BUILDING A REGIONAL GLACIER MELT MODEL TO ANALYSE THE IMPACTS OF CLIMATE CHANGE ON WATER RESOURCES IN THE TROPICAL ANDES

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INTRODUCTION

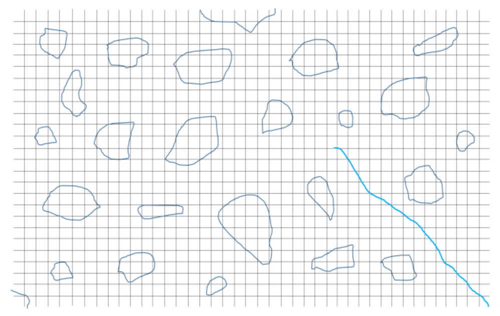
The water resources of many populations in the tropical Andes are highly dependent on glacial meltwater. However, climate change is causing accelerated glacier ablation, reducing the water storage capacity of glaciers. It is therefore essential to predict the effects of climate change on glacier melt in order to determine the resulting changes in runoff with time, so that the effects on downstream water resources can be assessed. At present, regional glacier melt models have not been developed for the tropical Andes as it is challenging to capture the spatial heterogeneity present on a regional scale; caused by the complex interactions between the extreme topography, climate and cryosphere.

AIM

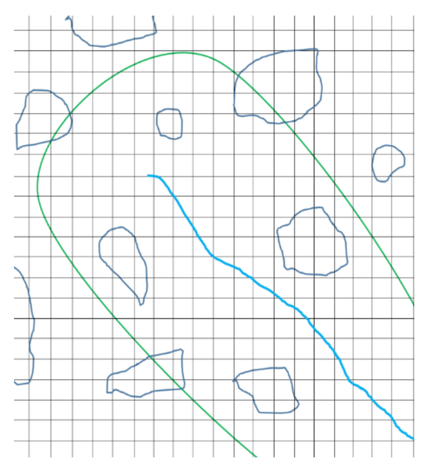
Develop a regional glacier melt model that is simple enough to be applicable to the entire region and complex enough to be representative of the interactions occurring in a glacierised catchment.

METHODOLOGY

The region was discretised into approximately 100m x 100m cells, creating a high resolution raster model. All data was also in raster format with a value for each cell. High resolution raster models were chosen for their ability to represent the spatial heterogeneity of mountainous regions well.



Cells containing glaciers were extracted and the melt in each cell was calculated using each of three glacier melt models:
- Mass balance model - Accelerated melt model -Positive degree-day model



To test the accuracy of each model, the results were subsequently compared with observed streamflow data from the Rio Santo basin, as observed melt data was not available. A water balance model was used to determine the discharge from non-glacierised areas of the basin. The melt predicted by each model for glaciers within the basin was then added to this to obtain the discharge predicted by each model, for comparison with observed data from 1970-1974.

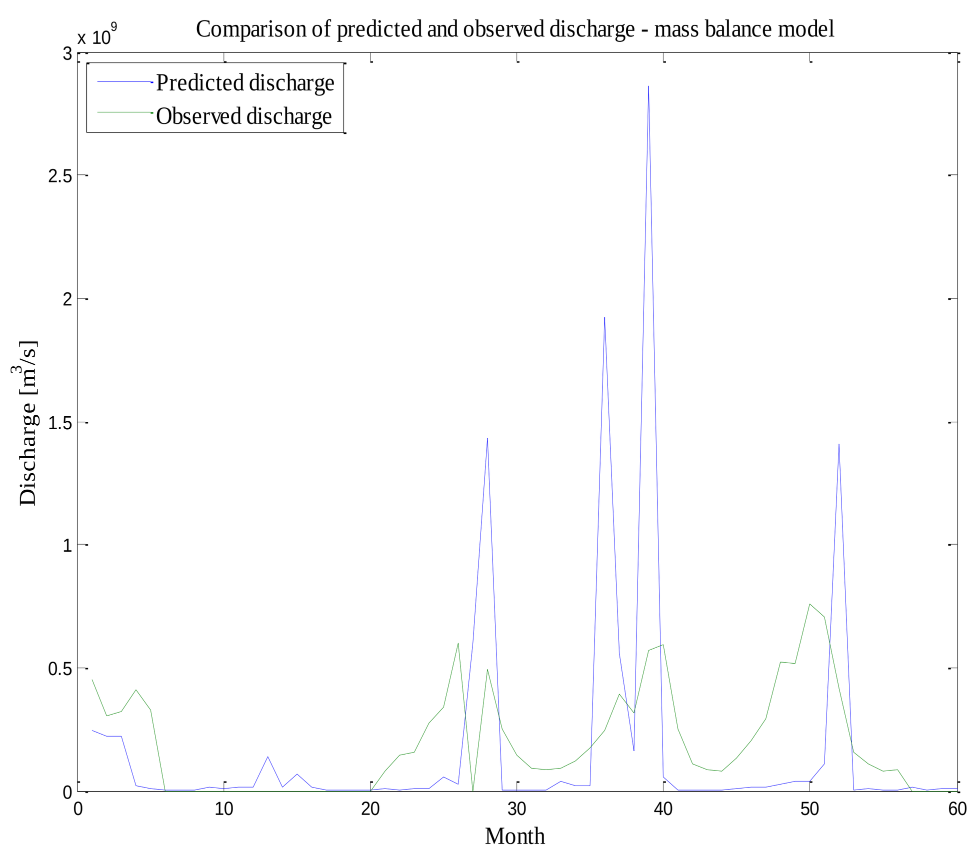
MASS BALANCE MODEL

Model developed by Kaser et al. (2010) which assumed equilibrium between glaciers and the environment, so total accumulation (precipitation) and melting were taken to be equal over the total time period under consideration. Sublimation was then accounted for by assuming that 20% of ablation is caused by sublimation.

Equation implemented in each cell:

$$\sum_{i=1}^{n} M_i = 0.8 \times \sum_{i=1}^{n} P_i$$

where n is the total number of months



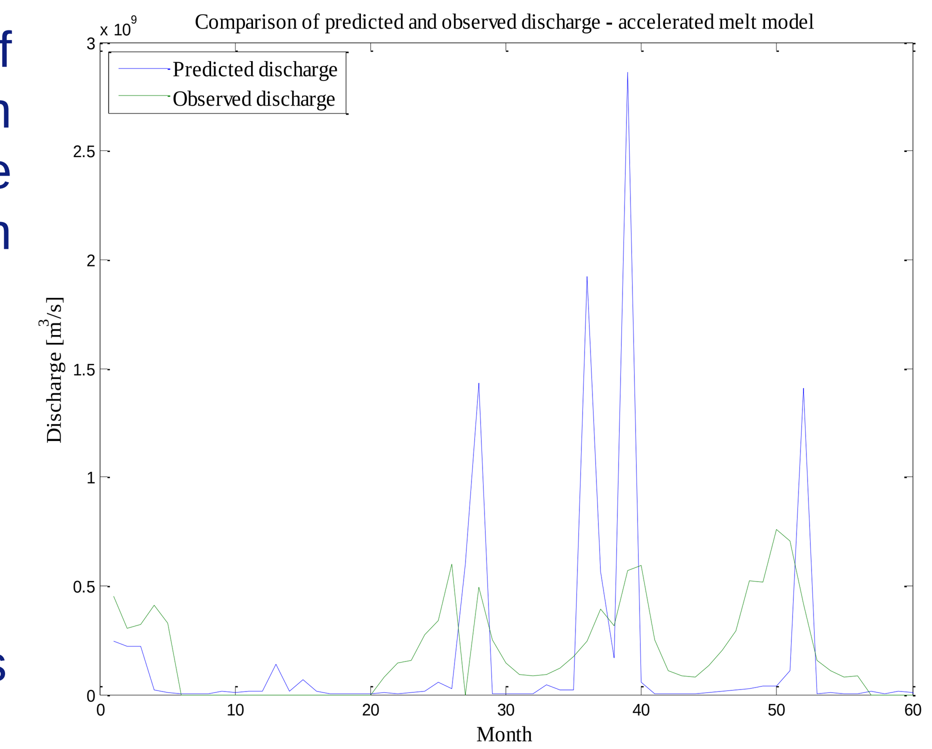
The general trend was captured and the total discharge was predicted to within an 8.3% accuracy of the observed discharge

ACCELERATED MELT MODEL

Extension of the mass balance model. Rates of change of glacier area were recorded from various studies; providing an area loss of 0.67% per year. It was hence assumed that over the 31 year period, there was 21% more ablation than accumulation.

Equation implemented in each cell:

$$\sum_{i=1}^{n} M_i = 1.21 \times 0.8 \times \sum_{i=1}^{n} P_i$$



The general trend was captured and the total discharge was predicted to within a 7.9% accuracy of the observed discharge.

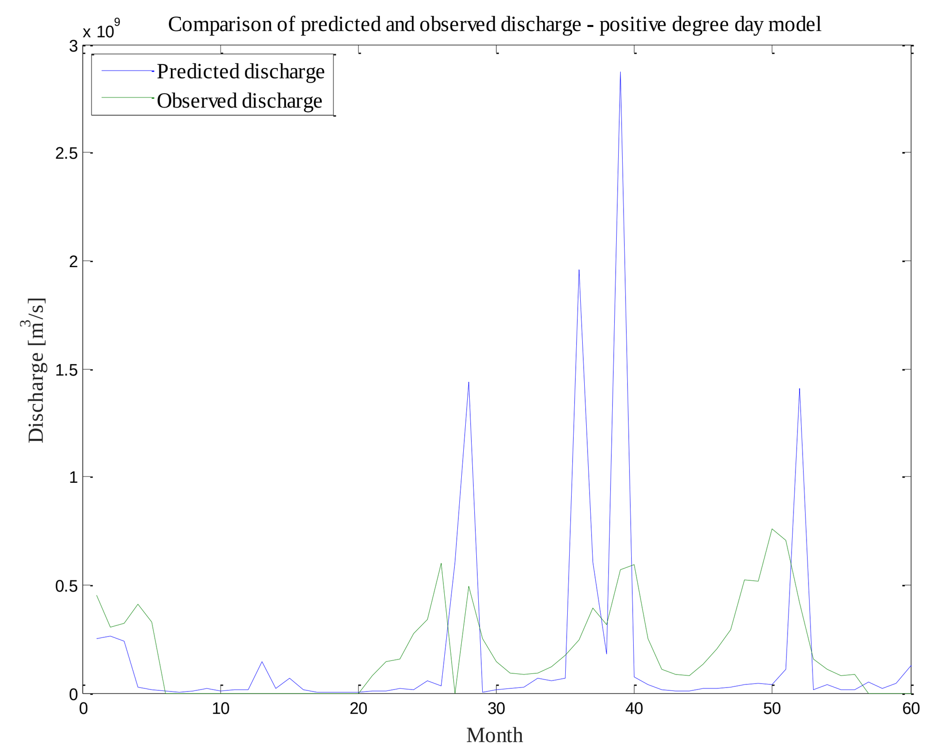
POSITIVE DEGREE-DAY MODEL

Based on the work of Maisincho et al. (2014), this model related daily melting to daily temperature, using degree-day factors (DDF) based on whether the melting related to snow or ice.

Equation implemented in each cell:

$$if\ T_i > T_{threshold}:\ m_i = DDF \times (T_i - T_{threshold})$$
$$if\ T_i \leq 0:\ m_i = 0$$

where m_i and T_i are the daily melt and temperature on day i



The general trend was captured and the total discharge was predicted to within a 1% accuracy of the observed discharge.

CONCLUSIONS

All models predicted the total quantity and general trend of discharge well and discharge was modelled with increasing accuracy by each of the models. Although the short-term fluctuations in discharge which are typical in melt affected regimes are not captured, the seasonal discharge is captured by all models; which is sufficient for determination of the evolution of streamflow with time. Therefore, it is not necessary to develop complex glacier melt models to obtain representative results that can be used to analyse the impacts of glacier melt on water resources.

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