46400: Measurement technique in wind energy

Group assignment AS02: Wind speed measurements

Introduction

In this assignment you will get practice in using different kinds of measured wind data – both from conventional instruments and lidars. You will perform some data quality control data and compare different sensor types. Lastly you will calculate some wind speed uncertainties.

Problem description

The assignment is designed to be tackled in 3 phases:

Firstly, you will be asked to identify and remove some typical data errors in the conventional instruments (cups, vanes, sonics and temperature).

Once you have confidence in the conventional data, you will go on and use this to make a comparison to the lidar measurements. In the process you will need to define some measurement sectors and decide on some filtering parameters for the lidar.

In the last phase you will calculate some uncertainties for the cup anemometer you have used in the comparison.

The assignment is based on measurements at the DTU Test Station at Høvsøre in West Jutland. A drawing of the mast is included at the end of this document. All the data you need is in an SQL table. The document *Dataset_as03_description.pdf* (the dataset you should use is called *dataset_as03* despite this being assignment as02) describes the data and how to access it from the SQL server. You will have to make sure you can access this data before starting the assignment.

Questions

1) Make 10 minute time-series plots of the different channels of mast data (cups, sonic, temperature and vane) including mean, minimum and maximum.

   Can you identify any outliers or other erroneous data in the cup, sonic or wind vane data? Find a way of excluding these points from the further analysis. A useful technique is to replace excluded values by NaNs in the dataset. This way they will not be inadvertently used in mean calculations or included in regression plots.

2) Plot the ratio of the cup anemometer and sonic wind speeds at 100m as a function of wind direction. Does the pattern you see agree with your understanding of how the instruments are mounted and their respective boom directions?

3) The coordinates of the mast are (56.440547°N, 8.150868°E). Noting the date of the dataset, examine the site on Google Earth as it was at the time of the measurements. Identify possible obstacles (especially neighbouring wind turbines). A mast should not be considered as an obstacle but what is the justification for this?

   Knowing the boom orientations and the position of the near-by obstacles, please choose a direction sector free of their influence. This will be an important filter in the subsequent tasks.

4) Make an initial investigation of how the Windcube wind speeds compare to the relevant cup anemometer, using the direction filters you have derived so far (you can also try without the filters). Perform linear regressions and use the gain, offset and R^2 as metrics. See how, in addition, using the lidar's availability as a filter affects the result. The availability parameter is described as follows:

   The Windcube has an internal Carrier to Noise Ratio (CNR) threshold of -23dB which means that if the CNR is below that level, there's no valid measurement of the speed and direction from the lidar. The availability parameter (a channel you will find in the data) is related to the CNR values and the CNR threshold. Basically, it shows the percentage of the measurements in a 10min period that had a CNR value above the threshold and are therefore valid.

   Show 3 or 4 different regression plots using different values of the parameters.

5) Filter the wind speed from the cup anemometer to exclude the possibility of ice on the cups. Explain how you have done this and report how many data points have been removed.

   A formal lidar calibration should only use wind speeds between 4 and 16 m/s. Explain why this is and perform this filtering on your dataset.

6) With all these filters applied, make a final regression of the lidar wind speed (y- axis) versus the reference cup anemometer speed (x-axis). Give the final regression results both for a regression allowing an offset and one with the offset fixed to zero ('forced regression').

   Remove just the direction filter from the set that you used in 8) and make a scatter plot of the lidar wind direction versus the wind vane wind direction. If there are groups of points at 0 or 360 degrees that are a long way from the regression line, think about why they are there and try and find a way of removing them. Give the results of the linear regression. Does it make sense to make a regression here with a forced (through zero) offset?

7) Calculate the uncertainty of the cup anemometer used for the lidar calibration. Use the following data as input to the calculation:

   - Wind tunnel uncertainty (U_{cal_1}): 0.06 m/s, k=2
   - 'Measnet' uncertainty (U_{cal_2}): $1/\sqrt{3}$ %, k=1
   - Class number k_c= A 0.8
   - Mounting uncertainty – you decide!

   Calculate the absolute uncertainty and the relative uncertainty at 4, 8 and 12 m/s. Remember to state the units and coverage factor in your results. How much of this cup uncertainty should we transfer to the lidar being calibrated?

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Reported results

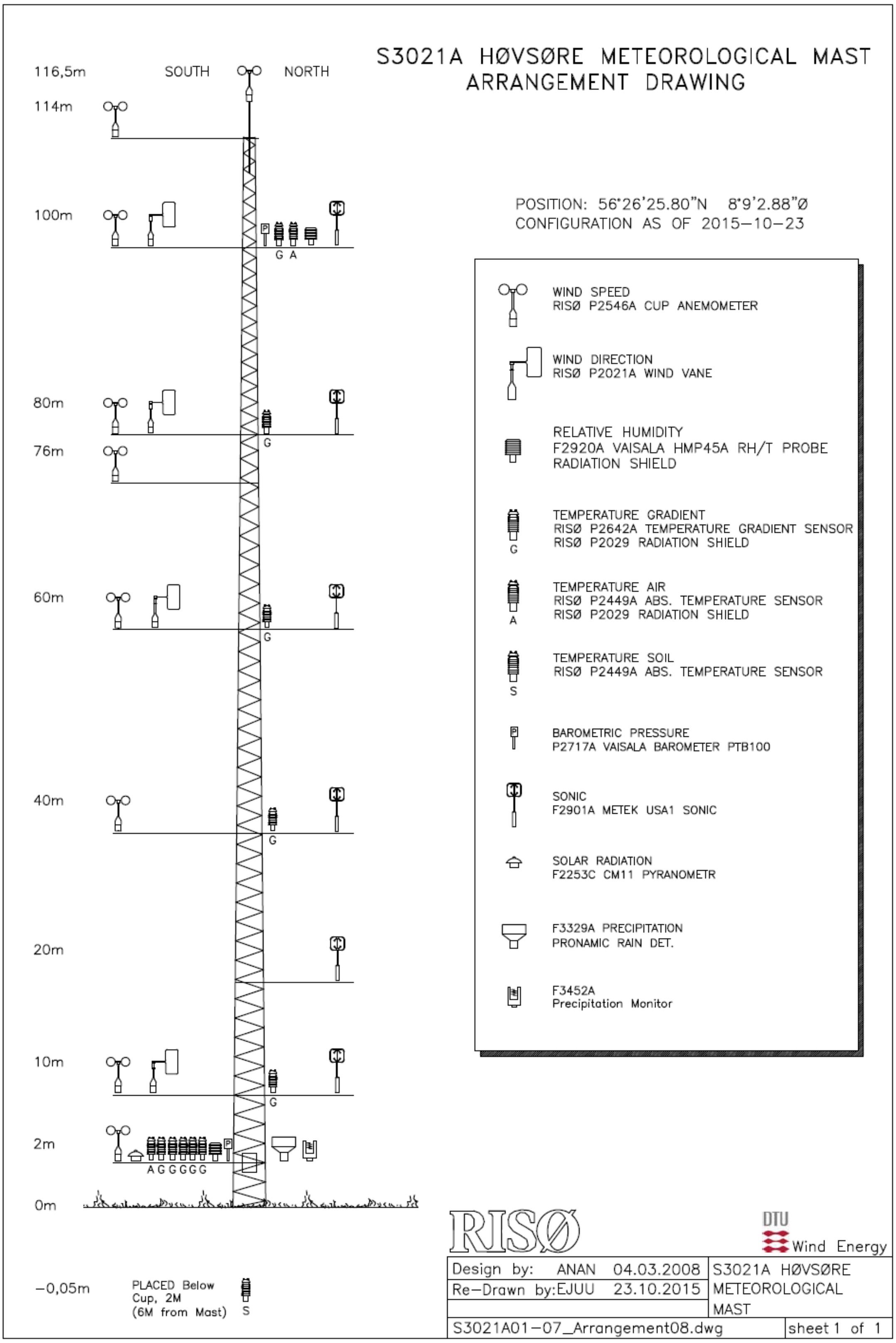
Make a short and clear document containing your answers to the 10 questions with brief explanatory text if necessary. Include all the relevant plots. Comment briefly on the results (do they look OK, are there unexpected features etc.) and explain any choices made (e.g. filtering thresholds).

It is fine to work in and submit a Jupyter notebook with code and the analysis. Please use markdown cells to explain what you are doing and give answers to the questions. Please also submit a pdf version of the notebook so that it can be checked for plagiarism. Remember to include the student participation table showing how the work has been performed.

Perform this assignment as a group assignment. In order to facilitate individual grades, it is mandatory to fill in the following table where you can also see the weighting of the different tasks.

Insert the student names in the header (instead of *Student 1* etc) and indicate the percentage of each task performed by each student. A score of 100% shows that that particular student performed all of the task (but try and avoid this if possible). Make sure that the sum of the student percentages is 100%

Question	Weight	*Student 1*	*Student 2*	*Student 3*	Sum (100%)
1)	10%				
2)	10%				
3)	10%				
4)	20%				
5)	10%				
6)	20%				
7)	20%				


S3021A HØVSØRE METEOROLOGICAL MAST
ARRANGEMENT DRAWING
116,5m
SOUTH
NORTH
114m
100m
G A
80m
G
76m
60m
G
40m
G
20m
10m
G
2m
A G G G G G
0m
−0,05m
PLACED Below
Cup, 2M
(6M from Mast)
S
POSITION: 56°26'25.80"N 8°9'2.88"Ø
CONFIGURATION AS OF 2015−10−23
WIND SPEED
RISØ P2546A CUP ANEMOMETER
WIND DIRECTION
RISØ P2021A WIND VANE
RELATIVE HUMIDITY
F2920A VAISALA HMP45A RH/T PROBE
RADIATION SHIELD
TEMPERATURE GRADIENT
RISØ P2642A TEMPERATURE GRADIENT SENSOR
RISØ P2029 RADIATION SHIELD
G
TEMPERATURE AIR
RISØ P2449A ABS. TEMPERATURE SENSOR
RISØ P2029 RADIATION SHIELD
A
TEMPERATURE SOIL
RISØ P2449A ABS. TEMPERATURE SENSOR
S
BAROMETRIC PRESSURE
P2717A VAISALA BAROMETER PTB100
SONIC
F2901A METEK USA1 SONIC
SOLAR RADIATION
F2253C CM11 PYRANOMETR
F3329A PRECIPITATION
PRONAMIC RAIN DET.
F3452A
Precipitation Monitor
RISØ
DTU
Wind Energy
Design by: ANAN 04.03.2008
Re−Drawn by:EJUU 23.10.2015
S3021A HØVSØRE
METEOROLOGICAL
MAST
S3021A01−07_Arrangement08.dwg
sheet 1 of 1