Hydraulic Conductivity Among Varied Elevation Gradients within Boulder Creek CZO & Niwot Ridge LTER

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Introduction

Alpine and sub-alpine ecosystems are highly susceptible to climate change, and also provide critical freshwater resources. The Niwot Ridge Long-Term Ecological Research (LTER) sites and Boulder Creek Critical Zone Observatory (CZO) sites are experiencing climate change, and are excellent locations for understanding how change will influence water resources and ecosystems. Hydraulic conductivity (K), or the ease with which water permeates soil, has been looked at within the CZO and LTER sites but has not been researched at these specific study plots. Understanding hydraulic conductivity will enable us to estimate the rate of water infiltration and ground water recharge, water availability to surrounding terrestrial and aquatic ecosystems, and stream flow in our watersheds. Measurements of hydraulic conductivity will contribute to collaborative efforts to develop hydrologic models that estimate snowmelt, surface and groundwater runoff, and infiltration in a changing climate.

Results

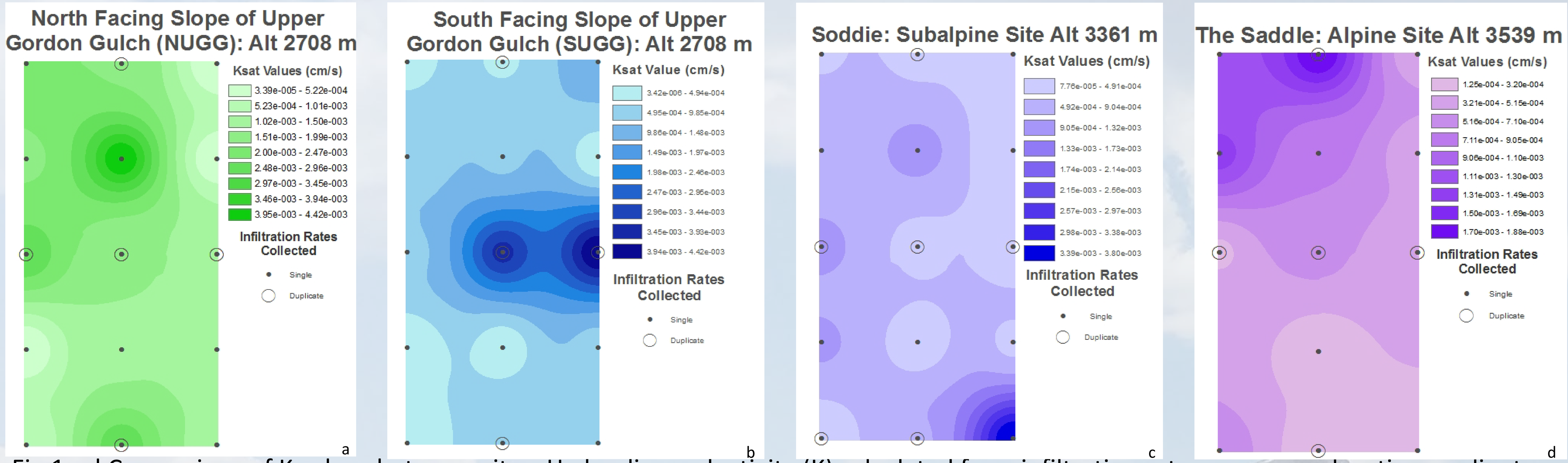

Fig.1a-d Comparison of K values between sites: Hydraulic conductivity (K) calculated from infiltration rates across an elevation gradient. Each point represents a sampling location where duplicate samples are circled thus showing that location's mean K value. The color represents the K value, where dark hues are high and light hues are low conductivity. All four survey plots had points of high and low infiltration rates although the range of K variation differed between sites.

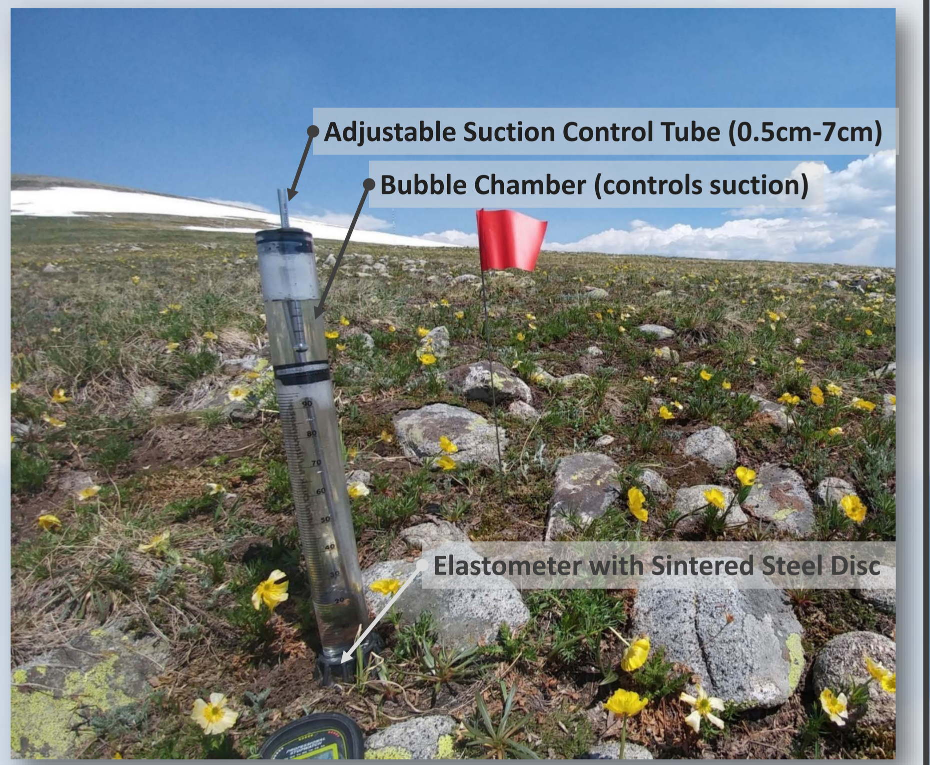

Fig.2 Decagon Mini Disk Infiltrometer at The Saddle alpine site. The Mini Disk measures infiltration of unsaturated soil, eliminating macropores.

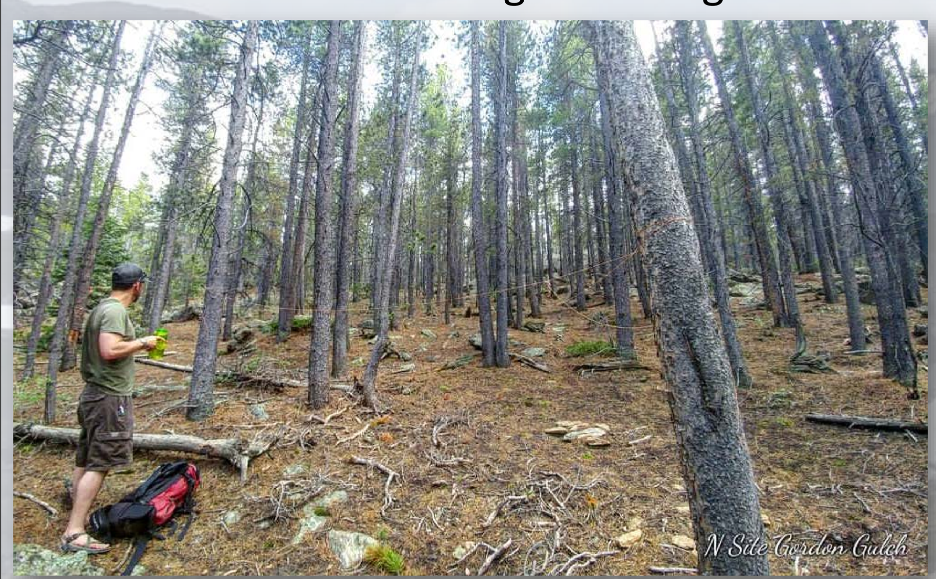

Fig.3 Webb at NUGG. Being the only north facing slope we collected from, this site is significantly different in spatial variation with a dense amount of lodgepole pine and sparse to no flora in the understory. There was a thick litter layer (approx. 1-2 inches) which kept the soil moist.

Fig.4 Webb at SUGG. This survey plot stood out with the largest amount of spatial and soil variation. The soils alternate from silty-loam and sandy-silt horizontally up the slope. The silty-loam areas were covered with grasses and/or shrubs while the sandy-silt soils had little (mostly sedums) to no vegetation.

Fig.5 South facing slope of the subalpine site, Soddie. This survey plot was the most saturated vertically down the center of the slope with a spring running from the bottom of the site and dryer towards either side. This unsaturated and saturated soil alternated vertically across the slope.

Fig.6 South facing slope of the alpine site, The Saddle. This survey plot was the most saturated of all four locations. The entire alpine slope had alternating horizontal variations from unsaturated soil to saturated soil to standing water.

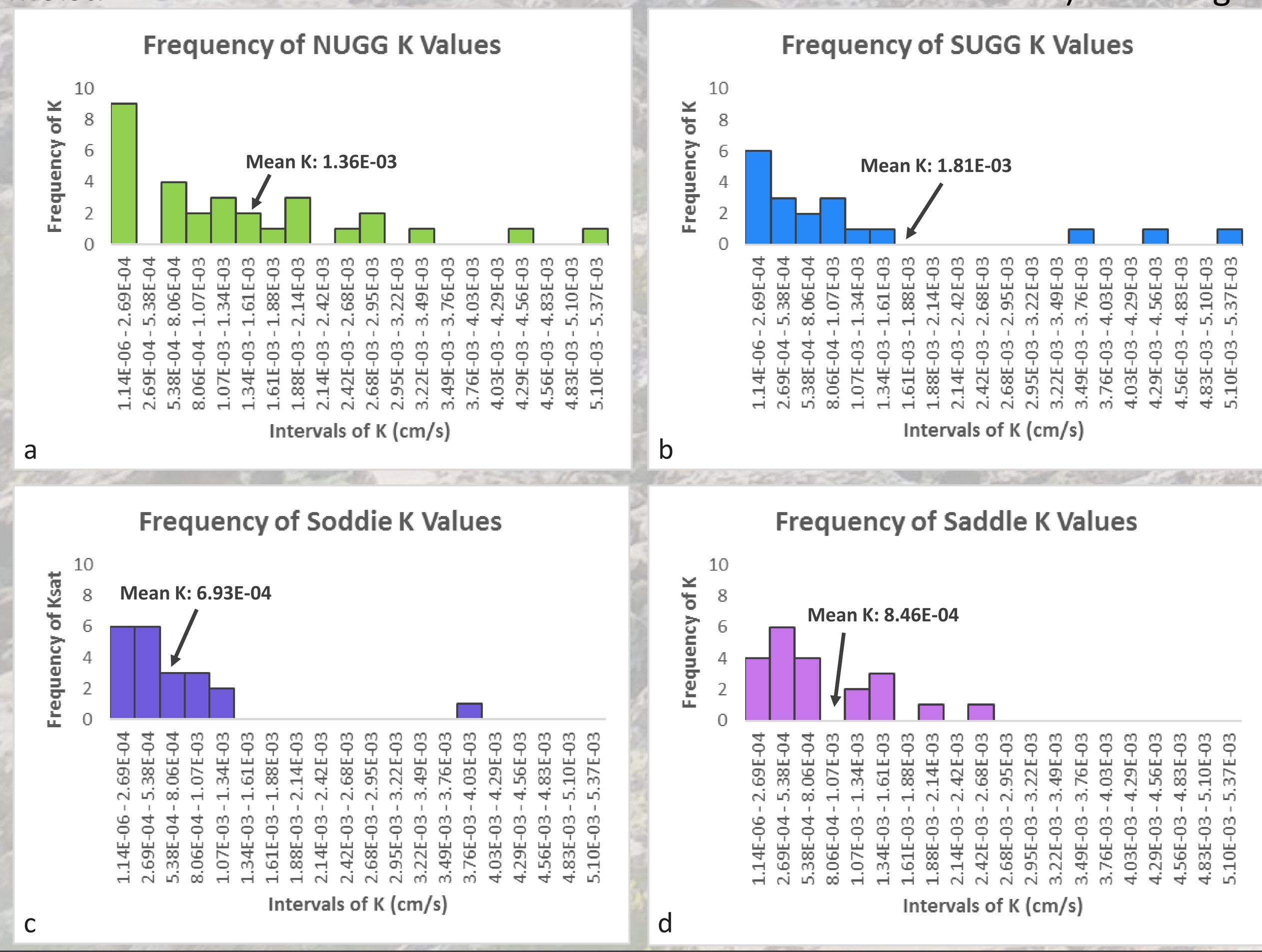

Fig.7a-d These figures (left) show the frequency of K values for each individual site. We can see that NUGG has a broad, but consistent range of K values. Between the south facing slopes, there is an inverse relationship; with increased elevation, variation of K values decrease.

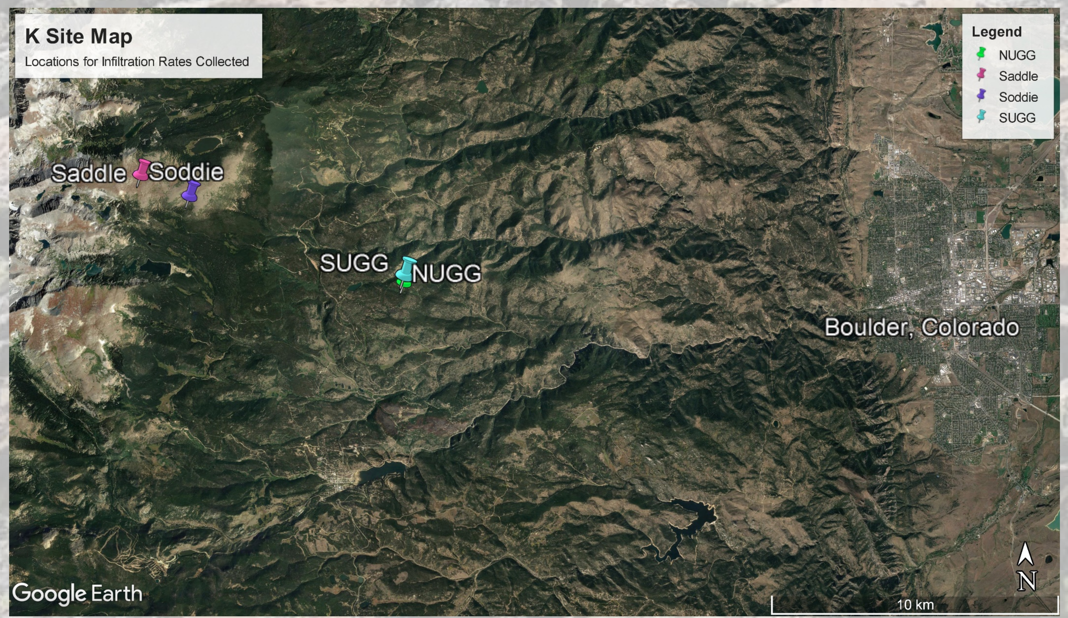

Fig.8 This site map (left) shows and overview of the four survey plots just west of Boulder, Colorado, USA.

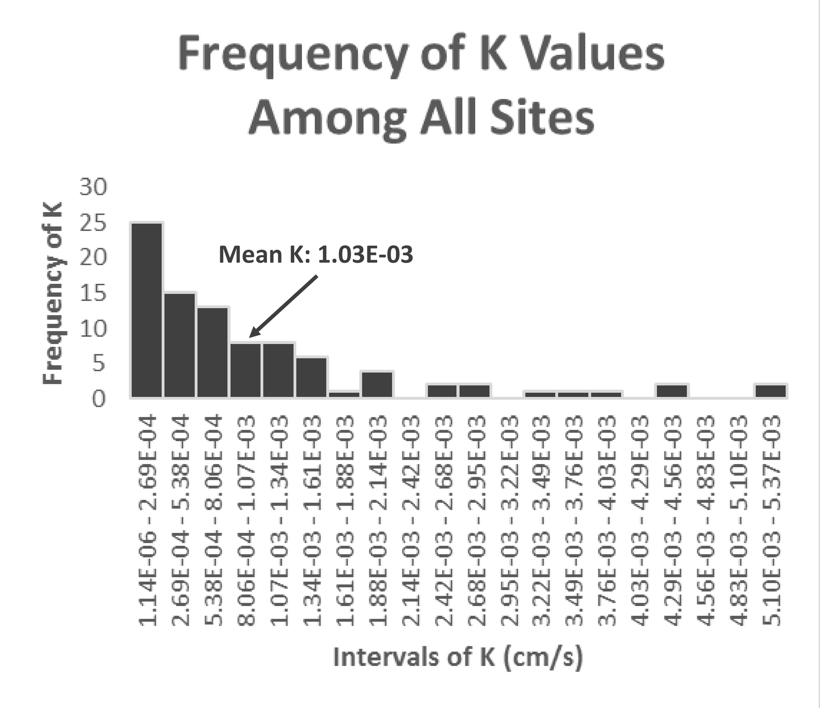

Fig.9 This histogram (above) shows the frequency of K values among all four sites. The majority of K values among all sites are between 1.14E-06 to 1.61E-03.

Methods

- At each of the four study plots, infiltration rates were measured at 15+ points (a min of 5 duplicates were collected at each site) across a 10m by 20m area (with the exception of The Saddle due to standing water). Values visualized per site with ArcMap (Fig.1a-d).
- A Decagon Mini Disk Infiltrometer (Fig.2) was used to measure infiltration rates at four sites: the north and south facing slopes in Upper Gordon Gulch of Boulder Creek's CZO, as well as the south facing slopes of Soddie (subalpine) and The Saddle (alpine) on Niwot Ridge LTER.
- Infiltration rates were then entered into an Excel spreadsheet to determine each points' hydraulic conductivity (K) through Darcy's Law, $Q = K\frac{\Delta_h}{L}A$, where K=conductivity, Δ_h=change in total head, L=length/distance, A=area of path.

Discussion

- When comparing the mean K for SUGG and NUGG to Burass' Gordon Gulch 2009 infiltration rates (who used a double ring infiltrometer, which has a larger radius than a mini disk, measuring saturated conductivity) the rates vary slightly but values lay within the same order of magnitude:
  - SUGG mean K 1.81E-03 vs Burass' open space site's mean 5.83E-03
  - NUGG mean K 1.36E-03 vs Burass' forested site's mean 6.94E-03
- K vs Soil Texture: Larger pores (sandy soils) with less density had higher K values, such as SUGG. Areas with lower K had slower infiltration which seem to correlate with the soil particle size/texture and density/resistance of the soil.
- SUGG (Figs.1b,4,7b) had a higher % of sand in the soil than other sites which contributed to higher K values. This site had an "outlier" K of 1.40e-02 cm/s, this anomaly was removed from data analysis (Figs.1b,7b,9).

Future Work

These K values will give Webb the baseline for modeling snowpack, and in particular, for modeling the interaction of snowmelt with the surface and soil water to determine where is melt water is going. Partitioning melt water to help inform future CZO and LTER studies addressing water movement through the environment, how and where water is stored, as well as what nutrient cycles in alpine and subalpine ecosystems are prominent in this biogeochemistry process.

References

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- *Mini Disk Infiltrometer Operator's Manual. Decagon Devices, Inc., 2016.*
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