**Basic Information**

- **Project No. and Title:** NRSP3 : The National Atmospheric Deposition Program (NADP)
- **Period Covered:** 11/01/2019 to 11/05/2020
- **Date of Report:** 12/27/2020
- **Annual Meeting Dates:** Meeting: Nov 4-5, 2020, Symposium Oct 28-30, 2020

**Participants**

An attendee listing for our Fall Meeting and Science Symposium (FY20) is available at our meetings page (http://nadp.slh.wisc.edu/conf/). The fall meeting and symposium had over 300 registered participants.

**Brief Summary of Minutes of Annual Meeting**

The NADP is comprised of a technical committee (all participants), an executive committee, several scientific committees, and a series of subcommittees focusing on specific areas of the ongoing project, including operations, quality assurance, critical loads and total deposition, outreach, and data management. All approved meeting minutes from our FY20 Spring and FY2020 Fall Meetings (and all other meetings) are available on the website (http://nadp.slh.wisc.edu/committees/minutes.aspx). Posting of committee minutes is controlled by each committee chair; some subcommittee minutes may be delayed for approval, but all are expected within 6 weeks after the respective meeting.

**Accomplishments**

The National Research Support Project – No. 3 (NRSP3) provides a framework for cooperation among State Agricultural Experiment Stations (SAES), the U.S. Department of Agriculture-National Institute of Food and Agriculture, and other cooperating

governmental and non-governmental organizations that support the National Atmospheric Deposition Program (NADP). The NADP provides quality-assured data and information on the exposure of managed and natural ecosystems and cultural resources to acidic compounds, nutrients, base cations, and mercury in precipitation and through dry deposition of several of these compounds. NADP data support informed decisions on air quality and ecosystem impacts related to precipitation chemistry and wet and dry deposition.

Specifically, researchers use NADP data to investigate the impacts of atmospheric deposition on the productivity of managed and natural ecosystems; the chemistry of estuarine, surface, and ground waters; and the biodiversity in forests, shrubs, grasslands, deserts, and alpine vegetation. These research activities address the mission of the NRSPs of "development of … support activities (e.g., collect, assemble, store, and distribute materials, resources and information)… to accomplish high priority research". Researchers also use NADP mercury networks and data to examine the effect of atmospheric deposition on the mercury content of fish, and to better understand the link between environmental and dietary mercury and human health. This fits with an agriculture research priority of food safety.

At the end of November 2020, NADP supported sample collection in almost all of the US States, Puerto Rico, the Virgin Islands, and Canada, and conducted scientific outreach and monitoring support in in Mexico, and countries in Southeast Asia. Operational support included 259 NTN, 85 MDN, 5 AIRMoN (discontinued operation in September 2019), 16 AMNet, and 112 AMoN locations across North America. Samples are collected to support continued research of atmospheric transport, ecosystem impacts, documentation of spatial and temporal trends, assent of air pollution mitigation success, development of computer simulations, and for community and educational outreach.

The NTN provides the only long-term nationwide record of base ion wet deposition in the United States. Sample analysis includes free acidity ($H^+$ as pH), specific conductance, and concentration and deposition measurements for calcium, magnesium, sodium, potassium, sulfate, nitrate, chloride, and ammonium. Bromide has been recently removed due to concerns associated with data quality. NADP also measures orthophosphate ions in the inorganic form, but only for quality assurance as an indicator of potential sample contamination. Currently, 48 NTN sites are operated at or near SAES, and an additional 13 have been associated with the SAES in the past. In addition, there are quality assurance and testing sites located in Colorado and Wisconsin. The AIRMoN has recently been discontinued; however in the past, it was an

important contributor to research of atmospheric transport and removal of air pollutants and the development of computer models of these processes. The MDN offers the only long-term and routine measurements of mercury in North American precipitation. Measurements of total mercury concentration and deposition (and optional methyl-mercury) are used to quantify mercury deposition to water bodies, some of which have fish and wildlife mercury consumption advisories and in the future may be used to meet the Minamata Convention monitoring requirements.

The NADP operates two gaseous atmospheric chemistry networks: the Atmospheric Mercury Network (AMNet) and the Ammonia Monitoring Network (AMoN). The goal of these networks is to provide atmospheric concentrations of mercury and ammonia, respectively, to estimate the rate of dry deposition (without precipitation), and to support the measurements required to understand atmospheric chemical processing and total deposition of nutrients and pollutants. In many cases, dry deposition could exceed the wet deposition of the same compound, thus, these are key parameters to understand ecosystem impacts. Through the reporting period, fourteen AMNet sites were collecting five-minute measurements of gaseous elemental mercury and (for a subset of sites) two-hourly average concentrations of gaseous oxidized mercury and particulate bound mercury. The AMNet provides the only long-term region-wide record of basic atmospheric mercury concentrations in the United States. The AMoN measures two-week average concentrations of atmospheric ammonia using passive sample cartridges. This low-cost network is designed to provide spatial and temporal estimates of ammonia in the atmosphere. These data are particularly important to the agricultural community, since many sources of ammonia are related to agricultural processes. In addition, gaseous ammonia deposition contributes to the total nitrogen deposition, an important parameter for understanding agricultural systems. In recent years the AMoN has been the fasting growing NADP network due to the interest of researchers and policy makers in ammonia in the environment. Data from both gaseous networks support continued research of atmospheric transport and removal through dry deposition, and the development of computer models of these processes.

Within this NRSP, there are three primary goals: 1) management and coordination of the NADP monitoring networks; 2) site support, chemical analysis, data validation, and data reporting for network sites; and 3) quality assurance and quality control (QA/QC) activities to ensure consistent operation and standard operational procedures, resulting in the highest data quality possible. During the performance period, all three of these goals were met. The major accomplishment of the NADP is the smooth and consistent operation of the monitoring networks. Operation, maintenance, management, quality assurance, and data distribution from these networks is the major outcome of this grant and project.

The principal output or deliverable from the NADP's networks is the database of precipitation chemistry and deposition rates, along with atmospheric gaseous concentrations intended for the development of dry deposition fluxes (AMoN, AMNet). This database is available free to users on the NADP website (http://nadp.slh.wisc.edu/data/). The wet deposition database has approximately 600,000 NTN, MDN, and AIRMoN observations available for download.

**Additional notable outcomes during the project period are as follows:**

The successful transition of the Mercury Analytical Laboratory (HAL) from the private laboratory subcontractor Eurofins-Frontier Geosciences, Inc. of Seattle Washington (the long-term subcontractor for laboratory services) to the University of Wisconsin-Madison's WSLH began in early 2019 and was completed with our first samples arriving during the summer of 2019 (June). Overall, the conversion of the laboratory has gone well, with upgrades to our laboratory space continuing through 2020 and into the near future. All new instrumentation is in place in our clean room laboratories, with additional equipment purchased during the first part of 2020. The HAL is fully staffed, and day to day processes are in place. No data gaps were seen during the changeover. The comprehensive Laboratory Readiness Verification Plan is available, and contain many specific performance metrics.

**Future Work/Directions:**

The WSLH and NADP have begun a strategic planning initiative, during the 2019 and 2020 meetings. The goal is to identify and address ongoing and new directions for the NADP stakeholders, supporters, and data users. Many ideas are being developed, with prioritization of the most important directions being reviewed now. Finalization of this document is occurring now.

Additionally, the Program Office is completing (now) an operational NADP supersite on the UW-Madison campus. The site (Eagle Heights) will support collaborations with NADP data users such as the College of Engineering, the College of Agricultural and Life Sciences, Department of Limnology, and the Department of Atmospheric and Oceanic Sciences. The goal is to expand the research opportunity and application for NADP data and infrastructure. Sampler base supports and electrical connections etc. were completed in October 2020, sampling equipment was added during December, with full start up expected during January 2021.

**Impacts**

1. Samples Collected: NADP principal output is the collection and analysis of precipitation chemistry and atmospheric chemistry samples obtained from network operations. At last count (August, 2020) total reported analytical samples consisted of approximately 11,897 NTN samples, 3,847 MDN samples (including 86 methyl mercury samples), and 2,504 AMON samples. Each of the NTN samples are ten separate analytes from each sample. The AMNet measured approximately 90,000 hourly and two-hourly ambient mercury fraction concentrations. All analytical results undergo an extensive quality assurance procedure prior to release to the public via the NADP website. The NADP primary focus is ensuring QA/QC for the analytical results. Sample results are now available through 2019 and well into 2020.

2. The NADP offers a full technical support to data users and site operators. The program has direct access to technical experts, via the web and toll free numbers, to address site operators questions and offer technical expertise on data interpretation and the outreach materials. Through the NADP Program Office (PO) thousands of inquiries are answered each year. The NADP experts also contribute to the broader scientific community through dissemination of program information at external conferences, meetings, and in peer reviewed publications.
3. NADP Database: Facilitating data access and availability is a key accomplishment/outcome of NADP, allowing support of continued research and outreach. Scientists, policymakers, educators, students, and others are encouraged to access data at no charge from the NADP website (nadp.slh.wisc.edu). This website offers online retrieval of individual data points, seasonal and annual averages, trend plots, concentration and deposition maps, reports, manuals, and other data and information about the program and from the NADP measurements. The NTN database is now populated by 439,711 observations of precipitation chemistry for all sites and all years. Additionally, the AIRMoN network (ended in 2019) has 29,139 individual event precipitation chemistry records. Together, NADP has documented the chemical analytes for approximately 469,000 precipitation samples across North America which are all available for use. Observations of precipitation mercury, gaseous mercury and ammonia are also available at our website. As of today, the 2019 calendar year

data are complete, final, and online, and the 2020 data are posted through generally June, with final QA to be completed in the next few months (final data QA is completed after the full year of data is available). Internet disbursement of precipitation chemistry and atmospheric data is the primary route of dissemination for the NADP project. Website usage statistics provide evidence that our data are being actively used. Internet disbursement of precipitation chemistry and atmospheric data is the primary route of dissemination for the NADP project.

4. **Map Summary**: The 2018 annual map series of atmospheric concentrations, wet deposition fluxes, and report was developed during fall of 2019 after all of the data and quality assurance checks were completed (http://nadp.slh.wisc.edu/lib/dataReports.aspx). The 2019 map summary was just completed in October 2020 and has just been printed, and distribution to sites and others was begun in December. These maps and summaries are used widely and are one of the major network products. Individual maps are filed by network, year, and constituent, and can be downloaded in several formats (http://nadp.slh.wisc.edu/data/annualmaps.aspx). NADP prints 1500 copies of the Annual Summary, and distribution occurs throughout the year, including disbursement to site operators and supporters, at scientific meetings and conferences, and for education and outreach activities. For each summary and calendar year, the NADP produces a series of 23 national maps of wet deposition concentration and flux maps for all of our analytes, and summary figures for each of the gaseous networks. These maps are used widely and are one of the major network products. Individual maps are filed by network, year, and constituent, and can be downloaded in several formats (http://nadp.slh.wisc.edu/data/annualmaps.aspx).

5. Fall Scientific Meeting and Spring Operational Meeting: The NADP hosted and organized several meetings over this project year. The Fall Scientific meetings were held in Boulder, CO from Nov. 4 - 8, 2019. The meeting was well attended, with approximately 150 participants. The 2020 Fall Scientific meeting were held digitally, due to the COVID-19 travel restrictions. This was our first all-digital scientific symposium, but it was very successful, despite the travel restrictions. One advantage is that we had twice the number of people (over 300 participants) and talks (64 oral presentations), and the meeting involved people from all over the globe. Therefore, even though we were limited in one area, we were able to expand our interactions. The meetings were held over three weeks to avoid long meeting periods, which seemed to work reasonably well. For each 2019 meeting, the reader can find the proceedings, the attendees lists, and abstracts for each

talk online now. For the 2020 meeting, we are planning to make available the recordings of all of the sessions. However, at the time of this writing, the video files are yet to be available. All conference records can be found here, sorted by year: http://nadp.slh.wisc.edu/conf/. Specific Committee minutes can be found here, as the individual committees finalize their minutes: http://nadp.slh.wisc.edu/committees/minutes.aspx.
The 2019 Fall Scientific (Boulder, CO) also included the Total Deposition Science Committee (TDEP) Workshop "Connecting Stakeholder and Science Perspectives to Better Understand the Linkages Between Agriculture and Reactive Nitrogen Deposition" and attended by over 100 participants. The goal was to provide a much better understanding of the measurements and modeling used to study reactive nitrogen and its connection to agricultural sources. The workshop had 12 individual speakers, and multiple panel discussions. See http://nadp.slh.wisc.edu/conf/2019/ for further information.

6. The Spring 2020 NADP Business Meeting (Technical Committee, subcommittees, Executive Committee) was originally scheduled to be held in Madison, WI. However, with the COVID-19 issues and resulting changes, the meeting was held as a digital meeting from May 11-14, 2020. Even with the quick change from a live to a digital meeting, few technical issues occurred, and the feedback from the meeting was that it went very well. The basic committee meetings were all held (Technical, Operations, Outreach, Executive, and several joint sessions), and included a 2-day organizational session for the Mercury in the Environment and Links to Deposition (MELD) Science Subcommittee. Total attendance for all days was 129 individuals (i.e. logged in). Details of this meeting are available here: http://nadp.slh.wisc.edu/committees/minutes.aspx.

7. The Summer Budget Meeting was also a digital meeting, and was just held (Aug 25 - 26, 2020). Approximately 20 members were in attendance.

8. The NADP supported 248 journal and report publications during the 2019 calendar year (our research support role and goals). As far as we know, this is the highest annual number to date. We are currently tracking publications for the 2020 year. More specifics can be found in the publications section of this report.

9. NADP continued to collaborate with Utah State University scientists to develop methods to measure dry deposition accurately and correctly. This study continues to expand and will generate valuable dry deposition data, and perhaps

expand the capabilities of the NADP to make dry deposition measurements directly (see Brahney, et al., 2020, A new sampler for the collection and retrieval of dry dust deposition, Aeolian Research, 45, 100600).

**Publications**

The NADP tracks the number of journal and report publications for each calendar year that use NADP data in their research. During CY2019, we found 248 publications (almost all refereed articles) that used NADP data in some important way to further their research (one of our objectives). This publication tracking continues in 2020 and will be reported after 2020 is complete. The complete list of journal articles used can be found here: http://nadp.slh.wisc.edu/lib/bibliography.aspx.

The following are a subset of journal articles using NADP data that should be of particular interest to agricultural researchers.

1. Ran, L., Yuan, Y., Cooter, E., Benson, V., Yang, D., Pleim, J., ... & Williams, J. (2019). An integrated agriculture, atmosphere, and hydrology modeling system for ecosystem assessments. Journal of Advances in Modeling Earth Systems, 11(12), 4645-4668.

The authors (EPA and university researchers) are developing a regional scale integrated model to account for compounds moving back and forth between agricultural systems, the atmosphere, and the hydrosphere. This current release adds a soil and water assessment tool to the model, and more fully integrating agricultural sources and systems into the predictions. A particularly important part of this model is nitrogen cycling. The authors are currently testing the model for accuracy against known values, and are particularly focused on a new "bidirectional ammonia" component. They are able to simulate relatively accurate ammonium concentrations in the Mississippi River Delta.

The model uses data from two NADP networks (AMON and NTN) over multiple years and incorporates our gaseous ammonia measurements and wet deposition ammonium measurements into the model predictions.

2. Botero-Acosta, A., Chu, M. L., & Huang, C. (2019). Impacts of environmental stressors on nonpoint source pollution in intensively managed hydrologic systems. Journal of Hydrology, 579, 124056.

The objective of this study was to simulate the impacts of Water Management Practices on the sediment and nitrate-nitrogen (NO3-N) stream loads in an intensively managed agro-ecosystem watershed. The authors develop a basic model in Illinois to track the cycling of NO3-N in these systems. The authors predict that WMPs, such as crop rotation and cover crops, presented the highest reductions of simulated NO3-N and sediment load, respectively. They also predict that climate conditions had a strong impact on the transport of pollutants.

The authors used, as model input, the NADP wet depositional and precipitation measurements from our IL11 site near Champaign for multiple years.

3. Groshans, G. R., Mikhailova, E. A., Post, C. J., Schlautman, M. A., Cope, M. P., & Zhang, L. (2019). Ecosystem services assessment and valuation of atmospheric magnesium deposition. Geosciences, 9(8), 331.

These authors studied the ecosystem services from atmospheric magnesium (Mg2+) deposition which is a source of naturally-occurring fertilizer and liming material that is rarely considered in modeling. They conclude that the atmospheric magnesium deposition flow was valued at $46.7 million U.S. dollars ($18.5M wet + $28.2M dry) based on an average 2014 price of agricultural dolomite (CaMg(CO3)2). Additionally, this resource "plays an important role in the pedosphere".

The authors used the wet deposition and estimated dry deposition of magnesium from all continental NADP sites for years 2000–2015. This data use also included the dry deposition measurements from our Total Deposition effort.

4. Ilampooranan, I. (2019). Modeling nutrient legacies and time lags in agricultural landscapes: a Midwestern case study. Doctoral Dissertation, Civil and Environmental Engineering (Water), University of Waterloo.

Ilampooran (Dissertation) studied the legacy nutrient storage of nitrogen in the subsurface, built up over decades of fertilizer application which contribute to time lags between the implementation of best management practices and water quality improvement. Legacy effects are not well quantified. The author's goal was a model to quantify legacy stores and time lags in intensively managed agricultural landscapes in the Midwestern US. The author estimated that the subsurface legacy nitrogen storage as 33.3 kg/ha/yr, and determined it to be a significant component of the overall mass budget; approximately 31% of the fertilizer added to the watershed every year. The findings highlight that using additional data sources to improve hydrological consistency of distributed models increases their robustness and predictive ability.

The authors used wet deposition measurements from four NADP sites in and around Iowa, and used NADP ammonium and nitrate measurements for the years 1985 to 2012. The authors used NADP information to estimate county level N deposition to the study areas (basically Iowa).

5. Jeong, H., Pittelkow, C. M., & Bhattarai, R. (2019). Simulated responses of tile-drained agricultural systems to recent changes in ambient atmospheric gradients. Agricultural Systems, 168, 48-55.

University of Illinois scientists studied the field-scale hydrology, nitrogen (N) dynamics, and crop yields in two tile-drained fields under a corn-soybean rotation in Illinois. They modelled root-zone water quality under changing nitrogen concentration and deposition conditions. Changing nitrate concentration in rain water "demonstrated a moderate impact on N dynamics (e.g. nitrate losses to tile drainage increased up to 5.8% compared to the baseline scenario)" and had a small impact on field scale hydrology and crop yield. Also, this decrease may partially be related to the slight improvements in water quality in Illinois during the last decades.

NADP nitrogen deposition information was used from the IL11 wet deposition site for multiple years, and the NADP nitrate concentration maps for the continental US (1990-2015).

6. Piña, A. J., Schumacher, R. S., Denning, A. S., Faulkner, W. B., Baron, J. S., Ham, J., ... & Collett, J. L. (2019). Reducing Wet Ammonium Deposition in Rocky Mountain National Park: the Development and Evaluation of A Pilot Early Warning System for Agricultural Operations in Eastern Colorado. Environmental Management, 64(5), 626-639.

The authors investigated the impact of agricultural emissions of ammonia (NH3) deposition in Rocky Mountain National Park (RMNP), and an early warning system of agricultural ammonia moving into the park. The system uses trajectory analysis, meteorological data, and NADP wet deposition data recorded in the park. They concluded that the system accurately predicted 6 of 9 high N deposition weeks at a lower-elevation observation site, but only 4 of 11 high N deposition weeks at a higher-elevation site. They also determined that 75% of local agricultural producers voluntarily responded to alerts and altered their practices.

The authors used weekly observations of N deposition at two locations in/near the Park for multiple years (1985-present), and use the observations as part of their model warning input data.

7. Birdsey, R. A., Dugan, A. J., Healey, S. P., Dante-Wood, K., Zhang, F., Mo, G., ... & McCarter, J. (2019). Assessment of the influence of disturbance, management activities, and environmental factors on carbon stocks of US national forests. Gen. Tech. Rep. RMRS-GTR-402. Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Research Station. 116 pages plus appendices, 402pp.

The authors (including USDA scientists) have developed a modeling system to estimate standing carbon stocks in US National Forests, and for individual forests and regional areas. The InTEC model is a process-based biogeochemical model driven by monthly climate data, vegetation parameters, and forest disturbance information to estimate the relative effect of disturbance (e.g., fires, harvests, insect outbreaks, disease) and nondisturbance factors (climate, carbon dioxide concentration, nitrogen deposition) on forest-level C accumulation and fluxes. They conclude that carbon stocks are generally increasing in forests of the eastern US, and individual western forests are either increasing or decreasing depending on recent effects of natural disturbances and climate change.

Nationwide NADP data was used as an input to the model, including multiple years of data and all NTN sites.

8. Lu, C., Zhang, J., Cao, P., & Hatfield, J. L. (2019). Are we getting better in using nitrogen?: Variations in nitrogen use efficiency of two cereal crops across the United States. Earth's Future 7(8), 939-952.

The authors (including an ARS scientist) studied the nitrogen use efficiency in separate crops at the state level for corn and winter wheat. These two crops account for 50% of fertilizer use in the US. Efficiency use in corn begins to decline when N fertilizer application rate exceeds ~150 kg N ha−1 yr−1, and that yield response of winter wheat slows down with annual N fertilizer input above ~50 kg N ha−1 yr−1. However, nitrogen use efficiency in both crops has risen in recent decades, which could potentially reduce N loss from agricultural production. Furthermore, this study indicates that annual dynamics of N surplus in corn is closely tied with grain yields, while that in winter wheat significantly correlates with N fertilizer input.

The authors used all NTN site data for nitrogen deposition information (2000 and on), and used the measurement data to extrapolate back in time for deposition for periods before dense measurements were available.

9. Mikhailova, E. A., Post, G. C., Cope, M. P., Post, C. J., Schlautman, M. A., & Zhang, L. (2019). Quantifying and mapping atmospheric potassium deposition for soil

ecosystem services assessment in the United States. Frontiers in Environmental Science 7, 74.

The authors estimated the contribution of atmospheric deposition of potassium as a "provisioning value" to soil ecosystem services, based upon its value as an essential element and component of many fertilizers. Atmospheric deposition flows (wet, dry, and total) had a total provisioning ecosystem value of atmospheric potassium deposition was over $406 million U.S. dollars ($179M wet +$227M dry) per year based on a 5-year moving average of $500 per metric ton of potassium chloride (KCl) fertilizer in the U.S (over 10 years). The highest ranked regions for total value of $K^+$ deposition per year were: (1) West ($86.5M), (2) South Central ($80.4M), and (3) Southeast ($80.2M), with the highest value in (1) Texas ($44.3M), (2) California ($18.3M), and (3) New Mexico ($1.35M). The results of this study provide a methodology to estimate potassium deposition value for ecosystem services assessments, and for conducting nutrient audits at various scales to address the United Nations (UN) Sustainable Development Goals.

The authors used NADP's annual deposition of potassium maps (all sites) from 2000 through 2015.

10. Zikalala, P., Kisekka, I., & Grismer, M. (2019). Calibration and global sensitivity analysis for a salinity model used in evaluating fields irrigated with treated wastewater in the Salinas Valley. Agriculture 9(2), 31.

The authors investigated an irrigation salinity water quality model for use for soil salinization information. The goal was to estimate the impact on blending treated wastewater into irrigation water and its impact on soil salinity and on different crops (vegetables, strawberries, artichoke). The model did predict long-term salinity trends, but underestimated electrical conductivity. Using a 50 year simulation, salt loading was estimated to be quite high, but root zone salinity did not exceed current thresholds.

NADP's weekly electrical conductivity of precipitation data was used from the closest site to the agricultural fields (Pinnacles National Park), from 2000 to current.