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Atmospheric Measurement Techniques Discussions

Interactive comment on "Cloud fraction determined by thermal infrared and visible all-sky cameras" *by* Christine Aebi et al.

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Summary

This script is concerned with an interesting and important field of research and should be published once major improvements are included.

Major comments:

1. I somewhat feel that the title could be more concise: Maybe you could add the word "comparison" and state the names of the used cameras.

2. Please discuss weaknesses / challenges of each studied system. How do the accuracies depend on (high) Linke turbidities, (low) solar angles or a "wet" atmosphere?

What other situations could lead higher deviations? This could be an own section (for each system or combined). Please discuss this quantitatively, with plots and figures.

3. Please add another section or at least a distinct paragraph in the introduction focused on the discussion of satellite cloud products and ground-based cameras. There is a Himawari-8 satellite, apparently with a cloud product down to 250 m and a sampling rate down to 2.5 min. The competition for ground-based cameras may not be human observers, but such satellites (see also minor comment 7). Where do you see the application of your cameras? What advantages do you see in comparison to satellites? This discussion could include the silhouette effect and projection uncertainties relevant to ground-based point-like observers, but not present for satellites.

4. The challenges being present regarding human cloud observation are partially addressed. However, you might be able to enhance the discussion. What is "not objective" (p1, line 24)? What are the differences if several experts evaluate images? You might be able to find such figures, which would significantly increase the quality of this argument. There is a reference missing on p2, line 1, for "nighttime determinations are difficult" - again, if you could find a reference, this would be an improvement.

5. Similar to major comment 3: If you state that "thin clouds cannot be distinguished from land" (p2, l9), you might as well enter into a full scale discussion of the weaknesses of satellites (beneficial to the quality of this paper). Please clarify the statement. Similar: "collect mainly from the highest cloud levels" (p2, l11) – Can't satellites, to some extent, differentiate? What are these limitations / what is the advantage of ground-based cameras? Same argument hold for the next sentence: "in order to retrieve. . ." – these statements are very absolute. How good are the cloud products of satellites, having multiple channels / sensors? To my knowledge, thin ice clouds can be differentiated from cumulus clouds quite well.

6. Maybe, there are more ways to determine cloud coverages, which were not mentioned in the introduction. For instance, cloud cover-

ages could be estimated from PV-data or using downward-facing cameras (https://doi.org/10.1016/j.solener.2017.05.074, https://doi.org/10.5194/asr-15-11-2018).

7. Please provide a cost estimate of all used systems.

8. P2, l. 28f: I'm not an expert on this, but radars (e.g. those rain radars in airplanes) have a "lack of information about the whole sky"?

9. P2, l. 30: Please clarify how a point-like measurement system such as a ceilometer can "detect", "with considerable accuracy", "a fully covered or cloud-free" situation. Isn't this just an assumption that the small measured cone is representative of the whole sky? Stationary clouds outside this cone would not be detected by the ceilometer.

10. P2, l. 33: "The most common all-sky cameras are the total sky imager" – could you provide some figures on that? How many systems has Reuniwatt (or other companies) sold? Given the known issues with the TSI, one of which is its age, this might not be a very good reference.

11. Update your references. You quote many old papers in an area of active research.

12. P. 3, l. 3: "low cost commercial cameras" "give no information during nighttime. There are several commercially available IR surveillance cameras out there. Are you sure that they are not used in meteorology as of today?

13. P. 3, l. 7ff: I think there are more IR systems, e.g. the Reuniwatt one. Maybe you can highlight the differences a bit more and improve the presentation (it is hard to get all the ranges out of the text).

14. Introduction: Please generally improve the readability and the structure of the introduction. Maybe sub-titles might help.

15. End of introduction: Clearly state your motivation to develop a new system? What are the advantages in comparison to other developments?

16. P4, l. 22: Is there any reason why you assume a flat response curve? For cameras in the visible spectrum, the curve is very far from being flat. Isn't there a data sheet available?

17. P5, l.1: I think I've just missed it: What does this calibration function include? Both the mirror deviations and potential deviations of the imaging system of the camera?

18. P5, l. 9: To my experience, calibrations (with cameras in the visible spectrum) conducted with the sun show relatively large deviations (as the sun disk is usually quite large). This is less of an issue for IR cameras. However, I wonder: Why did you choose the sun instead of the full moon or stars? Could you estimate the deviations (presumably very relevant for the algorithms in the circumsolar area) for this EOR?

19. Figure 3 c: Please provide a scatter density plot over all days similar to this figure. There seems to be an offset in the center, which might be better visible or disappear if more data are studied.

20. P6, l. 1: I was wondering about the mirror temperature and potential asymmetries. Could you briefly state if the one-sided heating of the sun leads to a temperature distribution on that mirror within your stated 1 K range? In Fig. 1, a wall is visible close to the IR-camera – is there a problem with radiated heat, e.g. during night-times? Could you briefly state something on the interplay between the ground temperature and that mirror? Do you expect aging effects on the mirror? How bad is the soling?

21. P6, l 7f: You are stating absolute values here, saying that there are no differences between night and day data. Does this also hold for relative figures (I assume that the temperatures at night are lower)?

22. P6, l. 18: I somewhat doubt if the "observed discrepancy of 4 K" is only caused by model parameters (which one? Your LUT?). Please make this discussion a bit more wholesome. Other attributing factors might be camera instabilities and maybe the effects named in major comment 20.

23. P6, l. 29: Please further motivate the threshold of 6.5 K. This might be done with an example image, including clouds. Was this threshold somewhat fitted to the data?

24. Section 2.1.1 – please enhance visualization, e.g. using a flow-chart or pseudo-code.

25. P7, l. 4: I'm wondering how big intra-cloud temperature variations are. Could it be that parts of the cloud are detected as such while some pixels within are below the thresholds? If so, algorithms such as region growing or compression based approaches might enhance the segmentation.

26. P7, l. 6: If possible, further motivate the threshold of 1.2 K – is there a physical explanation?

27. P7, l. 11: Quantify "usually". Elaborate on the whole paragraph (this corresponds to a general discussion of challenging situations and weaknesses of this device and does not have to be done at this position. I suggest dedicating a whole section to this discussion).

28. P7, l. 30: Why did you choose a custom resolution for the Mobotix camera? To my experience, 1/500 is a very bright exposure time (this might be solved by blocking out the sun, but I'm curious) – is this an issue? You are using ratios to segment clouds, why did you not use an automatic exposure time?

29. P8, l 4.: Please provide a brief statement on how good the Mobotix system performs under high turbidity conditions, using a simple threshold-based approach, as well as for low solar elevations.

30. Specify the total run time of each algorithm.

31. P8, l 19: 70° - isn't it quite a problem if the FOV of all systems is not the same? Cloud coverages might be correctly detected but yet different. The same holds for different occlusions.

32. Specify the distance between the cameras, provide example images for all.

33. Section 3.2: Aggregating the figures to 1/8-bins clearly reduces the deviations between the systems. This is good for many applications in nowadays meteorology. However, I wonder how much the deviations increase if the images are compared pixel-wise. Could you provide these figures?

34. Section 3.2.3: Please motivate why you assumed seasonal differences – what are the origins of the deviations? It is presumably not earth's inclination towards the sun. Identify these parameters and study them separately. Example: I could imagine that e.g. a wet atmosphere poses challenges for the IR system. A wet atmosphere can happen both during winter and during summer times (with different probabilities). Aggregating over many different conditions might make analyses more difficult.

35. You could separate a new section "Next steps" (or similar) from the conclusion, stating in more detail what could be made to further improve the system and why you think this would lead to more accurate results.

36. Figure 5.: There is an interesting offset visible at around 7.00 (please state time-zone, UTC+0?) – how comes? Is this caused by a different FOV or different occlusion affecting the systems?

37. Figure 6.: Please add a colorbar for Fig. 6b. Did you bother to mask out the camera arm and the suspension? The forest to the right is very finely masked out – couldn't there be minor issues due to moving trees?

38. Figure 7.: I might have missed it, but is there so far a discussion on this bias included in the script? (also Fig. 9). Could you provide the same plots for a Mobotix-Schreder comparison? This would help to evaluate the references.

39. In general: You compare cloud fraction estimations from different systems, all of which are not completely accepted by everyone in the community. Potentially, it could further strengthen your line of argumentation if you included a comparison against a

more established approach. This could be (1) satellites or (2) a comparison to a clear sky index derived from DNI measurements over the whole period (3), also unrealistic, from PV data or (4) from ceilometer data. Presumably, (2) is the way to do it.

40. Table 5.: 1 okta is quite a lot and I'm a bit concerned about the rather low values visible here (e.g. 59%). Maybe, looking at pixel-wise deviations (major comment 33) could cast a light on the origins of these rather large deviations. This is clearly as good as or even better than human observers, but I think satellite cloud products and other camera systems (e.g. https://doi.org/10.1002/pip.2968 or the works from Stefan Winkler) achieve smaller deviations.

41. Table 6.: You state that there are no significant deviations between the seasons. This is only partially backed by the figures in this table. Please clarify in greater detail.

Minor comments:

1. I'm just wondering: Is there no English name for "Physikalisch-Meteorologisches Observatorium Davos/..."?

2. In general, the language used could be a bit more fluent. Examples are "other study instruments" in the abstract ("other instruments used here") or "coverage of the sun with clouds" (p1, line 18).

3. A short summary of major comment no 2 (challenges) should find its way into the abstract.

4. I might have missed it, but why are there, in the abstract, two figures for low-level cloud, and one figure each for mid-level and high-level clouds?

5. Please rephrase the sentence between p1, line 17 and p1, line 19 (subpar English).

6. P1, line 20, the position of "globally" seems to be odd. I furthermore disagree with that statement - there are more cloud observations made by satellites than by human observers.

7. P1, line 21: Human observation has the "advantage" to be carried out "several times per day" - satellites have a higher sampling rate, what you also mention later.

8. P1, line 23: "there is no reference standard for human observers" - really? No manual from any organization?

9. P1, line 23: Humans are "independent of any technical failure" - please rephrase.

10. P2, l. 2, leave out "measurement"

11. P2, l. 2., This sentence could be rephrased to something like "Recent research has therefore been conducted to find automated cloud detection instruments to ..." (more concise English). You might mention the DWD objective to automate its stations in the next years.

12. P2, l.5, is "synoptic" the correct word here? What do you want to say?

13. P2, l. 5. "time resolution of 15 min", there is a rapid scan method with 5 min

14. P2, l. 11, "Earth" could be written "earth".

15. P2, l. 13, you measure the cloud coverage, not the cloud in general, "cloud measurement techniques".

16. P.2, l. 14: maybe "certain" instead of "different" (from what?). Also "radiometers" – do you mean scanning radiometers? For the clear-sky algorithms based on GHI and DHI measurements?

17. P2, l. 25: You use "reflected" and "scattered" in a very similar way. Maybe "backscattered" is better suited?

18. P3, l. 3: maybe "development" instead of "deployment"?

19. P3, l. 16: state also here which "commercial thermal camera" you use.

20. You might clarify the term FOV. Once it is used for the camera and once for the whole system. Is it really 180°?

21. P3, l. 27. Please clearly state also here the models of the used cameras.

22. P3, l. 28: “and a newly developed” -> “and the newly developed”

23. P4, l. 9, rephrase, there are too many “and”s

24. P4, l. 9, high -> large / tall

25. P5, l. 25f: Rephrase/shorten the sentence. You might try to shorten other sentences as well.

26. General: I think this is not your fault, but I’d prefer having the images directly in the text, not at the end of the script.

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