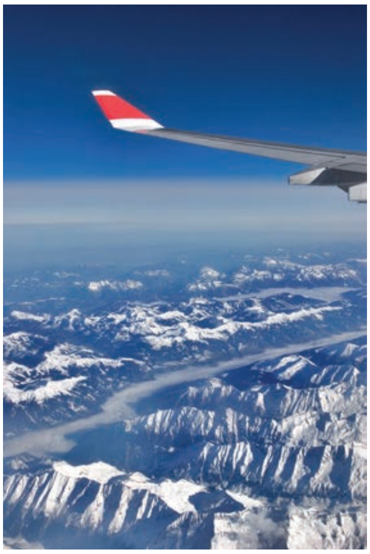
HAZARDOUS WEATHER PHENOMENA

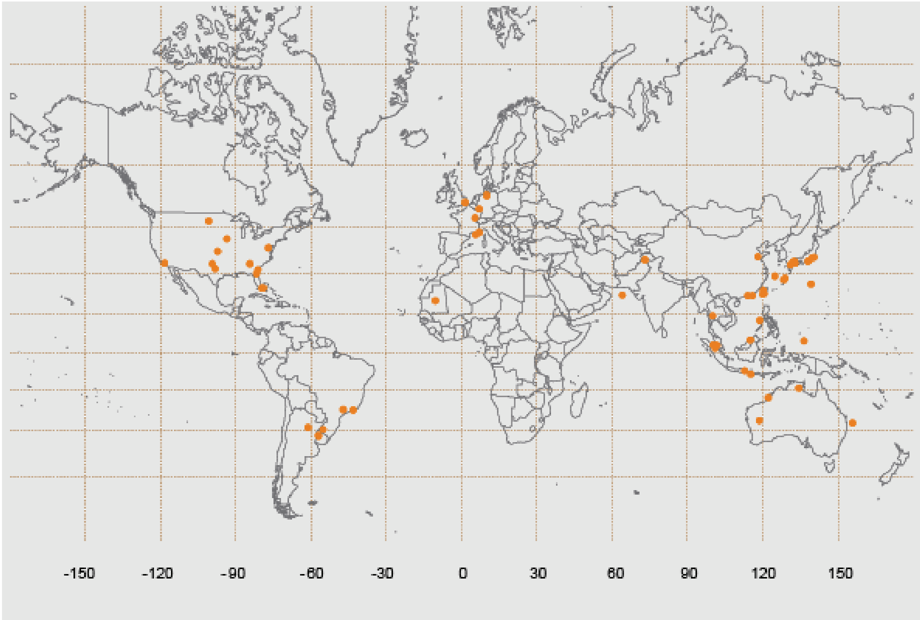
High Ice Water Content

Bureau of Meteorology › Aviation Weather Services



High ice water content (HIWC) presents a significant hazard to aircraft operating above 22,000 feet.

It can cause temporary power loss in jet engines, and around 60 per cent of known events since 1988 have occurred in South East Asia and Australasia.



Location of Ice Crystal Power-Loss Events
(Note: Latitude and longitude information is not available for all 100 events. This chart actually shows 67 events, some of which are overlaid.)

High ice water content

High ice water content (HIWC) is the name for atmospheric conditions where there are high concentrations of ice crystals. Such conditions are typically associated with deep convection storms in the tropics and subtropics. HIWC usually occurs at temperatures below -20° C where there tends to be a reduction in super-cooled liquid water and an increased ratio of ice particles.

Research has shown that convective updrafts associated with large convective cells have the ability to lift high concentrations of moisture to high altitudes where it can freeze into very small ice crystals.

Note the term "icing conditions" typically refers to weather conditions below 22,000 feet where supercooled liquid droplets form ice on cold airframe surfaces such as the wings and fuselage. In contrast, ice-crystal icing conditions connected to engine power loss are thought to be due to completely frozen ice crystals.

Engine impact

Ice crystals, regardless of size, will not adhere to a cold airframe of a plane. However, small ice crystals have the ability to partially melt and stick to warmer engine surfaces. The ingestion of very small ice crystals into the core of the engine causes the ice crystals to melt as they impact on the warm internal engine components. An increasing collection of super-cooled liquid produces a thin film over parts of the engine enabling the further capture of ice crystals. Over time ice crystals aggregate and reduce the internal temperature of the engine leading to various engine malfunctions.

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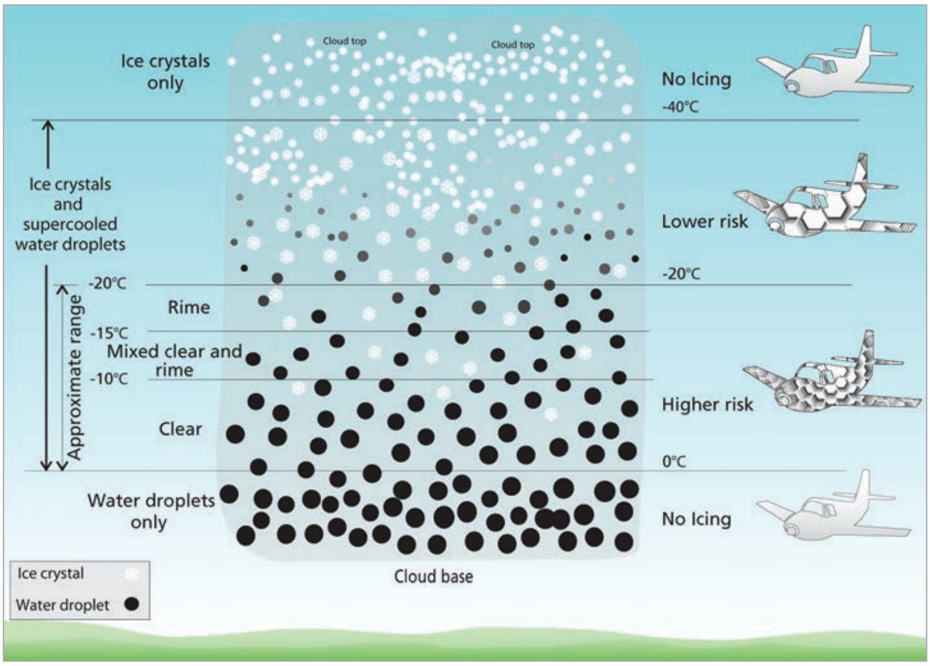
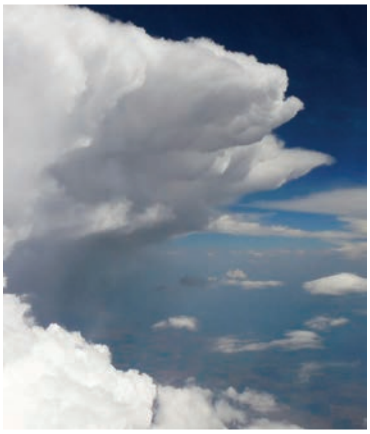


Risk of icing in different atmospheric conditions

Both older generation jet engines and the new generation of jet engines have the potential to be affected by HIWC. The actual mechanism in which the ice crystals cause engine power loss is dependent on the design characteristics of each particular engine, and tactical measures to remove the ice accretion may vary between engine types.


Anvil cloud

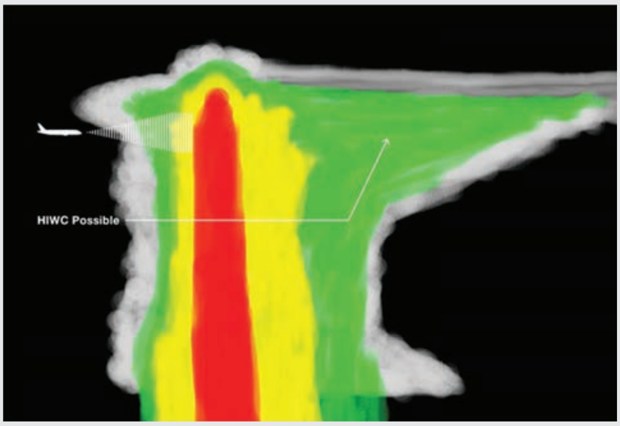
Icing in the atmosphere

The distribution of supercooled water droplets and ice within a cloud varies with temperature. In general the largest supercooled droplets are found at temperatures just below 0° C, i.e. at altitudes just above the freezing level (FZL). The size of the supercooled droplets tends to decrease with decreasing temperatures and/or increasing altitude.

Convective cloud types

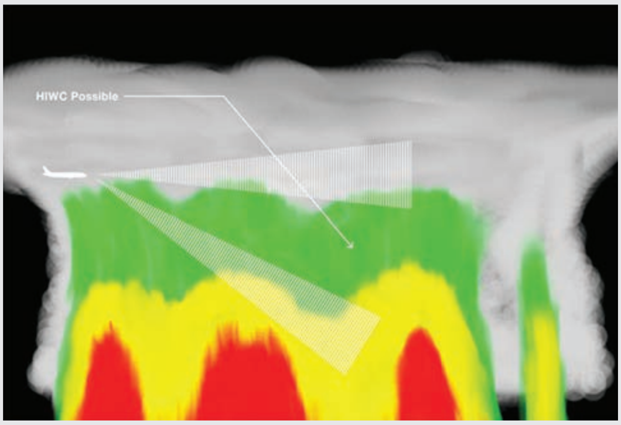
Engine power loss events resulting from HIWC have been associated with both strong and weak, or decaying, convective environments. Approximately 20 per cent of engine events occur in strong convection, while the remaining 80 per cent have occurred in weak convection associated with the convective anvil.

Strong convection: Strong convection can occur either over land or ocean where pilots have the ability to observe a defined moderate to strong radar signature to high altitudes. This provides flight crew with the ability to detect areas of strong convection and take tactical avoidance measures as necessary. In these systems, areas of HIWC are common within the anvil cloud regions on the downwind side of the cell. Pilots could avoid potential areas of HIWC by diverting to the upwind side of the cell. Unfortunately due to the small size of ice crystals in the anvil HIWC particle radar returns are usually weak or non-existent.



Example of single-cell convection radar return

This image depicts a vertical cross-section view. Colours represent standard Boeing aircraft radar returns where green is light, amber is moderate and red is heavy. The illustration annotates an area of high ice water content (HIWC) possible in the anvil cloud downwind from the convective core.(Image courtesy of Boeing)



Radar view of typical ice crystal engine conditions

This image depicts a cross-section view in a weak or decaying convective system. The light radar returns at flight level would not suggest an area of convection to flight crew. However, by employing the radar tilt function, moderate to heavy radar returns can be seen in the region below the aircraft. (Image courtesy of Boeing)

Weak/Decaying convection: Weak and decaying areas of convection consists of weak updrafts, diminishing radar signatures, and remanent regions of HIWC aloft. Areas of HIWC are often associated with residual areas of decaying convective cells which originally formed part of a larger convective system. As the stronger radar returns occur at lower altitudes there is often weak or no reflectivity at cruising flight levels, making it more difficult for pilots to identify areas of HIWC. In areas of organised convection the anvil of each convective cell is often indistinguishable as they merge to form larger areas of thick cirrus cloud. This poses a problem in identifying potential areas for HIWC.

Detection

The on-board weather radar does not have the ability to detect small particles such as ice crystals in large concentrations. During engine ice crystal power-loss the pilot may be presented with what appears to be conflicting information. The following conditions have been reported during HIWC encounters:

- no pilot reports of weather radar returns at the event location;
- temperature significantly warmer than standard atmosphere;
- light-to-moderate turbulence;
- areas of heavy rain below the freezing level;
- the appearance of precipitation on heated windshield, often reported as rain, due to tiny ice crystals melting;
- aircraft total air temperature (TAT) anomaly-reading zero, or in error, due to ice crystal build-up at the sensing element; and
- lack of observations of significant airframe icing.

There are still many unknowns associated with the science of HIWC. This phenomenon is still being researched through an international science initiative. This fact sheet will be updated as more information is discovered.

Avoidance

If practical, the probability of HIWC encounters can be reduced by minimising the length of planned track through large areas of cirrus cloud associated with:

- tropical cyclones;
- ex-tropical cyclones over land and water;
- large areas of strong convective activity at the Inter Tropical Convergence Zone (ITCZ); and
- the downwind cirrus anvil of large convective cells.

Incidences

Since 1988 there have been 108 jet engine power loss events recorded worldwide in which ice formed inside the core areas of the engine, leading to temporary shutdowns through surge, stall or flameout. Fortunately engine power loss was temporary in all cases, with the possible exception of the 2009 Air France 447 incident where it may have been a contributing factor. Most of these instances have occurred at altitudes greater than 22,000 feet where there is usually an absence of super cooled liquid water, the typical cause of airframe icing. Over 60 per cent of these events have occurred in Southeast Asia and Australasia.

Research

In early 2014, scientists from the Bureau of Meteorology participated in a research initiative with NASA working to improve aviation safety by studying high altitude ice crystals during a flight campaign in Darwin. High Altitude Ice Crystals (HAIC) / High Ice Water Content (HIWC) were detected by flying a French Falcon 20 aircraft into weather with these specific icing conditions to enable further study of ice characteristics. Instrumentation was mounted under the wing of the aircraft to measure the total water content in clouds that have high concentrations of ice crystals in the vicinity of oceanic and continental thunderstorms.

Reference List

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