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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Gravity-wave effects on tracer gases and stratospheric aerosol concentrations during the 2013 ChArMEx campaign" *by* Fabrice Chane Ming et al.

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Detailed reply to comments from the two anonymous referees of manuscript "Gravity-wave effects on tracer gases and stratospheric aerosol concentrations during the 2013 ChArMEx campaign" (acp-2015-889)

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Discussion paper

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First, we thank the anonymous reviewers for their helpful detailed comments and suggestions on our manuscript. In the following, comments of the reviewers are fully addressed and modifications have been made in the revised manuscript accordingly. Responses to comments of referee #2 are highlighted in red; those of referee #3 in blue as well as revised sentences and paragraph in the updated manuscript. A new version of the manuscript is attached as supplement.

Yours sincerely, Fabrice Chane Ming

Referee 3:

Major Comments

(MC1) The whole manuscript has been checked for clarity and consistency about discussion on multiple waves as it is supported by the spread of parameters in table 1 (horizontal wavelengths and ω/f) . Indeed, our methods of analysis of GW characteristics (Table 1) are focused on dominant GWs among wave packets. Modifications in the text are presented in our responses to specific comments.

(MC2) This part has been modified. The phase shift is now computed between RS2723 and RO2802 for which time variation and the distance are 1.8h and 179.14 km respectively. Because time variation is > 15 minutes, our calculation of phase shift takes into account the time variation using the estimated ω (Table 1). The authors think that it is important to report the estimation of wave parameter from GPS RO measurements because they also support observations of GWs (refer to comment 5 for more details).

Specific Comments

Comment (1 & 2): Response: The text has been modified as suggested by the re-

viewer. Change P2L31: Thanks to recent progress in computer technologies, current operational numerical weather prediction models have sufficient spatial and temporal resolution to resolve the portion of GW wave spectrum with horizontal wavelengths of 100-1000 km (Shutts and Vosper, 2011). However, global climate models as well as numerical weather prediction models still need a set of GW parameterizations with a large number of tunable parameters for a realistic representation of the middle atmosphere (Preusse et al., 2014). By comparison with observations, it has been shown that the resolved GWs are usually under-represented (Schroeder et al., 2009).

Comment (3): Response: The authors have compared GPS-RO dry and wet temperature profiles used in this study. They are similar above the altitude of 10 km. We mentioned that our study is focused on heights of 10-20 km because GW ïňĆuctuations in both wet and dry temperatures might be biased below 10 km heights.

Change P6L4: We have removed 'wet' from the text and included the following sentence "Because GW ïňĆuctuations in both wet and dry temperature profiles would be biased by the effect of water vapor at heights below 10 km, the study is focused on heights above 10 km.

Comment (4): Response: The authors have removed the last sentence at the end of Sect.3.3 and modified the text Change P9L3: "At a given altitude, the horizontal wavelength can be deduced from adjacent vertical proïňĄles of temperature close in time and space in order to observe the same GW packet. Thus, the time variation in the phase difference can be neglected (refer to equation 5 in Wang and Alexander (2010)) and the phase shift divided by the distance provides the horizontal wavenumber projected along the line connecting the two profiles. Ern et al. (2004) introduced this method to estimate horizontal wavelength of GWs and global absolute values of vertical ïňĆux of horizontal momentum at 25 km altitude from adjacent temperature profiles from Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere (CRISTA). The method is adapted to pairs and triads of RO temperature proïňĄles using the S-transform and CWT in the altitude range of 17.5–22.5 km with temporal windows of 4 h

and 2 h (Wang and Alexander, 2010; Faber et al., 2013). To better constrain estimated horizontal wavelengths and momentum fluxes, Schmidt et al. (2016) used temporal and spatial windows of 250 km and 15 minutes."

Comment (5): Response: The authors have modified the text and only compute the phase shift between RS2723 and RO2802 at the altitude of 17 km for which time difference is 1.8 h because of the ascent time of the RS. In addition, the calculation of the horizontal wavelength takes into account the time variation by using the value of period and the uncertainty of the direction of horizontal propagation (Phi) reported in Table 1. Fig. 7d has been removed. Scalograms of RO2802 and RO2812 have been preserved because they complete Fig6b. Indeed they support the presence of GWs with 2-3 km vertical wavelength in the troposphere and the lower stratosphere on 28 July like observations on RS2723.

Change P16L28: the text has been modified as follows: "Figure 7a visualizes temperature profiles from RS at 2303 UTC (hereafter called RS2723) on 27 July above Ile du Levant and RO at 0200 UTC (hereafter called RO2802) and 1200 UTC (hereafter called RO2812) on 28 July. As observed on the RS2723 temperature profile, GPS RO temperature profiles also show evidence of small-scale perturbations in the troposphere and the lower stratosphere. Scalograms of RO2802 and RO2812 temperature perturbations support the presence of dominant GW structures with vertical wavelengths of 2.5-3 km at heights of 10-18 km on 28 July (Fig. 7b, c). By assuming that the same GW packet is observed on RS2723 and RO2802 profiles in the LS, the phase shift (ïĄĘ) between perturbation profiles is calculated at the altitude of 17 km taking into account of the time variation (refer to section 3.3) using a GW period of 12 h at heights of 15-20 km and a time difference of 1.8 h at the altitude of 17 km between RS and RO measurements. Using a distance of 179.14 km between temperature profiles, the phase shifts (ïĄĘ) of 1.67 radians provide an horizontal wavelength of 673.6 km. The estimated horizontal wavelength is larger than the 'real' value by a factor 1/cos α, where α is the angle between the connecting line of the two profiles and the real horizontal

wave vector (Preusse et al., 2002). Thus the 'real' horizontal wavelength is ranged between 396 and 674 km (Phi=200±29°). The result is consistent with values of horizontal wavelengths derived from applying conventional methods on RS2723 profiles at heights of 13-20 km."

Comment (6): Response: Here we discuss multiple waves characterized by a dominant wavelike structure (peak of intensity). The word "both" has been removed.

Comment (7): Response: We have done the modification "°C2 km-1"

Comment (8): Response: Modifications have been done. Change P15L27: "In particular, the hodograph analysis reveals the presence of mesoscale inertia GWs"

Comment (9): Response: We have included suggestions of the reviewer concerning comparison with previous studies in summer mid latitudes. Change P16L5: "Our computed value of vertical flux of horizontal momentum (about 8 mPa) is well beyond values of 1 mPa and 0.02 m-2s-2 observed in the LS in summer midlatitudes respectively by Ern and Preusse (2012) over Europe from High Resolution Dynamics Limb Sounder (HIRDLS) observations and Zhang et al. (2014) from radiosondes over North America. Thus the value of vertical flux of horizontal momentum supports our statement that the case on 27 July 2013 represents a stronger GW event."

Comment (10): Response: We have added some explanation about the expected range of p and modified our statement. Change P16L10:" The ratio between kinetic and potential energy of GWs provides a spectral index (p) of about 2.6-2.9 which is larger than the theoretical values of p (about 5/3). However, Hertzog et al. (2002) find values of p in the range 1.5-2.2 for high-frequency GWs from superpressure balloon measurements in the stratosphere. They suggest that values greater than 5 could be caused by enhancements of the velocity spectrum near the inertial frequency."

Comment (11): Response: Refer to our response to comment (5). We provided a reference on paper of Schmidt and Alexander (2016) at the end of section 3.3.

Comment (12) Response: The authors agree with the reviewer that our approach is simplified and it does not take into account all possible GWs at heights from the ground to 26 km. However, our objectives are to produce simplified synthetic profiles of the dominant mesoscale GW at heights of 13-20 km in agreement with mean spectral characteristics of observed mesoscale GWs, the intensity of observed GW perturbations, phase relationships as well as energy densities and horizontal phase speed. Analyses of wave parameters from simulated profiles of perturbations and comparison between observed and simulated profiles support that the simplified synthetic profiles contain the main information about the dominant mesoscale GW at heights of 13-20 km which is useful in the next section to interpret the impact of GWs on stratospheric tracers and aerosols. The discussion about the variation of Brunt Vaisala frequency with height and the horizontal wavelength has been removed. The text of section 5.3 has been revised to mention clearly our assumptions and objectives. Change: refer to P17L26-P18L13

Comment (13) The authors believe that change in wavelength mean as a function of time provides information about the time evolution of GW distribution. They agree with the reviewer's comment that a given combination of wave parameters could preferentially be observed as a function of altitude and time depending on the background wind field. Change P18L31: "A given combination of wave parameters might preferentially be observed depending on the background wind field." at the end of 5.3: P19L6 "In conclusion, the GROGRAT simulation indicates that mesoscale GWs with a whole range of parameters around the mean parameter could be excited by the front and propagate to the location of Ile du Levant at heights of 13-20 km."

Comment (14) We have modified the sentence to discuss multiple waves instead of a single wave. Change P21L22 : "The methodology is illustrated on a case study on 27 July 2013 when mesoscale inertia GWs produced by the jet-front system were identified during a jet-streak event"

Other comments: all suggested modifications have been incorporated into the revised

text (refer to the modifications highlighted in blue). For a better quality, Fig. 9a is provided.

Please also note the supplement to this comment:
http://www.atmos-chem-phys-discuss.net/acp-2015-889/acp-2015-889-AC1-supplement.pdf

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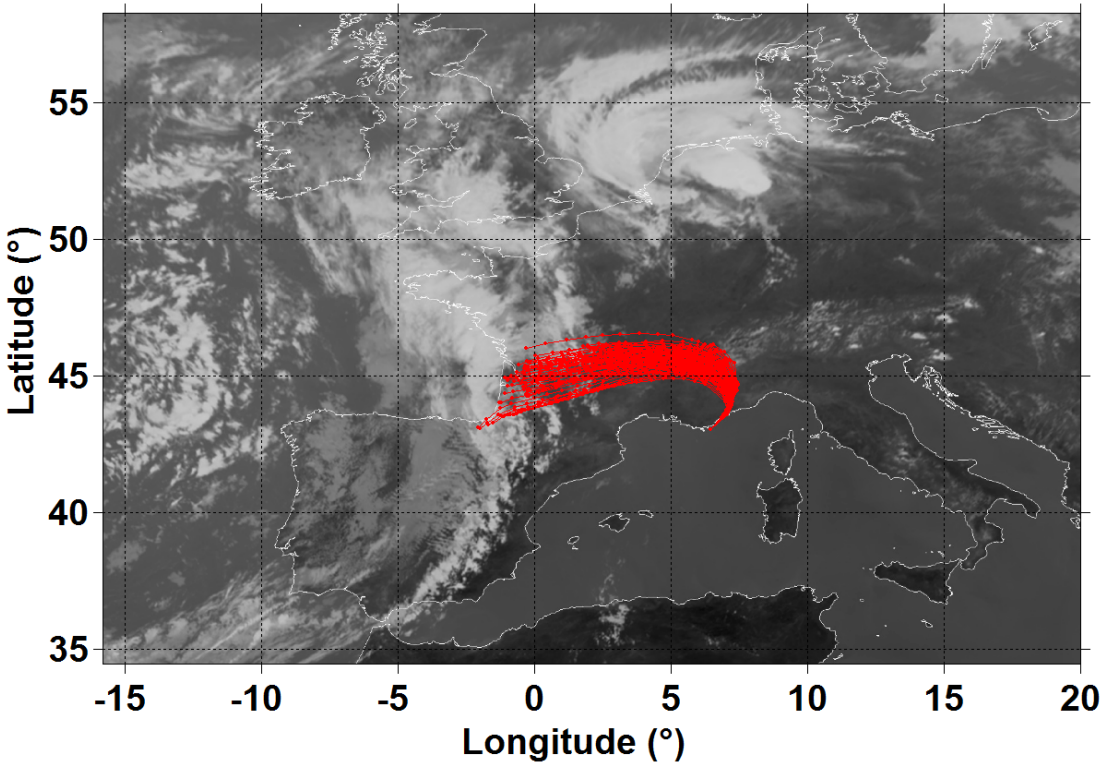

Fig. 1. Backward rays from Ile du Levant launched at 19 km height on 28 July at 0000 UTC onto (a) georeferenced infrared GMS-3 image

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