

Quantifying Turbulence for Tidal Power Applications

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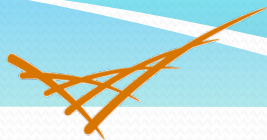
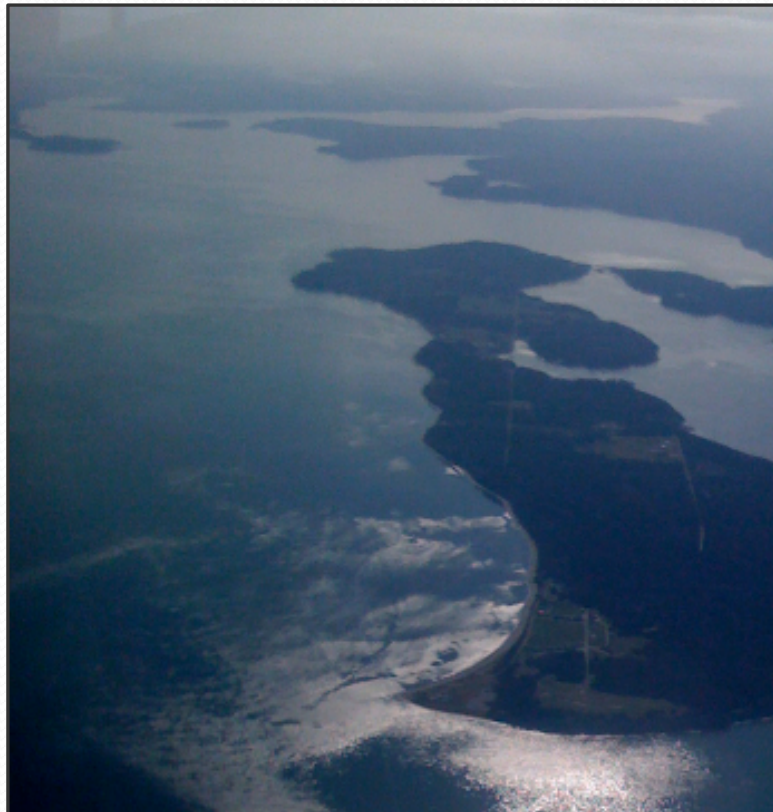
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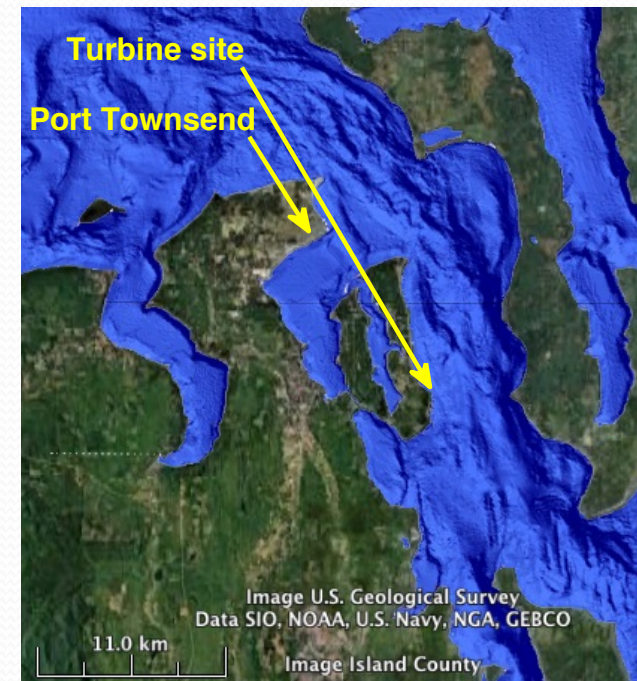
Motivation

- Turbine performance
- Turbine fatigue
- Environmental effects



Objectives

- Field measurements from an actual tidal power site
- Evaluation of metrics:
 - Turbulent intensity, $I = \sigma_v / \langle v \rangle$
 - Turbulent dissipation rate, ε
 - Coherence, $\langle v'_x v'_y \rangle$
- Best practices:
 - Sampling schemes
 - Rigorous treatment of errors



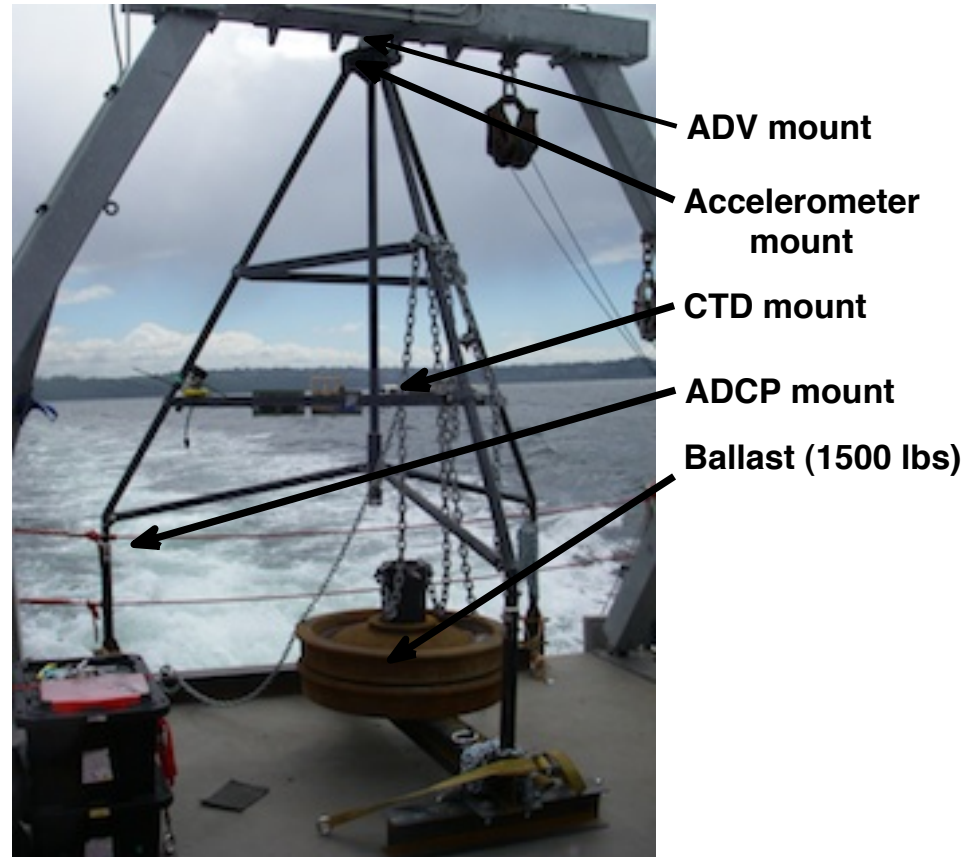
Instruments and sampling

- Acoustic Doppler Current Profiler (ADCP):

- volume sampling
** beam coordinates**
- 64 s @ 2 Hz = 128 points, every 30 min

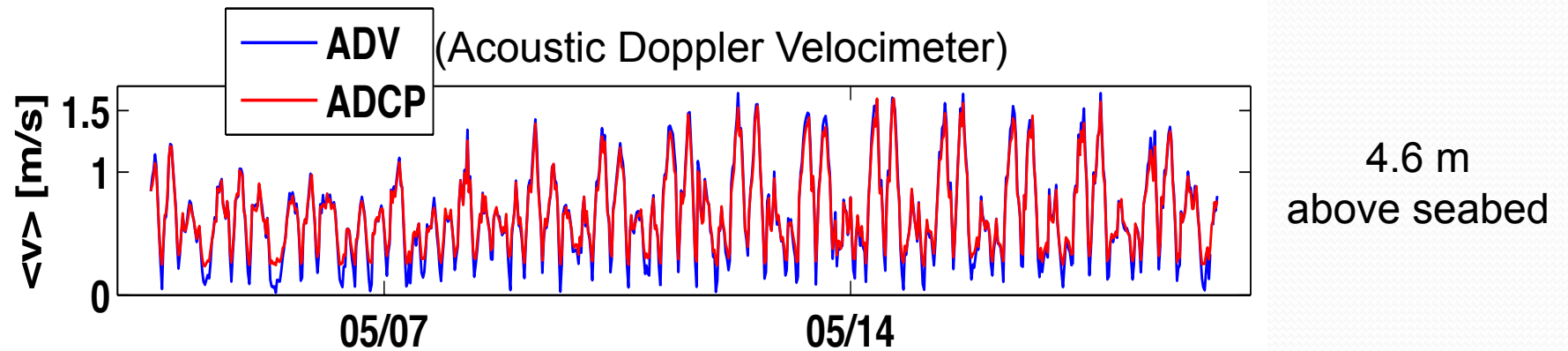
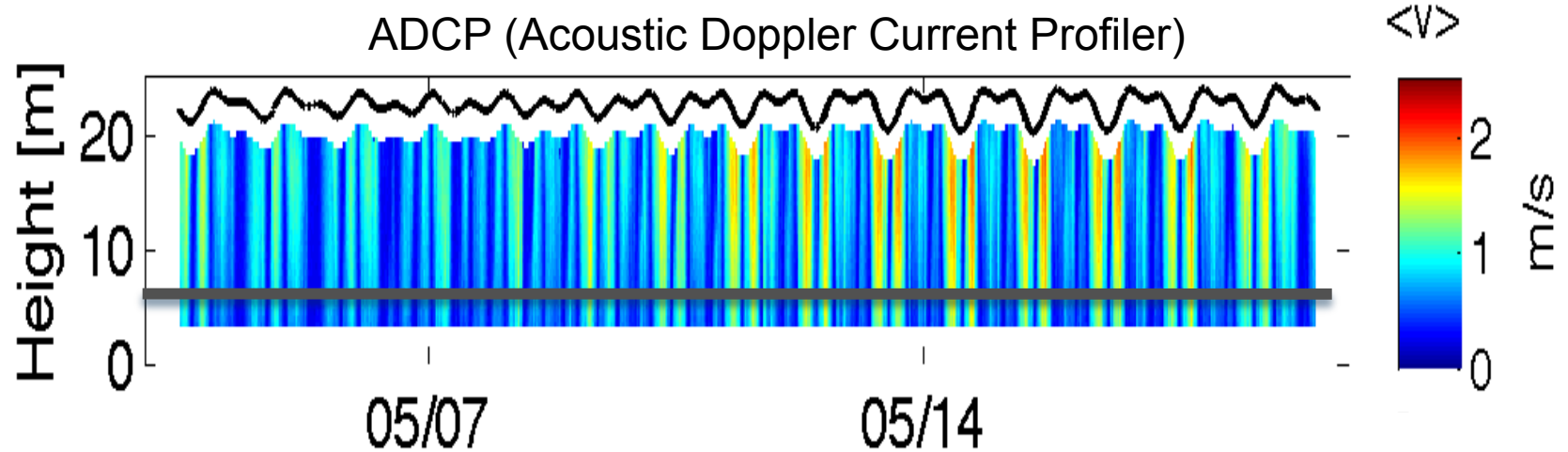
- Acoustic Doppler Velocimeter (ADV):

- point precision
- 64 s @ 32 Hz = 2048 pts, every 10 min

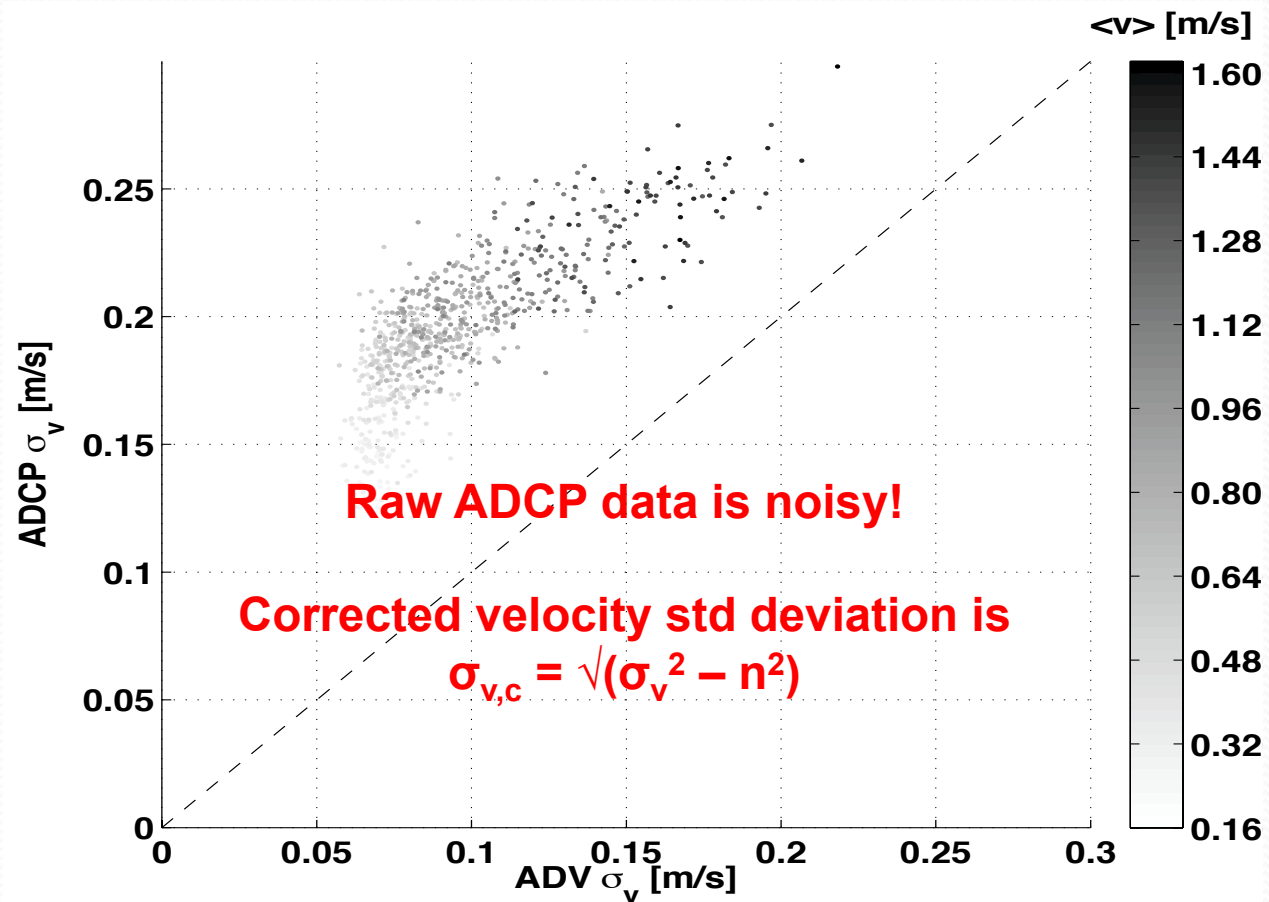


5 m tripod deployed in 22 m water depth

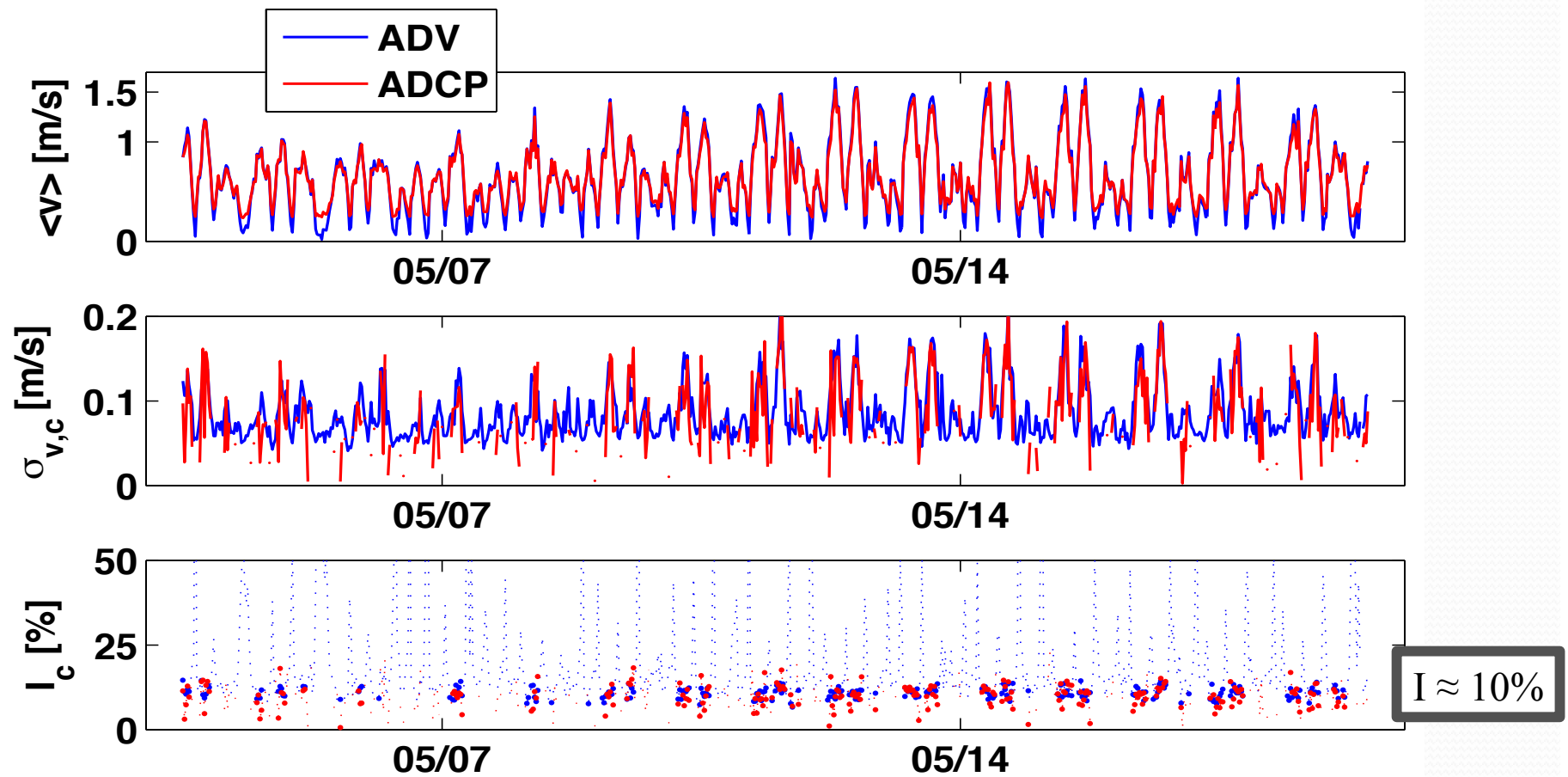
Mean velocities



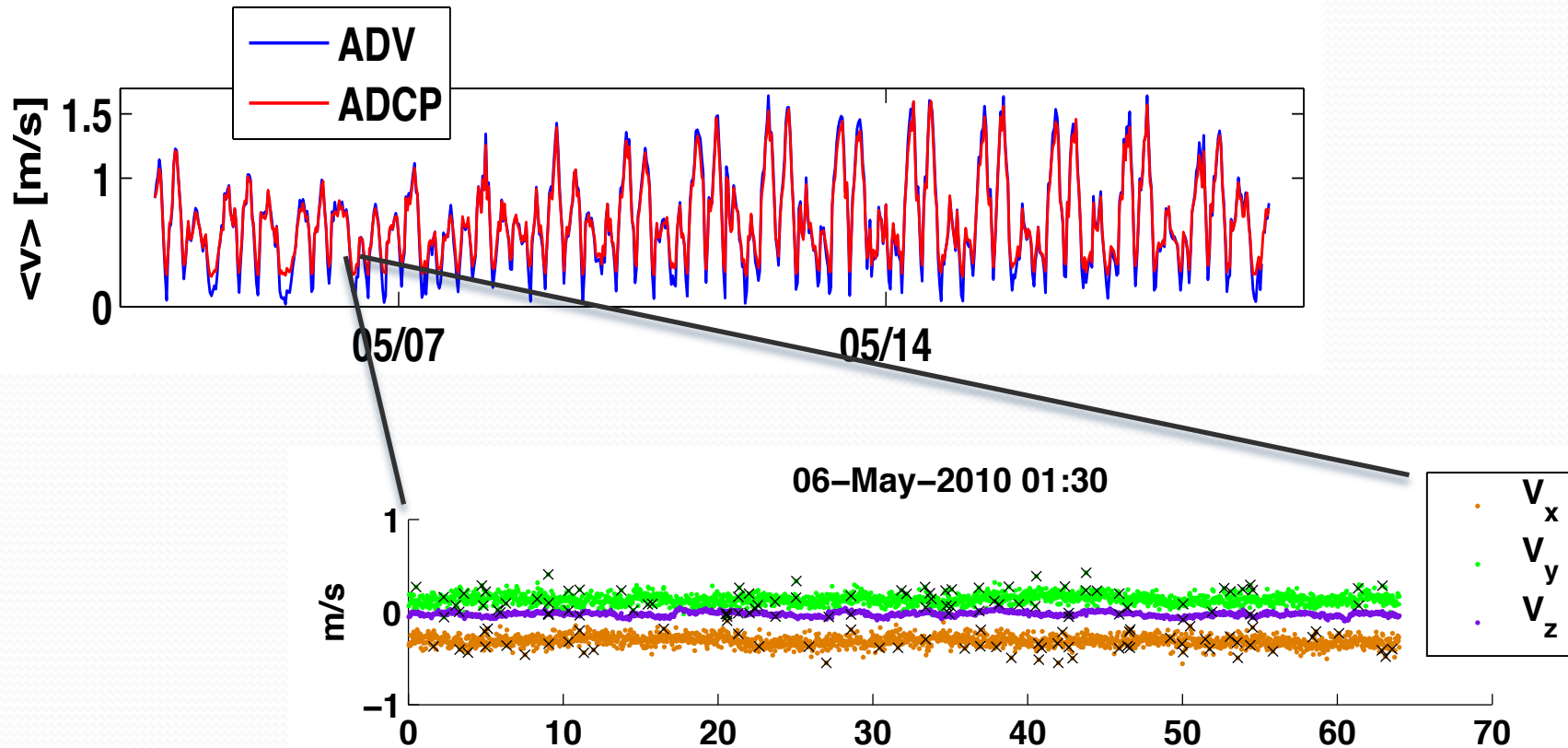
Raw velocity fluctuations



Corrected results



Stationarity (stable mean)

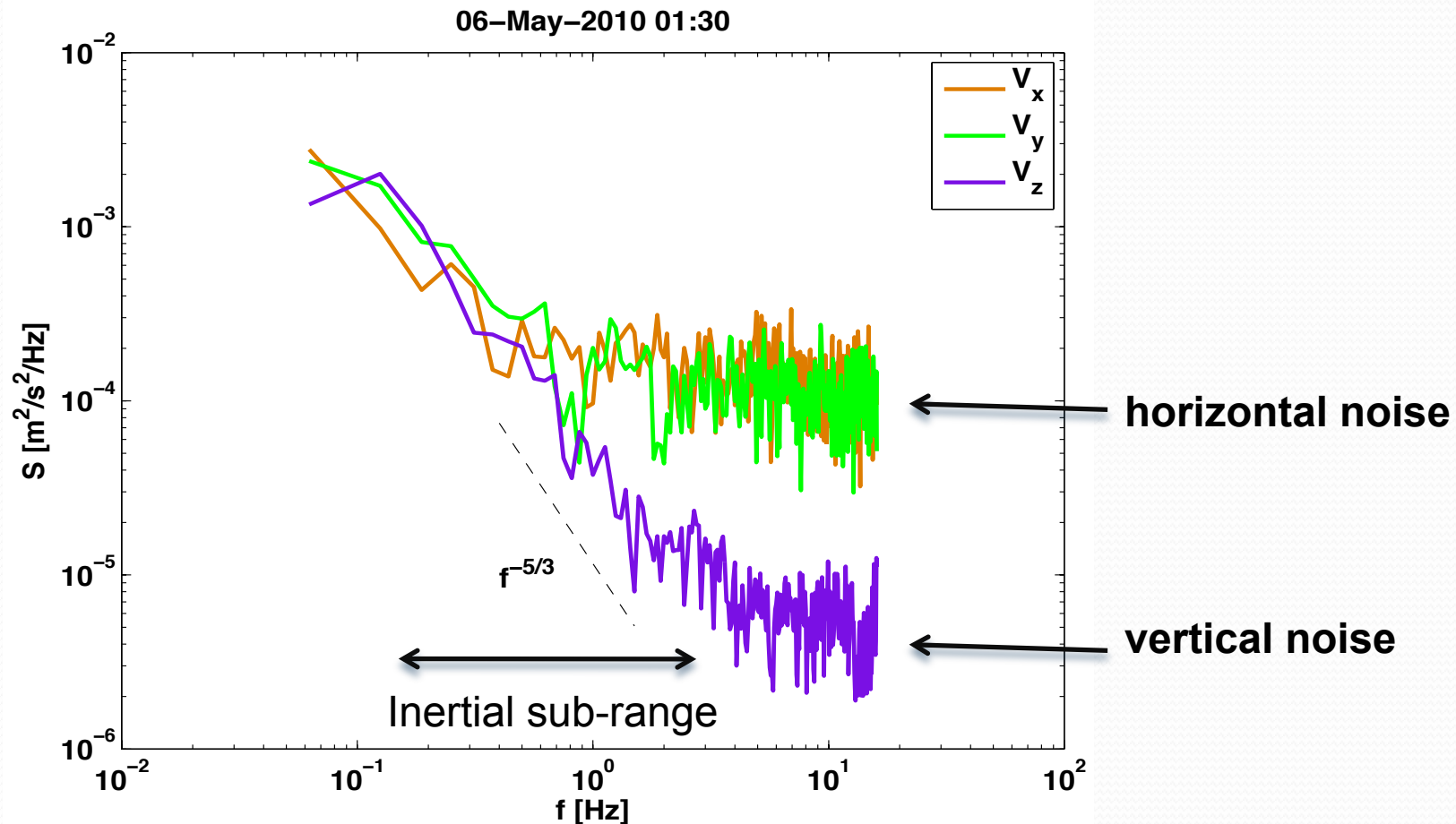


Short, but not too short, records (“bursts”) are necessary for robust statistics...

...see Polagye et al (in prep)

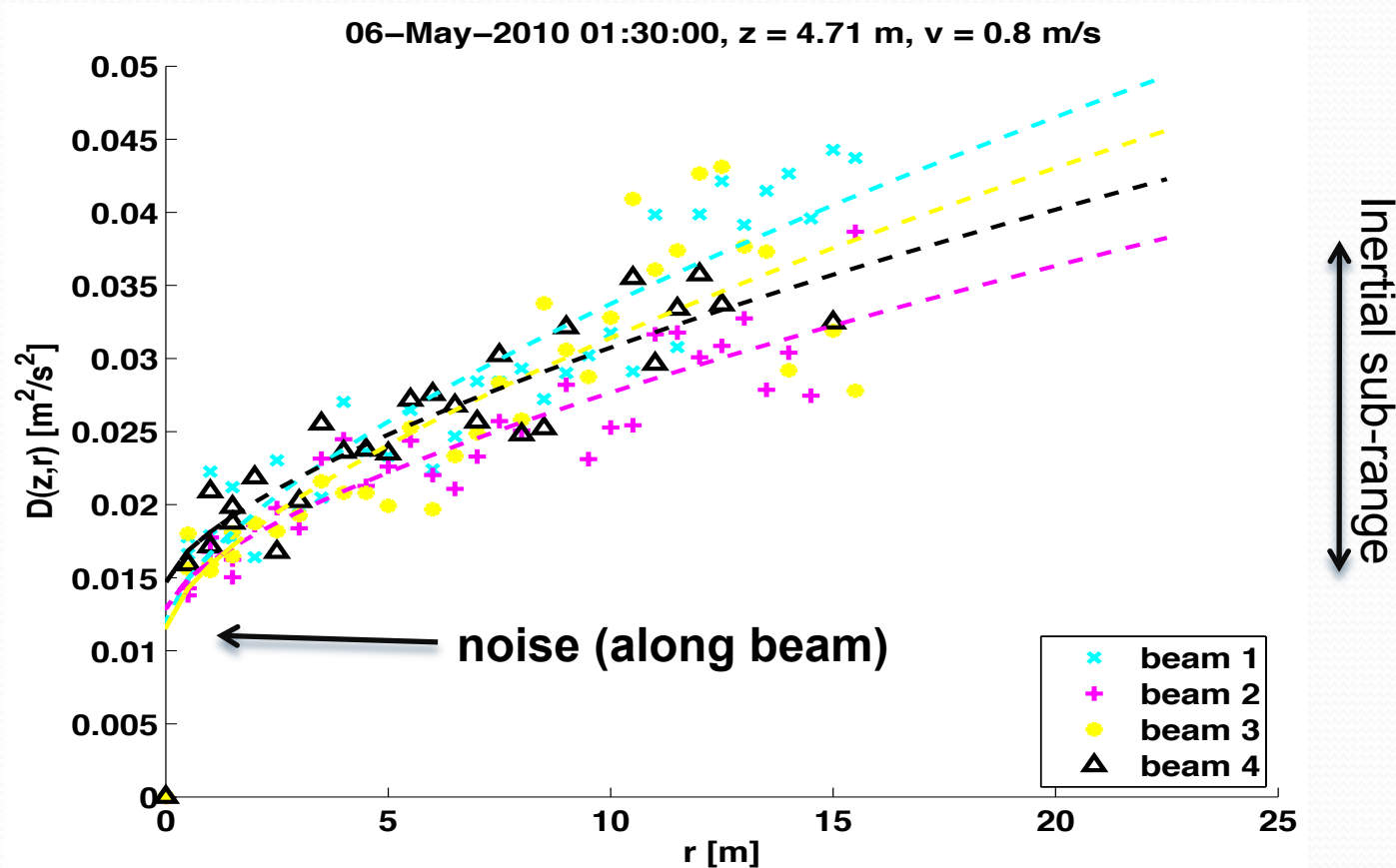
Dissipation rate

- Frequency spectra from ADV
- Inertial sub-range shows cascade of energy to small scales,
- Slope is rate of energy loss

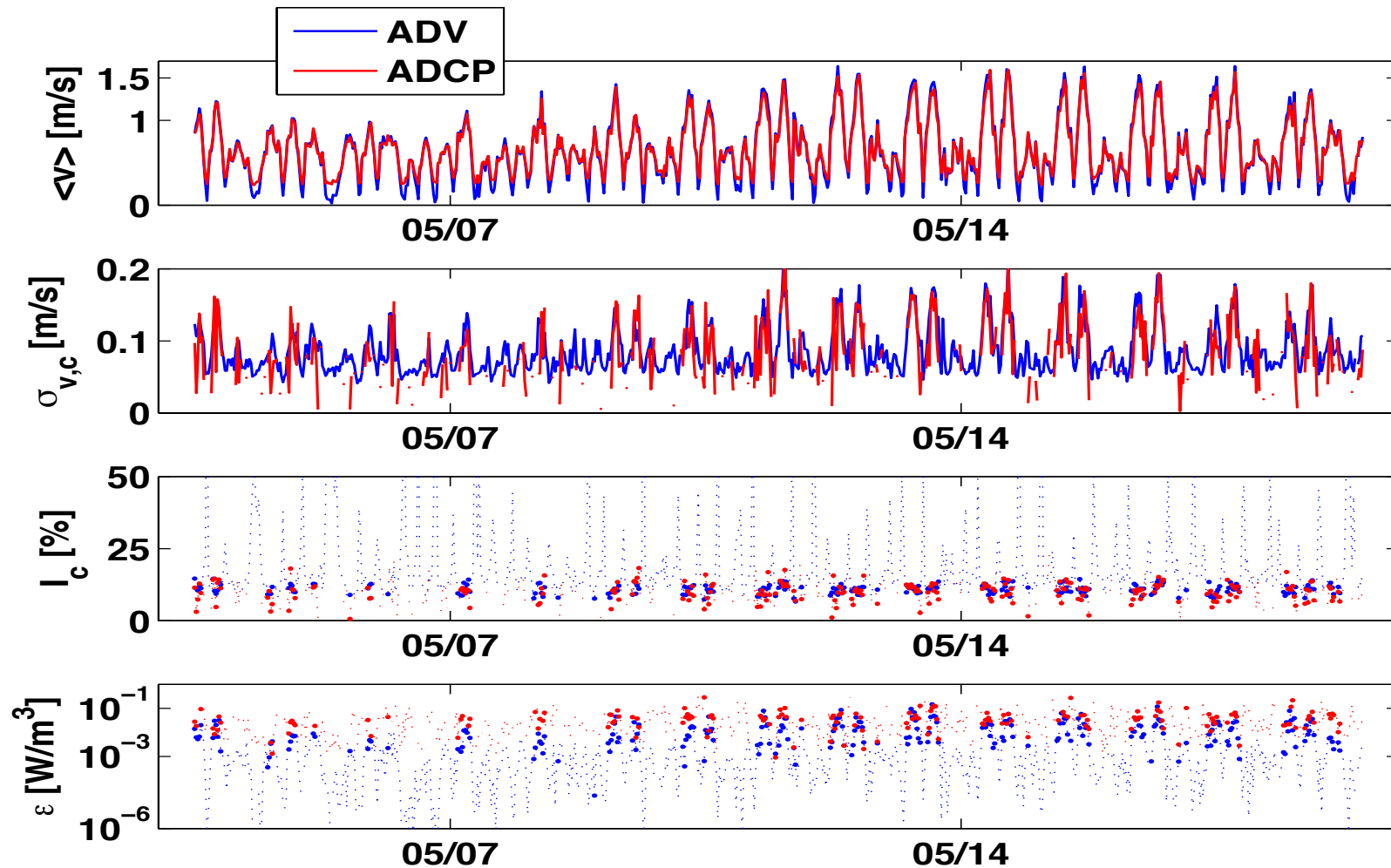


Dissipation rate

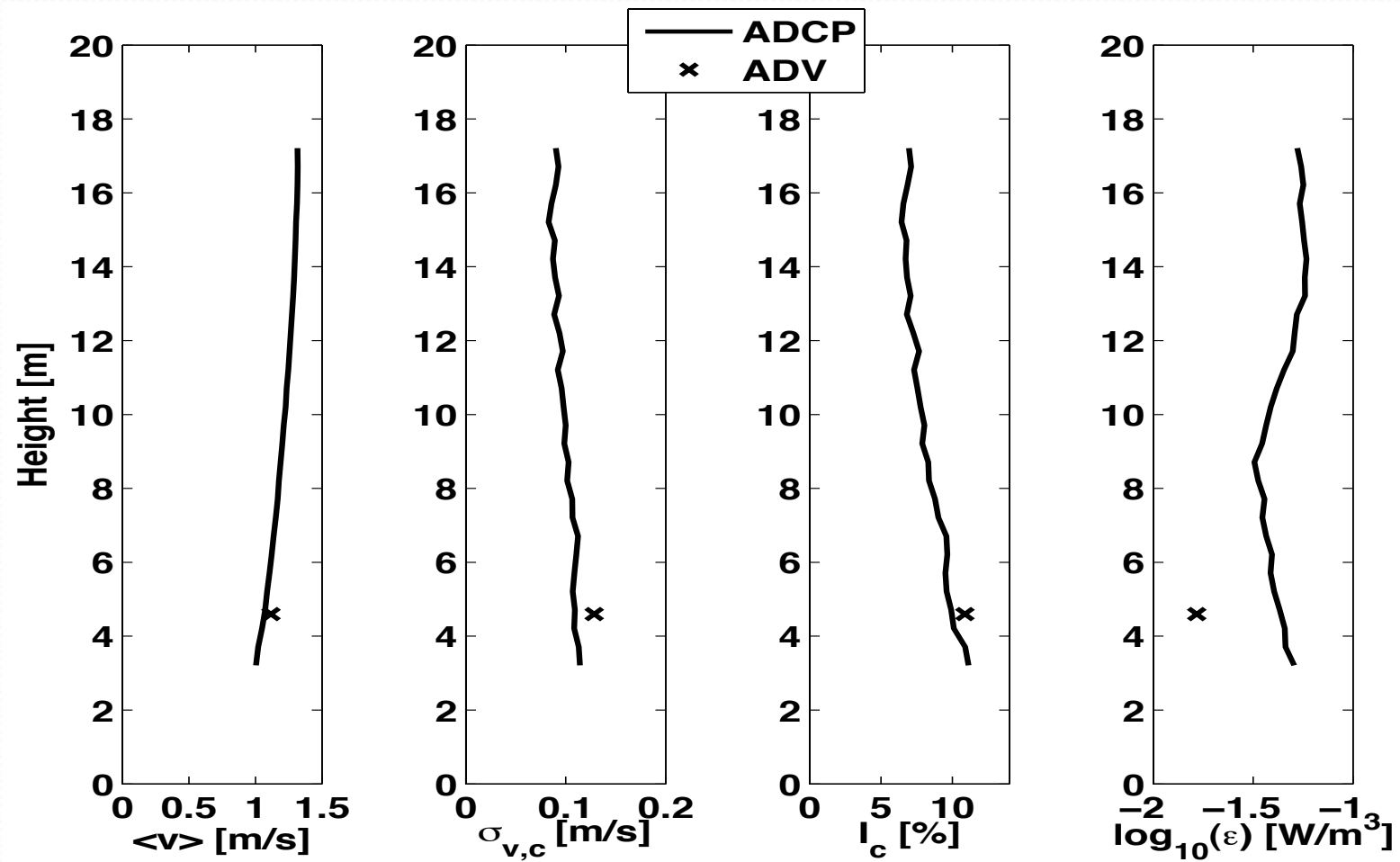
- Spatial structure from ADCP
- Inertial sub-range shows cascade of energy to small scales,
- Slope is rate of energy loss



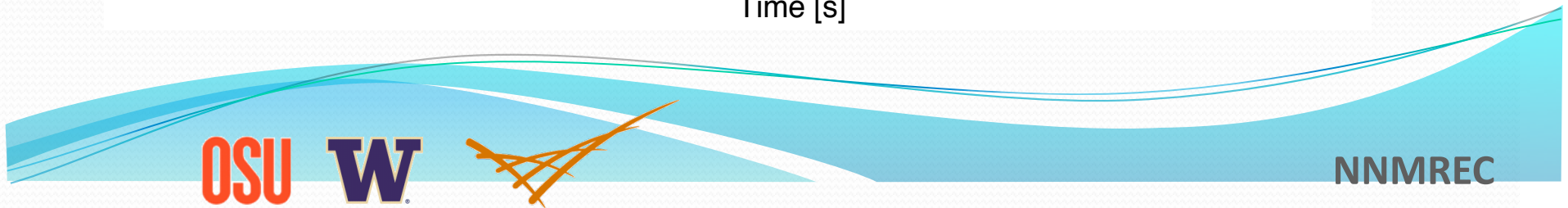
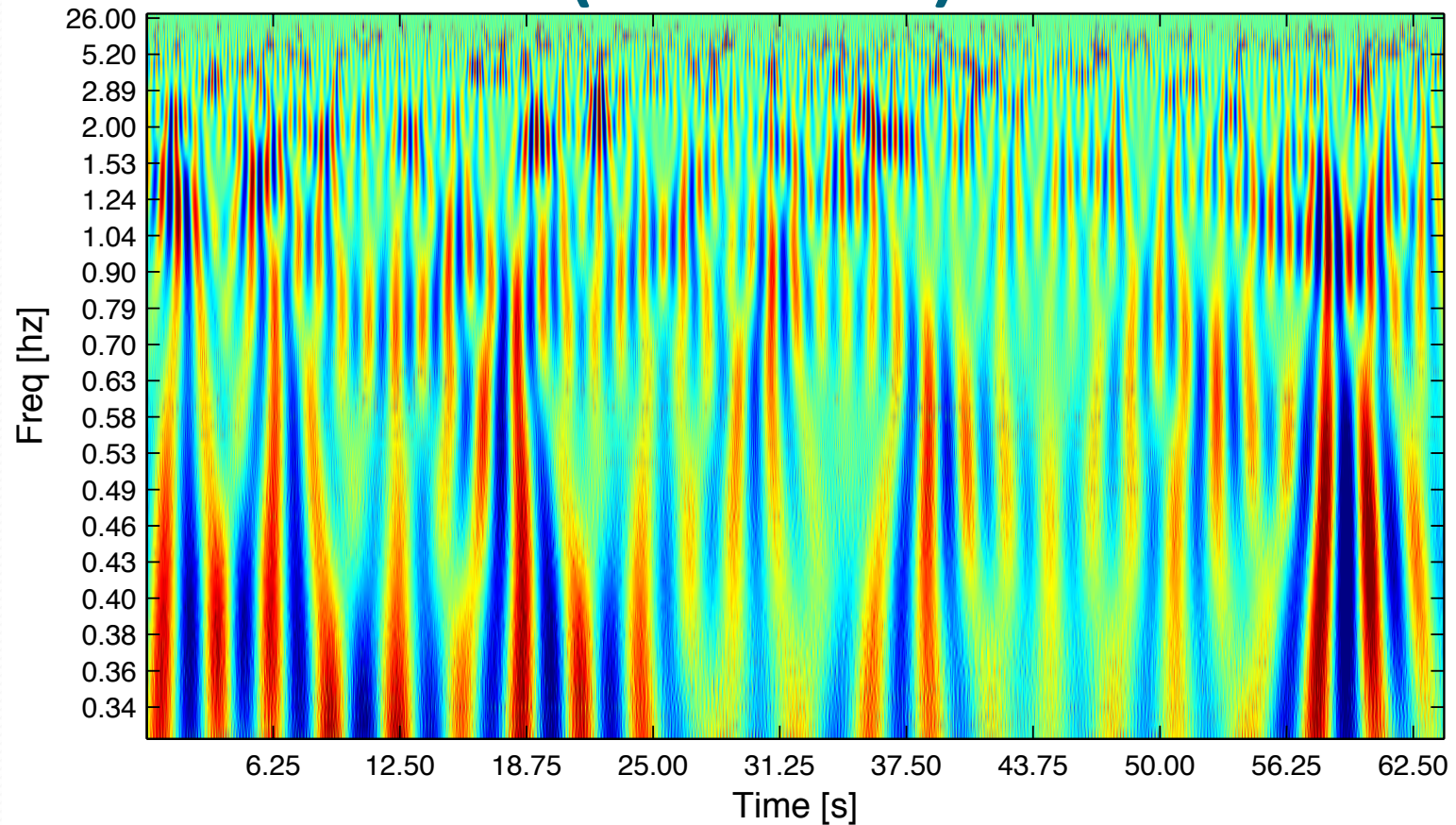
Combined results



Vertical dependence

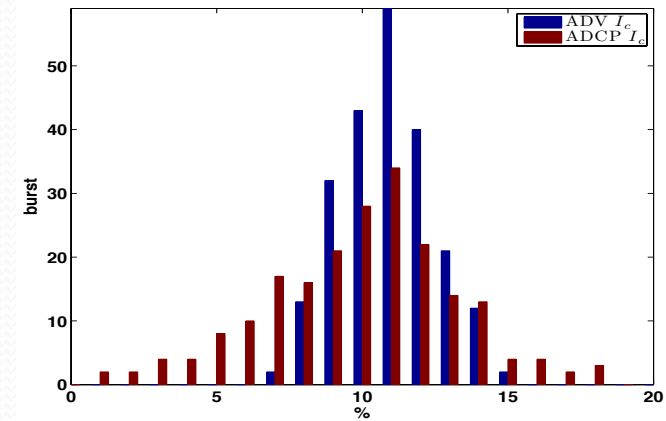


Coherent Turbulent Kinetic Energy (eddies)



Conclusions

- Turbulent intensity $\approx 10\%$
- Doppler measurement error (“noise”) can heavily bias observed velocity variance and **must be removed**.
- Dissipation rate has more dynamic range the turbulent intensity, but operational significance unknown
- Coherent TKE shows time-space scales of eddies



Acknowledgments

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- Boat ops: Capt. Andy Reay-Ellers, Alex deKlerk (UW-APL)



Tripod motion?

