

Aircraft Accident Report

In-Flight Turbulence Encounter

Korean Air

A330-300, HL7710

187 Miles East of Tianjin Binhai International Airport

February 13 2013



June 2014



AVIATION AND RAILWAY ACCIDENT INVESTIGATION BOARD

This aircraft serious incident report has been prepared in accordance with the Article 25 of the Aviation and Railway Accident Investigation Act of the Republic of Korea.

According to the provisions of the Article 30 of the Aviation and Railway Accident Investigation Act, it is stipulated;

The accident investigation shall be conducted separately from any judicial, administrative disposition or administrative lawsuit proceedings associated with civil or criminal liability.

And in the Annex 13 to the Convention on International Civil Aviation, Paragraphs 3.1 and 5.4.1, it is stipulated as follows:

The sole objective of the investigation of an accident or incident shall be the prevention of accidents and incidents. It is not the purpose of the activity to apportion blame or liability. Any investigation conducted in accordance with the provision of this Annex shall be separate from any judicial or administrative proceedings to apportion blame or liability.

Thus, this investigation report shall not be used for any other purpose than to improve aviation safety.

In case of divergent interpretation of this report between the Korean and English languages, the Korean text shall prevail.

Aircraft Accident Report

Aviation and Railway Accident Investigation Board. 187 Miles East of Tianjin Binhai International Airport, Turbulence Encounter at 23,600 feet, Korean Air, A330-300, HL7710, 13 February 2013. Aircraft Accident Report ARAIB/AAR-1302. Sejong Special Self-governing City, Republic of Korea.

The Aviation and Railway Accident Investigation Board (ARAIB), Republic of Korea, is a government organization established for independent investigation of aviation and railway accident, and the ARAIB conducts accident investigation in accordance with the provisions of the Aviation and Railway Accident Investigation Act of the Republic of Korea and Annex 13 to the Convention on International Civil Aviation.

The objective of the investigation by the ARAIB is not to apportion blame or liability but to prevent accidents and incidents.

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In-Flight Turbulence Encounter

- Operator : Korean Air
- Manufacturer : Airbus
- Type : A330-300 (Transport Aircraft)
- Registration Mark : HL7710
- Location : 187 miles east of Tianjin Binhai International Airport
(38° 33 ' 6.12 " N, 121° 15 ' 17.3 " E)
- Date & Time : 13 February 2013, about 11:47 (KST¹⁾)

Synopsis

On 13 February 2013, about 11:47 KST, an Airbus 330-300, HL7710, operated by Korean Air, encountered turbulence, 187 miles east of Tianjin Binhai International Airport, between Incheon and Tianjin at 23,600 ft. The aircraft was a regularly scheduled international passenger flight from Incheon International Airport to Tianjin Binhai International Airport in accordance with the Korean Aviation Act.

The Aviation and Railway Accident Investigation Board (ARAIB) was notified of HL7710's accident by the operator on 15 February 2013, about 19:00 and forwarded the notification of the accident to the Civil Aviation Administration of China (CAAC), but as the CAAC delegated the accident investigation to the ARAIB on 18 February 2013, the ARAIB conducted the investigation.

Aboard the airplane were two pilots, 10 flight attendants, and 223 passengers, and two flight attendants were seriously injured due to this accident.

The ARAIB determines the probable cause of this accident as follows: HL7710 encountered turbulence during cruising flight since fluid vortices occurred in the vicinity of a strong jet stream, and at this time, flight attendants tidying the galley fell to the floor and got seriously injured.

1) Unless otherwise indicated, all times in this report are Korean Standard Time (KST, UTC+9) based on 24-hour clock.

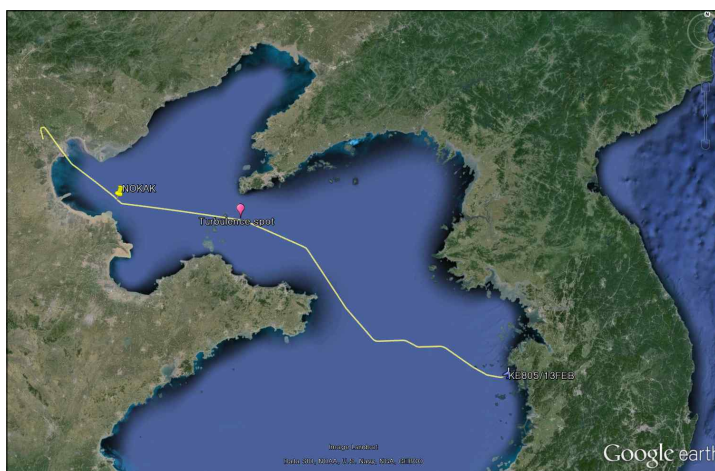
1. Factual Information

1.1 History of Flight

On 13 February 2013, about 10:54, an Airbus 330-300, HL7710 (hereafter referred to as "HL7710"), operated by Korean Air, took off from Incheon International Airport, en route to Tianjin Binhai International Airport (hereafter referred to as "Tianjin Airport"). HL7710 made first contact with Dalian air traffic control (ATC) about 11:18 while cruising at 23,600 ft. During its first contact, HL7710 reported to Dalian ATC that it deviated six miles to the right of its intended flight route at 27,500 ft, and Dalian ATC instructed HL7710 to descend to 21,650 ft about 11:24.

Dalian ATC instructed HL7710 to fly direct to NOKAK²⁾, then to CG³⁾ about 11:46. HL7710 encountered light to moderate turbulence near abeam of MAKNO at 23,600 ft at 11:47:16. After hitting turbulence, the captain immediately turned on the fasten seatbelt sign chime twice.

The captain reduced the engine thrust, following the first officer's advice that speed was increasing. At 11:47:38, HL7710 requested Dalian ATC to allow its descent and was cleared. At 11:49:00, HL7710 reached 21,650 ft at which the atmosphere got stable. Passengers were not injured by turbulence, but two flight attendants were seriously injured. HL7710 landed at Tianjin Airport at 12:34:09.



[Figure 1] Point of Turbulence Encounter

2) NOKAK: N38 25.00, E118 55.00.

3) CG: NDB (339.0), a point on airway A326, 3.5 NM southwest of Tianjin Binhai International Airport (N39 4.8, E117 23.04).

1.1.1 Captain's Statement

According to HL7710's flight plan, light to moderate turbulence was forecast. During a joint briefing, referring to preflight information⁴⁾, the captain briefed that light turbulence was forecast between Incheon and Tianjin, and that clear-air turbulence was predicted due to flight across the jet stream⁵⁾ although SIGMET (Significant Meteorological Advisory) did not indicate it. Therefore, he gave a briefing on turbulence response procedures⁶⁾.

When the atmosphere got stable after takeoff from runway 33L, the fasten seatbelt sign was off. The captain set a weather radar display at a range of 80 NM, while the first officer at a range of 160 NM. The weather radar was tilted between -0.5 and -1.0 degrees, and the ground clutter was set to be shown at the top of the navigation display.

At first, flight altitude was planned at 32,100 ft, but as there were a lot of airplanes en route to China, HL7710 was cleared for 27,500 ft initially, then 23,600 ft. The atmosphere en route was stable, and there were no clouds during all flight legs, but the haze was present at the legs including Tianjin Airport.

HL7710 was cleared for flight direct to NOKAK, then CG. While flying to CG, the aircraft initially encountered light turbulence near abeam of MAKNO at 310 kts, and thus, the captain turned on the fasten seatbelt sign. After a little while, as HL7710 hit moderate turbulence, he turned on the fasten seatbelt sign chime twice and reduced airspeed to approximately 280 kts.

4) During a joint briefing, flight information including weather conditions is provided on the Internet website.

5) Jet streams are fast flowing, narrow air currents found above the troposphere or near the tropopause. In general, they are westerly winds thousands of km long, hundreds of m wide, and several km thick. The WMO defines winds at more than 30 m/sec as jet streams. Severe turbulence is found especially in the center portion of jet streams, so pilots should use caution.

6) In case of light turbulence, the fasten seatbelt sign is on. In case of moderate turbulence, the fasten seatbelt sign chimes are on twice, and flight attendants sit down.

The captain asked the first officer to make a request for a descent from Dalian ATC, and after cleared, descended to 21,650 ft. At the start of the descent, vibration began to subside, then ceased. There was no PIREP (pilot weather report). He handed flight control over to the first officer and went out to check the cabin, which revealed that the purser had her ankle sprained.

1.1.2 First Officer's Statement

Visual meteorological conditions were prevailed, and HL7710 was flying at 23,600 ft. The atmosphere was stable without clouds. When the aircraft encountered light turbulence, the captain turned on the fasten seatbelt sign, and about 10 to 15 seconds later, when encountering moderate turbulence, he again immediately turned on the fasten seatbelt sign twice.

As the airspeed increased, the first officer gave the advice on speed to the captain, and he set thrust at "ATHR- Speed-Thr idle (FMA)" to reduce speed at 02:47:44. After cleared for a descent by Dalian ATC, HL7710 descended to a new altitude, at which the atmosphere got stable. The first officer got aware of the purser's injury through the captain's interphone conversation with the cabin.

According to the flight plan, moderate turbulence was forecast at about 25,000 to 50,000 ft, which was an area south of HL7710's flight route. Yet, there was possibility that turbulence was present due to jet steams.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Other
Fatal	0	0	0
Serious	2	0	0
Minor/None	0/10	0/223	0
Total	2	223	0

1.3 Damage to Aircraft

There was no damage to the aircraft.

1.4 Other Damage

There was no other damage.

1.5 Personnel Information

1.5.1 The Captain

The captain (male, age 44) held a valid air transport pilot license⁷⁾, A330 type rating⁸⁾, a first-class airman medical certificate⁹⁾, an aeronautical radio operator license¹⁰⁾, and a level 4 ICAO English Proficiency Certificate¹¹⁾.

The captain had accumulated 7,432 total flight hours, including 922 hours as pilot-in-command and 344 hours in A330 airplanes, 272 hours of which were as pilot-in-command. He had flown 175 and 56 hours in the last 90 and 30 days, respectively.

The captain completed his recurrent ground training and recurrent simulator training on 12 December 2012 and 16 December 2012, respectively. He passed his proficiency check and line check on 17 December 2012 and 31 August 2012, respectively.

The captain spent holidays in his home town on 10 - 11 February 2013. He

7) License No.: 11-002560 (acquired on 13 Apr. 2001).

8) Acquisition Date: 3 Jul. 2012.

9) Issue No.: 111-1501 (valid until 31 Aug. 2013).

10) License No.: 98-34-8-0035 (Issued on 23 Feb. 2004).

11) Expiration Date: 8 Nov. 2013.

returned home about 15:00, had dinner and took a rest, and went to bed about 22:00. On the day of the accident, he got up about 06:00, went to work about 08:00, and prepared for flight. He did not drink any alcohol or take any illegal medication in the 24 hours before the accident flight and was in good health.

1.5.2 The Flight Officer

The first officer (male, age 42) held a valid air transport pilot license¹²⁾, A330 type rating¹³⁾, a first-class airman medical certificate¹⁴⁾, an aeronautical radio operator license¹⁵⁾, and a level 6 ICAO English Proficiency Certificate.

The first officer had accumulated 13,780 total flight hours, including 2,360 hours in A330 airplanes. He had flown 173 and 44 hours in the last 90 and 30 days, respectively.

The first officer completed his recurrent ground training and recurrent simulator training on 2 October 2012 and 3 October 2012, respectively. He passed his proficiency check and line check on 4 October 2012 and 10 July 2012, respectively.

The first officer stayed in Mumbai on 10 - 11 February 2013, and arrived at Incheon International Airport on KE656 (Mumbai-Incheon) on 12 February 2013, about 13:00. He had dinner and took a rest, and went to bed about 22:00. On the day of the accident, he got up about 06:00 and went to work about 08:10. He did not drink any alcohol or take any illegal medication in the 24 hours before the accident flight and was in good health.

12) License No.: 3793 (acquired on 2 Jun. 2009).

13) Acquisition Date: 28 May 2009.

14) Issue No.: 111-1328 (valid until 31 May 2013).

15) License No.: 09-34-2-0673 (issued on 17 Dec. 2009).

1.6 Aircraft Information

HL7710 was manufactured¹⁶⁾ by the French Airbus Co. on 18 July 2002. Its engine was manufactured¹⁷⁾ by the US Pratt & Whitney Co.. Korean Air leased the aircraft as a secondhand from Duria Aviation Limited on 4 October 2002 and registered it as a transport aircraft. Since then, the airline has operated the aircraft.

HL7710 had 29,910 flight hours, and the TSN (time since new) of engine #1 and #2 was 51,345 and 29,753 hours, respectively. HL7710 held a valid airworthiness certificate¹⁸⁾, operating limitations specification¹⁹⁾, radio station license²⁰⁾, and aircraft registration certificate²¹⁾.

1.6.1 Weight and Balance

The weight and balance data of HL7710 is shown in [Table 1], and the aircraft was operated within the permissible range of weight and balance²²⁾.

Takeoff Weight (TOW): 169,860 kg	Max. Takeoff Weight (MTOW): 217,700 kg
Zero Fuel Weight (ZFW): 149,085 kg	Max. Zero Fuel Weight (MZFW): 169,000 kg
Landing Weight (LDW): 160,244 kg	Max. Landing Weight (MLDW): 179,000 kg
Takeoff Fuel: 20,775 kg	Trip Fuel: 9,616 kg
Payload: 21,768 kg	Center of Gravity (C.G.): 31.6% MAC

[Table 1] Weight and Balance Data

16) Serial No.: 0490.

17) Engine #1 Model No.: PW4168A, Serial No.: P733374CN, Manufacture Date: 28 Apr. 1997.

Engine #2 Model No.: PW4168A, Serial No.: P733540CN, Manufacture Date: 17 Apr. 2002.

18) Certificate No.: AS07102 (issued on 21 Sep. 2012).

19) Specification No.: ASOL07102 (issued on 29 Dec. 2009).

20) License No.: 46-2002-10-0000018 (issued on 06 Jul. 2002).

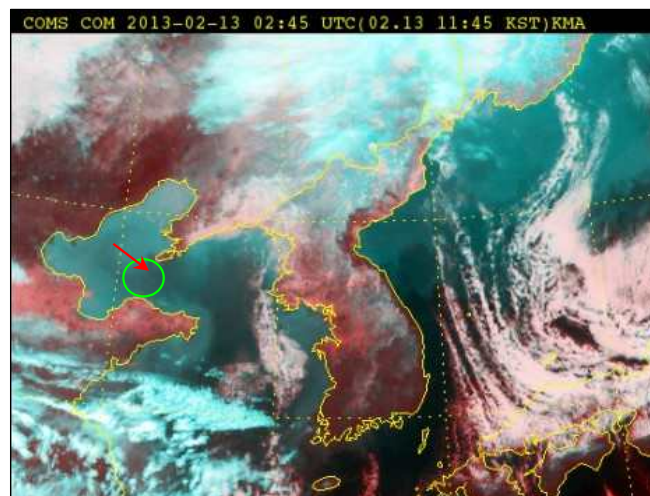
21) Certificate No.: 2008-082 (issued on 16 May 2008).

22) 16 - 39.3%

1.7 Meteorological Information

1.7.1 Korea Meteorological Administration

The Korea Meteorological Administration (KMA)'s weather satellite image taken on 13 February 2013, at 11:45, showed that, as shown in [Figure 2], the haze was present at the point where HL7710 encountered turbulence (arrow), but that cumulonimbus clouds²³⁾ and clouds with precipitation were not present.

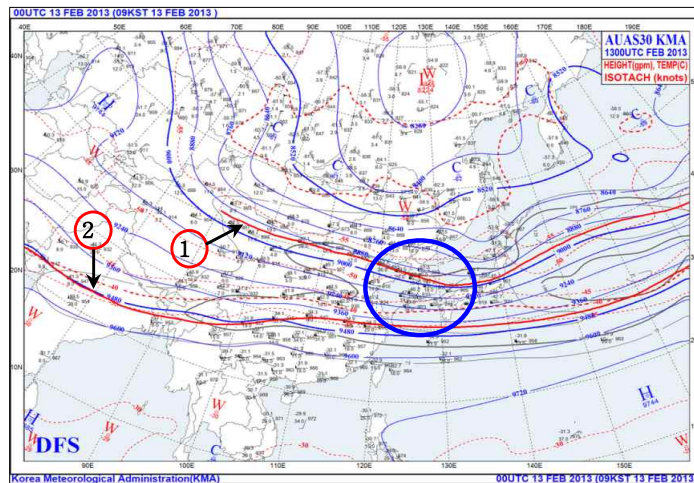


[Figure 2] Satellite Image at 11:45

The KMA produces an upper-level weather chart²⁴⁾ based on the weather observed at the ground level every 12 hours. The chart in [Figure 3] below, which was valid from 09:00, 13 February 2013, indicated two strong jet streams depicted as two red solid lines, ① and ②. One jet stream, ①, was extended from the Chinese continent to the Yellow Sea to central Korean Peninsula to Japan, and the other one, ②, was extended in the same manner south of ①.

23) Cumulonimbus is a dense towering vertical cloud, top of which touches the stratosphere. As it forms due to a temperature difference between the ground and the air, it frequently forms in the summer with a high temperature difference.

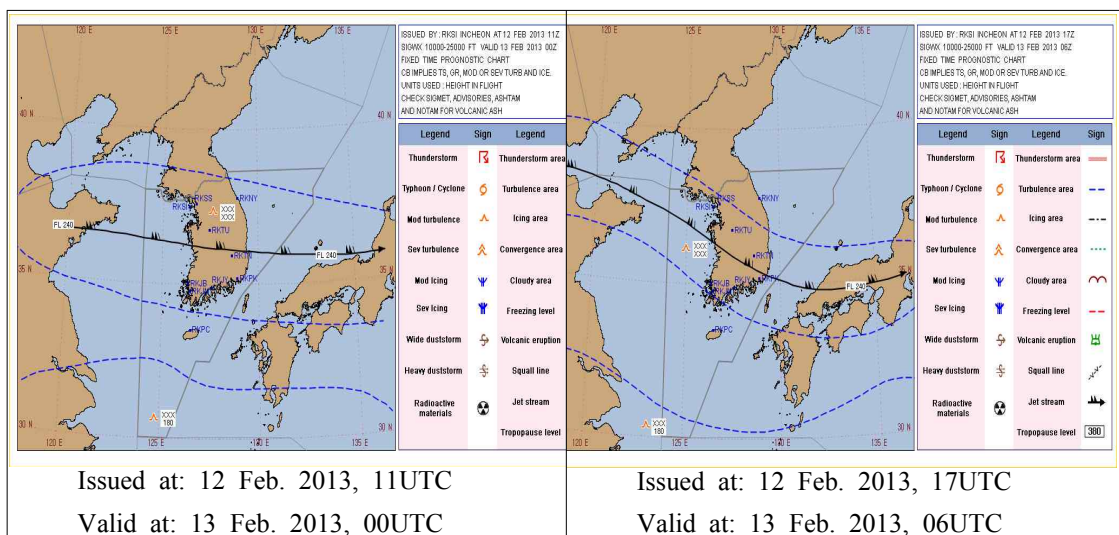
24) The chart is an analysis of upper-level weather conditions observed by about 600 balloons. It depicts a contour line (blue solid line), isotherm (red dotted line), air humidity, wind speed, high pressure, and low pressure.



[Figure 3] Upper-Level Weather Chart Produced by the KMA

1.7.2 Korea Aviation Meteorological Agency

The mid-level (10,000 ft - 25,000 ft) prognostic chart valid at 09:00, 13 February 2013 and issued by the Korea Aviation Meteorological Agency²⁵⁾ (KAMA) at 20:00, 12 February 2013 forecast that, as shown at the left of [Figure 4], a jet stream²⁶⁾ would blow at 110 kts at 24,000 ft, and that moderate turbulence would be likely to occur in a blue dotted portion of an area. The prognostic chart valid at 15:00, 13 February 2013 and issued at 02:00, 13 February 2013 is shown at the right of [Figure 4].



[Figure 4] Prediction of Mid-Level Jet Stream and Turbulence

25) The KAMA provides aeronautical meteorological products to Incheon FIR.

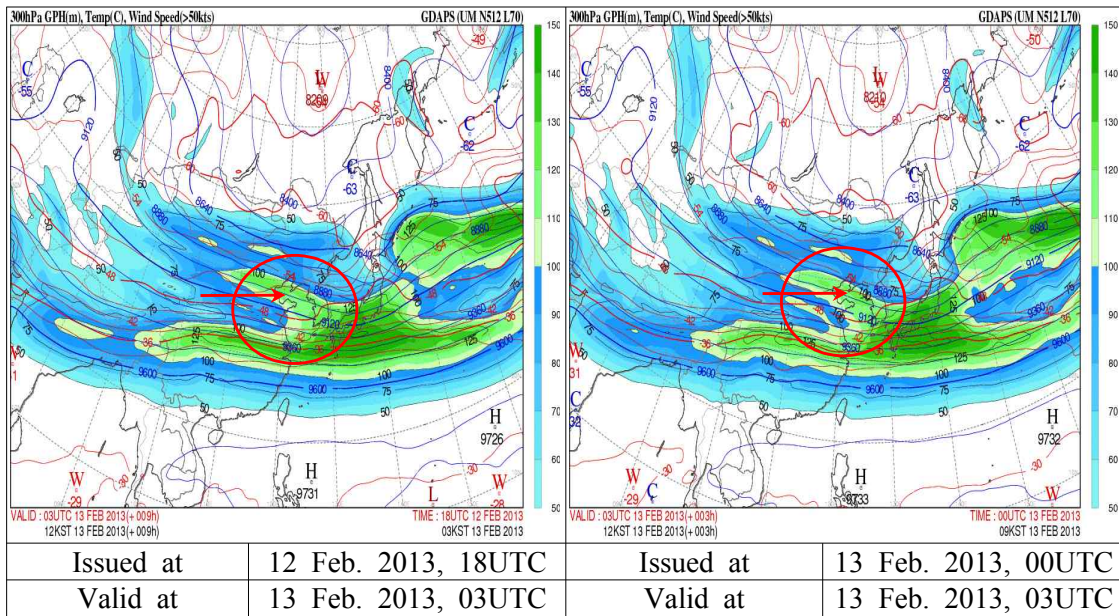
26) In the direction of a black arrow.

1.7.2.1 Global Data Assimilation & Prediction System

As shown in [Figure 5], the forecast chart produced by KAMA's global data assimilation and prediction system (GDAPS) depicts a contour line (about 28,000 ft), temperature, and wind speed (more than 50 kts) at 300 hPa.

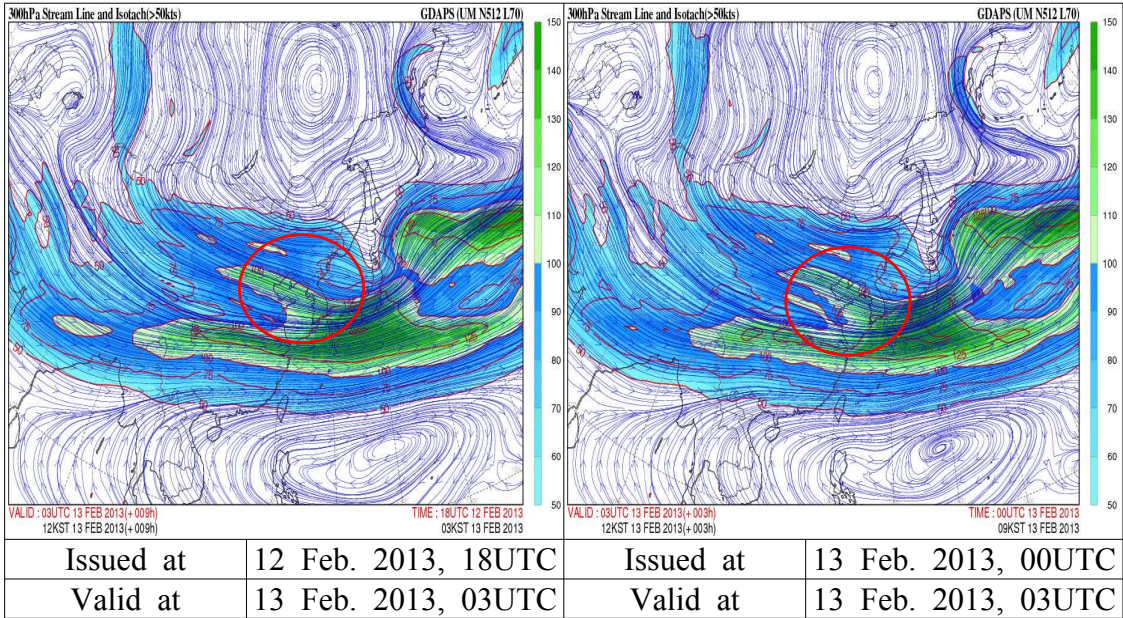
The left chart of [Figure 5] was issued at 03:00, 13 February 2013, forecasting the weather 9 hours later. Green and blue areas in the chart depict a strong jet stream at more than 100 kts and at less than 100 kts, respectively. The darker green the color, the faster the wind speed. The lighter blue the color, the slower the wind speed, and the chart shows winds at more than minimum 50 kts.

The right chart of [Figure 5] was issued at 09:00, 13 February 2013, forecasting the weather 3 hours later. Both charts cover the area from the Chinese continent to the Yellow Sea to the Korean Peninsula to Japan.



[Figure 5] Forecast Chart Produced by the GDAPS

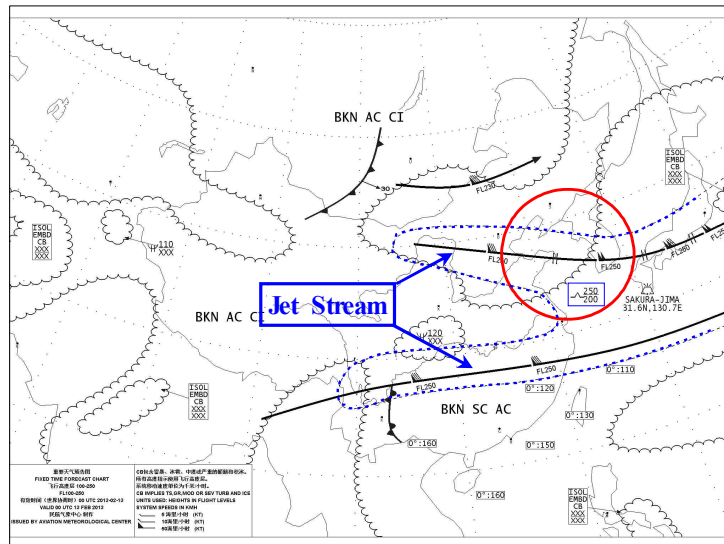
As shown in [Figure 6], the forecast chart produced by KAMA's GDAPS depicts streamlines (about 28,000 ft) and wind speed (more than 50 kts) at 300 hPa.



[Figure 6] Forecast Chart Produced by the GDAPS

1.7.3 China Meteorological Center

As shown in [Figure 7], the SIGMET chart issued by the China Meteorological Center (CMC) at 09:00, 13 February 2013 showed that two strong jet streams were extended from the Chinese continent to the southwest of the Korean Peninsular to Japan at 10,000 - 25,000 ft at 90 - 100 kts, and that moderate turbulence was likely to occur at 20,000 - 25,000 ft in a blue dotted line.



[Figure 7] SIGMET Chart Produced by the CMC

1.8 Aids to Navigation

Not applicable.

1.9 Communications

Not applicable.

1.10 Aerodrome Information

Not applicable.

1.11 Flight Recorders

HL7710's FDR and CVR data could not be retrieved and analyzed since the ARAIB was notified of the accident two days after the accident, and the aircraft was operated under a different flight number.

1.11.1 QAR data

The QAR data in [Table 2] showed that, when HL7710 encountered turbulence at 11:47:16, the aircraft was flying at 23,624 ft at a speed of 308 kts on a heading of 276° and that the speed of wind at 276° rapidly dropped by 13 kts per second to 73 kts from 86 kts.

Vertical acceleration recorded the maximum 1.684G at 11:47:16 and reduced to 1.547G six seconds later, which indicated a gradual decrease in amplitude. Subsequently, HL7710 started to descend at 11:47:46 and reached 21,650 ft at 11:49:00, where the atmosphere got stable.

Time	Altitude (Cap.)	Pitch	Roll	Vertical Accel.	Transverse Accel.	Wind		Airspeed		
						Direction	Speed	Instrument (Cap.)	Sonic	Calibrated
Unit	feet	deg	deg	g	g	deg	knot	knot	mach	knot
2:47:10	23593	0.8	1	0.91	-0.039	277.38	86	317	0.733	300
2:47:11	23629	0.5	2	0.828	-0.047	277.38	86	314.5	0.731	
2:47:12	23587	0.7	1	1.082	-0.004	277.38	86	309.5	0.716	
2:47:13	23595	0.4	1	0.832	-0.004	277.38	86	308	0.71	
2:47:14	23617	0.5	1	0.859	0.004	276.33	73	306.5	0.71	300
2:47:15	23650	1.1	-2	0.793	-0.055	276.33	73	304	0.716	
2:47:16	23624	1.6	-1	1.684	0.035	276.33	73	308	0.712	
2:47:17	23598	0.8	1	0.863	0.004	276.33	73	306	0.709	
2:47:18	23612	0.8	2	0.793	0.023	284.41	73	305	0.709	297
2:47:19	23642	1.1	2	0.77	-0.016	284.41	73	305	0.714	
2:47:20	23636	1.3	1	0.863	-0.047	284.41	73	311.5	0.728	
2:47:21	23678	1.4	2	0.832	0.008	284.41	73	314	0.712	
2:47:22	23638	1.7	3	1.547	0.059	285.47	75	304.5	0.715	284
2:47:23	23595	0.9	3	0.832	0.039	285.47	75	307.5	0.713	
2:47:24	23627	0.9	1	0.77	-0.027	285.47	75	306	0.708	
2:47:25	23635	1.1	0	0.895	-0.035	285.47	75	303.5	0.704	
2:47:26	23615	1.2	-1	0.965	-0.02	281.25	69	303	0.703	283

[Table 2] QAR Data at the Time of Turbulence

1.12 Wreckage and Impact Information

Not applicable.

1.13 Medical and Pathological Information

Any of pilots' medical and pathological evidence that could have affected their flight was not found. Pilots stated that they did not drink any alcohol or take any illegal medication that could have affected their flight in the 72 hours before the accident.

1.14 Fire

Not applicable.

1.15 Survival Aspects

Not applicable.

1.16 Tests and Research

Not applicable.

1.17 Organization and Management Information

Not applicable.

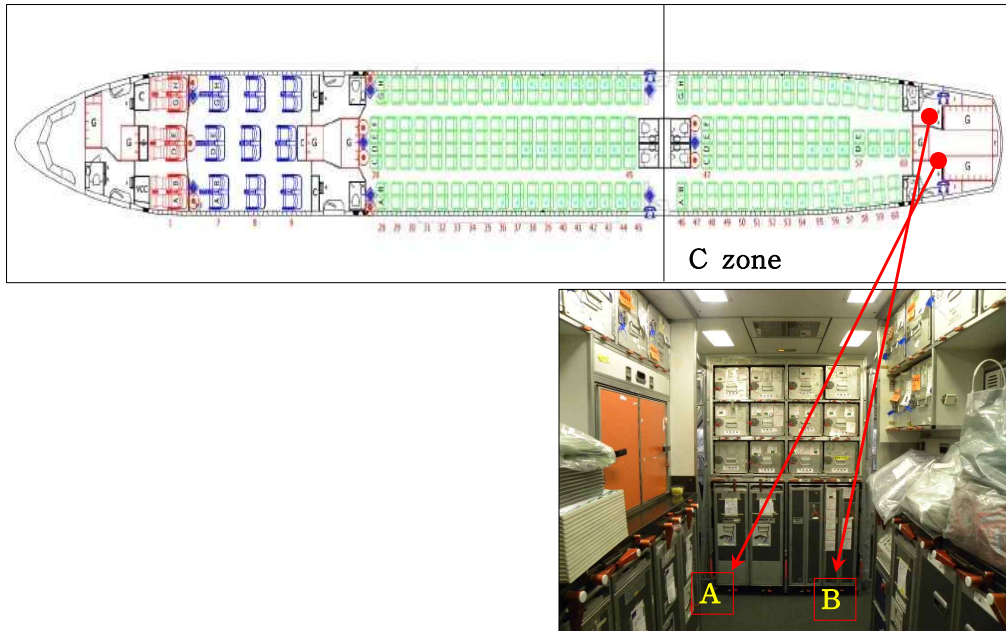
1.18 Additional Information

1.18.1 Purser's Statement

The purser stated that, when HL7710 encountered turbulence, some flight attendants were collecting meal trays from passengers and others were preparing for duty free sales, and that the "fasten seatbelt sign" was "off" and most of the passengers were seated.

The aircraft suddenly shook when the purser organized the collected meal trays at the entrance of the aft galley in the "C" zone, and the "fasten seatbelt sign" came "on". When a turbulence announcement was made, the chime was heard. When a worse turbulence was encountered, she was thrown upward about 10 cm and back down, having her left ankle sprained at the spot "A" in [Figure 8]. The flight attendant next to her was thrown upward and deposited on the floor at the spot "B", hurting her back.

During a turbulence encounter, four of ten flight attendants were in the "C" zone galley and at the entrance of the galley. Three carts were placed respectively at L4 jump seat, R4 jump seat, and the galley, and in the "B" zone galley, other flight attendants were preparing duty free sales carts.



[Figure 8] Locations of the Injured Flight Attendants

2. Analysis

2.1 General

The flight crew of HL7710 held proper qualification certificates for flight and valid airman medical certificates, and they took the required rest before flight.

HL7710 was registered in accordance with the Korean Aviation Act and held a valid airworthiness certificate. It was loaded with suitable fuel for flight, and the flight concerned was carried out within the proper limits of weight and balance.

2.2 Pilot Operation Manual

A330's Pilot Operation Manual (POM) specified that, if turbulence is unavoidable, the flight crew should reduce airspeed to Mach 0.78/260 kts and consider a descent so as to provide the best protection against the effect of gust on the structural limits, whilst maintaining an adequate margin above VLS.

According to the QAR data, HL7710 reduced airspeed from 310 kts to 300 kts and from 300 kts to about 284 kts when encountering an initial turbulence at 11:47:06 and a severe turbulence at 11:47:16, respectively. Then, the aircraft started to descend at about 280 kts at 11:47:44 while using the minimum thrust and reached an altitude of 22,773 ft at 11:48:35, after which the aircraft got stable and was cruising at 21,650 ft.

Given the findings above and the statements of the pilots, it is determined that the captain and the FO of HL7710, when encountering turbulence, adequately performed turbulence avoidance maneuvers in accordance with the POM.

2.3 Clear-Air Turbulence

The strongest jet stream is located in the East Asian region including Korea. Wind shear is highly likely to occur above and below this jet stream, in an area with a high circulation of air in the anticyclone, and jet exit. Also, moderate and severe turbulences are frequently encountered due to unstable inertia.

In particular, turbulence²⁷⁾ accompanied by strong northwest wind is frequently encountered in February and March on the Korean Peninsula, but predicting and detecting moderate or severe turbulence is very difficult since it is mostly clear-air turbulence (CAT), which occurs in the clear air without clouds or with stratiform clouds.

CAT consists of turbulence in no relation with clouds and turbulence that cannot be detected by a weather radar or with the naked eye. Jet streams are fast flowing, narrow air currents. They are normally located near the troposphere^{e28)} and resulted from a change in temperatures of air masses.

Not every jet stream is related to CAT, but vertical and horizontal wind shear can exist at its edges, which occasionally caused severe turbulence. Also, the strongest clean-air turbulence exists at a portion of the jet stream at the lowest temperature accompanied by the strongest wind shear.

2.4 Meteorological Factors

According to the KMA's satellite image of the area (in the vicinity of 38° 33' 6.12" N, 121° 15' 17.3" E) where HL7710 was cruising on 13 February 2013, about 11:45, there were no clouds. The pilot stated that "when turbulence

27) It is known that turbulence is irregular air flow, in which many unstable vortices appear, and that the more unstable the atmosphere becomes and the faster wind speed is, the stronger turbulence gets. There are meanders at its edges.

28) Located at the average altitude of 12 km.

was encountered, there was some haze". In addition, according to an upper-level weather chart valid at 09:00, 13 February 2013, a strong jet stream was extended from the Chinese continent to central Korean Peninsula at about 8.8 km above sea level, and the area likely to encounter turbulence was predicted in the vicinity of the jet stream.

The KAMA's mid-level prognostic chart valid at 09:00, 13 February 2013, forecast that a jet stream would be present at 100 kts at 24,000 ft south of the central Korea. The agency also predicted the area likely to encounter moderate turbulence. In addition, the forecast chart issued at 03:00, 13 February 2013, and produced by KAMA's GDAPS predicted the weather 9 hours later, showing a contour line (about 28,000 ft), temperature and wind speed (streamlines more than and less than 50 kts) at 300 hPa. According to this chart, a jet stream blowing from the Chinese continent to the Korean Peninsula travelled at 110 - 140 kts.

The CMC's SIGMET chart valid at 09:00, 13 February 2013, predicted that a jet stream was extended from the Chinese continent to the Yellow Sea to the south of the Korean Peninsula to Japan at 90 - 100 kts at 25,000 ft, and that moderate turbulence was likely to occur at 20,000 - 25,000 ft where a jet stream existed.

To sum up the above information provided by meteorological agencies, there was a northwesterly jet stream on HL7710's flight route, which included the area likely to encounter turbulence as well. Based on the characteristics of clear-air turbulence, HL7710 encountered turbulence during cruising flight since fluid vortices occurred in the vicinity of a strong jet stream, and at this time, flight attendants collecting meal trays from passengers fell to the floor and got seriously injured.

3. Conclusions

3.1 Findings

1. The pilots did not perform unusual activities before the flight, and health problems that might have affected the flight were not found.
2. The pilots held valid qualification certificates in accordance with Korean Aviation Act.
3. HL7710 was registered in accordance with the Korean Aviation Act and held a valid airworthiness certificate.
4. HL7710 was operated within the permissible range of weight and balance.
5. During a joint briefing, the captain briefed flight attendants on turbulence response procedures due to the possibility of turbulence encounter en route.
6. According to the data provided by the KMA, KAMA, and CMC, turbulence was forecast in the area between Incheon and Tianjin.
7. HL7710 encountered clear-air turbulence twice at an altitude of 23,600 ft.
8. Turbulence-related phenomena were not detected on HL7710's weather radar.
9. HL7710's flight plan showed a shear rate of less than 0.5.
10. When HL7710 encountered turbulence, the "fasten seatbelt sign" was "off".

11. When HL7710 encountered turbulence, flight attendants were collecting meal trays, thereby resulting in an injury to the two of them in the "C" zone.

3.2 Causes

The Aviation and Railway Accident Investigation Board determines the probable cause of this accident as follows:

1. HL7710 encountered turbulence during cruising flight since fluid vortices occurred in the vicinity of a strong jet stream, and at this time, flight attendants tidying the galley fell to the floor and got seriously injured.