

Interactive comment on “Temporal variability of tidal and gravity waves during a record long 10 day continuous lidar sounding” by Kathrin Baumgarten et al.

Anonymous Referee #1

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The paper by Kathrin Baumgarten and coauthors presents a continuous observation of middle atmosphere temperatures of unprecedented length. This is facilitated by newest advances in daylight capability as well as favorable observation conditions. The data are analyzed with a number of different techniques discussing the different effects of vertical and horizontal detrending. This is comprehensive and well presented. However, I do not agree with the interpretation of the findings in terms of a GW-induced change of the tidal amplitudes. This interpretation is based solely on the data without a clear discussion of the mechanisms. I would ask the authors to reconsider this part in the light of the major comments given below.

C1

Major comments

The central figure in terms of interpretation is Figure 10. The figure presents the temporal variation of the tides, the GWs and the background winds. The tides show a general tendency of decrease over the 10-day period with some variation seen only in the temporally-filtered data. GWs show several peaks with the strongest peak after day 10, after the wind reversal of both zonal and meridional winds. That peak is more outstanding in the temporally filtered data, but amplitudes are much larger in the vertically filtered data.

The only point which supports your hypothesis is that the strongest decrease in tidal amplitude and the strongest peak of GW amplitudes appear both at the same day, i.e. day 11, in the temporally filtered data. However, this is a single event! It may be coincidence, the two variations could be caused by a common reason or it could indeed be causality. In order to argue that it is not a coincidence you would need more data. You claim that you can find a strong correlation: that could be tested by actually calculating correlation coefficients. (Proof me wrong, but I do not expect you to find a correlation significant based on Student's t-distribution.)

In order to argue for causality you would need to describe the mechanism in more detail. Here I see several difficulties.

A) The (part-)global nature of tides. In general tides are understood to be a superposition of Eigenmodes of the atmosphere resonantly excited by solar heating (or chemical heating or latent heat release triggered by the solar cycle). In the superposition of different modes there may be locally varying amplitudes depending on the place of the observation. The relative phases then also would decide on the amplitude at a single observing station. In addition, non migrating tides may be excited by the interaction of tides and planetary waves (cf. e.g. Liebermann et al., JGR-Atmos., 2015). By the way, it is not correct that satellites do not observe short term variability, see this paper and also e.g. Pedatella et al., JGR-space, 2016.

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If you want to understand the cause for the variation at Kuehlungsborn you have to first find out which tidal modes are involved and whether these modes change amplitude or rather phase. Then you would need to look for mechanisms on a part-global scale. The column above Kuehlungsborn is definitely insufficient.

B) You would still have a stronger argument if you could show that the event considered is exceptionally strong. A single event may dominate the momentum flux of a whole latitude circle. You have climatologies from your own observations as well as from satellite data. Put your event into a context! That is a value of its own. In your discussion at the moment you focus on the temporally filtered data, because there you have only one peak while you have three in the vertically filtered data. However, GW momentum flux is proportional to the square of the temperature amplitude, which is a factor 9 (amplitude squared) larger in the vertically filtered data. Also the latter would be more susceptible to wind filtering and dissipation.

C) Also GWs propagate obliquely. And what causes the peaks? The question what the origin of the peaks in GW amplitude might be is probably the most obvious one. Again you try to answer this solely from the column above Kuehlungsborn. The wind reversal points to some cyclone or anticyclone in the vicinity. Is there frontal activity? Please consider also weather maps and search for potential sources. Also high resolution ECMWF data may be helpful (you show quite remarkable agreement) to find potential sources.

Overall, my recommendation is to strengthen the observational part by putting the observed event into a context: is it an unusually strong event? In addition, dig somewhat deeper into the sources of the GWs with the help of NWP data, potentially considering high resolution ECMWF data. Could UWaDi be helpful? Keep the ozone discussion short, local ozone does not tell you much. Then at the end you may suggest that the GWs could have an influence on the tides but do not build your whole paper around this hypothesis and do not quote this as an "elegant demonstration of the strong impact of gravity waves on the diurnal tide": you are missing the evidence!

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Specific comments:

P1L2 infected -> affected

P1L22 Separate your references for GWs and tides. There is also tidal excitation due to latent heat release, i.e. convection.

P2L1 therefore -> accordingly

P2L10 ground based = what remains on the ground = radar, lidar, airglow radiosonde, rocket: in situ

P2L35 data during the 10 days of continuous lidar data in May 2016 and

P3L6 flash-lamp pumped

P3L7 better signal-to-noise? In which way?

P3L27 below the initial retrieval altitude ?

P4L9 over the entire period are shown in Figure 1 as well.

P4L12 only contain tidal waves*; * also gravity waves as

P5L1 calculated using as a <- one or the other

P5L2 Please include the 50km altitude also in the text

P5L17 Within this altitude range clear waves What do you mean? The altitude range 40-55km or the ranges below and above? I cannot follow your discussion here: In both cases I see waves, though at different frequencies. Maybe waves in the upper panel weaken at the highest altitude. Is that the effect of the vertical Butterworth filter? It also appears to me that the change between receiving channels also causes a non-continuity in the waves - though that is hard to say as the line is in.

P6F3 vertically-filtered data

Please show also the low-pass filtered data in Fig.3

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P7F4 Wavelet spectra

P8L1 The unexpected decrease of the diurnal component shown above indicates a strong short-term variability for tidal components. What precisely do you want to infer here? That the tides have a boost at 50km which not yet reached 60km? Then: what is the vertical group velocity of tides? Your period is quite long. Shouldn't the high amplitudes you see at 6 May reach a few days later also 60km? Or do you mean simply that there is a strong variation at 50km with a peak at 6 May? Please clarify.

P8L1 referred to be constant (e.g. from the satellite community). a) Also in the satellite community there are quite a number of approaches b) Often some temporal coherency is used to identify a number of different migrating and non-migrating modes. These, evaluated at a single location, may result in apparently strongly varying amplitudes, albeit a constant amplitude was assumed for all these global modes. c) That amplitudes are assumed to be constant is then usually just the lack of data. So far we unfortunately do not possess the perfect observations with simultaneously global coverage and good coverage of local time.

Please omit the half sentence here. You can include some discussion in the introduction or summary section.

P8L15 That you need a closer look tells you that the differences cannot be huge ... Are you even sure that they are significant? Probably yes, as they seem to be consistent over a wider altitude range. However, that they match at 43km does not seem to be significant to me given the variations in the profile above.

P8L22 50 % : Sorry, I am bewildered. In Fig. 5 left panel, blue curves you have at 44km a mean amplitude of roughly 1.5K, and a minimum (dashed) of 1K = 30%. Just above at 46km the three curves are inside .2K at 2K mean amplitude, i.e. about 5% variation around the mean. For a global mode with long vertical wavelength such as a tide I would not assume the minor zigzagging to be real but indicative of the precision with which you can determine your amplitudes. On the other hand, the wavelet analysis

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indeed shows a change of a factor 2 in amplitude, so I am missing that special part of consistency. My interpretation would be that tidal amplitudes are stable, if periods of 7 days and larger are considered but that on shorter scales the local tidal amplitudes vary strongly.

P8L26 which could be Doppler shifted to *intrinsic* periods larger than the Coriolis period

P8L27 In the composites you implicitly assume a constant phase of the tide over the analysis interval. Phase variations hence would also be a reason for different results.

P9L17 we assume that the disappearance -> we want to investigate whether ????

P10L2 depends on wind conditions as well as on their interaction. Please be more precise, e.g. the propagation conditions of tides depend on the mean background winds and the propagation of GWs both on the mean wind and the tides.

P10L6 ECMWF is able to reproduce the meteorological situation above Kuehlungsborn.

P11L8 the sponge layer and the fact that there are basically no data above the stratopause assimilated.

P12L5 What do you mean: that the variation, albeit weak, is caused by PW or that the weakness of the perturbation is caused by PW

Fig10: Please assign panel indices (a,b,...). There seems to be a data gap after day 10 in the observations. There are some odd blue lines at the bottom of the plots in the middle row.

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