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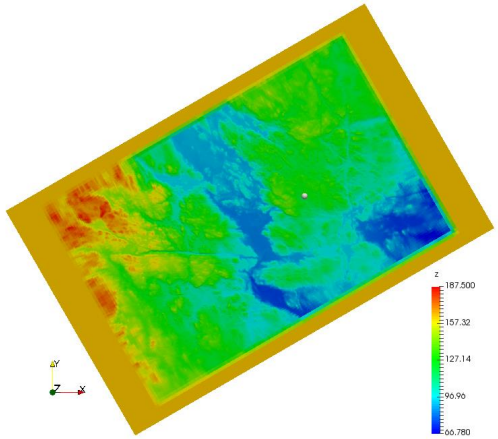
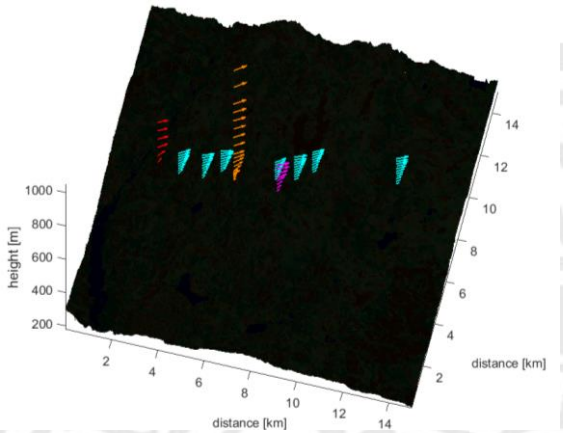
newa

Mätningar och modellering i svensk miljö, hur optimerar vi bäst modellkedjan, och hur validerar vi den?





Johan Arnqvist och **Stefan Ivanell**

Hans Bergström, Hugo Olivares, Stefan Söderberg, Matthias Mohr, Magnus Balchevsky, Gunnar Bergström, mfl

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Bakgrund

Många olika typer av osäkerheter inom vindresursbedömning

- Mätningar
  - Mätosäkerheter
  - Mätfel
  - Representativitet
    - Rumsvariationer
    - Tidsvariationer
- Modellering
  - Representativitet
    - Tidsvariationer
    - Rumsvariationer
  - Approximationer

NEWA, New European Wind Atlas, bedriver forskning på dessa områden

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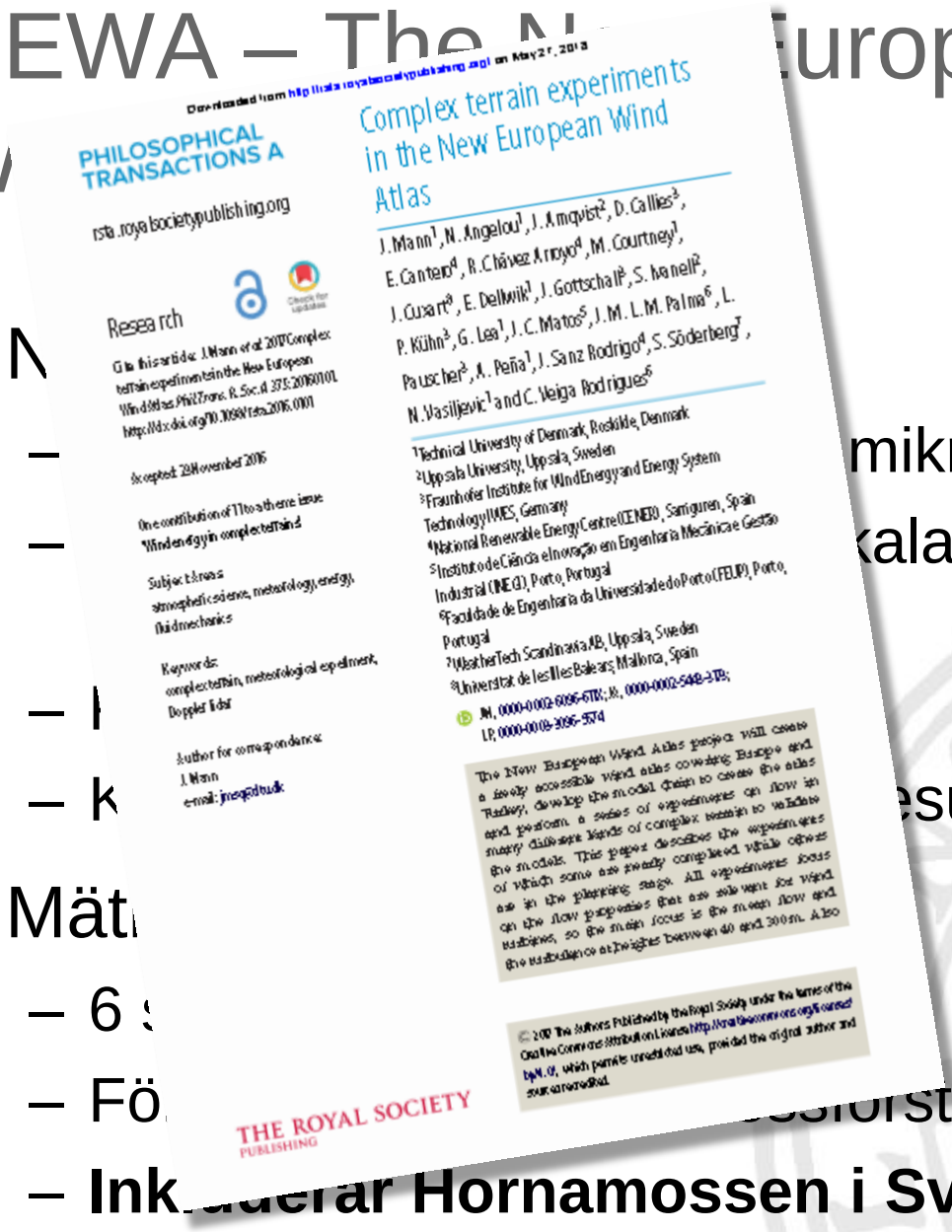
NEWA – The N uropean W

- N
  - mikroskala
  - kala, 30 års
  - k esursen
- Mät
  - 6
  - Fö ssförståelse
  - **Ink aderar Hornamossen i Sverige**



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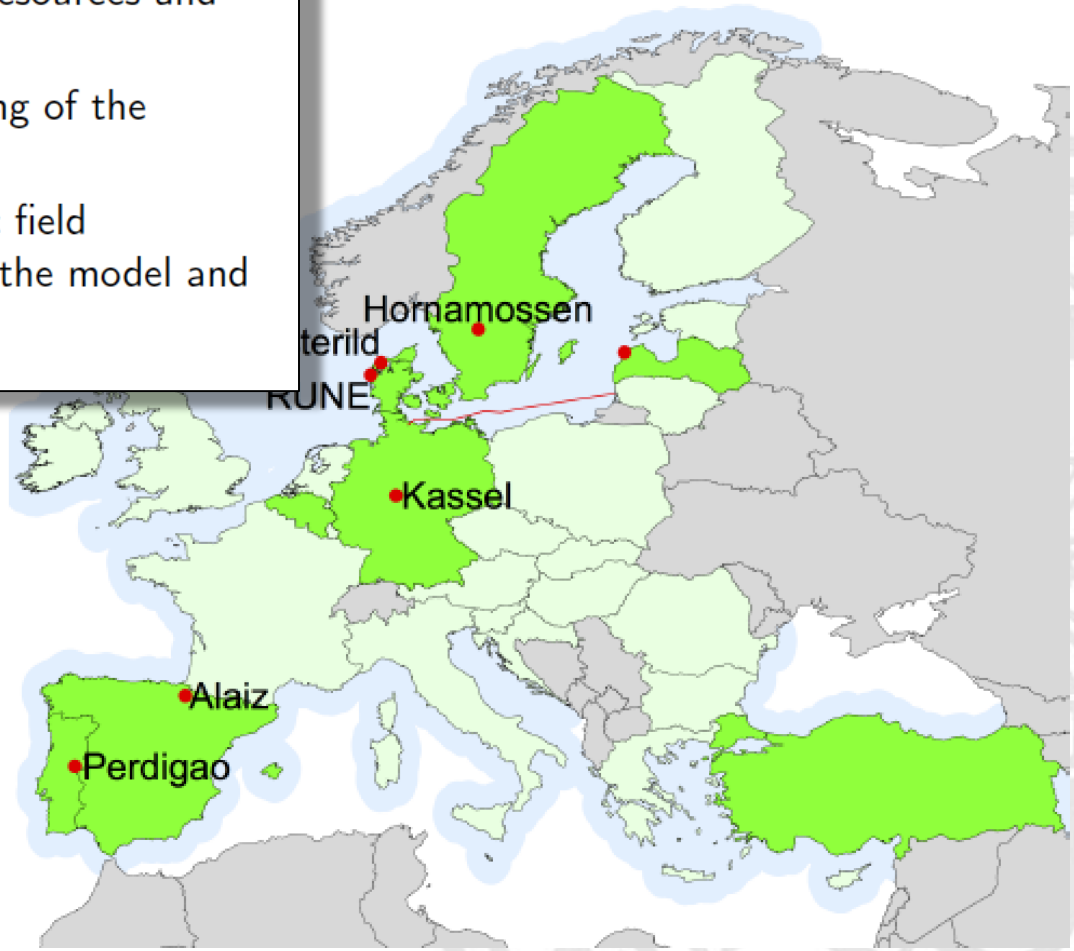
NEWA - New European Wind Atlas

- Accurate mapping of wind conditions for the estimations of resources and loads
- Development and testing of the model chain
- A series of atmospheric field experiment to validate the model and atlas.



- EU countries
- NEWA partners
- Offshore coverage
- Experimental sites

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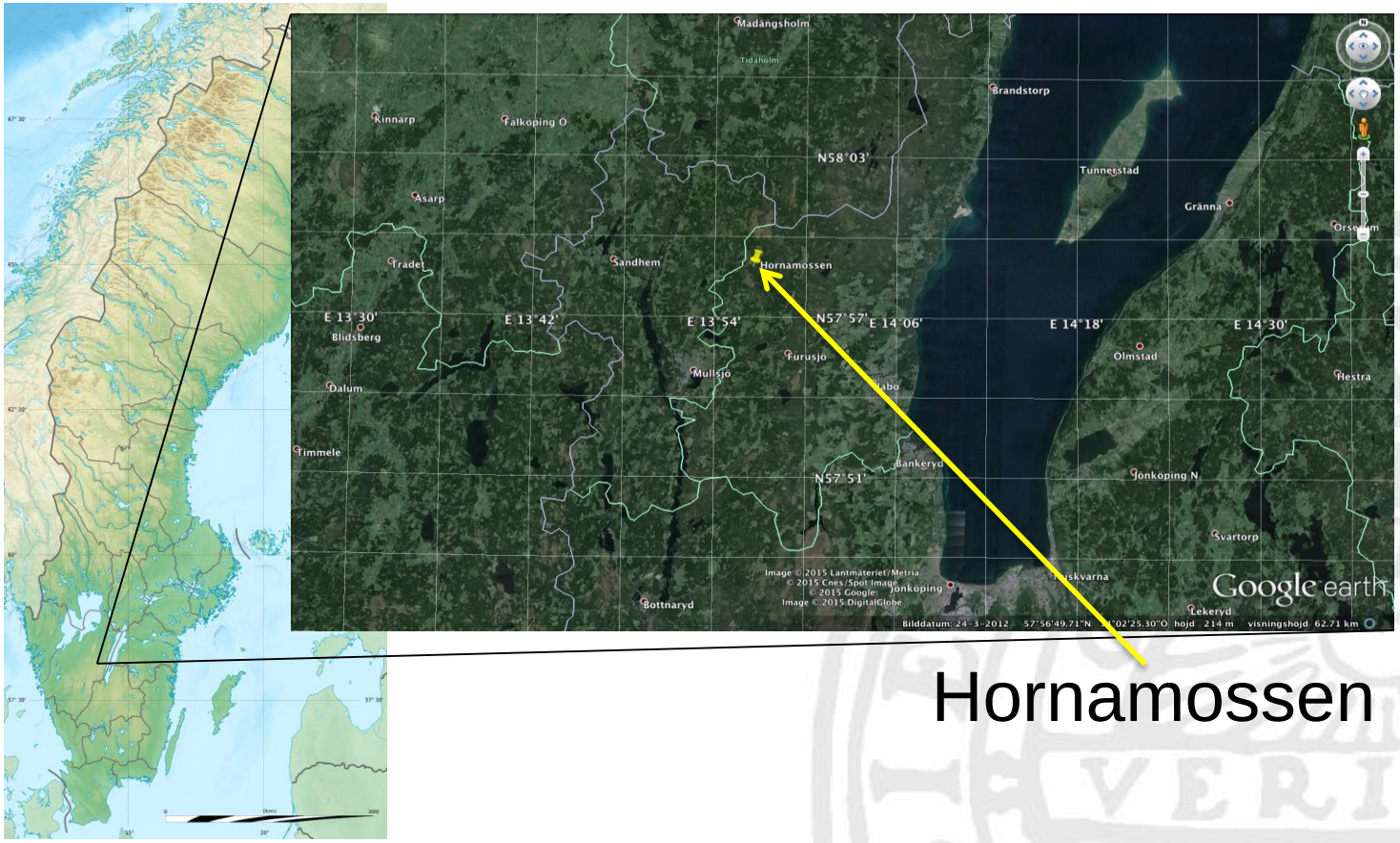
Den svenska siten - Hornamossen



Hornamossen

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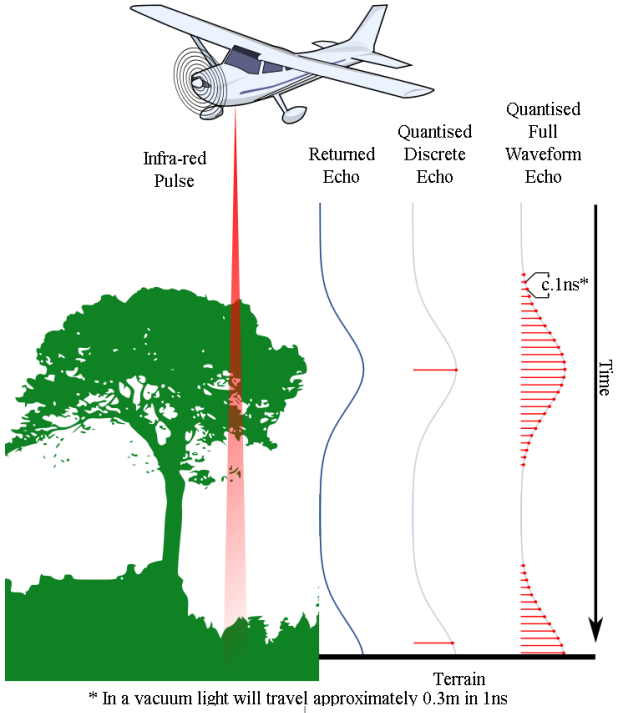
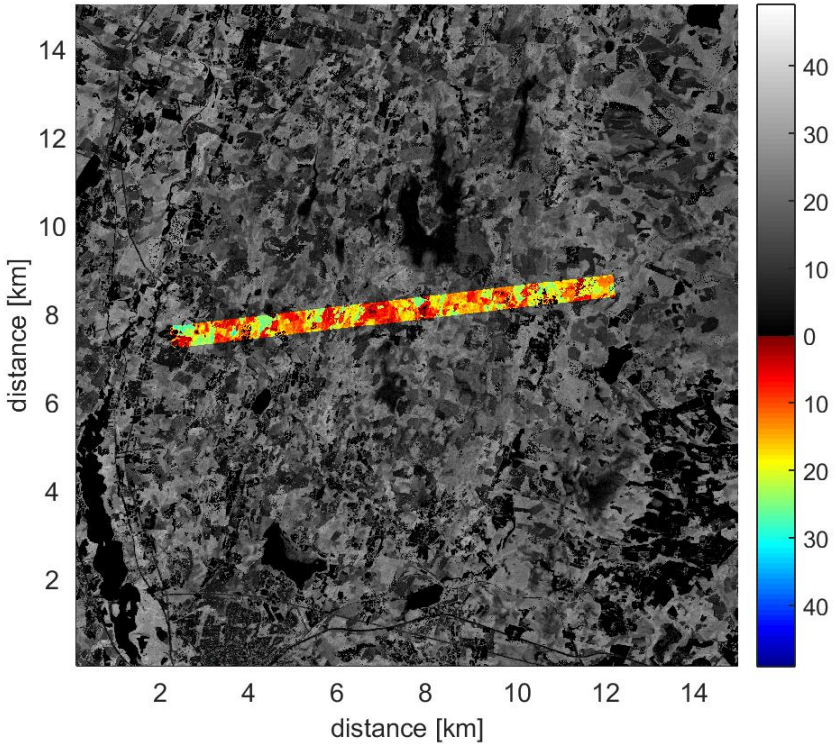
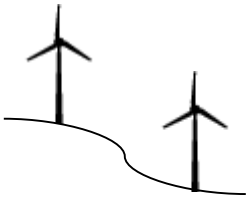
Mätningar av alla randvillkor + valideringspunkter för modellstudier

- Markhöjd, skogshöjd och skogsdensitet från laserscanningar







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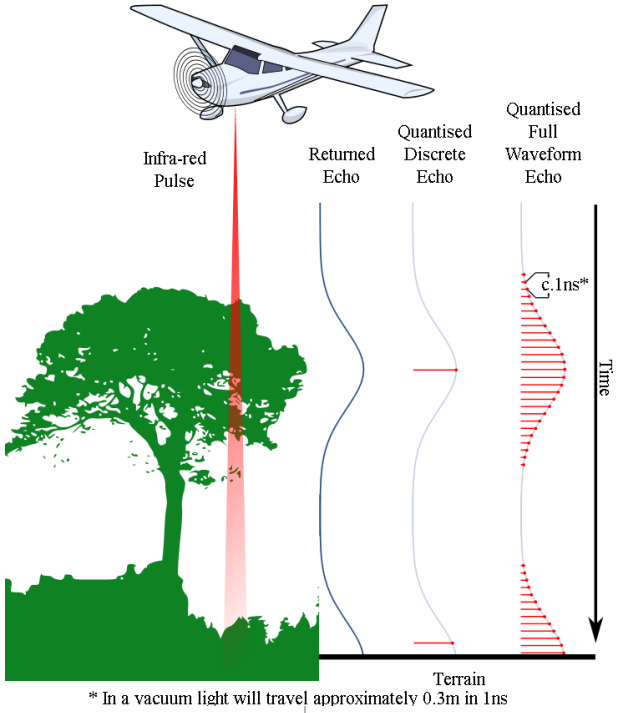

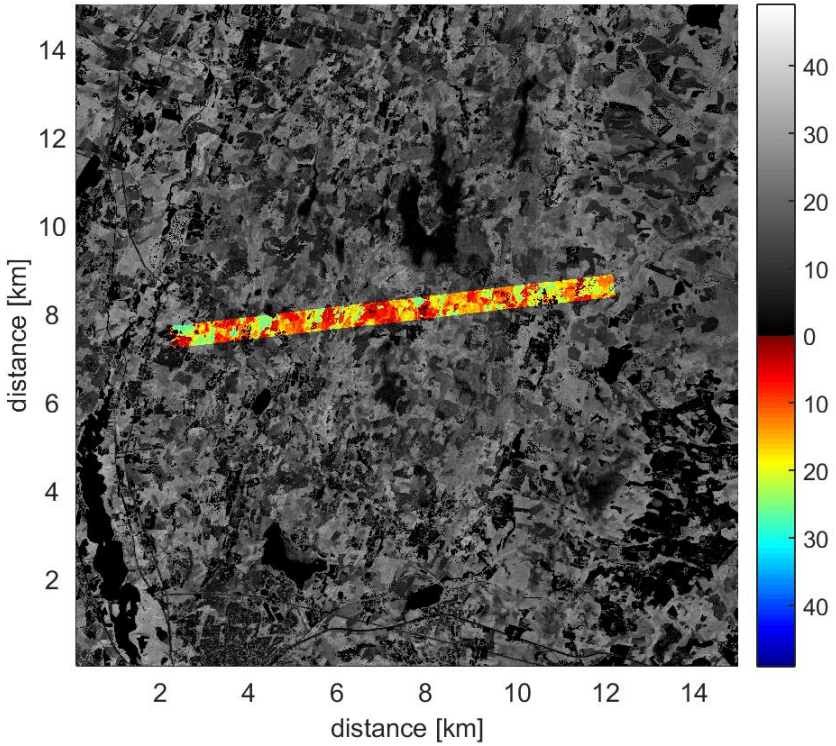

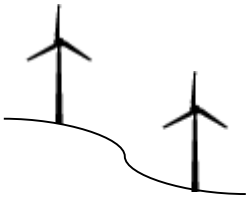

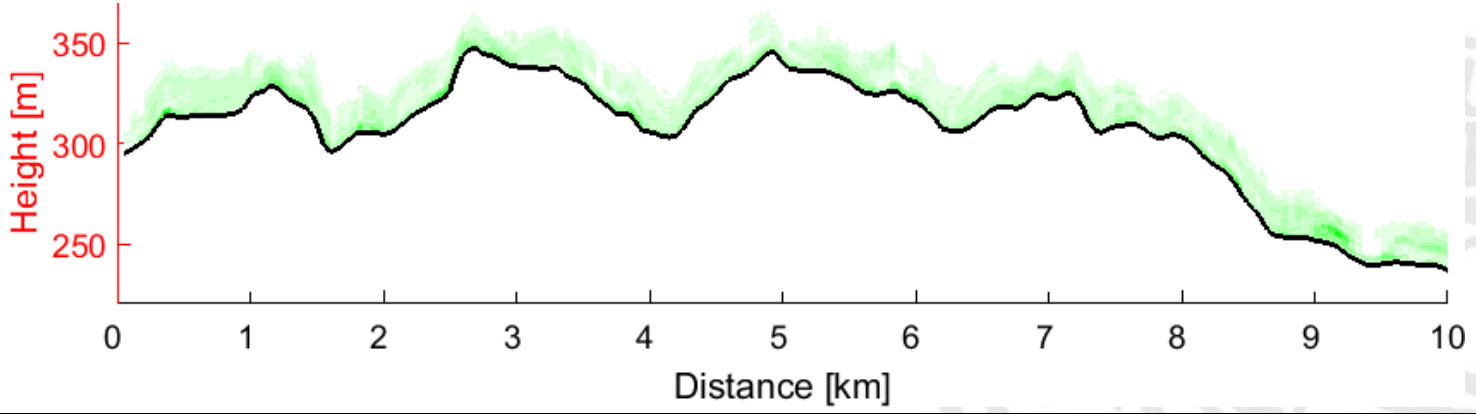

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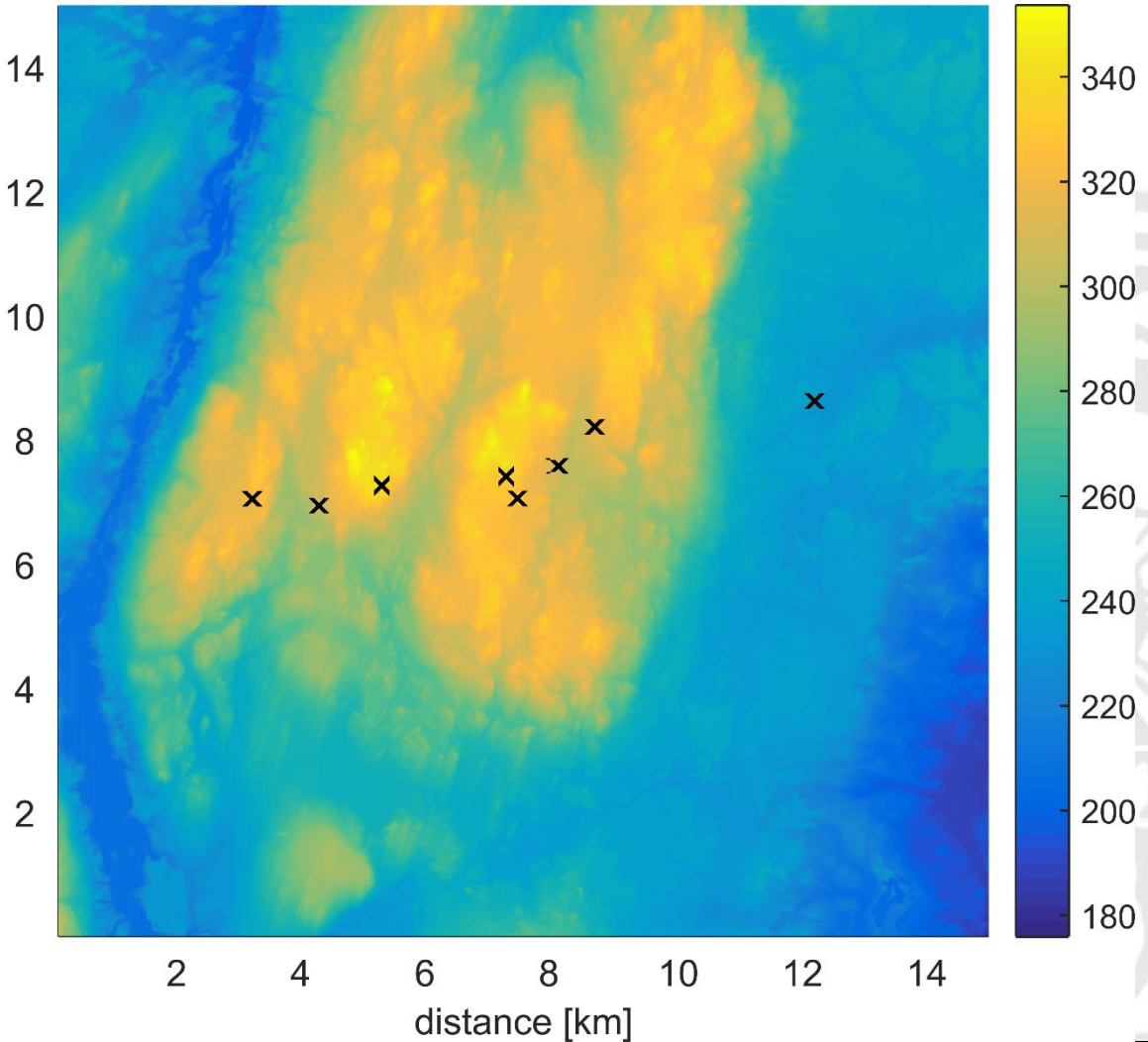
Mätningar av alla randvillkor + valideringspunkter för modellstudier

- Markhöjd, skogshöjd och skogsdensitet från laserscanningar
- Flöden (turbulens, värme, strålning) från mätmasten
- Vindprofiler (sodar)



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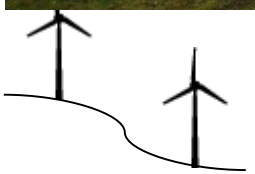
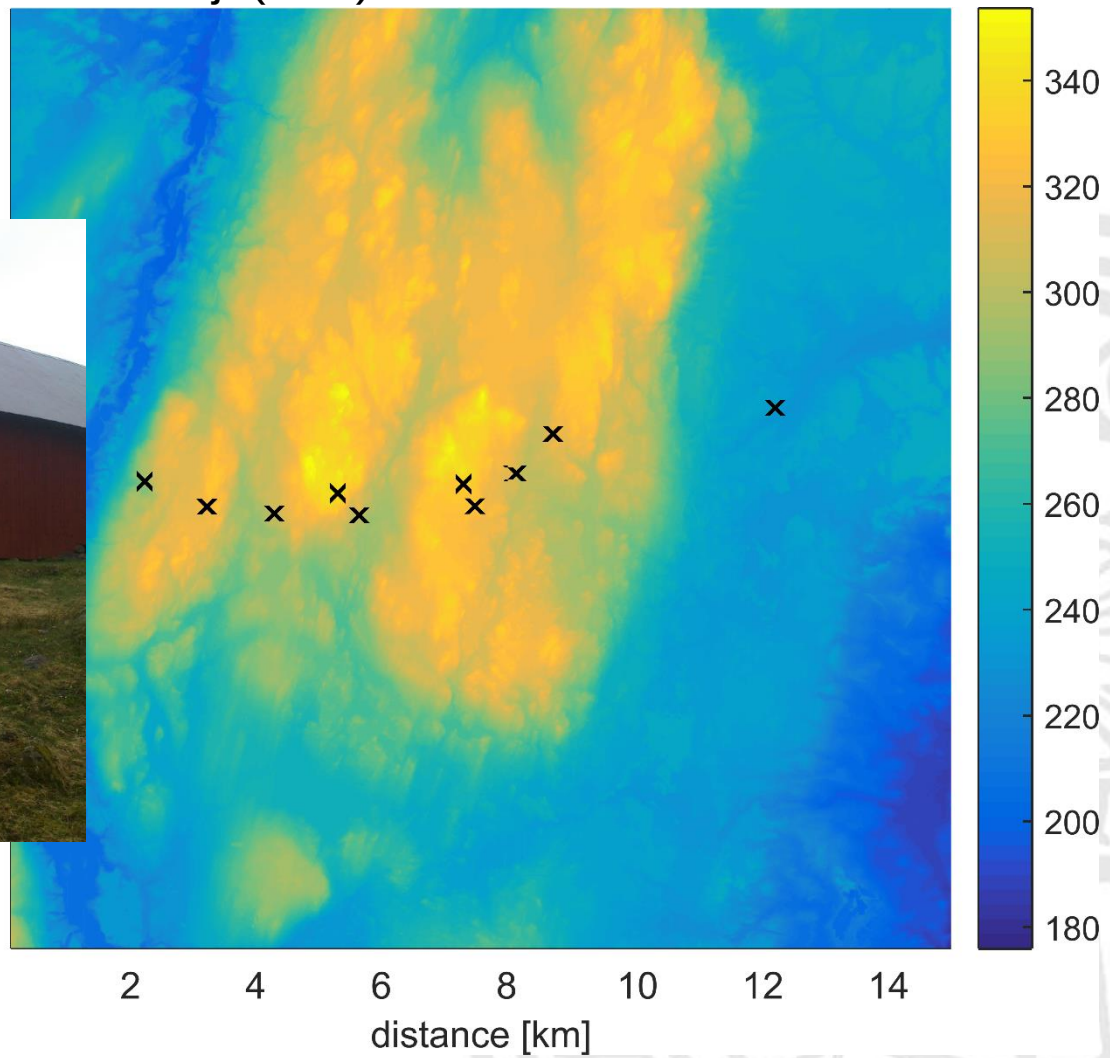
- Markhöjd, skogshöjd och skogsdensitet från laserscanningar
- Flöden (turbulens, värme, strålning) från mätmasten
- Vindprofiler (sodar)
- Vindprofiler och gränsskiktsöjd(lidar)





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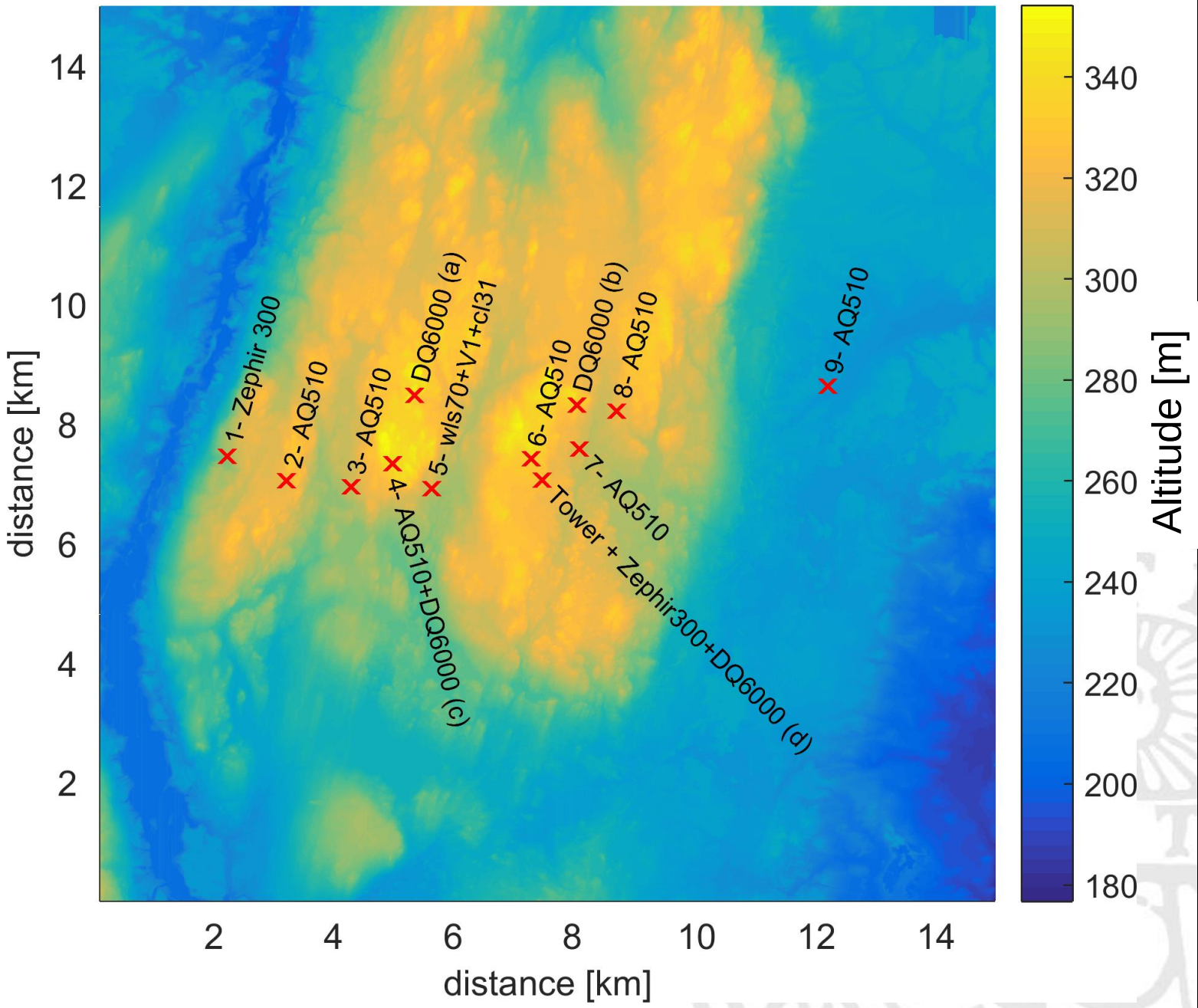

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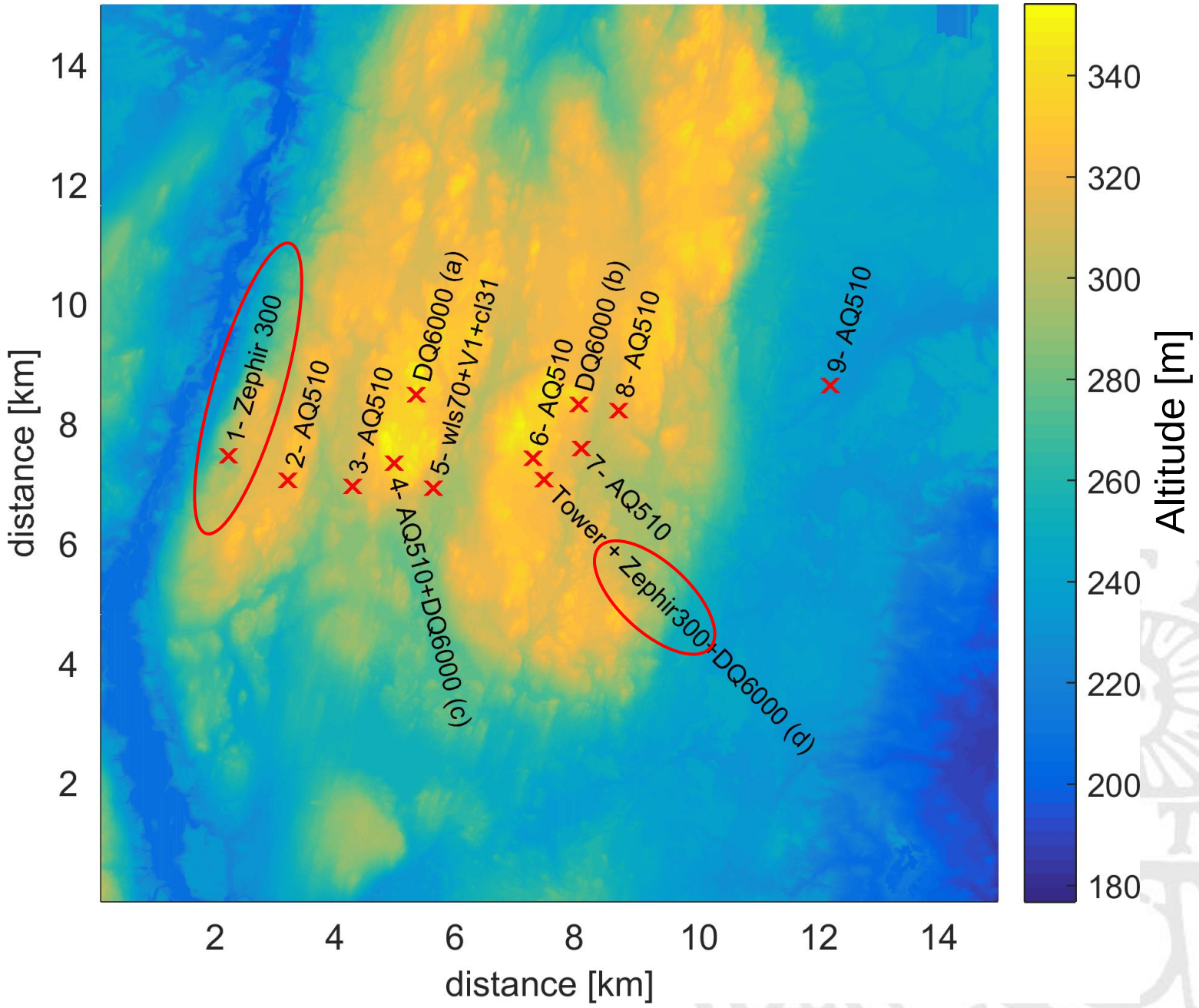

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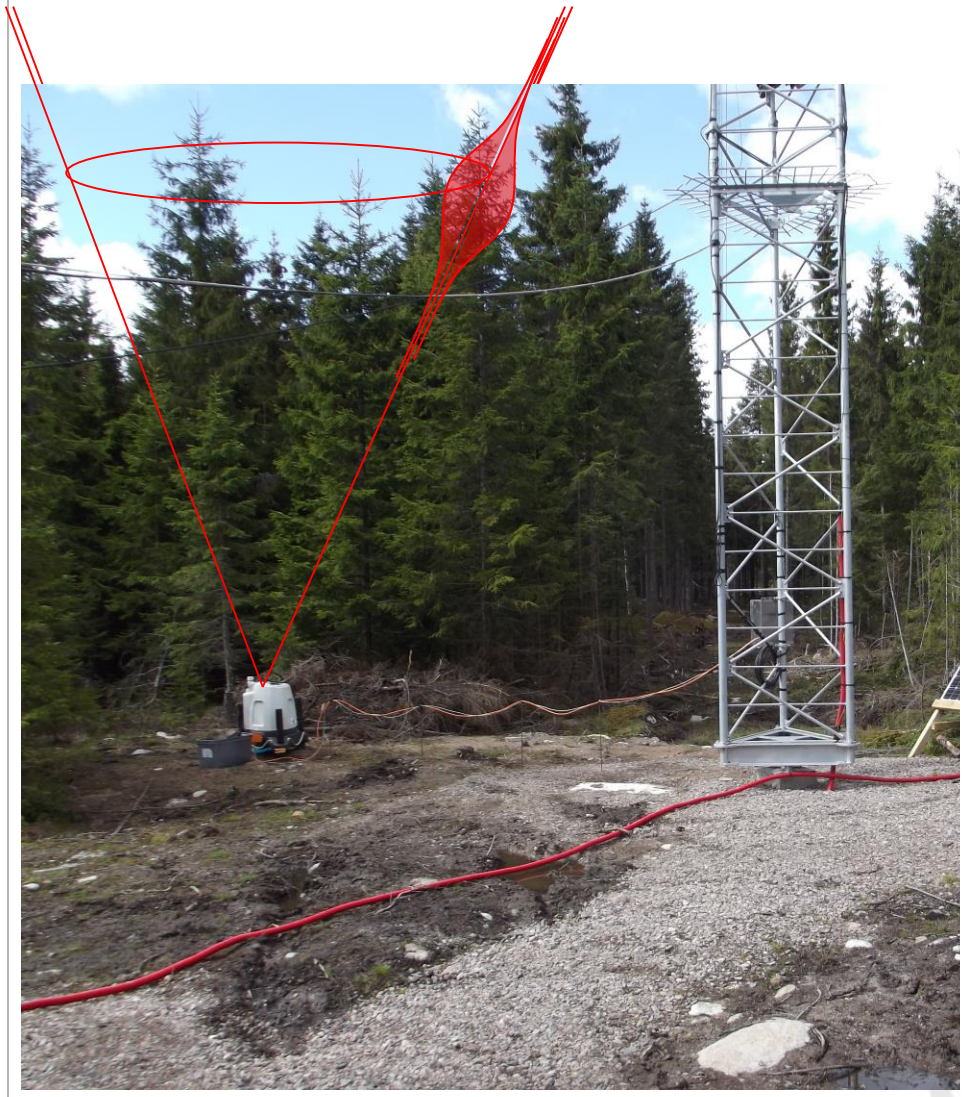
Zephir 300 lidar



2 locations,
Mean and **raw** data collected for 4 resp 7 months.

Over all:
Worked well

Main problem:

- Signal to noise ratio
- measurement volume (upper heights)
- Wind direction

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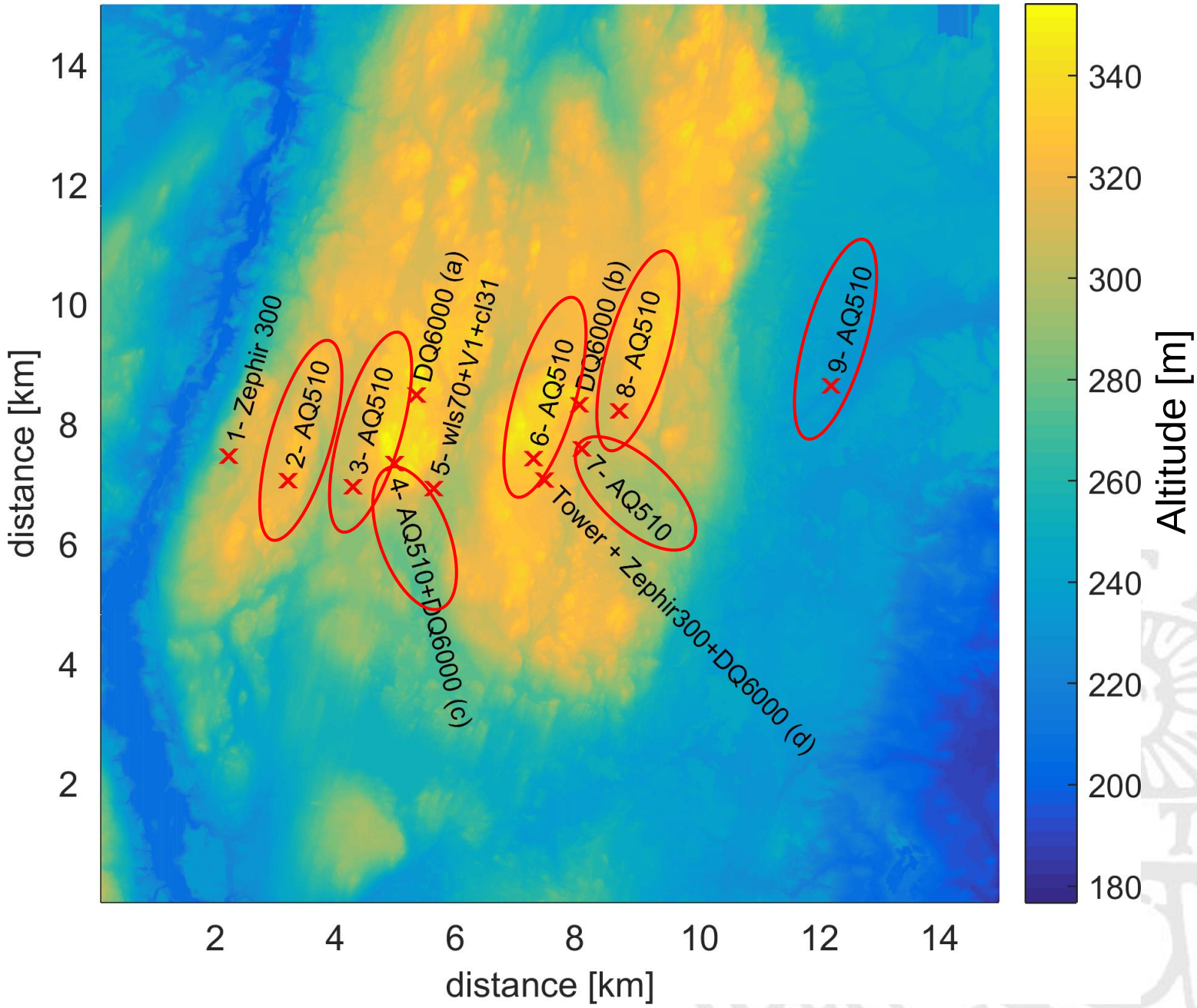

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AQ510 Sodar

7 locations,
Mean and **raw** data collected for 6 resp 8 months.

Over all:
Worked well

Main problem:
- Very stable conditions

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Example of unstable atmospheric conditions

Sodar, from wavelet transform
Sonic projected in SODAR direction

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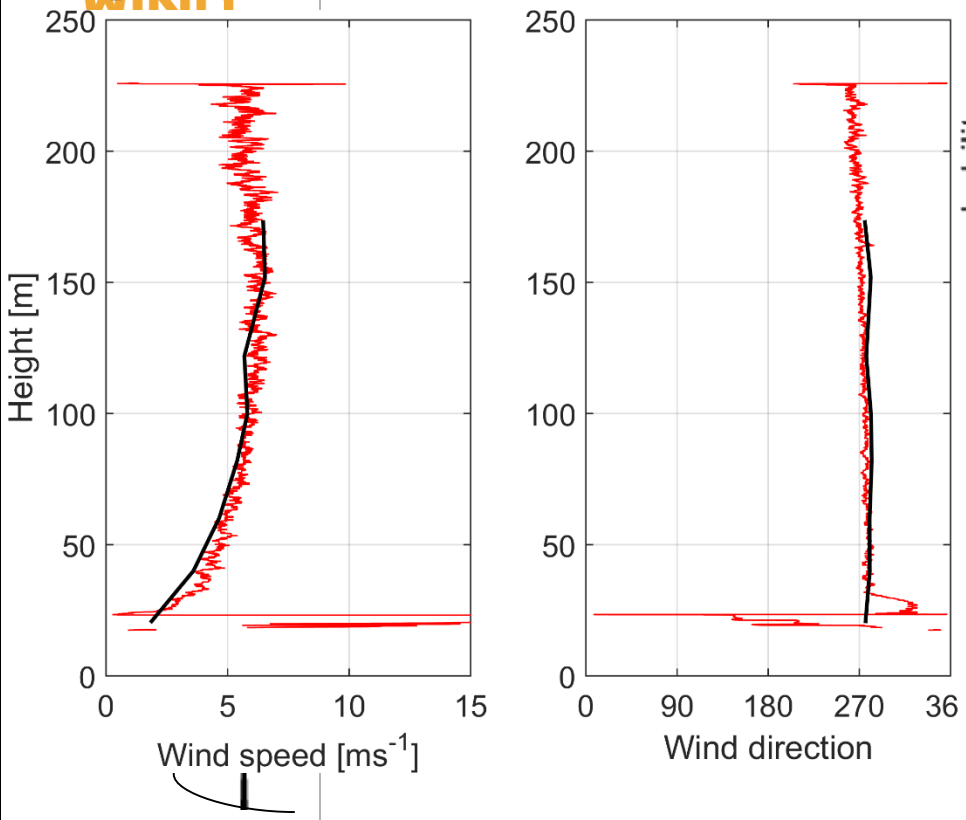
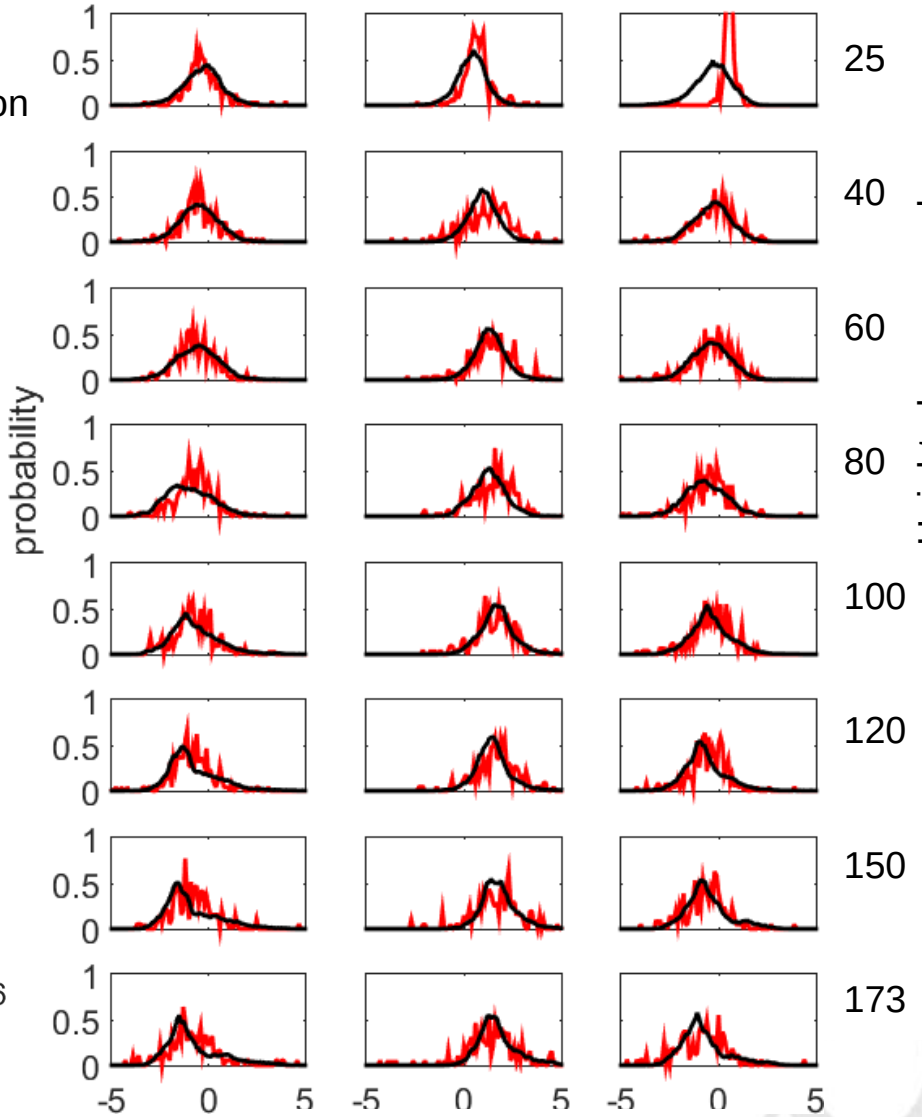
2016-07-18-14:00





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Example of very stable atmospheric conditions

Sodar, from wavelet transform
Sonic projected in SODAR direction

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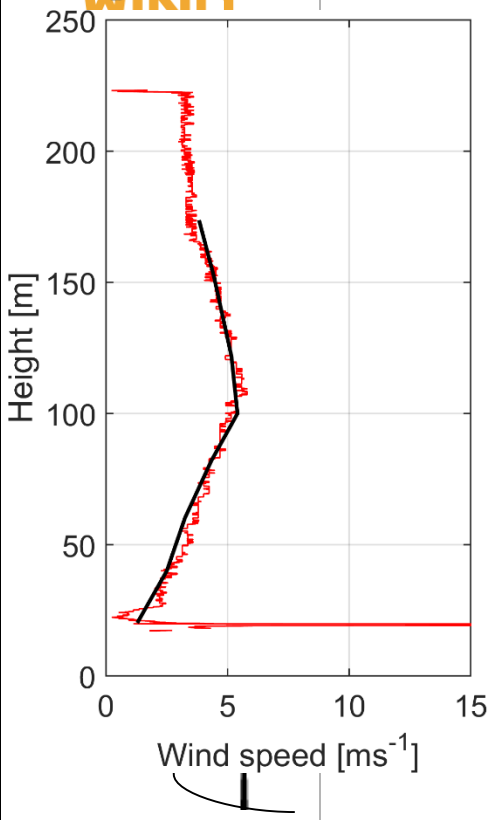
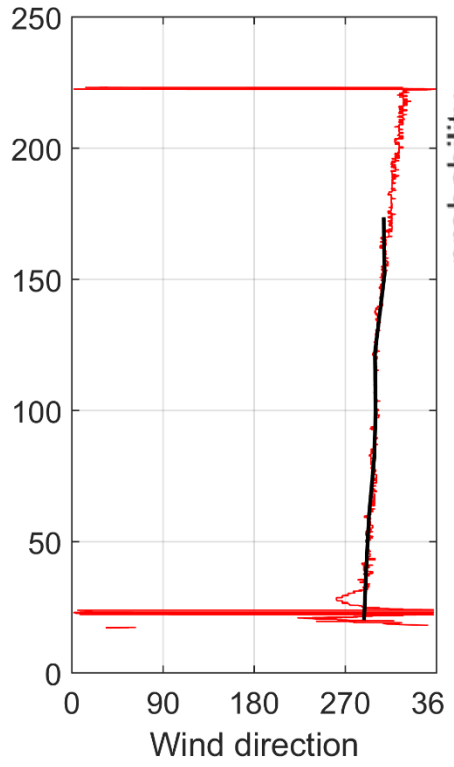
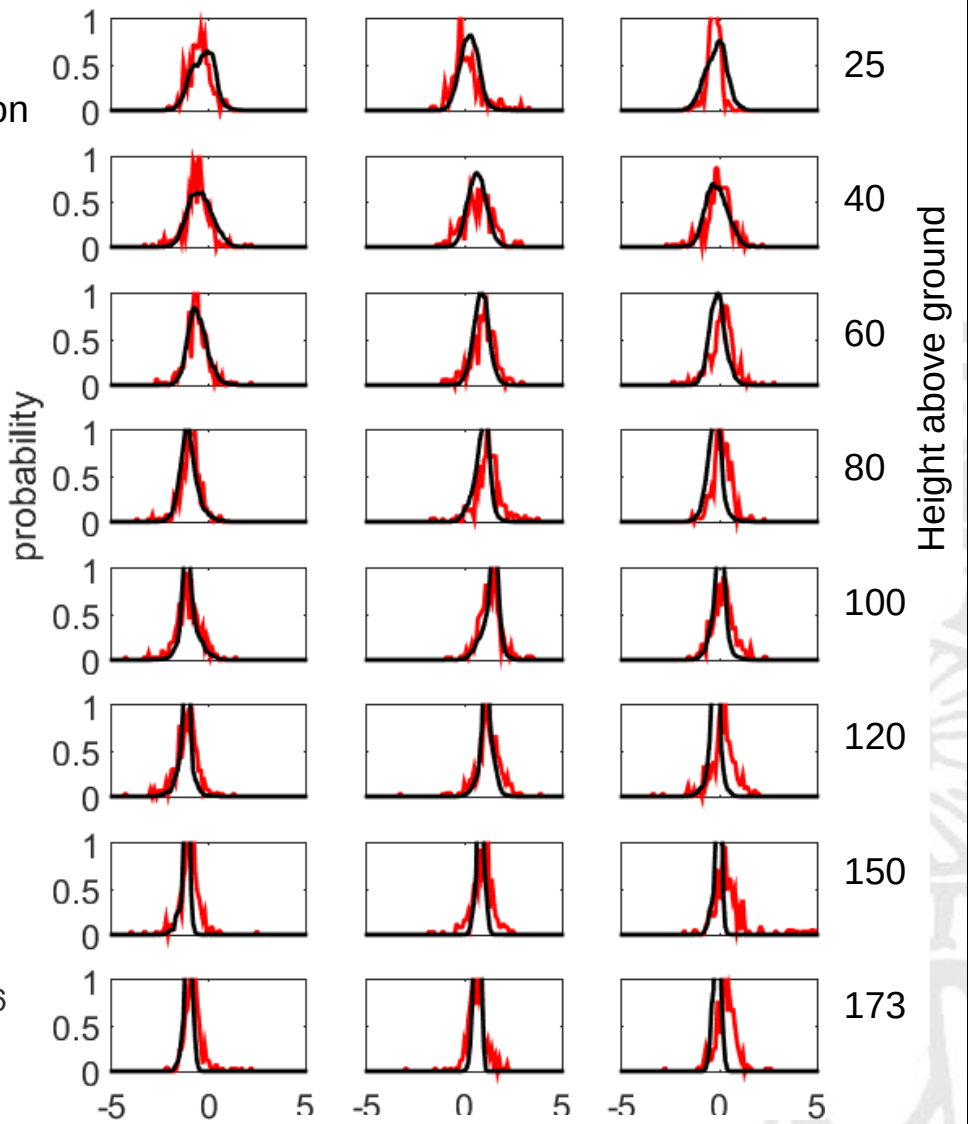
2016-07-19-05:00







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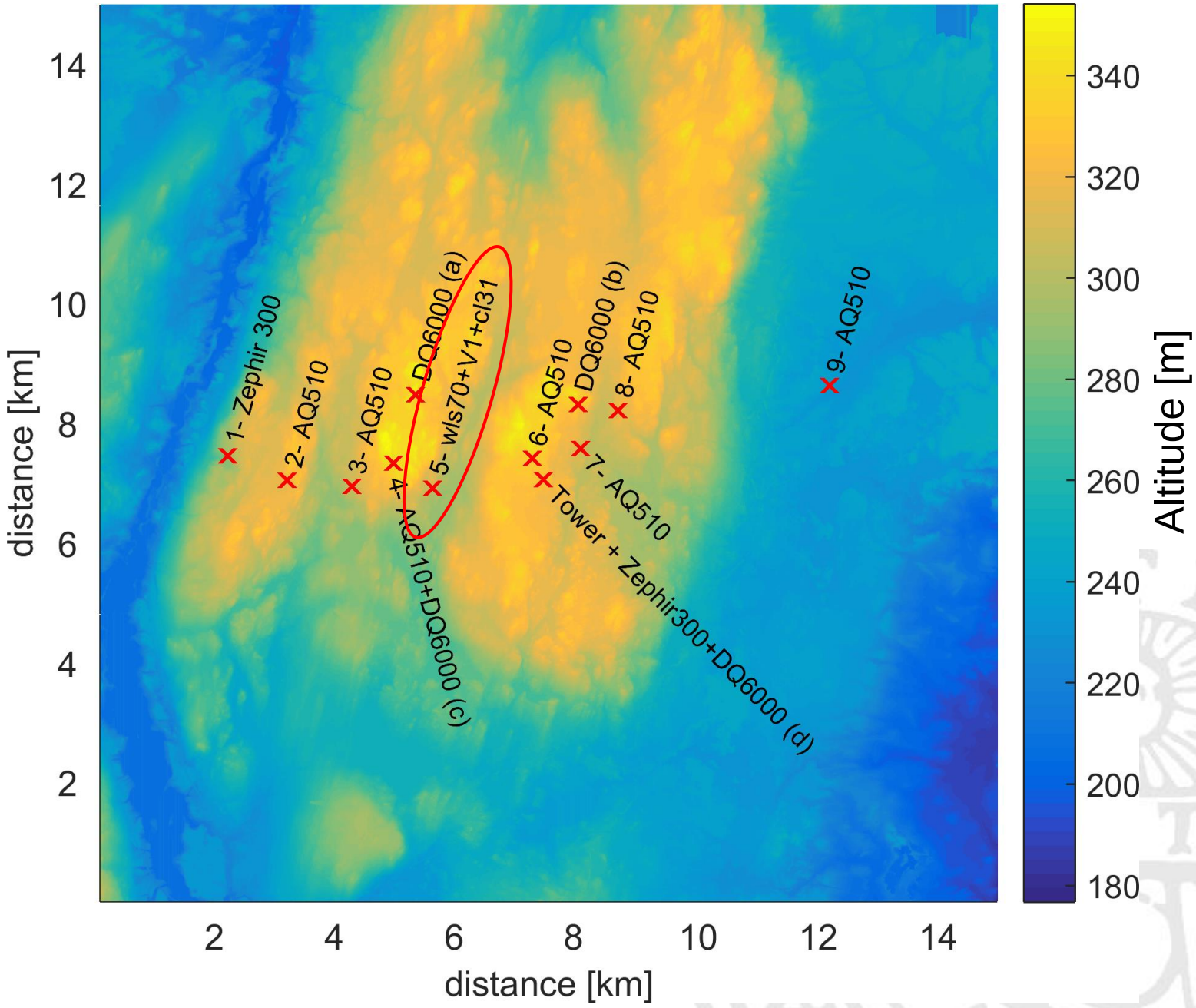

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WLS 70, V1, cailometer

1 location, **WLS70, V1** and **Vaisala ceilometer**. Mean and 1 Hz data

Over all:
Has not worked well (ceilometer not yet investigated)

Main problem:

- Overheating
- Signal to noise
- Wind shield wiper not working or wiping the whole timpe

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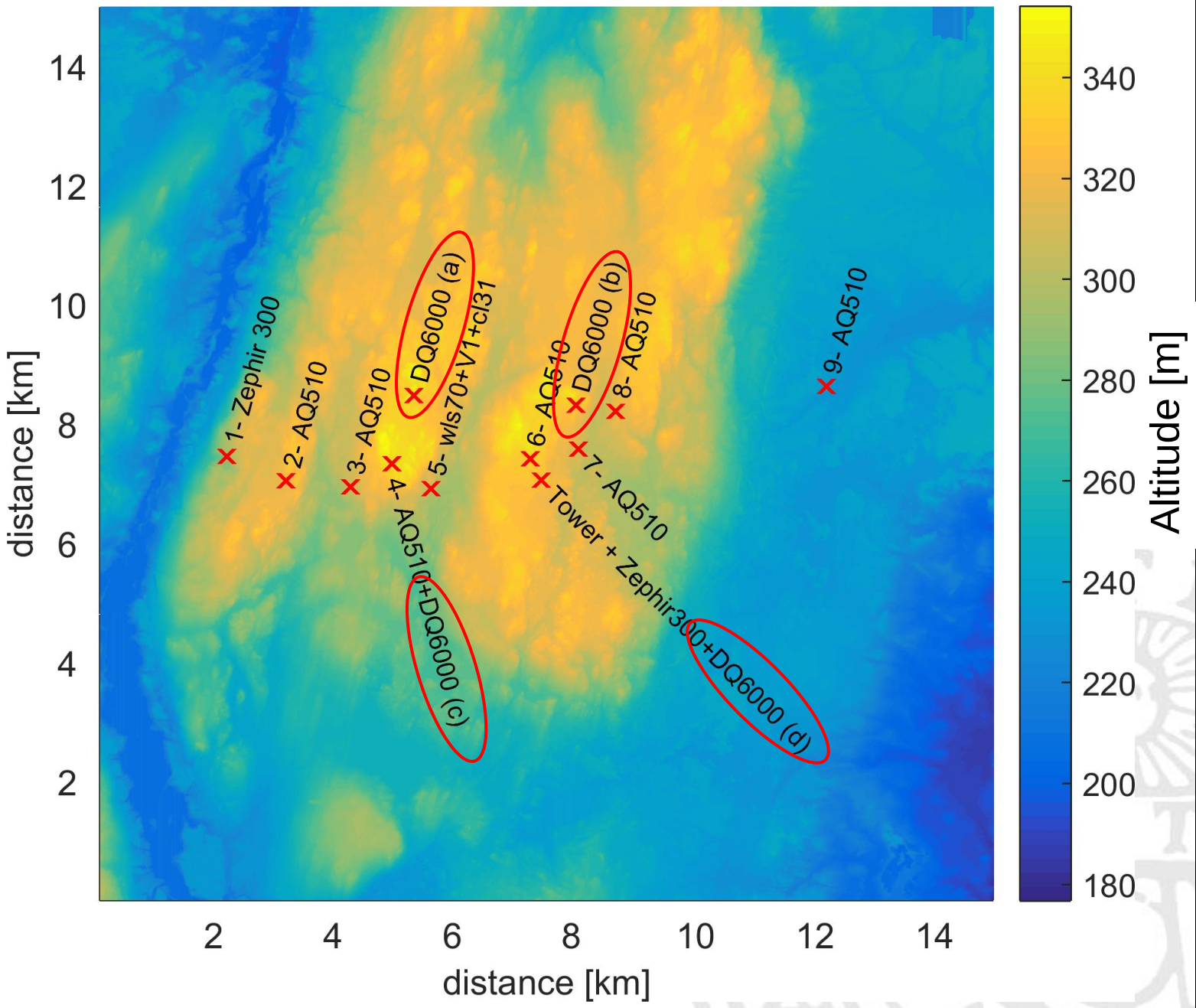

Digiquartz micro barometers

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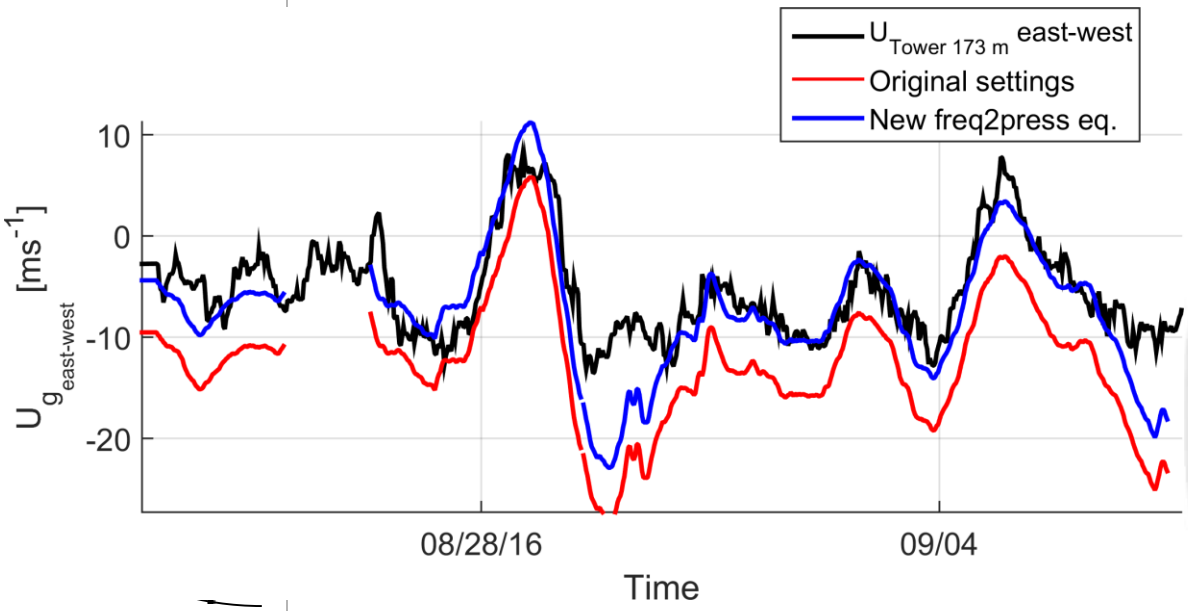
Model 6000-16B - RS-232 and RS-485 Output Pressure Transmitters

- 0.0001% Resolution
- ±0.08 hPa Accuracy
- High Reliability and Stability better than 0.1 hPa per year
- Bi-directional RS-232 and RS-485 Serial Interface.
- User Selectable Parameters through the RS-232 interface Includes Resolution, Update Rate, Engineering Units, Sampling Commands etc. with Supplied Software
- NIST Traceable - ISO 9001:2000 Quality System
- Directly Compatible with Model 715 Display
- Free zero adjustment
- Optional High Performance Pressure Port Available (DigiPort)
- Click here for a data sheet



4 locations, one value.

Over all: Difficult, but promising

Main problem:

- Temperature dependence
- Calibration
- Set too close apart

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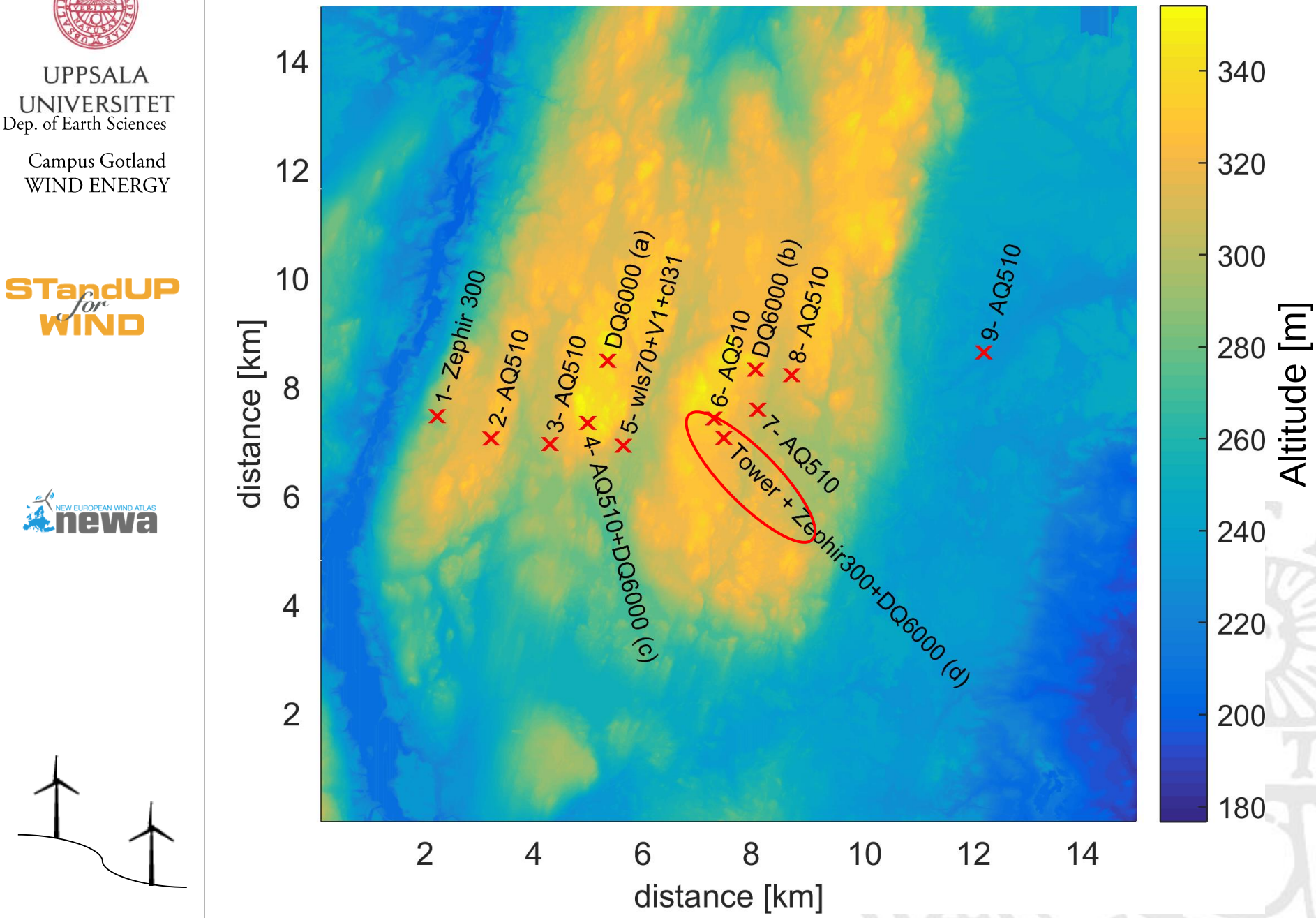

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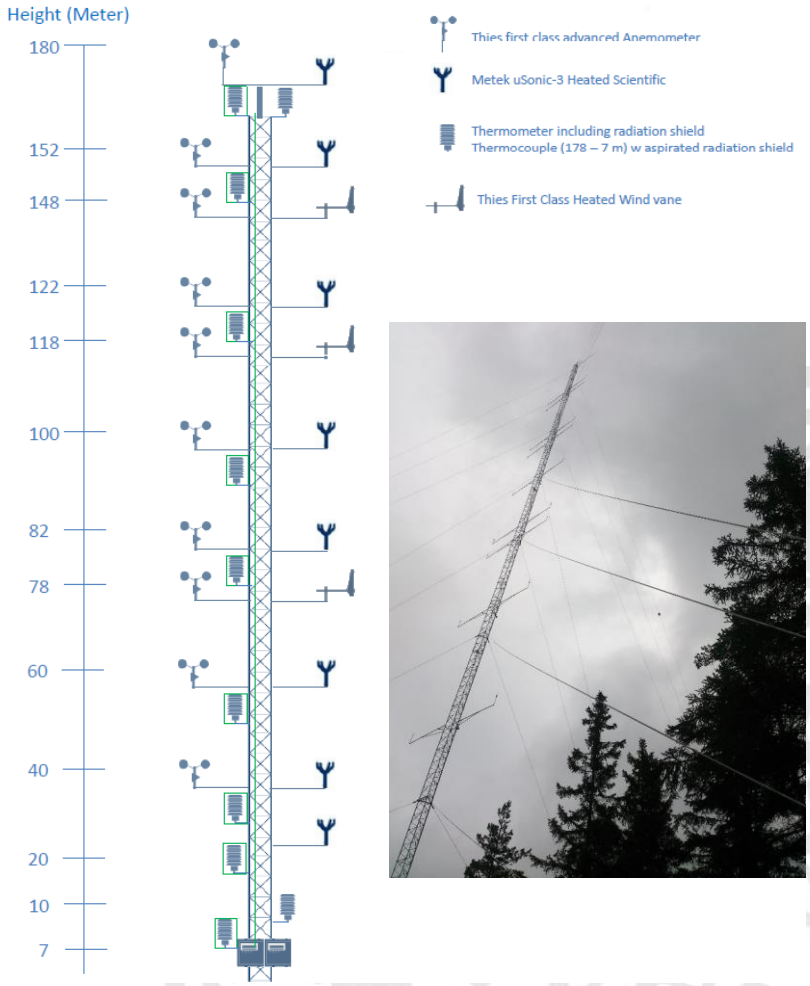
Tower

- Sonics
- Thies cups
- Vaisala cups
- Wind vanes
- Temperature profile
- Kipp & Zonen 4-way radiation sensors



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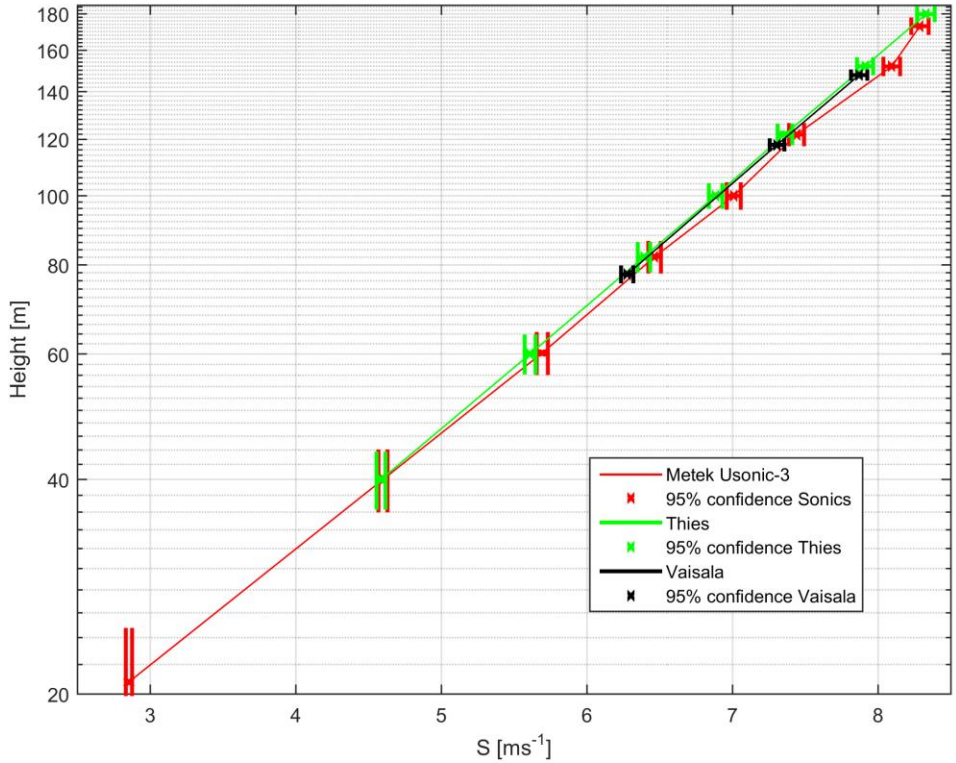
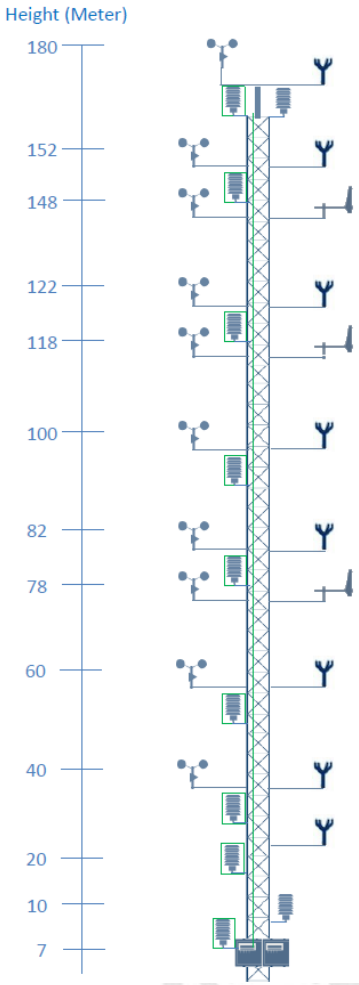
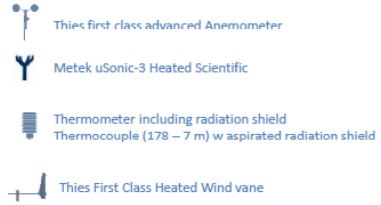
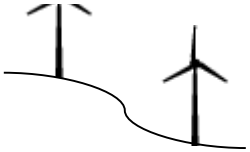
Comparision with the three anemometers (in good, strictly neutral conditions)









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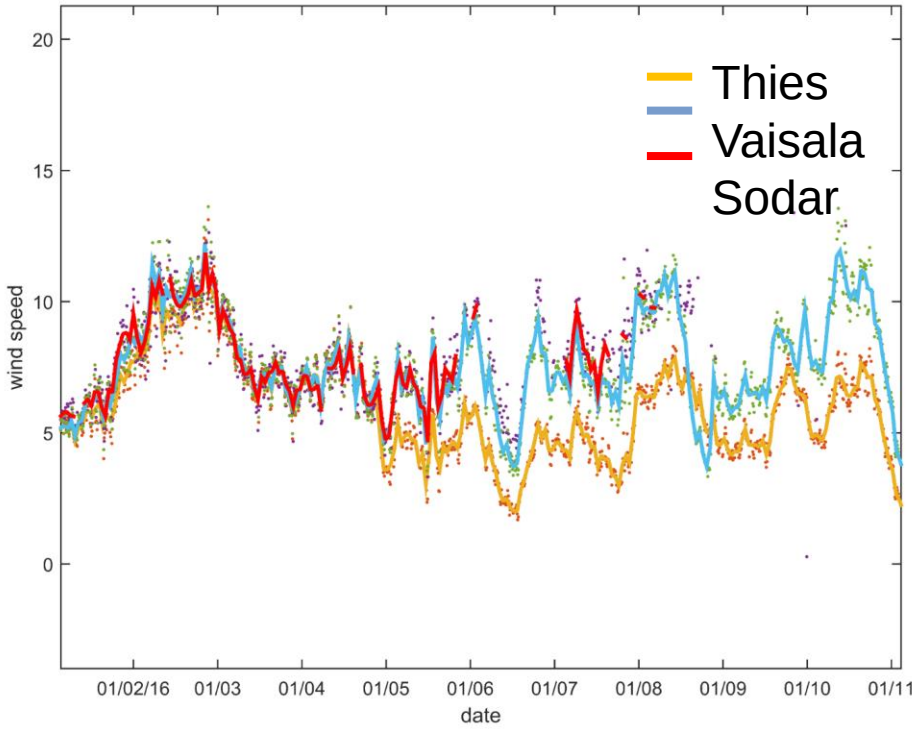
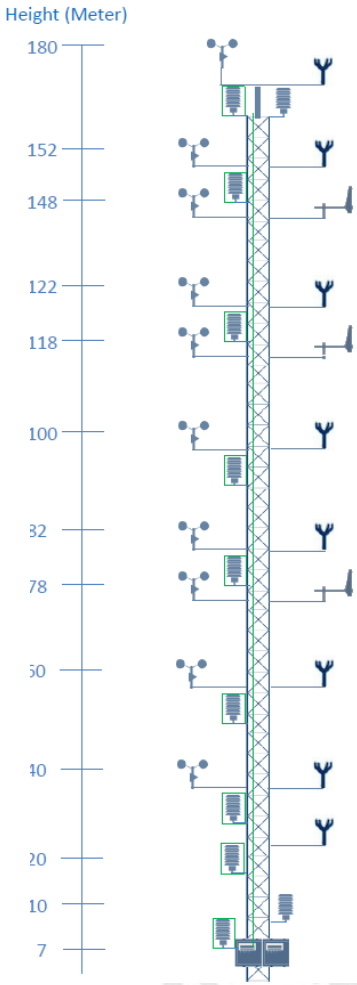
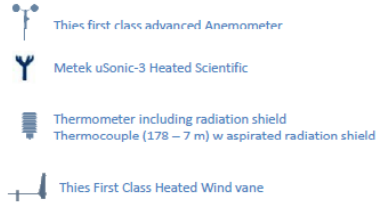
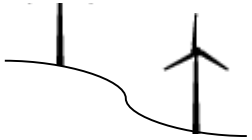
The Theis cups are unreliable in icing conditions









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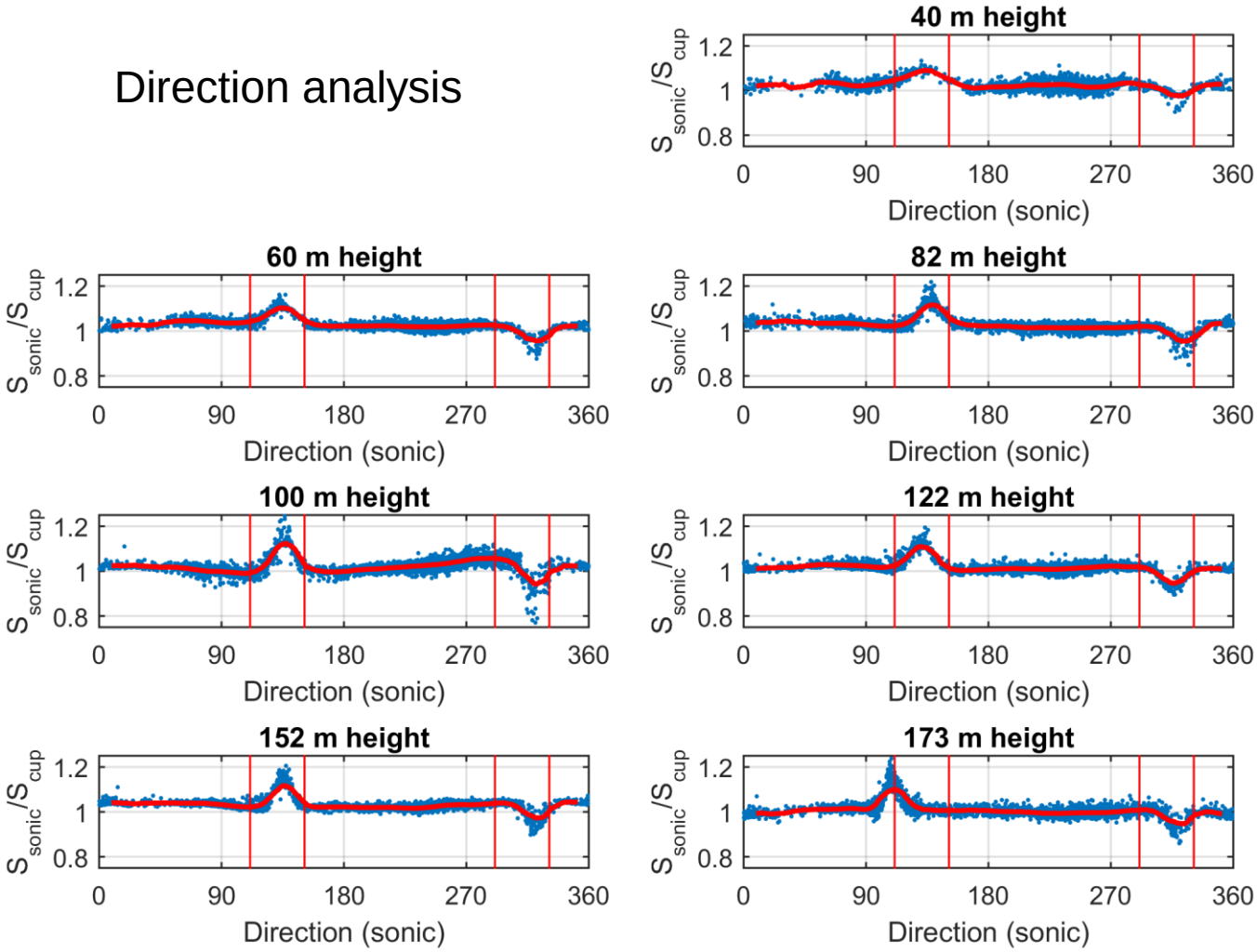
I VILKA RIKTNINGAR KAN VI FÖRVÄNTA OSS MASTSTÖRNINGAR?

Direction analysis



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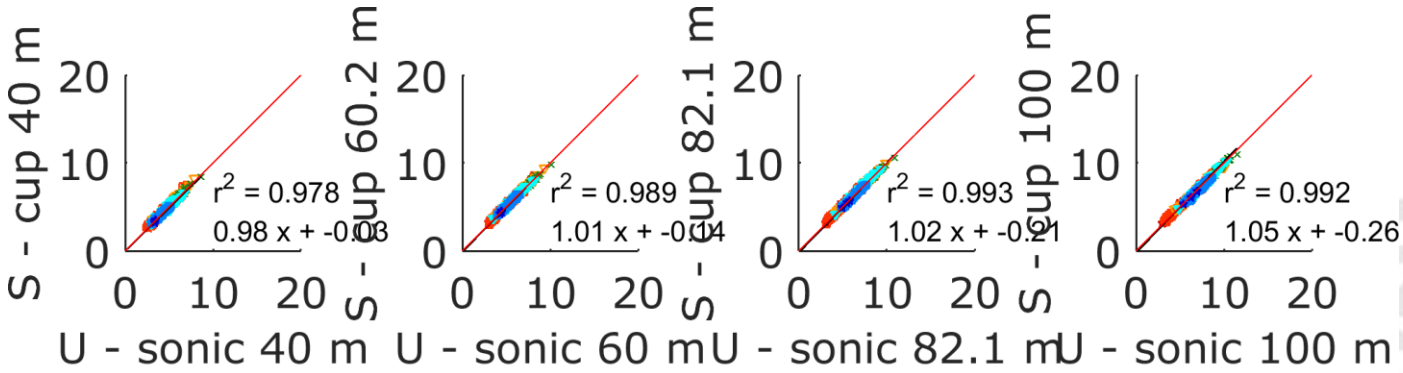
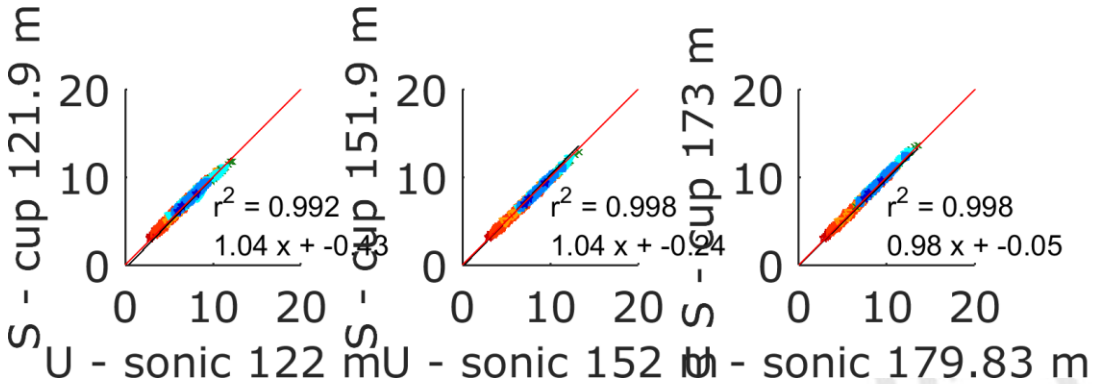
Remote sensing instruments

Cross validation of tower instruments





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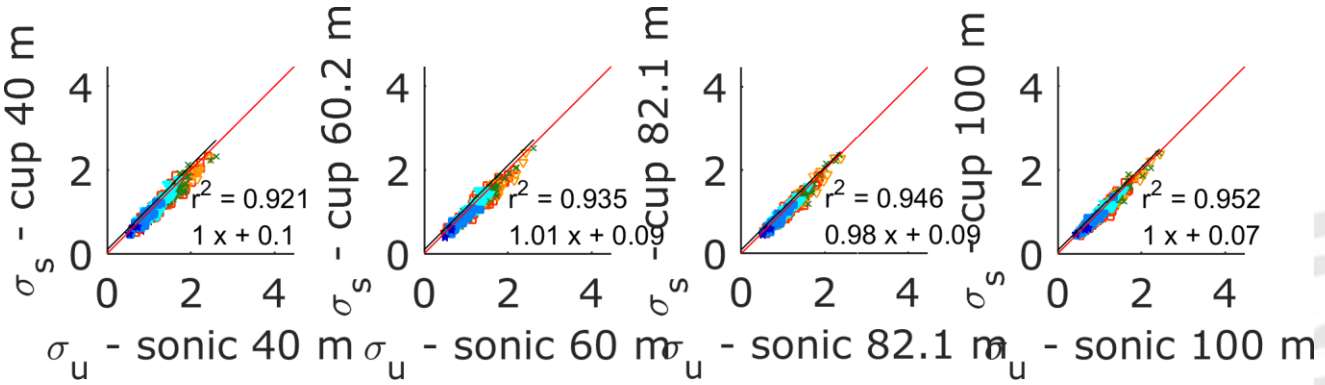

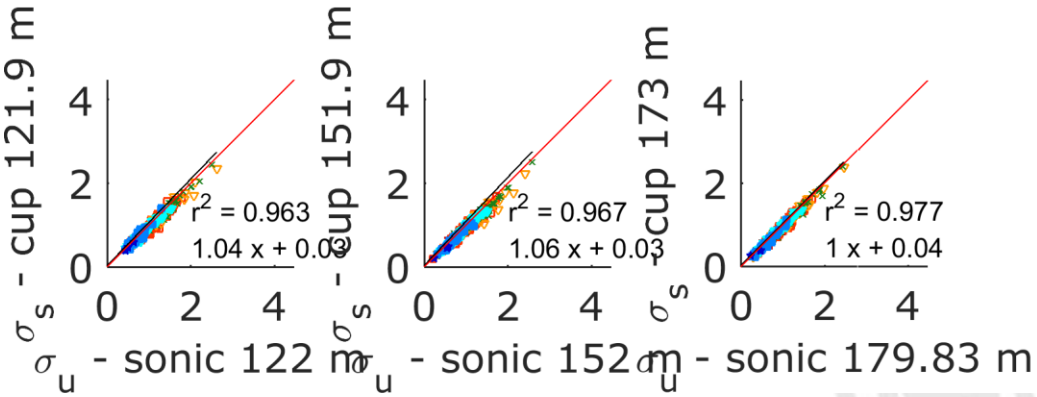

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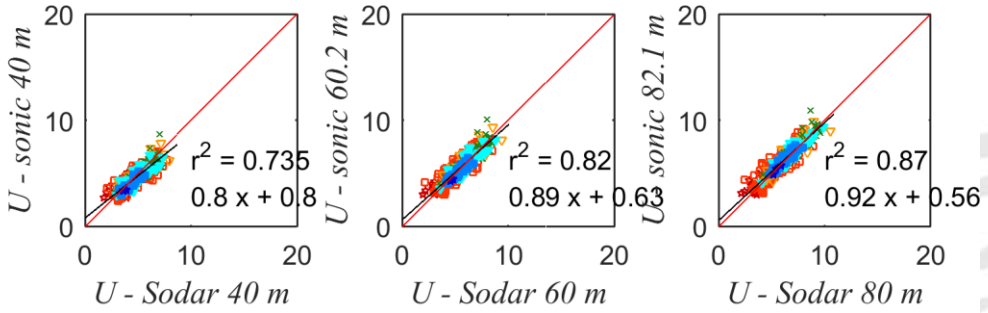
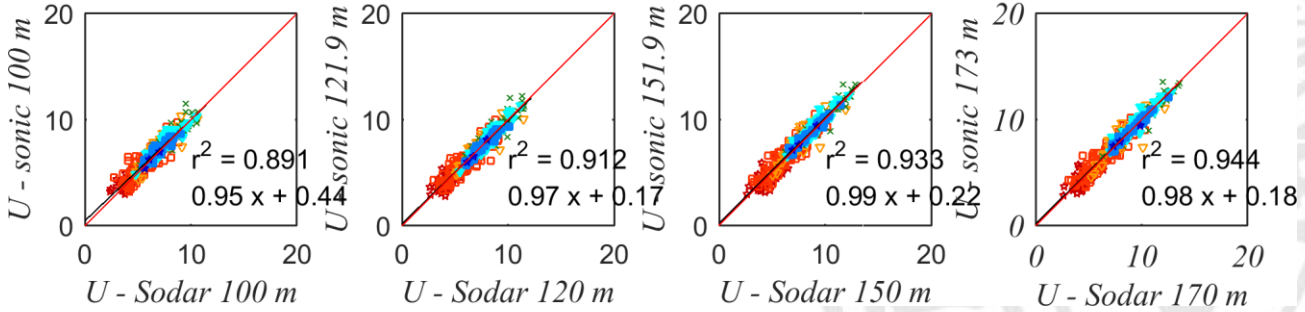
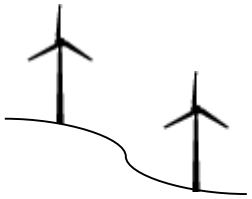
Remote sensing instruments

SODAR







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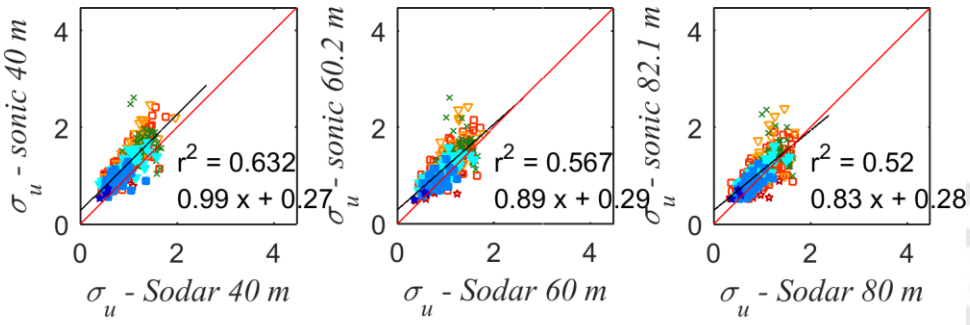
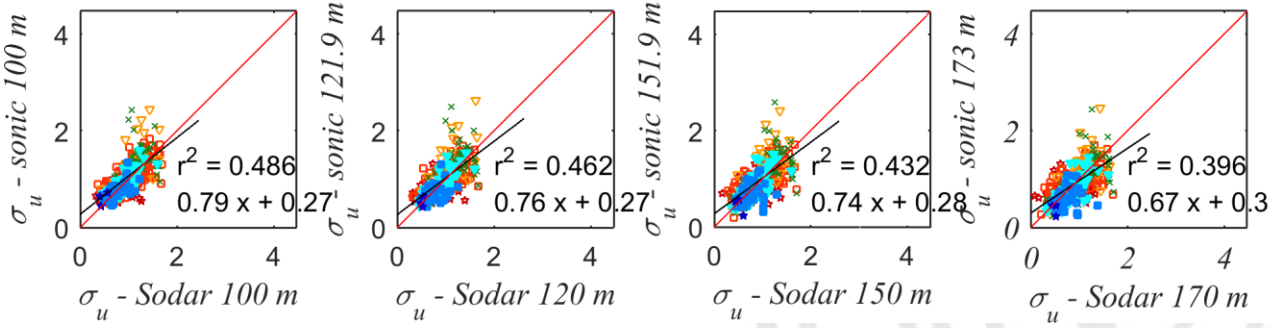
Remote sensing instruments

SODAR





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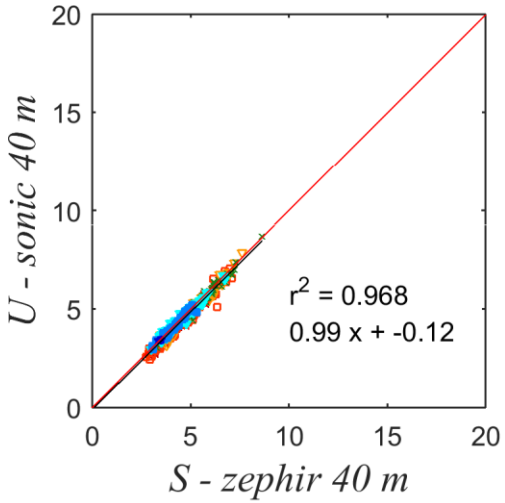

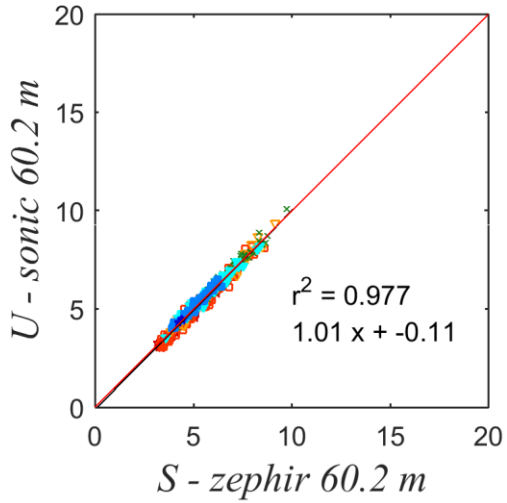

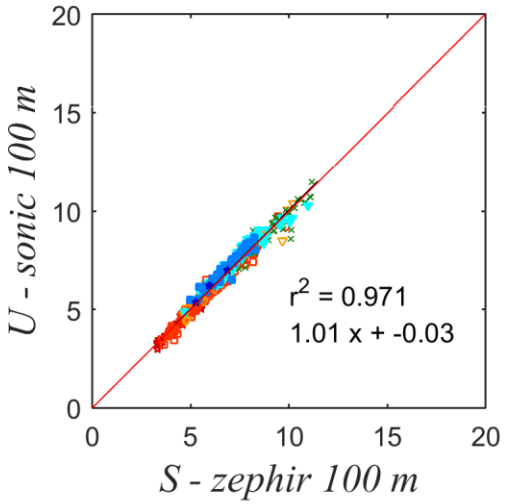

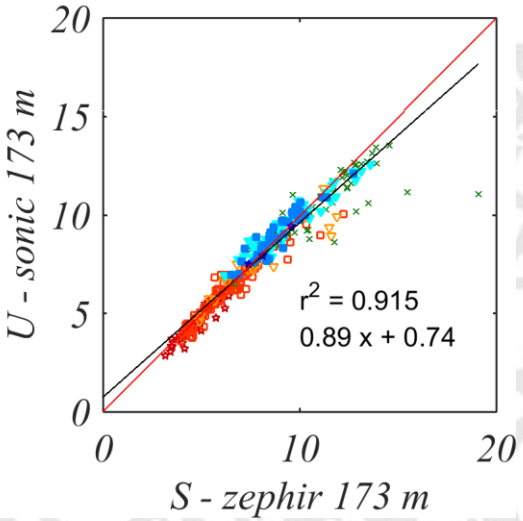

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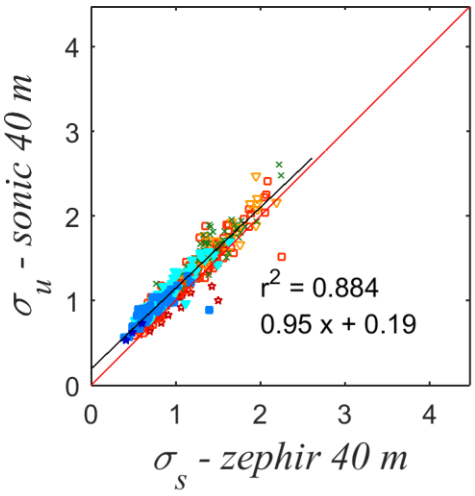

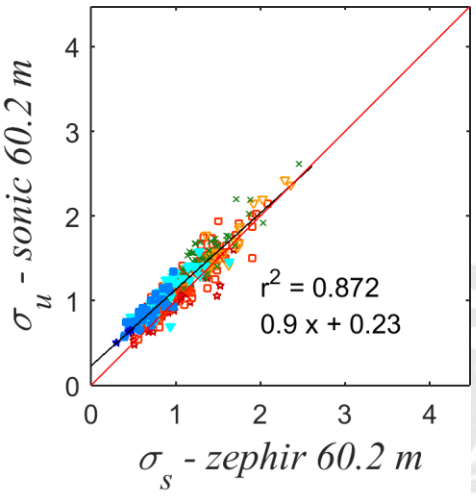

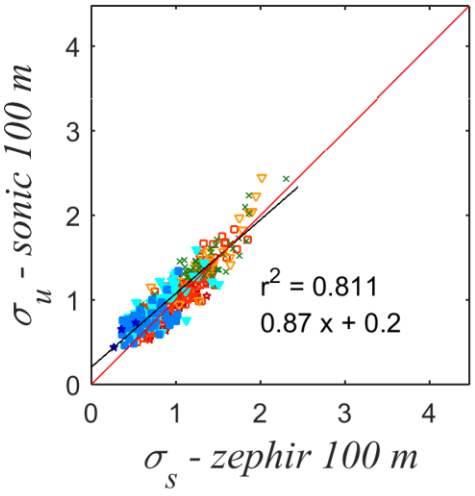

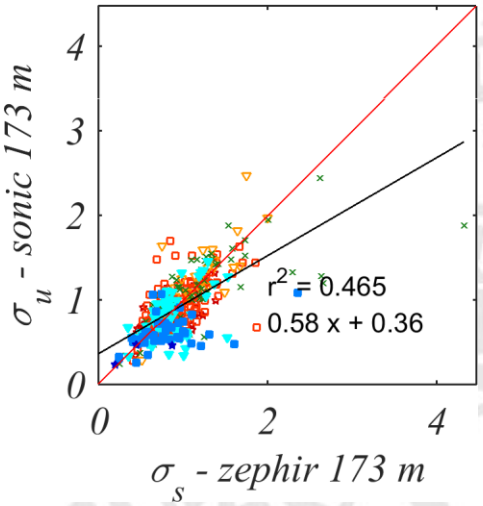

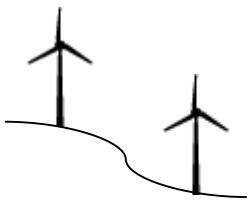

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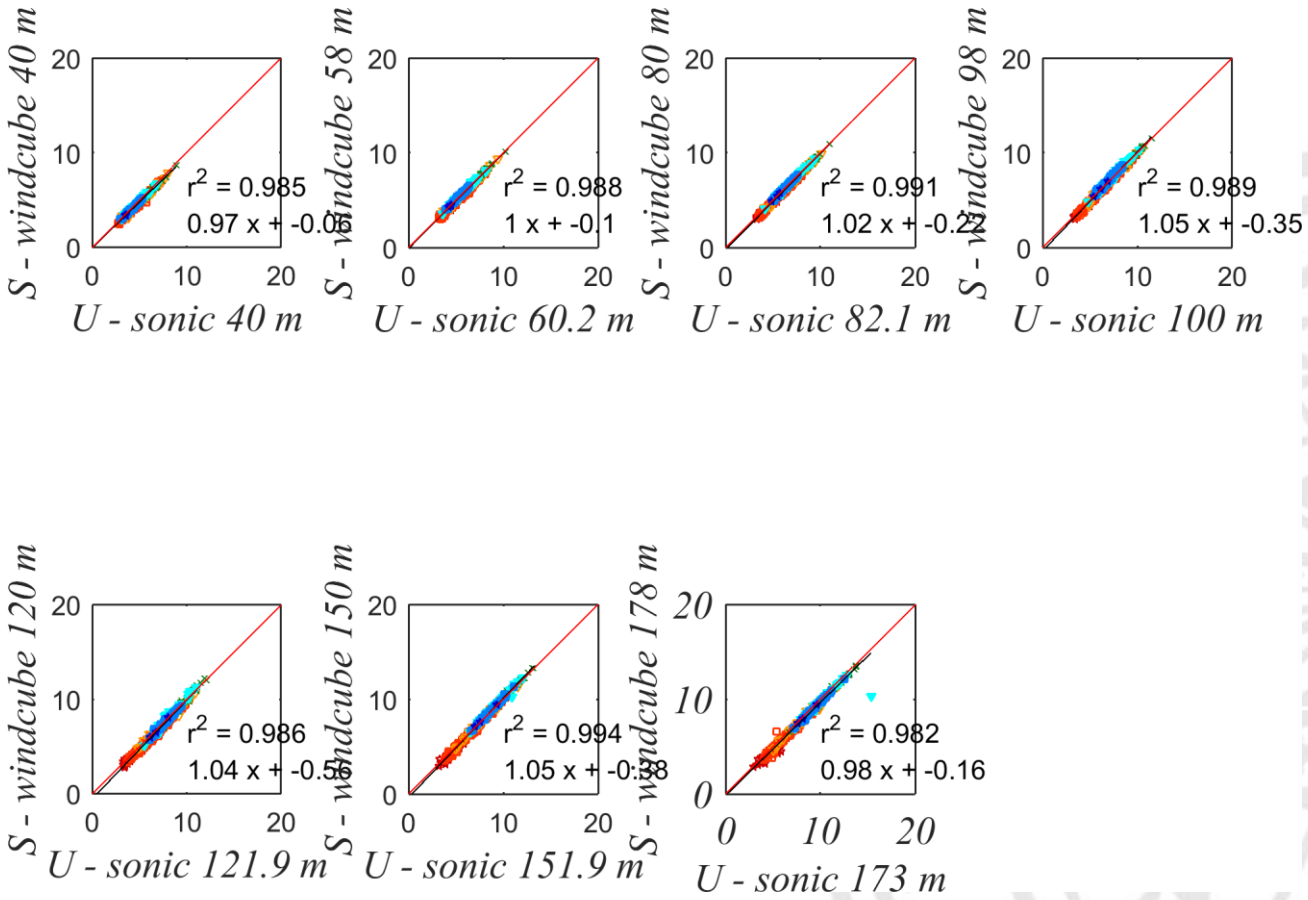
WindCube (V2)



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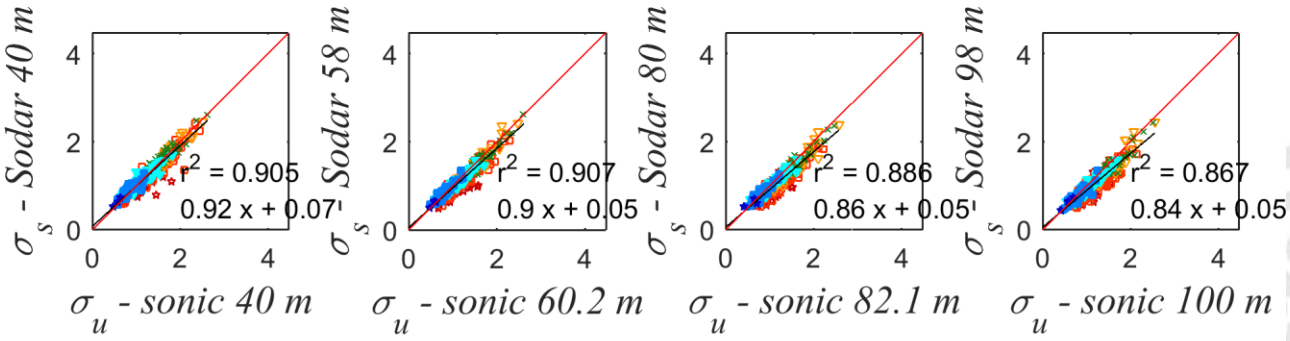

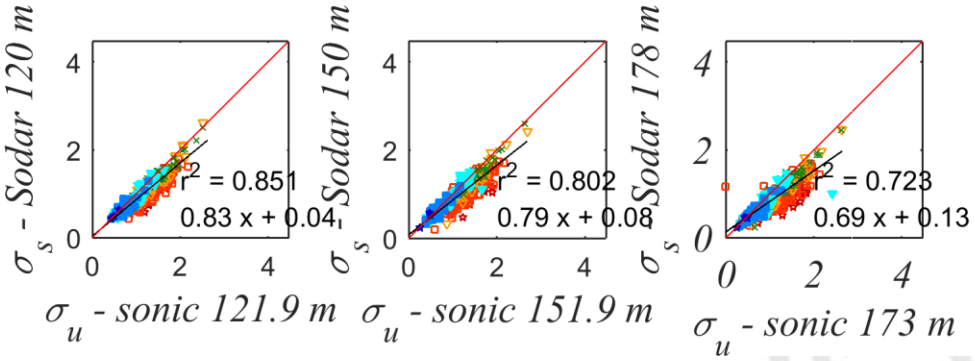

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Men!

Att använda korrelationskoefficient är ett dåligt mått på hur bra instrument är!

Det maximala r^2 som kan uppnås är en funktion av turbulensintensitet och avstånd mellan instrumenten

Fungerar bara bra om instrumenten sitter mycket nära varandra och mäter samma volym

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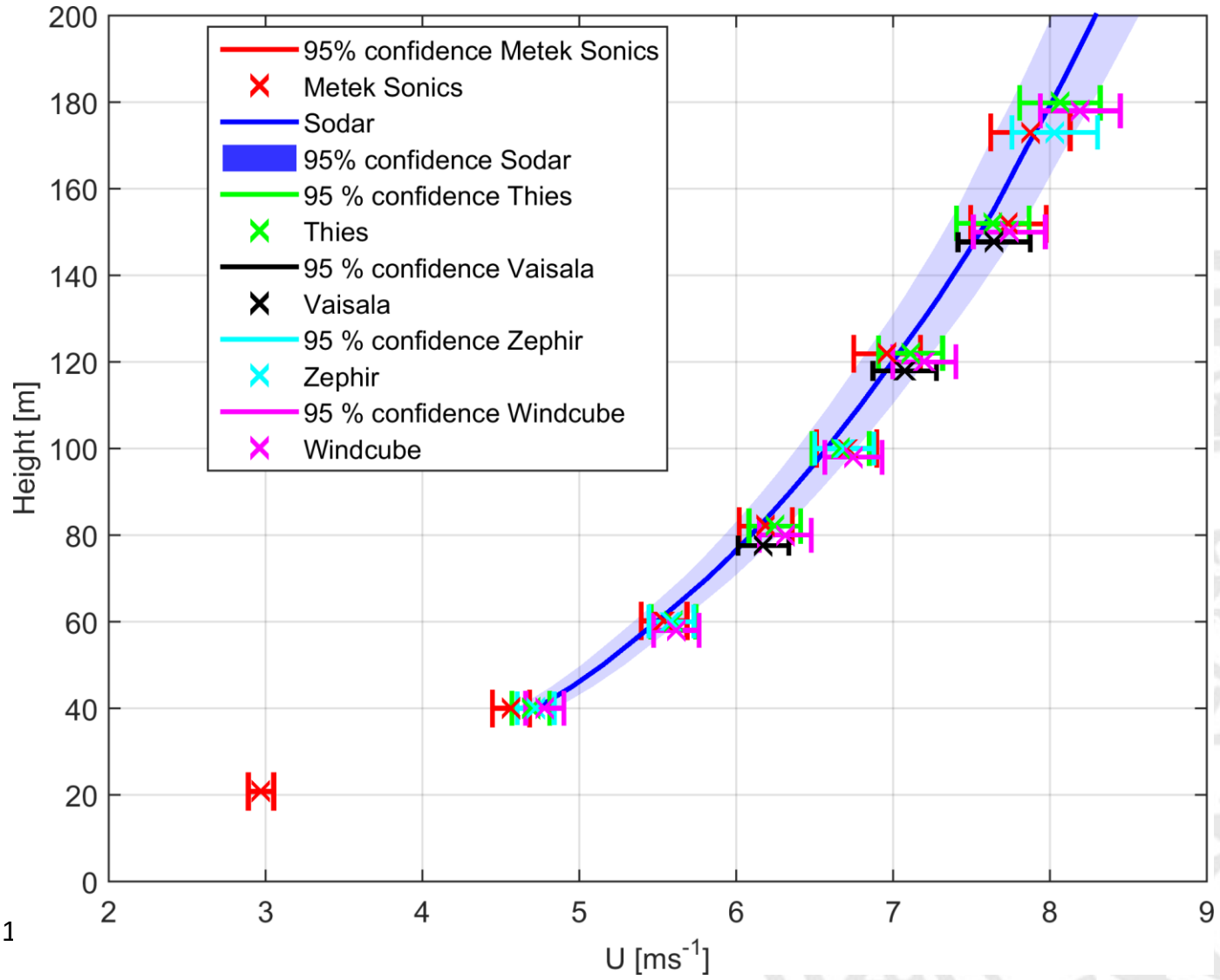
Windprofile from all systems



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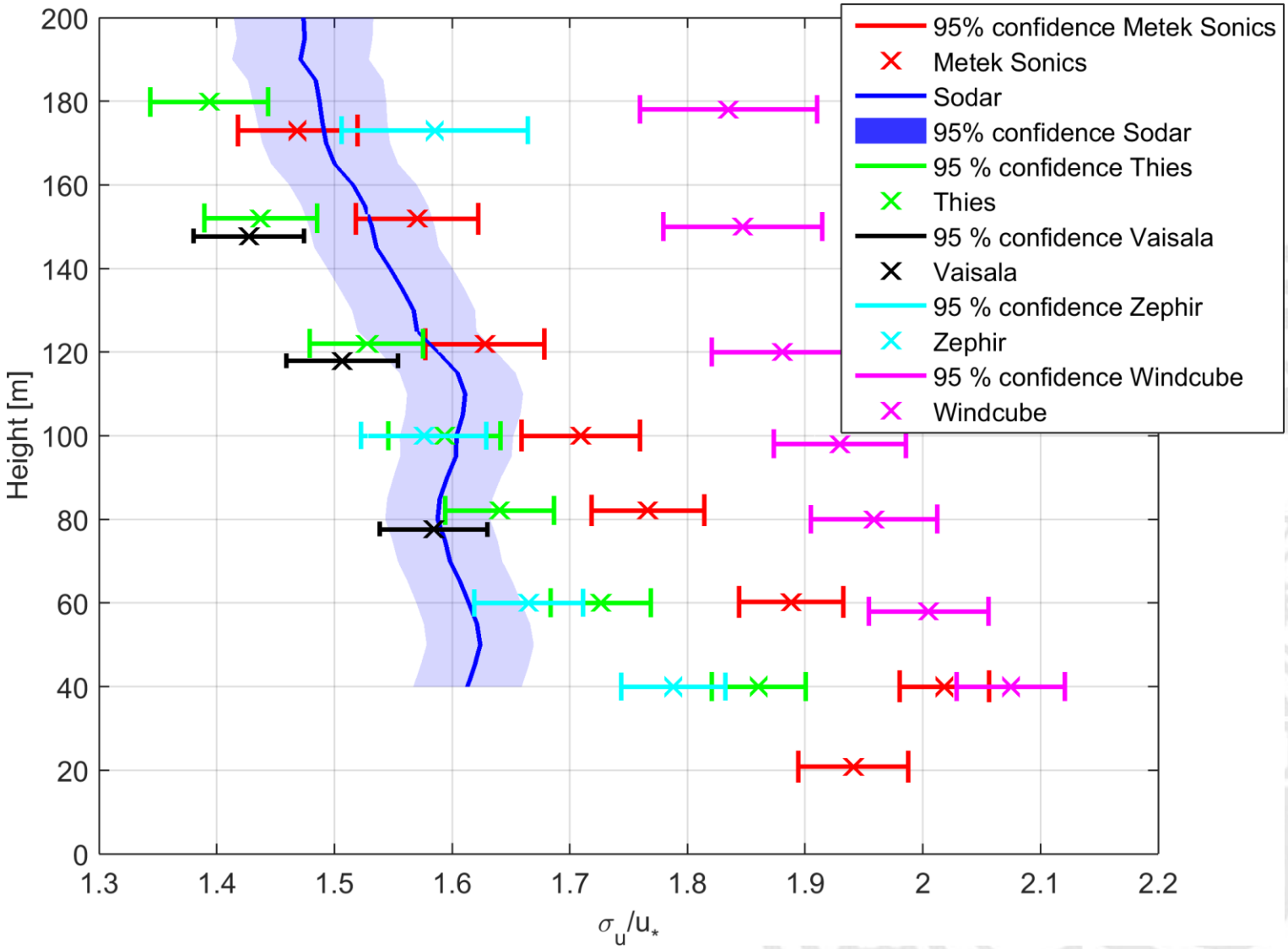
Turbulence profile from all systems



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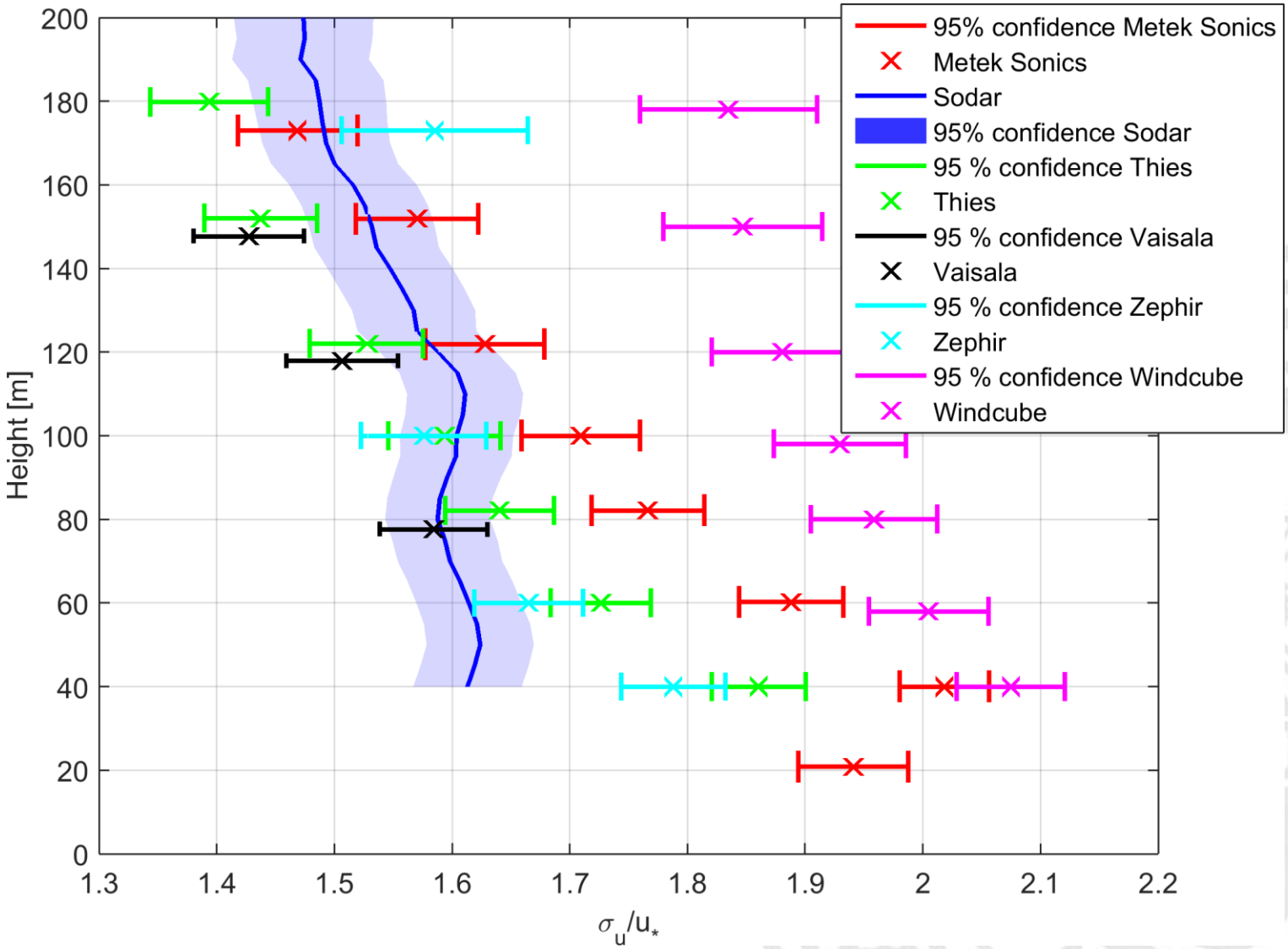
Turbulence profile from all systems



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Alla instrument har fördelar och nackdelar

Cup + vane

+ Reliable
+ Cheap
- Over speeding
- Response time
- Flow distortion

- **Sonic anemometer**

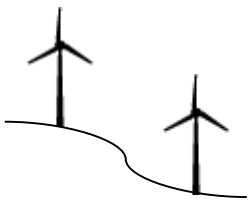
+ Temperature measurements
+ Reliable
+ Response time
- Expensive
- Flow distortion

- **Lidar**

+ Multipoint measurements
+ No flow distortion
+ (Cheap)
- (Expensive)
- Precipitation, clear air

- **Sodar**

+ Multipoint measurements
+ Cheap
+ No flow distortion
- Neutral conditions and low winds
- Frequency of high altitude measurements



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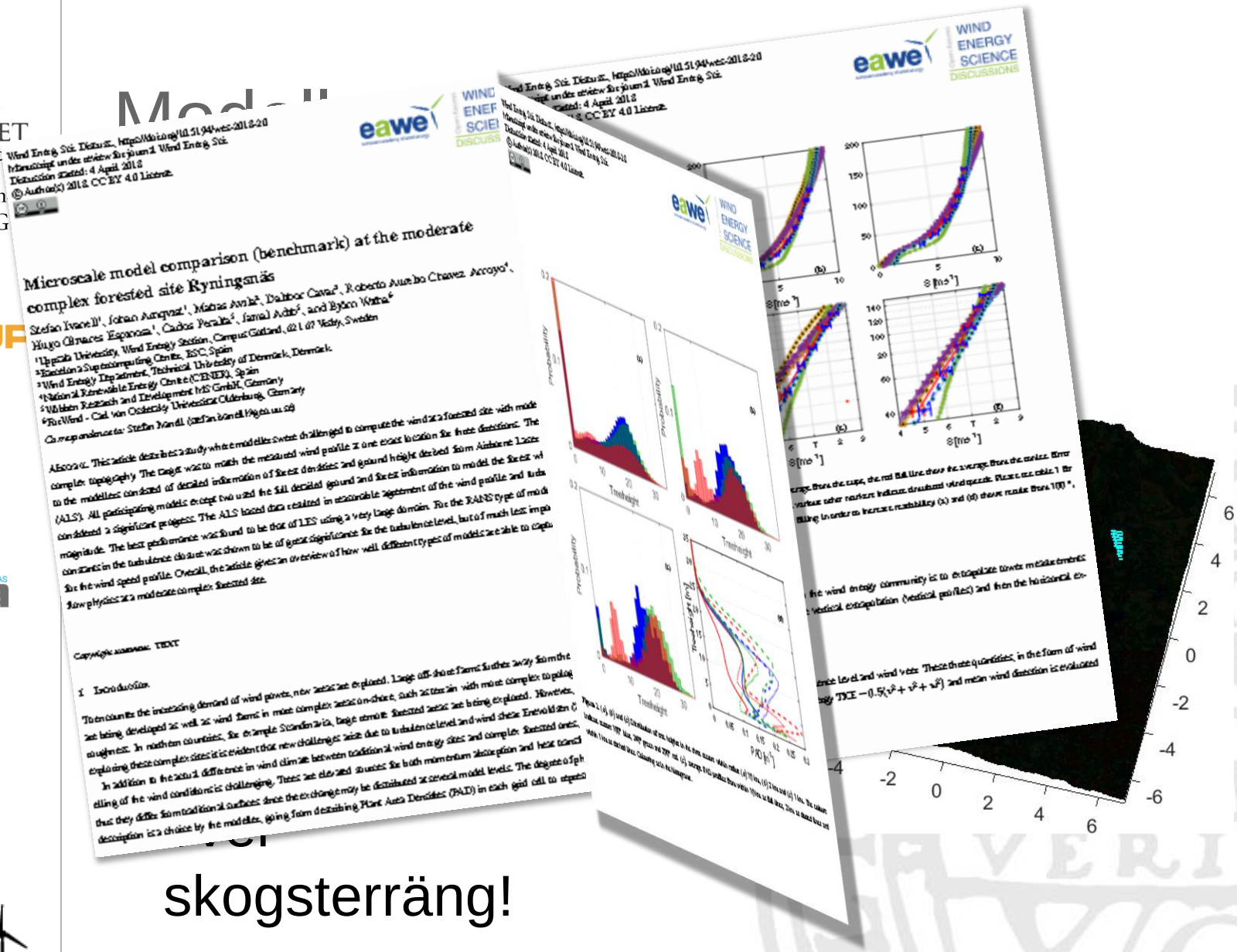
Mode

skogsterräng!



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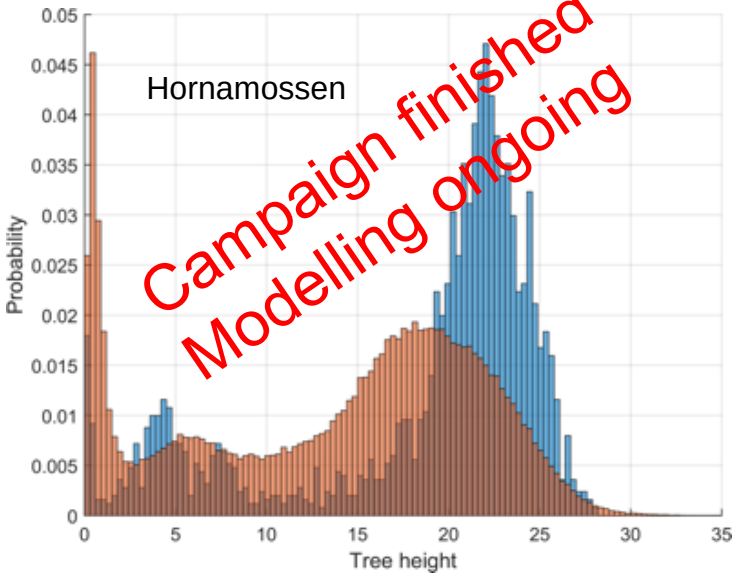

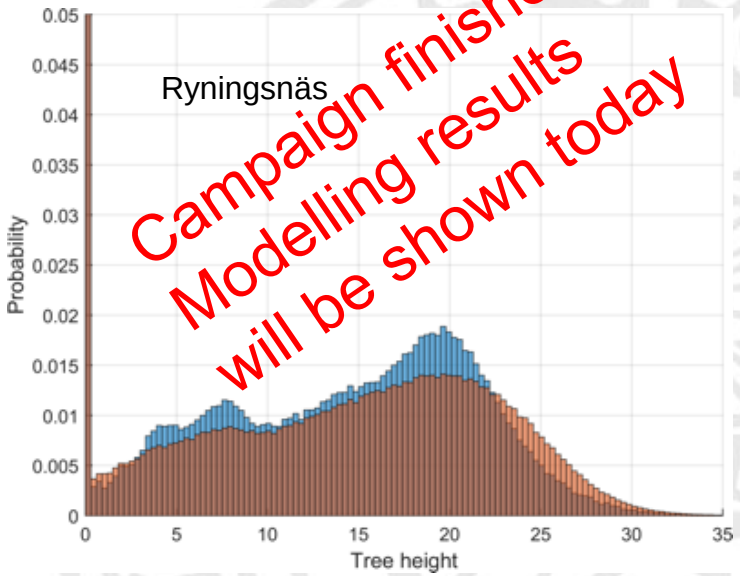

Whole region (40X40 Km)

500 m closest tower

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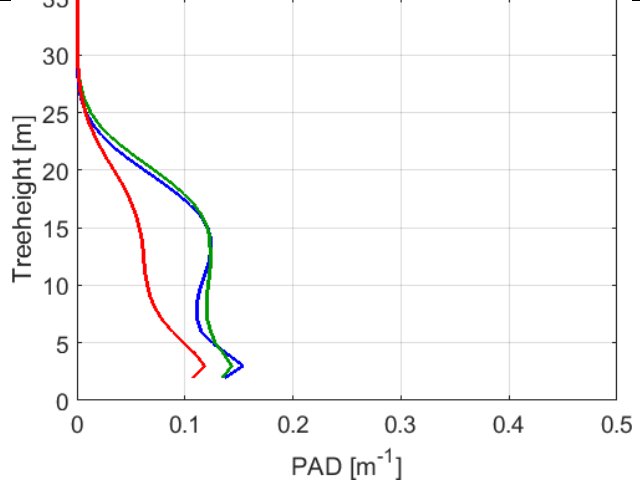
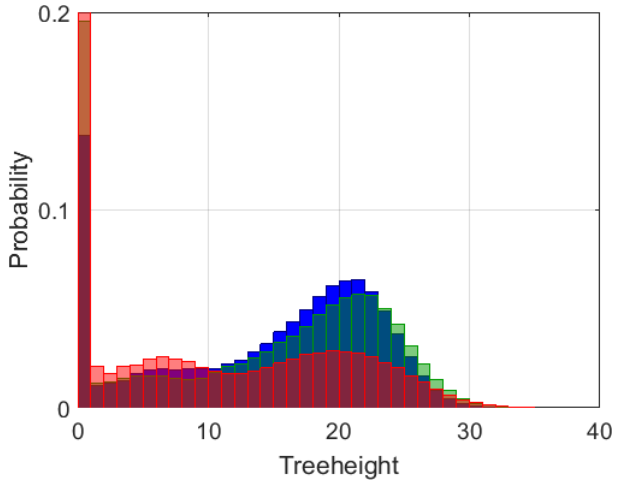
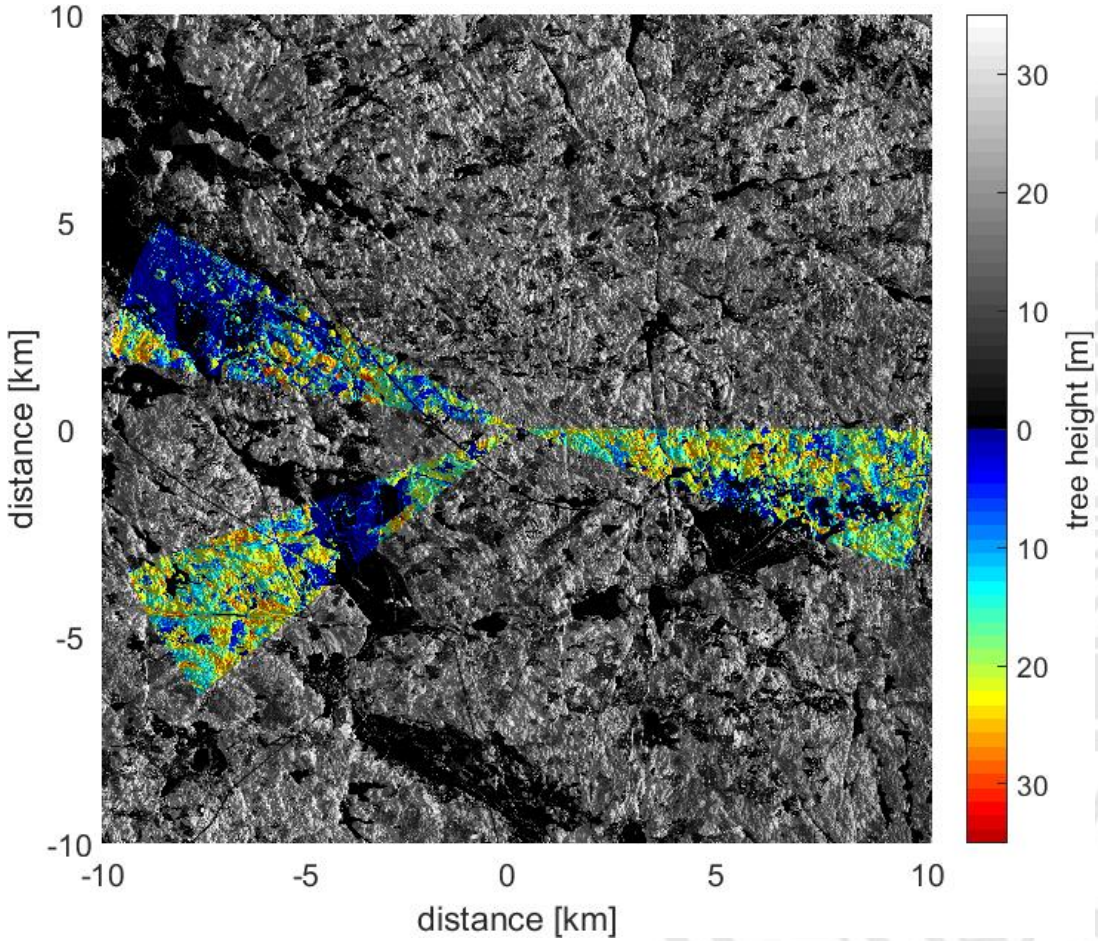
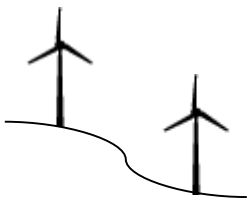
100
240
290





The three directions were selected
100, 240, 290 ∓10°





2013-08-22

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	Linear	RANS	LES	Laserscan as Input	Scale
Meteodyn (WRD)		X			PC
EllipSys3D (DTU)		X		X	Cluster
VestasFOAM (Vestas)		X			Cluster
OpenFOAM (CENER, CENAERO, Uni Uppsala)		X	X	X	Cluster
ALYA (Barcelona Supercomputing Centre)		X		X	Cluster
PALM (ForWind)			X	(X) Only average	Cluster

- **Koordinator:** **Uppsala universitet, (NEWA-Partner)**
  Stefan Ivanell (Coordination)
  Johan Arnqvist (Measurements, model comparison)
  Hugo Olivares Espinosa (Modelling SE)

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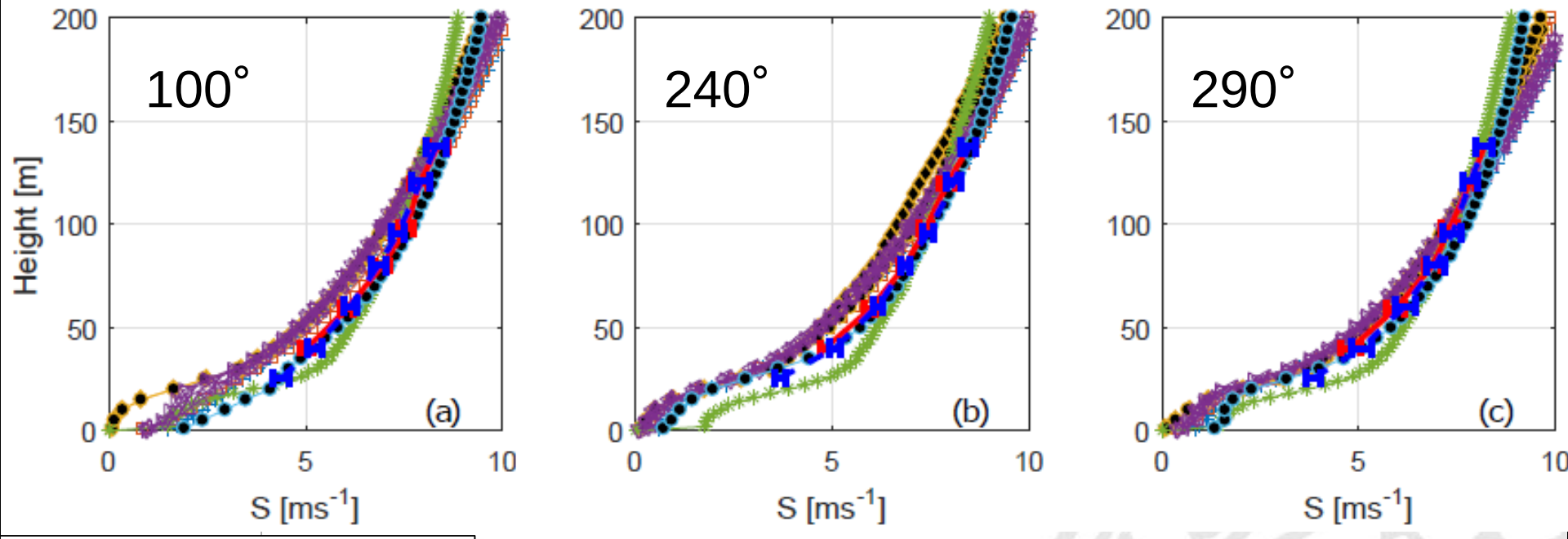
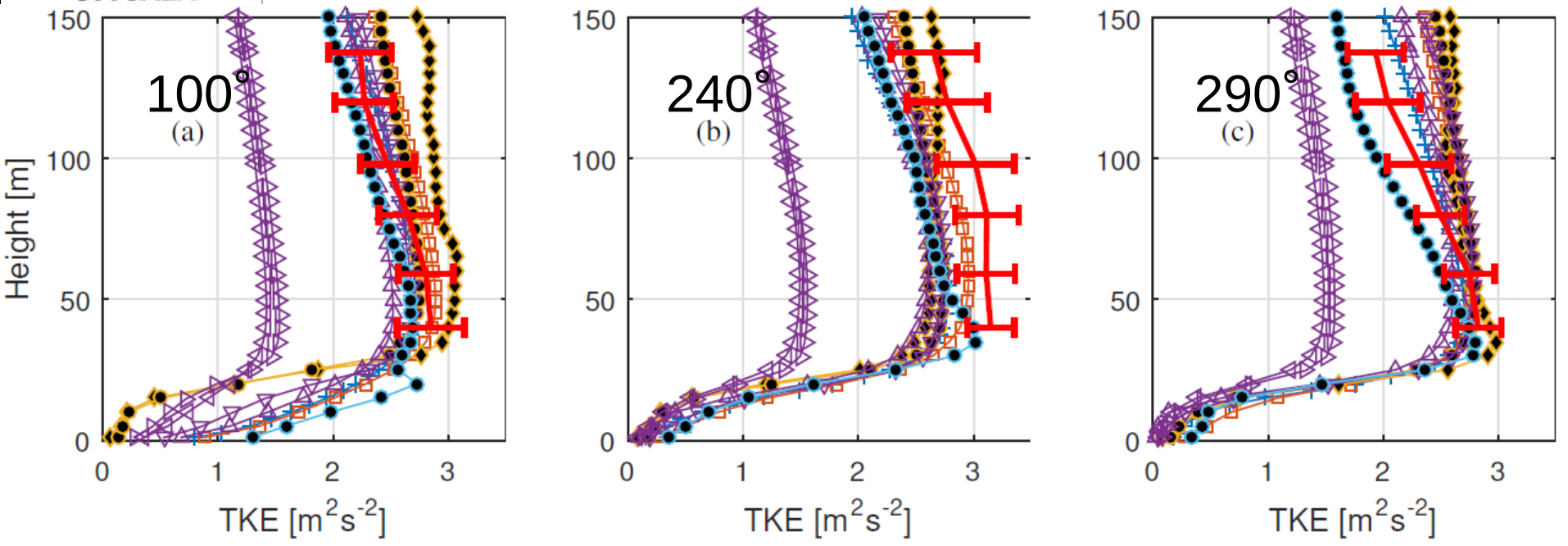
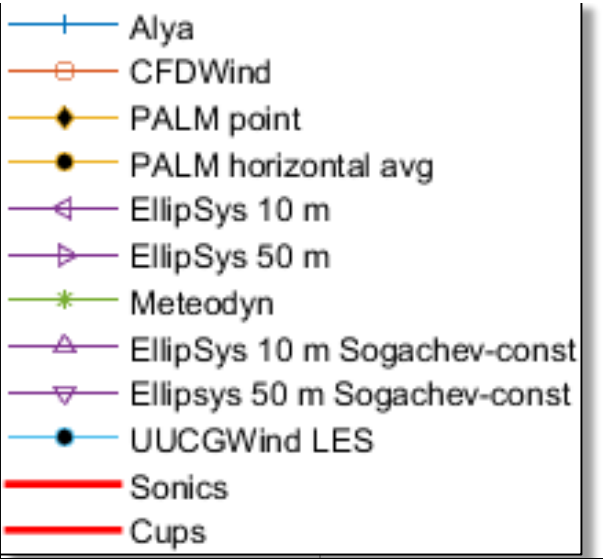
Vindhastighet



Alya
CFDWind
PALM point
PALM horizontal avg
EllipSys 10 m
EllipSys 50 m
Meteodyn
EllipSys 10 m Sogachev-const
Ellipsys 50 m Sogachev-const
UUCGWind LES
Sonics
Cups

Turbulent rörelseenergi





Varför blir det inte bättre resultat?

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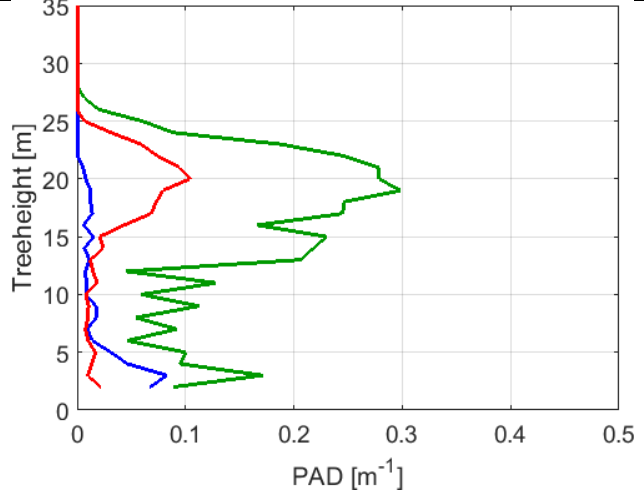
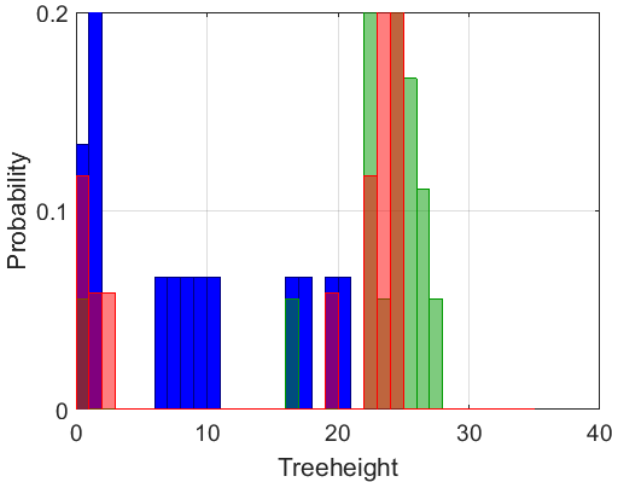
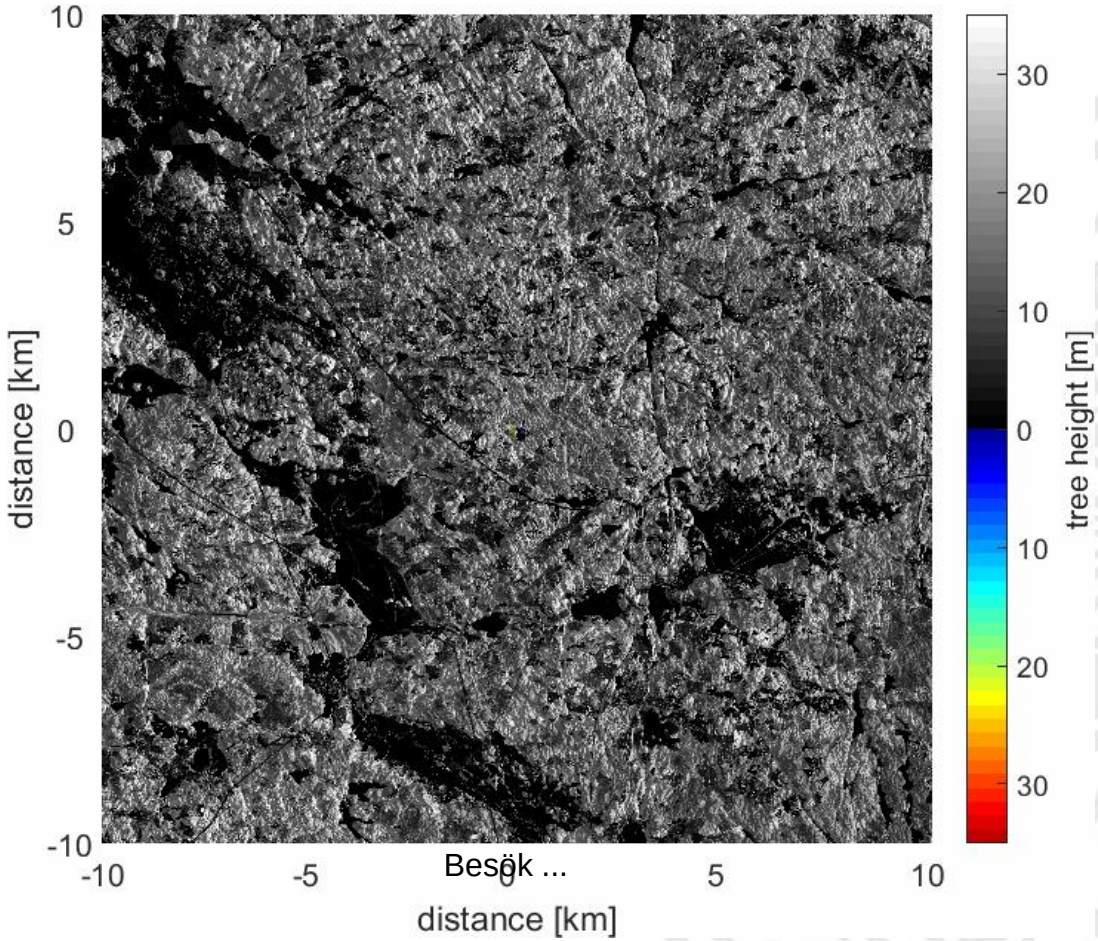
100
240
290





Within 1 km averages



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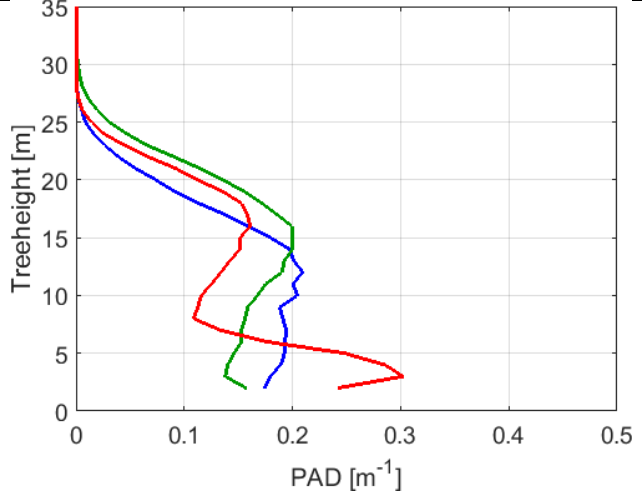
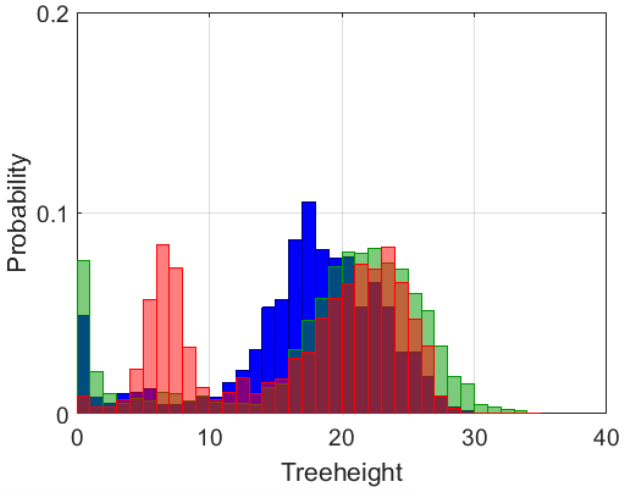
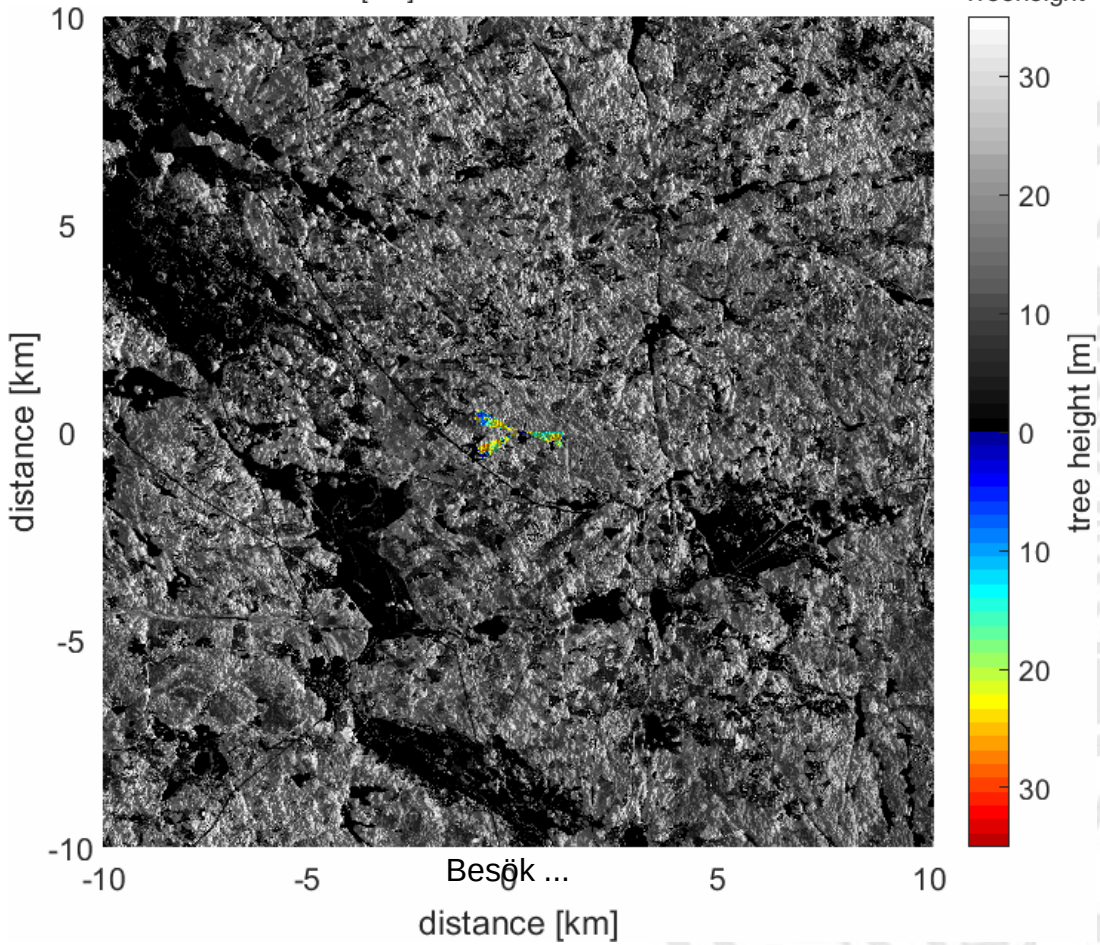
100
240
290





Within 5 km averages



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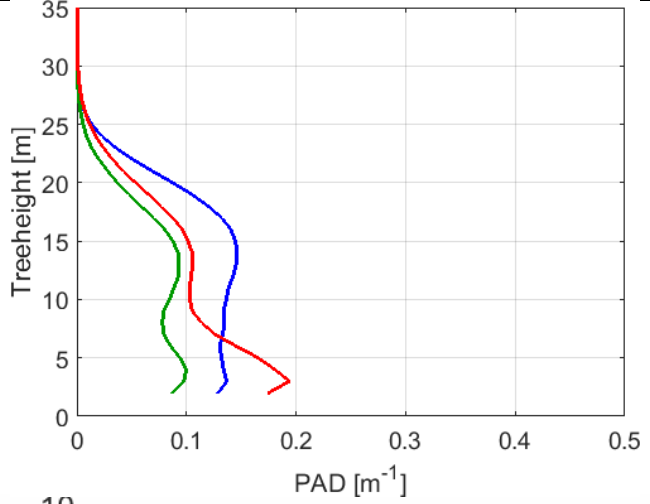
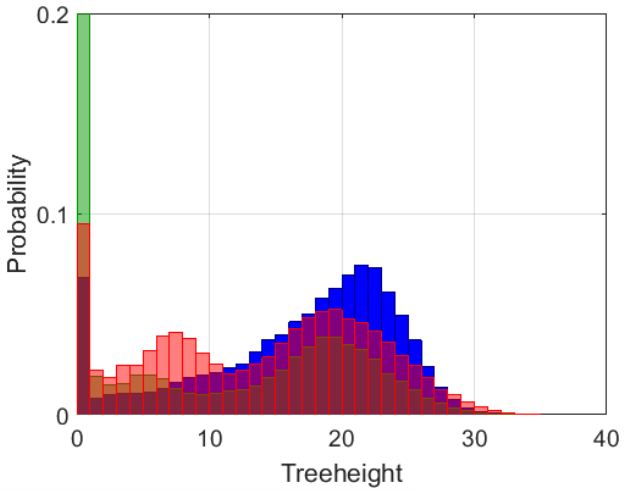
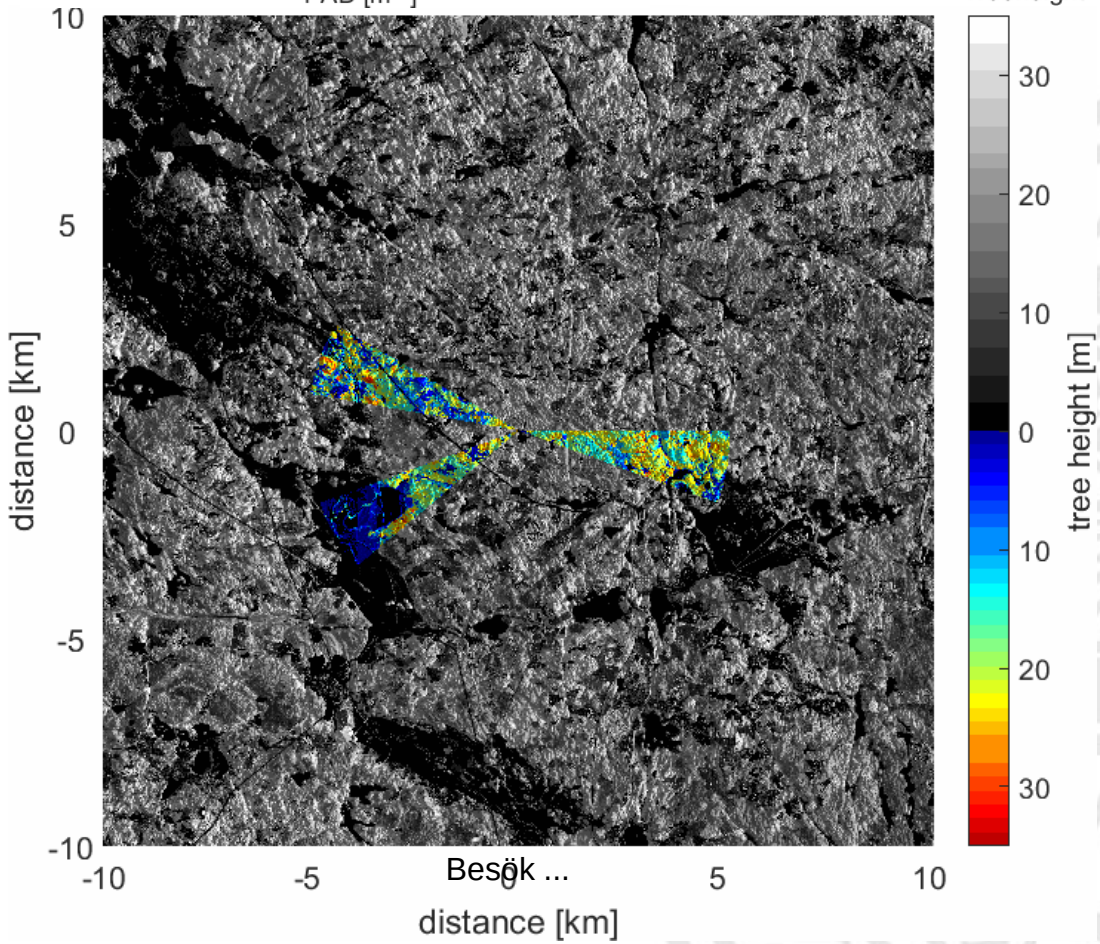
100
240
290





Within 10 km averages



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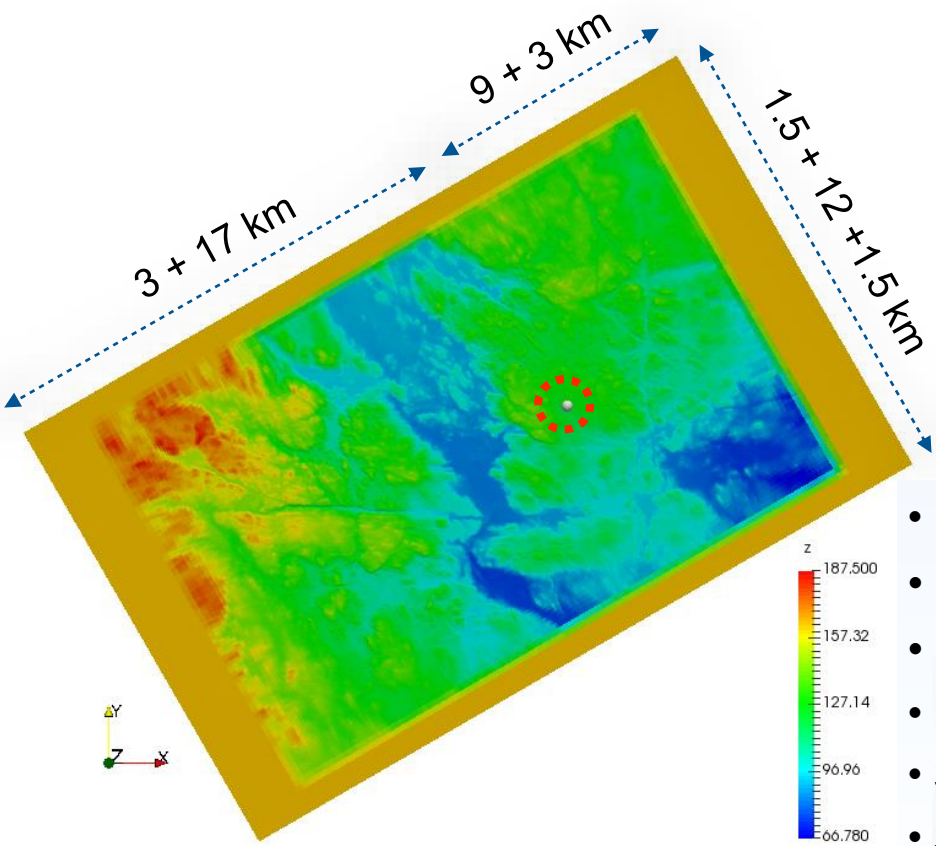
LES computations: Domain size



Edges: fixed PAD
Interior: PAD from LIDAR
Z_0=0,03

- CENER's WindMesh
- $\Delta_{x,y}$ = 25 m / edges 250 m
- $\Delta_{z,min} \simeq$ 5 m, ~1.05 growth
- N_{tot} = 41.2 X 10^6 cells
- Stabilization CPUh ≃ 150 000
- Sampling (physical 20 000s) ≃ 19 000

L_x X L_y X L_z = 32 km X 20 km X ~ 1.2 km

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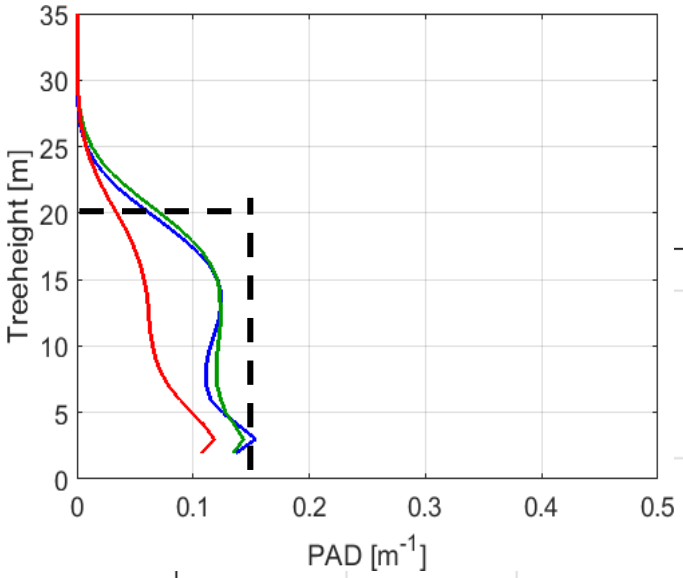
Wind speed matches the measured to a high degree



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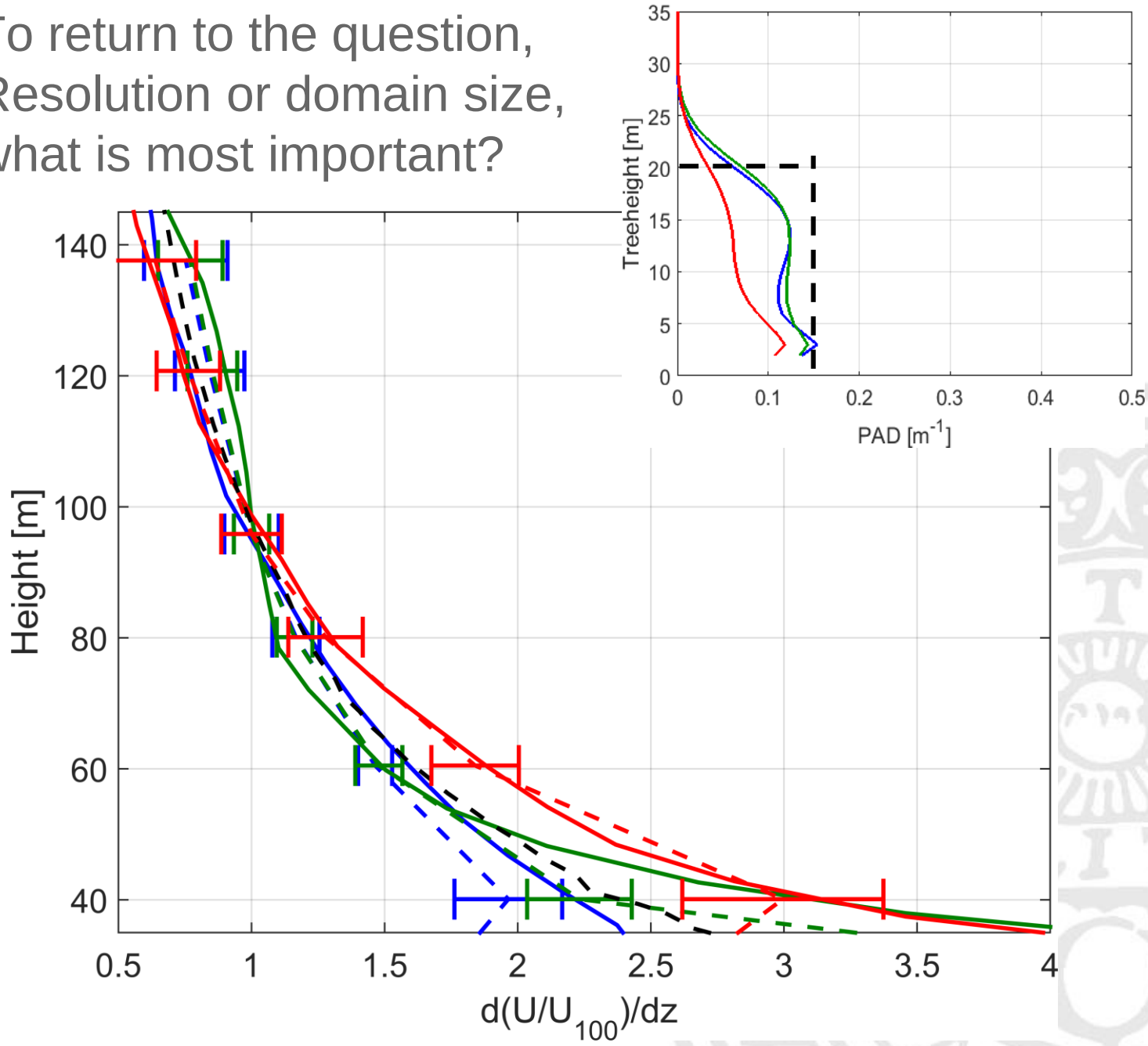
To return to the question, Resolution or domain size, what is most important?



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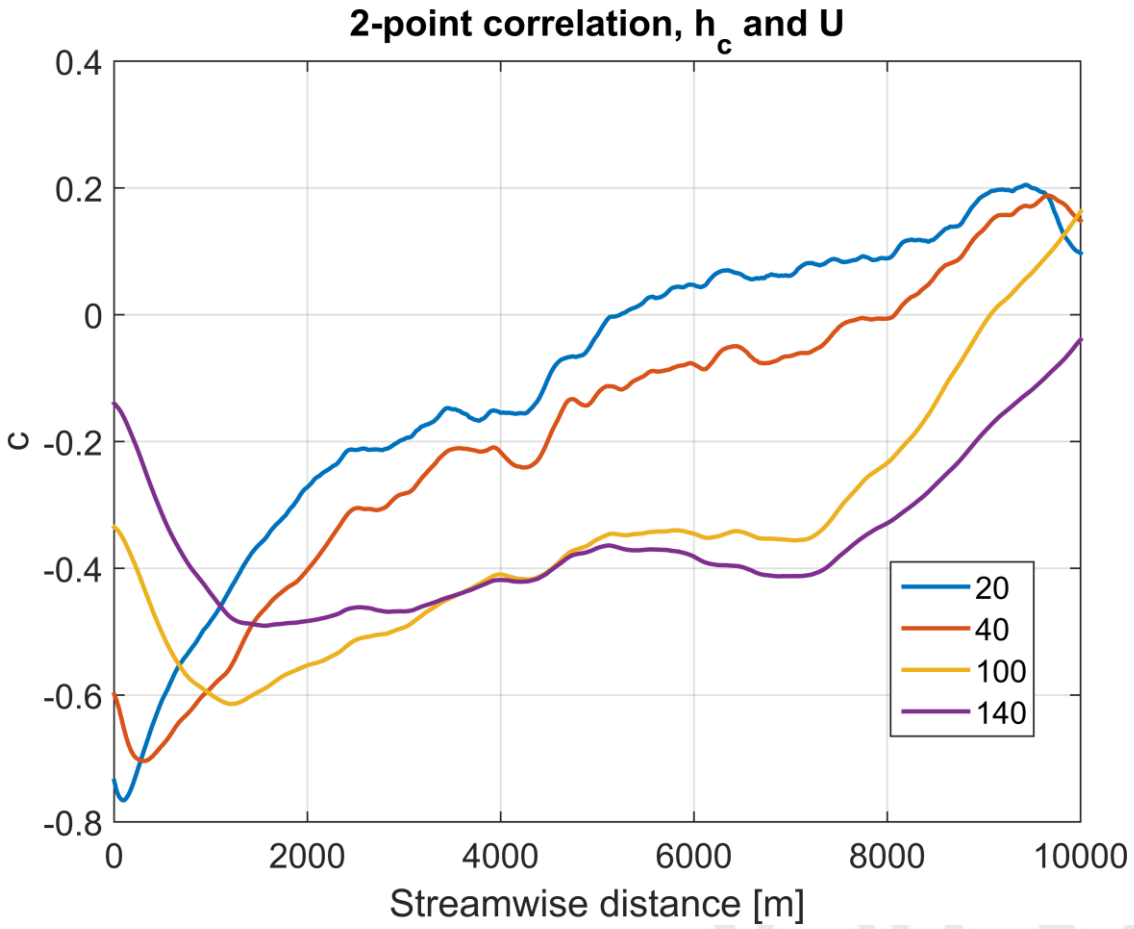
Footprint



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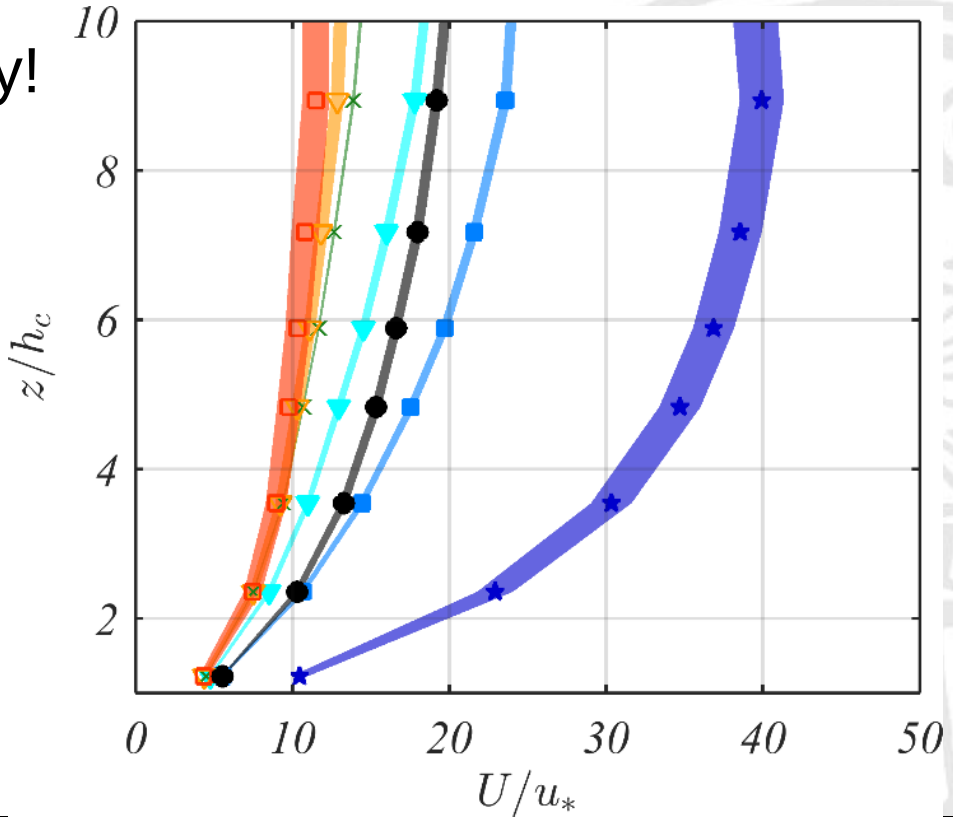
Så LES med stor domän verkar kunna matcha mätningarna. Men…. Om skiktningen inte är neutral?

Wide effect of stability!
And the effects does not cancel out!

- Very stable
- Stable
- Stable near neutral
- Neutral
- Unstable near neutral
- Unstable
- All data



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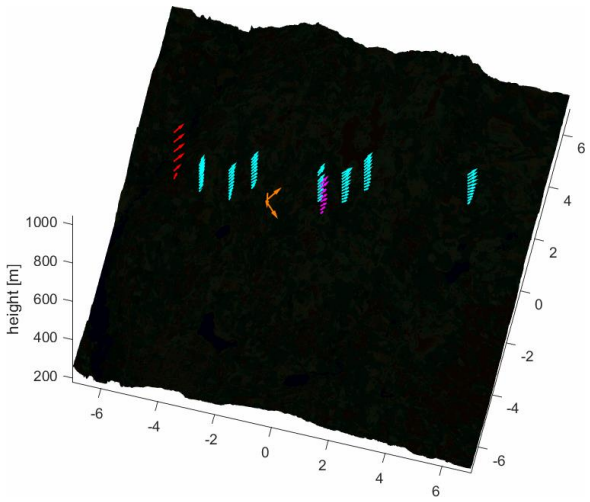
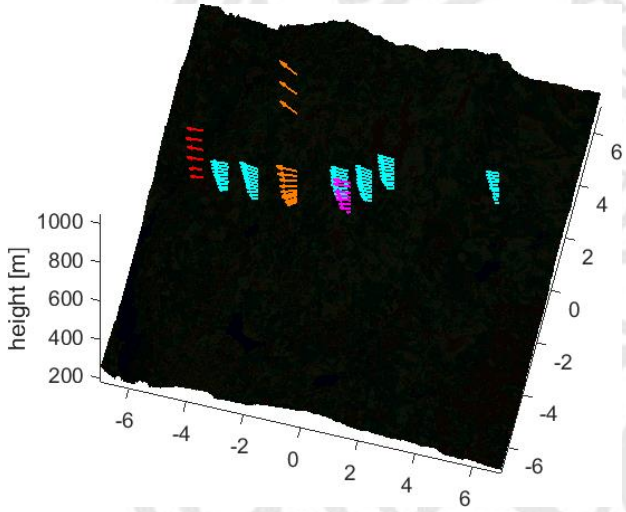
Hornamossen dygnscykel benchmark

- **Case west**
- WD 90 deg
- Ug ~12 m/s
- Barotropic, stationary conditions for 72 hours
- Varying cloud cover



- **Case east**
- WD 270 deg
- Ug ~12 m/s
- Barotropic, stationary conditions for 72 hours
- Mostly clear sky



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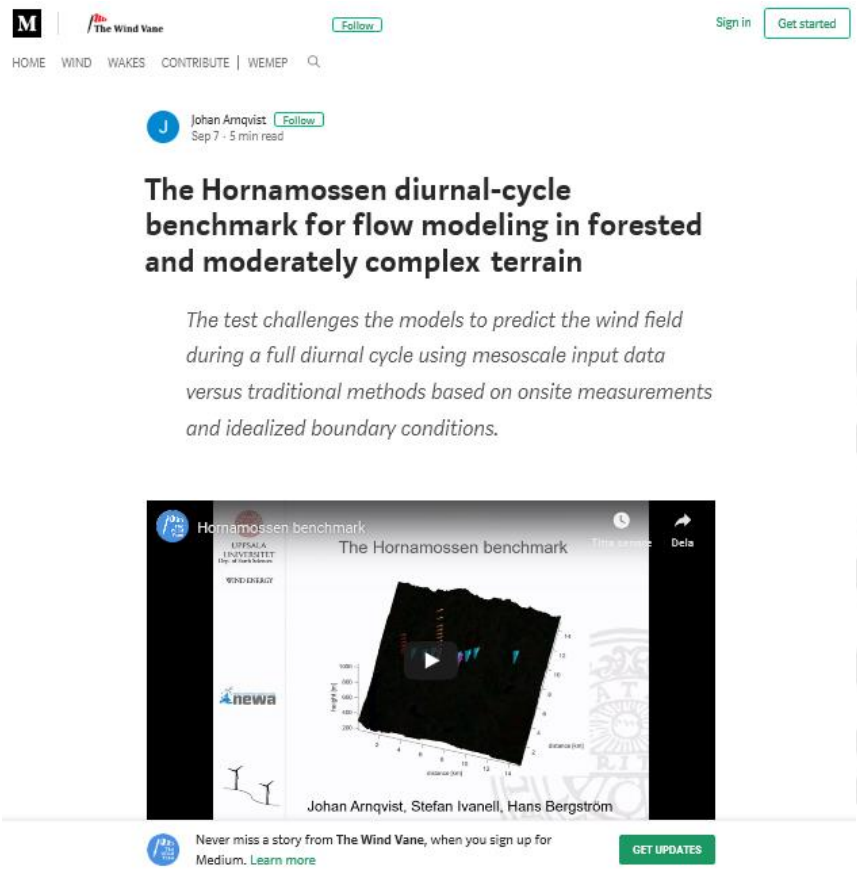
Vad händer nu?

Benchmark Hornamossen öppnar

- Testet kommer att utvärdera hela modellkedjan



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Vad händer nu?

Benchmark Hornamossen är öppnat

- Testet kommer att utvärdera hela modellkedjan

Produktionsberäkningarna färdigställs

- Färdigställande av databas.

Mikroskaleberäkningar startar

- Baserat på modellvalidering i flera Benchmarks

Atlasen sammanställs och publiceras

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Sammanfattning/slutsatser

- Laserdata gör det möjligt att i detalj modellera den faktiska skogen
- Skjuvning och turbulens kan kopplas samman med uppströms topografi och råhet
- LES med stor domän och riktig skog verkar kunna reproducera mätningarna, RANS är troligen för diffusiv
- Det verkar viktigare att ha stor domän än hög upplösning
- Modeller måste kunna reproducera ickeneutral skiktning!

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Tack för att ni lyssnat!
Frågor?
Kommentarer?

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NEW EUROPEAN WIND ATLAS
newa

Announcement:

May 22-24, 2019, Visby, Sweden

Welcome to Visby!

Stefan Ivanell & Jens Nørkær Sørensen

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eawe
european academy of wind energy

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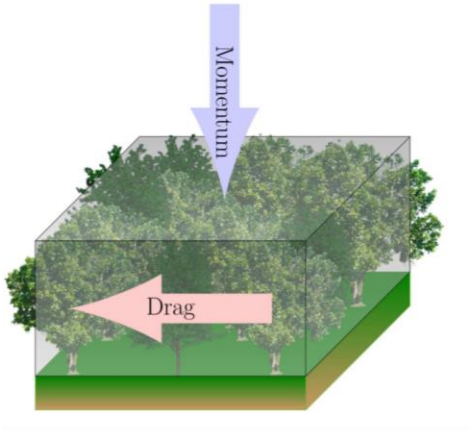
Forest model

- We wish to model the heterogeneities of the forest, obtained with LiDAR
- Drag force of the forest is implemented through the addition of sources in the momentum equation

$$\frac{D\left\langle \overline{u}_i \right\rangle}{Dt} = Pressure + Viscosity + F_{ABL,i} + F_{WT,i} + F_{D,i}$$

$$F_{D,i} = -C_D a \left|\overline{u}\right| \overline{u}_i$$



L.-E. Boudreault (2015)

- $F_{D,i}$ Net effect of the plant drag
- a Frontal Area Density, unif./non-unif.
- C_D Drag of the forest
- $F_{ABL,i}$ ABL-*driving* volume forces (pGrad & Coriolis)
- $F_{WT,i}$ AD/AL volume (sink) forces

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Forest model

- The SGS model also needs to be modified, to account for the "destruction" of TKE by the forest
- Another source term is introduced in the transport equation of TKE

$$\frac{\partial k}{\partial t} = Advection + Dissipation + Diffusion + Production - \varepsilon_{sgs}$$

$$\varepsilon_{sgs} = -\frac{8}{3} C_D a \left|\overline{u}\right| k$$

- Neutral conditions: This modification is implemented to a SGS model (Yoshikawa, 1986) that is available in the standard distribution of OF
- Non-neutral: A different model will be used, like that of Deardorff (1980)

Yoshikawa, A. (1986). Statistical theory for compressible turbulent shear flows, with the application to subgrid modeling. Phys. Fluids 29 (7).
Deardorff, J. (1980). Stratocumulus-capped mixed layers derived from a three dimensional model. Bound.-Layer Meteo. 18 (4).

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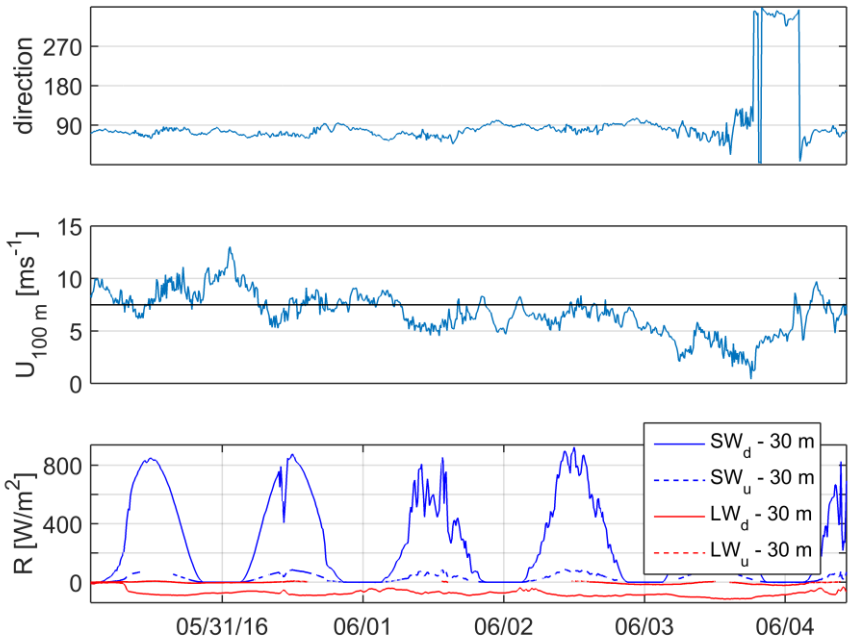
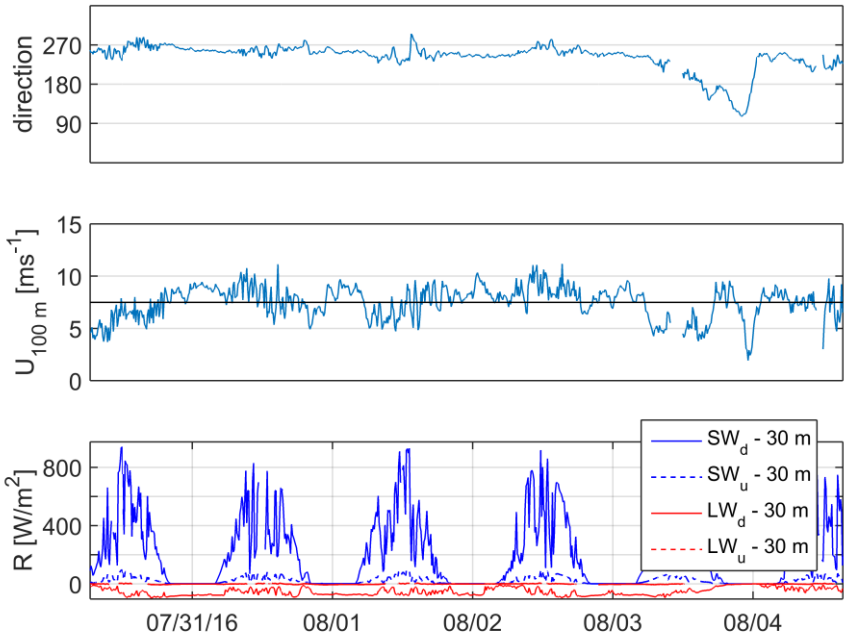
East case



West case



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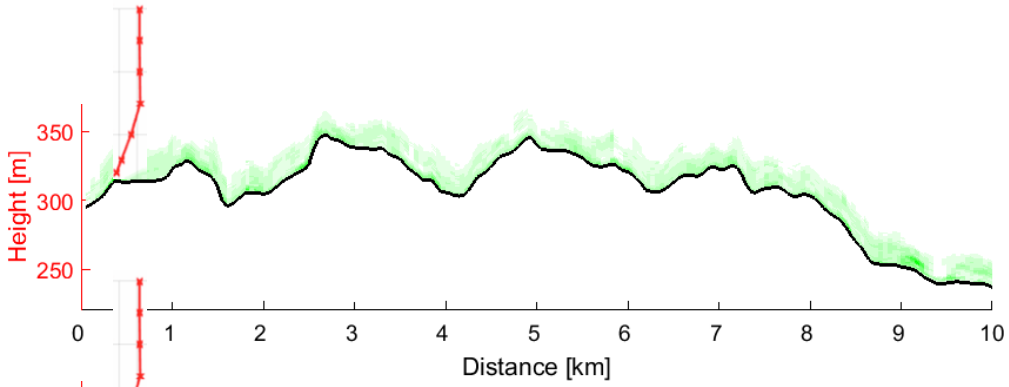
Level 4

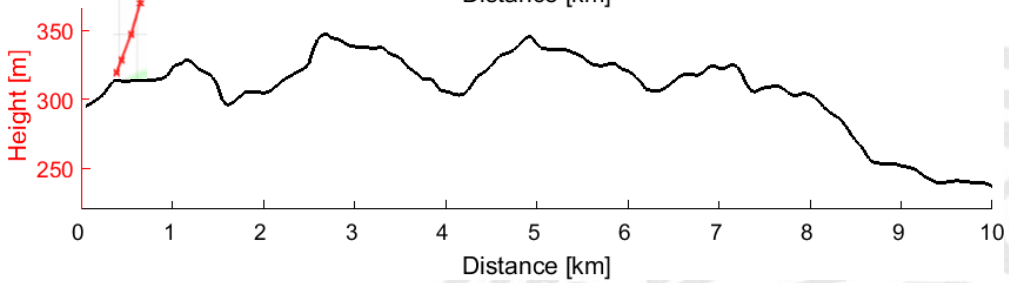
Level 3

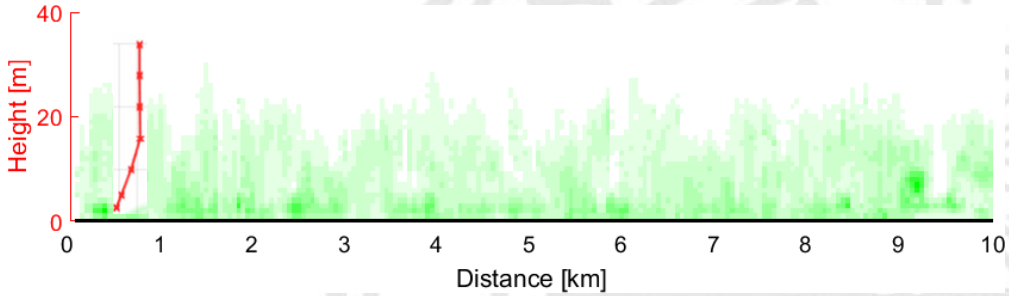
Level 2

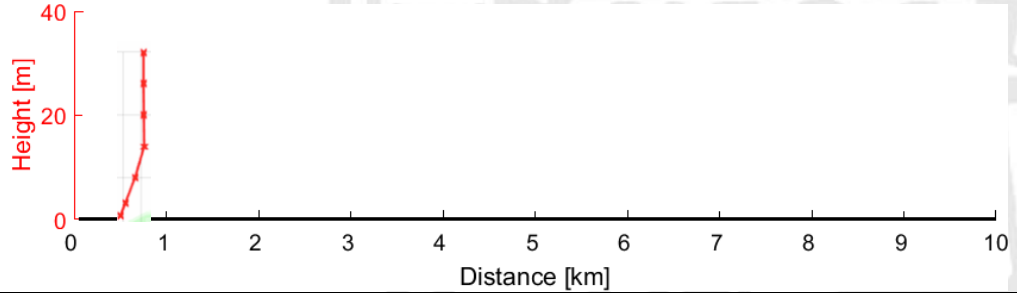
Level 1

Neutral-> Stable, Diurnal









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- PAD – Plant Area Density (often called LAD – Leaf Area Density)
  - The frontal area of the forest in the wind direction

- PAI – Plant Area Index (Often LAI – Leaf Area Index)
  - The vertically integrated PAD

Calculation of PAD from Airborne Laser Scans

- We use the Beer-Lambert law to determine the density based on the difference between incoming and transmitted intensity of the laser beam (*I*) between two canopy layers

$$\mathrm{PAD} = -2\cos\theta_l \ln\frac{I_2}{I_1}$$, Where θ_l is the angle of the beam.

- The intensity is calculated by: $$I_k = 1 - \sum_{i=1}^{k} r_{s_k}/r_{s_0}$$

Where r_{sk} is the (scaled) number of returns in the grid cell at a certain vertical level and r_{s0} is the (scaled) total number of returns in the grid cell.

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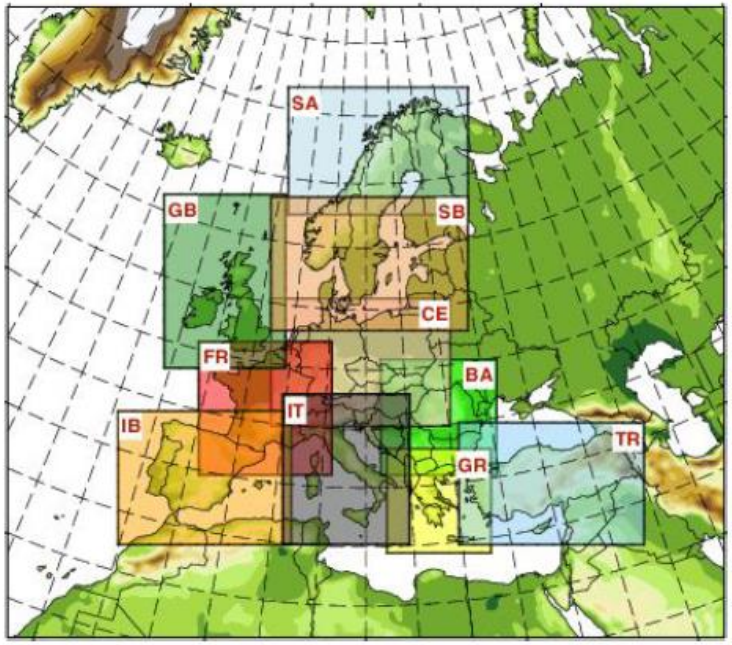
Mesoscale Production Runs – Final Setup

- WRF version: **modified v3.8.1** (PBL, icing)
- Grid: 27 km → 9 km → 3 km; 61 vertical levels
- **10 regions**
- **8-day runs** incl. 24 h spin-up, spectral nudging in D1
- **MYNN PBL scheme** (modified) + MO surface layer
- Forcing: **ERA5** reanalysis (0.3°)
- **OSTIA SST** and sea-ice (1/12°)
- Adaptive time step (where working)
- **CORINE 100 m land use data**, USGS where CORINE not available
- NOAH land surface model
- Icing (WSM5 + icing code + sum of qcloud and qice)
- Radiation time step = 12 minutes
- 480 cores, IO Quilting (1 node used for output)



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Hornamossen