الهيئة العامة للطيران المدني
GENERAL CIVIL AVIATION AUTHORITY

United Arab Emirates

Air Accident Investigation Sector

Accident

-Final Report -

AAIS Case Nº: AIFN/0002/2021

Severe Turbulence during Descent

Operator:	Emirates
Make and Model:	Boeing 777-31HER
Nationality and Registration:	The United Arab Emirates, A6-EPN
State of Occurrence:	Republic of Cyprus
Place of Occurrence:	Nicosia FIR, Cyprus
Date of Occurrence:	17 January 2021

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 requirements 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 practice. 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/0002/2021
Occurrence Category	:	Accident
Name of the Operator	:	Emirates
Manufacturer	:	The Boeing Company
Aircraft Model	:	777-31HER
Engines	:	Two, General Electric GE90-115B
Nationality	:	The United Arab Emirates
Registration	:	A6-EPN
Aircraft Serial Number	:	42333
Type of Flight	:	Scheduled Passenger
Flight Number	:	EK957
State of Occurrence	:	Republic of Cyprus
Place of Occurrence	:	Nicosia FIR, Cyprus
Date and Time	:	17 January 2021, 0804 UTC
Total Crewmembers	:	14 (two flight crew and 12 cabin crew)
Total Passengers	:	50
Injuries to Passengers and Crew	:	Seven (Serious injury: one passenger; minor injuries: two passengers and four cabin crew)

Investigation Process

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

Notifications of the occurrence was sent on 17 January 2021 by the AAIS to the Cyprus Aircraft Accident and Incident Investigation Board (AAIIB) being the investigation authority of the State of Occurrence, and to the National Transportation Safety Board of the United States (NTSB) being the investigation authority of the State of Manufacture and State of Design of the aircraft.

The AAIS led the investigation being the investigation authority of the State of the Operator and State of Registry. In accordance with the Air Accident and Incident Regulation and in line with the Annex 13 obligations, the AAIS appointed an investigator-in-charge (IIC), assigned Accident Investigation File Number AIFN/0002/2021, and formed an investigation team.

Accredited Representatives were assigned by the AAIIB and the NTSB.

Due to a serious injury to one passenger, the AAIS classified the occurrence as Accident.

The scope of this investigation was limited to the relevant flight operations and monitoring, meteorological information, related aircraft systems, and cabin safety during the turbulence occurrence.

Notes:

1. Whenever the following words are mentioned in this Final 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 of the flight.
   - (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 UTC time.
3. Local time in Cyprus and Beirut is UTC plus 3 hours.
4. Local time in the United Arab Emirates is UTC plus 4 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
AAL	Above aerodrome level
ACARS	Aircraft Communications Addressing and Reporting System
ACC	Area control center
AIRMET	Airmen's meteorological information
ATC	Air traffic control
CB	Cumulonimbus
CVR	Cockpit voice recorder
EASA	European Union Aviation Safety Agency
ETA	Estimated time of arrival
FCOM	*Flight crew operating manual*
FDR	Flight data recorder
FIR	Flight information region
FL	Flight level
ft	feet
FMS	Flight management system
g	G-load
GCAA	The General Civil Aviation Authority of the United Arab Emirates
HECC	Cairo FIR
IBM	International Business Machines Corporation
ICAO	International Civil Aviation Organization
IIC	Investigator-in-charge
kt	knots
LCCC	Nicosia FIR
LCLK	Larnaca International Airport
m	Meter
MWO	Meteorological watch office
ND	Navigation display
NCM	National Center for Meteorology of the United Arab Emirates
NM	Nautical miles
NTSB	National Transportation Safety Board of the United States
OFP	Operational flight plan
OLBA	Beirut International Airport
OLBB	Beirut FIR
OM	*Operations manual*

OMDB	Dubai International Airport
QAR	Quick access recorder
SEP	Safety and emergency procedures
SIGMET	Significant Meteorological Information (SIGMET is a government weather advisory that contains meteorological information concerning the safety of all aircraft.)
SIGWX	Significant weather chart
SMS	Safety management system
SOP	Standard operating procedure
UTC	Coordinated universal time
VMO	Maximum operating speed
WSI	Weather Services International
WXR	Weather radar

Synopsis

On 17 January 2021, an Emirates Boeing 777 Aircraft, registration A6-EPN, departed Dubai International Airport (OMDB), the United Arab Emirates for a scheduled passenger flight number EK957, to Beirut International Airport (OLBA), Lebanon. There were 64 people onboard: 2 flight crewmembers, 12 cabin crewmembers, and 50 passengers. After entering Nicosia flight information region (LCCC FIR), Cyprus, during descent, the Aircraft encountered moderate to severe air turbulence that lasted for approximately three minutes. The turbulence caused injuries to seven occupants.

The en route significant weather chart (SIGWX) contained in the operational flight plan (OFP) forecasted occasional isolated embedded cumulonimbus (CB) clouds affecting Nicosia FIR and Beirut FIR (OLBB). The OFP did not contain any significant meteorological information (SIGMET). During the preflight briefing, the Commander alerted the cabin crew about the possibility of in-flight turbulence during the descent to OLBA.

On 17 January 2021, Larnaca International Airport (LCLK) meteorological watch office (MWO) issued several SIGMET of thunderstorms and severe turbulence affecting areas within LCCC FIR. The flight crew were not aware of the SIGMET issued by LCLK when the Aircraft entered LCCC FIR.

With the Aircraft at the top of descent (at FL360 within LCCC FIR), the Commander, who was the pilot flying (PF), instructed the cabin crew to secure the cabin as he anticipated turbulence during descent and switched the seatbelt sign to ON.

About three minutes into descent, at approximately 0804 UTC with the Aircraft passing pressure altitude 29,200 ft, the Aircraft started to encounter turbulence. The Copilot immediately made a passenger announcement for cabin crew to take their seats. Soon after, the Aircraft encountered moderate to severe air turbulence. The flight crew believed the turbulence was “clear air turbulence” because there was no weather radar returns of precipitation displayed on the navigation display.

During the turbulence, the Aircraft autopilot and autothrottle remained engaged and the Aircraft remained inside its flight envelope.

The turbulence-generated acceleration forces caused several unsecured cabin crewmembers and passengers to be forcefully lifted off their feet and impact cabin furnishings resulting in a serious injury to one passenger. There was no reported damage to the Aircraft cabin.

The flight continued to the destination where the Aircraft landed uneventfully.

Table of Contents

List of Figures

List of Tables

1. Factual Information

1.1 History of the Flight

On 17 January 2021, an Emirates Boeing 777-31HER Aircraft, registration A6-EPN departed Dubai International Airport (OMDB), the United Arab Emirates, for operating a scheduled passenger flight number EK957, to Beirut International Airport (OLBA), Lebanon. There were 64 people onboard: 2 flight crewmembers, 12 cabin crew and 50 passengers.

The operational flight plan (OFP) was downloaded by the flight crew at 0146 UTC and indicated 0330 as the estimated time of departure, and 0755 arrival. In preparation for the flight, the Commander briefed the cabin crew of the possibility of in-flight turbulence during descent as indicated by the en-route significant weather chart (SIGWX) which forecasted occasional isolated embedded cumulonimbus clouds affecting Nicosia and Beirut flight information regions (FIR).

Actual departure from OMDB was at 0427, for about 4 hours 11 minutes' flight time. The Commander was the pilot flying at the departure.

In their interview with the Investigation, the flight crew stated that they had anticipated deviation from planned flight path before entering Nicosia FIR in order to avoid cumulonimbus (CB) clouds that were at approximately 80 nautical miles (NM) ahead of the Aircraft. The Commander stated that "The weather radar selection was always on AUTO but was switched to manual operation for a short period for better assessment of the radar returns, which was completed before top of descent."

At 0758, flight level (FL) 360, and the Aircraft within Cairo FIR, heading of 330 degrees, approximately 15 nautical miles (NM) before entering Nicosia FIR; the Copilot contacted air traffic control (ATC) at Nicosia area control center (ACC) who gave advisory information to fly direct to waypoint ZALKA instead of following the original flight path to PASOS. The flight crew accepted the ATC clearance because the revised heading of 042 degrees would have avoided the CB. ATC further requested the flight crew to advise whenever they needed to deviate for CB avoidance and the request was acknowledged by the Copilot.

The Commander stated that as they were on track towards waypoint ZALKA, "The weather radar was displaying weather returns approximately 120 NM at 12 o'clock position and another cell at about 50 NM from 9 to 11 o'clock."

As recorded by the Aircraft quick access recorder (QAR), at 0800:21 and FL360, with the Aircraft at the top of descent and 40 minutes before arrival to OLBA, the flight crew turned the seatbelt sign to ON and instructed the cabin crew to secure the cabin because of anticipated turbulence during descent. At 0800:55, the Aircraft started descent.

During descent, passing approximately pressure altitude 29,200 ft, the Aircraft began to encounter turbulence which prompted the Copilot to make an announcement over the passenger address system "Cabin crew take your seats". The Commander stated that shortly after the announcement "The turbulence increased rapidly with sudden airspeed increase, and violent jolts. Flight instruments were difficult to read."

To avoid overspeed, with the flight mode engaged in VNAV PATH, speed intervention was selected with a reduction towards 280 kt. As the Aircraft speed kept increasing, the Commander intermittently extended the speedbrake lever to prevent the speed incursions. During the turbulence encounter, the autopilot remained engaged and there was no overspeed, however,

because the vertical speed momentarily exceeded 5,000 feet per minute, the Commander selected the vertical speed (V/S) mode.

The Nicosia ATC recordings indicated that at 0804:21, the Copilot requested "…20 NM right of track due to weather." and shortly thereafter, the Commander initiated a deviation to the right with a new selected heading of 070 degrees. In the communication with ATC, the Copilot reported that the turbulence was "Moderate to heavy." At 0807:45, the Copilot informed ATC that the turbulence decreased and stated that it was light, and additionally informed ATC that the turbulence was encountered between FL300 and FL270.

Figure 1 illustrates the selected Aircraft positions over Cairo and Nicosia FIRs, and the approximate location of the turbulence encounter which was about 100 NM southwest OLBA.

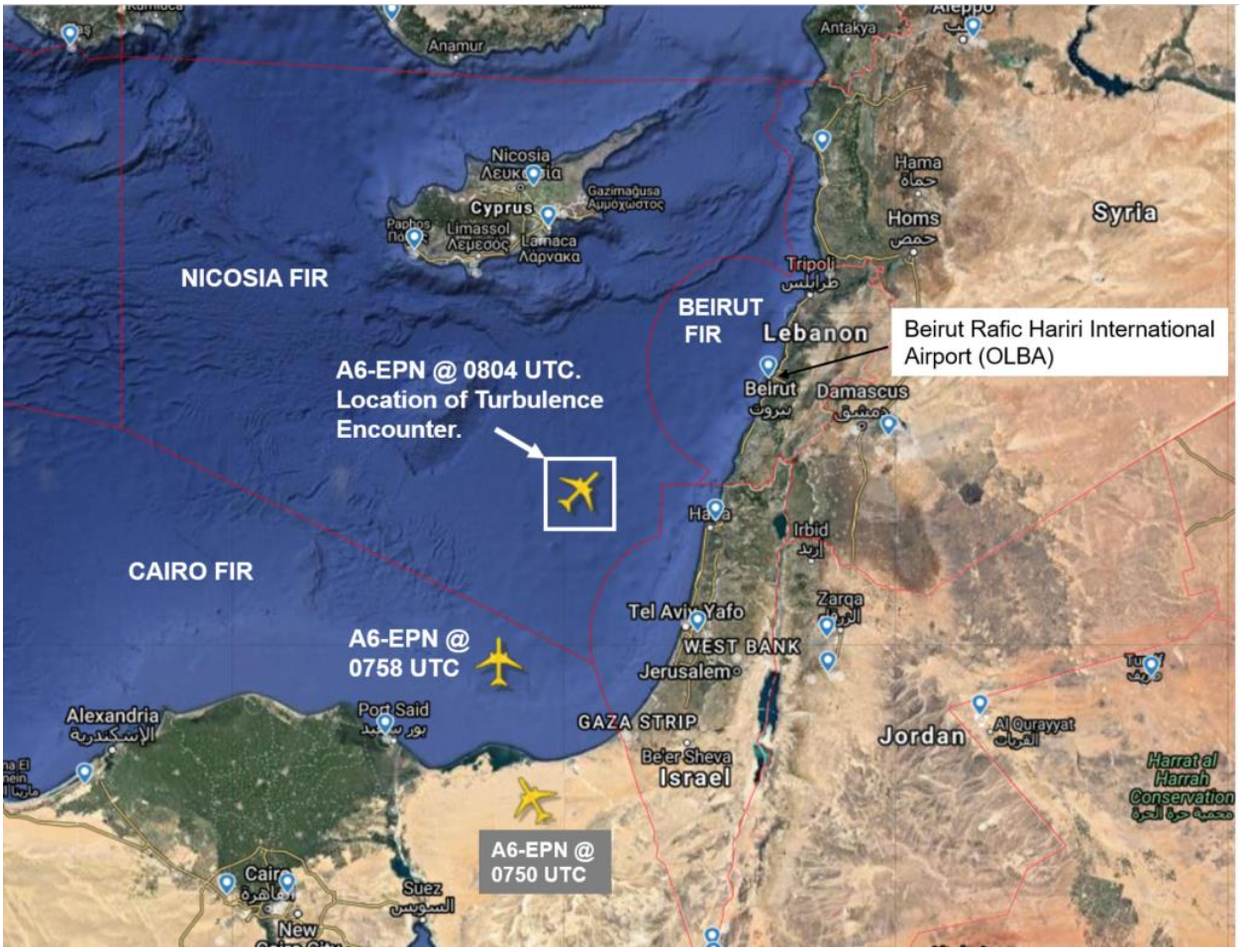

Figure 1. Aircraft approximate location at the turbulence encounter at 0804 UTC

The Commander stated that there was "No weather nor threat of red speckled patterns returns were displayed in either navigation display before or during the time of the event.", and he believes that the turbulence was due to clear air turbulence. The flight crew classified the turbulence as moderate to severe.

On passing approximately FL240, the flight crew contacted the cabin manager to assess the situation in the cabin, and the assessment revealed that two passengers and four cabin

crewmembers sustained minor injuries, whereas one passenger sustained right foot fracture serious injury.

The Commander stated that the Aircraft continued to encounter light turbulence for the remainder of the flight to OLBA. The Aircraft landed uneventfully at 0840.

The engineering team at OLBA performed the required severe turbulence inspection, and no damage was found. The Aircraft was released for service accordingly.

1.2 Injuries to Persons

Table 1 illustrates 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	4	2	6
None	2	8	47	57
TOTAL	**2**	**12**	**50**	**64**

1.2.1 Injuries to crewmembers

Four cabin crewmembers sustained minor injuries. After the turbulence, they were able to resume normal duties.

1.2.2 Injuries to passengers

Two passengers sustained minor injuries. A third passenger sustained right foot bone fracture serious injury.

1.3 Damage to Aircraft

There was no damage to the Aircraft.

1.4 Other Damage

There was no other damage reported.

1.5 Personnel Information

The flight and cabin crewmembers' rosters indicated that they all in compliance with the duty time requirements of the *Civil Aviation Regulations* of the United Arab Emirates.

The licenses and medical certificates of the flight and cabin crewmembers were valid at the time of the Accident.

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

1.6 Aircraft Information

1.6.1 General data

The Aircraft was Boeing 777-31HER wide-body, extended range, powered by two General Electric GE90-115B engines. It was configured for 360 passengers (8 first-class, 42 business and 310 economy) seats. The Aircraft was manufactured in June 2016 under serial number 42333.

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 Weather radar system

The Aircraft was fitted with Rockwell Collins weather radar, model WRT-2100 V2 MultiScan and MultiScan ThreatTrack, that consisted of receiver–transmitter unit, antenna, and control panel.

The Multiscan weather radar (WXR) collects data from different scans and merge the information into a total weather picture. When operating in the automatic mode (AUTO), multiple radar scans at pre-selected tilt angles detect short, mid, and long range weather. The *flight crew operating manual (FCOM)* instructs pilots that tilt and gain inputs are not required.

The weather radar data processing enables the radar display to project thunderstorm tops within 5,000 ft altitude of the aircraft until it no longer poses a danger. If the growing cell is predicted to intersect the aircraft flight level, an alert consisting of a field of red speckles surrounded by a red box is issued. This function is available out to 60 NM.

With the WXR selected to the recommended automatic mode (AUTO), the two-level turbulence detection displays severe turbulence with solid magenta areas while light-to-moderate turbulence areas display with magenta dots. According to the *FCOM,* turbulence is classified "severe" if alteration aircraft loads of 0.3 g or greater, and "light" for 0.2 g or less.

With the WXR selected to manual mode (MAN), the enhanced weather analysis features will not be available with the exception of severe turbulence detection. Ground clutter suppression and automatic tilt control are also not available in the manual mode.

The manufacturer of the weather radar stated that the automatic mode of the WXR is generally recommended for providing the flight crew with the most relevant and useful weather detection information. The *FCOM* states that it is not necessary to switch to manual mode during descent.

The precipitation severity of the radar returns of the clouds are indicated by the colors displayed on the navigation display. The most intense areas are displayed in red, less intense in amber, and the lowest in green.

Turbulence can be sensed by the WXR only when there is sufficient precipitation, and in such case it will be displayed in magenta. Clear air turbulence[1] cannot be sensed by the WXR since there will be no particles to reflect the radar transmitted.

Control of the weather radar is performed by the flight crew through weather control panel located on rear side of the cockpit center console, and weather information is displayed on each of the navigation displays. The weather radar manufacturer stated that except for windshear events, the system does not have the capability to record any weather that is displayed on the navigation display.

1.7 Meteorological Information

1.7.1 En-route significant weather

The high-level prognostic SIGWX included in the OFP forecasted occasional embedded CBs with tops of 30,000 ft affecting Nicosia and Beirut FIRs, and forecasted moderate turbulence with occasional severe turbulence between FL380 and FL280. The northern hemisphere jet stream was at FL370 with speeds of up to 170 kt close to latitude 32.0N. Figure 2 illustrates the

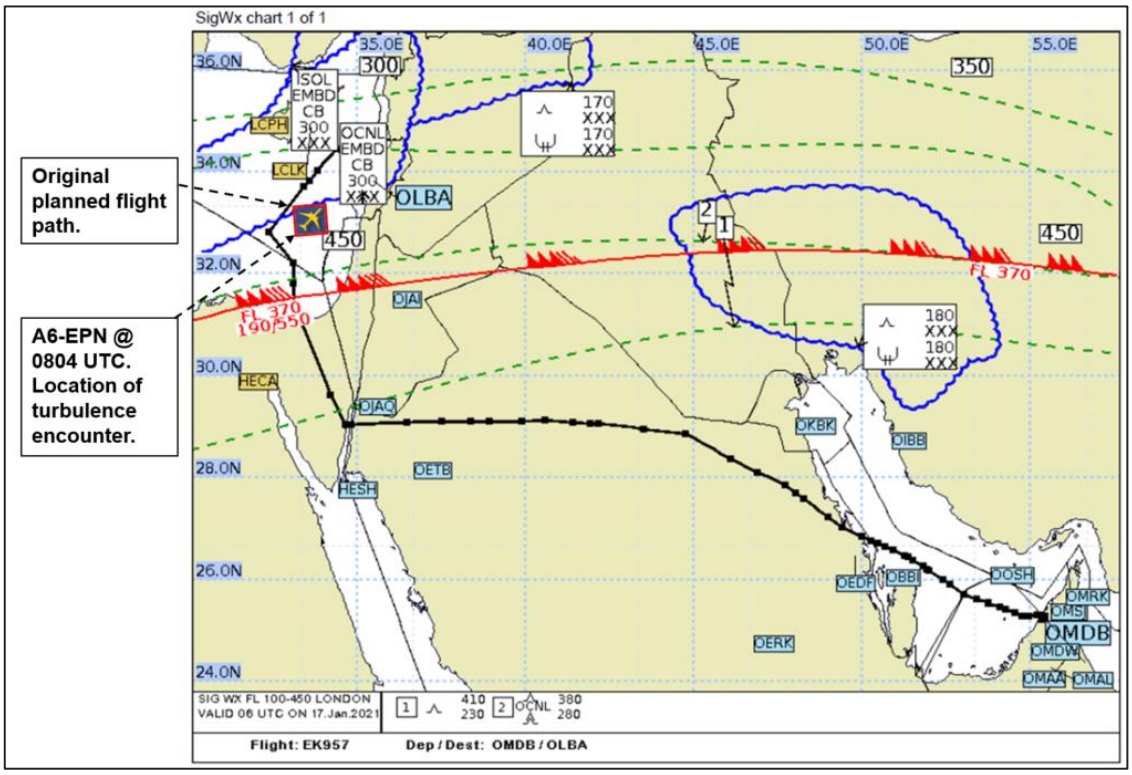

Figure 2. High-level prognostic significant weather chart over NICOSIA and BEIRUT FIR [Source:

[1] Clear air turbulence (CAT) is defined as "sudden severe turbulence occurring in cloudless regions that causes violent buffeting of aircraft." This term is commonly applied to higher altitude turbulence associated with wind shear. The most comprehensive definition is high-altitude turbulence encountered outside of convective clouds. This includes turbulence in cirrus clouds, within and in the vicinity of standing lenticular clouds and, in some cases, in clear air in the vicinity of thunderstorms. Generally, though, CAT definitions exclude turbulence caused by thunderstorms, low-altitude temperature inversions, thermals, strong surface winds, or local terrain features. (Source - Federal Aviation Administration (FAA) Advisory Circular (AC) No. 00-30C.)

high-level prognostic SIGWX and the approximate position of the Aircraft where the turbulence was encountered.

There was no en-route weather advisory significant meteorological information (SIGMET) in the briefing package when the OFP was downloaded by the flight crew at 0146 UTC.

1.7.2 Satellite multispectral image

A satellite image captured at 0800 on 17 January 2021 was provided to the Investigation by the UAE National Center for Meteorology (NCM). The image depicted the weather in Nicosia FIR and surrounding area over the Mediterranean (figure 3). Lightning strikes are indicated in red and yellow colors. The blue box in figure 3 illustrates the area that the Aircraft traversed when turbulence encounter occurred. The NCM assessment of the satellite image estimated that the cloud tops appear to be near to FL300 at the time of the turbulence encounter.

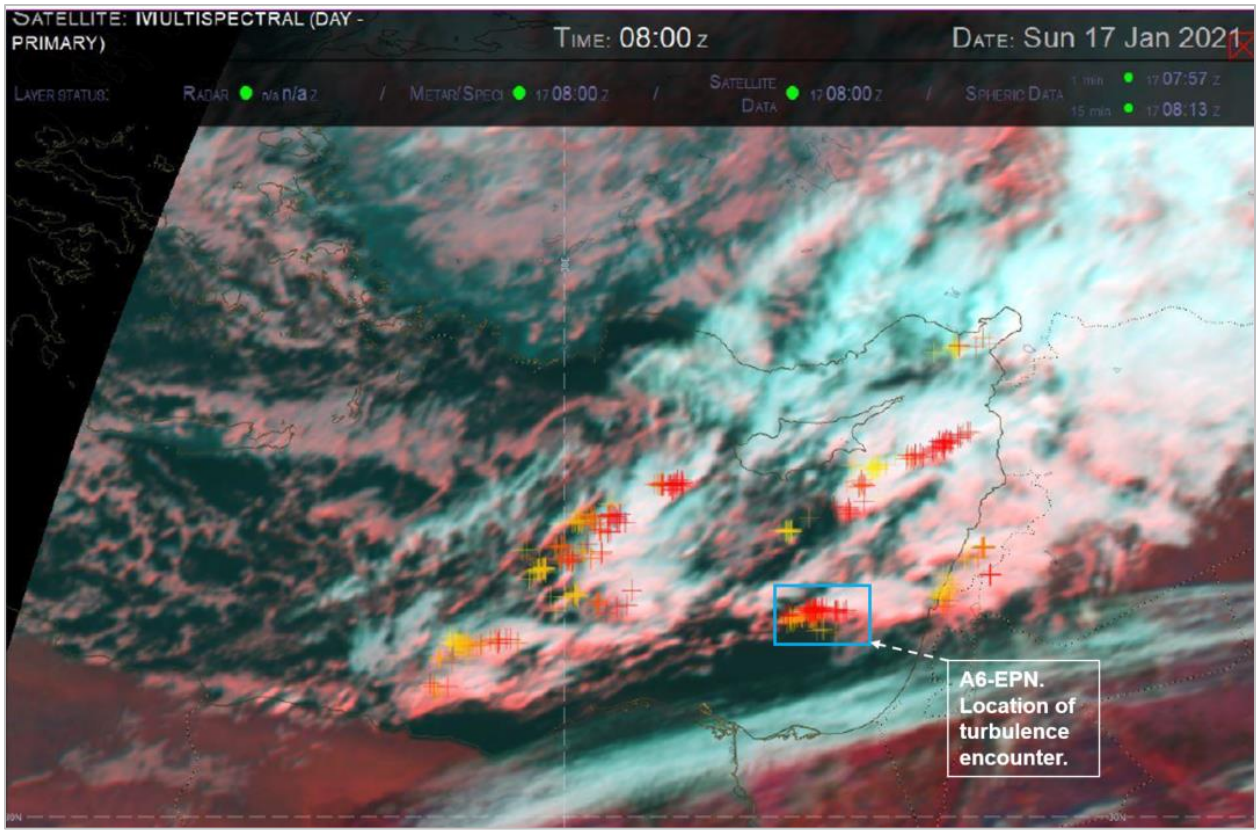

Figure 3. Satellite multispectral image over NICOSIA, Cyprus [Source: UAE NCM]

1.7.3 Nicosia FIR significant meteorological information

The Larnaca International Airport (LCLK) meteorological watch office (MWO) was the responsible weather station for issuing SIGMET reports for weather in Nicosia FIR.

The MWO had issued eight SIGMET on 17 January 2021. The first was issued at 0120 and the eighth at 1345. The following are SIGMET 1 to SIGMET 4 issued between 0120 and 0530:

(a) SIGMET 1: at 0120 UTC

"WSCY31 LCLK 170120
LCCC SIGMET 1 VALID 170130/170530 LCLK-
LCCC NICOSIA FIR OCNL SEV TURB FCST BTN FL260 AND FL390
S PART NC"

SIGMET 1 issued at 0120 UTC, for the period from 0130 to 0530 UTC, indicated occasional (OCNL) severe turbulence (SEV TURB), forecasted (FCST), [No location is stated], between flight levels 260 and 390 (BTN FL260 AND FL390), [movement or expected movement is not stated] South of (S [PART) – ICAO Annex 3 does not describe PART], with no change expected (NC) in intensity.

(b) SIGMET 2: at 0140 UTC

"WSCY31 LCLK 170140
LCCC SIGMET 2 VALID 170200/170600 LCLK-
LCCC NICOSIA FIR EMBD TS OBS AND FCST TOP FL300 MOC ENE
40KT NC"

SIGMET 2 issued at 0140 UTC, for the period from 0200 to 0600 UTC indicated embedded thunderstorm (EMBD TS) that was observed and forecasted (OBS AND FCST), [No location is stated], with tops at flight level of 300 (TOP FL300) [MOC is not described in ICAO Annex 3] [moving] east northeast (ENE) at 40 knots (40KT) with no change in intensity.

(c) SIGMET 3: at 0515

"WSCY31 LCLK 170515
LCCC SIGMET 3 VALID 170530/170930 LCLK-
LCCC NICOSIA FIR OCNL SEV TURB FCST BTN FL260 AND FL390
S OF N3430 NC"

SIGMET 3 issued at 0515 UTC, for the period from 0530 to 0930 UTC, indicted occasional (OCNL), severe turbulence (SEV TURB), forecasted (FCST) between flight level 260 and 390 (BTN FL260 and FL390), with location south of (S OF) latitude coordinates N3430 (N3430), with no change expected (NC) in intensity.

(d) SIGMET 4: at 0530

"WSCY31 LCLK 170530
LCCC SIGMET 4 VALID 170600/171000 LCLK-
LCCC NICOSIA FIR EMBD TS OBS AND FCST TOP FL300 MOV ENE
40KT NC"

SIGMET 4 issued at 0530 UTC, for the period from 0600 to 1000 UTC, indicated embedded thunderstorm (EMBD TS), that was observed and forecasted (OBS AND FCST), [No location is stated], with tops at flight level of 300 (TOP FL300), moving (MOV) east northeast (ENE), at 40 knots (40KT), with no change expected (NC) in intensity.

1.7.4 Beirut FIR significant meteorological information

The Beirut International Airport (OLBA) MWO weather station (responsible for issuing SIGMET for Beirut FIR) issued five SIGMETs on 17 January 2021, with the first issued at 0310 and the fifth at 2050. The following are SIGMET 1 and SIGMET 2 issued before and during the flight:

(a) SIGMET 1: at 0310 UTC

"WSLB31 OLBA 170310

OLBA SIGMET 1 VALID 170315/170715 OLBA-
OLBA BEIRUT FIR TS OBS AND FCST OVER OLBA FIR TOP ABV FL240
INTSF"

SIGMET 1 issued at 0310 UTC, for the period from 0315 to 0715 UTC, indicated thunderstorm (TS) observed (OBS) and forecasted (FCST), affecting over (OVER) Beirut FIR (OLBA FIR), with tops (TOP) above (ABV) flight level 240 (FL240), and intensifying (INTSF).

(b) SIGMET 2: at 0610 UTC

"WSLB31 OLBA 170610
OLBA SIGMET 2 VALID 170730/171130 OLBA-
OLBA BEIRUT FIR EMBD TS OBS AND FCST OVER OLBA FIR TOP ABV FL240 MOV NE INTSF"

SIGMET 2, issued at 0610 UTC, for the period from 0730 to 1130 UTC, indicated thunderstorm (TS) observed (OBS) and forecasted (FCST), affecting over (OVER) Beirut FIR (OLBA FIR), with tops (TOP) above (ABV) flight level 240 (FL240), with a direction of moving northeast (MOV NE), and intensifying (INTSF).

1.8 Aids to Navigation

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

1.9 Communications

The flight crew communications with the Nicosia area control center (ACC), while in Nicosia FIR, were normal. The Investigation was able to retrieve the communication transcript between EK957 and Nicosia ACC prior to and after the turbulence encounter.

1.10 Aerodrome Information

Not applicable to this Investigation.

1.11 Flight Recorders

The Aircraft was fitted with a flight data recorder (FDR), a cockpit voice recorder (CVR), and a quick access recorder (QAR).

The downloaded data from the FDR and QAR were valid and provided to the Aircraft manufacturer for analysis[2]. Appendix A of this Report illustrates EK957 turbulence flight recorder data plot. The CVR recording for the occurrence was overwritten.

[2] In addition to an evaluation of the recorded parameters, the Aircraft manufacture conducted a kinematic consistency (KinCon) analysis on the provided FDR data. The Aircraft manufacturer stated "KinCon is used to correct inherent inconsistencies often present in recorded data from different sensors because of the presence of instrumentation biases due to misalignment in inertial measurements, contamination of pressure and altitude measurements due to flow separation, and sample rate differences. The KinCon process uses integrated acceleration data to ensure basic inertial parameters such as altitude, ground speed, and drift angle are compatible and comparable. The output is a kinematically consistent set of data with acceleration biases removed, allowing calculations of wind data and other parameters."

The FDR data indicated that prior to commencing descent from FL360, the autopilot was engaged at the vertical navigation (VNAV) pitch mode and lateral navigation (LNAV) roll mode, while the autothrottle was engaged at speed (SPD) mode. The computed airspeed was approximately 275 kt with the Aircraft gross weight of 199,418 kg. The winds were out of the west southwest at a speed of approximately 170 kt and the Aircraft was flying north northeast, maintaining a magnetic heading of approximately 32 degrees.

When the Aircraft commenced descent, at 0800:55, the autothrottle mode transitioned from SPD mode to IDLE mode and the thrust levers reduced towards IDLE.

Significant turbulent conditions were recorded by the FDR during the period from 0803:56 to 0806:56, while the Aircraft was descending from pressure altitude 29,200 to 22,200 ft. During this period, the Aircraft encountered more energized turbulence between 0804:20 and 0805:08 (28,400 to 25,500 ft pressure altitude). With the Aircraft location near coordinates latitude 32.85685 degrees north and longitude 33.85498 degrees east, a peak negative vertical load factor of (-)0.49 g was recorded at 0804:41 followed approximately one second later by a peak positive vertical load factor of (+)1.72 g.

The FDR recorded another more energized turbulence was encountered during the period from 0805:29 and 0805:46 (24,620 to 23,860 ft). A peak positive vertical load factor of (+)1.71 g, and peak lateral load factor of (-)0.19 g (to the left) and +0.35 g (to the right).

The Aircraft manufacturer calculation of the wind determined that the horizontal wind reduced by approximately 49 kt over a period of time of approximately eight seconds from a peak of about 132 kt at 0804:29 to about 83 kt while the wind direction remained close to 250 degrees. Calculated wind speed and direction align closely with FDR recorded wind data in regions of unaccelerated flight. The calculated vertical wind speed was near zero feet per second on average reached a maximum of approximately +41 feet per second (updraft) at about 0805:31, and a minimum of approximately -24 feet per second (downdraft) at about 0805:40.

1.12 Wreckage and Impact Information

The Aircraft landed uneventful at Beirut International Airport.

1.13 Medical and Pathological Information

There was no evidence that a psychoactive substance, physiological or psychological factors, or incapacitation may have affected the performance of the flight crew.

1.14 Fire

There was no sign of fire.

1.15 Survival Aspects

The cabin manager (purser) stated that after receiving notification that the Commander wanted the cabin secured early in preparation for the landing, had started to make the passenger announcement for securing the cabin when the flight crew announced “Cabin crew take your seats”.

Several cabin crewmembers stated that the Aircraft entered into a severe turbulence in less than one minute from the flight crew’s request from the cabin crew to take their seats.

Some of the unsecured cabin crewmembers and passengers were lifted off and jolted by the effect of negative g-loads generated by the turbulence. After passing approximately FL240, the flight crew contacted the cabin manager to assess the situation in the cabin who found that two passengers and four cabin crewmembers sustained minor injuries, whereas one passenger sustained serious injury.

Due to the phase of flight, ground medical services was contacted after the Aircraft landed.

Figure 4 illustrates the location of the injured passengers (in blue) and cabin crewmembers (in red). The passenger who sustained the serious injury was standing next to the lavatory adjacent to L4 door (blue symbol 3 in figure 4), and close to seat 37C.

Referring to figure 4, the minor injuries were as follows:

(1) Passenger (indicated by blue symbol 1) was seated and suffered an impact to the knee.

(2) Passenger (indicated by blue symbol 2) was occupying the washroom adjacent to R4 passenger door. This passenger sustained a bloody nose and swollen bruised leg.

(3) The cabin crewmember (indicated by red symbol 1) stated that she was securing the galley equipment adjacent to L2A door when the severe turbulence started. The turbulence caused her to be lifted off her feet causing her to impact surrounding cabin furnishings.

(4) The cabin crewmember (indicated by red symbol 2) stated that he was on the left side of the cabin adjacent to passenger seat 24 preparing the cabin for landing. When the severe turbulence started, he was lifted off his feet a few times causing him to hit his knee with the armrest of the passenger seat.

(5) The cabin crewmember (indicated by red symbol 3) stated that she was assisting another passenger to secure an infant and child at seat 38G. The cabin crewmember was holding the child and was unable to secure herself during the turbulence. Together with the child, the cabin crew was forcefully lifted off her feet impacting the ceiling by her head.

(6) The cabin crewmember (indicated by red symbol 4) stated that he was securing the cabin and requesting passengers to take their seats. After hearing the flight crew announcement for “cabin crew to take your seats”, he was unable to secure himself to a passenger seat, 47D, and during the turbulence was forcefully lifted off the seat impacting the ceiling by his head.

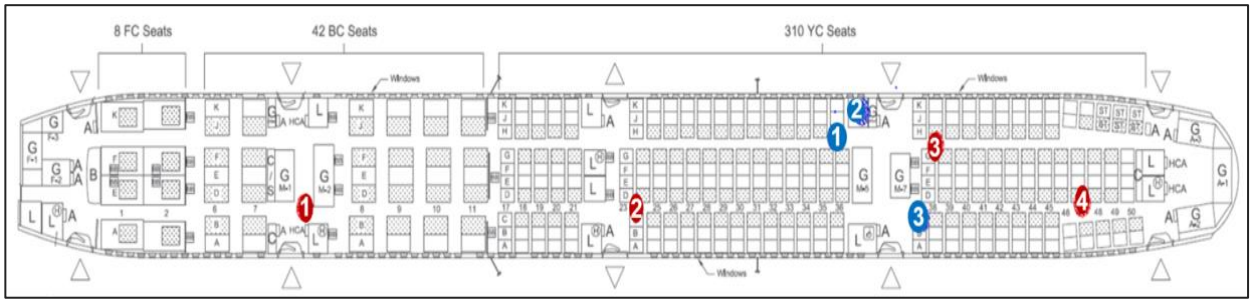

Figure 4. Aircraft cabin layout with the location of the injured occupants

1.16 Tests and Research

The Aircraft manufacturer provided an analysis of the atmospheric conditions affecting the Aircraft. This included using satellite images, atmospheric sounding, radio frequency lighting triangulation, convective available potential energy (CAPE in J/kg), and Ellrod Index.

The Ellrod Index was used for diagnosing the turbulence potential due to wind shear along the jet streams and weather fronts. For Nicosia and Beirut FIRs, the Ellrod Index is illustrated in figure 5[3]. The location where the Aircraft encountered the turbulence is marked by a red circle. The turbulence encounter occurred in a region with an Ellrod value of above 30 next to an area with a value above 50, which the Aircraft manufacturer stated was capable of producing strong turbulence. The computer models indicated that the jet stream peaked in strength just to the south and above the Aircraft location, reaching speeds of about 170 kt.

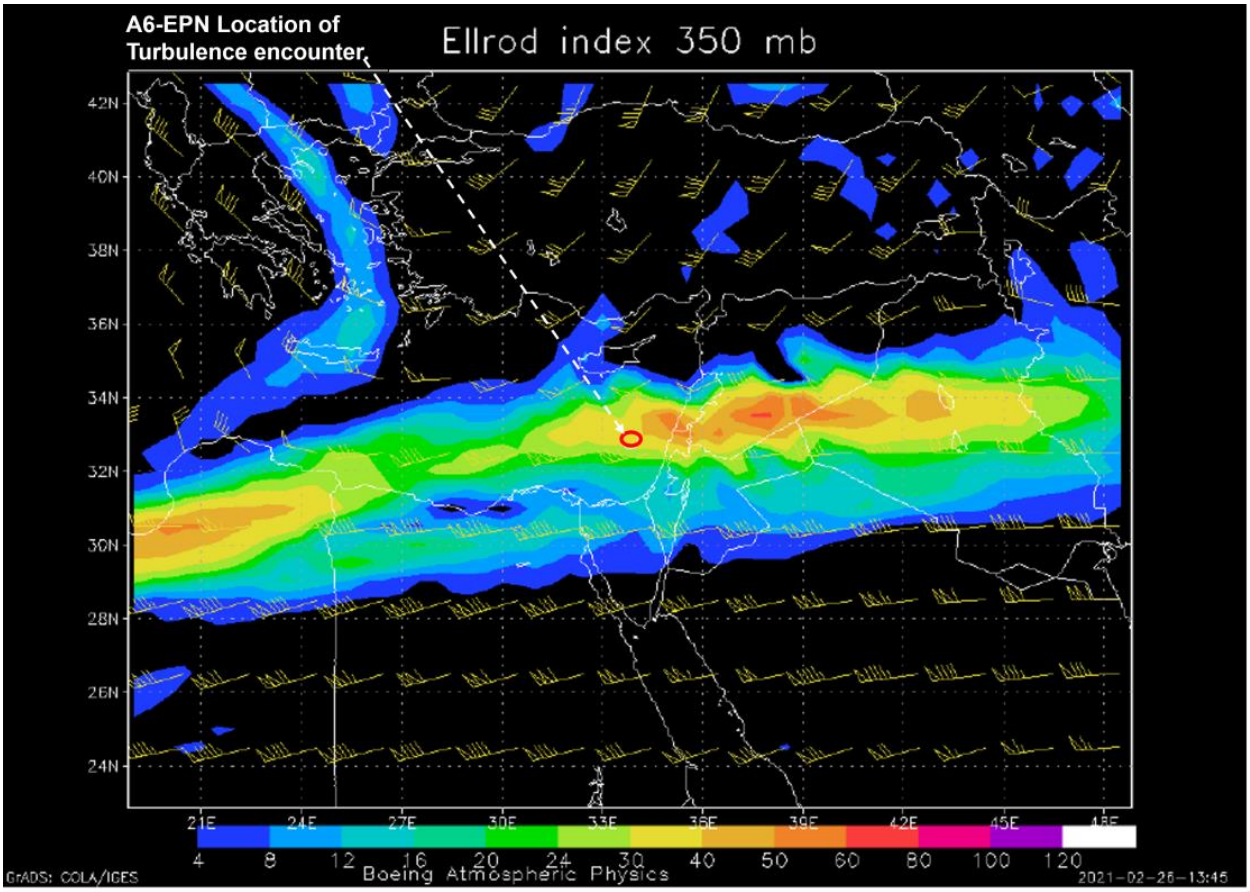

Figure 5. Ellrod Index for NICOSIA and BEIRUT FIR [Copyright of The Boeing Company]

The following summary is based on the Aircraft manufacturer analysis of the atmospheric conditions that existed during the time the Aircraft was in Nicosia FIR:

[3] This map is derived from short-term forecast model data which the Aircraft manufacturer stated it usually quite accurate

- The Aircraft was passing through significant jet stream shear on the northern underside of a jet core;
- Wind speed was changing both vertically and horizontally as the Aircraft descended out of and passed north of the 170 kt jet stream;
- The Aircraft flew just above, or perhaps through the tops of a line of thunderstorms at the same time.

1.17 Organizational and Management Information

1.17.1 The Operator's seatbelt policy

In accordance with the Operator's *Operations Manual* (*OM*), "The Commander must ensure that each person on board is briefed before take-off on how to fasten and unfasten his safety belt/harness. This is normally a video briefing and is part of the cabin crew pre-take-off activities."

The Operator's policy requires that the flight crew must switch the seatbelt sign ON, and all passengers shall fasten seatbelt in the following conditions:

> "a. Whilst taxiing, during take-off and for all phases of flight below 10,000 ft AAL [above aerodrome level].
>
> b. When at or below 25,000 ft AAL [above aerodrome level] during the descent. However, should holding or a delayed arrival be anticipated, switching on the Seat Belt sign may be delayed to 10,000 ft AAL at the latest.
>
> c. In turbulent conditions or when turbulent conditions are expected.
>
> d. At the Commander's discretion or as required by abnormal or emergency procedures.
>
> 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 restrain device, which is acceptable to the Authority."

1.17.2 Turbulence

As part of the Operator's annual flight and cabin crew recurrent training, as well as the safety and emergency procedures (SEP) training, theoretical and practical instructions include duties to be undertaken in the event of turbulence.

The Operator's *OM* provides criteria and guidance for the flight crew for assisting the crew in classifying the severity of turbulence (light, moderate, or severe), and the relevant crew actions.

For in-flight turbulence, the Operator's policy contained in the *OM* stated:

> "When turbulence is expected during the flight, the Flight Crew must advise the Cabin Crew how much time is available to secure the cabin, the level of turbulence and the expected duration." The *OM* states that the cabin manager (purser) is to ensure that the "cabin crew has secured all passengers" and "if required, the cabin crew are also secured".

1.17.3 Flight dispatch – Flight watch

According to the Operator's *Flight Dispatch Manual*, the responsibility of the flight dispatch department is to achieve the safest and most economical flight event possible. The *Flight Dispatch Manual* stated "All available means of data collection, distribution and communication

shall be used in the most efficient way to provide flight crew with relevant information and guidance for decision making." The flight watch responsibility of the dispatcher includes passing information to the flight crew of en-route severe weather.

The Operator's flight dispatch uses the flight watch application "Weather Services International (WSI)" Fusion, which is an International Business Machines Corporation (IBM) intelligent alerting system. The flight watch system continuously monitors conditions to identify and promptly notify operations personnel of potential problems that warrant attention and possible action.

The monitoring and alerting feature of the WSI Fusion includes en-route SIGMET. For SIGMET that intersects an aircraft flight path, the dispatcher initial flight watch action is to verify that the location and affected flight levels of the SIGMET impact the route of the flight. Any alerts generated by WSI Fusion requires the dispatcher to notify the applicable flight affected within the time specified by the Operator's policy. The Investigation was informed that this timing is normally five to ten minutes after the alert was generated.

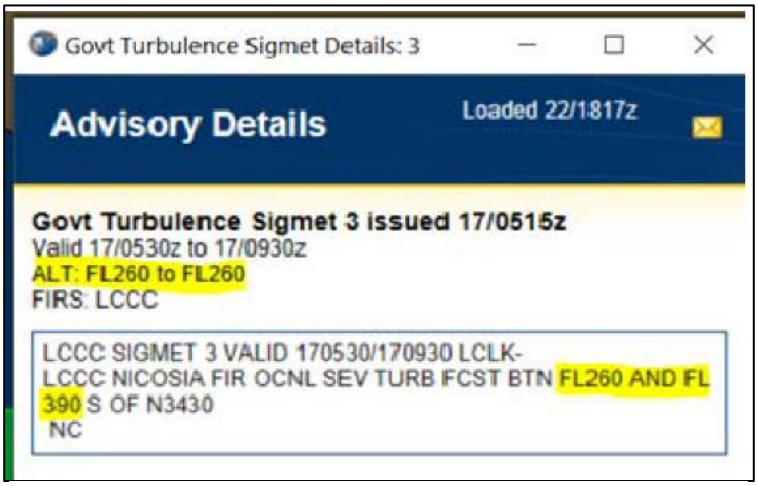

Figure 6. WSI Fusion advisory details of LCLK SIGMET 3 on 17 May 2021

As illustrated in figure 6, the Operator provided the Investigation with a copy of the flight EK957 'Advisory Details' that was automatically generated by WSI Fusion based on SIGMET 3 issued by LCLK MWO office. The flight level (highlighted in yellow) noted on the advisory under the heading of 'ALT' states "FL260 to FL260" whereas within the contents of the SIGMET, "FL260 AND FL390" is stated.

At 0805 an alert was generated by WSI Fusion when the Aircraft was passing FL260. At 0809 an Aircraft Communications Addressing and Reporting System (ACARS) message was sent to the Aircraft based on the WSI Fusion alert generated. The ACARS message was received electronically by the flight crew after the Aircraft landed at OLBA. The Commander stated "…after landing via ACARS indicating OCNL [occasional] SVR [severe] turbulence between FL250 [FL260] and FL390. This SIGMET was held back by ACARS because it was sent during a critical phase of flight."

The Operator's sterile cockpit policy required holding messages transmitted to the aircraft via ACARS by the fight dispatch in order to avoid distracting the crew during critical phases of flight. The held messages are then displayed after the sterile cockpit conditions finish. According to the policy, no ACARS messages were to be displayed in the cockpit during the twenty minutes that precedes the estimated time of arrival (ETA) plus three minutes elapsed time after selecting parking brakes on (ETA – 20 to parking brakes ON + 3). The Investigation could not determine the ETA entered to the Aircraft flight management system (FMS) and thus was unable to determine the ACARS message transmission hold-time.

1.18 Additional Information

1.18.1 Specifications related to SIGMET information

Annex 3 to the Convention on International Civil Aviation – *Meteorological Service for International Air Navigation*, Chapter 7.1 – *SIGMET Information*, states:

> "7.1.1 SIGMET information shall be issued by a meteorological watch office and shall give a concise description in abbreviated plain language concerning the occurrence or expected occurrence of specified en-route weather and other phenomena in the atmosphere that may affect the safety of aircraft operations, and of the development of those phenomena in time and space.

Annex 3, Appendix 6 – *Technical Specifications Related to SIGMET and AIRMET Information, Aerodrome Warnings and Wind Shear Warnings and Alerts*, states:

> "1.1.1 The content and order of elements in a SIGMET message shall be in accordance with the template shown in Table A6-1A."

Annex 3, Table A6-1A – *Template for issuance of SIGMET and Airmen's Meteorological Information (AIRMET) Messages*, describes the sequential information required. The mandatory part of every message is annotated by the letter 'M', and the information that should be conditionally included whenever applicable is annotated by the letter 'C'. SIGMET examples are included in Annex 3 explaining the contents of Table A6-1A and there are 'Notes' numbered 1 to 34 associated with the contents of Table A6-1A.

In summary, when reporting significant weather, the SIGMET format requires the elements description to be as per the following sequential order:

- The Phenomenon – Example: OCNL [occasional] TS [thunderstorm] or SEV TURB [severe turbulence];
- OBS [observed] or FCST [forecasted];
- Location - referring to latitude and longitude in degrees and minutes. Example: S [south] OF S4530;
- Level - Flight level or altitude. Example: BTN [between] FL260/FL390);
- Movement - Movement or expected movement (direction and speed). Example: MOV [moving] SE [southeast];
- Changes in intensity changes - Expected changes in intensity. Example: NC [no change].

The European Union Aviation Safety Agency (EASA) regulations (EU) No. 2020/469, effective 14 February 2020, states:

> "**MET.TR.250 SIGMET** - (a) The content and order of elements in a SIGMET shall be in accordance with the template shown in Appendix 5A."

Further detailed guidance and examples of SIGMET format can be found in ICAO EUR DOC 014 – *EUR SIGMET and AIRMET Guide*, issued on 25 September 2020, which states:

> "Meteorological Watch Office [MWO]– responsibilities and procedures related to SIGMET and AIRMET
>
> 2.2.1. SIGMET and AIRMET information is issued by the MWO in order to provide timely warning for the occurrence or expected occurrence of specified en-route

weather phenomena, affecting the safety of the flight operations in the MWO's Area Of Responsibility (AOR). SIGMET and AIRMET provide information concerning the location, extent, intensity and expected evolution of the specified phenomena.

…

2.2.8. In preparing SIGMET and AIRMET information, the MWOs have to strictly follow the format determined in Annex 3 (detailed format description is provided in Appendix 6, Table A6-1A of Annex 3). SIGMET and AIRMET should be issued **only** for those weather phenomena listed in Annex 3 and only when specified criteria for intensity and spatial extent are met."

1.19 Useful or Effective Investigation Techniques

The Investigation was conducted in accordance with the *Legislation*, *Air Accident and Incident Investigation Regulation* of the United Arab Emirates, and the AAIS approved policies and procedures, and in conformity with 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. The Aircraft systems, including the weather radar, and engines performed as designed.

2.2 Flight Crew Performance

The flight crew were aware of the forecasted significant weather prevailing in the destination airport (Beirut International Airport “OLBA”), as well as in Nicosia and Beirut flight information regions (FIR). The forecasted weather was contained in the operational flight plan (OFP) that was downloaded by the flight crew before departure from Dubai International Airport (OMDB).

As part of the preflight brief, the Commander briefed the cabin crew of the forecasted weather prevailing in Nicosia and Beirut FIRs, and that turbulence was expected during descent to OLBA.

The flight was operated in adherence to the Operator’s standard operating procedures (SOP) which required the flight crew to effectively utilize the weather radar system. During the flight, the flight crew maintained the weather radar at the automatic mode (AUTO) for most of the time and briefly selected manual mode (MAN) at the top of descent (at FL360).

Communication with Nicosia air traffic control (ATC) (area control center “ACC”) prior to the top of descent indicated that both ATC controller and the flight crew were aware of the significant weather. The initial decision taken by the flight crew was to request clearance for deviation from ATC as the weather radar was indicating cumulonimbus (CB) clouds approximately 80 nautical miles (NM) ahead of the Aircraft. ATC advised the flight crew to head directly to a new waypoint (ZALKA) which the Commander accepted and accordingly selected 042 degrees heading which would take the Aircraft south of the CB.

The flight crew were comfortable with the new heading especially as the weather returns on the navigation display indicated that the cloud cells were 50 to 120 NM to the north of the flight path.

In anticipation of turbulence during descent, the Commander turned the seatbelt sign to ON at FL360. The flight crew stated that, during the first three minutes of descent, there was no weather radar indication on the navigation display of any significant weather (including red speckles) or any cloud formation and precipitation that may form a kind of threat that would have warranted focused attention.

When the severe clear air turbulence started, the flight crew immediately implemented the SOP by arresting overspeed by use of the speedbrakes, and selecting the appropriate autopilot modes.

The Investigation concludes that the flight crew operational decisions were appropriate based on the available information. This included monitoring and settings of the weather radar, the OFP significant weather chart, communication with Nicosia ATC and the Aircraft automation.

The actions taken by the flight crew prior to the descent and during turbulence was in accordance with the Operator's SOP including reporting the turbulence to ATC.

2.3 Aircraft performance

The Aircraft weather radar was designed to detect cloud formation and turbulence containing precipitation and provide the flight crew with the necessary information on the navigation displays. The flight crew, who were competent in the operation of the weather radar, confirmed that during the descent from FL360, there were no areas of threat to the Aircraft as the radar returns did not display alerting colors (red, red speckles, amber, green or magenta).

The analysis of the flight data recorder (FDR) data indicated that the Aircraft systems were functioning as designed throughout all flight phases.

The Investigation concludes that the Aircraft systems operated as designed. When the Aircraft entered the turbulent atmosphere that resulted in the significant turbulence that lasted for about three minutes, together with the Aircraft autopilot and autothrottle automation and the flight crew inputs, the Aircraft control was maintained and the computed airspeed was kept below the maximum operating speed (VMO).

2.4 Meteorological Conditions

The significant meteorological conditions that were prevailing in Nicosia and Beirut FIRs were forecasted in the high-level prognostic significant weather (SIGWX) chart contained in the operational flight plan for flight EK957.

The forecast included information about occasional embedded CB with tops of 30,000 ft, and moderate turbulence, increase to severe occasionally, between FL380 and FL280, approximately north of latitude N32.0 where the Nicosia and Beirut FIR are within. In addition, the Aircraft flight path and altitude within Nicosia FIR took it just north of the northern hemisphere jet stream which was forecasted at FL370 with maximum speeds of up to 170 kt and close to latitude N32.0.

On the day of the flight, because of the prevailing significant weather phenomena of thunderstorms and severe turbulence, both MWO of LCLK and OLBA had published significant weather information (SIGMET) at regular intervals of approximately every four hours.

The significant weather affecting the FIR of Nicosia was confirmed by the satellite multispectral image captured at 0800 on 17 January 2021, which also indicated areas of lightening close to the Aircraft flight path in Nicosia FIR.

When the EK957 flight crew communicated with Nicosia ATC for the first time (at approximately 0757 UTC), SIGMET 3 and 4 reports issued by LCLK MWO were in effect for Nicosia FIR. Of the two SIGMET reports, SIGMET 3 provided information about severe turbulence forecast that would take place during the period from 0530 to 0930, between FL260 and FL390, south of latitude coordinates N3430, and no change was expected over the 4-hours period. The FDR data confirmed that the first region of severe turbulence that the Aircraft encountered occurred between pressure altitude 28,400 ft and 25,500 ft, close to N32.857 latitude coordinates which was almost similar to the SIGMET 3 forecasted flight level and location.

The turbulent atmosphere that the Aircraft entered was due to the sudden reduction in the horizontal wind magnitude of approximately 49 kt, which resulted in significant variation of g-loads on all axes. The calculated vertical wind speed was mostly near zero feet per second on average.

The Investigation concludes that the significant turbulent atmosphere the Aircraft transverse during the descent was due to the change in wind speeds that was most likely influenced because of the jet stream and the thunderstorms which was affecting Nicosia FIR. Based on the analysis and calculation performed by the Aircraft manufacturer, the influence of the jet stream and thunderstorm that were present in the area was capable of producing significant turbulence. Most likely, the turbulence encounter was associated with clear air turbulence.

2.5 Flight Watch

The Operator employed a software application that continuously monitors SIGMET existing in the vicinity of an aircraft flight path. The application, named Weather Services International (WSI) Fusion, provides the flight dispatch department with information about en-route severe weather which shall be timely disseminated to flight crews. For the EK957 flight, no alerts were forwarded to the flight crew before the Aircraft encountered the turbulence.

The WSI Fusion application reads the content of a SIGMET and then issues an 'Advisory Details' message. In the heading of this message, the affected altitude 'ALT' is extracted from the original SIGMET message.

On 17 January 2021, SIGMET 3, issued by LCLK MWO, contained forecast of occasional severe turbulence between FL260 and FL390. The SIGMET message was received by WSI Fusion interface. However, the text in the message was formatted as "BTN FL260 AND FL390" which was not a recognized format to the WSI Fusion. Consequently, the WSI Fusion could not compile the message and stopped analyzing the SIGMET information at the characters "FL260" because the free text 'AND' was not compatible with the software programming language. The standard format SIGMET of Annex 3 to the Chicago Convention utilizes slash '/' marks to separate the flight levels.

When SIGMET 3 was issued at 0515 by LCLK MWO, the Aircraft was in the cruise phase in Jeddah FIR, and was about 2 hours 43 minutes away from Nicosia FIR entry point. However, an alert was only generated at 0805 when the Aircraft flight level reached FL260 during the descent in Nicosia FIR and matched with the flight level recognized by the WSI Fusion.

When the ACARS alert message was eventually transmitted to the Aircraft at 0809, the sterile cockpit policy was in effect, therefore it was kept on-hold and not displayed to the flight crew. Even if the flight crew had access to the ACARS message, at the time the alert was transmitted it would not have benefited the flight crew because the Aircraft had already passed the flight level stated on the alert message.

All SIGMET reports should be given timely attention and communicated to flight crews that can assist their decision making process. When a hazard of turbulence is not timely alerted and avoided, mitigation opportunities of risk of severe jolts, structural damage to aircraft, airspeed fluctuations and huge variation in g-loads, and the consequent injury to crewmembers and passengers, will be compromised.

The Operator demonstrated that the WSI Fusion could assist the flight dispatchers to perform effective flight watch. However, similar to LCLK MWO SIGMET 1 and SIGMET 3, it can be expected that meteorological weather stations when issuing a SIGMET may make mistakes or have differences that is not accordance with ICAO Annex 3 Table A6-1A recommendations. The hazard of the blend between the software application and changes with SIGMET data format was not identified by the Operator as a risk and accordingly mitigations were not put in place. The

Operator's safety management system (SMS) did not identify the probability of format incompatibility.

The Investigation recommends that the Operator enhance the training of the dispatchers on the software application employed to read and compile SIGMET using this occurrence as evidence-based training. The Investigation also recommends that the Operator considers the risk of SIGMET format incompatibility in the safety management system and take mitigation actions to prevent miss-compilation by the Weather Services International (WSI) Fusion application.

2.6 Survival Aspects - Cabin Safety

The cabin crew were aware that turbulence was anticipated as they were briefed by the Commander during the preflight and prior to the start of the descent to OLBA. The Commander had stated that before top of descent, the cabin crew were advised to secure the cabin early due to possible turbulence during descent.

The Operator's policy regarding the seatbelts was to be turn signs to ON at 25,000 ft and below but not lower than 10,000 ft above aerodrome level (AAL). For flight EK957, and because of the anticipated threat of turbulence, the Commander decided to turn the seatbelt sign ON much earlier (before the start of the descent from FL360).

The flight crew commenced descent from FL360 after about 34 seconds from illuminating the seatbelt sign. During descent, at about 3 minutes 35 seconds from seatbelt sign illumination, the Aircraft started to encounter moderate turbulence almost simultaneous to the Copilot commanding the cabin crew, through passenger announcement, to take their seats. Soon after, the Aircraft entered into the first significant severe turbulence which lasted for about 48 seconds. After approximately 21 seconds, the Aircraft entered into another area of severe turbulence which lasted for about 15 seconds. In all, the Aircraft was flying for about three minutes in a volume of turbulent air that varied between moderate and severe.

The Operator's policy required the flight crew whenever a turbulence is expected during the flight to advise the cabin crew about: The time available for securing the cabin; the level of turbulence severity; and the time the turbulence will last. Because the flight crew of EK957 were most likely not expecting the Aircraft to encounter severe clear air turbulence within three minutes into descent, the Commander did not command the cabin crewmembers to take their seats when he switched the seatbelt sign to ON. At the time the Copilot called the cabin crew to take their seats, all cabin crewmembers were still securing the cabin and passengers, and several passengers were still not seated and secured.

The FDR recorded vertical g-forces resulting from the turbulence were significant enough to cause the unsecured cabin crewmembers and passengers to be lifted off their feet and impact the cabin furnishings. It is noted that of the seven occupants injured, five were in the aft cabin including the passenger who was seriously injured.

The Investigation concludes that the flight and cabin crews were aware of the threat of turbulence during the descent. However, because the weather radar, as designed, did not predict the clean air turbulence during the Aircraft descent, the flight crew were not warranted to command the cabin crew to take their seats as per the Operator's policy. However, it is possible that if the Commander was aware of the additional significant meteorological information (SIGMET 3) issued by LCLK MWO, similar to his decision to prepare the cabin early at the top of descent, there would have been urgency in having all passengers and cabin crewmembers securely seated before the descent was started.

2.7 SIGMET Format

On 17 January 2021, LCLK MWO issued eight SIGMET containing the necessary significant weather information of thunderstorm and severe turbulence prevailing in Nicosia FIR. However, the SIGMET format used by the MWO had differences to what was recommended in the templates of Annex 3 and EU regulation No. 2020/469.

The format of LCLK MWO SIGMET 1 report missed mentioning the location of turbulence that should have come after the “SEV TURB FCST [severe turbulence forecast]” information, whereas the location was mentioned after the range of flight levels in SIGMET 3. Similarly, SIGMET 2 and 4 did not state the location of the embedded thunderstorm (EMBD TS).

Both SIGMET 1 and 3 reports stated the range of turbulence-affected flight levels as “BTN FL260 AND FL390” which was not in accordance with the internationally recognized format that uses the slash ‘/’ mark to separate the flight levels. Consequently, the WSI Fusion could not compile the message and stopped analyzing the SIGMET information at the characters “FL260” because the free text ‘AND’ was not compatible with the software programming language.

Examples of the format of SIGMET that is available in ICAO EUR DOC 014 - EUR SIGMET and AIRMET Guide, dated 25 September 2020, also require that MWOs “strictly follow the format determined in Annex 3 Appendix 6, Table A6-1A.”

In order to mitigate risks of miss-compilation of SIGMET reports, LCLK MWO is recommended to revise the format of the SIGMET and align it with the templates contained the recommendations as stated in Annex 3 - *Meteorological Service for International Air Navigation,* Appendix 6, Table A6-1A and Appendix 5A to the European Union Aviation Safety Agency (EASA) regulation (EU) No. 2020/469, effective 14 February 2020.

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.

3.2.2 Findings relevant to the flight crew

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

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

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

(d) The flight crew were competent with the operation of the Aircraft weather radar.

3.2.3 Findings relevant to the cabin crew

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

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

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

3.2.4 Findings relevant to flight operations

(a) The flight was conducted in accordance with the Operator’s operational procedures.

(b) The operational flight plan (OFP) significant weather chart, SIGWX, contained forecasted occasional embedded cumulonimbus clouds with tops of 30,000 ft, and moderate turbulence, increasing to severe turbulence occasionally, between FL380 and FL280 affecting Nicosia FIR.

(c) During the Aircraft descent within Nicosia FIR, the weather radar returns displayed on the navigation display did not indicate any precipitation that could form a threat to the Aircraft.

(d) The flight crew turned the seatbelt sign to ON at the top of descent, 3 minutes 35 seconds before the Aircraft entered into the turbulence.

(e) During the turbulence, the Aircraft autopilot and autothrust remained engaged, and the Aircraft remained controllable.

(f) The Aircraft operational limitations were not exceeded during the turbulence encounter.

(g) The cabin crew were still securing the cabin and passengers when the severe turbulence started.

(h) Several cabin crew and passengers were unsecured when the Aircraft entered into the severe turbulence.

3.2.5 Findings relevant to the Operator

(a) The Weather Services International Fusion application (WSI Fusion) applied by the Operator's flight dispatch department did not generate a timely alert for SIGMET 3 report issued by Larnaca International Airport (LCLK) Meteorological Watch Office (MWO).

(b) The flight dispatch transmitted Aircraft Communications Addressing and Reporting System (ACARS) message containing the SIGMET 3 information was transmitted after the Aircraft had entered into the turbulence.

3.2.6 Findings relevant to the Larnaca International Airport (LCLK) Meteorological Watch Office (MWO)

(a) On 17 January 2021, eight SIGMET were issued by LCLK MWO for the weather prevailing in Nicosia flight information region (FIR).

(b) Two SIGMET (SIGMET 1 and 3) contained information related to forecasted severe turbulence between FL260 and FL390 in Nicosia FIR.

(c) The format of the SIGMET issued by LCLK MWO contained differences to the recommendations contained in Annex 3 and the European Union Aviation Safety Agency (EASA) regulation (EU) No. 2020/469 templates.

3.3 Causes

The Air Accident Investigation Sector determines that the cause of the Accident was the significant vertical g-forces imposed on the Aircraft because of severe clear air turbulence, which caused an unsecured passenger to be forcefully lifted off her feet and impact cabin furnishings resulting in her right foot fracture serious injury.

3.4 Contributory Factors

(a) The influence of the jet stream and thunderstorm in the flight path area was significant enough to produce severe turbulence.

(b) The flight crew decision making lacked critical information contained in SIGMET 3 issued by LCLK MWO (covering the period from 0530 to 0930) which forecasted severe turbulence between FL260 and FL390, south of latitude N3430.

(c) The format of the SIGMET issued by LCLK MWO was different from the recommendations contained in ICAO Annex 3 and EU regulation No. 2020/469 such that the Weather Services International Fusion application (WSI Fusion) applied by the Operator's flight dispatch department did not generate a timely alert for SIGMET 3 report issued by LCLK MWO.

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 of the United Arab Emirates (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

On 17 January 2021, SIGMET 3, issued by Larnaca International Airport (LCLK) Meteorological Watch Office (MWO) contained information forecasting occasional severe turbulence between FL260 and FL390 and was accepted by the Operator's Weather Services International (WSI) Fusion application. However, because the content of the affected flight levels in the message contained the free text 'AND' and not the standard '/', WSI Fusion application stopped analyzing the SIGMET information at FL260. Even though SIGMET 3 was issued at 0515 on 17 January 2021, there was no alert generated until at about 0805 when the Aircraft flight level had matched the flight level on the SIGMET of FL260. When SIGMET 3 was issued by LCLK at 0515, the Aircraft was in cruise within Jeddah flight information region (FIR) and about 2 hours 43 minutes before entering Nicosia FIR.

All SIGMET reports should be given timely attention and communicated to the flight crew that can assist their decision-making process. When a hazard of turbulence is not timely alerted and avoided, mitigation opportunities of risk of severe jolts, structural damage to aircraft, airspeed fluctuations and huge variation in g-loads, and the consequent injury to crewmembers and passengers, will be compromised.

In response, the Operator advised the Investigation that the following safety actions will be implemented:

> "
>
> (a) A case study of the events surrounding the EK957 flight will be included into the next dispatch recurrent training cycle.
>
> (b) A safety risk assessment of SIGMET format incompatibility and mitigation actions to ensure the timely and accurate provision of SIGMET information to flight crew."

4.2.2 Safety actions taken by Larnaca International Airport Meteorological Weather Office

A standard template for SIGMET format is contained in Annex 3 to the Chicago Convention - *Meteorological Service for International Air Navigation*, Appendix 6, Table A6-1A, and in the European Union Aviation Safety Agency (EASA) regulation (EU) No. 2020/469, Appendix 5A.

LCLK MWO issued eight SIGMET on 17 January 2021 with the necessary significant weather information of thunderstorm and severe turbulence prevailing in Nicosia FIR. However, the SIGMET format used by LCLK MWO was not in conformance with the internationally-recognized template contained in Annex 3 and EU regulation No. 2020/469.

In response, the Cyprus MWO advised the Investigation that the following safety actions will be implemented:

"

- Informed Aviation Forecasters about the issue through internal communication;
- issue relevant instructions in the online Forecaster's continuity book
- perform a corrective action (COR) to the Operation Manual OPR-S-10 (paragraph 3.2.1) as presented below:

SIGMET messages shall be prepared in abbreviated plain language using approved ICAO abbreviations and numerical values of self-explanatory nature supplemented. ~~If suitable approved abbreviations are not available, by the vocabulary of a national language, taken with its usual meaning in aviation.~~ SIGMETs (including their cancellations) must be issued as described in Appendix 3.

The change is compliant with the (EU) 2020/469 regulation."

4.3 Final Report Safety Recommendations

4.3.2 Safety recommendation addressed to the International Civil Aviation Organization (ICAO)

The flight crew of EK957 were not aware of SIGMET 3 issued by the MWO of LCLK that contained information forecasting occasional severe turbulence between FL260 and FL390. This was mainly due to the Operator's Weather Services International (WSI) Fusion application did not generate a timely alert because the content of the affected flight levels in SIGMET 3 contained the free text 'AND' and not the standard '/'. Thus, WSI Fusion application stopped analyzing the SIGMET information at FL260. Even though SIGMET 3 was issued at 0515 on 17 January 2021, there was no alert generated until at about 0805 when the Aircraft flight level had matched the flight level on the SIGMET of FL260.

LCLK MWO issued eight SIGMET on 17 January 2021 with the necessary significant weather information of thunderstorm and severe turbulence prevailing in Nicosia FIR. However, the SIGMET format used by LCLK MWO was not in conformance with the internationally-recognized template contained in Annex 3 and EU regulation No. 2020/469. This safety issue was addressed to LCLK MWO by the AAIS Investigation and they advised that the necessary safety actions will be put in place to avoid reoccurrence.

The Investigation did not review other MWO to determine if there were similar issues with conformance with the standard template for SIGMET format contained in Annex 3 to the Chicago Convention - *Meteorological Service for International Air Navigation*, Appendix 6, Table A6-1A, and in the EU regulation No. 2020/469, Appendix 5A.

ICAO is recommended to:

SRxx/2021

Engage EASA and the ICAO meteorology subject matter experts for the purpose of addressing the significance of MWO standardizing the publication of SIGMET to avoid incompatibility with airlines software application employed to read SIGMET.

Appendix A – EK957 Turbulence Flight Recorder Data Plot