Applying Continuity to Remotely Sensed Nearshore Currents

2.29 Numerical Fluid Mechanics

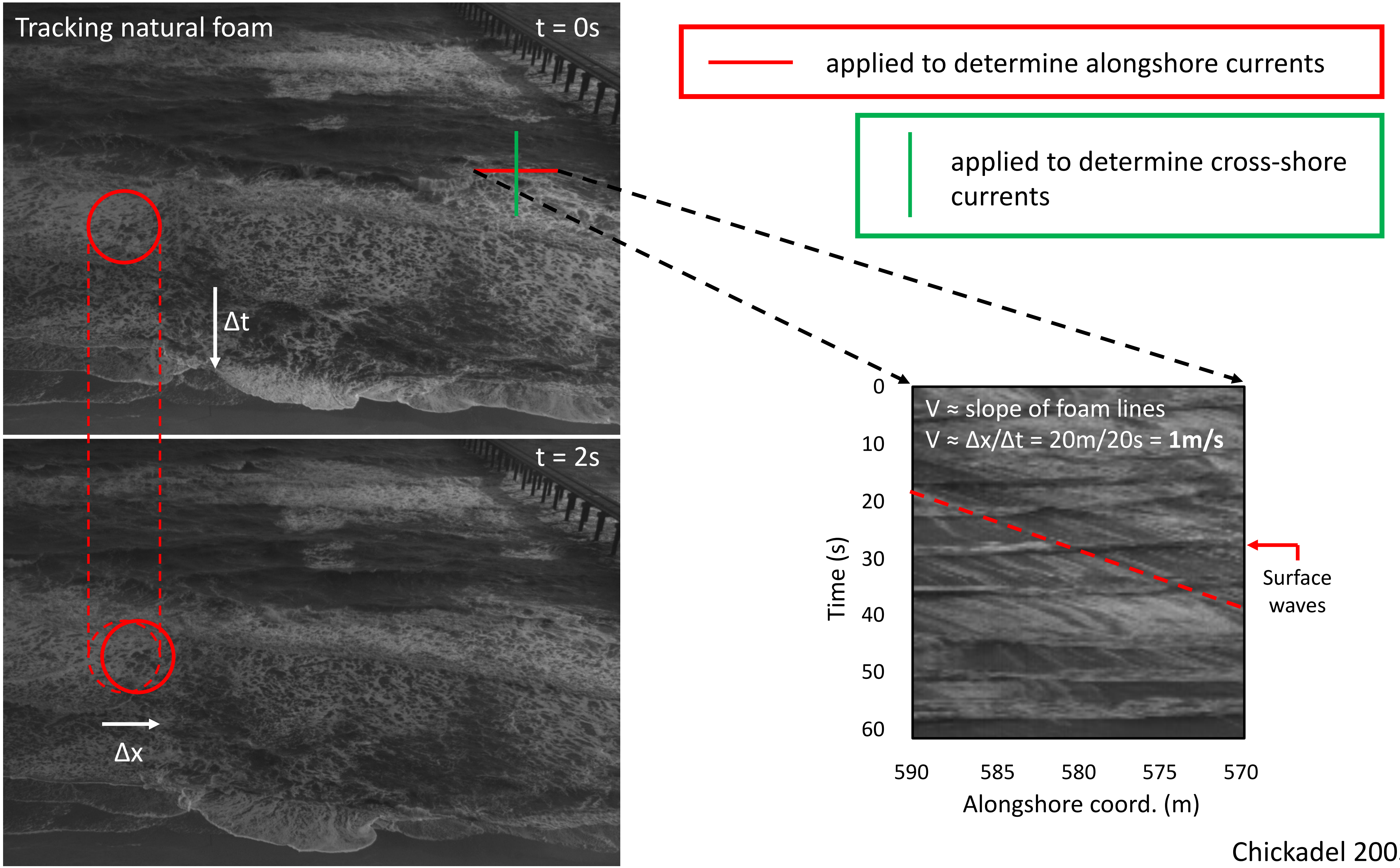
Ciara Dooley

May 20th, 2021

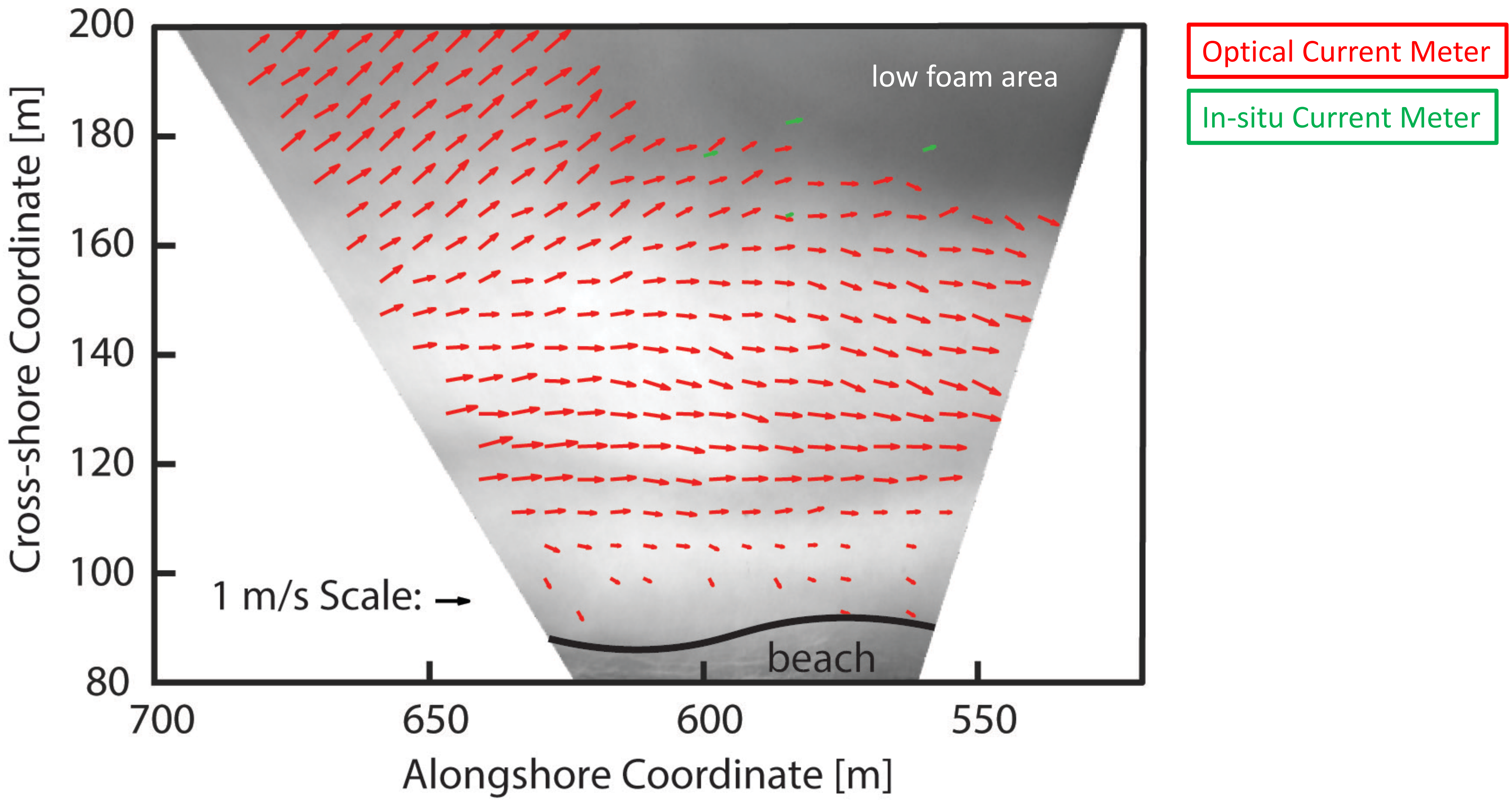
Why nearshore flows?

- Bacteria, pollutants, larvae, and sediment are transported through nearshore processes in the surfzone
- These processes impact beach safety, erosion, and marine wildlife
- 40% of US residents live in coastal counties

Boehm 2003, Cowen et al. 2006, Grant et al. 2005, Halpern et al. 2008



Chickadel 2003



Optical Current Meter
In-situ Current Meter
low foam area
1 m/s Scale:
beach
Cross-shore Coordinate [m]
200
180
160
140
120
100
80
700
650
600
550
Alongshore Coordinate [m]

Velocity estimates remain difficult to validate

- In-situ instrumentation does not measure surface currents, particularly in the cross-shore
  - Not always representative due to vertical velocity gradients in the surfzone (e.g., undertow)

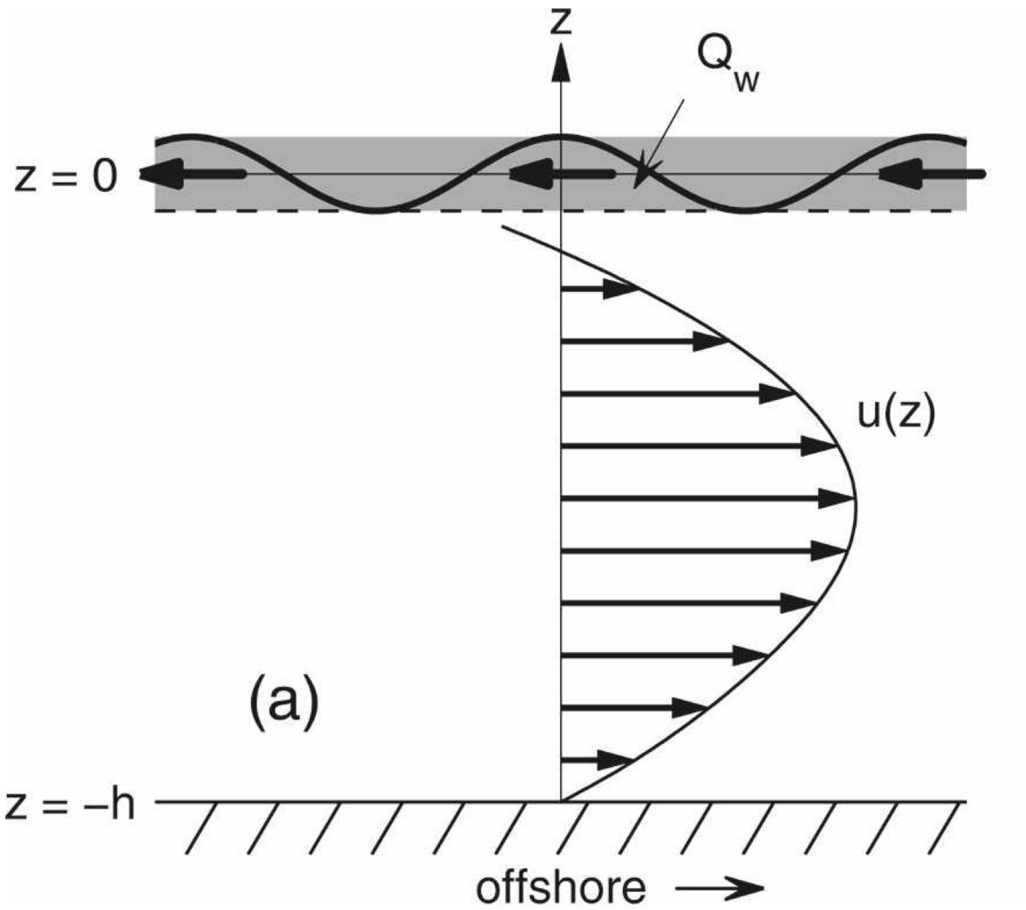


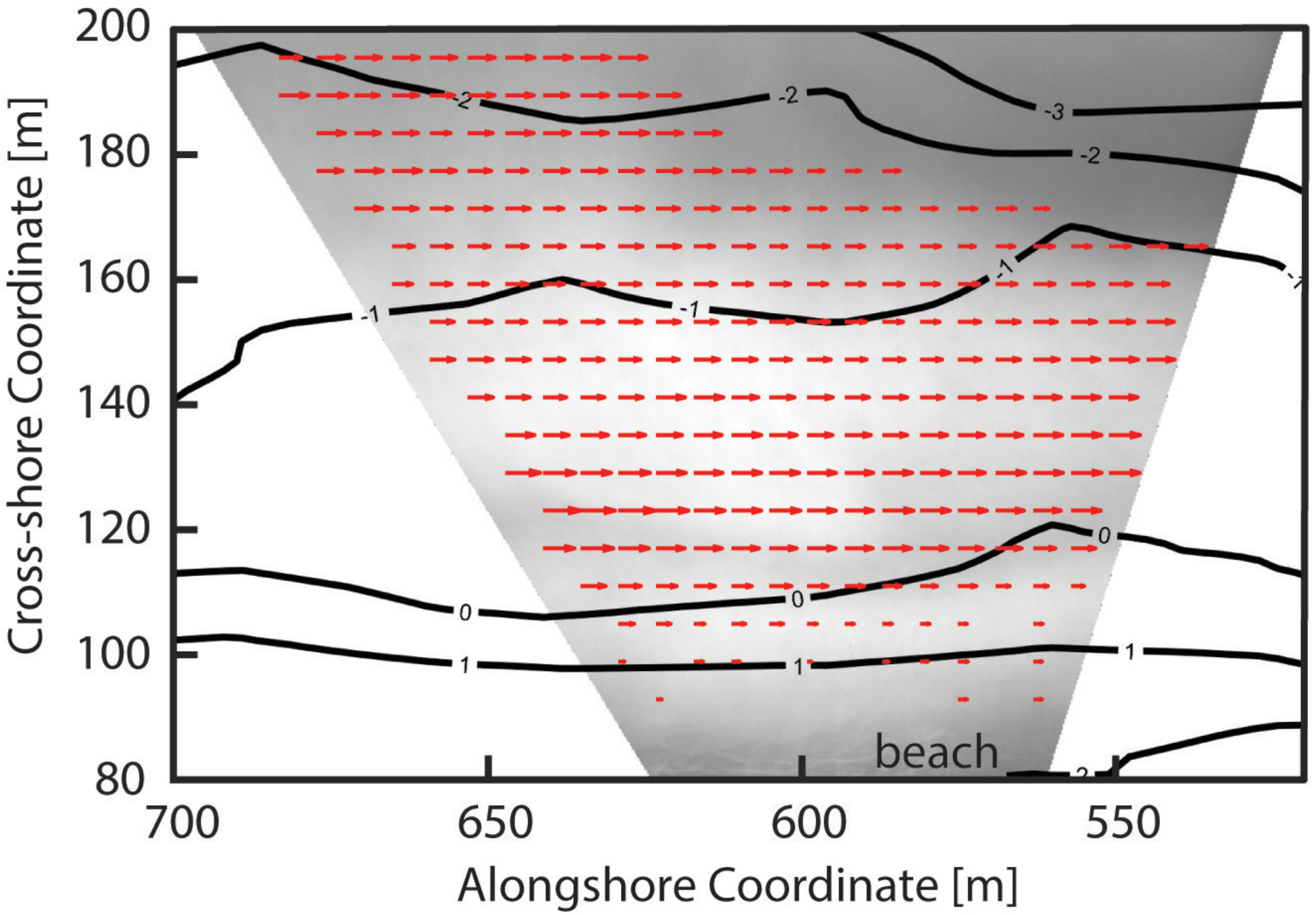
Fig: Lentz et al, 2008

Applying conservation of mass

Shallow water continuity equation:

$$\cancel{\frac{\partial \eta}{\partial t}} + \frac{\partial(\overline{u}_x D)}{\partial x} + \frac{\partial(\overline{u}_y D)}{\partial y} = 0$$

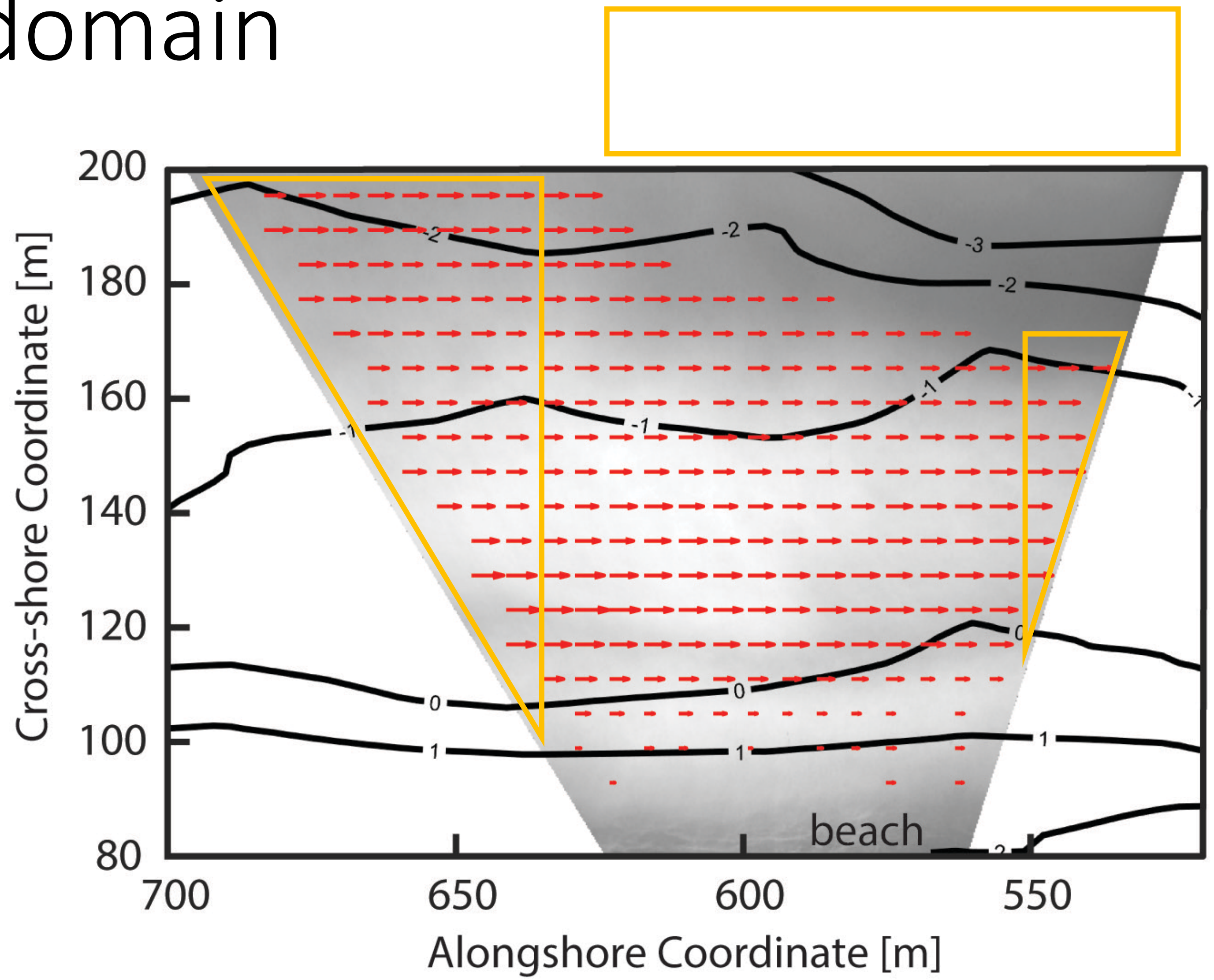
η = sea surface height
u_x = mean cross-shore velocity
u_y = mean along-shore velocity
D = depth



Wilson et al. 2014; Waves in Oceanic and Coastal Waters, 2007

Selection of model domain

- Select contour ($D < h$) to set no-flow boundary condition
- Remove estimates outside visible shoreline and low foam areas
- Confirm each node has neighbors for finite difference scheme



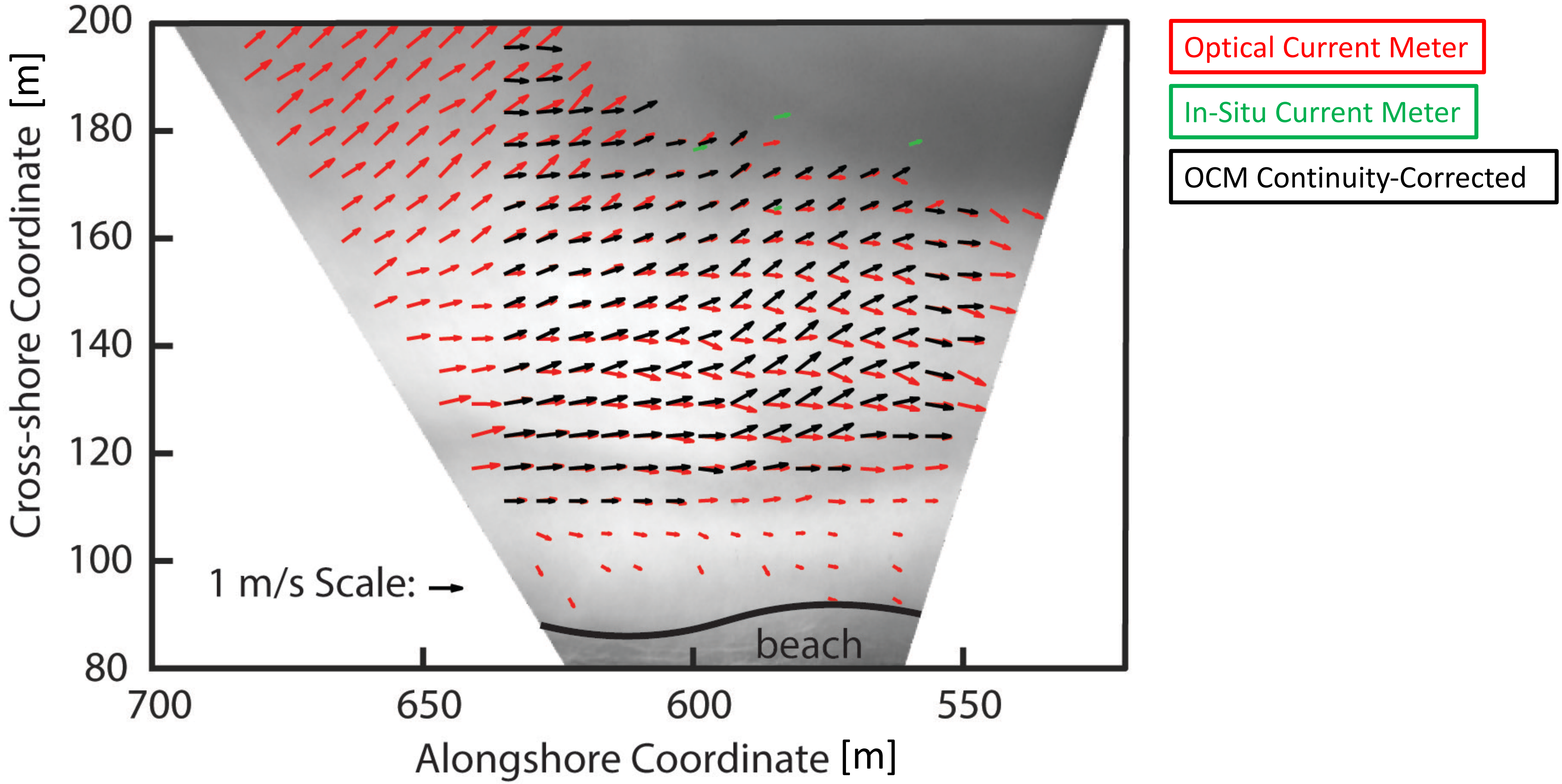
Finite Difference Scheme:

$$\frac{\partial \overline{u}_x D}{\partial x} = \frac{\overline{u}_{x_{i+1,j}} D_{i+1,j} - \overline{u}_{x_{i-1,j}} D_{i-1,j}}{2\Delta x}$$

$$\frac{\partial \overline{u}_x D}{\partial x} = \frac{3(\overline{u}_{x_{i,j}} D_{i,j}) - 4(\overline{u}_{x_{i-1,j}} D_{i-1,j}) + (\overline{u}_{x_{i-2,j}} D_{i-2,j})}{2\Delta x}$$

$$\frac{\partial \overline{u}_x D}{\partial x} = \frac{-(\overline{u}_{x_{i+2,j}} D_{i+2,j}) + 4(\overline{u}_{x_{i+1,j}} D_{i+1,j}) - 3(\overline{u}_{x_{i,j}} D_{i,j})}{2\Delta x}$$

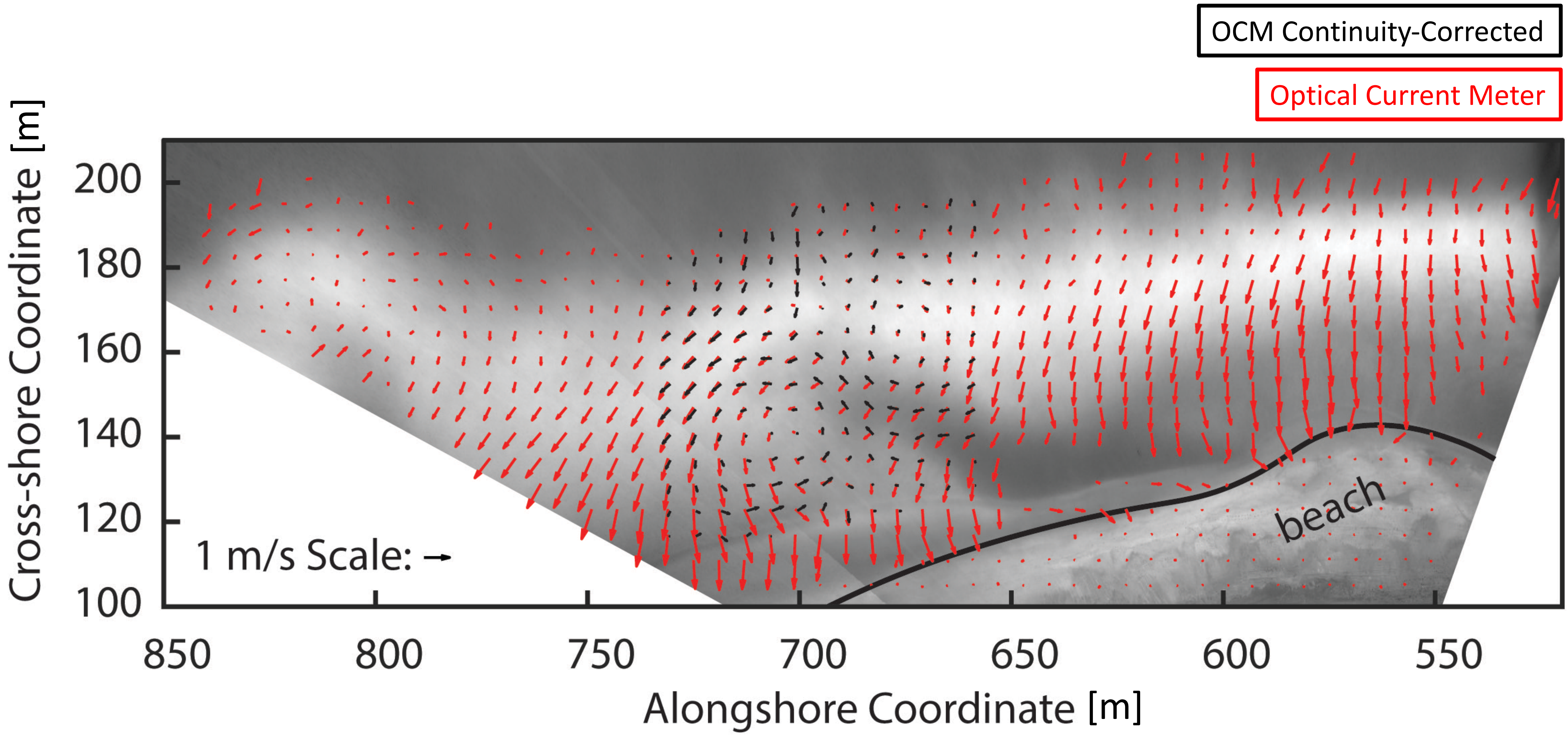
Constructed and solved linear system of equations with least squares solver (sparse matrix) in MATLAB



Optical Current Meter
In-Situ Current Meter
OCM Continuity-Corrected
200
180
160
140
120
100
80
Cross-shore Coordinate [m]
1 m/s Scale:
beach
700
650
600
550
Alongshore Coordinate [m]

Sources of Error

- Field data: boundary condition application, bathymetry D, mean alongshore velocity estimate u_y – main source
- Truncation error: finite difference scheme selected $O(h^2)$
  - Step size limited by optical current meter processing time
- Sensitivity analysis:
  - Step size (h): change Δx, Δy
  - Change bathymetry contour of boundary condition



OCM Continuity-Corrected
Optical Current Meter
Cross-shore Coordinate [m]
200
180
160
140
120
100
1 m/s Scale:
beach
850
800
750
700
650
600
550
Alongshore Coordinate [m]

Future goals/updates

- Field work this fall: gather more in-situ current meter data and compare with numerical model results
- Compare results with other remote sensing algorithms
- Current model: solves for u_x given u_y, D
- Expansion: solves for D given u_y, u_x

Questions?