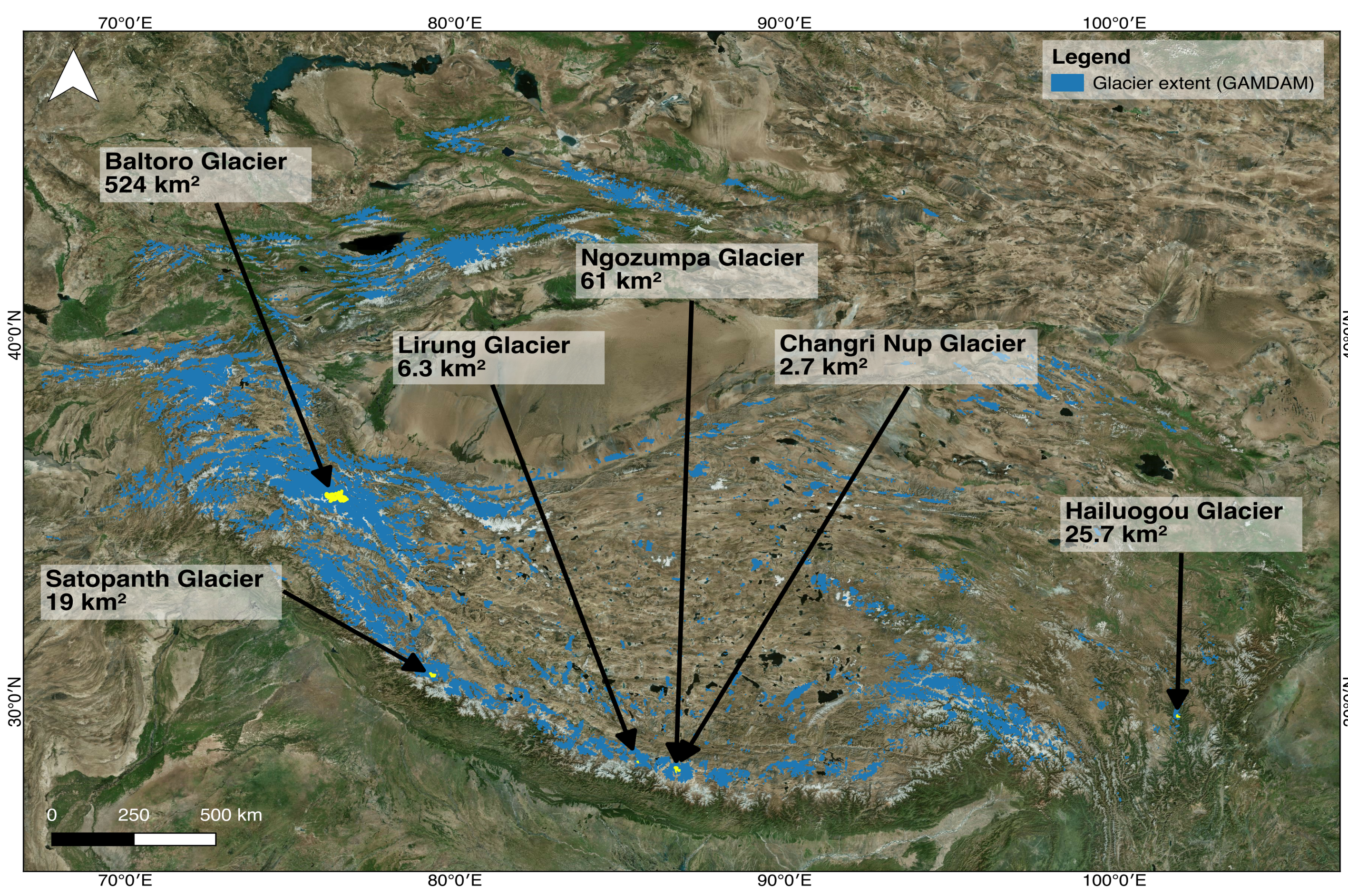
Glaciological controls on the spatial variability of supraglacial debris thickness in High Mountain Asia

Karla Boxall[1], Ian Willis[1] and Michael McCarthy[2]
[1]Scott Polar Research Institute, University of Cambridge, UK
[2]Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), Switzerland



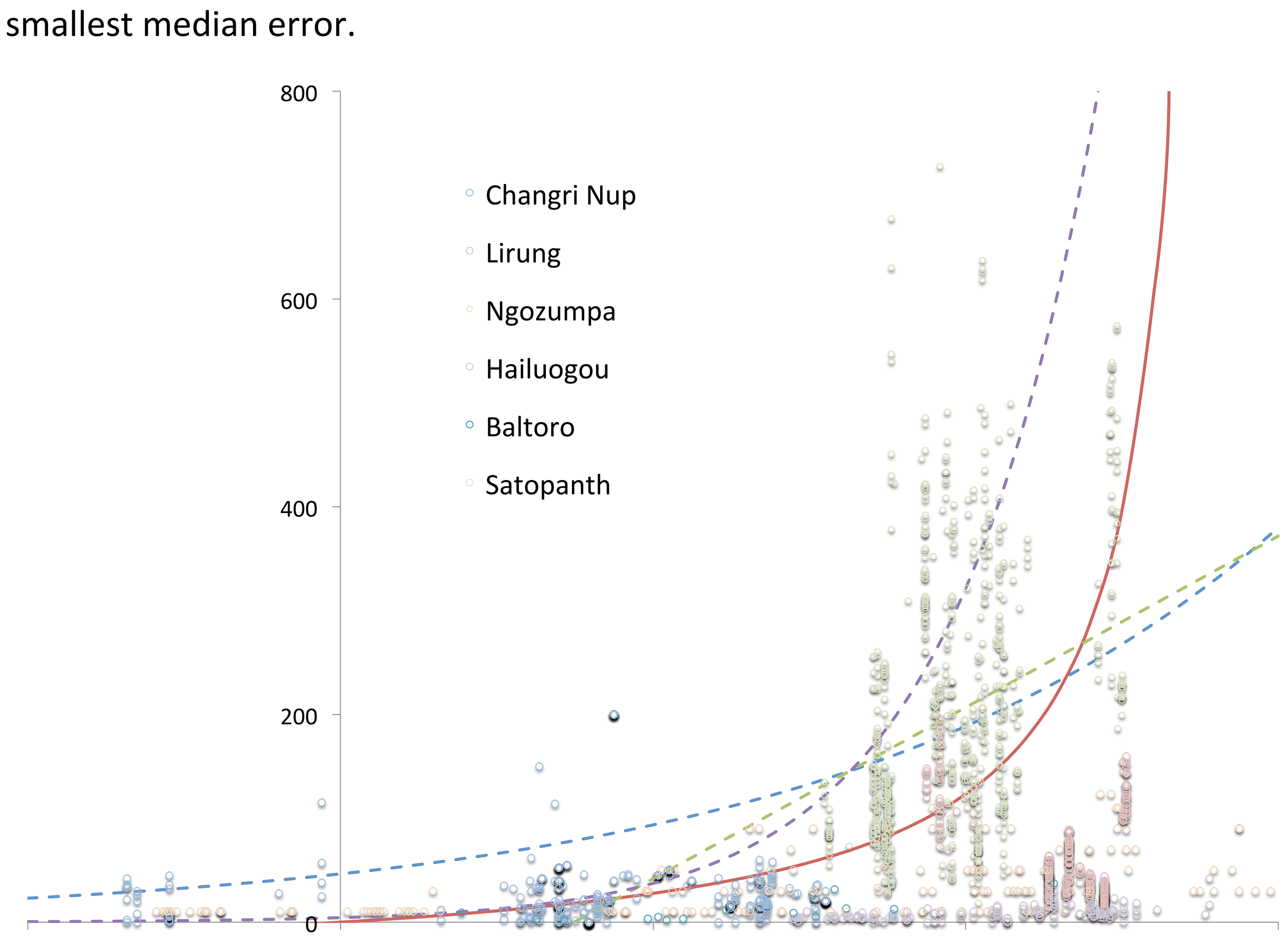
2. Research Aims

1. Improve the **mapping of debris thickness** at both the glacier and the mountain range scale
2. Quantify the **controls on the spatial distribution** of supraglacial debris thickness

3. Methods

1. K-fold cross validation used to determine best empirical relationship between mean melt season surface temperature (derived from Landsat 8 thermal imagery) and *in situ* debris thickness (collected from literature) for:
   - Six individual glaciers (Figure 1)
   - The HMA region, by collating and normalising the data (Figure 2)
2. Principal Components Analysis (PCA) of glaciological characteristics (slope, aspect, curvature, elevation, velocity) for the six glaciers. PCs regressed with debris thickness (derived for each glacier using local scale relationships).

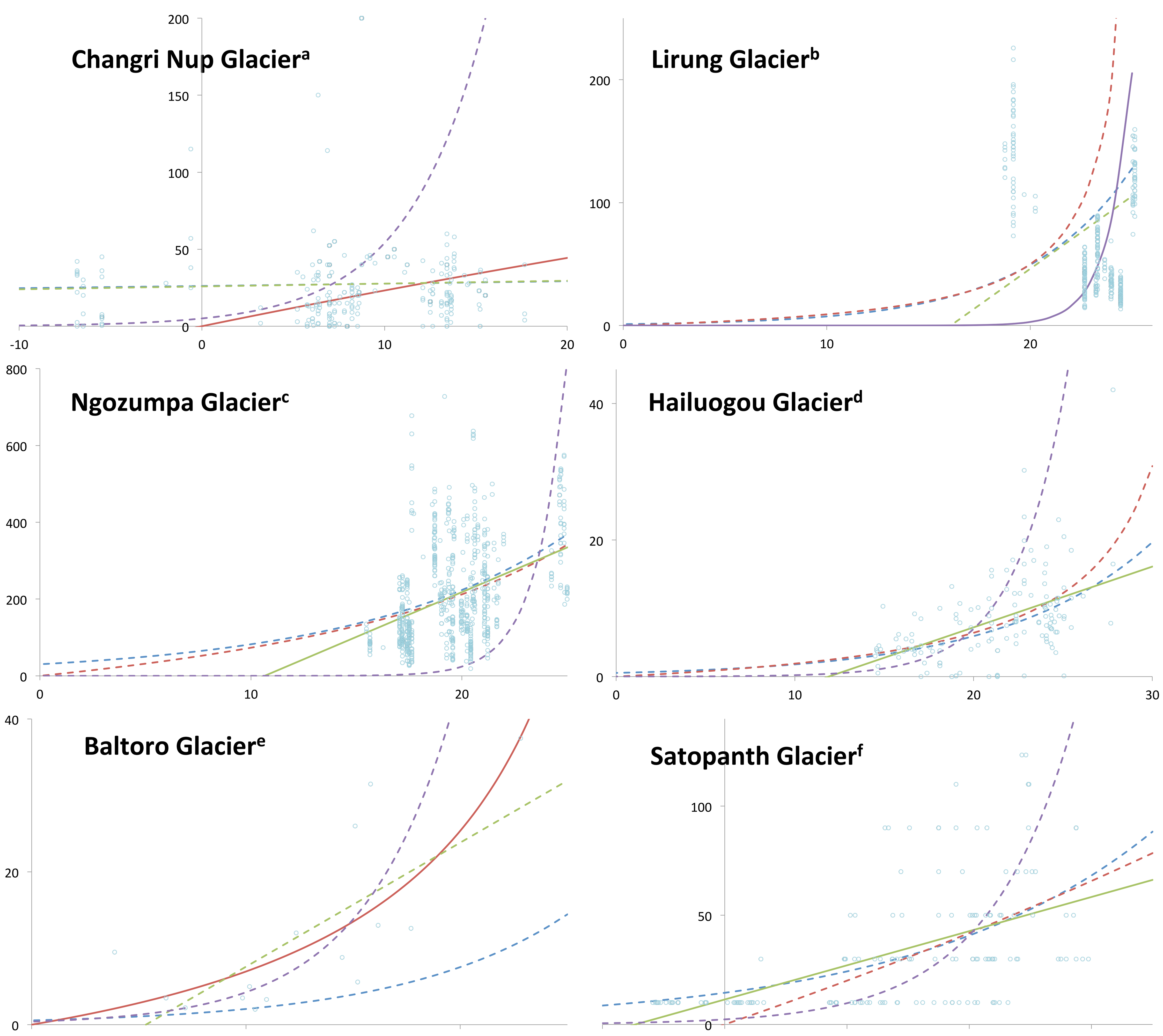
Figure 2: Surface temperature (°C) (x axis)/debris thickness (cm) (y axis) relationship for all collated data (rational curve, linear, Mihalcea *et al.* (2008) relationship, Kraaijenbrink *et al.* (2017) relationship). Solid line = relationship with smallest median error.



1. Introduction

11% of glaciers in High Mountain Asia (HMA) are debris-covered (Steiner *et al.*, 2018). Debris-covered glaciers respond differently to clean ice glaciers under the same climatic forcing (Nicholson and Benn, 2013). Beneath thin debris, ablation is enhanced, but beneath debris >~2 cm thick, ablation is inhibited (Østrem, 1959). Thus, the spatial variability of supraglacial debris thickness is significant in controlling the response of debris-covered glaciers to climate change.

Figure 1: Surface temperature (°C) (x axis)/debris thickness (cm) (y axis) relationships for six glaciers (rational curve, linear, Mihalcea *et al.* (2008) relationship, Kraaijenbrink *et al.* (2017) relationship). Solid line = relationship with smallest median error.



4. Results

1. **Rational curve** is the best relationship for Changri Nup and Baltoro; **linear** relationship is best for Ngozumpa, Hailuogou and Satopanth (Figure 1). **Rational curve** (equation below) is the best relationship for the larger HMA region (Figure 2).

$$dt = \frac{Ts}{0.558 + (-0.0198Ts)}$$

2. 1st Principal Components are dominated by the positive influence of **velocity**; 2nd Principal Components are dominated by the positive influence of **aspect**. Regressions show that debris thickness consistently has a negative relationship with PC1 (=debris thickness increases as velocity decreases), but either a positive or a negative relationship with PC2 (=debris thicker on E or W facing slopes, respectively).

5. Conclusions

- Use of a **rational curve** or **a linear relationship** improves estimations of spatial variability of supraglacial debris thickness, on both a glacier and mountain range scale, in comparison to relationships used in studies by Mihalcea *et al.* (2008) and Kraaijenbrink *et al.* (2017).
- **Velocity** and **aspect** statistically proven to be important controls on the spatial distribution of supraglacial debris thickness.

6. References

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