in the quadtree. The selection of the best model at a parent node becomes potentially problematic if different models were selected as best at the children nodes. The need to explicitly map different stochastic models to the quadtree nodes of a multiscale estimator is obviated in the ME approach because the relative weighting of the individual Kalman estimates is automatically determined based on the innovation sequences to provide an adaptive estimate of the elevations.

G11A-0247 0830h POSTER

Acquiring Research-grade ALSM Data in the Commercial Marketplace

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The Puget Sound Lidar Consortium, working with TerraPoint, LLC, has procured a large volume of ALSM (topographic lidar) data for scientific research. Research-grade ALSM data can be characterized by their completeness, density, and accuracy. Complete data includeat a minimumX, Y, Z, time, and classification (ground, vegetation, structure, blunder) for each laser reflection. Off-nadir angle and return number for multiple returns are also useful. We began with a pulse density of 1/sq m, and after limited experiments still find this density satisfactory in the dense second-growth forests of western Washington. Lower pulse densities would have produced unacceptably limited sampling in forested areas and aliased some topographic features. Higher pulse densities do not produce markedly better topographic models, in part because of limitations of reproducibility between the overlapping survey swaths used to achieve higher density. Our experience in a variety of forest types demonstrates that the fraction of pulses that produce ground returns varies with vegetation cover, laser beam divergence, laser power, and detector sensitivity, but have not quantified this relationship. The most significant operational limits on vertical accuracy of ALSM appear to be instrument calibration and the accuracy with which returns are classified as ground or vegetation. TerraPoint has recently implemented in-situ calibration using overlapping swaths (Latypov and Zosse, 2002, see http://www.terrapoint.com/News_damirACSM_ASPRS 2002.html). On the consumer side, we routinely perform a similar overlap analysis to produce maps of relative Z error between swaths; we find that in bare, low-slope regions the in-situ calibration has reduced this internal Z error to 6-10 cm RMSE. Comparison with independent ground control points commonly illuminates inconsistencies in how GPS heights have been reduced to orthometric heights. Once these inconsistencies are resolved, it appears that the internal errors are the bulk of the error of the survey. The error maps suggest that with in-situ calibration, minor time-varying errors with a period of circa 1 sec are the largest remaining source of survey error. For forested terrain, limited ground penetration and errors in return classification can severely limit the accuracy of resulting topographic models. Initial work by Haugerud and Harding demonstrated the feasibility of fully-automatic return classification; however, TerraPoint has found that better results can be obtained more effectively with 3rd-party classification software that allows a mix of automated routines and human intervention. Our relationship has been evolving since early 2000. Important aspects of this relationship include close communication between data producer and consumer, a willingness to learn from each other, significant technical expertise and resources on the consumer side, and continued refinement of achievable, quantitative performance and accuracy specifications. Most recently we have instituted a slope-dependent Z accuracy specification that TerraPoint first developed as a heuristic for surveying mountainous terrain in Switzerland. We are now working on quantifying the internal consistency of topographic models in forested areas, using a variant of overlap analysis, and standards for the spatial distribution of internal errors.

G11A-0248 0830h POSTER

Field Test Results of the CHARTS Airborne Coastal Mapping and Charting System

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The Compact Hydrographic Airborne Rapid Total Survey (CHARTS) system is the next generation airborne lidar system for coastal mapping and charting. CHARTS, owned by the US Naval Oceanographic Office, incorporates the knowledge and experience gained through over 7,000 hours of operating the US Army Corps of Engineer's SHOALS system. CHARTS is actually the fusion of three sensors; a 1,000 Hz hydrographic lidar, a 10,000 Hz topographic lidar, and a high resolutions digital camera. During August 2003 CHARTS was field tested in Ft. Lauderdale, FL, where it collected over 40 million hydrographic soundings and 90 million topographic elevations to assess a matrix of contractual specifications and requirements. This presentation will present the CHARTS system and results of the field tests.

G12A MCC: 3002 Monday 1600h

Airborne Laser Swath Mapping (ALSM): Technology, Applications, and Results II *(joint with H, GC)*

Presiding: **M Bevis,** University of Hawaii**; W E Carter,** University of Florida

G12A-01 1600h

NCALM: NSF Supported Center for Airborne Laser Mapping

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The National Science Foundation (NSF) recently awarded a grant to create a research center to support the use of airborne laser mapping technology in the scientific community. The NSF supported Center for Airborne Laser Mapping (NCALM) will be operated jointly by the Department of Civil & Coastal Engineering, College of Engineering, University of Florida (UF) and the Department of Earth and Planetary Science, University of California-Berkeley (UCB). NCALM will use the Airborne Laser Swath Mapping (ALSM) system jointly owned by UF and Florida International University (FIU), based at the UF Geosensing Engineering and Mapping (GEM) Research Center. The state-of-the-art laser surveying instrumentation, GPS systems, which are installed in a Cessna 337 Skymaster aircraft, will collect research grade data in areas selected through the competitive NSF grant review process. The ALSM observations will be analyzed both at UF and UCB, and made available to the PI through an archiving and distribution center at UCB-building upon the Berkeley Seismological Laboratory (BSL) Northern California Earthquake Data Center system. The purpose of NCALM is to provide research grade data from ALSM technology to NSF supported research studies in geosciences. The Center will also contribute to software development that will increase the processing speed and data accuracy. This presentation will discuss NCALM operation and the process of submitting proposals to NSF. In addition, it will outline the process to request available NCALM seed project funds to help jump-start small scientific research studies. Funds are also available for travel by academic researchers and students for hands-on knowledge and experience in ALSM technology at UF and UCB.

G12A-02 1615h INVITED

ALSM and GIS Analysis of Debris Flow Fan Variability, Death Valley, CA

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Analysis of form in geomorphology has gone through numerous transitions that began with the qualitative assessments of form through field observations as well as an attempt to unravel the historical development of landscapes. The dissatisfaction with the historical approach led to an emphasis on quantitative measures and analyses of planimetric (2D) boundary conditions of surficial features. The advent of Airborne Laser Swath Mapping (ALSM) and other remotely sensed techniques provided access to high-resolution data and permitted geomorphologic research to move beyond 2D measures to more closely approximate the form in 2.5D space. The current study presents preliminary results from a GIS analysis of ALSM data of alluvial fan form in Death Valley, CA. Functional surficial units, identified from field observations and DEM data, from debris flow fans were extracted from the ALSM point cloud. The functional units consisted of channels, levees, snouts, and interfluves between levees of two separate debris flow channels. The morphometric characteristics of these features were compared using spatial statistical analyses. The spatial interpretation provides a 2.5D assessment of within- and between-fan variability. It explains similarities and differences between the geomorphometric signatures of debris flow fans in a hyper-arid setting. The findings have implications for process-response models and planning/management of these often inhabited features.

G12A-03 1630h INVITED

Measuring Landscape Scale and Testing Landscape Evolution Models With an Airborne Laser Swath Map of the Gabilan Mesa, California

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High-resolution topographic data acquired through airborne laser swath mapping (ALSM) allows geomorphologists to observe and measure features that cannot be resolved in coarser topographic maps. One of the most promising applications of ALSM data in geomorphology is the measurement of landscape properties that can be used to calibrate and test landscape evolution models. We illustrate this process with examples from the analysis of an ALSM dataset covering 40 km^2 of the Gabilan Mesa, a soil-mantled landscape in central California's Salinas Valley. The fine-scale ridge-and-valley topography of the Gabilan Mesa is characterized by a regular spacing of 180m between adjacent ridgelines. This regular spacing, which is not apparent in coarser digital elevation models (DEMs), defines a dominant topographic "wavelength." The magnitude of this wavelength is hypothesized to reflect spatial and tectonic boundary conditions and the relative rates of hillslope and channel erosion. We apply signal processing techniques to the ALSM data to measure the magnitude and regularity of the topographic wavelength. We then extract topographic profiles and drainage areas from the ALSM data that, when combined with exposure ages obtained from cosmogenic radionuclides, allow us to calibrate hillslope and channel erosion laws. The output of a numerical model based on these erosion laws can be analyzed by the same signal processing techniques applied to the ALSM-derived DEM. In this way the DEM and the model can be compared statistically. We also consider several challenges posed by the acquisition, processing and analysis of ALSM datasets that are relevant to terrain analysis, including the potential distortion of small-scale topographic features by filtering algorithms and the computational load imposed by large data volumes and grid-based representations of topography.

G12A-04 1645h INVITED

Airborne Laser Swath Mapping (ALSM) for Enhanced Riparian Water Use Estimates, Basin Sediment Budgets, and Terrain Characterization

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The uses of Airborne Laser Swath Mapping (ALSM) or LIDAR for earth science applications beyond topographic mapping are rapidly expanding. The USDA-ARS Southwest Watershed Research Center, in collaboration with the Geosensing Systems Engineering Group at the Univ. of Florida and a wide range of other investigators, designed and conducted a multi-purpose ALSM mission over southeastern Arizona. Research goals include: 1) differentiate young and old riparian cottonwood trees to improve riparian water use estimates; 2) assess the ability of LIDAR to define channel bank steepness and thus cross-channel trafficability; 3) assess the ability of LIDAR to define relatively small, isolated depressions where higher soil moisture may persist; and, 4) quantify changes in channel morphology and sediment movement between pre- and post-monsoon flights. The first flight mission was successfully completed in early June and a post-monsoon mission is scheduled for October. Research goals, mission planning, and initial results will be further developed in this presentation. Acknowledgements: The Upper San Pedro Partnership, DOD-Legacy Program, EPA-Landscape Ecology Branch, U.S. Army-TEC, and the Bureau of Land Management are gratefully acknowledged for supporting this effort. The second author is supported by SAHRA (Sustainability of semi-Arid Hydrology and Riparian Areas) under the STC Program of the National Science Foundation, Agreement No. EAR-9876800.

G12A-05 1700h

Measuring Fault Slip - Why and How?

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To improve our understanding of earthquake physics, we must make observations of parameters that determine friction on the fault surface during rupture. Observables may include, for example, 3D point trajectories to fully record near-field dynamic phenomena such as slip pulses, as well as details of slip variation along strike. We have devised and tested new methods for observing these quantities in nature. First, we observed the details of topography along the 1999 Hector Mine surface rupture using Airborne Laser Swath Mapping. This allowed us to estimate slip variation along-strike of the fault, in some places, with higher spatial resolution than has ever before been possible. The results are, however, complex due to ground surface irregularity and pre-existing topographic features. Evidently, slip variations along strike are greater than previously recognized, implying extreme slip heterogeneity. We provide a simple explanation for how such rapid slip variations could provide the source for high-frequency seismically radiated energy, at least in the near field. Second, we have developed the concept for, and built a working prototype of, a GPS Fault Slip Sensor spanning the San Andreas fault. In addition to augmenting seismic early warning systems, such instrumentation could also provide unique records of near-field ground motions. Inertial sensors such as seismic instruments are not able to differ between a tilt and an acceleration, whereas GPS measurements can differentiate these, and can be made with respect to an absolute frame of reference. Other practical limitations exist, however, in both kinds of instrumentation and we will describe how they may best be integrated into a system that will achieve both the scientific observational objectives and support earthquake early warning.

G12A-06 1715h

Northern California LIDAR Data: A Tool for Mapping the San Andreas Fault and Pleistocene Marine Terraces in Heavily Vegetated Terrain

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Recent acquisition of airborne LIDAR (also known as ALSM) data covering approximately 418 square kilometers of coastal northern California provides a powerful new tool for mapping geomorphic features related to the San Andreas Fault and coastal uplift. LIDAR data has been previously used in the Puget Lowland region of Washington to identify and map Holocene faults and uplifted shorelines concealed under dense vegetation (Haugerud et al., 2003; see http://pugetsoundlidar.org). Our effort represents the first use of LIDAR data for this purpose along the San Andreas Fault. This data set is the result of a collaborative effort between NASA Solid Earth and Natural Hazards Program, Goddard Space Flight Center, Stennis Space Center, USGS, and TerraPoint, LLC. The coverage extends from near Fort Ross, California, in Sonoma County, along the coast northward to the town of Mendocino, in Mendocino County, and as far inland as about 1-3 km east of the San Andreas Fault. The survey area includes about 70 km of the northern San Andreas Fault under dense redwood forest, and Pleistocene coastal marine terraces both north and south of the fault. The average data density is two laser pulses per square meter, with up to four LIDAR returns per pulse. Returns are classified as ground or vegetation, allowing construction of both canopy-top and bare-earth DEMs with 1.8m grid spacing. Vertical accuracy is better than 20 cm RMSE, confirmed by a network of ground-control points established using high-precision GPS surveying. We are using hillshade images generated from the bare-earth DEMs to begin detailed mapping of geomorphic features associated with San Andreas Fault traces, such as scarps, offset streams, linear valleys, shutter ridges, and sag ponds. In addition, we are using these data in conjunction with field mapping and interpretation of conventional 1:12,000 and 1:6000 scale aerial photographs to map and correlate marine terraces to better understand rates of coastal uplift, and rates of strike-slip motion across the San Andreas Fault.

G12A-07 1730h

Full-Waveform, Wide-Swath Lidar Imaging of Forested and Urban Areas in Leaf-On Conditions: Development, Results and Future Direction

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Full-Waveform lidar measurements provide unprecedented views of the vertical and horizontal structure of vegetation and the topography of the Earth's surface. Utilizing a high signal-to-noise ratio lidar system, larger than typical laser footprints (10-20 m), and the recorded time history of interaction between a short-duration (10 ns) pulse of laser light and the surface of the Earth, full-waveform lidar is able to simultaneously image sub-canopy topography as well as the vertical structure of any overlying vegetation. These data reveal the true 3-D vegetation structure in leaf-on conditions enabling important biophysical parameters such as above-ground biomass to be estimated with unprecedented accuracy. An airborne lidar mission was conducted July-August 2003 in support of the North America Carbon Program. NASA's Laser Vegetation Imaging Sensor (LVIS) was used to image approximately 2,000 sq. km in Maine, New Hampshire, Massachusetts and Maryland. Areas with available ground and other data were included (e.g., experimental forests, FLUXNET sites) in order to facilitate as many bio- and geophysical investigations as possible. Data collected included ground elevation and canopy height measurements for each laser footprint, as well as the vertical distribution of intercepted surfaces. Data will be publicly distributed within 6-12 months of collection. Further details of the mission, including the lidar system technology, the locations of the mapped areas, and examples of the numerous data products that can be derived from the return waveform data products will be presented. Future applications including detection of ground and vegetation canopy changes and a spaceborne implementation of wide-swath, full-waveform imaging lidar will also be discussed.

G12A-08 1745h

Inferring Environmental Information from SHOALS-1000 Waveform Data

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In the SHOALS-1000 bathymetric laser system, water depth measurements are computed by time differencing the surface and bottom detections in multiple channels of the returned waveform data. The mechanics of this process are well understood and have been implemented in earlier generations of SHOALS technology (Guenther, 2000). Recently, there has been an increase in interest in using these waveforms to infer other environmental parameters. For example, (Wang and Philpot, 2003) have shown that the shape of the bottom return can be used to discriminate between land and water in very shallow water; (Elston, 2003) has shown that shape analysis can be used for benthic classification; and (Lee and Tuell, 2003) have shown that pseudoreflectance (an approximation of bottom reflectance at the laser wavelength) can also be used for classification. These are important innovations in that they contribute to our ability to conduct data fusion studies using decision-level algorithms as demonstrated by (Park, 2002). But other innovations are possible. Because the SHOALS waveforms are digitized at 1-ns intervals, it may soon be possible to use them to infer vertical structure of the water column. Here, we describe the data structure and availability of SHOALS waveform data and show pseudoreflectance imagery generated from recent data acquired at the South Florida Testing Facility.

URL: http://www.optech.on.ca