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Atmospheric Chemistry and Physics Discussions

ACPD

13, C6388–C6393, 2013

Interactive Comment

Interactive comment on "Observation and a numerical study of gravity waves during tropical cyclone Ivan (2008)" *by* F. Chane Ming et al.

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The text of the paper (supplement in pdf included) has been revised paying attention to interactive comments on "Observation and a numerical study of gravity waves during tropical cyclone Ivan (2008)" by F. Chane Ming et al. Figures have been preserved. Responses and modifications within the manuscript are mentioned below.

Anonymous Referee #1

Improvements regarding the following issues

1. The presentation of results has been improved taking account of the referee's comments. Also refer to answers for minor points. 2. These comments have been inserted

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Interactive Discussion

Discussion Paper

clearly in the new version of the paper. 3. Analyses strategies introduced in previous papers could be applicable with the current simulation results but the authors propose propose other efficient methods based on signal and image processing to analyze and visualize multi-scale structures of observed GWs. They could complete the other methods. Extraction and visualization of observed waves are important to support the reality of results. It is often neglected in some papers because it is not easy to do. In particular we show that multiscale analyses (CWT and 2-D FFT) are adapted to analyze multi-scale structures of TC-related GWs.

Minor points: P10765: modification done P10766: The following sentence has been added. “The chosen horizontal resolution is in the grey-zone regarding the representation of convection (Yu and Lee, 2010). But it is a good compromise for explicit convection in simulation to reproduce detailed structures of mesoscale convective sytems in TCs using a large horizontal domain (Klemp, 2006). Liu at al. (1999) and Lac et al. (2002) simulated convective GWs with short horizontal wavelengths of 15-80 km with MM5 and Meso-NH models with grid sizes of 6 km and 5 km respectively.” Some studies suggest that a grid size smaller than 1 km (up to 100 m) is necessary to fully represent convection for some systems (Petch et al., 2002; Bryan et al., 2003).

P10768: We have inserted P 10765 L3 “Radiosonde and GPS RO profiles explore low-frequency GWs with short vertical wavelengths limited by vertical height ranges in the UT/LS (Alexander and Barnet, 2007; Chane Ming et al., 2010). In addition the observational filter of GPS RO measurements sets the lower limit of periods at 2 h (Preusse et al., 2008).”

P10768 ‘on the other hand’ has been suppressed. The sentence has been replaced by ‘Upward energy peaks at 58-70% in the UT during landfall after the passage of the TC above Ivato.’

P10769 The sentence is now more explicite. “The contrast between UT and LS is consistent”

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P10770 L6 The method is defined in the sentence: “A spatial high-pass bi-directional 2D-filter, a separable eight-neighbor Laplacian (Pratt, 2001), is applied on vertical velocity derived from ECMWF analyses for edge detection of wavelike patterns.”

P10771 L18 Because of low vertical resolution ECMWF data of available data, vertical wavelengths are estimated from the other characteristics. They are estimated at 1-2 km for the dominant mode of 600 km horizontal wavelength and 12.8 h period. A vertical wavelength of 1-2 km is probably not resolved by the ECMWF. Wind field perturbations and GW poralization are not well-described and might explain partly the uncertainties. For the simulation, vertical wavelengths are estimated about 1.5 km and 3.3 km for horizontal wavelengths of 40-60 km and 300-500 km with dominant periods of 1.2 h and 12–48 h respectively (L10776 l15).

We have inserted at the end of part 5.2 “Estimated vertical wavelength of 1-2 km might be biased because it is probably not resolved by the ECMWF. Thus, the model describes mostly the low-frequency part of GW spectrum with horizontal wavelengths of 350-2000 km in agreement with Shutts and Vosper (2011).“

We have inserted at the end of part 5.3 “Vertical profiles of zonal and meridional wind perturbations are examined at the location where GWs are observed on 16 February at 1200UTC (Fig. 11c and 11d). They show evidence of a simulated vertical wavelength of 2.5-3 km for modes of horizontal wavelengths of 300-600 km, previously observed on Figure 9a. In addition perturbations only suggest that modes of 40-60 km horizontal wavelengths have vertical wavelengths < 2km because of the 500 m vertical resolution in the LS. Simulated wavelengths are in agreement with estimated vertical wavelengths. “

P10773 The referee is right to say that there could be many other possible reasons for the wind variations in the vertical. I suppressed the sentence and replaced it by “In addition eastward winds are observed east of the TC centre in the UT where GWs with phase speeds within the interval of values taken by the wind speed will likely dissipate

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at critical layers." L10-12 has also been suppressed.

P10774 Amplitudes of horizontal wind perturbations are about 3-4 ms-1 at 20 km heights for the simulation and agree with observation. The intensity and importance of each mode are described using FFT and CWT on Figure 12 P10775 L25. They are better mentioned in the text.

We have inserted P10772 L15 "GW activity increases in the UT at 15 altitudes between 13 and 15 km and ...a downward phase progression between $-$ 0.02 and $-$ 0.06 ms$-$1. Amplitudes of simulated horizontal wind perturbations ($\sim$ 3-4 ms$-$ 1) agree with observation."

P10775 Vertical momentum flux is computed with 10 min simulated perturbations of vertical and horizontal winds. It is described in [Sato et al., 1993; Kim et Chun, 2010]. Zonal and meridional wind perturbations are deïňĄned by subtracting domain-averaged zonal and meridional winds. Momentum fluxes are the sum of zonal and meridional momentum ïňĆuxes averaged over height ranges.

We have inserted the sentence P10772 "Time series of vertical GW momentum flux are computed with 10-min simulated vertical profiles of horizontal and vertical perturbations and averaged over height ranges in the UT (12-19 km) and LS (19-25 km) (Sato et al., 1993; Kim and Chun, 2010). They provide mean values of 0.01 and 5-6 10-4 N ms-2 in the UT and LS respectively above Tromelin and La Réunion islands. Sato (1993) mentioned a maximum momentum flux of 0.04 N m-2 at 20 km during TC Kelly (1987) and Kuester et al. (2008) estimated an integrated average value of 8.1 10-4 N m-2 in the LS during TC lifetime."

P10775 L11 The "binary image" was changed by "grayscale" because this word is ambiguous in image processing language. The color image is transformed into a grayscale image with 256 levels. A grayscale image is a digital image composed of shades of gray varying from black to white.

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P10775 L20 We have simplified the sentence and precised the second one. “FFT spectrum of vertical velocity provides a wide range of horizontal wavelengths between 20 and 2000 km with peaks at 60 km, 200 km, 500 and 1250 km at the latitude of TC eye in the LS. Mean values at latitudes of 9-21°S reveal that most energy of observed modes is located at the latitude of TC eye”

P10776 L12 This sentence has been suppressed. “In addition, amplitudes of GWs are larger than those of ECMWF analyses. It suggests that GWs are better represented in Meso-NH simulation.”

We have inserted at the end of part 5.3 “Finally, Meso-NH provides a realistic detailed description of low-frequency GWs in terms of perturbation amplitudes and phase relations.”

P10777 L5 The sentence is replaced by “The east-west (E-W) intensity ratio of maximum precipitation (IRMP) is about 0.7 (Fig.14a). The eye size is observed to be 132 km large.”

P10777 L21 yes

P10778 L1 We have modified the sentence “The rainbands have widths varying between 15 km and 60 km. Distance between TC rainbands ranges between 24 km and 76 km.”

P10779 L10 The orography of Madagascar peaks at Maromokotro (14°S, 49°E, alt: 2876m) and Andringitra (22.3°S, 46.9°E, alt: 2658m). TC Ivan hits Madagascar from the east between Masoala (16°S, 50.2°E) and Antanarivo (18.9°S, 47.8°E) where the orography is <1500m. Possible orographic waves might exist during landfalling of TCs over the lee side (refer to the case of TC Dina when approaching La Réunion island peaking at 3070 m (Jolivet et al., 2013)). We did not have described on what happened over the lee side after landfall because simulated outputs are biased (TC track is becoming uncorrect...). But Meso-NH simulation outputs don’t show clear evidence

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of orographic waves over the lee side in the whole troposphere and the lower stratosphere when TC is landfalling on Madagascar. Orographic waves are probably not well-resolved by the model because of the resolution of the orography. Refer to figure 3.b in Jolivet et al.(2013) for the representation of the orography of Reunion island in Meso-NH at with grid size of 4 km.

P10780 L1 the sentence has been modified

P10780 L1-12 The modification has been done

P10780 L13 This paragraph moved to the introduction.

Please also note the supplement to this comment:
http://www.atmos-chem-phys-discuss.net/13/C6388/2013/acpd-13-C6388-2013-supplement.pdf

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Interactive comment on Atmos. Chem. Phys. Discuss., 13, 10757, 2013.

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