The Cryosphere Discuss., 6, C1937–C1947, 2012
www.the-cryosphere-discuss.net/6/C1937/2012/

The Cryosphere Discussions

Interactive comment on "Review article of the current state of glaciers in the tropical Andes: a multi-century perspective on glacier evolution and climate change" *by* A. Rabatel et al.

Anonymous Referee #2

Received and published: 24 October 2012

This paper seeks to pull together a diverse set of research on tropical Andes glaciers. It is timely because these authors and other workers have made many important measurements and observations on this set of glaciers. Yet an outside worker would be challenged in any effort to summarize what is known about topical glaciers because the reports are diverse and cover many years of work. The authors are to be commended for their contribution to this key topic and for their efforts to synthesize it.

Having said that, this reviewer feels this effort is not living up to its full potential. It is hoped the authors consider the following comments and suggestions to improve transmission of their insights to the broader community.

General suggestions

Since this is a review, might a reordering be possible? For example because of the range of topics being covered, the methods, results, and to some part the discussion areare hard to follow because the topic is first introduced in the methods, then reintroduced in the results and then finally in the discussion. What if, for any topic, it was reported on completely - how the data was gathered, what it shows, how it links to other topics? Then move on to the next topic. The results have a broad framework of longer time scale moving toward shorter time scales and this may be a useful plan to follow.

It seems the main topics being reviewed are 1) glacier changes since the LIA, 2) glacier changes in the last 50 years, 3) mass balance observations, 4) links of mass balance to local/ regional climatology (including SST and El Nino). These may or may not what the authors feel are the key topics, but these are the ones that come across in the present draft.

The authors might consider a section on remaining/ current challenges. With these data sets in hand, what are the outstanding issues? What needs to be done next? Modeling, more data collection, more LIA studies, or expansion of the spatial coverage? All of these could benefit from the authors insights. However this section should not simply be a call for more work. What are the specific unresolved questions that the community must answer? Perhaps questions like: How are changes in SST transmitted to the glacier energy balance? What is the role of sublimation in the total mass balance? Are the inner and outer tropics glaciers likely to have similar or different responses to future climate change? How are changes in mass balance transmitted to glacier length? Is it the same for growing and shrinking glaciers?

This list is illustrative only and is it not suggested that these are the most important questions. In fact, the answers to some of these may be clear to the authors. Because the tropic glaciers exist in such a different climatology setting than many other glaciers,

the authors could identify which questions are necessary to answer.

Specific Comments/ Technical Corrections

2759:12 refers to page and line number.

Should indicate the spatial coverage of where the inner and outer tropics are located. Perhaps on on Fig. 1.

2479:10-16 - Confusing - especially line 13-14 - could the clause about percentage be removed.

2479:16 - Can one “variability” be removed/ changed in this sentence?

2479:23 - The relative importance of El Nino and troposphere temperature might be noted here.

2480:19-24 - This may be too much detail for the introduction. Can it be summarized some?

2482:5 - As written this sentence is a bit confusing - can it be shortened?

2482:19 - Which zones does “ tropical” refer to?

2482:20 - Give approximate geographic extent of each zone.

2482:23 - Which zone does “low latitudes” refer to?

2.1 In general it is hard to see the contrast between these two zones, but it is often hard to tell which zone is being referred to.

2483 - Why is lichenometry noted here and then in a separate paragraph? Combine the reports using this approach.

2485:22 - Some typo with the numbers.

Could section 2.3.5 be combined with section 2.1? In some ways section 2.3.5 is both the report of new data captured by various workers and the use of the NCEP/NCAR

data for analysis.

2489:8 - The first part of this paragraph contrasts different mountain ranges. The sentences here are talking about elevation. Do the elevation relationships refer to all mountain ranges (really latitude) or just some specific area?

2489:17 - This sentence is hard to follow.

2489:22 - What does “this” refer to?

2489:28 - Again this reference to elevation is hard to follow.

2490:9 - What is meant by “best”? You need some objective criteria for plotting some glaciers and omitting others. What is it?

2490:11 - A third main feature is that retreat has been underway since 1650. It may not be as fast as later recessions, but the trend is strong as shown in Fig. 3. There is also a minor recession expressed in all glaciers in 1750.

3.1 - There are other chronologies developed for the LIA that should be reported since this is intended to be a comprehensive review.

2491:21 -The reference to Fig 4 includes all the examples noted in this paragraph. The sentence should be rephrased or moved to indicate this.

2492:4 - The prior paragraph considered the entire geographical range. This paragraph is focused on just one area with a different metric. Some explanation of why the switch would allow the reader to better follow your logic. Also the reader might be confused because the reference to Fig 4 and 5 is in the section on Peru, but includes data from the entire tropics.

2492:7 - The break point suggestion is poorly supported because of the contrasting data before and after that time. Can this rephrased? This should show up better on Fig 4 because the plot is a rate or derivate of length, but it really is only seen in one glacier (S.N. del Cocuy) where it is very strong.

2492:20 - Again define what criteria is used to define the “best”.

2491:21- Can you assign some length to “small” to provide the reader with context (few m’s vs 100’s m).

2493:18 - What is meant by “intermediate information”?

2495:7 - There is something odd about the term “do not have a permanent accumulation zone” Without an accumulation zone it follows they will disappear. Is there any way to estimate when these low elevation glaciers lost their accumulation zone. A statement to that would convey a stronger message about the state of Andes glaciers.

2495:10 - Some sentence that ties the section heading to the mass balance would help the reader follow the details that come next.

2495:19 - Here and in several other places in the text there is reference to the size of the accumulation area and its elevation. Sometimes they are noted together, sometimes only one or the other. They are generally correlated, but perhaps some more quantification is needed rather than simply “large or high”. Fig 7 breaks them into elevations at 5400 m. On what basis was this elevation selected? Does this represent the upper most elevation of the accumulation area, the mean elevation of the glacier, or the lowest portion?

2495:21 - What does “maximum altitude dependency” mean?

2495:24 - This statement is well supported by your arguments and is a very important one. However, in other parts of the text this conclusion seems to be mixed in with the issue of interannual variability of precipitation. It should be clear to the reader how you rank the relative importance of these two differing factors. This may vary if different time scales are considered. If so the time scale should be noted.

2496:1 - Seems like the interannual variability would be superimposed on the long-term trend not the other way around.

2496:18 - This point may need some caution associated with. This time is also just after a marked increase in the number of records. Can some analysis be undertaken to show this is not an artifact of the of the number of data points used to derive the average?

2497:21 - This sentence is very hard to follow. Too many details and topics introduced.

2497:24 - There are two incidences of “its” at the end of the line - what do they refer to? This sentence is hard to follow. What is a primary control on melt?

2498:1 - Switching to long-wave radiation is not a clear connection with the prior sentence. The rest of the sentence is likewise confusing.

2498:5 - Need more explanation for most readers how the vertical mass balance is controlled by the radiation balance.

4.1 This entire section jumps around from on topic to the next without transitions. This is more a list of relationships than a discussion. Since it is the first section in the discussion, it should server to set the general direction to be taken. As is this lists details which are hard to understand. Are the points here different or same as glaciers in other regions. In some cases it seems the main point is total mass balance and in other cases it seems the main point is ablation. Can you discuss each (ablation and accumulation) in turn and then comment on the relative importance to total mass balance? Perhaps this has to be done for different time scales or different climate zones (inner or outer tropics). But there has to be some common thread that is not yet present.

2498:15 Too many topics for most readers to follow.

2498:26 This sentence is to vague to set the context for what comes next.

2499:5 - What is meant by sensitivity? Different workers have defined this differently, which definition is used here?

2499:7 - This concept needs some follow up. How does a rise in the freezing line impact the melt processes?

2499:10 - This is vague. Can the case where the ELA> freezing line be shown to have a (high or low) sensitivity whereas the case where ELA<freezing line has a (low or high) sensitivity?

2499:18 Sentence is too complex to understand. The concept of sublimation deserves more examination than a clause at the end of a sentence. Of if little is know about its relative importance, then that should be noted.

2499:22 - Very little mention is made of the runoff values - where did this information come from?

2499:26 - Does onset refer to the timing of the wet season? This entire section is generalizations without supporting data. The results sections largely focused on total mass balance changes, but did not explain the controls on the mass balance. Thus the reader here has not basis to evaluate statements like this one.

4.1.1 and 4.1.2 - These sections could be important in contrasting any understanding of glacier mass balance in these two climate zones. Some readers will not be able to extract the key differences after reading these two sections. Could some conceptual diagram of how all of this relates - one for the inner and one for the outer tropics - be given in a table or figure? The reader then could see the major differences and then be better prepared to review all the complicating factors within the text.

2500:19 - Citation/ evidence for this relationship?

4.1.3 This section gives a series of relationships, but they are not well supported nor are they quantified. Thus the reader may come away from this section with some of the complications in the relation between air temperature and ablation, but they will not come away if it is important or not. Given the extensive data set available to the authors, one wonders what a simple plot of air temperature and ablation would show.

That the reader should not take this a physical law, but rather as a first order empirical relationship, based on complex interaction physics, that can be expanded on the text.

2501:12 - Remind the reader if Ecuador is in the inner or outer tropics.

2501:14 - Hard to follow. What is meant by Feb to May being the maximum year to year variability?

2502:27 - The introduction of other atmospheric forcing are concluded to have an impact on the mass balance, but there is no supporting evidence presented to support that possibility.

4.2 - Generally this section can be followed. However once some general relationships are suggested, any exception is noted. Given the limited number of ENSO cycles that can be matched to the mass balance studies, is it possible that the general relationships are too simplistic? Some readers may view Fig 10 and wonder about the contrast the relationships after Feb 2000. For the inner tropics the inverse relationship between SST and mass balance seems strong. For the outer tropics, except for the time around Feb 98, the strength of the correlation is, at least visually, poor. Should this be discussed in the text?

2503:7 - The working term PME is perhaps useful to convey the time of maximum mass balance for each glacier. However since that time does vary from glacier to glacier, it complicates any attempt to identify a universal cause for the retreat from the LIA. Would it be better to simply take some common time slice and discuss retreat from that time to the present. The temporal limit is not perfect, but at least it would avoid the issue.

4.3 - The main conclusion of this section appears to be that decreases in precipitation are responsible for glacier retreat since the LIA. How do the authors remove the effect of the rise in temperature that has also occurred since the LIA to reach this conclusion?

2506:19 - The text talks about the elevation range of the ablation zone, but Fig. 11 uses the snout elevation to the mean elevation. These may be approximately similar,

but they are not the same. The authors should explain to the reader what the general relationship of the 12 month running mean of freezing level to the ablation level so the reader can understand the full significance of the sentence in 2506:22.

2506:25 - When is the recent marked increase in freezing levels?

2506:28 - It appears some word is missing or added in this line.

2507:4 - Should the Pacific SST be included someplace so the reader can evaluate the structure of temperature change?

2507:6 - Is the snout elevation assumed to be the same over this interval or does it change?

2507:20 - Rather than “last two years” say since 2010.

2508:5 - Here the message is that rising temperatures are responsible for the glacier evolution (taken as change in length or area). Why is that glacier evolution during the LIA is suggested to be under the control of precipitation and yet in the last $\sim$50 years evolution is suggested to be under the control of temperature? Can the authors comment on what would cause that change in control?

4.4.2 - Could the data in Fig 12 be plotted with the data from Fig 5? This would give the reader a direct comparison of surface are changes and at least the ablation factor. If the view that temperature is responsible for the retreat, there should be a very close correspondence between the two data sets.

2508:27 - This arguments might be stronger if the CROCUS model was explained briefly and some comment made if Zongo Glacier is representative of the Andes as a whole. The section with the Lejeune (2009) is a very specific example of what warming will do.

2508:6 - Make it clear you are projecting the regional prediction onto the Zongo Glacier.

2509:23 - At least in terms of percentage.

2509:25 - Most readers will visualize retreat in terms of glacier length or volume, but you are pointing out the mass balance change here. In the last sentence in this paragraph you are reverting back to length or volume.

2510:10 - Is the reader to infer that temperature is the primary control on the interannual variability of mass balance?

2510:11 - This summary point has too much information for the reader to grasp quickly. Can this be broken down into perhaps two paragraphs? One might focus on the impacts of the short wave radiation balance, and the other about the role of precipitation in the energy balance.

2511:5 - Since the whole issue of water usage is not covered, move this to your concluding statement, rather than keep as a summary point.

Fig 1. Can the approximate limits of the inner and outer tropics be shown? The large reg hexagon is hard to find.

Fig 2. Upper panel - what is the vertical axis with in each latitude band? It appears to be latitude? It is not clear from the figure caption. What are the white triangles? What is a glacier summit? What is the PME? The linkage between precipitation and PME is not as clear as suggested, a more cautious tone is needed. In the lower panel these records come from different latitudes can they be indicated in the same way the glacier records are ordered in the upper panel? Can you indicate which glaciers and which proxies are in the inner and outer zones. Would it help to make two diagrams - one for the inner and one for the outer? For each put both the glaciers and proxies together.

Fig 3. Some reference to the raw data source should be included.

Fig 4. Should some error estimate be attached to the Average value?

Fig 5. The vertical axis is hard to understand. Change in % -Just how much is 60 %. For the 0 % case, it could be taken to mean no change. For 100% change is could be taken as doubling in length. Can this label or scale be changed? The caption says

area and length. Plotting both on the same graph is confusing as area is unlikely to have a simple relationship to length. Can the raw data be of one or the other type - if possible then area would help the reader see the linkage to Figures 3 and 4. Figs 3 and 5 would have different time scales and Figs 4 and 5 would contrast area and rate.

Fig 6. Should include some latitude information for these two examples.

Fig 7. What is the attribute for separating high and low?

Fig 8. The error bars for the individual studies are shown, but what about the error assignment for the average. That is needed to get the sense that global and intertropical trends are the same or different. It would also be useful to indicate if the flips in the 1980's are real or not?

Fig 9 - Which are inner and which are outer tropics glaciers? What are the elevations of? It is interesting that any annual signal is not present.

Fig 11. The blue shaded area is from the lowest glacier snout to the mean elevation. The constant width of those area implies neither the snout or mean elevation of the glaciers have changed over this time interval. Is this correct? It would seem strange given the plots in Fig 5.

Fig 12 - Basically assumes some baseline constant level pre 1955. Why is that year chosen.

Interactive comment on The Cryosphere Discuss., 6, 2477, 2012.