Williwaw Engineering

October 5, 2015

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Subject: September 2015 Monthly Report – RCUH P.O. #Z10066105

Dear Luis,

The following constitutes my monthly report for the subject agreement for services associated with September 2015.

Work Completed under Task 3: Support HNEI in Device Performance Data Collection Throughout Development:

- Monitored the device regularly via remote connection to the NWEI host PC in Room 106, Battery French. Downloaded data from PC as necessary, and updated device control settings when necessary.

- Analyzed output power data to produce monthly power performance data plots; see Attachment 1 for results.

- Analyzed Azura float angle data using MATLAB to produce plots of 30 minute average float angle data for the deployment period. The data indicates that the Azura continues to settle very slowly in the water and is ballasted a little low now. Also note that during three periods of time on Sept 28, the device operated with the float on the offshore side of the hull after going "over the top" in seas of approximately 3m/7s. See Attachment 2 for a plot of this data.

- Analyzed 24V instrumentation supply voltage data recorded on board the Azura to determine the minimum and maximum power supply voltage throughout the deployment period. The minimum and maximum were 23.8 V and 24.2 V, well within the expected 24 ± 0.5 V tolerance of the power supply.

- Analyzed ground fault current data recorded by the bunker cRIO to determine the maximum ground fault current during the deployment period. The maximum ground fault current was 16.5 mA; however, due to an offset in the measurement a ground fault current of 15 mA had been measured with the subsea cable disconnected so that 16.5 mA is quite a low measurement.

- Produced further Response Amplitude Operator (RAO) plots from spectral analysis of NREL six degree of motion data, NWEI float angle data, and Waverider data:
  - For no load operation of the Azura
  - Comparing results for short period (T_e 6-7 s) and long period (T_e 10-11 s). The long period response is noticeably lower in the long period waves.

  Also compiled Waverider mean direction data and NREL GPS compass data to produce 30 minute wave direction and Azura heading data for RAO analysis periods.

The results show that the Azura heading was often 45° different from the mean wave direction during the data periods used. See Attachment 3 for RAO data summaries and plots.

- Plotted daily humidity sensor data for the cRIO enclosure and drybox on board the Azura. The results show that the drybox, which is entirely sealed from the Azura hull, has maintained very low humidity throughout the deployment period while humidity has slowly increased inside the cRIO enclosure since the June deployment. To date the humidity inside the cRIO enclosure is well below levels that would cause condensing moisture and equipment damage. See Attachment 4 for a plot of these results.

- Began analyzing data from a water pressure sensor on the side of the Azura hull to see if it is possible to calculate wave elevation data at the Azura location using this data together with NREL heave data. This work is not complete and will continue during the month of October.

Please let me know if you have any questions or comments concerning this project.

Sincerely,

Terry Lettenmaier

Attachment 1: Azura power performance data plots for September 2015

Attachment 2: Azura 30 minute average float angle data plots

Attachment 3: Azura Response Amplitude Operator plots and data

Attachment 4: Azura cRIO enclosure and drybox humidity

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Attachment 1

Azura power performance data plots for September 2015

Azura Power Performance – September 2015

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Summary

- Plots of Sept 2015 data only are shown on Slides 2-8
- Plots of cumulative data for the entire deployment period June-Sept 2015 are shown on Slides 9-15
- Azura was operated (output connected to grid) for 706 hours in August (98% of month). Most of the down time was for brief, intentional shut downs while device data was recorded at no load. This data is useful for comparison to computer model results.
- Device operation was continued throughout September the same as in July and August, cycling between six different constant hydraulic motor displacement settings
    - Settings changed every 30 minutes
    - Constant displacement control is the simplest method possible and is expected to be useful for comparison to computer model results.

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Azura Power Performance
Monthly Data September 2015

Azura Power Performance – September 2015

Data samples collected

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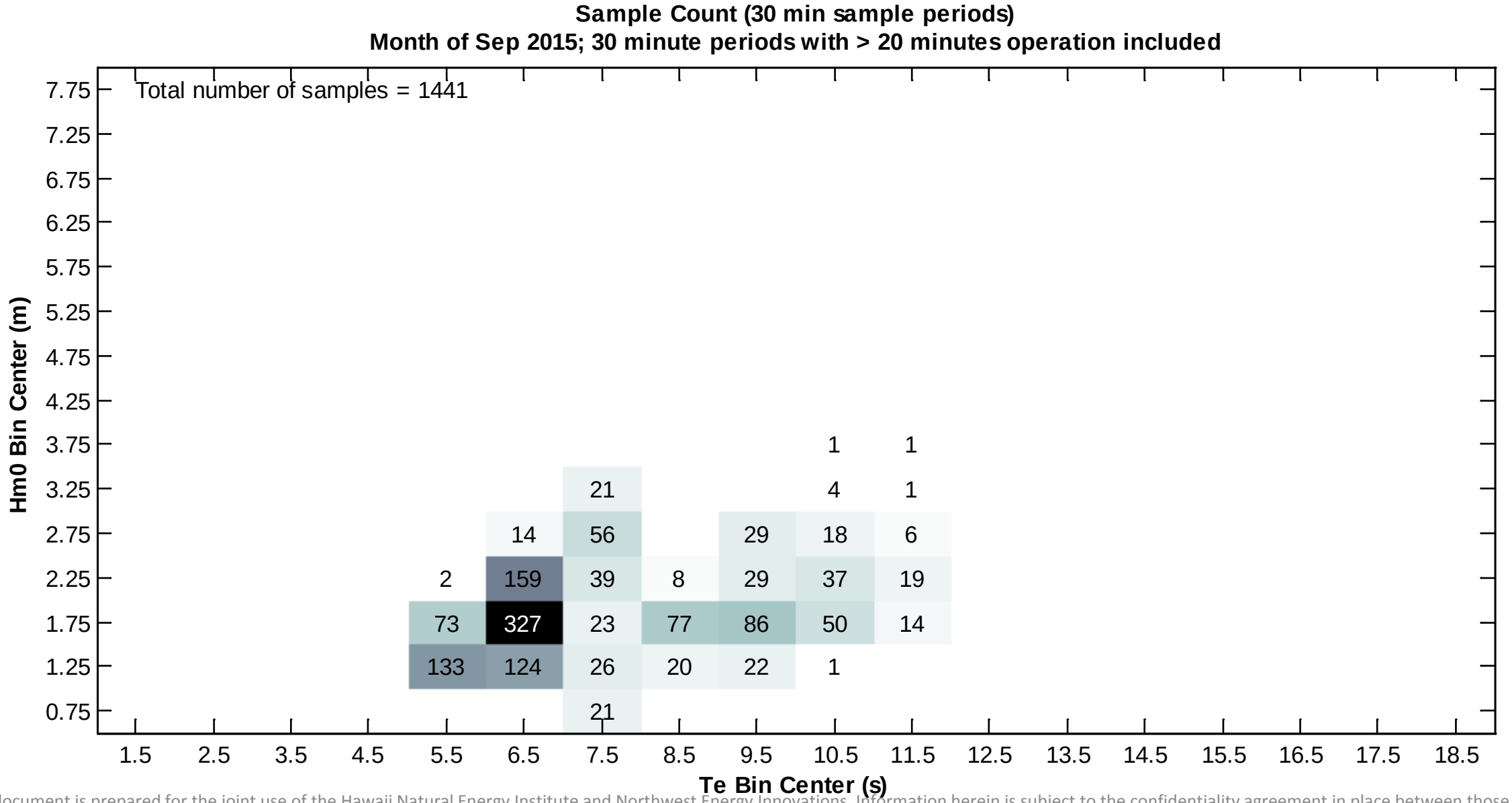

Azura Power Performance – September 2015

Mean power matrix

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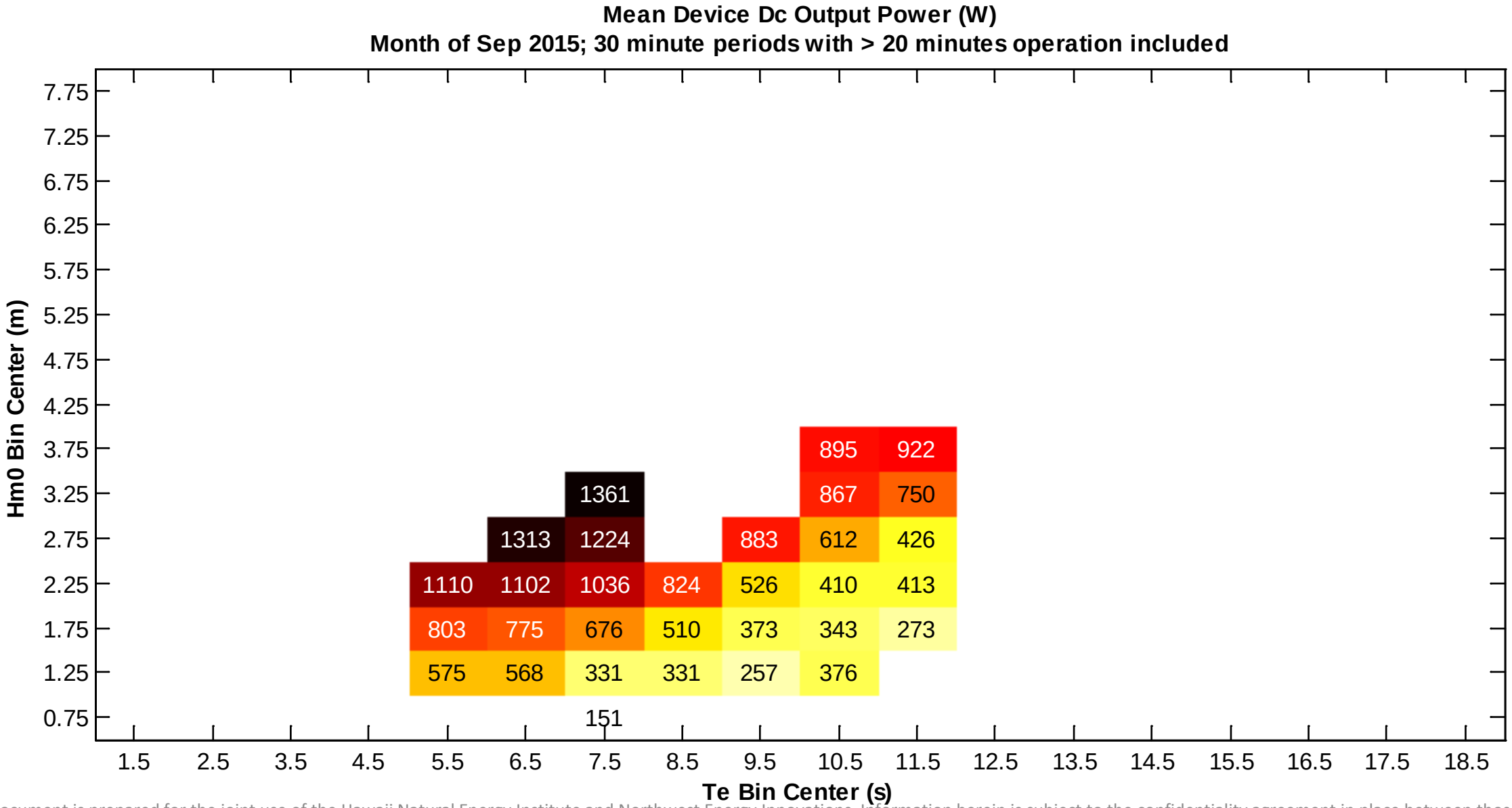

Azura Power Performance – September 2015

95th percentile power matrix

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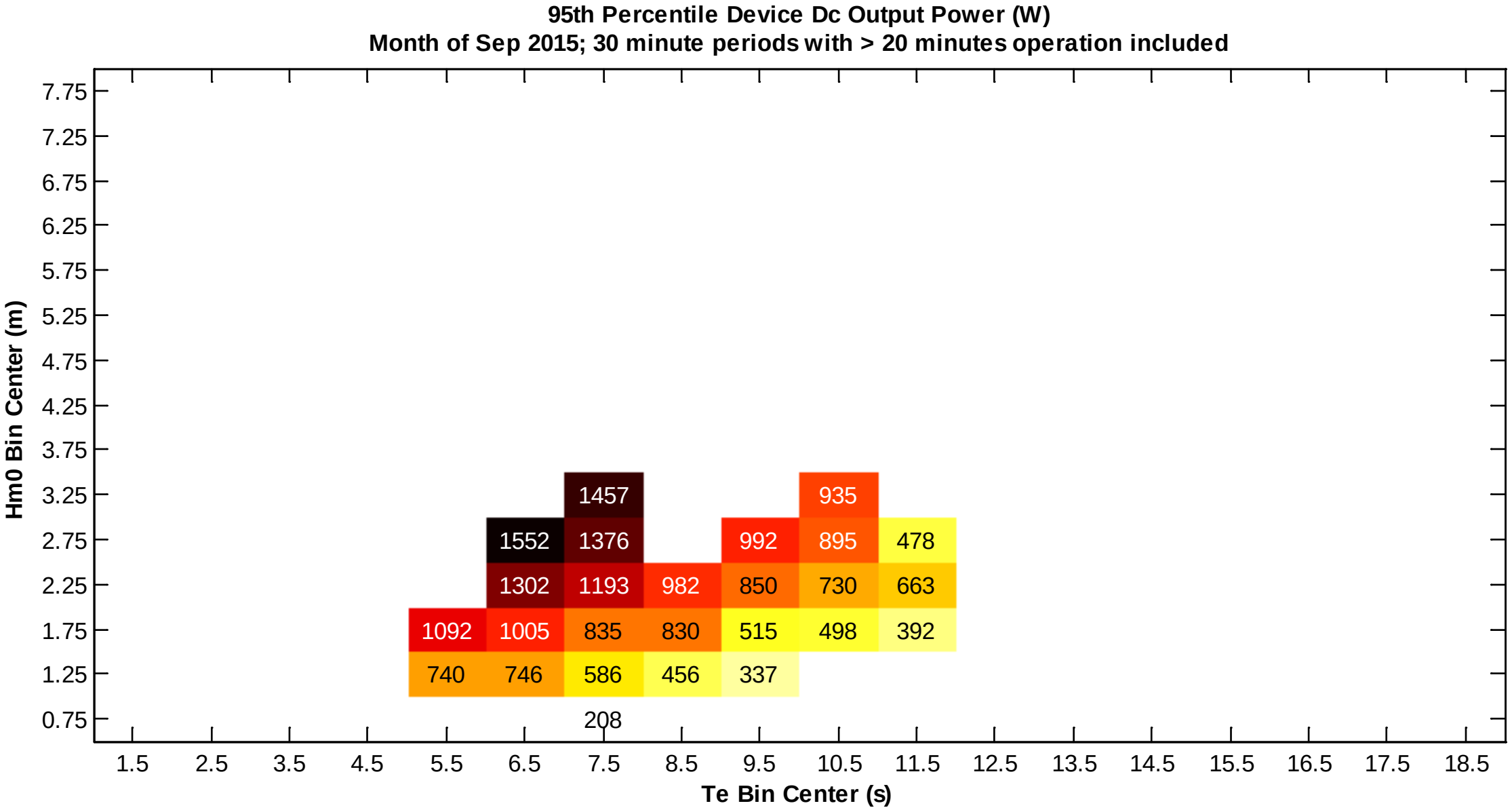

Azura Power Performance – September 2015

Standard deviation of power matrix

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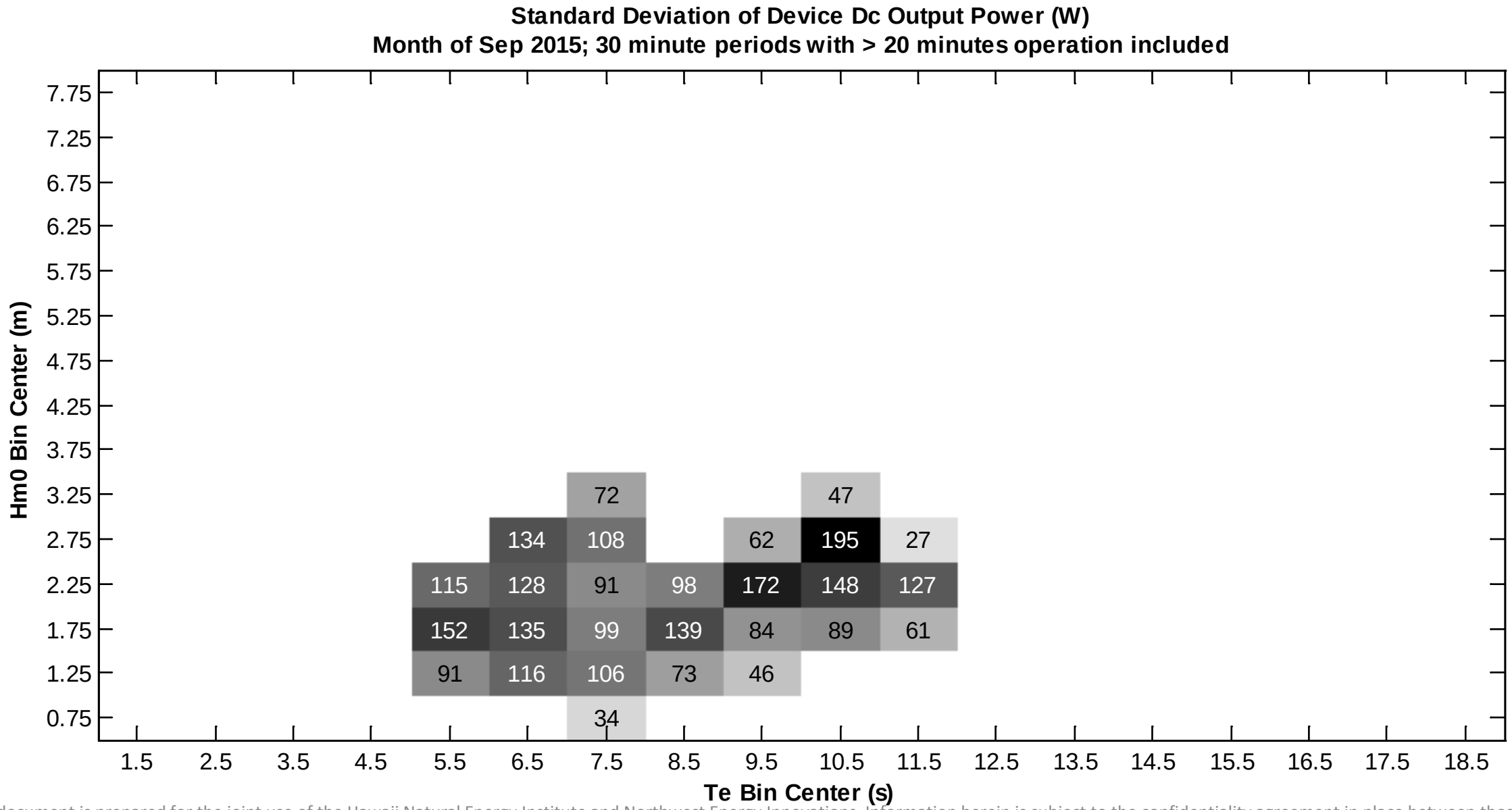

Azura Power Performance – September 2015

Mean capture length matrix

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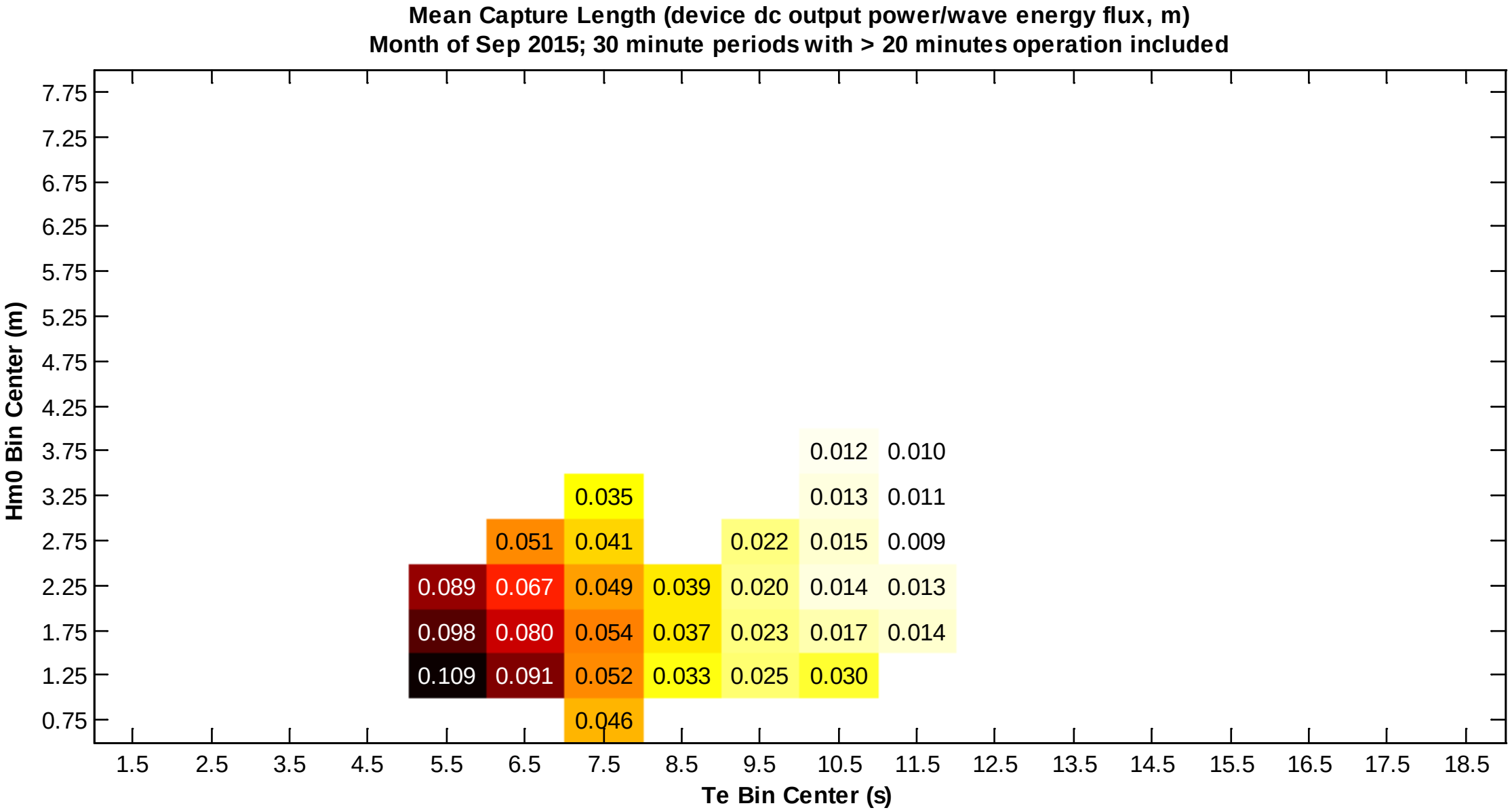

Azura Power Performance – September 2015

Standard deviation of capture length matrix

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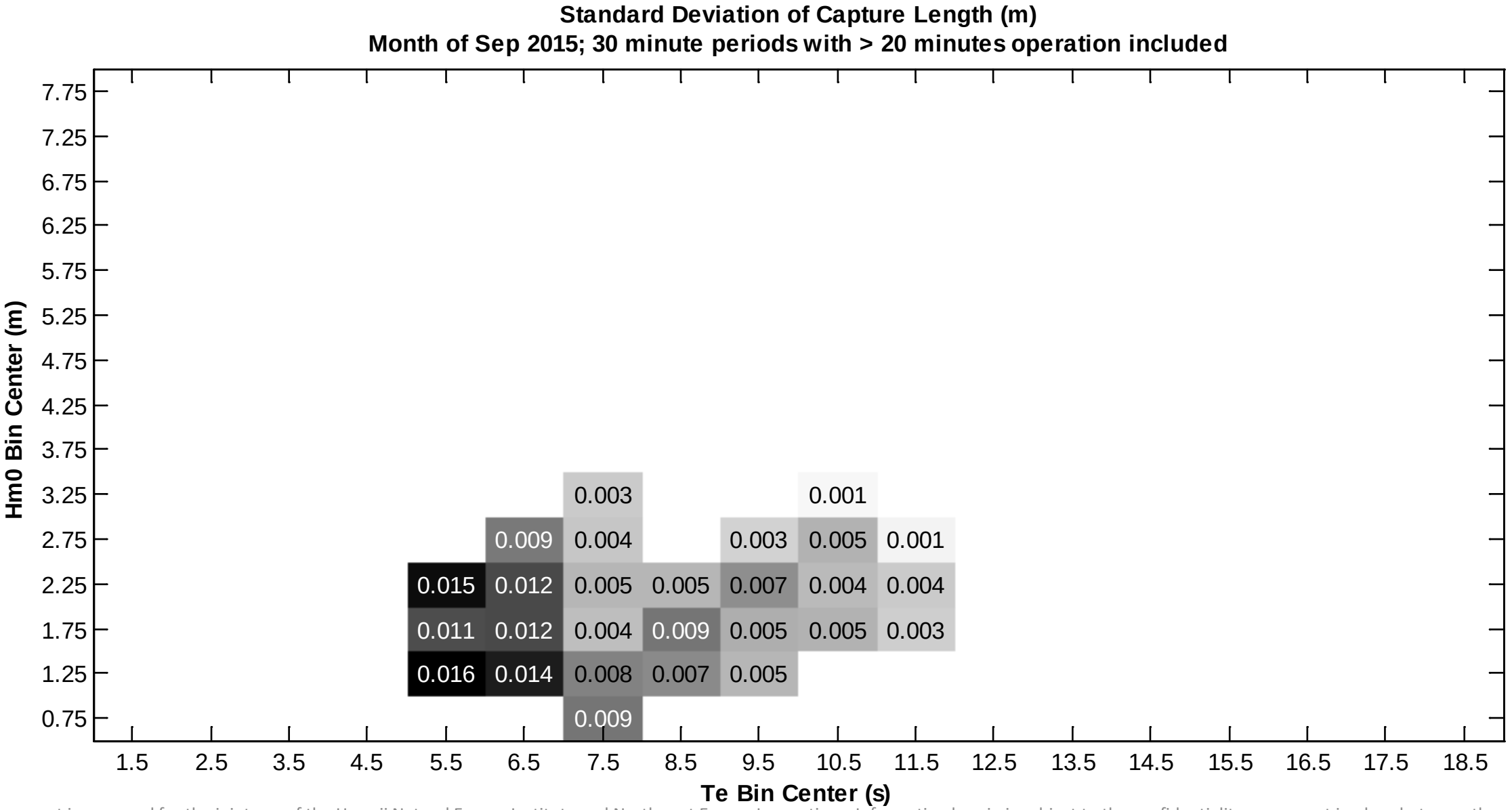

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Azura Power Performance
Cumulative Data June - September 2015

Azura Power Performance – June- September 2015

Data samples collected

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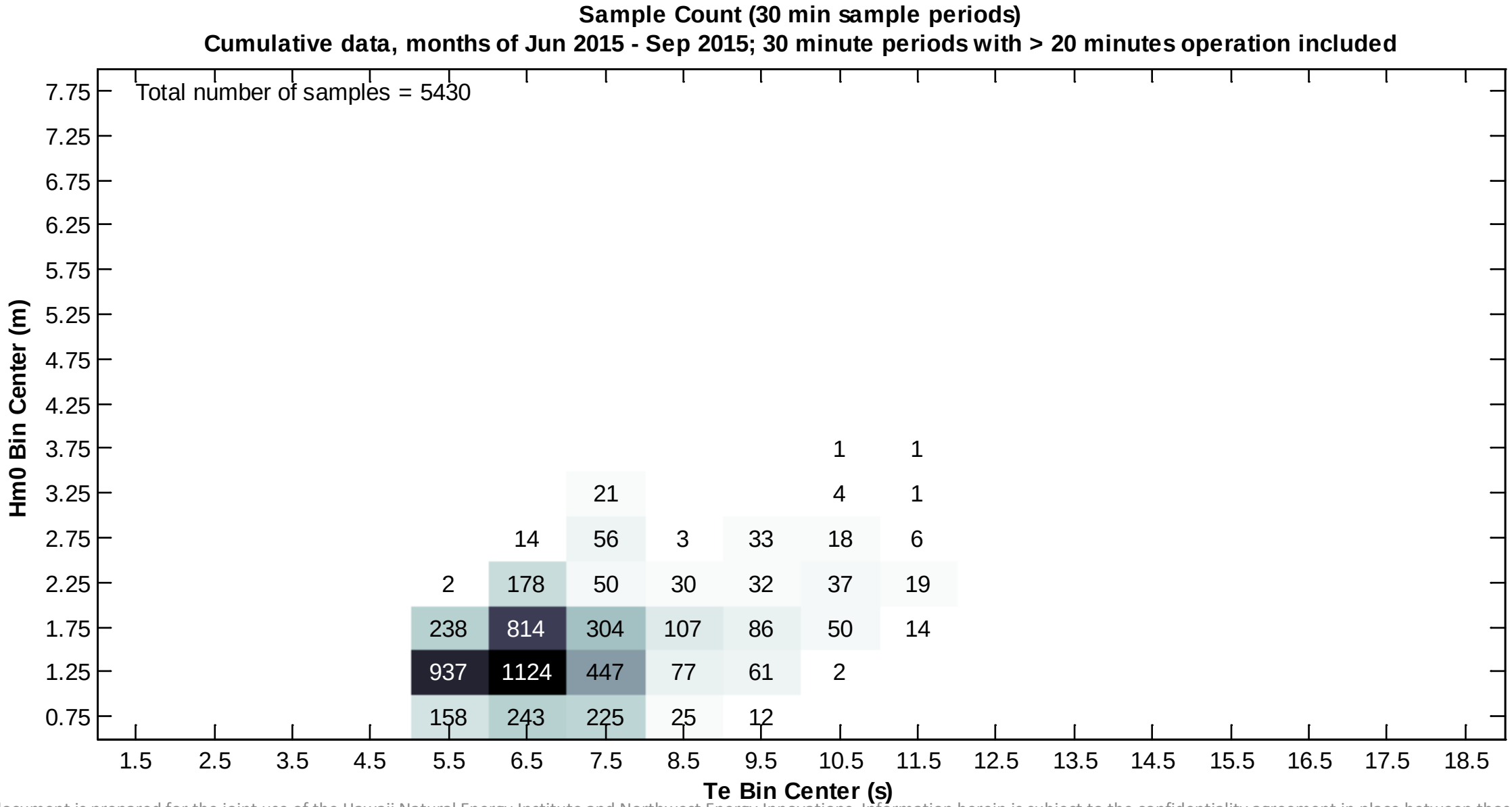

Azura Power Performance – June- September 2015

Mean power matrix

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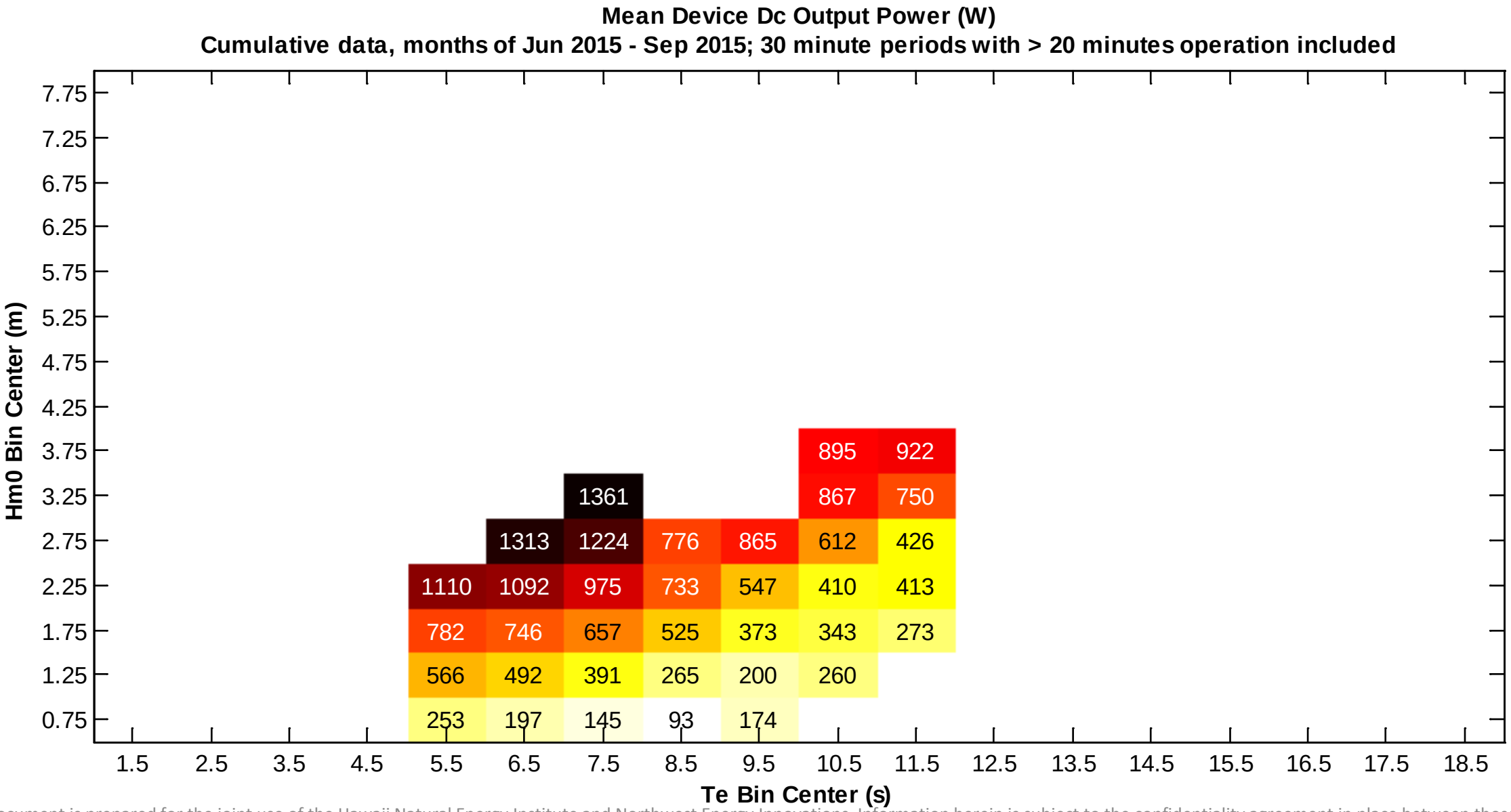

Azura Power Performance – June- September 2015

95th percentile power matrix

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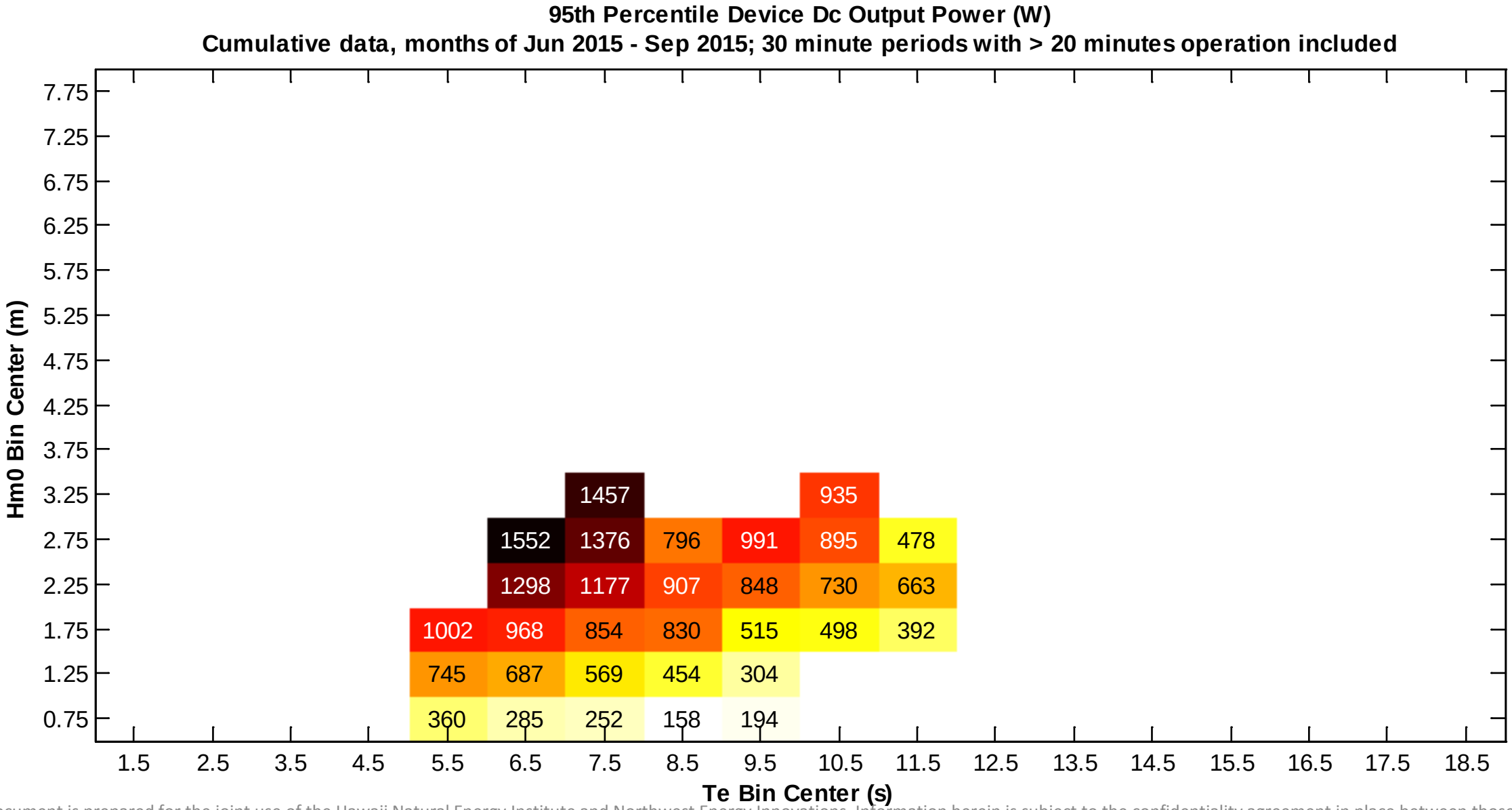

Azura Power Performance – June- September 2015

Standard deviation of power matrix

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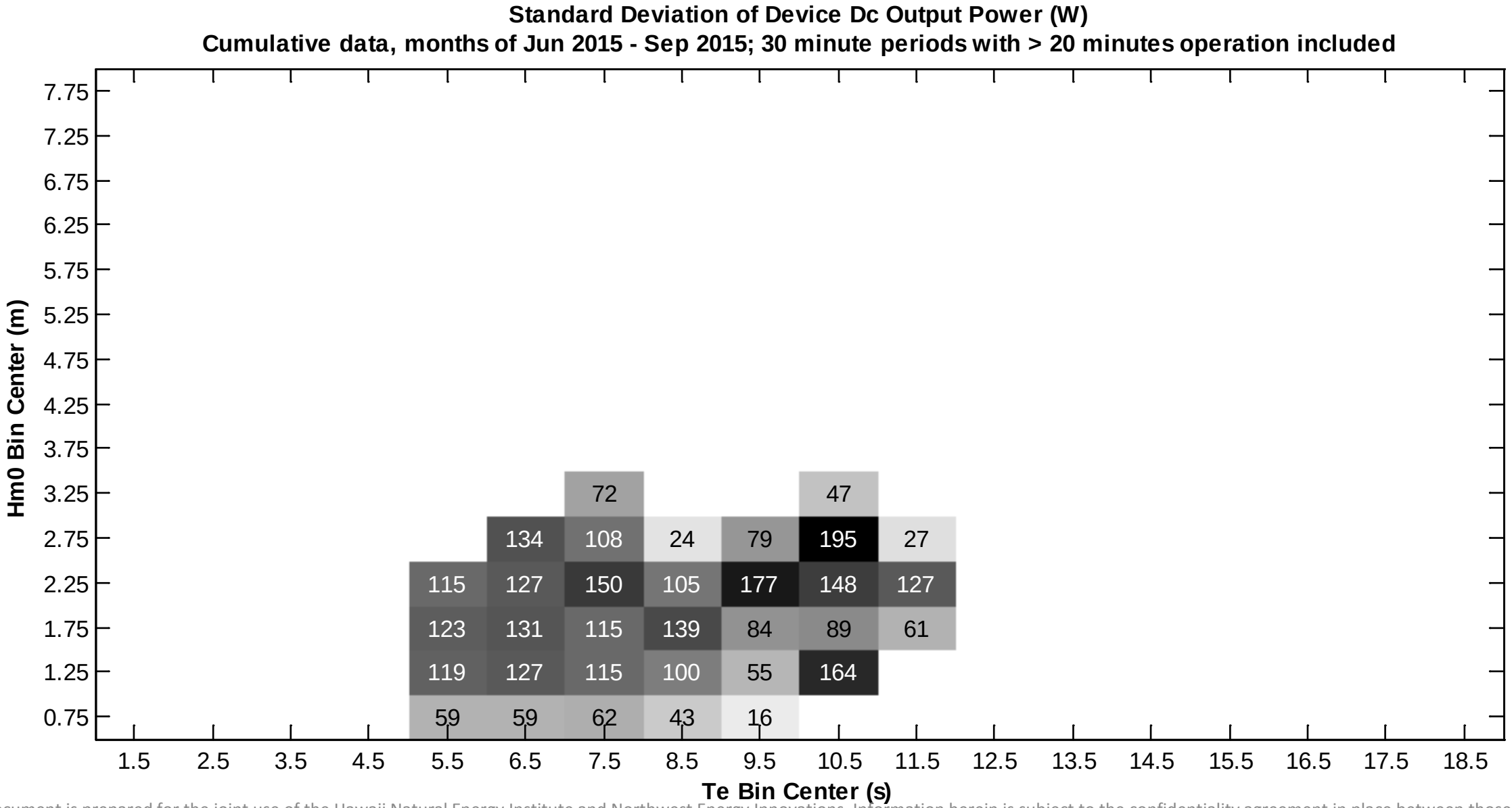

Azura Power Performance – June- September 2015

Mean capture length matrix

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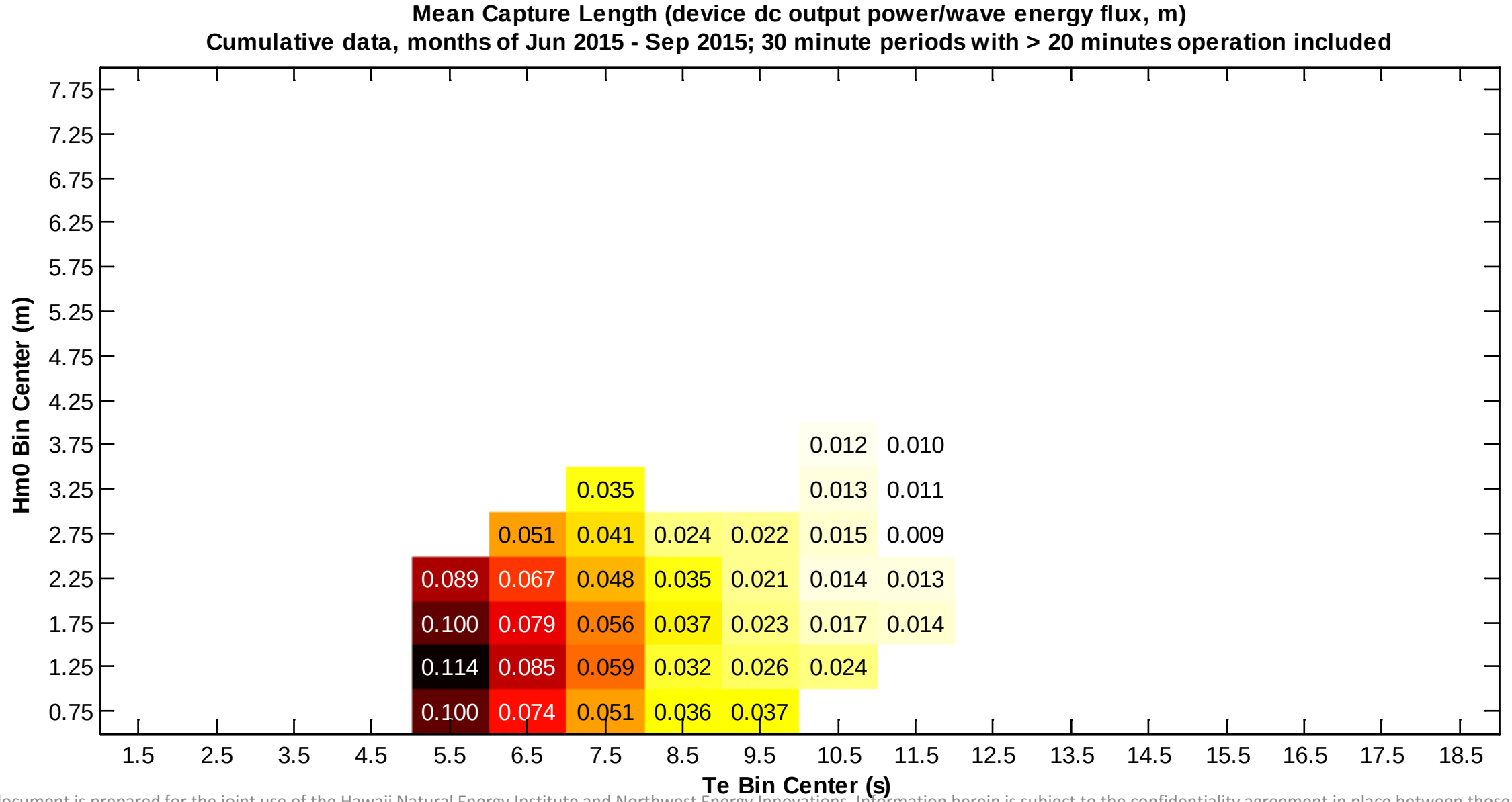

Azura Power Performance – June- September 2015

Standard deviation of capture length matrix

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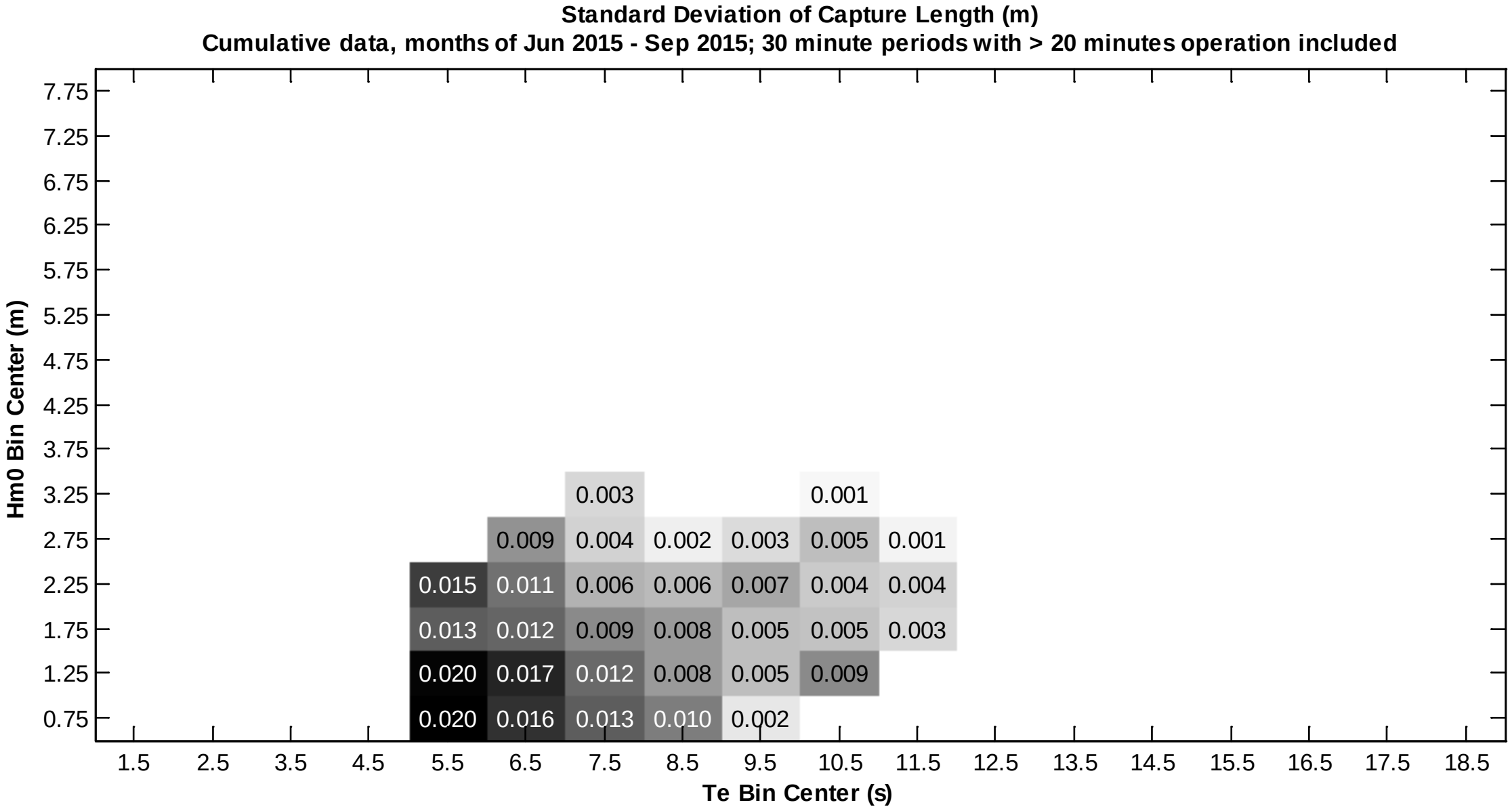

Attachment 2

Azura 30 minute average float angle data plots

Azura 30 min average float angle data through Sept 2015

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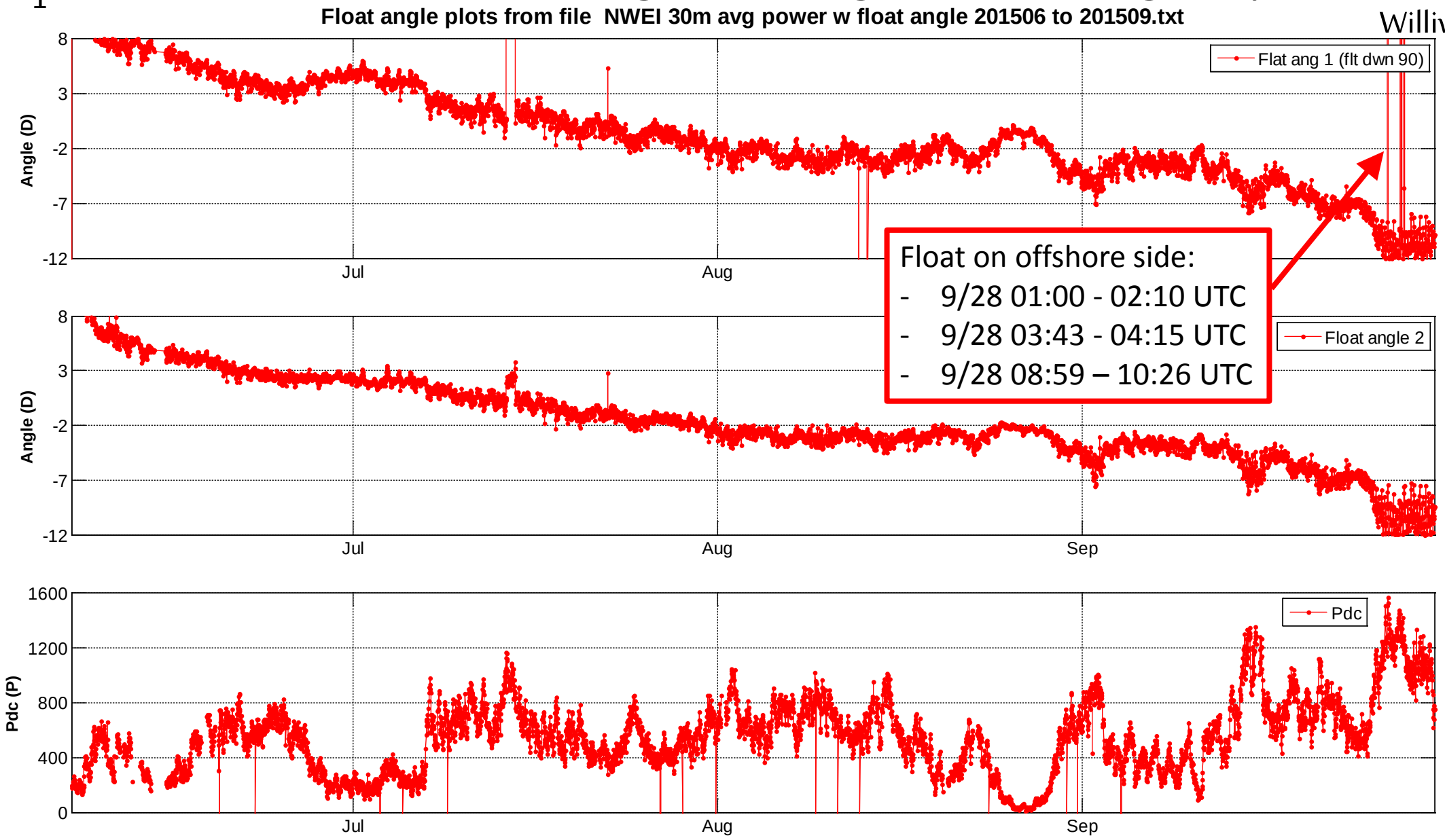

Attachment 3

Azura Response Amplitude Operator Plots and Data

Loaded RAO data with mean wave direction and Azura heading

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Date_time	Op_min	Pdc_W	Pgen_W	Damping recorded	WR_DateTime	Te_s	Hm0_m	MotDisp	Rdc_inv		Data period (NREL/NWEI data)	Data period (Waverider)	Mean wave direction 4-7s (degrees true)	Mean Azura heading (degrees true)
1.3m/5.5s														
20150730_0600	30	463	492	21.1	20150730_0606	5.56	1.42	30	20		20150730_0600	20150730_0606	72	24
20150730_0630	30	427	454	21.2	20150730_0636	5.56	1.34	35	20		20150730_0630	20150730_0636	80	24
20150730_0700	30	590	623	21.3	20150730_0706	5.7	1.32	45	20		20150730_0700	20150730_0706	72	24
20150730_0730	30	584	616	21.4	20150730_0736	5.61	1.22	55	20		20150730_0730	20150730_0736	69	25
20150730_0800	30	620	653	21.5	20150730_0806	5.65	1.33	65	20		20150730_0800	20150730_0806	69	25
20150730_0830	30	598	631	21.6	20150730_0836	5.59	1.35	80	20		20150730_0830	20150730_0836	71	25
1.3/6 s														
20150729_0600	30	468	497	21.1	20150729_0606	5.63	1.33	30	20		20150729_0600	20150729_0606	70	25
20150729_0630	30	472	501	21.2	20150729_0636	5.91	1.37	35	20		20150729_0630	20150729_0636	75	25
20150729_0700	30	559	590	21.3	20150729_0706	5.98	1.37	45	20		20150729_0700	20150729_0706	69	25
20150729_0730	30	575	606	21.4	20150729_0736	5.8	1.33	55	20		20150729_0730	20150729_0736	73	25
20150729_0800	30	583	615	21.5	20150729_0806	5.92	1.33	65	20		20150729_0800	20150729_0806	75	25
20150729_0830	30	633	667	21.6	20150729_0836	5.88	1.35	80	20		20150729_0830	20150729_0836	70	25
2m/6.5s														
20150714_0000	30	1052	1109	21.1	20150714_0006	6.79	2.02	30	20		20150714_0000	20150714_0006	58	26
20150714_0030	30	1161	1222	21.2	20150714_0036	6.93	2.16	35	20		20150714_0030	20150714_0036	51	25
20150714_0100	30	1154	1214	21.3	20150714_0106	6.76	2.15	45	20		20150714_0100	20150714_0106	53	25
20150714_0130	30	1102	1160	21.4	20150714_0136	6.78	2.1	55	20		20150714_0130	20150714_0136	52	26
20150714_0200	30	1120	1181	21.5	20150714_0206	6.71	2	65	20		20150714_0200	20150714_0206	52	26
20150714_0230	30	984	1039	21.6	20150714_0236	6.84	2.01	80	20		20150714_0230	20150714_0236	57	25
1.6m/7.5s														
20150807_1200	30	581	615	21.1	20150807_1206	7.59	1.64	30	20		20150807_1200	20150807_1206	26	26
20150807_1230	30	562	596	21.2	20150807_1236	7.67	1.65	35	20		20150807_1230	20150807_1236	34	25
20150807_1300	30	575	608	21.3	20150807_1306	7.63	1.67	45	20		20150807_1300	20150807_1306	41	26
20150807_1330	30	626	660	21.4	20150807_1336	7.51	1.69	55	20		20150807_1330	20150807_1336	38	27
20150807_1400	30	599	632	21.5	20150807_1406	7.61	1.75	65	20		20150807_1400	20150807_1406	34	26
20150807_1430	30	500	529	21.6	20150807_1436	7.55	1.67	80	20		20150807_1430	20150807_1436	34	26
2.5m/9s														
20150807_0000	30	764	810	21.1	20150807_0006	8.96	2.4	30	20		20150807_0000	20150807_0006	47	27
20150807_0030	30	713	756	21.2	20150807_0036	9.34	2.64	35	20		20150807_0030	20150807_0036	48	27
20150807_0100	30	805	851	21.3	20150807_0106	9.96	2.85	45	20		20150807_0100	20150807_0106	44	27
20150807_0130	30	792	837	21.4	20150807_0136	9.84	2.74	55	20		20150807_0130	20150807_0136	39	26
20150807_0200	30	750	794	21.5	20150807_0206	8.87	2.56	65	20		20150807_0200	20150807_0206	42	26
20150807_0230	30	796	843	21.6	20150807_0236	8.98	2.62	80	20		20150807_0230	20150807_0236	40	26

No load RAO data with mean wave direction and Azura heading

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Date_time	Op_min	Pdc_W	Pgen_W	Damping recorded	WR_DateTime	Te_s	Hm0_m	MotDisp	Rdc_inv		Data period (NREL/NWEI data)	Data period (Waverider)	Mean wave direction 4-7s (degrees true)	Mean Azura heading (degrees true)
1m/7s														
20150820_0800	0	NA	NA	NA	20150820_0806	6.97	1.02	80	NA		20150820_0800	20150820_0806	62	26
20150820_0830	0	NA	NA	NA	20150820_0836	7.04	1.02	80	NA		20150820_0830	20150820_0836	60	25
20150820_0900	0	NA	NA	NA	20150820_0906	7.22	0.98	80	NA		20150820_0900	20150820_0906	56	25
20150820_0930	0	NA	NA	NA	20150820_0936	7.13	1.06	80	NA		20150820_0930	20150820_0936	59	25
20150820_1000	0	NA	NA	NA	20150820_1006	7.12	1.04	80	NA		20150820_1000	20150820_1006	57	25
20150820_1030	0	NA	NA	NA	20150820_1036	7.04	1.03	80	NA		20150820_1030	20150820_1036	59	25
20150820_1100	0	NA	NA	NA	20150820_1106	7.09	0.99	80	NA		20150820_1100	20150820_1106	58	26
20150820_1130	0	NA	NA	NA	20150820_1136	6.79	0.87	80	NA		20150820_1130	20150820_1136	55	25
20150820_1200	0	NA	NA	NA	20150820_1206	6.78	0.88	80	NA		20150820_1200	20150820_1206	58	26
20150820_1230	0	NA	NA	NA	20150820_1236	7.13	0.88	80	NA		20150820_1230	20150820_1236	57	27
1.5/6 s														
20150801_0800	0	NA	NA	NA	20150801_0806	5.58	1.71	80	NA		20150801_0800	20150801_0806	55	25
20150801_0830	0	NA	NA	NA	20150801_0836	5.67	1.74	80	NA		20150801_0830	20150801_0836	58	24
20150801_0900	0	NA	NA	NA	20150801_0906	5.62	1.69	80	NA		20150801_0900	20150801_0906	60	25
20150801_0930	0	NA	NA	NA	20150801_0936	5.79	1.78	80	NA		20150801_0930	20150801_0936	60	25
20150801_1000	0	NA	NA	NA	20150801_1006	5.77	1.52	80	NA		20150801_1000	20150801_1006	62	25
20150801_1030	0	NA	NA	NA	20150801_1036	5.83	1.53	80	NA		20150801_1030	20150801_1036	63	25
20150801_1200	0	NA	NA	NA	20150801_1206	5.9	1.54	80	NA		20150801_1200	20150801_1206	65	25
20150801_1230	0	NA	NA	NA	20150801_1236	5.92	1.62	80	NA		20150801_1230	20150801_1236	67	25
20150801_1300	0	NA	NA	NA	20150801_1306	6	1.78	80	NA		20150801_1300	20150801_1306	62	25
20150801_1330	0	NA	NA	NA	20150801_1336	5.87	1.53	80	NA		20150801_1330	20150801_1336	59	26
2m/6.5s														
20150915_2030	0	NA	NA	NA	20150915_2036	6.36	2.23	80	NA		20150915_2030	20150915_2036	56	25
20150915_2130	0	NA	NA	NA	20150915_2136	6.43	2.13	80	NA		20150915_2130	20150915_2136	60	26
20150915_2200	0	NA	NA	NA	20150915_2206	6.42	1.94	80	NA		20150915_2200	20150915_2206	58	26
20150915_2230	0	NA	NA	NA	20150915_2236	6.45	2.14	80	NA		20150915_2230	20150915_2236	62	25
20150915_2300	0	NA	NA	NA	20150915_2306	6.46	1.93	80	NA		20150915_2300	20150915_2306	63	25

No load RAO data with mean wave direction and Azura heading

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Date_time	Op_min	Pdc_W	Pgen_W	Damping recorded	WR_DateTime	Te_s	Hm0_m	MotDisp	Rdc_inv		Mean wave direction 4-7s (degrees true)	Mean Azura heading (degrees true)
No load periods												
20150901_2130	1	NaN	NaN	NaN	20150901_2136	10.84	3.57	80	NaN		36	26
20150901_2200	0	NaN	NaN	NaN	20150901_2206	9.94	2.99	80	NaN		35	27
20150901_2230	0	NaN	NaN	NaN	20150901_2236	10.8	3.7	80	NaN		27	27
20150904_0630	0	NaN	NaN	NaN	20150904_0636	10.17	1.6	80	NaN		72	25
Mot disp 45 c/rev periods												
20150902_2230	30	416	411	21.3	20150902_2236	11.84	2.04	45	20		16	26
20150905_1300	30	238	235	21.3	20150905_1306	11.08	1.64	45	20		54	28
20150906_1300	30	287	284	21.3	20150906_1306	11.38	1.99	45	20		55	28
20150907_0100	30	483	478	21.3	20150907_0106	11.58	2.66	45	20		68	26
20150907_1900	30	267	263	21.3	20150907_1906	10.95	2.23	45	20		65	25

RAO plots for load and no load

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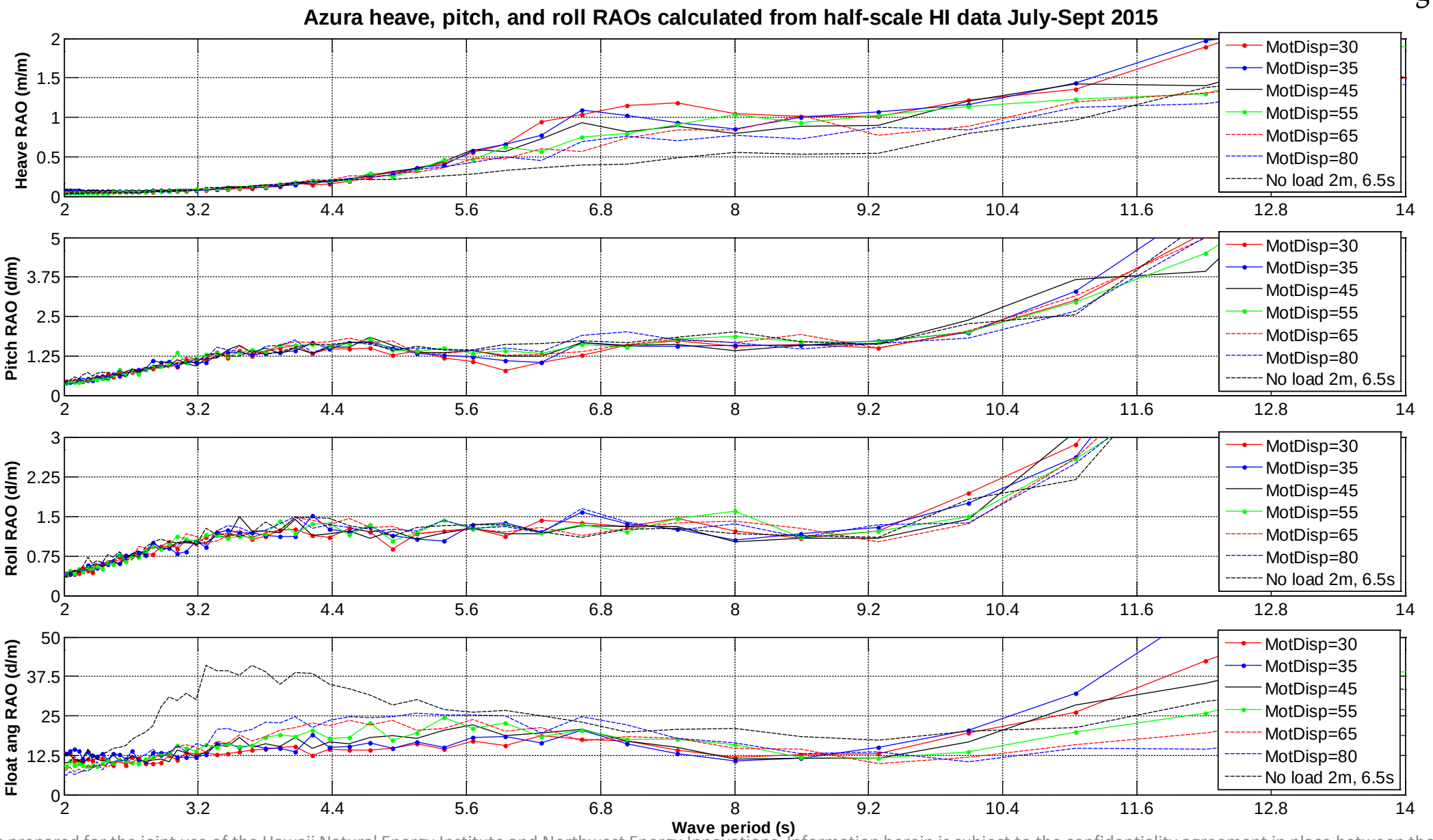

RAO plots for long and short period waves compared

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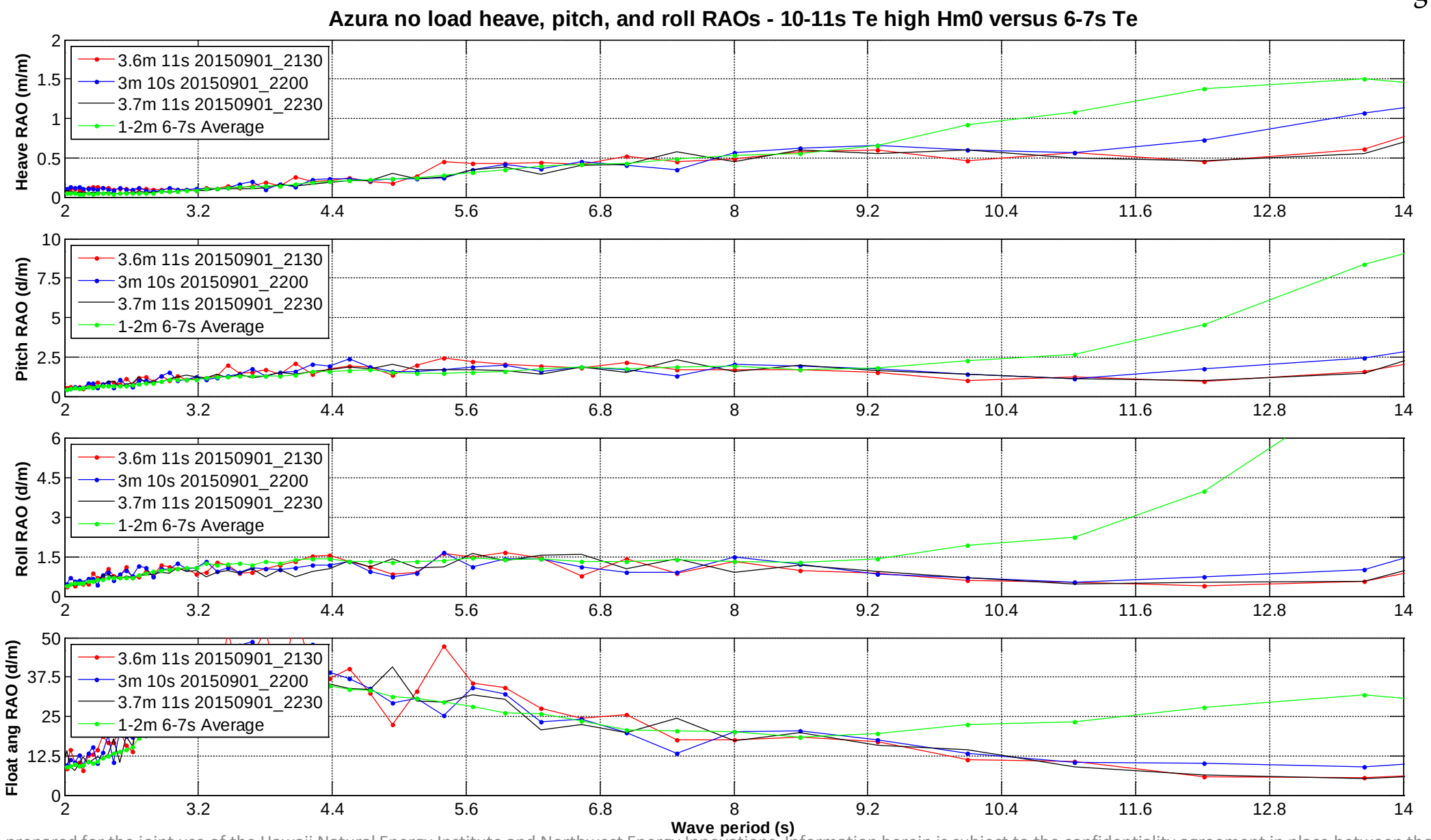

Attachment 4

Azura cRIO Enclosure and Drybox Humidity

Azura cRIO enclosure and drybox humidity Sept 2015

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