Icing Predictions for the Canadian Wind Energy Industry

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Background

- Icing on wind turbines

  => **Power reduction**, increased fatigue loads, ice throw…

- Goal: Develop an operational tool to forecast icing and associated power loss
  => Increases turbine performance, helps with grid balancing, etc.

- Participants: multidisciplinary experts from
 - The Meteorological Service of Canada (MSC)
  - Nergica

Meteorological Service of Canada

Canadian Scientific Agency that

- Provides Canadians with accurate information on weather (observations, forecasts and warnings)

- Warns Canadians about high-impact weather

- Provides data and services to support provinces + territories in many areas (energy, transportation..)

- Supports federal departments in delivering their mandates

MSC across Canada

~ 1400 employees in over **50** offices in **45** cities across Canada
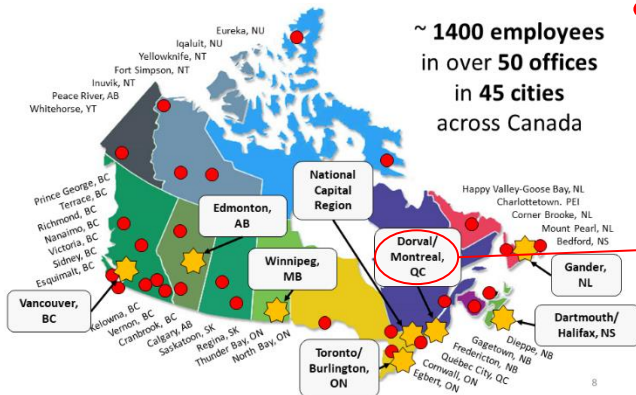
Canadian Meteorological Centre: national centre of numerical weather predictions on super computers

Nergica

NERGICA
Mission:

Creating new opportunities for renewables

Natural progression of the TechnoCentre éolien, **Nergica** is a centre of applied research that stimulates **innovation in the renewable energy industry** through

- Research
- Technology transfer
- Technical support for business and communities

R&D wind farm

Office

Environnement et Changement climatique Canada

Environment and Climate Change Canada

Canada

Numerics

Numerical Weather Prediction

**Local time Series
(temperature, wind, precipitation, …)**

Adjustable Parameters
Constants

**GPEO:
Ice and Energy
Loss Model**

**Ice Accretion
Rate**
Time Series

**Ice
Accumulation**
Time Series

Icing Losses
Time Series

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Numerics

Numerical Weather Prediction

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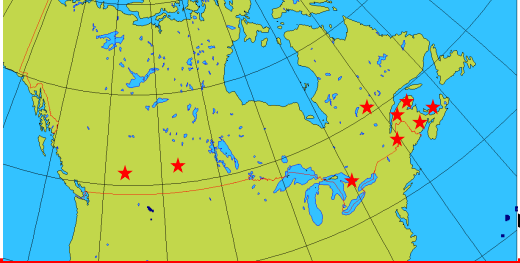
**GPEO:
Ice and Energy
Loss Model**

Ice Accretion Rate
Time Series

Ice Accumulation
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Icing Losses
Time Series

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Numerics: NWP

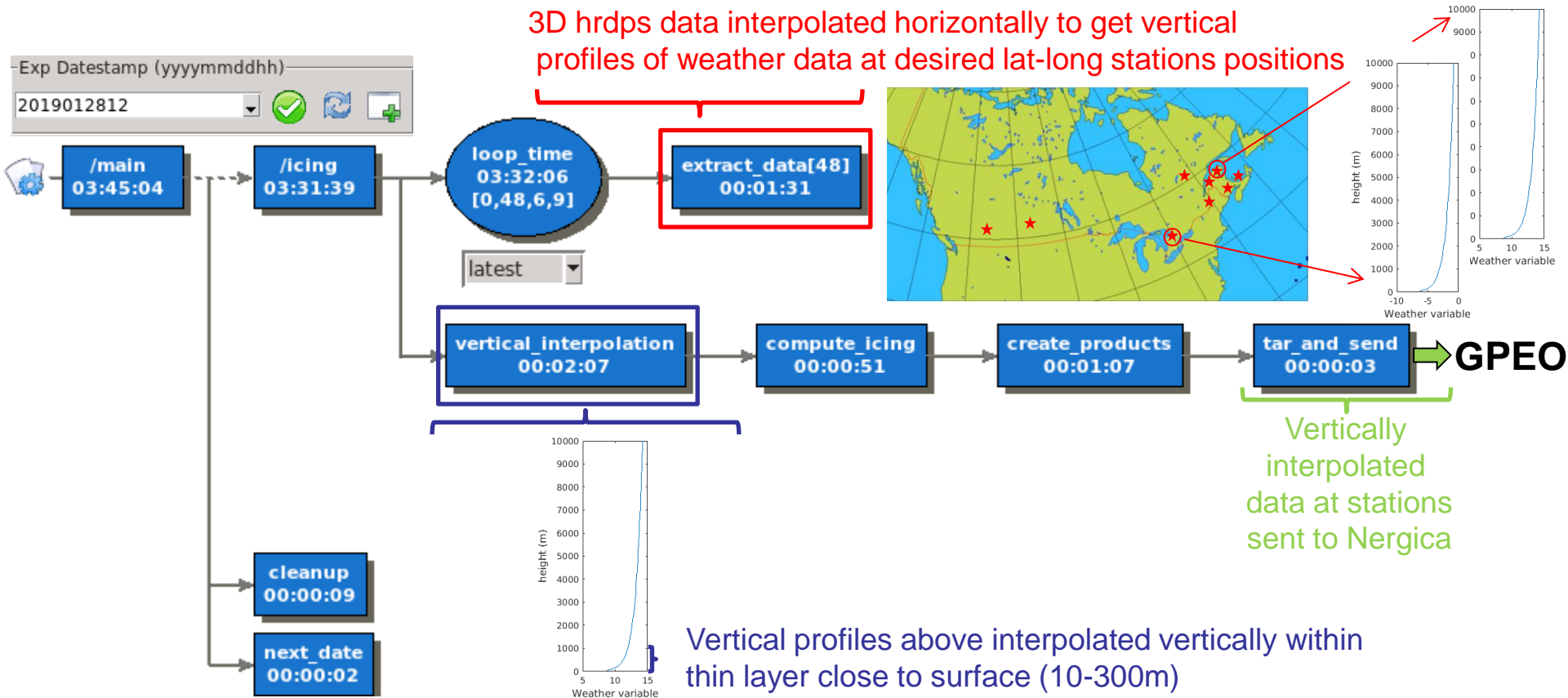## Numerical Weather Prediction (NWP)

Focus here on Gaspé region

- Operational model used for weather predictions in Canada
  - hrdps: high resolution (2.5km) deterministic prediction system
- 48 hours ahead, updated every 6 hours, 30 min. resolution
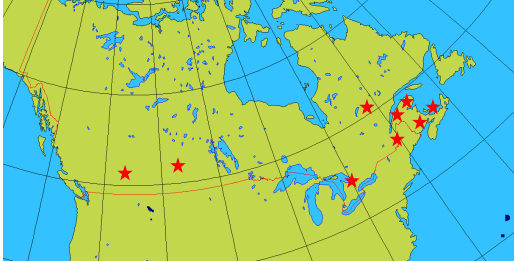- Data interpolated at farm locations + altitudes, fed to GPEO

Numerics: NWP post-processing

3D hrdps data interpolated horizontally to get vertical profiles of weather data at desired lat-long stations positions

Exp Datestamp (yyyymmddhh)
2019012812

/main 03:45:04

/icing 03:31:39

loop_time 03:32:06 [0,48,6,9]

extract_data[48] 00:01:31

latest

vertical_interpolation 00:02:07

compute_icing 00:00:51

create_products 00:01:07

tar_and_send 00:00:03

GPEO

cleanup 00:00:09

next_date 00:00:02

Vertically interpolated data at stations sent to Nergica

Vertical profiles above interpolated vertically within thin layer close to surface (10-300m)

Numerics

Numerical Weather Prediction

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**GPEO:
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Ice Accretion Rate
Time Series

Ice Accumulation
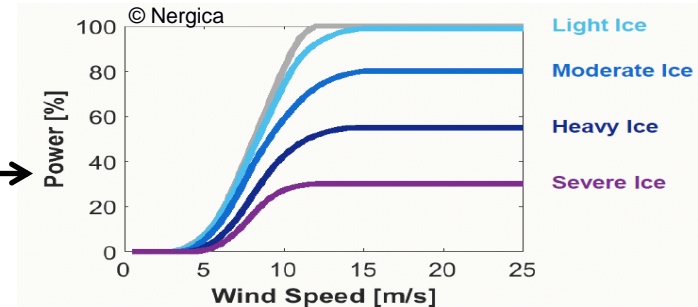Time Series

Icing Losses
Time Series

Numerics: GPEO

The Ice and Energy Loss Model (GPEO)

- 1. Ice accretion on a fixed cylinder
    - Freezing rain, in-cloud icing, wet snow
- 2. Event filtering
    - Remove unlikely small events, combine events close together
- 3. Ice ablation
    - Simplified ice fall model
    - Ice melting
- 4. Ice losses (via transfer function) →

Canada

Measurement data for validation
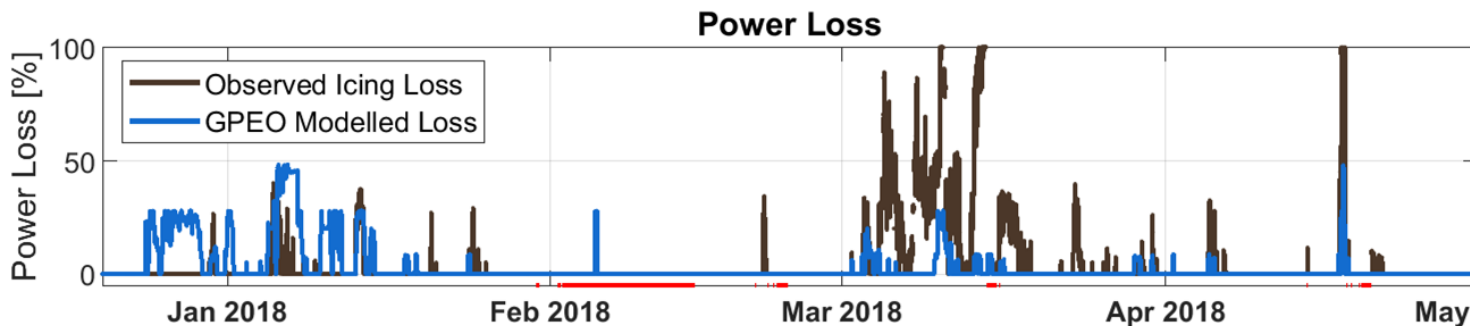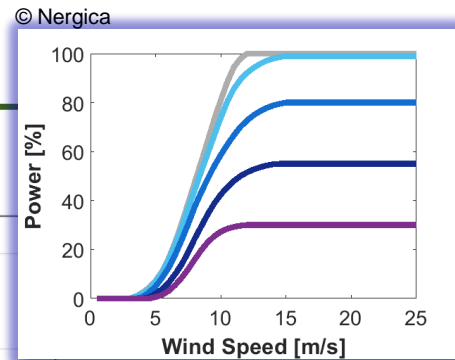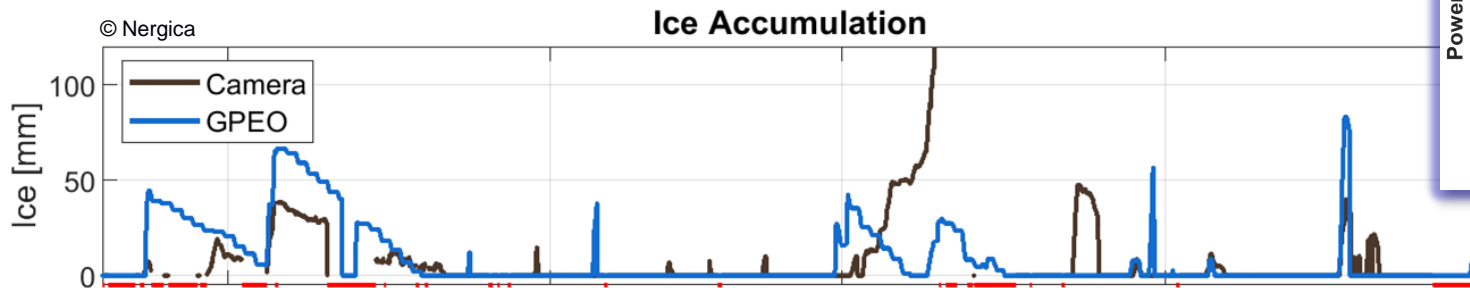
From Nergica's wind farm and test site

- Nacelle-mounted camera for image analysis (on 2MW turbine)
- Icing detectors (Combitech) on meteorological mast
- Turbine SCADA
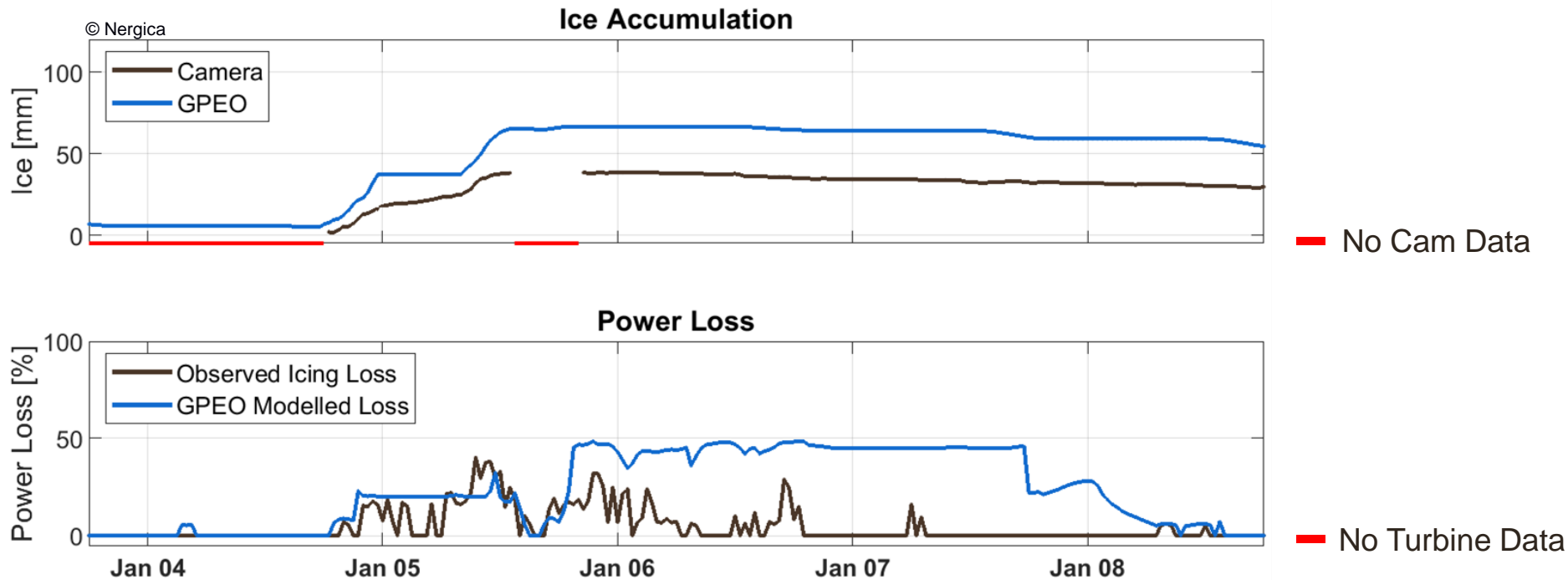- Double anemometry

R&D wind farm

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Results last winter

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Ice Accumulation

Legend: Camera, GPEO

Ice [mm]: 100, 50, 0

No Cam Data

Power Loss

Legend: Observed Icing Loss, GPEO Modelled Loss

Power Loss [%]: 100, 50, 0

Jan 2018, Feb 2018, Mar 2018, Apr 2018, May 2018

Power [%]: 100, 80, 60, 40, 20, 0
Wind Speed [m/s]: 0, 5, 10, 15, 20, 25

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8.6% loss

7.1% loss

No Turbine Data

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Results last winter (zoom)

© Nergica

Ice Accumulation
- Camera
- GPEO

Ice [mm]: 100, 50, 0

— No Cam Data

Power Loss
- Observed Icing Loss
- GPEO Modelled Loss

Power Loss [%]: 100, 50, 0

Jan 04   Jan 05   Jan 06   Jan 07   Jan 08

— No Turbine Data

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Results last winter

Winter 2017-2018
(Dec 20 to Apr 30)

Conclusions

- GPEO: model to perform icing and energy loss predictions
  - Relies on output from MSC's high resolution weather operational forecasts
  - Uses algorithm for ice accretion + ablation and transfer function for energy loss
- GPEO performance
  - Overall percentages good, similar to measurements
  - Ice accretion phase reasonably predicted, abalation needs improvement
  - Accurate weather forecasts are essential!
- Good collaboration between MSC and Nergica
  - MSC provides weather data tailored to the needs of Nergica
  - Both institutions work closely together on this ongoing project

Next steps

- Improvements to GPEO:
  - Ablation model (ice shedding)
  - Transfer functions
    - For different turbine types
    - Currently exploring artificial intelligence
  - Confidence intervals for forecasts

- GPEO continuously developed, to be used in other contexts, e.g.:
  - Climatic studies
  - Site assessment