NESTED-SCALE VELOCIMETRY IN A RIVER USING INFRARED

C. Chris Chickadel and Andrew T. Jessup

Applied Physics Laboratory, University of Washington, Seattle

1. INTRODUCTION

River flow is driven by along-channel pressure gradients and is modified by complex bathymetry that induces secondary flow. Riverine turbulence can be generated and enhanced by flow over sharp bathymetric features, obstructions, and bedforms, which produce macro-turbulent structures [1]. Understanding these details of river flow is challenging, yet important for their direct effects on sediment transport and mixing, which in turn affect biological processes (e.g. as fish passage and pollutant dispersal) and engineering efforts (e.g. construction and flow control). Three-dimensional river flow modeling has become capable of producing realistic flow maps and turbulent structures [2], however detailed in situ measurements needed to verify models are difficult to make thus result in sparse measurements that alias highly sheared flow.

Exploiting the strong temperature gradients in littoral and riverine settings, thermal infrared (IR) remote sensing [3] has been used to track and study turbulence flow patterns at the surface of an estuarine river with success. Our goal is to extend our analysis to estimating 2D surface flow patterns from the IR imagery capable of resolving large scale river flow (10m - 100m) and small scale turbulence (cm - m). Using the resulting surface flow maps we will plan to investigate bathymetry effects on surface flow in rivers and estuarine, quantify mean and turbulent, and provide data needed for guiding and testing river and estuary hydrodynamic models.

2. IR PIV

Previously we presented validation of a one-dimensional (1D) particle image velocimetry (PIV) technique applied to IR image data from an estuarine river mouth. A custom 2D PIV technique has been developed and implemented for application to IR data from a river. The technique is based on phase correlation [4] for efficient computation and robust estimation of data error. We apply the technique to IR data from a balloon platform resolving river wide flow (100m to 0.2m) and tower-based data viewing short-scale surface turbulence (3m to 0.5cm). The example shown in Figure 1 details the PIV velocity field associated with a passing boil in the short-scale imagery. Divergent velocity vectors associated with the center of the boil is consistent with a region of upwelling at the surface, and by applying conservation of mass it is possible to estimate the vertical component of velocity due to divergence or convergence at the surface. Comparisons against in situ estimates estimate of the vertical and horizontal velocity in this example compares well with the measured velocity.

Present analysis will continue validation of the PIV algorithm against in situ measurements. From short-scale PIV we plan to estimate relevant turbulent properties (e.g. turbulent kinetic energy, Reynolds stress, and dissipation) and use them in conjunction with in situ estimates to better understand the turbulent flow properties of the river. Large-scale PIV will be used to investigate remote retrieval of mean river velocities and to examine secondary flow effect due to bathymetry and bottom roughness.

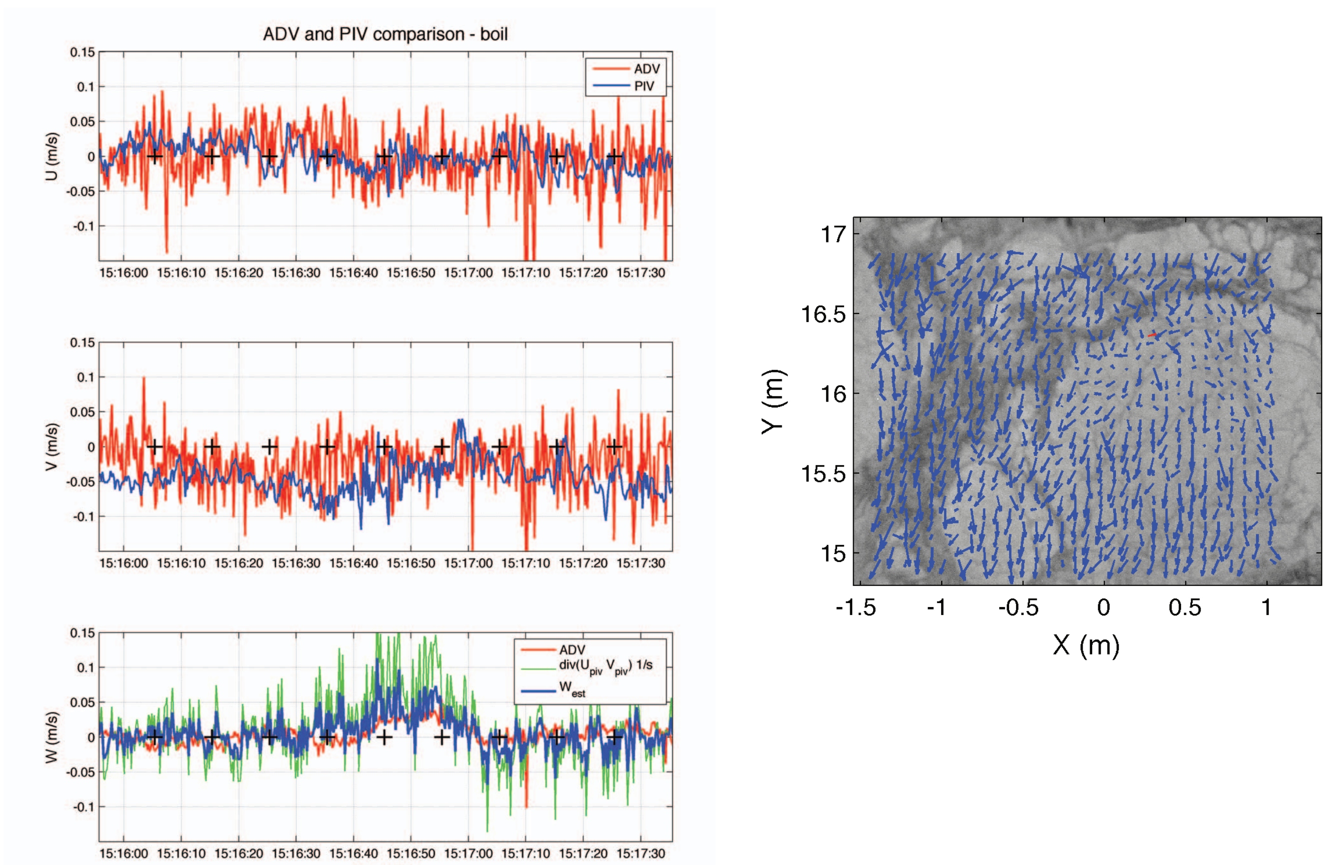

Figure 1. PIV and ADV comparisons of the cross-stream (top panel) and alongstream (middle panel) river flow bracketing the time of the IR snapshot and velocity PIV field shown in in the right panel. (bottom) Measured and surface PIV based vertical velocity of the flow associated with the passage of a boil.

3. REFERENCES

[1] Kostaschuka, R. A. and Church, M. A., “Macroturbulence generated by dunes: Fraser River, Canada,” *Sedimentary Geology*, pp. 25–37, 1993.

[2] Chickadel, C. C., Horner-Devine, A. R., Talke, S. A., and Jessup, A. T., “Vertical boil propagation from a submerged estuarine sill,” *Geophysical Research Letters*, 2009.

[3] Calhoun, R. J. and Street, R. L. “Turbulent flow over a wavy surface: neutral case,” *Journal of Geophysical Research*, pp. 9277–9294, 2001.

[4] Foroosh, H., Zerubia, J. B., and Berthod, M., “Extension of phase correlation to subpixel registration,” *IEEE Transactions on Image Processing*, pp. 188–200, 2002.