# ICE CONTROL

## Measurements and probabilistic forecasting of icing events in Austria and Germany

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Austria

Germany

# ICE CONTROL Project

ZAMG (PI)
Austrian Weather Service
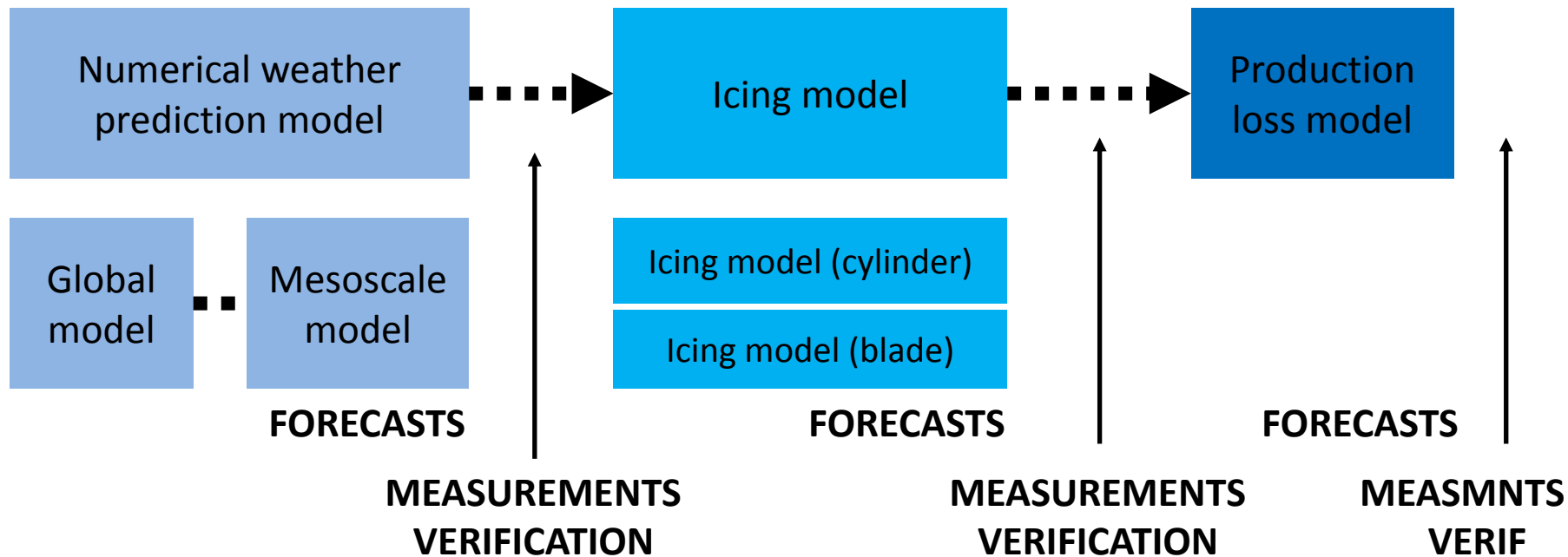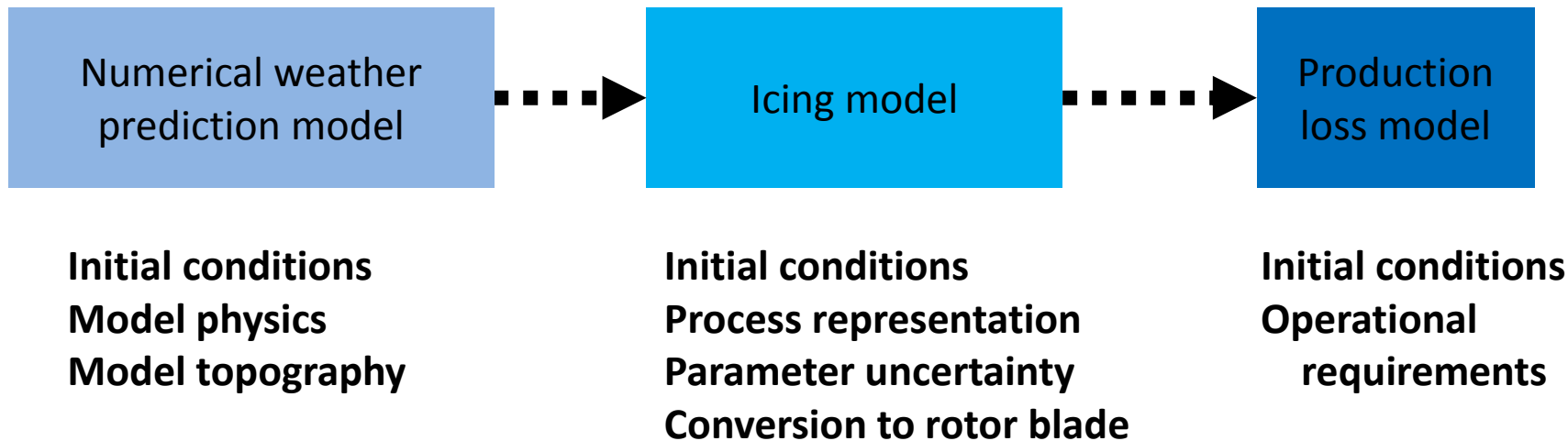
University of Vienna

VERBUND Hydro Power

Meteotest

- 04/2016 – 03/2019

- Austrian Climate and Energy Fund

- **Measurements, probabilistic forecasting and verification of icing on wind turbines**

  - Forecasts by ZAMG and University of Vienna
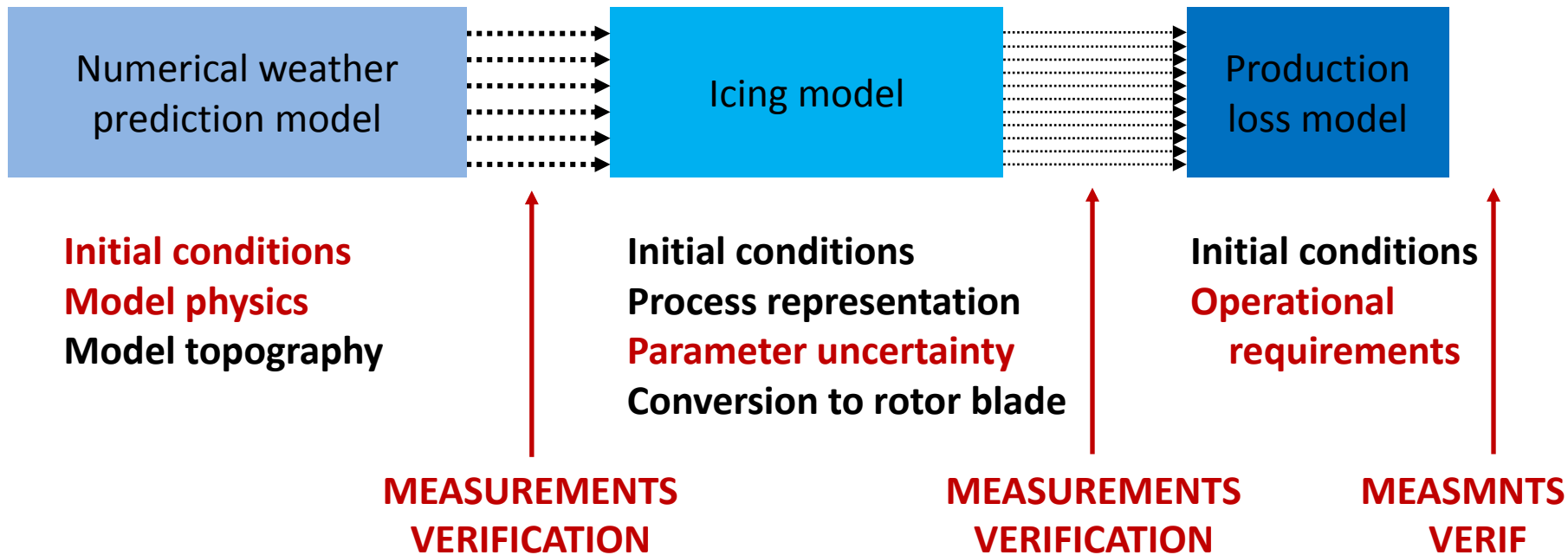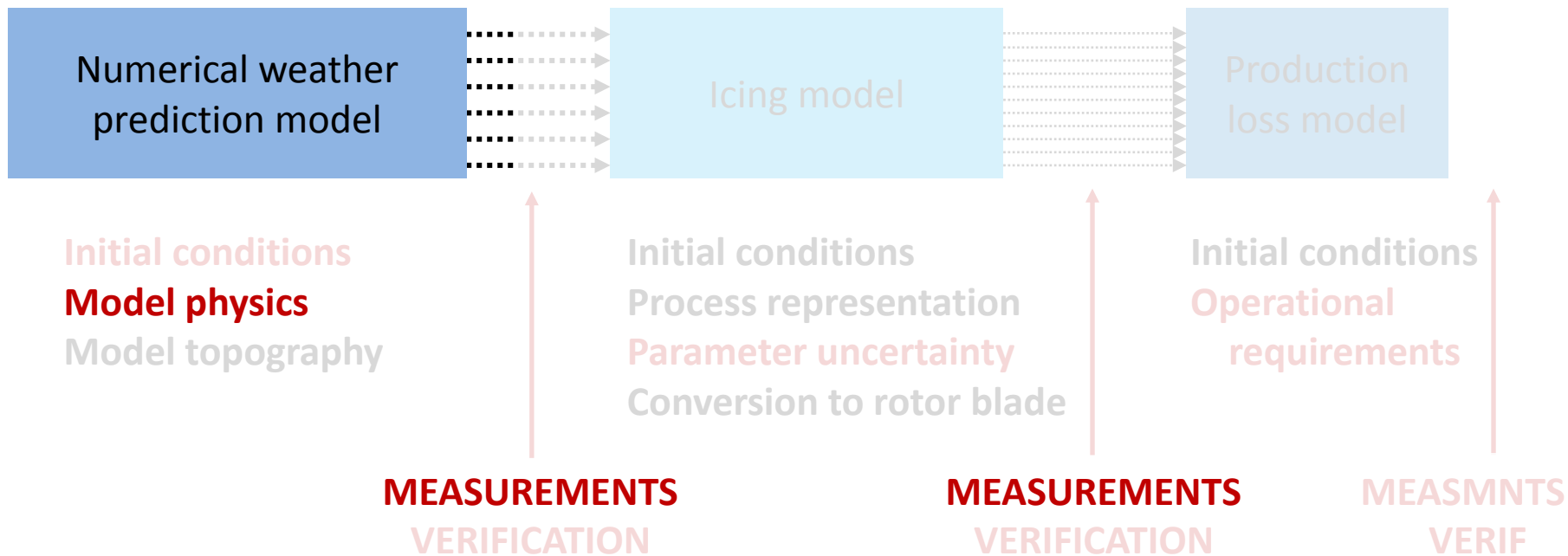  - Measurements by VERBUND and Meteotest in Germany
    Winters 2016/17, 2017/18

Lukas Strauss

http://imgw.univie.ac.at/en/research/amk/projects/ice_control

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## "Model chain"

## Model uncertainties

| Numerical weather prediction model | → | Icing model | → | Production loss model |

**Numerical weather prediction model**

**Initial conditions**
**Model physics**
**Model topography**

**Icing model**

**Initial conditions**
**Process representation**
**Parameter uncertainty**
**Conversion to rotor blade**

**Production loss model**

**Initial conditions**
**Operational requirements**

# FORECASTS, MEASUREMENTS & VERIFICATION

## Probabilistic forecasts

| Numerical weather prediction model | Icing model | Production loss model |
|---|---|---|

**Initial conditions**
**Model physics**
**Model topography**

**Initial conditions**
**Process representation**
**Parameter uncertainty**
**Conversion to rotor blade**

**Initial conditions**
**Operational requirements**

**MEASUREMENTS VERIFICATION**

**MEASUREMENTS VERIFICATION**

**MEASMNTS VERIF**

# Probabilistic forecasts

| Numerical weather prediction model | Icing model | Production loss model |
|---|---|---|

**Initial conditions**
**Model physics**
**Model topography**

**Initial conditions**
**Process representation**
**Parameter uncertainty**
**Conversion to rotor blade**

**Initial conditions**
**Operational requirements**

**MEASUREMENTS**
**VERIFICATION**

**MEASUREMENTS**
**VERIFICATION**

**MEASMNTS**
**VERIF**

# MEASUREMENTS



Ellern, Rhineland-Palatinate, Germany
Wind farm owned by VERBUND

# MEASUREMENTS





Hilly terrain in the Hunsrück Range
Up to 350 m above the surroundings
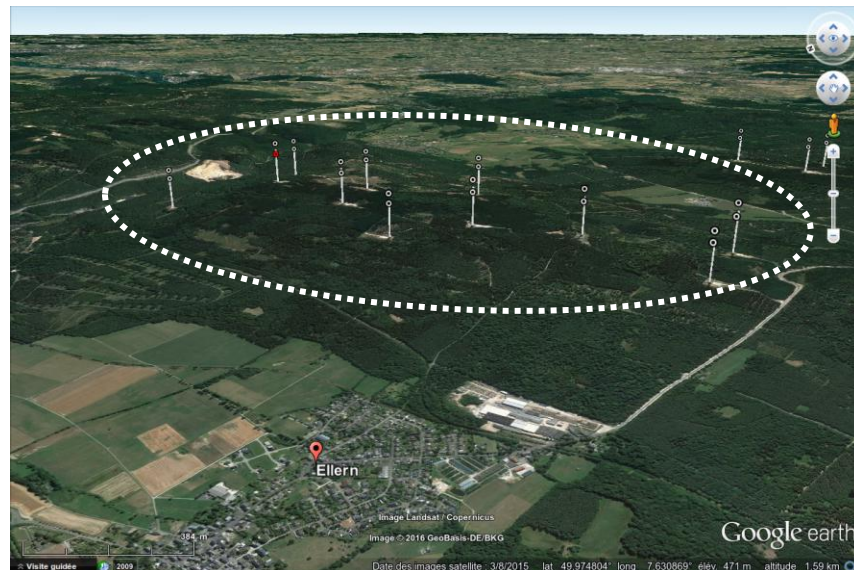
6 Enercon E-101          Total nominal capacity
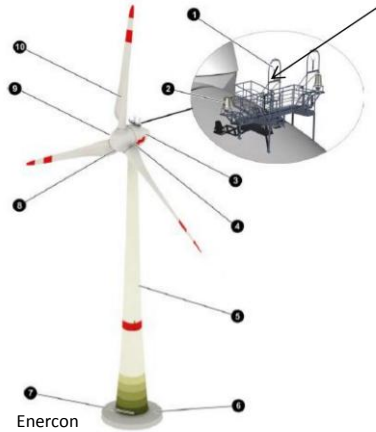5 Enercon E-126                          55 MW

# MEASUREMENTS



**Ellern
wind farm**

VERBUND

2017-01-02 16:35 UTC

2017-01-26 13:30 UTC

**Production losses
5-10 %**

# MEASUREMENTS

Enercon

VERBUND
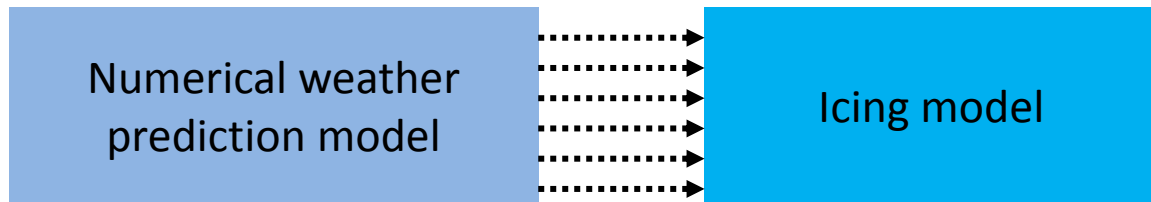
- Rotronic Sensor (T, RH)
- Thies Laser Distrometer (0.125 mm – 8 mm)
- Fog-Monitor FM-120 (2 µm – 50 µm)
- PWD 12 (visibility)
- Combitech IceMonitor
- eologix sensors
  2 on nacelle
  26 on rotor blades
- 3 web cams

# FORECASTS



| Numerical weather prediction model | ---> | Icing model |
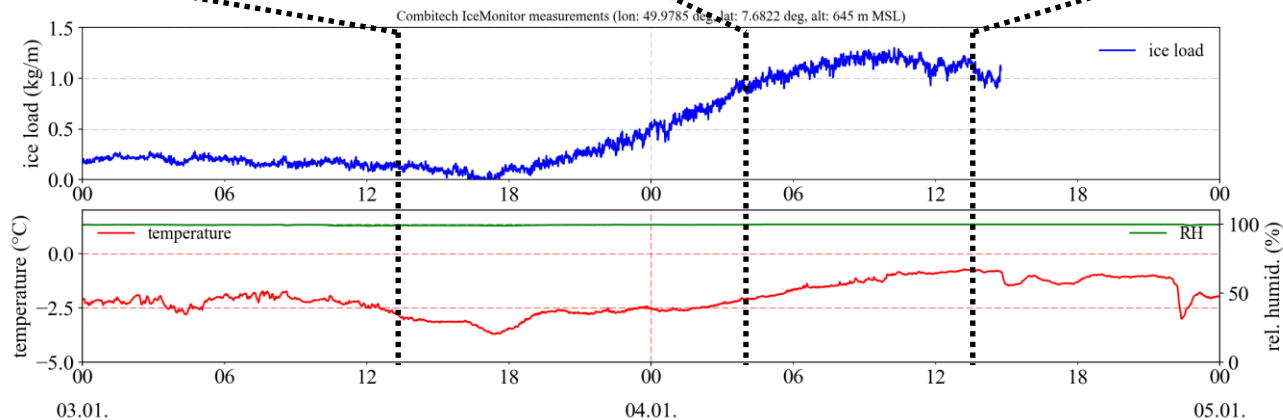
**Initial conditions**
<span style="color:red">**Model physics**</span> <---
**Model topography**

- **Land-surface**
- **Surface layer**
- **Boundary layer**
- **Microphysics**
- **Convection**
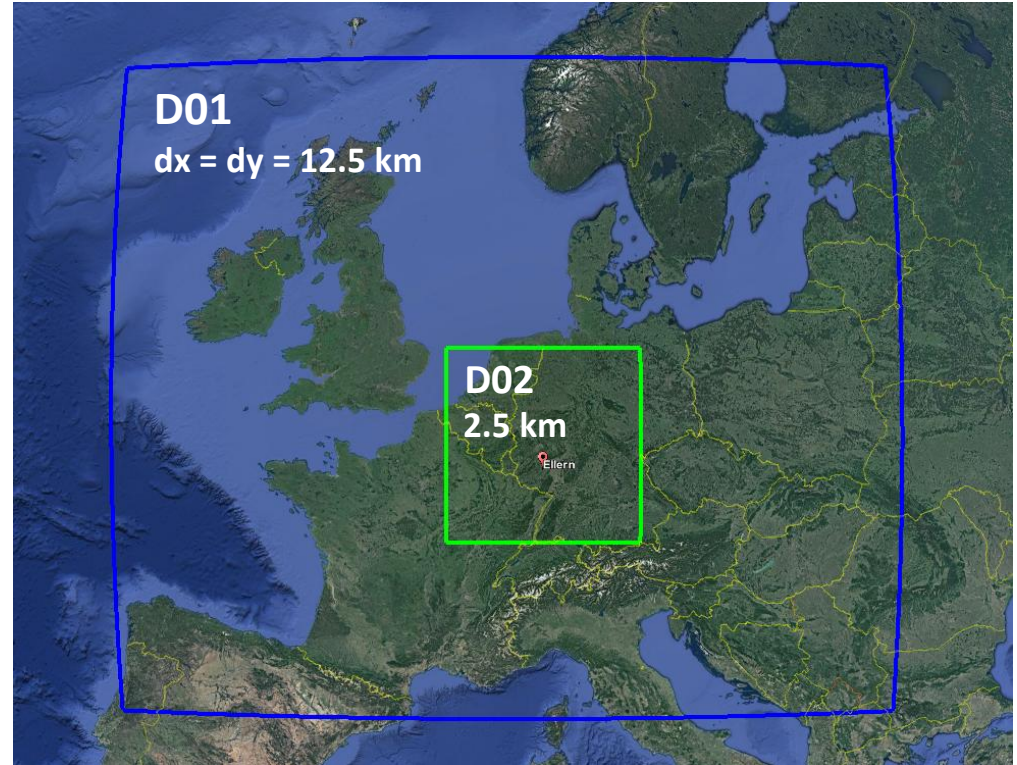- **Cloud fraction**
- **...**

**WRF**

<span style="color:red">**Are model physics uncertainties important for icing forecasts?**</span>

# FORECASTS

## WRF

- 10-member ensemble
- 2-domain configuration
  12.5 km, 2.5 km
- ICs from ECMWF EPS members
- Various **sets of physics schemes**



D01
dx = dy = 12.5 km

D02
2.5 km
Ellern

## WRF

- 10-member ensemble
- 2-domain configuration
  12.5 km, 2.5 km
- ICs from ECMWF EPS members
- Various **sets of physics schemes**
  - Land-surface
  - Surface layer
  - Boundary layer
  - Microphysics
  - Convection
  - Cloud fraction
  - ...

| ECMWF EPS Member | WRF ENSEMBLE DYN | WRF ENSEMBLE PHYS |
|:---:|:---|:---|
| 0 | Physics Set 1 (*) | Physics Set 1 |
| 1 | Physics Set 1 | Physics Set 2 |
| 2 | Physics Set 1 | Physics Set 3 |
| 3 | Physics Set 1 | Physics Set 4 |
| 4 | Physics Set 1 | Physics Set 5 |
| 5 | Physics Set 1 | Physics Set 6 |
| 6 | Physics Set 1 | Physics Set 7 |
| 7 | Physics Set 1 | Physics Set 8 |
| 8 | Physics Set 1 | Physics Set 9 |
| 9 | Physics Set 1 | Physics Set 10 |

(*) Physics Set 1: Schemes used in NOAA/NCEP operational
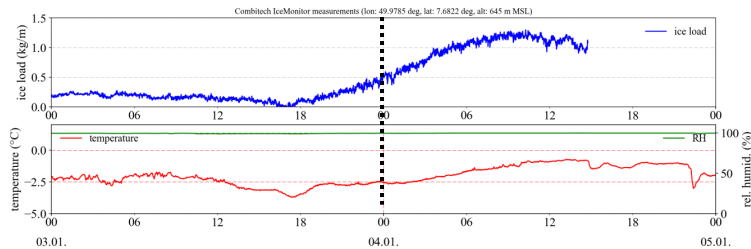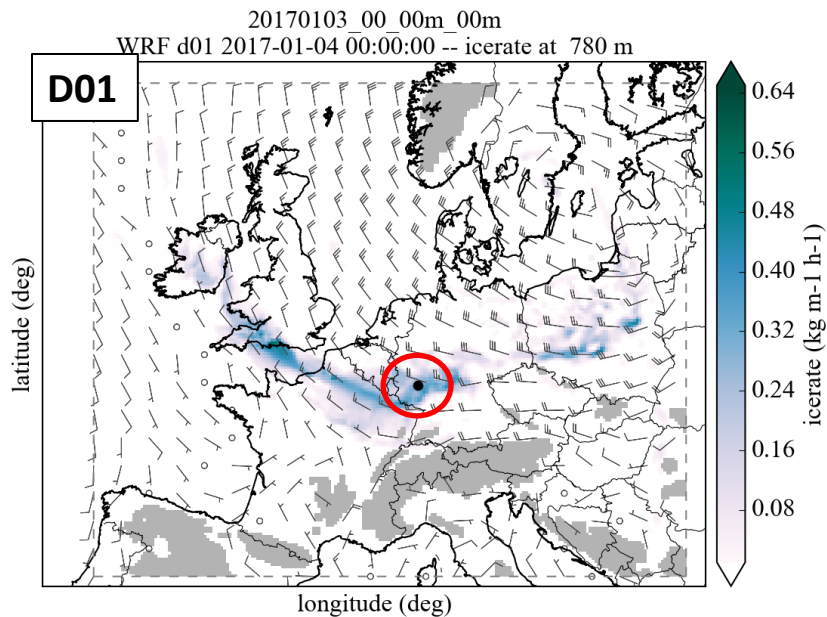models (Benjamin et al. 2016, MWR)

# CASE STUDY: 3-4 Jan 2017

**DYN**

**4 Jan
00 UTC**

**780 m**



20170103_00_00m_00m
WRF d01 2017-01-04 00:00:00 -- icerate at 780 m



**Icing rate**

$$\frac{\mathrm{d}M}{\mathrm{d}t} = \alpha_1 \alpha_2 \alpha_3 w \boldsymbol{v} A$$
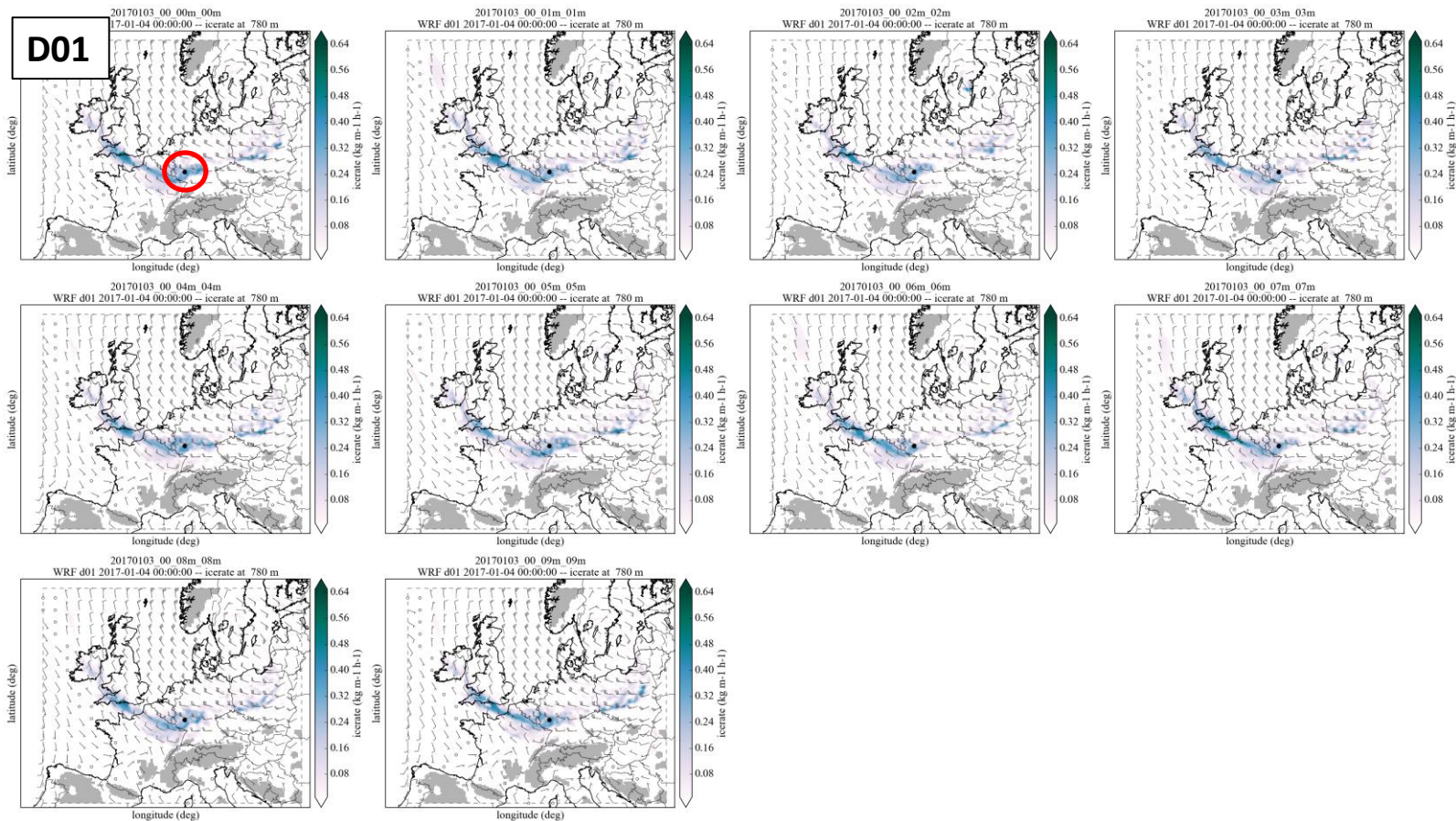
(Makkonen 2000)

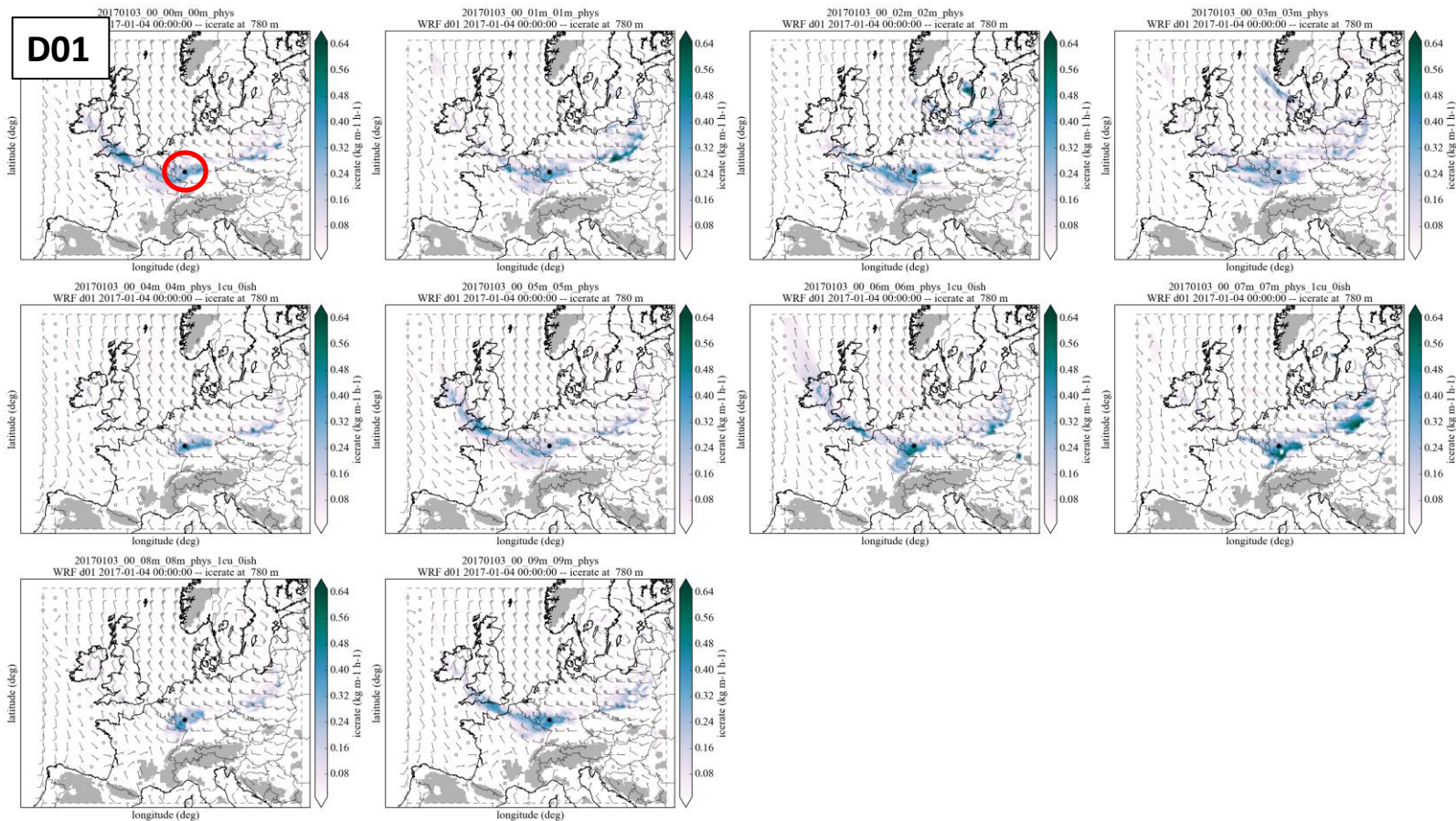# CASE STUDY:  3-4 Jan 2017

**DYN**

**4 Jan
00 UTC**

**780 m**

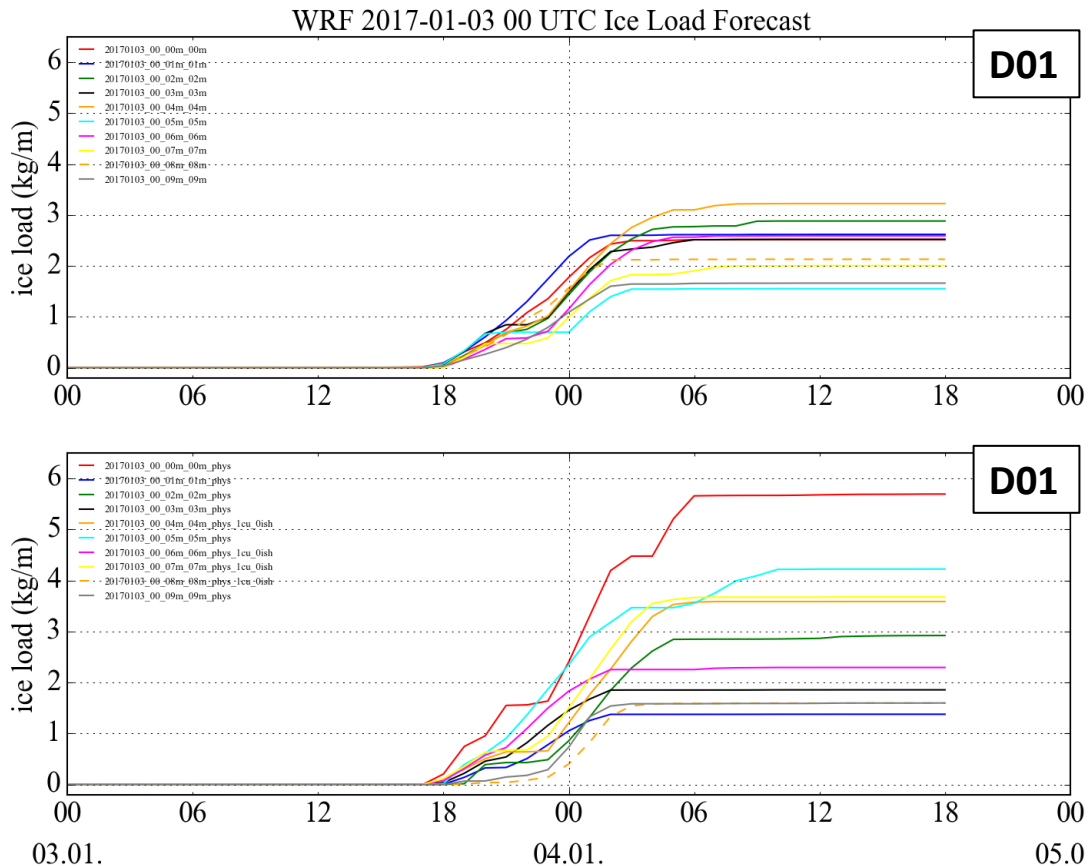# CASE STUDY: 3-4 Jan 2017

**PHYS**

**4 Jan
00 UTC**

**780 m**

# CASE STUDY: 3-4 Jan 2017

universität wien

**DYN**

**780 m turbine hub**
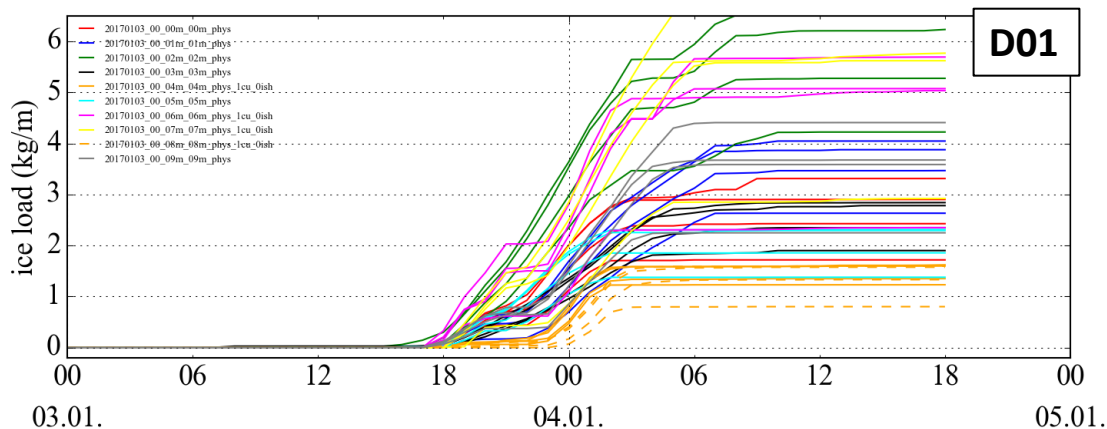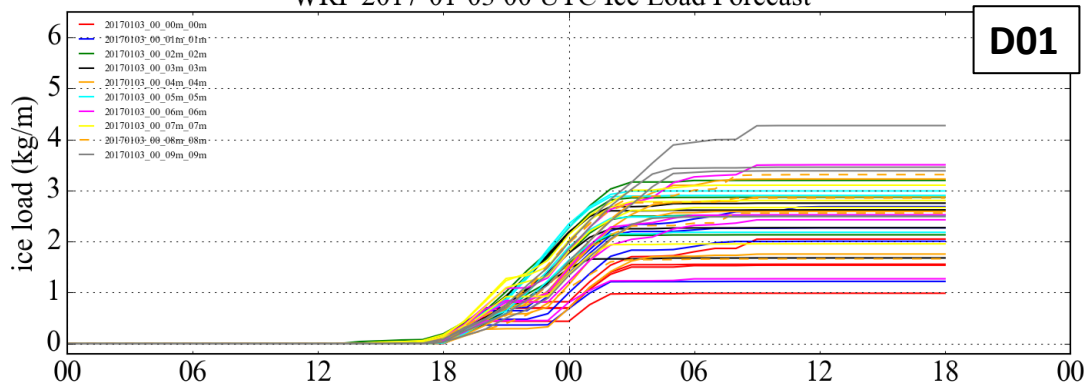
**PHYS**



WRF 2017-01-03 00 UTC Ice Load Forecast

# CASE STUDY: 3-4 Jan 2017

**DYN**

**+NEIGH**

**780 m turbine hub**

**PHYS**

**+NEIGH**



WRF 2017-01-03 00 UTC Ice Load Forecast

# SUMMARY

- The **ICE CONTROL** project aims at improving ice forecasts through
    - probabilistic forecasts, using **several approaches for the generation of meteorological ensembles** (ICs, physics parameterizations, DA)
    - **two-winter field campaigns** on site
    - **verification** at all steps of the "model chain"

- Results from the project will point to the **complexity of mesoscale ensemble prediction systems** required for **reliable icing forecasts**.

- Preliminary results suggest that **uncertainties from physics parameterizations** are substantial.

# OUTLOOK

- Evaluate **measurement data**
  - meteorological instruments
  - on-blade icing detectors (eologix)

- Further improve the **WRF PHYS and AROME ensemble configurations**
  - Run it for a **whole winter season**
  - **Verify** and **calibrate** (-> statistical significance!)

- Study **icing models**
  - Cylinder vs. blade icing models (Makkonen, iceBlade, ...)
  - Explore **parameter uncertainties**

Thanks for your attention!