ca. 1982

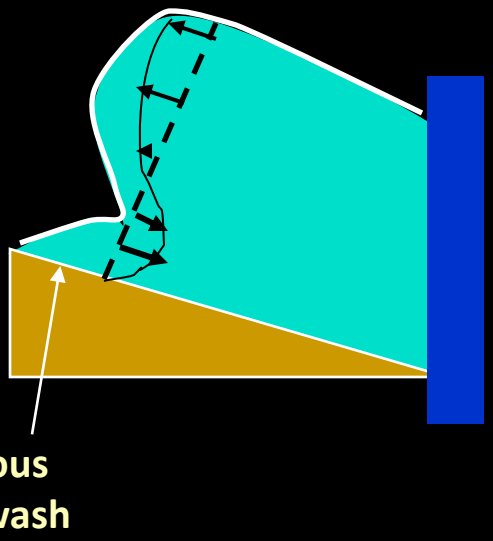
Swash-zone Velocity Profiles and Bed Stress on a Natural Beach

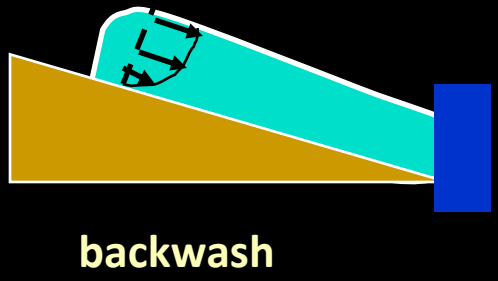
- Motivation
- Study area and deployment
- In situ velocity data, quality control and event description
- Logarithmic law
- Bed stress and friction
- Summary and future work

Jack A. Puleo
Center for Applied Coastal Research
University of Delaware
Grad students: Thijs Lanckriet,
Undergraduate students: Christine Sutkowski, Doug Innocent

Center for Applied Coastal Research

Motivation





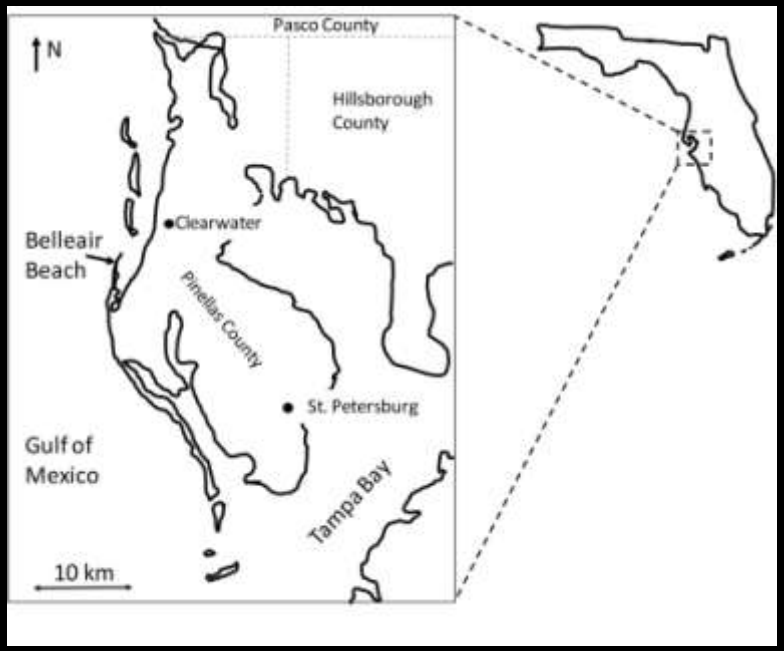
VELOCITY PROFILE: Limited data on variability as function of phase.

Lab: Measurements detailed but boundary layer development depends on mobility and roughness (PIV and LDV).

Field: Several data sets but with limited vertical coverage (Raubenheimer et al., 2004; Masselink et al., 2005).

Numerical: Generally smooth bed or quadratic drag law.

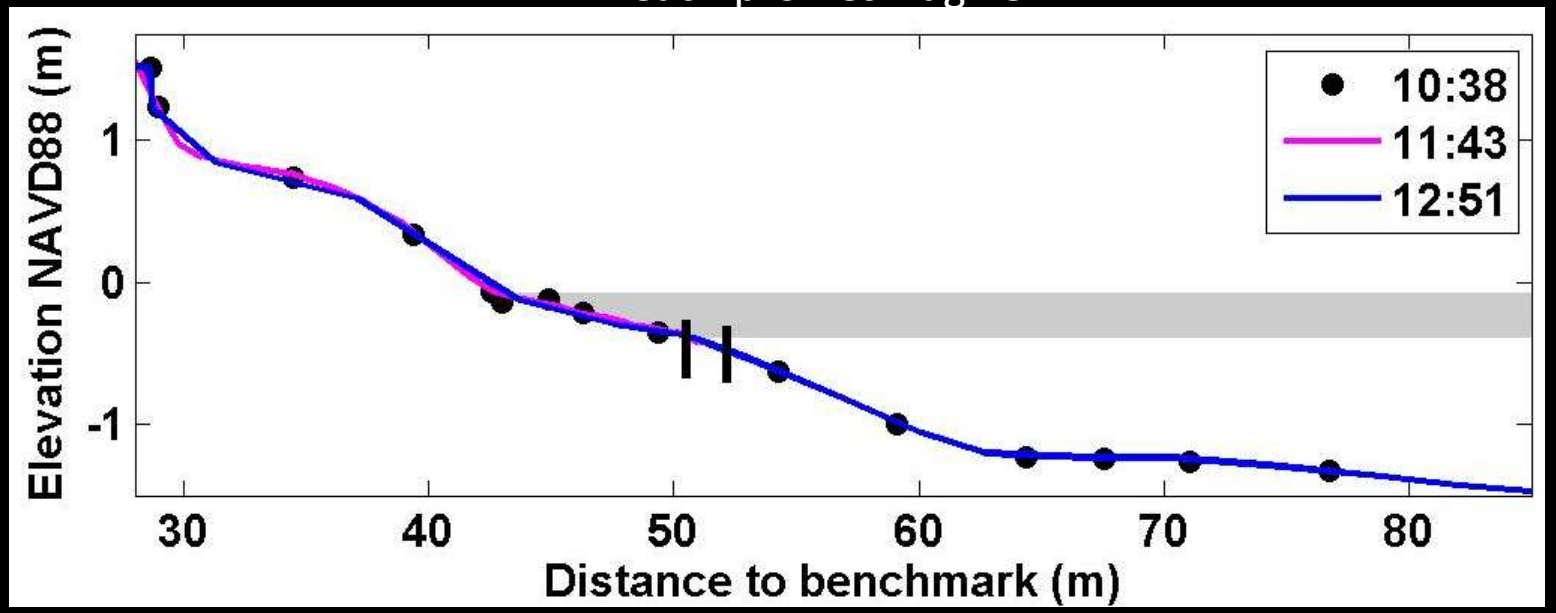
Belleair Beach, Pinellas County, FL



- Data collected Aug 18 and 19, 2010
- 3 Vectrino II's at different locations on foreshore
- Sample rate 100Hz or 60 Hz
- Bin spacing 1mm or 2mm

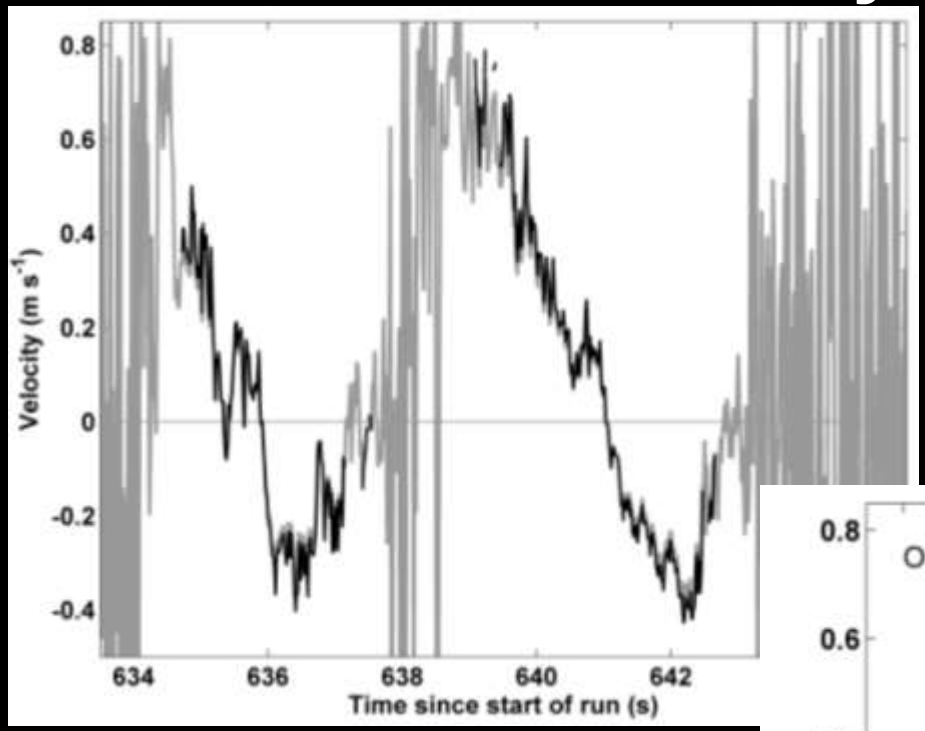
Belleair Beach, Pinellas County, FL

Beach profiles Aug 18



- Foreshore slope ≈ 1:20
- Beach step height of 0.1 – 0.2 m during slack tide
- Foreshore composed of fine sand and shell material (d_{50} = 0.2 mm)
- Significant wave heights = 0.2 to 0.4 m (considerable daily variability influenced by wind)
- Incidence angle small (not measured) but alongshore currents (max 0.3 m/s)

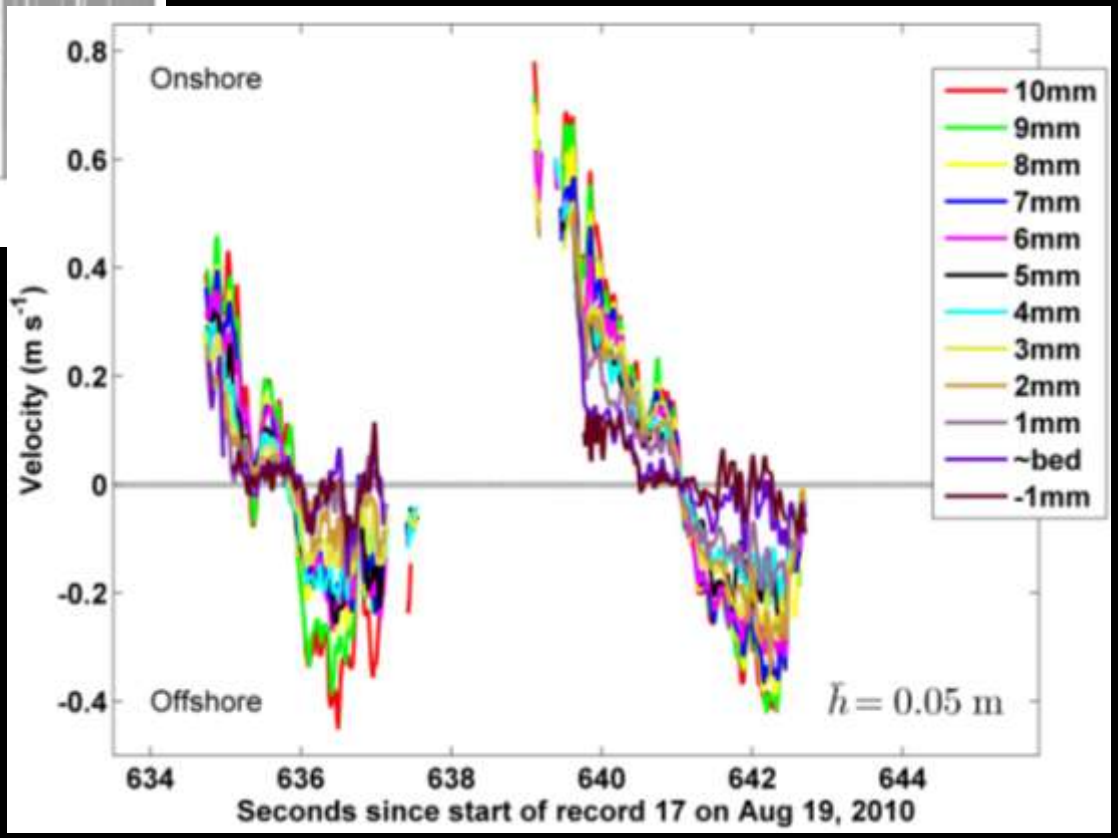
Velocity Data - QC



"swash" data

Raw

Clean



- 16 data records

<u>Data Removal if any beam</u>

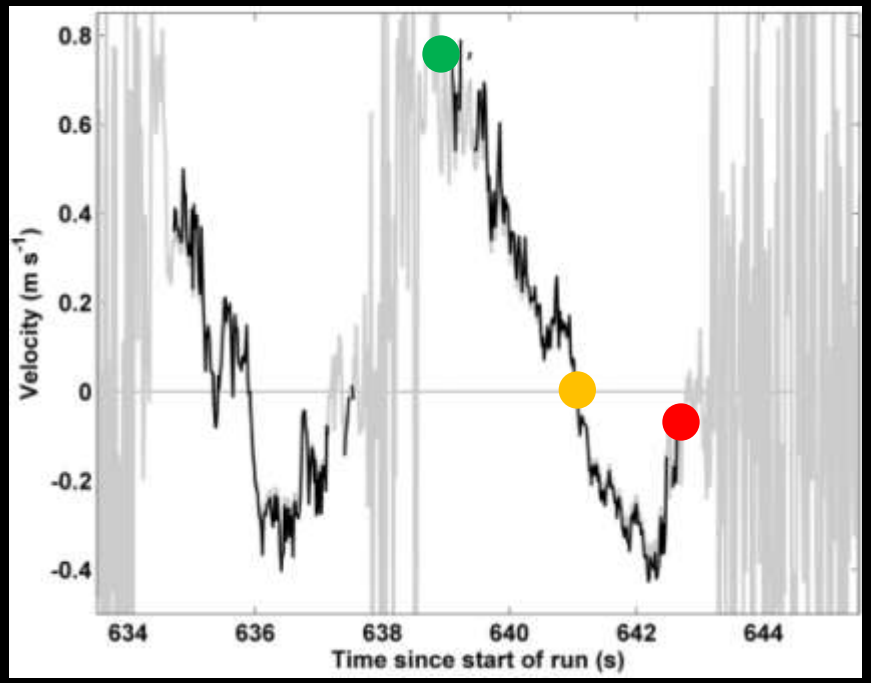
Amplitude < -10 dB (could also use SNR)

Correlation < 60-70

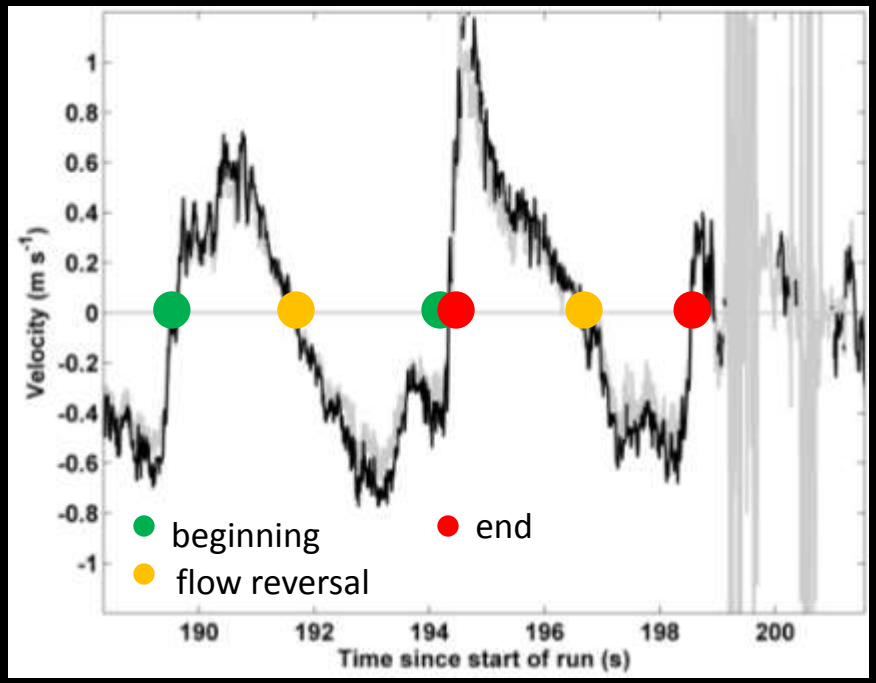
Event Description

Want to “look” at ensemble averages. How to do?

“swash”

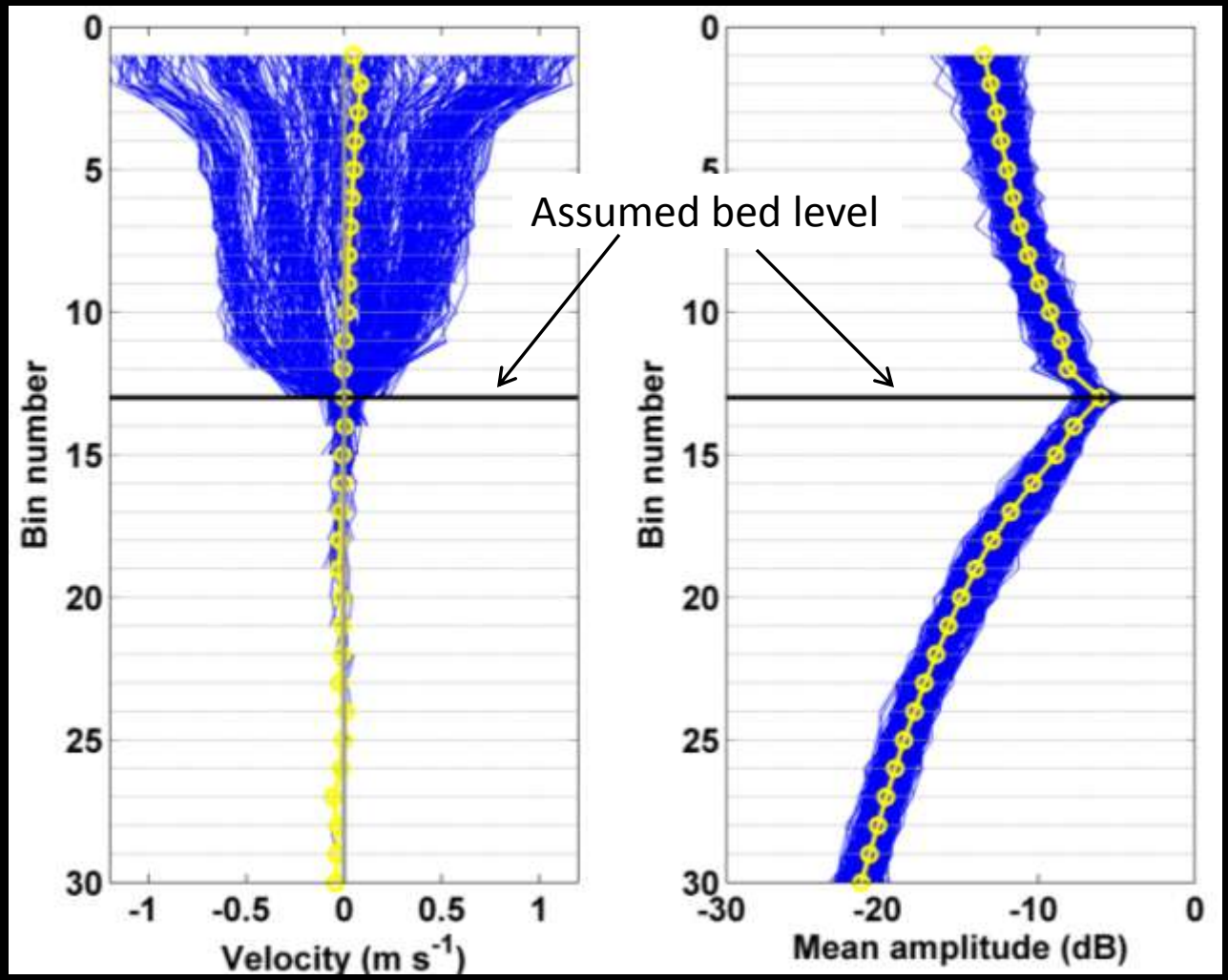


“inner surf”



- Normally zero up-crossing. Will not work here.
- All chosen by eye
- Cannot normalize by event duration
- Will corrupt phasing
- Better option is to ensemble about flow reversal

Bed Determination



- Assumed constant over event duration
- Used mean over 4 beams and event duration
- Find first “kink” in amplitude profile
- Manually fix when necessary (~40%)

Logarithmic Law

For fully rough turbulent (steady) flow

$$u = \frac{u_*}{\kappa} \ln\left(\frac{z - d_*}{z_0}\right)$$

u: cross-shore velocity
u_*: friction velocity
z: elevation
d_*: displacement thickness
z_0 : hydraulic roughness
κ: von karman's constant (0.4)

Fundamental definition of friction velocity

$$\tau = \rho u_*^2$$

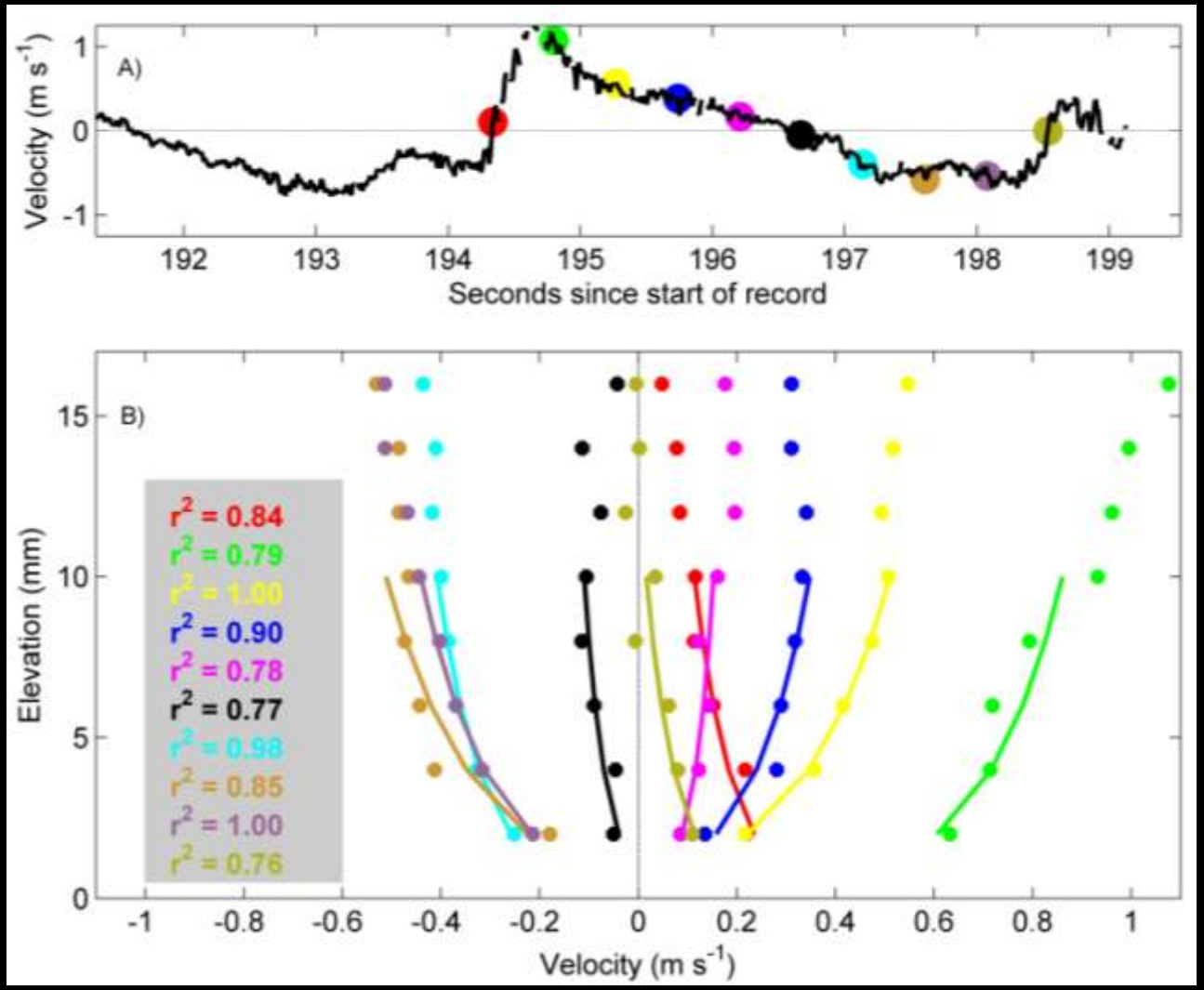
τ: bed shear stress
ρ: fluid density

Quadratic drag law assumption leads to friction coefficient estimation

$$f = \frac{2u_*|u_*|}{u|u|}$$

f: friction coefficient

Example Log Profiles



Issues:

how many to points to include in fit? 5

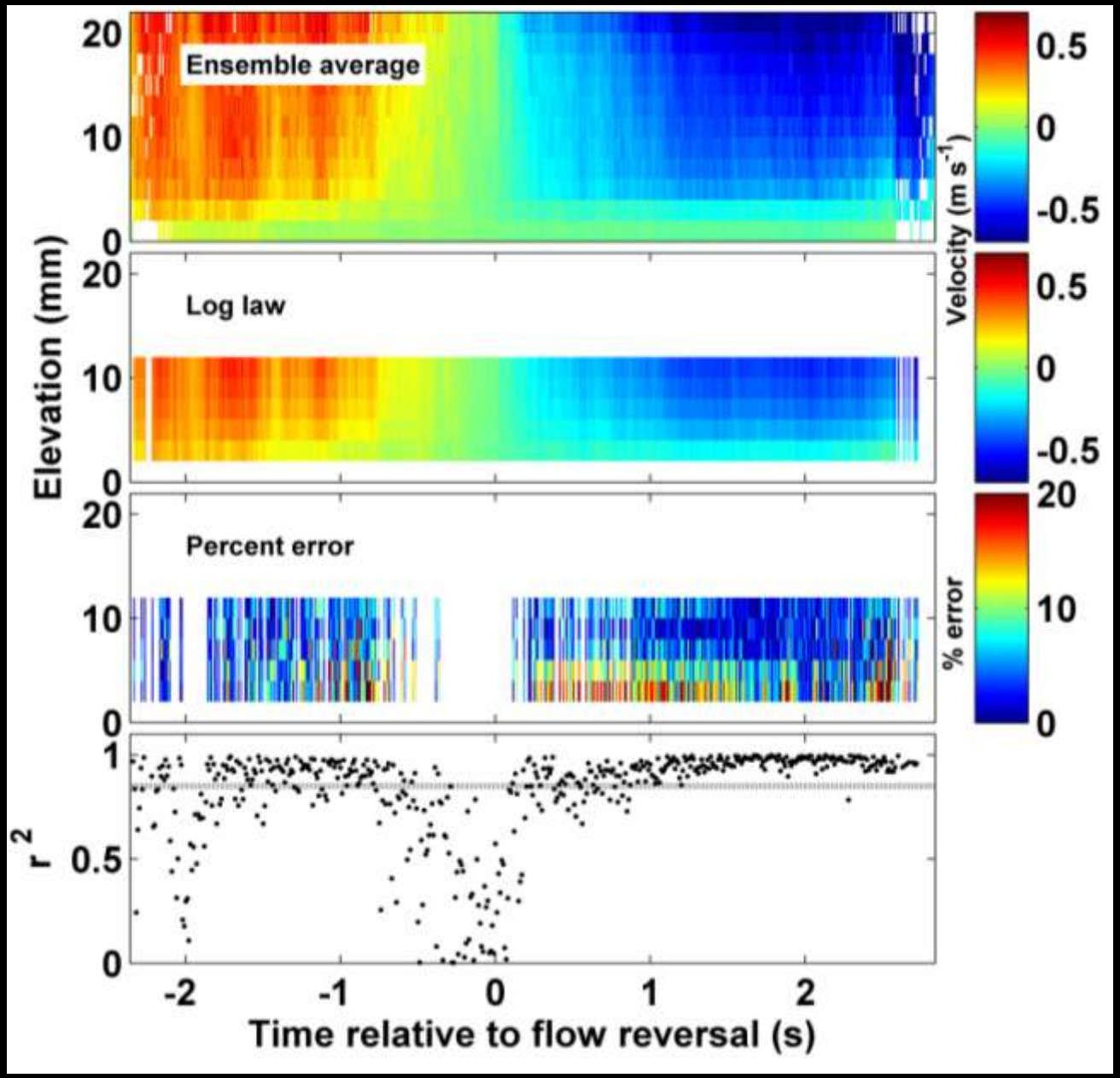
How high off bed for fit? 1 cm

Which r^2 constitutes "good" fit? 0.85

Example indicates "good" fits away from flow reversal

Single instances with no filtering.

Ensemble Average Example

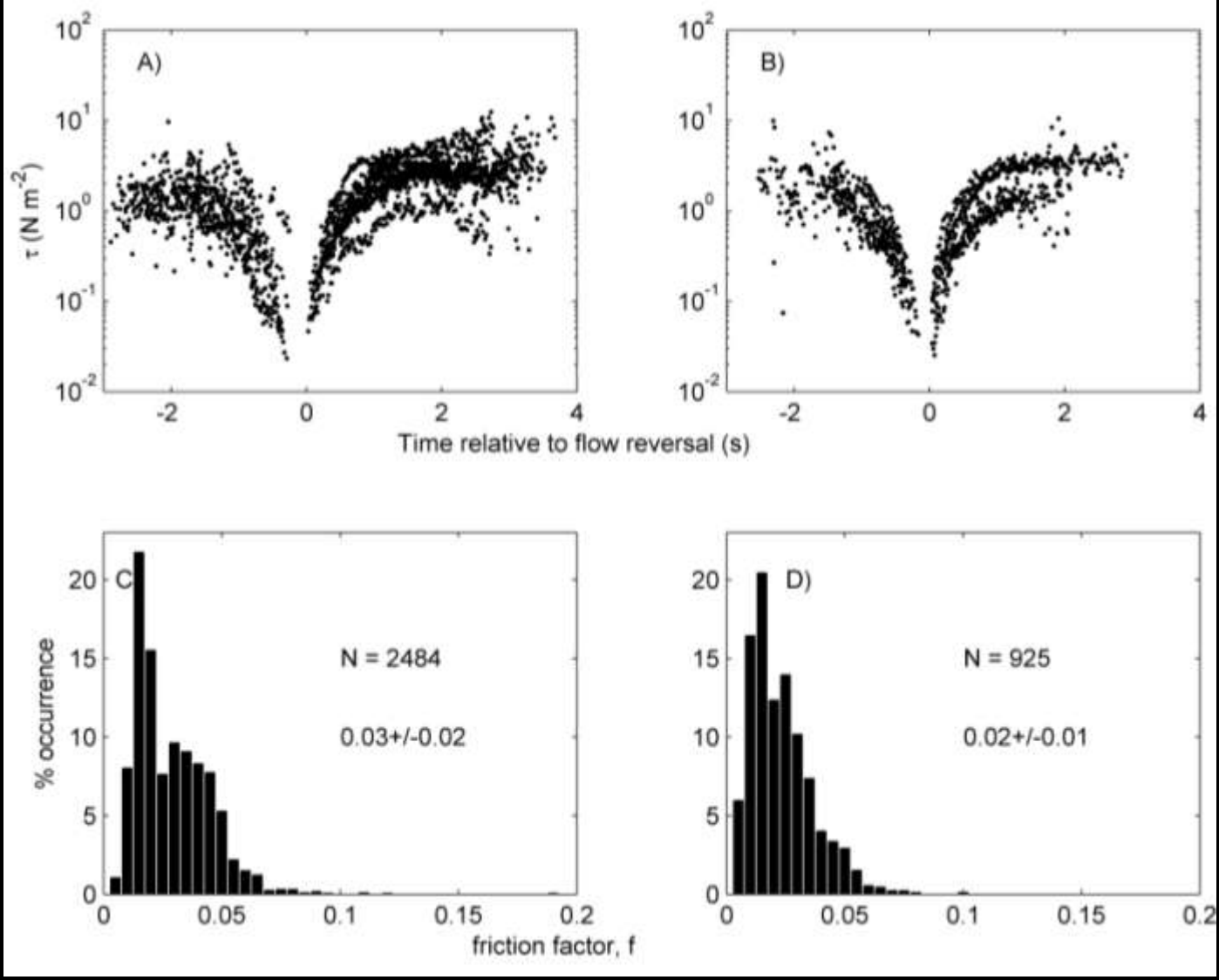


- Requires minimum of 6 data point at any spatio-temporal location
- Example with N = 16
- Other records had from 16 to 64 events
- Clear evolution of boundary layer
- Log law is robust for majority of ensemble average

Stress and Friction for All Ensembles

"Inner surf zone"

"Swash zone"



- Data points from 657 total events as 16 ensemble averages
- Shape similar to that found over fixed beds in the lab.
- Different than field effort using hot wire anemometer (Conley and Griffin, 2004)

Summary

- Vectrino II capable of resolving boundary layer profile on natural beach over mobile bed.

- To my knowledge, first time has been done at this resolution in the field

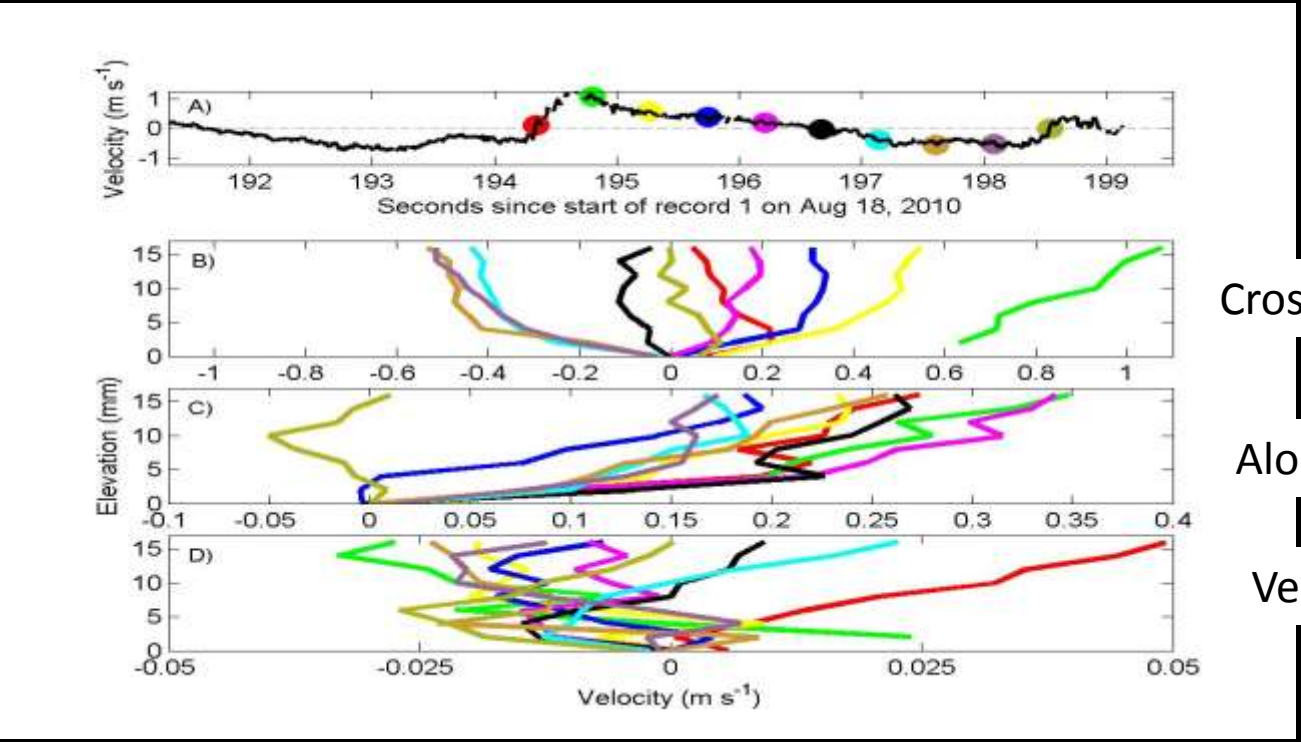
- Velocities during times away from initial shoreward movement and flow reversal conform to log law

- Determining bed level during event could be an issue

- Bed stresses from this model are commensurate with fixed-bed lab studies over much larger grains

Future Work

- Still in analysis phase for these data
- Submit paper based on log law, bed stress and friction coefficient
- Need to investigate alongshore and vertical velocities
- Near bed sediment suspension compared to velocities in boundary layer
- Can use the velocity profiles to extract TKE and dissipation



Questions









Motivation

- Velocity normally sampled using 1 or several (read as up to 3) electro-magnetic or ADV sensors.

- Must be placed a fixed height above bed (like any in situ current meter)

- No knowledge of the boundary layer profile, closest single-point measurements typically no lower than 2-3 cm.

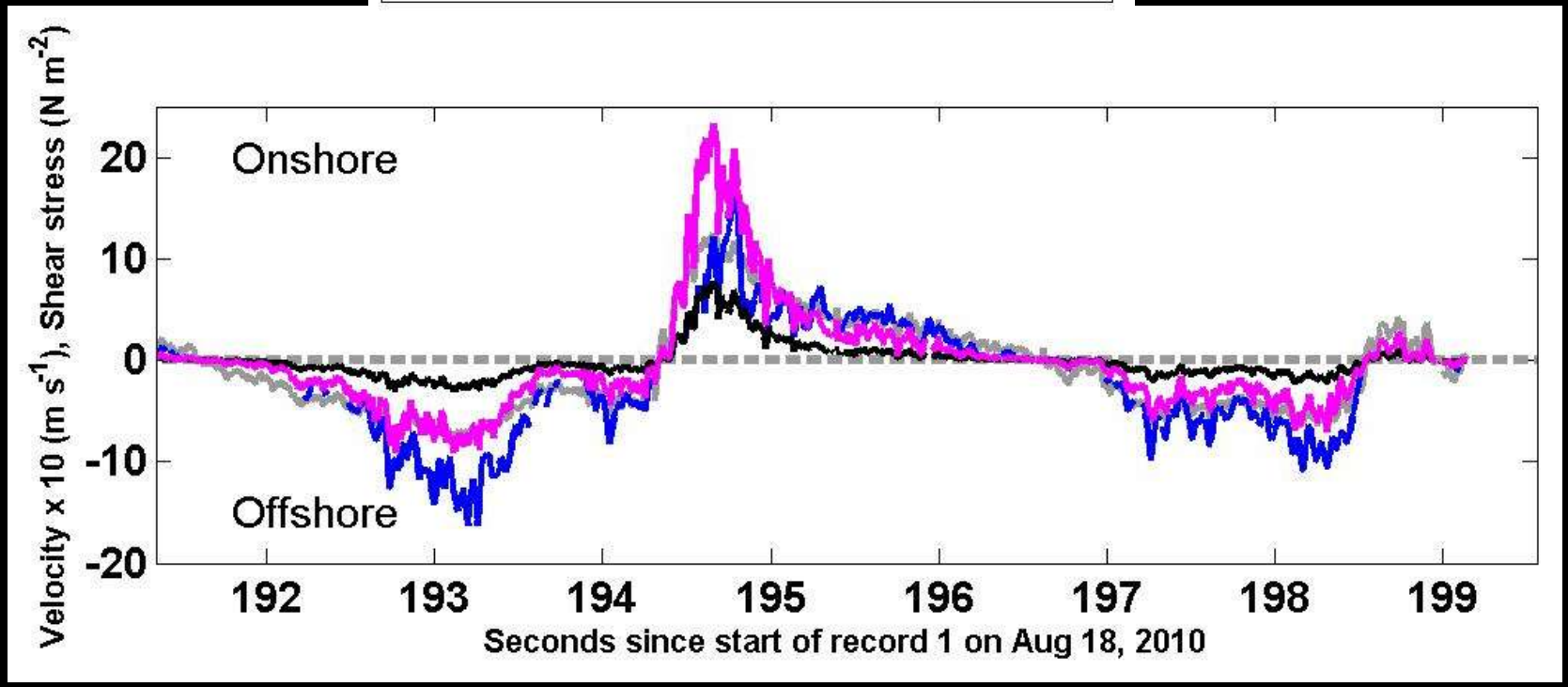
- Stress usually estimated from quadratic drag law

- Requires a friction coefficient that varies due to grain size, sediment mobility and Reynolds number.

- Can perform needed measurements in lab, but over a fixed bed.

- New measurements of the boundary layer under mobile bed conditions in the field are needed.

Bed Stress Example



- Depending on friction factor, drag law can over or under predict relative to log law approach
- Regardless of f: drag law predicts higher stress for shore-directed motion.
- Maximum stress magnitudes roughly equal for this event