الهيئة العامة للطيران المدني
GENERAL CIVIL AVIATION AUTHORITY

United Arab Emirates

Air Accident Investigation Sector

Accident

- Final Report -

AAIS Case Nº: AIFN/0001/2020

Severe Turbulence during Cruise

Operator:	Emirates
Make and Model:	Airbus A380-861
Nationality and Registration:	The United Arab Emirates, A6-EEN
Place of Occurrence:	BEIRA FIR
State of Occurrence:	The Republic of Mozambique
Date of Occurrence:	16 January 2020

This Investigation was conducted by the Air Accident Investigation Sector of the United Arab Emirates pursuant to *Civil Aviation Law No. 20 of 1991*, in compliance with *Air Accident and Incident Investigation Regulation*, and in conformance with the provisions of *Annex 13 to the Convention on International Civil Aviation*.

This Investigation was conducted independently and without prejudice. The sole objective of the investigation is to prevent future aircraft accidents and incidents. It is not the purpose of this activity to apportion blame or liability.

The Air Accident Investigation Sector issued this Final Report in accordance with the national and international standards and best practices. Consultation with applicable stakeholders, and consideration of their comments, took place prior to the publication of this Report.

The Final Report is publicly available at:

http://www.gcaa.gov.ae/en/epublication/pages/investigationReport.aspx

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Occurrence Brief

Occurrence file number	:	AIFN/0001/2020
Occurrence category	:	Accident
Name of the Operator	:	Emirates
Manufacturer	:	Airbus SE
Aircraft model	:	A380-861
Engines	:	Four, Engine Alliance GP7270
Nationality	:	United Arab Emirates
Registration	:	A6-EEN
Manufacturer serial number	:	0135
Type of flight	:	Scheduled passenger
Flight number	:	EK763
State of Occurrence	:	The Republic of Mozambique
Place of Occurrence	:	BEIRA FIR, Mozambique
Date and time	:	16 January 2020, 1314:24 UTC
Total crewmembers	:	26 (two flight and 24 cabin crewmembers)
Total passengers	:	500
Injuries to passengers and crew	:	One passenger serious injury

Investigation Process

The Air Accident Investigation Sector (AAIS) of the United Arab Emirates was notified of the occurrence by phone call from the Operator to the AAIS Duty Investigator (DI) Hotline number +971 50 641 4667.

The Instituto de Aviação Civil de Moçambique (IACM), being the investigation authority of the State of Occurrence, was notified of the occurrence. However, the IACM did not acknowledge the notification. The AAIS, being the investigation authority of the State of the Operator and State of Registry of the Aircraft, opened an investigation into this occurrence. In accordance with the United Arab Emirates Air Accident and Incident Investigation Regulation (AAIR) and in conformance with Annex 13 obligations.

The AAIS assigned Accident Investigation File Number AIFN/0001/2020 for the case, and formed an investigation team led by investigator-in-charge (IIC).

Due to a serious injury suffered by one passenger, the AAIS classified the occurrence as an ‘Accident’.

The AAIS notified the Bureau d’Enquetes et d’Analyses pour la securite de l’aviation civile (BEA), being the investigation authority of the State of Manufacture and State of Design of the Aircraft. An accredited representative was assigned by the BEA who was assisted by Advisers from Airbus. In addition, the Operator assigned a technical expert to the IIC.

The scope of this Investigation was limited to the relevant flight operations, related Aircraft systems and cabin safety during the turbulence encounter.

Notes:

1. Whenever the following words are mentioned in this Report, with the first letter capitalized, they shall mean the following:
   - (Accident). This investigated accident.
   - (Aircraft). The aircraft involved in this accident.
   - (Commander). The commander of the flight.
   - (Copilot). The copilot of the flight.
   - (Cabin Manager) The purser in-charge of the cabin.
   - (Investigation). The investigation into the circumstances of this accident.
   - (Report). This accident investigation Final Report.
2. Unless otherwise mentioned, all times in this Report are coordinated universal time (UTC).
3. Local time in the United Arab Emirates is UTC plus 4 hours.
4. Local time in the Republic of Mozambique is UTC plus 2 hours.
5. Photos and figures used in this Report are taken from different sources and adjusted from the original for the sole purpose of improving the clarity of the Report.

Abbreviations

AAIS	The Air Accident Investigation Sector of the United Arab Emirates
ACARS	Aircraft communication addressing and reporting system
AP	Autopilot
A/THR	Autothrust
CB	Cumulonimbus cloud
CVR	Cockpit voice recorder
EASA	European Union Aviation Safety Agency
EFB	Electronic flight bag
EFIS CP	Electronic flight instrument system control panel
FAOR	Johannesburg Tambo International Airport
FCOM	*Flight crew operating manual*
FCTM	*Flight crew techniques manual*
FDR	Flight data recorder
FIR	Flight information region
FL	Flight level
FSB	Fasten seat belt
ft	feet
g	G-load
GCAA	The General Civil Aviation Authority of the United Arab Emirates
IIC	Investigator-in-charge
ITCZ	Intertropical Convergence Zone
kt	knots
LOE	Line operational evaluation
Mach	Mach number is the ratio of true airspeed to the speed of sound
MMO	Maximum operating Mach
MSL	Mean sea level
NAV	Navigation mode
NCM	National Centre of Meteorology
ND	Navigation display
NM	Nautical miles
OFP	Operational flight plan
OM	*Operations manual*
OMDB	Dubai International Airport
PF	Pilot flying
PM	Pilot monitoring

QAR	Quick access recorder
RTS	Return to seat
RVSM	Reduced vertical separation minima
SEP	Safety and emergency procedures
SIB	Safety information bulletin
SIGMET	Significant meteorological information
SIGWX	Significant weather
TCAS	Traffic collision avoidance system
UTC	Coordinated universal time
VD	Vertical display
WX	Weather
WXR	Weather radar

Synopsis

On 16 January 2020, an Emirates Airbus A380 Aircraft, registration A6-EEN, operated a scheduled passenger flight, EK763, from Dubai International Airport (OMDB), the United Arab Emirates, to Johannesburg Tambo International Airport (FAOR), Republic of South Africa. The Aircraft had 526 persons onboard, consisting of two flight crewmembers, 24 cabin crewmembers and 500 passengers.

The Commander, occupying the left seat, was the pilot flying (PF). He stated that prior to the turbulence encounter, the daylight flight was uneventful with no avoidance actions required due to weather.

After entering BEIRA flight information region (FIR), Mozambique, at flight level (FL) FL400 close to waypoint OKBIM, the flight crew stated that there was light turbulence with the weather radar displaying that the weather was off-path on the navigation display (ND) and beneath the Aircraft. Soon after, several magenta spots appeared on the weather radar along the flight path indicating that there were areas of wet turbulence within 40 nautical miles (NM) ahead of the Aircraft.

At 1314:24 UTC, approximately six hours after departure from OMDB, the Aircraft experienced moderate to severe turbulence at FL400 within BEIRA FIR. The operational flight plan (OFP) significant aeronautical weather chart had forecast the occasional presence of convective weather activity containing embedded cumulonimbus clouds (CB) up to an altitude of 52,000 feet (ft) in this area.

During the turbulence encounter, the Aircraft autopilot and autothrust remained engaged and there were no operational exceedances.

The turbulence lasted for approximately 30 seconds and resulted in a serious leg injury to an unsecured passenger on the upper deck. There was no reported damage to the Aircraft cabin.

The Commander decided to continue the flight to the destination as the passenger's injury was non-life threatening and the Aircraft performance was not affected. The remainder of the flight, lasting 1 hour 46 minutes, was uneventful.

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1. Factual Information

1.1 History of the Flight

On 16 January 2020, a scheduled passenger flight, EK763, operated by an Airbus A380 Aircraft registered as A6-EEN, took off from Dubai International Airport (OMDB), the United Arab Emirates, at 0720 UTC[1] for an approximately 7 hours 45 minutes flight to Johannesburg Tambo International Airport (FAOR), Republic of South Africa. The flight had 526 persons onboard consisting of 2 flight crewmembers, 24 cabin crewmembers, and 500 passengers.

The Commander was the pilot flying (PF) and he occupied the left pilot seat. Sometime after takeoff, the seat belt sign was turned OFF. During the first six hours of the daylight flight, and prior to the turbulence encounter, the seat belt sign was switched ON three times.

The operational flight plan (OFP), which was produced by the Operator's flight dispatch department, indicated that there was no significant weather from departure until just prior to entering the BEIRA flight information region (FIR), Mozambique. The flight was planned to operate at flight level (FL) 400 within FIR in which was forecast a large area of significant weather activity with isolated embedded cumulonimbus clouds (CB) up to FL520 affecting an area over the central and eastern border area of Africa. As the Commander had flown this route on several previous occasions, he stated that convective weather systems over Africa are common during this time of the year.

For the flight, the weather (WX) push button was selected on the electronic flight instrument system control panel (EFIS CP). The Aircraft weather radar (WXR) and turbulence (TURB) functions were in active mode and weather information was displayed on the navigation display (ND).

After entering the BEIRA FIR, at FL400, and close to waypoint OKBIM, the flight crew stated that there was light turbulence with the weather radar echo on the ND displaying that the weather was off-path and beneath the Aircraft.

Data recorded by the flight data recorder (FDR) and the quick access recorder (QAR) indicated that at 1311:37, 2 minutes 47 seconds, and at a distance of 26 NM before the turbulence encounter, the Aircraft was cruising at FL400, at Mach 0.86, and on a heading of 206 degrees. Autopilot (AP) AP1, flight directors 1 and 2, and autothrust (A/THR) were engaged. The wind information indicated that there was a tailwind component of seven knots (kt).

The Commander stated that within the BEIRA FIR, there were three or four magenta spots appeared on the weather radar indicating that there were areas of wet turbulence within 40 NM of the Aircraft. As a precaution, at 1314:16, eight seconds before the turbulence encounter, the flight crew turned the seat belt sign ON but did not communicate any instructions to the cabin crew.

At 1314:24, at FL400, within BEIRA FIR, the Aircraft started to experience moderate to severe turbulence which lasted for about 30 seconds. Figure 1 illustrates the approximate geographical Aircraft location where the turbulence occurred.

[1] Unless otherwise mentioned, all times in this Report are UTC time. Local time in the United Arab Emirates is UTC plus 4 hours. Local time in Mozambique is UTC plus 2 hours.

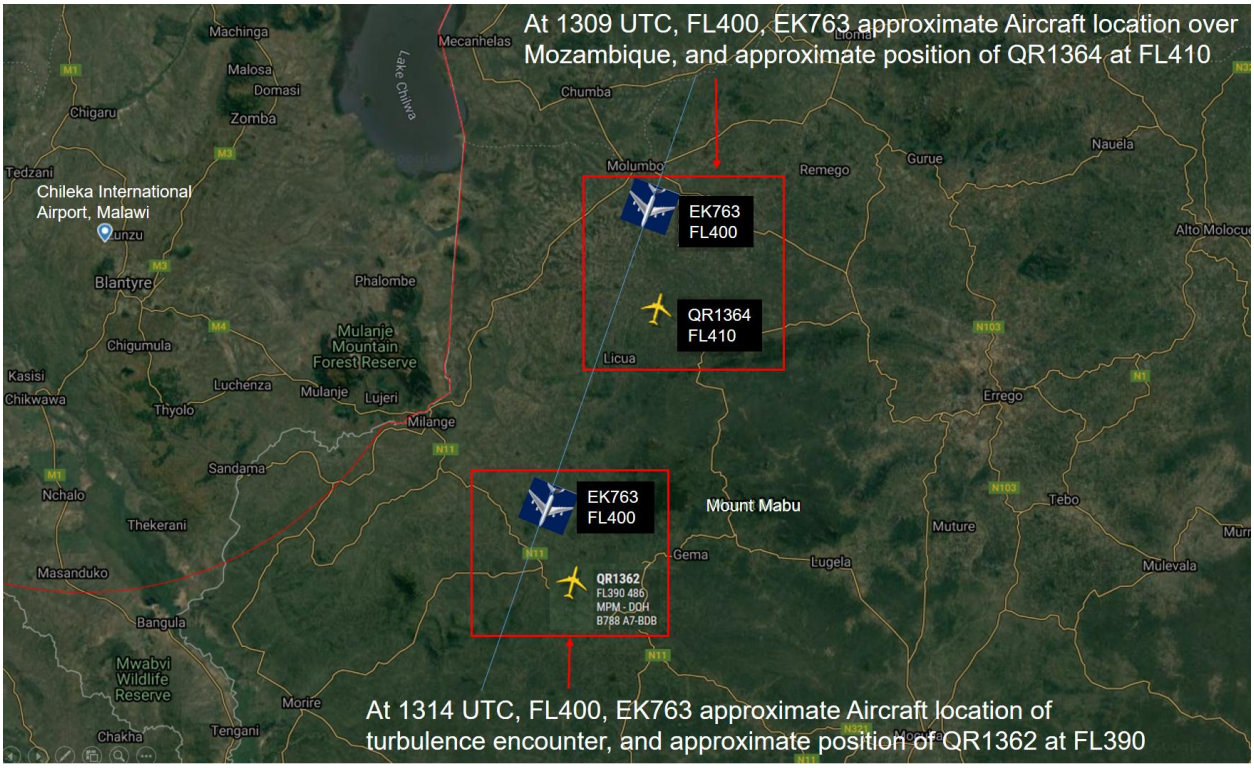


Figure 1. EK763 flight path at 1309 UTC and approximate location of Aircraft turbulence encounter at 1314 UTC

The Commander stated that shortly before seeing the magenta areas on the ND, the flight crew observed another aircraft at a lower level of FL390. This was a Qatar Airways aircraft, coming from the opposite direction. Figure 1 illustrates the approximate position of Qatar Airways flight, QR1362, at 1314.

Prior to the turbulence, the Commander stated that there were scattered clouds, with the weather radar indicating that the convective cells were below the Aircraft and off-path. He could not recall when the magenta area appeared on the ND but stated that after observing the magenta area, there was insufficient time to deviate or to make any changes to the weather radar settings.

The Commander stated that there were no active convective cells on the flight path when the Aircraft entered the turbulent area. He described the turbulence encounter as entering a cloud and losing visibility and associated with a sound similar to rain, which lasted for approximately 30 seconds. As the Aircraft entered the area of turbulence, the Copilot immediately made an announcement for the cabin crew to take their seats. After the turbulence encounter, the flight crew did not communicate the occurrence to air traffic control.

The autopilot and autothrust remained engaged during the turbulence encounter and there was no excessive altitude loss. No cockpit audio, visual warnings or alerts were generated. The maximum operating Mach (MMO) airspeed was not exceeded. Some speed fluctuation towards MMO occurred, which the flight crew reacted to by reducing the target speed to Mach 0.76 and manually extending the speed brake lever. Prior to the flight crew actions, the Aircraft automation also responded with automatic deployment of the wing spoilers. During the turbulence, the Aircraft remained within the normal flight envelope.

The turbulence encounter was composed mainly of a headwind and of vertical gusts of up to 4,900 feet per minute. During this period, the Aircraft experienced positive load factors ranging from between 1.75 to 0.17 g, with altitude deviation ranging between positive 300 ft and negative 180 ft.

The cabin crewmembers, in the upper deck aft business class galley, described that during the turbulence, the Aircraft felt as if it was descending followed by a "…sudden drop." and the Aircraft was "…shaking severely." For some time, they were unable to move as they had to brace themselves in the galley. They stated that they were "…lifted off their feet." several times.

One unsecured passenger in the upper deck business class sustained a serious injury during the turbulence encounter.

The flight crew established contact with the Operator's ground medical team to assess the condition of the passenger's injury. The decision was made by the Commander to continue to the destination airport as the medical assessment of the passenger's injury was not considered life-threatening and the Aircraft systems were not affected by the turbulence encounter.

The remainder of the flight until landing at FAOR were uneventful.

1.2 Injuries to Persons

Table 1 shows the number of injuries.

Table 1. Injuries to persons

Injuries	Flight crew	Cabin crew	Passengers	Total onboard
Fatal	0	0	0	0
Serious	0	0	1	1
Minor	0	0	0	0
None	2	24	499	525
TOTAL	**2**	**24**	**500**	**526**

1.2.1 Details of injuries

1.2.1.1 Crewmembers

There were no reported injuries to flight or cabin crewmembers.

1.2.1.2 Passengers

One business class passenger seated in the aft cabin of the upper deck was on her way to the lavatory when the turbulence occurred. She was lifted off her feet and fell to the floor close to the aft lounge adjacent to the U3R passenger door (see figure 9 for the location of the passenger). As a result, she suffered a fracture to her right lower leg. Bandages and splints were applied to her leg by the cabin crew and an onboard medical doctor.

1.3 Damage to Aircraft

There was no damage to the Aircraft.

1.4 Other Damage

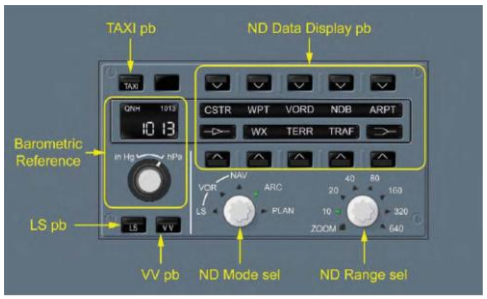
There was no other damage.

1.5 Personnel Information

The flight and cabin crew rosters indicated that they all met the rest period requirements of the *Civil Aviation Regulations* of the United Arab Emirates.

The flight crew pilot licenses and medical certificates were valid at the time of the Accident. All the cabin crew licenses and medical certificates were valid at the time of the Accident.

Every twelve calendar months, in accordance with the Operator's annual recurrent safety and emergency procedures (SEP) training on 'Duties to be undertaken in the event of encountering turbulence' had been attended by the flight and cabin crew.



EFIS CP on the glareshield

SURV Panel on the cockpit center console

Figure 2. EFIS CP and SURV Panel [Source Airbus]

1.6 Aircraft Information

1.6.1 General data

The Airbus A380-861, is a passenger transport aircraft having two passenger decks, upper and main, and is certified for a maximum number of 853 passengers. The Aircraft was configured for 517 passengers with 14 first class and 76 business seats on the upper deck, and 427 economy seats in the main deck.

All Aircraft records and maintenance records were valid and current with no significant technical defects at the time of the Accident.

1.6.2 Aircraft systems

1.6.2.1 Fasten seat belt

The flight crew command from the cockpit to turn on the fasten seat belt signs throughout the aircraft cabin is controlled by a three position switch, ON/AUTO/OFF, which is located on the cockpit center overhead control panel. For the passengers, the FASTEN SEAT BELT (FSB) and RETURN TO SEAT (RTS) signs are located throughout the passenger cabin overhead panels including in the lavatories, lounge areas and shower. The cabin crew areas including the galleys and crew rest compartment have FSB signs fitted.

When the switch is placed in the ON position, the FSB and RTS signs come on in the cabin continuously after flashing for five seconds. This is associated with a single low tone chime throughout the cabin, which is meant to draw the attention of the cabin crew and passengers.

1.6.2.2 Weather radar system

The Aircraft was fitted with a Honeywell RDR-4000 model WXR.

The WXR had a weather (WX) display function, a predictive windshear function, an auto-tilt, a turbulence (TURB) detection function and a ground mapping function.

The WXR computed the weather display along the vertical cut. One of the weather radar limitations was that it reflected only the presence of water. On the cockpit main flight display units, the flight crew could display the weather on the vertical display (VD) and on the ND by pressing the WX pushbutton located on the EFIS CP (figure 2).

The automatic mode (AUTO) was the default mode of the WXR. The WXR continuously scanned a volume of space ahead of an aircraft, and stored this data in a three dimensional (3D) buffer. The WXR manual modes could be selected by pulling on the associated control knobs located on the SURV panel (figure 2) that enabled the flight crew to adjust the sensitivity of the weather display on the ND.

The cockpit location of the displays and panels can be seen in Appendix A to this Report.

The WX display function enabled the flight crew to view precipitation in different colors (green, yellow, and red) depending on the intensity of the precipitation. The colors of the weather display were the same on the VD and the ND. The weather echo appears with a color scale that goes from red (high reflectivity) to green (low reflectivity).

The turbulence detection (TURB) function was based on the Doppler effect [2] and detected wet turbulence in a volume of space ahead of the Aircraft. This function is based on the movement of precipitation. The TURB detection function scanned ±60 degrees in azimuth, between 0 and 60,000 ft mean sea level (MSL), and up to 40 NM in front of the Aircraft. The ND displayed the areas of wet turbulence in a magenta color. As noted in figure 3, the magenta within the white box (the white box is used for illustration purpose only) is on-path wet turbulence. The magenta that is hashed within the blue box (the blue box is used for illustration only) is off-path wet turbulence. The VD does not display areas of wet turbulence.

Figure 3. TURB area indication (magenta) on ND
[Source: FCOM A380]

The TURB function does not detect clear air turbulence.

TURB detection is automatically active when the weather radar WX pushbutton is selected on the EFIS CP.

[2] The Doppler effect is the change in frequency of a signal caused by relative motion between the source of the signal and the receiver.

For weather to be displayed on the ND, the WX pushbutton must be selected. The *flight crew operating manual (FCOM)* states that WXR message[3] **TURB** (in white with a black background) would appear in the lower right hand corner of the ND when the WXR turbulence detection function system had detected wet turbulence close to an aircraft and the flight crew has not selected WX pushbutton on the EFIS CP. There was no cockpit audio alert associated with the TURB message. Some audio alerts can be triggered in case of predictive and reactive windshear.

The envelope associated with the TURB visual message was:

- 20 NM on both sides of aircraft heading
- ± 5,000 ft around the current aircraft altitude.

When the WXR is in automatic mode, it takes into account a vertical envelope along the vertical flight path of an aircraft and define the applicable weather echo returns, displayed on the ND, on aircraft flight path (on-path) or not (off-path).

The on-path weather is weather that an aircraft will encounter (i.e. weather inside the envelope) and appears on the ND in the conventional colors.

The off-path weather is weather that is not on an aircraft trajectory (i.e. weather outside the envelope and appears on the ND in black parallel lines, with reduced intensity.

For aircraft altitudes greater than 29,000 ft above MSL, the following are the envelope boundaries:

- For lower envelope boundary:
  - Flight altitude minus 4,000 ft; or
  - 25,000 ft MSL if there is convective weather detected.
- For upper envelope boundary:
  - Flight altitude plus 4,000 ft to a maximum of 60,000 ft.

During level flight, the on-path envelope extends from 4,000 above to 4,000 ft below the aircraft altitude. However, when the weather radar detects convective weather, the lower boundary is lowered to 25,000 ft around the convective weather. The upper boundary cannot be lower than 10,000 ft. Figure 4 illustrates level flight on-path and off-path envelope.

[3] Reference: *Flight crew operating manual (FCOM) DSC-34-20-30-10 P 12/18* section Aircraft Systems 34-Surveillance, WXR, System Description – Turbulence Detection (TURB) Function.

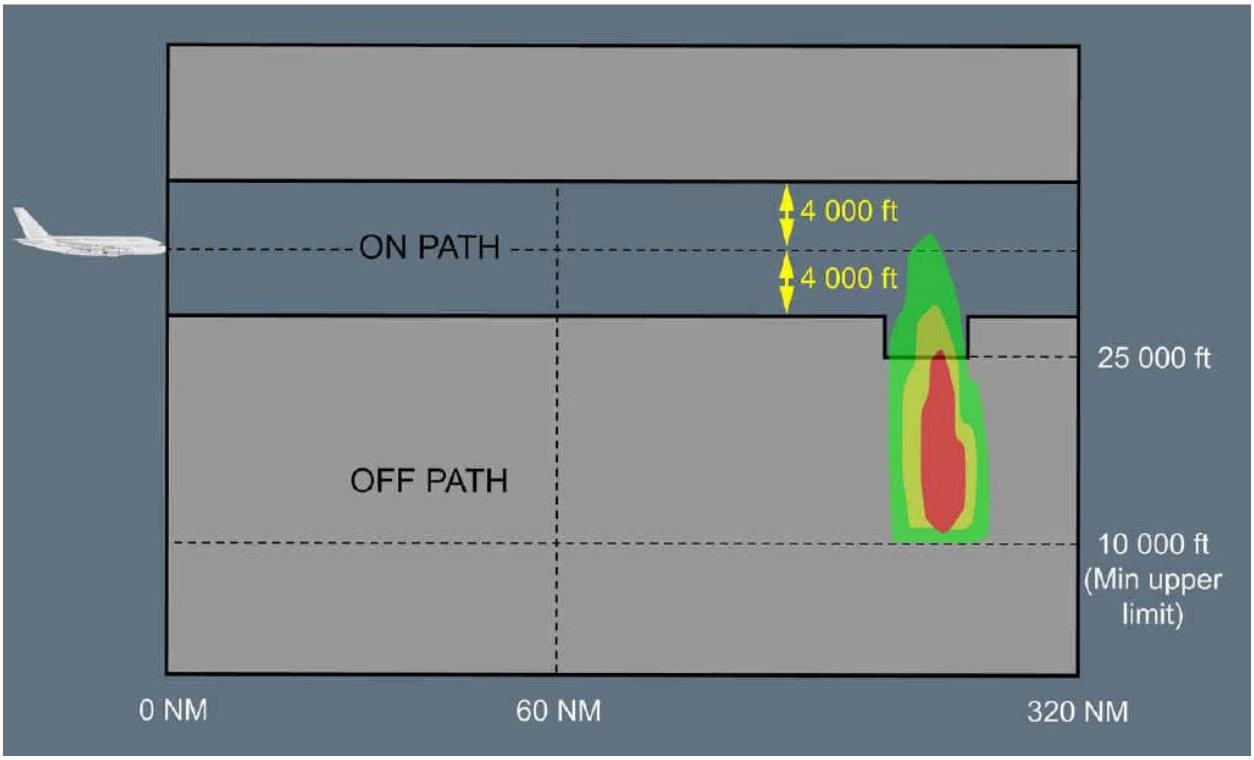


Figure 4. Level flight (cruise) weather radar display envelope [Source: *FCOM* A380]

1.7 Meteorological Information

The significant weather (SIGWX) forecast chart from the OFP on 15 January 2020, issued at 0347 UTC, illustrated the weather from 1200 UTC over the central and eastern border of Africa (figure 5). The approximate area of the Aircraft turbulence encounter was indicated by the red circle.

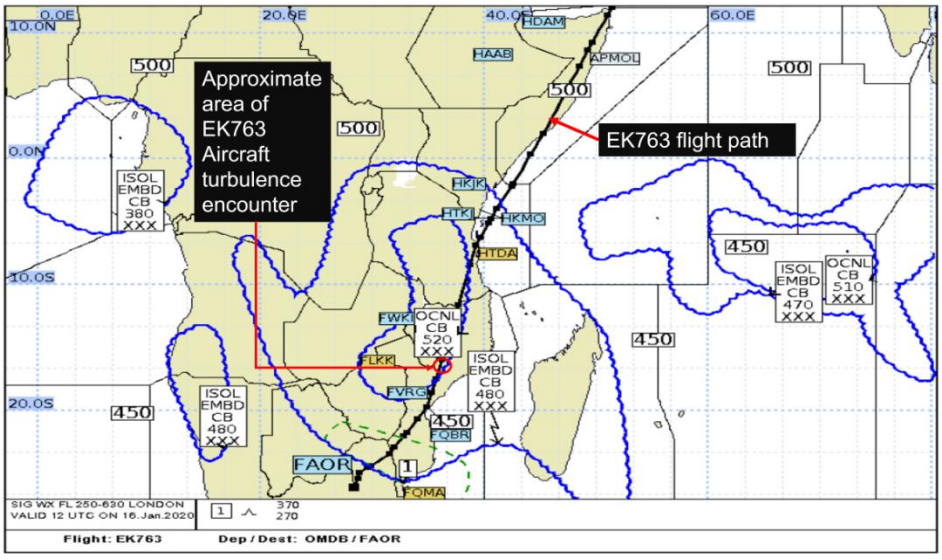


Figure 5. OFP significant weather chart valid 1200 UTC on 16 January 2020 [Source: Operator]

The satellite image, as illustrated in figure 6, was made available to the Investigation by the United Arab Emirates National Centre of Meteorology (NCM) and shows the weather in this area at 1315 UTC on 16 January 2020. The chart shows an area of convection activity with isolated embedded CB up to 48,000 ft and occasional CB up to 52,000 ft. Within this area of convergence, multiple isolated and embedded CBs can be identified. The NCM stated that thunderstorms are typical for this area of East Africa during this time of year because of the Intertropical Convergence Zone (ITCZ) affecting the area. In figure 6, a red circle illustrates the approximate area of the turbulence encounter.

The information provided to the Investigation indicated that there was no significant meteorological information (SIGMET) warning issued by the weather forecast office for the BEIRA FIR where the turbulence encounter occurred.

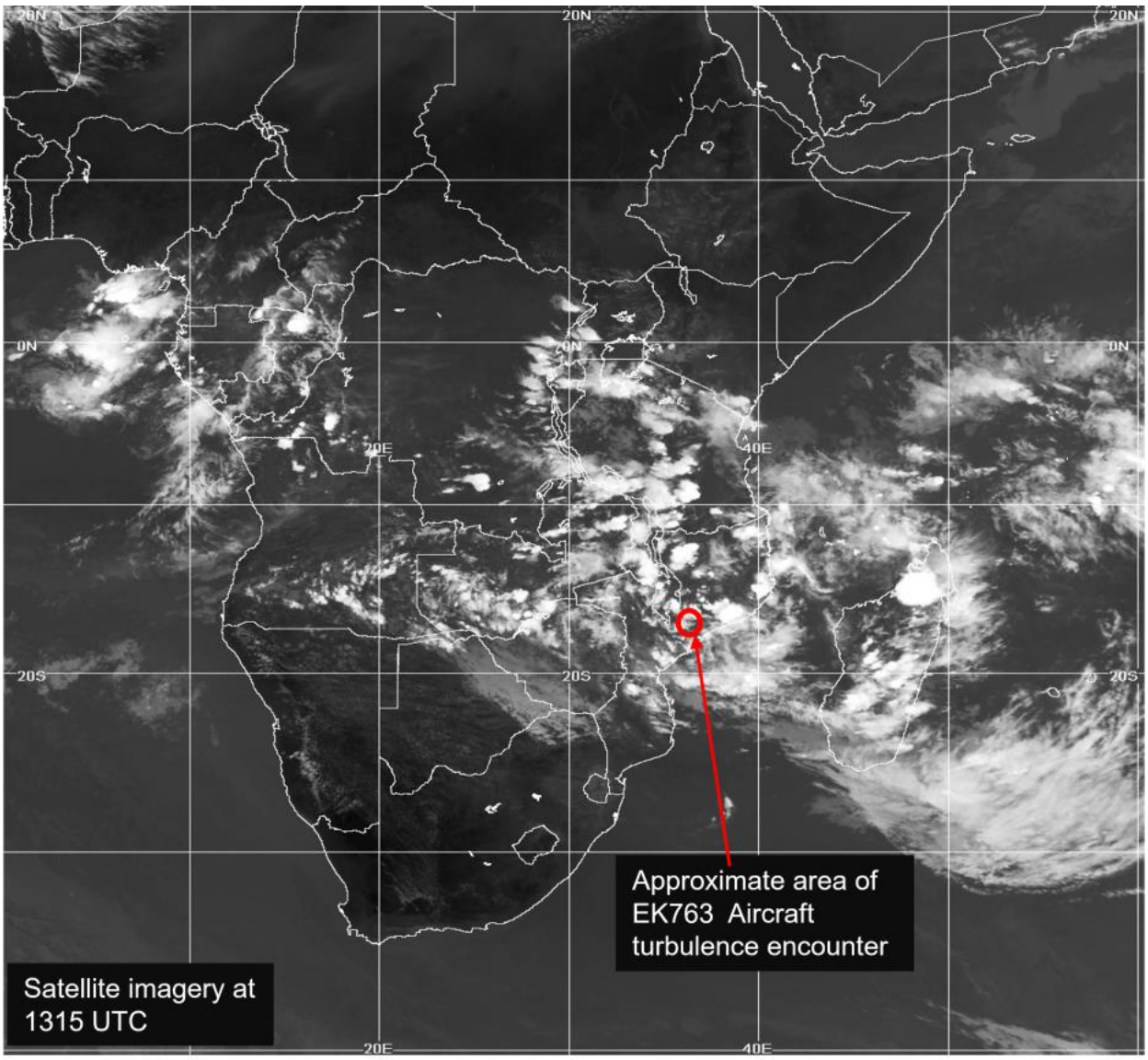


Figure 6. Satellite image at 1315 UTC [Source: UAE NCM]

1.8 Aids to Navigation

The Aircraft was equipped with the required navigational equipment. All ground and onboard navigation equipment was serviceable.

1.9 Communications

The flight crew stated that all Aircraft communications while in the BEIRA FIR were normal.

1.10 Aerodrome Information

The Accident occurred in-flight.

1.11 Flight Recorders

The Aircraft was fitted with FDR and a cockpit voice recorder (CVR). The FDR data was successfully downloaded and was provided to the Aircraft manufacturer for analysis.

Flight data was also retrieved from the Aircraft's QAR. In addition to the flight data, the QAR data was used to determine when the seat belt switch was moved to the ON position prior to the turbulence encounter, as noted in Appendix C to this Report.

Because the CVR had only recorded the last two hours of the flight, the audio recording of the turbulence encounter was overwritten and was not available to the Investigation.

From the FDR and QAR recorded data of flight EK763, the Aircraft manufacturer provided the Investigation with an Aircraft performance report. Because the FDR was not designed to capture weather radar information for displayed colors such as the green, yellow or red areas, a full assessment could not be performed of the distance between the trajectory of flight EK763 and the area of greatest threat displayed on the NDs during the turbulence.

The following is a summary of the recorded flight data prior to and during the turbulence encounter:

(a) When the Aircraft entered into the convective weather area that started at least 390 NM, or 47 minutes before flight EK763 crossed the turbulent area, the WXR on the Copilot side remained in AUTO mode and the WXR manual gain remained at 85% on Commander's side. The manual gain mode or elevation (ELVN) mode were not fully used.

(b) The WXR turbulence detection function permanently displayed wet turbulence on both of the flight crew NDs between 1311:37 and 1314:43. Figure 7 illustrates the weather radar wet turbulence detection envelope for EK763.

(c) The detection of wet turbulence areas in the form of magenta cells was displayed on the navigation display units starting some 2 minutes 47 seconds and at a distance of 26 NM before the Aircraft entered the turbulent area. See Appendix D to this Report.

(d) Approximately one minute before the turbulence encounter, the weather radar ND range was changed several times. The Commander changed the range from 80 to 10 NM, and the Copilot changed the range between 80 to 40 NM.

(e) The turbulence lasted 30 seconds starting at 1314:24 and ended at 1314:54. The Aircraft encountered the maximum vertical gust at 1314:43.

(f) The onset of the turbulence was caused by an updraft gust of around 4,900 feet per minute combined with a headwind gust of 10 kt. Figure 8 illustrates the winds during the turbulence encounter as reconstructed by the Aircraft manufacturer.

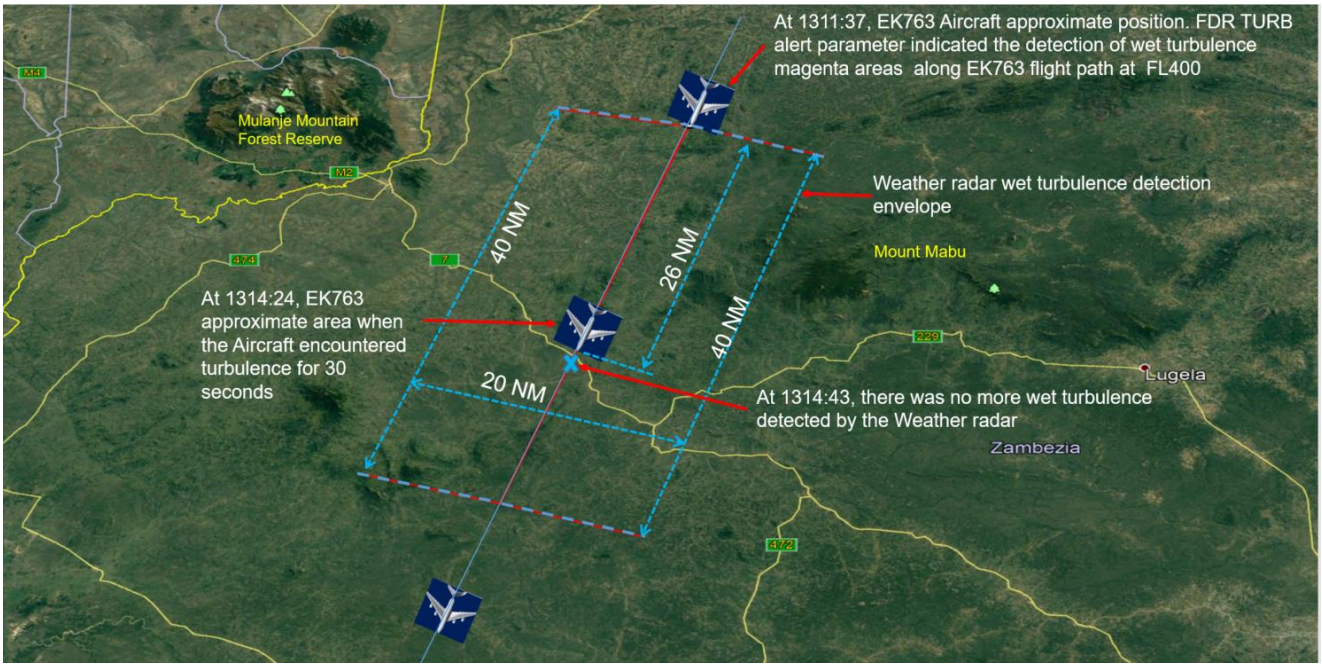


Figure 7. EK763 weather radar wet turbulence detection envelope

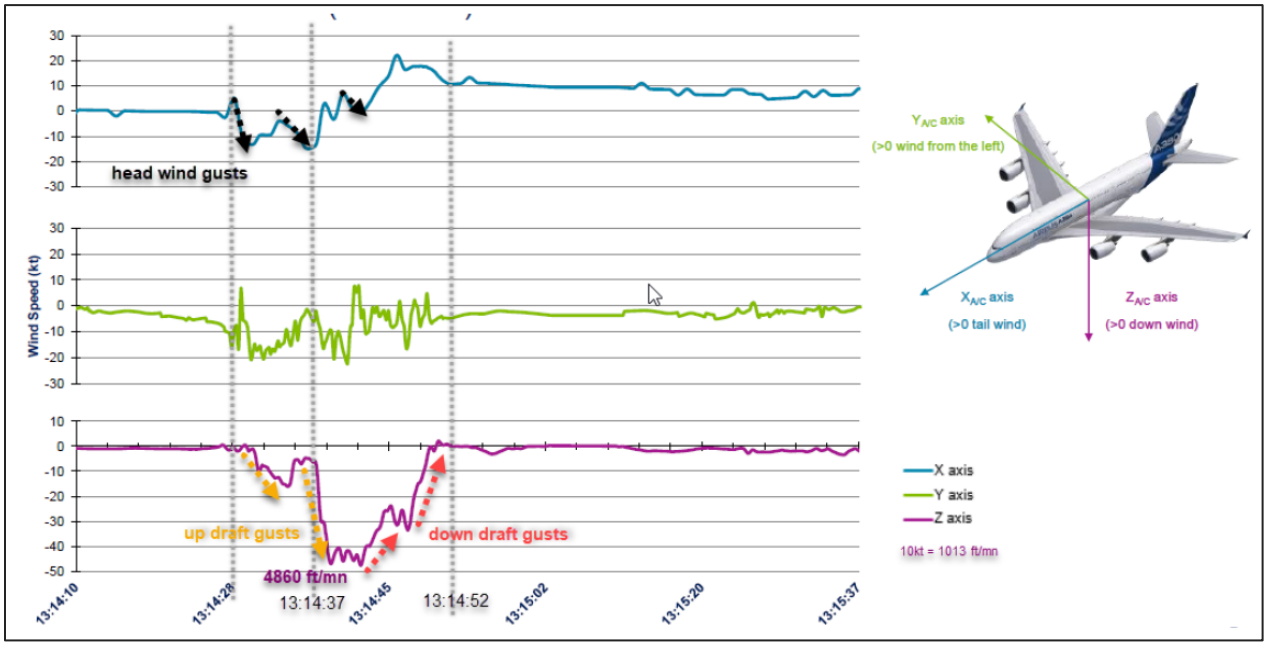


Figure 8. Wind reconstruction plots [Source: Airbus]

(g) During the onset of the airspeed increase towards MMO, all spoilers were automatically deployed when the airspeed approached values close to MMO of

0.89, together with a thrust reduction commanded by the autothrust system. The maximum airspeed increased to 0.884 Mach.

(h) At 1314:39, just after the second airspeed excursion towards MMO, the flight crew changed the Mach target to 0.76, followed by manual movement of the speed brake lever to half maximum deflection leading to partial deployment of all spoilers.

(i) Vertical load factor varied between positive 1.75 to positive 0.17 g.

(j) Vertical speed varied between a climb of 2,300 and descent of 3,120 feet per minute. The Aircraft altitude increased by 300 ft and descended by 180 ft.

(k) Roll movements were limited to two degrees left and two degrees right.

(l) Load analysis data from the FDR, indicated that the Aircraft operational load limits were not exceeded, thus no additional Aircraft inspection was required.

(m) The performance of the Aircraft was maintained within the operational envelope without any exceedances.

(n) The autopilot and autothrust remained engaged during the entire turbulence period.

(o) After the turbulence encounter, the turbulence detection function of the weather radar indicated that there were several wet turbulent areas as the Aircraft continued over Mozambique and Malawi confirming the accuracy of the convective weather forecast on the significant weather chart of the OFP.

The turbulence detection function of the weather radar indicated that several wet turbulent alerts were generated and displayed on the ND prior to the turbulence encounter which was confirmed by the weather radar manufacturer. These alerts occurred at:

- 1227:04. The Aircraft was approximately 390 NM from the turbulence encounter travelling at an average ground speed of 485 kt.
- 1232:59
- 1233:04
- During the three above wet turbulence alerts, the weather radar was maintained at ranges of 160 NM for the Commander and 320 NM for the Copilot.

1.12 Wreckage and Impact Information

The Aircraft was intact.

1.13 Medical and Pathological Information

There was no evidence that physiological factors or incapacitation had affected the performance of the flight crew.

1.14 Fire

There was no sign of fire.

1.15 Survival Aspects

The Cabin Manager stated that during the pre-flight briefing, the flight crew advised that most of the flight was expected to be normal, with a few areas of turbulence during descent into FAOR.

Eight seconds prior to the turbulence encounter, the seat belt sign was switched ON. The Cabin Manager stated that he did not hear the chime of the seat belt sign coming ON but did observe the seat belt sign flashing. Within a few seconds of the start of the turbulence, the Cabin Manager made an announcement for the cabin crew to take their seats.

After the seat belt sign was turned ON, no passenger announcement was made, either by the flight crew or by the cabin crew, directing passengers to return to their seats and fasten their seat belts.

Up to the time of the turbulence, the cabin crew were performing normal duties. Because the seat belt sign was OFF until eight seconds prior to the turbulence encounter, some passengers were not in their seats and a few were in the lavatories.

Because of the turbulence, several of the cabin crew and passengers were lifted off their seats and/or feet. The following effects were experienced by the concerned cabin crew and passengers:

- The Cabin Manager, who was seated at the crew work station, located on the lower deck forward cabin, was lifted up and his head struck the ceiling. He was uninjured and resumed normal duty.
- The cabin crewmembers, in the upper deck aft galley, were all lifted off their feet with one cabin crew striking her head against a cart that she was holding. She stated that she was able to lessen the impact by protecting her head with her hand. No crewmember was injured and all were able to resume normal duties.
- The passenger, who was seriously injured, was on her way to the lavatory adjacent to the aft cabin upper deck U3R door. As per the cabin crew statements, the passenger fell to the floor, which most likely indicates that she was lifted off her feet. Figure 9 illustrates, with a red circle, where the passenger was located at the time of the turbulence encounter.
- As reported by the Cabin Manager, another passenger struck her jaw whilst occupying the lavatory. This passenger did not report any injuries.

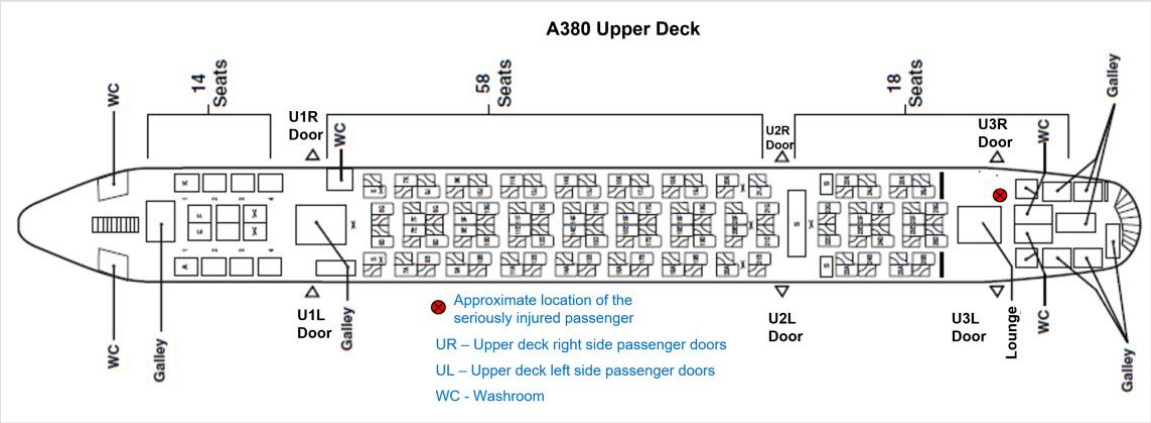


Figure 9. A380 Upper deck – location of the seriously injured passenger

The severity of the injury sustained by the passenger as a result of the turbulence encounter was considered to be non-life threatening. The injured passenger was assessed via communication between the flight crew and the Operator's ground medical team. Based on this assessment, a deviation was not considered to be necessary and the flight continued to FAOR where upon arrival, the injured passenger received further medical attention.

1.16 Tests and Research

Except for the Aircraft manufacturer's analysis of the environmental conditions and Aircraft performance during the turbulence encounter, no tests or research were carried out.

1.17 Organizational and Management Information

1.17.1 The Operator

1.17.1.1 Seat belt policy

The policy of the Operator, according to the *operations manual* (*OM*), stated that the seat belt sign must be switched ON and seat belts to be worn by all passengers under several conditions, which included "…in turbulent conditions or when turbulent conditions are expected.", and "…at the Commander's discretion or as required by abnormal or emergency procedures." The *OM* stated that "…whenever passenger seat belts are to be fastened, each person who is aged 2 years or more must wear a safety belt or be strapped in a child restraint device, which is acceptable to the Authority."

In July 2008, the Operator revised the policy and discontinued the automated audio announcement throughout all sections of the cabin to fasten seat belts when the seat belt sign was turned ON. The General Civil Aviation Authority of the United Arab Emirates (GCAA) accepted this policy change. The change followed a service delivery request to minimize the amount of cabin announcements especially during night flights, in order to minimize disturbance to the first and business class passengers. Following this change, the updated standard operating procedure required that the cabin crew:

"

- perform fasten seat belt announcement only in economy cabin together with a physical walk through the cabin to ensure that passengers seat belts were fastened and;
- for the premium cabin, first and business class, to perform a physical walk through the cabin to ensure that passengers seat belts were fastened.
- passengers before takeoff briefing includes advising to keep their seat belts fastened at all times whilst seated during the flight."

1.17.1.2 Ground Medical Support

Part E of the Operator's *OM* details the policy to be followed by the flight and cabin crew in case of onboard medical emergency and the first aid response process. For an emergency, the flight and cabin crew are required to communicate using the acronym NITS describing the **N**ature of the situation, the **I**ntension/initial action, **T**ime related information and **S**pecific instructions/information.

In the event of a serious and life threatening emergency onboard, the Operator requires that communication be established with the Operator's ground medical support. Medical direction and patient assessment is provided by the ground medical support which includes medication to

be administered to the patient, and in the event a diversion is recommended, liaise with the flight commander and the Operator's network control center.

1.17.1.3 Turbulence levels

As part of the Operator's annual flight and cabin crew recurrent training, theoretical and practical instructions included actions in the event of turbulence encounters.

The *OM* stated that as part of the pre-flight briefing, the flight crew must inform the Cabin Manager and the rest of the cabin crew about expected areas of turbulence during the flight.

In accordance with the *OM* flight procedures for anticipated turbulence during flight, flight crews are instructed that if the weather conditions, cloud structure and route forecast indicate that turbulence is likely, the cabin crew "shall" be advised. For a turbulence encounter that is imminent or unpredicted, the flight crew were required to switch the seat belt sign ON and advise passengers to return to, or remain in their seats, ensuring that their seat belts/harnesses were securely fastened. For cabin services, if the seat belt signs are switched ON during cruise due to turbulence, the flight crew were required to communicate with the Cabin Manager as to the level of cabin service that was appropriate.

Table 2 is a summary of the Operator's policy regarding the level of flight turbulence encountered and relevant crew actions.

Table 2. Flight turbulence level and crew actions

Level	Light	Moderate	Severe
Definition	Momentarily causes slight, rapid and rhythmic movements without change in aircraft altitude or attitude.	Causes rapid bumps or jolts. Moderate changes in aircraft altitude or attitude may occur but the aircraft remains in positive control as all times.	Causes abrupt changes in the aircraft altitude and attitude. Aircraft may be out of control for short periods.
Flight crew actions - Anticipated	- Advise the purser when turbulence is expected and to ensure that the passengers are secured in their seats; - Switch the seat belt sign ON; - At the discretion of the Captain, to advise the purser the level of cabin service.	- Advise the purser when turbulence is expected, to cease all cabin service, secure the galleys and for cabin crew to be seated; - Switch the seat belt sign ON; - Report turbulence to flight dispatch; - Record severe turbulence in the aircraft technical log.	
Flight crew actions - Unanticipated	- Switch the seat belt sign ON - At the discretion of the Captain, communicate with the purser the level of cabin service.	- Switch the seat belt sign ON; - Make a passenger announcement for cabin crew to take seats immediately; - Report turbulence to flight dispatch; - Record severe turbulence in the aircraft technical log.	

Cabin crew actions	- For economy class, make a passenger announcement to RTS and FSB. Ensure passengers in the lavatory RTS. Ensure all passengers and infants are seated and FSB. - In first and business class, individually inform passengers to RTS and FSB. - Secure the galleys and galley equipment; - Cabin crew will pass their area ready check to the purser - The purser will communicate to the Captain that 'Cabin Ready'	Anticipated moderate or severe turbulence: - For economy class, make a passenger announcement to RTS and FSB. Ensure passengers in the lavatory RTS. Ensure all passengers and infants are seated and FSB. - In first and business class, individually inform passengers to RTS and FSB. - Secure the galleys and galley equipment; - All cabin crew shall be seated on their jump seats with seat and shoulder belts fastened; - Cabin crew will pass their area ready check to the purser - The purser will communicate to the Captain that 'Cabin Ready'.
		Unanticipated moderate or severe turbulence: - If possible, make a passenger announcement to RTS and FSB. - Secure hot liquids, galleys and galley equipment; - All cabin crew to be seated immediately on any seat and FSB and those on jump seats to fasten seat and shoulder belts.

1.17.1.4 Adverse weather operation

For adverse weather, the *FCOM* stated that the flight crew should monitor the weather, by selecting long and also short ND ranges, in order to determine the best trajectory to avoid areas of adverse weather. To avoid thunderstorms, the *FCOM* recommended that the pilot monitoring (PM) select a range of 160 NM on the ND and the PF a range of 80 NM.

To avoid a large thunderstorm, or area of greatest threat, flight crew were instructed to decide at least 40 NM ahead of the thunderstorm what action to take to avoid any identified area of greatest threat, keeping a distance of at least 20 NM from the weather. When in doubt, the flight crew were required to use lateral deviation in preference to vertical deviation. Figure 10 illustrates the margins and distances.

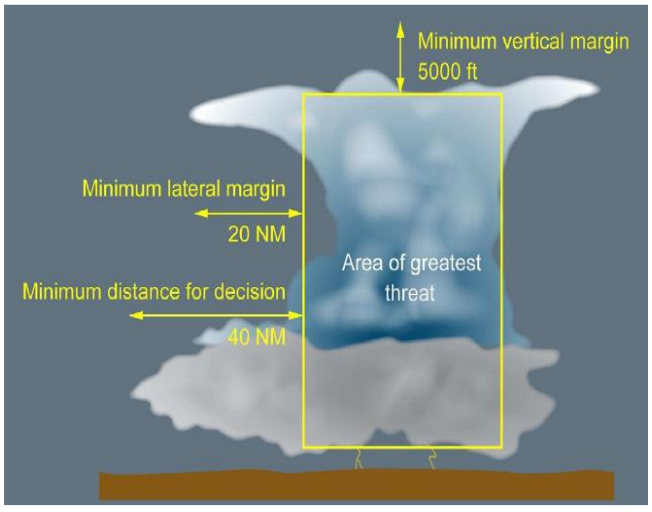


Figure 10. Summary of margins and distances
[Source: FCTM A380]

The AUTO mode is the default operational mode of the WXR. The AUTO mode is adapted and optimized for all flight phases. The flight crew can temporarily use the manual modes if needed, depending on the operational context. In order to analyze the WXR echo returns with increased precision, the *FCOM* procedure *PRO-SUP-91-30 – Weather Radar*, and *flight crew techniques manual* (*FCTM)* information to cope with

adverse weather stated that the flight crew could use manual gain as this mode adjusts the sensitivity of the weather display on the ND. As a result, the weather signal will appear either stronger (increased gain) or weaker (decreased gain). The *FCOM* recommended using the WXR manual mode temporarily "…in order to monitor thunderstorm development and to obtain the best cell echo."

As part of pilot training and *FCOM* procedure, the Operator advised avoidance of:

- Areas of severe turbulence by flying the aircraft above, or around, these areas.
- All yellow, red, or [associated] magenta areas by at least 20 NM.
- Single magenta areas of turbulence that are not associated with heavy precipitation, by at least 5 NM.
- Penetrating a cell.
- Clearing its top by less than 5,000 ft vertically, because turbulence may occur at the top of the clouds.
- Overflying a cell if its top is at or above 25,000 ft, because turbulence may be stronger than expected.
- Flying under a thunderstorm or convective cloud, because of possible windshears, microbursts, severe turbulence, or hail.

When the WXR was in AUTO mode, the *FCTM* stated that off-path weather was displayed on the ND with black parallel lines. In such cases, and if the ND displayed off-path weather in either yellow, red or magenta colors, the flight crew were required to perform a detailed analysis of the corresponding convective cell.

The *FCTM* stated that flight crew must be aware that the radar top may not be the visible top of the convective cloud, and that convective cloud and associated areas of threat (e.g. turbulence) may extend significantly above the radar top, as illustrated in figure 11.

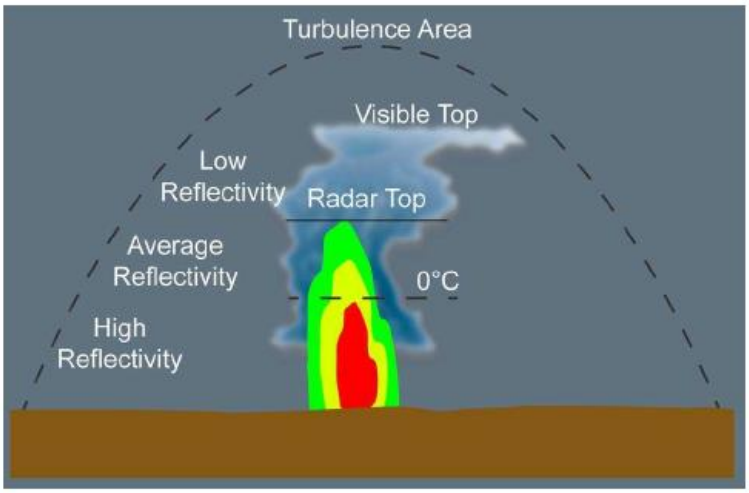


Figure 11. Turbulence area above the 'visible top'
[Source FCTM A380]

The Operator's policy in the *OM-A* for reduced vertical separation minima (RVSM) contained in the section on C*ontingency Procedures* states that the flight crew must report to air traffic control as soon as possible whenever there is moderate or severe turbulence, and particularly when a 300 ft or more deviation in altitude occurs, giving position, altitude, wind velocity and direction.

Flight crew training consisted of an eLearning turbulence presentation; operations manual policy for thunderstorm avoidance; recurrent training 'flight in turbulence'; weather radar

batch-6 presentation for the Airbus A380; Honeywell weather radar differences; and severe turbulence events during line operational evaluation (LOE).

For updated weather information en-route, the Operator stated that flight crew were able to contact air traffic control to get the latest SIGMET and pilot reports. In addition, they could request weather updates from the Operator's flight dispatch throughout the flight using the aircraft communication addressing and reporting system (ACARS), or alternatively by contacting flight dispatch via voice communication using Satphone. The Operator stated that pilots were unable to get updated weather information on the electronic flight bag (EFB) during flight.

The *FCOM – Abnormal and Emergency Procedures* for *Overspeed Prevention*, provides the operating techniques when the aircraft encounters significant speed variations close to MMO. This procedure requires keeping the autopilot and autothrust ON, reducing the selected speed and if the speed trend approaches MMO, using the speed brakes as required.

1.18 Additional Information

1.18.1 Operator's cabin service unit handholds

On the Operator's A380 fleet, the Investigation reviewed the location of the handholds in the lavatory, wet and dry galleys, cabin work stations, lounge areas and crew rest compartment. These observations were made previously in the Final Report of the air accident investigation file[4] AIFN/0009/2019 issued by the AAIS. The observations are attached in Appendix B to this Report.

1.18.2 Other traffic information

During cruise in the BEIRA FIR, the Aircraft QAR data, Flightradar24, and the Commander's report, confirmed that there was other traffic flying in the opposite direction with a vertical separation maintained in accordance with RVSM.

The Aircraft's QAR data recorded another aircraft up until 1309:45, which was 1,000 feet above and 21.5 NM behind EK763 and indicated that there was no traffic avoidance collision system (TCAS) threat. From Flightradar24, this traffic was identified as QR1364, an Airbus A350 aircraft.

For approximately 20 minutes, between 12:49:54 on a heading of 18 degrees at FL390 and 13:09:56 on a heading of 21 degrees at FL410, there was no recorded Flightradar24 data for QR1364. The distance flown by QR1364 during this period was approximately 157.1 NM. The calculated ground speed was 471 kt or 7.84 NM per minute, consistent with Flightradar24 ground speed of 485 kt recorded at 12:49:54 and 486 kt recorded at 13:09:56.

At 1249:54, QR1364 was approximately 101.1 NM from the area of turbulence encountered by EK763. Covering 7.84 NM per minute, this aircraft would have crossed the turbulent area after 12 minutes 54 seconds or at approximately 1302:48. At this time, EK763 was approximately 11 to 12 minutes away from entering the turbulent area.

Shortly before the turbulence at 1314:24, the EK763 flight crew reported seeing other traffic at FL390 flying in the opposite direction. At 1309:46, the QAR data confirmed that there was an aircraft flying 1,000 ft below EK763 at a distance of 70.19 NM presenting no TCAS threat to EK763. From Flightradar24, this traffic was identified as QR1362, a Boeing 787 aircraft.

[4] https://www.gcaa.gov.ae/en/ePublication/admin/iradmin/Lists/Incidents%20Investigation%20Reports/Attachments/133/2019-Final%20Report%20AIFN-0009-2019%20UAE449.pdf

Flightradar24 information for QR1362 indicated that for 14 minutes 41 seconds, between 1305:09 on a heading of 35 degrees and 1319:50 on a heading of 18 degrees, no flight information was captured by Flightradar24. The distance covered during this period was 117.95 NM with a calculated groundspeed of 482 kt or 8.03 NM per minute. This is consistent with Flightradar24 data, which captured an average groundspeed during this period of 489 kt at FL390 for QR1362.

At 1305:09, QR1362 was approximately 71 NM from the area of turbulence encountered by EK763. Flight QR1362, covering a distance of 8.03 NM per minute, would have crossed this area at approximately 1314 at FL390 and within sight of the EK763 flight crew. EK763 QAR data indicates that the closest distance between EK763 and QR1362 occurred at 1314:04 when the separation was 1.25 NM. Thereafter, the separation started to increase as QR1362 was behind EK763.

1.19 Useful or Effective Investigation Techniques

The Investigation was conducted in accordance with the legislation and *Air Accident and Incident Investigation Regulation (AAIR)* of the United Arab Emirates, in accordance with the AAIS approved policies and procedures, and the Standards and Recommended Practices of Annex 13 to the Chicago Convention.

2. Analysis

2.1 General

The flight and cabin crewmembers were appropriately licensed and medically fit to operate the flight.

The Aircraft was maintained in accordance with the maintenance program approved by the General Civil Aviation Authority of the United Arab Emirates (GCAA), and there were no technical anomalies prior to the turbulence encounter. The Aircraft systems and engines performed as designed.

2.2 Flight Planning

For the flight from Dubai to Johannesburg, the operational flight plan (OFP) provided to the EK763 flight crew contained the significant en-route weather charts, which were effective from 1200 UTC on 16 January 2020. The planned flight route took the Aircraft over the eastern border of central Africa passing through a large area containing cumulonimbus clouds.

A satellite weather image taken at 1315 UTC on 16 January 2020, provided to the Investigation but not available to the flight crew, showed that the large area of adverse weather was still active with isolated embedded cumulonimbus (CB) up to 48,000 ft and occasional CB up to 52,000 feet (ft).

During this time of the year, the Intertropical Convergence Zone (ITCZ) affects Central and Eastern Africa and it is common to have widespread thunderstorms with associated turbulent conditions. The Commander had flown this route on several occasions previously and was aware that during this time of the year, the area along the eastern side of Africa could be affected by thunderstorm conditions.

As this route is regularly flown by flights operated by the Operator, the Operator's flight dispatch department had gained experience of the risk involved and the appropriate mitigating actions necessary to minimize exposure to turbulence due to the effects of the ITCZ. For EK763 flight planning, the Investigation concludes that the flight preparation and the OFP met the required best practice and regulatory requirements taking into consideration the significant weather predictions.

2.3 Flight Crew Performance

The flight crew decided to maintain the planned flight path as the weather radar was showing the weather as off-path, indicating that the weather system threat was below the Aircraft by at least 5,000 ft. The flight crew did not receive any pilot reports nor air traffic control reports of turbulence or deviation within BEIRA flight information region (FIR), Mozambique, to influence their decision.

When updated en-route weather information is required, flight crew have the option to contact the Operator's flight dispatch as the Operator does not provide live en-route weather information utilizing the flight crew electronic flight bag.

The flight crew stated that before entering the eastern region of central Africa, the flight was uneventful with no significant weather and they were aware of the threat of thunderstorms when flying through this area of Africa at this time of the year.

From 1311:37, with the Aircraft at 26 NM and 2 minutes 47 seconds from the turbulence encounter, the weather radar wet turbulence function detected wet turbulence which was visible

as magenta on the navigation display (ND). This was confirmed by the Aircraft recorded flight data. However, it is most likely that the flight crew did not observe the on-path magenta cells from their onset. As reported by the Commander, when they eventually saw the magenta indications, they did not have time to make any changes to the ND gain. There was only sufficient time to turn the seat belt sign ON which was done just eight seconds before the turbulence commenced.

During the turbulence encounter, which was composed of headwinds and updrafts of up to 4,900 feet per minute, the Aircraft experienced load factors which changed rapidly to positive 1.75 g with a lowest value of positive 0.17 g, and altitude deviations ranging between positive 300 ft and negative 180 ft. The flight crew correctly executed the *flight crew operating manual (FCOM) – Abnormal and Emergency Procedures* for *Overspeed Prevention*. The Commander extended the speed brakes and reduced the selected speed. An exceedance of maximum operating Mach (MMO) was avoided by the appropriate actions of the flight crew and the Aircraft automated systems. During the 30 seconds of the turbulence encounter, the Aircraft stayed within the normal flight envelope with the autopilot and autothrust engaged.

The Investigation concludes that had the flight crew observed the magenta wet turbulence from the onset, it may have been possible to assess whether taking avoiding action would have steered the Aircraft away from any area of threat in addition to allowing more timely notification to the cabin crew to enable them to prepare the cabin in case of any turbulence.

In order to assist flight crew decision making regarding weather conditions, the Investigation recommends that the Operator enhance the ability of pilots to access updated weather information through the electronic flight bag.

2.4 Aircraft Performance

For the different flight phases, including the cruise at FL400, the Aircraft was operated in the correct configuration and attitude with the autopilot and autothrust engaged.

At the beginning of the turbulence encounter at 1314:24, the flight data recorder (FDR) data indicated significant wind variations. This caused significant variations in the Aircraft attitude, altitude and a sudden airspeed increase. The Aircraft systems automatically responded and successfully avoided any overspeed.

Based on the Airbus analysis, the turbulence encounter resulted in the Aircraft its occupants experiencing significant variations of vertical and lateral load factor, which were consistent with the adverse wind variations.

The Investigation concludes that throughout the severe turbulence encounter the Aircraft remained controllable. The Aircraft systems functioned as designed, and automatically responded to sudden flight variations in order to avoid the overspeed.

2.5 Aircraft Weather Radar

The Aircraft's weather radar system was of the latest modification status available from the Aircraft manufacturer and was standard across the Operator's A380 fleet. The A380 weather radar (WXR) incorporates several automated functions with manual options for the flight crew. Pilots introduced to the capabilities of the weather radar as well as the meaning of the different colors displayed on the ND by eLearning sessions.

In accordance with standard operating procedures, for the flight, the Aircraft WXR and turbulence (TURB) functions were active with weather information displayed on the ND.

The weather radar turbulence (TURB) function detects wet turbulence and displays the area as magenta on the ND within the envelope of WXR TURB detection function being 40 NM ahead, 20 NM on both side of current Aircraft heading, plus/minus 5,000 ft of the Aircraft altitude. With the WXR in AUTO mode, the only indication of wet turbulence detection is the appearance of magenta on the ND as there are no cockpit alerts generated by the Aircraft systems.

For wet turbulence within a range of 40 NM ahead of the Aircraft, and provided the magenta is observed from the onset, the flight crew are required to make an immediate decision to divert by at least 5 NM from a single magenta cell and 20 NM in case of magenta when associated with other precipitation. As the decision on what action is required is based on when the flight crew observes the magenta and then processing this information, in case the flight crew fails to observe the magenta from the onset, means that there is a greater possibility that the aircraft will be affected by wet turbulence. For an aircraft in cruise, the distance covered in one minute is approximately 8 NM, thus the Investigation believes that without any aural cockpit alerting system for when wet turbulence is detected, reduces the time for the flight crew to make an appropriate decision.

Within 390 NM of the turbulence encounter, the Aircraft recorded flight data indicated that three times within a six-minute period the weather radar detected wet turbulence ahead of the Aircraft and displayed it in magenta on the ND. Again from 1311:37, and 26 NM from the turbulence, magenta areas were displayed on the ND within the WXR turbulence detection envelope of 40 NM ahead of the Aircraft. The detection of wet turbulence starting from 1311:37 is illustrated in Appendix D to this Report.

With the Aircraft less than 26 NM from the turbulence encounter, the Commander had reported that there was no indication of on-path precipitation except for some wet turbulence magenta areas which the Commander most likely observed less than two minutes before the turbulence occurred. Because the weather radar display on the ND of green, yellow and red areas are not recorded by the FDR, or quick access recorder (QAR), or cannot be deduced from indirect recorded parameters as done for magenta areas, the Aircraft manufacturer was not able to identify at the time of the event the area of greatest threat and the actual vertical and lateral margin between this area and the EK763 Aircraft trajectory.

Because the flight crew were not aware of the periods of wet turbulence from the onset, the WXR manual gain mode and elevation (ELVN) mode were not fully used to obtain the best cell echo, enabling the flight crew to assess the location of the area of greatest threat and the distance margin from the planned flight path. Even though the WXR AUTO mode is optimized for all flight phases, to assist the flight crew decision making the *FCOM PROSUP- 91-30 – Weather Radar*, procedure recommends using the WXR manual mode temporarily “in order to monitor thunderstorm development and to obtain the best cell echo”.

The risk of a turbulence encounter in convective weather operation can be minimized by using all of the radar capabilities to identify the area of greatest threat and adopt the best trajectory providing sufficient separation from the area of adverse weather.

The Investigation concludes that the Aircraft weather radar was operating as designed. Similarly to the turbulence encounter as stated in Final Report of investigation file AIFN/0009/2019 (Appendix B to this Report), the EK763 flight crew did not use the full capabilities of the weather radar by adjusting the range and they did not effectively make use of the manual modes to enhance the echo returns. This would have assisted them in their assessment of the convective weather system. Knowing the capabilities and limitations of the weather radar installed on an aircraft is essential as well as being familiar with the techniques for using the weather radar effectively to optimize the opportunity to detect and avoid convective weather and wet turbulence.

The Investigation recommends that the Operator enhance the weather radar training information available to pilots including using the full capability of the weather radar to better analyze adverse weather situations to facilitate decision-making.

2.6 Cabin Readiness

In order to maintain a good shared mental model, the pre-flight briefing of the flight and cabin crew is the initial phase when any forecast significant weather and its possible effects on flight conditions are shared. The flight crew had informed the cabin crew of the expected turbulence events during descent into Johannesburg Tambo International Airport (FAOR) and provided the estimated flight times.

Prior to the turbulence encounter, all cabin crewmembers were on duty. However, passenger cabin service was minimal and no serving trolleys were in the cabins.

When the flight crew turned the seat belt sign ON, eight seconds before the turbulence encounter, the Cabin Manager did not hear the seat belt chime but was aware of the seat belt signs flashing. This did not allow enough time to make a passenger announcement.

It was only during the turbulence encounter that the Cabin Manager made a passenger announcement for all cabin crew and passengers to take their seats and to fasten their seat belts. At this time, it was too late to prevent a serious injury to one passenger. The severity of the turbulence resulted in significant vertical g-loads between positive 0.17 g and positive 1.75 g. As a result, some passengers and cabin crewmembers were tossed about with some being lifted off their feet. The Aircraft oscillations were more significant in the aft cabin and aft galleys for both the upper as well as the main cabin.

Even though there was insufficient time for the cabin crew and passengers to react, the Investigation believes that the importance of switching the seat belt sign ON was not appropriately addressed. The Operator's flight procedures policy requires that for anticipated turbulence during flight, flight crew are instructed that if the weather conditions, cloud structure and route forecast indicate that turbulence is likely, the cabin crew "shall" be advised. Thus, taking into consideration the time it will take to secure passengers, cabin crew and galley equipment, timely warning from the flight crew is critical in order to avoid injuries and aircraft damage.

The action of the flight crew in turning the seat belt sign ON, meant that they were preparing for an unknown level of turbulence along the flight path. The flight crew's expectation, was for all passengers to return to their seats and fasten their seat belts. However, this expectation was not verbally communicated to the Cabin Manager.

With the introduction of the Operator's A380 in July 2008, the automated audio announcement throughout the cabin to fasten seat belt feature when the seat belt sign was turned ON was progressively discontinued from all aircraft. This was to reduce the audio disturbances to passengers in first and business class. After July 2008, cabin crew were required to make passenger announcements for economy passengers only. Had this feature been functional on this Aircraft, the cabin crew would have received notification to prepare the cabin and the passengers would have been immediately informed to return to their seats and fasten their seat belts.

There is always a risk of persons onboard suffering injury because of turbulence, especially if the cabin is not ready. For an aircraft such as the A380 with over 500 occupants, it may not be possible for the cabin crew to stop cabin services, stow galley equipment, and visually verify that each passenger is seated with their seat belt fastened unless there is sufficient notice from the flight crew.

In case of turbulence, the Operator had installed handholds at the galley units, lavatories and other areas in the cabin to be used to help secure cabin crew and passengers. However, due to their locations and also a lack of handholds, a person may not be able to secure themselves in sufficient time in case of unanticipated turbulence. This possibility was highlighted in a previous investigation which included safety recommendations intended to address the findings. See Appendix B to this Report.

When turbulence is anticipated during the flight, the flight crew should turn the seat belt sign ON and advise the cabin crew as to the amount of time available to secure the cabin, the level of turbulence and its expected duration. Thereafter, it is the duty of the cabin crew to ensure that all passengers and cabin crew are safe, galleys are secured, and then notify the flight crew that the cabin is ready.

The Investigation recommends that the Operator improve:

(a) the communication procedure between the flight crew and the cabin crew when the seat belt sign is turned ON with information on the anticipated level of turbulence and the cabin services allowed.

(b) the automated passenger announcement when the seat belt sign is turned ON.

(c) The cabin chime audibility when the seat belt signed is turned ON.

2.7 Wake Turbulence

Prior to the turbulence encounter at FL400, an Airbus A350 aircraft, had passed through this area approximately 11 to 12 minutes earlier. Because of insufficient information, the flight level of QR1364 at this stage of flight could not be confirmed as the aircraft was climbing from FL390 to FL410.

European Union Aviation Safety Agency (EASA) *Safety Information Bulletin SIB No. 2017-10 – En-route Wake Turbulence Encounters*, issued on 22 June 2017, indicates that the basic effects of wake turbulence encounter on an aircraft are induced roll, vertical acceleration (can be negative), and loss or gain of altitude, while emphasizing that the greatest danger is typically the induced roll that can lead to a loss of control and possible injuries to cabin crew and passengers. EK763 did not experience any significant disturbance on the lateral axis as the roll was a maximum of two degrees to the left and right during the 30 seconds of turbulence.

The *SIB* states that en-route, the wake vortices evolve at altitudes at which the rate of decay leads to a typical persistence of two to three minutes, with a typical sink rate of about 400 feet per minute. Taking into consideration that QR1364 had transitioned through the area of turbulence approximately 11 to 12 minutes before EK763 turbulence encounter; any wake vortices generated by QR1364 would have decayed in the interim.

The Investigation concludes that the changes to attitude and altitude of EK763 during the turbulence encounter were not due of wake turbulence and were most likely related to the prevailing convective weather wet turbulence cells.

3. Conclusions

3.1 General

From the available evidence, the following findings, causes, and contributing factors were determined with respect to this Accident. These shall not be read as apportioning blame or liability to any particular organization, or individual.

To serve the objective of this Investigation, the following sections are included in the Conclusions heading:

- **Findings.** Statements of all significant conditions, events or circumstances in this Accident. The findings are significant steps in the Accident sequence but they are not always causal nor do they indicate deficiencies.
- **Causes.** Actions, omissions, events, conditions, or a combination thereof, which led to the Accident.
- **Contributing factors.** Actions, omissions, events, conditions, or a combination thereof, which, if eliminated, avoided or absent, would have reduced the probability of the Accident occurring, or mitigated the severity of the consequences of the Accident. The identification of contributing factors does not imply the assignment of fault or the determination of administrative, civil or criminal liability.

3.2 Findings

3.2.1 Findings relevant to the Aircraft

(a) The Aircraft was certified, equipped, and maintained in accordance with the *Civil Aviation Regulations* of the United Arab Emirates.

(b) The Aircraft was airworthy when dispatched for the flight, and there was no evidence of any defect or malfunction that could have contributed to the Accident.

(c) The Honeywell RDR-4000 weather radar (WXR) fitted to the Aircraft was of the latest modification standard.

3.2.2 Findings relevant to the flight crew

(a) The flight crewmembers were licensed and qualified for the flight in accordance with the *Civil Aviation Regulations* of the United Arab Emirates.

(b) The flight crewmembers were medically fit and rested for the flight.

(c) The flight crewmembers had attended the annual recurrent safety and emergency procedures (SEP) training, which provided actions required in the event of turbulence encounters.

3.2.3 Findings relevant to the cabin crew

(a) The cabin crewmembers were licensed and qualified for the flight in accordance with the *Civil Aviation Regulations* of the United Arab Emirates.

(b) The cabin crewmembers were medically fit and rested for the flight.

(c) The cabin crewmembers had attended the annual recurrent SEP training, which included actions required in the event of turbulence encounters.

3.2.4 Findings relevant to flight operations

(a) The Aircraft WXR and turbulence (TURB) detection functions were in active mode and weather information was displayed on the navigation display (ND).

(b) At 1311:37, 2 minutes 47 seconds before the turbulence encounter, the Aircraft recorded flight data indicated that the wet turbulence (TURB) detection function of the weather radar detected and displayed wet turbulence cells ahead of the Aircraft in magenta on both navigation displays.

(c) The Aircraft recorded flight data indicated that the WXR manual mode/s was not selected on the SURV panel.

(d) The flight crew turned the seat belt sign ON eight seconds before the turbulence encounter at 1314:16.

(e) No communication was established between the flight crew and the Cabin Manager after the seat belt sign was turned ON.

(f) At 1314:24, approximately six hours after departure from Dubai International Airport (OMDB), the Aircraft encountered severe to moderate turbulence, which lasted for approximately 30 seconds.

(g) When the airspeed started to increase, the flight crew correctly executed the *FCOM – Abnormal and Emergency Procedures for Overspeed Prevention*, and kept the autopilot and autothrust ON, and extended the speed brakes.

(h) The Aircraft systems responded automatically as designed in order to avoid any exceedances.

(i) During the turbulence, the Aircraft autopilot and autothrottle remained engaged, and the Aircraft remained controllable.

(j) The Cabin Manager reported that he did not hear the chime of the seat belt sign coming ON.

(k) Due to insufficient time, the cabins were not prepared for turbulence as required after the seat belt sign was switched ON.

(l) During the turbulence encounter, the Cabin Manager made a passenger announcement for all cabin crew and passengers to take their seats and to fasten their seat belts.

(m) The flight crew did not notify air traffic control that the Aircraft had experienced turbulence.

3.2.5 Findings relevant to the Operator

(a) The operational flight plan (OFP) significant aeronautical weather chart had forecast the presence of convective weather activity containing embedded cumulonimbus clouds up to an altitude of 52,000 ft within BEIRA flight information region (FIR), Mozambique.

(b) The Operator does not provide updated en-route weather information to flight crew through use of the electronic flight bag.

3.2.6 Survivability

(a) The serious injury suffered by the passenger was non-life threatening.

(b) Because of the turbulence, some unsecured passengers and cabin crewmembers were forceful lifted off their feet.

(c) The movements of the Aircraft were more significant in the aft cabins.

3.3 Causes

The Air Accident Investigation Sector of the United Arab Emirates (AAIS) determines that the cause of the Accident was the severe turbulence of vertical gust forces imposed on the Aircraft as it operated within an area associated with wet turbulence cells, resulting in the forceful movement of unsecured passengers and cabin crewmembers.

3.4 Contributing Factors

The Investigation determines that the following were contributory factors to the Accident:

(a) After entering BEIRA FIR and wet turbulence was detected by the weather radar turbulence function, the flight crew did not use the full capabilities of the weather radar to obtain an accurate assessment of the distance of the area of greatest threat from the Aircraft flight path.

(b) There was insufficient time for the cabin crew to secure the cabin after the seat belt sign was turned ON.

4. Safety Recommendations

4.1 General

The safety recommendations listed in this Report are proposed according to paragraph 6.8 of *Annex 13 to the Convention on International Civil Aviation*, and are based on the conclusions listed in part 3 of this Report. The Air Accident Investigation Sector (AAIS) expects that all safety issues identified by the Investigation will be addressed by the receiving States and organizations.

4.2 Safety Actions Taken

4.2.1 Safety actions taken by Emirates

(a) In Section 2.3 of this Report, it was recommended to the Operator:

"To assist flight crew decision making regarding anticipation and evaluation of weather conditions, the Investigation recommends that the Operator enhance the ability of pilots to access updated weather information through the electronic flight bag."

With reference to AAIS investigation Report AIFN/0009/2019 issued on 12 August 2020, the Operator had responded to a similar safety recommendation stating:

> "Emirates are currently evaluating this functionality and there is on-going work to provide real time weather and turbulence data once on-board connectivity is established."

(b) In Section 2.5 of this Report, it was recommended to the Operator:

"To enhance the weather radar training information available to pilots including using the full capability of the weather radar to better analyze adverse weather situations to facilitate decision making."

With reference to AAIS investigation Final Report AIFN/0009/2019 issued on 12 August 2020, the Operator had responded to a similar safety recommendation stating:

> "This forms part of the Weather Radar Differences Course that is currently ongoing. Airbus updated the FCOM on the 23rd Jan 2020 to reflect the Weather Radar changes in Batch 6 and to provide guidance to the crew. Based on the FCOM changes, a video was created on e-learning for the crew."

(c) In Section 2.6 of this Report, it was recommended to the Operator:

"To improve the communication procedure between the flight crew and the cabin crew when the seat belt sign is turned ON with information on the anticipated level of turbulence and the cabin services allowed."

With reference to AAIS investigation Final Report AIFN/0009/2019 issued on 12 August 2020, the Operator had responded to a similar safety recommendation stating:

> "Training Review Committee (TRC) developed a learning module for flight and cabin crew on 5th September 2019 that includes a discussion on enhancing communications between the flight and cabin crew when dealing with the use of the seatbelt sign. This module is ongoing in eLearning since 15th January 2019. Additionally, a Turbulence

> Awareness Campaign was conducted for all crews during November 2019 at the EGHQ [Emirates Group Headquarters]."

(d) In Section 2.6 of this Report, it was recommended to the Operator:

"To improve the automated passenger announcement when the seat belt sign is turned ON."

With reference to AAIS investigation Final Report AIFN/0009/2019 issued on 12 August 2020, the Operator had responded to a similar safety recommendation stating:

> "The seatbelt sign announcement has been revised with the addition of 14 languages from February 2020.
>
> The IFE has the seatbelt awareness message as part of the passenger communication strategy… [the Operator presented a slide of the message on the IFE with the message 'We are experiencing turbulence. Please fasten your seat belt, infants must be removed from bassinets and toilets should not be used at this time']"

(e) Section 2.6 of this Report, it was recommended to the Operator:

"To improve the cabin chime audibility when the seat belt signed is turned ON."

With reference to AAIS investigation Final Report AIFN/0009/2019 issued on 12 August 2020, the Operator had responded to a similar safety recommendation stating:

> "The volume of the seatbelt chime has been increased on the A380 as of 19th September 2019."

4.3 Final Report Safety Recommendations

There are no new safety recommendations issued in this Final Report because the AAIS Final Report of the investigation case file AIFN/0009/2019, issued on 12 August 2020, addresses similar findings with relevant safety recommendations.

Appendix A – Cockpit layout [Source Airbus]

Appendix B – AAIS Investigation AIFN/0009/2019

On 10 July 2019, an Emirates Airbus A380 aircraft, was operating a scheduled passenger flight from Auckland, New Zealand, to Dubai, the United Arab Emirates. In Indian airspace above the Bay of Bengal, the aircraft experienced severe turbulence approximately 13 hours after departure. The turbulence lasted for about four minutes and resulted in 27 persons onboard suffering injuries.

With the aircraft within five minutes of the turbulence encounter, the FDR/QAR data indicates that some wet turbulence was detected ahead of the aircraft within the envelope of the WXR turbulence detection function. The detected turbulence area was displayed in magenta on both NDs. At about the same time, the Commander turned the seat belt sign ON approximately 40 NM before the turbulence encounter but he did not communicate this action to the cabin crew. Except for the weather radar gain changes, the flight crew did not attempt to make use of the full capabilities of the weather radar to better analyze the adverse weather situation.

A review of the cabin turbulence mitigation aids involved an Investigation of the location of handholds in the lavatories, wet and dry galley workstations, cabin workstations, lounge areas and the crew rest compartment.

Lavatories for people of determination had multiple handholds at different heights, which were easily reachable in all circumstances. Other lavatories had either one or two handholds. The orientation in lavatories with a single handhold, was either horizontal or vertical, and those with two were oriented one horizontal and the other vertical. The handles were placed on the lavatory wall and within reachable distance and height only for a person who was seated on the toilet. None of the lavatories had handholds adjacent to the lavatory wash sink. In some lavatories, if the occupant was using the wash sink, the installed handhold was behind their back.

The wet galleys had handholds that were mostly placed close to the top of galley units and sometimes between the upper storage doors. These handles were of the same colour as the surrounding structure of the galley. The number of handholds on the wet galley units depended on the size of each unit. The small units had one handhold and the larger units had either two or three handholds. Most of the handholds were above the galley counter tops and at a height above the heads of the cabin crew. One galley vertical wall adjacent to the cabin aisle had a slot cutout which acted as a handhold. The size of the handholds and slot, would allow for a single hand only

The dry galleys and work stations had no handholds. Most of lounge areas had handhold. The shower had a single handhold adjacent to the shower seat. Each of the nine cabin crew rest bed compartments, which were located in the aft section of the cabin, had a single seat belt which restrained the wearer at the waist. There was no handhold any of the bed compartments. The interior walls were made of fiber glass reinforced plastic.

The following recommendations were made for the Operator to address:

(a) Standardize and improve the accessibility of the lavatory handholds, the accessibility and identification of handholds in the wet and dry galleys and the accessibility of the handholds in the showers.

(b) Provide head protection material within the crew rest bed compartments.

The final report AIFN/0009/2019 can be accessed at the following link:

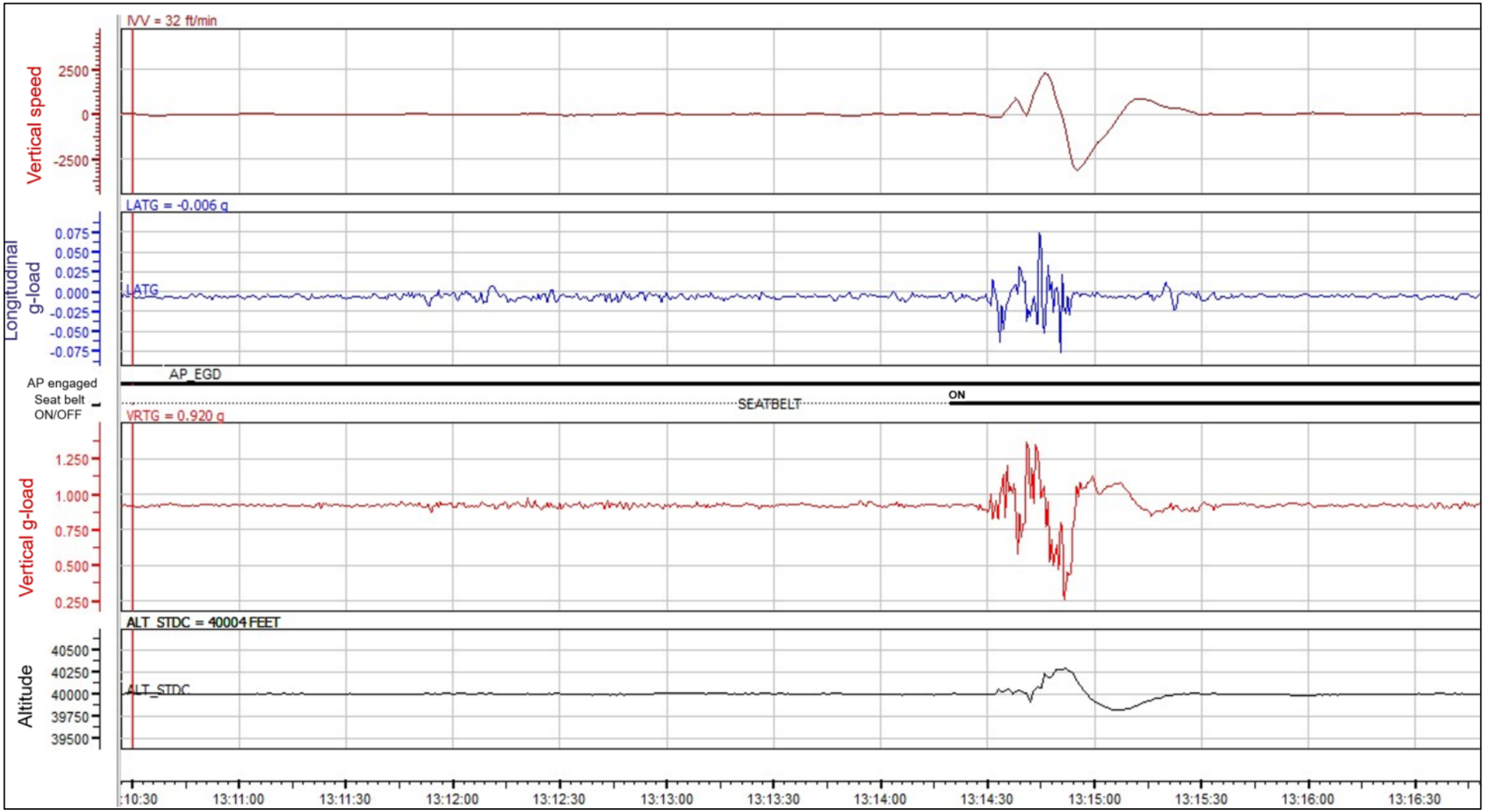
https://www.gcaa.gov.ae/en/ePublication/admin/iradmin/Lists/Incidents%20Investigation%20Reports/Attachments/133/2019-Final%20Report%20AIFN-0009-2019%20UAE449.pdf

Lavatory with two handholds

Lavatory with a single handhold

Typical galley installation with location of handholds

Appendix C – Seat belt sign status and G-loads [Source: Emirates]



Appendix D – Flight Data related the weather radar mode [Source: Airbus]