Attribution Concepts for Sub-meter Resolution Ground Physics Models

76th MORS Symposium
US Coast Guard Academy

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1. **REPORT DATE**  
   **01 JUN 2008**

2. **REPORT TYPE**  
   **N/A**

3. **DATES COVERED**  
   **-**

4. **TITLE AND SUBTITLE**  
   **Attribution Concepts for Sub-meter Resolution Ground Physics Models**

5a. **CONTRACT NUMBER**  
5b. **GRANT NUMBER**  
5c. **PROGRAM ELEMENT NUMBER**

6. **AUTHOR(S)**

7. **PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**  
   **US Coast Guard Academy**

8. **PERFORMING ORGANIZATION REPORT NUMBER**

9. **SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)**

10. **SPONSOR/MONITOR’S ACRONYM(S)**

11. **SPONSOR/MONITOR’S REPORT NUMBER(S)**

12. **DISTRIBUTION/AVAILABILITY STATEMENT**  
   **Approved for public release, distribution unlimited**

13. **SUPPLEMENTARY NOTES**  

14. **ABSTRACT**

15. **SUBJECT TERMS**

16. **SECURITY CLASSIFICATION OF:**  
   **a. REPORT**  
   **unclassified**
   **b. ABSTRACT**  
   **unclassified**
   **c. THIS PAGE**  
   **unclassified**

17. **LIMITATION OF ABSTRACT**  
   **UU**

18. **NUMBER OF PAGES**  
   **20**

19a. **NAME OF RESPONSIBLE PERSON**

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*Standard Form 298 (Rev. 8-98)*  
*Prescribed by ANSI Std Z39-18*
Focus for ERDC R&D
In Military Engineering

Adaptive Maneuver and Protection
Developing Solutions Faster Than The Threat Can Adapt

Collaborators - Stakeholders - Partners
Academia  Warfighters  Government Labs  Industry

Protection

• Multi-Use Integrated Materiel Solutions
• Engineer Assessments
• Phenomenological Understanding

Maneuver

Integrated Adaptive Warfighter Solutions
• Adaptive Protection
• Scalable Weapons Effects
• Near Surface Computational Testbed
• Austere Entry and Maneuver

High Performance Computational Testbeds

First-Principles Phenomenology
Emerging Materials
Multi-Scale Physics
Near Surface Physics

Experimental Characterization & Validation  Multi-Scale Modeling  Scene Generation

ARMY STRONG – ENGINEER READY
Virtual Autonomous Navigation Environment (VANE)

Scene Generation Models
Colors, Stereo Images, Geology, Vegetation, Material Databases

Component Models
Vehicle Dynamics, Sensor, Power Requirements

Controlled, Repeatable Statistically Significant Performance Evaluations of Sensors and UMS Missions

Global and Local Data Fusion

Environment For Local Sensor Perception

Autonomous Tactical Behavior Evaluations

Accurate Local Sensor Evaluations

Sensor Designs and Evaluations of Autonomous Tactical Behaviors

Vegetation Models
Thermal, Geometry, Reflectivity, Ray Casting

Soil Models
Strengths, Moistures, Thermal, Electromagnetics

ARMY STRONG – ENGINEER READY
Historic Soils Dataset TR-08-2
14000 Records From 10 TR’s
Physical Properties of Soils,
Location, Attribution Consistent
with CTB Inputs
Geostatistical Data Needs

- How to Define Rocks within Strata
- Layering and Variance in Layers
- What are the Input Data correlations
- Correlations with Time and Distance
Spatial Distribution of Rocks In Soil Mass

Rocks are extracted and Highlighted in Red
Spatial Distribution of Rocks In Soil Mass

\[ \gamma(h) = 0.8324 \left( 1 - e^{-\left( \frac{h^2}{0.0924} \right)} \right) \]
Spatial Distribution of Rocks In Soil Mass

Vertical Locations of Rocks Are Extracted in the Same Manner
Spatial Distribution of Rocks
In Soil Mass

• Program to define distribution from digital photographs
  - Number of Rocks
  - Size
  - Location
  - Orientation
Low Moisture indicates Changes whose Spatial Structure is Random

However Density Variations were predictable
High Resolution Data

Read Field Data
Generate Matching SemiVariogram and Frequency For High Resolution Grid

Create Transitional Probability Matrix

Generate Multiple Realizations
Correlations for Missing Data

\[ k_s = C_3 \left( \frac{e^3}{1 + e} \right) \]

Field Measured Permeability

20 cm Depth

Surface

10 cm Depth

\[ k_s = C_2 D_{10}^2 \]
Layering Effect in Density and Porosity

- Number of Samples vs. Porosity
- Graph showing density and porosity layers
- Particle Size (mm) vs. Percent Finer
- Comparison of 20-cm Sample, Surface Sample, and Bulk Sample
ERDC research is now heavily focused on using high performance computing simulation testbeds.

Simulations like VANE involving sensor-terrain interaction will require relevant and realistically heterogeneous attributions for large scale, high resolution, numerical models.

- Techniques for characterizing spatial variability at multiple scales including sub-meter resolutions
- Techniques for populating sparsely measured attributions using material attribute correlations to densely measured attributions
Iterations and Residuals

Final Configuration

Conditional Matrix Match

Frequency Distribution

Number of Samples

Porosity

0 10 20 30

0.44 0.46 0.48 0.50 0.52 0.54
The Generation of Moisture & Density for Subsurface Changes.

Low Moisture indicates Changes whose Spatial Structure is Random

Density & Porosity Increase with Depth
Initial Soil Moisture From LSM and Satellites

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