

Near-Surface Variability of Shear and Compression Wave Speeds due to Wet/Dry Cycles

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Introduction

- About The Project
- Common Knowledge & Assumptions
- Terminology
- Objectives

Method

- Experimental Set-Up
- Analytical Tools and Methods
- Quantifications

Experimental Results

- Analysis of S-Wave
- Analysis of P-Wave
- Conclusions & Suggestions

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- ▶ Ph.D. Candidate, Department of Mathematics, Purdue University
- ▶ Dynamic Inverse Problems, X-ray Tomography, Scattering Theory
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- ▶ Collaboration between ERDC-GSL and ERDC-CRREL laboratories
- ▶ Experimental design and data acquisition have been conducted by Oliver Taylor and Amy Cunningham (ERDC-GSL) as well as general methodology of the experiment
- ▶ ERDC-CRREL provides analytical and statistical tools to analyze the seismic data
- ▶ Wet/dry cycles on sand lead to different V_p and V_s

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- ▶ Wet/dry cycles on sand lead to different V_p and $V_s \rightarrow$ **GOAL**
Quantify the degree of variability for different saturations

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- ▶ As a consequence, Shear and Compression wave speeds are the same for the same conditions

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- ▶ **Unconfined sand:** Represent natural setting for near-surface seismic propagation

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- ▶ Quantify the degree of variability through the non-parametric probability density function estimates: Unconditional and moisture content conditional scenarios

Set-Up

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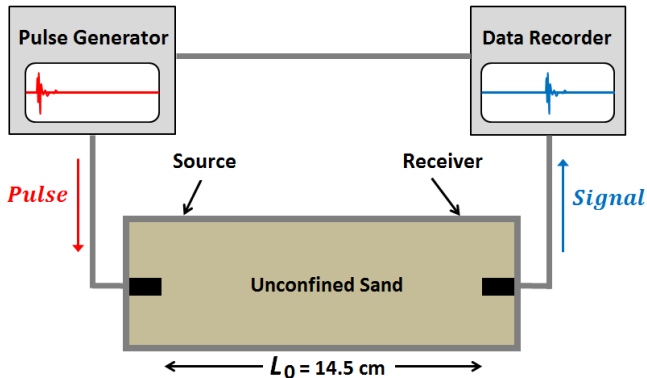
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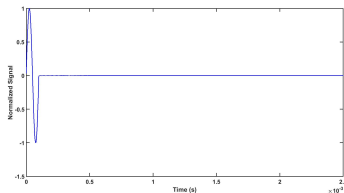
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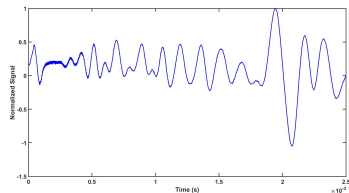
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(a) Source Signal



(b) Received Signal

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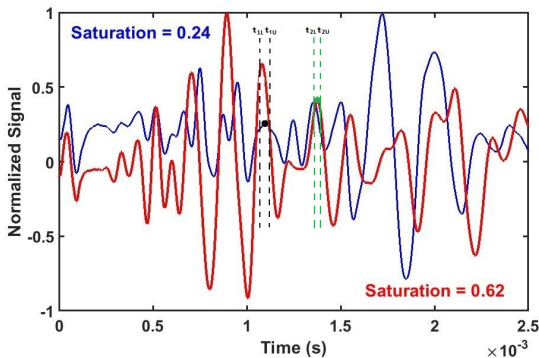
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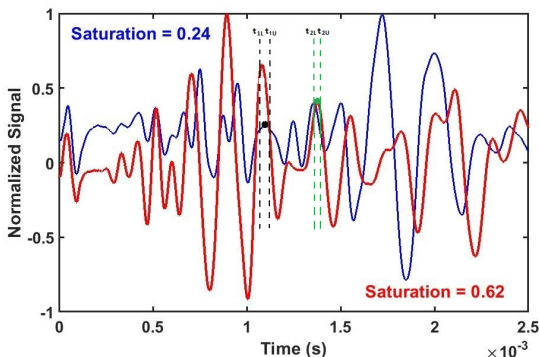
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- ▶ Consider two reference points for $V_{s_i}^{ref}$ and find the corresponding travel time via $t_i = \frac{L_0}{V_{s_i}^{ref}}$ for $i = 1, 2$,
- ▶ Identify the corresponding time intervals around the travel time t_i where the exact peaks at each saturation reference points $Sat_1 = 0.24$ and $Sat_2 = 0.62$ occur

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- Interpolate the boundaries of intervals via

$$\tau_L(Sat) = t_{1L} + \frac{t_{2L} - t_{1L}}{Sat_2 - Sat_1} (Sat - Sat_1)$$

$$\tau_U(Sat) = t_{1U} + \frac{t_{2U} - t_{1U}}{Sat_2 - Sat_1} (Sat - Sat_1)$$

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Calculate V_p :

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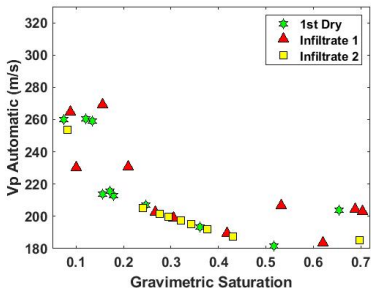
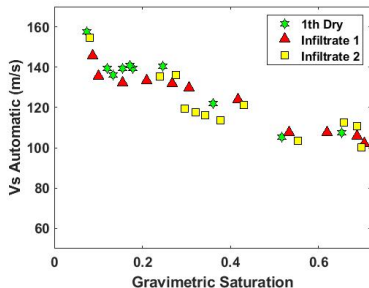
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- ▶ **Cross-validation:** Choose the bandwidth to maximize the likelihood function of data occurrence

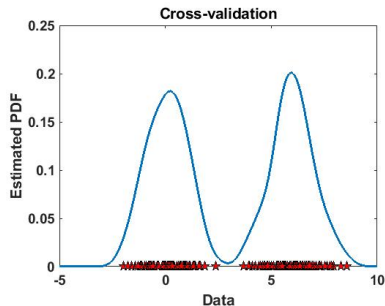
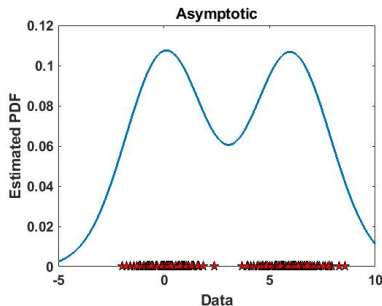
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- ▶ Generate an artificial data from 2 Gaussian distributions with different means specifically with no overlap

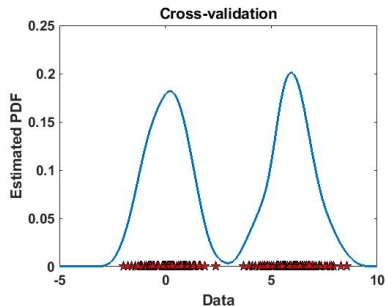
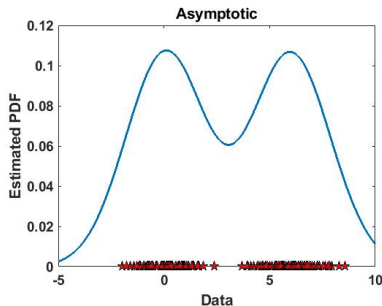
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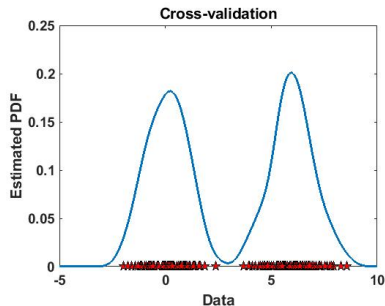
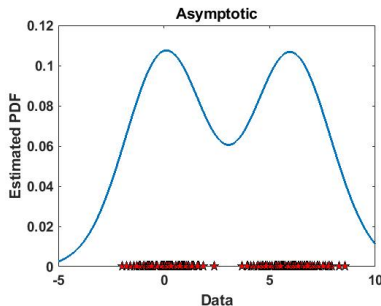
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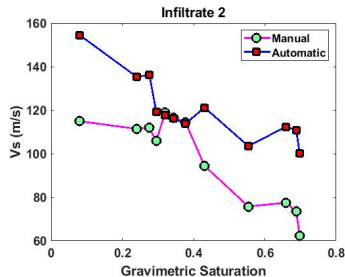
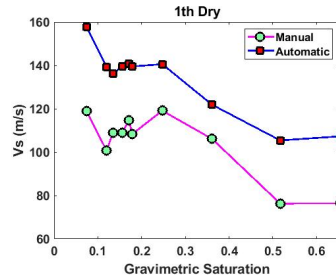
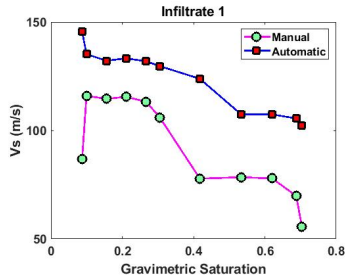


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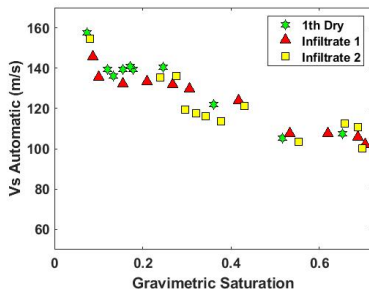
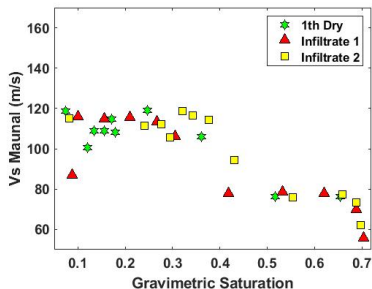
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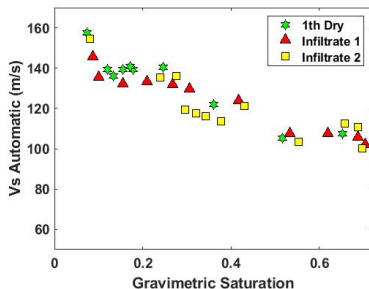
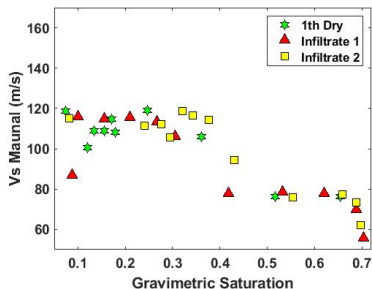
- ▶ Cross-validation provides a better PDF estimates for the bimodal distribution



S-wave Velocities: Manual vs Automatic

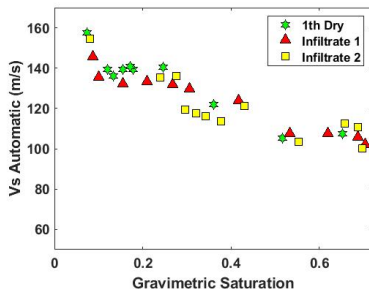
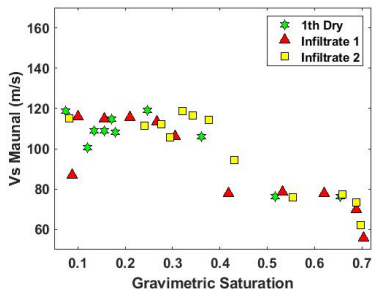


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- ▶ Ultimate goal is to quantify the variability at each saturation level
- ▶ Not feasible due to lack of data

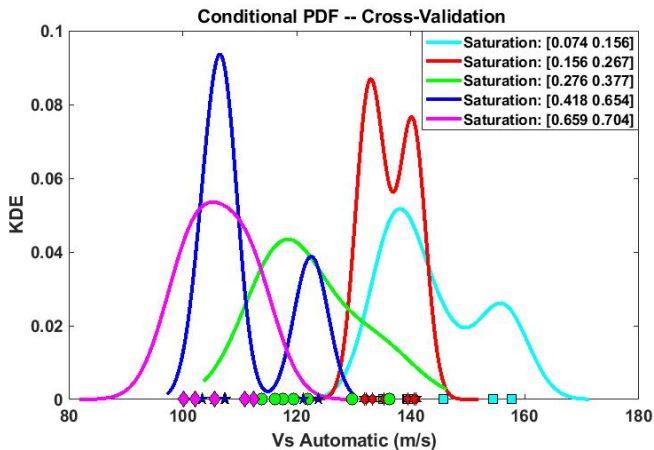
Conditional Moisture Content

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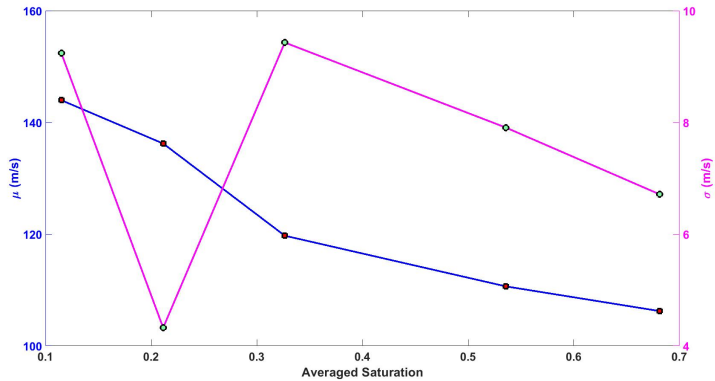
- ▶ Separate the whole saturation levels into 5 bins (intervals)

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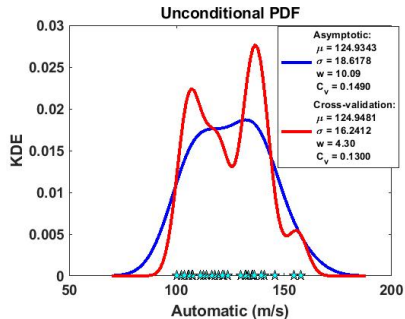
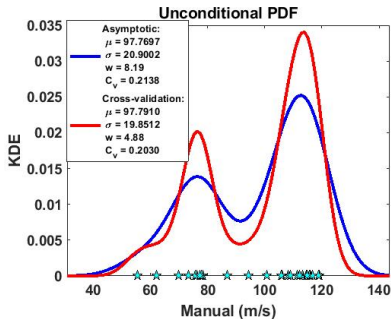
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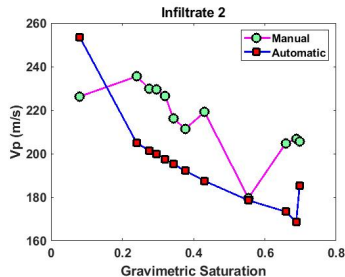
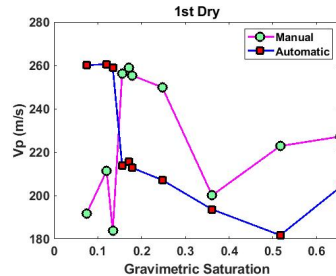
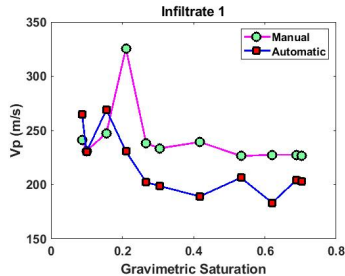


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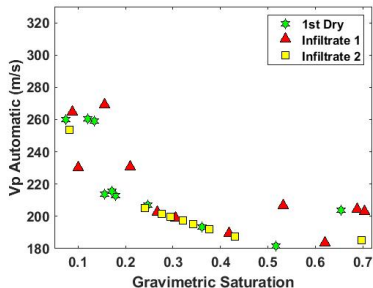
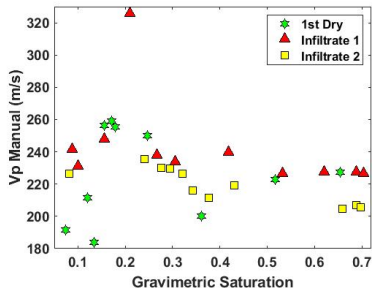


Unconditional PDF: Manual vs Automatic

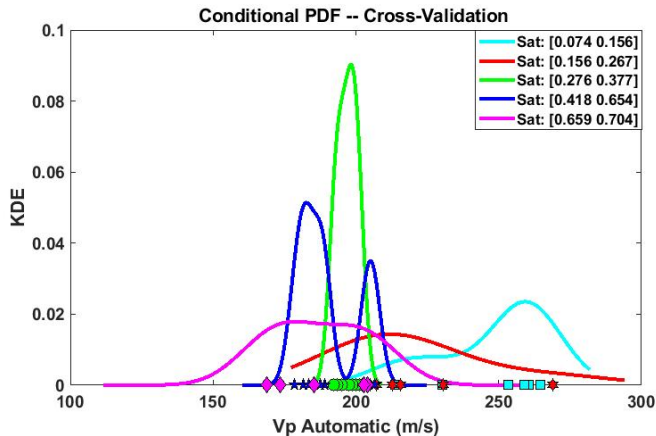




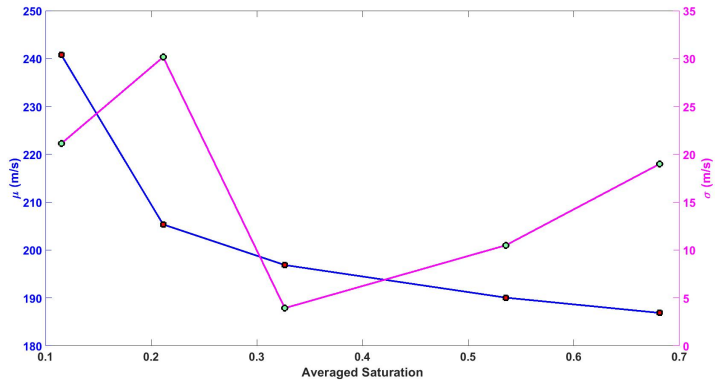
P-wave Velocities: Manual vs Automatic



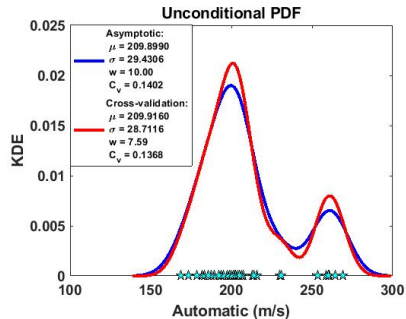
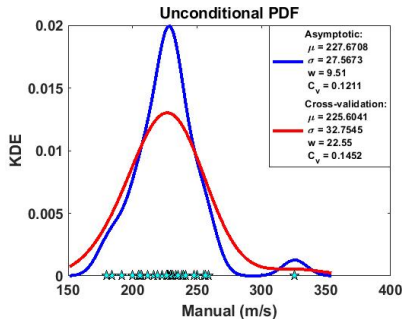
Conditional Moisture Content



Conditional Moisture Content



Unconditional PDF: Manual vs Automatic



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- ▶ Conditional (binned) variability of S-wave, $\%2 \leq C_v \leq \%14$ which is less consistent

Suggestions

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- ▶ Run the experiment on a larger scale cube to reduce the noise on V_p and V_s recording

Acknowledgement

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Thank you

THANK YOU!