Marine Wind Speed Climatology for the Approaches to Portland Maine Harbor from National Weather Service Buoy Reports 1985- 2020

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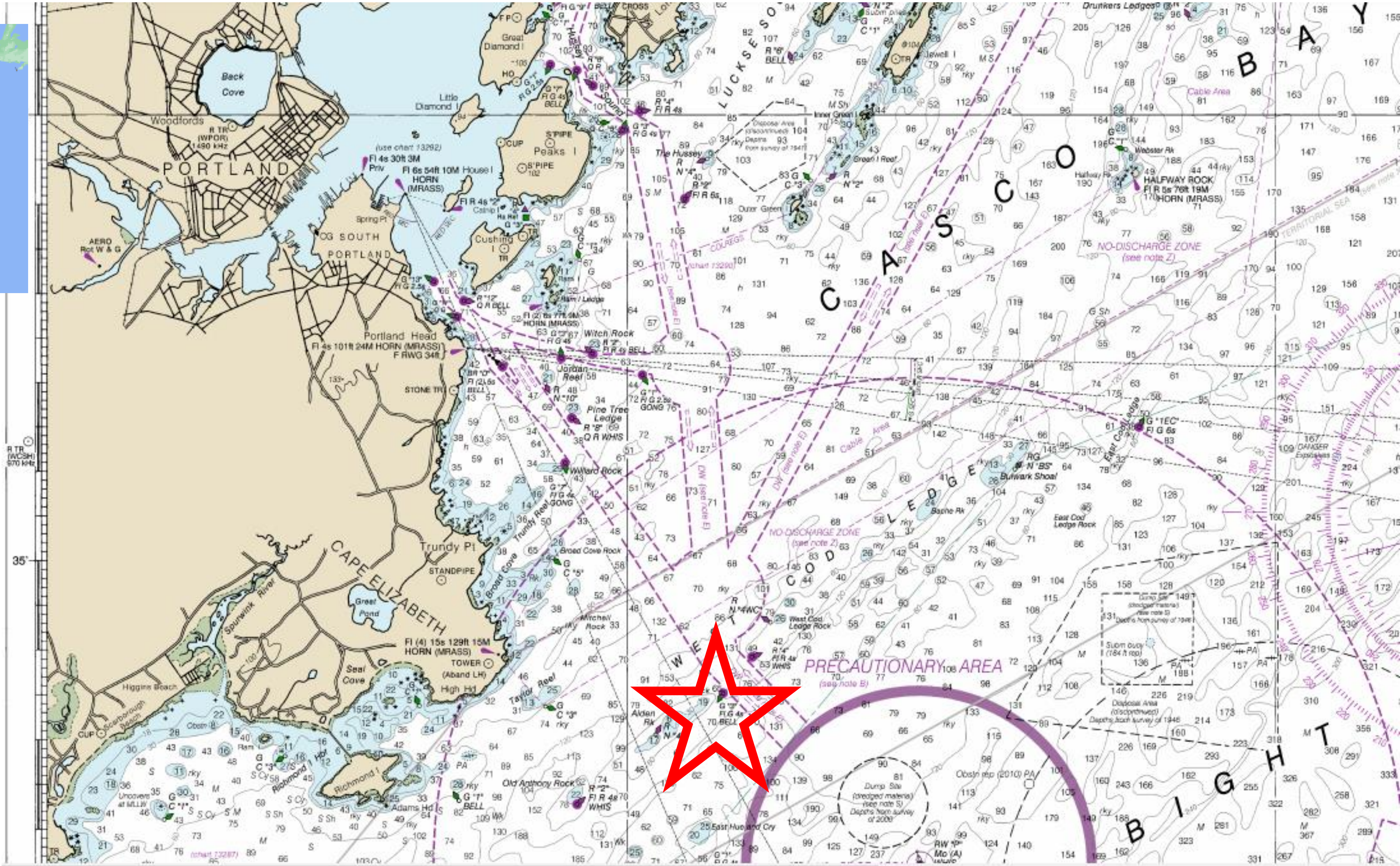
Background

- Use knots because original climatology was in knots; US marine winds are reported in knots
- The National Weather Service (NWS) has operated a marine meteorological buoy (44007) in the approaches to Portland Maine harbor (Fig. 1) since Feb 1982
- Through May 2020 the buoy has provided 292,884 wind speed reports
- NWS compiled a climatology for 44007 from 1982 through 2008 (https://www.ndbc.noaa.gov/data/climatic/44007.txt) (Fig. 2)
- Wind speeds were "as-is" – as received at NDBC, not adjusted for various anemometer heights and different sampling methods
- Worked at National Data Buoy Center for 15 years
- Originally from Maine

Constructed Homogenous and Extended Climatology

- Bouchard *et al*., 2021 constructed a homogenous and extended (added 12 years) (1982-2020) database that identified a defective anemometer from 1982 to 1984. The database was then limited to 1985-2020 to avoid discontinuities because of changing sampling methods & the defective anemometer.
- 1985-1994 wind speeds were adjusted to 5-m reference level (Fig. 3) following Hsu *et al.,* 1994 from 13.8-m anemometer height (resulting 5-m winds were about 11% less than the 13.8-m speeds).
- Here we present the updated climatology with Period of Record (Fig. 3 and Table 1), monthly (Figs. 4-9), yearly (Fig2. 10-11), and seasonal (Figs. 12-15 and Table 2) statistics and trends.
- Inspired by Gemmrich *et al.,* 2011 where changes in the wave record could be attributed to non-geophysical changes

Fig. 1: 44007 is 12 nautical miles (22 km) Southeast of Portland Maine



Buoy occupies transition zone between stable land measurements and offshore remotely sensed measurements

Fig 2: Monthly and Annual Wind Speed Climatology Portland Maine Buoy 44007 1982-2008

https://www.ndbc.noaa.gov/data/climatic/44007.txt

STATION: 44007

1 - MONTHLY AND ANNUAL FREQUENCY AND CUMULATIVE PERCENT FREQUENCY (10THS)

ELEMENT: AVERAGE WIND SPEED (KNOTS) -- POR: (2/1982 - 12/2008) (212768 RECORDS, 94.9% HAVE ELEMENT)

	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		ANN	
	F	CPF	F	CPF	F	CPF	F	CPF	F	CPF	F	CPF	F	CPF	F	CPF	F	CPF	F	CPF	F	CPF	F	CPF	F	CPF
47	-	-	-	-	1	#	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	#
46	-	-	-	-	1	999	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	999
45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	#	-	-	-	-	-	-	1	999
44	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	999
43	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	999	1	#	-	-	-	-	2	999
42	-	-	-	-	-	-	2	#	-	-	-	-	-	-	1	#	-	-	-	-	-	-	-	-	3	999
41	2	#	1	#	-	-	-	-	-	-	-	-	-	-	-	-	1	999	-	-	3	#	-	-	7	999
40	-	-	-	-	-	-	1	999	-	-	-	-	-	-	1	999	-	-	-	-	-	-	-	-	2	999
39	1	999	1	999	1	999	1	999	-	-	-	-	-	-	-	-	1	999	1	999	1	999	-	-	7	999
38	-	-	1	999	-	-	1	999	-	-	-	-	-	-	-	-	-	-	-	-	1	999	1	#	4	999
37	8	999	4	999	3	999	1	999	-	-	-	-	-	-	1	999	-	-	3	999	5	999	2	999	27	999
36	3	999	1	999	3	999	3	999	-	-	-	-	-	-	1	999	-	-	1	999	2	999	4	999	18	999
35	21	999	4	999	1	999	3	999	2	#	-	-	-	-	-	-	1	999	4	999	14	999	14	999	64	999
34	18	998	5	999	5	999	4	999	-	-	-	-	-	-	-	-	-	-	6	999	5	998	18	999	61	999
33	36	997	23	999	22	999	5	999	3	999	1	#	-	-	-	-	2	999	10	999	22	998	50	998	174	999
32	23	995	14	997	14	998	16	999	-	-	-	-	-	-	2	999	1	999	17	999	16	997	40	995	143	998
31	85	994	37	996	37	997	26	998	5	999	-	-	-	-	1	999	4	999	34	998	42	996	86	993	357	998
30	36	989	36	994	42	995	24	996	5	999	-	-	1	#	3	999	1	999	50	996	32	993	71	988	301	996
29	120	987	73	992	66	993	24	995	10	999	2	999	2	999	2	999	11	999	68	993	65	991	115	984	558	994
28	79	980	62	987	69	989	35	994	3	999	2	999	-	-	3	999	4	999	56	990	73	987	109	978	495	992
27	235	976	125	983	127	985	48	992	20	998	4	999	4	999	3	999	23	998	91	987	93	982	170	972	943	990
26	180	963	177	975	170	978	55	989	20	997	15	999	2	999	6	999	17	997	106	982	107	976	179	963	1034	985
25	333	952	243	963	195	968	94	986	47	996	25	999	5	999	19	999	39	996	134	976	211	970	284	953	1629	980
24	258	934	248	947	154	957	120	980	50	993	13	997	3	999	8	998	32	994	132	969	172	956	262	937	1452	973
23	523	919	351	931	322	949	159	973	81	991	36	997	7	999	34	997	69	992	252	962	327	946	492	923	2653	966
22	395	890	326	908	252	931	148	964	85	986	33	995	9	999	16	996	65	989	199	948	227	925	400	896	2155	953
21	643	868	494	886	502	916	276	956	139	981	107	993	23	998	74	995	167	985	391	937	495	911	702	874	4013	943
20	495	832	463	854	422	888	274	940	153	973	95	987	32	997	29	991	114	976	296	916	362	879	533	836	3268	924
19	919	804	763	824	805	864	491	924	330	965	237	981	86	995	125	989	354	970	699	901	760	857	1007	806	6576	909
18	919	752	726	774	793	819	610	896	371	946	231	968	176	991	194	983	398	951	812	863	828	809	986	751	7044	878
17	723	701	603	726	686	774	538	860	390	925	238	955	171	981	166	973	331	929	596	819	611	757	702	697	5755	845
16	1049	660	835	687	1031	736	739	829	553	903	449	942	358	972	396	964	670	911	984	787	975	718	1059	659	9098	818
15	774	601	662	632	772	678	666	787	592	872	438	917	330	952	318	944	546	875	692	735	715	657	813	601	7318	775
14	1087	558	915	589	1127	634	940	748	790	838	715	893	656	934	676	927	957	846	1138	697	1083	612	1166	556	11250	741
13	859	497	640	529	789	571	843	694	760	794	669	853	562	898	574	892	750	794	845	636	753	543	818	492	8862	688
12	1271	449	1136	487	1250	527	1312	646	1248	751	1285	816	1071	868	1342	863	1404	753	1454	591	1089	496	1258	447	15120	646
11	832	377	675	412	802	456	886	570	984	680	947	745	832	809	958	793	892	677	954	513	711	427	763	378	10236	575
10	938	331	889	368	1050	411	1266	519	1379	625	1509	692	1471	764	1591	744	1461	629	1358	462	984	382	1018	337	14914	527
9	714	278	587	310	715	352	933	446	1140	547	1238	608	1194	684	1171	662	1073	550	854	389	691	320	707	281	11017	457
8	874	238	794	271	1075	312	1259	392	1455	482	1640	539	1738	619	1891	601	1643	492	1301	343	890	277	893	242	15453	405
7	571	189	526	219	742	251	960	320	1177	400	1328	448	1515	524	1470	503	1171	403	826	273	600	221	623	193	11509	333
6	736	157	719	185	990	209	1120	264	1449	333	1587	374	1964	442	1997	427	1559	339	1106	229	746	183	748	159	14721	278
5	570	116	560	138	760	154	1028	200	1363	251	1500	286	1778	335	1686	324	1305	255	893	169	635	136	595	118	12673	209
4	544	84	619	101	769	111	950	140	1154	174	1364	203	1692	238	1715	237	1321	184	876	121	612	96	574	85	12190	150
3	296	53	309	60	408	68	569	86	737	109	873	127	1021	145	1023	148	734	113	489	74	352	57	367	54	7178	92
2	341	37	321	40	411	45	506	53	658	67	782	78	905	90	995	95	737	73	489	48	294	35	323	34	6762	59
1	145	18	126	19	155	22	216	24	311	30	357	35	380	40	391	44	246	33	183	22	134	17	160	16	2804	27
0	167	9	165	11	228	13	194	11	225	13	268	15	363	20	450	23	365	20	225	12	130	8	135	7	2915	14
75PCTL		18.3		17.7		16.7		14.6		12.4		11.5		10.1		10.5		12.4		15.6		17.2		18.3		14.8
50PCTL		13.6		12.8		12.1		10.1		8.7		8.0		7.2		7.4		8.6		11.1		12.6		13.6		9.9
25PCTL		8.7		8.0		7.4		6.2		5.4		5.1		4.5		4.7		5.4		7.0		7.8		8.7		6.0
MEAN		13.8		13.1		12.4		10.8		9.3		8.5		7.6		7.8		9.2		11.6		12.8		13.7		10.8
S.D.		6.8		6.7		6.5		5.9		5.1		4.6		4.1		4.4		5.1		6.2		6.4		6.8		6.2
TOTAL		17823		15259		17767		17346		17689		17988		18351		19333		18471		18626		15868		18247		212768
MAX		40.8		40.8		46.7		41.8		35.2		32.9		29.5		42.0		44.7		42.8		41.0		38.3		46.7
DATE		1989012116		1988021220		1993031400		1991042120		2005052401		1998061417		1992070913		1991081921		1985092722		1988102214		1990110613		1992122601		1993031400
MIN		0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0
DATE		2005011320		2008022209		2007032506		2008042702		2003052909		2008061502		2008070509		2007082806		2008090300		2006100413		2006112716		2008120905		2008120905

(* < 0.05% , # = 100.0%)

Fig. 3: **Buoy 44007 5-m Wind Speed (Adjusted for Height) from 01 Feb 1985 through 31 Jan 2020**

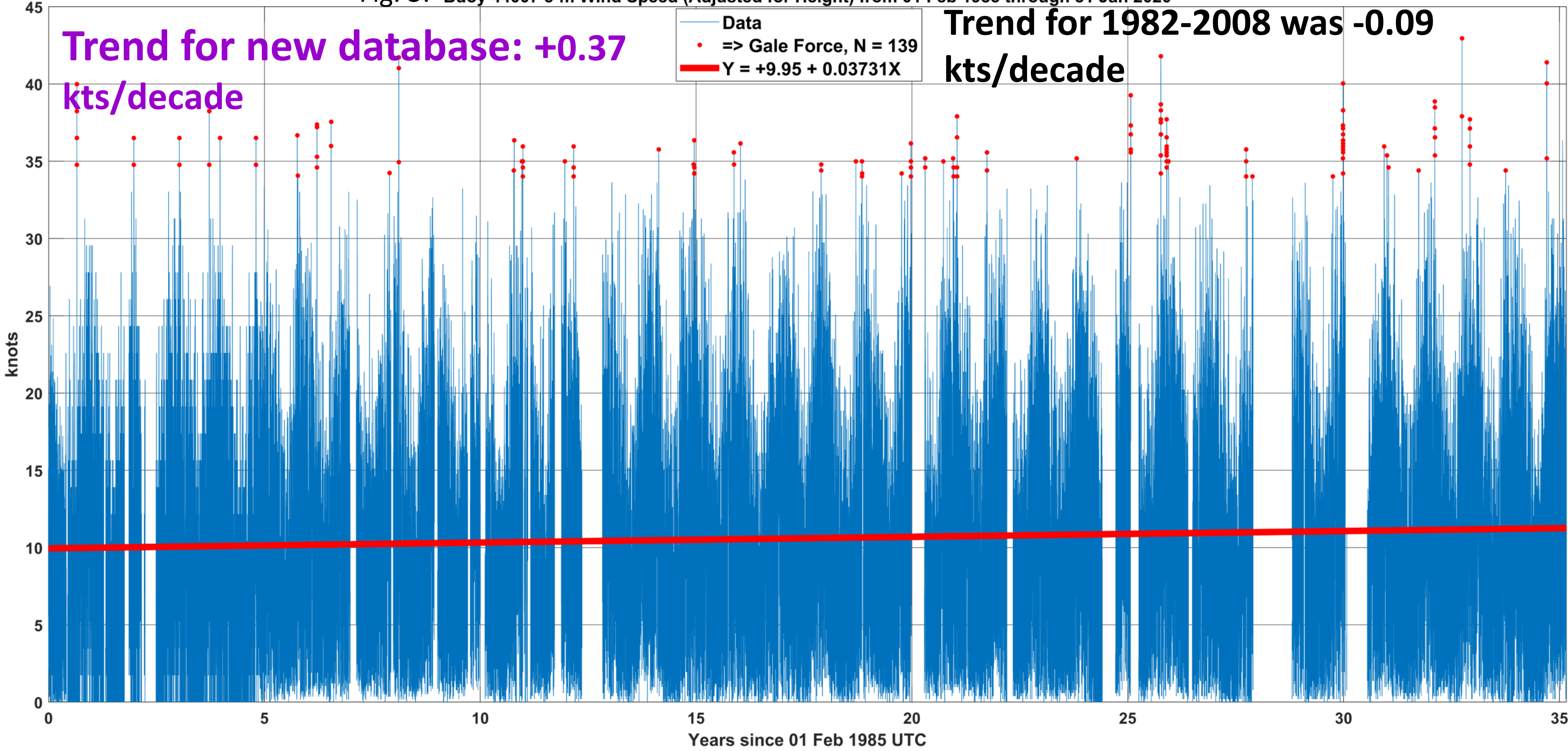


Table 1: Comparison of 1982-2008 and 1985-2020 Wind Speed Climatologies (knots)

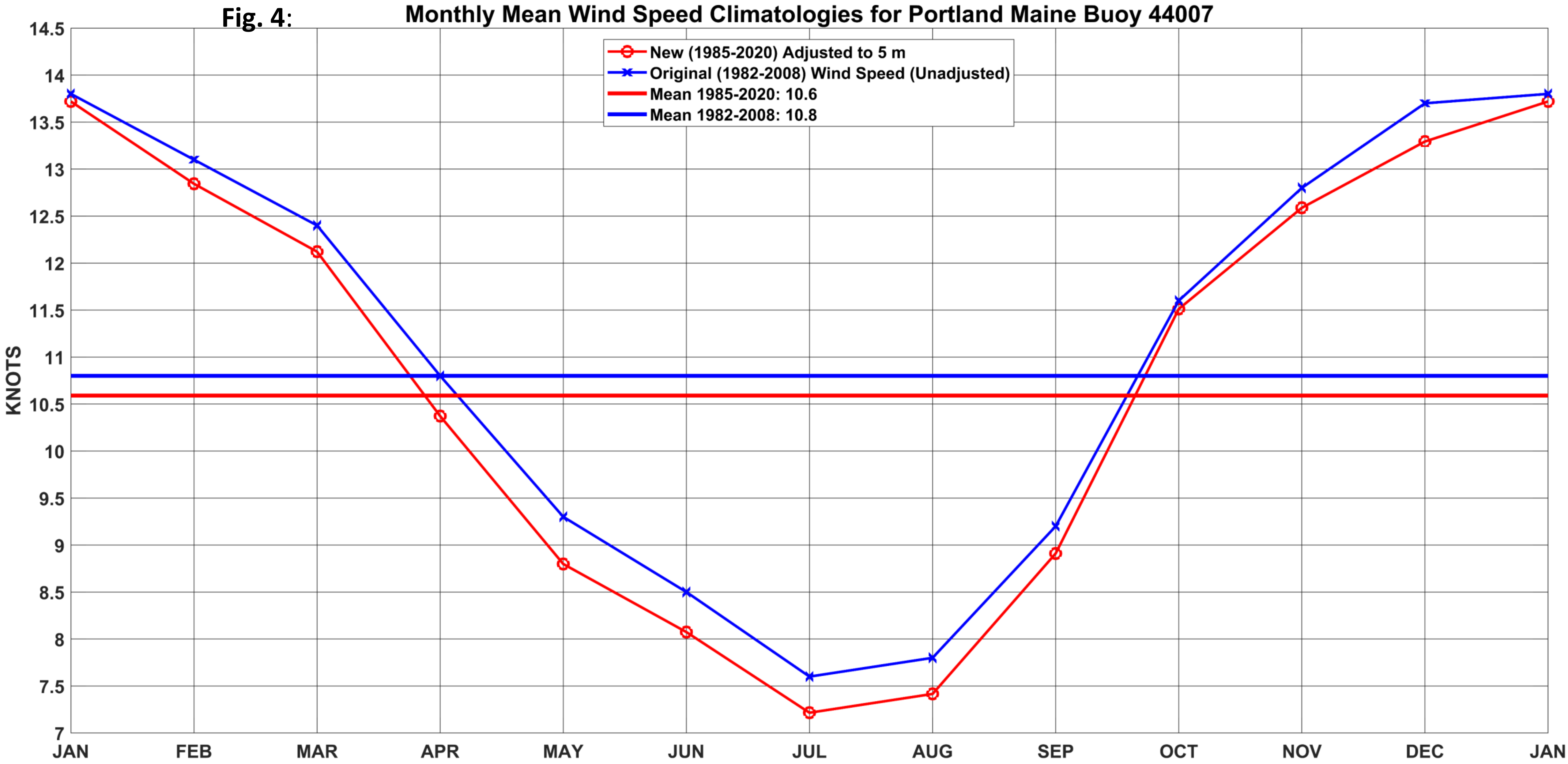
Statistic	***1982-2008 Climatology***	***1985-2020 Climatology***	***Difference***	***Percent Difference***
Gale Force Winds/1000 Reports	0.721	0.509	**-0.212**	-29.4
Maximum	46.7	43.0	**-3.7**	-7.9
Mean	10.8	10.6	**-0.2**	-1.9
Standard Deviation	6.2	6.1	**-0.1**	-1.6
# Reports	212768	261197	+48429	+22.8

Monthly Aggregated Statistics

- Monthly averages are lower for the New 1985-2020 climatology (Fig. 4) with the largest decrease (~5%) for May through August (Fig. 5).
- Maximum winds are generally lower except for May and June and new records are set for October and November (Fig. 7).
- The percent of data available[1] is also lower for the New 1985-2000 climatology except for November and December (Fig. 8).
- Frequency of occurrence of Gale Force winds is also lower except for June and July where both climatologies show zero occurrence (Fig. 9).

[1] Percent of data available is (100*Data Available)/ Data Expected. Data Available are the data that are distributed to the public in real-time. Data expected is one report per hour. The difference is data not received or not passing quality control.

Fig. 4:



Monthly Mean Wind Speed Climatologies for Portland Maine Buoy 44007
New (1985-2020) Adjusted to 5 m
Original (1982-2008) Wind Speed (Unadjusted)
Mean 1985-2020: 10.6
Mean 1982-2008: 10.8
KNOTS
14.5
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN

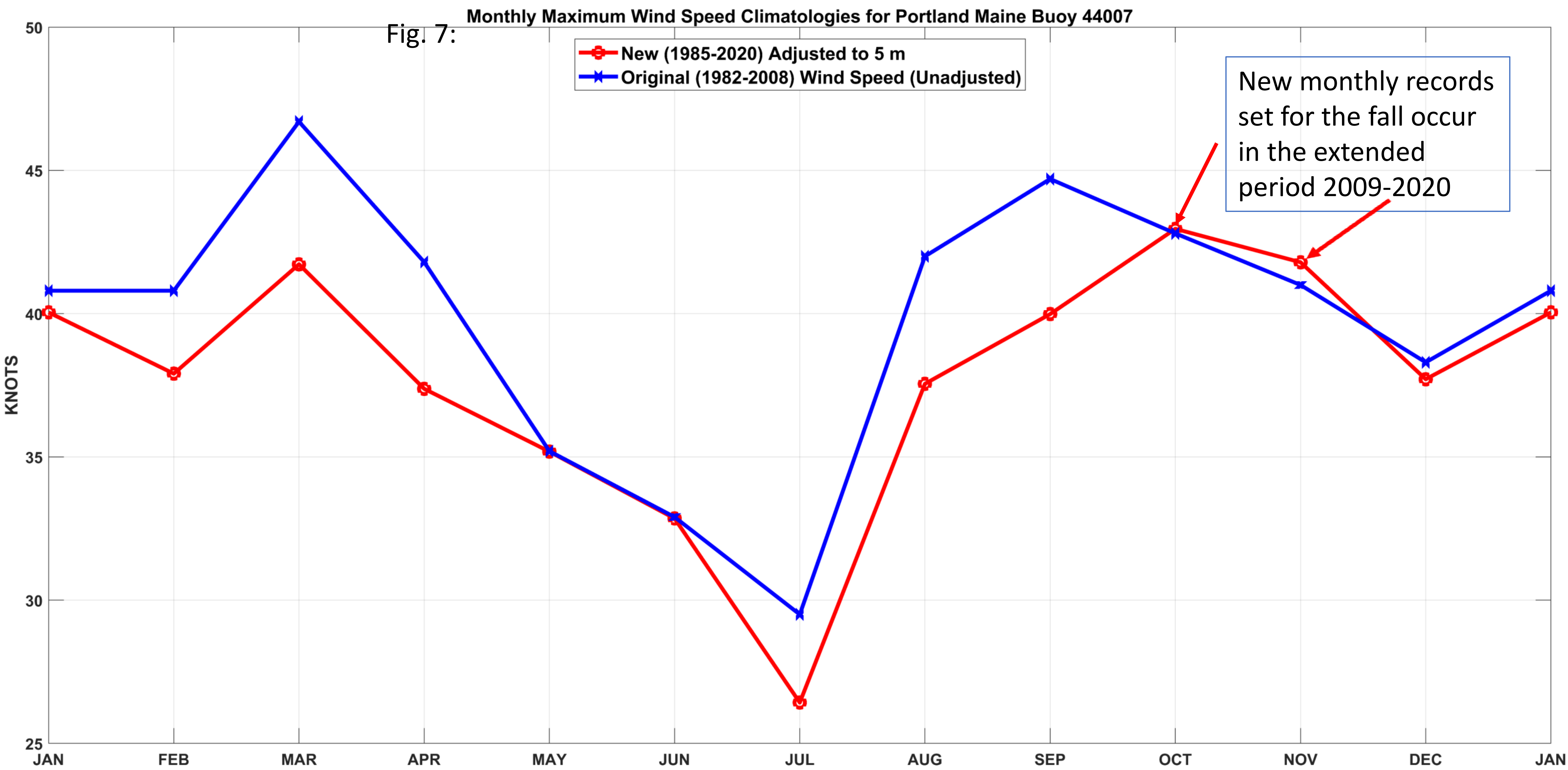
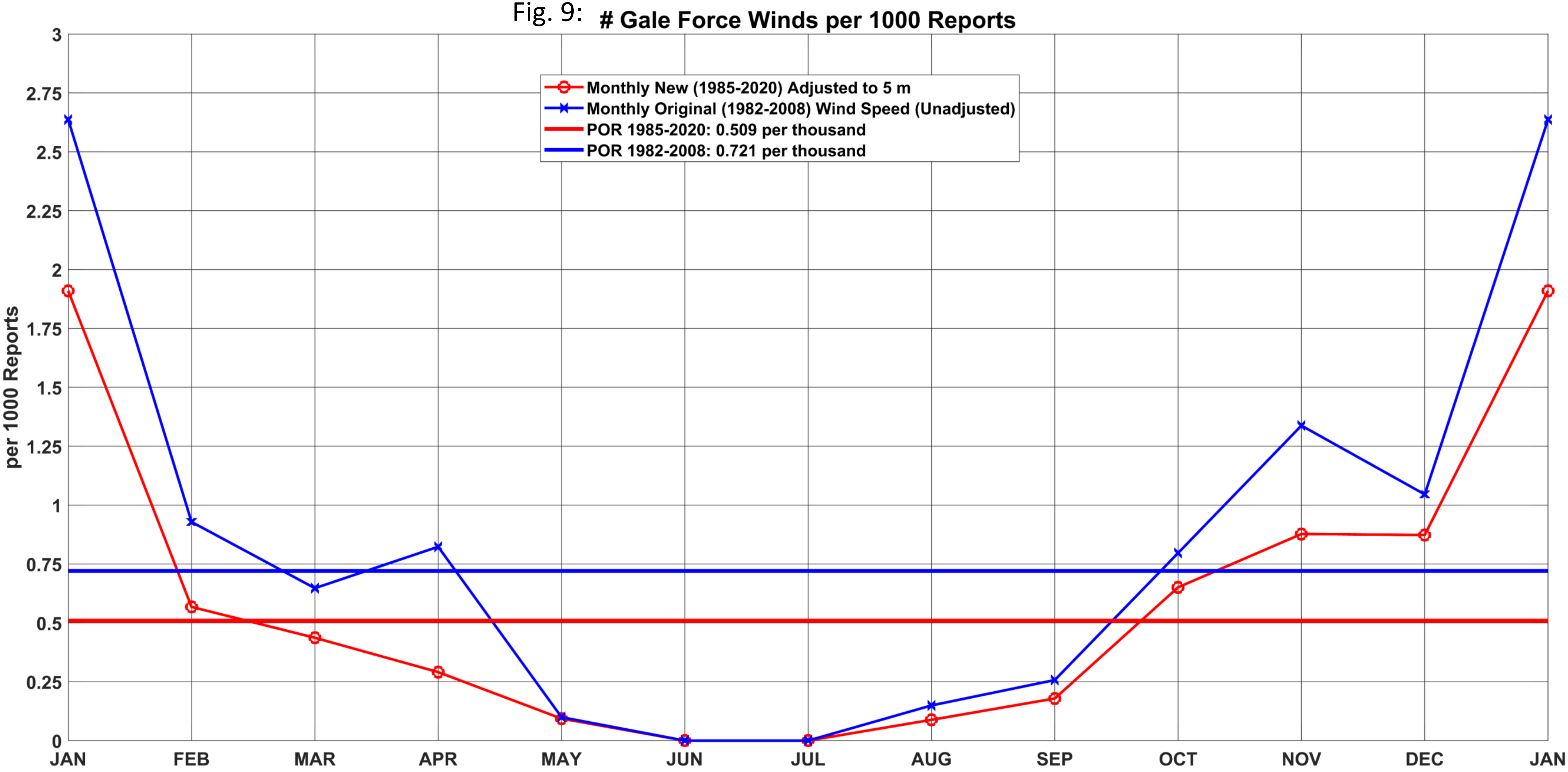
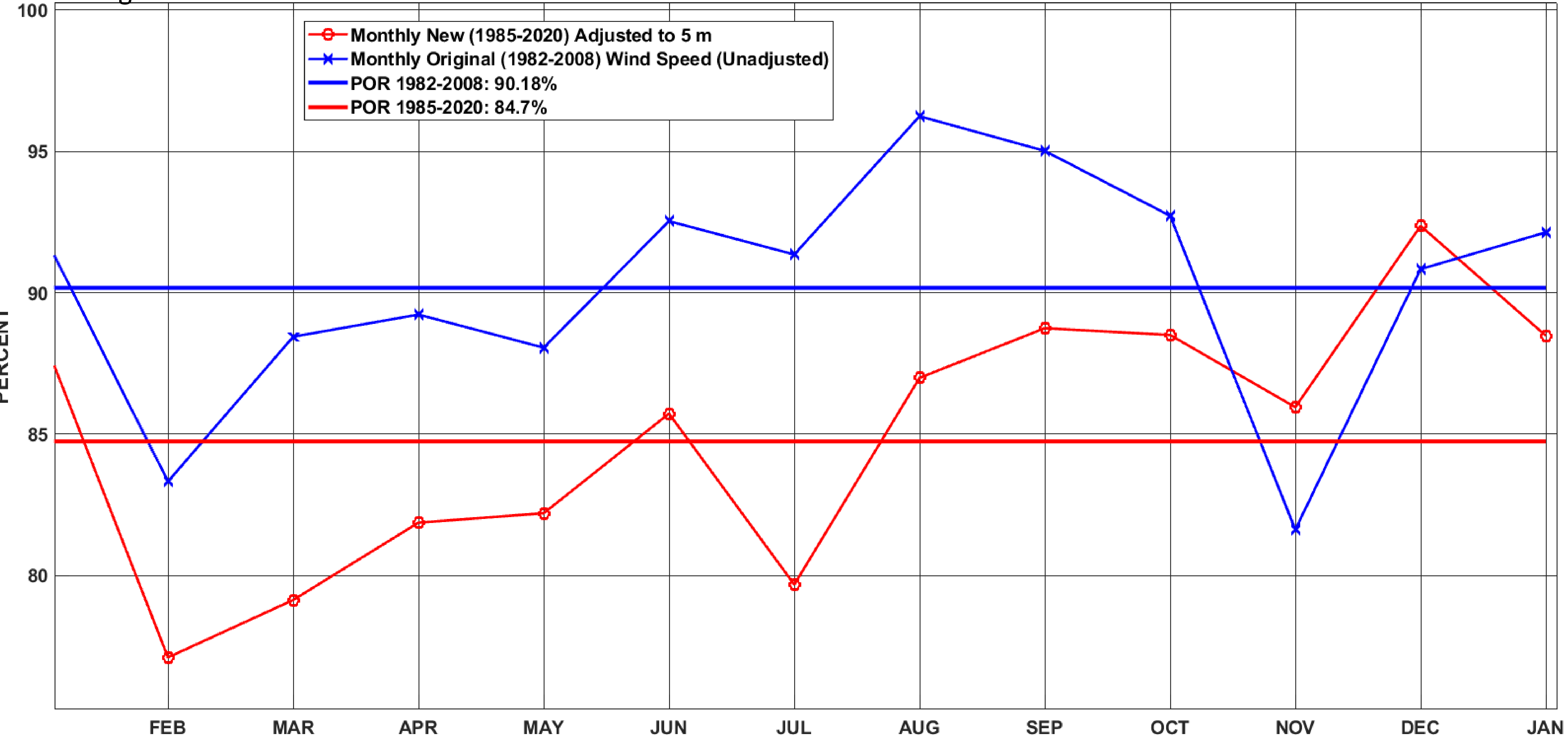

Monthly Maximum Wind Speed Climatologies for Portland Maine Buoy 44007
Fig. 7:
New (1985-2020) Adjusted to 5 m
Original (1982-2008) Wind Speed (Unadjusted)
New monthly records set for the fall occur in the extended period 2009-2020
KNOTS
50
45
40
35
30
25
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN

Fig. 9:



Gale Force Winds per 1000 Reports
Monthly New (1985-2020) Adjusted to 5 m
Monthly Original (1982-2008) Wind Speed (Unadjusted)
POR 1985-2020: 0.509 per thousand
POR 1982-2008: 0.721 per thousand
per 1000 Reports
3
2.75
2.5
2.25
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN

Fig. 8: **Monthly and Period of Record (POR) Data Availability Wind Speed Climatologies for Portland Maine Buoy 44007**



Yearly Aggregate Statistics

- The New 1985-2020 climatology shows lower wind speeds in the 1985-1994 period when anemometer heights were reduced to 5 m (Fig. 10).
- The anomalous high yearly wind speeds for 2013 and 2015 (Fig. 10) are due to the absence of the lower speed Spring and Summer 2013 and Summer 2015 (Table 2) that also contribute to the two years of lowest data availability (Fig. 12).
- Yearly maxima (Fig. 11) also reflect the lowered wind height in the early years, but show an increasing trend during the later (2013-2019) years.

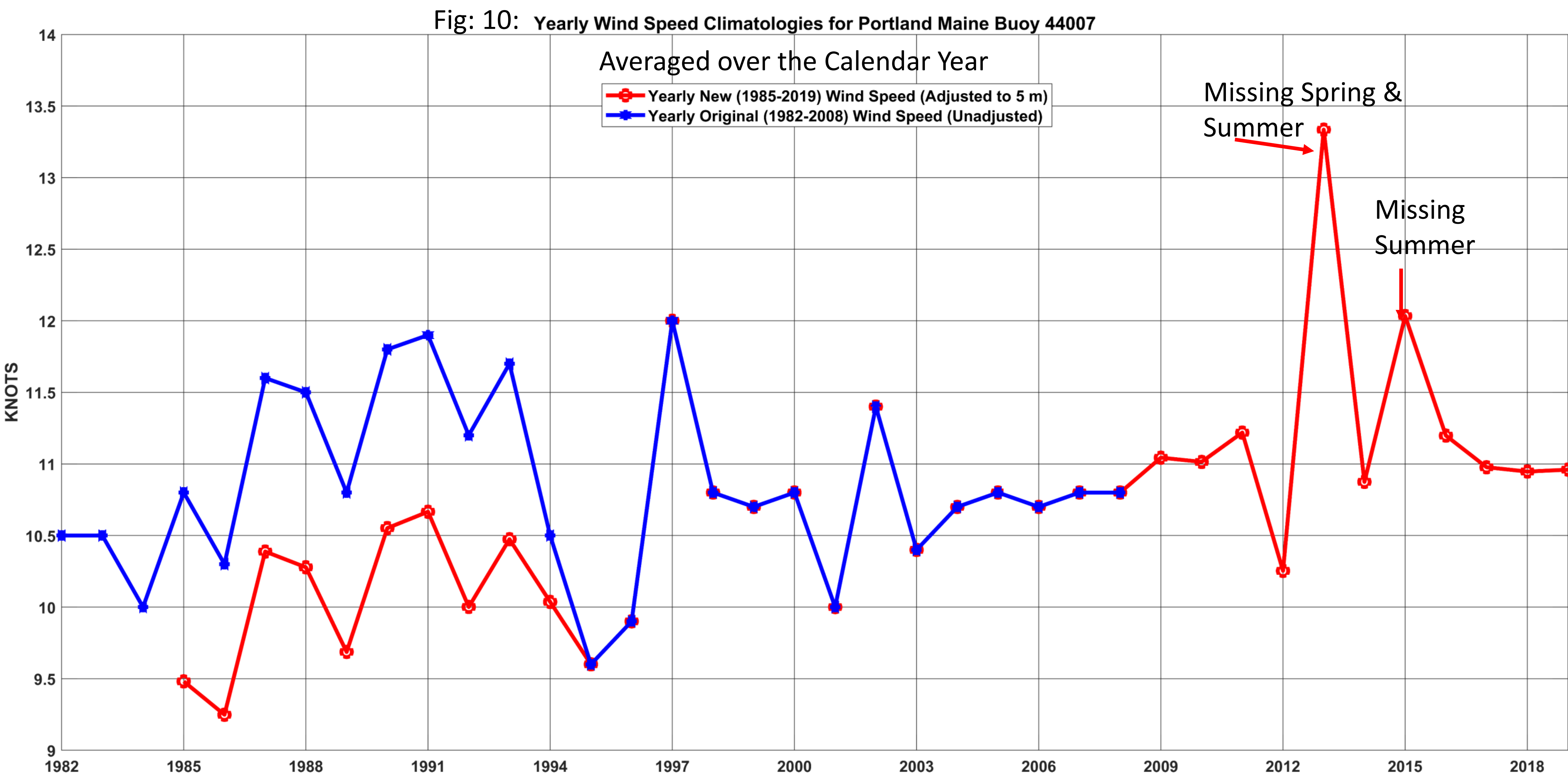


Fig: 10: Yearly Wind Speed Climatologies for Portland Maine Buoy 44007
Averaged over the Calendar Year
Yearly New (1985-2019) Wind Speed (Adjusted to 5 m)
Yearly Original (1982-2008) Wind Speed (Unadjusted)
Missing Spring & Summer
Missing Summer
KNOTS
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
2015
2018

Fig. 12: **Yearly Data Availability**

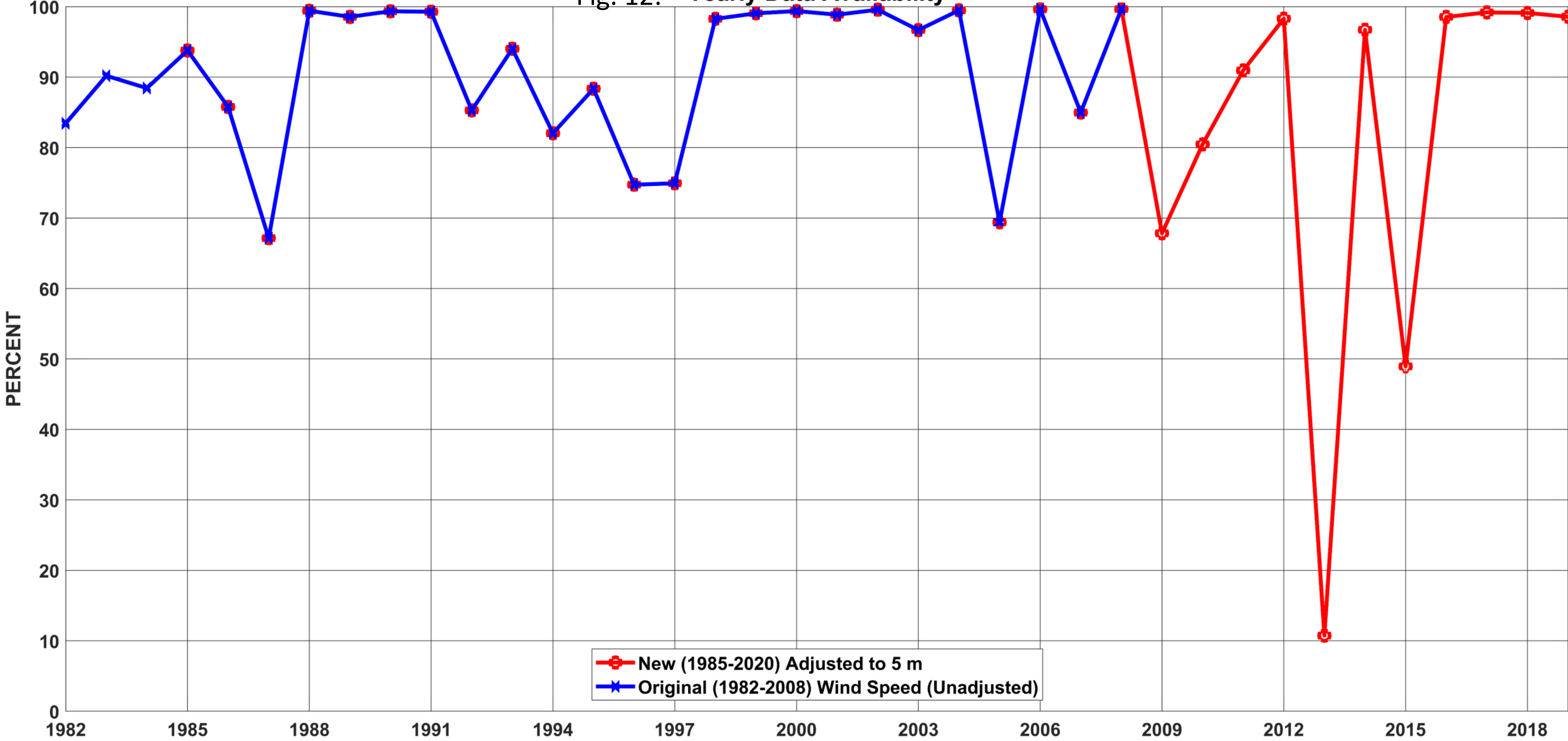
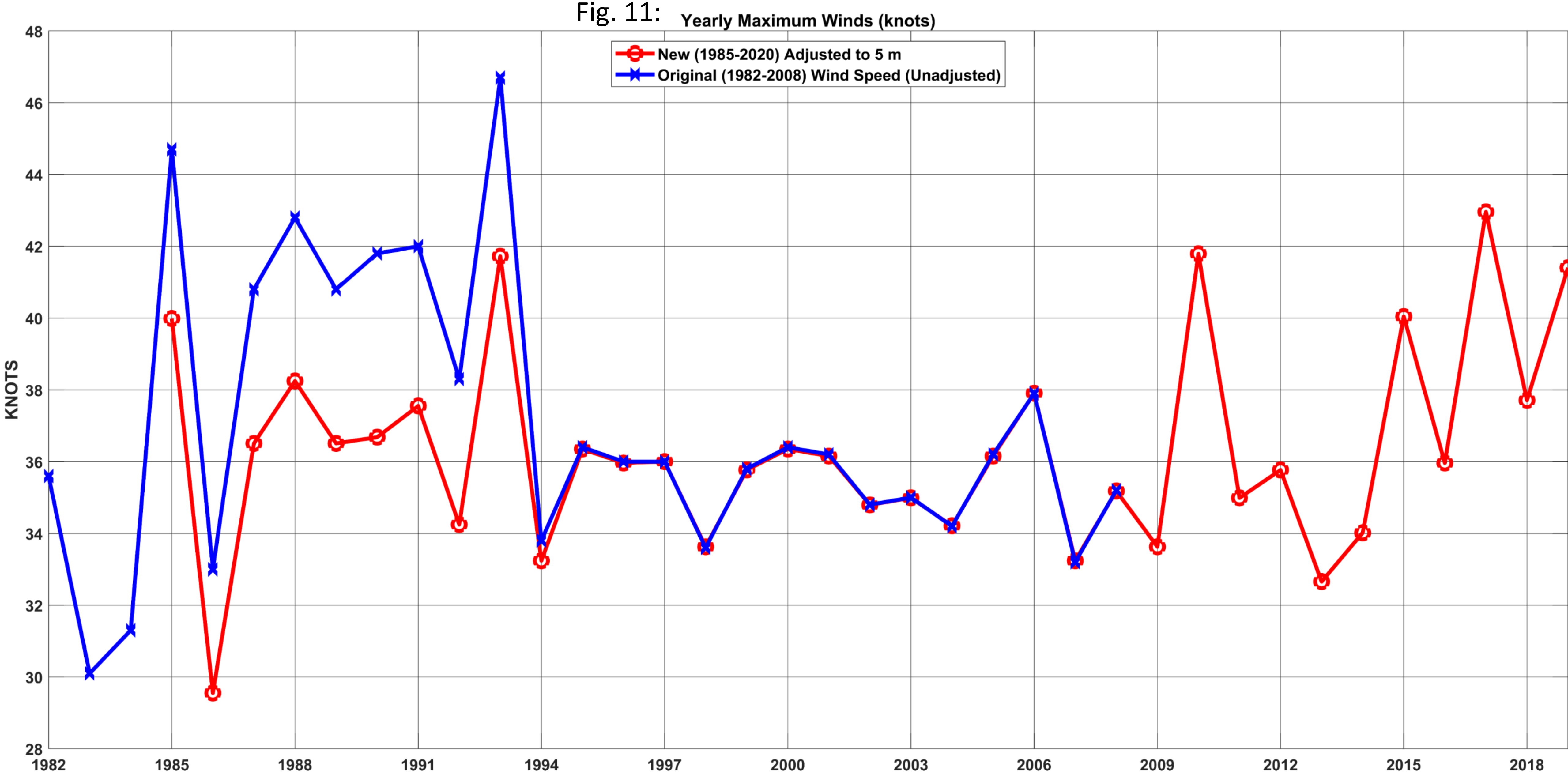


Fig. 11:



Yearly Maximum Winds (knots)
New (1985-2020) Adjusted to 5 m
Original (1982-2008) Wind Speed (Unadjusted)
KNOTS
48
46
44
42
40
38
36
34
32
30
28
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
2015
2018

Seasonal Aggregate Statistics

- The NWS 1982-2008 climatology does not provide aggregate statistics, only probability density functions by wind speed ranges.
- Seasons are: Spring: Mar-May; Summer: Jun-Aug; Autumn: Sep-Dec; and, Winter: Dec-Feb. The span is Spring 1985 through Autumn 2019, as there are no Feb 2020 data.
- Winter has the highest mean winds (Fig. 13).
- Spring, Summer, and Autumn show increasing trends (Fig. 14).
- Summer shows a decreasing trend possibly due to:
  - Low data availability in the latter higher wind speed regime (2013, Table 2 and Figure 12)
  - Fewer tropical/extratropical systems after 2008 (Fig. 16).
- Seasonal maximum winds show increasing trend (Fig. 15).

Fig. 13: **Seasonal Mean Winds Spring 1985 - Autumn 2019**

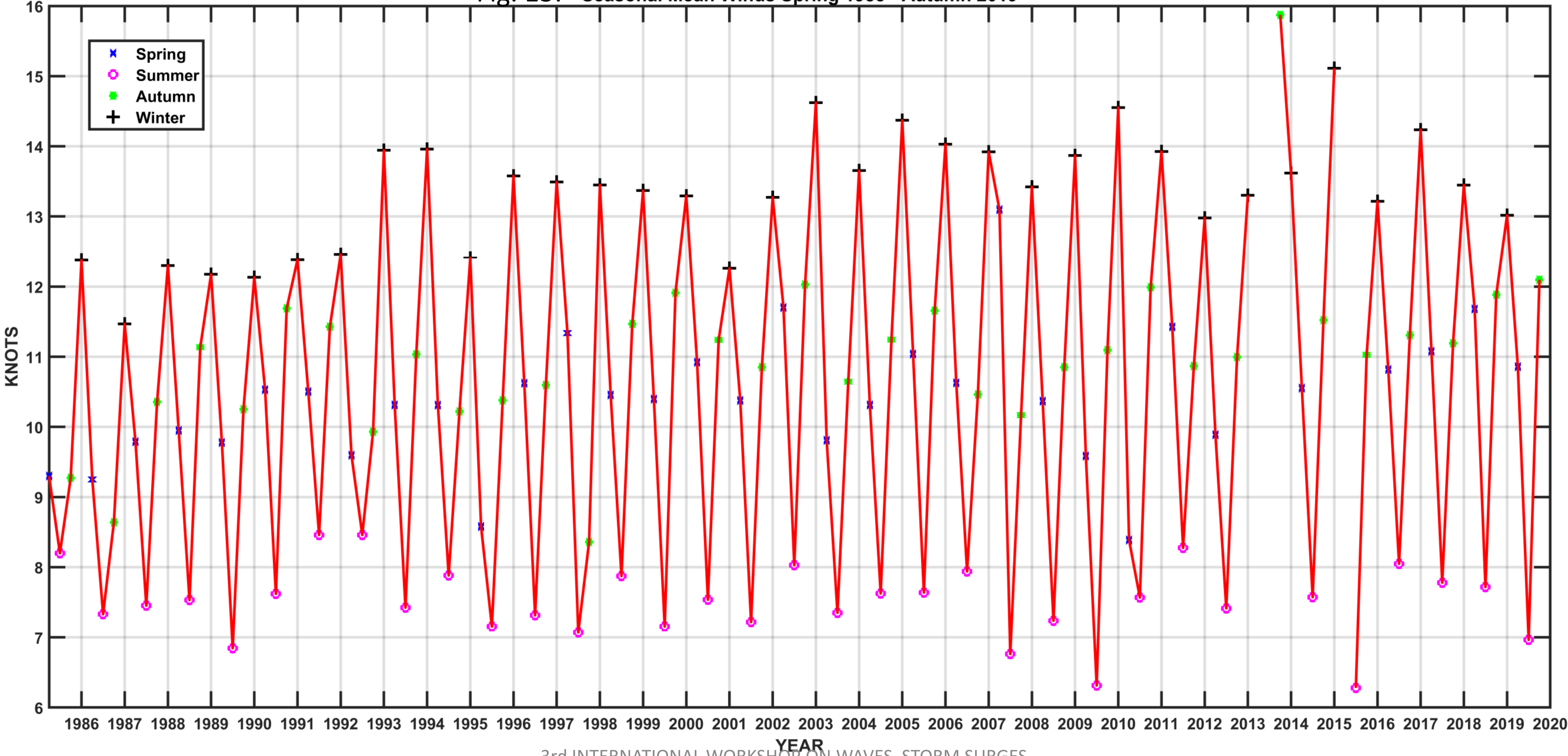


Fig. 14: **Seasonal Mean Winds with Least Squares Linear Fit (LSQ)**

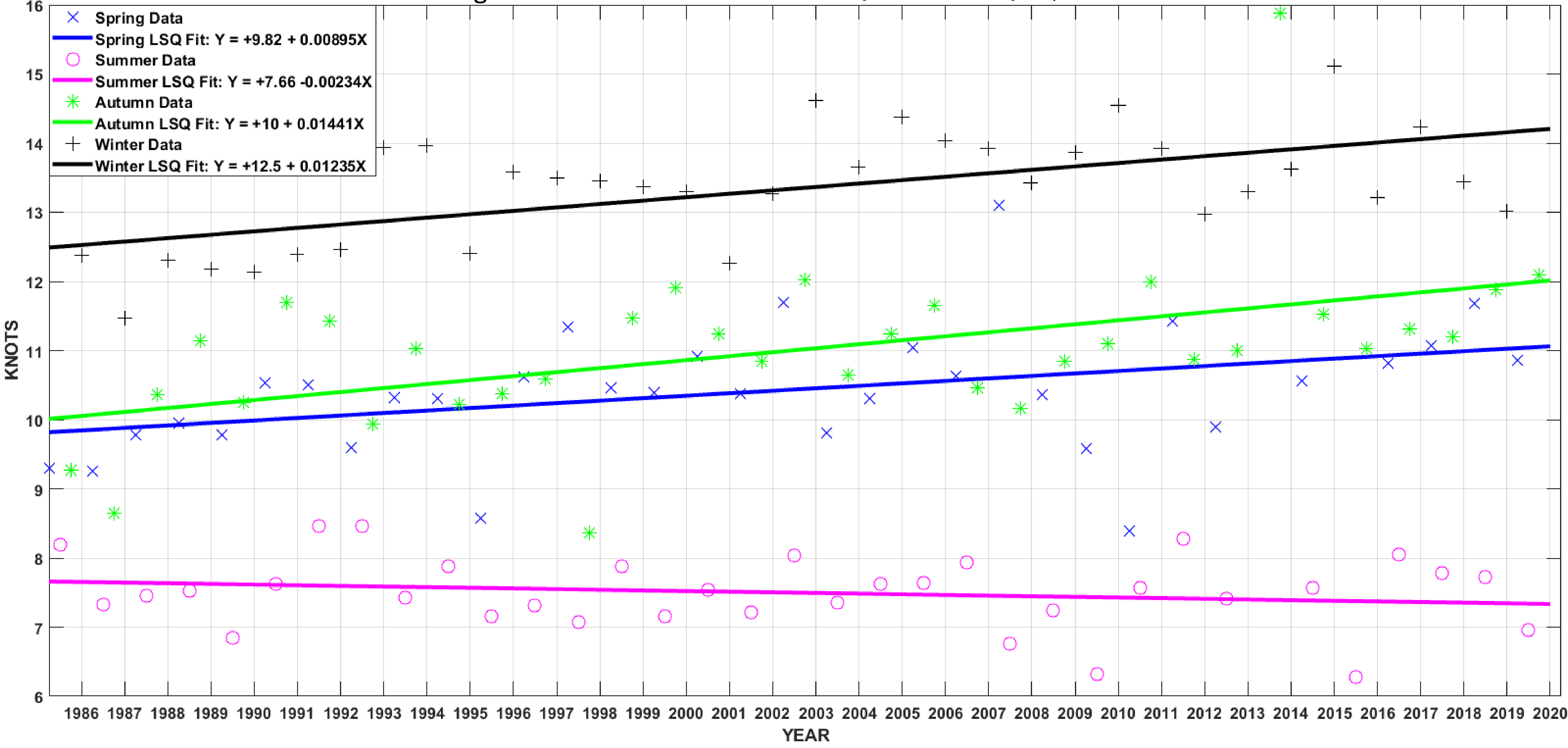


Table 2:

Seasonal Statistics (Knots) Spring 1985 through Autumn 2019

Statistic	Spring	Summer	Autumn	Winter
# of Seasons	33[1]	34[2]	35	33[3]
Span of Hours	77280	77280	76440	71472
# of Reports	62647	65007	67072	64348
Data Availability %	**81.1**	84.1	85.0	**90.0**
Mean	10.4	7.6	11.0	13.3
Standard Deviation	5.9	4.2	6.0	6.6
Maximum	41.7	37.6	43.0	40.0
# Gale Force Wind Reports	17	2	38	76
# Gale Force Winds/1000 Reports	0.272	0.031	0.558	1.18
Trend (Knots per decade)	**+0.36**	**-0.094**	**+0.58**	**+0.49**

[1] No reports 2013 and 2015

[2] No reports 2013

[3] Missing 1984-85 and 2019-2020, outside of PoR

Fig.16: TS or > Passing within 65 nautical miles of 44007

Source: Historical Hurricane Tracks, 2020

9 in the 1985-2008 climatology, but only Andrea in extended record 2012-2020

ET ANDREA June 2013

ET HANNA Sep 2008

ET BARRY June 2007

TS HERMINE Aug 2004

ET CINDY July 2000

TS/ET FLOYD Sep 1999

TS BERTHA July 1996

Hurricane/TS BOB Aug 1991

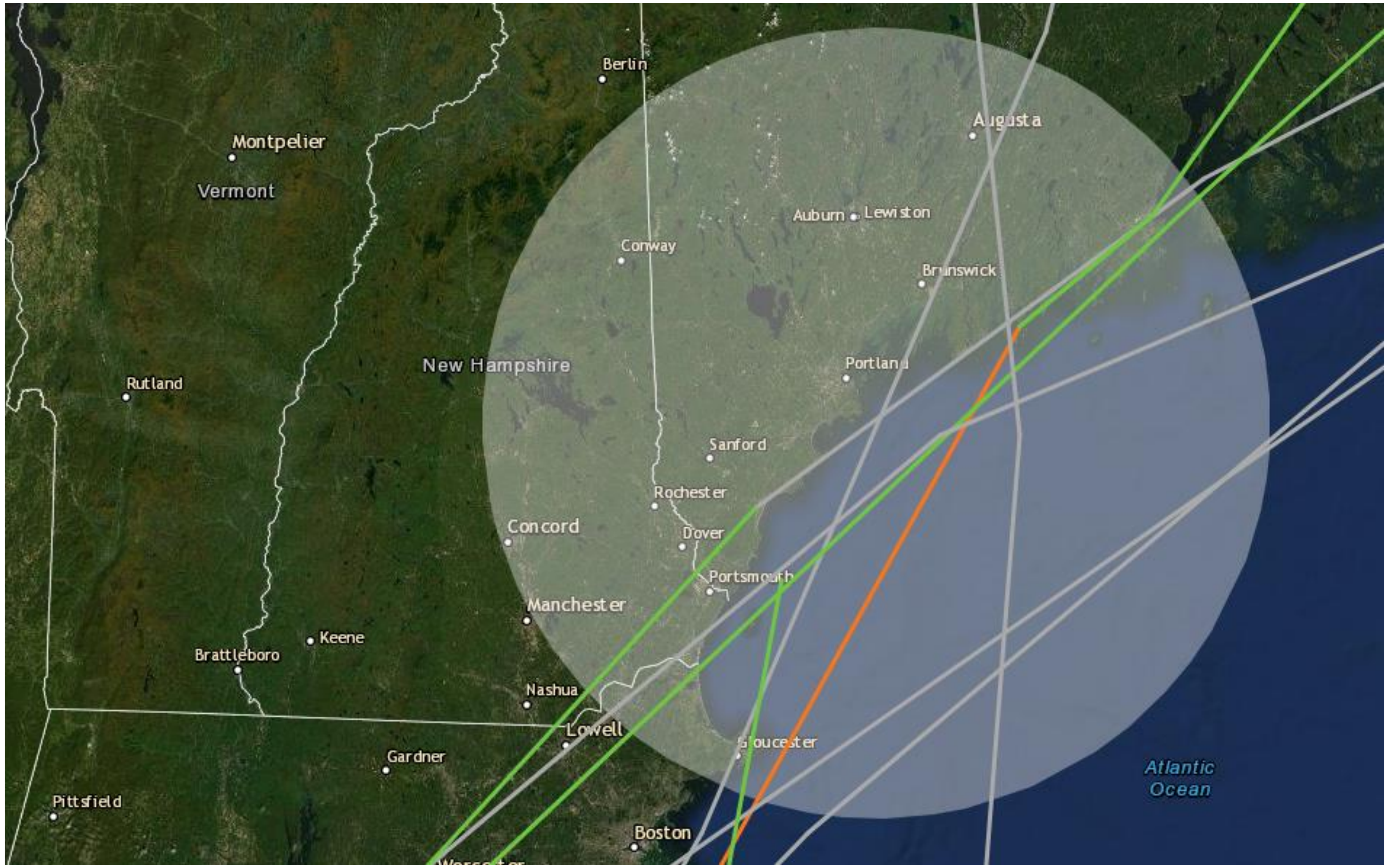
ET CHRIS Aug 1988

Hurricane/ET Gloria Sep 1985

Distribution:

7 Summer

3 Fall



Conclusions and Summary

- The New 1985-2020 climatology show generally lower wind speeds due to the reduction in reference heights in the early period (1984-1994) than the original 1982-2008 climatology.
- The general tend is for increasing means and maximum winds
- The exception is Summer, which shows a decreasing trend, possibly due to the lower data availability during the higher wind speed regime and fewer tropical/extratropical systems passing close to 44007.
- Counts Count! Data availability skews some of the yearly, seasonal, and monthly averages because of the absence of data in the lower wind speed Spring and Summer seasons

References

- Bouchard, R.H., R.E. Jensen, and L. Fiorentino, 2021: “A Study of Marine Wind Speed Climatology for the Approaches to the Portland Maine Harbor from National Weather Service Buoy Reports: 1982–2020”, *Proc. 101st AMS Annual Meeting,* On-line at: https://ams.confex.com/ams/101ANNUAL/meetingapp.cgi/Paper/381461
- Gemmrich, J., B. Thomas, and R. Bouchard, 2011: "Observational changes and trends in northeast Pacific wave records." *Geophysical Research Letters* 38.22, https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2011GL049518
- Hsu, S. A., E. A. Meindl, and D. B. Gilhousen, 1994: Determining the power-law wind-profile exponent under near-neutral stability conditions at sea. *J. Appl. Meteorol*., v.*33*(6), pp. 757-765. On-line at: https://journals.ametsoc.org/view/journals/apme/33/6/1520-0450_1994_033_0757_dtplwp_2_0_co_2.xml
- *National Hurricane Tracks*, NOAA Office for Coastal Management, 2020: On-line at: https://www.coast.noaa.gov/hurricanes/#map=4/32/-80

Supplementary Slides

Fig. 15: **Seasonal Maximum Winds Spring 1985 - Winter 2018**

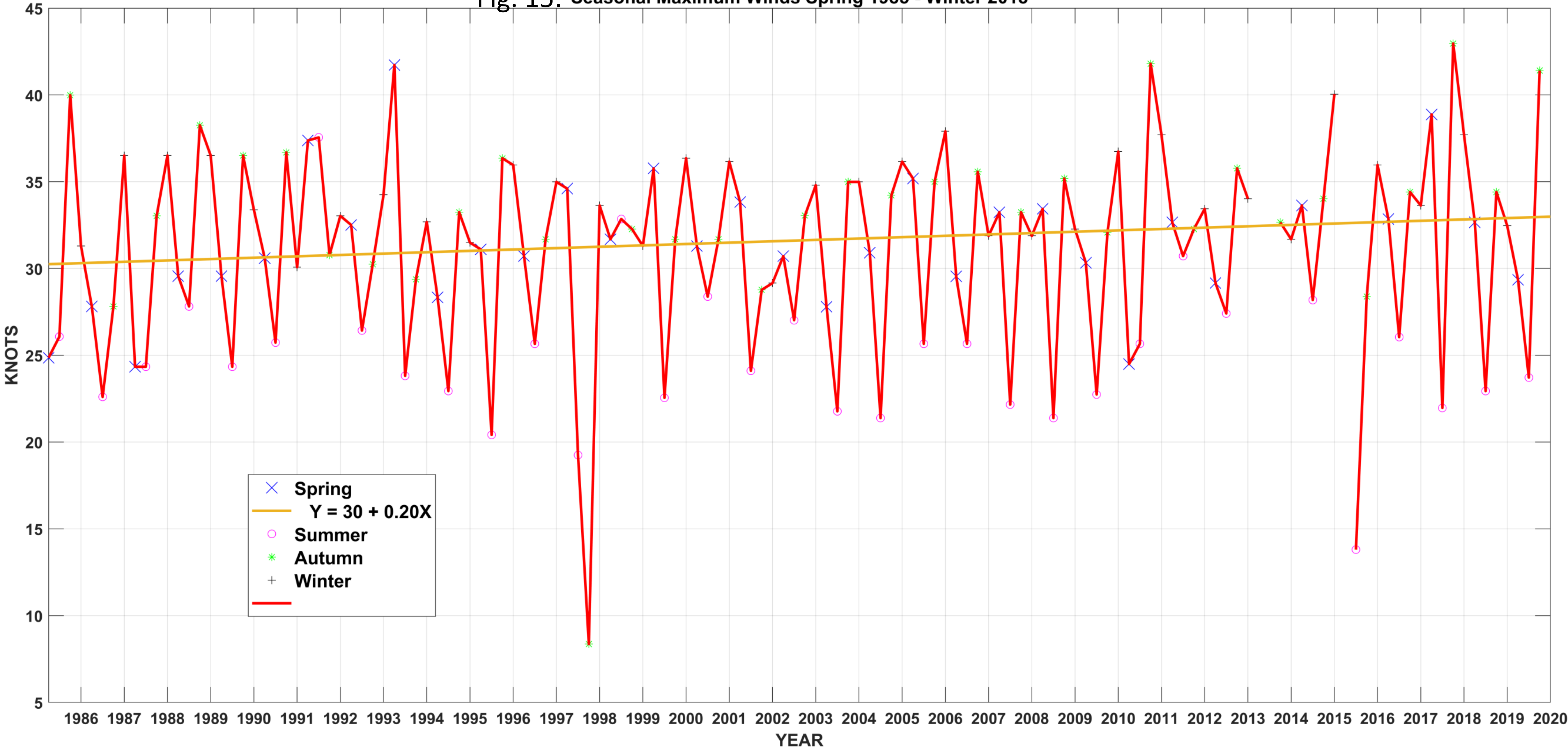


Table 2:

Seasonal Statistics (Knots) Spring 1985 through Autumn 2019

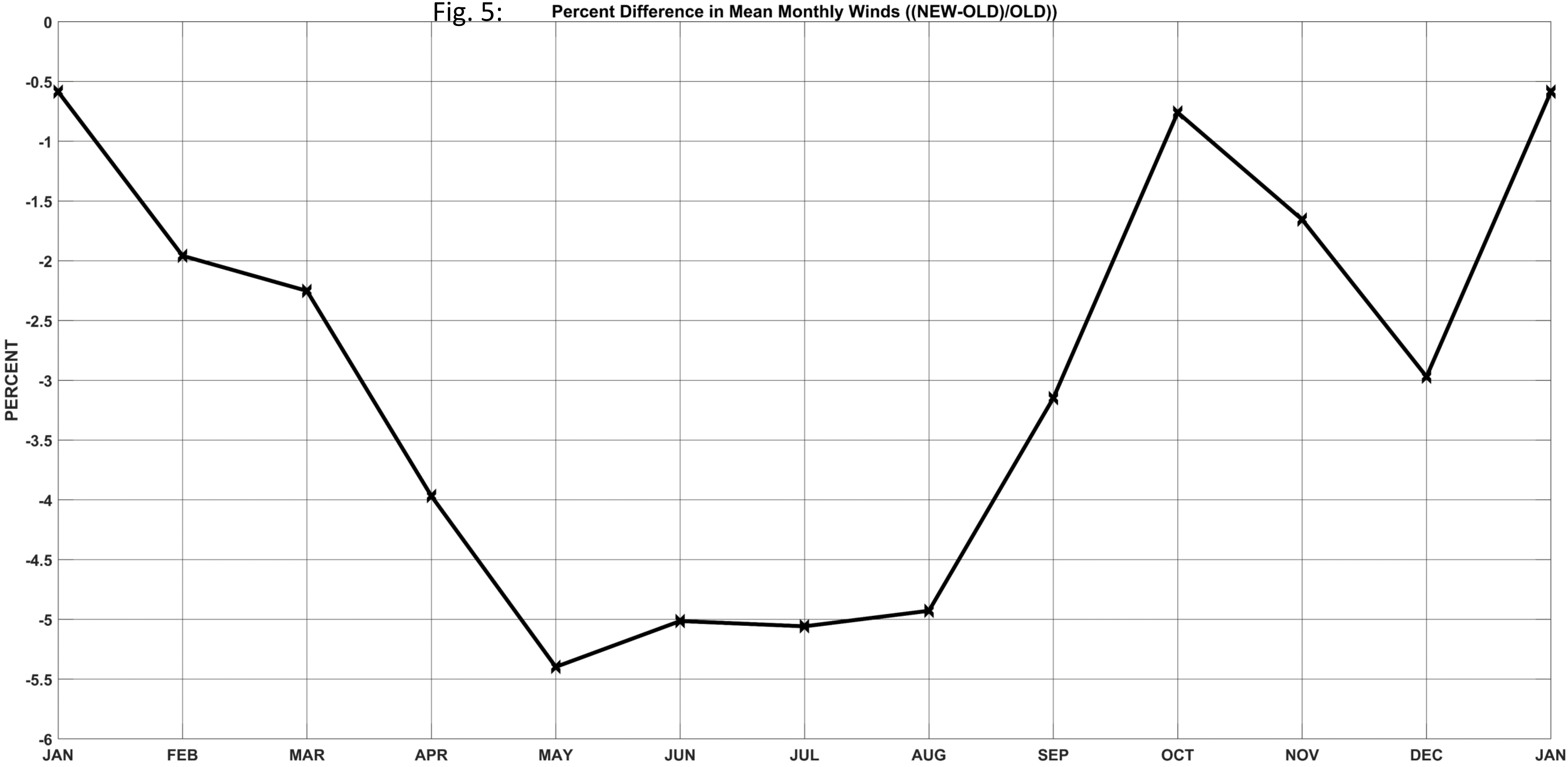
Statistic	Spring	Summer	Autumn	Winter
# of Seasons	33[1]	34[2]	35	33[3]
Span of Hours	77280	77280	76440	71472
# of Reports	62647	65007	67072	64348
Data Availability %	**81.1**	84.1	85.0	**90.0**
Mean	10.4	7.6	11.0	13.3
Standard Deviation	5.9	4.2	6.0	6.6
Maximum	41.7	37.6	43.0	40.0
# Gale Force Wind Reports	17	2	38	76
# Gale Force Winds/1000 Reports	0.272	0.031	0.558	1.18
Trend (Knots per decade)	**+0.36**	**-0.094**	**+0.58**	**+0.49**

[1] No reports 2013 and 2015

[2] No reports 2013

[3] Missing 1984-85 and 2019-2020, outside of PoR

Fig. 5:

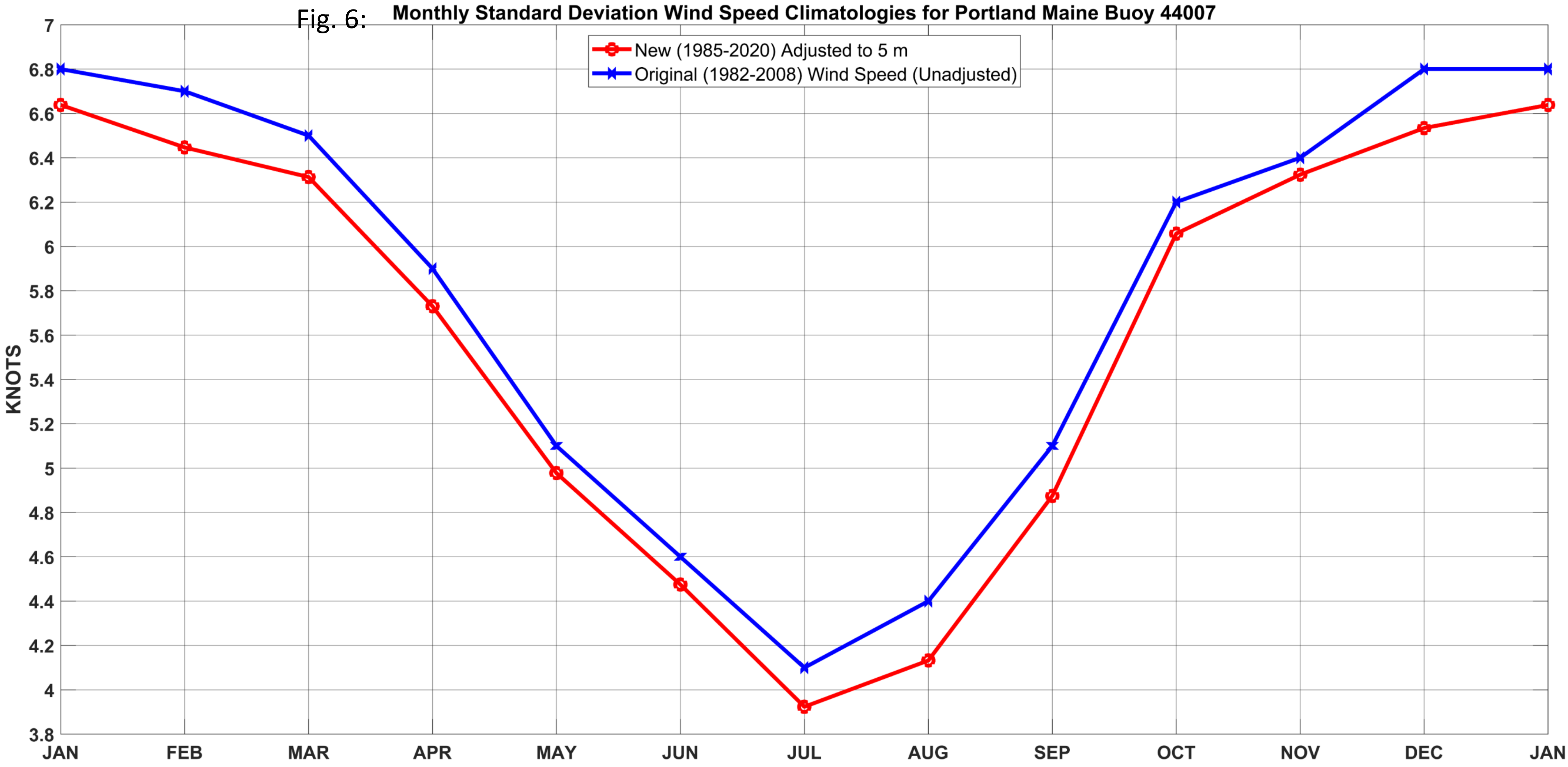


Percent Difference in Mean Monthly Winds ((NEW-OLD)/OLD))
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
-5
-5.5
-6
PERCENT
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN

Table 1: Comparison of 1982-2008 and 1985-2020 Wind Speed Climatologies (knots)

Statistic	1982-2008 Climatology	1985-2020 Climatology	Difference	Percent Difference
Gale Force Winds/1000 Reports	0.721	0.509	**-0.212**	-29.4
Maximum	46.7	43.0	**-3.7**	-7.9
75th Percentile	14.8	14.4	**-0.4**	-2.7
Mean	10.8	10.6	**-0.2**	-1.9
50th Percentile	9.9	9.7	**-0.2**	-2.0
25th Percentile	6.0	5.8	**-0.2**	-3.3
Standard Deviation	6.2	6.1	**-0.1**	-1.6
# Reports	212768	261197	+48429	+22.8

Fig. 6:



Monthly Standard Deviation Wind Speed Climatologies for Portland Maine Buoy 44007
New (1985-2020) Adjusted to 5 m
Original (1982-2008) Wind Speed (Unadjusted)
KNOTS
7
6.8
6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN

Wind Adjustments

- **Anemometer Height Adjustment: Power-Law Wind Profile, Near-Neutral Stability (Hsu *et al.,* 1994):**

$$\ln \frac{U5}{Uz} = 0.11 * \ln \frac{5}{Uz}$$

0.11* $\frac{U5}{U10}$ = 92.7% **Apply to winds Feb 1982 to 31 Jan 1985 2300 UTC**

$\frac{U5}{U13.8}$ = 89.4% **Apply to winds from 01 Feb 1985 0000 UTC through 09 May 1994 1250 UTC**

- **Vector to Scalar Averaging adjustment (Gillhousen, 1987):**
  - **Vector 7% lower than scalar when greater than 8 m/s**
  - <= 15.6 kts (8 m/s), no adjustment
  - > 15.6 kts (8 m/s), boost vector averaging by 1.075
  - **Apply to winds from Feb 1982 through June 1984**