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Creating an icing climatology using downscaling techniques

Results from Vindforsk project V-313

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What do we mean by an ”icing climatology”?

A mapping of icing should give answers to questions as:

- **How often icing occurs**
- **How long the icing persists**
- **How large the amounts of ice are**

The most important questions may be:

- **How often do active icing occur?**
- **How is the production affected?**

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An icing climatology could be based upon todays NWP models (Numerical Weather Prediction) or upon meteorological observations.

Data from weather models (NWP)

or

Data from meteorological observations

Model of ice load
(Makkonen)

$$\frac{dM}{dt} = E \cdot w \cdot V \cdot D - Q$$

Modelled ice load

Comparisons with observations of ice load

dM/dt=**ice growth** (M = ice mass, t = time)
E = **accretion efficiency**
w = **liquid water content**
V = **wind speed**
D = **diameter**
Q = melting, sublimation

Gives ice growth on a 0.5 m long cylinder with 30 mm diameter.

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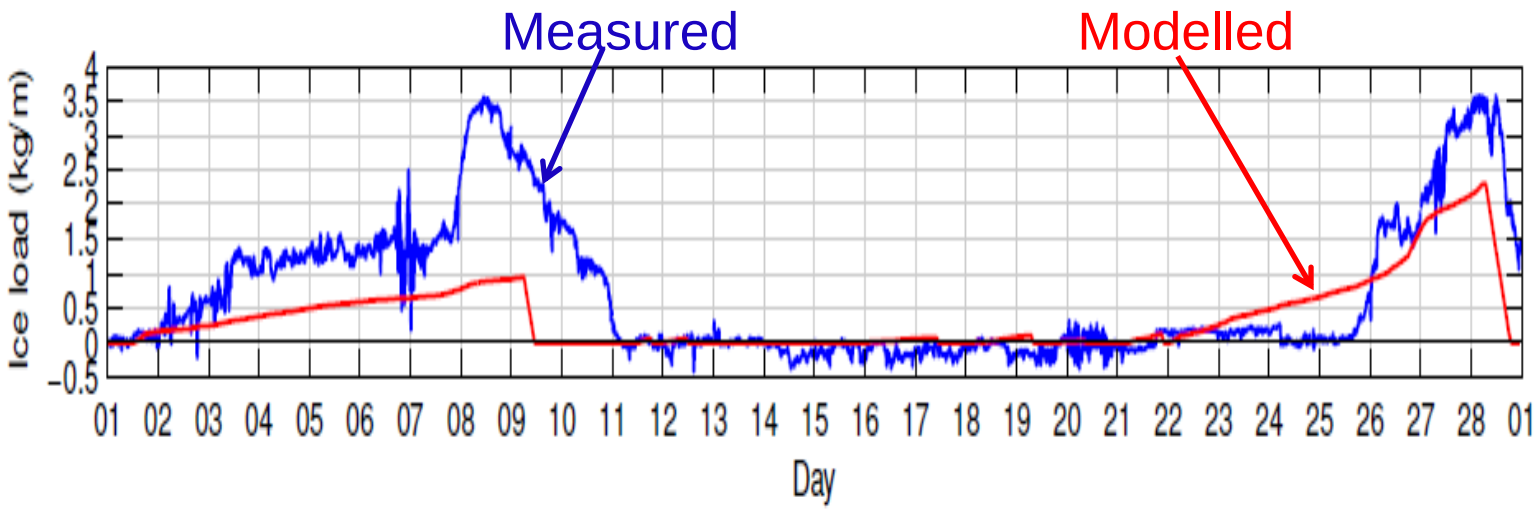
Icing modelling - what do we know today?

- Models catch the icing events quite well
- But sometimes large differences between modelled and measured ice amounts
- Measuring ice loads very difficult



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Icing climatology:

Two problems to balance:

- The need for period length to get a representative estimate of the climate
- The need for resolution to get a result accurately reproducing the geographical variations

Our options

- A long period (30 years) is dynamically modelled using low resolution (9 km) – the results are then dowscaled to desired resolution (1 km).
- A limited number of periods is modelled with high resolution – the periods are chosen to be representative for the icing cimate.

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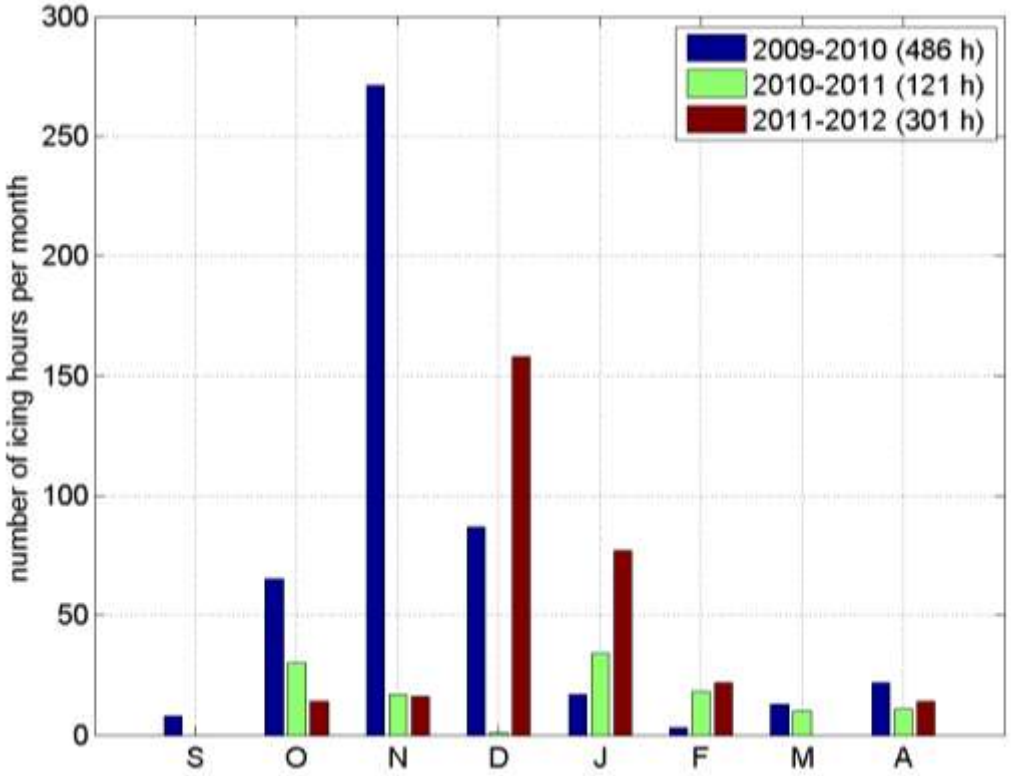
Icing climatology: Is 30 years really needed?

This example shows variability between seasons.

Monthly numbers of icing hours according to measurements at a site in northern Sweden

How representative is a single year? Not at all!
Or 10 or 30 years?



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Icing climatology: Downscaling

Step 1: Downscale to 9 km resolution from reanalysis data (ERA-Interim, NCEP/NCAR, GFS) using a mesoscale NWP. Here WRF & COAMPS have been used.

Result is a 30 year climatology.

Step 2: Statistical downscaling from 9 km to 1 km resolution.

What is needed?

Icing is dependent on wind speed, temperature and liquid water content (also precipitation).

Thus all must be included in the downscaling.

To take account of seasonal (and annual) variations, the statistical downscaling is made on a monthly basis.

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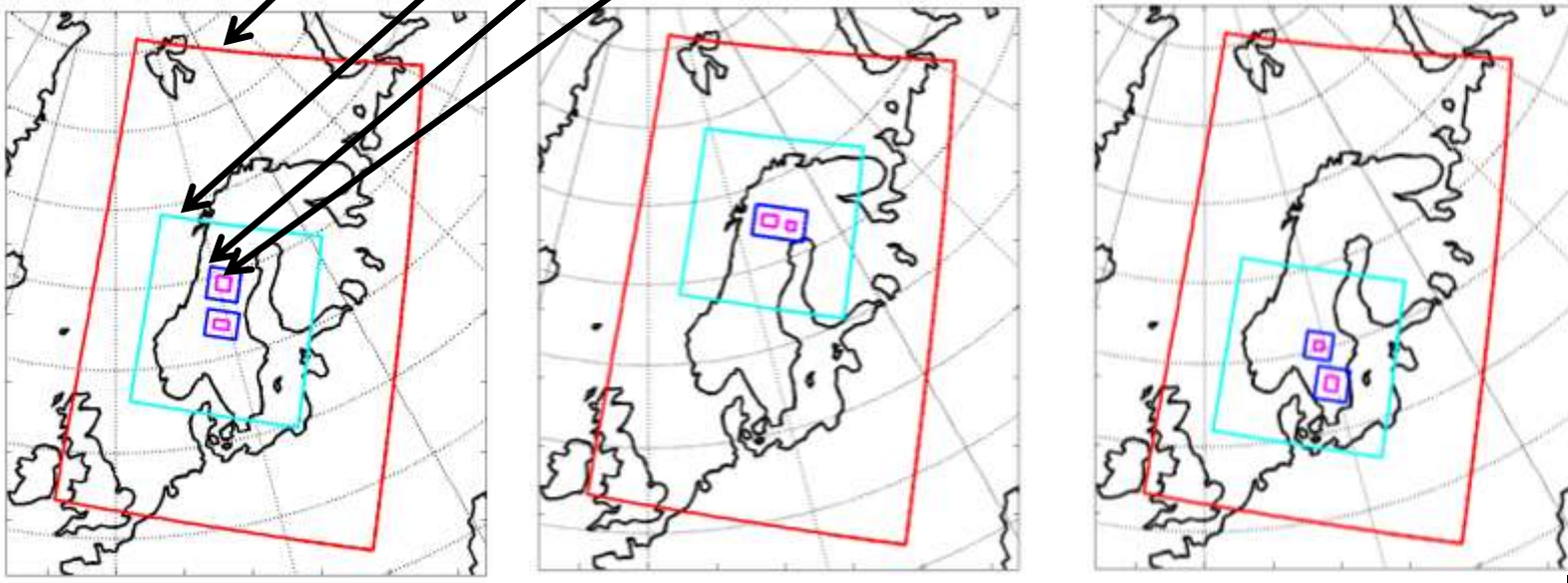
Model domains – COAMPS/WRF: Outer mesh forced by GFS

Grid resolutions: 27x27, 9x9, 3x3, 1x1 km^2



Winter seasons 2010/2011 and 2011/2012.

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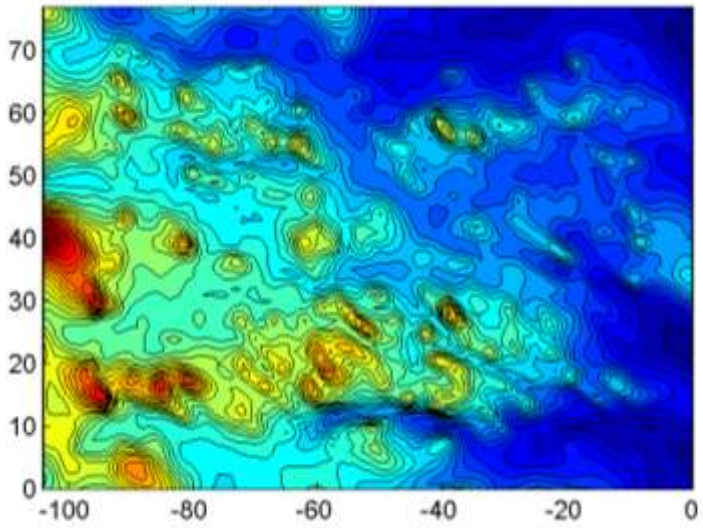
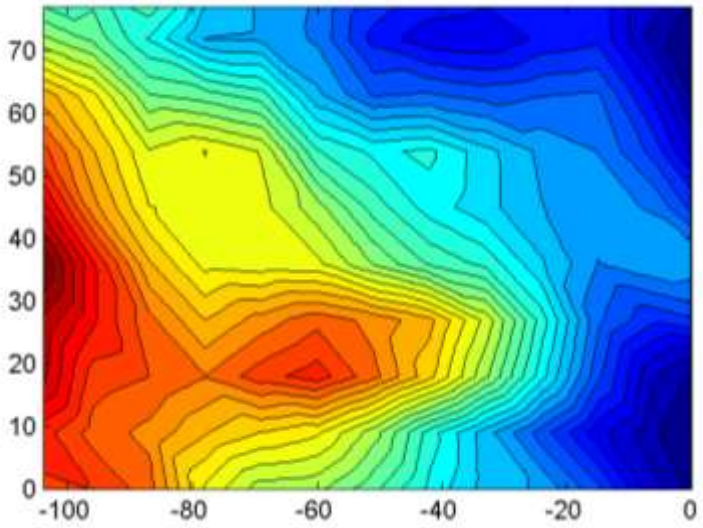
Statistical downscaling:

1) Interpolate 9 km resolution **topography** data to the 1 km resolution grid.

1 km resolution topography



9 km resolution topography



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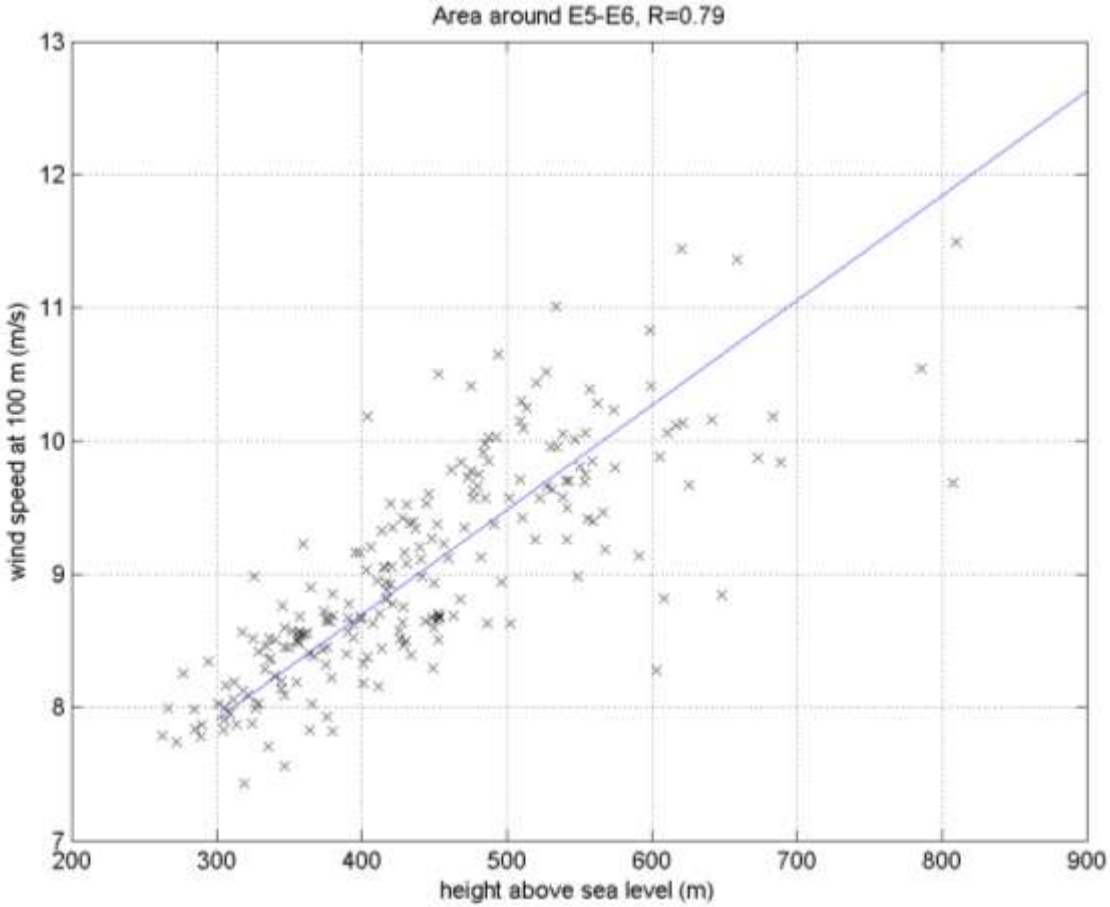
Statistical downscaling:

2) Interpolate 9 km resolution **wind speed** data to the 1 km resolution grid.

Wind speed versus height – monthly averages at each 1 km grid point.



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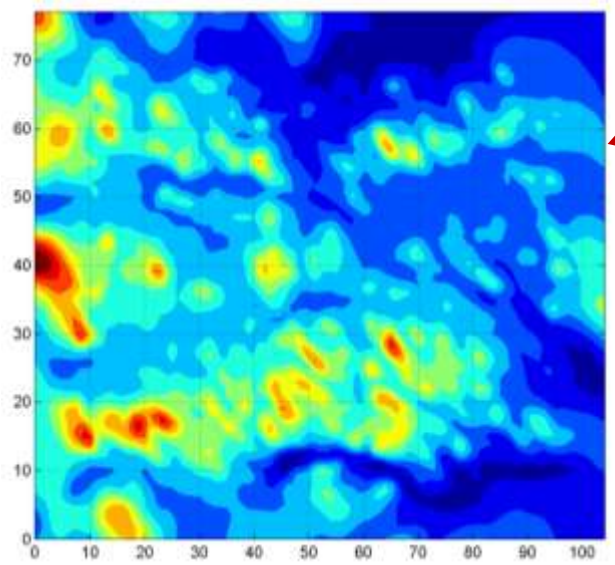
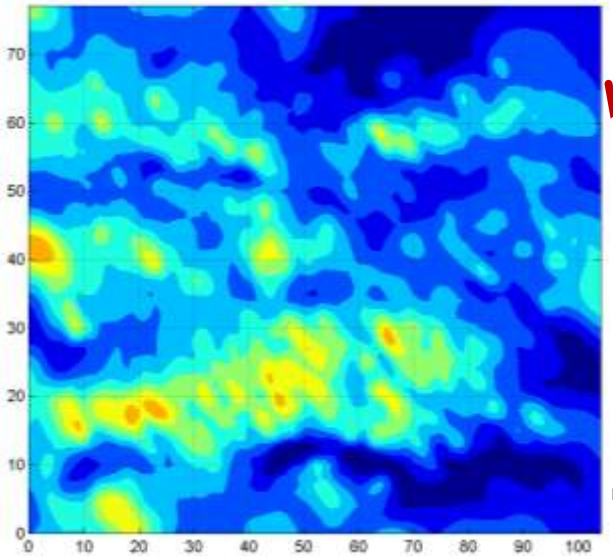
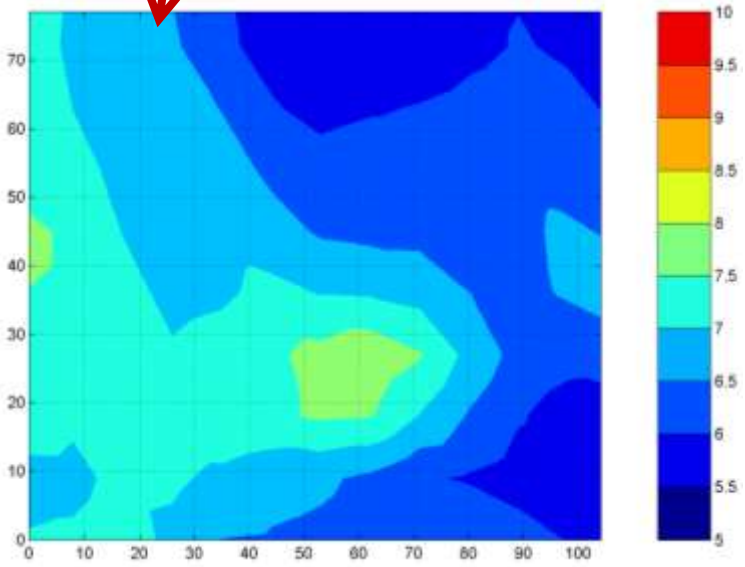




Downscaled to 1 km resolution

Modelled at 1 km resolution

Modelled at 9 km resolution



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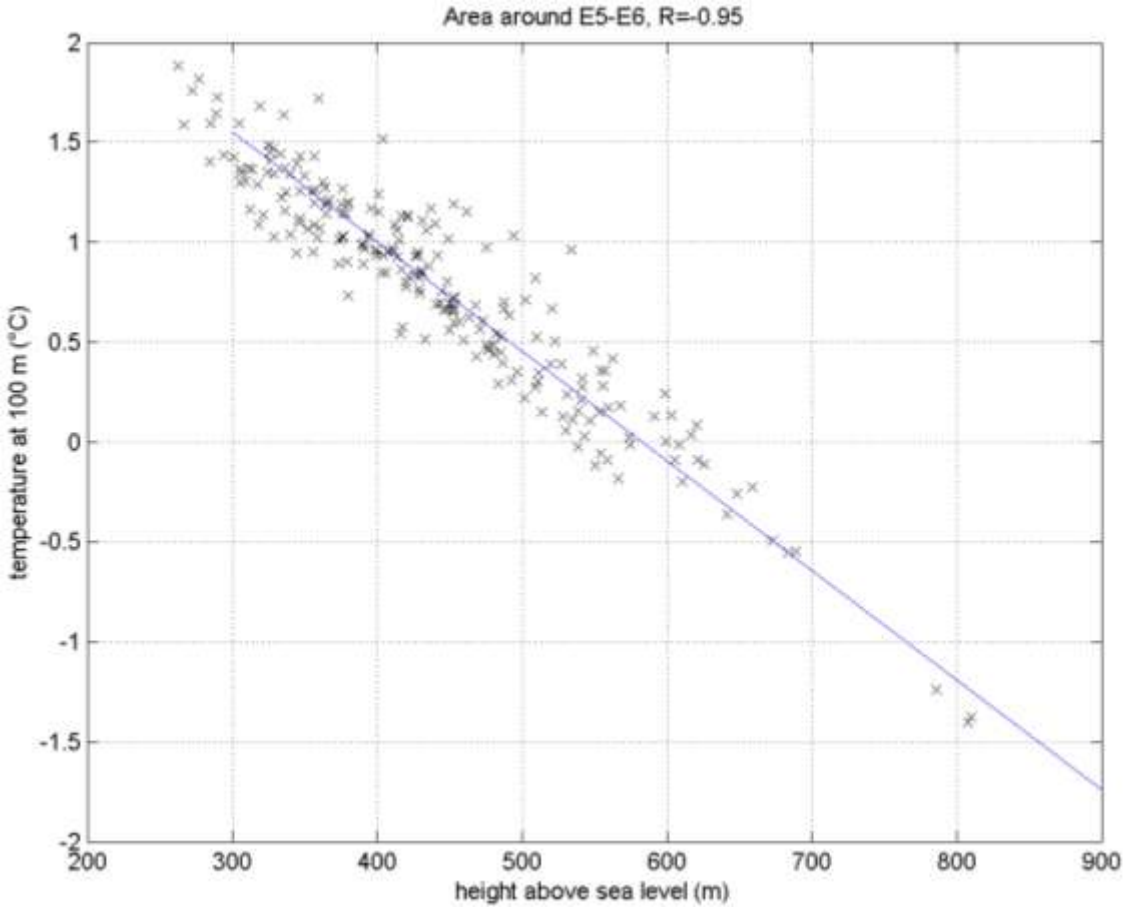
Statistical downscaling:

3) Interpolate 9 km resolution **temperature** data to the 1 km resolution grid.

Temperature versus height – monthly averages at each 1 km grid point. A month with typical decrease of temperature with height.



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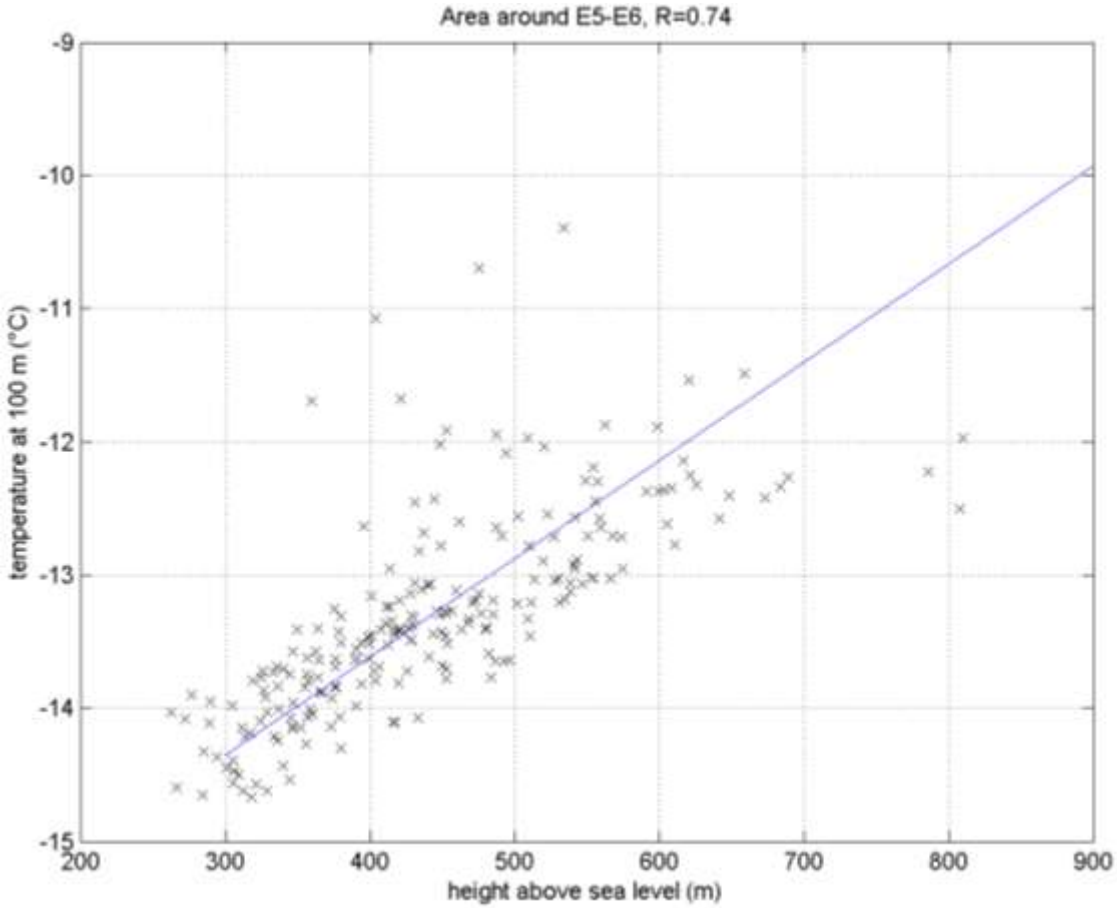
Statistical downscaling:

3) Interpolate 9 km resolution **temperature** data to the 1 km resolution grid.

Temperature versus height – monthly averages at each 1 km grid point. A month with temperature **inversions**.



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Statistical downscaling:
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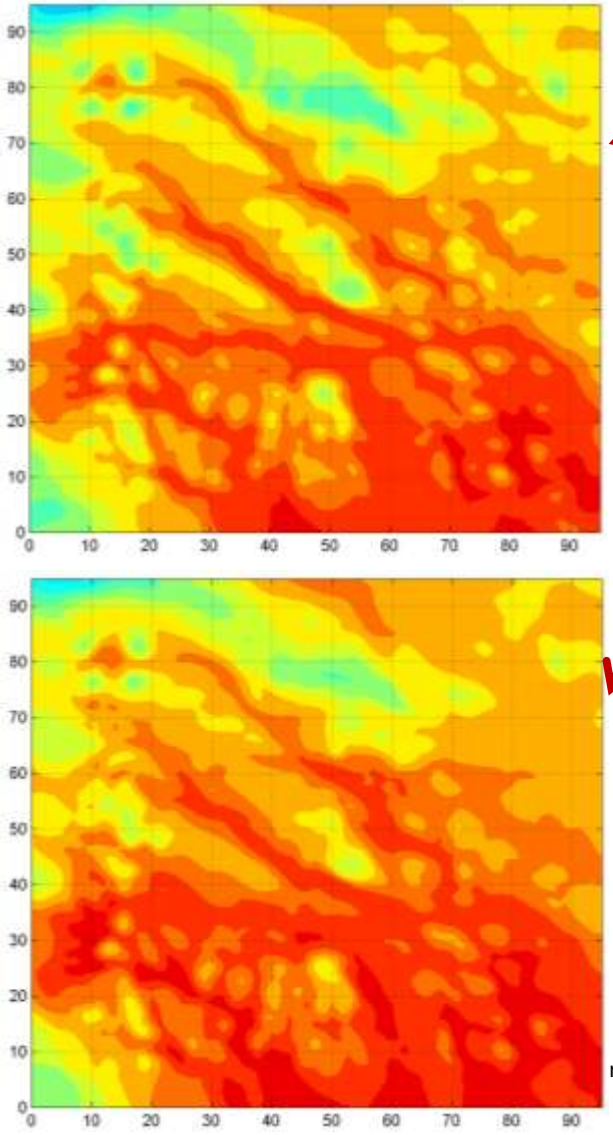
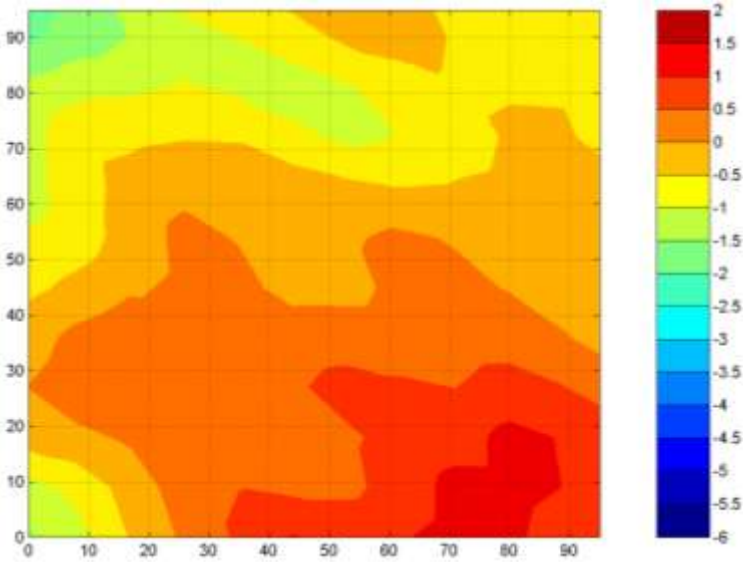


Downscaled to 1 km resolution

Modelled at 1 km resolution

Modelled at 9 km resolution



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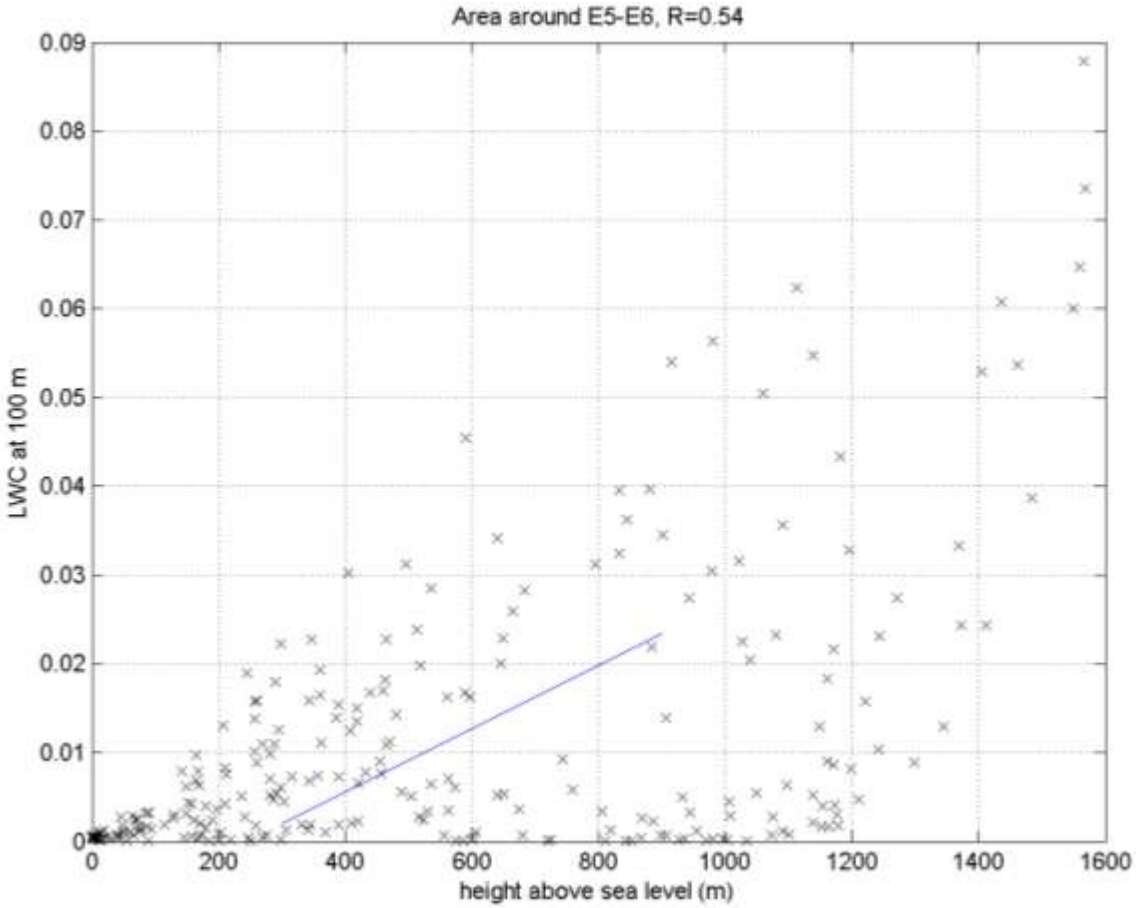
Statistical downscaling:

4) Interpolate 9 km resolution **liquid water content (LWC)** data to the 1 km resolution grid.

LWC versus height – monthly averages at each 1 km grid point. Poor relation – NOT USED!



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Statistical downscaling:

4) Interpolate 9 km resolution **liquid water content (LWC)** data to the 1 km resolution grid.

Alternative: Use 9 km temperature and specific humidity. Assume specific humidity is preserved:

Lift temperature from 9 km terrain height to 1 km height

↓

Gives new temperatures at corrected height

↓

Determine specific humidity at saturation

↓

If super-saturated, increase LWC until 100 % rel.humidity

↓

Use Makkonen's equation to estimate icing

↓

If ice accretion > 10 g/h count as "icing hour"

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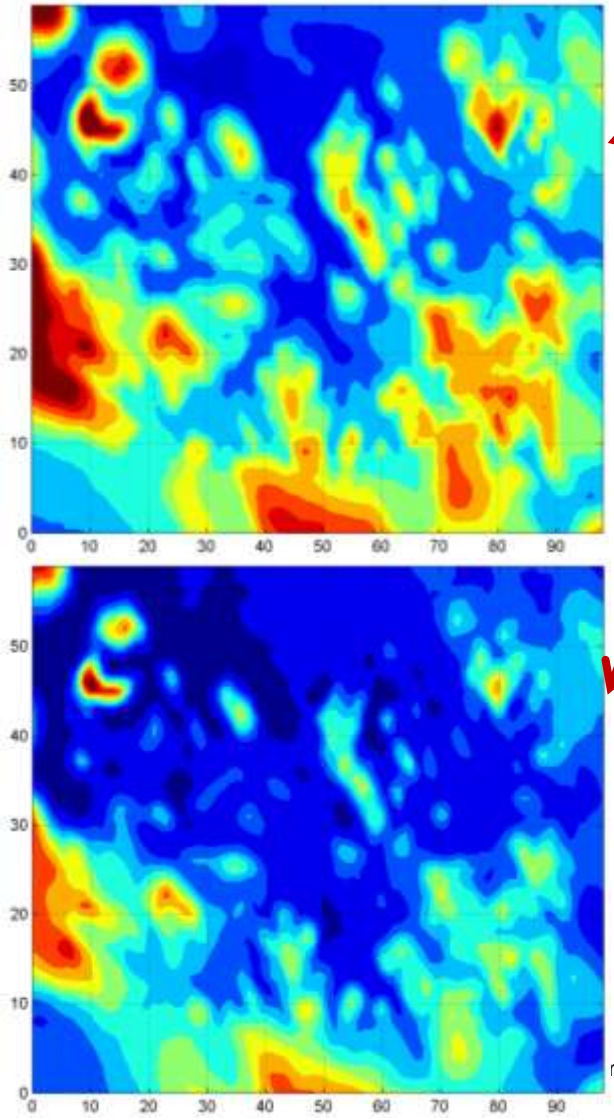
Statistical downscaling:

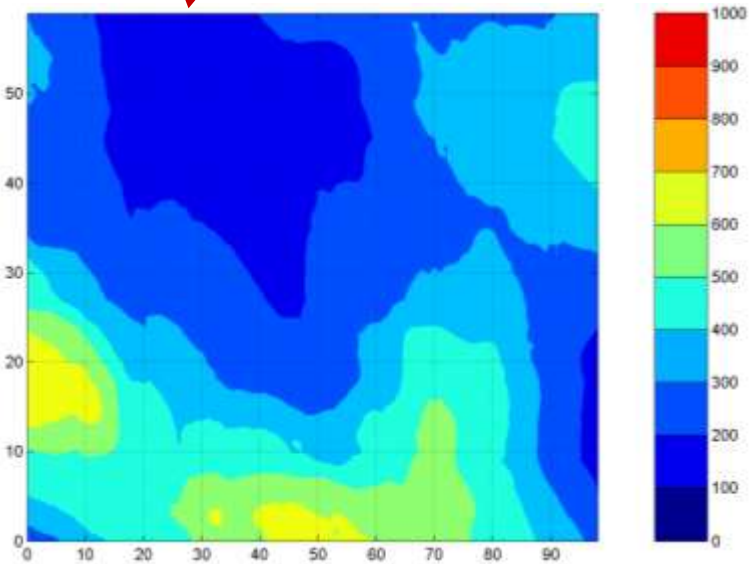
4) Number of icing hours interpolate from 9 km resolution to 1 km resolution grid.



Downscaled to 1 km resolution

Modelled at 1 km resolution

Modelled at 9 km resolution



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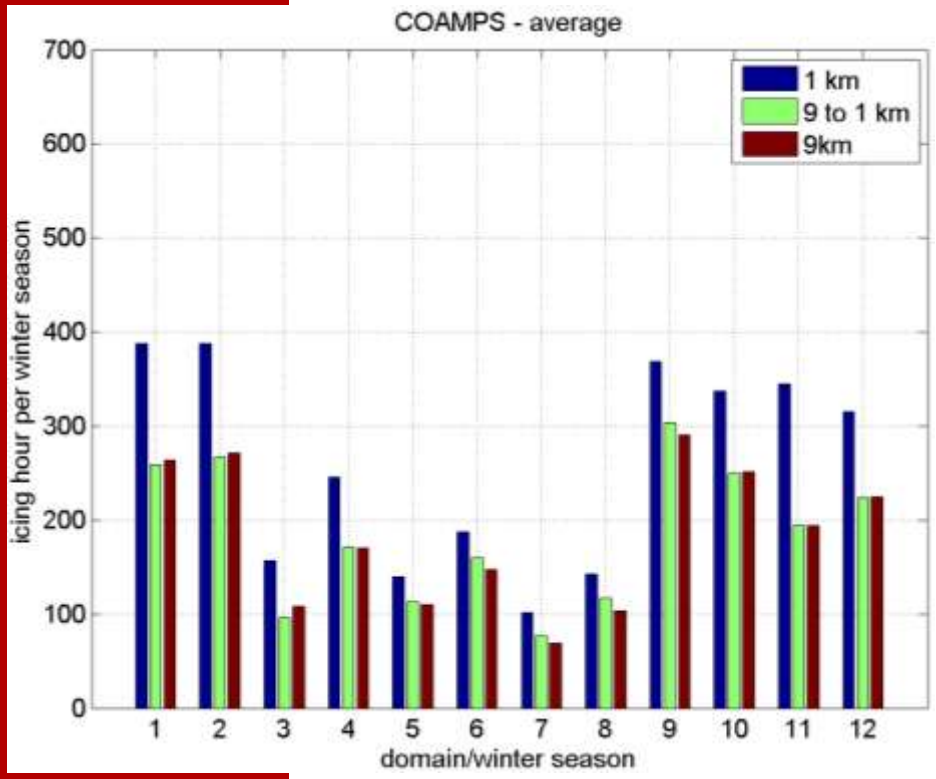
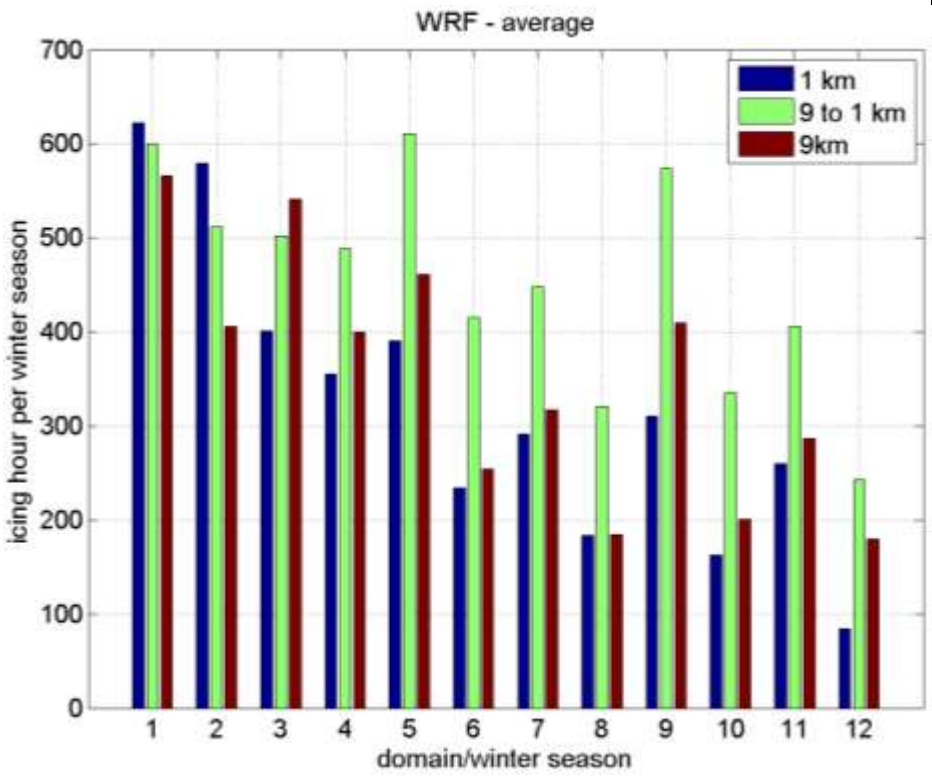
Statistical downscaling:

Domain averages of seasonal number of icing hours.

Larger differences between models than from using statistical downscaling.





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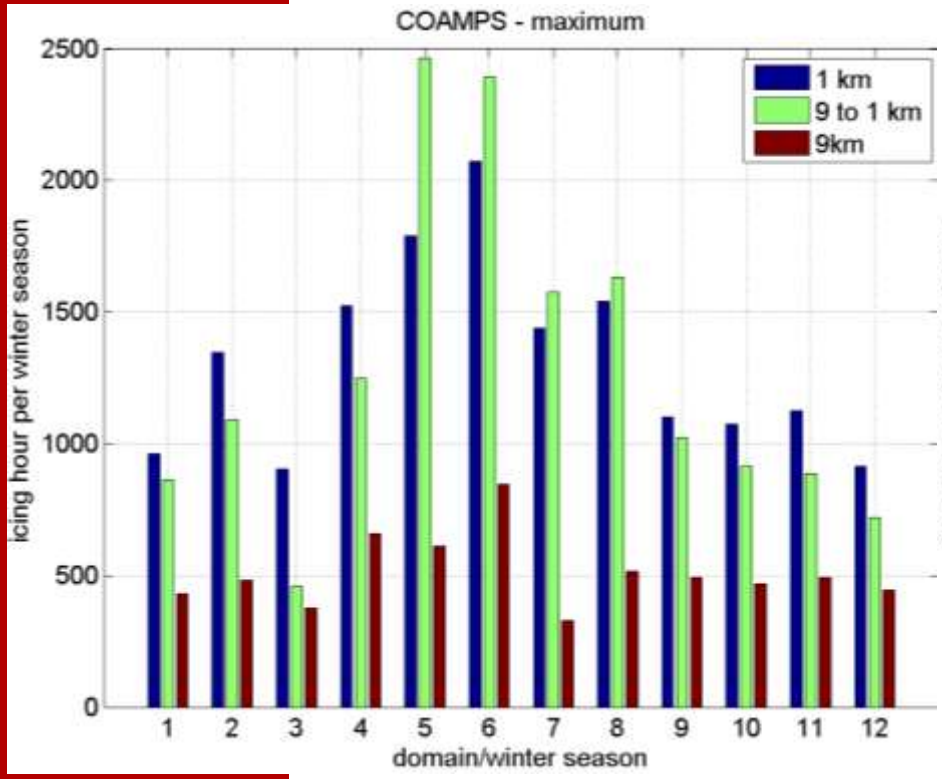
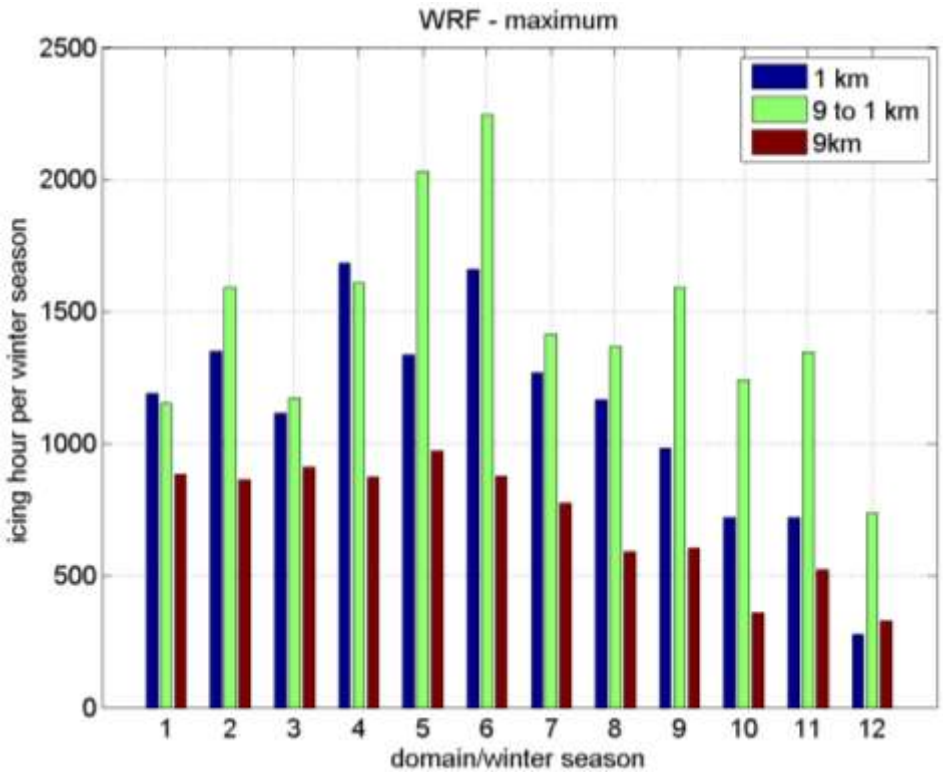
Statistical downscaling:
Domain maximum of seasonal number of icing hours.

Differences between models not so large.
9 km resolution results underestimate the maximum.
Statistical downscaling in reasonable agreement with 1 km resolution results.





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Summary and conclusions

Statistical downscaling possible to use.

Comparing 1 km resolution model results to statistically downscaled results:

- Advantage: We gain accuracy as regards climatological representativity – possible to use long enough periods
- Drawback: We may loose accuracy as regards local terrain response.

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Summary and conclusions

Alternative to statistical downscaling: Model representative periods with high resolution?

- Advantage: We directly model with 1 km resolution – no downscaling needed.
- Drawback: We loose some accuracy as regards climatological representativity.
  How representative are the chosen periods?

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Future work

What method to use for a climatology:
Statistical downscaling or representative periods?

- Statistical downscaling: Needs less computer time but a larger amount of man months.
- Representative periods: Not so many man months needed but large amounts of computer time as at least five years are needed for a reasonable accurate climatology.

Regarding the final accuracy of the results it is difficult to say which method is to be recommended – uncertainties due to a shorter period length has to be weighed against statistical uncertainties with the downscaling,

AND – the differences are sometimes large between the models used – maybe this is the largest uncertainty.

MORE RESEARCH IS NEEDED to increase the accuracy**!**

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Thank you for your attention

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V-313 Windpower in cold climates

Report will be published here (likely in March 2013):
http://www.elforsk.se/Programomraden/El--Varme/Vindforsk/reports/reports_area_1_2/