HYDRO 2016
ROSTOCK-WARNEMÜNDE
08.–10. NOVEMBER

ROCKLAND SCIENTIFIC

Quantifying Turbulence in Tidal Channels

Presenter: Dr. Fabian Wolk, Rockland Scientific Inc.

HYDRO 2016, Rostock-Warnemünde, November 9, 2016

Session 4A – In situ and remote hydrography

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Who We Are

Focus

Turbulence measurements and instrumentation

Location

- Victoria, B.C. Canada

Team

- 17 full-time staff / + students
- Oceanographers
- Mechanical / Electronics Engineers
- Software Developers
- Technologists
- Administration

Cumulative Experience

- 50 years in oceanographic turbulence research
- 22 years in oceanographic instrumentation
- > 50 publications on turbulence measurements

Key Markets

- Scientific research
- Security
- Hydrography

Why is turbulence important?

http://www.windturbinesyndrome.com/wp-content/uploads/2011/11/cloud-528.jpg

- Tidal Channels are the **most turbulent places on the planet**

Turbulence in Tidal Channels

- Rate of energy dissipation is **up to 10^6 x stronger** than in the ocean interior
- Density of water is **10^3 x higher** than air

- Turbulence occurs over a wide range of time and length scales
- Affects different parts of the structure

Turbulence Impacts

- Device Performance
  → Energy Extraction
- Device Loading and Fatigue
  → Time to Failure
- Investment and Insurance Risk

Industry wants:

- Lunar-Cycle Time-Series for Statistical Confidence.
- Spatial Variations over scales from Rotor Diameter to Blade Chord Length.
- Spatial Variations around a Site.

What is turbulence?

$$u' = u - \overline{u}$$

fluctuating velocity ← u'

u → **mean velocity**

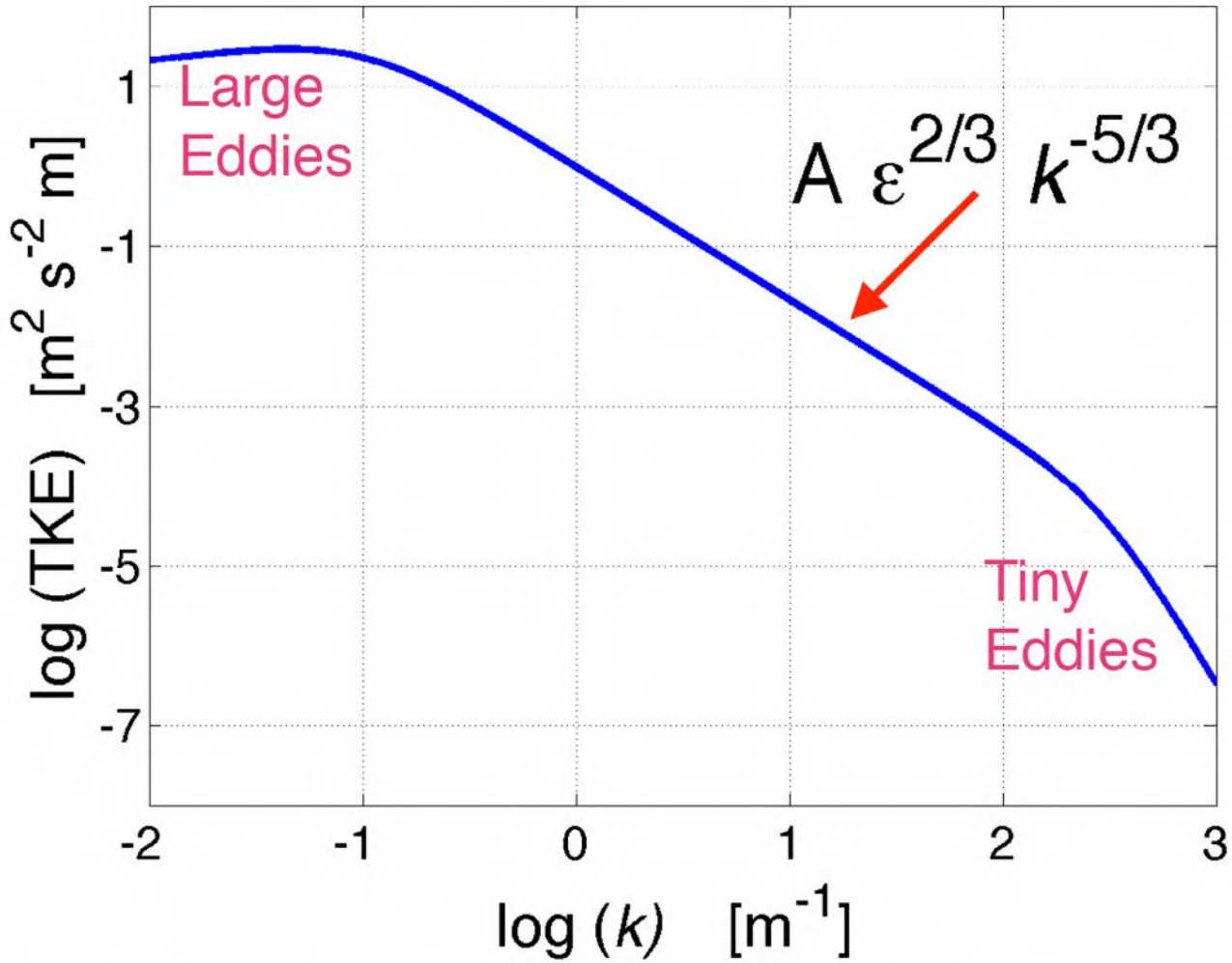
u → **total velocity**

$$I = \frac{u'}{\overline{u}}$$

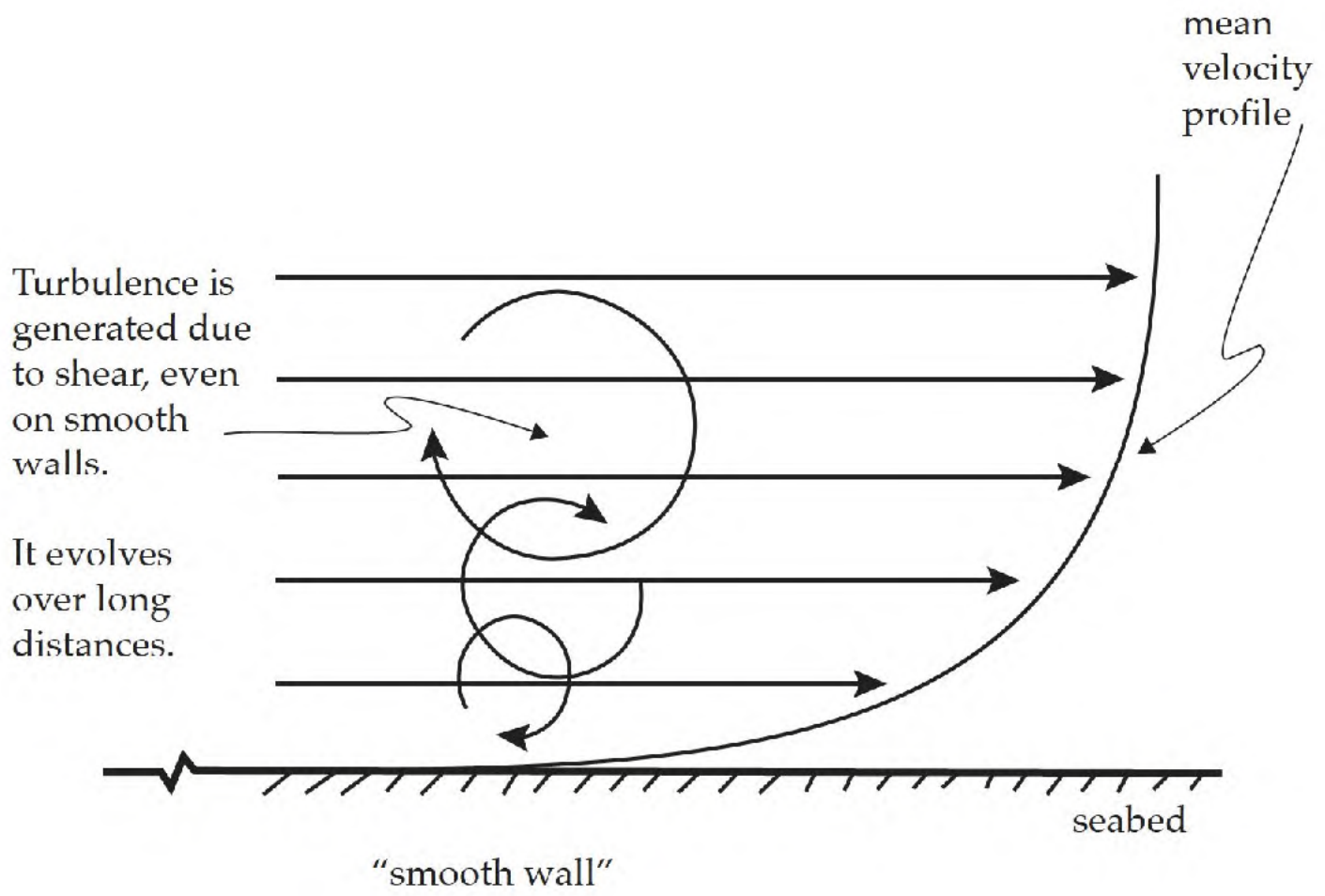
Turbulence intensity %

Dissipation rate ε

- ε is the most important parameter characterizing turbulence.
- ε is required for turbulence modelling of channel flow
- ε is required for turbulence modelling of rotor stress.

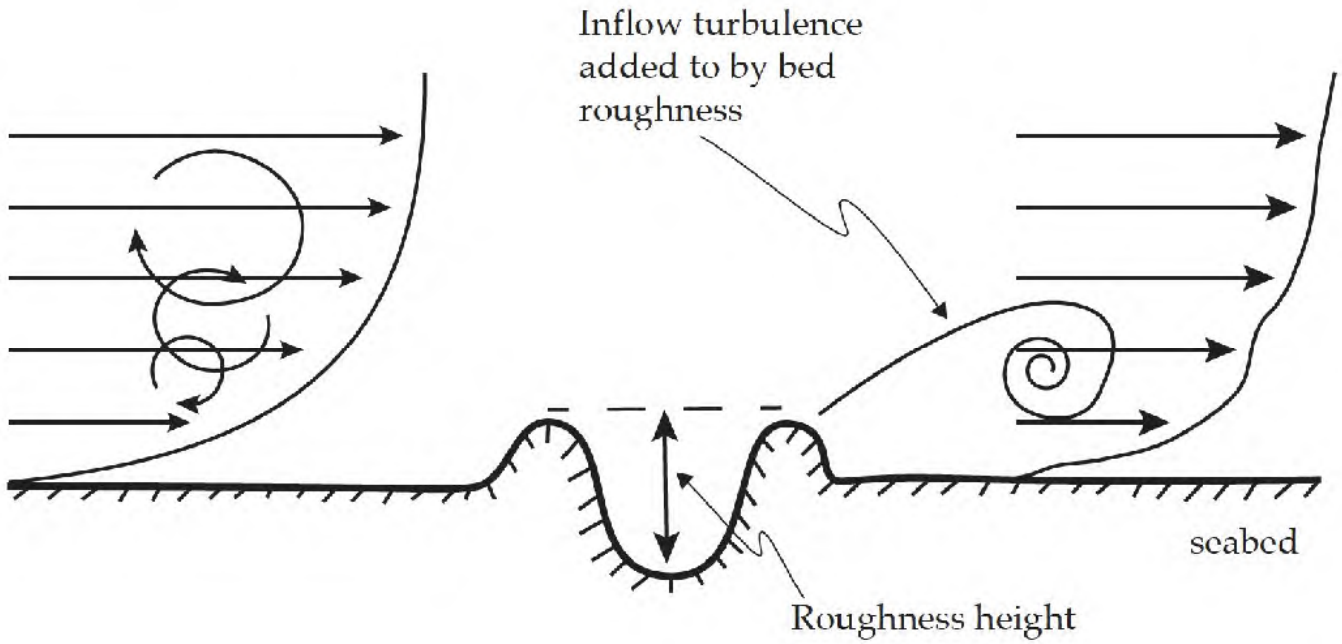


Sources of Turbulence



Source: Clark et al, 2015: Turbulence: Best practices for data processing, classification and characterisation of turbulent flows.

Seabed roughness adds coherent structural content to an already turbulent inflow



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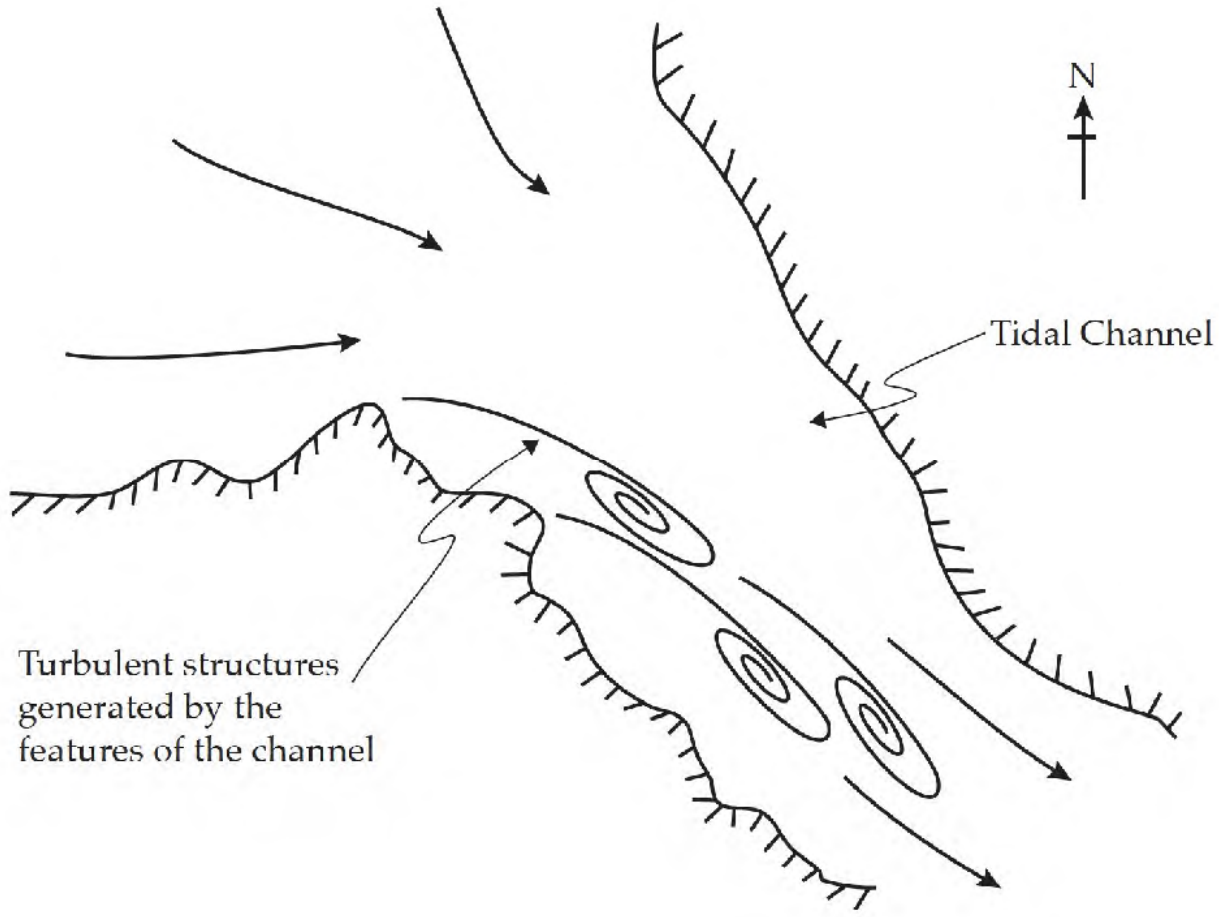
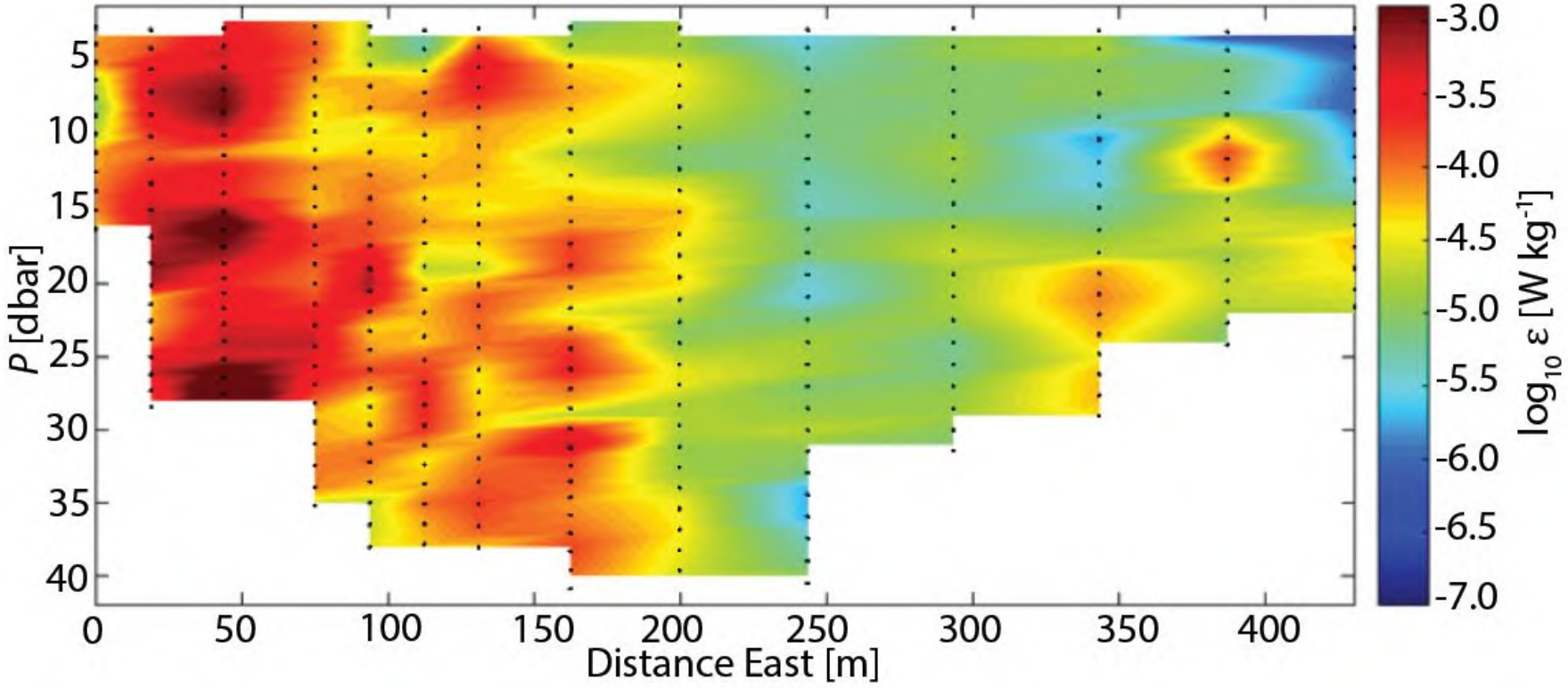


Channel shape creates vertical turbulent eddy structures

Source: Clark et al, 2015: Turbulence: Best practices for data processing, classification and characterisation of turbulent flows.

Cross-channel section of the rate of dissipation of kinetic energy, ϵ, in Islay Sound during an ebb tide.

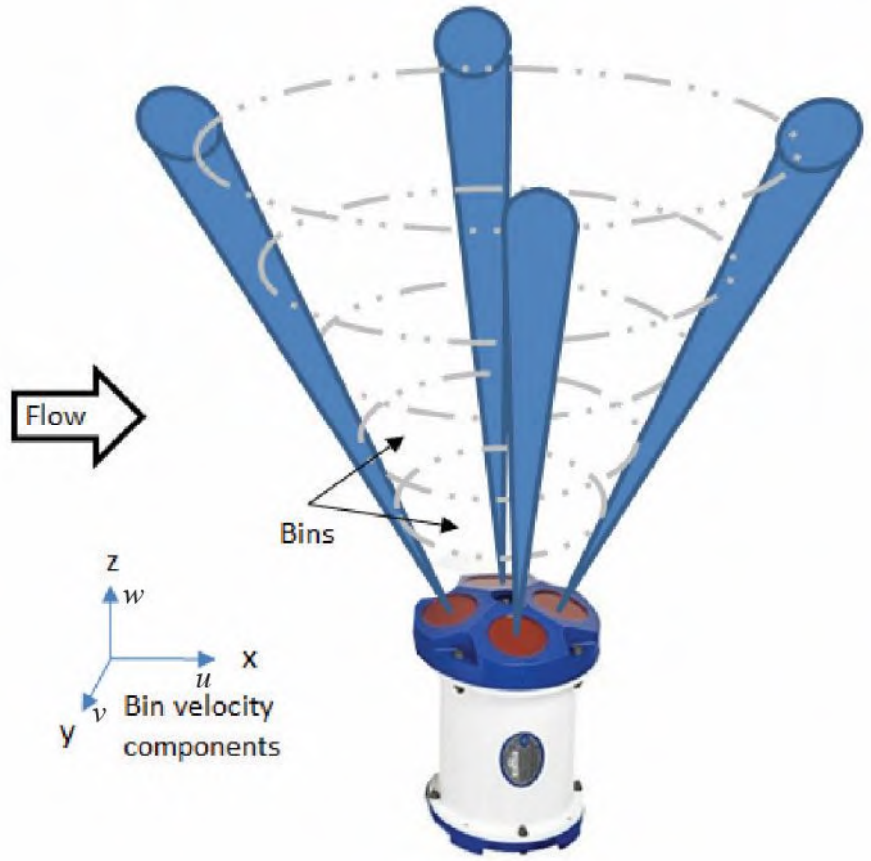
Figure from Lueck et al. (2016).



How to measure turbulence

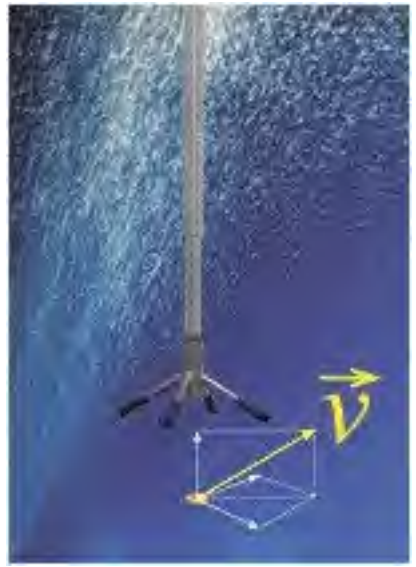
ADCP

- Remote detection of fluctuating velocities
- Easy deployment and installation
- Only delivers time- and space-averaged quantities because of beam spread
- Not suitable for tank installation

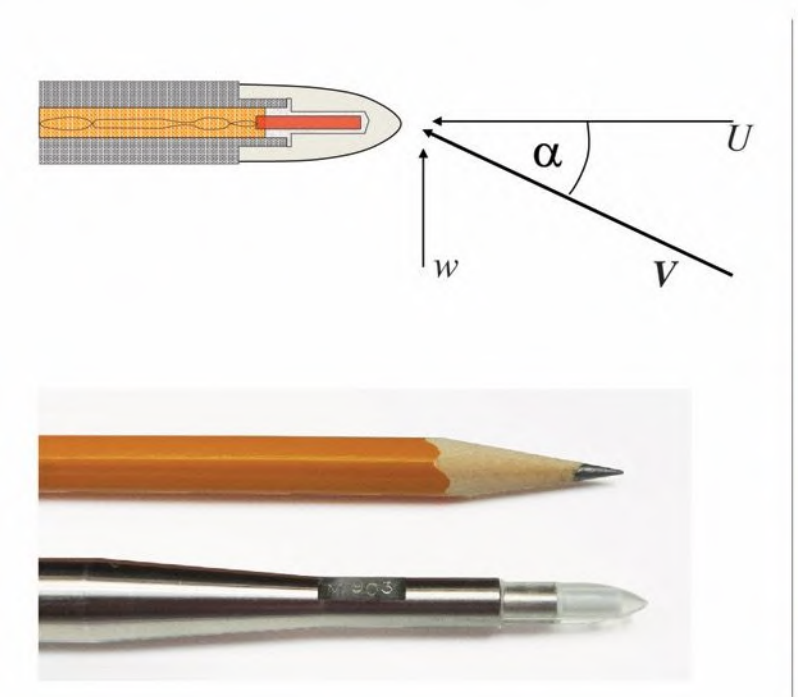


ADV

- Point measurements of mean and fluctuating velocities
- High temporal and spatial resolution
- Response depends on acoustic scatterers

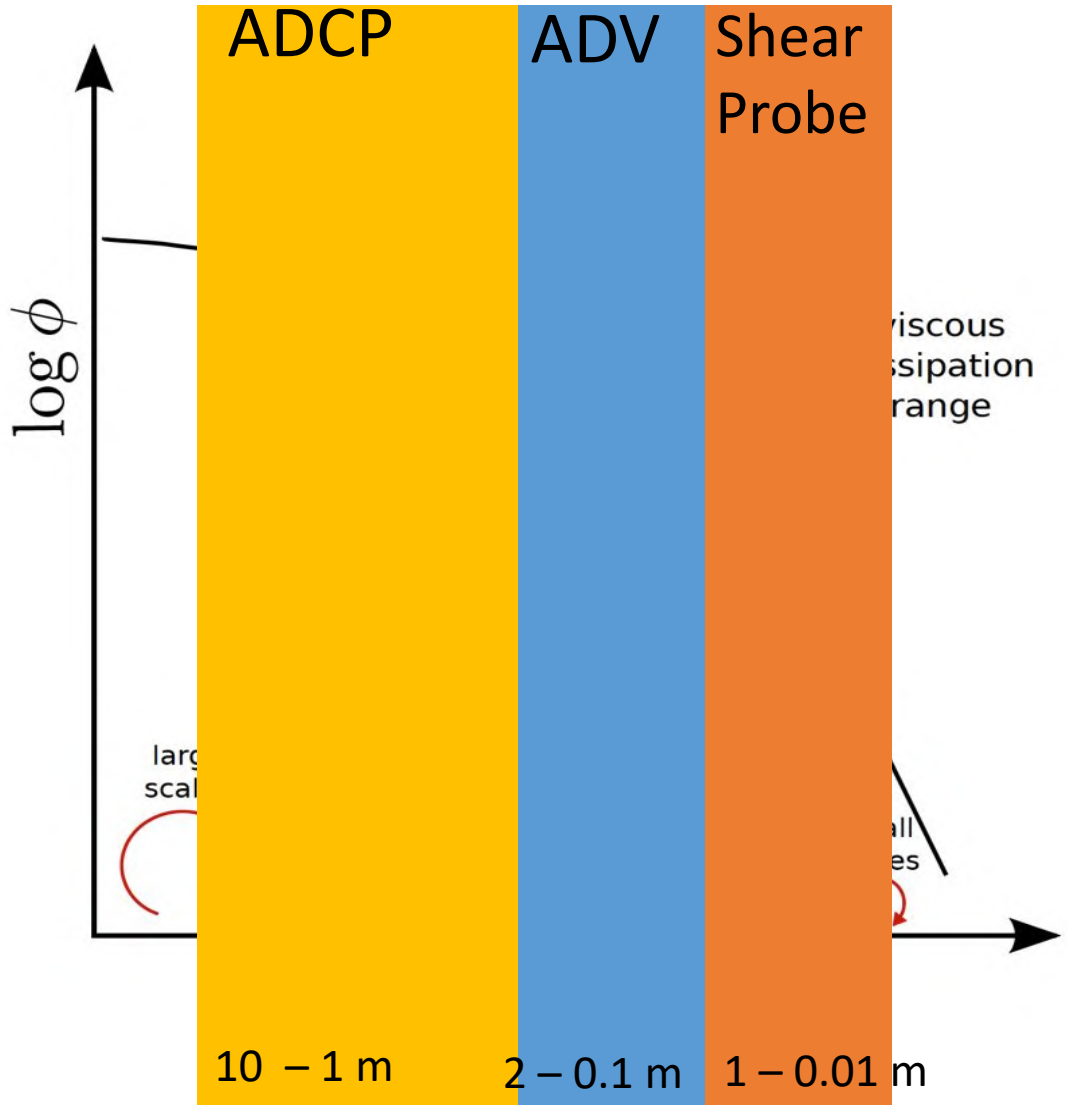


Shear probe



- Point measurements of fluctuating velocities
- High temporal and spatial resolution
- Cannot detect mean flow

Full-scale resolution of turbulence



InSTREAM

Turbulence Characterization & Modeling

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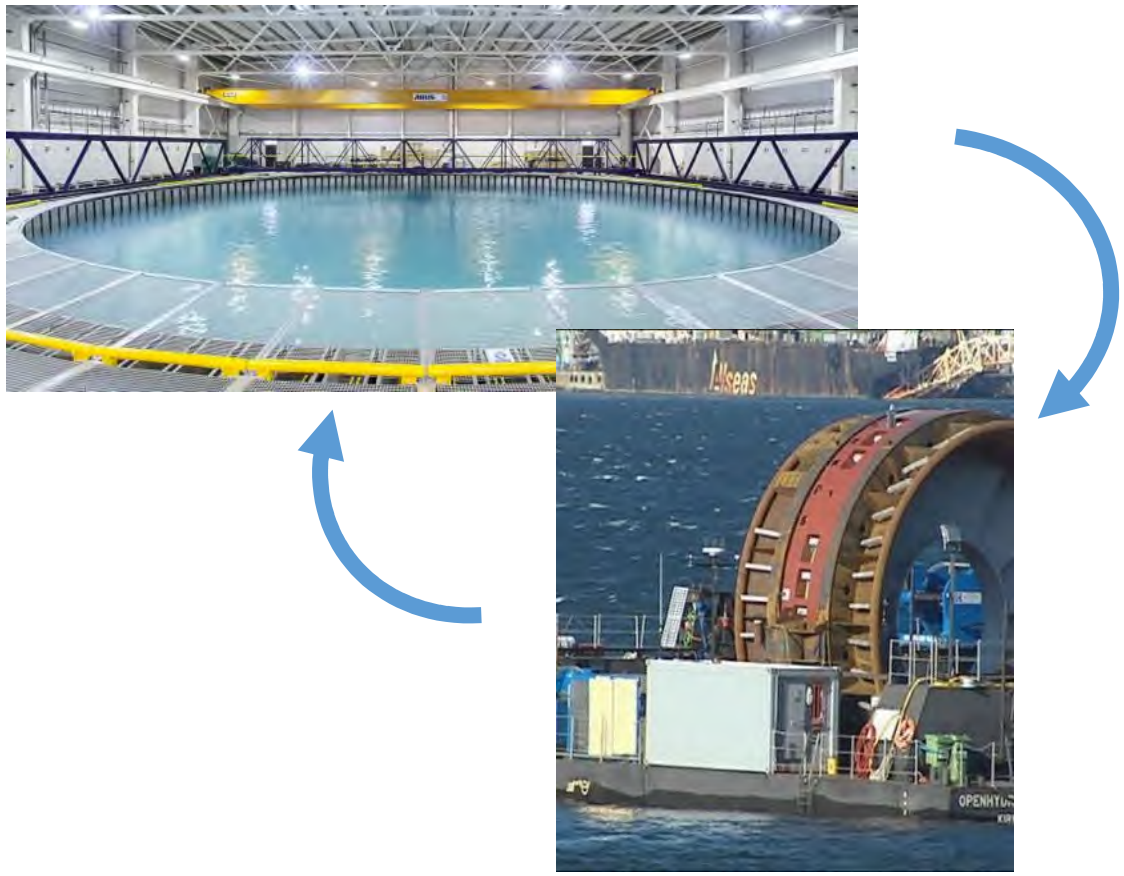

Objectives

- Developing sensor system for turbulence that can be used in the laboratory and in the field
- Using this technology to understand the translation between laboratory and real world

InSTREAM
Turbulence Characterization & Modeling

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BLACK ROCK TIDAL POWER

DALHOUSIE UNIVERSITY

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Funding

- Nova Scotia Department of Energy (OERA)
- Canadian Government (IRAP)
- UK Government (Innovate UK)
- Project partners (Rockland, Black Rock, EMEC, Ocean Array Systems)

Consortium of six partners in Canada & UK

OCEAN ARRAY SYSTEMS

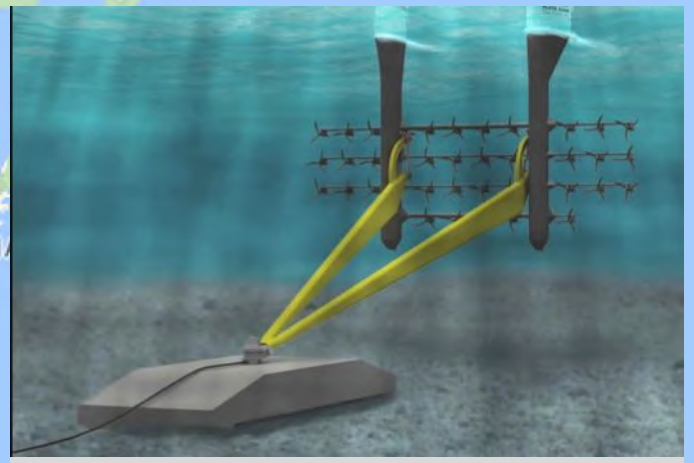
FloWave

EMEC ORKNEY
THE EUROPEAN MARINE ENERGY CENTRE LTD

Technology test sites

European Marine Energy Centre (EMEC)

- Orkney Islands, Scotland
- Fall of Warnness



Minas Passage (FORCE)

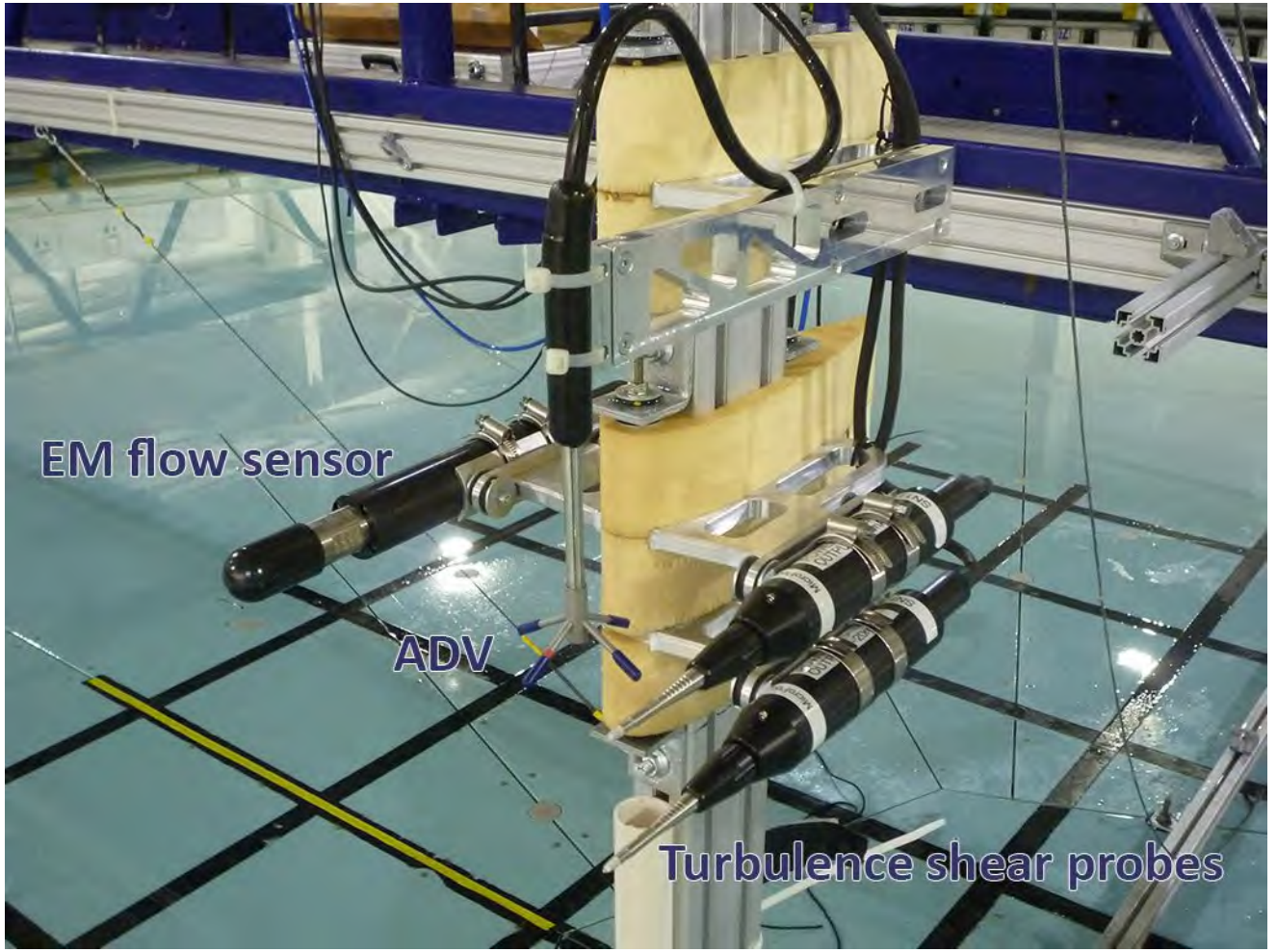
- Black Rock / Schottel test berth

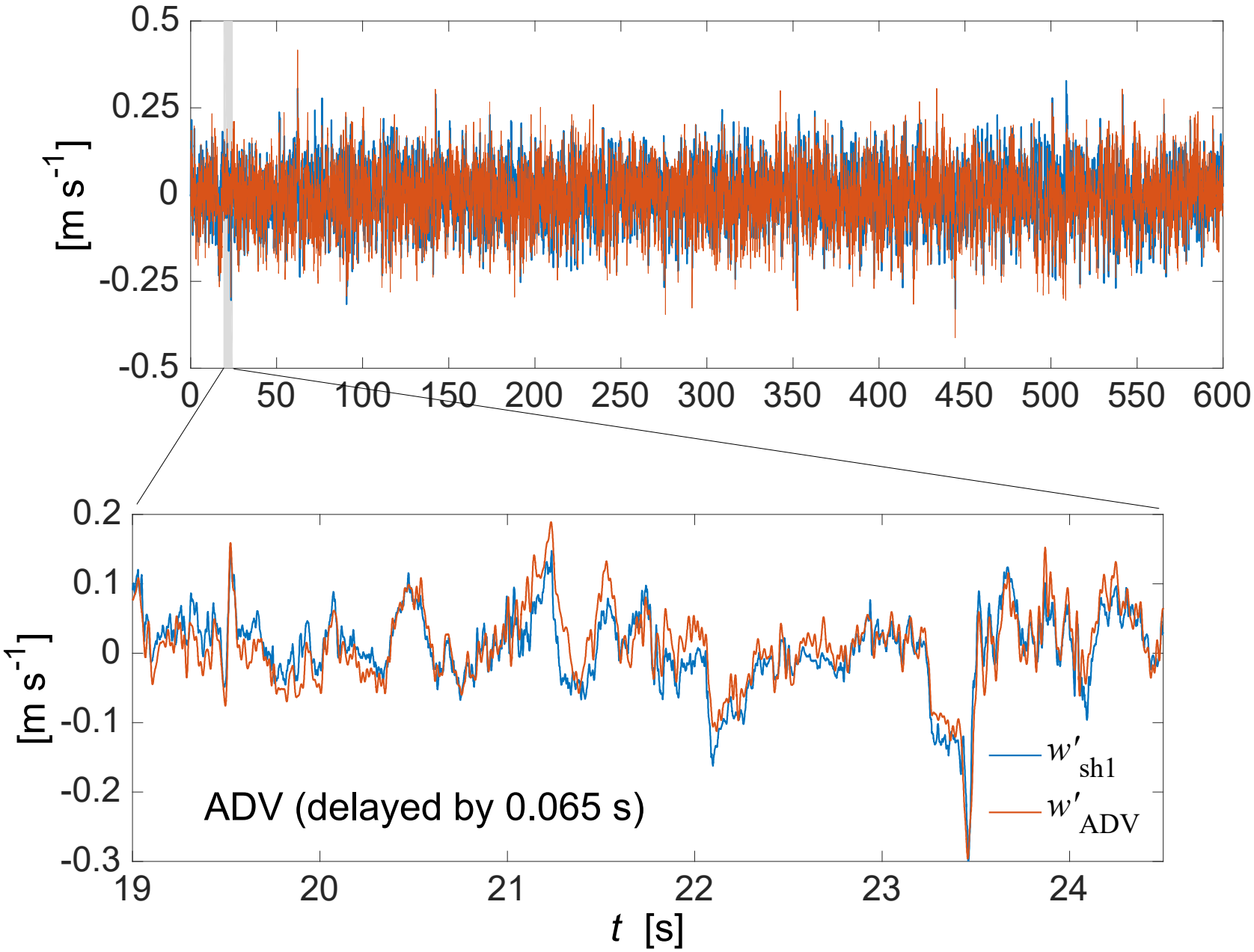
FloWave Ocean Simulator

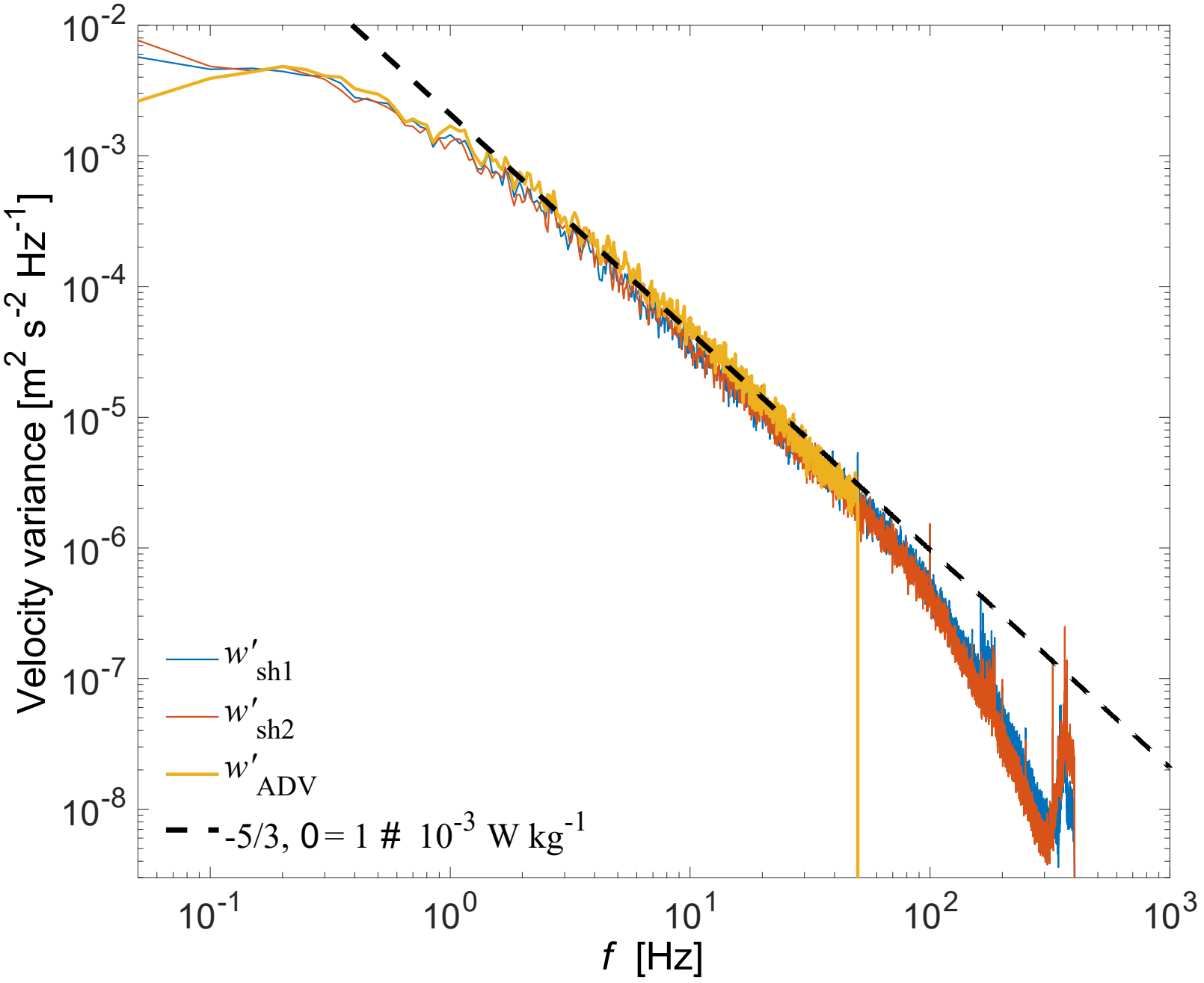
- Circular flume
- 25 m diameter / 5 m depth
- 28 flow drive units
- 168 wave paddles

1) FloWave TT

Test setup May 2016



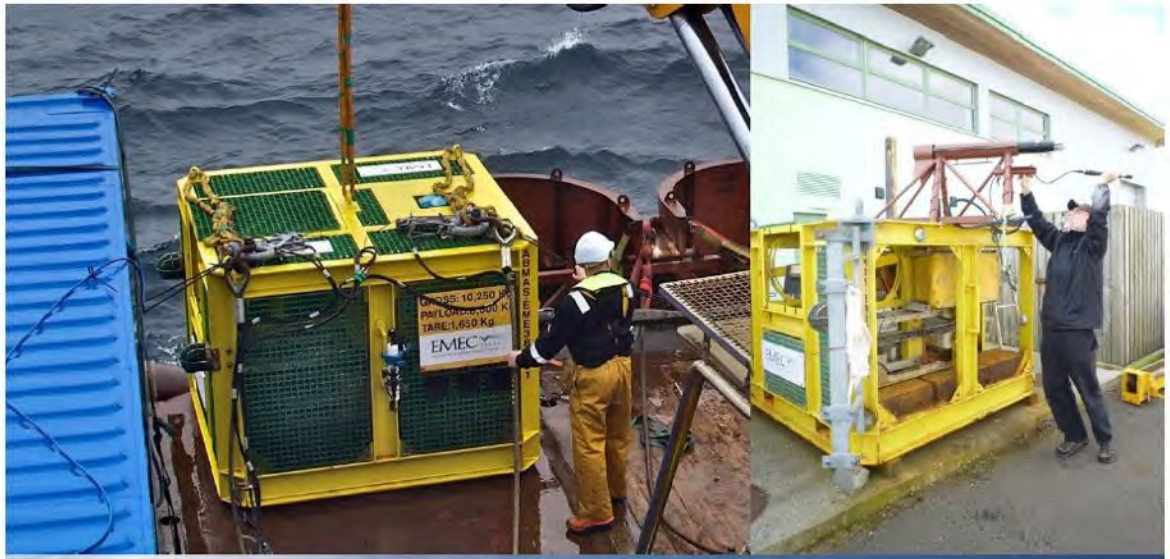

0.5
0.25
0
-0.25
-0.5
[m s-1]
0
50
100
150
200
250
300
350
400
450
500
550
600
0.2
0.1
0
-0.1
-0.2
-0.3
[m s-1]
ADV (delayed by 0.065 s)
w′sh1
w′ADV
19
20
21
22
23
24
t [s]

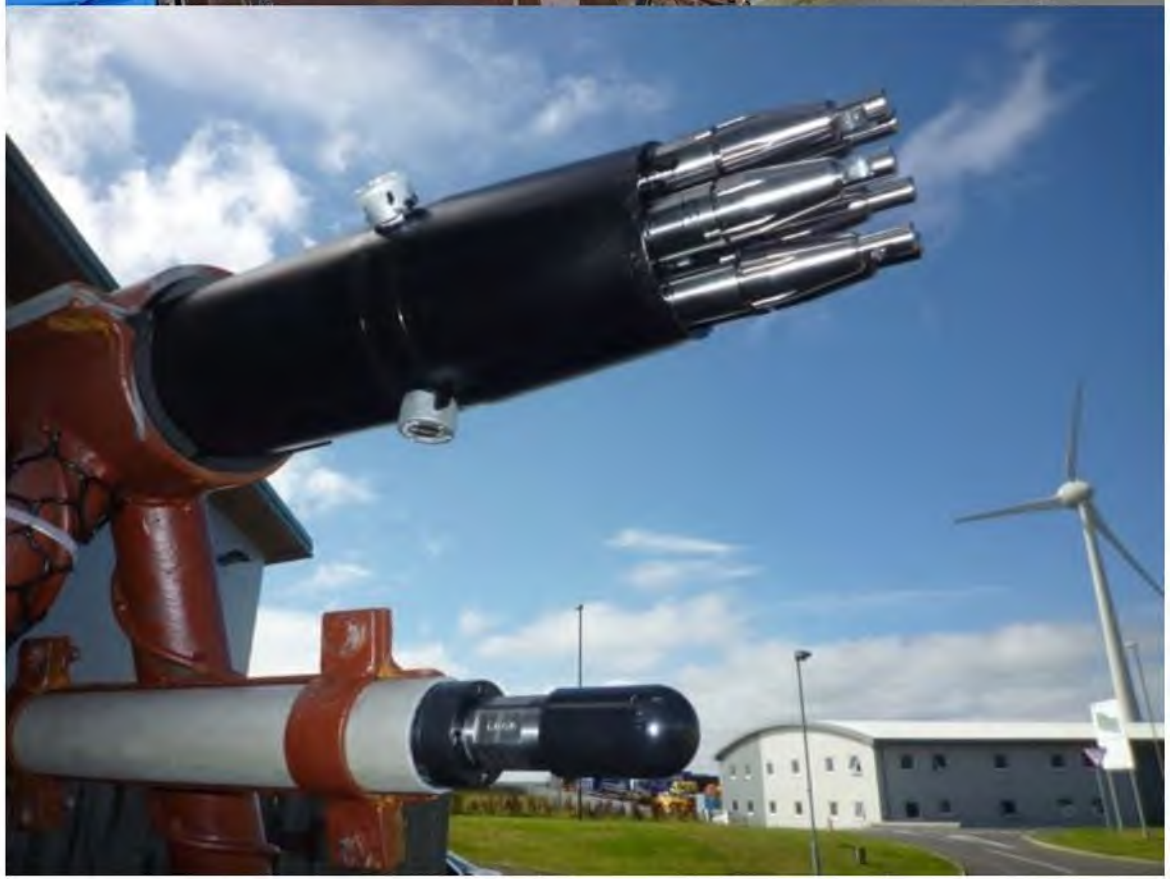


$$Re_\lambda = \frac{\langle \mathbf{u}' \rangle_{\mathrm{rms}} \, \lambda}{\nu}$$

2) EMEC Installation

- Seabed platform connected to shore station
- Shear probes and EM current meter
- Long-term deployment with periodic data downloads
- Provides high resolution time series of turbulence parameters near turbine site
- Planned deployment October 2016

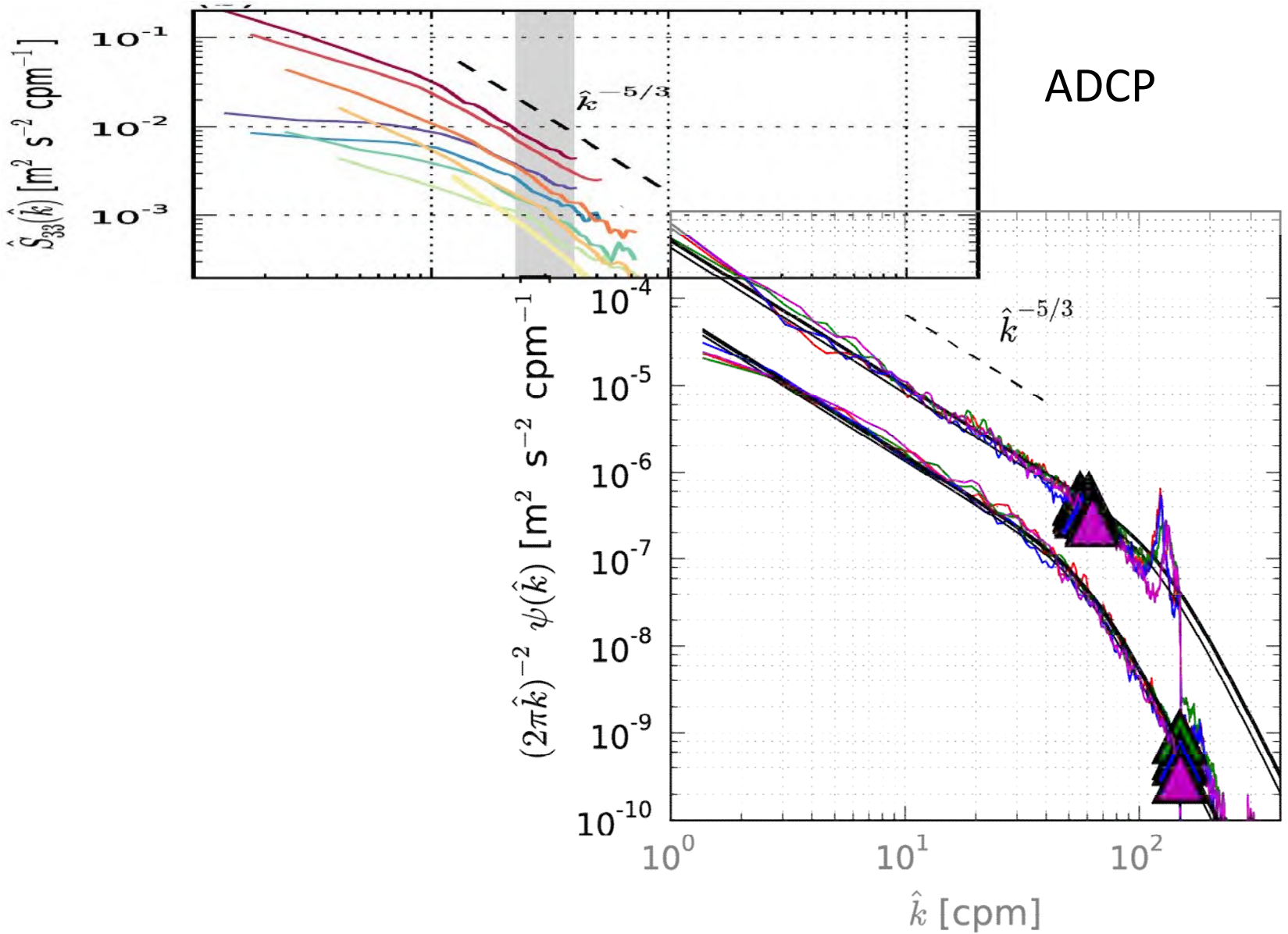




3) Minas Passage

- ”Nemo” float
  - Shear probes
  - ADV
  - 600kHz ADCP
- 2 Nemo deployed upstream / downstream of Schottel turbine berth site
- 14-day deployment in September 2016

Nemo in Grand Passage



ADCP

Shear Probe

Summary

1. Objectives: measure turbulence over a wide range of temporal and spatial scales to capture time-averaged turbulence quantities as well as turbulent intermittency
2. Measurement system combining remote (acoustic) sensors and point sensors capture turbulent flow over all relevant length and time scales
3. Shear probes can be used in vertical profiling resolving spatial variations for site selection