Field measurements of near-surface soil moisture content to validate and inform aeolian sediment transport models

Savannah DeVoe[1,2] & Nicholas Cohn[2]

1. ORISE Postdoctoral Fellow; Correspondence: savannah.devoe@unh.edu
2. Coastal and Hydraulics Laboratory — Field Research Facility, U.S. Army Engineer Research and Development Center, Duck, NC, USA

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BACKGROUND

Aeolian (wind-driven) sediment transport:

- Can contribute to significant morphological change in coastal regions[1].
- Provides a potential mechanism for transport from the intertidal zone to the dune[2-3].
- Can be limited by the amount of moisture present in surficial & near-surface sediments[4-6].

Above: Bedforms generated by wind on the foreshore at the FRF.

BUT: There are few comprehensive observations of surface moisture content (MC), groundwater (GW), & swash dynamics to inform aeolian transport modeling on the foreshore & in the subaerial zone[7-10].

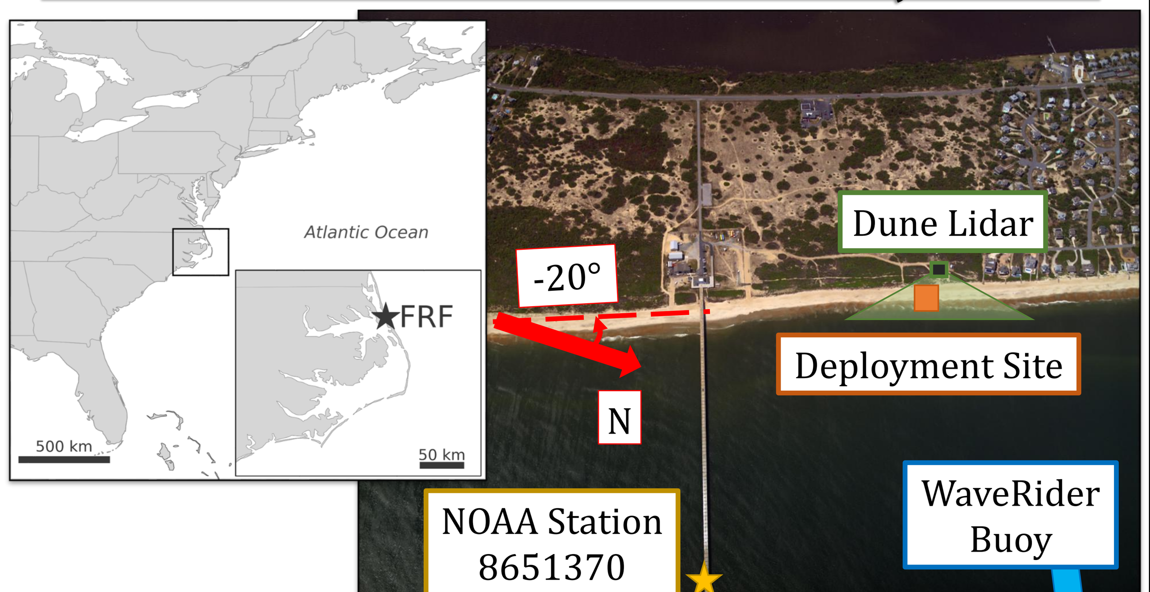
OBJECTIVE

To characterize spatiotemporal MC patterns & mechanisms driving MC variability on a dynamically complex, intermediate beach.

Because MC serves as a first-order control on sediment availability for wind-driven sediment transport, improved MC parameterization will improve aeolian flux estimations in coastal systems[3, 4, 6, 11].

METHODS

FIELD RESEARCH FACILITY — DUCK, NC USA

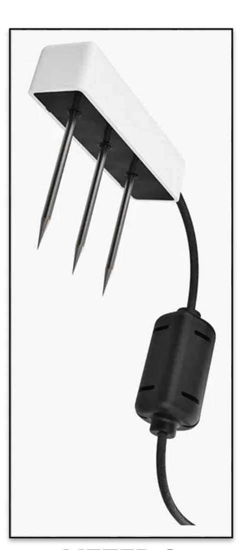


Source: NOAA Coastal Imagery Viewer

FRF Data:

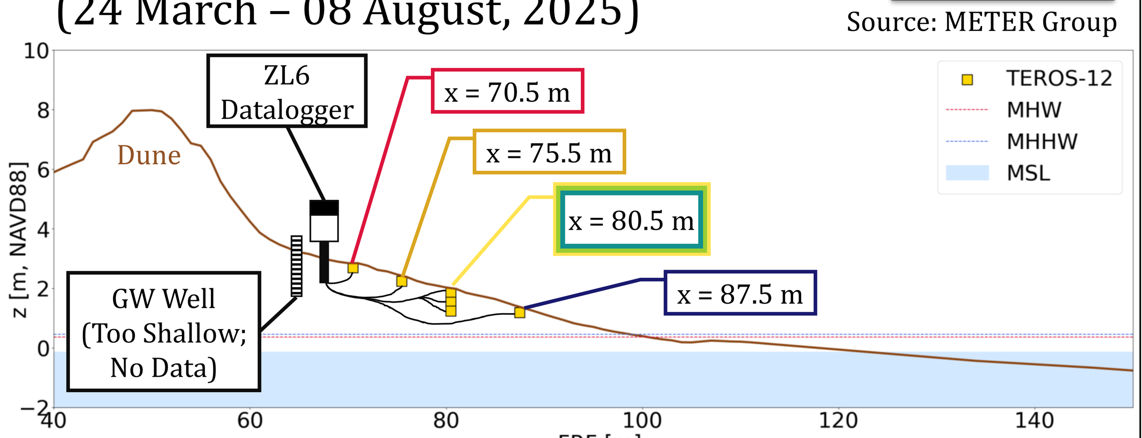
- $H_{o,perp}$ & T_p: Significant Wave Height (shore-normal) & Peak Period at ~26 m depth (deep water)
- Beach Profile; Digital Elev. Model; Runup; TWL: Total Water Level
- SWL: Still Water Level; u_w & ϕ_w: Wind Speed & Direction; Rainfall (cumulative in 10 min. period); T_{air} & P_{air}: Air Temperature & Pressure; Relative Humidity; Solar Radiation

FIELD DEPLOYMENT



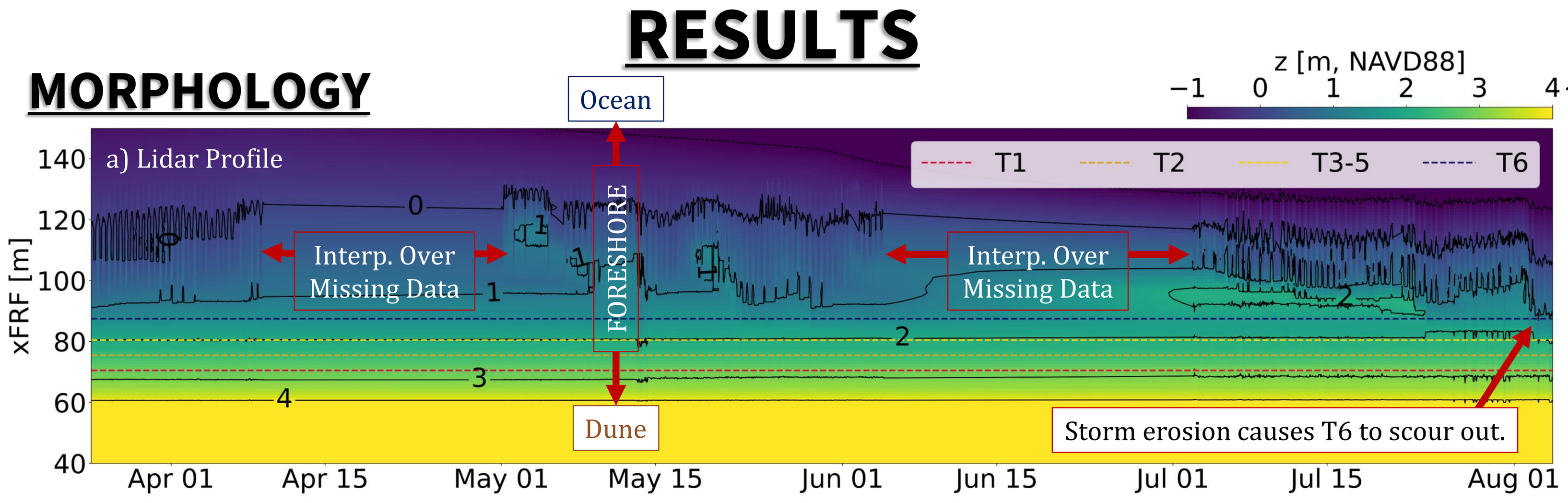
Source: METER Group

- (6) METER Group TEROS-12 MC, temp., & electrical conductivity sensors:
  - (4) Near-surface (<10 cm depth) cross-shore array: T1, T2, T3, T6
  - (2) Additional subsurface (30 & 50 cm depths) vertical array: T4, T5
- 4 months of data sampled at $dt = 60\ s$ (24 March – 08 August, 2025)

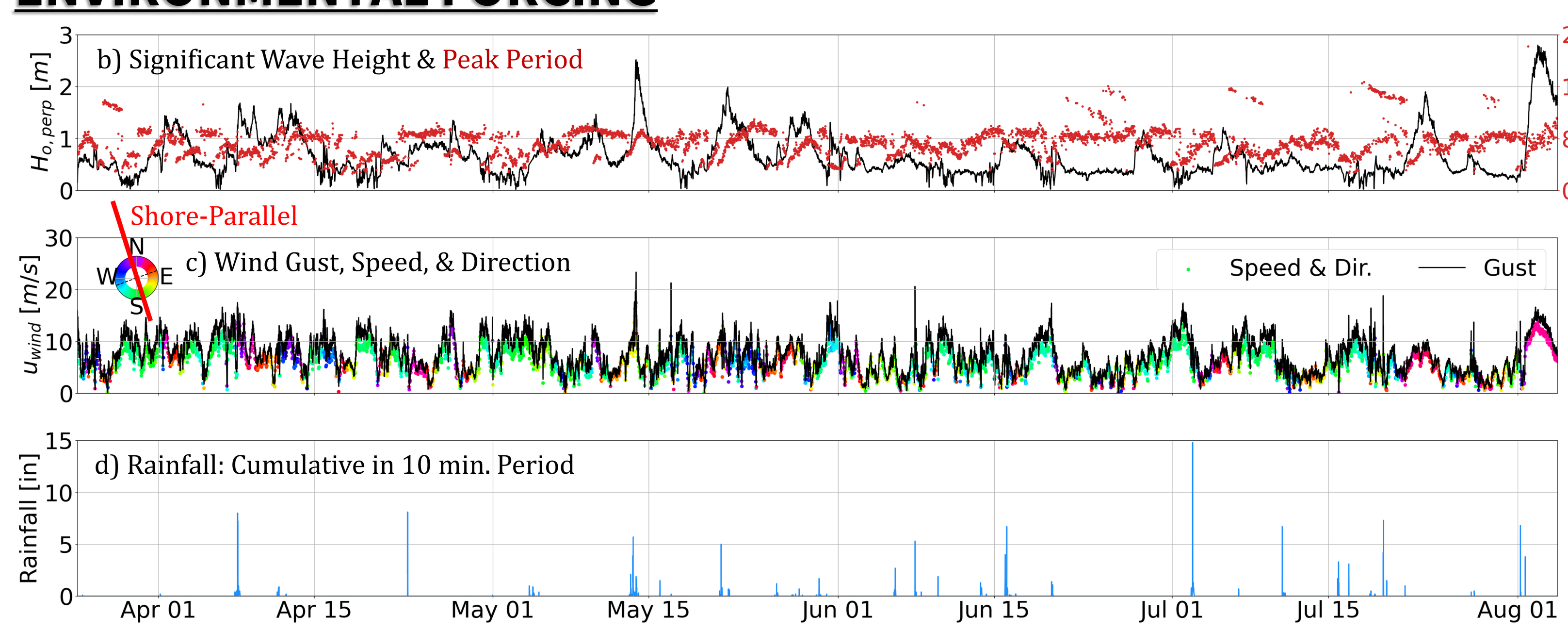


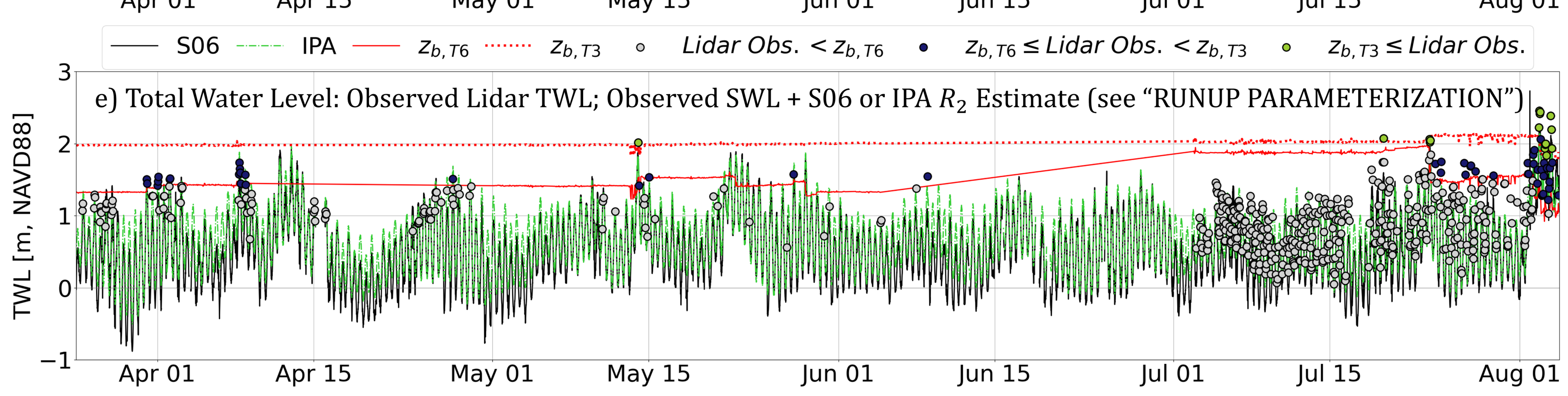
RESULTS

MORPHOLOGY

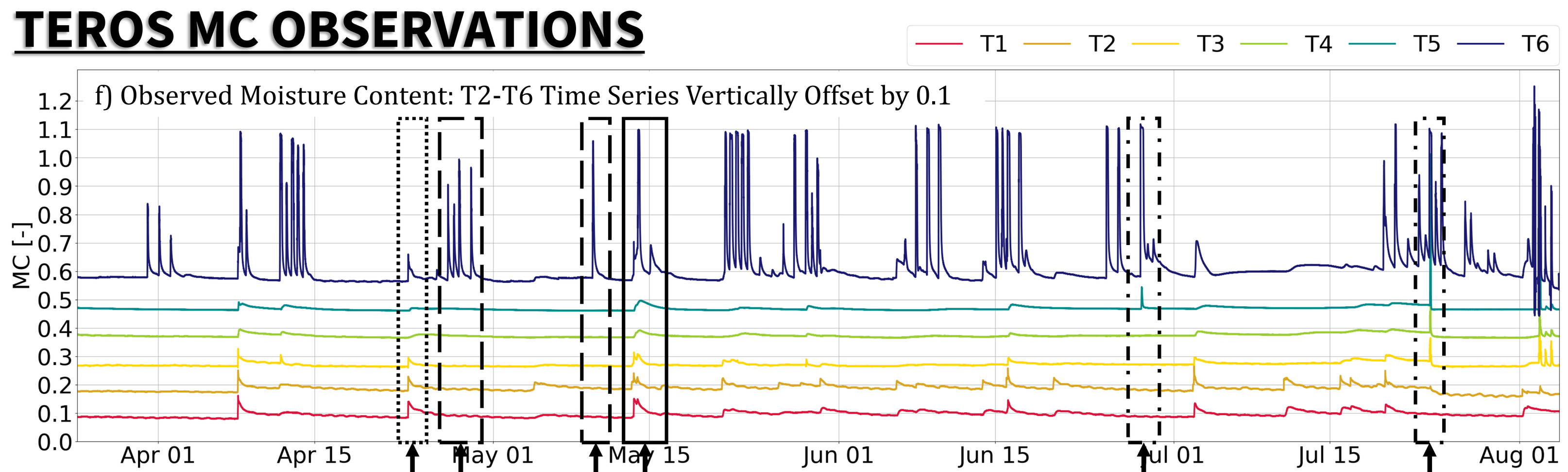


ENVIRONMENTAL FORCING





TEROS MC OBSERVATIONS



RAINFALL & INFILTRATION	RUNUP/TWL EXCEEDANCE	COMBINED EFFECTS	GROUNDWATER OSCILLATIONS
MC increases at all surface sensors; infiltration when MC also increases at subsurface sensors.	MC only increases at specific sensor when TWL exceeds sensor elevation.	MC increases at all sensors when runup, rainfall, and/or GW oscillations present.	MC increases at subsurface sensor(s), but NOT surface sensors.

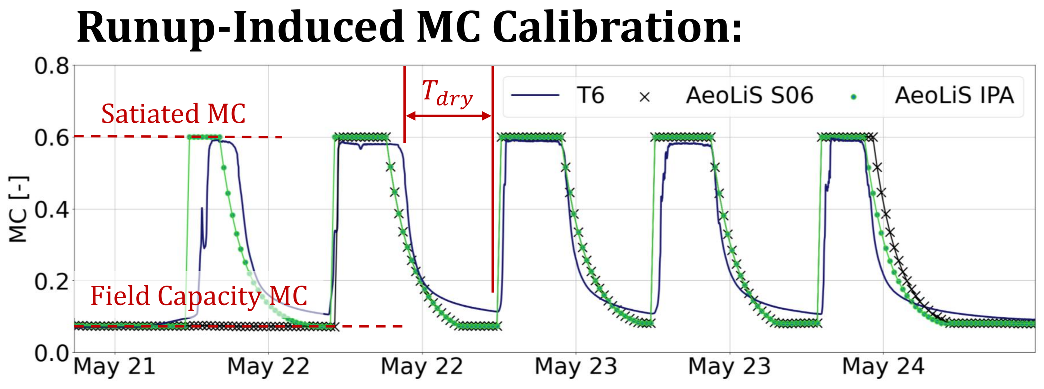
TAKE-AWAY: Mechanisms Driving MC Variability

AeoLiS MODELING

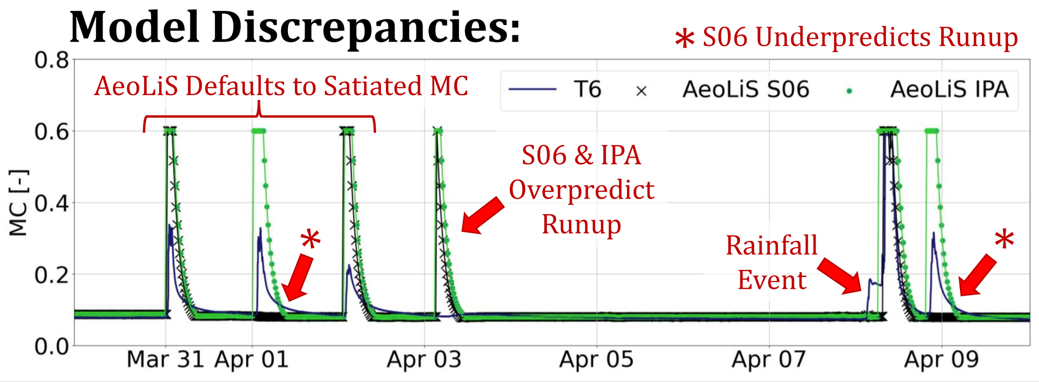
- Process-based, supply-limited aeolian transport model[3, 6, 12, 13, 14].
- Simulation performed using env. forcing from deployment, with both S06 & IPA runup; $\overline{\beta_f} = 0.08$ (see "RUNUP PARAMETERIZATION").

About AeoLiS:

Runup-Induced MC Calibration:



Model Discrepancies:

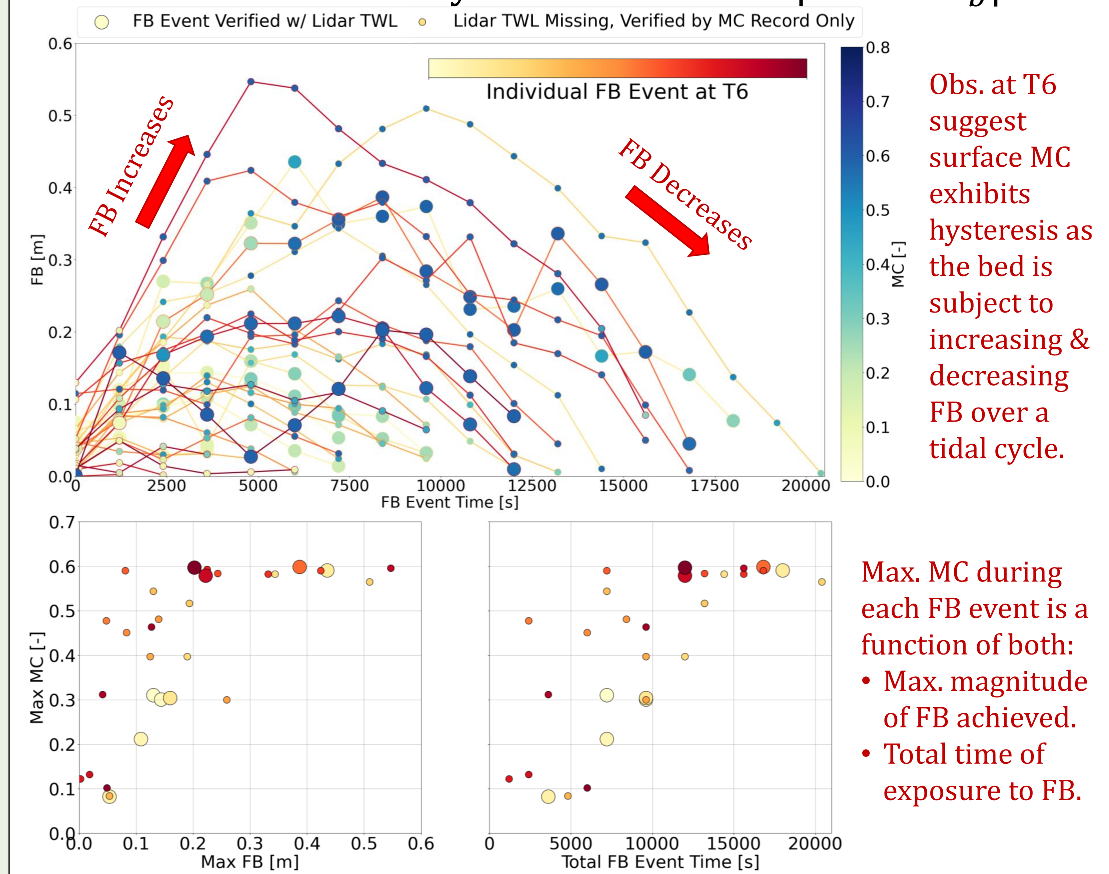


TAKE-AWAYS:

- **FRF drying curve timescale (T_{dry}~5,000 s or 1.4 hr) consistent w/ other sites.**
- When calibrated, **AeoLiS does a good job of replicating overall swash zone MC dynamics.**
- Model **errors occur due to over/under-prediction of empirical runup** & not accounting for freeboard event dynamics.

FREEBOARD EVENTS

Freeboard events occur when TWL > z_b (bed elevation), & the bed becomes locally inundated. FB = |TWL − z_b|.



TAKE-AWAY:

Max. MC at z_b is proportional to the magnitude & time of freeboard present above z_b.

R_2 RUNUP PARAMETERIZATION

AeoLiS Default: Stockdon Equation ("S06")[15]:

$$(1)\ R_2 = \begin{cases} 1.1\left(0.35\beta_f (H_o L_o)^{0.5} + \frac{\left[H_o L_o\left(0.563\beta_f^2 + 0.004\right)\right]^{0.5}}{2}\right), & \xi_o \geq 0.3 \\ 0.043(H_o L_o)^{0.5}, & \xi_o < 0.3 \end{cases}$$

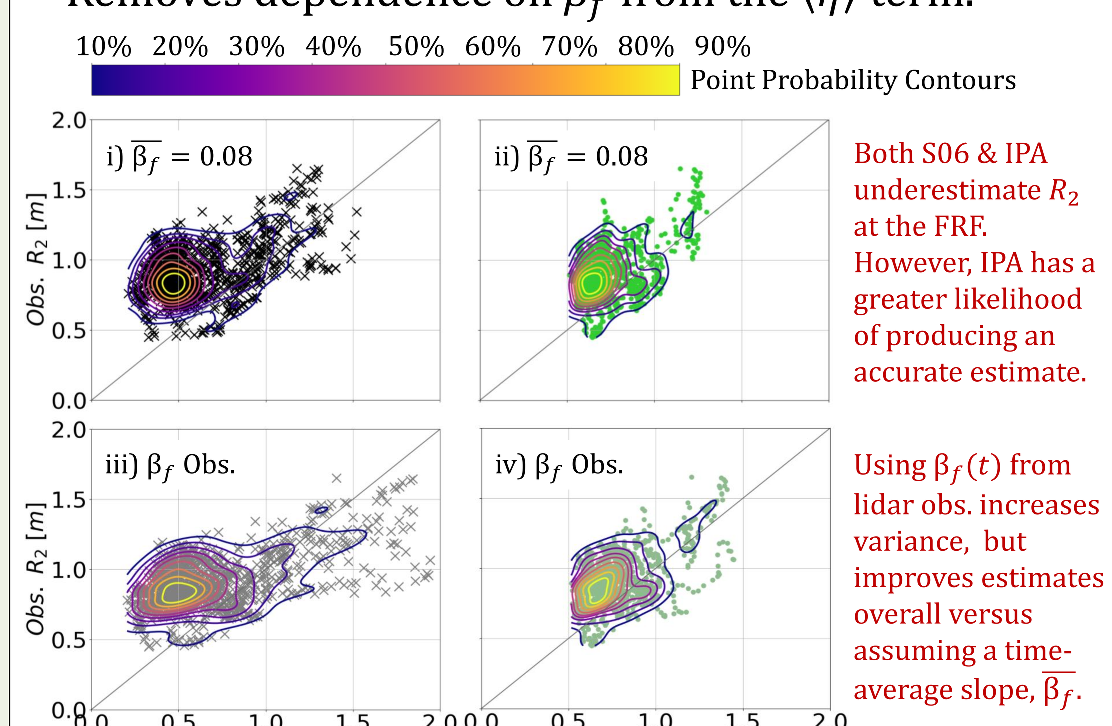
- Setup, $\langle\eta\rangle$, & sea-swell, (SS) = f(beach slope, β_f).
- Empirical approximation, so doesn't always result in accurate representation of swash dynamics.

Has implications for predictions of aeolian processes.

Integrated Power Approximation ("IPA")[16]:

$$(2)\ R_2 = 0.27 \int_{SS} E(f)^{0.25} f^{-1} df + 2\left[\left(0.60\beta_f^2 + 0.010\right)\int_{SS} E(f)^{0.5} f^{-2} df\right]^{0.5}$$

- Broader picture of incident wave climatology.
- Removes dependence on β_f from the $\langle\eta\rangle$ term.



TAKE-AWAY:

IPA (or other empirical approaches) **could improve AeoLiS MC predictions by improving R_2 estimates.**

ONGOING WORK

Possible incorporation into AeoLiS:

- Infiltration corrections to estimate MC at depth based on surface value.
- Effect of both magnitude of & time of exposure to FB on maximum MC.
- Further coupling with GW dynamics.

REFERENCES & DIGITAL POSTER COPY: