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The Correlation of Mercury, Ions, and Weather Conditions at PA-47

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Abstract

Research conducted in the 1970s found that the emissions of SO2 and NOx proved to be a widespread problem through the formation of acid rain. In 2002, PA-47 was established to close an NTN/MDN measurement gap in south-central Pennsylvania, and sample collection conducted by Millersville University (MU) meteorology students has continued uninterrupted ever since. PA-47 is located approximately three kilometers from the MU Weather Information Center where a full suite of meteorological variables are recorded and archived. This research uses ion/Hg analyses and meteorological data from 2004 through 2013 to understand the correlation between the variability observed in the NADP record and the weather conditions that could have contributed to the variability. This period corresponds to the availability of trajectory analyses using the HYSPILT – Hybrid Single Particle Lagrangian Integrated Trajectory Mode, which will be employed in this study. Anomalies were found as deviations from the mean concentrations of mercury, sulfate, potassium, calcium, magnesium, sodium, ammonium, and chlorine. This resulted in the isolation of those weeks that exhibited anomalies that were one and two standard deviations outside the mean. The meteorological conditions were found for the anomalies and categorized according to wind direction and time of year, and HYSPLIT was used to obtain back trajectories to determine source regions for this air. Results suggest that weather conditions are well correlated with variability in the weekly ion and mercury data. Our preliminary data show that highest concentrations are found when the wind direction is from the southwest in the summer seasons and in moderate precipitation events that occur after an extended period of dry conditions.

In 2002, Millersville University (MU) established a precipitation collection site to close a measurement gap of mercury and ion concentrations. This collection site is located approximately three kilometers from the MU Weather Information Center where a full suite of meteorological variables are recorded and archived. Sponsored by the National Atmospheric Deposition Program (NADP) and named PA-47, meteorology students have conducted the collection process uninterrupted ever since inception.

Background

The NADP uses acid deposition as an air pollution monitoring technique. Wet deposition is used in the form of precipitation and dry deposition. Rainwater is naturally slightly acidic (just below pH 7) through naturally-sourced chemicals. However, the introduction of anthropogenic-sourced chemicals has enhanced rainwater chemistry to where pH values average to 5 or lower in the eastern US (as of the 1980s). In 1977, in conjunction with the EPA, the US State Agricultural Experiment Stations established the project to measure atmospheric wet and dry deposition and study its effects on the environment. The following year, site operations began around the nation to provide precipitation data on the amounts, trends, and geographic distributions of acids, nutrients, and base cations. The project exponentially grew throughout the 1980s, expanding into the current five networks of the NADP. PA-47 collects wet deposition data for the National Trends Network (NTN) and the Mercury Deposition Network (MDN). The NTN investigates ion concentrations of inorganic chemicals found in precipitation, and the MDN investigates total mercury concentration and deposition. Both networks are the only two providing a ubiquitous long-term record of US precipitation chemistry. Researchers use these datasets to find correlations between ion and mercury concentrations and its effects biologically, hydrologically, economically, and meteorologically.

Motivation of Project

One of the site collectors was curious regarding why the collection data was displaying abnormally low pH values. With Lancaster County located within one of the largest non-irrigated plots of farmland in the United States, it was thought the low values were strongly correlated to high density farming in the local area. Although there is some contribution, it has since been discovered to not exactly be the case. More work needs to be completed; however, our current research suggests that not only does the local area influence our sample with possible higher concentrations but also from regions surrounding our collection site. We want to learn where main areas of pollution are originating as well as how they are affecting our local region.

Methodology

The research uses ion/Hg analyses and meteorological data from 2004 through 2013 to understand the correlation between the variability observed in the NADP record and the weather conditions that could have contributed to the variability. This period corresponds to the availability of trajectory analyses using the HYSPLIT – Hybrid Single Particle Lagrangian Integrated Trajectory Mode, which was employed in this study. HYSPLIT is a computer model that derives air parcel trajectory paths based on model data and helped us determined potential sources regions of atmospheric pollutants. After looking through the data, we found only a six year period would be valid (2006-2011). This was due to availability of HYSPLIT trajectory data and insufficient sample periods in 2012 and 2013. Weeks in NTN labelled ‘nn’ (information never reported and will not be known) or ‘ns’ (no chemistry data reported due to an infraction) were eliminated. Weeks in MDN given a quality report grade ‘C’ (invalid data, not used for summary statistics) were eliminated. These omitted weeks are not included in the descriptive statistics for either dataset. Weeks with significant, single precipitation events (> 0.10 inches) during meteorological summer periods with maximum wind speeds from the East-South-West were isolated to further study our hypotheses. Weeks with

significant precipitation events following a prolonged dry period were also isolated. The weeks that best satisfied the criteria were identified, and three case studies were selected based on the best matched weeks during the month of June for 2006, 2008, and 2009. HYSPLIT back trajectories were used to further analyze the datasets.

Discussion

Anomalies were found as deviations from the mean concentrations of mercury, sulfate, potassium, calcium, magnesium, sodium, ammonium, and chlorine. This resulted in the isolation of those weeks exhibiting anomalies that were one and two standard deviations (sigmas) outside the mean. The meteorological conditions were found for the anomalies and categorized according to wind direction and time of year; HYSPLIT was used to obtain back trajectories to determine source regions for this air. Initial results suggest weather conditions are well correlated with variability in the weekly ion and mercury data. Preliminary data shows the highest concentrations are found when the wind direction is from the southwest in the summer seasons and in moderate precipitation events that occur after an extended period of dry conditions. Based on the HYSPLIT analyses, in all cases, air parcels followed a southeasterly to southerly track toward PA-47, crossing the Delmarva Peninsula and the DC/Baltimore metropolitan areas. These areas have high concentrations of coal-burning power plants and commercial factories emitting mostly mercury (Hg), and Calcium (Ca), magnesium (Mg), ammonium (NH4), nitrate (NO3), and chlorine (Cl), respectively. This also provides a potential source region for these pollutants. In June 2006 (Case 1), a significant rainfall (totaling 9.87 in) occurred over five days following a relatively dry 16-day period consisting of hot and humid conditions. Hg and all ions, but Cl, are within one sigma from the summer means (Cl lies within two sigma). June 2009 (Case 3) followed a similar pattern after a relatively dry 11-day period. Ion data are inconclusive for Case 3, due to an invalid sample. However, Hg is barely within one sigma due to an abnormally high Hg concentration from the previous week. June 2008 (Case 2) did not succeed a dry period, but rather several significant precipitation events. Conditions were very hot and humid prior to the rainfall and weeks preceding and succeeding this case. All ion and Hg concentrations in Case 2 are within one sigma from the summer means.

Conclusion

An overall rise in mean Hg concentrations for 2006 and 2009 could suggest there was increase in emissions from the power plants during these periods' weather conditions. Further research is needed to target specific source regions. Unfortunately, this analysis does not support either hypothesis; most mean concentrations were within one sigma of their respective summer means, regardless of weather conditions. We plan to extend this research into other seasons and wind directions and compare PA-47's data with surrounding sites.

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