ROSENSTIEL SCHOOL of MARINE & ATMOSPHERIC SCIENCE

PASSIVE OPTICAL MEASUREMENT OF VERY NEAR-SURFACE CURRENTS

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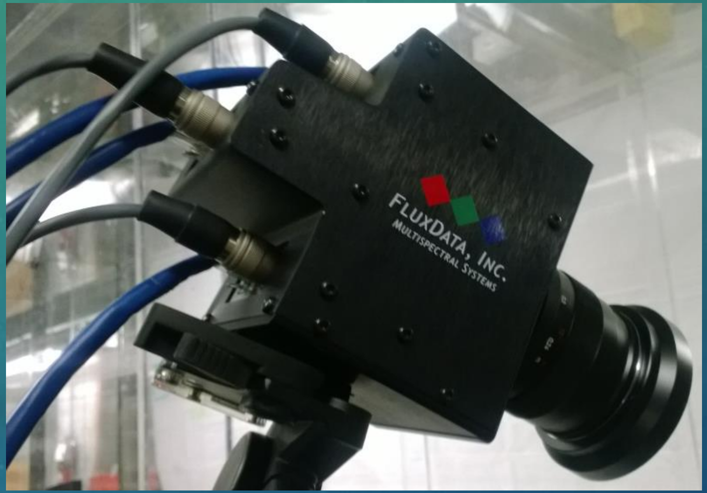
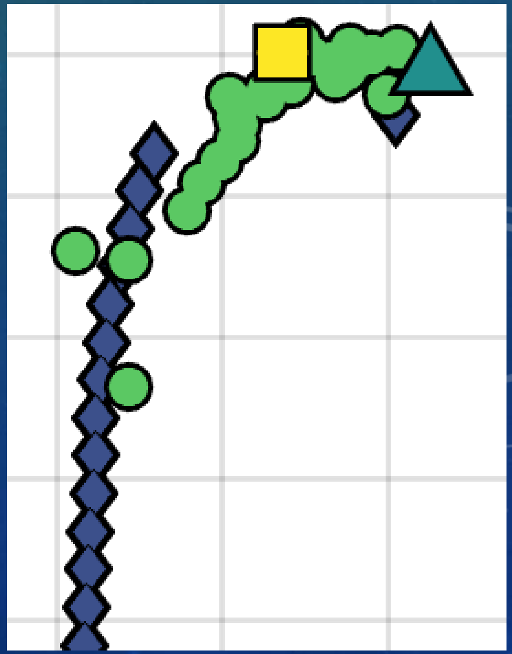
AIR-SEA GAS FLUX WORKSHOP, 2016

WHAT I HOPE TO ACCOMPLISH TODAY

1. Present a technique which allows us to remotely observe the near-surface current profile. Demonstrate its capability in a laboratory study.



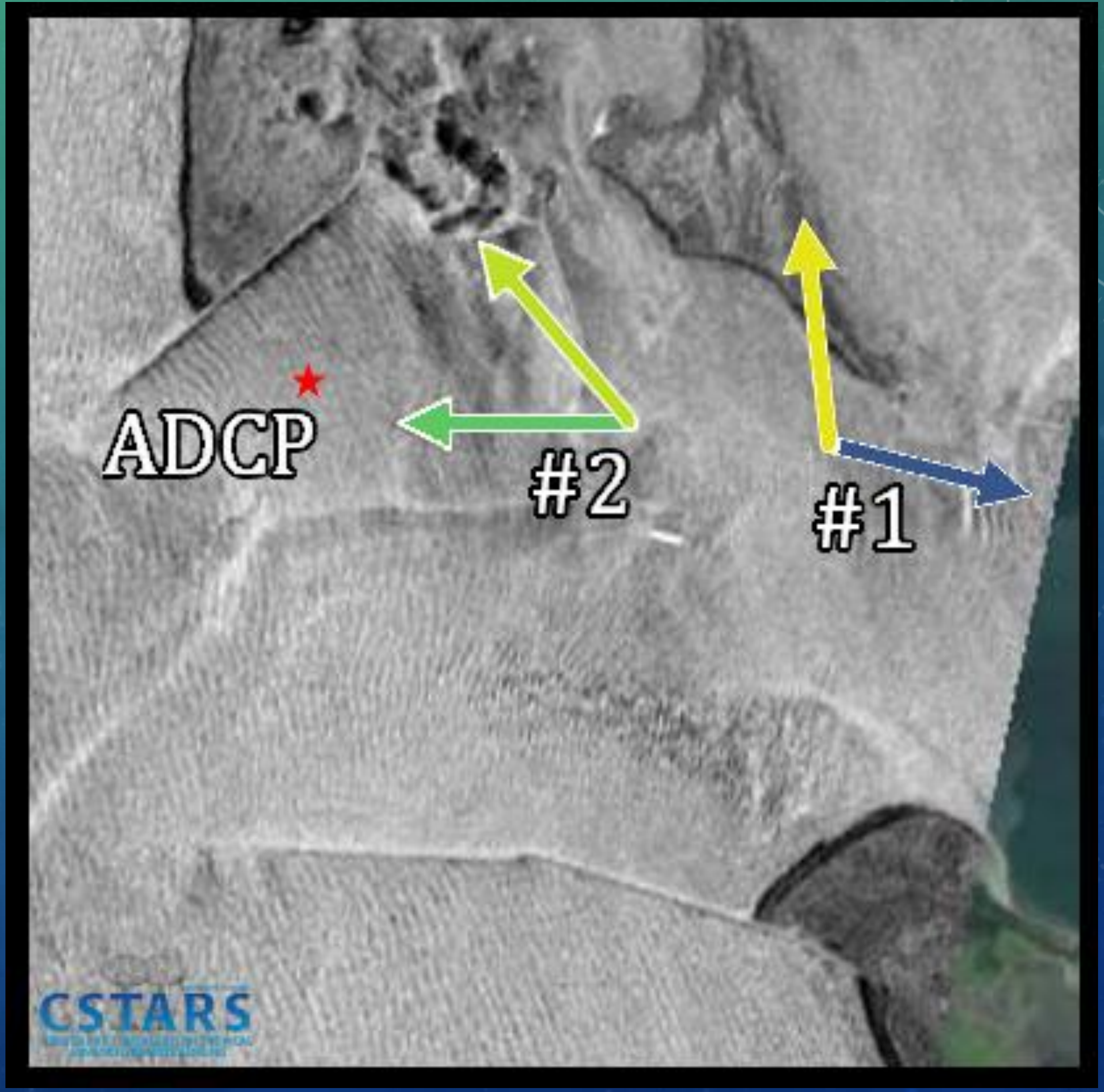


WHAT I HOPE TO ACCOMPLISH TODAY

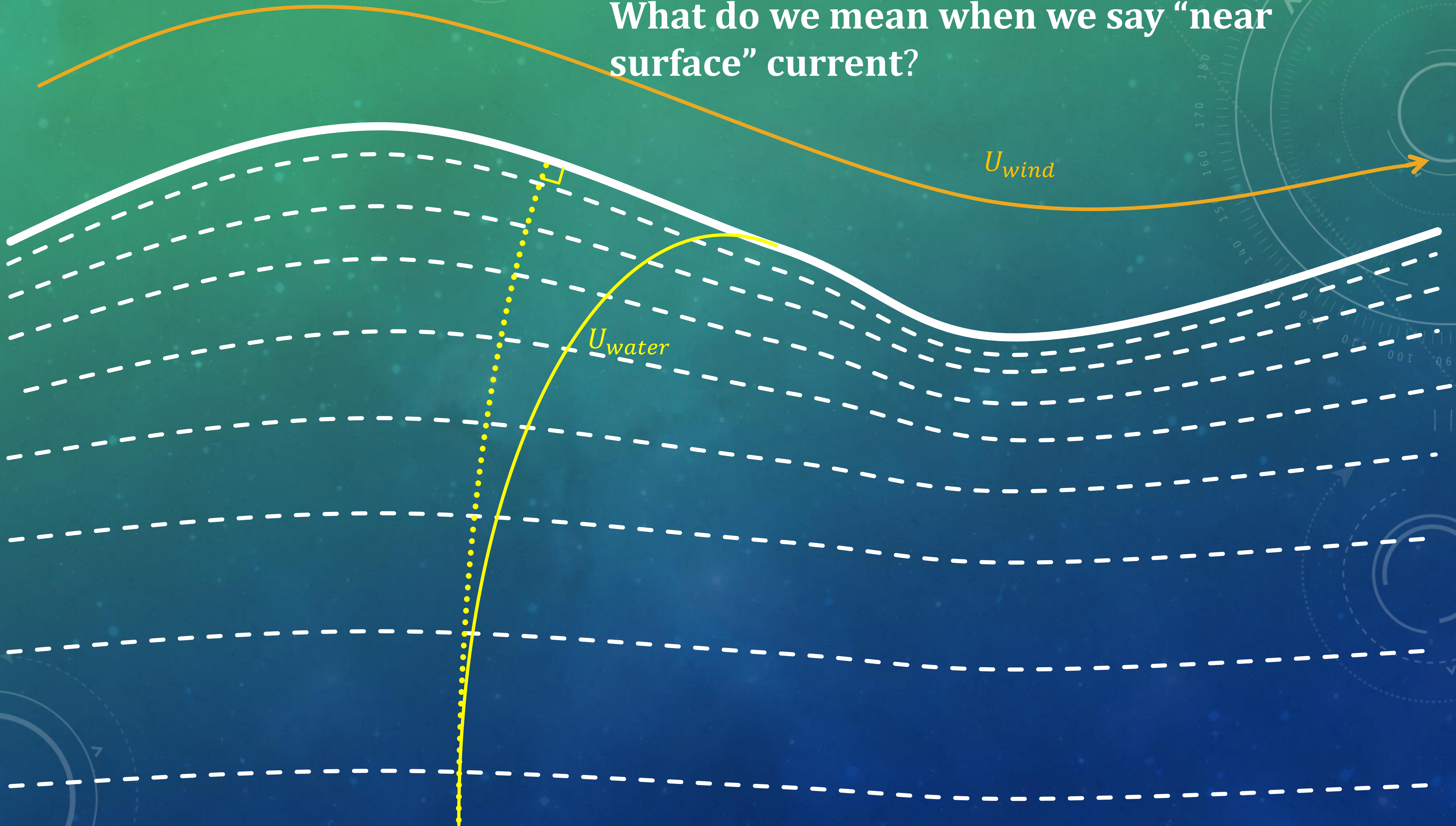
2. Demonstrate the technique’s feasibility outside of the laboratory.

WHAT I HOPE TO ACCOMPLISH TODAY

3. Use the method to study the near-surface current profile in the field environment.

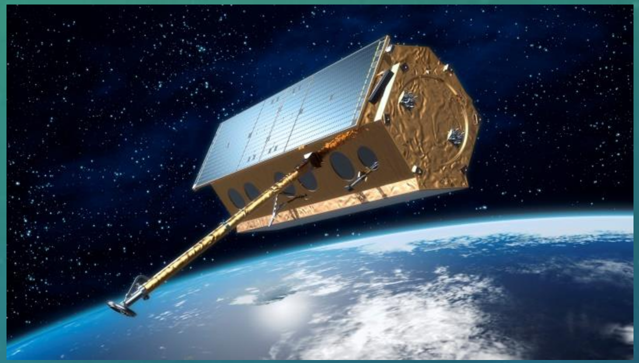


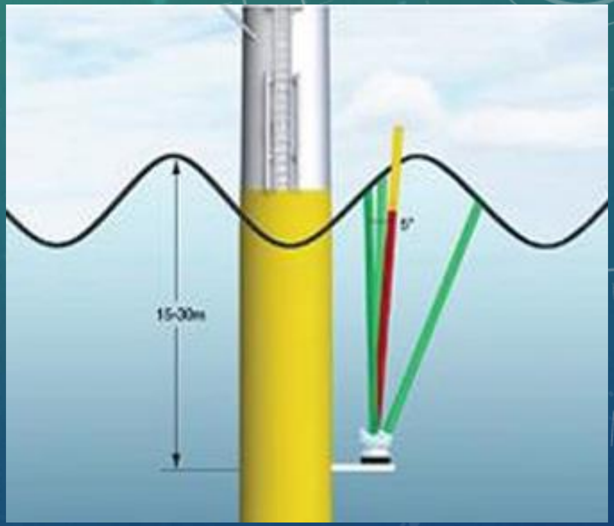
What do we mean when we say "near surface" current?



HOW CAN WE OBSERVE THE "NEAR-SURFACE"?

There is a gap in the capability to observe near-surface current, with existing methods offering complementary, but incomplete measurements.





Short ocean surface waves are sensitive to very near surface currents (as well as wind, larger waves, surfactants etc.)

The deep water, gravity-capillary linear dispersion relation, in the presence of a background current…

$$\omega = \sqrt{gk + \frac{\sigma}{\rho}k^3} + kU\cos\theta$$

$$\left(\omega - \vec{k}\cdot\vec{U}\right)^2 = gk + \frac{\sigma}{\rho}k^3$$

$$\Downarrow$$

Giving way to:

$$U\cos\theta = \frac{1}{k}\left(\omega - \sqrt{gk + \frac{\sigma}{\rho}k^3}\right)$$

IN OTHER WORDS…

Given this:

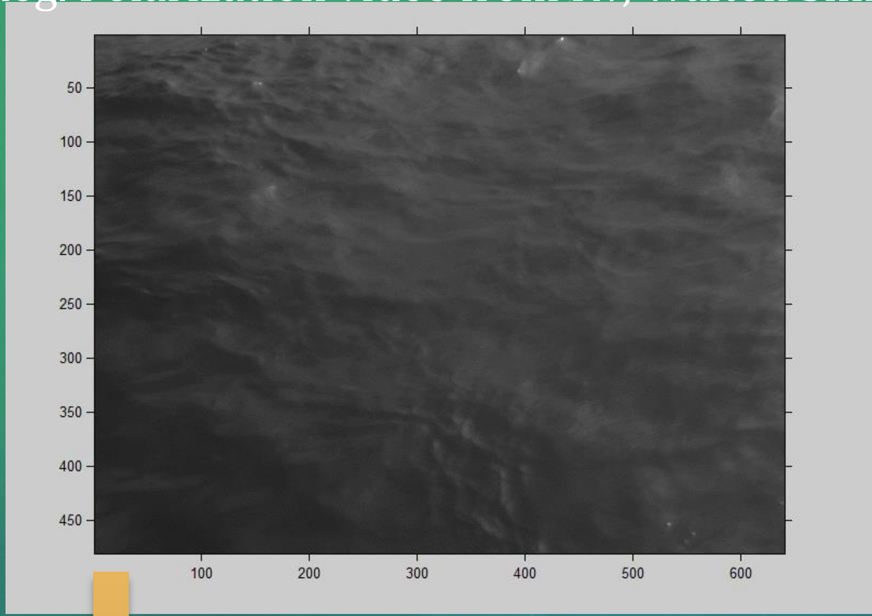
$$\frac{1}{k}\left(\omega - \sqrt{gk + \frac{\sigma}{\rho}k^3}\right)$$

We can get this:

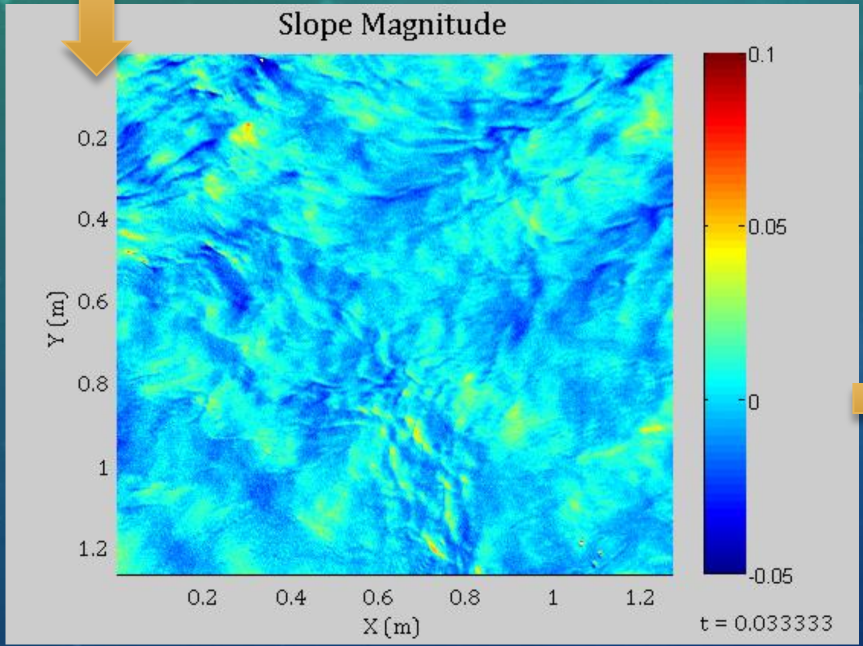
$$U\cos\theta$$

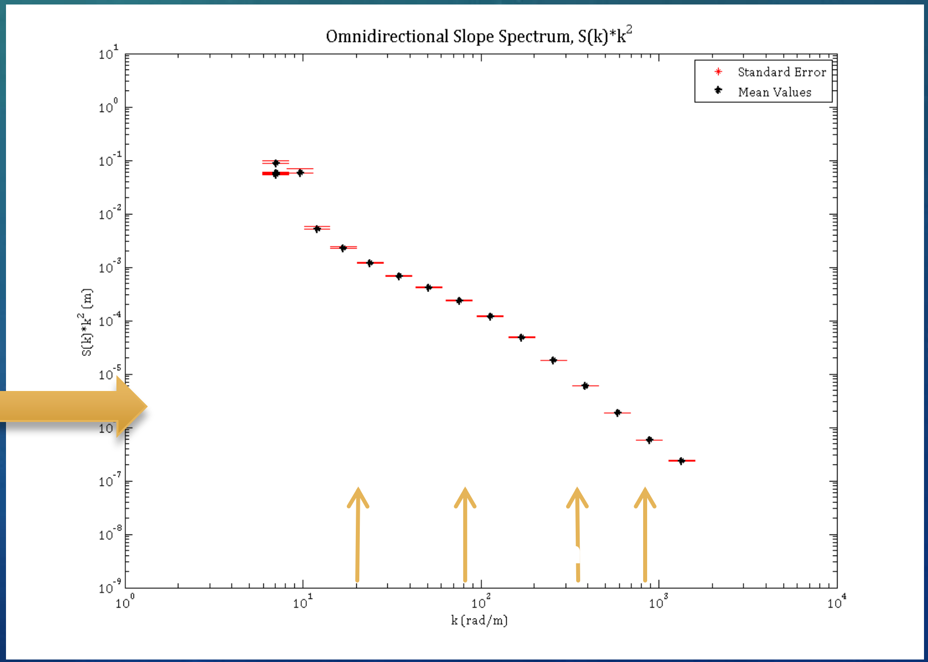
i.e., the current vector

0 deg. Polarization video from RV, Walton Smith during GLAD,



POLARIMETRIC SLOPE SENSING (LAXAGUE ET AL. 2015) SURFACE SLOPE SPECTRUM EVERY FRAME (60 HZ). FOLLOWING ZAPPA ET AL. 2008.



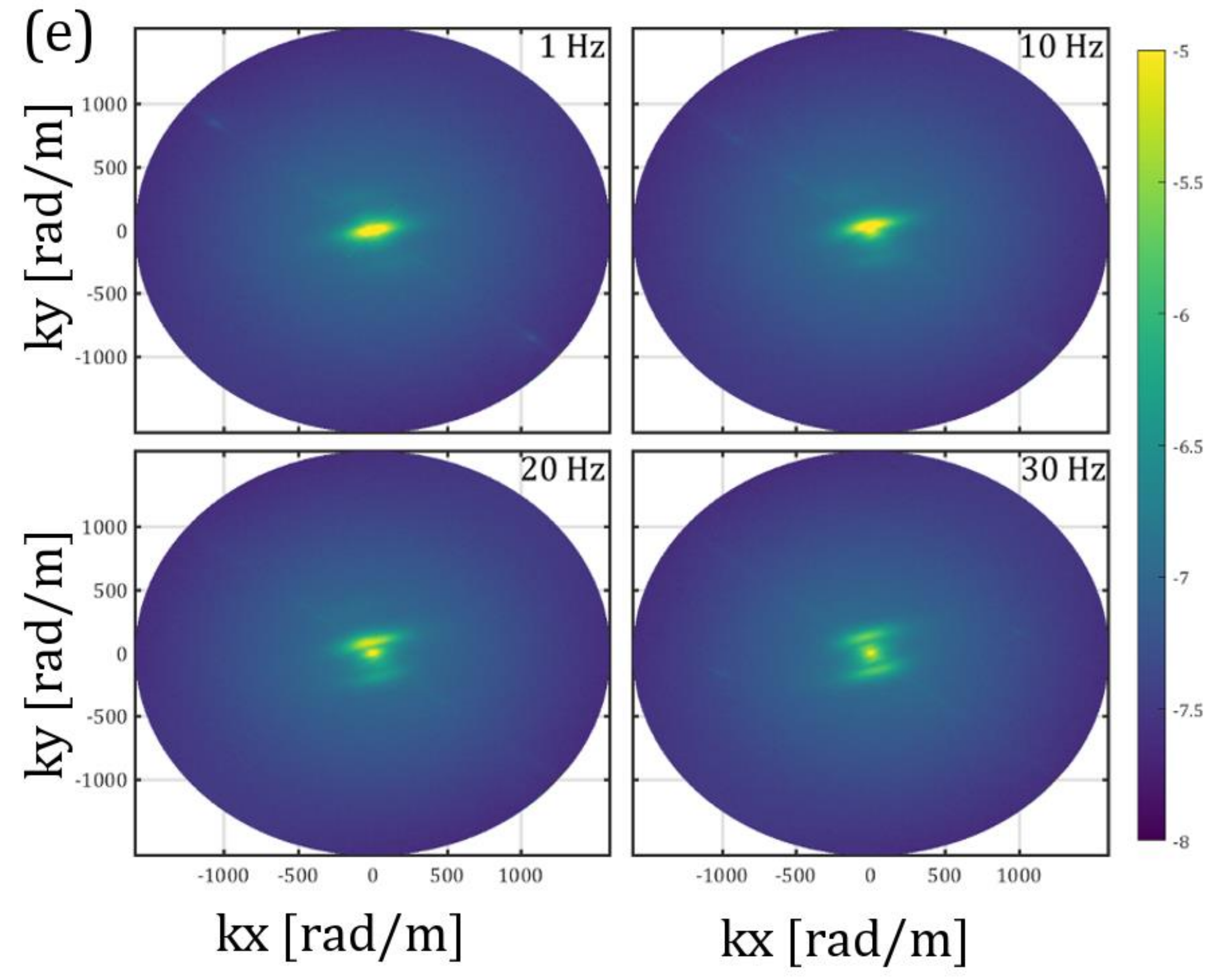


Bottom: Motion corrected, scaled slope field

FROM x, y, & t, WE WANT k_x, k_y, AND ω

A special camera acquires the high-resolution polarization state of light reflected from a patch of water.

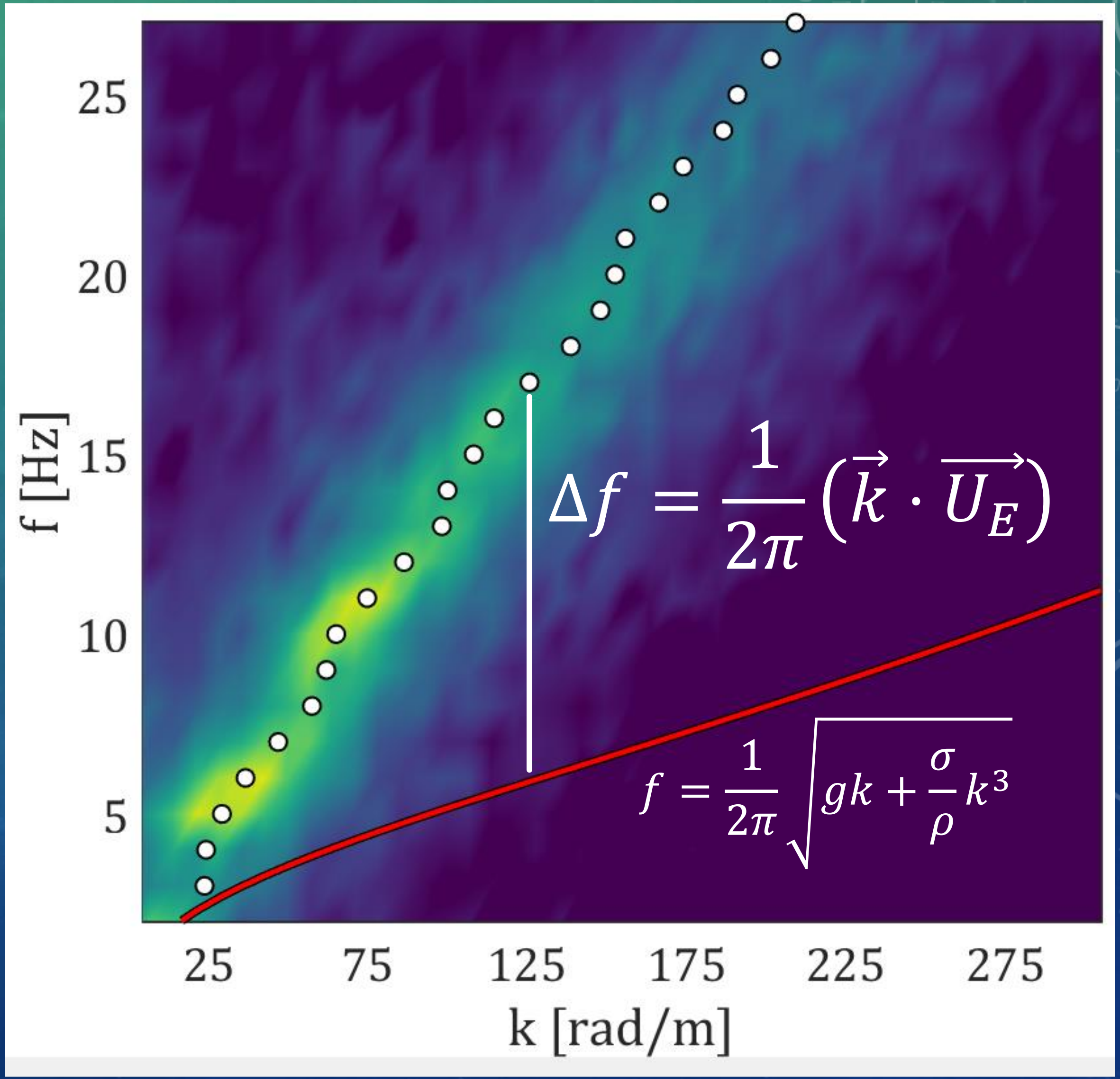
A three-dimensional Fourier transform is applied to the record, yielding a wavenumber-frequency spectrum.



APPLYING DISPERSION CURVE TECHNIQUE TO A NEW REGIME

Let's take a slice in the peak short-wave direction.

Deviations from the full, deep water linear dispersion relation are interpreted as Doppler-shifting currents.

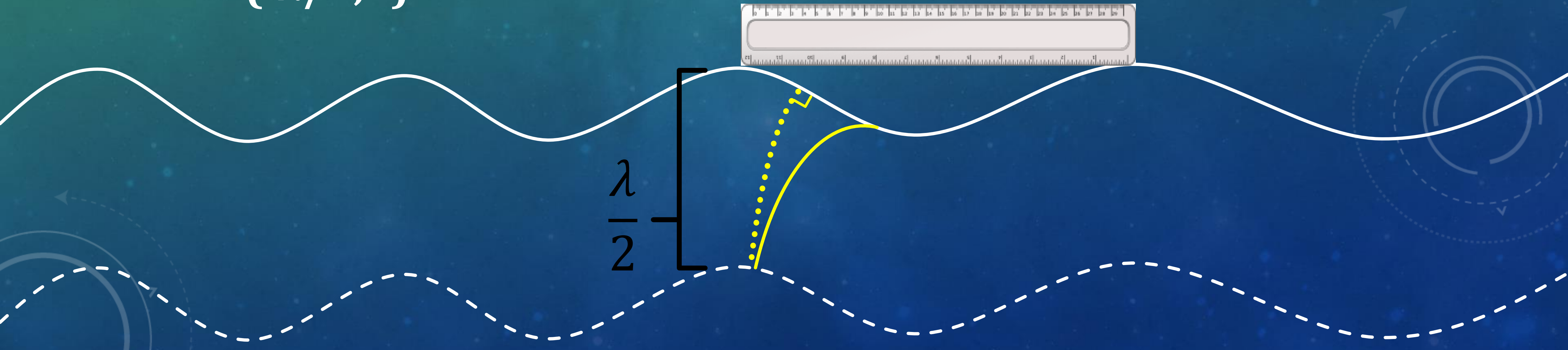


EXTRACTING THE CURRENT PROFILE

The "encounter current" *$U_E(k)$* is the mean current felt by a wave on the depth interval (-λ/2,0).

$$\left(z_i = -\frac{\pi}{k_i}\right)$$

$$U_E(k_n)\cos(\theta_n) = \frac{1}{n}\left(\sum_{i=1}^{n} U(z_i)\cos(\theta_i)\right)$$



GETTING THERE FROM HERE

$$n \cdot U_E(k_n)\cos(\theta_n) = \sum_{i=1}^{n} U(z_i)\cos(\theta_i)$$

$$n \cdot U_E(k_n)\cos(\theta_n) = U(z_n)\cos(\theta_n) + \sum_{i=1}^{n-1} U(z_i)\cos(\theta_i)$$

iterate

$$\underline{U(z_n)\cos(\theta_n)} = n \cdot U_E(k_n)\cos(\theta_n) - \boxed{\sum_{i=1}^{n-1} U(z_i)\cos(\theta_i)}$$

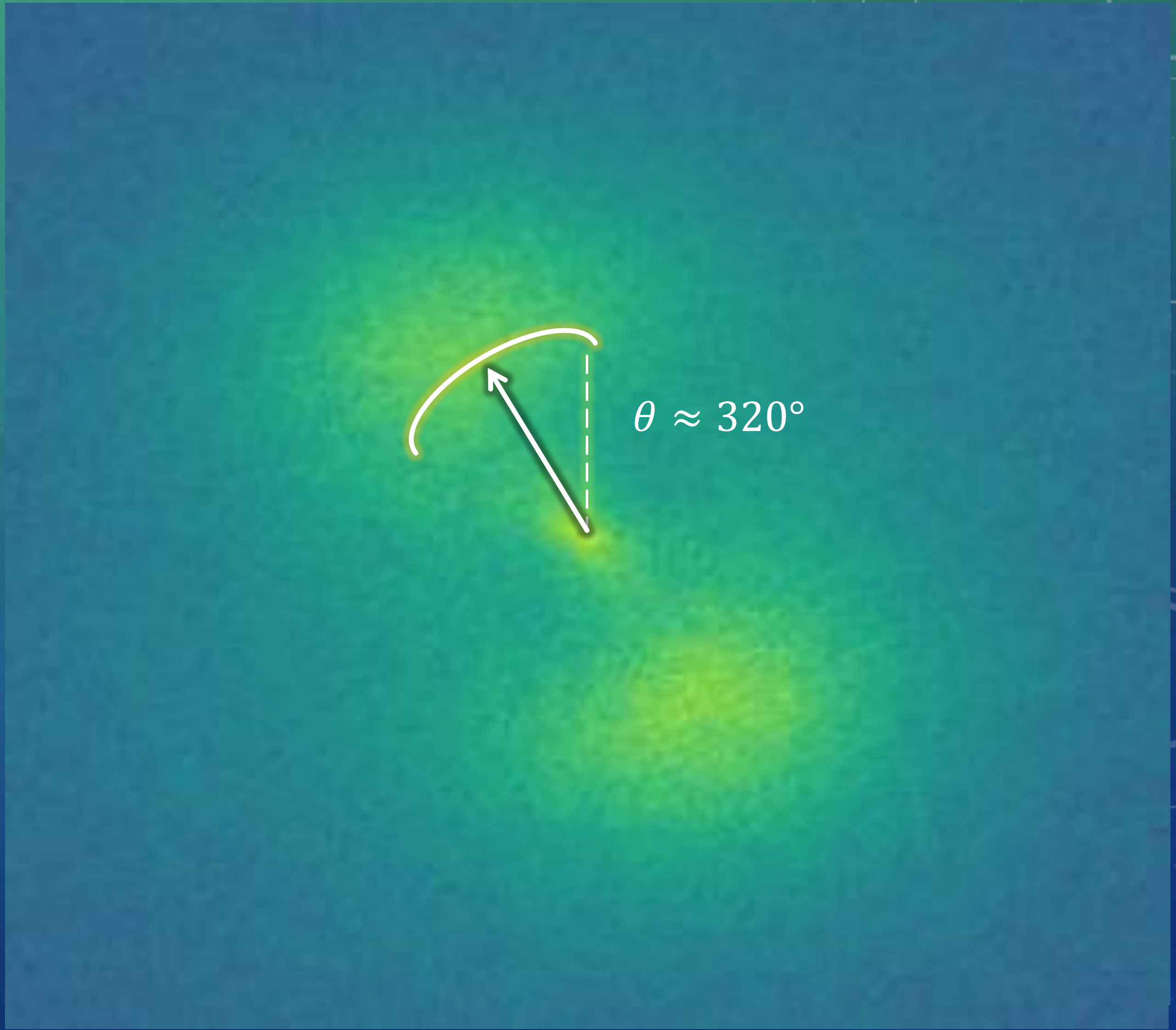
objective

measure

DIRECTIONAL CURRENT DETERMINATION

The dispersion shell is shifted according to the direction of the current with respect to the wave propagation direction.

Specifically, the direction of maximum shift is the current direction



LABORATORY VALIDATION OF THE METHOD

This method was applied alongside PIV, surface drifter, and dye-tracking techniques for U_{10} ranging from 5 m/s – 23 m/s

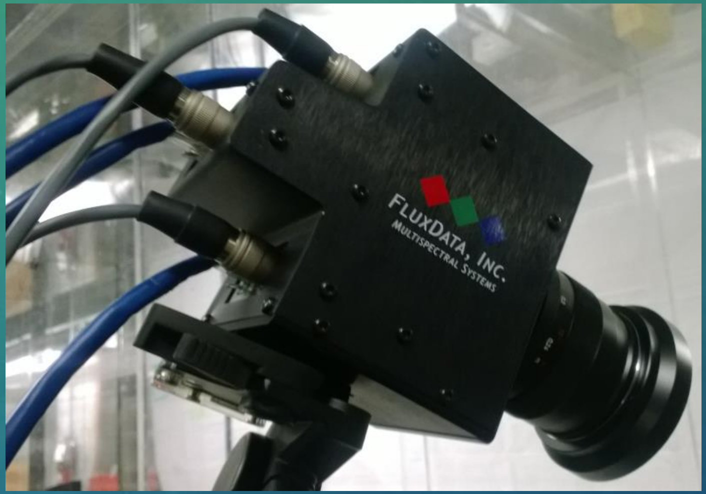


Photo by Naomi Gorta

A SLEW OF EXAMPLE SPECTRA

U_{10} =

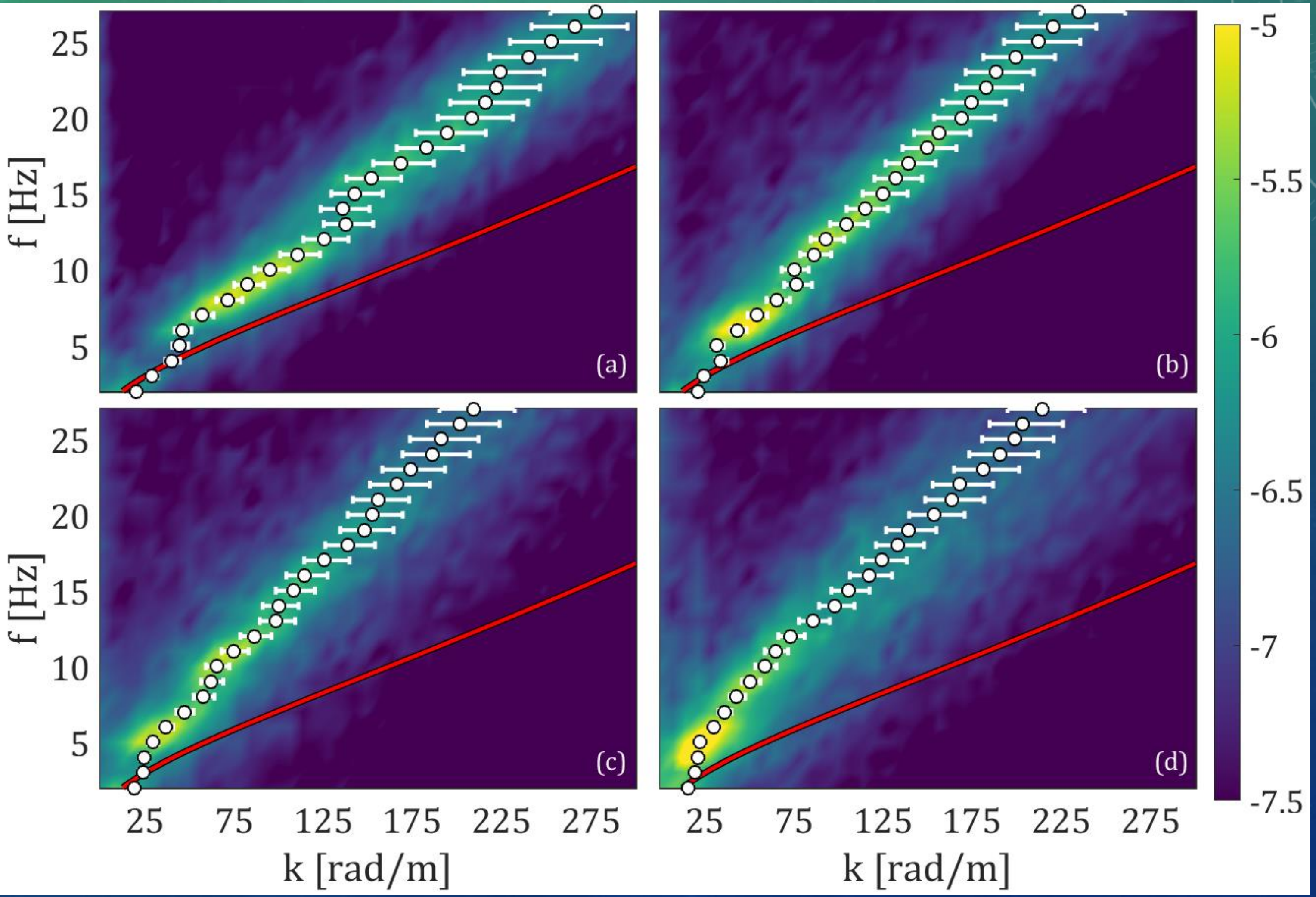
(a) 8.17 m/s

(b) 11.56 m/s

(c) 15.15 m/s

(d) 18.96 m/s

$$f = \frac{1}{2\pi}\sqrt{gk + \frac{\sigma}{\rho}k^3}$$



AND THE EXTRACTED PROFILES

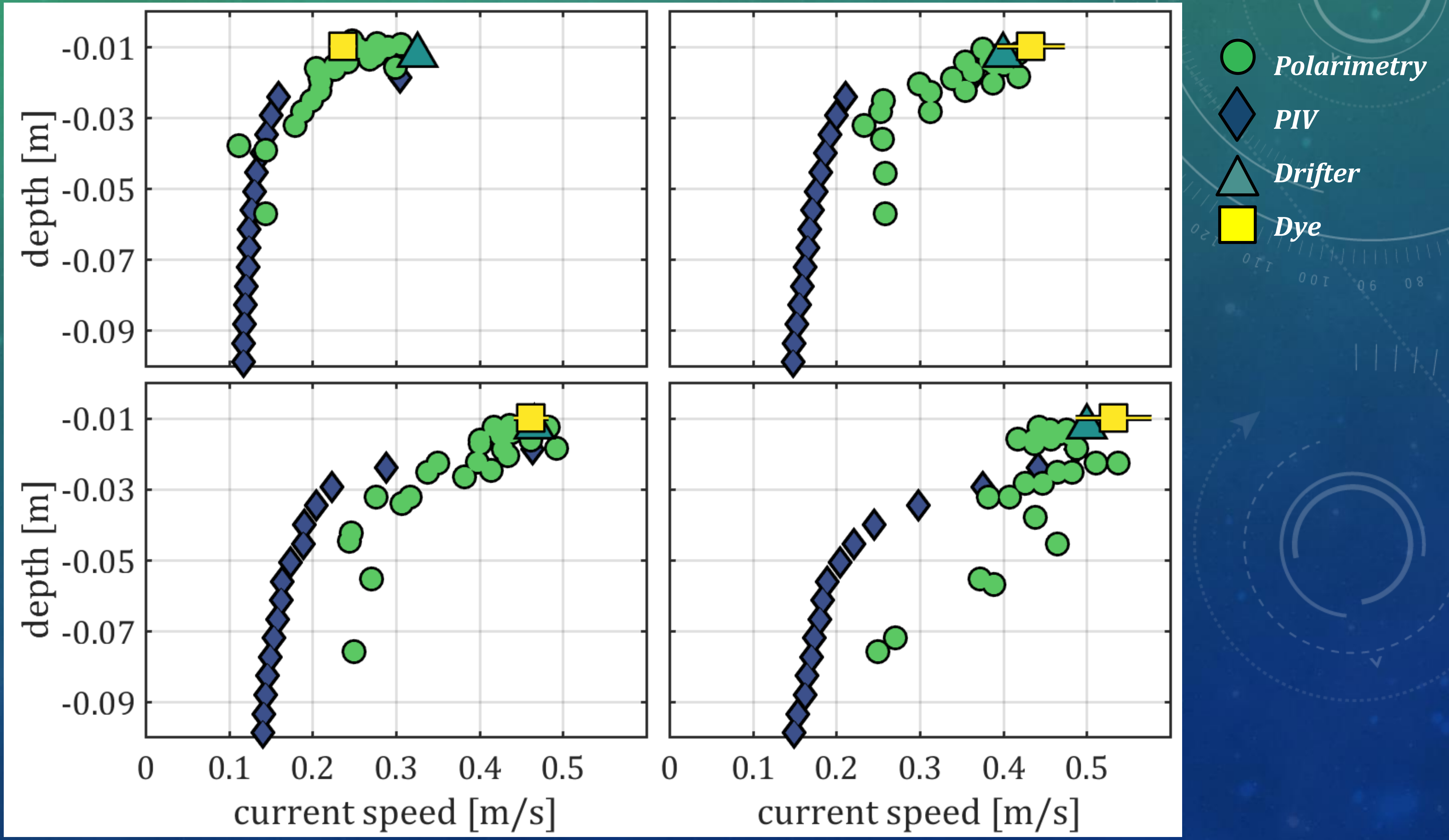
U_{10} =

(a) 8.17 m/s

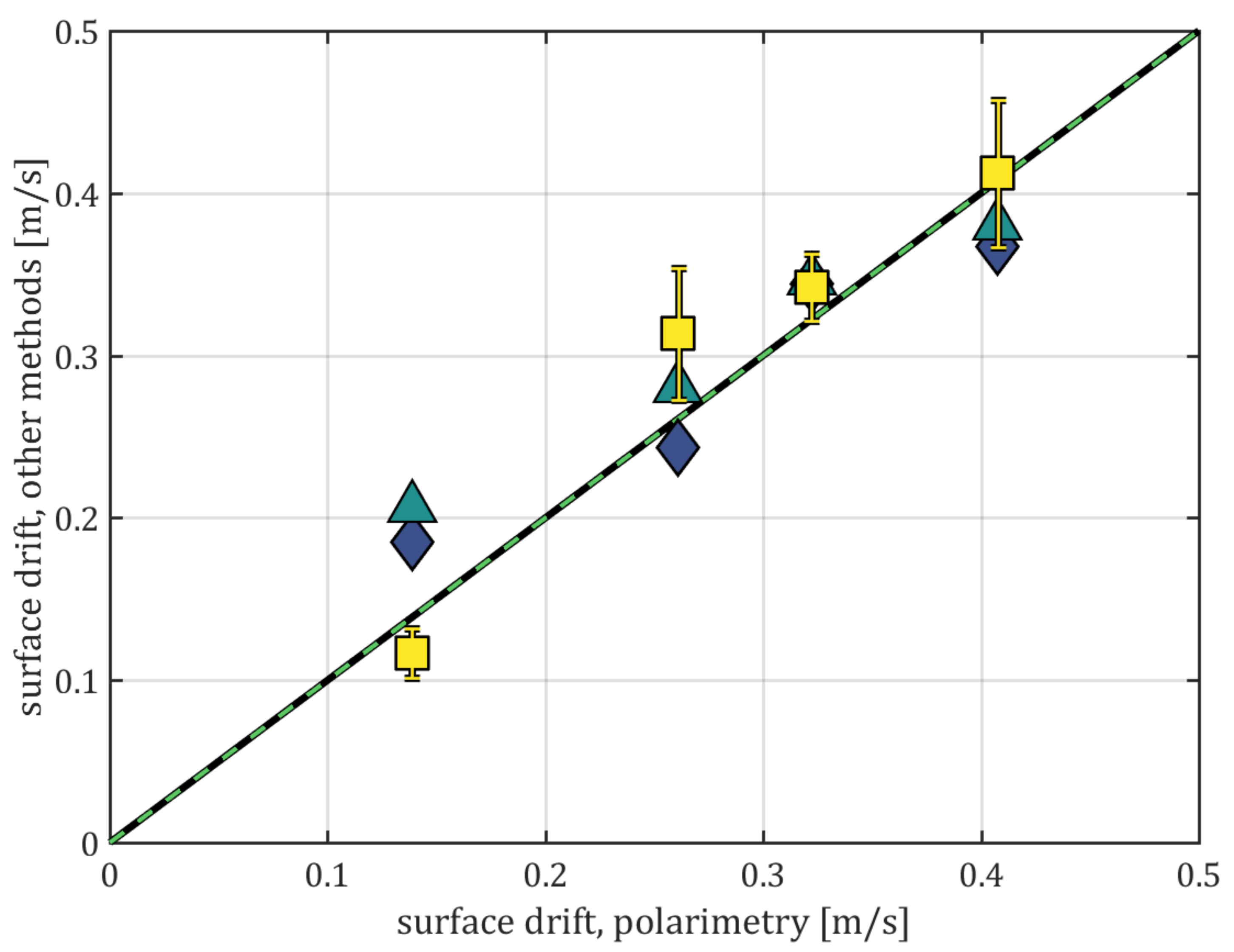
(b) 11.56 m/s

(c) 15.15 m/s

(d) 18.96 m/s



INTER-METHOD COMPARISON, NEAR-SURFACE CURRENT

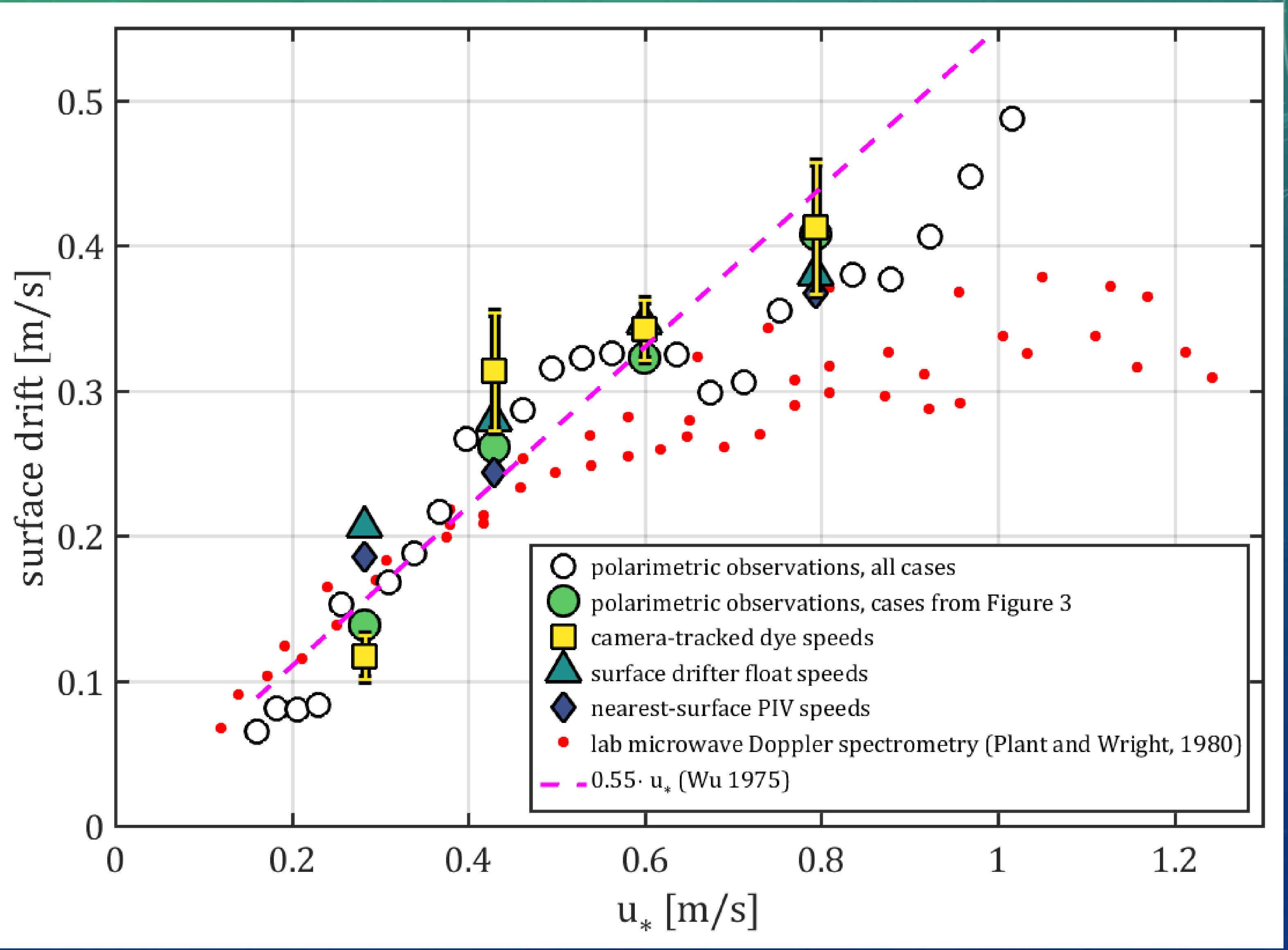


PIV – R^2 = 0.88

Drifter – R^2 = 0.84

Dye – R^2 = 0.91

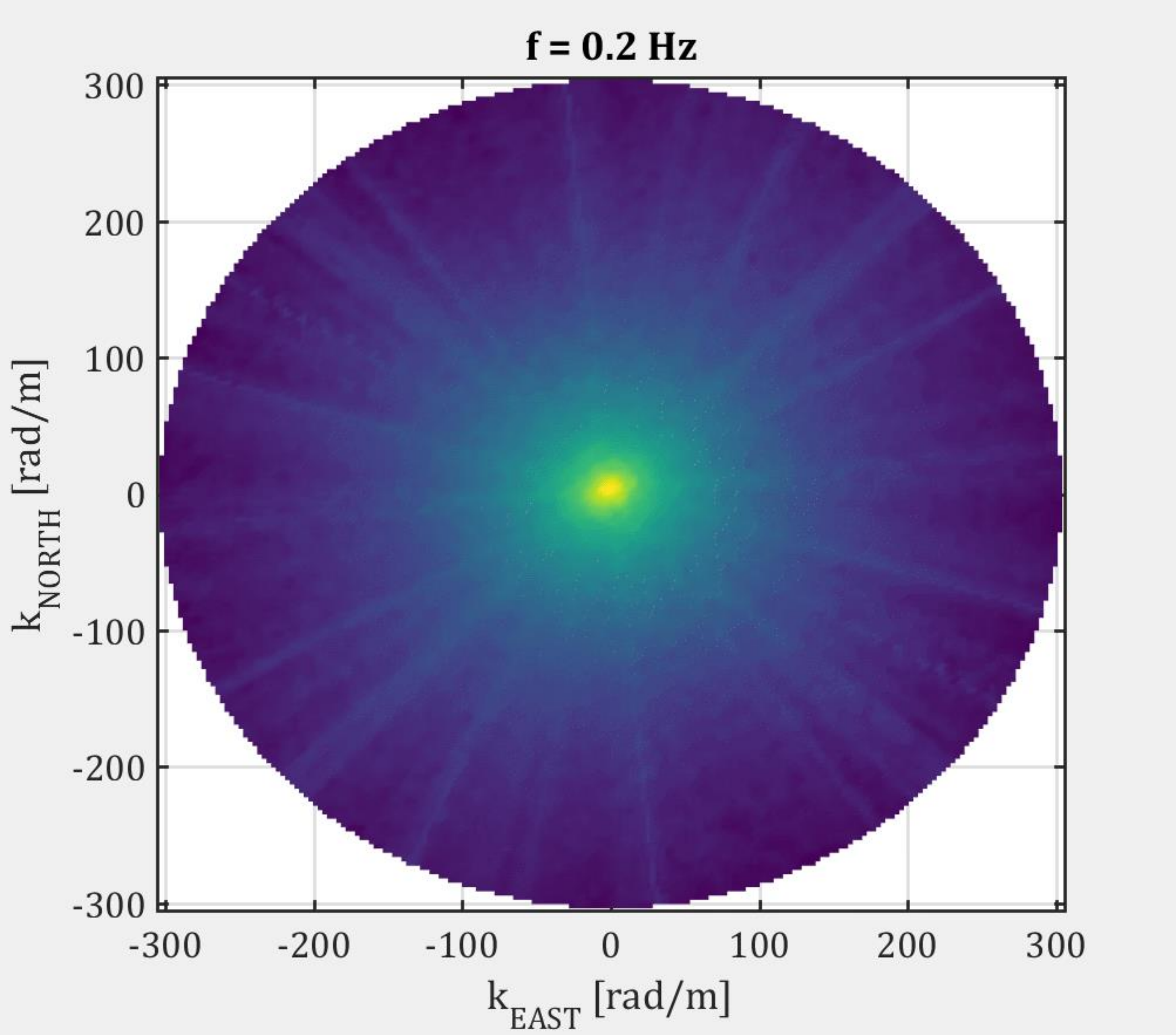
ISOLATION OF WIND/WAVE-INDUCED CURRENT



APPLICATION IN THE FIELD ENVIRONMENT

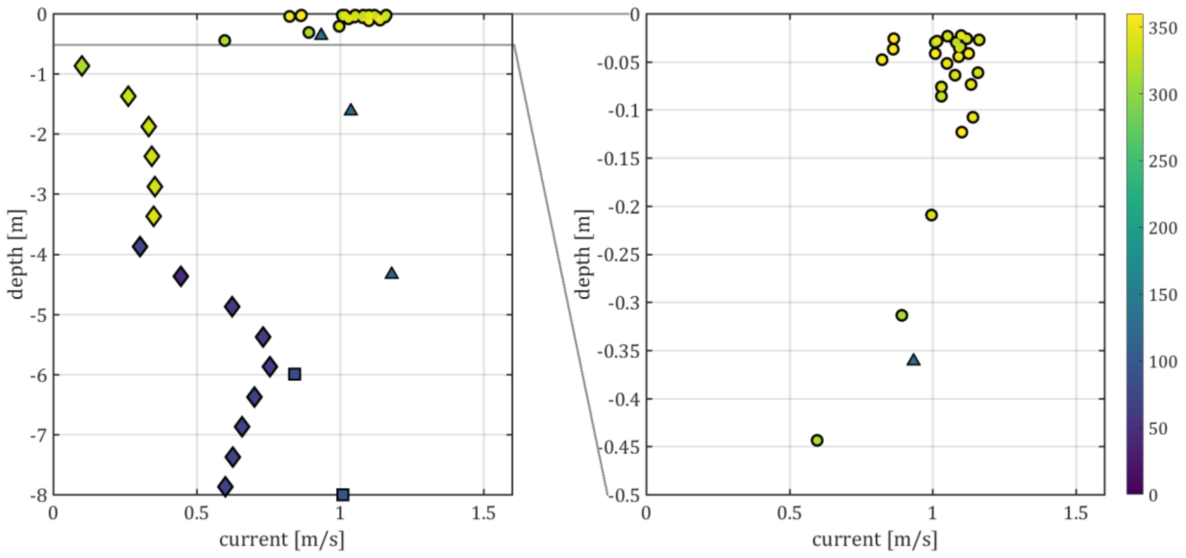
Step one: account for the ship's translational motion.

Step two: compute the wavenumber-frequency spectrum.

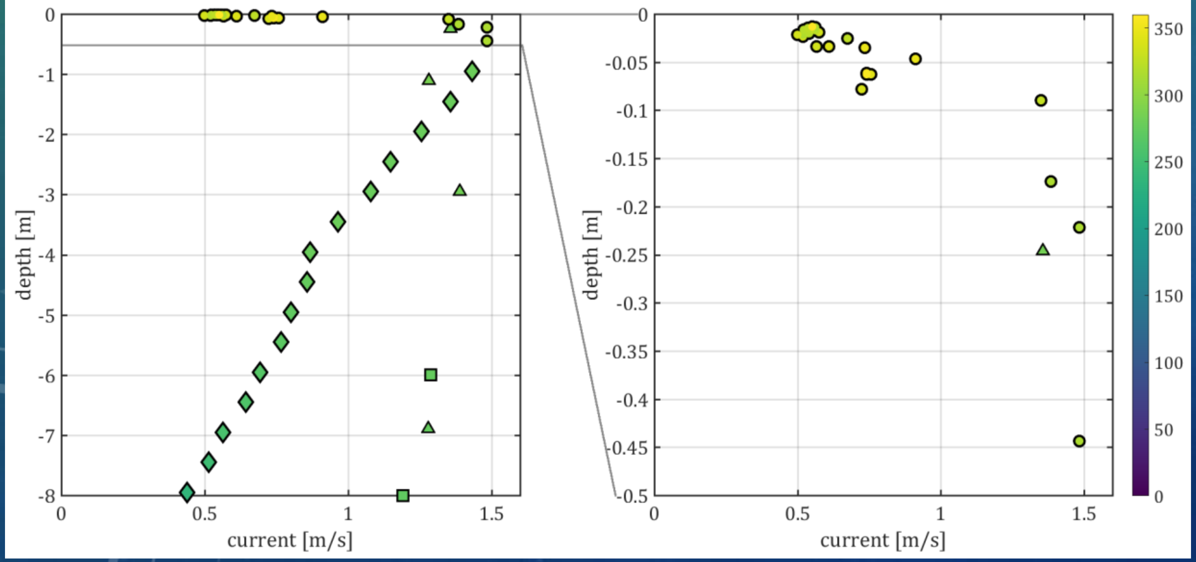


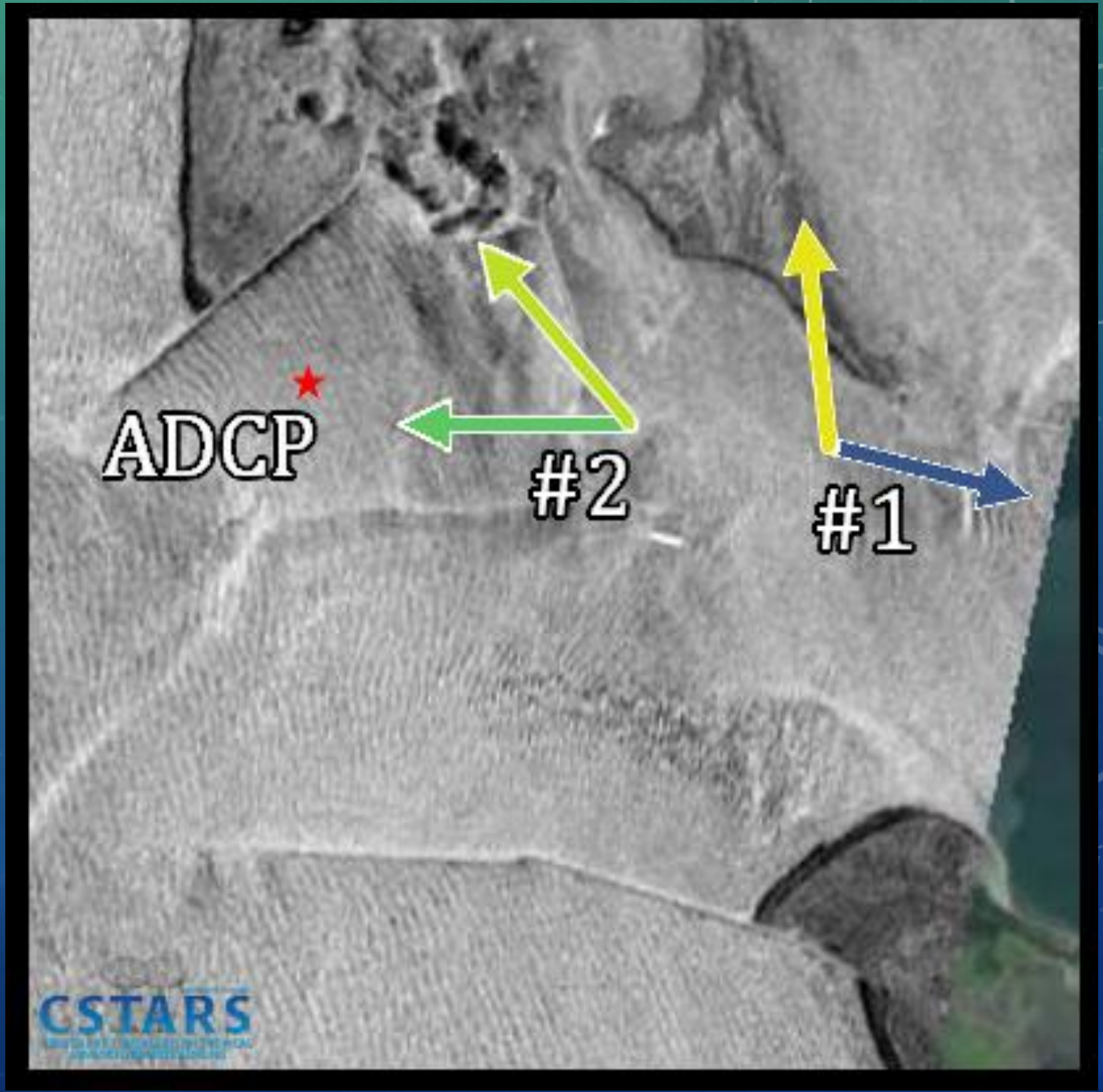
MOUTH OF THE COLUMBIA RIVER, OR/WA

#1

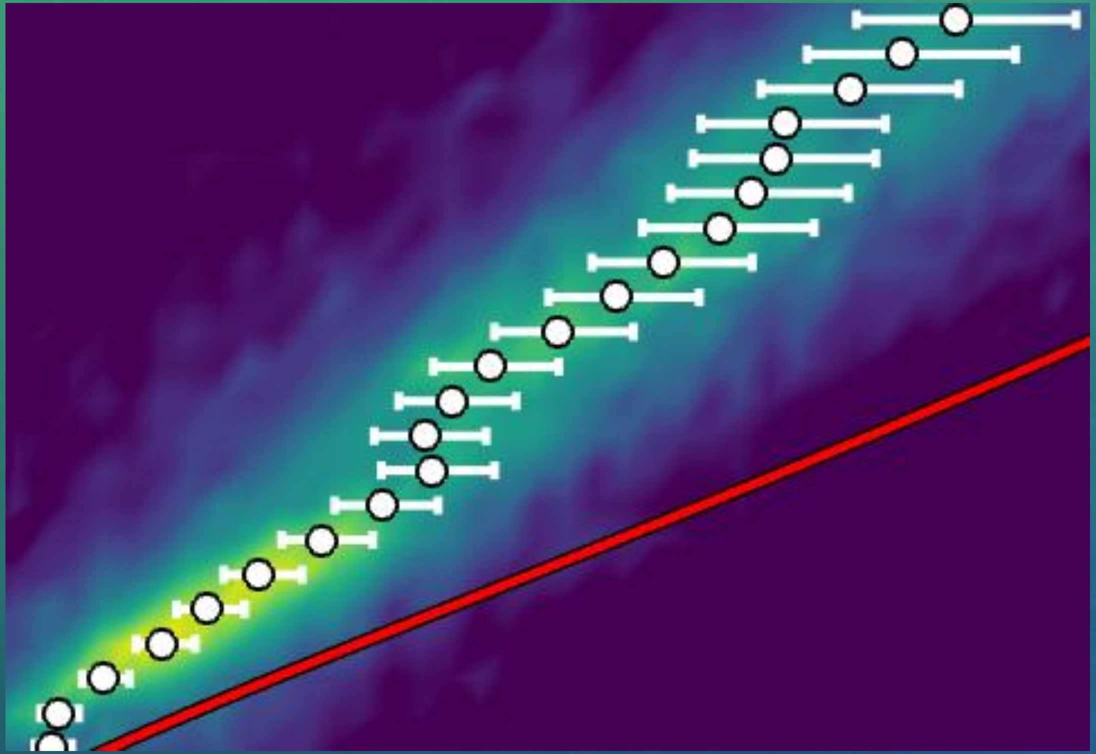


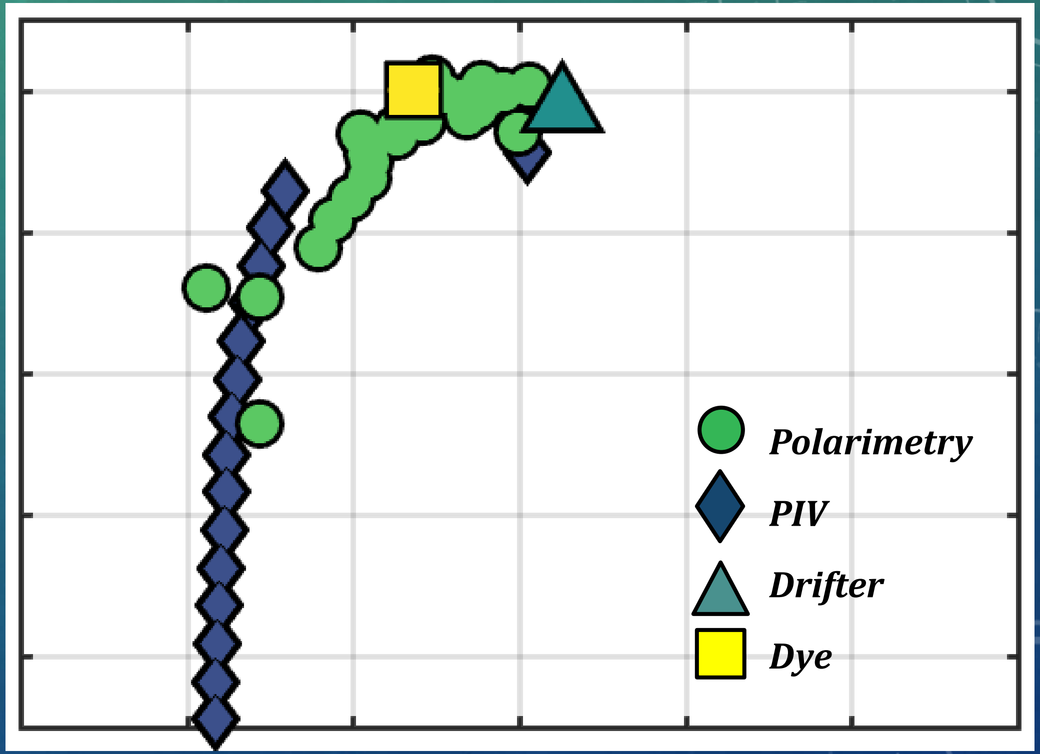
#2





IN SUMMARY

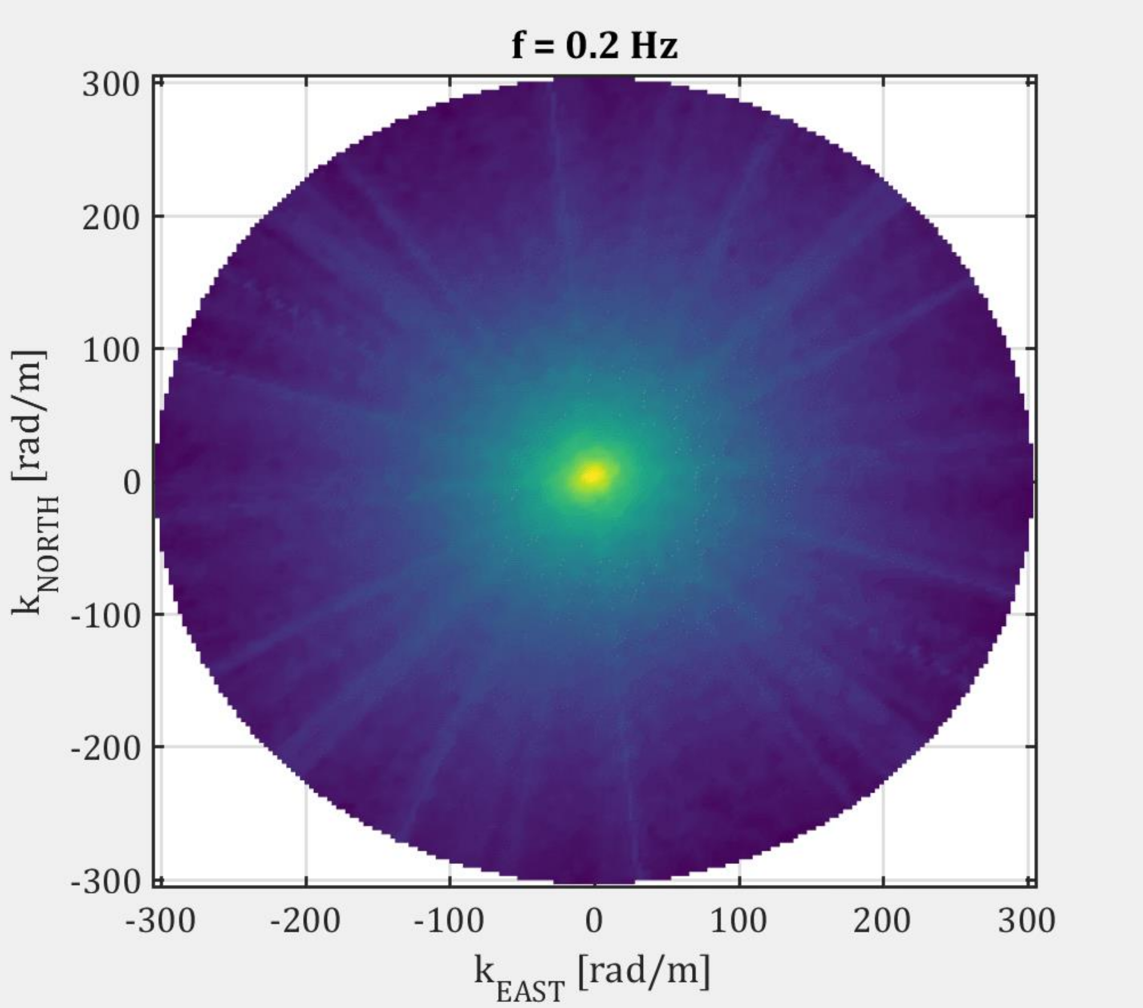




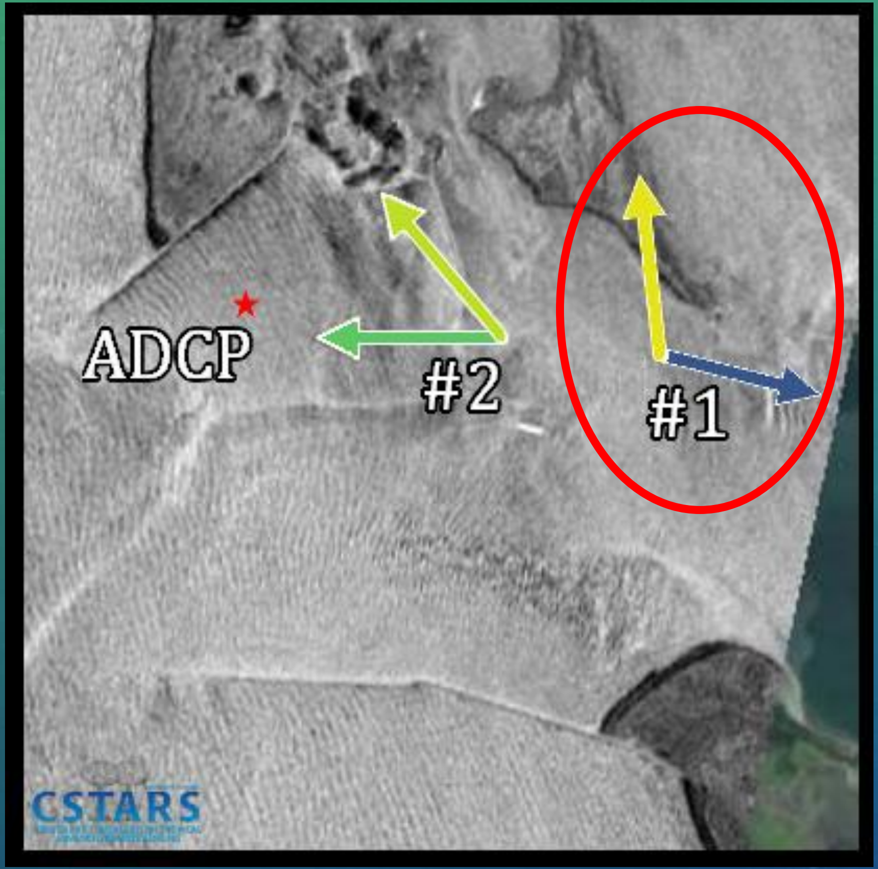
Wavenumber-frequency spectral analysis of short-scale ocean waves allows one a glimpse of the near-surface current profile without disturbing the air-sea interface.

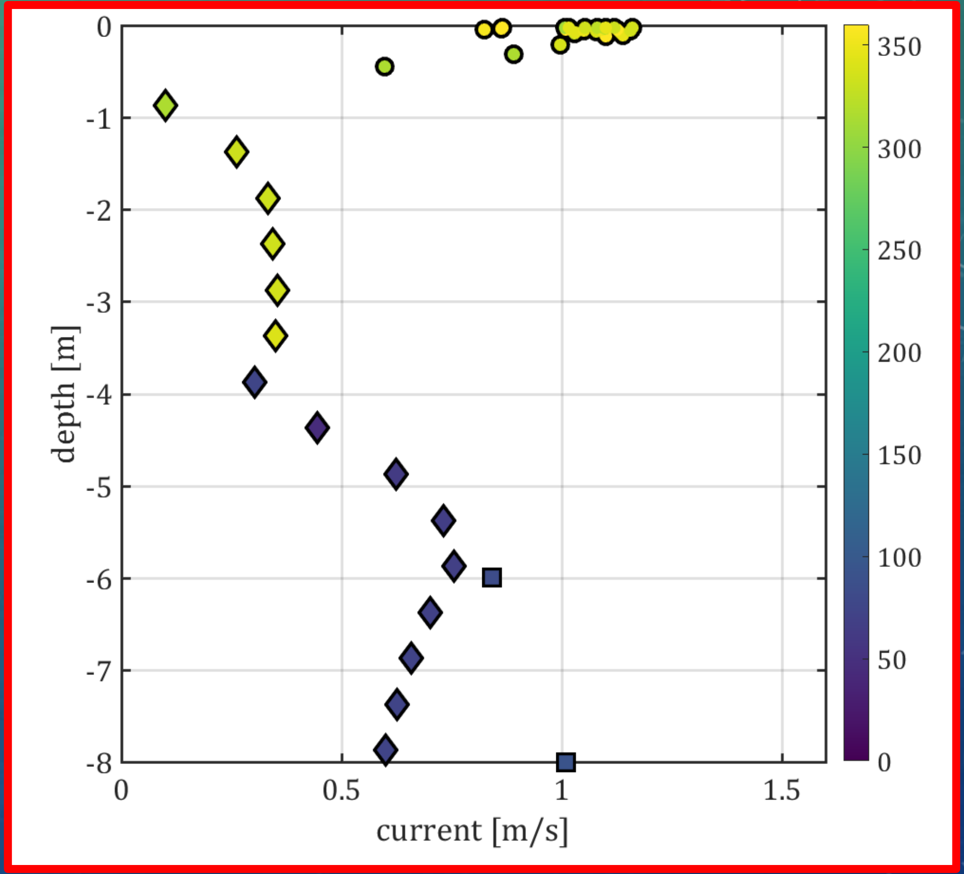
IN SUMMARY

Furthermore, this method may be performed aboard a moving vessel, offering remote determination of near-surface current under certain conditions.



IN SUMMARY





Use of these techniques reveals a strong, near-surface current that may depart significantly from background flows, apparently orienting into the observed wind stress direction.

FUTURE WORK: THE LASER FIELD CAMPAIGN

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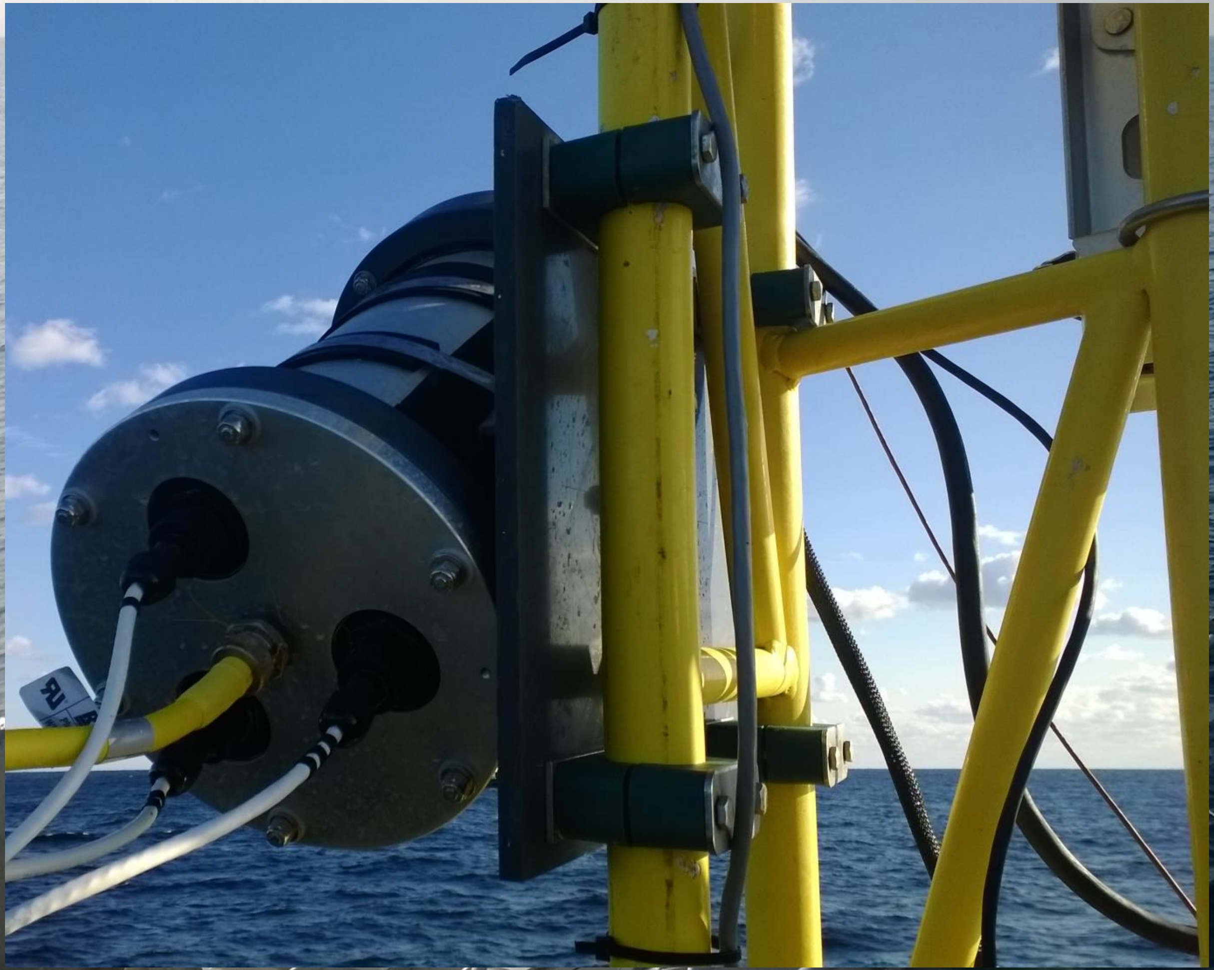
Incident polarization



Reflected polarization