Business from technology

WET SNOW

Lasse Makkonen

VTT Technical Research Centre of Finland

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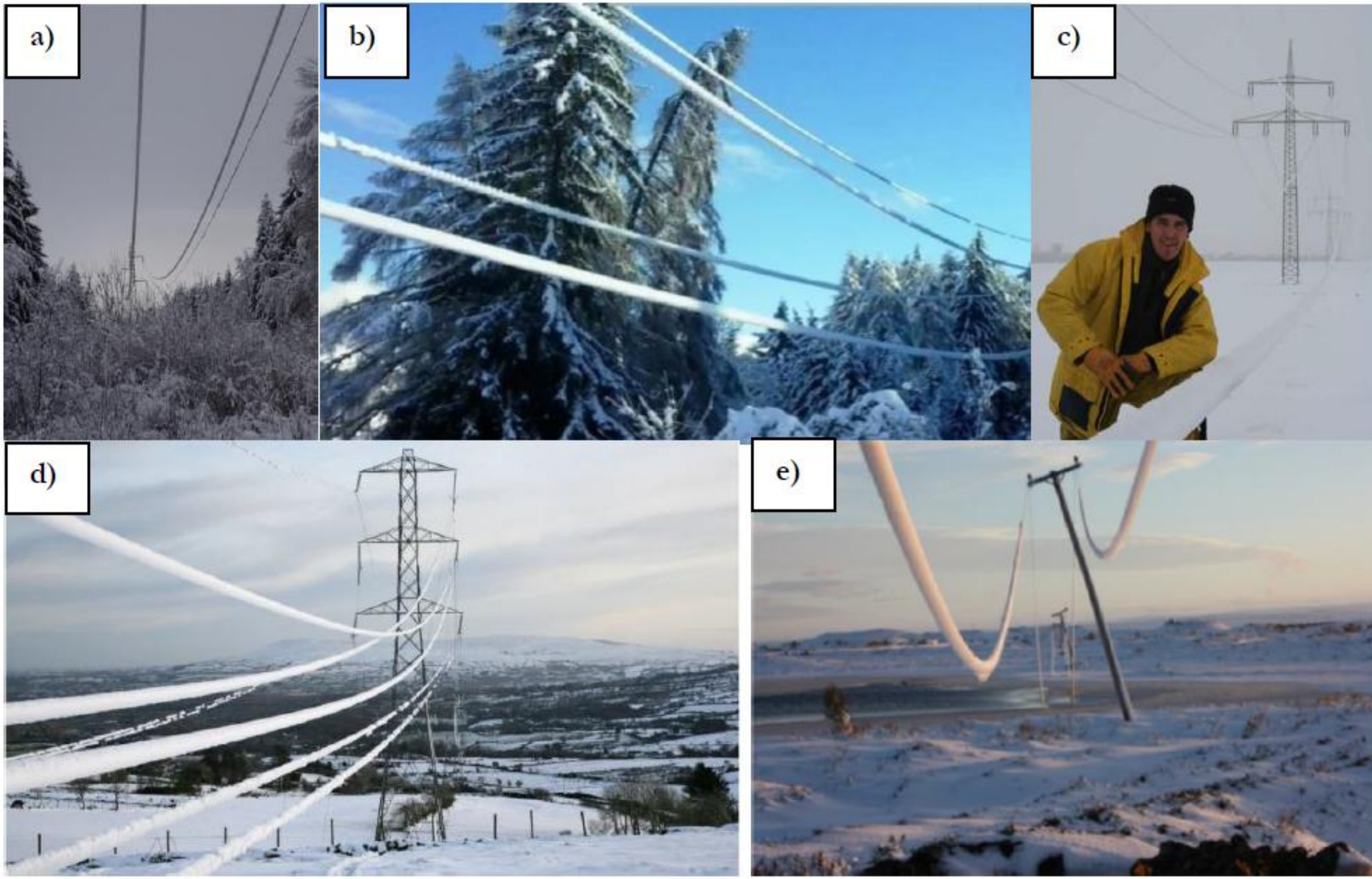

Figure 1-1. Examples of wet snow accumulation on overhead power lines. Photos from France (RTE) (a), Italy (b), Germany (c), Great Britain (d) and Iceland (e).

Bulgaria

Germany 2005

Damage to power lines => Also indirect losses

Figure 5-2 Left: Collapsed tower number 96. Right: Remaining ice on the broken earth wire, three days after the incident.

HOW?

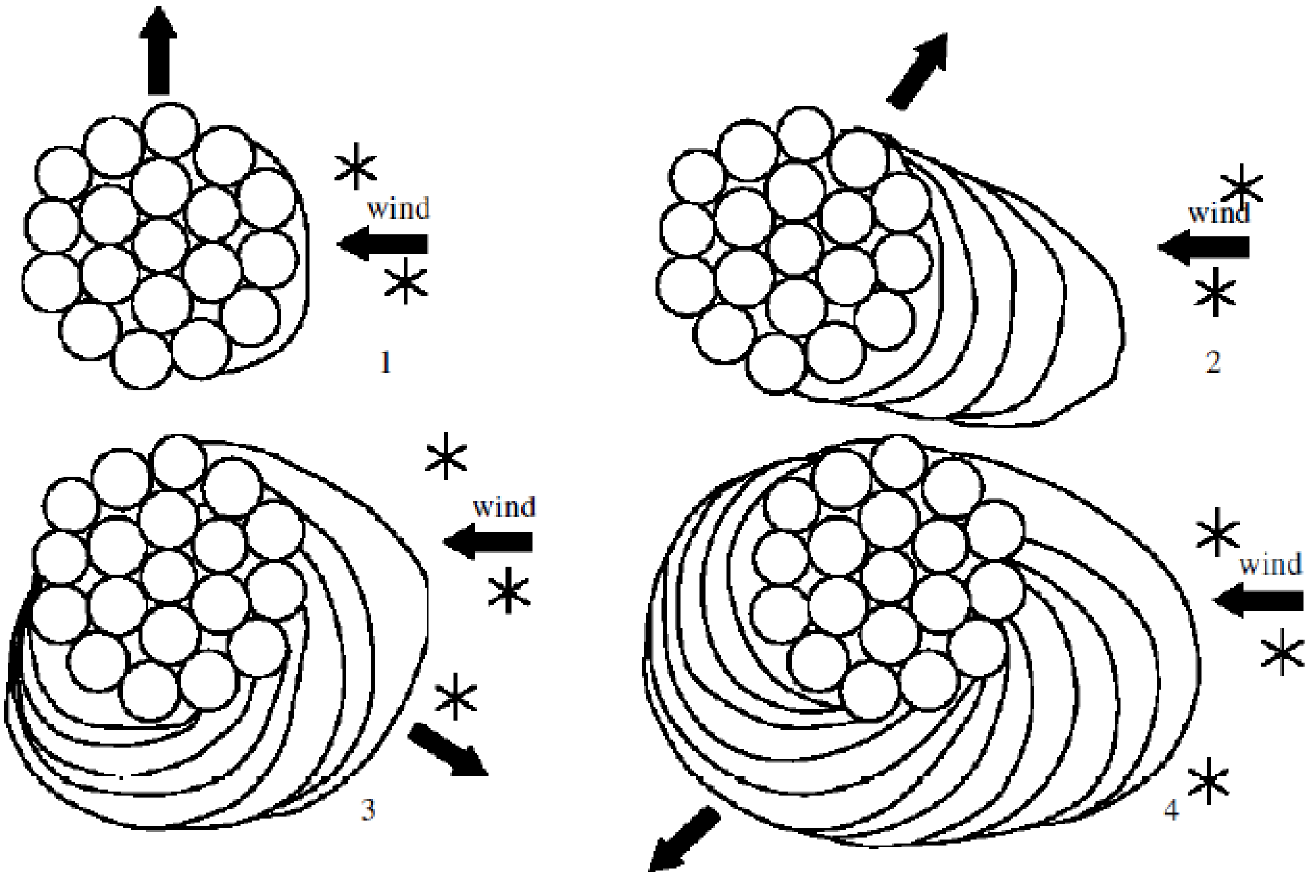

Figure 2-1: Wet-snow accretion on a stranded wire having low torsional rigidity (Sakamoto, 2000).

Figure 2-4. Upper: cylindrical wet snow deposit caused by rotation of conductor. Lower: "Cork screw" wet snow on a stranded conductor cable. (photos: A-J. Eliasson, Iceland).

WHEN ?

$T_{wb} \geq 0\ ^{o}C$ (Makkonen, *Met. Mag.* 1981)

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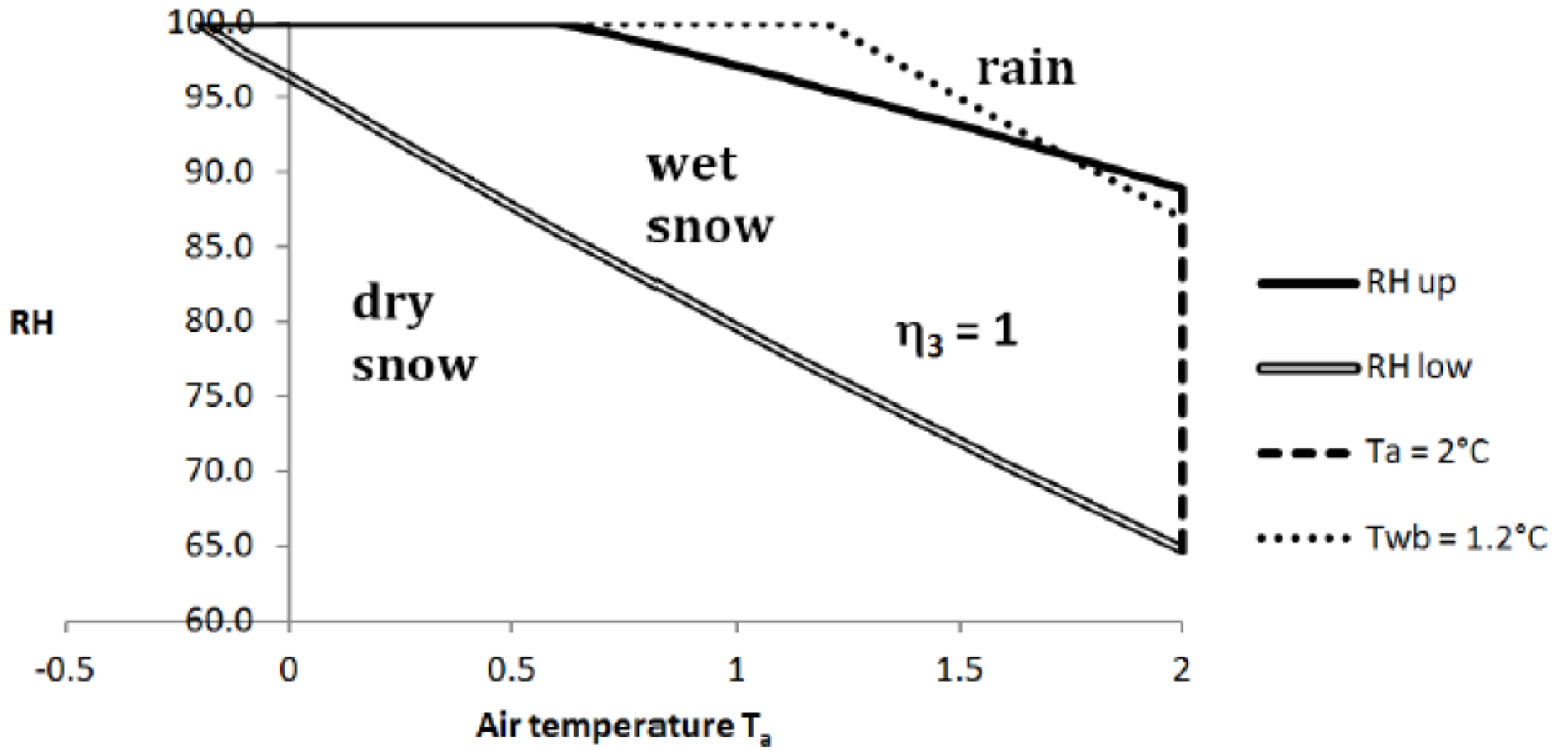
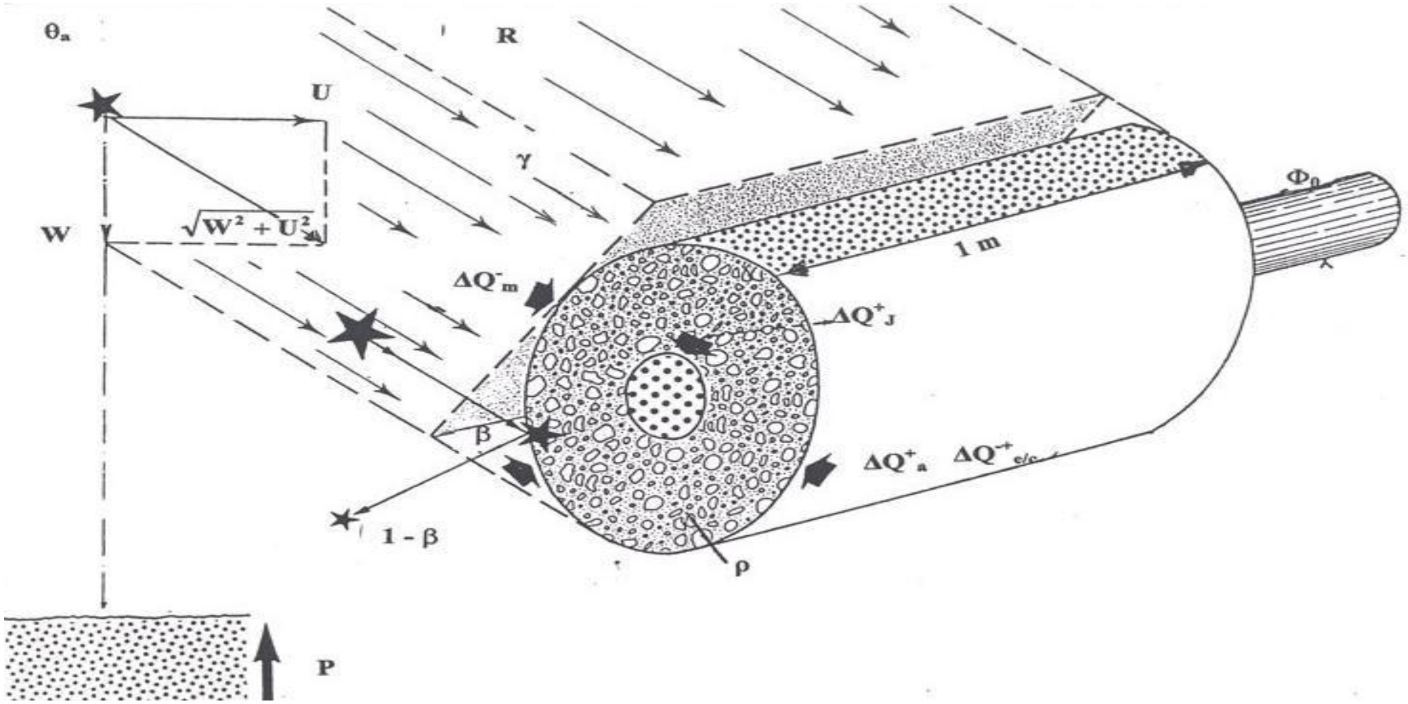


Figure 2-2 Meteorological "window" for occurrence of wet snow (Ducloux and Nygaard, 2014)

HOW MUCH ?



$dM/dt = \alpha U w A$

α is the sticking efficiency
Snow concentration **w** from precipitation rate and fall velocity
Impact speed **U** from wind speed and fall velocity

Makkonen (1989)

$dM/dt = \alpha \; U \; w \; A$

Experiments: **$\alpha \sim 1/U$** and **Visibility $V_m \sim f(w)$**

=> $dM/dt = V_m \; A$

$$I = 2100\,[V_m]^{-1.29} \qquad day-time$$
$$I = 2100\,[0.5\,V_m]^{-1.29} \qquad night-time$$

HOW STICKY ?

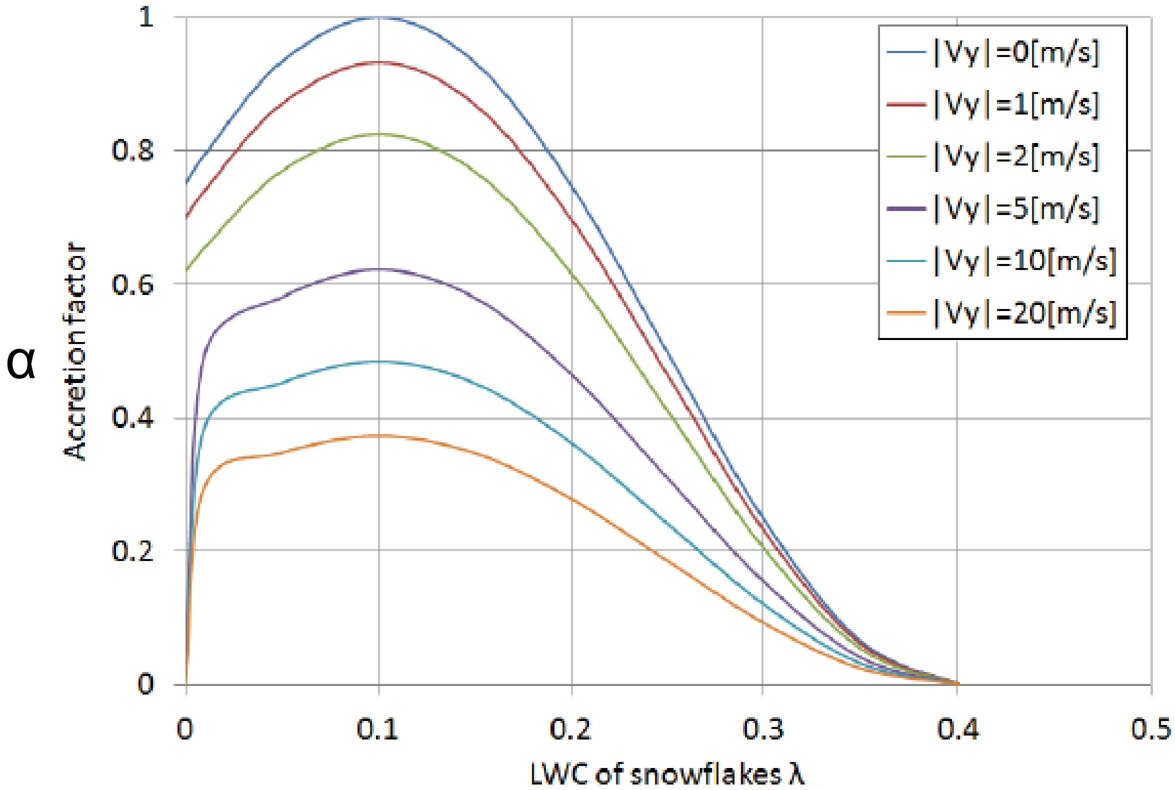
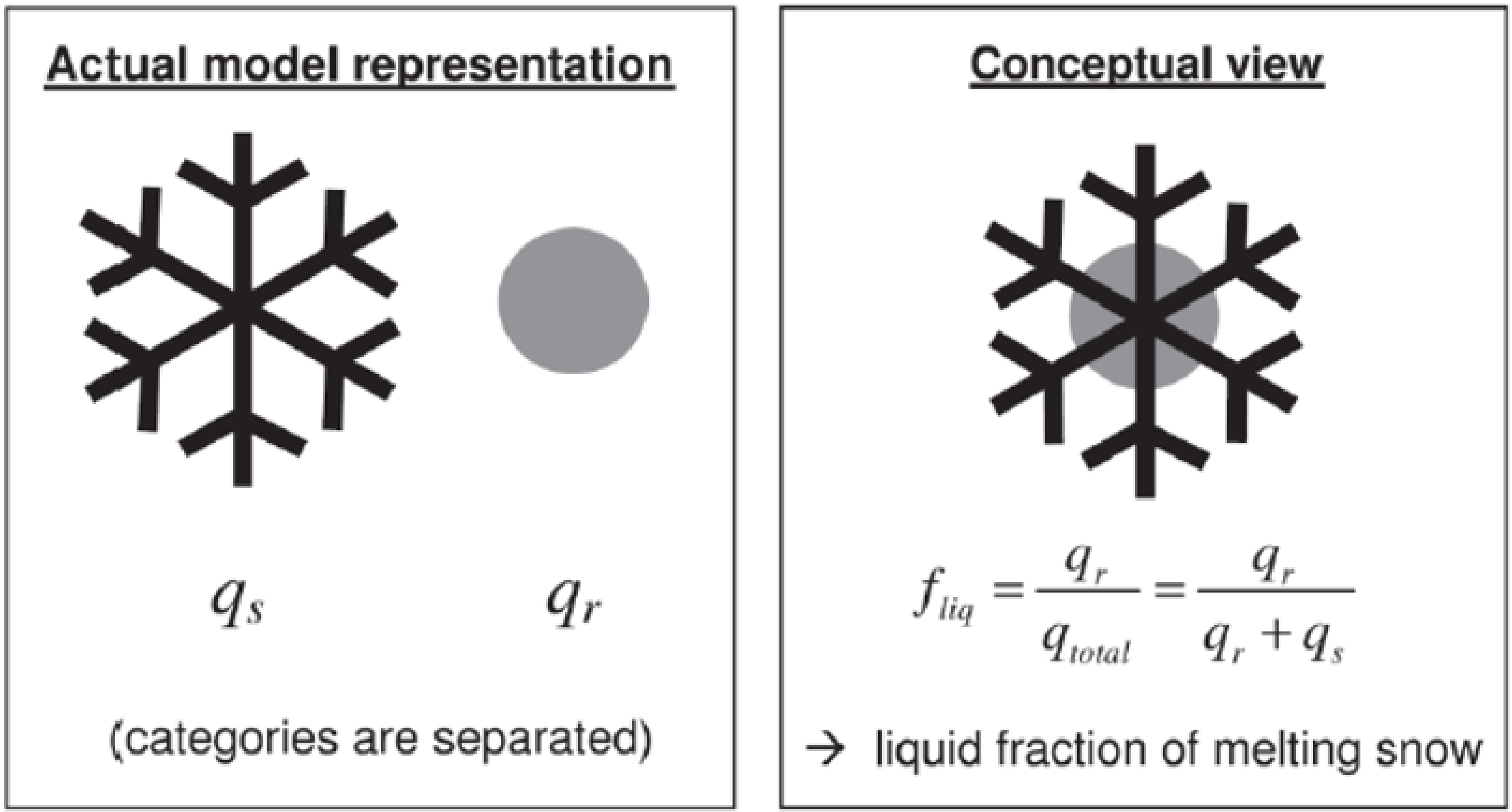


Figure 2-9 Sticking efficiency from Ueno et al. (2015) based on Nygaard et al (2013). In this figure the wind speed is denoted by |Vy|.

A freely available state-of-the-art NWP model is the Weather Research and Forecasting (WRF) model, currently being used for various downscaling purposes including studies of ground structural icing (e.g. Nygaard et al. 2014; Makkonen et al. 2014).

In the three dimensional grid of the WRF model, as the snowflakes begin to melt approximately as they cross the $T_w=0$ line and pass through the melting layer, their mass is gradually transferred from a snow category to a rain category. The fall velocity of the melting snow is a function of the degree of melting. The liquid fraction of the melting snow is estimated as a bulk value for all snow and not for individual bins in the size distribution. An estimate of f is attained by the ratio of the melted mass concentration in the air (rain category) to the total mass concentration of all precipitation particles. Furthermore, the mass concentration of wet snow in the air W can be directly calculated as the sum of snow and rain (and possibly other precipitation types, depending on the complexity of the cloud microphysical scheme). Since wind velocity, temperature and air humidity are all prognostic variables easily obtained, all necessary parameters for wet snow modeling are available.

LIQUID FRACTION



Milbrandt et al. *MWR* 2012

Event	Temperature [°C]	Relative humidity [%]	Wet bulb temperature [°C]	Precipitation intensity [mm/10min]	Freezing level [m]	Lapse rate of temperature [°C /100m]	Mean liquid water fraction of snowflakes
①2011/12/03 23:10-23:30	0.35	99.8	0.31	0.67	483	0.08	0.38
②2013/04/21 15:20-15:50	0.75	96.9	0.49	0.50	365	0.22	0.44
③2014/12/17 00:20-00:40	0.82	94.6	0.41	0.50	395	0.22	0.36
④2015/03/02 05:50-06:10	1.16	93.4	0.64	0.83	386	0.32	0.43
⑤2015/11/27 04:20-04:40	0.75	95.1	0.37	0.67	445	0.18	0.34
Mean	0.77	96.0	0.44	0.63	415	0.20	0.39
Standard deviation	0.26	2.23	0.12	0.12	43	0.08	0.04

Ueno and Nishihara *IWAIS 2017*

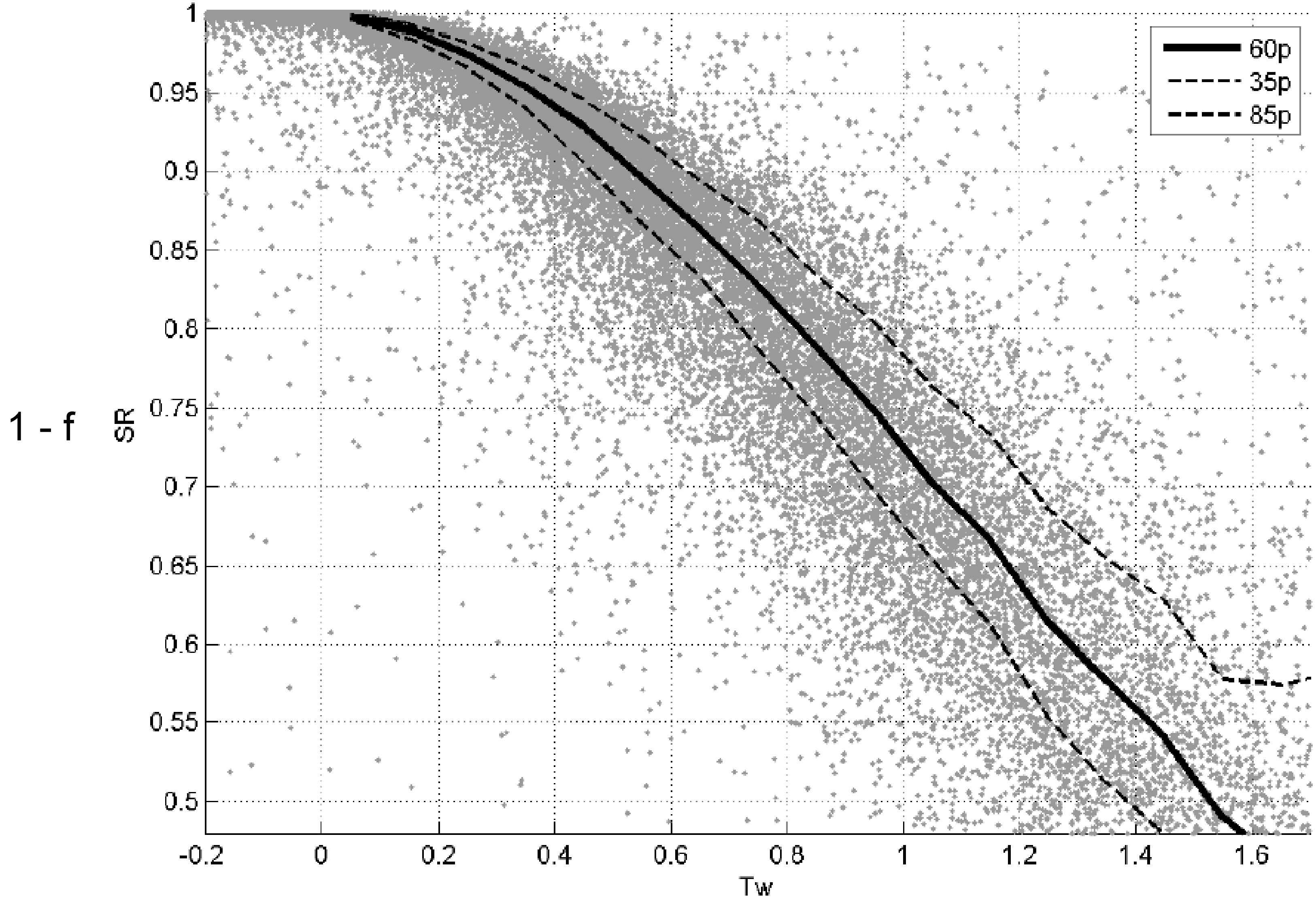
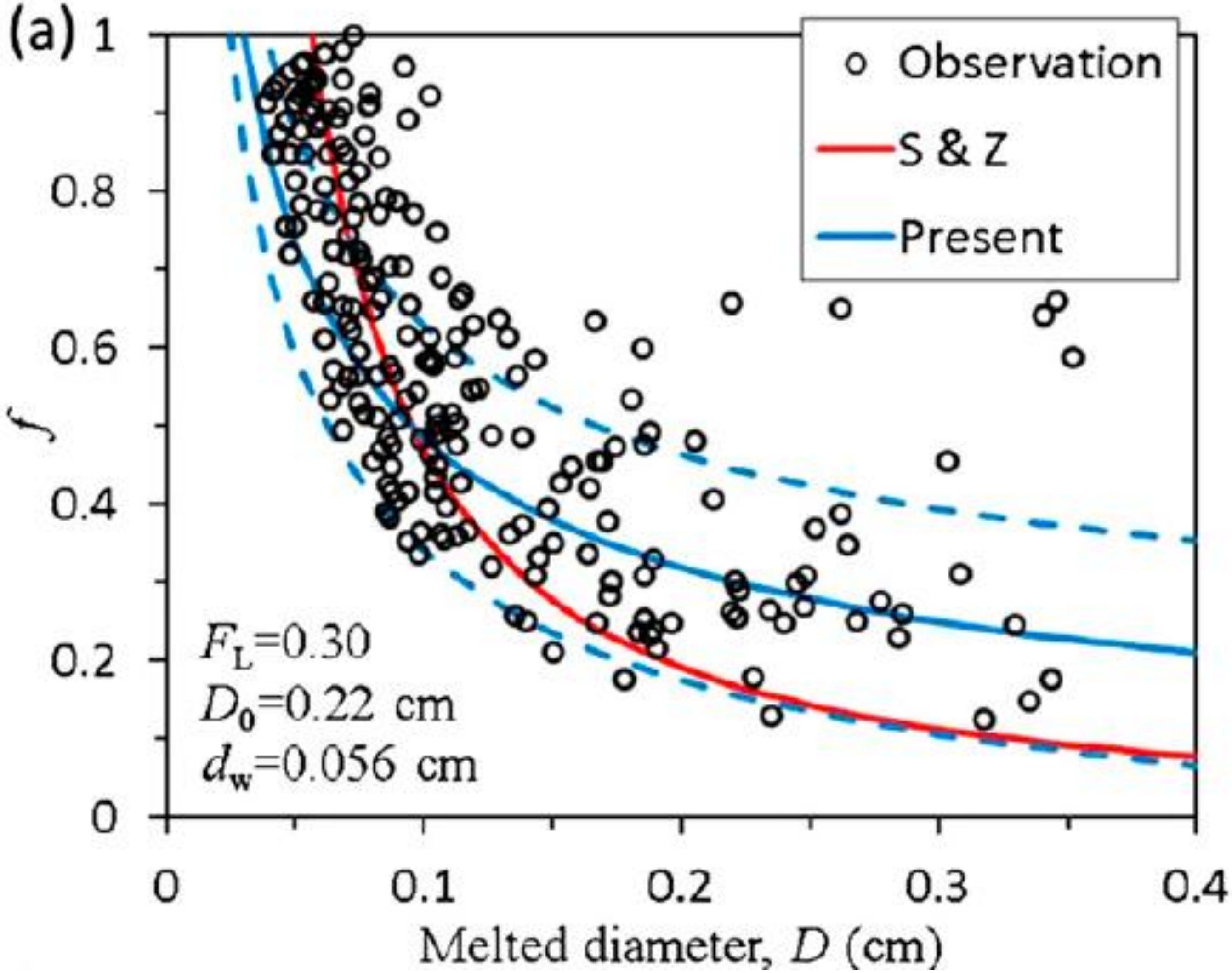


Figure 2-3 Relation between solid fraction (SR=1-f) of snow and wet-bulb temperature (T_w) based on a case study with the NWP model WRF at 500m grid spacing. Grey dots show model results where snow content is higher than 0.3 g/m^3. The black line is a line of best fit to the distribution, obtained by calculating the 60^{th} percentile inside each temperature bin. The dashed lines indicate the 35^{th} and the 85^{th} percentile.



Misumi et al. *JAMC* 2014

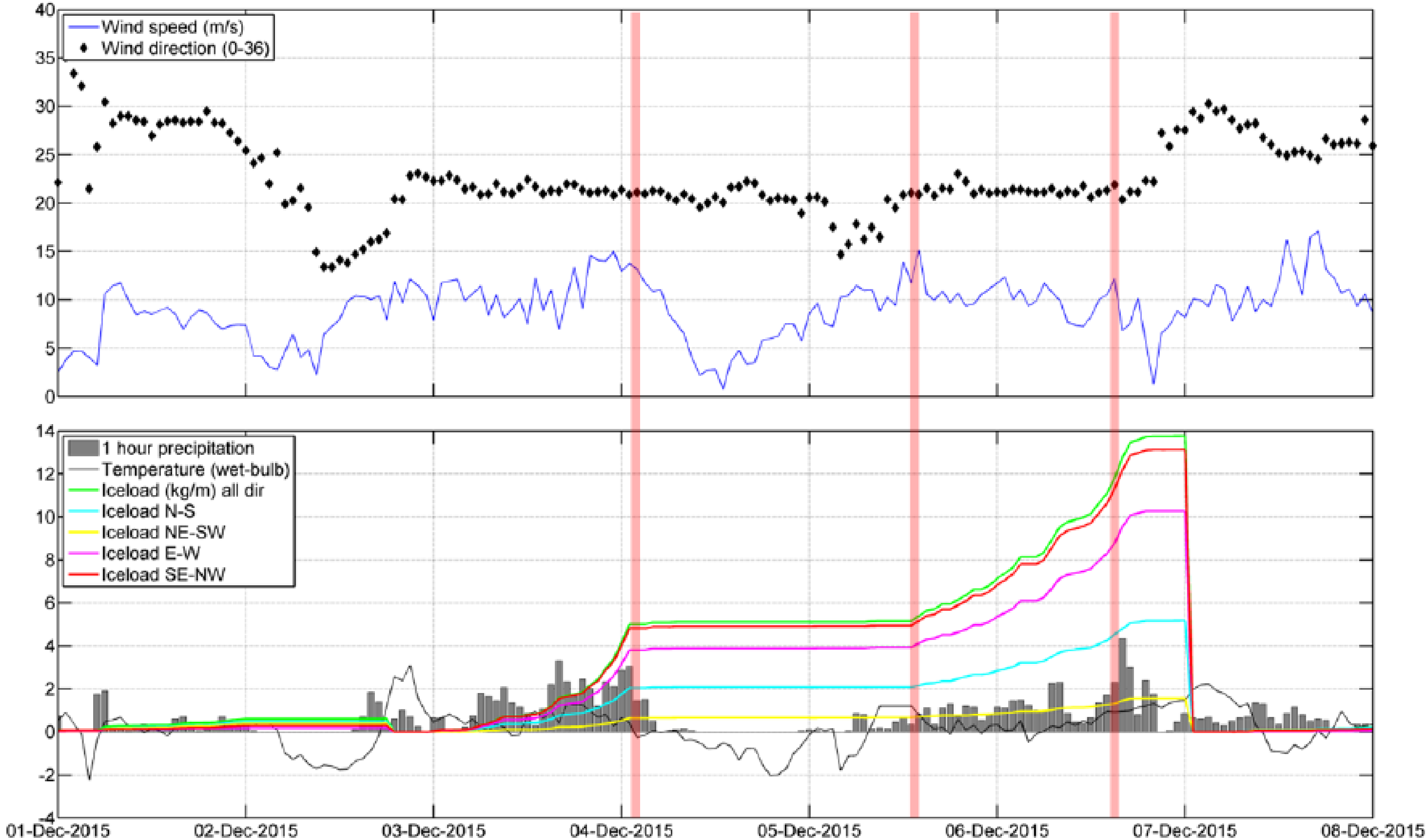
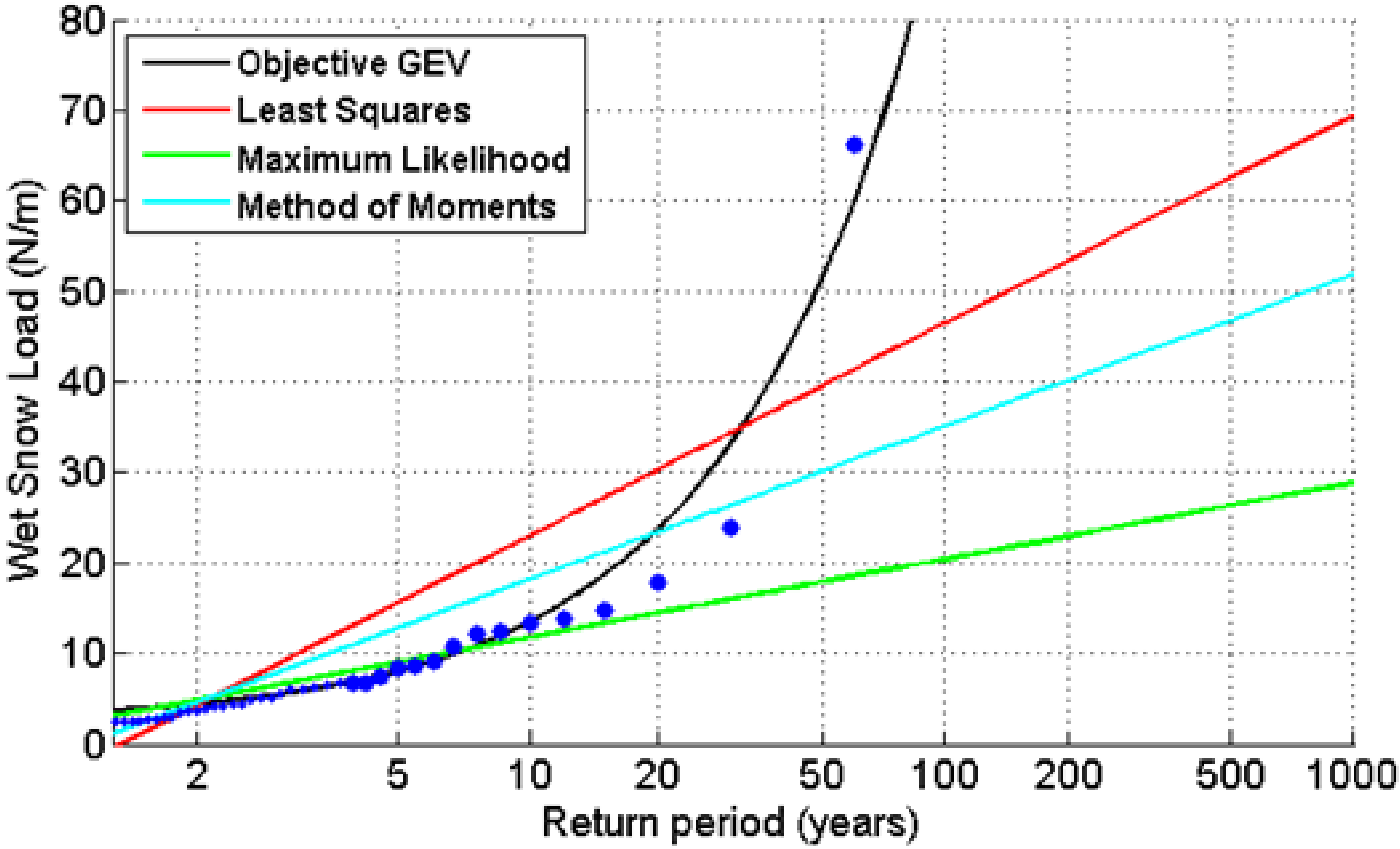


Figure 2-12 Predicted meteorological parameters from WRF and modelled ice load during a wet snow storm that caused the collapse of a 220 kV line in Norway, December 2015. The vertical red lines indicate tower failures: first a partial failure, which then led to the collapse of the line.

HOW OFTEN ?



Makkonen and Wichura *CRST* 2010

Figure 2-10: Estimated wet snow load in Britain with 50-year return period interpolated to a regular grid of 500m resolution by regression kriging. Black dots: Locations of the weather stations used in the analysis.