This dissertation investigates the hydroclimatic controls on drainage network dynamics and characterizes the variation of drainage density in various climate regions. The methods were developed to extract the valley and wet channel networks based on Light Detection and Ranging (LiDAR) data including the elevation and intensity of laser returns. The study watersheds were selected based on the availability of streamflow observations and LiDAR data. Climate aridity index was used as a quantitative indicator for climate.

The climate controls on drainage density were revisited using watersheds with minimal anthropogenic interferences and compared with the U-shape relationship reported in the previous studies. A curvature-based method was developed to extract a valley network from 1-meter LiDAR-based Digital Elevation Models. The relationship between drainage density and climate aridity index showed a monotonic increasing trend and the discrepancy was explained by human interventions and underestimated drainage density due to the coarse spatial resolution (30-meter) of the topographic maps used in previous research.

Observations of wet channel networks are limited, especially in headwater catchments in comparison with the importance of stream network expansion and contraction. A systematic method was developed to extract wet channel networks based on the signal intensities of LiDAR ground returns, which are lower on water surfaces than on dry surfaces. The frequency distributions of intensities associated with wet surface and dry surface returns were constructed. With the aid of LiDAR-based ground elevations, signal intensity thresholds were identified for extracting wet channels. The developed method was applied to Lake Tahoe area during recession periods in five watersheds. A power-law relationship between streamflow and wet channel length was obtained and the scaling exponent was consistent with the reported findings from field work in other regions.

Perennial streams flow for the most of the time during normal years and are usually defined based on a flow duration threshold. The streamflow characteristics of perennial streams in this research were assessed using the relationship between streamflow exceedance probability and wet channel ratio based on wet channel networks extracted from LiDAR data. Non-dimensional analysis based on the relationship between streamflow exceedance probability and wet channel ratio showed that results were consistent with previous research about perennial stream definition, and provided the possibility to use wet channel ratio to define perennial streams.

Wetlands are important natural resources and need to be monitored regularly in order to understand their inundation dynamics, function and health. Wetland mapping is a key part of monitoring programs. A framework for detecting wetland was developed based on LiDAR elevation and intensity information. After masking out densely vegetated areas, wet areas were identified based on signal intensity of ground returns for barrier islands in East-Central Florida. The intensity threshold of wet surface was identified by decomposing composite probability distribution functions using a Gamma mixture model and the Expectation-Maximization algorithm. This method showed good potential for wetland mapping.

The methodology developed in this dissertation demonstrated that incorporating LiDAR data into the drainage networks, stream network dynamics and wetlands results in enhanced understanding of hydroclimatic controls on stream network dynamics. LiDAR data provide a rich information source including elevation and intensity, and are of great benefit to hydrologic research community.

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The public is welcome to attend.