Comparison of Satellite and Ground-based Measurements of Total Column Ozone and Nitrogen Dioxide from Edgewood, MD in July 2011

Andra J. Reed[1], A. M. Thompson[1], D. K. Martins[1], J.R. Herman[2]

[1]Department of Meteorology, Penn State University, State College PA (axr5145@psu.edu) ~ [2]JCET, University of Maryland Baltimore County, Greenbelt, MD

Introduction

In July 2011, NASA began a multi-year campaign called DISCOVER-AQ, or **D**eriving **I**nformation on **S**urface **Co**nditions from Column and **Ver**tically Resolved Observations Relevant to **A**ir **Q**uality. DISCOVER-AQ is designed to allow atmospheric scientists to gain a better understanding of air quality and its ability to be predicted by satellites. As part of the campaign, 13 ground stations were set up in and around the areas of Washington D.C., and Baltimore, MD during July 2011. In addition to ground based air quality measurements made at these locations, data were also collected from flights made by NASA's P-3B and UC-12 Aircraft, as well as by a plane from the University of Maryland. Satellite data pertaining to the region during the campaign are also used in this analysis.

Figure 1: Flight path of the NASA P-3B Aircraft during DISCOVER-AQ, July 2011. Edgewood, MD is marked by the red star.

In addition to the ground stations, aircraft, and satellites, a network of Pandora spectrometers was deployed during July 2011 throughout the region. This network was designed to be used to evaluate Ozone Monitoring Instrument (OMI) NO_2 and Ozone products, as well as to study gradients in the Baltimore and Washington, D.C. area.[3]

Research Goals:

The goal of this study is to consider the variability in NO_2 and ozone products measured by Pandora and OMI at one station, and in one grid point measured by OMI. An in-depth study of the agreements and disagreements between the two instruments at one location will provide insight into potential influences on column amounts measured by the two instruments.

Methods and Data

Pandora, operated at Edgewood, MD

- Small direct-sun spectrometer connected to a sensor head by a fiber-optic cable[4]
- Uses the Differential Optical Absorption Spectroscopy (DOAS) method to obtain total column measurements of ozone and NO_2.[4]
- Operated by Jay R. Herman

Figure 2: Pandora Spectrometer[4]

Ozone Monitoring Instrument (OMI)

- Dutch-Finnish Ozone Monitoring Instrument, launched on the NASA Earth Observing System Aura satellite in July, 2004[2]
- Ground-pixel size is dependent on viewing zenith angle, and ranges from 13-26 km long and 24-128 km wide[2]
- For our study, we are interested in the NO_2 column found using a DOAS fit[2], and the ozone column found using the Total Ozone Mapping Spectrometer (TOMS) algorithm[1]
- We isolate the ground pixel from OMI that contains Edgewood, and use column NO_2 and ozone measurements from this pixel for comparisons with ground-based measurements

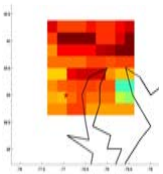


Figure 3: OMI NO_2 column amounts at Edgewood, MD (marked by the red star) on 1 July 2011

Results

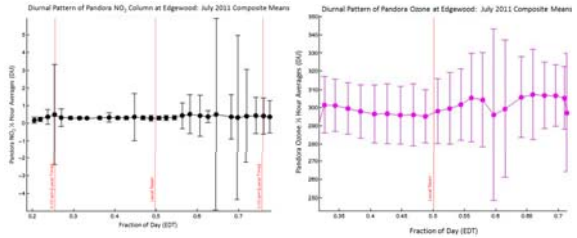


Figure 4: Diurnal Patterns of Pandora total column NO_2 and Pandora total column Ozone measured at Edgewood, MD during July 2011. As expected due to rush-hour traffic patterns, we see a bimodal pattern in NO_2 levels, with peaks in the morning and afternoon. Also, we see the expected increase of Ozone levels throughout the afternoon as photochemistry becomes more effective.

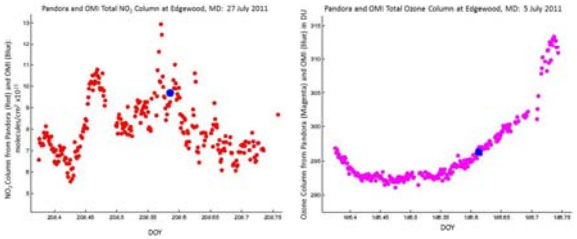


Figure 5: Plots of Pandora and OMI total column NO_2 from 27 July 2011, and Pandora and OMI total column ozone from 5 July 2011. These two days show the best agreement between Pandora and OMI total column amounts. The percent difference between Pandora and OMI total column NO_2 on 27 July was 0.8939%; the percent difference between Pandora and OMI total column ozone on 5 July was 1.6424%

Note that we see a drastic increase in the ozone column amount measured by Pandora during the afternoon hours of July 5. The unusually high ozone column amounts exhibited in this plot are due to the presence of a bay-breeze at Edgewood on this particular day.[5]

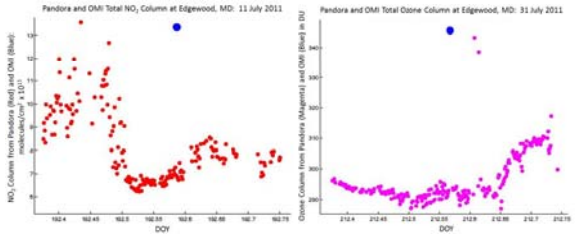
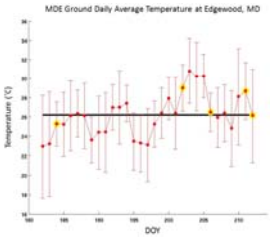


Figure 6: Plots of Pandora and OMI total column NO_2 from 11 July 2011, and Pandora and OMI total column ozone from 31 July 2011. These two days show the worst agreement between Pandora and OMI total column amounts. The percent difference between Pandora and OMI total column NO_2 on 11 July was 61.2345%; the percent difference between Pandora and OMI total column ozone on 31 July was 16.2804%

Five days from July 2011 show greater than a 35% difference between Pandora and OMI NO_2 column amounts, and five days from July 2011 show greater than a 10% difference between Pandora and OMI ozone column amounts. Further analysis is required to determine the cause of these discrepancies.

Figure 7: Plot of the daily average temperature measured by the Maryland Department of the Environment (MDE) at Edgewood, MD during July 2011. The black line indicates the monthly average of daily temperature, and days highlighted in yellow indicate the five days with the greatest disagreement between Pandora and OMI total column ozone amounts. Here we see that days with poor agreement between column amounts from the two instruments were generally relatively warm. This, and similar analyses of other relevant variables with respect to both NO_2 and ozone column amounts may reveal trends that cause poor agreement between column amounts from Pandora and OMI.



Statistics

Fig. 8 illustrates the distribution of percent differences between Pandora and OMI NO_2 and ozone column amounts at Edgewood during July 2011. The distributions are skewed to the right.

Percent differences were calculated as:

$$\text{Percent Difference} = \frac{|(\text{Pandora column}) - (\text{OMI column})|}{\frac{(\text{Pandora column}) + (\text{OMI column})}{2}} \times 100\%,$$

where Pandora column amounts are 1-hour averages centered on the OMI overpass time.

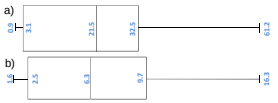


Figure 8: Box and whiskers plots of the percent difference between Pandora and OMI a) NO_2 column measurements using a sample of 21 days, and b) ozone column measurements using a sample of 24 days.

Conclusions

Diurnal patterns of Pandora total column NO_2 and ozone amounts, as illustrated by Fig. 4, exhibit the expected diurnal patterns.

- Total column NO_2 shows a bimodal pattern, with peak amounts during both the morning and afternoon rush hours. Note: the afternoon peak is not as clearly defined, likely due to the known fact that the time at which people leave work varies more than the time at which people go to work.
- Total column ozone generally shows a rising trend in ozone levels throughout the afternoon hours, which is expected due to the photochemistry required to form ozone.

A comparison of daily Pandora and OMI total column NO_2 and ozone amounts yields mixed results.

- As illustrated in Fig. 5, many days throughout July 2011 illustrate very good agreement between NO_2 and ozone column amounts from the two instruments at Edgewood, MD. This agreement is expected since we are considering two measurements of the same quantity.
- As illustrated in Fig. 6, not all days during July 2011 illustrate the expected agreement between Pandora and OMI total NO_2 and ozone column amounts at Edgewood, MD. Several days during the month show quite poor agreement between measurements from the two different instruments, though the instruments are measuring the same quantity.

Future Work

Further analysis of data collected at Edgewood, MD during July 2011 is required to determine why some days during this time period show poor agreement between Pandora and OMI total column NO_2 and ozone amounts. This work will include a study of differences in time and space as comparisons are made, as well as an in-depth analysis of variables such as relative humidity and aerosol amounts that may impact the amount of light received by the Pandora spectrometer.

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