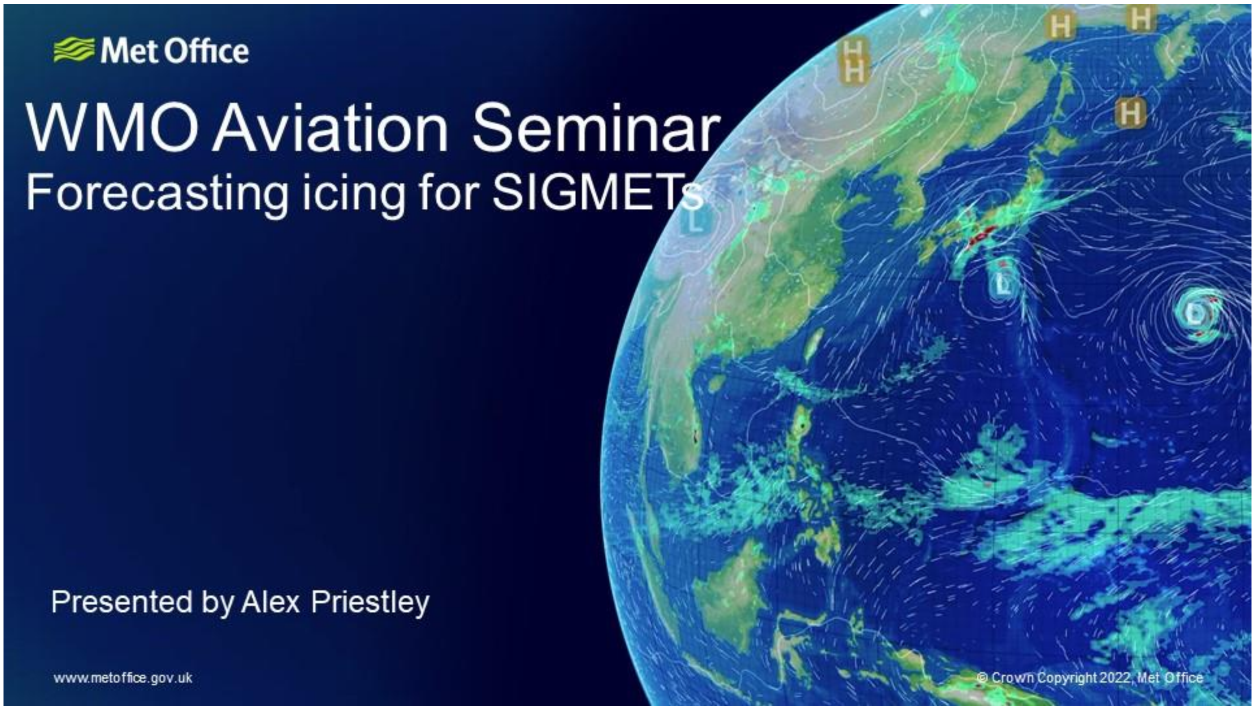


Hello and welcome to the second WMO Aviation Seminar on icing.

Last time we introduced in-flight icing, and in this session we are going to be looking at forecasting icing for inclusion in SIGMETs.

Met Office

Session aim

- Understand how to forecast in-flight icing and how to warn for it through SIGMETs.

The aim of this session is to understand how to forecast in flight icing and how to warn for it through SIGMETs.

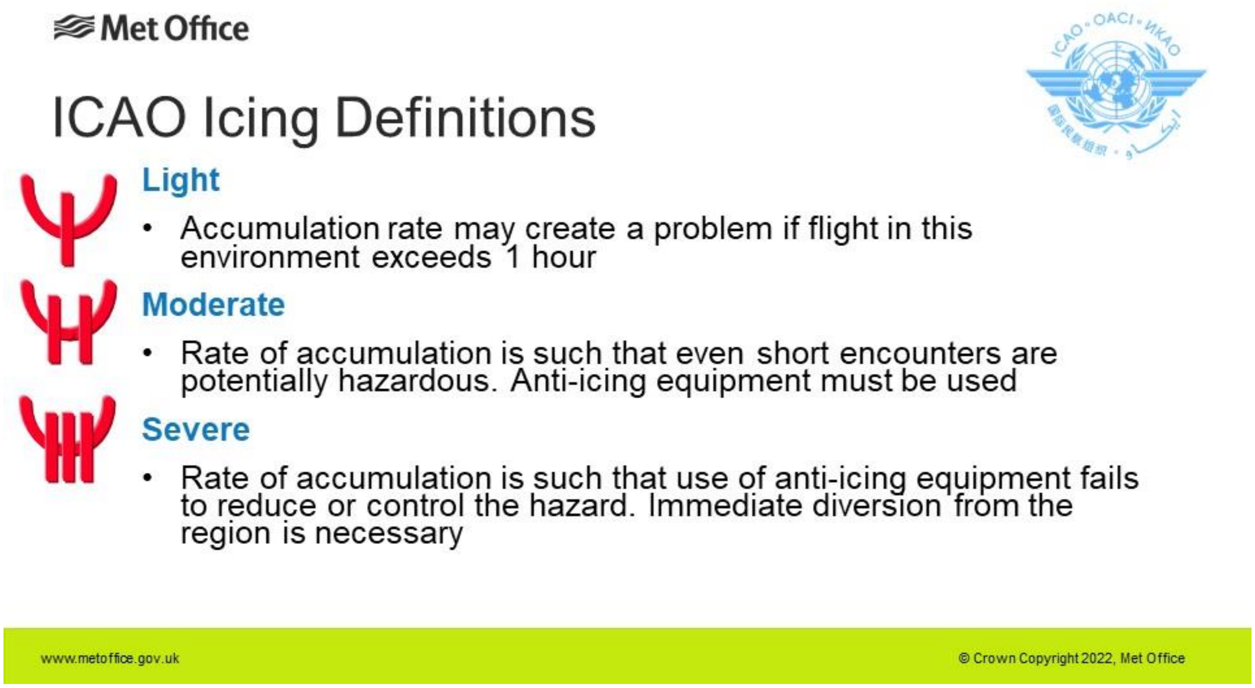
Met Office

Session objectives

- Understand how icing severity is defined
- Analyse the severity of icing
- Forecast its expected development
- Apply the SIGMET code correctly for icing

The objectives of this session:

- Understand how icing severity is defined
- Analyze the severity of icing
- Forecast its expected development
- Apply the SIGMET code correctly for icing

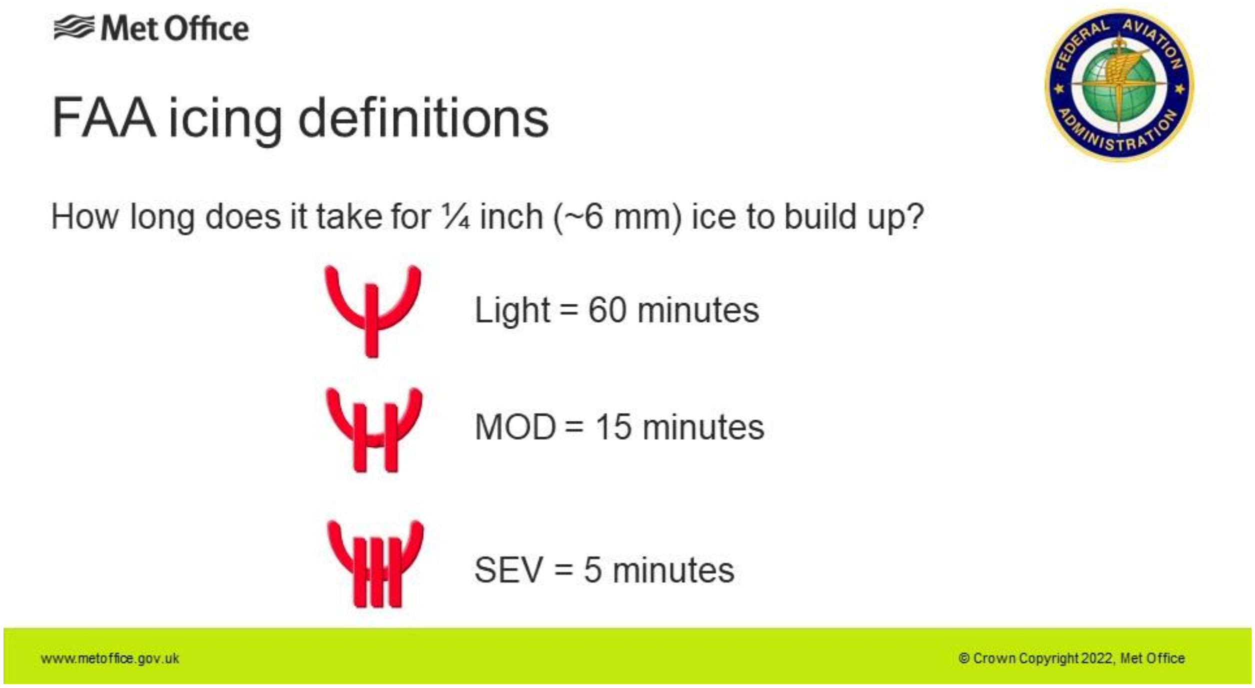


How do we define icing severity? The ICAO definitions are based on the effect the icing has on an aircraft.

For light icing: this amount of icing may create a problem if you're flying through it for an hour or more.

Moderate icing builds up quickly enough that even a short encounter is possibly hazardous, and anti- icing equipment must be used.

Severe icing: the rate of the accumulation of ice is such that anti-icing equipment will fail to reduce or control the hazard and you must immediately divert from the region.



In North America, the Federal Aviation Administration defines it slightly differently, and they look at how long it takes for 1/4 of an inch or about 6 millimetres of ice to build up. And this amount of ice is empirically what it is noticeable to a pilot.

If 6 millimetres of ice builds up in 60 minutes that is light icing, and if it takes 15 minutes to build up that is moderate icing, and in 5 minutes is severe icing.

Met Office

Forecasting icing

Focus on principles – what **can** we predict?

Think about **relative** severity – we can often say, for example:
"**this cloud will be worse than that cloud**"

Be aware of the limitations of the definitions of icing severity

Let us look at forecasting icing.

Due to the different ways that we can define icing, we need to focus on principles of what we can predict, and it is best to think about relative severity.

It is a lot easier to say, for example, "this cloud will be worse than that cloud" for icing, rather than thinking in absolute terms. We always need to be aware of the limitations of the definitions of icing severity that we have just looked at.

Met Office

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 from our first session, what do we need for airframe icing?

We need the ambient air temperature to be below 0 Celsius, and we need there to be supercooled liquid water droplets present.

And remember that the droplet size is important when we are thinking about the severity of the icing. Things that will enhance the risk of icing are rising air, and then the temperature range that optimum icing occurs in is typically around minus three to minus 15 Celsius.

Met Office

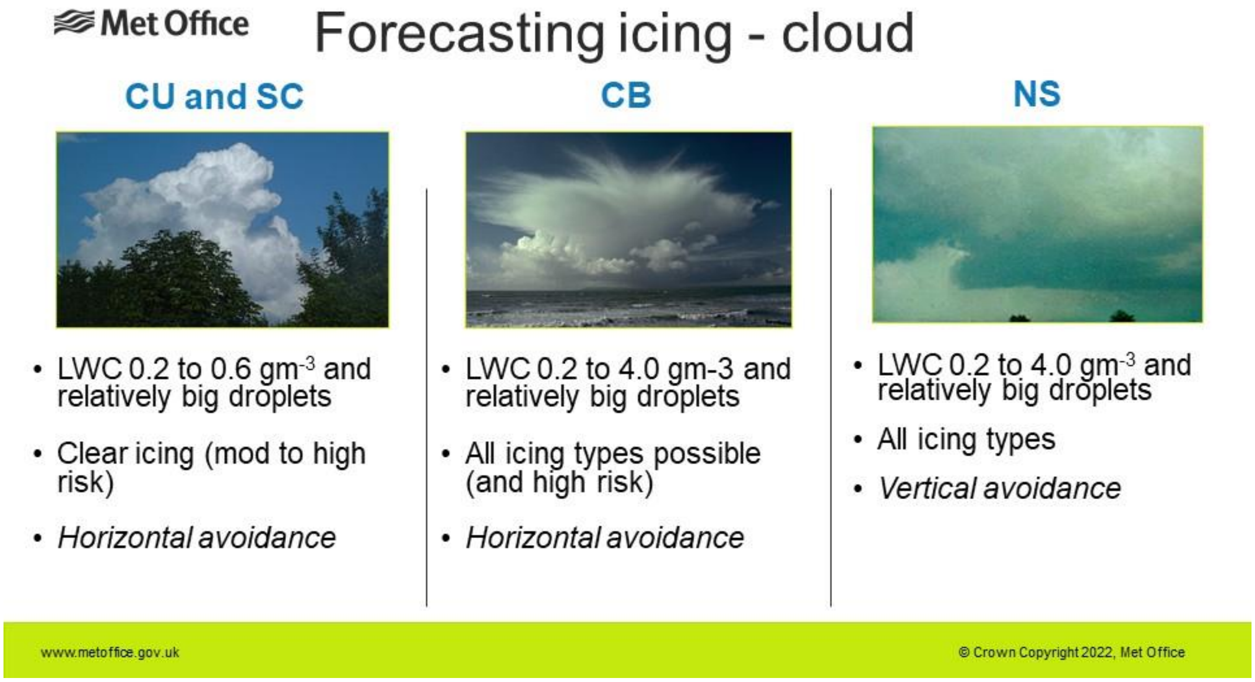
Forecasting icing

The key factors we need to forecast are:

- Cloud type
- Temperature
- Supercooled liquid water content
- Relative humidity
- Droplet size
- Vertical motion

If we are going to forecast icing, we need to be able to forecast these key factors:

- Cloud type
- Temperature
- The amount of supercooled liquid water
- The relative humidity
- Droplet size
- Whether there's any vertical motion in the atmosphere.



Let us look at cloud.

On the left we have Cumulus and Stratocumulus. The liquid water content in these clouds is typically about 0.2 to 0.6 grams per metre cubed with relatively big droplets. This tends to cause clear icing with a moderate to high risk. In flight the best tactic here is to avoid horizontally I.e. to fly around these clouds.

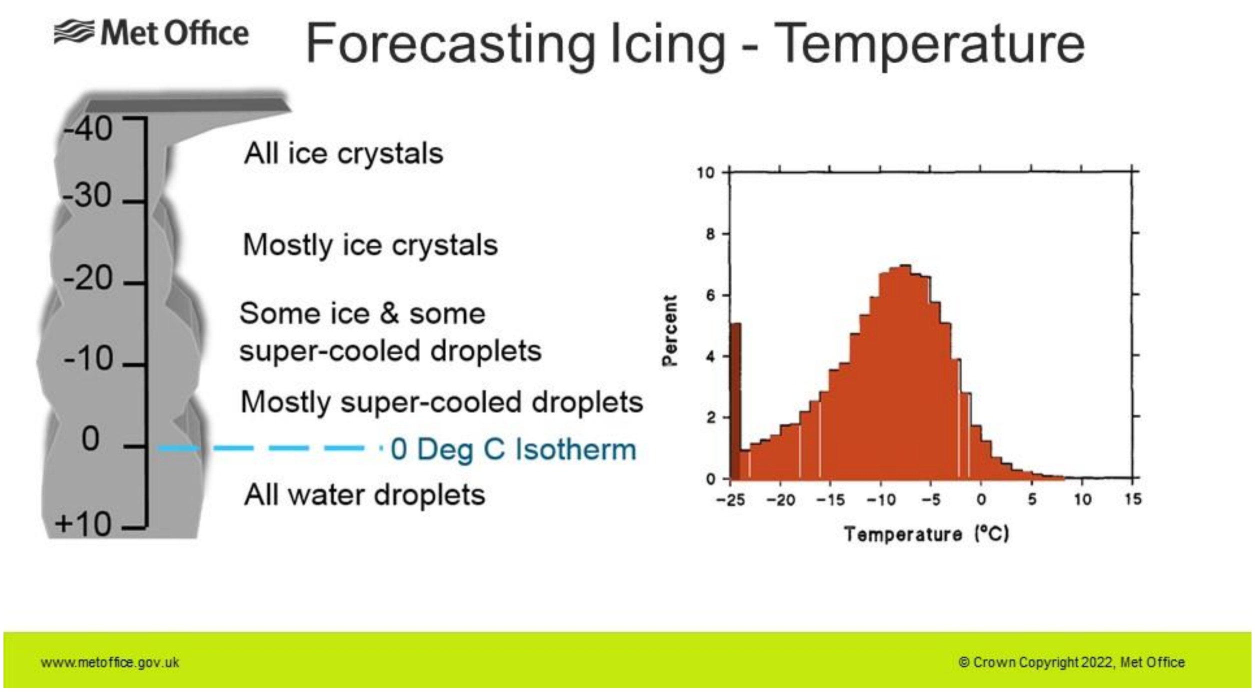
Next, is cumulonimbus which is well known for having a risk of severe icing.

It has a high liquid water content, possibly up to 4 grams per meter cubed, again with relatively big droplets, and all icing types are possible in a cumulonimbus. These generally can be avoided horizontally, so flying around the cloud is the best form of avoidance.

The last cloud to look at for icing risk is nimbostratus.

We have got similar liquid water content to cumulonimbus, so up to 4 grams per meter cubed. That's quite high, with relatively big droplets.

Again, we can expect all icing types, but due to the horizontal extent of nimbostratus in its typical form, this needs vertical avoidance I.e. we need to either descend from the icing zone or ascend out of it.



Next then we can look at temperatures.

How does temperature affect icing?

On the left we have a typical convective cloud looking at the distribution of water droplets through that cloud. We need to be looking above the freezing level, but only down to about minus 15 for optimum icing.

That is where we have got mostly supercooled droplets or some ice and some liquid supercooled droplets.

On the right this figure shows the percentage of pilot reports of icing and corresponding to different temperatures, and you will see that the majority of icing reports occur with temperatures from around minus five to about minus 15 Celsius, so that corroborates our previously discussed optimum icing temperature.

Met Office

Forecasting icing – liquid water content

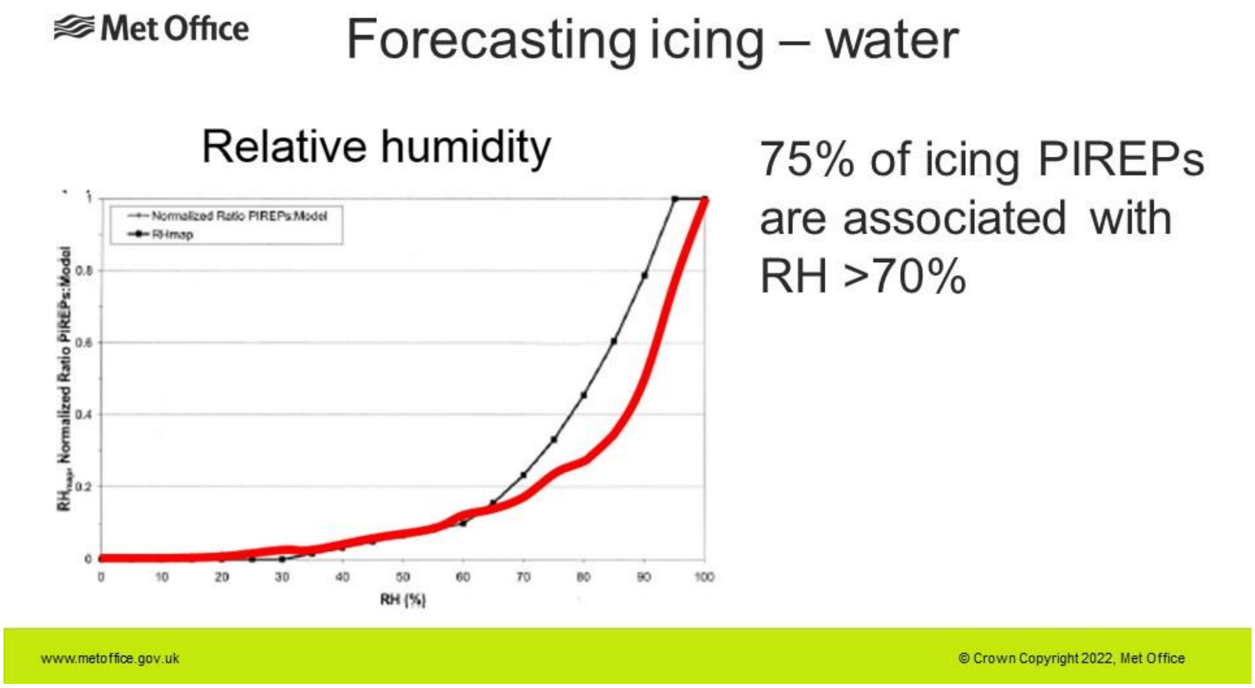
Cirrus	0.03 gm^{-3}
Fog	0.05 gm^{-3}
Stratus	0.1–0.5 gm^{-3}
Cumulus	0.1–0.5 gm^{-3}
Stratocumulus	0.1–0.5 gm^{-3} but up to 1.0 gm^{-3} in upper regions
CB (growing) and Ns	0.2–4.0 gm^{-3}
CB (dissipating)	1.0–1.5 gm^{-3}
Altostratus	0.1–0.3 gm^{-3}
Orographic	0.1–0.5 gm^{-3}

The higher the super-cooled LWC, the more water is available to form ice and the quicker the build-up will be.

How do we forecast the liquid water content?

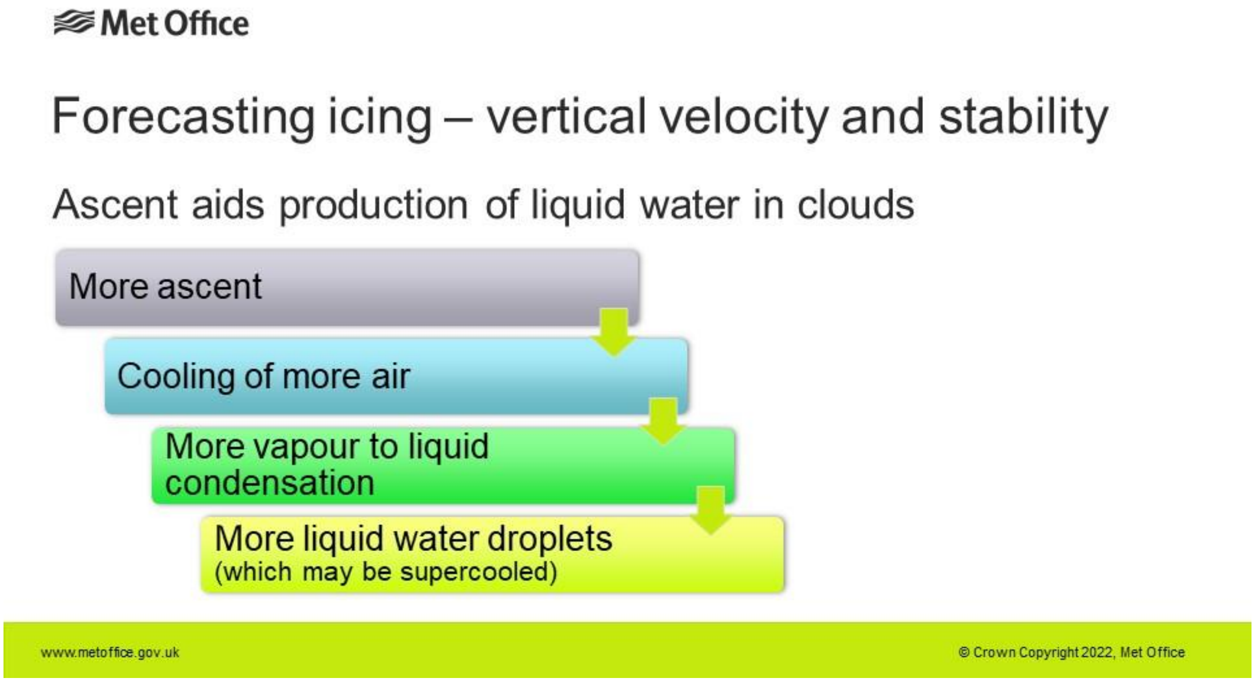
We know that the higher the supercooled liquid water content, the more water there is available to form any ice and the quicker that ice will build up, so the greater the severity of the icing.

On the left, in this table we have got a list of the typical liquid water contents of some common clouds. We have cirrus and fog at the top of the table with rather low liquid water contents and then heading down through the table you can see cumulonimbus and nimbostratus have higher amounts.



To account for the water content of the cloud, we also need to look at the relative humidity.

75% of icing pilot reports in a study were associated with a relative humidity of greater than 70%. When there is a higher relative humidity, we have got a higher risk of icing.



We need to look at vertical velocity and stability vertical motion in the atmosphere.

This is because ascending air aids production of liquid water in the cloud. If we have more ascent, we are cooling more air, more vapour condenses into liquid, then we have got more liquid water droplets and if those become supercooled then we have a risk of icing.

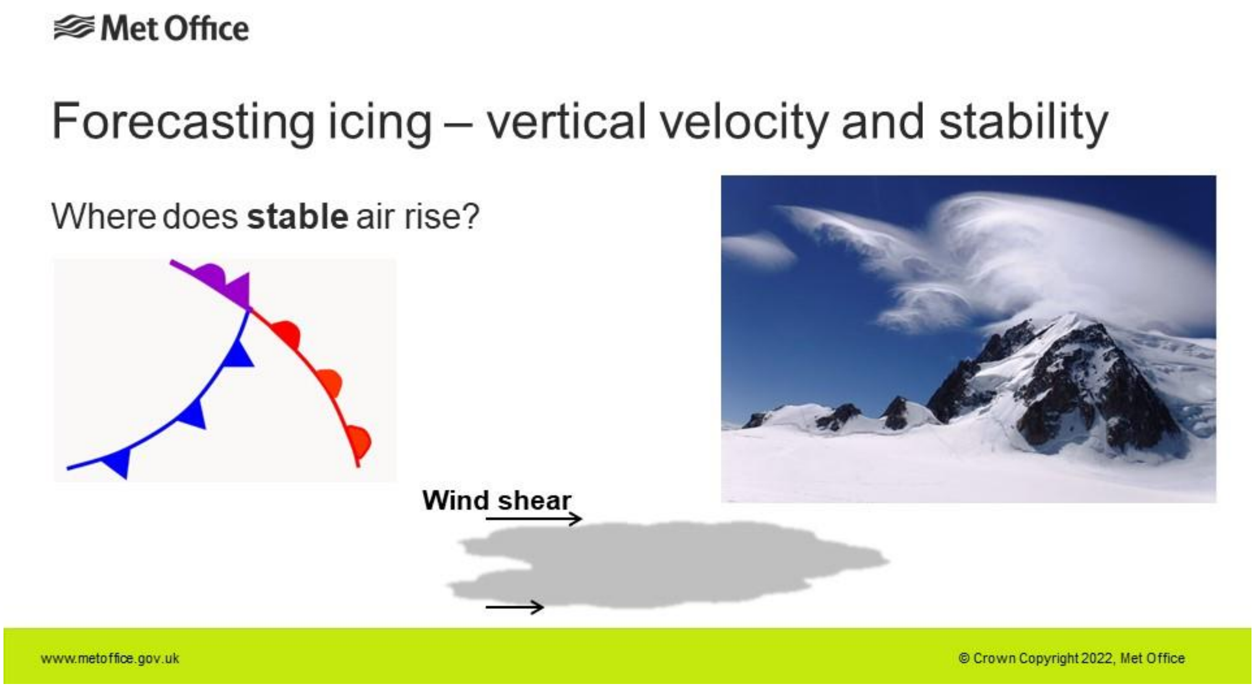
Met Office

Forecasting icing – vertical velocity and stability

Where does **unstable** air rise?

Where does unstable air rise? How do we know that there is unstable air?

An obvious example is convective cloud and particularly cumulonimbus clouds like this one in the picture on the right hand side.

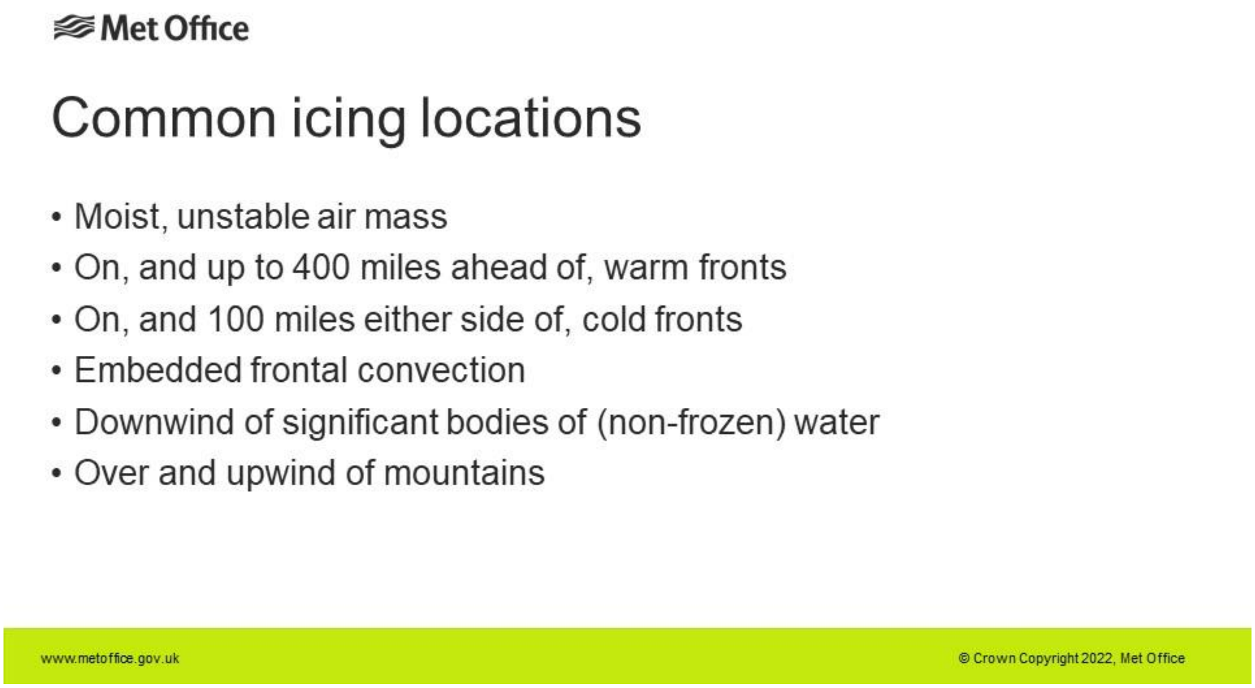


Of course, we don't just get rising air in convective situations.

Stable air also can be forced to rise. We know that stable air is forced to rise around frontal systems.

Air can be forced to rise over mountains, and we can also get vertical motion in stable air caused by wind shear.

If we have any of these factors, then they are going to increase the vertical motion and increase the risk of icing.



Bearing those criteria in mind for both for stable and unstable air, here are some common icing locations:

- Moist unstable air mass
- On and up to 400 miles or about 700 kilometres, ahead of warm fronts
- On and up to about 100 miles or 160 kilometres either side of a cold front
- Embedded convection along a frontal band
- Downwind of significant bodies of non-frozen water, so either the oceans or it could be large lakes inland as well
- Vertical motion over and upwind of mountains can give common icing locations

Identifying icing

- Radiosonde ascents
- NWP and satellite imagery
- Special air reports from aircraft

- Icing severity will depend on the aircraft type, its cruising altitude and its speed. Some aircraft are better equipped to deal with icing than others using de-icing equipment
- If we forecast it well, aircraft will avoid it and we will not get any PIREPs!

How do we identify icing?

Well, our main tools are radiosonde ascents.

We also need to look at numerical weather prediction data, particularly model radiosonde ascents, satellite imagery and then also we might receive reports from aircraft.

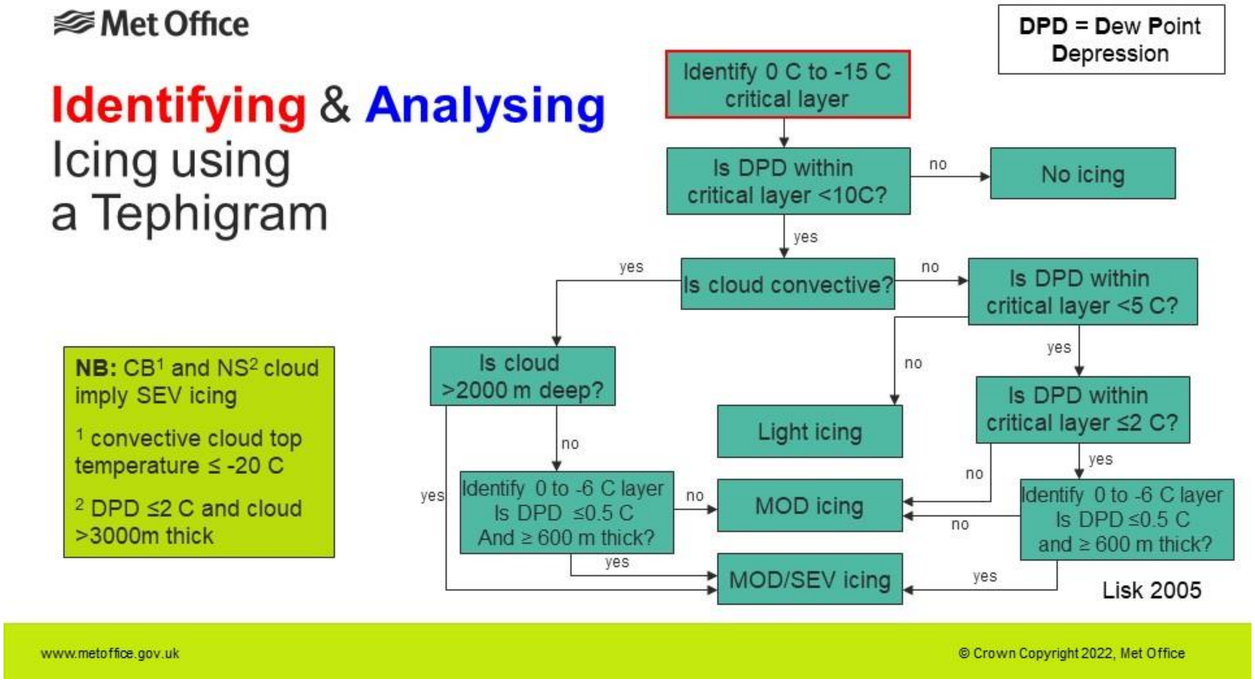
Do you remember how we define icing severity?

The icing severity reported will depend on the aircraft type, what altitude it was cruising at, what speed it was going at.

And remember that some aircraft are better equipped to deal with icing than others, and some aircraft don't have any deicing equipment at all.

If we are doing our job correctly, if we forecast the icing well, then hopefully the aircraft will avoid it and we will not get any reports of the icing.

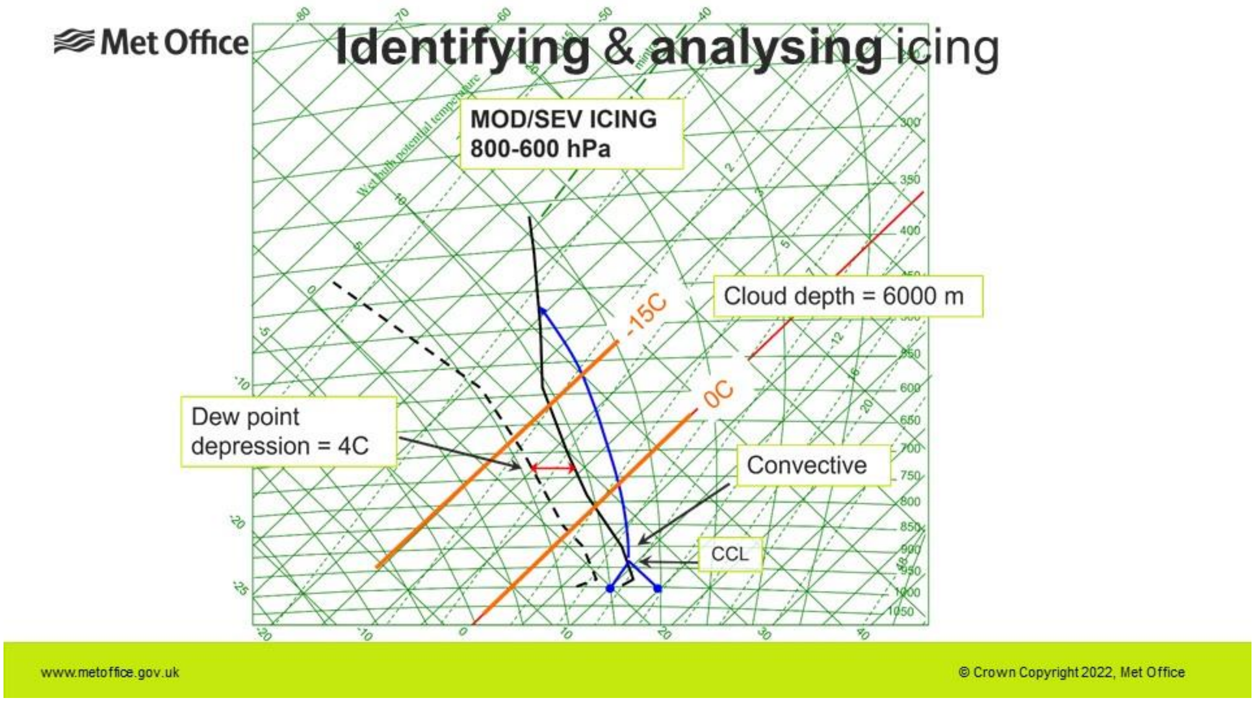
Sometimes get not getting any reports is a good thing, because we have produced a good forecast.



Using tephigrams are one of the main tools that we use to identify and forecast icing, and these can either be observed telegrams from a radiosonde ascent, or they can be model output tephigrams too.

This is a flow diagram that helps us decide whether the tephigram that we're looking at has a high risk of icing.

I will not read all the way through it, but I'll leave it up on the screen for you to have a look at and then on the next slide we will have a quick go through an example.



We can go through that flow diagram on the previous chart to see whether this tephigram on this slide represents a risk of icing.

First of all, we need to identify our critical layer between zero and minus 15 Celsius, marked on between the orange lines.

We then need to look at the dew point depression within that layer, is it less than 10 Celsius? It is about 4 Celsius, and the answer ‘yes’.

Is this ascent convective?

From a Normand point construction to calculate our condensation level, we can see that this ascent is convective.

How deep is the cloud then? The cloud on this ascent is greater than 2000 meters deep, it is approximately 6000 meters deep.

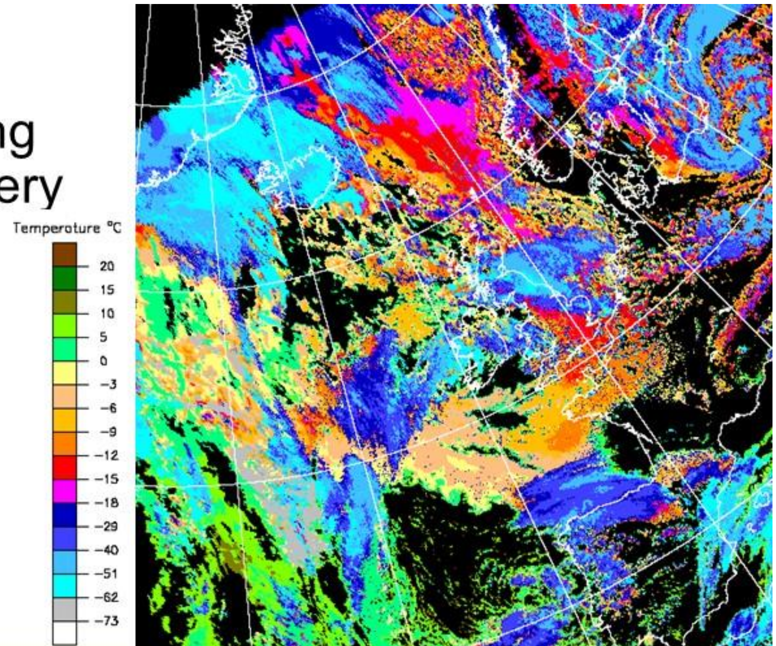
That means we do have a risk of moderate or severe icing and that's between 800 and 600 hectopascals on this ascent.

Met Office

Icing diagnosis using MSG satellite imagery

Cloud Top Temperature

- Gives some idea
- BUT can't see the whole depth of cloud



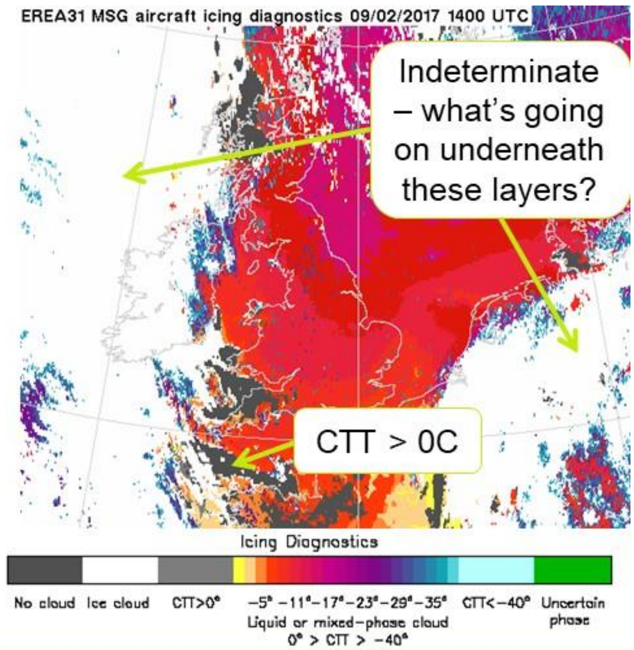
We can also diagnose icing risk using satellite imagery and so the two examples we have here are from Meteosat Second Generation satellite imagery.

Firstly, we can look at the cloud top temperature image like the one on the right. This gives us an idea of when the cloud is at the optimum temperature for icing, but we cannot see the whole depth of the cloud so if the cloud tops are higher than our critical icing layer, then we will not be able to see that, but it can highlight areas of high icing risk.

Met Office

MSG Aircraft Icing diagnostic

- 24 hours a day
- Uses thermal infrared channels only
- Combination of 8.7 μm and 10.8 μm to get phase information
- Highlights areas of supercooled water cloud



www.metoffice.gov.uk

We can also use satellite products that are specifically designed to help us diagnose aircraft icing, such as this one from Meteosat Second Generation, and this is available 24 hours a day and highlights areas of supercooled water clouds – cloud that is at high risk of having some supercooled water present.

Some of the limitations of this include if you do have high ice cloud, such as the areas highlighted in white on this image, then we don't know what is going on underneath those layers, making it impossible to know what is going on underneath. Where we do not have high ice cloud, we can see areas of liquid or mixed phase clouds highlighted in orange and red colours on the image.

Met Office

Producing the icing SIGMET

Once you have identified the risk of icing:

- Where is it moving?
- Is it likely to change and develop/weaken?
- Produce the SIGMET

Once we have identified the risk of icing, we need to then produce the icing SIGMET.

For this we need to think about where the icing is moving or if it's moving at all.

Is it changing, is it developing or weakening?

And then we can produce the SIGMET.

Met Office

SIGMET example 1

EGTT LONDON FIR SEV ICE OBS E OF LINE W00220 FL100/180 MOV E 20KT NC=

1	2	3	4	5	6
Location indicator of the FIR or CTA	Name of the FIR or CTA	Description of the phenomenon	Observed or forecast	Location	Level
<CCCC>	<name> FIR or CTA	<Phenomenon>	OBS [AT<GGggZ>] or FCST	Geographic location given by coordinates, geographic object, location indicators	FL <nnn> FL <nnn/nnn> [TOP, ABV, BLW]

www.metoffice.gov.uk

We have a few examples of SIGMETs just to look at the coding techniques that we use to code icing.

First of all, looking at the text highlighted in red here, this is one for the London FIR.

We put severe ice in the description of the phenomenon section, we can describe whether this is observed or forecasted.

We can then talk about the location, and there are different ways that we can do that. In this example, we have said that the icing was observed east of a line and then we can put coordinates in there. And then we put the level of the of the icing. In this case flight level 100 up to flight level 180.

Met Office

SIGMET example 2

SAEZ BUENOS AIRES FIR SEV ICE FCST WI

S3030 E01512 - S3119 E02345 - S3401 E02847 - S3612 E02230 - S3700 E02327 - S3523 E01520 - S3030 E01512 FL160/380 MOV NE 20KT WKN=

1	2	3	4	5	6
Location indicator of the FIR or CTA	Name of the FIR or CTA	Description of the phenomenon	Observed or forecast	Location	Level
<CCCC>	<name> FIR or CTA	<Phenomenon>	OBS [AT<GGggZ>] or FCST	Geographic location given by coordinates, geographic object, location indicators	FL <nnn> FL <nnn/nnn> [TOP, ABV, BLW]

In this example for Argentina, instead of being observed like the last one, this icing is forecasted.

And then when we have looked at the location, we have said WI, that means ‘within’.

We have then described a polygon using coordinates that we are expecting the risk of icing to fall within.

And then again, we put the level at which the icing is occurring, in this case flight level 160 to 380.

Met Office

SIGMET example 3

EGTT LONDON FIR SEV ICE OBS E OF LINE W00530 FL100/180 MOV E 20KT NC=

7	8
Movement or expected movement	Change in intensity
MOV <direction, speed> or STNR	INTSF or WKN or NC

Moving back to the London example, the last part of the icing SIGMET, we look at whether the icing is moving or if it is expected to move.

In this case, this is moving east at 20 knots.

Lastly in the last group of the segment we look at whether the hazard is changing in intensity. We can either describe it as intensifying, weakening, or NC, meaning no change.

In this example we are expecting no change to the risk.

Met Office

SIGMET example 4

SAEZ BUENOS AIRES FIR SEV ICE FCST WI

S3030 E01512 - S3119 E02345 - S3401 E02847 - S3612 E02230 - S3700 E02327 - S3523 E01520 - S3030 E01512 FL160/380 MOV NE 20KT WKN=

7	8
Movement or expected movement	Change in intensity
MOV <direction, speed> or STNR	INTSF or WKN or NC

www.metoffice.gov.uk

Looking at this example from Buenos Aires again, this time we have described the icing as moving northeast at 20 knots and this time it is weakening.

Met Office

Monitoring the SIGMET

- Check any new NWP/observations
- Observe satellite imagery for any evidence of SEV icing
- Monitor any special air reports
- Cancel SIGMET if required

Once you have issued the SIGMET, it needs to be monitored and you need to keep checking on new numerical weather prediction data, new model runs and new observations. You need to monitor satellite imagery to keep an eye out for any evidence of severe icing, and if you receive any pilot reports you need to monitor those too.

Do not forget that if you feel the need to cancel this SIGMET, you must do that as soon as possible.

Met Office

Summary

- Icing severity is defined differently by ICAO and FAA
- Tephigrams, pilot reports and satellite imagery are the primary tools for observing and forecasting icing
- Icing is denoted in a SIGMET using similar language to other phenomena

www.metoffice.gov.uk

In summary for this session, we have looked at how icing severity is defined, and it's defined differently by the ICAO and the Federal Aviation Administration.

The primary tools that we use to identify and forecast icing are tephigrams, pilot reports and satellite imagery.

We have looked at how to describe icing in a SIGMET and this is using similar language to another SIGMET types.

Met Office

Questions?

- On the page forum
- Live sessions

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

In the live session we have some suggested discussion points for you to think about before coming along:

- In-flight icing
    - What types of icing are common in your area?
    - What impact do these have on aviators?
- Forecasting icing
    - Which methods discussed are most suitable for your area?
    - Are there additional methods or resources you use to forecast icing?

We'd love to hear you share those in the in the live sessions.

That is this session finished, thanks for listening and see you in November.

Thank you.