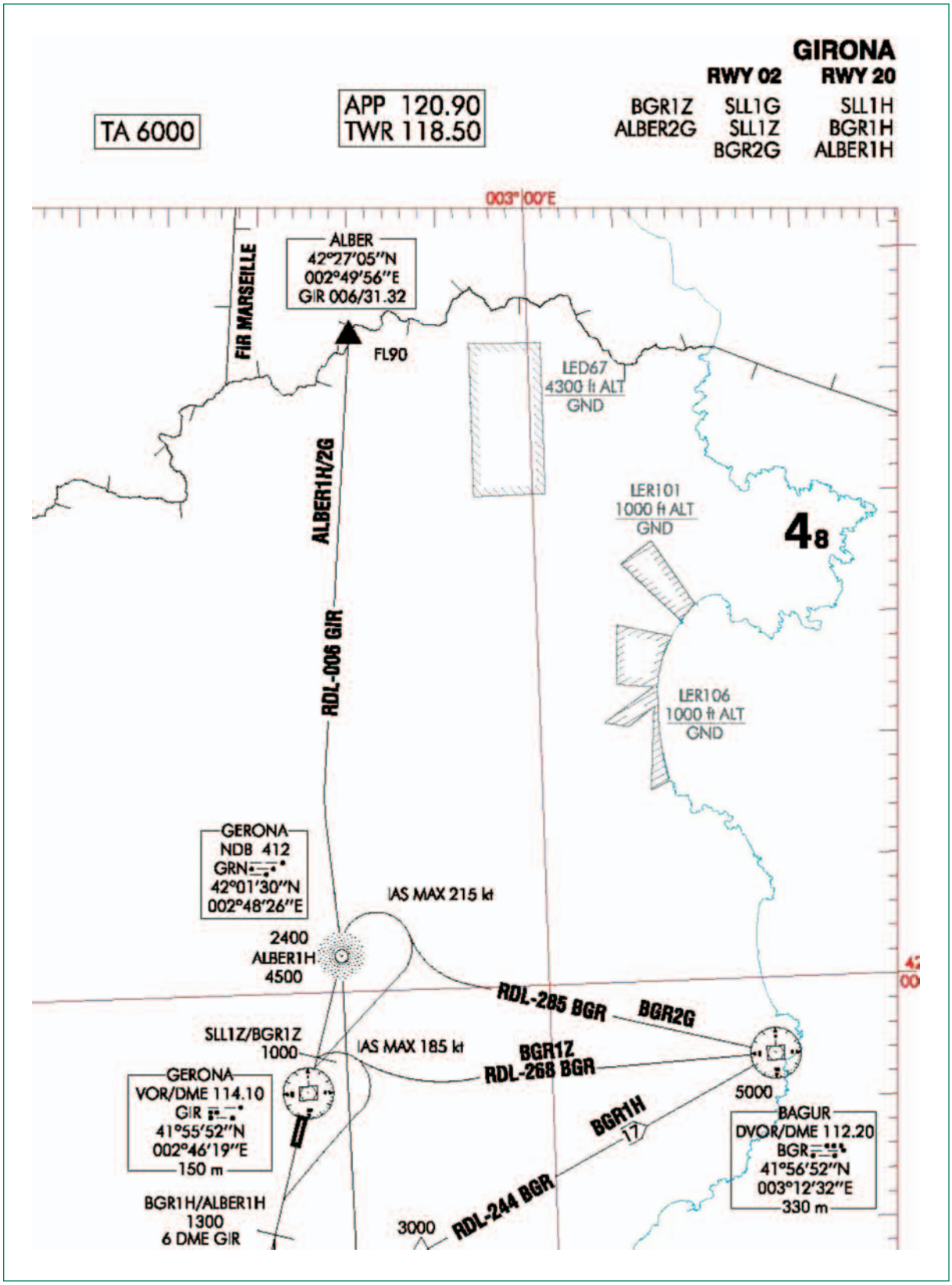

Figure 6. Standard Instrument Departures of Girona Airport

1.8. Use of the weather radar

Current on-board weather radars can only detect precipitation (water droplets, rain, hail, snow, etc.) inside clouds. Clear air turbulence or turbulence inside clouds without precipitation is not detected by this equipment. Awareness and avoidance of flight above or below hazardous clouds taking into account this limitation is the only means to prevent turbulence affecting the aircraft.

The use of the TILT capability (i.e. the change of the angle of the antenna with a horizontal surface) of the weather radar is considered one of the most critical factors to be able to detect level of precipitation inside a cumulo-nimbus cloud. If this feature is not conveniently used, the effectiveness of the weather radar can be reduced to the point where the flight crew may not be able to detect the hazard levels associated to a cloud area. In the case of the accident flight, with the aircraft in a climb level attitude, the precipitation level below the aircraft path would not be noticed unless the appropriate TILT was used in the antenna.

2. ANALYSIS

From the statements gathered it is concluded that the relevant meteorological information was provided by the operations department of the operator to the crew before the flight. This information showed that, because of the strong winds that were «turning» or changing their direction with increasing flight levels, turbulence could be encountered close to the coast in the province of Girona.

The ATC provided the standard instrument departure BAGUR 1Z, which included heading for the Bagur VOR and then turning north to KANIG waypoint.

The flight was normal after the takeoff from GRO. The flight crew were flying the aircraft with visual reference to the surrounding clouds, being aware that their proximity to one of those clouds could pose a hazard over the aircraft because they were towering cumulus, i.e. cumulus developing vertically to a high altitude. It is normal to fly in S-turns to avoid the presence of hazardous clouds either by visual reference or by reference to the weather radar, whose use was required in this case by the procedures of the operator.

Therefore, the crew was aware, both by previous meteorological information, and by their visual observations of surrounding clouds, of possible turbulence encounters. However, it is obvious that they did not anticipate that such turbulence could be as severe as that encountered a few minutes afterwards. In any case, the flight crew waited until they reached 10,000 ft of altitude to release the cabin crew for service after takeoff,

instead of 3,000 ft which is the moment specified by the company procedures in smooth air conditions.

After the outcome of the event, it seems that the release of the cabin attendants should have been done later, in view of the foreseen conditions, and a recommendation in this sense is made to the operator to reflect this fact in their procedures.

Afterwards, compliance with ATC instructions to fly direct to KANIG imposed the need to fly towards a big cloud noticed by the crew. Although they tried to keep away from it, both vertically (approximately 1,000 or 1,500 ft) and laterally (approximately 10 NM), the quick expansion of the cloud, according to the crew's recall of the event, left little time to react and to carry out a 180° turn to escape from the cloud. The turbulence was severe, especially in the downwards sense, although the certified limits of flight loads on the aircraft were not exceeded (vertical accelerations between +2.096 g and –0.255 g, compared with the limit loads of +2.5 g and –1.0 g with flaps up).

The operational procedures of the operator provided advice regarding the hazards associated to thunderstorms, and it was mentioned that they should be over flown at least with 5,000 ft of vertical separation and 5 to 10 miles of lateral separation between 0 and 20,000 ft of flight altitude depending on the intensity of the echoes in the weather radar. In this case, the top of the cloud was over flown lower than the recommended altitude (1,500 ft instead of 5,000 ft according to the pilot in command recalls), but the cloud activity was lower than in a thunderstorm and therefore the procedures could not be totally applicable.

In any case, the pilot informed that nothing appeared on the weather radar. It is unknown the exact antenna tilt angle used, because given the cloud area showed in Figure 4, it is likely that at least some echoes should have appeared in the on board weather radar. Therefore, it is considered convenient to issue a safety recommendation to recommend that additional information on the effective use of the weather radar is distributed to flight crews.

Once the aircraft entered the top of the cloud and turbulence began, the autopilot and autothrottle remained engaged, which was in accordance with the operating procedures of the operator and the manufacturer in the first case, but not in the case of the autothrottle. It is probable that the sudden and unexpected situation left the flight crew with little time to react as required by those procedures.

All the passengers were seated and with the seat belts fastened, but the cabin crew had already been released for service. The two crew members that were at the rear part of the aircraft were the most affected occupants of the aircraft, as it has been found in past turbulence related events. The damage to the interior of the aircraft was minimized because their quick decision to re-stow the trolley which otherwise could have been violently thrown against the cabin ceiling producing major damage.

After those injuries were produced, it took an estimated period of 8 min for the flight crew to learn that at least a flight attendant was apparently seriously injured. Then the pilot in command quickly made the decision to go back to GRO. This was a conservative and sound decision from a safety point of view, because there were no medical personnel on board and Paris was still approximately one hour and a half away from their position. It is considered that the seriousness of the injuries of cabin attendant number 3 warranted this decision.

It is a usual practice in passenger commercial air transportation to recommend the passengers to keep their seat belts fastened all the time when they are seated, although this is not mandatory except in certain phases of flight or when requested by the crew. This practice intends to decrease the number of injured passengers due to turbulence encounters, which is probably one of the most important causes of personnel damage in airline flights.

However, this accident shows again the risk due to turbulence encounters faced by cabin crew members that are standing in the cabin during several phases of the flight to provide an essential safety service on board as well as other commercial services also very important for the companies. This risk is in general due to two types of turbulence: clear air turbulence (CAT) and turbulence associated to clouds and precipitation.

Due to its own characteristics, it is very difficult to anticipate or to prevent sudden encounters with clear air turbulence, similar to those produced over the Atlantic Ocean (for example, the CIAIAC is currently investigating a CAT encounter on 26-2-2004 of a B-747 en route from Buenos Aires to Madrid in which a passenger was seriously injured, and also another event happened on 20-1-2005 to a B-767 in cruise flight from Santo Domingo to Madrid in which a cabin attendant was seriously injured).

However, more efforts should be devoted to minimize the incidence of encounters with turbulence produced by clouds or precipitation that may be anticipated to some extent, by means of the adequate use of the pre-flight weather information, of the on board weather radar, and of the adoption of conservative measures to have all the aircraft occupants with the seat belts fastened like when some probability of turbulence exists, event if it is necessary to delay or cancel the on board commercial services provided by the flight attendants.

3. CONCLUSION

It is considered that the cause of the accident was a turbulence encounter of unexpected severity after the cabin attendants have been released for passenger service because of the proximity of the flight path with a towering cumulus.

4. SAFETY RECOMMENDATIONS

REC 11/05. It is recommended to the operator of the aircraft that their operational procedures are amended to include the minimum conditions under which the cabin attendants may be released for passenger service when turbulence encounters are expected after takeoff.

REC 12/05. It is recommended to the operator of the aircraft that additional training is provided to flight crews regarding effective use of the weather radar and its limitations regarding detection of turbulence.