Introduction & Background

Geomorphic change analysis examines the quantity and causation of landform alteration. Previous analyses of geomorphic change have relied on fine (<20 m) spatial resolution remotely sensed data or in situ data. Despite their noted accuracy and precision, these traditional approaches are limited in spatial extent and temporal frequency (Smith et al. 2006). Within the past three decades, satellite-sensed data have begun to supplant traditional methods of geomorphic change assessment enabling change analysis over large, inaccessible areas with predictable repetition.

Digital elevation models (DEMs) are the most widely used data to derive details on surface terrain such as volume, mass, slope, and aspect. Fine spatial resolution airborne data are the most commonly used source of information in DEM generation (Schiefer and Gilbert 2007). Coarse spatial resolution (>20 m) DEMs from spaceborne sensors such as Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and Shuttle Radar Topography Mission (SRTM) are less common in change detection studies owing to relatively coarse spatial resolution ( Stevens et al. 2004).

The geomorphic change literature has primarily focused on assessing change resulting from natural processes and not from anthropogenic processes (Toudj 2008). However, landscape change resulting from human activities has greatly outpaced change from natural processes and is a major component in sediment movement and surface alterations (Rivas et al. 2006). Human induced geomorphic change has only been examined indirectly through land use effects on sediment transportation, excavation, and deposition but remotely sensed data in the form of coarse spatial resolution DE Ms have not been extensively utilized to assess human geomorphic change over time.

Southern New England, in particular central Massachusetts, is currently undergoing tremendous landscape changes resulting from increased urbanization. The state’s rigorous environmental protection laws protecting low lands from development has made uplands a target for new development. The rate of geomorphic change occurring from this demand makes the region an ideal study area to examine the utility of coarse resolution DEMs in anthropogenic geomorphic change analysis (Woodcock et al. in Progress).

The objective of this study is to examine the accuracy of ASTER based DEMs, in combination with the SRTM DEM, to a ground based reference map and to use these DE Ms to map anthropogenic geomorphic change in a 135 km² area in Central Massachusetts, USA, over a 6 year period (2000-2006).

Study Area

Data

A February 2000 SRTM DEM and October 2006 ASTER DEM were acquired for geomorphic change analysis. An SRTM DEM rather than an ASTER DEM was acquired for 2000 due to the unavailability of ASTER data for the time period and study area. ASTER spectral imagery for August 2001 and July 2006 were acquired as well as a USGS topographic map, a Massachusetts state surficial geology map, a land-cover map, and orthophotos. Field data were collected for 78 drumlin locations within the study area recording both quantitative hypsometer data and qualitative data.

Methods

Digital Elevation Model Accuracy Assessment: The SRTM and ASTER DEM datasets and topographic map were systematically sampled for elevation differences in areas experiencing no change in land composition over the 10 year period. A Normalized Difference Vegetation Index (NDVI) change image, produced from the ASTER spectral imagery, and the four most dominant land-cover types were used to stratify the landscape. 90 points (50 points per-land-cover type) were generated along the topographic map gradients. The differences in elevation values between the datasets were used to determine Root Mean Square Error (RMSE) and Mean Average Error (MAE).

Geomorphic Change Analysis: Using data collected in the field, a stratified sample of 9 drumlins were selected for geomorphic change detection (6 altered and 3 unaltered) based on date and extent of alteration. The 2006 ASTER DEM was subtracted from the 2000 SRTM DEM to create a geomorphic change image containing only the 9 specified drumlin spatial extents determined from the geology map.

Results

MAE and RMSE Statistics: SRTM, ASTER, and USGS Topographic Map

<table>
<thead>
<tr>
<th>Data Set</th>
<th>DEM Temporal Resolution</th>
<th>DEM Spatial Resolution</th>
<th>Topographic Mapping</th>
<th>RMSE</th>
<th>MAE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRTM-ASTER</td>
<td>6 - 15 m</td>
<td>30 m</td>
<td>15 m</td>
<td>3 m</td>
<td>2 m</td>
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<td>SRTM-USGS</td>
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<td>30 m</td>
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<td>ASTER-USGS</td>
<td>10 - 20 m</td>
<td>15 m</td>
<td>15 m</td>
<td>3 m</td>
<td>2 m</td>
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Geomorphic Change Analysis- Map Validation: The results of the geomorphic change detection (type and spatial extent of change) were verified for accuracy through a combination of ground field data and orthophotos.

Discussion & Conclusion

Preliminary results indicate DEM errors are sufficiently low to provide an accurate assessment of landform alterations. The SRTM DEM was more accurate than mission specified (3.46 m RMSE compared to 16 m RMSE (Global scale) and 6 m RMSE (Local scale)) and the ASTER DEM was more accurate than mission specified (13 m RMSE compared to 25 m RMSE). The level of agreement between the SRTM and ASTER DEMs was also reasonable at 13.9 m RMSE. The low variability in elevation values over the four land-cover types indicates these data can accurately represent complex landscapes in the study area with minimal error.

The ASTER DEM in combination with the SRTM DEM successfully detected geomorphic change on known, altered drumlin features. The 0 to 44 m elevation loss and the spatial extent and alteration characteristics were consistent with field measurements. The accuracy of the ASTER On-Demand Level 3 product to detect fine scale geomorphic changes resulting from anthropogenic alteration and development provides another tool for monitoring human interactions with the environment. ASTER DEMs, as well as other coarse spatial resolution DEM-capable spaceborne sensors, offer accurate data sources with the advantages of low cost, large extent, and predictable temporal frequency, as alternatives to traditional data in anthropogenic geomorphic change analyses.

References


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Geomorphic Change Analysis using ASTER and SRTM Digital Elevation Models in Central Massachusetts, USA