ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

How to verify gusts in boreal environment?

Irene Suomi
Carl Fortelius
Timo Vihma
Sven-Erik Gryning

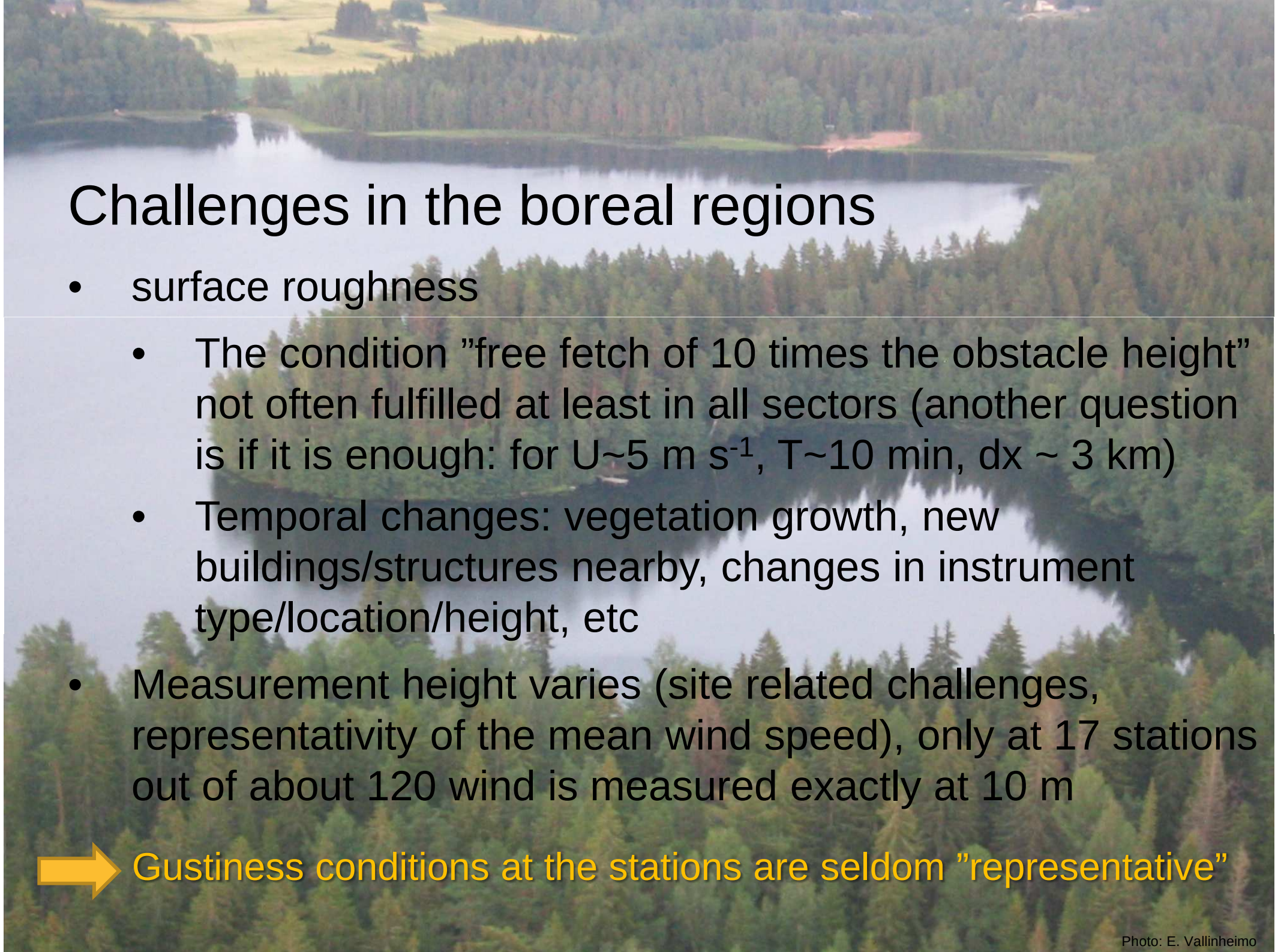
Why gusts?

- Strong gusts cause damage: forest cuts, wide-ranging power cuts, etc

Other applications:

- air quality / air pollution diffusion, wind energy, aviation
- Finnish wind warning system is based on gusts
- Gusts can be used for roughness length estimation and exposure corrections

Photo: E. Vallinheimo



Challenges in the boreal regions

- surface roughness
  - The condition ”free fetch of 10 times the obstacle height” not often fulfilled at least in all sectors (another question is if it is enough: for U~5 m s^{-1}, T~10 min, dx ~ 3 km)
  - Temporal changes: vegetation growth, new buildings/structures nearby, changes in instrument type/location/height, etc
- Measurement height varies (site related challenges, representativity of the mean wind speed), only at 17 stations out of about 120 wind is measured exactly at 10 m

➡ Gustiness conditions at the stations are seldom ”representative”

Photo: E. Vallinheimo

Definitions

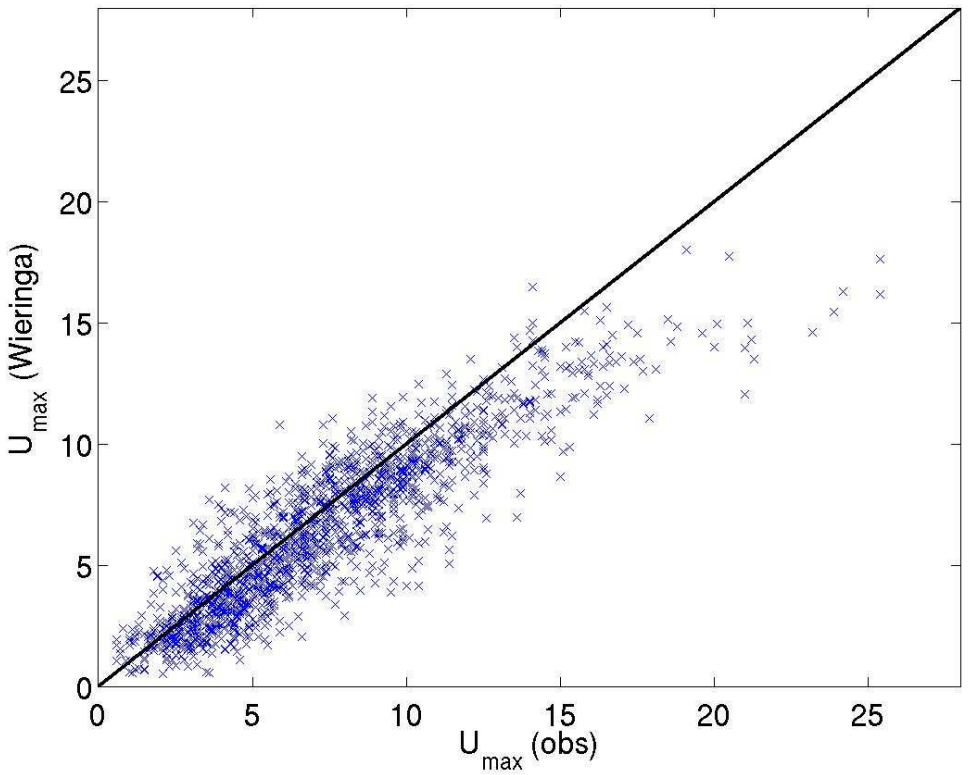
- Gusts at Finnish AWS stations are recorded as a maximum of 3 s averages during a 10 min sampling period (WMO standard)
- Mean wind speed is an average over 10 min period
- Gustiness is a measure of how much the gust wind speed differs from the mean wind speed

- Gust factor: $G = \frac{U_{\max}}{U}$
- Peak factor: $g_{t,T} = \frac{U_{\max} - U}{\sigma_U}$

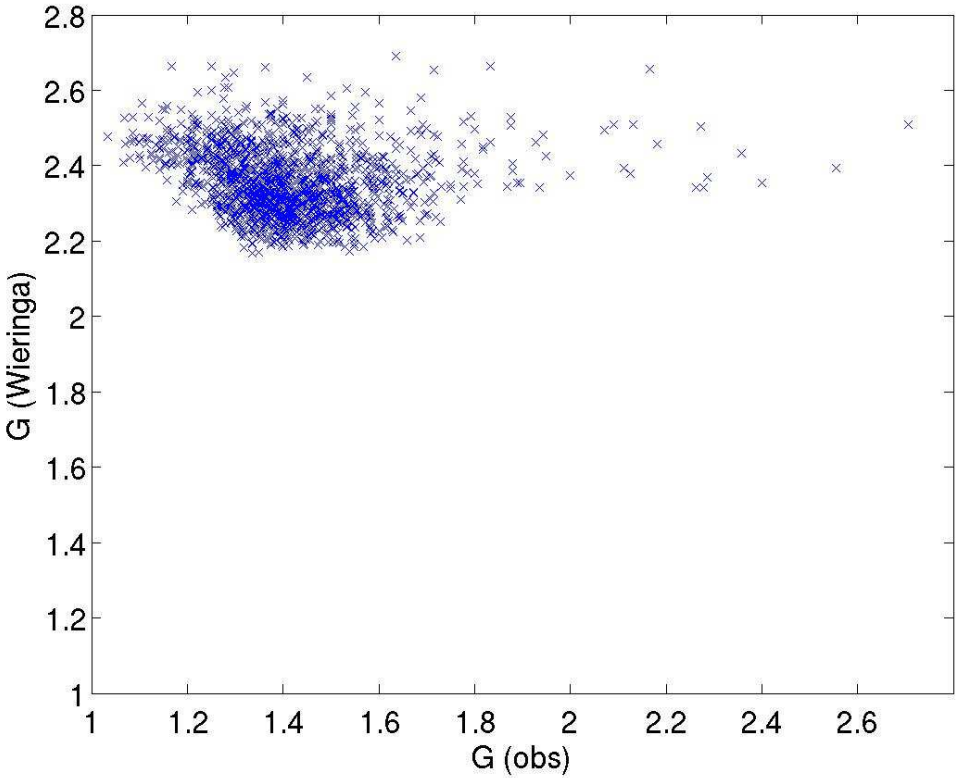
Gust verification?

$$G = \frac{U_{\max}}{U}$$

U_{max} (model) vs U_{max}(obs)



G (model) vs G (obs)

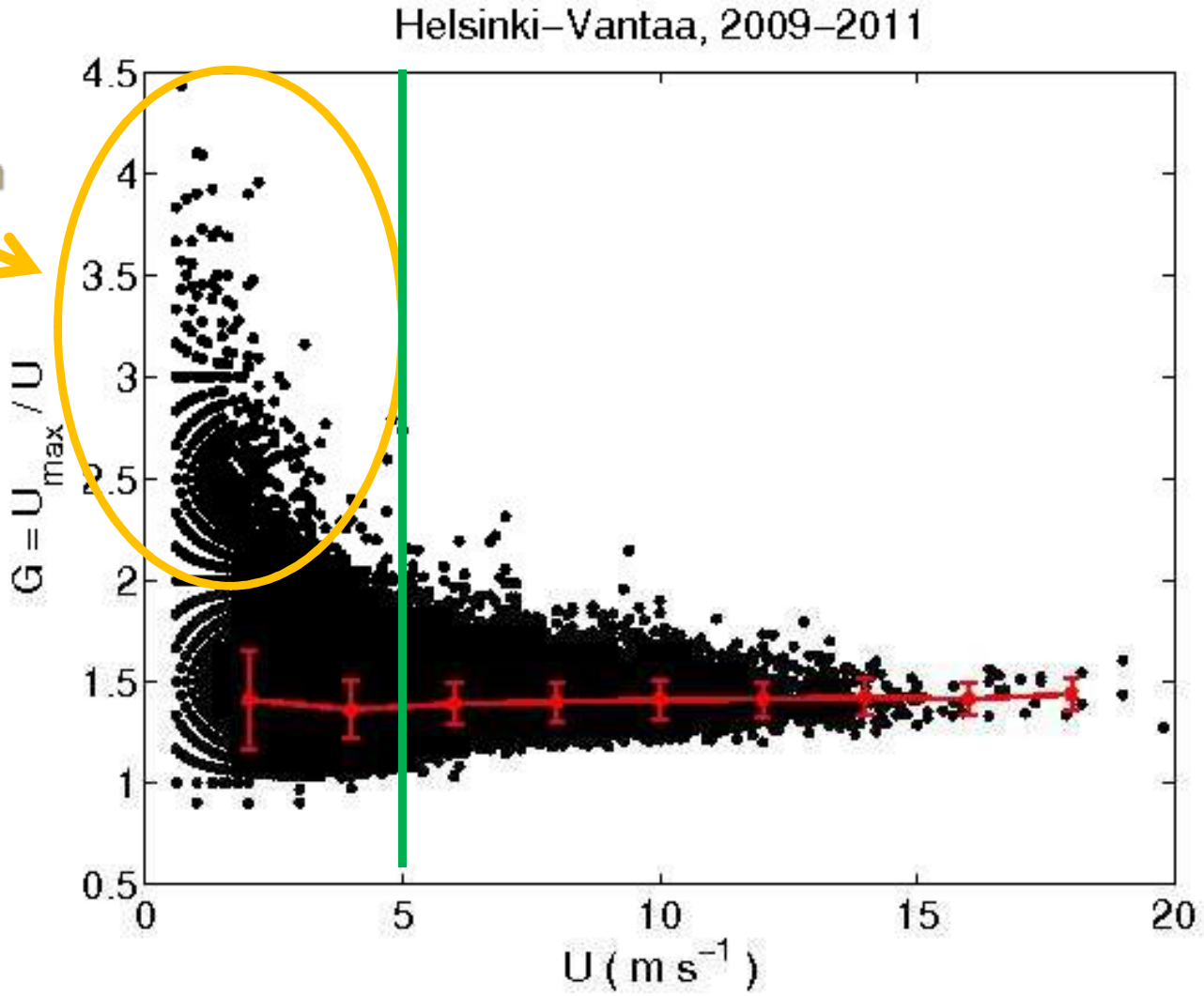


IS THERE SOMETHING ELSE WE WOULD LIKE TO KNOW ABOUT GUSTS?

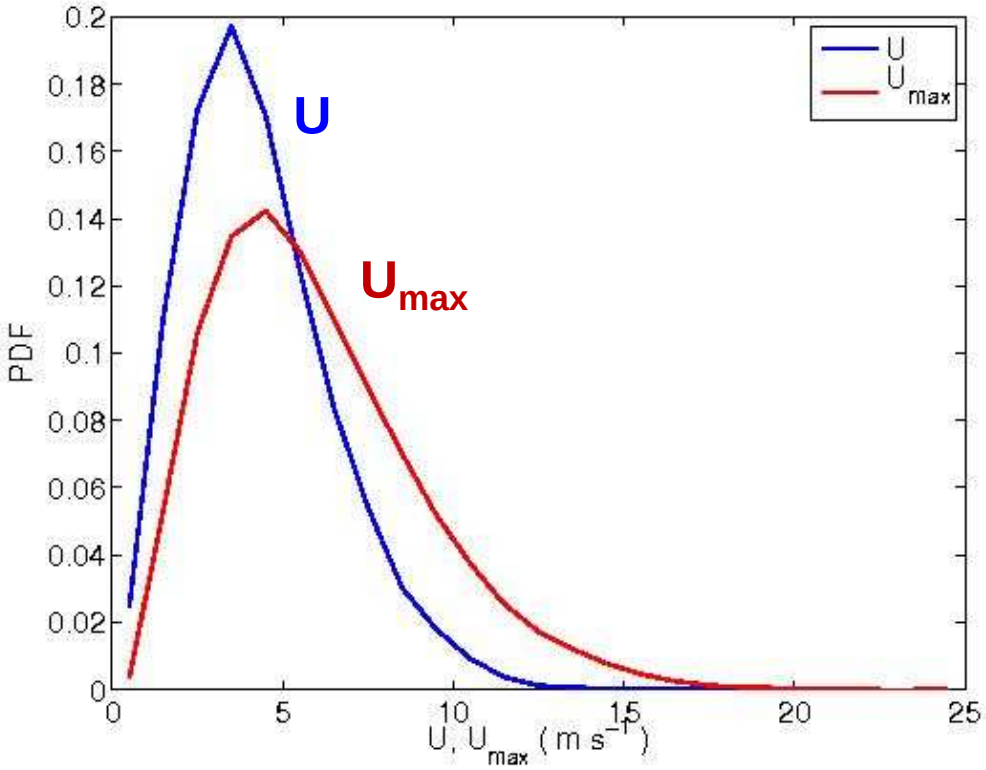
Gust factor and wind speed

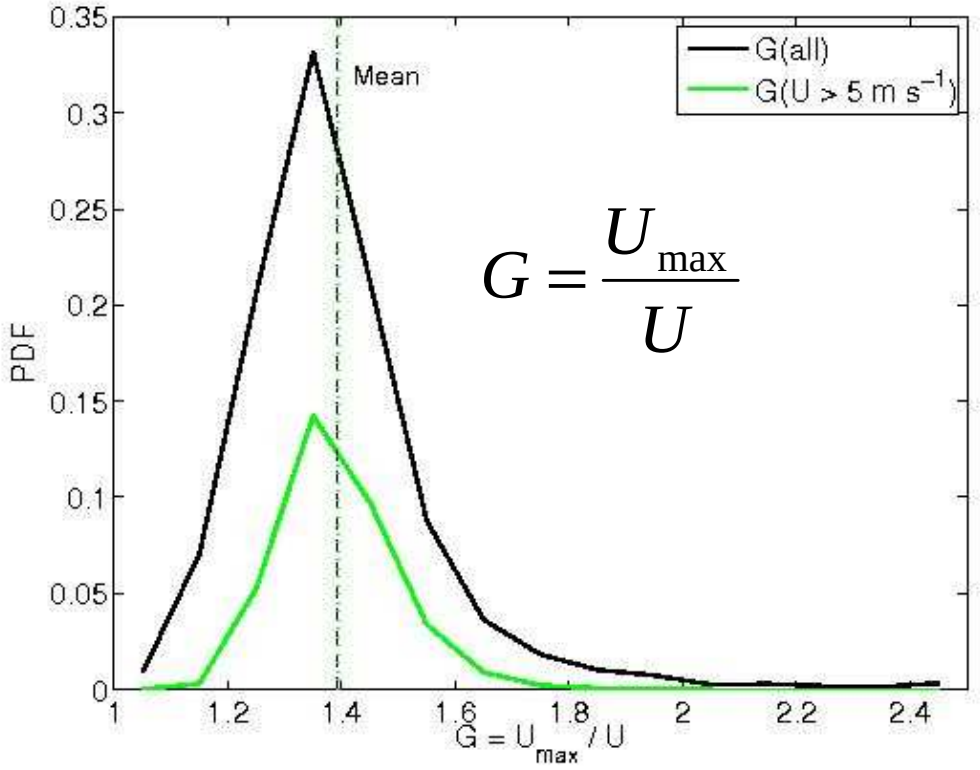
we are not interested in these

$$G = \frac{U_{\max}}{U}$$

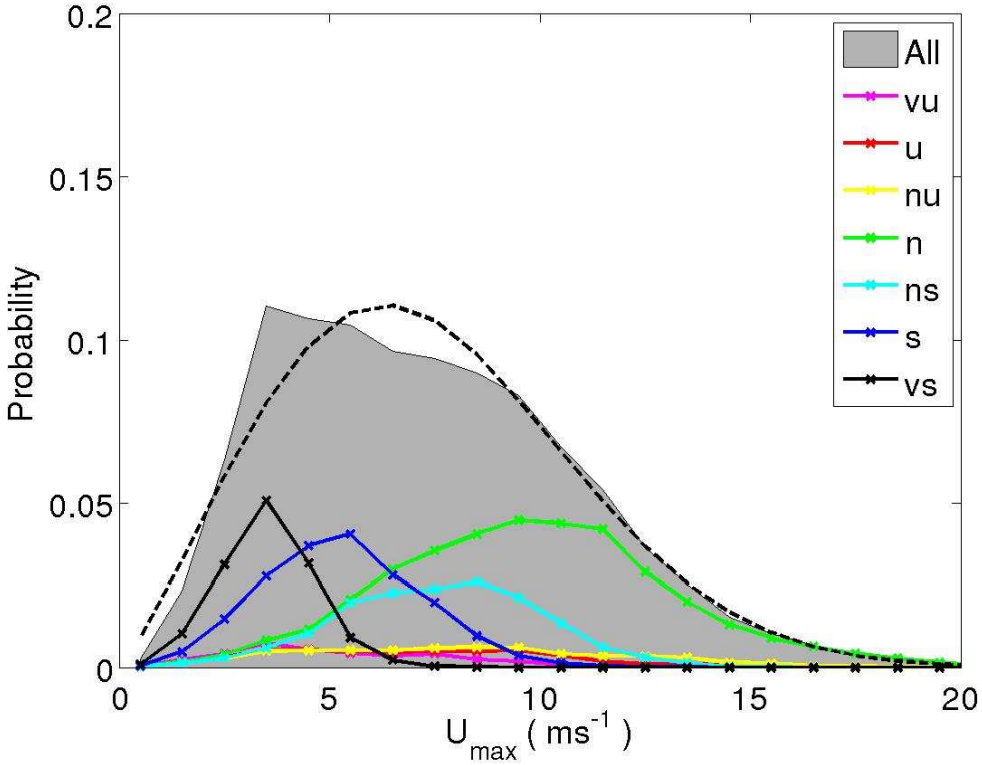


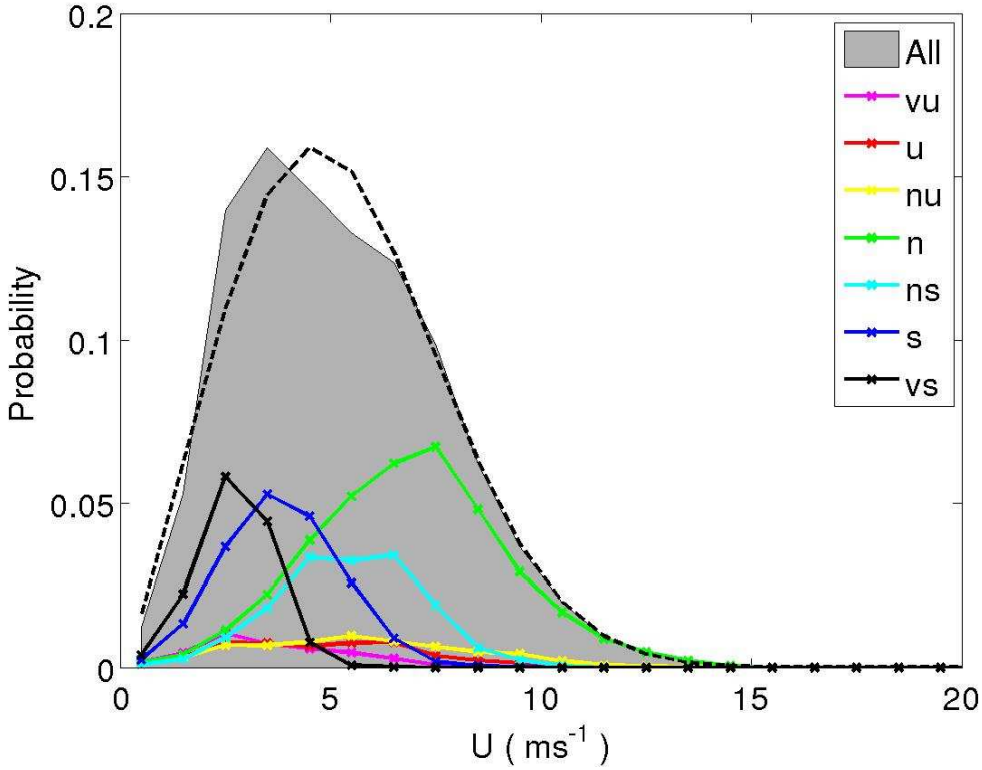
Distribution of gust factor





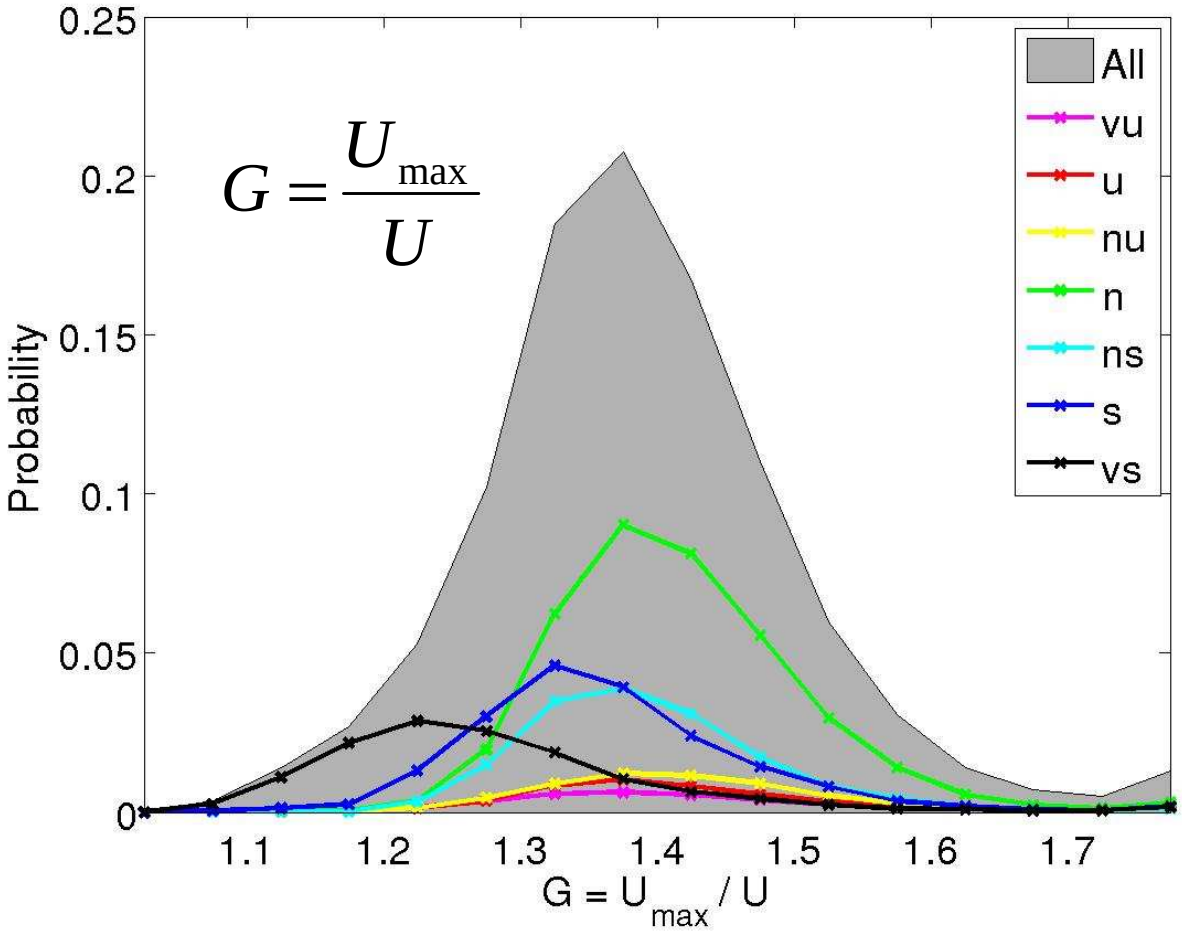
Stability effects on gusts and wind speed





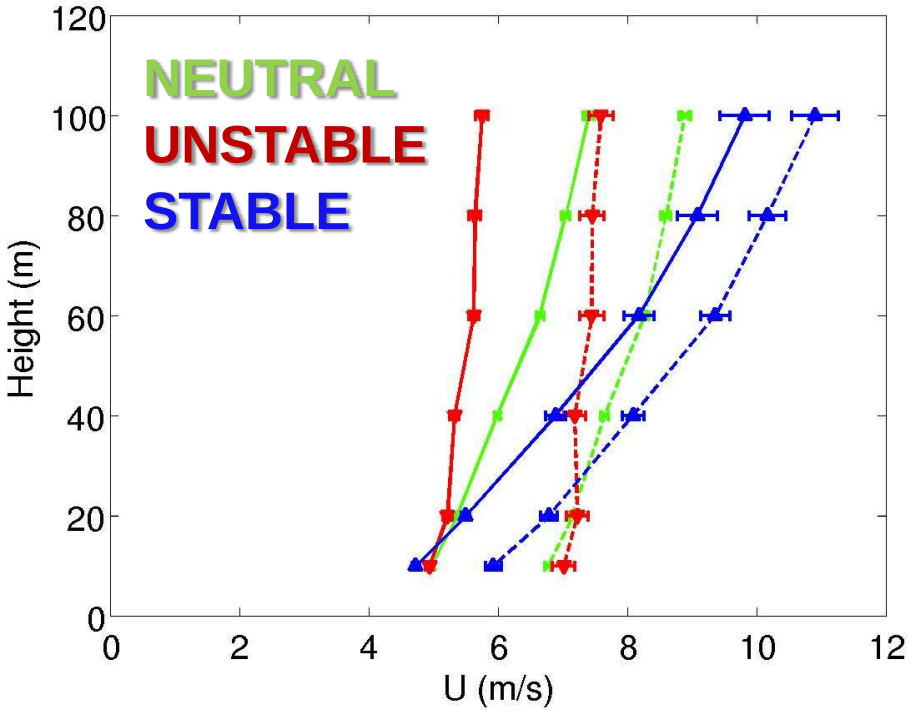
Gust and mean wind speeds in near neutral conditions (green) are larger than in stable conditions (black/blue), unstable conditions (red) are spread over a large interval.

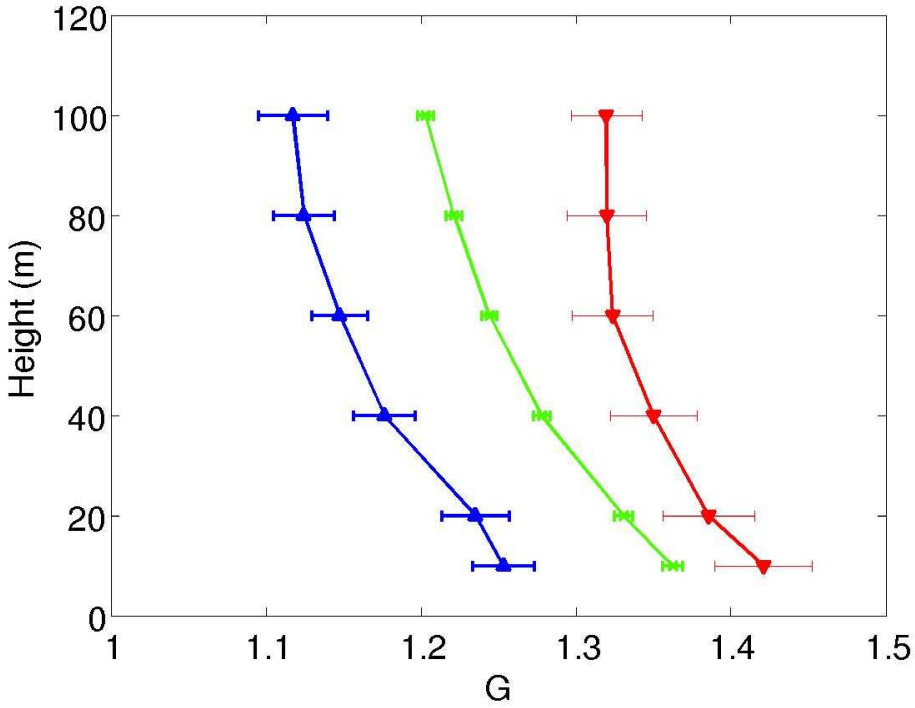
Stability effects on gust factor



- In stable conditions, gust factors are smaller than in neutral/unstable
- Large values (>1.7) originate from very low wind speeds

Profiles and stability





$$G = \frac{U_{\max}}{U}$$

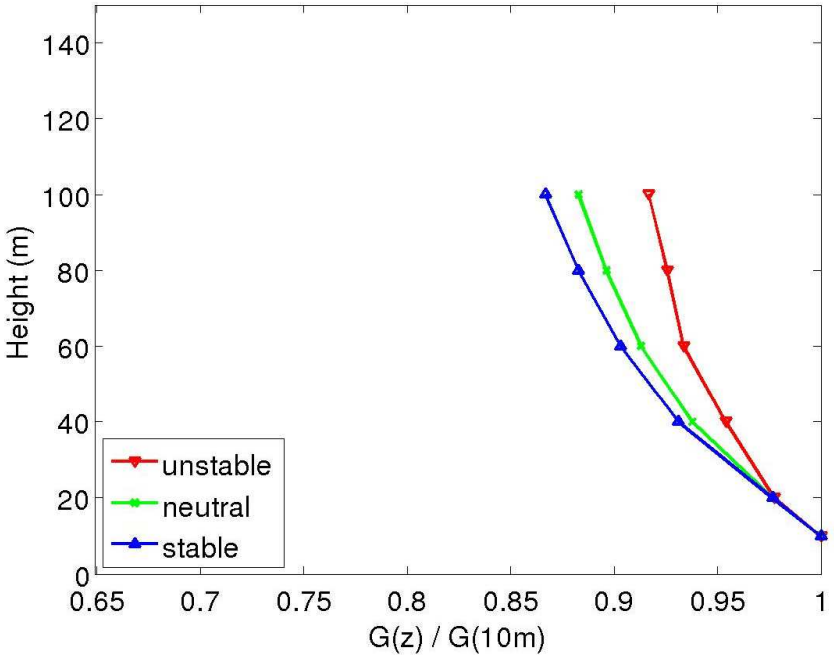
These cases include profiles for which the 10 m level mean wind speed is within the range 4.5 - 5.5 m s^{-1}

Height dependence of gust factors

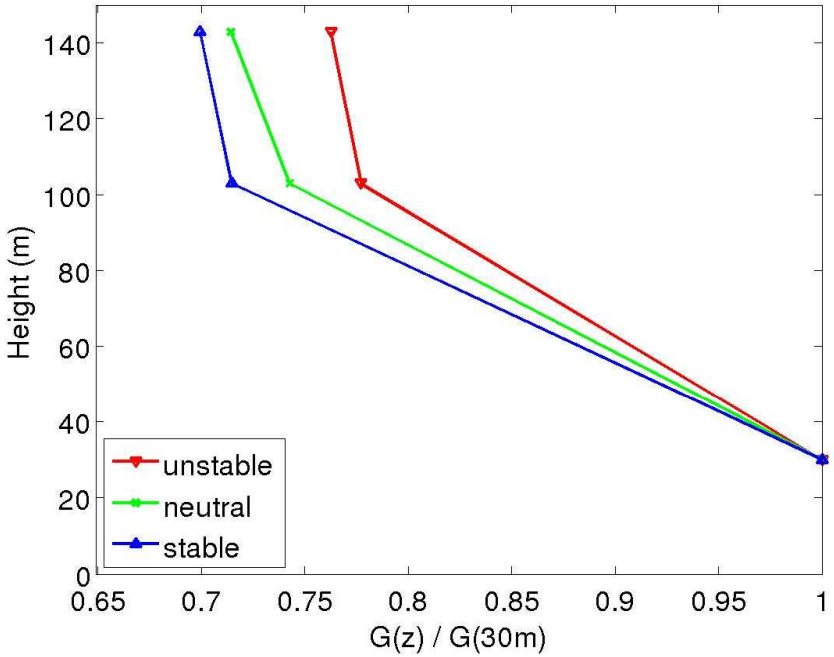
Over a flat grassland

$$G = \frac{U_{\max}}{U}$$

Over a forest



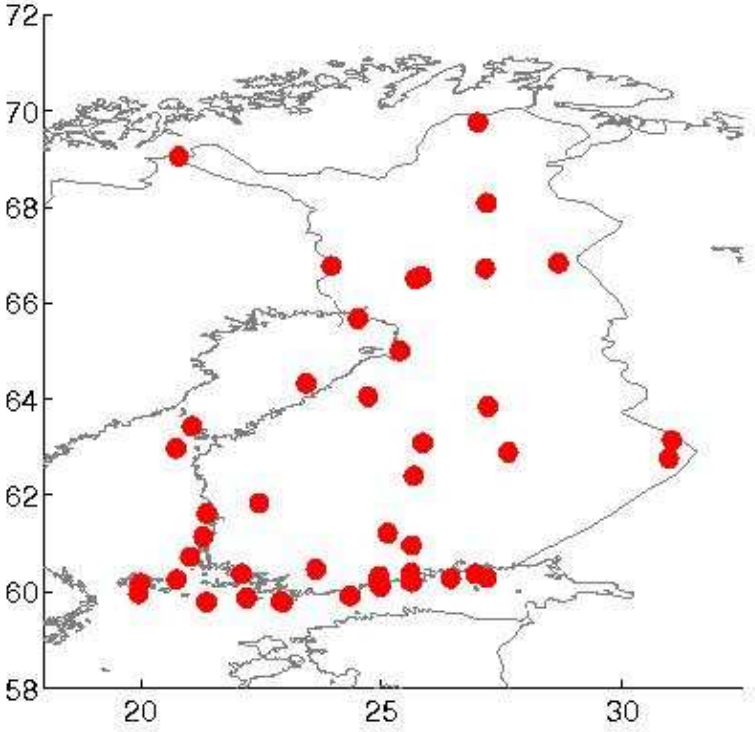
15 %



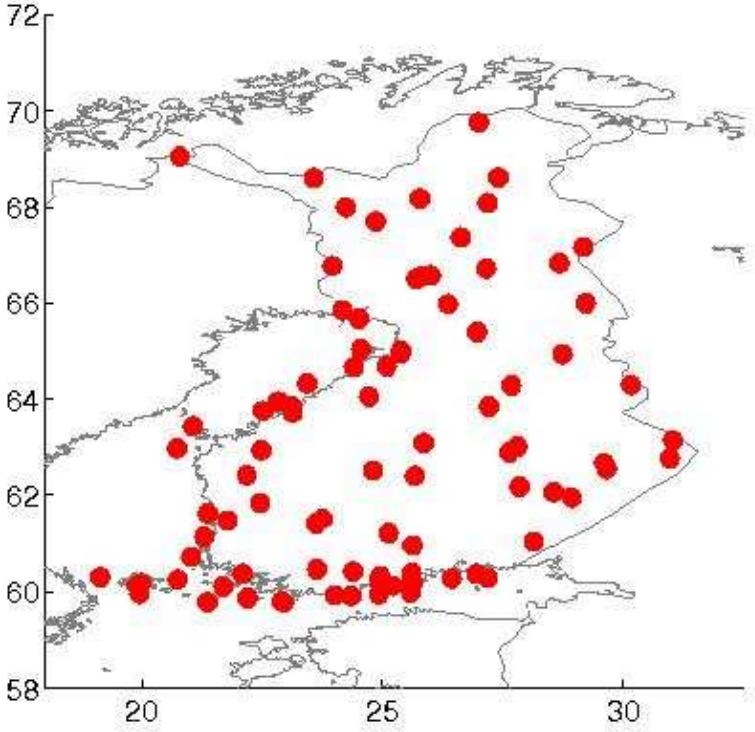
30 %

Gust stations in Finland

Jan 2007



Jan 2009

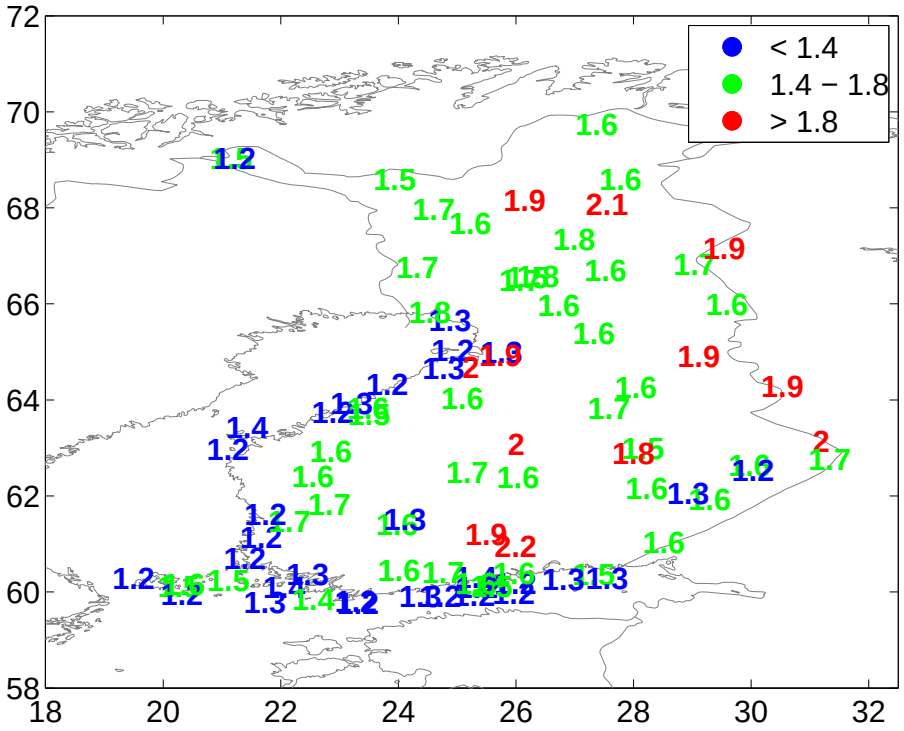


10 min data mainly available from 2006 onwards, except Helsinki Kaisaniemi (from 2001)

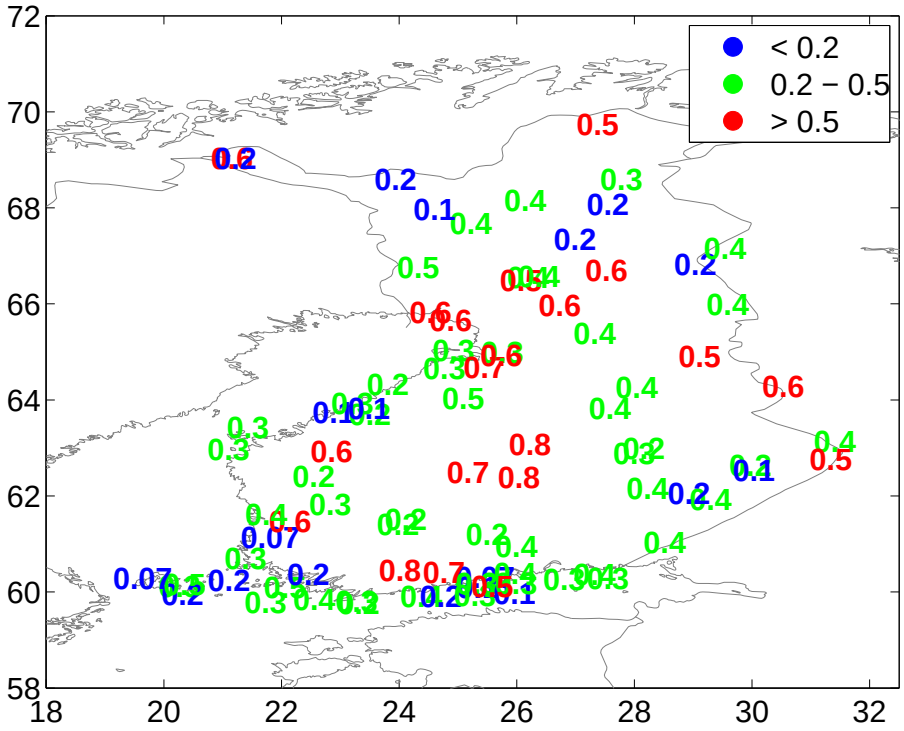
Gust factors, differences between stations

$$G = \frac{U_{\max}}{U}$$

Mean G



Sector mean G: max – min

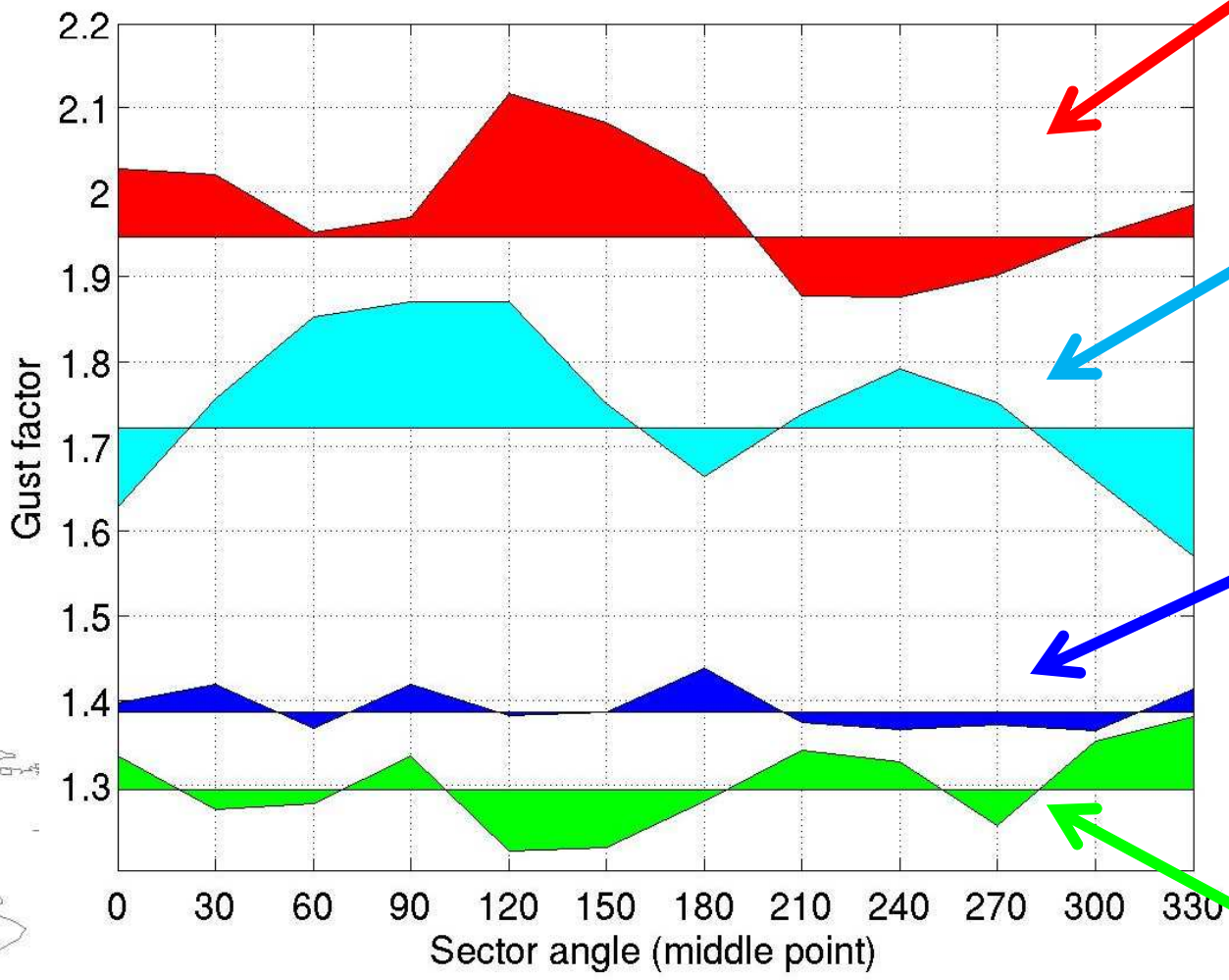


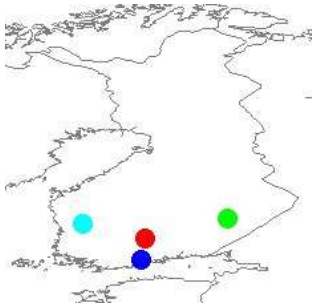
Gusts at Finnish EWGLAM stations

Station	WMO	G	ΔG
Inari Ivalo airport	9601	1.6	0.3
Sodankylä	7501	1.8	0.2
Kajaani airport	4601	1.6	0.4
Siilinjärvi Kuopio airport	3601	1.5	0.2
Liperi Joensuu airport	3801	1.6	0.2
Jyväskylä airport	2401	1.6	0.8
Tampere-Pirkkala airport	1215	1.6	0.2
Lappeenranta airport	1701	1.6	0.4
HKI-Vantaa airport	301	1.4	0.1

Gust factor: differences between stations

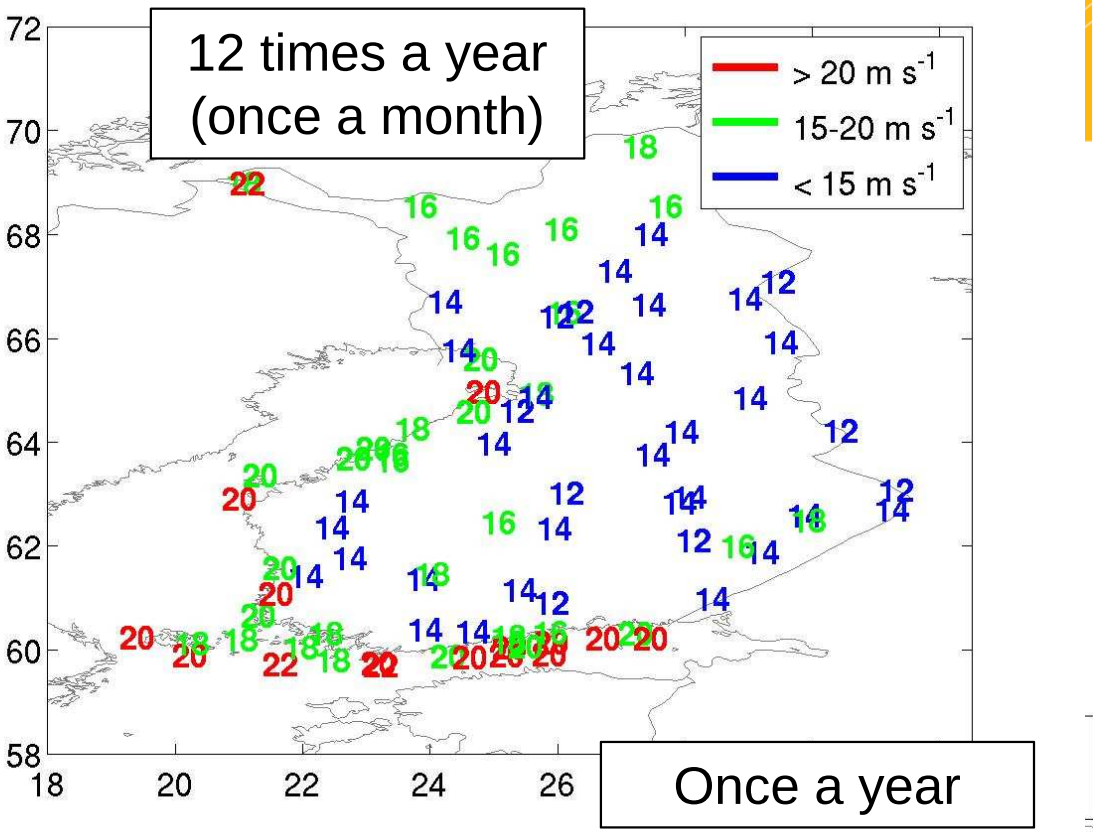
$$G = \frac{U_{\max}}{U}$$

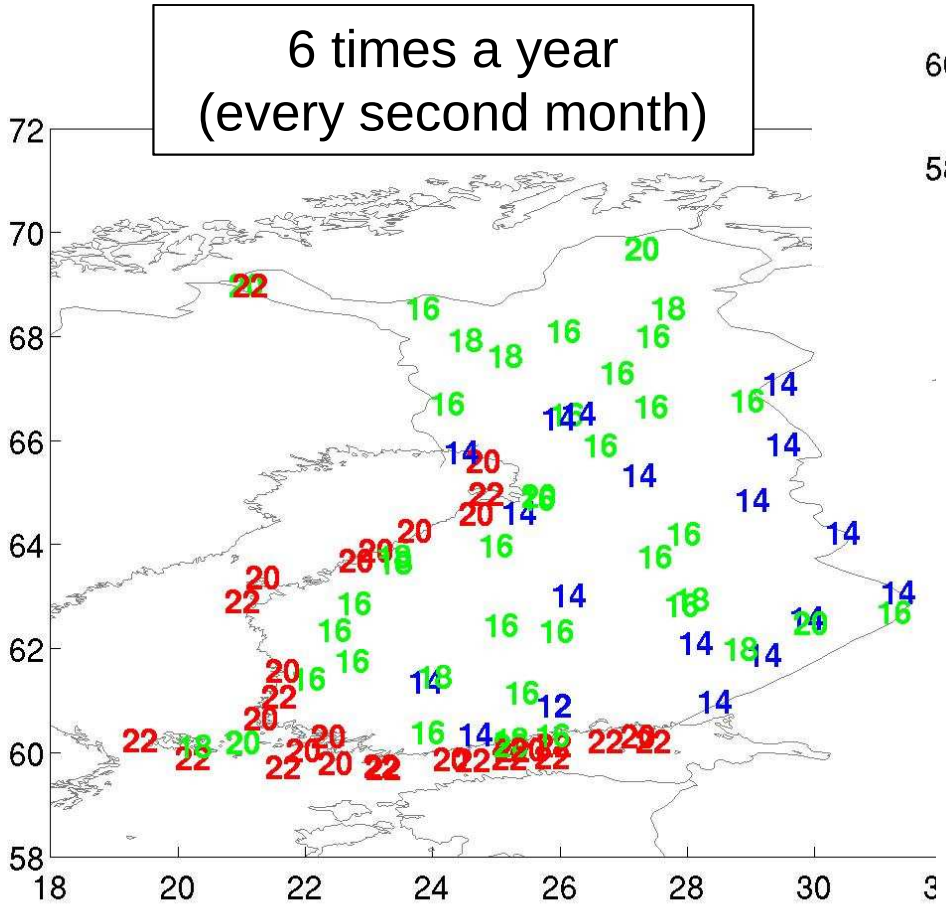


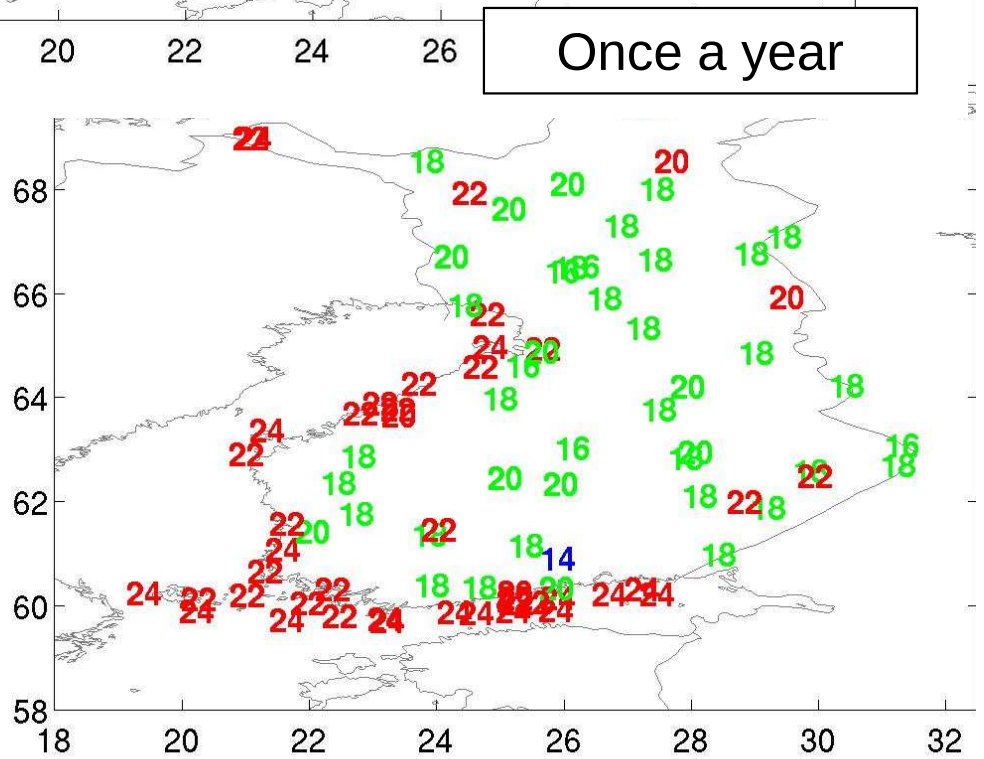


ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

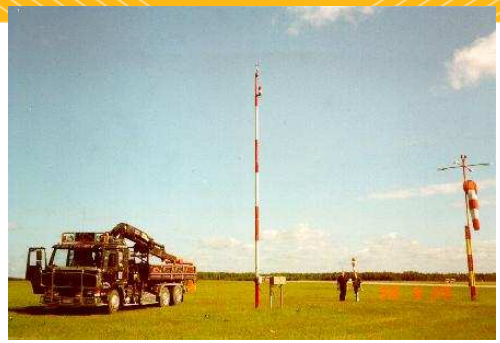
Daily extreme gusts



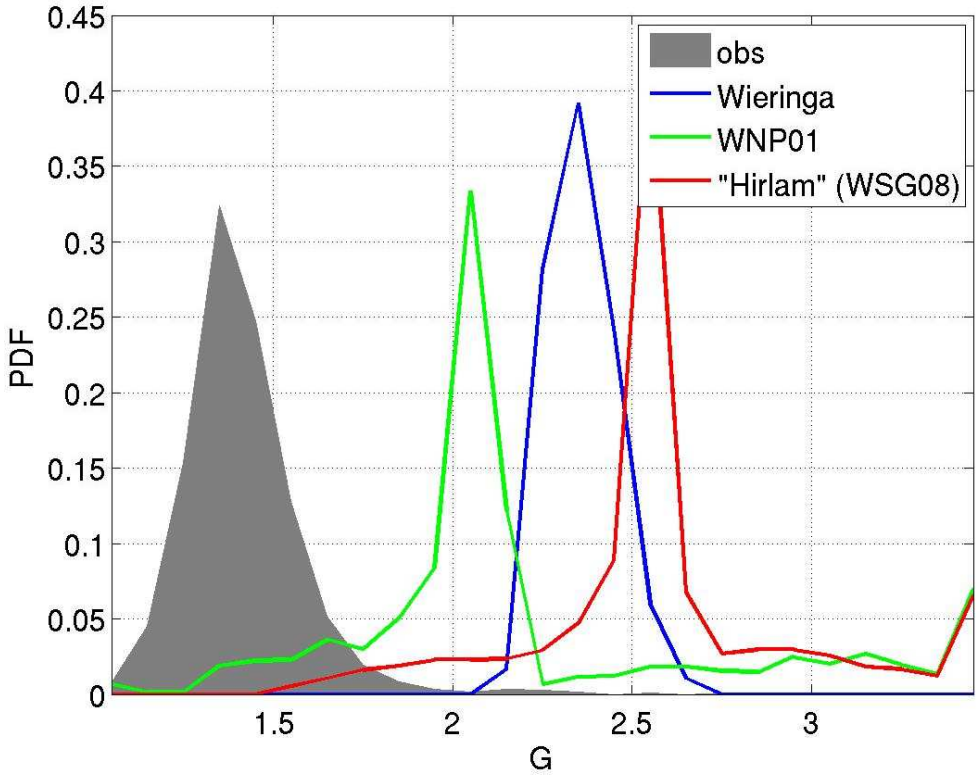


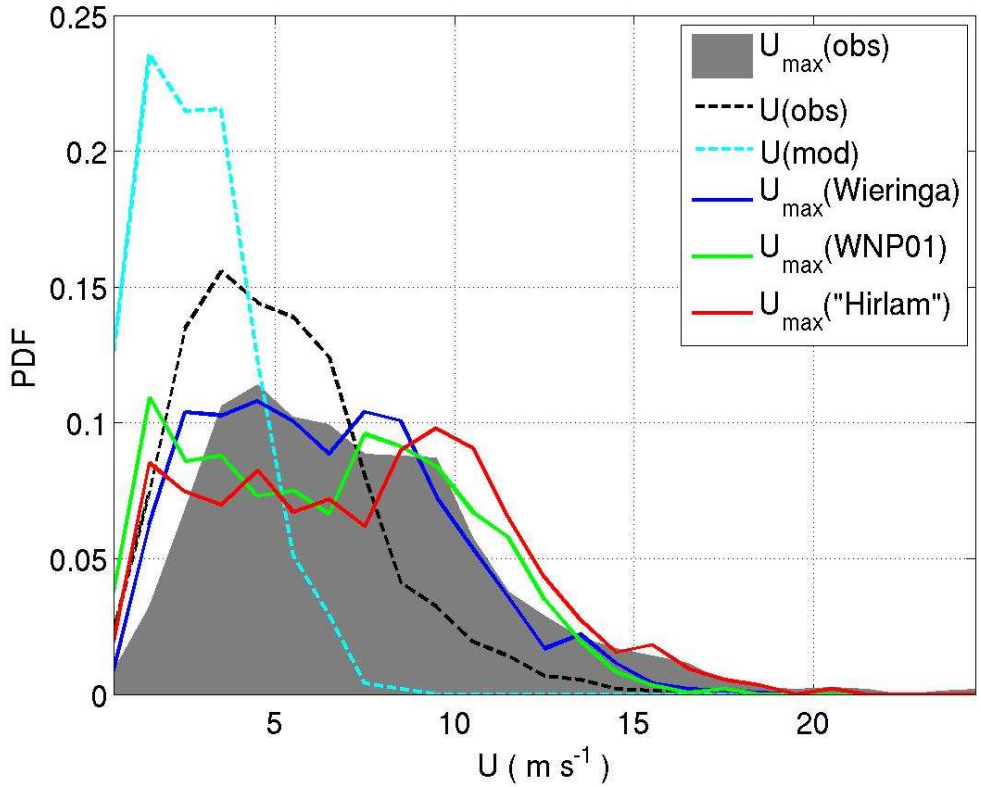


Comparison of model results: Helsinki-Vantaa



HKI-Vantaa, z = 16 m



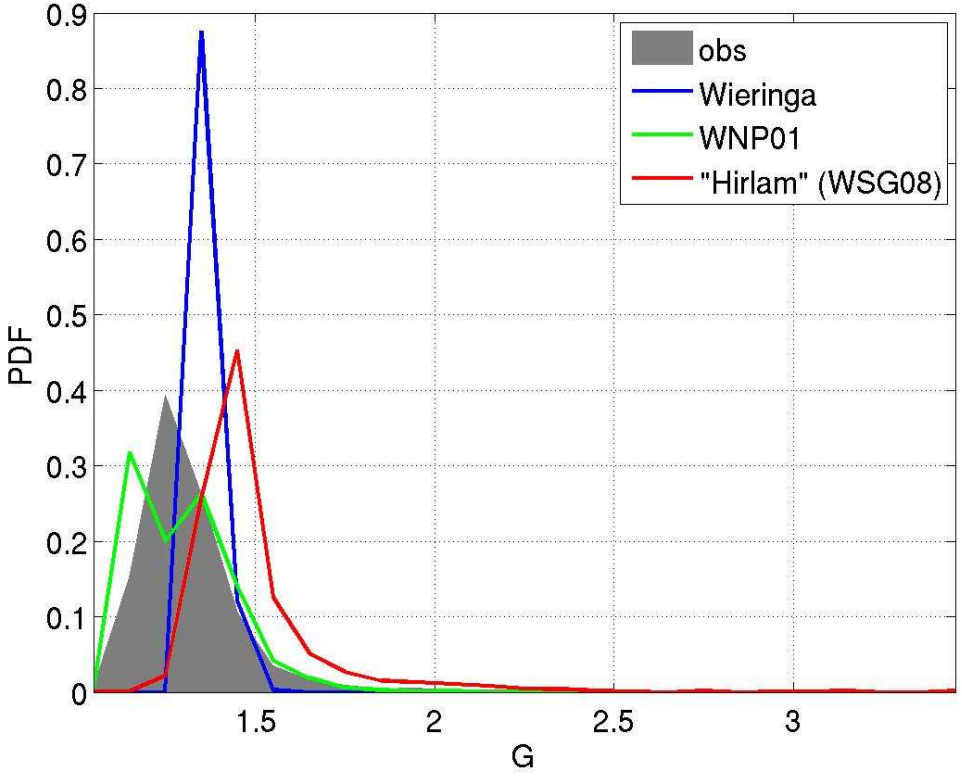


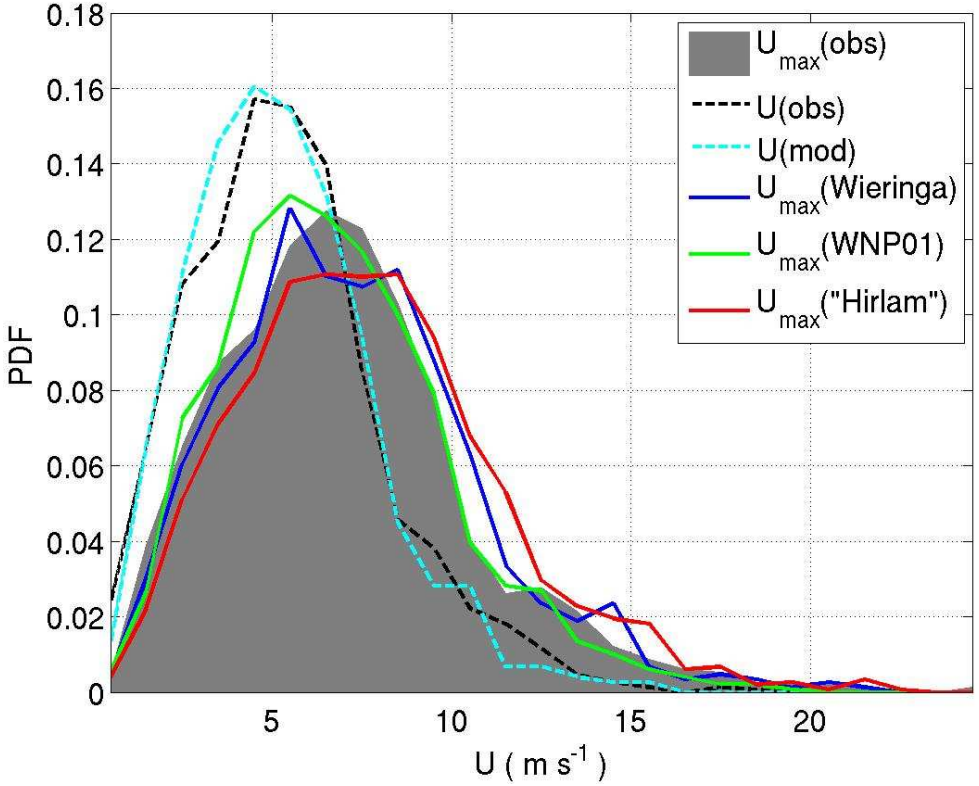
$$G = \frac{U_{\max}}{U}$$

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

Comparison of model results: Rantasalmi (lake)

Rantasalmi, z = 12 m



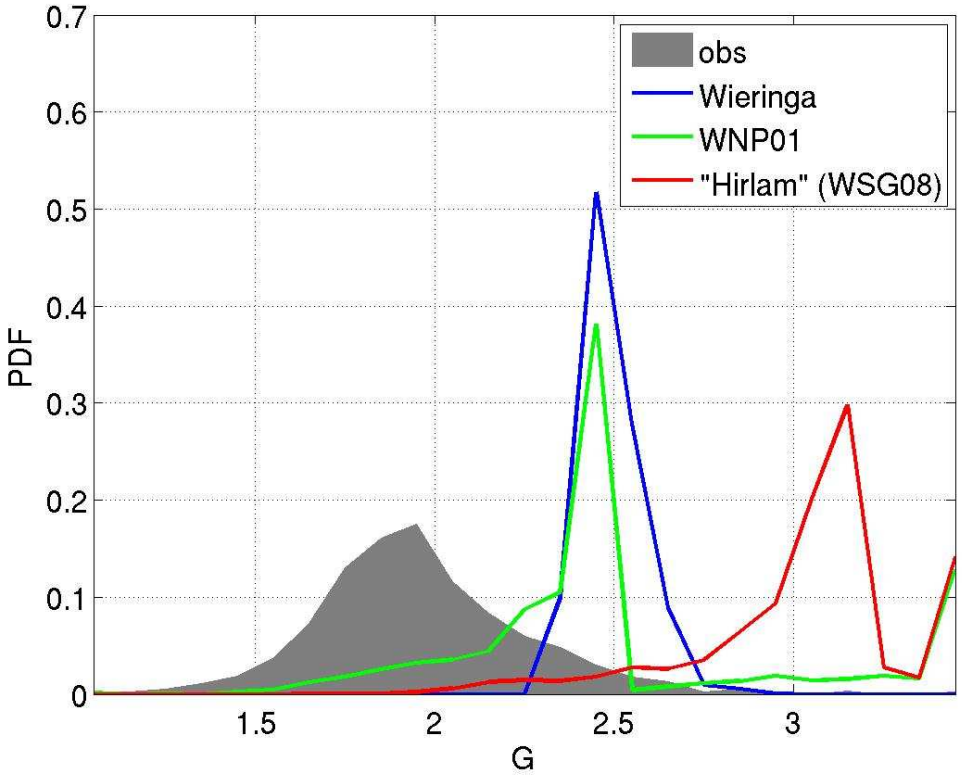


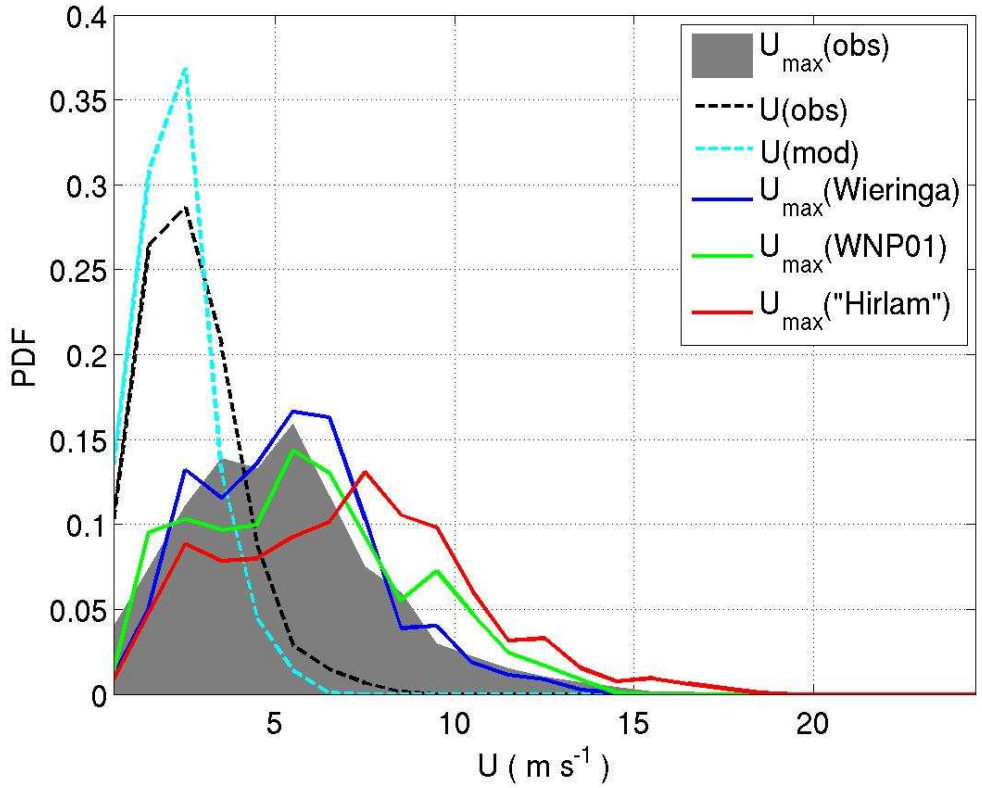
$$G = \frac{U_{\max}}{U}$$

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

Comparison of model results: Lammi Evo (forest)

Lammi Evo
z = 31 m





Summary

- The largest factor determining the gust factor is surface roughness
- Gustiness conditions at Finnish AWS stations are highly variable
- Gust factor forecast is good over lake (and coastal regions), but has large differences over land: model roughness is too large in the example cases
- Gust wind speed forecast can be good even though the gust factor is overestimated and/or the mean wind speed is too small in the model
- Future work:
  - The most sophisticated gust parametrizations take into account the stability effects on gusts. Can we distinguish this signal hidden behind the variable roughness conditions?
  - Comparison of different gust parametrization methods

Acknowledgement

This research has received funding from the European Research Council under the European Community's 7th Framework Programme (FP7/2007-2013) / ERC grant agreement number 227915, project PBL-PMES