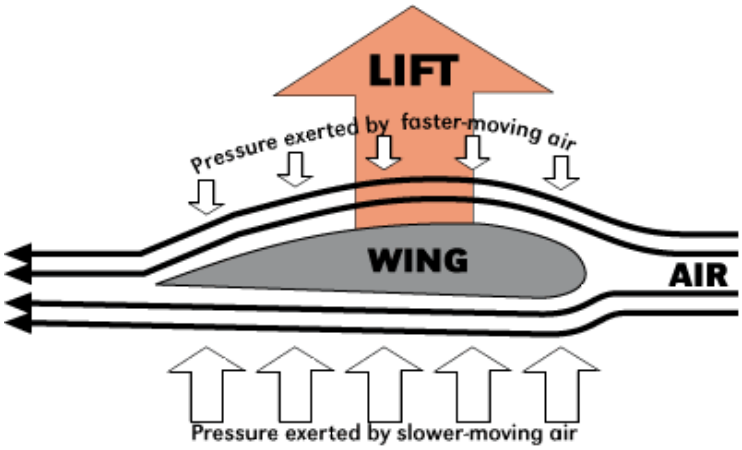
Naval Aviation Professional Knowledge Supplement

Learning Objective

1. Understand the impact of the following weather phenomena on flight operations.
    a. Crosswind
    b. Wind shear
    c. Fog
    d. Icing
    e. Turbulence
    f. Thunderstorms

I. Weather and Flight Operations[i]

Flight Basics



Aircraft flight is accomplished by virtue of Bernoulli's Principle of Differential Pressure. Put simply, the principle states that the pressure of a moving fluid (liquid or gas) varies with its speed of motion. As the velocity of a moving fluid (liquid or gas) increases, the pressure within the fluid decreases. Since air is recognized as a body and it is accepted that it must follow the above laws, one can begin to see how and why an airplane wing develops lift. As the wing moves through the air, the flow of air across the curved top surface increases in velocity (the air must travel faster to cover the greater distance) creating a low-pressure area. The slower-moving air on the bottom of a wing creates an area of higher pressure. This pressure differential produces an upward force on the wing, otherwise known as lift.

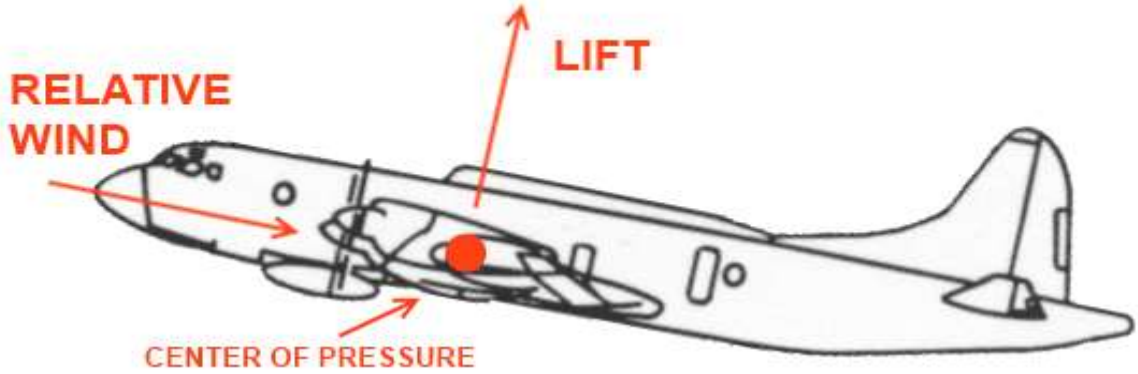


As the amount of air passing above and below the wing increases, the amount of lift produced likewise increases. It is for this reason that air-capable ships, such as aircraft carriers, are positioned into the wind during flight operations. The headwind encountered by aircraft preparing for launch provides a "headstart" to the aircraft, allowing it to produce a small amount of lift while standing still. This results in the aircraft having to attain a lower relative speed – and cover a shorter

distance over the ground – to produce sufficient lift to overcome the weight of the aircraft.

Relative Wind

The direction of the air's movement as it encounters the wing (airfoil) of an aircraft is referred to as ***relative wind*.** The relative wind for an airplane in flight flows in a direction parallel with and opposite to the direction of flight; therefore, the actual flight path of the airplane determines the direction of the relative wind.



Crosswind

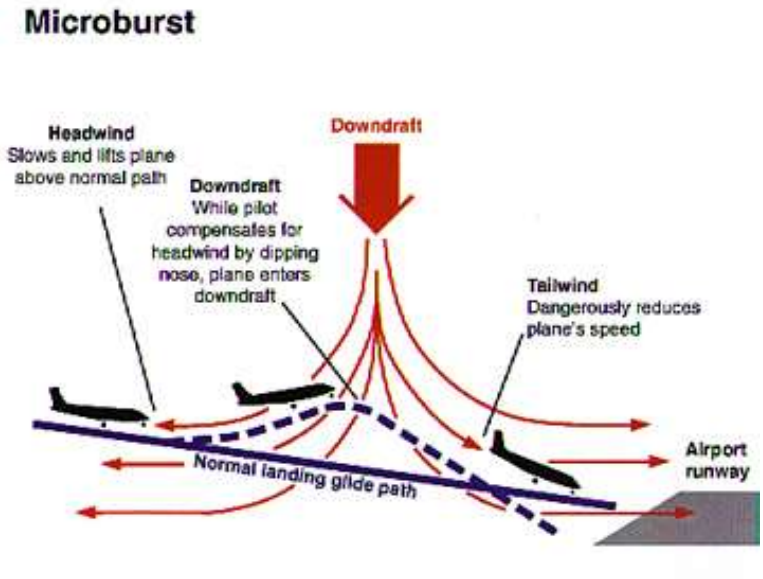


Crosswind refers to the component of wind that an aircraft encounters that is perpendicular to the direction of travel. Ideally, aircraft would always fly into the wind during takeoff and landing (to provide as much relative wind to the aircraft during slow flight) and with the wind during enroute phases (to maximize the aircraft's speed over the ground). In reality however, this is usually not possible, and a certain amount of crosswind is unavoidable. Pilots are trained to counteract the effects of crosswinds by lowering the windward wing, however excessive crosswinds can present serious hazards during critical phases of flight as parts of the aircraft risk striking the deck.

Weather

Weather is a primary concern during flight operations since aircraft in flight are particularly vulnerable to the hazards associated with changing atmospheric conditions. The primary weather hazards for aircraft include:

a. Wind Shear: A sudden, drastic change in wind speed and/or direction over a very small area. Wind shear can subject an aircraft to violent updrafts and downdrafts, as well as abrupt changes to the horizontal movement of the aircraft. While wind shear can occur at any altitude, low-level wind shear is especially hazardous due to the proximity of an aircraft to the ground. Directional wind changes of 180° and speed changes of 50 knots or more are associated with low-level wind shear. Low-level wind shear is commonly associated with passing frontal systems, thunderstorms, and temperature inversions with strong upper level winds (greater than 25 knots). The rapid changes in wind direction and velocity change the wind's relation to the aircraft disrupting the normal flight attitude and performance of the aircraft. One critical type of shear associated with convective precipitation is known as a ***microburst***. A typical microburst occurs in a space of less than one mile horizontally and within 1,000 feet vertically. The lifespan of a microburst is about 15 minutes during which it can produce downdrafts of up to 6,000 feet per minute (fpm). It can also produce a hazardous wind direction change of 45 degrees or more, in a matter of seconds. When encountered close to the ground, these excessive downdrafts and rapid changes in wind direction can produce a situation in which it is difficult to control the aircraft.

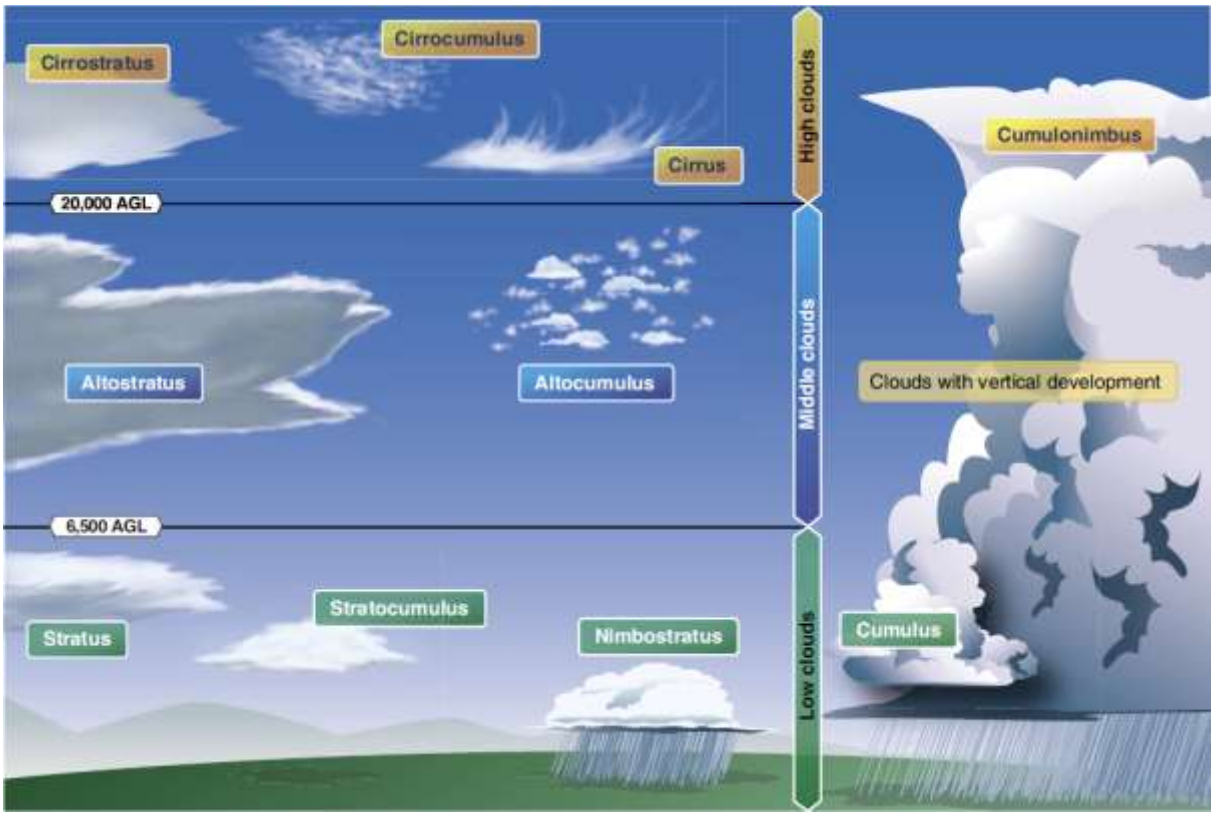


b. Icing: When present above the freezing level, water becomes supercooled, meaning it retains its liquid form despite being below the freezing temperature. Supercooled water freezes on impact with an aircraft, and can disrupt the smooth flow of air over the wings. If enough ice accumulates on an aircraft, it can quickly lose lift and stall.

c. Fog: Fog is a cloud that begins within 50 feet of the surface. It typically occurs when the temperature of air near the ground is cooled to the air's dew point. At this point, water vapor in the air condenses and becomes visible in the form of fog. Fog is classified according to the manner in which it forms and is dependent upon the current temperature and the amount of water vapor in the air. Fog is hazardous to flight operations primarily

due to it causing very low visibility near the surface. In very cold weather (–25 °F or colder), “ice fog” can form, posing an additional hazard to aircraft.

d. Clouds: Although clouds are not considered a major hazard by themselves, there are special considerations that need to be taken into account during flight operations. Clouds are visible indicators and are often indicative of future weather. Further, flight operations



are frequently impacted by what is referred to as the ***ceiling***, defined as the lowest layer of clouds reported as being broken (5/8-7/8 of the sky covered) or overcast (total sky coverage), or the vertical visibility into an obscuration like fog or haze. Clouds are classified according to the height of their bases as low, middle, or high clouds, as well as clouds with vertical development:

i. ***Low clouds*** are those that form near the Earth’s surface and extend up to 6,500 feet above ground level (AGL). They are made primarily of water droplets, but can include supercooled water droplets that induce hazardous aircraft icing. Fog is also classified as a type of low cloud formation. Clouds in this family create low ceilings, hamper visibility, and can change rapidly. Because of this, they influence flight planning and can make visual flight impossible.

ii. ***Middle clouds*** form around 6,500 feet AGL and extend up to 20,000 feet AGL. They are composed of water, ice crystals, and supercooled water droplets.

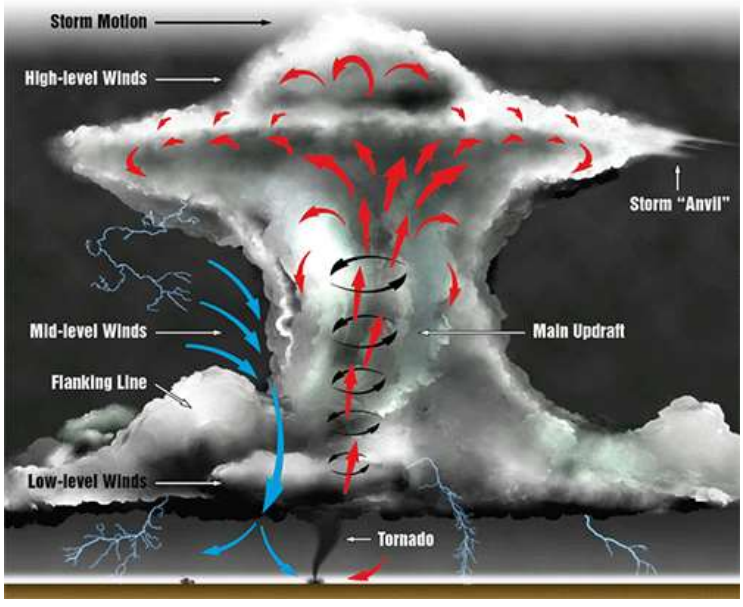
Typical middle-level clouds include altostratus and altocumulus. These types of clouds may be encountered on cross-country flights at higher altitudes. Altostratus clouds can produce turbulence and may contain moderate icing. Altocumulus clouds, which usually form when altostratus clouds are breaking apart, also may contain light turbulence and icing.

iii. ***High clouds*** form above 20,000 feet AGL and usually form only in stable air. They are made up of ice crystals and pose no real threat of turbulence or aircraft icing.

iv. ***Clouds with extensive vertical development*** are cumulus clouds that build vertically into towering cumulus or cumulonimbus clouds. The bases of these clouds form in the low to middle cloud base region but can extend into high altitude cloud levels. Towering cumulus clouds indicate areas of instability in the atmosphere, and the air around and inside them is turbulent. These types of clouds often develop into cumulonimbus clouds or thunderstorms. Cumulonimbus clouds contain large amounts of moisture and unstable air, and usually produce hazardous weather phenomena, such as lightning, hail, tornadoes, gusty winds, and wind shear. These extensive vertical clouds can be obscured by other cloud formations and are not always visible from the ground or while in flight. When this happens, these clouds are said to be embedded, hence the term, embedded thunderstorms.

e. Turbulence: Turbulence occurs when instability in the atmosphere creates vertical air movements that disrupt aircraft flight. Most turbulence results in only minor impact to flight operations, however severe turbulence – such as that found in thunderstorms – can cause violent shuddering of an aircraft and injure the flight crew. Small, light aircraft, such as carrier-based platforms, can be especially vulnerable to turbulence.

f. Thunderstorms: Thunderstorms represent one of the most dangerous hazards to aviation since they contain multiple individual hazards all at once, producing extreme turbulence, damaging hail, tornadoes, icing, and wind shear. Lightning strikes can puncture the skin of an aircraft and damage communications and electronic navigational equipment. Further, nearby lightning can blind the pilot, rendering him or her momentarily unable to navigate either by instrument or by visual reference. It can also induce



permanent errors in the magnetic compass. Lightning discharges, even distant ones, can disrupt radio communications on low and medium frequencies. While most likely to occur near or in a thunderstorm, hazards associated with severe storms can be encountered up to 20 miles away.

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[i] FAA-H-8083-25A (Pilot's Handbook of Aeronautical Knowledge). Available at https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/pilot_handbook/