TAbMEP Assessment: ICARTT NO_2 Measurements

1. Introduction

Here we provide the assessment for the nitrogen dioxide (NO_2) measurements taken from two aircraft platforms during the summer 2004 ICARTT field campaign [*Fehsenfeld et al.*, 2006, *Singh et al*., 2006]. This assessment is based upon the three wing-tip-to-wing-tip DC-8/WP-3D intercomparison flights conducted during the field campaign. Detailed analyses were not conducted on the BAe-146 data due to instrument problems during installation. Recommendations provided here offer TAbMEP assessed uncertainties for each of the measurements and a systematic approach to unifying the ICARTT NO_2 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 NO_2 Measurements

Two different NO_2 instruments were deployed on the two aircraft. Table 1 summarizes these techniques and gives references for more information.

Table 1. NO_2 measurements deployed on aircraft during ICARTT

Aircraft	Instrument	Reference
NASA DC-8	Thermal Dissociation-Laser Induced Fluorescence (TD-LIF)	*Thornton et al.* [2000]
NOAA WP-3D	UV Photolysis followed by NO chemiluminescense (P-CL)	*Ryerson et al.* [2000]

3. Summary of Results

Table 2 summarizes the assessed 2σ precisions, biases, and uncertainties for the DC-8 and WP-3D instruments for 20 second data. These assessments listed in Table 2 are only recommended for the NO_2 concentrations observed during the intercomparisons (0 – 800 pptv). For the DC-8 and WP-3D analyses, 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, which should be treated as the upper limit value. It is clearly shown in Section 4.2 that the measurement precision is a strong function of the ambient NO_2 levels and improves significantly at higher levels. The precision estimate given in Table 2 is largely driven by the data population concentrated at low NO_2 values. 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 2σ uncertainty is taken as the PI reported uncertainty because the PI uncertainty sufficiently covers all difference between the two instruments (see section 4.2). The data sets are consistent and suitable for integrated analysis. The assessed bias is well within the accuracy values reported for DC-8 and WP-3D measurements.

Table 2. Recommended ICARTT NO_2 measurement treatment

Aircraft/ Instrument	Reported 2σ Uncertainty	Assessed 2σ Precision	Assessed Bias (pptv)	Assessed 2σ Uncertainty
NASA DC-8 TD-LIF	Accuracy: 5% Point by point, average: 62%[a]	50%	$-0.52 - 0.0311\ NO_{2\text{-}DC8}$	PI uncertainty
NOAA WP-3D P-CL	Accuracy: 8% Precision: ± 40 pptv	32%	$0.49 + 0.0292\ NO_{2\text{-}WP3D}$	PI uncertainty

[a] The average encompasses only the comparison periods for the DC-8/WP-3D.

Figures 1a through 1c display the precisions, biases, and recommended uncertainties for the two NO_2 instruments. The assessed measurement biases are well within the accuracy values provided by the DC-8 and WP-3D PIs.

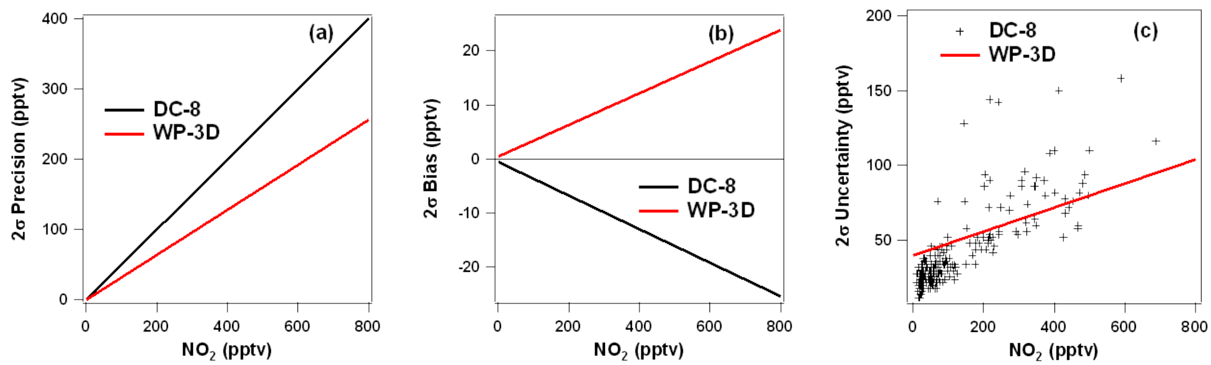

Figure 1. 2σ precision (panel a), 2σ bias (panel b), and 2σ uncertainty (panel c) for DC-8 (black) and WP-3D (red) as a function of NO_2. Values were calculated based upon data shown in Table 2. The DC-8 uncertainty is the PI reported point by point uncertainty during the DC-8/WP-3D comparison periods.

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 time series plots and correlations for each of the WP-3D vs. DC-8 comparisons. The time series plots are based on 1 second data for both the DC-8 and WP-3D, and the correlations are based on 20 second data. The PI reported 20 second DC-8 data was used and the PI reported WP-3D 1 second data was averaged into the DC-8 time intervals. The linear relationships listed in Table 3 were derived from the regression equation shown in Figure 3. The data used in Figure 3 was 20 second data. The 20 second average was chosen to minimize noise and better represent the overall trend, given that there is a substantial portion of data at very low values, i.e., <60 pptv. The reference standard for comparison (RSC), as defined in the Introduction, is constructed by averaging the NOAA WP-3D and NASA DC-8. The resulting RSC can be expressed as a function of the DC-8 NO_2 measurement as the following:

$$RSC_{NO2} = 0.52 + 1.031\ NO_{2\text{-}DC8}$$

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) is arbitrary, and has no impact on the final recommendations. Table 3 summarizes the assessed measurement bias for the WP-3D and DC-8 ICARTT NO_2 measurements. Note that additional decimal places were carried in the calculations to ensure better precision.

Table 3. ICARTT NO_2 bias estimates

Aircraft/ Instrument	Linear Relationships[a]	Best Estimate Bias (a + b NO_2) (pptv)
NASA DC-8 TD-LIF	$NO_{2\text{-DC8}} = 0.00 + 1.000\ NO_{2\text{-DC8}}$	$-0.52 – 0.031\ NO_{2\text{-DC8}}$
NOAA WP-3D P-CL	$NO_{2\text{-WP3D}} = 1.05 + 1.062\ NO_{2\text{-DC8}}$	$0.49 + 0.029\ NO_{2\text{-WP3D}}$

[a]Derived from Fig. 3.

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 NO_2 instrument and twice that value is listed in Table 2 as the assessed 2σ precision. It should be noted that IEIP is dependent on concentration and this can account for the large difference between the IEIP for the DC-8 instrument between 07/22 and 08/07. The average DC-8 concentration on 07/22 is 399 pptv, whereas the average concentration on 08/07 is 109 pptv. The aforementioned averages are for the entire flight (not just comparison periods) because IEIP is calculated for the entire flight.

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. Figure 4 shows the magnitude of the bias for each intercomparison. As shown in the figure, the residuals are well within the 2σ PI reported uncertainties. The assessed values of the observed variability are displayed in Figure 5. As can be seen in this figure, the variability is dependent on concentration. On 07/22 and 08/07 the variability is much higher because the sampling during the comparison period was at lower concentration levels, whereas 07/31 was at higher concentration levels and has a much lower variability.

The final analysis results are shown in Table 2. Well over 90% of the data falls within the combined PI reported uncertainties for each intercomparison, which is consistent with the TAbMEP guideline for unified data sets. Therefore, no change to the PI uncertainty is recommended.

Table 4. ICARTT NO_2 precision (1σ) comparisons

Flight	Platform	IEIP Precision	Expected Variability	Observed Variability	Adjusted Precision
07/22	DC-8	15%	19%	26%	21%
	WP-3D	12%			16%
07/31	DC-8	15%	19%	9%	25%
	WP-3D	12%			12%
08/07	DC-8	23%	27%	24%	23%
	WP-3D	15%			15%

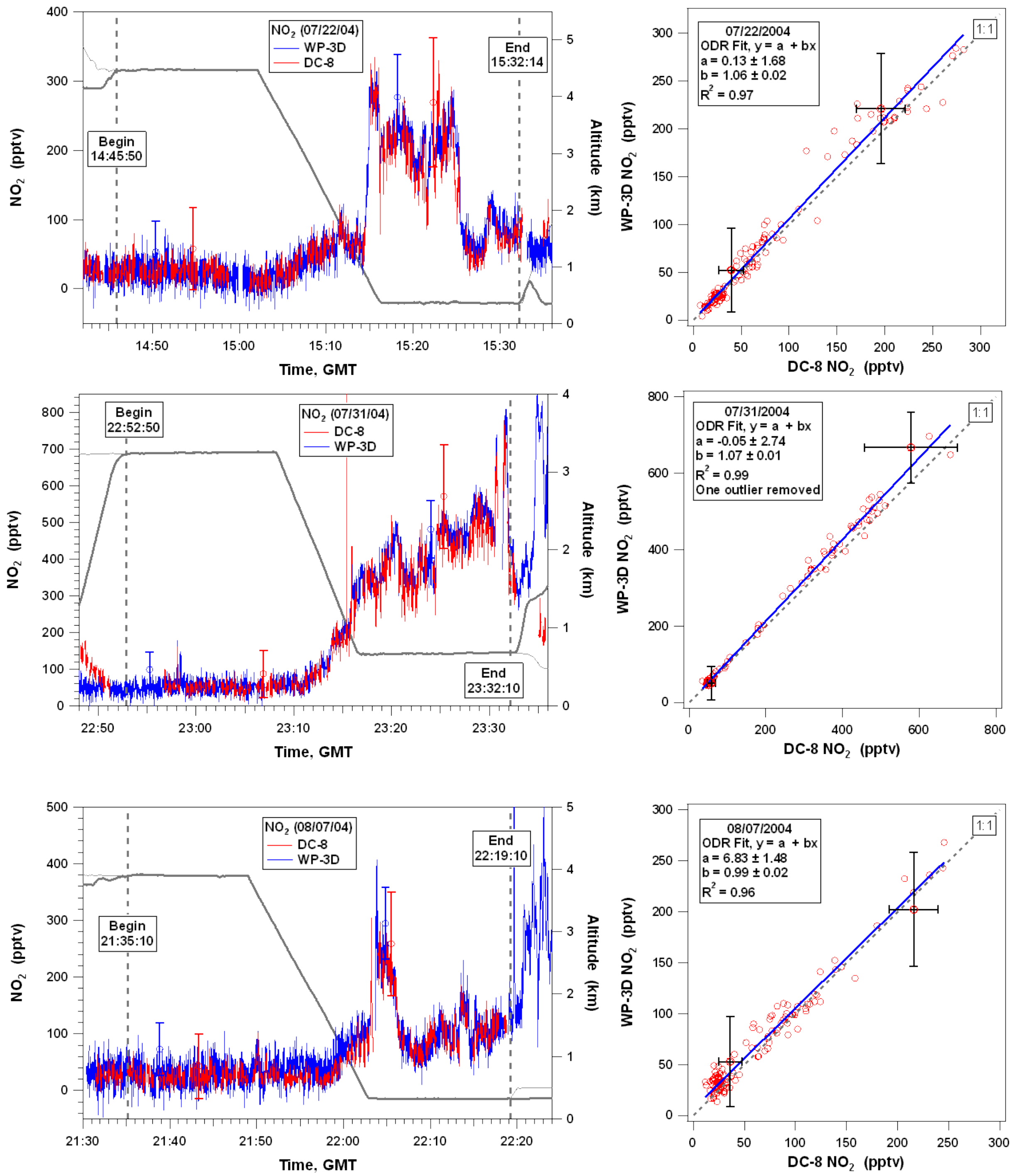

Figure 2. (left panels) Time series of NO_2 measurements and aircraft altitudes from two aircraft on the three intercomparison flights between the NASA DC-8 and the NOAA WP-3D. Note that the DC-8 and WP-3D data is 1 second in the time series plot. (right panels) Correlations between 20 second averages of the NO_2 measurements on the two aircraft. PI reported DC-8 20 second data is used in the regression figures and WP-3D 1 second data was averaged into the DC-8 time intervals.

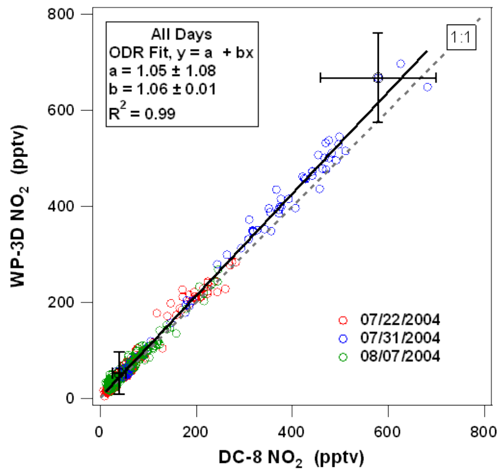

Figure 3. Correlation between 20 second averages of the NO_2 measurements on the DC-8 and WP-3D for 7/22, 7/31, and 8/7 2004.

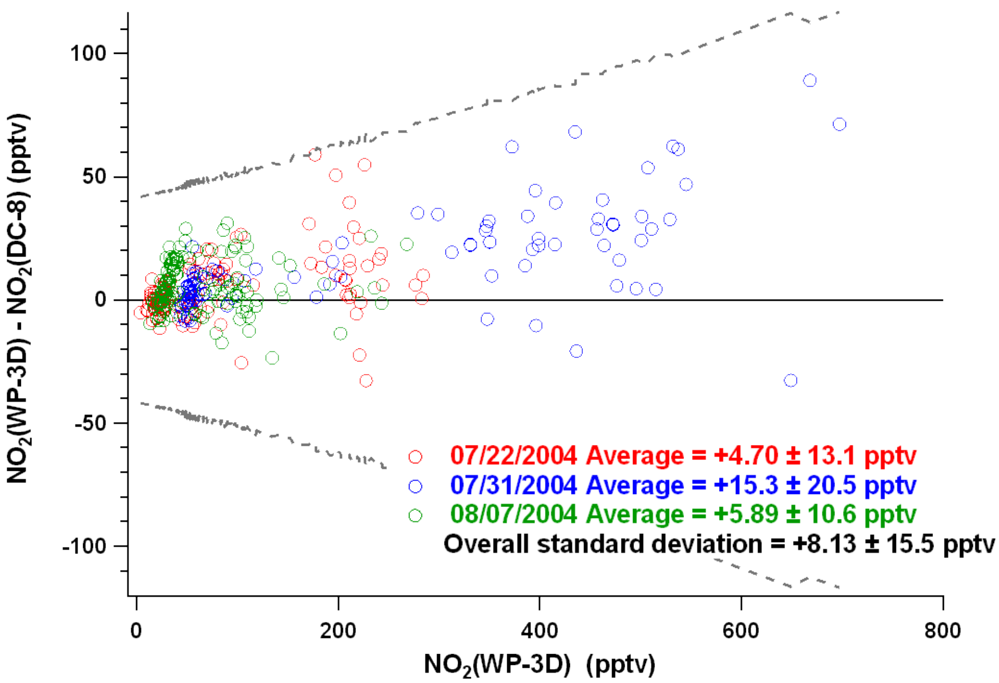

Figure 4. Difference between NO_2 measurements from the three DC-8/WP-3D intercomparison flights as a function of the WP-3D NO_2. The dashed lines indicate the range of the results expected from the reported 2σ measurement uncertainties.

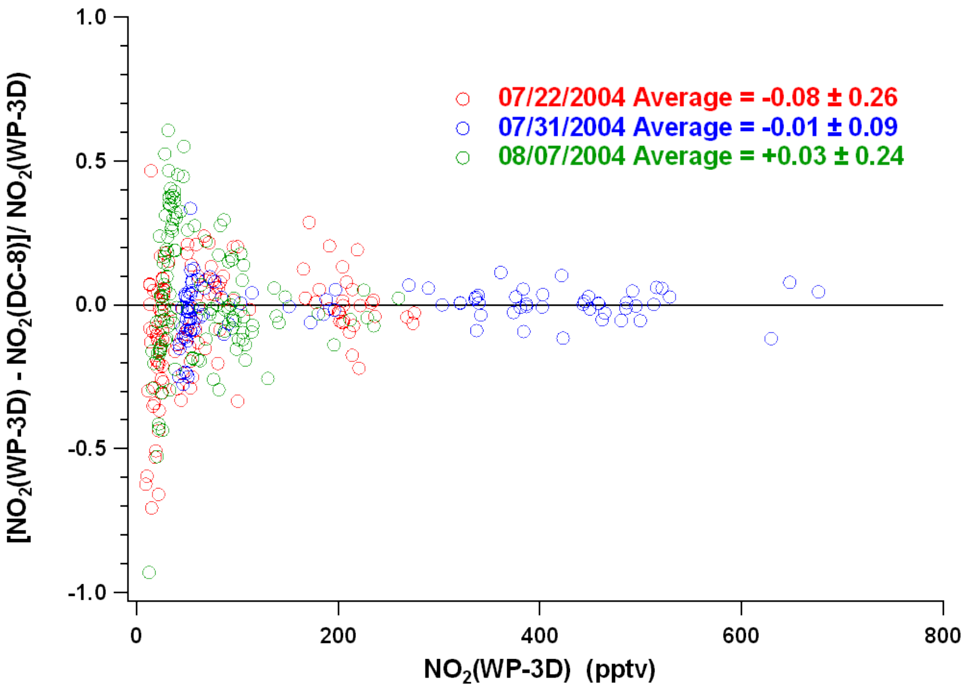

Figure 5. Relative difference between NO_2 measurements from the three DC-8/WP-3D intercomparison flights as a function of the WP-3D NO_2. A correction was made to account for bias. One outlier at about -2 is not shown for 07/22.

References

Fehsenfeld, F. C., et al. (2006), International Consortium for Atmospheric Research on Transport and Transformation (ICARTT): North America to Europe—Overview of the 2004 summer field study, *J. Geophys. Res.*, *111*, D23S01, doi:10.1029/2006JD007829.

Ryerson, T.B., E. J. Williams, and F. C. Fehsenfeld. (2000), An efficient photolysis system for fast-response NO_2 measurements, *J. Geophys. Res.*, 105(D21), 26,447–26,461, doi:10.1029/2000JD900389.

Singh, H. B., et al. (2006), Overview of the summer 2004 Intercontinental Chemical Transport Experiment-North America (INTEX-A), *J. Geophys. Res.*, *111*, D24S01, doi:10.1029/2006JD007905.

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