Comparisons of Ozone Distributions Using CONTRAST Data, MERRA-2, and ERA-Interim Reanalysis Simulations

Kathryn Steinmann and Minghui Diao
Department of Meteorology and Climate Science, San Jose State University

1. INTRODUCTION

Important for atmospheric chemistry, ozone (O_3) is observed throughout the troposphere and stratosphere. Understanding O_3 trends will provide better representation in model simulations (Pan *et al.* 2015). One such simulation is reanalysis, where observations from the ground and satellites are combined with general circulation model simulations (Wargan *et al.* 2017). Due to the lack of validation for O_3 in reanalysis simulations, scientists use other simulation types for O_3 data (Wargan *et al.* 2017).

2. MOTIVATION

Previous studies have found positive correlations between high O_3 concentrations and low water vapor mixing rations (i.e. Fueglistaler *et al.* 2009). A recent study by Pan *et al.* (2015) found a bimodal distribution of O_3 concentration in the Tropical Western Pacific. The two modes were observed at O_3 concentrations of 20 ppbv and 60 ppbv. The study then restricted relative humidity (RH) to between 45% and 100%. When this was done, only the 20 ppbv mode was observed.

3. OBJECTIVE

This study will use data from the 2014 NSF Convective Transport of Active Species in the Tropics (CONTRAST) campaign to compare with reanalysis data.

4. DATA

In-situ data used in this study are from the CONTRAST campaign, which were collected using the NSF/NCAR Gulfstream-V (GV) research aircraft. Two simulations were used for the reanalysis data; the Modern-Era Retrospective Analysis for Research and Applications version 2 (MERRA-2) from NASA's Global Modeling and Assimilations Office, and ERA-Interim from the European Centre for Medium-Range Weather Forecasts (ECMWF).

5. EXPERIMENTAL DESIGN

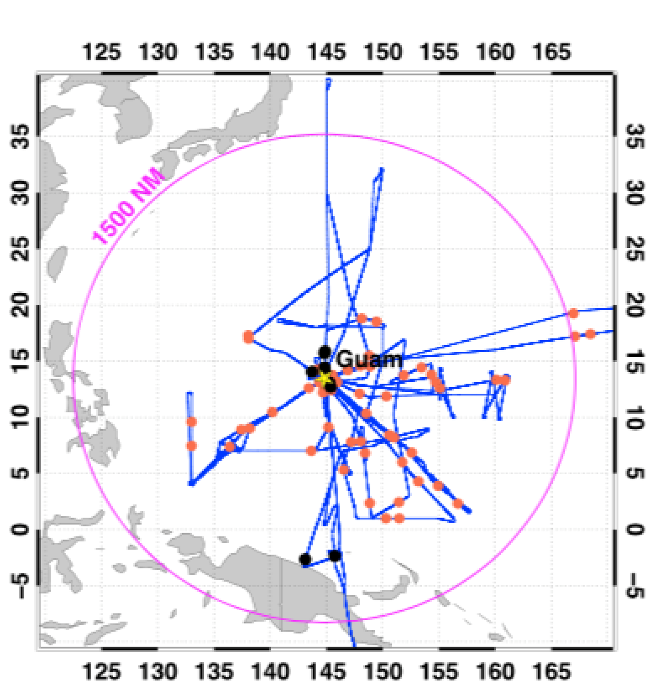

Figure 1. Map of the GV flight paths during the CONTRAST campaign. Adapted from Pan *et al.* (2015).

In order to compare the in-situ data and the reanalysis data, longitude and latitude were restricted to 130°E to 160°E and 0°N to 20°N, respectively. Pressure was also restricted to between 150 hPa and 1000 hPa. Frequency plots, layer normalized frequency plots, and vertical profiles of ozone concentration will be examined for the CONTRAST, MERRA-2, and ERA-Interim data.

5. Frequency Distribution

Frequency distributions of ozone concentration for CONTRAST, MERRA-2, and ERA-Interim are shown in Figures 2a, b, and c, respectively. Both the MERRA-2 and ERA-Interim distributions show less variability than the CONTRAST distribution. Similar to the findings of Pan *et al.* (2015), a bimodal distribution of ozone concentration is observed for the CONTRAST data (Fig. 2a). The primary mode is observed around 20 ppbv, while the secondary mode is observed around 60 ppbv. Both reanalysis simulations show a bimodal distribution, but the modes differ from the in-situ data. The primary mode for the MERRA-2 reanalysis data (Fig. 2b) is found to be around 33 ppbv and the secondary mode is found to be around 44 ppbv, while the ERA-Interim reanalysis data (Fig. 2c) shows the primary and secondary modes to be found around 36 ppbv and 44 ppbv, respectively.

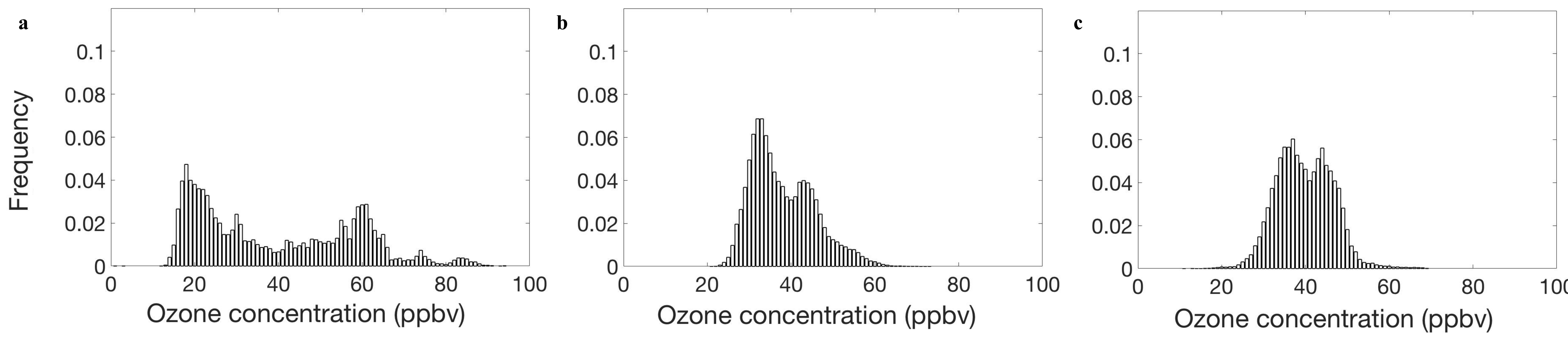

Figure 2. Frequency distributions of O_3 concentration for the CONTRAST data (a), the MERRA-2 reanalysis simulation (b), and the ERA-Interim reanalysis simulation (c). Following the work of Pan *et al.* (2015), potential temperature is restricted to between 320K and 340K. O_3 is binned by 2 ppbv.

Figure 3 is the same as Figure 2 expect RH is restricted to above 45%, as shown in Pan *et al.* (2015). Both of the reanalysis simulations (Fig. 3b and Fig. 3c) show less variability in O_3 concentration than compared to the CONTRAST distribution, similar to Figure 2. All three distributions show a uni-modal O_3 distribution. An O_3 concentration mode around 18 ppbv was observed in the CONTRAST data (Fig. 3a), where as the reanalysis simulations show modes in the thirties. All three distributions did not show the secondary mode when RH was restricted.

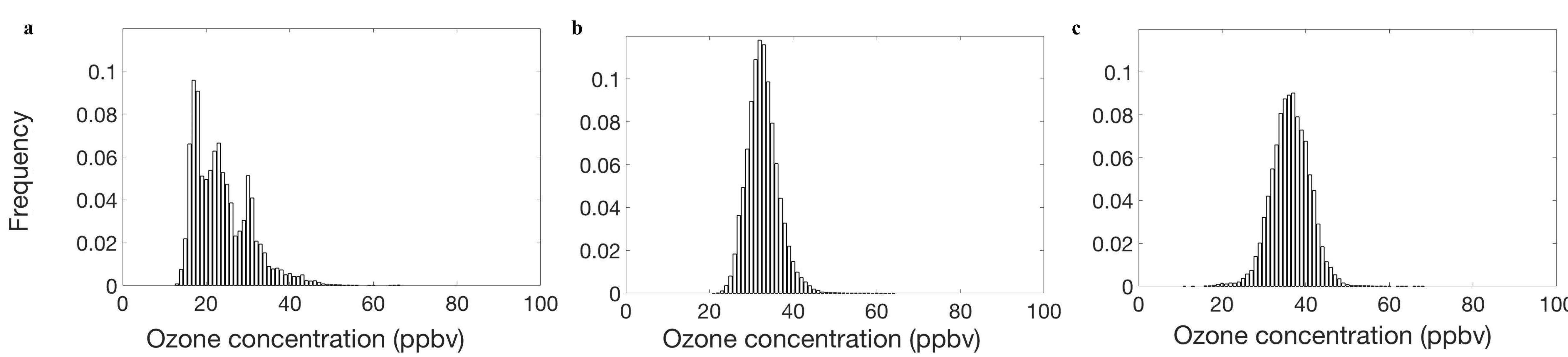

Figure 3. Frequency distributions of O_3 concentrations for the CONTRAST data (a) ,the MERRA-2 reanalysis simulation (b), and the ERA-Interim reanalysis simulation (c). Potential temperature is restricted to between 320K and 340K. RH is restricted to above 45%. O_3 is binned by 2 ppbv.

6. O_3 Vertical Distribution

O_3 vertical profiles are shown in Figure 4. Between 300 hPa and 800 hPa, the CONTRAST profile (Fig 4a) shows more variability than the MERRA-2 and ERA-Interim reanalysis profiles (Fig. 4b and Fig. 4c, respectively). The reanalysis simulations overestimates the average O_3 concentration at the 1000 hPa and 150 hPa pressure levels. In contrast, the reanalysis simulations underestimates the average O_3 concentration at 500 hPa. Between 150 hPa and 500 hPa, a decrease in O_3 concentration with height is observed. This decrease with height was not found in the ERA-Interim reanalysis profile.

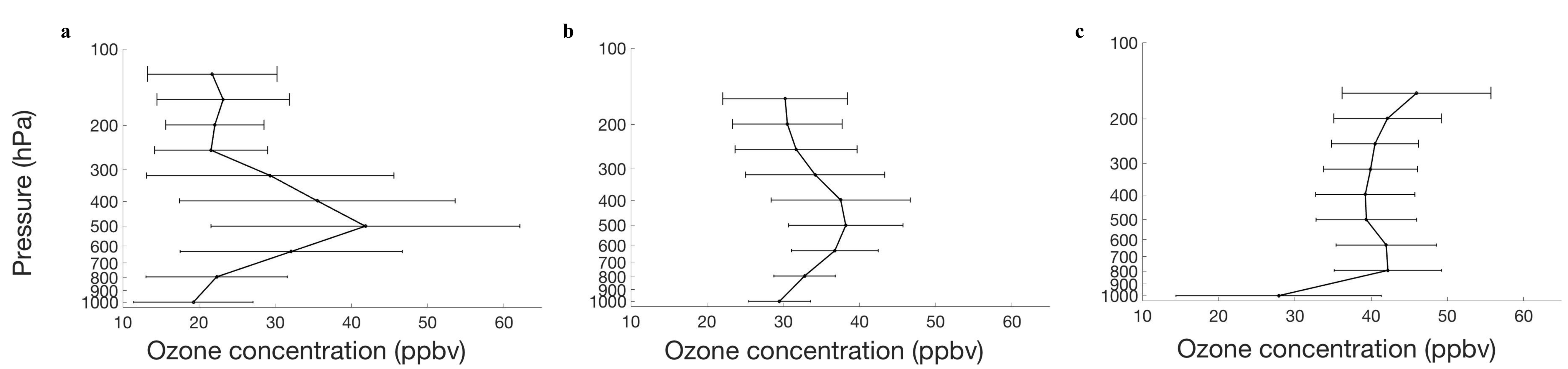

Figure 4. Vertical profiles of O_3 concentrations for the CONTRAST data (a), the MERRA-2 reanalysis simulation (b), and the ERA-Interim reanalysis simulations (c). O_3 is binned by 0.1 Log_{10}hPa. Standard deviation is shown in the horizontal error bars.

7. O_3 and RH

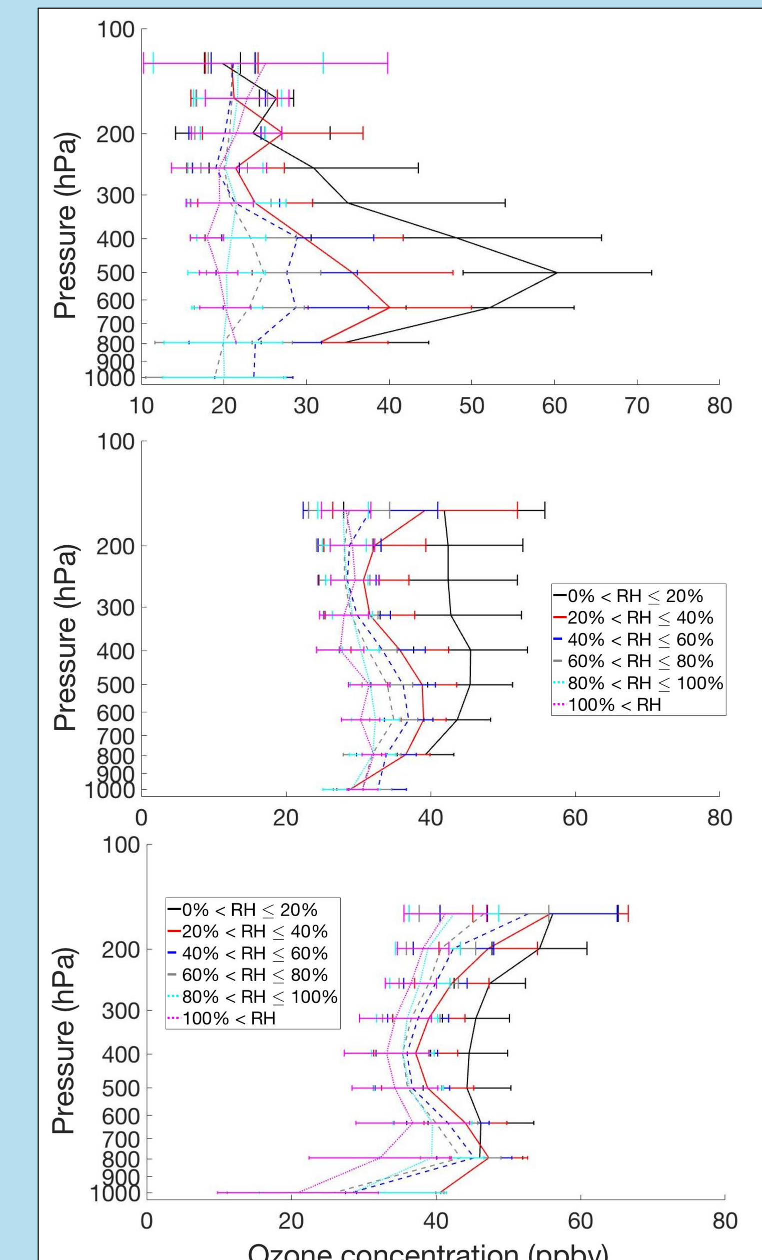

Figure 5. Vertical profiles of O_3 concentration separated into different RH ranges (0% < RH ≤ 20%, 20% < RH ≤ 40%, 40% < RH ≤ 60%, 460% < RH ≤ 80%, 80% < RH ≤ 100%, and 100% < RH) for the CONTRAST data (a), the MERRA-2 reanalysis simulation (b), and the ERA-Interim reanalysis simulation (c). O_3 is binned by 0.1 Log_{10}hPa. The horizontal error bars represent the standard deviation.

Similar to Figure 4, Figure 5 shows O_3 vertical profiles separated by RH. When RH > 40%, the reanalysis simulations (Fig. 5b and Fig. 5c) overestimates the maximum average O_3 concentrations, while they underestimates the maximum average O_3 concentrations when RH ≤ 40%, compared to the in-situ data (Fig. 5a).

8. CONCLUSIONS

-Frequency distributions of the reanalysis simulations show a bimodal distribution of O_3 concentration for all RH, similar to the in-situ data
-The reanalysis simulations overestimates the primary mode and underestimates the secondary mode.
-When RH > 45%, the frequency distributions of the reanalysis simulations show a uni-modal distribution of O_3 distributions, similar to the in-situ data, which was also found in Figure 5.
-Vertical profiles show that the MERRA-2 simulation follows the shape of the in-situ data and the ERA-Interim simulation over estimates the average O_3 concentrations above 300 hPa.

9. REFERENCES

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Pan, L.L., *et al.*, 2015: Bimodal distribution of tropospheric ozone over the tropical western pacific revealed by airborne observations. *Geophys. Res. Lett.* **42**. 7844 – 7851.
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