Response to Referee Comments on egusphere-2022-126, "Responses of CIPS/AIM Noctilucent Clouds to the Interplanetary Magnetic Field"

We would like to thank the anonymous referee #2 for his time and effort reviewing our manuscript. We have found the comments to be very insightful, and very helpful to improve our study. Particularly, in line with them a new and more reasonable mechanism has been proposed. All of the following comments have been addressed.

General Comments

This paper investigates possible connections between the interplanetary magnetic field (IMF) By component and Noctilucent clouds (NLCs) in Earth's mesosphere. The paper is mostly written well, although there is a tendency for very long sentences, and there are instances when the ideas are poorly expressed.

We thank the referee for the comments. The long sentences have been rewritten to express our ideas more clearly.

The Authors show some reasonably convincing correlations between NLC properties observed by CIPS and measurements of By. Still, the results might be more convincing if there were one or two examples of the By - NLC relationship. For example, they could show a time series of the relevant measurements where we can see that the NLC properties indeed do change concurrent with By variations.

We are very appreciated for this suggestion, and a new Figure has been plotted, which clearly shows a positive relationship of NLCs with *IMF* B_y for the 2008/2009 summer season in the Southern Hemisphere (SH). The time series of them also support that the response of NLCs to solar activity is concurrent with a nearly zero-day delay.

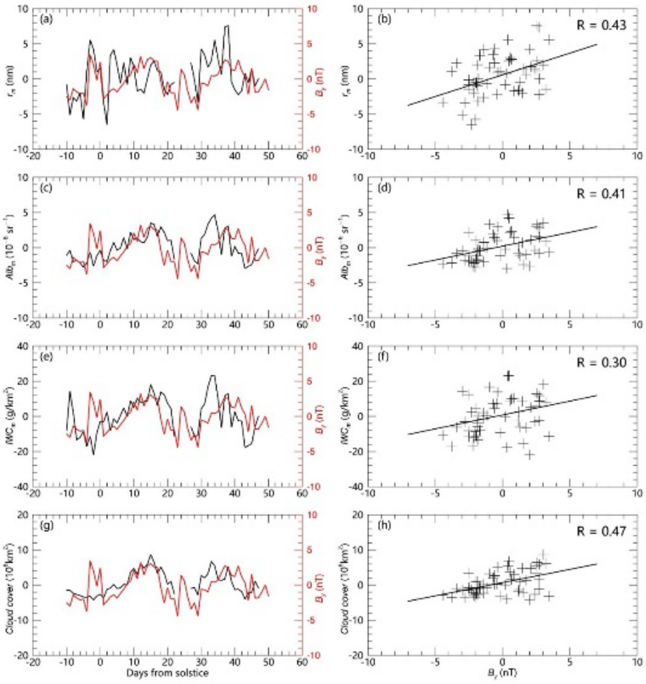

Figure 2. The (left) show the relationships of the daily *IMF* B_y with the anomaly of mean ice particle radius (r_m), mean albedo (Alb_m), mean ice water content (IWC_m), and cloud cover in the 2008/2009 NLCs season for SH, the anomaly of NLCs data are obtained by removing the 40-day running mean. The (right) present the correlation coefficients between the daily *IMF* B_y and the anomaly of NLCs characters.

The main problem with this study is that the Authors do not present a believable mechanism that would explain the connection between IMF By and NLCs. They very casually invoke cloud microphysics as a possible explanation, but do almost nothing to explore a plausible pathway. Regarding the microphysics of NLC/PMCs, there are many published studies that could offer some clues here. First off, are the candidates for ice nucleation, which include sulfate droplets, proton hydrates, and meteoric smoke particles (Rapp and Thomas, 2006; Duft et al., 2016), in addition to homogeneous nucleation (Murray and Jensen, 2009). More recent studies indicate that meteoric smoke is contained within NLC particles (Havnes and Næsheim 2007; Hervig et al., 2012), making it perhaps the most likely candidate. Note also that ice - ice coagulation is generally considered unimportant in NLCs. It is relevant that model studies show that increasing the number of ice nuclei can reduce the size of ice particles in PMCs (Megner, 2010), and that changing the ice nucleation rate can alter the concentration and size of NLC particles (Wilms et al., 2016). These later papers may be of particular interest to the present study, and there are certainly more papers to consider than are listed here. The present study would be much more convincing if the Authors present a survey of the relevant literature, and derive a convincing pathway by which the IMF can impact NLC.

These suggestions are very constructive for us, and we are grateful for the referee. We have added a new section in the Introduction part to help understand the results, which includes the nucleate process in NLCs by citing the suggested and relevant references. Moreover, the Discussion part was also re-written to propose a new mechanism, and the key points in the mechamisn are listed here:

1) The basic assumption is that the negatively charged meteoric smoke particles (MSPs) are more effective than neutral MSPs, and changes of the amount of charged MSPs might have a major influence on the nucleate process in NLCs.
2) The NLCs locate in the D-region ionosphere, where the ionization rate caused by solar radiation changes exponentially with altitudes, and thus there will exist significant gradient of conductivity σ in this region. According to the Gauss's law, net space charges will be created by the electric field gradient. As a result, when a downward electric current J_z flow through the mesosphere, $E = J_z/\sigma$, net positive space charges will be generated, requiring a reduction in the amount of negatively charged MSPs.
3) The conductivity of the D-region ionosphere varies exponentially with altitudes, the gradient of electric field is larger at lower altitudes, resulting in that the number density of net space charges at the bottom of NLCs or lower is larger than that at the upper region of NLCs. In consideration of the dominate upward vertical winds in the summer pole of mesosphere, the larger changes of negatively charged MSPs concentration at lower altitudes can be transported to NLCs. In short, the upward winds may further amplify the change of charged MSPs number density in NLCs.
4) The nucleation rate will vary in pace with the change of charged MSPs concentration, in that the charged MSPs are quite efficient in forming ice nuclei at low temperature. If the nucleation rate increases, the number density of ice particle will increase, while due to the limited water vapor in NLCs, the radius of ice particle will decrease instead.
5) In conclusion, when *IMF* B_y increases, the ionospheric potential and the downward current J_z will increase in the SH, requiring an increment of net positive space charges

in the D-region ionosphere, thus the amount of negatively charged MSPs will decreased. Therefore, the nucleation process in NLCs caused by negatively charged MSPs will slow down, and the number density of ice particle will also reduce. Finally, due to the competition of the limited water vapor in NLCs, the ice particle radius will increase in the SH. Conversely, the ionospheric potential and the downward current J_z in the NH will decrease when $IMF\ B_y$ increases, thus the ice particle radius will decrease in NH, opposite from that in SH.

This new mechanism is consistent with the results of our paper, and we believe it is more convincing to explain the link between solar activity and NLCs.

It is applicable to this study that the CIPS particle size and IWC results can be used to calculate the column number density of ice particles (i.e., the # of ice particles in the vertical column, #/cm2). This quantity may prove enlightening, especially if you are considering microphysical processes. For example, if ice nucleation is suspect, then the concentration of ice crystals may be expected to change.

This suggestion is quite helpful, we are really appreciated and have applied already. The column number density of ice particle N_{ice} has been estimated by dividing the IWC by the mass of ice particle, that is $N_{ice} \approx IWC\ /\ m_{ice}$, where $m_{ice} = \frac{4}{3}\pi r^3 \rho_{ice}$. The correlation coefficients between ice particle concentration and $IMF\ B_y$ are -0.14±0.06 in the SH and 0.09±0.04 in the NH, which is interestingly opposite from that of the ice particle radius (0.25±0.04 in SH and -0.13±0.04 in NH, as shown in Fig. 2). The above results can be explained by the competition for the limited water vapor in NLCs, where the ice particle concentration and ice particle radius are usually anti-correlated, and therefore their responses to solar activity are supposed to be opposite.

Specific Comments

line 23: Here you should introduce the term polar mesospheric cloud (PMC), and state that PMC and NLC are essentially the same phenomena. In the rest of the paper it would be preferred to use only one term, NLC or PMC, but not both.

Done.

line 24: You could state "140K or lower", temperatures of <120K have been observed.

Done, thanks.

line 24: The sentence starting “The long-term trends…” is long and could be 2 sentences.

Done.

line 33: It is not the water vapor and temperature of NLCs, but rather the water vapor and temperature in the NLC region.

Corrected.

line 77: Define the acronym IWC

Done.

line 95: Start a new sentence at the semicolon.

Done.

lines 116-118: Is there a reference that supports this claim? Alternately can you include a figure (perhaps a scatter plot) that demonstrates these relationships?

Done. We have added the reference of Lumpe et al., 2013 to support the relationships.

figure 6: The axis label should be frequency of occurrence

Corrected.

line 174: This sentence is confusing. In particular the phrase “by setting the albedo of NLCs varying by 5×10-6 sr-1,” is not clear.

Done. We have rewritten this paragraph to make the Figure 8 more readable.

line 186: This sentence continues to line 194, and is far too long. In addition, the ideas here are not expressed clearly. line 192: This statement is unclear. For example, by “the growth of coagulation” do you mean “growth by coagulation”? The next idea, that ice particle coagulation would enhance the formation of ice nuclei, is nonsense. Ice nuclei in the upper mesosphere are likely meteoric smoke particles (there are recent references that discuss this that you should include). Perhaps if ice particle charge had the opposite polarity as smoke particles, then there would be an attraction. In any case. the ideas here are potentially important and need to be more clearly expressed.

Agreed. The above ideas have been abandoned. We have rewritten the Discussion section, focusing on the nucleation process of the charged MSPs, and the new mechanism has been mentioned in details in previous reply.

line 207: Note that Lyman-alpha radiation also varies on an 11-year cycle.

Done.