



Icing atlas and forecasts for Iceland

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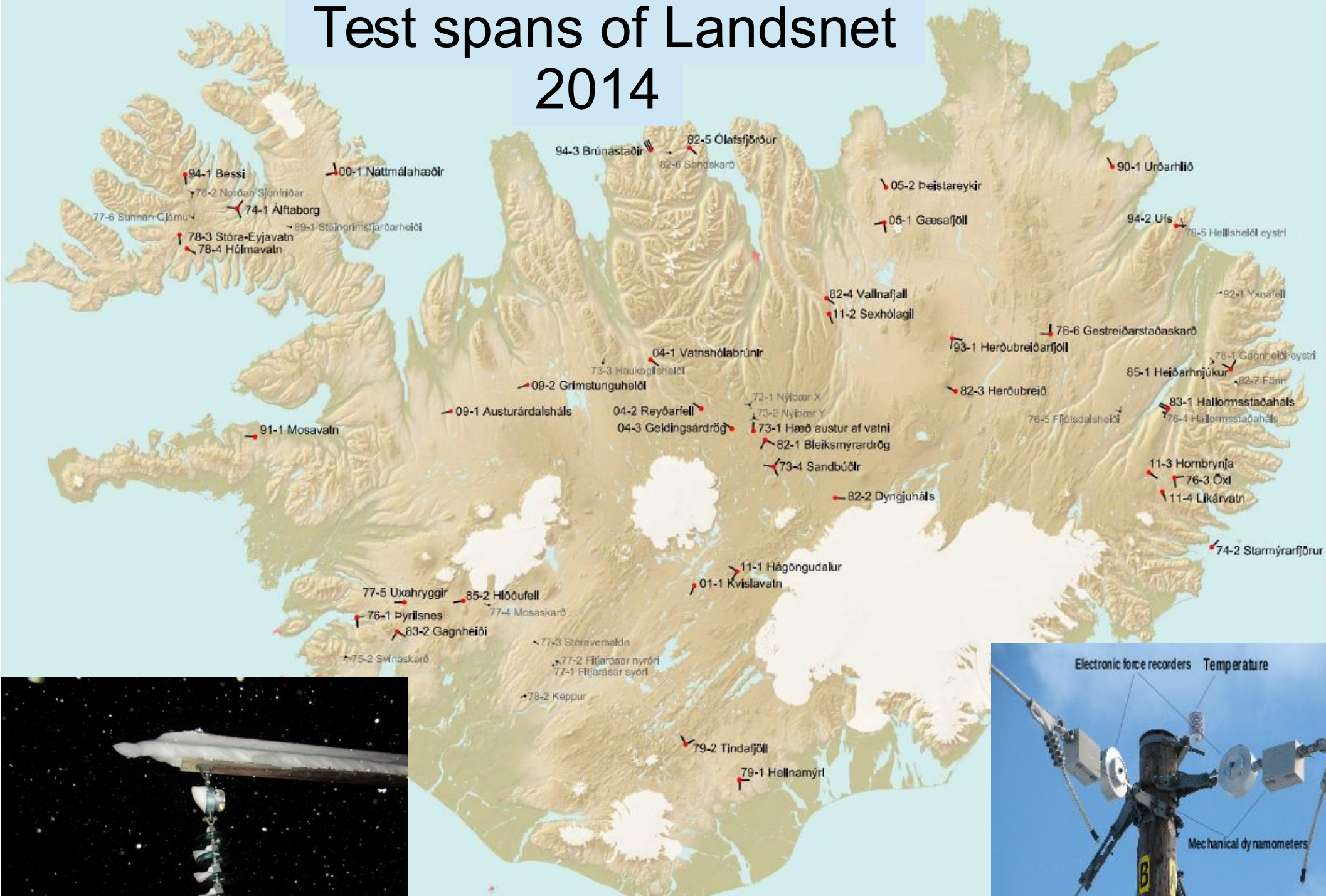
Wet-snow accretion



In-cloud icing



Test spans of Landsnet 2014



Photos: Árni Jón Elfásson

Wet-snow accretion

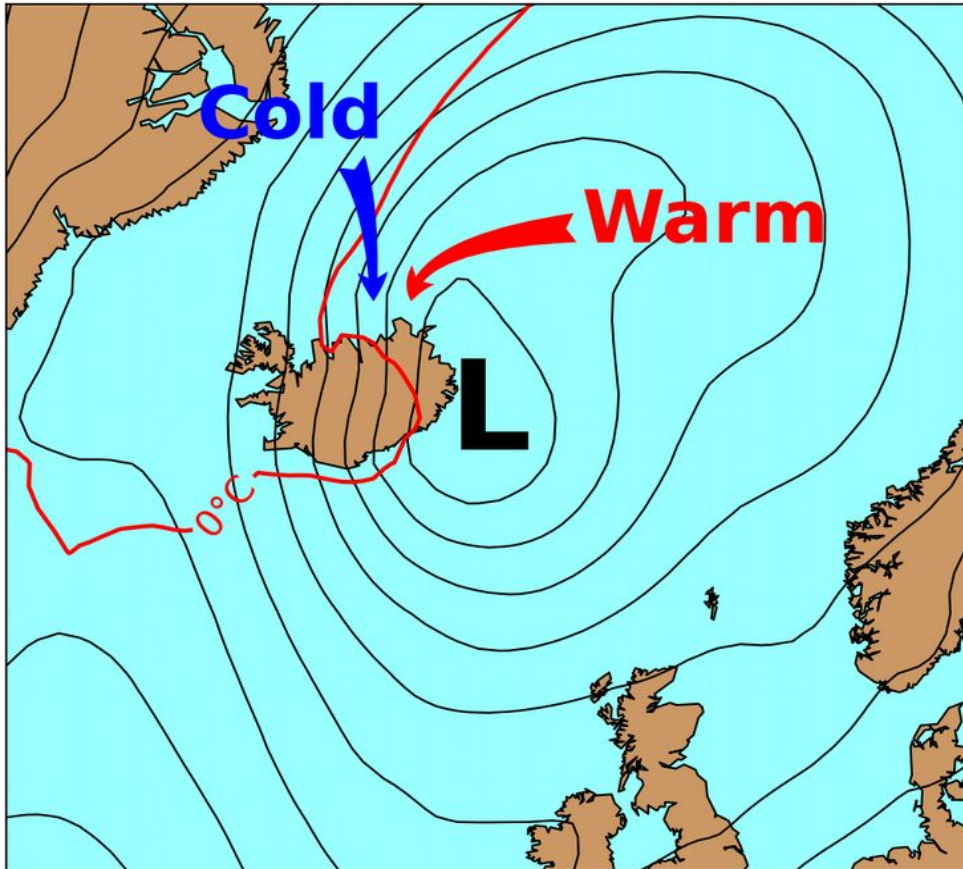
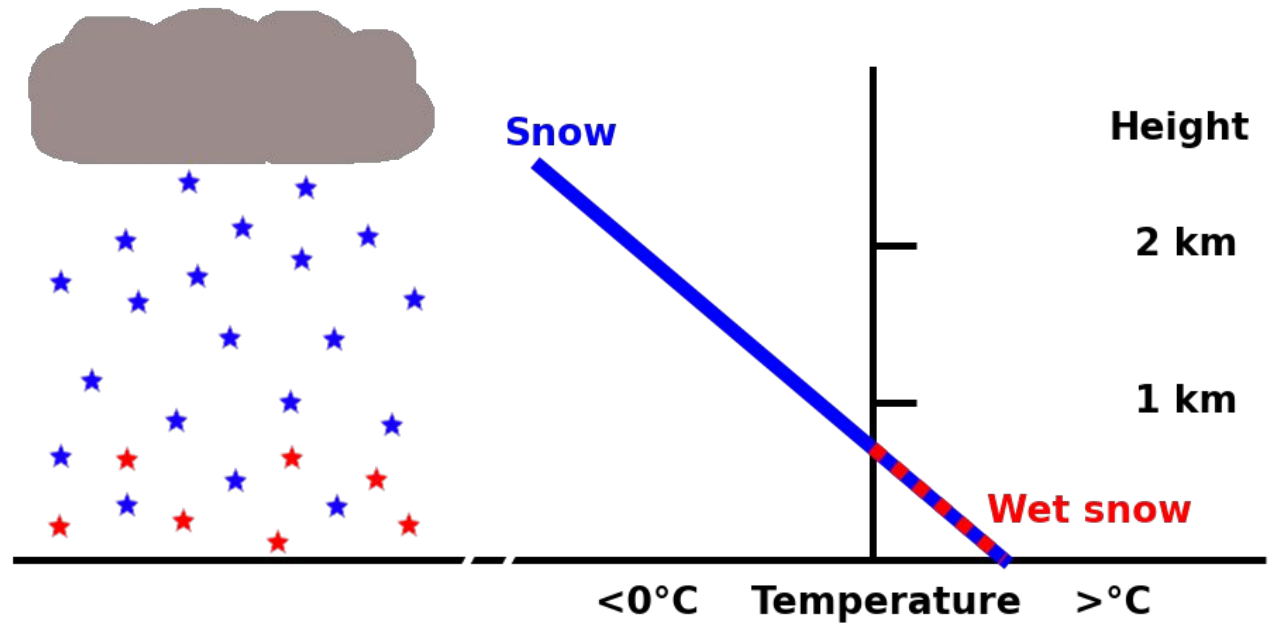
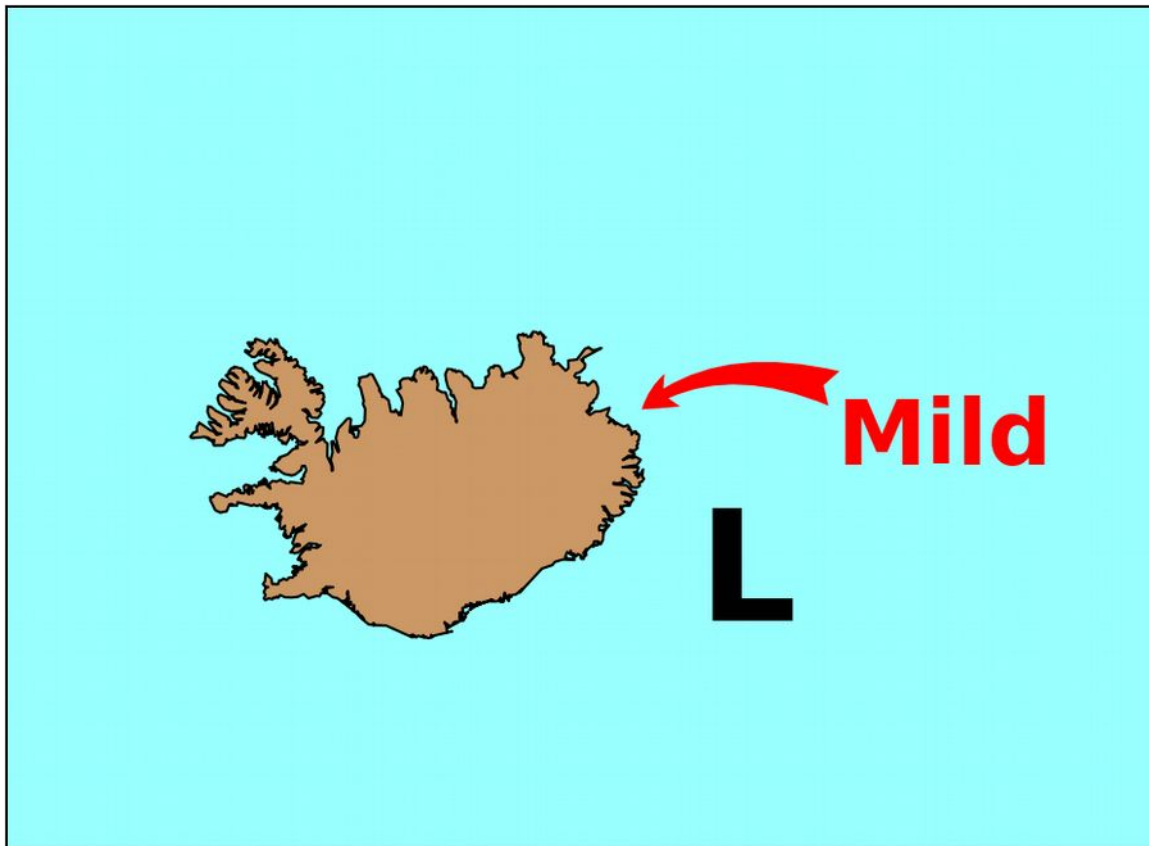
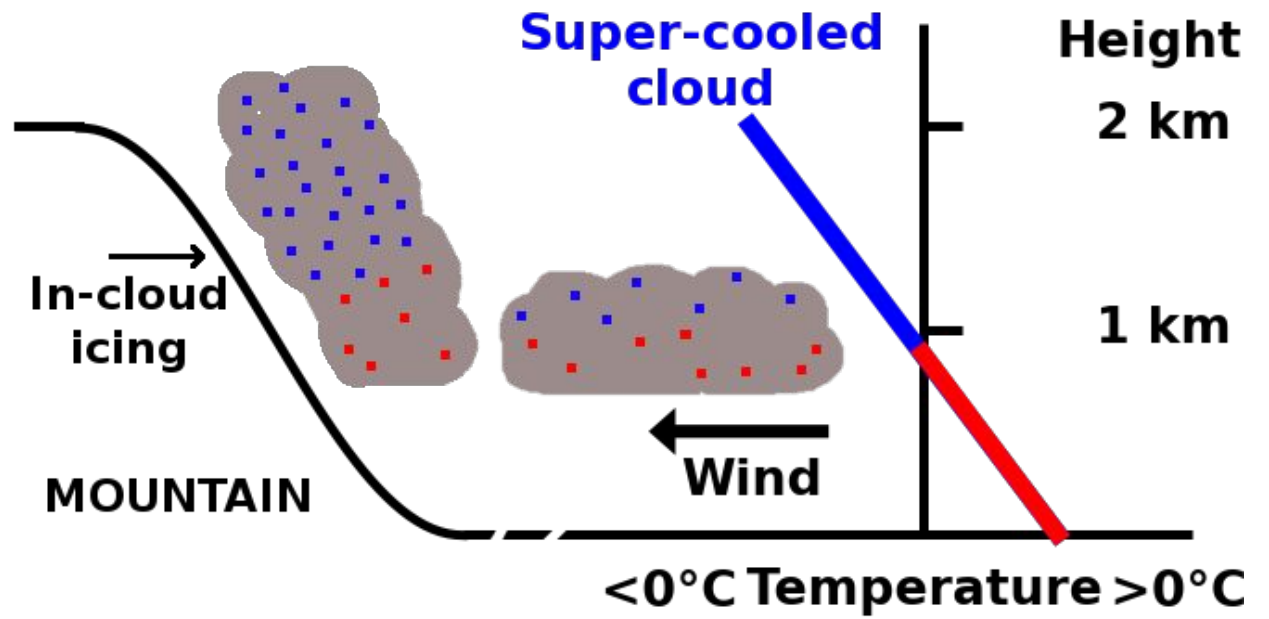


Photo: Finnur Baldursson

In-cloud icing



How to model atmospheric icing?

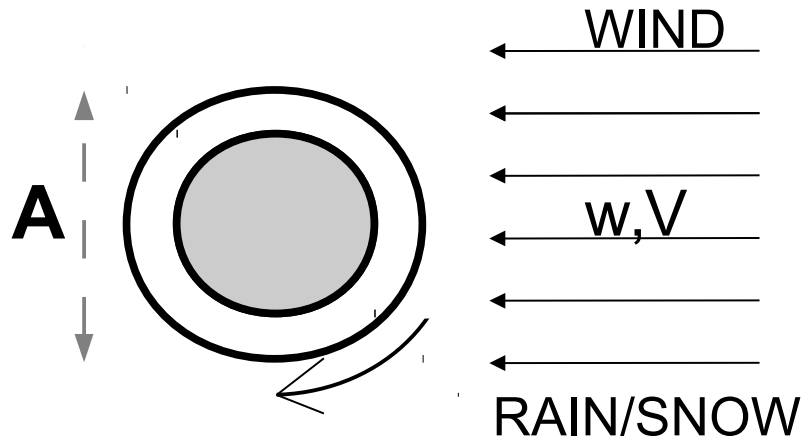
In-cloud



Wet-snow



How to model atmospheric icing?



Makkonen (ISO-standard):

$$dM/dt = \alpha_1 \alpha_2 \alpha_3 w A V$$

w: mass of atmospheric water,

A: collision area of cylinder

V: wind speed

α_1 : Collision efficiency

α_2 : Sticking efficiency

α_3 : Accretion efficiency

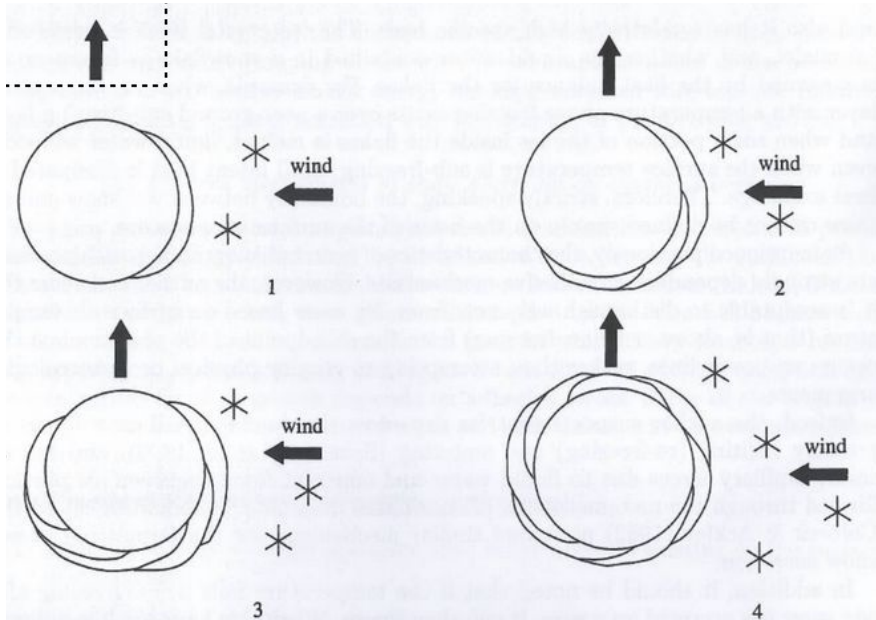
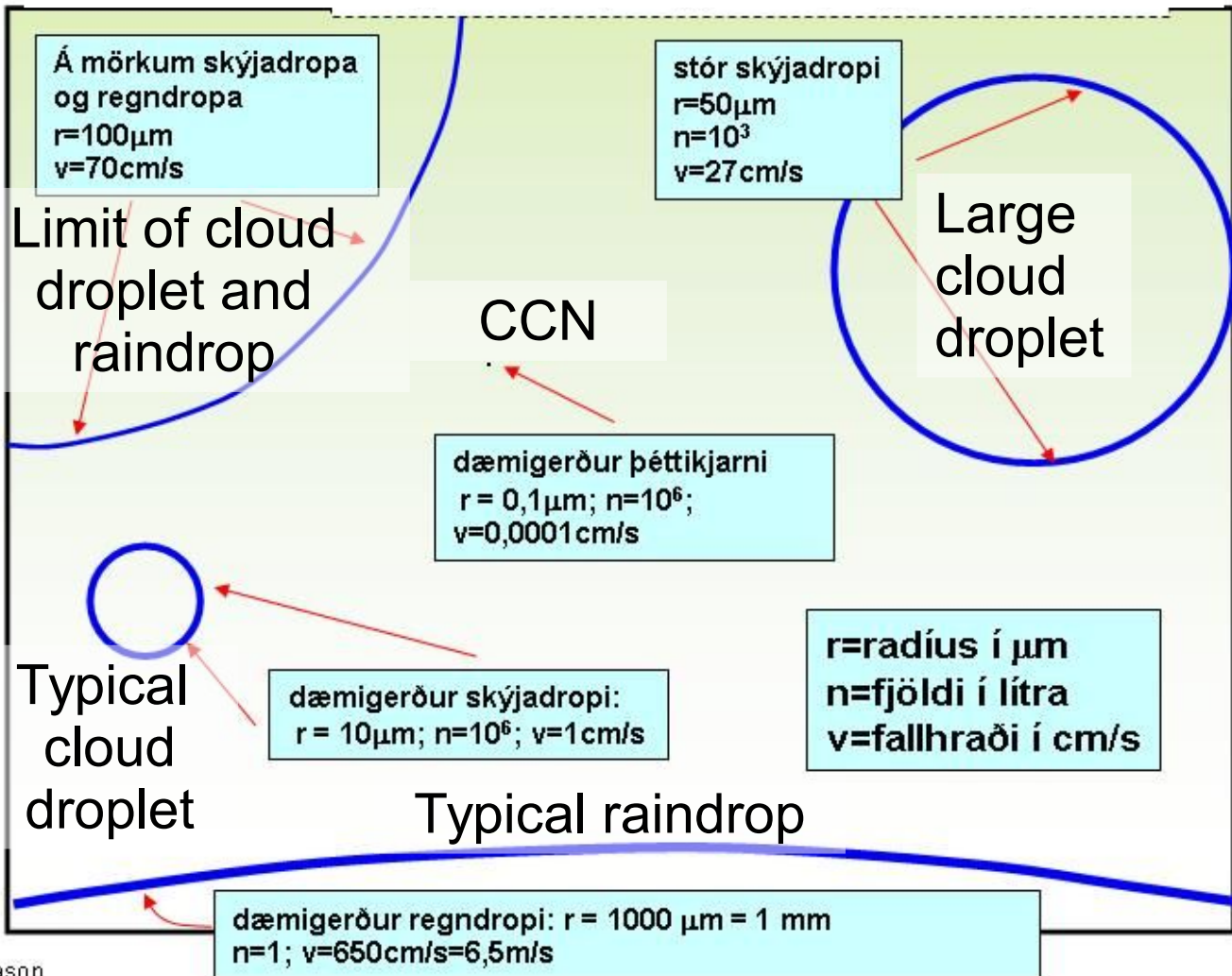


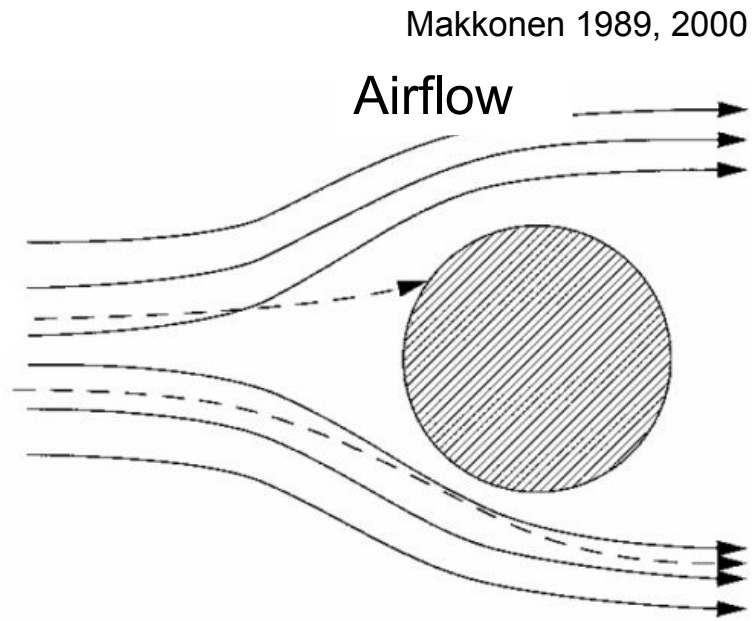
Photo: Árni Jón Eliasson

Typical sizes of rain and cloud droplets



$$\alpha_1$$

Small particles are less likely to hit

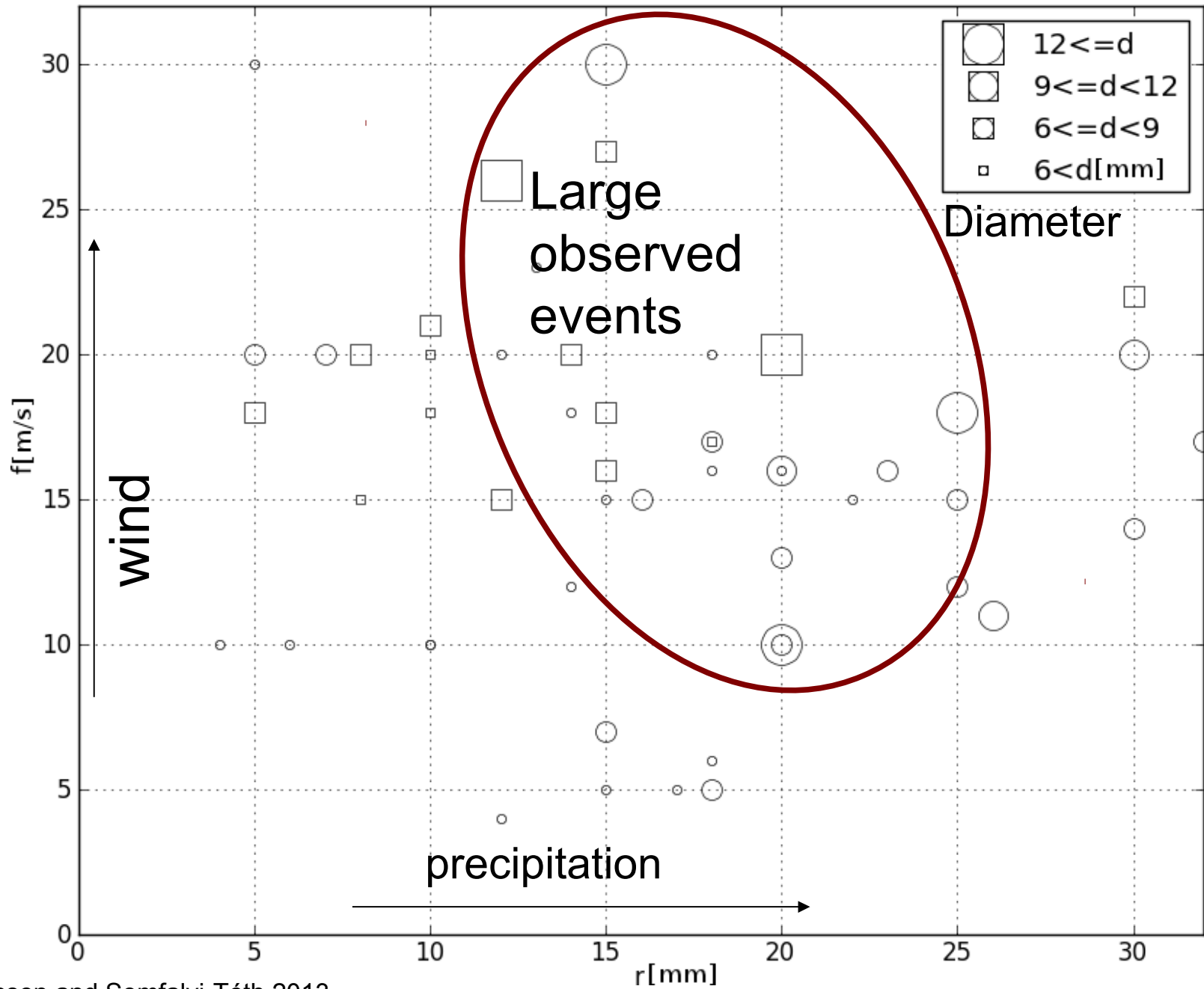


J. E. MacDonald (1958) and Wallace and Hobbs (2006), in Icelandic by Trausti Jónsson.

Large drops hit
Small drops miss

Makkonen 1989, 2000

α_2 - Is it a hit and run impact?



α_3 - Water mass may be lost if $T \approx < 0^\circ\text{C}$



Input data for modeling?

- Atmospheric data from a numerical model:
 - A-WRF version 3-4-1.
 - ETA PBL-scheme.
 - Thompsons microphysics.
 - Corine corrected landuse.
 - ECMWF atmospheric analysis.
 - 9-3-1 km horizontal resolution.
 - 55 levels in the vertical.
- Numerical data is used as input to wet snow accretion models.
 - Wind, temperature, liquid water content of snow, influx of atmospheric water

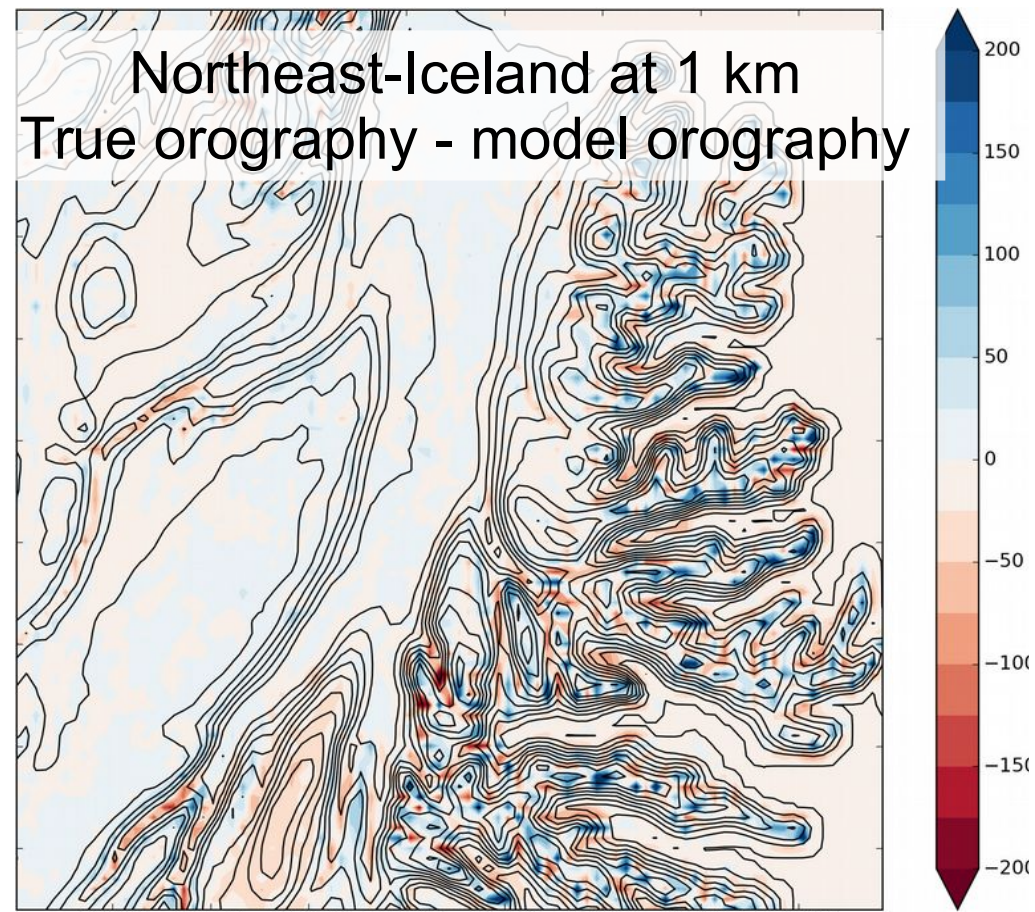
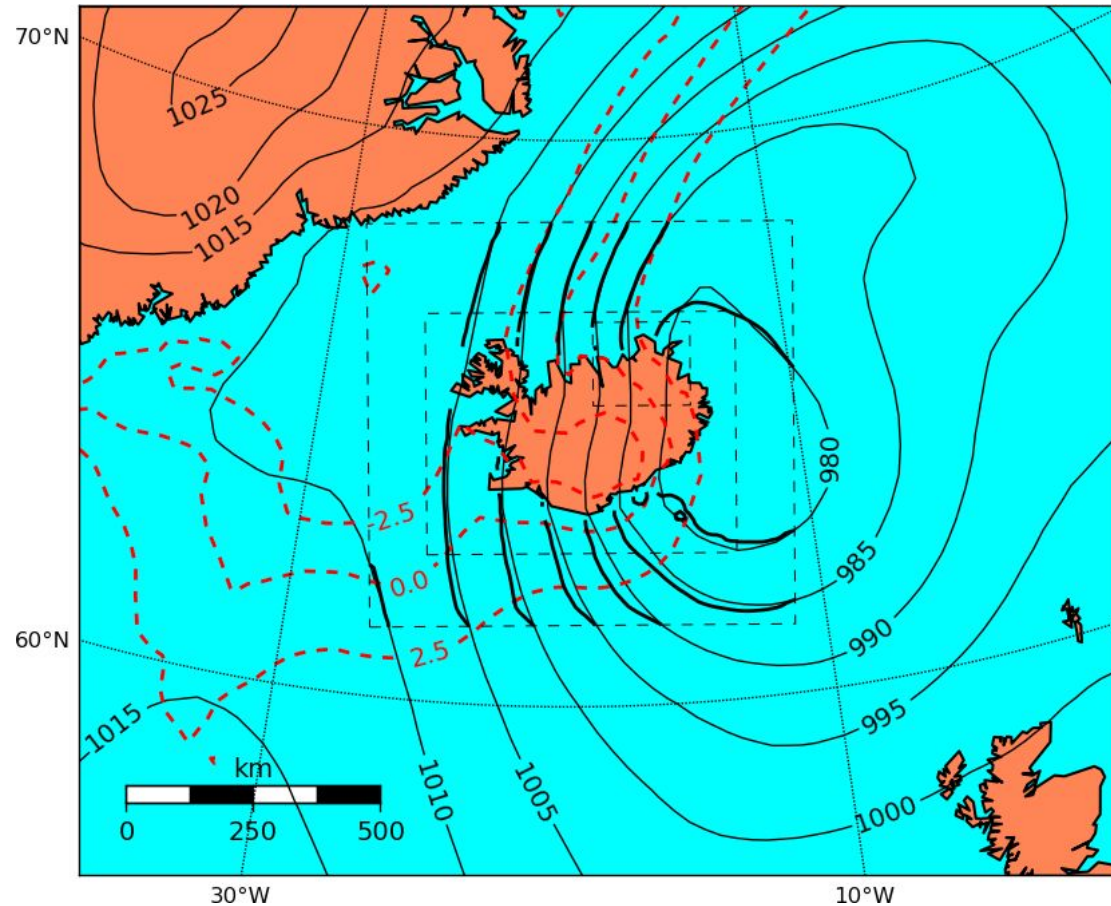


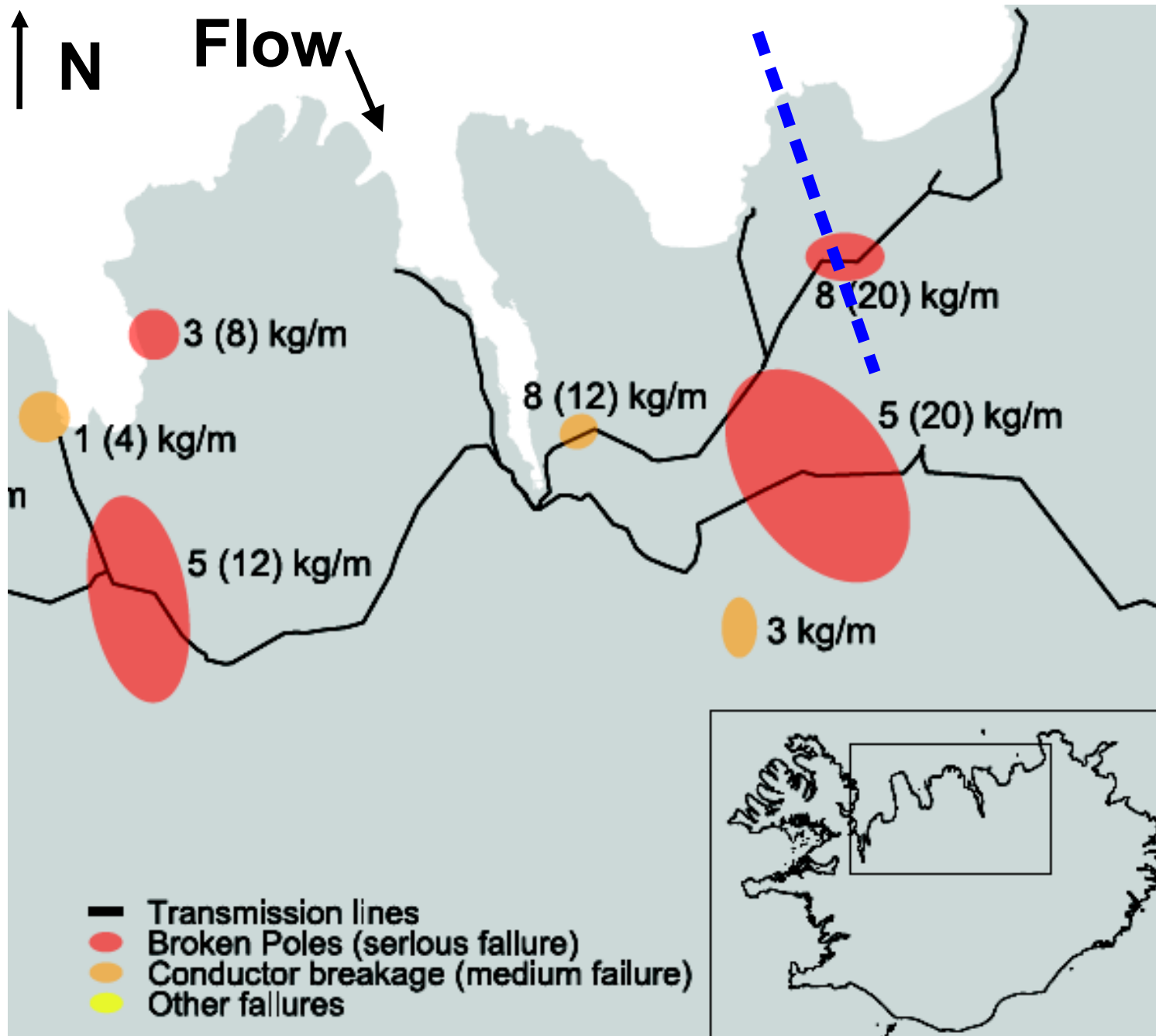
Photo: Árni Jón Elíasson

An extreme wet snow event

- Extreme snowfall early in the autumn, 10. september 2012
- Temperatures 0-2°C at approx. 200-400 m
- Mean NW-wind > 20 m/s
- Accumulation up to 15 kg/m on suspended overhead powerlines
- Load cell in energized overhead transmission line



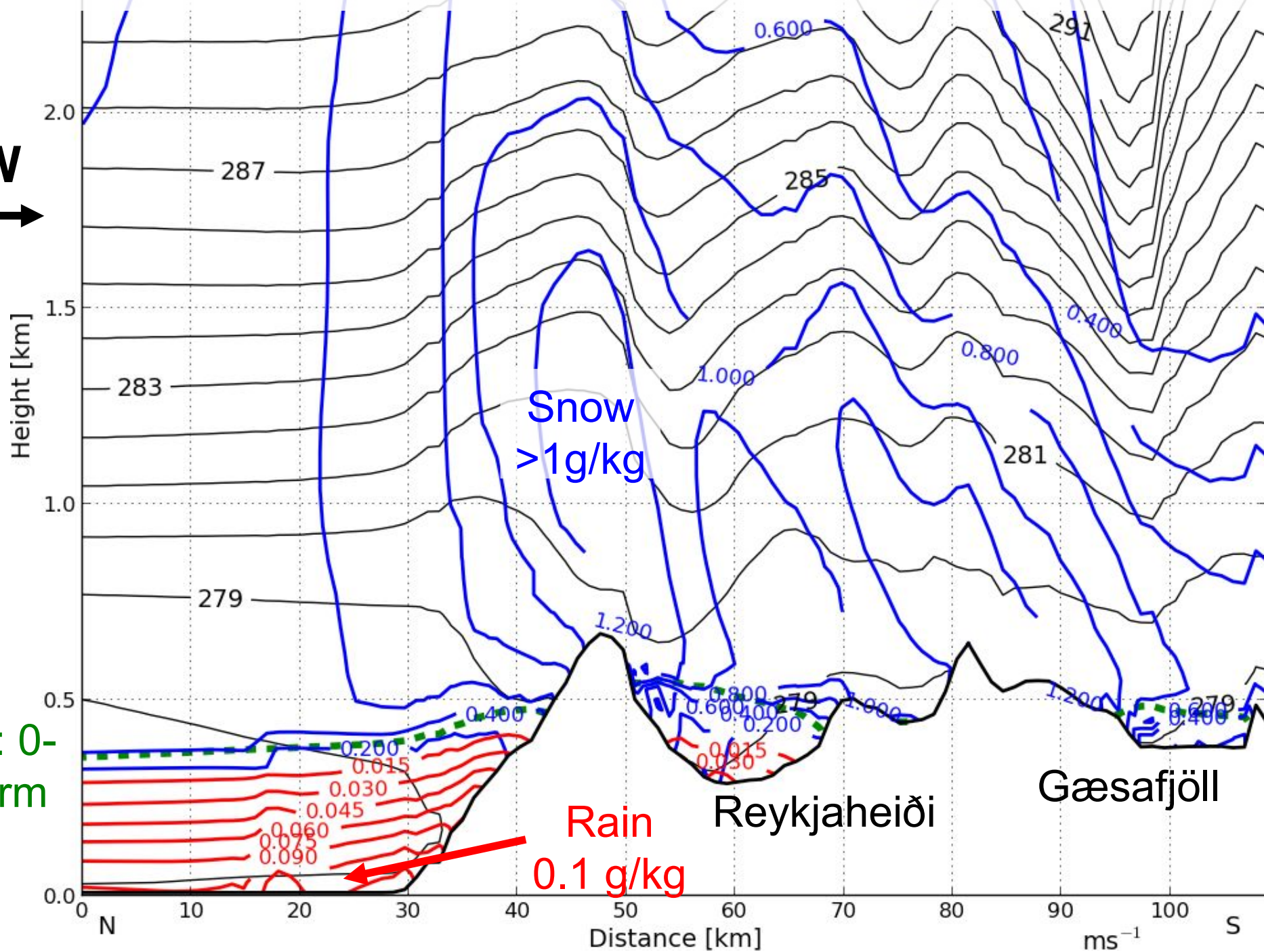
Icing loads and damage observed



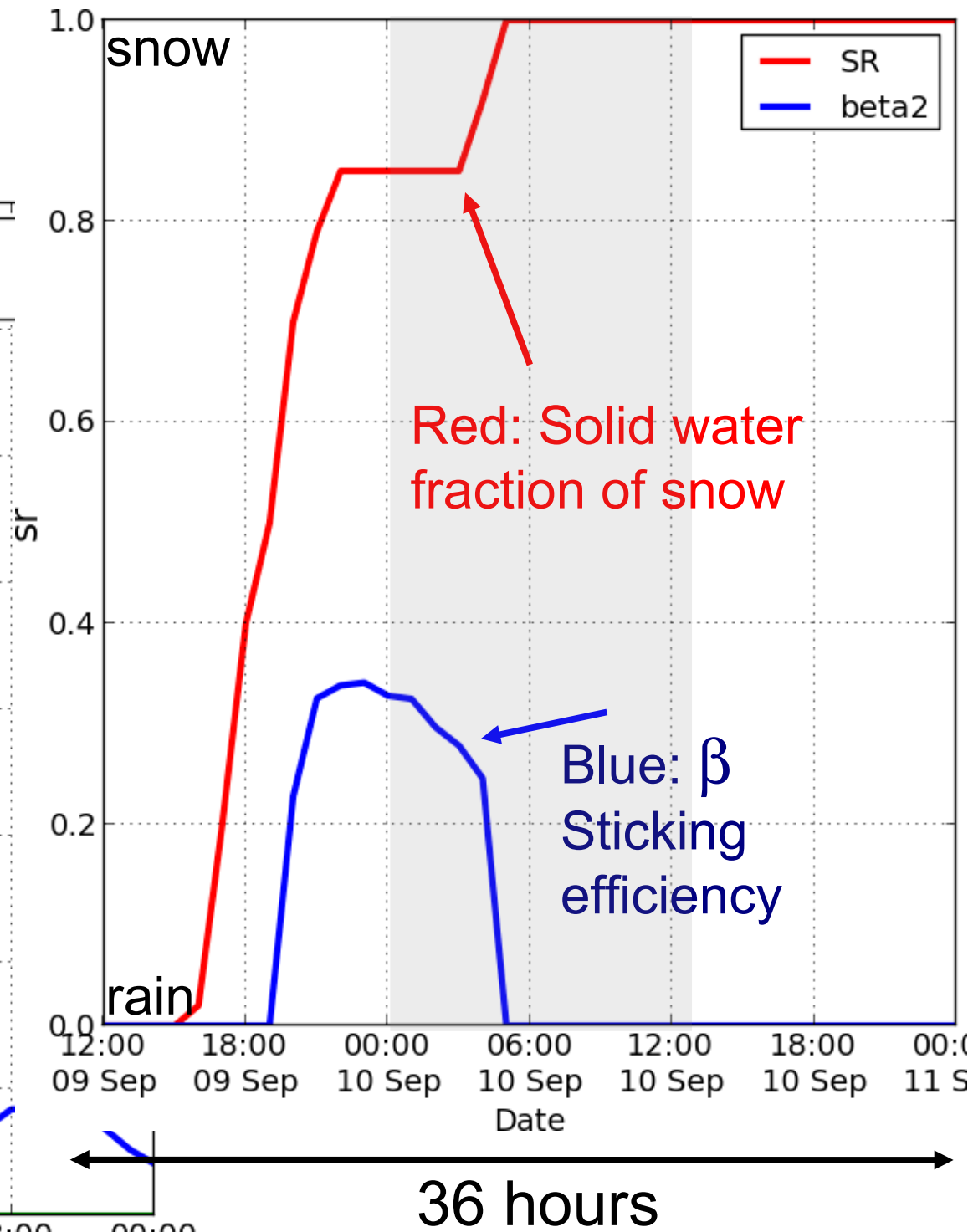
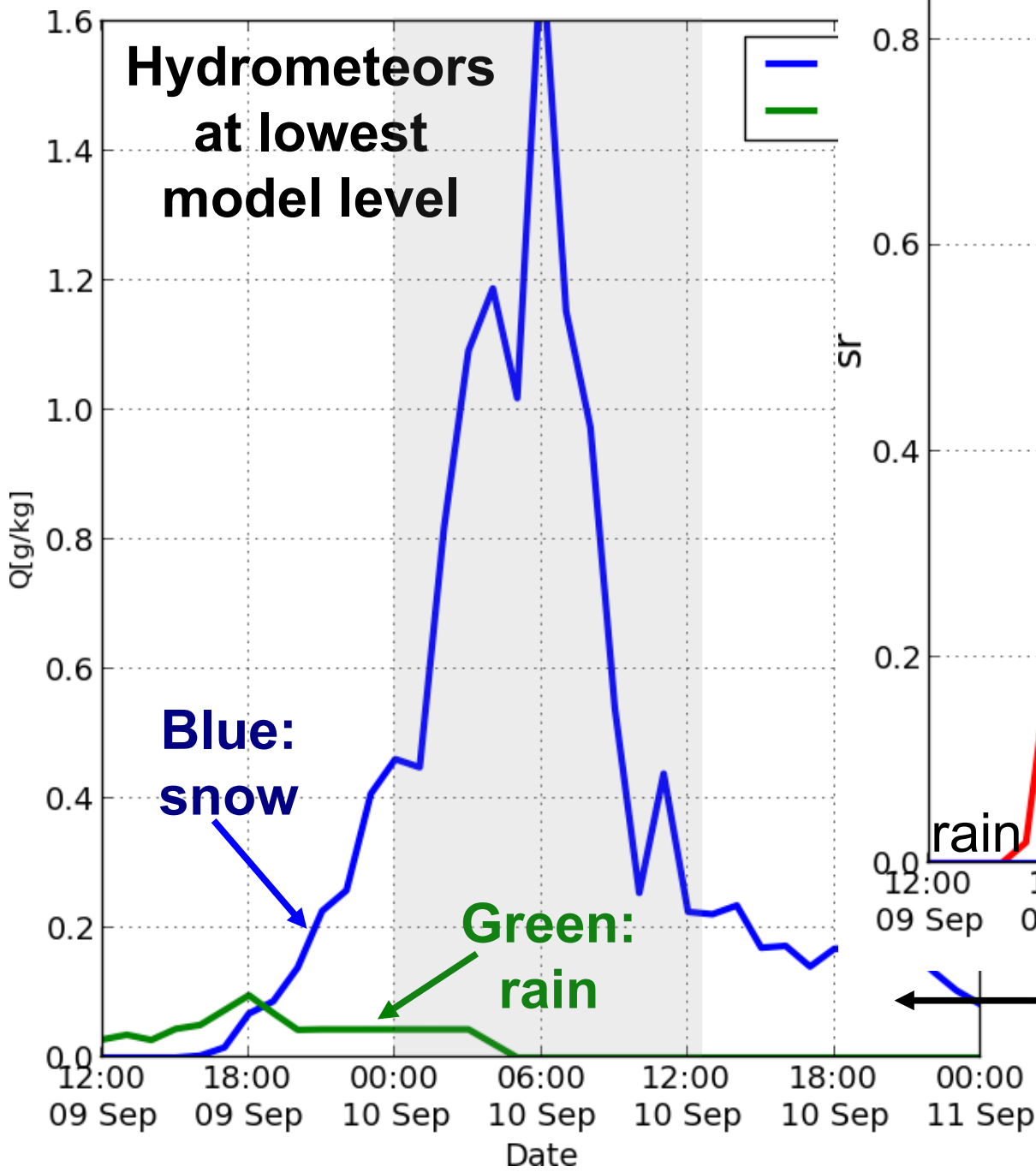
Simulated atmospheric water in section

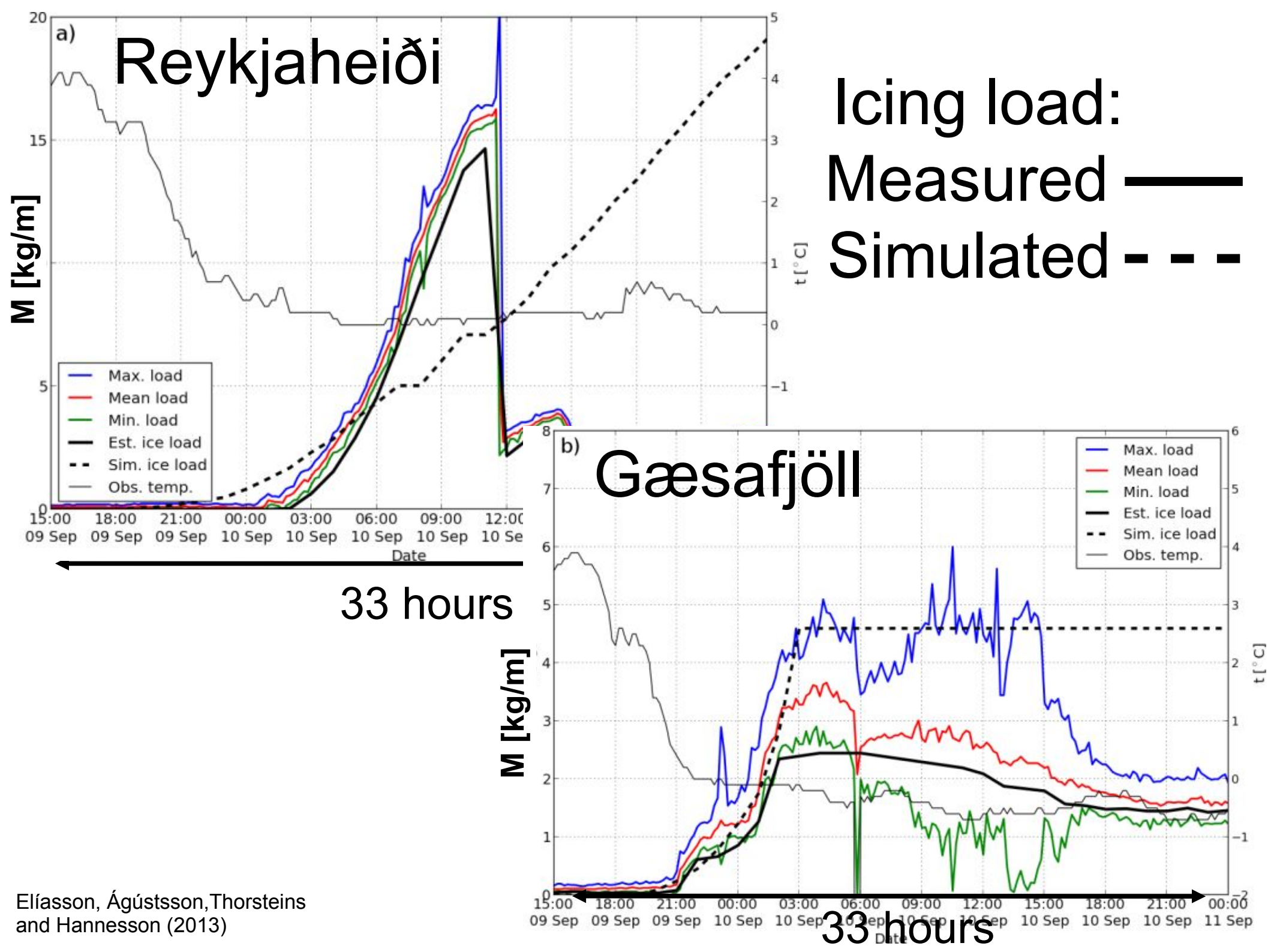
FLOW
→

Green: 0-
isotherm



Simulated values

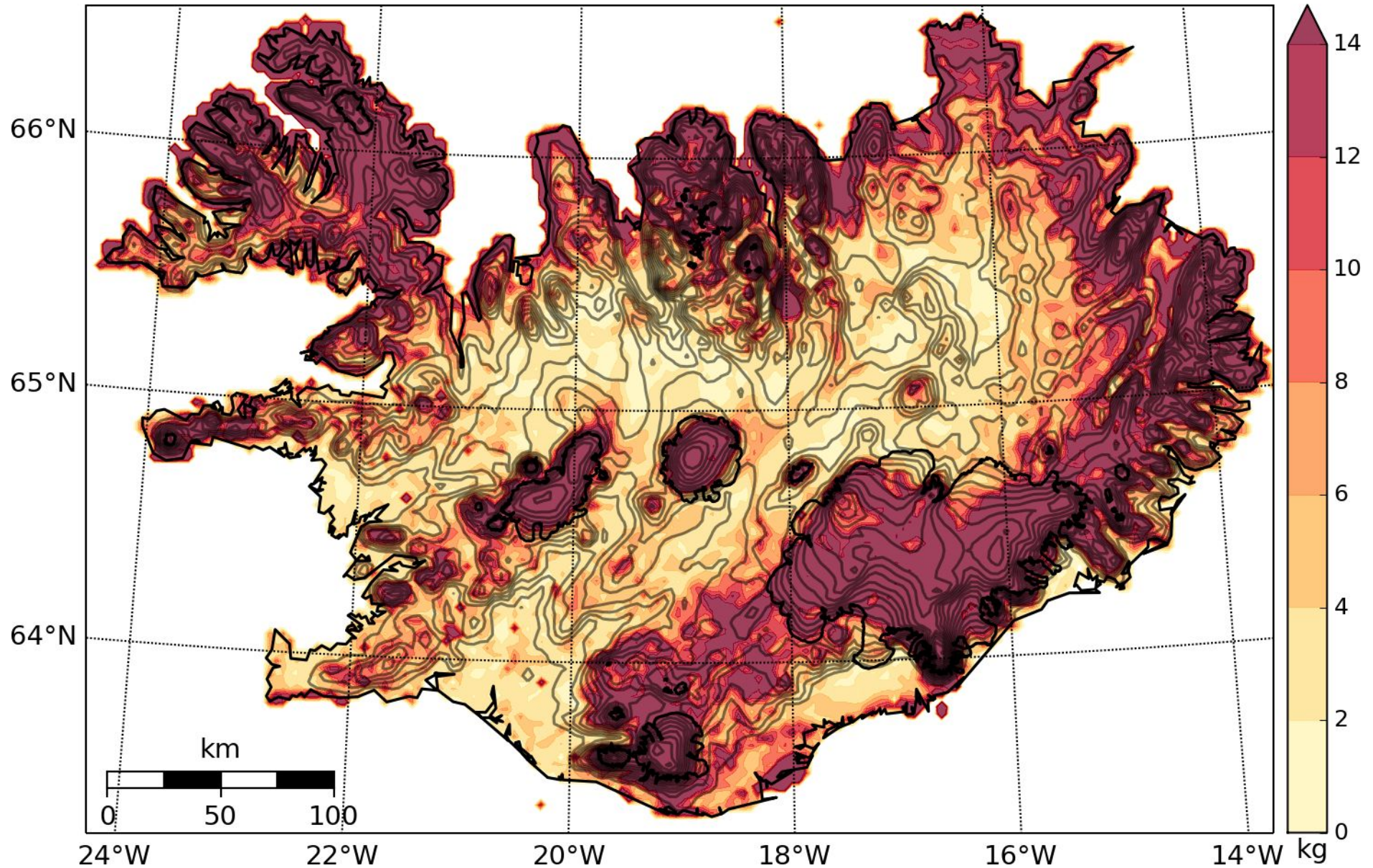




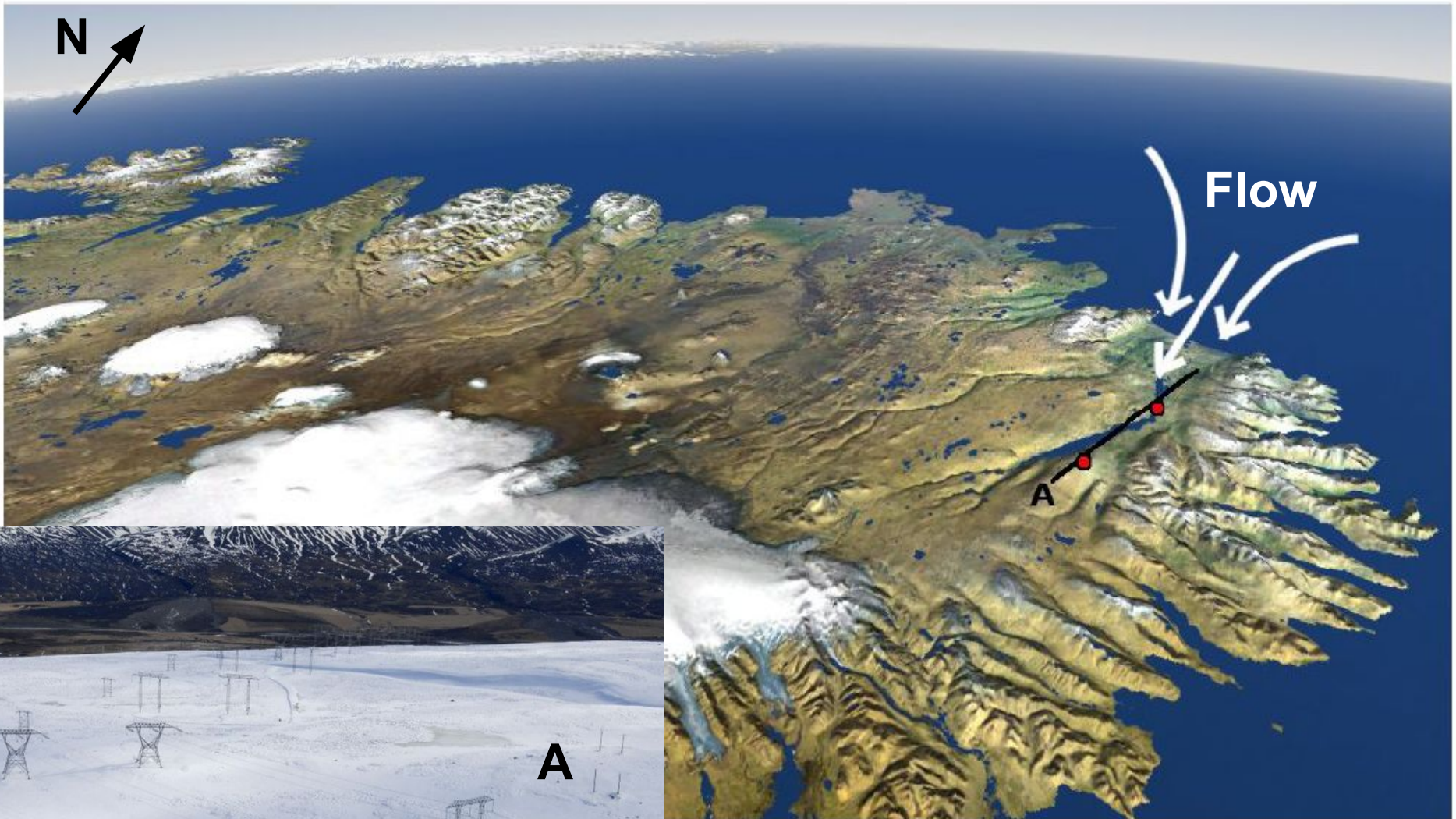
Elíasson, Ágústsson, Thorsteins and Hannesson (2013)

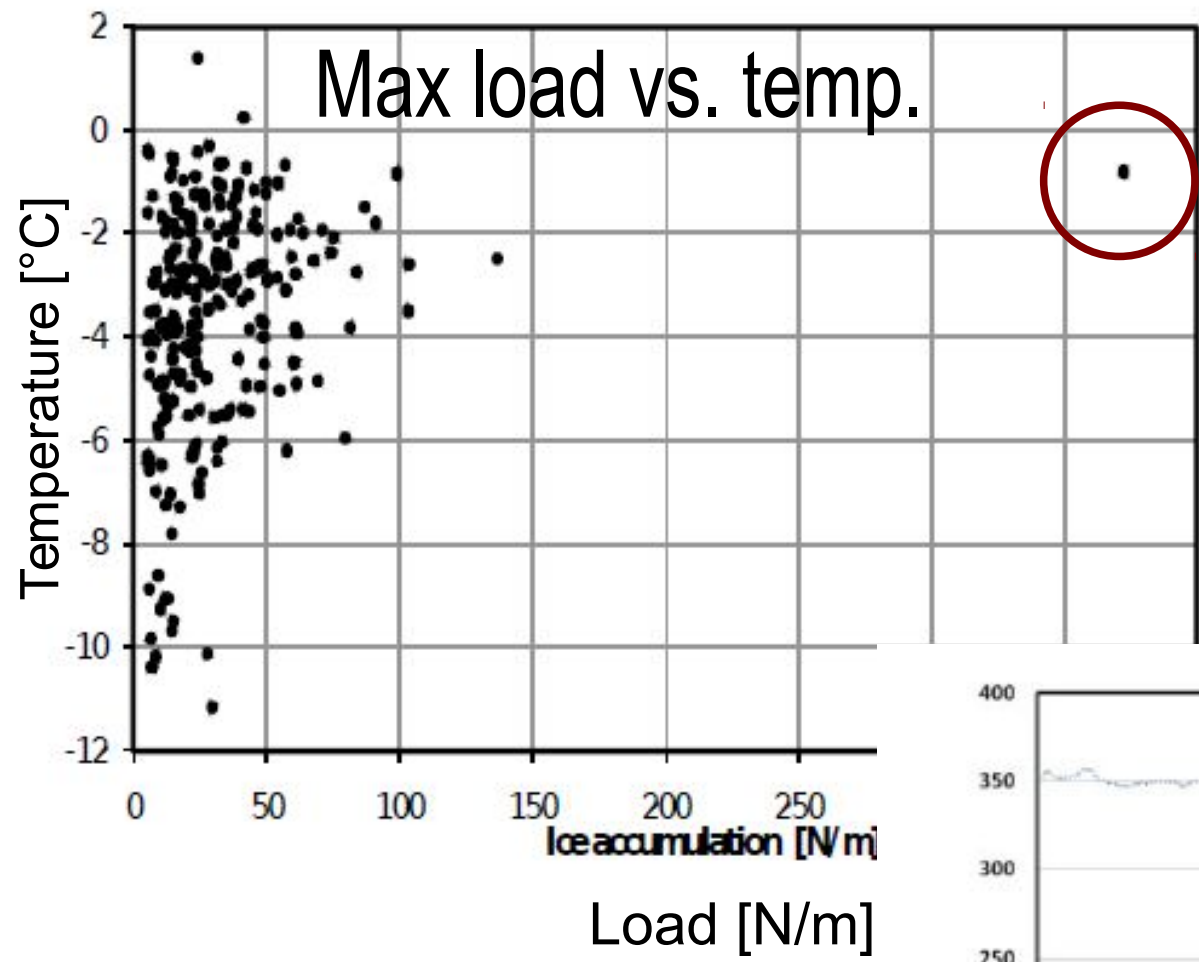
Maximum wet-snow load in 17 years

Preliminary results, RÁV (WRF), 1994-2011, 3 km resolution



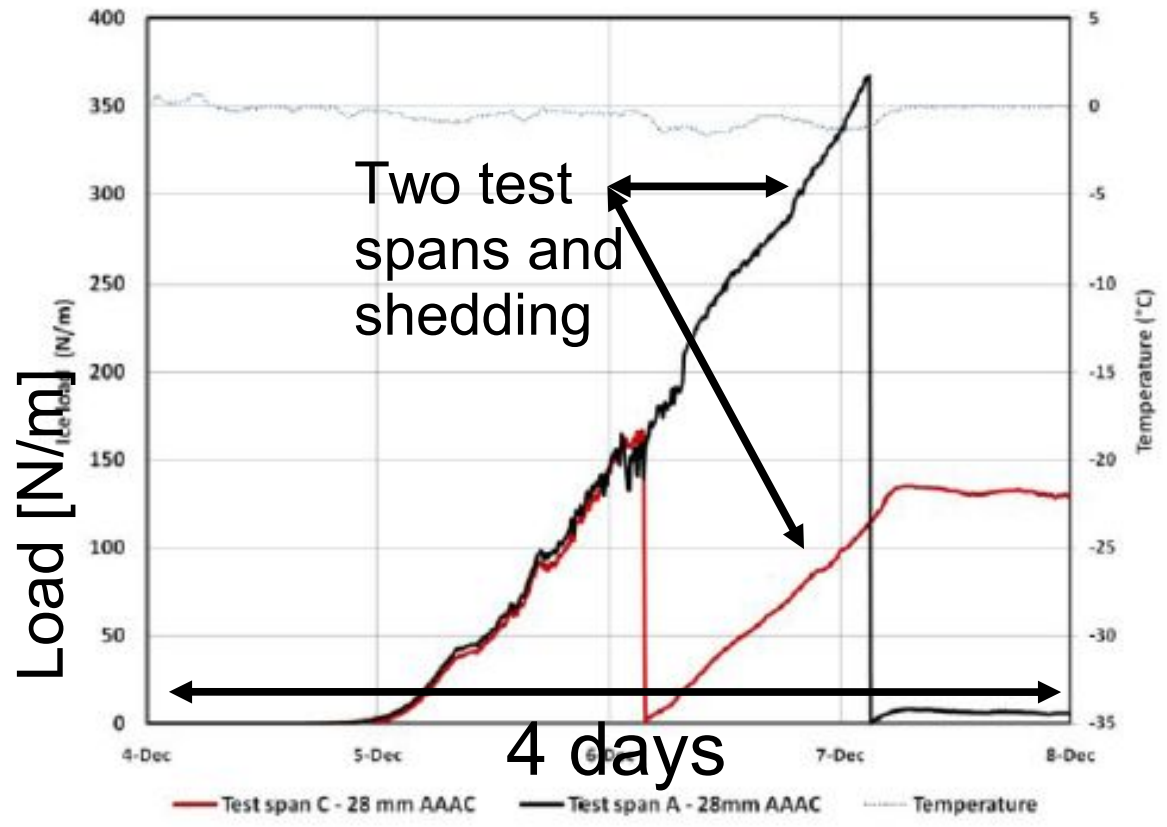
In-cloud icing at Hallormsstaðaháls



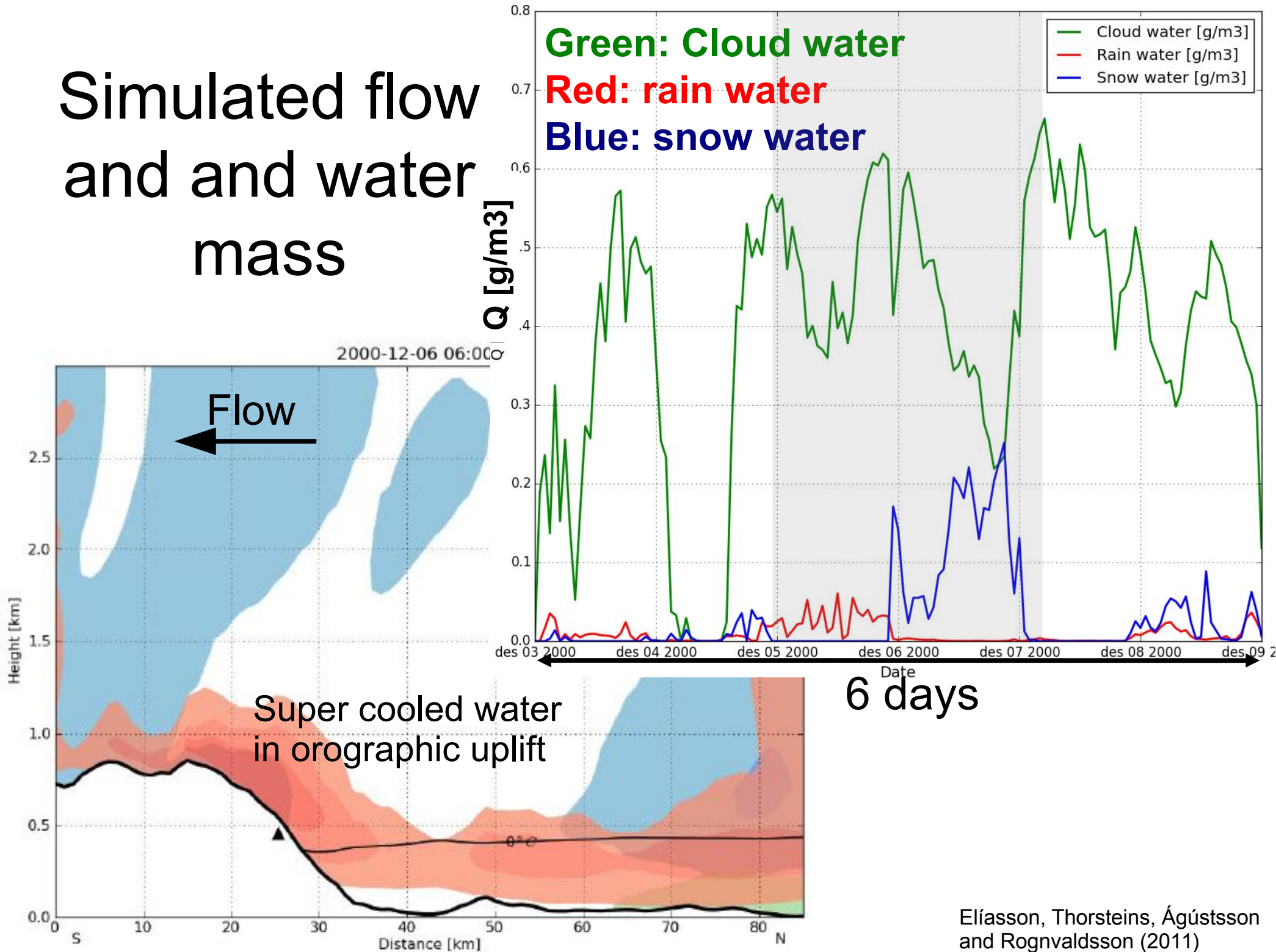


Load [N/m]

Observed
in-cloud ice
load

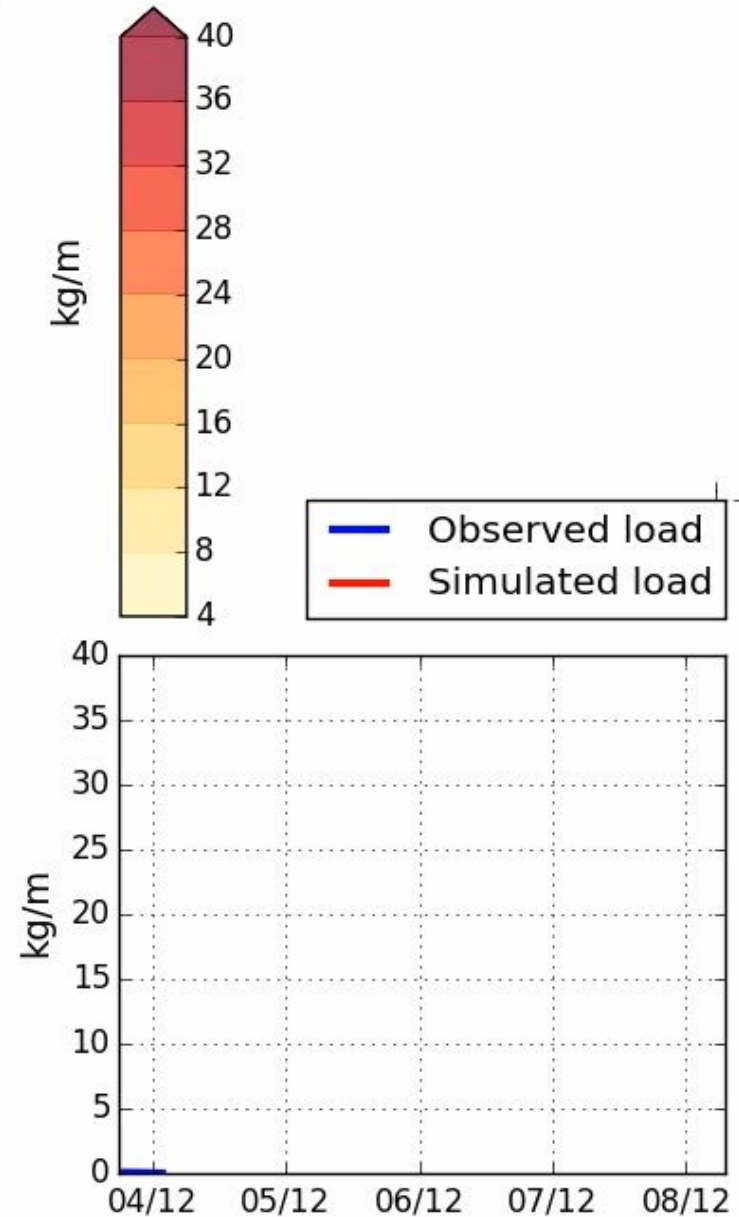
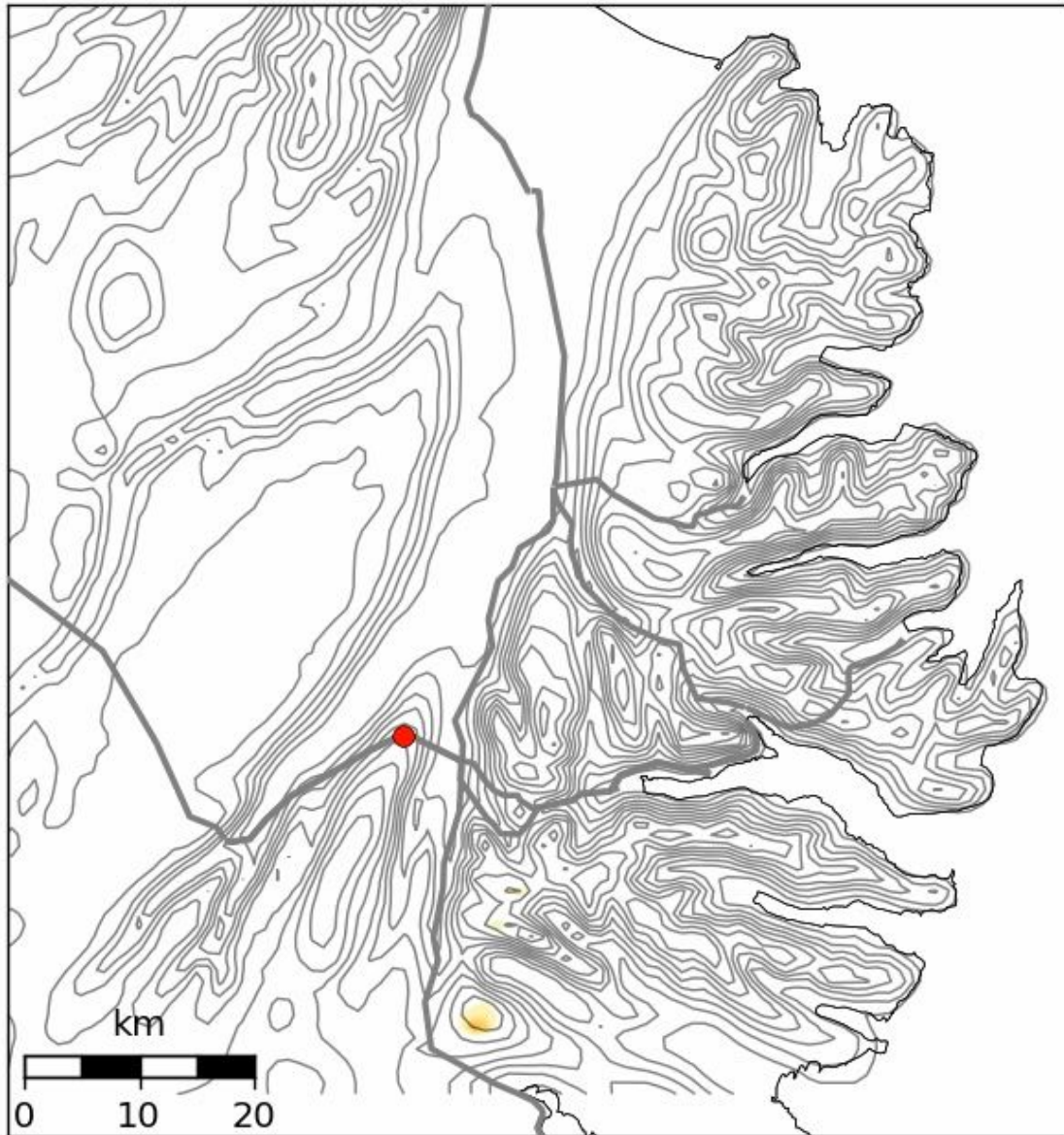


Simulated flow and water mass



Simulated in-cloud icing Dec. 2000

2000-12-04 03:00:00

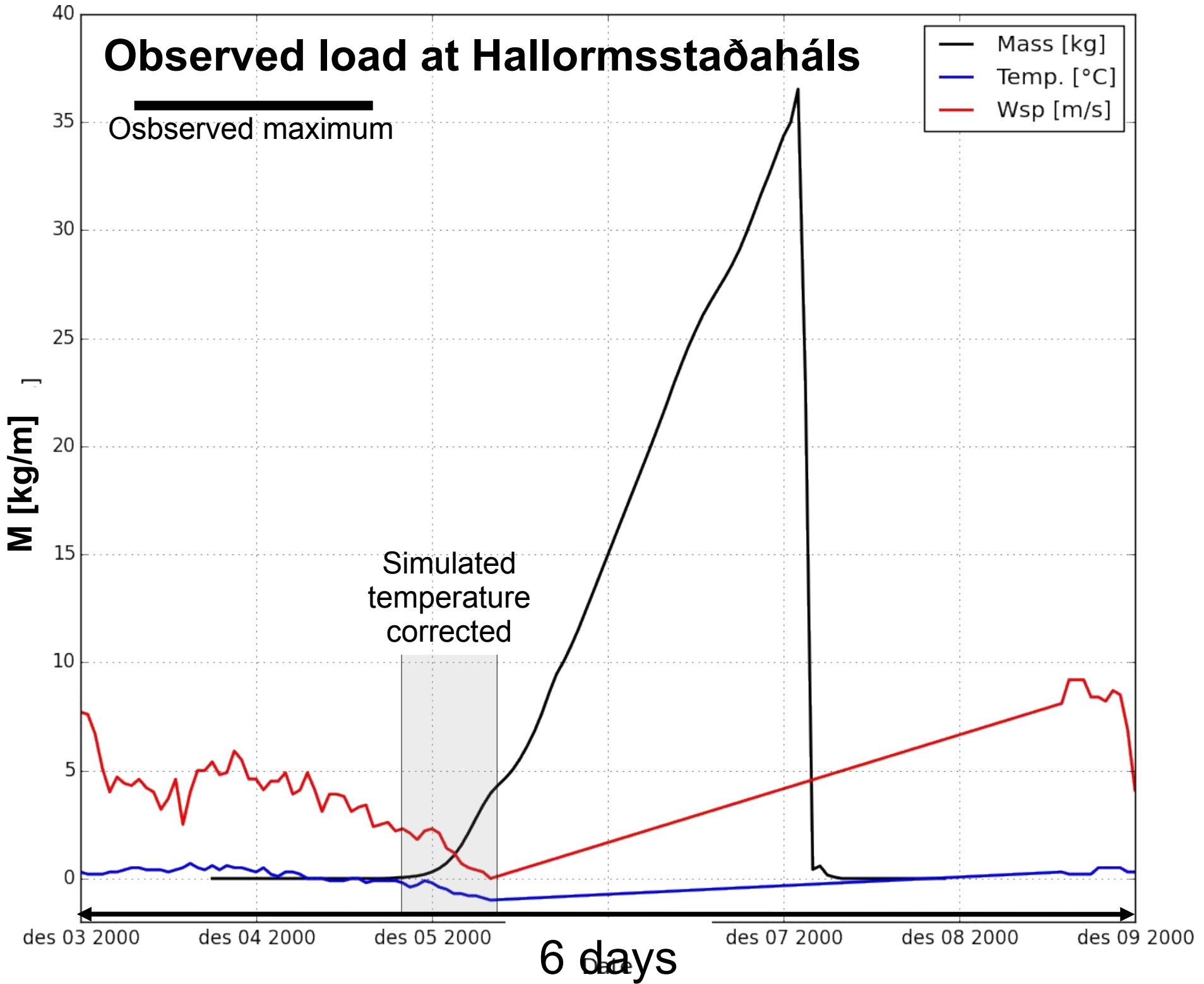


Observed load at Hallormsstaðaháls

- Mass [kg]
- Temp. [°C]
- Wsp [m/s]

Observed maximum

Simulated temperature corrected



6 days

Simulated load at Hallormsstaðaháls

- Mass [kg]
- Temp. [°C]
- Wsp [m/s]

Observed maximum

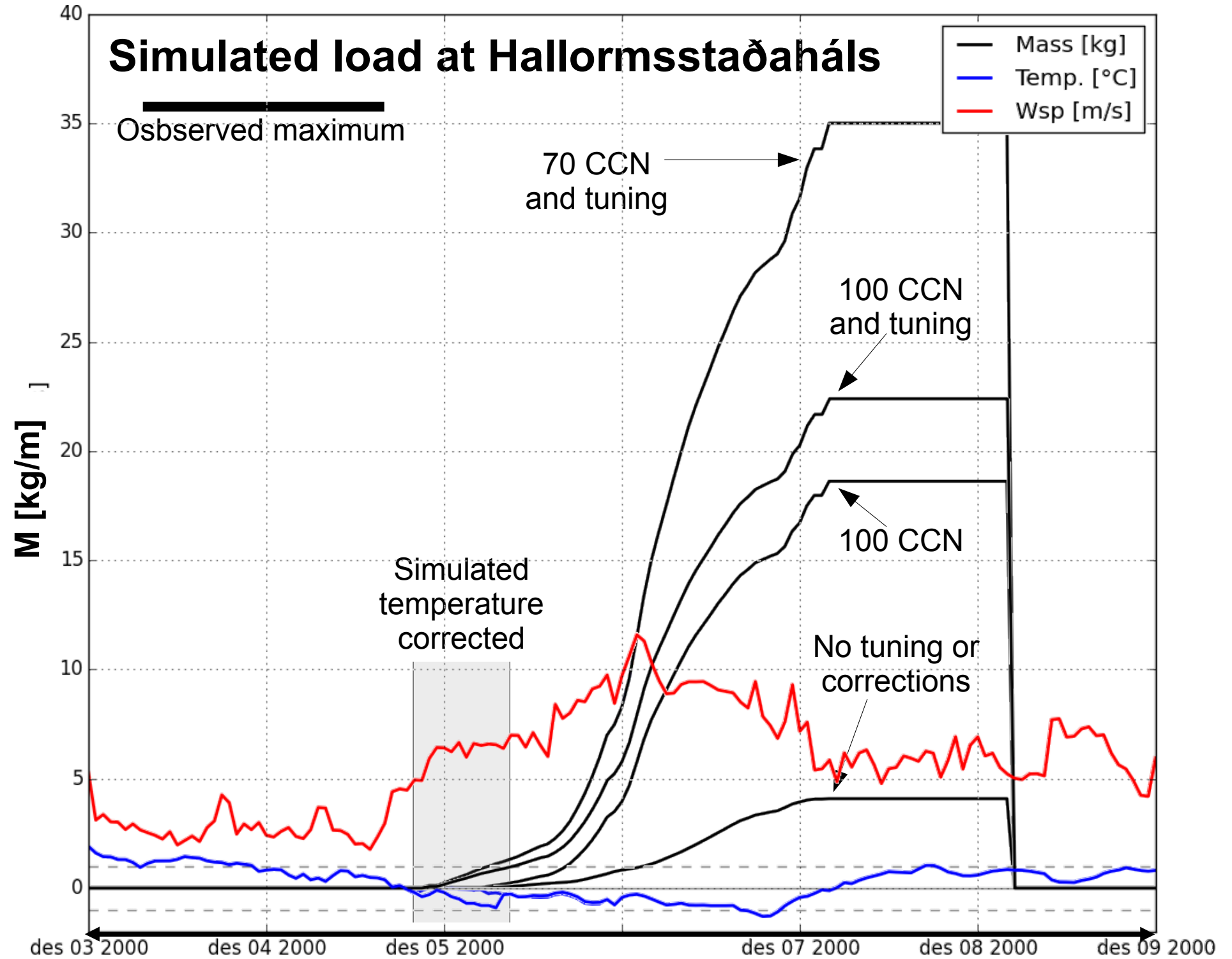
70 CCN and tuning

100 CCN and tuning

100 CCN

Simulated temperature corrected

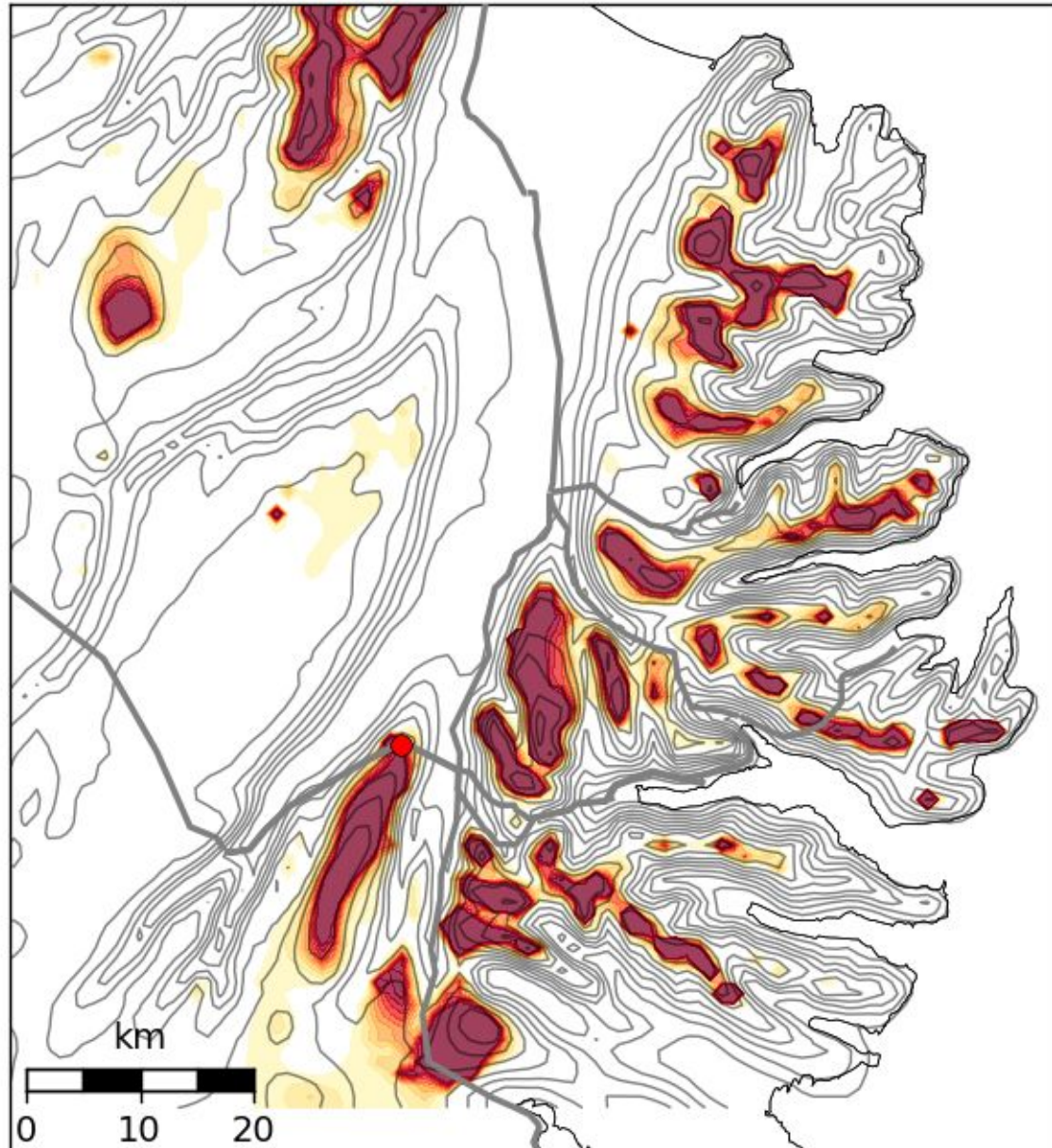
No tuning or corrections



6 days

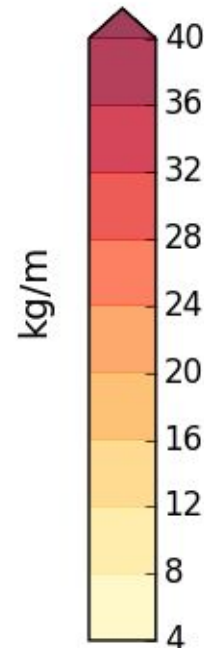
In-cloud icing load during 17 years

In preparation, RÁV (WRF), 1994-2011, 3 km resolution



Maps of e.g. accretion frequency and max ice load are being prepared.

Shedding, height correction etc are being accounted for.



To summarize

Atmospheric icing in Iceland is mainly an issue for overhead structures, i.e. powerlines, transmission towers and masts.

- Wet snow accretion:
 - Relatively rare and short (3-12 hrs).
 - Any elevation.
- In-cloud icing:
 - May last weeks/months.
 - Frequent above 600 m.
 - Will be a problem for future wind turbines.




Photo: Icelandic coast guard

To summarize and look forward

- Icing has been modeled with an accretion model, with input from an atmospheric model.
 - Preliminary icing maps and operational forecasts have been developed.
 - Systematic observations of ice loads were invaluable and are unique for Iceland.
- Success is critically dependant on the accuracy of the meteorological variables:
 - Forecasts should be based on high-resolution ensembles.
 - Longer and higher resolution downscaled atmospheric datasets are needed.



A large, textured ice formation, possibly a snowman or a natural ice structure, stands prominently on a snowy mountain peak. The ice has a rough, layered appearance. A small figure of a hiker is visible on the right side of the peak, providing a sense of scale. The background is a clear blue sky.

And some
icing on
the cake

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Photo: Ingvar Baldursson