TAbMEP Assessment: ICARTT O_3 Measurements

1. Introduction

Here we provide the assessment for the ozone (O_3) measurements taken from four aircraft platforms during the summer 2004 ICARTT field campaign [*Fehsenfeld et al.*, 2006, *Singh et al.*, 2006]. This assessment is based upon the five wing-tip-to-wing-tip intercomparison flights conducted during the field campaign. Recommendations provided here offer TAbMEP assessed uncertainties for each of the measurements and a systematic approach to unifying the ICARTT O_3 data for any integrated analysis. These recommendations are directly derived from the instrument performance demonstrated during the ICARTT measurement comparison exercises and are not to be extrapolated beyond this campaign.

2. ICARTT O_3 Measurements

Four different O_3 instruments were deployed on the four aircraft. Table 1 summarizes these techniques and gives references for more information.

Table 1. O_3 measurements deployed on aircraft during ICARTT

Aircraft	Instrument	Reference
NASA DC-8	NO Chemiluminescence Detector (NO CLD)	*Fairlie et. al.* [2007]
NOAA WP-3D	NO CLD	*Ryerson et al.* [1998]
FAAM BAe-146	TECO 49 UV photometric (TECO UVP)	Not available
DLR Falcon	TECO UVP	Not available

3. Summary of Results

Table 2 summarizes the assessed 2σ precisions, biases, and uncertainties. More detailed descriptions are provided to illustrate the process for assessment of bias and precision in Sections 4.1 and 4.2 respectively. The assessed 2σ precisions reported in Table 2 are equal to twice the highest adjusted precision value for that instrument listed in Table 4. Table 2 also reports an assessed bias (see Section 4.1 for details) that can be applied to maximize the consistency between the data sets. The assessed bias should be subtracted from the reported data to 'unify' the data sets. The assessed bias is derived from intercomparison periods only and may be extrapolated to the entire mission if one assumes instrument performance remained constant throughout the mission. The recommended 2σ uncertainty is the larger of either the uncertainty reported by the PI or the quadrature-sum of the assessed 2σ precision and assessed bias listed in Table 2.

Table 2. Recommended ICARTT O_3 measurement treatment

Aircraft/ Instrument	Reported 2σ Uncertainty	Assessed 2σ Precision	Assessed Bias	Recommended 2σ Uncertainty[a]
NASA DC-8 NO CLD	3% or 3 ppbv	5.6%	$1.26 - 0.029\ O_{3\text{-DC8}}$	3 ppbv or Quadrature Sum[b]
NOAA WP-3D NO CLD	0.1 ppbv + 3%	4.2%	$-0.37 - 0.008\ O_{3\text{-WP3D}}$	Quadrature Sum
FAAM BAe-146 TECO UVP	None	6.4%	$-2.12 + 0.047\ O_{3\text{-BAe146}}$	Quadrature Sum
DLR Falcon TECO UVP	5%	4.0%	$-0.83 + 0.035\ O_{3\text{-Falcon}}$	2 ppbv[c] or 5%

[a] Recommendations based on test ranging from 10 to 100 ppbv.
[b] Recommended 2σ uncertainty is 3ppbv for $O_{3\text{-DC8}} < 56$ ppbv.
[c] Derived from absolute precision IEIP analysis.

Figures 1a-1c display the precisions, biases, and recommended uncertainties for the four O_3 instruments. Except for low O_3 values measured by the TECO UVP aboard the Falcon (and to a lesser extent the NO CLD aboard the DC-8), the uncertainty is driven by the precision.

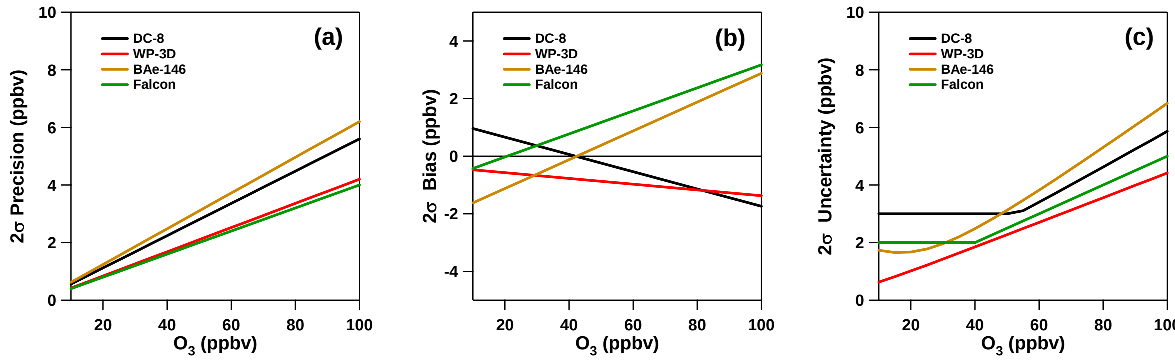

Figure 1. 2σ precision (panel a), 2σ bias (panel b), and 2σ uncertainty (panel c) for DC-8 (black), WP-3D (red), BAe-146 (gold), and Falcon (green) as a function of O_3 level. Values were calculated based upon data shown in Table 2.

4. Results and Discussion

4.1 Bias Analysis

Section 3.3 in the introduction describes the process used to determine the best estimate bias. Figure 2 shows the correlation and time series plots for each of the three WP-3D vs. DC-8 comparisons. The linear relationships listed in Table 3 were derived from the regression equations found in Figures 3 through 5. In the case of ozone, the regression equations for the NOAA WP-3D, FAAM BAe-146, and DLR Falcon are manipulated algebraically to be expressed as a function of $O_{3\text{-DC8}}$ shown in Table 3. The reference standard for comparison (RSC), as defined in the introduction, is constructed by averaging the NOAA WP-3D and NASA DC-8 and DLR Falcon measurements, as they are best maintained and calibrated instruments. The BAe-146 is not included in constructing RSC since the instrument calibration record is incomplete. The resulting RSC can be expressed as a function of the DC-8 O_3 measurement as the following:

$$RSC_{O3} = -1.26 + 1.029\ O_{3\text{-DC8}}$$

The RSC is then used to calculate the best estimate bias as described in Section 3.3 of the introduction. It should be noted that the initial choice of the reference instrument (DC-8 NO CLD) is arbitrary, and has no impact on the final recommendations. Table 3 summarizes the assessed measurement bias for each of the four ICARTT O_3 measurements. Note that additional decimal places were carried in the calculations to ensure better than 0.1 ppbv precision.

Table 3. ICARTT O_3 bias estimates

Aircraft/ Instrument	Linear Relationships[a]	Best Estimate Bias (a + b O_3) (ppbv)
NASA DC-8 NO CLD	$O_{3\text{-DC8}} = 0.00 + 1.00\ O_{3\text{-DC8}}$	$1.26 – 0.029\ O_{3\text{-DC8}}$
NOAA WP-3D NO CLD	$O_{3\text{-WP3D}} = -1.61 + 1.020\ O_{3\text{-DC8}}$	$-0.37 – 0.008\ O_{3\text{-WP3D}}$
FAAM BAe-146 TECO UVP	$O_{3\text{-BAe146}} = -3.54 + 1.079\ O_{3\text{-DC8}}$[b]	$-2.12 + 0.047\ O_{3\text{-BAe146}}$
DLR Falcon TECO UVP	$O_{3\text{-Falcon}} = -2.16 + 1.066\ O_{3\text{-DC8}}$	$-0.83 + 0.035\ O_{3\text{-Falcon}}$

[a]Derived from Figs. A2-A4.
[b]Not included in RSC derivation, text for details.

4.2 Precision Analysis

A detailed description of the precision assessment is given in Section 3.1 of the introduction. The IEIP precision, expected variability, observed variability, and the adjusted precision are summarized in Table 4. Based on the results presented in Table 4, the largest "adjusted precision" value is taken as a conservative precision estimate for each ICARTT O_3 instrument and twice that value is listed in Table 2 as the assessed 2σ precision.

To minimize the effect of bias, we make corrections for bias before computing the observed variability, as the bias may have a significant impact on the observed variability. Figures 6 – 8 show the magnitude of the bias for each intercomparison. The assessed values of the observed variability are displayed in Figures 9 – 11. The final analysis results are shown in Table 2. Over 90% of the data falls within the combined recommended uncertainties for each intercomparison, which is consistent with the TAbMEP guideline for unified data sets.

Table 4. ICARTT O_3 precision (1σ) comparisons

Flight	Platform	IEIP Precision	Expected Variability	Observed Variability	Adjusted Precision
07/22	DC-8	1.2%	1.8%	2.7%	1.8%
	WP-3D	1.4%			2.1%
07/31	DC-8	1.3%	1.3%	2.9%	2.3%
	WP-3D	1.0%			1.8%
08/07	DC-8	1.2%	1.6%	2.3%	1.8%
	WP-3D	1.0%			1.5%
07/28	DC-8	1.2%	1.8%	4.2%	2.8%
	BAe-146	1.4%			3.2%
08/03	BAe-146	0.9%	2.2%	2.1%	0.9%
	Falcon	2.0%			2.0%

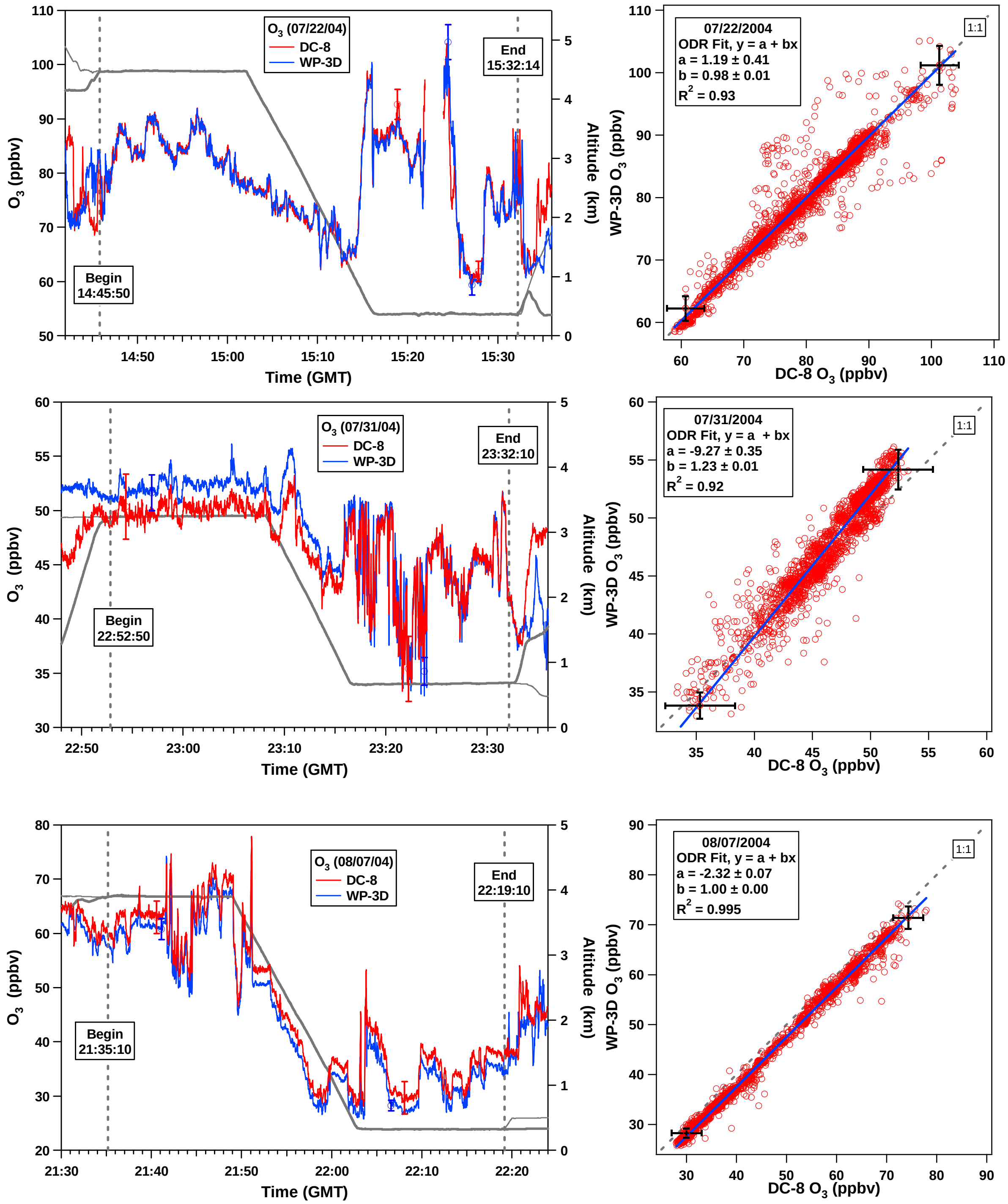

Figure 2. (left panels) Time series of O_3 measurements and aircraft altitudes from two aircraft on the three intercomparison flights between the NASA DC-8 and the NOAA WP-3D. (right panels) Correlations between the O_3 measurements on the two aircraft. Error bars shown depict the reported measurement uncertainties.

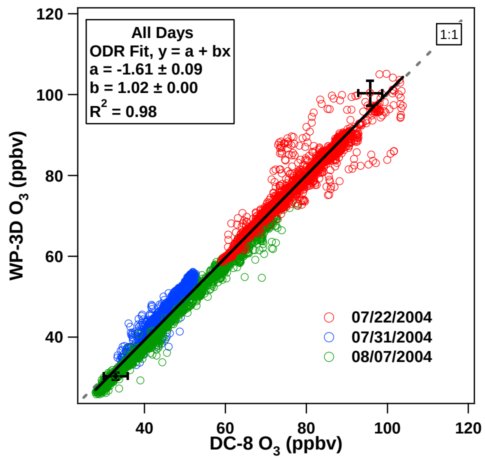

Figure 3. Correlation between the O_3 measurements on the DC-8 and WP-3D for 7/22, 7/31, and 8/7 2004. Error bars shown depict the reported measurement uncertainties.

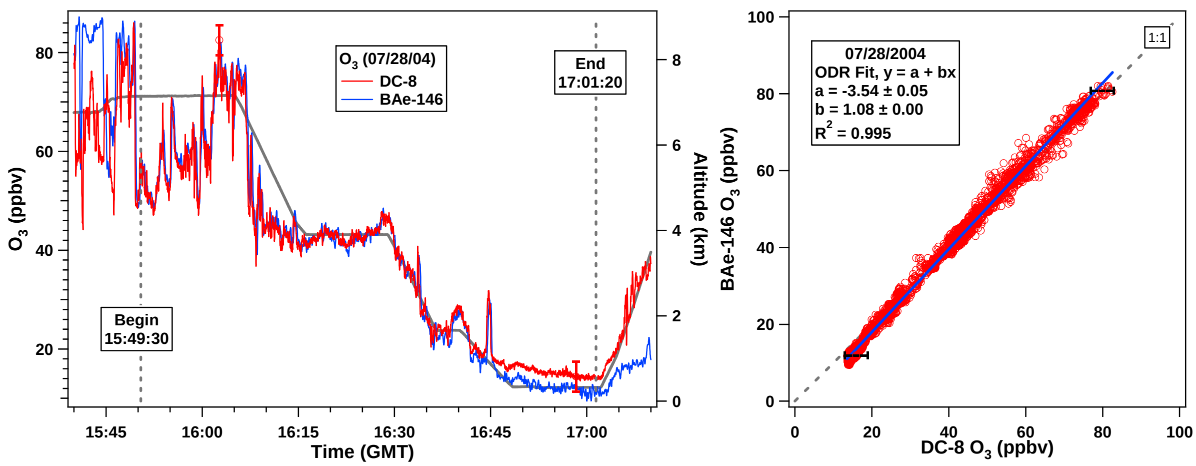

Figure 4. (left panel) Time series of O_3 measurements and aircraft altitudes from the intercomparison flight between the NASA DC-8 and the FAAM BAe-146. (right panel) Correlations between the O_3 measurements on the two aircraft. Error bars shown depict the reported measurement uncertainties.

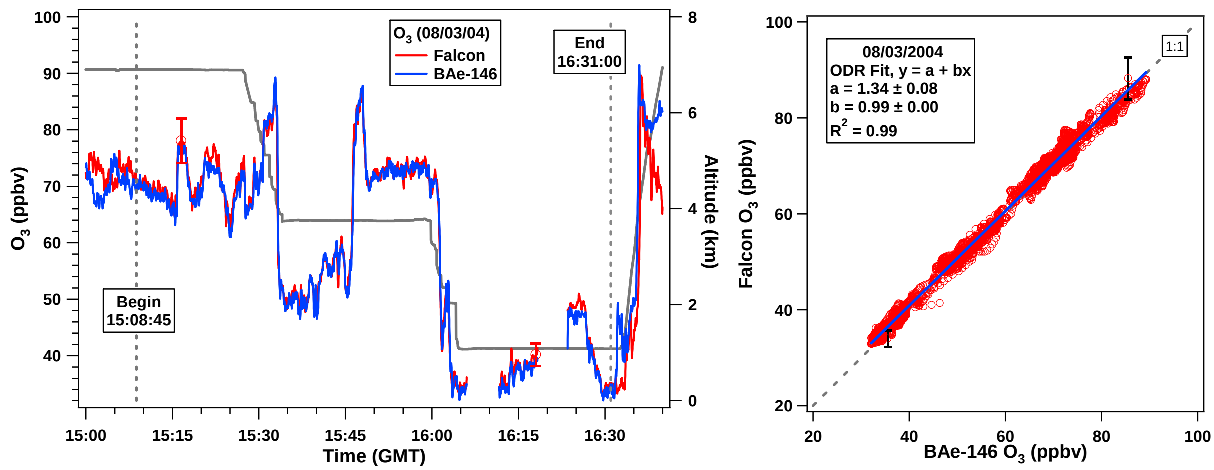

Figure 5. (left panel) Time series of O_3 measurements and aircraft altitudes from the intercomparison flight between the FAAM BAe-146 and the DLR Falcon. (right panel) Correlations between the O_3 measurements on the two aircraft. Error bars shown depict the reported measurement uncertainties.

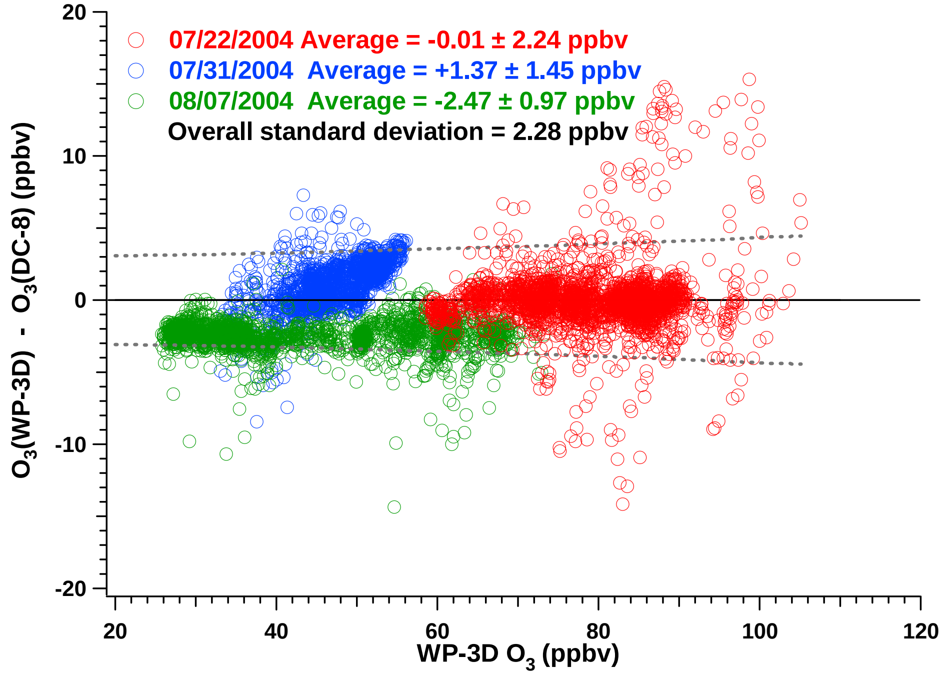

Figure 6. Difference between O_3 measurements from the three DC-8/WP-3D intercomparison flights as a function of the WP-3D O_3. The dashed lines indicate the range of the results expected from the reported 2σ measurement uncertainties.

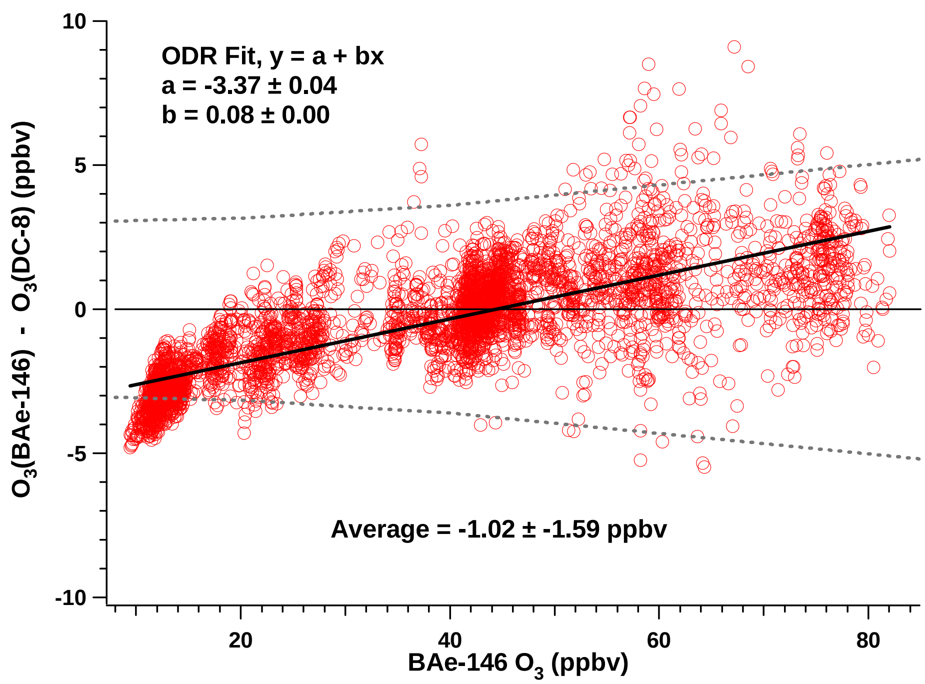

Figure 7. Difference between O_3 measurements from the DC-8/BAe-146 intercomparison flight (07/28) as a function of the BAe-146 O_3. The dashed lines indicate the range of the results expected from the reported 2σ measurement uncertainties. For the purposes of this graph, BAe-146 uncertainty was assumed to be 5% based on similar instruments.

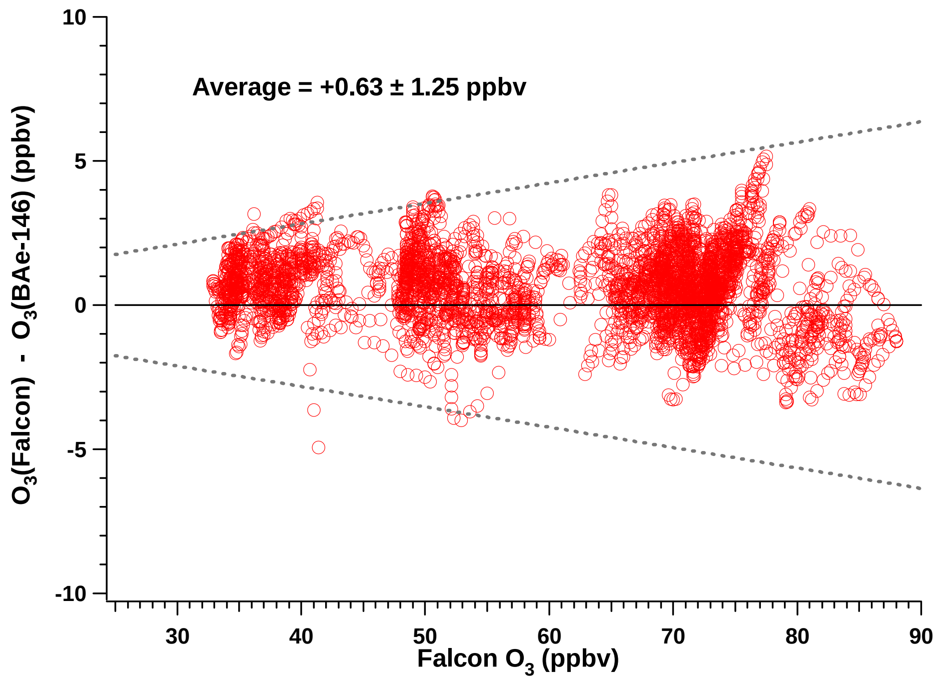

Figure 8. Difference between O_3 measurements from the BAe-146/Falcon intercomparison flight (08/03) as a function of the Falcon O_3. The dashed lines indicate the range of the results expected from the reported 2σ measurement uncertainties. For the purposes of this graph, BAe-146 uncertainty was assumed to be 5% based on similar instruments.

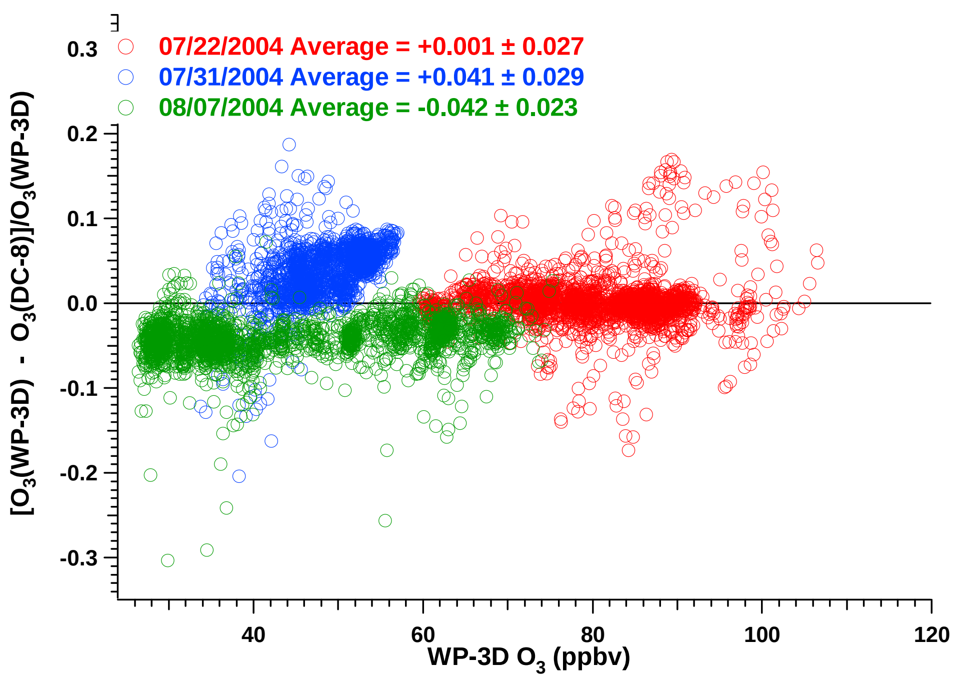

Figure 9. Relative difference between O_3 measurements from the three DC-8/WP-3D intercomparison flights as a function of the WP-3D O_3. A correction was made to account for bias.

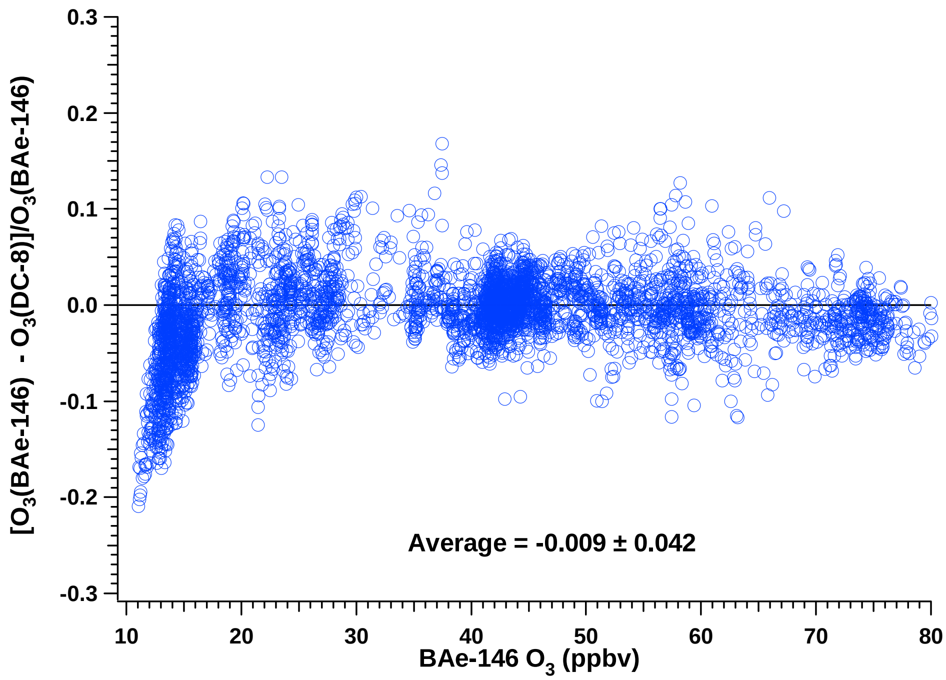

Figure 10. Relative difference between O_3 measurements from the DC-8/BAe-146 intercomparison flight (07/28) as a function of the BAe-146 O_3. A correction was made to account for bias.

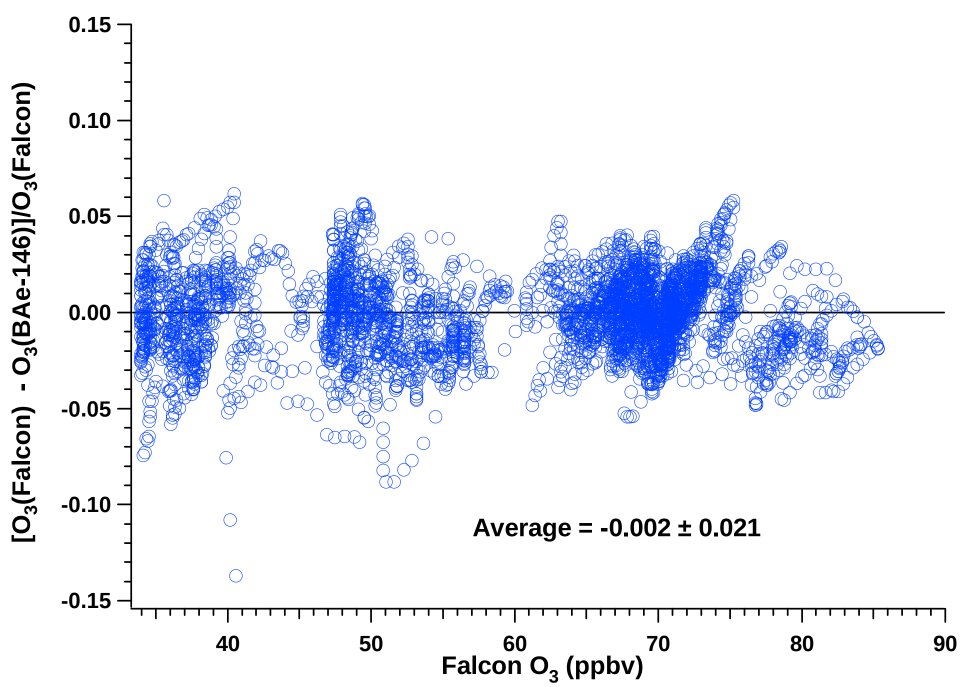

Figure 11. Relative difference between O_3 measurements from the BAe-146/Falcon intercomparison flights as a function of the Falcon O_3. A correction was made to account for bias.

References

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