ALB Beam Diagnostics using an Underwater Optical Detector Array

Matt Birkebak, Firat Eren, Shachak Pe'eri

Center for Coastal and Ocean Mapping/Joint Hydrographic Center

mbirkebak@ccom.unh.edu

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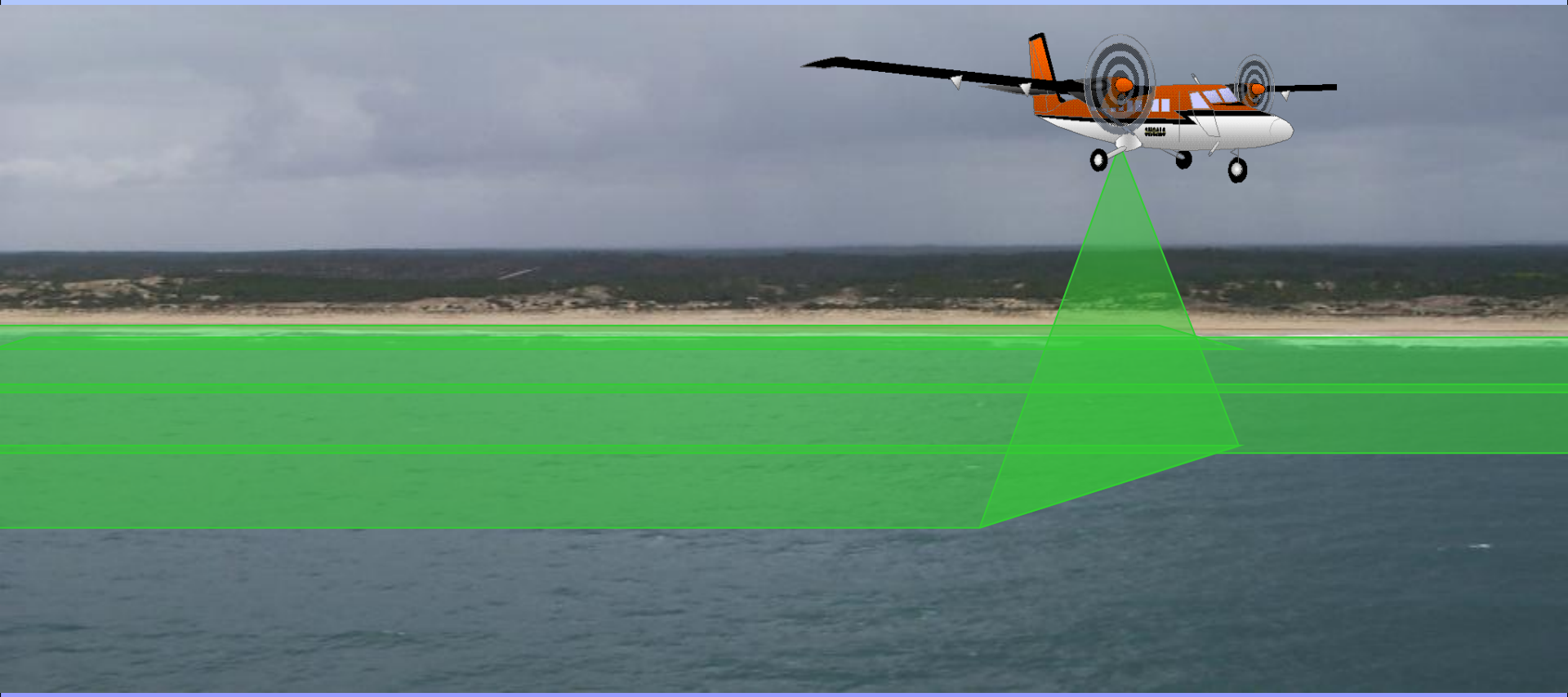
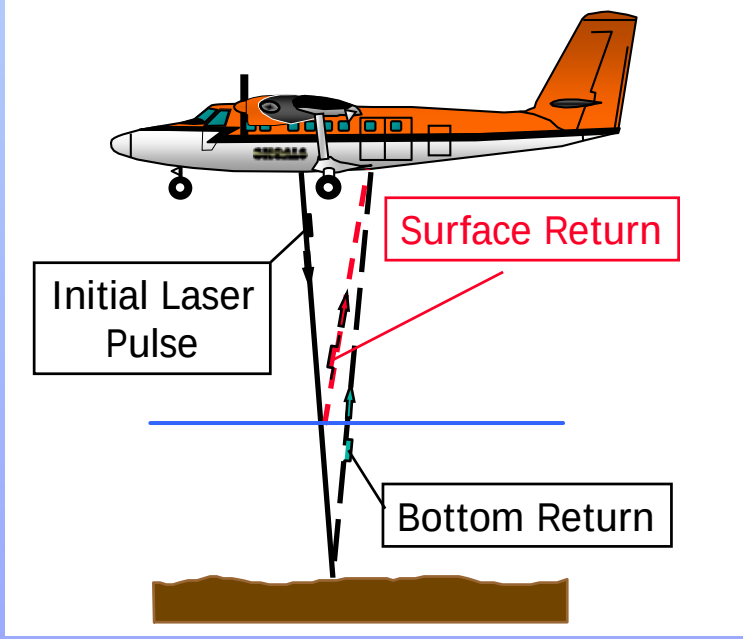
Outline

Detector Array → Measuring Waves → Beam Diagnostics



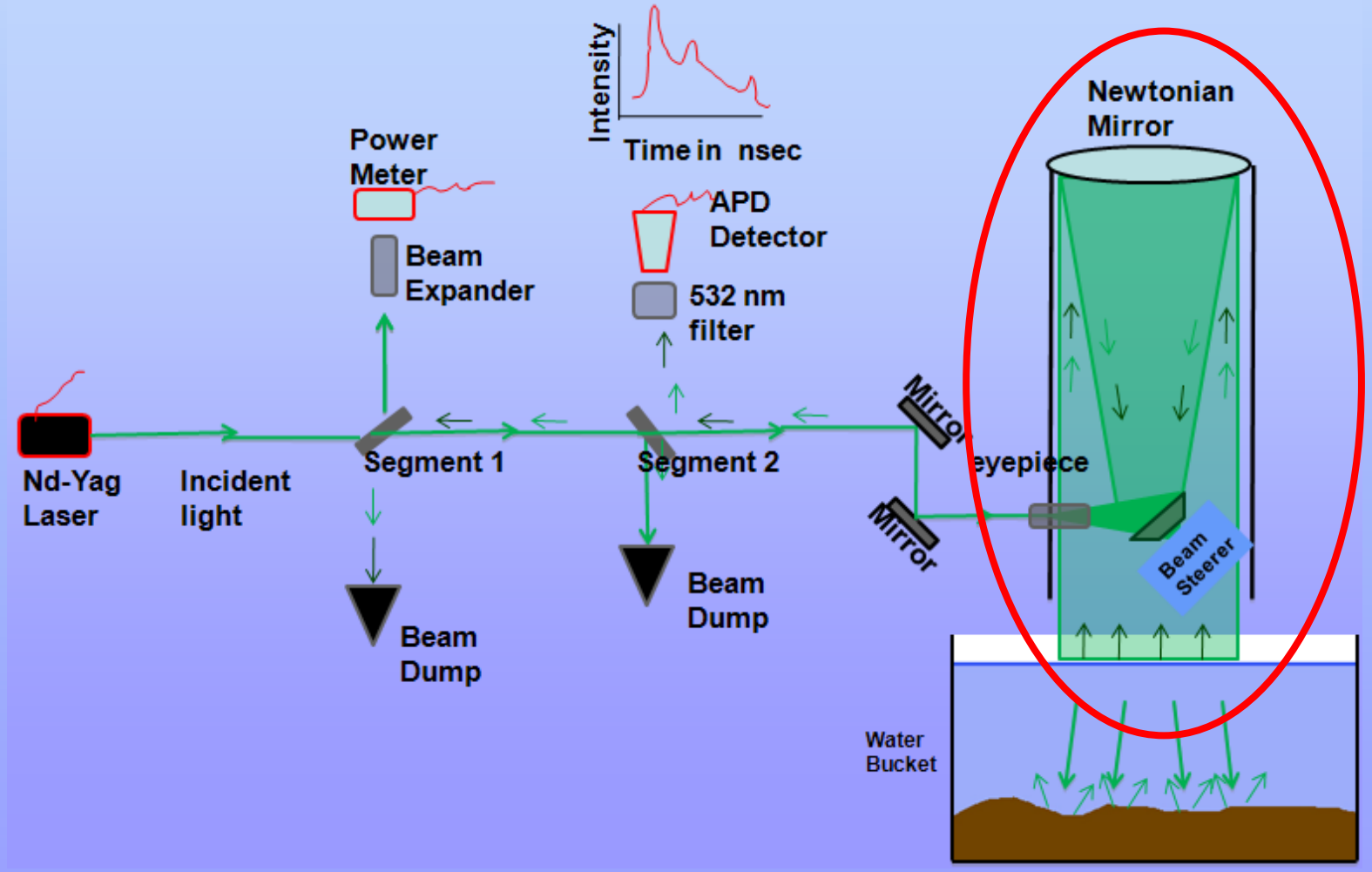
ALB pulse propagation

- **Atmosphere**
- **Air-water interface**
  - Surface waves
- **Water column**
  - Absorption
  - Scattering
- **Seafloor characteristics**
  - Slope
  - Bottom composition



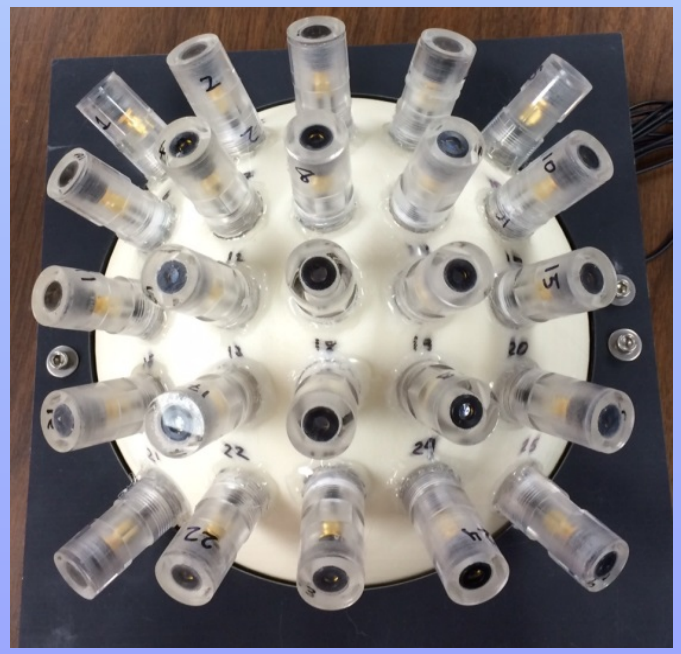
Fundamental of Ocean Mapping I OE 874

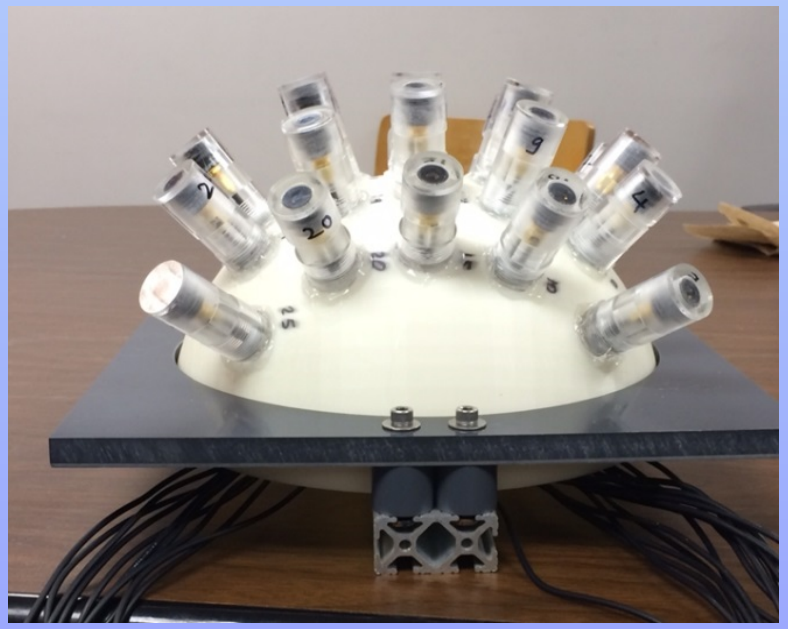
LIDAR Simulator



AUV Guidance System

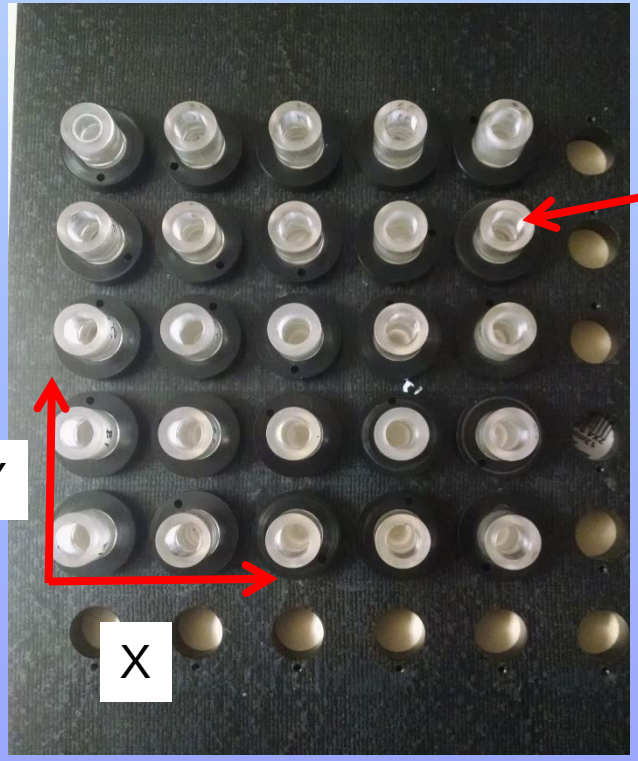
Spherical Detector Array





F. Eren, Pe'eri, S., Rzhanov, Y., Thein, M. - W., and Celikkol, B., “Detector Array Design for Optical Communication Between Unmanned Underwater Vehicles (UUVs)”, *IEEE Journal of Oceanic Engineering*, vol. 40(1). IEEE Oceanic Engineering Society, pp. 18-26, 2016.

Planar Detector Array



Acrylic fixtures

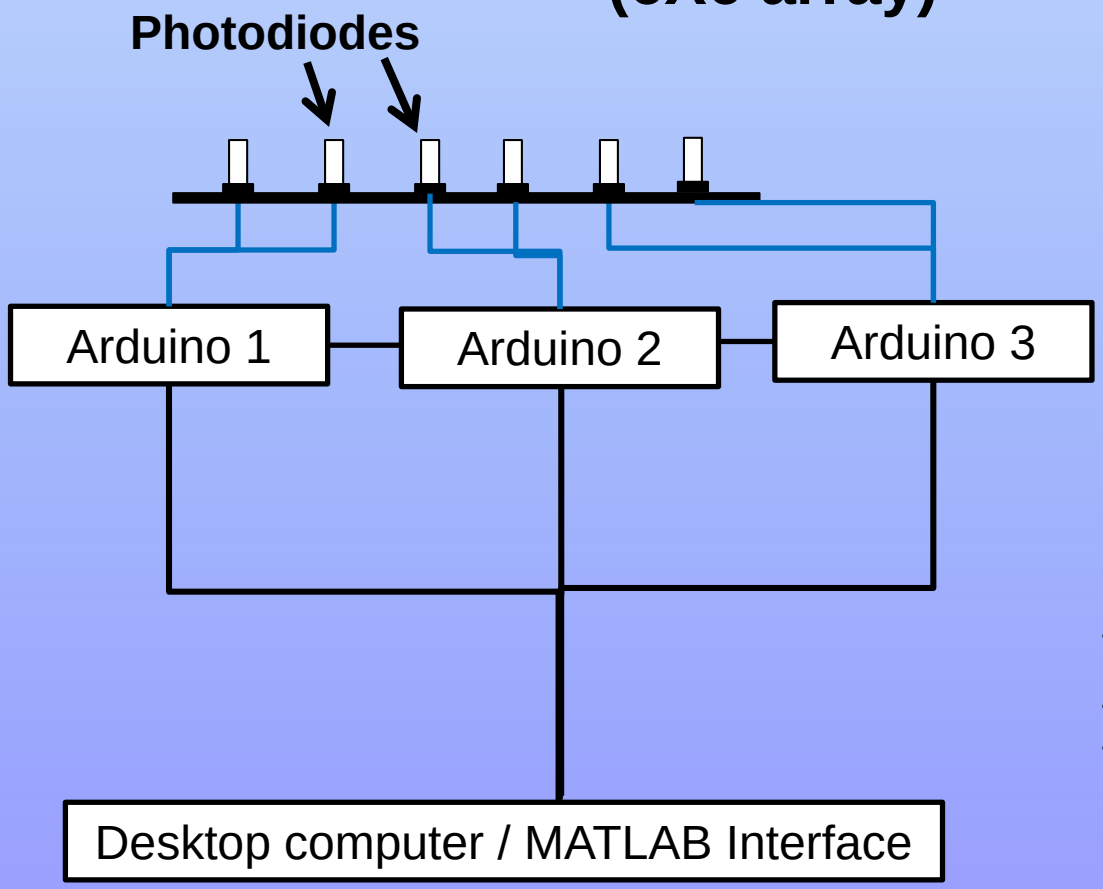
5X5 setup

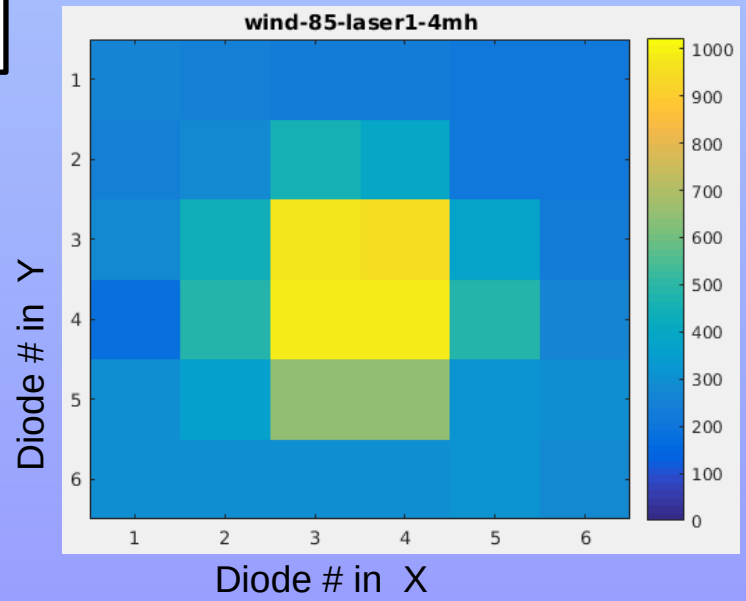
Concept expanded from Dr. Firat Eren's AUV guidance system

6X6 setup

Detector Array Concept

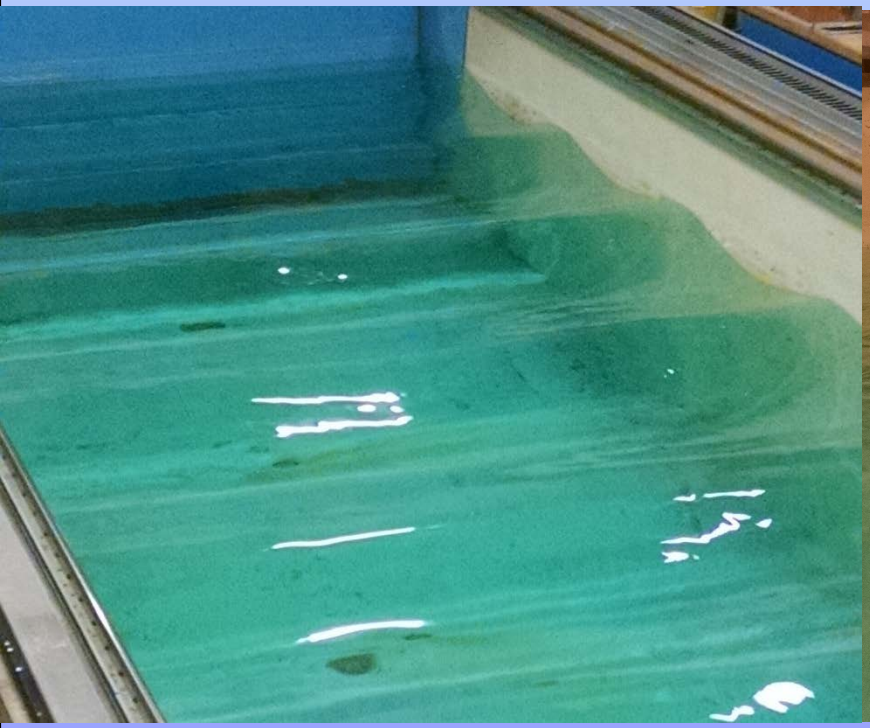
OPTICAL MODULE (6X6 array)



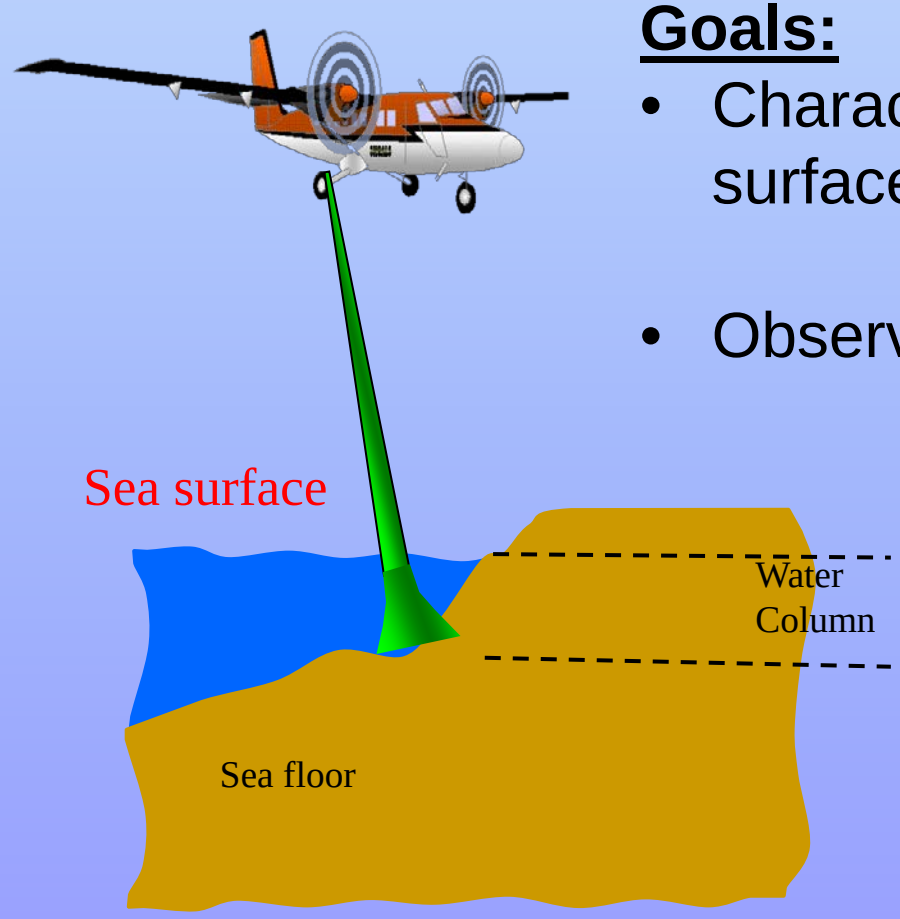


ALB Uncertainty due to Environmental Factors

Water Surface Uncertainty due to Waves



Research Goals

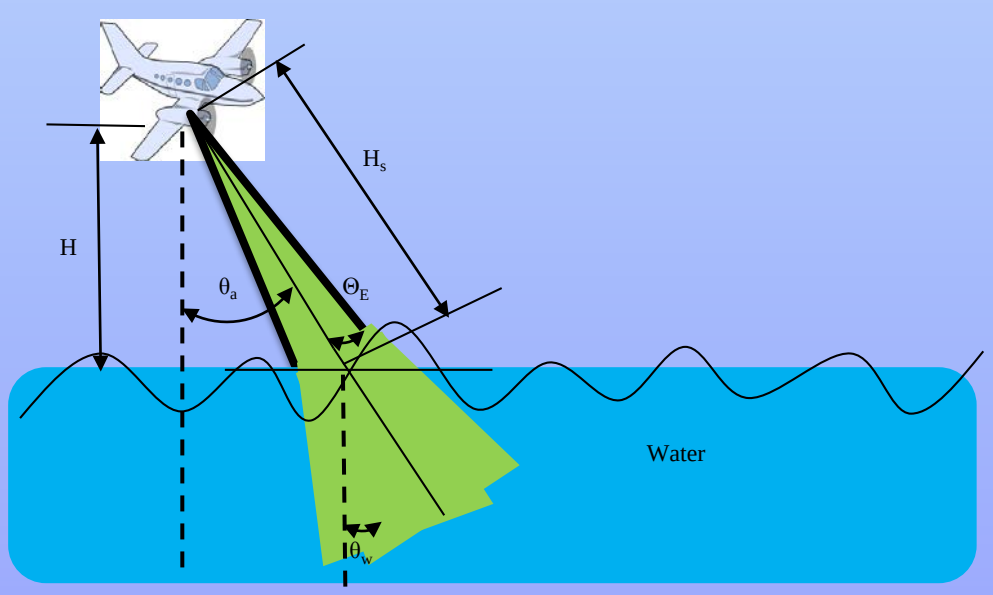


Goals:

- Characterize the uncertainty due to surface waves.
- Observe changes to the beam footprint.

Surface waves in ALB

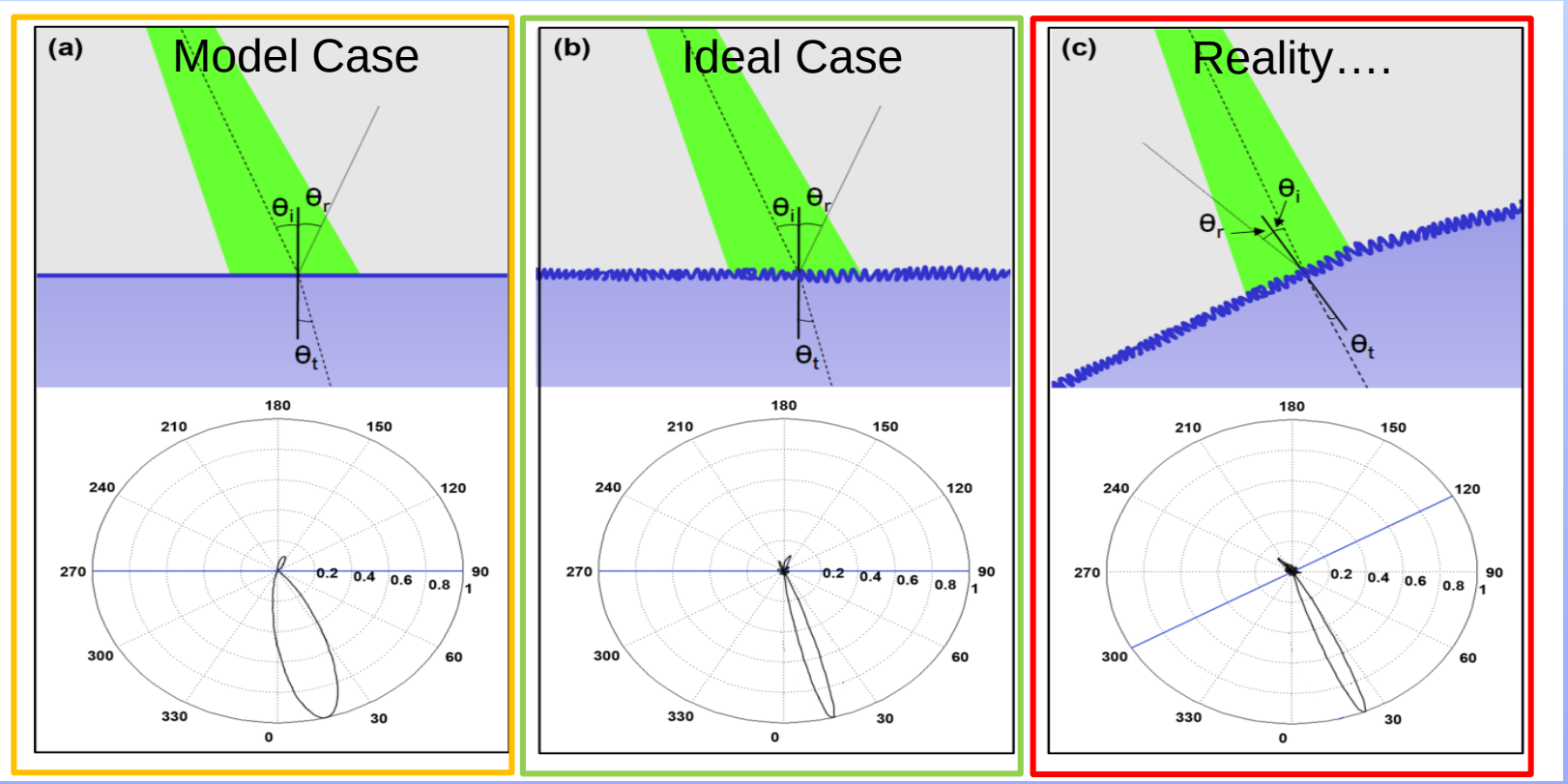
Most ALB surveys low pass filter the water surface and correct large waves only.



In reality….

Surface waves create uncertainty.

Optical Refraction

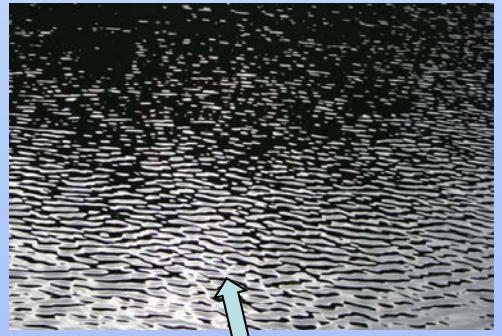


(a) Smooth Conditions (b) Surface ripples (c) Gravity waves

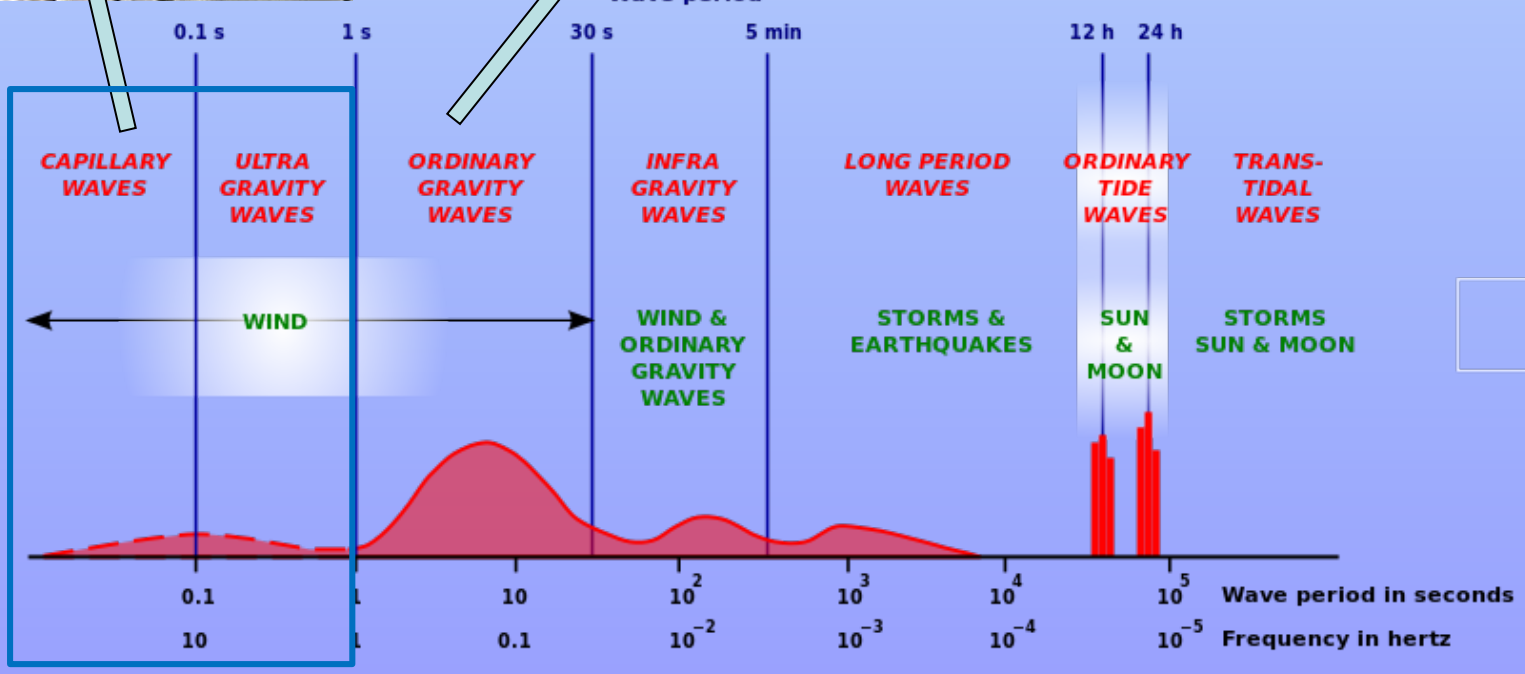
Surface ripples (short wavelength ~1cm) < Beam diameter (25cm)
Gravity waves (wavelength 1cm and up)

Pe'eri, Weber, Karlsson,2016

Ocean Waves



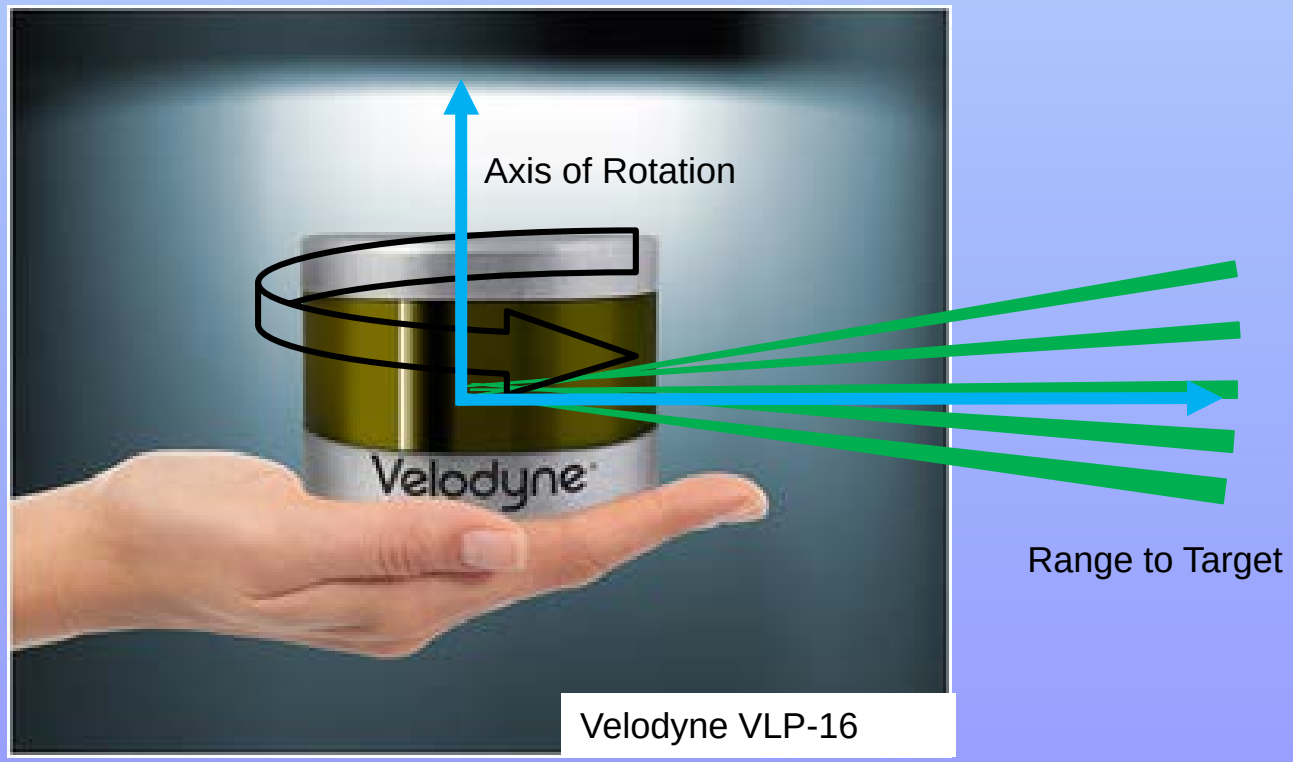
- Wind speed
- Fetch
- Duration



Walter Munk 1950

Measuring Waves

- 905nm laser reflects off water.
- Centimeter resolution with 20Hz sampling rate.
- 8° field of view on the water surface (flat surface).



Velodyne VLP-16

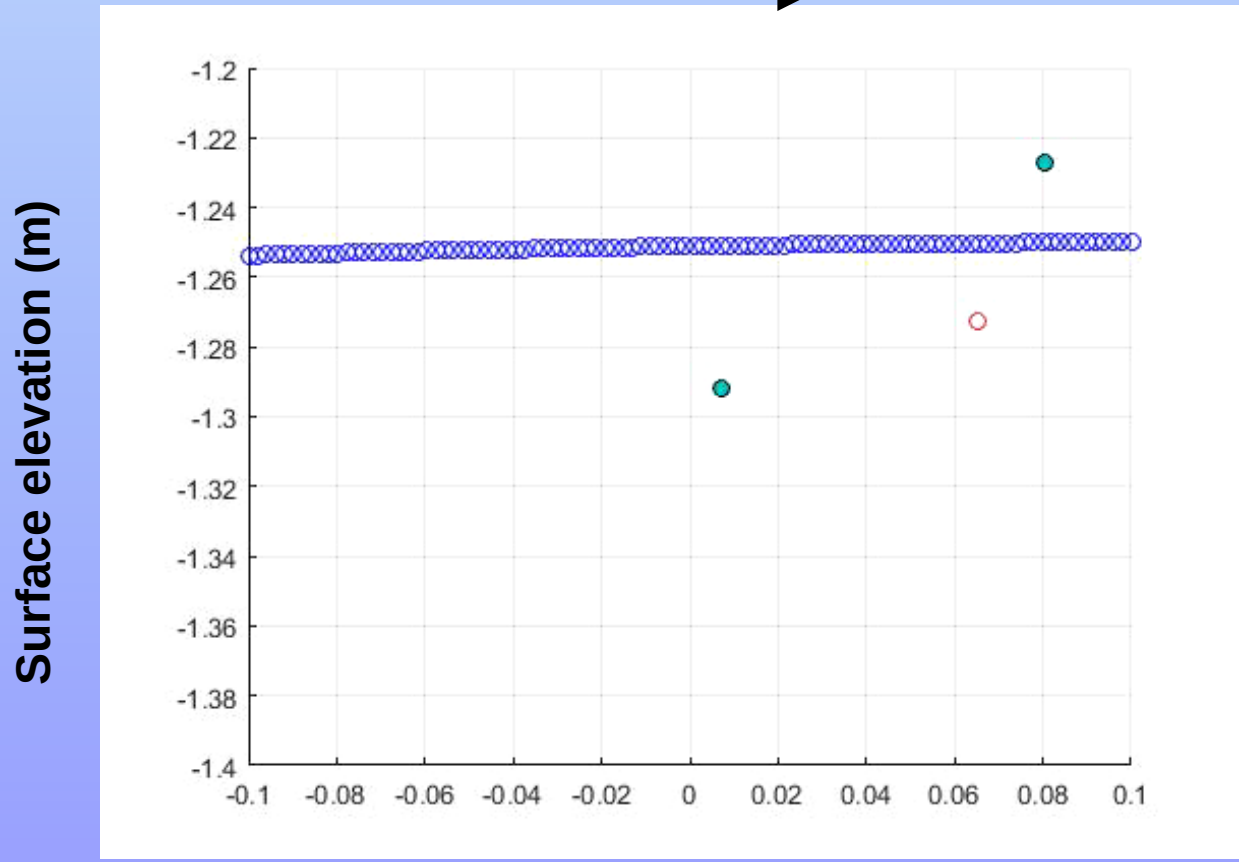
Water Surface Detection

Can laser scanning devices be used to estimate wave heights and slopes?

Velodyne Laser Scanner (VLP-16)

Wave Measurements

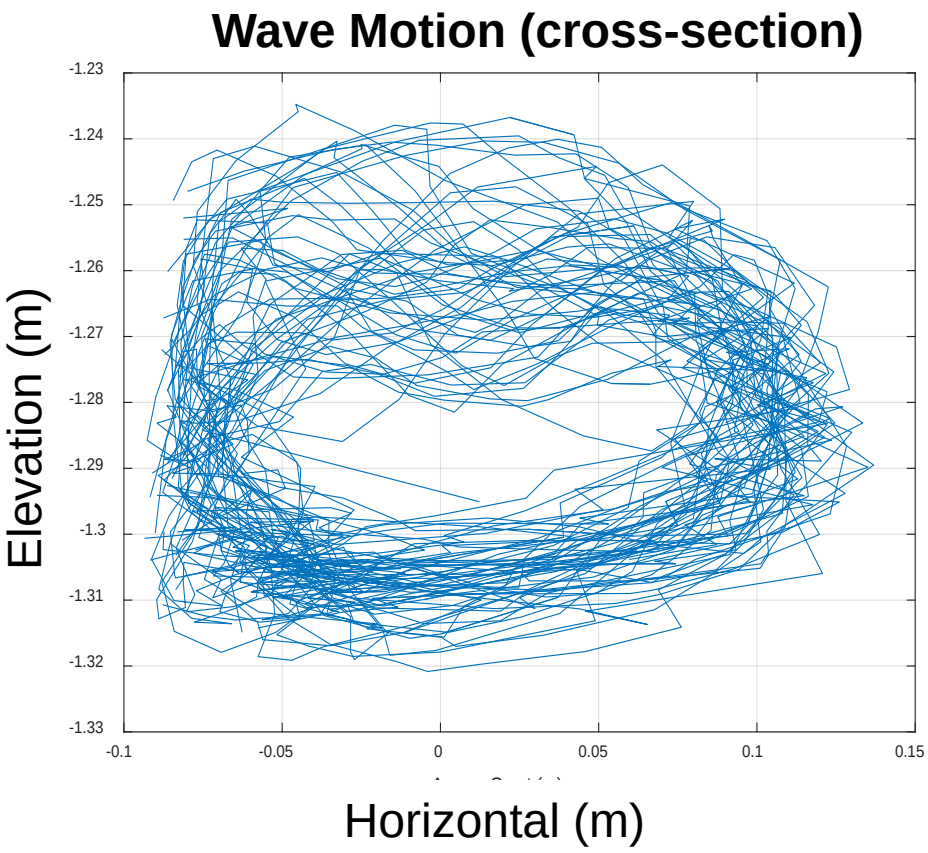
Direction of wave propagation

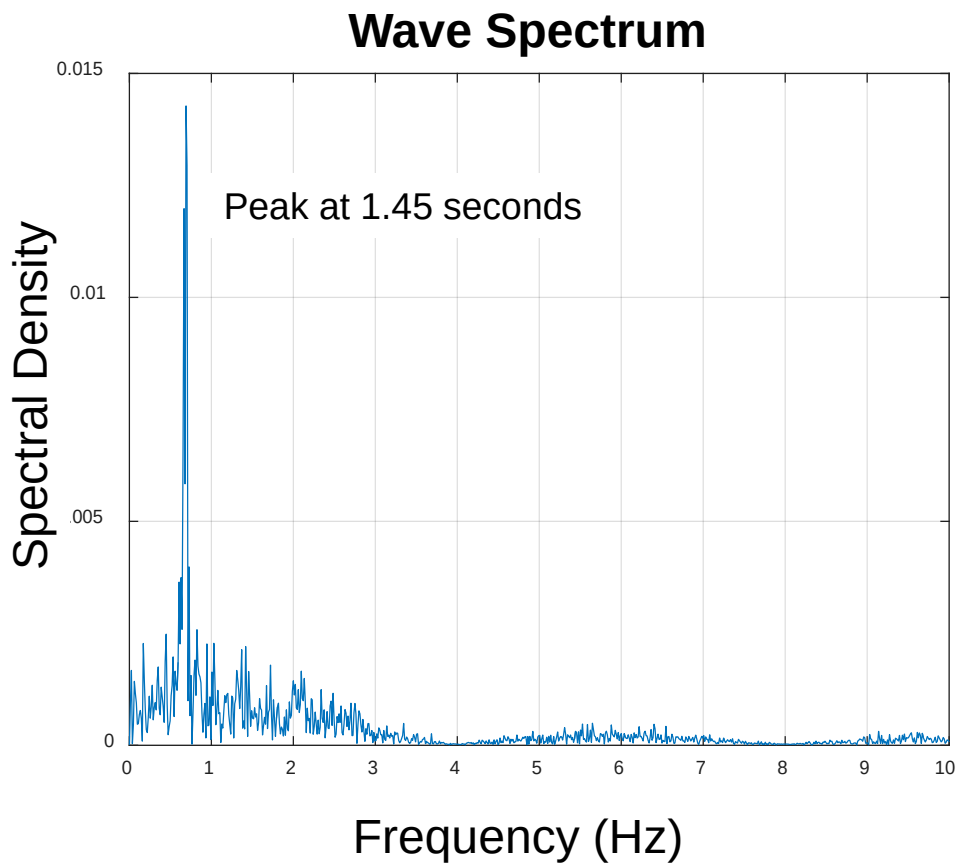


Surface elevation (m)

Horizontal distance (m)

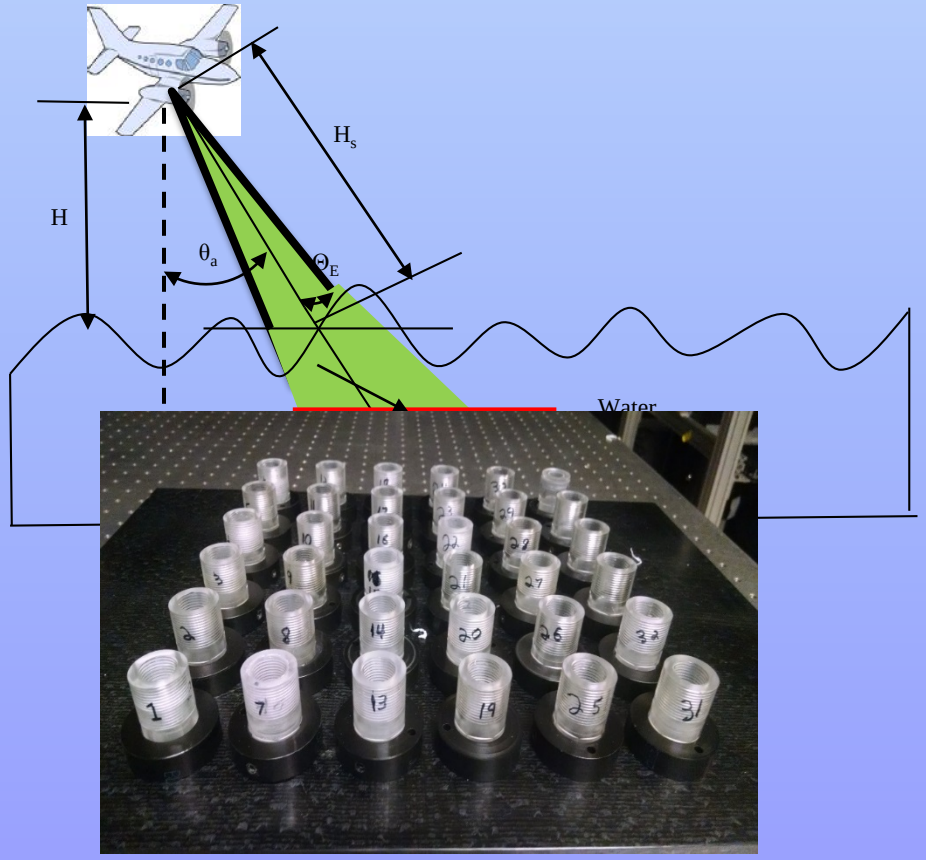
Wave Spectrum





Surface Detection

We can measure wave height and slope using laser scanner.

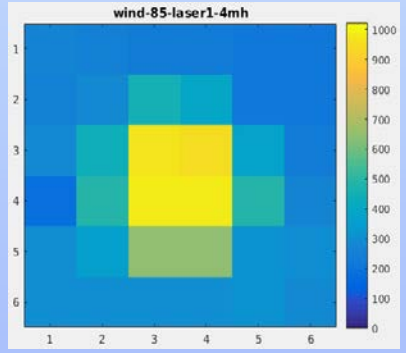


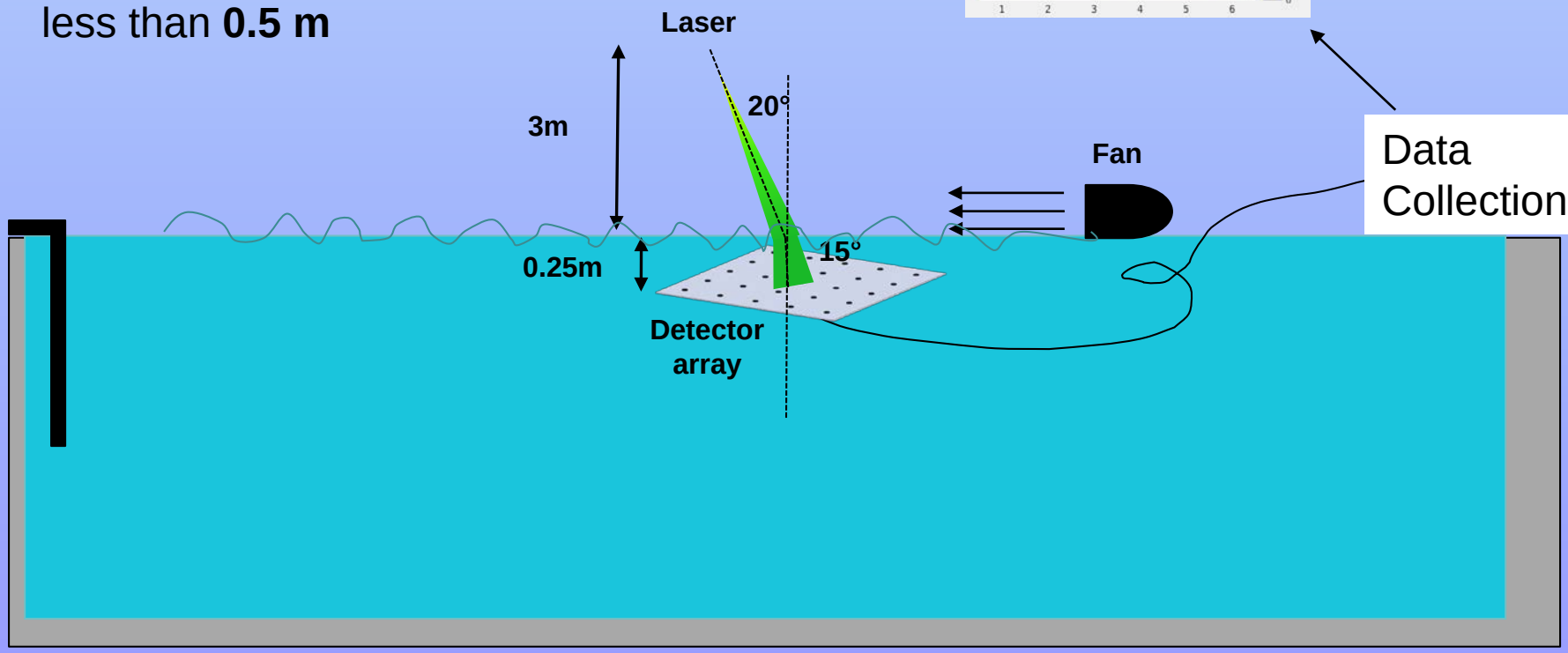
Next, visualize the beam just below the surface.

Water Surface Experiments

$$h > \frac{L}{2}$$

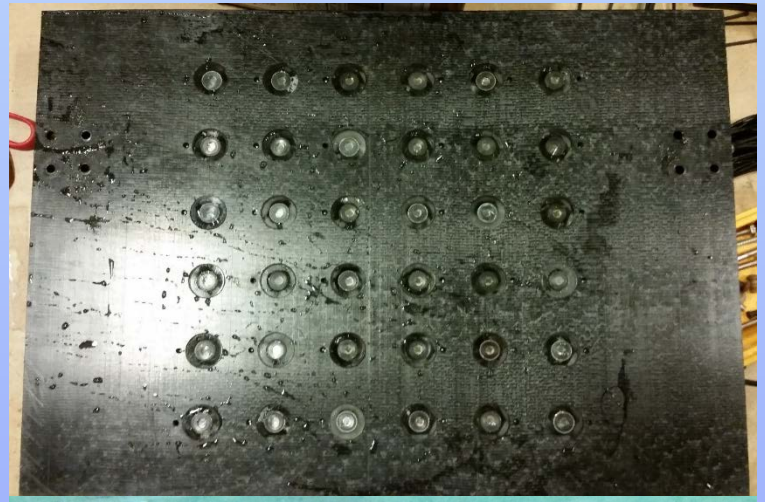
Deep water conditions limited to wavelengths less than **0.5 m**

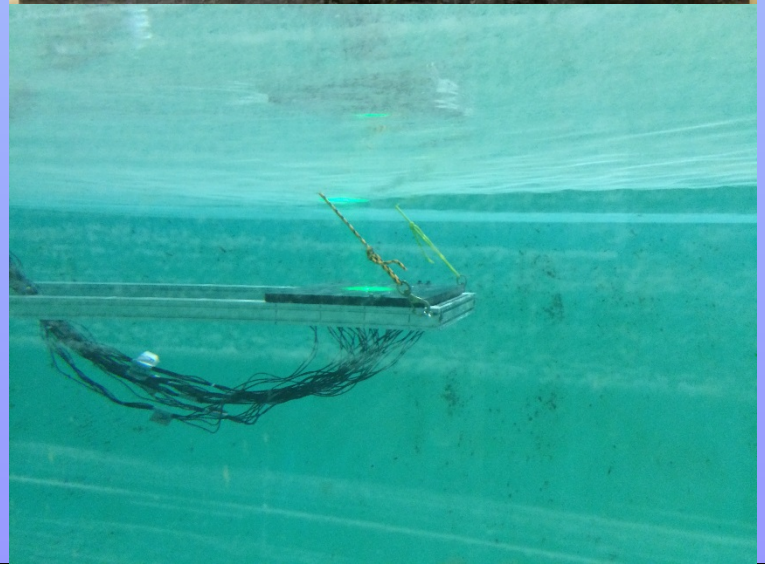


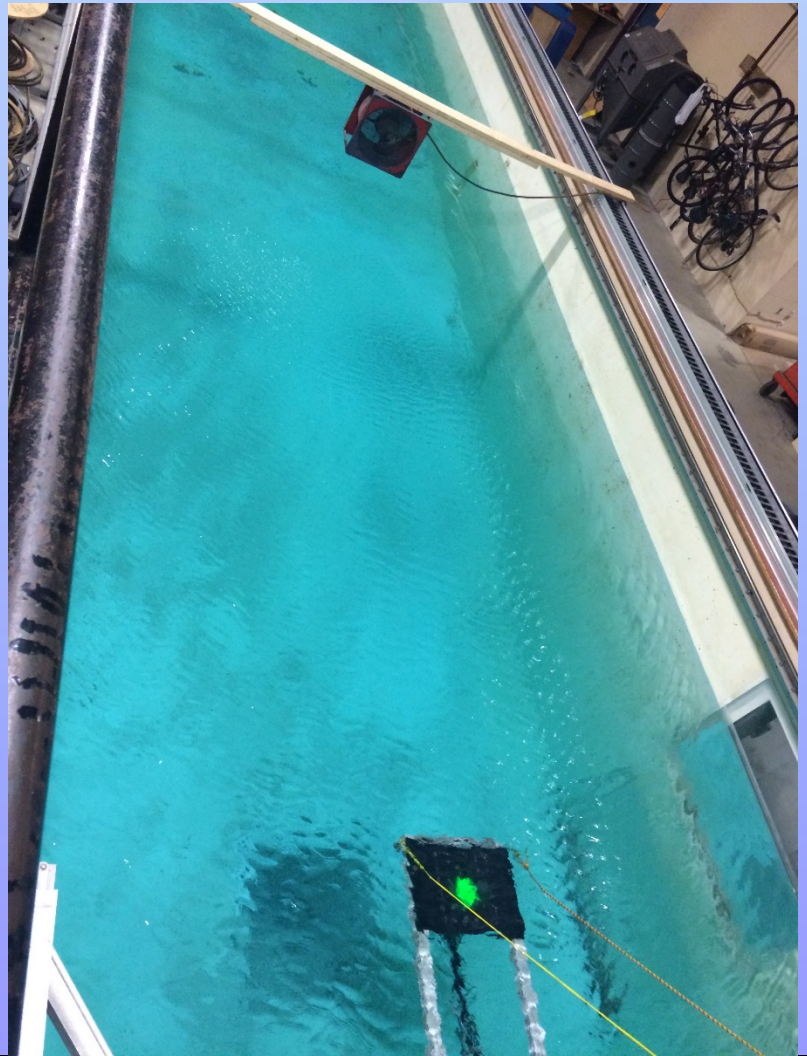


Data Collection

Water surface measurements





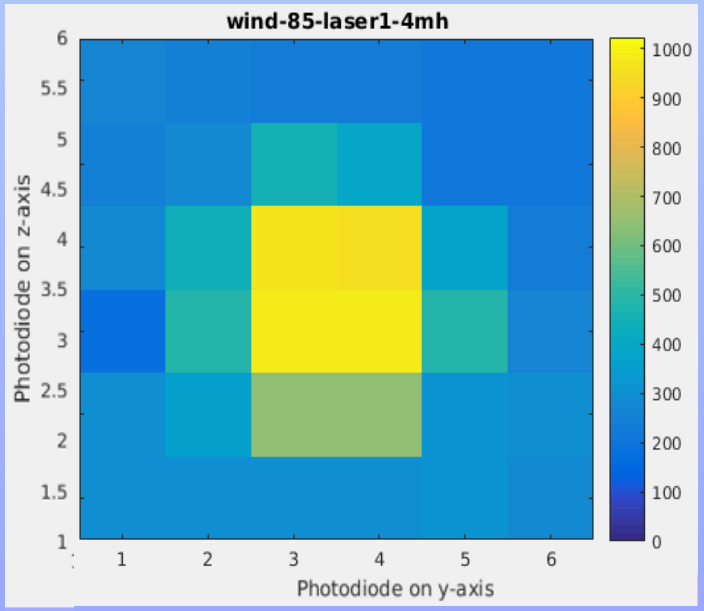


Water Surface Experiments

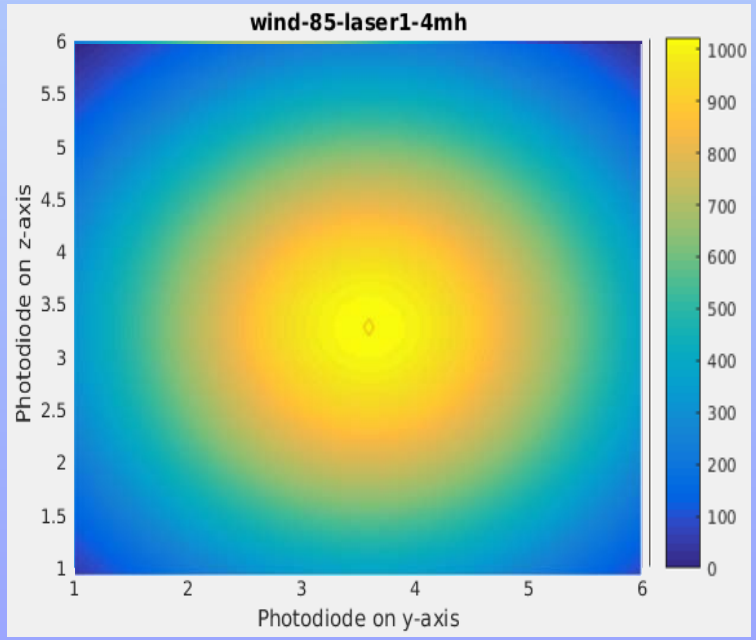
Water Surface Experiments

Gaussian Modeling

In order to better model the raw data Gaussian models were fit to the pixels.



Raw Data



Gaussian Fit

(Images courtesy of Sean Kelley)

Image Moments Invariants (Incident Angle Estimation)

Algorithm

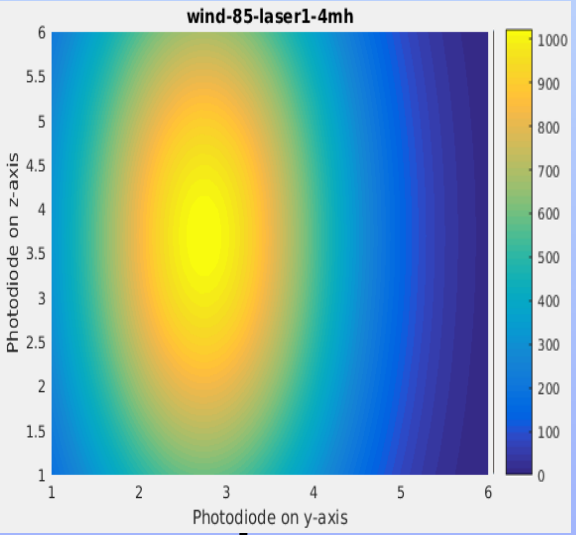
Sub-pixel accuracy

$$M_{pq} = \frac{1}{S}\sum_{i,j}(y_i - y_o)^p (z_j - z_o)^q I_{i,j}$$

$$S = \sum_{i,j} I_{i,j}$$

$$P_{max} = (y_o, z_o)$$

$$\frac{M_{23}}{M_{32}} = Incident\ \ angle$$



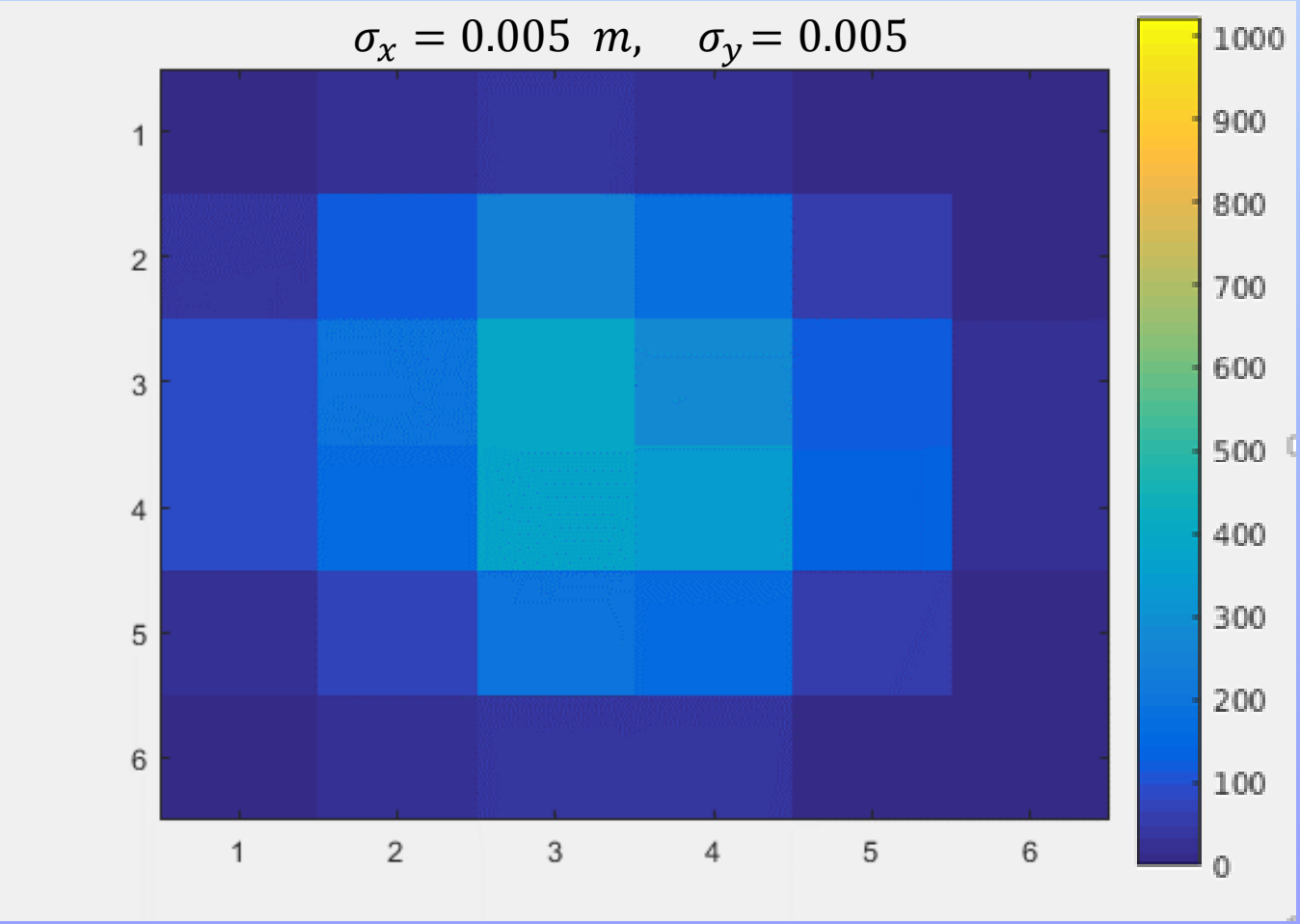
Moment Invariants Table for a pose

1.000	0.000	10.327
-0.522	0.001	-6.754
9.511	-0.023	101.821

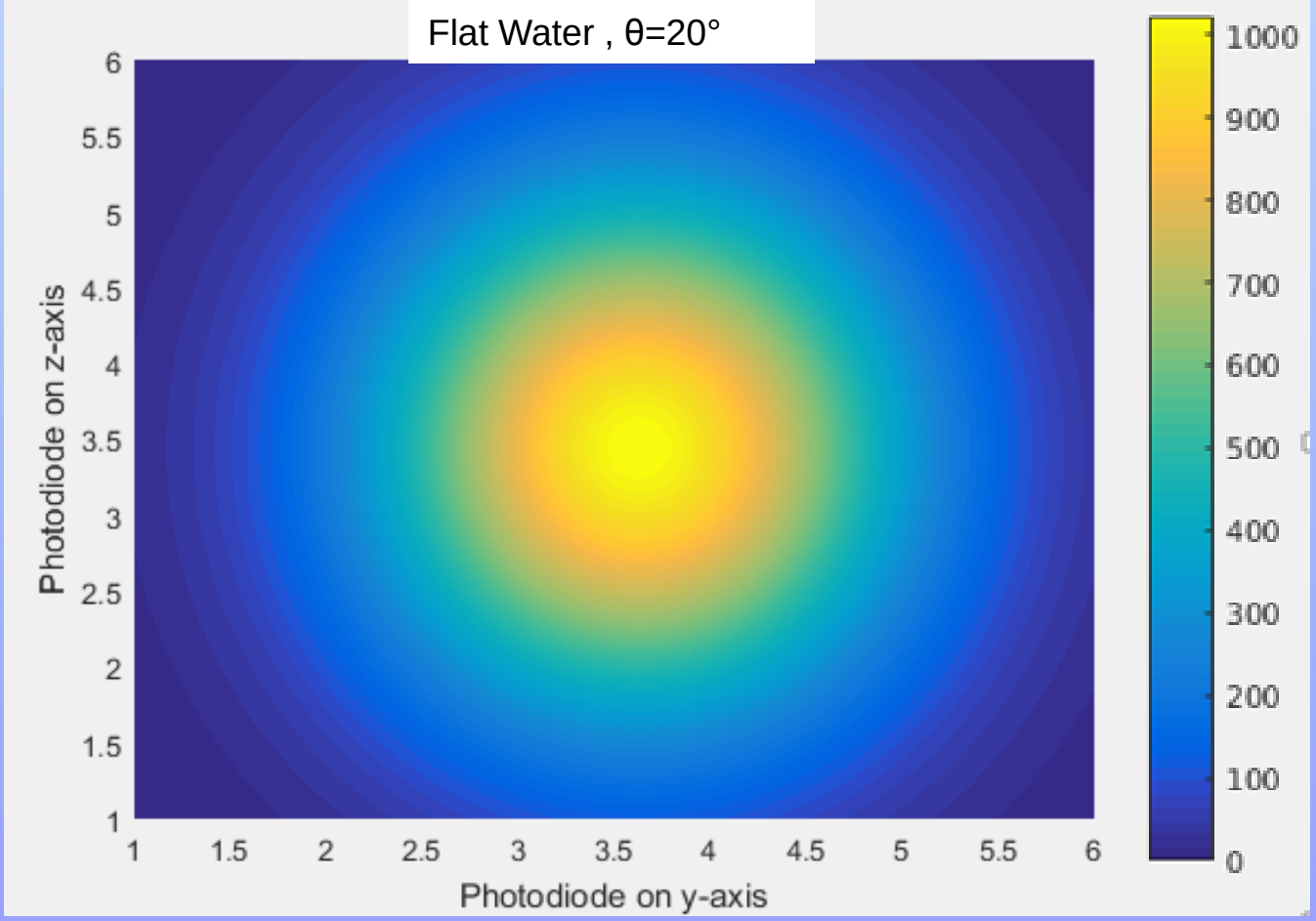
Y. Rzhanov, Eren, F., Pe'eri, S., and Thein, M. - W., "An image processing approach for determining of relative pose of unmanned underwater vehicles", Oceans'14 MTS/IEEE. Taipei, Taiwan, 2014.

Preliminary Results

Still Water Surface, θ=20°

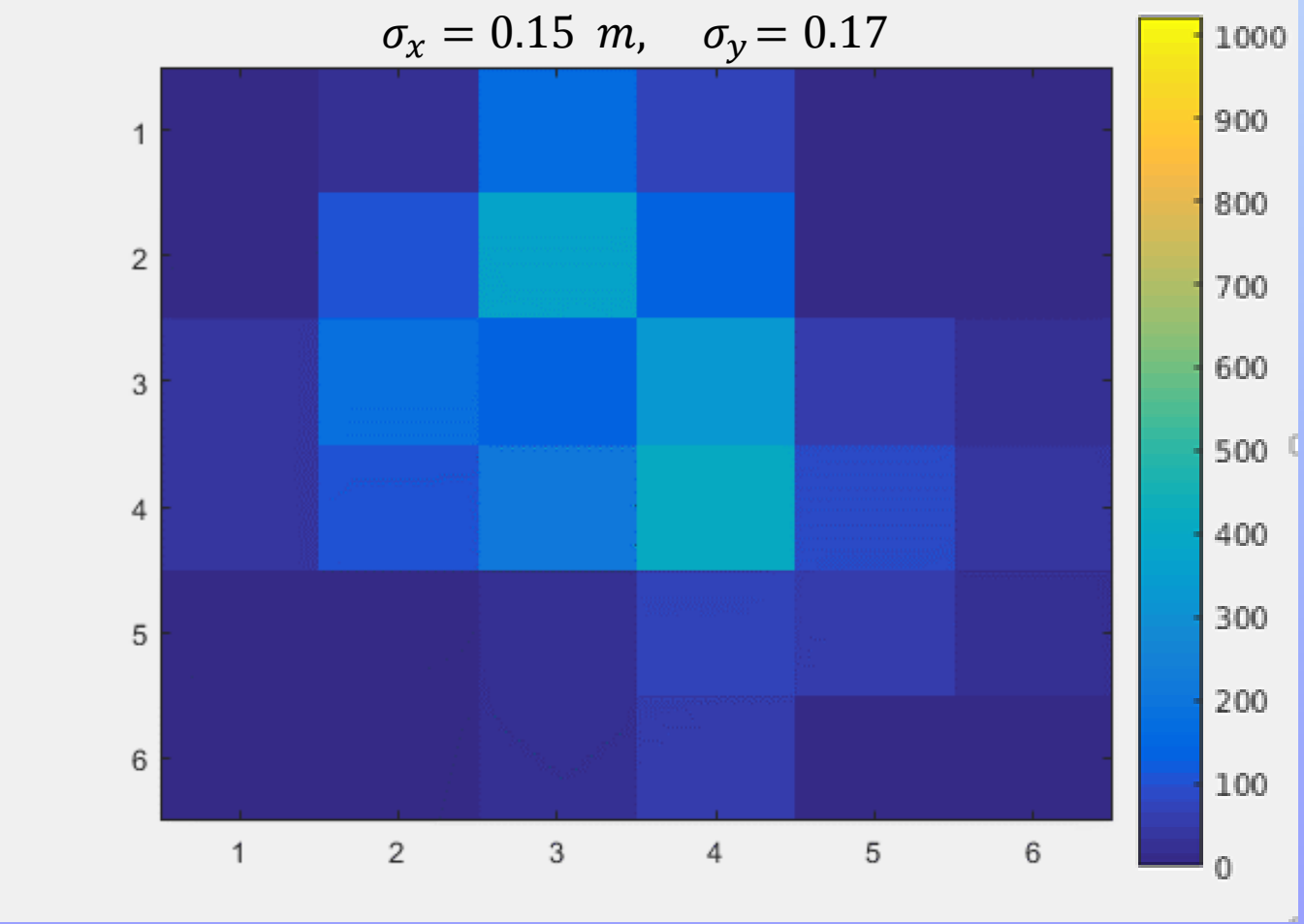


Preliminary Results



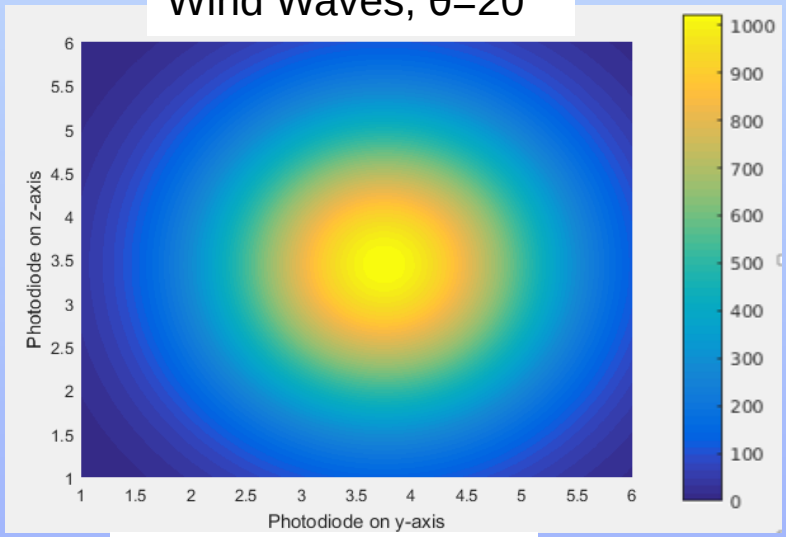
Preliminary Results

Wind Driven Water Surface, θ=20°

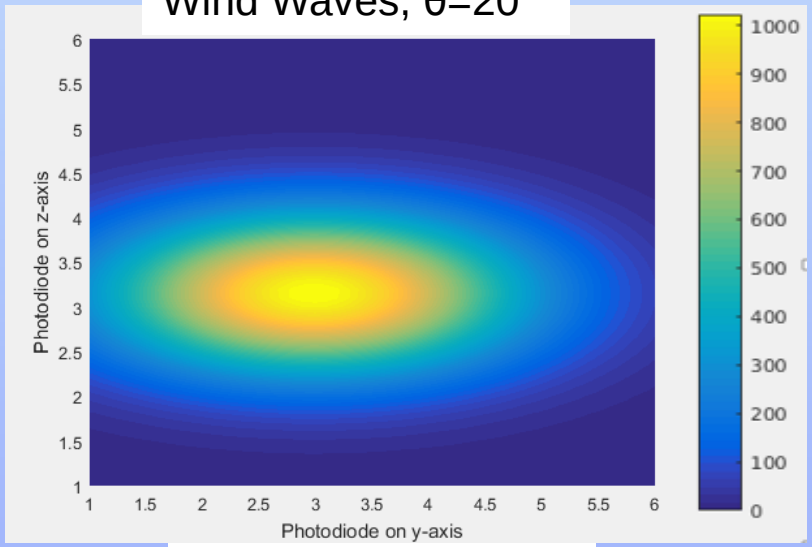


Preliminary Results

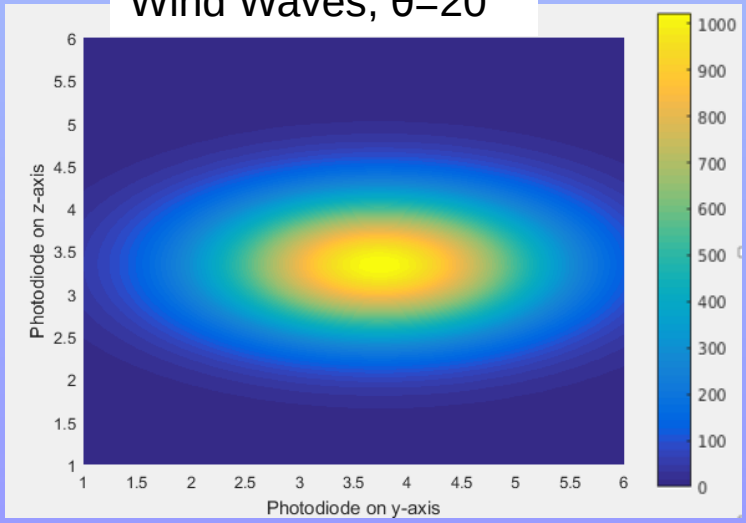
Wind Waves, θ=20°



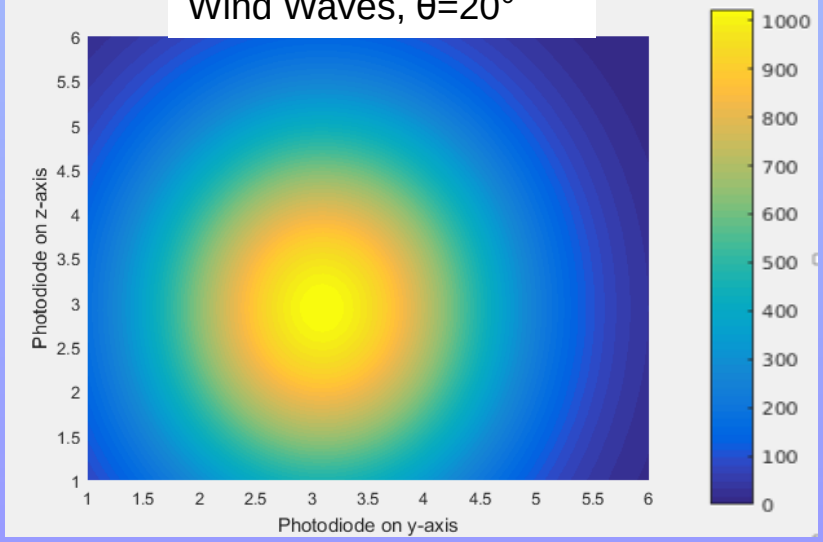
Wind Waves, θ=20°



Wind Waves, θ=20°

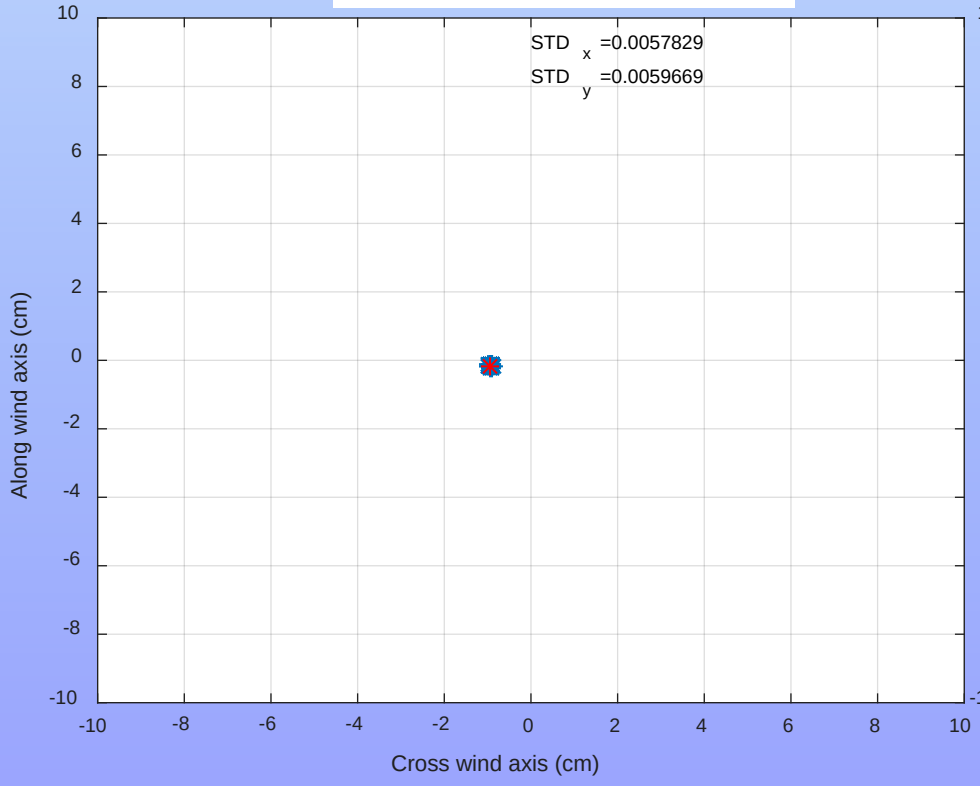


Wind Waves, θ=20°

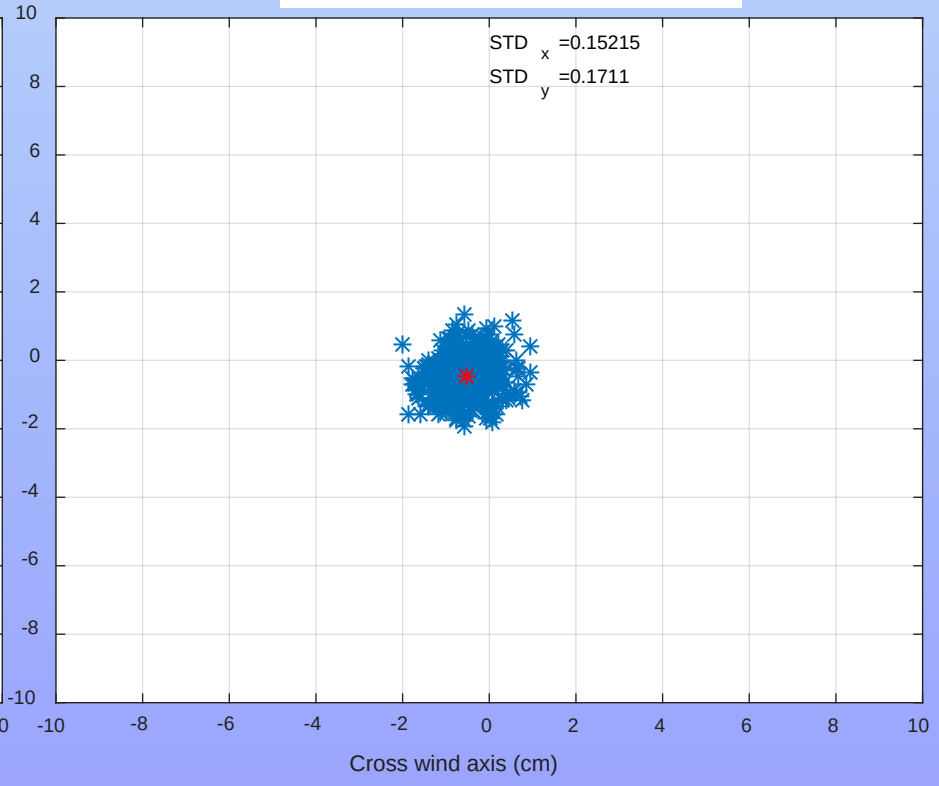


Beam Centroid

Still water, θ=20°

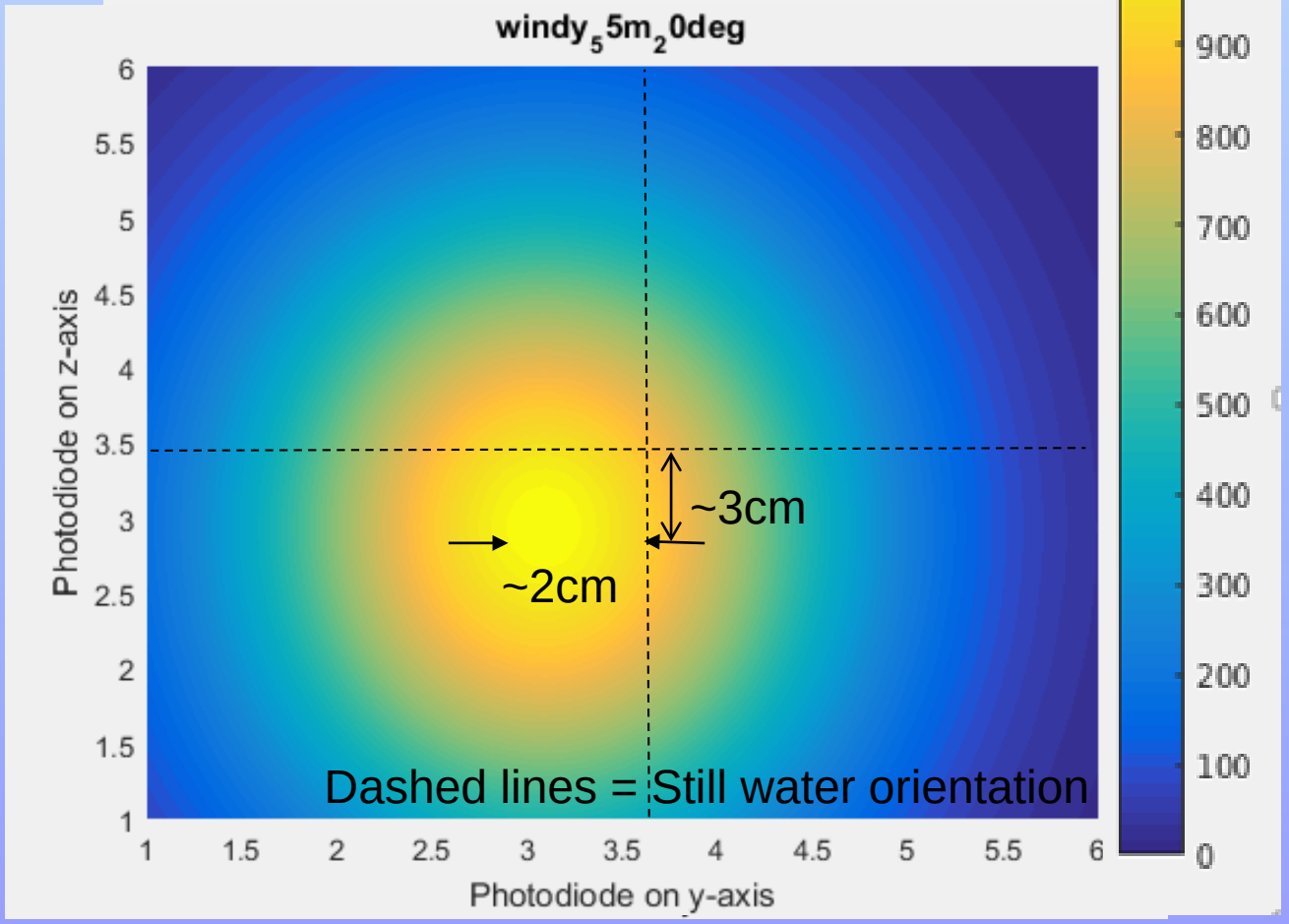


Wind waves, θ=20°



Beam Center Shift

Shift of beam center from still water reference



Next steps

Analysis is still in progress…

Next objectives are:

- Statistics of horizontal beam shift.
- Provide measurement uncertainty for over varied wind speed values.
- Study effect of waves on waveforms.

To be continued

Thanks…

Acknowledgements

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  - Dr. Martin Renken (NAVSEA – Keyport, WA)
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  - Yuri Rzhanov (CCOM,UNH)