The Cryosphere Discuss., 5, C250–C255, 2011
www.the-cryosphere-discuss.net/5/C250/2011/

The Cryosphere Discussions

Interactive comment on "Characterization of glacier debris cover via in situ and optical remote sensing methods: a case study in the Khumbu Himalaya, Nepal" *by* K. A. Casey et al.

T. Bolch (Referee)

tobias.bolch@geo.uzh.ch

Received and published: 19 April 2011

General remarks: The manuscript contains analyses and novel results of high interest. In addition, this paper introduces some methods (esp. mineralogical analysis) and data (esp. Hyperion, EO-1 ALI) which are uncommon but promising for the glaciological research. However, the manuscript is currently too long and misses the focus. The main message of the paper should be presented more concisely. The authors are sometimes very detailed (e.g. description of sensors) and refer on the other hand sometimes only to the cited literature while some more information would be of interest for the less informed readers. This especially the case when the authors refer to own work (e.g. for

the flow velocity calculations or debris cover determination). The authors should stay in similar level of detail, do not present background knowledge and focus on the really important issues. Repetitions should be avoided. Some of the presented techniques are well known and confirm previous results (e.g. velocity estimates, surface temperature). The authors present many different interesting methods and techniques and in most cases one or two examples for application. However, in order to clearly show the suitability for a special purpose the accuracy of the results remain vague (e.g. with TIR emissivity for debris-cover mapping, spectral angle mapper classification etc.) and the usefulness of the analysis and techniques need to be addressed more in detail. Sound numbers and uncertainty estimates should be included in several cases. The authors mention which important results could be obtained when combining the different methods but do not include really convincing results and remain descriptive. The content would be in my mind much stronger and convincing when the authors really apply the promising combination of the different techniques to obtain new promising results instead of just naming the possibilities. In this respect additional analysis and data needs to be integrated. The authors may then think to split the manuscript into two papers, e.g. one containing the mineralogical part of this paper which fits to a more mineralogical or geological related journal and the more applied and cryospheric related topics should remain then in The Cyrosphere. Or the content may be splitted in a Part I and Part II paper in The Cryopshere if the editors agree. However, this is the author's decision. The included references are comprehensive regarding the remote sensing and cryospheric related topics and also for the mineralogical part as far as I can evaluate it as a non-expert in mineralogy.

The contents of the manuscript should ultimately be published but the content needs to be consolidated and presented more precisely.

Specific comments:

Abstract L. 1-14: The word order and wording of the first sentences are similar. It is not wrong but it reads a bit stereotyped.

Context L26ff: You may include one additional reference which also deals with surface velocity based on optical imagery which is not from one of the authors (e.g. Scherler et al. 2008 and/or Bolch et al. 2008 which are cited later in the manuscript). P502, L3: The “3rd pole” comprises of the Tibetan Plateau and its surrounding mountains including the Himalaya. Correct or omit. L6: Just write “and sea-level rise” L 14ff: You may mention some publications using thermal data for studying debris-covered glaciers and its characteristics (e.g. Suzuki et al. 2007, Mihalcea et al. 2008) in the introduction (see comment below).

2 Optical remote sensing of glacier debris

2.1 Sensors This section can be shortened significantly (∼half a TDC page). It is not necessary to describe the basics of remote sensing and the characteristics of the also in glaciology widely used MSS, TM, ETM+ and ASTER sensors. You may include the bands and resolution in table 2 and refer to a reference for further reading. However, it is worth mentioning more details of Hyperion and ALI as they are not very common in cryospheric research.

2.2 Measuring lithology P.505L21 to P506L10: This would fit better in the introduction. You would also avoid repetition (e.g. the double citing of papers like Bolch et al. 2007 or Paul et al. 2004 in the same context).

Study area P507L1f: Who observed “significant melt”? The authors during their field work? Is this common or was this melt exceptional? There is meteorological data from the Pyramid near Khumbu Glacier available which could be used herefor.

Data and Methods Please include some information about the co-registration of the data and also a short statement of the accuracy of the terrain corrected data.

P510L25 to 511L9 can be shortened a bit as it is presented in table 2. P511L10-12: Sentence and reference would fit better in the chapter “2.1 Sensors”. Eq. 1: You may omit equation 1. You refer to the reference which is sufficient.

Results P512L19-21: I suggest omitting.

5.1 Field spectrometry P 513L9-11: Six references in a row for this statement are too much, I suggest to reduce to three.

5.3 Optical satellite data General. You show nicely that different lithology can be visualized. You may also provide some information about the possibility and accuracy of a classification. The first section may be shortened a bit. Why is only ASTER addressed in this first part of 5.3 but later different remote sensing data are addressed? Either address all data here or provide the information in the respective section. I suggest the latter.

P516L26ff: ASTER band 3-9 match remarkably well, while esp. band one seems to be a little bit too high. You may include a short comment on this. P517L14: Delete the brackets. L22: The atmospheric effects are clearly visible in Fig. 8. I suggest you may indicate the affected are in the figure with an arrow or similar for the non specialists. L26ff: It is not needed to name all the software for atmospheric corrections just refer to the reference.

5.3.2 Shortwave and thermal false colour composites P518L23f: Be a bit more precise. How can glaciers with debris-cover detected with thermal data? What are the drawbacks? You have already mentioned the debris-cover glacier mapping with thermal data in the Introduction. Hence, provide the required information there which also avoid duplication.

5.3.3 Mineralogic mapping P. 519 L 16f.: Avoid duplication of the figure captions and the text. I suggest shorten the captions accordingly. Please provide a zoom of the mentioned confluence to Khumbu Glacier in figure 9. You may also mention that the different lithology is also to a certain degree visible in true colour images.

TIR emissivity to map silica abundance

P522 L 13: Show only the years in brackets. L20f: How was the threshold of 60%

obtained? By visual checking? P523L7f: I agree that the thematic map shown in fig. 11 provides a hint about the extend of debris-covered ice. However, if you are familiar with this area you can immediately see several misclassifications. Hence, the authors should make this statement with more caution.

Spectral angle mapper This section needs clarification. How was “SAM was evaluated in this study” (using ASTER L1B data) and what does it mean that “preliminary SAM analysis on Khumbu glacier provided successful first-order differentiation of bare ice, snow, silica, calcite, and vegetation land cover” Can some numbers be presented?

5.3.4 Land surface temperature The section confirms mainly previous measurements. The authors should provide some more information about the suitability of the thermal information for glacier mapping. Could a “cooling effect” due to the underlying ice or exposed ice cliffs be detected? You may also consider the relation of the temperature to the colour.

5.3.5 Glacier velocity, streamlines Also this section more or less repeats (and confirms) the result of several previous research as correctly stated in the manuscript. The presented results are a bit vague. More details are needed so that it would make sense to present one more data on surface velocity for this area. . L6: What threshold was used? What does “some remaining spurious” mean exactly? How was the possible uncertainty estimated? L7. I do not understand why the authors use the from 2005 and 2009 to “ensure that the glacier surface velocities did not change significantly between 2000–2002 and the time of our in situ sampling”. What does it mean that no “significant trend were found”. It would be interesting to know if there are no significant trends throughout the glacier or if a decrease in velocity as suggested by Quicey et al. (2009) is found for parts of the glacier.

Synthesis The synthesis is little bit hypothetic. The authors present several hypothesis but the authors should back up their suitability by presenting more examples and refer to references.

Conclusions The conclusions should be shortened and more focussed.

Figures The captions are in several cases quite long. I suggest to shorten provide the information in the main text as usual. The authors would also avoid then also repetitions. In addition, a legend can be included in some figures. This is especially useful when symbols are presented (e.g. Fig. 8).

References: The correct citation for Buchroithner and Bolch (2006) is: Buchroithner, M. F. and Bolch, T.: An automated method to delineate the ice extension of the debris-covered glaciers at Mt. Everest based on ASTER imagery, Grazer Schriften der Geographie und Raumforschung, 43 (= Proc. of the 9th Int. Symp. on High Mountain Remote Sensing Cartography, 14-22 Sep. 2006, Graz, Austria), 71–78, 2007.

Please check the following reference: Casey, K. A., Xie, R., Ryset, O., and Keys, H.: Alpine glaciers in the Himalayas, New Zealand and Norway: investigation of trace elemental abundances, in: International Symposium on Earth’s Disappearing Ice, International Glaciological Society, Columbus, Ohio, USA, 15–20 August 2010, 59A029, 2010. Is there a conference proceeding available or do the authors just refer to the abstract?

Additional references within the review:

Suzuki, R., Fujita, K. and Ageta, Y.: Spatial distribution of thermal properties on debris-covered glaciers in the Himalayas derived from ASTER data, Bulletin of Glaciological Research, 24, 13–22, 2007. Mihalcea, C., Mayer, C., Diolaiuti, G., D’Agata, C., Smiraglia, C., Lambrecht, A., Vuillermoz, E. and Tartari, G.: Spatial distribution of debris thickness and melting from remote-sensing and meteorological data, at debris-covered Baltoro glacier, Karakoram, Pakistan, Ann. Glaciol., 48, 49–57, 2008.

Interactive comment on The Cryosphere Discuss., 5, 499, 2011.