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Preface

Geospatial technologies and geomorphological mapping

L. Allan James [a,*], Stephen J. Walsh [b], Michael P. Bishop [c]

[a] Department of Geography, University of South Carolina, United States
[b] Department of Geography, University of North Carolina, Chapel Hill, United States
[c] Department of Geology and Geography, University of Nebraska, Omaha, United States

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1. The symposium

The 41st International *Binghamton Geomorphology Symposium* (BGS) was hosted by the USC Geography Department at the University of South Carolina (USC), Columbia from October 15th to 17th, 2010. The BGS was convened to address the applications and capabilities of modern mapping technology and geospatial analyses to geomorphic science. The scientific basis for generating and understanding modern *digital geomorphic mapping* (DGM) was examined. For the sake of the symposium, the concept of DGM was interpreted broadly to extend well beyond static two- and three-dimensional digital representations. DGM is used here to include three-dimensionally distributed geo-referenced databases, the capabilities of dynamic visualization and virtual reality, remote sensing technologies and applications, geomorphometry and digital terrain modeling, landscape evolution models and other geospatial modeling systems, information-extraction technologies, and a variety of other modern subfields.

No previous BGS has specifically addressed the topic of geomorphic mapping and modern geospatial techniques. Nor, to our knowledge, has any other dedicated geomorphic conference. The time seemed right, therefore, for an integration and synthesis in this field. The need for standardized DGM data structures, tools, analytical protocols, visualization symbology, and reporting errors is growing rapidly as data and analytical systems proliferate. Digital systems that provide data and tools for geomorphic analysis and visualization, which may be referred to as *geomorphic decision support systems* (GDSS), are becoming more common. Even more common are broad-based decision-support systems (DSS) and spatial data clearinghouses that provide geomorphic data and analytical software along with other applications. These resources may provide spatial data and toolboxes that can be accessed remotely and used by a wide range of clients varying in technical or geomorphic training and proficiency. Thus, a coming together of scholars, scientists, and technicians, who routinely develop, provide, and use these data and products, is timely for the purpose of discussing standard procedures and formats and modern capabilities and limitations of these rapidly changing technologies.

2. Papers in this volume

The papers in this volume begin with a broad introduction by Bishop et al. that is followed by the convocation by Alan Howard that opened the Symposium and highlights the use of landscape evolution. Those papers are followed by a series of papers on methods of remote sensing including hyperspectral imaging, LiDAR (Light Detection and Ranging), microwave remote sensing, shallow geophysics, and river mapping. The next section is a series of papers that outline key areas of geographic information science including digital terrain modeling, geomorphometry, spatial and temporal analysis, concepts of scale, applications to snow modeling, and visualization. Finally, a list of posters presented at the Symposium is provided as Appendix A.

2.1. Introduction

Michael Bishop et al., in a paper titled *Geospatial Technologies and Digital Geomorphological Mapping: Concepts, Issues and Research*, provide a broad overview of a variety of developments, issues, and needs in several geospatial fields related to geomorphology. Advances in remote sensing, geographic information technology, and numerical modeling of surface processes have revolutionized geomorphic analyses (Bishop and Shroder, 2004). New data and methods permit Earth scientists to go beyond traditional mapping to diagnostic assessments and modeling of the surface to achieve an improved understanding of scale, patterns, and processes of features and systems. Early small-scale physiologic maps were highly influential because of their unique visualizations, but are theoretically obsolete. Thus, a resurgence of regional scale mapping is anticipated in the post-tectonic era using modern DGM methods that are reviewed at length. The authors point to the need for standardization of DGM data, methods, and formats, as well as the need to develop and apply theories of GIScience to DGM.

* Corresponding author.
E-mail address: AJAMES@mailbox.sc.edu (L.A. James).

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The Symposium opened with a presentation by Alan Howard, who has long been a pioneer in landscape evolution, simulation modeling, titled *Taking the Measure of a Landscape*: *Comparing Simulated and Natural Landscapes in the Virginia Coastal Plain*, *USA*. Howard simulates the evolution of the Potomac River in Virginia over 3.5 Ma. Difficulties of applying landform evolution modeling (LEM) to a specific landscape are acknowledged, especially in vegetated low-relief regions where base-level changes are involved. The solution here is to generalize hillslope processes, focus on the fluvial system, and incorporate sea level rise and fall over millennial time scales juxtaposed on long-term epeirogenic uplift. The timing of sea level changes is inferred from the oxygen isotope record. The Mars Simulation model (Marssim) is utilized with rock weathering, mass wasting, fluvial detachments, and fluvial transport and deposition components for which the governing functions are briefly outlined. A large number of geomorphometric parameters were measured to compare natural and simulated landscapes for model calibrations and evaluations of results.

2.2. Remote sensing

Fred Kruse, *Mapping Surface Mineralogy Using Imaging Spectrometry*, describes the status of hyperspectral imaging (HSI) and how it can be used for mapping surface mineralogy. Historically, landform identification has been performed dominantly through the use of topographic data; e.g., DEMs, yet the underlying processes are controlled, in part, by structures and geologic materials. Hyperspectral remote sensing (spectrometry) can and should play a more important role in geomorphic mapping. Key spectral signatures of iron, clay, silicate, carbonate, sulfate, and other minerals, can be accurately identified while precisely recording their geographic locations. These capabilities of spectrometry are ideal for the purposes of geomorphic mapping and can be combined with InSAR, LiDAR, or DEM data to enhance interpretability and accuracy of geomorphic and geologic maps. Case histories are presented using HSI with DEMs as visualization tools to improve structural maps, identify sediment sources, and distinguish between relict and active hydrothermal systems.

Remke Van Dam, *Landform Characterization Using Geophysics — Recent Advances*, *Applications*, *and Emerging Tools*, outlines the modern capabilities of shallow geophysical sensors for terrestrial subsurface mapping. Modern developments, strengths, and weaknesses are described for ground penetrating radar (GPR), electrical resistivity (ER), seismicity, and electromagnetic (EM) induction. New developments include multi-offset systems in GPR, multi-electrode systems and time lapse monitoring in ER, and the use of plane-wave EM induction for landform studies. Passive sensing and the use of multiple methods are also discussed. Three case studies illustrate potential uses of some methods: patterned ground in Michigan, glaciotectonic deformation in Michigan, and aeolian dune structures in New Zealand.

The paper by Patrice Carbonneau et al. – read by Mark Fonstad – is entitled *Making Riverscapes Real*. It describes the ‘riverscape’ approach to modeling the structure and function of rivers, as opposed to qualitative models or quantitative discontinuous approaches such as downstream hydraulic geometry. This paper examines the riverscape approach using 3-cm color aerial photographs with 5-m DEMs for the River Tromie, Scotland. A suite of high resolution remote sensing tools, referred to as the *Fluvial Information System*, is used to extract channel morphological variables including width, depth, particle size, and elevation from which geomorphic and hydraulic variables are drawn such as flow velocity, stream power, Froude number, and shear stress. This high-resolution, spatially distributed approach to river science, which has roots in landscape ecology, demonstrates highly heterogeneous river conditions in the downstream direction. Surprisingly, this finding contradicts prevailing geomorphic theories derived from downstream hydraulic geometry and ecologic theories derived from the concept of the river continuum.

Dorothy Hall et al., *Relationship between Satellite-Derived Snow Cover and Snowmelt Runoff Timing and Stream Power in the Wind River Range*, *Wyoming*, present a paper analyzing 10 years of snow cover in the Wind River Mountains of Wyoming, USA. They compare the extent of snow cover derived from Moderate Resolution Imaging Spectroradiometer (MODIS) data with streamflow and conclude that MODIS-derived snow-cover data can be used to predict streamflow. Spearman rank correlation analysis of the extent of snow-cover explained 89% of the variance in maximum monthly river discharge downstream. They computed stream power for upper Bull Lake Creek proportional to the product of discharge and slope, which was determined from a 300-m DEM derived from Shuttle Radar Topography Mission (SRTM) 30-m data. They found a significant decline in maximum monthly stream power over the 40-year period of available discharge data.

2.3. Geographic information science

The next session began with a paper by Ian Evans entitled *Geomorphometry and landform mapping*: *what is a landform*? This paper outlines several of the challenges before us in the field of geomorphometry, including operational definitions of landforms, treatment of fuzzy boundaries, scale dependencies, and classification. By addressing the question, ‘What is a landform?’, and noting a difference between landforms and land-surface forms, Evans makes the distinction between *general geomorphometry* concerned with entire landscapes vs. *specific geomorphometry* constrained to a particular landform (Evans, 1972). Although general geomorphometry has dominated the field, as data resolutions improve and analyses focus on increasingly narrow classes of landscapes, general and specific geomorphometry are converging. The paper begins with specific geomorphometry; i.e., difficulties mapping specific landforms such as the need for an accurate ontology of landforms, delimitation of closed polygons, and the presence of fuzzy boundaries. The paper then moves to general geomorphometry.

John Wilson, *Digital Terrain Modeling*, describes the historical evolution of methods and data sources for DEMs. Three general classes of DEM data are identified: (1) ground survey techniques, (2) interpolations from existing topographic maps, and (3) remote sensing; initially using passive sensors but now increasingly using active sensors. Wilson describes the present state-of-the-art for data capture, preprocessing, DEM generation, and calculation of primary and secondary land-surface metrics. The paper includes discussions of the influence of DEM grid-cell spacing on accuracies, filling sinks for mapping drainage networks, use of the ANUDEM model, incorporation of auxiliary information with DEMs, and how LiDAR and RADAR are changing the methods of DEM generation. Much of the paper is concerned with the computation of parameters from DEMs. Finally, the paper addresses the types of errors common to DEMs and how they may be propagated through subsequent analyses and data products.

The paper by Helena Mitasova et al., *Scientific Visualization of Landscapes and Landforms*, opened many virtual doors to how spatial analyses can be presented. The paper begins with a discussion of how the potential for visualization has been expanded and changed by new data resolutions and technological capabilities. The discussion covers visualization techniques ranging from relief shading on static two-dimensional maps to multi-dimensional renditions, time cubes, web-based applications (e.g., Google Earth©), animations, and 3D immersion in interactive virtual environments. Examples are presented using multiple-return LiDAR data to go beyond bare-Earth representations and include vegetation canopies, anthropogenic