ADV measurements for turbulent inflow characterization in the East River New York City

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1. Background

Acoustic Doppler velocimeter (ADV) measurements at the centerline of the energy extraction plane, or turbine hub elevation, provide high resolution characterization of the inflow conditions from which available hydrokinetic power and hydrodynamic loading can be calculated at a site. Tidal power is predictable as its availability is governed mainly by the lunar and solar orbital period. This measurement provides variation of tidal cycle and speed at the site, which can provide accurate information to a utility on when the supply will be available and in what quantities.

2. Field site and data collection

The East River is a tidal strait with semidiurnal characteristics. The study site is in the immediate vicinity of Roosevelt Island, just south of Hell Gate. The channel section is approximately 240 m wide and has a mean lower low water of 7.6 m and mean high water of 9.14 m (Fig. 1a and 1b). Hub-height ADV measurements were conducted continuously for two months. The long term deployment resulted in extensive biofouling, including deposition of barnacles, corrosion, and ultimately instrument failure (Fig. 1c and 1d).

Figure 1 (a) Plan view of the site (b) Verdant Gen4 tidal turbine deployment at site (c) Underwater signal processor infested with barnacles (d) ADV transmitter damage due to biofouling

The two months of data consist a large amount of samples (~10^8), and was divided into several sets before post-processing. ORNL ADV post-processing algorithms [1] were used for QA/QC and obtaining relevant parameters. The peak longitudinal velocity at spring and neap tide can differ by 0.5 m/s (Fig 2a.). Fig 2b shows the typical variation of all three velocity components over tidal cycles.

3. Preliminary results

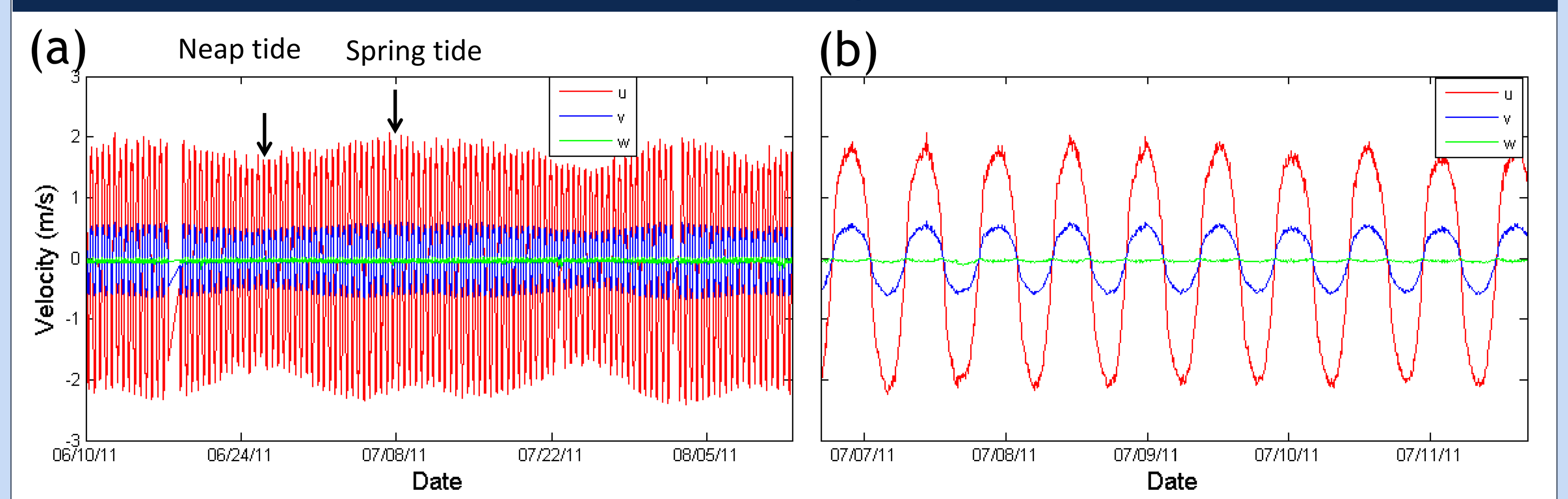

Figure 2 (a) Velocity timeseries over the whole period of records (b) zoomed view of the velocity timeseries

Hydrokinetic power is predictable because the currents high enough to produce power occur in each tidal period. The SED peaks at period T = 12.43 hours (f = 2.24x10^{-5}Hz) in Fig 3, which corresponds to the period of the mean velocity fluctuation shown in Fig. 2, and the period of the main lunar semidiurnal constituent (M2), the primary driver of the tidal energy.

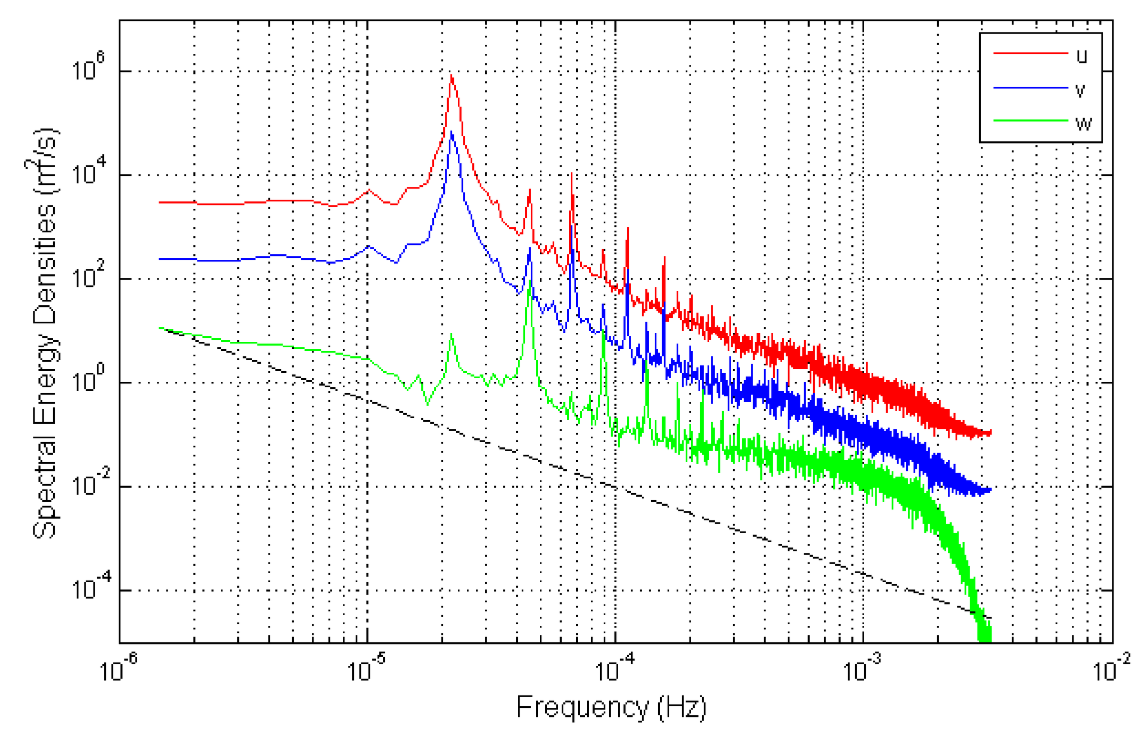

Figure 3 Velocity spectra at low frequency

The theoretical hydrokinetic power density (P/A) at a site can be calculated using the formula:

$$P/A = 0.5\,\rho\,(U_p)^3$$

with A = the energy extraction plane area, ρ = water density and U_p = water speed along the principal axis of the flow. Preliminary calculations based on the collected data yields a mean P/A of 1.98 kW/m² (Fig 4a), which is an order of magnitude higher than in the recent tidal energy resource assessment map (200-300 w/m²) [2].

The technical resource available is a portion of the theoretical resource that can be captured by a certain technology. This is calculated by including the operating conditions of the turbine, which include the turbine cut in speed and rated speed, which are of 1.0 and 2.1 m/s for the Verdant "Gen5" turbine. The values of other limitation parameters are assumed according to [3]. The calculated technical resource at the site is therefore 0.78 kW/m² (Fig 4b).

3. Preliminary results (continued)

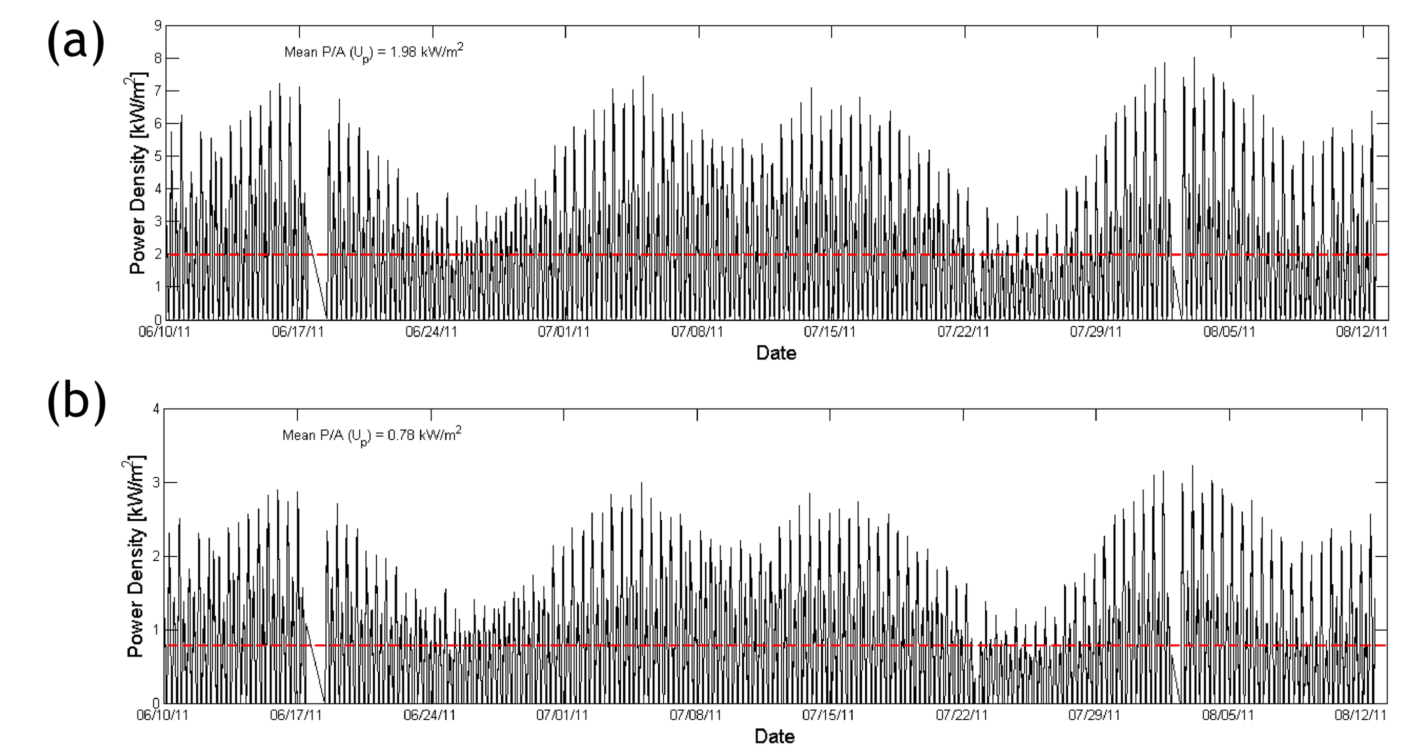

Figure 4 Timeseries of (a) theoretical power density (b) technical power density

4. Conclusions

1. While useful for identifying high power density sites regionally, tidal energy resource assessment maps only provide coarse assessment of resource potential at the project and machine scale. This study shows that maps can greatly under-predict the available hydrokinetic energy at the hydrokinetic site, and highlights the importance of local, representative current measurements for tidal energy site development.
2. Long term ADV deployments should be carefully planned to avoid instrument failure due to environmental factors.

5. References

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2. Defne, Z., Haas, K.A., Fritz, H.M., Jiang, L., Shi, X., French, S.P., Smith, B.T., Neary, V.S. and Stewart, K.M. (In-Press, 2012) National geodatabase of tidal stream power resources in the USA. *Renewable and Sustainable Energy* Reviews.
3. Hageman, G., Polagye, B., Bedard, R. and Previsic, M. (2006) Methodology for estimating tidal current energy resources and power production by tidal in stream energy conversion (TISEC) devices. EPRI.

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7. Point of Contact

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