Toward mapping soils and geomorphology by remote sensing: an example of multi-sensor data fusion from the Dry Valleys

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Since the work of Jensen (Jensen, 1916), several researchers have studied soils in the Antarctica. Soil-landscape relations were described by Campbell and Claridge (1987) and Bockheim (2002), and numerous geological/geomorphic studies have been conducted (Tedrow, 1966; Everett et al., 1970; Denton et al., 1989 and Hallet et al., 2003) facilitating the understanding of soils and their distributions. These studies investigated many different parts of the ice-free landscapes in Antarctica, but seldom were the soils of the intended research area considered. This fact makes it difficult to relate one study to another or to take the findings from one study and extrapolate it to other areas. Point pedon data also has not been scaled to larger areas. Bockheim (personnel communication, 2003) has developed a geo-referenced pedon database that can be related to different land forms and soil types.

Detailed mapping and monitoring of the ice free areas in polar regions cannot easily be accomplished by using traditional, well-known, and proven techniques. Taking the required accuracy, the hostility and inaccessibility of the area into account, mapping becomes an enormous challenge. Satellite and airborne systems are constantly collecting data with different sensors and at different wavelengths, providing complementary and redundant information about the earth's surface and its dynamics. We have used these data for mapping soils and geomorphology in the polar environment. To achieve this goal, we extracted relevant data and merged them in a consistent spatial reference frame.

There is a vast amount of remote sensing data, including multi- and hyperspectral satellite imagery (Landsat, SPOT, ASTER, HYPERION), ERS, RADARSAT and JERS SAR imagery, and high resolution topographic data collected by the NASA ATM airborne scanning laser system for the ice free regions of Antarctica. The McMurdo Sound region has been the focus of geologic mapping for many decades, and geologic maps covering a significant portion of the Dry Valleys are available digitally. Satellite image maps are available from USGS and satellite and airborne remote sensing data have been used in several studies to map bedrock structures, volcanic and glacial geomorphology (e.g., Paulsen and Wilson, 2004 and Csatho et al., 2003). The main goal of the research presented here is combining pattern recognition and landscape analysis techniques for delineation of soil landscape units and other geomorphic features. Other objectives are inferring the physical properties and composition of the surface, and generating numerical measurements of geomorphic features.

For example, most of the terrain on the valley floors exhibits some form of patterned ground. Patterned ground is better defined in the regions near glaciers and along rivers, such as the river flowing into Lake Vanda. This suggests that water from melting glaciers has a major influence on soil formation. We have analyzed the spectral and textural information from satellite and airborne imagery with pattern recognition techniques to delineate areas of patterned ground. Different spatial operations, including morphological filtering and active contour modeling have been used to extract the boundaries of the polygons and to compute statistics of polygon properties (size, relief, etc.).

Landforms and soil units will be linked to a geospatial database, which will include DEMs, information about the composition of the different units, etc. The end product will be a prototype soils/geomorphology map that can be used by researchers interested in many different processes within Antarctica.

USDA-NRCS in cooperation with researchers from New Zealand have established a series of soil/air climate stations within selected areas of the McMurdo Dry Valleys. These stations have been in place for five years and all of the sites have shown a steady increase in the thickness of the active layer that can be attributed to warmer soil temperatures. It should be noted that in 2004 there was a reversal of

this trend and there was some cooling this data has not all been processed to date. Data from these sites and other proposed sites needs to be linked with soil maps so that the affect this may have on soil development can be better understood and assist in predictions of future changes to the soils in Antarctica.

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