Client: RMC Power

Person: Master RMC

Date: 2012/10/31

Wind Data Analysis Report

For

Balisay 4031

Tsubasa Windfarm Design

Key Comments to Analysis Result

Page Number	*What it shows*	*Comments*
2	Tables showing periods of data received, missing and invalid data	Roughly two years of data were received starting from 2010/8/13. Data recovery rate is reasonable; the only significant period of missing data started from mid January 2012 to mid Feburary 2012. This might be related to possible logged damage by lightning as NRG commented. Replacement logger was installed on 2012/3/23. The 58m vane (Channel 8) was found to be drifting out from other vane channels from end November 2011. Cause of this drifting is unknown but other direction data seems fine.
3	Wind speed time series for all anemometer channels	Apart from periods of missing data (grey shaded area), no abnormalities are detected.
4	Wind direction time series for all vane channels	Apart from periods of missing data (grey shaded area) and Channel 8 drifting out occurred in 2011 November, no abnormalities are detected.
5	Wind direction time series for all vane channels (November 2011)	The timing of the drifting of Channel 8 lied in between 11/27 and 11/28.
6	Wind direction time series for all vane channels (2011/11/27 - 28)	The drifting of Channel 8 is found to start from 2011/11/27 7:40.
7	Annual mean wind speed	Annual mean wind speed varies depending on the period. Averaging at 6.02m/s with minimum data recovery rate set at 95%
8	Annual wind speed frequency distribution of the top anemoemter	The mean annual wind speed is 6m/s at 60m for the year 2011.
9	Monthly mean wind speed for all anemometer channels	High monthly mean of above 7m/s for months in December 2010, January to March 2011. Wind speed is relatively low from June to September 2011.
10	Table of values of monthly mean wind speed	Values shown here are plotted on page 8. Data recovery rate for values of each month is also shown.
11	Monthly Extreme wind speed	All maximum gust and maximum 10 minute average wind speeds fall below IEC standards. The highest gust has a value of 29.6m/s recorded on 2011/7/26 23:20.
12	Annual wind rose showing wind direction and wind strength	The wind rose is dominated by strong wind from the North-East sectors (30 to 80 degrees)
13	Monthly wind rose for year 2011	The wind system of the region can be clearly visible. Strong North-East seasonal wind from October to May. Easterly trade wind is present in May and June. And finally, the South-West Monsoon blows from May to October.
14	Turbulence Intensity (TI) at 60m - 10 degrees wind direction 36 sectors compare with IEC standards (2nd Edition)	High turbulence increases fatigue and reduce turbine life. In all direction sectors the characteristic TI (yellow line) is lower than the IEC lines (red and orange lines). For the main wind direction, 30 to 80 degrees, TI is very low and stable around 0.1 for wind speed above 5m/s. Low TI means wind speed is steady wth little fluctuation. This is expected because the wind comes from the sea and the terrain is flat before it reaches the mast, so terrain-induced turbulence is minimal.
15	Turbulence Intensity (TI) at 60m - 10 degrees wind direction 36 sectors compare with IEC standards (3rd Edition)	Same comments as above.
16	Average Turbulence Intensity (TI) at all anemometer heights - 10 degrees wind direction 36 sectors compare with IEC standards	Turbulence in general decreases with height. This can be seen from most of the graphs where TI is highest for 30m and start decreasing as the height increases from 30m to 60m. The TI lines is observed to cross the IEC lines for direction 250 and 300 degrees. But this is not a concern at all because of the very low occurrance frequency for these two sectors (see annual wind rose on page 10).
17	Vertical Shear Exponent between 60m and 40m - 10 degrees wind direction 36 sectors and compare with IEC	The wind shear exponent is a parameter linking two wind speeds at two heights. The higher the value the bigger the wind speed difference. Very high shear or negative shear can cause operational problems. For the main wind directions, 30 to 80 degrees, the exponent is very stable and has a values of around 0.1, which is lower than the IEC standard of 0.2.
18	Diurnal Wind Speed - Temperature and Turbulence Intensity (TI) by months for year 2011 at all anemometer heights. Values are all averages values by hour	From May to September, the temperature rises rapidly from hour 5 to around hour 12 and at the same time, the turbulence intensity also rises rapidly. This might be due to high surface temperature which enhances vertical mixing or circulation of air. Also, for the same months, the wind speed difference between lower (30m) and higher level (60m) is found to be varying by hours; larger difference or higher shear in early morning and late afternoon than in the day time. This trend is not being observed in the low temperature months October to April.

Periods of Data Received, Missing Data and Invalid Data

Data Received

From	*To*	*Period*	*Units*
2010/8/13 13:00	2012/6/8 8:50	664.8	days

Missing Data

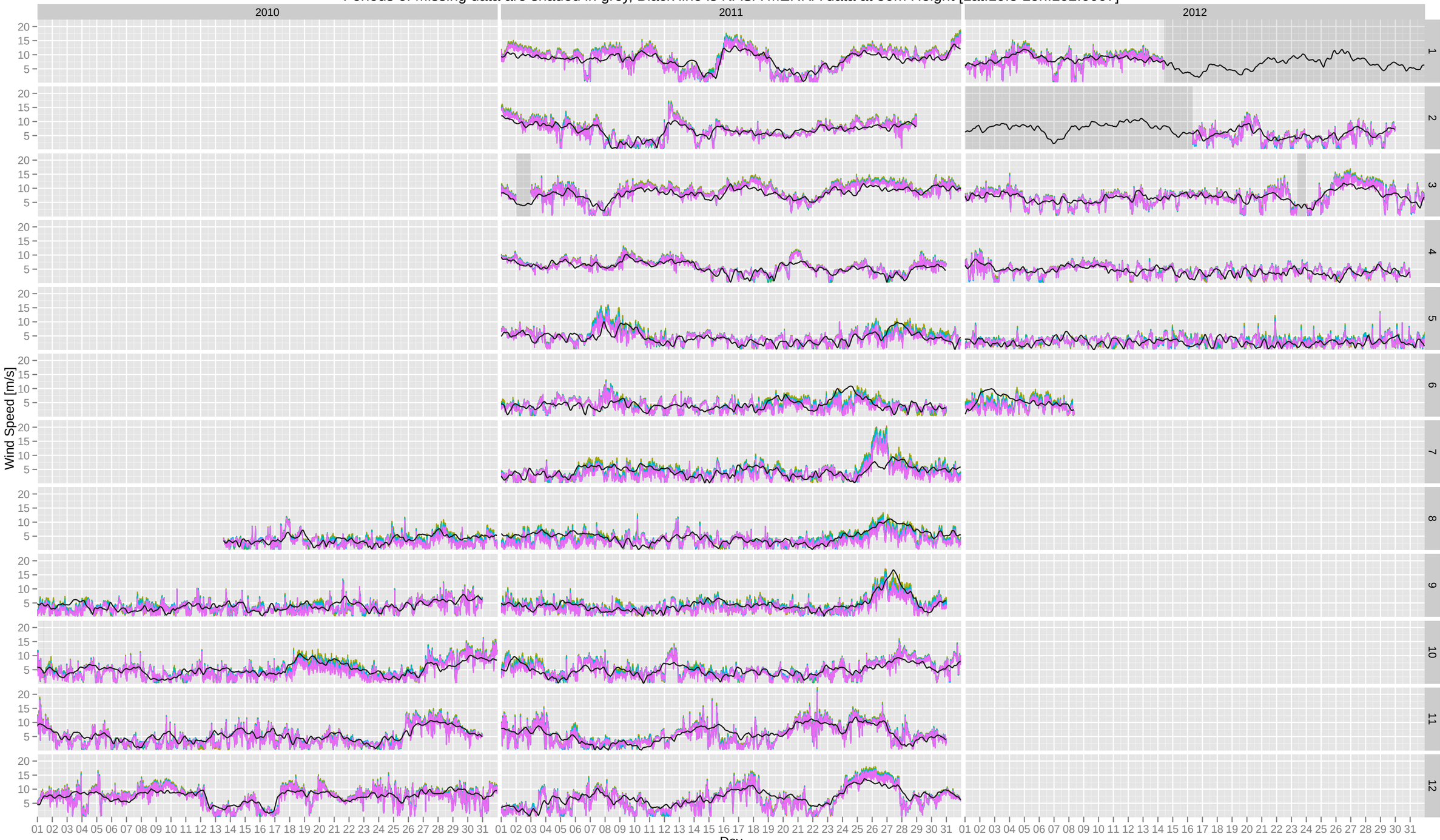
From	*To*	*Period*	*Units*
2010/10/1 10:00	2010/10/1 10:50	50.0	minutes
2011/3/2 0:00	2011/3/2 23:50	23.8	hours
2012/1/14 10:00	2012/2/16 8:10	32.9	days
2012/3/23 10:00	2012/3/23 23:50	13.8	hours
	Total	34.5	days

Invalid Data

From	*To*	*Period*	*Units*	*Channel*
2011/11/27 7:40	2012/6/8 8:50	194.0	days	Ch8

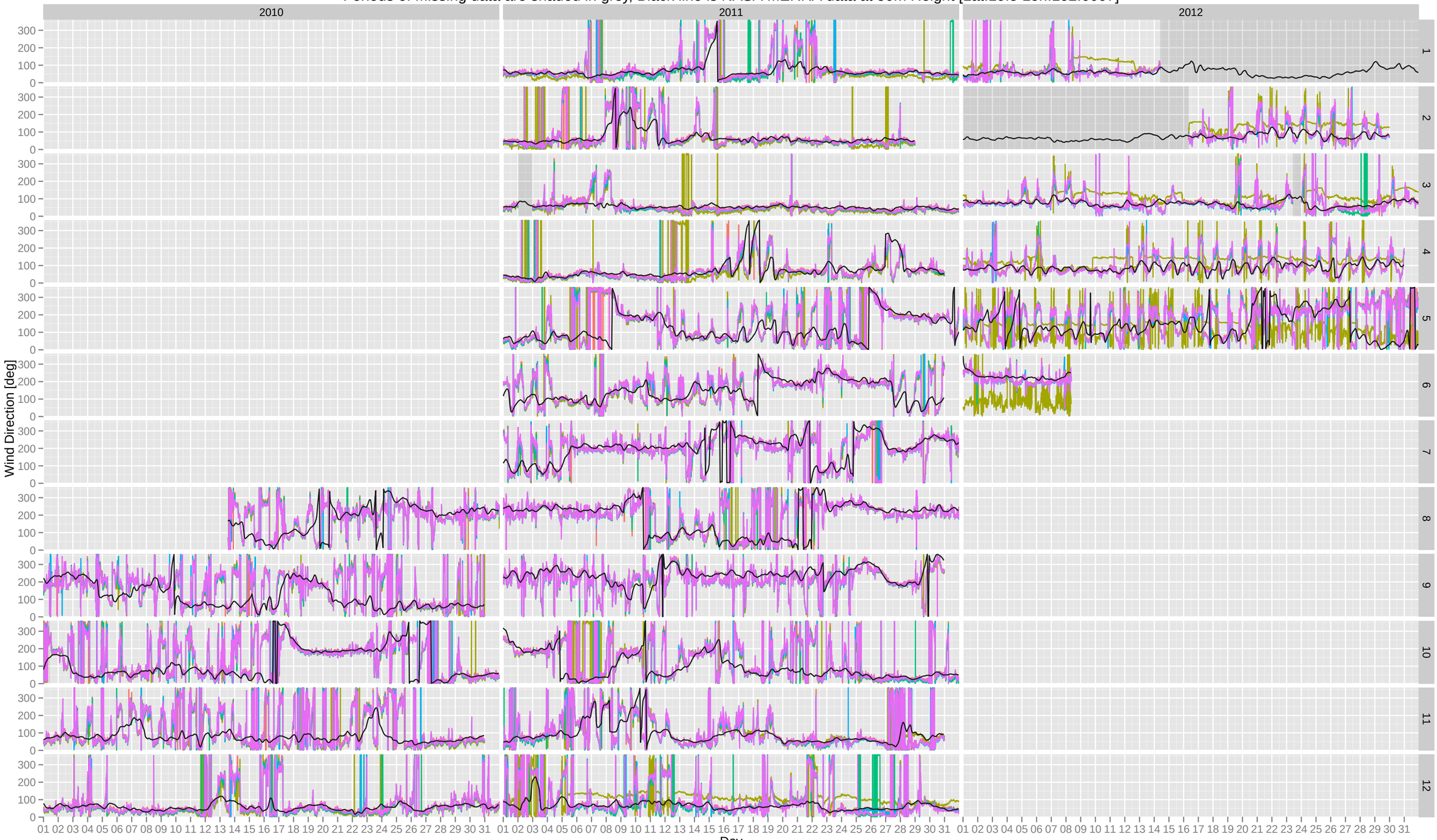
Balisay_4031_Wind Speed_Time_Series (Data Period: 2010−08−13 13:00:00 − 2012−06−08 08:50:00)

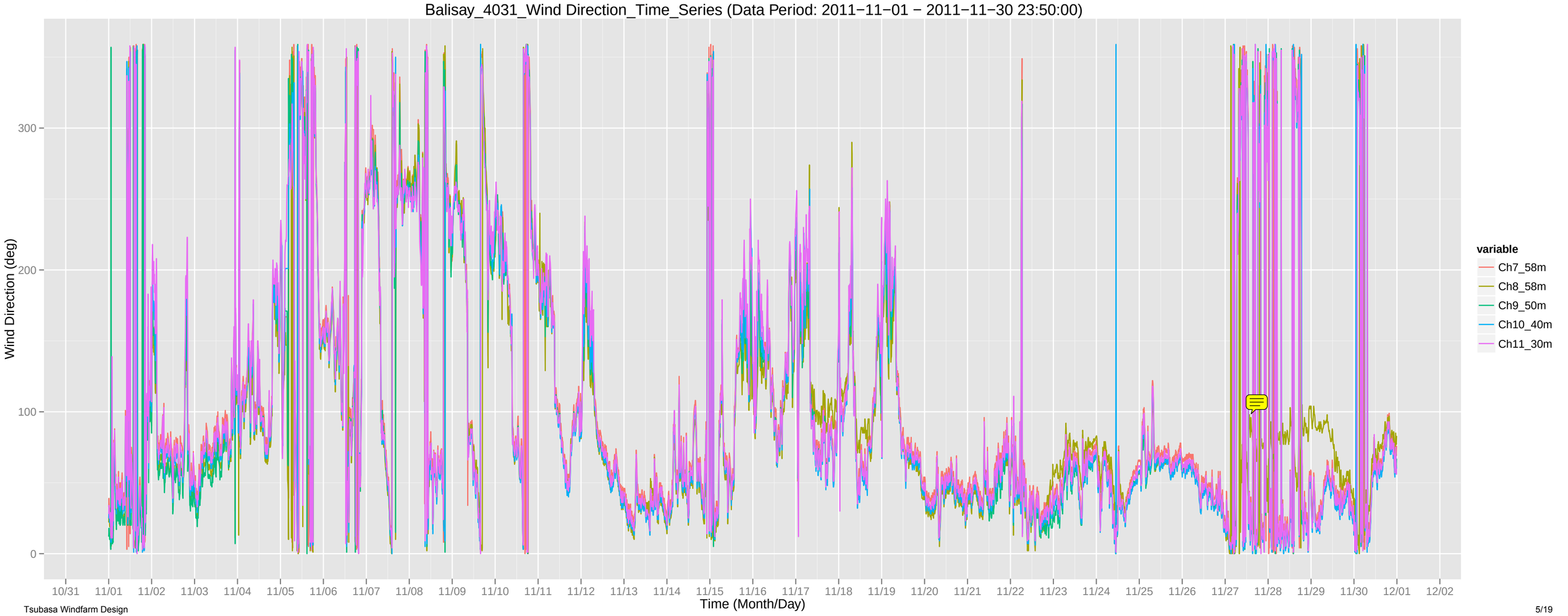
Periods of Missing data are shaded in grey, Black line is NASA MERRA data at 50m Height [Lat:13.5 Lon:132.6667]

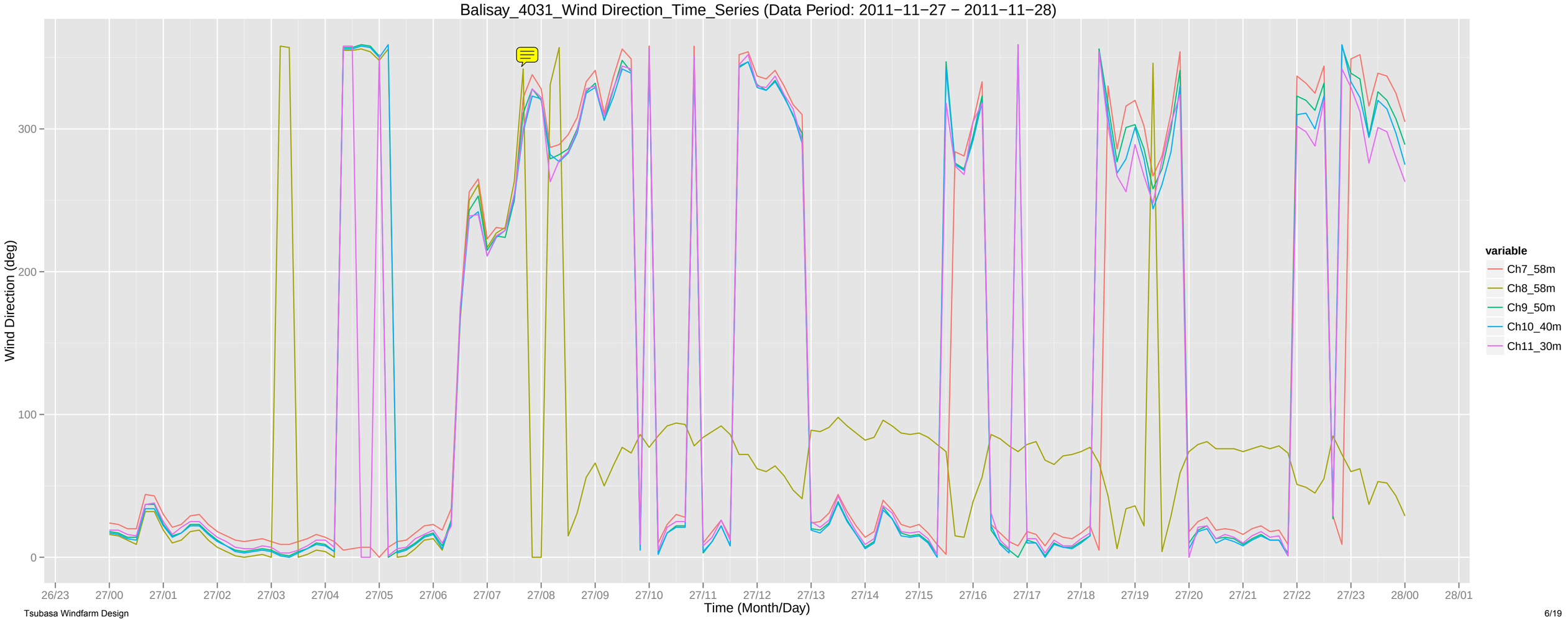


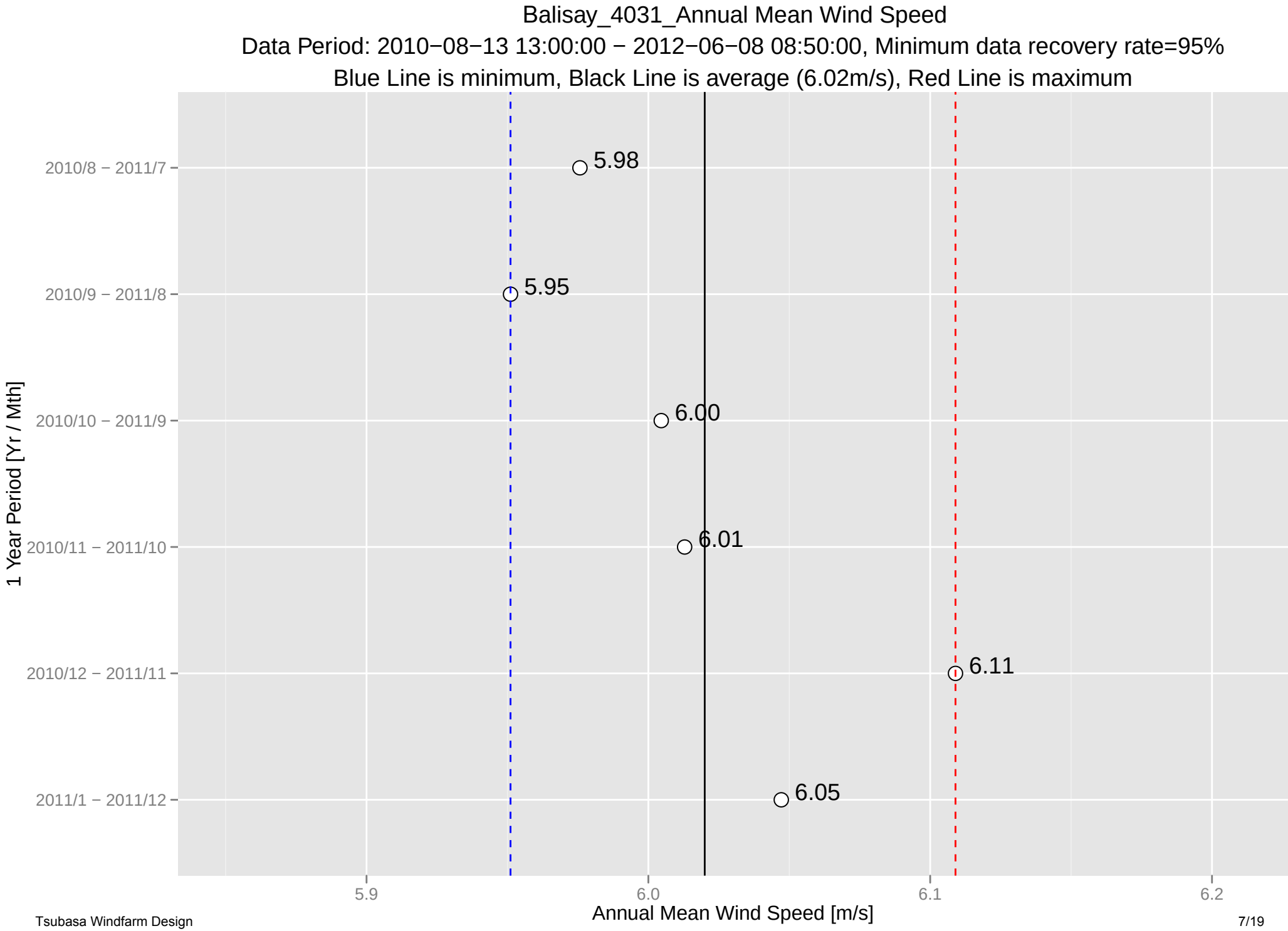
Balisay_4031_Wind Direction_Time_Series (Data Period: 2010−08−13 13:00:00 − 2012−06−08 08:50:00)

Periods of Missing data are shaded in grey, Black line is NASA MERRA data at 50m Height [Lat:13.5 Lon:132.6667]




Balisay_4031_Wind Direction_Time_Series (Data Period: 2011−11−01 − 2011−11−30 23:50:00)
Wind Direction (deg)
0
100
200
300
10/31
11/01
11/02
11/03
11/04
11/05
11/06
11/07
11/08
11/09
11/10
11/11
11/12
11/13
11/14
11/15
11/16
11/17
11/18
11/19
11/20
11/21
11/22
11/23
11/24
11/25
11/26
11/27
11/28
11/29
11/30
12/01
12/02
Time (Month/Day)
variable
Ch7_58m
Ch8_58m
Ch9_50m
Ch10_40m
Ch11_30m


Balisay_4031_Wind Direction_Time_Series (Data Period: 2011−11−27 − 2011−11−28)
Wind Direction (deg)
0
100
200
300
26/23
27/00
27/01
27/02
27/03
27/04
27/05
27/06
27/07
27/08
27/09
27/10
27/11
27/12
27/13
27/14
27/15
27/16
27/17
27/18
27/19
27/20
27/21
27/22
27/23
28/00
28/01
Time (Month/Day)
variable
Ch7_58m
Ch8_58m
Ch9_50m
Ch10_40m
Ch11_30m

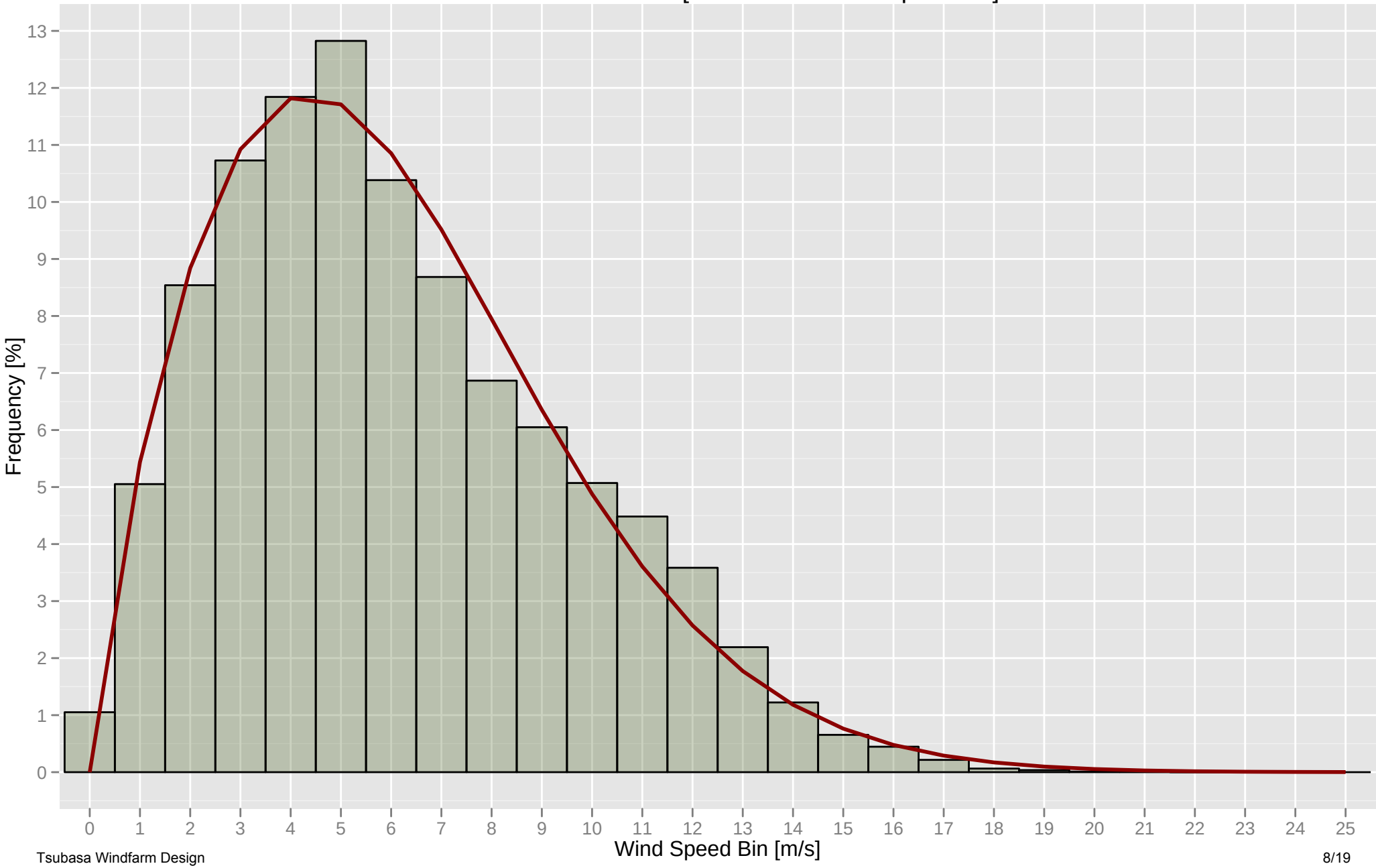

Balisay_4031_Annual Mean Wind Speed
Data Period: 2010−08−13 13:00:00 − 2012−06−08 08:50:00, Minimum data recovery rate=95%
Blue Line is minimum, Black Line is average (6.02m/s), Red Line is maximum
1 Year Period [Yr / Mth]
2010/8 − 2011/7
2010/9 − 2011/8
2010/10 − 2011/9
2010/11 − 2011/10
2010/12 − 2011/11
2011/1 − 2011/12
5.98
5.95
6.00
6.01
6.11
6.05
5.9
6.0
6.1
6.2
Annual Mean Wind Speed [m/s]

Balisay_4031_Wind Speed Frequency Distribution

Data Period: 2011−01−01 − 2011−12−31 23:50:00, Data Channel: Ch2_60m

Total Number of Data:52416, Data Recovery Rate:99.7%, Average Wind Speed=6m/s

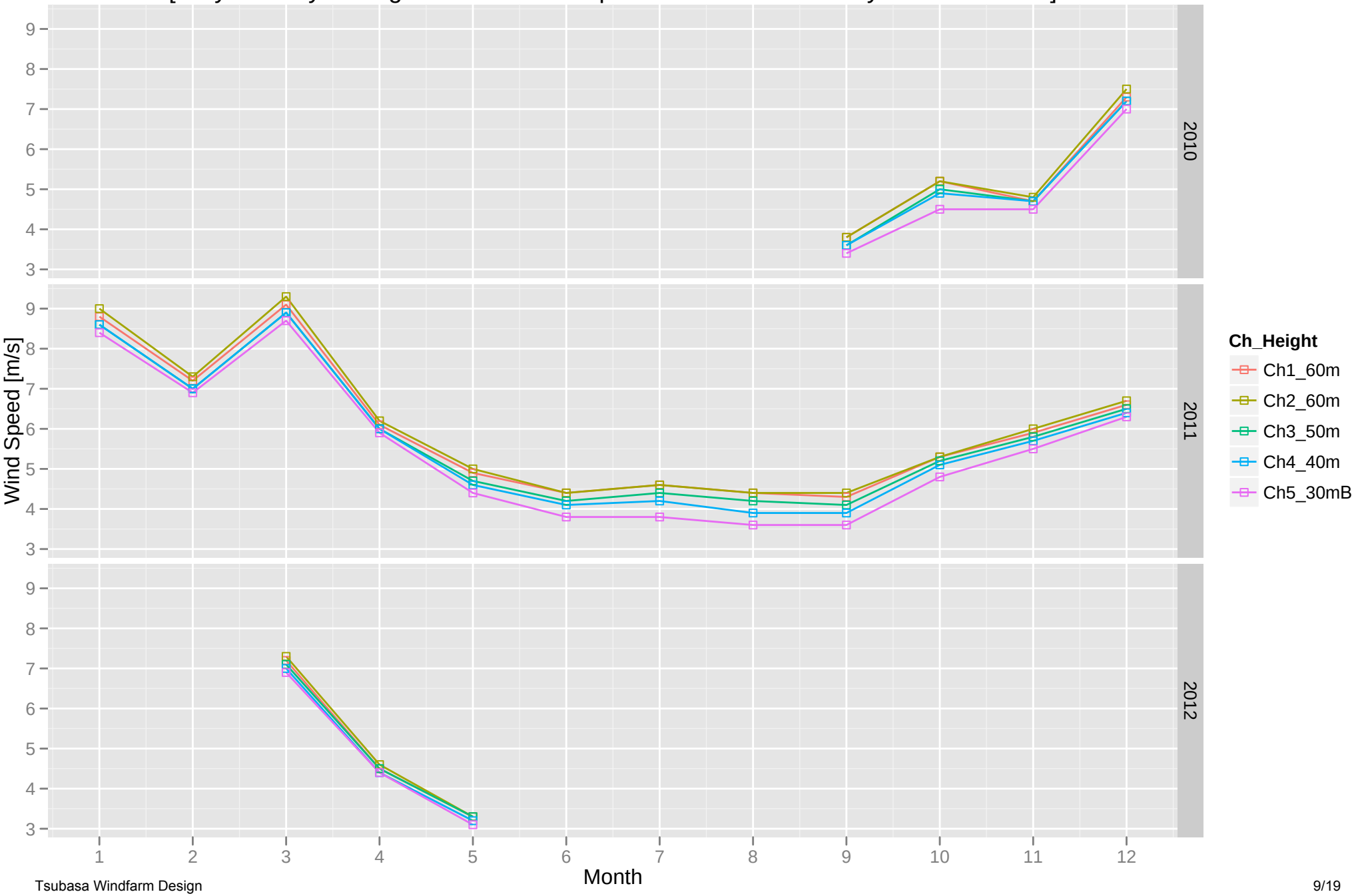
Red line is Weibull Fit [Scale=6.8 and Shape=1.81]



Balisay_4031_Monthly Average Wind Speed

Data Period: 2010−08−13 13:00:00 − 2012−06−08 08:50:00

[Only monthly average with above or equal to 80% data recovery rate are shown]

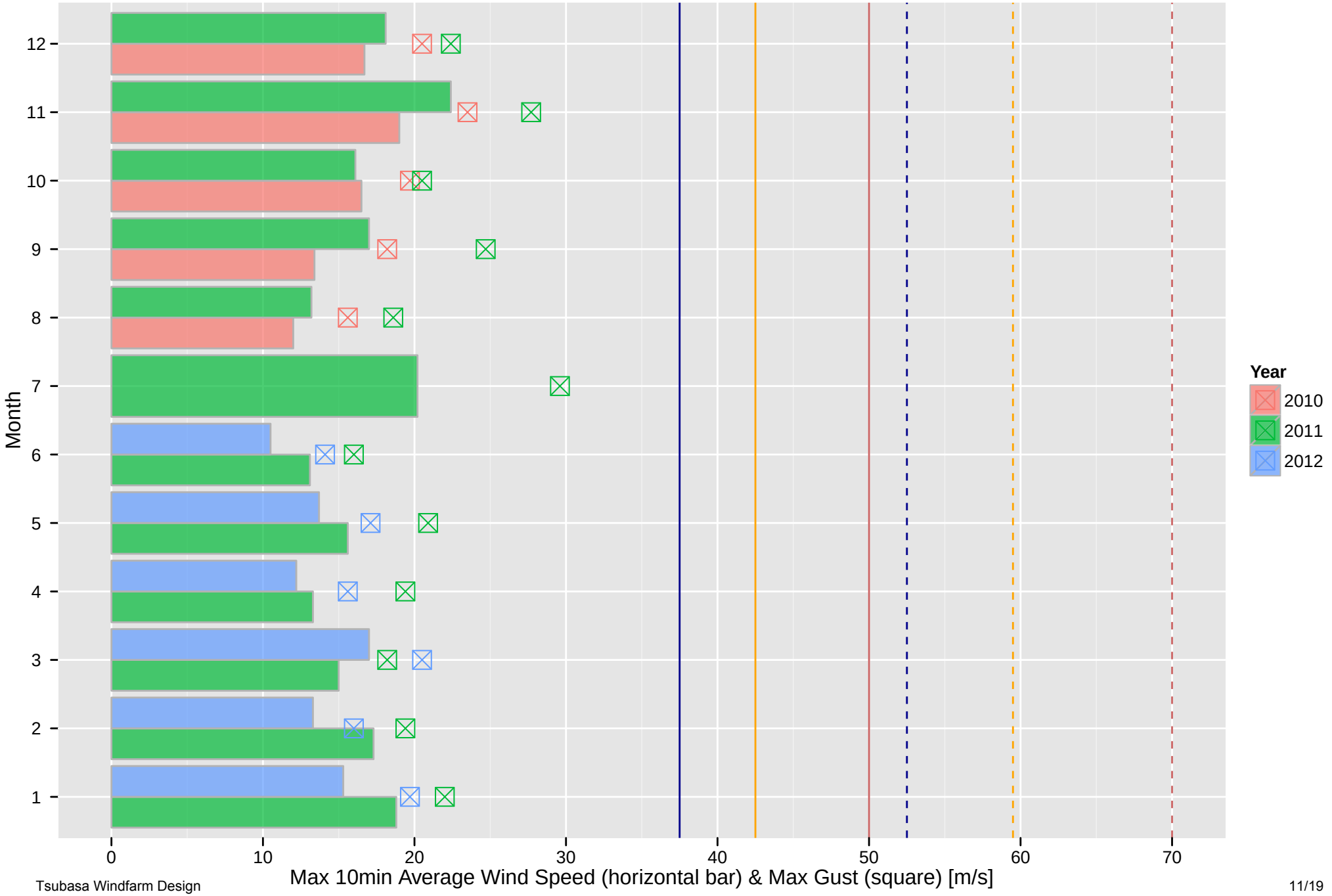


Monthly Average Wind Speed

Year	Channel	Height (m)	1	2	3	4	5	6	7	8	9	10	11	12
2010	Ch1	60								3.9]	3.8	5.2)	4.7	7.3
2010	Ch2	60								3.9]	3.8	5.2)	4.8	7.5
2010	Ch3	50								3.6]	3.6	5)	4.7	7.2
2010	Ch4	40								3.5]	3.6	4.9)	4.7	7.2
2010	Ch5	30								3.2]	3.4	4.5)	4.5	7
2011	Ch1	60	8.8	7.2	9.1)	6.1	4.9	4.4	4.6	4.4	4.3	5.3	5.9	6.6
2011	Ch2	60	9	7.3	9.3)	6.2	5	4.4	4.6	4.4	4.4	5.3	6	6.7
2011	Ch3	50	8.6	7	8.9)	6	4.7	4.2	4.4	4.2	4.1	5.2	5.8	6.5
2011	Ch4	40	8.6	7	8.9)	6	4.6	4.1	4.2	3.9	3.9	5.1	5.7	6.4
2011	Ch5	30	8.4	6.9	8.7)	5.9	4.4	3.8	3.8	3.6	3.6	4.8	5.5	6.3
2012	Ch1	60	8.3]	4.9]	7.2)	4.5	3.3	4.8]						
2012	Ch2	60	8.4]	5]	7.3)	4.6	3.3	5]						
2012	Ch3	50	8.1]	4.8]	7.1)	4.5	3.3	4.6]						
2012	Ch4	40	8]	4.7]	7)	4.4	3.2	4.2]						
2012	Ch5	30	7.8]	4.7]	6.9)	4.4	3.1	3.8]						

Data Recovery Rate :
+ : >100%
) : 80%-100%
] : <80%
- : 0%

Balisay_4031_Extreme Wind Speed based on Ch2_60m
Data Period: 2010−08−13 13:00:00 − 2012−06−08 08:50:00
IEC Standard [2nd ed] − Solid Line (10min Average) − Dotted Line (50yr gust) − Blue (Class III) − Orange (Class II) − Red (Class I)

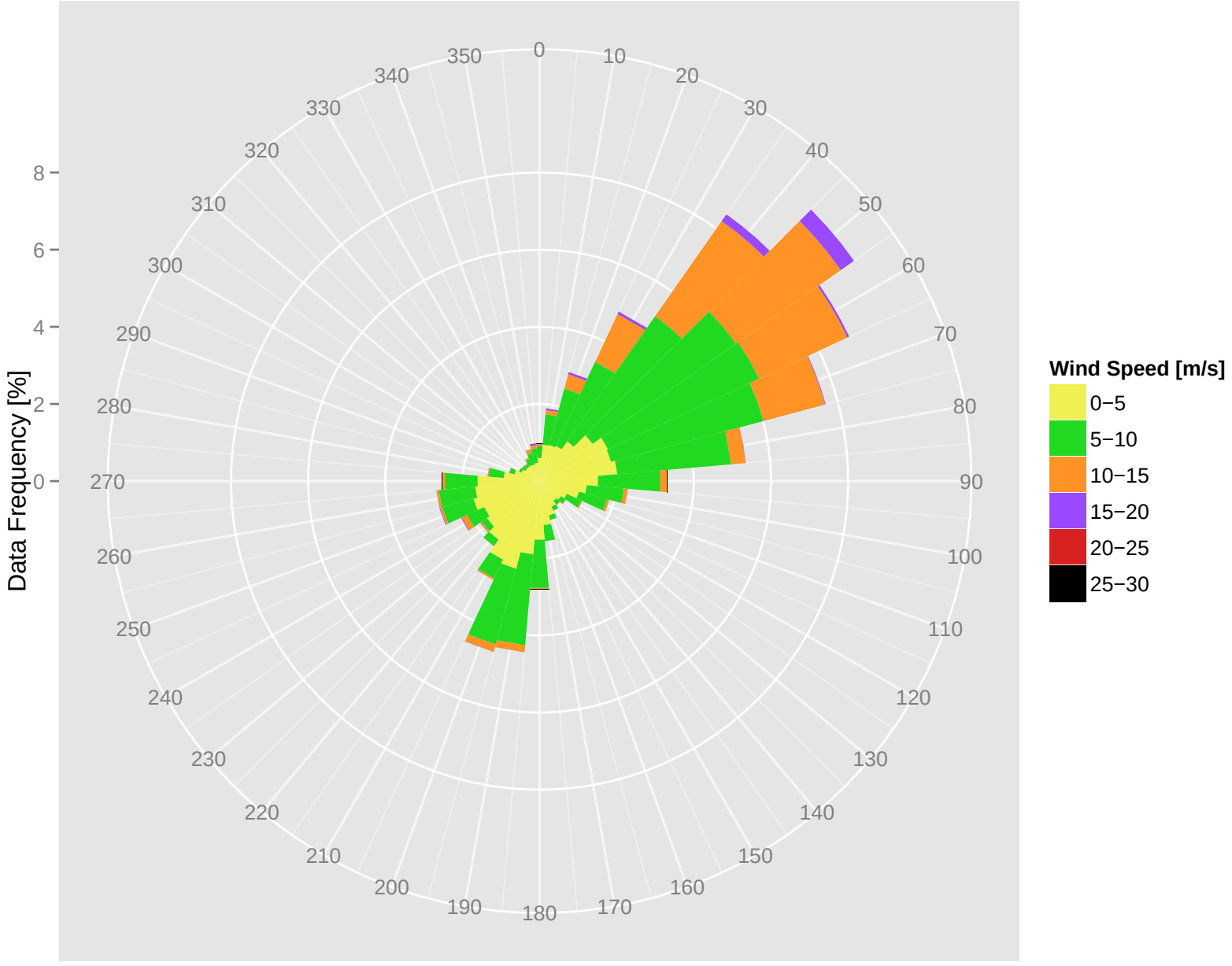


Balisay_4031_Wind Rose

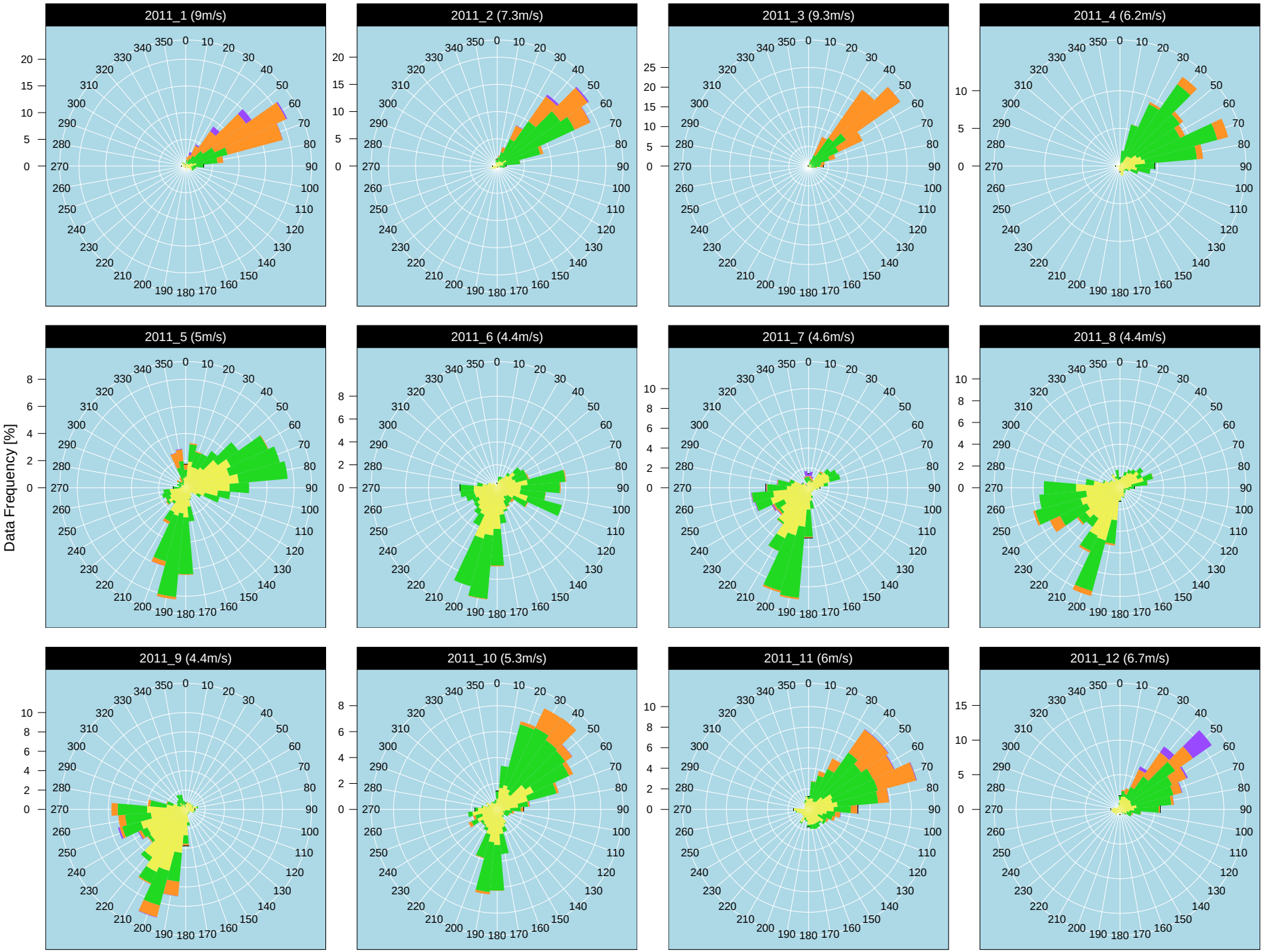
Data Period: 2011−01−01 − 2011−12−31 23:50:00

Data Channel: Speed Ch2_60m, Direction Ch7_58m

Total Number of Data:52416, Data Recovery Rate:99.7%, Average Wind Speed=6m/s



Balisay_4031_Monthly_Rose
Data Period: 2011−01−01 − 2011−12−31 23:50:00
Data Channel: Speed Ch2_60m, Direction Ch7_58m
Total Number of Data:52416, Data Recovery Rate:99.7%, Average Wind Speed=6m/s

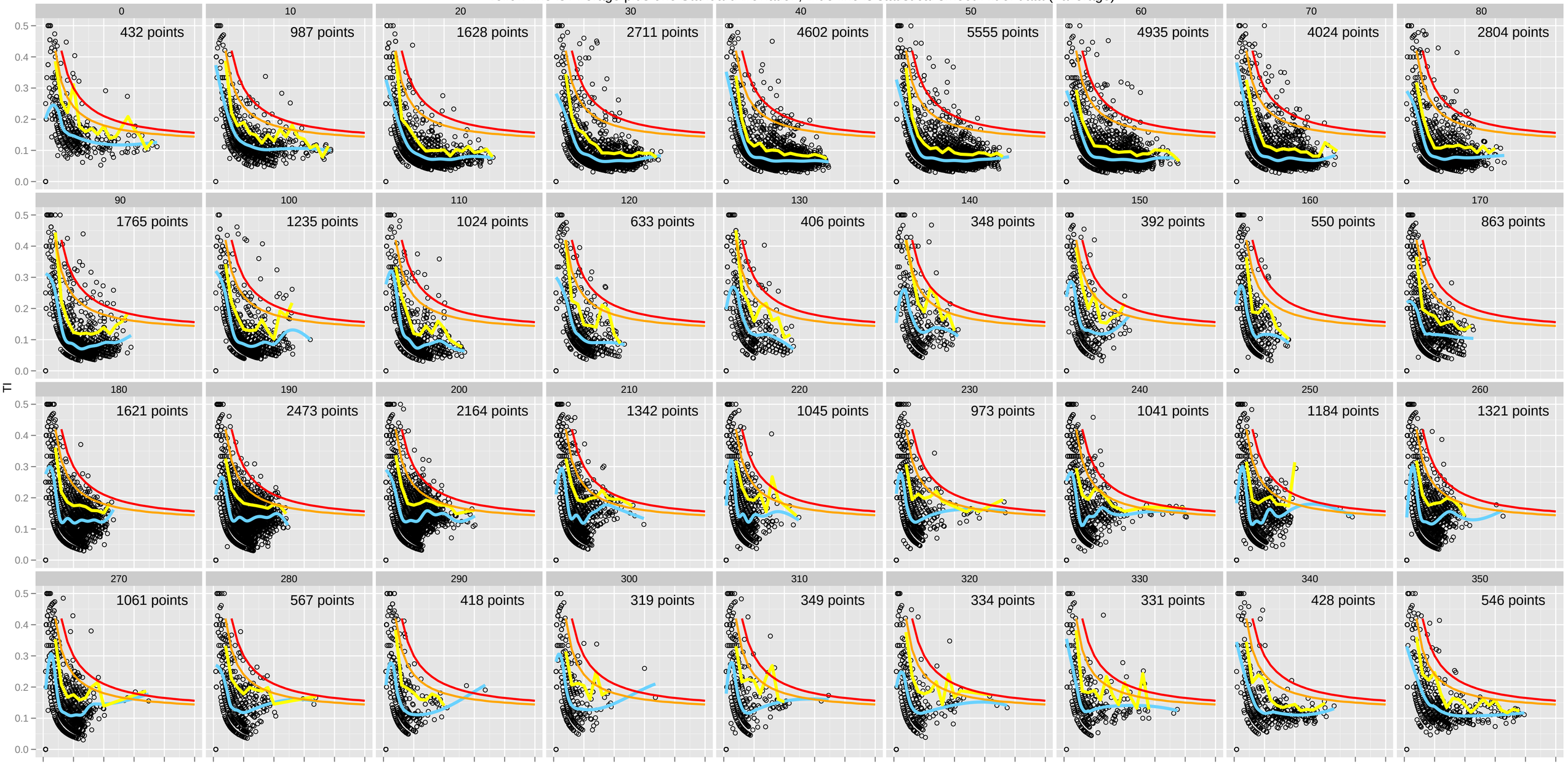


Balisay_4031_Turbulence Intensity (TI)_36 Direction Sectors

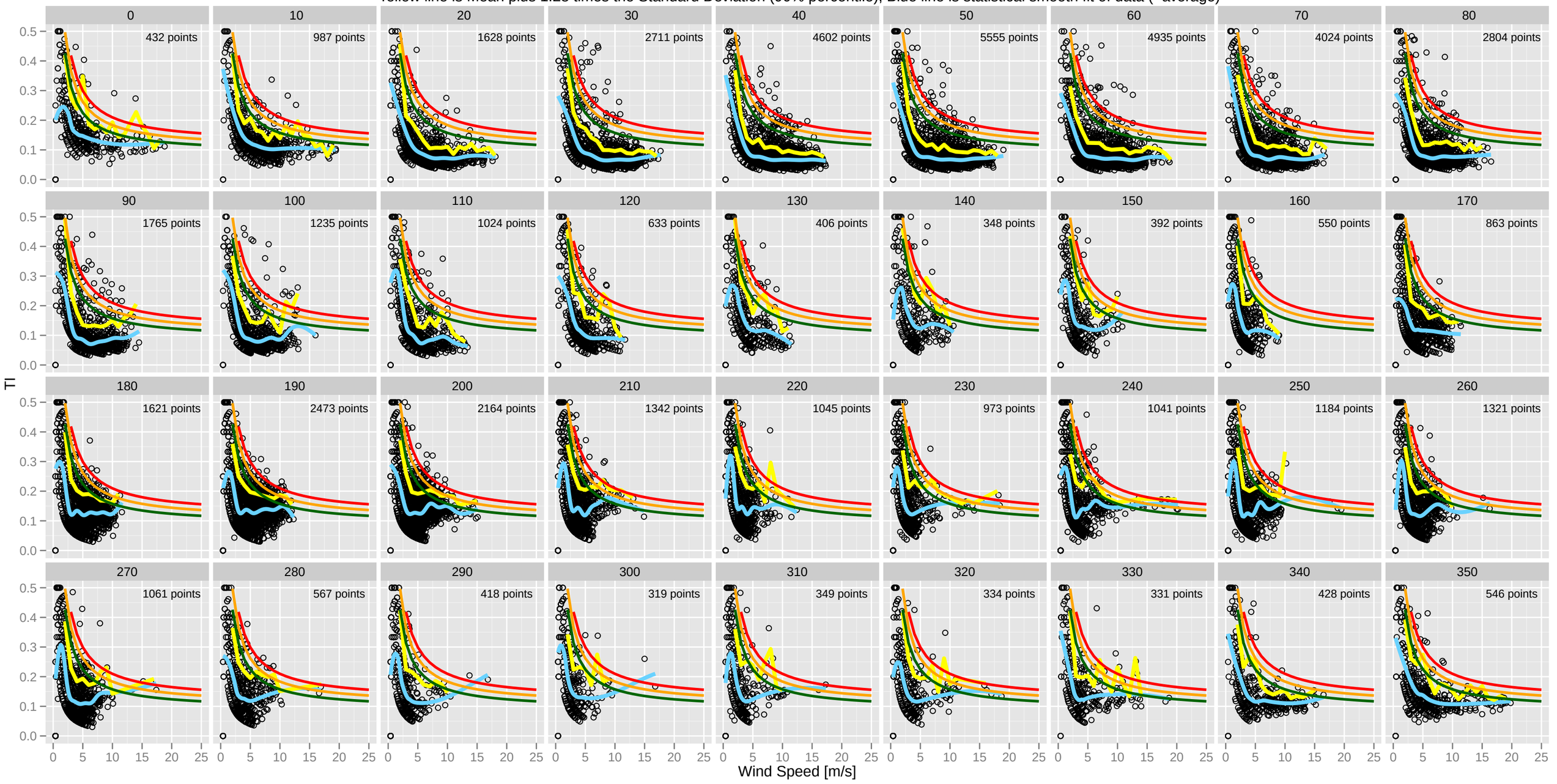
Data Period: 2010−08−13 13:00:00 − 2011−08−13 13:00:00 , Data Channel: Speed Ch2_60m, Direction Ch7_58m

Total Number of Data:52411, Data Recovery Rate:99.7%, Red line is IEC Class A, Orange line is IEC Class B (IEC 61400−1 2nd edition)

Yellow line is Average plus one Standard Deviation, Blue line is statistical smooth fit of data (~average)



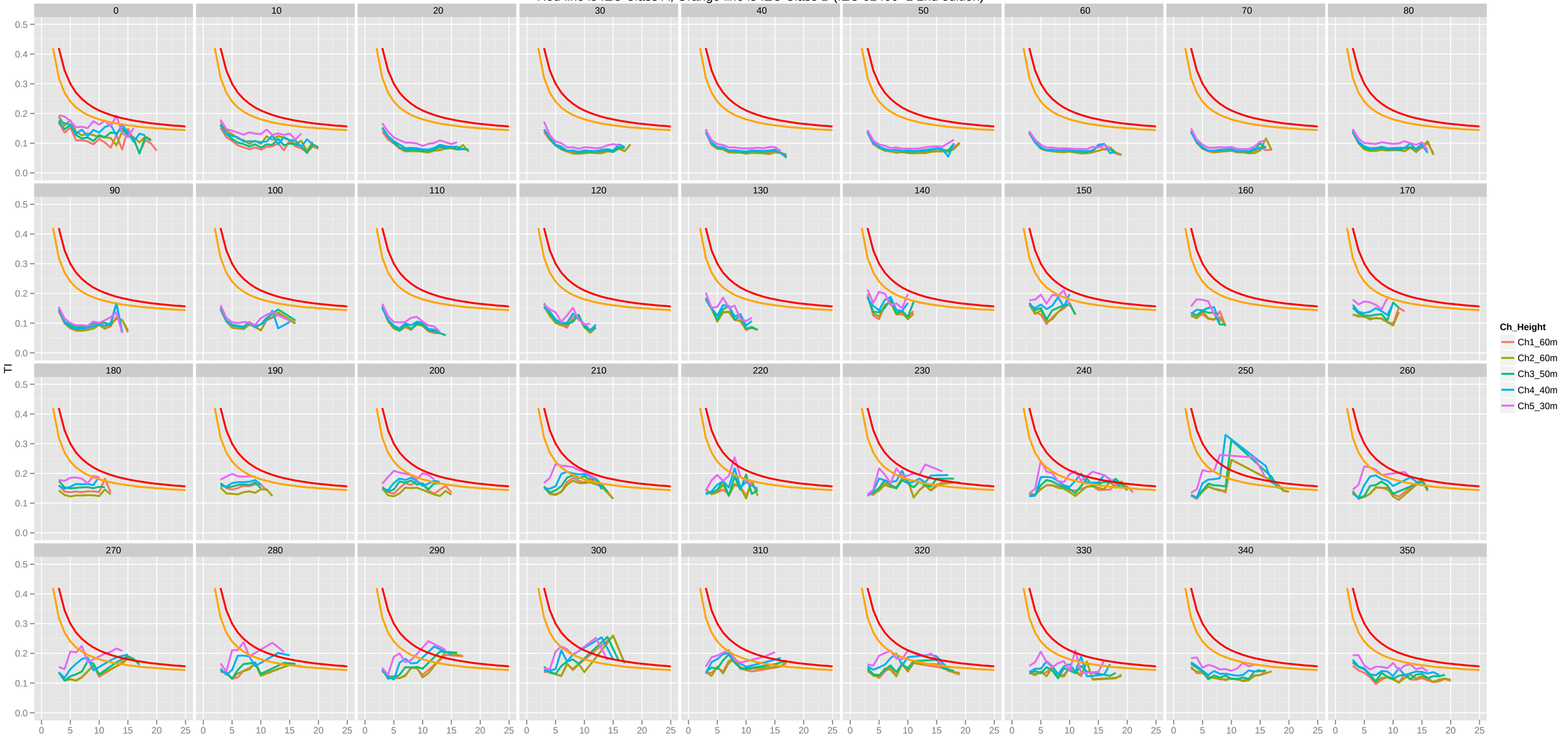
Balisay_4031_Turbulence Intensity (TI)_36 Direction Sectors
Data Period: 2010−08−13 13:00:00 − 2011−08−13 13:00:00 , Data Channel: Speed Ch2_60m, Direction Ch7_58m
Total Number of Data:52411, Data Recovery Rate:99.7%, IEC 3rd ed: Red line − Class A, Orange line − Class B, Green Line − Class C
Yellow line is Mean plus 1.28 times the Standard Deviation (90% percentile), Blue line is statistical smooth fit of data (~average)



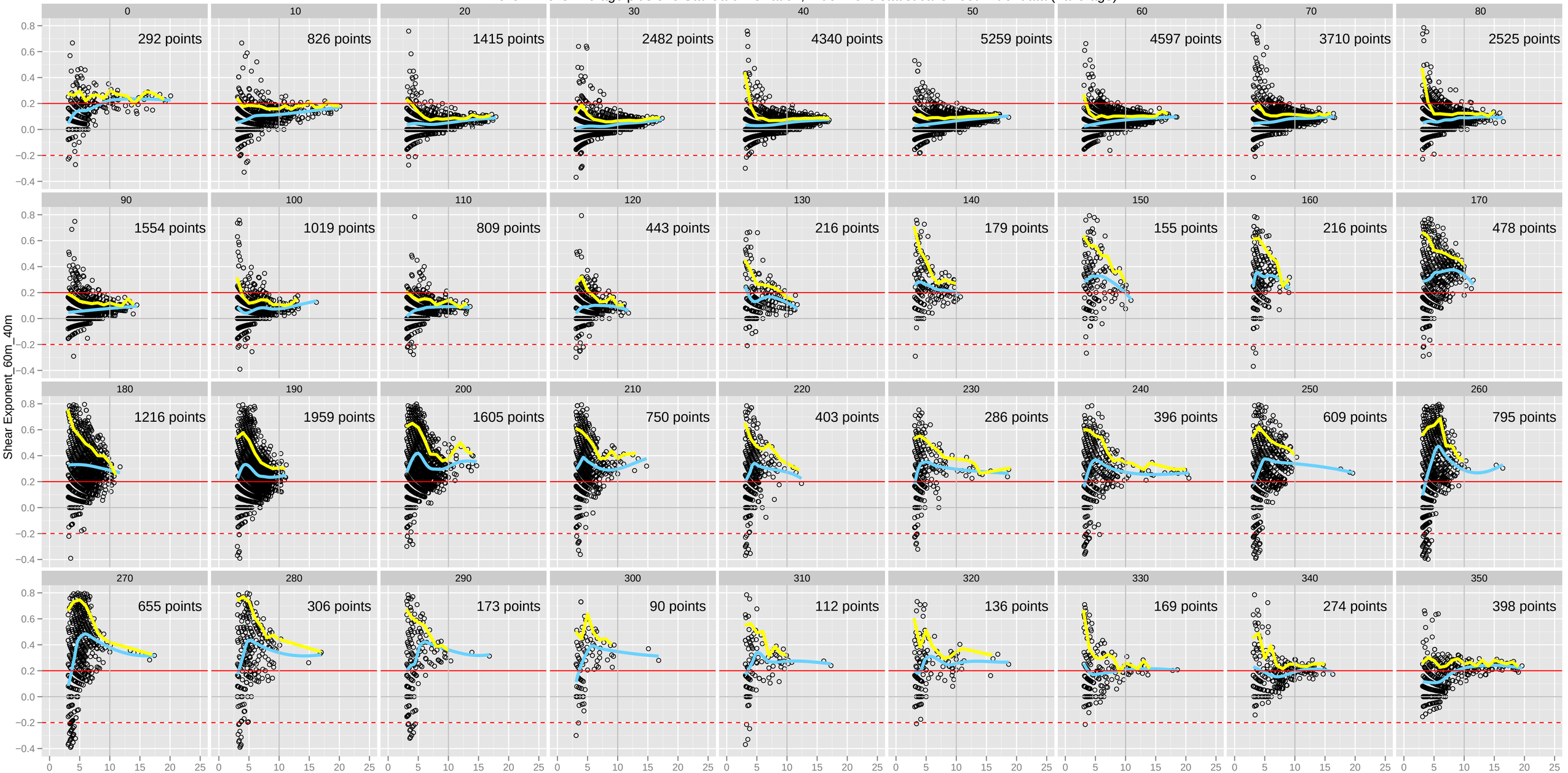
Balisay_4031_Average_Turbulence_Intensity (TI)_36 Direction Sectors

Data Period: 2010−08−13 13:00:00 − 2011−08−13 13:00:00, Data Channel: Direction Ch7_58m

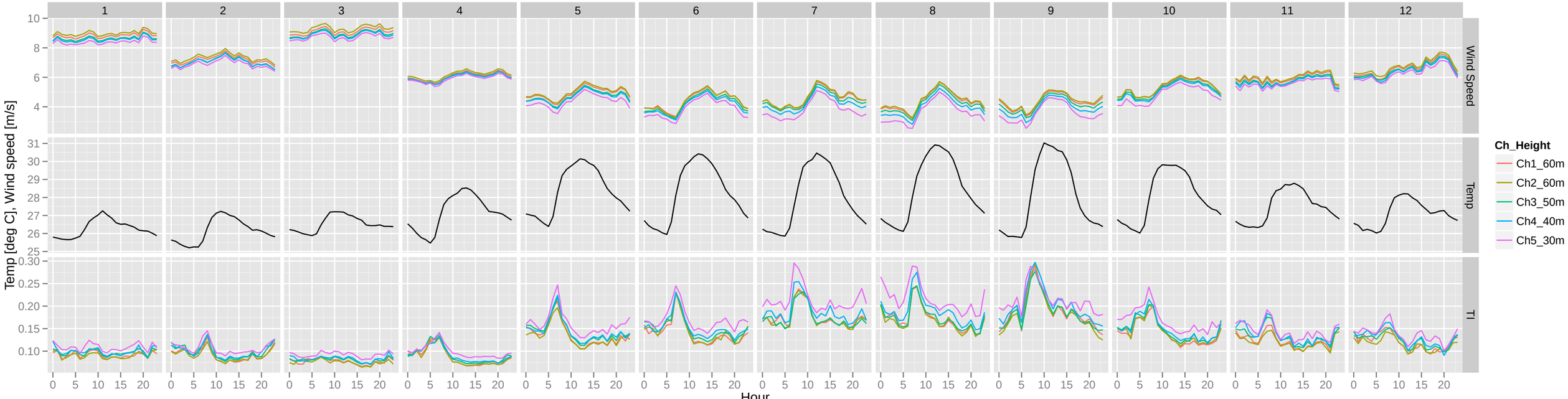
Red line is IEC Class A, Orange line is IEC Class B (IEC 61400−1 2nd edition)



Balisay_4031_Vertical_Shear_Exponent_36_Direction_Sectors
Data Period:2010−08−13 13:00:00 to 2011−08−13 13:00:00, Data Channel: Speed Ch1_60m Ch4_40m, Direction Ch7_58m
Total Number of Data:40847, Data Recovery Rate:99.7%, Red Line is IEC Standard Line
Yellow line is Average plus one Standard Deviation, Blue line is statistical smooth fit of data (~average)



Balisay_4031_Diurnal Wind Speed − Temperature − TI by Month
Data Period: 2011−01−01 − 2011−12−31 23:50:00
Total Number of Data:52416, Data Recovery Rate:99.7%



Appendix - Mast and Sensor Details

Site Balisay

Mast ID	4301
Mast Height	60m
Mast Coordinates	N 13 30' 33.15", E 132 56' 32.50" (WGS84)
Logger	NRG Symphonie
Installation Date	2010/8/13 13:00
Logger Replacement	2012/3/23 11:20

Channel	*Height (m)*	*Type*	*Manufacturer*	*Model*	*Boom Orientation*
1	60	Anemometer	NRG	NRG #40C	0
2	60	Anemometer	NRG	NRG #40C	180
3	50	Anemometer	NRG	NRG #40C	0
4	40	Anemometer	NRG	NRG #40C	0
5	30	Anemometer	NRG	NRG #40C	0
7	58	Vane	NRG	NRG # 200P	0
8	58	Vane	NRG	NRG # 200P	180
9	50	Vane	NRG	NRG # 200P	180
10	40	Vane	NRG	NRG # 200P	180
11	30	Vane	NRG	NRG # 200P	180
12	8	Temperature	NRG	NRG # 110S	-