Challenges in measuring the vertical structure of near-surface currents

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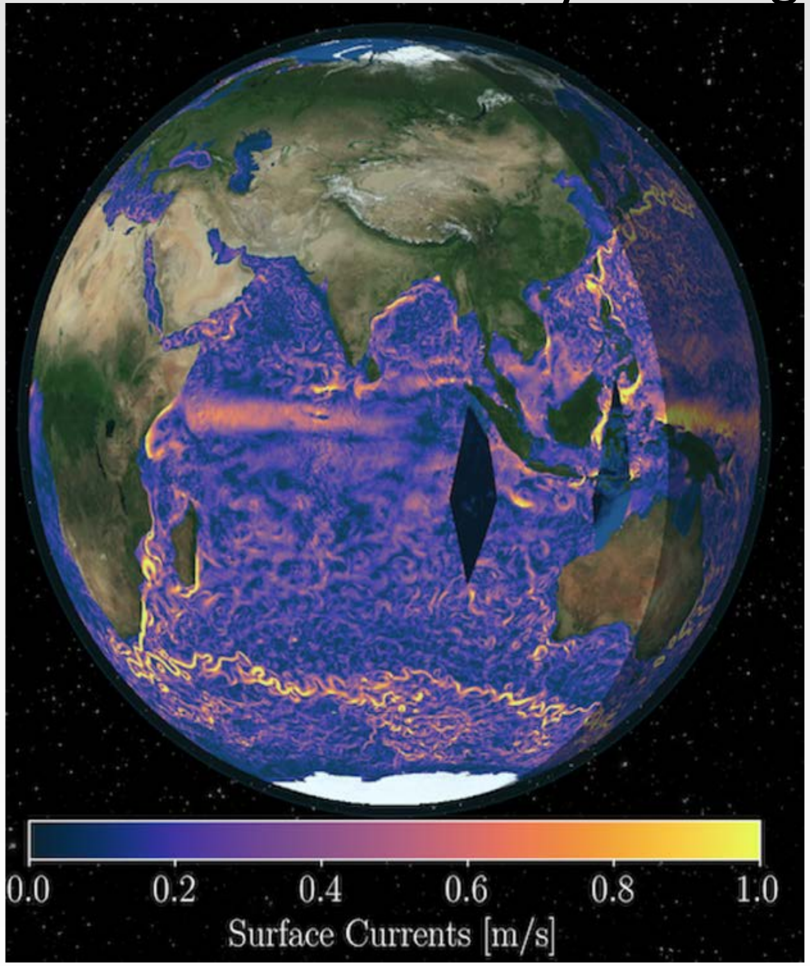
Upper Ocean Processes
Woods Hole Oceanographic Institution

We want to know how to relate the velocity at one depth to that at another

For example, given measurements of sea surface currents, what could we say about the mixed layer currents?

Could we use drifters drogued at 15 m to calibrate or validate satellite surface velocity measurements?

WaCM simulated 1-day coverage



We want to know how to relate the velocity at one depth to that at another

This talk is about what makes that difficult (and interesting):

(1) Near surface shear depends on the turbulent momentum flux divergence

$$\underbrace{\frac{\partial u}{\partial t} - fv}_{} = \underbrace{\frac{\partial \tau_x}{\partial z}}_{} - \frac{\partial p}{\partial x}$$

$\vec{u}(z)$ depends on $\vec{\tau}(z)$ (vertical profile of turbulent momentum flux divergence)

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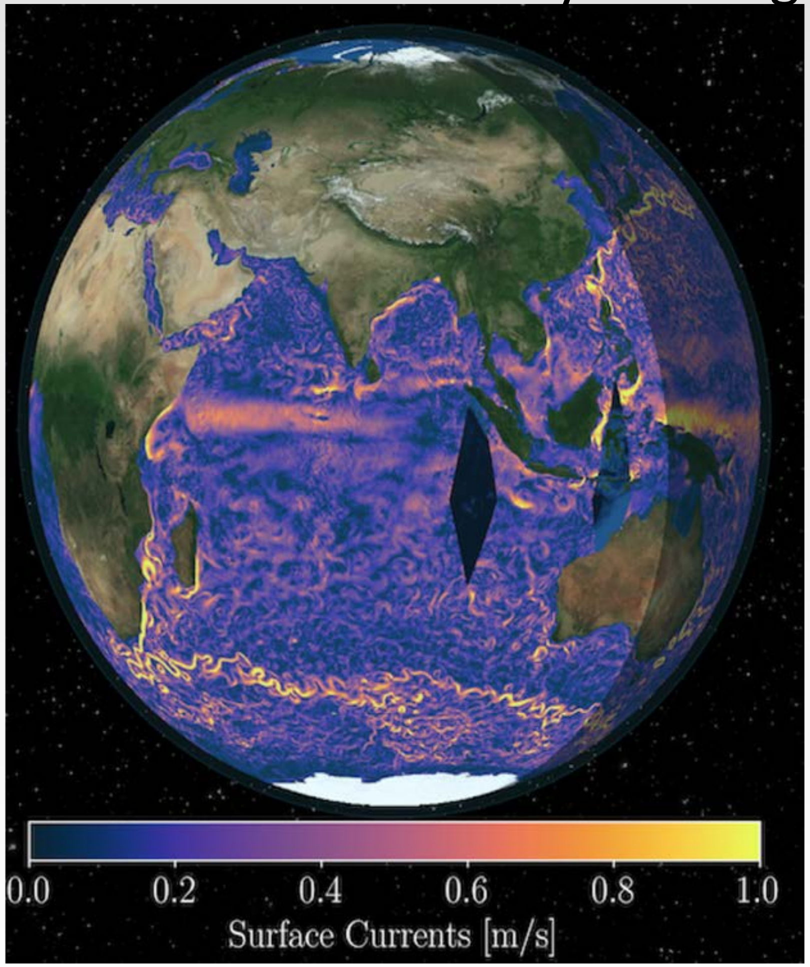

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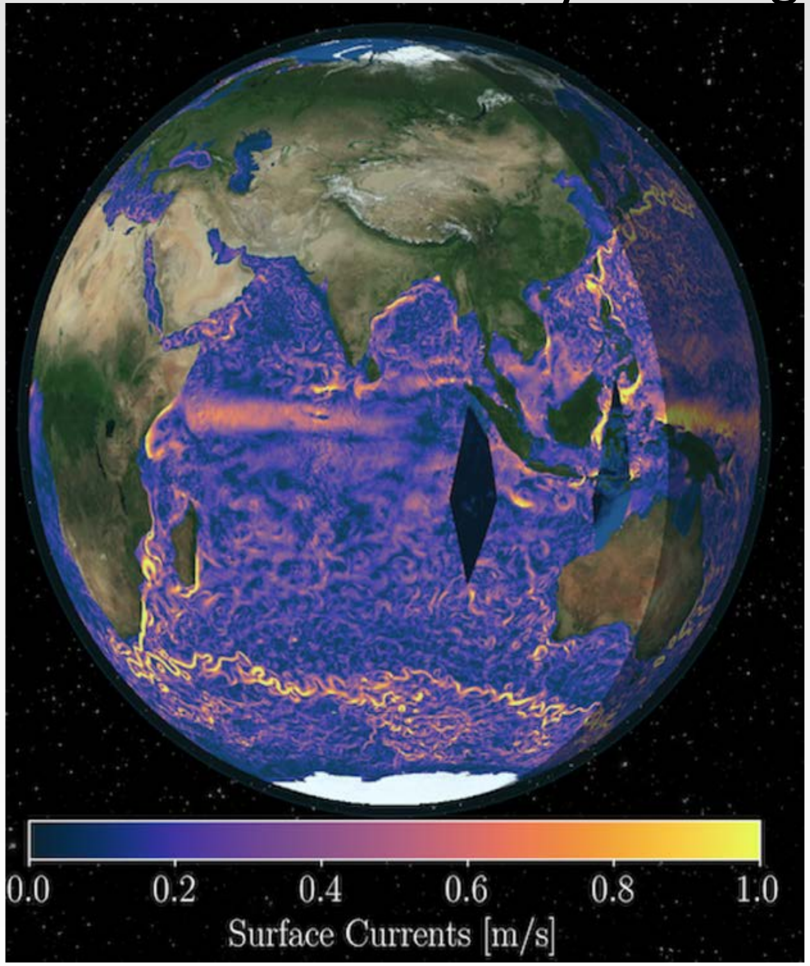

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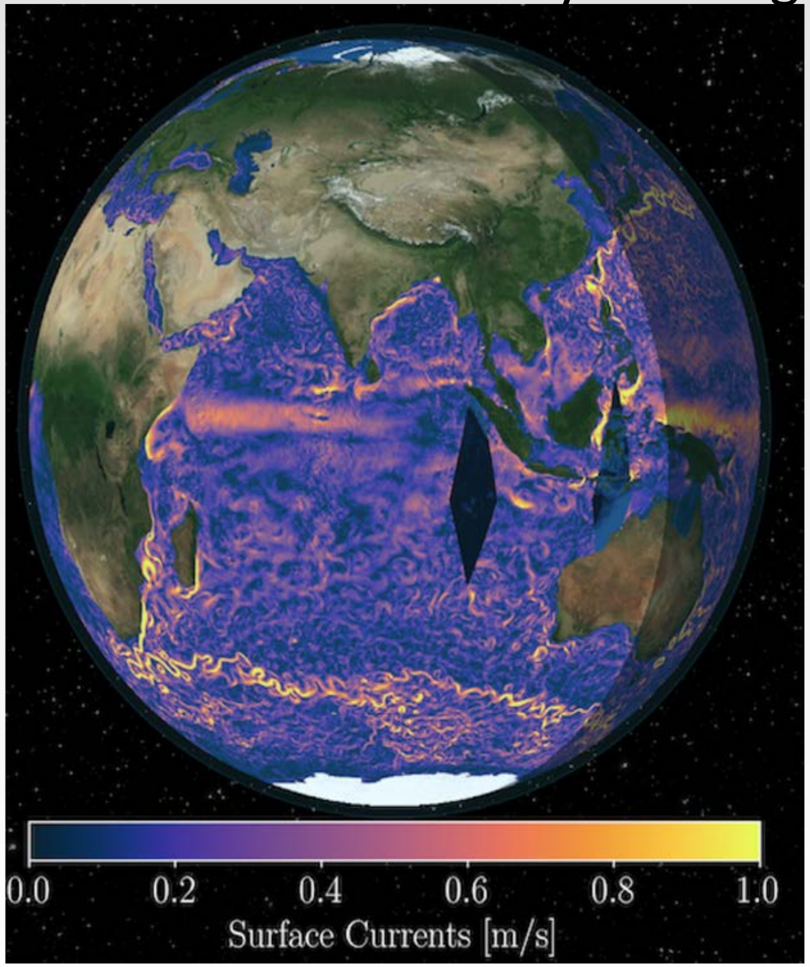
This talk is about what makes that difficult (and interesting):

(1) Near surface shear depends on the turbulent momentum flux divergence
(2) The vertical shear is probably a strong function of length scale and time scale
(3) Measurements of near-surface vertical shear are very difficult because of biases and errors associated with surface waves

WaCM simulated 1-day coverage



Wave orbital velocities

Consider a monochromatic linear wave:

$$\eta = a\sin(kx - \omega t)$$

$$u = a\omega e^{kz}\sin(kx - \omega t)$$

Current meter at a fixed position, $[x_0, z_0]$

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$$\xrightarrow{\text{Time average}} \boxed{\langle u \rangle = 0}$$

As we all know, the Eulerian mean is zero

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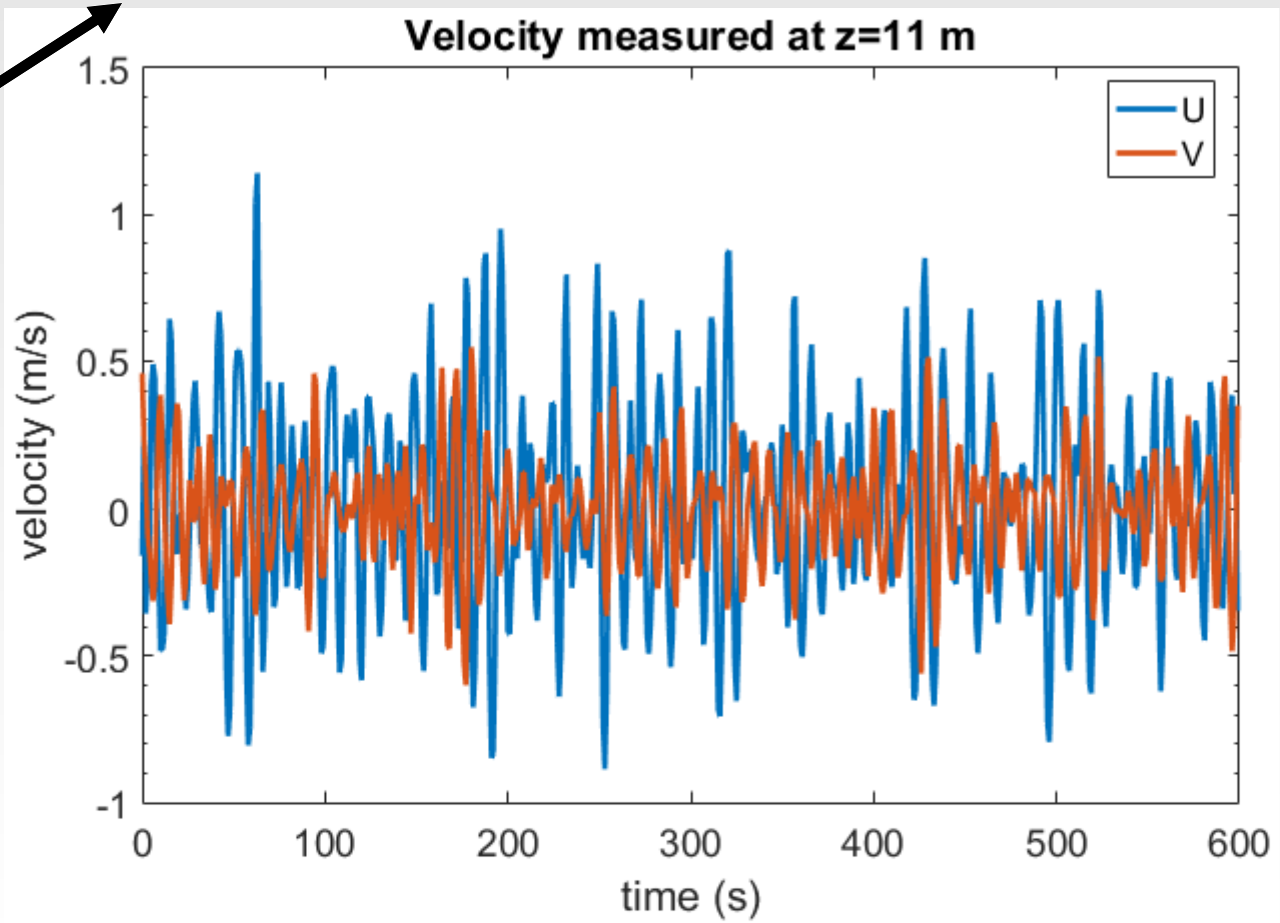
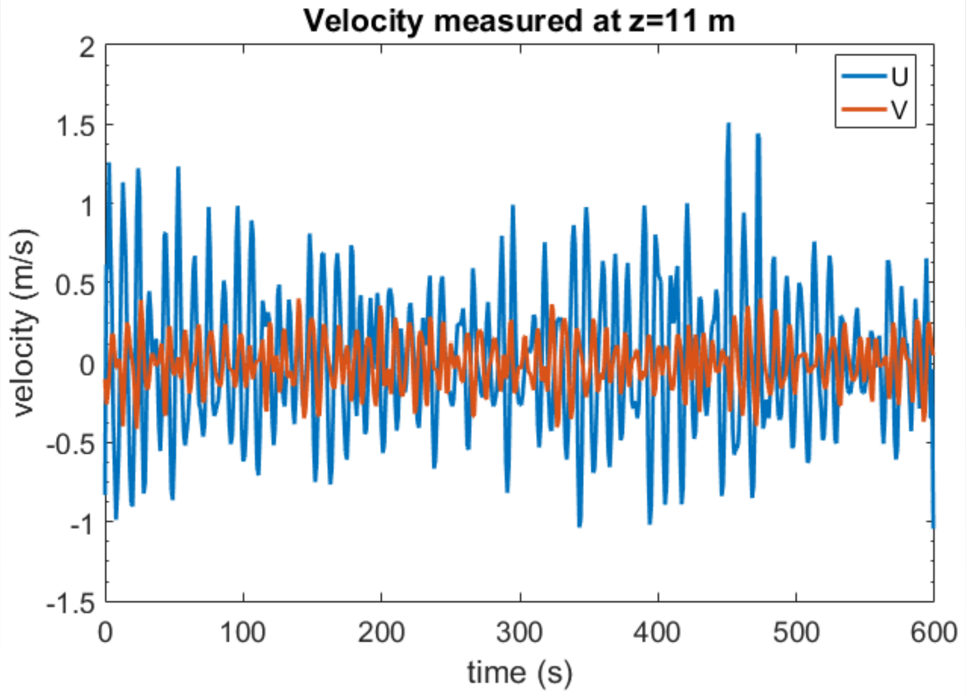
Wave orbital velocities pose a mechanical and sampling problem



Mechanical/sampling problems

- Pumping (of historical note)
- Flow distortion/wake
- Aliasing
- Tilting/heaving correlated with flow



Deep-Sea Research, 1973, Vol. 20, pp. 261 to 268. Pergamon Press. Printed in Great Britain.

Interpretation of near-surface current meter observations*

RAYMOND POLLARD†

A classic but forgotten paper:
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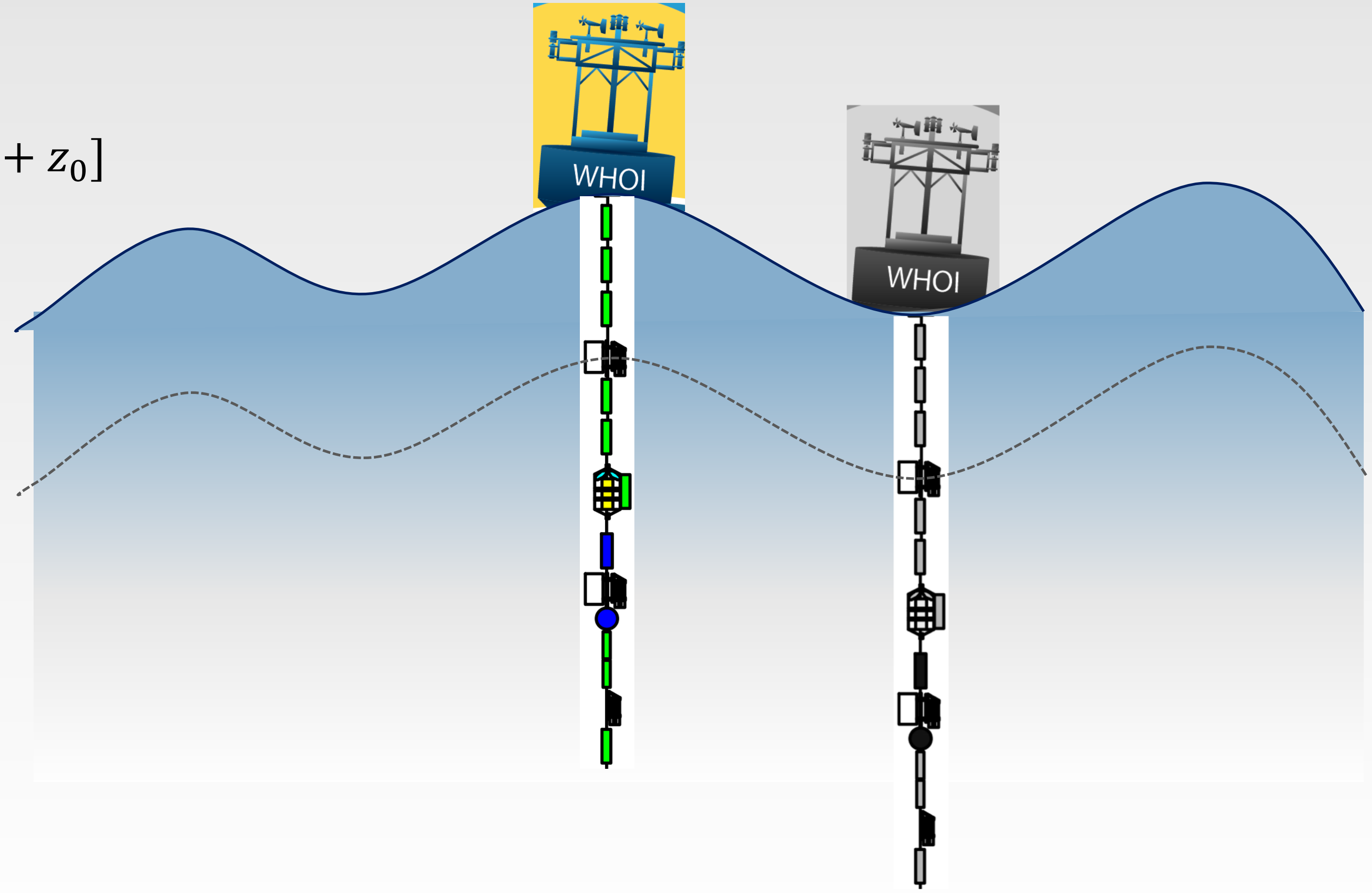

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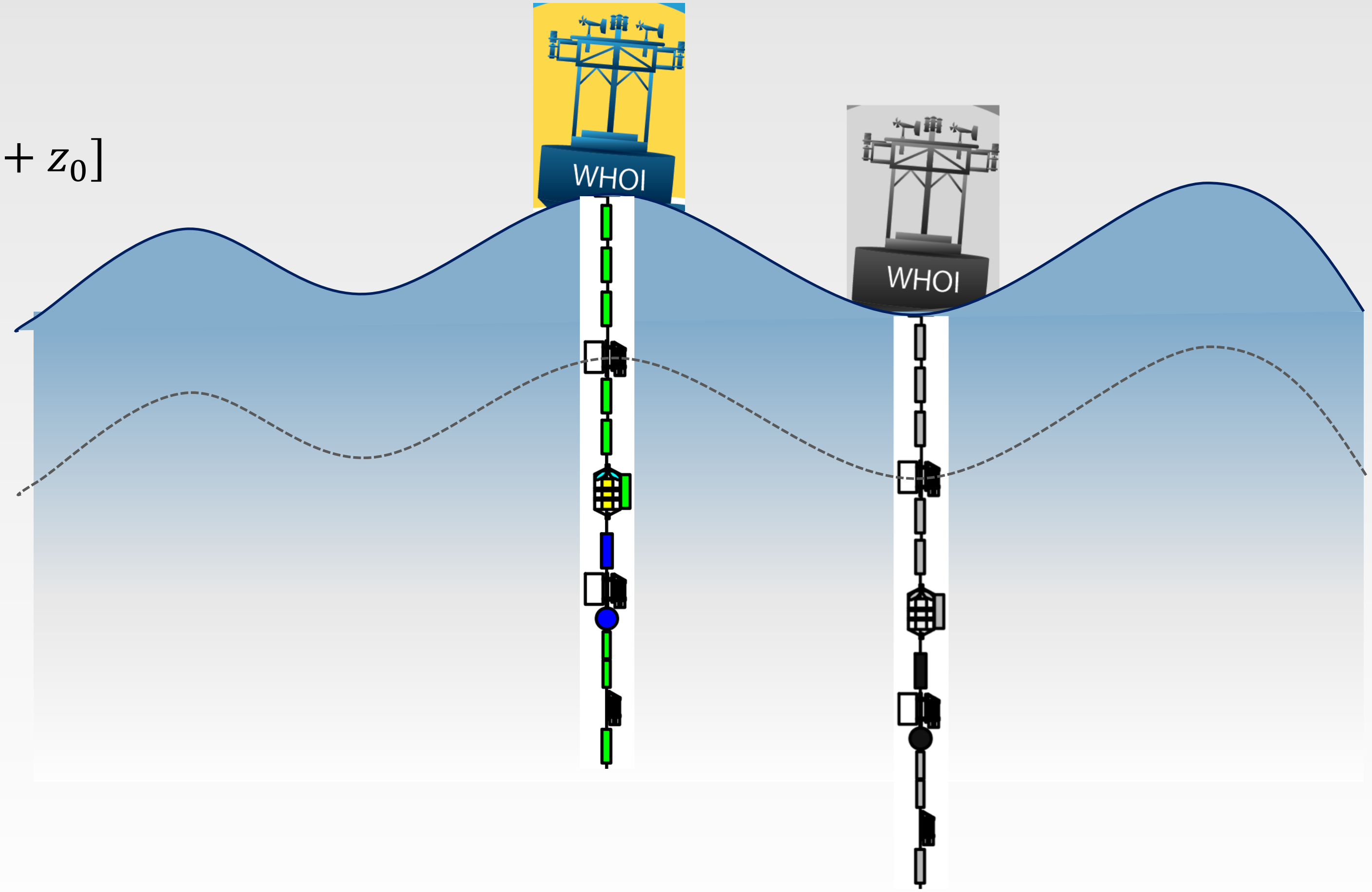

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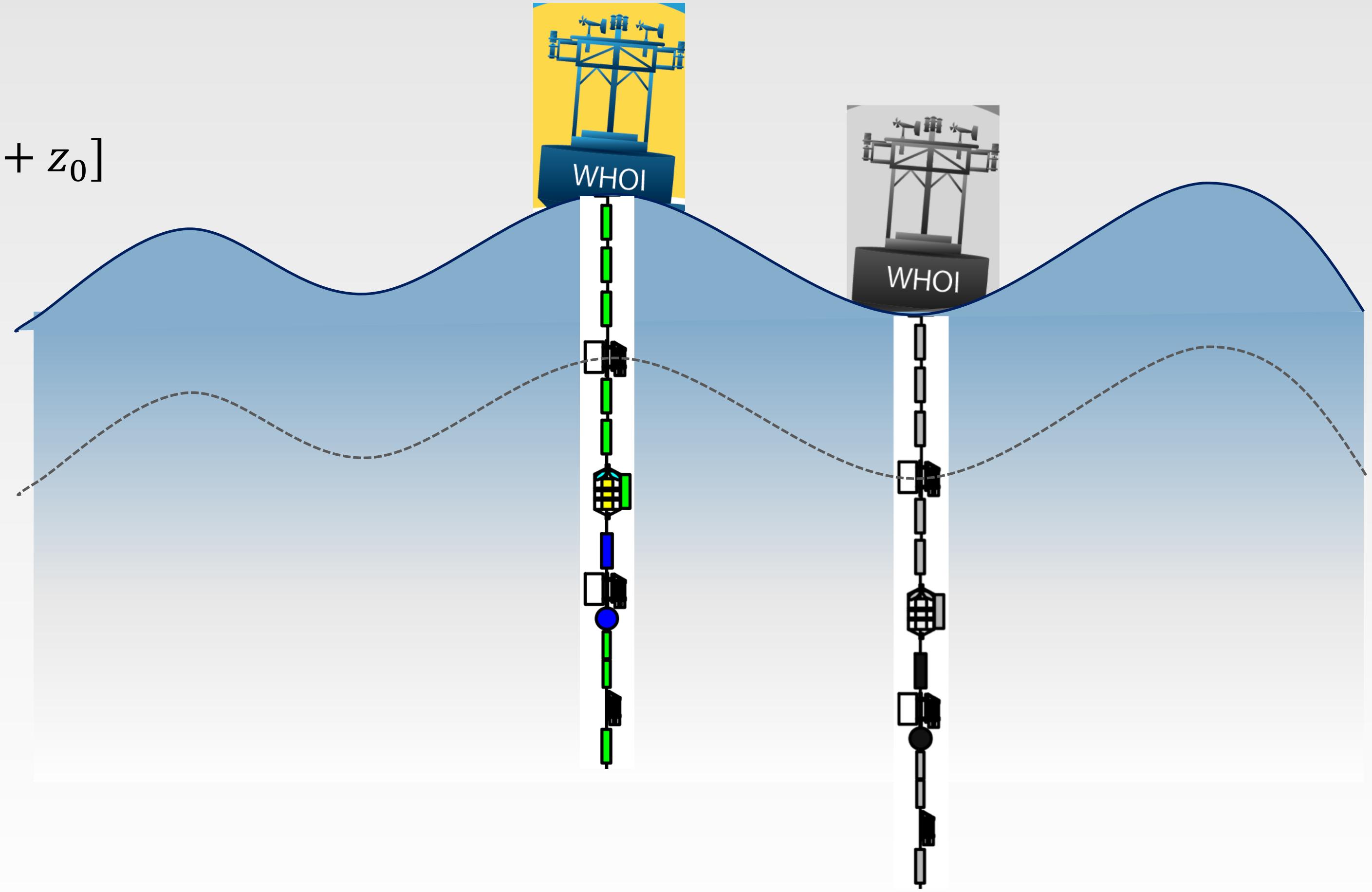
Time average $\longrightarrow$ $\boxed{\langle u\rangle = \frac{1}{2}a^2\omega k e^{kz_0}}$



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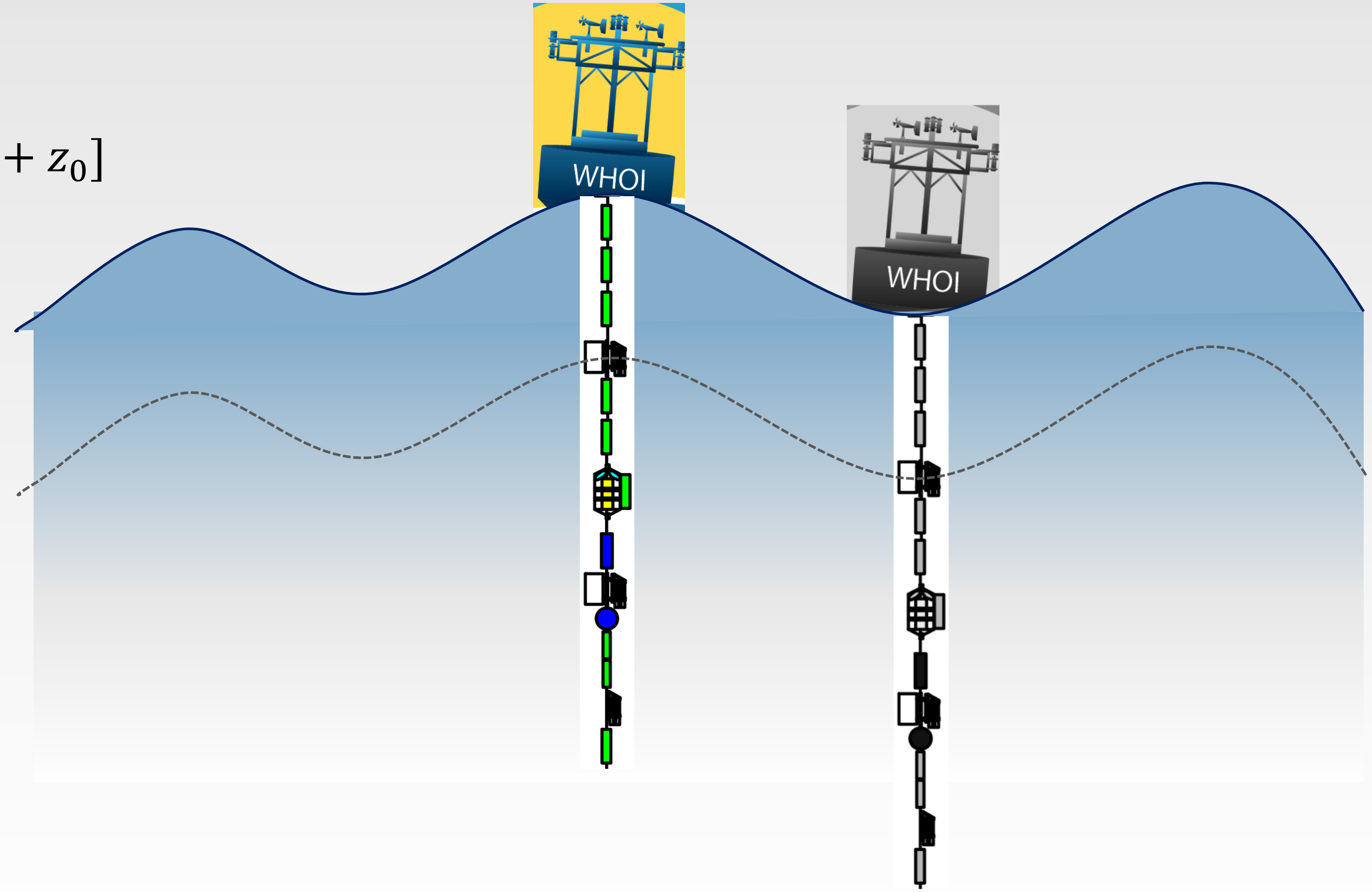

Compare to Stokes drift current:

$$\boxed{\langle u \rangle_{\text{Stokes}} = a^2 \omega k e^{2kz_0}}$$

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Pure vertical motion is an optimistic assumption; things can be worse when the buoy also moves side-to-side

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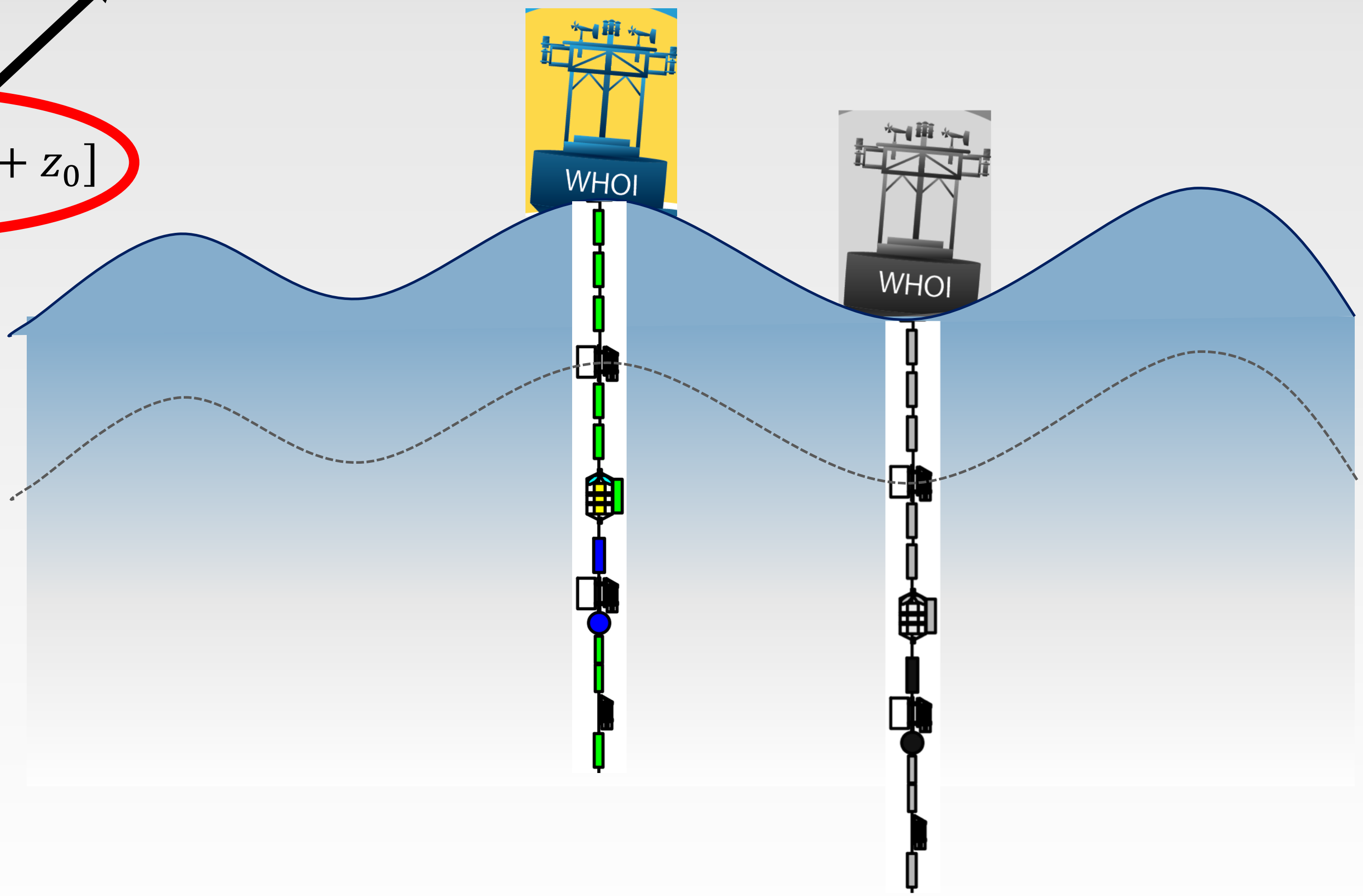
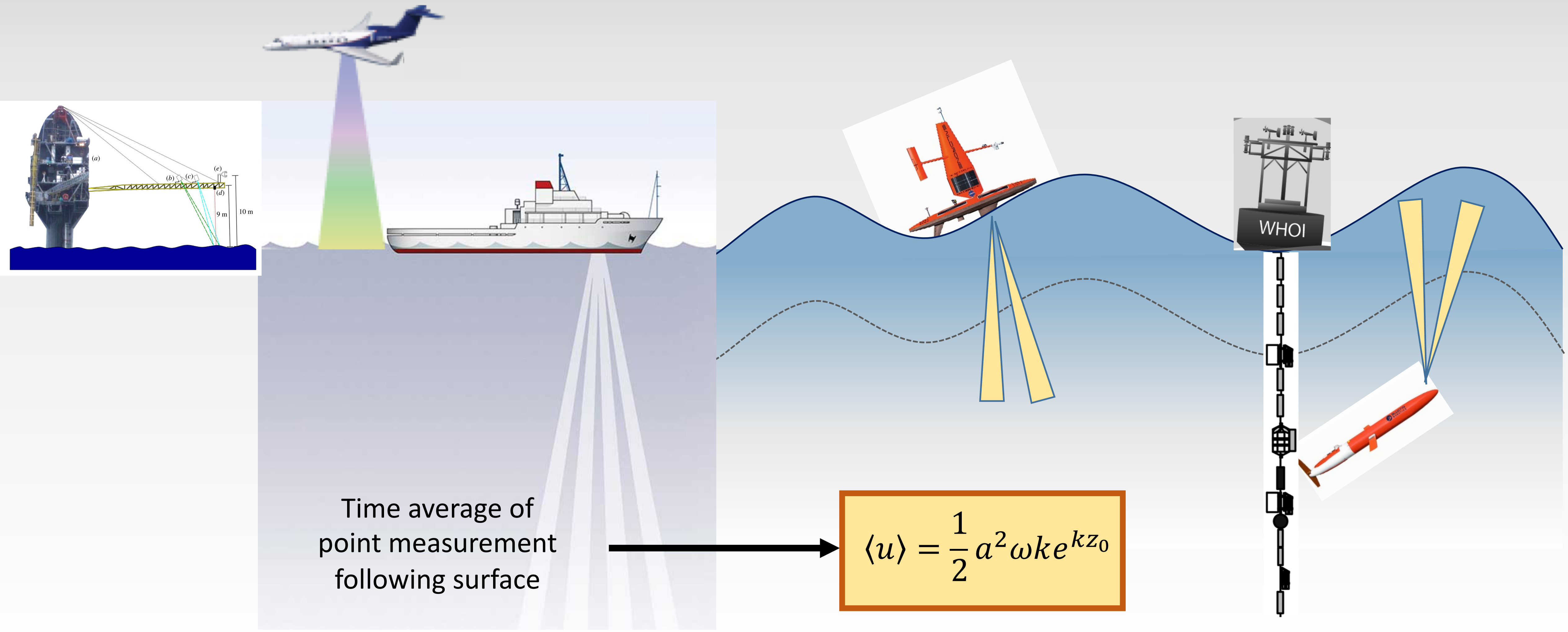


Something similar happens for all other velocity measurements that are not purely Eulerian or Lagrangian

(Amador et al., 2017 looked at this for AUVs)



Time average of
point measurement
following surface

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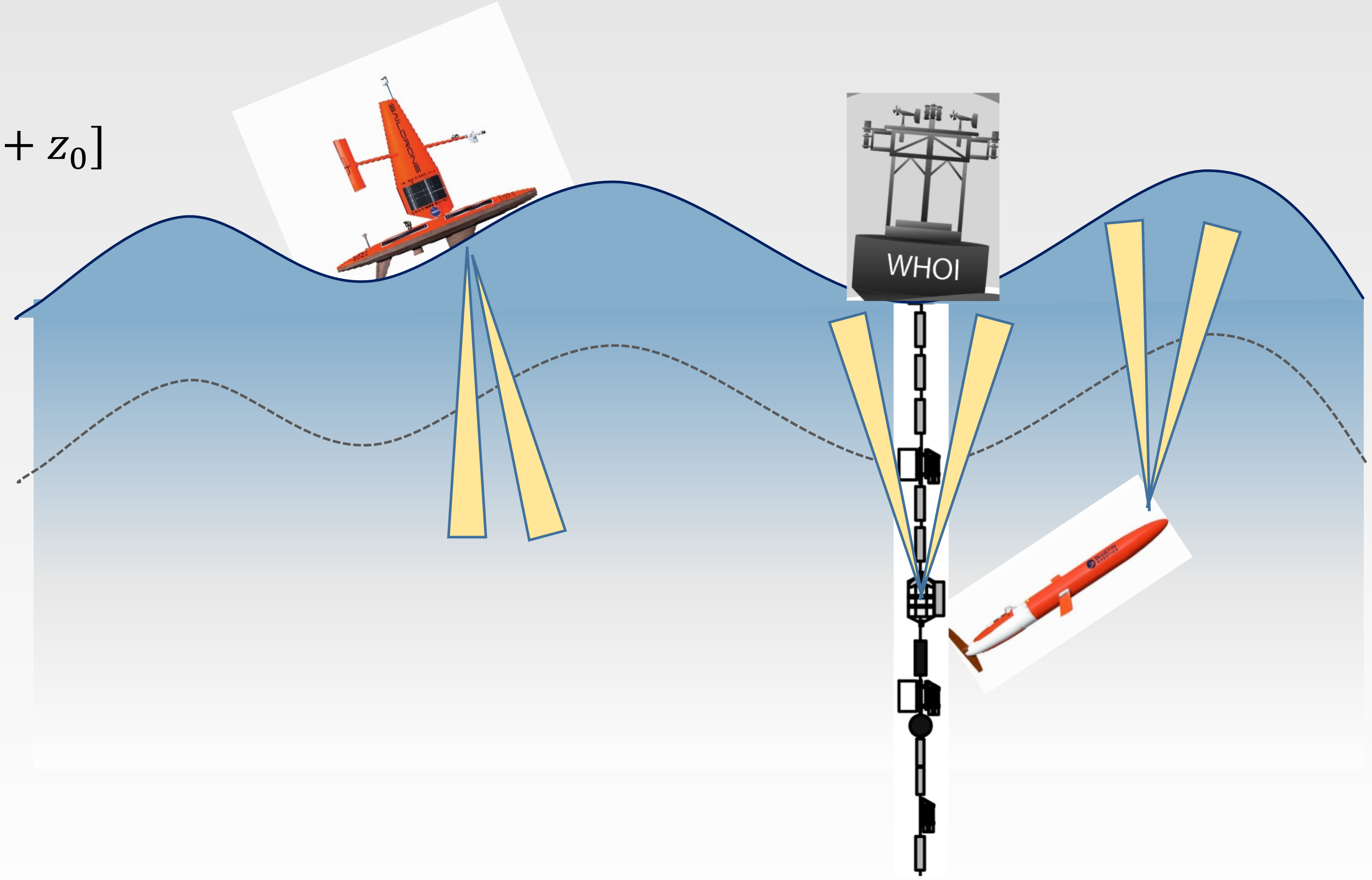

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Goal: do a realistic simulation of this effect (an OSSE), with a realistic wavefield and instrument sampling

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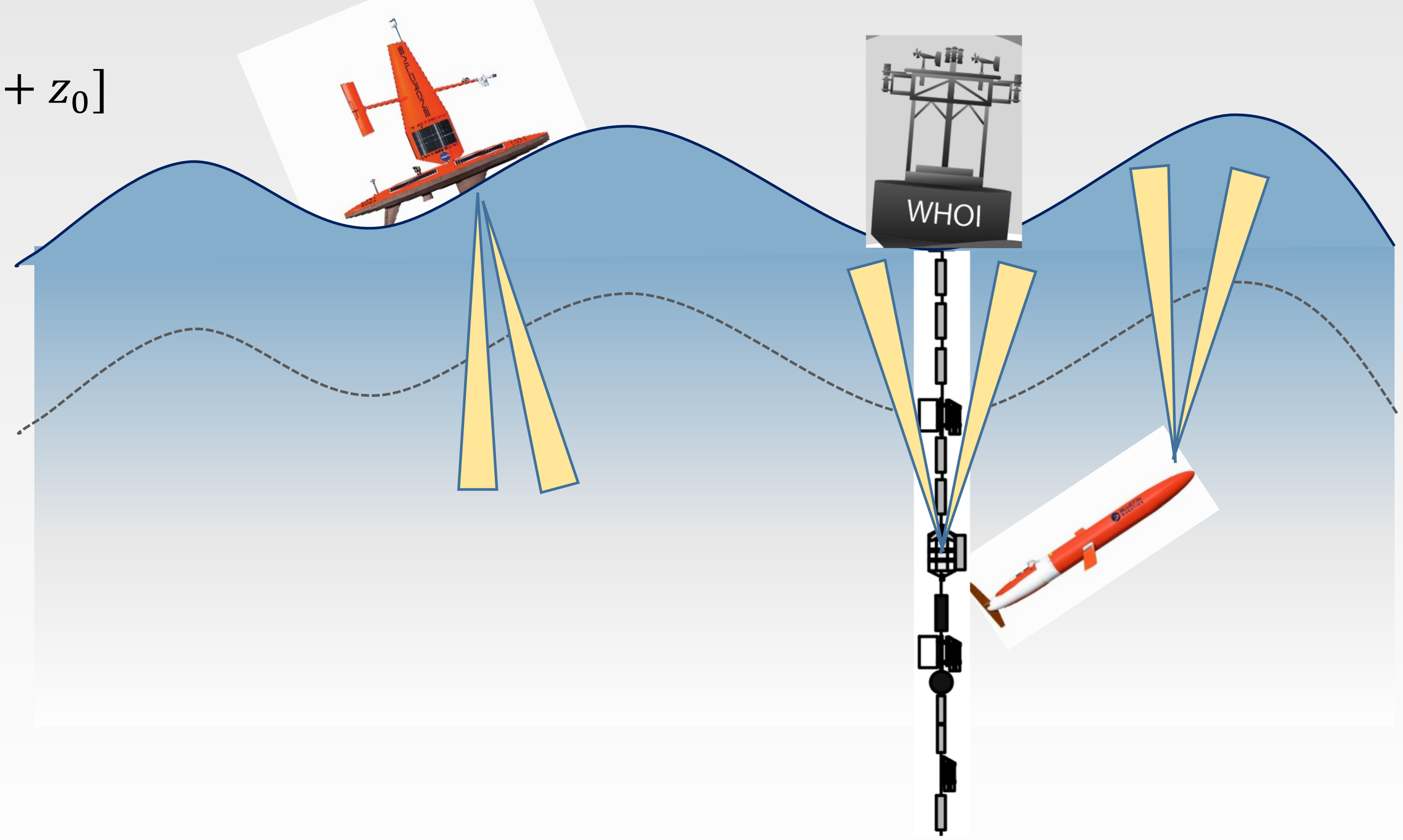
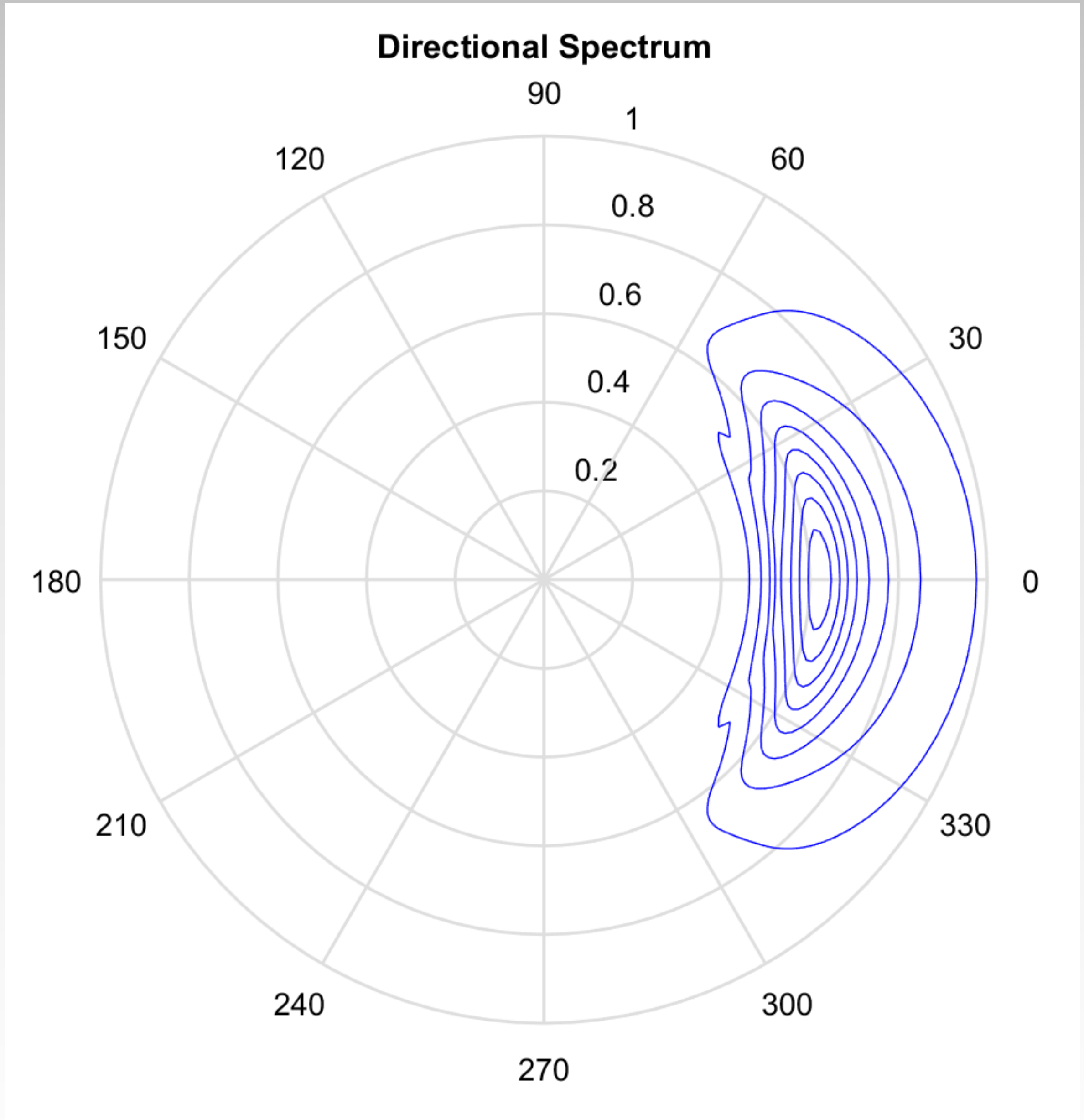


Simulated wave field

JONSWAP directional wave spectrum:
Sig. Wave Height=5 m
Peak period= 10 s



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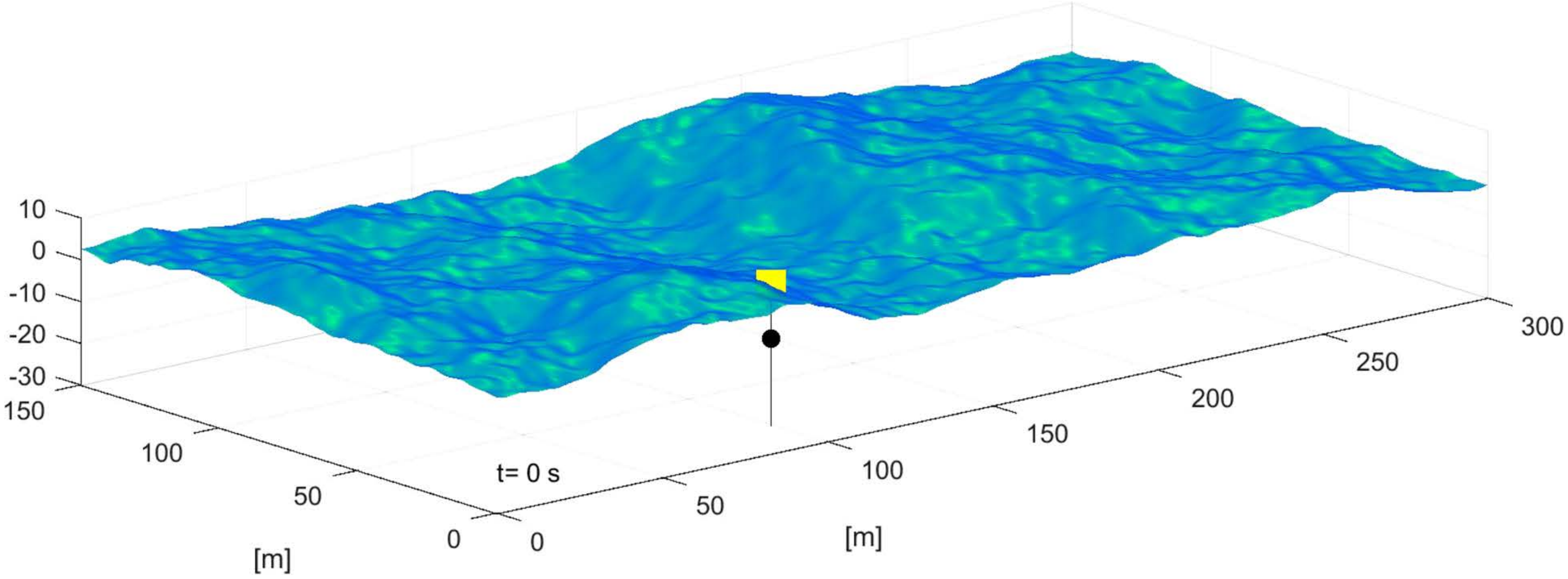
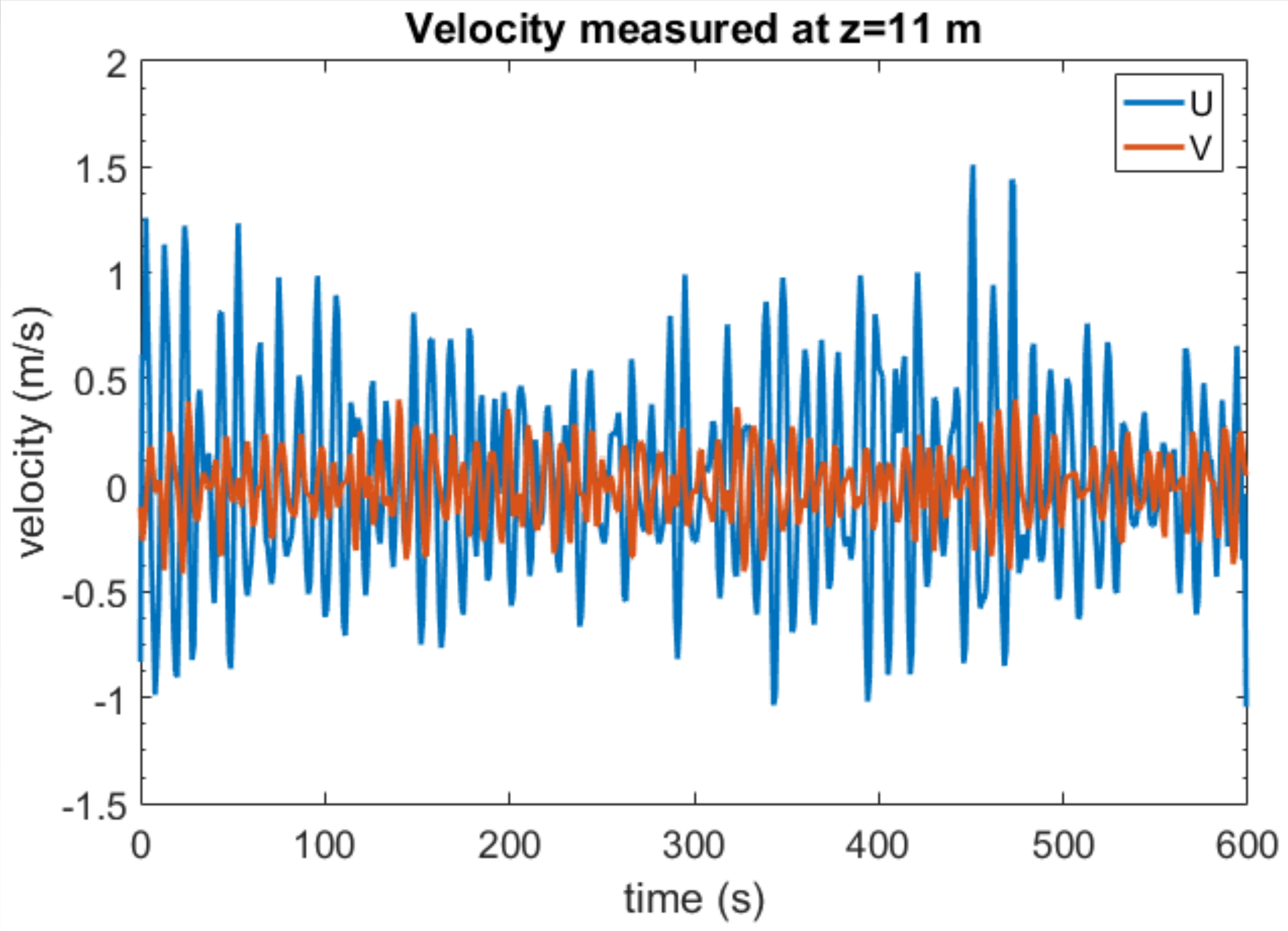


Simulated velocity of moored current meter at 11 m depth (surface following)



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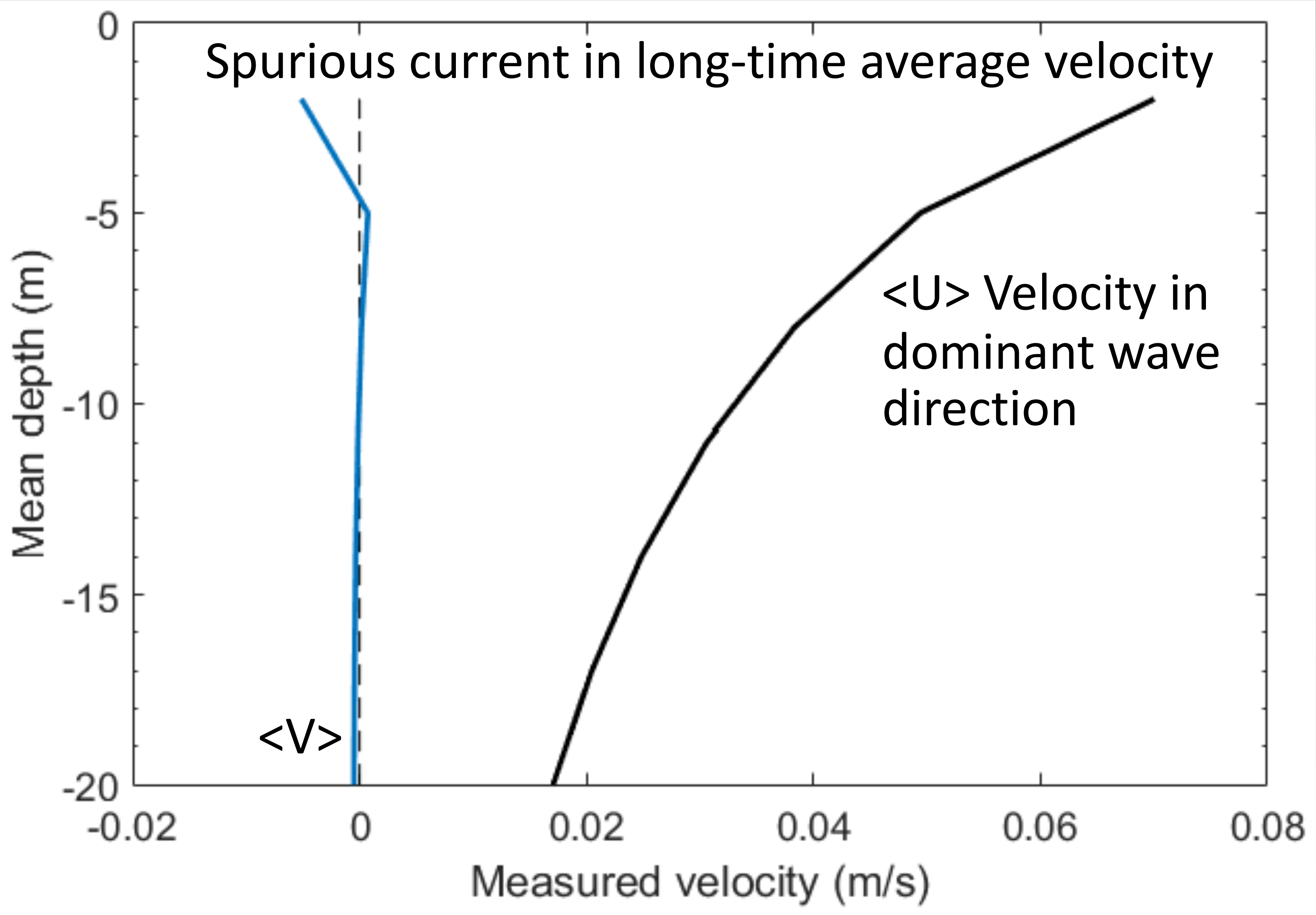

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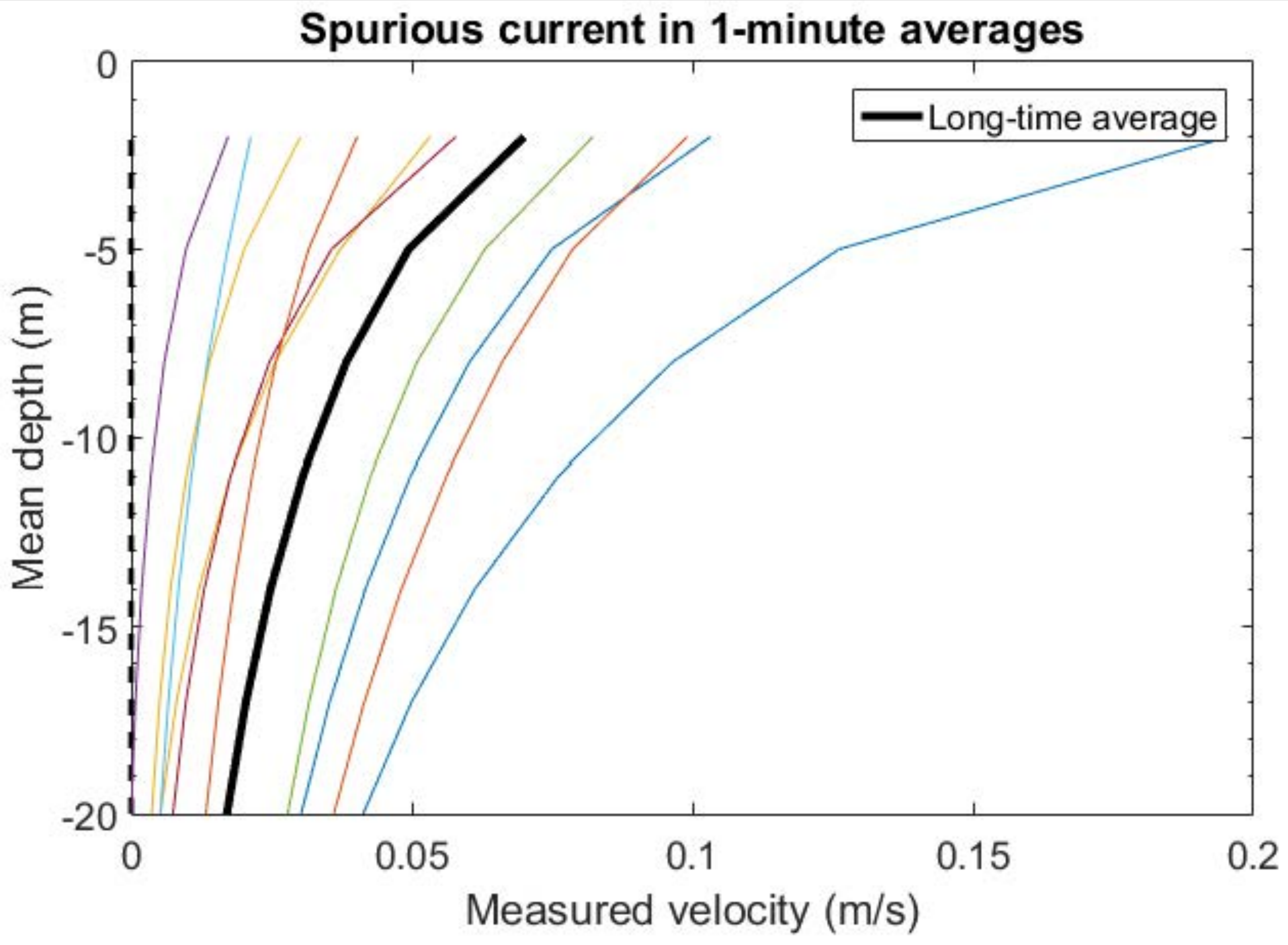

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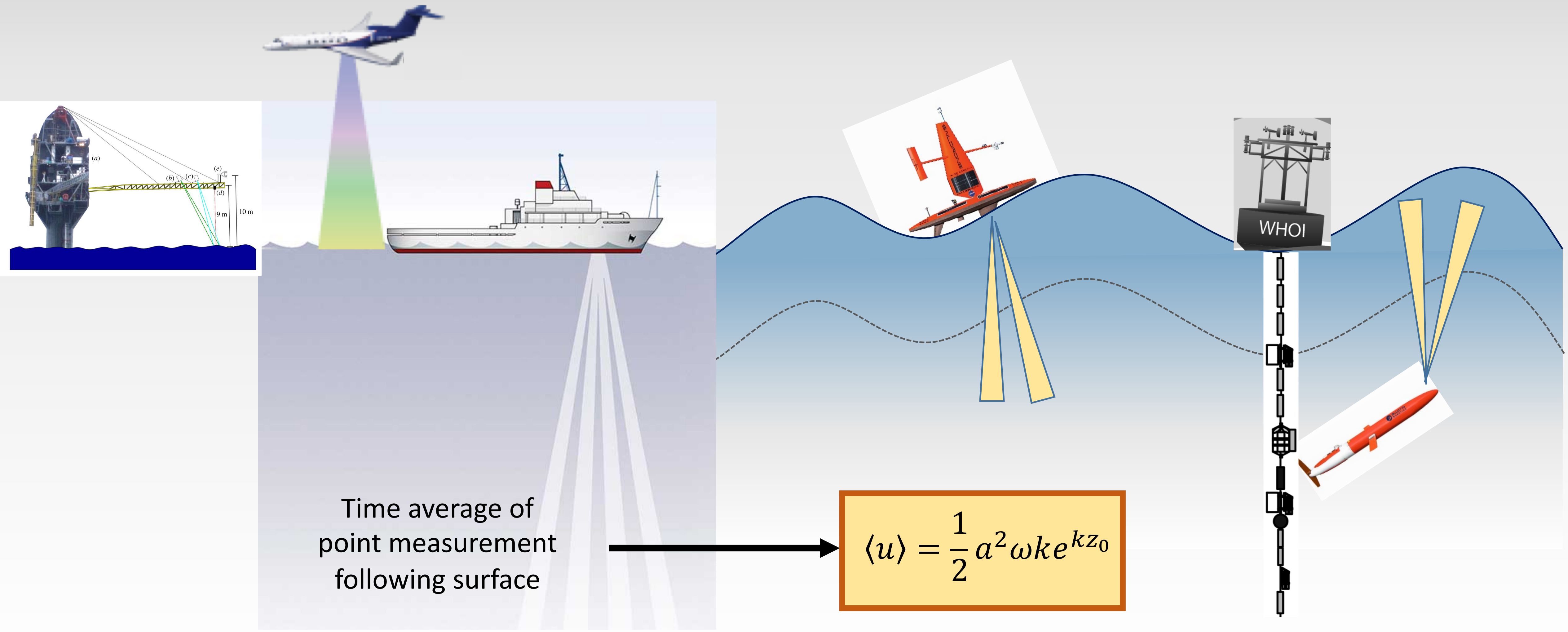


I find the different ways Stokes drift appears in different velocity measurements confusing

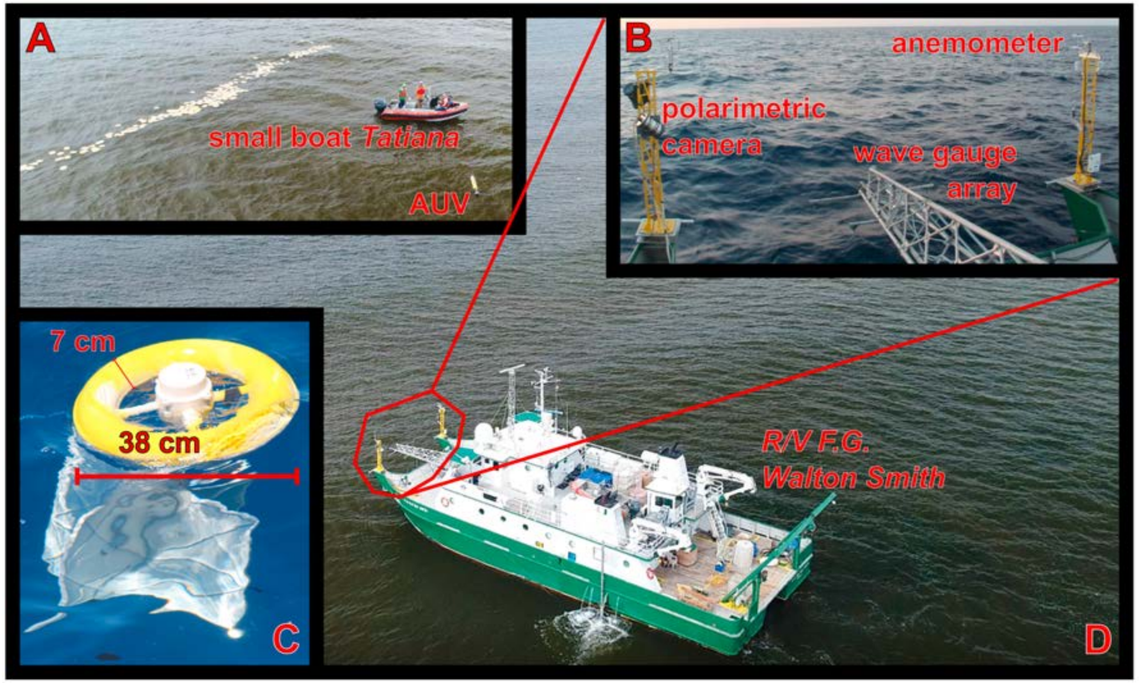
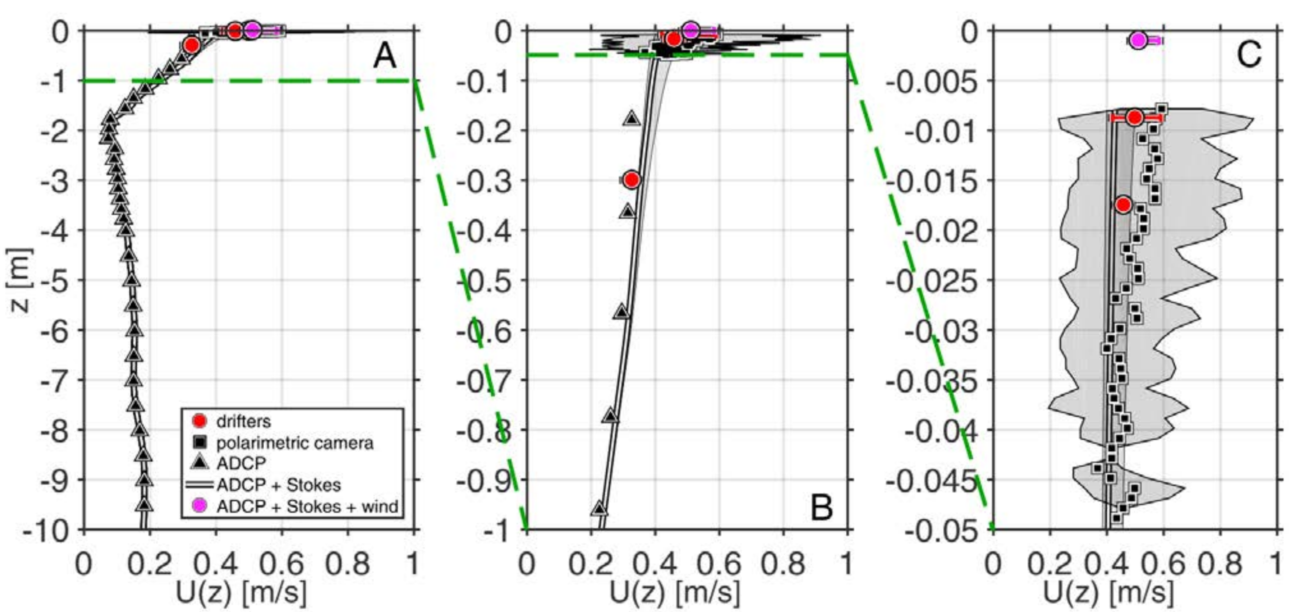


Figure 1. Images of *R/V F.G. Walton Smith* and observational tools: (a) Close-up of bamboo plates in wind row adjacent to the small boat Tatiana. (b) View of bow-mounted instruments. (c) Close-up of GPS-tracked drifter, with white drogue visible below surface. (d) Drone shot of *R/V F.G. Walton Smith*.

Laxague et al. (2018)



Conclusion:
Surface wave contamination can be severe, and it is present to some degree in all near-surface velocity measurements

- Flow distortion/wake
- Aliasing
- Tilting/heaving correlated with flow

Other points of note:

(1) Near surface shear depends on the turbulent momentum flux divergence

(2) The true vertical shear is probably a strong function of length scale and time scale