Chapter 3 Case studies and analysis of aircraft turbulence-related accidents

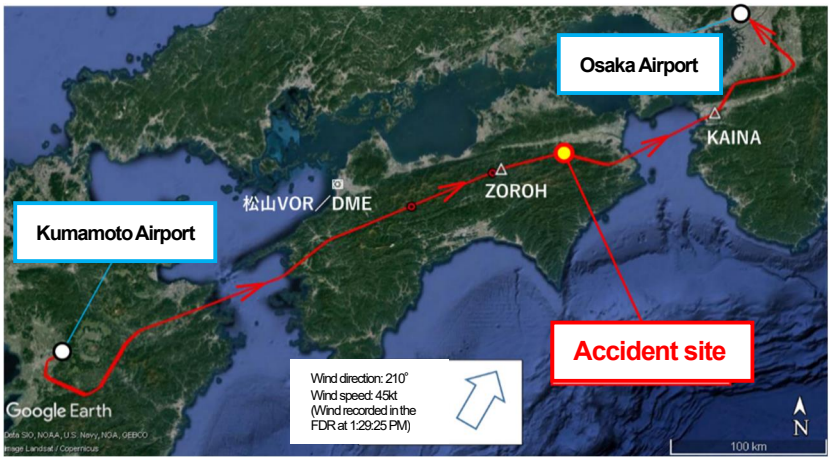
From this point onward, we will introduce case studies from accident investigation reports analyzed in Chapter 2 and explain the factors that led to the accidents, as well as key points highlighted in these reports for accident prevention.

1. Introduction of accident cases

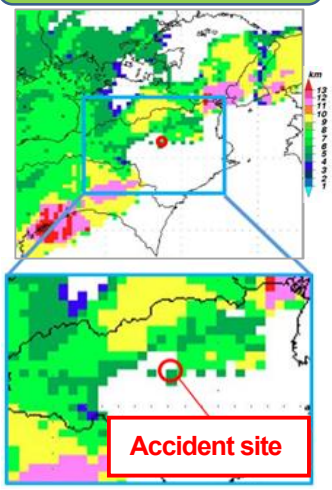
Case 1

Summary: A Bombardier DHC-8-402 aircraft operated by Company A encountered turbulence caused by convective clouds at 5:35 PM on Saturday, June 25, 2022, while en route from Kumamoto Airport to Osaka International Airport on a scheduled flight. As a result of the severe aircraft movement, one cabin crew member sustained serious injuries.

Estimated flight path diagram



Rader composite images (echo top altitude)



Weather conditions

Based on radar composite images (echo top altitude), it is highly probable that convective clouds had developed near the accident site, reaching altitudes between 5 km (16,403 ft) and 6 km (19,685 ft).

Aircraft turbulence

The FDR records show that between 1: 29:08 PM and approximately 12 seconds later, the vertical acceleration fluctuated between +0.2 G and +2.1 G. During this time, the aircraft was likely flying near developed convective clouds, encountering turbulence caused by these clouds, which resulted in significant aircraft movement.

Flight crew's weather assessment and seatbelt sign management

The flight crew probably kept the seatbelt sign off until the aircraft encountered significant vertical turbulence, as they believed they could avoid the echo by altering course and considered passenger needs. Regarding seatbelt sign operation, it is advisable for flight crews to take a more safety-conscious approach when there is a possibility of aircraft turbulence.

Probable Cause: This accident most likely has been occurred when the aircraft encountered turbulence caused by convective clouds while the seatbelt sign was off, resulting in severe aircraft movement, then a cabin crew member, who was crouching and working in the galley at the rear of the aircraft, was lifted off the floor, lost balance, and fell, sustaining injuries. The aircraft's encounter with turbulence from convective clouds was likely due to insufficient evasive maneuvers based on onboard weather radar displays of convective clouds. Additionally, the presence of developing convective clouds, which were difficult to detect on the onboard weather radar, likely have contributed to the inability to maintain an appropriate distance from the turbulence.

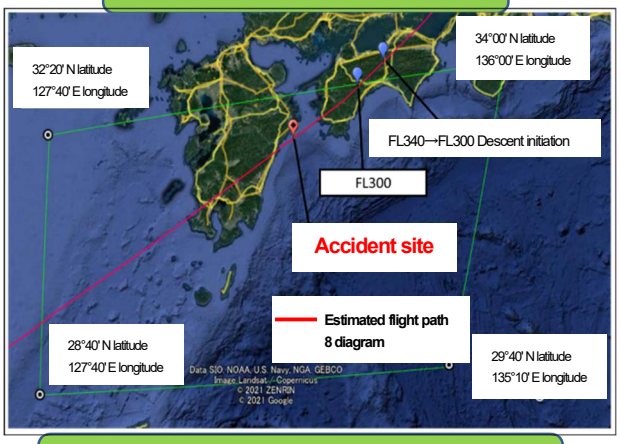
The accident investigation report for this case has been published on the committee's website (published on October 26, 2023).
https://jtsb.mlit.go.jp/eng-air_report/JA854A.pdf

Case 2

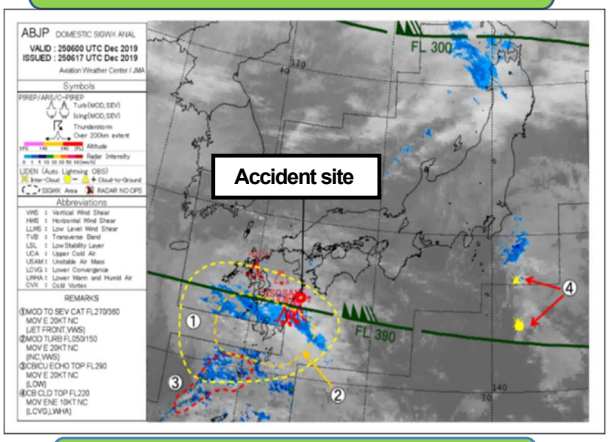
Summary: An Airbus A320-232 aircraft operated by Company B encountered wind shear near a jet stream at approximately 4:12 PM on Wednesday, December 25, 2019, while en route from Hakodate Airport to Taiwan Taoyuan International Airport on a scheduled flight. This resulted in significant aircraft movement, causing serious injuries to one cabin crew member and minor injuries to one passenger and two other cabin crew members.

Note: "Wind shear" refers to a phenomenon where wind direction and speed change rapidly over a localized area.

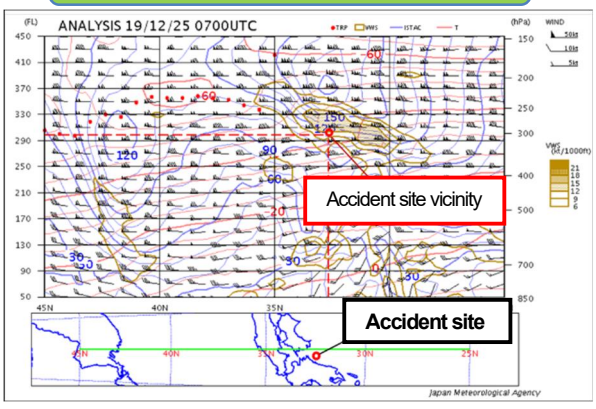
Estimated flight path diagram



Domestic severe weather analysis chart



Hourly atmospheric analysis chart



Weather conditions and aircraft turbulence

It is most likely that a strong wind shear existed along the jet stream near the accident site, as a transverse line of upper clouds and a vertical shear zone were observed. The aircraft most likely have experienced significant turbulence due to this wind shear. As a result of this turbulence, the senior cabin crew member, who was moving through the aisle to return from the rear of the cabin to the front jump seat, highly probably fell and fractured their right ankle.

Flight Crew's Decision-Making

The flight crew, based on the weather data reviewed before the flight, the onboard weather radar display, and pilot reports, more likely expected some turbulence but did not anticipate encountering turbulence of such severity. However, if they had obtained the SIGMET information issued by the Japan Meteorological Agency at 2:00 PM, it probably has been useful for the flight crew to proactively assess the need for altitude and route changes, seatbelt enforcement, and the timing of safety information dissemination to the cabin.

The Company's Operational Support System

The Operation Control Center (OCC) more likely have not obtained the SIGMET information issued by the Japan Meteorological Agency at 2:00 PM. Since SIGMET information provides critical updates on significant weather changes affecting flight safety, it probably be beneficial for OCC to acquire such information in a timely manner and appropriately relay it to the flight crew to help prevent similar accidents.

*"SIGMET information" refers to warnings issued for hazardous weather that may significantly impact aircraft operations and is expected to persist.

Autopilot Disengagement

When the aircraft experienced significant turbulence, the first officer probably had unintentionally pushed the sidestick forward. It is probable that the amount of input exceeded the autopilot disengagement threshold set for the aircraft (5° forward), causing the autopilot to disengage. The autopilot disengagement more likely had influenced the subsequent behavior of the aircraft.

Probable Cause: This accident most likely has been occurred when the aircraft encountered wind shear near the jet stream, causing significant turbulence, which led to a cabin crew member falling while moving through the aisle and sustaining a serious injury.

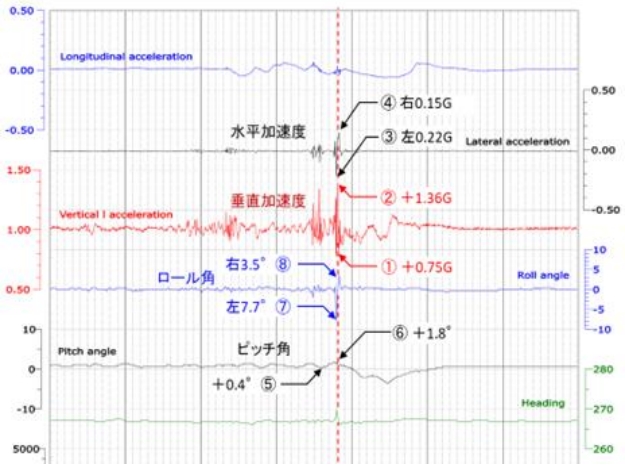
The accident investigation report for this case has been published on the committee's website (published on March 24, 2022).
https://jtsb.mlit.go.jp/eng-air_report/B50001.pdf

Case 3

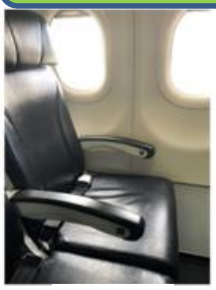
Summary: An Airbus A320-214 operated by Company C was flying as a scheduled flight from Tokyo International Airport to Kitakyushu Airport on Sunday January 16, 2022. At approximately 7:48 PM, while flying over Okayama City at FL280, the aircraft experienced turbulence, injuring one passenger. The passenger, who was wearing a seatbelt, struck their right side against the right armrest of the seat after encountering clear-air turbulence.

Estimated flight path diagram

QAR records



Injured passenger's seat



seat 23A

Weather conditions and aircraft turbulence

Although no cloud echoes were observed near the accident site, it is probable that clear-air turbulence caused by the jet stream was present. At the time of the accident, PIREP reports indicated that clear-air turbulence had occurred around 7:48 PM at FL300, approximately 14 nm northwest of the accident site.
* "PIREP" stands for "Pilot Report," which refers to in-flight weather observations reported by pilots that may impact flight safety.

The vertical acceleration fluctuated between +0.75G and +1.36G, while the horizontal acceleration ranged from 0.22G to the left to 0.15G to the right. Given the presence of a vertical shear zone on the hourly atmospheric analysis chart and the absence of clouds, it is probable that the turbulence was caused by clear-air turbulence resulting from the influence of the jet stream.

Passenger injury

The armrest of the seat in question is 20 cm above the seat cushion, which aligns with the rib area for a relatively small person. The passenger remained seated with their seatbelt fastened at all times during the flight, even after the seatbelt sign was turned off. However, considering the aircraft's horizontal acceleration (ranging from 0.22G to the left to 0.15G to the right), roll angle (from 7.7° left to 3.5° right), and roll rate (4.5°/sec), it is probable that when the aircraft experienced turbulence, the passenger's body was thrown from left to right, causing them to strike their right ribcage against the right armrest of the seat, resulting in a fracture of the ninth rib.

Probable Cause: This accident more likely have occurred when the aircraft encountered clear-air turbulence caused by the influence of the jet stream. The turbulence caused the aircraft to jolt to the left, leading to the passenger striking their right ribcage against the right armrest of the seat and sustaining a serious injury.

Preventive measures

➢To enhance passenger safety, cabin crew should continuously remind passengers to keep their seatbelts fastened securely and low on their waist at all times while seated. Additionally, cabin crew should be attentive to passengers' body types and ensure that seatbelts are properly fastened.

The accident investigation report for this case has been published on the committee's website (published on June 29, 2023)
https://jtsb.mlit.go.jp/eng-air_report/JA24MC.pdf

2. Causes of accidents and key points for prevention

Based on the factual information identified in accident investigations, we have extracted key points from the 36 accident investigation reports published over the past 20 years (2004–2023), including the cases introduced above. These key points can be broadly categorized into three groups: "Information sharing," "Cabin safety measures," and "Onboard equipment operations."

i) Information sharing

This includes insufficient information sharing between flight crew and cabin crew, as well as between flight crew and flight dispatchers. Overall, there is a noticeable tendency for turbulence-related information obtained after departure to be inadequately shared. Additionally, several reports have pointed out the need for improvements in procedural aspects, such as turbulence reporting systems.

Currently, PIREP provided from aircraft serves as the primary means for obtaining turbulence information among the means of obtaining real-time information on shaking during flight. However, enhanced sharing of onboard observational data using ACARS[1] is also needed.

Information sharing	Flight crew ↔ Cabin crew	Provision of turbulence information Provision of safety-related information Accurate information on flight routes (Japanese only) Information on expected aircraft turbulence Reporting of cabin crew injuries to the captain Recognition and reporting of injured passengers
	Flight crew ↔ Flight dispatchers	Provision of turbulence information as per regulations (Japanese only) Provision of information to flight crew from the ground (Japanese only) Provision of analytical information based on real-time weather monitoring (Japanese only) Provision of the latest meteorological and external monitoring information Acquisition and distribution of SIGMET information Utilization of SIGMET information related to turbulence
	Flight crew ↔Air traffic control authorities	Reporting turbulence intensity based on unified standards (Japanese only) Captain's reports on adverse weather Reporting of turbulence-related information

*Click on the blue text links to view the relevant pages of each accident investigation report.

ii) Cabin safety measures

This category includes issues related to in-flight service and seatbelt use. In recent trends, there has been an increasing focus on how seatbelts are fastened.

Additionally, some reports have highlighted concerns regarding physical aspects of the cabin, such as handrails and seating.

[1] "ACARS" (Aircraft Communications Addressing and Reporting System) refers to a system that digitally transmits essential operational information between aircraft and ground stations.

Cabin Safety Measures	Seatbelt	Proper seatbelt fastening	Proper seatbelts use 1 Proper seatbelts use 2
		Seatbelt sign operation	Operation of seatbelt sign during flying in clouds (Japanese only) Considerations for turning on the seatbelt sign Safe-side operation of the seatbelt sign
	Seat	Seating posture	Seating arrangements for infants during seatbelt sign activation Seat design and seating posture adopted to different body types Seating posture for cabin crew
	In-flight services	Services	Familiarization with service manuals for treating injuries (Japanese only) Active verbal engagement during cabin walkthroughs Improvements of coffee pots and implementation of burn prevention measures (Japanese only) Formulation and implementation of in-flight service plans
		Training	Awareness of aircraft turbulence handling through regular training Reinforcement of key learnings from similar accidents
		Announcements	Proactive announcements for cautionary measures Captain's announcements on weather conditions (Japanese only)
	Response to turbulence	Response procedures	Handling differences in turbulence conditions across various locations in the cabin Response to unexpected aircraft turbulence Measures to mitigate injury risks (Japanese only)
		Cabin equipment	Installation of handles in aisles Storage of luggage in overhead compartments and under seats

iii) Operation of Onboard Equipment

This category primarily involves the effective use of onboard weather radar, along with recommendations regarding the operation of the autopilot system.

While turbulence-related accidents are often caused by natural phenomena and can sometimes be unavoidable, accidents can be significantly reduced by utilizing onboard weather radar to avoid turbulence laterally or vertically and by obtaining real-time turbulence reports from other aircraft to activate the seatbelt sign earlier.

Furthermore, the provision of more detailed turbulence forecasts, as well as the potential future implementation of aircraft-mounted Doppler Lidar[2] systems for detecting clear-air turbulence and utilizing new technologies for aircraft control, are highly anticipated.

[2] "Aircraft-mounted Doppler Lidar" is a device that emits laser beams from an aircraft, receiving scattered light from aerosols (such as fine water droplets and dust) in the atmosphere. By analyzing wavelength changes due to the Doppler effect, it can detect clear-air turbulence, which cannot be detected by onboard weather radar.

Utilization of onboard equipment	Onboard weather radar	Methods of utilization	Utilization during route changes to avoid adverse weather Understanding and utilizing data for hard-detect weather conditions (Japanese only) Proactive use of onboard weather radar (Japanese only) Characteristics, limitations, and effective use of onboard weather radar Avoidance of convective clouds echoes Understanding and avoiding conditions around cumulonimbus clouds
	Autopilot system	Methods of operation	Operations in compliance with aircraft operation regulations Operation of autopilot during turbulence encounters
		Training	Recovery procedures and training for wake turbulence encounters Providing information and training on maximum operation speed
	Utilize new technologies	Turbulence prediction	Enhancing prediction accuracy with Doppler Lidar Research and development of meteorological analysis techniques and forecast accuracy improvements

Many of the aforementioned recommendations have been addressed by operators through revisions to manuals and other preventive measures following accidents. However, in reality, similar accidents continue to be occurred due to factors such as sudden turbulence that was too abrupt for the prescribed manual response to be effective, unanticipated sudden local wind changes that were not predicted in pre-flight weather information, and insufficient avoidance of developing convective clouds.

Based on these analysis results, the next chapter will introduce potential accident prevention measures, including those that can be implemented by operators.

Chapter4 Measures to prevent aircraft turbulence-related accidents

For preventing turbulence-related accidents, drawing from the statistical analysis in Chapter 2, the findings from accident investigation reports in Chapter 3, and interviews with operators conducted during the creation of this digest, the main points for consideration can be broadly categorized into the following three areas.

1. Lack of unawareness in information sharing

Information sharing among crew members

- By sharing turbulence forecast information not only before the flight but also promptly and thoroughly during operations, cabin crew can prepare for turbulence by adopting protective postures and taking appropriate measures such as requesting passengers to fasten their seatbelts.
- It is important for crew members to share information regarding the timing and method of in-flight service based on turbulence conditions. If the likelihood of turbulence increases, consideration should be given to turning on the seatbelt sign regardless of the progress of service.
- Since turbulence conditions can vary significantly between the cockpit and the rear cabin, it is essential for crew members to share real-time turbulence information. Additionally, cabin crew should request the activation of the seatbelt sign when necessary.
- When the aircraft experiences turbulence, it is crucial to quickly assess the extent of passenger injuries and cabin conditions, accurately report the situation to the captain, and coordinate with ground personnel to ensure an effective