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Interactive Comment

Interactive comment on "Assimilation of GNSS radio occultation observations in GRAPES" *by* Y. Liu and J. Xue

Anonymous Referee #1

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Overall the results show a stable NWP model coupled to the GRAPES 3D-Var assimilation system. It should be stated that most of this work is not unique, and the differences from previous research highlighted which are predominantly the configuration of the system (the low model top and the choice to assimilate just conventional and GNSS-RO observations), the vertical thinning of the data to the nearest model level, and presumably the observation error. However, even though the abstract teases the reader that the "tuning of the observation error" will be included this is never presented. The specification of the observation error is obviously of great importance to a variational assimilation system so more details on this and the "tuning" done would be helpful, as well as make this work distinctive. I realize this may be redundant with the paper "in press" but since this is unattainable at present it leaves one unsatisfied. The

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Interactive Discussion

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quality of the results suggest there may be some merit in the way the observation error was tuned which could be of benefit to the larger community.

Along with the other reviewer I was confused as to the potential temperature not being listed with the state variables, as it is needed in subsequent calculations. I am not sure what is trying to be said on page 7617, around line 20 about the potential temperature. What is required for the temperature computation in Eq. 13 is the Exner pressure and the potential temperature.

The bi-weight method used in the QC, would seem to reject data near the surface due to the large variability in the signal near the surface. However, I would be cautious about saying blankly that the quality of the RO data is not good. Due to the considerations that the RO signal covers a large horizontal extent and that it becomes ambiguous in the presence of horizontal moisture gradients which are common in the lower atmosphere. This can cause a great variability in the RO near the surface. So something more long-winded and more specific could be useful.

A bit of an aside but it is with regard to the quite striking improvement shown for Figure 2 (and note that the text on page 7624 never states what level this RMSE is from, though the figure caption does). I wonder since what was assimilated were temperature and moisture profiles from a 1D-Var retrieval using ECMWF a priori. Would the results be drastically different if ECMWF profiles were assimilated at the occultation locations? A better proxy for GRAPES-Var may be to do a 1D-Var retrieval with the NWP model in GRAPES as a priori instead. This is out of the context of the study, but I just think since the a priori is from a different model, many will consider that there is a lot of information coming from that external model into GRAPES, and less from the GNSS-RO which was really the point.

I was also surprised to see in Figure 3 that the observation counts in the vertical (which are not labeled or referred to), dropped in the region of greatest sensitivity $\sim$10km-24km. Is this due to the observation error specification, which is then causing rejects

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due to the innovation vector exceeding four times the observation error? This is a very peculiar behavior as I believe most systems show the peak in the observation counts in this area.

Lastly, in the second paragraph of the Summary section on page 7628, it was a bit ambiguous what was meant by the "sparseness" of radiance data. Do you mean the radiance data have broad vertical sensitivities as compared to GPS-RO? Because the hyperspectral IR sounders do have sensitivity through the depth of the GNSS-RO vertical coverage, and the MW sounders also cover this area and have sensitivity much higher, with some with sensitivity up to 90km. What has been shown and is critical is the complementary nature of the GNSS-RO and the radiance observations. As radiances require bias correction, GNSS-RO can help to "anchor" these biases. Further these radiance observations now "anchored" by GNSS-RO indirectly spread this information with better horizontal resolution. Lastly, radiance observations are not blind to model temperature biases which lie along an atmosphere in which the mass is exponentially decaying.

Some suggestions for corrections and typos:

Page 7616, line 16: . . . system with an emphasis on the direct . . .

Page 7616, line 17: . . . semi-implicit semi-Lagrangian . . . grid point model . . .

Page 7616, line 20: . . . in a high performance . . .

Page 7616, line 21: . . . The development of GRAPES . . . system (referred to . . .

Page 7617, line 26: . . . is a three dimensional variational assimilation . . . four dimensional variational system . . .

Page 7618 line 7: The RO measurements undergo .... stages when moving from the . . . , to bending angle, to refractivity and to the retrieval. . .., any of which can then be assimilated.

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Page 7618 line 17: However, these assimilated data . . . and due to the longer processing path contain the most approximation . . ..

Page 7618 line 19: . . . propagation of the observation error is more complex when using the retrievals.

Page 7625 line 16: . . . is significantly reduced from that of the . . ..

Page 7626 line 9: . . . tropical region, an observation providing information on the mass fields will not . . .

Page 7626 line 12: . . . available, the reduction of model bias and the . . .

Page 7627 line 1: . . . rather we would like to test the . . .

Page 7627 line 2: . . . cycling system can run stably without . . .

Page 7627 line 11: . . .. The RMSE of geopotential height increases 10 times from 30 meters . . . to 300 meters . . .

Page 7628 line 2: and the GPS, GLONASS and Galileo navigation satellite systems . . .

Page 7633 Fig 2 caption: . . . GRAPES and NCEP analyses . . .

Page 7634 Fig 3 caption: The observation counts are now in the figure but are not labeled or mentioned in the caption or the text.

Page 7637 Fig 6 caption: RMSE of geopotential . . .

Interactive comment on Atmos. Meas. Tech. Discuss., 7, 7613, 2014.