Agenda

- Scenario
  - KRNO to KPAO
    - Planning
    - Preflight
    - Taxi
    - Takeoff
    - En route
    - Approach
    - Post flight
- Time limits preclude complete coverage of
  - Aircraft de-ice systems
  - Winter operations
  - Weather ice hazards
  - Non-structural icing

What does icing refer to?

- Structural
  - Wings
  - Tail
  - Windshield
  - Propeller
- Induction
  - Carburetor
  - Air filter
  - Inlet (turbine)
- Instrument
  - Pitot tube
  - Static ports

Why is structural ice bad?

- Drag
  - Increased
- Lift
  - Reduced
  - Stall at lower angle of attack
  - Stall at higher calibrated airspeed
- Weight
  - Increased
- Control
  - Compromised
    - Control surface movement obstruction
    - Control surface airflow disruption
    - Asymmetric lift
    - Asymmetric ice shedding

Scenario: KRNO to KPAO

- Aircraft: C-182 (normally aspirated)
- Season: Winter
- Time of day: dusk trending toward night
- Weather
  - It's been snowing on and off all day
  - Temperature -6°C
  - KRNO OVC040, KSAC OVC035, KPAO OVC015
- You have not received a good weather briefing
- You remove the snow from the plane
- There is no frost?
- You ask that the engine be pre-heated?
- You check-defrost and pilot heat
- You file IFR
- You're in a hurry to get home!

Preflight considerations

- Weather briefing
  - IFR or VFR?
- Equipment capability
  - None
  - Supplemental protection
  - Flight-into-known-ice systems
- Pilot capability
- Outs
  - VFR laterally
  - VFR-on-top
  - Low terrain
  - Above-freezing air aloft or at surface

Flight into known ice?

- Definition of known Ice?
  - Icing temperature with precipitation ("visible moisture") or a pilot report of icing
- AFM/POH limitations will state if the plane is approved for "flight into known icing." Icing approval involves a rigorous testing program
  - Piper Seneca III
    - Propeller heat
    - Windshield heat plate
    - Wing and tail surface leading edge inflatable boots
  - Cirrus SR-22, Diamond DA42
    - TKS weeping porous leading edge panels, propeller spray, windshield spray bar, redundant pumps, ice light
- Ice protection equipment must be installed and operational, else prohibited from venturing into icing areas
  - All planes are prohibited into severe icing

Priorities in coping with ice

- Before and during every phase of flight, your priorities are to
  1. *Avoid*
     - icing regions entirely if possible
  2. *Minimize*
     - duration and distance of exposure to ice, whether encountered intentionally or unintentionally
  3. *Escape*
     - ice immediately if strategies above fail,
     - via emergency authority if necessary

Use all available resources

- SRM: Single-Pilot Resource Management
  - Get ATC assistance *early*
    - Proactive climb, descent, or re-route
    - Request vectors to an area where you can descend
      - Sometimes this will be off-airway (Medford flight)
    - Actively solicit PIREPs
  - Downlink weather (Garmin or Avidyne)
    - Temperatures aloft (winds)
    - Precipitation areas (NEXRAD)
    - Topo and terrain clearance (map)
  - Use weather briefing knowledge
    - Where ceilings are higher
    - Height of tops
    - Shortest route through a front
  - Declare an emergency

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Scenario: Route

- Route
  FMG
  V200
  SIGNA
  V392
  SAC
  V334
  SUNOL
- Altitude
  12000

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Ramp, preflight, and taxi

- Is the plane ready for winter flying?
- Do you have the right amount of fuel?
- Remove all frost, snow and ice
- Check landing gear, especially retractable gear
  - This should be done after flight too
- Check all anti- or de-ice equipment
- Taxi slowly: possible icy runways, taxiways
- Take warm emergency clothes

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Cleared for takeoff

- Double check wings clear of snow
- Abort plan
- Anti-icing systems on
  - Carb heat off at start of takeoff run
- Maintain directional control
  - No brakes
  - V_{MCG} (rudder authority)

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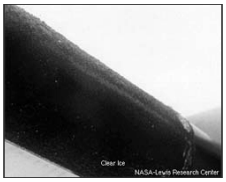
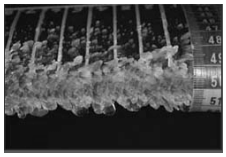
Takeoff climb

- At 1000 AGL, below the clouds, you hear a splat on the windshield
- Then there is engine roughness and a drop in manifold pressure
- At night you take your flashlight and check out the wings





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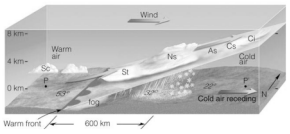
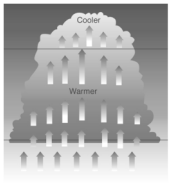
Clear ice below overcast

- In VMC
  - Freezing rain, drizzle
  - Inversion, warm front
- In cumulus clouds
  - Cloud tops
    - Vertical cloud development continues until ascending water freezes
  - Small horizontal extent
  - Deep vertical extent
  - Risk: rapid formation with moderate to severe intensity
  - Solution: know cumulus tops
    - Divert around (request ATC approval)
    - Sharp cloud edges mean liquid water
    - Fly in clear air above





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You go back!

- Declare an emergency
- Even in a "known ice" plane with severe icing you go back
- How to fly VFR with ice:
  - Stall speed is increased
  - Rough engine
  - Defroster on high and heater off
  - Don't use the autopilot
  - Long runway if possible

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Departure

- You enter the cloud bases and start losing airspeed
- Looking out the side window and windshield with your flashlight you see some snow like covering
- You can't climb and you're at 8000 MSL and airspeed is decreasing more!
- Mixed ice
  - Contact ATC for help

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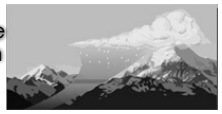
Mixed ice in cloud



- -10°C to -15°C
- Combination of clear and rime ice with characteristics of both
- Forms a rough accumulation when ice particles become embedded in clear ice
- Along a cold front, cold air plows under warm air, lifting it rapidly and resulting in formation of moist cumulus
- Near mountains and lakes
  1. Air flowing over a mountain range can produce serious icing hazards,especially along the windward side of a major range
  2. Icing risks increase near large bodies of water, since moisture is added

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With ATC's help

- In a "flight into known ice" plane:
  - Prop de-ice or alcohol or TKS on
  - Boots inflate
  - Windshield on low or alcohol or TKS spray on
  - TKS system on (normal) prior to ice penetration
- Request vectors; give information on ice
- Just like the VFR descent
  - Stall speed is increased
  - Rough engine
  - Defroster on high and heater off
  - Don't use the autopilot
  - Request vectors to final and hopefully an ILS
- ILS (or or other precision) approach
  - Longer runway, typically
  - Stabilized approach without intermediate level-off

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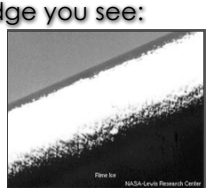
Climbing higher

- You were lucky and climbed to 12000 MSL
- Your airspeed has decreased but you are now VFR-on-top
- You are at SIGNA intersection in moderate turbulence
- Looking at the leading edge you see:
- You decide to?



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You decide to divert to SJC

- You need to fly through a freezing layer
- You want a long runway
- Say intentions and request ILS approach
- You do not want to descend until on localizer and cleared
- Don't expect to shed ice in the clear
  - No flaps
  - High approach speed
    - Higher approach category
    - Practice with CFI!
  - Fly airplane to runway surface

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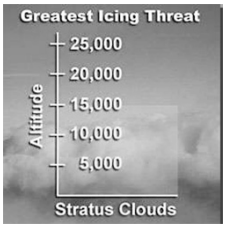
Rime ice on approach

- Intermediate altitudes at KSJC
- Coastal (Bay Area) stratus
  - Little or no convection
  - Wide lateral extent, narrow (3000 foot deep) vertical extent
  - Rime ice
    - -15°C to -20°C. Forms when small droplets freeze immediately on contact with aircraft.
    - Has a milky, opaque appearance resulting from air trapped when it strikes leading edge of airfoil.
    - Less dense and tends to form wedge-shaped accretions that do not disturb airflow as much as clear ice.
  - Risk: light intensity, but lengthy exposure
  - Solution: altitude change



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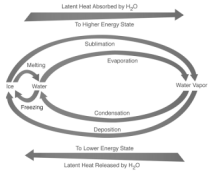
Physics of icing

- Liquid water does not necessarily freeze at 0°C
  - Phase change from liquid to solid releases heat (heat of fusion)
  - Probability liquid water has frozen increases from near zero at 0°C to near certain at -40°C



- "Supercooled" describes liquid water in a below-freezing environment
  - "Below freezing environment" can include the structure of an aircraft

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What causes icing?

- Lifting of liquid water to super cooled temperature altitude
  - Fronts
  - Mountains (orographic)
  - Convection
    - Cumulus
    - Cumulonimbus: automatic warning that thunderstorms imply severe icing which is not explicitly reported

- Descent of liquid water into colder air
  - Fronts
    - Especially warm fronts
    - Inversions (warm air above cold)
  - Freezing rain hazard
  - Freezing drizzle hazard

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Icing temperature ranges

- 0°C < +4°C
  - Theoretically possible due to local aerodynamic flows or aircraft structure
- -10°C < 0°C
  - Clear ice
  - Slow to freeze: runback
- -15°C < -10°C
  - Mixed ice
- -25°C < -15°C
  - Rime ice
  - Instantaneous freezing: air trapped
- -40°C < -25°C
  - Rare but possible
- < -40°C
  - Extremely rare except laboratory or deep convection

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Structural ice formation

- Supercooled water strikes aircraft structure
- Droplet size and ambient/aircraft temperatures determine icing type and accumulation
  - Large drops, "warm" temperature:
    - Slow freezing, run-back, clear ice
  - Small drops, "cold" temperature:
    - Rapid freezing, leading-edge formation, rime ice

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Super cooled droplet size

Droplet description	Droplet size code	Droplet diameter	METAR precipitation code	AIRMET/ SIGMET/FA abbreviation	PIREP icing intensity	Where and what?
Super cooled cloud droplets	SCCD	20 μm	-	ICGIC	LGT-MOD	Normal icing in clouds condition
Super cooled drizzle drops	SLD/ SCDD	100 μm	FZDZ	ICGIP	SEV	Freezing drizzle below cloud including VMC
Super cooled large droplets	SLD	1000 μm to 5000 μm	FZRA	ICGIP	SEV	Freezing rain below cloud including VMC

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AIRMET and SIGMET

- AIRMET (WA) ZULU
  - Issued only for large areas (> 3000 mi^2)
  - Actual icing occurrence within WA area is typically isolated
  - Scheduled every six hours coincident with FA
  - Light or moderate severity only
  - Area paragraph and freezing levels paragraph
    - CLR, MIXED, RIME, ICG, ICGIC, ICGIP, ICGICIP
    - Surface
    - Multiple freezing levels
    - Inversions
- SIGMET (WS) NOVEMBER to YANKEE
  - Unscheduled: on demand
    - 4 hours validity
  - Issued for severe icing
    - By definition, "severe" exceeds the capability of aircraft anti-icing systems

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Observations

- METAR

```
KCLE 140102Z 23015G22KT 2 1/2SM -SN BLSN FEW018 SCT026 OVC039
M07/M10 A2992
```

  - Precipitation descriptor
    - DR drifting, BL blowing (DRSN, BLSN)
    - FZ freezing (FZDZ, FZRA)
  - Precipitation (RA, DZ, SN, PL, GS)
  - Temperature (negative preceded by M)
- PIREP

```
CVG UA /OV CVG190010/TM 2325/FL080/TP CRJ7/SK OVC035-TOP070/TA
M12/IC LGT RIME 050-070
```

  - UA (normal) or UUA (urgent)
  - /IC observed ice
  - /TA outside air temperature
  - /WX precipitation
  - /SK clouds (bases and tops)

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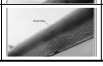
PIREP ice criteria

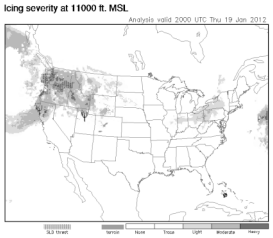
Intensity	PIREP code	Picture	Airframe accumulation	De-ice or anti-ice equipment operation	Pilot action
Trace	TRACE		Ice becomes perceptible. Rate of accumulation slightly greater than sublimation	Not used unless encountered for an extended period of time (over 1 hour)	None unless encountered for 1 hour or more
Light	LGT		May create a problem if flight is prolonged in this environment (over 1 hour)	Occasional use removes or prevents accumulation	Heading or altitude change required
Moderate	MOD		Even short encounters become potentially hazardous	Continuous use necessary	Heading or altitude change or diversion required
Severe	SEV		Deicing/anti-icing equipment fails to reduce or control the hazard	By definition, exceeds equipment capability	Immediate diversion required

Forecasts

- Terminal Area Forecast (TAF)
  - Cloud bases (and type CB)
  - Precipitation type
  - Temperature at some military reporting points
- Area Forecast (FA)
  - Synopsis
    - Location of fronts
  - Significant clouds and weather
    - Cloud tops
    - Cloudy areas
    - Precipitation areas
- Winds Aloft (FD)
  - Temperature group

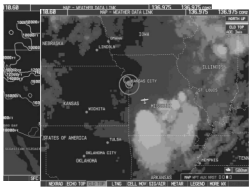
Supplementary icing

- Current (CIP)/Forecast (FIP)
  - "By FAA policy CIP is a Supplementary Weather Product for enhanced situational awareness only and **must** be used with one or more **primary** products such as an AIRMET or SIGMET (see AIM 7-1-3)."
  - FIP gives better resolution than AIRMET ZULU
    - Lateral
    - Vertical
      - Icing probability by altitude
      - Altitude of maximum icing potential
    - Temporal
      - Hourly forecast out to +12 hours



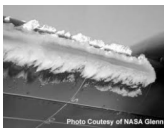
Datalink weather (XM, FIS-B)

- Garmin GDL-69
  - GNS 430/530, GMX 200
    - NEXRAD
    - METAR/TAF
  - G1000 only:
    - Freezing level
    - Cloud tops
    - AIRMET/SIGMET
    - Winds aloft
- Terrain, of course!



Ice symptoms

- Visible: buildup on fine structures
  - Antennas
  - Windshield corners
  - OAT probes
- Instruments: reduced airspeed with no power change, or power increase to maintain airspeed
  - AI: increased cruise pitch angle



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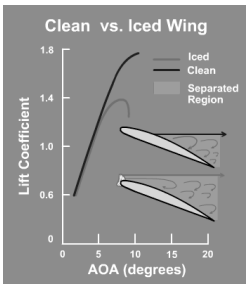
Stall cues

- Buffet at higher than normal speed
- Uncommanded
  - Roll
    - Asymmetric wing stall
    - Asymmetric ice shedding
  - Pitch
    - Difficulty maintaining
    - After flap extension
    - At high speed (~V_{FE})



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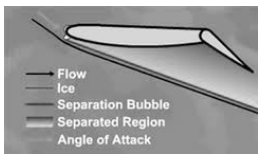
Tailplane stall

- Smaller radius leading edge
  - More rapid ice accumulation
- Not visible to pilot
- Increased angle of attack
  - Nose up input
  - Propeller downwash
  - Flap extension downwash
  - Center of gravity



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Stall recovery

- Main wing
  - Lower nose
    - Accept altitude loss (*not* a stall exercise!)
  - Add power
- Tailplane
  - Raise nose
  - Retract flaps (to previous setting)
  - Reduce power
  - *Opposite of normal stall training!*

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Limitations and autopilot

- Know AFM/POH limitations
  - Minimum/maximum speeds in ice
  - Autopilot
    - Minimum/maximum speeds
    - Maximum flap extension
- Autopilot use in ice is hazardous
  - Pilot has *no* tactile feedback
    - Pre-stall buffets
    - Compensated out-of-trim rolls and pitches
  - Autopilot can gradually pitch airplane up in response to increased drag to the point of a stall

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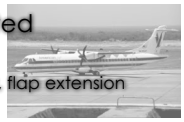
Icing?/autopilot? accidents



- Accidents suspected or refuted
  - Roselawn, IN: ATR-72 (AAR9602.pdf)
    - Severe SLD ice, holding, autopilot, flap extension
  - Reno, NV: Cirrus SR-22 (LAX05FA088)
    - Supplemental TKS, severe icing in cloud tops, mountain conditions, failed parachute deployment
  - Buffalo, NY: Dash-8 Q400 (AAR1001.pdf)
    - Disproved tailplane stall recovery attempt caused roll inverted and crash; ice determined no factor
  - Ekalaka, MT: Cessna 310N (SEA08FA006)
    - Stall/mush due to insufficient airspeed on instrument approach after in-flight ice accumulation

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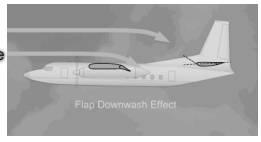
Recap: Icing airmanship

- Avoid configuration changes
  - Avoid flap extensions
    - Drag increase
    - Center of lift change
    - Tailplane downwash change
    - Asymmetric ice shedding
    - Any or all can trigger a sudden main wing or tailplane stall



  - Avoid low airspeed and high load factor
    - Higher angle of attack
    - Steep turns
- Vary propeller RPM to shed ice

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Recap: I have ice!

- Anti-, de-icing systems on
- Get help from ATC early
  - Traffic conflict may result in denied request
- Change something!
  - Altitude
    - Stratus (rime) usually confined to a 4000 foot deep stratum
    - Climb to colder (or warmer) air, or above cloud tops
      - Tops known? (FA, PIREP)
      - May not be possible in, e.g., non-turbo
      - Risk of lower climb airspeed, underwing ice buildup, prolonged exposure
    - Descend to warmer air or below bases
      - Terrain
      - MEAs, GNSS MEAs, or MOCAs
  - Route
    - Including 180° turn back to previous non-icing region

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