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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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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 2:

Major comments:

1.) The reviewer suggests that the GW patterns in the ECMWF analyses look like concentric. This observation is unclear and the authors think that we should be cautious about interpreting ECMWF analyses as true representation of GW patterns. However, the authors are planning to use a mesoscale model (WRF model) to assess the wave process and investigate complexity of a jet-front system as a source of GWs.

2.) This part has been modified as the other reviewer suggested. The explanation of the calculation is described in five lines and therefore it does not need to be moved to an appendix (refer to comment P5).

3.) The conclusion has been modified accordingly.

4.) The language has been improved by a native English speaker. Some additional introductory or explanatory sentences have been included in the text.

5.) We have modified the conclusion to address the reviewer's comment.

6.) The authors hope that the figure quality is now satisfactory for the reviewer. For a better quality, the Fig. 9 is provided. In addition all high quality figures can be provided separately.

6b) We have made consistency of the maps. For Fig. 6a, we can not extend the latitude range at -20°E because it is beyond the size of the image.

Specific comments: P7L11 We have specified " Background temperature and horizontal wind profiles". P7L18

P9L1 GPS-RO measurements have vertical resolution varying from about 0.5 km in the lower stratosphere (LS) to 1.4 km at 40 km heights in the middle atmosphere (refer to P6L2). So GWs with vertical wavelengths of 2-4 km can be observed. Indeed Fig. 6b shows evidence of a variability of GW energy from a vertical wavelength of 1.5 km in GPS RO profiles.

P9L28 The authors agree with the reviewer. We have reformulated the sentence. Change P10L9: "The validity of the Wentzel-Kramers-Brillouin (WKB) approximation based on the slow variation of the vertical wavenumber with height ensures the integration of the ray equations. Previous studies have shown that GROGRAT is an efficient tool to identify GW sources (Guest et al., 2000, 2002; Pramitha et al., 2015) and to simulate GW-background interactions such as GW effects, wave filtering, space and time variability of GW activity and characteristics (Wei and Zhang, 2015)."

P11L9 The modification has been done.

P11L13 The modification has been done.

P11LL29/Figure2: We have described more clearly the use of such charts. Change P12L10: "Ucellini and Koch (1987) and Koch and O'Handley (1997) produced similar charts to depict synoptic environment of jet streak typifying occurences of mesoscale GWs at the exit region of the upper-level jet streak." P12L15 " Maximum wind speeds at 300 hPa visualize the jet core at west of Portugal. In addition wind speeds >50 ms-1

from 1200 UTC indicate the presence of a significant jet streak."

Figure 4: Figures have been redrawn to address the reviewer's comments.

P14L6 We have specified what is precisely in quadrature. Hodographs of u' and v' is based on the phase quadrature between u' and v' and they have been intensively used to visualize and to extract elliptical structures. These structures are characteristic of GWs independently on the orientation of the wave vector. The orientation of the ellipse provides the direction of the wave vector ($\pm\ \pi$). Change P14L22: " RS horizontal wind perturbations (u' and v')"

P14LL20 and Fig 5b: In the present version, we have focused on GWs with horizontal wavelengths <1200 km observed at latitudes between 42° and 48°N (refer to new figures 5) for which the horizontal wavelengths can be correctly estimated and are clearly visible on the data series. The previous Fig 5b has been removed as redundant. Revised Figure 5 provides the main information: location of wavelike structures and presence of waves with horizontal wavelengths of 400-800 km. Indeed, some small-scale perturbations with long wavelengths could be a noise in ECMWF data.

Fig 5d: The new Fig 5c reveals a continuous spectrum of GWs with horizontal wavelengths of about 400-800 km. We can observe several peaks at latitude of 46.5° with a dominant one at about 400 km. Thus, we do not discuss subharmonics.

Change P14L1-9: " Spectral density of vertical velocities is calculated for longitudes of 10°W-20°E at latitudes between 42° and 48°N. In particular, the energy of mesoscale wavelike structures with horizontal wavelengths in the eastÂ■west direction ïĄňx<500 km is well-localized at the latitude of 46 °N which corresponds to the latitude of the exit region of the jet streak. Figure 5b displays the energy distribution of dominant wavelike structures at latitudes of 42-48°N for horizontal wavelengths ïĄňx<1200 km. In particular, it highlights a continuous spectrum of GWs with horizontal wavelengths ïĄňx of 400-800 km with a dominant mode of 400 km at latitudes of about 46°N. The spectral densities at latitudes of 42-48°N and 46°N confirm that the mode of 400 km is dominant at 46°N within the wavelength range of 400-800 km (Fig. 5c). "

Figure 6a: The map has been redrawn to keep consistency of maps (refer to major comment 6b)

P15 The first paragraph has been revised to address the reviewer's suggestion. Change P14L12-19: "The waves from this event can be identified in GPS-RO soundings as well. Figure 6a shows an overview of the GPS-RO soundings over western Europe for the days 26 to 29 July, 2013. We selected profiles for longitudes of 2.5°-6° E and latitudes of 40-50° N for spectral analysis of the altitude range of 10-20 km. The results are shown in Figure 6b. The individual spectra are labeled by the day and UTC of the measurement (e.g. 2605 for 26 July; 05 UTC) and marked also accordingly in Figure 6a. As one can see from results for consecutive days, GWs are enhanced starting from 27 July, peak at 28 July and are still active on 29 July. Spectral density peaks are found for wavelengths 2-3.5 km"

Table 1: The methods used to obtain parameters provide characteristics of dominant GWs, e.g., peaks of wave parameter distributions. For example, at heights of 3-7 km, we have reported three values of horizontal wavelengths because the hodograph analysis provides three peaks in the ω/f distribution. Change P32: "Characteristics of dominant GWs on 27 July at 2303 UTC above Ile du Levant using a hodograph analysis and combined conventional methods (grey cells) on observed and simulated (marked by *) profiles. Values are derived from peaks of wave parameter distributions."

P16LL12 The text about possible reasons for phase shift uncertainty has been removed because effects are supposed to be minor or difficult to quantify. Indeed, previously published papers on retrieval of horizontal wavelengths from GPS RO phase shift were not focused on such uncertainties and therefore in this paper we also do not discuss such uncertainties. In addition the part about phase shift has been modified according to comments of another reviewer. In the present study, time variation is taken into account because the value of ω has been previously estimated. The details of the

analysis based on five concise lines do not need to be moved into an appendix.

Change: refer to P16L28- P17L12 for modification about the computation of the phase shift in taking into account time variation. We have added an explanation, as suggested by the reviewer P17L12: "The estimate is somewhat lower but compatible with the value of 0.05 m2s-2 derived from the radiosonde measurements"

Page 18L1: The modification has been done.

P18 first paragraph: Few rays break near the tropopause in particular for large horizontal wavelengths (450-550 km). If we extend the range of ω/f and horizontal wavelengths we can observe a wider dispersion in the termination altitude, time and location. The authors have verified the termination condition at the altitude of the jet core. It is not simply because of the tropopause because the tropopause is located at about 15 km heights and rays are traced back to 10 km heights. Thus, in this paper we only present the results for which we can provide explanations. In our future research, a more detailed description of the wave process will be investigated using a mesoscale model (WRF). Change P18L26: "Because rays pass over a convective region when the front system moves eastward, some GWs produced by convective sources might also be captured."

Please also note the supplement to this comment:
http://www.atmos-chem-phys-discuss.net/acp-2015-889/acp-2015-889-AC2-supplement.pdf

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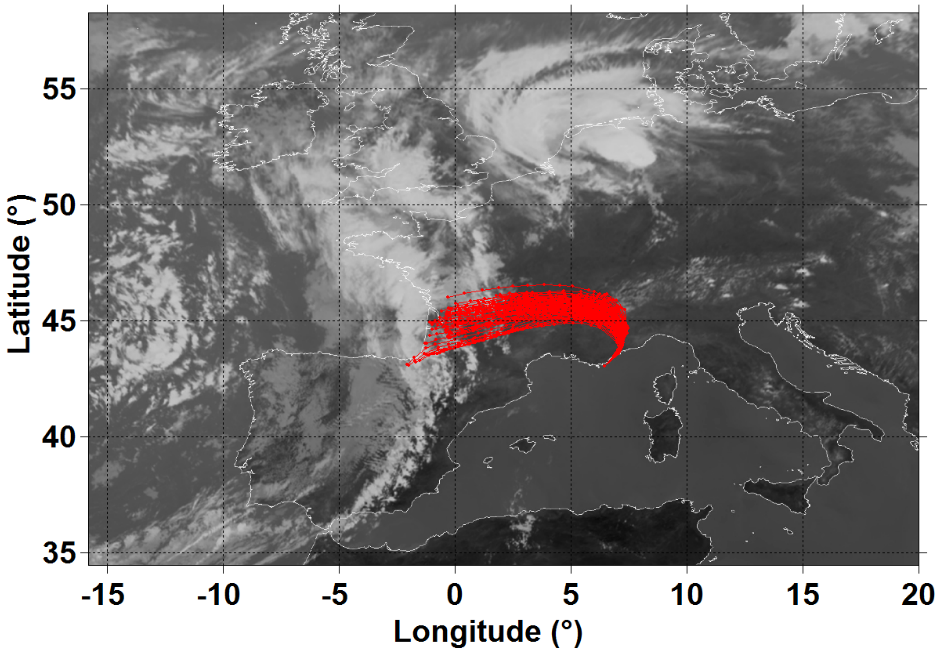

Fig. 1. Backward rays from Ile du Levant launched at 19 km height on 28 July at 0000 UTC onto (a) georeferenced infrared GMS-3 image