CIAIAC

COMISIÓN DE
INVESTIGACIÓN
DE **A**CCIDENTES
E **I**NCIDENTES DE
AVIACIÓN **C**IVIL

Technical Report A-011/2004

Accident to aircraft Boeing B747-300, registration TF-ATJ, operated by Iberia LAE, during flight over the Atlantic Ocean tropics on 26 February 2004

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DE FOMENTO

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SECRETARÍA GENERAL DE TRANSPORTES

COMISIÓN DE INVESTIGACIÓN DE ACCIDENTES E INCIDENTES DE AVIACIÓN CIVIL

Foreword

This report is a technical document that reflects the point of view of the Civil Aviation Accident and Incident Investigation Commission (CIAIAC) regarding the circumstances of the accident and its causes and consequences.

In accordance with the provisions of Law 21/2003 and Annex 13 to the Convention on International Civil Aviation, the investigation has exclusively a technical nature, without having been targeted at the declaration or assignment of blame or liability. The investigation has been carried out without having necessarily used legal evidence procedures and with no other basic aim than preventing future accidents.

Consequently, any use of this report for purposes other than that of preventing future accidents may lead to erroneous conclusions or interpretations.

This report has originally been issued in Spanish language. This English translation is provided for information purposes only.

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Abbreviations

00 °C	Degrees centigrade
00 °K	Degrees Kelvin
00° 00′ 00″	Degrees, minutes and seconds
AMM	Airplane maintenance manual
ATC	Air traffic control
CAP	Captain
CAT	Clear air turbulence
CB	Cumulonimbus
CIT	Convectively induced turbulence
Cu	Cumulus
DFDR	Digital flight data recorder
E	East
FAA	Federal Aviation Administration
FL-	Flight level in hundreds of feet
ft	Feet
g	Acceleration due to gravity
h	Hours
hh:mm	Time expressed in hours: minutes
hPa	Hectopascal
IAS	Indicated airspeed
ICAO	International Civil Aviation Organization
ITCZ	Intertropical convergence zone
kt	Knot(s)
mb	Milibars
min	Minute(s)
N	North
NE	Northeast
NM	Nautical miles
OAT	Outside air temperature
RAT	Ram air temperature
SE	Southeast
TAS	True air speed
TAT	Total air temperature
UTC	Coordinated universal time
W	West
WAFS	World area forecast, ICAO

Synopsis

Date of approval: 27 September 2006

On 26 February 2004 a B747-300 aircraft, registered TF-ATJ, was completing scheduled flight IB-6740 from Buenos Aires to Madrid with 19 crew members and 401 passengers aboard. At 05:57 UTC, while overflying the equator over Atlantic international waters at flight level 340, the aircraft encountered sudden moderate-to-strong turbulence which caused serious injury to one passenger. Some eleven other passengers and one flight attendant suffered light concussions or anxiety attacks. The aircraft was not damaged.

The aircraft diverted its course to Las Palmas airport, where the seriously injured passenger with signs of hemiplegia was disembarked to be taken to a hospital for medical assistance.

There was no forecast turbulence in the area where the accident occurred. There were no visible clouds. No turbulence announcements were given and the fasten seat belt signs remained off.

1. FACTUAL INFORMATION

1.1. History of the flight

In the early morning of 26 February 2004, at 00:37 UTC[1], flight IB-6740 operated by Iberia L.A.E. airlines, took off from Ezeiza airport in Buenos Aires; a B747-300 aircraft, registered TF-ATJ, destination Madrid. Aboard the aircraft there were 19 crew members and 401 passengers. The departure of the flight was delayed 36 hours due to aircraft unavailability. According to the Operational Flight Plan, the aircraft was to overfly the Brazilian Atlantic coast before entering the Atlantic Ocean tropical zone. Afterwards the flight would continue to the Isle of La Sal and the Canary Islands. The scheduled duration of the flight was 10:55 hours.

Significant weather charts at cruise flight levels forecast a large front at latitudes of about 25° South and a turbulence area in the vicinity of the Canary Islands.

During the flight, Brasilia Control Centre approved a course deviation, at the captain's (CAP) discretion, to try to avoid the weather front. The flight was carried out normally, without further complications, and on-board passenger service was completed.

After five hours of flight had elapsed, the on-board service had been finished and the cabin lights were dimmed, and turbulence was suddenly encountered. The aircraft was flying at flight level 340, over international waters at the equator and in clear air "without a single cloud", according to the captain's statement and without experiencing any other onset of turbulence. The turbulence lasted for about three minutes.

Ten minutes before the event, the relief pilot had occupied the left seat, although the captain was still present in the flight deck, and he retook on his immediately seat afterwards.

According to the captain, "the turbulence caused an uncontrollable high-rate descent, of about three- to four thousand feet per minute, followed by a high-rate climb in the opposite direction".

During the event, a passenger who was on foot and walking down the left aisle towards the rear of the aircraft, at row 47-48 level, returning to her seat D40, suffered serious head contusions. This was immediately made known to the CAP.

The injured passenger was attended to by other passengers, medical physicians, who initially reduced a haemorrhage and also observed serious internal injuries that produced hemiplegia and lack of mobility and sensitivity from the waist down.

[1] Time references are expressed using UTC (Coordinated Universal Time). Local time in Buenos Aires is UTC-3. Local time in Gran Canaria in winter is the same as UTC.

As the doctors determined that she needed to be taken to a hospital for immediate medical assistance, the aircraft set course to Las Palmas de Gran Canaria, where it landed at 09:26. Medical services awaiting the arrival of flight IB-6740 transferred the passenger and her husband from the airport to a hospital by helicopter.

During the event, 11 other passengers and a flight attendant who was standing in the "grand class" area were injured or showed signs of anxiety. Except for the two passengers that disembarked in Gran Canaria, the rest of the occupants remained on board during the refuelling of the aircraft, which, after a transit check, was cleared to continue the flight to Madrid, where it finally landed at 13:05.

The passengers who so requested received medical attention at the door of the aircraft in Madrid.

1.2. Injuries to persons

Injuries	Crew	Passengers	Total in the aircraft	Others
Fatal				
Serious		1	1	
Minor/none	19	400	419	Not applicable
TOTAL	**19**	**401**	**420**	

1.3. Damage to aircraft

There was no damage to the aircraft.

1.4. Other damage

There was no other damage.

1.5. Personnel information

1.5.1. *Pilot in Command*

Nationality: Spanish

License: Airline Transport Pilot

Medical certificate expiry date:	04-04-2004
Total flight time:	18,415 hours
Flight time previous 90 days:	173 hours
Flight time in aircraft type:	3,032 hours

1.5.2. *Copilot*

Nationality:	Spanish
License:	Airline Transport Pilot
Medical certificate expiry date:	11-13-2004
Total flight time:	6,819 hours
Flight time previous 90 days:	173 hours
Flight time in aircraft type:	639 hours

1.5.3. *Relief Copilot*

Nationality:	Spanish
License:	Airline Transport Pilot
Medical certificate expiry date:	05-09-2004
Total flight time:	7,973 hours
Flight time previous 90 days:	146 hours
Flight time in aircraft type:	2,969 hours

1.5.4. *Flight Engineer 1*

Nationality:	Spanish
License:	Flight Engineer
Medical certificate expiry date:	05-09-2004
Total flight time:	12,001 hours
Flight time previous 90 days:	109 hours
Flight time in aircraft type:	7,700 hours

1.5.5. *Flight Engineer 2*

Nationality:	Spanish
License:	Flight Engineer
Medical certificate expiry date:	07-16-2004
Total flight time:	15,254 hours
Flight time previous 90 days:	139 hours
Flight time in aircraft type:	2,361 hours

1.5.6. *Cabin crew*

The cabin crew consisted of a supervisor, a senior flight attendant and 12 flight attendants, all of whom held valid up-to-date licenses and had passed all training courses and mandatory periodic courses.

1.6. Aircraft information

1.6.1. *Airframe*

Make:	Boeing
Model:	747-300
Serial number:	24108
Registration:	TF-ATJ
MTOW:	377,842 kg
Owner:	ILFC
Operator:	Iberia

1.6.2. *Airworthiness Certificate*

Number:	804
Class:	Normal
Purpose:	Public passenger transport
Date of issuance:	02-05-2000
Date of expiry:	01-31-2005

1.6.3. *Maintenance log*

The aircraft logbook does not show any entry concerning the turbulence incident.

1.7. Meteorological information

1.7.1. *Significant weather chart*

The significant weather chart that was given to the flight crew (see Appendix A2) summarizes the information they had for the planning of the flight.

The aircraft took off from Buenos Aires's Ezeiza airport at the 34° South parallel and then took a North Northeast heading. Just before entering Brazil, the scheduled route would take them into an extensive frontal area with isolated cumulonimbus (CB) between parallels 25° and 20° South.

In the tropical regions, between latitudes 10° S and 5° N, there were two limited areas with significant weather warnings, one over the continent and the other over the Atlantic Ocean, separated by 350 NM. The scheduled route went between these two areas. Thermo convective activity with CB-type clouds were forecast for those areas, which implied moderate to severe turbulence conditions. CB would be isolated and embedded or hidden amongst other layers of vertical development clouds up to 49,000 ft. The height of the Tropopause at those latitudes was 50,000 ft.

No significant weather was forecast further along in the route until passing latitudes above 22° N where a jet stream was encountered, at flight level 340, with wind speeds up to 70 kt in a South Southwesterly direction. The jet stream produced turbulence between flight levels 280 and 380. North of the jet stream, the height of the Tropopause descended from 50,000 to 39,000 feet.

1.7.2. *Weather information files*

The forecast significant weather chart (see Appendix A3) issued by the London's World Weather Forecast Centre integrated in ICAO's World Area Forecast System (WASF) for 00:00 UTC on 24 February 2004 for the regions of Africa, South Atlantic and South America, and indicated that where the accident occurred, isolated cumulonimbus could be expected up to flight level 440. These cumulonimbus would be embedded in a cloud mass that would extend North and South of where the accident occurred, and to the West-Northwest.

The significant weather forecast (see Appendix A4) for 06:00 UTC for the same day and location showed no indication of these cumulonimbuses, but did forecast them

in nearby areas to the East up to flight level 440, and to the West up to flight level 400.

Although at low resolution, water vapor and infrared satellite pictures (see Appendices A5 and A6) for the location, day and time of the accident, showed that slightly more than a geographic degree of distance North of the place where the accident occurred (just over 60 NM), and extending in a Northeasterly direction, there was a strip of organized cumulonimbus clouds, with higher tops the further they were from that point.

1.7.3. *Tropical weather*

Solar warming of areas near the equator causes settling of surface atmospheric low pressure areas.

Winds flow from high pressure subtropical latitudes, like the Azores High, towards the equator's low pressure areas, having a Northerly component in the Northern Hemisphere and a Southerly component in the Southern Hemisphere. The Coriolis force, due to Earth's rotation, deflects the trajectory of these winds in an Easterly direction in both hemispheres. The resulting winds are called trade winds.

The Northern Hemisphere's Northeasterly trade winds converge at the equator with the Southern Hemisphere's Southeasterly trade winds thus defining the Intertropical Convergency Zone (ITCZ), in which pressure gradients are small, light winds (the equatorial belt of calms, or doldrums), and where the rising air mass results in great vertical development clouds that reach as high as the Tropopause, which at those latitudes is about 50- to 55,000 feet high. The air that rises to levels below the Tropopause feeds high-altitude winds blowing North in the Northern Hemisphere and South in the Southern Hemisphere. The Coriolis force makes these winds take a Westerly direction and since this force increases upon reaching subtropical latitudes, the wind greatly increases in speed, becoming a jet stream. Subtropical jet streams are generally found at latitudes of 25° to 30°. It is not a continuous jet stream along Earth's parallel. The active stream segments can measure several thousands of nautical miles.

The main difference between polar and subtropical jet streams lies in the fact that polar jet stream formation is linked to frontal generation while in subtropical jet stream formation there is no participation of convergent air masses with different characteristics.

The absence of Coriolis force near the equator prevents hurricanes and tropical cyclones from forming in latitude areas below 5°.

1.7.4. *Atmospheric turbulence*

Like the polar jet stream, the subtropical jet stream is found in places where there are breaks in the Tropopause. Like the polar jet stream, strong clear air turbulence (CAT) can be found in the areas surrounding the subtropical jet stream. A high percentage of CAT can be associated with different types of jet streams.

Strong surface winds at the level of ground obstacles, consisting of mountains and mountain ranges, are responsible for other CAT episodes. In these cases, low-level disturbances are transmitted by undulating movements to cruise levels and to the stratosphere. Even though a high-altitude mountain wave is not turbulent but rather very laminar, it can nevertheless produce strong updrafts and downdrafts.

In tropical regions, with the absence of jet streams and strong surface winds, turbulence is generally due to thermal convection, but in those cases it usually comes with large vertical development clouds (CB). This turbulence is usually called Convection Induced Turbulence (CIT) and can happen inside the clouds and also above the top and on the leeward side of the cumulonimbus crest.

Advection or horizontal movement of air masses can carry different air mass properties from one place to another. High altitude vortex regions can be carried to other areas, thereby producing cases of atmospheric turbulence.

In the tropics, CAT phenomena are infrequent; their dimensions are usually limited to a few tens of nautical miles and they are short-lived. Forecasting them is almost impossible, and even pilot reports have little value in low-transit routes. Reported turbulence can disappear and not be felt by following traffic, or the next aircraft might not pass over exactly the same spot where turbulence was initially experienced.

1.8. Aids to navigation

Navigation systems had no influence on the accident.

1.9. Communications

Communications were normal.

There were no communications coming from other traffic that flew in the area that would warn about turbulence encountered.

The aircraft that suffered the accident notified ATC of the incidence of turbulence and requested via radio to Canarias Control that they coordinate medical aid for the injured passenger.

1.10. Aerodrome information

Not relevant.

1.11. Flight recorders

The aircraft had a digital flight data recorder, and a readout of the progress of several parameters has been made, such as indicated airspeed, lateral acceleration, altitude, low stage compressor rpm of engines 1 and 4, total air temperature and pitch and roll of the aircraft.

Vertical acceleration was not recorded due to a failure of the vertical accelerometer at the beginning of the flight. The accelerometer was later changed, on February the 28th.

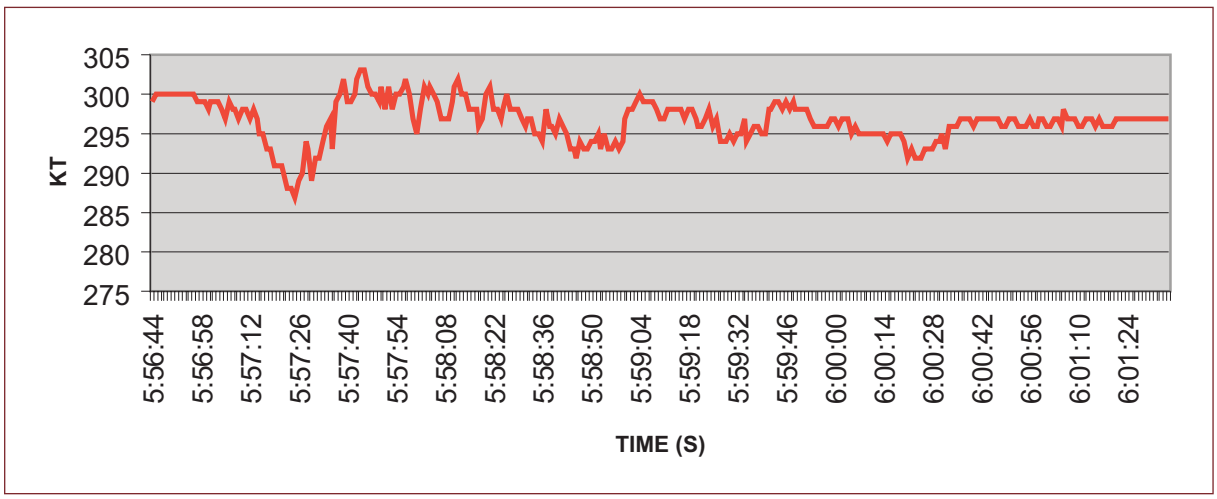


Figure 1.11.1. Aircraft's indicated airspeed

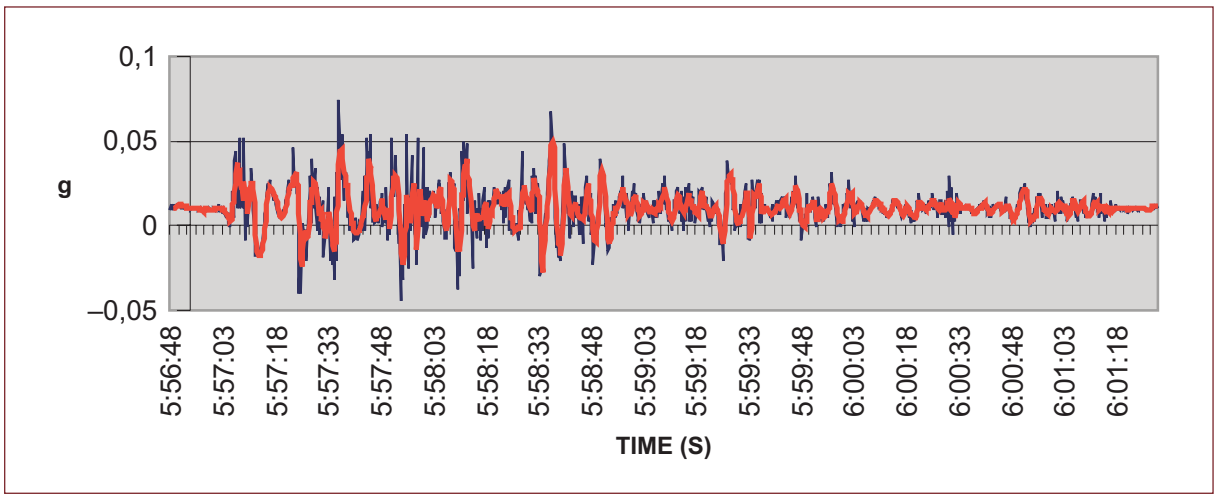


Figure 1.11.2. Lateral acceleration

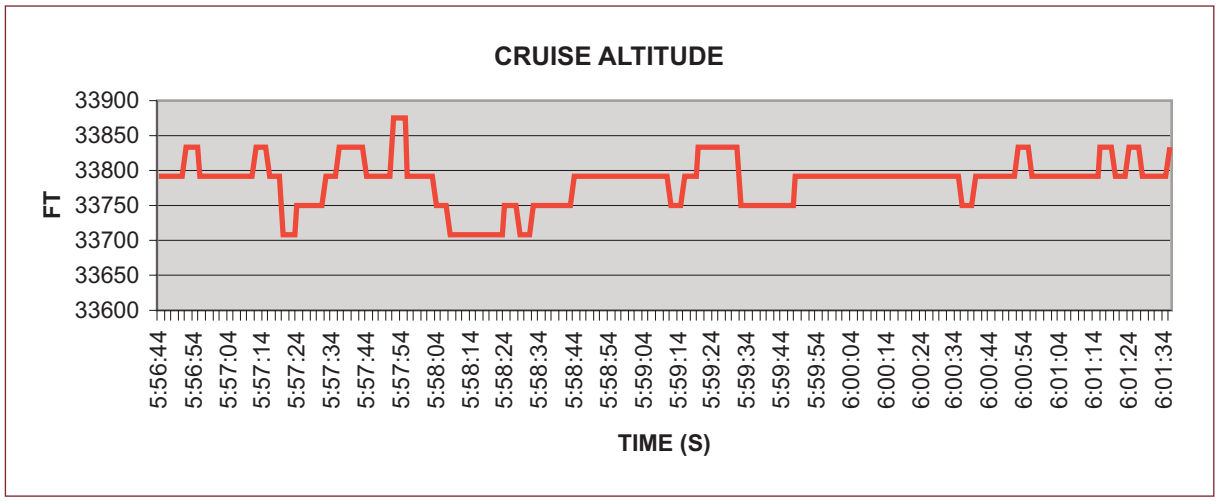


Figure 1.11.3. Flight level

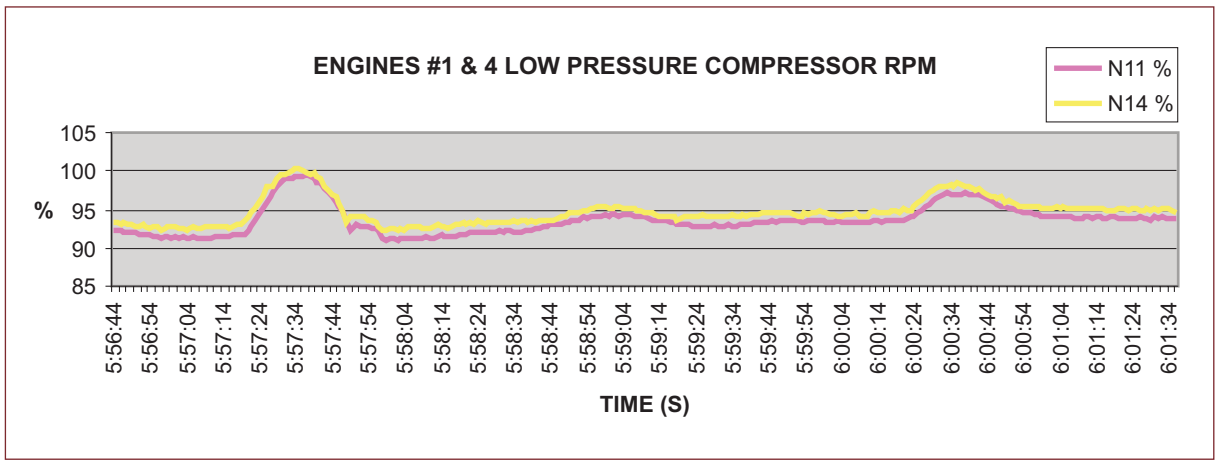


Figure 1.11.4. Engines 1 and 4 rpm

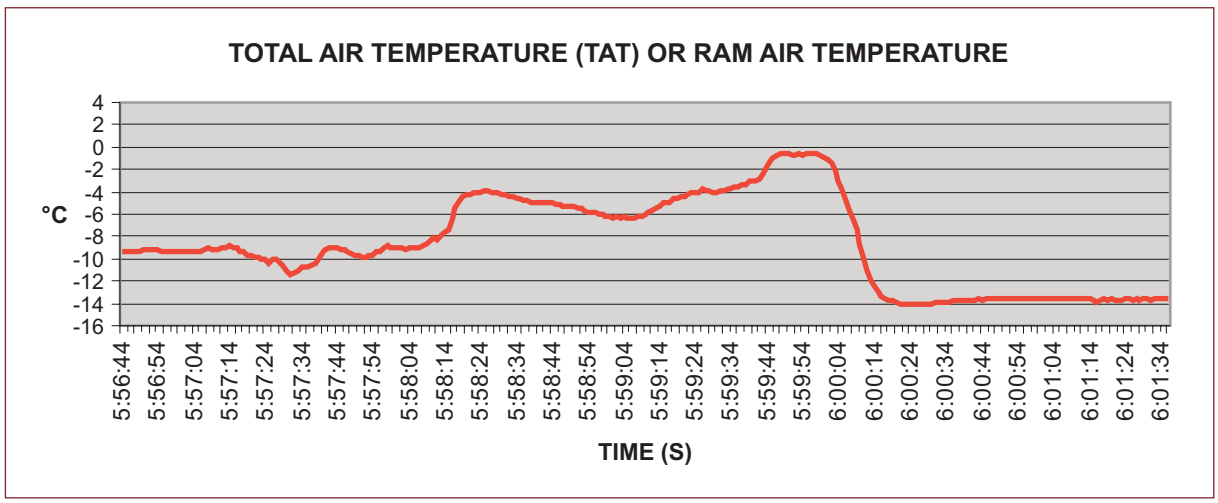


Figure 1.11.5. Total air temperature (Appendix A1 shows that TAT tends to recover values prior to the penetration of the turbulence as the aircraft flies away)

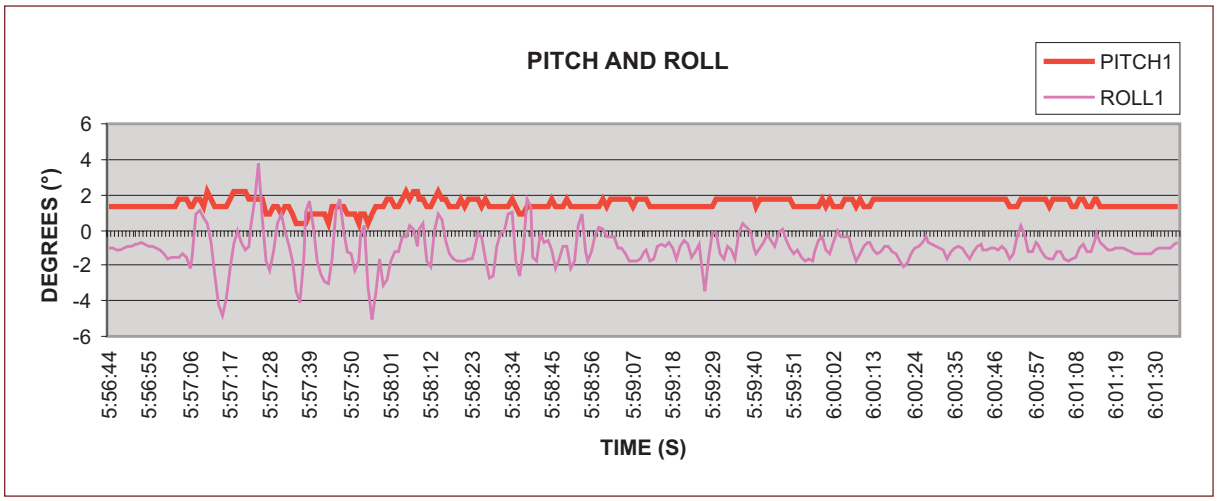


Figure 1.11.6. Pitch and lateral aircraft roll

1.12. Passenger cabin layout information

The interior configuration was defined for 404 passengers (12 grand class seats, 46 in business class and 346 in tourist class), arranged in 49 rows, numbered from 5 to 60, with two aisles, left and right. The tourist cabin began at row 19, where there was a lavatory area and the intermediate galleys, and ended in the lavatory area behind row 60. Between rows 42 and 47 there was another rear galley area.

See Appendix B for the main passenger cabin layout.

1.13. Medical and pathological information

During the event, a passenger was seriously injured and eleven others received some bruises and light contusions, and suffered anxiety attacks.

The seriously injured passenger suffered a blow to the head while she was walking down the left aisle at row 47-48 level, proceeding towards her assigned seat, D40.

The cabin crew observed that she had facial contusions, and a big cut in the eyebrow with haemorrhaging. Three doctors, also passengers on that flight, assisted the patient in a conditioned area with blankets in the rear galley of the aircraft.

After first aid assistance, using the on-board first aid kit, the doctors observed a serious condition in the passenger, noting that she felt nothing from the waist down and determined that she needed to be taken to hospital as soon as possible.

The flight was diverted, and upon arrival at Gran Canaria, the woman was again checked by the airport physicians, who found her in a prone position, conscious and fully aware. She had a bruised incisive wound in the right temporal region and presented left hemiplegia.

She was disembarked from the aircraft and transferred by helicopter to the island's Juan Negrín Hospital, where she remained in the ICU (Intensive Care Unit) for two days. She was hospitalized a few days longer in Las Palmas before returning to Scotland, to Glasgow's Queen Elizabeth's Hospital, until she was given leave on May 21st 2004, three months after the accident.

At the time of writing this report, there has been notable improvement in all injuries; she has regained motility, although she suffers slight sequelae.

In addition to the seriously injured passenger, another young boy of age 10 received assistance on board the aircraft, during the Gran Canaria stopover for a light cranial temporal lobe contusion.

When they arrived in Madrid, some passengers received medical assistance from the airline's medical staff at the door of the aircraft.

1.14. Fire

There was no fire.

1.15. Survival aspects

A clear air turbulence phenomenon does not usually pose a risk of damage to the aircraft or injury to the passengers and occupants if they are adequately secured by their safety belts and there are no loose objects of considerable mass that can move around and cause impacts.

1.16. Tests and research

1.16.1. *Aircraft weight estimate at the time of the accident*

The weight and balance sheet for the flight dispatch shows that the aircraft took off from Buenos Aires with 401 passengers and with a total weight of 360,970 kg. Considering a normal fuel consumption for five hours of flight of about 72,000 kg, we can estimate that the aircraft reached the place of the accident with a weight of 289,000 kg.

1.16.2. *Aircraft position at the time of the accident*

Approximate geographical location at the time of the turbulence encounter has been determined as the point 300 NM past Natal on the Operational Flight Plan. Natal is located at the coordinates S05° 55.5' W035° 14.9'. From there, with a 050° heading, they would reach the coordinates 00.02°S and 032.12°W, where the event supposedly occurred. That point falls between the Operational Flight Plan route points INTOL and EPODE. The estimated time for that flight plan from take-off from Buenos Aires was 5:17 hours.

Take-off actually took place at 00:37, and the turbulence encounter happened at 5:57, which means that 5:20 hours had elapsed since take-off, very close to the scheduled time.

1.16.3. *Aircraft parameters at the time of the accident*

The aircraft was flying at 299 kt IAS, equivalent to a flight level and temperature deviation of 10° with respect to standard atmosphere, to Mach 0.852 and a TAS speed of 503 kt.

The disturbance lasted little more than 3 minutes, which at TAS of 503 kt corresponds to a length of 25 NM.

After the disturbance, the aircraft was travelling at a speed of 296 kt IAS, equivalent in environmental conditions to Mach N° 0.847 at the same flight level and a temperature deviation of 7 °C with respect to standard.

The aircraft moved between flight levels separated by 165 ft (50 m). The up and down periods were no longer than 10 seconds, according to the oscillations represented on graph 1.11.3.

In the absence of recorded data from the DFDR regarding vertical accelerations, it has been estimated that the maximum acceleration achieved would be around 1 g. Adding this acceleration to gravity, it can be suggested that the aircraft, crew and passengers suffered load factors of around 0 g to + 2 g.

Checking the Buffet Boundary in the aircraft performance, it can be observed that for the actual weight of 289,000 kg, a speed of M .85 and a flight level of 340, the load factor that causes high and low speed stall is 1.53 g.

1.16.4. *Kinetic warming and TAT*

Total Air Temperature (TAT) is the temperature obtained when all of the air's kinetic energy is transformed adiabatically into heat. It is obtained at still points of the air flow and it is also known as ram air temperature (RAT) or impact temperature.

The value of TAT depends on the outside air temperature (OAT) and the speed of the aircraft.

If we know TAT and speed, expressed in Mach number, it is possible to estimate the outside air temperature (OAT):

Condition	TAT °C	Mach number	OAT °C
Before the disturbance	–9.5 °C	0.852	–43.0 °C
After the disturbance	–14.0 °C	0.847	–46.5 °C

Passing through the turbulence, the temperature dropped 3,5 °C.

1.17. Organizational and management information

1.17.1. *Turbulence according to the maintenance manual*

The AMM 5-51-03 (Aircraft Maintenance Manual paragraph 5-51-03) defines severe turbulence as that which causes abrupt changes in altitude and attitude. Loss of aircraft control can occur during short periods of time. It usually causes large variations in airspeed. Occupants are violently thrown against their seat belts and loose objects move around.

Paragraph 2.B(1) specifies that "the pilot must determine if a structural inspection is required" after a turbulence episode.

On the other hand, it states that the limits in the FAA Aircraft Flight Manual of + 2.5 g and – 1.0 g are not directly applicable to severe or unusual turbulence and that inspections for severe or unusual turbulence may be required even though those limits were not exceeded.

1.17.2. *Turbulence according to the operations manual*

The operating airline's BOM (Basic Operations Manual), updated on 26 May 2002, states that:

> "Before the commencement of a flight, the flight crew will inform the cabin crew of all turbulence probability during the flight, if it has been forecast. However, if there is no forecast turbulence at the beginning of the flight, cabin crew will be informed with as much anticipation as possible, before entering atmospheric turbulence, in order to allow the flight attendants time to prepare the passenger cabin."

Another paragraph states that flight through storm cells and through known or forecast areas of strong turbulence should be avoided. It warns that: "However, in the tropics, CB can reach 50,000 or 60,000 ft, with strong turbulence having been encountered at 45,000 ft".

Regarding the in-flight procedures and aircraft control, it warns that considerable fluctuations can be expected in airspeed indicator readings and that "the recommended turbulence penetration speed must be kept as accurate as possible, without forcing speed observation (no speed chasing). Abrupt changes in thrust or pitch shall not be made, and aircraft attitude shall be the main reference to take into account".

The procedure includes the reminder that "In jet aircraft flying at high altitude, severe turbulence can cause high speed stalls".

A recent Flight Safety Bulletin, an internal operations management publication, includes an article about the use of the weather radar's TILT[2] function. It mentions an IATA work group, in which different airlines participated, Iberia amongst them, and the fact that an incorrect use of the TILT can be a contributing factor leading to numerous incidents.

1.18. Additional information

1.18.1. *Statement by the flight attendant who first assisted the passenger*

The flight attendant who assisted the passenger declared that he was in the second-to-last galley with a passenger who was ordering something to drink. "Suddenly the aircraft made a strange movement and we were lifted to a considerable height, we almost hit the ceiling with our heads, and following that, we fell hard on the floor ending up half-sitting, half-lying down."

The flight attendant stated that someone told him that there was a person lying on the floor of the left aisle. He does not know if she was walking about or returning from the lavatories. He found her lying between rows 47 and 48, with her head towards the front part of the aircraft and her feet towards the rear, from which position he deduced she was returning to her seat in row 40.

He noticed that she was bleeding from her head, he left her under the care of her husband while he informed the senior flight attendant of the matter and asked for a doctor over the PA. The first doctor to arrive took the passenger to the rear galley, a place with more room, so that she could be examined. Two other doctors appeared and first aid was administered using the first aid kit.

[2] TILT, control of the vertical angle of the weather radar antenna.

1.18.2. *IB Maintenance communications*

Neither the pilot nor the day chief reported the suffered turbulence to the IB Maintenance organization.

According to AMM 5-51-03, the pilot must determine if a structural inspection is required (see 1.17.1 above). After the Maintenance organization contacted the CAP, he stated that it was not necessary to perform a severe or unusual turbulence inspection as specified in the manuals.

1.19. Useful or effective investigation techniques

None have been used.

2. ANALYSIS

2.1. Flight planning and execution

The flight, which had been dispatched after a long delay due to aircraft unavailability, was planned normally. There was a high occupancy and take off weights were within structural limits.

The flight, after a slight deviation to avoid a few clouds at 25° latitude, was on schedule when it reached the equator after 5:20 h of flight time, according to the flight plan.

In a totally unexpected manner, turbulence appeared at 5:57 UTC, and was labelled as clear air turbulence (CAT), probably of severe- to strong intensity.

The passenger cabin was quiet at those hours of the night, after the completion of the on-board passenger service, and the CAP had been relieved in the flight deck without any foreseen difficulty.

Almost all passengers in a nearly fully-booked flight were probably well secured, as evidenced by the small number of people affected by the turbulence; however, since there was no way of knowing what was going to happen, some people were standing.

The turbulence caused moments of weightlessness that caused people to float or levitate from the floor. The following updrafts caused high load factors that did not surpass 2 g according to estimations, based on recorded vertical displacements. Recorded vertical acceleration is not available from the DFDR due to a failure of the corresponding accelerometer. This sensor was changed on February 28th, after the accident. Lateral acceleration, which oscillated from one side to the other, could have caused lateral impacts of unsecured passengers.

Flying according to procedures and recommendations of the Basic Operations Manual, the aircraft speed was maintained within a margin of ± 13 kt. The pitch angle only suffered ± 1° variations and lateral roll of ± 5°.

Flight level jumps remained within ± 84 ft and due to turbulence-induced vertical acceleration, the aircraft could have entered a high or a low speed stall, in fact causing momentary loss of control, since at that flight level, speed and weight, they were very close to the "coffin corner", when they probably exceeded 1.53 g of acceleration.

The response of engines 1 and 4, with similar low-stage compressor variations, lead us to assume that they penetrated the turbulence frontally.

In general, it does not seem that the turbulence was severe, and it was the captain's evaluation that it was not necessary to record it in the flight log for maintenance considerations.

However, weightlessness could have caused contact with the ceiling or the overhead bins. Positive vertical accelerations could have resulted in blows or violent impacts against the floor or the seats' arm rests, etc.

The seriously injured passenger hit her head, causing a contusion, but it was not possible to determine the precise surface where she hit or if the wound to her eyebrow was the only impact she received.

The aircraft over the Atlantic, some 300 NM from Natal, was moving away from the Brazilian coast the following minutes, while the doctors were evaluating the injured passenger. When the decision was made to land and seek hospital treatment without delay, the nearest airport was the Island of La Sal, which was to be overflown at 7:30, yet the decision was made to continue another two hours and reach Gran Canaria, where there they expected to find more complete medical service, and the aircraft arrived at 9:26.

They disembarked the injured passenger and her companion in Gran Canaria, and after a transit check that did not register any damage to the aircraft, and the refueling of the plane, it completed its flight to Madrid with no other incidents, arriving at 13:05.

2.2. Attention given to the injured passenger and cabin crew response

If the passenger was coming out of the aft lavatories and returning to her seat, she would have been able to walk about 10 m in the direction of the flight. The crew was warned of the incident by passengers seated nearby. The cabin crew member who first gave assistance was located at the intermediate galleys, about 26 rows forward (about 20 m away), of the passenger's position at the time of the accident. He also was standing and suffered the turbulence.

It took him just a few seconds to reach the site, and it can be concluded that attention and first aid was given to the passenger from the first moments until her evacuation by helicopter. The rapid hospitalization of the patient supposedly contributed to the recovery she experienced a few months later.

Among the other hundreds of passengers, it is only known that one 10-year-old boy needed medical attention due to minor injuries. Other passengers simply showed signs of anxiety attacks.

Immediately after the turbulence encounter, the fasten seat belt signs were switched on.

A properly secured passenger would have probably received no harm. It is considered that the accelerations suffered could have been borne even by passengers standing up but firmly secured using their arms and hands.

The element of surprise and the absence of advance warning of the CAT lead to the incident with a seriously wounded passenger.

The importance of having seat belts fastened during the whole flight, or at least while seated, even if turbulence is not expected, is once again confirmed.

In the same way as demonstrations of evacuation, oxygen and life vest and flotation devices are carried out for the benefit of passengers before the flight, additional instructions could be given regarding self-protection against turbulence, especially on long flights.

2.3. Weather and turbulence forecast at the equator

2.3.1. *Weather information provided to the crew*

Weather information provided to the crew prior to the flight forecast thermal convective activity, with embedded CB clouds in two zones of the tropical regions. This implied conditions of moderate-to-strong turbulence, with hail and the possibility of ice accretion. The air route was scheduled to pass through these zones, between latitudes 10° S and 5° S. The meteorological information provided also indicated CAT in the vicinity of the subtropical jet stream, which was located over the Canary Islands.

2.3.2. *Probable weather at the place of the accident*

The charts forecast by London's WAFC for 0000 and 0600 UTC of the day of the accident already showed the presence of embedded cumulonimbus at the approximate position of the B747-300 or surrounding areas.

Although with low resolution, satellite images for 0600 UTC also showed developing convective clouds slightly North of that location, which could have also been developing at the location of the accident, but with less growth, and therefore not visible in the images.

Considering all of the above, it is probable that the accident was due to the aircraft's flying into turbulence caused by thermal convection, in turn due to the presence of cumulonimbus-type storm clouds at the coordinates of the aircraft's position, or in nearby areas.

2.3.3. *Weather information provided by IB6740 flight itself*

In the flight logbook it was recorded that the crew experienced unexpected CAT turbulence flying in clear air without a single cloud, and the DFDR shows several recordings that confirm the turbulence encounter.

In particular, the TAT (total air temperature) graph shows not only the disturbance but also the outside ambient temperature drop. Before the disturbance, TAT was –9.5 °C and afterwards, it dropped to –14 °C.

It is estimated that the TAT variation was due, in some part, to the decrease in airspeed and in also to the actual drop in outside air temperature of about 3.5 °C.

It is observed that TAT regained previous normal values for the area, once the aircraft moved away from the turbulence.

A micro-scale phenomenon such as this turbulence and a local OAT drop is not easily forecast. As of today, early warning detection from a distance is not feasible either. Weather radars do not detect turbulence if there is not any liquid water present.

In regard to the information provided by the crew that "there wasn't a single cloud", it can be concluded that since it was a moonless night over the ocean, the only illumination would be astronomical, apart form the lights of improbable passing ships or airplanes. If there had been good visibility and the starry sky could be seen, it would evidently mean that there were no clouds above flight level 340. However, at first sight it could not be determined whether they were above clouds at lower levels. From the statement that there were no clouds, it can be concluded that the weather radar had been used to monitor the atmosphere and no returns of big water-filled cumulonimbus had been received, but this element has not been confirmed. In fact, the weather radar when used correctly, permits the detection of convective cells of strong activity. The weather radar has a TILT function to vary the angle of the antenna, aiming downward to detect CB at lower levels. Complete information regarding the conditions of the use of the weather radar in this flight has not been received.

With the information available, it can be estimated that there were probably some CB near the aircraft location at a lower level or laterally displaced, with some remaining thermal activity from the day before, held at high altitude during the night through the energy of the latent heat of vaporization released during cloud condensation. The resulting CB could have been detected by the weather radar.

3. CONCLUSIONS

3.1. Findings

— The aircraft was airworthy and was properly prepared for the flight.
— The crew had the corresponding licenses and adequate experience for the flight.
— All flight preparations had been completed according to approved procedures.
— Turbulence was not expected in the area, neither by flight planning information nor by direct cockpit observation.
— The turbulence appeared suddenly, surprising some passengers and crew members who were standing up away from their seats.
— The aircraft suffered some movements, possibly severe, which violently threw a passenger who was walking along the left aisle in the rear part of the aircraft between rows 47 and 48, causing her to suffer contusions and bruises to her head, as well as serious internal injuries which provoked hemiplegia.
— The aircraft diverted its course towards Gran Canaria, where it landed four hours after the accident.
— The aircraft sustained no damage.
— Some passengers suffered bruises, minor contusions and anxiety attacks.
— In equatorial areas it is difficult to forecast turbulence.

3.2. Causes

The accident was caused by the penetration of the aircraft in an area of turbulence when passengers were not secured with their seat belts.

The seat belt signs were not lit, because turbulence was not expected.

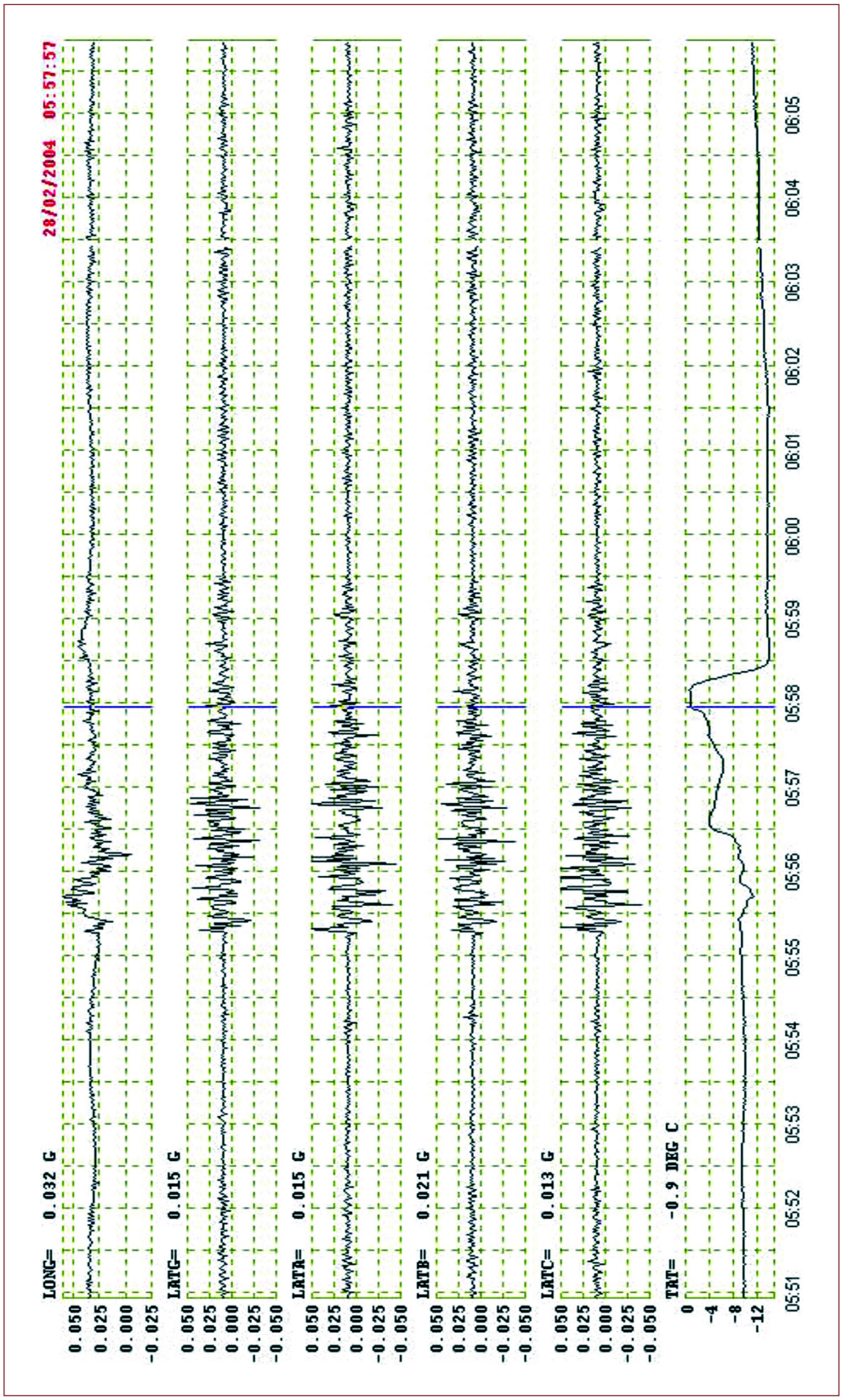
The turbulence was probably of a convectively-induced turbulence (CIT) nature and was neither detected nor were people warned.

4. SAFETY RECOMMENDATIONS

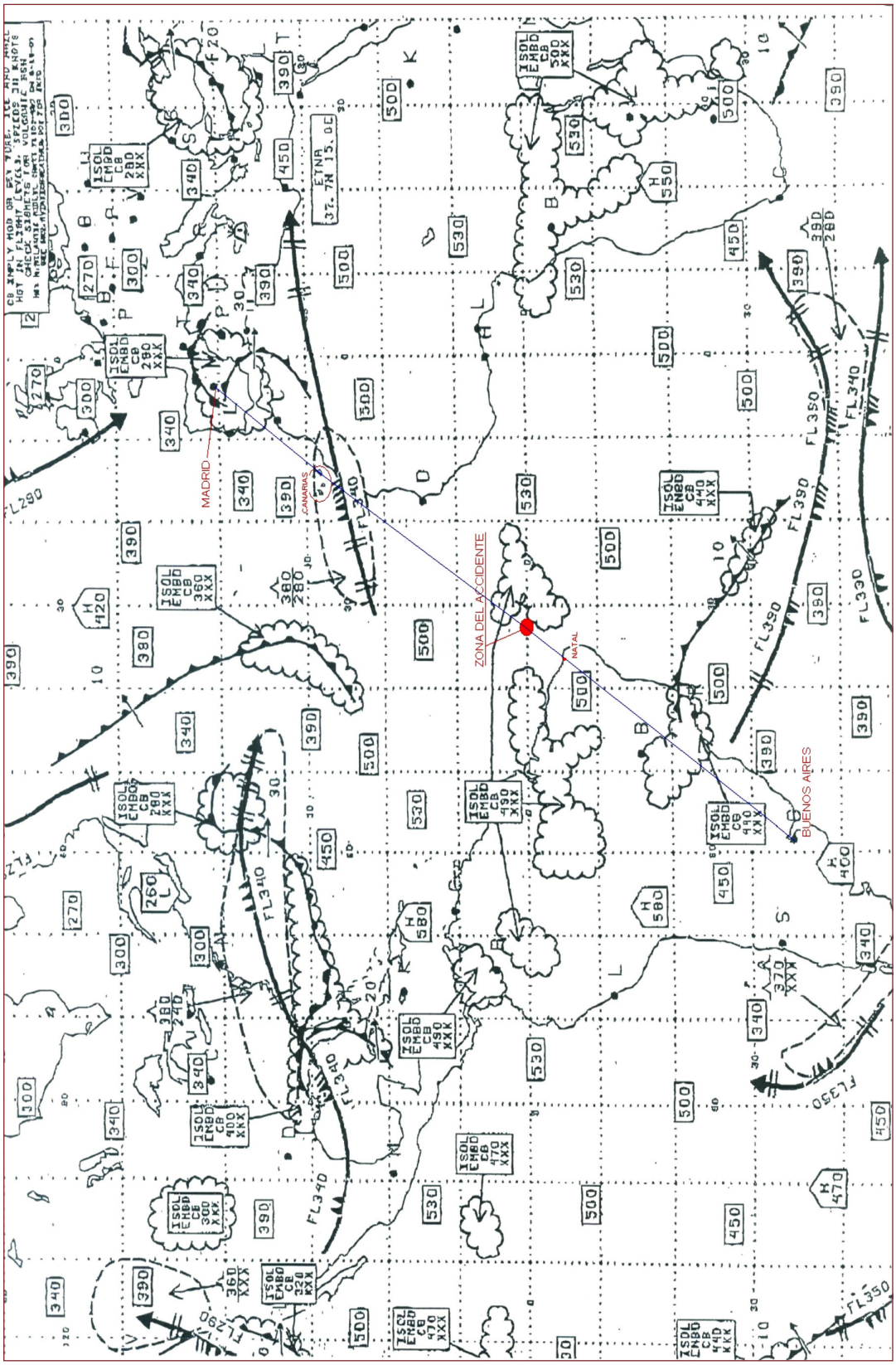
None.

APPENDICES

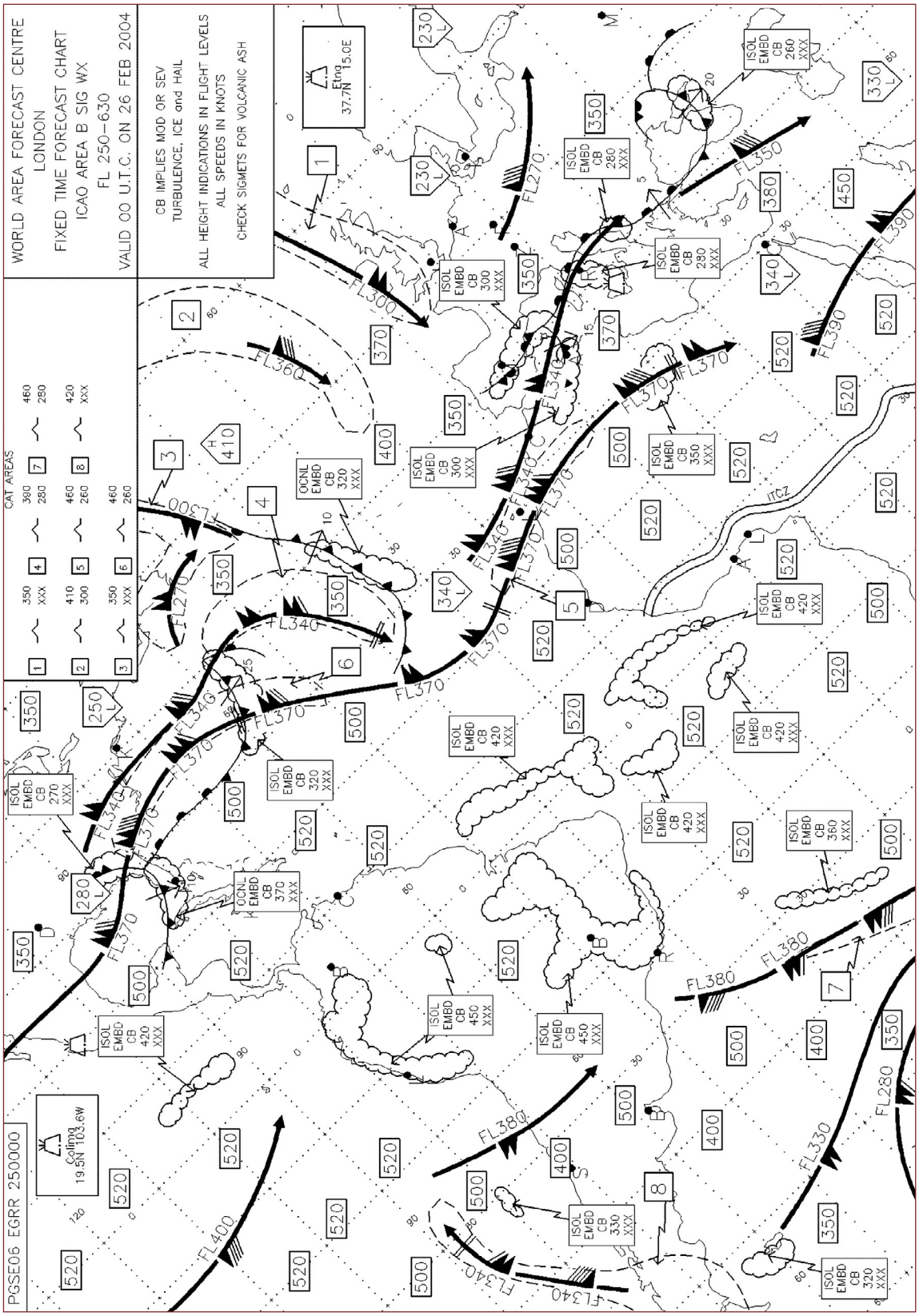
APPENDIX A
Graphs of DFDR and SIGMET weather map



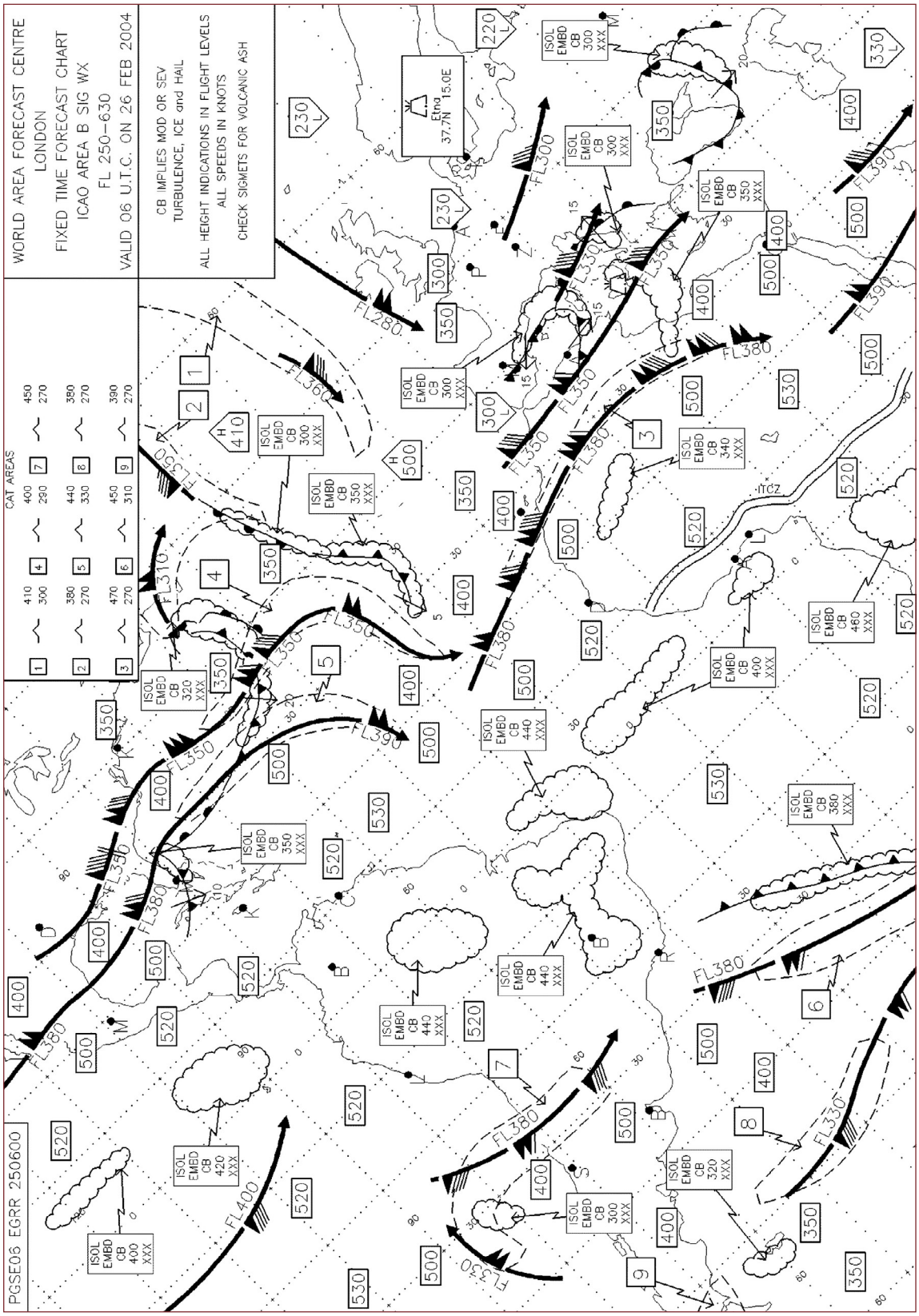
Appendix A1. *General DFDR graphs*



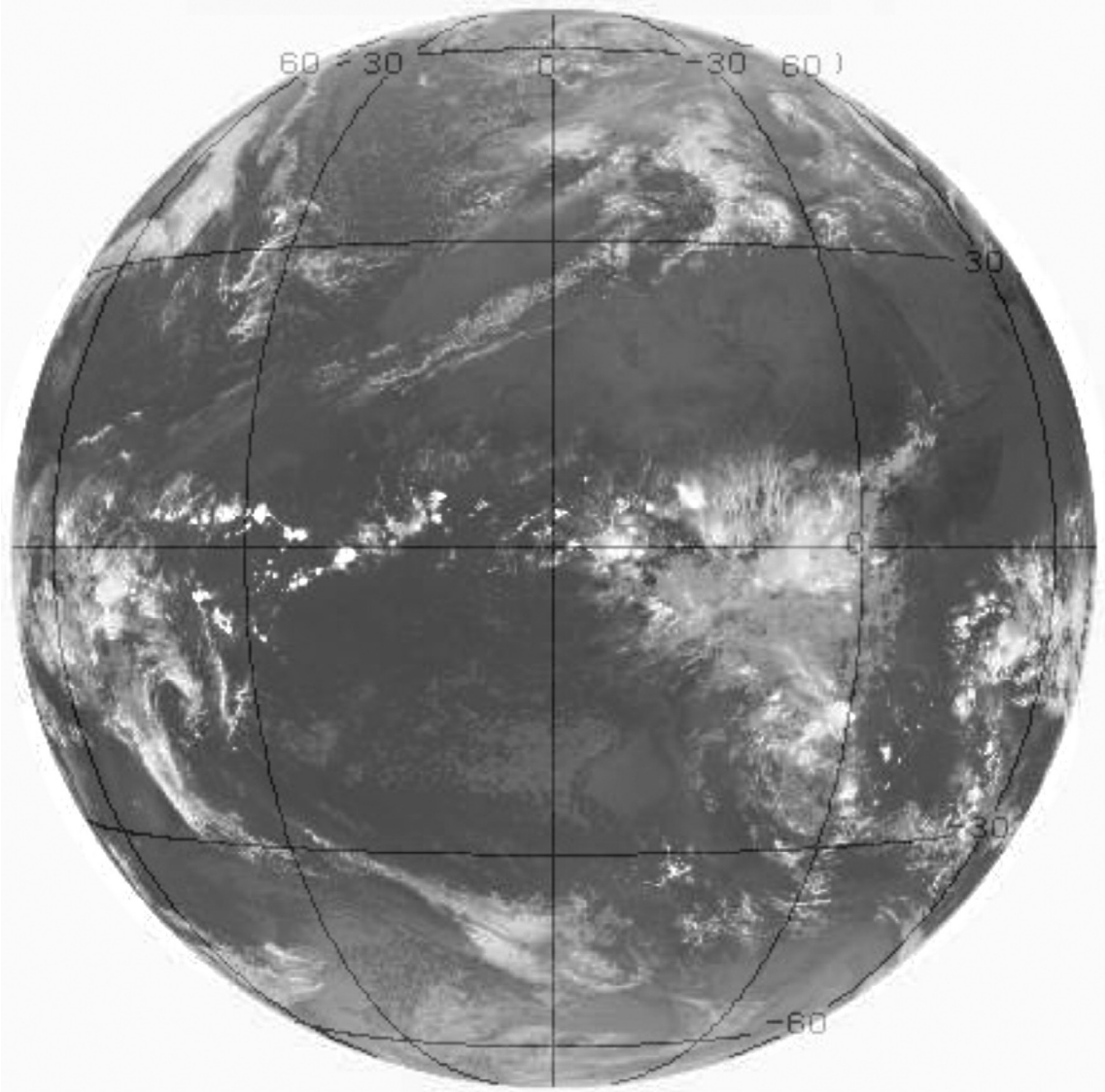
Appendix A2. *SIGMET weather map for flight dispatch*



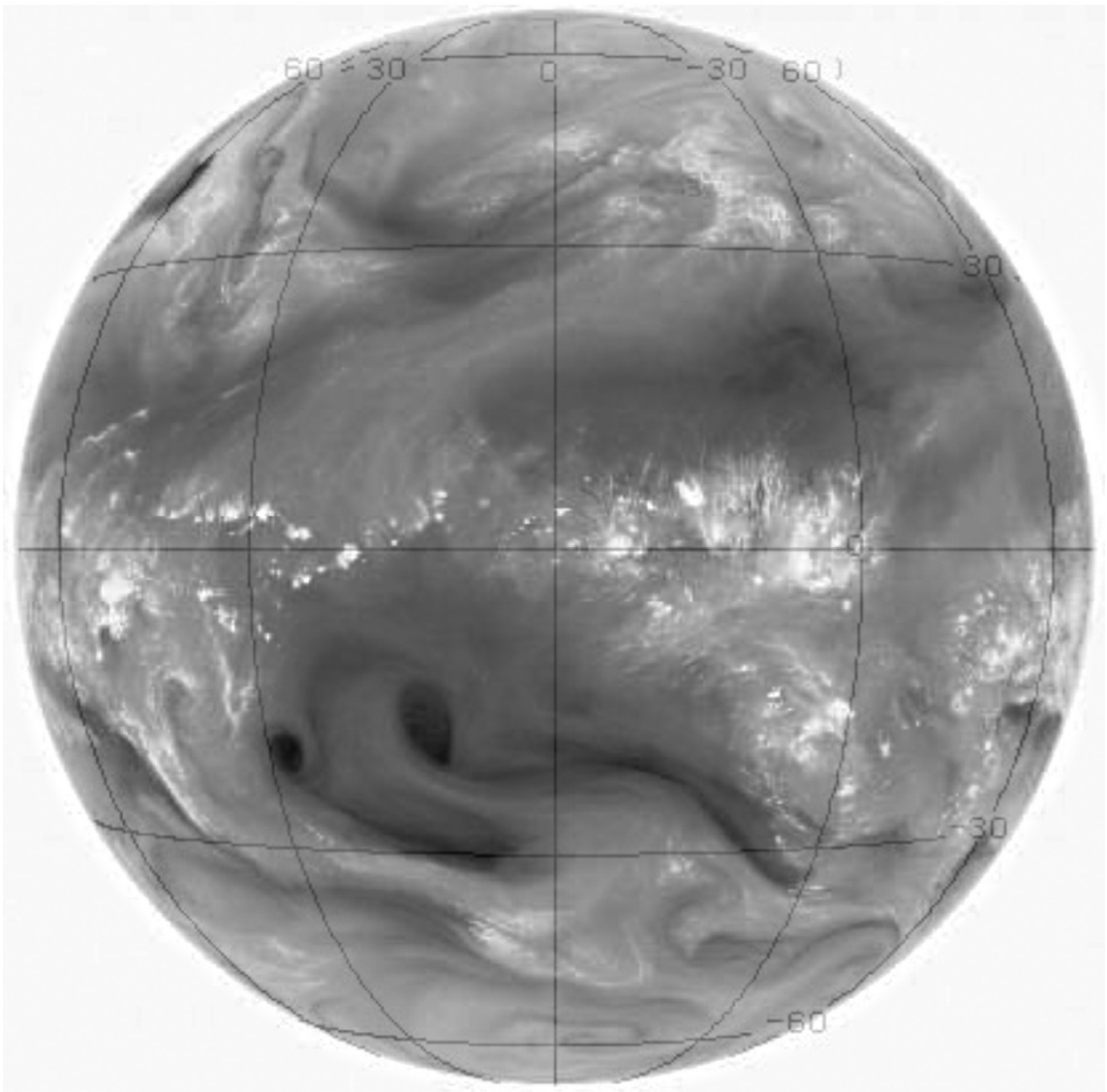
Appendix A3. *Forecast SIGMET weather map 00:00 UTC*



Appendix A4. *Forecast SIGMET weather map 06:00*

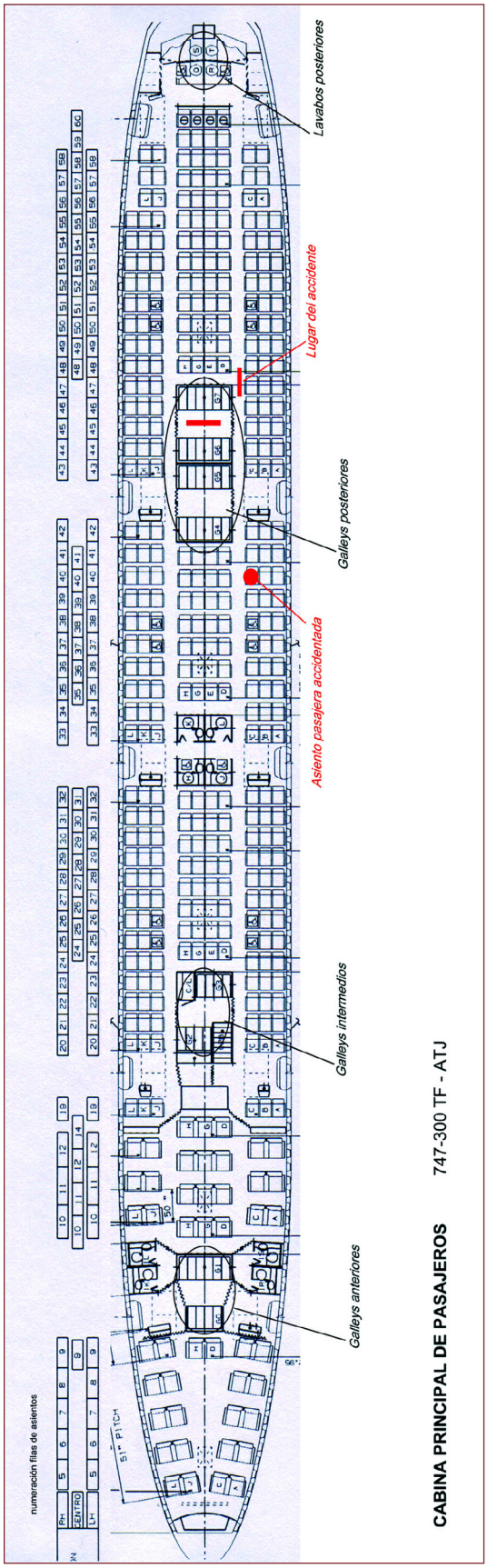


Appendix A5. *Satellite image: visible*



Appendix A6. *Satellite image: infrared*

APPENDIX B
Main passenger cabin layout


Lavabos posteriores
Lugar del accidente
Galleys posteriores
Asiento pasajera accidentada
Galleys intermedios
Galleys anteriores
CABINA PRINCIPAL DE PASAJEROS
747-300 TF - ATJ
numeración filas de asientos