U.S. Department
of Transportation
Federal Aviation
Administration

Advisory Circular

Subject: Clear Air Turbulence Avoidance | **Date:** 3/22/16 | **AC No:** 00-30C
Initiated by: AFS-400 | **Change:**

1 PURPOSE. This advisory circular (AC) describes various types of Clear Air Turbulence (CAT), some of the weather patterns associated with CAT, and turbulence reporting systems and networks. Also included is information on turbulence forecasts and products.

2 CANCELLATION. AC 00-30B, Atmospheric Turbulence Avoidance, dated September 9, 1997, is canceled.

3 AUDIENCE. This AC pertains to pilots, aircrew members, dispatchers, and other operations personnel.

4 RELATED READING MATERIAL (current editions).

- AC 00-6, Aviation Weather for Pilots and Flight Operations Personnel.
- AC 00-45, Aviation Weather Services.
- FAA-H-8083-25, Pilot's Handbook of Aeronautical Knowledge.

5 BACKGROUND.

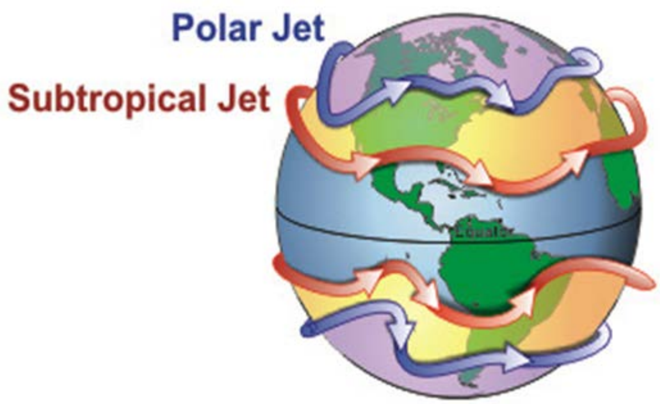
5.1 CAT is defined as "sudden severe turbulence occurring in cloudless regions that causes violent buffeting of aircraft." This term is commonly applied to higher altitude turbulence associated with wind shear. The most comprehensive definition is high-altitude turbulence encountered outside of convective 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.

5.2 CAT is a recognized problem that affects all aircraft operations. CAT is especially troublesome because it is often encountered unexpectedly and frequently without visual clues to warn pilots of the hazard.

6 DISCUSSION.

6.1 One of the principal areas where CAT is found is in the vicinity of the jet streams. Jet streams are relatively narrow bands of strong wind in the upper levels of the atmosphere. In jet streams, winds blow from west to east, but the flow often meanders southward and northward in waves. Jet streams follow the boundaries between hot and cold air. Because these hot and cold air boundaries are most pronounced in winter, jet streams are the strongest for both the northern and southern hemisphere winters. There are, in fact, three jet streams: the polar-front jet stream, the subtropical jet stream, and the polar-night jet stream. (This AC does not address the polar-night jet stream, as it is a phenomenon in the stratosphere.)

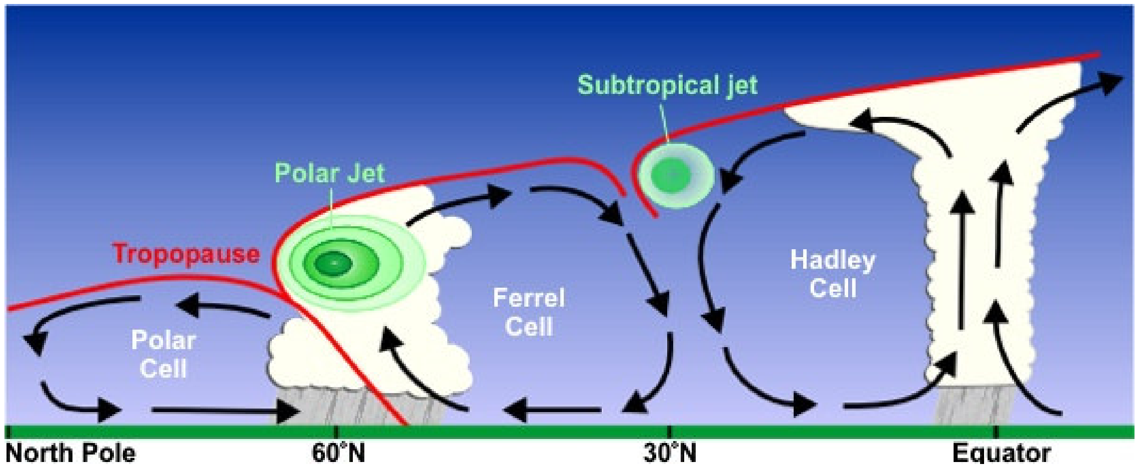
Figure 1. Illustration of Polar and Subtropical Jet Streams and Their Relative Location Around the Globe



6.2 The 50°–60° N/S latitude region is where the polar jet is located, and the subtropical jet is located around 30° N latitude. Jet streams vary in height from flight level (FL) 200 to FL 450 and can reach speeds of more than 240 knots (kts).

Figure 2. Location of Polar and Subtropical Jet Streams with Respect to General Global Circulation

Note: This figure looks toward the east in the Northern Hemisphere. More information on upper air structure can be found in AC 00-6.



6.3 Jet streams result from the complex interaction between many variables, such as the location of high and low pressure systems, warm and cold air, and seasonal changes. They meander around the globe, dipping and rising in altitude and latitude, splitting at times, forming eddies, and even disappearing altogether to appear somewhere else. Jet streams shift on a seasonal basis, moving into Canada by summer. As autumn approaches and the sun's elevation decreases, the jet stream moves south into the United States, helping to bring cooler air to the country.

6.4 CAT associated with a jet stream is most commonly found in the vicinity of the tropopause (the boundary region between the troposphere and the stratosphere) and upper-air fronts. CAT is most frequently found on the poleward side of the jet stream (over the United States, this is to the left side when facing downwind). CAT is also common in the vicinity of a jet stream maxima, a region of stronger winds within the jet stream that translates along the jet stream core.

6.5 There are several patterns of upper-level winds that are associated with CAT. One of these is a deep, upper trough. The word "trough" refers to winds that dip southward, then rise northward, forming a trough-like pattern. A "ridge" is the opposite, where the winds move northward, then dip southward, forming a ridge-like pattern. CAT is found most frequently at, and just upwind of, the base of the trough, especially just downwind of an area of strong temperature advection. Another area of the trough in which to suspect CAT is along the centerline of a trough area, where there is a strong horizontal wind shear between the jet core and winds to the poleward side of the jet core. CAT is also found in the west side of a trough in the vicinity of a wind maxima as the maxima passes along the trough.

6.6 One noteworthy generator of CAT is the confluence of two jet streams. On occasion, the polar-front jet stream will dip south and pass under the subtropical jet stream. The wind shear effect between the two jet streams in the region of confluence and immediately downstream is often highly turbulent.

6.7 CAT intensity can vary significantly along any flightpath. Common dimensions of a turbulent area associated with a jet stream are on the order of 100 to 300 miles long, elongated in the direction of the wind, 50 to 100 miles wide, and 5,000 feet deep. These areas may persist from 30 minutes to 1 day.

6.7.1 The threshold wind speed in the jet stream for CAT is generally considered to be 110 kts. The probability of encountering CAT increases proportionally with the rapidity of the decrease in wind speed away from the jet core. This is known as wind shear. It is not the wind speed itself that causes CAT; it is the wind shear, or difference in wind speed from one level or point to another, that is turbulent to an aircraft as the atmosphere bounces in waves or actually overturns (see Figure 3, Wind Shear Example). Wind shear occurs in all directions, but for convenience, it is measured along vertical and horizontal axes, thus becoming horizontal and vertical wind shear. Moderate CAT is considered likely when the vertical wind shear is 5 kts per 1,000 feet or greater, and/or the horizontal wind shear is 40 kts per 150 miles or greater.

6.7.2 Jet streams stronger than 110 kts (at the core) have potential for generating significant turbulence near the sloping tropopause above the core, in the jet stream front below the core, and on the low-pressure side of the core.

6.7.3 Wind shear and its accompanying CAT in jet streams are more intense above, and to the lee of, mountain wave ranges. CAT should be anticipated whenever the flightpath traverses a strong jet stream in the vicinity of mountainous terrain.

6.7.4 Both vertical and horizontal wind shear are, of course, greatly intensified in mountain wave conditions. Therefore, when the flightpath traverses a mountain wave type of flow, it is desirable to fly at turbulence-penetration speed and avoid flight over areas where the terrain drops abruptly, even though there may be no lenticular clouds to identify the condition.

6.7.5 Turbulence is also related to vertical shear. If vertical shear is greater than 5 kts per 1,000 feet, turbulence is likely.

6.7.6 Curving jet streams are more apt to have turbulent edges than straight ones, especially jet streams that curve around a deep pressure trough.

6.7.7 Wind-shift areas associated with pressure troughs and ridges are frequently turbulent. The magnitude of the wind shear is the important factor.

Figure 3. Wind Shear Example

7 MODERN TURBULENCE REPORTS AND FORECASTS.

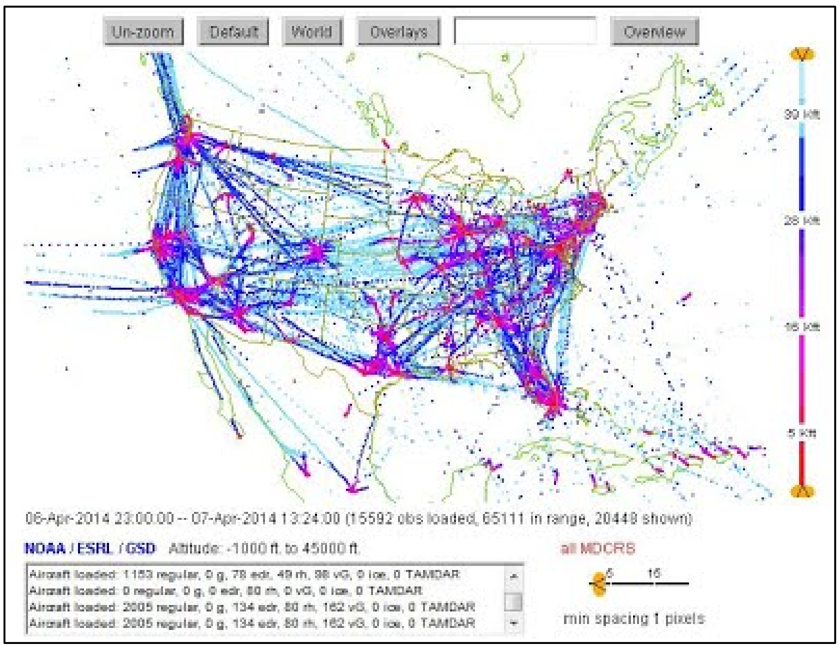
7.1 Advancements. Since the 1990s, several innovations have improved the quality and availability of turbulence reports and forecasts. Automated turbulence reporting systems are common on many commercial aircraft using the Aircraft Meteorological Data Relay (AMDAR) system. Airline pilot reports are now being relayed to others by the airline's aircraft dispatchers and by meteorologists working at the Federal Aviation Administration's (FAA) air route traffic control centers (ARTCC). Automated, high-resolution turbulence forecasts are now produced for the contiguous United States and the world.

7.1.1 AMDAR. Modern commercial aircraft are equipped with meteorological sensors and associated sophisticated data acquisition and processing systems. These systems continuously record meteorological information on the aircraft and send these observations at selected intervals to ground stations via satellite or radio links where they are processed and disseminated.[1] Participating airlines add turbulence information with these reports. These automated turbulence reports are used by meteorologists and automated turbulence forecast systems. In the United States, the program to capture, process, and distribute this automated meteorological reporting is referred to as the Meteorological Data Collection and Reporting System (MDCRS). The specific content does not reach the general public, but is reflected in higher quality turbulence forecasts.

7.1.2 Eddy Dissipation Rate (EDR). AMDAR reports turbulence in terms of EDR. EDR is the International Civil Aviation Organization (ICAO) standard dimension for automated turbulence reporting. EDR is a state-of-the-atmosphere measure rather than a state-of-the-aircraft measure, and so it is independent of aircraft type.

Figure 4. A Plot of AMDAR Reports Received During a 24-Hour Period in 2014

Note: This information is restricted.



7.1.3 Relay. Until recently, pilot report dissemination was performed only through FAA facilities, such as Flight Service Stations (FSS) and air traffic control (ATC) facilities. In the early 2000s, airline dispatchers and Center Weather Service Unit (CWSU) meteorologists obtained the ability to relay pilot reports directly to the National Oceanic and Atmospheric Administration's (NOAA) Aviation Weather Center (AWC). The AWC processes these reports and sends them to users, meteorologists, and automated forecast systems. Users can see all pilot reports, including those transmitted by airline dispatchers, on the AWC Web site. Those provided by dispatchers and CWSUs are designated in the

[1] In 2014, it was estimated that the National Oceanic and Atmospheric Administration (NOAA) was receiving about 140,000 wind and temperature observations per day, 100,000 of which are over the continental United States. These data come from more than 4,000 aircraft. (From http://amdar.noaa.gov/FAQ.html.)

"remarks" column as "AWC-WEB" plus the airline identifier or CWSU three-letter identifier. Airlines, which sponsor the collection of information from AMDAR, are helping to improve the accuracy of turbulence forecasts and advisories for everyone. Pilots also improve the quality of turbulence forecasts through pilot reports. Dispatchers help by disseminating pilot reports from their crews through the AWC.

7.1.4 Algorithms. There is no lack of algorithms (i.e., mathematical techniques) to predict turbulence magnitude using atmospheric model output. The turbulence product known as Graphical Turbulence Guidance (GTG) was developed by the National Center for Atmospheric Research (NCAR) and is operationally produced by the AWC. GTG computes the results from more than 10 turbulence algorithms using output from NOAA's High-Resolution Rapid Refresh model. It then compares the results of each algorithm with turbulence observations from both pilot reports and AMDAR data to determine how well each algorithm matches reported turbulence conditions from these sources. GTG then weighs the results of this comparison to produce a single turbulence forecast. Note that the success of GTG is proportional to the number of quality pilot reports and AMDAR reports available to verify the algorithms. This means the accuracy of GTG improves during daylight hours and where there is more traffic making pilot reports and sending AMDAR data. GTG produces its forecasts every hour. GTG has separate forecasts for each hour through the first 3 hours, followed by forecasts at 3-hour intervals through 12 hours. GTG forecasts are available for every 1,000 feet of altitude from 10,000 mean sea level (MSL) through FL 450, inclusive.

7.1.5 Gridded Forecasts. Gridded, high-resolution turbulence forecasts are now available for the globe through the World Area Forecast System (WAFS). These gridded forecasts are sanctioned by ICAO and the FAA for use in flight planning. They are available for various levels from forecast hours 6 to 36, in 3-hour time steps. Although intended for integration with dispatcher and pilot flight planning systems, this gridded information can also be viewed on the AWC Web site (under "WAFS Forecasts") at http://www.aviationweather.gov/wafs.

8 IN-FLIGHT AVIATION WEATHER ADVISORIES.

8.1 In-flight weather advisories (e.g., significant meteorological information (SIGMET) and Airmen's Meteorological Information (AIRMET)) are used to disseminate important information on atmospheric turbulence, both convective and CAT. In-flight aviation weather advisories in the contiguous United States are issued by the AWC, as well as 20 CWSUs. The AWC also issues advisories for portions of the Gulf of Mexico, Atlantic and Pacific Oceans, which are under the control of ARTCCs with oceanic flight information regions (FIR). The Weather Forecast Office (WFO) in Honolulu issues advisories for the Hawaiian Islands and a large portion of the Pacific Ocean. In Alaska, the Alaska Aviation Weather Unit (AAWU) issues in-flight aviation weather advisories along with the Anchorage CWSU.

8.2 More information on in-flight aviation advisories can be found in AC 00-45.

8.3 In-flight aviation weather advisories are available to pilots through flight service, ATC, and over the hazardous in-flight weather advisory service (HIWAS).

9 RECOMMENDATIONS.

9.1 The aircraft operator's philosophy toward the CAT problem is a crucial element in an effective turbulence avoidance system. Operators should establish the avoidance of atmospheric hazards as a high organizational priority. Operators should be willing to expend resources on the safest operational practices and resist the expedient. The philosophy of avoidance is an integral part of flight planning.

9.2 The first step in avoidance of atmospheric hazards, especially turbulence, is to establish access to available weather information for planning flight operations. Direct access to a meteorological support service (in-house or outside-source) by the operator's planning and dispatch function is a major factor in a successful turbulence avoidance system. Use of graphical forecasts portraying pilot reports and areas of probable turbulence is essential. The ability to integrate high-resolution, gridded, and frequently updated turbulence analyses and forecasts information into flight management and planning systems to augment SIGMET and AIRMET advisories for turbulence is beneficial. In this way, the latest up-to-date forecasts of CAT are available for flight planning and monitoring.

9.3 All pilots and other personnel concerned with flight planning should carefully consider the hazards associated with flight through areas where pilot reports or aviation weather forecasts indicate the presence of CAT, including mountain wave turbulence. The hazards associated with turbulence include severe jolts that cause structural damage to aircraft, airspeed fluctuations and G-loading that lead to high-altitude upset or low-speed buffeting, and/or injury to passengers.

9.4 It is beneficial for the purpose of turbulence forecast accuracy for airlines to include turbulence observations through AMDAR.

9.5 Airline Safety Management Systems (SMS)[2] should:

1. Include a training program for pilot and dispatcher (or operational control) personnel, which contains background information on the causes of CAT and the potential effects and use of modern analysis and forecast products, such as GTG and WAFS gridded turbulence forecasts.
2. Thoroughly train aircrews and dispatch personnel in the techniques of timely and accurate pilot reports. An efficient communications system should be established and supported to permit quick and easy interchange of flight critical information between the aircraft and the operational control function.

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[2] SMS is the formal, top-down business approach to managing safety risk, which includes a systemic approach to managing safety, including the necessary organizational structures, accountabilities, policies, and procedures. (Refer to the current edition of FAA Order VS 8000.367, Aviation Safety (AVS) Safety Management System Requirements.)

Less-than-efficient communications will result in an ineffective program for the tracking and avoidance of CAT or any other atmospheric hazards.

3. Promulgate a corporate philosophy of avoidance as the first line of defense, which includes a process to reduce CAT encounters and mitigate the result of CAT encounters.
4. Ensure that archiving of turbulence information and products are stored in easily accessed databases for use by the display or operational control personnel and are available for periodic review by the generating office.
5. Ensure the short- and long-term success of a carrier's turbulence avoidance and tracking system, which requires a dedicated and continuing training program for aircrews, dispatchers, meteorologists, and other operational control personnel.

10 WHERE YOU CAN FIND THIS AC. You can find this AC on the FAA's Web site at http://www.faa.gov/regulations_policies/advisory_circulars.

11 FEEDBACK. If you have suggestions for improving this AC, you may use the Advisory Circular Feedback Form at the end of this AC.

John Barbagallo
Deputy Director, Flight Standards Service

Advisory Circular Feedback Form

If you find an error in this AC, have recommendations for improving it, or have suggestions for new items/subjects to be added, you may let us know by contacting the Flight Technologies and Procedures Division (AFS-400) or the Flight Standards Directives Management Officer at 9-AWA-AFS-140-Directives@faa.gov.

Subject: AC 00-30C, Clear Air Turbulence Avoidance

Date: _____________________

Please check all appropriate line items:

☐ An error (procedural or typographical) has been noted in paragraph ____________ on page _______.

☐ Recommend paragraph _____________ on page __________ be changed as follows:

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☐ In a future change to this AC, please cover the following subject: *(Briefly describe what you want added.)*

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☐ Other comments:

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☐ I would like to discuss the above. Please contact me.

Submitted by: ________________________________ Date: ______________________