MET 451: Aviation Meteorology
(3 Credit Hours)

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https://github.com/jeffjay88/Aviation-Meteorology

Google Classroom Code: 63zl2i

LECTURE 5

Recommended Links and Media

- https://www.youtube.com/watch?v=9I40DQcK_6U
- https://www.youtube.com/watch?v=TJ2Xgn-E8WA

ICING

Icing occurs if precipitation aggregates on the aircraft or at or within parts of it.

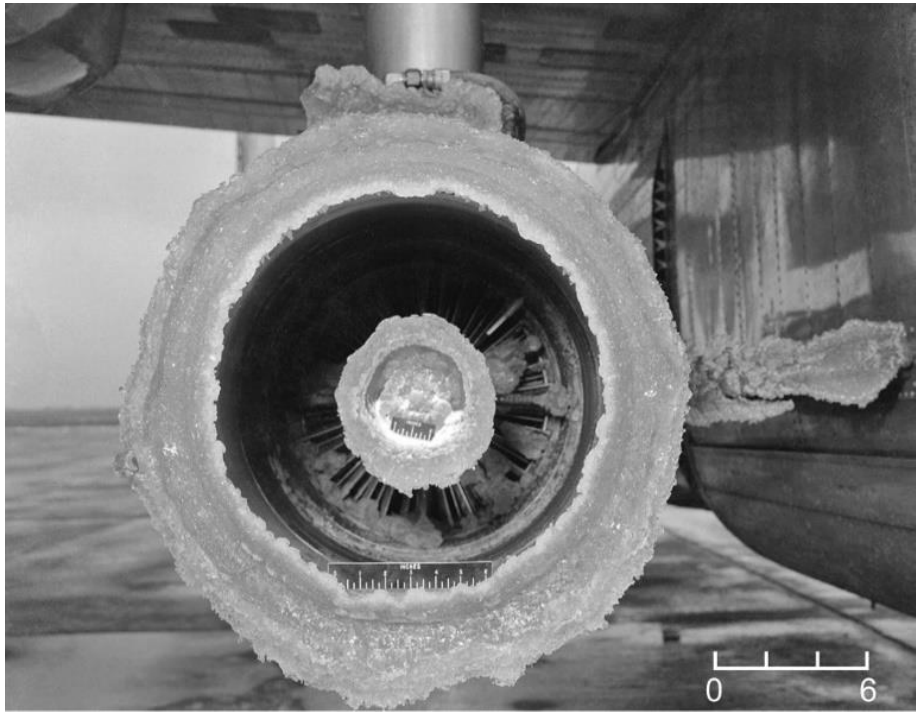
There are several impact mechanism.

The dominant one is that super-cooled liquid water impinges on the aircraft and freezes instantaneously.

Icing may occur

- in-flight

or at the surface: - ground icing.



Icing may be categorized into:

- airframe icing
- engine icing

Normally, forecasts of icing are for airframe icing only.

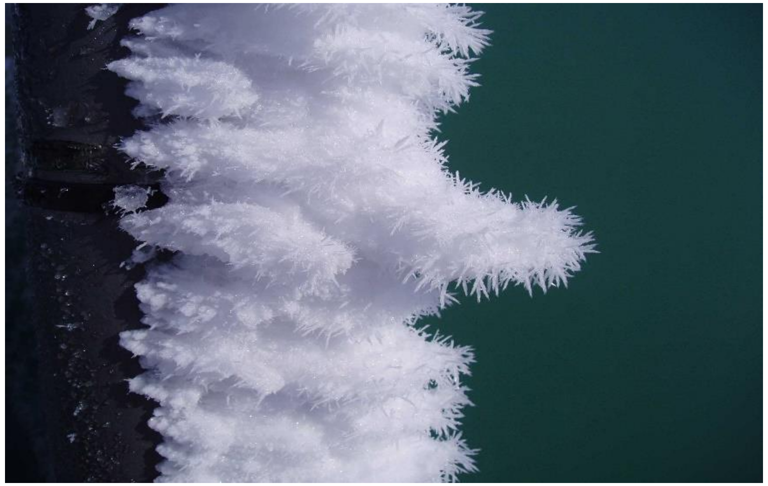
There are three strategies to cope with aircraft icing:

(i) aircraft must be certified for icing,

(ii) aircraft have to be cleaned of ice prior to take-off (clean wing principle),

(iii) aircraft are equipped with de-icing equipment.

Airframe icing normally occurs when the ambient air temperature is below 0° C and super-cooled water droplets are present.



TYPES

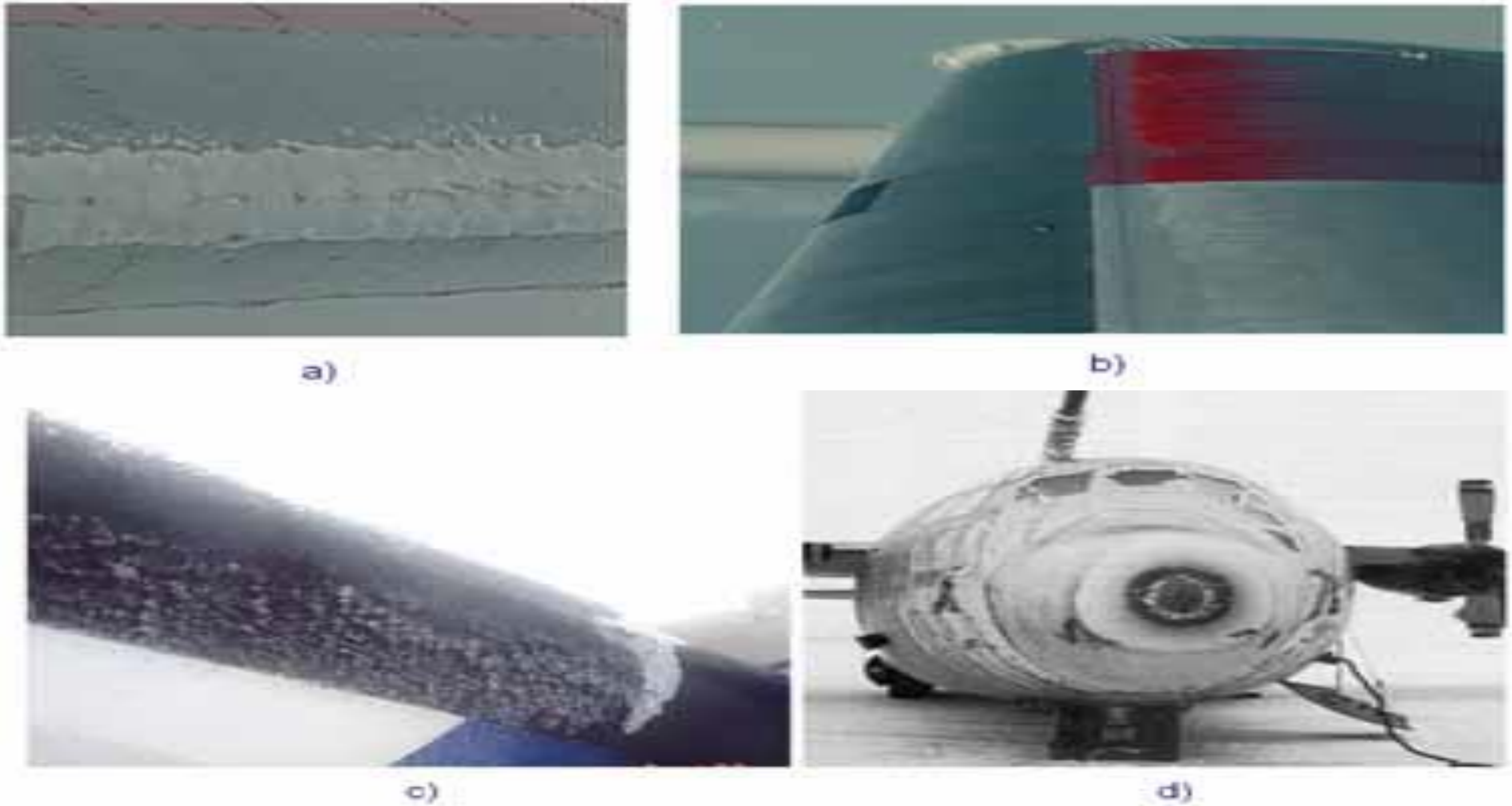
- **Rime Ice** – white, porous, opaque, brittle and rough, so disruptive to airflow. This occurs at low temperatures (<10°C).

- **Clear Ice (also known as glaze ice)** – clear, tough, adhesive, dense, heavy and smooth so little effect on airflow. It occurs usually at warm temperatures >10°C.

➢**SLD- super-cooled large drops or drizzle drops-** with diameters ranging between 50 and 500 μm. SLD may flow after impingement behind the protected zones on the wing and freeze there. If supercooled rain drops with diameter larger than 500 μm hit the aircraft, extreme accretion of ice may occur (freezing rain).

➢**Hoar frost** – thin ‘coating’ occurring in the absence of rain or cloud usually when aircraft is parked outside on cold winter nights.

➢**Rain and snow mixed (sleet)** is similar to freezing rain and can also lead to ‘pack snow’ that can block air intakes and other aircraft openings



Examples of: a) rime icing; b) clear (glaze) icing; c) mixed icing; d) freezing rain.

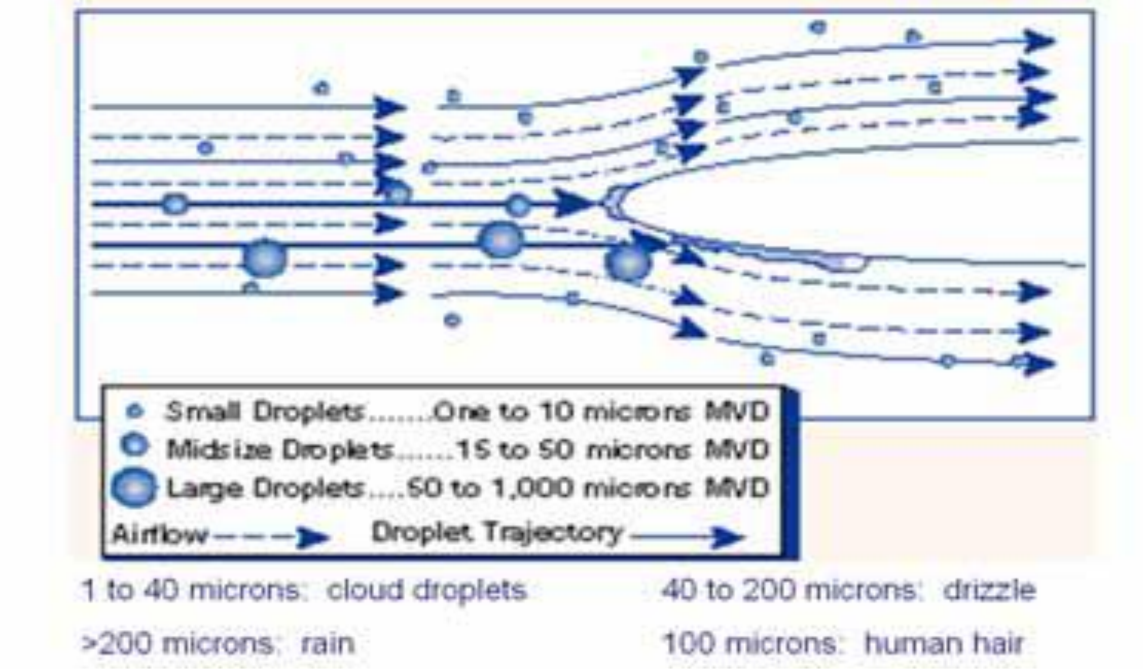
Effects on Aircraft

Small super-cooled cloud droplets freeze rapidly on contact with the aircraft, trapping in the ice to give a deposit of white rime on forward-facing surfaces. Larger droplets take longer to freeze, spreading out across the airframe before solidifying.

The intensity of icing is defined as follows:

Light Accumulation rate may create a problem if flight in this environment exceeds 1 hour.

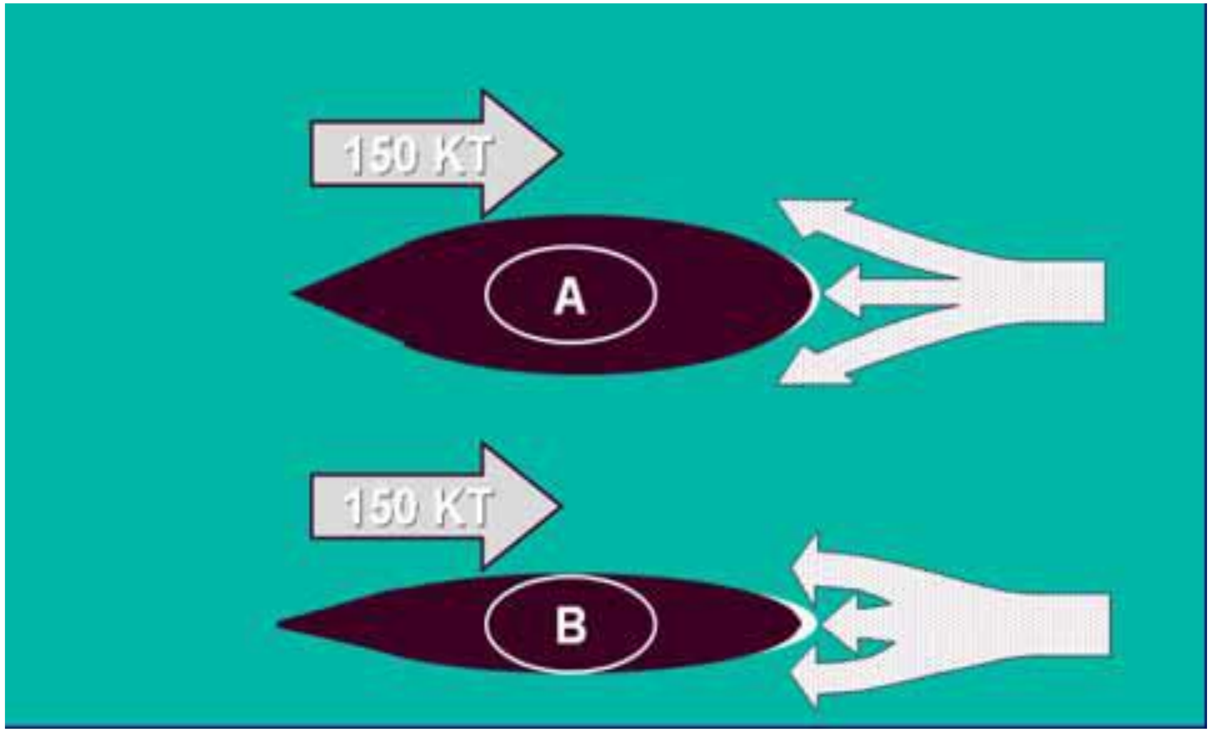
Moderate Rate of accumulation is such that even short encounters are potentially hazardous. Anti-icing equipment must be used.



Droplet trajectories in the vicinity of an airfoil

Severe Rate of accumulation is such that use of anti-icing equipment fails to reduce or control the hazard. Immediate diversion from the region is necessary.

Aside from meteorological factors, the rate of ice build-up on the airframe also depends on the characteristics of the aircraft. Fast aircraft with thin wing cross-sections are more susceptible to deteriorating aerodynamics, and hence are more susceptible to ice accretion.



Helicopters are particularly vulnerable to icing, since build-up of ice on the rotors can lead to imbalance, de-stabilising the aircraft.

Class Discussion

Airframe icing is a serious aviation hazard.   How???

The possible range of effects on an aircraft are listed below:

- Reduction in the aerodynamic properties
- Change in flight performance
- Increase in weight and uneven loading
- Engine intakes become blocked
- Undercarriage retraction/extension problems
- Control surfaces jam or become stiff
- Pitot tubes become blocked
- Communications affected
- Vision impaired

HAZARDOUS EFFECT OF AIRCRAFT ICING

- Increases stalling speed
- Destroys optimal aerodynamic flow over the aircraft
- Increases drag
- Decreases lift
- Causes engine failures
- Causes propeller vibration
- Reduces visibility

-horizontal: due to precipitation

-Vertical: due to obscuring cloud

In jet engines, damages compressor blades and interferes with

- Control surfaces and landing gears

-Instrument readings (eg air speed, altitude and vertical speeds)

-Communication system

Empirical Forecasting Techniques

Severity of airframe icing is dependent on temperature, liquid water content, droplet size and vertical motion. To determine the above, it is necessary to utilise actual and forecast vertical profiles of the atmosphere, rainfall radar and satellite imagery together with knowledge and understanding of the characteristics of different types of cloud.

Forecast considerations

In considering the likelihood of icing, the following factors should be considered:

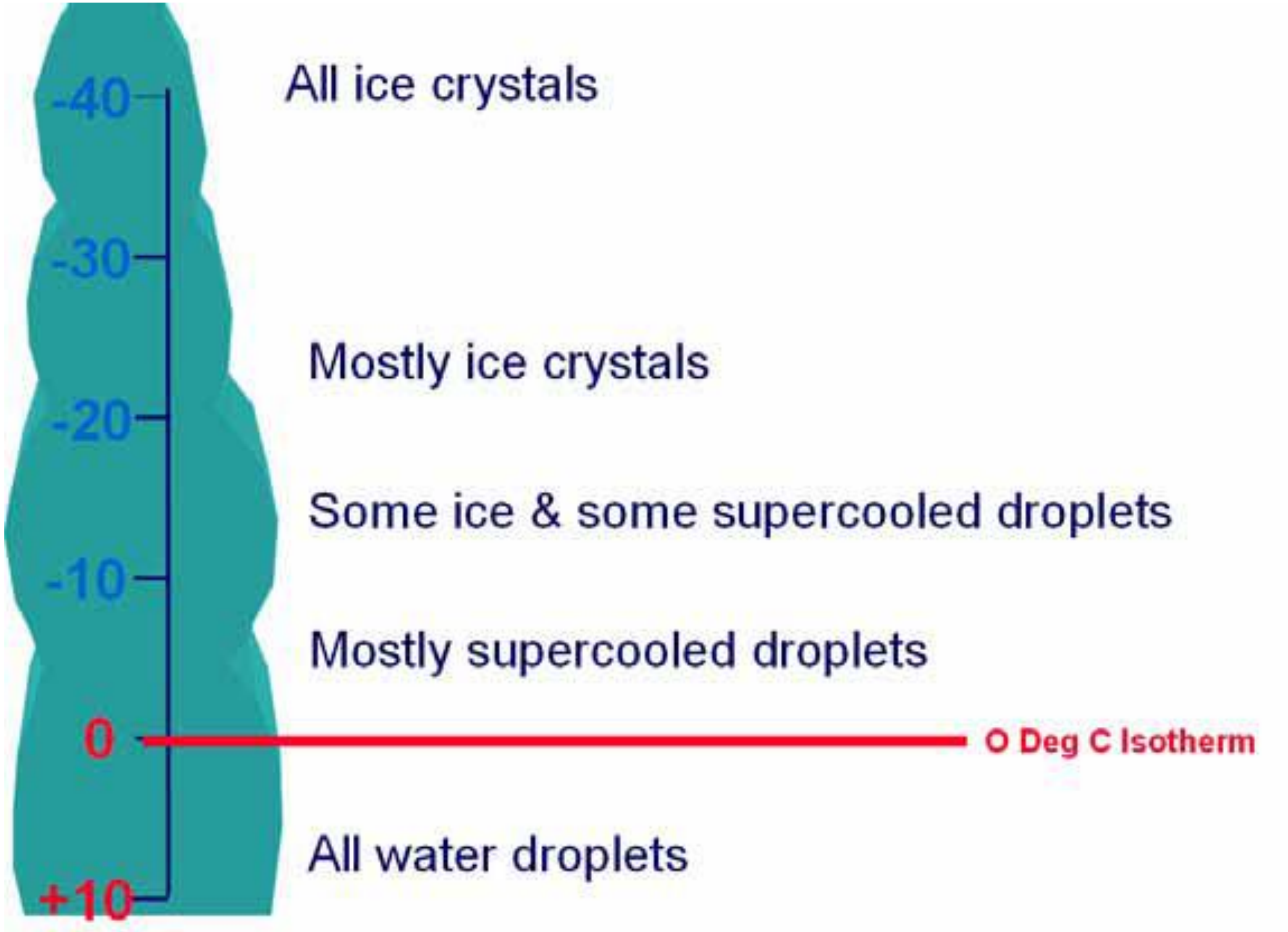
- For icing to occur super-cooled water must be present in the atmosphere (liquid water droplets with a temperature below 0° C).

- The more super-cooled water there is present (Super Cooled Liquid Water Content), the more significant is the icing risk. SLWC decreases with decreasing temperature.

- The larger the super-cooled water droplet, the more significant the risk.

- Only very small droplets seem to remain super-cooled below -20° C, hence the worst icing is likely between 0 C and -15 C.

- Super-cooled water droplets cannot exist with temperatures below -40° C.

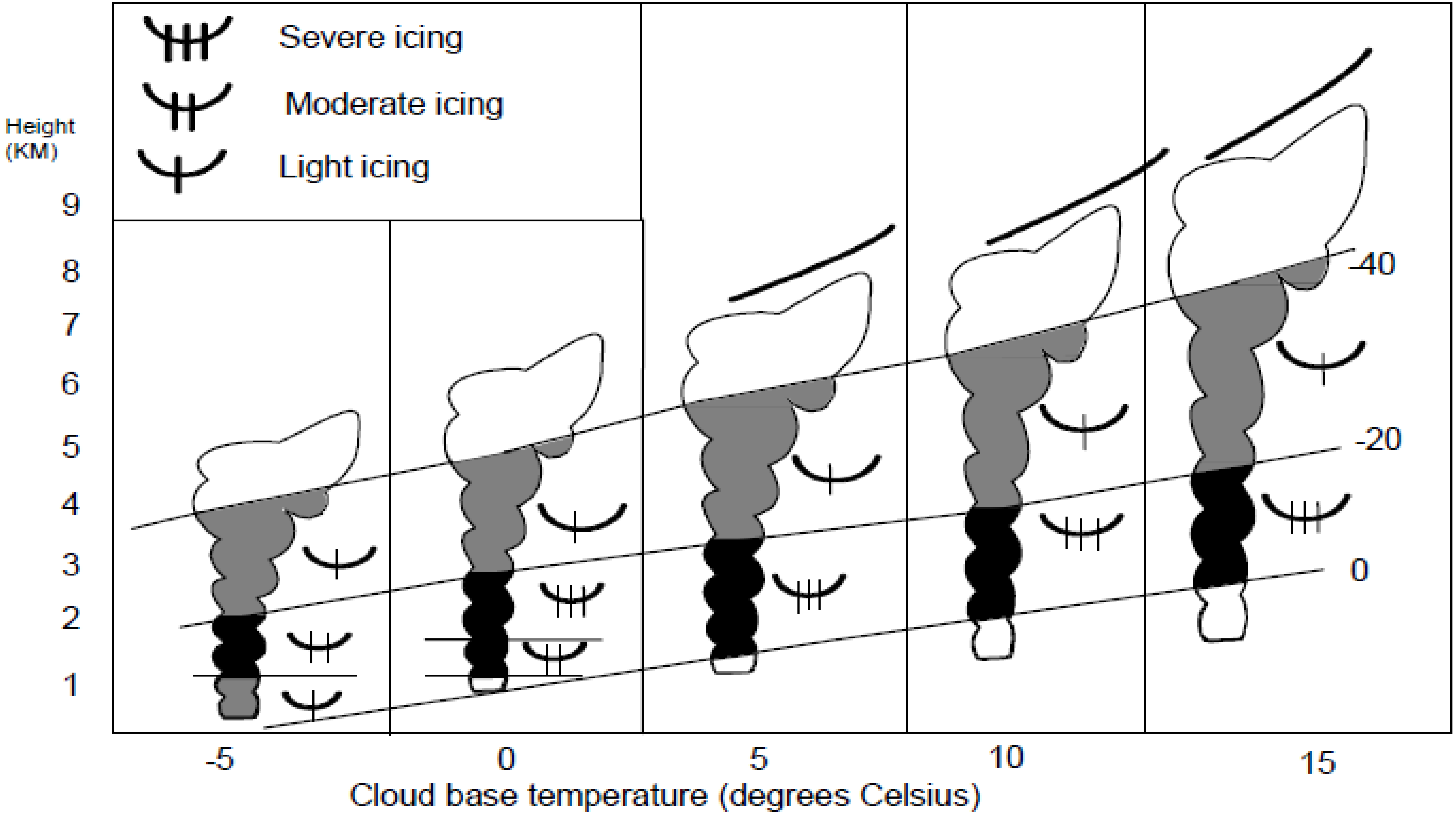


Water phase changes in relation to falling temperature with height

Probability and intensity of icing associated with different cloud types

Cloud type	Probability of icing	Intensity of icing	Likely Icing Type	Water content gm-3
CB	High	SEV	All	0.2– 4.0
CU	MOD/High	MOD/SEV	Clear	0.2-0.6
NS	High	SEV	All	0.2-4.0
SC, AC	MOD	Rarely more than MOD*	Mixed	0.1– 0.5
AS	Low	MOD/light	Rime	0.1– 0.3
ST	Low	Light	Rime	0.1– 0.5

Note that: (a) prolonged flight within a super-cooled, layered cloud can give rise to a greater degree of icing than suggested here.
(b) stratocumulus (SC) can sometimes give unexpected severe icing, particularly when it lies in a sub-zero layer just below an inversion over the sea.


Severe icing
Moderate icing
Light icing
Height
(KM)
9
8
7
6
5
4
3
2
1
-40
-20
0
-5
0
5
10
15
Cloud base temperature (degrees Celsius)

Other factors

- Risk and severity of icing increases in sub-zero clouds over hills and mountains due to vertical motion.
- The source and nature of SLD is still under investigation. But observations tell that shear layers close to the top of a cloud supercooled cloud are prone for SLD.
- The same holds for overshooting cumulus tops.
- The impact of SLD on aircraft performance varies with type. Typically, smaller aircraft, such as turboprop, are more susceptible to SLD icing.
- Risk and severity of icing increases in sub-zero clouds over and downwind of significant bodies of (non-frozen) water due to higher SWLC and larger super-cooled water droplets.
- Friction induces kinetic heating raising airframe temperature. eg +1° C at 100 kt and +25° C at 500 kt.

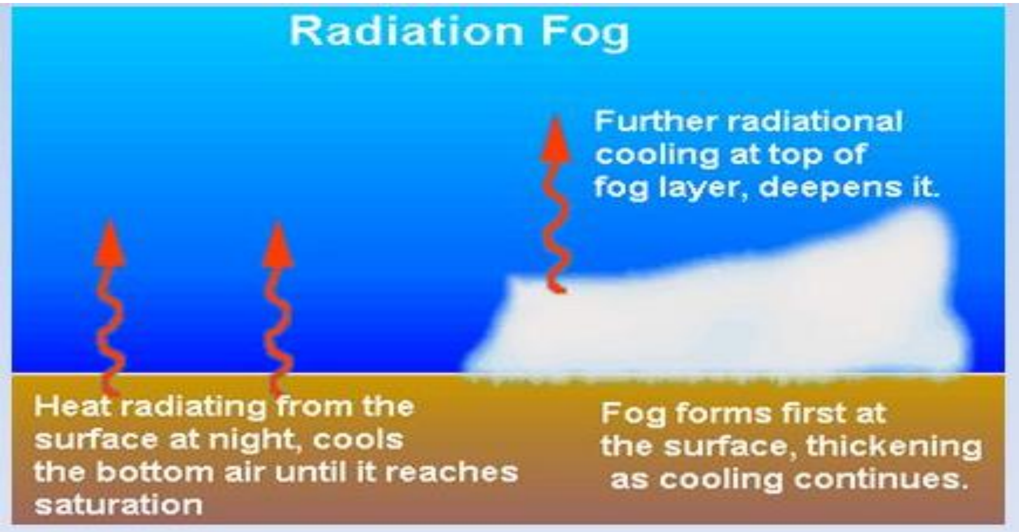
Synoptic Weather Considerations: Forecasting Fog and Low Stratus;

To assess whether a fog or stratus event is possible, you must evaluate the synoptic-scale influences that will drive the local conditions. Most of these are forced primarily by advective or dynamic processes (although radiation does play a role).

Radiation fog cannot form unless the necessary conditions and **key ingredients** coincide. When they do, **radiative cooling** and **formation of a stable layer** precede fog formation. Surface heat exchange is an important factor influencing these processes.

The key low-level ingredients required to generate a radiation fog are

- moisture,
- rapid cooling, and
- calm or light winds.



Low-level anticyclones can create favourable conditions for radiation fog by suppressing surface winds and drying the air aloft through subsidence. Dry air aloft enhances radiative cooling at the surface.

Radiation fog is very unlikely to form unless there is sufficient moisture in the boundary layer. Such moisture may be advected into an area, or derived through daytime evaporation from surface sources such as wetlands or wet soil.


Questions?

RECAP OF LECTURE

1. Icing
2. Radiation Fog and Low Stratus