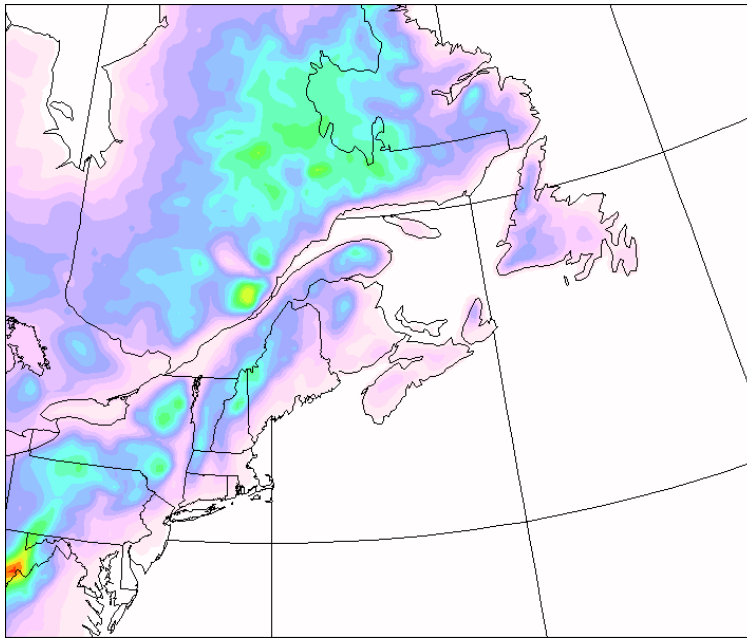
Environment Canada Environnement Canada

Hydro Québec Distribution

Simulation of icing events in Gaspé

Jing Yang[1]
Wei Yu[2]
Julien Choisnard[3]
Slavica Antic[3]
Alain Forcione[3]
Robert Morris[1]



1 Adaptation and Impacts Research Section,, Environment Canada
2 Environmental Numerical Prediction Research Section, Environment Canada
3 Hydro Québec, Montréal, Canada

Outline

- Introduction
- Observations from Wind Power Plants
- Model and simulation strategy
- Comparison of simulations with observations
  - For a freezing rain event (glaze)
  - For an in-cloud icing event (rime)
  - Will compare simulated vs observed meteorological fields
  - And with observed power loss
- Summary

Introduction

Icing types: focus on rime and glaze

- ***Rime:*** **white (cloudy) ice deposition, results from dry growth during in-cloud icing/fog; super-cooled droplets freeze quickly onto a substrate with T < 0 °C, no liquid layer, no run-off, air bubbles trapped give cloudy appearance.**

- ***Glaze:*** **smooth, transparent, homogeneous (clear) icing coating occurring when freezing rain/drizzle hits a surface; a liquid layer on the accretion surface; freezing takes place beneath this layer; wet growth, longer freezing time; no bubbles ; clear appearance.**

- ***Wet snow:*** **An agglomeration of flakes and a mixture of ice, water and air.**
- ***Frost:*** **Not important for turbine performance**

Introduction

Icing impacts for wind power:

- Large amounts of accumulated ice breaks power lines and damages equipment
- Leads to load imbalances, causing wind turbines to shut off
- Decreases wind energy power production
- Affects (non-heated) anemometer measurements (leading to false wind speed measurements)

Part 2- Simulation

Model: GEM-LAM, a mesoscale meteorological model

- **Dynamics:** Semi-Lagrangian and fully implicit numerical scheme
- **Physics:** Sophisticated physical schemes (land surface, Boundary layer, implicit and explicit precipitation scheme…

Explicit precipitation: *Double-moment microphysics scheme*

- Predicts number concentration and mixing ratio of rain, warm rain, ice pellets (sleet), graupel, snow, and hail, accumulated freezing drizzle, freezing rain.
- Give the temporal evolution of droplet size distribution of each hydrometeor.

GEM-LAM configuration

Triple-nested domain

Domain 1: 10km, 154x154

Domain 2: 3km, 234x234

Domain 3: 1km, 414x414

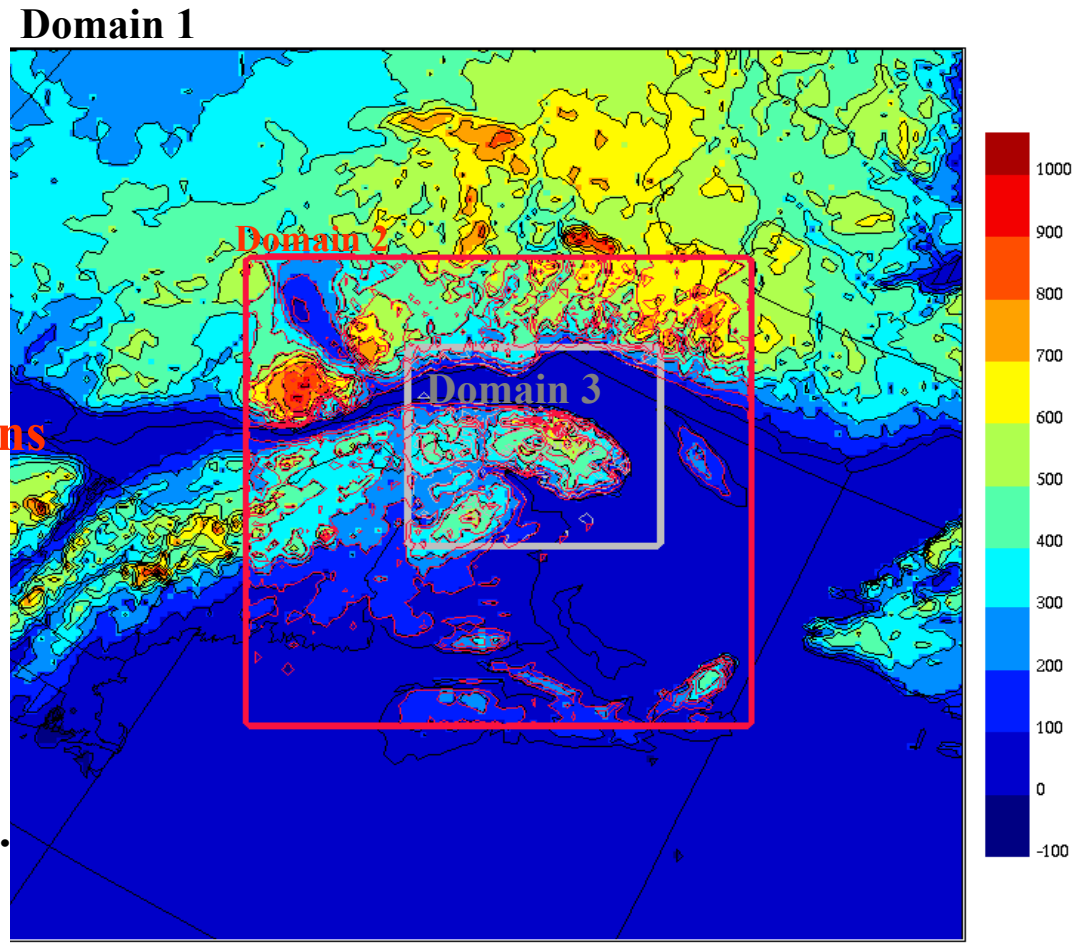
Initial and boundary conditions

CMC 6-hourly regional analysis data, (~33km/16 levels)

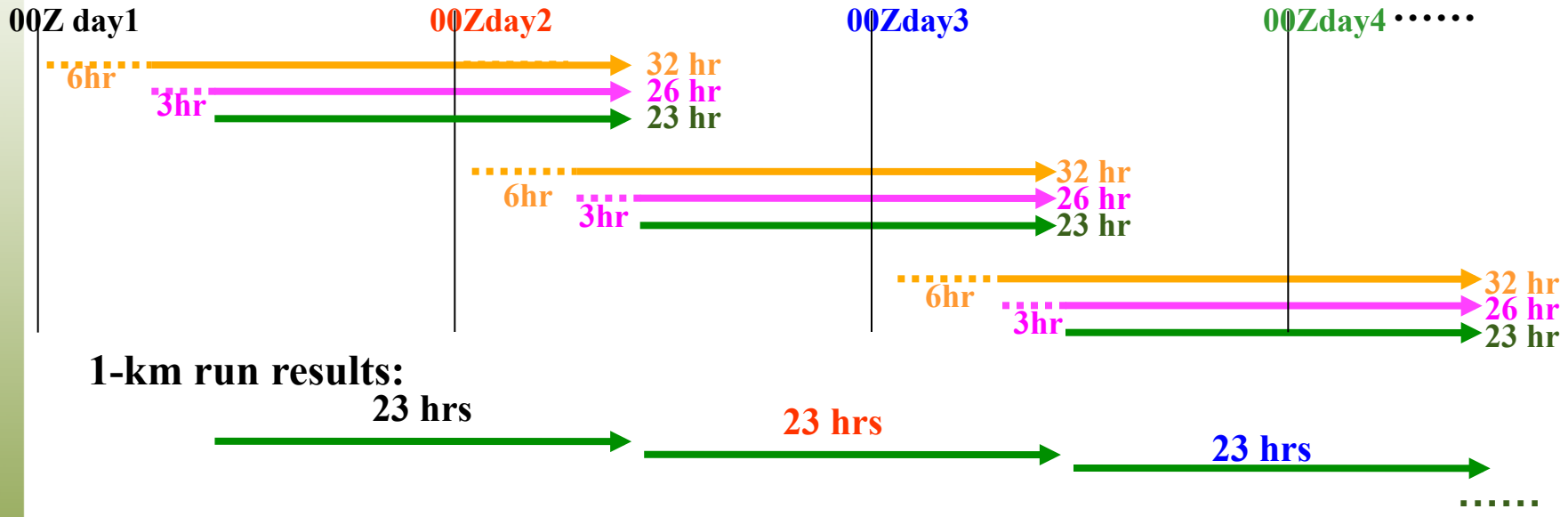
Study cases:

1. Freezing rain, 11~16 Feb, 2009.

2. Riming, 28Jan~1Feb, 2008



Simulation strategy



Resolution	Time-step	Spin-up	Nesting interval
10km ~ 0.08993	300s	/	6 hr
3km ~ 0.02698	60s	6hr	900s
1km ~ 0.008993	30s	3hr	600s

Case 1 (Freezing rain)

Case 1: Freezing rain / Wet snow

Time: 11 Feb ~ 16 Feb, 2009

Results:

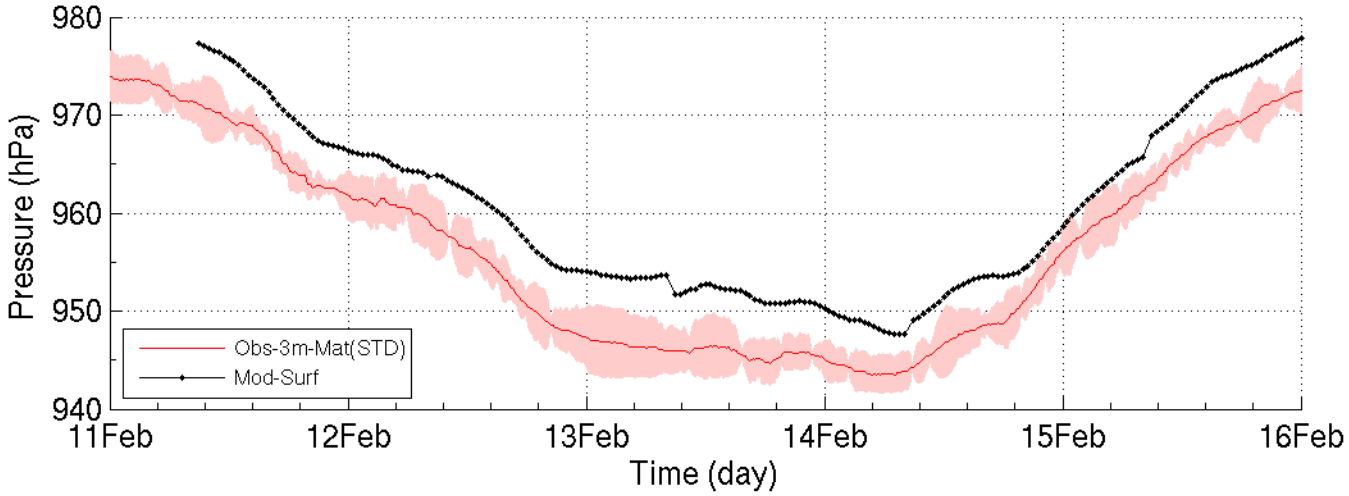
Simulated meteorological fields compared to observations

Simulated precipitation compared to power loss

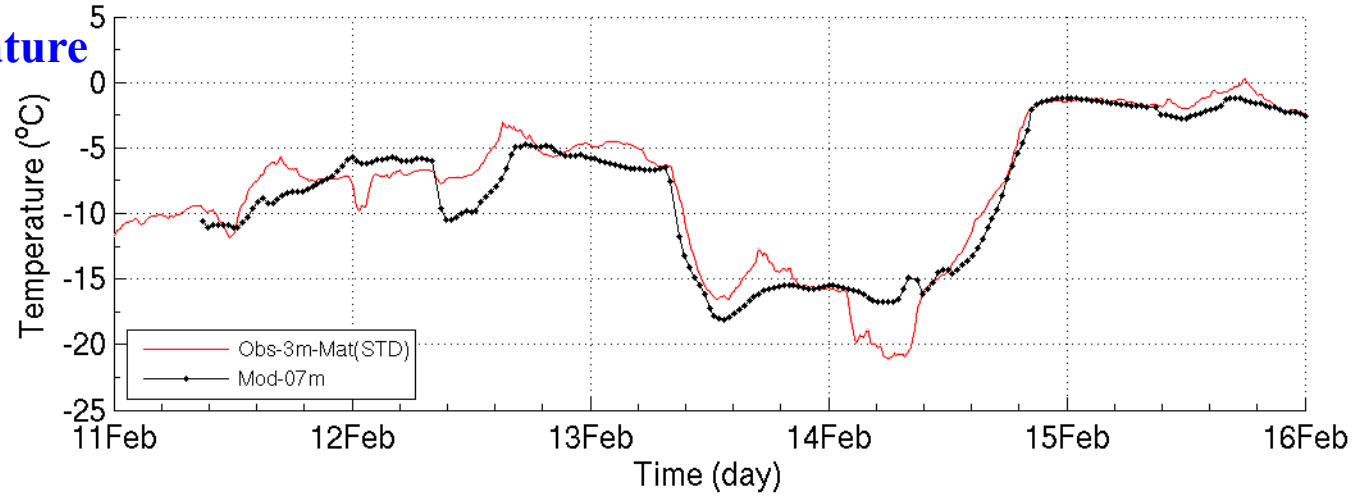
Freezing rain case – Model vs. Obs.

Observed (10-min) and simulated (half hourly) pressure and Temp. from 11 to 16Feb, 2009

Pressure



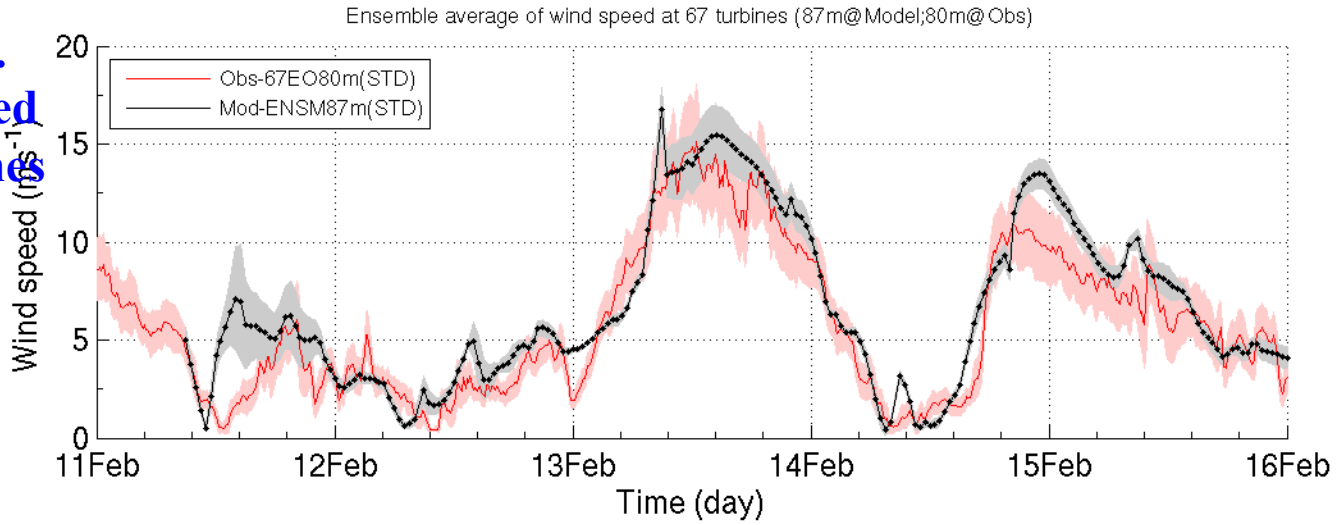
Temperature



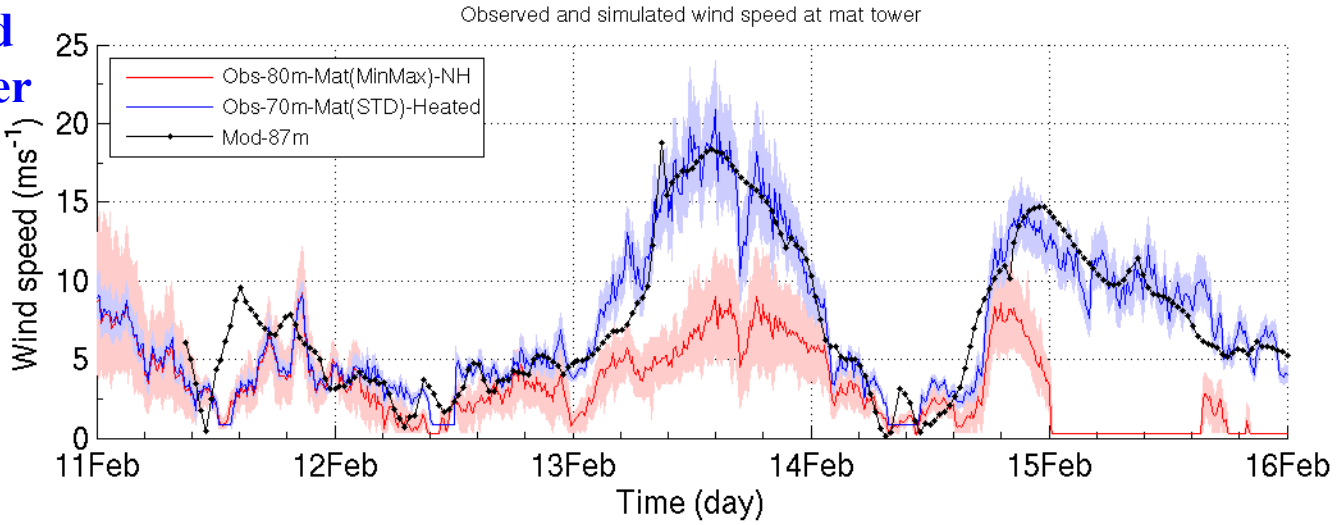
Freezing rain case – Model vs. Obs.

Observed (10-min) and simulated (half hourly) wind speed @ 67 turbines and one met. tower

Ensem Ave. of wind speed @ 67 turbines



Wind speed at met tower



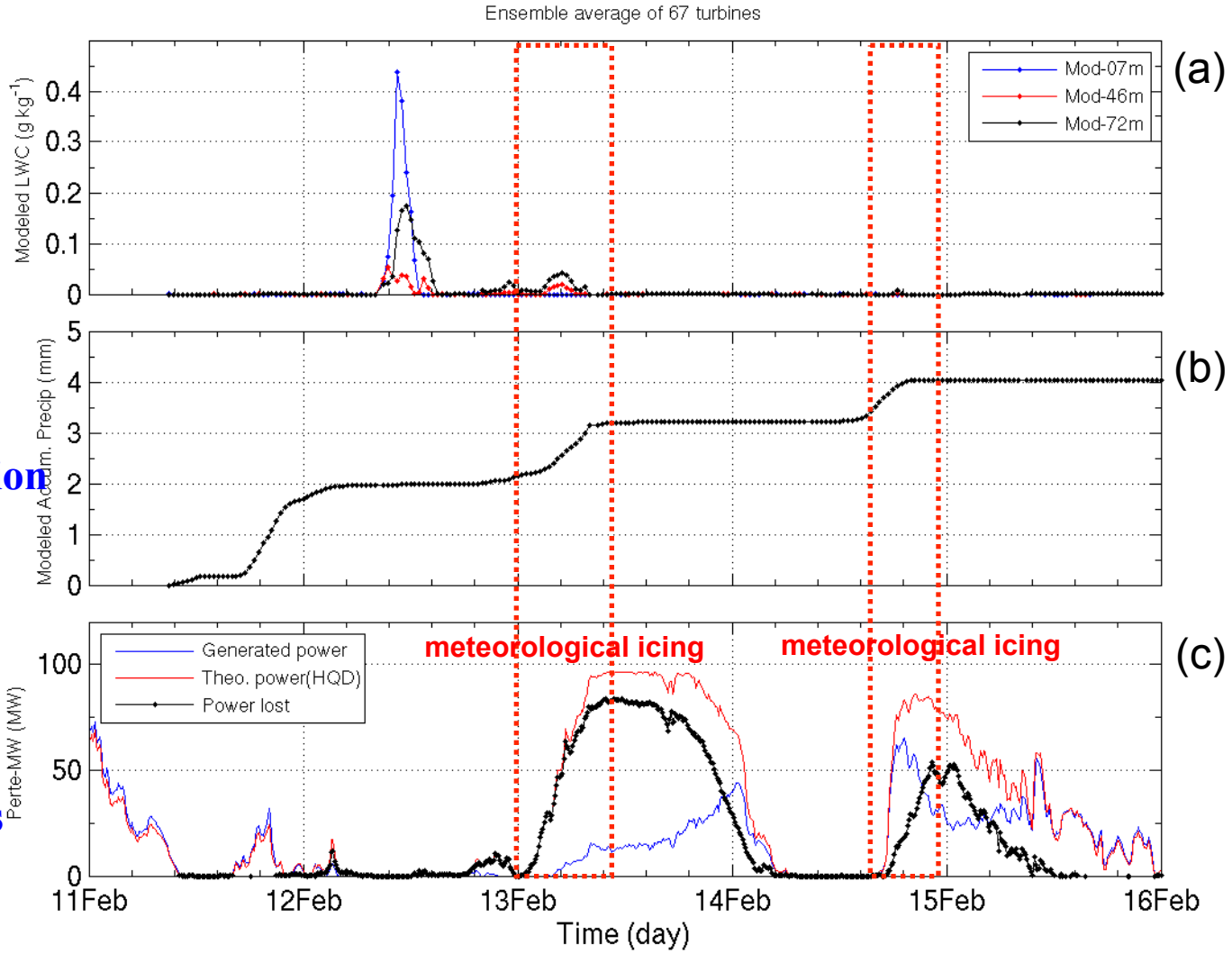
Freezing rain case – Model vs. Obs.

Simulated (half hourly) LWC & precipitation (a, b), observed power & power loss (c)

Modeled LWC

Modeled precipitation

Observed power & power loss



Power loss increased at meteorological icing periods.

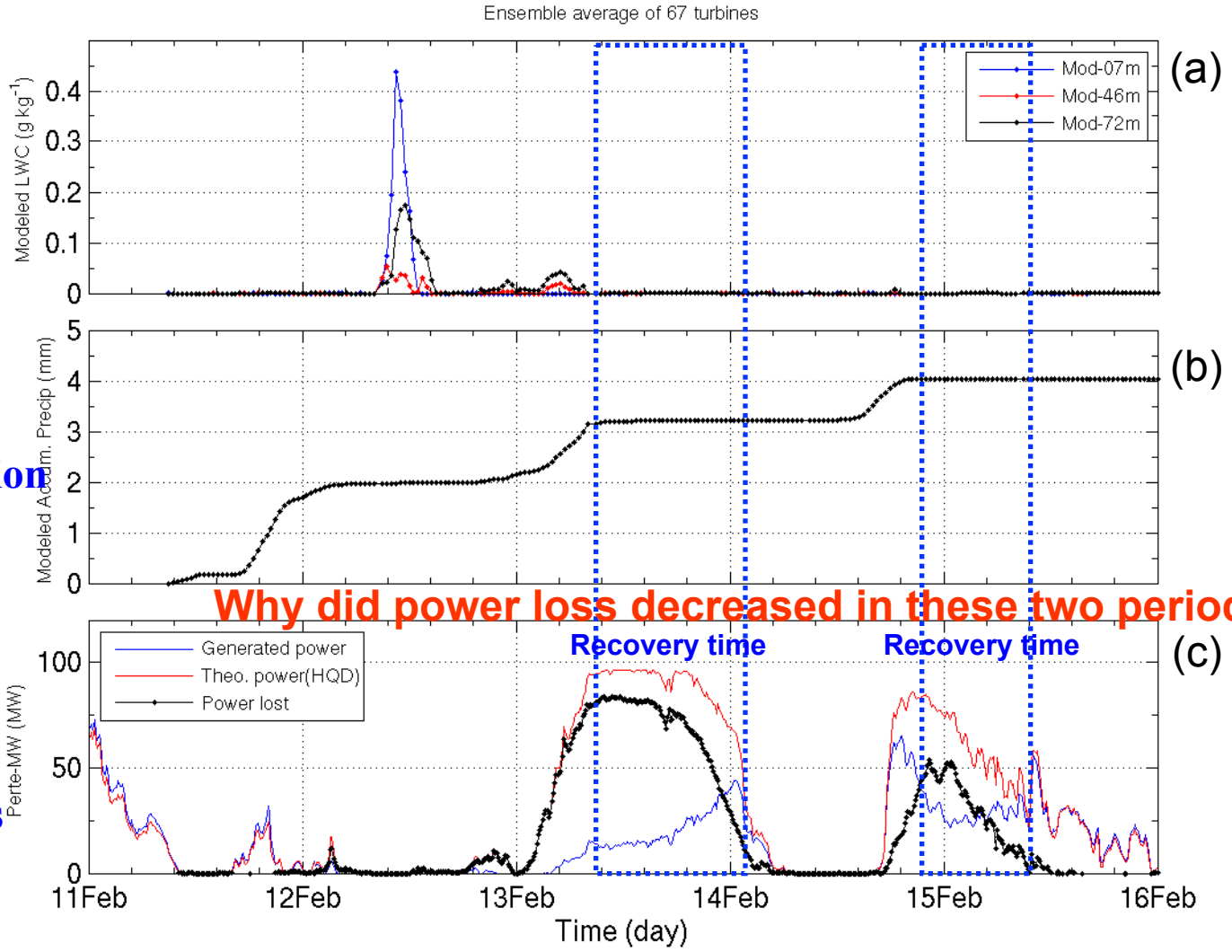
Freezing rain case – Model vs. Obs.

Simulated (half hourly) LWC & precipitation (a, b), observed power & power loss (c)

Modeled LWC

Modeled precipitation

Observed power & power loss



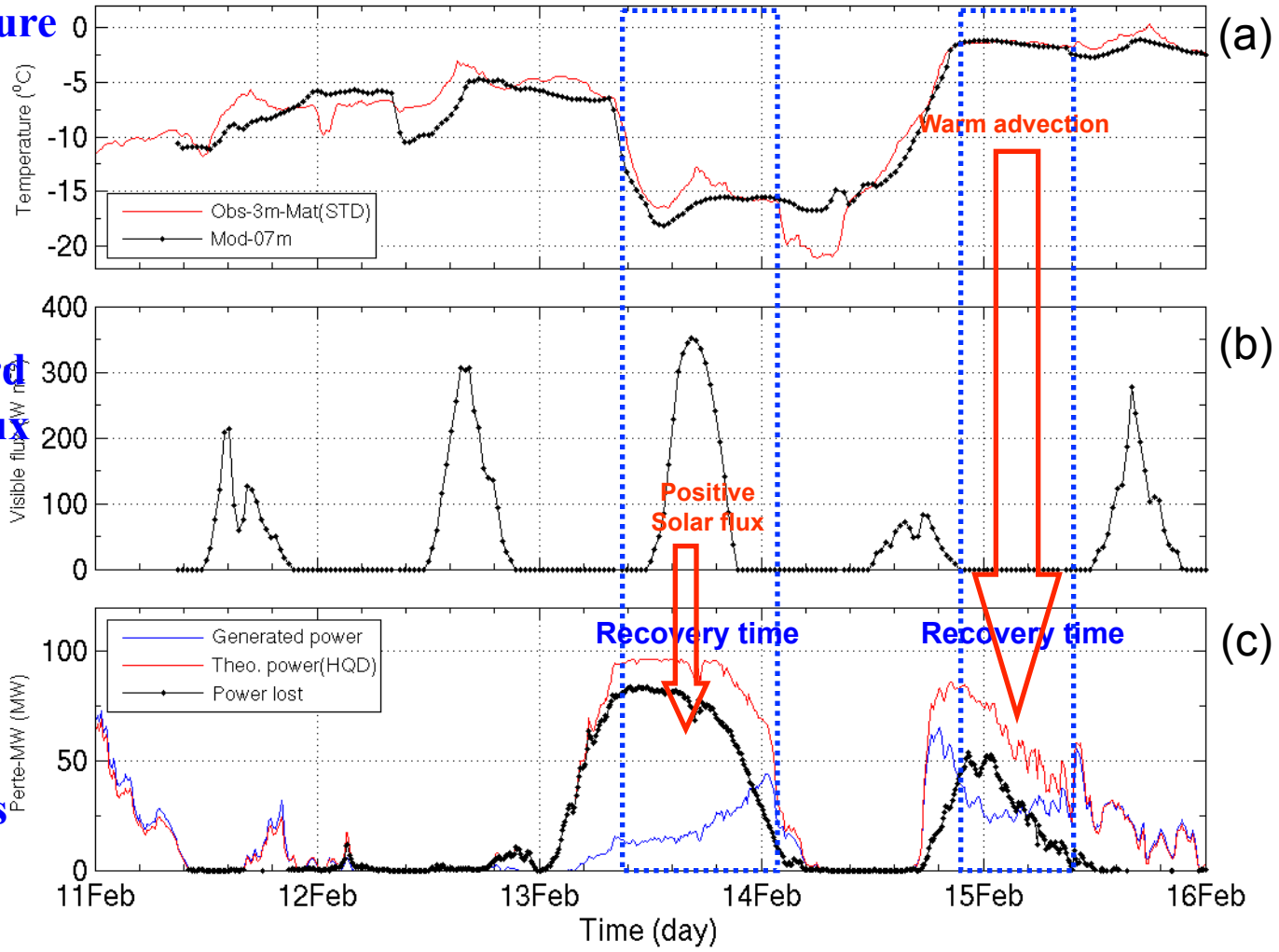
Freezing rain case – Model vs. Obs.

Simulated (half hourly) T & Visible Flux (a, b), observed power & power loss (c)

Temperature

Modeled downward visible flux

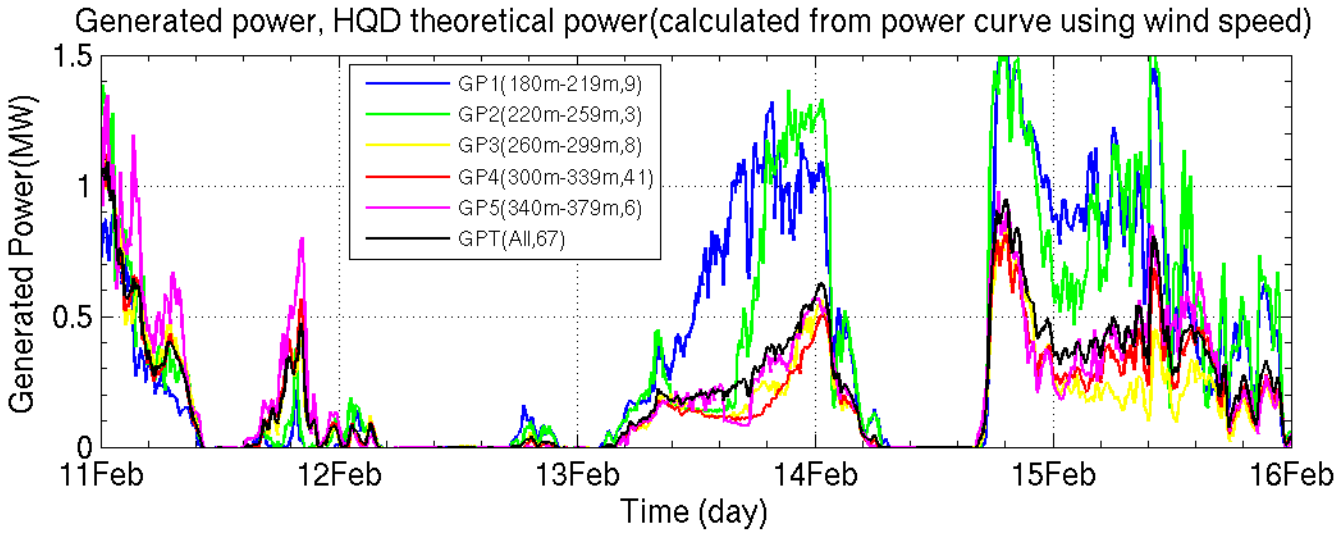
Observed power & power loss



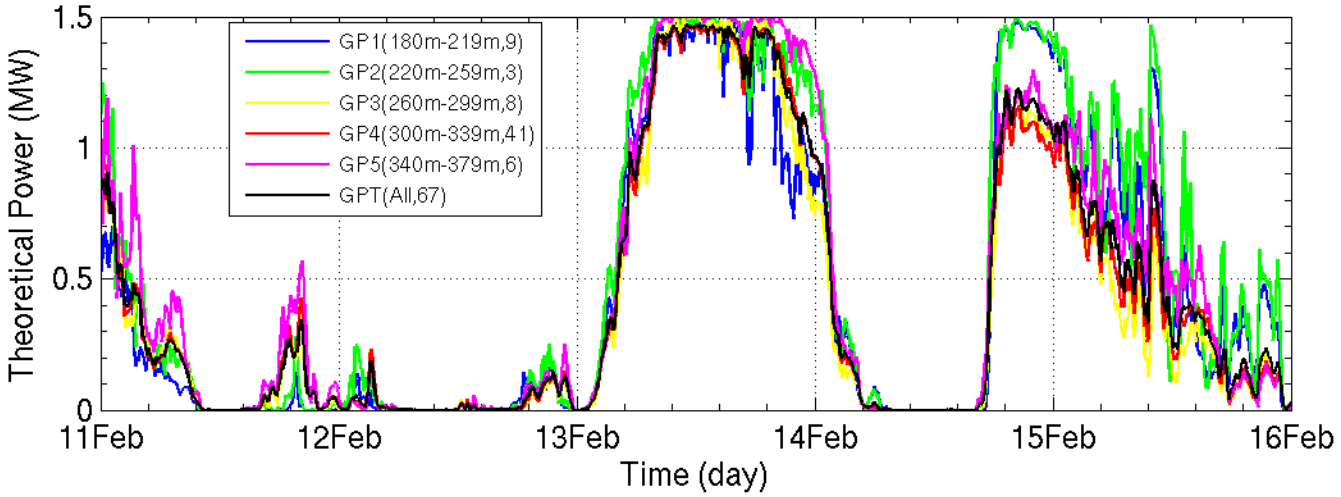
Freezing rain case – Observed power

Observed power in 5 groups (Turbines are rearranged according to altitude at base)

Real generated power



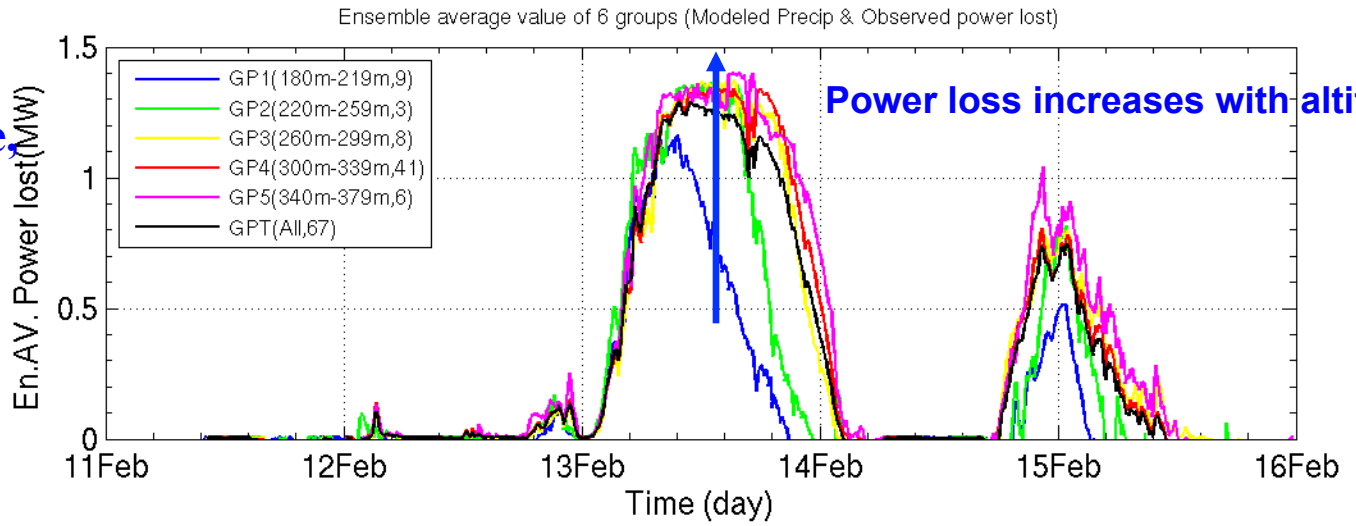
Theoretical generated power (max)



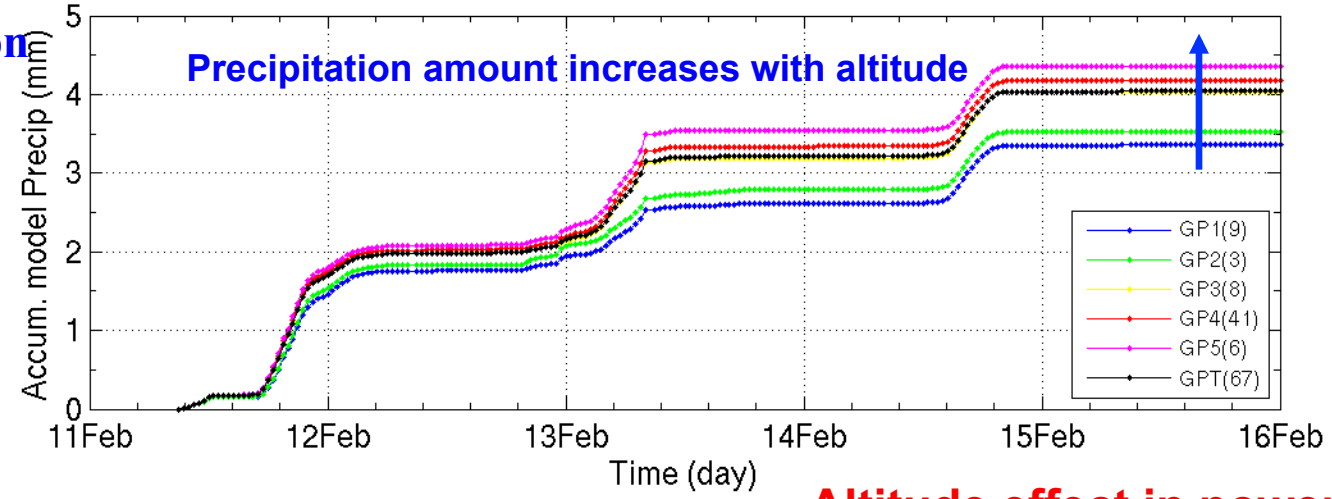
Freezing rain case – Model vs. Obs.

Observed power loss and simulated precipitation in 5 groups (group based on their heights)

Power loss (power curve, observed V)



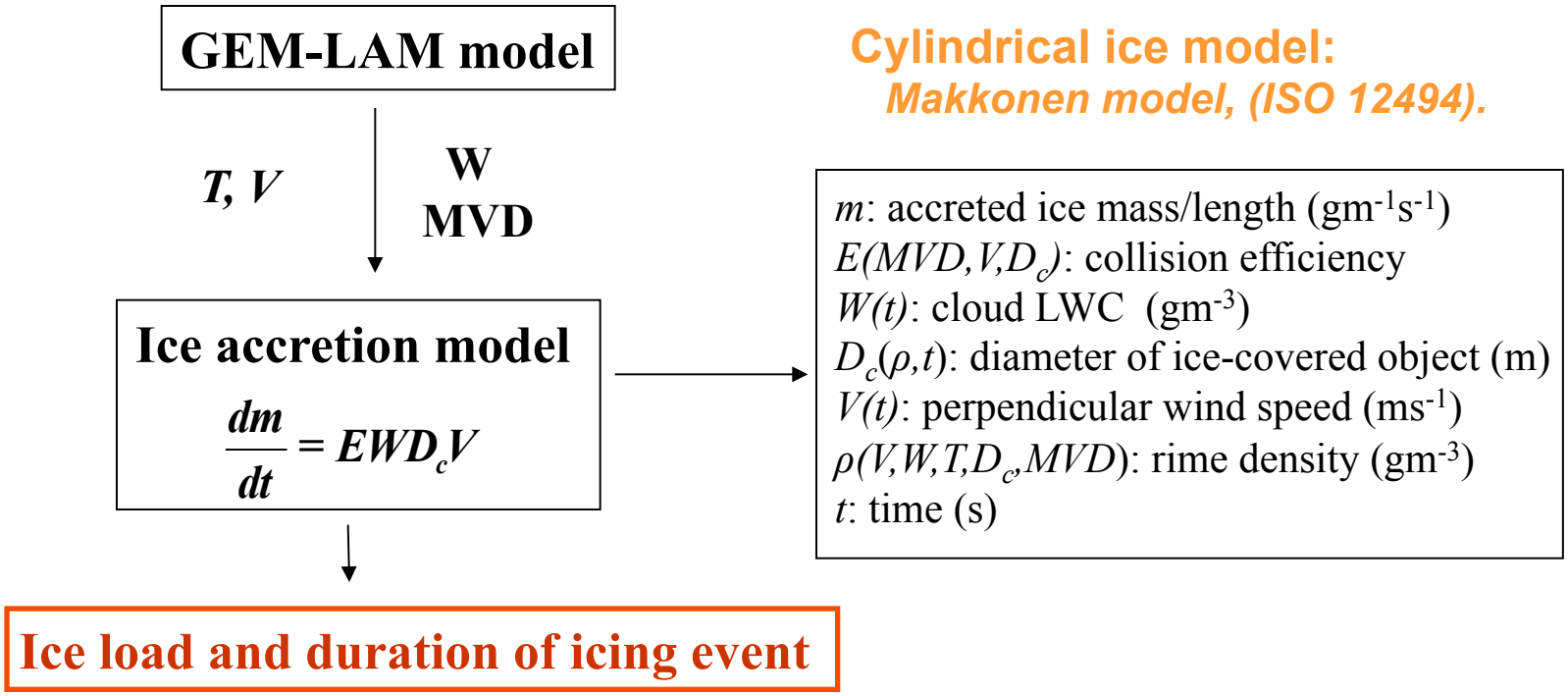
Simulated precipitation



Altitude effect in power loss

Case 2 (Riming – Jan 28 to Feb 1, 2008)

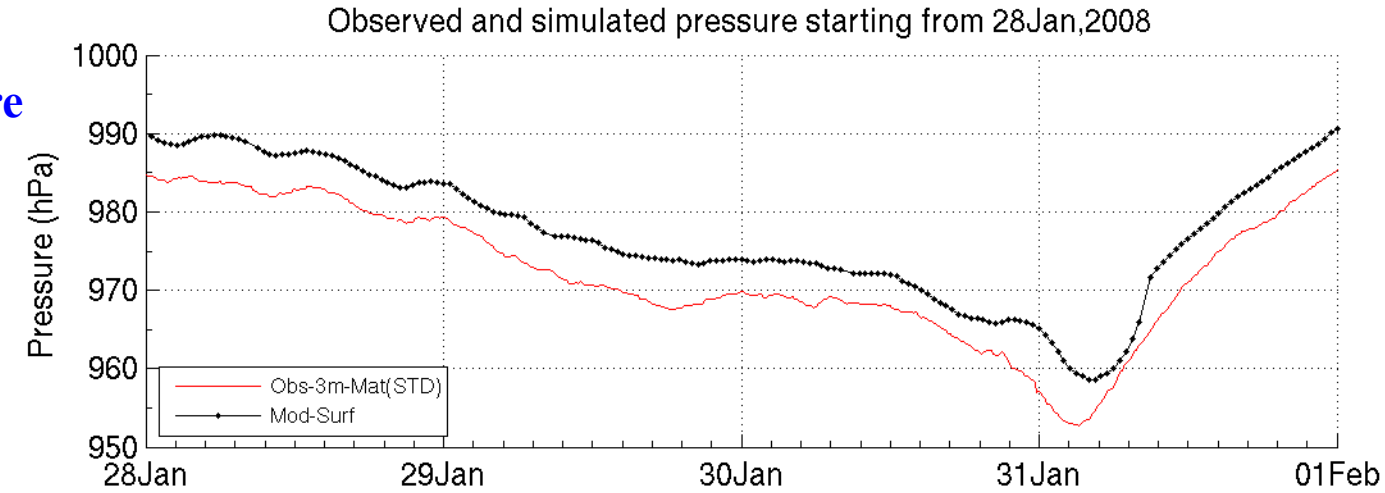
GEM-LAM output used to drive in-cloud icing model



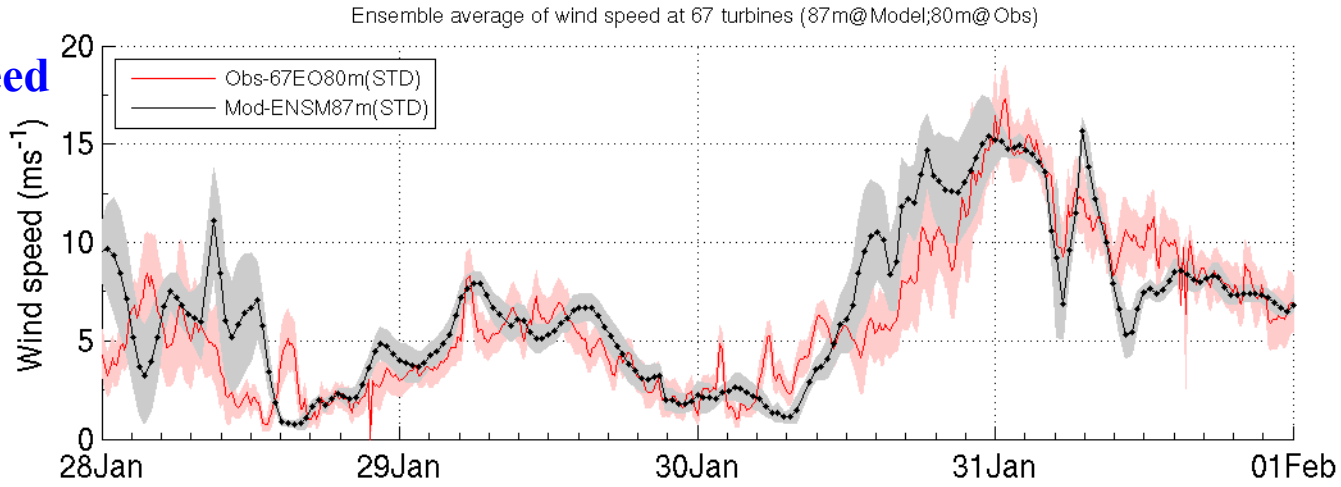
Riming case – Model vs. Obs.

Observed (10-min) and simulated (half hourly) pressure and wind speed from 28Jan to 01Feb, 2008

Pressure



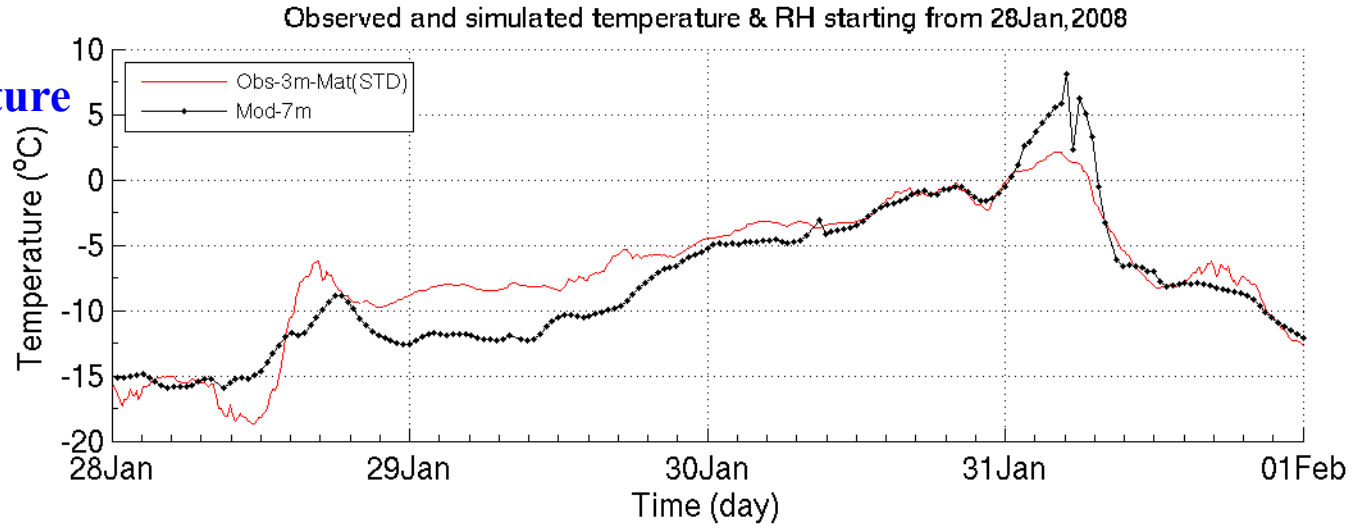
Wind speed



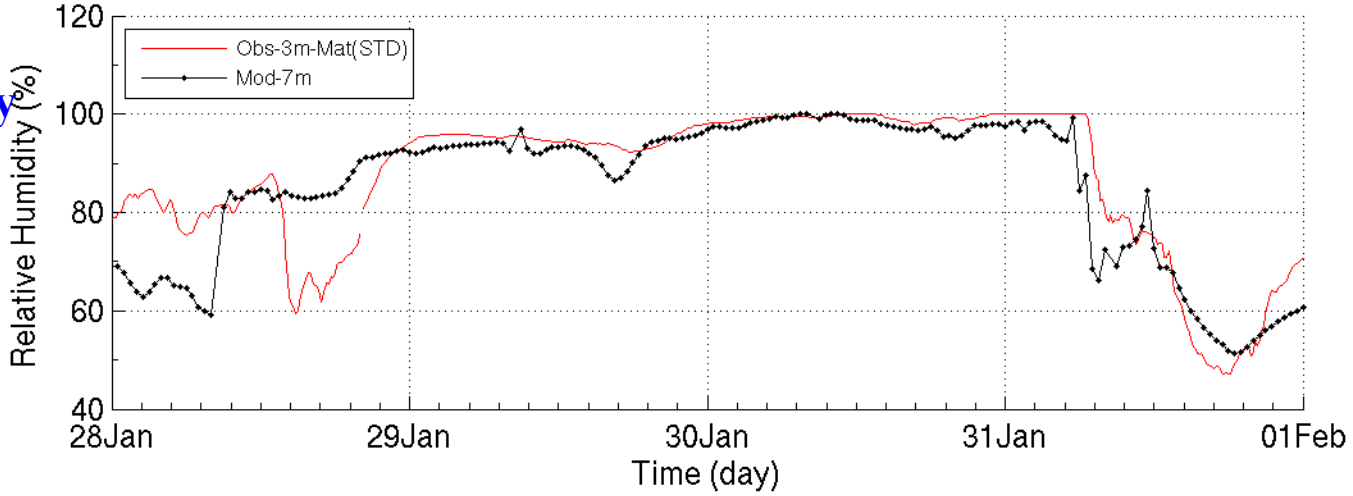
Riming case – Model vs. Obs.

Observed (10-min) and simulated (half hourly) Temp. and RH from 28Jan to 01Feb, 2008

Temperature



Relative Humidity



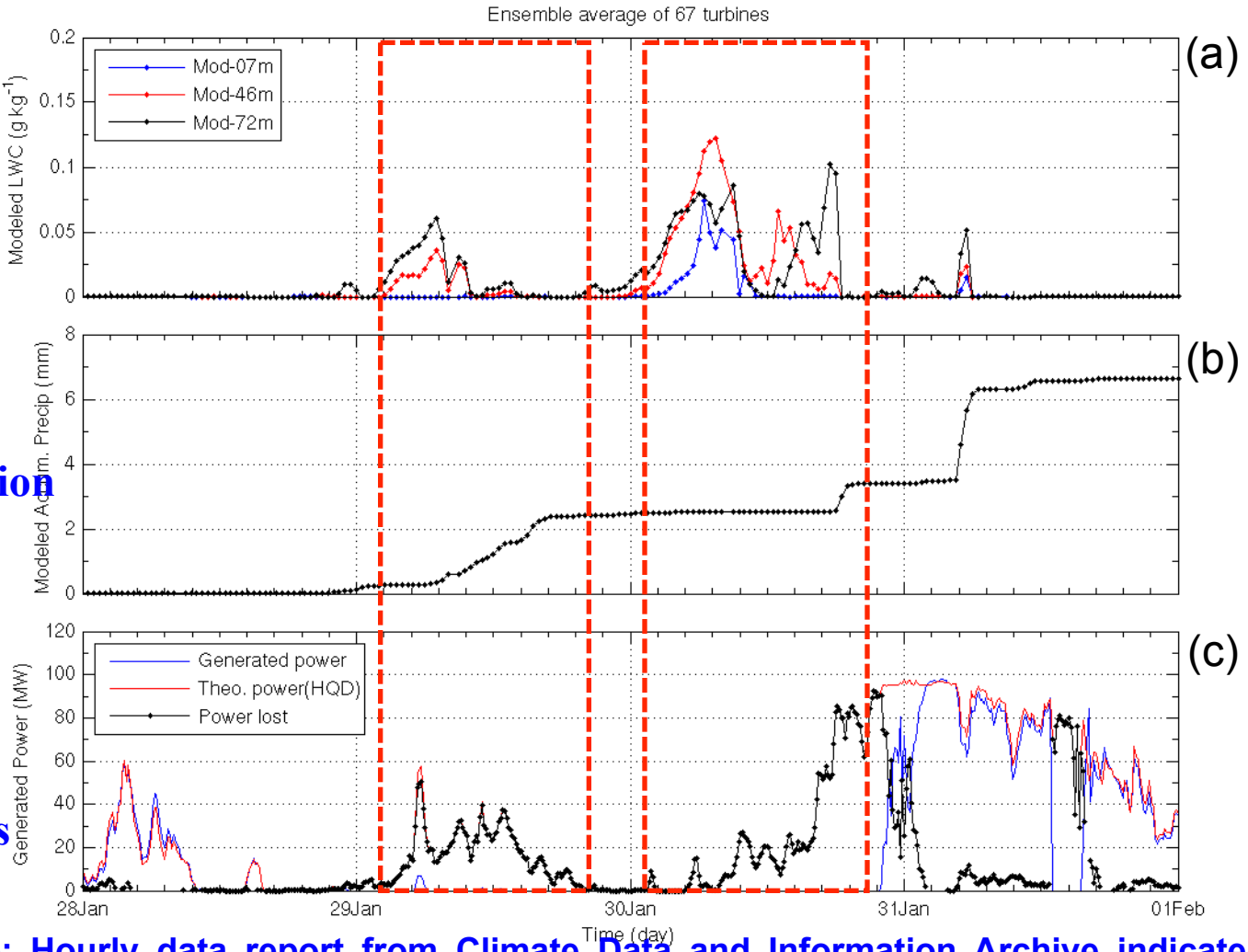
Riming case – Model vs. Obs.

Simulated (half hourly) LWC & precipitation (a, b), observed power & power loss (c)

Modeled LWC

Modeled precipitation

Observed power & power loss



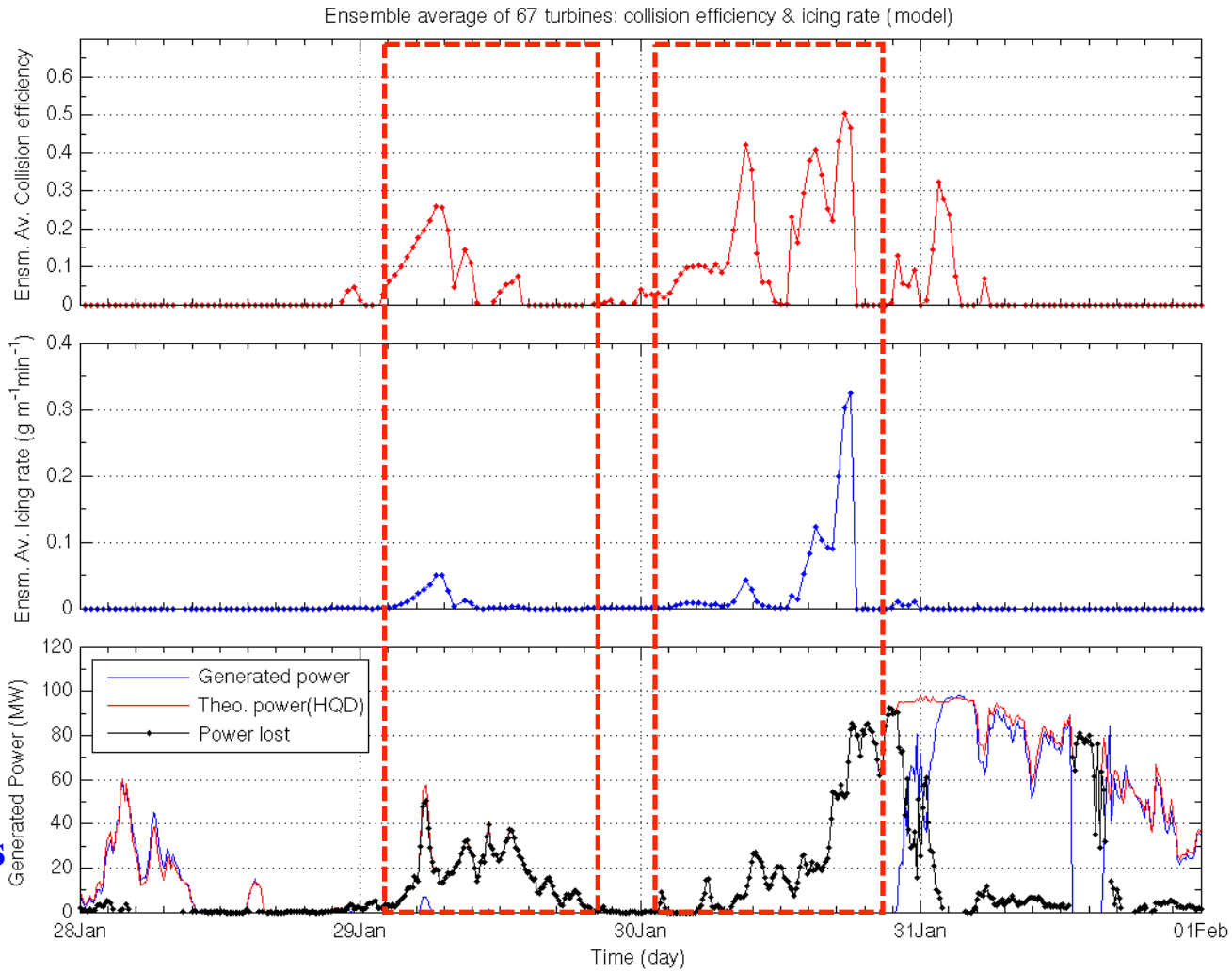
Note: Hourly data report from Climate Data and Information Archive indicated freezing rain/drizzle, fogs during 0800, 29 Jan~1100 LCT, 30 Jan.

Riming case – Model vs. Obs.

Modeled collision efficiency

Modeled ice rate

Observed power & power loss



Summary

1. Simulated icing events over eastern Quebec with GEM-LAM;
2. GEM-LAM captured the time evolution of meteorological conditions of icing events well, e.g., surface wind speed, air temperature;
3. GEM-LAM predicted the altitude dependent power loss for icing events.
4. GEM-LAM captured the onset time and duration of icing events, and can be used for wind power output forecasts;
5. The meteorological fields from GEM-LAM can be used as input to an icing model to calculate icing loads and duration.

Future work

- simulate other icing events, and compare with observations.
- Operational test of overall power plant (clusters) responses to icing impacts.
- propose “ice triggered power loss risk index”.