Winter Weather Flying

Nick Czernkovich

“Aircraft Icing”

- Aircraft icing can be broken down into 2 categories:
  - Induction System Icing
  - Structural Icing

Structural Icing

Ground Icing

In-Flight Icing

Some General Statistics

- 10.8 % of all weather accidents result from icing
- 3 leading factors:
  - 51.2 % - Carburetor icing
  - 41.4 % - In-Flight icing
  - 7.7 % - Ground Icing
- PIC average flight time: 1,964 hrs
- Average time on type: 306 hrs
- Percent Instrument Rated: 71 %

In-Flight Icing Statistics

- Cause of approximately 30 fatalities and 14 injuries per year in U.S.
- Result of US $96 million per year in personal injury and damage

- Between 1978 and 1989, contributed to 298 fatalities in Canada

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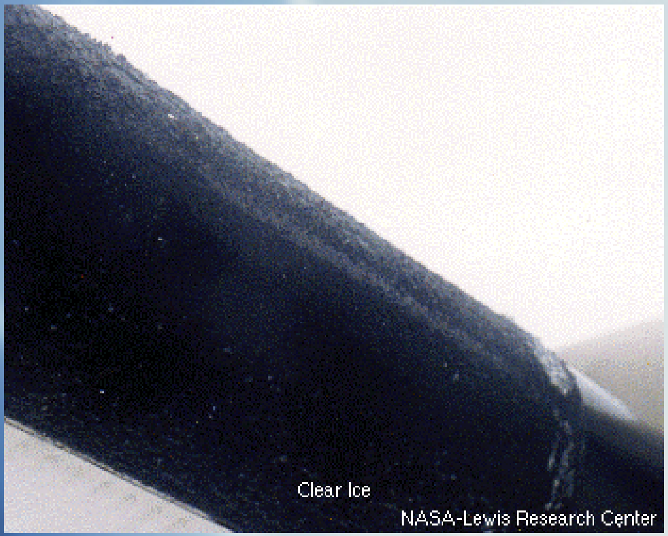
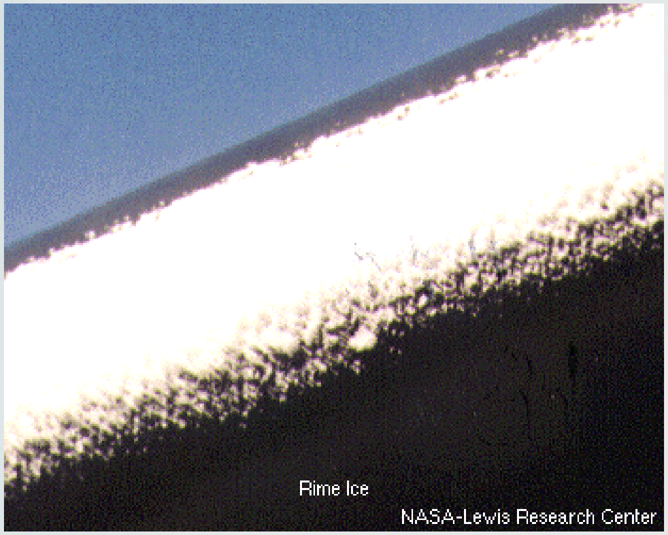
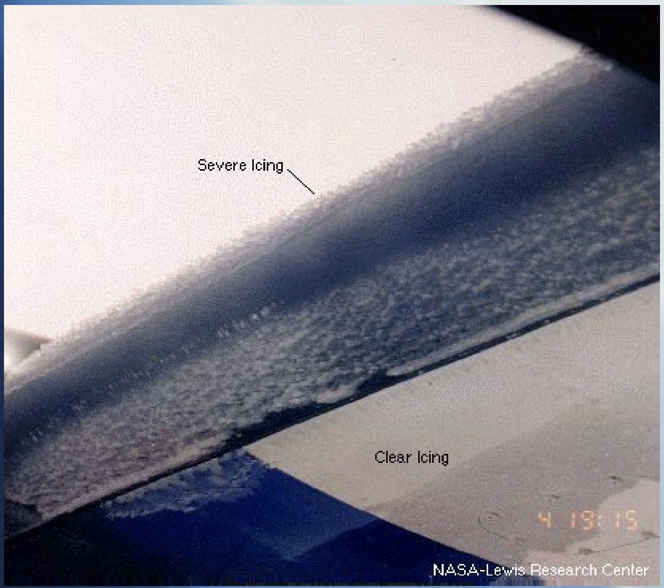
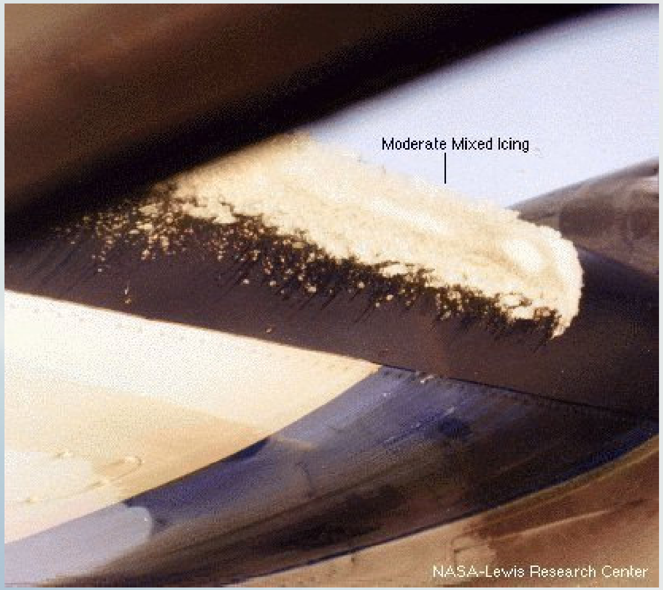
- **In 57% of icing accidents pilots had received an icing forecast**

Some Pictures









Physical States (Phases)

- Three physical states:
  - Solid
  - Liquid
  - Vapour
- Water can exist in the atmosphere in all three phases
- Transition between phases takes place all the time, results in “Weather”
- Phase changes consume/release *latent heat*

Two Points to Remember

- Ice will always melt at 0 C, but liquid water ***will not*** necessarily freeze at 0 C

- Evaporation, sublimation and deposition need not occur at any specific temperature

Warm Cloud Process

- Definition: Entire depth of cloud is above 0 C
- Expect to find only liquid droplets
- Often forms due to:
  - Frontal lifting
  - Orographic Lifting
  - Buoyancy
  - Convergence
  - Turbulence

Warm Cloud Process:
Formation of Cloud Droplets

Vapour condenses onto tiny particles called CCN

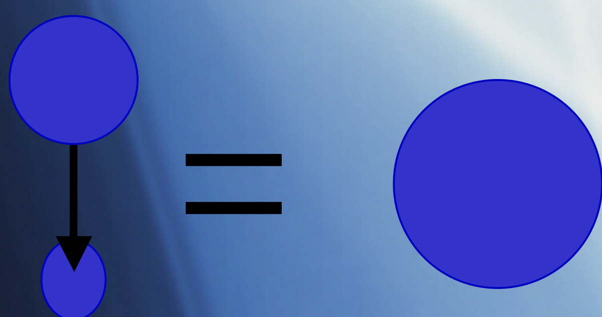
CCN are always abundant in the atmosphere

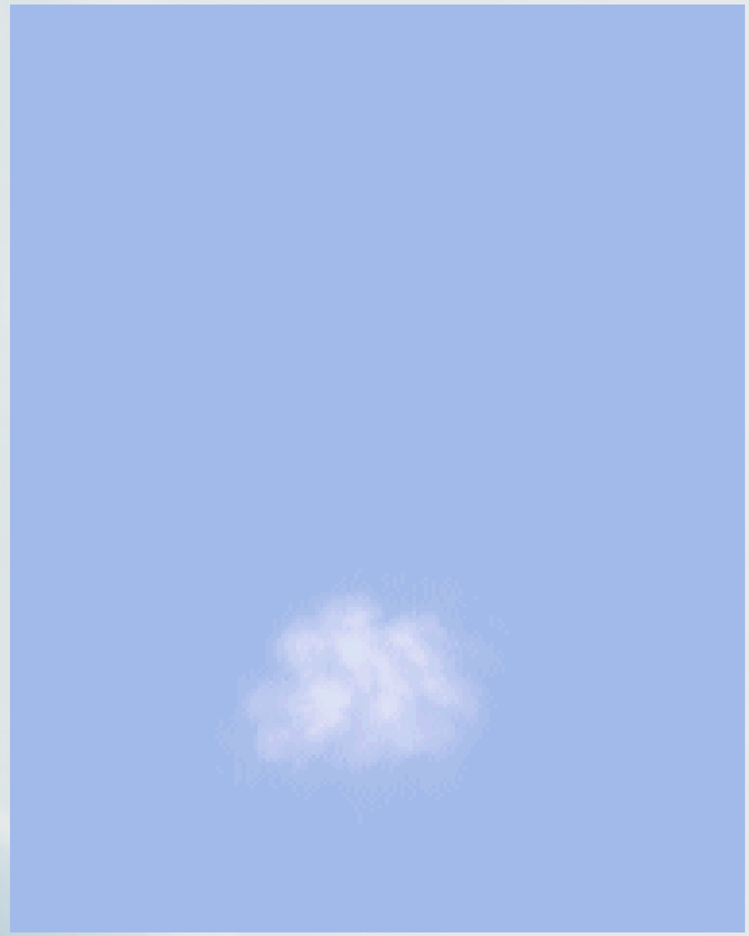
Typical cloud droplet size ~10 to 20 microns

1 micron = 1/1000 mm

Warm Cloud Process:
Cloud Droplets to Rain

- Drops grow by condensation up to 20 microns
- After 20 microns *collision-coalescence* dominates





Warm Cloud Process:
Summary

- Clouds develop as air is lifted to saturation
- CCN become activated
- Cloud droplets grow by condensation up to about 20 microns
- After 20 microns collision-coalescence dominates
- When fall speeds of drops exceed updraft speed in cloud → Precipitation

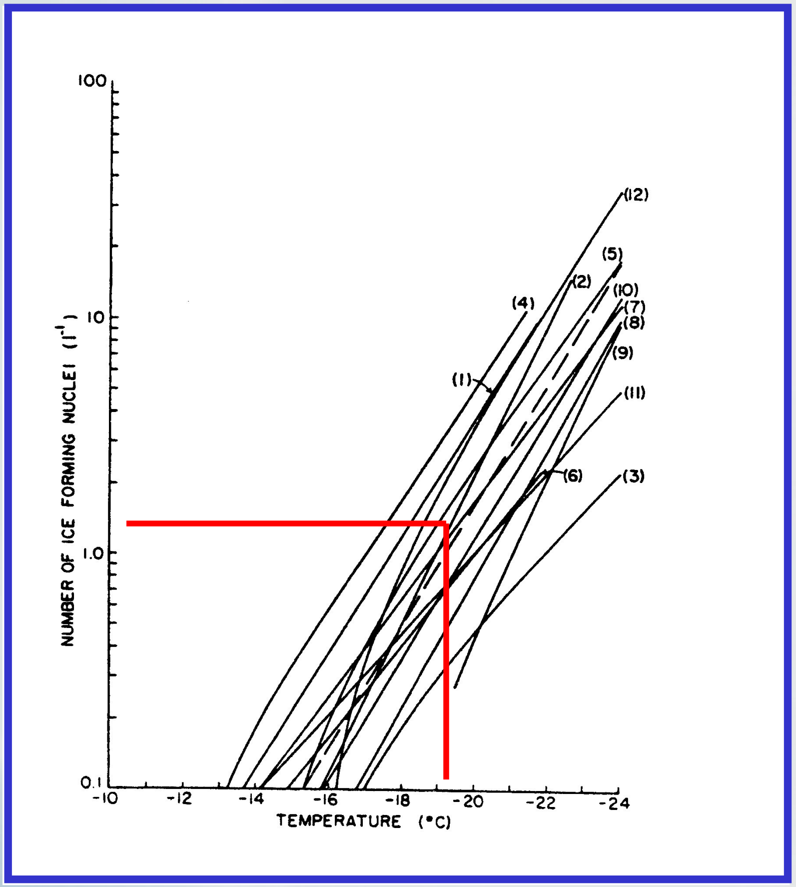
Cold Clouds

- Definition: Some or all of the cloud is at or below 0 C
- Formed through the same process as warm clouds
- Possibility of forming ice particles
- Ice particles must form onto aerosols called Freezing Nuclei (FN)

Cold Clouds

Reality of Freezing Nuclei

- Liquid drops being carried above the freezing level → Drops must contact a FN to freeze
- If no FN present liquid droplets form on CCN



Cold Clouds

Some points…

- FN are functions of temperature
- FN become more important as T< -15C
- CCT < -15C can glaciate cloud from top down (BUT DON'T EXPECT THIS)
- ***Ice and Liquid can co-exist*** in equilibrium
- Liquid water is possible down to –40C

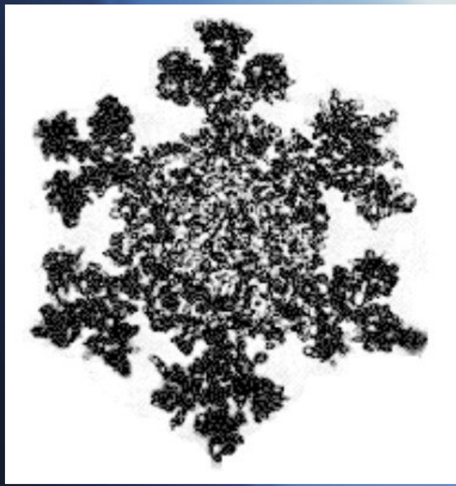
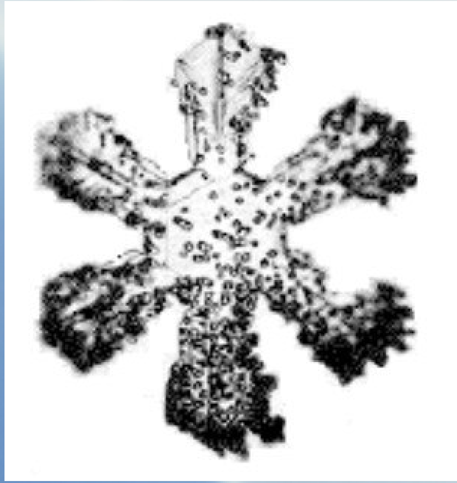
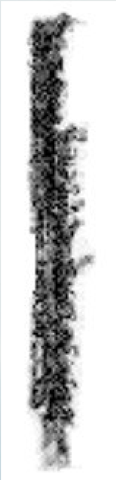
Inferring Icing Conditions From Precipitation Observations

- Snow (SN)
- Graupel/Snow Pellets (GS)
- Freezing Rain (FZRA)
- Ice Pellets (PL)
- Freezing Drizzle (FZDZ)

Inferring Icing Conditions

Snow: What you can infer

- Likelihood of icing in lowest layer reduced
- Liquid Cloud layers above the ice are unlikely
- BUT…Rimed snow suggests SLW aloft


Inferring Icing Conditions

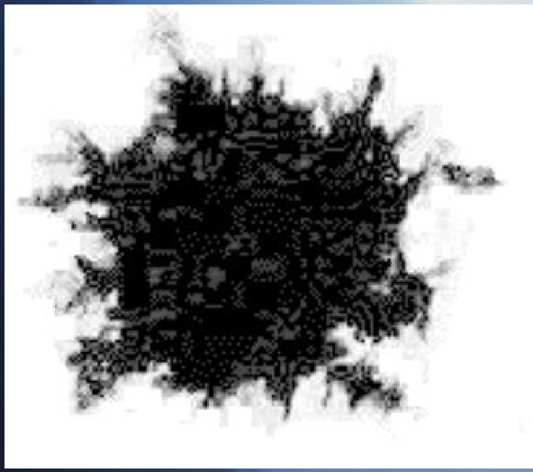
Snow: What you CANNOT infer

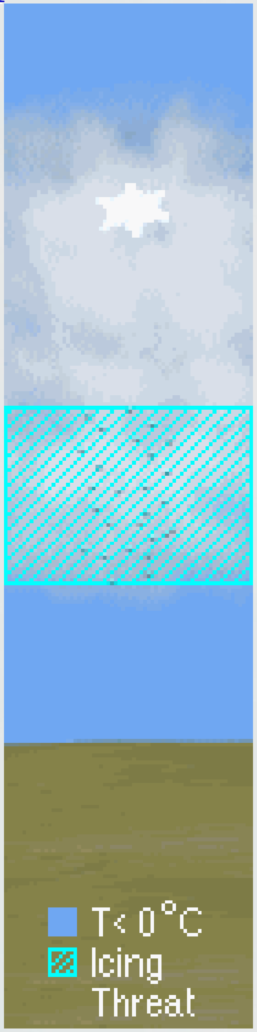
- Only ice exists aloft
- No SLW exists aloft
- Small amount of SLW exist

Inferring Icing Conditions

Graupel: What you can infer

- Formed when snowflakes become heavily rimed
- Significant SLW exists aloft

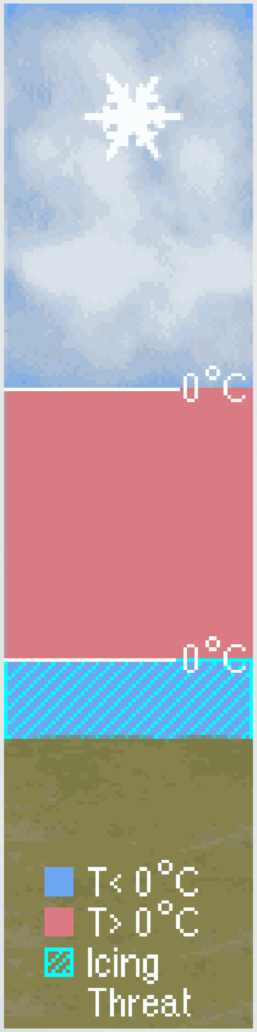


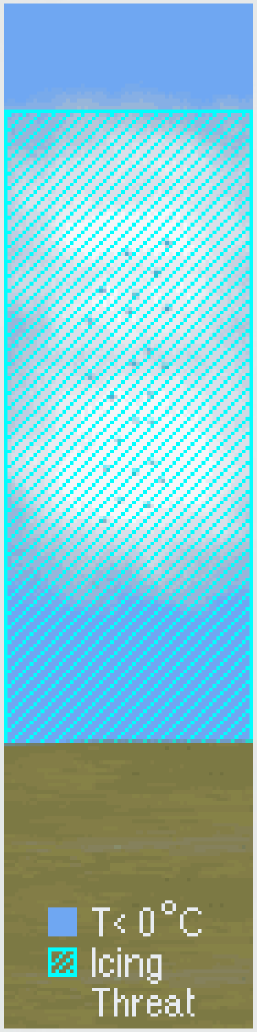


Inferring Icing Conditions

Freezing Rain: What you can infer

- Could be formed by classical or non-classical mechanism
- Freezing rain exists from the surface up to some level
- Dangerous icing conditions likely exist

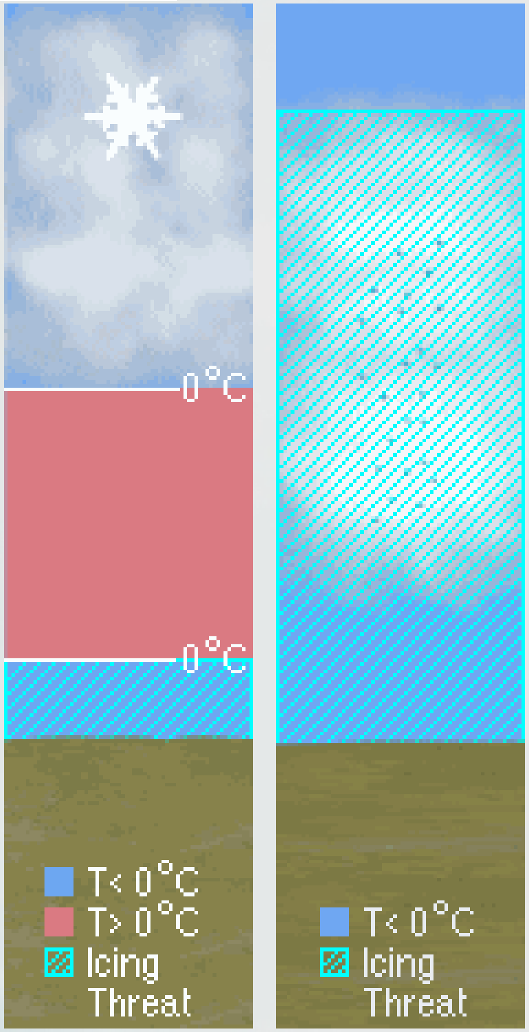




Inferring Icing Conditions

Freezing Rain: What you CANNOT infer

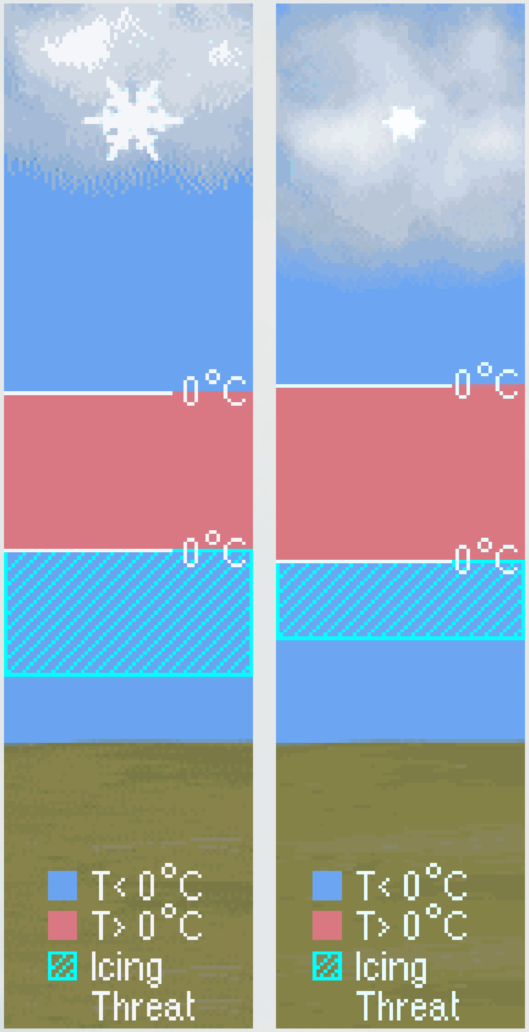
- A warm layer exists aloft
- Freezing rain layer is relatively shallow



Inferring Icing Conditions

Ice Pellets: What you can infer

- A layer of freezing rain or drizzle exists at some level aloft
- If a melting layer exists it is likely to be shallow
- SLW formed through collision-coalescence can also exist



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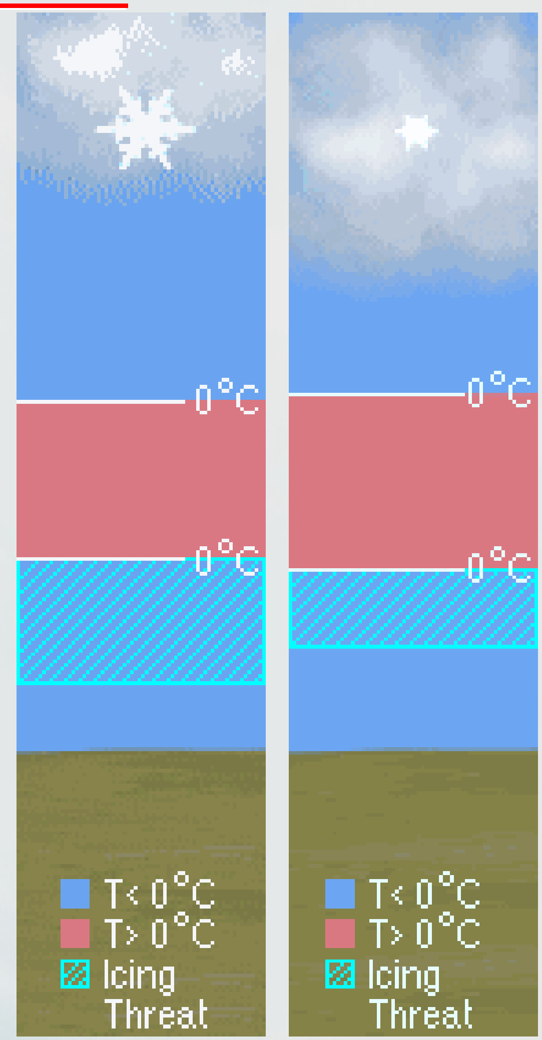
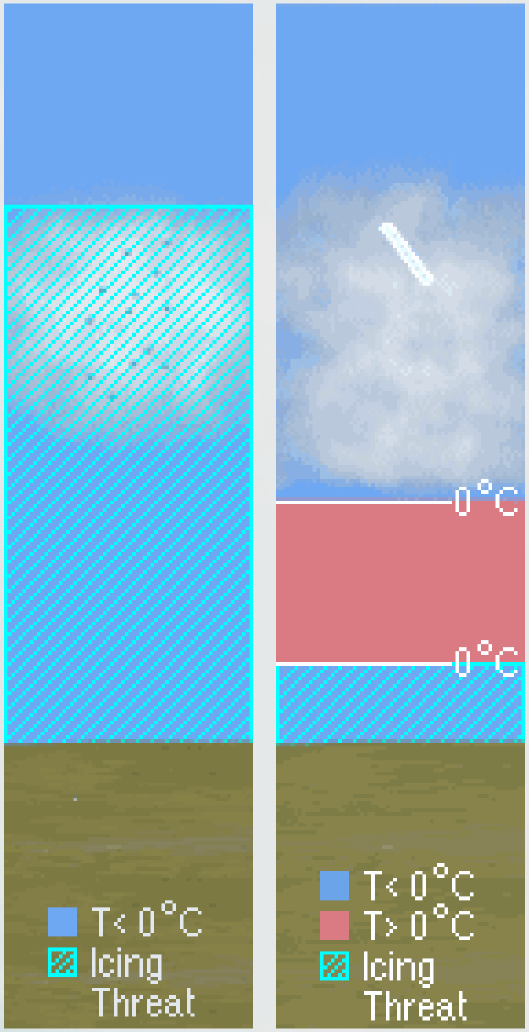


Inferring Icing Conditions

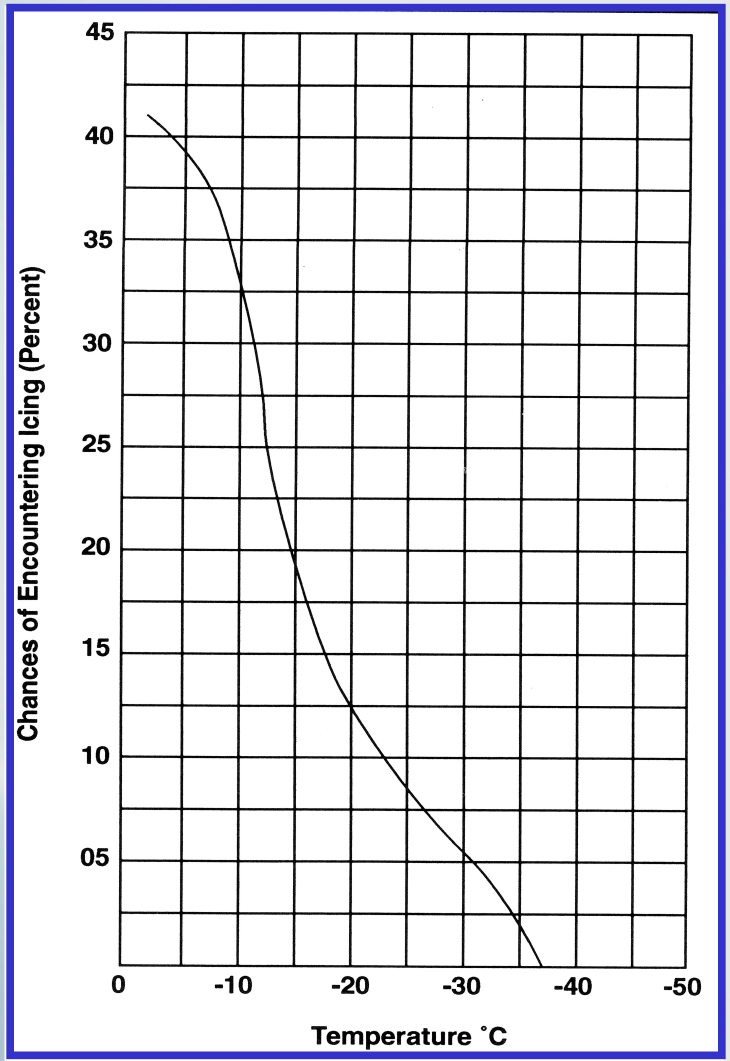
Freezing Drizzle: What you can infer

- Could be formed by classical or non-classical mechanism
- Freezing drizzle exists from the surface up to some level
- Collision-coalescence more likely



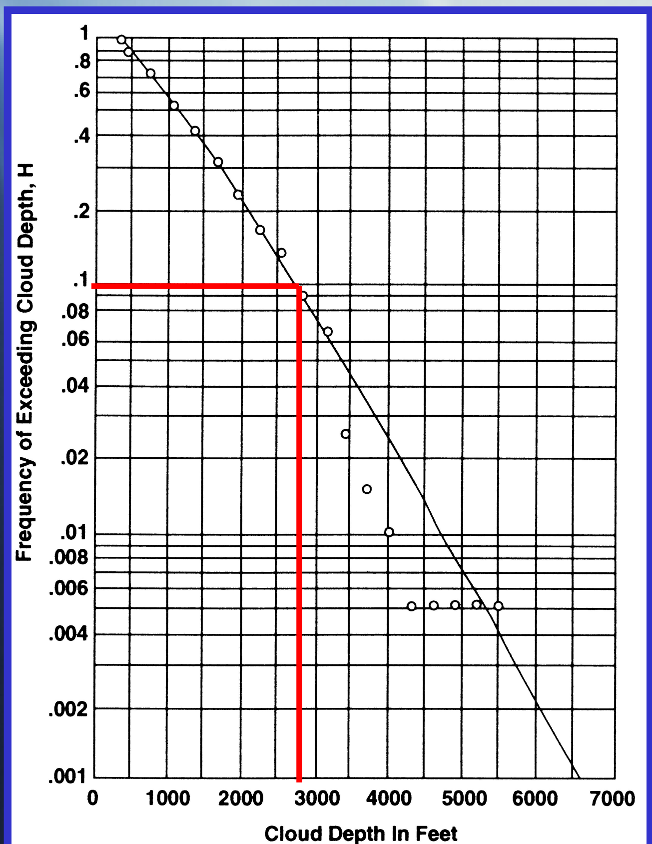
Icing in Cloud: Probability

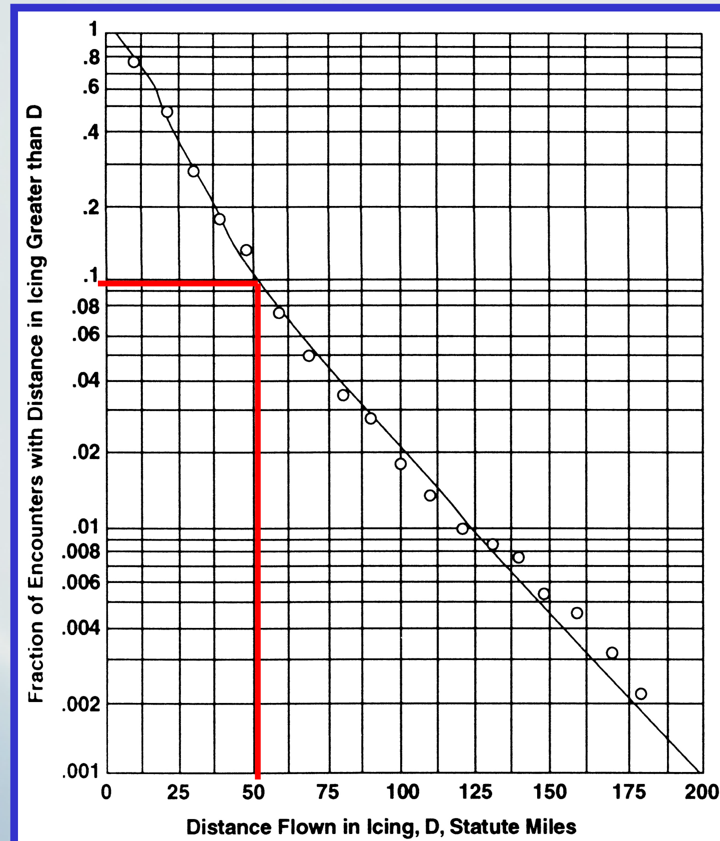
- 40 % chance of encountering icing in cloud below 0 C
- 14 % chance of encountering icing in cloud below –20 C



Icing in Cloud: What to Expect

- 90 % of layered clouds have vertical extents of 3000 ft or less
- 90 % of icing encounters last 50 sm or less





Mechanics of Icing

Total Air Temperature vs Static Air Temperature

- TAT = SAT + Kinetic Effects
- Temperature at stagnation point will be higher than SAT due to local pressure increase
- Temperature can vary across wing surface

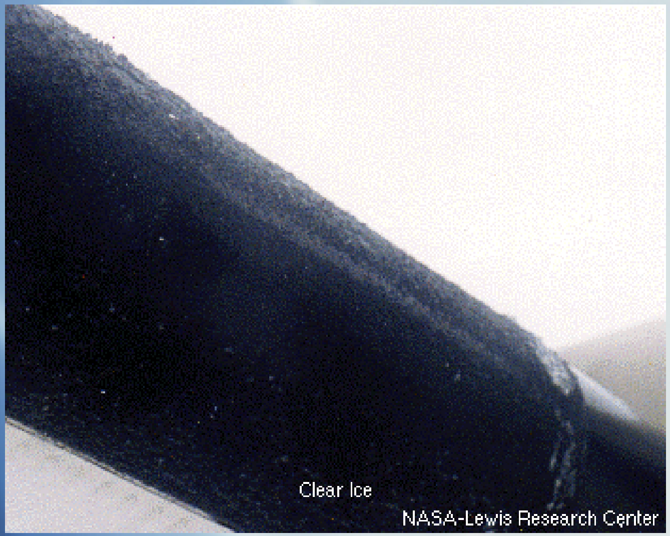
- One Example:
  - Standard Airfoil
  - 150 kts TAS
  - 1.9 C drop across airfoil

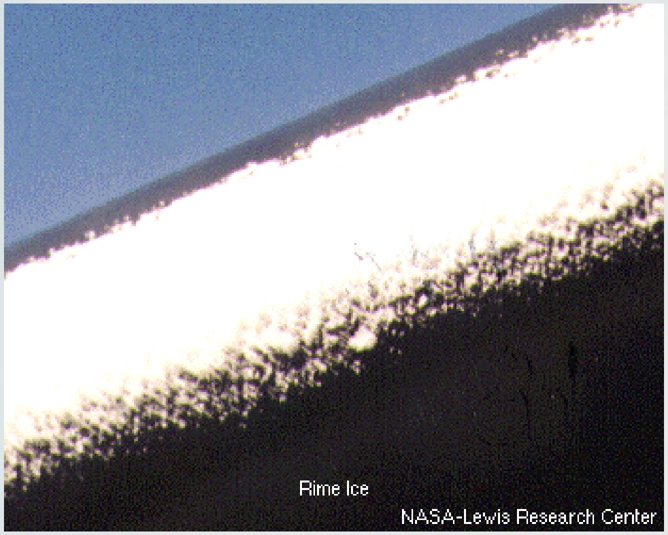
THE POINT

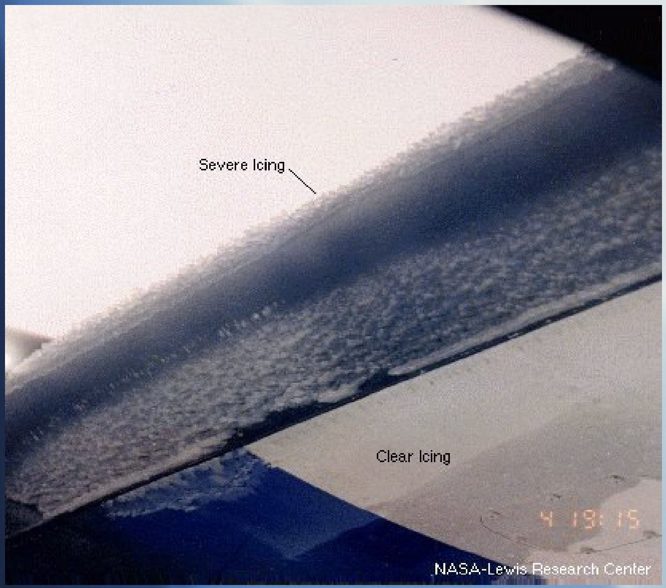
Icing can occur even when temperatures are above 0 C!

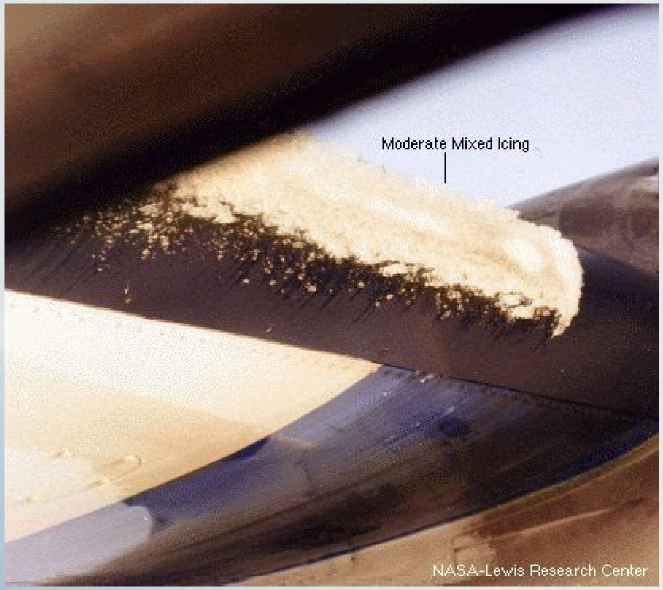
(Up to ~+4 C)

Some Pictures









Icing Types

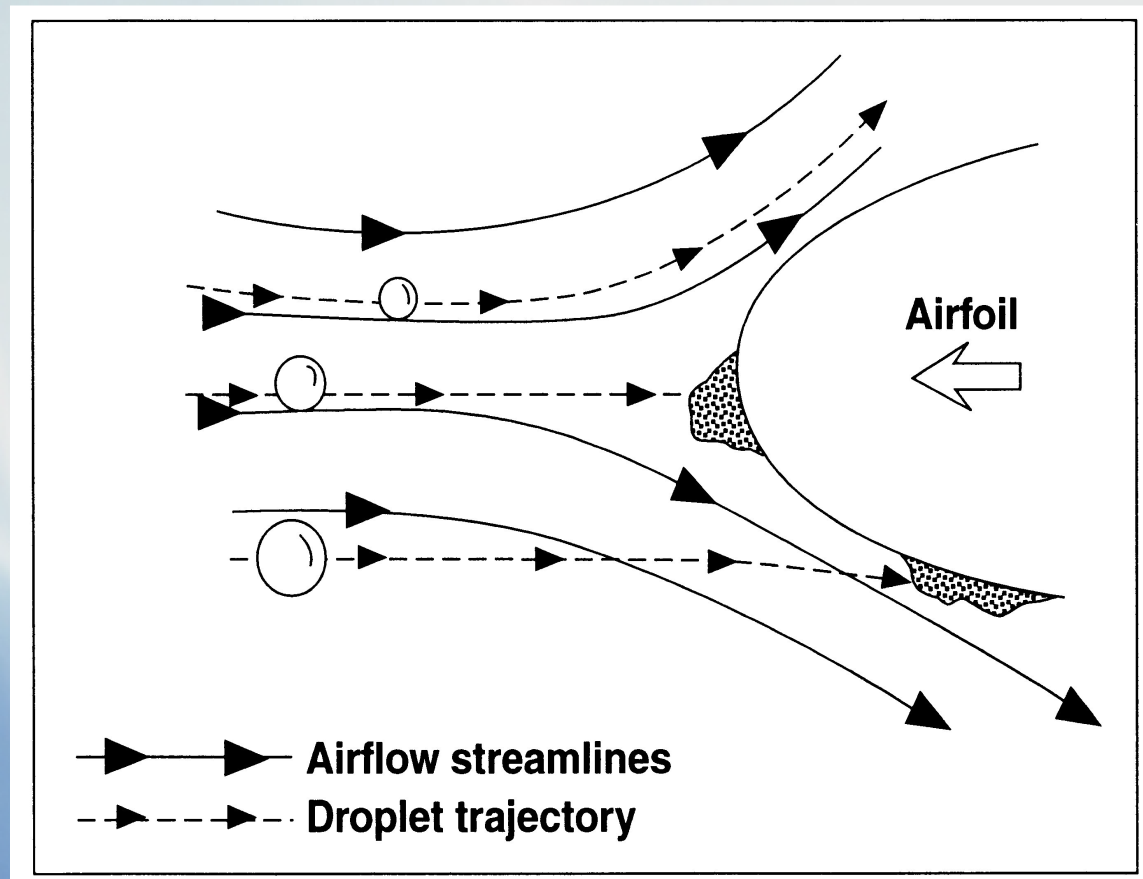
Summary

- General Observations:
  - Clear → 0 C to –10 C
  - Mixed → –10 to –15 C
  - Rime → –15 C to –20 C
- Typically:
  - Rime – Stratiform
  - Clear – Cumuliform
- Temperature + Drop Size → Icing Type
- LWC + Drop Size → Accretion Rate
- Airspeed also a factor (Kinetic Heating)

Dynamics of Icing

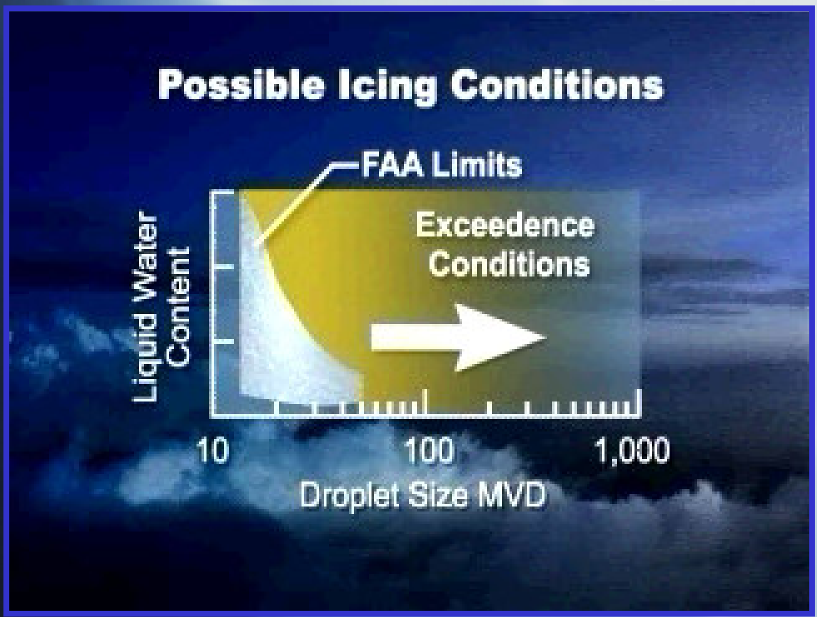
Collection Efficiency of an object

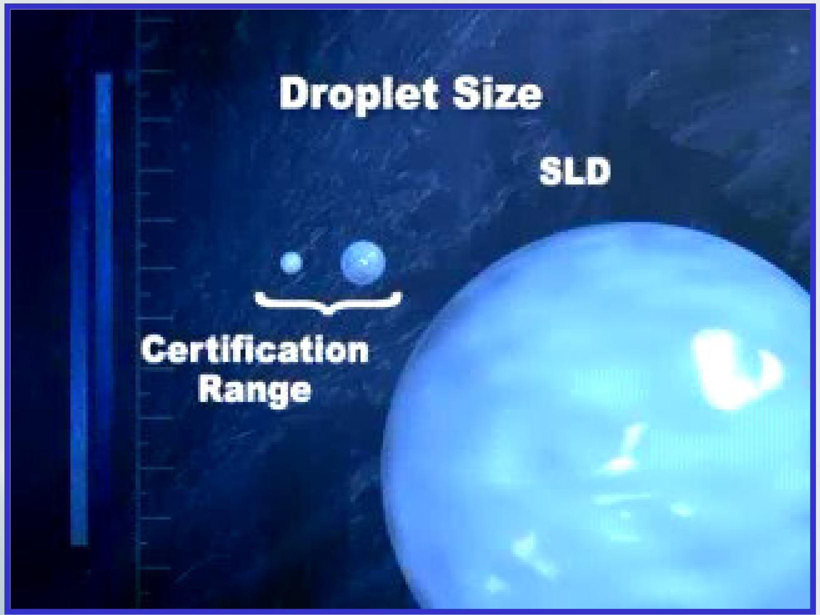
- Droplet Size
- Object Shape
- Airspeed



SLD

- Drop sizes much larger than 50 microns have been found to exist
- These are called Supercooled Large Droplets (SLD)

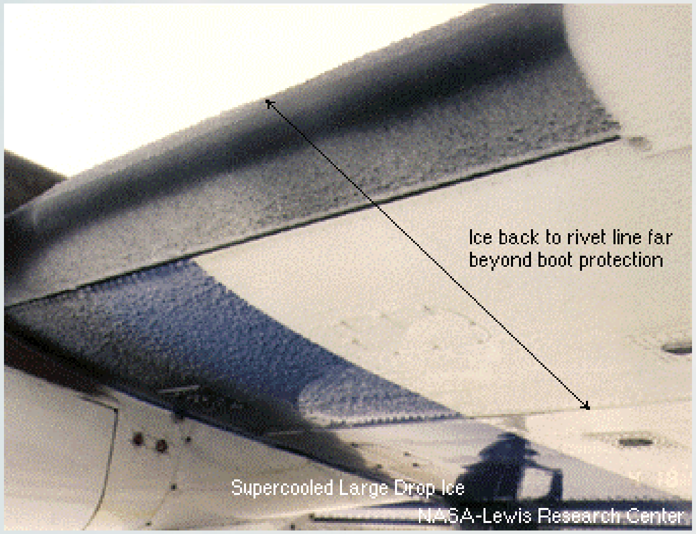


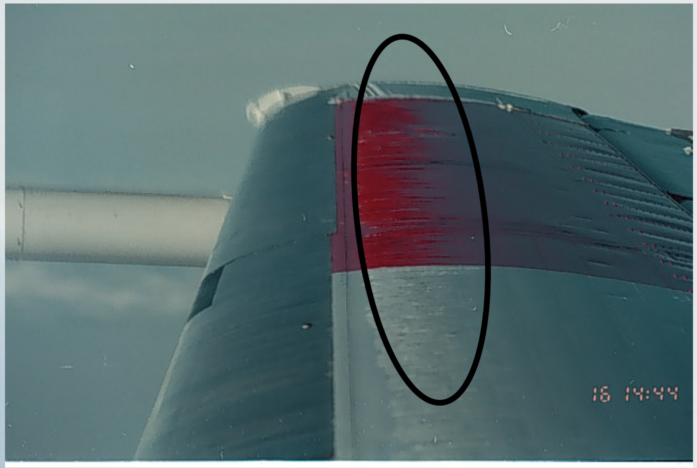


Dynamics of Icing

Dangers of Ice Outside CAR 525-C

- Large Droplets:
  - Ice aft of protected surface
  - Ridging
- High LWC
  - Runback
  - Ridging





Performance Penalties

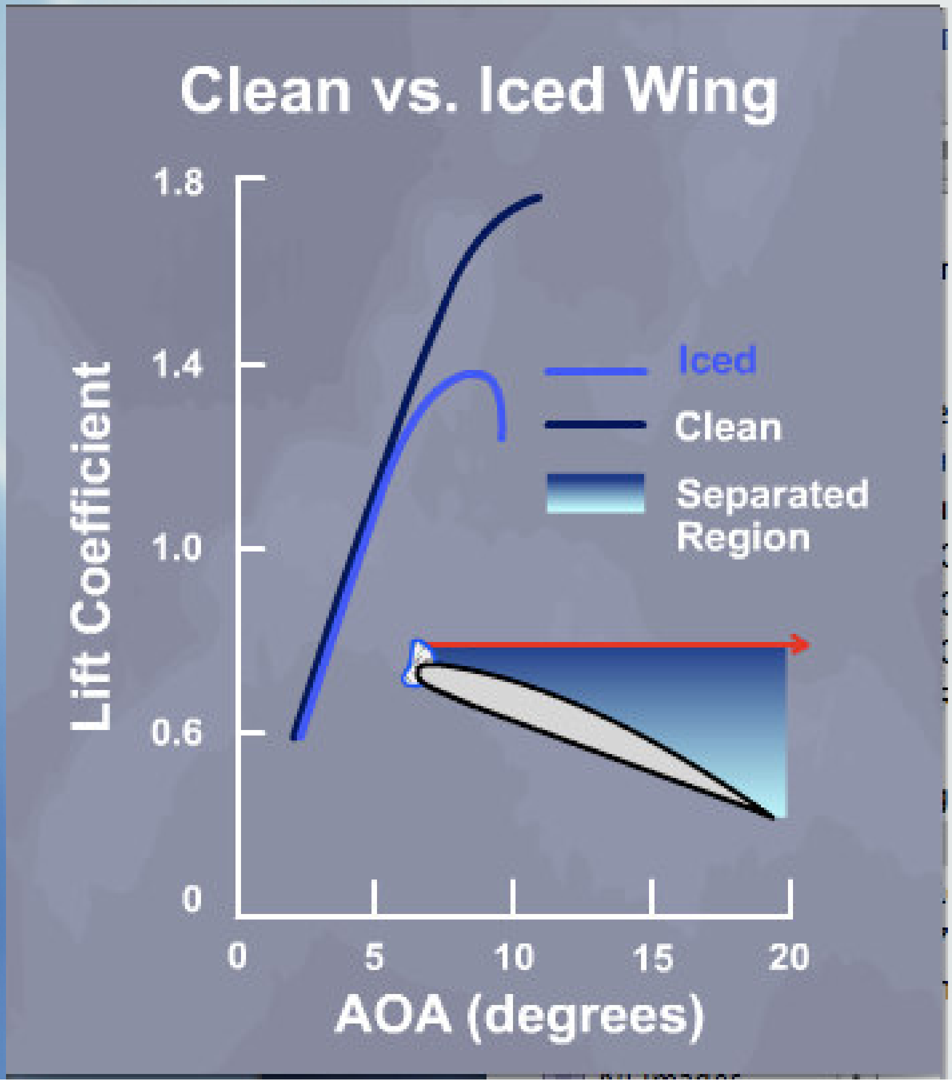
- Decreased Lift
- Increased Drag
- Decreased Stall Angle
- Increased Stall Speed
- Increased Vibration
- Changes in Pressure Distribution
- Early Boundary Layer Separation
- Reduced Controllability

Performance Penalties

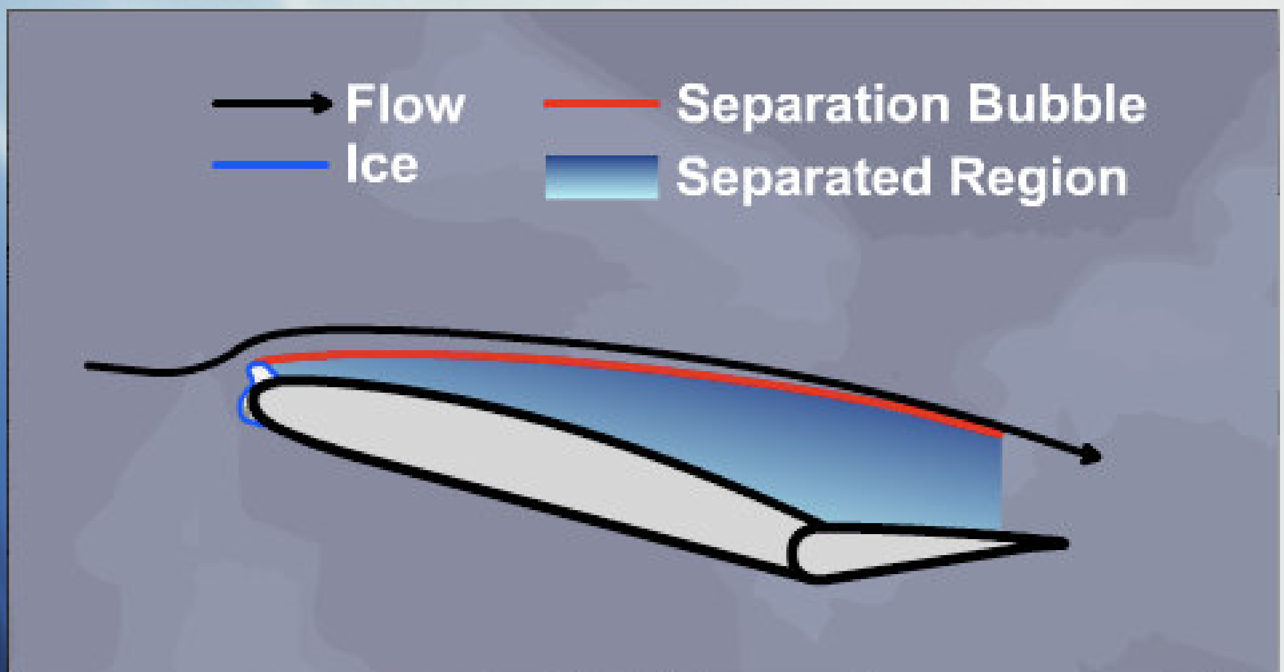
- Studies have shown
  - Drag increase up to 40 % or more
  - Lift decrease up to 30 % or more
  - Stall speed increase of 15 to 20 %
    - (Even with a very small coating of ice)
  - Propeller efficiency decrease of 19 %

  - One incident during research:
    - 36 % drag increase resulting from ice on unprotected surfaces, after boots were cycled

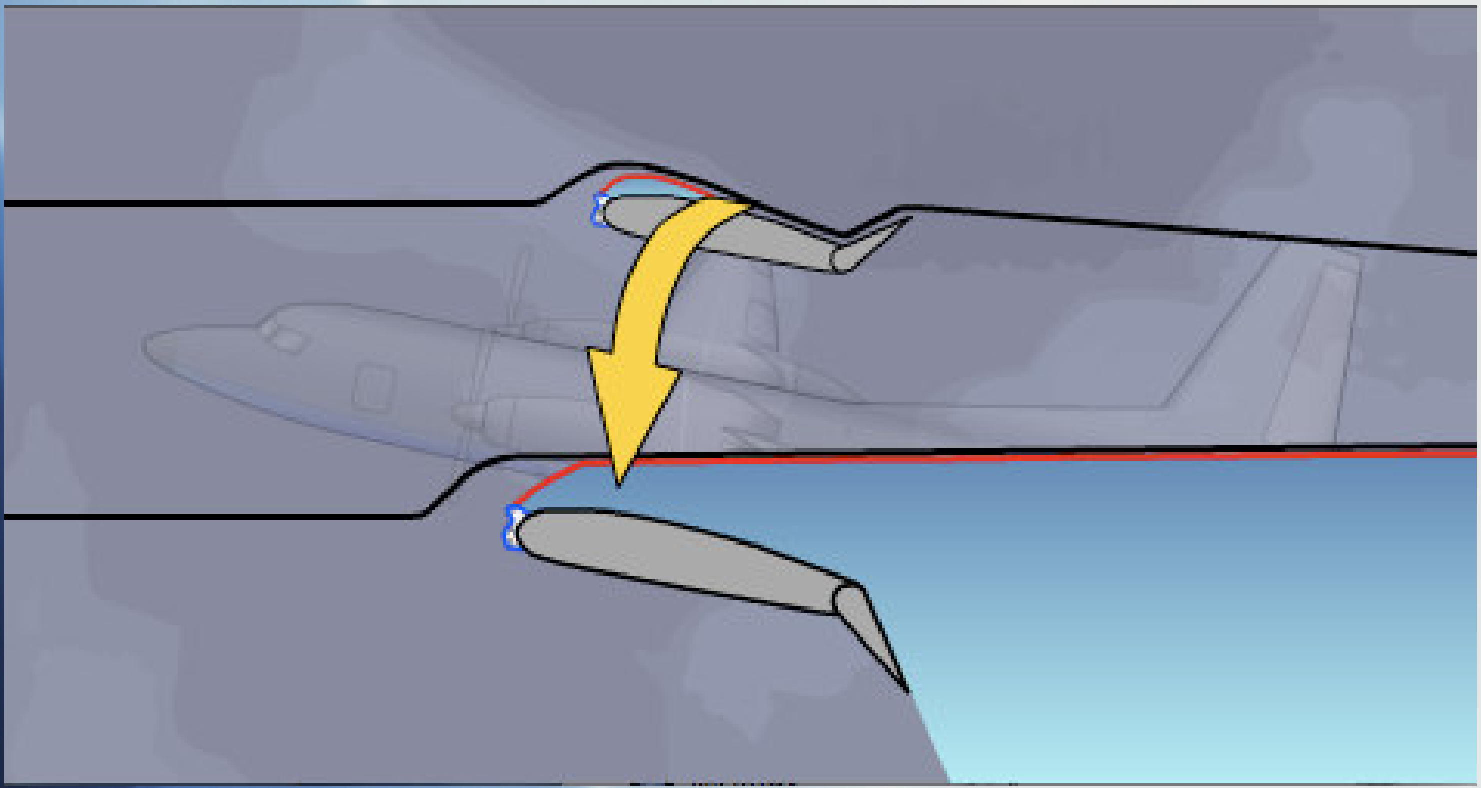
Wing Stall Comparison



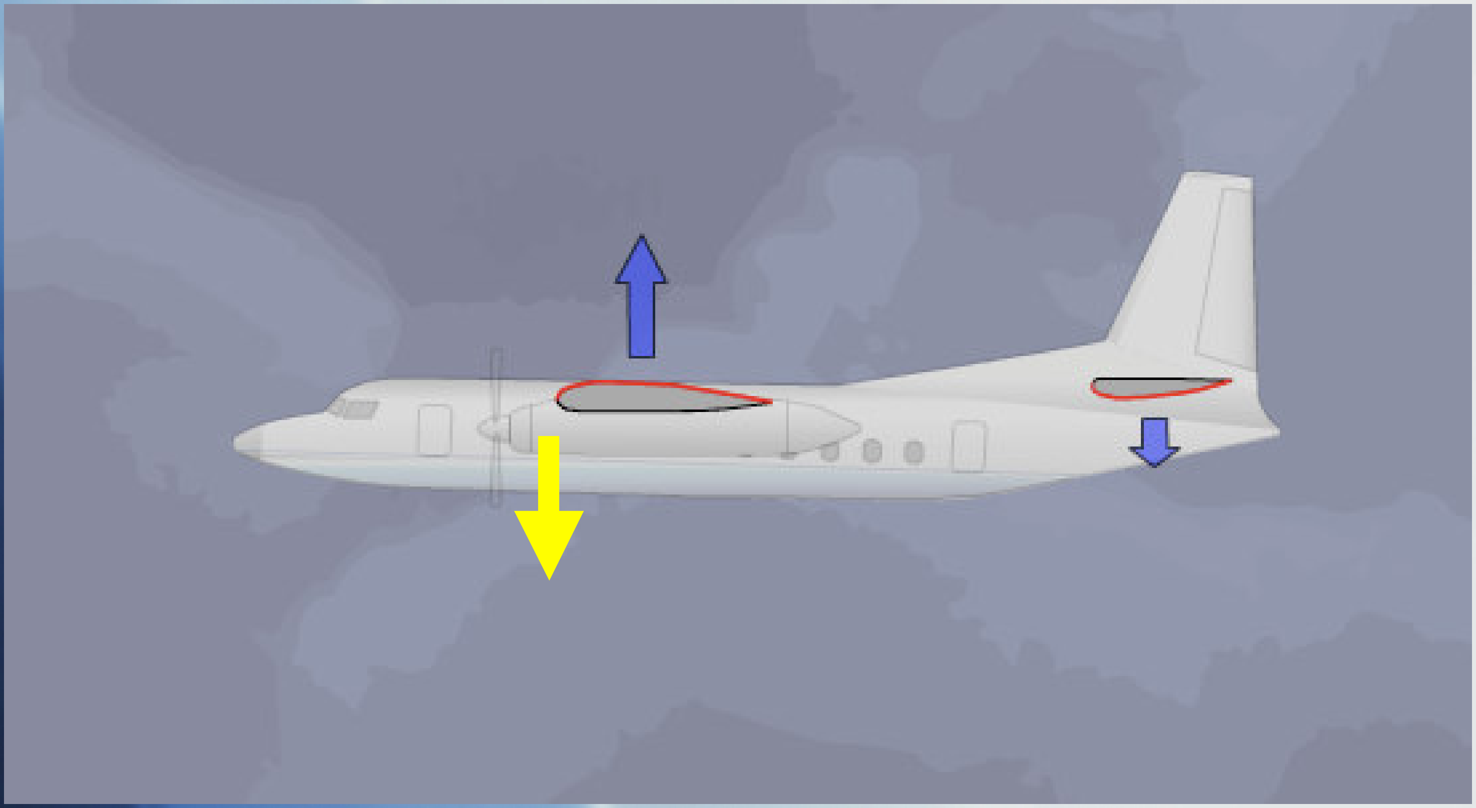
Aileron Snatch Due To Ice



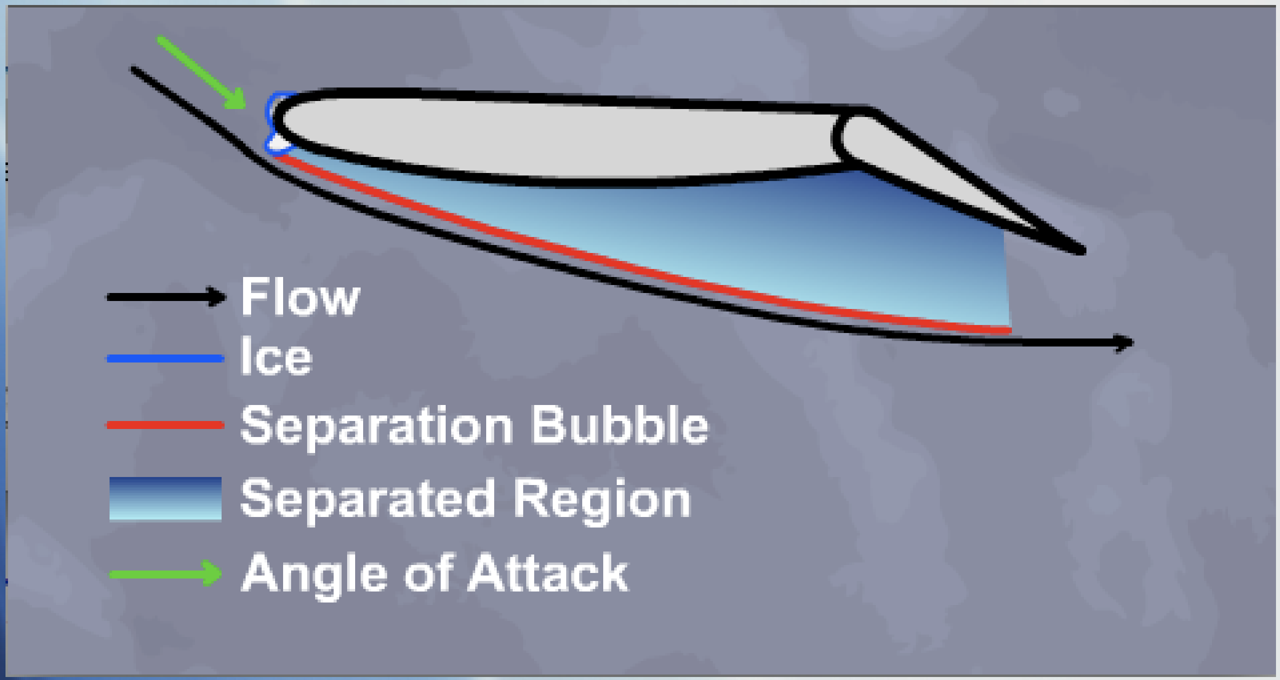
Uncontrolled Roll



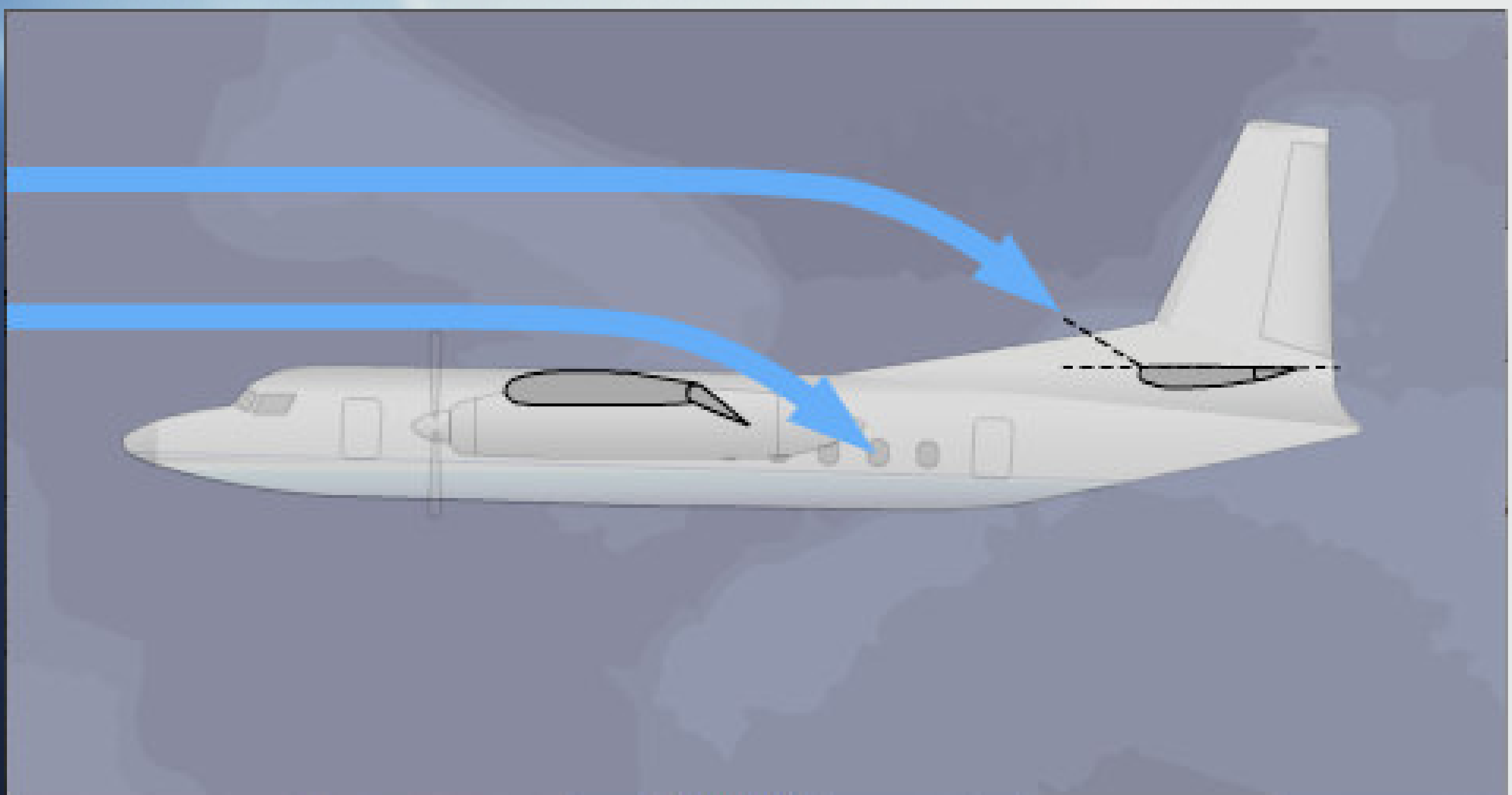
Balance Of Forces



Elevator Snatch Due To Ice



Lowering Flaps



Stall Recognition

- **WING STALL**
  - Wing Buffet
  - Wing drop
  - High/moderate angles of attack
  - Tends to happen at the low end of the speed regime

- **TAIL STALL**
  - Lightening of the controls
  - Dramatic nose drop
  - Often after flap extension
  - High end of the flap extension range

Recovery Techniques

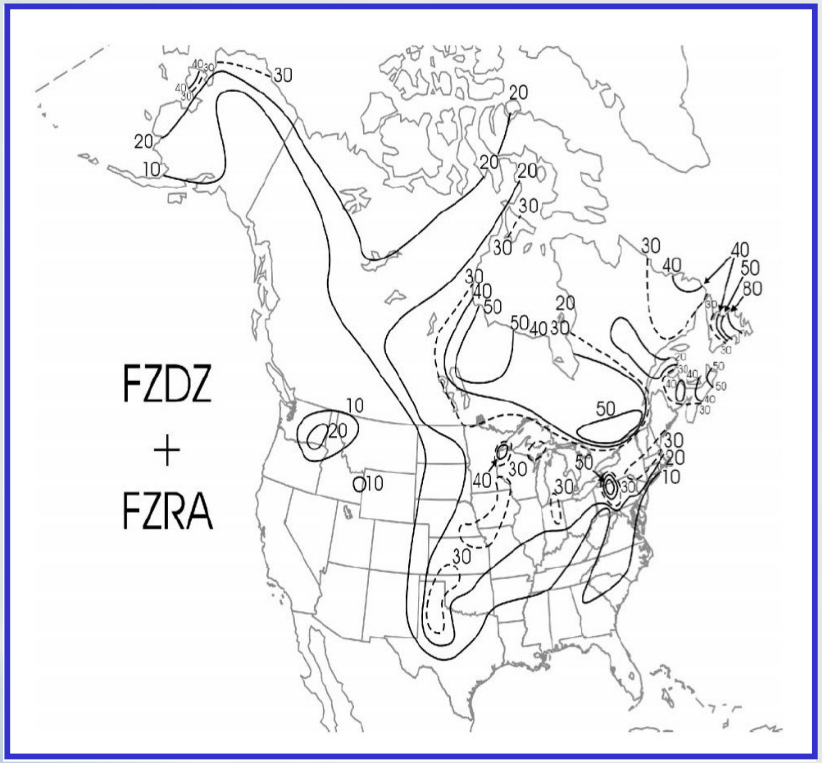
- **WING STALL**
  - PUSH FORWARD on the yoke
  - Add power
  - Maintain directional control with rudder
- **TAIL STALL**
  - PULL BACK on the yoke
  - Reduce power
  - Retract flaps to previous setting

Flight Planning

Checking the Weather

Remember the Physics of Icing

- Climatology
  - 53 % - near mountainous terrain
  - 14 % - near large bodies of water
  - 33 % - other



- 95 % of accidents occur during approach, landing, holding and go-around

- Forecasting Rule #1
  - Know your terrain!

Checking the Weather

Get the "BIG" Picture

- Review Surface Analysis
  - Low Pressure Areas (Cyclones)
  - Fronts (Warm/Cold/Occluded)
  - Observe winds, look for areas of lift (Fronts,Terrain,Convergence,etc..)

- Review the Upper Air Charts

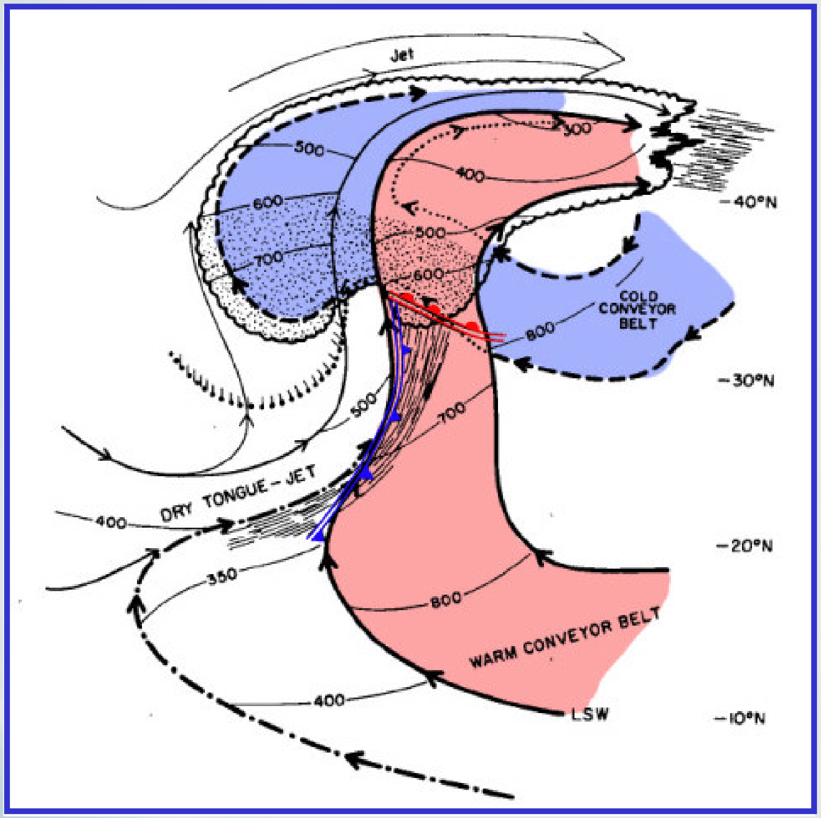
Checking the Weather

Fronts

- Check surface and upper air stations for airflow
  - Warm Conveyor Belt
  - Cold Conveyor Belt

- Check source of airflow (warm & moist flow over cold arctic air → Good chance of Freezing Precipitation

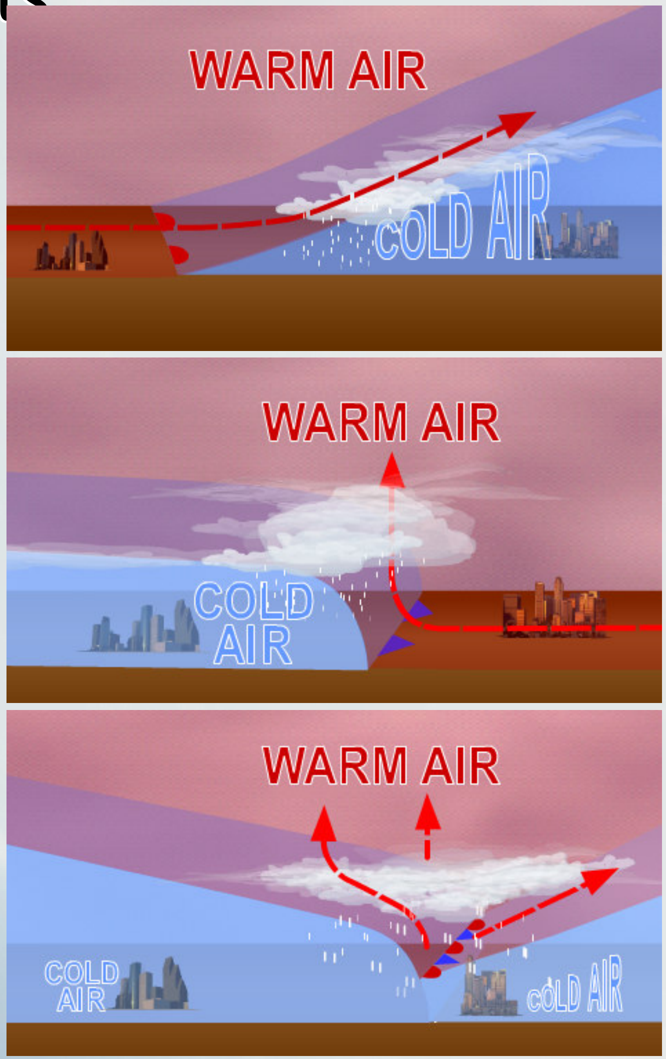
- Max precipitation usually W/NW quadrant



Checking the Weather

Fronts

- Warm Fronts →
  - 1:200
  - Icing up to +300 nm ahead of surface front
  - Icing in clouds and freezing precipitation
- Cold Fronts →
  - Icing ahead & behind up to +130 nm
  - FZRA/FZDZ aloft
- Occluded Fronts →
  - In cloud either side of front
  - FZRA/FZDZ possible



Checking the Weather

- Forecast Information
  - Graphical Area Forecasts (GFA)
  - Terminal Area Forecasts (TAF)
  - AIRMETS
  - SIGMETS

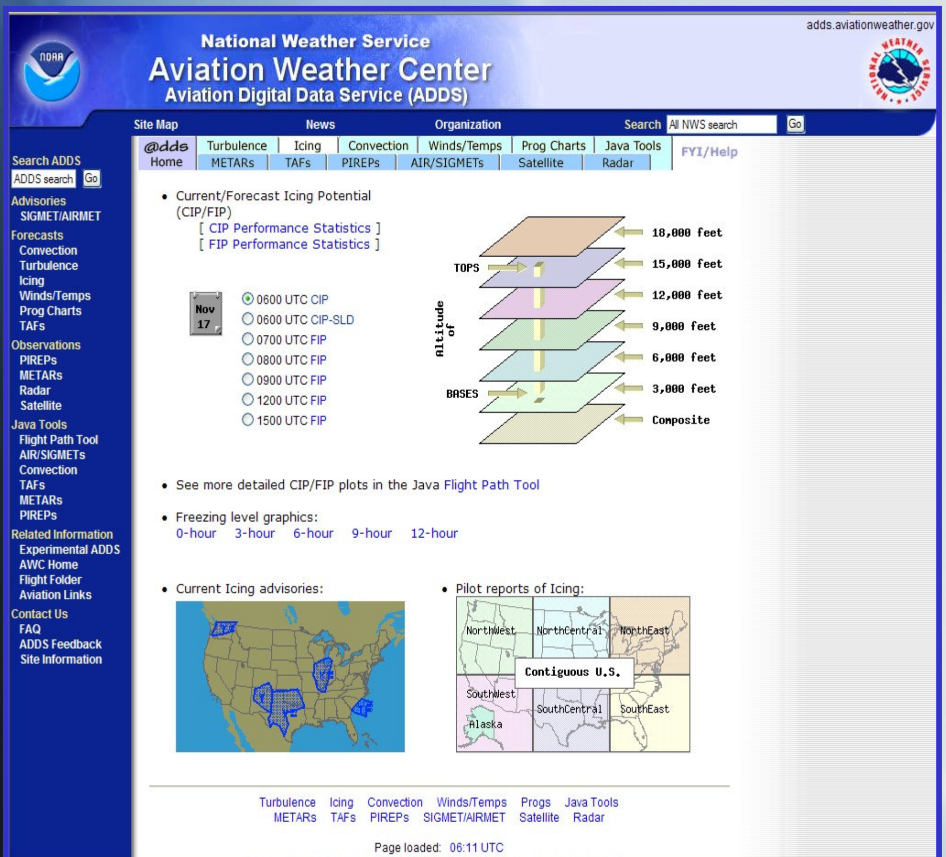
- Observations
  - METARs
  - PIREPS

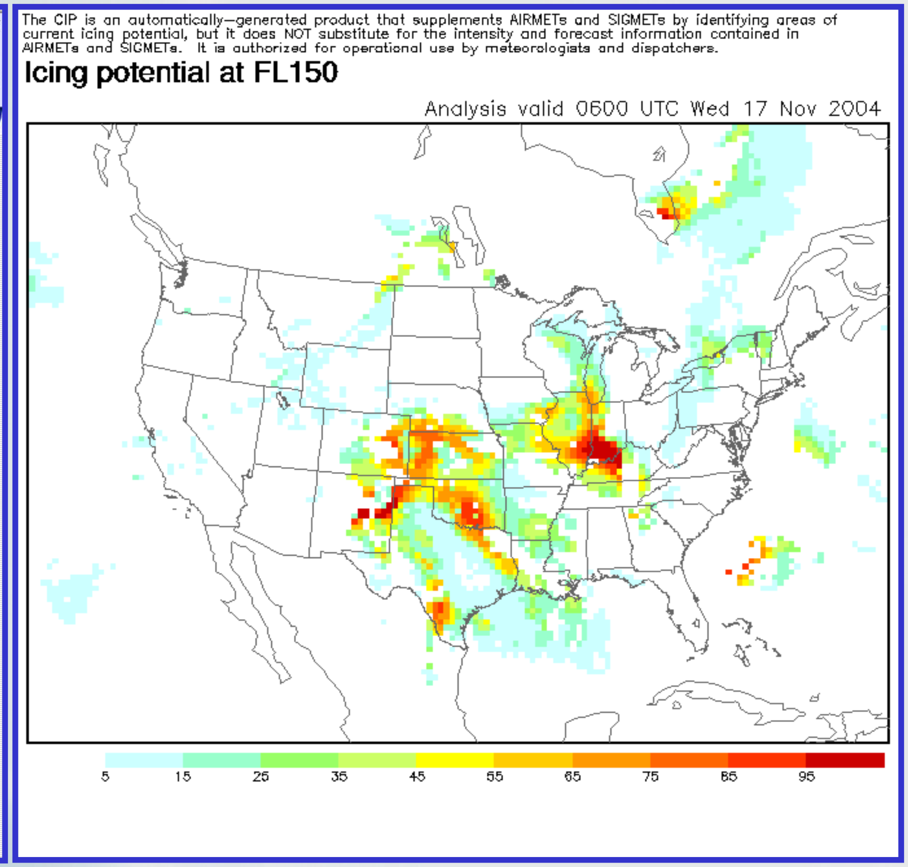
MAKE SURE EVERYTHING AGREES!

IF IT DOESN'T, UNDERSTAND WHY

Current/Forecast Icing Potential

http://adds.aviationweather.noaa.gov/





Checking the Weather

What you NEED to know

- Extent of cloud coverage
- Cloud tops
- Cloud bases
- Frontal positions (current & forecast)
- Precipitation
- Freezing level

Filing the Flight Plan

A Few Things to Remember

ALWAYS HAVE AN OUT FOR EVERY PHASE OF THE FLIGHT!

- Piston aircraft → Reduced thrust margin
  - Usually cruise at 75-85% power
- Iced wing will not climb as efficiently
- Be mindful of MEA
- Penetrate fronts at a 90 degree angle
- Fly on LEEWARD side of mountain ranges

Monitoring the Weather

Don't make it your last priority!

- A change in weather may warrant the cancellation of your flight

- Update Weather and Reassess your outs
  - PIREPS (Icing)
  - METARS (Clouds,Precipitation,Fronts)
  - Forecasts (Make sure they are holding)

Canada (126.7 MHz) & US (122.0 MHz)

In-Flight Strategies

If Ice is Encountered

- Start working to get out

- Possible Options:
  - Climb
  - Descend
  - Continue
  - Divert
  - Return
  - Declare an Emergency

In-Flight Strategies

If Ice is Encountered

- Remember:
  - 90 % of icing encounters are 50 sm or less
  - 9 out of 10 times a change of 3000 ft will take you out of icing conditions
    - Be mindful of MEA
    - Be cautious of cloud tops
  - Use a safe airspeed to maneuver
  - Keep bank angles to a minimum

Lake Effect Snow

Lake Effect Snow

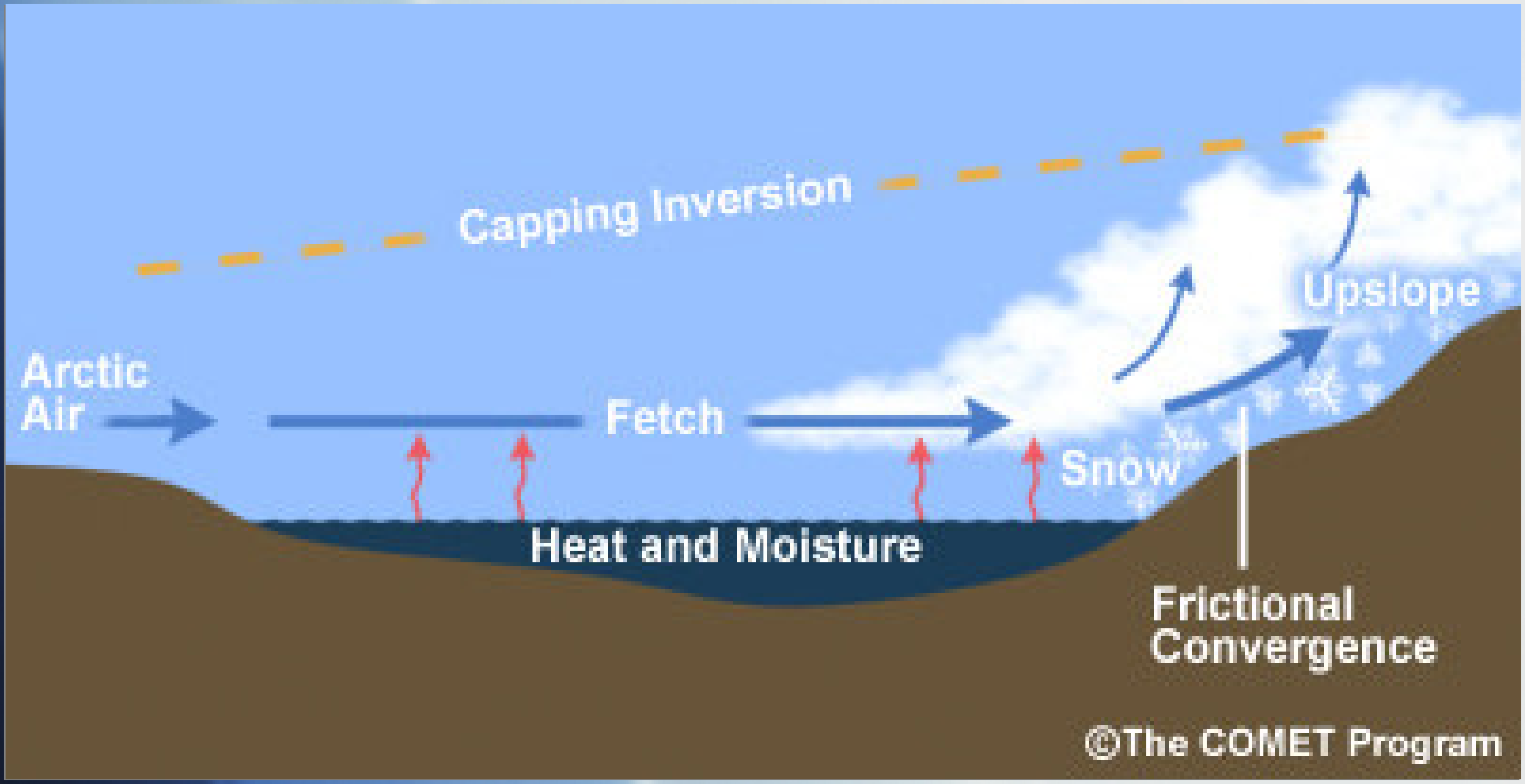
Ingredients

- Open body of water
- Cold arctic air flowing over relatively warm water
- Typically occurs when a polar vortex slides south

- Factors affecting amount of LES:
  - Water surface to 850 mb temperature difference (minimum 13 C)
  - Low shear (ideally < 0-30 deg sfc-700mb)
  - Long Fetch

Lake Effect Snow

How it Forms



Lake Effect Snow

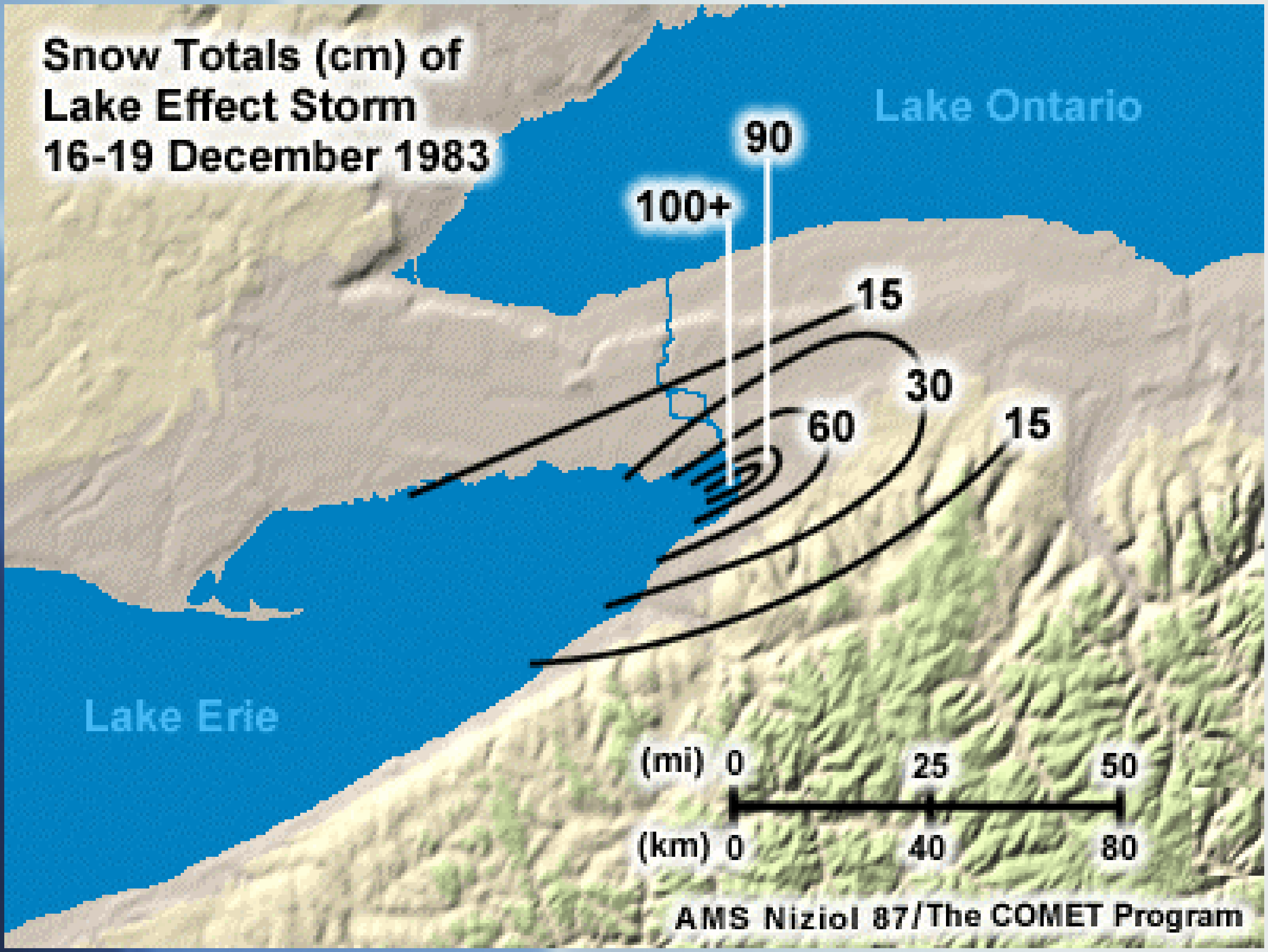
The Impact

- Zero-Zero conditions almost instantly
- Severe icing (particularly near water)
- Rapid snow accumulations (several cm/hr)

- Fairly low level phenomenon (5000-7000 ft)
- Generally quite localized

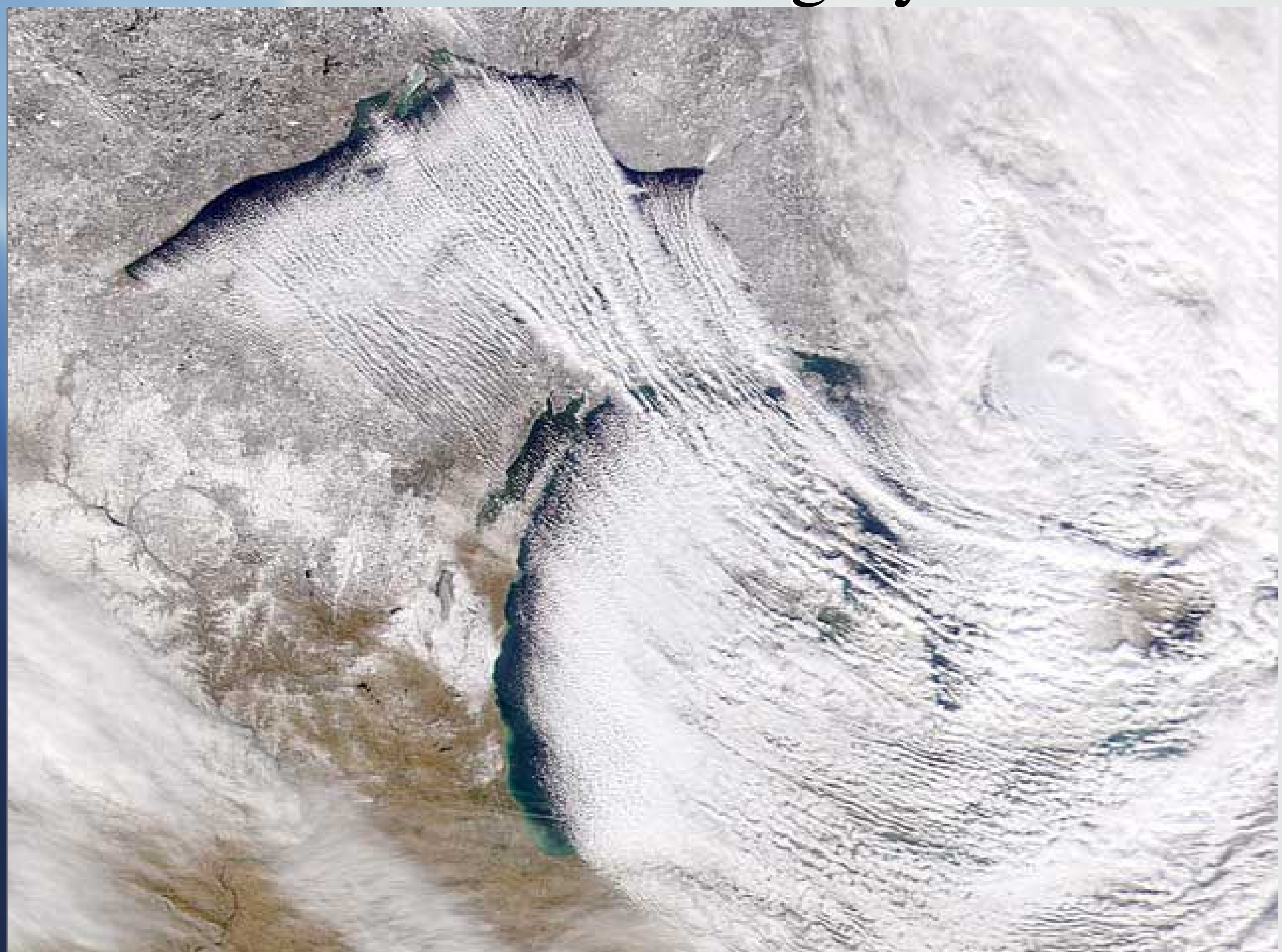
Lake Effect Snow

The Impact



Lake Effect Snow

Satellite Imagery



Lake Effect Snow

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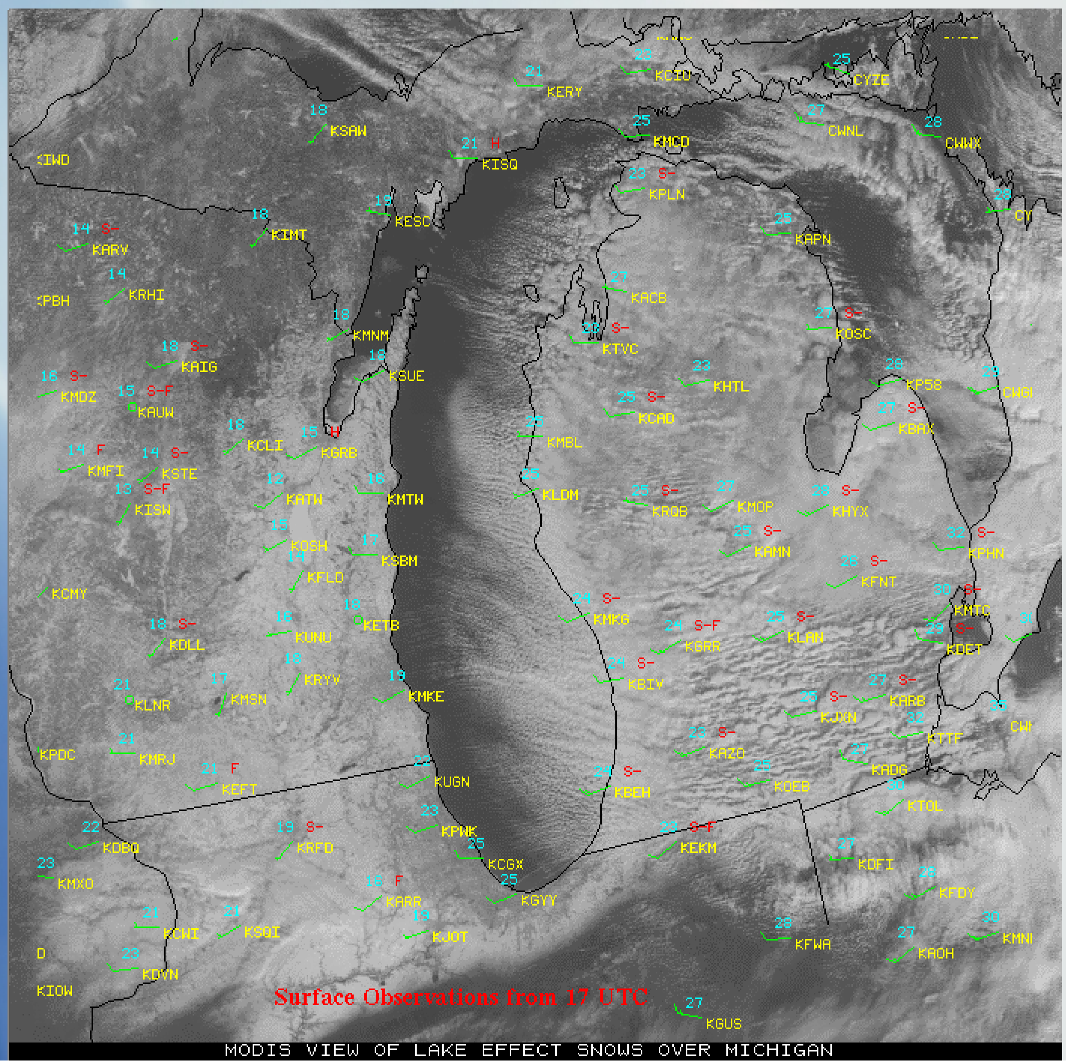

www.aerosafety.ca