

Response to referee 2

Dear Referee 2, thank you for carefully reading our paper and for your helpful and constructive comments and suggestions. We have revised the paper based on those comments and recommendations, and have provided detailed answers to their questions. We would like to extend our appreciation for taking the time and effort necessary to provide such insightful guidance.

References are missing concerning high-latitudes GW observations, especially Suzuki, S., Shiokawa, K., Hosokawa, K., Nakamura, K., and Hocking, W.K., Statistical characteristics of polar cap mesospheric gravity waves observed by an all-sky airglow imager at Resolute Bay, Canada, J. Geophys. Res., 114, A01311, doi: 10.1029/2008JA013652, 2009, and

Suzuki, S., Lubken, F.-J., Baumgarten, G, Kaifler, N., Eixmann, R., Williams, B.P., and Nakamura, T., Vertical propagation of a mesoscale gravity wave from the lower to the upper atmosphere, J. Atmos. Solar-Terr. Phys., 97, 29–36, 2013

The suggested references are added in the paper on pg. 2, line 27.

There are several radars operating from Andoya Island which is in the NLC imager field of view... - The authors should mention that NLC are not visible every night, which is one of the reasons (with the weather conditions) they have so few events over 4 summer seasons.

Reasons for fewer gravity wave events were explained on page 4, line 24-26. In addition to the short observational periods and challenging scattering conditions, bad weather conditions have been included as an additional reason for the small number of wave events over the four summer seasons as suggested by the referee.

Even if the number of GW events is limited, it would be interesting to see the evolution of the GW characteristics during the summer, especially the directionality. - On figure 9, it is surprising that the waves seem to originate from regions north of the FOV. These waves should be seen as propagating southward. At the same time, the waves observed by the NLC imager and propagating towards NNE don't seem to come from the 5 or 60km altitudes, which still leave their origin opened. - Is it possible to ray-trace backward the actual waves to see where they are coming from? As mentioned before, there are available radar wind data from northern Norway for high altitudes. Wind models can be safely used for lower altitudes as they are not as strong.

Yes, it is possible to ray-trace backward to identify the sources of the actual waves. However, we found that the backward ray tracing was sensitive to the background wind as a result most of the waves were evanescent. Such a backward ray tracing requires 4D winds as they

should be adjusted at every time step of the model. That is why we used the statistical approach, with a uniform distribution of waves, to see if such waves would make it from the troposphere or stratosphere to the NLC region. The results show that they do not. In addition, the statistical analysis of the data presented in the paper indicates that these waves belong to a different population than those in the other direction, from which we drew the conclusion that they were due to instabilities.

Minor comments:

p1 l 10: remove second "high latitudes"

It is corrected

p2 l 23: as their source regions, are essential (add comma)

It is corrected

p2 l 27: add Suzuki et al. references

The references are added on p2 line 27.

p3 l 22: not sure why the cadence depends on the solar elevation angle

The cadence comes from:

1) 2 x exposure time (actual Image + background Image), 2) Transfer time from Camera to PC, and 3) Image analysis to calculate new exposure settings. The transfer time is about 10 seconds and another 5 second might be due to the image analysis. We usually expect the time between images to be slightly below 20 seconds and in that case we get three pictures per minute, otherwise we get two pictures per minute. We have rephrased the sentence in the paper as follows.

"The camera takes pictures throughout the twilight period with exposure times of 0.5s and 0.6s depending on the solar elevation angle with a cadence ranging between two to three frames per minute."

p3 l 24: of an NLC image

It is corrected.

p4 l 16: not nice, could be "Figure 2 is the processed NLC picture shown in Figure 1, projected onto..."

It is corrected

p5 2nd paragraph: not clear. Why not use 2D FFT to get the direction and WL?

We have explained the reason why we haven't used the 2D FFT in the paper (p5, line 5-8): Although this fitting method is more labour intensive and more subjective than the Pautet et al. (2011) method, given the low contrast of these high latitude observations it was necessary to manually identify the wave parameters.

p6 l 3: a short explanation on what an Hovmoller diagram is would be nice

In a Hovmöller diagram, meteorological fields are plotted over time (y-axes) and longitude or latitude (x-axes). It is often used to properly present the wavelike character of a meteorological field. As suggested by the referee, we have added the following text in the paper (p. 6, line, 4-6):

“The Hovmoller diagram shows wave along its direction of propagation at different time slices. This lets the wave coherency and propagation direction to be determined.”

p7 l 9: longitude

it is corrected

p7 l 10: determine the waves

It is corrected

p8 l 26: remove "of" after "phase speed"

It is corrected

p9 l 1: replace "of waves" by "of events"

It is corrected.

p9 l 7: mesosphere instead of stratosphere

It is changed in the paper.

p9 l 22: remove one "in"

It is corrected

p10 l 19: airglow

It is corrected

p10 l 21: were found

It is corrected

p11 l 23, 28 and p12 l 2: gravity waves

It is corrected as gravity waves.

Figure 2 doesn't show much the NLC structures, especially with the superimposed coastline of Norway. Maybe using an image after correction of the Rayleigh scattering would be better.

We agree with the reviewer that the NLC structures are not enhanced in figure 2. As explained above, the primary purpose of figure 2 is to show the geographic extent covered by the imager and the typical size of the analysis region while figure 1 shows the wave structures clearly.

I don't understand fig 5d, 6d and 7d!

Figure 5d, 6d and 7d are the relative amplitudes of the gravity waves present in the NLC. Section 3.2 of this paper discusses how these relative amplitudes are estimated. Captions for figures 5d, 6d and 7d are modified to explain them better.

How can the total percentage of waves be way above 100%!!! Maybe the horizontal axis should be "event number"?

This has been corrected as "wave event index".

To answer one of reviewer #1 comments concerning the bias due to the wave tilt, wintertime all-sky airglow observations from Andoya exhibit the same directionality (not published yet), with 2 main directions of propagation: NNE and SW, thus, results from this paper are possibly real and not biased by the limitations due to the observation technique.