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Atmospheric Measurement Techniques Discussions

Interactive comment on "Tropospheric dry layers in the TropicalWestern Pacific: Comparisons of GPS radio occultation with multiple data sets" *by* Therese Rieckh et al.

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We thank the anonymous referee for the review and the helpful and constructive comments. We will implement the following changes according to the referee's suggestions. We have answered all comments below (for easier comparison the referee comments are included in italic).

Page 2, lines 2-3: In my opinion there is no doubt in the literature that super-refraction conditions do exist. I therefore recommend to reformulate: "if super-refraction conditions exist" → "under super-refraction conditions".
Thank you, we corrected the sentence to make a clearer statement.

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Section 2.2 ("The CONTRAST experiment"): For the reader's sake, there should be a very brief explanation of the sensors used for the aircraft observations, in particular the derivation of water vapor pressure, as this is a central quantity in this study. The Pan et al. paper has no full reference and could not be found.
We added the complete Pan et al. (2016) reference (see below) and the following paragraphs:

"Water Vapor was measured by the Vertical Cavity Surface Emitting Laser (VCSEL) hygrometer (absolute concentration of water vapor in molecules per cubic cm). It is designed to work throughout the troposphere (and also the lower stratosphere), and has an accuracy of $\pm 6\,\%$ mixing ratio +0.3 ppmv and a precision of $\leq 3\,\%$ (see Zondlo et al. (2010) for details). Temperature was measured by two Harco heated total air temperature sensors (estimated accuracy: $0.5\,°$C, precision: $< 0.01\,°$C), pressure was measured using the Parascientific Sensor, Model 1000 transducer (accuracy: 0.1 hPa, precision: <0.01 hPa)[1]. From the CONTRAST netcdf files, the variables used for T, e, and p are ATX, EW_VXL, and PSXC."

Section 2.3 ("ERA-Interim Reanalysis") and section 2.4: The ERA-Interim dataset is available on the original 60 model levels, as well as interpolated to a predefined set of (coarser) pressure levels. It appears that the limited vertical resolution of the latter is visible in some figures (e.g. fig. 2 and 3). The same may apply to GFS model versus pressure-level data. Models do certainly suffer from too strong numerical diffusion. Nevertheless, did the authors verify that their use of pressure-level instead of model-level data does not have any impact on the comparisons in sections 3 and 4?
Since both reviewers commented on the vertical resolution of ERA and GFS, we provide a response here adressing all concerns of both reviewers:

[1] https://www2.acom.ucar.edu/sites/default/files/seac4rs/StateParameters.pdf

Vertical profiles from the ERA and GFS analyses interpolated to RO locations are provided by COSMIC CDAAC for pressure levels (while the RO physical profiles are given on a 100 m grid). GFS is given on the following pressure levels: from 1000 hPa to 250 hPa every 50 hPa, and additionally on 975 hPa and 925 hPa (plus additional levels above 250 hPa which are not relevant here). ERA is given on the following pressure levels: from 1000 hPa to 750 hPa at 25 hPa steps, and from 750 hPa to 250 hPa at 50 hPa steps (plus additional levels above 250 hPa which are not relevant here). Assuming a scale height of 8 km, this yields a total of 18 levels for ERA and 15 levels for GFS where RO provides reliable moisture information (below 8 km, about 375 hPa). There are 80 RO levels between the surface and 8 km. Thus the vertical resolution of the ERA and GFS analyses provided by CDAAC is much lower than that of the RO observations.

CDAAC does not provide RO-collocated model profiles on model levels. Thus we downloaded an example day of the ERA fields for both pressure and model levels and converted model levels to pressure levels ourselves. Assuming a scale height of about 8 km, ERA provides 18 pressure levels below 8 km (corresponding to about 375 hPa) and 25 model levels. A few of these extra model levels are at very low altitudes (near the surface, at altitudes with pressure greater than 1000 hPa, which is the lowest given pressure level for ERA on a pressure grid). Consequently, this leaves only a few more extra model levels that would increase the vertical resolution when compared to pressure levels.

Assuming again a scale height of 8 km, a pressure of 750 hPa corresponds to 2.4 km. This yields 8 pressure levels for GFS and 11 pressure levels for the ERA between 1000 hPa and 750 hPa (surface to 2.4 km). The vertical separation between levels increases further when going to higher altitudes. The smoothness (lack of vertical detail) of the GFS and ERA profiles compared to the RO and CONTRAST profiles is an indication of the lower vertical resolution of these models compared to RO and CONTRAST. The important point is that the overall shape of the GFS and ERA profiles

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is similar to the overall shape of the higher-resolution profiles (RO and CONTRAST). Other factors such as model physics or limited observations could not increase the vertical resolution of the GFS and ERA profiles, but they could change the overall shape.

The bottom line: increasing the vertical resolution of the GFS and ERA profiles by adding a few more levels in the vertical would not change the overall shape nor the conclusions. We are confident in our comments on P6 L18 and P10 L8 that the less sharp vertical gradients in moisture at the top of the moist layers in the model analyses are "partly due to lower vertical resolution".

Page 12, figure 5: the caption should refer to the (central) wavelengths of the MTSAT-2 IR channel used here (10.8 μm and 6.75 μm).
We added the wavelengths of the used MTSAT-2 channels to the figure caption.

Section 5: given the scatter plots in fig. 7, the authors should have noticed that the models appear to simulate very dry situations with comparable frequencies, while the aircraft data tend to show very dry situations with a significantly higher frequency. The "RO relative humidity vs. CONTRAST" in fig. 6 (bottom-right) shows a similar pattern. I do not assume that the authors could explain the reason for these (common) features, but they should at least mention this apparent discrepancy.
Section 5, Fig.7: We changed the discussion about RH in Figs. 6 and 7 on page 12 lines 16-17 to:

"RH plots (bottom right) are highly scattered and have a lower correlation coefficient of around 0.78 with a bias and large spread in the data sets. The moist bias of RO for very dry air was already noted in the paragraph above. Thus CONTRAST shows a much higher frequency of very low RH values than both RO (Fig. 6 lower right) and ERA (Fig. 7, left). The large spread can be explained by several factors: 1) RH is sensitive to both small variations in T and q, thus representativeness differences or errors of both T and q contribute to differences in RH; 2) RH does not have a vertical profile with a mean structural or climatological variation in the vertical as N, T, q do (with an overall decrease with altitude); and 3) RH can undergo extremely strong changes in the vertical..”

We added the following paragraph to the discussion of q (page 12, line 15):

“Because of the highly accurate aircraft water vapor and temperature measurements and the very small scale of the observation (essentially a point observation), the CONTRAST measurements are capable of detecting extremes of dry and moist air more frequently than RO observations or model estimates, whose data represent averages over larger scales.”

Page 13, figure 6: given the distribution of points in the scatter plots, and that refractivity primarily depends on density resp. pressure, did the authors consider to use a logarithmic scale for refractivity?

We have also made the same plot using logarithmic scales, but because N has much less variability than q, using logarithmic scales does not reveal any additional features.

Section 7, conclusion 7: “When compared to CONTRAST, RO has a moist bias for low humidity values, and a dry bias for high humidity values”. While this may be true for low humidity values, I am less convinced by the results from section 5 that this is true for high humidity values, as the correlation fit is assumed to be valid for the full (log-scale) humidity range. Restricting the fit to e.g. the range $q < 1$ g/kg, there appears to be only a small bias.

The dry bias is difficult to see in Fig. 6 lower left, but it is there. Plotting on a linear-linear scale rather than log-log scale clearly shows a dry bias of RO for higher humidity values (see Fig. 1).

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Fig. 1. Same as Fig. 6 lower left in the manuscript, but plotted on a linear-linear scale.

Technical corrections: Page 4, lines 6-7: The official spelling is "Metop", not "METOP". See EUMETSAT's web site or the WMO OSCAR database. Similarly "TerraSAR-X", not "TerrSarX".

Thank you, we corrected the spelling of Metop and TerraSAR-X.

References: Pan et al.: journal reference? Randel et al.: more details needed (journal ref)

Pan et al.: journal reference: BAMS, included now; Randel et al.: journal reference: JGR, included now.

References

Pan, L. L., Atlas, E. L., Salawitch, R. J., Honomichl, S. B., Bresch, J. F., Randel, W. J., Apel, E. C., Hornbrook, R. S., Weinheimer, A. J., Anderson, D. C., Andrews, S. J., Baidar, S., Beaton, S. P., Campos, T. L., Carpenter, L. J., Chen, D., Dix, B., Donets, V., Hall, S. R., Hanisco, T. F., Homeyer, C. R., Huey, L. G., Jensen, J. B., Kaser, L., Kinnison, D. E., Koenig, T. K., Lamarque, J.-F., Liu, C., Luo, J., Luo, Z. J., Montzka, D. D., Nicely, J. M., Pierce, R. B., Riemer, D. D., Robinson, T., Romashkin, P., Saiz-Lopez, A., Schauffler, S., Shieh, O., Stell, M. H., Vaughan, G., Ullmann, K., Volkamer, R., and Wolfe, G.: The Convective Transport of Active Species in the Tropics (CONTRAST) Experiment, BAMS (in press), 2016.

Randel, W. J., Rivoire, L., Pan, L., and Honomichl, S.: Dry layers in the tropical troposphere observed during CONTRAST and global behavior from GFS analyses, JGR, submitted, 2016.

Zondlo, M. A., Paige, M. E., Massick, S. M., and Silver, J. A.: Vertical cavity laser hygrometer for the National Science Foundation Gulfstream-V aircraft, J. Geophys. Res., 115, 2010.

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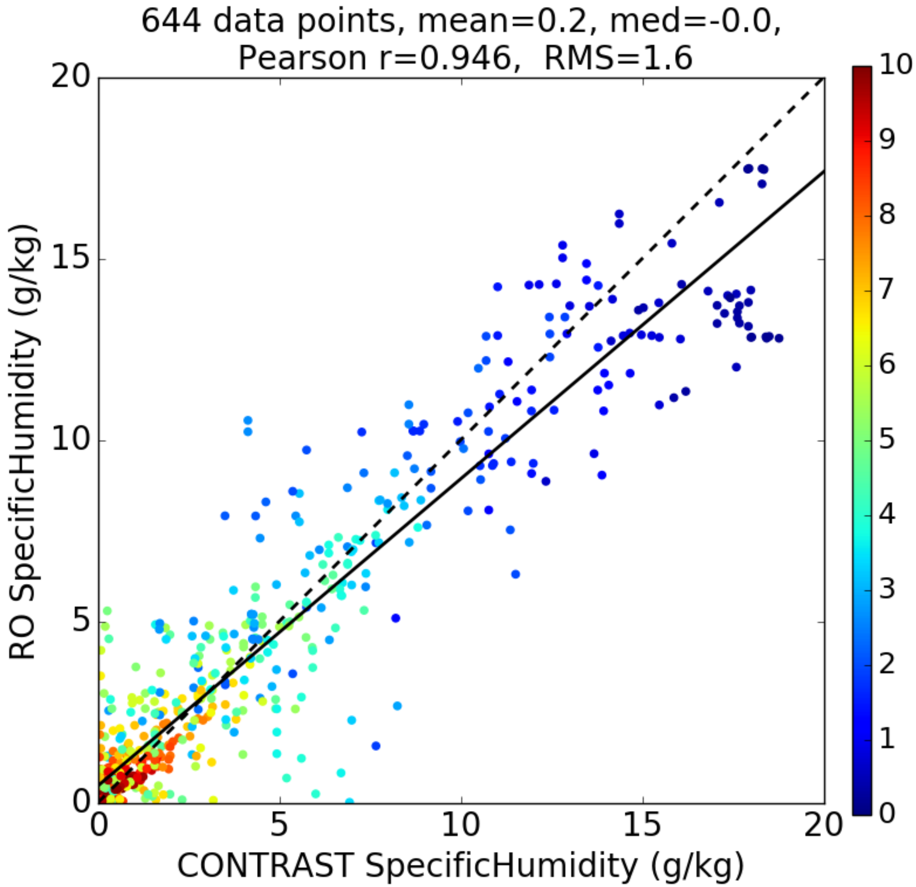
644 data points, mean=0.2, med=-0.0,
Pearson r=0.946, RMS=1.6
RO SpecificHumidity (g/kg)
CONTRAST SpecificHumidity (g/kg)
0
5
10
15
20
0
5
10
15
20
0
1
2
3
4
5
6
7
8
9
10

Fig. 2.