Comparison between simulated and measured icing in test spans

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Test spans in Iceland

Hallormsstaðaháls

Hallormsstaðaháls

Modeling in-cloud ice accretion

- The state of the atmosphere is simulated at high resolution using the WRF-model. The model is forced with the ECMWF-analysis as well as observations from Egilsstaðir for one sensitivity test.

- Atmospheric moisture is parameterized using the Thompson bulk scheme, with 100 droplets/cm^3 which is considered characteristic for a maritime climate. The scheme predicts cloud water (Q_c), ice (Q_i), rain (Q_r), snow (Q_s) and graupel (Q_g).

- Ice accretion is modeled according to ISO 12494-2000 (Makkonen model). Assuming horizontal cylinder approach. Using wind speed, temperature and water phases from the WRF simulation. Three water phases can lead to icing: cloud water (Q_c), rain (Q_r) and snow (Q_s). Droplet number assumed as N_d=50 droplets/cm^3.

WRF models used in study

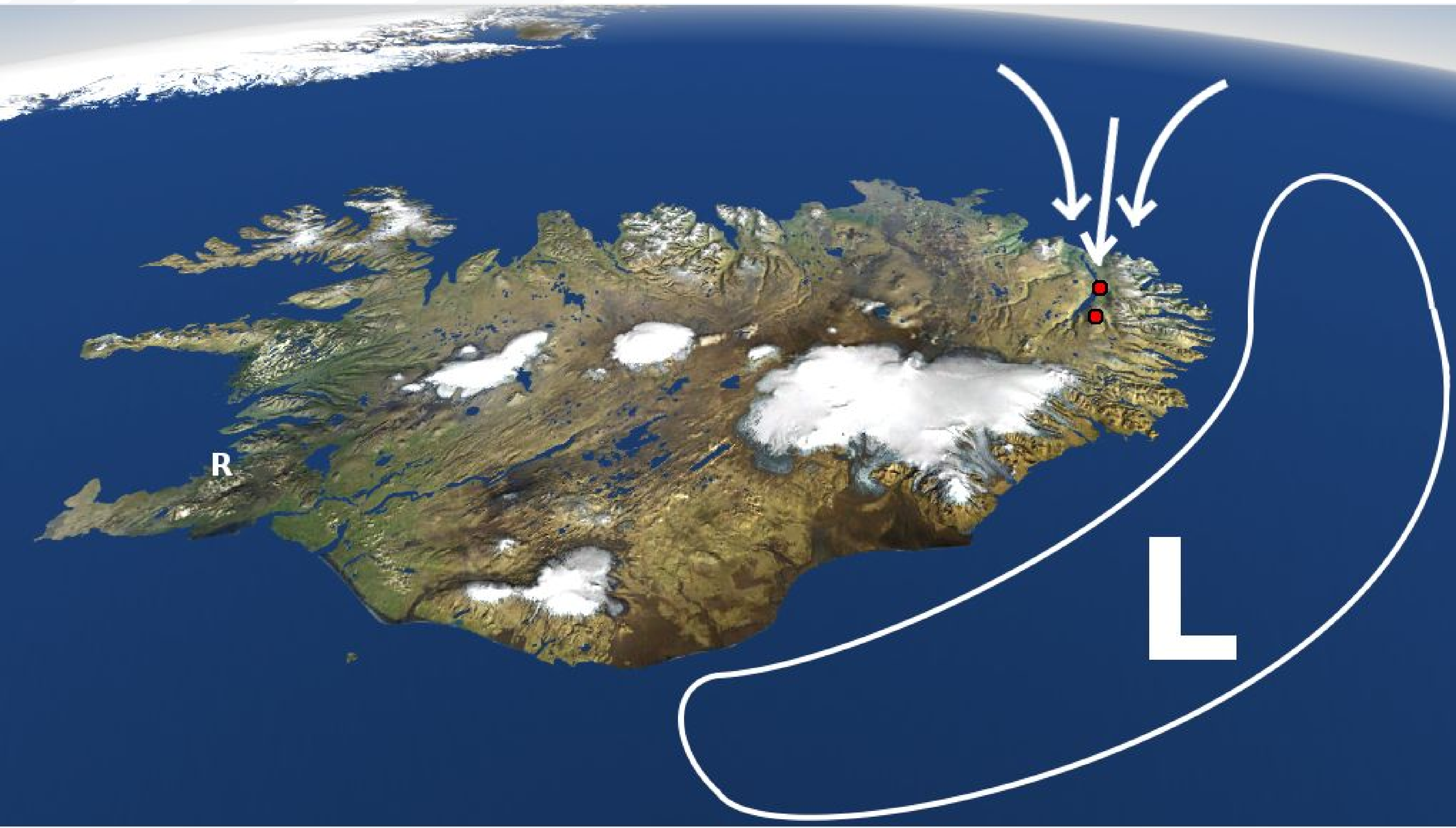
Six different input series from WRF simulations are used for the icing model.

Model	Grid spacing [km]	Comment
WRF_{1km}	1	
WRF_{1km-F}	1	Forced through observation at Egilsstadir
WRF_{3km}	3	
$WRF_{0.3km}$	0.33	
$WRF_{1km-F-A}$	1	Same as WRF_{1km-F}, but measured temperature used and 3m/s added to simulated wind
WRF_{1km-A}	1	Same as WRF_{1km}, but measured temperature used and 3m/s added to simulated wind

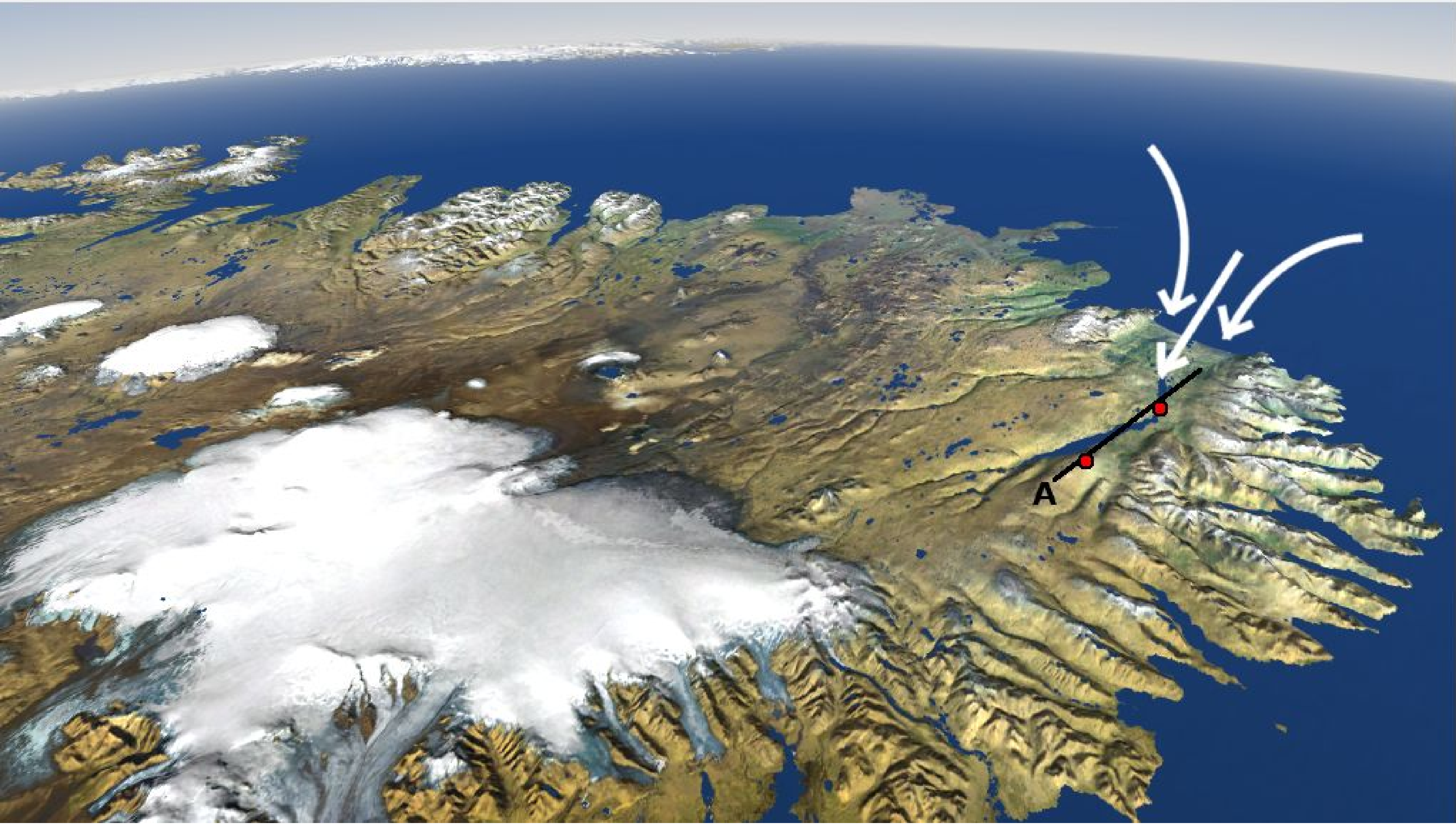
F = Forced through observation at Egilsstadir

A = Adjusted, wind increased by 3 m/s and observed temperature from site used.

In-cloud icing episodes are associated with northerly winds and a low of East-Iceland

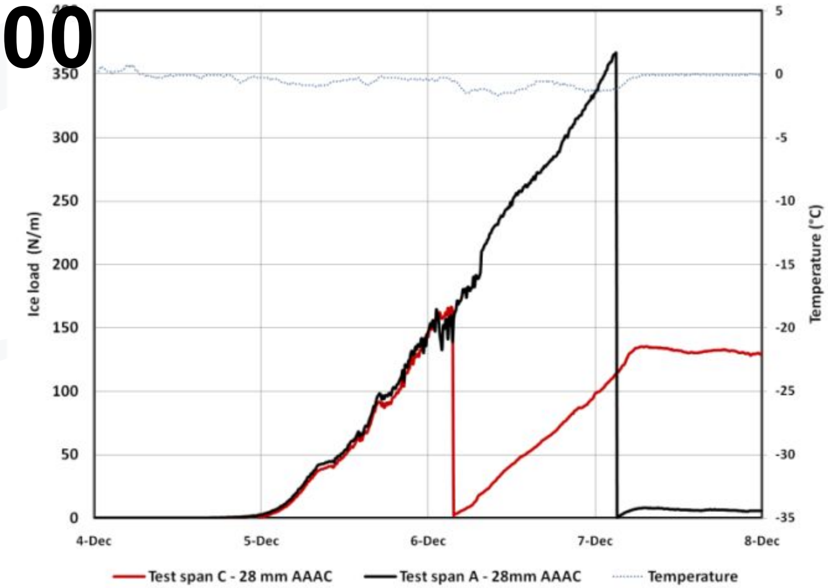


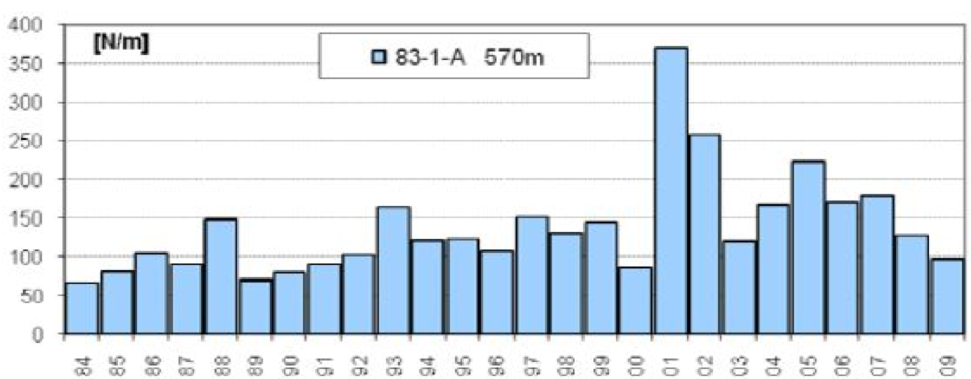
In-cloud icing episodes are associated with northerly winds and a low of East-Iceland

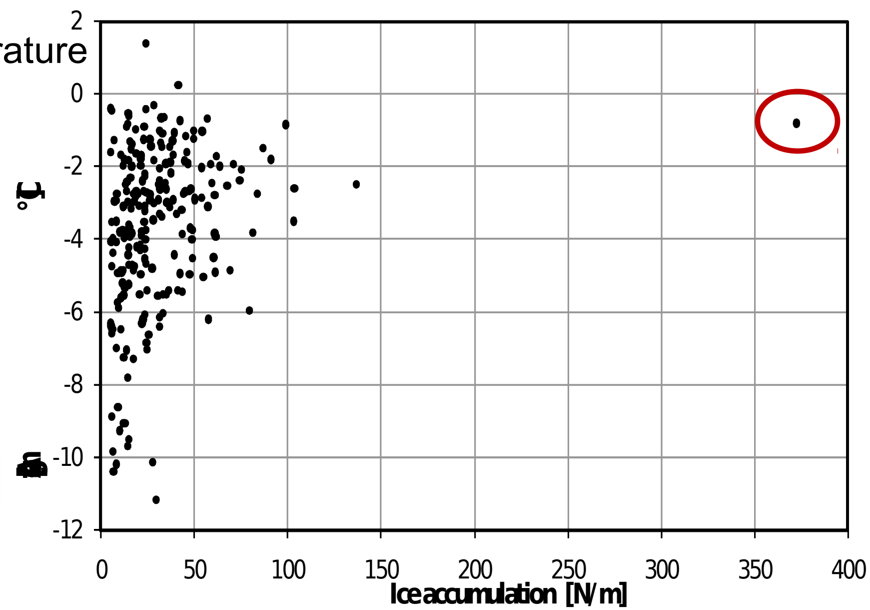


In-cloud icing 4-6 Dec. 2000

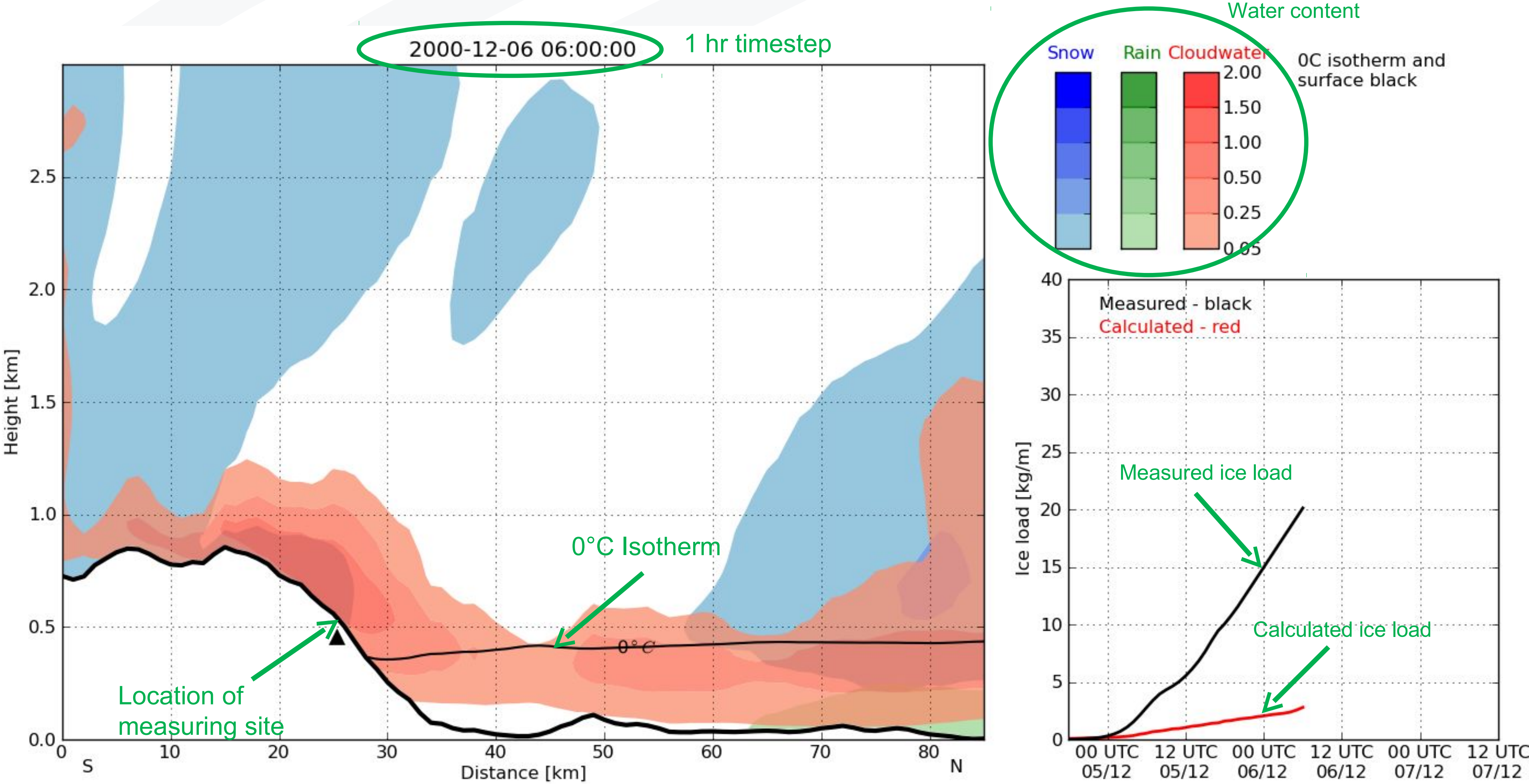
- Continuous accumulation for 52 hours, while temperature was slightly below zero. Icing also observed on parallel test span, but ice shedding influenced ice loading.
- Highest icing observed during 1983-2010



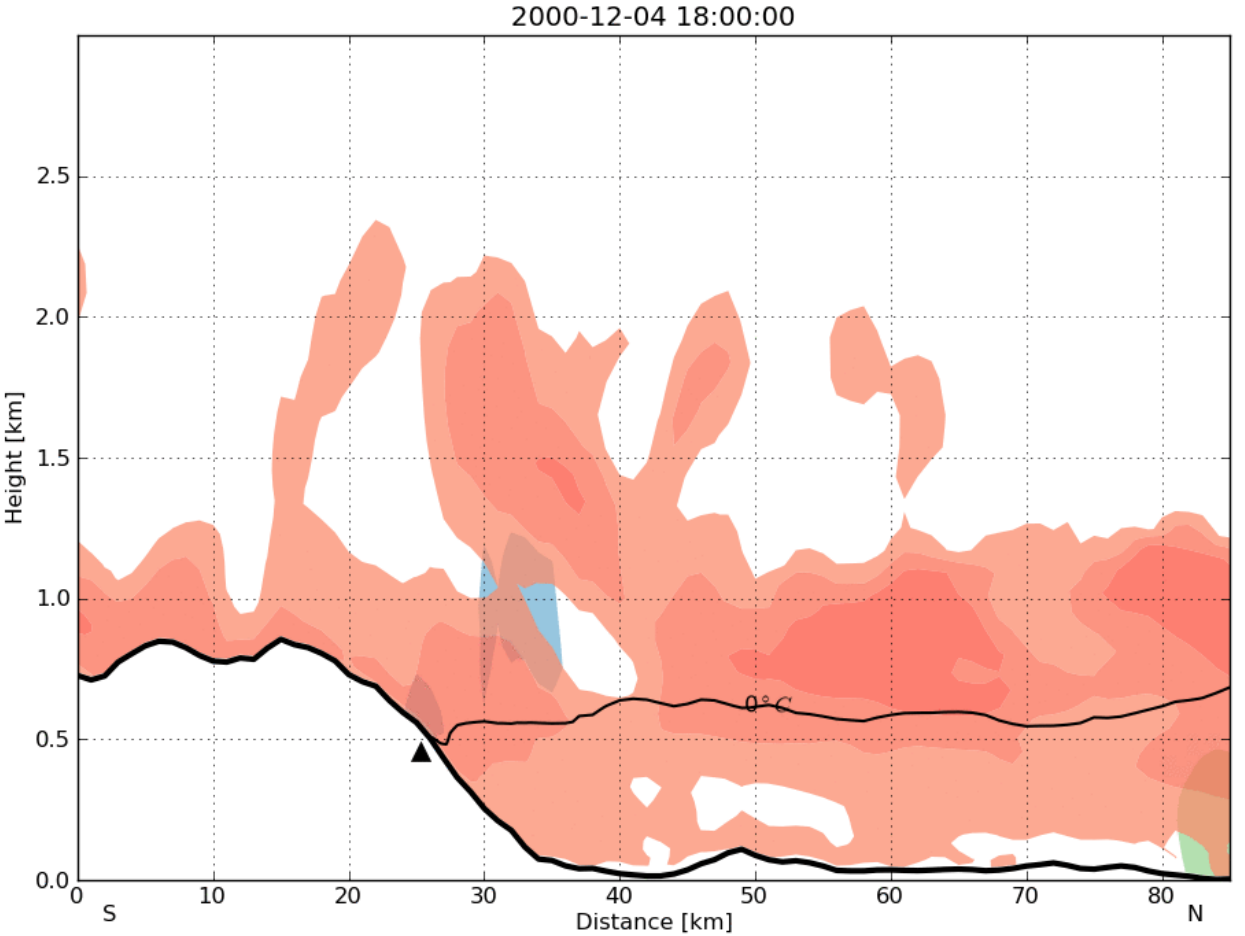


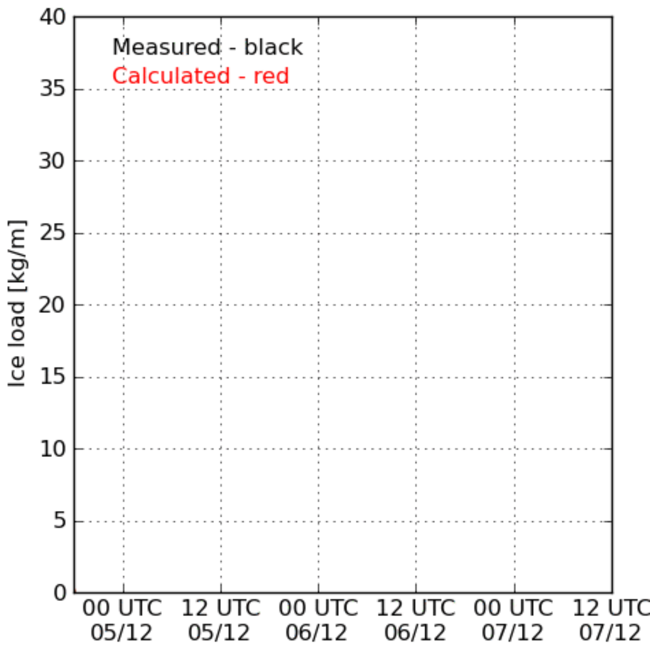


Sections along simulated flow

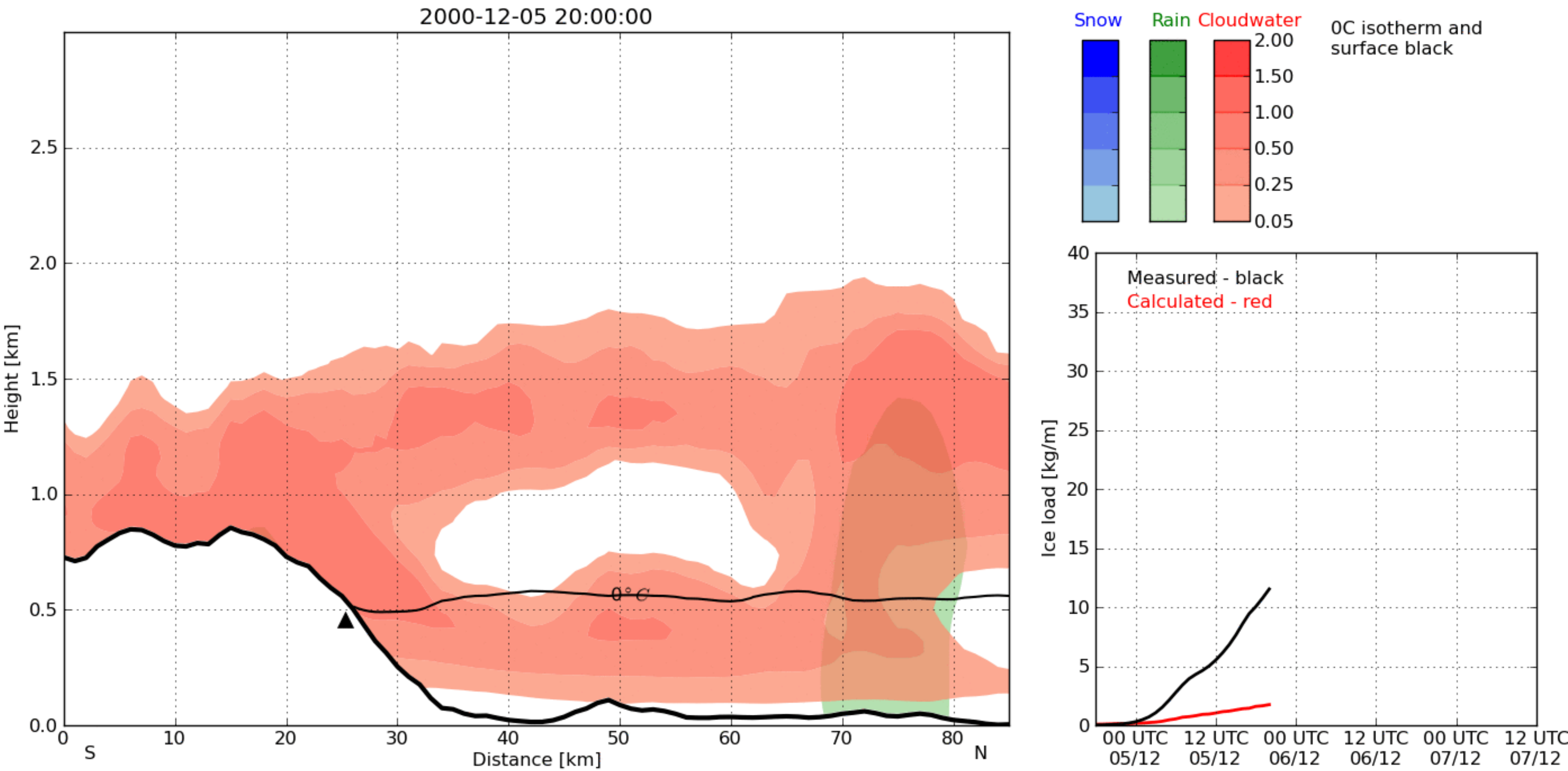


WRF$_{\text{1km-Forced}}$ simulation 4-6 Dec. 2000

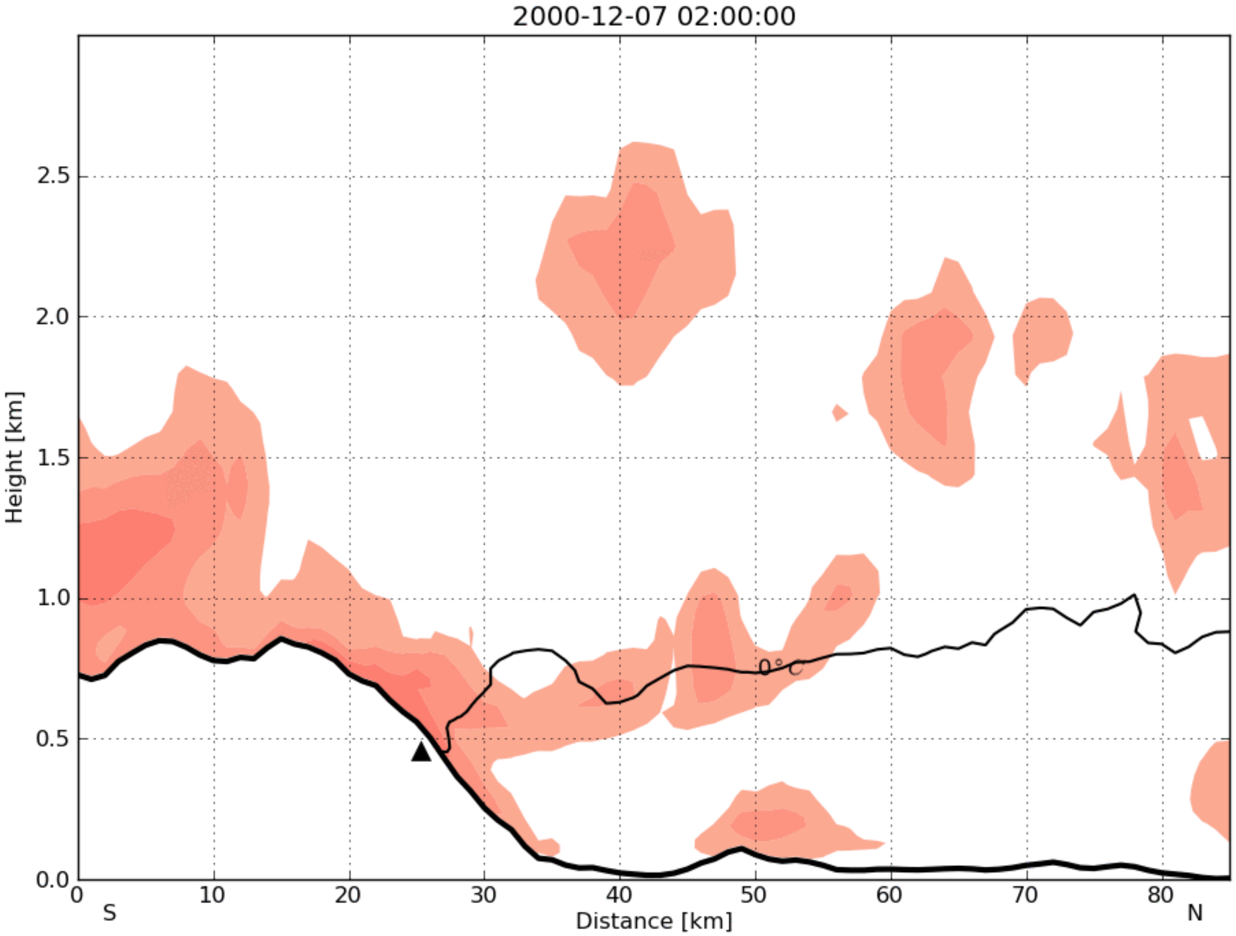


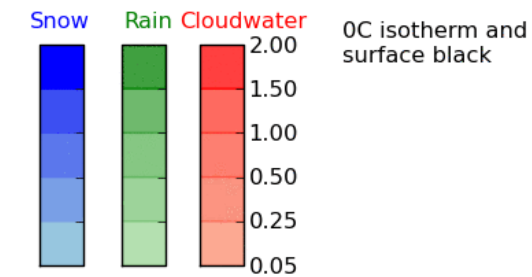


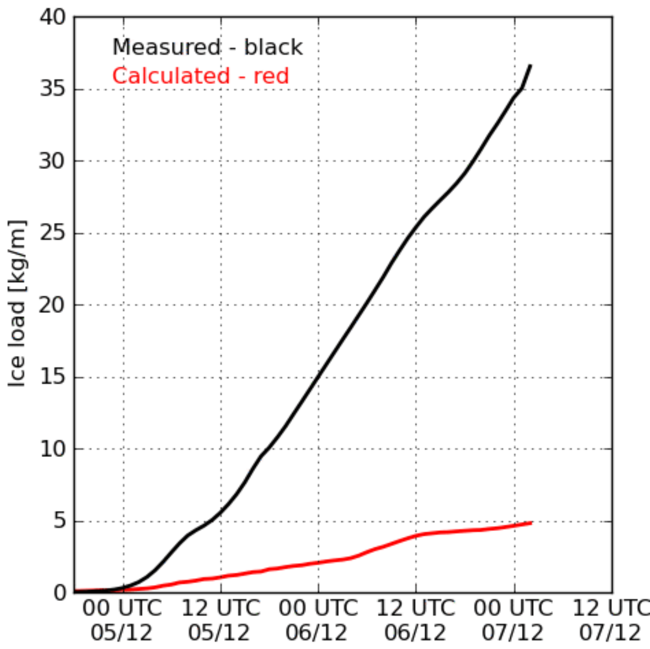
WRF$_{1km\text{-}Forced}$ simulation 4-6 Dec. 2000



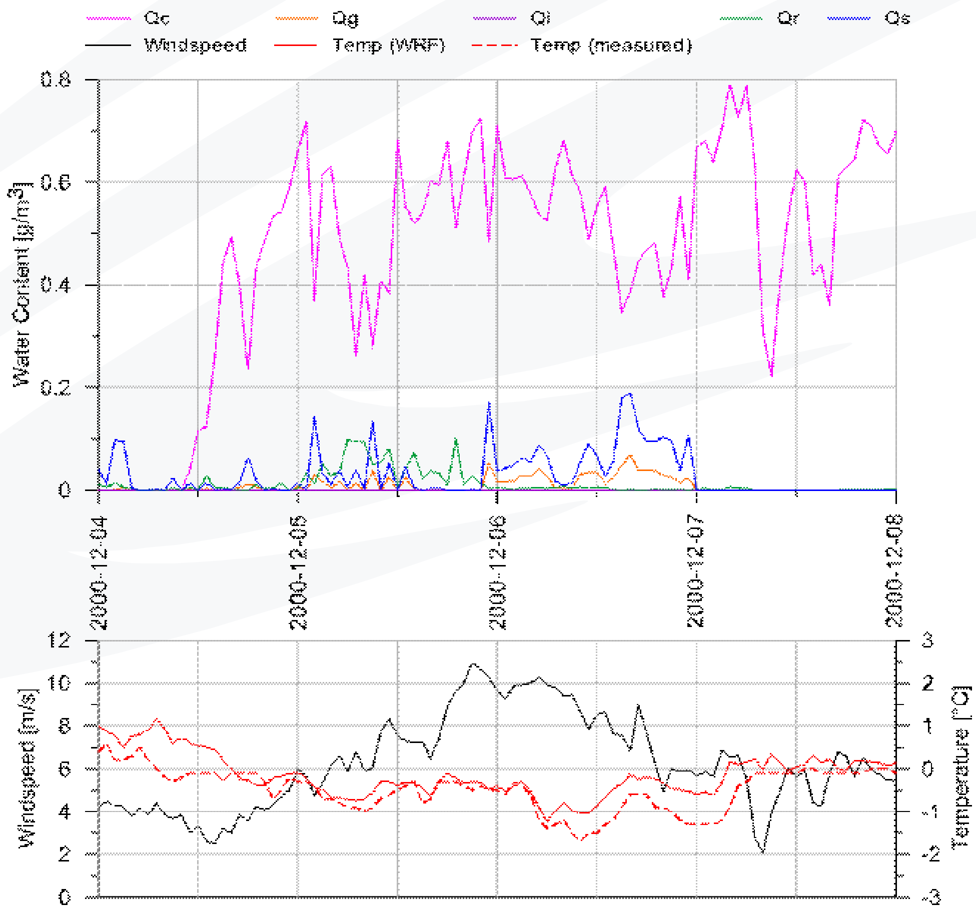
WRF$_{1km\text{-}Forced}$ simulation 4-6 Dec. 2000





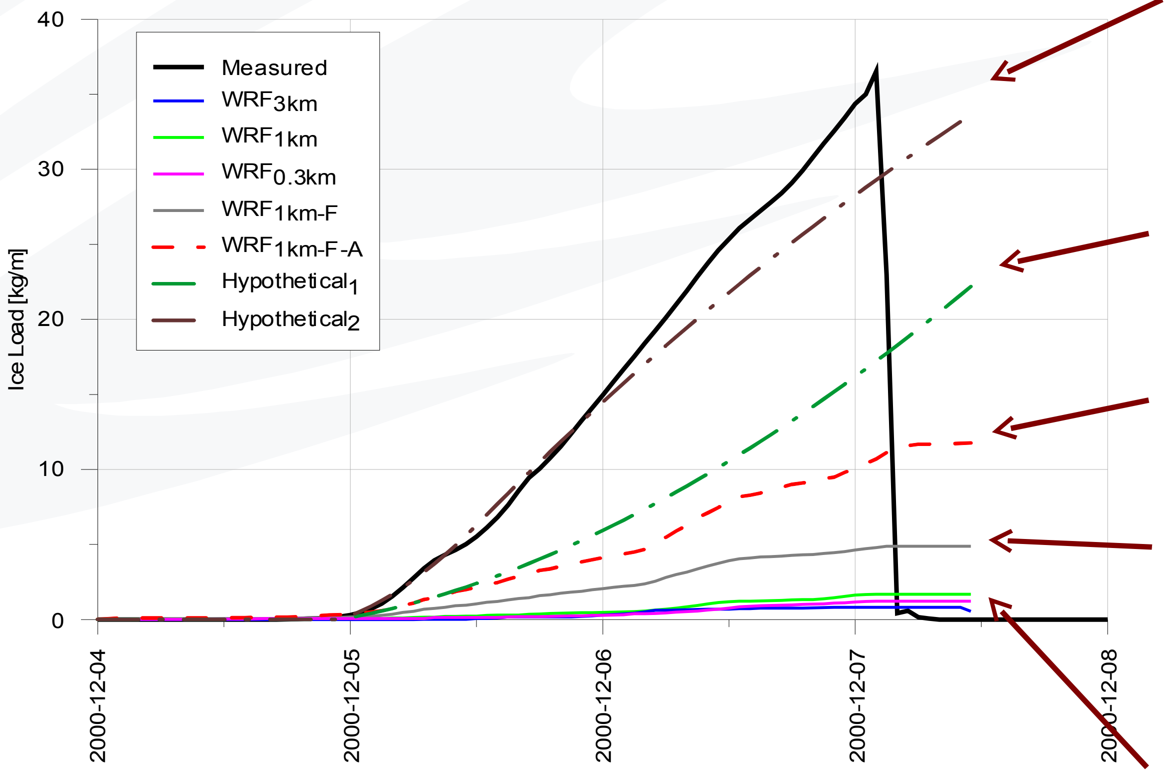


4-6 Dec. 2000 - WRF$_{\text{1km-Forced}}$ results with 1 km grid



- Lot of cloud water (Qc). Some snow and freezing drizzle
- Temperature simulated quite well
- Wind speed not high. Possibly slightly underestimated
- Improved results when forcing simulation through observation at Egilsstaðir

In-cloud icing during 4-6 Dec. 2000



Hypothetical 2.
w = 0.6 g/cm³, V=14 m/s, T= -2°C

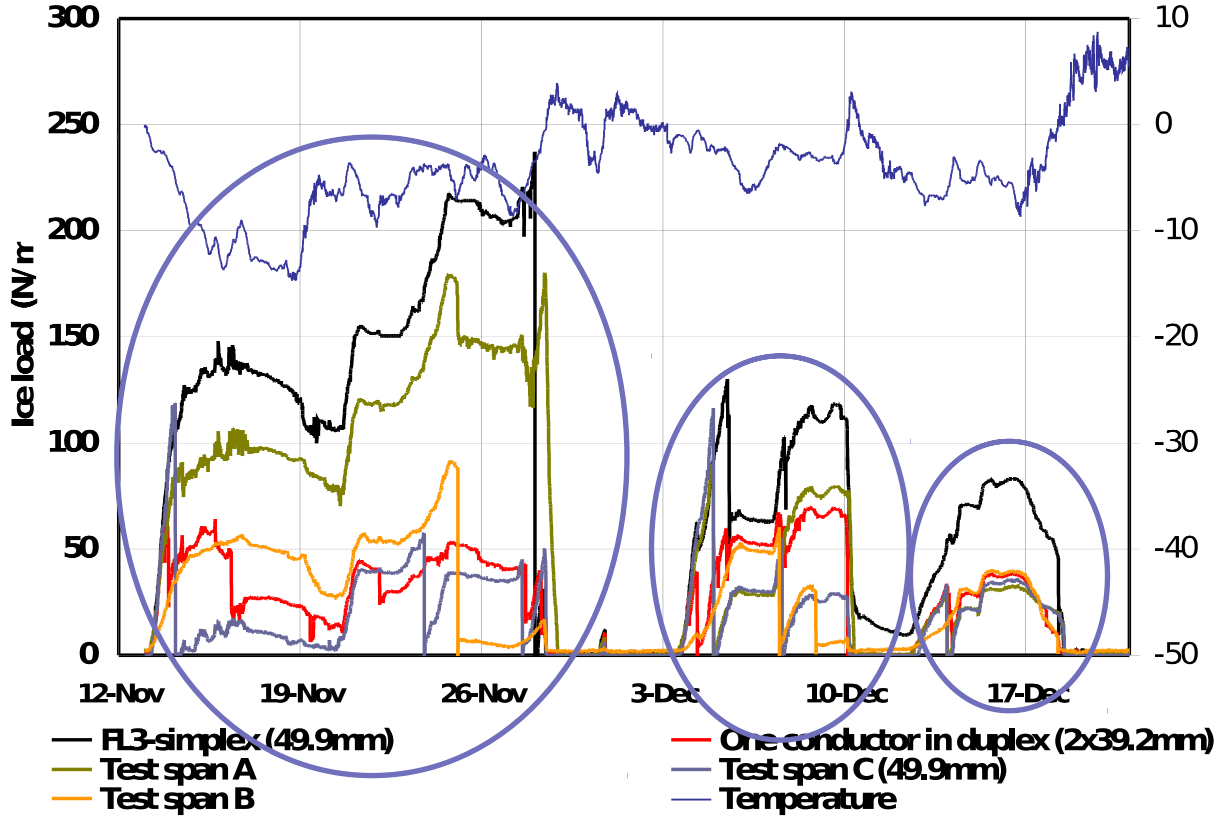
Hypothetical 1.
w = 0.6 g/cm³, V=14 m/s, T= -1°C

Increasing wind by 3m/s, temperature from site

WRF$_{1km}$ with extra forcing from nearby observations performs better

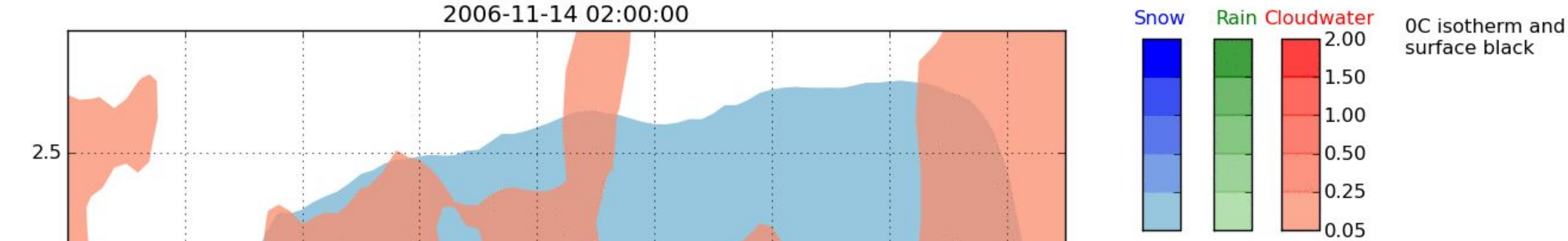
WRF models without forcing, performs badly

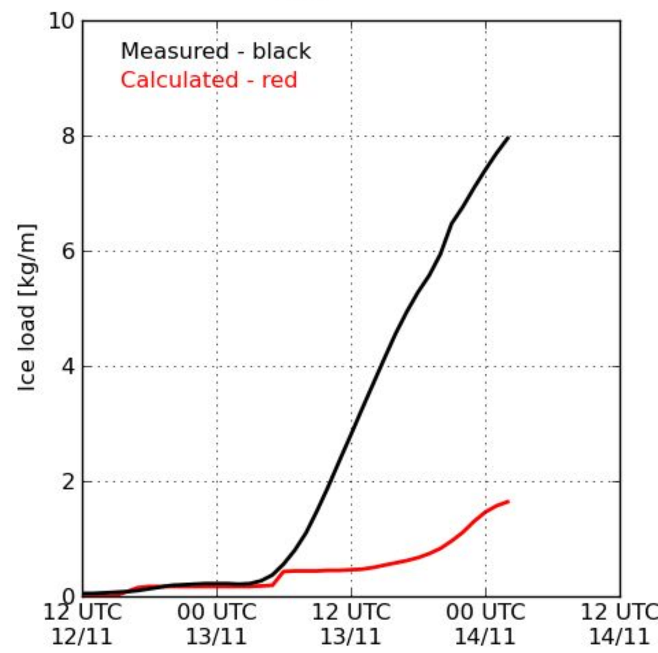
Icing in the period 12 Nov. to 20 Dec. 2006



- Three events in the period 12. Nov. to 20 Dec. 2006
- Five icing measuring setups captured the icing at site. Only measurements from test span A are used.

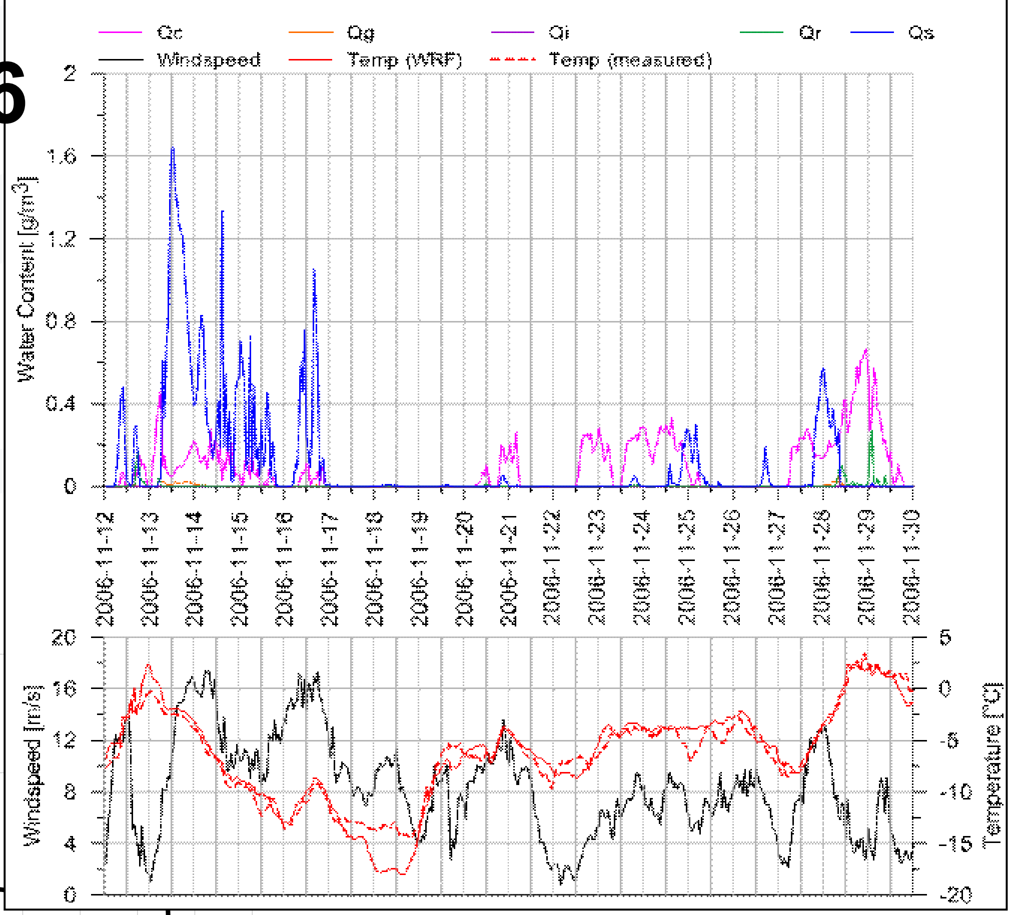
WRF$_{1km}$ simulation 12-14 Nov. 2006

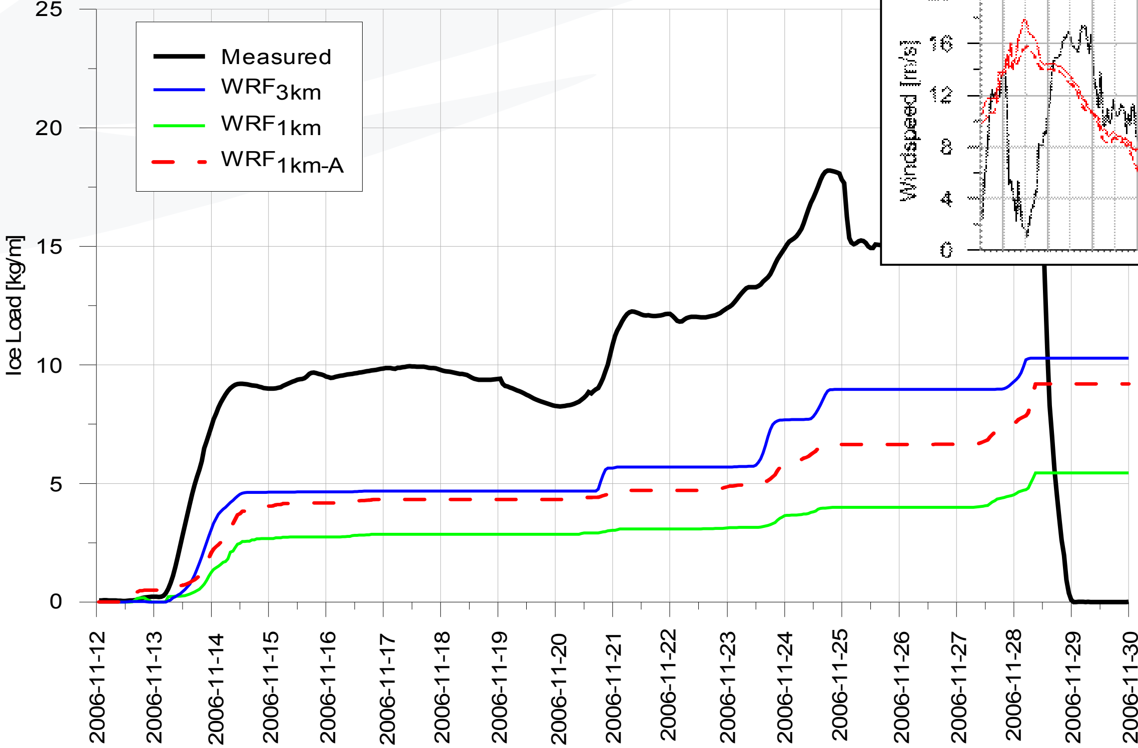




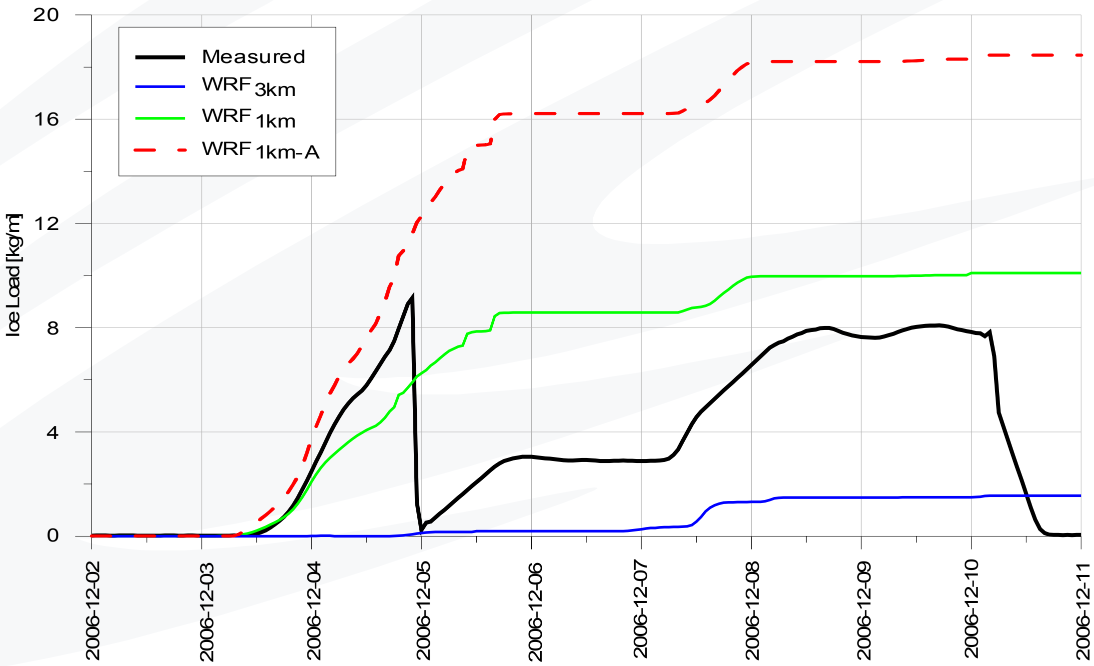
Icing 13-30 Nov. 2006

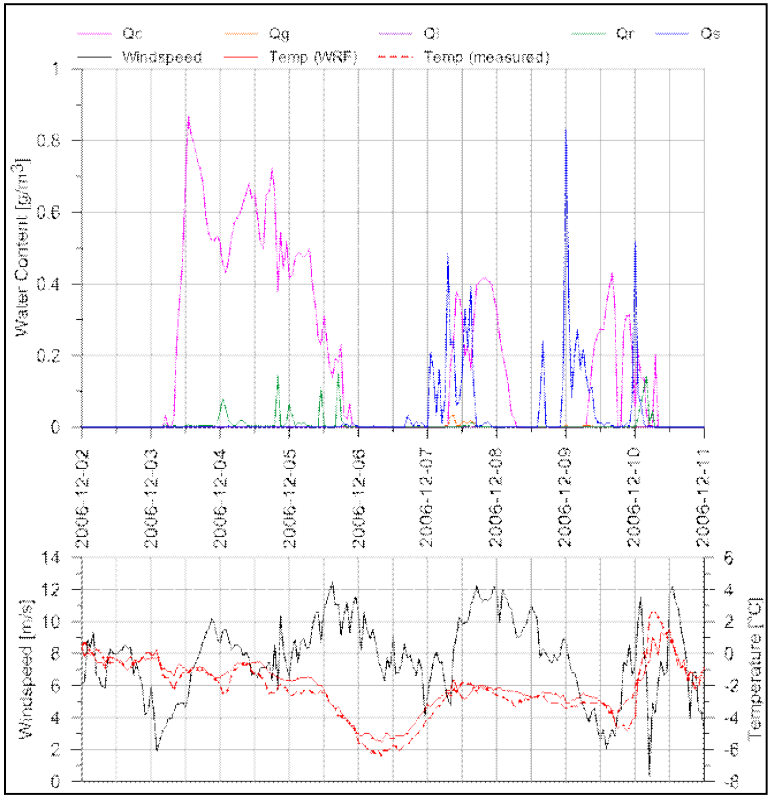
- All models underestimates icing.
- WRF_{1km} predicts high mass of snow and low mass of super-cooled cloud droplets.
- 60% of WRF_{3km} icing is freezing drizzle and wet snow icing.





Icing 4-12 Dec. 2006





- The WRF_{3km} model highly underestimates the icing accretion
- The WRF_{1km} model performs reasonably but underestimates the observed icing by a factor of 1.7 when the ice shedding is taken into account. Part of the explanation may be the relative high amount of snow particles 7-9 Dec.
- The $WRF_{1km\text{-}A}$ model gives increased accretion and it fits measurements quite well in the period of 3-6 Dec. The accumulation on the 7 Dec. is underestimated

Conclusions – WRF model

- On average, WRF correctly identifies icing events.

- Simulations predict considerable water content, capture reasonably well the temperature while winds may be underestimated.

- The WRF-simulations use 100 droplets/cm^3. Reducing droplet number in the WRF-simulation leads to a somewhat different water particle distribution.

- Nudging of surface observations 25 km upstream improves results at icing site.

- Model performance increases with increased resolution, especially when going from 3 km to 1 km.

Conclusions – Icing model

- Ice accretion rate is in general underestimated, especially for high ice loading.

- Model is not validated for loads above 15 kg/m and large ice diameters, which often have a rough surface, leading to incorrect formulas for collision and accretion efficiency, and ice density.

- The model is sensitive to temperatures slightly below 0°C, as the heat balance at the icing surface will not allow all particles to freeze.

- Dry snow (T < 0°C) causes no icing, which may not be valid for snow-fall through surface clouds with high water content and temperatures slightly below 0°C.

- The icing model is very sensitive to droplet size and increased accumulation occurs if droplets are fewer than 50 droplets/cm^3.

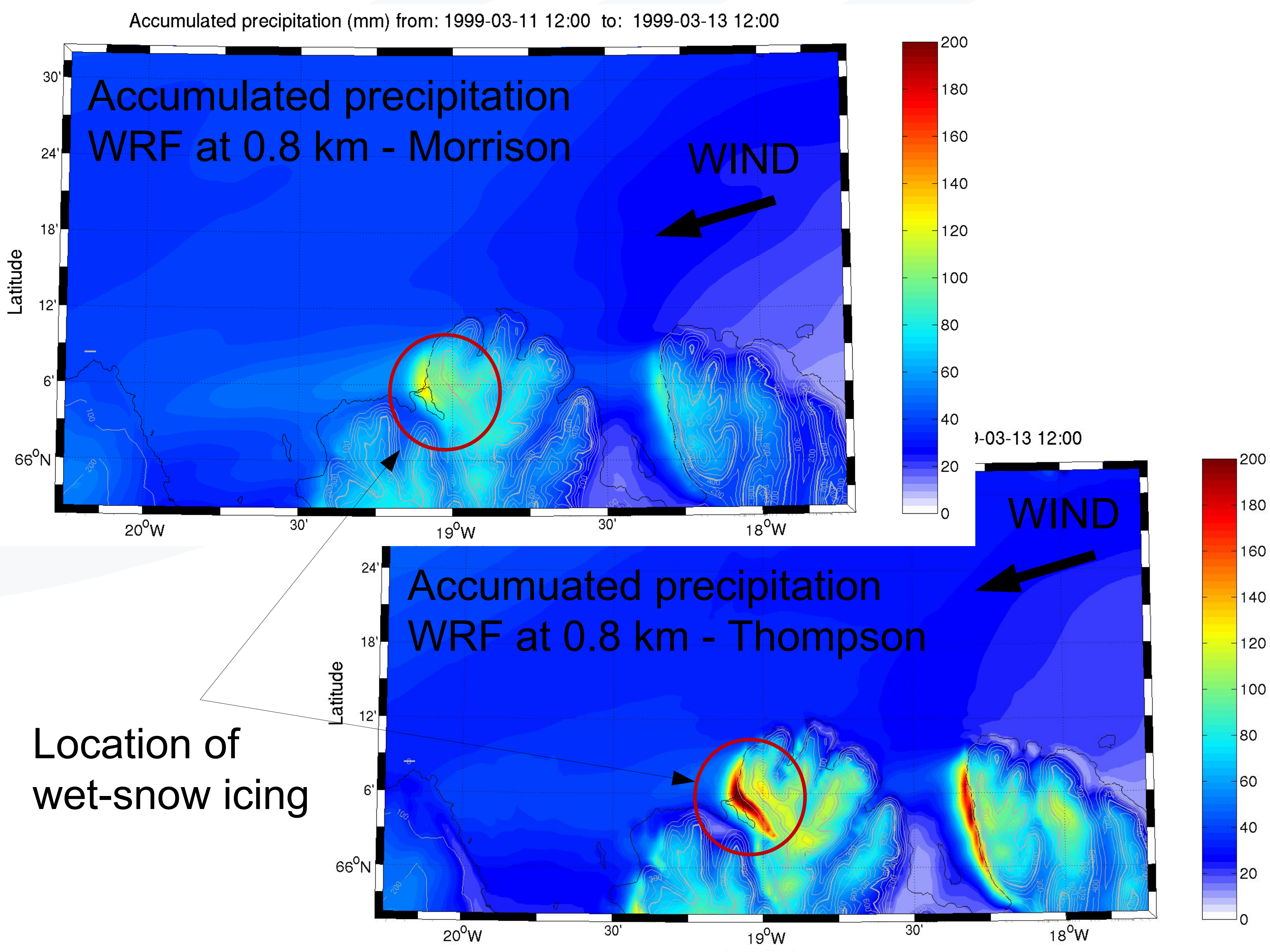
- Possible overestimation of observed icing due to other load distribution.

- Sensitivity of accretion to possibly underestimated winds, as well as small errors in e.g. the simulated locations of the 0°C isotherm and the maximum amount of super-cooled cloud condensate.

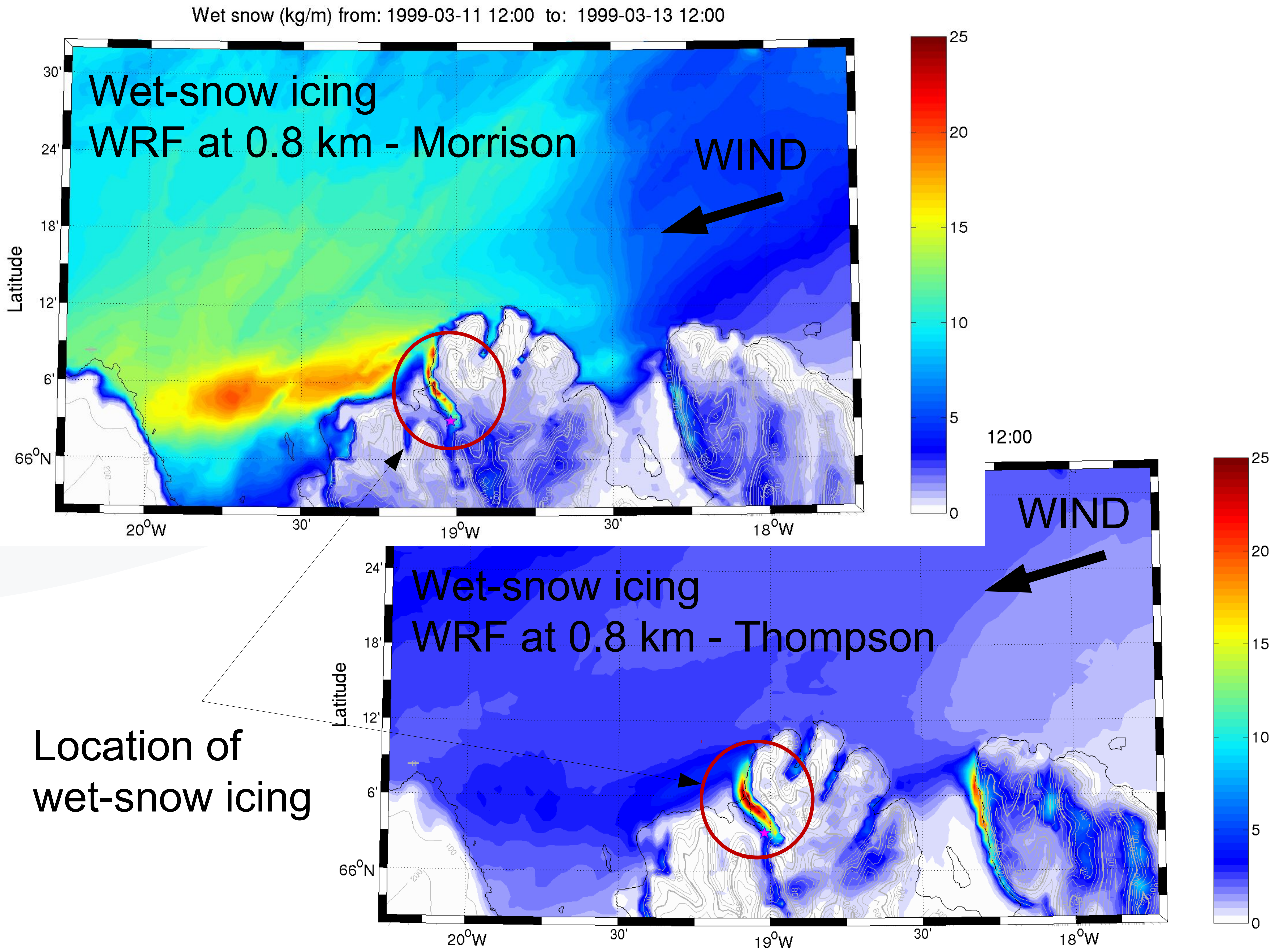
Wet-snow icing - "Work in progress"

For wet snow icing we need temperatures between approx 0°C and 2°C and water content of snow approx 10% to 40%

Wet-snow icing events in North-Iceland



Accumulated precipitation (mm) from: 1999-03-11 12:00 to: 1999-03-13 12:00
Accumulated precipitation
WRF at 0.8 km - Morrison
WIND
Latitude
30'
24'
18'
12'
6'
66°N
20°W
30'
19°W
30'
18°W
200
180
160
140
120
100
80
60
40
20
0
-03-13 12:00
WIND
Accumuated precipitation
WRF at 0.8 km - Thompson
Location of
wet-snow icing


Wet snow (kg/m) from: 1999-03-11 12:00 to: 1999-03-13 12:00
Wet-snow icing
WRF at 0.8 km - Morrison
WIND
30'
24'
18'
12'
6'
66°N
Latitude
20°W
30'
19°W
30'
18°W
25
20
15
10
5
0
12:00
WIND
Wet-snow icing
WRF at 0.8 km - Thompson
24'
18'
12'
6'
66°N
Latitude
20°W
30'
19°W
30'
18°W
25
20
15
10
5
0
Location of
wet-snow icing


Thank you for your attention !