S1 List of tall towers

Table S1: List of tall towers within the Tall Tower Dataset. The ISO ALPHA-2 code has been utilized to present the country where the tower is located. Latitudes and longitudes are shown in decimal degrees. *POR* stands for Period Of Record.

Tower name	Institution	Country	Longitude	Latitude	POR start	POR end
42361	Shell International E&P	US	-92.49	27.55	200507	201612
42362	Enven Energy Corporation	US	-90.65	27.80	200507	201612
42363	Shell International E&P	US	-89.22	28.16	200507	201606
42364	Shell International E&P	US	-88.09	29.06	200709	201612
42365	Shell International E&P	US	-89.12	28.20	201201	201311
42369	BP Inc	US	-90.28	27.21	201005	201612
42370	BP Inc	US	-90.54	27.32	201005	201211
42375	BP Inc	US	-88.29	28.52	201005	201612
42394	Shell International E&P	US	-89.24	28.16	201409	201612
42887	BP Inc	US	-88.50	28.19	200911	201612
Abadan	SATBA	IR	48.31	30.45	200709	200908
Abadeh	SATBA	IR	52.25	31.09	200606	200711
Abarkooh	SATBA	IR	53.66	31.30	200608	200801
Abhar	SATBA	IR	49.39	36.11	200706	200907
Afriz	SATBA	IR	58.96	33.45	200608	200802
Agh Ghala	SATBA	IR	54.47	37.11	200607	200710
Ahar	SATBA	IR	47.22	38.59	200811	201504
American Samoa	ESRL	AS	-170.56	-14.25	199406	201605
Ardakan	SATBA	IR	54.27	32.59	200609	200802
Asfestan	SATBA	IR	47.60	37.93	200503	200602
BAO	ESRL	US	-105.00	40.05	200706	201607
Bardkhoon	SATBA	IR	51.49	27.98	200606	200802
Barro Colorado Island	Princeton Environmental Institute	PA	-79.85	9.17	200112	201710
Barrow	ESRL	US	-156.61	71.32	198801	201605
Barzook	SATBA	IR	51.14	33.81	201506	201601
Behabad	SATBA	IR	56.12	31.78	200606	200801
Binalood	SATBA	IR	59.39	35.99	200212	200309
Bojnoord	SATBA	IR	57.25	38.14	200608	200805
Bonab	SATBA	IR	46.03	37.40	200607	200710
Boroojen	SATBA	IR	51.31	31.97	200606	200711
Boseong	Yonsei University	KR	127.35	38.27	201404	201610
Braschaat	INBO	BE	4.52	51.31	199512	201412
BURL1	NBDC	US	-89.43	28.91	198402	201612
Butler Grade	Bonneville Power Administration	US	-118.68	45.95	200208	201804
bygl1	NOAA's National Ocean Service	US	-90.42	29.79	200502	201612
Cabauw	KNMI	NL	4.93	51.97	198602	201703
Cape Point	South African Weather Service	ZA	18.48	-34.35	200701	201311

Table S1: Continued

Tower name	Institution	Country	Longitude	Latitude	POR start	POR end
Cardington	UKMO	GB	-0.42	52.10	200405	201303
Chabahar	SATBA	IR	60.66	25.33	200807	200912
Chaldoran	SATBA	IR	44.45	39.05	200607	200710
Changbaishan	Institute of Applied Ecology	CN	127.72	41.70	200212	200511
Chinook	Bonneville Power Administration	US	-119.53	45.83	200601	201611
CHLV2	NBDC	US	-75.71	36.91	198408	201606
CVO	Cape Verde Atmospheric Observatory	CV	-24.87	16.85	201110	201807
Davarzan	SATBA	IR	56.81	36.27	200607	200803
Dehake Saravan	SATBA	IR	62.67	27.14	200606	200712
Deilaman	SATBA	IR	49.91	36.88	201001	201012
Delgan	SATBA	IR	59.46	27.49	200608	200712
Delvar	SATBA	IR	51.05	28.84	200609	200801
DESW1	NBDC	US	-124.49	47.68	198408	201612
Docking Shoal	Centrica	GB	0.65	53.16	200606	200908
Eghlid	SATBA	IR	52.62	30.89	200606	200805
Egmond aan Zee	ECN	NL	4.39	52.61	200508	201012
Enjilavand	SATBA	IR	50.67	34.94	201105	201207
Esfaryen	SATBA	IR	57.40	37.05	200608	200803
Eshtahard	SATBA	IR	50.69	35.73	200807	200912
Fadashk	SATBA	IR	58.79	32.78	200608	200802
Falideh	SATBA	IR	49.40	36.81	200207	200403
Fino1	Fino Project	DE	6.59	54.01	200401	201710
Fino2	Fino Project	DE	13.15	55.01	200707	201711
Fino3	Fino Project	DE	7.16	55.20	200909	201711
fmoa1	NOAA's National Ocean Service	US	-88.02	30.23	200810	201612
fsnm2	NOAA's National Ocean Service	US	-76.53	39.22	201604	201612
Fuji Hokuroku	NIES	JP	138.76	35.44	200512	200911
FWYF1	NBDC	US	-80.10	25.59	199106	201612
Ganje	SATBA	IR	49.46	36.86	200207	200310
Gardaneh Almas	SATBA	IR	48.67	37.59	200906	201009
Ghadamgah	SATBA	IR	59.01	36.06	200609	200803
Ghoroghchi	SATBA	IR	51.00	33.59	201305	201408
Ghorveh	SATBA	IR	47.75	35.18	200810	200912
Goodnoe Hills	Bonneville Power Administration	US	-120.55	45.78	200201	201804
Greater Gabbard MMX Mast	Innogy SE; SSE Renewables	GB	1.90	51.86	201205	201501
Greater Gabbard MMZ Mast	Innogy SE; SSE Renewables	GB	1.92	51.94	200509	201412

Table S1: Continued

Tower name	Institution	Country	Longitude	Latitude	POR start	POR end
Gunfleet Sands	Development Back of Japan - Marubeni Corporation; Dong Energy	GB	1.20	51.73	200201	200711
Gwangneung Deciduous Forest	Seoul National University	KR	127.15	37.75	200312	200811
Gwynt Y Mor	UK Green Investment Bank	GB	-3.51	53.48	200509	200804
Hadadeh	SATBA	IR	54.73	36.25	200608	200802
Haft Chah	SATBA	IR	52.43	27.72	201002	201107
Halvan	SATBA	IR	56.30	33.96	200607	200802
Hamburg University	Hamburg University	DE	10.10	53.52	200401	201812
Hegyhatsal	Hungarian met service	HU	16.65	46.96	199408	201611
Hendijan	SATBA	IR	49.77	30.12	201004	201110
Hesarak	SATBA	IR	51.32	35.80	201102	201201
Hormozgan University	SATBA	IR	56.44	27.26	201402	201601
Hoseinieh	SATBA	IR	48.18	30.80	200711	200908
Huisun	National Chung Hsing University	TW	121.13	24.08	201012	201311
Humber Gateway	E.ON	GB	0.27	53.64	200910	201210
Hyytiala	Helsinki university	FI	24.29	61.85	199512	201710
Ijmuiden	ECN	NL	3.44	52.85	201111	201603
Inner Dowsing	UK Green Investment Bank	GB	0.44	53.13	199908	200802
Jangal	SATBA	IR	59.21	34.70	200607	200803
Jask	SATBA	IR	58.11	25.69	200608	200709
Javim	SATBA	IR	54.09	28.19	200606	200711
Jirandeh	SATBA	IR	49.78	36.71	200303	200407
Juelich	Research Center Juelich - Institute for Energy and Climate Research (IEK-8)	DE	6.22	50.93	201110	201712
Kaboodar Ahang	SATBA	IR	48.75	35.35	200607	200710
Kahak Garmsar	SATBA	IR	52.32	35.12	200607	200802
Kahrizak	SATBA	IR	51.32	35.47	200708	200903
Kennewick	Bonneville Power Administration	US	-119.12	46.10	200201	201804
Kentish Flats	Vatenfall AB	GB	1.09	51.46	200210	200501
Kerend Gharb	SATBA	IR	46.19	34.43	201204	201407
Khaf	SATBA	IR	60.31	34.49	200707	200903
Khalkhal Bafrajerd	SATBA	IR	48.57	37.54	201109	201410
Khalkhal Eilkhichi	SATBA	IR	48.25	37.63	200906	201103
Khash	SATBA	IR	61.06	28.10	200606	200712
Khomein	SATBA	IR	50.16	33.80	200607	200709
Kohein	SATBA	IR	49.71	36.34	201105	201504
Korit	SATBA	IR	56.95	33.44	200607	200801
Langrood	SATBA	IR	50.23	37.26	200607	200804

Table S1: Continued

Tower name	Institution	Country	Longitude	Latitude	POR start	POR end
Larijan	SATBA	IR	52.22	35.98	201006	201105
Latman	SATBA	IR	51.23	35.77	200708	200808
Likak	SATBA	IR	50.12	30.86	201009	201106
Lindenberg	DWD	DE	14.12	52.17	199901	201701
London Array	E.ON; Caisse; Dong Energy; Masdar	GB	1.39	51.59	200412	201012
Lootak Zabol	SATBA	IR	61.39	30.73	200606	201001
lopl1	Louisiana Offshore Oil Port	US	-90.03	28.89	201108	201612
Lutjewad	Gronigen university	NL	6.35	53.40	200012	201701
Mae Klong	National Institute of Advanced Industrial Science and Technology	TH	98.84	14.58	200212	200411
Mahidasht	SATBA	IR	46.73	34.39	200606	200709
Mahshahr	SATBA	IR	49.09	30.58	200709	200908
Malin Head	Met Eireann	IE	-7.33	55.35	198801	201712
Manjil	SATBA	IR	49.40	36.74	200402	200411
Marvdasht	SATBA	IR	52.92	29.98	200606	200711
Mauna Loa	ESRL	US	-155.58	19.54	199101	201605
Mayan	SATBA	IR	46.05	38.09	200607	200801
Megler	Bonneville Power Administration	US	-123.88	46.27	200210	201804
Meshkin Shahr	SATBA	IR	47.73	38.27	200811	201003
mhrn6	NOAA's National Ocean Service	US	-74.16	40.64	201505	201612
Mil Nader	SATBA	IR	61.16	31.09	201009	201203
Mir Javeh	SATBA	IR	61.44	29.03	200905	201008
Mir Khand	SATBA	IR	49.40	36.67	200207	200310
Moalleman	SATBA	IR	54.57	34.87	200608	200802
Moghar	SATBA	IR	52.18	33.57	200606	200711
Nahavand	SATBA	IR	48.21	34.27	200607	200709
Namin	SATBA	IR	48.38	38.38	200607	200712
Nanortalik	DTU	DK	-45.23	60.14	200706	200906
Naselle Ridge	Bonneville Power Administration	US	-123.80	46.42	201002	201804
Nikooye	SATBA	IR	49.53	36.31	200911	201206
Nir	SATBA	IR	47.98	38.03	201305	201411
NOAH	FoundOcean	GB	-1.49	55.14	201209	201403
Nosrat Abad	SATBA	IR	60.16	29.81	200606	200712
NWTC M2	NREL	US	-105.23	39.91	199609	201701
NWTC M4	NREL	US	-105.23	39.91	201201	201604
NWTC M5	NREL	US	-105.23	39.21	201208	201705
Obninsk	Institute of Experimental Technology	RU	36.60	55.11	200712	201604
Oestergarnsholm	Uppsala university	SE	18.98	57.43	200306	201412

Table S1: Continued

Tower name	Institution	Country	Longitude	Latitude	POR start	POR end
Ohio State University	Ohio State University	US	-84.71	45.56	200701	201707
Old Aspen	UCAR	CA	-106.20	53.63	200210	200912
Palangkaraya	Hokkaido Universit	ID	114.04	2.35	200112	200511
Papooli	SATBA	IR	50.06	36.08	200907	201011
Pasoh	Kyoto University	MY	102.30	2.97	200212	200911
Puijo	Finnish Meteorological Institute	FI	27.65	62.91	200510	201512
Qianyanzhou	Northwest Plateau Institute of Biology	CN	115.07	26.73	200212	200411
Race Bank	Race Bank	GB	0.75	53.31	200606	201304
Rafsanjan	SATBA	IR	56.22	30.32	200606	200807
ROAM4	NBDC	US	-89.31	47.87	198310	201612
Roodab	SATBA	IR	57.35	36.05	200808	201003
Rostamabad	SATBA	IR	49.49	36.90	200201	200307
Sakaerat	National Institute of Advanced Industrial Science and Technology	TH	101.92	14.49	200012	200311
Sanar	SATBA	IR	51.31	36.50	200607	200708
Sarakhs	SATBA	IR	61.14	36.31	200609	200711
Saravan	SATBA	IR	62.26	27.42	201010	201110
Saveh Site	SATBA	IR	50.40	35.08	200805	200909
Semnan	SATBA	IR	53.45	35.62	200907	201011
Seven Mile	Bonneville Power Administration	US	-121.27	45.63	200201	201804
SGOF1	NBDC	US	-84.86	29.41	200310	201612
Shahr Abad	SATBA	IR	56.20	37.65	201104	201112
Shahr Babak	SATBA	IR	55.22	30.09	200609	200807
Shandol	SATBA	IR	61.66	31.15	201010	201201
Shell Flats Mast 1	Centrica UK	GB	-3.29	53.86	201107	201312
Shell Flats Mast 2	Centrica UK	GB	-3.20	53.87	201107	201401
Sheykh Tapeh	SATBA	IR	45.08	37.52	201207	201504
Shiraz Site	SATBA	IR	52.61	29.37	200712	200906
Shooshtar	SATBA	IR	48.76	31.79	200711	200908
Shorjeh	SATBA	IR	49.44	36.07	200807	201001
skmg1	Skidaway Institute of Oceanography	US	-80.24	31.53	200409	200801
Sodankyla	FMI	FI	26.64	67.36	200012	201412
South Carolina	Savannah River National Laboratory	US	-81.83	33.41	200904	201712
South Pole	ESRL	US	-24.80	-89.98	197901	201605
spag1	Skidaway Institute of Oceanography	US	-80.57	31.38	200401	200909
STDM4	NBDC	US	-87.23	47.18	198407	201612

Table S1: Continued

Tower name	Institution	Country	Longitude	Latitude	POR start	POR end
Summit	ESRL	GL	-38.48	72.58	200806	201605
Tafresh	SATBA	IR	50.06	34.68	201009	201302
Taleghan Site	SATBA	IR	50.57	36.12	200712	201002
Tange Hashi	SATBA	IR	52.96	29.18	201503	201509
Tarom	SATBA	IR	49.03	36.66	201106	201306
Tiksi	Roshydromet - Finnish Meteorological Institue U.S. National Oceanic and Atmospheric Administration	RU	128.89	71.60	201008	201809
Too Takaboon	SATBA	IR	49.52	36.91	200204	200312
Trinidad Head	ESRL	US	-124.15	41.05	200204	201605
Troutdale	Bonneville Power Administration	US	-122.40	45.56	201002	201804
Tumbarumba	CSIRO Marine and Atmospheric Research	AU	148.15	-35.66	200101	201412
tybg1	Skidaway Institute of Oceanography	US	-79.93	31.63	200401	200801
upbc1	NOAA's National Ocean Service	US	-122.12	38.04	201302	201612
Varzaneh	SATBA	IR	52.62	32.46	200606	200810
Vasf	SATBA	IR	50.93	34.19	200809	200902
Vielsalm	Universite Catholique de Louvian	BE	6.00	50.31	199608	200904
Wallaby Creek	University of Western Australia	AU	145.19	-37.43	200501	200812
Walnut Grove	ESRL/DOE	US	-121.49	38.27	200508	201611
Wasco	Bonneville Power Administration	US	-120.77	45.50	200509	201804
wdel1	Shell International E&P	US	-89.55	28.66	200812	201609
West Branch	ESRL; IOWA university	US	-91.35	41.72	200801	200807
WLEF	ESRL	US	-90.27	45.95	200301	201711
WM01	Republic of SouthAfrica - dept. of Energy	ZA	16.66	-28.60	201006	201701
WM02	Republic of SouthAfrica - dept. of Energy	ZA	19.36	-31.52	201006	201701
WM03	Republic of SouthAfrica - dept. of Energy	ZA	18.42	-31.73	201006	201701
WM04	Republic of SouthAfrica - dept. of Energy	ZA	18.11	-32.85	201005	201306
WM05	Republic of SouthAfrica - dept. of Energy	ZA	19.69	-34.61	201005	201701
WM06	Republic of SouthAfrica - dept. of Energy	ZA	20.69	-32.56	201009	201612
WM07	Republic of SouthAfrica - dept. of Energy	ZA	22.56	-32.97	201005	201701

Table S1: Continued

Tower name	Institution	Country	Longitude	Latitude	POR start	POR end
WM08	Republic of SouthAfrica - dept. of Energy	ZA	24.51	-34.11	201008	201701
WM09	Republic of SouthAfrica - dept. of Energy	ZA	25.03	-31.25	201009	201612
WM10	Republic of SouthAfrica - dept. of Energy	ZA	28.14	-32.09	201008	201612
WM11	Republic of SouthAfrica - dept. of Energy	ZA	28.07	-30.81	201510	201707
WM12	Republic of SouthAfrica - dept. of Energy	ZA	30.53	-29.85	201510	201707
WM13	Republic of SouthAfrica - dept. of Energy	ZA	32.17	-27.43	201510	201707
WM14	Republic of SouthAfrica - dept. of Energy	ZA	29.54	-27.88	201510	201707
WM15	Republic of SouthAfrica - dept. of Energy	ZA	27.12	-28.62	201509	201707
wslm4	Great Lakes Environmental Research Laboratory	US	-85.14	45.84	201504	201612
Xishuangbanna	Xishuangbanna Tropical Botanical Garden	CN	101.20	21.95	200212	200511
Zahedan	SATBA	IR	60.81	29.47	201101	201201
Zarrineh2	SATBA	IR	46.93	36.06	201503	201601
Zartoshtabad	SATBA	IR	48.50	37.61	201408	201504

S2 QC main tests

S2.1 Plausible values

Wind speed and wind direction records falling outside a physically possible range of values are commonly found within the time series. They are mainly produced by gross errors in the data loggers or storage. This test detects and flags unrealistic values such as negative wind speed values or observations above a maximum allowed threshold. The absolute maximum limit has been set to the maximum wind gust measurement ever recorded on the earth surface, which is 113.3 ms^{-1} measured in Barrow Island (Australia) under the effects of Olivia cyclone in April 1996 (Courtney et al., 2012). A lower threshold can be selected from which wind speed values can be flagged as suspect. This value is set to 75 ms^{-1}, which is the one suggested by the WMO (WMO, 2007) and besides, this fixed-value also corresponds to Vaisala's sensors highest measurable value. Wind direction values falling outside the range from 0 to 360 degrees are also flagged as erroneous.

S2.2 Difference between extreme values of the wind distribution

One of the potential uses of the Tall Tower Dataset is the detection of severe weather events by looking at the extreme values of the empirical wind speed distribution. However, some of these extreme measurements might be erroneous and need to be flagged accordingly. This QC check detects and flags unrealistic extreme wind speed values of the time series by checking the difference between the maximum and the second maximum values of the distribution of wind speed values. If the difference between them exceeds the absolute value of the second maximum, the first maximum is flagged as suspect. This test runs iteratively until the previously mentioned condition is not satisfied.

S2.3 Persistence test

Wind time series are usually characterized by strong variability, alternating periods of high and low fluctuations. Nevertheless, the presence of long periods of extremely low variability can be unrealistic since they can be produced by errors in the measuring sensors or instrumental drift. The persistence test detects and flags sequences of wind speed and wind direction observations with abnormally low variability. However, it is important to take into consideration those relatively long periods with very low variability and mean wind speed values close to zero are typical of the observed natural variability (e.g., static high-pressure systems during several days in a row producing weak winds). Hence, these data cannot be considered erroneous. Thus, the persistence test does not introduce any flag to wind speeds weaker than 0.5 ms^{-1}. These measurements are then flagged as calms.

The WMO proposes that 1-minute data should vary at least 0.5 ms^{-1} over 60 consecutive wind speed values, and 10 degrees in the case of wind direction records. Otherwise data should be flagged as doubtful. These thresholds have been adapted to the resolutions reported by the towers. Thus, wind speed periods are flagged as suspect if the wind speed does not change more than 0.7 ms^{-1} in 60 consecutive values. Wind direction values will be considered suspicious when the range between the maximum and the minimum values in a sequence of 60 records is lower than 5 degrees.

The example plotted in Figure S1 shows wind speed observations measured at 18 meters at the top of the Barrow tower (Arctic Circle) during 51 consecutive days. In except of the two spikes on 14^{th} October and 3^{rd} November, wind speed values range from 4.8 ms^{-1} to 5.3 ms^{-1}. This variability is significantly low when compared with the rest of the wind series (not shown). Although the *Persistence test* flags the records as a suspect, a visual inspection reveals that they are potentially erroneous and should not be used as reliable data.

S2.4 Flat line

A sequence of numbers with null standard deviation is the extreme case of a period with low variability and indicates that several constant values are observed consecutively. The probability of recording constant values in a row decreases with the number of significant figures that a sensor can record, being almost unlikely to have more than five consecutive exact matches for wind speed (IOSS, 2017) and 40 for wind direction measurements. In this sense, data fail the *flat line* test when there exist 6 -or more- constant wind speed values in a row. This threshold is increased to 40 for the wind direction variable. Observing

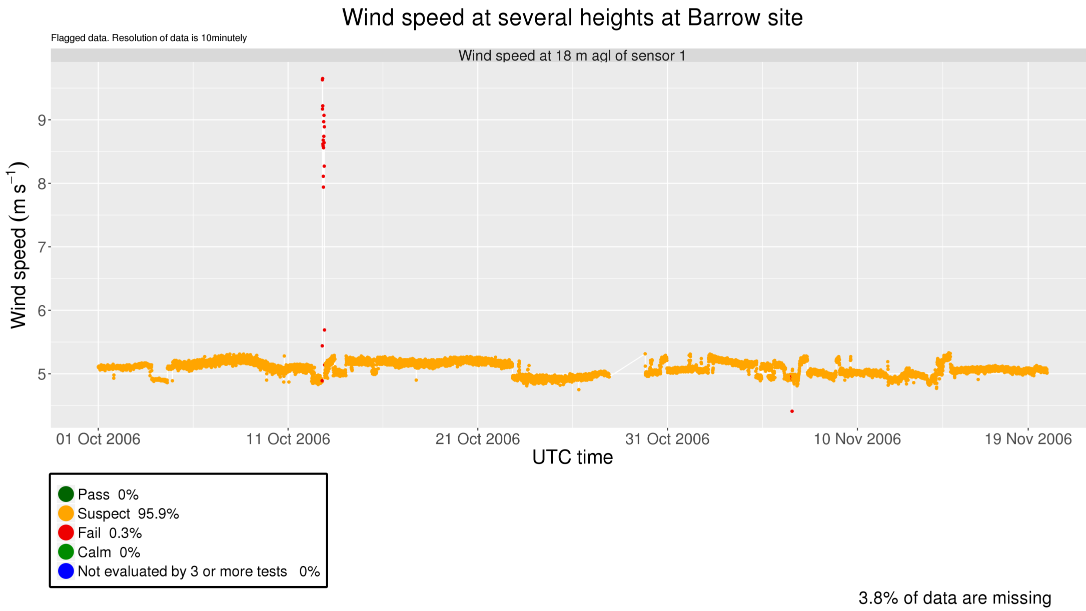

Figure S1. Wind speed time series at 18 meters above ground level at Barrow site (71.32ºN 156.61ºW, 11 m), USA

3, 4 or 5 exact consecutive matches is more likely for wind speed values, but still unlikely to happen frequently. Therefore, the tests flags as suspect those flat sequences. Analogously for wind direction data, flat sequences containing 20 to 40 wind direction records are flagged as suspect. It is also frequent to observe an alternation of no data periods with null speed values, which are usually produced by failures in the sensors or data loggers. If the period containing this alternating pattern exceeds 30 days, all the measurements within this period are flagged as erroneous.

A detection of a flat line is shown in Figure S2. Various sequences of constant values are encountered at the three different levels between September 14^{th} and September 20^{th}. Like that, flat lines are often detected simultaneously at all levels of the tower.

S2.5 Icing

Freezing rain or fog usually frosts the anemometers and vanes placed along the tall tower preventing them from measuring non-zero wind speed values and changes in the wind direction. Hence, these records should be detected by checking wind and temperature observations simultaneously. Based on Jiménez et al. (2010), data are considered wrong when the *Icing test* detects 4 or more days with 0 ms^{-1} as the maximum wind speed value and below zero temperatures during all the same period.

Wind speed series at different heights at Hegyhatsal tower are represented in Figure S3. A flat line is observed in the two uppermost levels from December 8^{th} to December 18^{th} 2002. However, the air temperature observations (Figure S4) reveal that negative Celsius temperatures occurred during all the ten days in the two top levels of the tower. Given these conditions, it is very likely that an icing event happened and frosted the two upper anemometers.

S2.6 Abnormal variations

Random and gross errors in the measurements might produce periods of abnormally high or abnormally low variability and usually, appear embedded in the wind speed time series. Various authors have proposed several different thresholds that define a period with extreme variability (see Jiménez et al. (2010)) since the threshold selection should depend on the local wind features. In an attempt of generalisation, in this work it is proposed that these limits are defined by statistical parameters

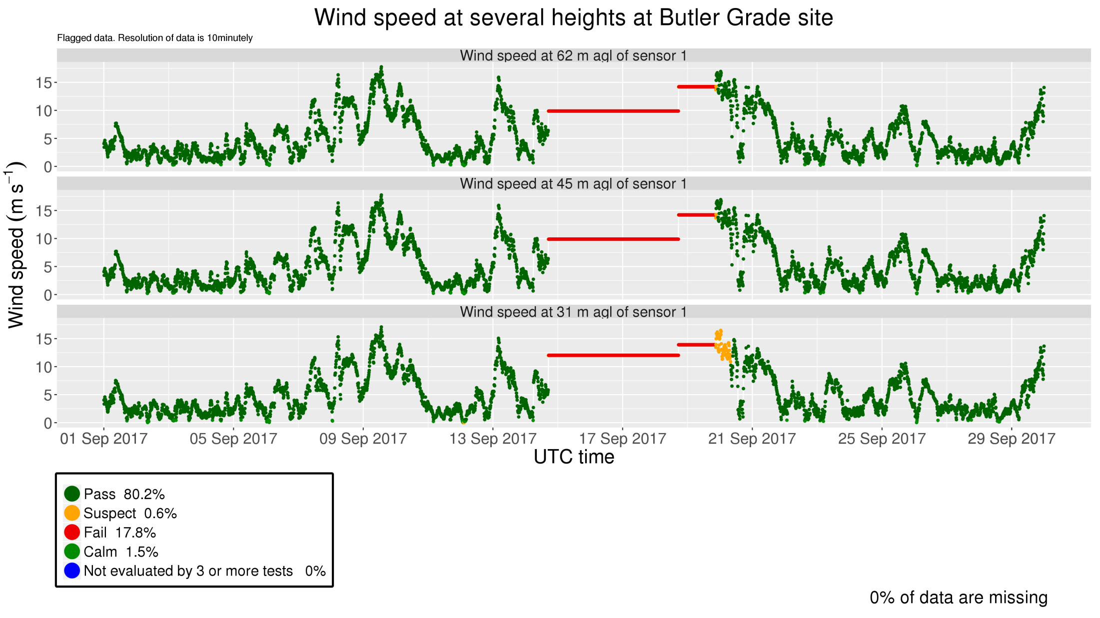

Figure S2. Wind speed time series at 31, 45 and 62 meters above ground level at Butler Grade site, USA (45.95ºN, 118.68ºW, 545 m).

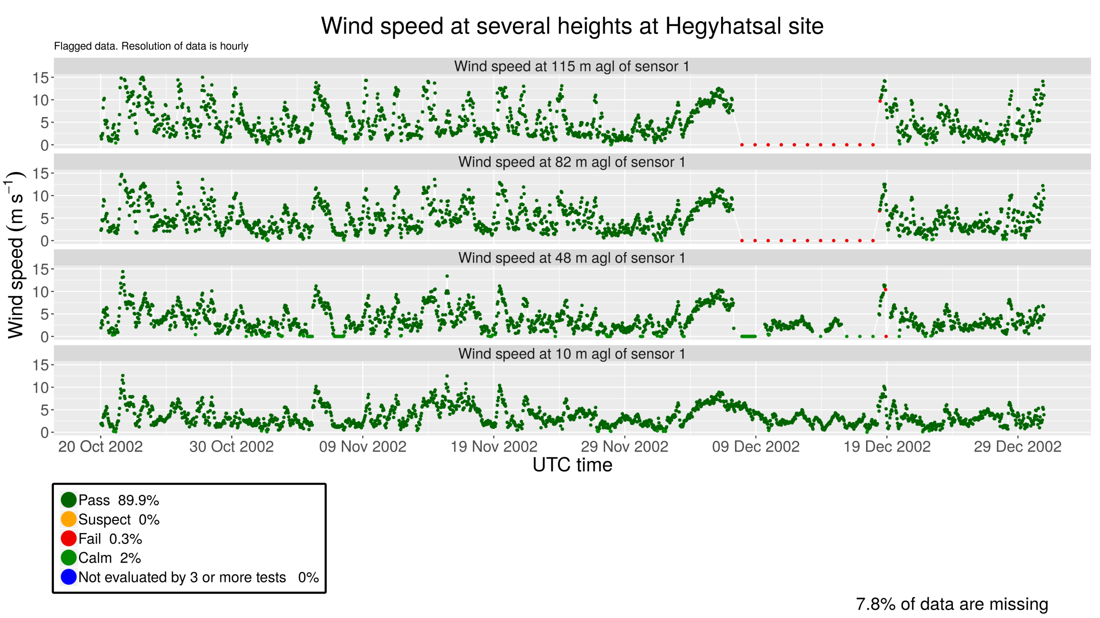

Figure S3. Wind speed time series at 10, 48, 82 and 115 meters above ground level at Hegyhatsal tall tower, Hungary (46.96ºN, 16.65ºE, 248 m).

derived from the wind distributions themselves. In this way, the abnormal variations check compares the variability (computed

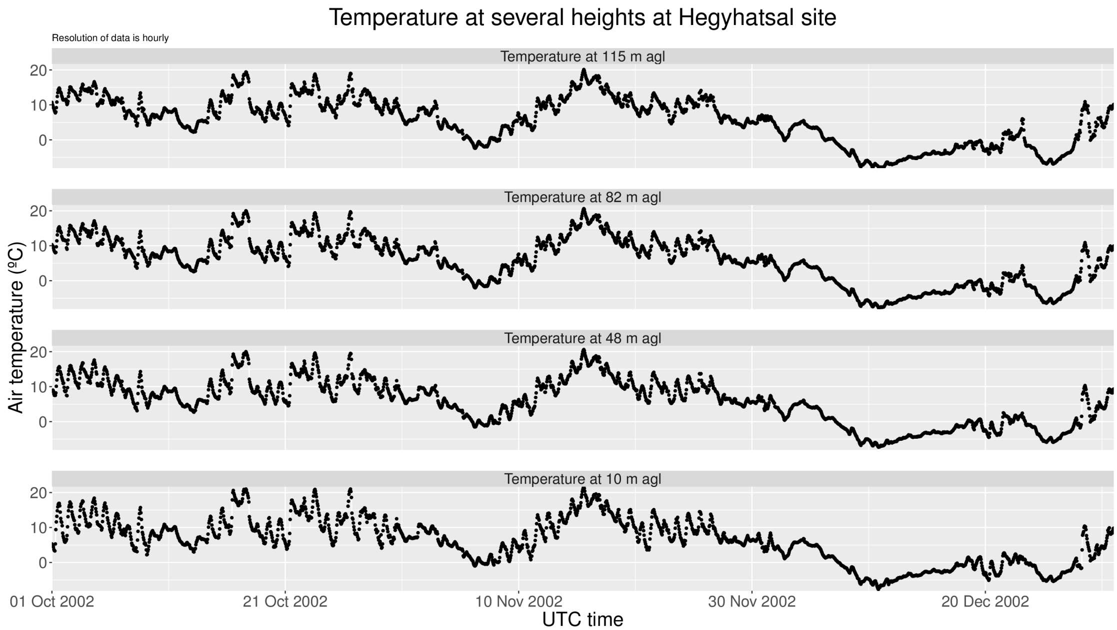

Figure S4. Temperature measurements at 10, 48, 82 and 115 meters above ground level at Hegyhatsal tall tower, Hungary (46.96ºN, 16.65ºE, 248 m).

as the variance) of 30-day periods with the mean variance of all 30-day periods of the time series using moving variances. If the standard deviation of a specific 30-day period departs more than four standard deviations from the mean standard deviation, records within these 30 days are all flagged as suspect.

S2.7 Systematic errors

Another approach to detecting random and systematic errors in the experimental measurements is based on the computation of moving averages. Similar to the abnormal variations check, this QC routine computes the mean wind speeds over a 30-day moving window. Wind speed values within a 30-day period whose average departs more than four standard deviations from the mean value of all 30-day moving means are all considered suspect.

In Figure S5, the *Systematic errors* check flags as suspect 12 consecutive days of wind speed measurements taken at the top of Hegyhatsal tower. A close inspection reveals that the minimum wind speed record is over 5 ms^{-1} during all the mentioned period, which is in disagreement with the wind speeds observed at lower levels. Indeed, the three anemometers located at 10, 48, and 82 meters report weaker winds or even calm during these 12 days. It is likely that an offset value could have been inserted in the data logger producing the inconsistency observed in the uppermost wind speed measurements. In this case, these 12 days of winds at 115 meters should not be considered reliable.

Figure S6 shows a false detection of a systematic error at WLEF tall tower. Although the test flags as suspect a period of 2 months of wind speed data at the 122-meter level, a visual inspection and comparison with winds reported at other tower heights does not reveal any inconsistency in the suspicious observations. Hence, these data should not be discarded unless a sensor failure is reported in the metadata of the site.

S2.8 Quartile occurrences

A third method to detect periods containing gross errors in the measuring process is suggested here by looking at the number of consecutive days where no value is above or below the first, second and third quartiles of the empirical wind speed distribution.

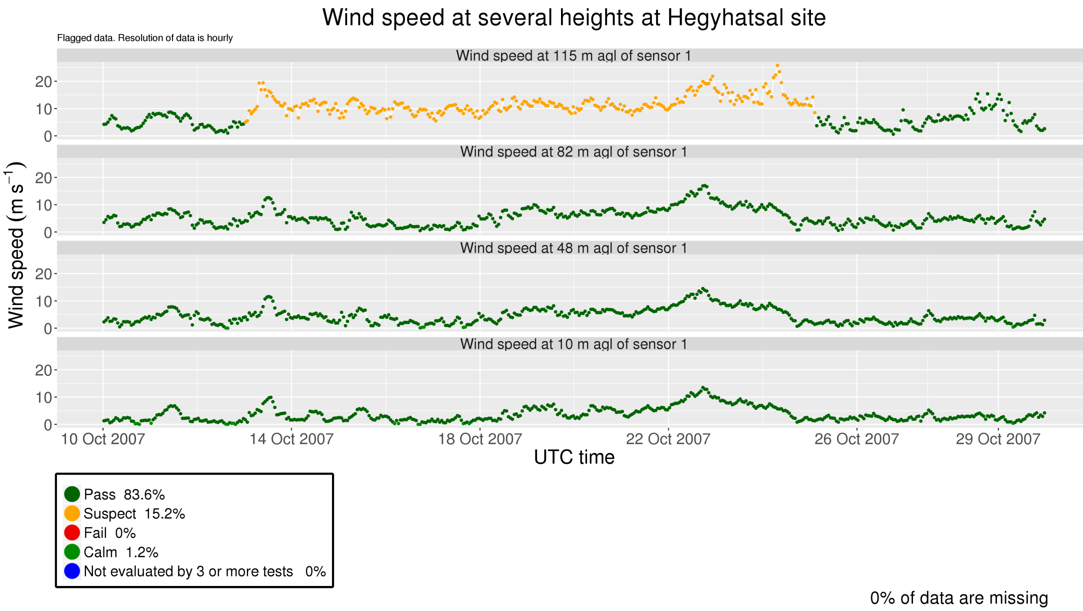

Figure S5. Wind speed time series at 10, 48, 82 and 115 meters above ground level at Hegyhatsal tall tower, Hungary (46.96ºN, 16.65ºE, 248 m).

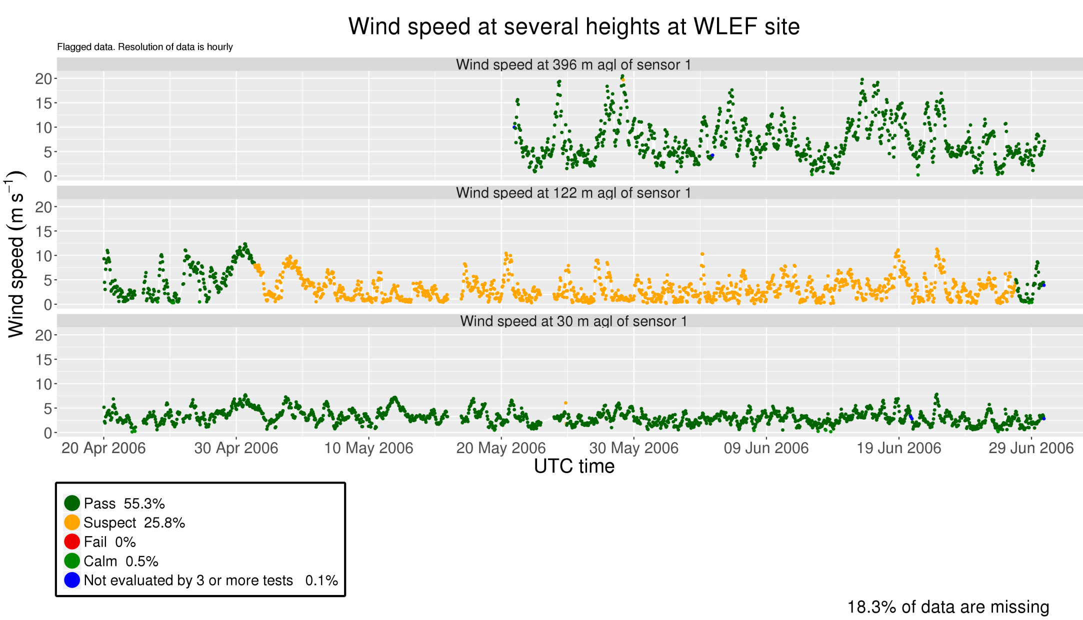

Figure S6. Wind speed time series at 30, 122, 396 meters above ground level at WLEF tall tower, USA (45.95ºN, 90.27ºW, 472 m).

Table S2 summarizes the different thresholds (in days) that define the trustworthiness of an observation. As an example, the first row indicates that if all the observations in 30 days fall above the first quartile, data within this period will be flagged as erroneous. Observations are suspicious when the period without any occurrence within the first quartile ranges between 15 and 30 days. Spans shorter than 15 days without any value falling within the first quartile are considered correct by this test.

Table S2. Threshold values (in days) that set the different levels of confidence for the *Quartile occurrences* check.

All the observations are...	Pass	Suspect	Fail
>1st quartile	<15	[15,30]	>30
>2nd quartile	<10	[10,20]	>20
>3rd quartile	<5	[5,10]	>10
<1st quartile	<5	[5,10]	>10
<2nd quartile	<10	[10,20]	>20
<3rd quartile	<15	[15,30]	>30

S2.9 Rate of change

The presence of spikes in the wind series is usually observed during extreme wind phenomena events. However, the magnitude of these peaks is constrained to a specific allowable range of values specially when the very high-frequency wind data are averaged in periods of several minutes (which is the case of the observations within the Tall Tower Dataset). This test compares pairs of adjacent observations. To pass the test successfully, differences between consecutive values must be lower than a specific threshold, that can be either dynamically established or fixed (IOSS, 2017). The *Rate of change* test uses the interquantile range (IQR) of the considered series, defined as the difference between the third and first quartiles of the empirical distribution. When the difference between two consecutive values exceeds three times the value of the IQR, both values are considered wrong. If the difference is between twofold and threefold the IQR, the pair of observations is considered as suspect.

S2.10 Step test

The *Step test* uses a similar methodology as the *Rate of change* test to detect spurious peaks of wind speed data. In the *Step test*, the maximum permissible difference between two consecutive observations is fixed to 20 ms^{-1} (WMO, 2007), instead of using a statistic derived from the wind series. Although the WMO suggests this limit specifically for 2-minutely averaged wind speed data, their usage has been deemed appropriate for the data within the Tall Tower Dataset since the time stamp samplings observed in this collection are larger. Indeed, by averaging data in longer periods, one can expect a general smoothing of the series, hence reducing the possibility of observing big data spikes.

S2.11 Repeated sequences

This check looks for sequences of observations that appear repeated within the same time series. Duplicated sequences of at least 30 wind speed values are flagged as erroneous if data do not contain any decimal places. The threshold is decreased to 20 wind speed observations if data are measured with one or more decimal digits. Wind direction series are also checked for duplicate sequences, and they are flagged when the length of the repeated sequence exceeds 30 values.

Duplicated sequences have been found in the three parallel wind time series at Abadan tall tower time series (Figure S7). A careful inspection reveals that the values within the two black rectangles in the top series match perfectly. An analogous situation is noticed for the two lower levels. This is probably due to an standard procedure to fill in no-data periods, which takes previously observed wind speed sequences of data. However, it has been deemed appropriate to the detect and consider erroneous these sequences of data.

S2.12 Tower shadow

One of the singularities of the tall tower data is that wind measurements are not taken at the top of a pole where a sensor is placed. Instead, anemometers and wind vanes are distributed along with the vertical structure of the tall tower, which usually

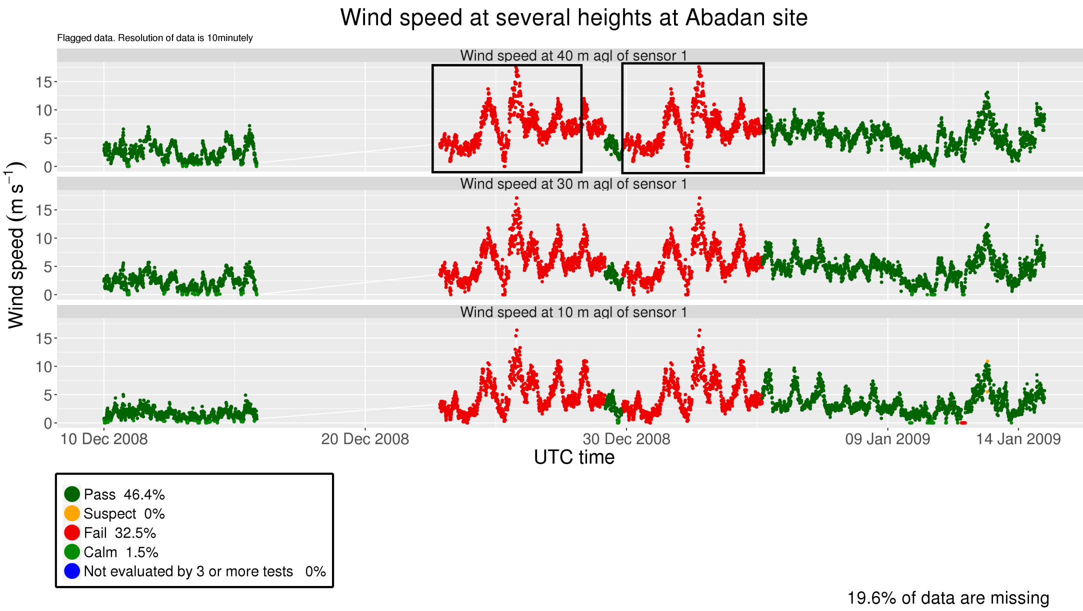

Figure S7. Wind speed time series at 10, 30 and 40 meters above ground level at Abadan met mast, Iran (30.45ºN, 48.31ºE, 4 m). The two black boxes in the upper graph represent two duplicated sequences of wind speed values within the same time series.

consists of a solid vertical cylinder or a lattice structure that inherently produces a wind shadow in the downwind area. If an anemometer is measuring in the shadow area, wind speeds are affected by this shadow and cannot be considered reliable.

To help overcome this handicap, a common practice in the instrumental installation is to place redundant sensors at the same height in booms oriented to different cardinal directions. As mentioned in Sect. **??**, shadowed records can be replaced by those from a sensor not affected. The *Tower shadow* test identifies first the shadowed directions and anemometers by dividing wind speeds from two sensors at the same level. Ideally, they should measure the same values so that the ratio is expected to be equal to the unit unless the winds from one sensor are shadowed. Then, all wind speed ratios are grouped in wind direction sectors of 1 degree. The 5^{th} and 95^{th} percentiles of the distribution generated by all the ratios are calculated next. Those directions showing ratios below the 5^{th} percentile and above the 95^{th} are considered to be in the wake of the tower. After identifying the shaded directions for each anemometer, the test marks as suspect those wind speed values affected.

Figure S8 exemplifies the previous explanation presenting the ratios between simultaneous wind speeds observations measured by redundant sensors at 60 and 100 meters at the FINO3 met mast in the North Sea. The quotient between wind speeds reported by two different sensors is approximately one for most of the wind directions. However, wind speeds coming from 50±5 and 170±5 degrees of direction are affected by the vertical pole at the two measuring levels. Thus, the anemometer measuring the weakened winds is identified, and those records should not be considered correct.

S2.13 Vertical ratios

QC checks that employ nearby stations are not suitable for meteorological variables with remarkably localized features such as precipitation or wind speed, because the correlation between neighbor series is considerably lower when compared to temperature or pressure time series (Dunn et al., 2012). In addition, those tests require a dense network of stations, which is not the case of the Tall Tower Dataset. However, another particularity of tall tower data is the simultaneous records taken at the same time at different heights along the mast. These series can be compared among them as they are expected to be highly correlated. The *Vertical ratios* is a particular test which considers pairs of time series measured at different heights and computes the mean ratio ($\overline{r}$) of all the pair-wise measurements ratios (r_i). To avoid duplication and save computation time, the

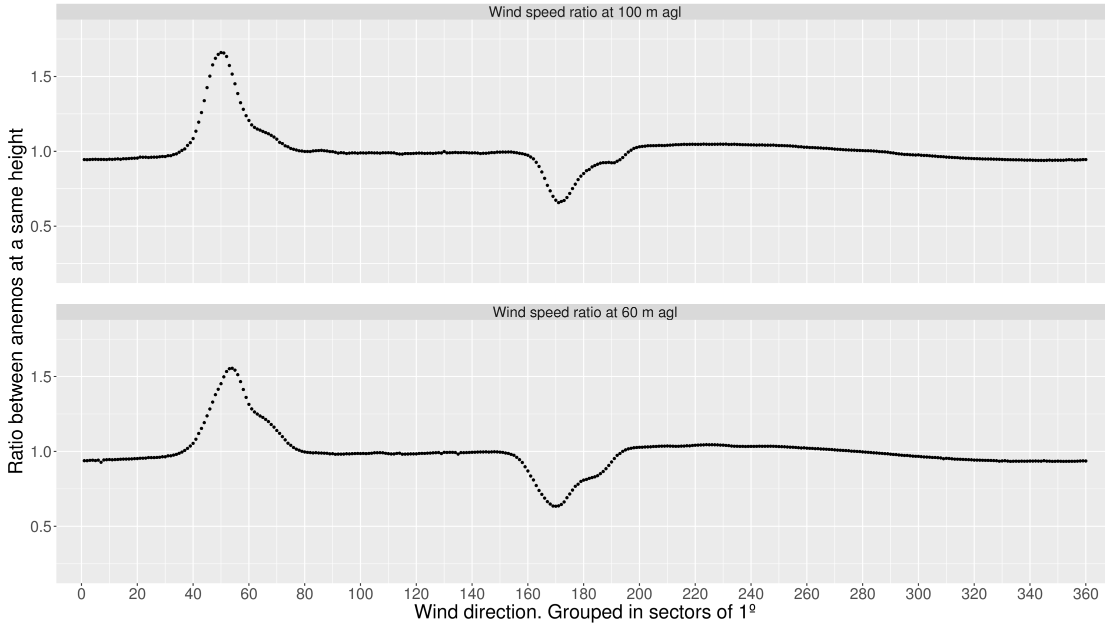

Figure S8. Ratio between simultaneously measured wind speed values at 60 and 100 meters at FINO3 met mast, Germany (55.20ºN, 7.16ºE, 0 m).

test only computes the ratio between one level an all the lower levels. In except local effects such as low-level jets, wind speeds tend to increase in height, so the computed mean ratio is expected to be greater or equal to unity. Taking this assumption into account, the *Vertical ratios* test will detect and flag as erroneous those pairs which ratio (r_i) satisfies the following condition:

$$r_i \geq \overline{r} + 30 \tag{1}$$

Values are considered dubious when the following condition is satisfied:

$$r_i \geq \overline{r} + 15 \tag{2}$$

Even though the allowable ranges of ratios was initially chosen somewhat arbitrarily, it has been tested and adjusted using the data within the Tall Tower Dataset to ensure that only gross errors are detected and flagged as erroneous. Wind speeds under 1 ms^{-1} are not considered in this test.

S2.14 Isolated pass

After running some of the QC tests, a certain amount of sequences might be flagged as wrong or dubious. These sequences can be found close in time and encircle values marked as correct by the QC checks. However, it is very likely that those presumably correct values are not be acceptable since a prolonged sensor failure may have occurred, but the previously run QC checks missed it. The *Isolated pass* check is applied after running at least one QC test and attempts to detect those apparently correct (we note that calms are also identified as good data) sequences of observations surrounded by wrong or suspect values, and change their flag into erroneous or suspect. Besides, we also force to be wrong those scattered individual records appearing randomly within long no-data periods.

A total of 12 predefined sequences (see Table S3) containing data flagged as correct ('Pass' or 'Calm') but surrounded to the left and right by, wrong ('Fail'), dubious ('Suspect') or absent ('Missing') records have been defined. Wherever these series are found, the central 'Pass' or 'Calm' values are changed from 'Pass' to 'Fail'. Table 6 defines similar sequences, but their central records will be changed from 'Pass' to 'Suspect'.

Table S3. Explicit definition of the sequences to be searched within the wind time series which central value or values flag will be changed from 'Pass' or 'Calm' to 'Fail'.

$Fail, Fail, Fail, Pass, Fail, Fail, Fail$
$\underbrace{Fail, ..., Fail}_{5}, Pass, Pass, \underbrace{Fail, ..., Fail}_{5}$
$\underbrace{Fail, ..., Fail}_{10}, Pass, Pass, Pass, \underbrace{Fail, ..., Fail}_{10}$
$\underbrace{Fail, ..., Fail}_{15}, Pass, Pass, Pass, Pass, \underbrace{Fail, ..., Fail}_{15}$
$\underbrace{Fail, ..., Fail}_{25}, Pass, Pass, Pass, Pass, Pass, \underbrace{Fail, ..., Fail}_{25}$
$\underbrace{Missing, ..., Missing}_{50}, Pass, \underbrace{Missing, ..., Missing}_{50}$
$\underbrace{Missing, ..., Missing}_{50}, Calm, \underbrace{Missing, ..., Missing}_{50}$

Table S4. Explicit definition of the sequences to be searched within the wind time series which central value or values will be changed from 'Pass' flag to 'Suspect'.

$Suspect, Suspect, Suspect, Pass, Suspect, Suspect, Suspect$
$\underbrace{Suspect, ..., Suspect}_{5}, Pass, Pass, \underbrace{Suspect, ..., Suspect}_{5}$
$\underbrace{Suspect, ..., Suspect}_{10}, Pass, Pass, Pass, \underbrace{Suspect, ..., Suspect}_{10}$
$\underbrace{Suspect, ..., Suspect}_{15}, Pass, Pass, Pass, Pass, \underbrace{Suspect, ..., Suspect}_{15}$
$\underbrace{Suspect, ..., Suspect}_{25}, Pass, Pass, Pass, Pass, Pass, \underbrace{Suspect, ..., Suspect}_{25}$

S2.15 Occurrences of 0s and 360s values

The lack of coordination concerning the data storage and formatting conventions in the original data may produce some issues that must be detected. For example, in the wind speed time series, missing records are sometimes set to zero, thus leading to a spurious increase in the occurrence of the zero value. Similarly, some conventions use the value 0 degrees to refer to the northern wind direction while others identify this direction with 360 degrees. Stations with properly detailed metadata information include the convention adopted by the data managers. Regrettably, most of the stations whose data was accessed to be included in the Tall Tower Dataset did not attach such complete information. In those cases, the original basic standards such as assigning the 0 or the 360 value to the north direction need to be inferred.

This routine computes the percentage of occurrence of each of these three cases:

1. Occurrences of 0s within the wind speed time series,
2. occurrences of 0s within the wind direction series and
3. occurrences of 360s within the wind direction series.

The *Occurrences of 0s and 360s values* does not flag individual records, but provides a value for each of the series indicating the percentage of the aforementioned occurrences to the total data. The whole series is considered incorrect if any of these occurrences exceeds 30%, which has been chosen appropriately to take into account that a considerable percentage of calms may exist.

S2.16 Internal consistency

Whenever a null wind speed is recorded, the associated wind direction value is meaningless since it is very likely that the wind vane is still pointing to the direction defined by the last non-zero wind speed observation. According to the WMO guidelines, whenever a null wind speed is reported, the simultaneous wind direction measurement must be forced to be null as well. However, in the Tall Tower Dataset the zero wind direction value indicates the true North. Therefore, for null wind speed records, wind direction must be set to NA. We note that the condition must be only applied for wind measurements taken at the same height above ground level.

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