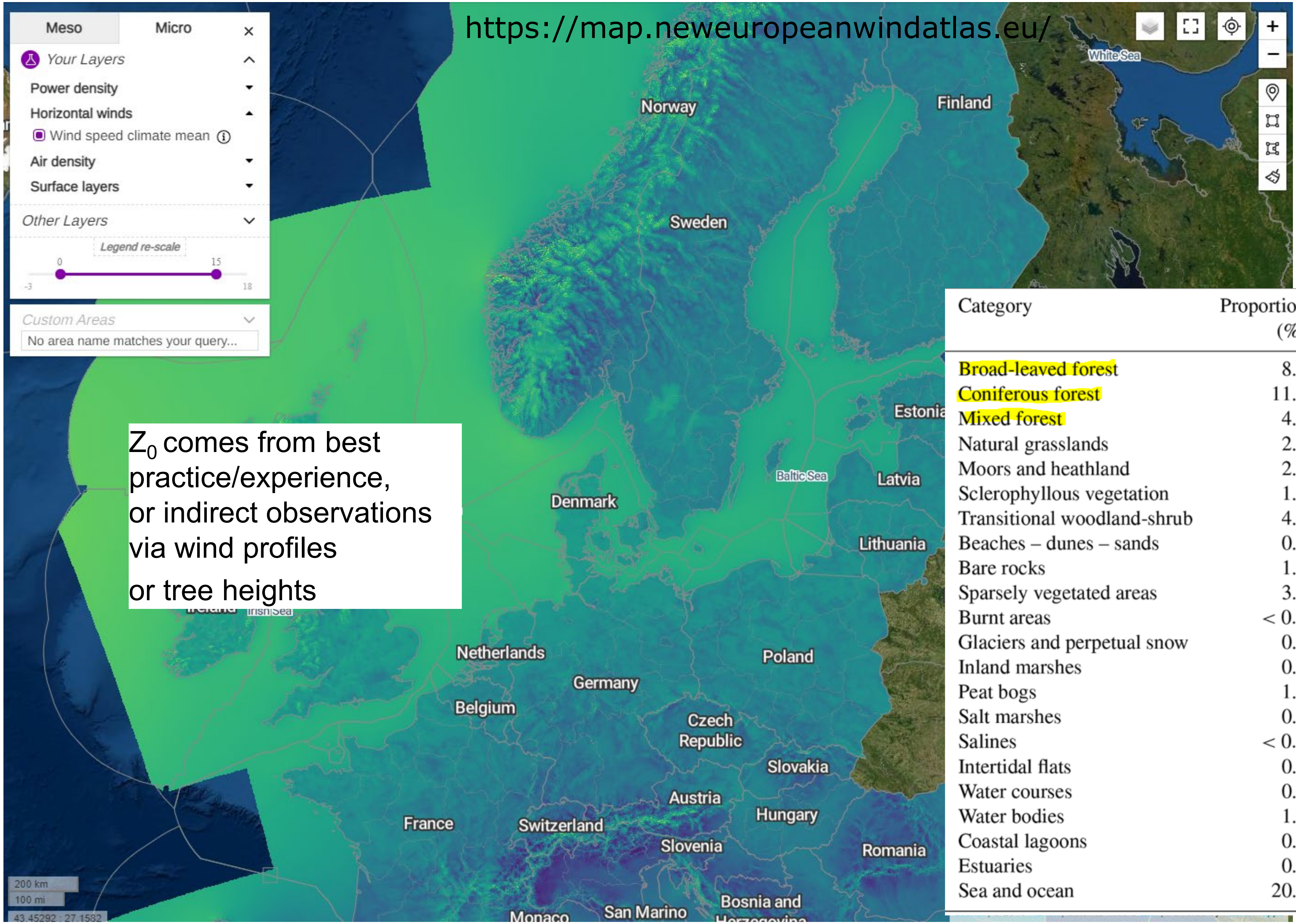
(Old and) Novel concepts in land surface parameterisation with a special emphasis on forestry

Ebba Dellwik

https://map.neweuropeanwindatlas.eu/



Z_0 comes from best practice/experience, or indirect observations via wind profiles

or tree heights

Category	Proportion (%)	WAsP z_0 (m)	WRF z_0 (m)
Broad-leaved forest	8.0	1.0	0.9
Coniferous forest	11.1	1.2	0.9
Mixed forest	4.2	1.1	0.5
Natural grasslands	2.9	0.1	0.1
Moors and heathland	2.4	0.12	0.12
Sclerophyllous vegetation	1.5	0.12	0.12
Transitional woodland-shrub	4.1	0.4	0.12
Beaches – dunes – sands	0.1	0.01	0.01
Bare rocks	1.3	0.05	0.01
Sparsely vegetated areas	3.2	0.03	0.01
Burnt areas	< 0.1	0.2	0.01
Glaciers and perpetual snow	0.2	0.005	0.001
Inland marshes	0.2	0.05	0.001
Peat bogs	1.6	0.03	0.001
Salt marshes	0.1	0.02	0.001
Salines	< 0.1	0.005	0.001
Intertidal flats	0.2	0.001	0.001
Water courses	0.2	0.0002	0.0001
Water bodies	1.8	0.0002	0.0001
Coastal lagoons	0.1	0.0002	0.0001
Estuaries	0.1	0.0002	0.0001
Sea and ocean	20.1	0.0002	0.0001

Dörenkämper et al (2020): https://doi.org/10.5194/gmd-13-5079-2020

Outline

- Why the forest roughness should be high:
  - New answers from the Single Tree Experiment
  - New concept of “direct observation”

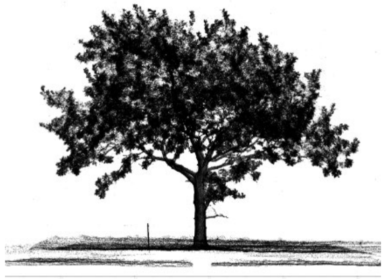
- Why the roughness should not be sooo high:
  - Answers from the Ryningsnäs experiment

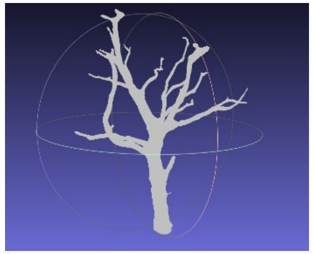
- Where are we today in terms of being able to predict microscale flow variability in forested areas using CFD, where the trees are vertically resolved as a distributed drag force?
  - Preliminary answers from Johan Arnqvist at Uppsala University

- Take home messages

”The Single Tree Experiment”

- One European oak tree
- 15 sonic anemometers
- Strain gauges on stem
- Surveillance camera
- Campaign with DTU WindScanner
- Tree structure models





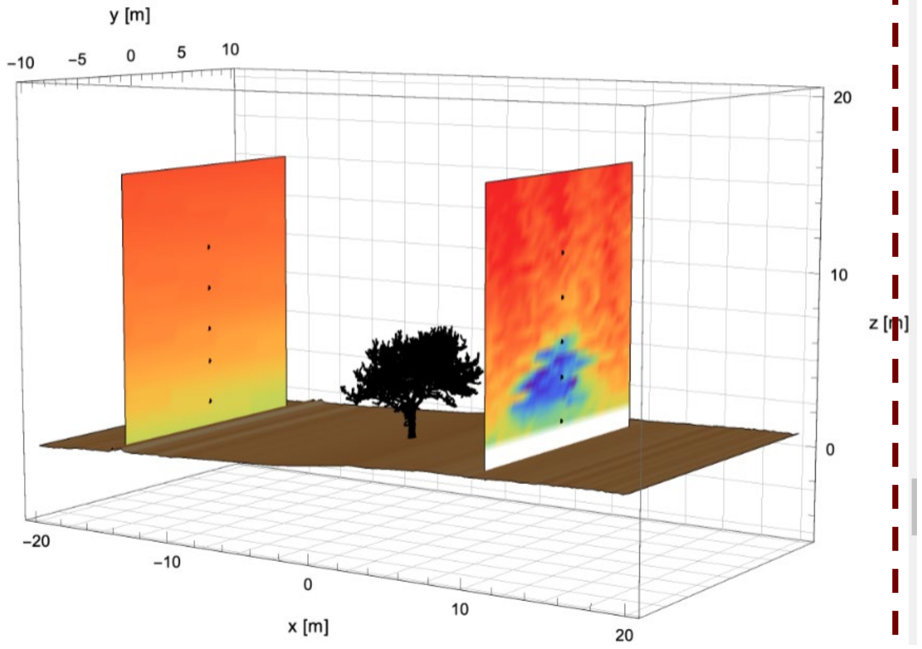
Assessing the drag force on a tree

$$F = \frac{1}{2} C_d A \rho U^2$$

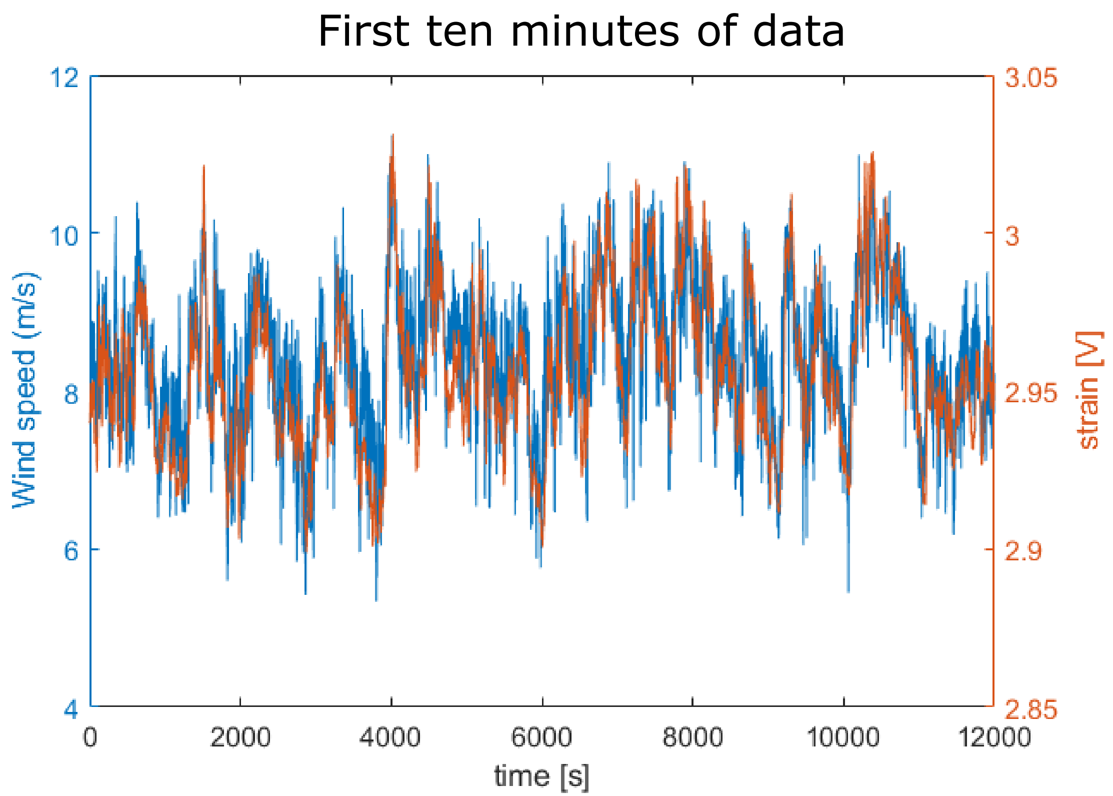
Wind tunnel –
mount tree on calibrated drag force sensor

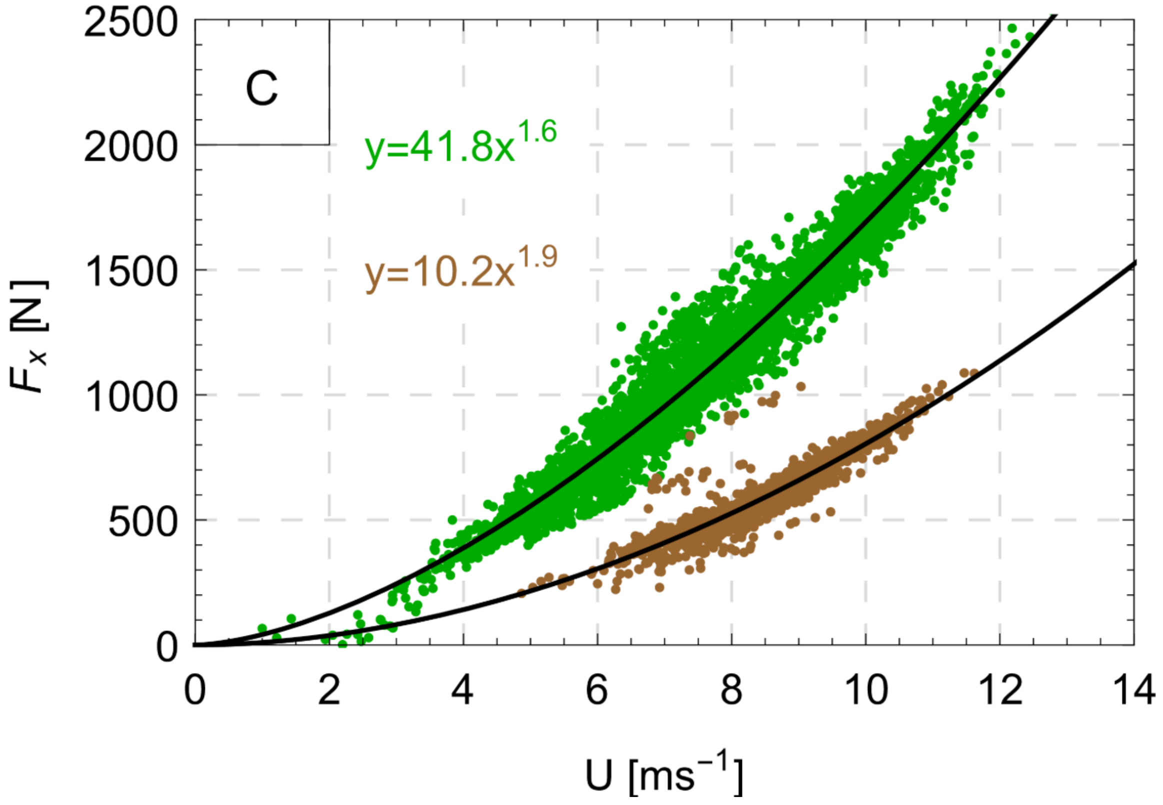
Nature: two methods

Blackburn, 1997



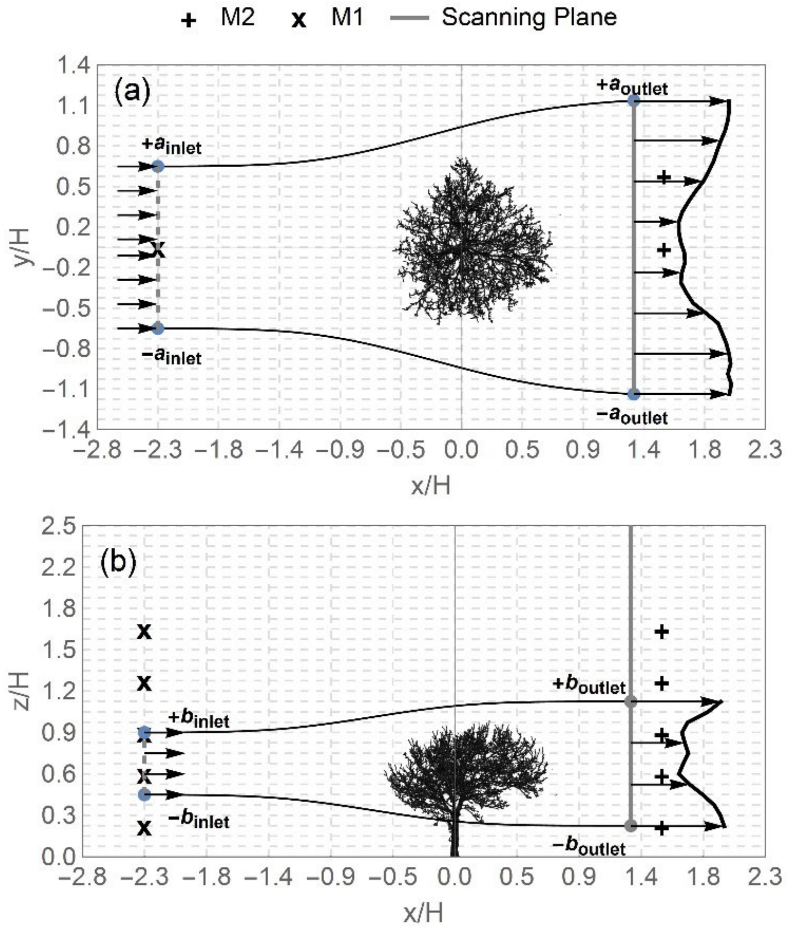
Drag force from tree mounted sensor

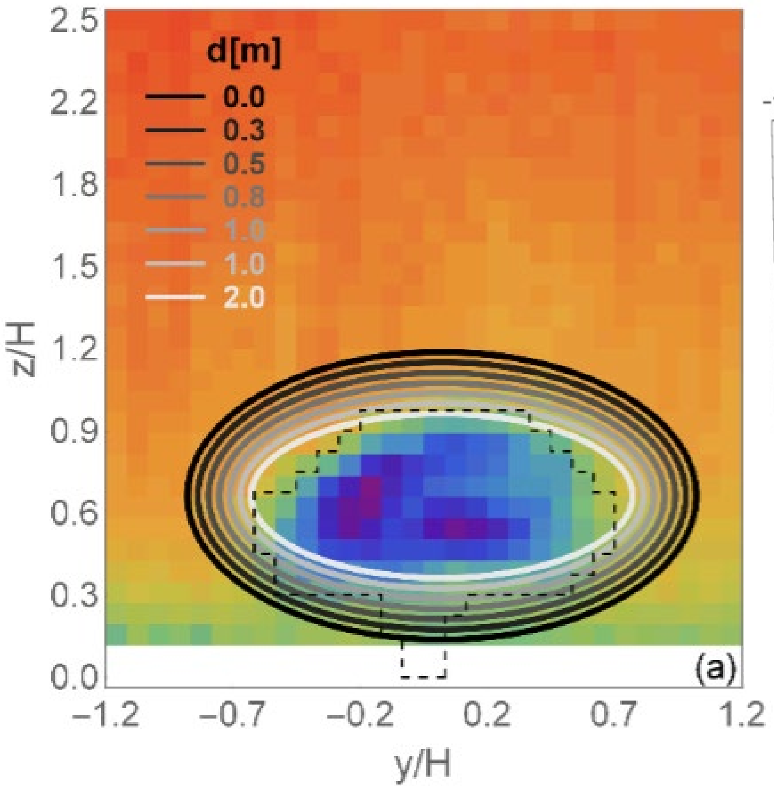


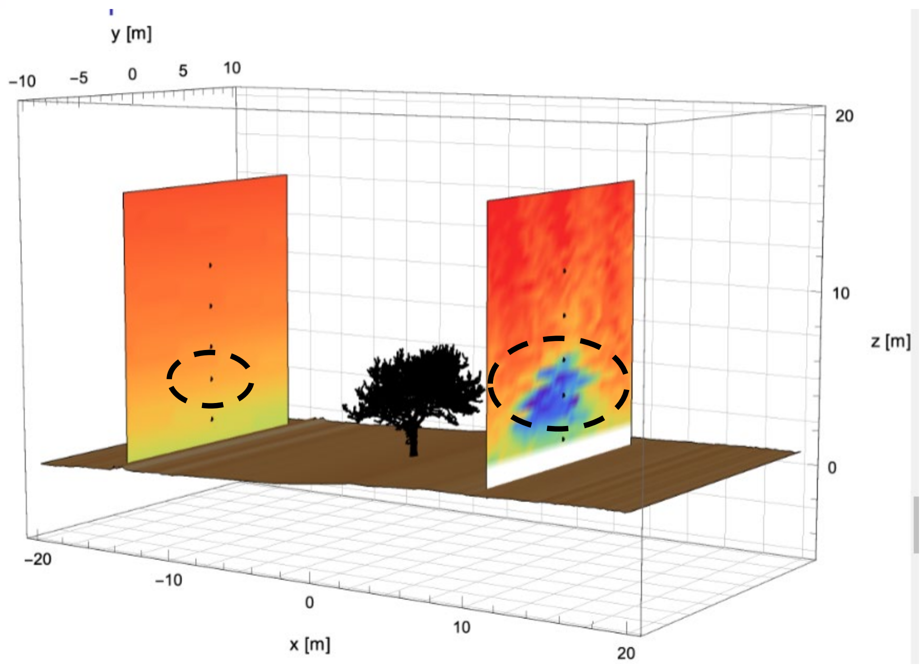


 Angelou Dellwik Mann 2019: DOI https://doi.org/10.1093/forestry/cpz026

Determining the drag force from the momentum deficit in the wake

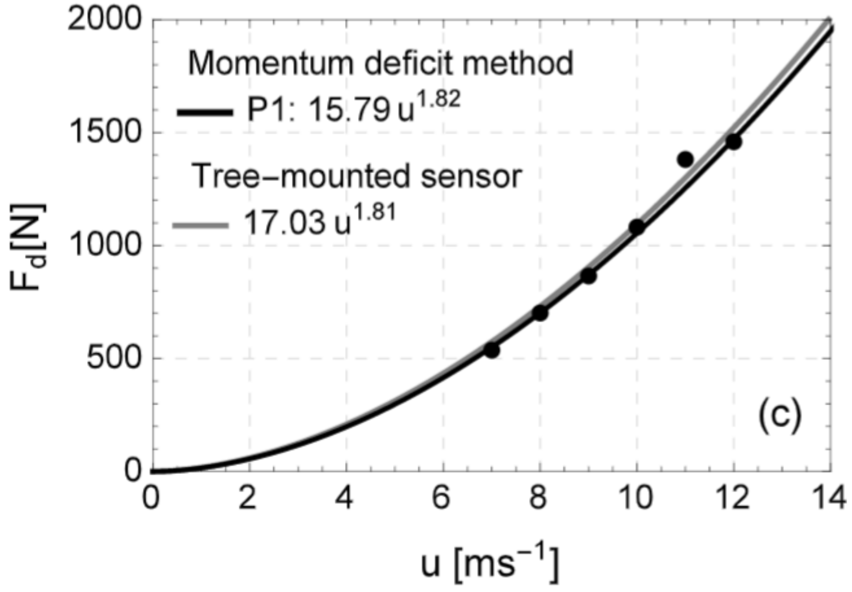






Angelou, Mann, Dellwik(2021) doi:10.1017/jfm.2021.275

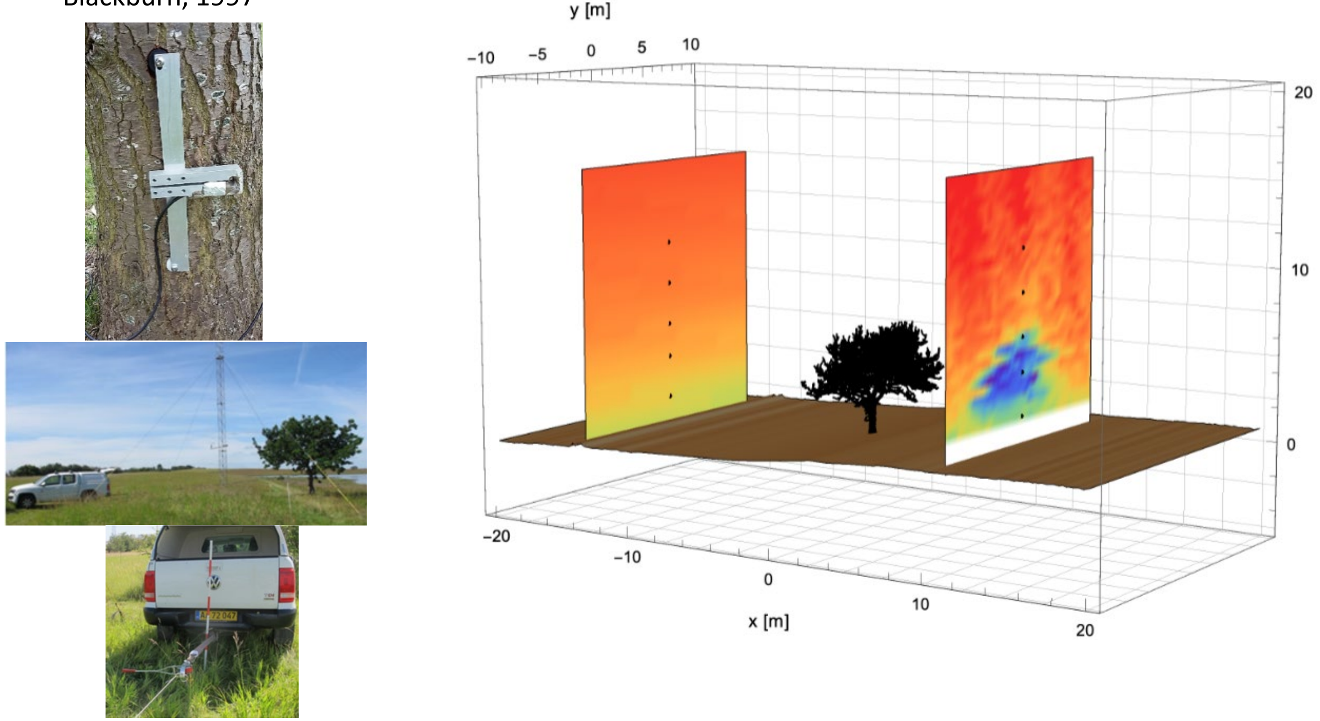
New concept: direct observation of land surface drag



$$F = \frac{1}{2} C_d A \rho U^2$$

Nature: two methods

Blackburn, 1997



Angelou, Mann, Dellwik(2021) doi:10.1017/jfm.2021.275

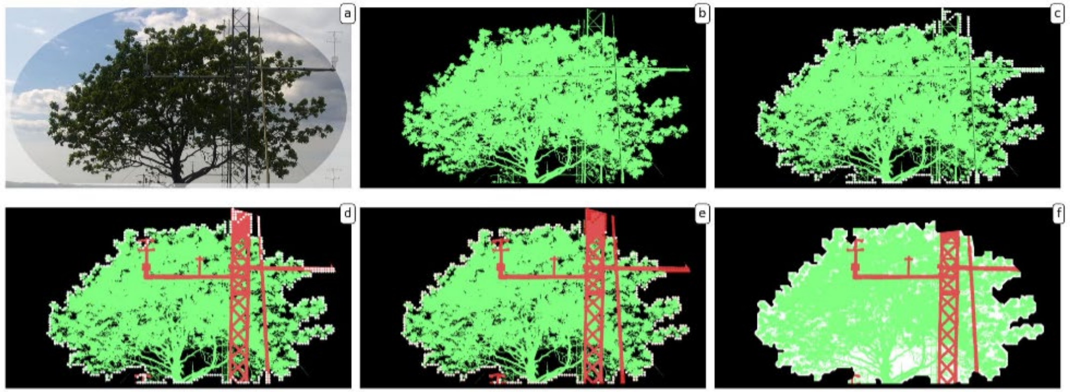
Assessing the frontal area of a tree using a surveillance camera



$$F = \frac{1}{2} C_d A \rho U^2$$

Results on Cd:

$$F = \frac{1}{2} C_d A \rho U^2$$

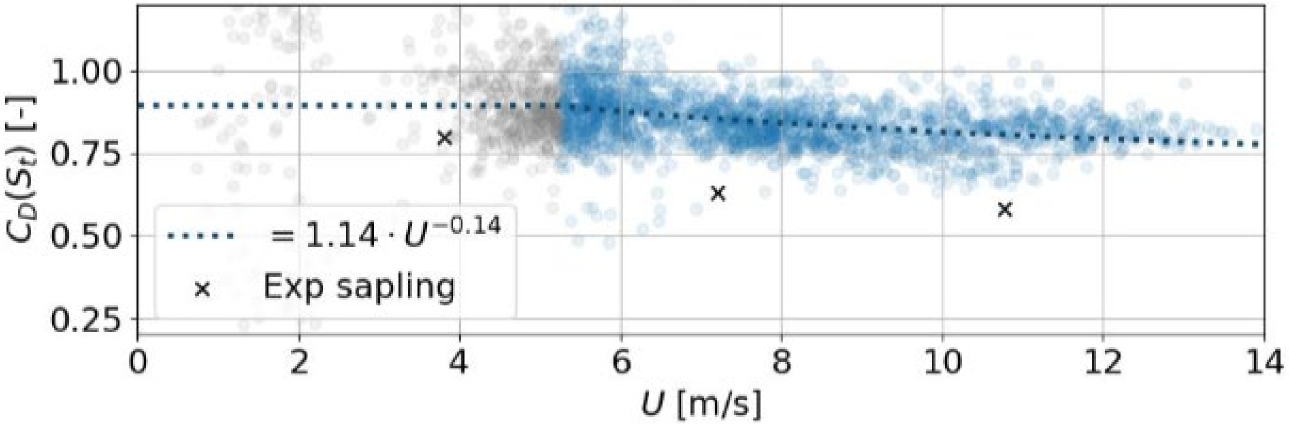


Tree: ~0.8

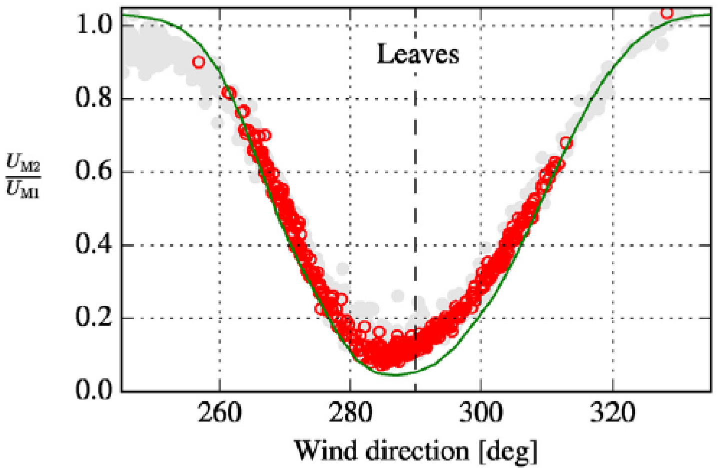
Sphere: 0.2 - 0.4

Cylinder: 0.2 - 0.4

Wind turbine: ~ 0.5



Why the roughness over forested areas should be high?



Relative wind deficit in the wake of a tree

Because trees so efficiently remove momentum from the wind, strong mean wind gradients are created.

The high gradients are reflected with a high value of the roughness typically between 1.5 and 3 m.

Dellwik et al. 2019, DOI https://doi.org/10.1016/j.agrformet.2018.10.015

Why the roughness should maybe not always be so high? Answers from the Ryningsnäs experiment

Vattenfall (2008-2009):

Well-instrumented tower

DTU and Uppsala University (2010-2011):

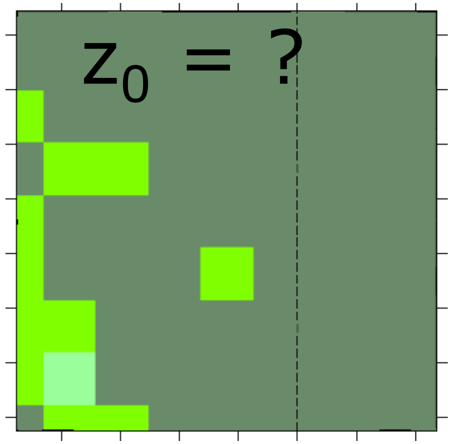
Six sonic anemometers

Surface energy balance

Campaigns with remote sensing instruments

Arnqvist et al. 2015: https://doi.org/10.1007/s10546-015-0016-x

1. The roughness is stability dependent



Wind Statistics from a Forested Landscape

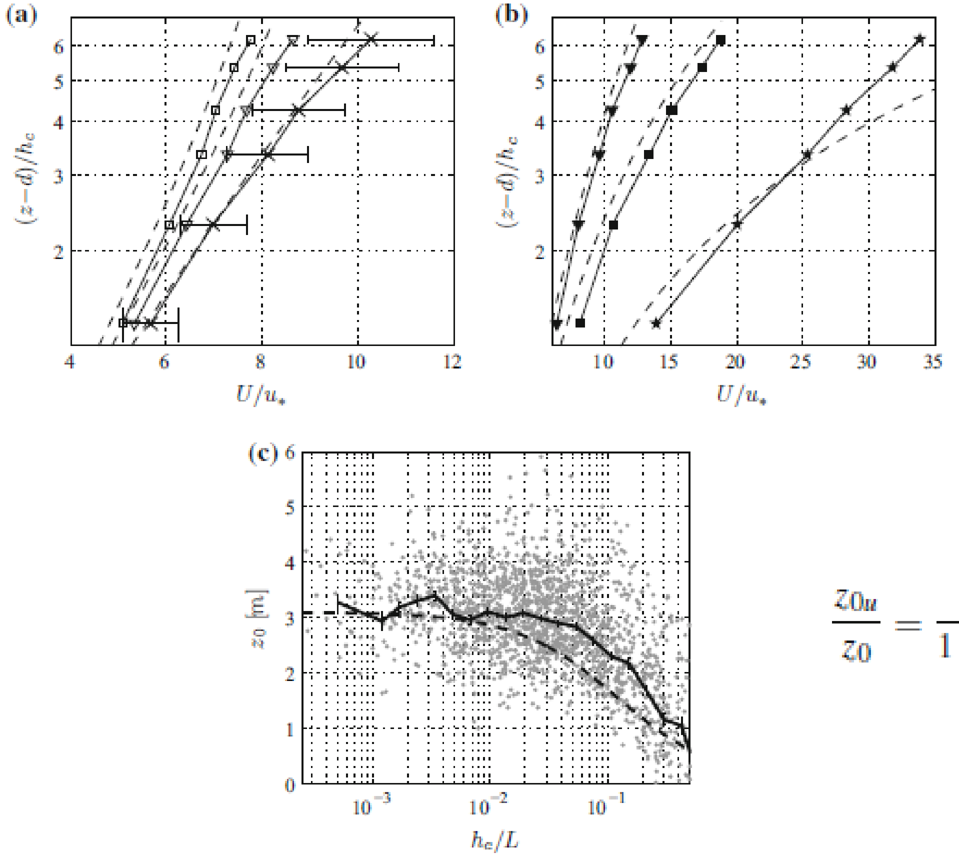
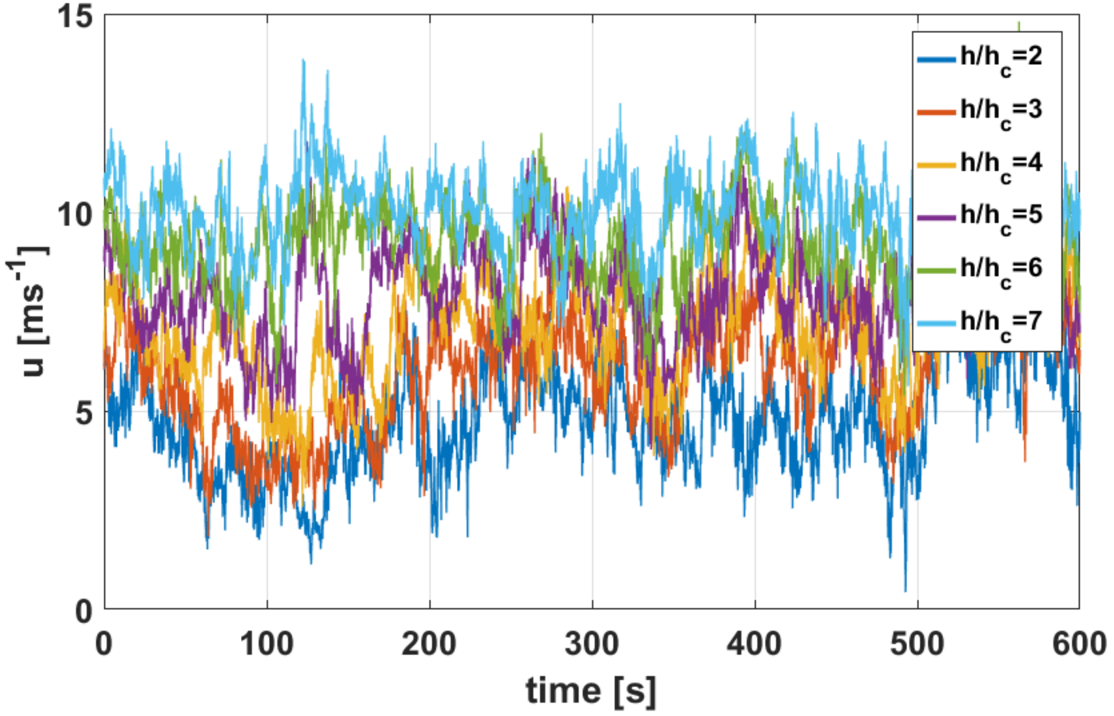


Fig. 9 Wind-speed profile in the western sector for different diabatic conditions, **a** unstable and neutral data, **b** stable data. *Symbols* of the measurements refer to the different stability conditions listed in Table 2. The results obtained with Monin–Obukhov similarity theory and using a constant $z_0 = 3$ m are shown by *dashed lines*. **c** Shows the roughness length obtained from matching the data to a surface-layer wind profile in stable conditions. The *solid line* is the bin average of the individual points with one standard deviation of the mean value indicated by *bars*. The *dashed line* is the Zilitinkevich (2009) formulation

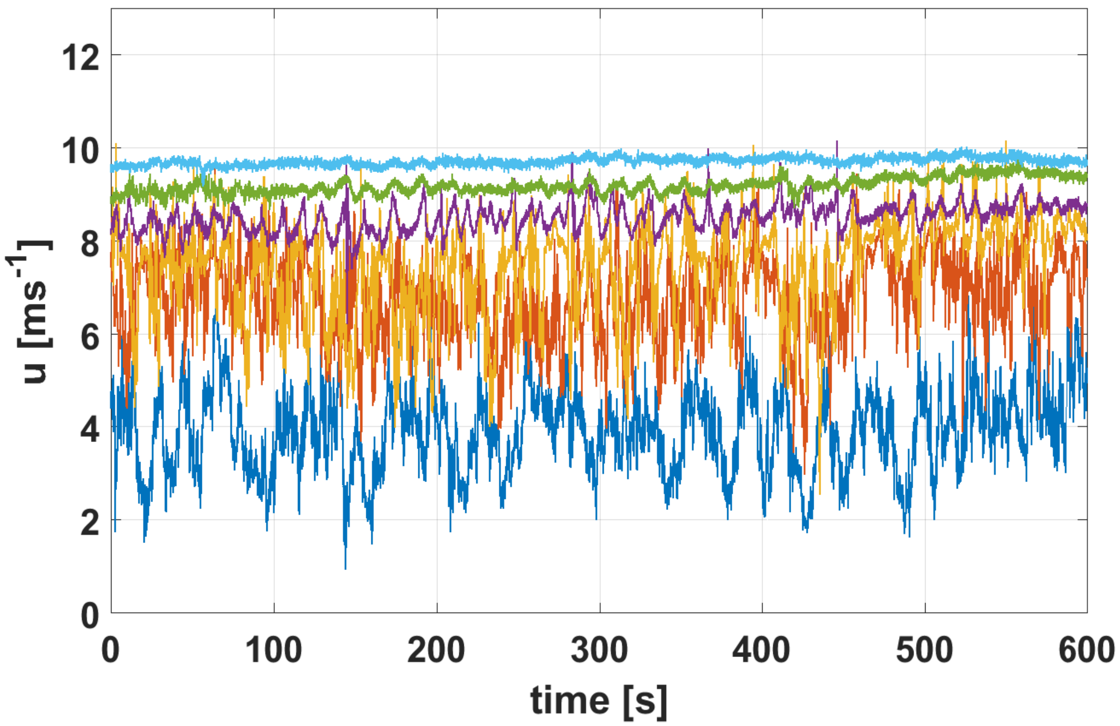
$$\frac{z_{0u}}{z_0} = \frac{1}{1 + C_{ZS} h_0 / L},$$

2. Stable conditions may lead to very shallow boundary layers, leading to high gradients in turbulence

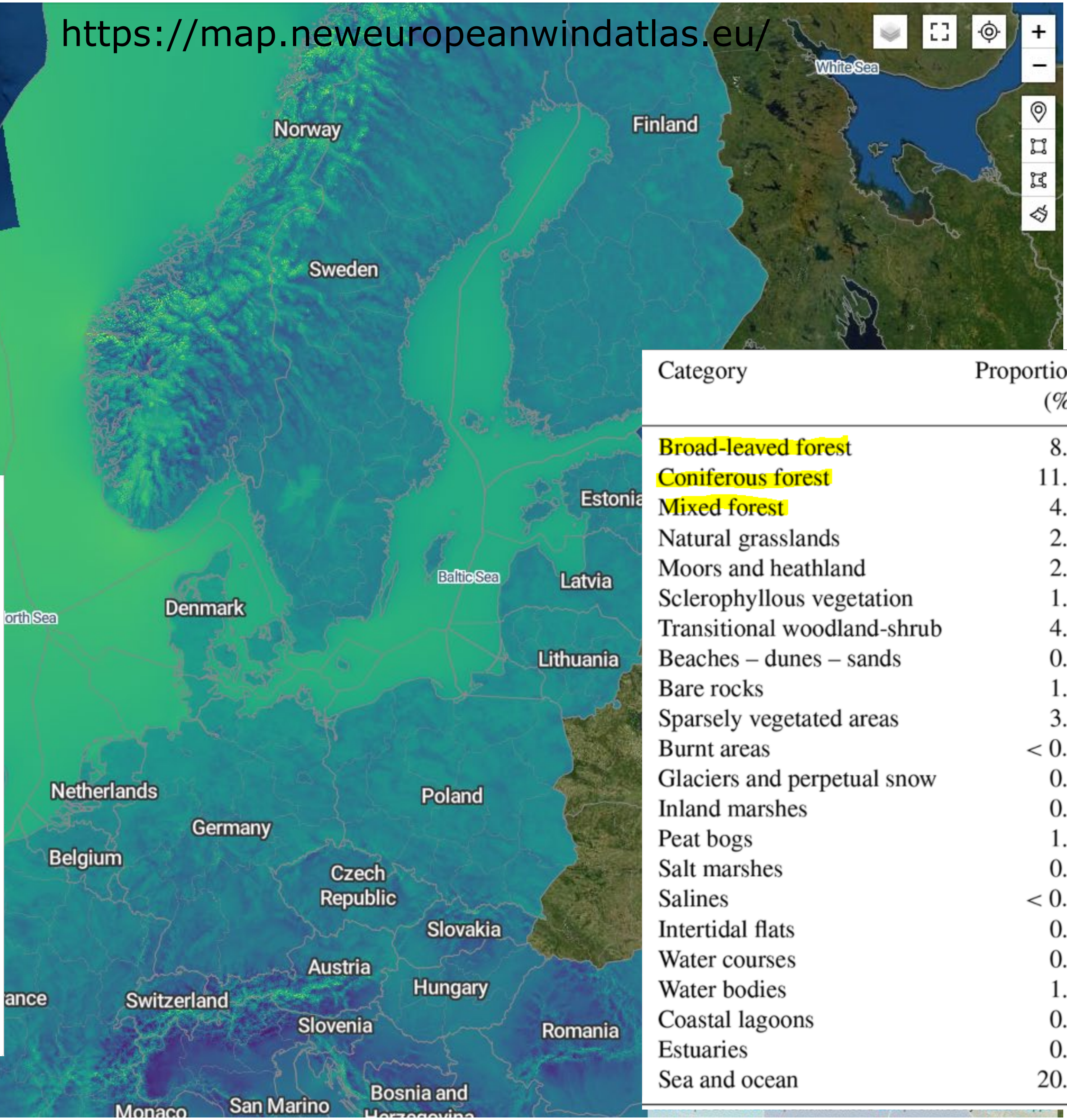
Neutral

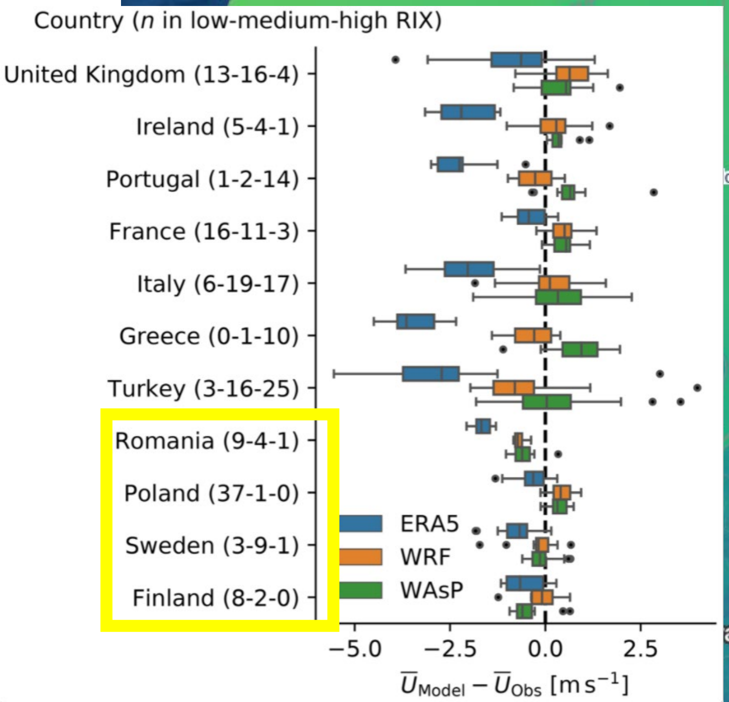


Stable



https://map.neweuropeanwindatlas.eu/





Category	Proportion (%)	WAsP z_0 (m)	WRF z_0 (m)
Broad-leaved forest	8.0	1.0	0.9
Coniferous forest	11.1	1.2	0.9
Mixed forest	4.2	1.1	0.5
Natural grasslands	2.9	0.1	0.1
Moors and heathland	2.4	0.12	0.12
Sclerophyllous vegetation	1.5	0.12	0.12
Transitional woodland-shrub	4.1	0.4	0.12
Beaches – dunes – sands	0.1	0.01	0.01
Bare rocks	1.3	0.05	0.01
Sparsely vegetated areas	3.2	0.03	0.01
Burnt areas	< 0.1	0.2	0.01
Glaciers and perpetual snow	0.2	0.005	0.001
Inland marshes	0.2	0.05	0.001
Peat bogs	1.6	0.03	0.001
Salt marshes	0.1	0.02	0.001
Salines	< 0.1	0.005	0.001
Intertidal flats	0.2	0.001	0.001
Water courses	0.2	0.0002	0.0001
Water bodies	1.8	0.0002	0.0001
Coastal lagoons	0.1	0.0002	0.0001
Estuaries	0.1	0.0002	0.0001
Sea and ocean	20.1	0.0002	0.0001

Dörenkämper et al (2020): https://doi.org/10.5194/gmd-13-5079-2020

Outline

- Why the forest roughness should be high:
  - New answers from the Single Tree Experiment
  - New concept of “direct observation”

- Why the roughness should not be sooo high:
  - Answers from the Ryningsnäs experiment

- Where are we today in terms of being able to predict microscale flow variability in forested areas using CFD, where the trees are vertically resolved as a distributed drag force?
  - Preliminary answers from Johan Arnqvist at Uppsala University

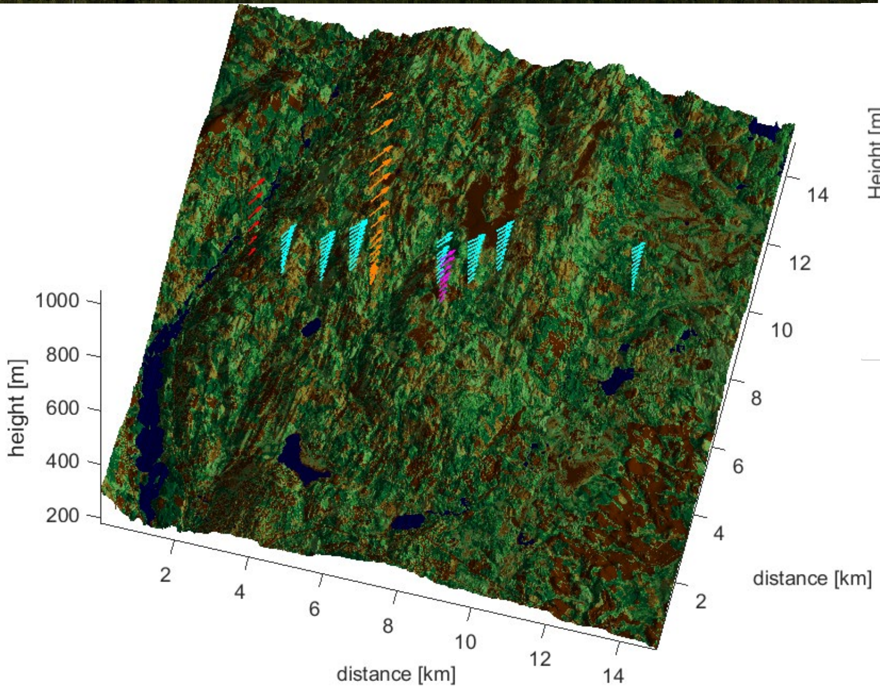
SEMI-NEW CONCEPT

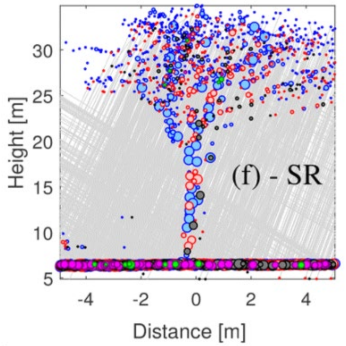
- Take home messages

Ongoing evaluation of flow models at Hornamossen[1]

simulation of a daily cycle at 100m height

- Instrumentation: cups and sonics in 180 m tower, 6 sodars, 2 lidars
- Forested, mildly complex terrain
- Test case for different atmospheric stabilities from 72 hours of observations
- 10 participants from universities and industry



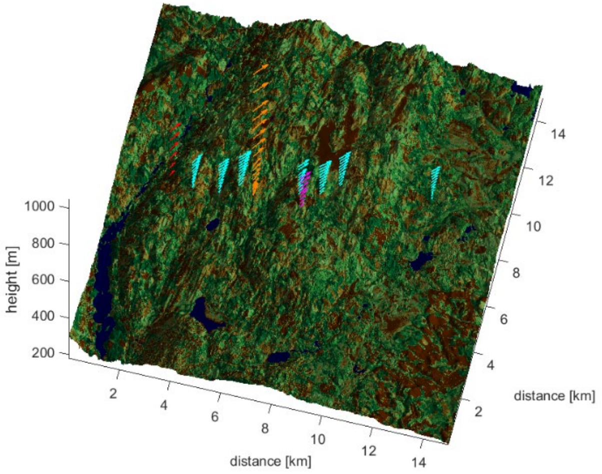


Real forest density variability from surface model based on airborne lidar scans (Arnqvist, Freier, Dellwik, BG, 2020)

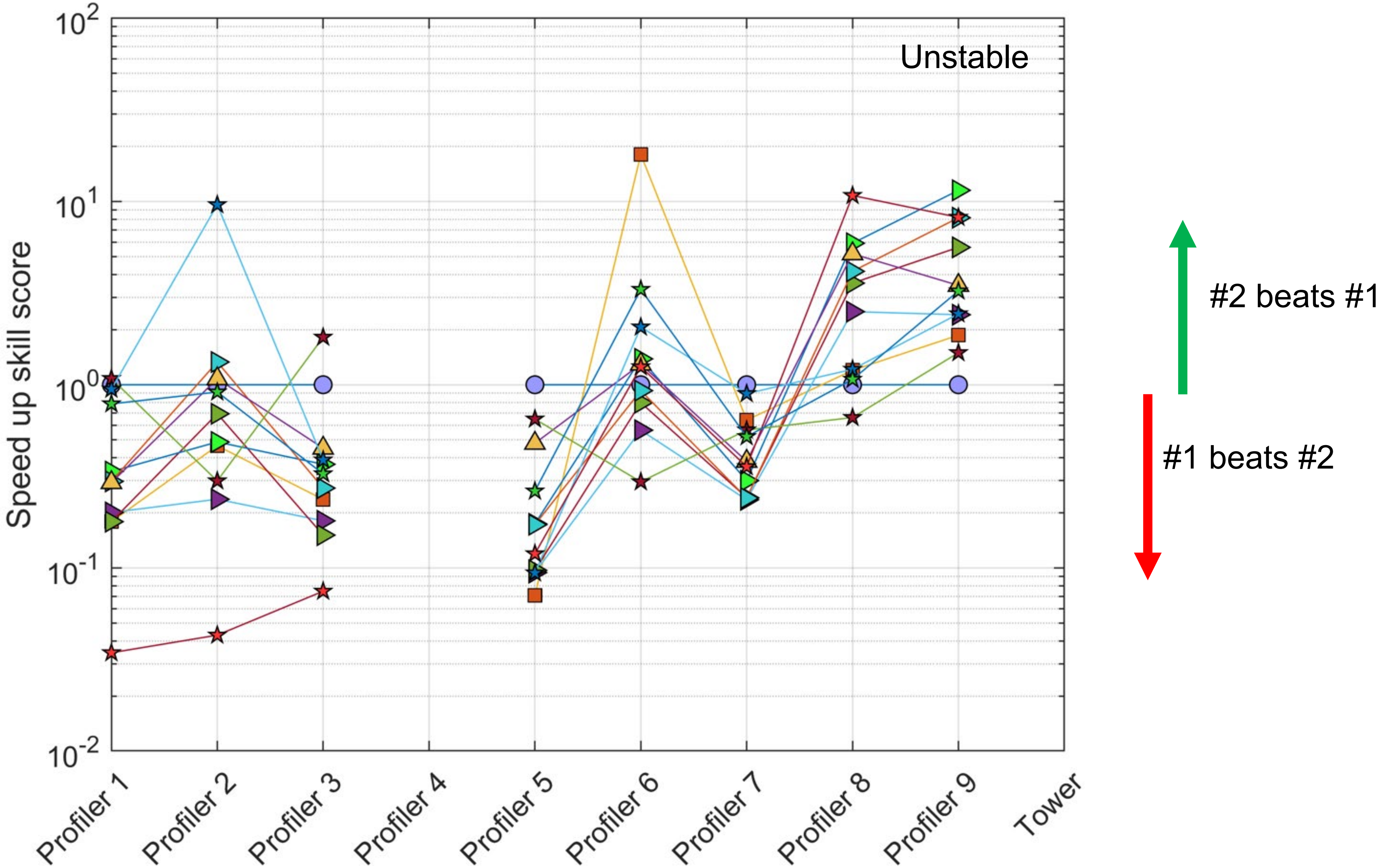
1. Contact Johan Arnqvist at Uppsala University: johan.arnqvist@geo.uu.se

[Mann et al (2017) https://doi.org/10.1098/rsta.2016.0101](https://doi.org/10.1098/rsta.2016.0101)

Ongoing evaluation of flow models at Hornamossen[1]

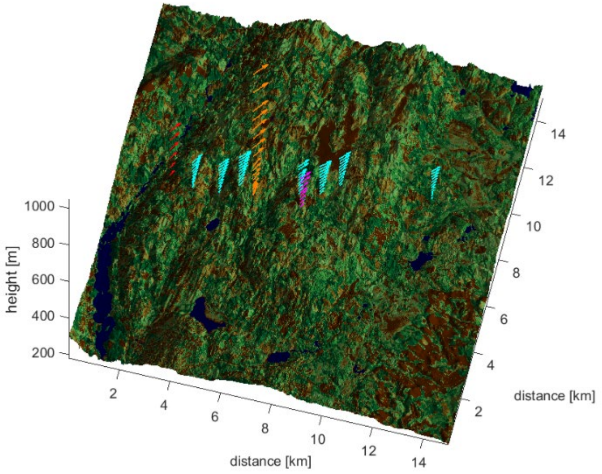


Comparison of two predictions:
#1. "The wind at 100m is the same everywhere."
#2. CFD model predictions.



1. Contact Johan Arnqvist at Uppsala University: johan.arnqvist@geo.uu.se

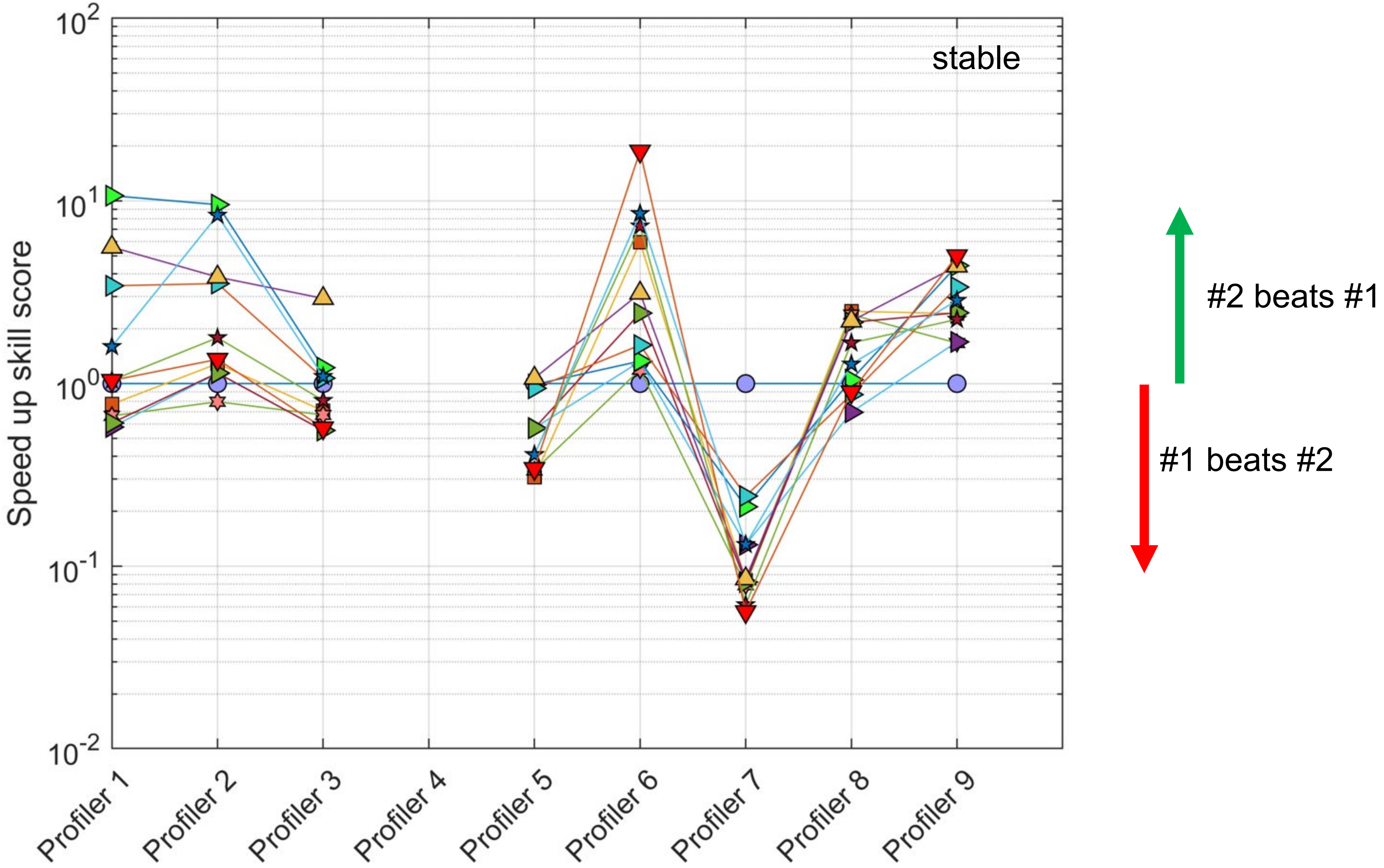
Ongoing evaluation of flow models at Hornamossen[1]



<u>Comparison of two predictions:</u>

#1. "The wind at 100m is the same everywhere."

#2. CFD model predictions.



1. Contact Johan Arnqvist at Uppsala University: johan.arnqvist@geo.uu.se

Outline

- Why the forest roughness should be high:
  - New answers from the Single Tree Experiment.

- Why the roughness should not be sooo high:
  - Answers from the Ryningsnäs experiment

- Where are we today in terms of being able to predict microscale flow variability in forested areas using CFD where the trees are vertically resolved as a distributed drag force?
  - Preliminary answers from Johan Arnqvist at Uppsala University

- **<u>Take home messages: Keep measuring! Modellers, please keep working!</u>**

Thank you for listening!

ebde@dtu.dk