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Atmospheric Chemistry and Physics Discussions

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Interactive Comment

Interactive comment on "Simultaneous lidar observations of temperatures and waves in the polar middle atmosphere on both sides of the Scandinavian mountains: a case study on 19/20 January 2003" *by* U. Blum et al.

U. Blum et al.

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Answers to the comments of the second reviewer, A. Dörnbrack

We thank the reviewer for his comprehensive and helpful comments. We particular thank him for providing detailed ECMWF T511 maps describing the meteorological situation. In the revised manuscript we have taken his comments into account.

General comments

The reviewer doubts the orography as source of the observed waves. He argues that

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the meteorological situation was not adequate for the propagation of orographically induced gravity waves. He proposes instabilities at the edge of the polar vortex as a possible source and suggests to re-analyse the present case, using the enlarged meteorological data set he has provided.

We see the point of the reviewer that the meteorological situation during the measurements was quite different from common winter situations and that the discussion of possible wave sources needs improvement. Thus we added in section 4 (Meteorological background) a paragraph describing in detail the particular meteorological situation during the measurements and added Fig. 3 to illustrate this specific situation at different altitudes and for different times. In section 6 (Discussion) we now give a more detailed discussion of possible wave sources. The data indicate that the observed waves are stationary which is consistent with orographically induced gravity waves. However, we discuss instabilities at the edge of the vortex as well as a tropospheric jet as additional possible sources. Although an unambiguous determination of the wave source is not possible, most probably the observed waves were induced orographically.

Detailed Discussion

- Title
  The reviewer suggests to change the title by deleting the words "and waves" and by replacing the words "both sides" by east - west.
  We replaced "both sides" by "east and west side" but we did not remove the words "and waves" as we observe temperatures and also temperature fluctuations which we associate with waves.

- Abstract
  The reviewer asks to explain in more detail what the extensive effects of gravity waves on the atmospheric circulation and the temperature structure are.
  Gravity waves influence the temperature structure in the stratosphere as well

as in the mesosphere. In particular breaking gravity waves deposit momentum at their breaking levels which in turn modifies the circulation. We have added several references in section 1 (Introduction).

The reviewer emphasises the necessity of discussing the excitation as well as the propagation conditions for gravity waves.
We adopted his suggestions and now give a detailed description of the excitation and propagation conditions for gravity waves during the measurements in section 4 (Meteorological background) and discuss their impact in section 6 (Discussion).

The reviewer has concerns about the formulation that the "wave patterns show random distribution". He associates a random pattern with turbulence.
The term 'random distribution' refers to the variation with time. The observed temperature fluctuations at the Esrange are quite stable with time whereas the fluctuations at ALOMAR show large variances with time. These characteristics can be caused by gravity waves rapidly changing with time, i.e. the excitation and propagation conditions are changing rapidly. We did not change the formulation in the abstract; a detailed explanation is given in section 5 (Observations on 19/20 January 2003).

- Introduction
  The reviewer suggests to give a more comprehensive description of the current state of the knowledge of stratospheric mountain waves above Scandinavia.
  We do not think that it is helpful to recapitulate the recent results on mountain waves in the lower stratosphere. Our measurements were performed in an altitude region which is well above that of the most recent works. The results on gravity waves in the lower stratosphere are probably not directly comparable to our measurements. Further our measurements cover also the lower mesosphere. However, we included some more references on stratospheric as well as on mesospheric gravity waves.

  The reviewer misses the discussion of other measurements during the January

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2003 period.
We think that the data collected in the current paper are very interesting in itself. Indeed it would be of great interest to combine our data with the other measurements. In particular results of mesoscale models above 30 km altitude (limit of MM5) would be appreciated. We would like to start a close cooperation to incorporate other measurements and model results to get a more accurate picture of the observation. However, this is not easy for the altitude range addressed in this paper. Incorporating other data sets deserves to be treated in a separate manuscript, though.

The reviewer asks if gravity waves really drive the global circulation.
This is true at least for the mesosphere as shown in the references given in the introduction.

The reviewer corrects the spelling of Størmer
We prefer the spelling as it appears in the original paper in Nature which uses the Danish/Norwegian ø.

The reviewer comments on the Scorer parameter and critical levels, mentioned in the introduction.
We reworded the formulation in the introduction to more general statements. The detailed description of necessary mechanisms is given in section 3 (Analysis method).

The reviewer asks how we identify atmospheric waves based just on T'-profiles and if the observed fluctuations are always present.
The wave-like character of the temperature fluctuations T' is a strong indicator for the observation of gravity waves. This method is well established and described in several papers (e.g. *Wilson et al.*, 1991; *Whiteway and Carswell*, 1995).
The type of temperature fluctuations presented in the paper occur often above the Esrange and – if present – their exact shape is very variable. Fig. 8 in the revised version shows an example for quiet conditions without gravity waves a

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year earlier on 20/21 January 2002.
The reviewer suggests to add an outline of the paper
We added an outline of the paper at the end of section 1 (Introduction).

- Data Set
  We changed the section title to ”Lidar data”.

  The reviewer recommends to discuss the particular meteorological background and asks why we expect to observe wave signatures upstream of the mountains.
  We included a description and discussion of the particular meteorological situation in section 4 (Meteorological background).
  We removed the formulation that we expect wave signatures upstream the mountains.

  The reviewer asks if the seed temperature is consistent with the ECMWF data used in the study.
  ECMWF analysis does not reach up to the altitudes at which the seed temperature is required. Our seed temperatures are taken from CIRA86 and MSISE90 which are the climatological temperature profiles available in the altitude range 70 – 80 km where the temperature integration starts.

- Method
  We changed the section title to ”Analysis method”.

  The reviewer comments on the formulation ”simplified dispersion relation”.
  We changed the formulation.

  The reviewer questions on the discussion about meridional and zonal propagation of gravity waves.
  If the observed phase speed is zero, the absolute value of the intrinsic phase speed is equal to the horizontal wind in direction of wave propagation. For the calculation of the critical levels we have to consider the horizontal wind in the

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propagation direction of the waves. Because we cannot determine the propagation direction from our measurements, we have to assume a direction and check for critical levels. We chose two perpendicular states: zonal and meridional propagation. For clarification we reworded the manuscript in section 3 (Analysis method), 5 (Observations on 19/20 January 2003), and 6 (Discussion).

- Meteorological background

  The reviewer suggests to distinguish between tropospheric and stratospheric conditions.

  We added a new paragraph in section 4 (Meteorological background) to describe and discuss the meteorological background more comprehensively and added also a new figure (Fig. 3) to take the concerns of the reviewer in account.

  The reviewer suggests to add in Fig. 1 that the T-field is the nightly mean temperature.

  We included this information in the caption of Fig. 1.

  The reviewer mentions that the critical level filtering does not depend on the T-structure.

  We corrected our misleading formulation.

  The reviewer states that λ_{max} does not refer to conditions with significant wind turning and asks for the discussion of possible excitation mechanisms.

  The determination of critical levels by calculation of λ_{max} includes information about the wind direction as shown in section 3 (Analysis method). For the comparison of wave dominated and quiet atmospheric conditions we use the change of the wind direction to detect the critical levels (Fig. 9).

  We added a discussion on possible wave sources in section 6 (Discussion).

- Observations

  The reviewer suggests to rename "temperature profiles" by "temperature perturbations" with respect to Fig. 4 (in the revised paper).

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Shown are the temperature profiles, calculated from the lidar observations, so we did not change the figure caption.

The reviewer asks for a comparison of temperature profiles in periods with and without gravity waves.
We added Fig. 8 which shows temperature profiles during quiet conditions.

The reviewer asks why T'(z) does not increase exponentially with increasing altitude as expected for vertically upward propagating waves.
If the amplitude of a monochromatic single gravity wave does not increase exponentially with twice the scale height, the wave loses energy; i.e. it is damped on its way up. Fig. 6 of the revised paper shows that indeed the atmosphere is not fully transparent for these waves. This is discussed in section 6 (Discussion).

The reviewer wonders about the formulation "quasi critical level".
We removed the discussion of quasi-critical level and stuck to the common terminology.

References

Whiteway, J. A., and A. I. Carswell, Lidar observations of gravity wave activity in the upper stratosphere over Toronto, *J. Geophys. Res.*, *100*, 14113–14124, 1995.

Wilson, R., M. L. Chanin, and A. Hauchecorne, Gravity waves in the middle atmosphere observed by Rayleigh lidar. 1. Case study, *J. Geophys. Res.*, *96*(D3), 5153–5167, 1991.

Interactive comment on Atmos. Chem. Phys. Discuss., 4, 969, 2004.

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