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Interactive comment on "Seasonal changes of ice surface characteristics and productivity in the ablation zone of the Greenland Ice Sheet" *by* D. M. Chandler et al.

Anonymous Referee #1

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General comments

This manuscript described the seasonal change of physical and biological properties on the ablation surface of Greenland Ice Sheet based on in situ field observations and satellite images. Variations in surface albedo of the Greenland Ice Sheet have been high-lightened by many researchers in recent years since they could largely affect the melting of the ice sheet. The surface descriptions based on in situ observations during entire melting season have rarely been studied, thus, the data shown in this study are very worth to understand the physical and biological process of the albedo change of the Greenland Ice Sheet. However, the discussion on the correlations among the surface albedo, characteristics, and microbial productivity are logically weak, in partic-

ular, those in the larger spatial scale of satellite image. I would strongly recommend following major revisions before publication.

The major problems are:

1. Authors have examined very well the relationship between surface characteristics and productivity in centimeter to meter scale on the ice surface, however, discussion the relationship among the surface albedo, characteristics, and biological activity in kilometer scale (spatial resolution of satellite image) is still logically weak to conclude their correlations are significant. Connections between the different spatial scales have to be discussed more carefully. For example, since results showed the areal proportion of the surface types seasonally varied, it is necessary to explain how the areal proportion could quantitatively affect the surface albedo in the kilometer scale, and total carbon productivity on the surface.

2. Testing the correlation between surface albedo and productivity does not physically make sense. Because the productivity is change of carbon amounts per certain period of time, but surface albedo is determined by the total storage of carbon on the ice. Authors should discuss it carefully. Furthermore, statistical analysis is necessary to discuss the correlations.

3. In discussion, authors explained that surface characteristics were largely affected by weather conditions, such as warm/cold or cloudy/sunny. However, because authors didn't show any data of the weather conditions, this discussion appeared to be very speculative. Authors should show the data of at least, air temperature, solar radiation, and wind velocity during the study period, and explain relationship between the weather conditions and observed physical process of the surface.

4. It is not clear that measured ablation values (melt rate, mm d-1) are represented in direct surface level change or water equivalent. Melt rate is usually expressed in water equivalent, which should be better.

Other comments:

1. P1338 L20-21 As authors shown in the discussion, correlation between albedo and cryoconite hole coverage was mainly due to disappearing the superimposed ice covering the cryoconite holes. If this is correct, the correlation is not true during the main melt season, but only the early melt season.

2. P1338 L20-21 Please use the term of “cryoconite hole productivity” carefully. Does this mean the productivity within cryoconite holes or the contribution of cryoconite hole productivity to entire ice surface? Furthermore, correlation between albedo and productivity does not make sense as mentioned above.

3. P1343 L13 Probably "the albedo of the ice surface" instead of "the albedo of the cryoconite holes"

4. P1343 L14 Takeuchi 2010 (probably Takeuchi et al., 2010) is not listed in the references.

5. P1344 L4-5 It is better to explain the difference between the study site and the dark region in terms of the surface characteristics used in this study.

6. P1344 L10-12 The ablation should be represented in water equivalent as mentioned above.

7. P1345 L23 How much is the volume of water put in the bottle? The volume might affect the measured values (e.g. productivity unit, mg L-1 h-1).

8. P1346 L21 The oxygen production is expressed in mg L-1 h-1. "L" in the unit probably means the water volume in the bottle. If it is right, I wonder that this unit properly expresses the production rate on the ice surface. The measured production rate might be determined by the amount of cryoconite debris (or microbes) rather than volume of water.

9. P1349 L1-14 Please show the solar radiation data in Fig. 6 together with air tem-

perature and wind velocity.

10. P1351 L2-4 Is this description of the melt crust formation based on observations in this study or cited from other study? Probably, this structure corresponds to “weathered crust” described in many papers previously (e.g. Mullar and Keeler (1969), Gribbon (1979), Irvine-Fynn and Edwards (2014)).

11. P1352 L7 Probably, "C storage rate" instead of "C storage"

12. P1352 L9 The sentence is unclear. Which correlation is not significant?

13. P1352 L20 Cryoconite hole size should be cryoconite hole diameter. Didn’t you measure cryoconite hole depth? Depth could also affect the productivity.

14. P1354 L3-4 Reference is necessary.

15. P1354 L5 Please specify how much the precipitation.

16. P1354 L13 Please show the weather conditions.

17. P1354 L17 What does the “cryoconite coverage” mean? Coverage of holes or dispersed debris?

18. P1355 L3-5 Please explain why the warm, cloudy conditions cause cryoconite holes to melt out. Please show the weather data. Reference is necessary.

19. P1356 L2-3 How did you know Fig.8b structure is a remains of lid? Need explanation.

20. P1356 L18-24 This part is generally very speculative discussion without data. Reference is necessary.

21. P1357 L2-14 As many previous studies showed, the albedo decrease in the early melting season can be explained by disappearance of winter snow. If authors want to say that appearance of cryoconite holes further decrease the surface albedo, it should be discussed more carefully. Authors have to explain why the decrease can not be

explained by only snow melt and how the two effects can be distinguished in the results.

22. P1359 L19-25 How about the effect of hole-depth on the productivity. Depth of cryoconite hole can affect the intensity of solar radiation reaching to the bottom of the hole. The hole-depth can change seasonally depending on weather conditions.

23. P1360 L15-16 Again, please explain how authors concluded that the AVHRR-derived albedo responded to both the snow melt AND cryoconite hole exposure. Furthermore, contribution of DI to albedo reduction seems to be more significant than cryoconite hole coverage because cryoconite holes can be hidden in an image with a certain viewing angle as authors mentioned in P1355.

24. P1360 L19-21 I would think that the uncertainty is too large to predict C fluxes from the AVHRR-derived albedo.

25. P1361 L20-22 This statement needs to be revised substantially. If authors could properly explain the points that I mentioned above, the correlation might be apparent, but only between albedo and cryoconite hole coverage, and in only the Periods 3. Again, use carefully the term of “cryoconite hole productivity”.

26. Table 1: Please indicate the size of cryoconite holes, at which the carbon flux was measured in each study.

27. Table 3 "C storage" at 3rd row in the table should be "C storage rate". Please indicate the areal percentiles of each type to calculate the total C flux in the table.

28. Fig.1 Please show the photographs of all of the surface type defined in Table 2. Thick debris deposits shown in (b) was not listed in Table 2, and thus reader can’t understand how this deposit is significant for C flux or surface structure to the total ice area. I would recommend removing it.

29. Fig.2 Please indicate the scale in the photograph.

30. Fig.3 It is better to show a map of the entire Greenland Ice Sheet and where this

area is.

31. Fig.5 Please indicate the depth of the holes.

32. Fig.6 Ablation should be shown as water equivalent (mm w.e. d-1)

33. Fig.11 "CS" in the legend is not consistent with that in the caption "CH".

34. Fig.14 Please show the change of areal proportions of CS and DI together with the C flux.

35. Photographs in Fig.2, 4, 5, 8, 9 could be moved to Supplementary.

Interactive comment on The Cryosphere Discuss., 8, 1337, 2014.