Atmos. Chem. Phys. Discuss.,
https://doi.org/10.5194/acp-2017-644-AC3, 2017

Atmospheric Chemistry and Physics Discussions

Interactive comment on "First tomographic observations of gravity waves by the infrared limb imager GLORIA" *by* Isabell Krisch et al.

Isabell Krisch et al.

i.krisch@fz-juelich.de

Received and published: 26 October 2017

Dear Referee #3,

Thank you very much for these very helpful comments!

According to comment #2 we will include details on the smoothing filter used for the generation of the a-priori field. Further, we will include a figure with a comparison of GLORIA and in-situ measurements (comment #4). As mentioned by the Referee, this will further support the capabilities of GLORIA. Regarding comment #5, the authors want to clarify, that for the derivation of Equation (2), the mid-frequency approximation

Printer-friendly version

Discussion paper

was not used. However, the low and high frequency terms of Equation (6) in Ern et al. (2004) have been omitted in our paper, as their impact on the result is below 1% in the measured gravity wave range. This will be addressed in the revised manuscript. Comment #6 has been mentioned in a similar way by all referees. We will include more details on how the occurrence probabilities are determined. A comparison of GLORIA measurements with ECMWF shows that for the case discussed in our paper, the GWMFs have a similar magnitude. Therefore, we have confidence that the statistics derived from ECMWF are a meaningful way to set our event into a broader context.

In addition, we will address all other minor comments in the paper. A detailed list of all changes can be found below.

Again, thank you very much for helping us to present the theoretical background accurately and for improving the discussion and interpretation of results.

Sincerely, Isabell Krisch

Reviewer comment: Could you be more specific here regarding the “regularization term” or provide a reference where the use of this term is better detailed?
Authors response: More details on the used regularization can be found in Ungermann et al. (2010). This citation will be mentioned in the text.

Reviewer comment: Similarly, could you be more specific on the smoothing you are using in the raw ECMWF fields?
Authors response: More details will be included in the text.
Text changes: This smoothing was done by applying a low-pass Fourier filter with cut-

off wavenumber 18 in zonal direction. In height and latitude direction Savitzky-Golay (SG) filter (Savitzky and Golay, 1964) was applied with 4th order polynomials over 11 and 25 neighbouring points respectively. On the one hand, the so generated a-priori field improves the convergence speed of the iterative minimization, as this temperature structure is close to the true values due to the high quality of the ECMWF model. On the other hand, the smoothening ensures that any GW signature in the retrieval result does not stem from the used a priori data. If the a-priori data exerts any influence, it would dampen the GW structure.

Reviewer comment: Could you please state the airplane altitude during GLORIA measurements?
Authors response: This point will be included in the manuscript.
Text changes: The aircraft flight altitude during this time was between 12.5 km and 13.5 km. Towards low altitudes, the GLORIA measurements were limited by clouds reaching up as far as 9 to 10.5 km.

Reviewer comment: One primary goal of the article is to show how GLORIA observations can be used to accurately retrieve gravity-wave fluctuations. I am therefore surprised that you did not try to show comparisons between the retrieved 3D temperature field and in-situ observations performed by the airplane before the hexagonal path or with the dropsonde measurements, as well as with the resolved gravity-wave structures in the ECMWF analyses. In my opinion, such comparison should further support the capabilities of GLORIA, and perhaps also provide an additional way of characterizing the instrument performances.
Authors response: A comparison of the GLORIA measurements with in-situ measurements and ECMWF will be included as a new figure (Fig. 4). Both measurements agree well within the spatial resolution range of GLORIA.
Text changes: Fig. 4 shows a comparison of the retrieval results with in-situ measure-

ments and ECMWF operational analyses with T1279/L137 resolution. The retrieval results and model data were interpolated onto the in-situ measurement locations. The GLORIA measurements agree well with the in-situ measurements. Some very short scales are beyond the spatial resolution of GLORIA. The ECMWF analysis catches the main variations, but the temperature oscillations are not as strong as in reality. GLORIA can better reproduce peaks as for example the one around 10:40 UTC. This comparison underlines the high quality of the GLORIA measurement data.

Reviewer comment: It may be worth stating that Equation (2) actually only applies in the socalled mid-frequency approximation, where "pseudo-momentum" and "momentum fluxes" are stricly equivalent. Otherwise, the sentence here may be slightly confusing. I furthermore wonder whether this approximation is really valid in this case study. The ratio of horizontal/vertical wavelengths seems to imply relatively long waves, for which inertial effects in Equation (2) could not be totally neglected.
Authors response: For the derivation of Equation (2), the mid-frequency approximation was not used. However, the low and high frequency terms of Equation (6) in Ern et al. (2004) have been omitted as their impact on the result is below 1% in the measured gravity wave range. A full discussion of the importance of these low and high frequency terms can be found in Ern et al. (2017). This point will be clarified in the manuscript.
Text changes: Low and high frequency terms are omitted here due to simplicity. Deviations from the full equations derived by Ern et al. (2004) are less than 1% in the observational range of GLORIA. For a full discussion of the relevance of all correction terms see the supporting information in Ern et al. (2017).

Reviewer comment: Section 3.1, last paragraph: this comparison looks somewhat biased to me: if I have well understood, the GWMF for the Iceland case study are in one hand estimated from GLORIA observations, while in the other hand they are compared to a distribution of GWMF computed with ECMWF operational analyses. There is actually no garanty that ECMWF analyses accurately resolve such mountain wave events, and e.g. Jewtoukoff et al. (2015) have reported a significant underestimation of GWMF in ECMWF operational analyses.

Authors response: This point was mentioned by all three reviewers. We will include the details on how the occurrence probabilities are determined in the manuscript. A comparison of GLORIA measurements with ECMWF shows that for the case discussed in our paper, the GWMFs have a similar magnitude. Therefore, we have confidence that the statistics derived from ECMWF are a meaningful way to set our event into a broader context.

Text changes: To classify this event, a comparison of all GW events in January 2016 has been performed in the 6-hourly operational analyses of ECMWF. First the temperature background was isolated, as described in Sec. 2.1 for the a-priori field, and subtracted from the original field. The remaining temperature residuals were analyzed for GWs using the 3D sinusoidal fit algorithm described above. The GWMFs for all cubes were calculated. The GWMFs from all 124 analyses fields were combined to obtain the probability of GW occurrence (Fig. 6*, former Fig. 5*). Here, all GWMF values were considered independent of the horizontal and vertical wavelengths. Removing wavelengths larger than 2.5 times the cube size in order to filter less significant fits (not shown) induced no major changes in the general shape of the distribution. This indicates that GW events with less certain fits do not bias the probability distribution.

For the GW event over Iceland similar GWMF magnitudes were determined from the ECMWF analyses and from the GLORIA measurements. Thus, a comparison of the measurement results with the occurrence probability determined from the ECMWF analyses seems reasonable. According to Fig. 6 the measured GW event can be classified as a very strong case since the sum of all occurrence probabilities of stronger events is far below 1%.

References

Ern, M., Hoffmann, L., and Preusse, P.: Directional gravity wave momentum fluxes in the stratosphere derived from high-resolution AIRS temperature data, Geophys. Res. Lett., 44, 475–485, doi:{10.1002/2016GL072007}, 2017.

Ern, M., Preusse, P., Alexander, M. J., and Warner, C. D.: Absolute values of gravity wave momentum flux derived from satellite data, Journal of Geophysical Research: Atmospheres, 109, doi:10.1029/2004JD004752, http://dx.doi.org/10.1029/2004JD004752, 2004.

Jewtoukoff, V., Hertzog, A., Plougonven, R., de la Camara, A., and Lott, F.: Comparison of gravity waves in the southern hemisphere derived from balloon observations and the ecmwf analyses. Journal of the Atmospheric Sciences, 72(9):3449–3468, doi:10.1175/JAS-D-14-0324.1, https://doi.org/10.1175/JAS-D-14-0324.1, 2015.

Savitzky, A. and Golay, M. J. E.: Smoothing and Differentiation of Data by Simplified Least Squares Procedures., Analytical Chemistry, 36, 1627–1639, doi:10.1021/ac60214a047, http://dx.doi.org/10.1021/ac60214a047, 1964.

Ungermann, J., Kaufmann, M., Hoffmann, L., Preusse, P., Oelhaf, H., Friedl-Vallon, F., and Riese, M.: Towards a 3-D tomographic retrieval for the air-borne limb-imager GLORIA, Atmos. Meas. Tech., 3, 1647–1665, doi:10.5194/amt-3-1647-2010, 2010.

Interactive comment on Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2017-644, 2017.

Printer-friendly version

Discussion paper

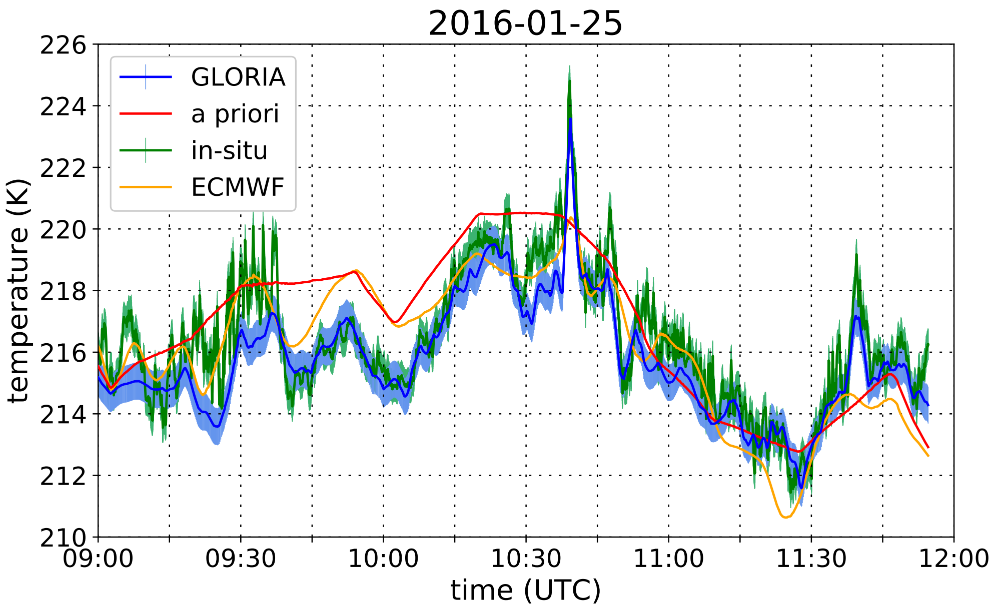

Fig. 1.

Printer-friendly version

Discussion paper