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Comment on acp-2021-160

Anonymous Referee #2

Referee comment on "Propagation paths and source distributions of resolved gravity waves in ECMWF-IFS analysis fields around the southern polar night jet" by Cornelia Strube et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2021-160-RC2, 2021

The study describes a detailed analysis of the propagation of waves into the lower stratosphere, bringing evidence that lateral propagation of several thousand kilometers can be common already at lower stratospheric heights. The methodology is well explained, the figures are clear, the analysis and the discussion are convincingly carried out. The illustration of this lateral propagation and the conclusions are of great interest to the community interested in gravity waves, their parameterization and their impacts on stratospheric circulation. However, some of the choices in the methodology would need to be further justified, or sensitivity to these choices should be explored a bit: using temperature perturbations as the key variable for identification of the waves (point 1), the calculation of the gravity wave momentum fluxes (point 2), the choice of the analysis altitude (point 3). The discussion of the origin of the waves should be strengthened slightly (point 4), even if a detailed discussion is outside the scope of the present study. Once these concerns have been addressed, this study should constitute a valuable reference for the understanding and modeling of atmospheric gravity waves.

Major Points

1. The investigation is carried out with the identification of gravity wave packets as a starting point. This identification focuses on temperature. This makes sense and is related to the relevance of this variable and the corresponding dignostic tools in observations. However, since the analysis is carried out on model data, other variables could be used. The vertical velocity in particular is available, and variations will naturally be dominated by gravity waves (no or much less need to remove background large-scale gradients). What are the results of the S3D method on the vertical velocity field (or on other fields, e.g. meridional wind, ageostrophic wind, divergence..)? What is the

sensitivity of the method to the choice of the reference variable
for the identification of wave packets and what does this imply
for the overall interpretation?

2. The gravity wave momentum flux (GWMF) is calculated, it seems,
from the wave characteristics ('GWMF depends both on the squared
temperature amplitude and the ratio of horizontal to vertical wavelengths',
line 264). Yet from the model output there is much more information
available, allowing a direct calculation of the momentum fluxes from
the different variables involved, including velocity components. Although
such validation is not the focus of the manuscript, a comparison of the
two estimates would bring much more confidence to the estimates of GWMF,
which is a central quantity in the study of gravity waves. Reducing the
uncertainty on the estimate of these fluxes is important and worthwhile.

3. Although the tool used for ray-tracing does not require validation,
as it has been used and its relevance demonstrated many times, it could
be useful to explore a bit the sensitivity of the analysis to some
of the methodological choices: if the analysis of the waves is carried out
at 30 km instead of 25 km, or at 20 km, are the results essentially unchanged?
How well do rays launched from 30 km correspond to the wavefield present at 20 km
when they have propagated down to 20 km (with the reserve in mind that part
of the waves present at 20 km do not propagate up to 30 km)? Of course,
the questions suggested here would require more work than is reasonable,
but it would be useful to give some indications for the sensitivity of the
analysis to different choices that need to be made in the process.

4. The origin of the non-orographic waves deserves some more
discussion. Although it is quite acceptable that "A detailed discussion
of the source processes is however beyond the scope of this study," (l359)
some indications of what the sources could be, and some references, should
be included. In particular, some information may be present in the output
of the ECMWF-IFS. In addition to the vertical velocity plotted in figure 11,
the divergence of the horizontal wind should be plotted. It highlights a
different part of the spectrum relative to vertical velocity, and is
particularly relevant for non-orographic waves, which often have low intrinsic
frequencies.

Minor Points

l4 parts of the discrepancy -> part of the discrepancy

l17 remove e.g.?

l49-50: this is slightly misleading because the distances over which horizontal propagation will matter are much larger than those over which vertical propagation matters. The propagation is in line with the aspect ratio of the wave.

l70-74 another study investigating such wide lateral propagation from observations is the study by Thurairajah et al (2017)

p8, Fig 2: please find a way to add a fine line indicating the locations of the two cross-sections on the maps, this will be helpful (of course the latitude and longitude suffice in principle, and it is good not to overload figures, but it should nonetheless be helpful)

l256 expected wavelengths for GW range between 5 and 20 km: should it be added 'in the present case', to remove ambiguity. The sentence may otherwise read as a generality, although GW with shorter vertical wavelengths are common

l271-280: is it the right choice to represent the ground-based period (or frequency)? The intrinsic period will be related to the horizontal and vertical wavelengths. These have variations within the ellipses I, S and E, but seem rather smooth nonetheless. In contrast, the ground based period (Fig 3e) shows very large variations within region I (strongly positive and strongly negative values are present side by side). If the ground based frequency is calculated from the estimation of the intrinsic frequency, the wavevector, and the background wind, the multiple sources of uncertainty can lead to large uncertainty.

l287: 'an intermediate, positive ground-based period': figure 3e rather suggests an ill-defined ground based period, with strong spatial variations

l293: 'the influence of imperfections in the background removal is less important for higher amplitude waves': as propagation is linear, why would this be the case? Is it rather that characterization of the waves is less uncertain for higher amplitude waves, for obvious reasons that the signal is clearer for higher amplitude waves?

l296: missing citation

l300-305: no reason to separate the two paragraphs

l317-318: could the authors recall the time resolution available to interpolate in time? How sensitive are solutions to this time resolution and to the interpolation?

l325-330: Are the ray-tracing results sensitive to the choices described in section 2.3 to define the background flow?

Legend of figure 4: it is slightly odd to start by describing the right column then the left one; would it be better to change the order in the figure, or in the caption? Also, the percentage of stratospheric GWMF is in the upper-right corner of the figures (of the right column).

l381: non -> none ; where -> were

Legend of figure 10: mention the unit for the pressure contours

l453: what is the apparent contradiction mentionned here, between the numerical and observational studies referred to?

l541-543: paragraph containing a single sentence - should this not be avoided?

l545-549: the balloon observations have also been investigated to relate the observed waves to background wind speeds: it has been found that gravity wave momentum fluxes are systematically enhanced in the regions of stronger background wind speed in the balloon observations (Plougonven et al 2017). This makes the statement put forth by the authors more precise: it is not just a geographical statement (balloons observed GWMF at 60°S), but a dynamically meaningful statement (balloons observed enhanced GWMF in the jet) which is consistent with the findings of the manuscript. It supports the generality of the findings obtained from the detailed investigation of the propagation paths carried out in this case study.

l573-575: this point is very interesting and should perhaps be more emphasized. Are the waves that end up at 25 km those that have found strong winds to propagate into successively in the troposphere and the stratosphere? (It is mentionned that both jets are strong, but they are not colocated in latitude..)

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Plougonven, R., A. de la Camara, V. Jewtoukoff, A. Hertzog and F. Lott (2017).
On the relation between gravity wave and wind speed in the lower stratosphere.
J. Atmos. Sci., 74, p1075-1093, 10.1175/JAS-D-16-0096.1

Thurairajah, B., D. E. Siskind, S. M. Bailey, J. N. Carstens, J. M. Russell III, and
M. G. Mlynczak (2017), Oblique propagation of monsoon gravity waves
during the northern hemisphere 2007 summer, J. Geophys. Res. Atmos., 122, 5063-5075,
doi:10.1002/2016JD026008.