# Mesoscale modelling of icing climate: Sensitivity to model and model setup

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Winterwind 2013 - Östersund

Vindforsk V-313, Wind power in cold climates

- develop methods for estimating the icing climate and production losses due to icing.

Tools:

- Observations
  wind speed, temperature, ice load, wind farm data
- Ice load model
  ISO 12494:2001 – Atmospheric icing on structures
- Mesoscale models:
  WRF, COAMPS® (US Navy), AROME (e.g., SMHI), different forcings, microphysics, and PBL schemes

## Ice measuring devices

# Observations

11 sites, 3 winter seasons: telecommunication masts, met towers, and wind turbines.

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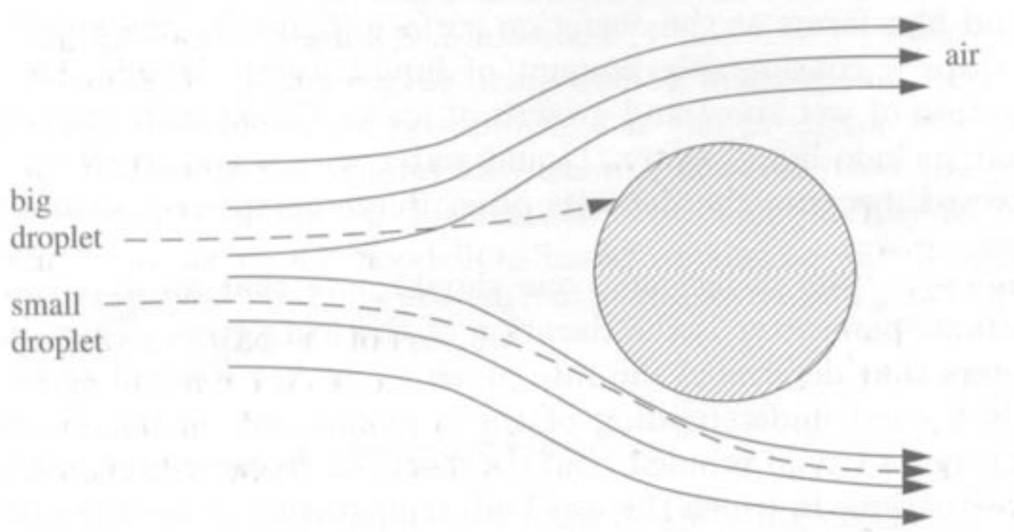
# Ice accretion model

A modified version of the "Makkonen model"

$$\frac{dM}{dt} = \alpha_1 \alpha_2 \alpha_3 w * A * \vec{V} - melt - subl$$




Assume a rotating cylinder

Growth

- $\alpha_1$ collision efficiency
- $\alpha_2$ sticking efficiency
- $\alpha_3$ accretion efficiency
- wAV water flux

Melting when T > 0 °C

- energy balance

Sublimation when T < 0 °C

- transition from ice to vapour

dM/dt = F(wind, temperature, pressure, LWC, droplet size distribution)

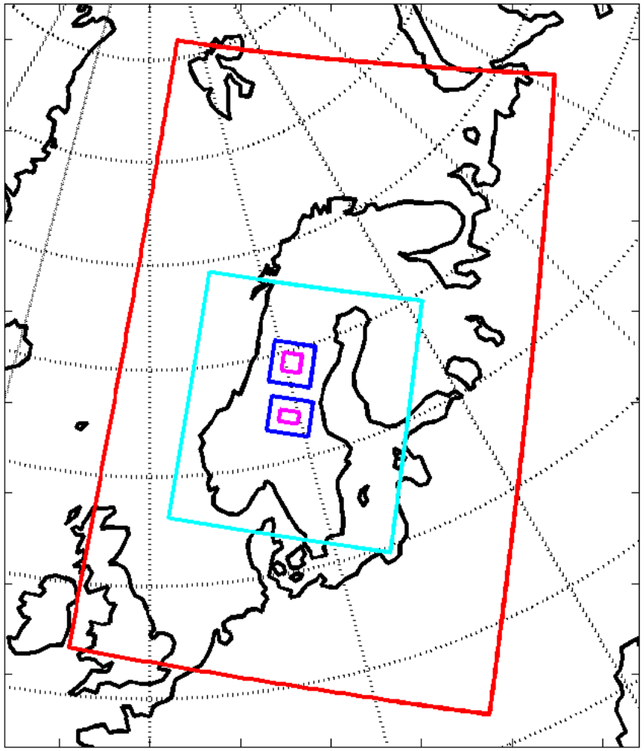
# Numerical experiment setup

Initial and lateral boundary conditions:
- i) NCEP Final Analysis (FNL from GFS)
  ii) ERA Interim
  iii) NCEP/NCAR Reanalysis

Vertical grid configuration:
- 11 levels in the lowest 300 m

Horizontal grid configuration:
- nested grids
  Outer nest: 27 x 27 $km^2$
  3:1 nest ratio
  Innermost nest: 1 x 1 $km^2$

Example of model domains



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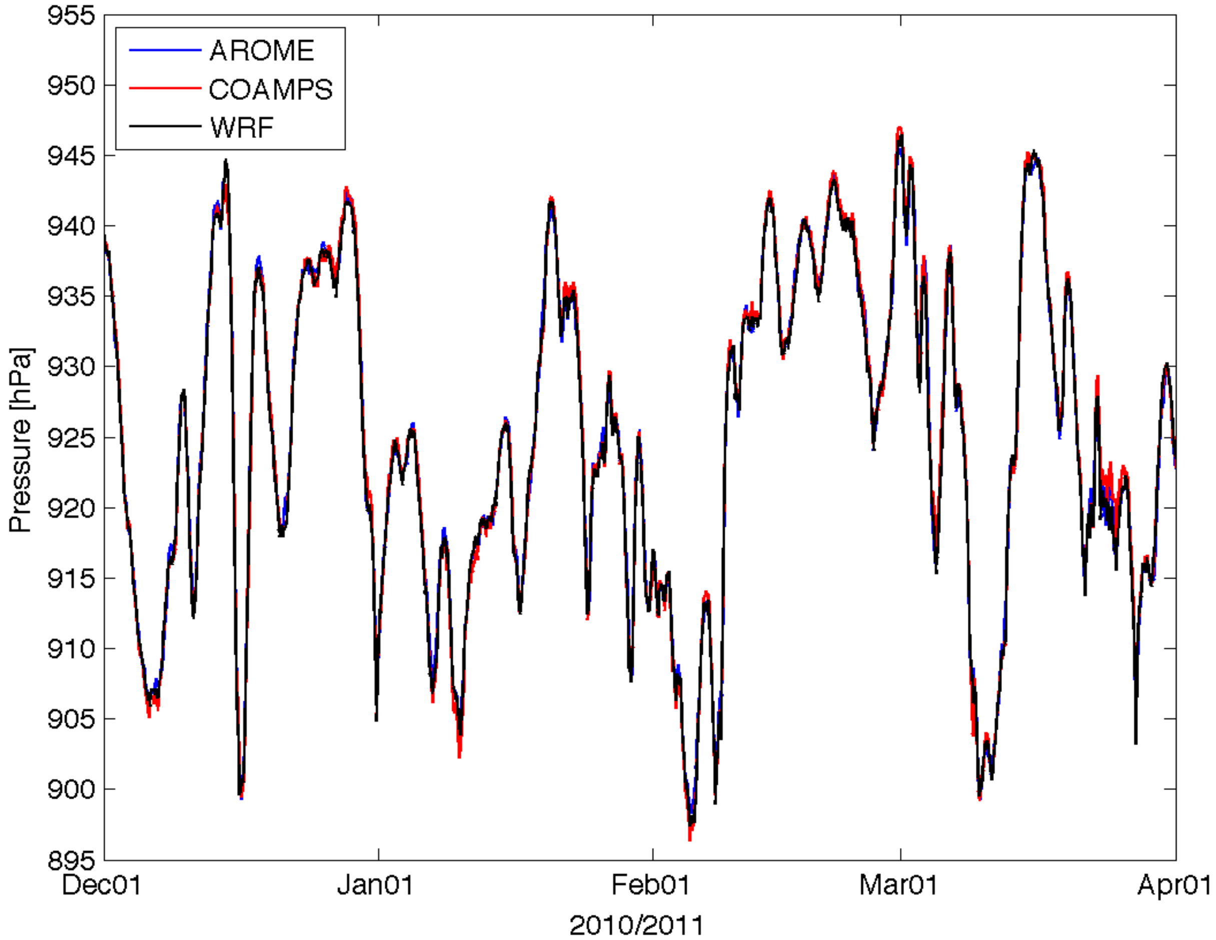
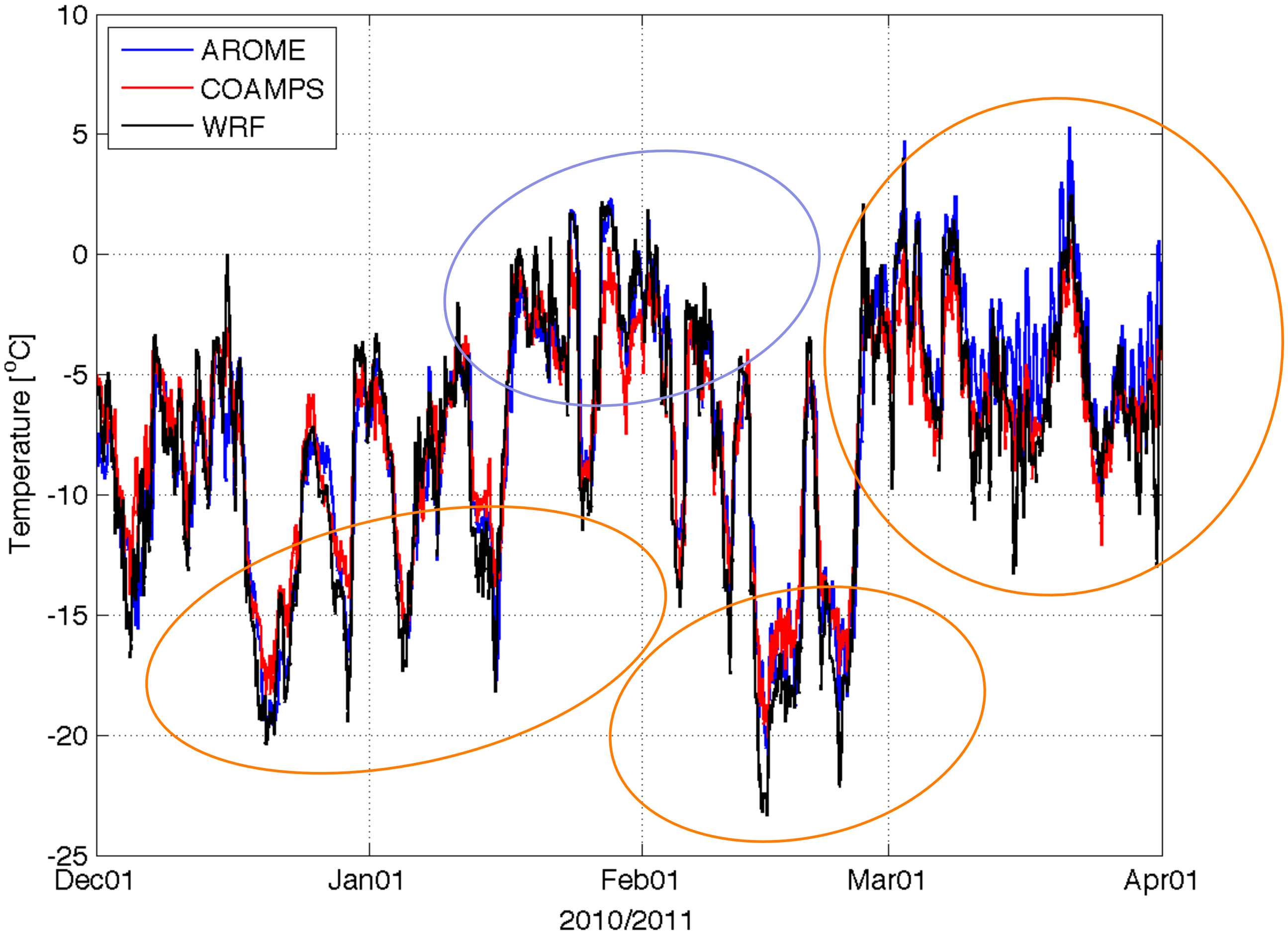
# Model results – pressure




Large scale weather systems captured in a similar way in all three models

# Model results – temperature




Differences found during cold periods and in March.

Differences in temperature close to 0 °C have a strong influence on the ice load.

# Model evaluation – brief summary

- Standard meteorological variables (wind, temperature, pressure) are well captured by all three models (AROME, COAMPS®, WRF).
- In the upcoming Vindforsk report statistics for all sites are given.

# Why so many models?

It is important to understand:

- A model is a model, not a perfect description of the real world. Each model has its strengths and weaknesses.
- A modern weather forecast model should be viewed as a model system.
- The results depend not only on choice of model but also on model setup.

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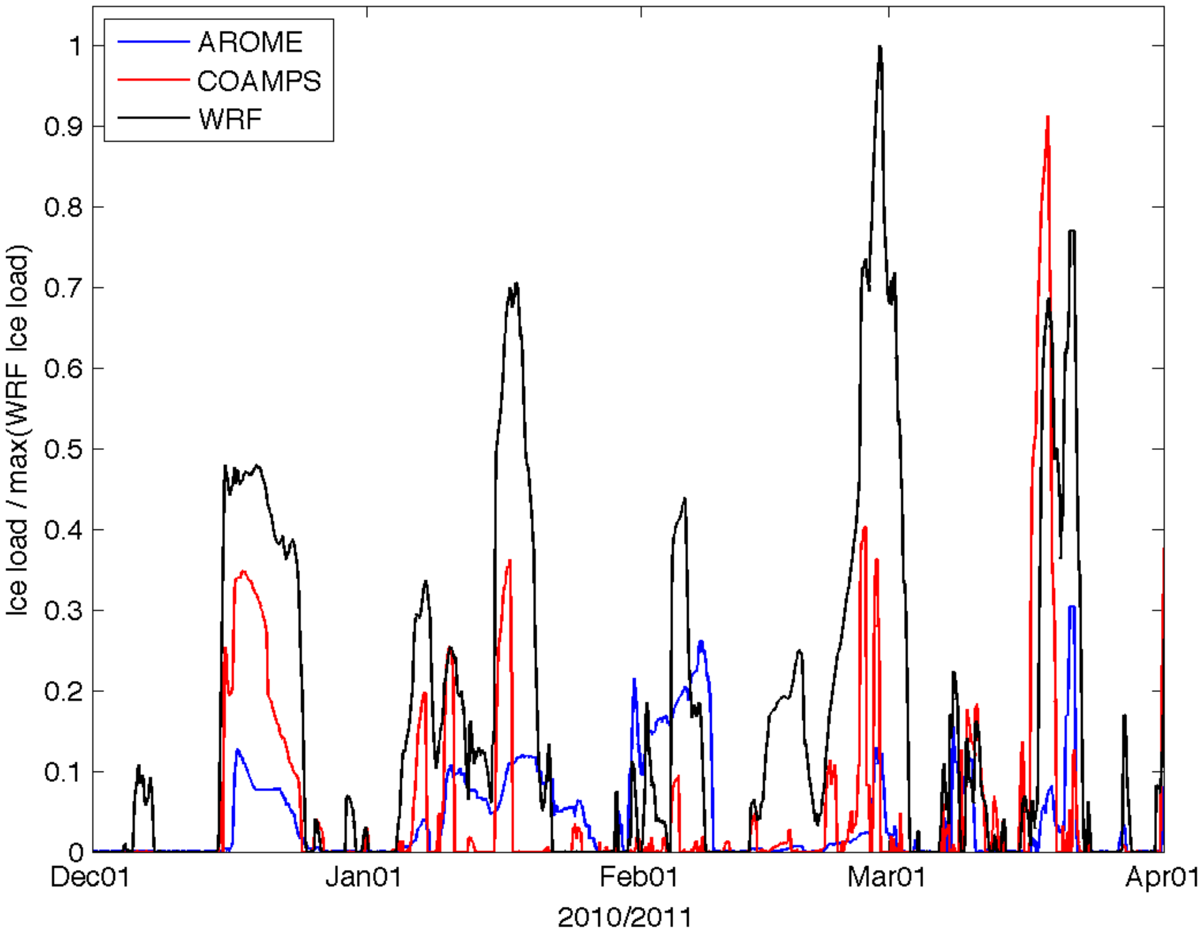
# Modelled ice load – 3 models



# Modelled ice load – 3 models

Number of hours with active icing, ice growth > 10 g/h

| | 2010/2011 | 2011/2012 |
|---|---|---|
| AROME | 138 | 337 |
| COAMPS | 290 | 641 |
| WRF | 389 | 604 |

Not the same model that gives the largest number of hours with active icing over the two seasons.

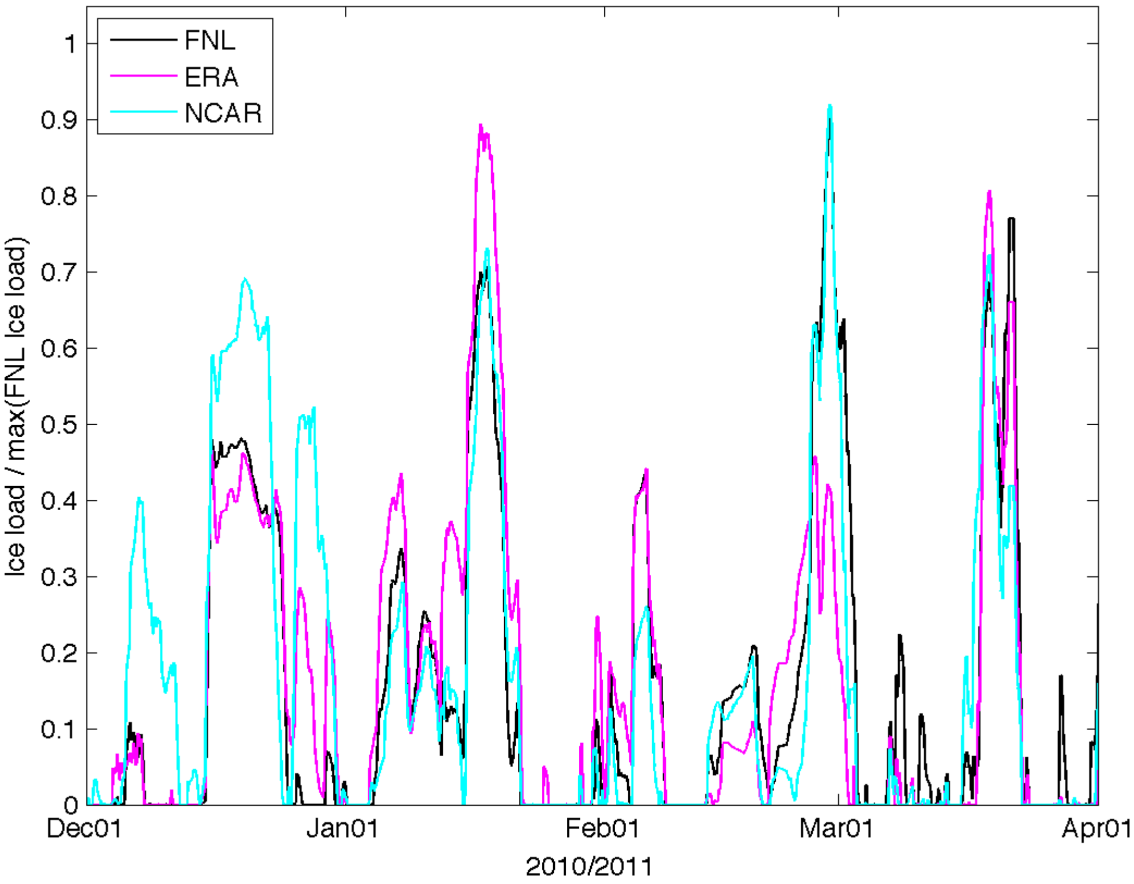
# WRF sensitivity study

| | Full name | Category | Description |
|---|---|---|---|
| **FNL** | GFS Final analysis | Forcing | Final analysis of GFS operational forecast |
| **ERA** | ERA Interim | Forcing | Re-analysis produced by ECMWF |
| **NCAR** | NCEP/NCAR | Forcing | Re-analysis produced by NCEP/NCAR |
| **WSM3** | WRF Single-Moment 3-class | Microphysics | Simple, efficient scheme with ice and snow processes |
| **WSM6** | WRF Single-Moment 6-class | Microphysics | A scheme with ice, snow and graupel processes |
| **Morr** | Morrison 2-moment | Microphysics | Prognostic mixing ratio for 6 classes and double-moment ice, snow, rain and graupel |
| **MYJ** | Mellor-Yamada-Janjic | PBL | Eta operational scheme. Prognostic turbulent kinetic energy scheme with local vertical mixing |
| **QNSE** | Quasi-Normal Scale Elimination | PBL | A TKE-prediction option that uses a new theory for stably stratified regions |
| **MYNN2** | Mellor-Yamada Nakanishi and Niino Level 3 | PBL | Predicts TKE and other second-moment terms. |

# WRF sensitivity study

| | Microphysics | PBL | Surface layer | Radiation | Land surface | Cumulus | Forcing |
|---|---|---|---|---|---|---|---|
| **FNL** | Thompson | YSU | Eta-MM5 | RRTM+ Dudhia | Noah | Kain-Fritsch | FNL |
| **ERA** | - | - | - | - | - | - | ERA |
| **NCAR** | - | - | - | - | - | - | NCEP/ NCAR |
| **wsm3** | WSM3 | - | - | - | - | - | - |
| **wsm6** | WSM6 | - | - | - | - | - | - |
| **Morr** | Morrison | - | - | - | - | - | - |
| **myj** | - | MYJ | | | | | |
| **qnse** | - | QNSE | | | | | |
| **mynn2** | - | MYNN2 | | | | | |

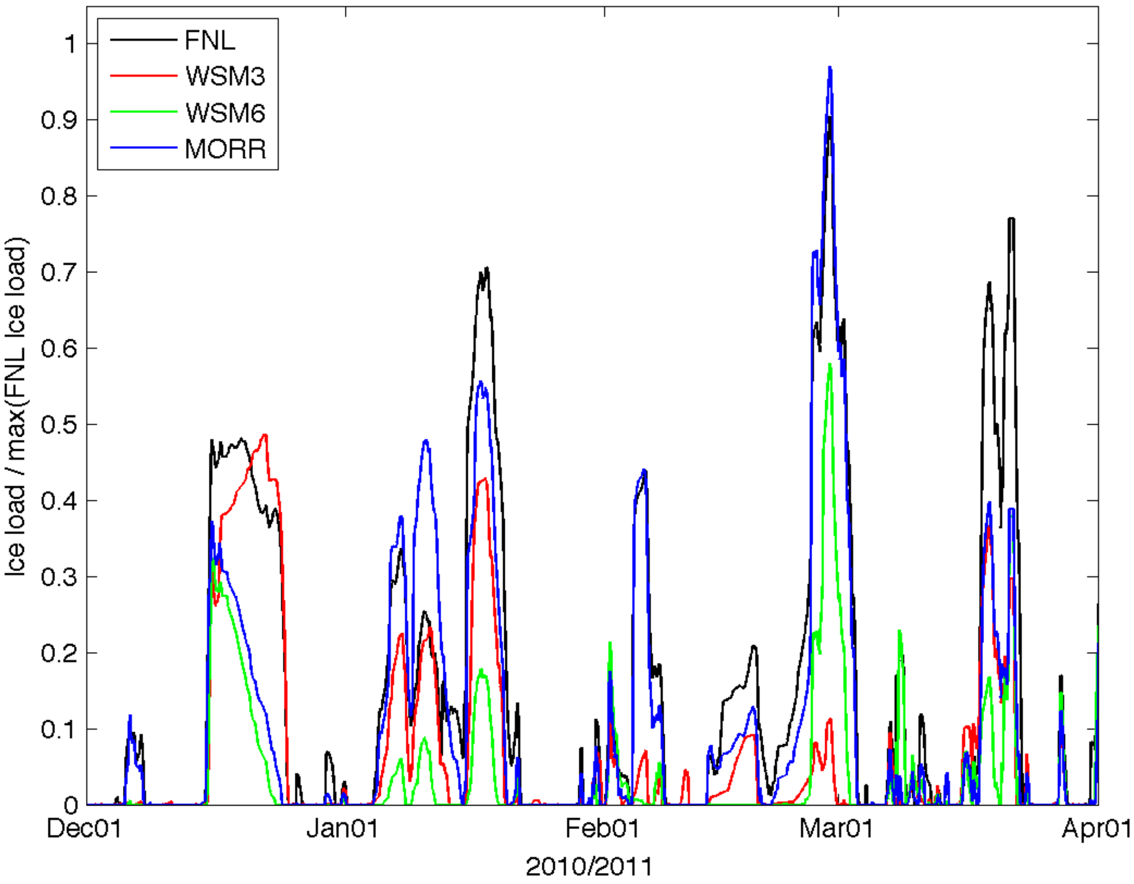
# Modelled ice load – forcing




Number of hours with active icing, ice growth > 10 g/h

| | 2010/2011 |
|---|---|
| FNL | 389 |
| ERA | 379 |
| NCAR | 337 |

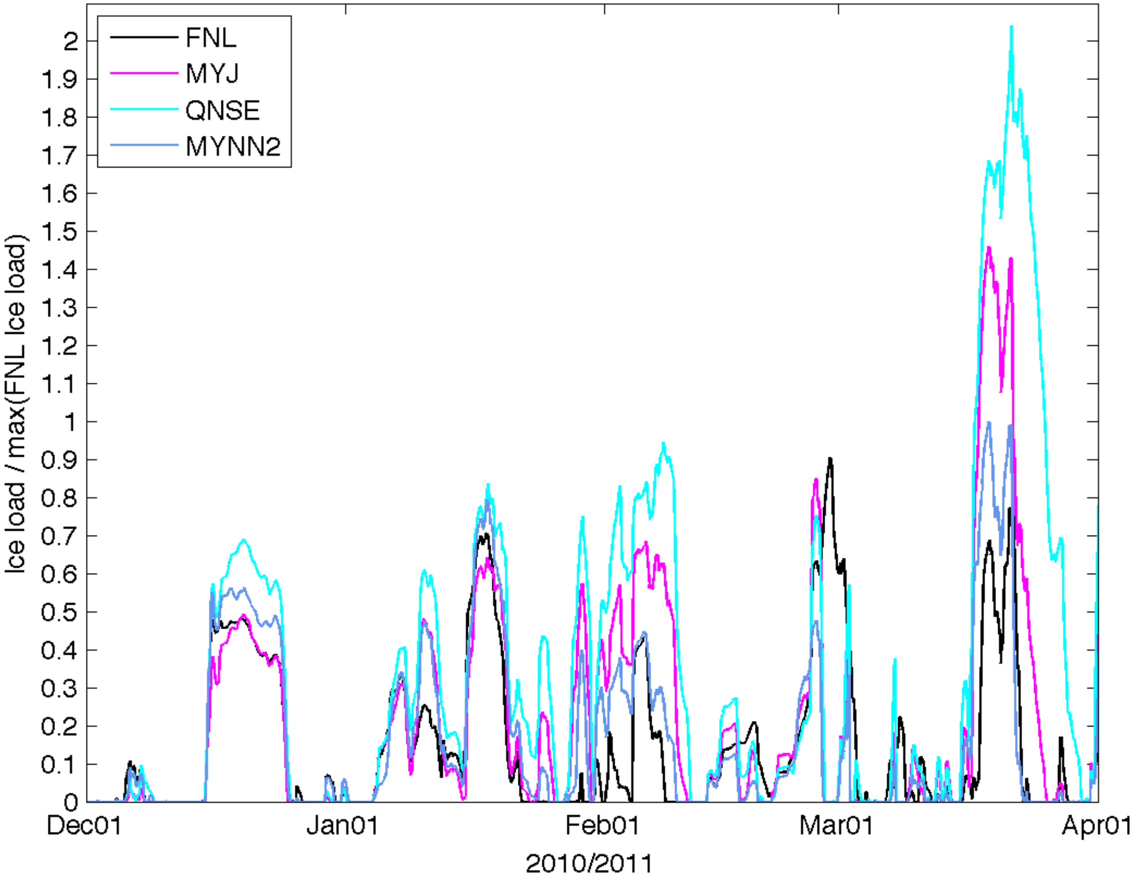
# Modelled ice load – microphysics




Number of hours with active icing, ice growth > 10 g/h

| | 2010/2011 |
|---|---|
| FNL(THO) | 389 |
| WSM3 | 211 |
| WSM6 | 228 |
| MORR | 350 |

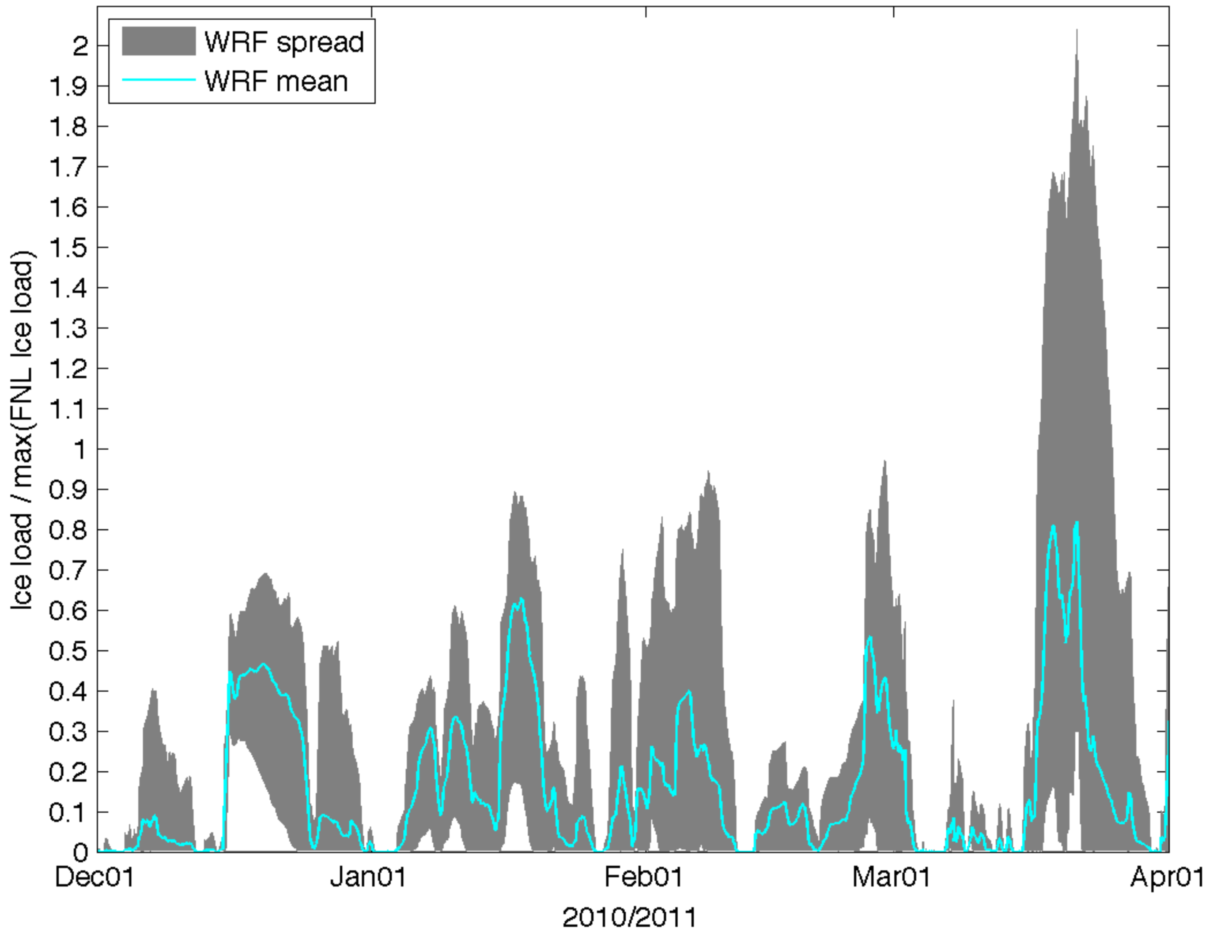
# Modelled ice load – PBL



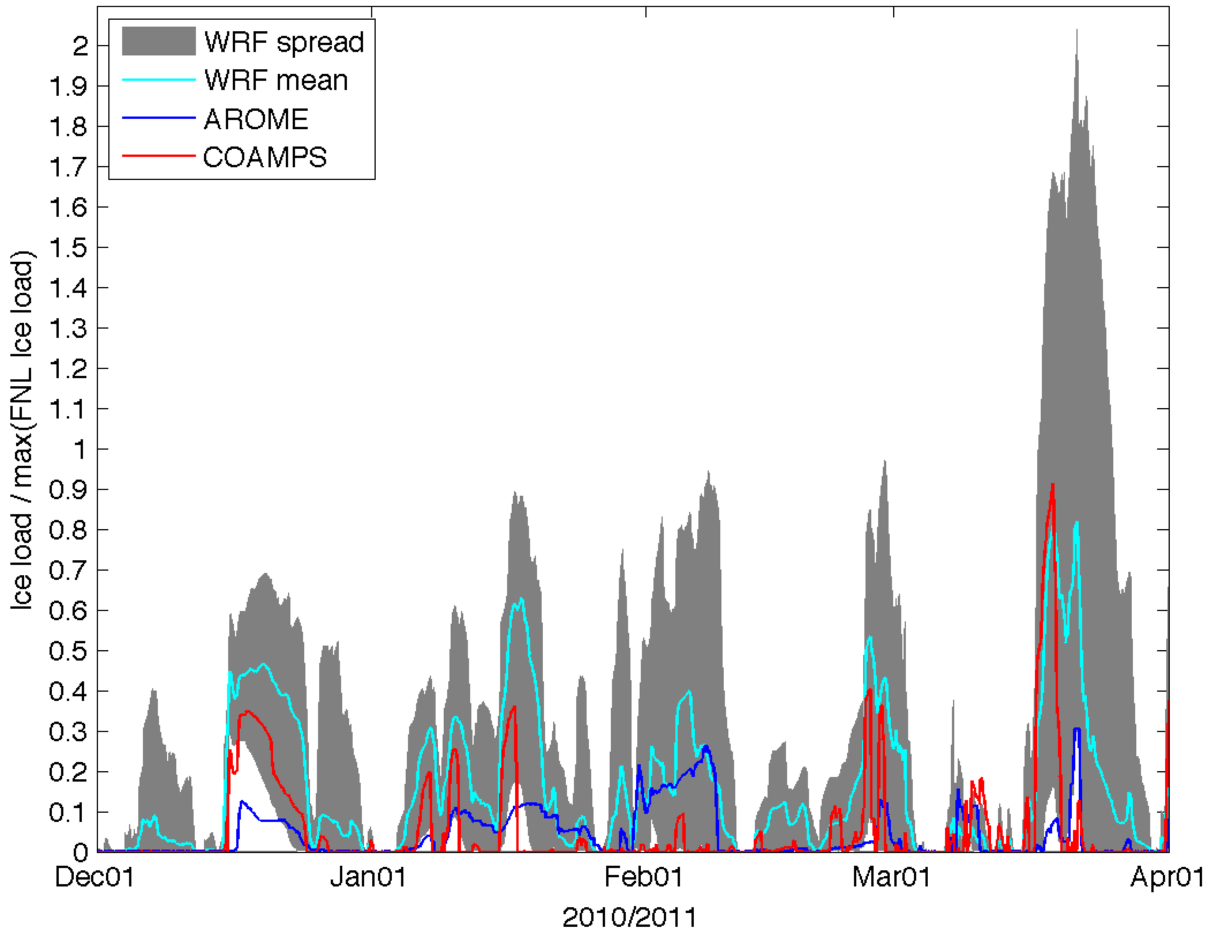

Number of hours with active icing, ice growth > 10 g/h

| | 2010/2011 |
|---|---|
| FNL(YSU) | 389 |
| MYJ | 585 |
| QNSE | 781 |
| MYNN2 | 455 |

# Modelled ice load – WRF spread



# Modelled ice load – AROME, COAMPS, WRF spread



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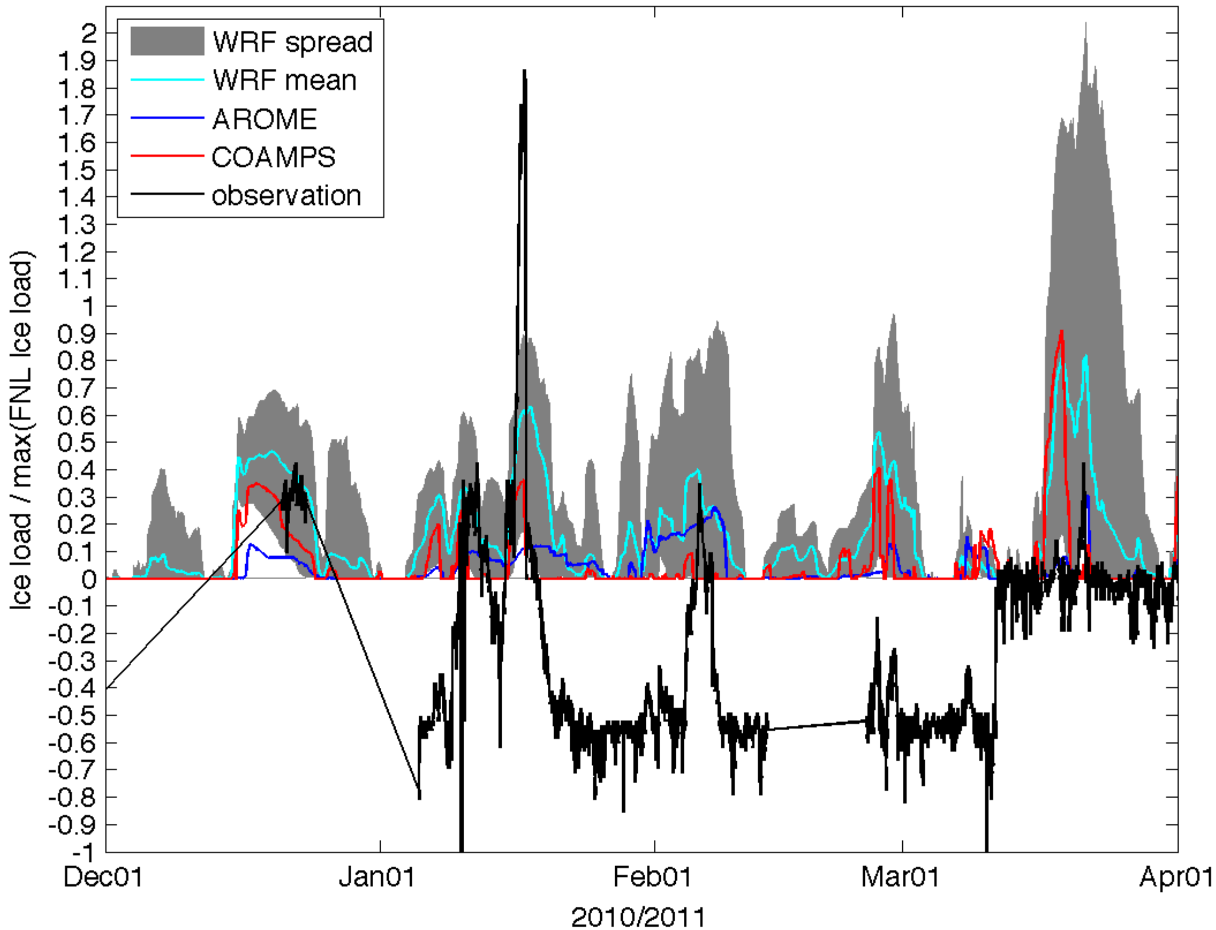
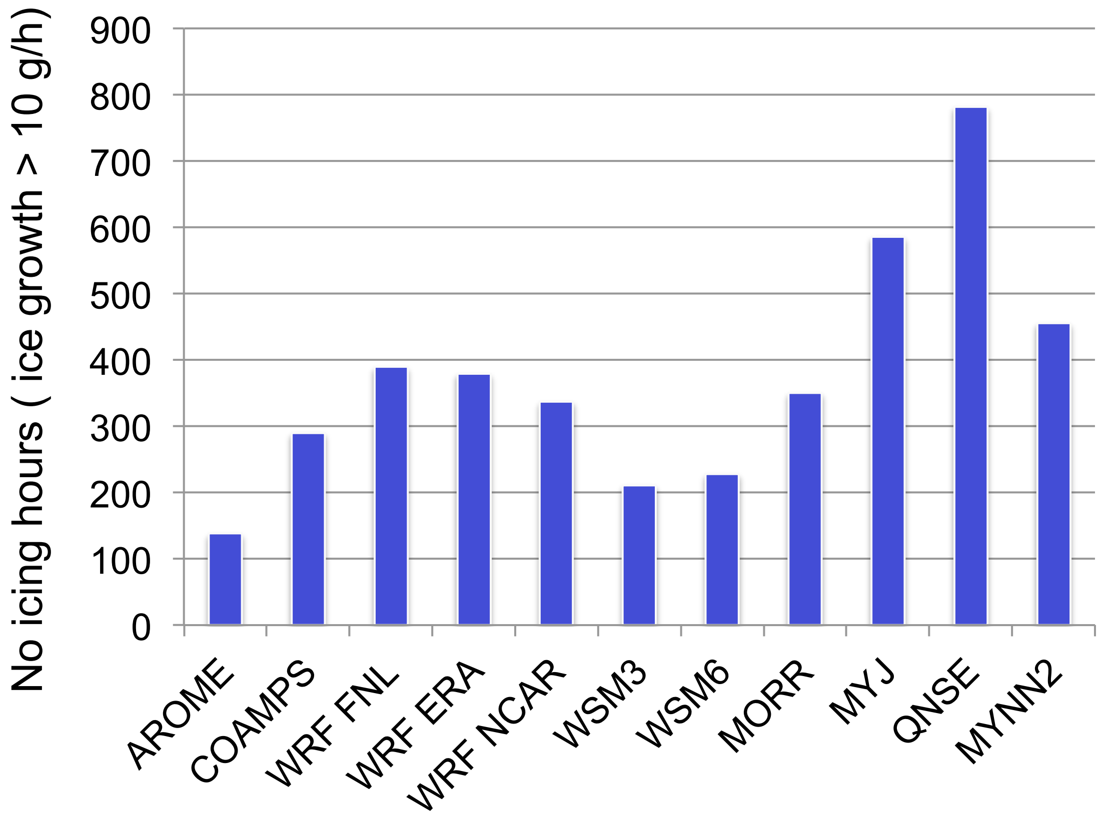
# Ice load – AROME, COAMPS, WRF spread, obs



# Active icing – AROME, COAMPS, WRF spread




| Model/Model setup | Hours of active icing 2010/2011 |
|---|---|
| AROME | 138 |
| COAMPS | 290 |
| WRF FNL | 389 |
| WRF ERA | 379 |
| WRF NCAR | 337 |
| WSM3 | 211 |
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# Conclusions

- Modelling ice load is not straight forward. The end result depend on which model that is used and how the model is set up.
- Measuring ice is not trivial. State of the art instruments are not accurate enough.

=> On a scientific level we cannot say which model and model setup that is “the best”.

But (don’t despair!)

- The timing of the icing events are quite well captured.
- A newly developed power loss model have shown promising results (Magnus Baltscheffsky at 10.30 tomorrow).