Tidal Energy Resource Characterization and Turbulence Assessment at AMEC's Tidal Energy Test Site

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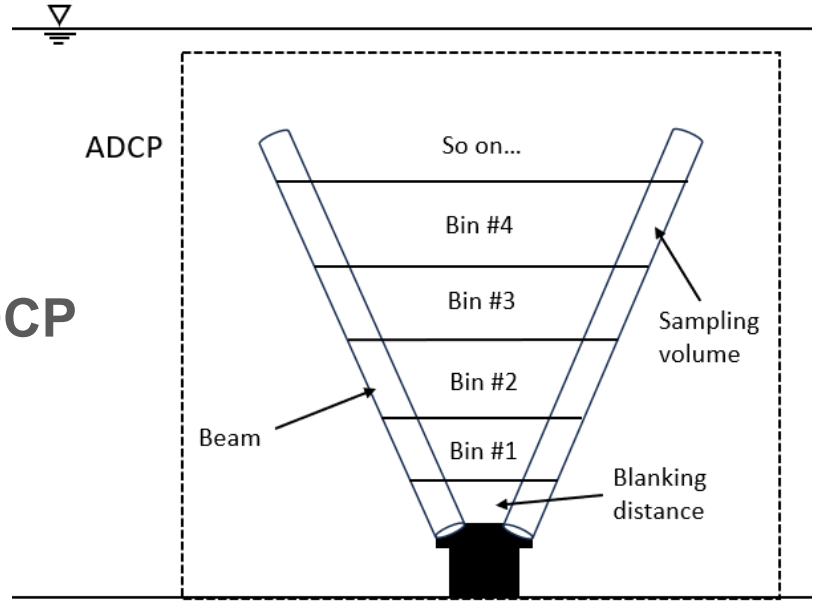
Motivation

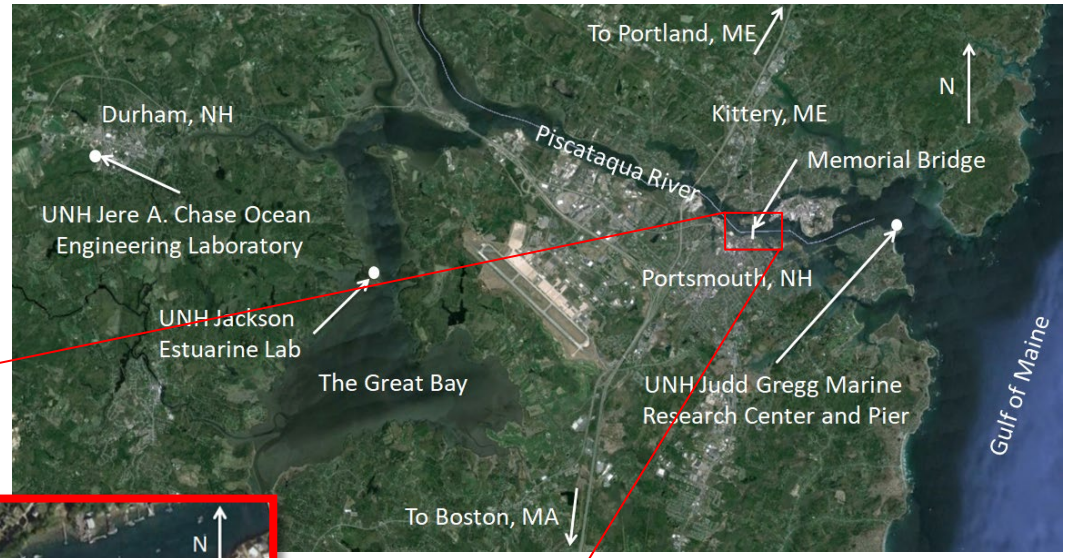
- A tidal energy resource characterization aims to provide details on average flow conditions at a specific test site

- Is this information detailed enough to inform design?
  - Acoustic Doppler Current Profilers (ADCPs) are typically used
  - Acoustic Doppler Velocimeters (ADVs) can capture what an ADCP would miss



Where is AMEC's tidal energy test site?

Right: Map of the Great Bay/Piscataqua River Estuary. Imagery ©2017 Google, Data SIO, NOAA, U.S. Navy, NGA, GEBCO, Map data ©2017 Google.

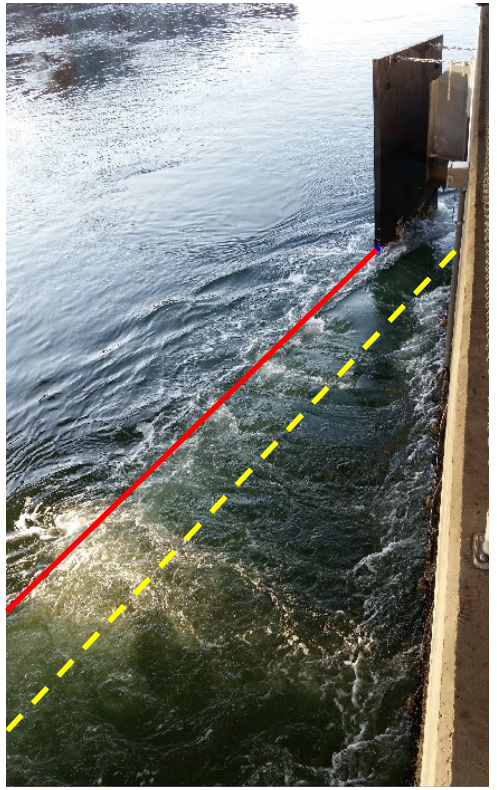


Left: Map of the deployment site. Imagery ©2017 Google, Map data ©2017 Google

AMEC's Tidal Energy Test Site ("Living Bridge Project")

- Tidal Energy Test and Demonstration Site
- Deployment off 15m x 6m floating test platform, turbines up to D~3m (cross flow/axial flow)
- Maximum currents >2.5 m/s during ebb tide, stronger ebb than flood at site
- Nominal depth ~18m, tidal range ~3.7m, platform attached to bridge pier via vertical guide posts

- Separated flow / shear layer shed from bridge pier (yellow)
- Tip vortex and wake from fender, with air entrainment (red)



Additional Questions

- Where is the transverse shear layer relative to the turbine deployment position / moon pool of the TDP?

- How does it affect the local resource characterization values?
  - Power
  - Forces

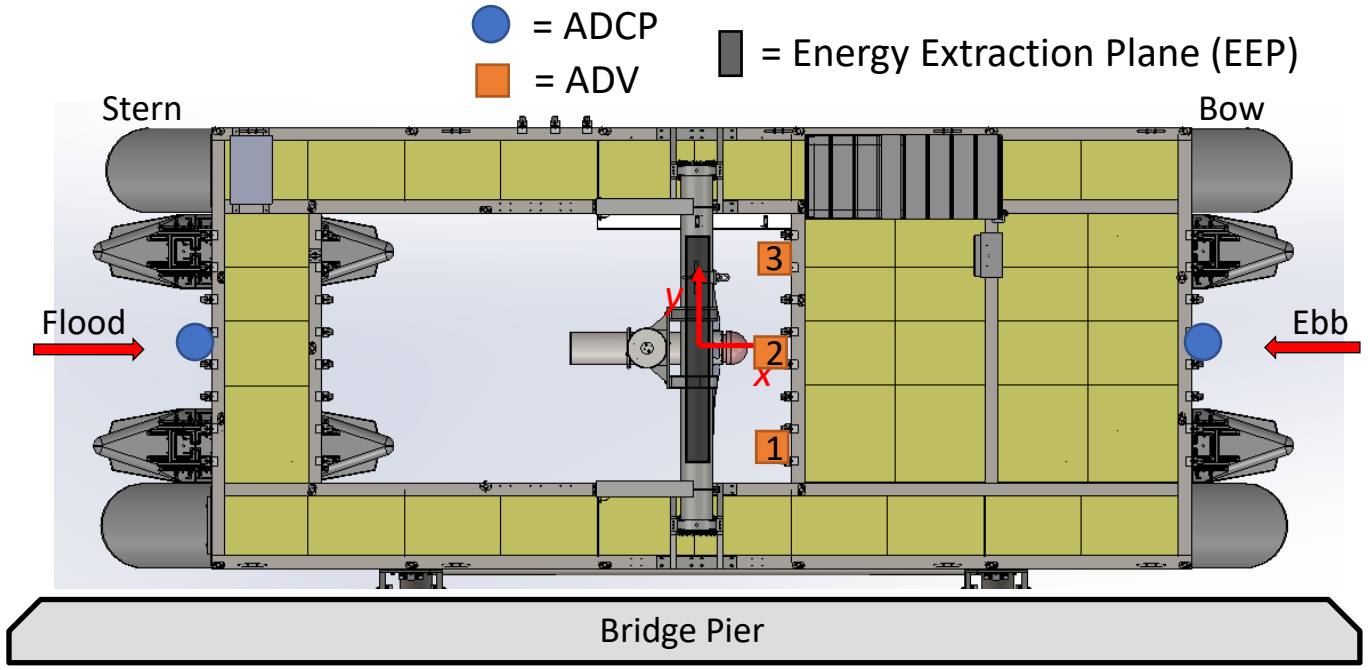
Instrumentation set up

- 3 x Nortek Vector ADVs

	ADV 1	ADV 2	ADAV 3
Streamwise offset from EEP [m]	0.5	0.5	0.5
Cross Stream offset [m]	-1.25	0	1.25
Orientation	Downward Facing	Downward Facing	Downward Facing
Deployment Depth [m]	2.0	2.0	2.0
Record Dates	8/17/23 - 10/20/23	8/17/23 – 10/20/23	8/17/23 – 10/20/23
Sampling Rate [Hz]	64	64	64

- 2 x Nortek Signature 1000 ADCPs

	ADCP 1	ADCP 2
Streamwise offset from EEP [m]	-6.4	6.4
Cross Stream offset [m]	0	0
Orientation	Downward Facing	Downward Facing
Deployment Depth [m]	0.45	0.45
Record Dates	8/17/23 - 12/15/23	8/17/23 – 12/15/23
Sampling Rate [Hz]	1	1
Bin size [m]	0.2	0.2
Blanking Distance [m]	0.2	0.2
Number of bins	108	108

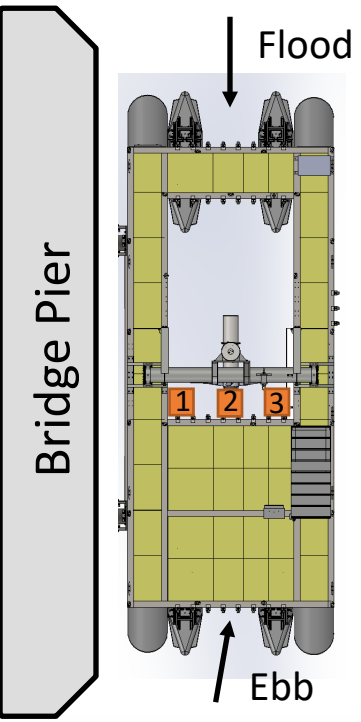


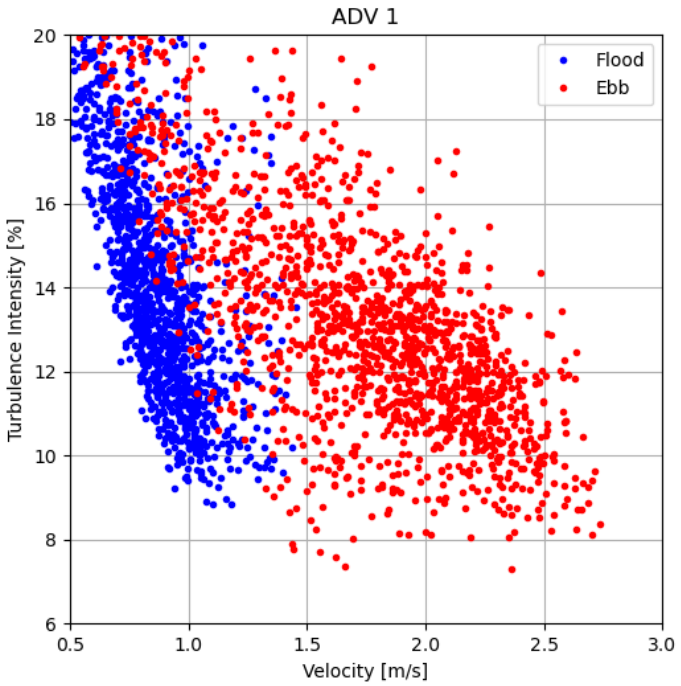
- Data synchronization and logging
  - UNH-MODAQ (Modular Ocean Data Acquisition) system for the ADVs
  - ADCPs continuously synced to an NTP and internally logging
  - UNH-MODAQ was developed in partnership with the National Renewable Energy Lab (NREL)

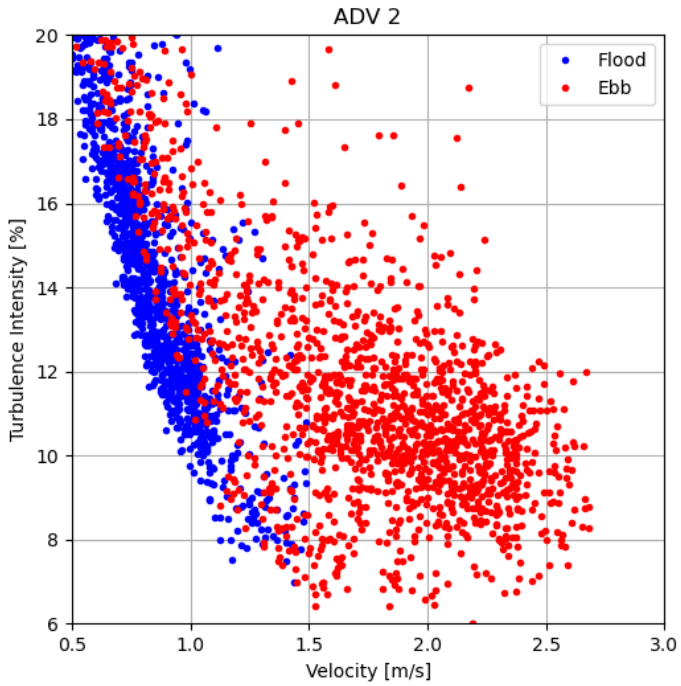
Turbulence statistics

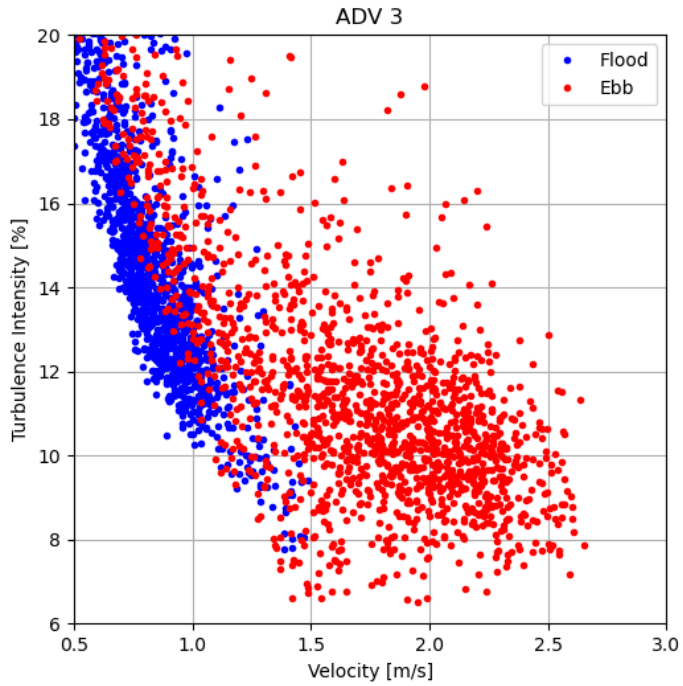
- **Turbulence intensity using 2-minute ensembles**
  - $TI = \frac{\sigma(u')}{\bar{u}} * 100\ (\%)$

	ADV 1 [%]	ADV 2 [%]	ADV 3 [%]
Flood	15.0	15.1	15.2
Ebb	13.9	12.3	12.3





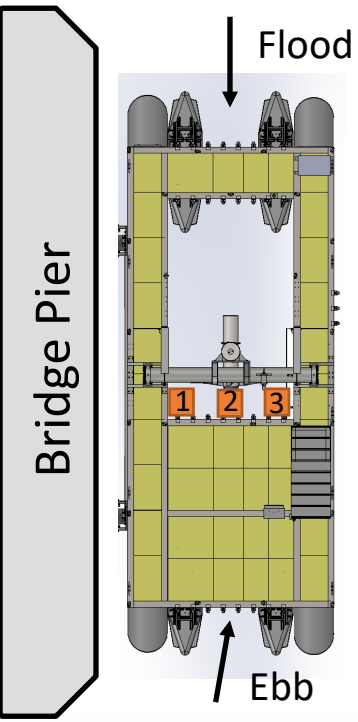


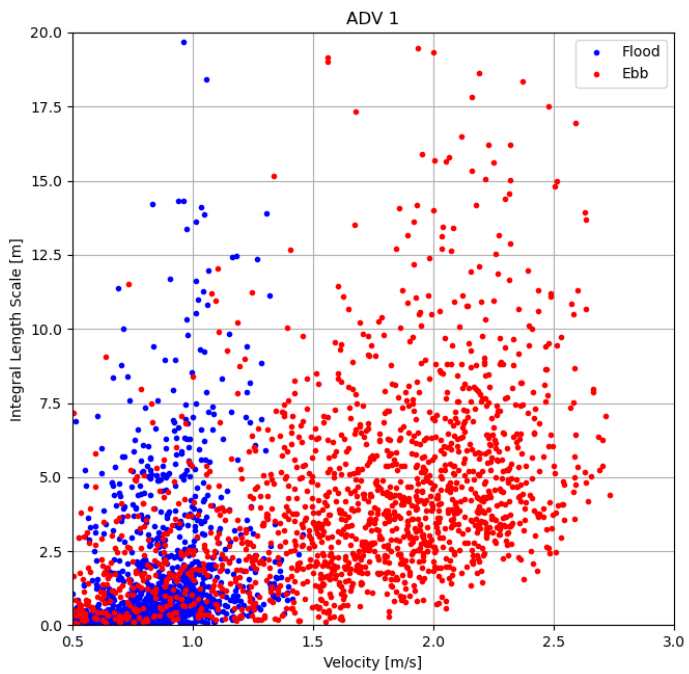


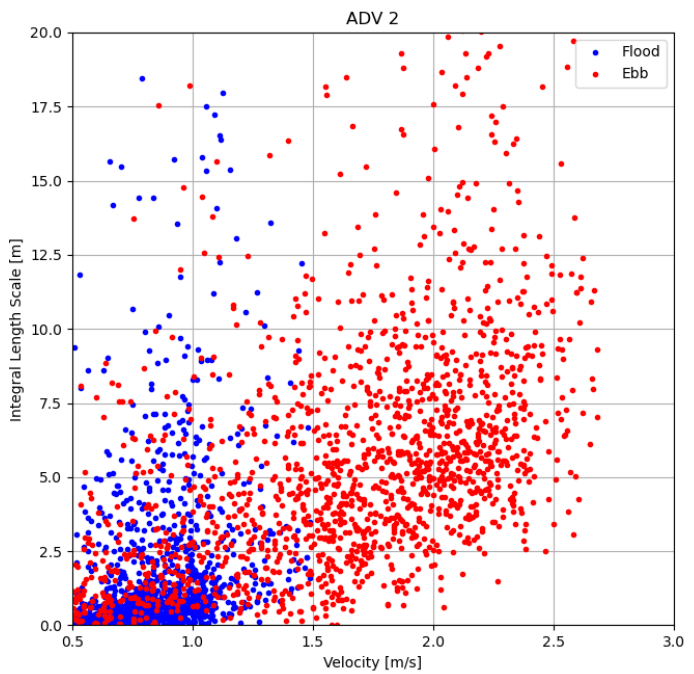
Turbulence statistics

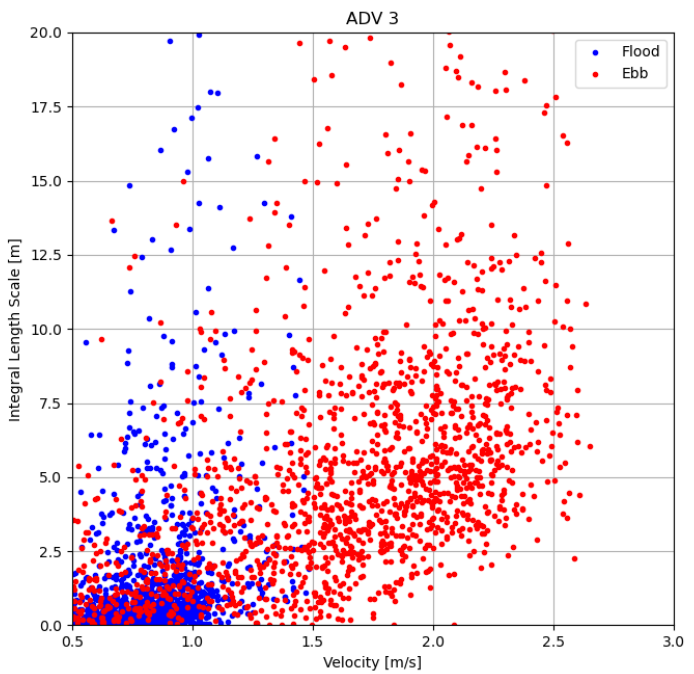
- **Integral length scale using autocorrelation**
  - $ILS = \bar{u} \int_0^T \frac{\langle u'(t)u'(t-dt)\rangle}{u'^2} dt$

	ADV 1 [m]	ADV 2 [m]	ADV 3 [m]
Flood	1.62	1.82	1.60
Ebb	4.33	5.95	5.67







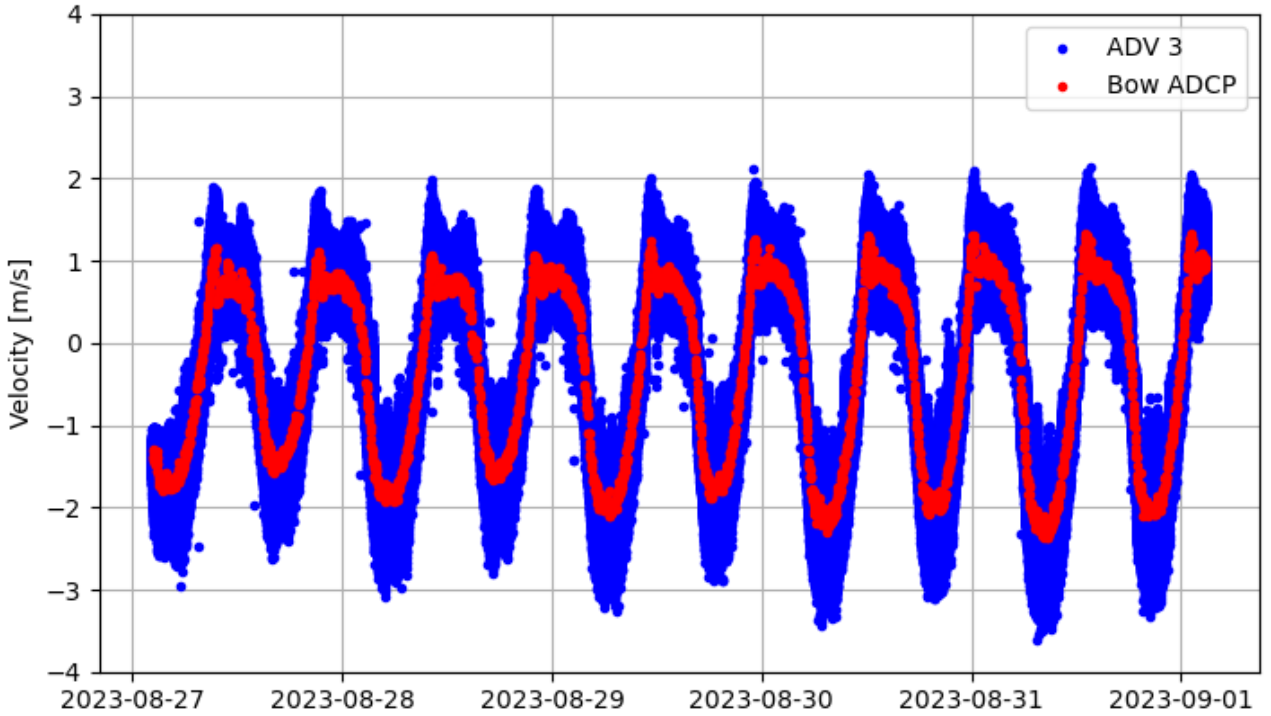


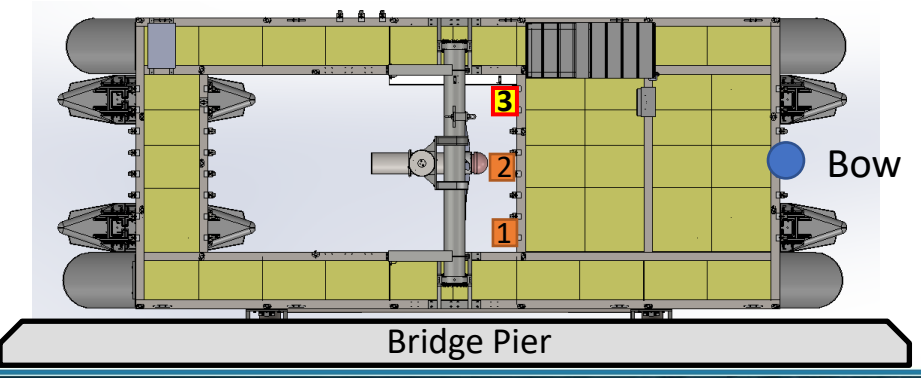
Time series of both ADCP and ADV

- A typical tidal energy resource characterization can provide useful averages

Force Density [N/m²]	Power Density [W/m²]	Max. Velocity [m/s]
699	863	2.37

- An additional turbulence assessment can give information on smaller scale dynamics
  - At ADV 3, 37% more power, 20% more drag than bow ADCP





	ADV 1	ADV 2	ADV 3
Force Density [N/m²]	808	867	836
Power Density [W/m²]	1089	1251	1186
Max. Velocity [m/s]	3.56	3.45	3.46

Preliminary Conclusions

- **Evaluation of smaller scale structures leads to higher estimates of power and loading**
- **Effects of shear layer may extend less than halfway through the moonpool**
- **Shear layer exhibits higher turbulence and lower power density**

Future analysis

- Manipulate averaging window based on more relevant timescales
- Examine directional effects of the shear layer
- Spectral analysis, including cross-spectra
- Power weighted velocity via method of bins over project device area in accordance with IEC standards
- Uncertainties, error bars, other error statistics

References and Acknowledgments

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Questions?

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