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Supplement of

Determining the ideal length of wind speed series for wind speed distribution and resource assessment

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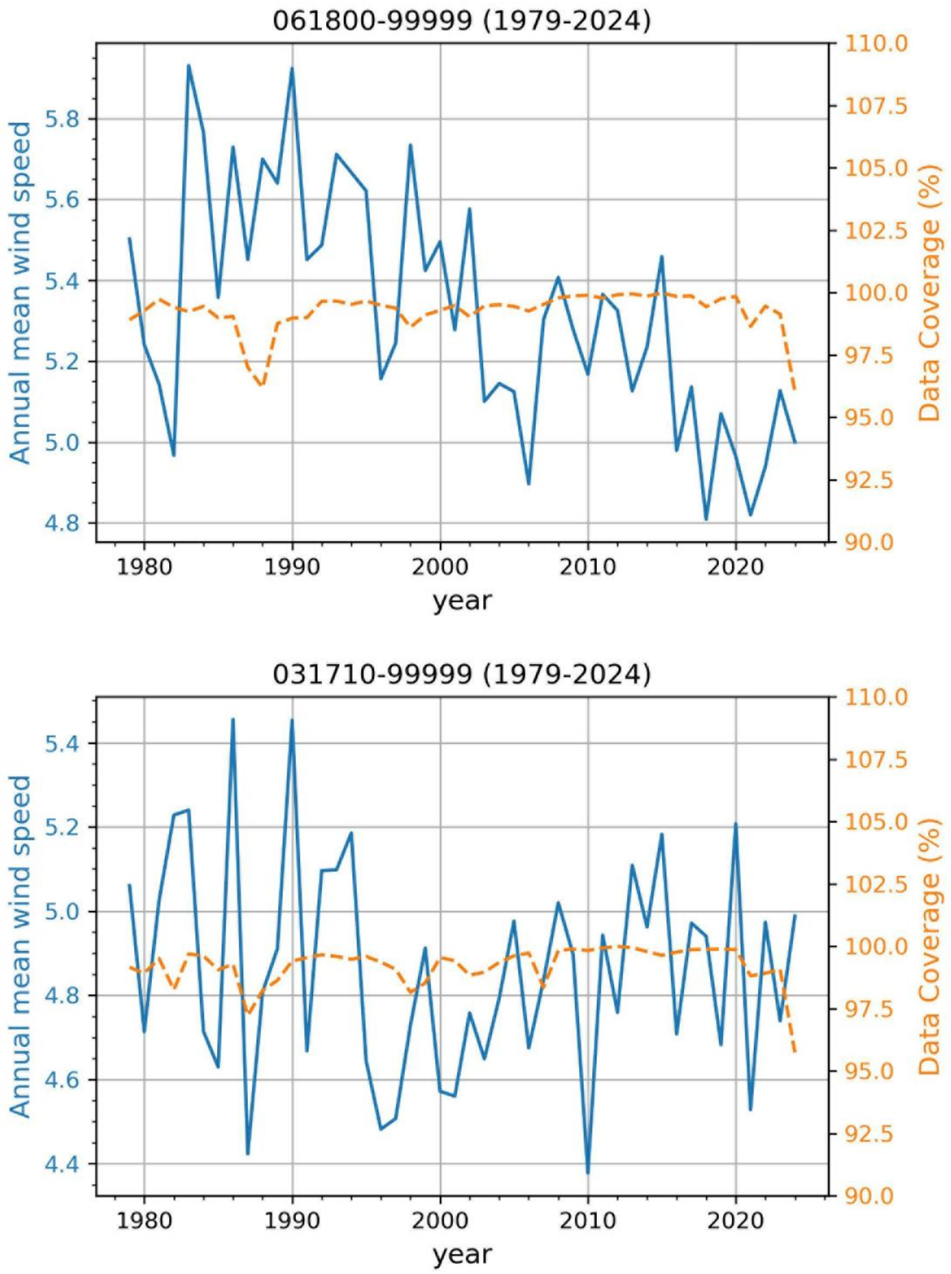

Figure S1 Annual mean wind speed and data coverage for each year from 1979 to 2024.

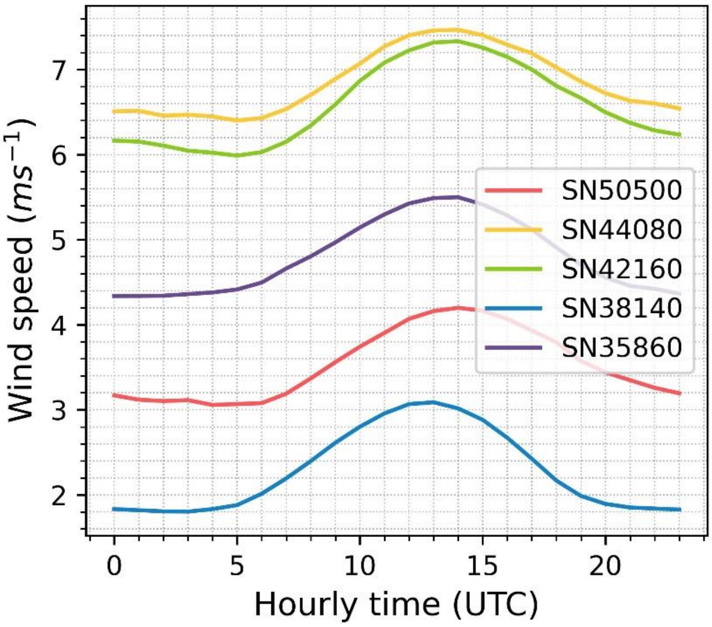

Figure S2 Mean wind speed at each time point across five stations, based on 16 years of hourly observations at each station.

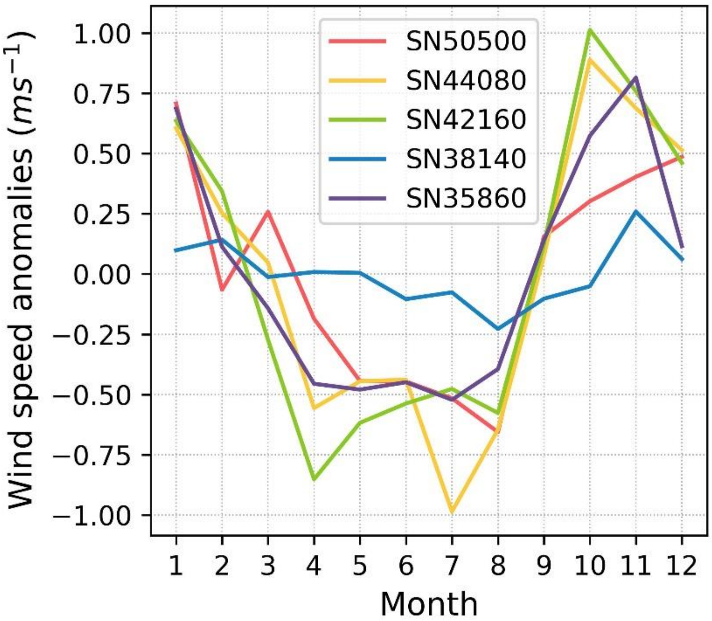

Figure S3 Mean wind speed anomalies (calculated as the mean monthly wind speed minus the annual mean wind speed) for each of the 12 months across five stations, based on 16 years of hourly observations at each station.

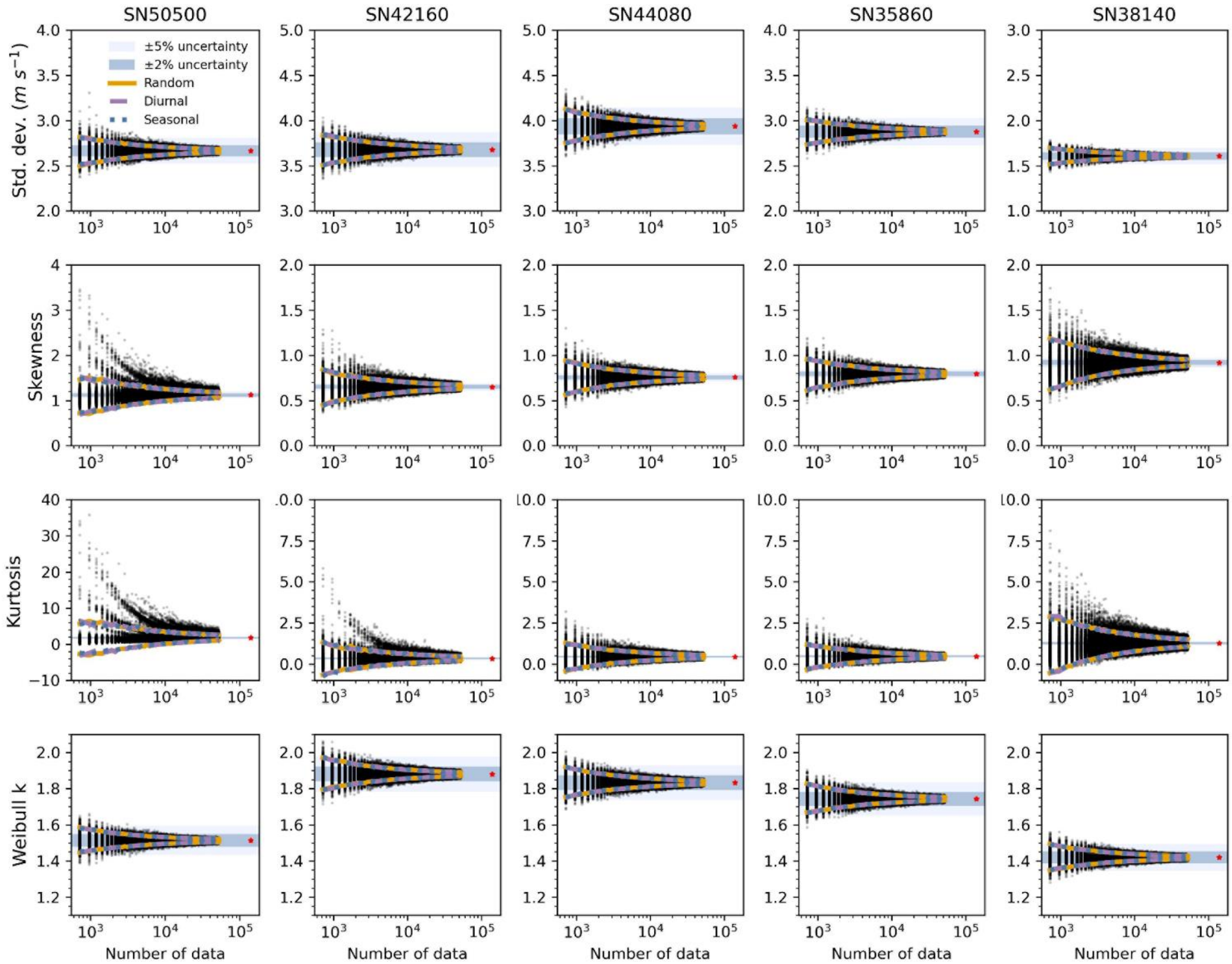

Figure S4 Estimates of standard deviation, skewness, kurtosis and Weibull shape parameter from three sampling strategies, based on in situ observations from five Norwegian stations. The 90% confidence intervals (CIs) are shown for each sampling method: random (orange), diurnal-cycle-retained (purple dashed), and seasonality-retained (blue dotted). Each black dot represents a parameter estimate from a single sampling realization of random sampling. Sample sizes range from 720 to 52 560, increasing in 240-hour increments, with 1 000 realizations per size. Red asterisks indicate the reference values from the full 16-year hourly dataset (see Table 2). Shaded areas represent ±2% (dark blue) and ±5% (light blue) deviation ranges from full-series values.

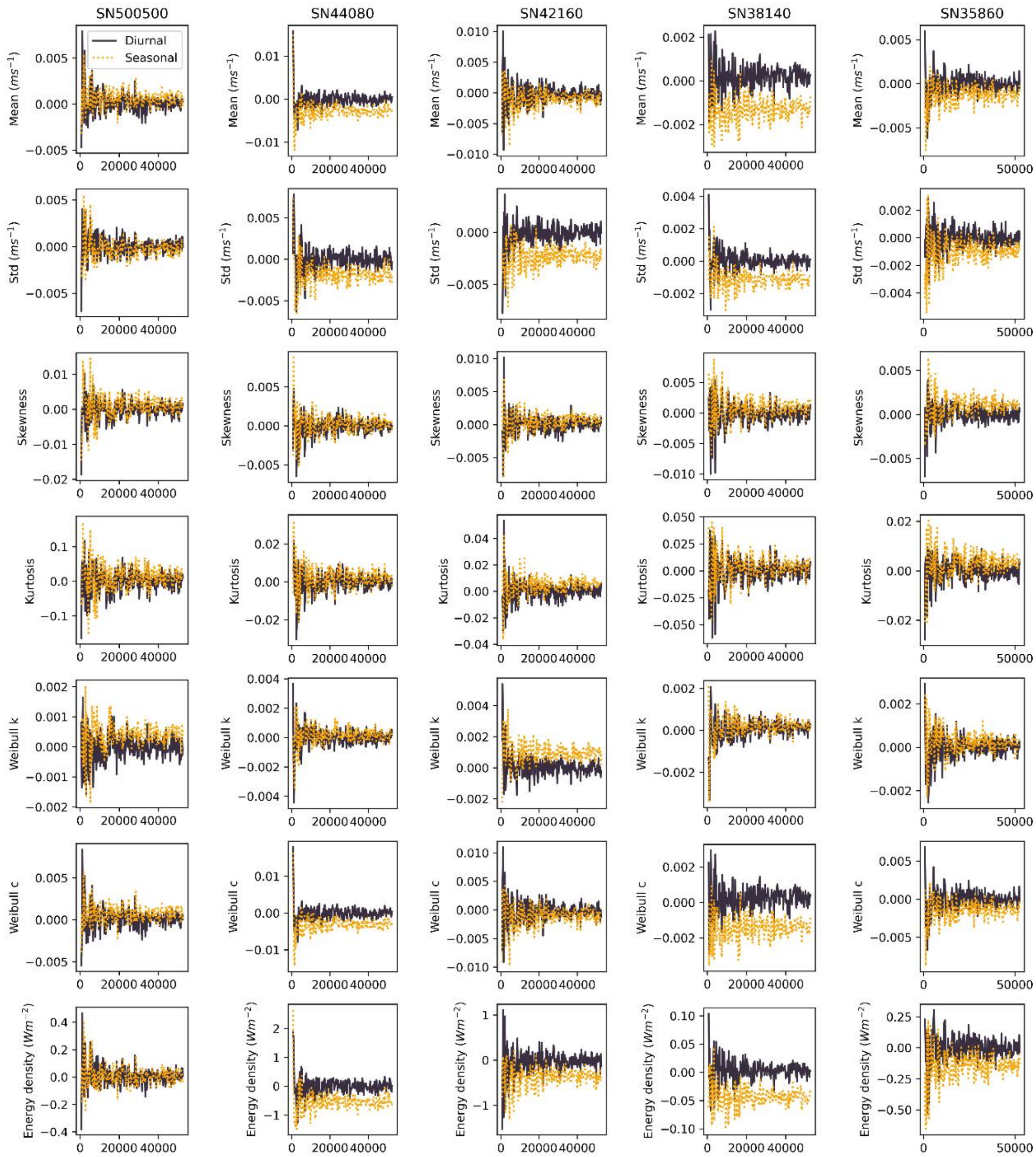

Figure S5 Differences in the 90% confidence intervals derived from in situ observations between random sampling and diurnal-cycle-retained sampling (represented by black lines), and between random sampling and seasonality-retained sampling (represented by orange lines).

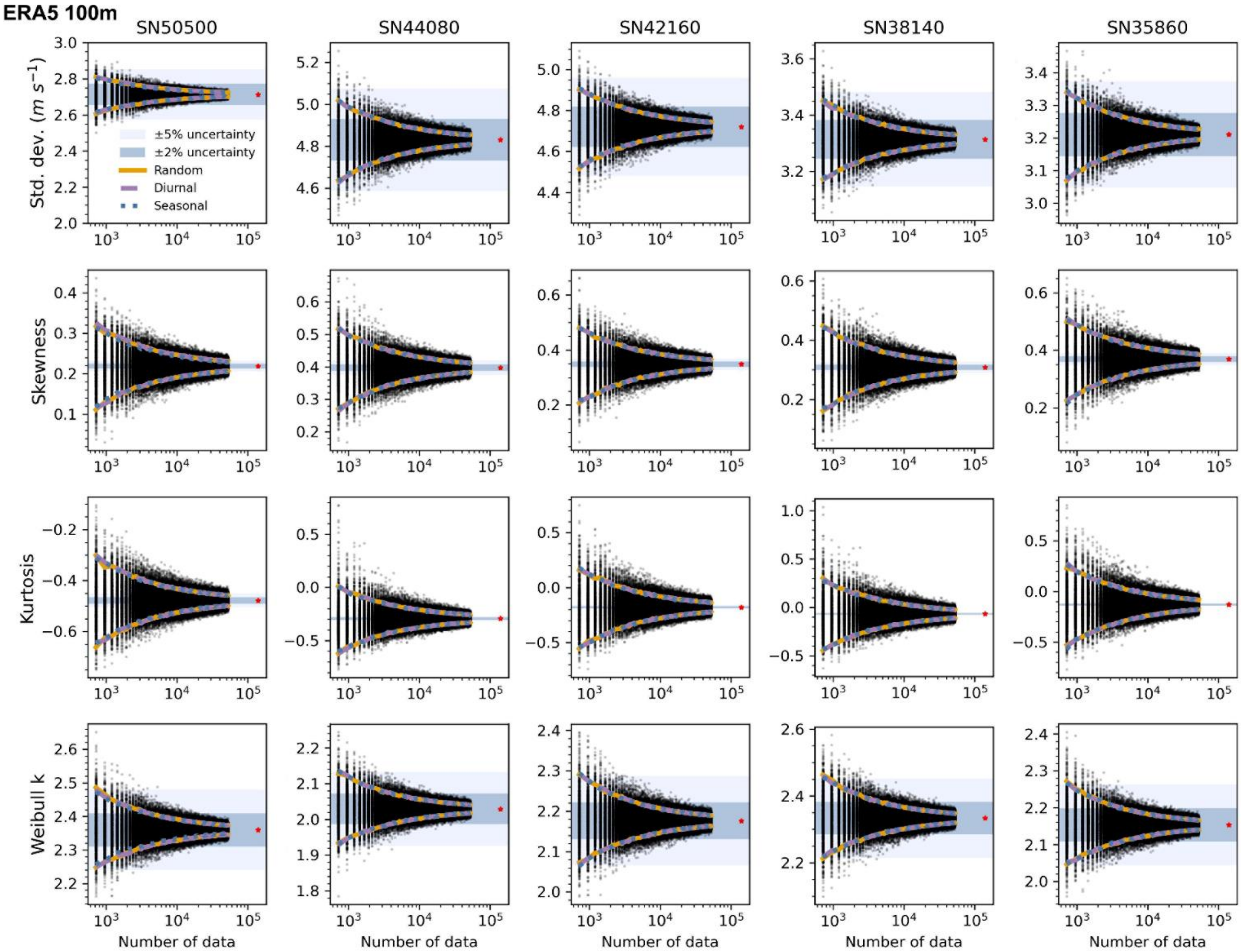

Figure S6 Estimates of standard deviation, skewness, kurtosis and Weibull shape parameter from three sampling strategies based on ERA5 100 m data. Sampling methods and visualization are consistent with Figure S2. Red asterisks indicate values from the full 16-year ERA5 100 m dataset. Shaded areas represent ±2% (dark blue) and ±5% (light blue) deviation ranges from full-series values.

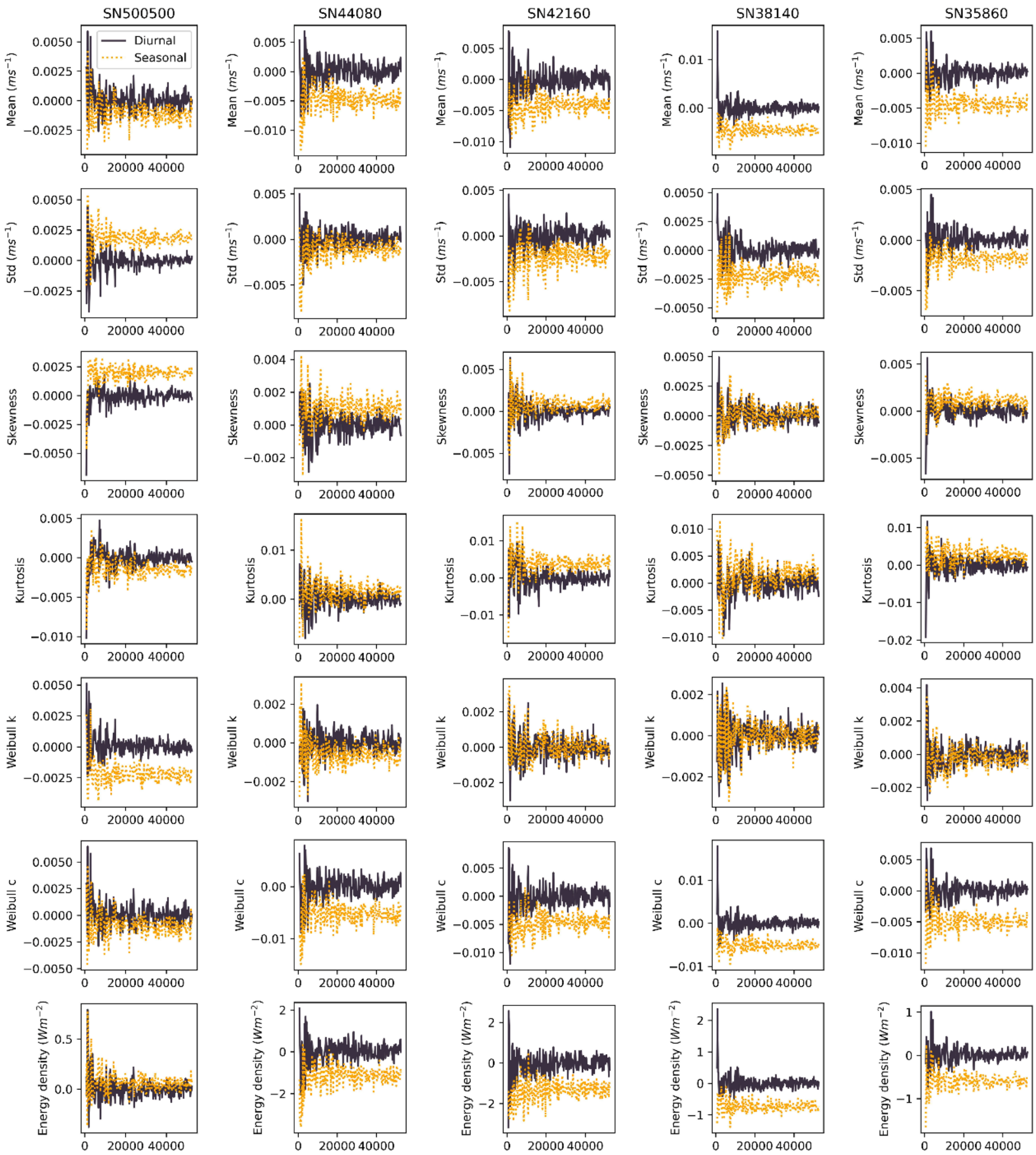

Figure S7 Differences in the 90% confidence intervals derived from ERA5 100 m dataset. Visualization is consistent with Figure S5.

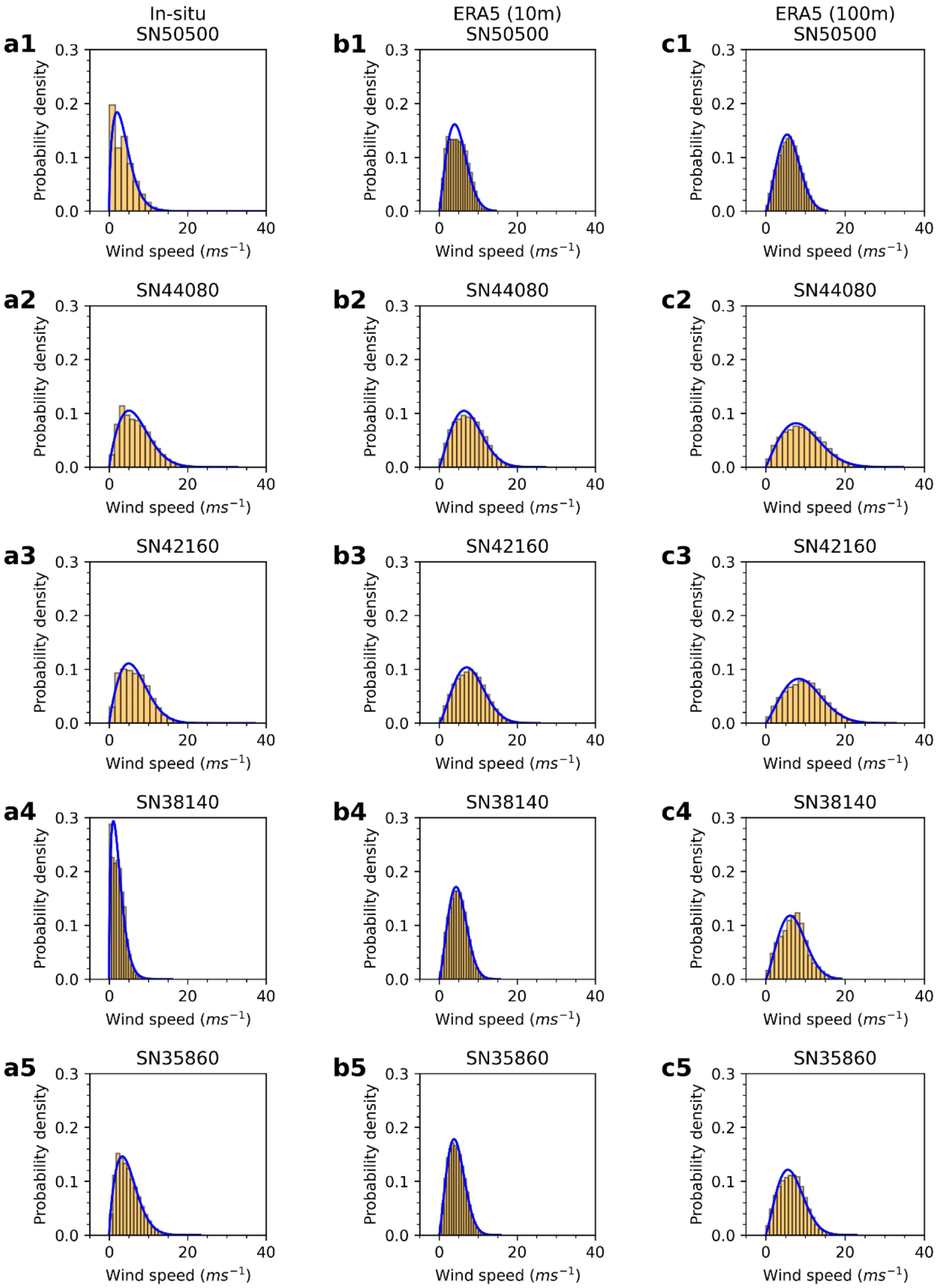

Figure S8 Wind speed distribution at five stations from both in situ weather measurements and ERA5 reanalysis data (10m and 100m). Note: for ERA5 products, the station ID indicates the corresponding grid point location.

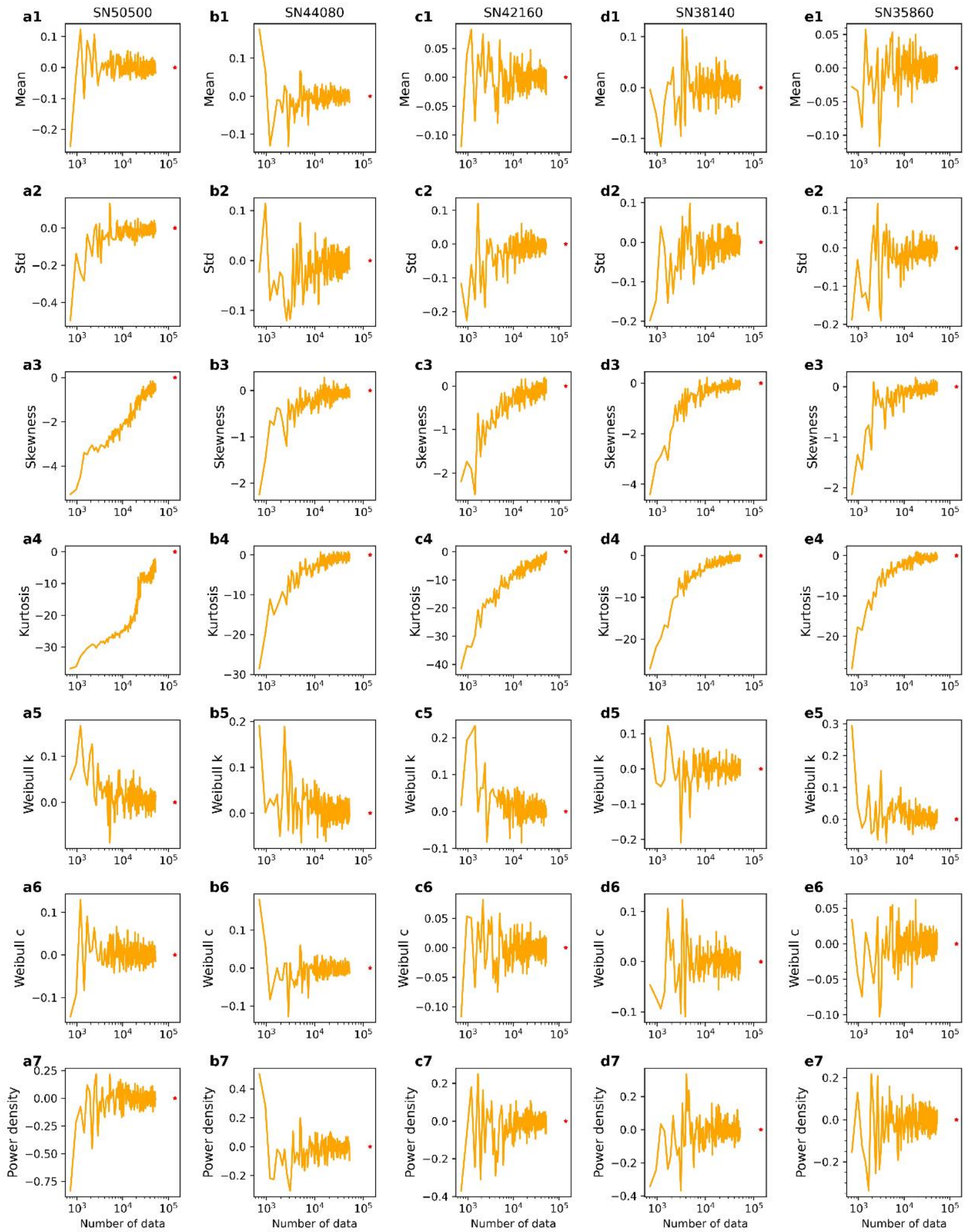

Figure S9 Relative percentage error of the median estimate of each parameter across resampling groups, relative to the corresponding parameter estimated from the full in situ time series.

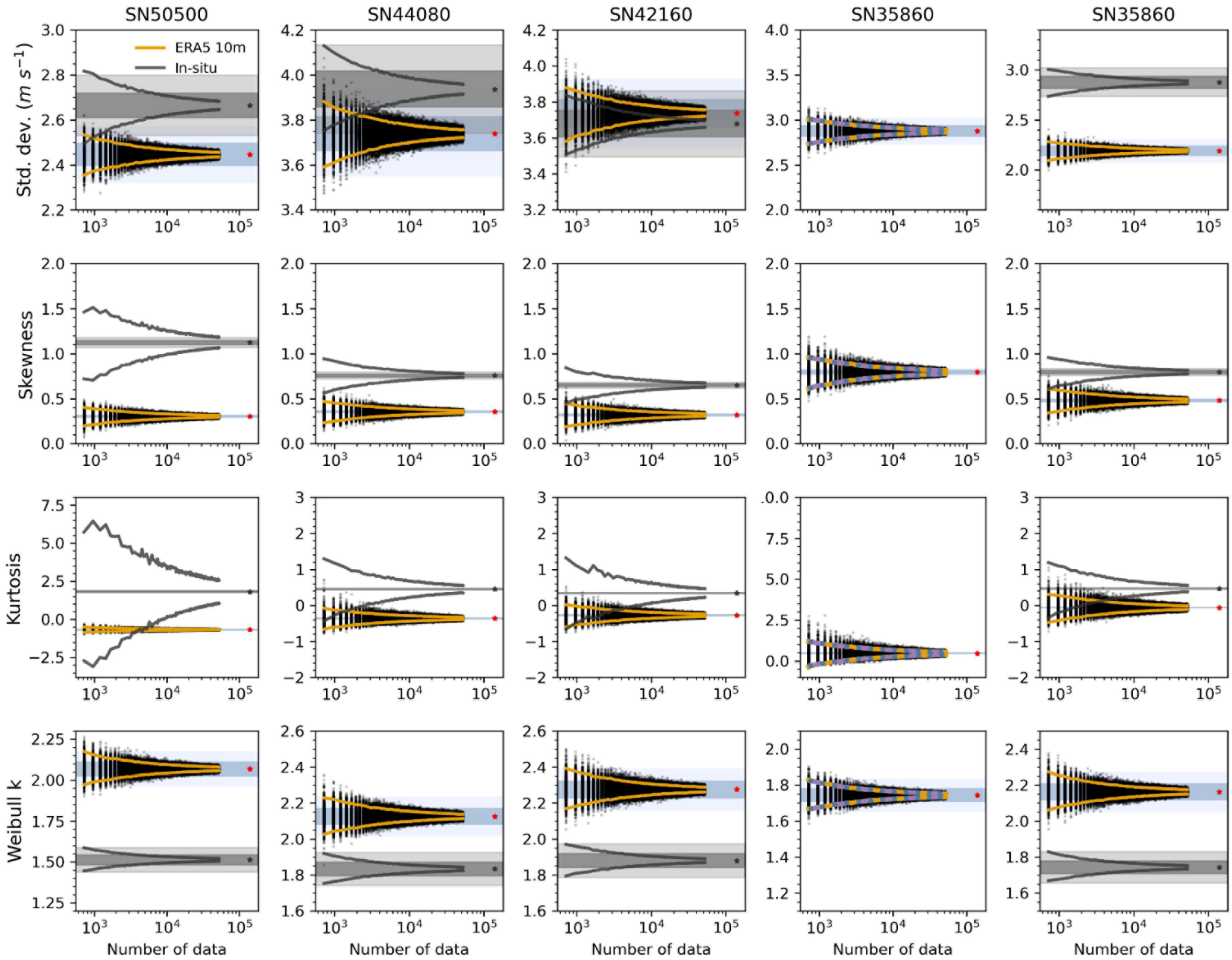

Figure S10 Estimates of standard deviation, skewness, kurtosis and Weibull shape parameter based on random sampling of ERA5 10 m reanalysis data (black dots) across five Norwegian stations. The sampling strategy is consistent with Fig. 2. The 90% confidence intervals (CIs) are shown as orange lines (ERA5) and grey lines (in situ observations). Red asterisks denote reference values derived from the full 16-year ERA5 10 m dataset; grey asterisks represent the corresponding values from in situ observations. Blue shading represents ±2% (dark) and ±5% (light) uncertainty margins around ERA5 10m reference values, while grey shading indicates the same margins around in situ reference values.

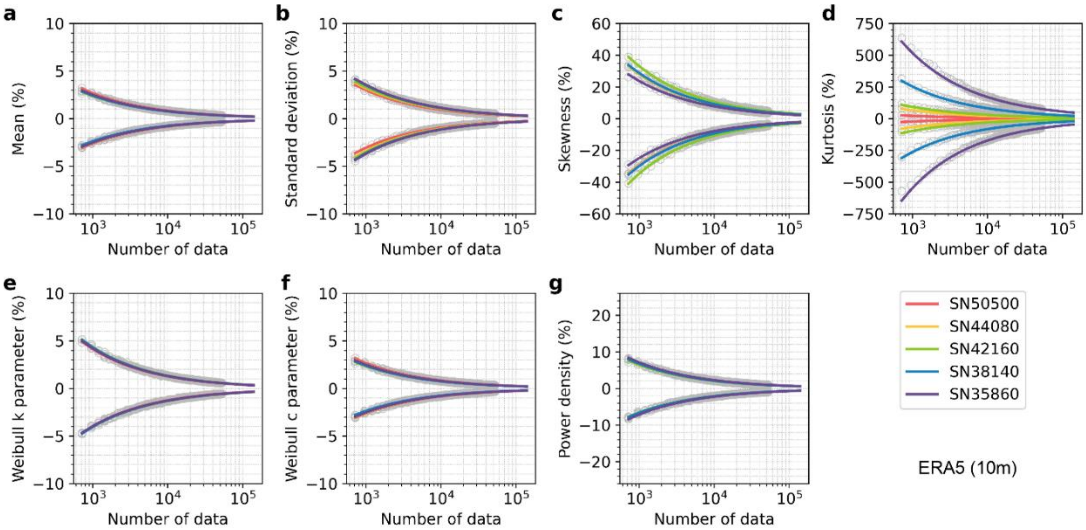

Figure S11 The relationship between the percent error (Y) and sample size (*n*) (number of hourly samples) across five stations based on ERA5 10 m dataset. Curves are fitted for n = 720 - 140 160, with n = 720 being equivalent in size to 30 days of hourly data and 140 160 being equivalent to 16 years. The equations of fits are shown in Table S4. Grey circles indicate the values used to fit the 90% confidence intervals for the percent error shown.

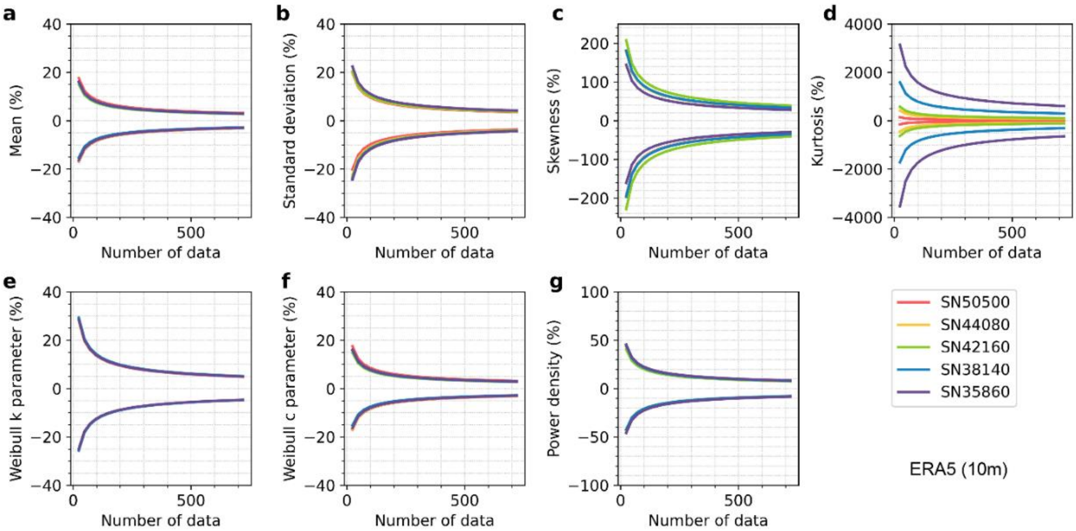

Figure S12 Same as Fig. 4 but for the hourly observations in the range *n* = 24 - 720 across five stations. These intervals are calculated using the same fits as shown in Fig. S13. 4

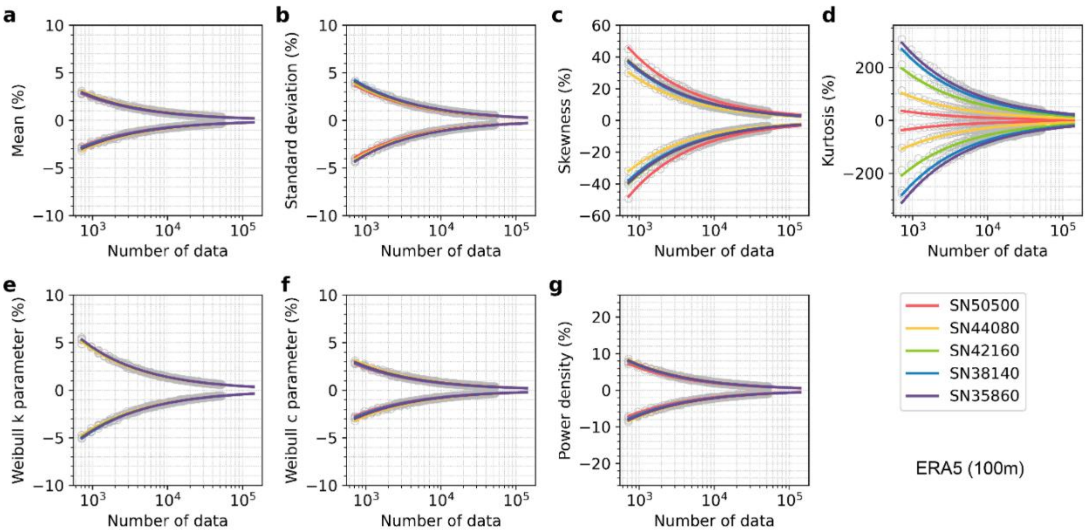

Figure S13 Same as Figure S11, but for ERA5 100 m dataset. The fits to get the required data density are shown in Table S6.

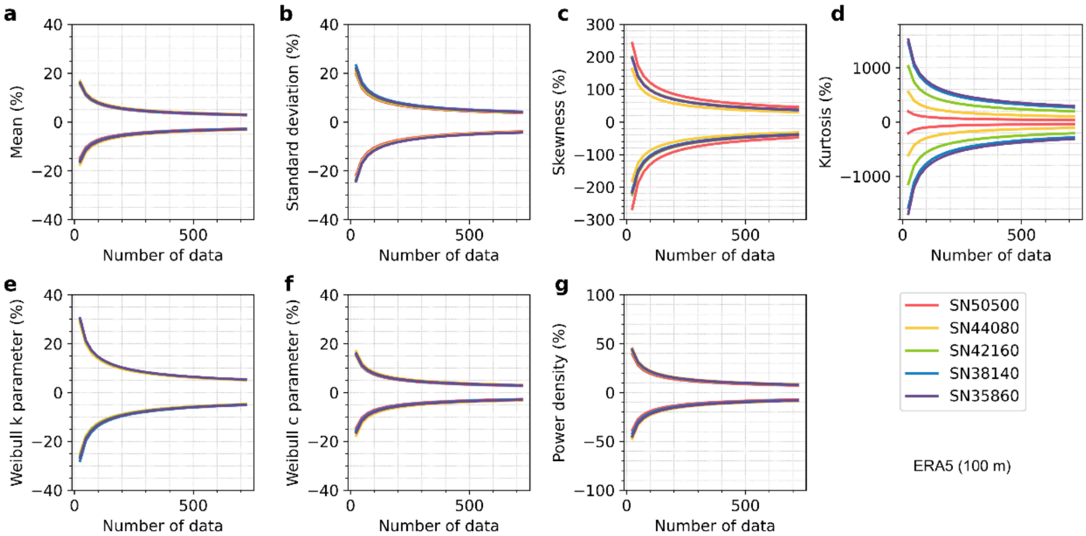

Figure S14 Same as Figure S12, but for ERA5 100 m dataset. The fits to get the required data density are shown in Table S6.

Source: Google Earth. Map data © Google. Imagery © Landsat/Copernicus; CNES/Airbus; Maxar Technologies

Figure S15 Locations of the five Norwegian stations analyzed in this study, shown with cropped satellite imagery from Google Earth to illustrate their spatial context and surrounding terrain of each station. Source: Google Earth. Map data © Google. Imagery © Landsat/Copernicus; CNES/Airbus; Maxar Technologies.

Table S1. Selected years (Yr.) and percentage of observation times (Obs. Tim.) for five Norwegian stations used in this study.

SN38140		SN35860		SN42160		SN44080		SN50500	
Yr.	Obs. Tim.	Yr.	Obs. Tim.	Yr.	Obs. Tim.	Yr.	Obs. Tim.	Yr.	Obs. Tim.
1996	100.00	2001	100.00	1998	99.47	1995	99.22	1974	100.00
1998	99.47	2002	99.97	2000	99.32	1996	99.58	1975	99.82
2002	100.25	2003	99.60	2001	99.93	1997	99.57	1976	100.00
2003	100.25	2004	99.77	2002	100.00	1998	99.50	1977	99.77
2004	99.86	2008	99.68	2004	99.25	1999	99.92	1978	99.95
2009	99.99	2009	99.99	2008	99.98	2000	99.99	1979	100.00
2010	99.98	2010	99.43	2009	100.00	2001	99.57	1980	99.97
2011	99.95	2014	99.77	2010	100.00	2002	99.95	1981	100.00
2012	99.65	2015	99.59	2011	100.00	2003	99.52	1982	99.99
2014	99.87	2016	100.00	2012	99.99	2004	100.00	1983	99.73
2015	99.85	2017	99.99	2013	99.09	2006	99.60	1984	99.98
2017	99.55	2018	99.99	2016	99.76	2009	99.97	1985	99.90
2018	99.53	2019	99.99	2018	99.14	2010	100.00	1986	99.89
2019	99.38	2020	99.99	2020	99.59	2011	98.58	1987	99.92
2020	98.87	2021	100.00	2022	99.89	2012	98.45	1988	99.90
2021	99.06	2022	99.44	2023	99.63	2013	99.19	1990	99.77
Total	99.72	Total	99.82	Total	99.69	Total	99.54	Total	99.91

Table S2. Root mean squared error (RMSE) of 90% confidence interval (CI) bounds between random sampling and two temporal-structure-preserving sampling methods: diurnal cycle-retained sampling (denoted as "Diurnal") and seasonality-retained sampling (denoted as "Seasonal"), based on in situ measurements and ERA5 100 m data from five Norwegian stations. The RMSE is computed for both the lower and upper bounds of 90% CI across all the sampling density, for each statistical parameter.

		SN50500		SN44080		SN42160		SN38140		SN35860		Average	
Parameters	Methods	In situ	ERA5 100 m	In situ	ERA5 100 m	In situ	ERA5 100 m	In situ	ERA5 100 m	In situ	ERA5 100 m	In situ	ERA5 100 m
Mean	Diurnal	0.0023	0.0016	0.0026	0.0027	0.0025	0.0029	0.0013	0.0023	0.0018	0.0019	0.0021	0.0023
	Seasonal	0.0023	0.0105	0.0040	0.0057	0.0025	0.0051	0.0016	0.0050	0.0022	0.0050	0.0025	0.0063
Std. dev	Diurnal	0.0016	0.0011	0.0019	0.0019	0.0018	0.0018	0.0010	0.0014	0.0013	0.0013	0.0015	0.0015
	Seasonal	0.0021	0.0028	0.0027	0.0022	0.0028	0.0031	0.0014	0.0024	0.0017	0.0022	0.0021	0.0025
Skewness	Diurnal	0.0083	0.0012	0.0020	0.0013	0.0024	0.0015	0.0029	0.0014	0.0018	0.0015	0.0035	0.0014
	Seasonal	0.0075	0.0025	0.0022	0.0016	0.0025	0.0017	0.0032	0.0015	0.0022	0.0018	0.0035	0.0018
Kurtosis	Diurnal	0.1229	0.0021	0.0106	0.0030	0.0193	0.0040	0.0210	0.0037	0.0084	0.0044	0.0364	0.0034
	Seasonal	0.1138	0.0029	0.0113	0.0038	0.0233	0.0056	0.0230	0.0044	0.0084	0.0052	0.0360	0.0044
Shape k	Diurnal	0.0007	0.0012	0.0009	0.0011	0.0010	0.0012	0.0008	0.0013	0.0008	0.0011	0.0008	0.0012
	Seasonal	0.0009	0.0033	0.0008	0.0012	0.0014	0.0011	0.0008	0.0013	0.0008	0.0011	0.0009	0.0016
Scale c	Diurnal	0.0025	0.0018	0.0029	0.0031	0.0028	0.0032	0.0016	0.0025	0.0021	0.0022	0.0024	0.0026
	Seasonal	0.0024	0.0116	0.0045	0.0064	0.0029	0.0058	0.0018	0.0056	0.0025	0.0055	0.0028	0.0070
Power density	Diurnal	0.1396	0.1552	0.4855	0.7918	0.3858	0.8559	0.0292	0.3100	0.1589	0.2731	0.2398	0.4772
	Seasonal	0.1687	0.8931	0.7466	1.4477	0.5161	1.6094	0.0498	0.7847	0.2311	0.6521	0.3425	1.0774

Table S3 Required number of randomly selected ERA5 10-meter reanalysis (unit: hours) to obtain an estimate within ±10%, ±5%, ±2%, and ±1% of the parameters from the entire observed time series (157 465 data points), calculated at the 90% confidence level. The fits to obtain the required data density are shown in Table S4.

Error margins	Location	Mean	Std. dev.	Skewness	Kurtosis	Shape *k*	Scale *c*	Power density
±10%	SN50500	73	96	8172	5016	180	73	471
	SN44080	66	117	8313	44143	185	67	472
	SN42160	57	126	11723	95190	194	56	427
	SN38140	60	134	8735	711310	195	59	460
	SN35860	64	139	6207	3540359	185	64	508
	average	64	123	9262	944804	188	64	468
±5%	SN50500	290	378	32016	19838	695	288	1856
	SN44080	264	461	32714	178285	730	266	1877
	SN42160	229	495	46455	392676	761	227	1711
	SN38140	238	528	34605	2908557	751	232	1825
	SN35860	254	547	24898	14867900	716	254	2041
	average	255	482	34138	3673452	731	254	1862
±2%	SN50500	1780	2314	200956	124202	4155	1777	11362
	SN44080	1642	2826	208777	1128607	4469	1649	11743
	SN42160	1443	3016	298655	2556252	4626	1424	10706
	SN38140	1461	3244	221711	18715159	4468	1430	11298
	SN35860	1587	3343	165203	99101050	4294	1587	12890
	average	1583	2949	219061	24325054	4403	1574	11600
±1%	SN50500	7030	9113	809645	498171	16071	7032	44916
	SN44080	6548	11134	848415	4558267	17597	6563	47679
	SN42160	5802	11843	1220400	10544961	18114	5721	43071
	SN38140	5777	12805	903642	76526556	17220	5660	45063
	SN35860	6368	13141	691404	416179369	16643	6348	51972
	average	6305	11608	894702	101661465	17129	6265	46541

Table S4. Fitted equations describing the relationship between the percent error (Y) and sample size (n), based on random sampling results from ERA5 10 m reanalysis data. Note: the station ID indicates the corresponding grid point location.

Parameters	SN50500	SN44080	SN42160	SN38140	SN35860
Mean (P)	Y=exp[-0.505ln(n)+4.47]	Y=exp[-0.496ln(n)+4.356]	Y=exp[-0.494ln(n)+4.275]	Y=exp[-0.504ln(n)+4.368]	Y=exp[-0.498ln(n)+4.365]
Mean (N)	Y=-exp[-0.499ln(n)+4.413]	Y=-exp[-0.501ln(n)+4.404]	Y=-exp[-0.498ln(n)+4.316]	Y=-exp[-0.498ln(n)+4.304]	Y=-exp[-0.5ln(n)+4.38]
Std. dev (P)	Y=exp[-0.504ln(n)+4.576]	Y=exp[-0.488ln(n)+4.535]	Y=exp[-0.489ln(n)+4.568]	Y=exp[-0.497ln(n)+4.688]	Y=exp[-0.493ln(n)+4.671]
Std. dev (N)	Y=-exp[-0.506ln(n)+4.61]	Y=-exp[-0.506ln(n)+4.711]	Y=-exp[-0.507ln(n)+4.754]	Y=-exp[-0.505ln(n)+4.775]	Y=-exp[-0.506ln(n)+4.802]
Skewness (P)	Y=exp[-0.497ln(n)+6.767]	Y=exp[-0.494ln(n)+6.749]	Y=exp[-0.492ln(n)+6.901]	Y=exp[-0.493ln(n)+6.766]	Y=exp[-0.484ln(n)+6.511]
Skewness (N)	Y=-exp[-0.508ln(n)+6.875]	Y=-exp[-0.508ln(n)+6.891]	Y=-exp[-0.505ln(n)+7.038]	Y=-exp[-0.505ln(n)+6.887]	Y=-exp[-0.5ln(n)+6.67]
Kurtosis (P)	Y=exp[-0.499ln(n)+6.546]	Y=exp[-0.497ln(n)+7.613]	Y=exp[-0.489ln(n)+7.91]	Y=exp[-0.492ln(n)+8.935]	Y=exp[-0.483ln(n)+9.587]
Kurtosis (N)	Y=-exp[-0.504ln(n)+6.598]	Y=-exp[-0.507ln(n)+7.717]	Y=-exp[-0.502ln(n)+8.044]	Y=-exp[-0.503ln(n)+9.046]	Y=-exp[-0.5ln(n)+9.762]
Weibull k (P)	Y=exp[-0.512ln(n)+4.962]	Y=exp[-0.506ln(n)+4.943]	Y=exp[-0.508ln(n)+4.979]	Y=exp[-0.514ln(n)+5.011]	Y=exp[-0.512ln(n)+4.973]
Weibull k (N)	Y=-exp[-0.502ln(n)+4.839]	Y=-exp[-0.489ln(n)+4.767]	Y=-exp[-0.488ln(n)+4.771]	Y=-exp[-0.494ln(n)+4.808]	Y=-exp[-0.493ln(n)+4.779]
Weibull c (P)	Y=exp[-0.504ln(n)+4.463]	Y=exp[-0.495ln(n)+4.348]	Y=exp[-0.494ln(n)+4.261]	Y=exp[-0.504ln(n)+4.353]	Y=exp[-0.498ln(n)+4.36]
Weibull c (N)	Y=-exp[-0.5ln(n)+4.419]	Y=-exp[-0.502ln(n)+4.41]	Y=-exp[-0.499ln(n)+4.313]	Y=-exp[-0.498ln(n)+4.301]	Y=-exp[-0.5ln(n)+4.378]
Power density (P)	Y=exp[-0.506ln(n)+5.416]	Y=exp[-0.495ln(n)+5.329]	Y=exp[-0.493ln(n)+5.266]	Y=exp[-0.503ln(n)+5.384]	Y=exp[-0.497ln(n)+5.398]
Power density (N)	Y=-exp[-0.498ln(n)+5.332]	Y=-exp[-0.502ln(n)+5.393]	Y=-exp[-0.5ln(n)+5.33]	Y=-exp[-0.497ln(n)+5.326]	Y=-exp[-0.499ln(n)+5.413]

Table S5 Required number of randomly selected ERA5 100-meter reanalysis (unit: hours) to obtain an estimate within ±10%, ±5%, ±2%, and ±1% of the parameters from the entire observed time series (157 465 data points), calculated at the 90% confidence level. The fits to obtain the required data density are shown in Table S6.

Error margins	Location	Mean	Std. dev.	Skewness	Kurtosis	Shape k	Scale c	Power density
±10%	SN50500	56	110	16201	8729	198	54	374
	SN44080	73	123	7056	81022	189	74	521
	SN42160	61	133	11263	328841	205	62	468
	SN38140	58	137	15661	2453346	222	57	435
	SN35860	64	137	11069	795574	211	64	480
	average	63	128	12230	701703	205	63	456
±5%	SN50500	223	434	65875	38941	767	215	1501
	SN44080	289	483	27566	329399	745	294	2067
	SN42160	247	523	44785	1367095	803	247	1867
	SN38140	239	528	39510	2240186	816	234	1808
	SN35860	255	535	44939	3346344	815	255	1916
	average	251	501	44535	1464393	790	249	1832
±2%	SN50500	1391	2651	427303	248311	4604	1347	9434
	SN44080	1786	2950	176226	2103464	4560	1819	12841
	SN42160	1551	3187	290902	8991336	4889	1552	11635
	SN38140	1481	3272	247668	14218455	4903	1457	11209
	SN35860	1587	3244	296038	22351593	4884	1590	12125
	average	1560	3061	287628	9582632	4768	1553	11449
±1%	SN50500	5556	10417	1757931	1008422	17854	5394	37889
	SN44080	7091	11598	717060	8551751	17952	7217	51955
	SN42160	6236	12509	1198029	37379775	19172	6231	47065
	SN38140	5891	12995	998600	57540275	19027	5801	44825
	SN35860	6341	12685	1232216	94015313	18917	6340	48981
	average	6223	12041	1180767	39699108	18585	6197	46143

Table S6 Fitted equations describing the relationship between the percent error (Y) and sample size (n), based on random sampling results from ERA5 100 m reanalysis data. Note: the station ID indicates the corresponding grid point location.

Parameters	SN50500	SN44080	SN42160	SN38140	SN35860
Mean (P)	Y=exp[-0.5ln(n)+4.315]	Y=exp[-0.497ln(n)+4.402]	Y=exp[-0.494ln(n)+4.305]	Y=exp[-0.502ln(n)+4.357]	Y=exp[-0.498ln(n)+4.361]
Mean (N)	Y=-exp[-0.495ln(n)+4.254]	Y=-exp[-0.503ln(n)+4.458]	Y=-exp[-0.498ln(n)+4.354]	Y=-exp[-0.5ln(n)+4.335]	Y=-exp[-0.501ln(n)+4.383]
Std. dev (P)	Y=exp[-0.492ln(n)+4.533]	Y=exp[-0.489ln(n)+4.559]	Y=exp[-0.489ln(n)+4.593]	Y=exp[-0.501ln(n)+4.731]	Y=exp[-0.493ln(n)+4.656]
Std. dev (N)	Y=-exp[-0.506ln(n)+4.685]	Y=-exp[-0.506ln(n)+4.739]	Y=-exp[-0.507ln(n)+4.783]	Y=-exp[-0.503ln(n)+4.76]	Y=-exp[-0.508ln(n)+4.803]
Skewness (P)	Y=exp[-0.49ln(n)+7.047]	Y=exp[-0.494ln(n)+6.659]	Y=exp[-0.49ln(n)+6.854]	Y=exp[-0.497ln(n)+6.868]	Y=exp[-0.486ln(n)+6.817]
Skewness (N)	Y=-exp[-0.504ln(n)+7.187]	Y=-exp[-0.509ln(n)+6.815]	Y=-exp[-0.505ln(n)+7.015]	Y=-exp[-0.505ln(n)+6.958]	Y=-exp[-0.501ln(n)+6.972]
Kurtosis (P)	Y=exp[-0.495ln(n)+6.837]	Y=exp[-0.494ln(n)+7.888]	Y=exp[-0.486ln(n)+8.482]	Y=exp[-0.496ln(n)+8.86]	Y=exp[-0.483ln(n)+8.858]
Kurtosis (N)	Y=-exp[-0.504ln(n)+6.93]	Y=-exp[-0.508ln(n)+8.03]	Y=-exp[-0.501ln(n)+8.633]	Y=-exp[-0.506ln(n)+8.974]	Y=-exp[-0.498ln(n)+9.015]
Weibull k (P)	Y=exp[-0.511ln(n)+5.007]	Y=exp[-0.506ln(n)+4.955]	Y=exp[-0.507ln(n)+5.002]	Y=exp[-0.511ln(n)+5.037]	Y=exp[-0.512ln(n)+5.041]
Weibull k (N)	Y=-exp[-0.489ln(n)+4.776]	Y=-exp[-0.489ln(n)+4.78]	Y=exp[-0.493ln(n)+4.298]	Y=-exp[-0.502ln(n)+4.924]	Y=-exp[-0.493ln(n)+4.849]
Weibull c (P)	Y=exp[-0.5ln(n)+4.293]	Y=exp[-0.496ln(n)+4.404]	Y=-exp[-0.499ln(n)+4.358]	Y=exp[-0.502ln(n)+4.347]	Y=exp[-0.497ln(n)+4.352]
Weibull c (N)	Y=-exp[-0.495ln(n)+4.249]	Y=-exp[-0.503ln(n)+4.468]	Y=exp[-0.493ln(n)+5.305]	Y=-exp[-0.5ln(n)+4.333]	Y=-exp[-0.501ln(n)+4.387]
Power density (P)	Y=exp[-0.499ln(n)+5.256]	Y=exp[-0.496ln(n)+5.385]	Y=-exp[-0.501ln(n)+5.382]	Y=exp[-0.502ln(n)+5.376]	Y=exp[-0.496ln(n)+5.362]
Power density (N)	Y=-exp[-0.496ln(n)+5.225]	Y=-exp[-0.503ln(n)+5.451]	Y=exp[-0.494ln(n)+4.305]	Y=-exp[-0.496ln(n)+5.312]	Y=-exp[-0.501ln(n)+5.396]

Table S7. Comparison of observed wind statistics at 10 m height with estimates from ERA5 and the Global Wind Atlas (GWA) at selected stations. Units for mean wind speed and power density are m s^{-1} and W m^{-2}, respectively. ERA5 and GWA values are extracted from the nearest grid points closest to each station.

Station ID	Mean wind speed		Power density	
	Observed	GWA	Observed	GWA
SN50500	3.53	5.47	81	261
SN44080	6.85	7.88	417	651
SN42160	6.57	7.77	358	534
SN38140	2.28	4.03	21	105
SN35860	4.80	6.11	152	254
061800-99999	5.32	5.30	165	155
031700-99999	4.87	6.34	171	338