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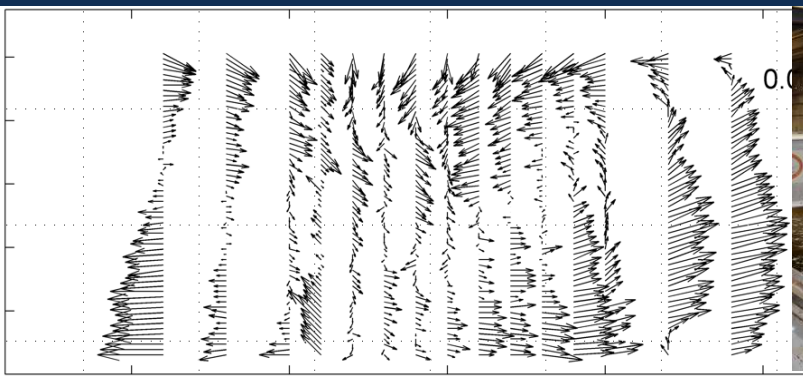
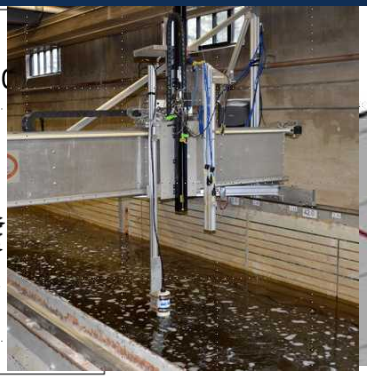
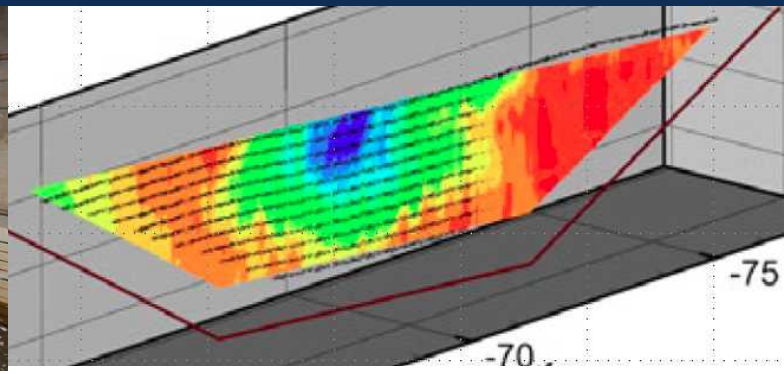




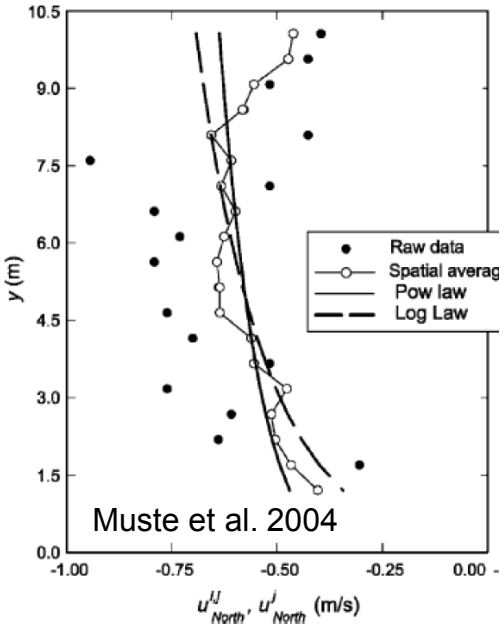


Error assessment for spatio-temporally averaged moving vessel ADCP measurement in a large laboratory channel

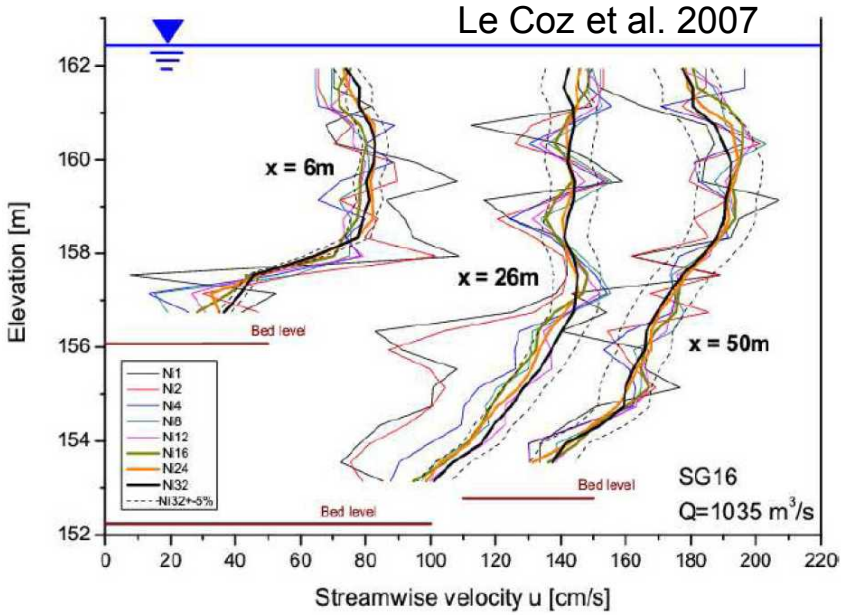
Budi Gunawan, Vincent Neary, Craig Hill

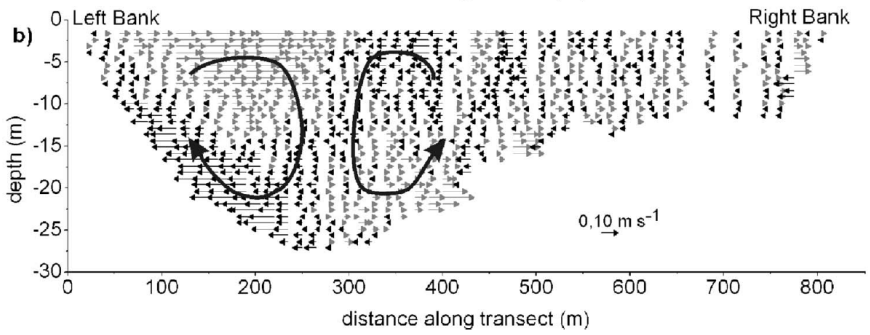
ASCE Hydraulic Measurements & Experimental Methods Conference, Durham, NH, July 9-12, 2017

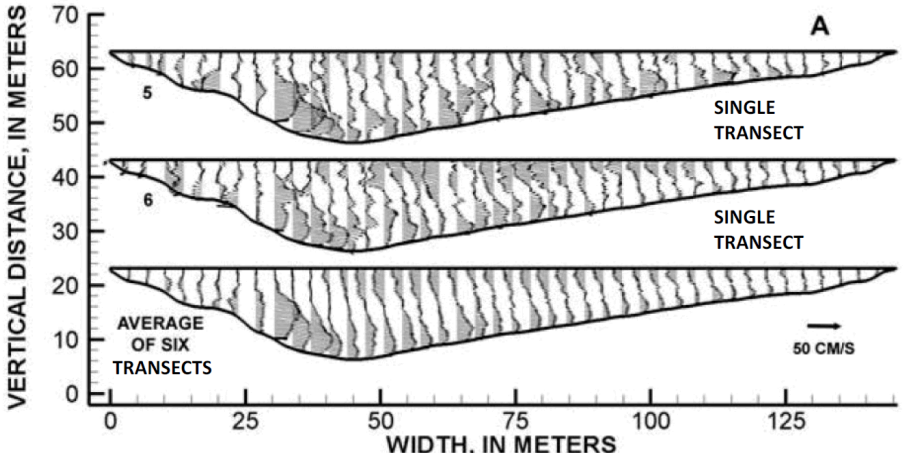
Spatio-Temporal Averaging (STA)



Le Coz et al. 2007







Szupiany et al. 2007

Dinehart & Burau 2005

Research Questions

- How much improvement can STA make?
- How does boat speed (ybin) affect STA accuracy?

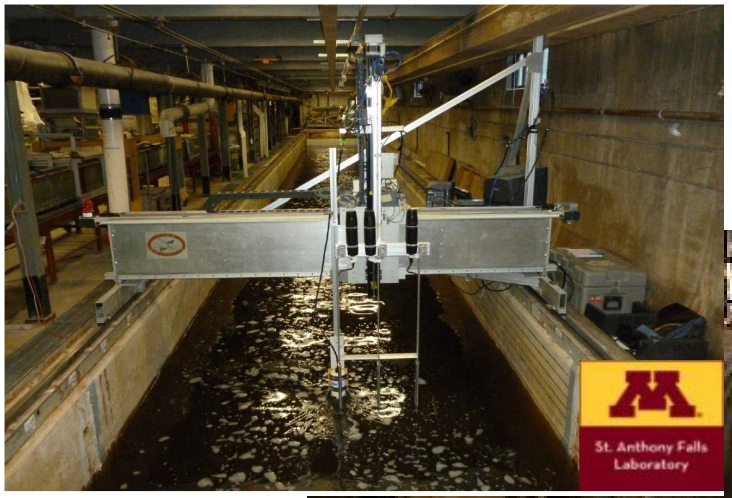
Approach taken:

Controlled laboratory testing – eliminate:

- Changes in flow condition
- Different ADCP paths
- Change in beam orientation

Test Setup

- SAFL Main Channel – 85 m long, 2.75 m wide & 1.8 m deep
- Avg. velocity 0.4 m/s; h = 1.15 m, Q = 1.27 m^3/s
- Re = 10^6, Fr = 0.12

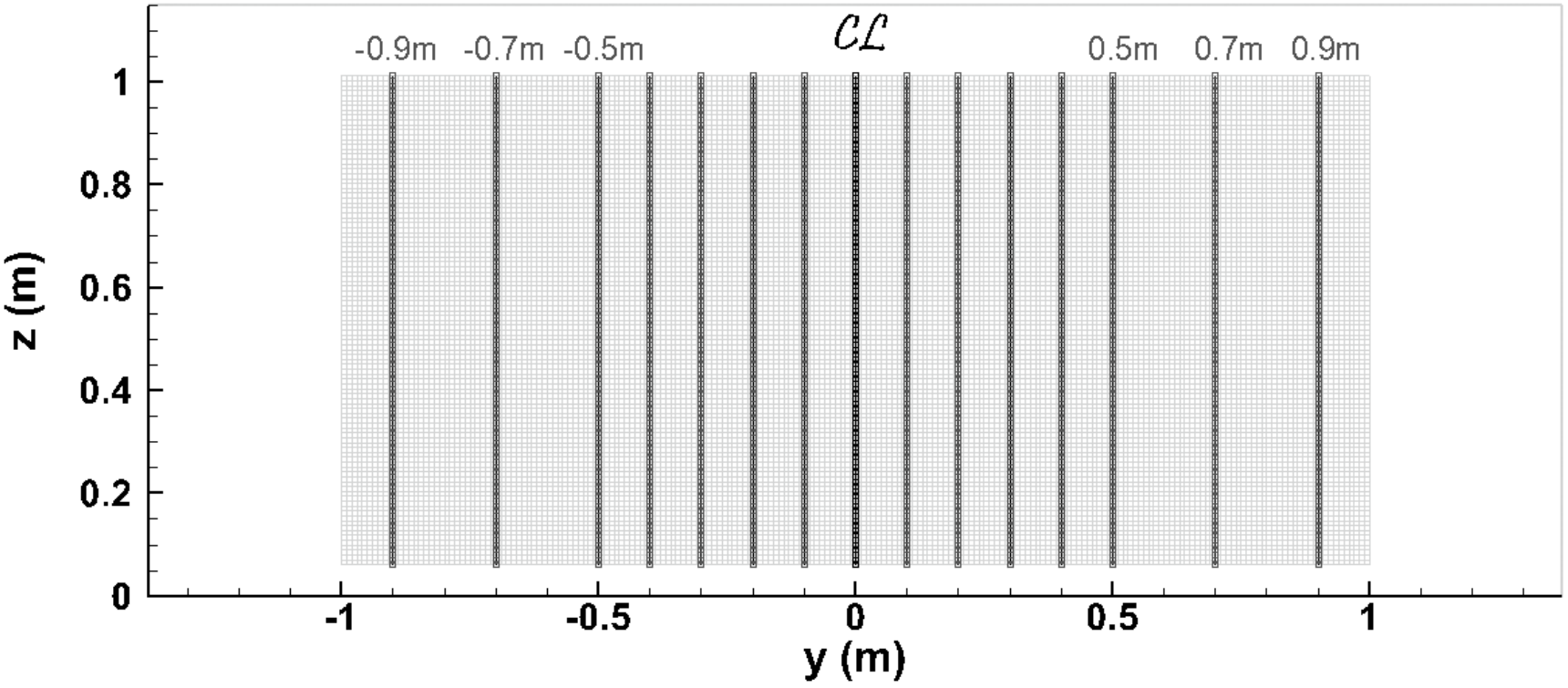


Test Setup

- Sontek 1.5MHz PC ADP (3-beam, 15 deg. slant angle, 1Hz data output rate, first bin ~ 13cm below surface)
- Automated sensor carriage system with 0.01 mm positioning accuracy

Measurement Cases

- 15 fixed-vessel (FV) measurements (5 minutes sampling each)
- MV measurements with 3 different horizontal bin (ybin) sizes: 8mm, 16 mm and 32 mm – zbin = 16 mm



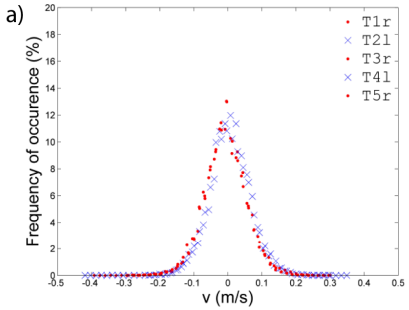
Data Processing

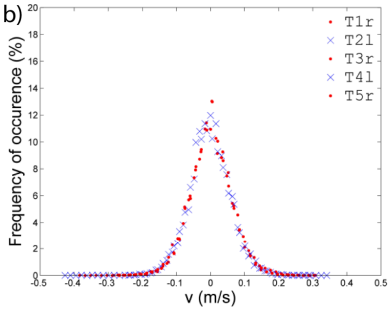
- Correction of lateral velocity

Raw data

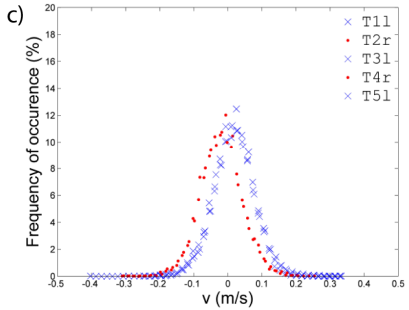
Corrected data

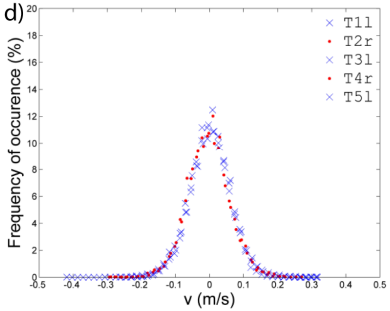
Ybin = 8 mm



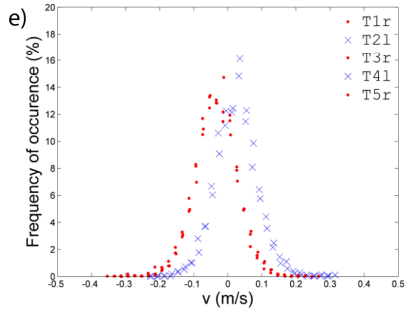


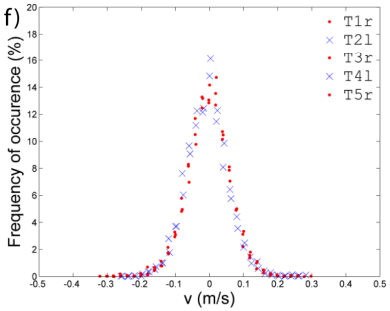
Ybin = 16 mm





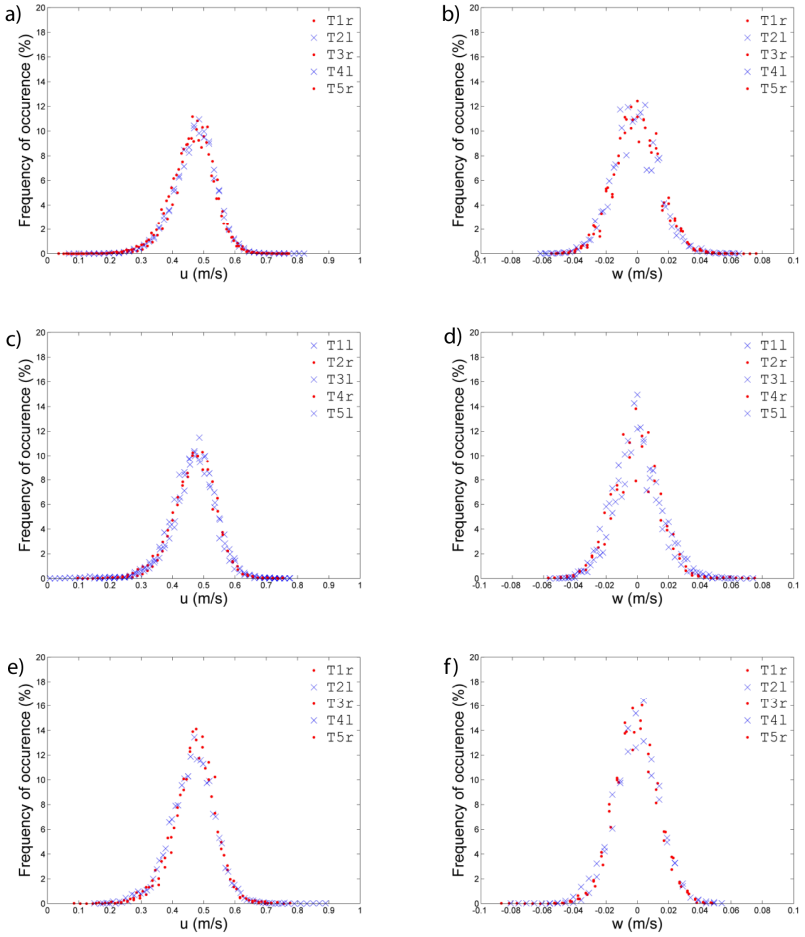
Ybin = 32 mm





Data QA/QC

- No indication of directional bias



Q: Single transect Vs. avg. transects

Y bin	delta
8 mm	1.2 % (mean)
16 mm	1.2 % (mean)
32 mm	1.0 % (mean)
32 mm	2.8 % (max)

U bulk = 0.47 m/s for FV and all MV measurements

Velocity Fields

Sandia National Laboratories

U

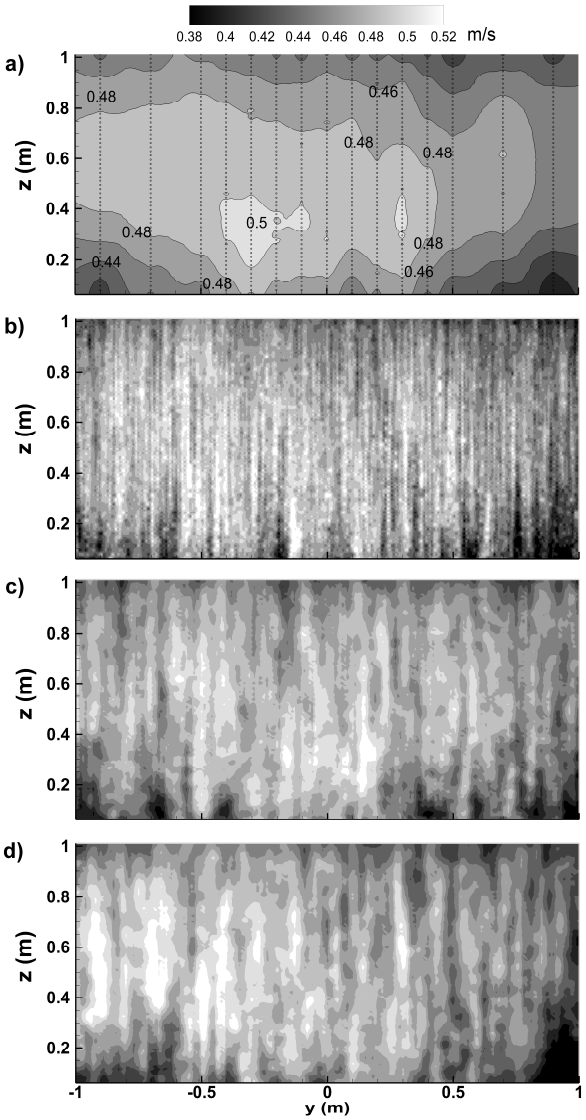
VW

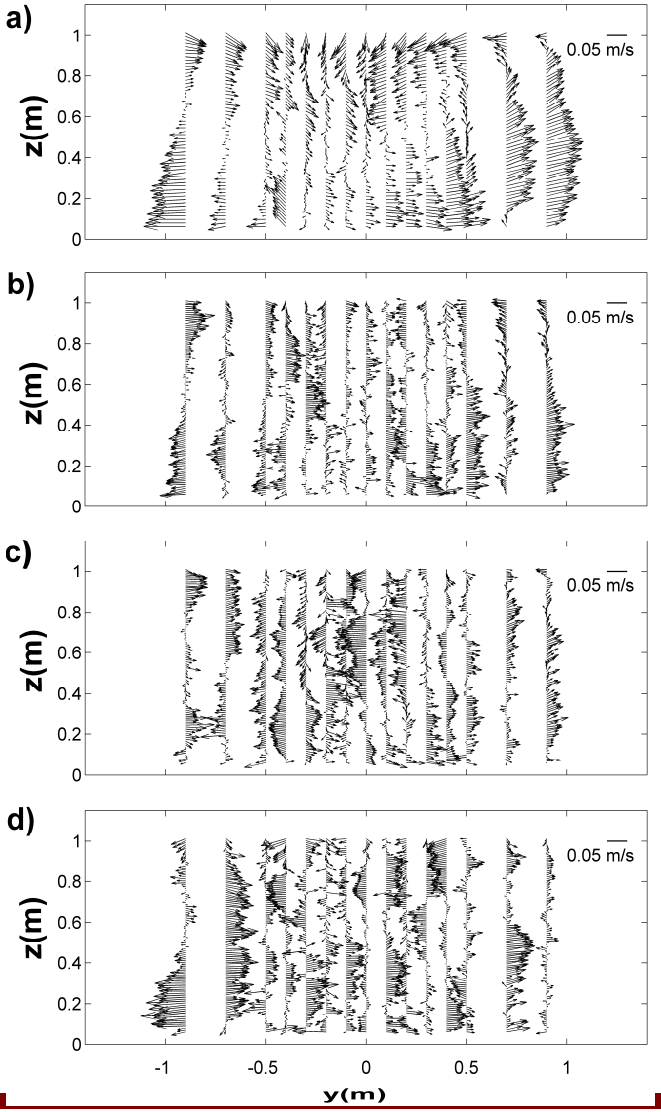
FV

Ybin = 8 mm

Ybin = 16 mm

Ybin = 32 mm

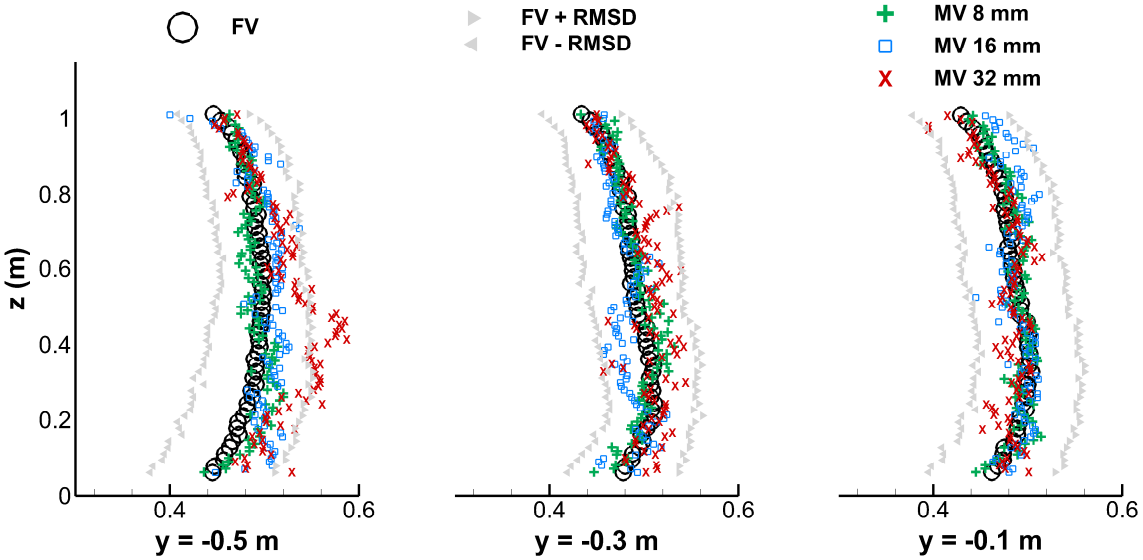


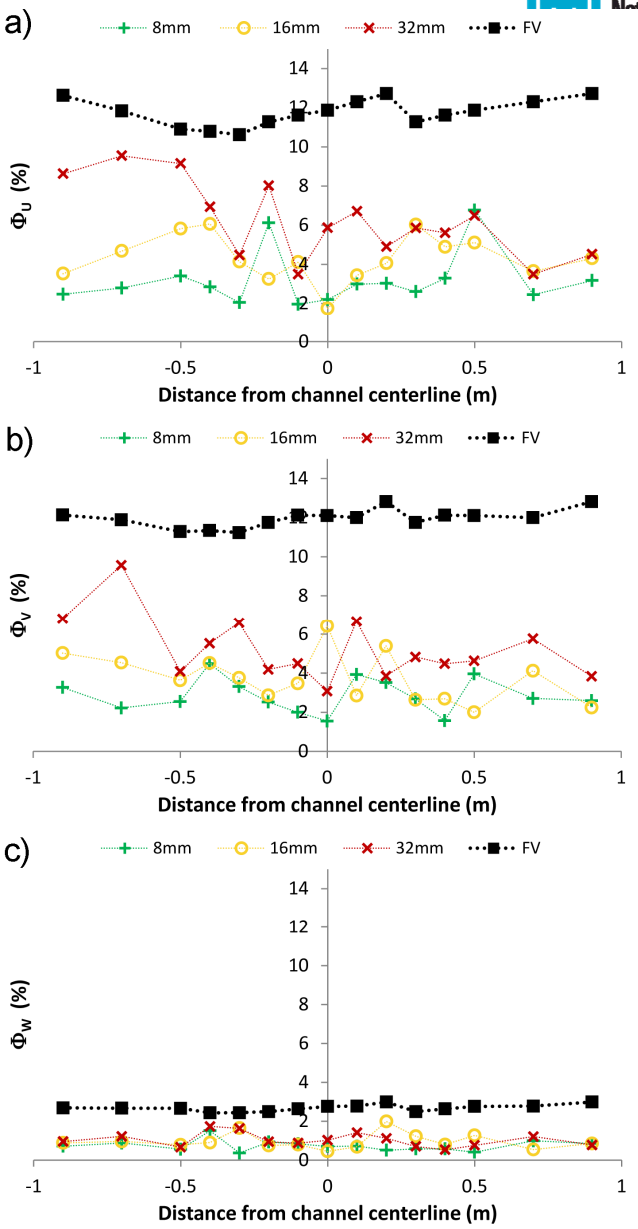


Velocity Profile Error

$$\Phi_{\bar{x}} = \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_{STA\,i} - \bar{x}_{FV\,i})^2}}{\langle \overline{u_{FV}} \rangle}$$

$$\Phi_{\bar{x}} = \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\frac{1}{m}\sum_{j=1}^{m}(x_{FV\,i_j} - \bar{x}_{FV\,i})^2\right)}}{\langle \overline{u_{FV}} \rangle}$$





Bulk Error

Measurement case	$\overline{\Phi_{\overline{u}}}$ (%)	$\overline{\Phi_{\overline{v}}}$ (%)	$\overline{\Phi_{\overline{w}}}$ (%)
STA MV - 8 mm bin	3.2	2.9	0.7
STA MV - 16 mm bin	4.3	3.7	1
STA MV - 32 mm bin	6.2	5.2	1
FV	11.8	12	2.7
Single-ping MV - 8 mm bin	12.8	12.1	3.0
Single-ping MV - 16 mm bin	14.7	13.5	3.1
Single-ping MV - 32 mm bin	14.3	13.2	2.7

Conclusions

- Applying STA decreased MV errors (u & v) by an order of magnitude
- Decreasing traverse speed improved the MV & STA-MV accuracy (u & v), but not the flow discharge
- Moving the boat increased single-ping error (indication)
- STA decreased the MV measurement accuracy to within the individual ping FV measurement error

Measurement case	$\overline{\Phi_{\bar{u}}}$ (%)	$\overline{\Phi_{\bar{v}}}$ (%)	$\overline{\Phi_{\bar{w}}}$ (%)
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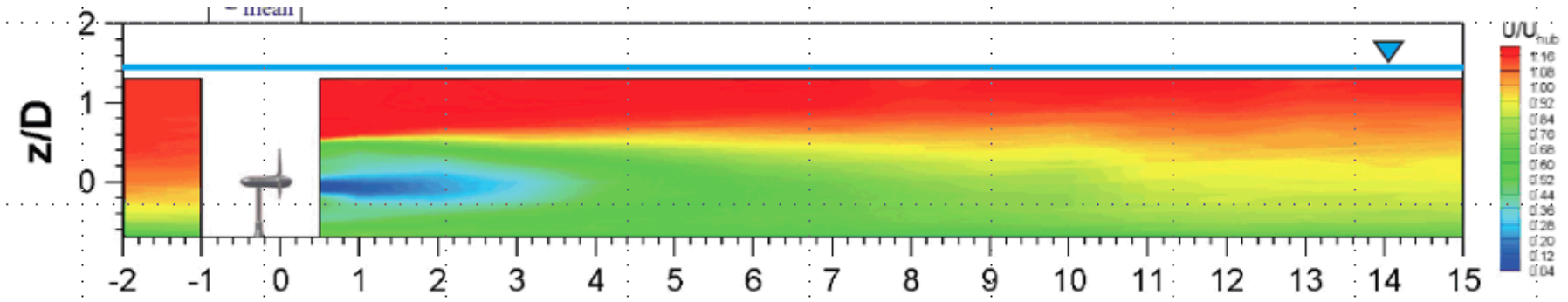
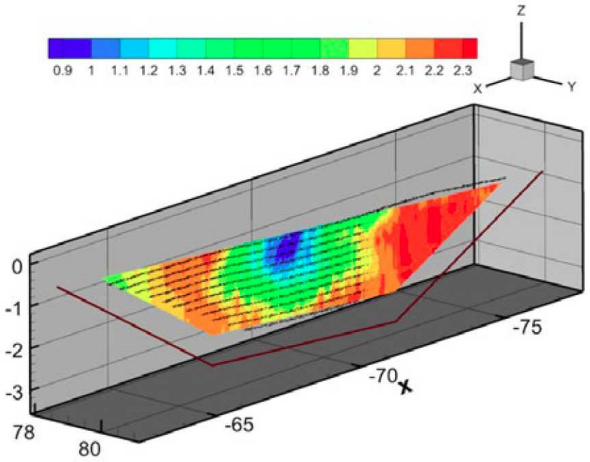
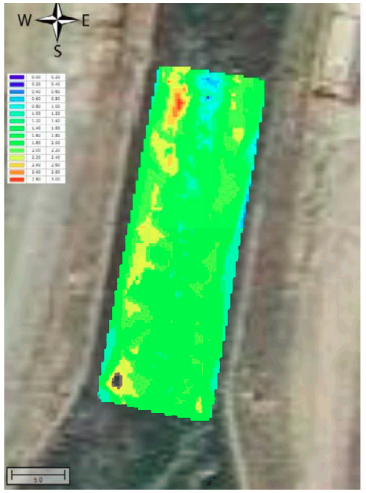
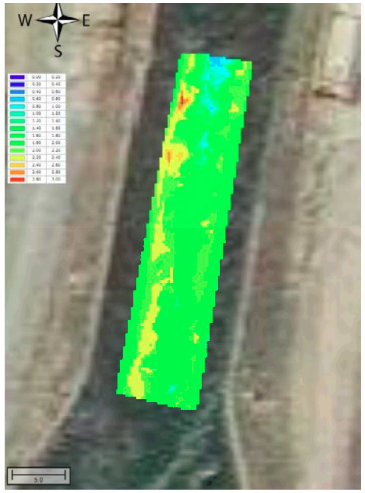
Gunawan, B., Neary, V.S. and Hill, C. (2017) Comparison of fixed and moving vessel ADCP measurements in a large laboratory flume. ASCE Journal of Hydraulic Engineering, Vol. 143, Issue 5

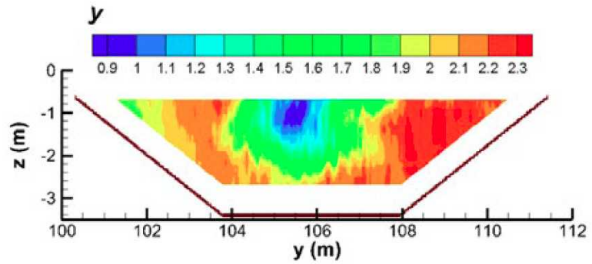
What Next?











https://www.osti.gov/scitech/biblio/1245828

Questions?

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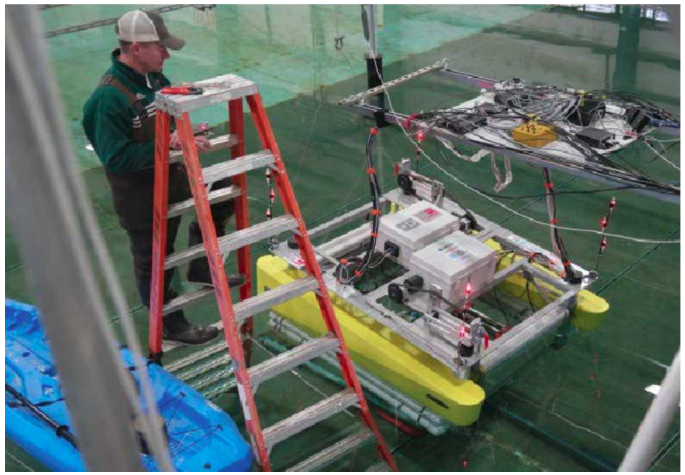
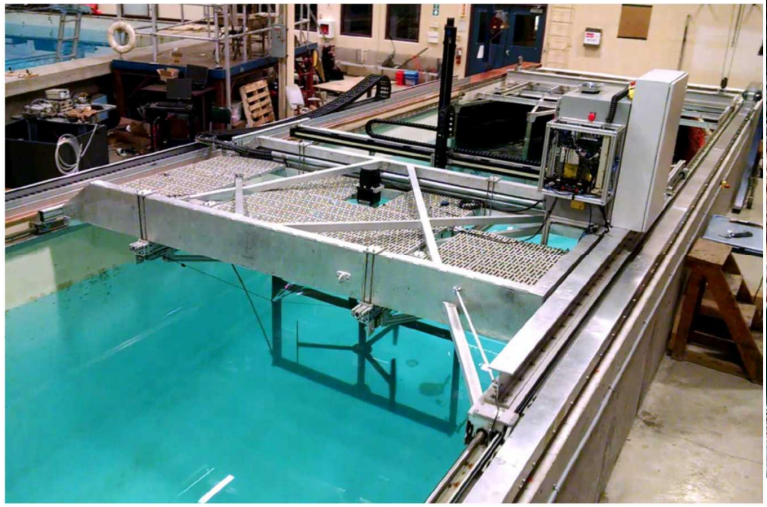
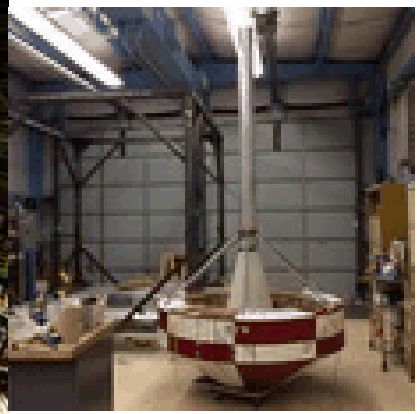
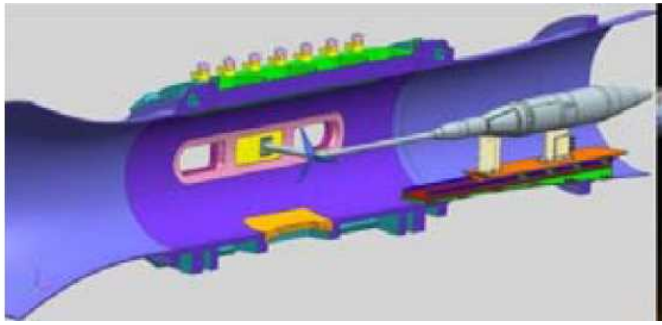
RM1: Tidal turbine
RM2: River turbine









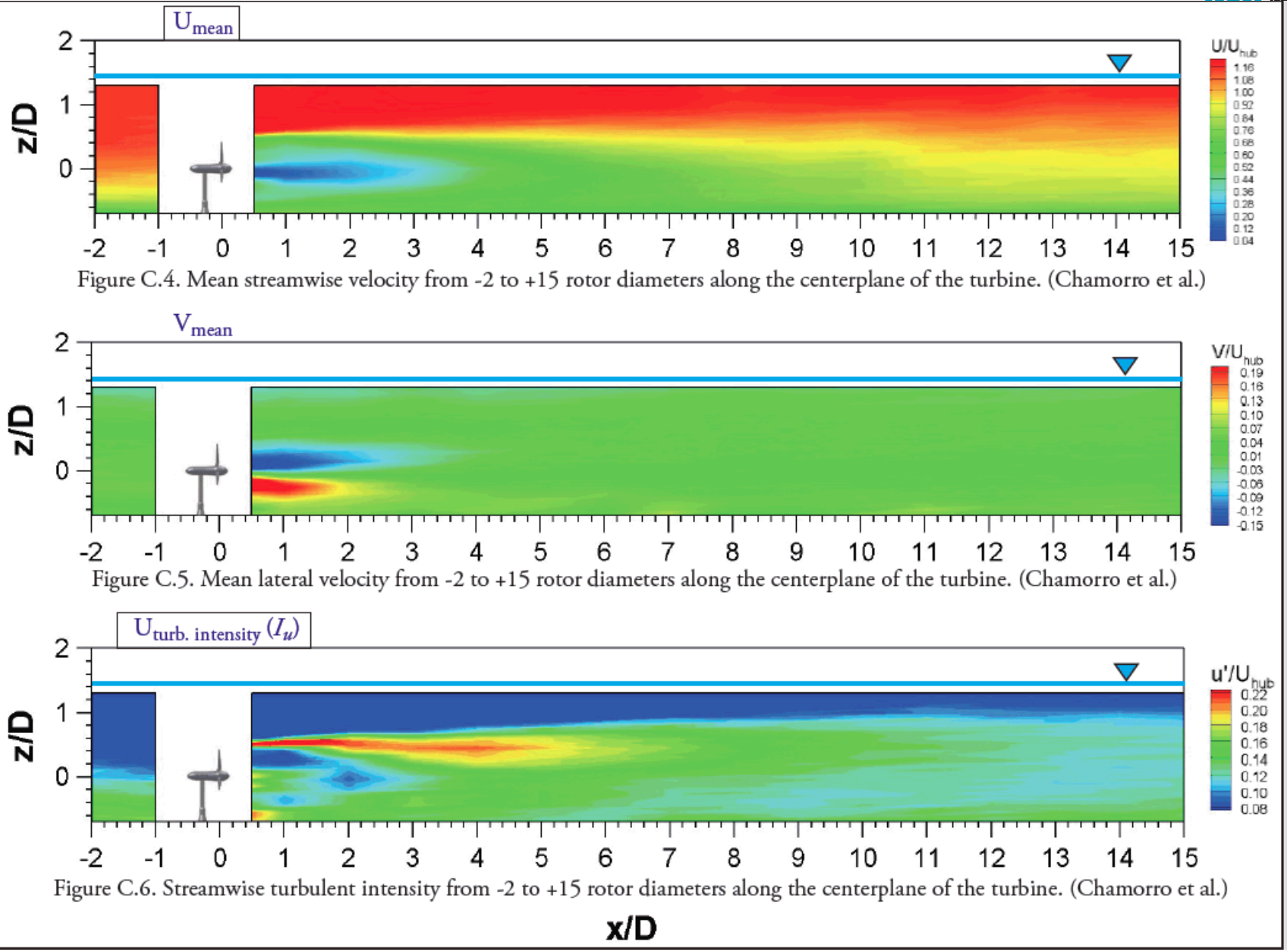
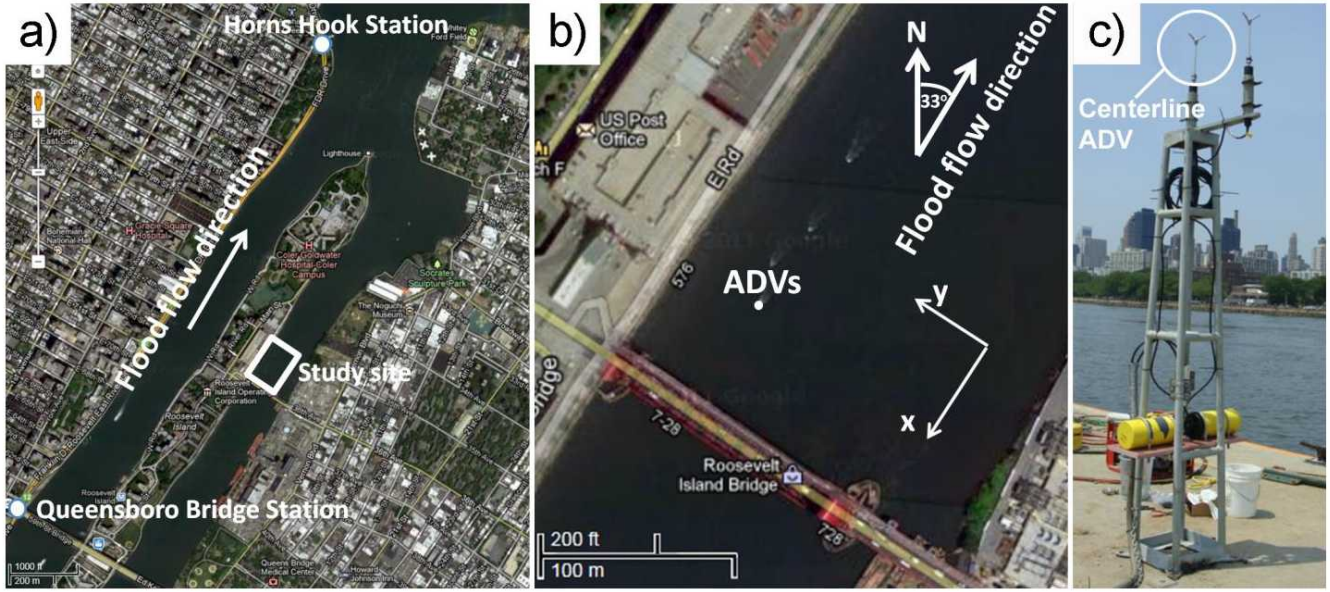
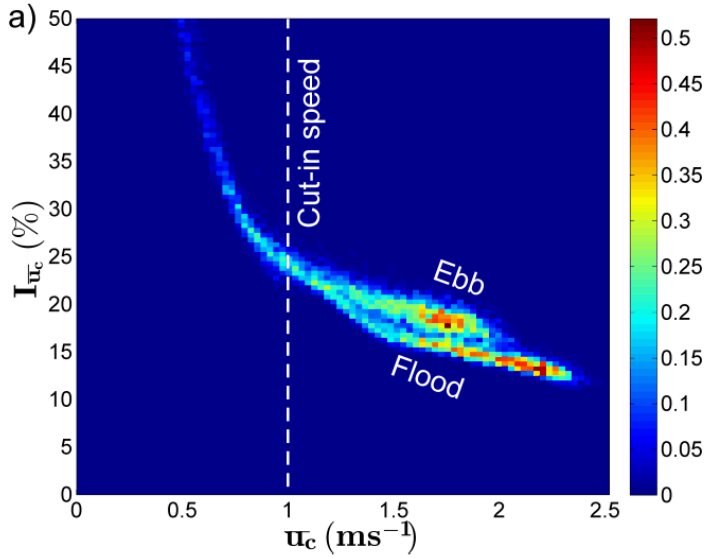


Figure C.4. Mean streamwise velocity from -2 to +15 rotor diameters along the centerplane of the turbine. (Chamorro et al.)

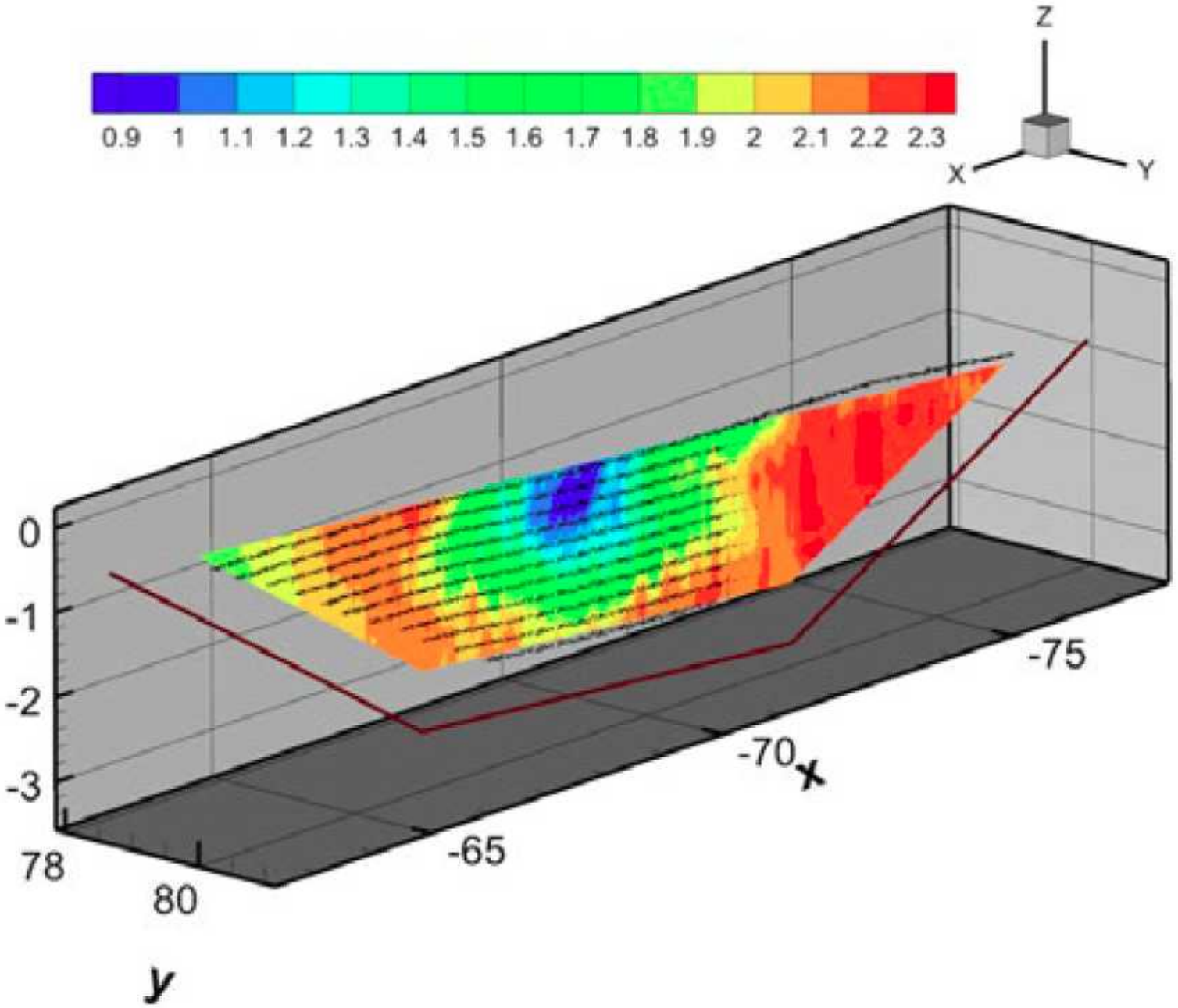
Figure C.5. Mean lateral velocity from -2 to +15 rotor diameters along the centerplane of the turbine. (Chamorro et al.)

Figure C.6. Streamwise turbulent intensity from -2 to +15 rotor diameters along the centerplane of the turbine. (Chamorro et al.)





Gunawan, B., Neary, V.S. and Colby, J. (2014) Tidal energy site resource assessment in the East River Tidal Strait, near Roosevelt Island, New York, New York. Renewable Energy, Volume 71, November.



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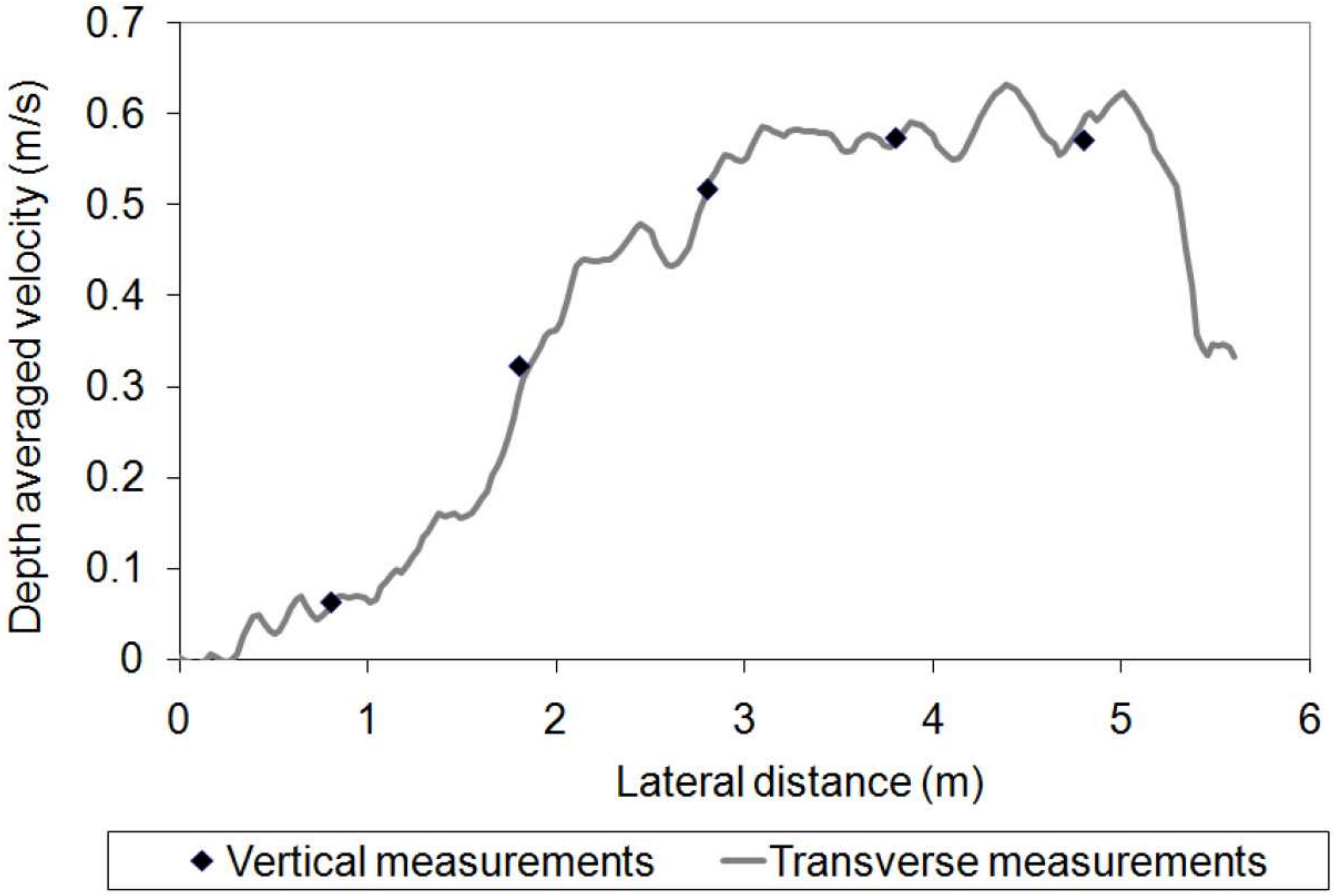

Gunawan, B., Sterling, M. and Knight, D.W. (2010)
Using an Acoustic Doppler Current Profiler in a small river. Water and Environment Journal, Vol. 24 no. 2.

U,V,W

- We also calculated the single-ping MV measurement errors to provide a more direct error comparison between MV and FV measurements, to provide an insight whether spatial averaging improve the MV measurement results. Note that the MV measurements here are the MV data that are not spatio-temporally averaged. MV measurements, from each of the five transects, adjacent to the locations of the 15 FV profiles (within 0.02 m from the FV profiles, or less) were used for this analysis. The normalized RMSDs for each profile were calculated using equation 5.

$$\Phi_{\bar{x}} = \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n}\overline{(x_{MV\,i} - \bar{x}_{FV\,i})^2}}}{\langle\overline{u_{FV}}\rangle}$$

V profile