Evaluation of CMAQ Forecasts of NO_2 Column Amounts Using In-situ and Remote Sensing Data from DISCOVER-AQ

Kenneth E. Pickering[1], James Crawford[2], Clare Flynn[3], Melanie Follette-Cook[4], Pius Lee[5], Jeff McQueen[6], Lok Lamsal[4], Nickolay Krotkov[1], Andrew Weinheimer[7], Jay Herman[8], and James Szykman[9]

[1] NASA Goddard Space Flight Center, [2]NASA Langley Research Center, [3]AOSC, University of Maryland, College Park, [4]GESTAR/GSFC, [5]NOAA Air Resources Laboratory, [6]NOAA National Weather Service, [7]NCAR Atmospheric Chemistry Division, [8]JCET/UMBC/GSFC, [9]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 NO_2 and other gases and aerosols 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. Here we evaluate the column amounts of NO_2 in CMAQ forecasts using DISCOVER-AQ in-situ and remotely-sensed measurements.

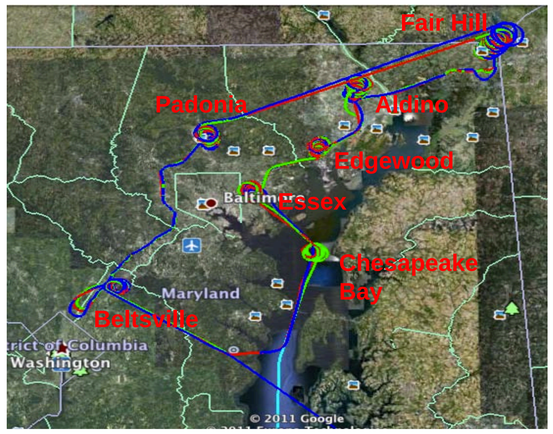


Figure 1: Example P-3B flight track for July 26 flight, showing spirals flown over the six surface monitoring sites and a research vessel labeled in red.

Data

In situ trace gas volume mixing ratio data were collected during spirals conducted by the P-3B over each Maryland Department of the Environment (MDE) surface monitoring site multiple times during flight days. Surface-level volume mixing ratio data for NO_2 were collected at the Edgewood and Padonia sites by the Environmental Protection Agency (EPA). Remote sensing of NO_2 columns was conducted at each of the six MDE sites using Pandora spectrometers. Tropospheric column NO_2 was also available from the OMI instrument on NASA's Aura satellite, processed with the new NASA Goddard algorithm. Forecasts of NO_2, other gases and aerosols from an experimental version of the CMAQ model (Version 4.6 driven by WRF-NMM meteorology) were provided by NOAA during the deployment.

Measurement Details

- The P-3B payload contained a chemiluminescent detector for NO which also was used for measuring NO_2 following conversion to NO using a photolytic convertor.
- EPA supplemented the MDE instrumentation at Edgewood and Padonia with chemiluminescent NO detectors with photolytic convertors for NO_2.
- Pandora spectrometers (Herman et al., 2009, *JGR*) were deployed at MDE sites as well as 7 other sites in the Baltimore-Washington area. The sun-tracking Pandoras detected solar radiation in the 280 to 525 nm wavelength band. NO_2 was retrieved using a Differential Optical Absorption Spectroscopy (DOAS) method. Tropospheric columns were obtained by subtracting the OMI-derived stratospheric columns.
- The Ozone Monitoring Instrument on the Aura satellite detects backscattered UV and visible radiation for the retrieval of NO_2 column amounts along with other gases and aerosols. Estimates of stratospheric NO_2 are subtracted to obtain tropospheric columns. Data affected by the OMI "row anomaly" or the presence of cloud radiative fractions >50% have been screened out.

NO_2 Column Time Series Plots

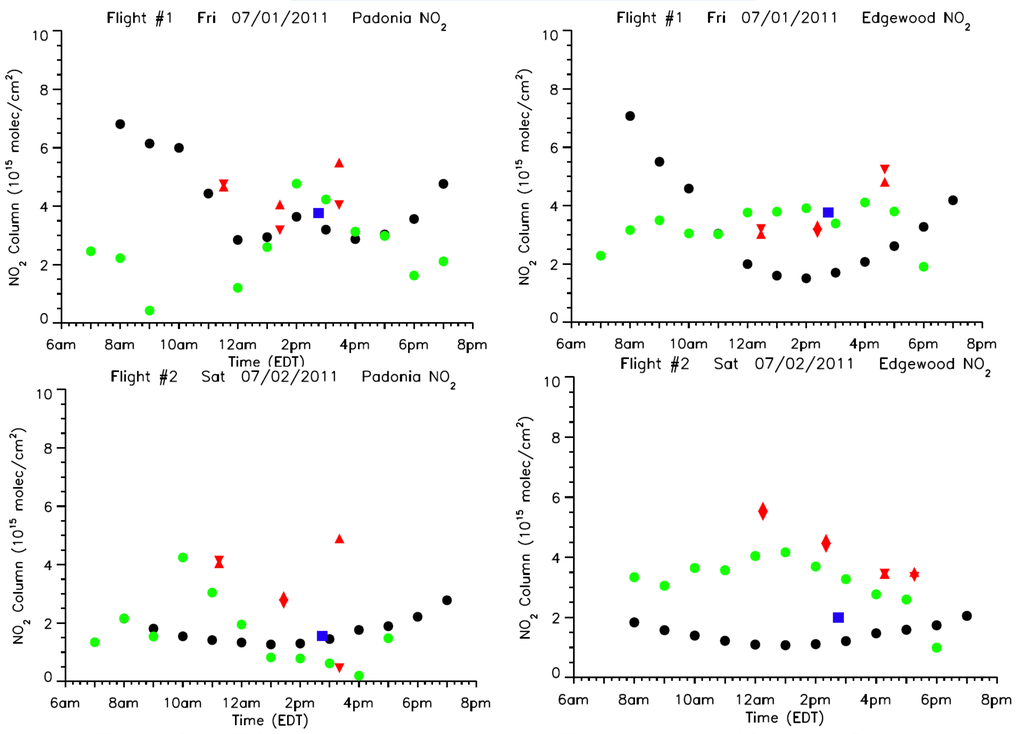


Figure 3: NO2 column time series for Friday, July 1, 2011 and Saturday, July 2, 2011 at Padonia and Edgewood, Maryland.

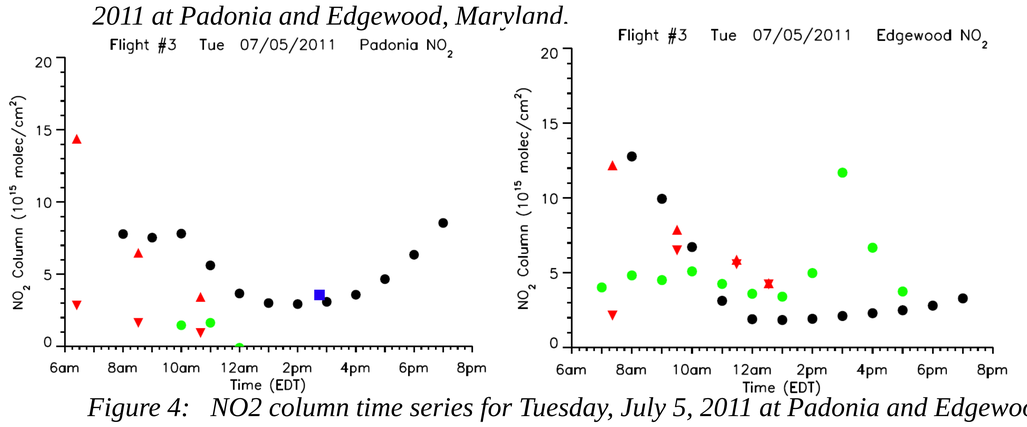


Figure 4: NO2 column time series for Tuesday, July 5, 2011 at Padonia and Edgewood.

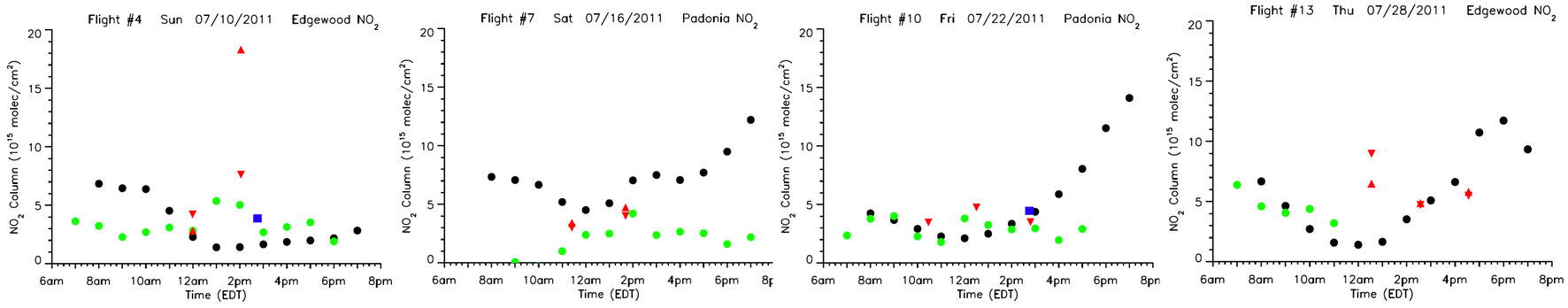


Figure 5: NO2 column time series for Edgewood on 7/10 and 7/28 and for Padonia on 7/16 and 7/22.

Black circles – CMAQ columns calculated to the altitude of the P3 profile

Green circles – Pandora tropospheric column = Pandora total column – OMI strat.

Blue square – OMI tropospheric column

Red triangle up – P-3B Column_ground

Red triangle down – P-3B Column_air
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 by extending the surface mixing ratio value to the lowest aircraft level.

Summary Table

Ratio	Edgewood	Padonia
CMAQ/Column_air	0.72 (± 0.38)	1.31 (± 1.18)
CMAQ/Column_ground	0.65 (± 0.30)	0.83 (± 0.44)
CMAQ/OMI	0.89 (± 0.38)	1.47 (± 1.34) 0.89 (± 0.36)*
CMAQ/Pandora	1.30 (± 5.06)	1.65 (± 5.45)**

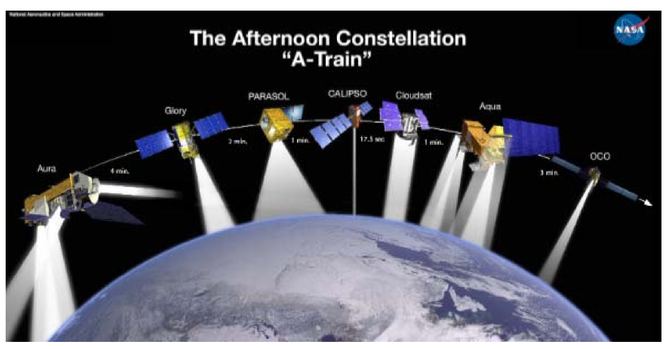
*after elimination of two days with ratios of 4.0 and 4.1
**after elimination of two hours with ratios of 72 and 95

Conclusions

Holiday weekend NO_x emissions in CMAQ appear to be too small in the vicinities of Edgewood and Padonia. Early morning emissions on the following workday as well as many others appear to be too large. The model misses many features of the temporal variability observed. Overall, the model is biased low for NO_2 at Edgewood, except in comparison with Pandora. The results are more uncertain at Padonia. We need to examine the NO_2 profiles obtained from tethered balloon to determine the most realistic method to fill the gap between P-3B profile bottom and the surface.

Results

CMAQ has a low bias during the afternoon of Friday, July 1 and most of the day on Saturday, July 2, the July 4 Holiday Weekend getaway days. A very different pattern emerges for the return to work day of Tuesday, July 5. On this day CMAQ has a high bias at both Edgewood and Padonia in the morning. Other weekends in July are represented by Edgewood (Sun., 7/10) and Padonia (Sat., 7/16), which both show high biases in the morning, with a transition to low bias in the afternoon at Edgewood. Friday, 7/22 at Padonia shows good comparison with observations except in the late afternoon/early evening. Thursday, 7/28 at Edgewood shows good comparison except in midday where CMAQ misses an observed peak.



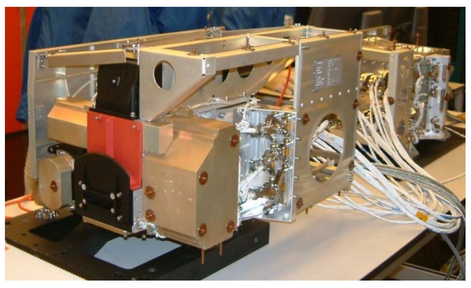


Figure 2: Aura satellite in the A-Train; OMI instrument; Pandora spectrometer; NASA P-3B aircraft; NCAR NO/NO2/NOy instrument

Acknowledgements:
This research is supported by the NASA DISCOVER-AQ project. Thanks to Gao Chen (NASA/LaRC) for providing the P-3B NO_2 columns.