Uncertainties of Modelled Production Losses due to Icing

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Winterwind 2021, April 21st

EMD International

Introduction

- **Motivation:**
  - Losses due to icing is *(still)* an important part of windfarm pre-construction
  - Uncertainties exist in relation to the unofficial industrial standard for assessing the losses


(Windpowermonthly, 2021)

- **Presentation:**
  - Discuss the unofficial industrial standard
  - Present EMD's icing model

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Introduction

- EMD is a software-house working from the mission of:

Collecting and systematizing the **latest research**, development and experience in sustainable energy systems and translates this knowledge to innovative and value-added **software products** and consulting services for the benefit of our customers.

windPRO

Icing loss assessment for windfarm pre-construction will be based on **industry accepted standards**.

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The Unofficial Industry Standard

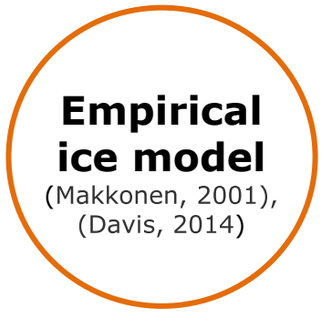
..for production loss assessment for icing.

- Outputs: Aggregated Production losses or production over time for site/WTs

The Unofficial Industry Standard

..for production loss assessment for icing.

- Outputs: Ice load, ice intensity and icing periods



Driven by:

- Modelled atmospheric data from numerical weather prediction (NWP) models

- Outputs: Aggregated Production losses or production over time for site/WTs

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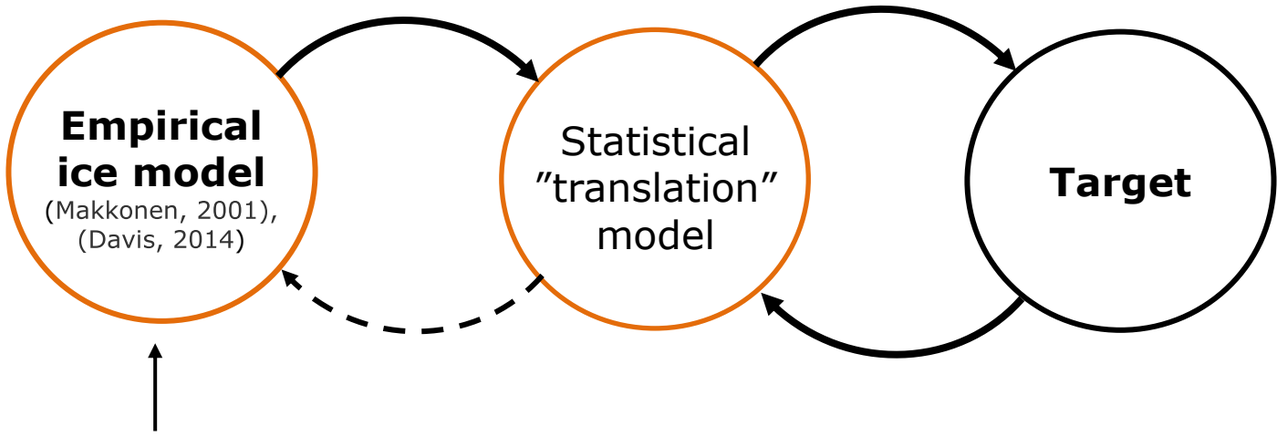

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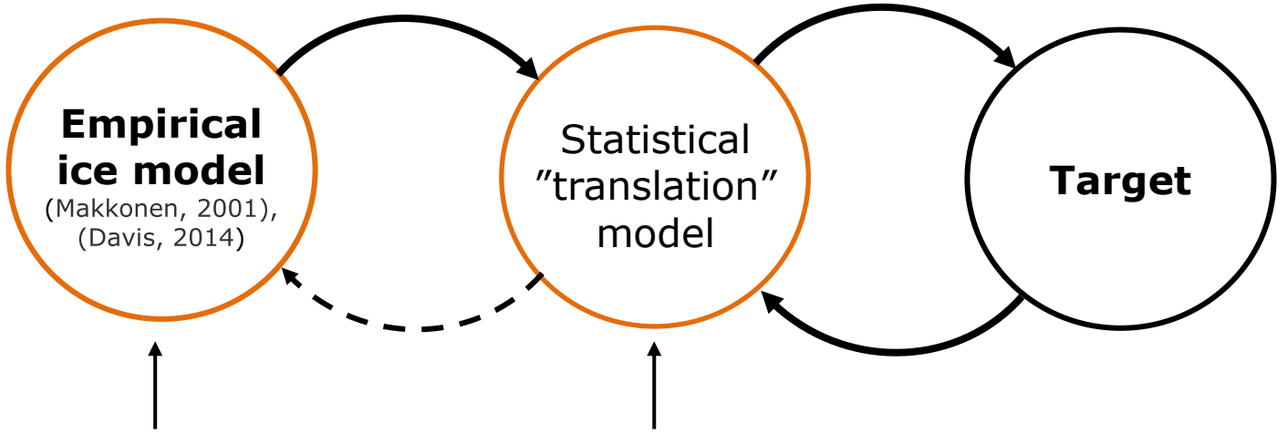

Driven by:
- Modelled atmospheric data from numerical weather prediction (NWP) models

Training/validation by:
- SCADA data from cold climates sites

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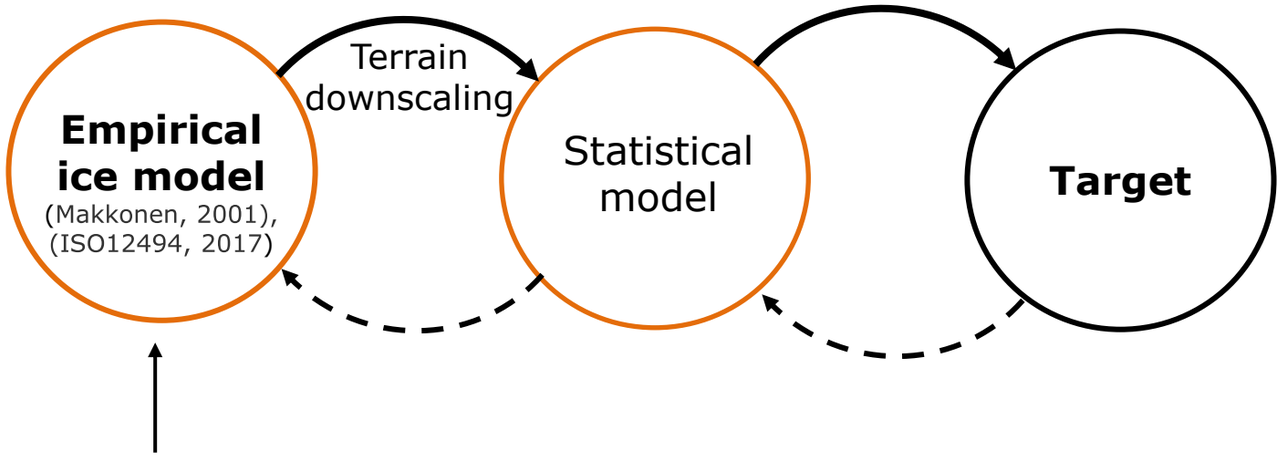
Model Development Framework at EMD

Following (ISO12494, 2017):

- Outputs: timeseries ice load, ice intensity and icing periods (active, passive icing)

- Outputs: Production losses or production over time for **site** and **WTs**



Driven by:

- EMD WRF OD (ERA5) (Thøgersen, 2021)

Based on the:

- IEA Ice Classification system
- More will come..

Uncertainties and Validation of framework

- We will validate each part of the modelling chain.
- Vattenfall has kindly provided met mast data and SCADA data for the project
  → SCADA data study ongoing during 2021

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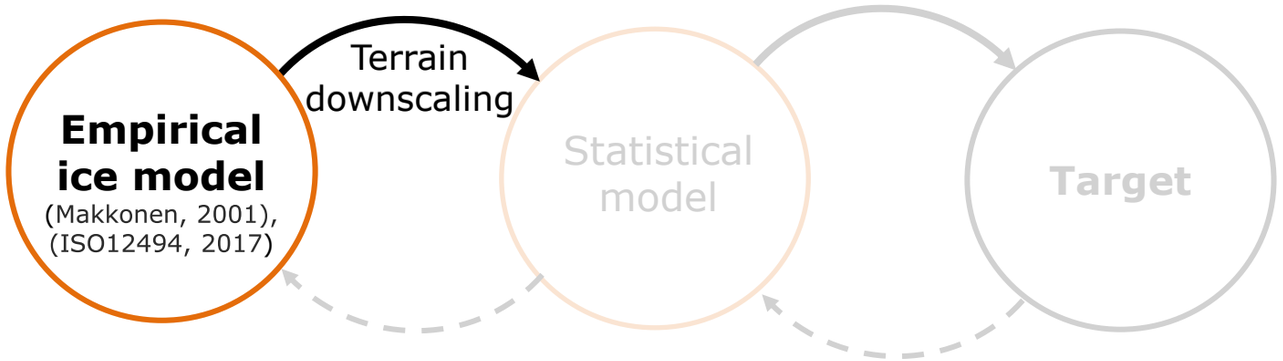
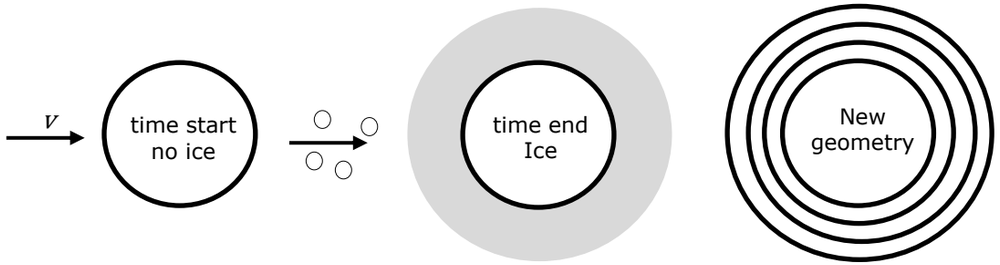


Empirical Icing Model

- Following the ISO12492 (2017) standard:

$$\frac{dM}{dt} = \eta_1\eta_2\eta_3 \cdot w \cdot v \cdot A - (\text{melting} + \text{shedding} + \text{sublimation})$$



  - The icing rate is transformed into an ice load (M_{ice}) (Makkonen, 1988)
  - Melting, shedding and sublimation is considered

- Used definitions:
  - Active icing: defined when dM/dt > 10 g/h (ISO12492, 2017)
  - Passive icing: defined when M_{ice} > 10 g (Hämäläinen, 2017)

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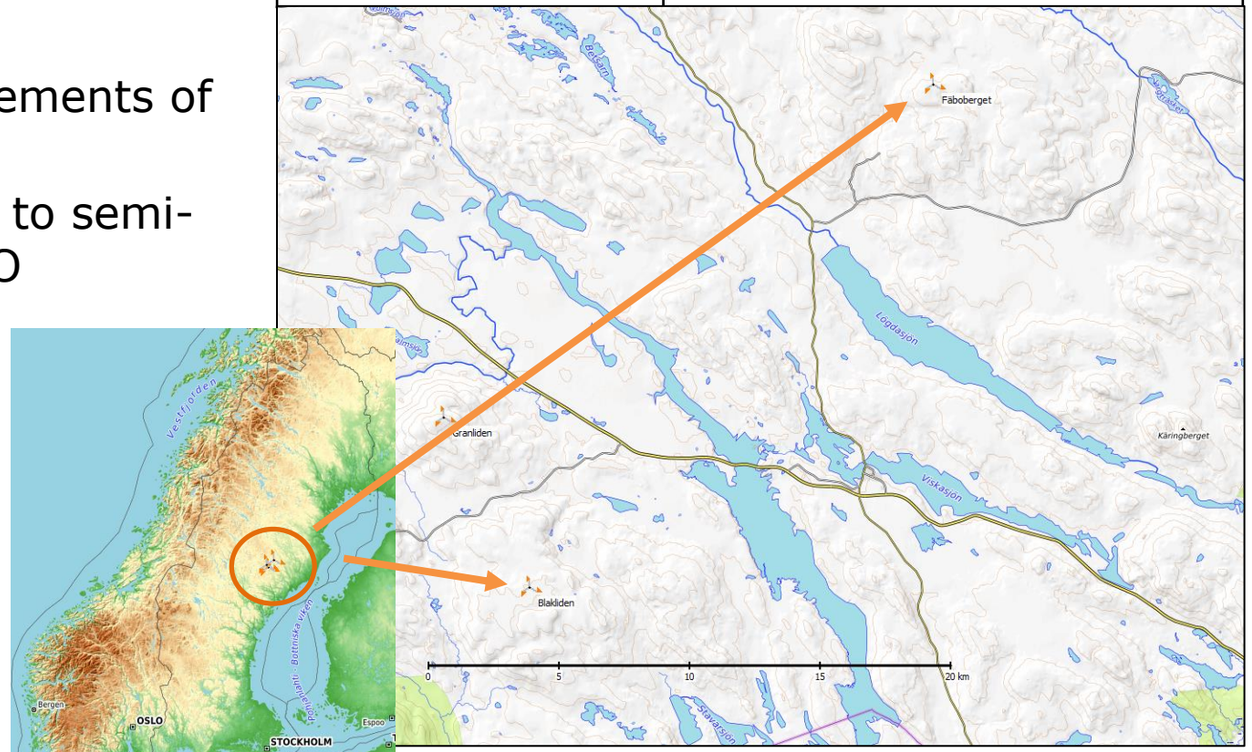
Met-Mast Data

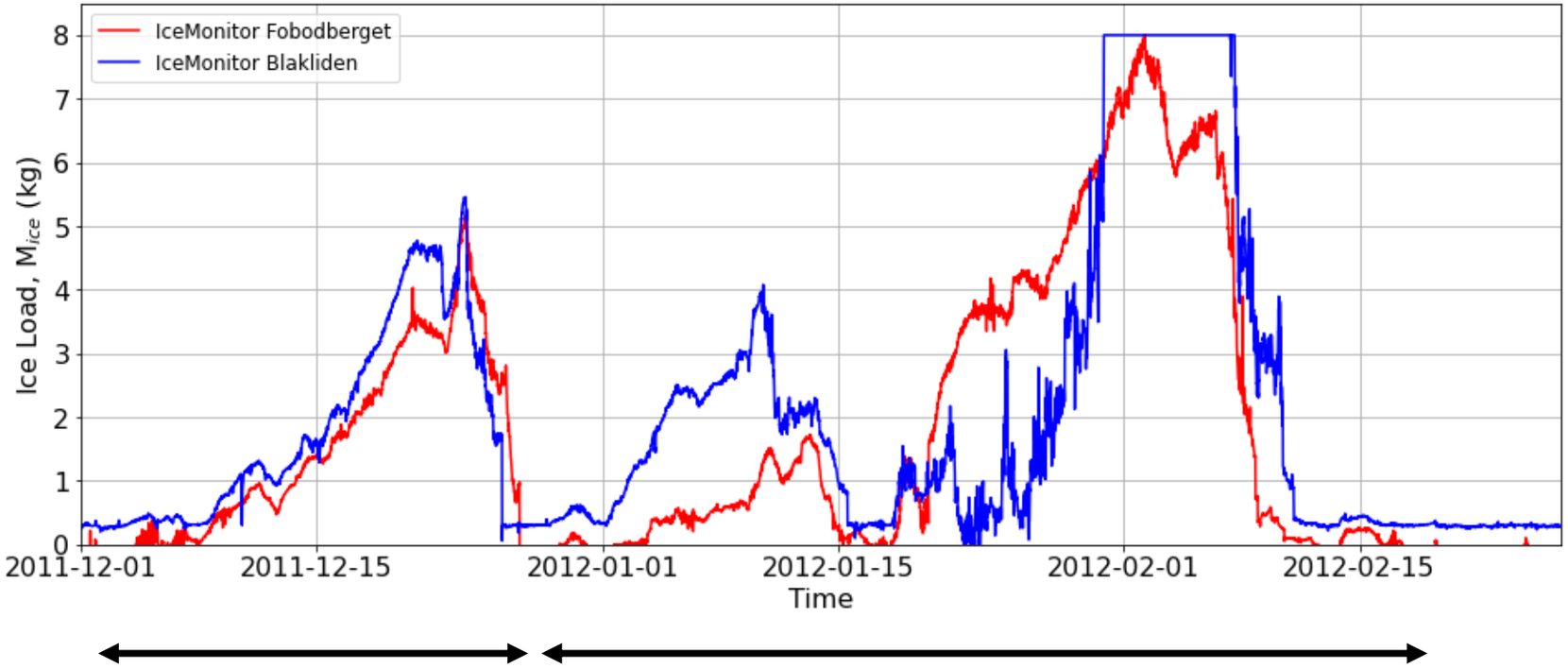
- Data from met masts close to Stor-Rotliden windfarm
  - IceMonitor data used: 2010.12.01 – 2012.04.30
- Objectives:
  - Direct comparison to the raw measurements of ice load
  - Compare modelled instrumental icing to semi-automatically screened using windPRO

Location:	Period
Blakliden, SE	2010.12.01 – 2012.04.30
Fåbodberget, SE	2010.12.01 – 2012.04.30

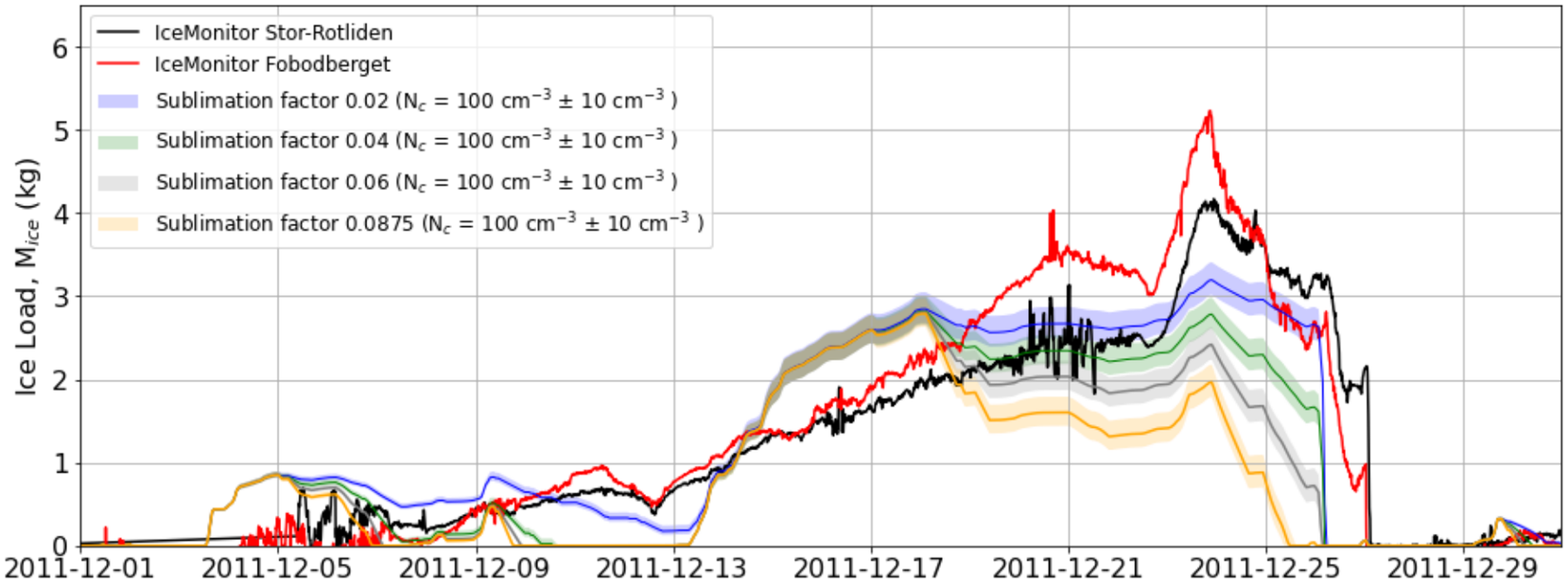


Saab Combitech IceMonitor

Met-Mast Data – measured ice load



Comparison of Modelled and Measured Ice Load



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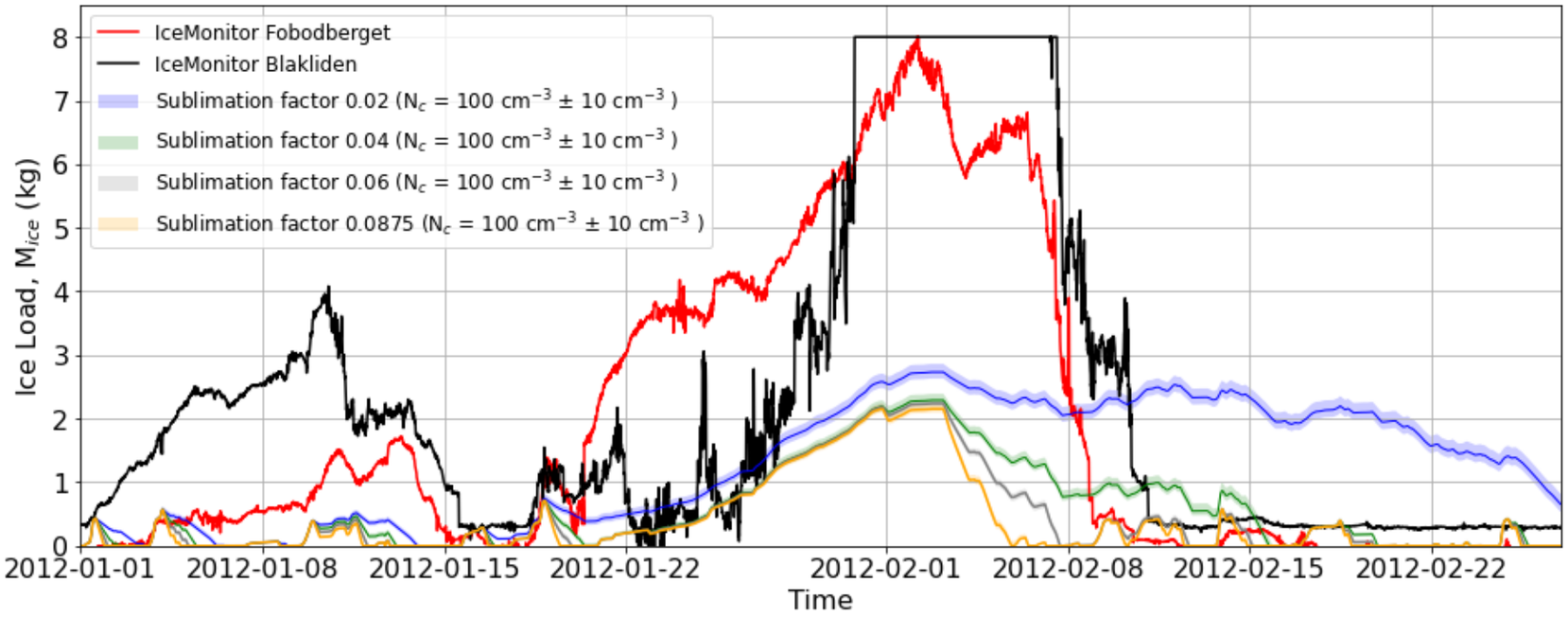
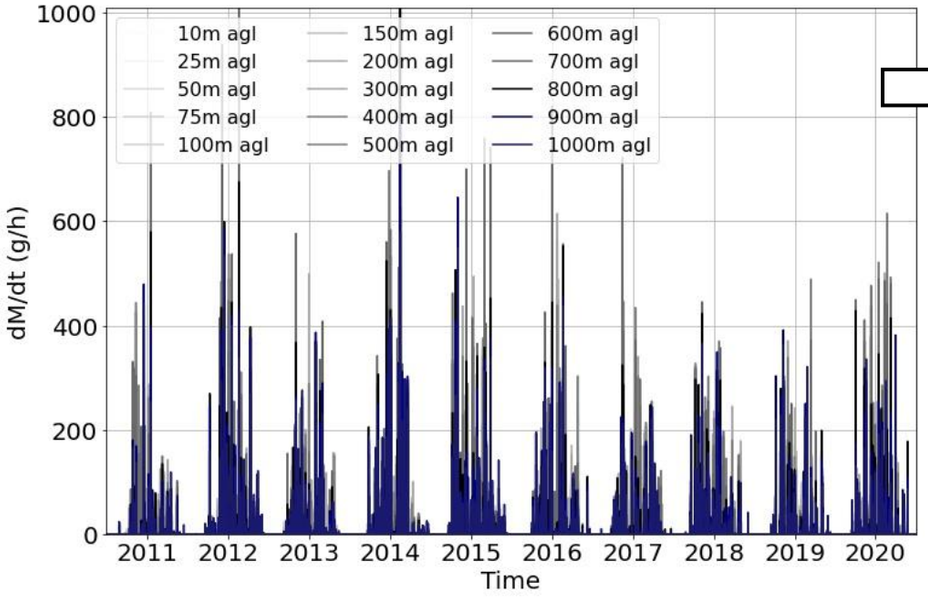
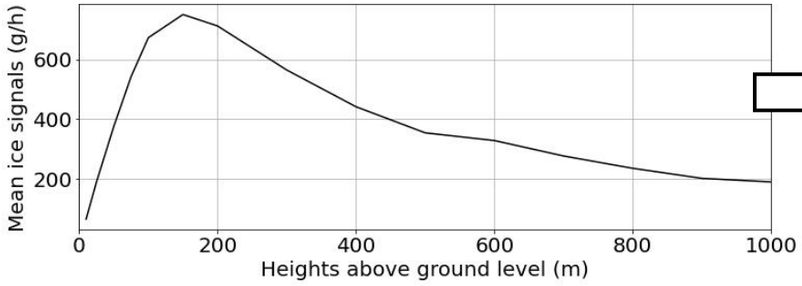
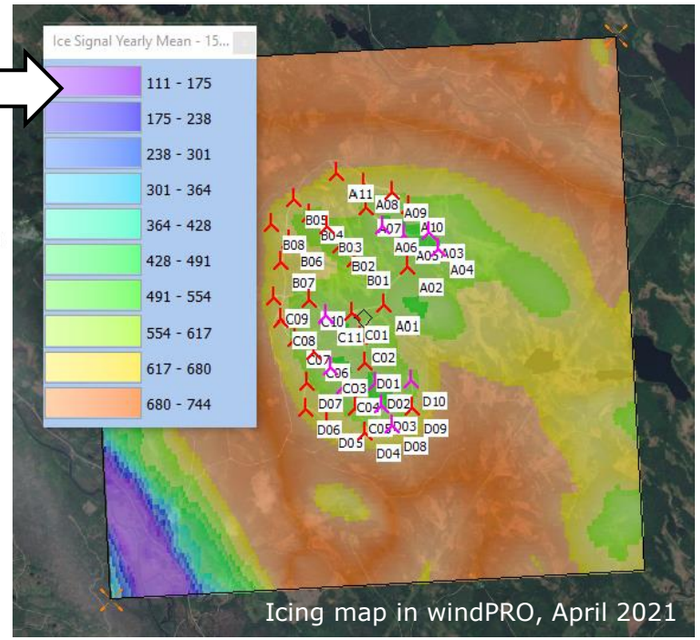


Downscaling – Icing Maps

1. Model long term icing (10 years, 13 heights above ground level)
2. Creating site specific downscaling function
3. Downscaling to real terrain height (or WT positions)







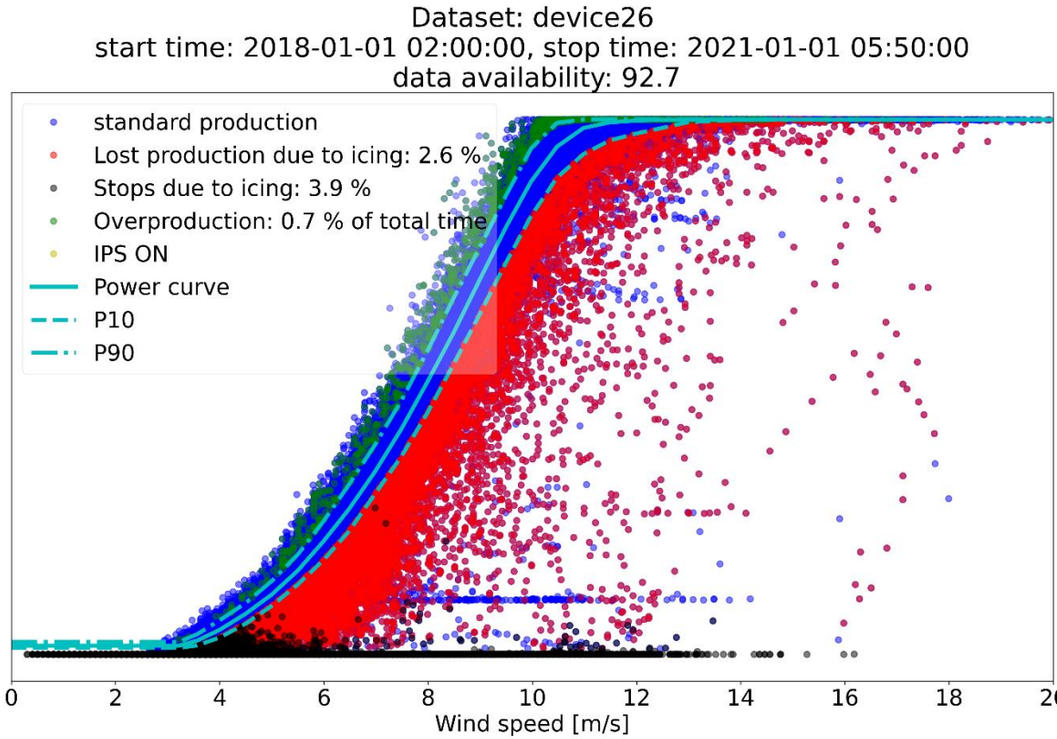
Downscaling and target Production Losses

Validation and training by SCADA data – project runs in 2021

Data from 8 windfarms (so far..)

- Identifying icing losses from SCADA data
    1. Using the T19 – Ice Loss Method
    2. Using Performance Check module in windPRO

- Compare SCADA losses to modelled losses
- Evaluate, refine and train modelling chain



Example of using the T19 tool.

Future plans

- Finalise validation studies
- Towards EMD-WRF-OD icing services
  - EMD Icing report
  - Icing maps 50m-300m
    - Mean yearly **icing hours**
    - IEA ice **class** and **loss**
  - Icing time series

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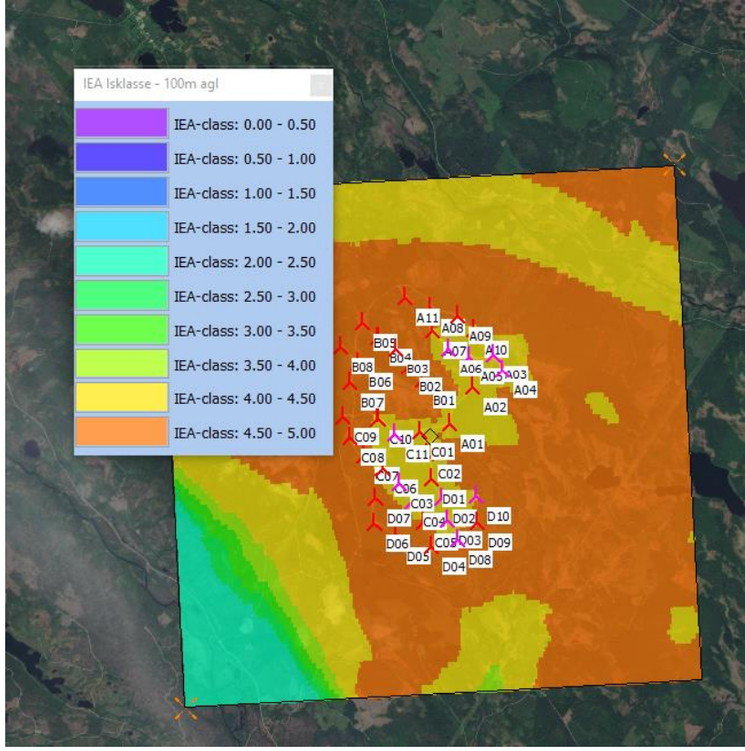

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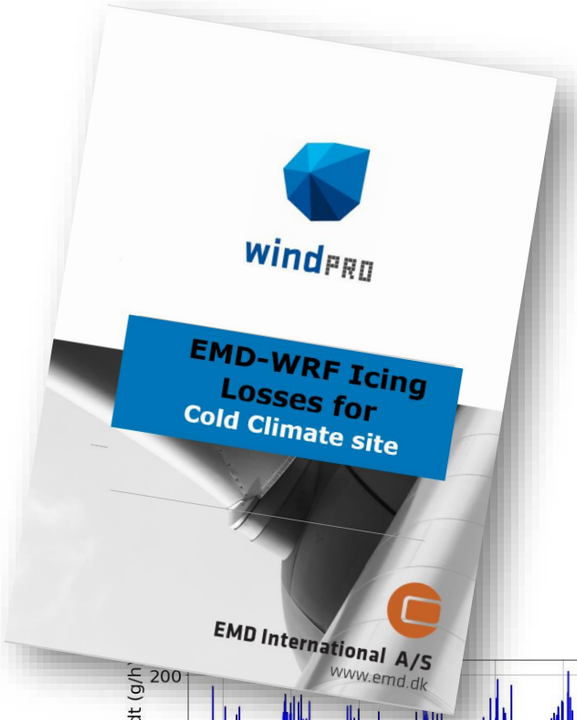

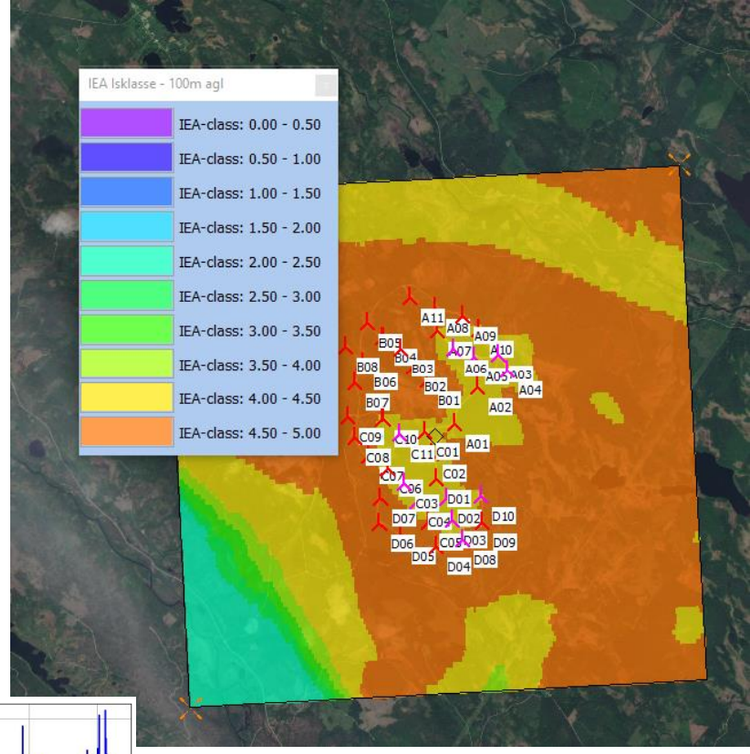

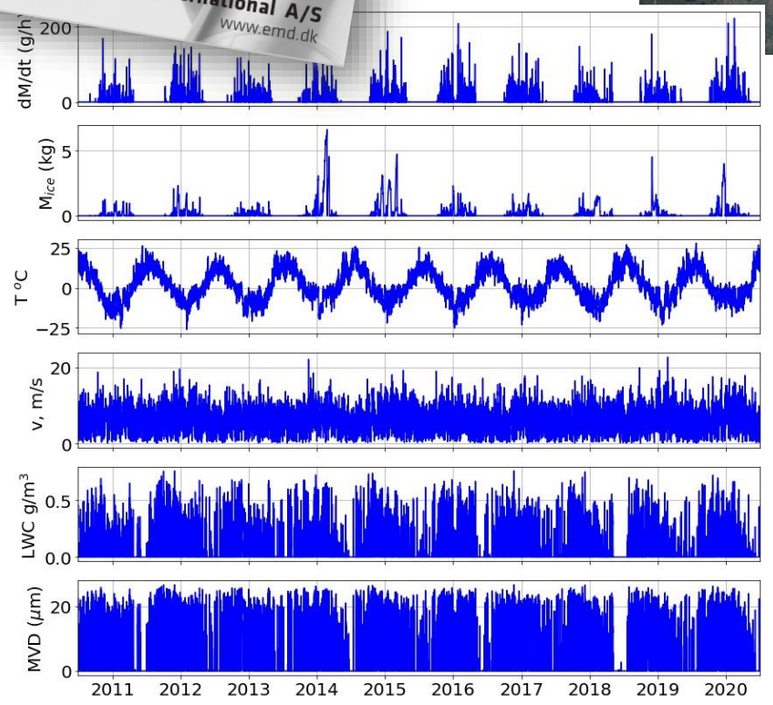

Accessible from

- EMD API-service (api.emd.dk)
- windPRO (emd.dk\windPRO)

Thank you

And special thanks to Jan Coelingh and Helena Wickman from Vattenfall.

Please do not hesitate to contact us, if You need to know more, have user inputs or want to discuss future collaborations.

Marie Cecilie Pedersen (mcp@md.dk)

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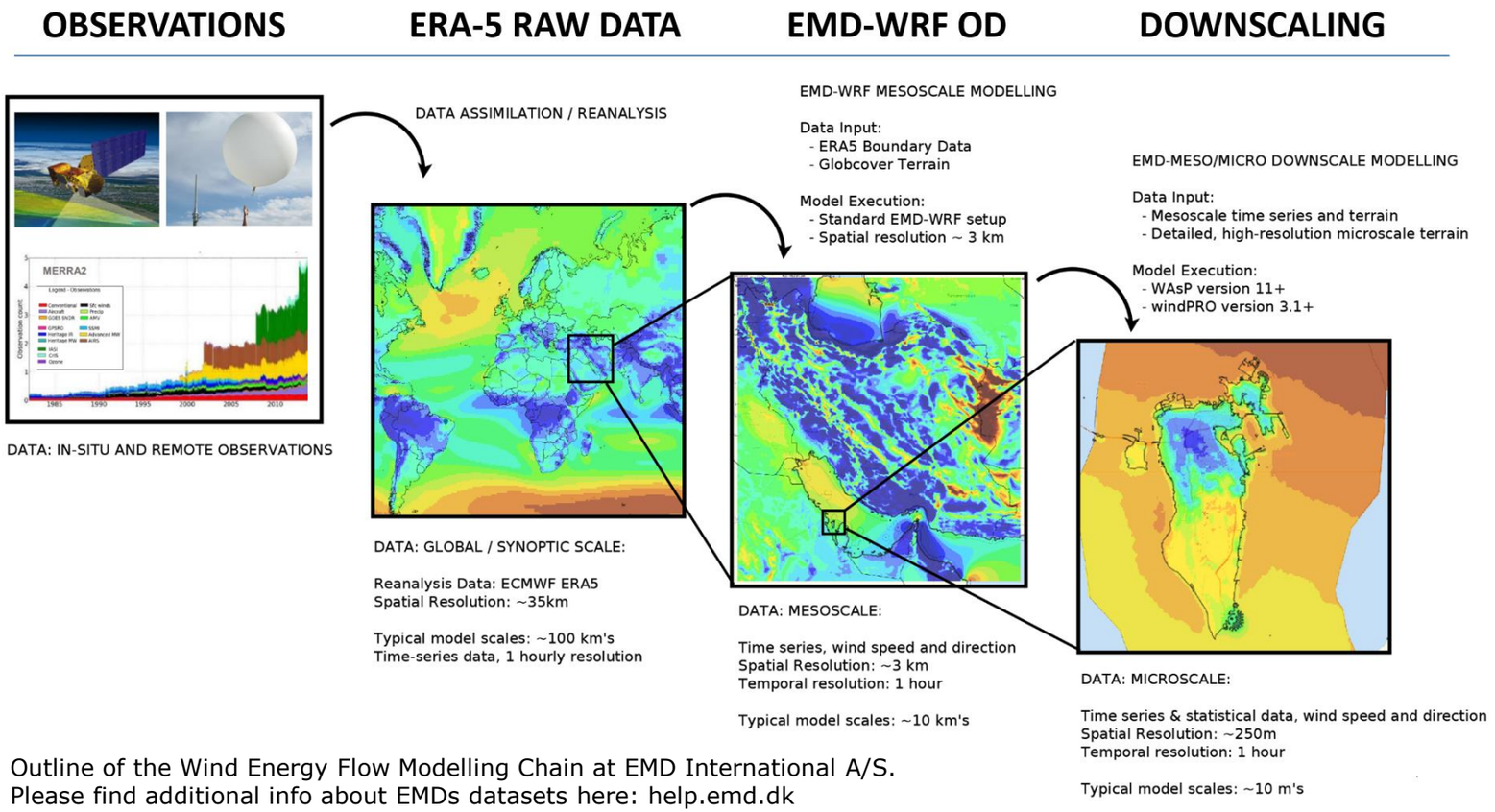
EMD-WRF On-Demand and Custom-Area

- The EMD-WRF On-Demand service is the NWP model component that is used for ice-modelling at EMD.
- Special configuration of the EMD-WRF OD model aimed at cold-climate modelling.



Outline of the Wind Energy Flow Modelling Chain at EMD International A/S.
Please find additional info about EMDs datasets here: help.emd.dk

EMD-WRF On-Demand and Custom-Area for icing

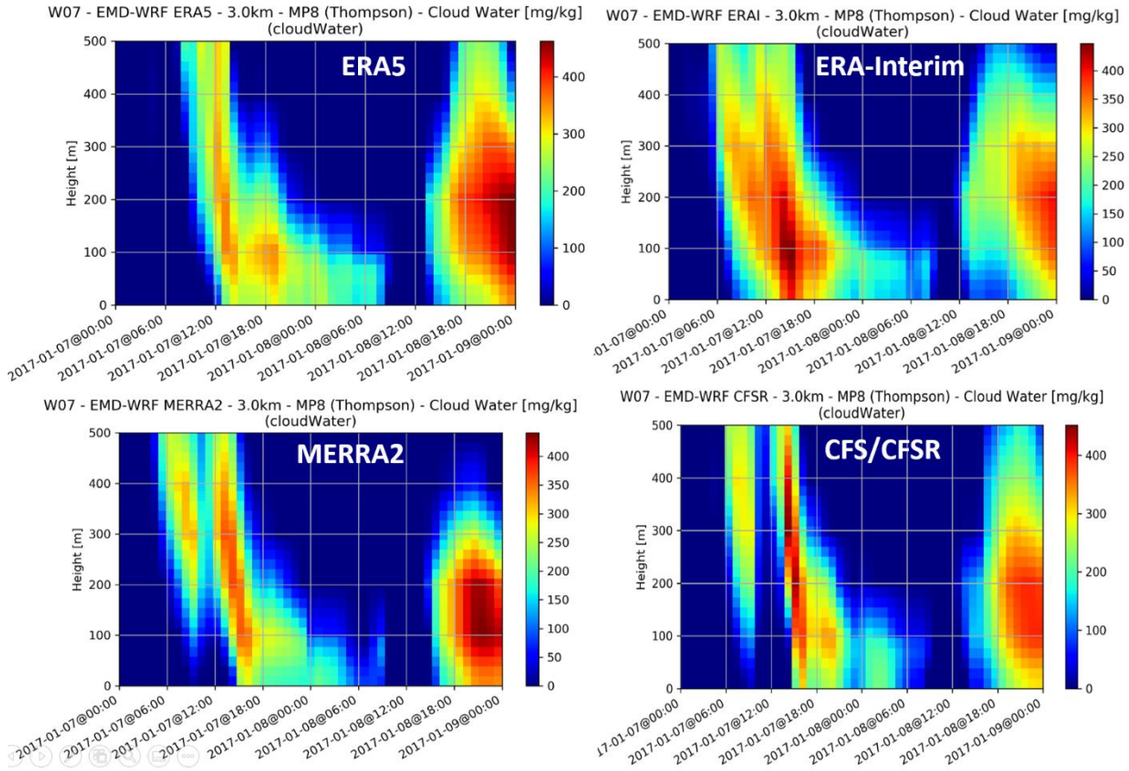
- A special configuration of the EMD-WRF OD model aimed at cold-climate modelling.
- The main model configuration parameters for this cold-climate setup are shown below.

WRF Model Setup

Spatial resolution: Varies (typically 3 km)
Time span: 10+ years
Land use: Globcover (300m), Copernicus Global Land (100m) or Corine (100m)
Global Boundary Data: ERA5 (typical), MERRA2, ERA-Interim or CFSR

WRF Parameterization Schemes

Microphysics: Thompson
Surface Layer: Janjic
Planetary boundary layer: Mellor-Yamada-Janjic
Land-surface model: Noah
Radiation: GFDL



Cloud Water Content from an Icing Event Modelled by EMD-WRF OD and with Four Different Boundary Conditions: ERA5, ERA-Interim, MERRA2 and CFS/CFSR.