Atmospheric Measurement Techniques Discussions

Interactive comment on "Thermodynamic phase retrieval of convective clouds: impact of sensor viewing geometry and vertical distribution of cloud properties" *by* E. Jäkel et al.

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This paper presents results from ground based experiments to monitor the vertical distribution of cloud thermodynamic phase using measurements of near-infrared spectral reflectance, capitalizing on the differences between liquid water and ice spectral absorption. Forward modeling and sensitivity analysis was conducted to examine the influence of solar and viewing geometry on the phase retrieval, essentially the slope of radiance at two near-infrared radiances. Results indicate that the retrieval is robust, even with varying geometry, and that an unambiguous retrieval exists over a broad

range of viewing and solar angles. Additional sensitivity studies investigated impacts of cloud vertical inhomogeneities, and variability in effective cloud particle size and cloud water content. Again, the retrieval was shown to work over a broad range of conditions and even successfully identified mixed phase layers. Examples were provided from a case study and validated by independent measurements of lidar depolarization. Although similar phase discrimination methods have been tested before on ground, airborne, and satellite platforms, there is still a considerable amount of new information provided in this study which warrants its publication in AMT. The sensitivity to geometry in particular, to my knowledge has not been shown before in any prior studies. In addition, the other sensitivity analyses cover a broad range of conditions over which cloud properties are likely to be derived and the authors follow up with some real measurements, including limitations such as cloud shadowing from real inhomogeneous clouds. The passive method is validated with additional measurements of lidar depolarization. Cloud-side scanning with optical measurements is becoming a common tool of cloud remote sensing. This paper presents an important first step in that process, deriving vertical distributions of cloud phase. I recommend publication providing that the following issues are addressed.

1. In the abstract, p. 7730, l. 1, a combined active-passive remote sensing method is introduced. I found this to be misleading. I would define combined active-passive to be a retrieval which relies on the joint active and passive measurements. Instead, if I understand correctly, what was presented was two independent methods of retrieval. And even with that interpretation, the paper is almost exclusively focused on the passive approach, with only little discussion of independent validation from lidar for the experimental results. This does not fall into a classification of combined active-passive remote sensing – they were not combined. I suggest that the authors state this differently in the abstract and elsewhere in the paper.

2. p. 7730, l. 7: "... spectral solar and radiance ..." Presumably a typographical error.

3. p. 7730, l. 8 (first occurrence): "Lidar" should not be capitalized; "lidar"

4. p. 7730, l. 15: Saying "Clouds are relevant components of the Earth's climate" is quite an understatement. Be more specific – for example, "strong modulator"

5. p. 7730, l. 22: change "relation" to "relationship"

6. p. 7730, l. 14: "To investigate these complex interactions vertical profile measurements on microphysical. . ."; should be "To investigate these complex interactions, vertical profile measurements of microphysical. . ."

7. p. 7731, l. 1: "Radar" to "radar"; "mostly based" to "based mostly"

8. p. 7731, l. 20-23: misplaced modifier.Perhaps: "Since multiple scattering also increases the depolarization ratio of liquid water clouds with increasing penetration depth, how δ, which contains the information about the thermodynamic phase, changes with depth has to be examined"

9. p. 7732, l. 1: There are new studies which derive vertical properties of cloud layers, at least for the upper portions. See Kokhanovsky, A. and Rozanov, V. V.: Droplet vertical sizing in warm clouds using passive optical measurements from a satellite, Atmos. Meas. Tech., 5, 517-528, doi:10.5194/amt-5-517-2012, 2012. There are other examples as well, based on a study by Platnick et al. on wavelength dependent weighting functions for reflectance. .

10. p. 7732, l. 2: "based mostly"

11. p. 7732, l. 8-9: Be specific: what are the "certain assumptions?"

12. p. 7732, l. 19 (first occurrence): "exemplarily" is not common. Suggest changing to "for example"

13. p. 7733, l. 10: "It is shown, if there is a threshold which defines liquid, ice and mixed cloud phase." Something is missing.

14. p. 7733, l. 21: There are simplifying procedures in Monte Carlo models to compute radiance that do not rely on tracing paths of individual photon events throughout the

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atmosphere – that would take too long. Suggest adding some qualifier to this sentence about additional procedures required to compute radiance.

15. p. 7733, l. 24: "enabled" change to "required"

16. p. 7734, l. 8: "water" change to "liquid water"

17. p. 7734, l. 11: ". . .extraterrestrial solar spectrum from. . ."; delete "as taken".

18. p. 7734, l. 16: "entrance optic"

19. p. 7735, l.1: "photodiodes"; presumably this is a linear photodiode array? Suggest writing that instead.

20. p. 7735, l.5: "ice index" is misleading since it may indicate liquid water! Suggest changing to "thermodynamic phase index" or simply "phase index".

21. p. 7735, l.15: "The depolarization backscattering Lidar system (ALS300 from Leosphere, France) is primarily used for geometric information on the observed cloud." Change "on" to "of" but more importantly, I don't know what this means. Please be more specific about the "geometric information".

22. p. 7735, l. 23: "wavelength" not required.

23. p. 7736: This section should be restructured. Since cloud droplet/ice crystal absorption will scale directly with the product of particle size and absorption coefficient, separating phase discrimination (due to differences in bulk absorption coefficient) from size dependence is very important. This appears to be a glaring weakness of the paper until the reader find at the bottom of the page that the authors did assess the sensitivity of the phase index to particle size. Please mention this much earlier. By the way, this ambiguity is one of the reasons why measurements beyond 2000 nm (discussed in Pilewskie, P., and S. Twomey, J. Atmos. Sci., 44, 3419, 1987) are very helpful for retrieving phase. Perhaps the authors can mention this in discussion section.

24. p. 7736, l. 25-26: "The ice index of liquid water, regardless of particle size, is

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almost always lower than zero, . . ."

25. p. 7737, l. 1: "In summary, clouds . . ."

26. p. 7737, l. 8: "mostly" change to "most"

27. p. 7737, l. 8: the placement of (above 20%) may be confused with water content rather than the phase index. Suggest: ". . . is most variable, more than 20%, . . ."

28. p. 7737, l. 13: "vertical direction" change to "the vertical"

29. p. 7737, l. 14: delete "as"

30. p. 7737, l. 19: delete "wavelength"

31. p. 7737, l. 24: I think more needs to be said about how "the mixed layer can be identified." Please be quantitative.

32. p. 7738, l. 1: "where the IWC is much lower than . . ." I found this a little confusing. How does the IWC vary in the simulation?

33. p. 7738, l. 8: delete "part"

34. p. 7738, l. 14: "high velocity"; how fast were they moving? I think the authors need to be specific about how rapidly the scene changed relative to sampling time of the measurement. That is what is relevant, not horizontal velocity of clouds which is rarely classified as "high"

35. p. 7738, l. 14: "low"change to "small"

36. p. 7738, l. 15: "extension" change to "extent"

37. p. 7738, l. 16: "included precipitation" change to "were precipitating"

38. p. 7738, l. 17: delete "phase"

39. p. 7738, l. 20: delete "wavelength"

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40. p. 7738, l. 21: "situation" change to "scene"

41. p. 7738, l. 23-24: ". . .because the origin of the multi-scattered radiance is unknown." This is awkward. Suggest the authors be more specific about why the signal from shadowed cloud is contaminated.

42. p. 7738, l. 24: delete "also"

43. p. 7738, l. 5: comma after "7"

44. p. 7739, l. 2: "index values" change to "indices"

45. p. 7739, l. 2: ". . . after the mixed-phase cloud was observed."

46. p. 7739, l. 11: comma after "3" and delete "also"

47. p. 7739, l. 14: "steps"

48. p. 7739, l. 17-18: an effective radius and phase index were not simulated; they were derived or retrieved.

49. p. 7740, l. 5: "dealing with" change to "cloud were composed of"

50. p. 7740, l. 12: I still think a more qualitative description of how mixed-phased was derived is required. This should be simple, based on the figures.

51. p. 7740, l. 20: "with reff of" change to "to be"

52. p. 7740, l. 21: "fast moving clouds" change to "fast changing cloud scenes"