Aeolian sediment transport on a wet beach

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Research Question: How does the saltation concentration profile and transport flux change over wet surfaces in a field environment?

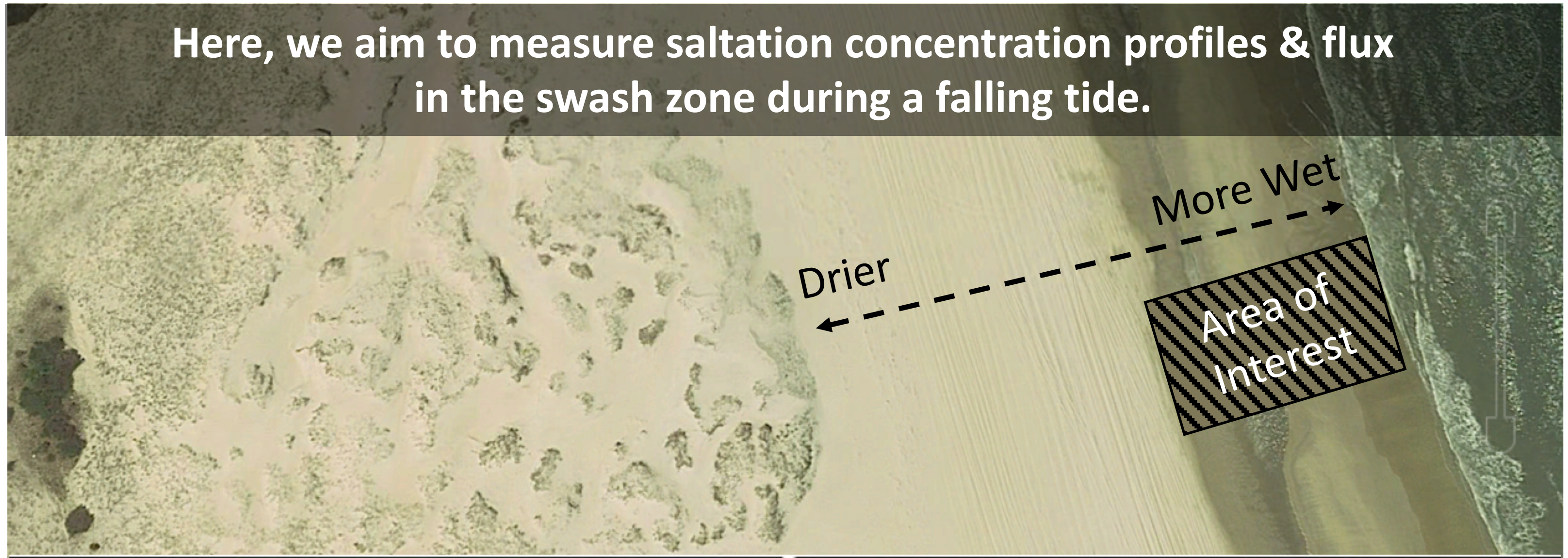
(1) Saltation height, speed & transport flux change with surface moisture content

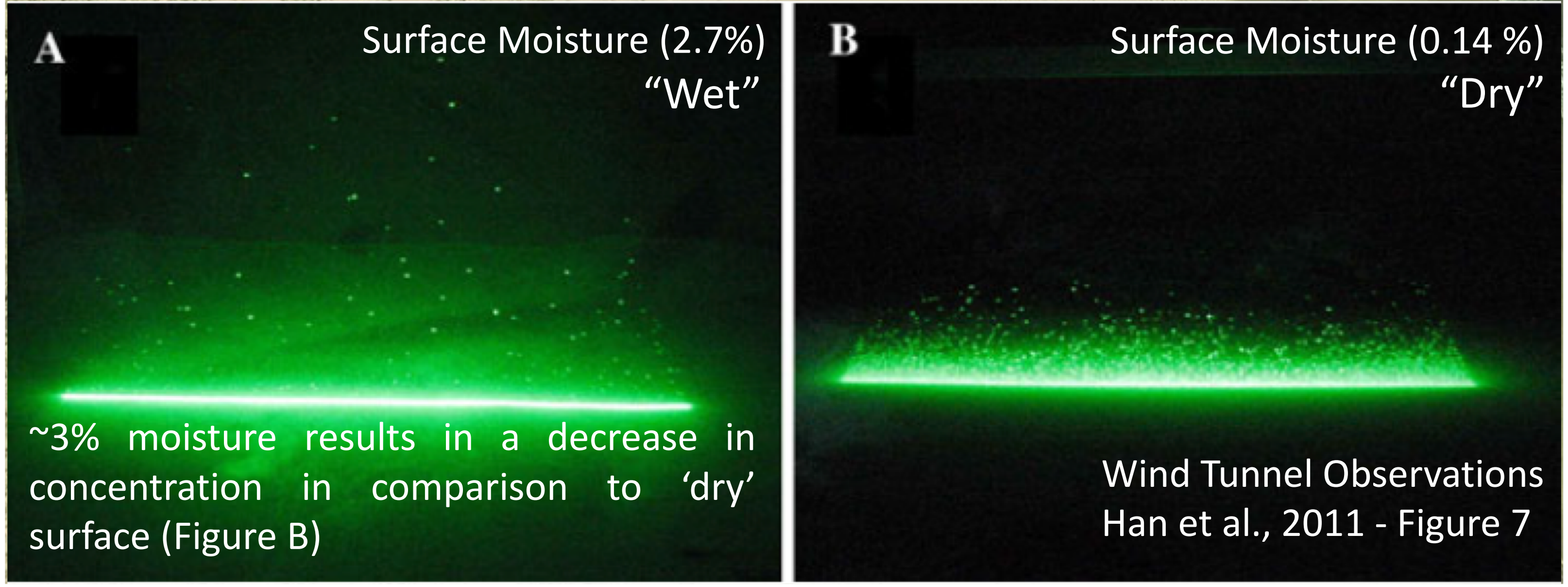
[Svasek & Trewindt, 1974; Hotta et al. 1984; Sarre, 1988; van Dijk et al. 1996; McKenna-Neuman and Scott, 1998; Wiggs et al. 2004; Han et al., 2011; Nield and Wiggs, 2011]

(2) Transport models developed for dry surfaces, and we modify empirical coefficients to predict transport models for wet surfaces

(3) Over wet surfaces, laboratory and field studies have found:

- <u>Saltation height and total flux increases</u> over a wet surface as particles retain more of their energy upon impact/rebound
- <u>Saltation flux decreases</u> due to limited availability of sediment to move (too wet)
- <u>Saltation flux decreases</u> because saltators become trapped by wet surfaces
- Moisture content of 2% has <u>little to no impact</u> on transport flux

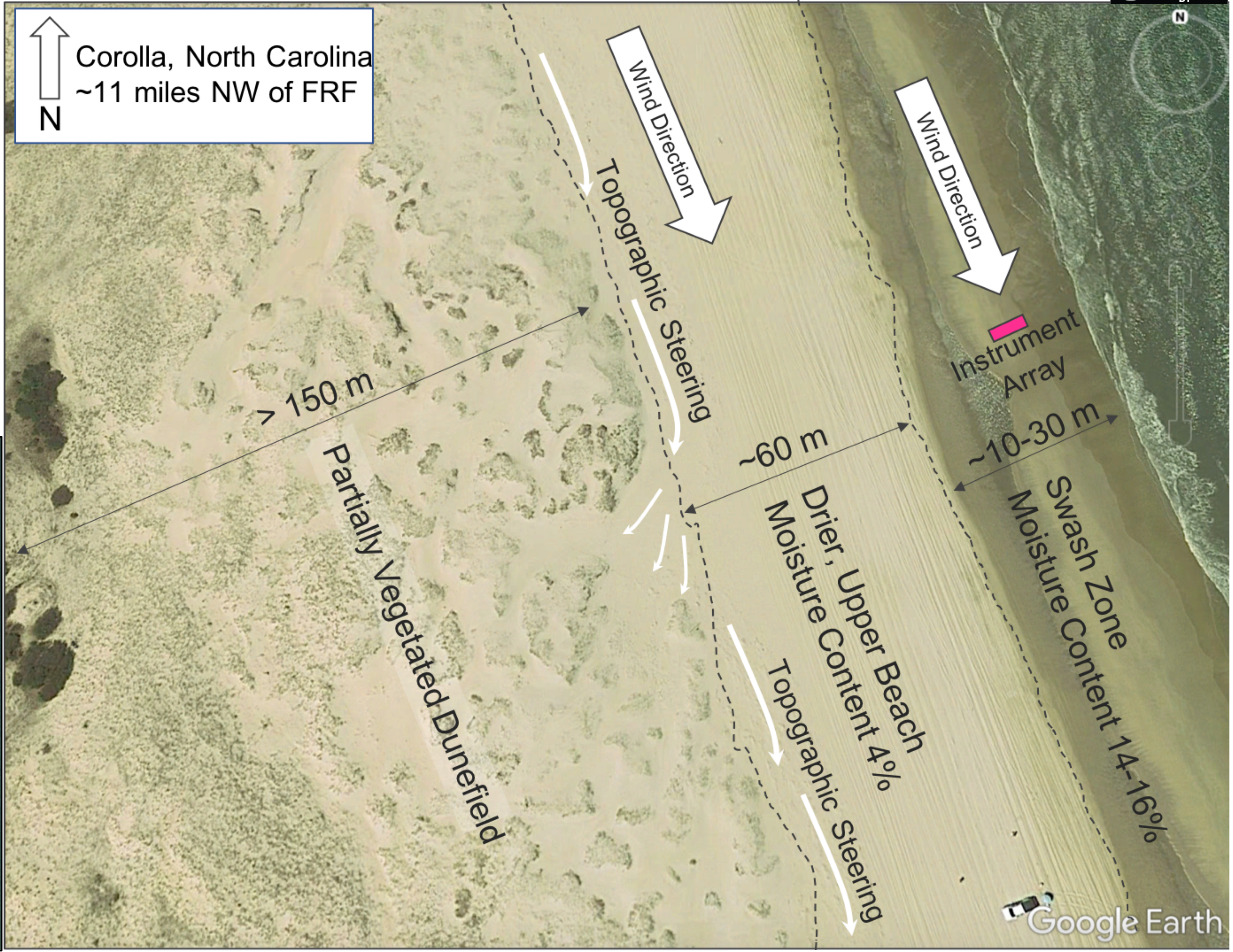




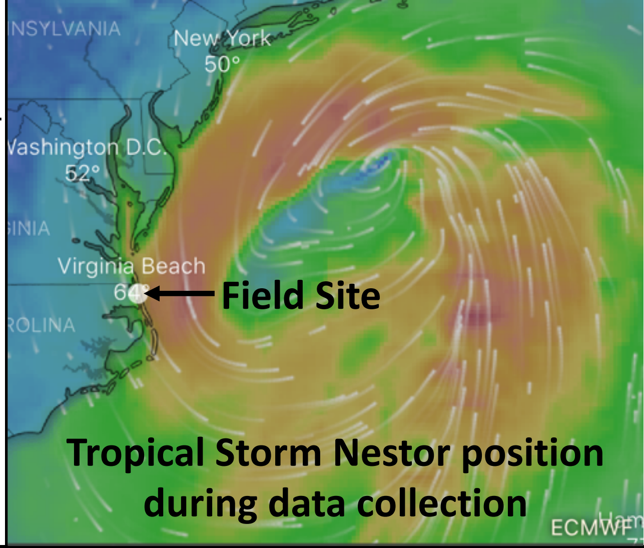
Field Site

Corolla, North Carolina, USA

Beach Orientation: NNW – SSE
Beach Type: Dissipative
Grain Size: Very fine – medium size quartz sand (d = 0.17 mm)
Wind Direction: Aligned with beach orientation – unlimited fetch
Instrument Array: In the swash zone, very high moisture content



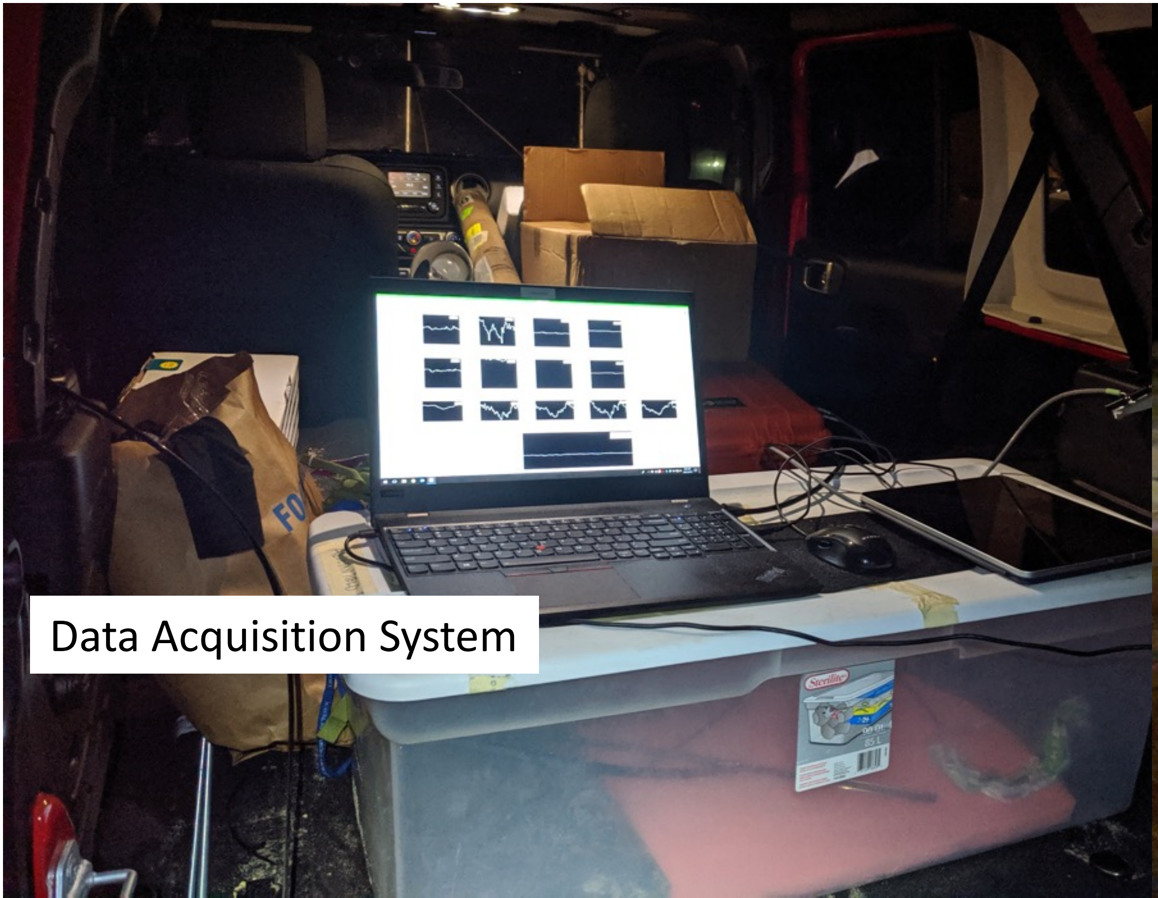
Field Observations: Passage of Tropical Storm Nestor (0600-0730 hours)



Wind Observations
- 3D Velocity Fluctuations via Sonic Anemometers
- Vertical Array of Cup Anemometers

Saltation Concentration Profiles
- Vertical Array of Saltation Traps

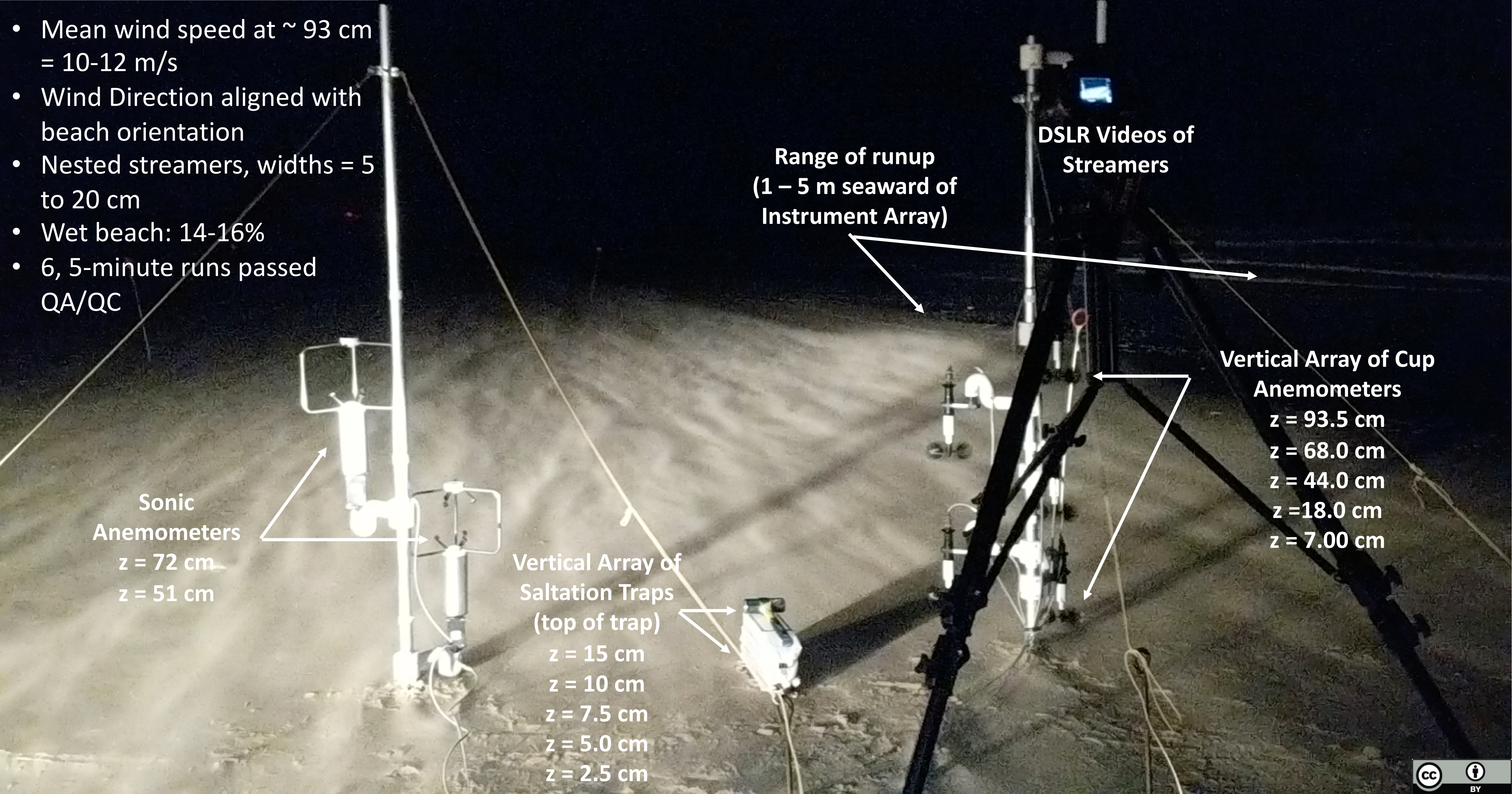
Gravimetric Moisture Content
- Surface Samples
  - Upper Beach
  - Swash Zone
- Vertical Array of Saltation Traps


Data Acquisition System


Instrument Array

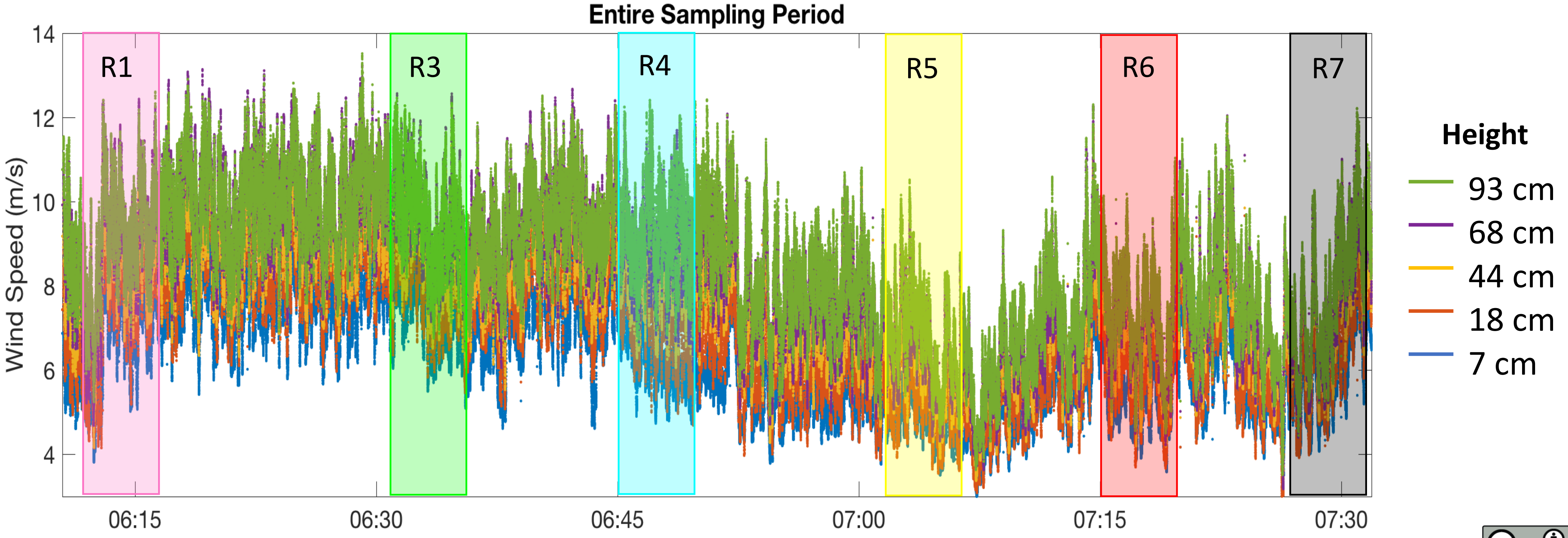
Field Observations

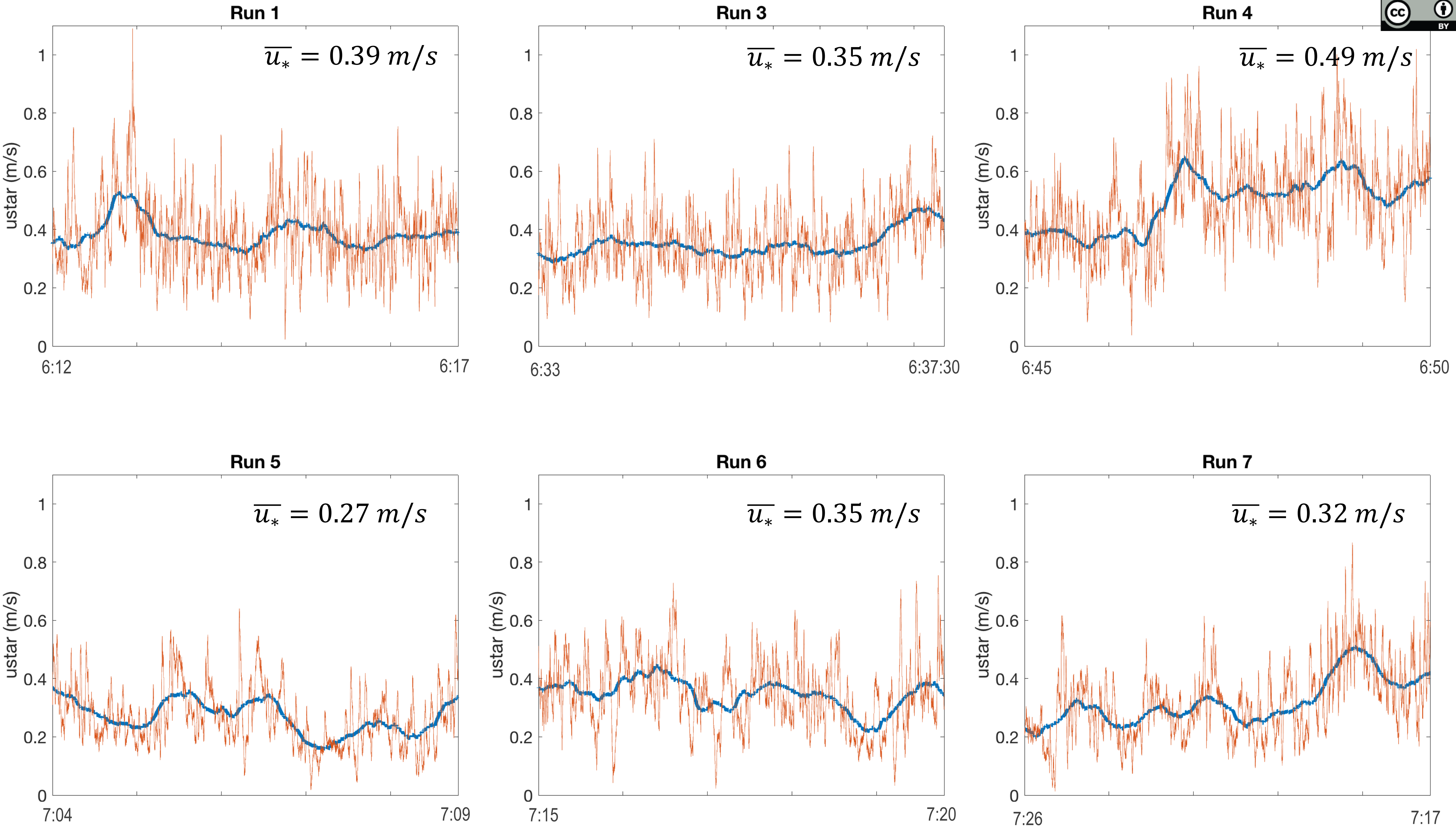
- Mean wind speed at ~ 93 cm = 10-12 m/s
- Wind Direction aligned with beach orientation
- Nested streamers, widths = 5 to 20 cm
- Wet beach: 14-16%
- 6, 5-minute runs passed QA/QC



Data Summary:

- 7 Runs over 2 hours during strong winds
- Falling Tide = 3.8 ft average water level above MLW (mean low water)
- Surface eroded 0.5 cm during 1.5 hour data collection period
- Transport was continuous for 5 minutes for R4 (largest volume of saltation caught in traps)
- Transport seemed to be dependent on upwind saltators (i.e. no increase in shear velocity to induce motion)

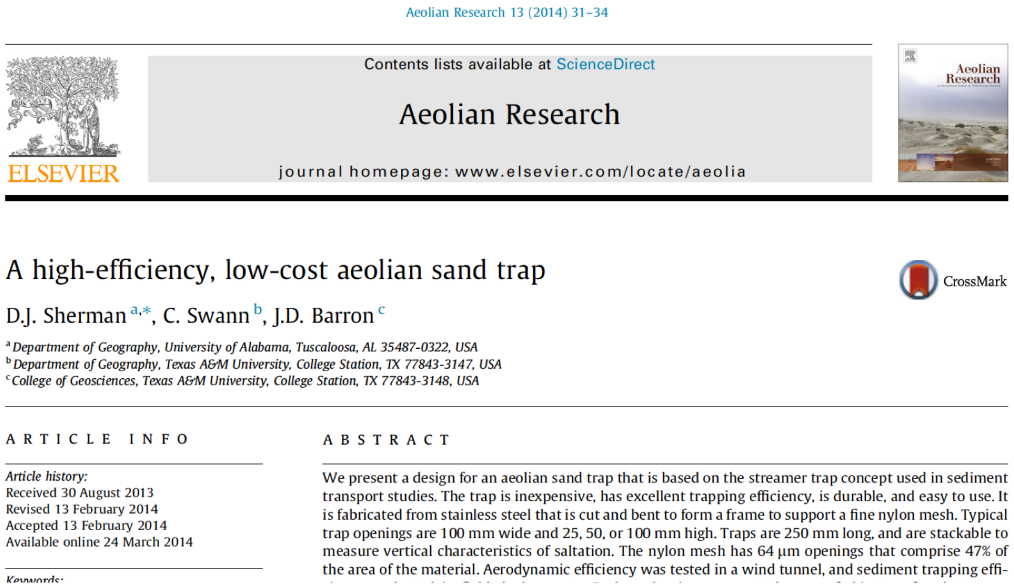


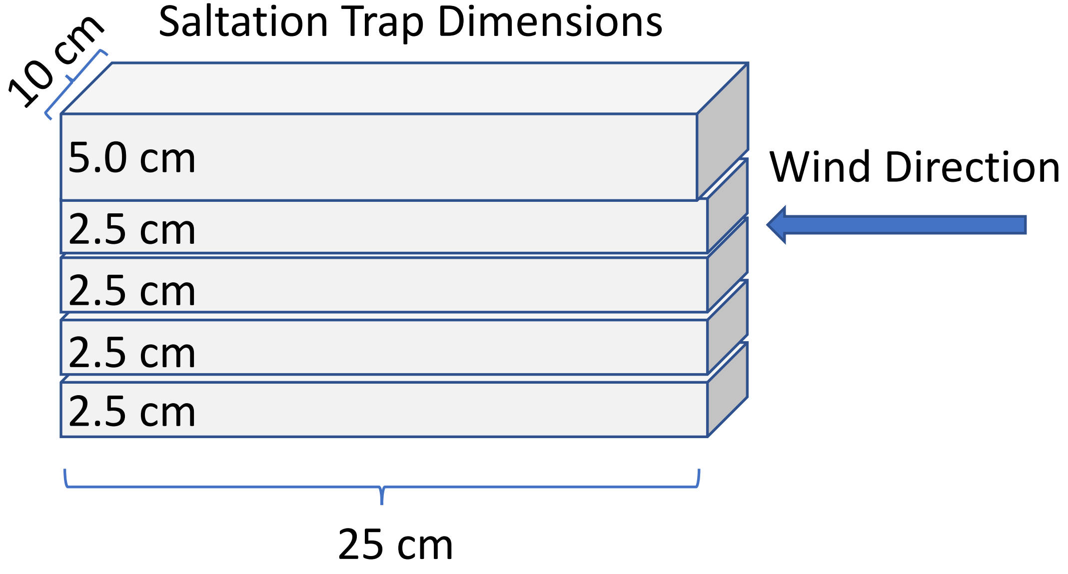

Run 1
$\overline{u_*} = 0.39\ m/s$
6:12
6:17
Run 3
$\overline{u_*} = 0.35\ m/s$
6:33
6:37:30
Run 4
$\overline{u_*} = 0.49\ m/s$
6:45
6:50
Run 5
$\overline{u_*} = 0.27\ m/s$
7:04
7:09
Run 6
$\overline{u_*} = 0.35\ m/s$
7:15
7:20
Run 7
$\overline{u_*} = 0.32\ m/s$
7:26
7:17
ustar (m/s)
0
0.2
0.4
0.6
0.8
1

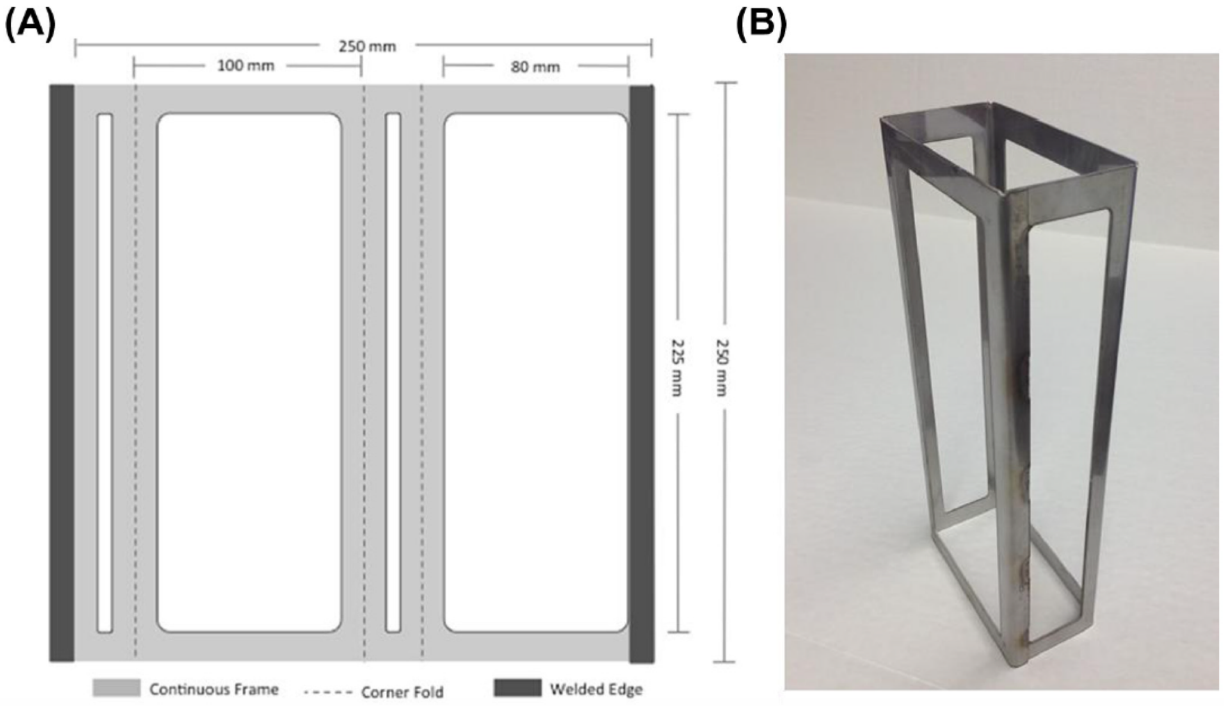
Saltation Trap Data

Grain size and moisture content acquired for each sample

- 35 samples from traps
- 3 grab samples for moisture content
- Removed Run 2 – sample collection failure in field (attributed to lack of coffee at 0600 hours)



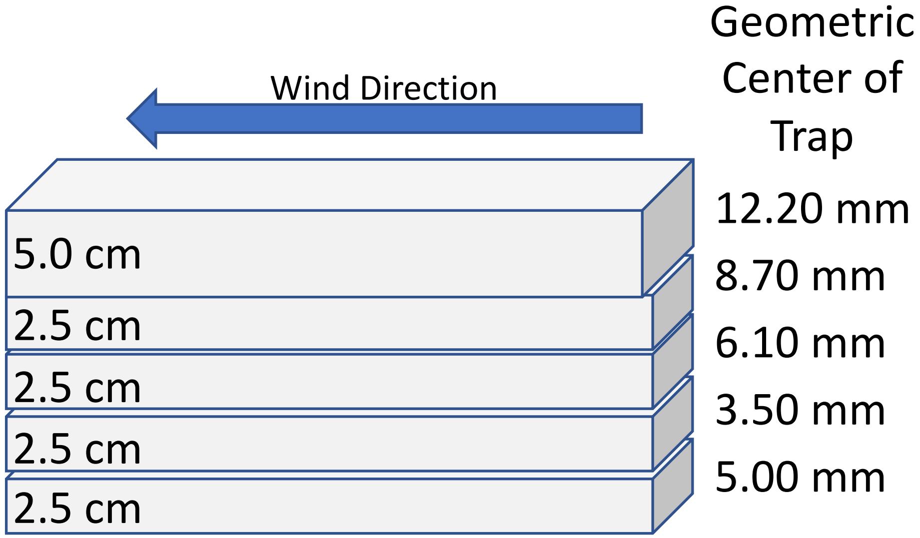


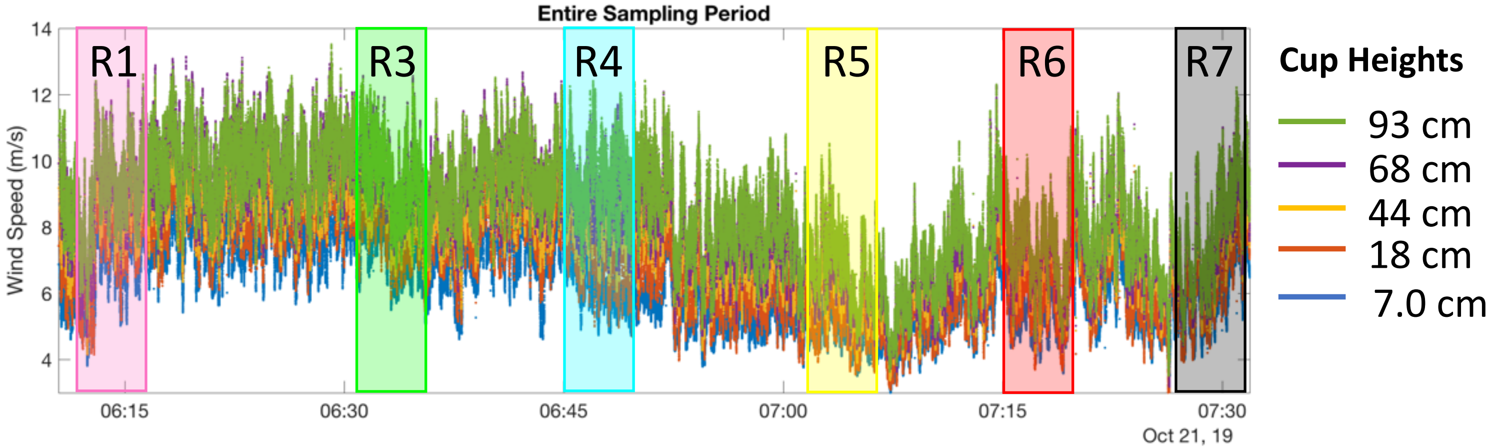


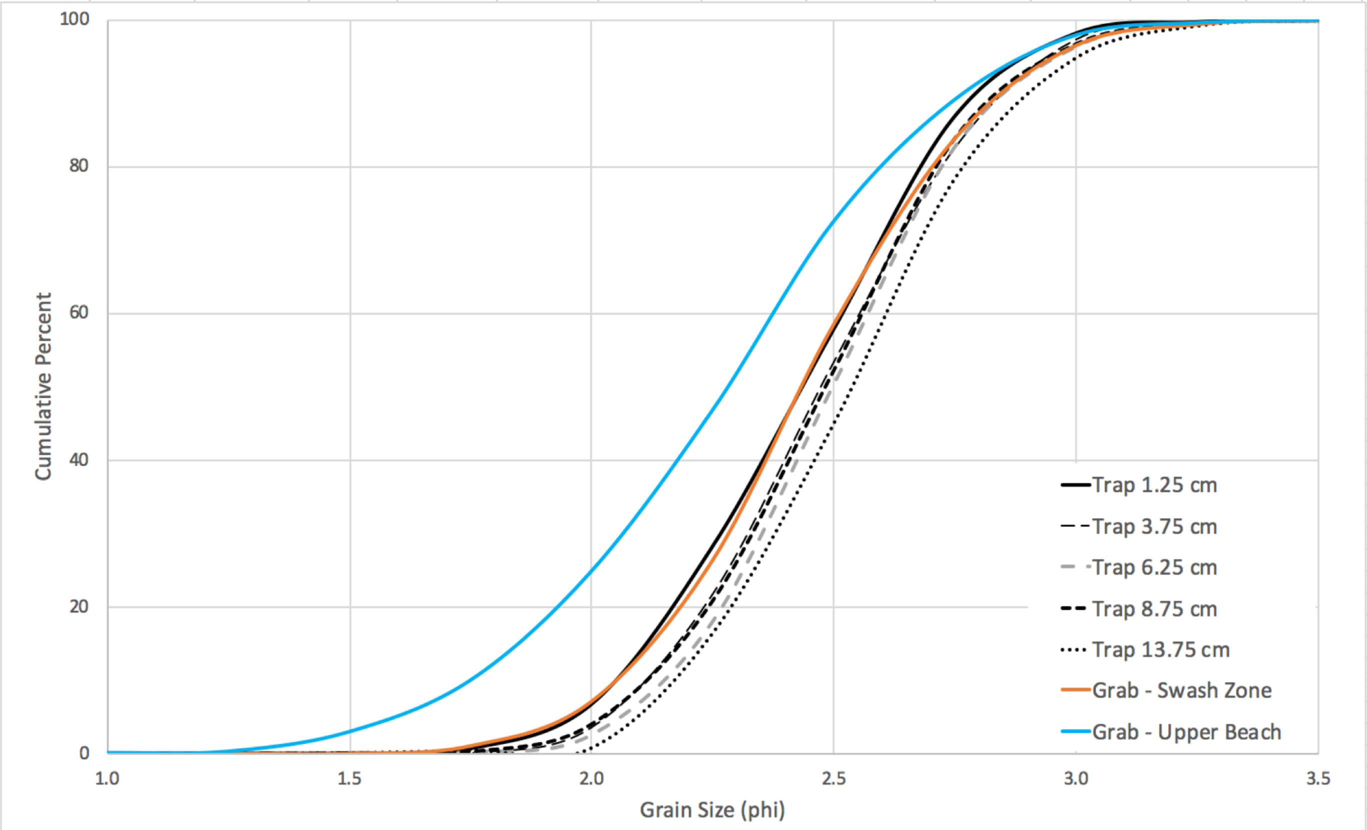
Saltation Trap Data

Grain population consistent between trap and swash zone grab samples

- Surface population and saltators have similar grain size distribution, with an slight increase in grain size with the highest trap
- Upper beach sediments coarser than saltators and swash zone sediments





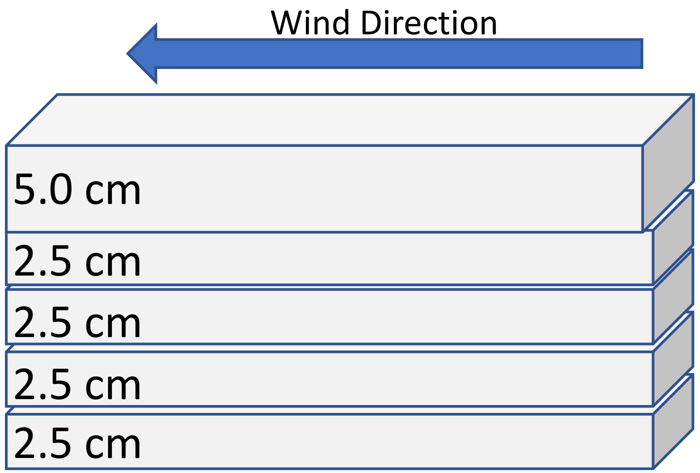


Saltation Trap Data

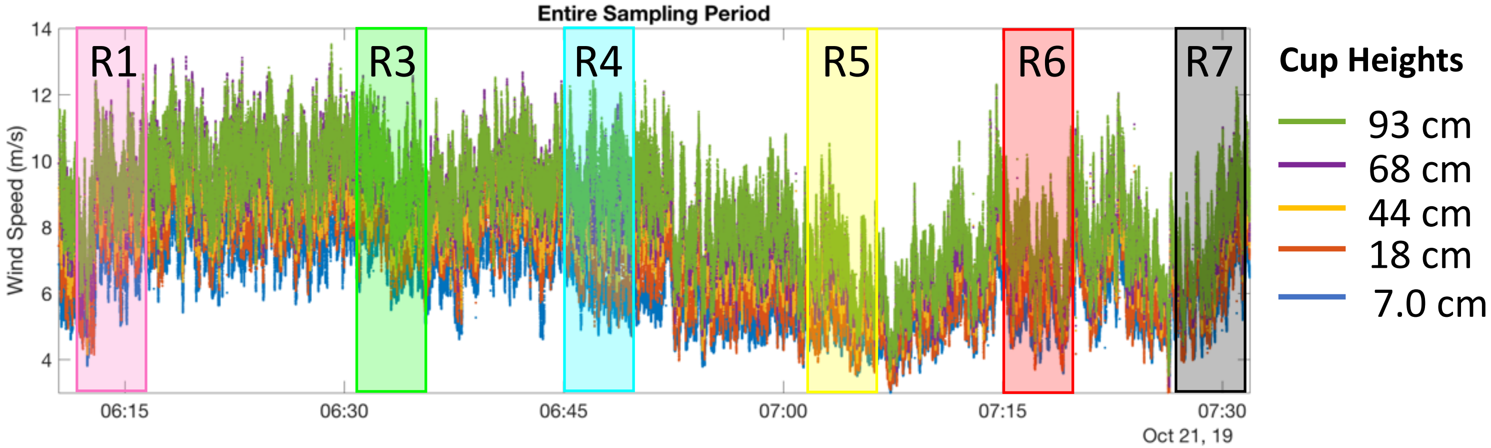
Normalized Flux, Q_{ni}:

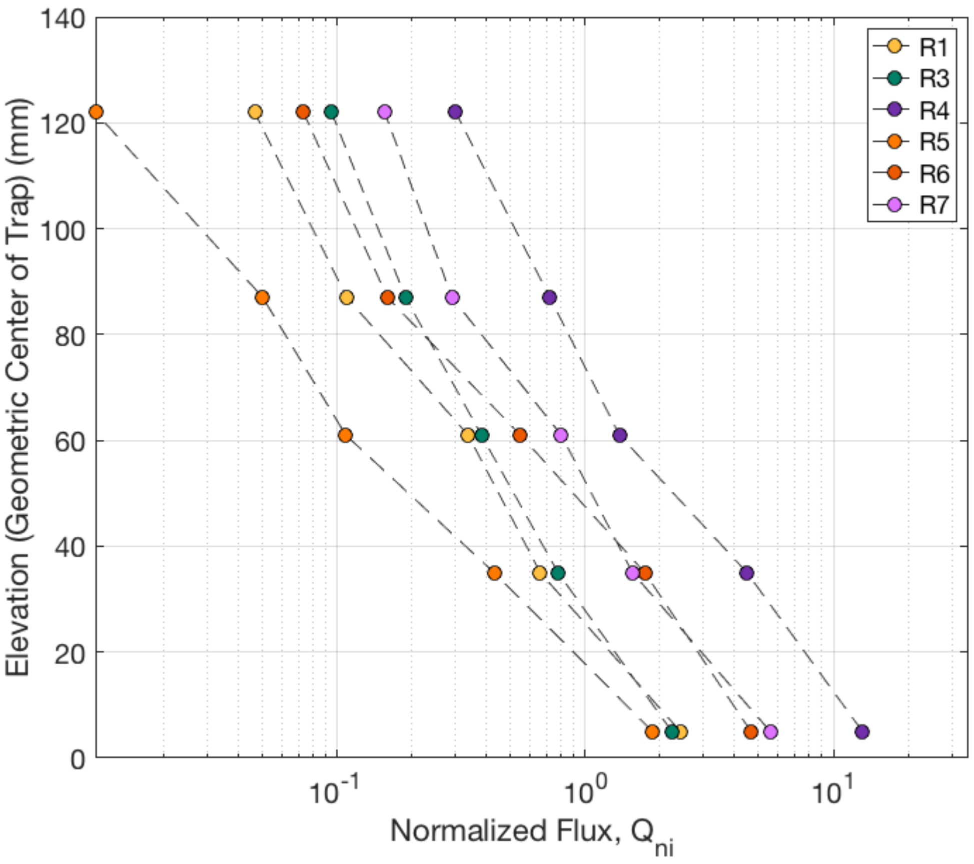
$$Q_{ni} = \frac{\frac{Q_i}{h_{ti} - h_{bi}}}{\sum_{i=1}^{5}(Qi)}$$

where,
h_{ti} = z at the top of the trap
h_{bi} = z at the bottom of the trap
Q_i = flux in individual trap



Geometric Center of Trap
12.20 mm
8.70 mm
6.10 mm
3.50 mm
5.00 mm

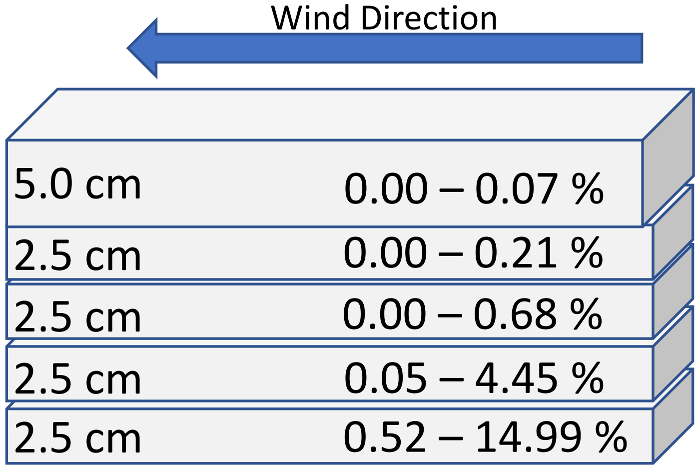


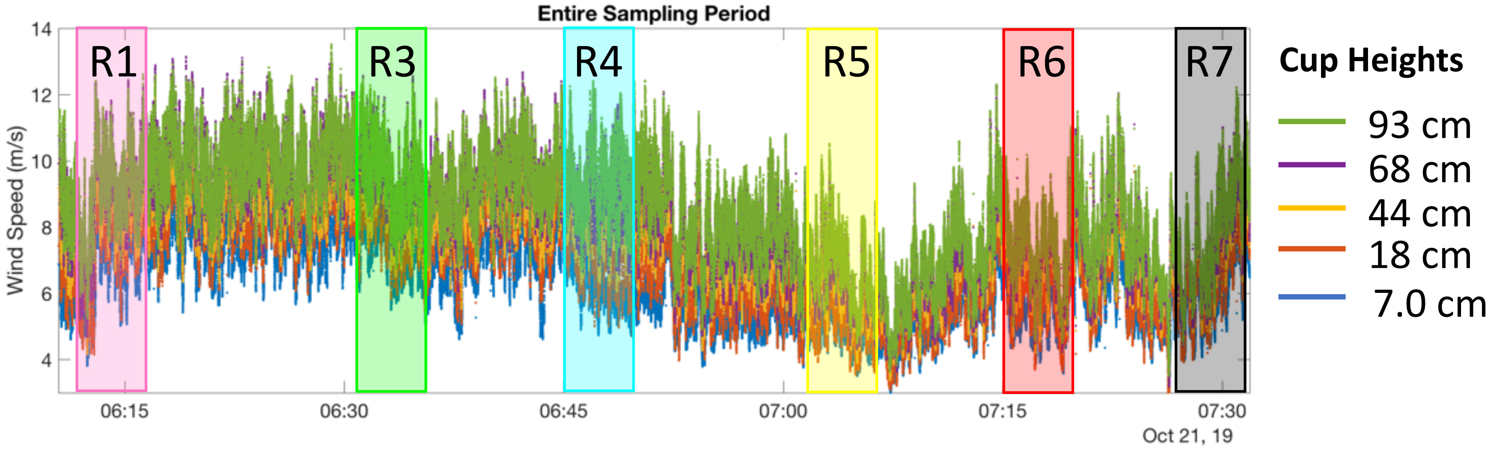


Saltation Trap Data

Moisture content varied with height

- Moisture content high in lowest traps (0 - 14.99%)
- Moisture content varied with each run
- Moisture content of surface samples are not correlated with increases in mean shear velocity
- Suggests dependency on impact-driven transport



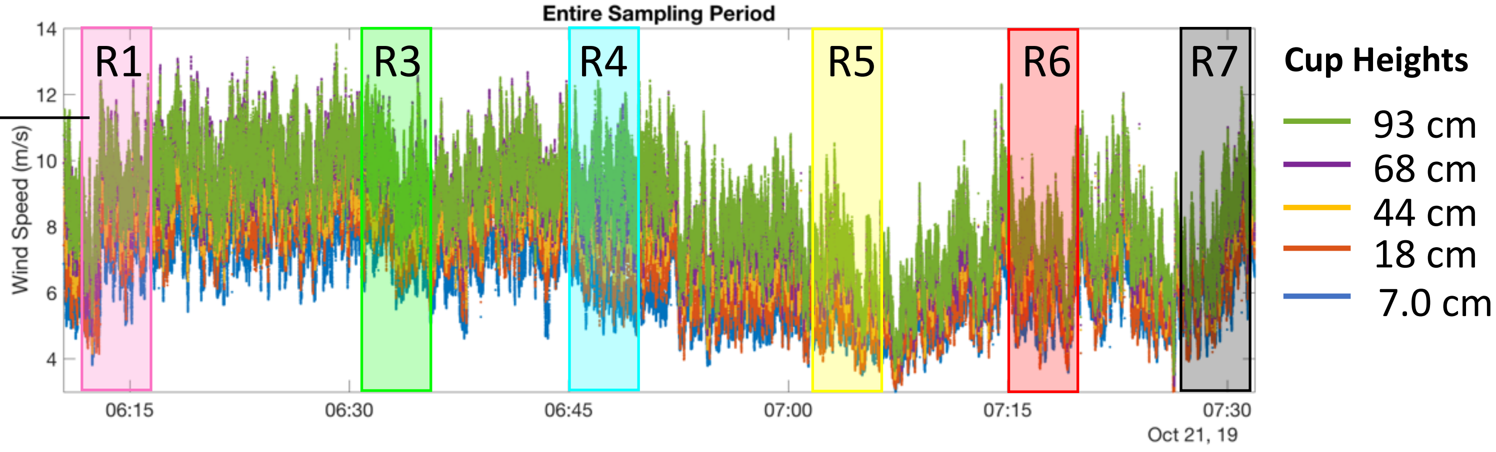


Gravimetric Moisture Content (%)

	Trap 1	Trap 2	Trap 3	Trap 4	Trap 5
Top of Trap (m)	0.025	0.05	0.075	0.1	0.15
Geometric Center (m)	0.005	0.035	0.061	0.087	0.122
R1	6.52	0.21	0.07	0.03	0.07
R3	1.40	0.91	0.08	0.02	0.04
R4	14.99	4.45	0.00	0.21	0.04
R5	0.52	0.05	0.31	0.00	0.00
R6	4.04	0.86	0.09	0.02	0.05
R7	1.28	0.96	0.68	0.00	0.04

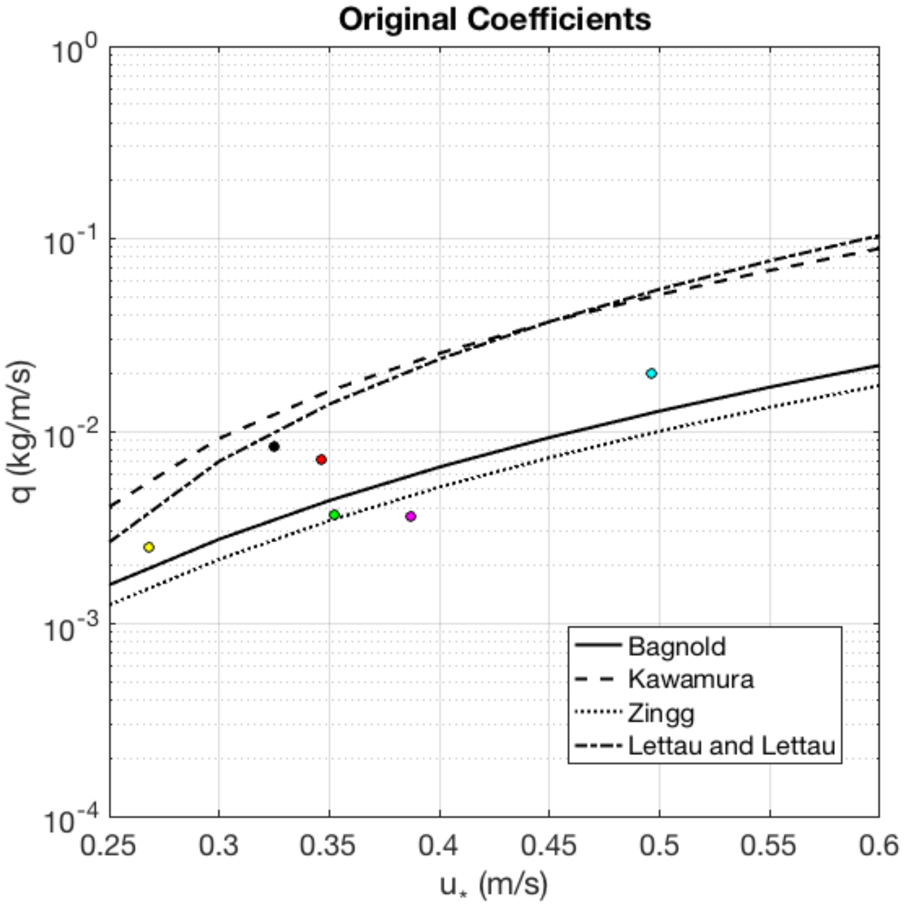
Error or real?

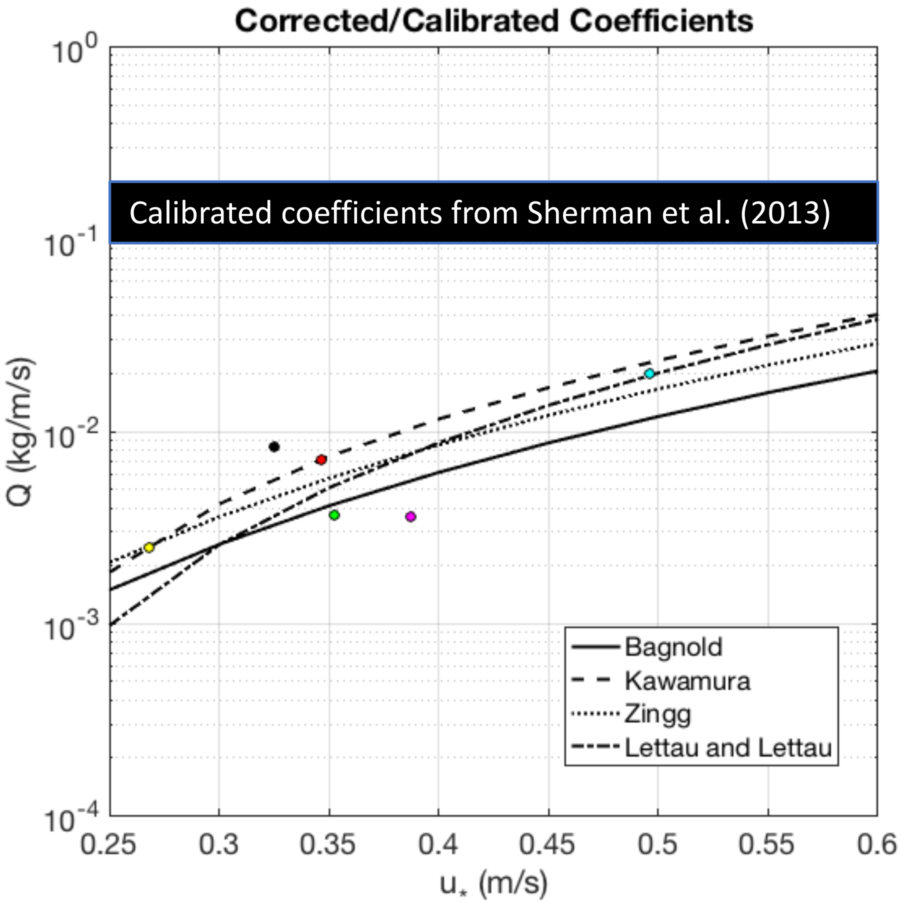
Model Comparison



Predicted vs Observed transport rate

- Observations align well with calibrated coefficients
- Note log scale – so there is still some error in model prediction





Saltation Profile Comparison: This study versus profiles over dry surfaces

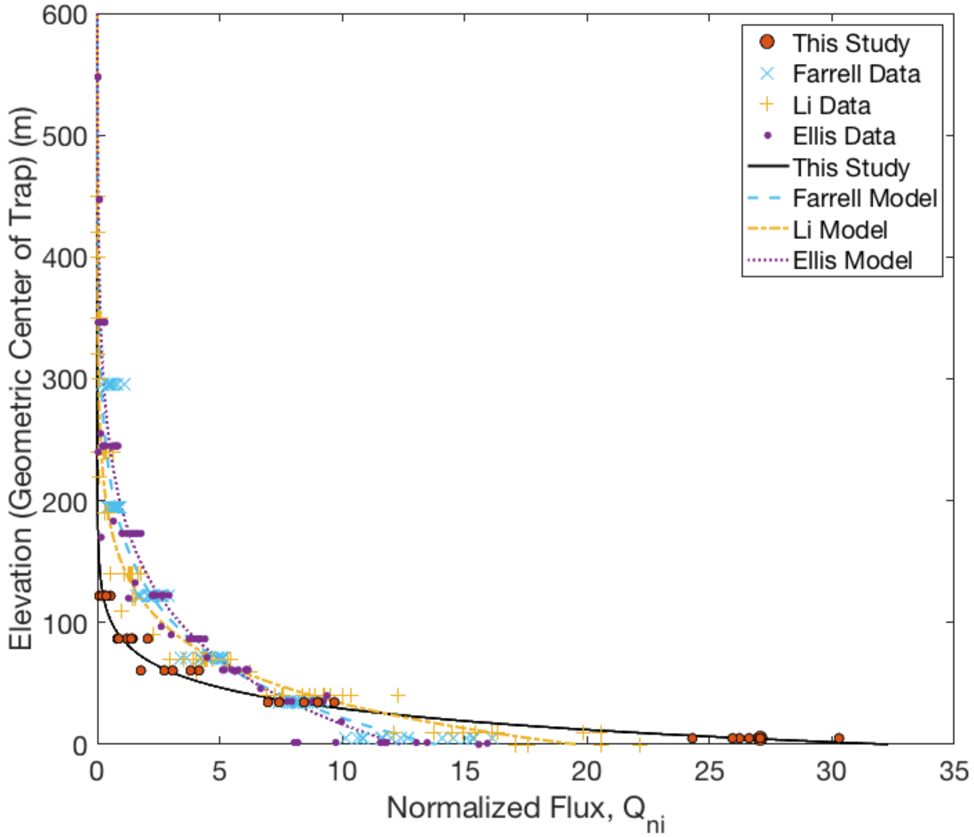
Saltation profile significantly different than for a dry surface

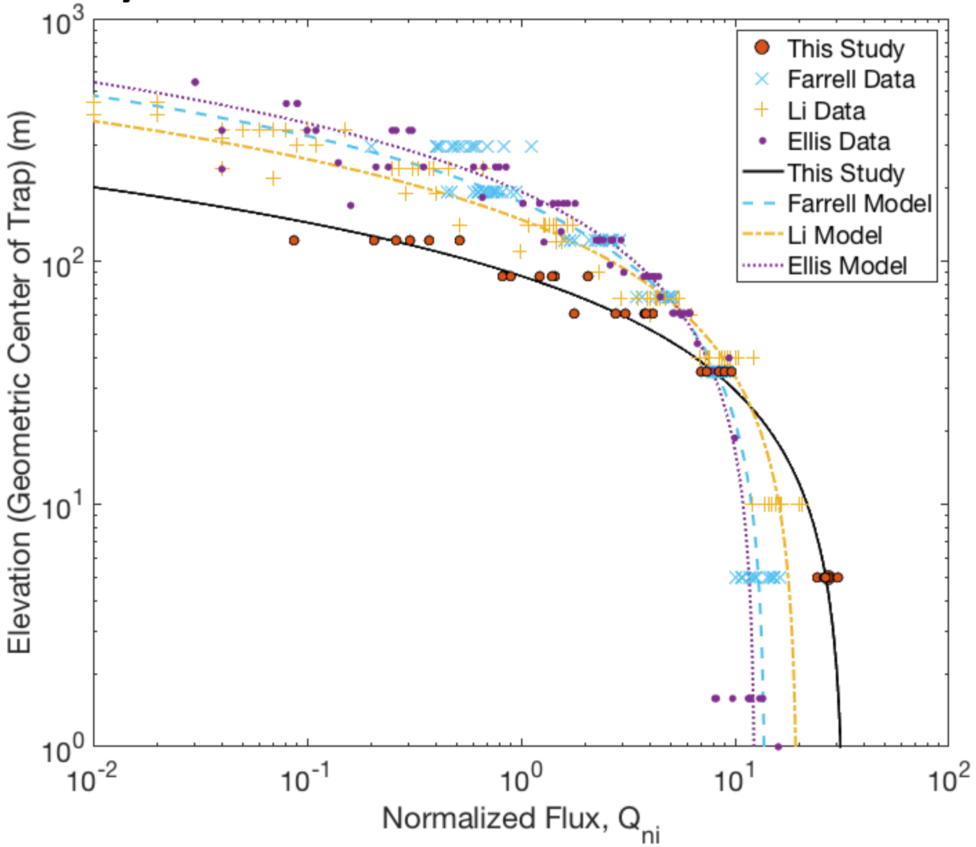
- **61 – 76%** of total transport occurs below 2.5 cm for the **wet** surface
- Transport over dry surfaces show much lower estimates

Percent of transport below 2.5 cm for **dry** surfaces:

- 32-36% Ellis et al. (2009)
- 37-52% for Farrell et al. (2012)
- 42-63% for Li et al. (2009)
- (note percentages are calculated from normalized flux)

Note: Elevation is on the y axis





Saltation Profile Comparison: This study versus profiles over dry surfaces

Comparison to saltation profiles over dry surfaces reveals more transport a lower heights

- Saltation profiles follow an exponential function (Ellis et al. 2009)

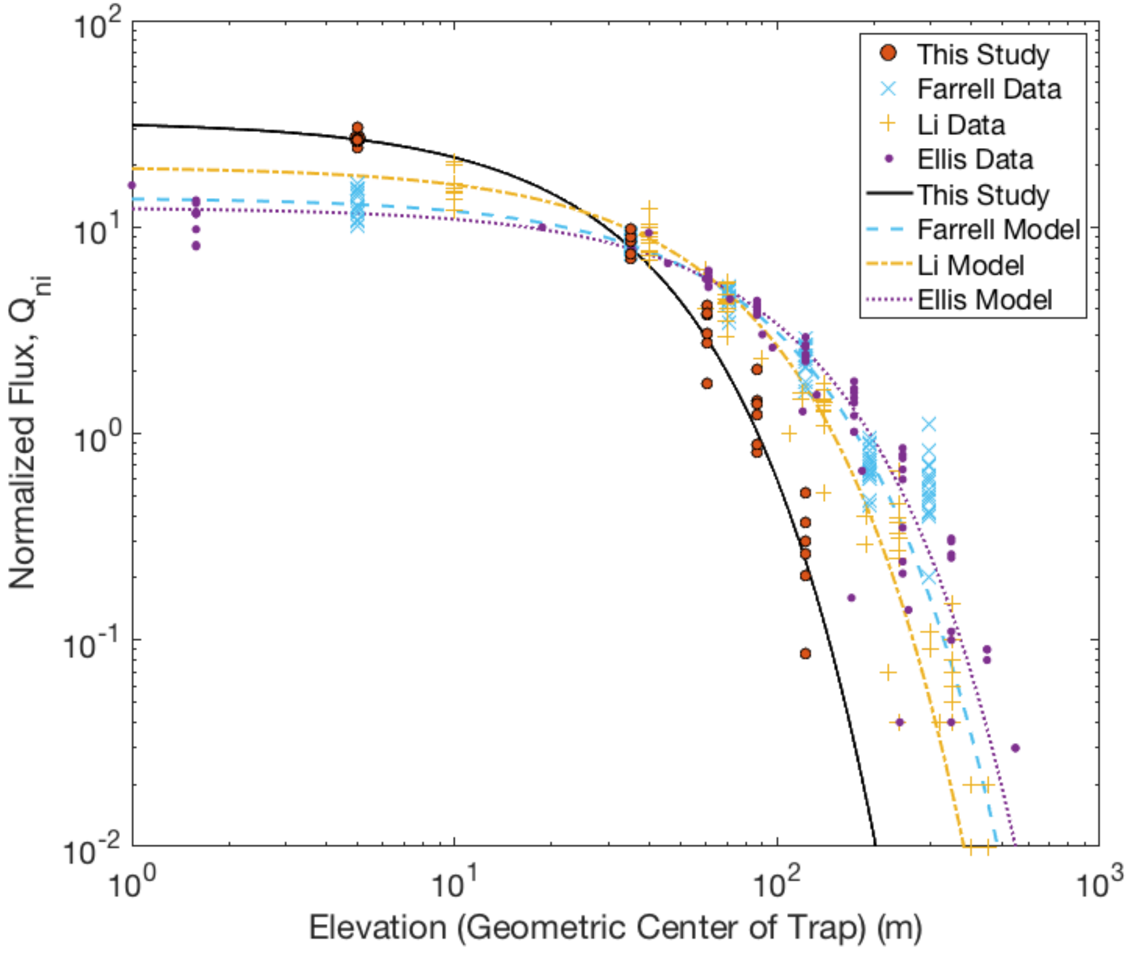
$$Q_{ni} = \alpha e^{\beta h}$$

- Larger portion of flux occurring below 2.5 cm
- Possibly due to smaller grain size of particles in this study (see Table)
- Possibly due to wet particles in motion having more mass from absorbed water/films – thus, saltation trajectories are altered

Empirical Coefficients for Exponentional Expression of Saltation Flux

	d (mm)	α	β	R^2	Site Characteristics
Ellis et al. (2009): Dry Sand	0.39	12.41	-0.013	0.93	Flat, sand Sheet
Farrell et al. (2012): Dry Sand	0.26-0.35	13.86	-0.015	0.96	Dry rippled surface
Li et al. (2009): Dry Sand	0.27 - 0.35	19.57	-0.02	0.96	Near top of large parabolic
This Study: Wet Sand (14-16%)	0.17	32.41	-0.04	0.99	In swash zone

Field-derived saltation profiles
Wet vs. Dry Surfaces



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