

Memo to: All readers of DNV GL reports 10129033-R-6-E and 10129033-R-7-D Memo No:10129033-M-1-APrepared by:Andreas MarkVerified by:Bastian SchmidtDate:2020-01-07

Detailed description of data filtering methodology for FLS pre-deployment validations at Fugro's test site Frøya, Norway.

In chapter 3.3 of the reports 10129033-R-6-E (WS187) and 10129033-R-7-D (WS188), a special data filtering method is described:

Due to coastal effects in combination with the large separation distance between RLL and FLS, some datasets are not suitable for the validation because the wind conditions are different between both positions. Therefore, such datasets are excluded from the evaluation using the following two filters.

- 1. For levels 40 to 100m, only wind from 90° to 320° is used to avoid disturbed wind from land. This filter is only applied for the WS comparison but not for the WD comparison.
- 2. Data is excluded when the ratio between the reference wind speed and its moving mean (see footnote ¹) is outside the range 0.85 to 1.15. This filter is applied for WS and WD comparison for wind speeds above 4 m/s (see footnote ²). This filter is used to remove periods with high variability/fluctuations in the wind speed.

Table 1: Special filter criteria

Exclude data if:	Applied for WS comparison	Applied for WD comparison
HEIGHT <= 100 & (WD_REF < 90 WD_REF > 320)	Yes	No
WS_REF > 4 & (WS_RATIO < 0.85 WS_RATIO > 1.15)	Yes	Yes

In previous revisions of the reports 10129033-R-6-E and 10129033-R-7-D, such events were manually filtered by visual identification and exclusion of such periods. To avoid the subjective character of the visual identification, the above described filter algorithm was developed to perform a generalized data filtering methodology.

The applied filter is independent from the FLS measurements. The filter is only "looking" to the measurements of the Reference Land Lidar (RLL).

It is assumed that the wind direction filter does not require a detailed explanation. Examples for the effect of the moving mean filter are shown in Figure 1 and Figure 2. Figure 3 and Figure 4 show the Wind Speed Ratio (WS_RATIO) versus wind direction and wind speed.

Since the future validation buoys at Frøya are planned to be deployed closer to the Reference Land Lidar, a special filtering is probably not required because the comparability will be higher at shorter separation distances.

¹ WS_REF_MOV is a moving mean with a window size of 5. This means that the moving mean value is calculated from the current value, the two past values and the two future values. WS_RATIO is calculated by WS_REF/WS_REF_MOV.

² To avoid that too many datasets are excluded at lower wind speeds, the filter was only applied for wind speeds above 4 m/s. DNV GL Headquarters, Veritasveien 1, P.O.Box 300, 1322 Høvik, Norway. Tel: +47 67 57 99 00. www.dnvgl.com





Figure 1: Effect of the filter to the 120m evaluation of WS188 – Total period



Figure 2: Effect of the filter to the 120m evaluation of WS188 - Detail





Figure 3: WS188 Wind Speed Ratio vs. Wind Direction at 120m (red circles = excluded datasets)



Figure 4: WS188 Wind Speed Ratio vs. Wind Speed at 120m (red circles = excluded datasets)

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The following example is intended to test the applicability of the new filter to other FLS which were validated in the past at Frøya with a large separation distance between RLL and FLS. The re-evaluation of the WS140 validation shows that the new filter leads to improved results. WS140 was deployed separated 950m from the RLL during the period 03/05/2016 13:30 to 15/08/2016 07:40 for 103.8 days.

WS Bins / [m/s]	2to3	3to 4	4to 5	5to 6	6to 7	7to 8	8to 9	9 to 10	10to 11	11 to 12	12 to 14	14to 16	16to 18	18 to 20	20 to 22	22 to 24
Bin Center	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	13	15	17	19	21	23
Level / [m]		RLL number of 10 m in data entries per WS bin - AFTER filtering for data to be used for regression analysis														
40	992	1479	1844	1740	1463	1254	798	461	320	196	198	54	4	0	0	0
60	880	1339	1621	1701	1455	1264	980	583	375	261	252	85	12	1	0	0
80	798	1264	1554	1624	1429	1278	971	702	410	303	309	117	18	4	0	0
100	785	1202	1494	1524	1452	1200	997	711	483	341	338	152	25	7	2	0
120	791	1159	1463	1484	1392	1172	957	777	508	353	372	176	38	13	2	0
140	813	1112	1433	1445	1343	1145	960	773	549	360	390	191	55	10	5	0
160	818	1083	1406	1401	1293	1137	954	788	564	359	399	192	76	11	5	0
180	817	1068	1377	1358	1270	1108	953	792	539	388	403	202	90	11	8	0
200	827	1035	1362	1301	1241	1074	955	754	541	390	358	199	111	14	9	0

Database as reported in GLGH-4270 16 13920 258-R-0002-C:

Wind speed results as reported in GLGH-4270 16 13920 258-R-0002-C:

WS comparison		slope regr. coeff.		WS RLL avg	WS FLD avg	WS diff.	relative WS diff.
		К	Pls				
Level / [m]	#	X _{mws}	R ² _{mws}				
40	10803	1.035	0.963	5.97	6.19	0.21	3.6%
60	10809	1.016	0.971	6.29	6.39	0.10	1.6%
80	10781	1.009	0.974	6.50	6.56	0.06	1.0%
100	10713	1.006	0.977	6.64	6.68	0.05	0.7%
120	10657	1.004	0.977	6.74	6.78	0.04	0.6%
140	10584	1.004	0.978	6.81	6.85	0.04	0.6%
160	10486	1.004	0.976	6.87	6.91	0.04	0.6%
180	10384	1.003	0.976	6.92	6.95	0.03	0.5%
200	10171	1.003	0.971	6.92	6.96	0.04	0.6%



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WS140 database re-evaluated with new filter:

WS Bin/[m/s]	2 to 3	3 to 4	4 to 5	5 to 6	6 to 7	7 to 8	8 to 9	9 to 10	10 to 11	11 to 12	12 to 14	14 to 16	16 to 18	18 to 20	20 to 22	22 to 24	24 to 26	26 to 28	28 to 30
Bin Center / [m/s]	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	13	15	17	19	21	23	25	27	29
Level / [m]								# of d	ata poi	nts left	after fi	ltering							
200	827	1035	1134	1147	1087	940	871	704	508	366	319	172	109	14	9	0	0	0	0
180	817	1068	1164	1213	1132	1002	885	743	527	372	364	188	89	11	8	0	0	0	0
160	818	1083	1192	1255	1172	1030	907	758	550	346	363	184	76	11	5	0	0	0	0
140	813	1112	1241	1309	1229	1053	920	747	540	347	360	183	55	10	5	0	0	0	0
120	791	1159	1281	1344	1294	1087	907	745	496	344	349	175	38	13	2	0	0	0	0
100	413	603	605	628	626	494	437	288	185	147	178	125	25	7	2	0	0	0	0
80	411	655	605	693	571	529	408	280	171	153	169	107	17	4	0	0	0	0	0
60	455	690	629	677	555	524	413	252	177	132	158	82	12	1	0	0	0	0	0
40	539	721	691	627	572	508	375	230	154	119	148	53	4	0	0	0	0	0	0

WS140 Wind speed results with new filter:

	# values	slope	R ²	WS-avg RLL (Reference)	WS-avg WS140 (Test)	mean diff.	rel. mean difference
	-	-	-	[m/s]	[m/s]	[m/s]	%
WS-range		KPI X _{mws}	KPI R ² mws				
			200	m level			
AII >= 2 m/s	9242	1.003	0.977	6.90	6.95	0.043	0.62%
			180	m level			
AII >= 2 m/s	9583	1.003	0.980	6.92	6.96	0.035	0.51%
			160	m level			
All >= 2 m/s	9750	1.004	0.980	6.88	6.93	0.041	0.59%
			140	m level			
All >= 2 m/s	9924	1.003	0.980	6.83	6.86	0.037	0.55%
			120	m level			
AII >= 2 m/s	10025	1.004	0.980	6.75	6.79	0.040	0.59%
			100	m level			
All >= 2 m/s	4763	1.010	0.986	6.70	6.78	0.075	1.12%
			80	m level			
All >= 2 m/s	4773	1.012	0.985	6.57	6.66	0.084	1.27%
			60	m level			
All >= 2 m/s	4757	1.015	0.982	6.39	6.49	0.101	1.58%
			40	m level			
All >= 2 m/s	4741	1.024	0.977	6.13	6.29	0.156	2.55%







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The following table shows the impact of the new filter to the database in comparison to the old evaluation without filter. It can be seen in the wind rose that a lot of the wind came from the sector which is excluded for the heights 40m to 100m. This explains the high numbers (red) in the table.

WS Bin/[m/s]	2 to 3	3 to 4	4 to 5	5 to 6	6 to 7	7 to 8	8 to 9	9 to 10	10 to 11	11 to 12	12 to 14	14 to 16	16 to 18	18 to 20	20 to 22	22 to 24	24 to 26	26 to 28	28 to 30
Bin Center / [m/s]	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	13	15	17	19	21	23	25	27	29
Level / [m]	# of data points left after filtering																		
200	0	0	-228	-154	-154	-134	-84	-50	-33	-24	-39	-27	-2	0	0	0	0	0	0
180	0	0	-213	-145	-138	-106	-68	-49	-12	-16	-39	-14	-1	0	0	0	0	0	0
160	0	0	-214	-146	-121	-107	-47	-30	-14	-13	-36	-8	0	0	0	0	0	0	0
140	0	0	-192	-136	-114	-92	-40	-26	-9	-13	-30	-8	0	0	0	0	0	0	0
120	0	0	-182	-140	-98	-85	-50	-32	-12	-9	-23	-1	0	0	0	0	0	0	0
100	-372	-599	-889	-896	-826	-706	-560	-423	-298	-194	-160	-27	0	0	0	0	0	0	0
80	-387	-609	-949	-931	-858	-749	-563	-422	-239	-150	-140	-10	-1	0	0	0	0	0	0
60	-425	-649	-992	-1024	-900	-740	-567	-331	-198	-129	-94	-3	0	0	0	0	0	0	0
40	-453	-758	-1153	-1113	-891	-746	-423	-231	-166	-77	-50	-1	0	0	0	0	0	0	0



The following table shows the impact of the new filter to the wind speed results in comparison to the old evaluation without filter. The slope does not change a lot but the R² results are clearly improved.

Level	Slope minus 1 (old evaluation)	Slope minus 1 (new evaluation)	R ² minus 1 (old evaluation)	R ² minus 1 (new evaluation)
[m]	-	-	-	-
WS >= 2 m/s	KPI X _{mws}	KPI X _{mws}	KPI R ² _{mws}	KPI R ² _{mws}
200	0.003	0.003	-0.029	-0.023
180	0.003	0.003	-0.024	-0.020
160	0.004	0.004	-0.024	-0.020
140	0.004	0.003	-0.022	-0.020
120	0.004	0.004	-0.023	-0.020
100	0.006	0.010	-0.023	-0.014
80	0.009	0.012	-0.026	-0.015
60	0.016	0.015	-0.029	-0.018
40	0.035	0.024	-0.037	-0.023

The application of the new filter method was successfully tested at separation distances of 690m (WS187), 960m (WS188) and 950m (WS140). It is assumed that the new filter method will also be applicable at other buoys at Frøya with similar separation distance (e.g. 600m to 1000m). For future validations at Frøya, it is planned by Fugro to avoid deployments with separation distances above approx. 500m.

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