

Design Load Estimation for Tidal Turbines from a Multi-Year Measurement Time Series



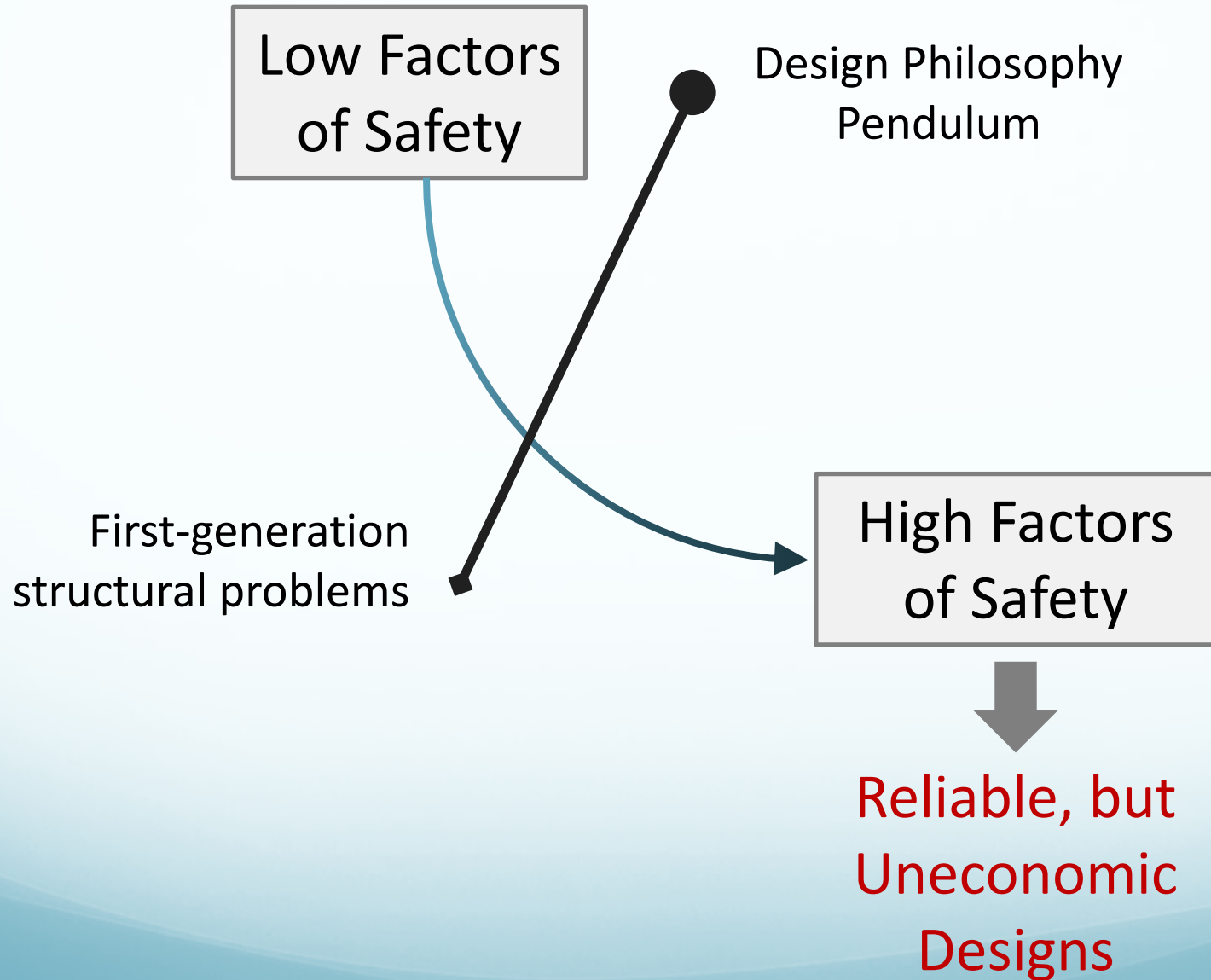
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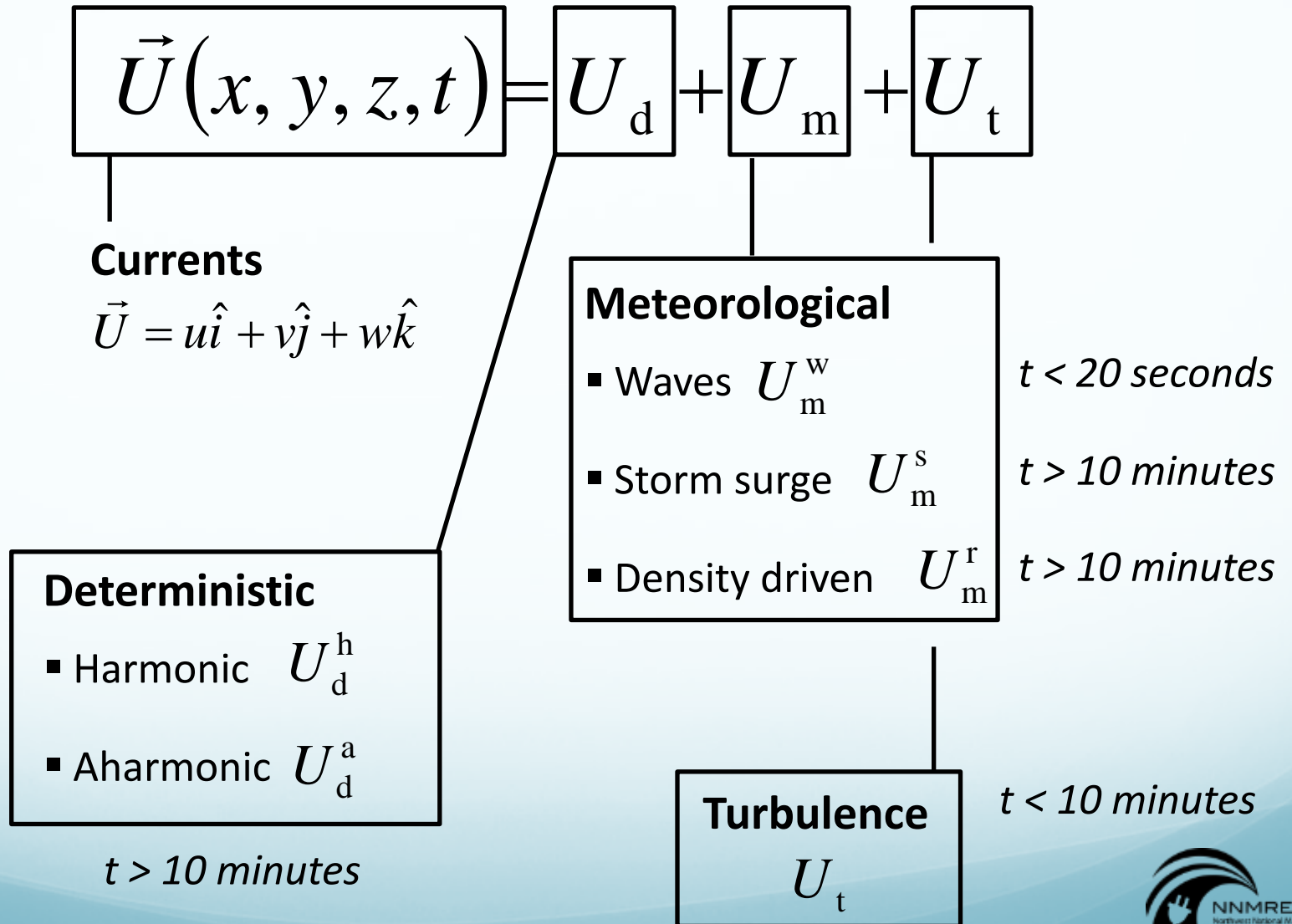
Numerical Modelling – Critical Learning before Getting Wet

November 6, 2014

Motivation



Components of Currents at Tidal Sites



Design Velocity Framework

- Partition design velocity according to time scales
- Treat wave contribution separate from currents

$$\tilde{U}(x, y, z) = \left(\sum \alpha_d^i \tilde{U}_d^i + \sum_{j \neq w} \alpha_m^j \tilde{U}_m^j \right) \tilde{I}_U + \alpha_m^w \tilde{U}_m^w$$

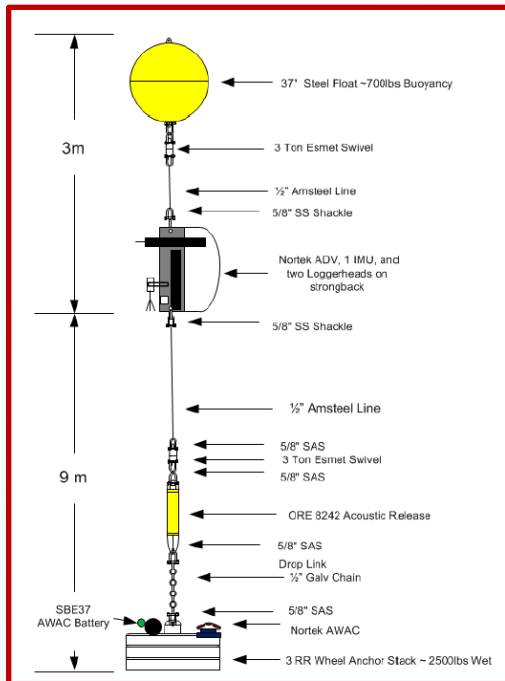
Design Velocity (m/s)

Design Velocity Component (m/s)

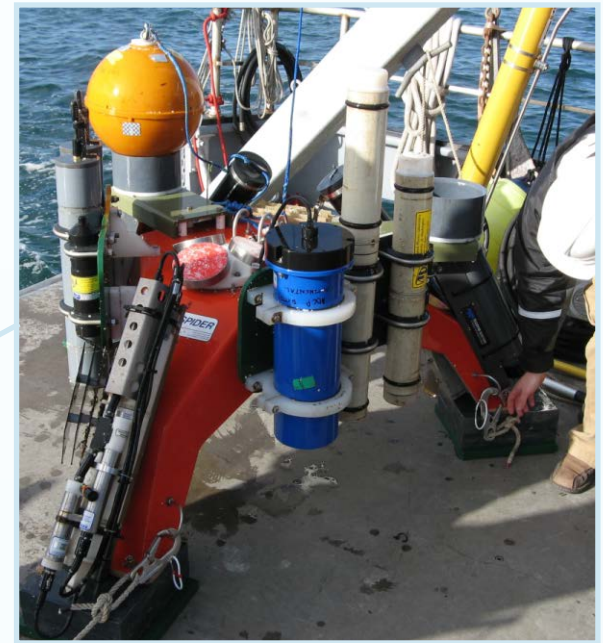
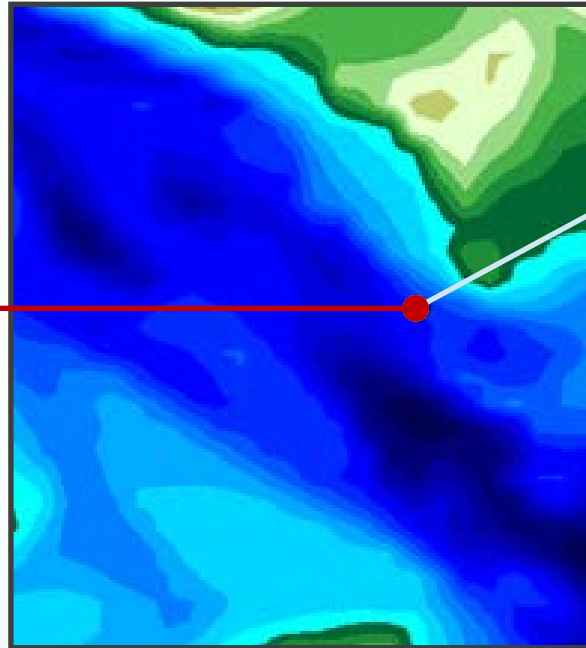
Simultaneous Occurrence Factor

Turbulence Multiplier

Case Study Overview



Admiralty Inlet Puget Sound, WA (USA)



Sea Spider

- 782 days (gaps)
- < 10 m cluster
- $\Delta z = 1$ m
- $\Delta t = 1$ minute

TTM

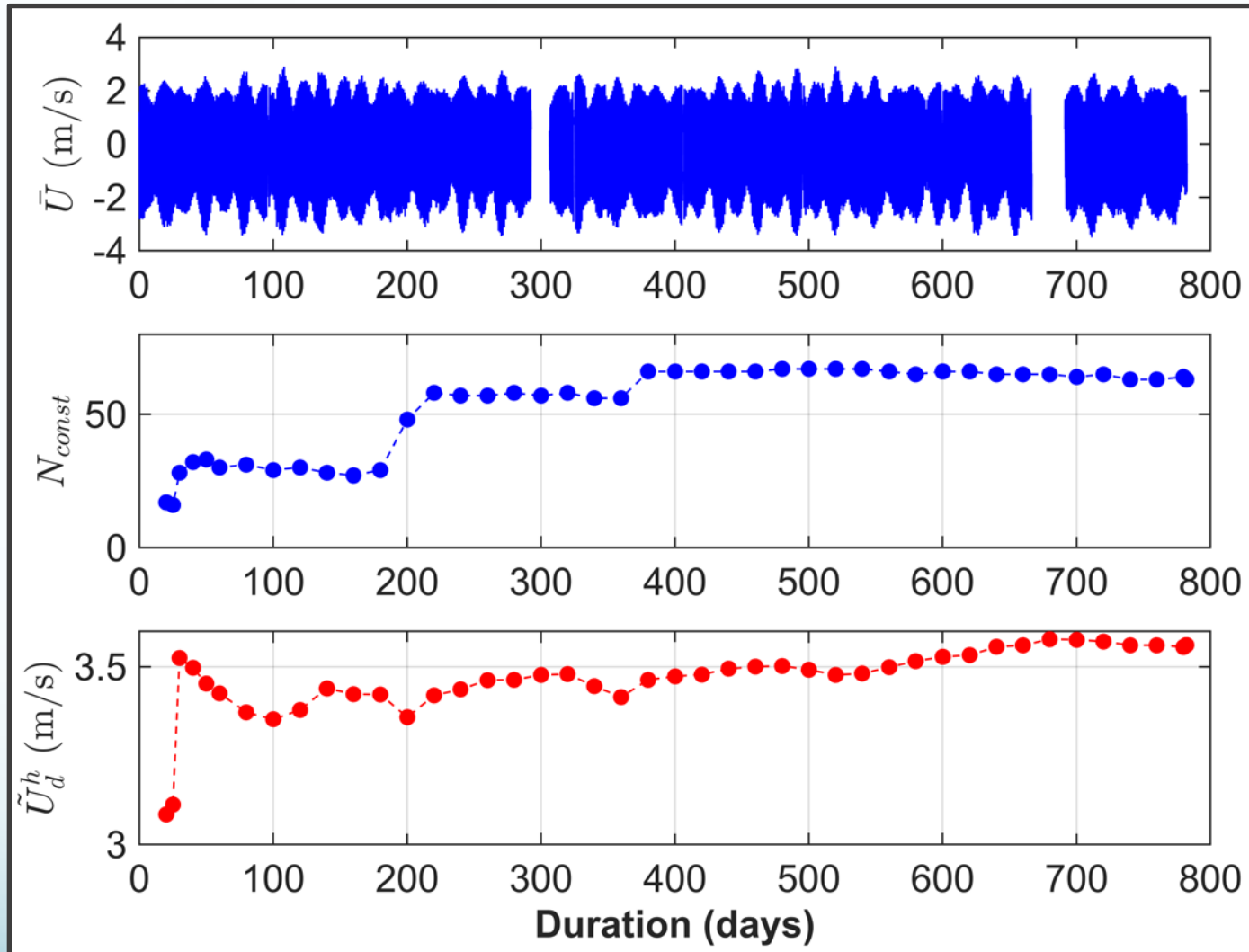
- 2 days
- $z \approx 13$ m
- $\Delta t \approx 0.1$ s

Thomson, J., L. Kilcher, M. Richmond, J. Talbert, A. deKlerk, B. Polagye, M. Guerra, and R. Ceinfuegos (2013) Tidal turbulence spectra from a compliant mooring, *Proceedings of the 1st METS Symposium*.

Polagye, B. and J. Thomson (2013) Tidal energy resource characterization: methodology and field study in Admiralty Inlet, Puget Sound, US, *Proc. Inst. MechE, Part A: J. Power and Energy*.

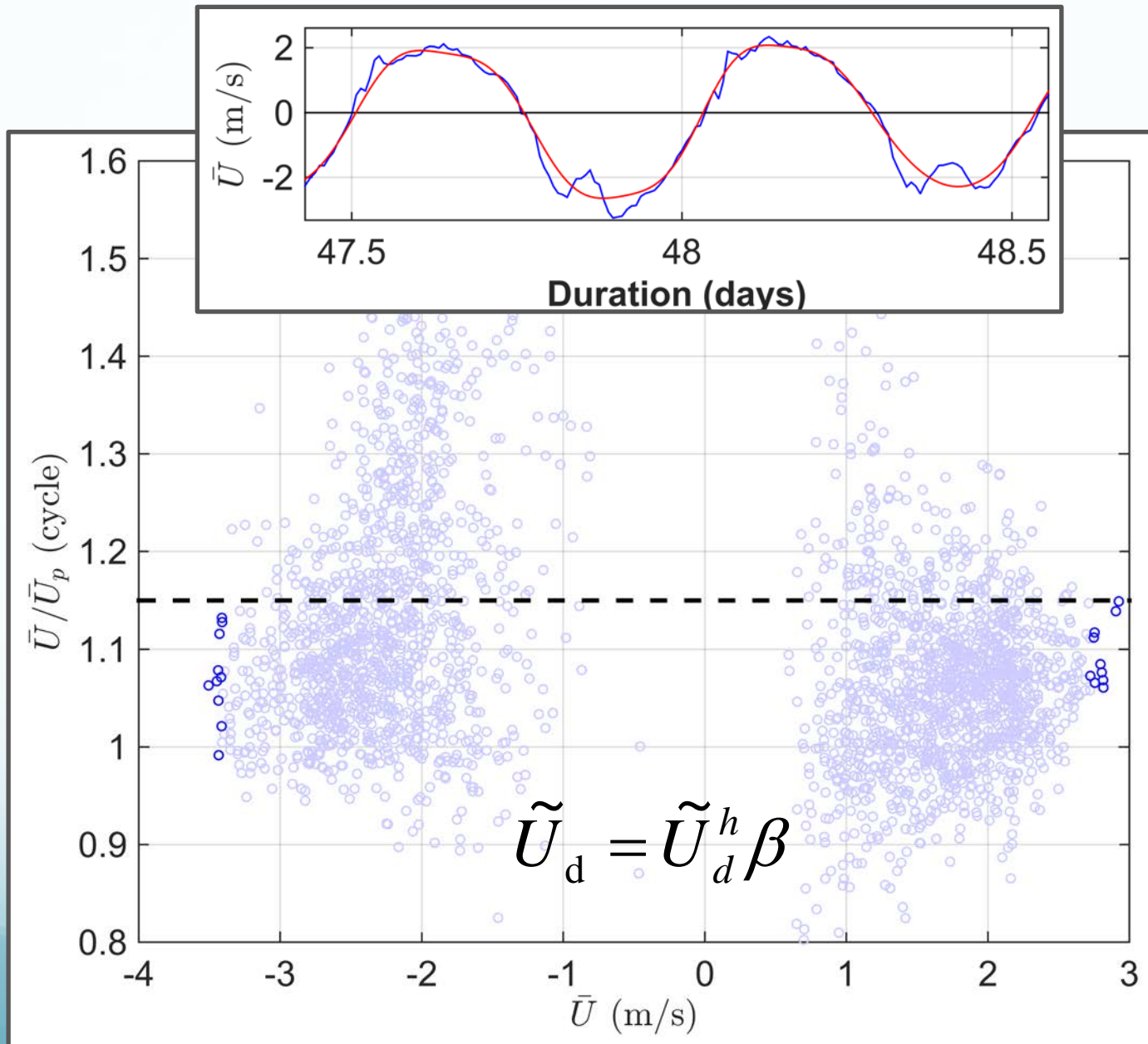


Harmonic Currents



Slow change in predictions of epoch extreme

Aharmonic Currents



Turbulence

$$\bar{I}_U = \frac{\sigma_U}{\langle U \rangle} \quad \begin{array}{l} \text{Statistical Quantity} \\ \text{(Observable by an ADCP)} \end{array}$$

Instantaneous Quantities
(Not Observable by an ADCP)

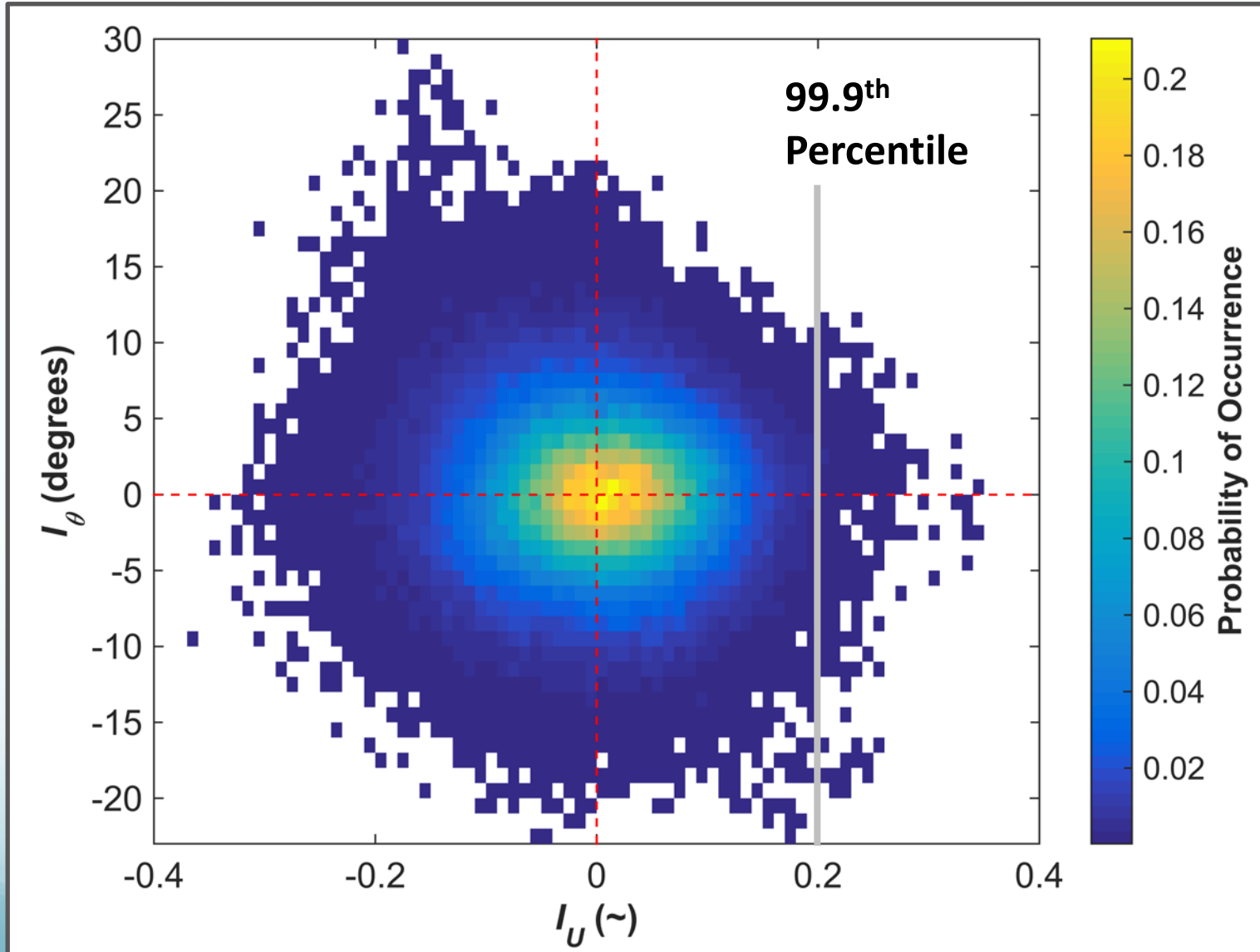
$$U' = U - \langle U \rangle \quad \theta' = \theta - \langle \theta \rangle$$



$$I_U(t) = \frac{U'}{\langle U \rangle}$$

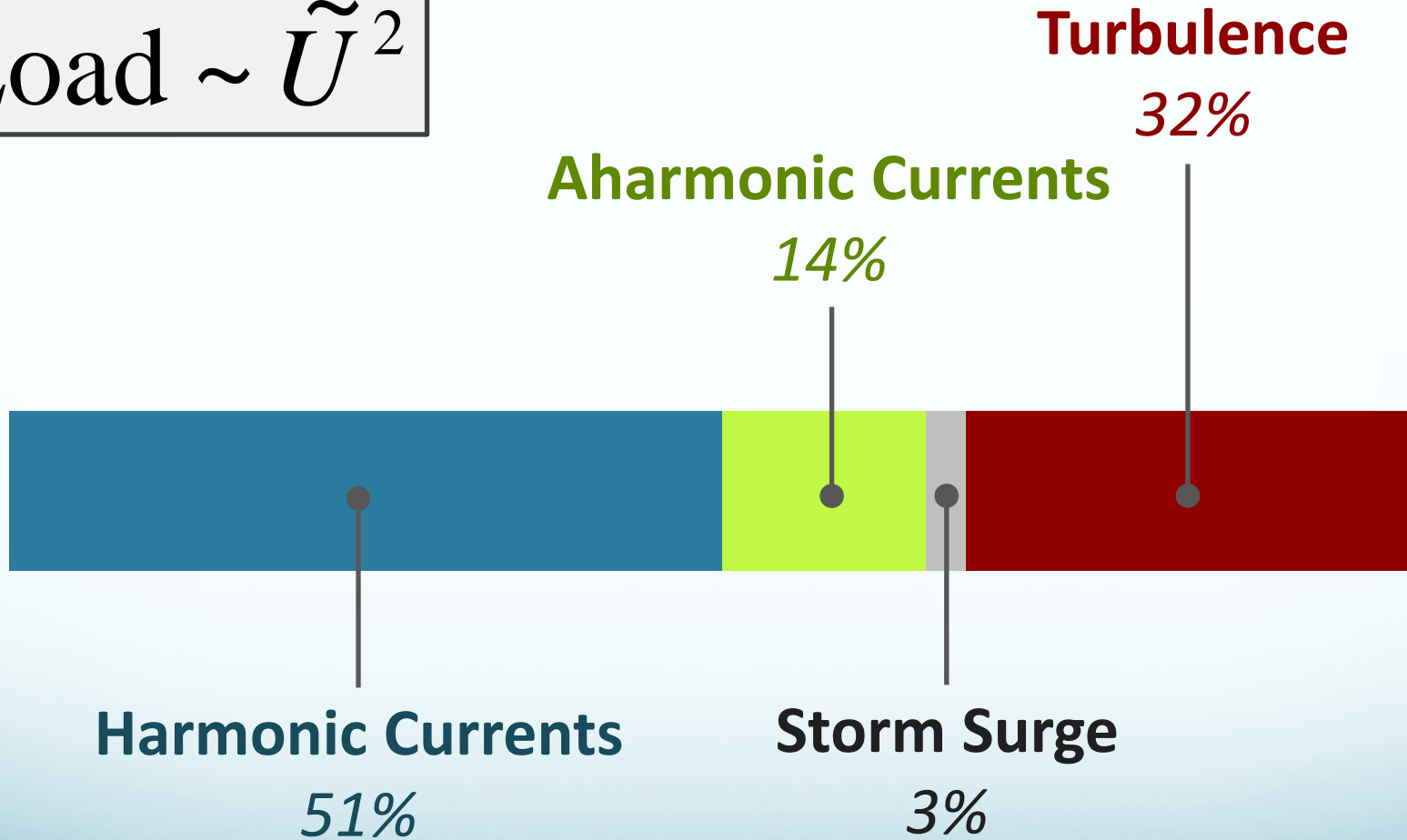
$$I_\theta(t) = \theta'$$

Statistical Representation

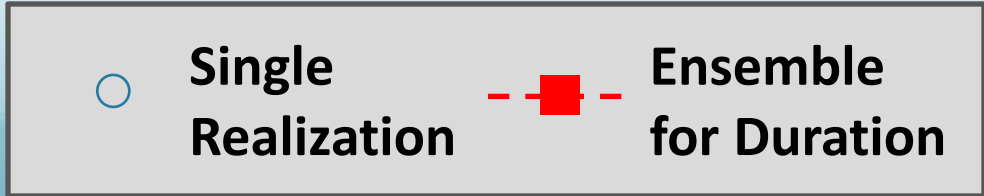
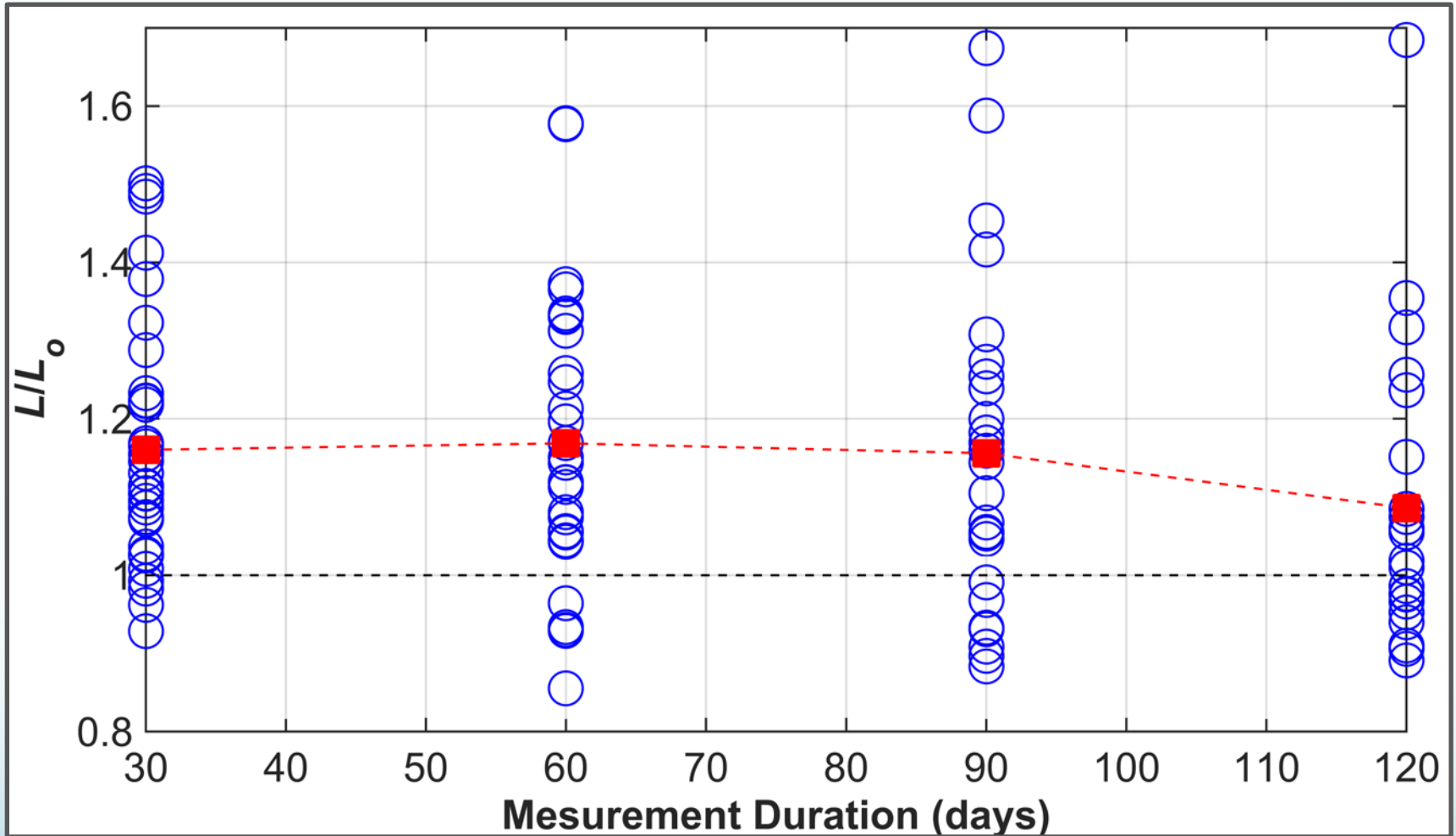


Contribution to Design Loads

$$\text{Load} \sim \tilde{U}^2$$



How about a Shorter Measurement?



Conclusions

Multi-year current records are helpful to explore hypotheses about shorter (*cheaper*) measurements

Detailed standards are needed to reverse pendulum motion on turbine design towards lower (*cheaper*) safety factors

- Each component of design velocity
- Simultaneous occurrence factors

Acknowledgements



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