Comparing climate changes in the tropics and mid/high latitudes - Does precipitation drive tropical glaciations ?

Vincent R. Rinterknecht, L-DEO vincent@ldeo.columbia.edu
Jörg M. Schäfer, L-DEO schaefer@ldeo.columbia.edu
Richard Seager, L-DEO seager@ldeo.columbia.edu
Arthur M. Greene, L-DEO amg@ldeo.columbia.edu

1. Abstract

Paleoclimate reconstructions are essential for evaluating the future evolution of natural climate variability. Reconstructing climate conditions from the Last Glacial Maximum (LGM) to the Holocene represents the unique opportunity to understand the climate variability from full glacial conditions to modern warm conditions. To explain the stunning amplitude consistency of glaciations all over the earth related to the LGM and to the late-glacial cold reversal (e.g. Denton, 1999), summer temperature changes were suggested to be the very dominant drivers of glaciations on a global scale, whereas "local" changes of precipitation patterns only account for short-term "glacial flickering (years to decades)" overlying the general glacial dynamics. If correct, this allows to establish a detailed paleo-summer thermometry by reconstructing amplitude and timing of glacial advances. To test this spectacular theory, we propose to investigate the amplitude, timing, and driving mechanisms of glaciations in the tropics, i.e. the most precipitation-influenced area on earth. We attempt to investigate the amplitude and mechanisms of climate changes in the tropics during the late-glacial. For this purpose we will establish a detailed chronology of the deglaciation in Ecuador using surface exposure dating. Recent progresses have proved the methodology to be applicable for dating millennial time scale events (Stone *et al*. 2003). Specifically we will address: (1) the amplitude and timing of the LGM and the late glacial event, respectively, in the tropics in comparison to mid- to high-latitude events, and (2) the question of distinct drivers underlying glaciations in the tropics. If precipitation is indeed of minor importance as a driver for glaciations world-wide, then the moraine stratigraphy representing the LGM and the late-glacial should be consistent with classic records in mid- (Swiss Alps, Chilean Lake District, New Zealand) and high-latitudes (North-Central Europe, Scandinavia). The methodological merit of this work will be: (1) to contribute to the poorly documented deglacial chronology in the Equatorial region and (2) to increase the range of applicability of surface exposure dating. We will pioneer SED using ^{10}Be contained in granodiorite at low latitude and high altitude. Future work to be submitted as a proposal to the NSF will add a detailed mapping and modeling components to the project.

al., 2002). These studies support the leading hypothesis that the Tropics lead the world wide glacial-interglacial cycle (Cane and Evans, 2000). An independent test for this "early-deglaciation" hypothesis is represented by improving the poorly constrained timing of the tropical deglaciation using the moraine record.

By mapping and dating the glacial sequence in the Equatorial Andes we will contribute to answer the still open question: are climate changes underlying tropical glacial events different or similar in amplitude than in much less humid mid and high-latitudes, i.e. how is the relative importance of precipitation and temperature, respectively, for climate reorganizations on the decadal to millennial scale driving glaciations? Better insight in this problem will in turn improve our understanding of the fundamental character of climate changes in the humid tropics compared to changes recorded elsewhere and thus yield a better understanding of the role of the tropics in climate change in general.

3: Proposed Study

We propose to investigate the amplitude and timing of climate changes in the equatorial Andes and compare the possible mechanisms driving these climate changes during the late Pleistocene to mid- and high-latitudes records.

Glacial mapping: Because the equatorial region is a sensitive area for climate change due to its radiative energy storage and release capacities, it is highly suitable to investigate the climate change characteristics (i.e. precipitation and temperature) driving all glaciers. In the Equatorial Andes, Clapperton (1987) conducted detailed field studies in the Potrerillos Plateau leading to the definition of a late-glacial event constraint by ^{14}C dates (Clapperton *et al,* 1997). The plateau culminates at 4500 m on the eastern side of the Cordillera (Cordillera Real) and the landscape in the vicinity is dominated by the Antisana, an ice-capped volcano culminating at 5897 m. Large boulder-bearing moraines, rock surface with striations and polish attest for the plateau past glacial history. Characterization of the climate change amplitude will be done by reconstructing former tropical equilibrium line altitudes using the altitude ratio method and the accumulation-area ratio method. We will use detailed topographic maps (1:25 000) provided by our collaborator in Ecuador, Minard Hall at the Geophysical Institute in Quito.

Dating by SED: We will construct a robust glacial chronology using SED. The diverse lithology of the Potrerillos Plateau offers the possibility to use several cosmogenic isotopes, thus providing multiple independent ways to obtain the deglacial chronology. Potential sites for sampling are shown on the detailed geomorphologic map (Fig. 1). We will date quartz-bearing rhyolite and ignimbrite with ^{10}Be. ^{3}He concentrations (to be measured at the L-DEO) will be used to date olivine-bearing andesite, and ^{36}Cl will be used to date andesite.

This pilot project will serve as a platform for a proposal to the NSF combining surface exposure dating and climate modeling to investigate the climatological significance of former equatorial glaciations by making use of the expertise on drivers of tropical glaciations summarized in Greene *et al*. (2002).

Drivers underlying tropical glaciations: The mechanisms of climate changes will be investigated using the model developed by Greene *et al*. (2002). First, we will map the LIA extent, for which we have a relatively good data base of the driving forces from tropical SST and precipitation records. We will than map and date the late-glacial (presumably Younger Dryas (YD)) and check with the model if the same set of drivers might be reasonable to explain the late glacial advance, i.e. check if the cooling-precipitation change driving the LIA can explain the YD. Finally, we will apply the model to the LGM.

4. Description of related funded research by the Investigator

Schäfer J. is co-PI on an approved LIF proposal, which covers the establishment of the cosmogenic dating lab at L-DEO. This includes building a hydrofluoric chemistry lab (to separate and decontaminate quartz from rocks for the cosmogenic measurements), as well as the establishment of the column chemistry procedure to extract the in situ cosmogenic nuclides from the quartz separates.

5. References

Alley, R.B., and Clark, P.U., 1999, The deglaciation of the northern hemisphere: a global perspective: Annual Review of Earth and Planetary Science, v. 27, p. 149-182.

Bond, G.C., Showers, W., Eliot, M., Evans, M., Lotti, R., Hajdas, I., Bonani, G., and Johnson, S., 1999, The North Atlantic's 1-2 kyr Climate Rhythm: Relation to Heinrich Events, Dansgaard/Oeschger Cycles and the Little Ice Age, *in* Clark, P.U., Webb, R.S., and Keigwin, L.D., eds., Mechanisms of Global Climate Change at Millennial Time Scale, Volume 112: Washington, DC, American Geophysical Union, p. 35-58.

Cane, M., and Evans, M., 2000, Do the Tropics Rule?: Science, v. 290, p. 1107-1108.

Clapperton, C.M., 1987, Glacial geomorphology, Quaternary glacial sequence and palaeoclimatic inferences in the Ecuadorian Andes, *in* Gardiner, V., ed., International Geomorphology Part II: Amsterdam, p. 843-870.

Clapperton, C.M., Hall, M., Mothes, P., Hole, M.J., Still, J.W., Helmens, K.F., Kuhry, P., and Gemmel, A.M.D., 1997, A Younger Dryas Icecap in the Equatorial Andes: Quaternary Research, v. 47, p. 13-28.

Denton, G.H., Andersen, B.G., Heusser, L.E., Moreno, P.I., Marchant, D.R., Lowell, T.V., Heusser, C.J., and Schluchter, C., 1999, Geomorphology, stratigraphy, and radiocarbon chronology of Llanquihue drift in the area of the southern Lake District, Seno Reloncavi, and Isla Grande de Chiloe, Chile: Geographiska Annaler, v. Series A: Physical Geography 81, p. 167-229.

Greene, A.M., Seager, R., and Broecker, W.S., 2002, Tropical snowline depression at the Last Glacial maximum: Comparison with proxy records using a single-cell tropical climate model: Journal of Geophysical Research, v. 107, p. 10.1029/2001JD000670.

Rinterknecht, V.R., 2003, Cosmogenic ^{10}Be Chronology for the Last Deglaciation of the Southern Scandinavian Ice Sheet. [Manuscripts thesis]: Corvallis, Oregon State University.

Seltzer, G.O., Rodbell, D.T., Baker, P.A., Fritz, S.C., Tapia, P.M., Rowe, H.D., and Dunbar, R.B., 2002, Early Warming of Tropical South America at the Last Glacial-Interglacial Transition: Science, v. 296, p. 1685-1686.

Stone, J.O., Balco, G.A., Sugden, D.E., Caffee, M.W., Sass III, L.C., Cowdery, S.G., and Siddoway, C., 2003, Holocene Deglaciation of Marie Byrd Land, West Antarctica: Science, v. 299, p. 99-102.

Stute, M., Forster, M., Frischkorn, H., Serejo, A., Clark, J.F., Schlosser, P., Broecker, W.S., and Bonani, G., 1995, Cooling of Tropical Brazil (5 °C) during the Last Glacial Maximum: Science, v. 269, p. 379-383.

Thompson, L.G., Mosley-Thompson, E., Davis, M.E., Lin, P.-N., Henderson, K.A., Cole-Dai, J., Bolzan, J.F., and Liu, K.-b., 1995, Late Glacial Stage and Holocene Tropical Ice Core Records from Huascarán, Peru: Science, v. 269, p. 46-50.

Visser, K., Thunell, R., and Stott, L., 2003, Magnitude and timing of temperature change in the Indo-Pacific warm pool during deglaciation: Nature, v. 421, p. 152-155.

6. Itemized budget (in US $)

Airfare New-York-Quito-New-York	$ 640
Per diem expenses (14 days @ $60)	$ 840
Car rental (10 days)	$ 300
AMS analysis (8 ^{10}Be, 4 ^{36}Cl samples at $350)	$4200
Total amount:	**$5980**

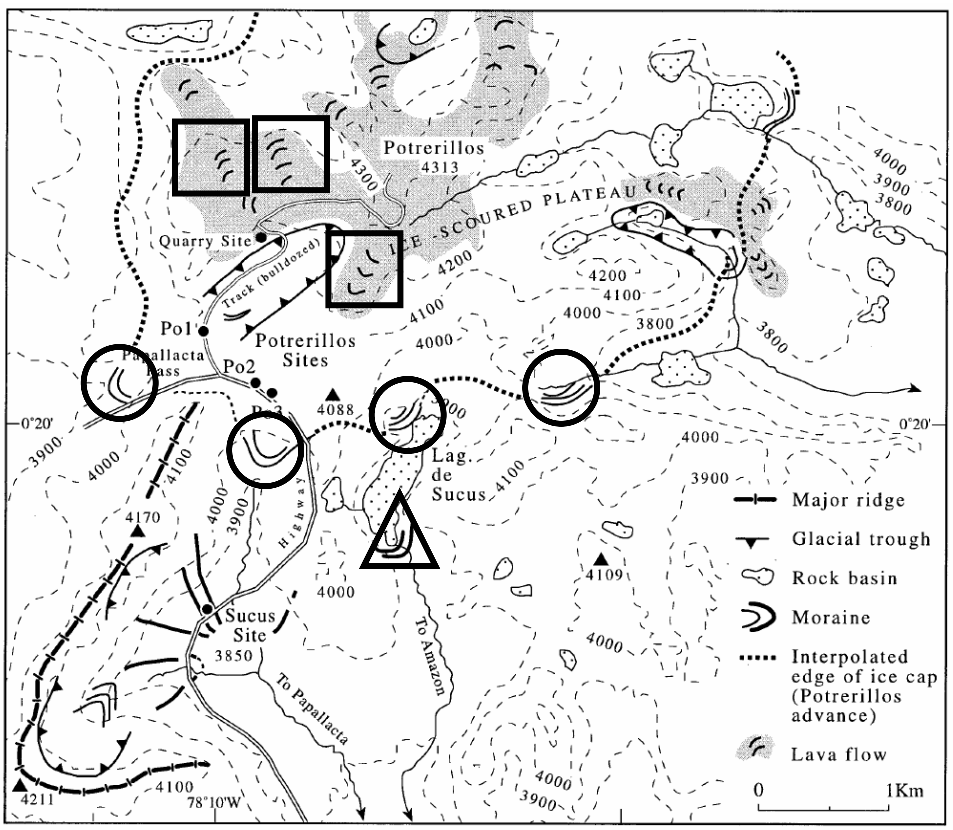

Fig. 1: Geomorphologic map of the study area adapted from Clapperton *et al*. (1997).
Black triangle is a sampling site for the pre-Potrerillos advance (possibly the regional LGM). Black circles are sampling sites for the Potrerillos advance (associated with the YD cold event). Black squares are sampling sites for a post-Potrerillos advance (possibly the LIA).