A Climatological Estimate of Icing Frequency at the Puijo, Finland Instrumented Tower

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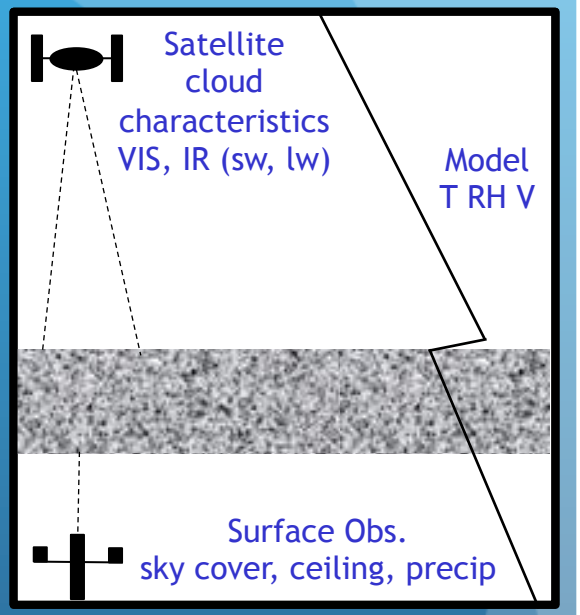
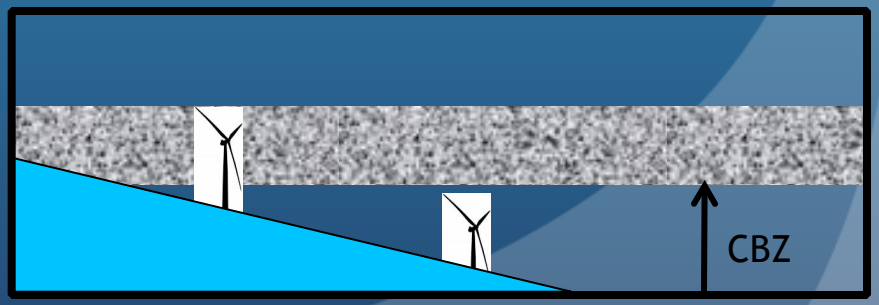
LOWICE – A Quick Overview

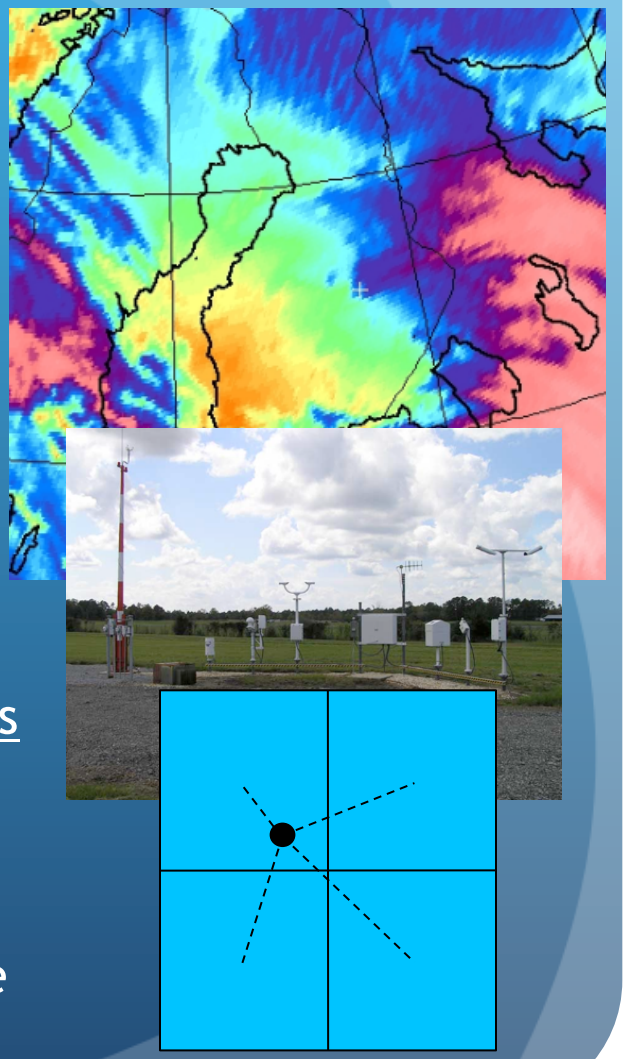
- Climatological version
  - 10 wind farm sites, plus Puijo tower
  - Readily-available archives
    - Satellite data (Meteosat)
    - Surface observations
    - GFS model
    - Some detail in next slides
  - Blend data, identify…
    - Cloud presence, top, base
    - Cloud height relative to hub heights
    - Precipitation occurrence, type (FZDZ)
- Infer presence of icing
  - SLWC, Intensity
  - Ice Load, affect on power
  - Frequency





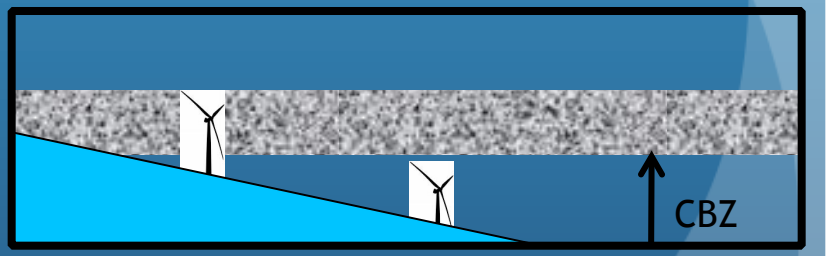
Data Sources

- SATELLITE: METEOSAT-8, -9 (geostationary)
  - Visible, Long- and short-wave IR
  - Pixels: 3.68 km x 12.26 km at 65^{o}N
  - Map nearest pixel to Puijo site (+)
- SURFACE OBSERVATIONS:
  - 26 stations within 160 km of Puijo
  - Closest site: Kuipio (14 km)
    - Sky cover, Ceiling, Present wx (FZDZ)
    - Distance implies relevance
    - Timing of observations varies
- MODEL: GFS (Global Forecast System) analysis
  - 1^{o} x 1^{o} horiz, 25-mb vert, 6-hourly
  - 3-D fields: T, RH, winds
  - Spatial average of 4 nearest grid points
  - Column of data, vertically interpolate to site



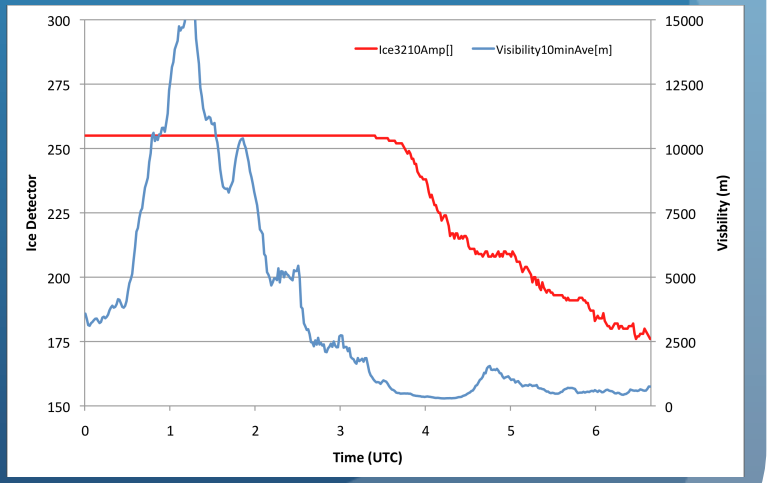
Icing Assessment (brief)

- Is it cloudy in the column?
  - Rule-based system
- Find cloud base height
  - Nearest reported ceiling (Kuopio)
  - Assumes CBZ similar at Puijo (14 km)
- Is site within this cloud layer vertically?
  - Is site above cloud base?
  - Is it within ~100 m of cloud base?
    - Local variability. Save ΔZ.
- Temperature: cold enough for icing?
- If YES, then calculate LWC
  - Adiabatic assumption within cloud
  - Assign very low LWC below cloud, using ΔZ.
  - Deplete LWC when precipitation is present
- ICErate ≈ LWC * V * A (V=GFS wind; A=0.015 m^2). Efficiencies set to 1
- 2005-2010 monthly % of all hours with "active icing"



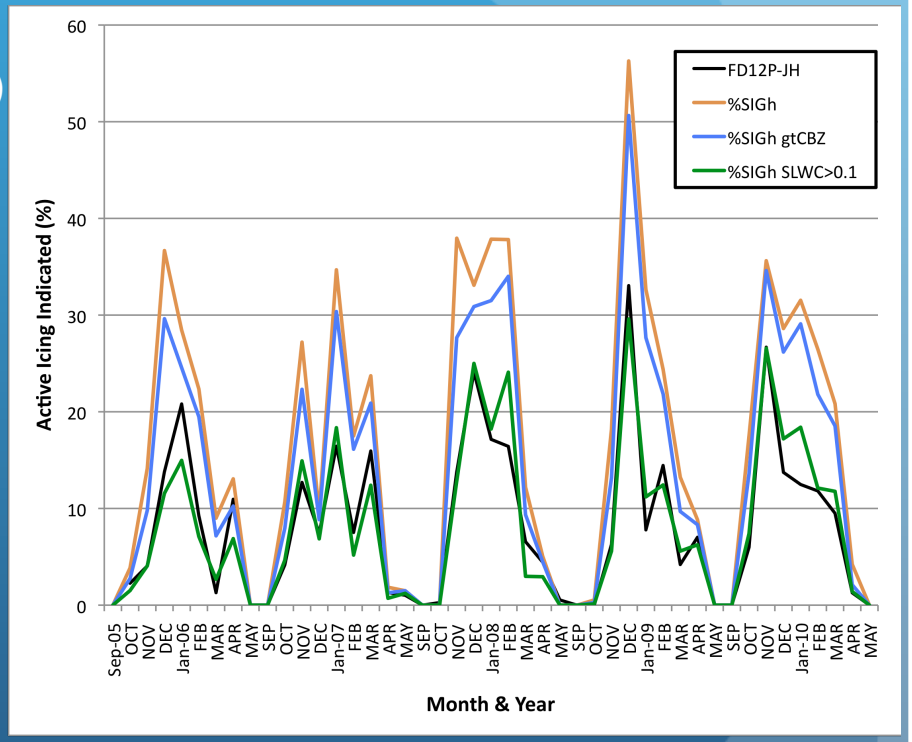
Observations at Puijo Tower

- Observation tower Pujio, Finland
  - 306 m MSL (224 above nearby lake)
  - 75 m tower (381 m MSL)
  - Two ice detectors
  - Automated wx station (FD12P)
    - T, RH, Wspd/dir, vis, pres wx
  - Web-cam images (every 15 min)
- Numerous cases
  - 2009-2010 icing season
  - Ice observed by detectors & other fields
- For climatology, icing surrogate developed
  - Portin et al. (2009)
  - T<0ºC and VIS<200m
    - Not perfect (Ex. light icing case)
    - VIS: tradeoff PODy and FAR
    - Reasonable for climatology
    - Updated for 2005-2010 (JH)



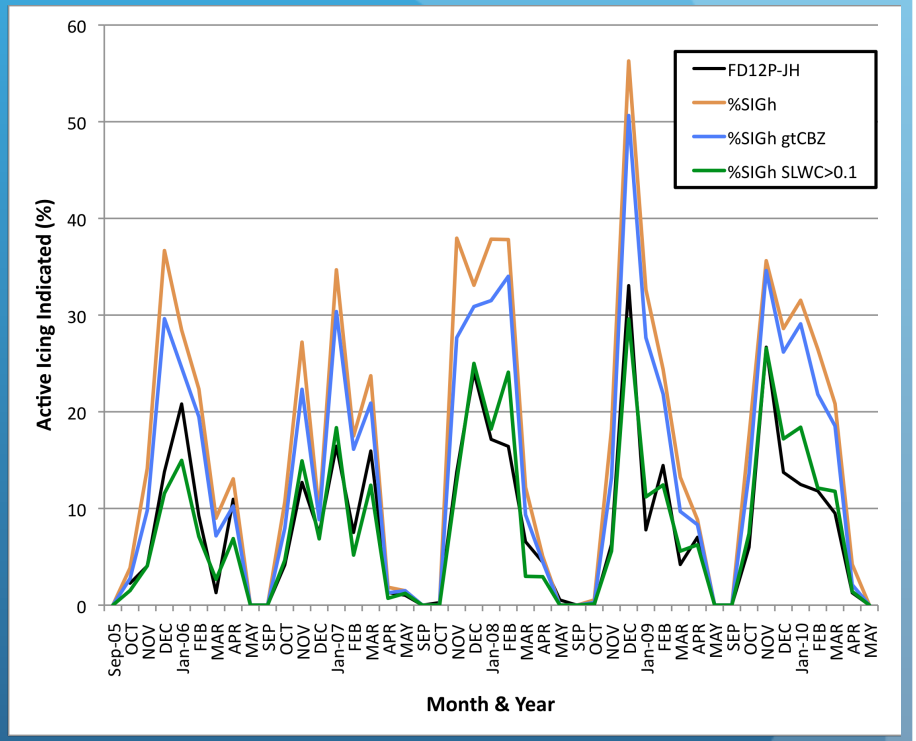
Comparison of Estimates

- JH results for 2005-2010 (black line)
  - NOT ABSOLUTE GROUND TRUTH!
  - Recall: VIS<200 misses light events
  - Bad VIS obs – iced over (Jan '09,'10)
  - Patterns
- LOWICE results – three versions
  - Standard (tan - %SIGh)
  - Icing if CBZ at/above tower (blue)
  - Icing if SLWC ≥ 0.1 gm^{-3} (green)
- Traces track nicely (peaks, trends)
- Normal LOWICE: Overestimate?
  - Includes many events w/CBZ>tower
  - Includes many low LWC events
- Eliminate events w/CBZ>tower: better
  - Recall: Kuopio only 14km away
- Eliminate events where SLWC < 0.1 gm^{-3} is expected
  - Very close match (black and green lines) – differences in early 2008, 2010
  - Very light events, perhaps many missed by VIS<200m method



Implications and Conclusions

- Revision of VIS threshold for icing
  - Capture more light icing events
  - Test trade-offs, examine icing rates
    - VIS thresholds for LGT, MDT…
- Is standard LOWICE too aggressive?
  - Icing when cloud base above site
    - Minimum ΔZ of 100 m
    - When DIST(nearclg) = 0 km
    - Increases to 304.8 at 160 km
    - Account for variation in CBZ
      - Distance, steep terrain
    - Decrease smallest ΔZ to 0 m?
- Eliminate icing when SLWC < 0.1 gm^{-3}?
  - Don't capture very light events – do we want that?
  - Is LOWICE overestimating or is VIS<200 underestimating? Both? Neither?
    - More testing needed
- LOWICE seemed to do a good job



Questions?

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