Wind turbine icing weather and power forecast algorithm assessments in Scandinavia

Frank McDonough

Dendrite Weather Consultants

Talk overview

- Scandinavia wind farm
- Data sets (one month)
  - Power (% farm capacity)
  - Camera Observations
  - Weather Observations
  - Algorithm power forecasts
- 4 events analyzed
  - 2 icing
  - 1 stand still
  - 1 recovery
- Each case
  - Observed Power and Wind
  - Weather and Icing observations
  - Algorithm Power predictions

Icing and Power Loss Algorithms

- ## 3 power loss algorithms tested
  - Input:
    - Numerical weather prediction models
    - Observations
  - Output:
    - Atmospheric Variables (Wind, T, RH, LWC, pressure, density)
    - Associated iced and non-iced power predictions
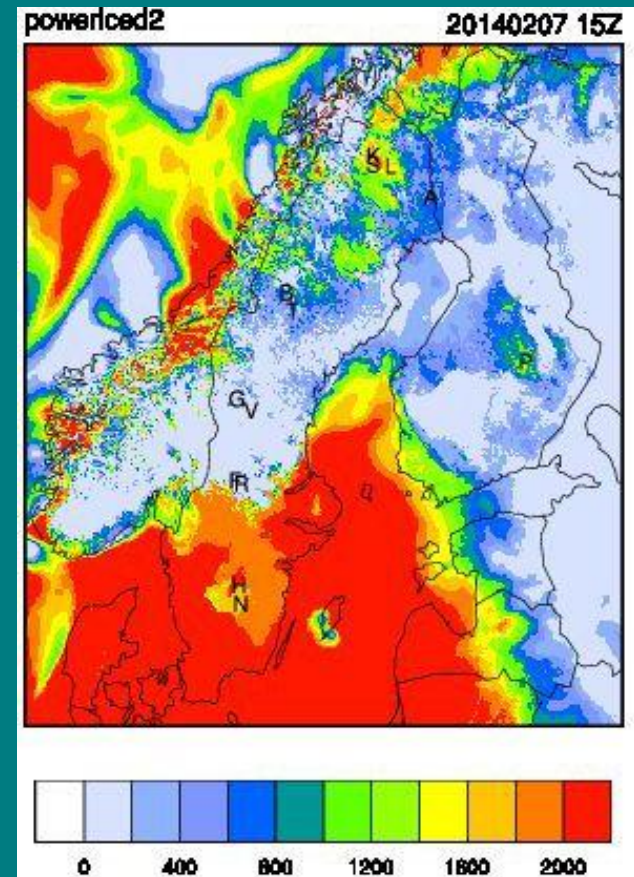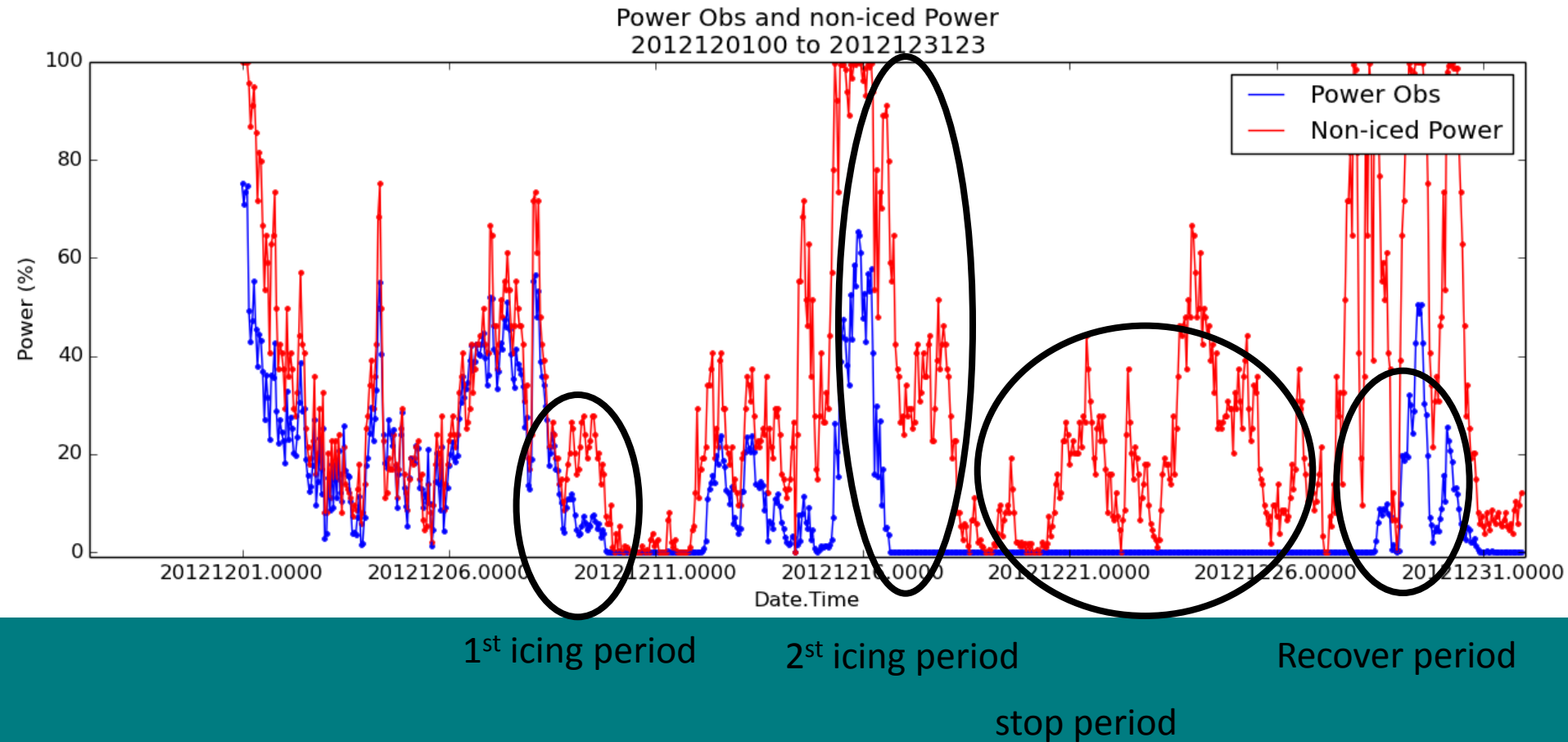
Camera Images

Non-iced Power Calculation

Derived Power
Curve

Calculate farm
mean wind speed
(W) from Nacelle
anemometers

QuickTime™ and a
decompressor
are needed to see this picture.

Calculate non-iced
farm power from
(W) and derived
curve

Wind farm observed power and non-iced power

Power Obs and non-iced Power
2012120100 to 2012123123

1st icing period   2st icing period   Recover period
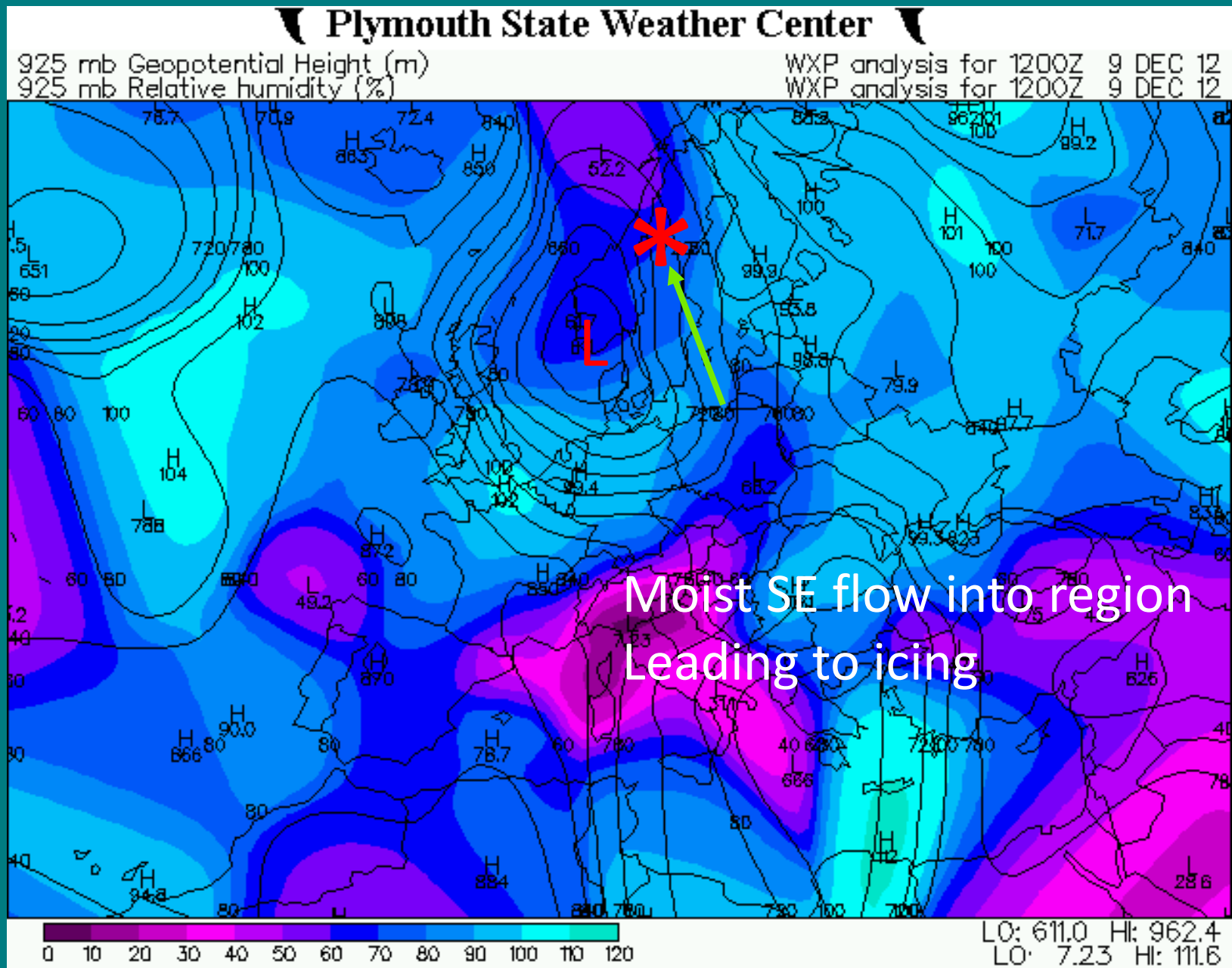
stop period

1st Icing period

Power Obs and non-iced Power
2012120100 to 2012123123
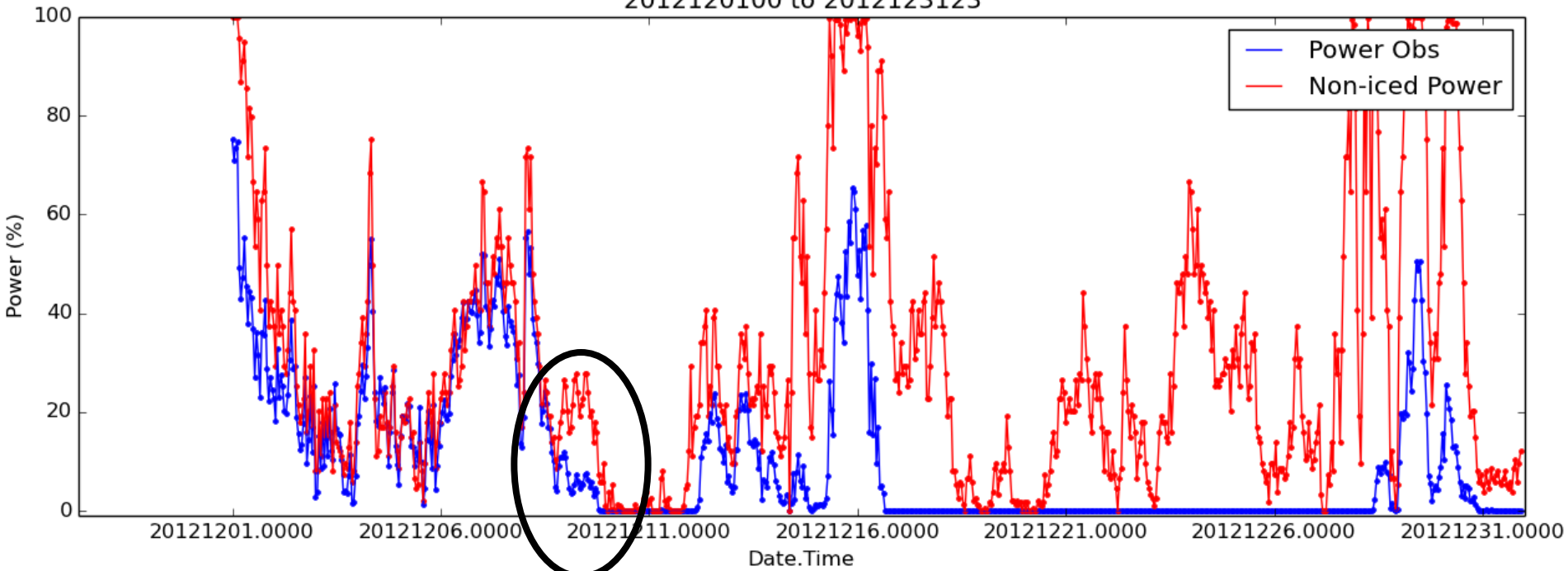
1st icing period

1st icing period weather set up

Plymouth State Weather Center
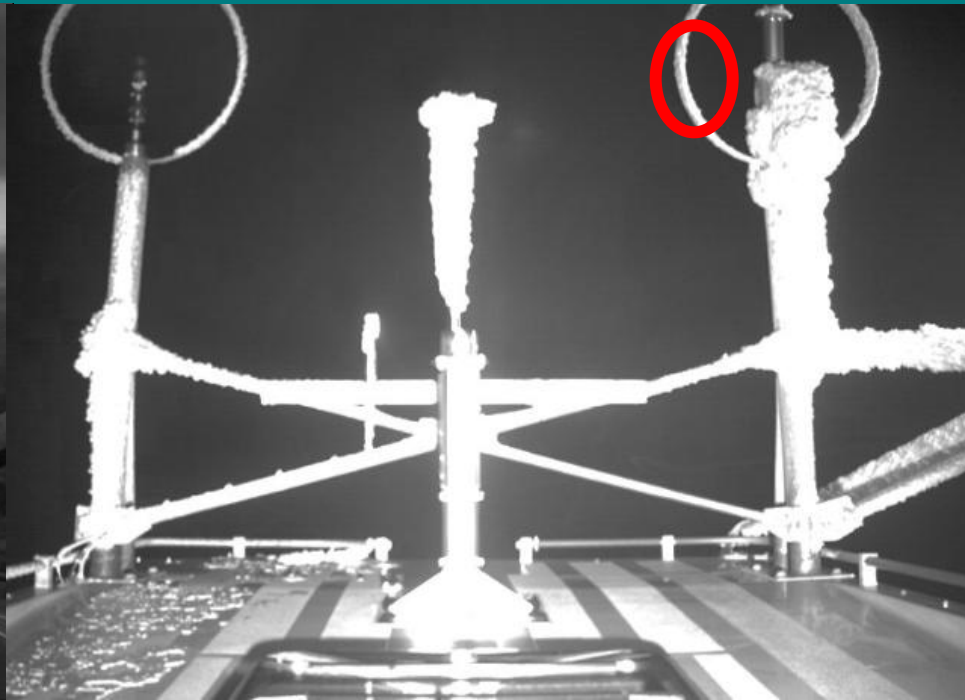
925 mb Geopotential Height (m)
925 mb Relative humidity (%)

WXP analysis for 1200Z   9 DEC 12
WXP analysis for 1200Z   9 DEC 12

Moist SE flow into region
Leading to icing

LO: 611.0   HI: 962.4
LO: 7.23   HI: 111.6

1st Icing Period (winds and power)

Winds
2012120809 to 2012121000

Power Obs and non-iced Power
2012120809 to 2012121000

Reduced power
from icing

Power Obs
Non-iced Power
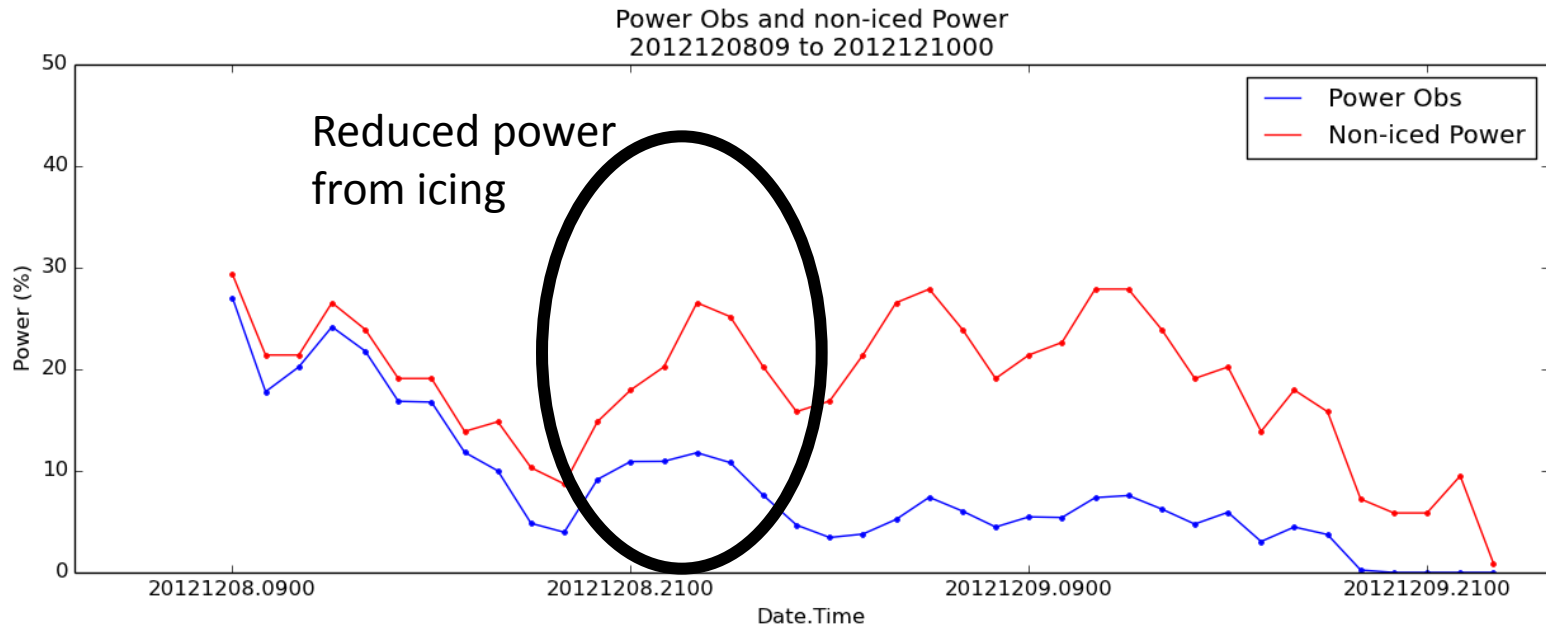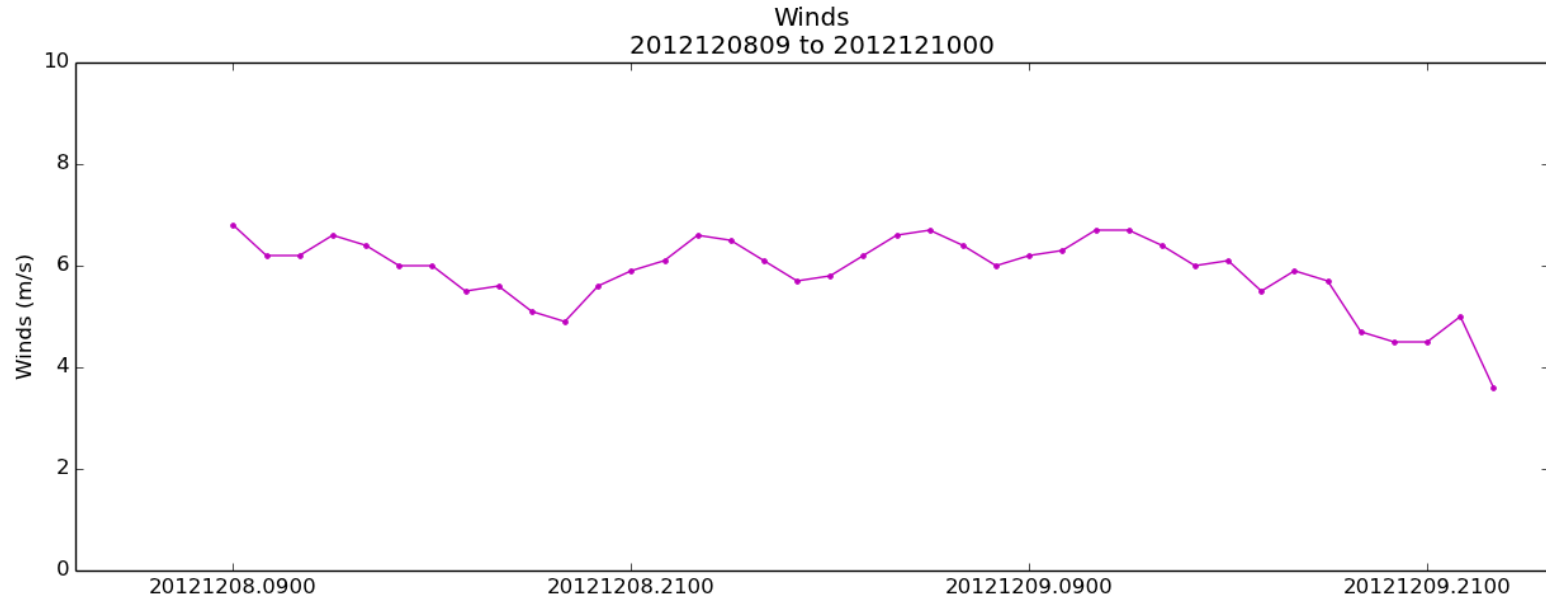
Camera observations -1st icing period

Just before 1st icing event

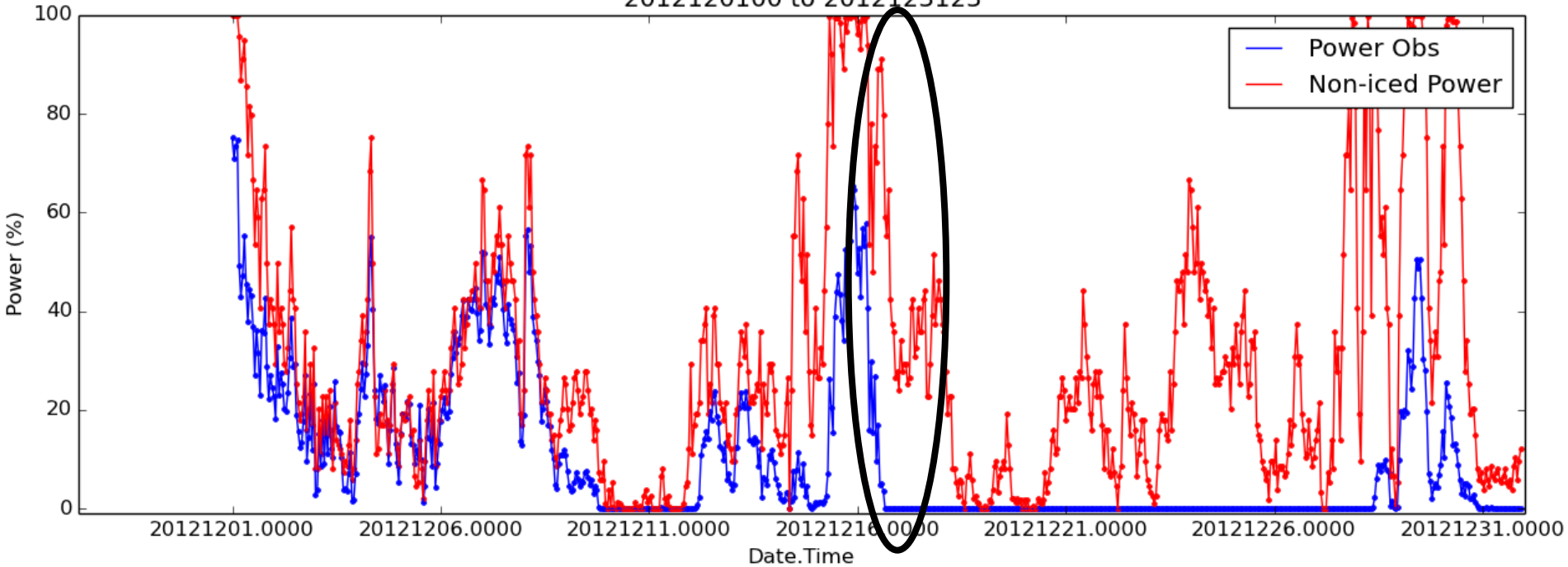Just after 1st icing event

Turbines after 1st icing period

No ice near tips

Ice near hub
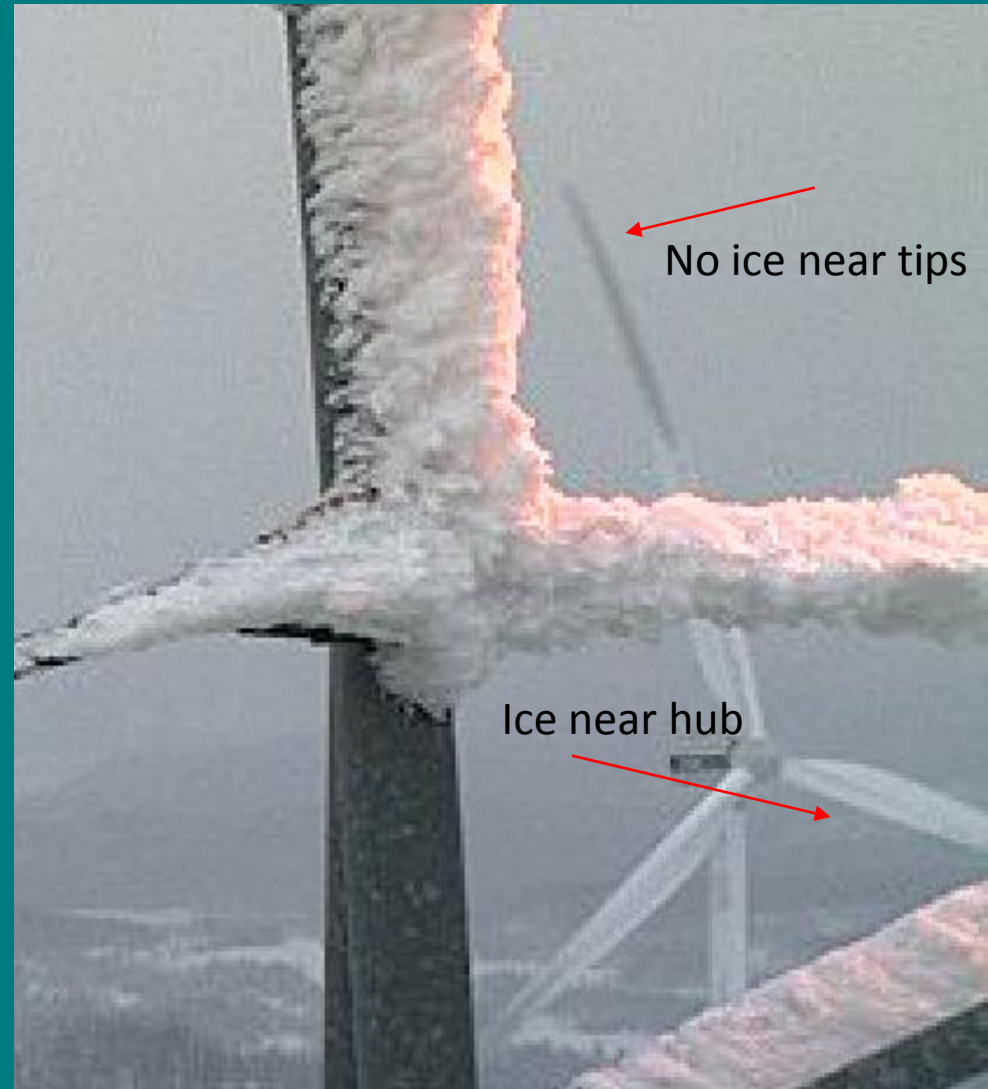
Algorithm Power Forecasts for 1st icing period
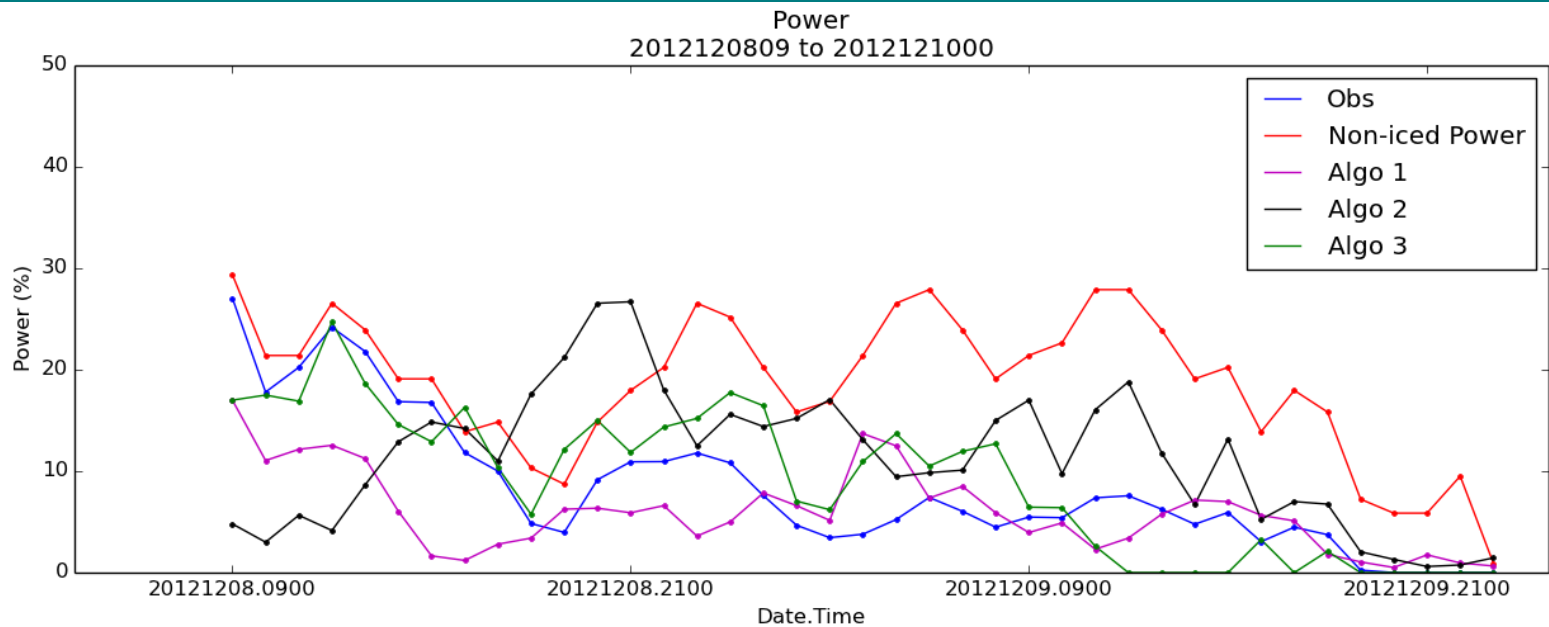
All 3 algorithms seem to have lower predicted power than the non-iced power.

2nd Icing period

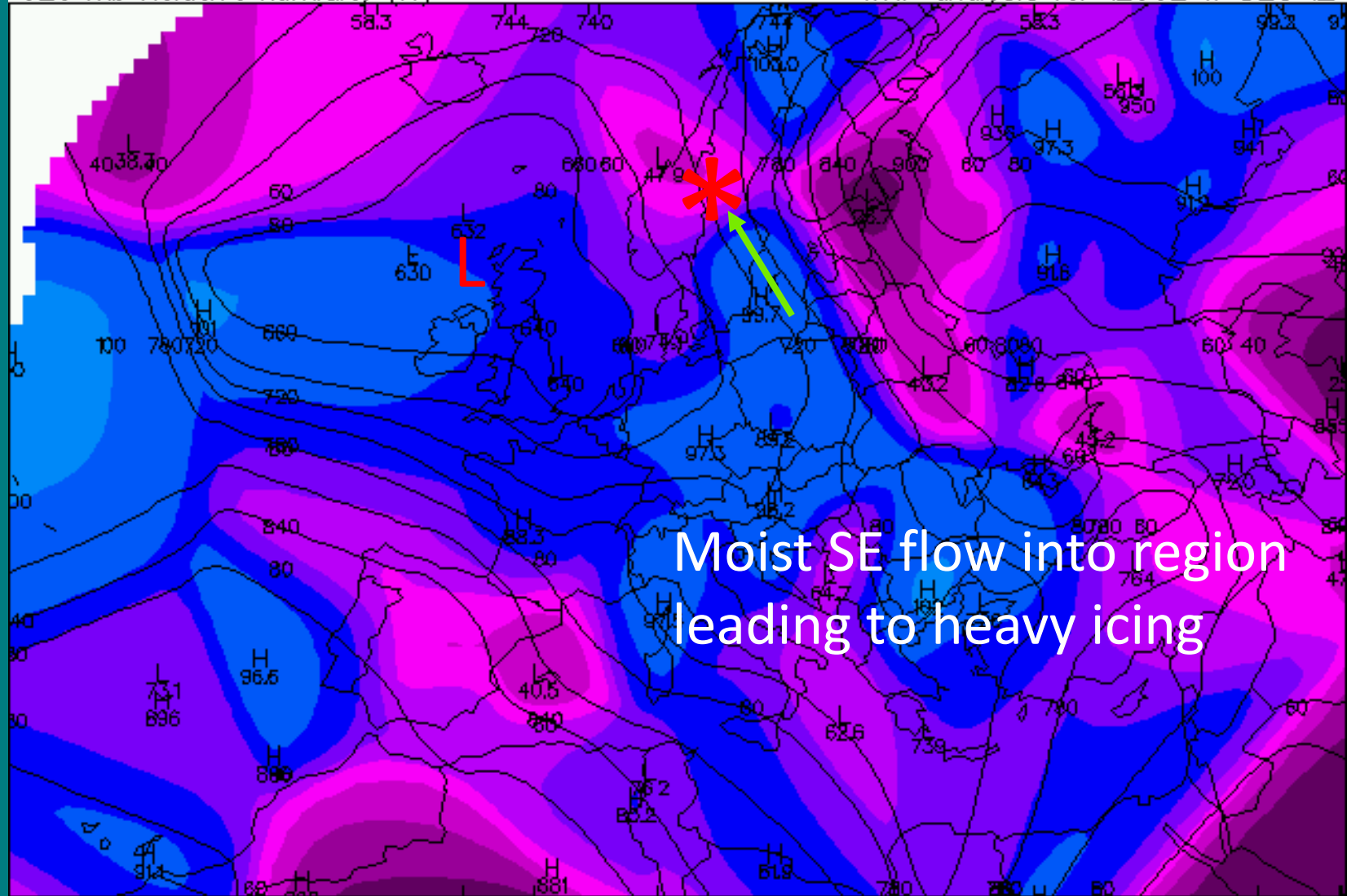Power Obs and non-iced Power
2012120100 to 2012123123

2st icing period

2nd Icing Period

2nd Icing Period (winds and power)

Winds
2012121512 to 2012121803

Power Obs and non-iced Power
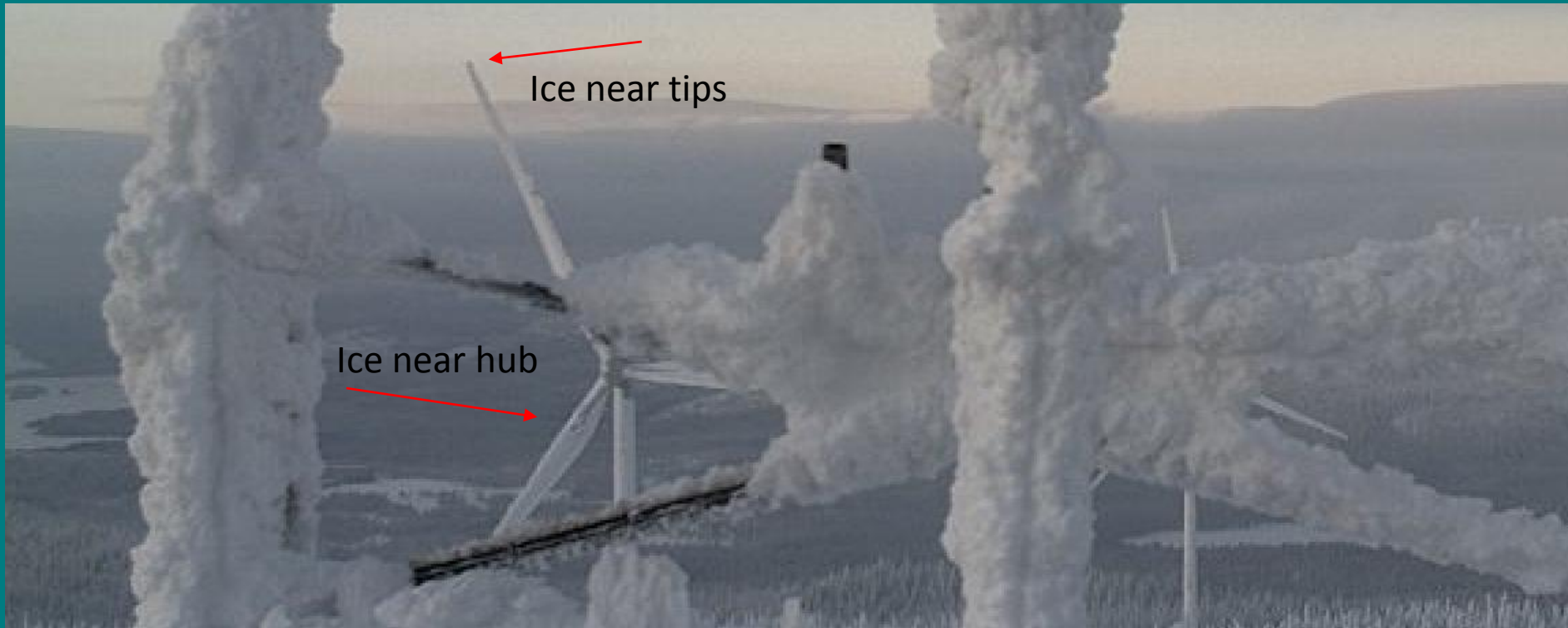2012121512 to 2012121803

Reduced power from icing

Camera Observations of 2nd icing event

34 hour loop - covers: Dec 16, 2012 1700 UTC – Dec 18, 2012 0300 UTC

Turbines at end of 2nd icing period
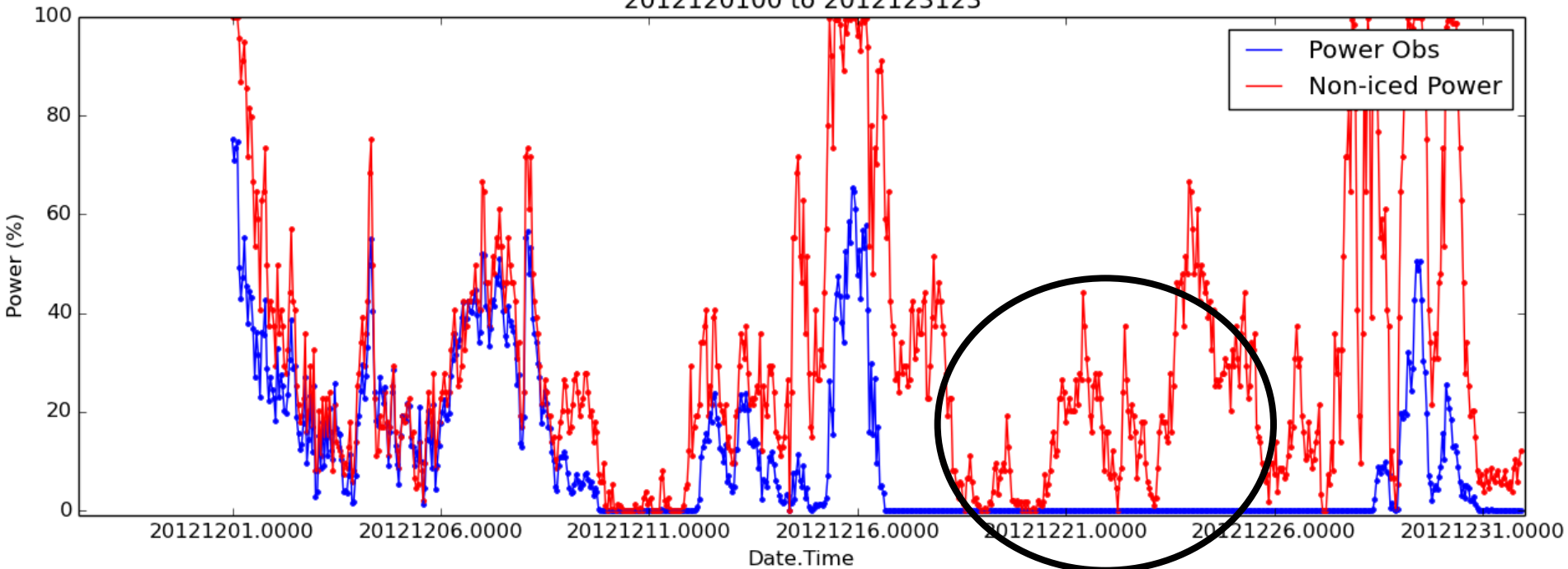

Ice near tips

Ice near hub

Algorithm Power Forecasts for 2nd icing event
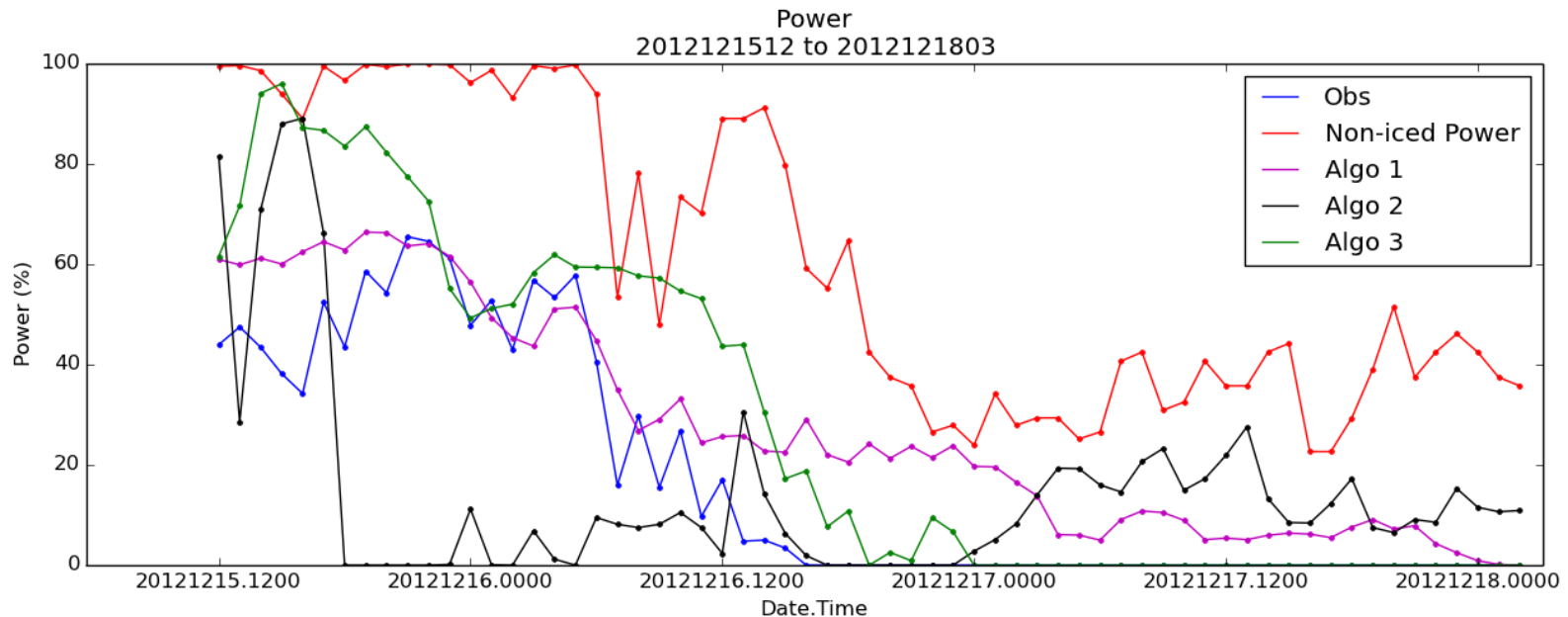
Algo 1 suggests icing on turbines but does not reduce power to 0
Algo 2 iced too early, later reduced power predicted but not enough
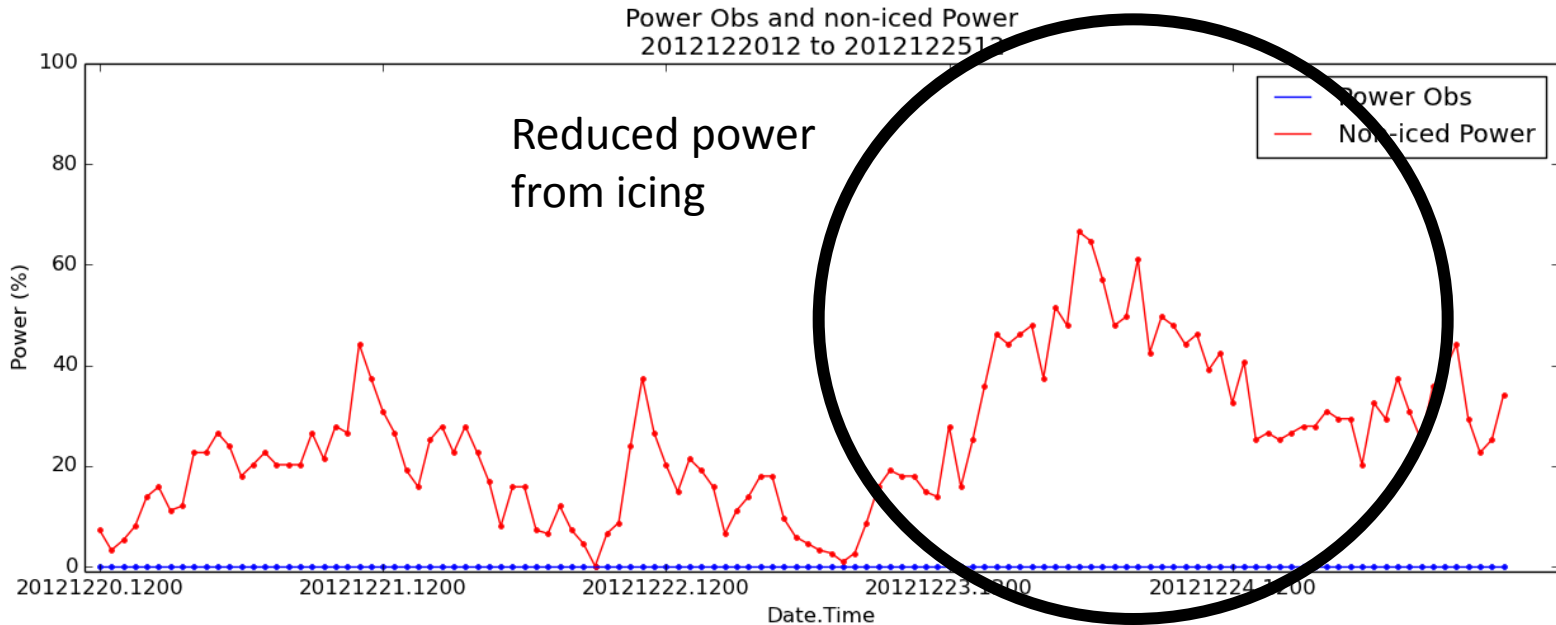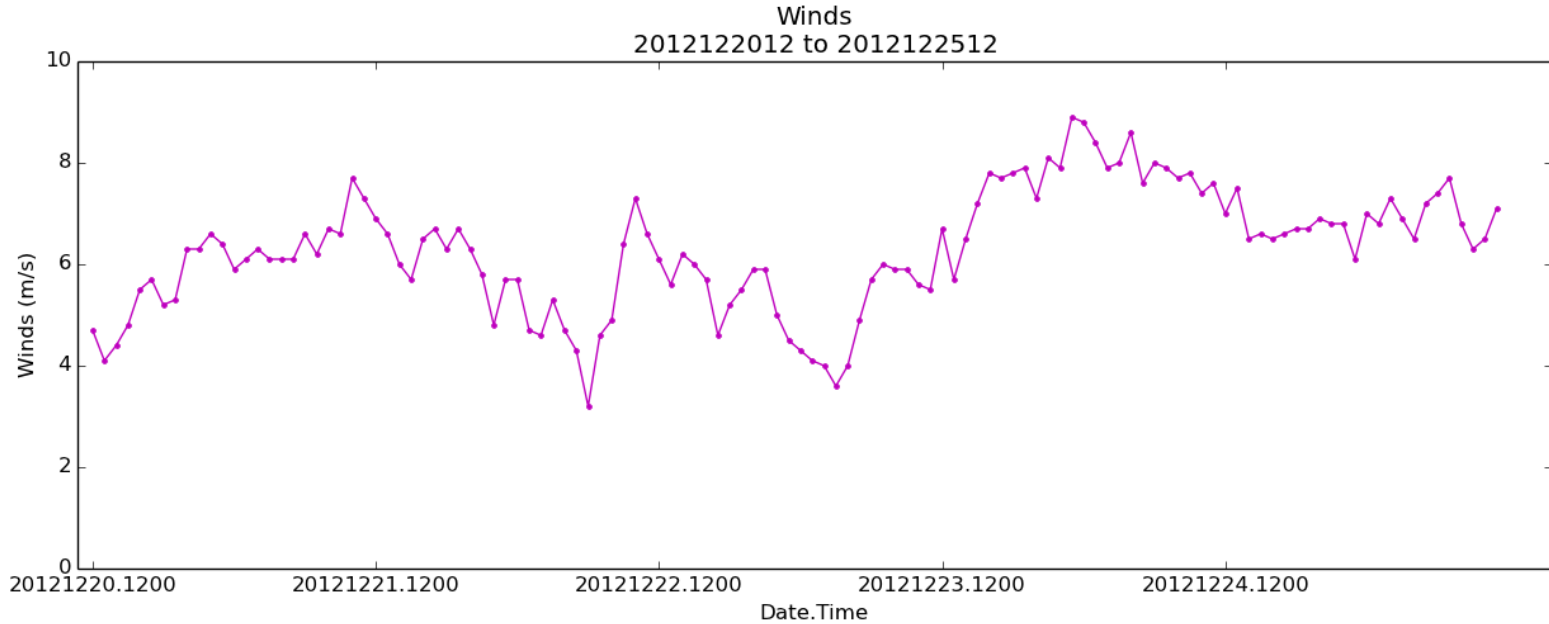Algo 3 initially too high but reduces power to 0 later in period

Stop period
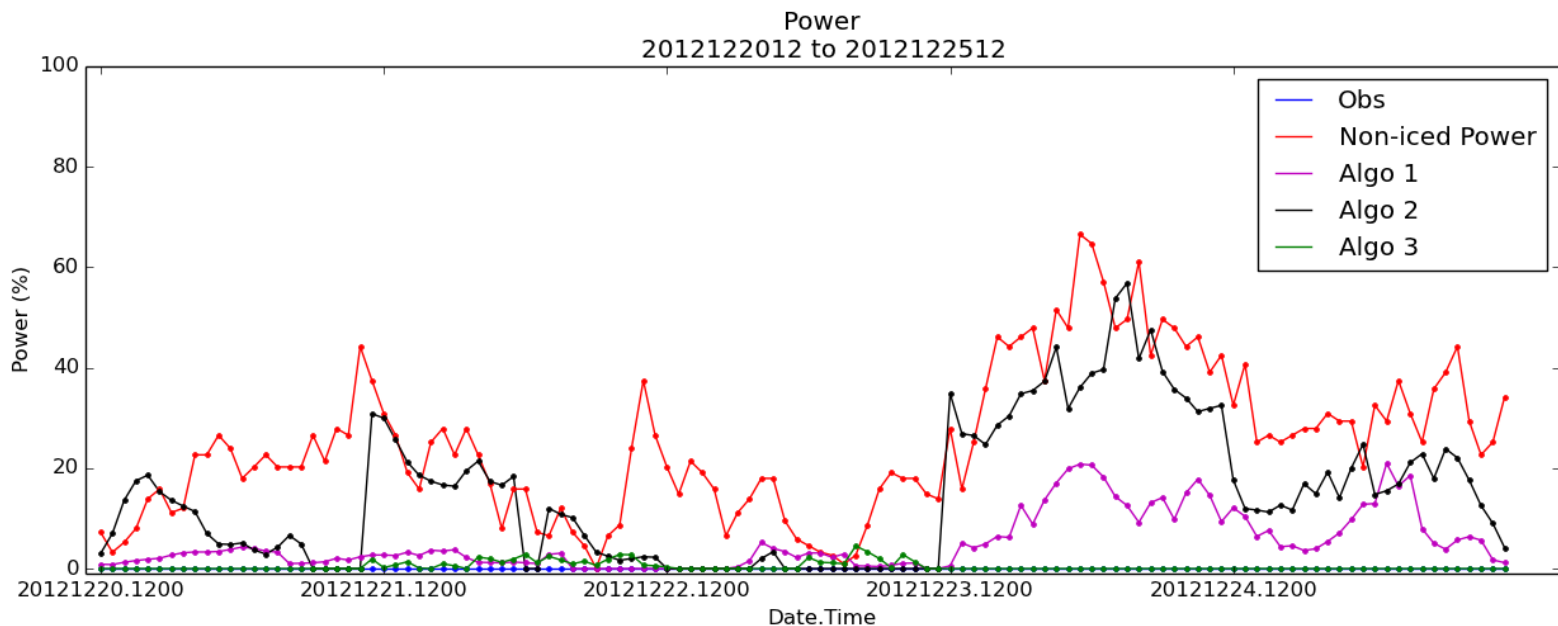

stop period

Full stop period (winds and power)

Reduced power from icing

Camera Images

Heavy Ice on all structures
Additional icing over period

Algorithm Power Forecasts for stop event

Power
2012122012 to 2012122512

Algo 1 does good job but sheds ice a little to quickly
Algo 2 sheds ice to quickly
Algo 3 matches the observations well

Recover period

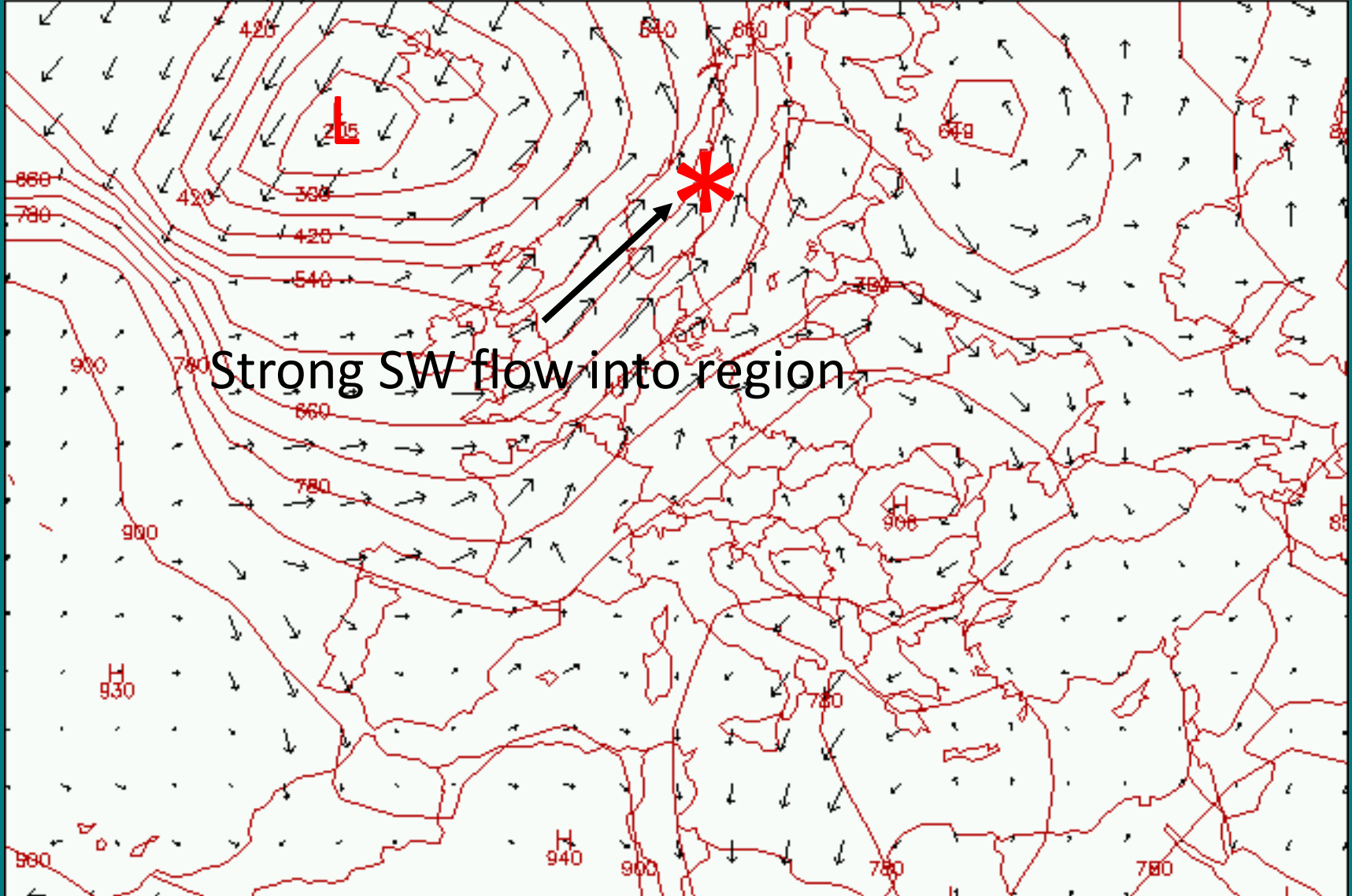Power Obs and non-iced Power
2012120100 to 2012123123
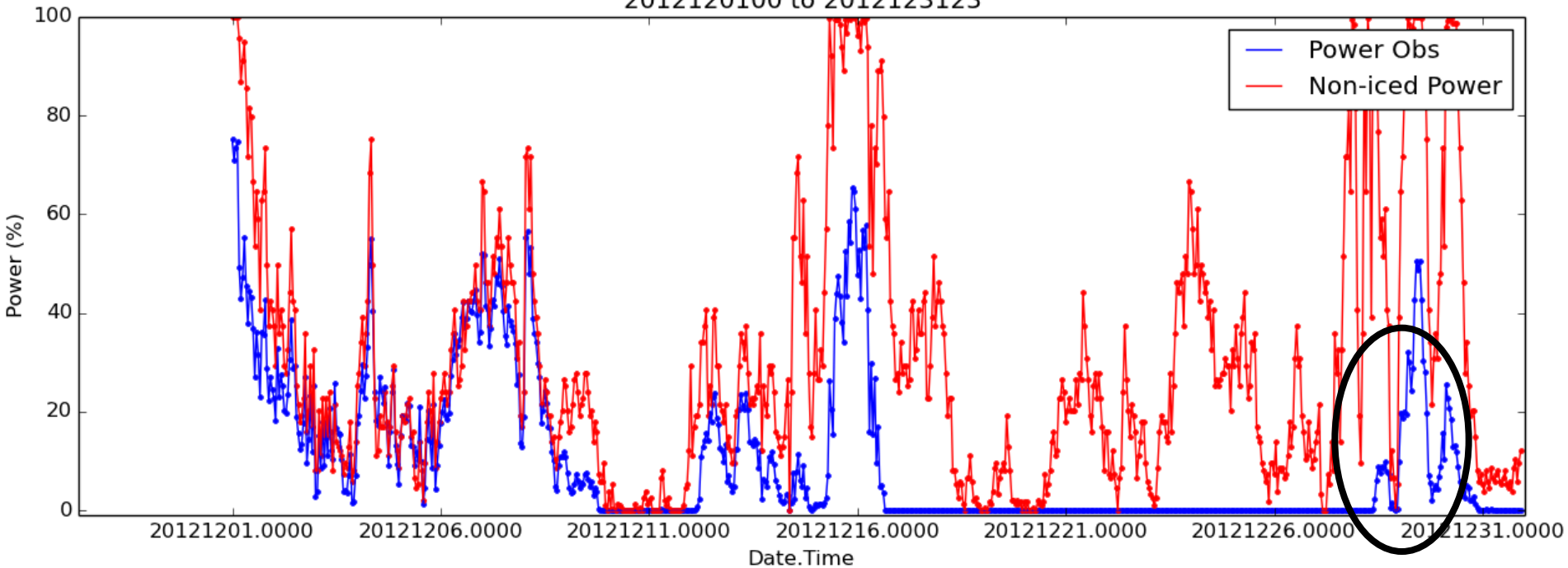
Recover period

Strong SW flow into region

Recovery period (winds and power)

Winds
2012122712 to 2012123006

Strong winds restart turbines

Power Obs and non-iced Power
2012122712 to 2012123006

Power Obs
Non-iced Power
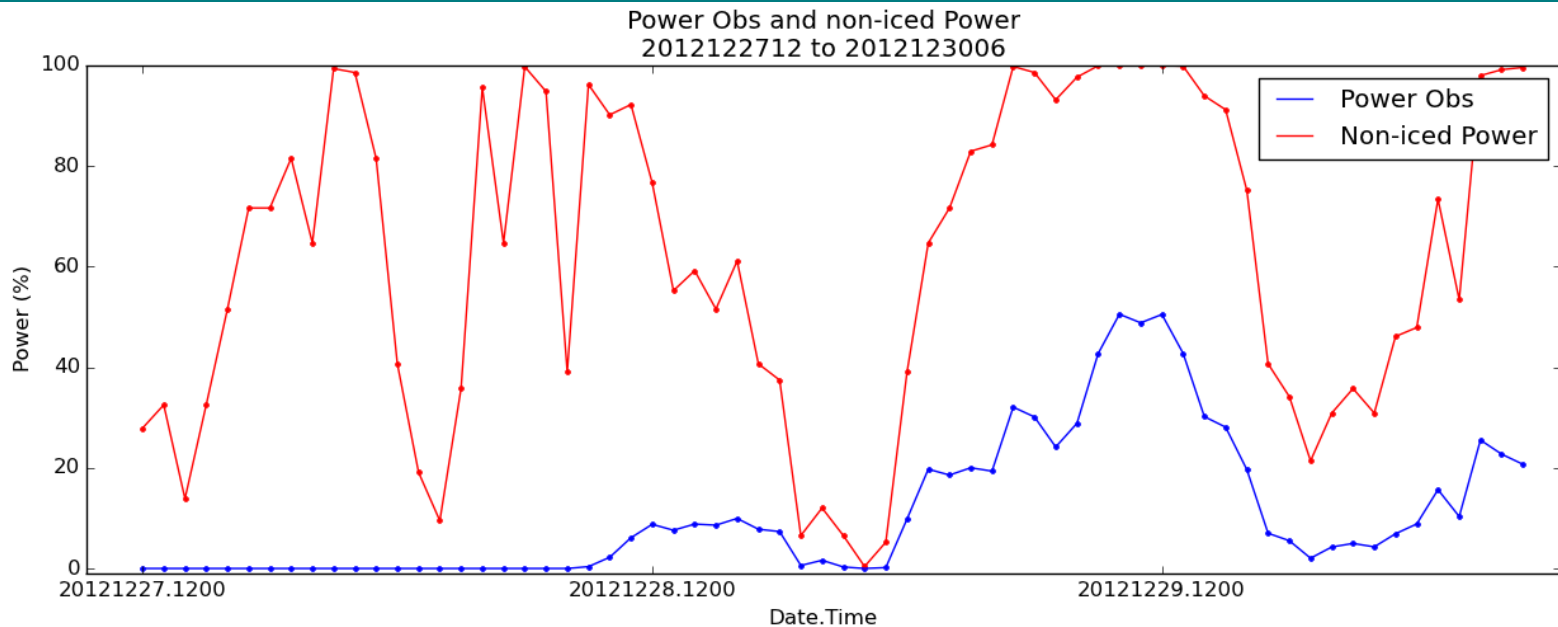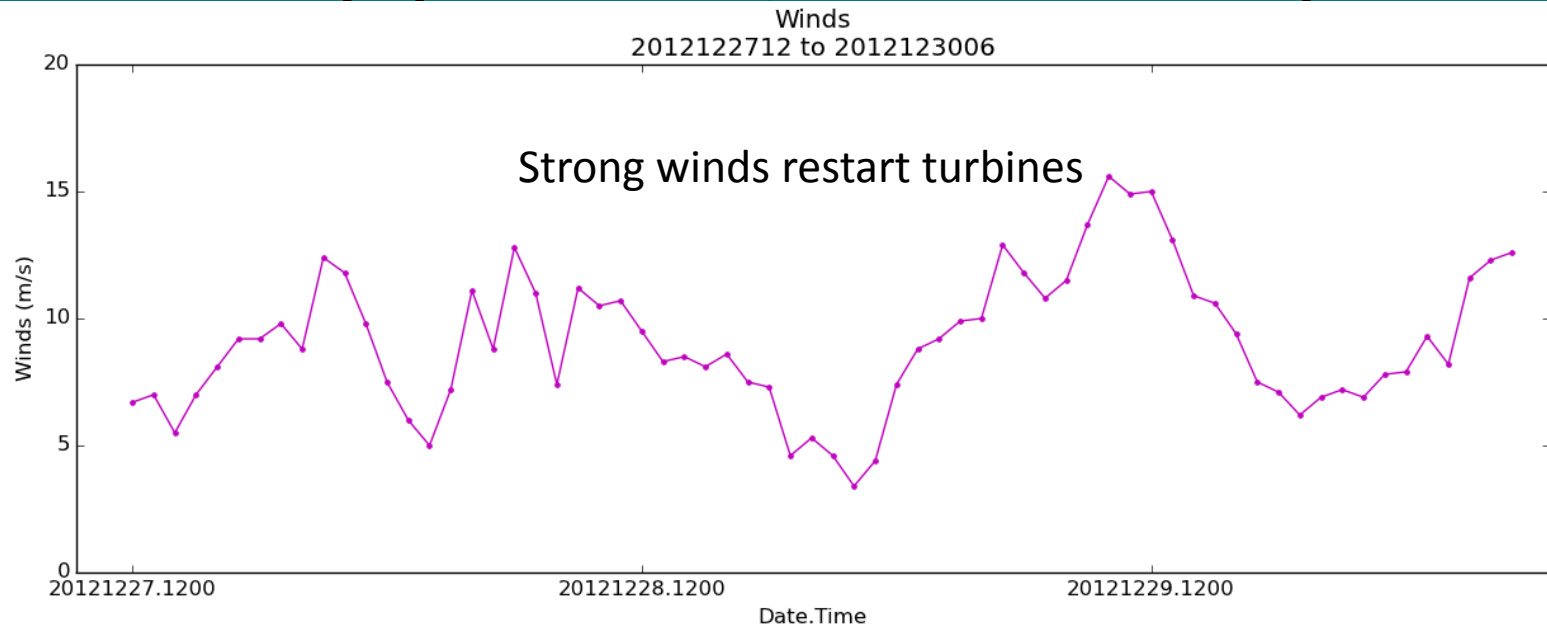
Camera images at time of recovery

Recovery period (winds and power)

Power
2012122712 to 2012123006
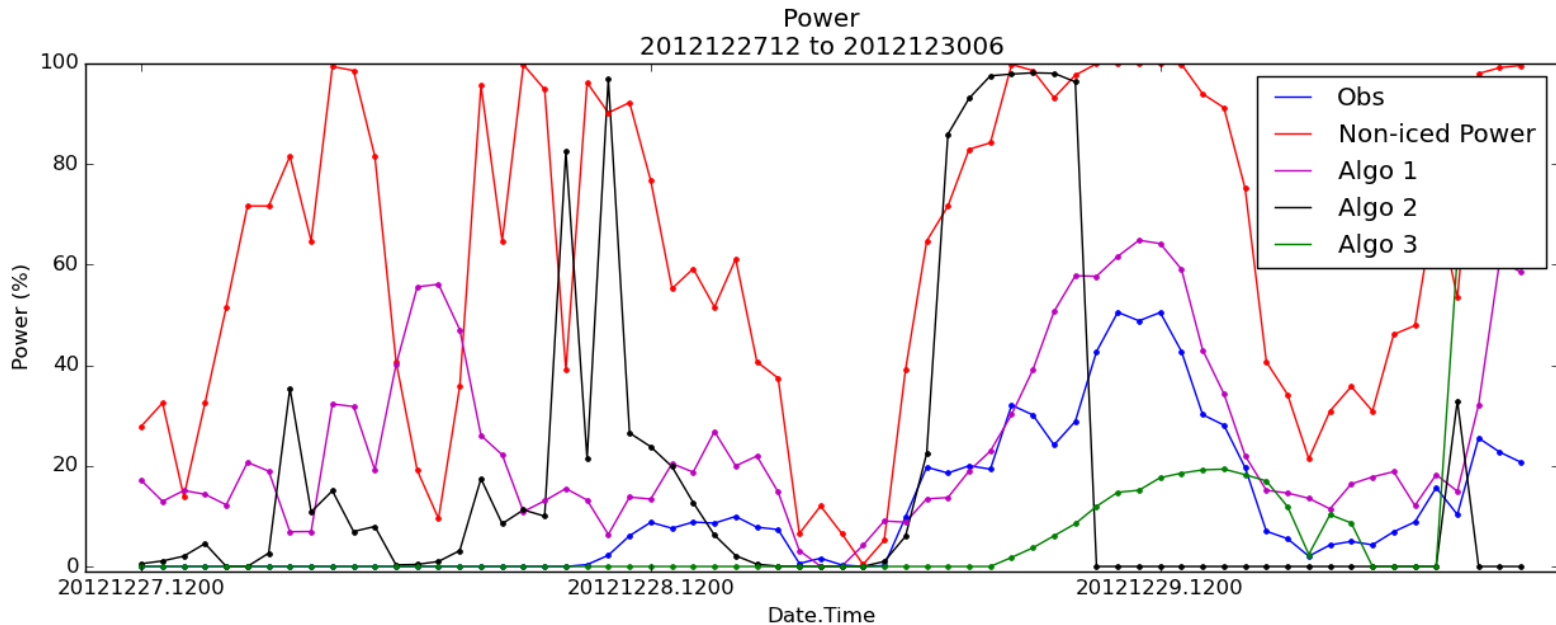
Algo 1 starts turbines a bit early but does an excellent job later in period
Algo 2 does not have enough ice
Algo 3 starts turbines correctly but is a little low with the power

Algorithm Power Forecasts month
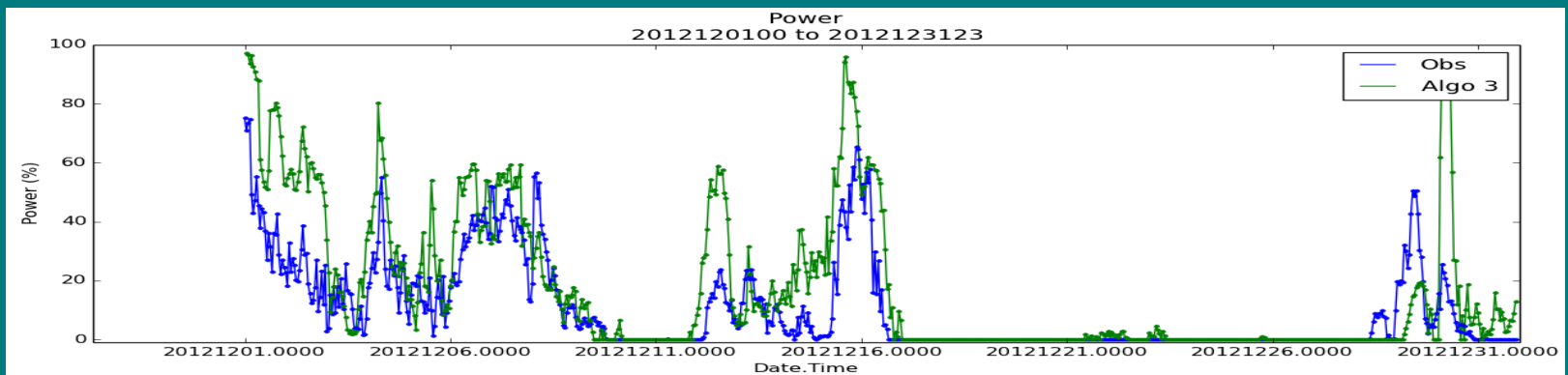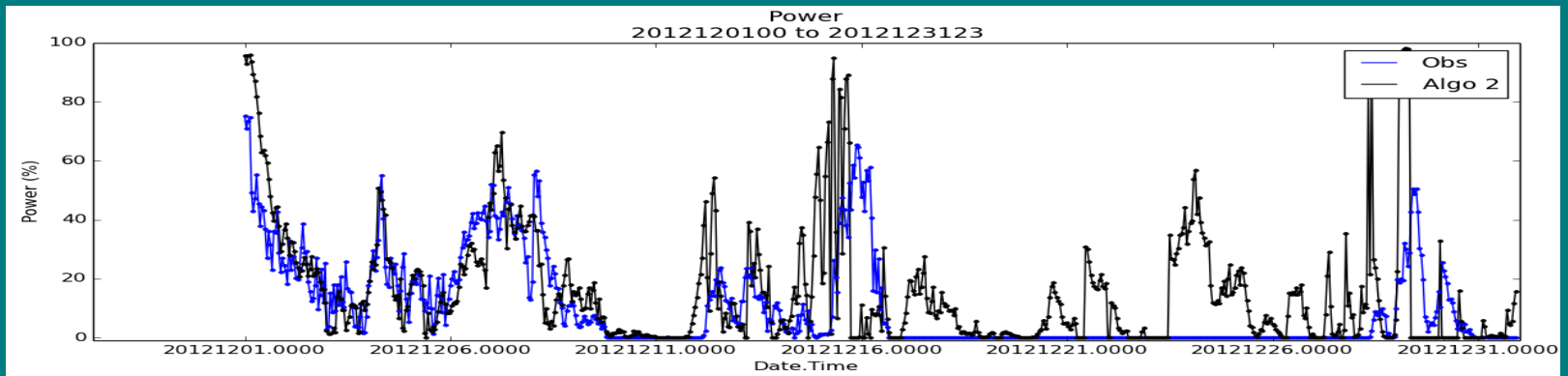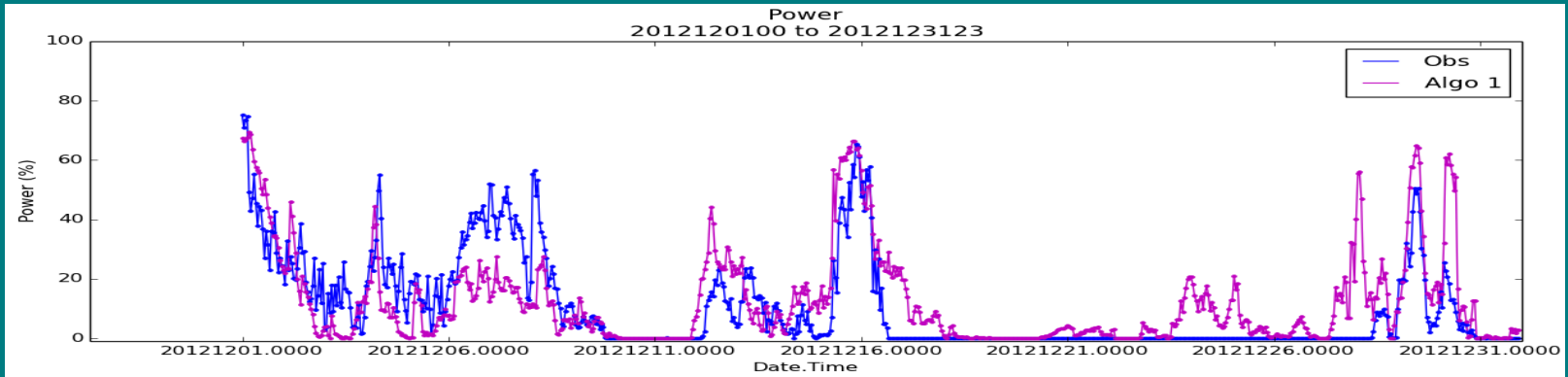
Summary

- Severe icing month analyzed
- Southeast winds associated with 2 icing events
- Icing clearly visible from camera observations
- Very difficult problem for algorithms
  - identify icing conditions
  - identify ice accretion/shedding from turbines
- Power predictions from 3 algorithms tested and compared to truth
- Algorithms show skill in predicting iced power

Thank You

Frank McDonough
Dendrite Weather Consultants
Boulder, CO USA
frankmcdonough.wx@gmail.com