

Sea Basin Checkpoints - Lot 4

"Black Sea"



NKUA/AM&WFG

WP2: Challenge 1 - Wind farm siting

TPD3:

Assessment of the confidence limits of the data base

National & Kapodistrian University of Athens,

School of Physics,

Atmospheric Modeling & Weather Forecasting Group

Assessment of the confidence limits of the data base

BY MEANS OF EVALUATION OF THE TWO INVOLVED NUMERICAL MODELS:

WAVE MODEL WAM

Parameter: Significant wave height H_s

ATMOSPHERIC MODEL SKIRON

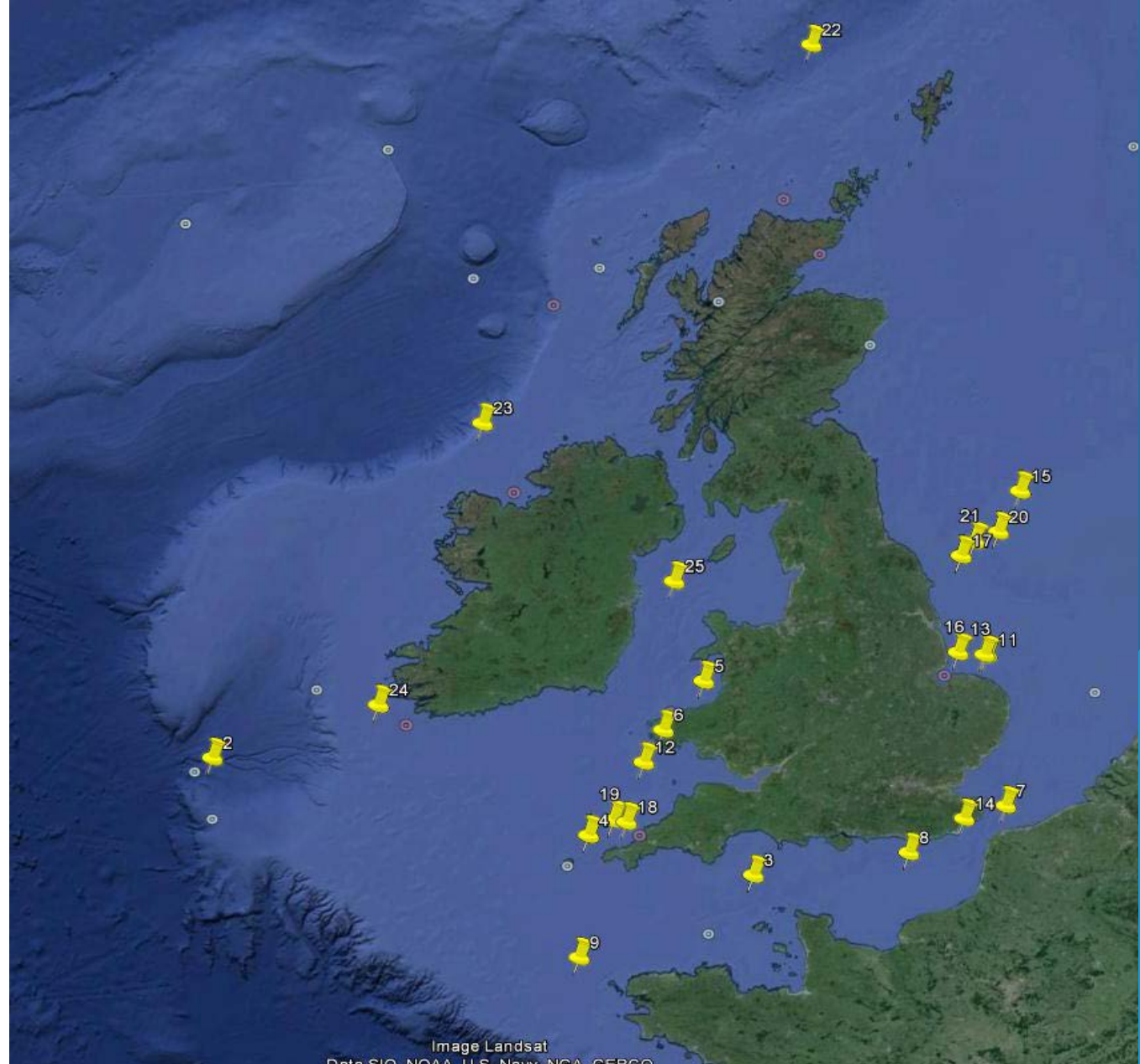
Parameter: Wind Speed (10m)

Buoys (Observations) for Hs

- ▶ Time period/ interval : 2001-2010
- ▶ Geographical regions of interests:
 - Mediterranean Sea
 - ❖ Greece # 11
 - ❖ Italy #14
 - ❖ France #1
 - ❖ Spain #4
 - North Atlantic Ocean
 - ❖ Spain #11
 - ❖ Portugal #2
 - ❖ France #1
 - ❖ UK #18
 - ❖ Ireland #4
 - Baltic Sea
 - ❖ Sweden #7



MEDITERRANEAN SEA



(NORTH) ATLANTIC SEA



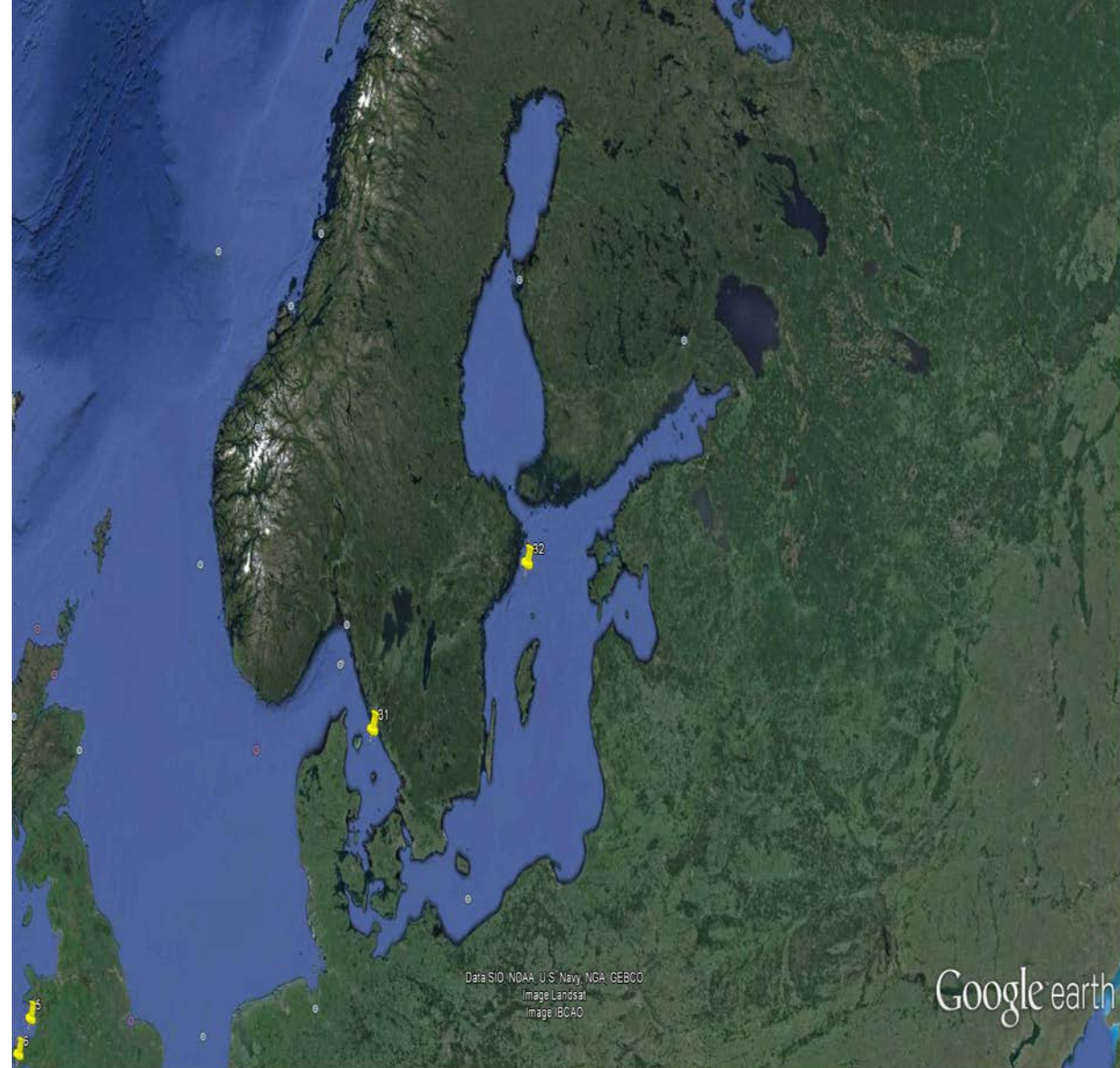
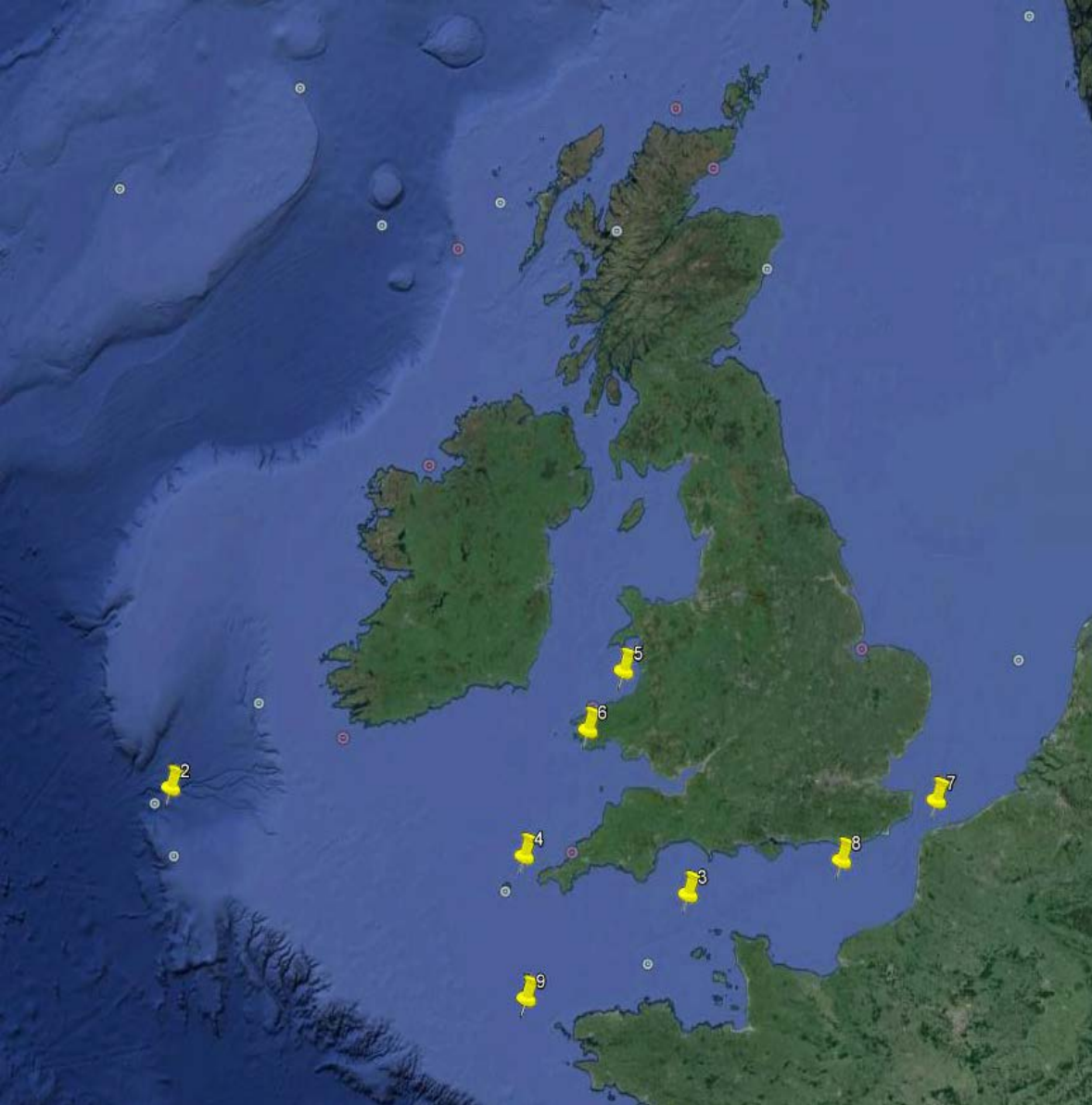
BALTIC SEA

Buoys (Observations) for Wind Speed

- ▶ Time period/ interval : 2001-2010
- ▶ Geographical regions of interests:
 - Mediterranean Sea
 - ❖ Greece # 11
 - ❖ Spain #1
 - North Atlantic Ocean
 - ❖ Spain #7
 - ❖ Portugal #2
 - ❖ France #2
 - ❖ UK #7
 - Baltic Sea
 - ❖ Sweden #2



(NORTH) ATLANTIC SEA/MEDITERRANEAN SEA
Greece-Spain-France



(NORTH) ATLANTIC SEA/BALTIC SEA
United Kingdom- Sweden

Statistical Indicators

▶ Bias
$$\text{Bias} = \frac{1}{N} \sum_{i=1}^N (\text{model}(i) - \text{Obs}(i))$$

▶ RMSE
$$\text{Rmse} = \sqrt{\frac{1}{N} * \sum_{i=1}^N (\text{model}(i) - \text{obs}(i))^2}$$

▶ Standard Deviation
$$\text{Stad.Dev.} = \sqrt{\frac{1}{N} * \sum_{i=1}^N (\text{model}(i) - \text{obs}(i) - \text{Bias})^2}$$

▶ Coefficient of determination
$$R^2 = 1 - \frac{\sum_{i=1}^N (\text{model}(i) - \text{obs}(i))^2}{\sum_{i=1}^N (\text{model}(i) - \text{obs})^2}$$

▶ Scatter Index
$$\text{SI} = \frac{\text{Rmse}}{\frac{\sum_{i=1}^N \text{Obs}(i)}{N}}$$

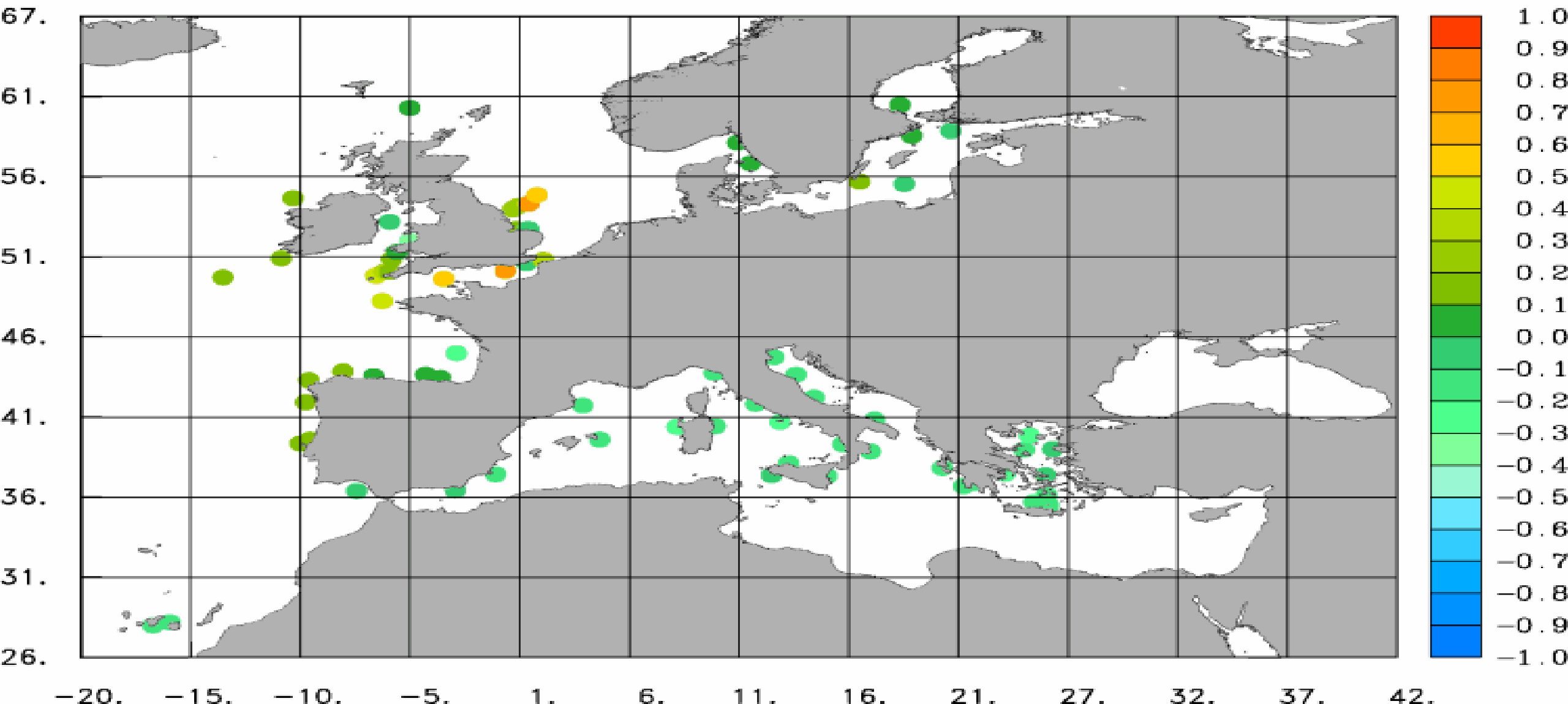
▶ Nash-Sutcliffe coefficient
$$E = \frac{\sum_{i=1}^N (\text{model}(i) - \text{obs}(i))^2}{\sum_{i=1}^N (\text{Obs}(i) - \text{Obs})^2}$$

Hs

Bias

University of Athens (AM&WFG)

Significant wave height – bias (m-o)

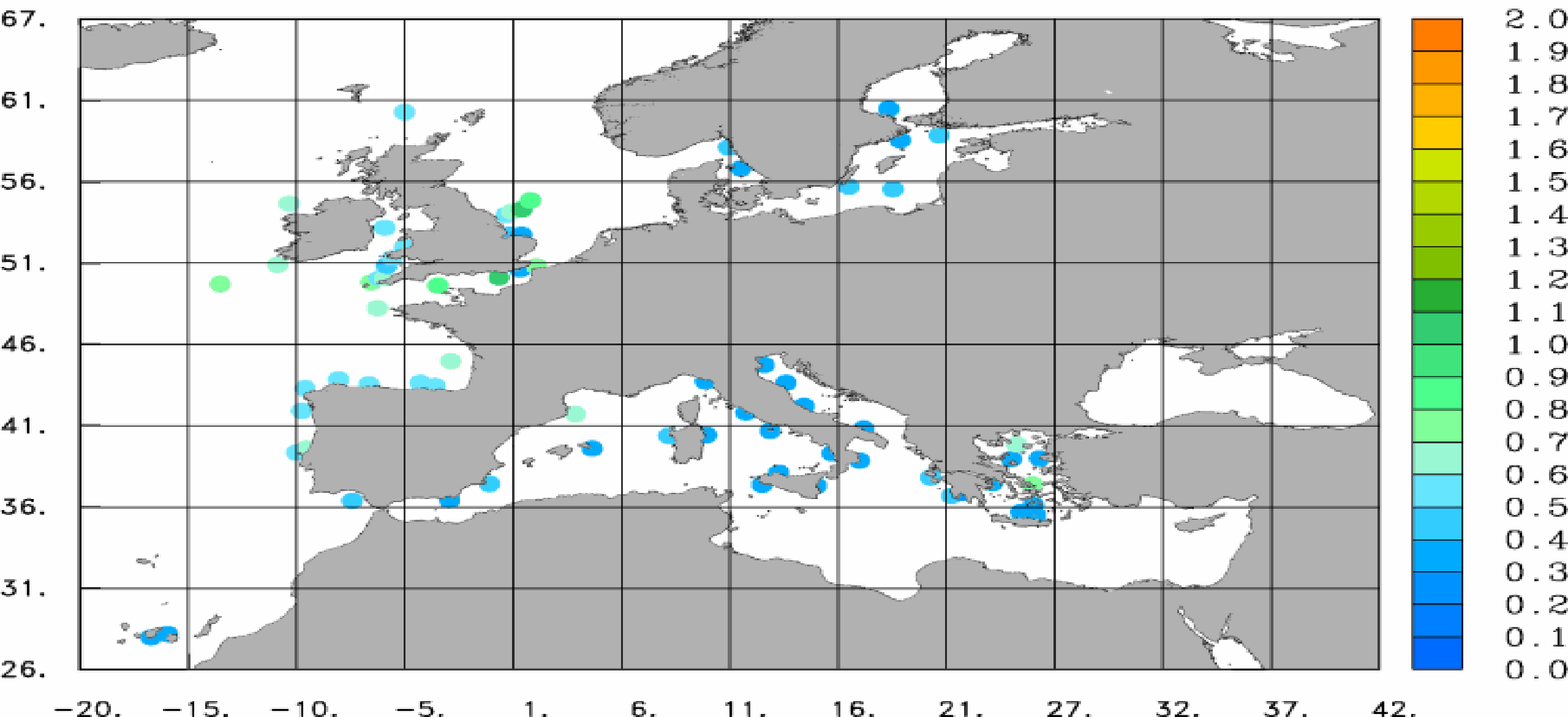


Hs

RMSE

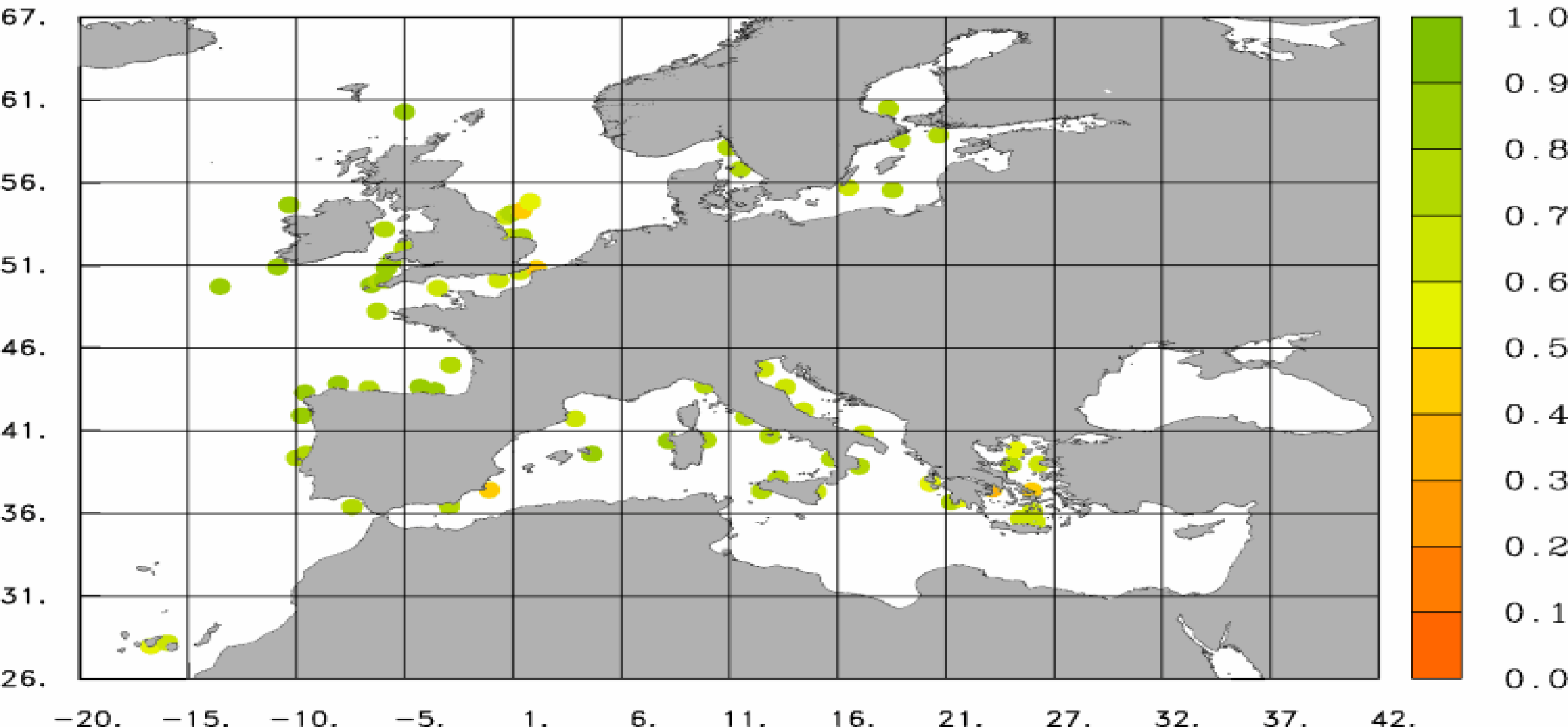
University of Athens (AM&WFG)

Significant wave height – RMSE



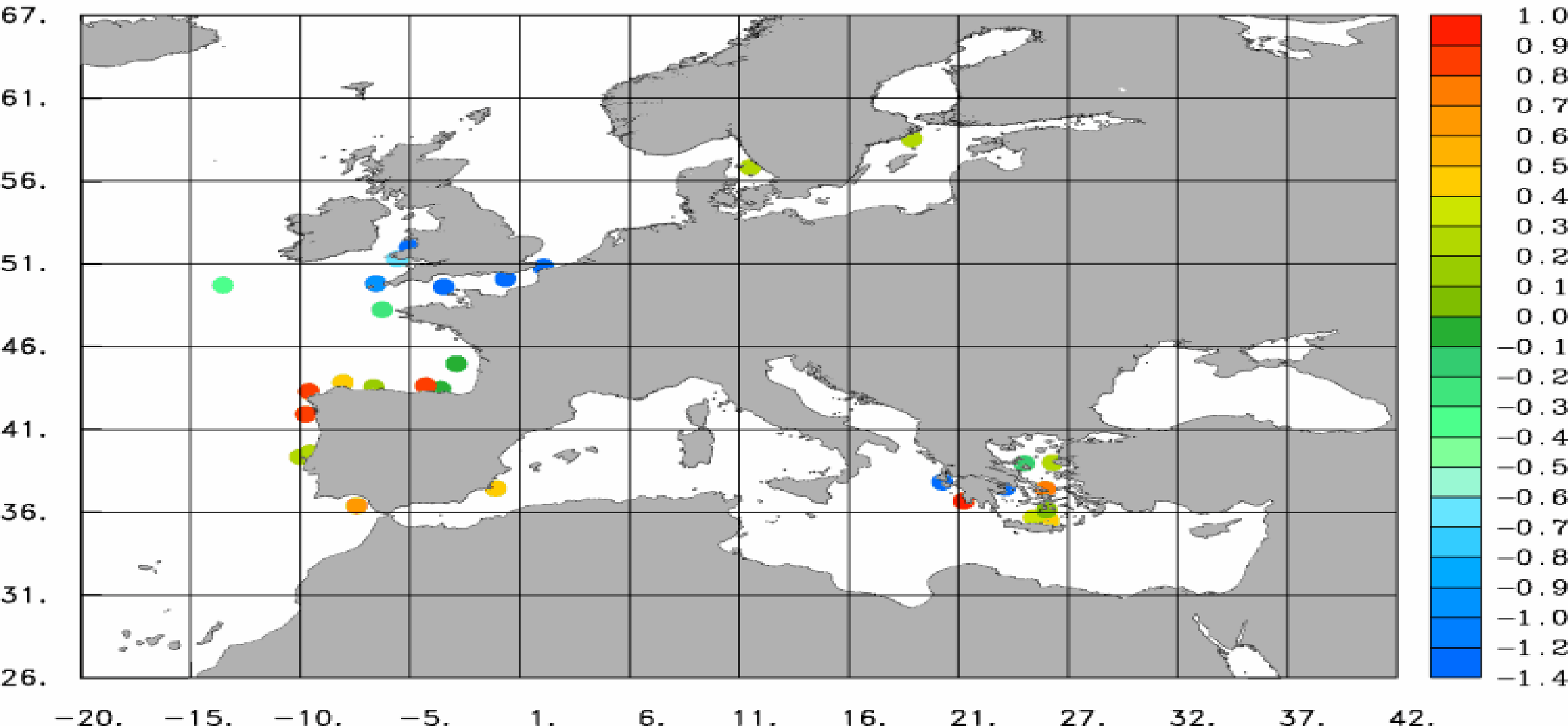
R^2

University of Athens (AM&WFG)

Significant wave height – R²

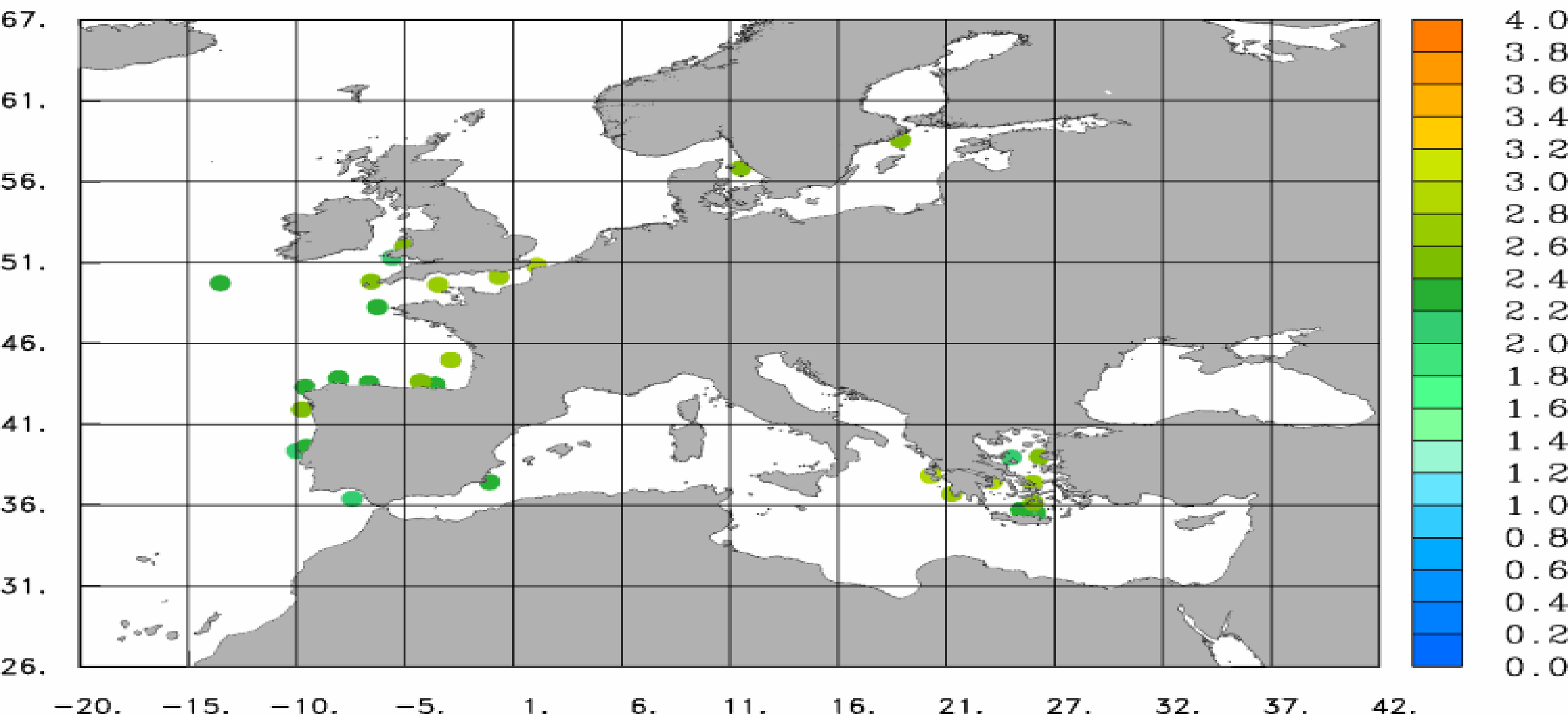
University of Athens (AM&WFG)

Wind Speed 10m - Bias (m-o)



University of Athens (AM&WFG)

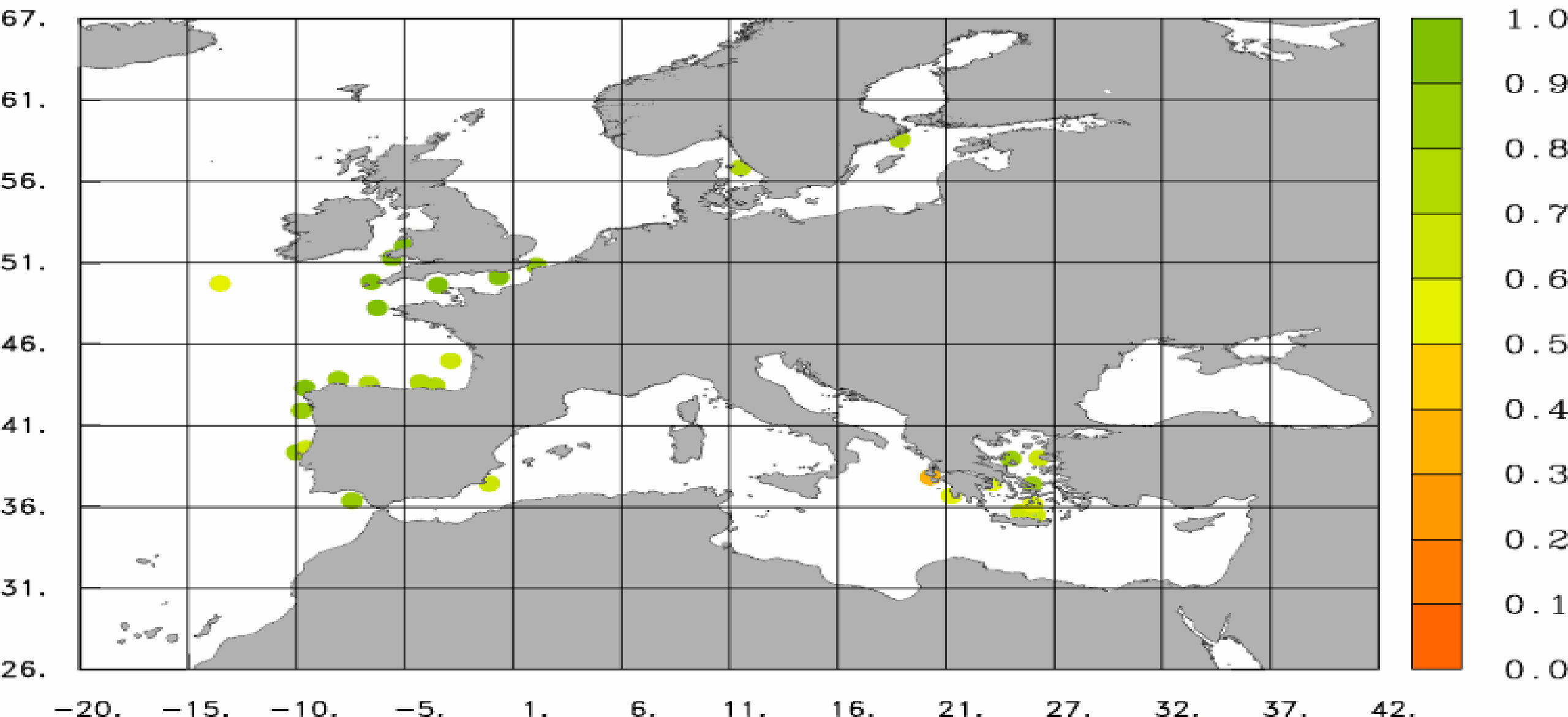
Wind Speed 10m – RMSE



R^2

University of Athens (AM&WFG)

Wind Speed 10m - R 2



Open Sea station/buoy

- ▶ Spanish buoy : 62083
- ▶ Lat: 43.5
- ▶ Lon: -9.25
- ▶ 2002-2010

Hs

Descriptive Statistics:62083.2002-2010 lat:43.5 lon:-9.25 Obs

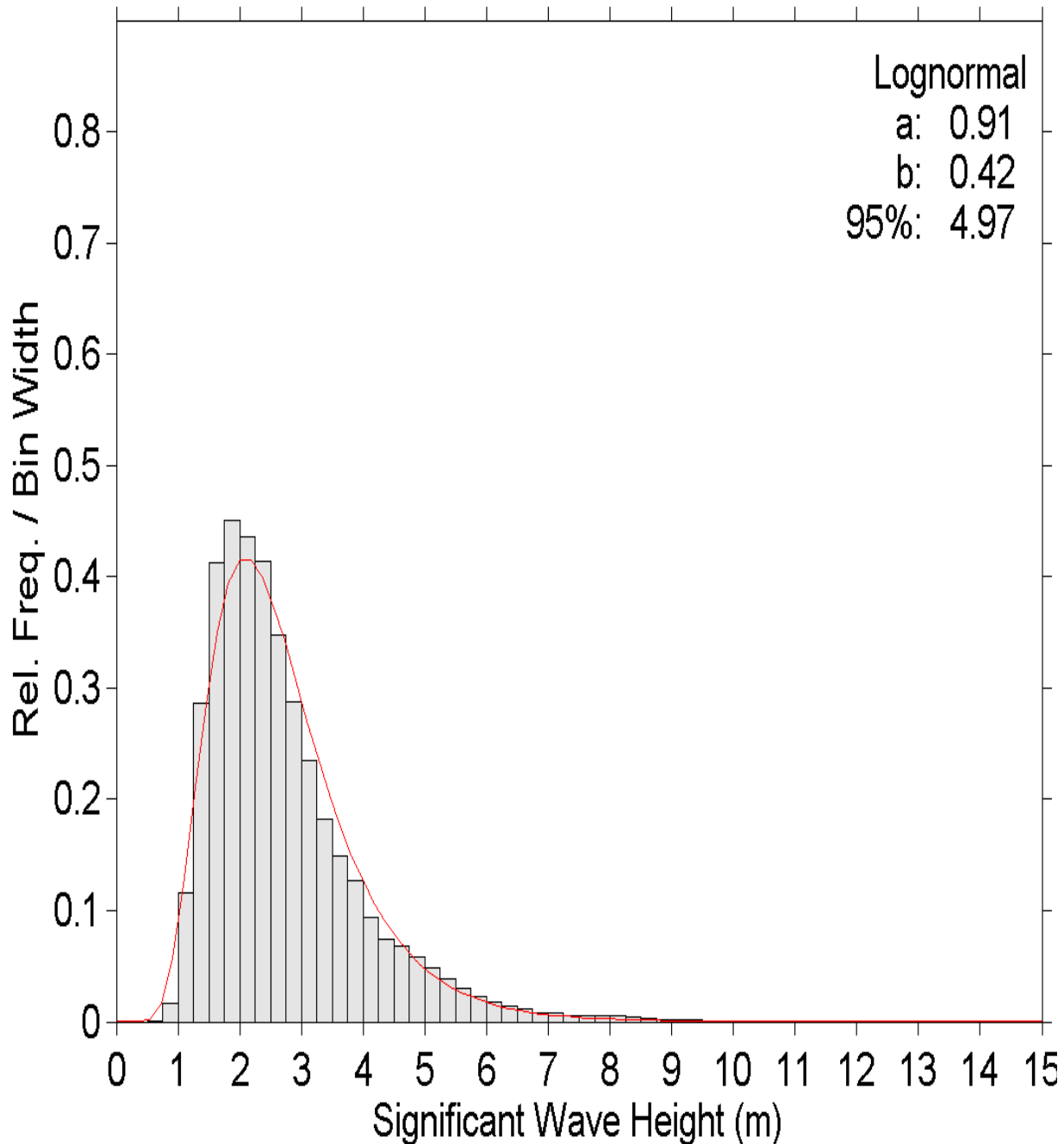
	Hs(m)
Mean	2.54
St. Dev.	1.23
Var. Coeff.	0.49
St. Error.	0.01
Skewness	1.70
Kurtosis	7.58

Descriptive Statistics:62083.2002-2010 lat:43.5 lon:-9.25 Model

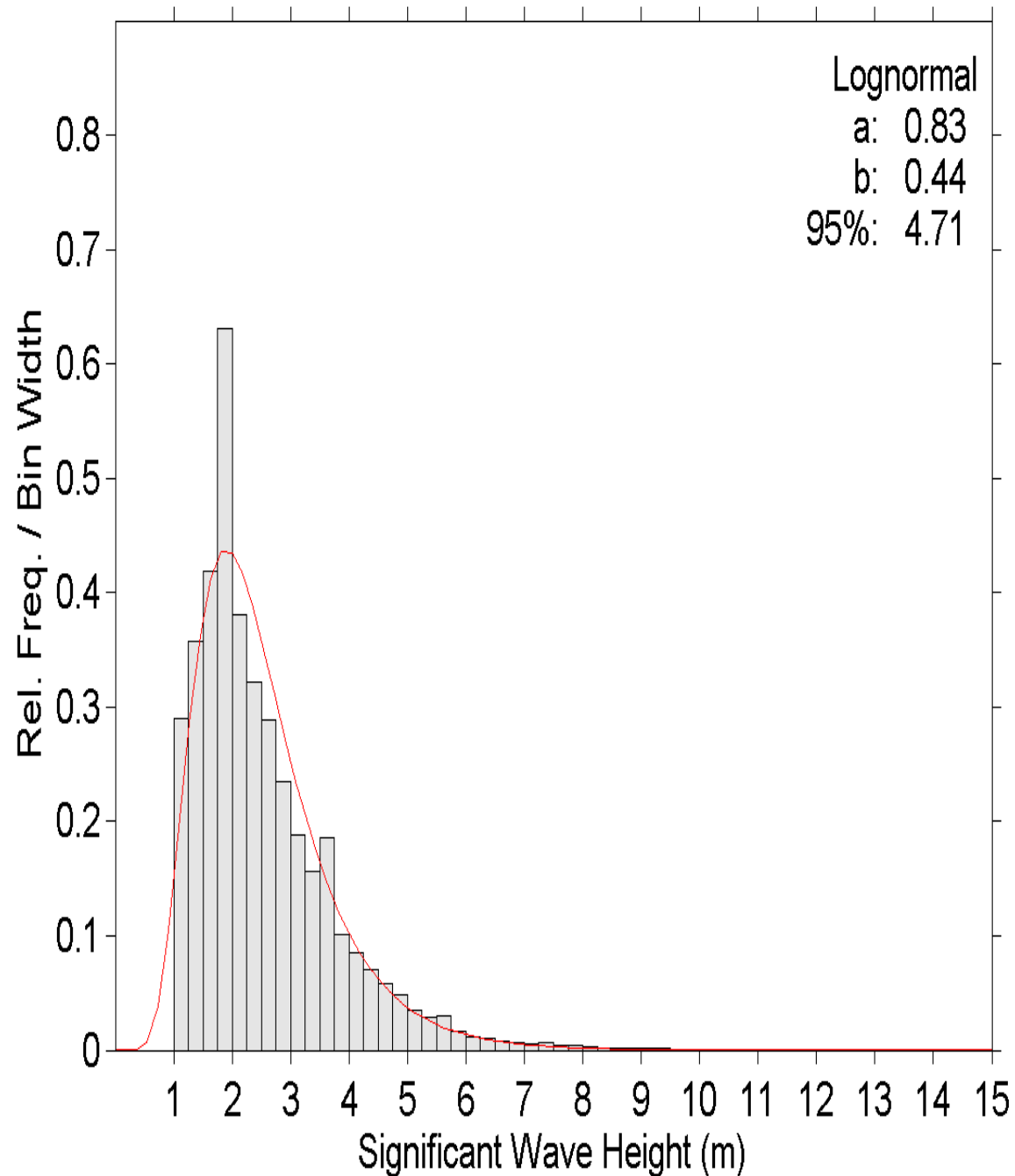
	Hs(m)
Mean	2.74
St. Dev.	1.31
Var. Coeff.	0.48
St. Error.	0.01
Skewness	2.04
Kurtosis	10.61



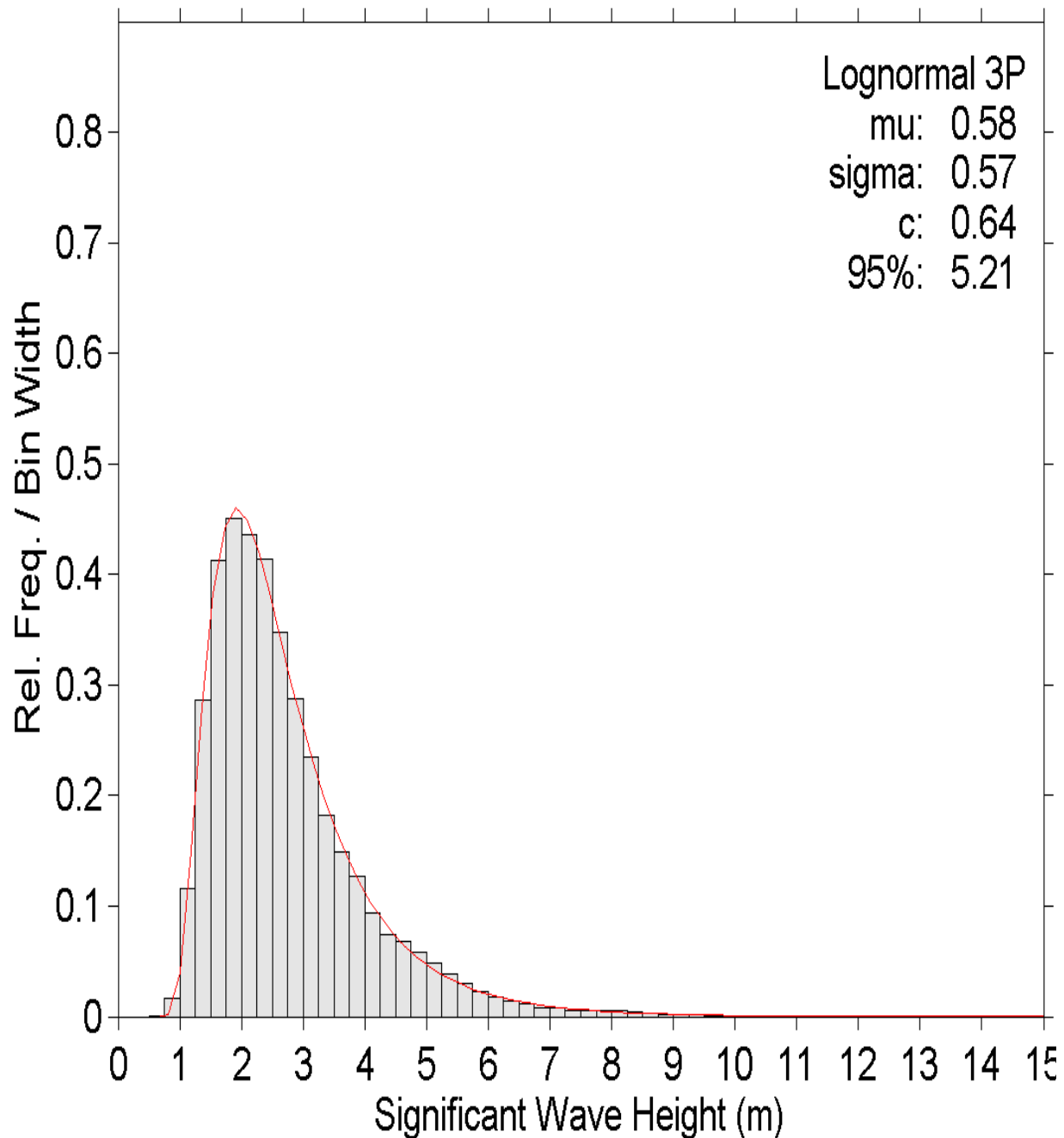
62083.2002-2010 lat:43.5 lon:-9.25 Model



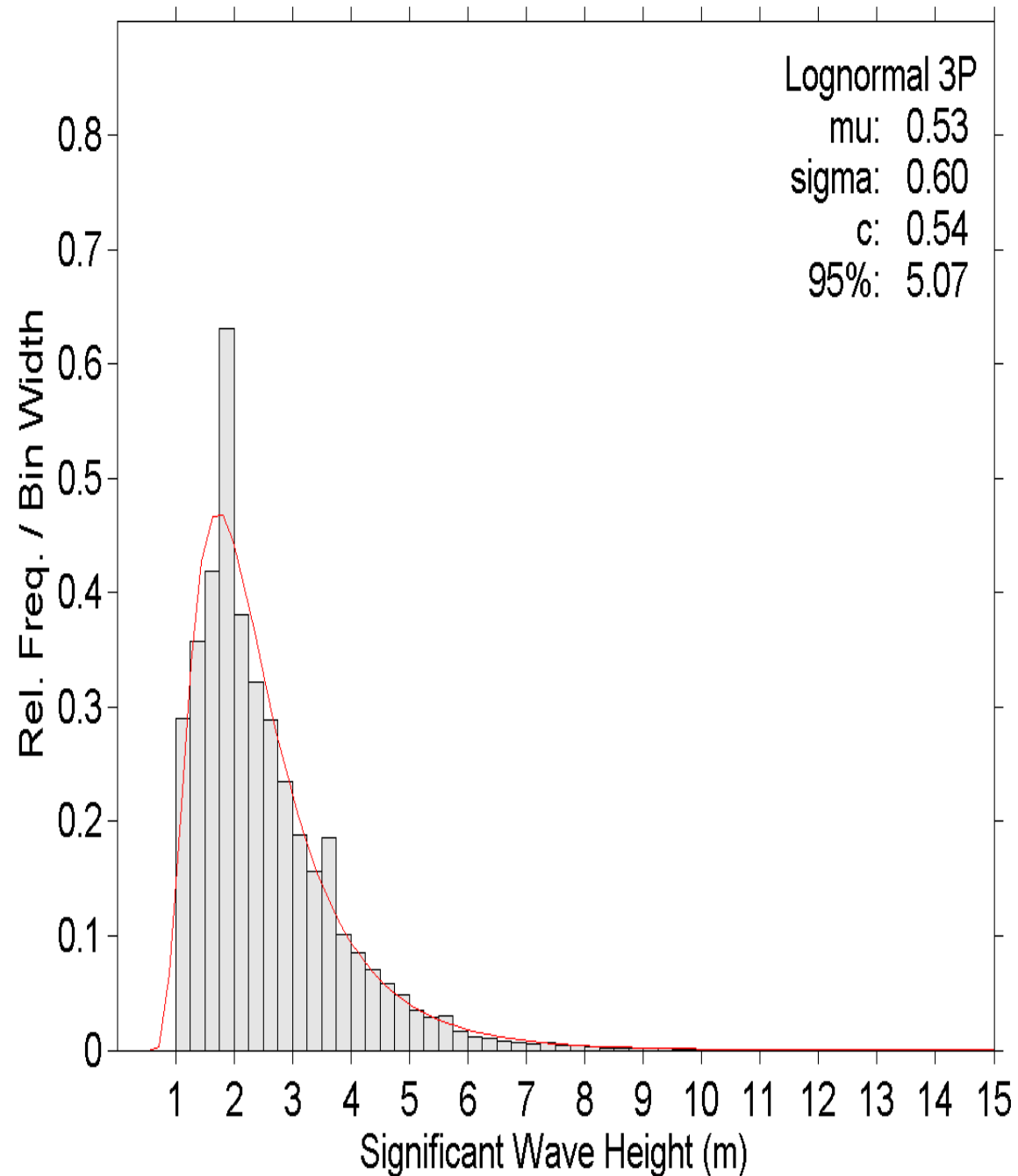
62083.2002-2010 lat:43.5 lon:-9.25 Obs



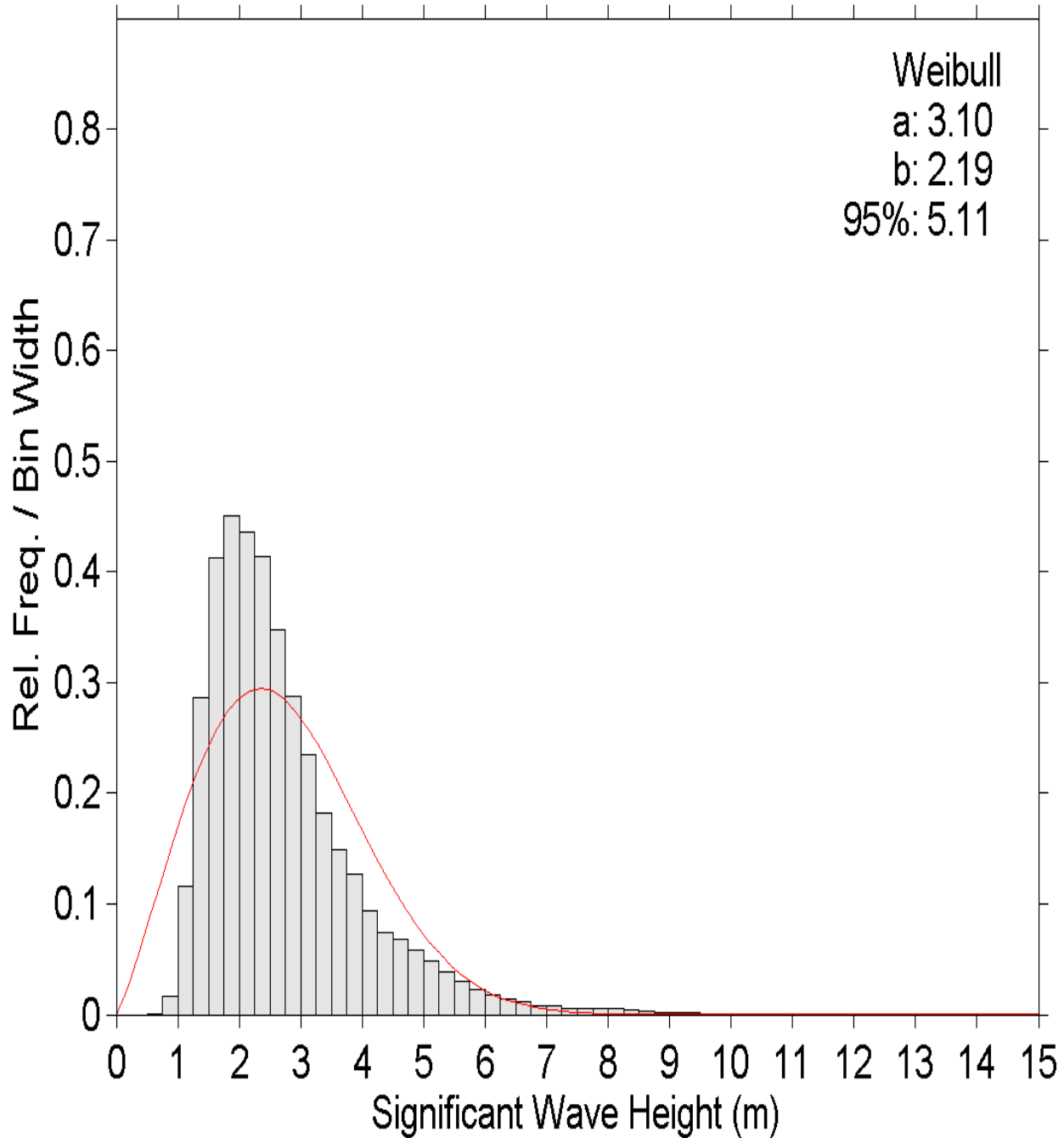
62083.2002-2010 lat:43.5 lon:-9.25 Model



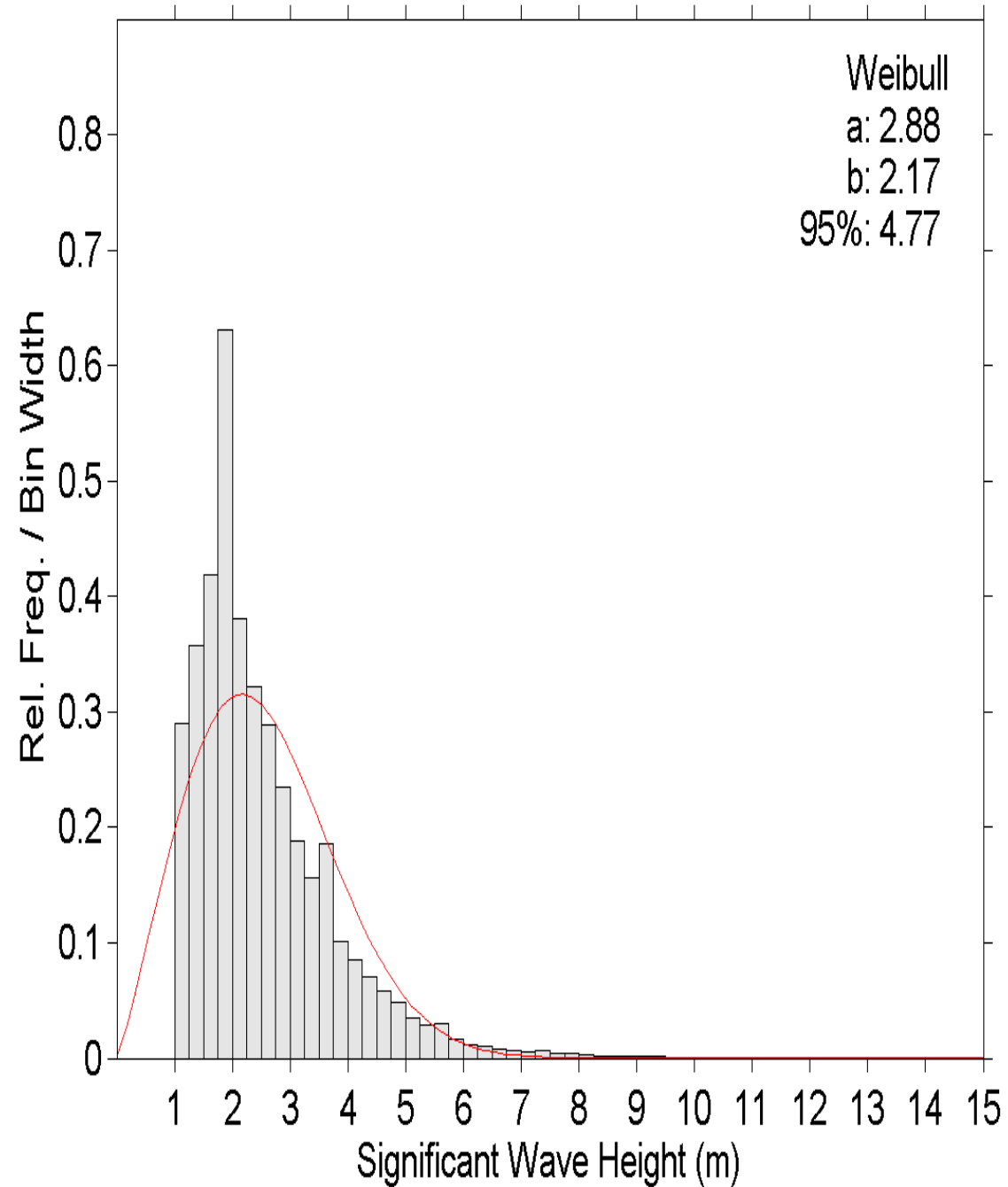
62083.2002-2010 lat:43.5 lon:-9.25 Obs



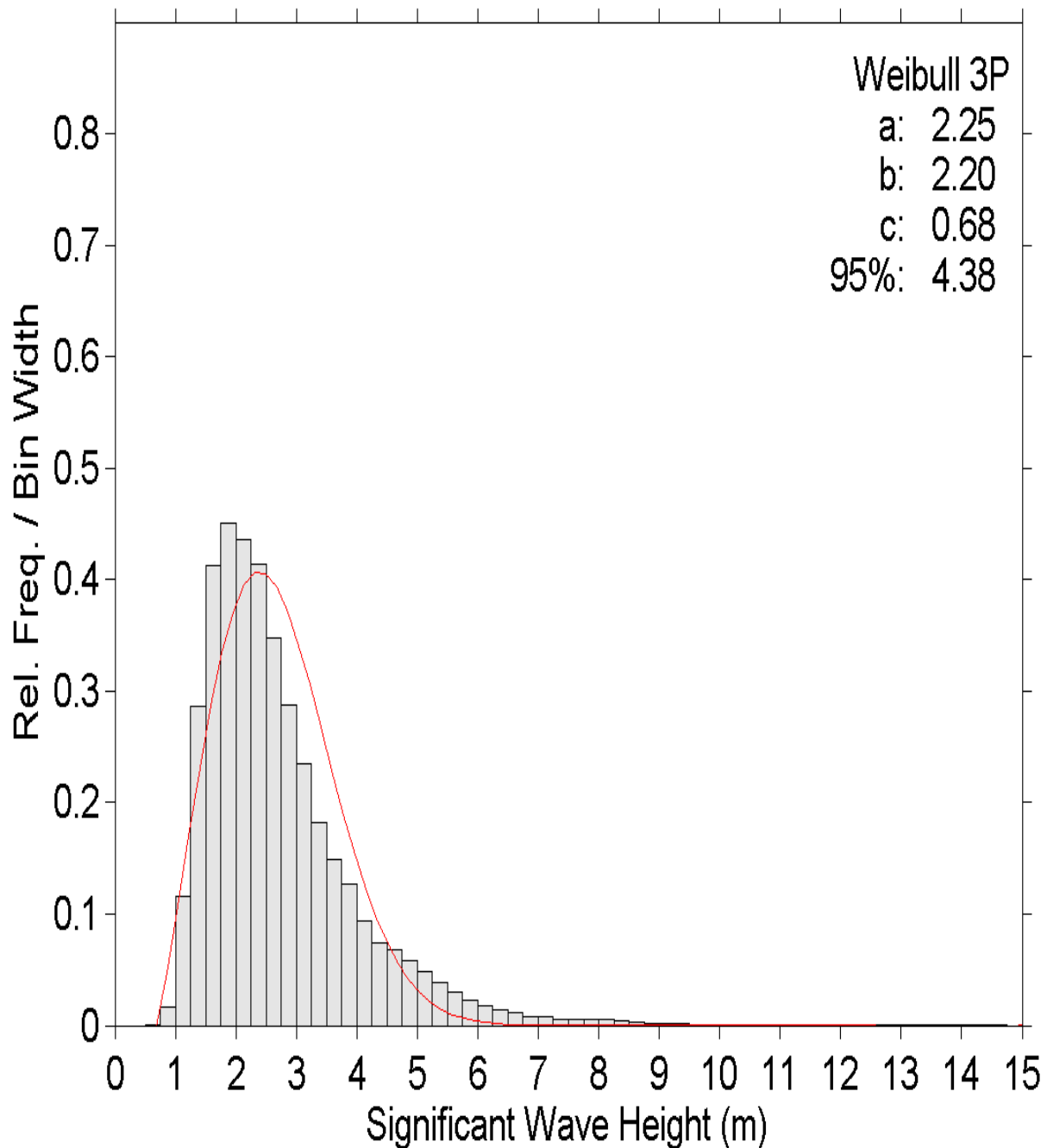
62083.2002-2010 lat:43.5 lon:-9.25 Model



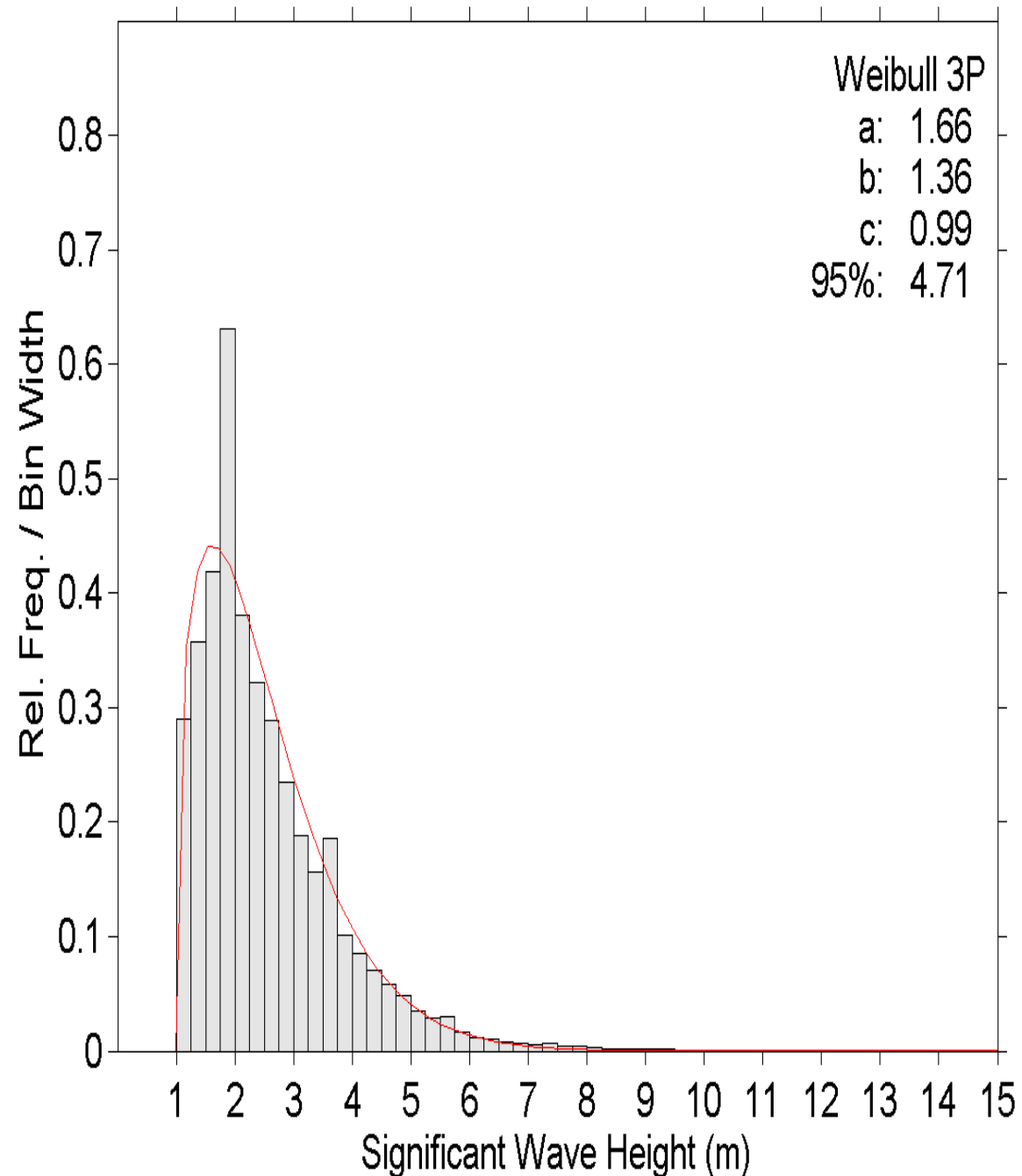
62083.2002-2010 lat:43.5 lon:-9.25 Obs



62083.2002-2010 lat:43.5 lon:-9.25 Model

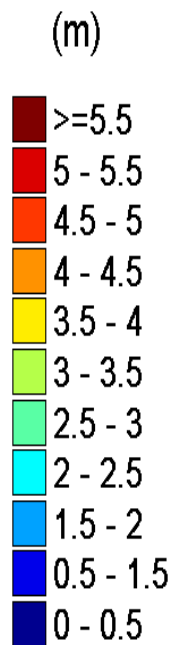
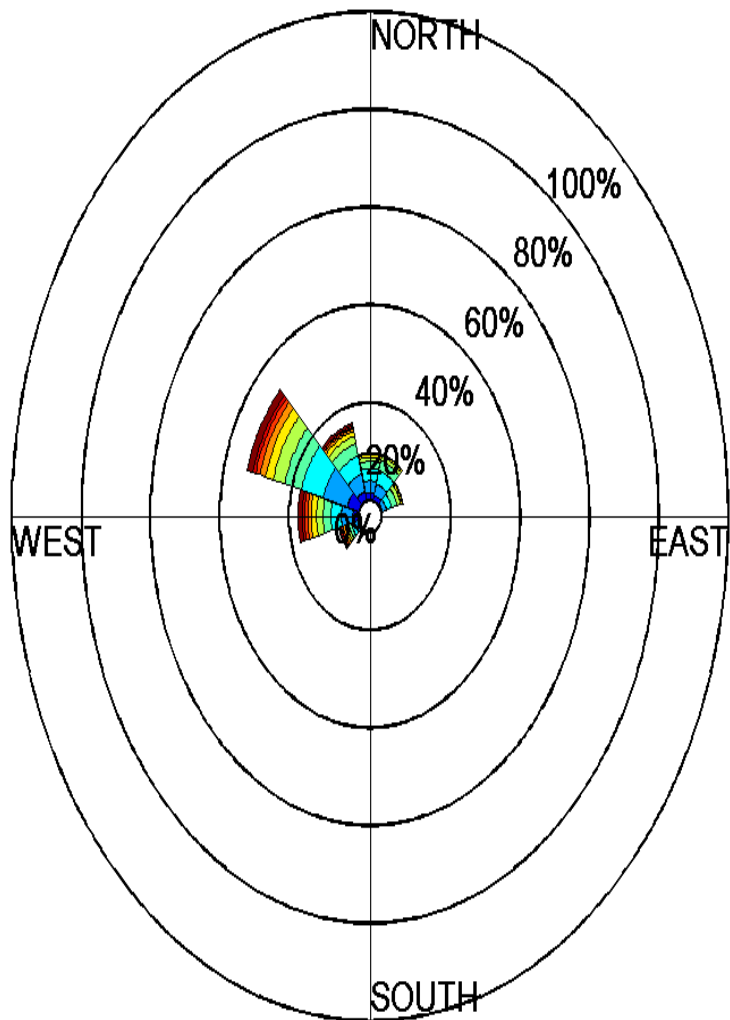


62083.2002-2010 lat:43.5 lon:-9.25 Obs



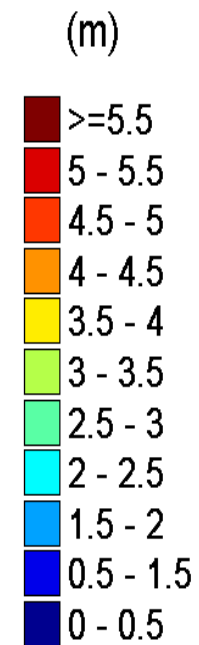
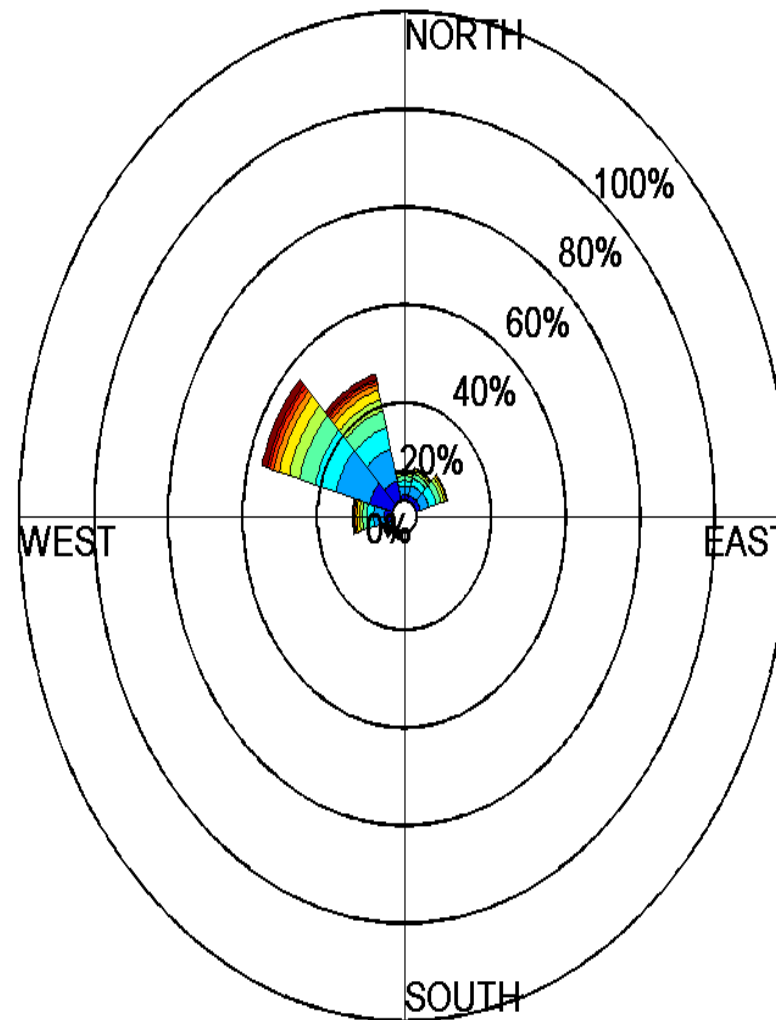
Significant Wave Height

62083.2002-2010 lat:43.5 lon:-9.25 Model

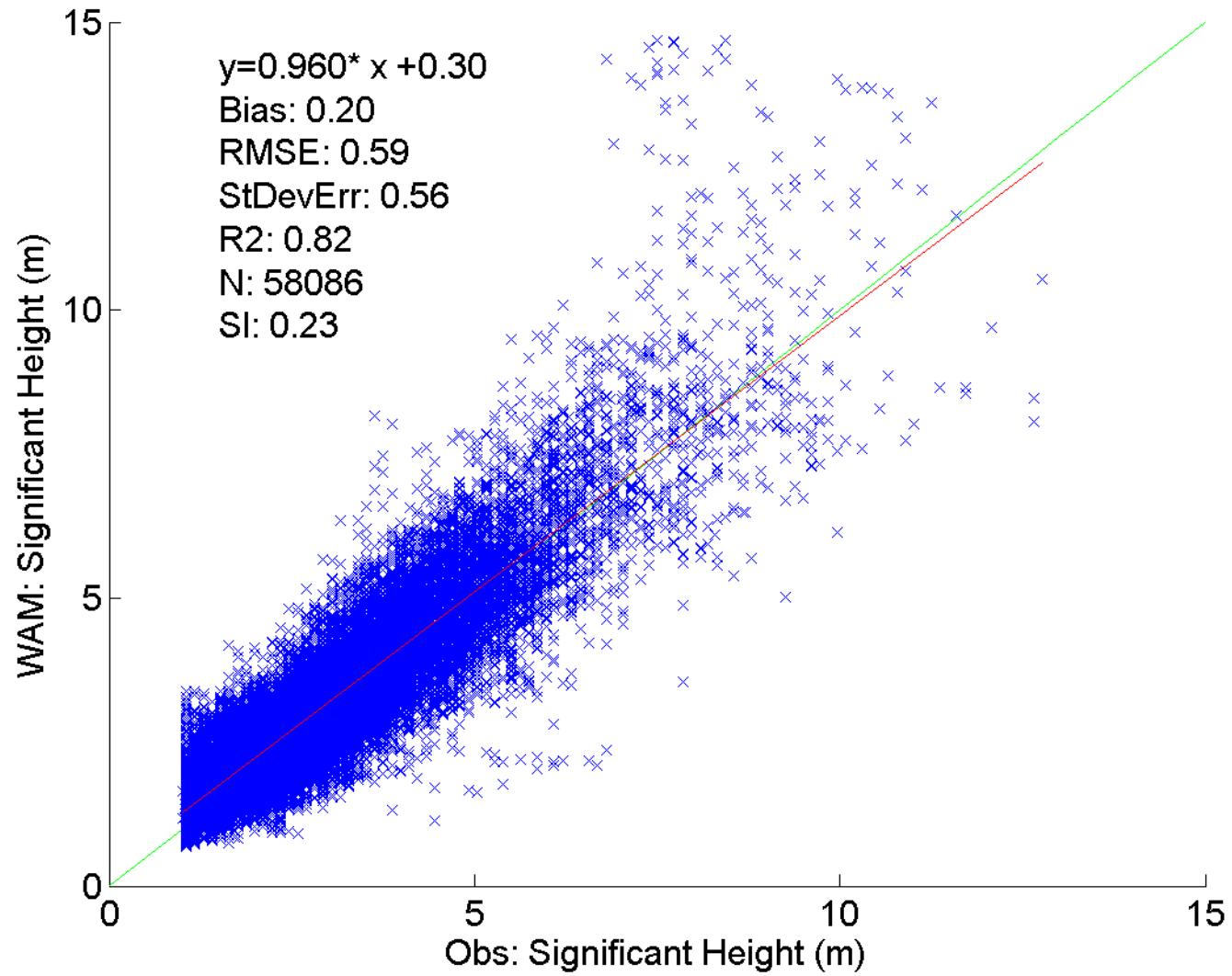


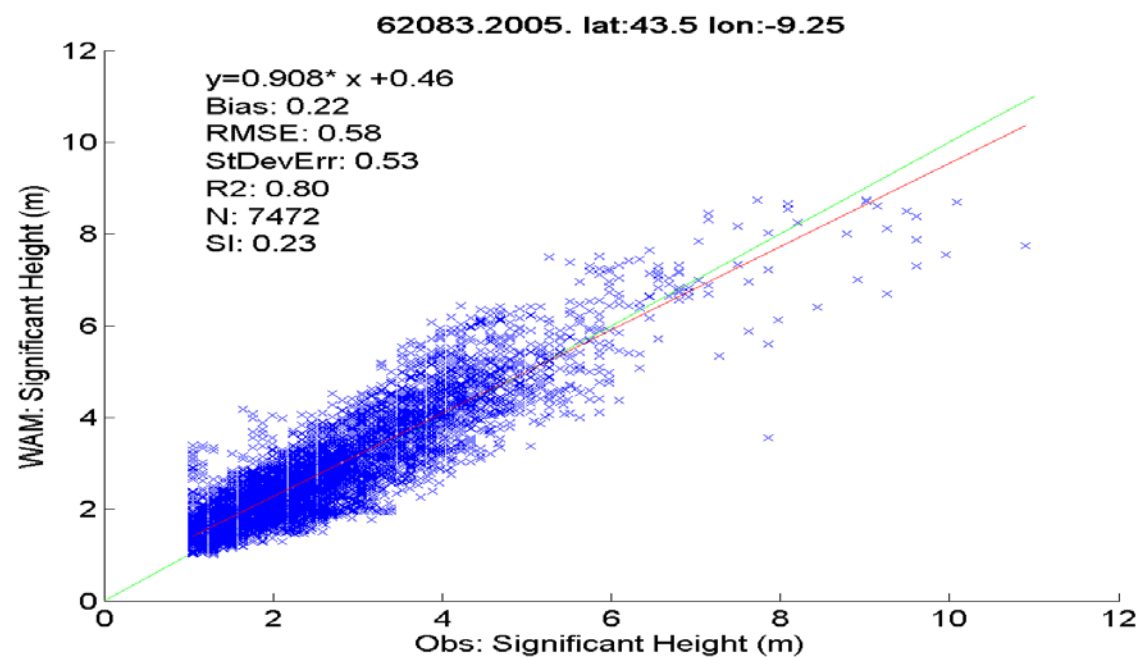
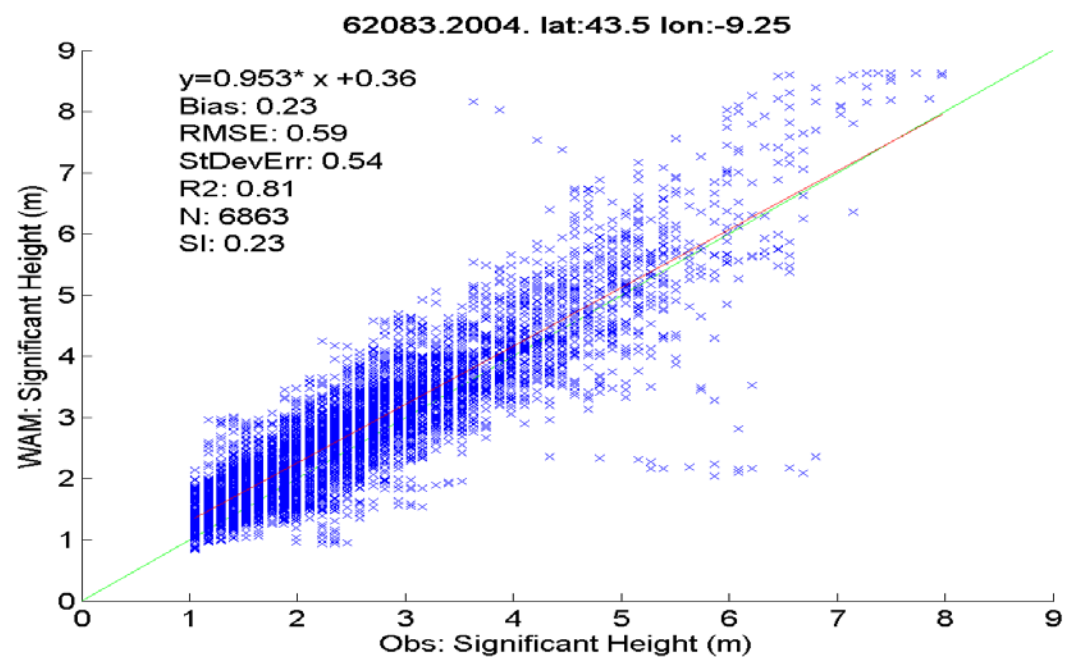
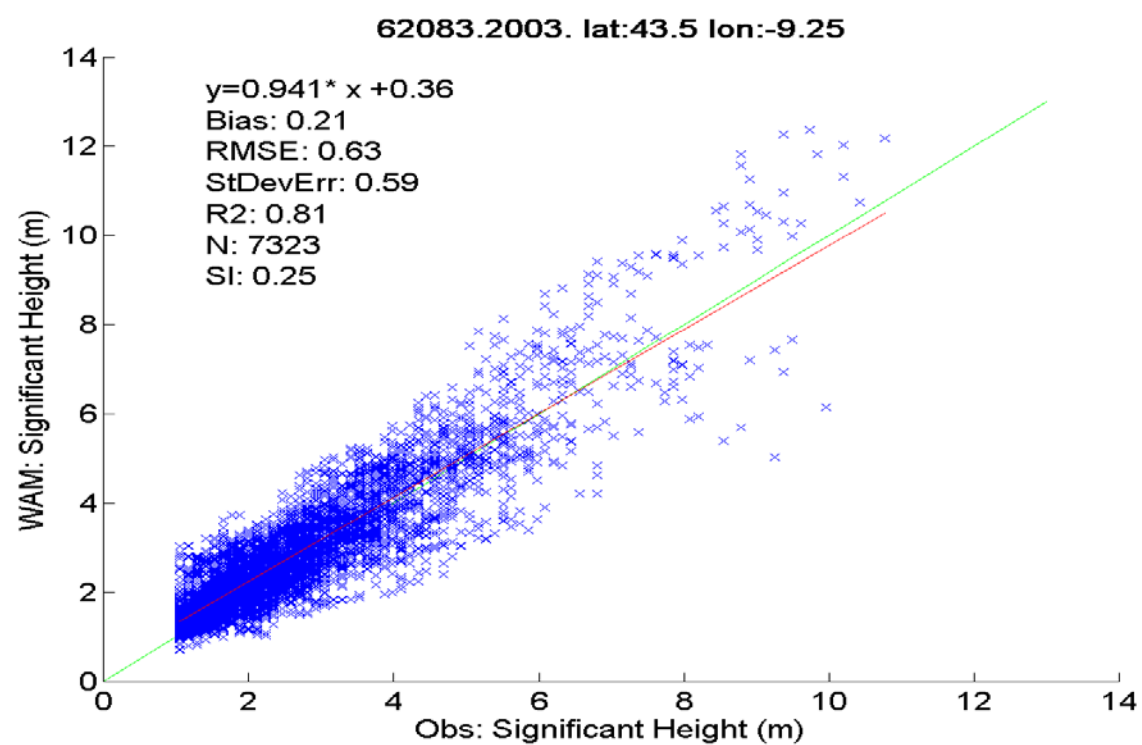
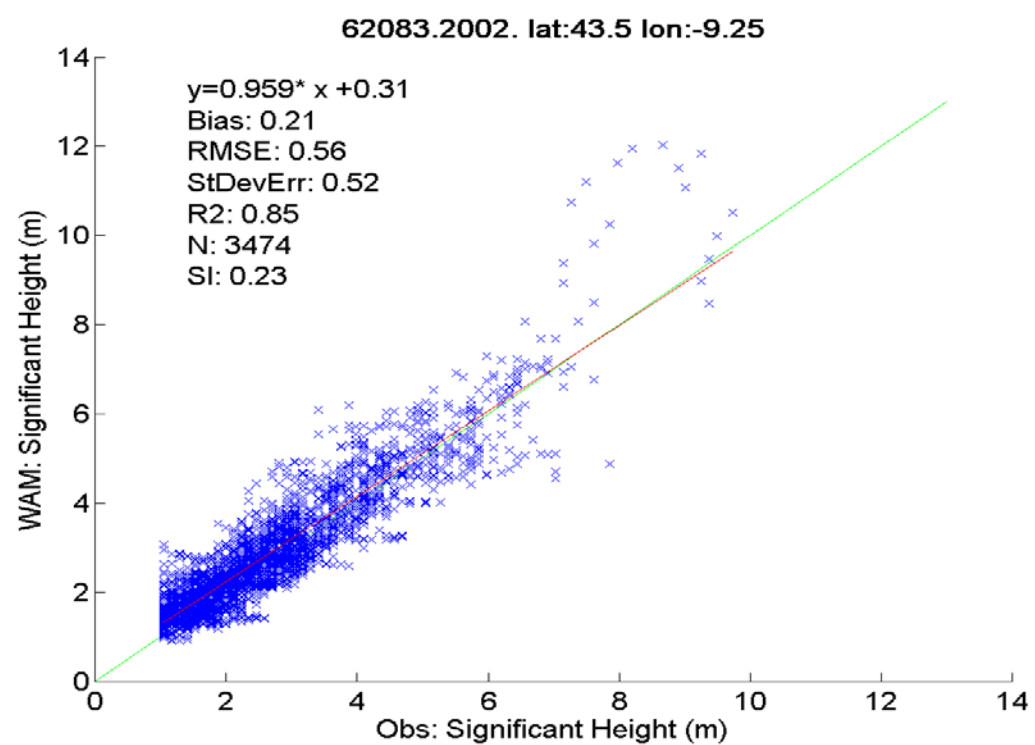
Significant Wave Height

62083.2002-2010 lat:43.5 lon:-9.25 Obs

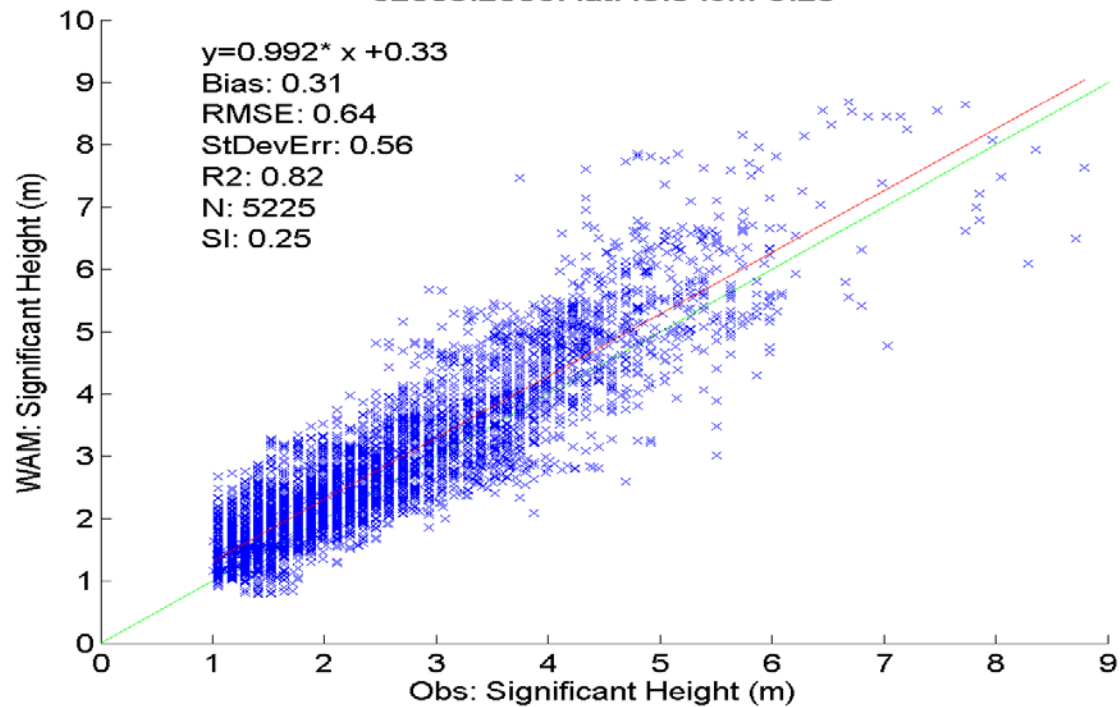


62083.2002-2010 lat:43.5 lon:-9.25

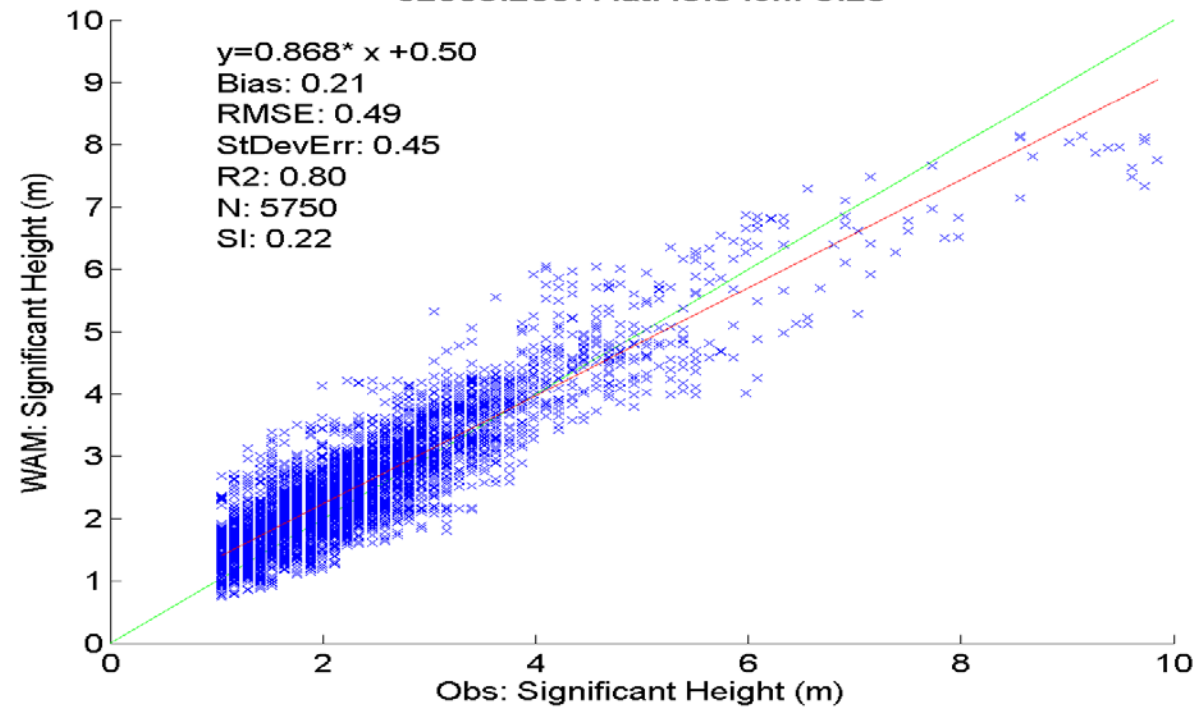




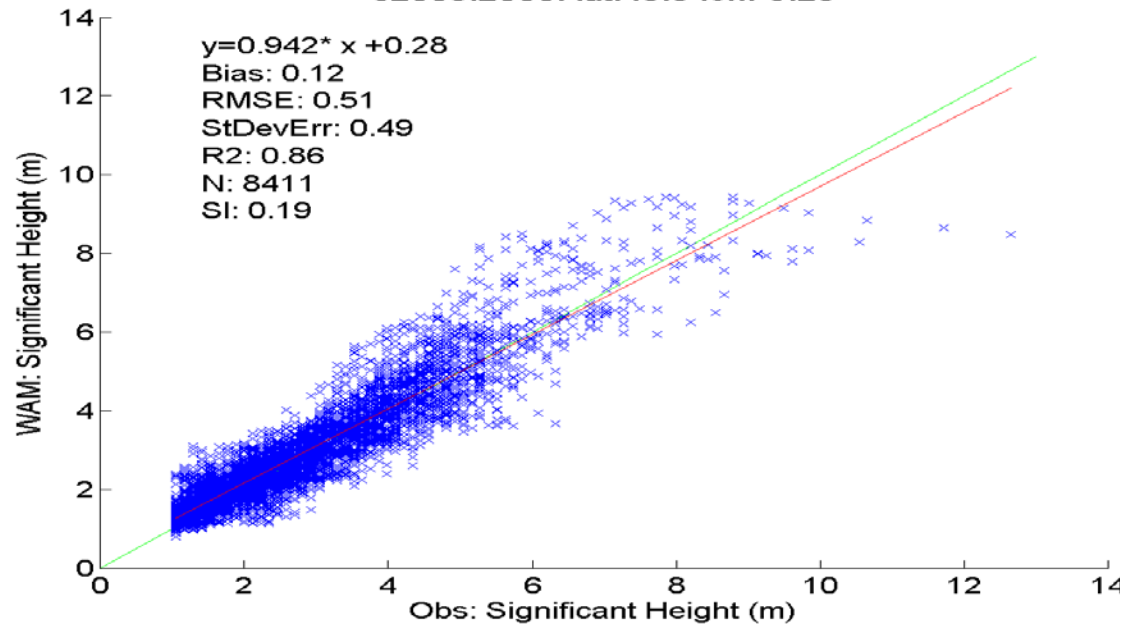
62083.2006. lat:43.5 lon:-9.25



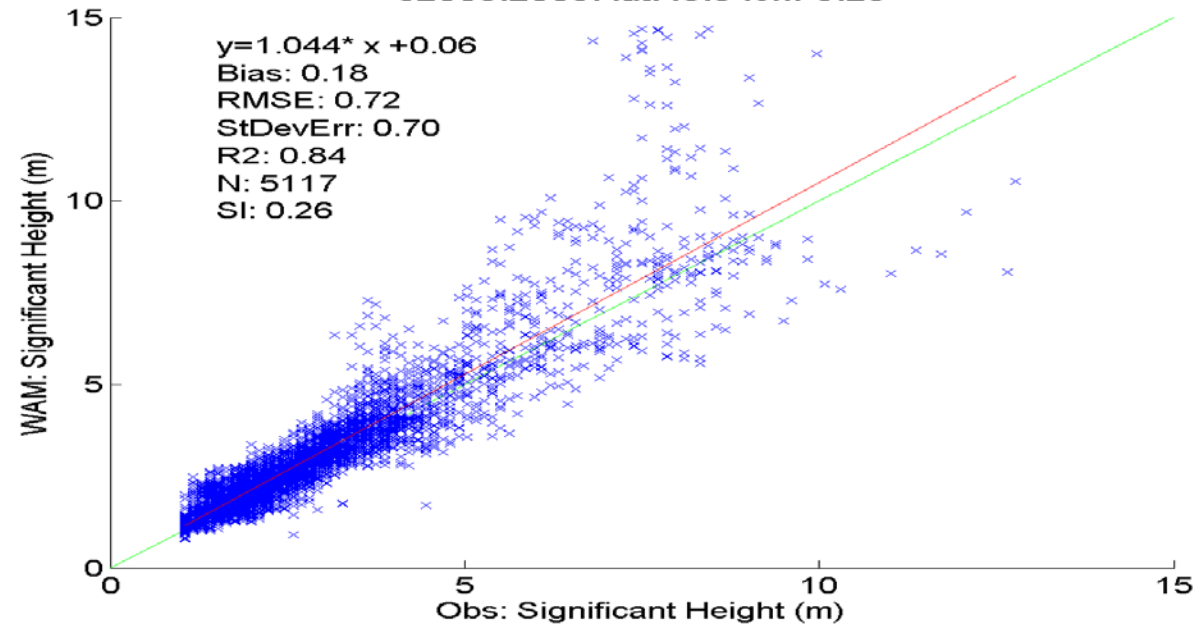
62083.2007. lat:43.5 lon:-9.25



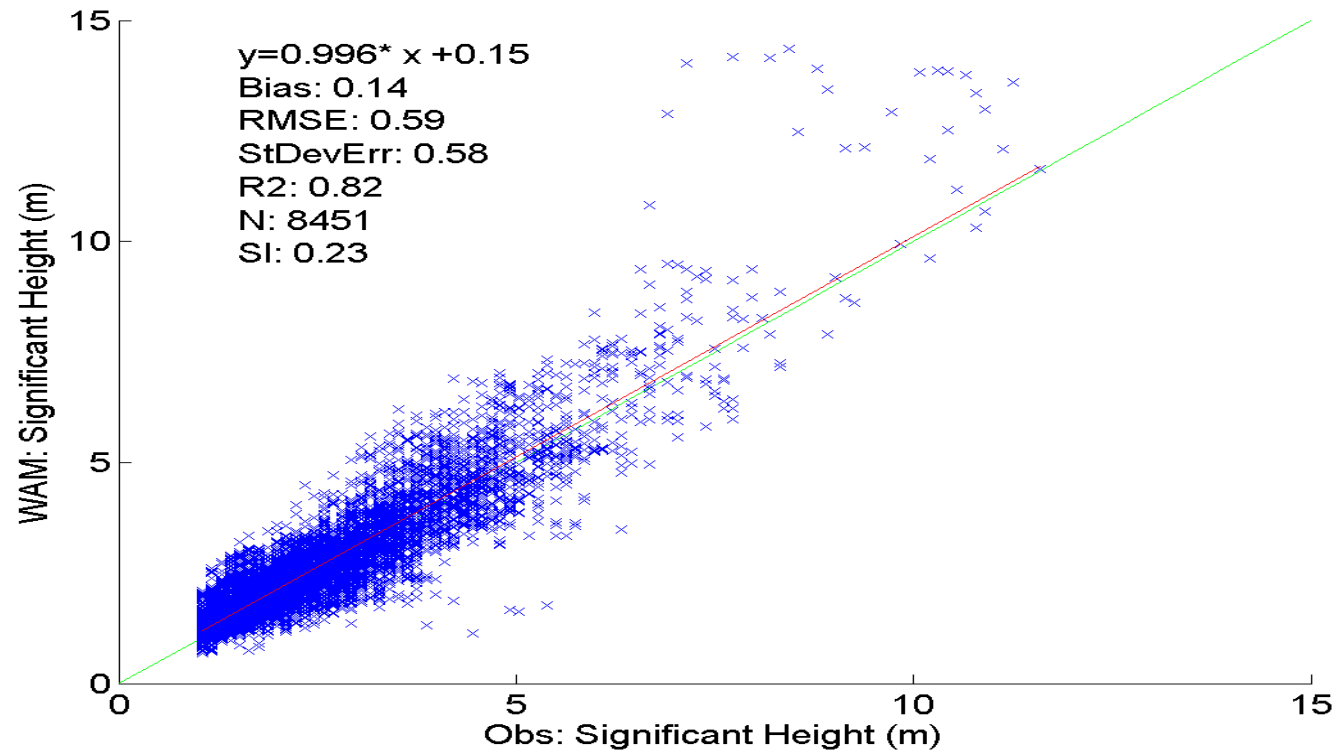
62083.2008. lat:43.5 lon:-9.25

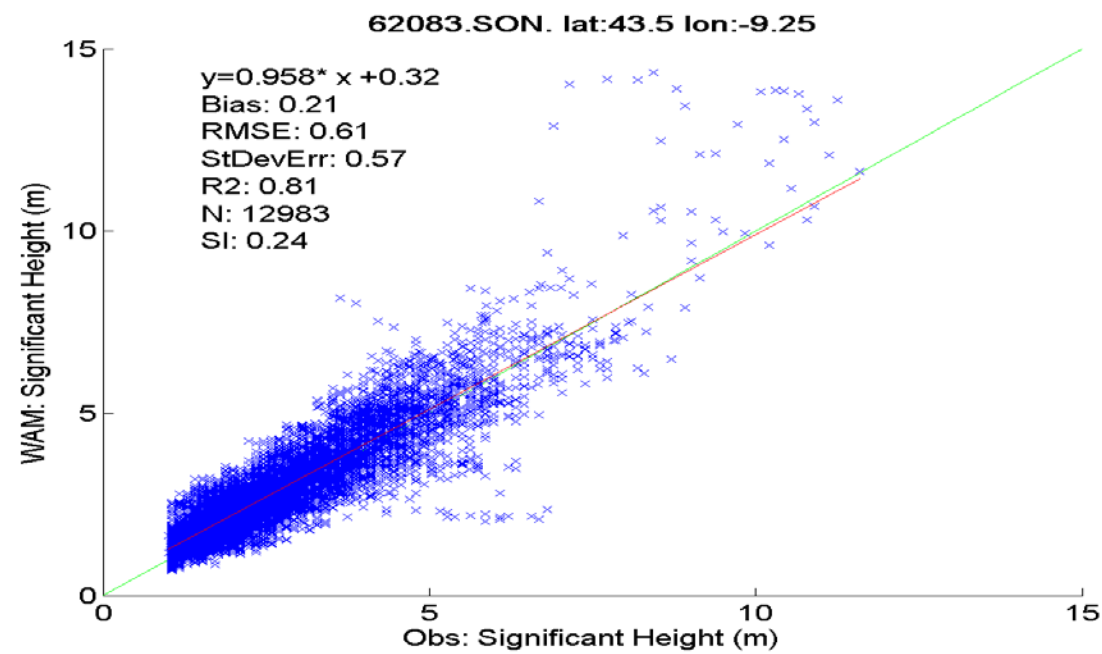
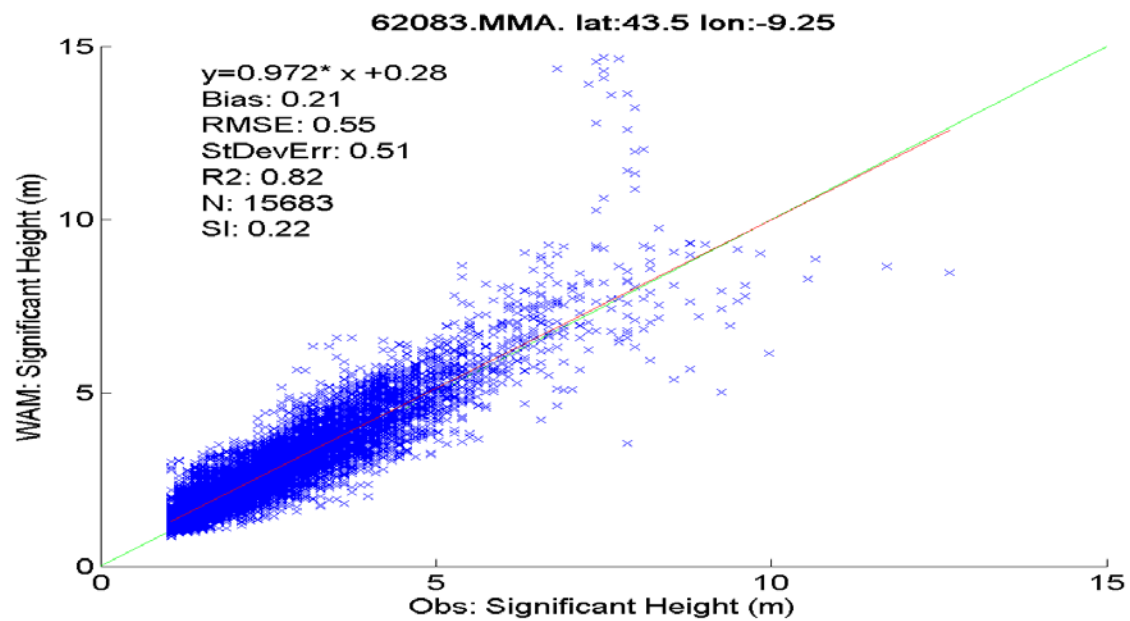
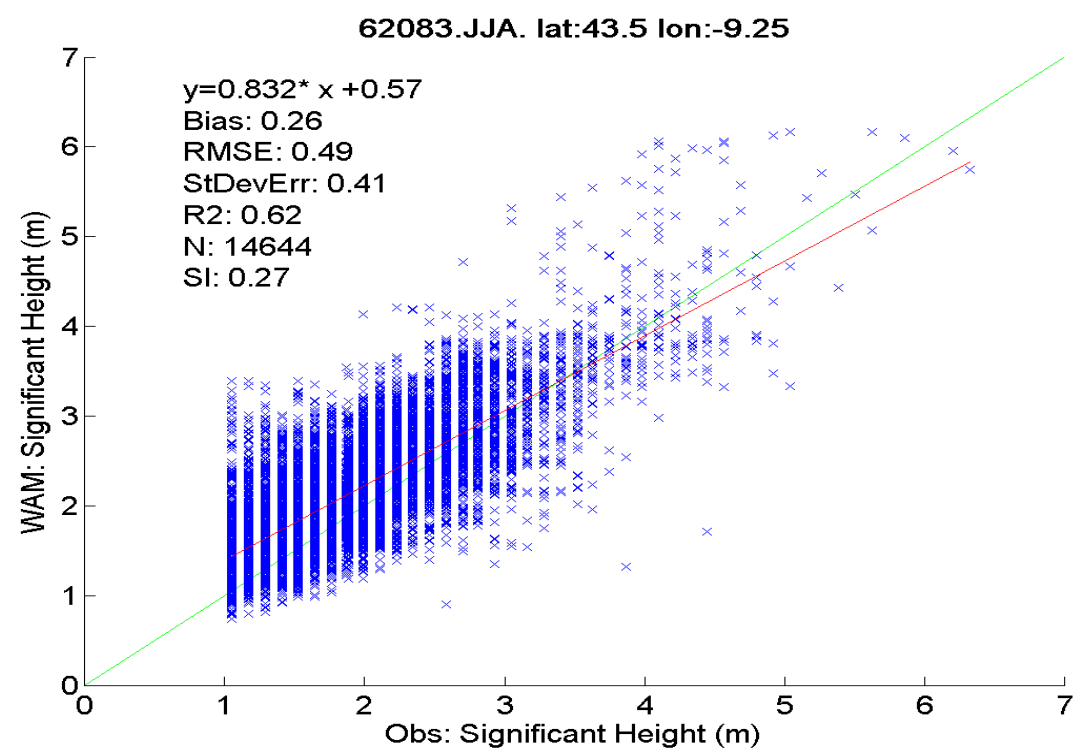
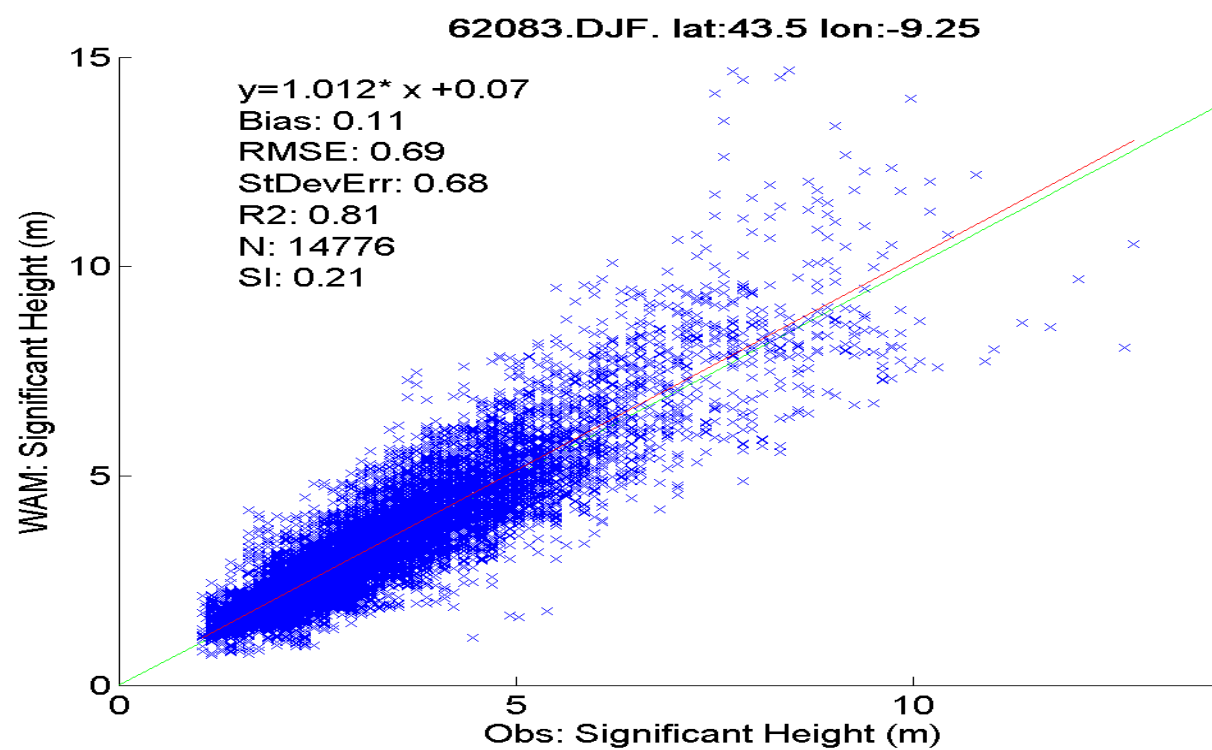


62083.2009. lat:43.5 lon:-9.25



62083.2010. lat:43.5 lon:-9.25





62083.Hsig (m).2002-2010.lat:43.5-lon:-9.25

	Bias:	RMSE:	StDevErr:	R²:	N:	SI:
All:	0.20	0.59	0.56	0.82	58086	0.23
2002:	0.21	0.56	0.52	0.85	3474	0.23
2003:	0.21	0.63	0.59	0.81	7323	0.25
2004:	0.23	0.59	0.54	0.81	6863	0.23
2005:	0.22	0.58	0.53	0.80	7472	0.23
2006:	0.31	0.64	0.56	0.82	5225	0.25
2007:	0.21	0.49	0.45	0.80	5750	0.22
2008:	0.12	0.51	0.49	0.86	8411	0.19
2009:	0.18	0.72	0.70	0.84	5117	0.26
2010:	0.14	0.59	0.58	0.82	8451	0.23
JJA:	0.26	0.49	0.41	0.62	14644	0.27
SON:	0.21	0.61	0.57	0.81	12983	0.24
DJF:	0.11	0.69	0.68	0.81	14776	0.21
MMA:	0.21	0.55	0.51	0.82	15683	0.22

Wind Speed

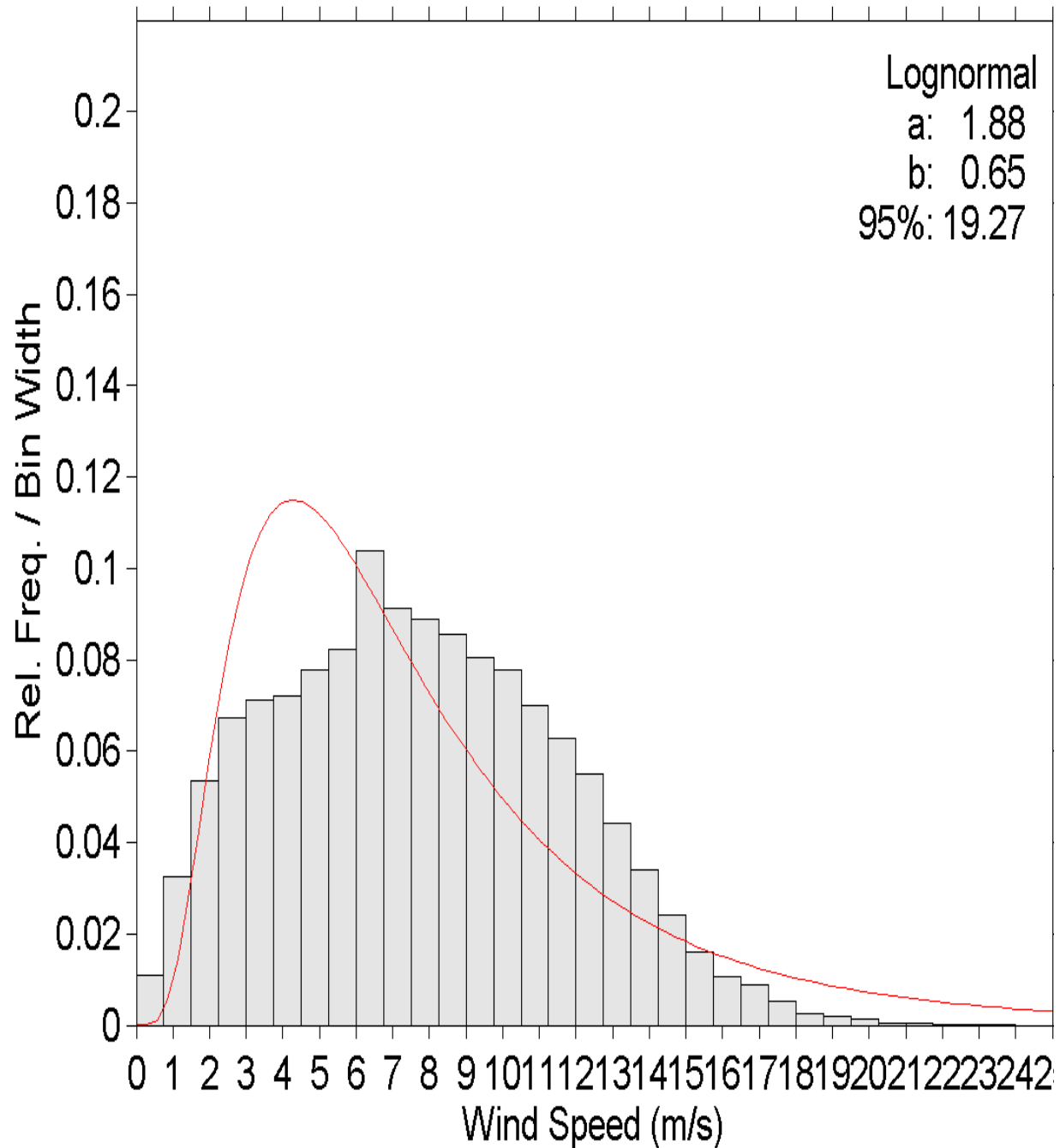
Descriptive Statistics:62083.2002-2010 lat:43.5 lon:-9.25 Obs

	Ws(m/s)
Mean	6.88
St. Dev.	3.47
Var. Coeff.	0.50
St. Error.	0.02
Skewness	0.32
Kurtosis	2.69

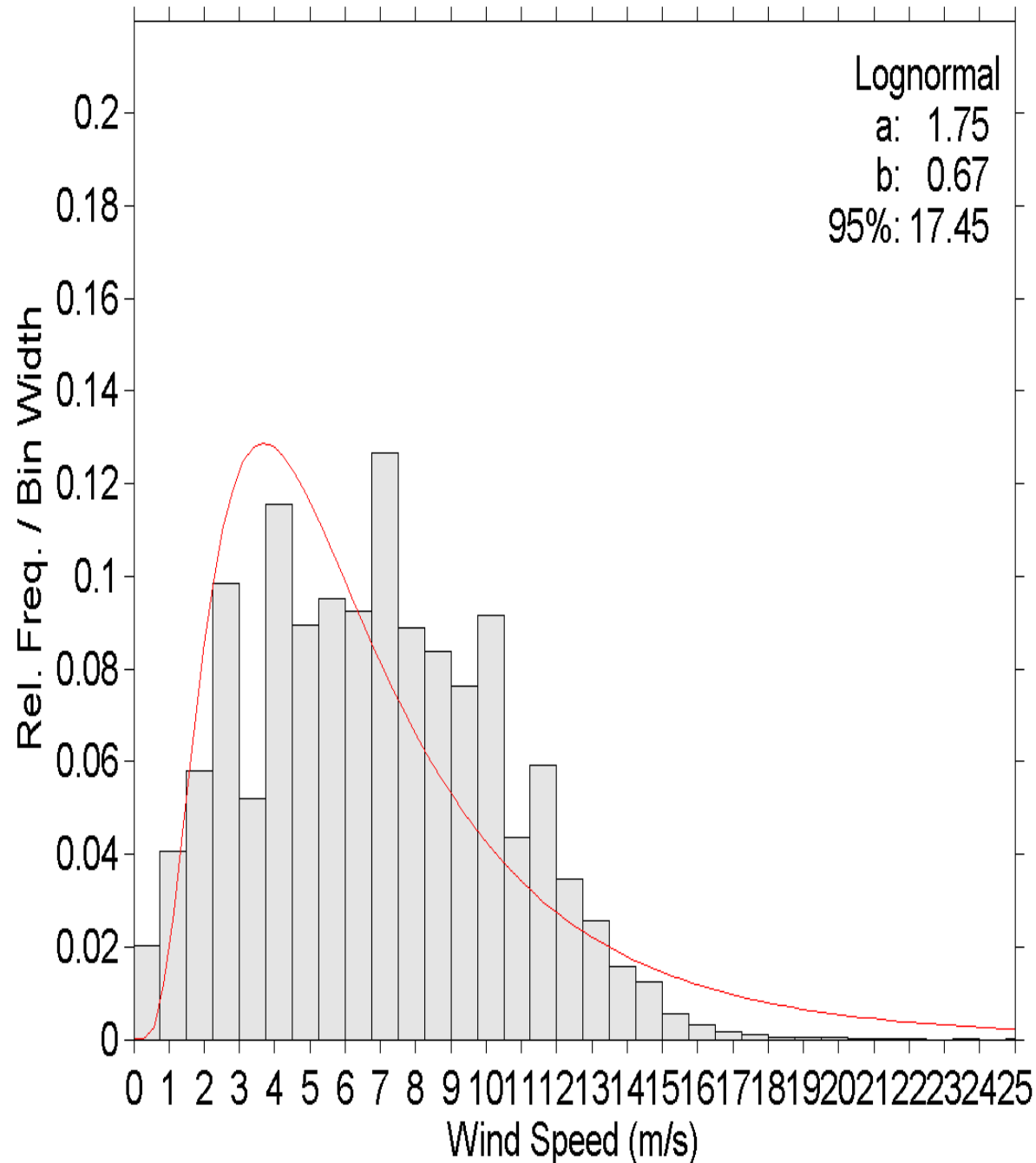
Descriptive Statistics:62083.2002-2010 lat:43.5 lon:-9.25 Model

	Ws(m/s)
Mean	7.77
St. Dev.	3.89
Var. Coeff.	0.50
St. Error.	0.02
Skewness	0.31
Kurtosis	2.57

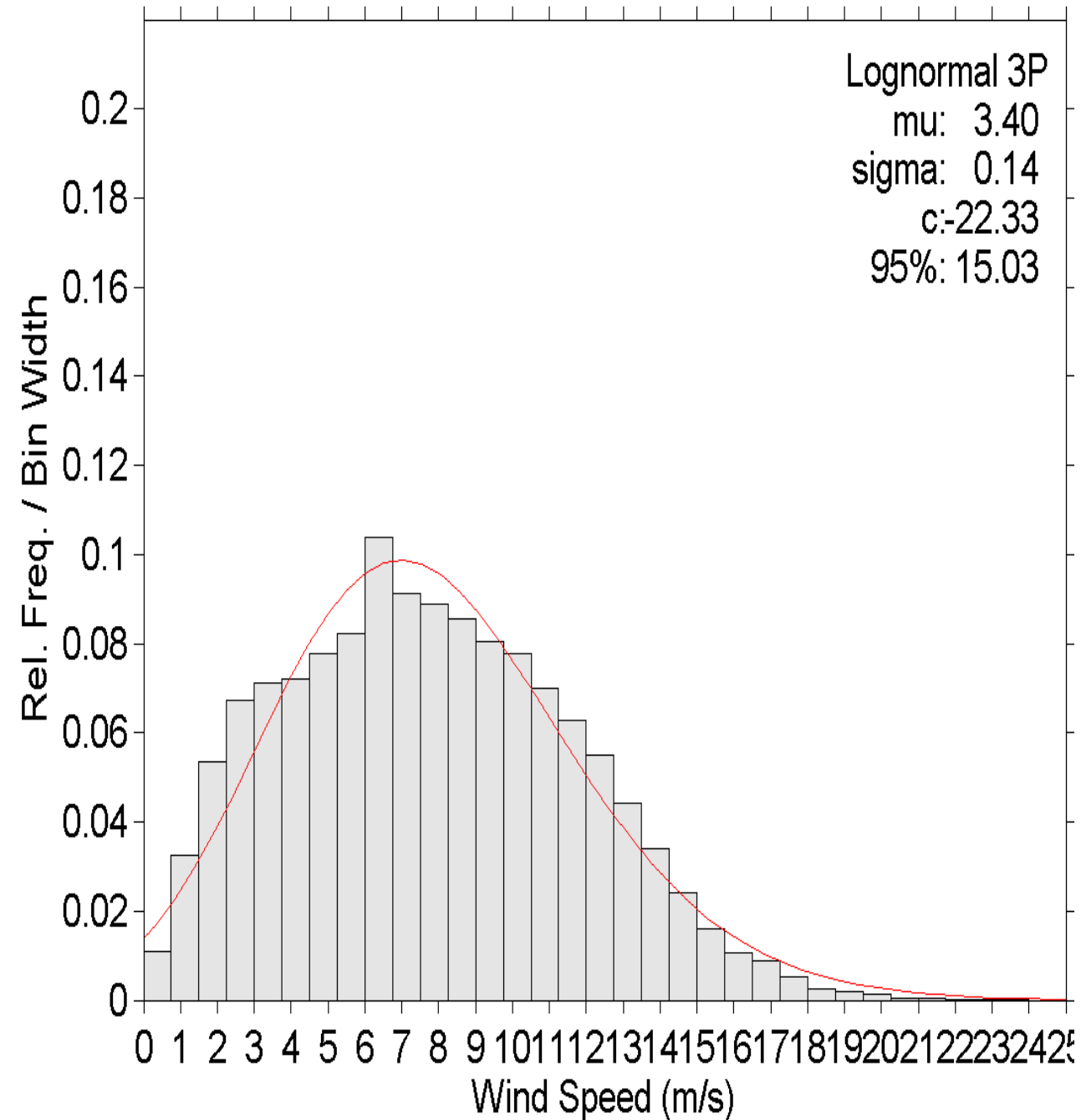
62083.2002-2010 lat:43.5 lon:-9.25 Model



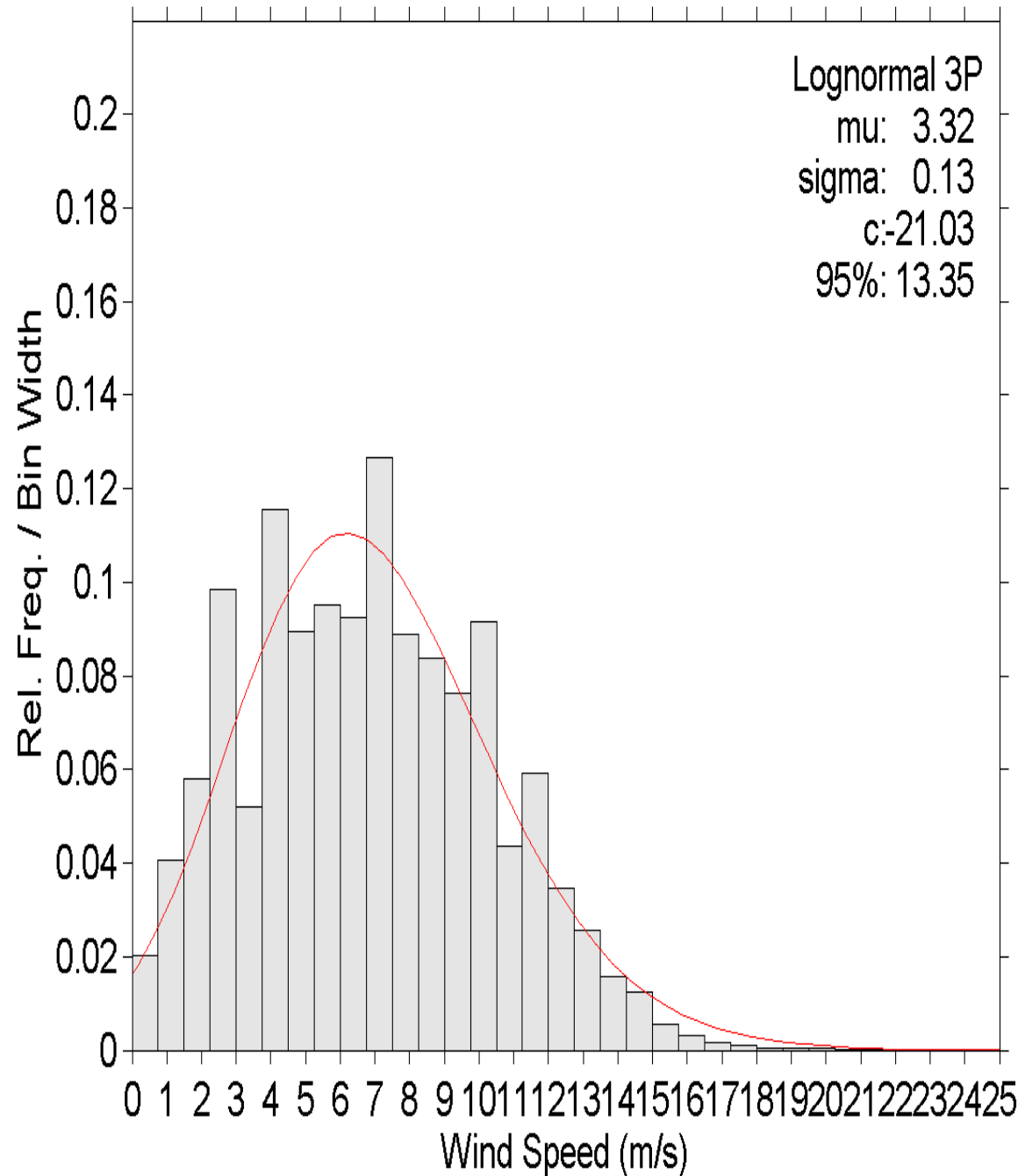
62083.2002-2010 lat:43.5 lon:-9.25 Obs



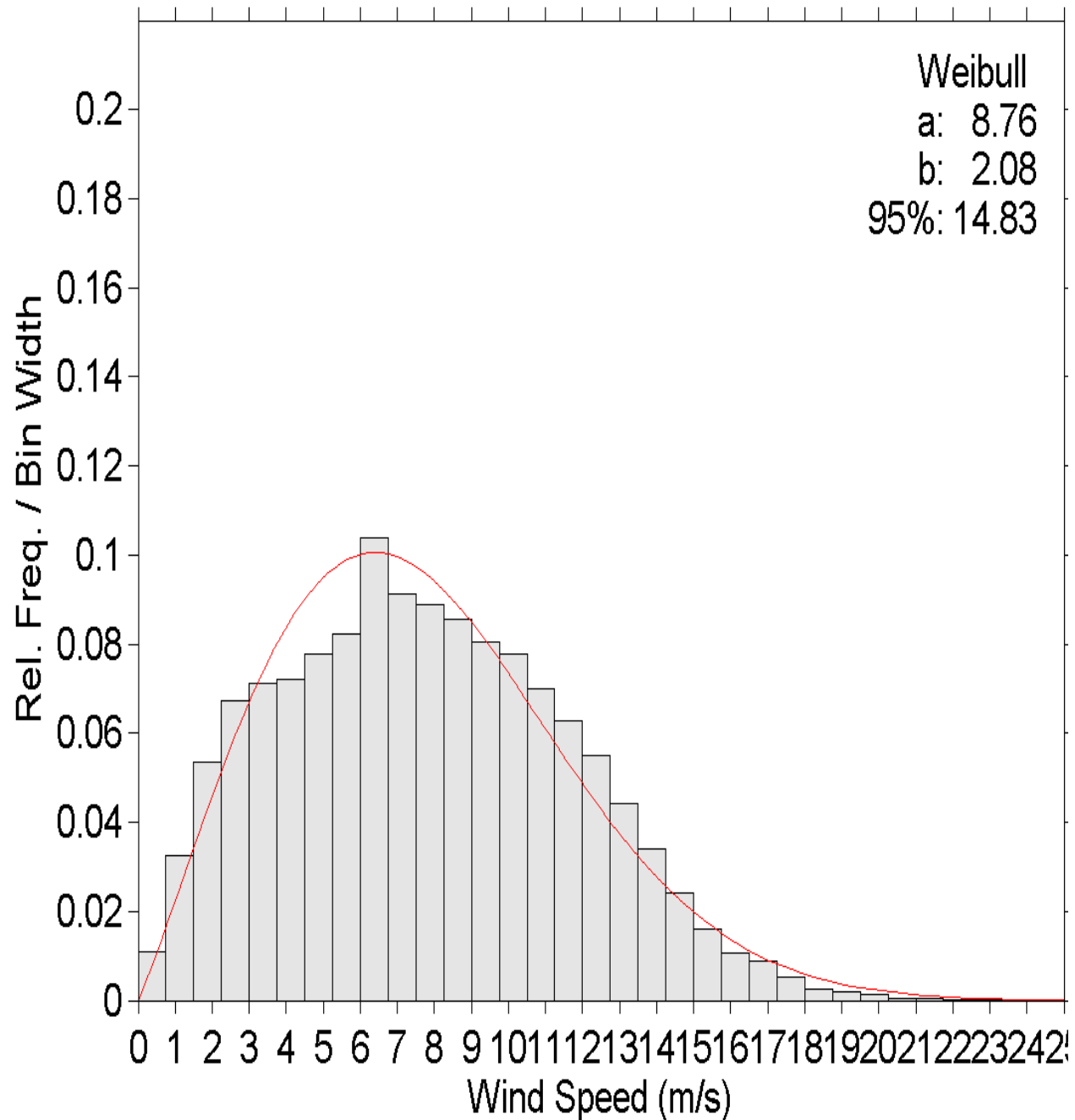
62083.2002-2010 lat:43.5 lon:-9.25 Model



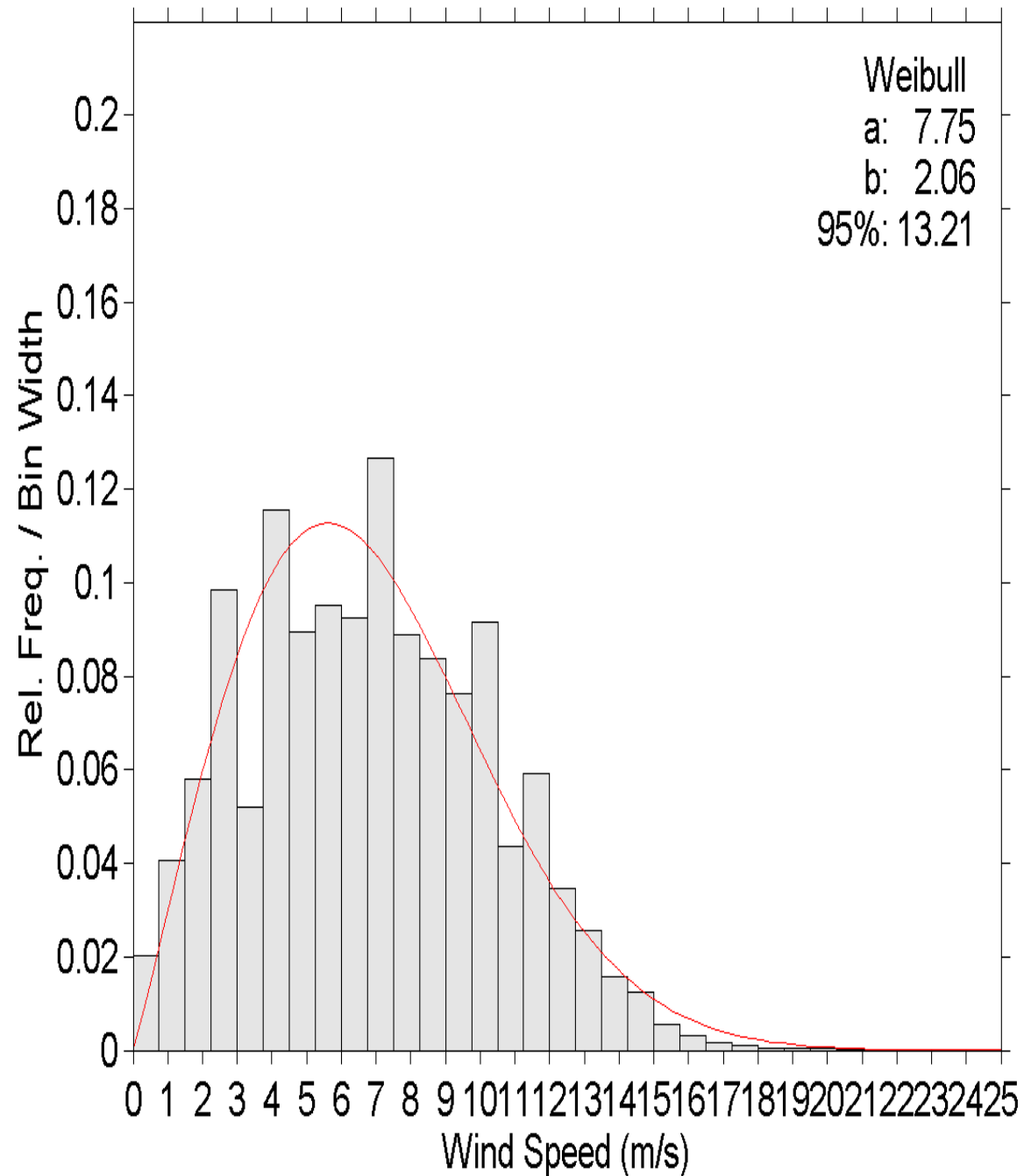
62083.2002-2010 lat:43.5 lon:-9.25 Obs



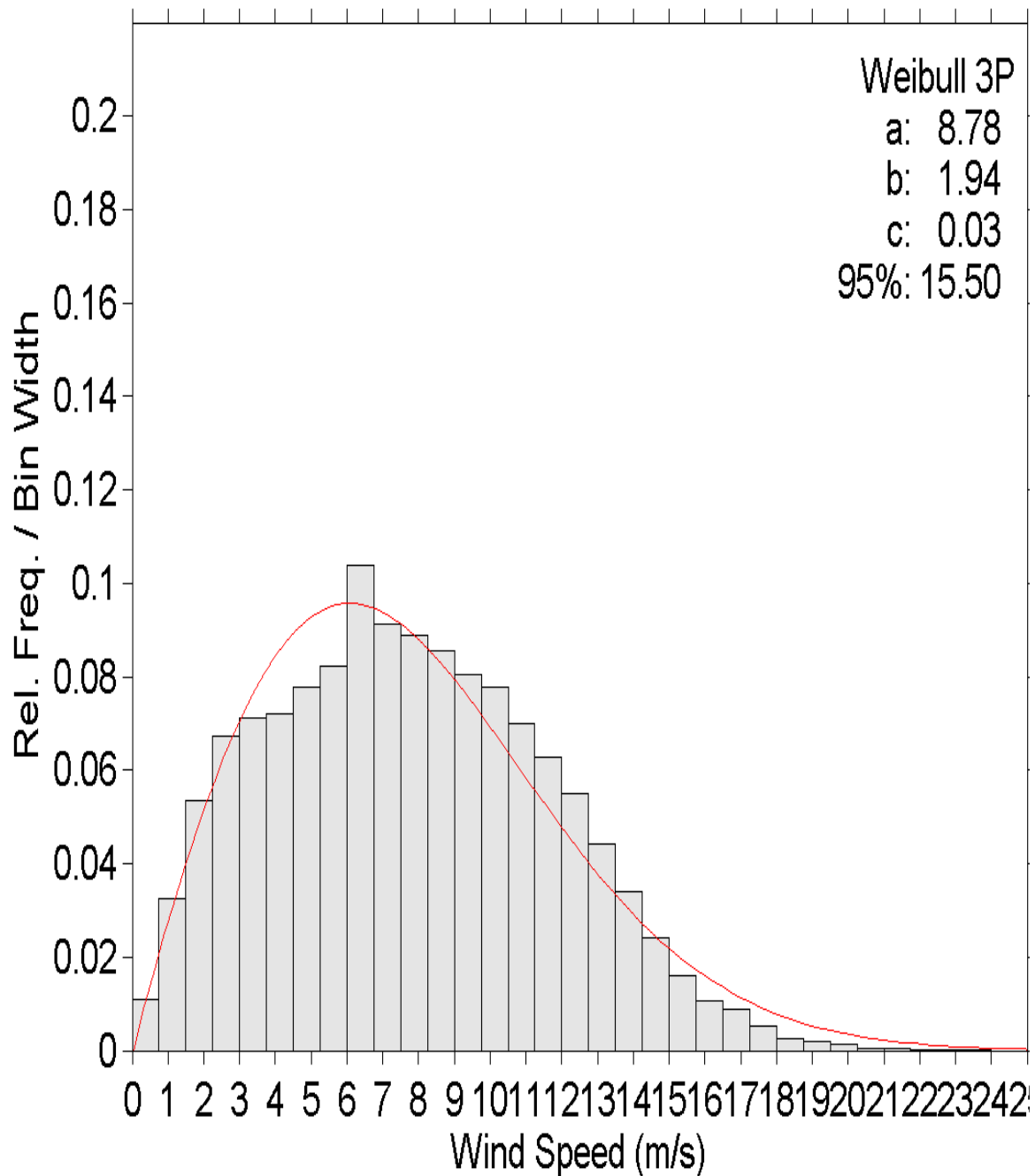
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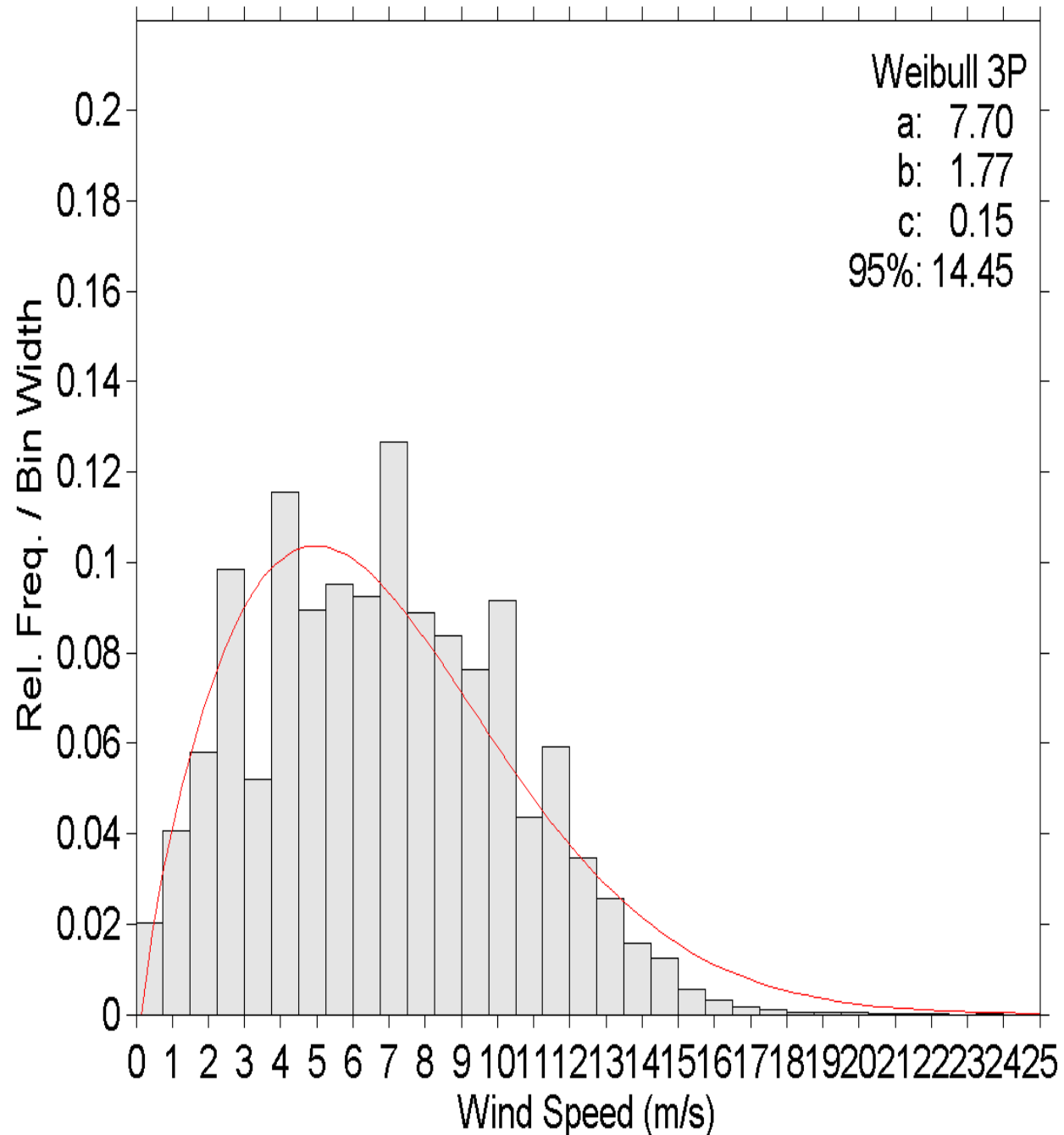
62083.2002-2010 lat:43.5 lon:-9.25 Obs



62083.2002-2010 lat:43.5 lon:-9.25 Model

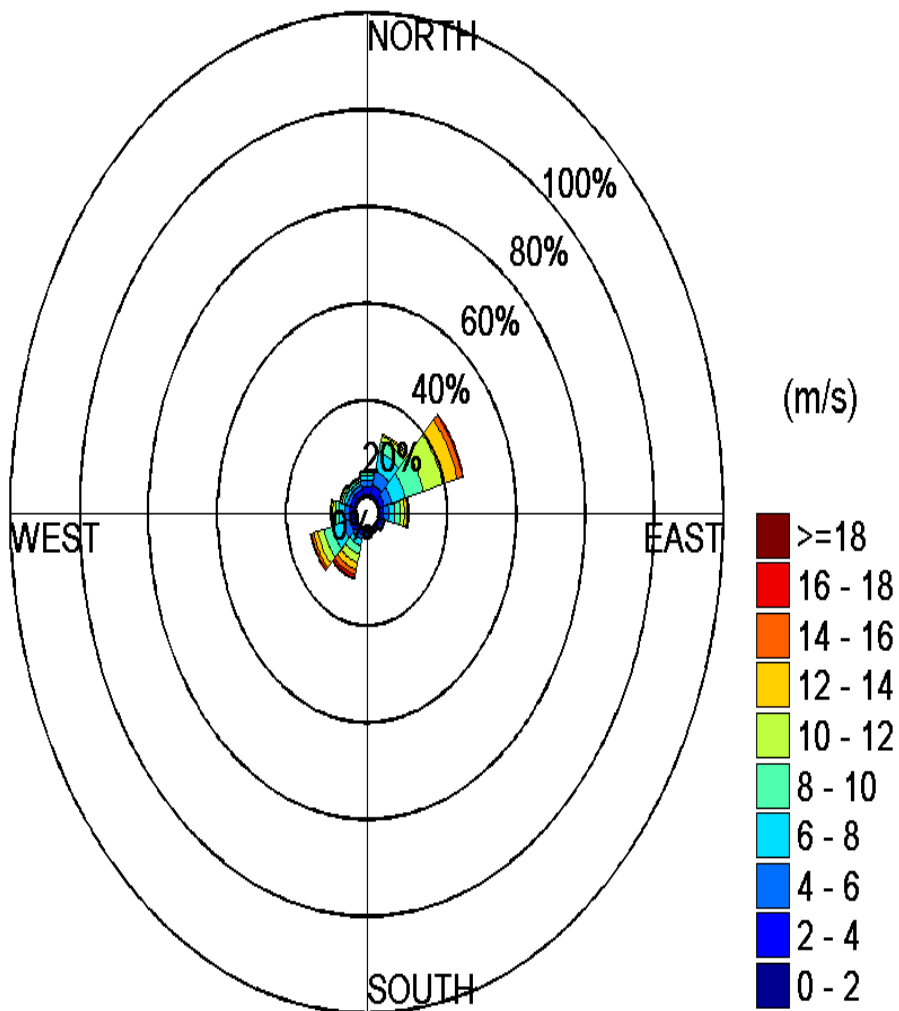


62083.2002-2010 lat:43.5 lon:-9.25 Obs



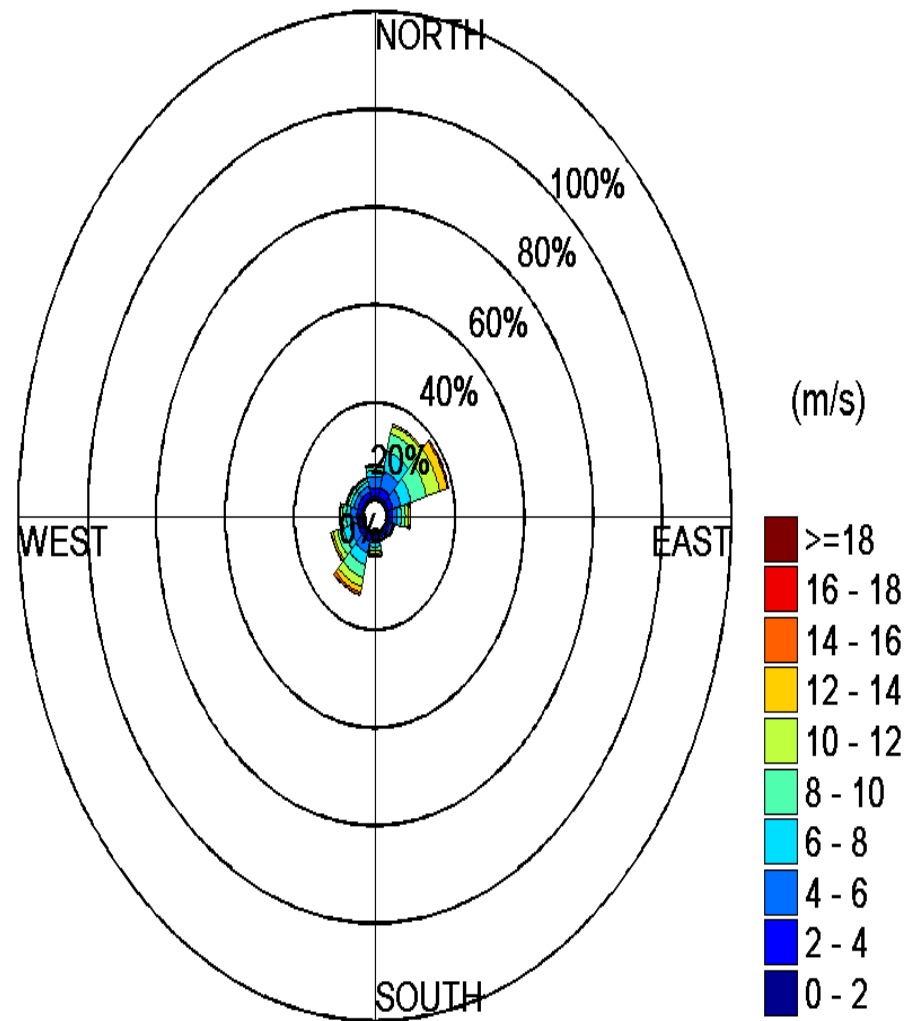
Wind Speed

62083.2002-2010 lat:43.5 lon:-9.25 Model

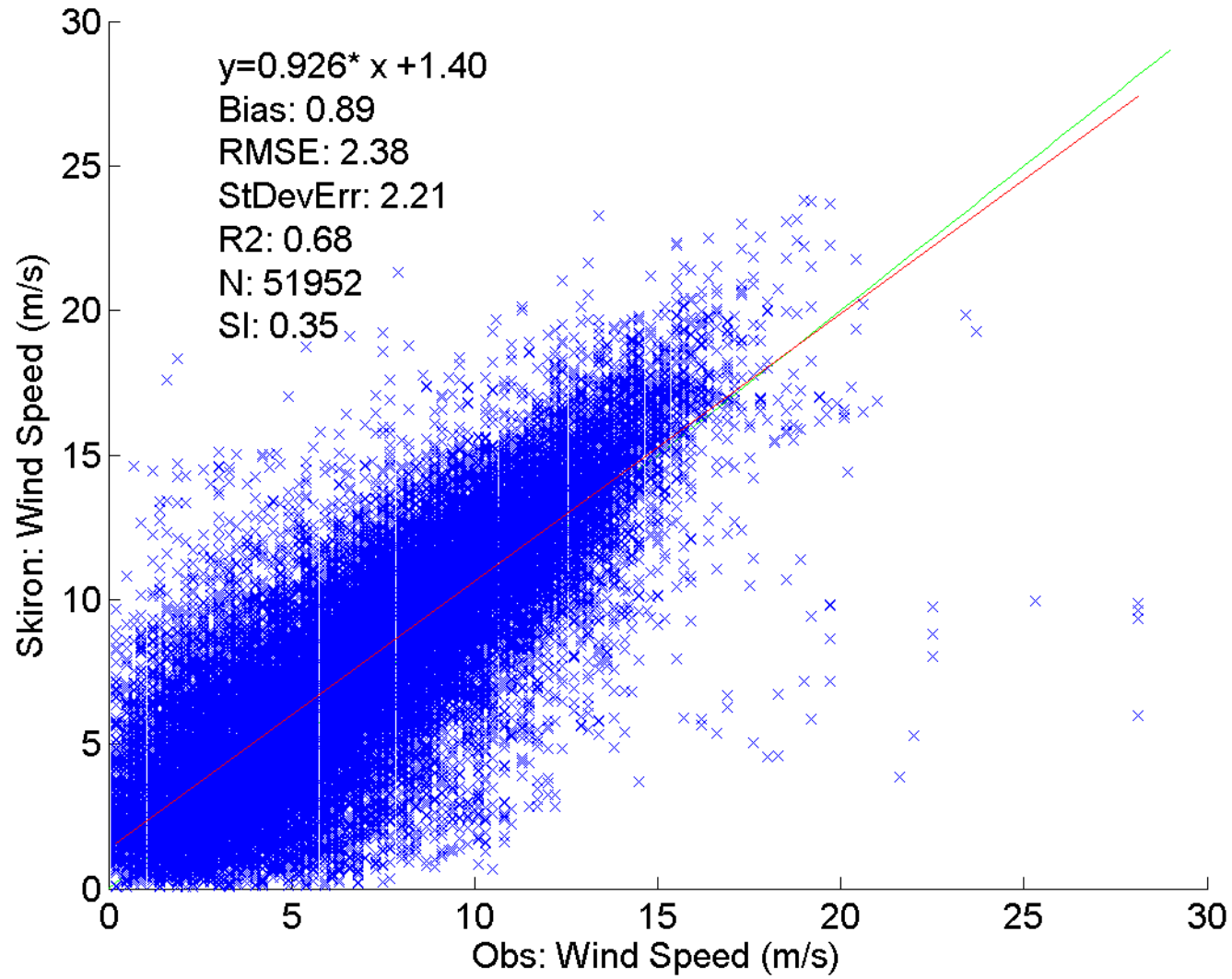


Wind Speed

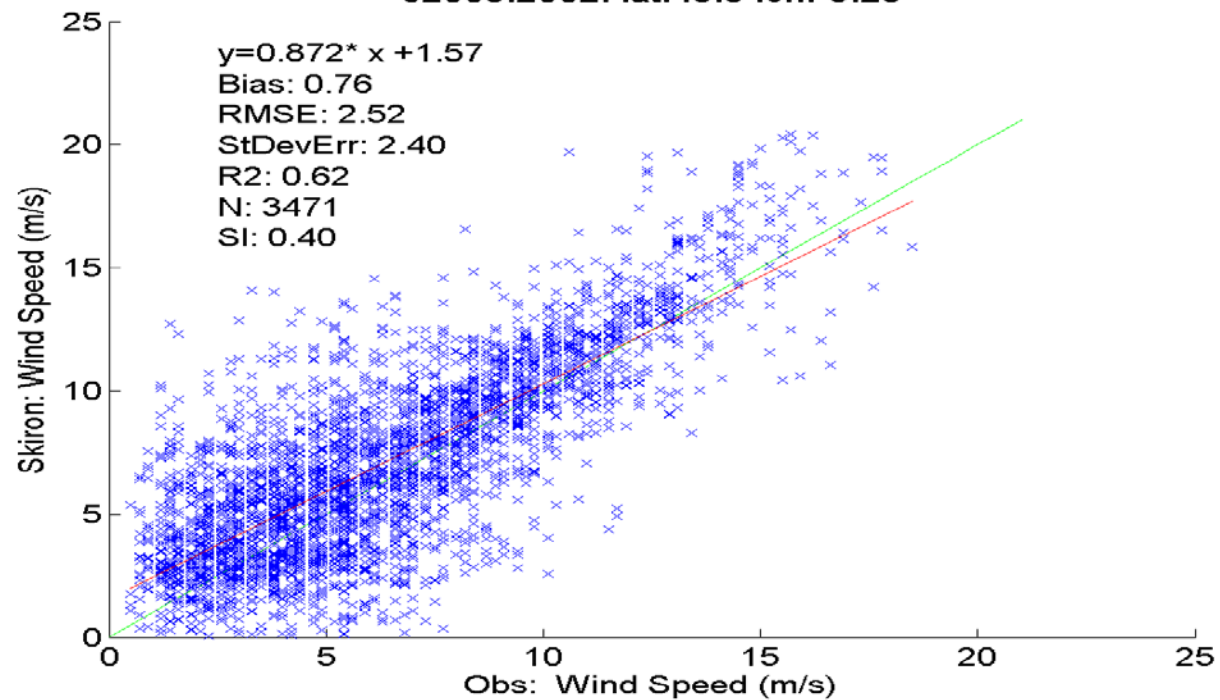
62083.2002-2010 lat:43.5 lon:-9.25 Obs



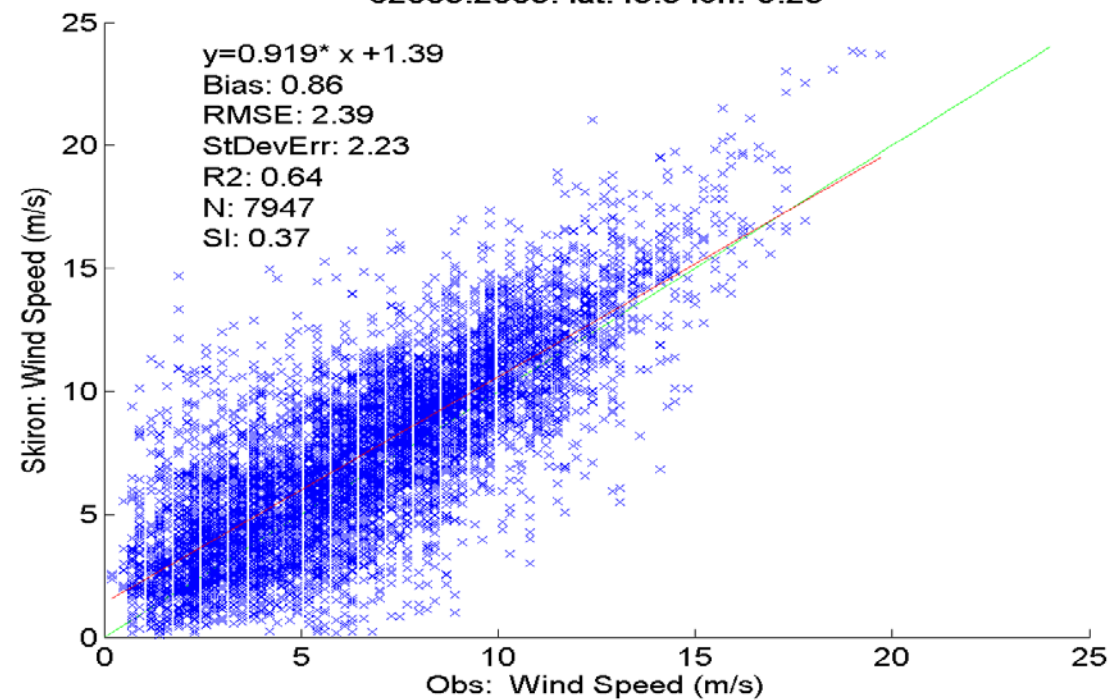
62083.2002-2010 lat:43.5 lon:-9.25



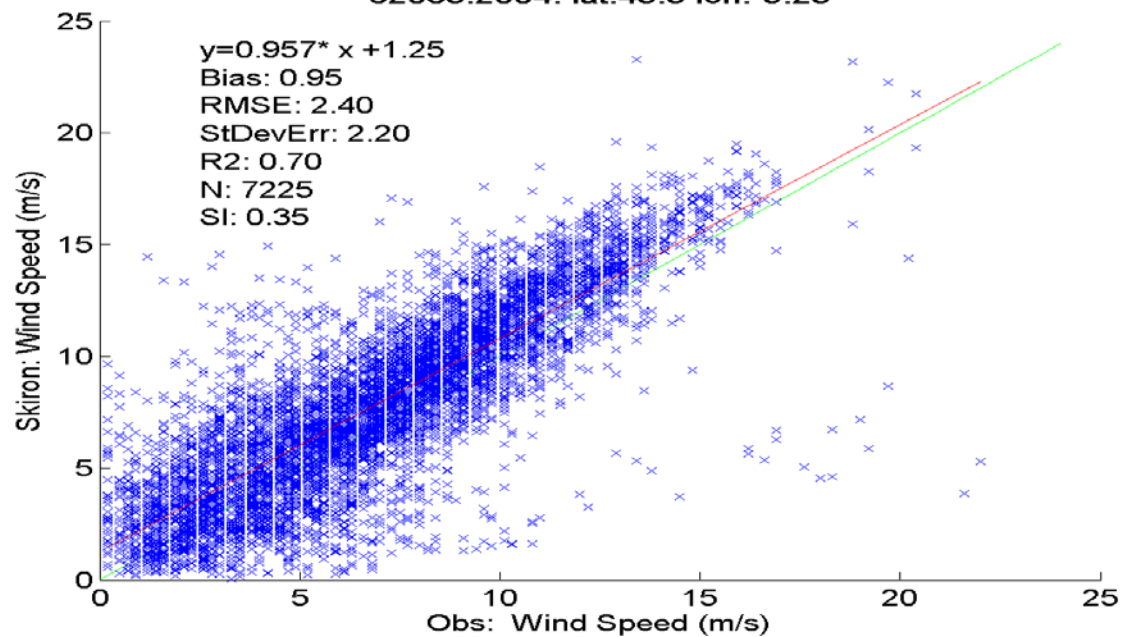
62083.2002. lat:43.5 lon:-9.25



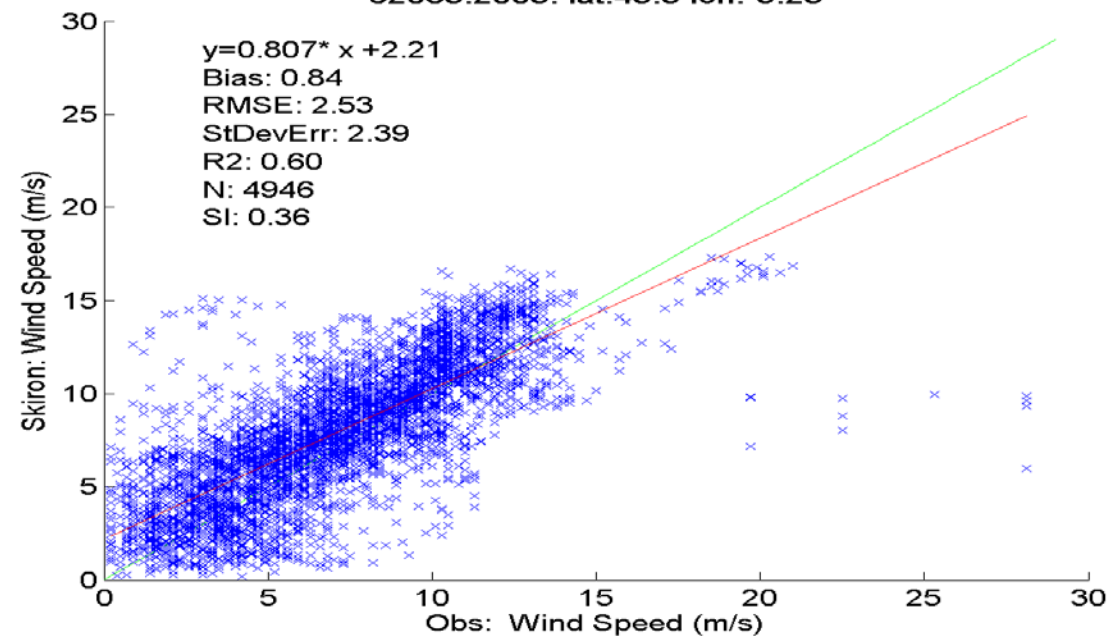
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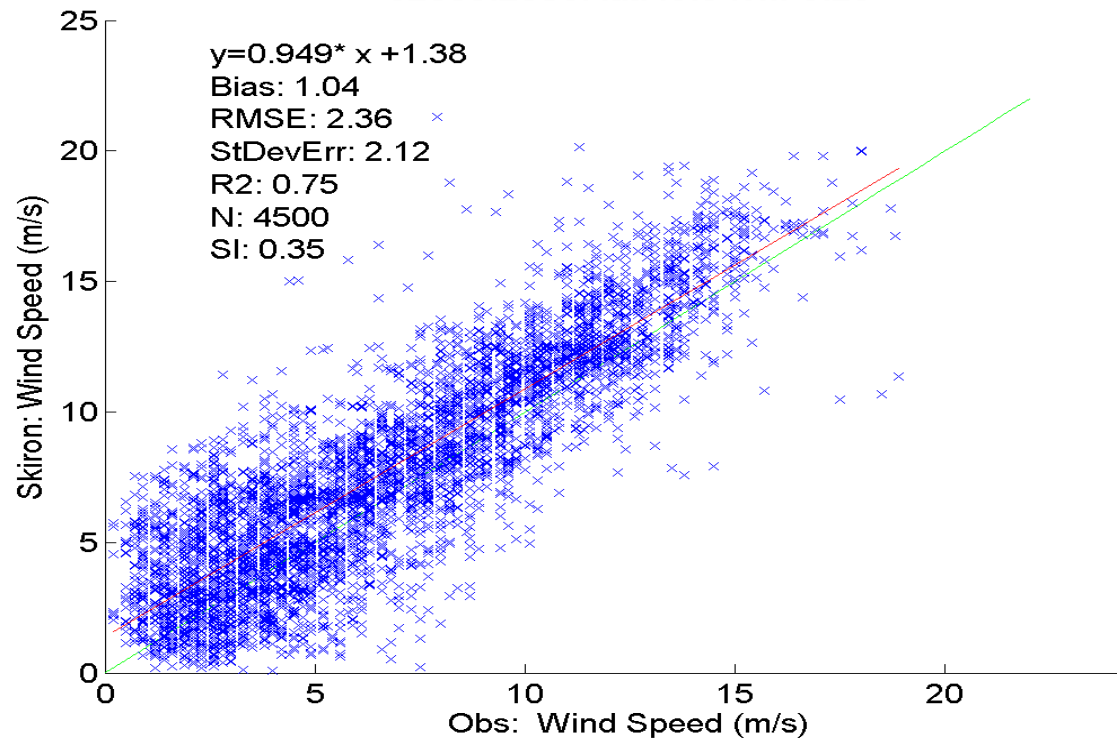
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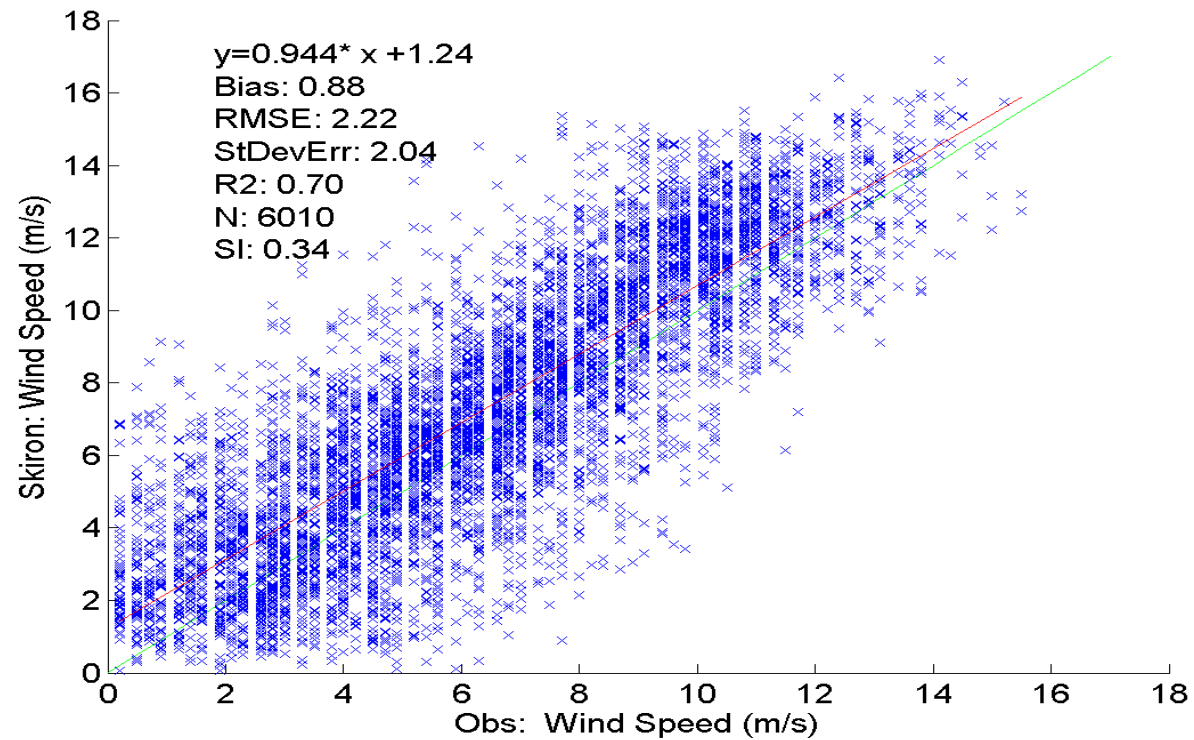
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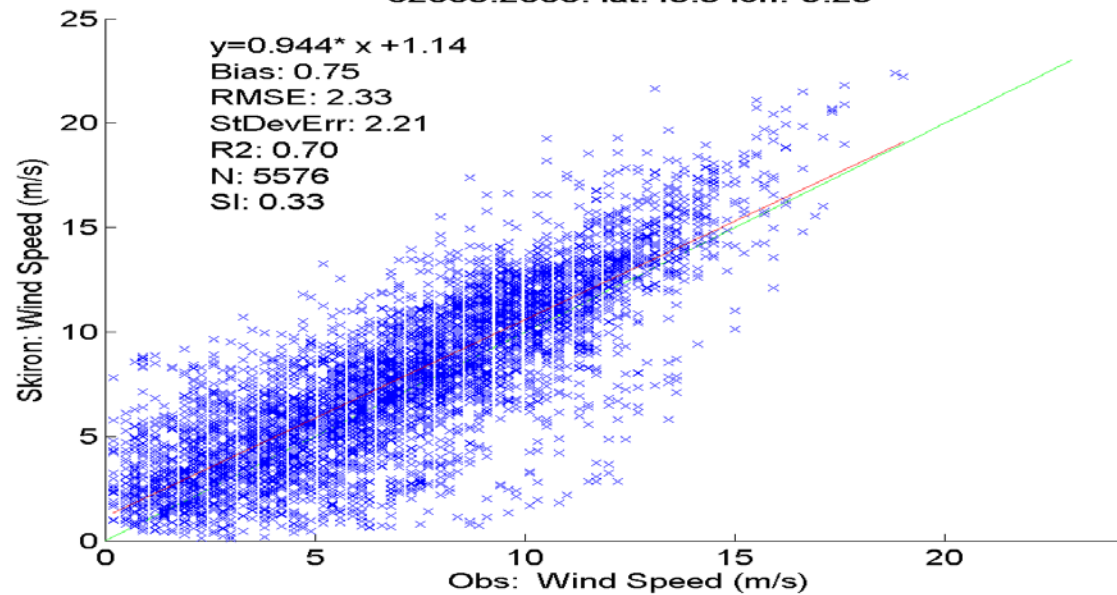
62083.2006. lat:43.5 lon:-9.25



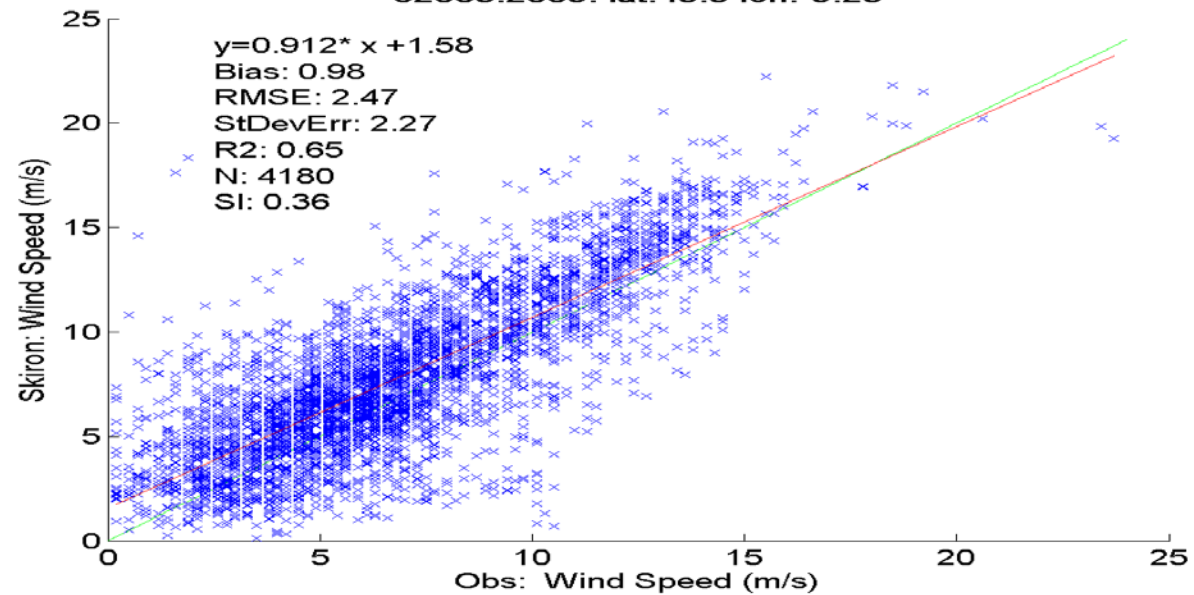
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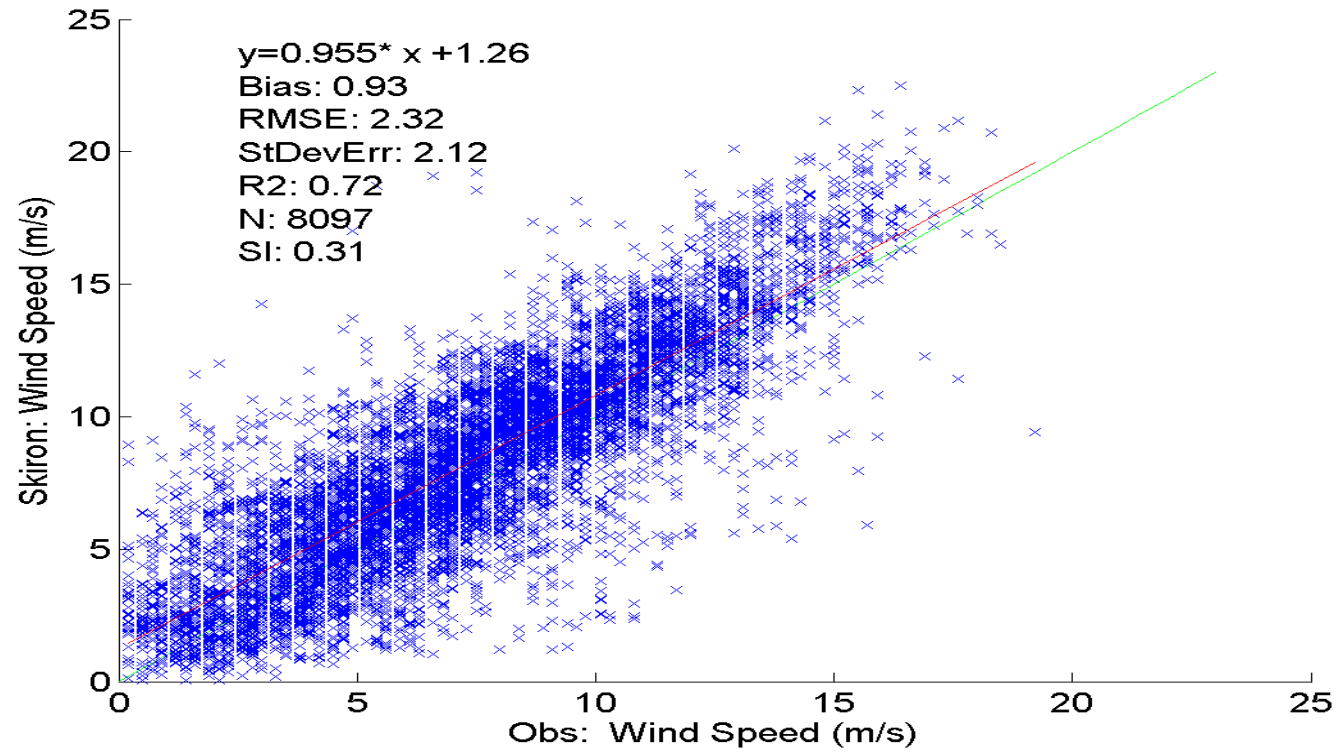
62083.2008. lat:43.5 lon:-9.25



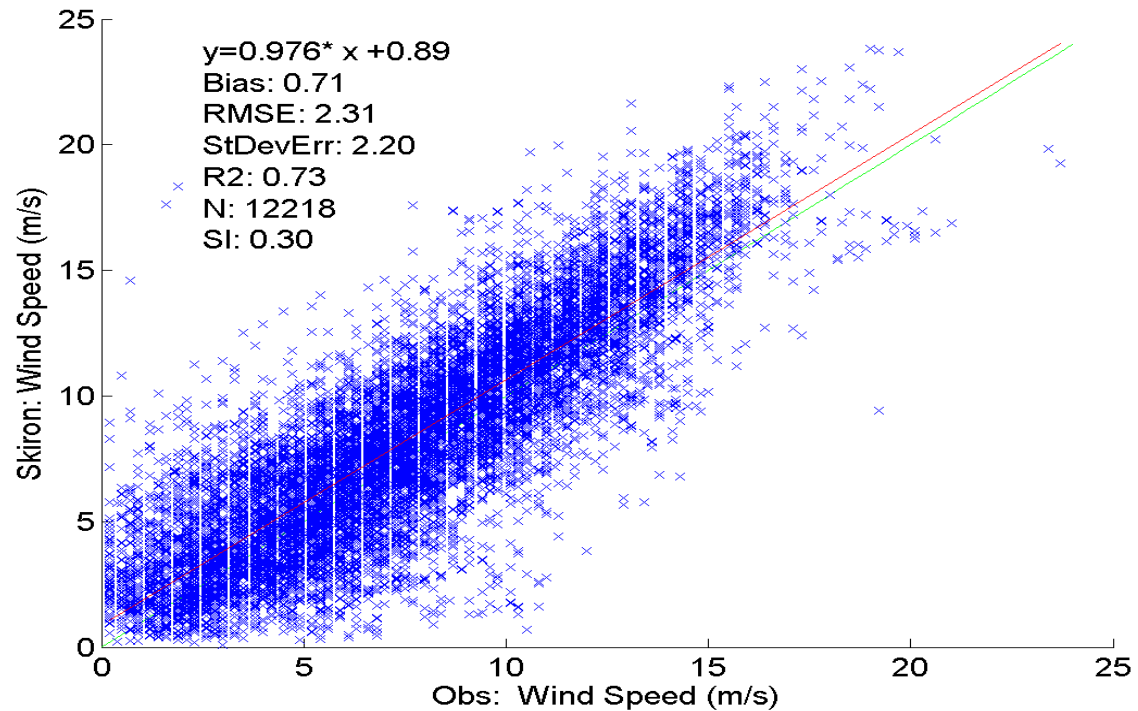
62083.2009. lat:43.5 lon:-9.25



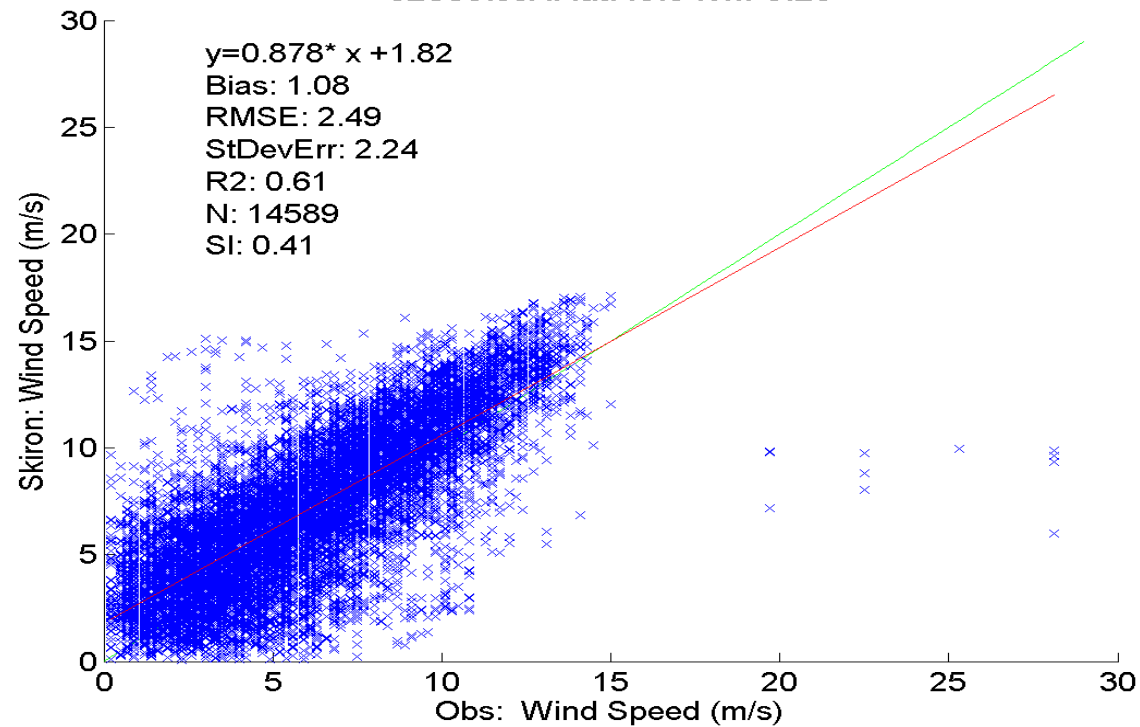
62083.2010. lat:43.5 lon:-9.25



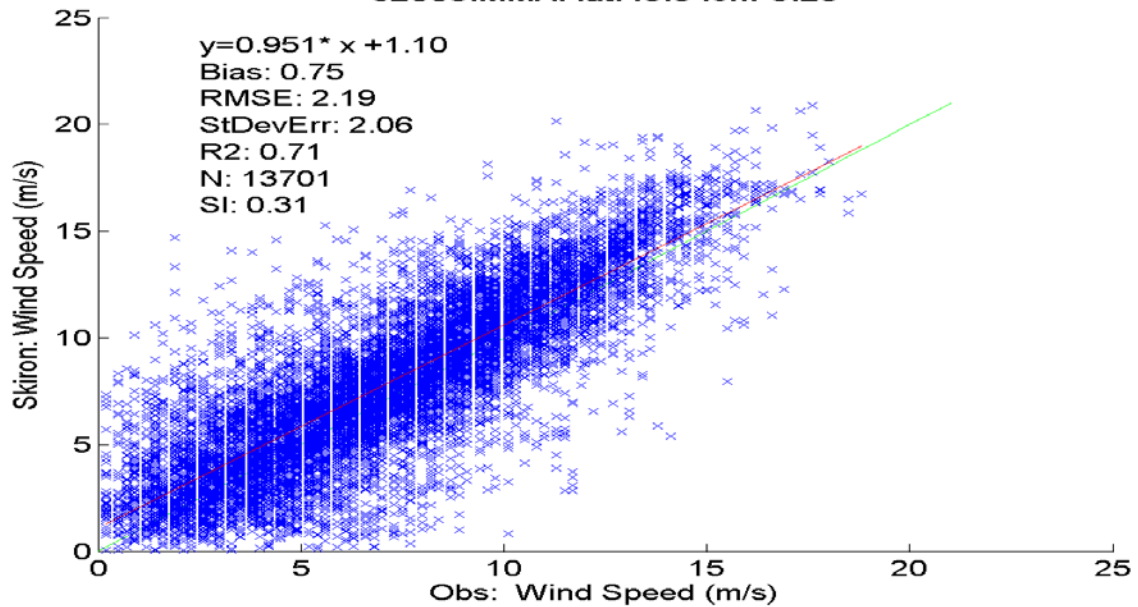
62083.DJF. lat:43.5 lon:-9.25



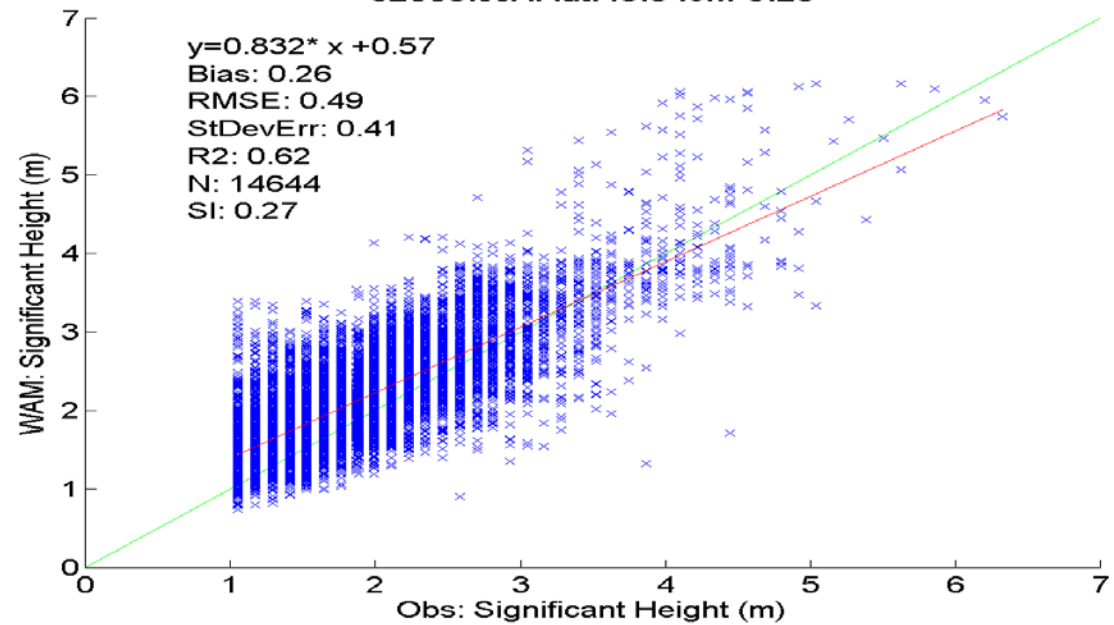
62083.JJA. lat:43.5 lon:-9.25



62083.MMA. lat:43.5 lon:-9.25



62083.JJA. lat:43.5 lon:-9.25



62083.Wind Speed (m/s).2002-2010.lat:43.5-lon:-9.25

	Bias:	RMSE:	StDevErr:	R²:	N:	SI:
All:	0.89	2.38	2.21	0.68	51952	0.35
2002:	0.76	2.52	2.40	0.62	3471	0.40
2003:	0.86	2.39	2.23	0.64	7947	0.37
2004:	0.95	2.40	2.20	0.70	7225	0.35
2005:	0.84	2.53	2.39	0.60	4946	0.36
2006:	1.04	2.36	2.12	0.75	4500	0.35
2007:	0.88	2.22	2.04	0.70	6010	0.34
2008:	0.75	2.33	2.21	0.70	5576	0.33
2009:	0.98	2.47	2.27	0.65	4180	0.36
2010:	0.93	2.32	2.12	0.72	8097	0.31
JJA:	1.08	2.49	2.24	0.61	14589	0.41
SON:	1.01	2.53	2.32	0.66	11444	0.37
DJF:	0.71	2.31	2.20	0.73	12218	0.30
MMA:	0.75	2.19	2.06	0.71	13701	0.31

Coastal station/buoy

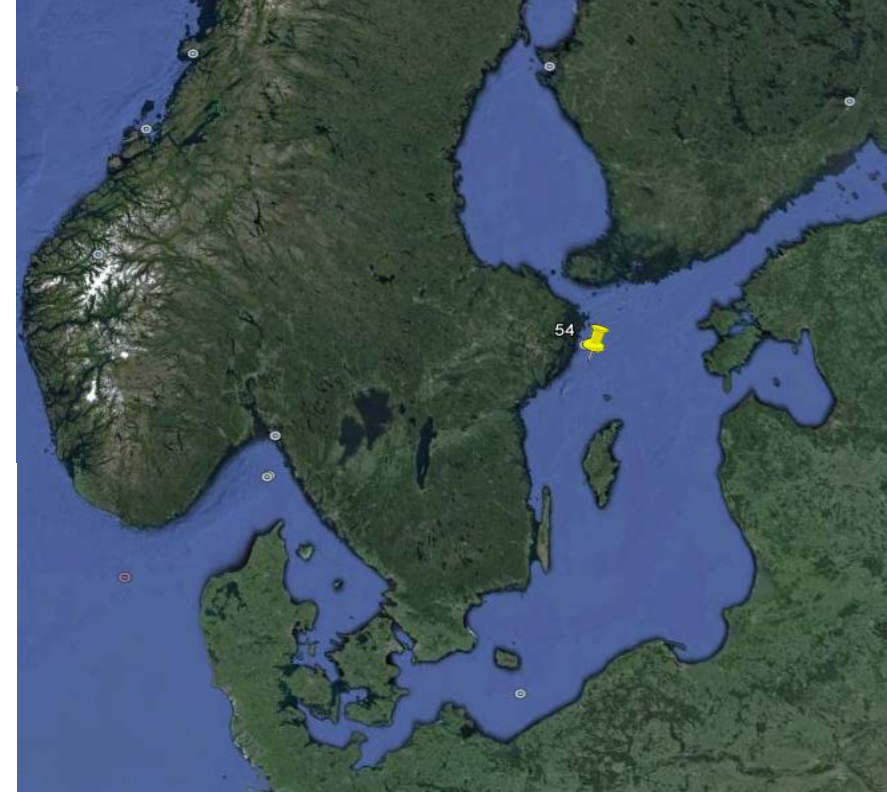
- ▶ HuvudskarOst
- ▶ Lat: 58.95
- ▶ Lon: 19.15
- ▶ 2001-2010

Descriptive Statistics:HuvudskarOst.2001-2010 lat:58.95 lon:19.15 Obs

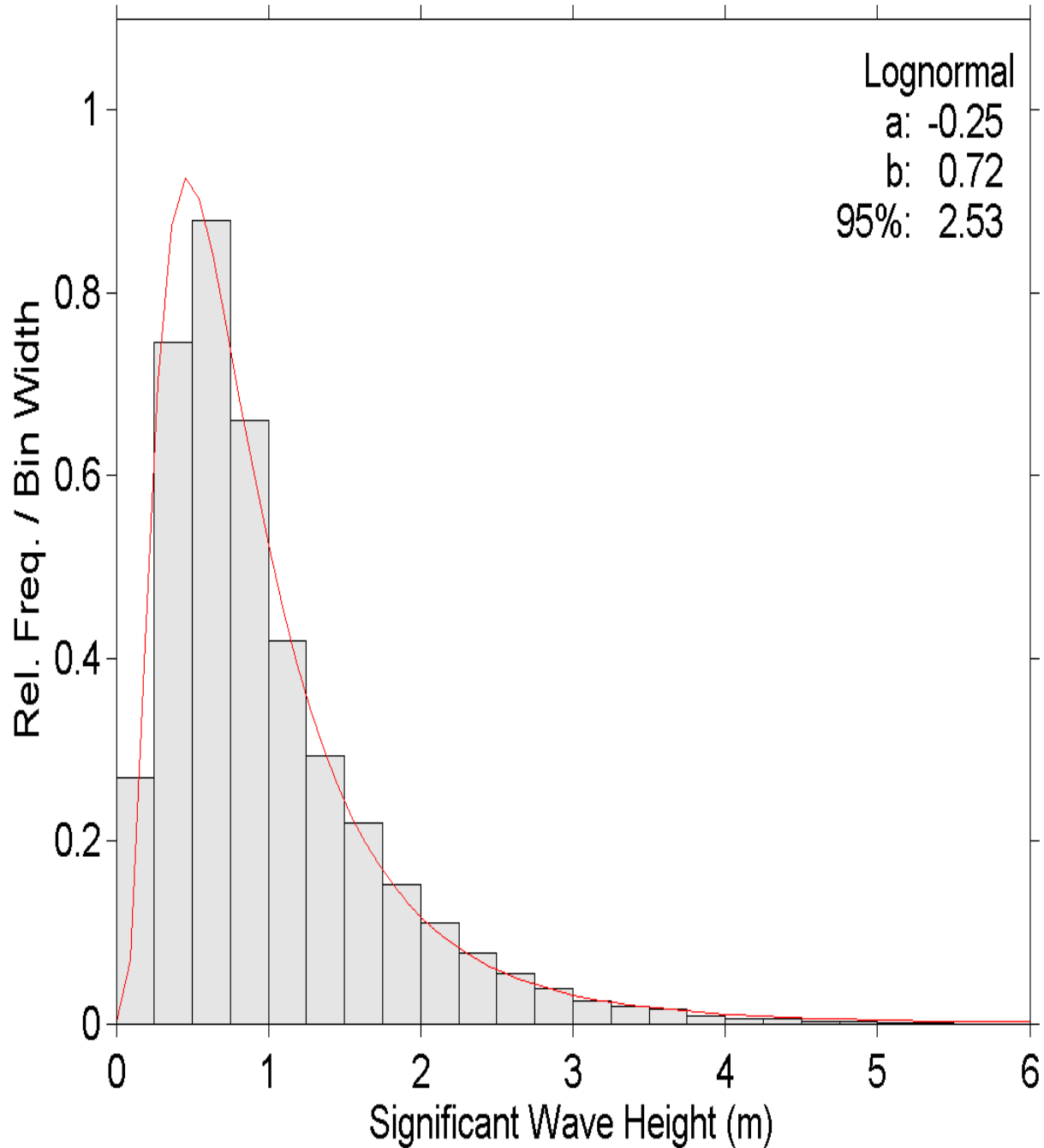
	Hs(m)
Mean	0.98
St. Dev.	0.66
Var. Coeff.	0.67
St. Error.	0.00
Skewness	1.50
Kurtosis	6.19

Descriptive Statistics:HuvudskarOst.2001-2010 lat:58.95 lon:19.15 Model

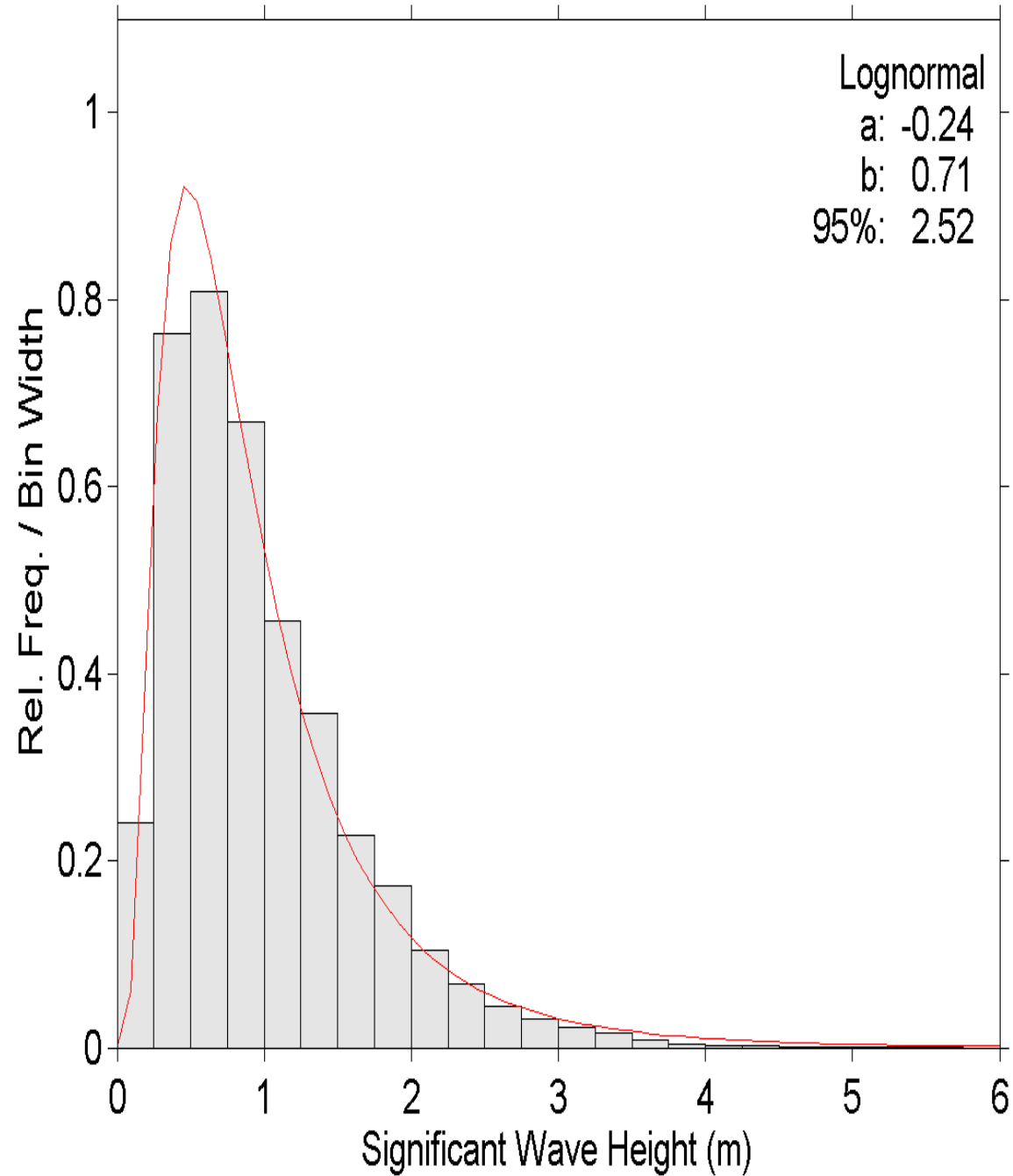
	Hs(m)
Mean	0.99
St. Dev.	0.71
Var. Coeff.	0.72
St. Error.	0.00
Skewness	1.71
Kurtosis	6.93



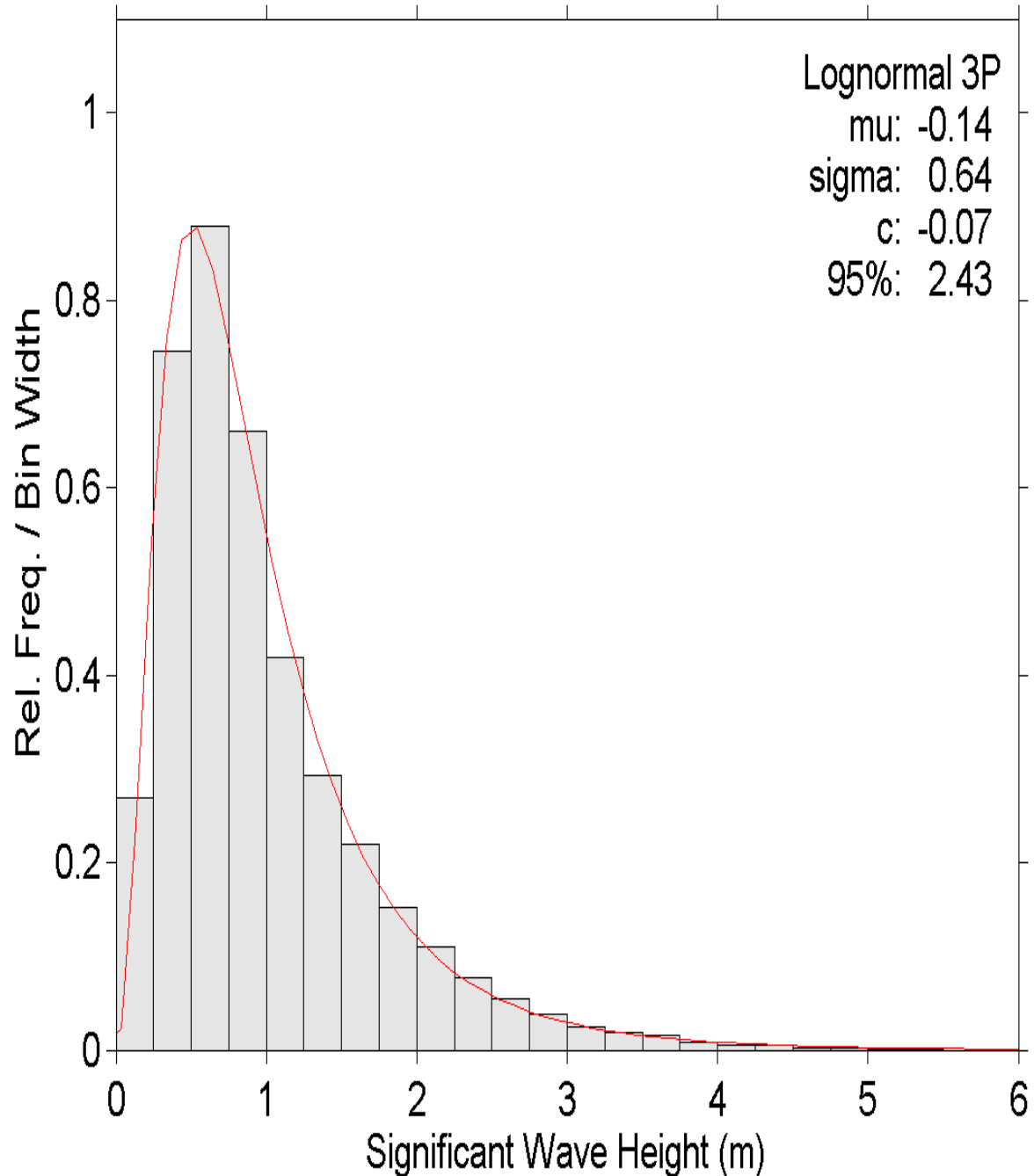
HuvudskarOst.2001-2010 lat:58.95 lon:19.15 Model



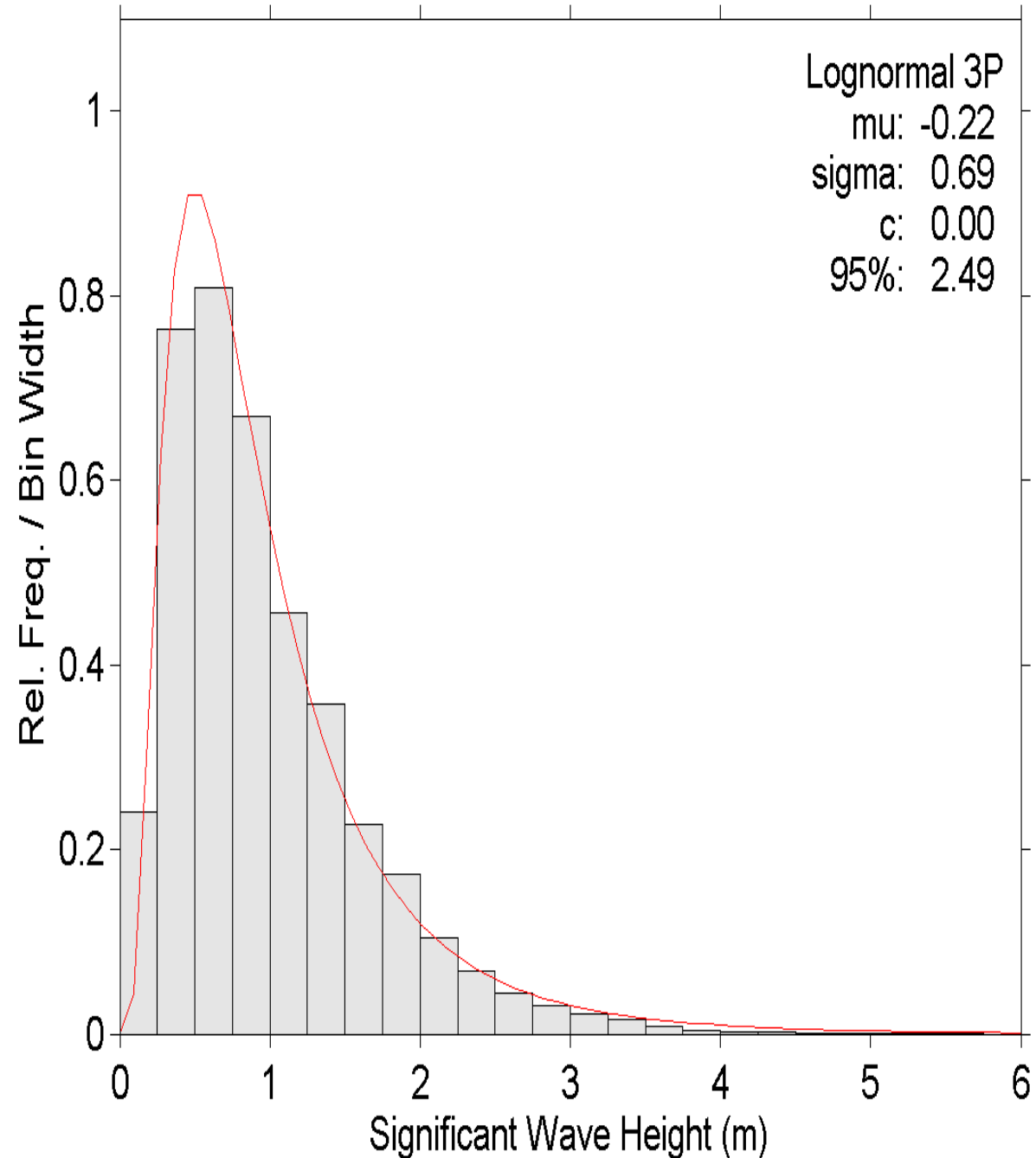
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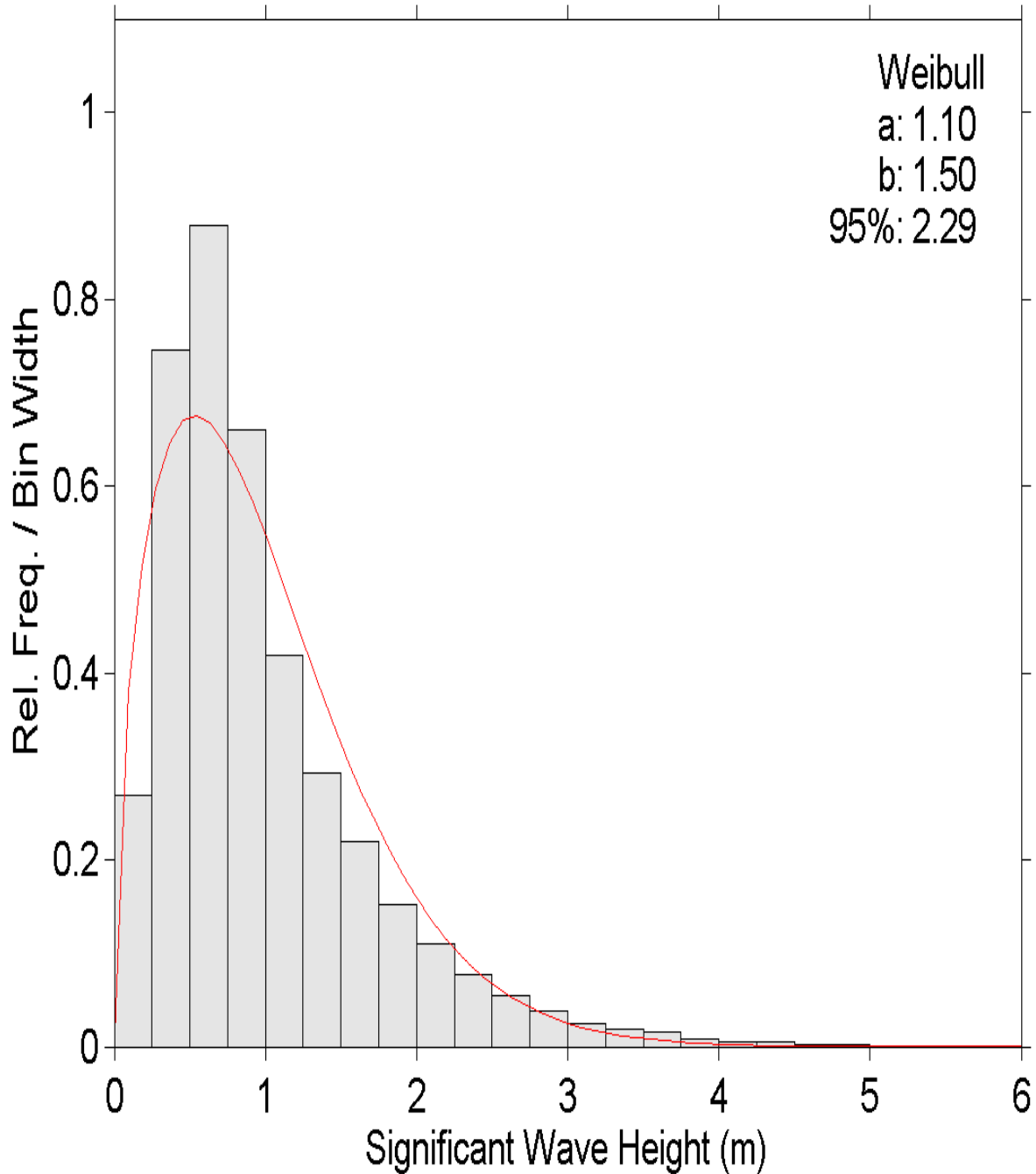
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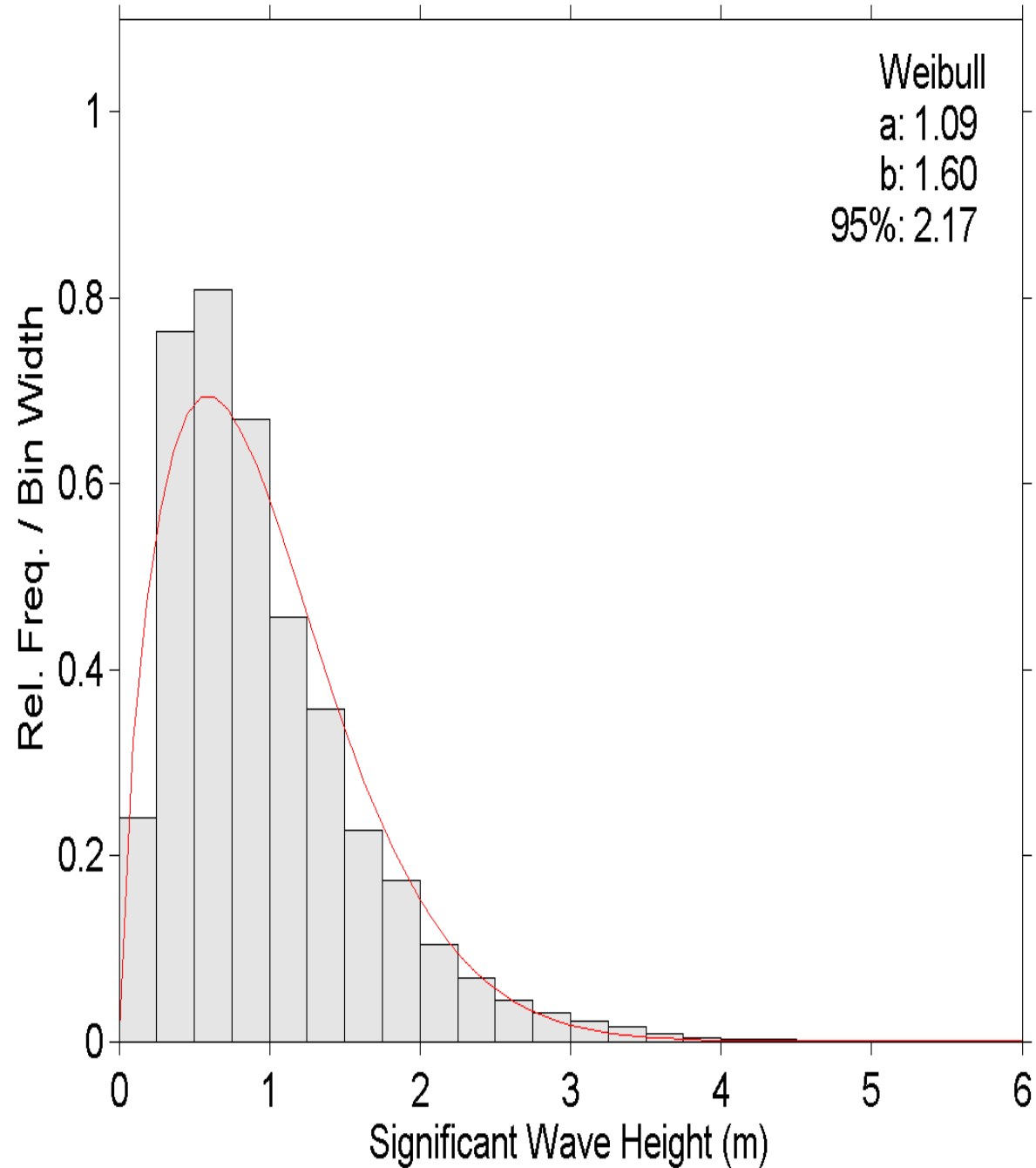
HuvudskarOst.2001-2010 lat:58.95 lon:19.15 Obs



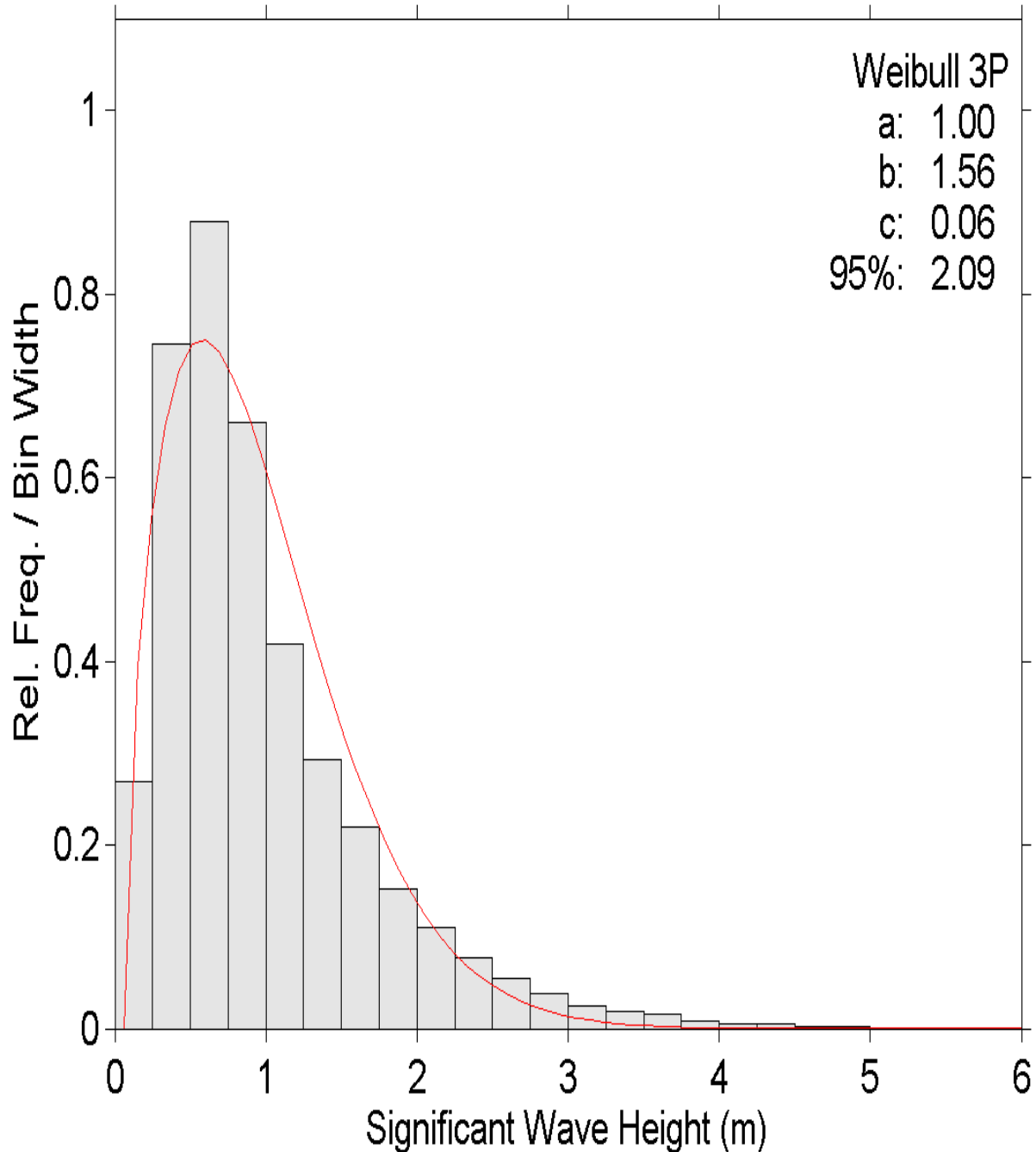
HuvudskarOst.2001-2010 lat:58.95 lon:19.15 Model



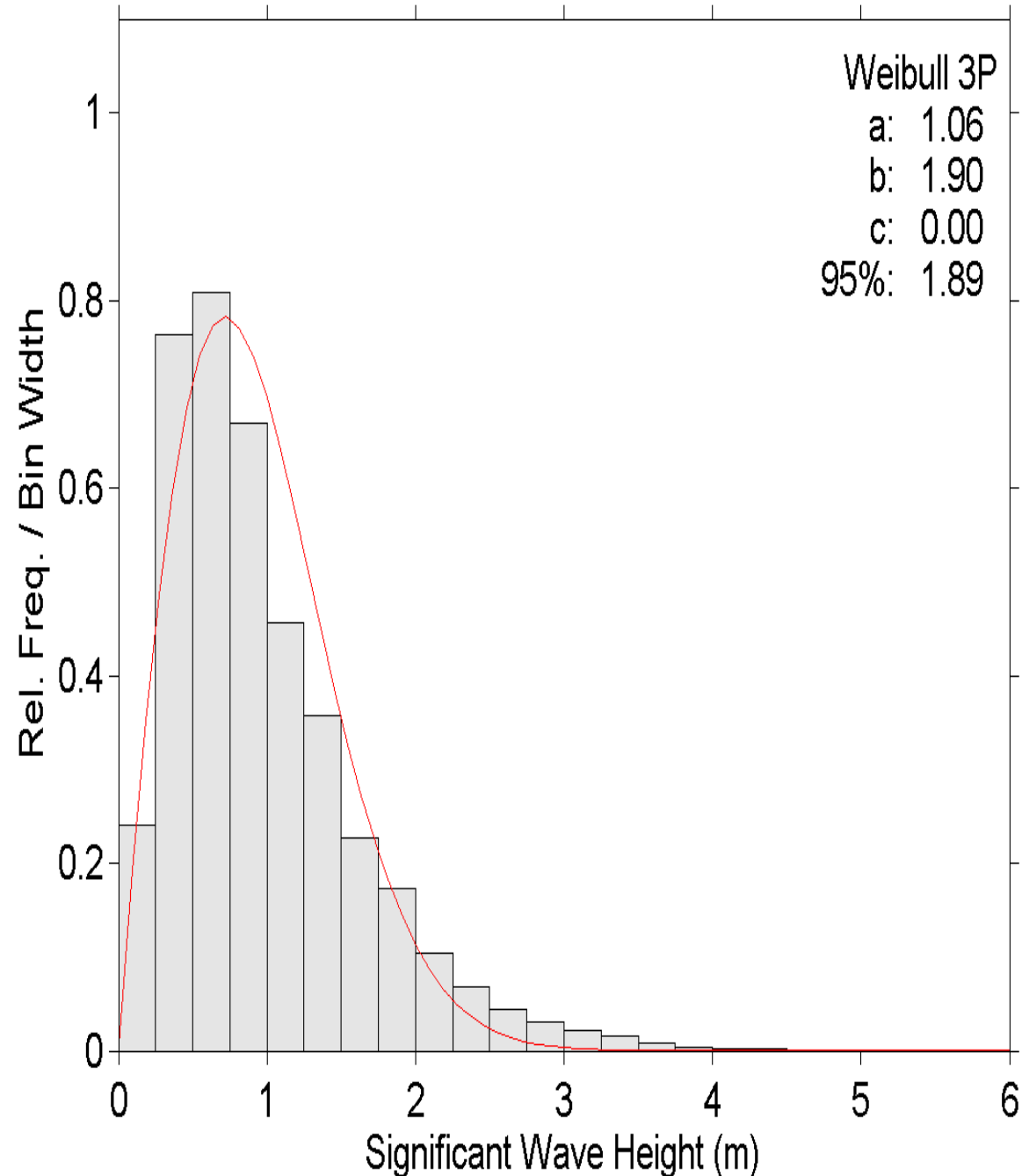
HuvudskarOst.2001-2010 lat:58.95 lon:19.15 Obs



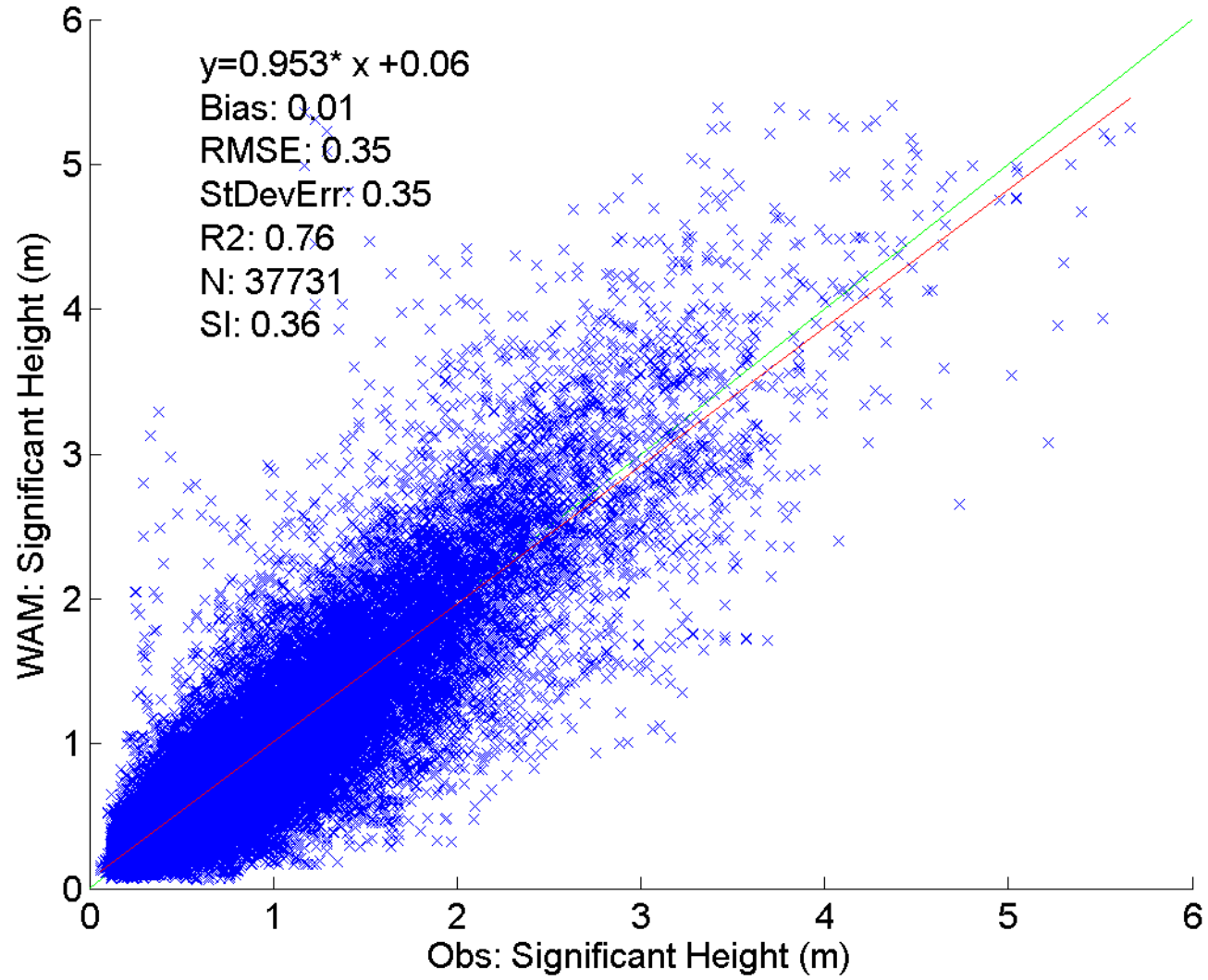
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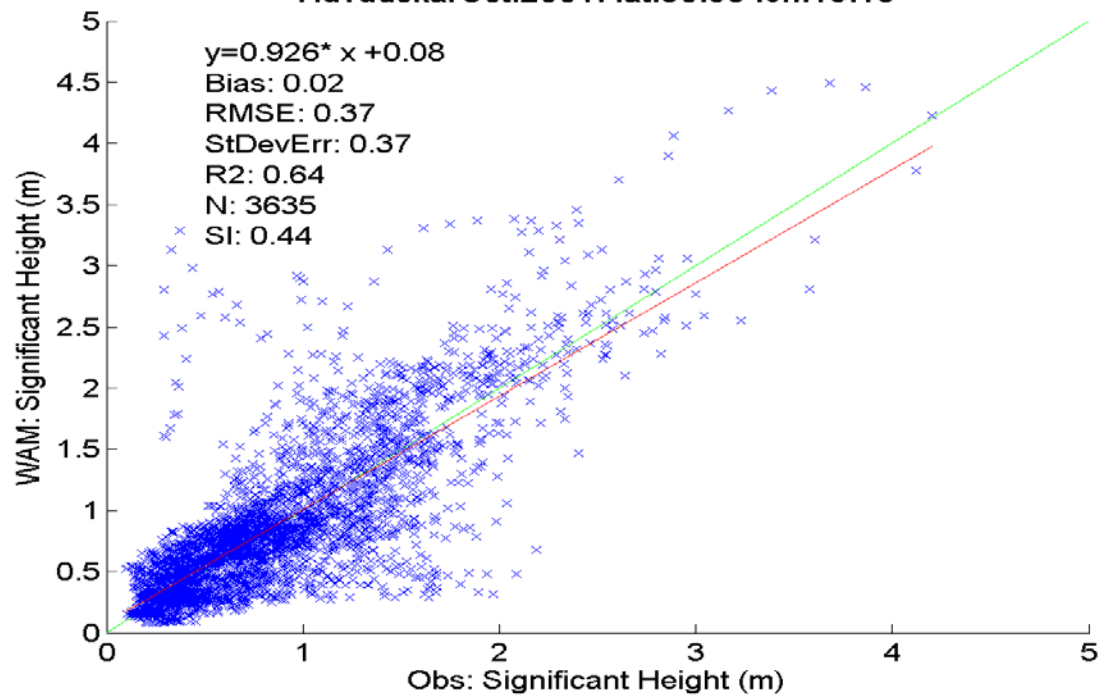
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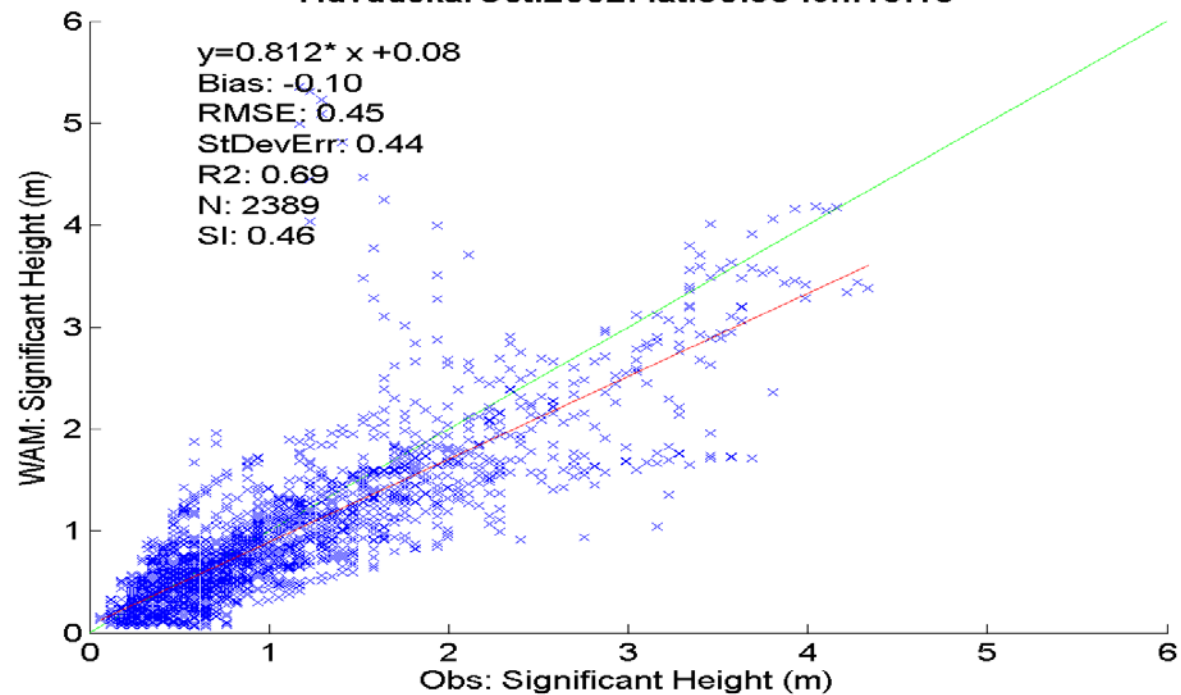
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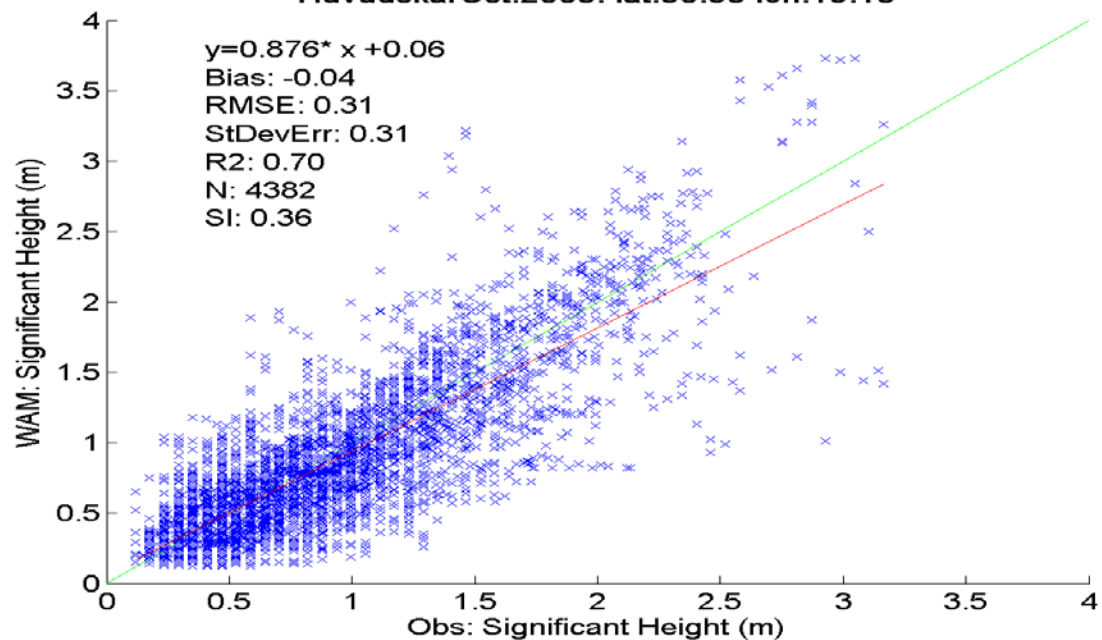
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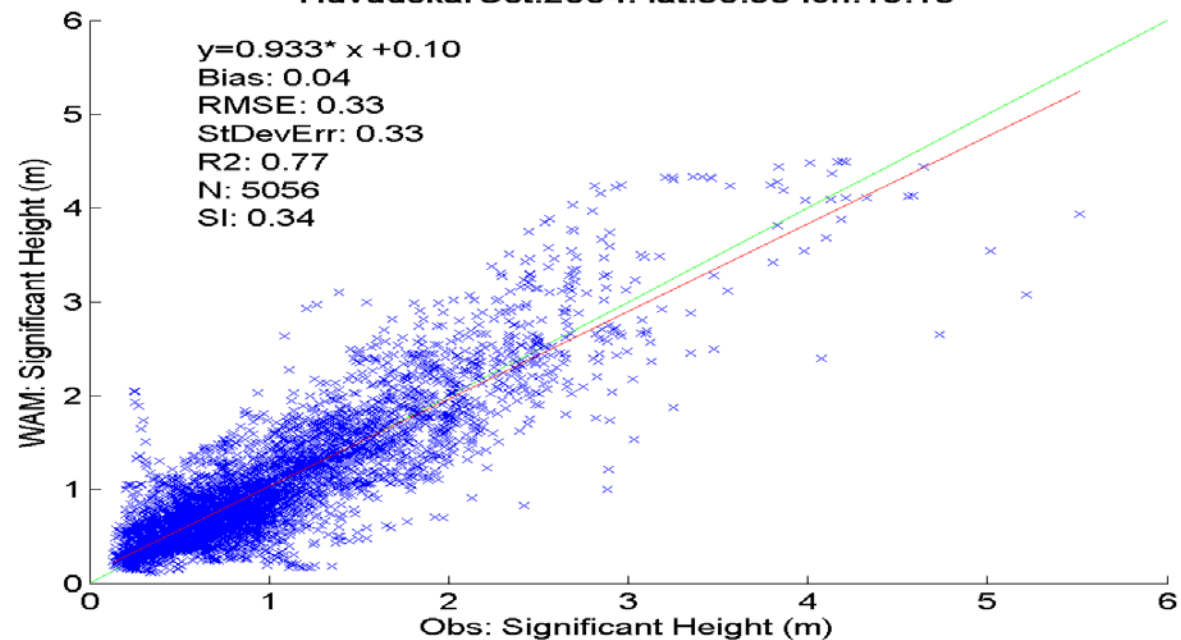
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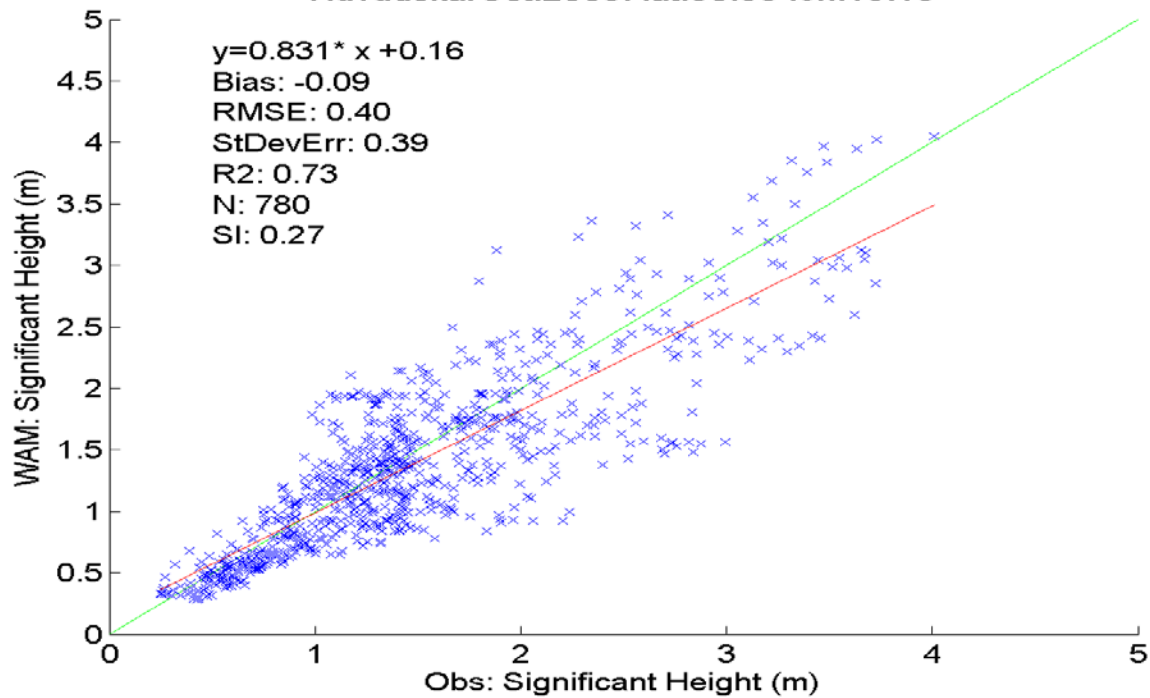
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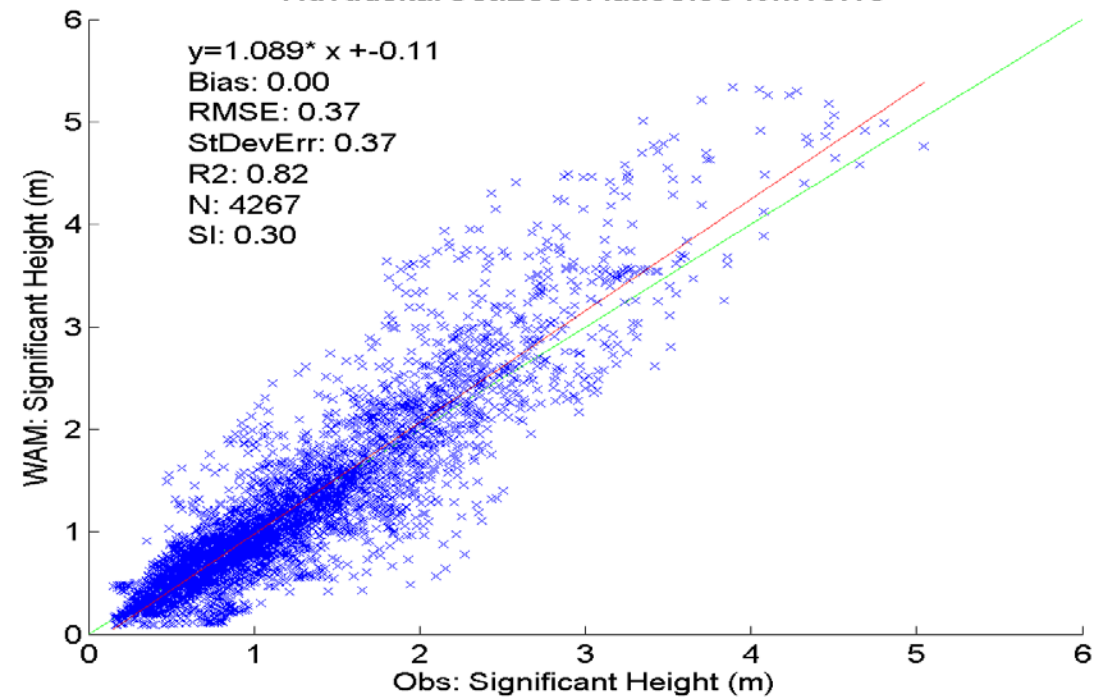
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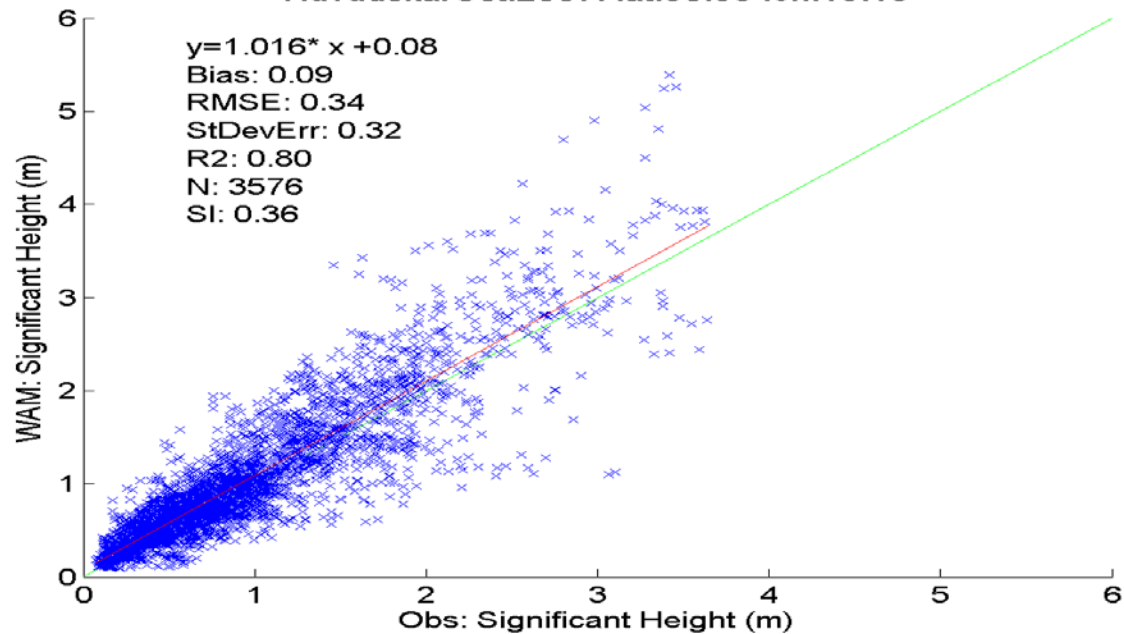
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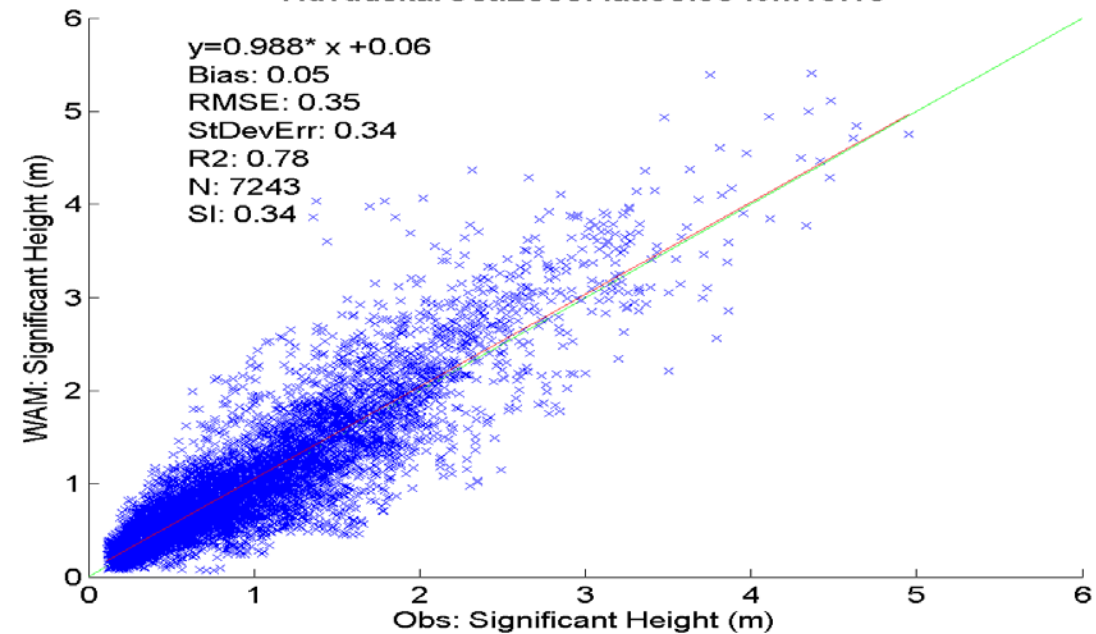
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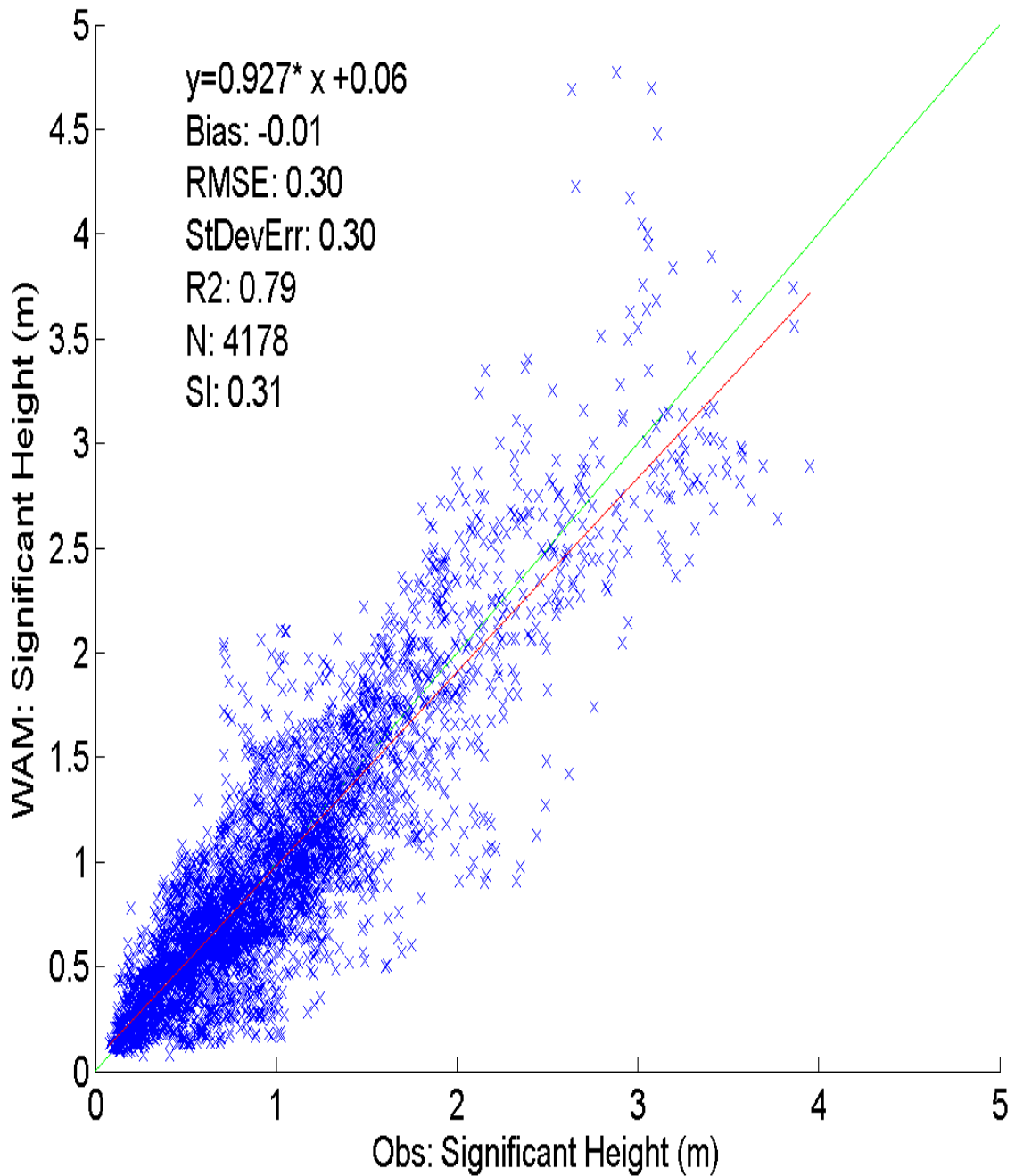
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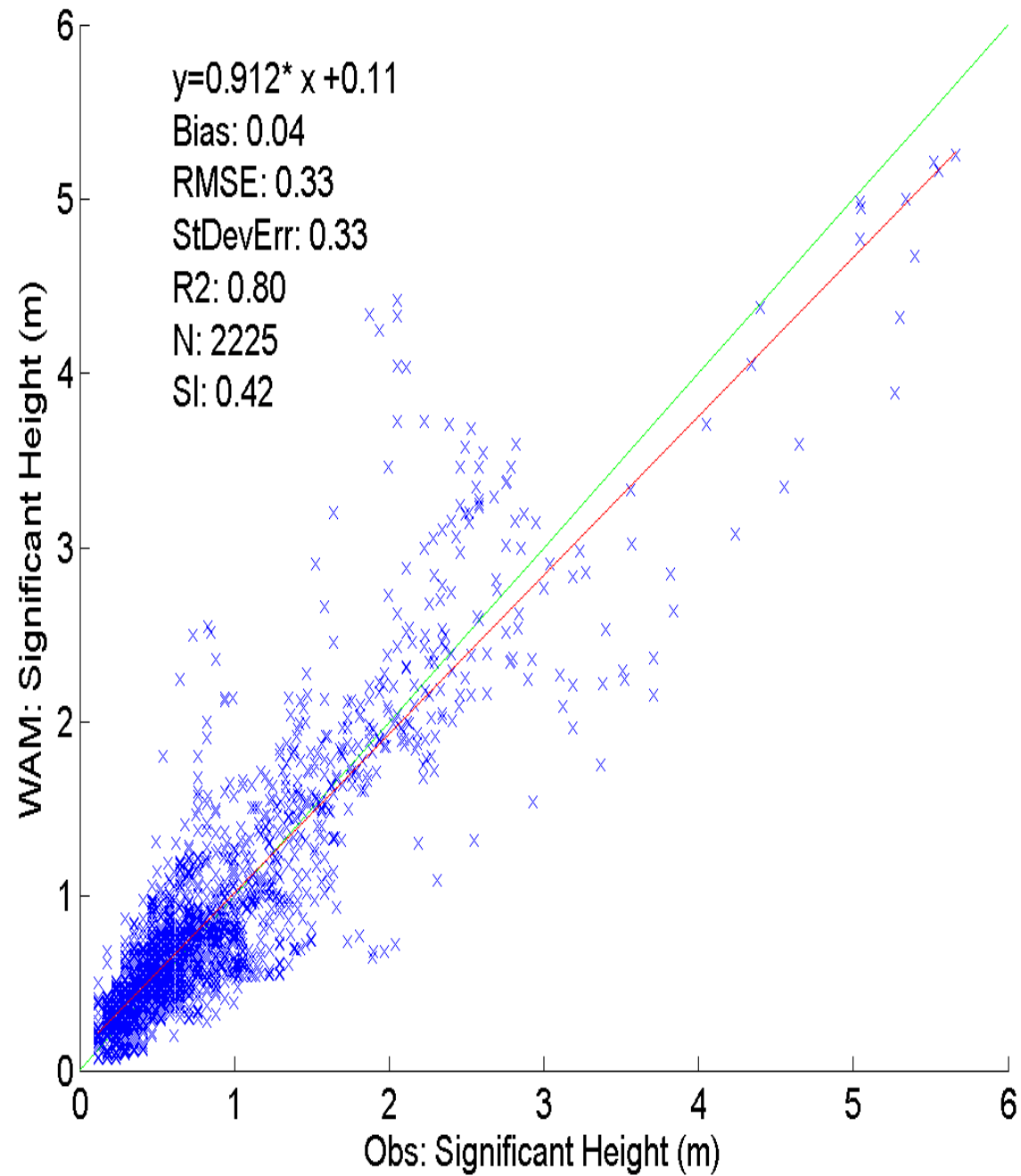
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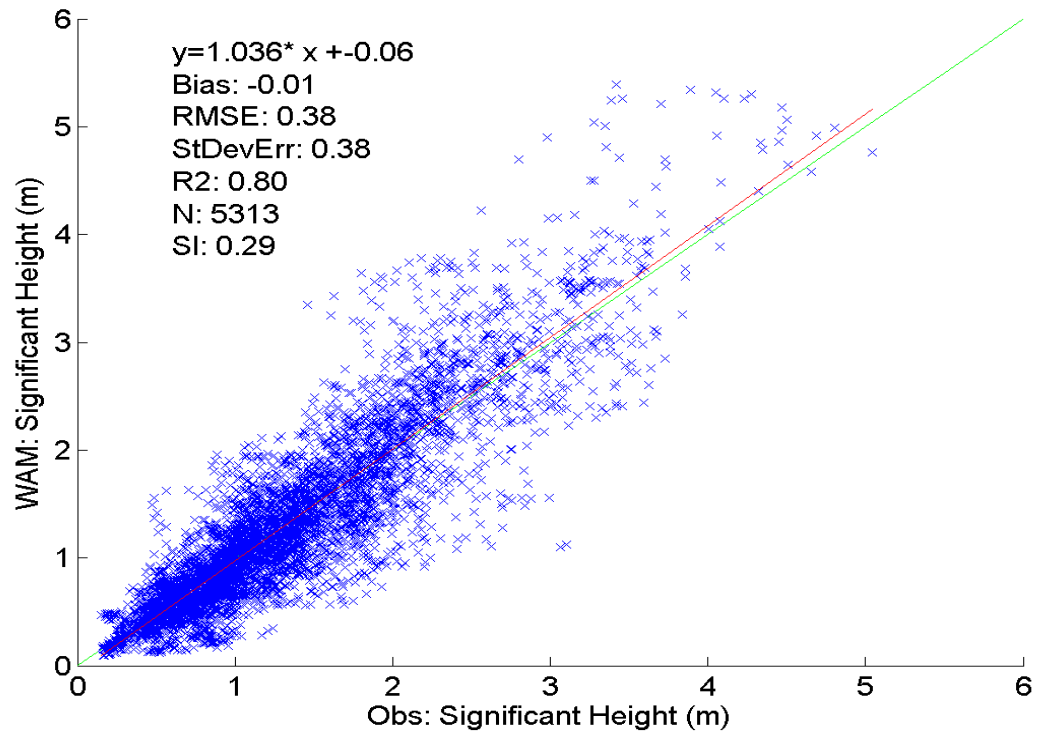
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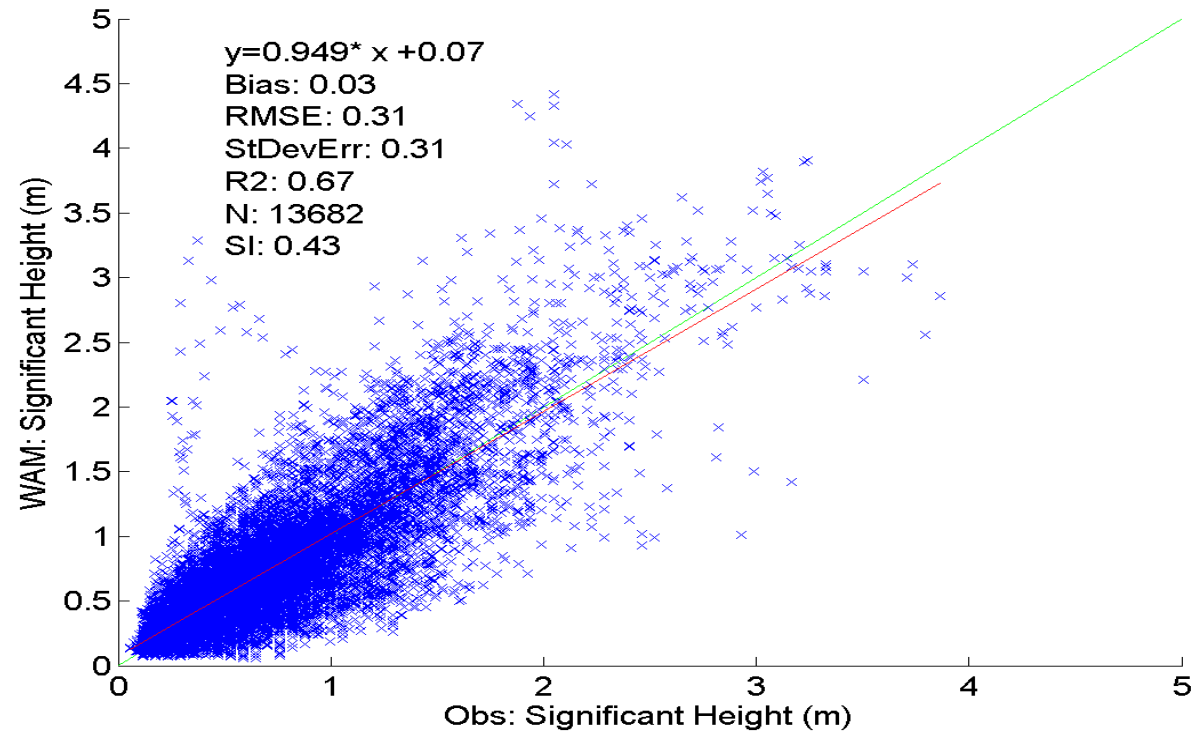
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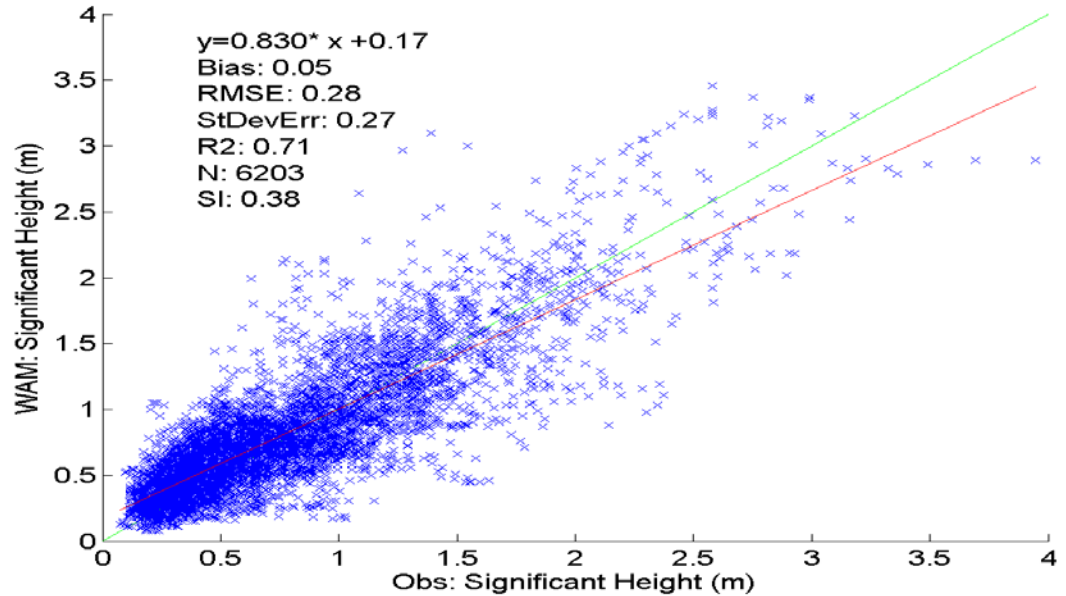
HuvudskarOst.DJF. lat:58.95 lon:19.15



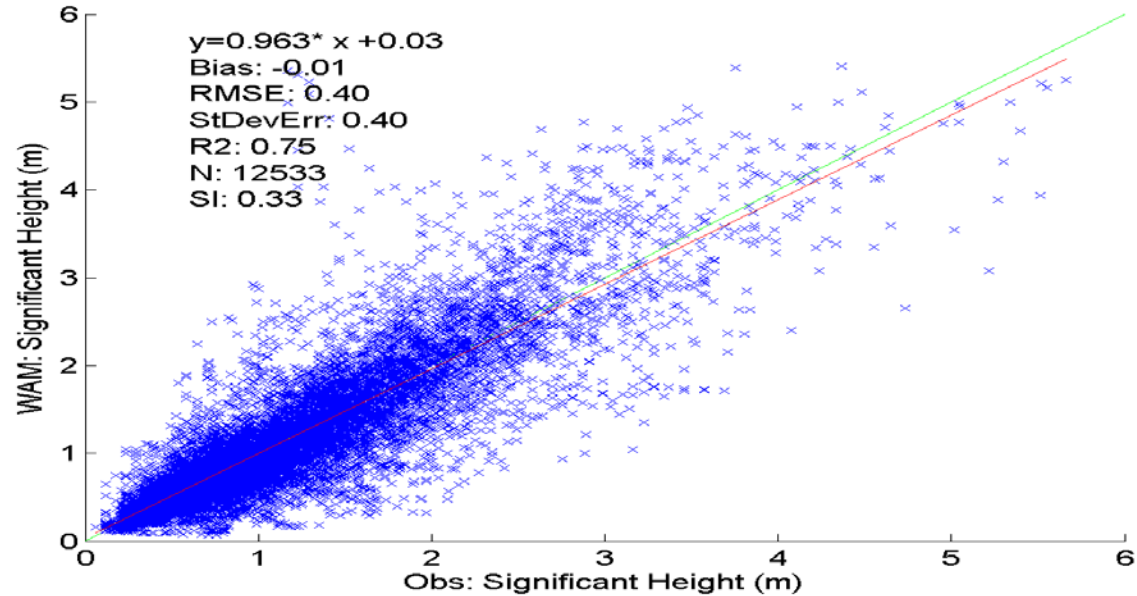
HuvudskarOst.JJA. lat:58.95 lon:19.15



HuvudskarOst.MMA. lat:58.95 lon:19.15

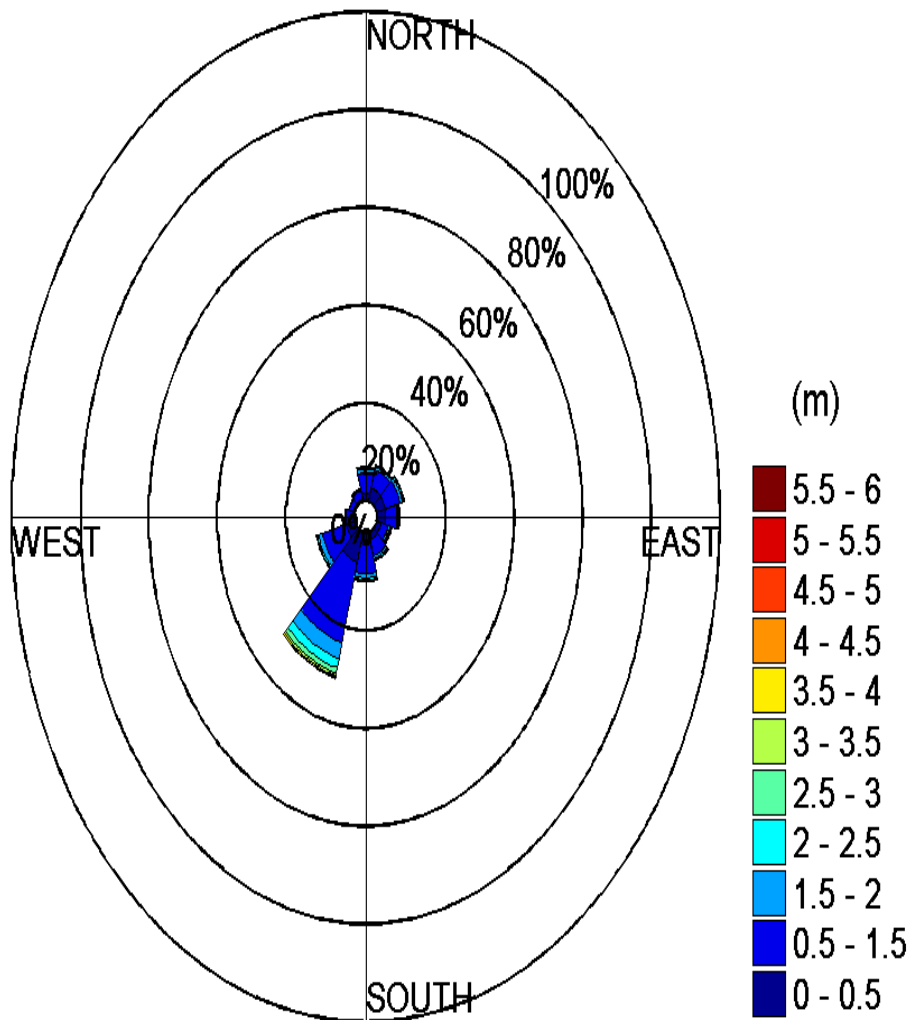


HuvudskarOst.SON. lat:58.95 lon:19.15



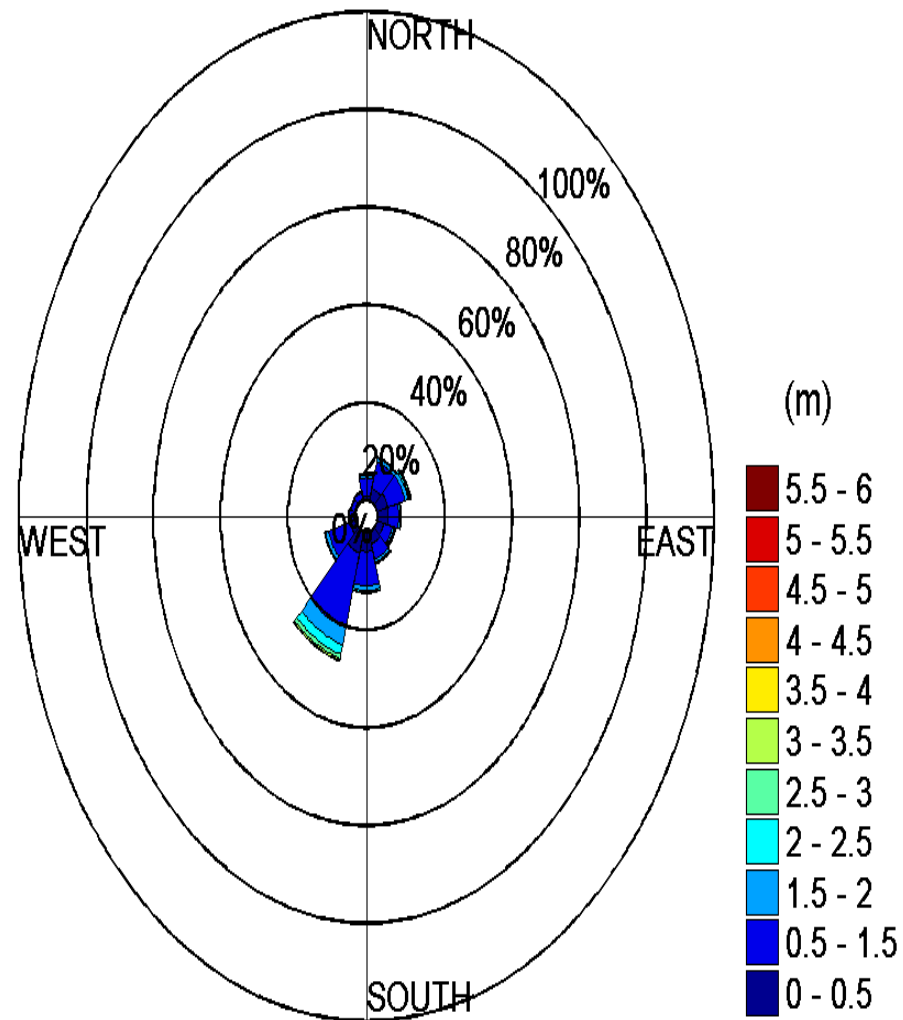
Significant Wave Height

HuvudskarOst.2001-2010 lat:58.95 lon:19.15 Model



Significant Wave Height

HuvudskarOst.2001-2010 lat:58.95 lon:19.15 Obs



HuvudskarOst.Hsig (m).2001-2010.lat:58.95-lon:19.15

	Bias:	RMSE:	StDevErr:	R²:	N:	SI:	E:
All:	0.01	0.35	0.35	0.76	37731	0.36	0.72
2001:	0.02	0.37	0.37	0.64	3635	0.44	0.51
2002:	-0.10	0.45	0.44	0.69	2389	0.46	0.64
2003:	-0.04	0.31	0.31	0.70	4382	0.36	0.64
2004:	0.04	0.33	0.33	0.77	5056	0.34	0.73
2005:	-0.09	0.40	0.39	0.73	780	0.27	0.70
2006:	0.00	0.37	0.37	0.82	4267	0.30	0.74
2007:	0.09	0.34	0.32	0.80	3576	0.36	0.72
2008:	0.05	0.35	0.34	0.78	7243	0.34	0.72
2009:	-0.01	0.30	0.30	0.79	4178	0.31	0.76
2010:	0.04	0.33	0.33	0.80	2225	0.42	0.78
JJA:	0.03	0.31	0.31	0.67	13682	0.43	0.54
SON:	-0.01	0.40	0.40	0.75	12533	0.33	0.69
DJF:	-0.01	0.38	0.38	0.80	5313	0.29	0.73
MMA:	0.05	0.28	0.27	0.71	6203	0.38	0.68

Wind Speed

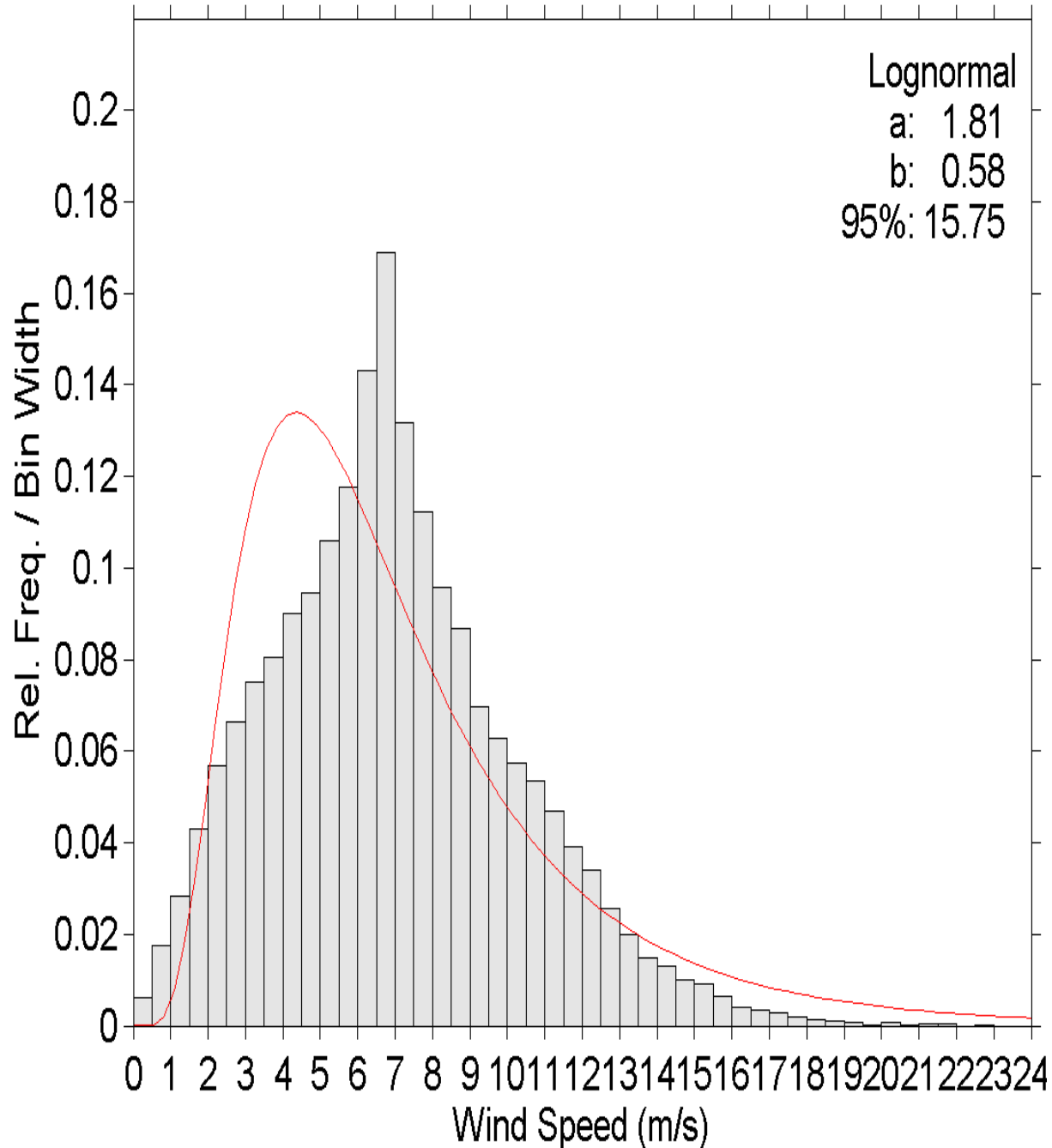
Descriptive Statistics:HuvudskarOst.2001-2010 lat:58.95 lon:19.15 Obs

	Ws(m/s)
Mean	6.67
St. Dev.	3.42
Var. Coeff.	0.51
St. Error.	0.02
Skewness	0.58
Kurtosis	3.48

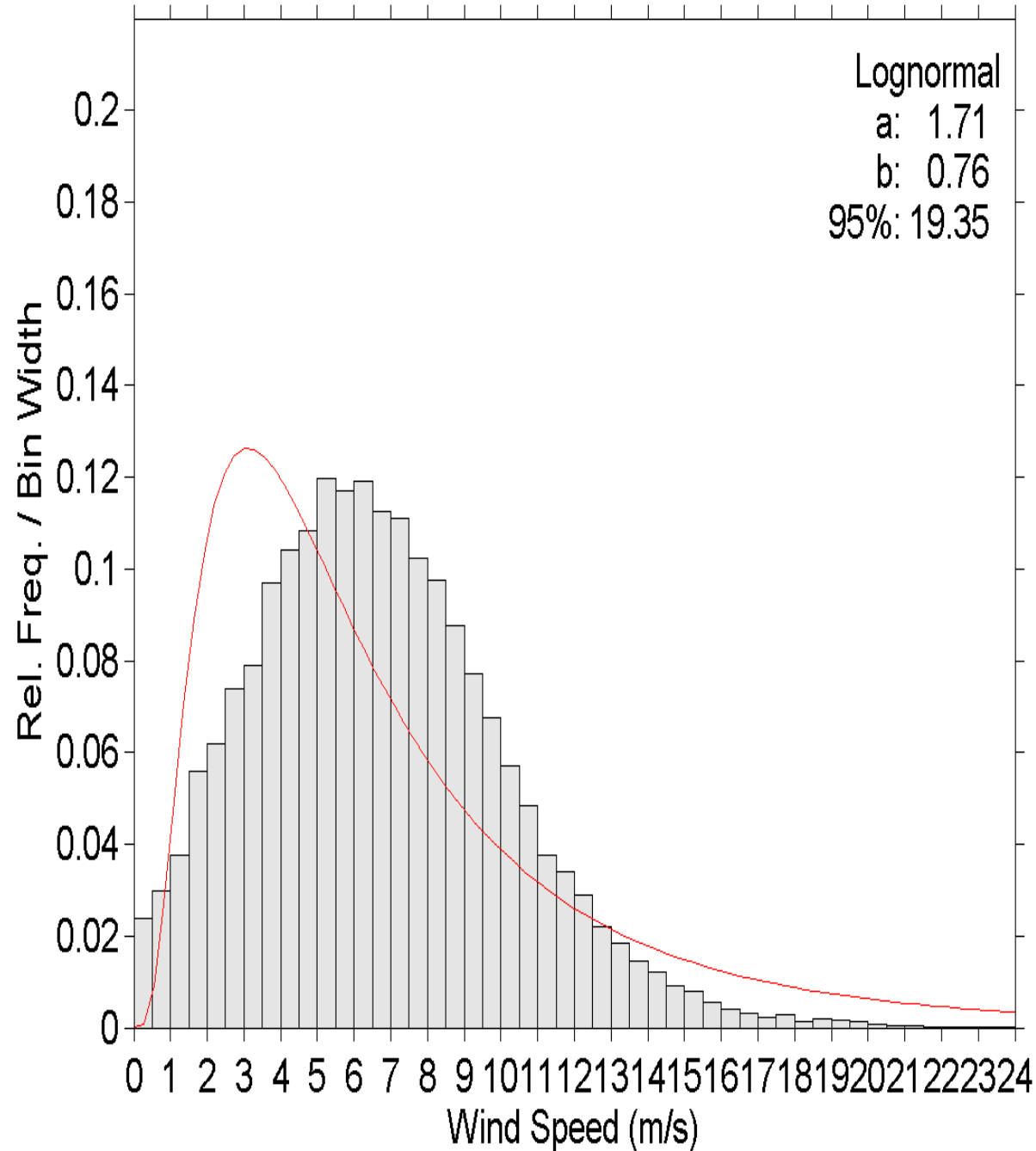
Descriptive Statistics:HuvudskarOst.2001-2010 lat:58.95 lon:19.15 Model

	Ws(m/s)
Mean	6.97
St. Dev.	3.26
Var. Coeff.	0.47
St. Error.	0.02
Skewness	0.55
Kurtosis	3.40

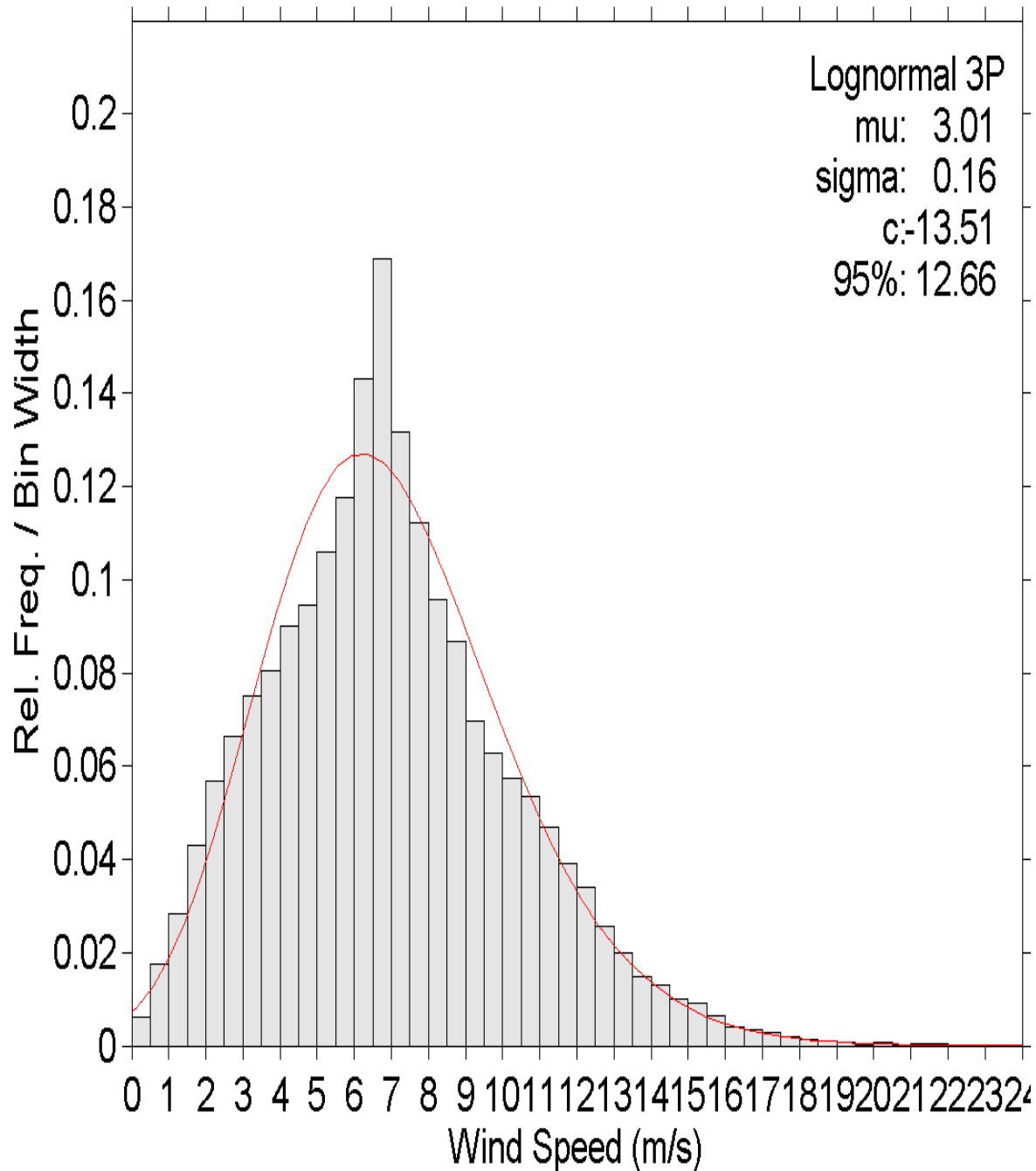
HuvudskarOst.2001-2010 lat:58.95 lon:19.15 Model



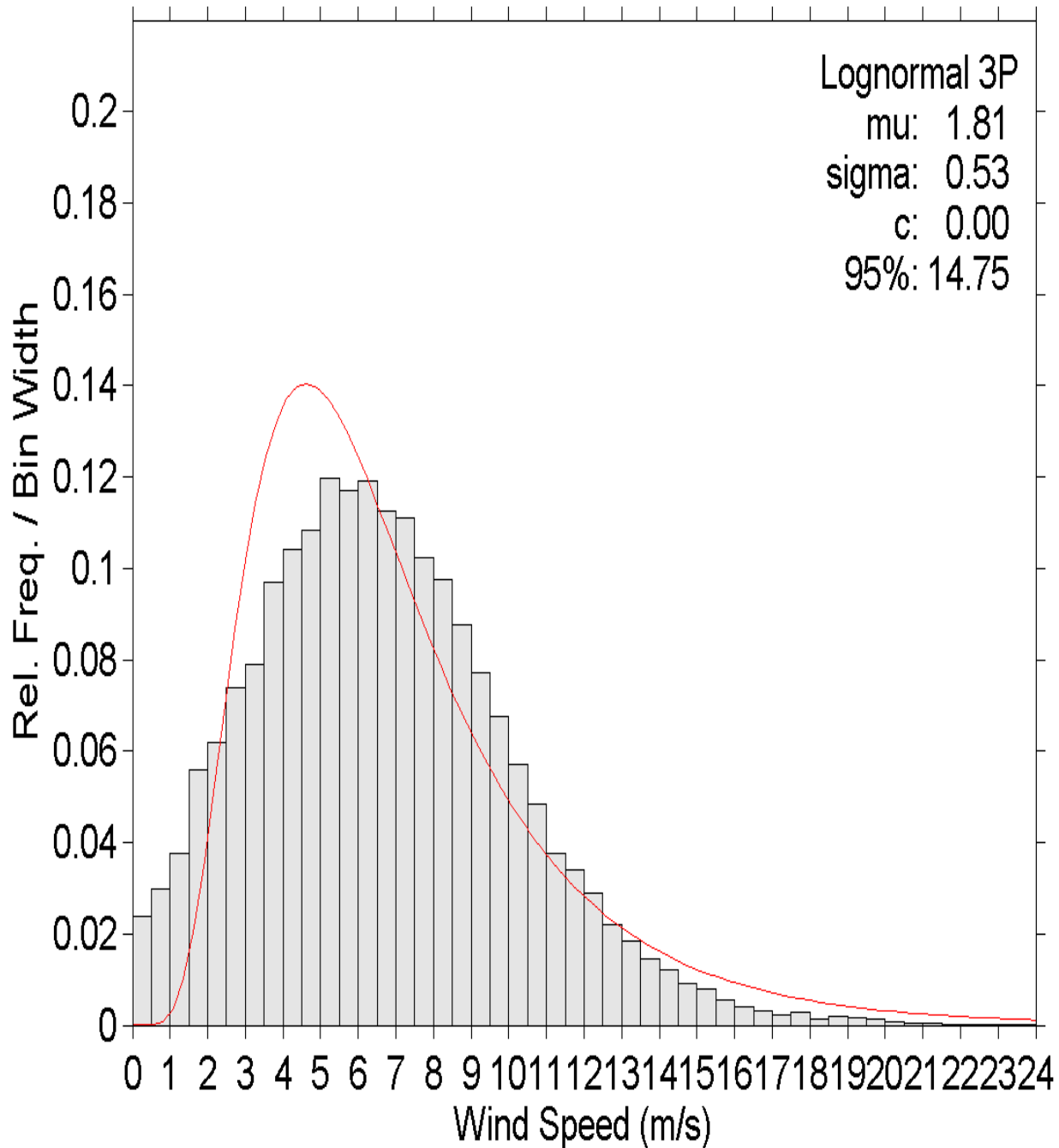
HuvudskarOst.2001-2010 lat:58.95 lon:19.15 Obs



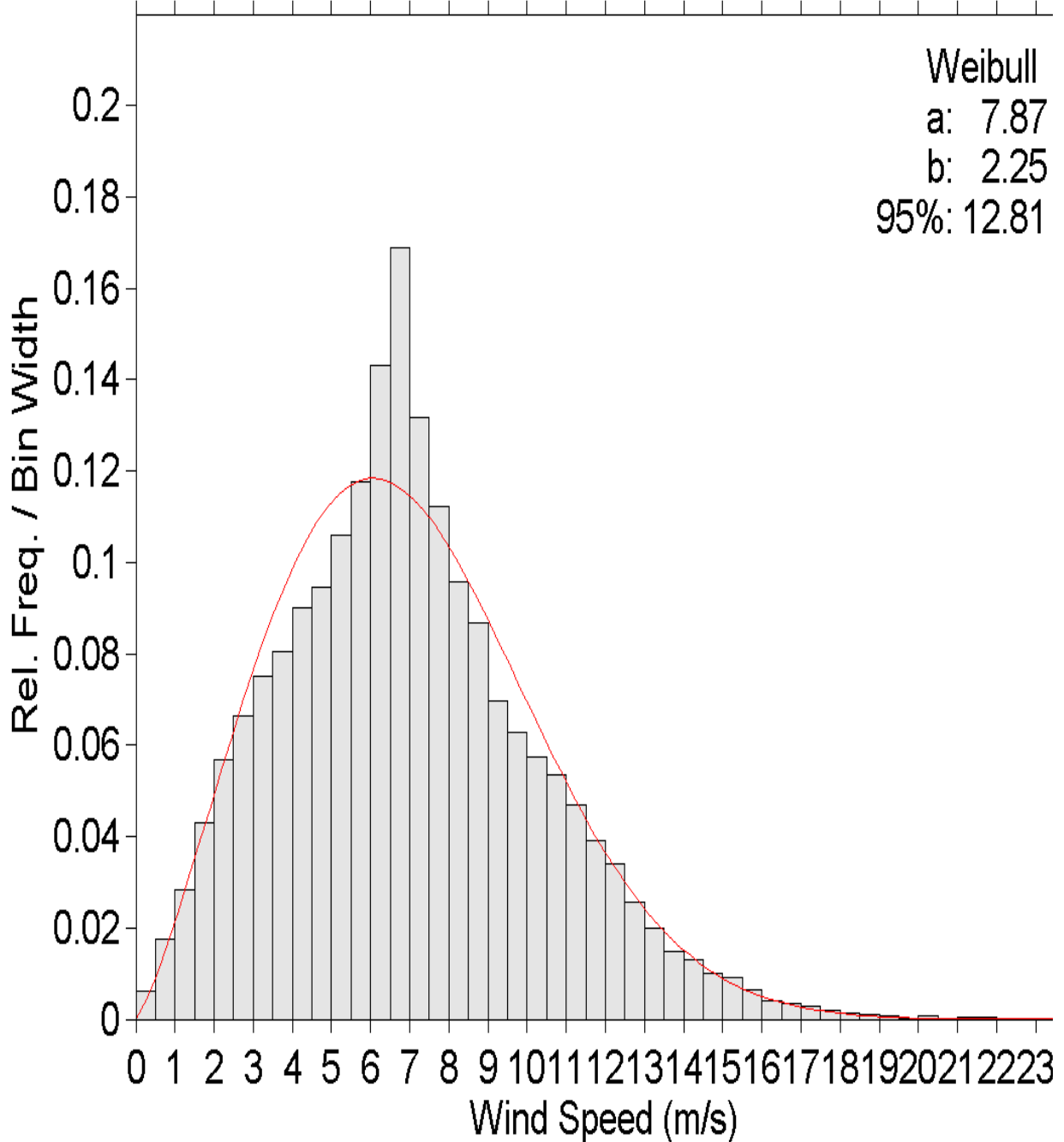
HuvudskarOst.2001-2010 lat:58.95 lon:19.15 Model



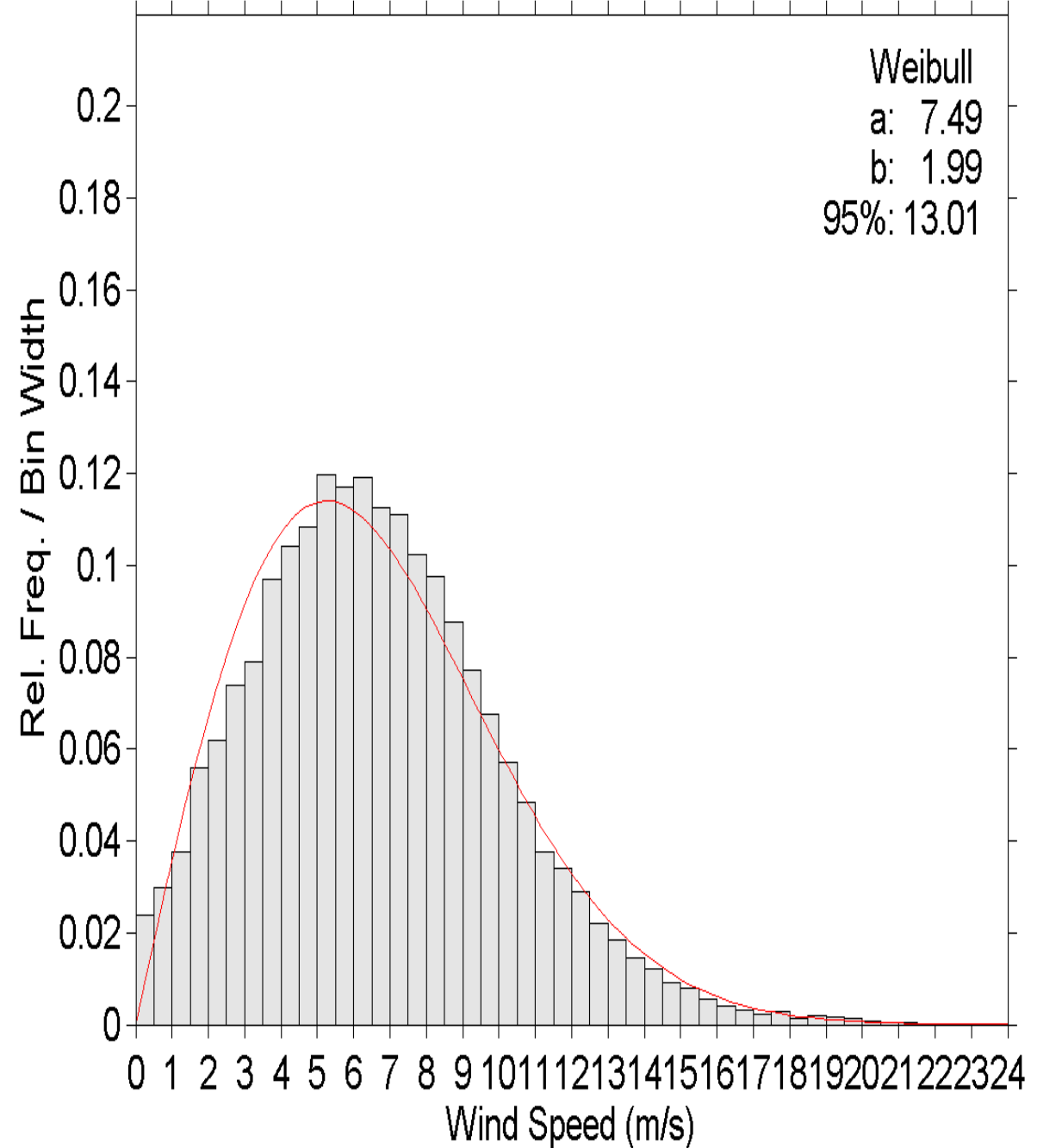
HuvudskarOst.2001-2010 lat:58.95 lon:19.15 Obs



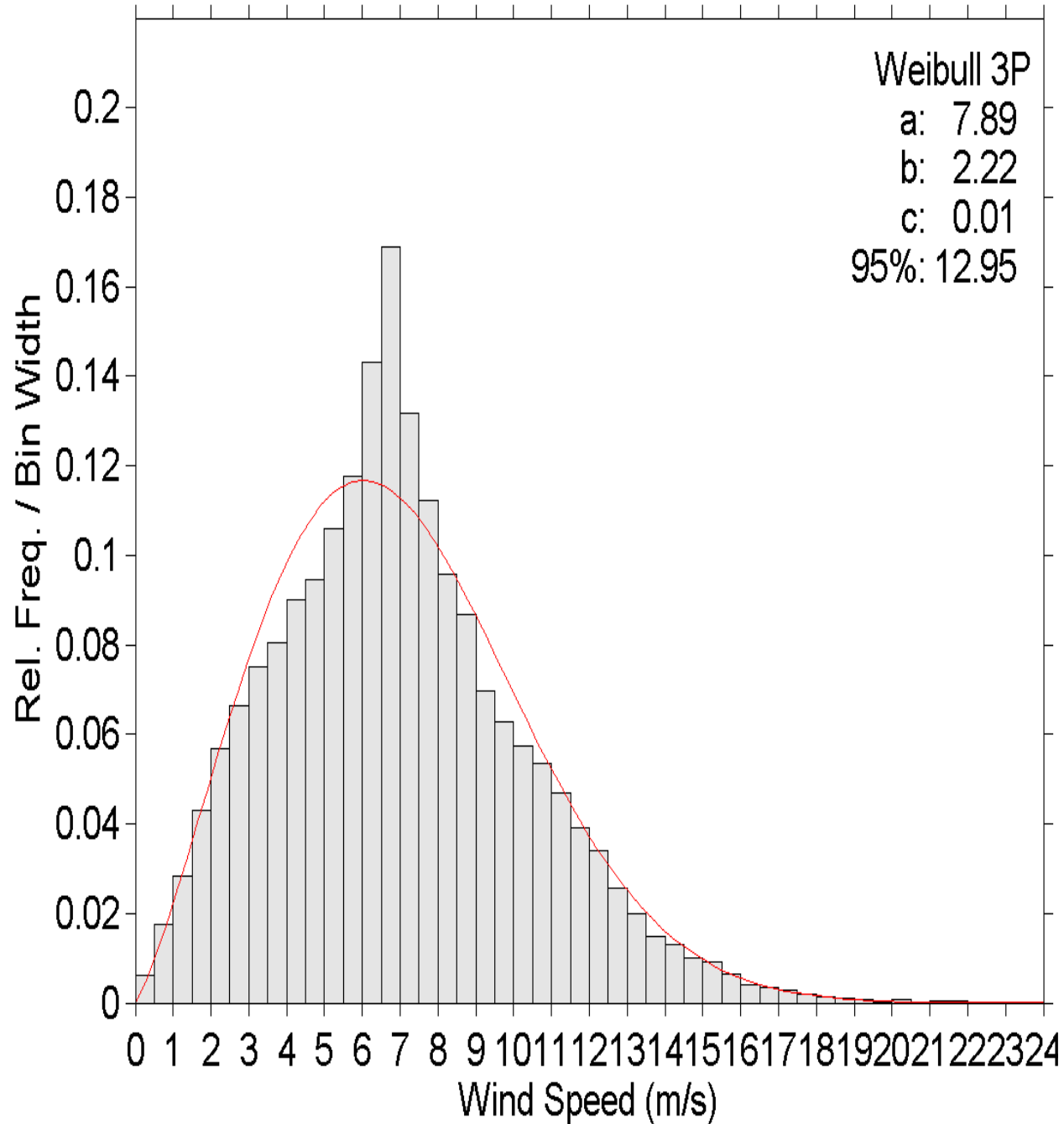
HuvudskarOst.2001-2010 lat:58.95 lon:19.15 Model



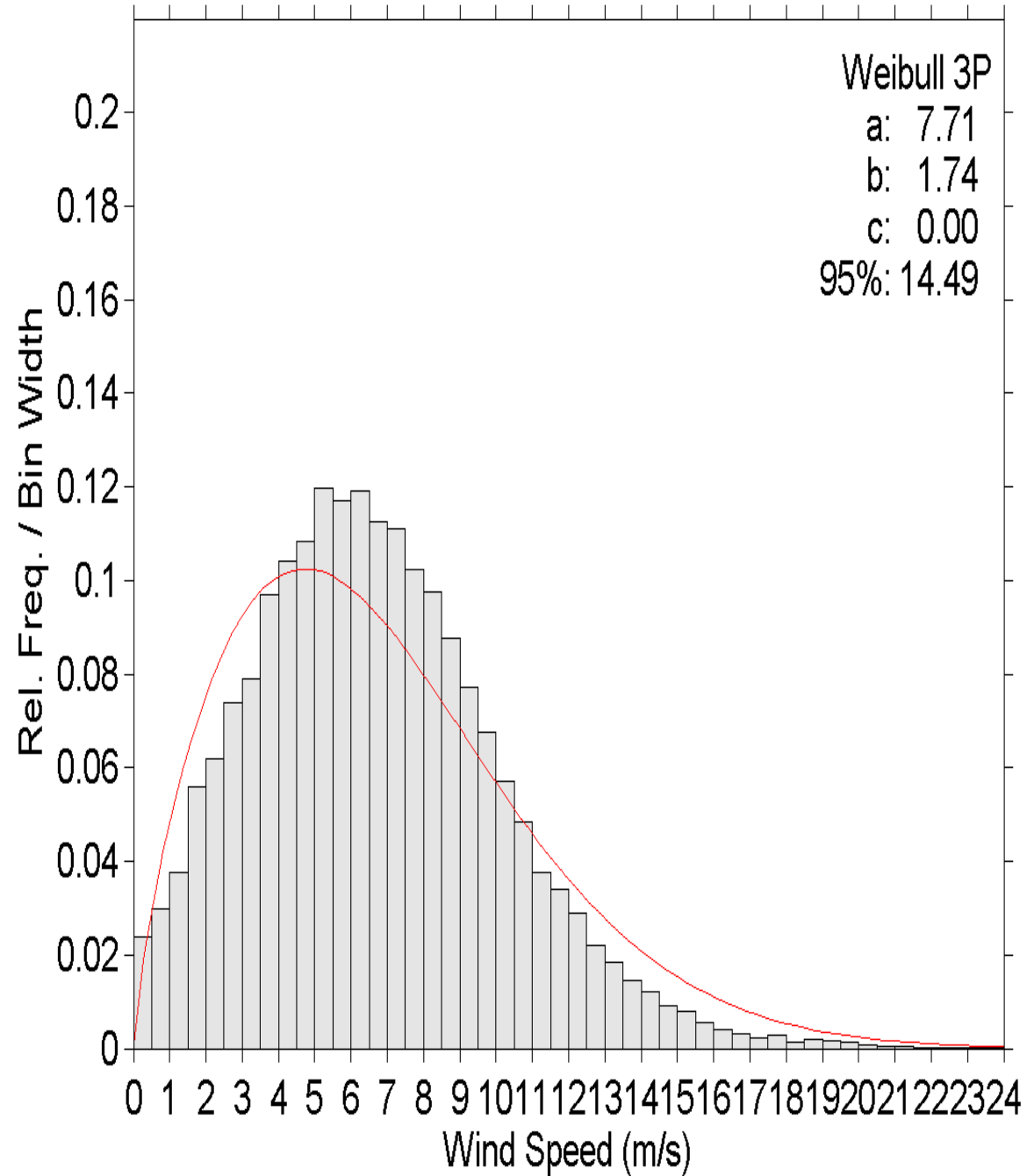
HuvudskarOst.2001-2010 lat:58.95 lon:19.15 Obs



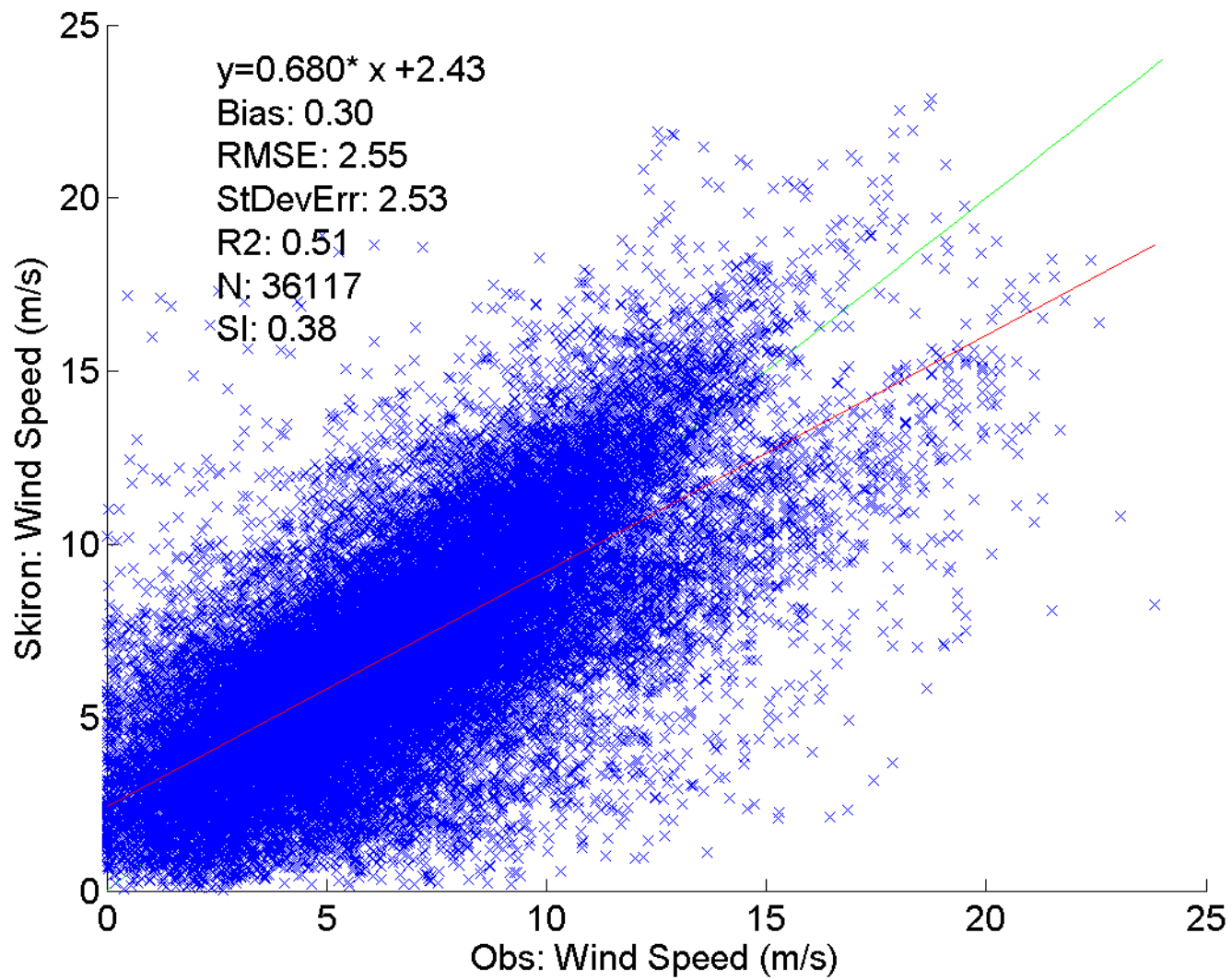
HuvudskarOst.2001-2010 lat:58.95 lon:19.15 Model



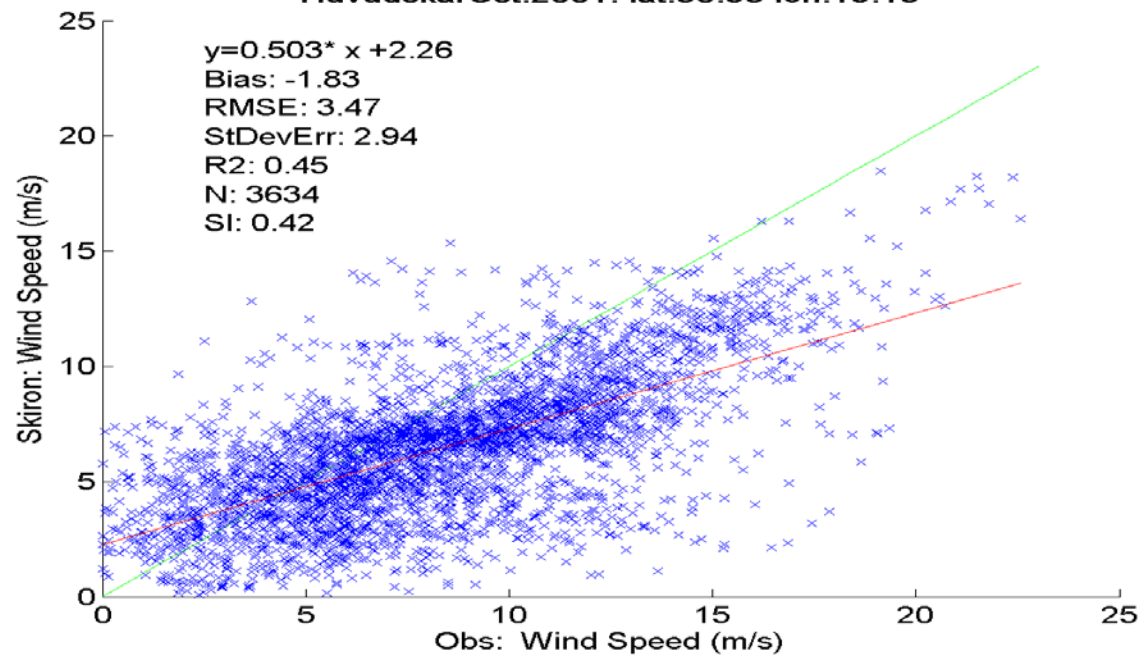
HuvudskarOst.2001-2010 lat:58.95 lon:19.15 Obs



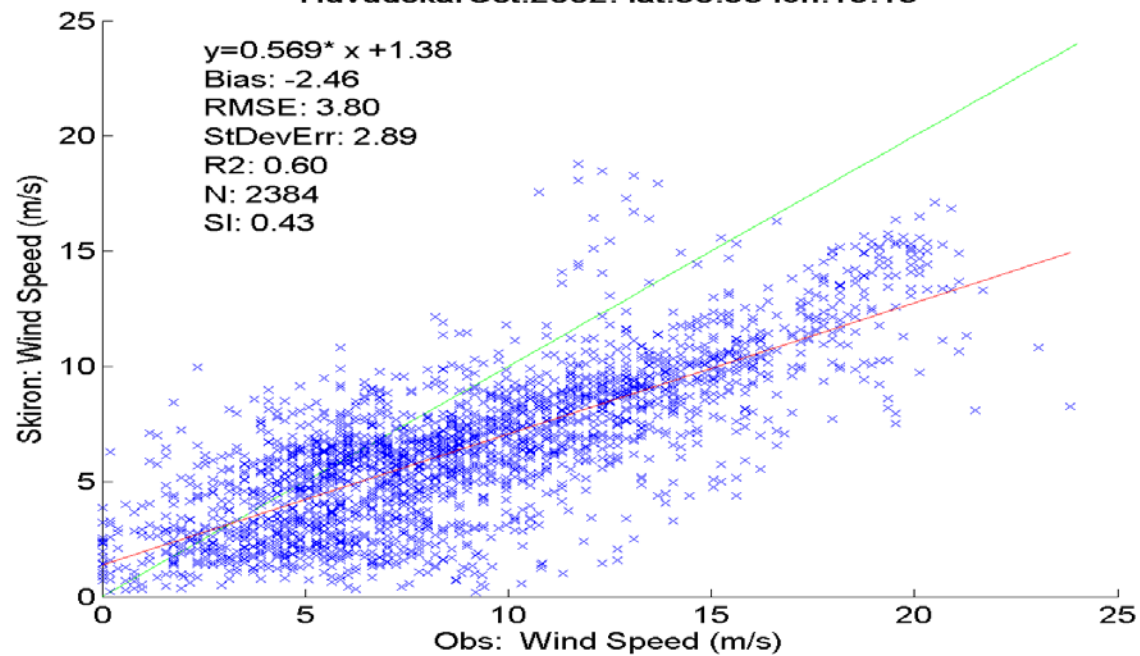
HuvudskarOst.2001-2010 lat:58.95 lon:19.15



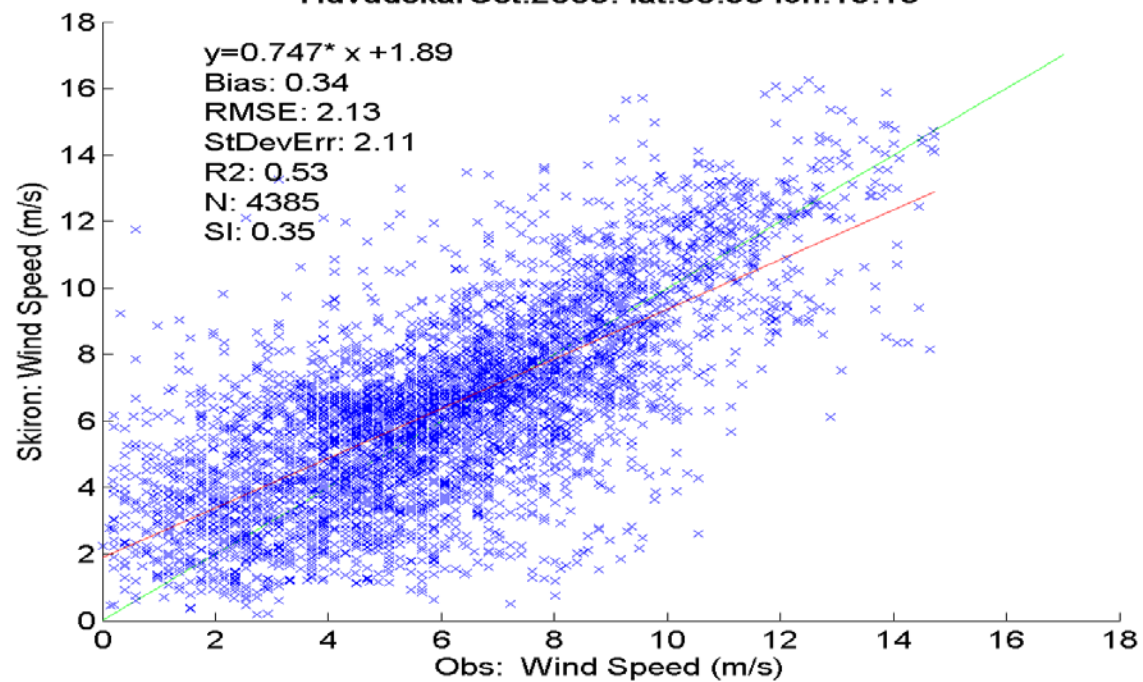
HuvudskarOst.2001. lat:58.95 lon:19.15



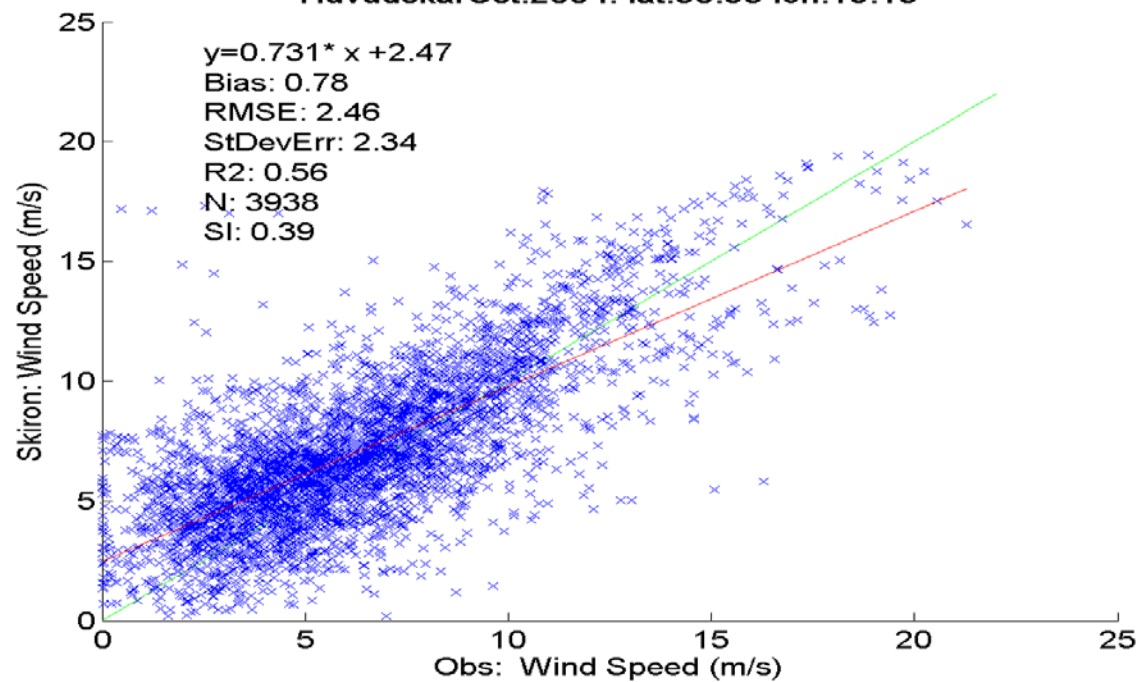
HuvudskarOst.2002. lat:58.95 lon:19.15



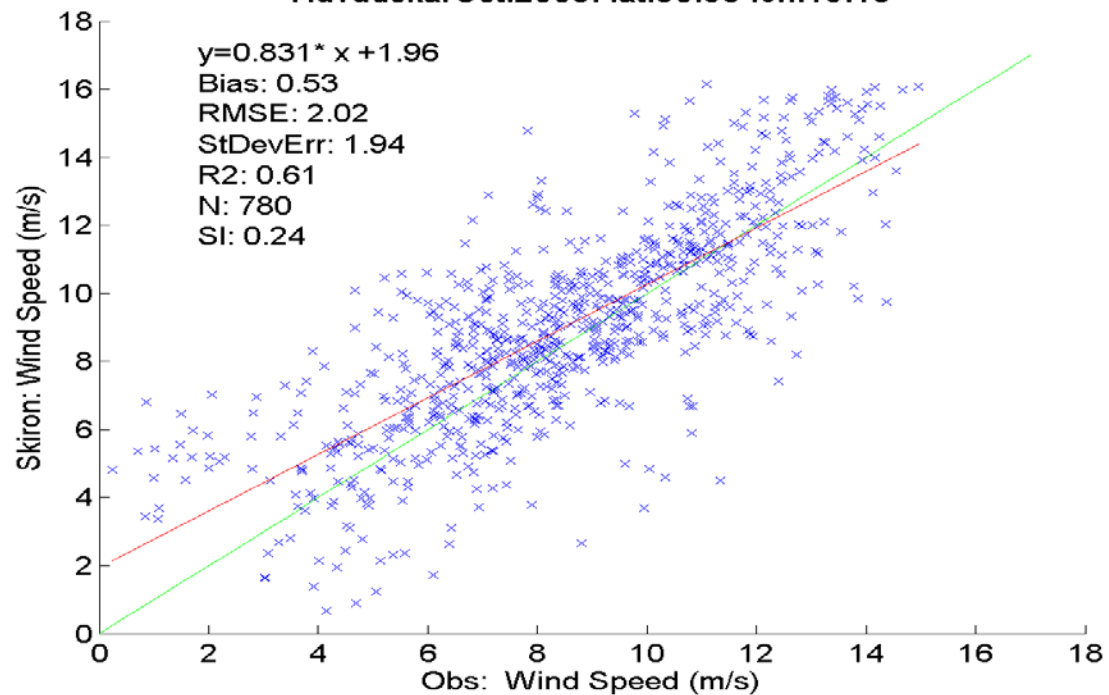
HuvudskarOst.2003. lat:58.95 lon:19.15



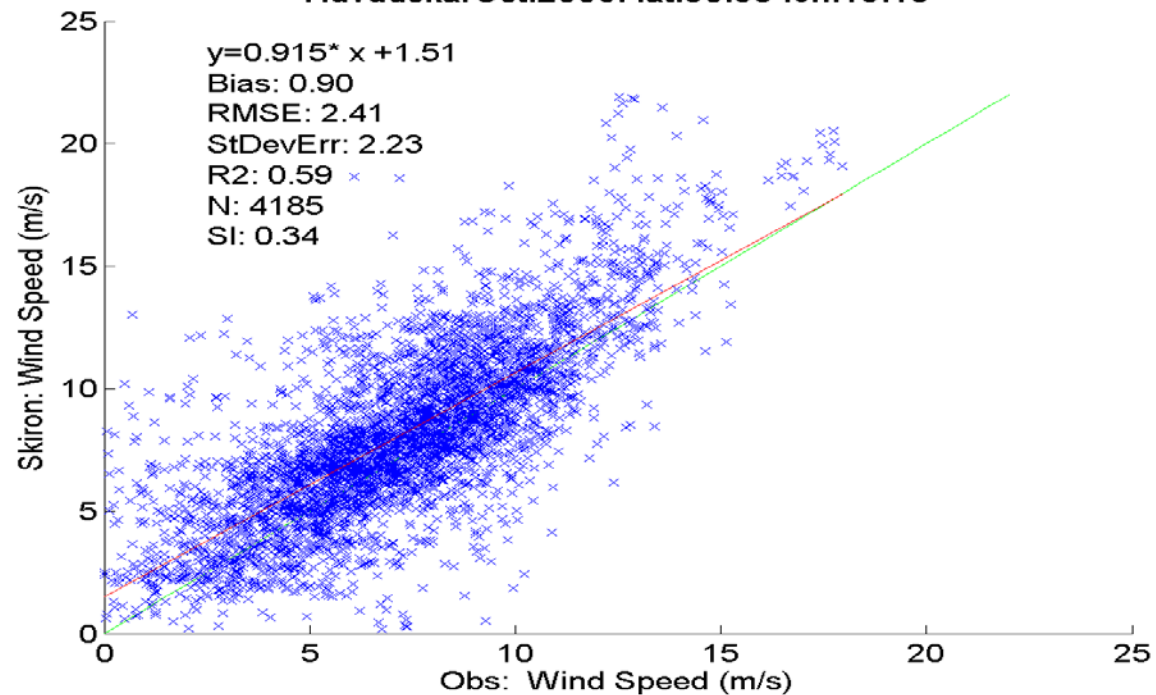
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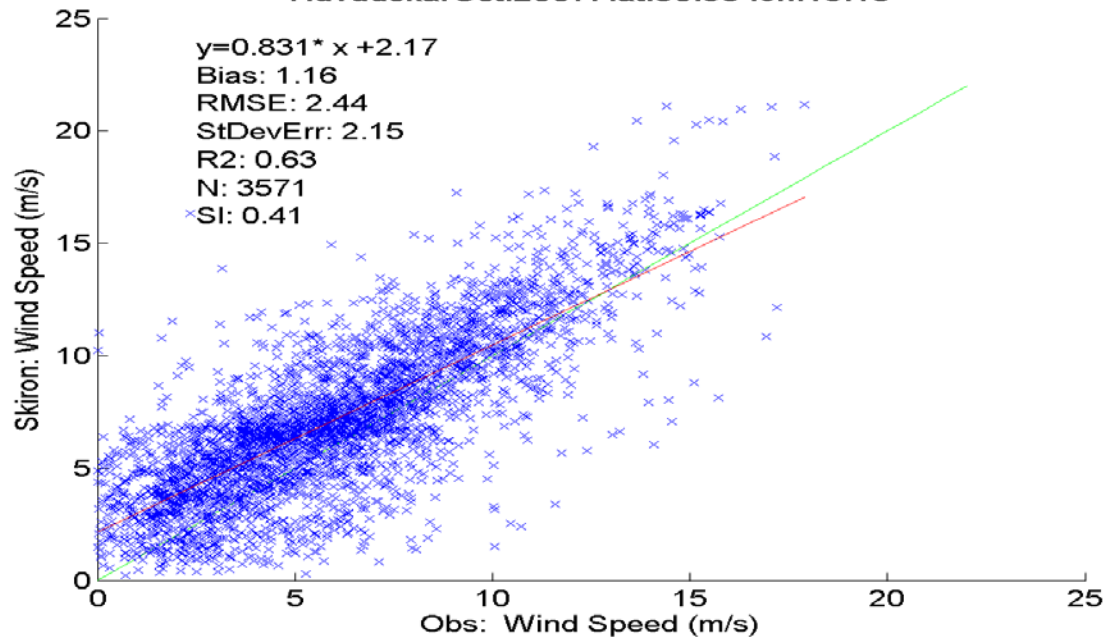
HuvudskarOst.2005. lat:58.95 lon:19.15



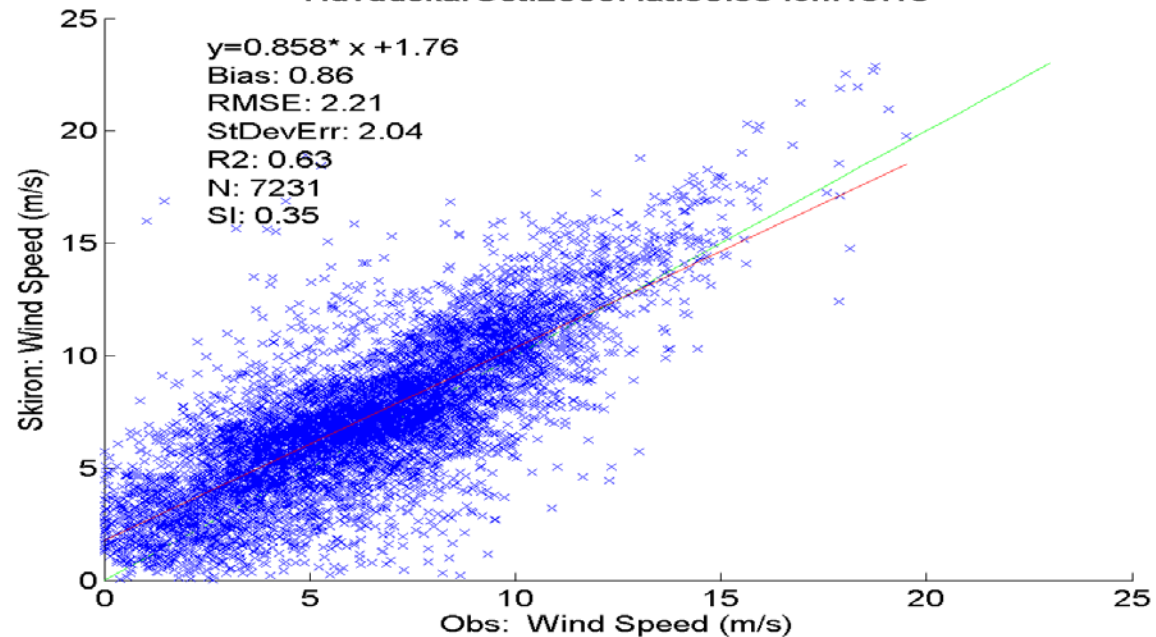
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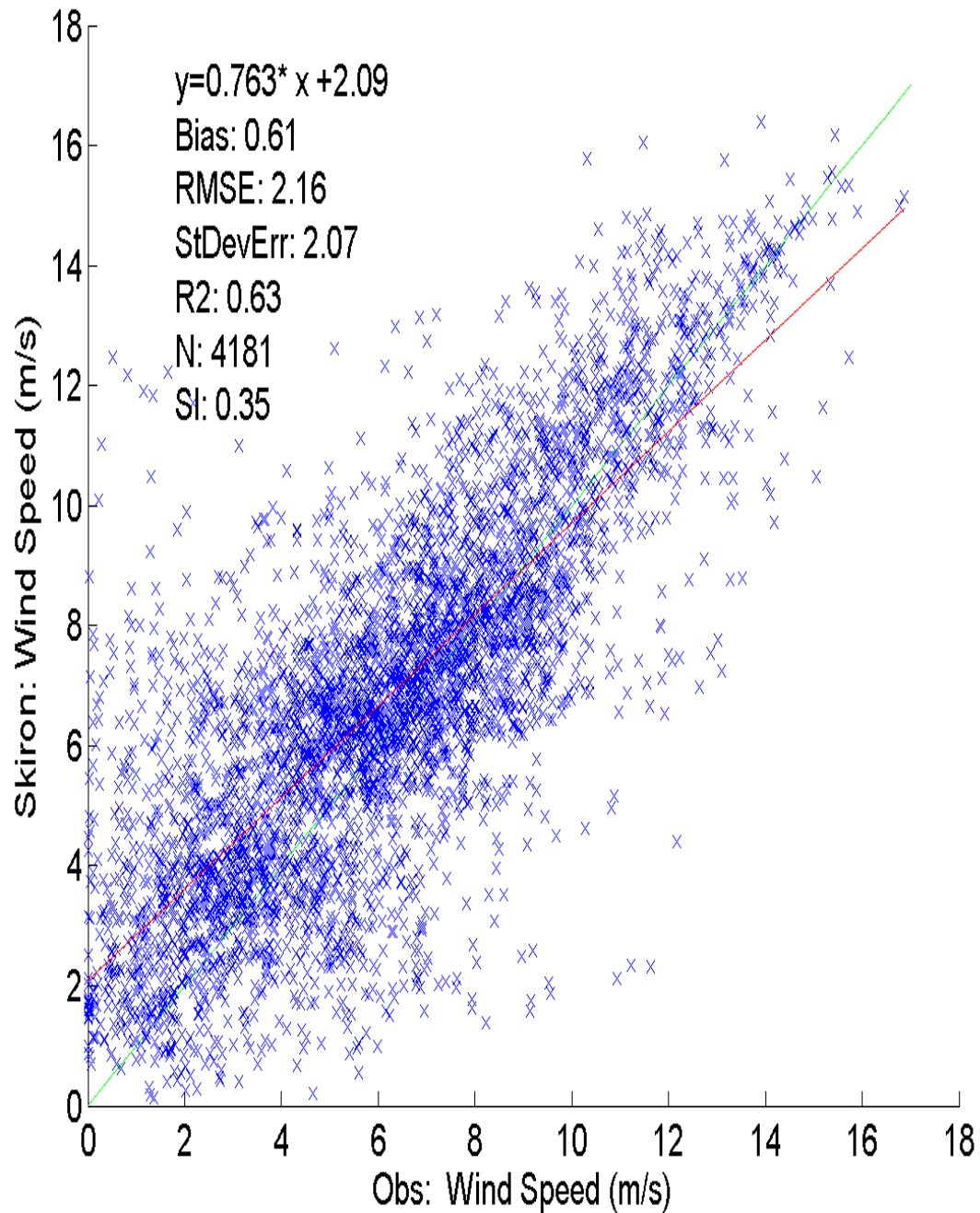
HuvudskarOst.2007. lat:58.95 lon:19.15



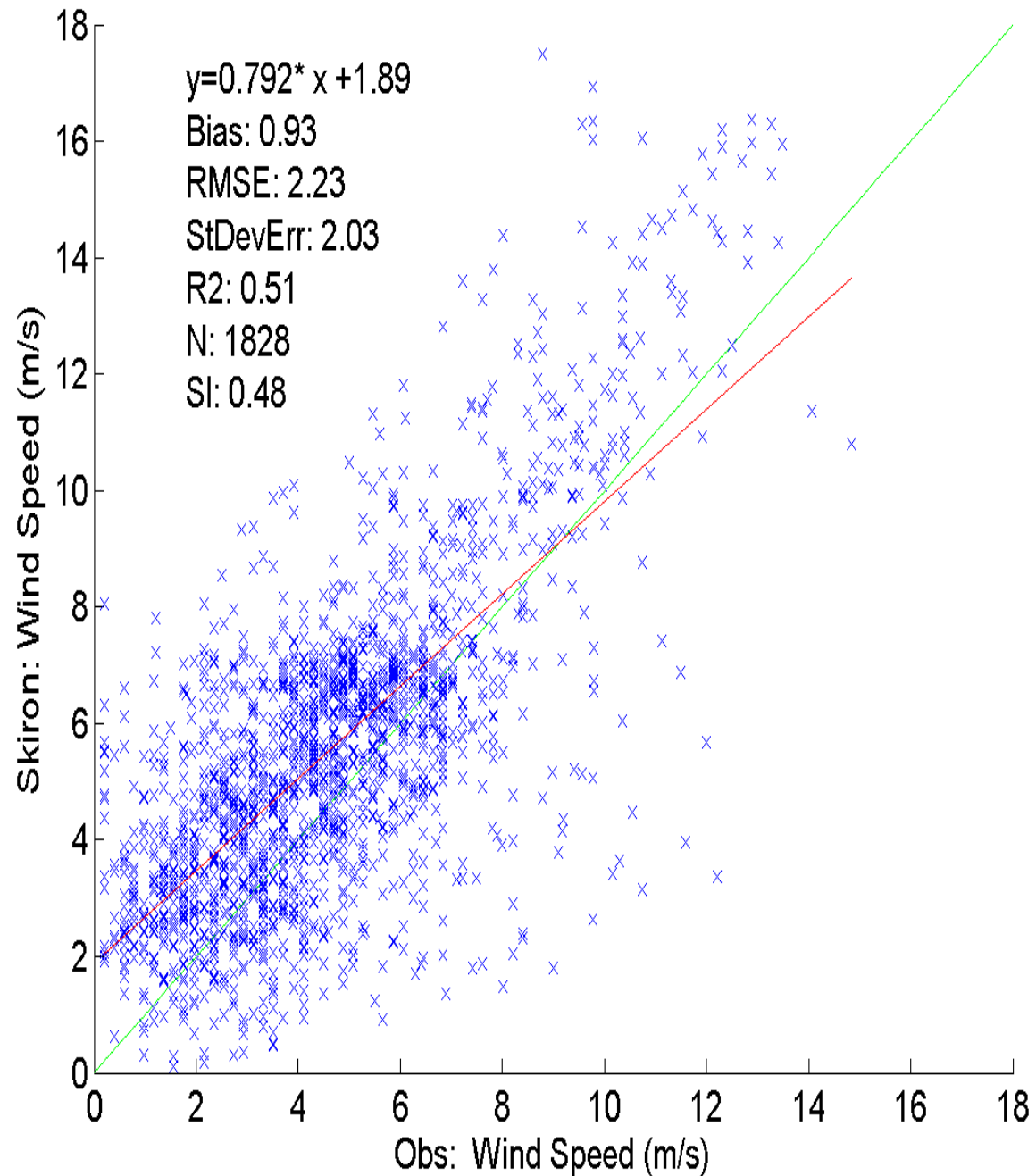
HuvudskarOst.2008. lat:58.95 lon:19.15



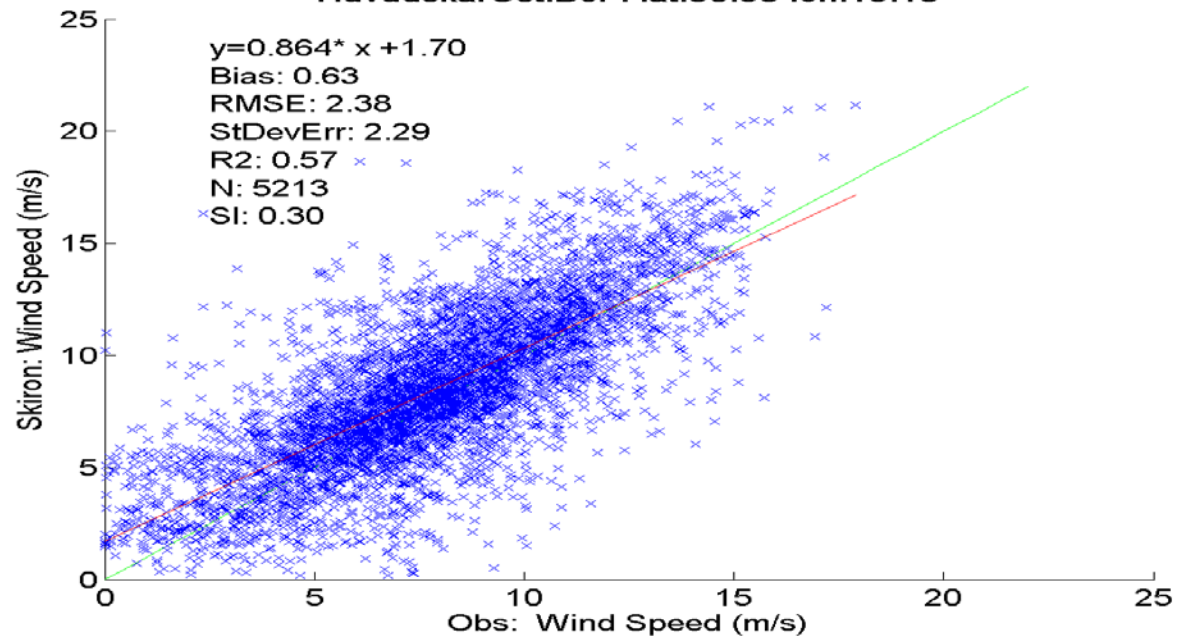
HuvudskarOst.2009. lat:58.95 lon:19.15



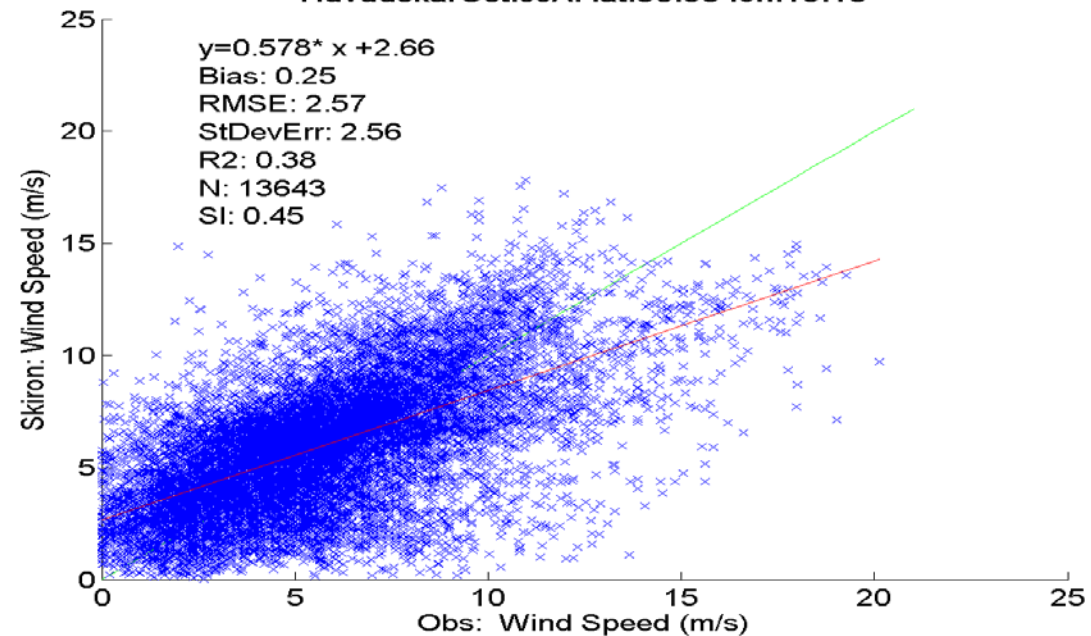
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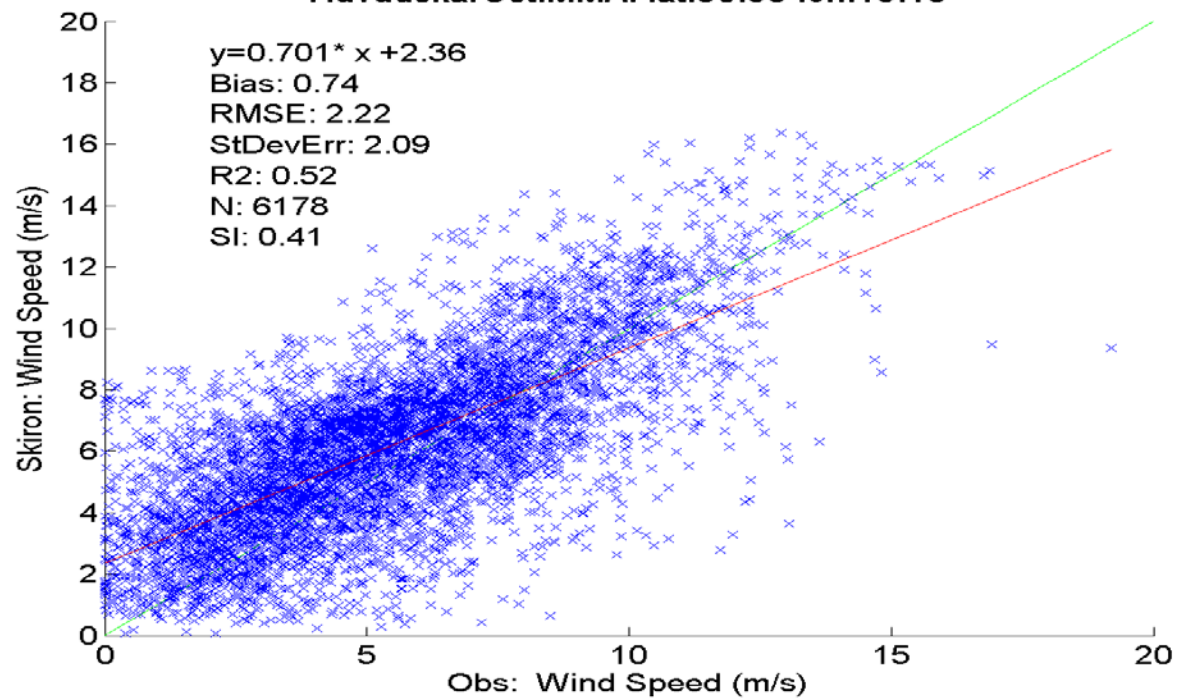
HuvudskarOst.DJF. lat:58.95 lon:19.15



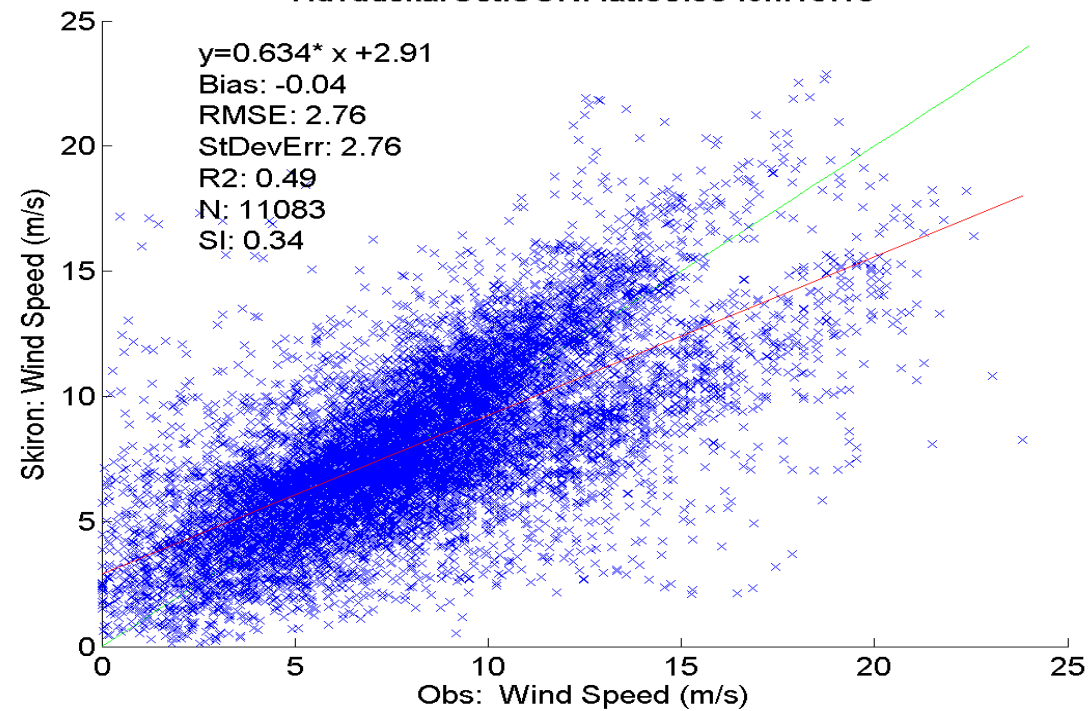
HuvudskarOst.JJA. lat:58.95 lon:19.15



HuvudskarOst.MMA. lat:58.95 lon:19.15

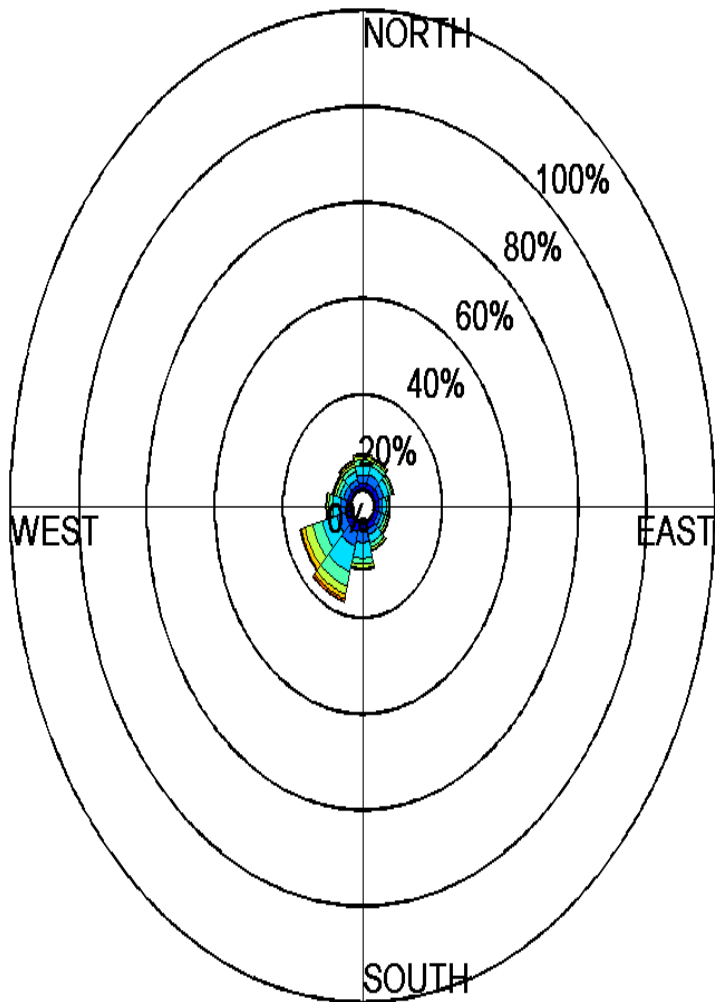


HuvudskarOst.SON. lat:58.95 lon:19.15

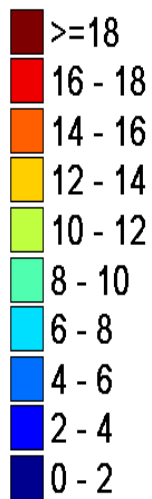


Wind Speed

HuvudskarOst.2001-2010 lat:58.95 lon:19.15 Model

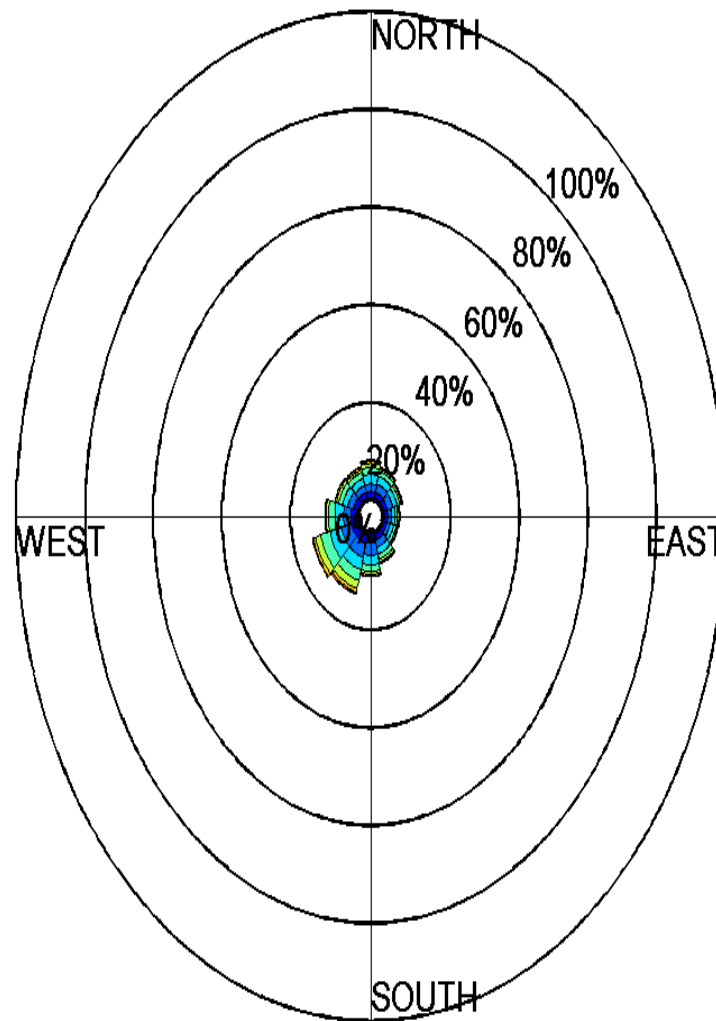


(m/s)

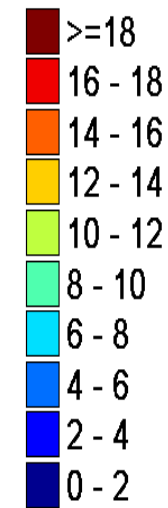


Wind Speed

HuvudskarOst.2001-2010 lat:58.95 lon:19.15 Obs



(m/s)



Main Conclusions on the Confidence Limits - Credibility of the data base

- ▶ A general very good estimation of the average wind and wave conditions is revealed
- ▶ In particular for the 10mwind speed the Bias ranges between ± 1 m/s, while for H_s between -0.4 m and 0.2 m
- ▶ Variability as well as asymmetry measures of the modeled data are very close to the corresponding indexes for observations
- ▶ The RMSE and the SI are associated with the existence of turbulence in the wind field and the ability of the model to resolve the high frequency perturbations
- ▶ Low uncertainty is associated with the database values
- ▶ In wind data the error variability is increased
- ▶ The Weibull and Lognormal distributions seem to optimally describe the wind and wave data

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