Using a Distributed Hydrological Model in a Tropical Glacier Basin, Cordillera Blanca, Peru

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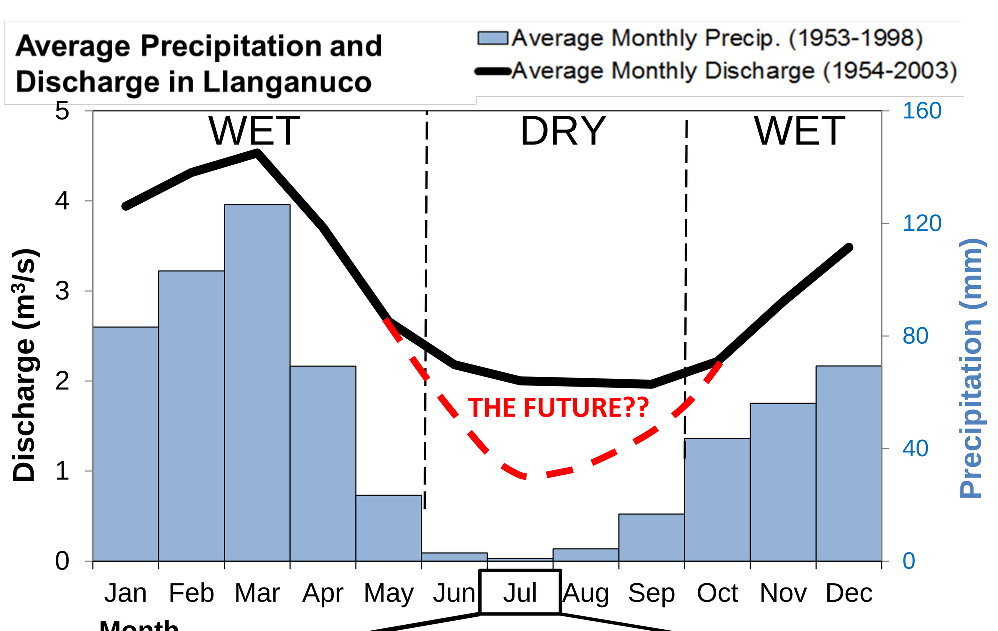
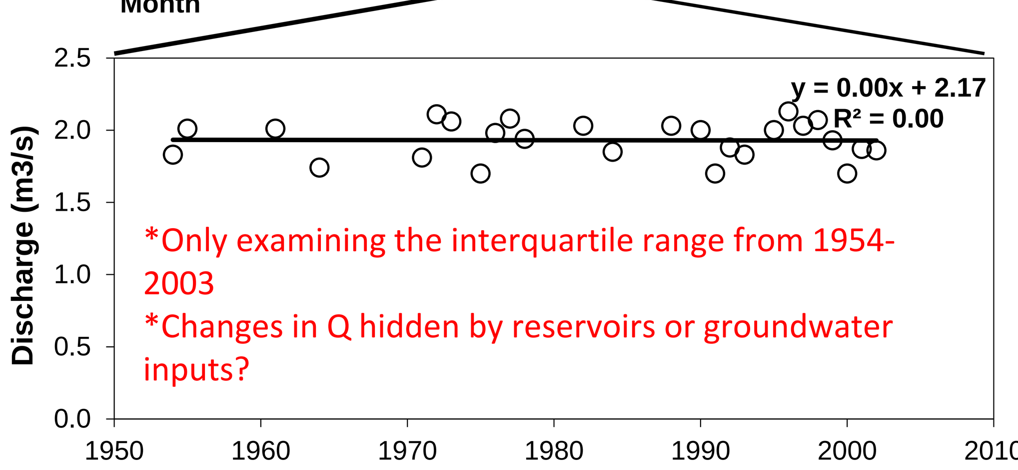
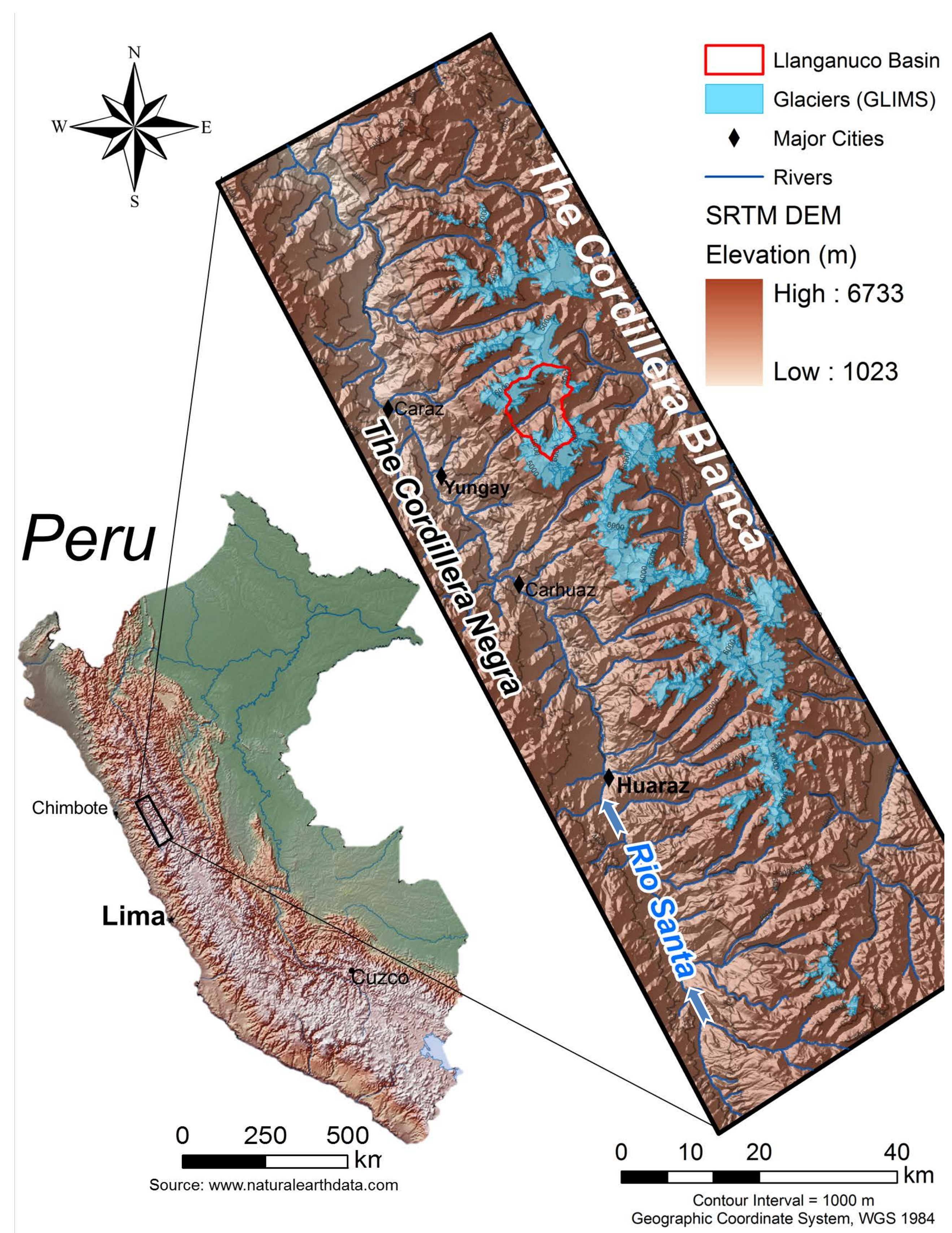
INTRODUCTION

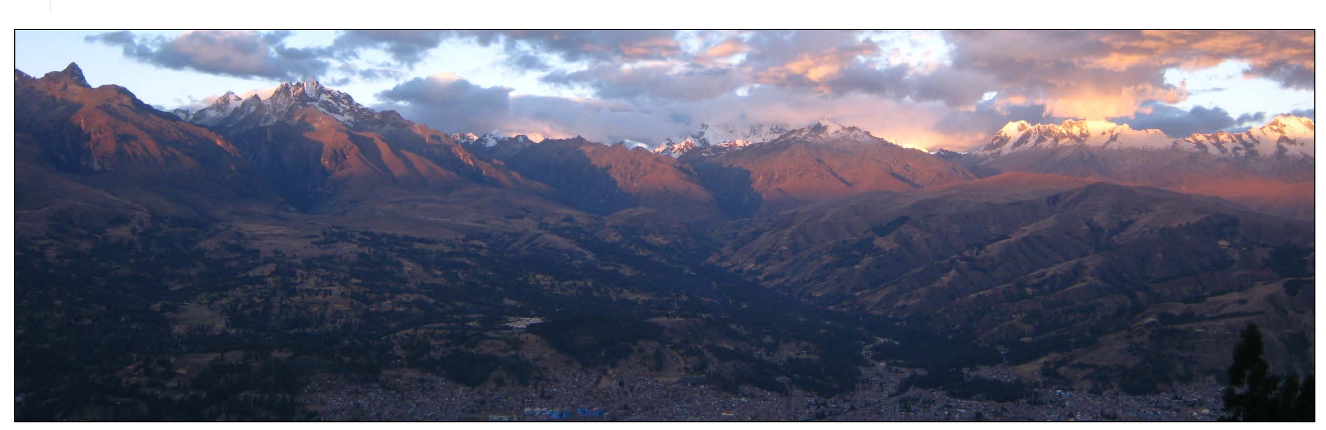
Glaciers in the Cordillera Blanca of the Peruvian Andes lost 22% of their area between 1970 and 2003[1]. This loss in glacier area and volume will have consequences for dry season water resources since this region, called the Cajellon de Huaylas (pop. ~267,000[2]), receives little precipitation from June to September (the dry season) and relies heavily on snow and glacier melt. We ultimately seek to quantify the effect that glacier recession has had on this region using the **D**istributed **H**ydrology **S**oil and **V**egetation **M**odel (**DHSVM**). In this study, we focus on a test basin of the Cajellon de Huaylas, namely Llanganuco (90 km^2, 30% glacierized), and examine the change in glacier extent using remote sensors. Furthermore, we describe our initial efforts to collect data for use in DHSVM and associated challenges. Finally we use an isotopic mixing model to make estimates of the relative contributions of glacier melt and groundwater to streamflow during a period of the 2011 dry season.



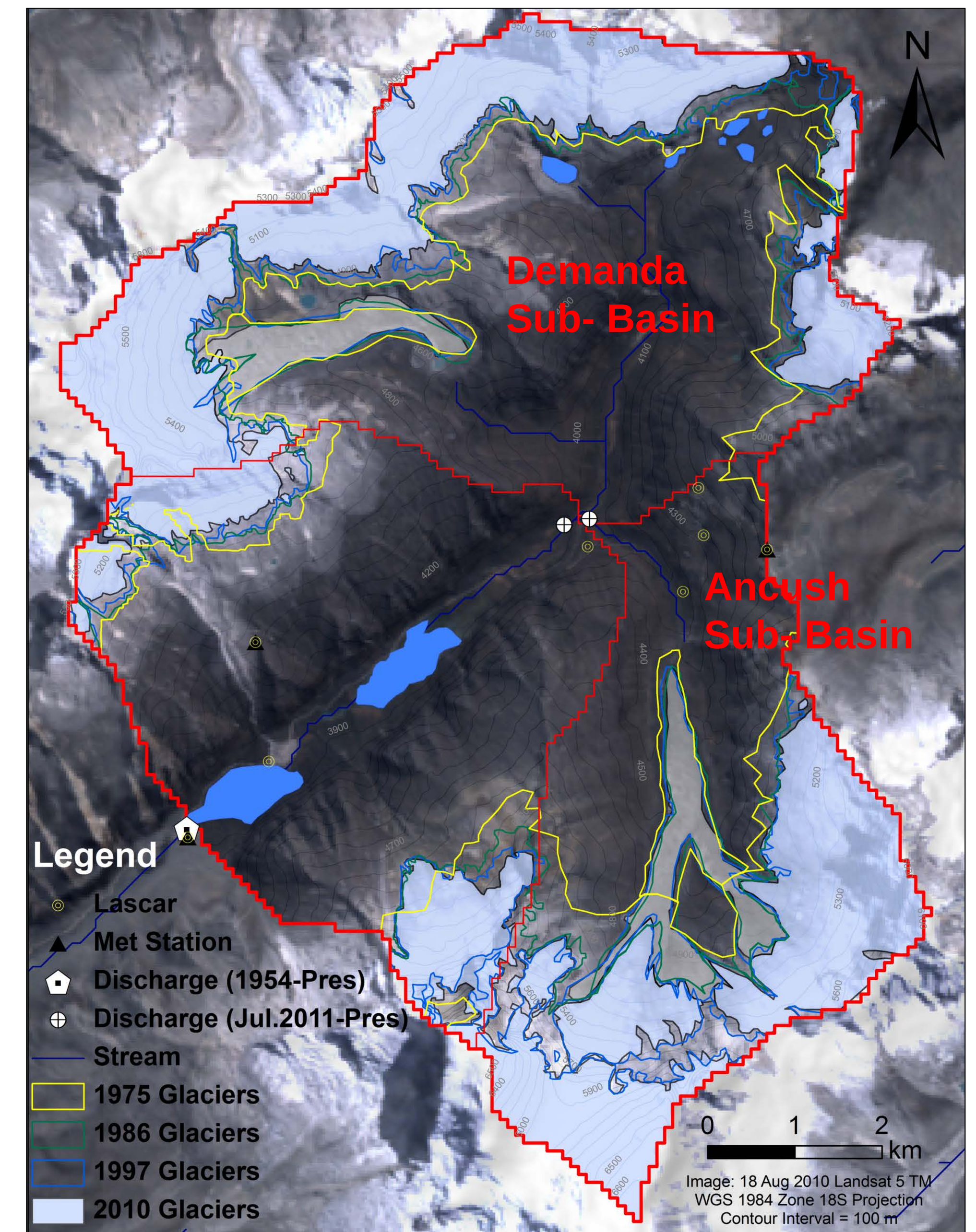


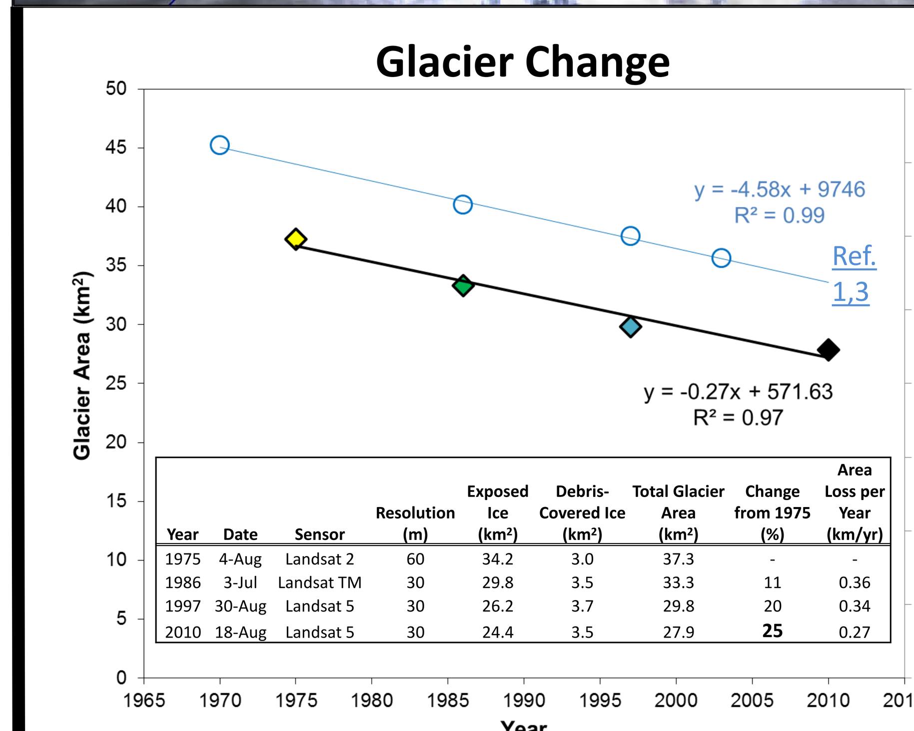
STUDY SITE



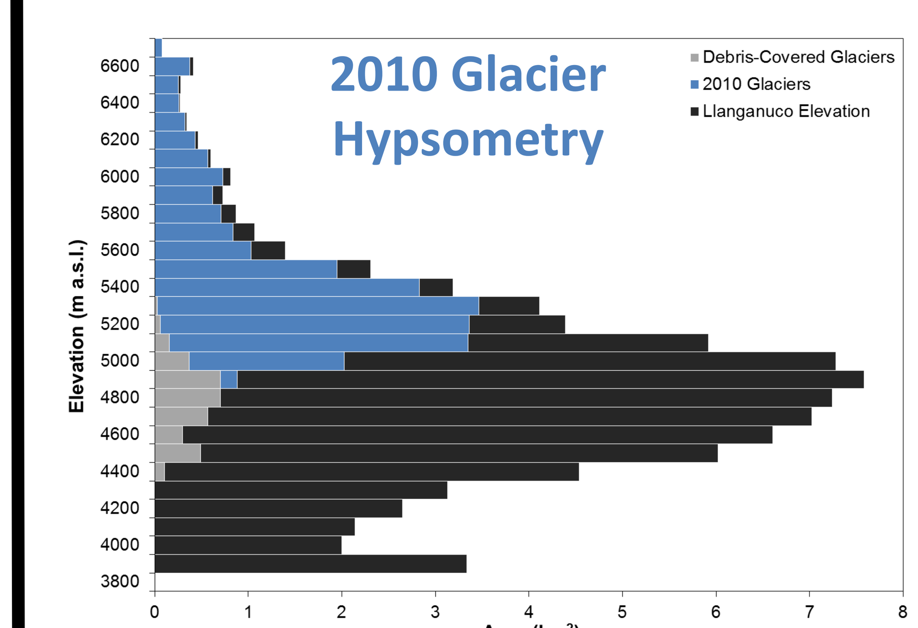


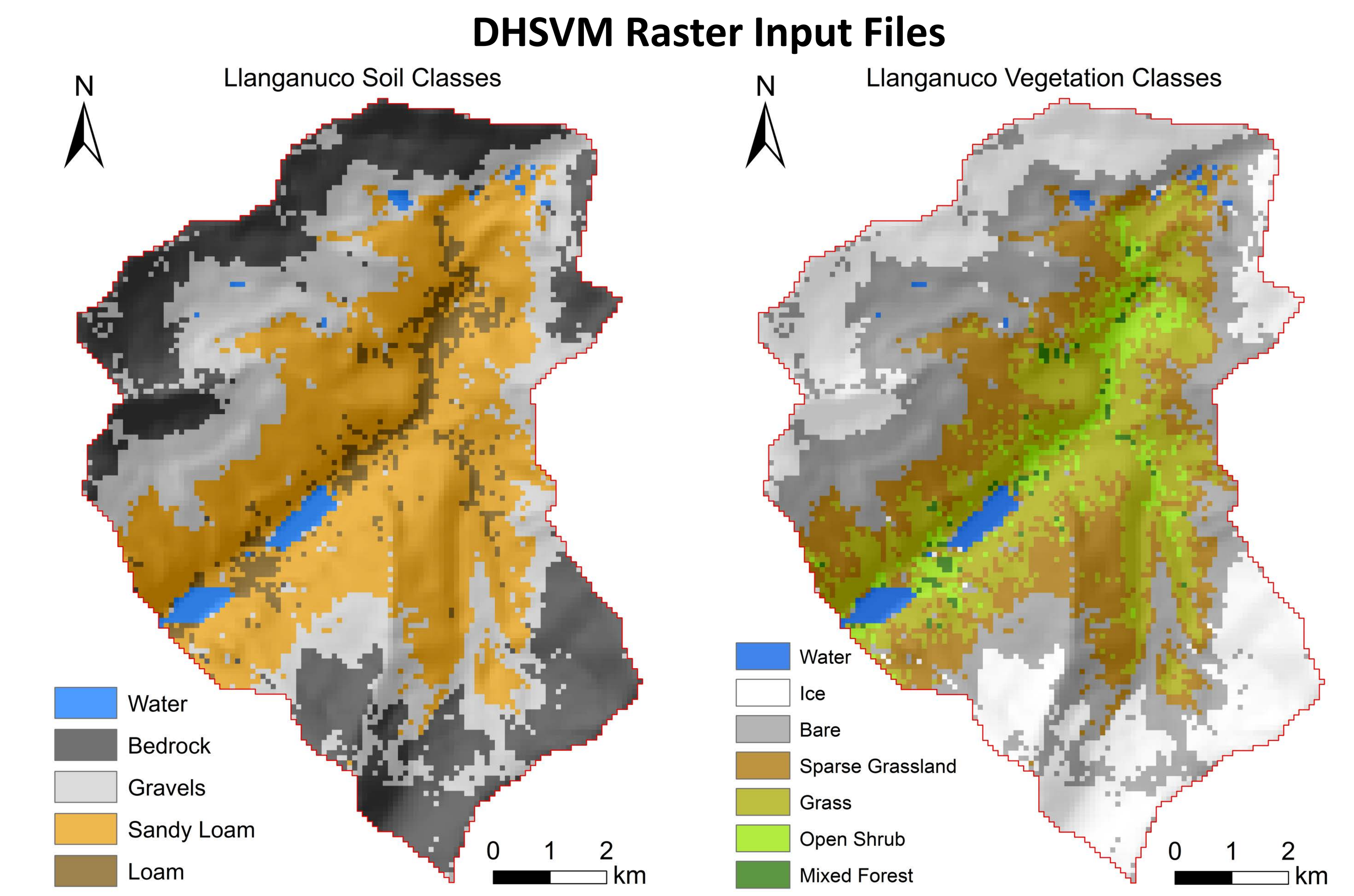
RESULTS

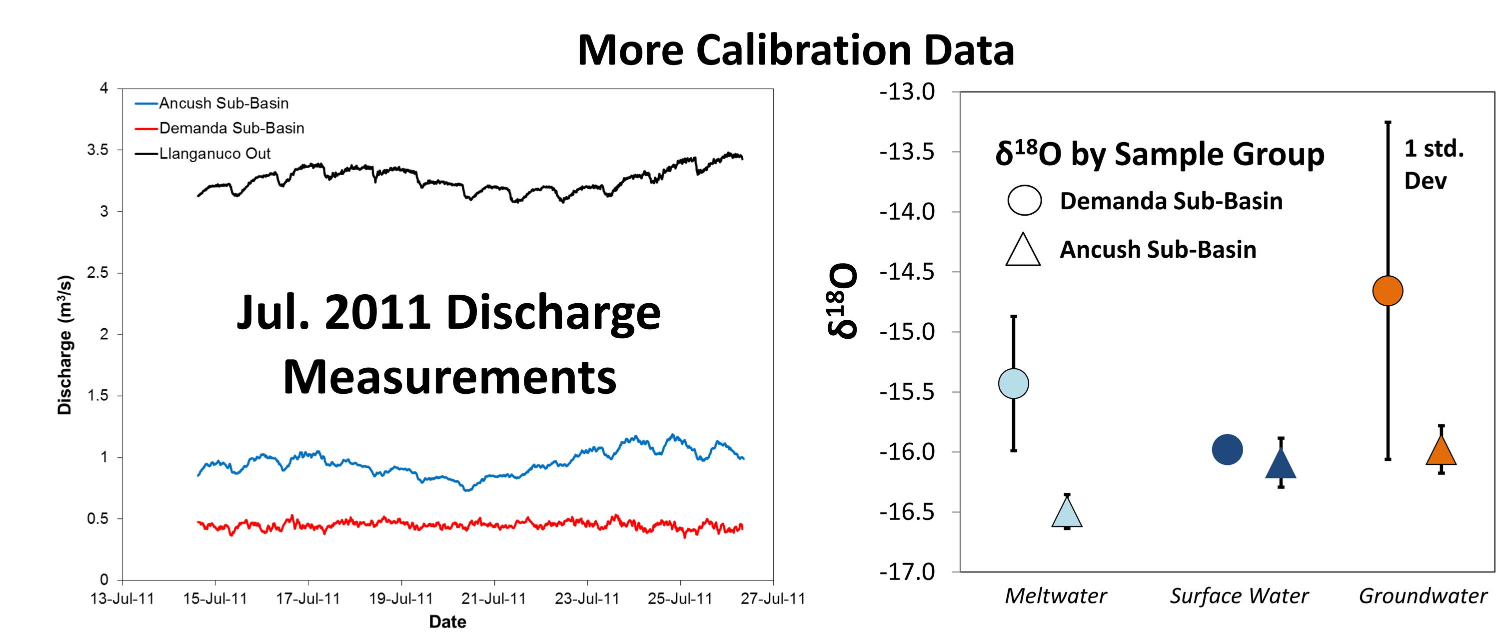




Year	Date	Sensor	Resolution (m)	Exposed Ice (km²)	Debris-Covered Ice (km²)	Total Glacier Area (km²)	Change from 1975 (%)	Area Loss per Year (km/yr)
1975	4-Aug	Landsat 2	60	34.2	3.0	37.3	-	-
1986	3-Jul	Landsat TM	30	29.8	3.5	33.3	11	0.36
1997	30-Aug	Landsat 5	30	26.2	3.7	29.8	20	0.34
2010	18-Aug	Landsat 5	30	24.4	3.5	27.9	**25**	0.27







DATA SOURCES AND METHODS

Model Component	Source	Details	Date of Acquisition
Topography	CGIAR-CSI SRTM DEM	90 m resolution	2000 Feb.
Soils	ONERN (Peru); Field Data	Entisols and Inceptisols; Textures: peat, silt loam, sandy loam, sand (see DHSVM raster)	Field Data: 2011 Jul.
Vegetation	NDVI; Field Data; GeoEye (3.2m) Imagery	7 classes (see DHSVM raster)	NDVI: 2010 Aug. Field Data: 2011 Jul. GeoEye: 2002 Dec.
Meteorological	Automated Weather Station (B.M. Ohio State Univ); Possibly ECMFW-ERA reanalysis data	AWS located within basin; ECMFW-ERA	AWS: ~2004 to Pres., hourly ERA: 1979-Pres., sub-daily
Discharge	ElectroPeru/Duke Energy; B.M., Ohio State Univ	3 stations: Llan Out, Llan Main, and Ancush	Llan Out: 1953-2004 (monthly), 2004-Pres (sub-hourly); Llan Main: 2011 Jul; Ancush: 2011 Jul

- Glacier outlines were created by visually inspecting false color Landsat scenes and creating polygons in ArcGIS v.9.3. This is the most accurate method of measuring glacier extent. We also plan to use the **N**ormalized **D**ifference **G**lacier **I**ndex (NDGI) for comparison and additional measurements. For Landsat scenes,

$$NDGI = \frac{(B4-B5)}{(B4+B5)}$$, where B4 = NIR and B5 = SWIR

- We plan to run DHSVM at 90 m resolution on a 3 hour time step over multiple years. The data we have collected thus far to run and validate the model are shown in the **Table** to the left.
- As an additional check on DHSVM, we collected groundwater, meltwater, and surface water samples for use in an isotopic mixing model. $\delta^{18}O$ was measured using a mass spectrometer. At a specific point in the stream, the results are reported as percent meltwater and percent groundwater.

DISCUSSION

- Glacier area change occurring in Llanganuco mirrors that of the overall change seen in the Cordillera Blanca.
- The change in glacier area does not appear to have affected July dry season discharge in this basin yet. A change in discharge could be masked by storage in the two large lakes above the outflow or by groundwater inputs.
- Further isotopic analysis is necessary to more accurately constrain end members for the mixing model. However, meltwater may be recharging springs in the basin during the dry season.
- Selectively choosing end members yields an estimated contribution of **75% glacier meltwater and 25% groundwater** above the confluence.

NEXT STEPS

- Locate high resolution meteorological data prior to 2004
- Calibrate and validate the model with historical discharge data.
- Run the model on a 3 hour time step at 90 m resolution over multiple years.
- Use future climate projections to model glacier change and estimate future dry season discharge.

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