Wind sensing with LTA

(back to basics)

- Kite
  - **Tesserenc de Bort , L. P. The Franco-scandinavian Station For Aerial Soundings 1902**
  - **Hobbs, S E. *A Quantitative study of a Kite Performance in Natural Wind with Application to Kite Anemometry. Cranfield : Cranfield Institute of Technology, 1986.***
  - ***BALSLEY BEN B. et al: The Use Of State-of-the-art Kites For Profiling The Lower Atmosphere 1998, CIRES Boulder USA***

- Tethered balloon(**>>2347)**
  - **Bamler,K. : Scientific Ballooning And Weather Forecasts. Monthly Weather Review 1908**
  - **Meisner, LeRoy: Free-balloon experiments**
  - **Glauert, H. The stability of a body towed by a light wire. London : Aeronautical Research Committee, 1930.**
  - **Glauert, H. Heavy Flexible Cable for Towing A Heavy Body Below An Aeroplane. London : Aeronautical Research Committee, 1934.**
  - **Bryant, L W, Brown, W S and Sweeting, N E. Collected Researches on the Stability of Kites and Towed Gliders. 1942.**
  - **Landwebber, L and Protter, M H. The shape and Tension of a Light, Flexible Cable in a Uniform Current. Washington D.C. : United States Navy, 1944.**
  - **Neumark, S. Equilibrium Configurations of Flying Cables of Captive Balloons, and Cable Derivatives for Stability Calculations. London : Aeronautical Research Council, 1963.**
  - **DeLaurier, J D. A Stability Analysis of Cable-Body Systems Totally Immersed in a Fluid Stream. Washington D.C. : National Aeronautics and Space Administration, 1972.**

A short intercomparison of atmospheric sampling techniques

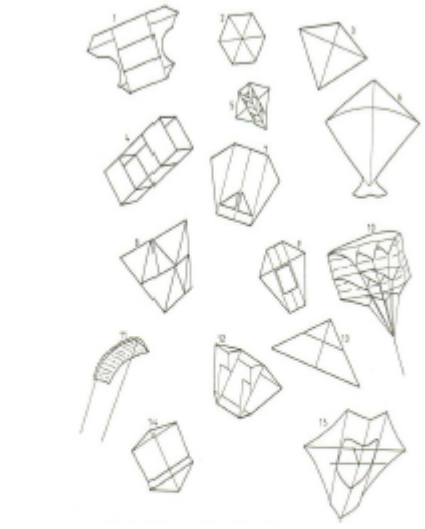
ITEM	KITES	Tethered balloons	Standard balloon-sondes	Aircraft	Towers
Maximum altitude coverage*	>5 km	≤ 1-2 km	>30 km	≤18 km	≤ 300 m
Very low-level sampling	yes	yes	yes	no	yes
Constant-height sampling	yes	yes	no	yes	yes
Eulerian measurements	yes	yes	no	no	yes
Lagrangian measurements	no	no	questionable	difficult	no
Max payload weight	≈10 kg	≈100 kg	≤ 3 kg	≈500 kg	large
FAA clearance needed	yes	yes	no	no	no
Height resolution	≤ 1-10 m	≤ 1-10 m	50 m	<10 m	< 1 m
System costs	$10-20k	$10-200k	$10k	$50 k-$6M	$1-800k
Cost/profile	very low	≈low	low-high	≥avg.	low
Wind requirements	>5-7 (m s^{-1})	≤ 12 (m s^{-1})	≤ 10 (m s^{-1}) (launch)	minimal	none
All weather?	no	no	yes	typically	yes
Portable	yes	yes	yes	yes	no
Payload recovery	yes	yes	very difficult	yes	yes
Telemetry	yes	yes	yes	yes	yes
Payload vertical velocity	0- 5 (m s^{-1})	0-5 (m s^{-1})	≈4-6 (m s^{-1})	0- 5 (m s^{-1})	0- 5 (m s^{-1})
Vertical profiling	yes	yes	yes	expensive**	possible

* The highest altitude (9,740 m) achieved by a train of kites occurred in 1919 at Lindenberg, Germany (Yolen, 1968).

** Measurements of the spatial turbulent statistics in the vertical direction are difficult with airplanes.

Balsley et al

Kites(experimental)



1 Cody War Kite
2 Hexagon
3 Malay
4 Square Box
5 French Rescue
6 Indian Fighter
7 Sled
8 Bell's Multi-celled Tetrahedral
9 Winged Box / Conyne
10 Parafoil
11 Flexifoil
12 Flare
13 Delta
14 Roller
15 Dunford Flying Machine

Advantages:

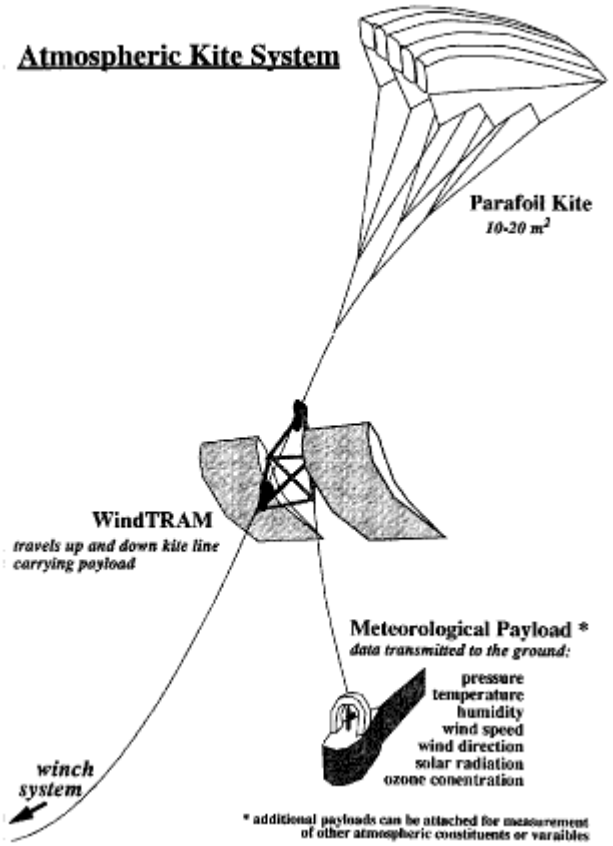
- relatively simple, lightweight, portable, structures that operate in winds ranging from roughly 5-20 m s^{-1}
- Data collection using kites is relatively inexpensive, since the instrument packages are not lost
- Telemetry solutions
- Altitude range: Up to several km

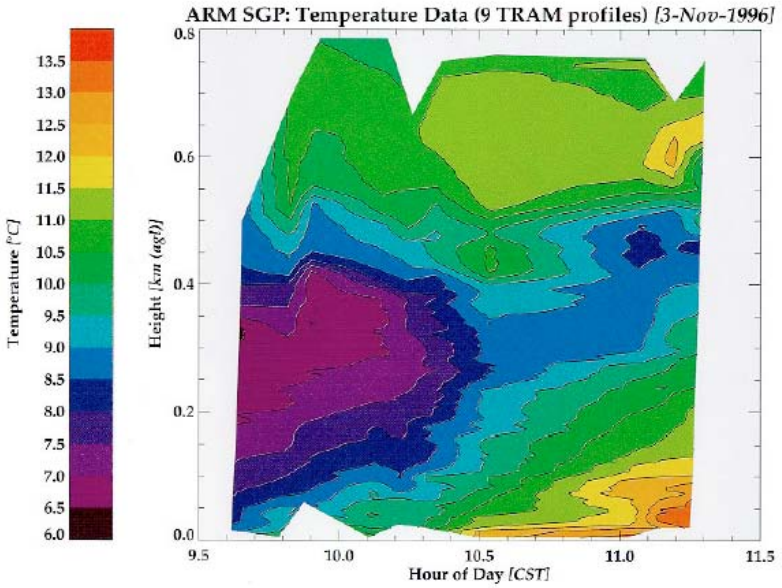
Disadvantages:

- Minimum 5-7 m s^{-1}
- Kites are not all-weather systems, and cannot fly during periods of high convective activity or in strong storm conditions
- Restriction because of aircraft regulations

The CIRES system

- 3-D turbulence measurements, chemical components measurements





- 5–10 kg for a tether-mounted payload
- 2–5 kg for a payload carried by the WindTRAM

Balloons(or mix)

- Different focus (LABL,UABL, troposphere..)

Understanding atmospheric processes operating at a range
of spatial and temporal scales is paramount in explaining local wind fields and
boundary layer characteristics in mountainous terrain.

Sturman et al : An Investigation of Atmospheric Boundary Layer Processes in Complex Terrain. American Meteorology Society 2003

Sounding systems were used to obtain measurements of the wind and thermodynamic structure of the atmospheric boundary layer. These include:

Doppler sodar, pilot balloons, and radiosondes, as well as
instrumented tethered balloons and
kites.

air and soil temperature,
atmospheric humidity, wind speed and
direction, precipitation, and solar radiation
Ground level energy balance measurement equipment

Balloon(Floatograph Aerostat)

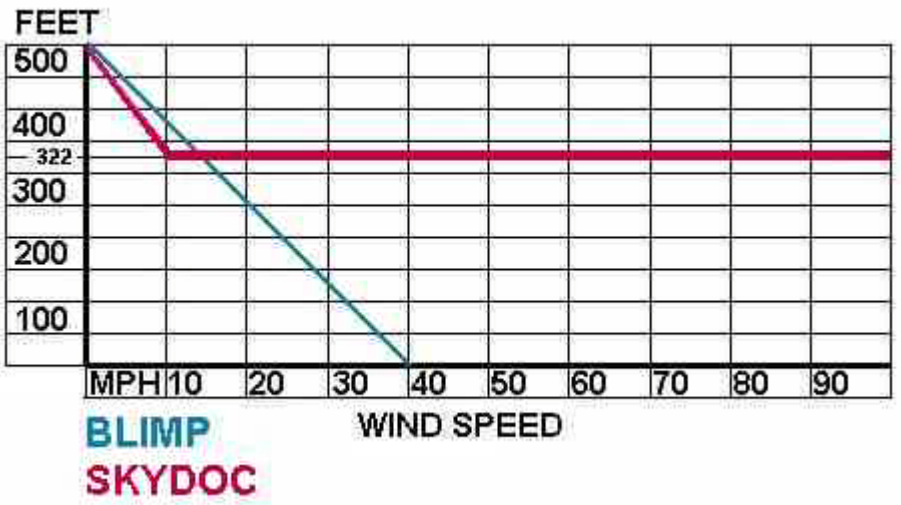
4.4 kN at 40 m/s
10 kg at no wind

Advantages:

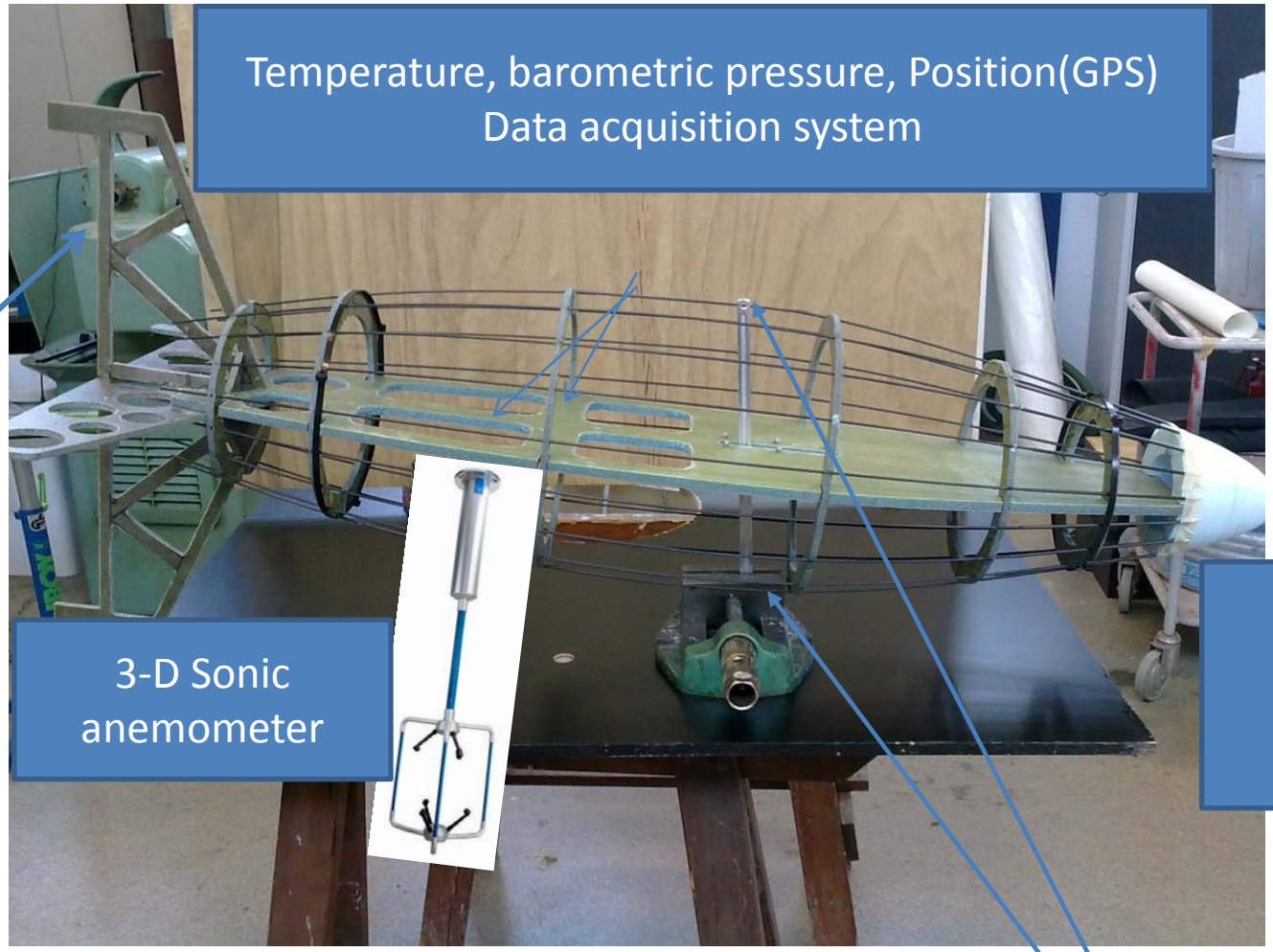
- High pay load possible(~Volume)

Disadvantages:

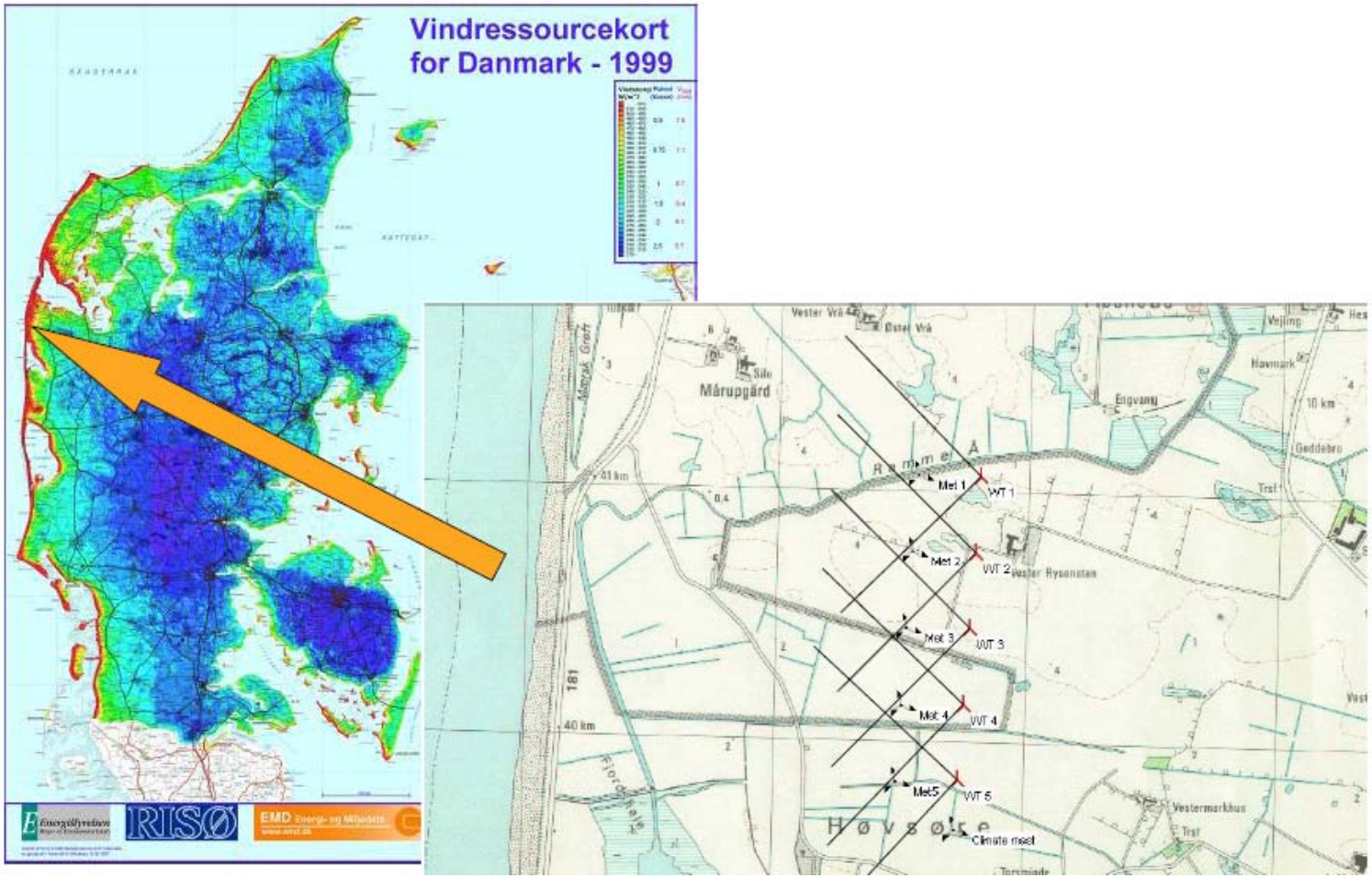
- Buoyancy at a loss of gas(Helium)
- High drag at the cost of height h/L
- Dynamic loads with dynamic wind force



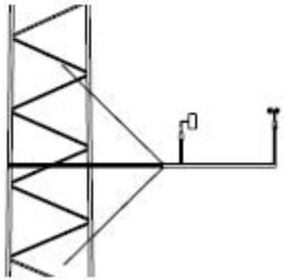
The measurement container

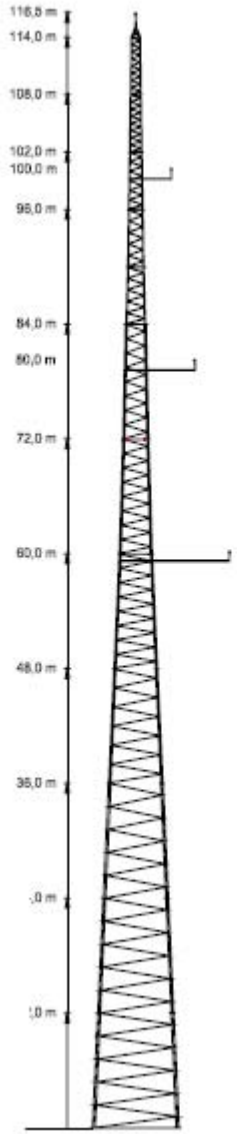


Høvsøre Test Site



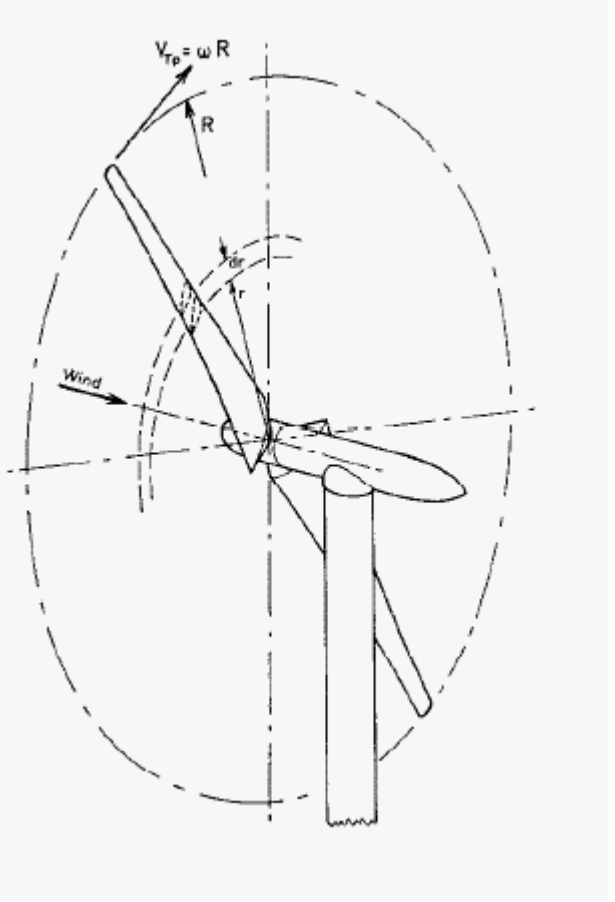
Instrument mounting configurations





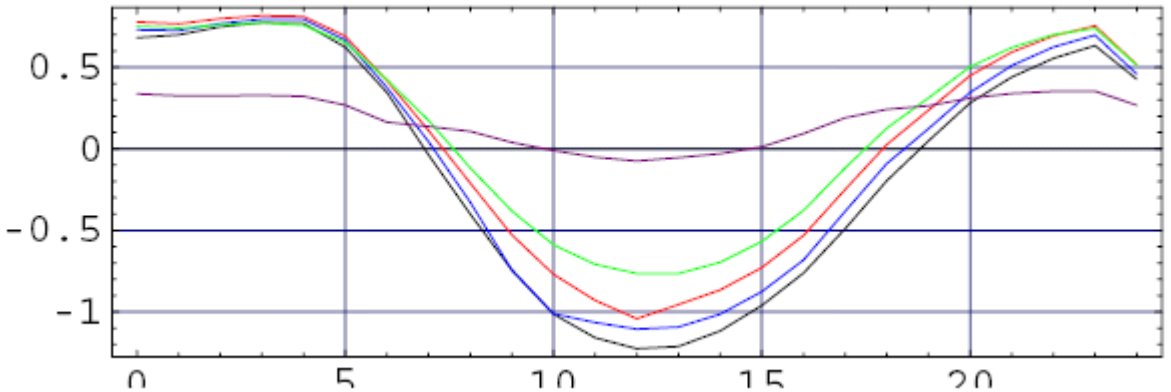
Wind turbine row

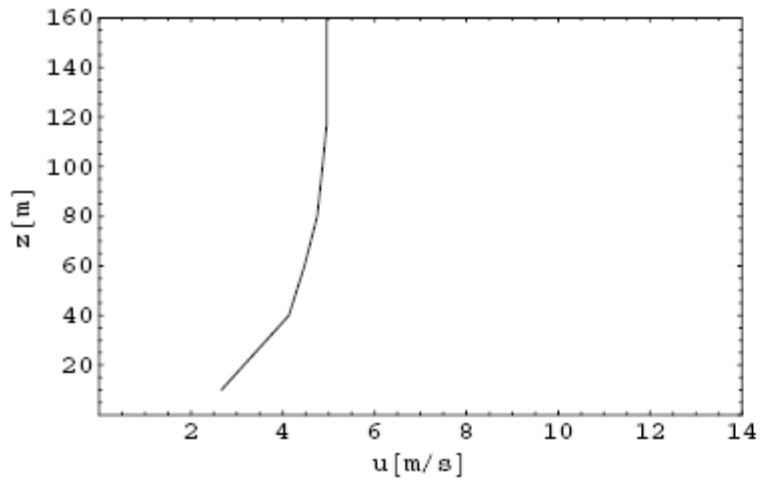
- 5 MW wind turbines , 100-120 m Rotor Diameter
- Instrumentation:
  - wind speed(cup anemometer)
  - Temperature(absolute and differential Tdiff)
  - air barometric pressure(absolute)
  - turbulence with heights up to 160m (Sonic)



Høvsøre specifics

Tdiff(z,2m) at z: 100m, 80m, 60m,40m and 10m during night and day time

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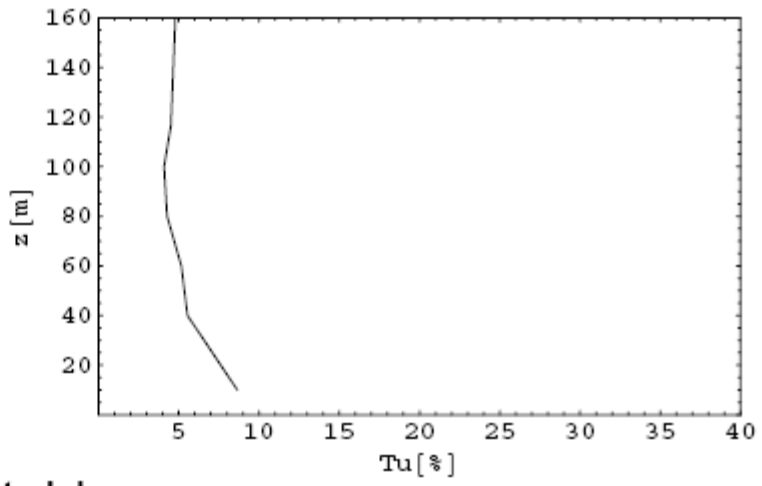
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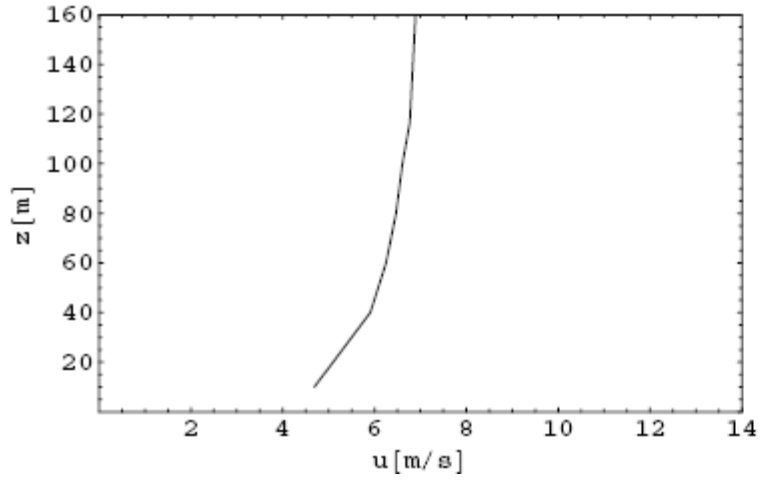
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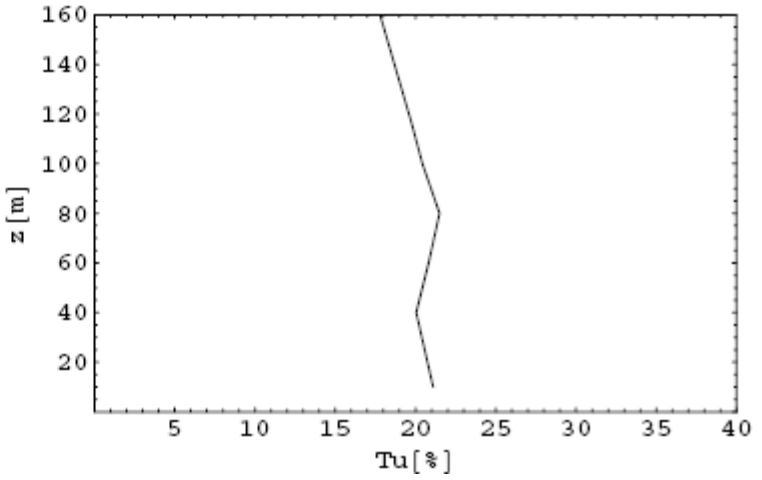
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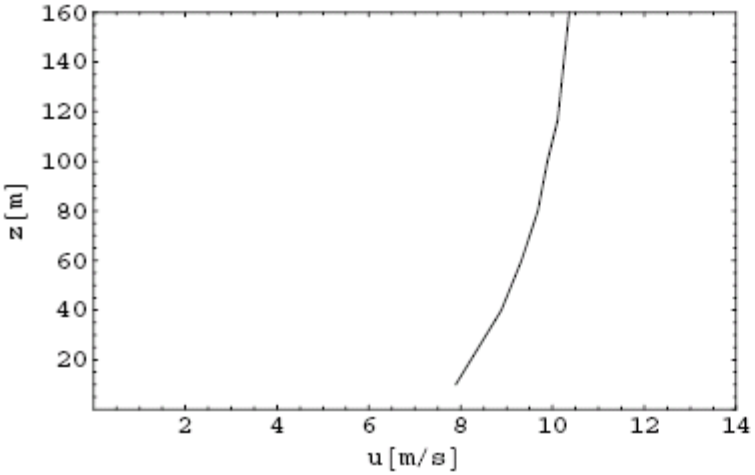
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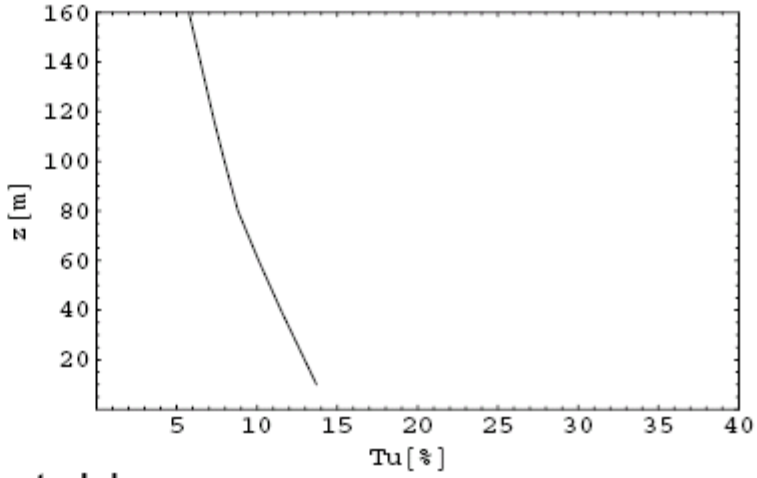
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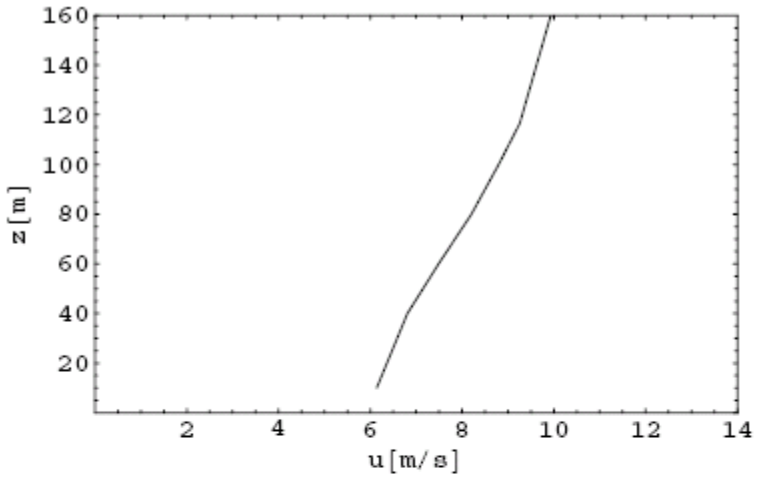
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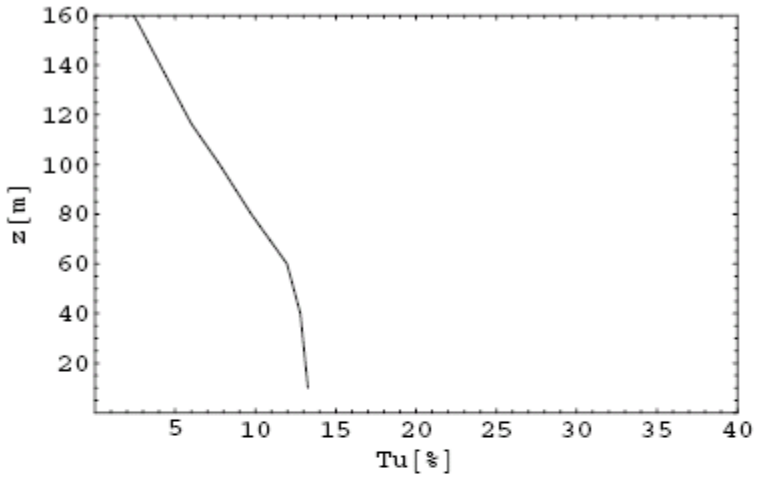
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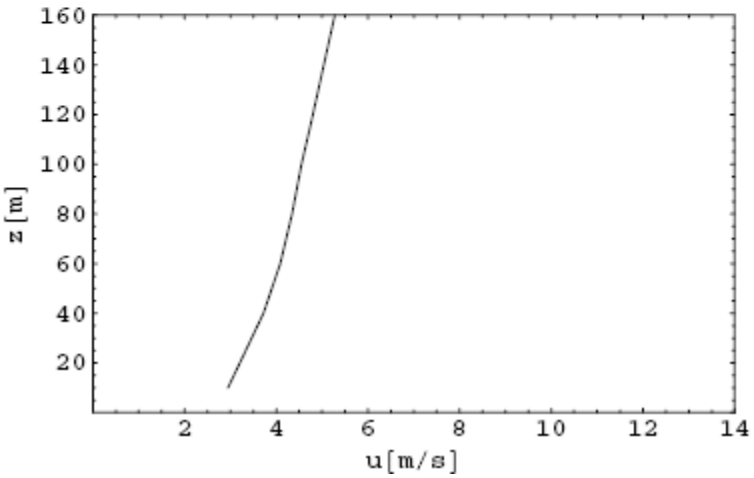
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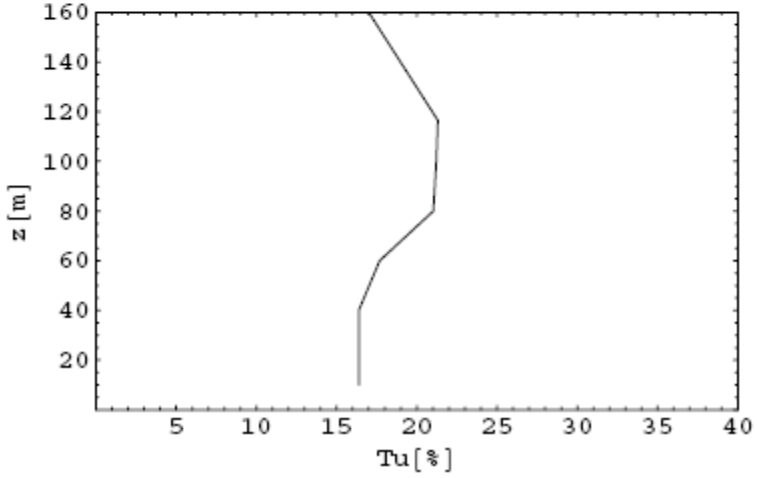
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Challenges

-Flight week(permissions from land owners)

-Controls of balloon(altitude, speed and direction)

-Payload fulfilment (Buoyancy 15 % less at 460m height)

-Limitation of weight (DAQ, sensory system, chord)

Outlook

- Description of the dynamics of the sonde and the LTA
  - Prediction model with turbulent wind

- Satisfactory resolution of the variables(angles <1 deg, speed < 0.1 m/s)
- Satisfactory uncertainty of variables (approx 0.1-0.3 m/s)
- High band width fs~50 kHz with potentially digital low pass filter
- System for data capture of several GByte