Atmos. Meas. Tech. Discuss., 7, C1957–C1964, 2014
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Atmospheric Measurement Techniques Discussions

Interactive comment on "Automatic cloud top height determination using a cost-effective time-lapse camera system" *by* H. M. Schulz et al.

Anonymous Referee #2

Received and published: 30 July 2014

Review of manuscript AMTD-7-2783-2014

Automatic cloud top height determination using a cost-effective time-lapse camera system

by H. M. Schulz, S.-C. Chang, B. Thies, and J. Bendix

Major comments This paper describes a technique to derive the height of cloud tops and/or fog from the imagery of a time-lapse camera system located above the cloud layer within a mountain gorge/valley. Cloud top height is calculated by first determining the image locations where the cloud layer touches the terrain (contact points) and then matching these points to a digital elevation model projected to the view of the camera. The technique is reasonable and the topic fits the scope of AMT. The paper is generally

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well written, although the algorithm description is, at times, difficult to follow without explanatory figures. The results section is rather short, but this might be acceptable considering that the main goal of the paper is presenting the algorithm with preliminary validation. What the paper lacks, in my opinion, are (1) an error analysis and (2) a more detailed discussion of the technique's limitations. These points should be included or expanded upon in a revised manuscript.

Regarding issue (1), the contact point locations are presumably determined with some uncertainty (2 pixels, 1 pixel, half a pixel, please advise), which then introduces some error in the calculated cloud top heights. Could the authors provide at least a back-of-the-envelope error analysis, which estimates the cloud top height error due to the expected uncertainty in contact point location as a function of the steepness of the mountain slope and perhaps distance to camera? You mention that areas farther than 10 km from the camera as well as steep slopes are excluded from the calculations. But were these thresholds on horizontal distance and slope derived by a quantitative error analysis? In addition, is it possible to obtain spurious contact points with (far-away) terrain features that are not part of the gorge and for which the assumption of the cloud layer touching the terrain is not valid? Does the algorithm filter out such spurious contact points?

Regarding issue (2), the algorithm has been partially validated during springtime in a snow-free valley. Is the technique limited to snow-free mountains? Cloud detection over bright (snow- or ice-covered) surfaces is a difficult problem, at least for space-based retrieval methods.

In Tables 1 and 2 you present a 2x2 confusion matrix. Could you also calculate the Matthews correlation coefficient (MCC; Matthews, 1975; Bley and Deneke, 2013)? MCC is generally considered as one of the best-balanced measures of a confusion matrix, even if the true/false positive/negative classes are of significantly different sizes. For example, in Table 1 there are more than 3-times as many true negatives (n00) as true positives (n11). The situation is better in Table 2, where n00/n11 $\sim$1.4.

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Furthermore, Tables 1, 2, and 3 combine results for all lighting conditions. You mention that the algorithm works for complex lighting conditions (near sunrise/sunset) as well as in the presence of shattered clouds over the valley fog, and present Figures 13 and 14 as respective examples. In addition to the overall results, could you perhaps provide validation tables separately for a few classes of different lighting conditions? For example, you could separate your scenes into high sun, moderate sun, and low sun bins based on the solar zenith angle. Or scenes could be classified as clear-sky or cloudy-sky above the mountain fog. Such stratification of your validation results could reinforce your claim, in a quantitative manner, that the algorithm works equally well under different lighting conditions. Given the relatively small number of validation scenes I don't expect a very detailed analysis, only a few simple classes if possible.

Overall, I recommend the paper for publication in AMT, but I hope the authors make an attempt at addressing the issues outlined above.

Minor comments

The title could be made more specific, indicating that the method has been developed specifically for mountain gorges/valleys.

Although the method is mostly automated, "empirically derived thresholds" have been mentioned six or seven times throughout the manuscript. These thresholds probably need significant refining for each different mountain valley; so perhaps "fully automated" could be replaced with a weaker formulation.

Page 2784, line 24: "If zDEM is equal to or below zCB. . ." Shouldn't it be above zCB?

Page 2785, line 8: "...that is far away from perfect." Far from perfect sounds better.

Page 2785, line 11: "...cloud radar devices." Cloud radars would suffice; "device" is not necessary. Also in line 13.

Page 2785, lines 15-17, first sentence of the paragraph: This sentence is convoluted and difficult to follow. Could you rephrase and simplify? E.g. The lack of

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cloud height data in remote regions also impedes the design of ground fog detection schemes/networks.

Page 2785, line 17, next sentence: "...inter-diurnal dynamic of cloud heights..." Do you mean diurnal variability of cloud heights?

Page 2785, line 25: MODIS, spell out the acronym.

Page 2785, line 27: "...the mentioned problems..." Aforementioned might be better.

Page 2786, lines 7-10: The sentence starting with "The necessity of manual..." is confusing. You could just remove the part "for any comprehensive statistical investigation as the mentioned preliminary studies" to make it sound better.

Page 2787, section 2.1: The first and the third sentences sort of say the same thing, that is, the Taroko Gorge is well suited for testing cloud top height retrieval techniques. Maybe you can combine the two sentences.

Page 2787, line 11: "...can be considered as suited for the installation.." as suited is not necessary.

Page 2788, line 1: "...usually form in different heights..." at different heights sounds better.

Page 2788, line 8: "...in a distance of about 200 m." at a distance of ...sounds better.

Page 2788, lines 22-23: Spell out acronyms ASTER and METI.

Page 2789, line 23: "...in a temporal resolution of..." at a temporal resolution of

Page 2789, lines 24-28: The first two sentences ("Scenes are discarded if...") are awkward, what with the parenthesis and the word "therefore". Could you rephrase? Also, it should be "an undifferentiated image".

Page 2791: The discussion on adjusting the camera based on the virtual and true horizons is a bit difficult to follow. Could you describe verbally too what the fit quantity

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in equation (1) represents?

Page 2792, the first bullet (-) point: You exclude terrain farther than 10 km from the main camera. Was this horizontal distance threshold derived by an error analysis, in order to limit the errors in cloud top height retrievals? Also, you filter out slopes (edges) whose steepness exceeds 400 m and 200 m per pixel, respectively, for the northern and southern parts of the gorge. If the goal is to eliminate areas where cloud top height retrievals are sensitive to a small error in the camera parameters, why the different thresholds for the two different parts of the gorge? Why do you use a more conservative value for the southern parts of the gorge? In addition, the word "adulterate" seems out of place here; you could say instead that near steep edges the retrieval of zCT is very sensitive to small errors in camera parameters, or something to that effect.

Page 2792, the third bullet (-) point: You mention k-means clustering, which requires setting the number of clusters k, which is an input parameter. How many clusters do you use for fine segmentation? The number of optimal clusters presumably depends on the local topography and, thus, is different for each valley. This seems to be another parameter that needs to be tuned on a case-by-case basis (cf. fully-automated method).

Page 2793, lines 14-15: "...that is degenerated by the factor of 4 in..." ...that is decreased by a factor of 4 in...

Page 2794, lines 7-10: The sentence "Despite the fact that..." is not clear. Do you mean in addition to/besides the fact that..., rather than despite?

Page 2794, line 17: "...the distance depended influence..." ...the distance dependent influence...

Page 2797, line 8: "...for each fine segments..." ...for each fine segment...

Page 2797, lines 17-18: "The weighted RMSD times 1.2 has proven to be a good size for the height interval in which zCT segment is determined." How have you determined

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this factor of 1.2? By visual validation? Could you elaborate?

Page 2797, line 25: "...on a fine segments base..." ...on a fine segment(s) basis...

Page 2798, lines 2-3: "Since clouds are overall brighter than non cloud covered terrain..." What about snow- or ice-covered terrain? Could you comment? Page 2798, last line: Spell out CSV, presumably comma-separated values, or simply leave out the file type, which is irrelevant to the discussion.

Page 2800, lines 21-23: "Thus the validation results show to what extent the presented method is suited to determine zCT with a precision of 50 m." More precisely, you have validated the method at one particular height, that of the validation camera (2377 m). In Figure 12 you show retrieved cloud top heights ranging from 2000 to 2600 m. Strictly speaking, the method has not been validated over the full range of possible cloud top heights, although it might be reasonable to assume that your error estimates obtained at the validation camera height hold over the entire range.

Page 2802, line 11: "...cannot be reasonably be derived from..." remove the first be

Page 2802, last sentence of section 4.3.1: "After this exclusion the validation results can be interpreted as the answer to the question if the top height of clouds is derived correctly if they have been detected." This sentence is awkward, could you rephrase it? E.g. After this exclusion, the validation results indicate the fraction of detected cloud tops with correctly retrieved heights. Or something to that effect.

Page 2802, section 4.3.2: This section validates cloud detection, rather than cloud top height retrievals. For clarity, you could change the section heading to "Visual validation of (automated) cloud detection" and contrast it to section 4.3.1, which could be "Validation of retrieved cloud top heights using the validation camera".

Page 2804, line 19: "...HKD and the POD are quite high and the POD and FAR are low." Shouldn't it be POFD?

Page 2804, lines 23-25: "The presence or absence of clouds can already be deter-

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mined from satellite data with a high degree of certainty (Reuter et al., 2009)." I would disagree with such a definitive statement, although this point has little bearing on the merits of the presented algorithm. The GEWEX Cloud Assessment has revealed significant differences between the existing satellite cloud climatologies. For example, the global total cloud amount varies between 0.56 and 0.74, depending on satellite sensor. A more in-depth analysis is given by Stubenrauch et al. [2013].

Page 2805, line 26: "...satellite derived cloud tops heights..." ...cloud top heights...

Fig. 2: The red lines are rather difficult to see, especially in the hard-copy version. Could you use a brighter color that gives more contrast (yellow, bright green, etc.)?

Fig. 6: Please specify in the caption what the reddish/greenish colors refer to (southern/northern slopes). What do color shades correspond to, distance classes? Also, "...fines segments..." should be "fine segments", I suppose. The masked out white areas are mainly steep slopes?

Fig. 7: The red lines are more visible here, but a brighter color might still be better.

Fig. 11: A color palette would be better here. It's rather difficult to read numerical cloud top height values from this grey scale plot. And "Cloud tops heights..." should be "Cloud top heights..."

References Bley, S. and Deneke, H.: A threshold-based cloud mask for the high-resolution visible channel of Meteosat Second Generation SEVIRI, Atmos. Meas. Tech., 6, 2713–2723, doi:10.5194/amt-6-2713-2013, 2013.

Matthews, B. W.: Comparison of the predicted and observed secondary structure of T4 phage lysozyme, Biochim. Biophys. Acta, 405, 442–451, 1975.

Stubenrauch et al.: Assessment of global cloud datasets from satellites, BAMS, doi:10.1175/BAMS-D-12-00117.1, 2013.

Please also note the supplement to this comment:

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http://www.atmos-meas-tech-discuss.net/7/C1957/2014/amtd-7-C1957-2014-supplement.pdf

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Interactive comment on Atmos. Meas. Tech. Discuss., 7, 2783, 2014.