Point by point reply to the reviewers' comments

We thank the editor and reviewer 2 for their comments on this manuscript. We provide a point-by-point reply to the reviewer's comment below.

The additional clarifications around HWI have been useful. It would be useful if the conclusions could also try to draw physical conclusions from the meteorological changes i.e. less westerly airflow, more stable in future. Although I am slightly confused by the stability argument as I would expect warmer temperatures at the surface compared to aloft to decrease stability.

Reply: We thank the reviewer for the excellent suggestion. We have now added physical conclusions in the revised manuscript in the abstract and conclusion. The reviewer is correct in their interpretation regarding the temperature stability. However, in this study we are referring to the near-surface temperatures at the 850 hPa pressure level and not the temperature at the surface. We have now changed the word 'near-surface' to 'lower troposphere' to avoid any confusion.

Abstract:
Lines 28-30: More frequent haze conducive weather (HWI>1) during winter over the NCP is found to be associated with an enhanced warming of the troposphere and weaker north-westerlies in the mid-troposphere over the NCP.

Conclusions:
Lines 666-669: We also find that enhanced vertical thermal stability due to the warming of the troposphere and weaker northwesterlies over the NCP in the mid troposphere will collectively lead to more frequent haze conducive weather over the NCP.

The discussion of the attribution of variability to "parametric effect" is confusing, and rather focused on analytical techniques rather than physical meaning. I think the explanation is that the differences in model physics lead to different model evolutions with climate which therefore lead to increased spread as climate change progresses.

Reply: Here we find that some of the differences in model's future mean states arise due to the physical parametrizations or as the reviewer eloquently puts it difference in model physical parametrization leads to different model climate evolution. Therefore, it is important to consider the parametric uncertainty for a more comprehensive range of plausible future projections. We have now stated this more clearly in abstract.

Abstract:
Lines 35-38: This shows that the different model physical parameterizations lead to a different evolution of model's mean climate particularly towards the end of the 21st century. Therefore, it is desirable to consider PPE in addition to the initialized and multimodel ensembles for a more comprehensive range of plausible future projections.

Abstract
Lines 31-34: This description of the effect of parametrizations is rather technical for an abstract. What is the key scientific point you want readers to take away?

Reply: The key takeaway here is that the model parametrizations have significant influence on future projections of haze conducive and clear weather and therefore it is desirable to also consider PPE in additional to initialized and multimodel ensembles for a more

comprehensive range of future projections. We now state this more clearly in abstract at lines 35-38 as noted above.

Lines 36-39: This point about the influence of climate change is very similar to the points made in lines 21-24. I think you are trying to make about statistical attribution, but this doesn't come across.
Reply: We agree with the reviewer that it is repetitive. We have now merged the two sentences as follows:

Abstract:
Lines 21-26: The PPE generated using the UK Met Office HadGEM-GC3 model shows that under a high-emission (RCP8.5) scenario, the frequency of haze conducive weather (HWI>1) is likely to increase whereas the frequency of clear weather (HWI<-1) is likely to decrease in future, with a growing influence of climate change over the 21st century. Nevertheless, a change of opposite sign with lower magnitude in the frequencies, though less likely, is also possible.

Lines 67-69: Surely the opposite is true? Warmer surface temperatures lead to decreased stability.
Reply: We are referring to the near-surface temperatures and not at-surface temperatures. We have now replaced near-surface to lower tropospheric temperatures (~850 hPa) for better clarity in the manuscript.

Lines 224-226: The warmer lower troposphere compared to the upper troposphere should increase ventilation, not decrease it.
Reply: Please see our above response to this comment.

Lines 431-456: This discussion of the "parametric effect" was not very clear. I think you are showing that the variability between PPE members is small for current climate, but the members diverge with increasing climate change.
Reply: The difference in mean frequencies across ensemble members can arise due to the internal variability or the parametric effect. Therefore, here we examined if the variance in mean frequencies can be explained by the internal variability or not. The reviewer makes a good point regarding changes in variance across time periods. We have now rephrased this paragraph as follows:

Lines 445-456: Figure 6b shows that the difference in mean frequencies across PPE members (as shown by PPE member variance) is small for the historical and near future but increases for mid and far future periods. For the historical and near future periods, the PPE member variance lies within the range sampled by the internal variability for both haze conducive weather (HWI>1) and clear weather (HWI<-1). This shows that there is no discernible influence of the parametric effect on the frequency of haze conducive weather or clear weather conditions for the historical and near future periods.

For mid future, the PPE member variance for clear weather lies within the whiskers and therefore no discernible influence of the parametric effect is detected. In contrast, the PPE member variance for haze conducive weather lies outside the whiskers and the internal variability can explain ~33% of the variance across PPE members and the remaining ~67% arises due to the parametric effect.

Section 6:

It’s not quite clear what this section is trying to achieve. Why is the trend in HWI over specific future periods useful? Is the idea that the change in HWI stops after 2060? I think the units for figure 11 should be frequency per winter per year.

Reply: We thank the reviewer for pointing out the units. We have now corrected this in the revised submission. Regarding Section 6, we show the trends for shorter periods in this section as these are important for near-term policies extending out to a few decades (around 30 years) in the future. While the long-term trends show an increase in the frequency of haze conducive weather and a reduction in clear weather, the shorter-term trends may not show similar results as they are subjected to higher internal variability, e.g., multidecadal oscillations. Therefore, we have examined this aspect and most importantly show the influence of anthropogenic climate change and parametric effects on short term trends in this section to determine if the signal emerges for these effects on shorter term timescales.