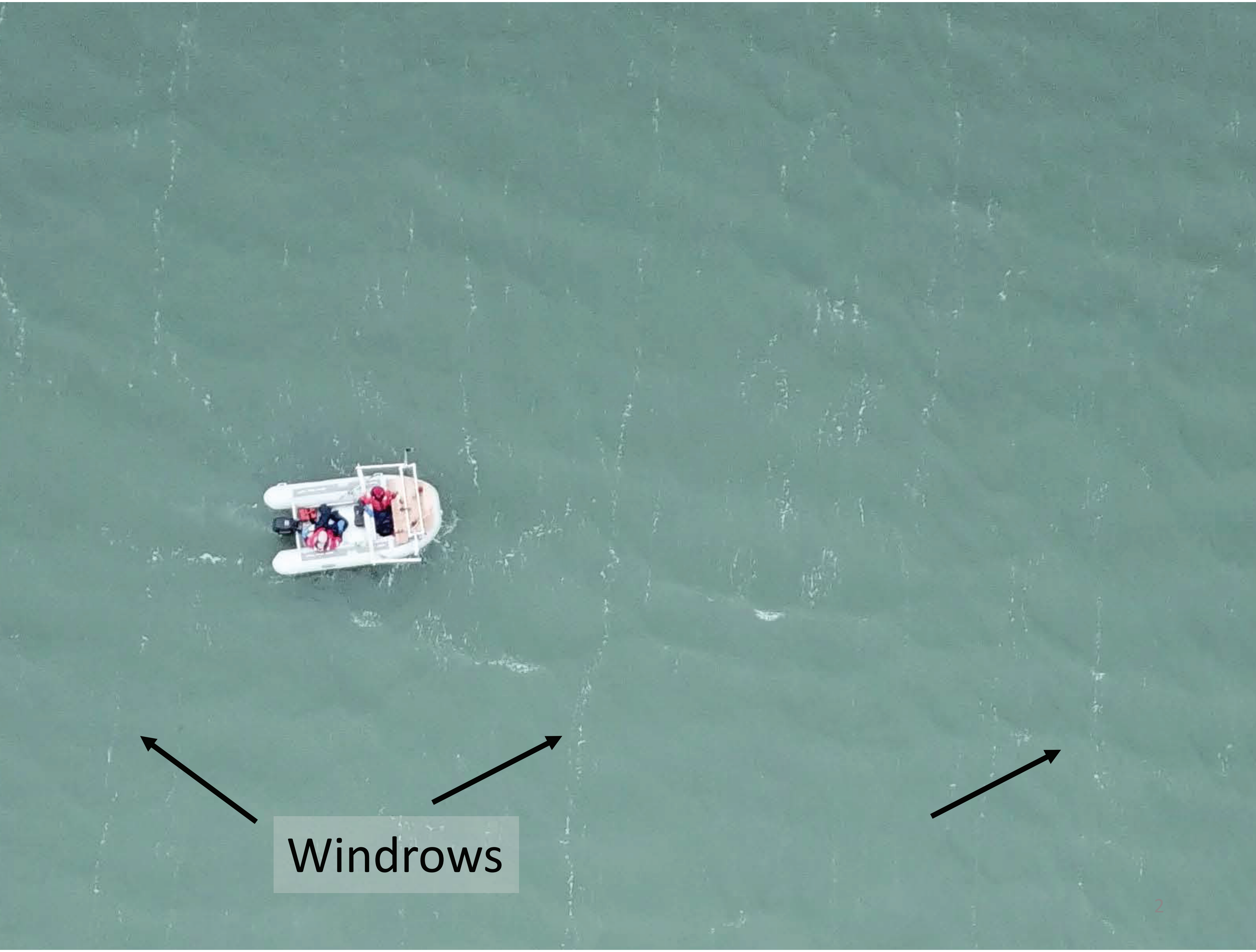
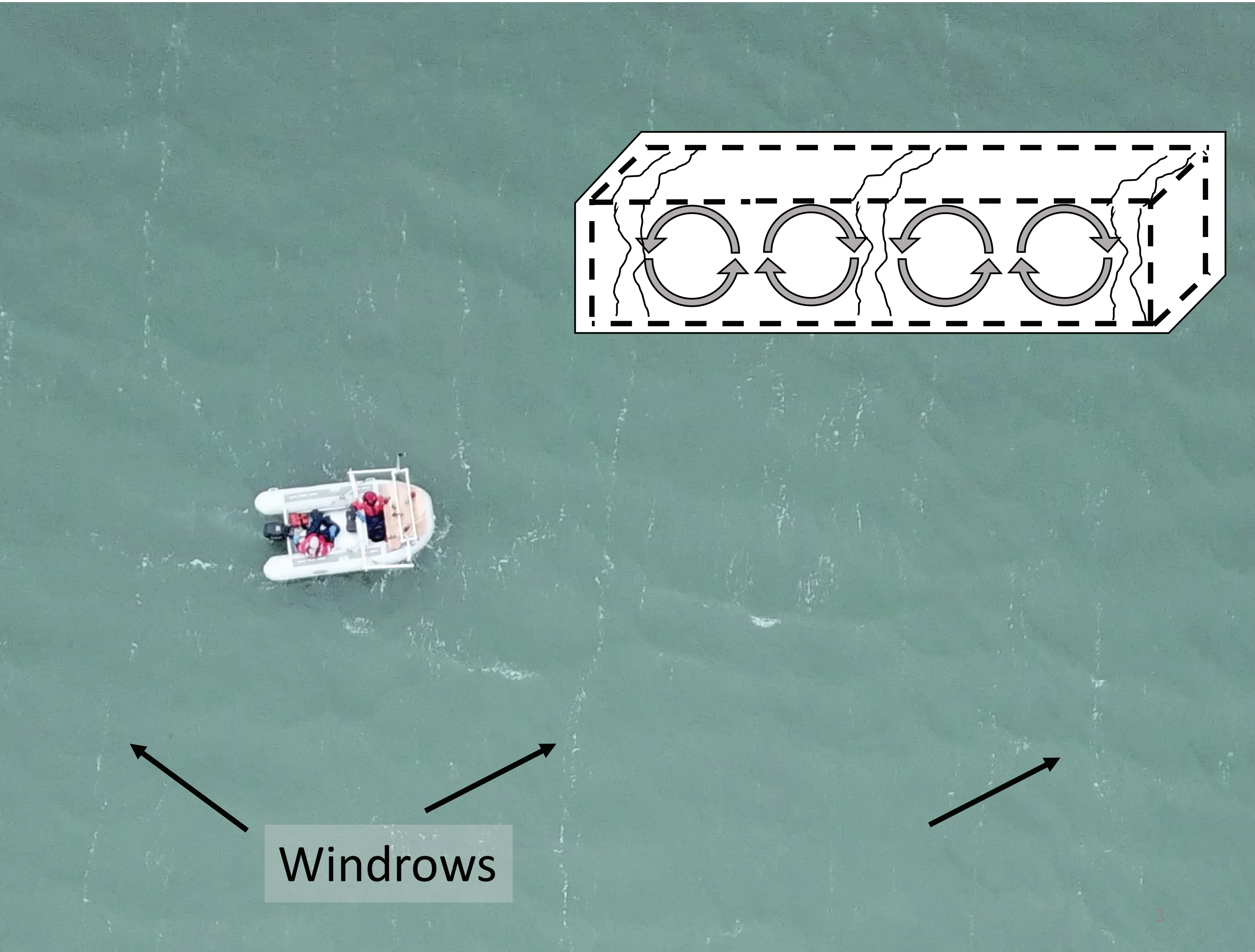
The Circulation, Geometry, and Turbulence of Windrows

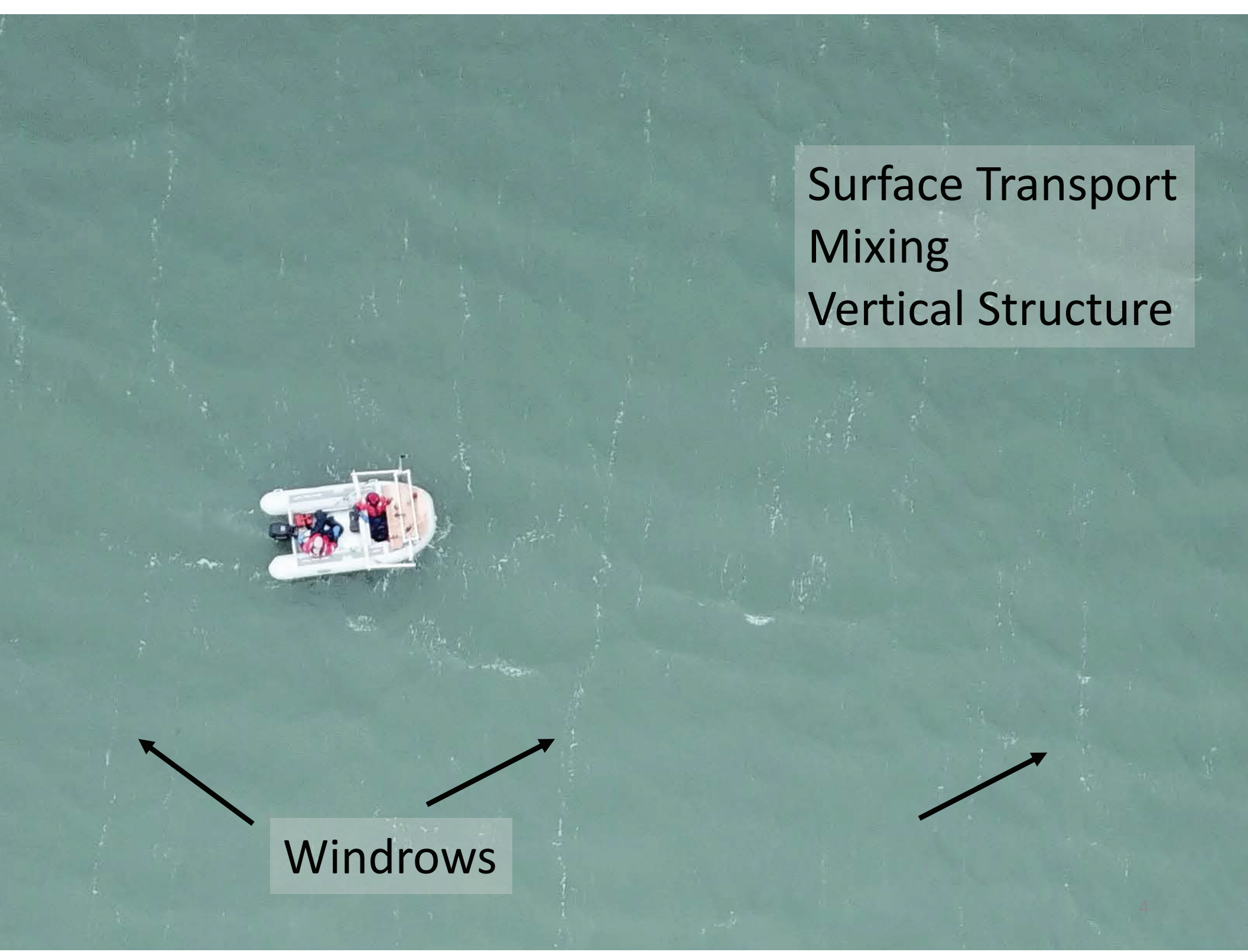
Measurements from the St. Lawrence Estuary

Seth Zippel

Malcolm Scully, Ted Maksym, Peter Sutherland, Dany Dumont

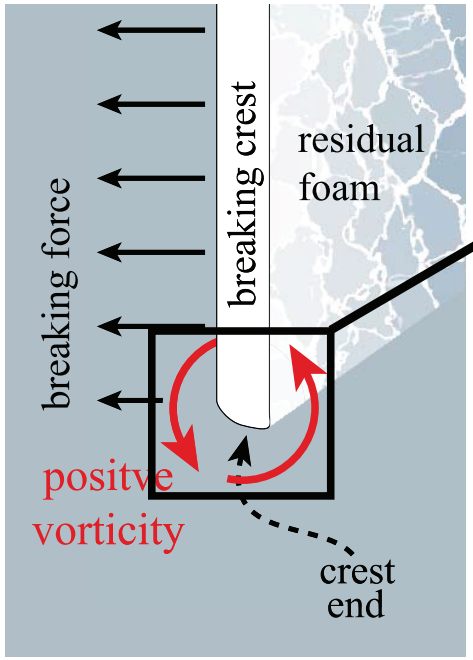

Windrows


Windrows


Surface Transport
Mixing
Vertical Structure
Windrows

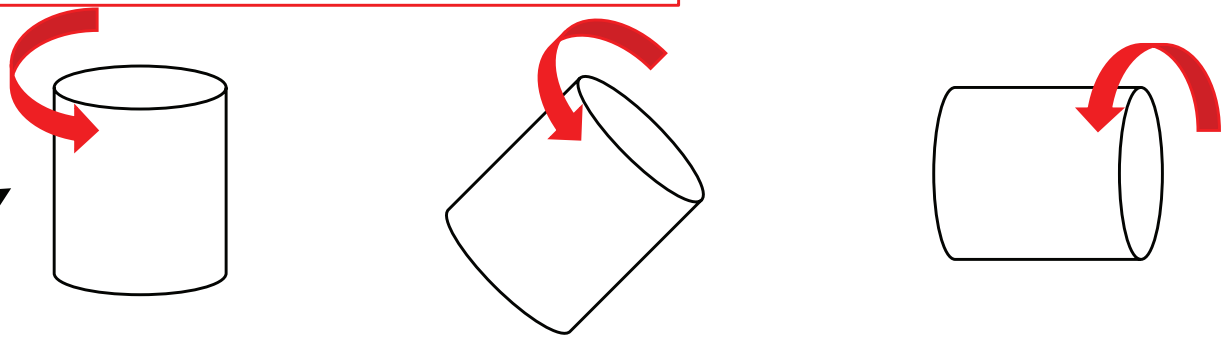
How are Windrows created?

Wave-Breaking Makes Vorticity



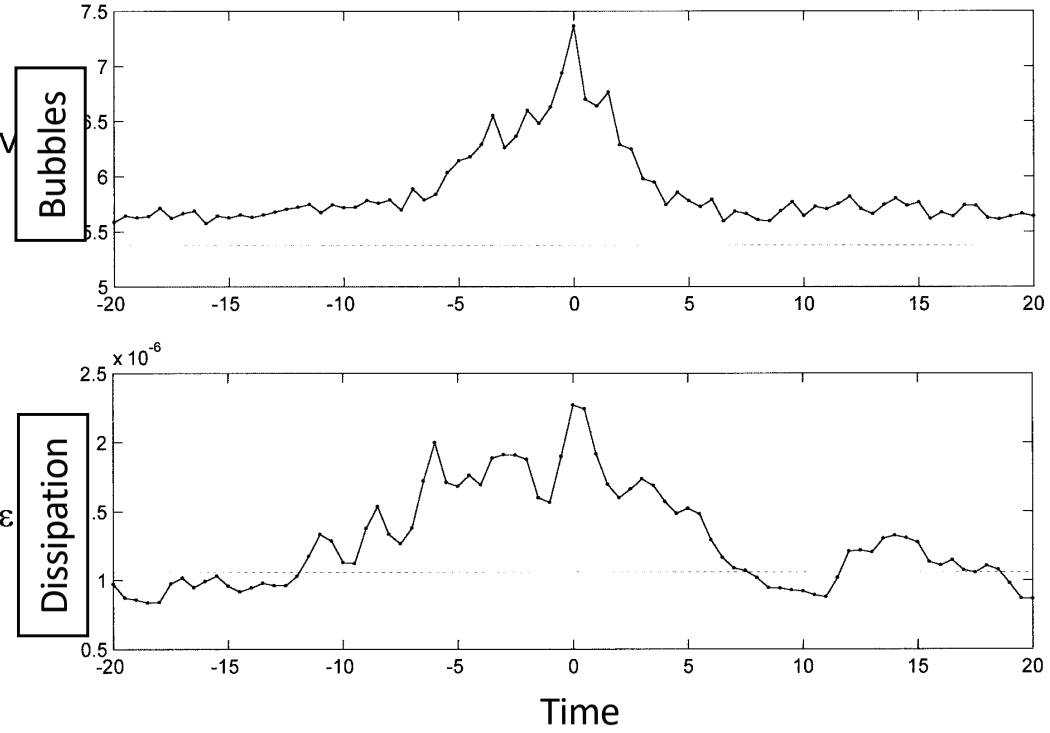
Clark et al. (2012) *Geo. Res. Lett.*

Vorticity is Rotated from Stokes Drift Shear



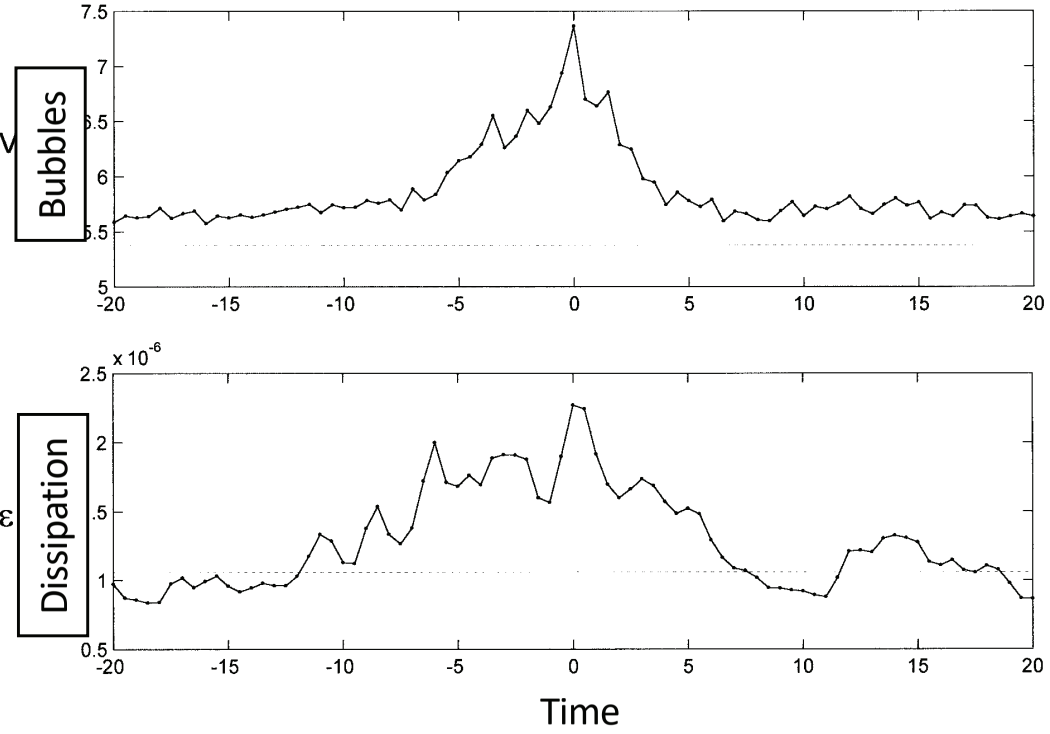
Background: Turbulence Enhancement

Thorpe et al. 2003: Dissipation enhancement

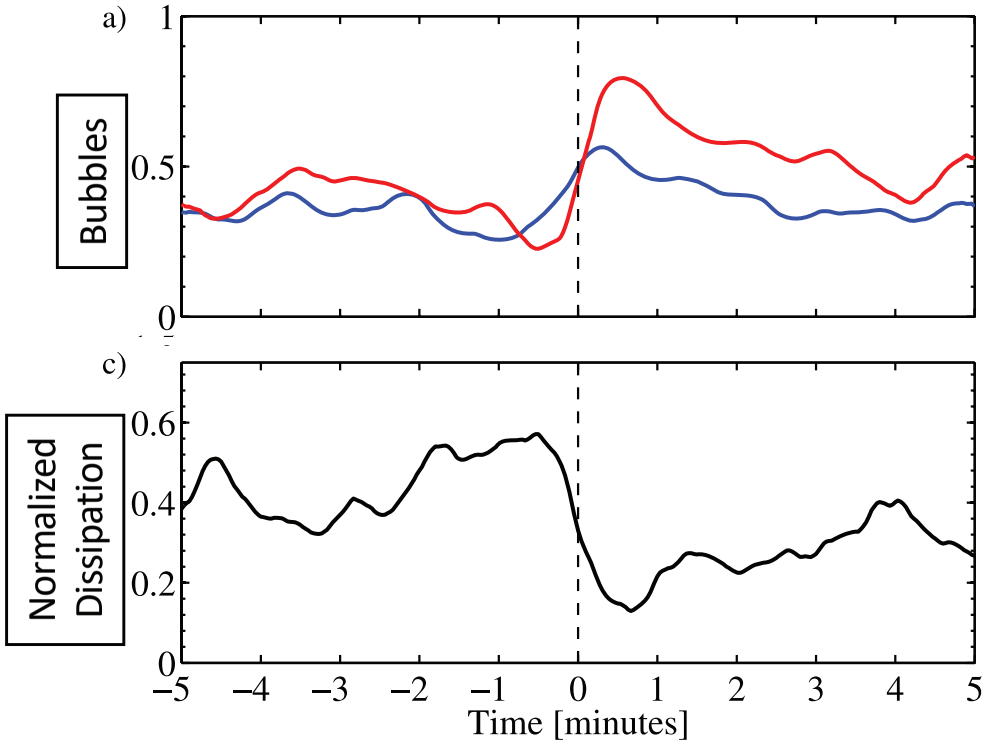


Background: Turbulence Enhancement

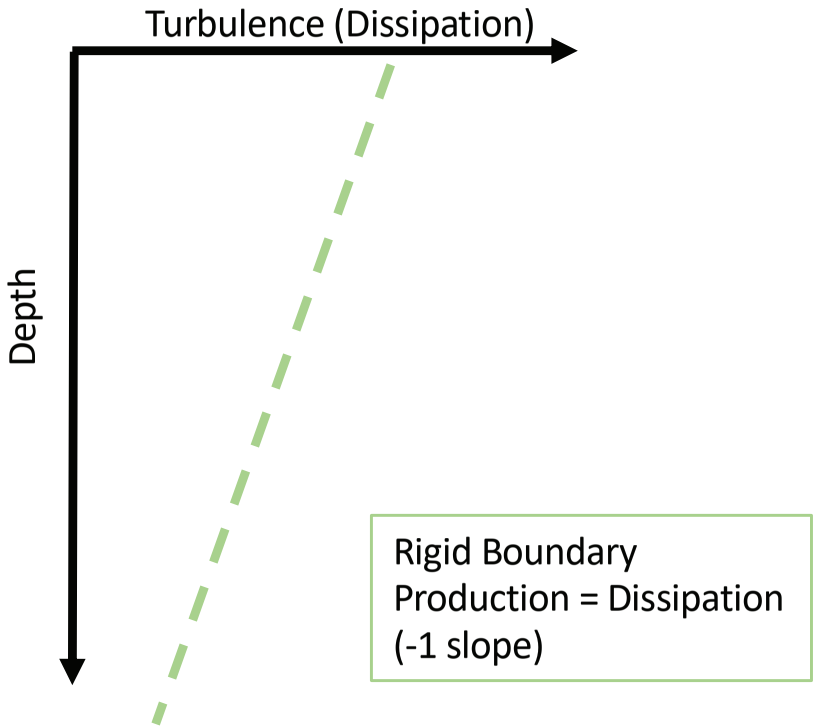
Thorpe et al. 2003: Dissipation enhancement

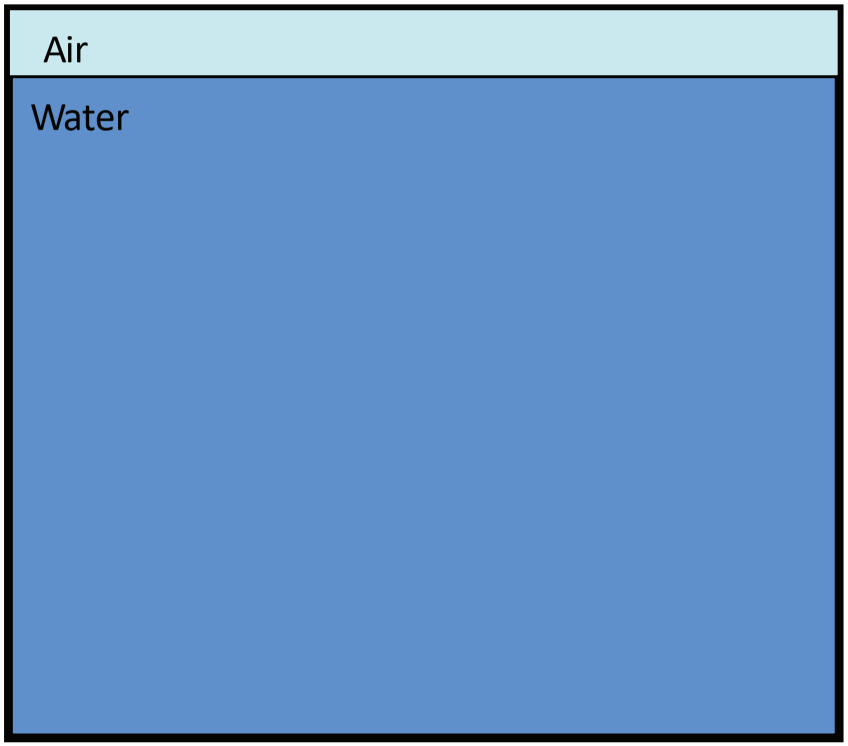


Gemmrich 2012: Dissipation suppression



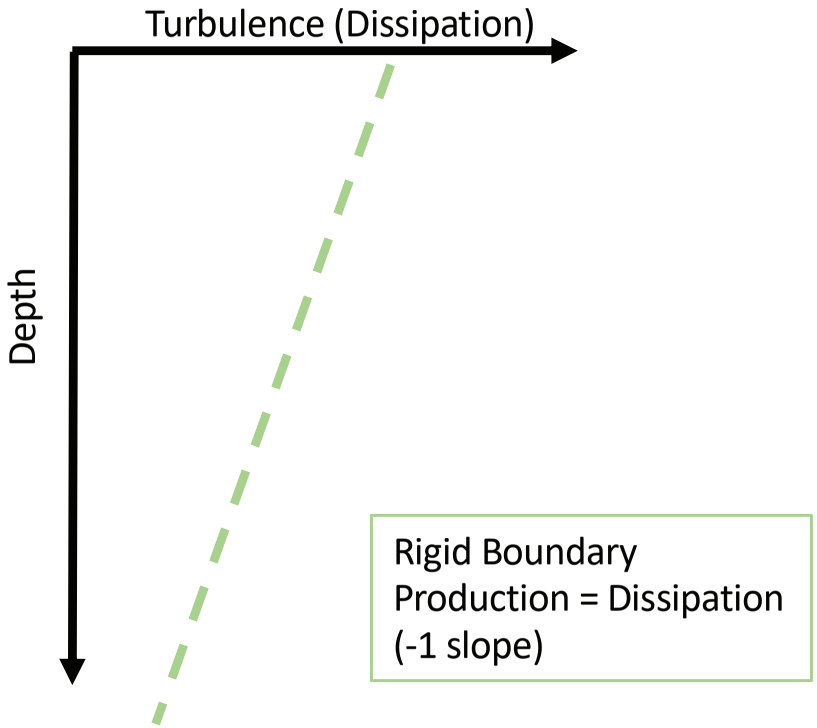
Enhanced from what? (Surface Turbulence Scales)

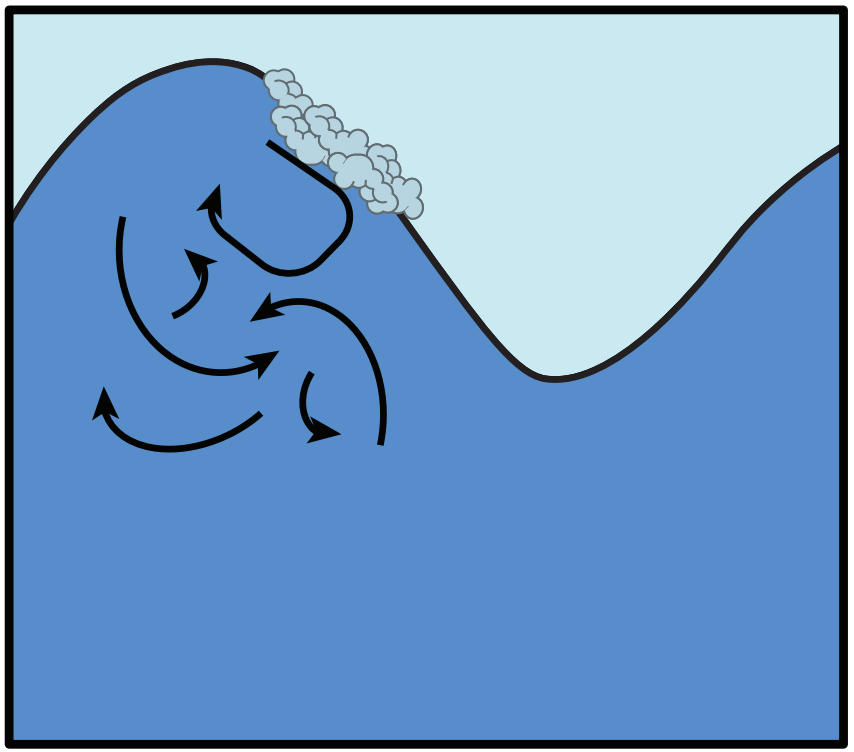




Adapted from Gerbi et al. (2009)

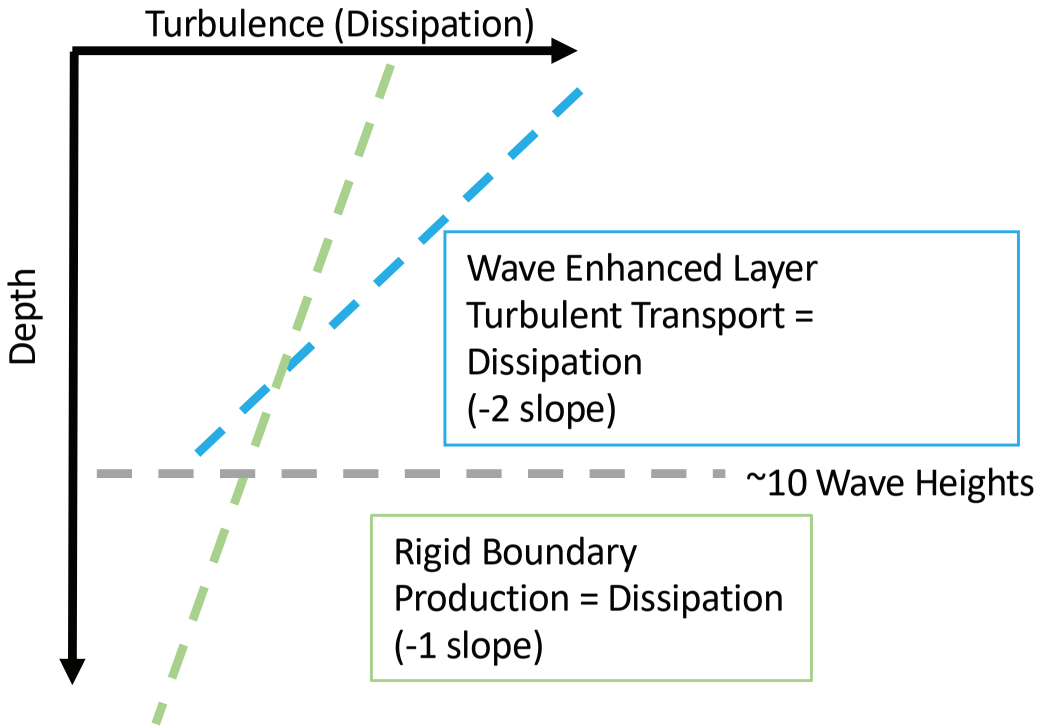
Enhanced from what? (Surface Turbulence Scales)

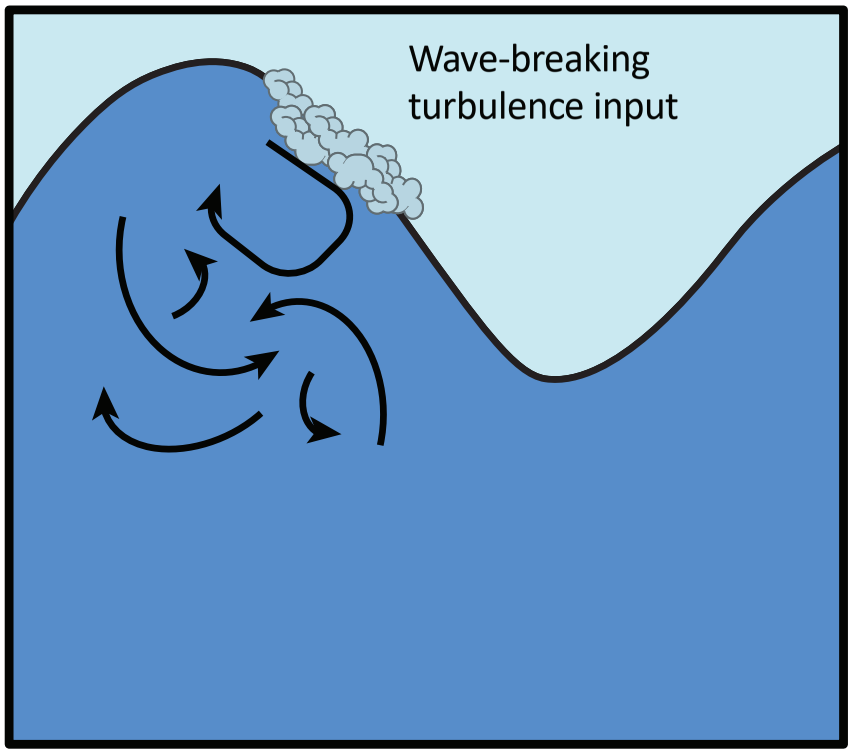




Adapted from Gerbi et al. (2009)

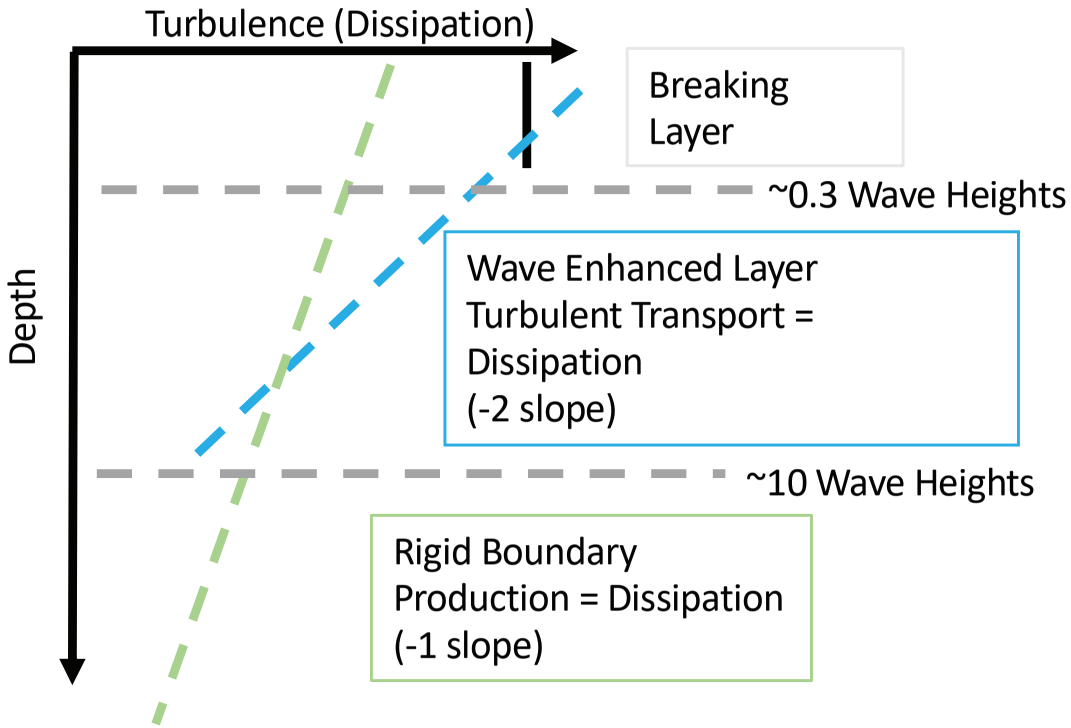
Enhanced from what? (Surface Turbulence Scales)

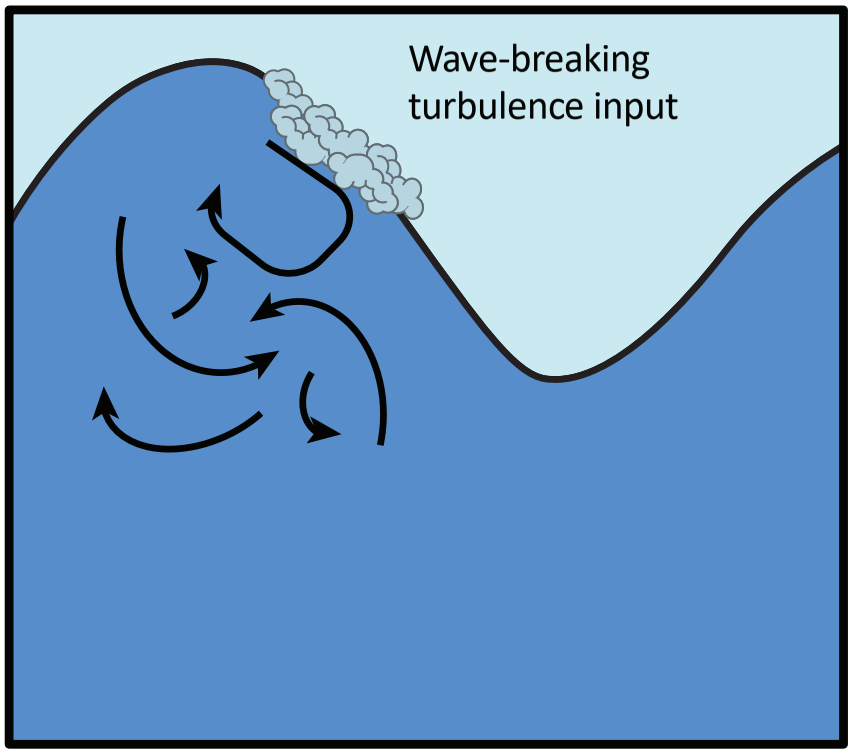




Adapted from Gerbi et al. (2009)

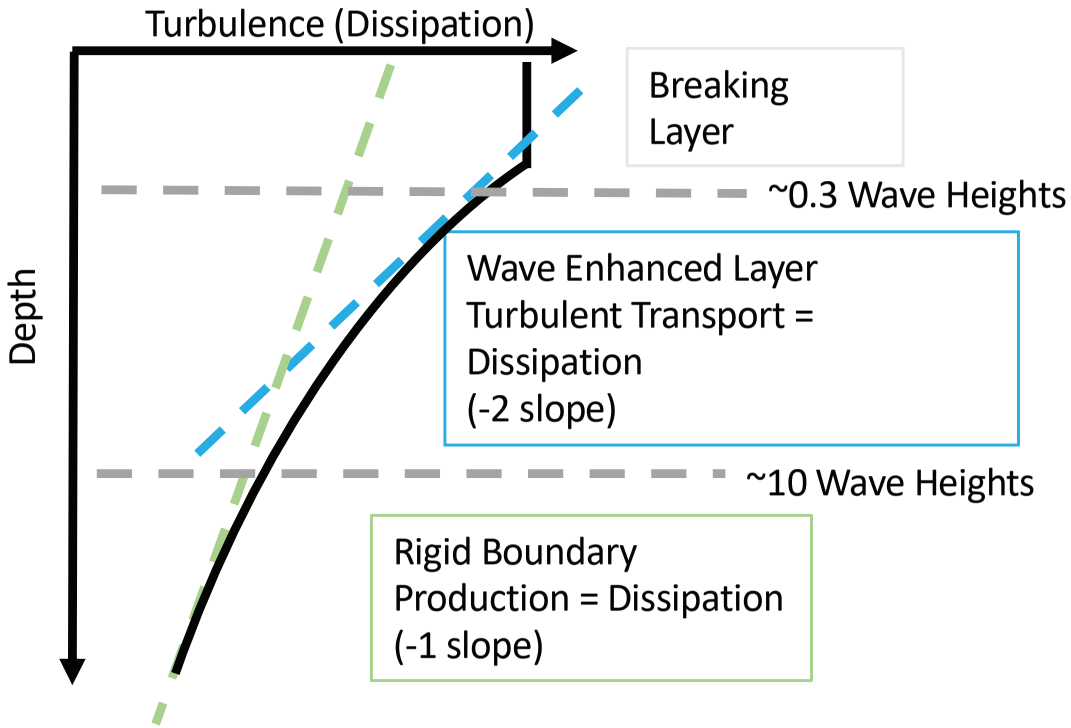
Enhanced from what? (Surface Turbulence Scales)

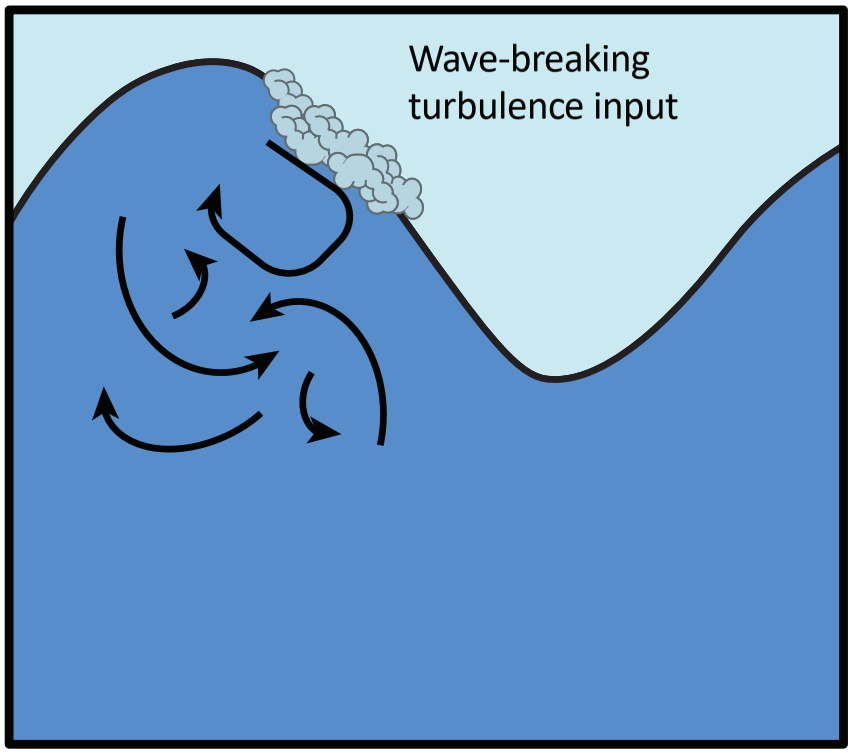




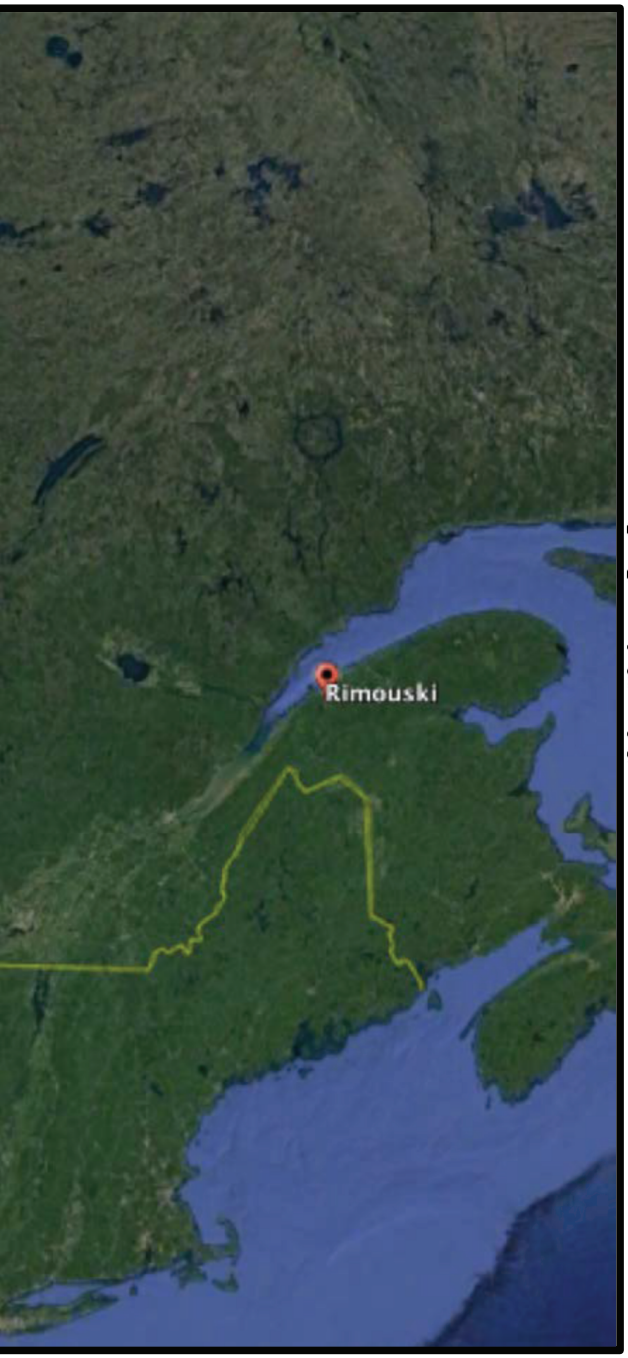
Adapted from Gerbi et al. (2009)

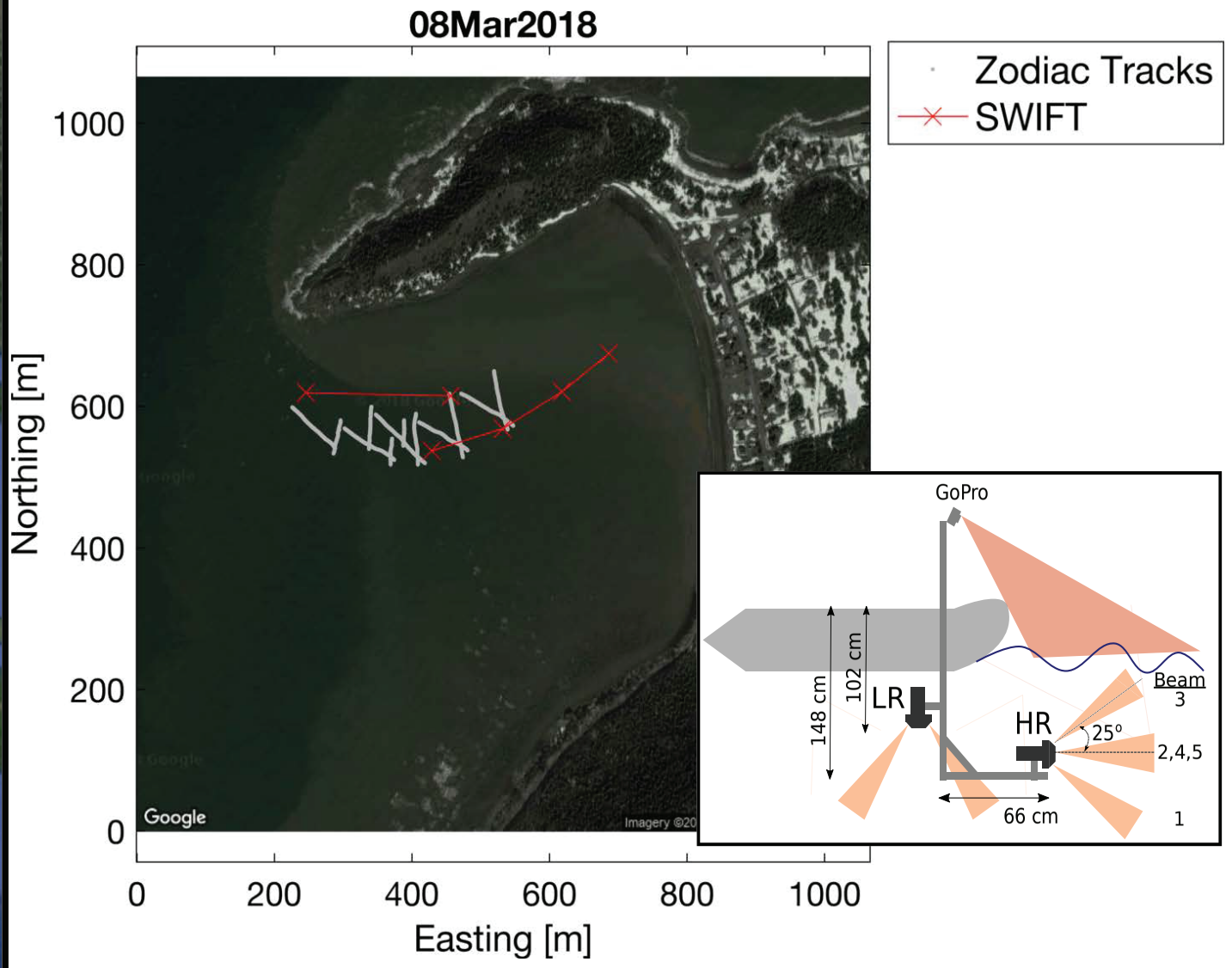
Enhanced from what? (Surface Turbulence Scales)

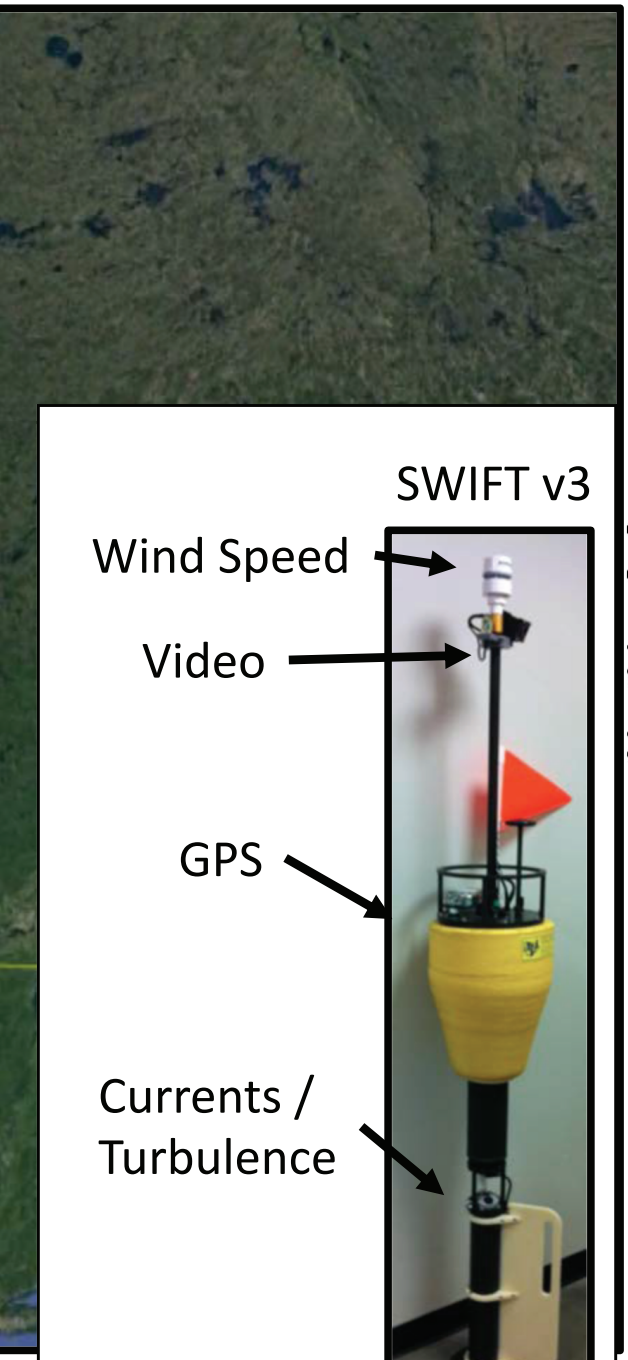




Adapted from Gerbi et al. (2009)


Rimouski


08Mar2018
Zodiac Tracks
SWIFT
Northing [m]
Easting [m]
0
200
400
600
800
1000
Google
GoPro
148 cm
102 cm
LR
HR
25°
Beam
3
2,4,5
1
66 cm



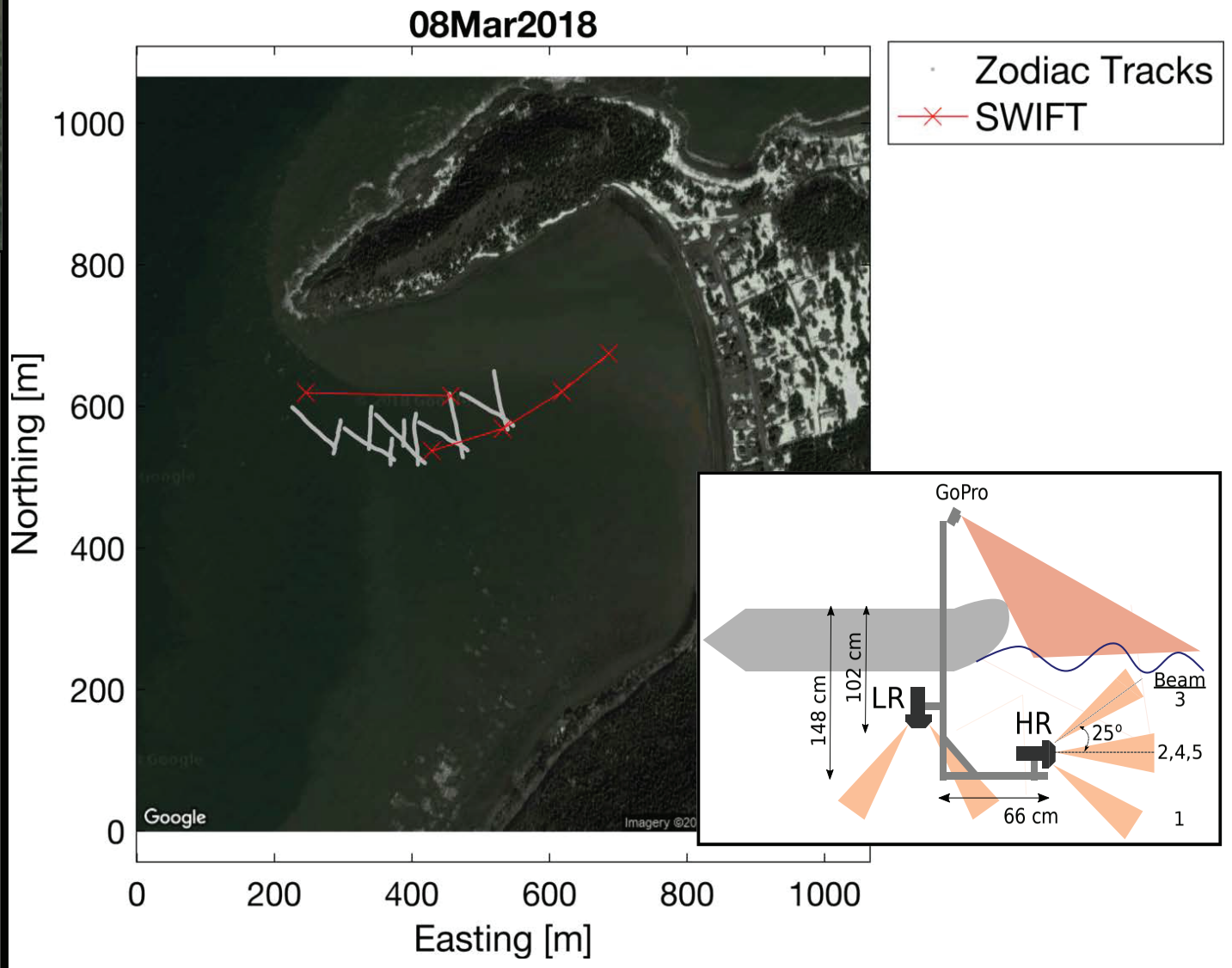
SWIFT v3

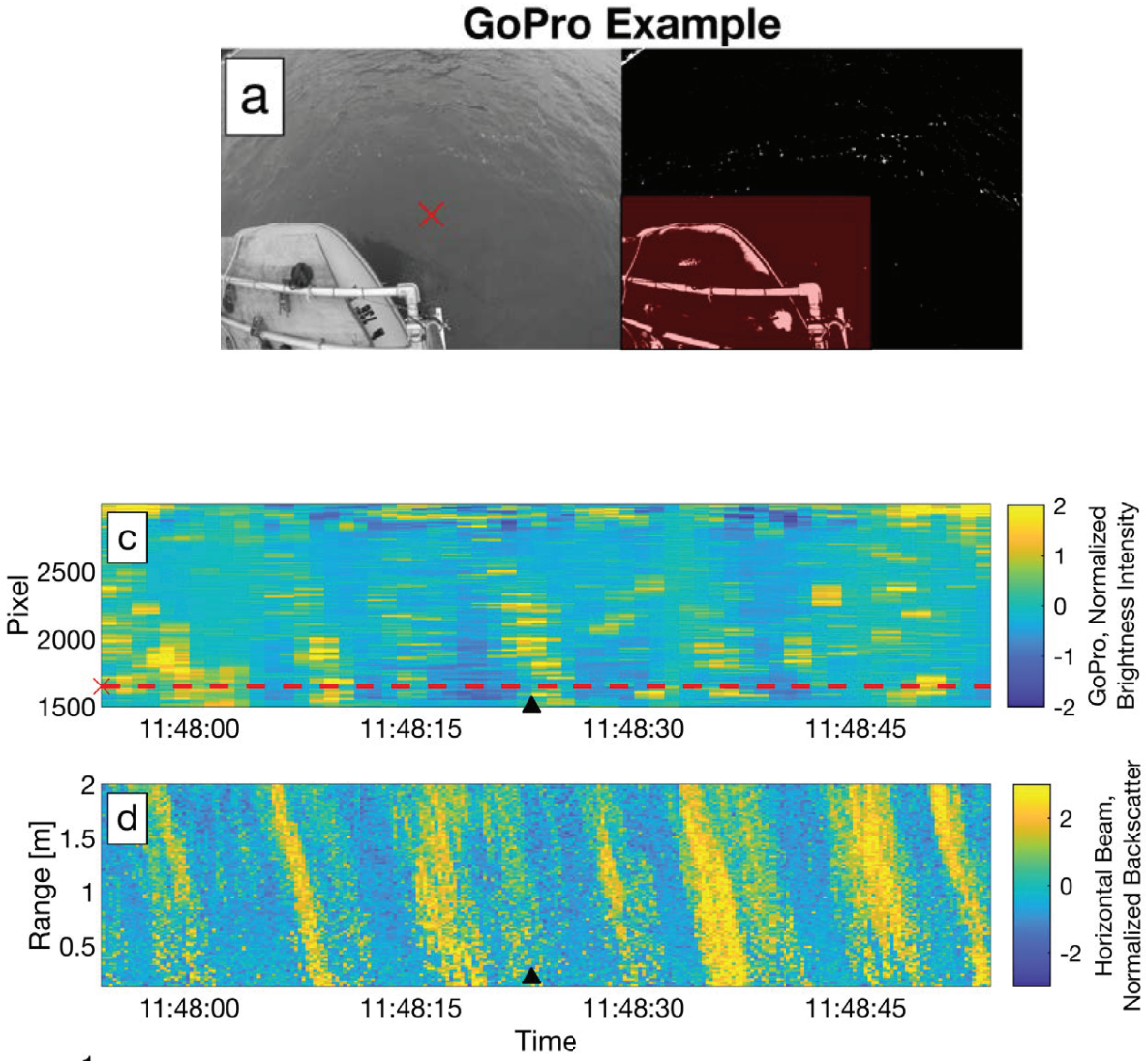
Wind Speed

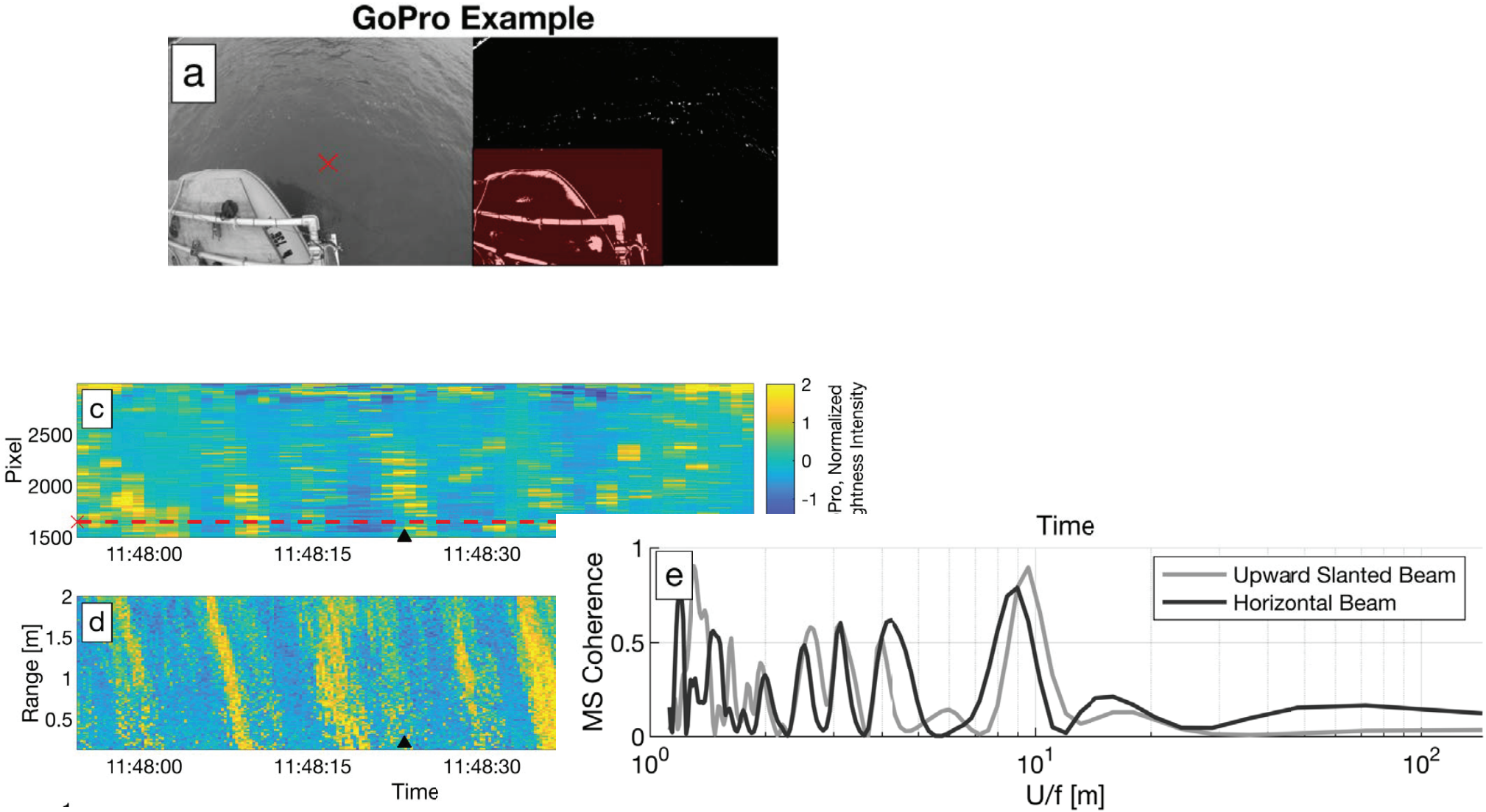
Video

GPS

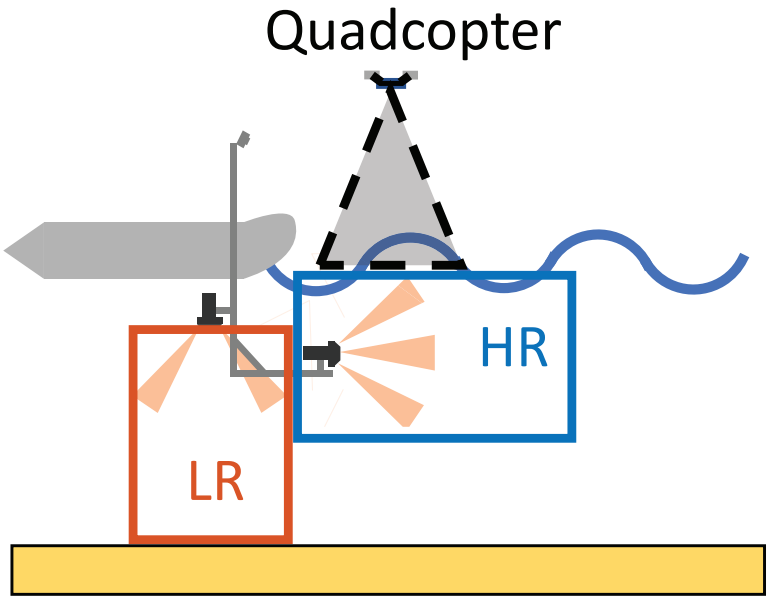
Currents / Turbulence



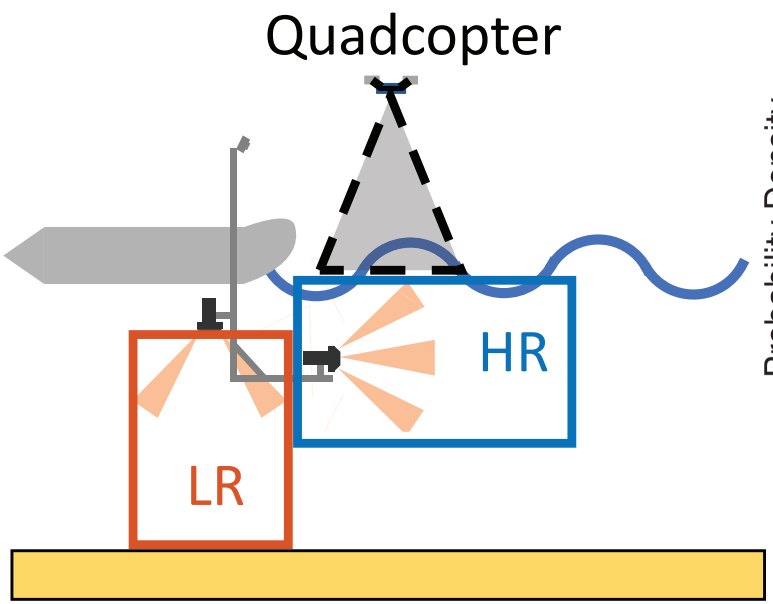

GoPro Example
a
c
Pixel
2500
2000
1500
11:48:00
11:48:15
11:48:30
11:48:45
2
1
0
-1
-2
GoPro, Normalized Brightness Intensity
d
Range [m]
2
1.5
1
0.5
11:48:00
11:48:15
11:48:30
11:48:45
Time
2
0
-2
Horizontal Beam, Normalized Backscatter

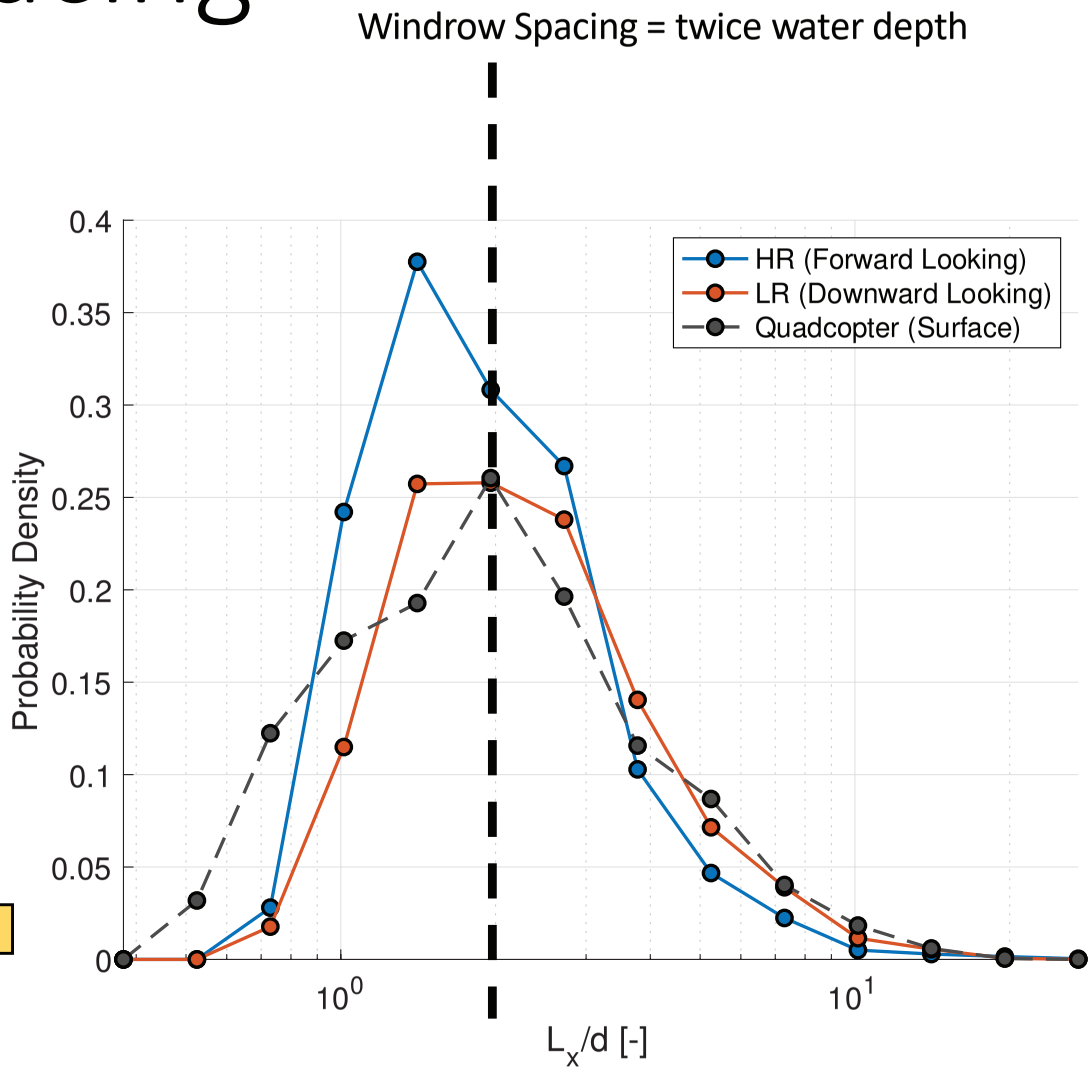

GoPro Example
a
c
Pixel
2500
2000
1500
11:48:00
11:48:15
11:48:30
2
1
0
-1
Pro, Normalized
ghtness Intensity
d
Range [m]
2
1.5
1
0.5
11:48:00
11:48:15
11:48:30
Time
Time
e
MS Coherence
1
0.5
0
10^0
10^1
10^2
U/f [m]
Upward Slanted Beam
Horizontal Beam

Windrow Spacing

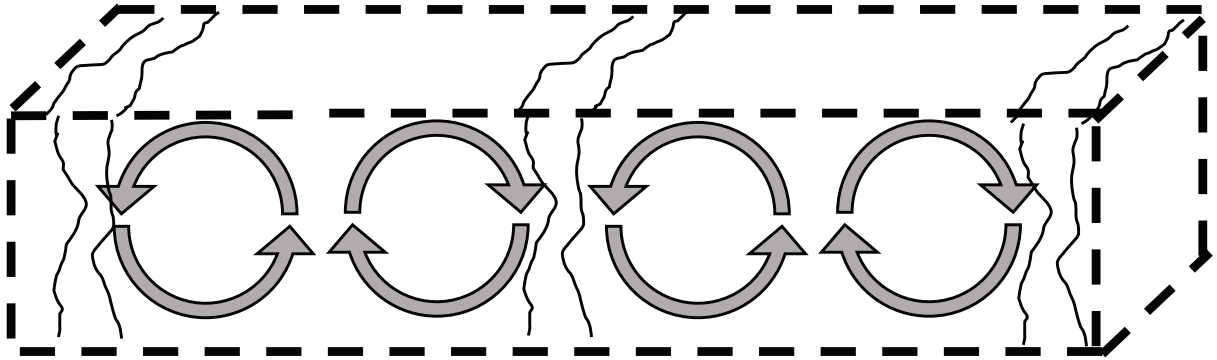


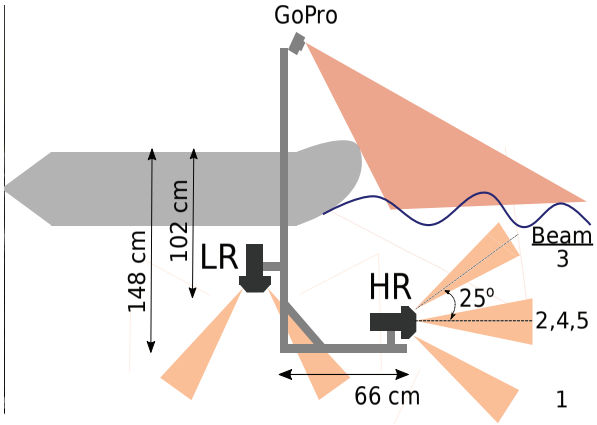
Windrow Spacing



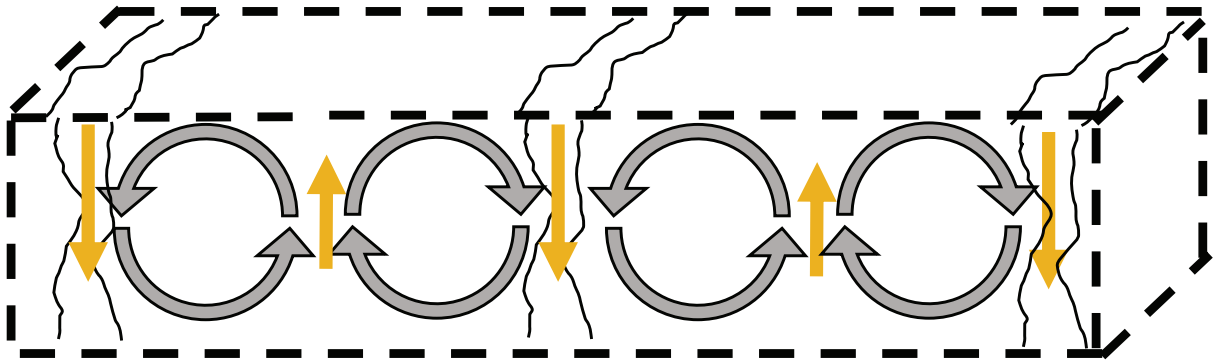


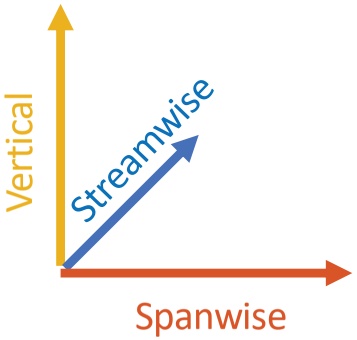
Circulation

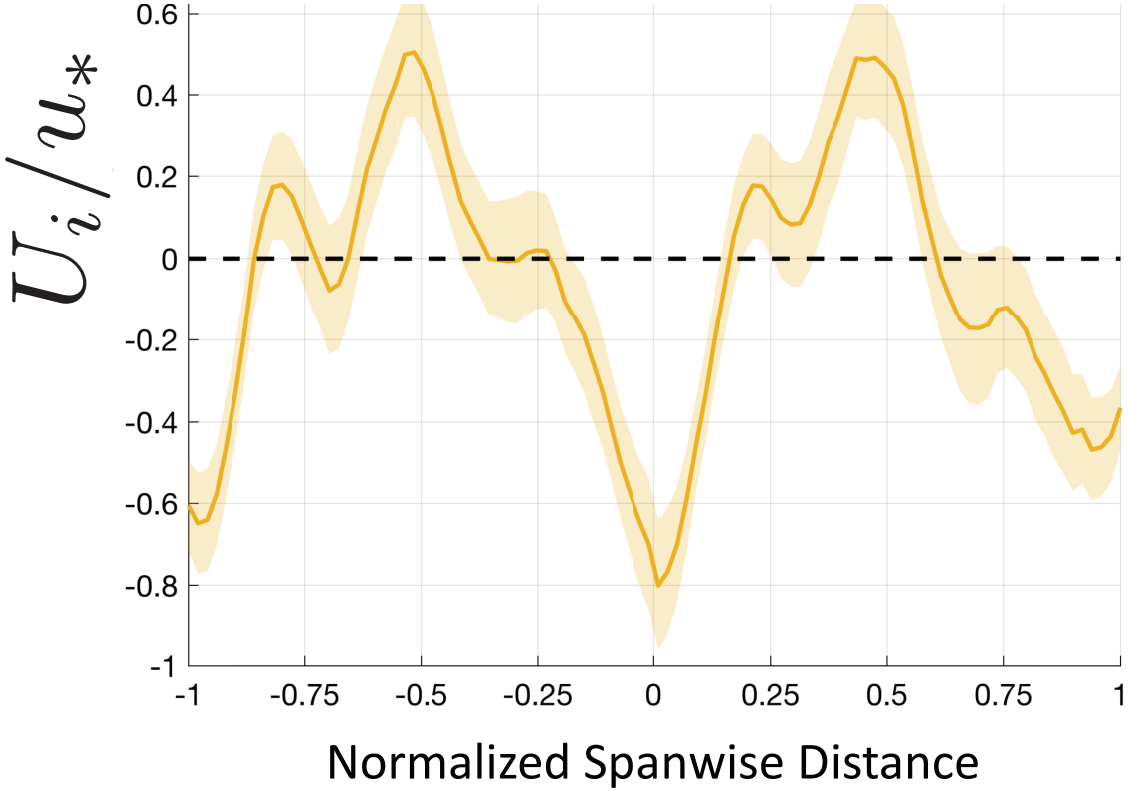




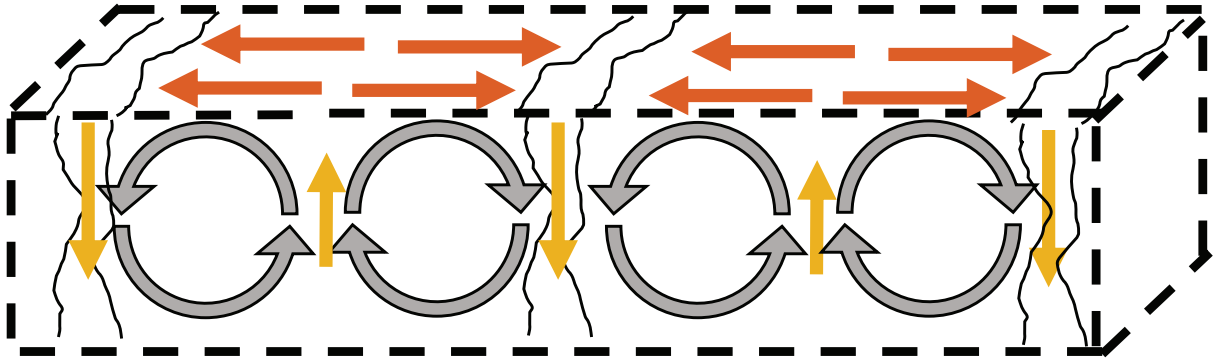
Circulation

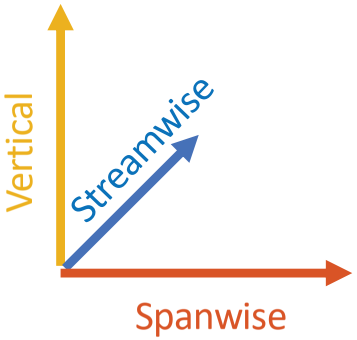


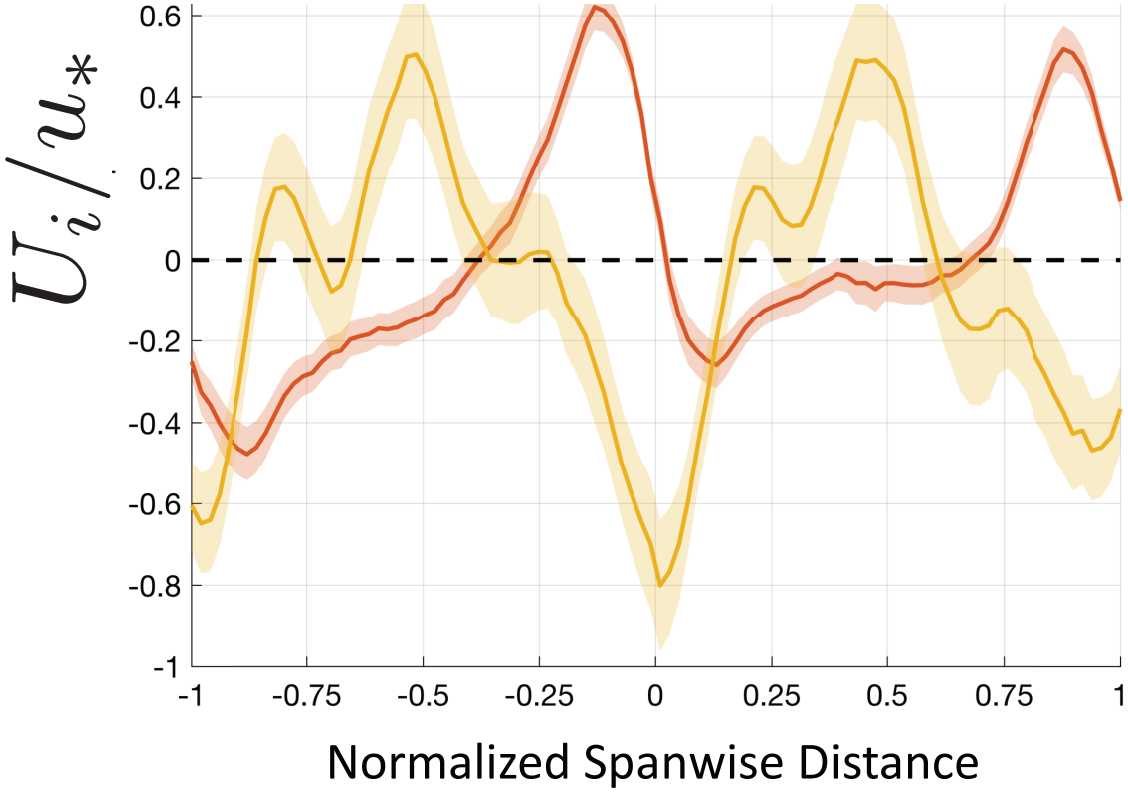




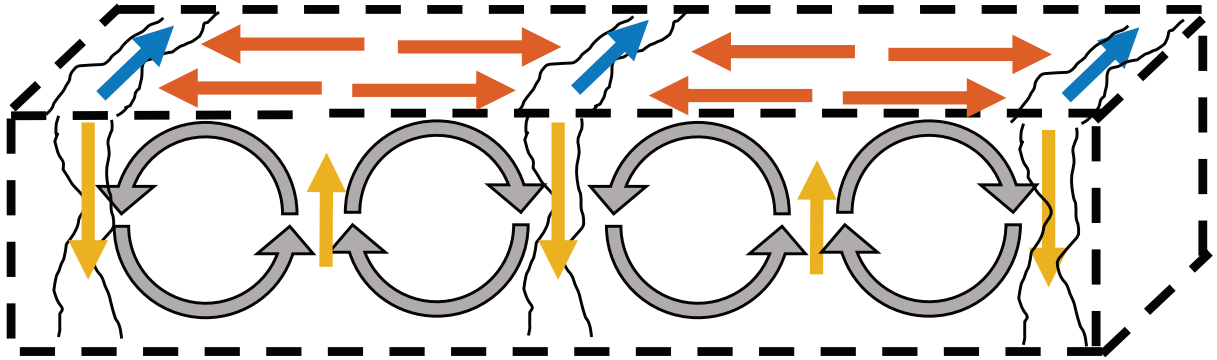
Circulation

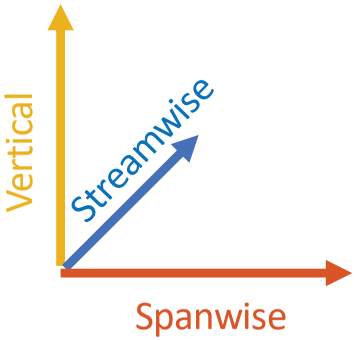


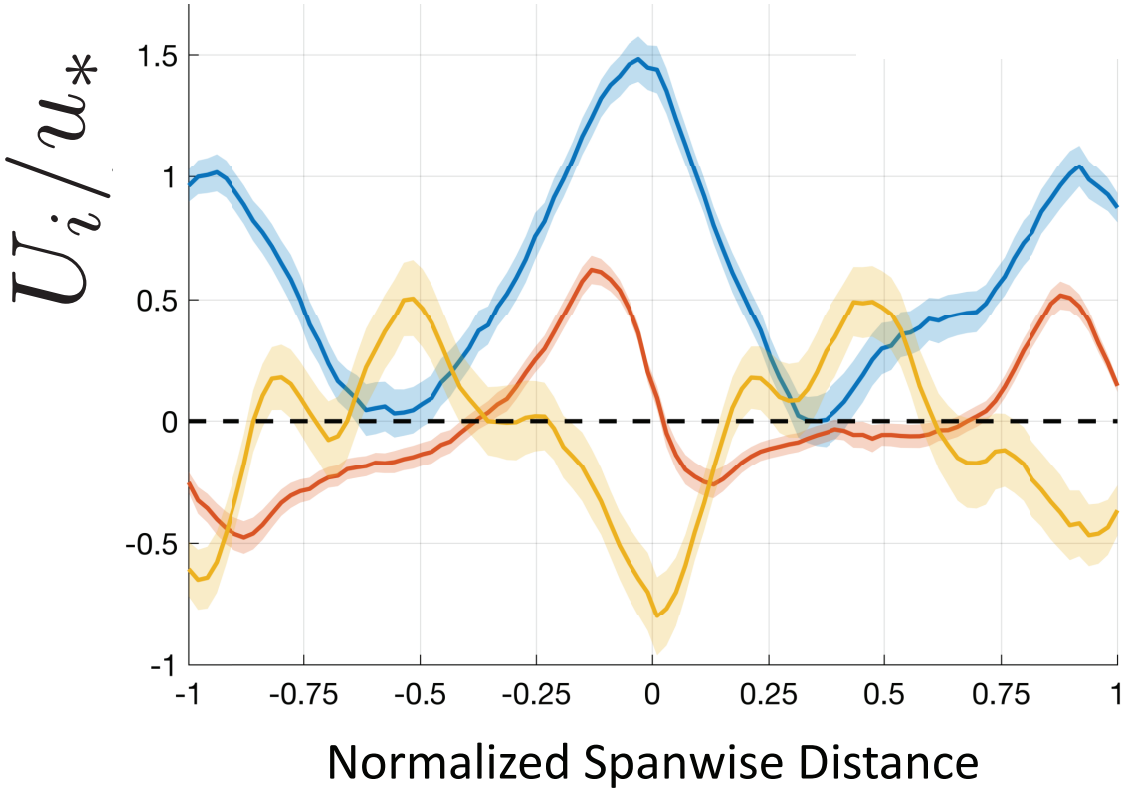




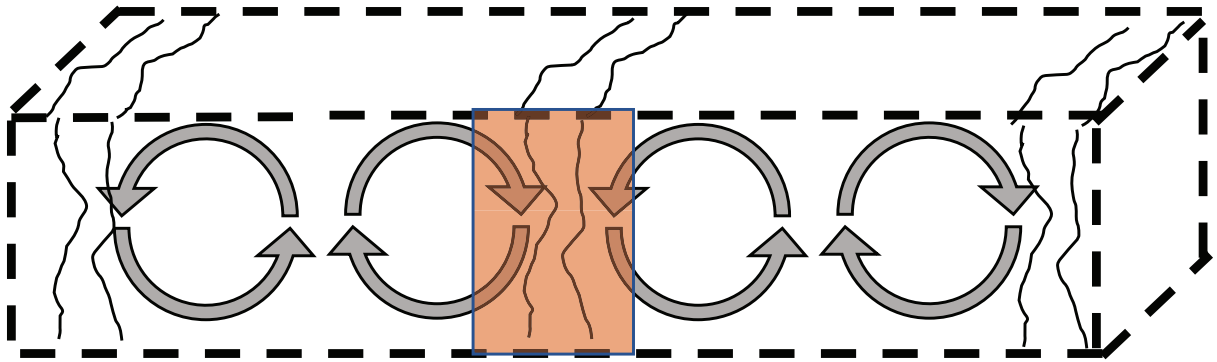
Circulation

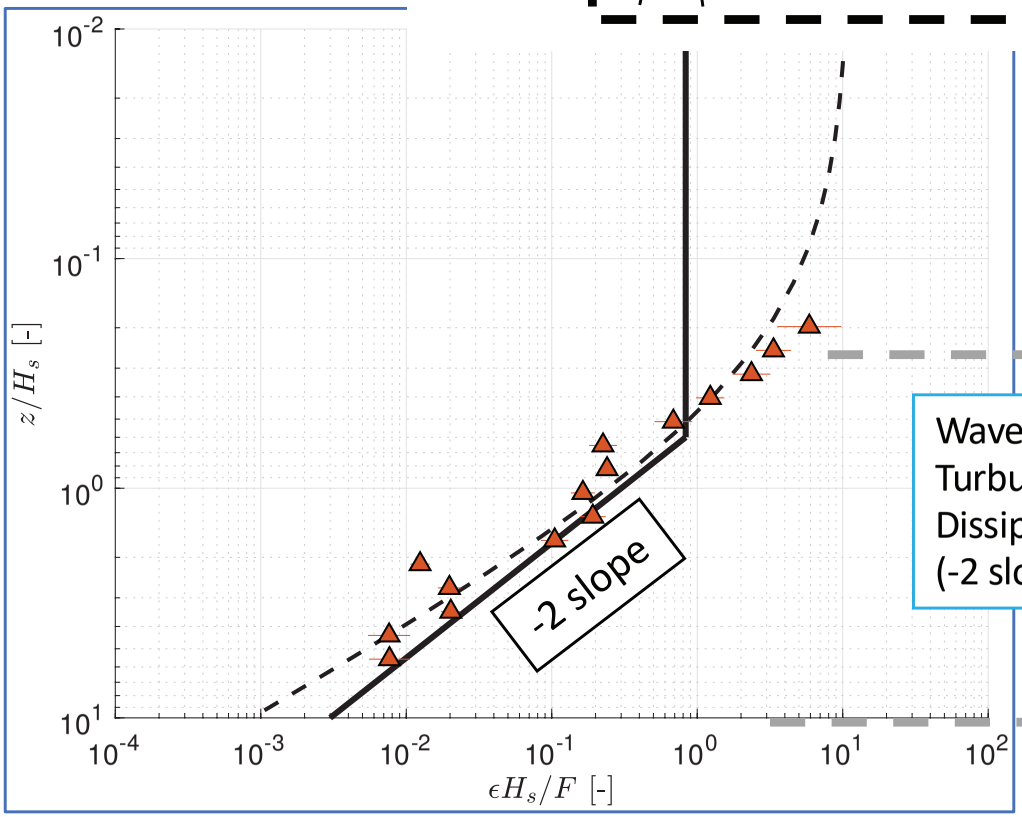






Turbulence





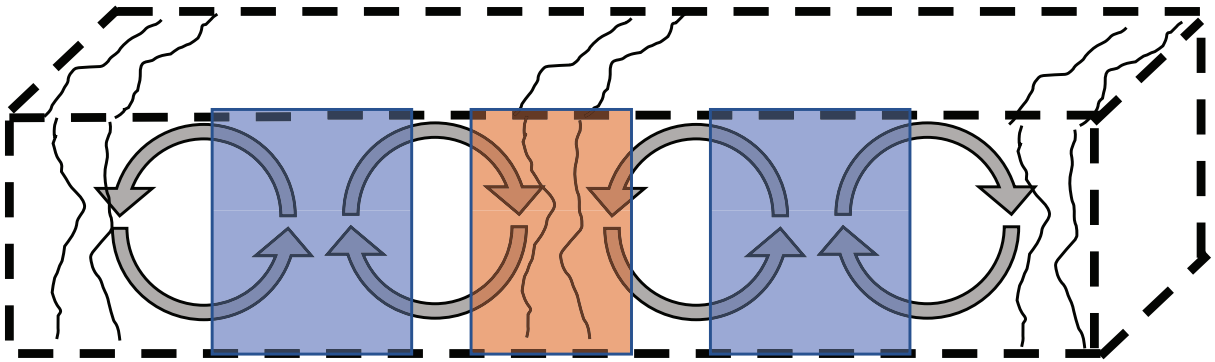
Breaking Layer

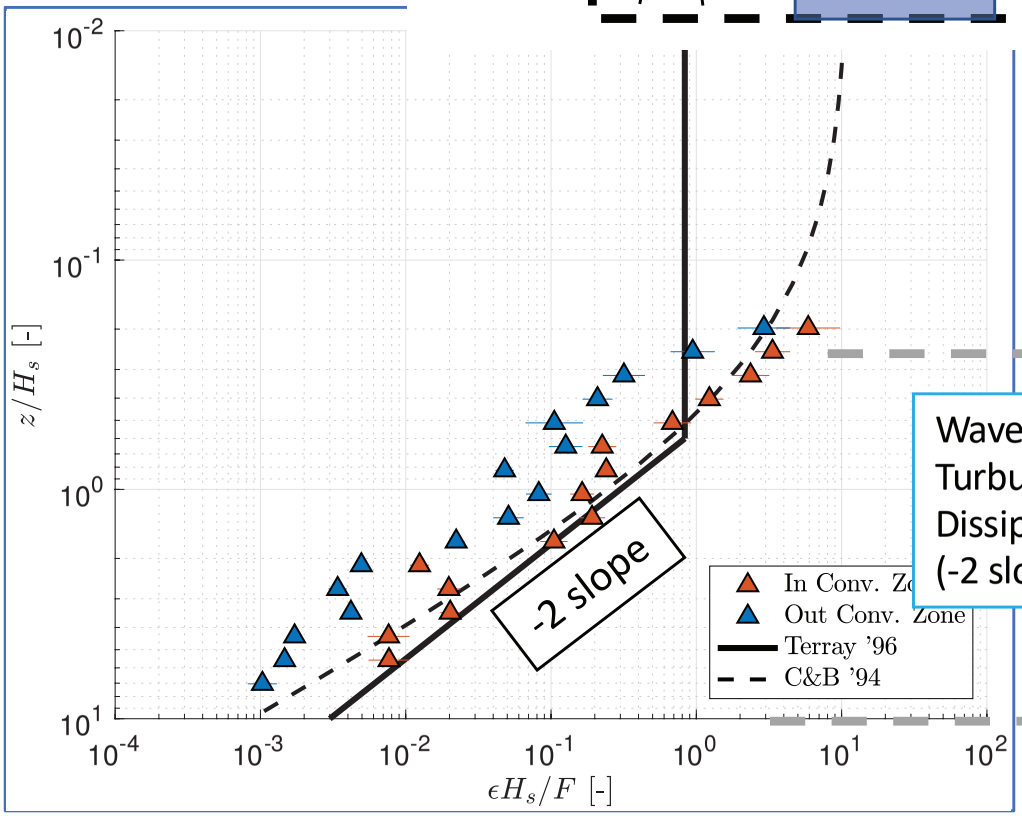
~0.3 Wave Heights

Wave Enhanced Layer
Turbulent Transport = Dissipation
(-2 slope)

~10 Wave Heights

Turbulence





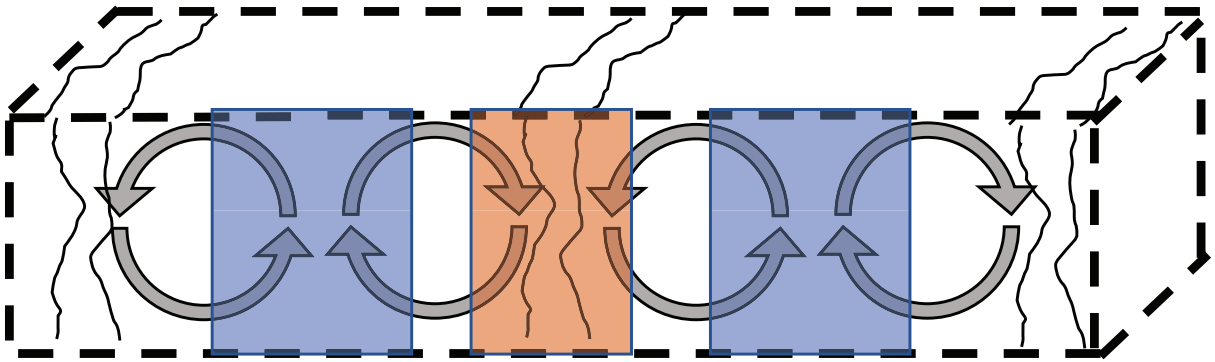
Breaking Layer

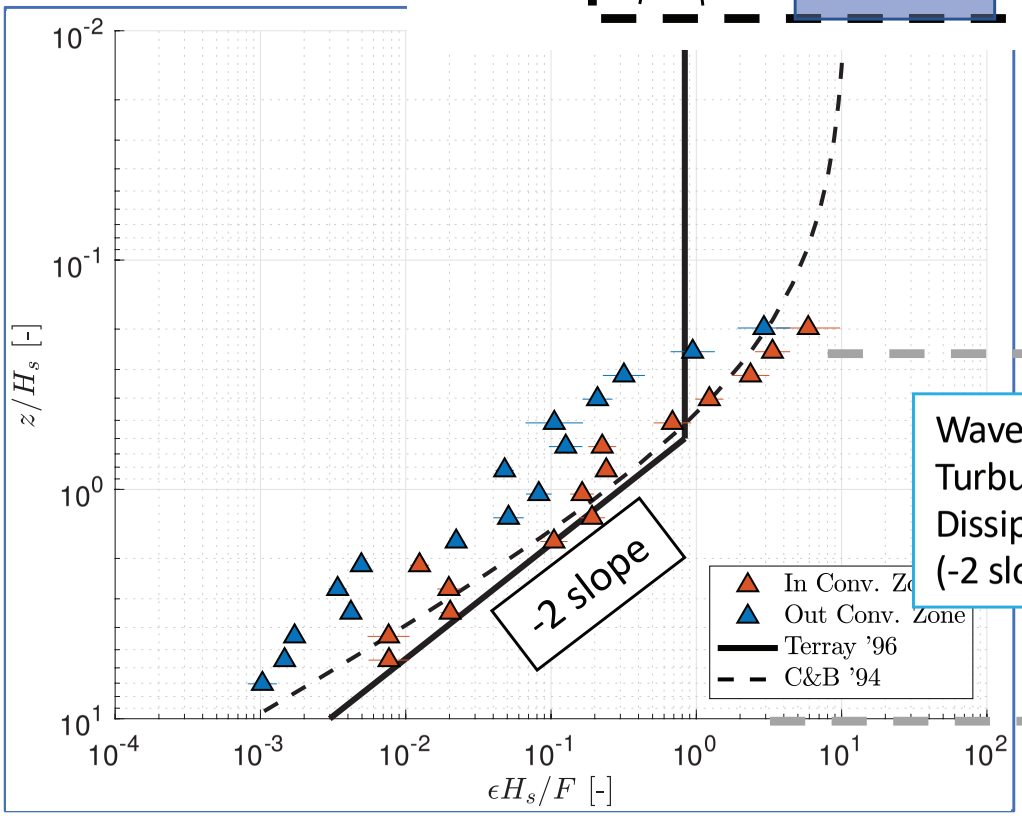
~0.3 Wave Heights

Wave Enhanced Layer
Turbulent Transport = Dissipation
(-2 slope)

~10 Wave Heights

Turbulence





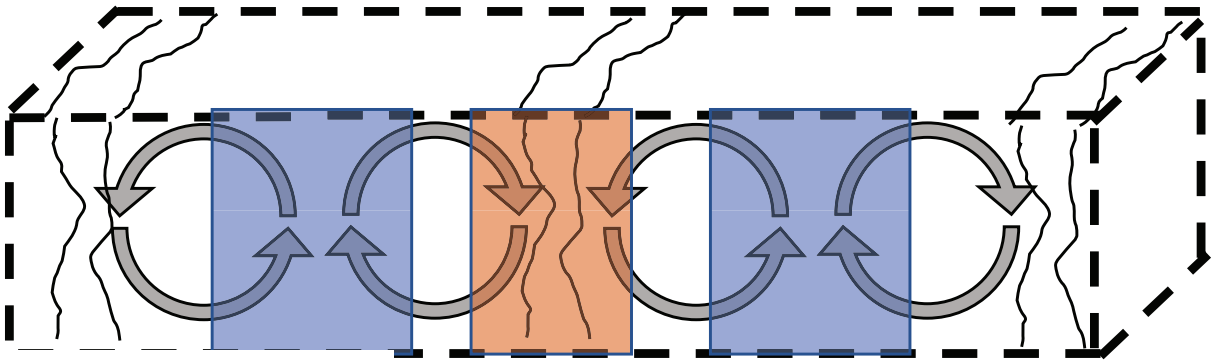
Breaking Layer

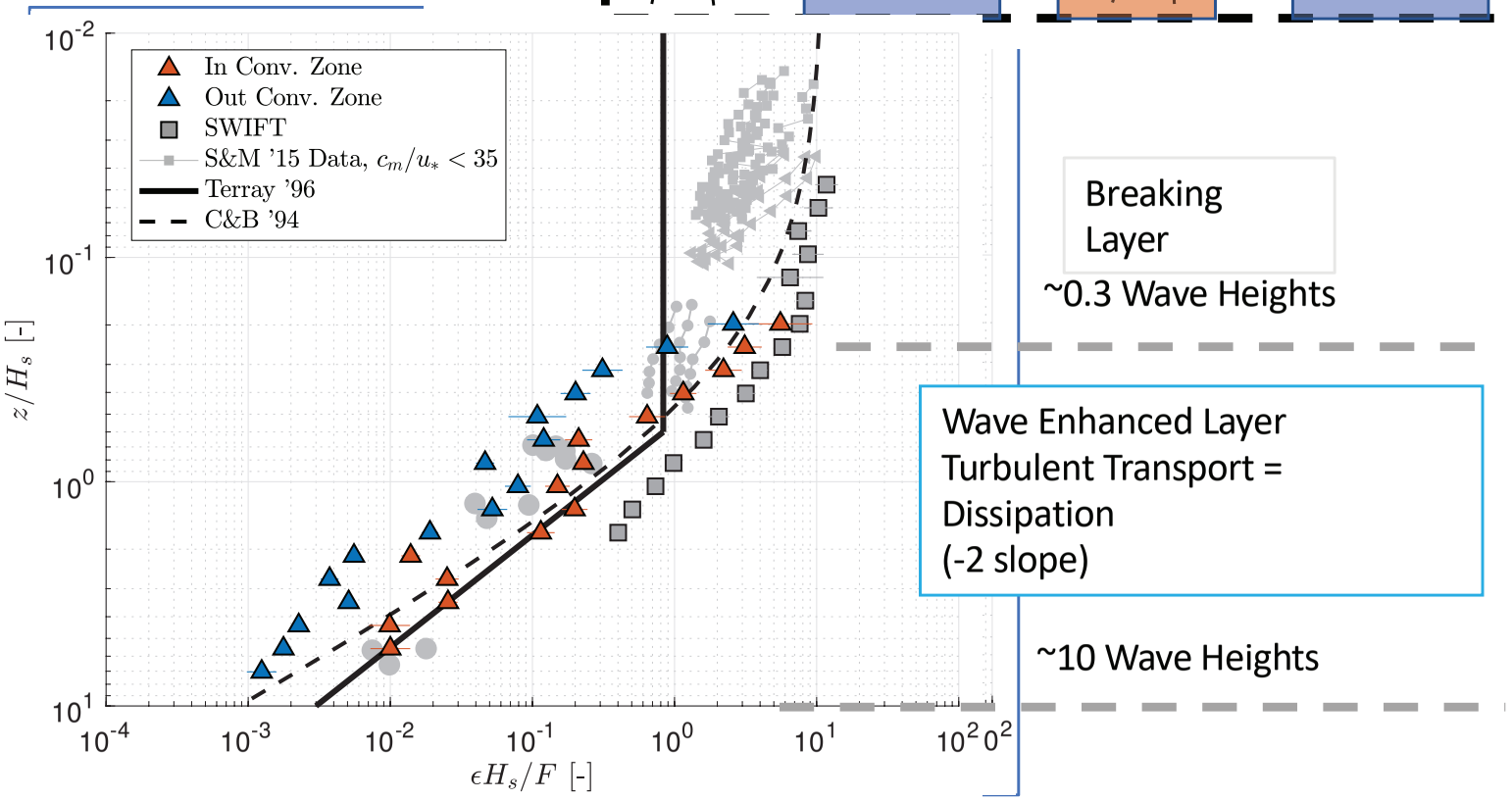
~0.3 Wave Heights

Wave Enhanced Layer
Turbulent Transport = Dissipation
(-2 slope)

~10 Wave Heights

Turbulence





Breaking Layer

~0.3 Wave Heights

Wave Enhanced Layer
Turbulent Transport = Dissipation
(-2 slope)

~10 Wave Heights

Summary

- Windrow velocities are on the order of u_* and are consistent with counter-rotating wind aligned vortex pairs
- TKE dissipation rates are larger in convergence zones, and the vertical structure is consistent with wave breaking scaling

Thoughts

- Buoyant drifters don’t always measure the mean
- Secondary wave/turbulent effects (?)
- Measurement Challenges:

Thoughts

- Buoyant drifters don't always measure the mean
- Secondary wave/turbulent effects (?)
- Measurement Challenges:

$$\frac{DTKE}{Dt} = P + B + \nabla \cdot T - \epsilon \quad + P_{stokes}$$

Shear Production | Buoyancy | Transport Divergence | Dissipation | Stokes Production

Thoughts

- Buoyant drifters don't always measure the mean
- Secondary wave/turbulent effects (?)
- Measurement Challenges:

$$\frac{DTKE}{Dt} = P + B + \nabla \cdot T - \epsilon + P_{stokes}$$

Shear Production · Buoyancy · Transport Divergence · Dissipation · Stokes Production