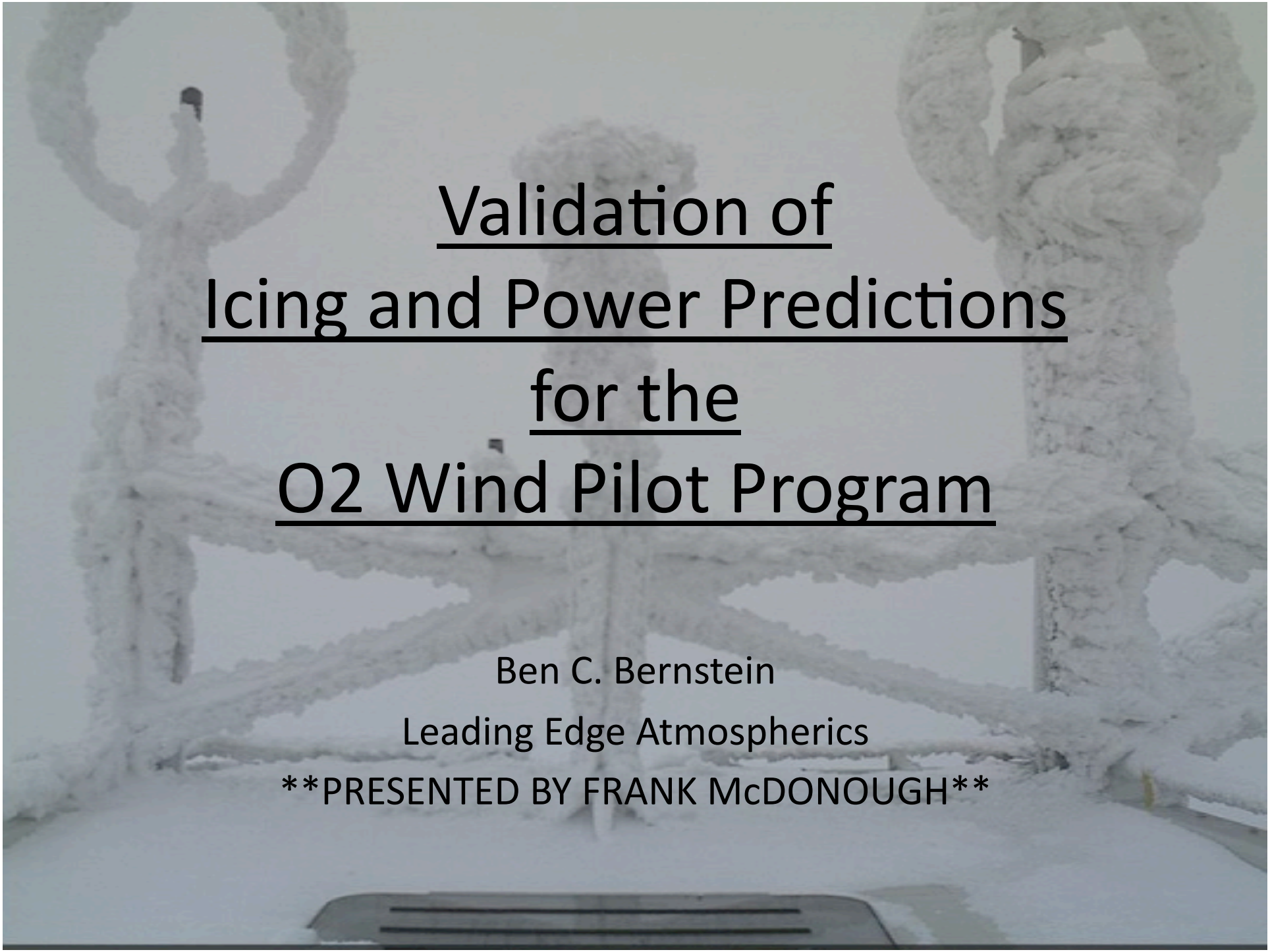

Validation of Icing and Power Predictions for the O2 Wind Pilot Program

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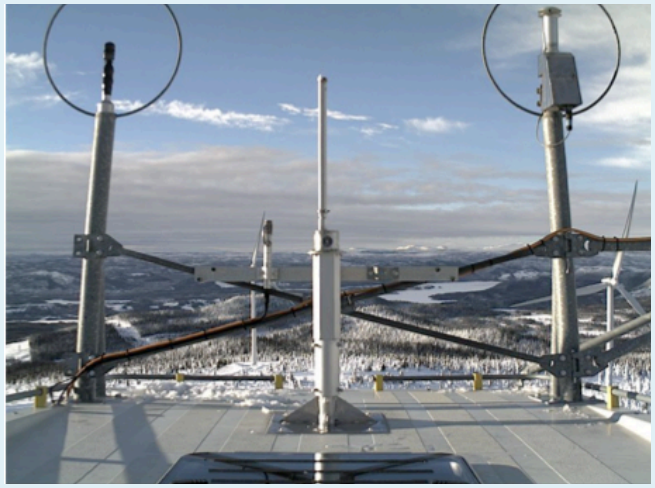
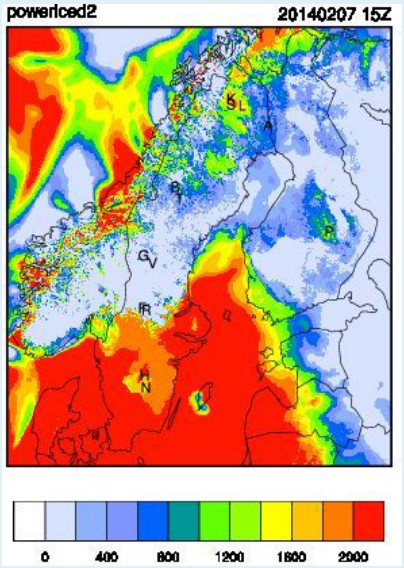
Leading Edge Atmospherics

PRESENTED BY FRANK McDONOUGH

O2 Wind Pilot Program

- Outstanding project
- Real & Planned Wind Farm Sites
  - Across Sweden
  - Heavily Instrumented
    - Measure Icing & related parameters
      - Icing load, Temperature, visibility, etc.
    - Web cam imagery
    - POWER DATA from several sites
  - All available in REAL-TIME

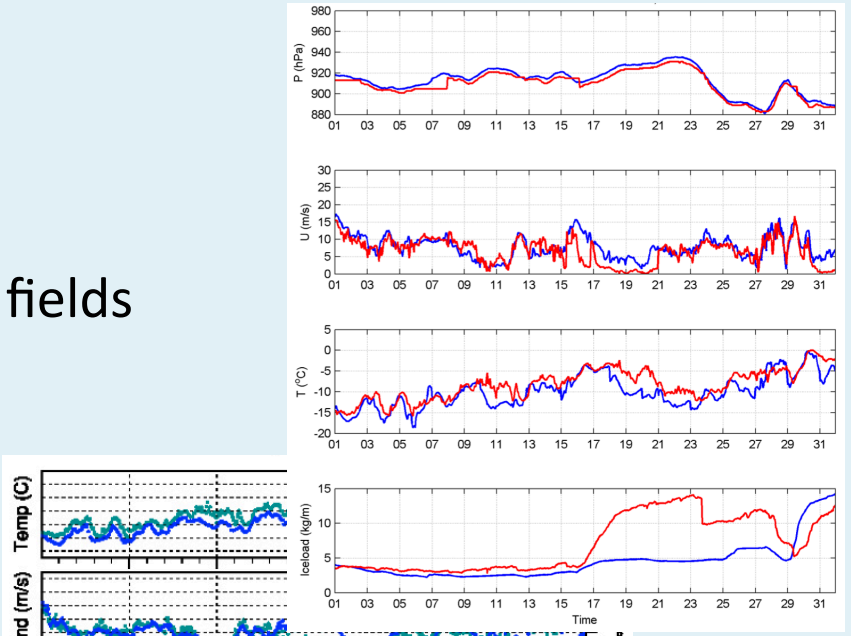


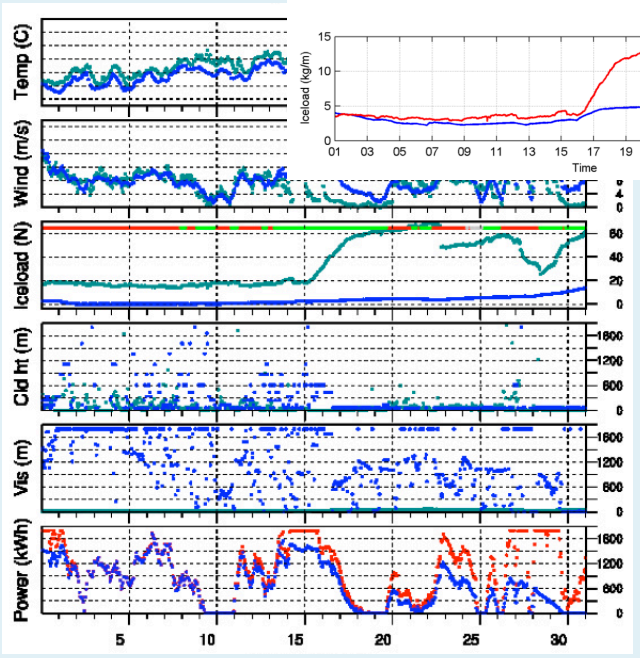


- Four meteorology teams
  - Generate diagnoses & forecasts
  - Icing, Power and <u>POWER LOSS</u> due to icing

Assessment: First Seasons

- Four meteorology teams
  - Four unique methods
  - Plotting, validation
    - Different colors, scales, even fields
  - Self assessment
    - Plots, statistics
- One Reference Group
  - Assess quality
  - Versus observations
    - each other
  - Very difficult job
    - Especially given differences

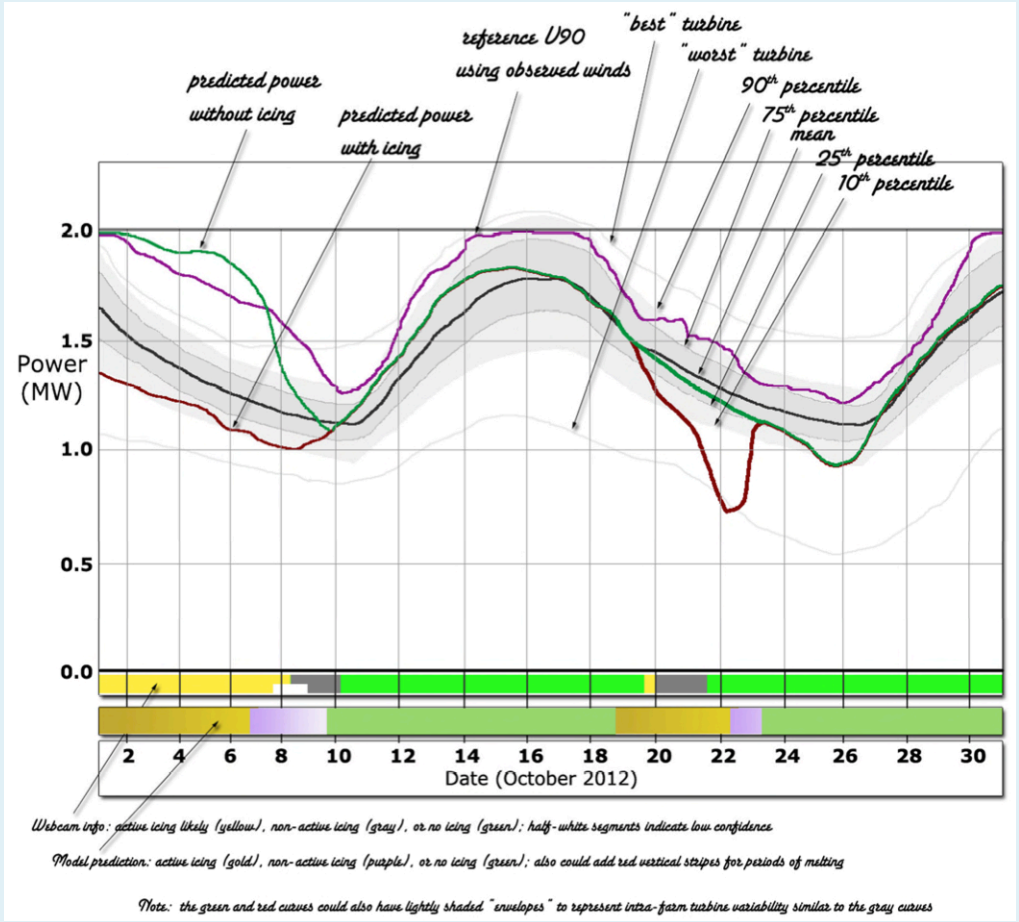




Standards Needed

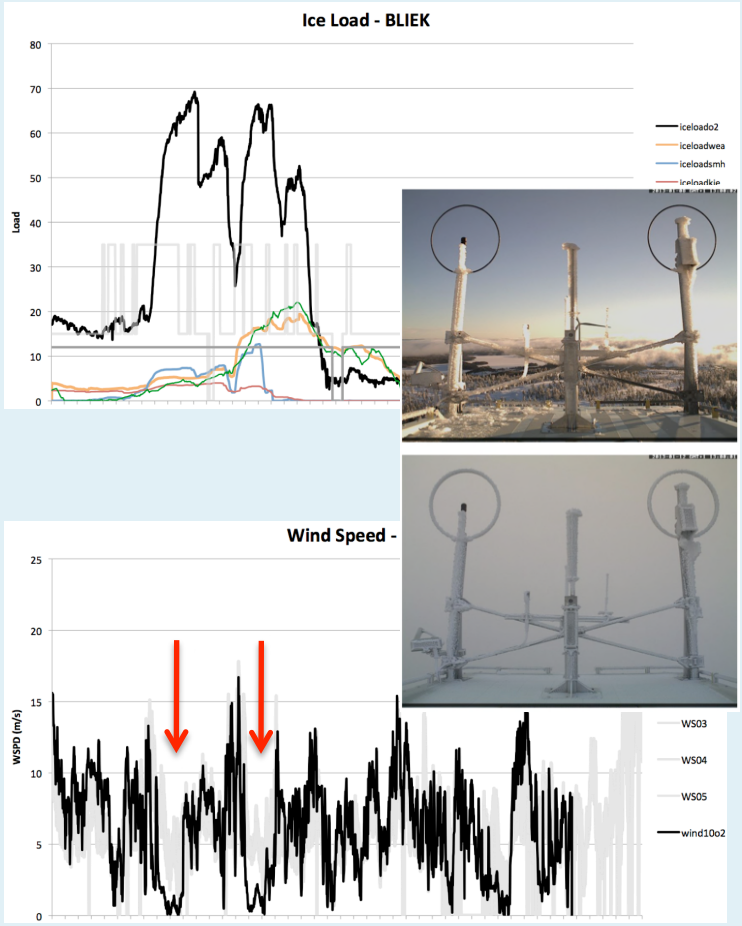
- Difficult to compare
  - Output with observations
  - One team to another
- Need standards!

- Better Plotting
  - Make comparisons easier
- To validate, we must:
  - Define ground truth
    - Icing, Power Loss
    - Objectively, subjectively
  - Derive methods
    - Fair, consistent



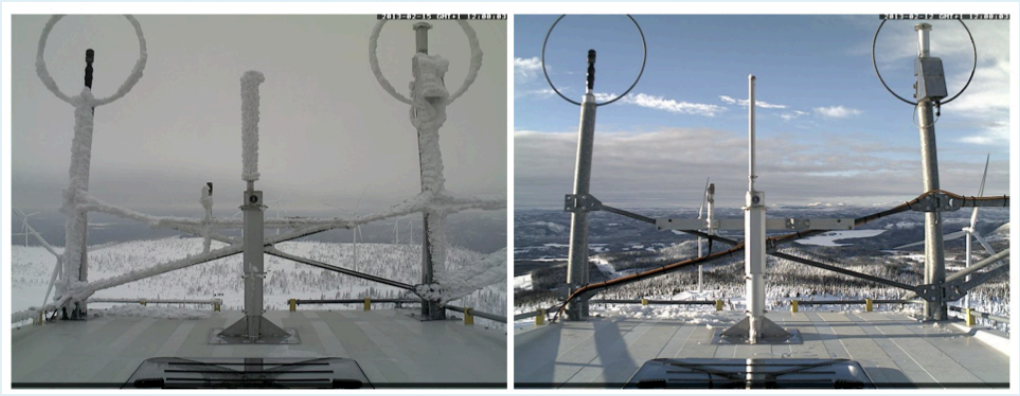
Icing – OBJECTIVE Ground Truth

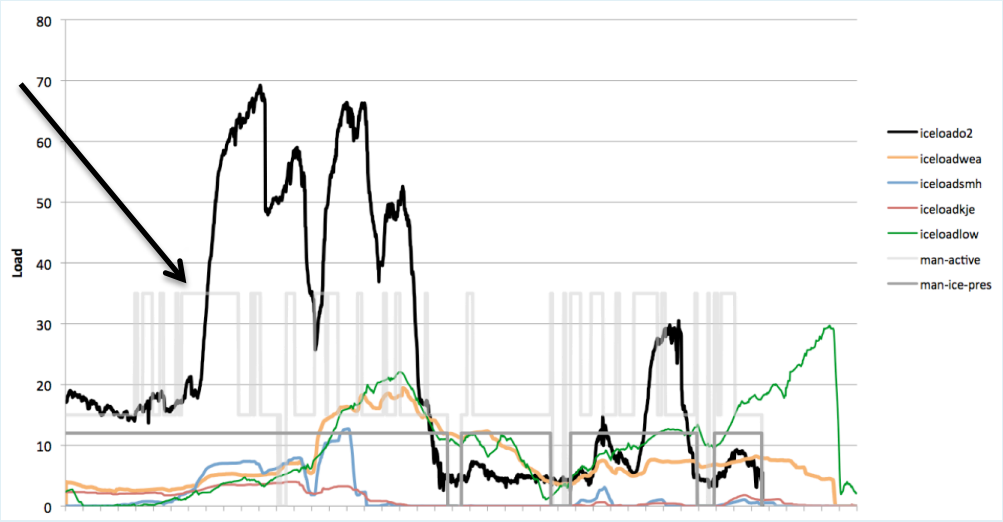
- Datasets:
  - Icing load
    - Changes over time
      - Hourly, 3-hourly
  - Temp, visibility
    - Alternative: T, ceiling
  - Temp, glaciations (Holooptics)
  - Wind speed differences
    - Mast vs. Turbine
- Result:
  - Hour-by-hour icing likelihood
    - Floating point values
    - Apply thresholds to say icing = “yes” or ”no”



Icing – SUBJECTIVE Ground Truth

- Manual Inspection
  - Hour-by-hour
    - Ice presence
    - Active ice growth
- Same measurements
- Web cam imagery
  - Every 20 min
  - Animate
- MORE RELIABLE
- Some ambiguity
  - Thin glaze
  - Partially iced camera
  - Moonlight
- Supporting obs helpful

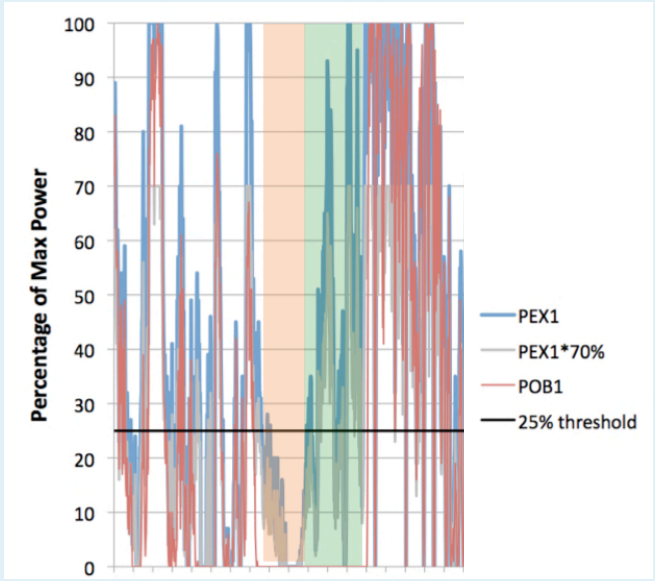




Power Loss - Objective Ground Truth

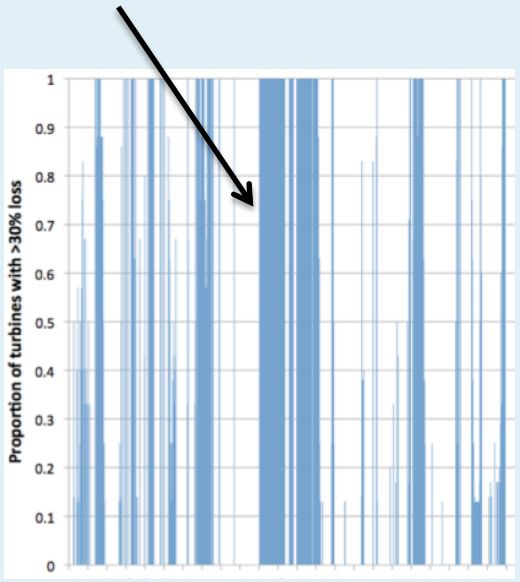
- Datasets:
  - Turbine-measured
    - Power
    - Winds
      - Use power curve
      - Derive *expected clean power*
    - Loss(%)

      = 100% x ([expected-observed]/expected)
    - Threshold loss percentage
      - Get POWER LOSS = “yes” or ”no”

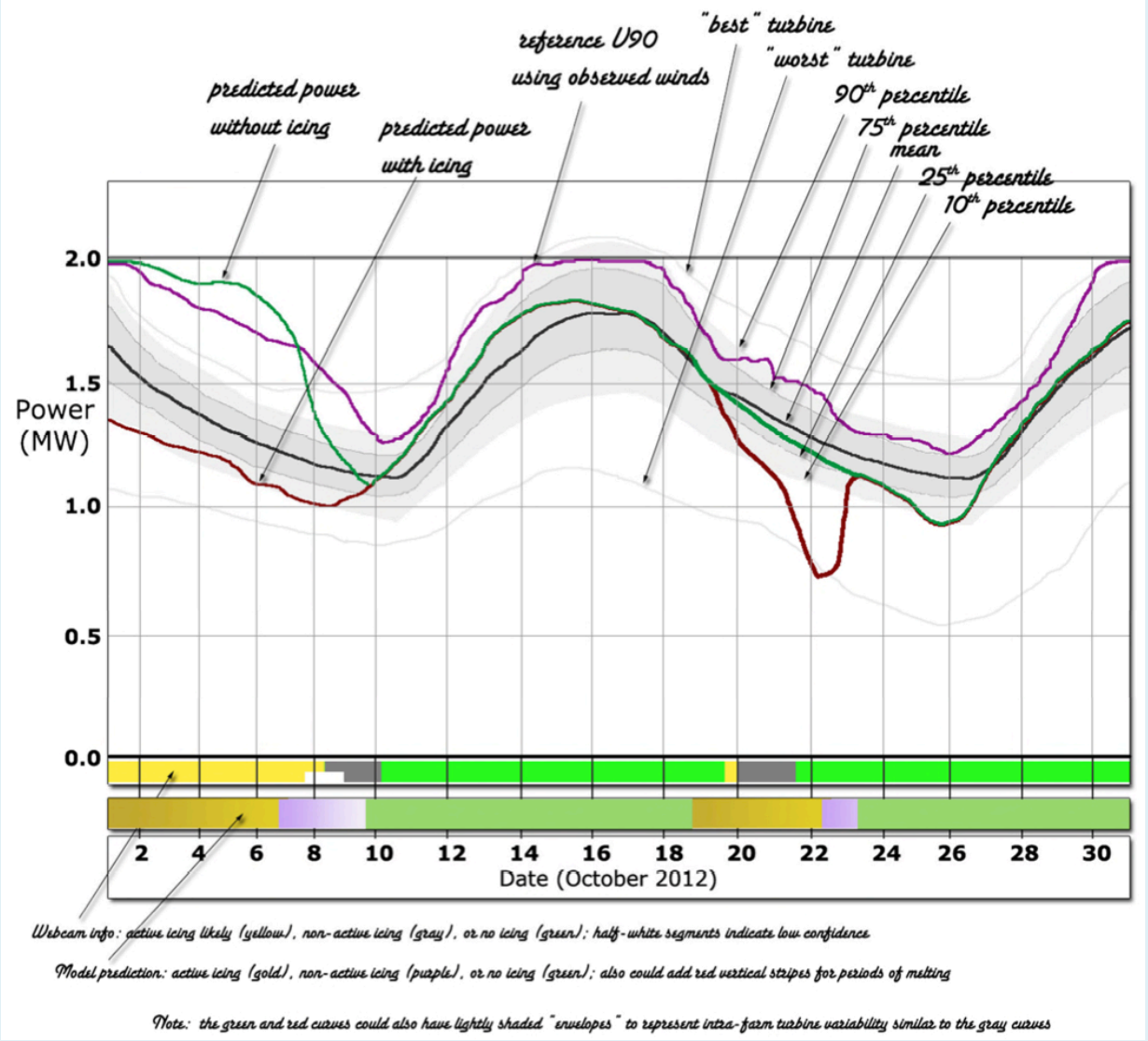


Power Loss - Objective Ground Truth

- Datasets:
  - Minimum thresholds
    - Expected power
      - Need adequate wind speed
        - To get meaningful results
        - Above cut-in range
      - Is POWER LOSS > 25% of max power?
    - At least ½ (or ¾…) of the turbines met all criteria
      - If YES, then POWER LOSS = “YES”
    - This is just one possible method
      - Certainly others can be used (and have been used)

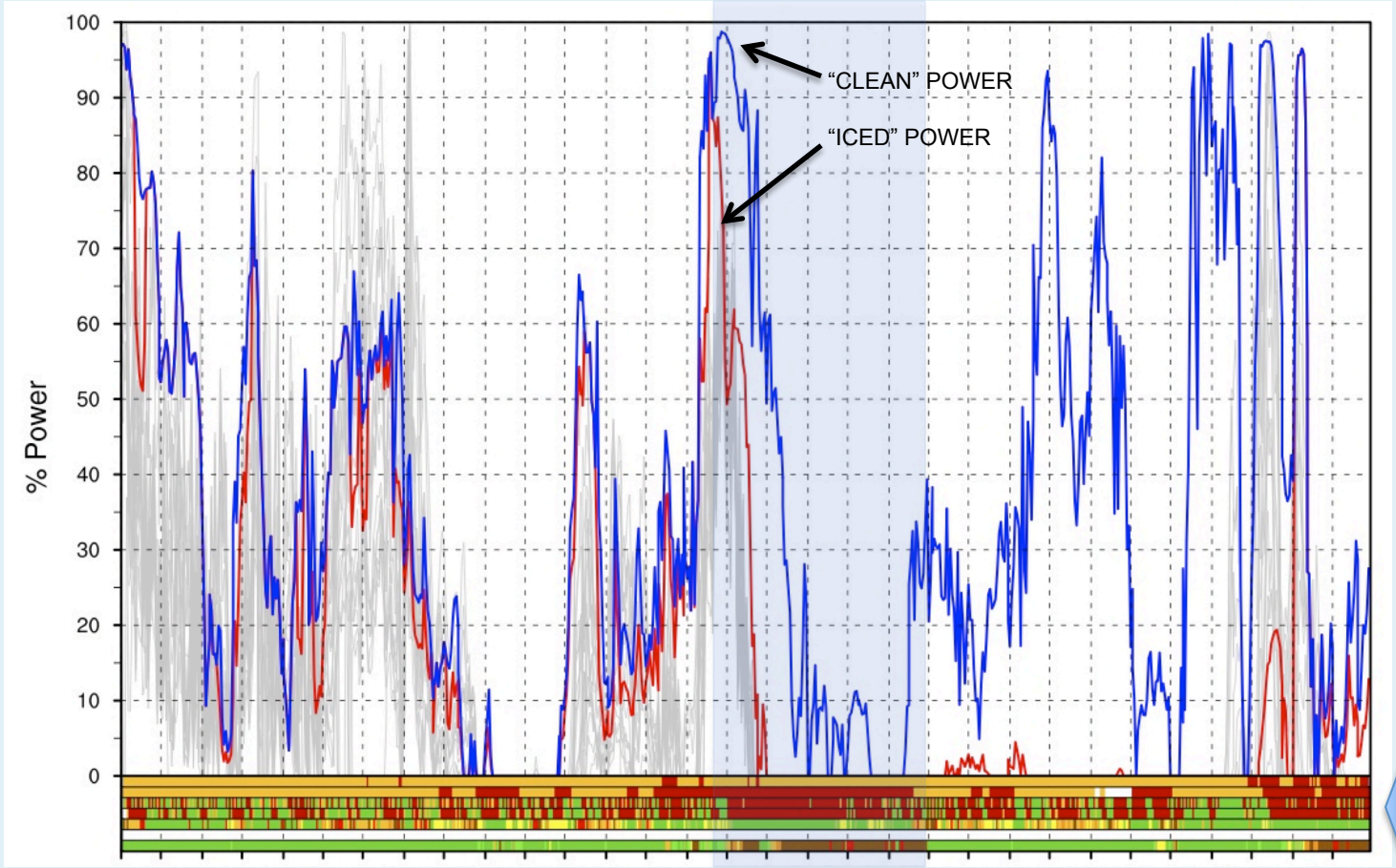


Reference Group Plots – The Dream



Reference Group Plots – Reality

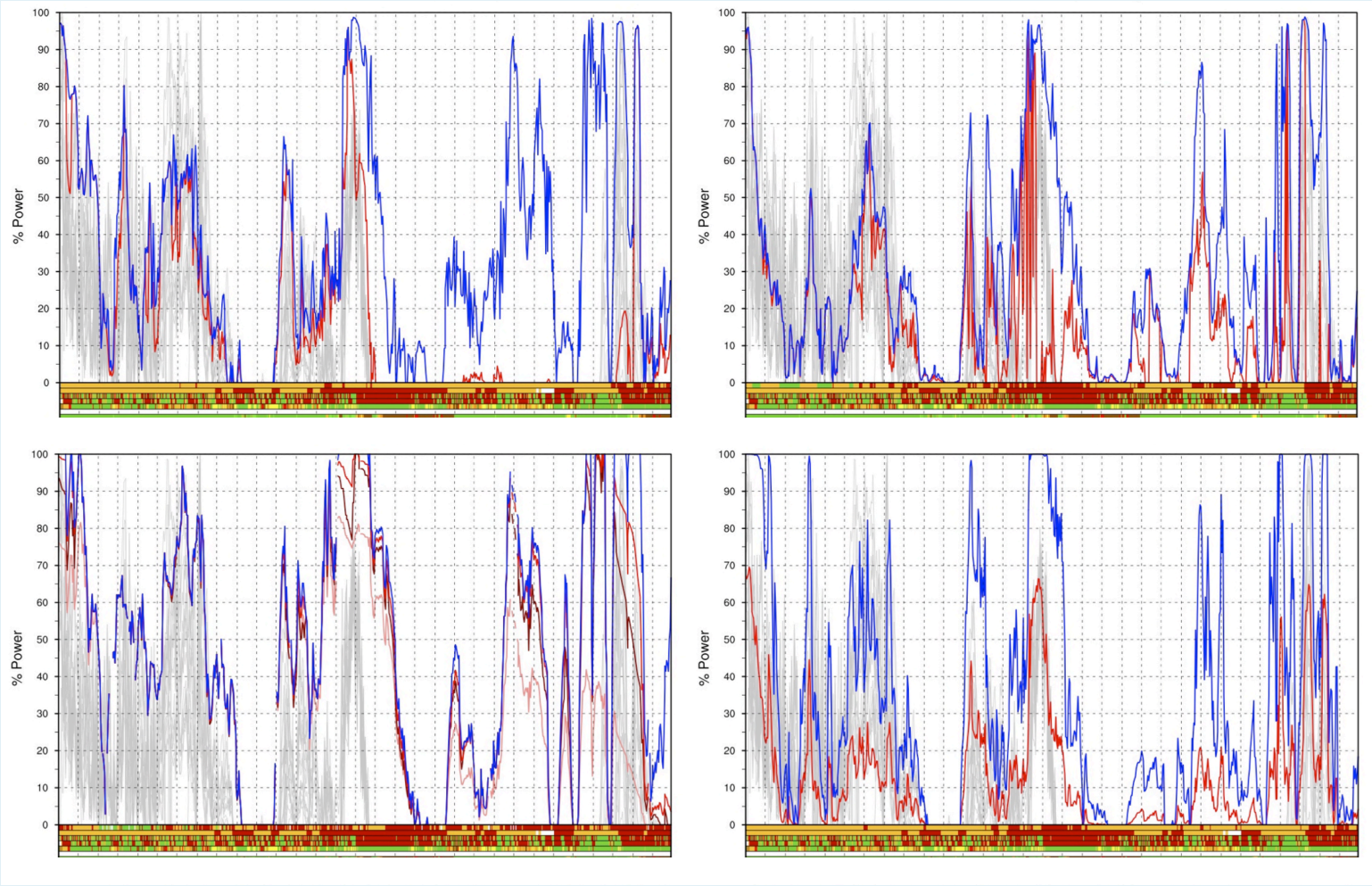
- Complicated, powerful. Results depend on interpretation



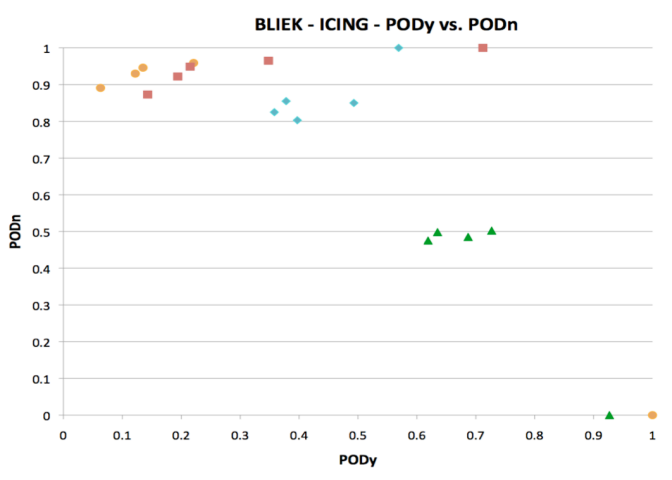
Predicted Icing (Active, Inactive)
Observed – Manual
dLoad/dt – Version1
dLoad/dt – Version2
Temperature/visibility
Temperature/glaciations
Anemometer degradation

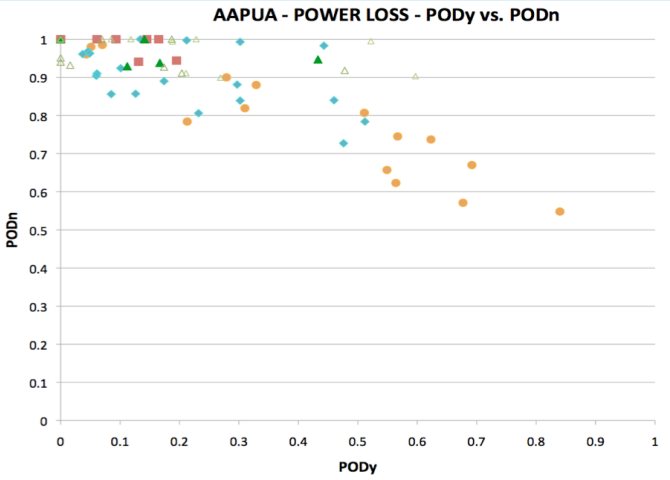
CAN ADD OBSERVED POWER LOSS

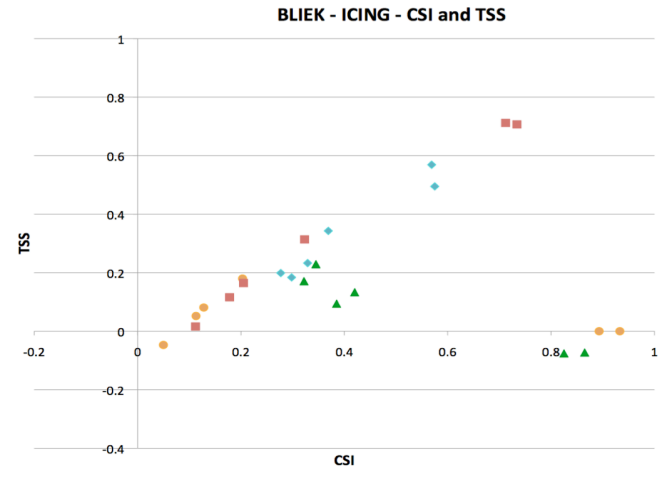
Comparable

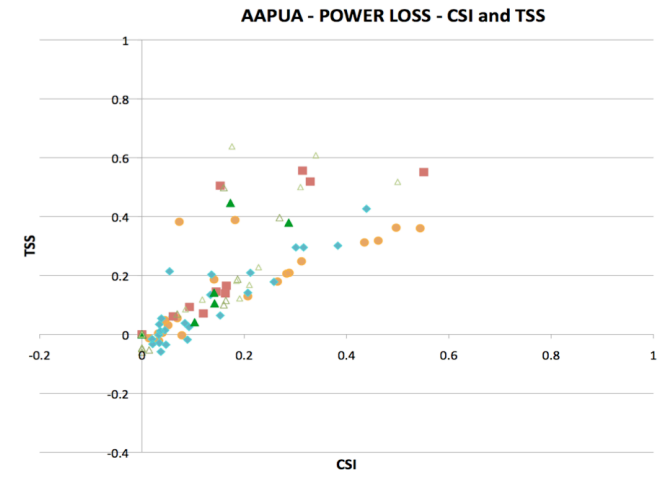


Verification – Stats, Plots





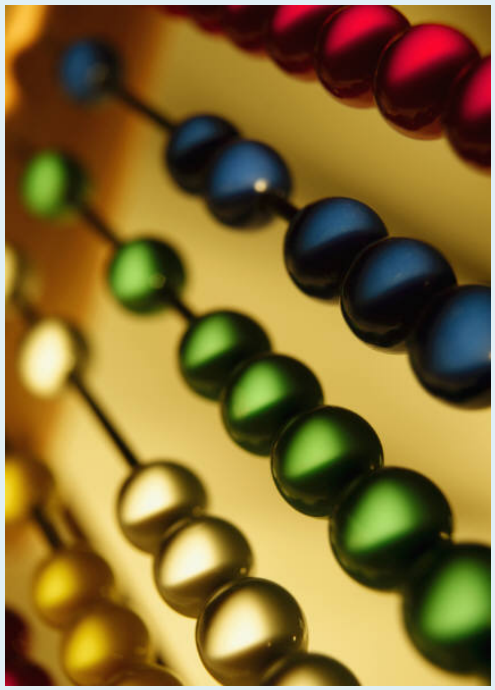




- Results depend on station, location and period of test

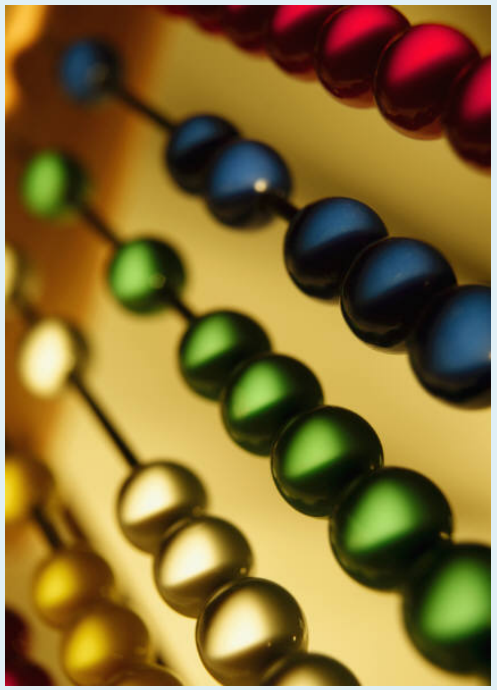
Summary – Part 1

- Compare systems, observations
  - Same data
  - Same methods
  - Same plots
- Verification data
  - Limited, flawed
  - STILL VERY USEFUL!
- A lot has been gained through standardization



Summary – Part 2

- Results
  - Complicated!
  - Output is quite similar
  - There are significant differences
    - Site to site
    - Parameter chosen
      - Temp, Wind Speed, Load, Power, Loss
    - Statistic chosen
      - PODyes, PODno (Probability of catching “yes” and “no” events)
      - FAR (False Alarm Rate), CSI (Critical Success Index), TSS



Summary – Part 3

- There is ***NO ABSOLUTE "TRUTH"***
  - No one answer tells the story
- What field/measure is most important to you?
  - Depends person, requirement, etc.
  - POWER LOSS – often most critical
  - Other measures are important, too
    - Learn WHY the power loss forecasts succeed *and* fail
- Each of the 4 systems "wins" some of the time
  - Each has it's strengths and weaknesses
  - Through verification, we can all learn and improve

Thank You!

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