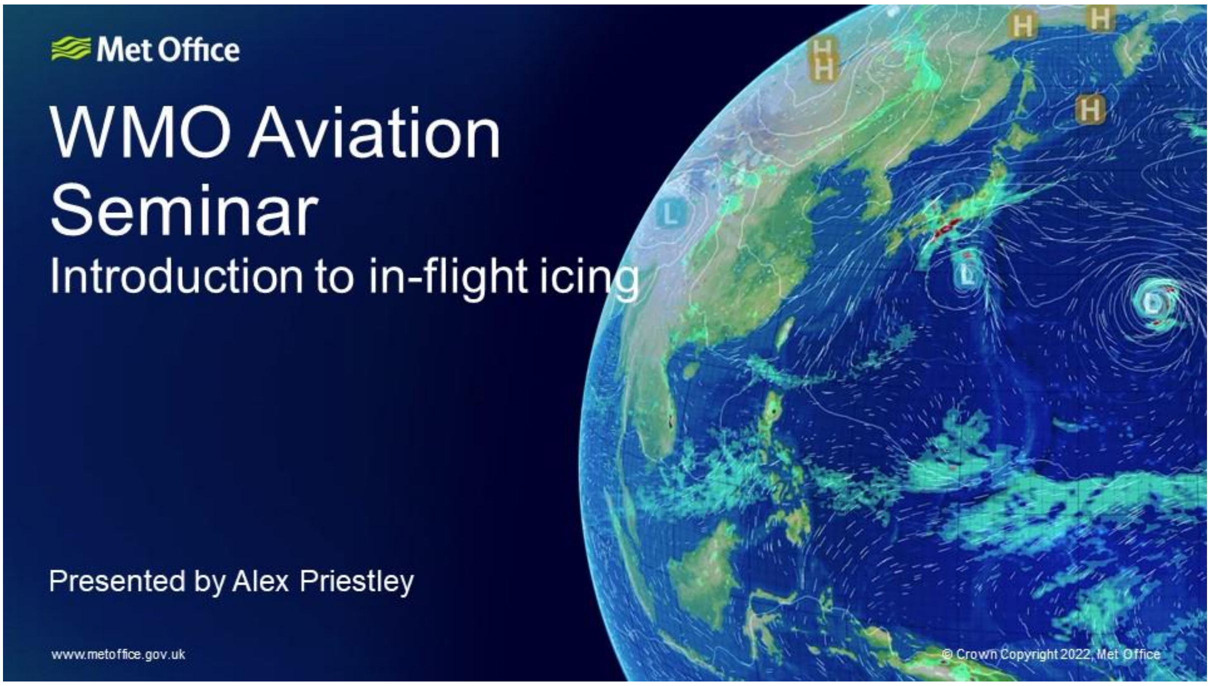

Hello and welcome to this WMO Aviation Seminar where we are going to be looking at in-flight icing.

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Session aim

- Understand why icing is a significant aviation hazard

The aim of this session is to understand why icing is a significant aviation hazard.

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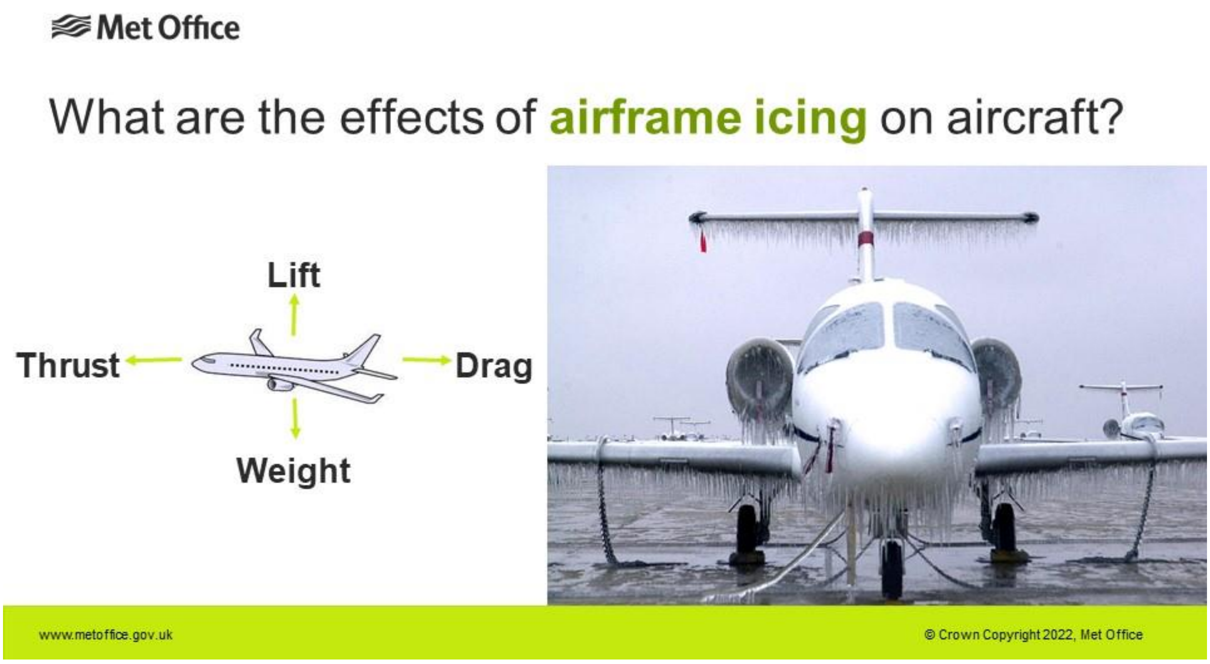
Session objectives

- Describe the effects of ice accumulation on aircraft performance.
- List the different forms of airframe and engine icing.
- Explain the processes and factors which contribute to each of the types of airframe icing.

For the objectives of this session, we are going to describe the effects of ice accumulation on aircraft performance. We are going to list the different forms of airframe icing and engine icing, and we are going to have a look at the processes and factors which contribute to each of the types of airframe icing.



First of all, what are the effects of airframe icing on an aircraft? We have a particularly extreme example here in the photograph.

The effects of airframe icing: it affects the weight of the aircraft. It increases the ‘all-up’ weight of the aircraft. It can affect the thrust created by the engines by affecting engine performance. Ice on wings and tails can affect the amount of lift available, and it can increase the drag on the aircraft.

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Effects of icing on aircraft

- Aerodynamics changes
- All up weight increases
- Vibration due to uneven loading
- Engine intakes may become blocked
- Undercarriage retraction/extension problems
- Control surfaces may jam or become stiff
- Pitot tubes blocked (gives the air speed)
- Communications affected
- Impaired vision through windscreens
- Increased fuel consumption

Ice can cause antennas to vibrate so severely that they break

Here is a more complete list of the effects of icing on aircraft:

- It changes the aerodynamics; it can increase the ‘all-up’ weight or the total weight of the aircraft
- Ice build-up can cause vibration due to uneven loading, and as an example, this photograph on the right shows ice on an antenna which if they start to vibrate, they can be damaged or break
- Ice can block engine intakes
- It can affect the undercarriage retraction and extension
- Control services such as ailerons and flaps may become stiff or get jammed
- Pitot tubes can become blocked, and they are very important because they give the air speed
- It can affect communications
- It can block vision through the windscreen
- It can increase fuel consumption

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2 Main Types of Icing

Airframe Icing

Occurs when:

- The airframe temperature is below freezing **and**,
- Super-cooled water droplets are present.

Engine Icing

Occurs when:

- Air is cooled adiabatically inside piston engine
- Ice crystals ingested into jet engine

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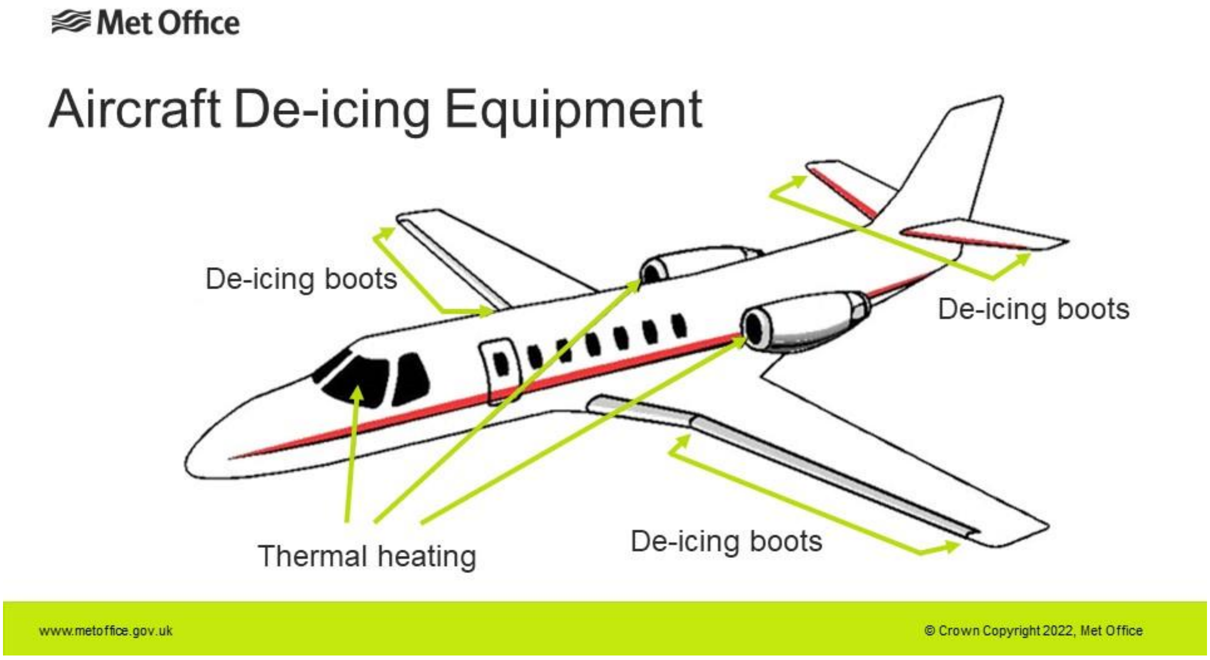
There are two main types of icing that we are going to look at in this session. The first type is airframe icing, and this is ice build-up on the aircraft airframe. This occurs when the airframe temperature is below freezing and there are supercooled water droplets present in the atmosphere.

The second type of icing is engine icing, and there are two types of engine icing that we are going to briefly look at today. There is icing that occurs when air is cooled adiabatically inside a piston engine, and then there is ice crystal icing. This is where ice crystals are ingested into jet engines and effect jet engine performance.



What equipment do aircraft sometimes or often have to deal with icing?

This is a schematic diagram of some of the typical equipment that aircraft have. They can have thermal heating elements. this is there to melt the ice, often on the windscreen, and on engine intakes, and sometimes on their wing surfaces as well.

Some aircraft have de-icing boots. These are features that can be expanded once ice is built up, and this breaks the ice off the surface it has built up on.

It is worth remembering that not all aircraft have any de-icing equipment, and it varies a lot between different aircraft types and different aircraft sizes, so the effect of icing can vary markedly between different types of aircraft.

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What do we need for airframe icing?

Need:

- Ambient air temperatures below 0°C
- Super-cooled water droplets (droplet size is important)

Enhanced when:

- Rising air
- Temperature range for optimum icing is typically between -3°C and -15°C

To recap, what do we need for airframe icing? As we saw before, we need the airframe and the ambient air temperature to be below freezing, and we need there to be supercooled liquid water droplets present, and the droplet size is important. We will come back to that shortly.

How can airframe icing be enhanced if we have got the two basic criteria being met? The airframe icing is enhanced when we have got rising air, and the temperature range for optimum icing is typically between minus three and minus 15 degrees Celsius.

The effect of icing is very aircraft dependent, and so aircraft with lots of pointy or sharp surfaces such as helicopters (like in the image on the slide here) are more prone to icing.

Areas of the aircraft such as helicopter blades and tail fins of aircraft are often more prone than the wings of aircraft.

Smaller aircraft and light aircraft may not have de-icing equipment at all, so they can be more affected than aircraft with de-icing equipment. Icing can affect the operation of autopilot systems as well.

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Types of Airframe Icing

1) Rime Ice
2) Clear Ice or Glaze Ice
3) Mixed Ice
4) Rain Ice

There are four main types of airframe icing that we're going to look at today and these are:

- Rime ice
- Clear or glaze ice
- Mixed ice
- Rain ice

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1. Rime Ice

Small super-cooled drops that freeze quickly, trapping air

- Rough, porous and brittle
- Opaque, white/milky colour
- Forms on leading edges, and can protrude into the airflow
- Relatively easily dealt with using de-icing equipment
- Temperature Range - MS15 to MS40

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Rime ice forms with small, supercooled liquid water drops. They freeze quickly, and they trap air. Because they trap air, this gives them a white or opaque colour. It's quite rough and porous, and it's quite brittle.

It tends to form on the leading edges of aircraft wings and tails and protrudes into the airflow so it can affect the aerodynamics. Because it is quite brittle it is relatively easily dealt with by using de-icing equipment. A typical temperature range for rime ice is between about minus 15 and minus 40 Celsius.

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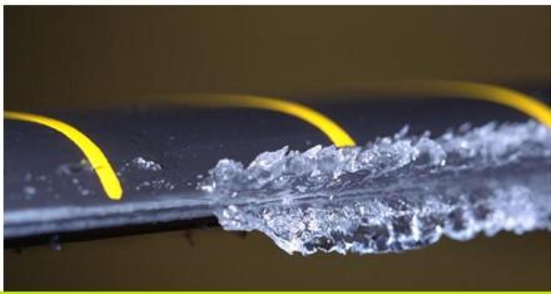
2. Clear Ice

- Larger super-cooled drops that freeze slowly
- No trapped air
    - Smooth, tough, adhesive
    - Clear, dense and heavy
    - Runs back along the wings and fuselage
    - Tricky to remove away from the leading edges of the wings
    - Temperature range - Zero to MS10



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The second type of icing is clear ice and for clear ice we need larger supercooled droplets. These freeze slowly and because they freeze slowly there is less air trapped or no air trapped.

This means that clear ice is denser and heavier than rime ice, and it's also tougher and more adhesive.

Because it forms slowly, it can run back along wings and the fuselage, and this, combined with the fact that it’s tougher, means that it is more difficult to remove using de-icing equipment.

A typical temperature range for clear ice is from zero to minus 10.

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3. Mixed Ice

- A combination of rime ice and clear ice
- Droplet size, water content and temperature varies with time
  - Dense and heavy
  - Disruptive to airflow
  - De-icing equipment can be ineffective
  - Temperature range - MS10 to MS15

The next type is mixed ice. This is just a combination of rime ice and clear ice. And this is when the droplet size and the water content and temperature vary through time, so it can combine dense and heavy ice with less dense and more brittle ice.

It is very disruptive to airflow around wings and tails, and de-icing equipment can be ineffective with mixed ice.

It typically forms in in a temperature range of about minus 10 to minus 15 Celsius.

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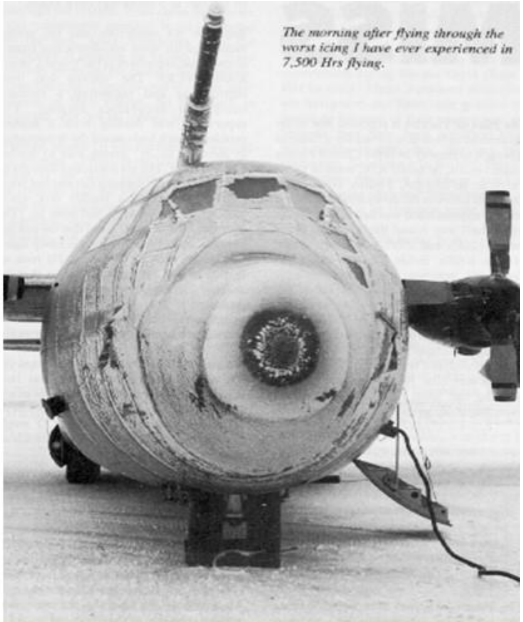
4. Rain Ice

- Freezing rain or freezing drizzle
- Very large super-cooled droplets
  - Dense
  - Clear ice
  - Lumpy and uneven
  - Very disruptive to airflow
  - **De-icing equipment is ineffective**



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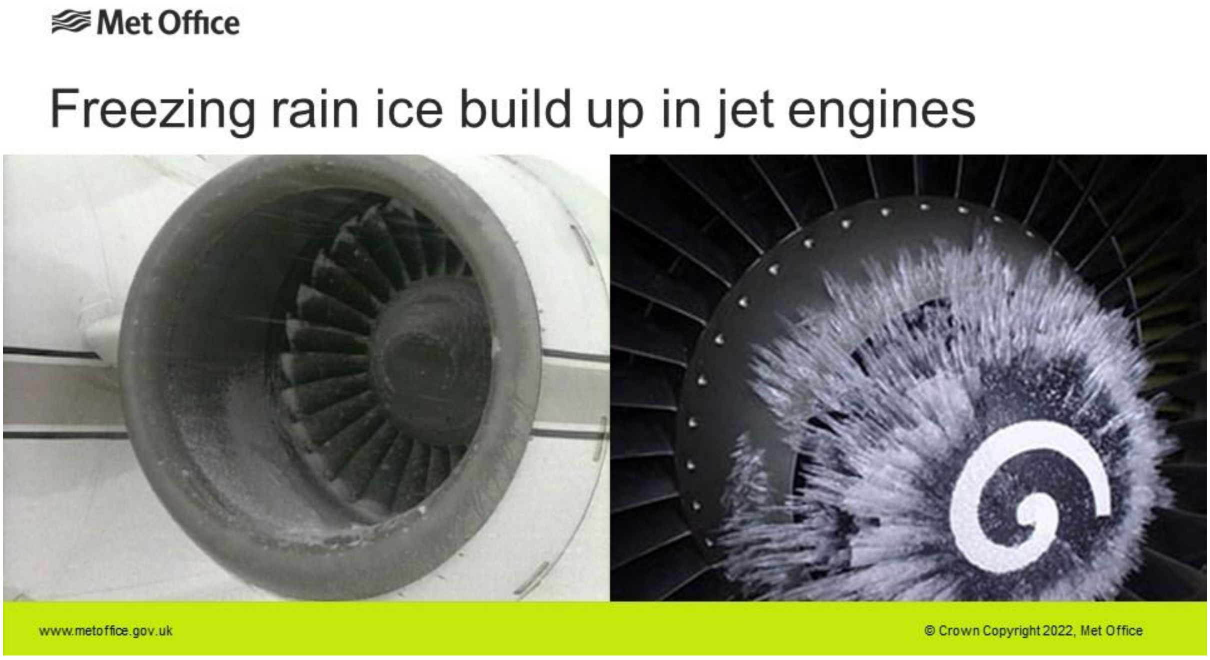
And lastly, rain ice. This is formed through freezing precipitation: freezing rain or freezing drizzle and these are very large, supercooled water droplets. This ice is dense and clear.

It is often lumpy and uneven, so therefore it is very disruptive to airflow and de-icing equipment is ineffective against it. Rain ice is the worst type of ice for aircraft performance, and this picture on the right hand side shows an aircraft, a C-130 that has landed after flying through some freezing drizzle. You can see a huge amount of ice is built up on that aircraft, so rain ice is the worst kind of ice.



Freezing rain can also build up inside jet engines and cause problems with engine operation as well.

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Engine carburettor icing

Affects piston-engine aircraft

- Adiabatic cooling as air accelerates into carburettor, between 2 and 5 C
- Refrigeration cooling as fuel evaporates in the carburettor, between 10 and 15 C

Most common with RH >60% and air temperature above zero

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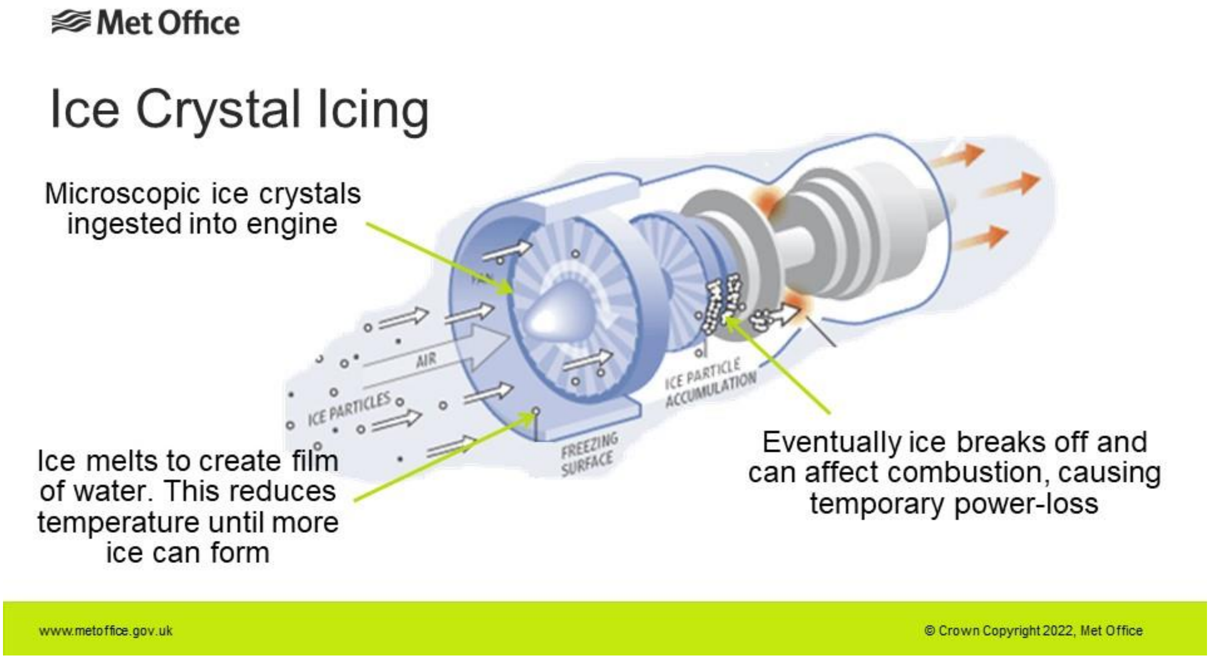
Those were the types of airframe icing and now we're going to have a quick look at engine icing. Engine carburettor icing occurs in piston engine aircraft and therefore typically older aircraft.

Air cools adiabatically as it is taken into the carburettor, and this cools here by about 2 to 5 Celsius, and then as fuel evaporates in the carburettor that can then further cool by between 10 to 15 Celsius. This can lead to up to 20 Celsius of cooling.

This effect is most common with relatively high relative humidity (greater than 60%), and it does occur with ambient air temperatures above 0 Celsius, so this is not restricted to above the freezing level and can occur at lower altitudes.



The other type of engine icing is ice crystal icing.

This occurs when microscopic ice crystals in the atmosphere are taken into jet engines, and this ice melts as it goes into the engine and creates a film of water. This reduces the temperature of these surfaces that the water is on, until ice can form. Eventually once this ice is built up, this ice can break off and pass through the engine, where it can affect combustion, and it can cause temporary power loss as well.

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Ice crystal icing conditions

- Near convective weather systems, especially in the tropics and over the ocean
- In relatively warm air above 20,000 ft
- During descent, when engines are idling, or after prolonged exposure in the cruise

Pilots often report at the same time:

- Heavy rain below the freezing level
- Some turbulence (usually light to moderate)
- St Elmo's fire
- No airframe icing

The conditions that ice crystal icing occurs in are typically found near convective weather systems, particularly in the tropics and over oceans.

It occurs when the air is relatively warm above about 20,000 feet, and it can affect engines more when they're at low power, so when they're idling during descent or after prolonged exposure during a cruise.

Pilots who report ice crystal icing have often reported these phenomena at the same time. They have often reported heavy rain occurring below the freezing level, they've often reported some turbulence, usually light or moderate, and there are occasional reports of St Elmo's fire too.

Crucially, they don't usually report any airframe icing.

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Summary

- In-flight icing can have dangerous impacts on aircraft control, weight, aerodynamics and lift
- The main types of airframe icing are rime, clear and mixed ice
- Freezing precipitation can cause the most severe airframe icing
- Engines can also be affected by icing in-flight

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In summary, we have introduced the different types of airframe icing today, we have looked at how in-flight icing can have dangerous impacts on aircraft control, weight, aerodynamics and lift. We have looked at the main types of airframe icing. We have concluded that freezing precipitation i.e. freezing rain and freezing drizzle can cause the most severe airframe icing, and we've also had a look at the different types of engine icing.

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Questions?

- On the page forum
- Live sessions

If you have any questions please put them on the page forum, or you can ask them during the live sessions in November.

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Live session discussion points

- In-flight icing
    - What types of icing are common in your area?
    - What impact do these have on aviators?

For the live sessions in November, we'd just like to introduce a couple of discussion points for you to think about in advance and maybe bring along to the Q&A session:

- In-flight icing
    - What types of icing are common in the area that you work in?
    - What sort of impacts do these types of icing have on aviators in your area?