WIND KNOWLEDGE | IS WIND POWER

WindSim Flow Model Uncertainty

WindSim 13th User Meeting, Hamburg 24 September 2018

PRESENTED BY: Di Li

windsim

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- Common Requirements on Flow Model
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- Conceptual Test
- Discussion

Background

Source of uncertainty	[GWh/yr]	Standard Uncertainty
Measurement	11.0	2.5%
Long-term Correction	10.6	2.4%
Vertical Extrapolation	9.2	2.1%
Horizontal Extrapolation	28.6	6.5%
Loss factors (10 year)	11.9	2.7%
Inter-annual Variability (10 year)	10.1	2.3%
Overall Energy Uncertainty (10 year)	37.1	8.4%

Common Requirements on Flow Model

- Model verification
- Appropriateness of model simplifications
- Model input data
- Flow field resolution
- Flow variable resolution
- Model validation
- Model sensitivity analysis

Methods

2% - 10%

$$u = A\,d + B$$

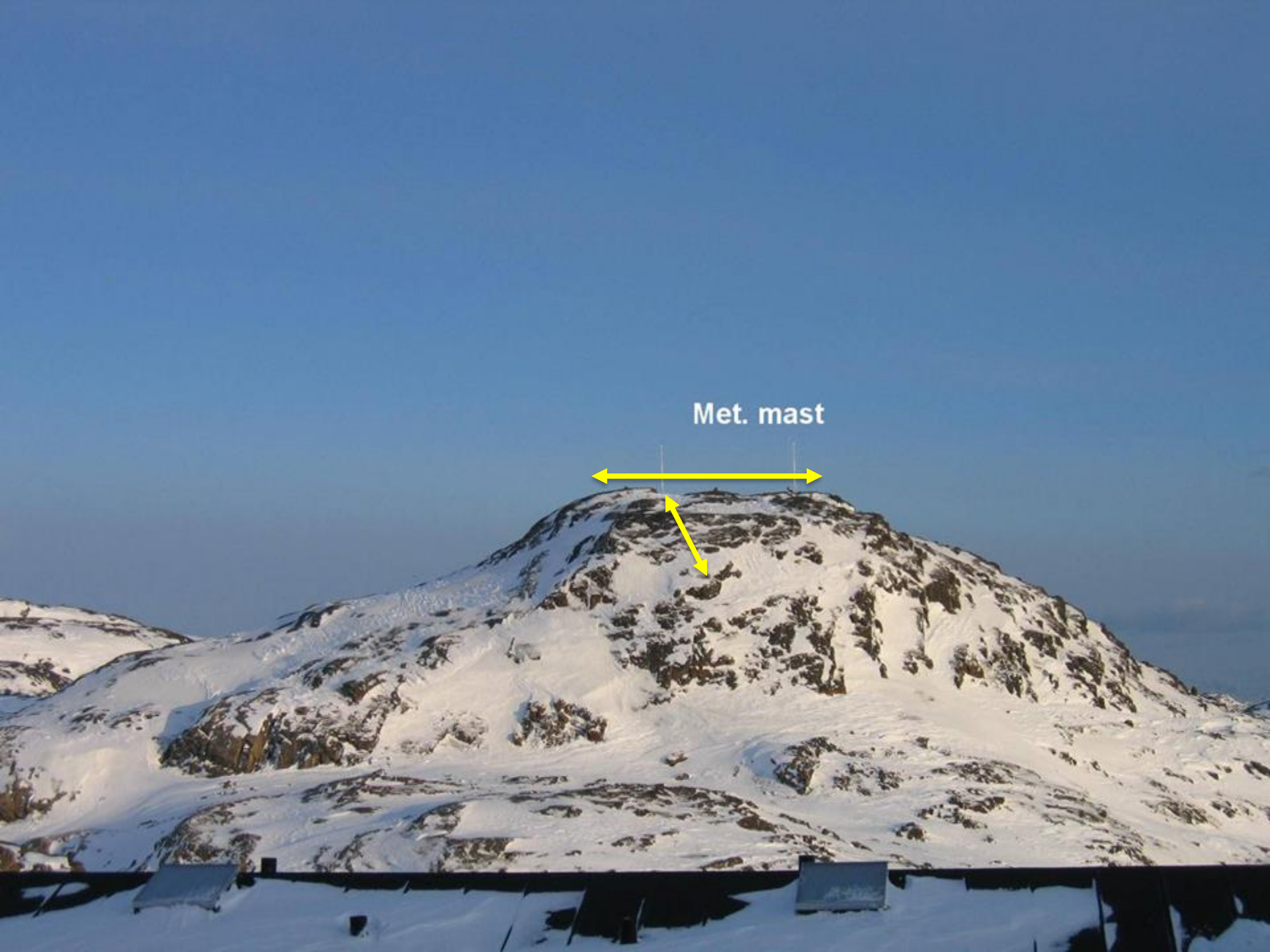
$$u = A\,Dt$$

$$u = f\,(Dw)$$

Methods

$$u = A\,d + B$$

- A, B – Constants, cross prediction
- d - distance between turbines and met mast
- Simple to apply
- Not really work in complex site


Met. mast

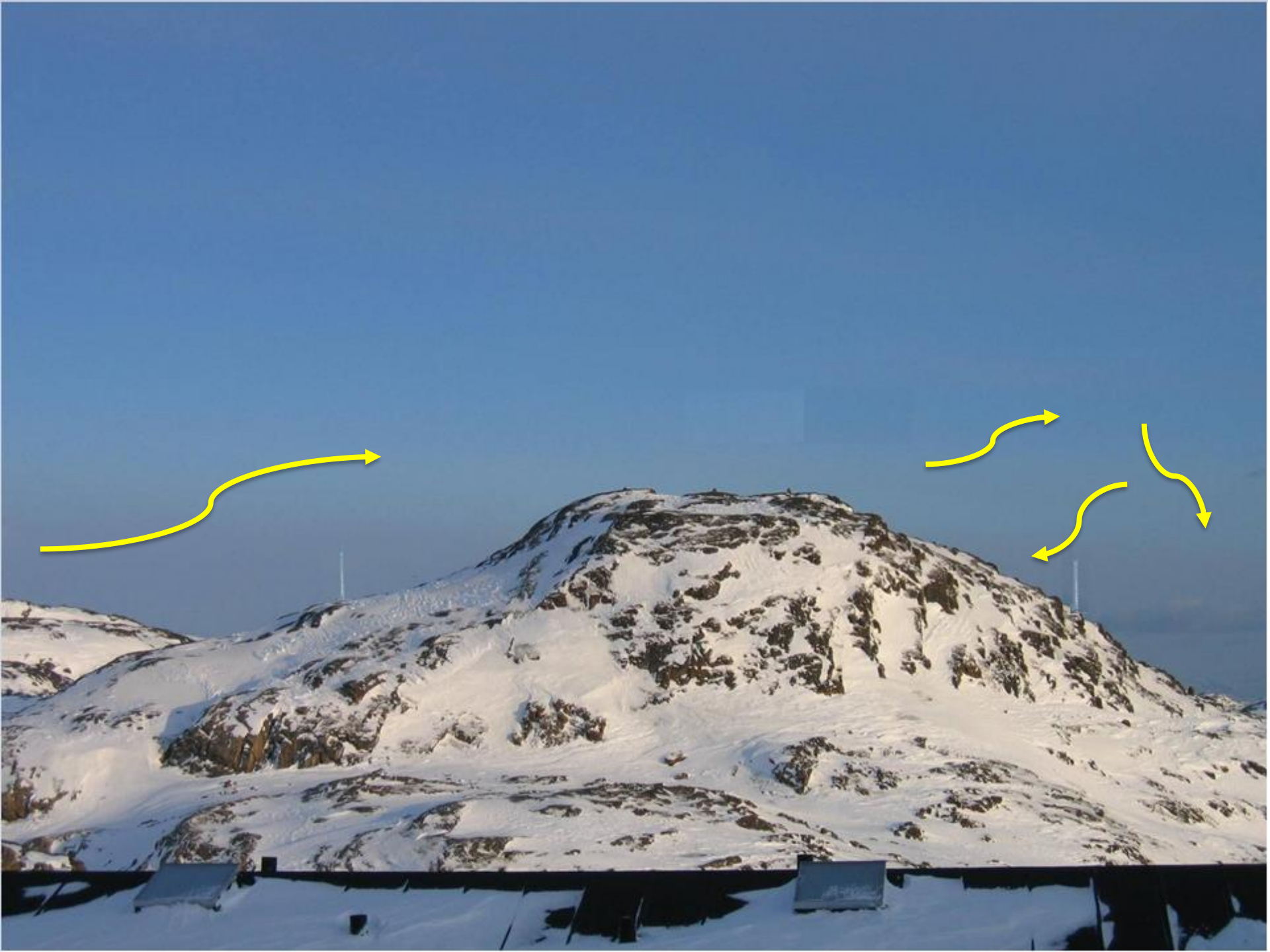
Methods

$$u = A\ Dt$$

- A – Constant, cross prediction, previous cases

- Dt – terrain change index, based on elevation and roughness change of surronding terrain.

- May not work in some situation in complex site



Methods

$$u = f\,(Dw)$$

- f() – cross prediction, previous cases
- Dw– wind change index, based on wind speed and direction change in flow model.

Basic assumptions:

- Flow model should be capable for the case
- If wind change more, uncertainty is higher

$$y = A\,x\ ,\ R^2$$

Methods

$$u = B\left(1 - Cu\frac{C_1}{U + C_1} - Cd\frac{C_2}{D + C_2}\right)$$

- B – Constant, base uncertainty, highest limit
- C_u – Constant, related to wind speed change, $C_u + C_d$ should be 1 or bit less than 1.
- C_d – Constant, related to wind direction change
- C_1 – Constant, related to how sensitive the uncertaitny to wind speed change
- C_2 – Constant, related to how sensitive the uncertaitny to wind direciton change

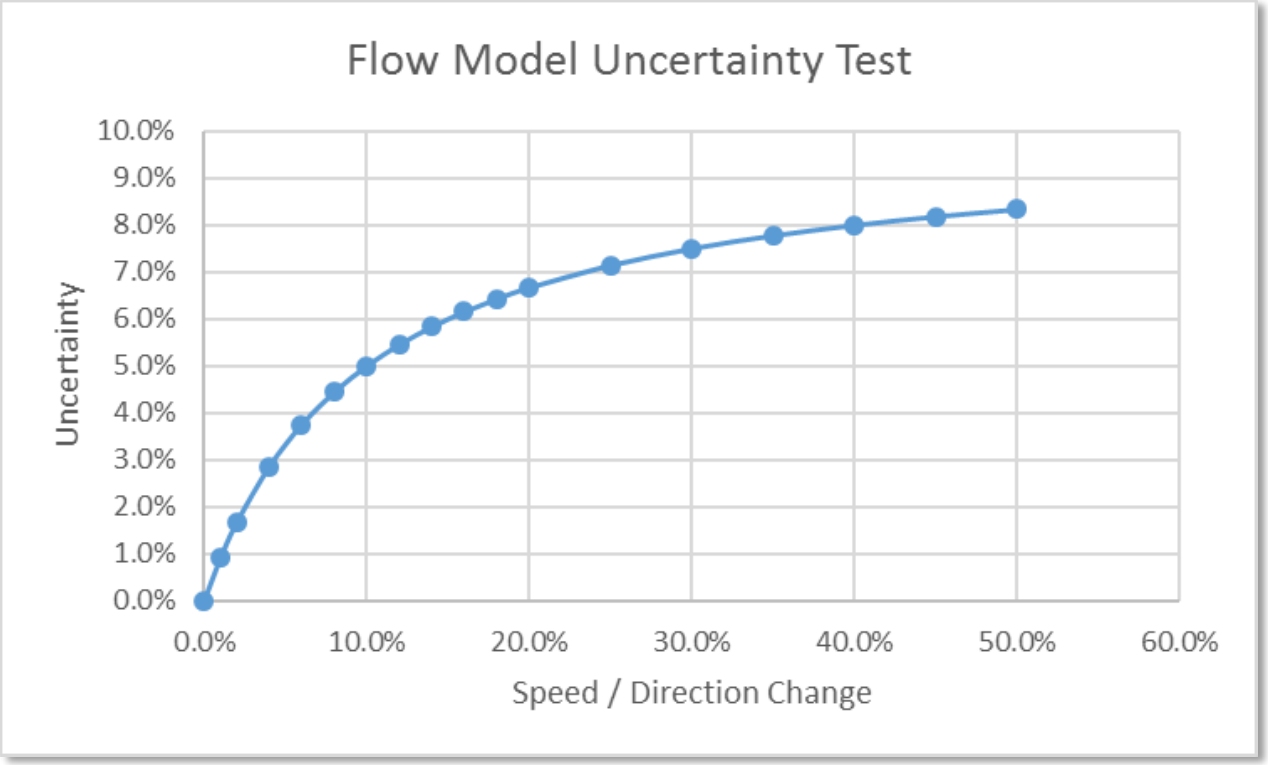
$$U = \sqrt{\sum\left[f_t(\frac{v_t}{v_r} - 1)\right]^2}$$

$$D = \sqrt{\sum[f_t - fr)]^2}$$

- U – Indicator of wind speed change.
- D – Indicator of wind direction change.
- f – Direction frequency, t as target, r as reference
- v – Mean wind speed, t as target, r as reference

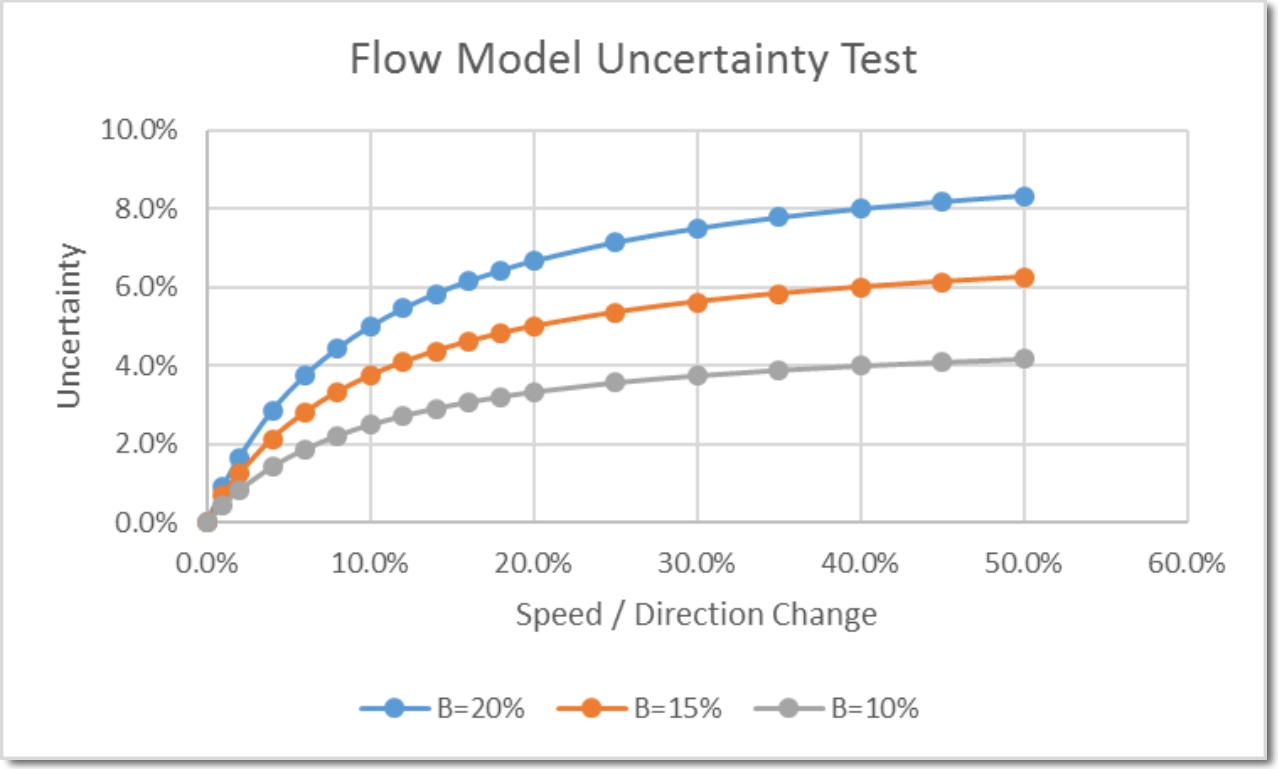
Conceptual test

- B = 20%;
- C_u = 0.5;
- C_d = 0.5;
- C_1 = 0.1;
- C_2 = 0.1
- D = 0
- U – variable



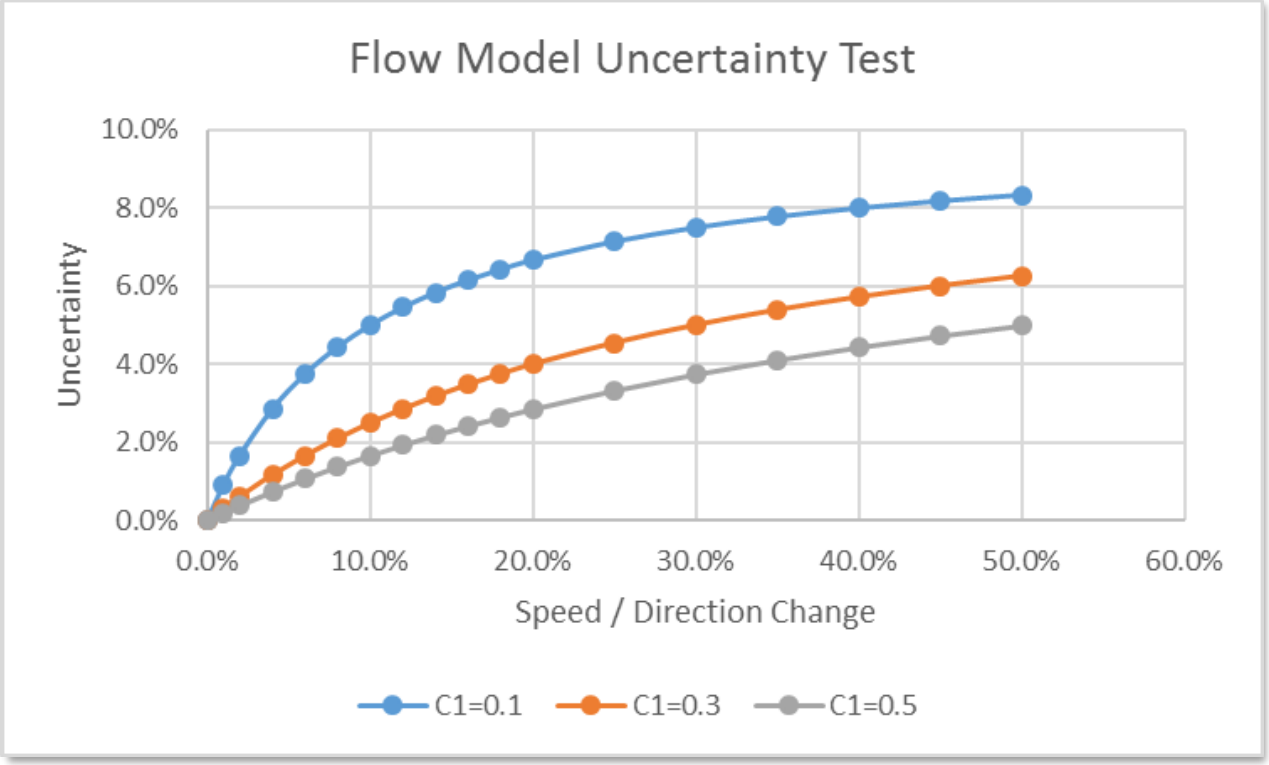
Conceptual test

- B = 20%, 15%, 10%;
- C_u = 0.5;
- C_d = 0.5;
- C_1 = 0.1;
- C_2 = 0.1
- D = 0
- U – variable



Conceptual test

- B = 20%;
- C_u = 0.5;
- C_d = 0.5;
- C_1 = 0.1, 0.3, 0.5;
- C_2 = 0.1
- D = 0
- U – variable



Conceptual test

```
WECS number        :          2CRLF
WECS name          : Turbine_SCRLF
Manufacturer       : windsimCRLF
Type               : ws2000CRLF
Nominal effect     :       2000CRLF
Hub height         :      100.0CRLF
x (local)          :     5775.8CRLF
y (local)          :     3024.7CRLF
x (global)         :   721775.8CRLF
y (global)         :   222024.7CRLF
Density (kg/m2)    :    1.22500CRLF
CRLF
```

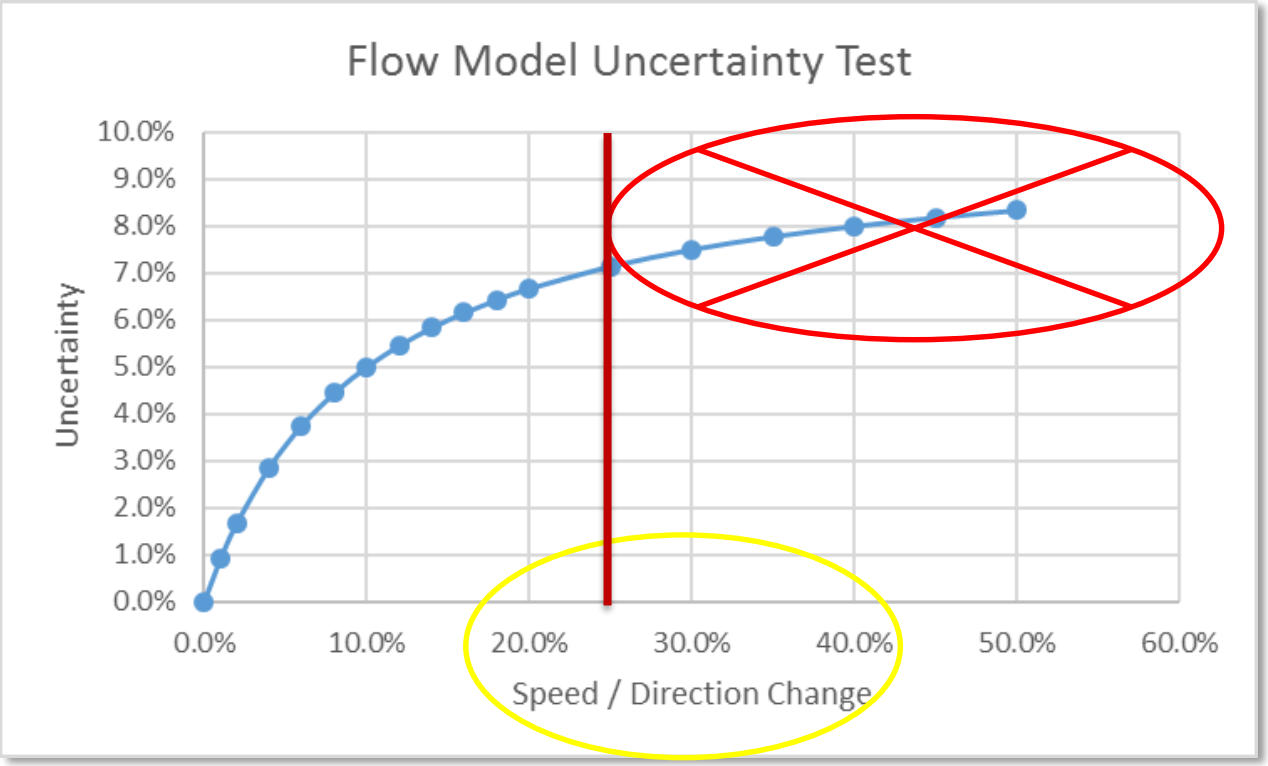
Sector	Energy (MWh/y)	Speed wecs (m/s)	Speedup (-)	Speed ref (m/s)	Freq, ref	A, ref	k, ref	Freq, turb	A, turb	k, turb	Power den. (W/m2)l
1	15.8	2.27	0.943	2.41	0.0522	2.64	1.53	0.0522	2.75	1.66	0.95CRLF
2	2.3	1.43	0.620	2.31	0.0397	2.47	1.33	0.0397	1.37	1.15	0.22CRLF
3	0.5	1.32	0.873	1.52	0.0229	1.72	1.53	0.0229	1.84	1.97	0.09CRLF
4	3.5	1.68	0.956	1.76	0.0238	1.89	1.22	0.0238	1.99	1.32	0.28CRLF
5	324.0	4.74	0.911	5.21	0.0920	5.82	1.41	0.0920	5.70	1.59	18.99CRLF
6	3073.8	8.38	1.107	7.57	0.3545	8.77	2.01	0.3545	9.78	2.07	262.61CRLF
7	66.7	3.26	1.006	3.24	0.0309	2.38	0.77	0.0309	2.36	0.77	5.37CRLF
8	3.0	1.36	1.000	1.36	0.0130	1.36	0.91	0.0130	1.37	0.91	0.18CRLF
9	5.2	1.33	0.852	1.56	0.0172	1.39	0.79	0.0172	1.66	0.98	0.31CRLF
10	4.8	1.40	0.467	3.01	0.0776	3.14	1.23	0.0776	1.74	1.48	0.46CRLF
11	175.6	3.10	0.939	3.30	0.1808	3.41	1.23	0.1808	3.61	1.41	11.23CRLF
12	55.4	2.67	0.997	2.68	0.0954	2.86	1.37	0.0954	2.87	1.38	3.25CRLF
1 - 12	3730.5	4.72	1.007	4.69	1.0000	4.64	1.12	1.0000	4.47	1.02	303.93CRLF

$$U = \sqrt{\sum \left[f_t \left(\frac{v_t}{v_r} - 1 \right) \right]^2}$$

$$D = \sqrt{\sum [f_t - fr)]^2}$$

Conceptual test

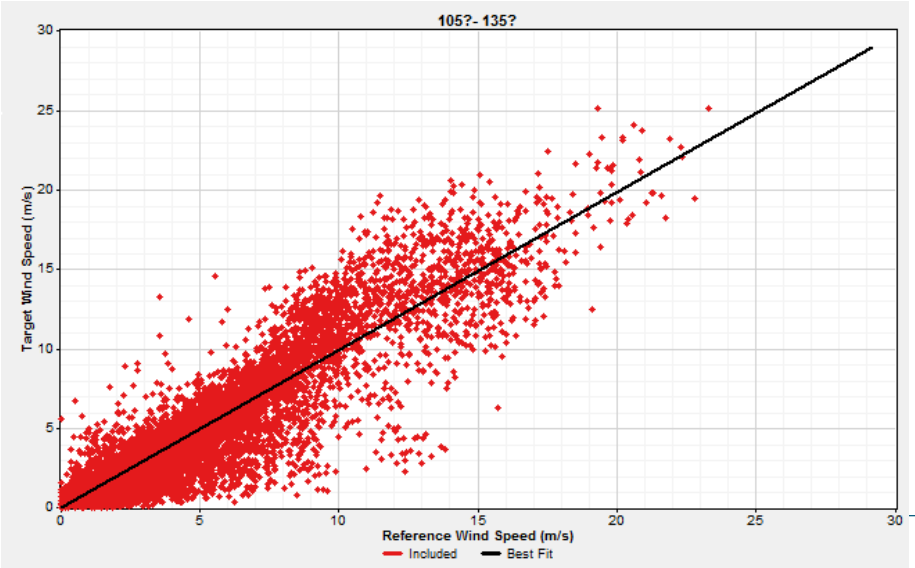
- Limitation

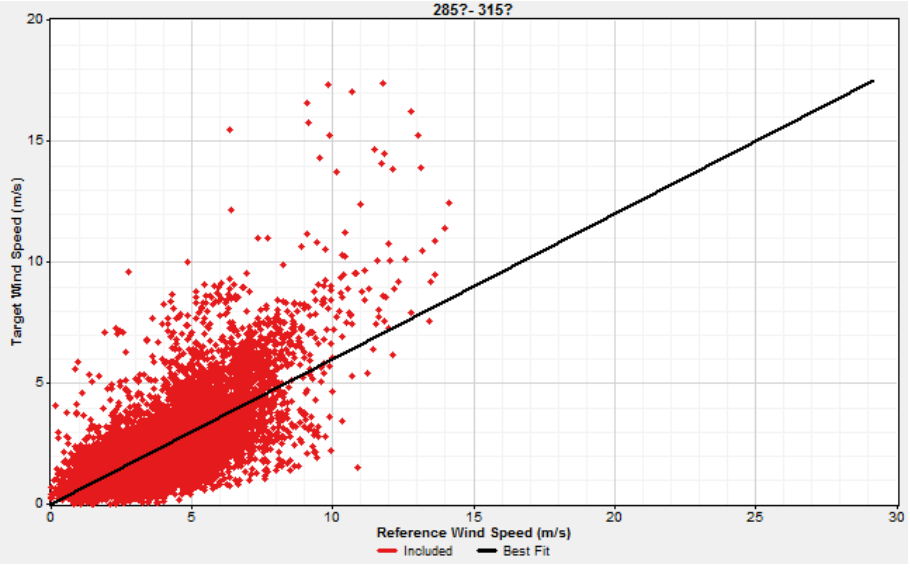


Conceptual test

- Limitation

Sector	Time Steps	Best-fit Intercept (m/s)	Best-fit Slope	R2
345?- 15?	4,032	0.000	0.672	0.496
15?- 45?	507	0.000	0.698	0.293
45?- 75?	335	0.000	1.282	0.179
75?- 105?	714	0.000	0.829	0.765
105?- 135?	8,456	0.000	0.992	0.820
135?- 165?	17,900	0.000	1.154	0.681
165?- 195?	801	0.000	1.111	0.667
195?- 225?	136	0.000	1.082	0.173
225?- 255?	168	0.000	1.246	0.156
255?- 285?	598	0.000	0.795	0.407
285?- 315?	8,097	0.000	0.601	0.451
315?- 345?	12,688	0.000	0.675	0.606
All	54,432			0.626





Thank you

di.li@windsim.com

WindSim AS
Fjordgaten 13
3125 Tønsberg, Norway
Tel: +47 33 38 18 00

WindSim Americas
2945 Townsgate Road Westlake Village
California 91361, USA
Tel: +1 805 216 0785

WindSim Brasil
Market Place II, Av. Doutor Chucri Zaidan, 940
16º andar, Vila Gertrudes
São Paulo – SP 04583-110, Brasil
Tel: +55 11 5095 3430

WindSim China
No. 101 Shaoyang Beili
Chaoyang District
100029 Beijing, China
Tel: +86 186 1029 1570

WindSim France
3 Rue du Fin
F-60410 Saint Vaast de Longmont, France
Tel: +33 683 26 08 27

WindSim India
Suite # 617 Regus Milenia Business Park
Phase 2, Level - 6, Campus 4B, No - 1 43,
Dr.M.G.R Road Kandanchavady, Perungudi
Chennai 600 096, India
Tel: +91 98 4032 2786

WindSim Sub-Saharan Africa
16th Floor Norton Rose House Riebeeck Street
Cape Town, 8000, South Africa
Tel: +27 79 367 2593