Correlation analysis of column-integrated P-3B data with surface mixing ratio for *in situ* observations and model for O_3 and NO_2

Clare M. Flynn[1], Kenneth E. Pickering[1,2], Pius Lee[3], Youhua Tang[4], Andrew Weinheimer[5], Ronald Cohen[6], and James Szykman[7]

[1] Department of Atmospheric and Oceanic Science, University of Maryland, College Park [2] NASA Goddard Space Flight Center; [3] NOAA Air Resources Laboratory, [4] NOAA National Weather Service, [5] NCAR Air Chemistry Division, [6] Department of Chemistry, University of California, Berkeley, [7]EPA, Office of Research and Development

Introduction

The first deployment of the Earth Venture-1 DISCOVER-AQ project was conducted during July 2011 in the Baltimore-Washington region. *In situ* sampling of trace gases was performed by the P-3B aircraft over fourteen flight days, allowing profiles of O_3 and NO_2 to be obtained over surface air quality monitoring sites. These flight days captured a range of conditions, including clean days and pollution episodes during July 1-5 and July 20-23. A major goal of DISCOVER-AQ is to relate column observations to surface conditions for key trace gases. An objective of this study is to investigate the degree of correlation that exists between the column-integrated amounts and the surface-level mixing ratio data for the P-3B data and the CMAQ model.

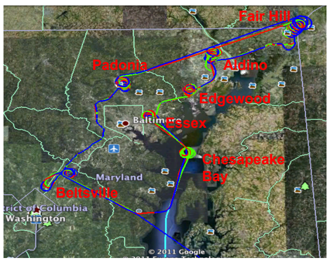

Figure 1: Example P-3B flight track for July 26 flight. Surface monitoring sites labeled in red.

Method

Column amounts for O_3 were computed through integrations of the P-3B profile after linear interpolation of the profile to the surface. Two different column amounts were computed for NO_2, column_air and column_ground. Column_air was computed through integration of the NO_2 profile after extension of the lowest aircraft mixing ratio value (at ~1000 ft. AGL) to the surface. Column_ground is computed in the same manner, but extends the surface mixing ratio value to the lowest aircraft level, when a surface value is available. Column_air and column_ground therefore represent the outer bounds of where the true NO_2 column lies. Model column amounts for O_3 and NO_2 were computed through integration of the model profile from the model surface through the depth of the P-3B profiles for each site.

A correlation analysis was performed between column amounts and the surface data for O_3 and NO_2 for each site for the P-3B data and the model. The linear Pearson correlation coefficient R was computed for each site as a measure of the degree of fit of a linear relationship.

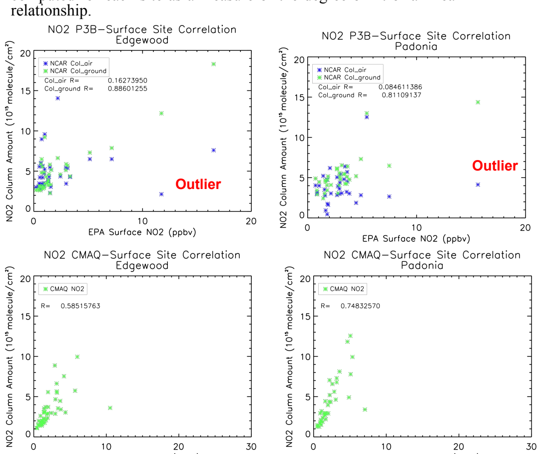

Figure 2: Scatter plots of of NO_2 columns (10^{15} cm^{-2}) versus surface NO_2 mixing ratio (ppbv) for Edgewood and Padonia for the P-3B (top) data and CMAQ (bottom). Correlation coefficient (R) given in top left of each plot.

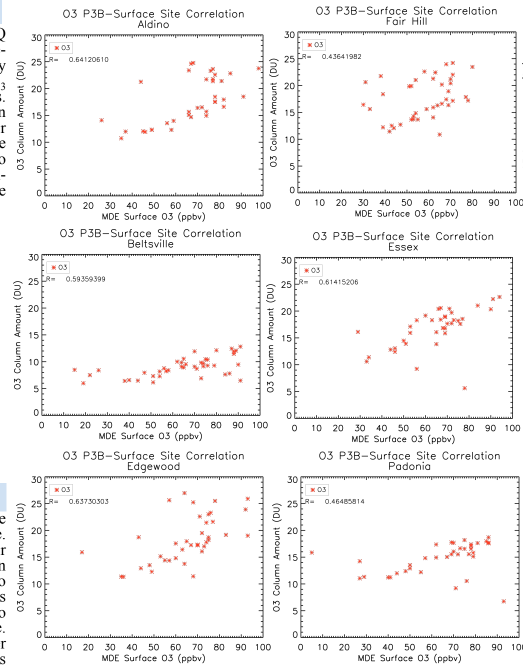

Figure 3: Scatter plots of of O_3 columns (DU) versus surface O_3 mixing ratio (ppbv) for all 6 sites for the P-3B data. Correlation coefficient (R) given in top left of each plot.

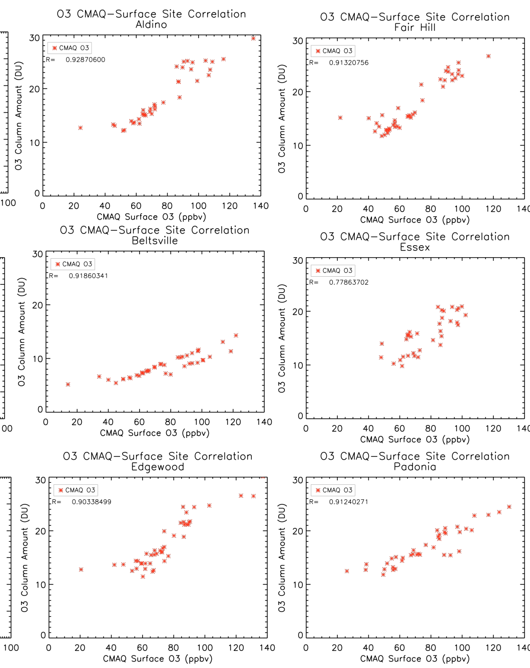

Figure 4: Scatter plots of of O_3 columns (DU) versus surface O_3 mixing ratio (ppbv) for all 6 sites for the CMAQ model. Correlation coefficient (R) given in top left of each plot.

Data

In situ trace gas volume mixing ratio data were collected by the P-3B over each surface monitoring site multiple times during flight days. Surface-level volume mixing ratio data were made available for these monitoring sites by the Maryland Department of the Environment (MDE) and Environmental Protection Agency (EPA). Forecasts of O_3 and NO_2 from an experimental version of the CMAQ model (Version 4.6 driven by WRF-NMM meteorology) were provided by NOAA during the deployment.

NO_2 Correlations in Aircraft Data and Model

The scatter plots (Figure 2) for Edgewood and Padonia display the correlation between the column amount and NO_2 surface mixing ratio for all flight days. Correlations for both column_air and column_ground are presented for each site. The scatter plots for CMAQ display the correlation between the model column amounts and model surface values for the model grid point nearest each monitoring site. Only model profiles occurring at the nearest hour to a P-3B profile were chosen in this analysis for better comparison to the P-3B analysis. The aircraft plots demonstrate much greater scatter than the CMAQ plots upon initial inspection, indicating that CMAQ underestimates the variability in the lower tropospheric column. The degree of correlation is low for column_air at both sites. Column_air may not be representative of near surface conditions. The degree of correlation is high for column_ground at both sites. However, this result is expected. Column_ground relies heavily on the surface value, and this likely causes the high degree of correlation. CMAQ demonstrates moderate correlation for both sites. CMAQ also generally captures the range of surface values seen in the EPA measurements. The CMAQ correlations may be closer to a correlation based upon the true NO_2 columns.

O_3 Correlations in Aircraft Data and Model

The scatter plots (Figures 3 and 4) for all 6 sites display the correlation between the column amount and O_3 surface mixing ratio for all flight days. Model profiles corresponding to a P-3B profile and for the grid point nearest the surface sites were chosen. The CMAQ plots for O_3 demonstrate less scatter than the P-3B plots, similar to the NO_2 results. However, the range of surface values is larger in the model than the MDE measurements. The aircraft data demonstrate a moderate degree of correlation. However, the correlations obtained from the model are much larger for all 6 sites, mainly due to the model underestimation of the variability in the lower tropospheric column. The P-3B profiles demonstrate larger concentrations of O_3 in the free troposphere than in CMAQ, indicating that the model may lack sufficient pollutant vertical transport and keeps O_3 production primarily in the boundary layer.

Conclusions

The results of correlation analyses between columns amounts and surface mixing ratio values have been presented for O_3 and NO_2 for the P-3B and CMAQ model for 6 air quality monitoring sites. Moderate correlation was obtained for the P-3B O_3 data. Large correlation was obtained for NO_2 column_ground, while low correlation was obtained for NO_2 column_air. **These results suggest that observations from satellite instruments with sufficient sensitivity to the lower troposphere can be meaningful for surface air quality analysis.** For CMAQ, large correlation was obtained for O_3 and moderate correlation for NO_2. **For both gases, the model underestimates the variability observed in the lower troposphere**. A next step is to examine the O_3 and NO_2 profiles obtained from tethered balloon data to determine the most realistic method to fill the gap between P-3B profile bottom and the surface. Conditions associated with the outliers will also be investigated.

Acknowledgements:
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