

# Principles of Flying - Understanding Jet Streams

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Jet streams are a very important part of commercial flying. Pilots are always searching for them because they save time, fuel and money. But what exactly are they? The following article explains the concept of jet streams. If you are a flight training student, this is a good thing to know.

Jet streams are fast flowing, narrow air currents found in the atmosphere. The main jet streams are located near the tropopause, the transition between the troposphere (where temperature decreases with height) and the stratosphere (where temperature increases with height). The major jet streams on earth are westerly winds (flowing west to east). Their paths typically have a meandering shape; jet streams may start, stop, split into two or more parts, combine into one stream, or flow in various directions including the opposite direction of most of the jet. The strongest jet streams are the polar jets, at around 23,000–39,000 feet above sea level, and the higher and somewhat weaker subtropical jets at around 33,000–52,000 ft. The northern hemisphere and the southern hemisphere each have both a polar jet and a subtropical jet. The northern hemisphere polar jet is situated over the middle to northern latitudes of North America, Europe, and Asia, while the southern hemisphere polar jet mostly circles Antarctica all year round.

Jet streams are caused by a combination of atmospheric heating (by solar radiation and, on some planets other than earth, internal heat) and the planet's rotation on its axis. They form near boundaries of adjacent air masses with significant differences in temperature, such as the polar region and the warmer air to the south. Meteorologists use the location of the jet streams as an aid in weather forecasting. The main commercial relevance of the jet streams is in air travel, as flight time can be dramatically affected by either flying with or against a jet stream. Clear-air turbulence, a potential hazard to aircraft, often is found in a jet stream's vicinity. One future benefit of jet streams could be to power airborne wind turbines.

Other jets also exist. During the northern hemisphere summer, easterly jets can form in tropical regions, typically in a region where dry air encounters more humid air at high altitudes. Low level jets also are typical of various regions such as the central United States.

## Discovery

Jet streams may have been first detected in the 1920s by Japanese meteorologist Wasaburo Ooishi. From a site near Mount Fuji, he tracked pilot balloons, also known as pibals (balloons used to determine upper level winds), as they rose into the atmosphere. Ooishi's work largely went unnoticed outside of Japan. American

pilot Wiley Post, the first man to fly around the world solo in 1933, is often given some credit for discovery of jet streams. Post invented a pressurized suit that let him fly above 20,000 ft. In the year before his death, Post made several attempts at a high-altitude transcontinental flight, and noticed that at times his ground speed greatly exceeded his air speed. German meteorologist H. Seilkopf is credited with coining the term "jet stream" (Strahlströmung) in a 1939 paper. Many sources credit real understanding of the nature of jet streams to regular and repeated flight-path traversals during World War II. Flyers consistently noticed westerly tailwinds in excess of 100 mph in flights, for example, from the US to the UK.

## Description

Polar jet streams are typically located near the 250 hPa pressure level, or 7 kilometers (4.3 mi) to 12 kilometers (7.5 mi) above sea level, while the weaker subtropical jet streams are much higher, between 10 kilometers (6.2 mi) and 16 kilometers (9.9 mi) above sea level. In each hemisphere, both upper-level jet streams form near breaks in the tropopause, which is at a higher altitude near the equator than it is over the poles, with large changes in its height occurring near the location of the jet stream. The northern hemisphere polar jet stream is most commonly found between latitudes 30°N and 60°N, while the northern subtropical jet stream located close to latitude 30°N. The upper level jet stream is said to "follow the sun" as it moves northward during the warm season, or late spring and summer, and southward during the cold season, or autumn and winter.

The width of a jet stream is typically a few hundred miles and its vertical thickness often less than three miles.

Jet streams are typically continuous over long distances, but discontinuities are common. The path of the jet typically has a meandering shape, and these meanders themselves propagate east, at lower speeds than that of the actual wind within the flow. Each large meander, or wave, within the jet stream is known as a Rossby wave. Rossby waves are caused by changes in the Coriolis effect with latitude, and propagate westward with respect to the flow in which they are embedded, which slows down the eastward migration of upper level troughs and ridges across the globe when compared to their embedded shortwave troughs. Shortwave troughs are smaller packets of upper level energy, on the scale of 1,000 kilometers (620 mi) to 4,000 kilometers (2,500 mi) long, which move through the flow pattern around large scale, or longwave, ridges and troughs within Rossby waves. Jet streams can split into two due to the formation of an upper-level closed low, which diverts a portion of the jet stream under its base, while the remainder of the jet moves by to its north.

The wind speeds vary according to the temperature gradient, exceeding 92 kilometers per hour, although speeds of over 398 kilometers per hour have been measured. Meteorologists now understand that the path of jet streams steers cyclonic storm systems at lower levels in the atmosphere, and so knowledge of their course has become an important part of weather forecasting. For example, in 2007, Britain experienced severe flooding as a result of the polar jet staying south for the summer.

The polar and subtropical jets merge at some locations and times, while at other times they are well separated.

## Cause

In general, winds are strongest under the tropopause (except during tornadoes, hurricanes or other anomalous situations). If two air masses of different temperatures or densities meet, the resulting pressure difference caused by the density difference (which causes wind) is highest within the transition zone. The wind does not flow directly from the hot to the cold area, but is deflected by the Coriolis effect and flows along the boundary of the two air masses.

All these facts are consequences of the thermal wind relation. The balance of forces on an atmospheric parcel in the vertical direction is primarily between the pressure gradient and the force of gravity, a balance referred to as hydrostatic. In the horizontal, the dominant balance outside of the tropics is between the Coriolis effect and the pressure gradient, a balance referred to as geostrophic. Given both hydrostatic and geostrophic balance, one can derive the thermal wind relation: the vertical derivative of the horizontal wind is proportional to the horizontal temperature gradient. The sense of the relation is such that temperatures decreasing polewards implies that winds develop a larger eastward component as one moves upwards. Therefore, the strong eastward moving jet streams are in part a simple consequence of the fact that the equator is warmer than the north and south poles.

## Aviation

The location of the jet stream is extremely important for aviation. Commercial use of the jet stream began on November 18, 1952, when Pan Am flew from Tokyo to Honolulu at an altitude of 25,000 ft. It cut the trip time by over one-third, from 18 to 11.5 hours. Not only does it cut time off the flight, it also nets fuel savings for the airline industry. Within North America, the time needed to fly east across the continent can be decreased by about 30 minutes if an airplane can fly with the jet stream, or increased by more than that amount if it must fly west against it.

Associated with jet streams is a phenomenon known as clear air turbulence (CAT), caused by vertical and horizontal wind shear connected to the jet streams. The CAT is strongest on the cold airside of the jet, next to and just underneath the axis of the jet. Clear air turbulence can be hazardous to aircraft, and has caused fatal accidents, such as United Airlines Flight 826 in 1997.

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