Aeolian sediment transport on a wet beach

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### Research Question:

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

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1. **Saltation height, speed & flux change with surface moisture content**

- Saltation height, speed, and 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; Davidson-Arnott et al. 2005; Davidson-Arnott and Bauer, 2009; Delgado-Fernandez et al. 2011; Han et al., 2011; Nield and Wiggs, 2011; de Vries et al. 2014]

2. **Over wet surfaces, laboratory and field studies have found conflicting results**

   - Saltation height and/or total flux increases over a wet surface as particles retain more of their energy upon impact/rebound [van Dijk et al. 1996; McKenna-Neuman and Scott, 1998]

   - Saltation flux increases ultimately from impact-driven transport – results in highly intermittent transport [Davidson-Arnott et al. 2005]

   - Saltation flux decreases due to limited availability of sediment to move (too wet) – can also drive intermittency [Davidson-Arnott and Bauer, 2009; Delgado-Fernandez et al. 2011]

   - Saltation flux decreases because saltators become trapped by wet surfaces [Han et al. 2011]

   - Moisture content of 2% has little to no impact on transport flux [Wiggs et al. 2004]

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Here, we aim to measure saltation concentration profiles & flux in the intertidal zone during a falling tide.

What will we see in the field?

Wind Tunnel Observations
Han et al., 2011 - Figure 7
**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

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

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

Saltation Concentration Profiles
- Vertical Array of Saltation Traps

Tropical Storm Nestor position during data collection

Passage of Tropical Storm Nestor (0600-0730 hours)
Sonic Anemometers
z = 72 cm
z = 51 cm

Vertical Array of Traps ($h_{ti}$)
z = 15 cm
z = 10 cm
z = 7.5 cm
z = 5.0 cm
z = 2.5 cm

Range of runup (1 – 5 m seaward of Instrument Array)

Vertical Array of Cup Anemometers
z = 93.5 cm
z = 68.0 cm
z = 44.0 cm
z = 18.0 cm
z = 7.00 cm

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Field Observations

- Wind Direction aligned with beach orientation
- Nested streamers: 5 to 20 cm
- Wet beach: 14-16%
- 6, 5-minute runs passed QA/QC

LINK TO VIDEO (Run 4): https://drive.google.com/open?id=1JSvhteyCQssvepGrnFrhVJ8BnN3Z2R

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Cup Anemometer & Flux Data

Strong winds & transport during the passage of Tropical Storm Nestor

- R1, R3, R4: Sustained speeds @ 93 cm of 10 m/s
- R5: Slowest speeds
- 5-minute $u_*$ ranged from 0.27 m/s (R5) to 0.49 m/s (R4)
- R4: Largest transport rate

Sediment Trap Data

R1: $\bar{u}_* = 0.39 \text{ m/s}$
$q = 3.57 \text{ g/m/s}$

R3: $\bar{u}_* = 0.35 \text{ m/s}$
$q = 3.68 \text{ g/m/s}$

R4: $\bar{u}_* = 0.49 \text{ m/s}$
$q = 19.98 \text{ g/m/s}$

R5: $\bar{u}_* = 0.27 \text{ m/s}$
$q = 2.47 \text{ g/m/s}$

R6: $\bar{u}_* = 0.35 \text{ m/s}$
$q = 7.18 \text{ g/m/s}$

R7: $\bar{u}_* = 0.32 \text{ m/s}$
$q = 8.37 \text{ g/m/s}$

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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 Dimensions

<table>
<thead>
<tr>
<th>10 cm</th>
<th>5.0 cm</th>
<th>2.5 cm</th>
<th>2.5 cm</th>
<th>2.5 cm</th>
<th>2.5 cm</th>
<th>25 cm</th>
</tr>
</thead>
</table>

Wind Direction

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Saltation Trap Data

Grain population consistent between trap and swash zone grab samples

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

<table>
<thead>
<tr>
<th>Grain Size (mm)</th>
<th>Trap</th>
<th>Geometric Center of Trap</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.20</td>
<td></td>
<td>5.0 cm</td>
</tr>
<tr>
<td>8.70</td>
<td></td>
<td>2.5 cm</td>
</tr>
<tr>
<td>6.10</td>
<td></td>
<td>2.5 cm</td>
</tr>
<tr>
<td>3.50</td>
<td></td>
<td>2.5 cm</td>
</tr>
<tr>
<td>5.00</td>
<td></td>
<td>2.5 cm</td>
</tr>
</tbody>
</table>

Cup Heights

- R1: 93 cm
- R3: 68 cm
- R4: 44 cm
- R5: 18 cm
- R6: 7.0 cm
- R7: 7.0 cm

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Saltation Trap Data

Normalized Flux, $Q_{ni}$:

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

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

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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

Moisture content varied with height:
- R4: 14.99% moisture consistent with surface moisture (14-16%)
- Suggests the surface was active in the saltation process, i.e. the surface was not simply a passive surface that particles were transporting over, but actually mobile
- Surface eroded by 0.5 cm reduction in surface height (between 0600 and 0730 hours)

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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

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Saltation Profile Comparison: Saltation profiles over wet vs 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

Note: Same plot as (A) – here with log axes

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Comparison to saltation profiles over dry surfaces reveals more transport at 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 over wet surface
- 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

Field-derived saltation profiles: Wet vs. Dry Surfaces

<table>
<thead>
<tr>
<th>Site Characteristics</th>
<th>d (mm)</th>
<th>α</th>
<th>β</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ellis et al. (2009) modified: Dry Sand</td>
<td>0.39</td>
<td>12.41</td>
<td>-0.013</td>
<td>0.93</td>
</tr>
<tr>
<td>Farrell et al. (2012): Dry Sand</td>
<td>0.26-0.35</td>
<td>13.86</td>
<td>-0.015</td>
<td>0.96</td>
</tr>
<tr>
<td>Li et al. (2009): Dry Sand</td>
<td>0.27 - 0.35</td>
<td>19.57</td>
<td>-0.02</td>
<td>0.96</td>
</tr>
<tr>
<td>This Study: Wet Sand (14-16%)</td>
<td>0.17</td>
<td>32.41</td>
<td>-0.04</td>
<td>0.99</td>
</tr>
</tbody>
</table>

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Tropical Storm Nestor position during data collection

Data Acquisition System

- Instrument Array
  - Gravimetric Moisture Content
    - Surface Samples
      - Upper Beach
      - Swash Zone
    - Vertical Array of Saltation Traps
  - Wind Observations
    - 3D Velocity Fluctuations via Sonic Anemometers
    - Vertical Array of Cup Anemometers
    - Saltation Concentration Profiles
      - Vertical Array of Saltation Traps

Field Observations

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