

NADP Total Deposition Science Committee (TDep) Annual Report 2020

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Introduction

The National Atmospheric Deposition Program's (NADP) Science Committees focus on key areas of atmospheric deposition, scientific interest and/or applications. They are approved by the NADP Executive Committee and must be dissolved or renewed every four years. The Total Deposition Science Committee (TDep) was established in 2011 and the charter was most recently renewed in 2020. The TDep mission is to improve estimates of atmospheric deposition by advancing the science of measuring and modeling atmospheric wet, dry, and total deposition. TDep provides a forum for the exchange of information on current and emerging issues among atmospheric scientists, ecosystem scientists, resource managers, and policy makers. The committee is open to anyone interested in contributing to the mission. The specific charges of TDep are:

- Support the national networks that monitor atmospheric deposition by providing information on emerging measurement techniques, model development, and uncertainties associated with these approaches;
- Identify and prioritize knowledge gaps in the field of measuring and modeling atmospheric deposition and advocate for research to address those gaps;
- Coordinate with NADP's Critical Loads of Atmospheric Deposition (CLAD) Science Committee and other groups to advocate for the use of the most scientifically defensible deposition estimates for critical loads and other environmental assessments;
- Provide expertise and advice on present and potential decisions and regulatory actions pertaining to the field of measuring and modeling atmospheric deposition; and
- Encourage greater communication and collaboration between groups from different disciplines and countries with interests in atmospheric deposition.

Additional information can be found on the TDep website (<http://nadp.slh.wisc.edu/committees/tdep/>).

TDep is currently headed by two **Co-chairs**, Greg Beachley (U.S. Environmental Protection Agency; EPA/Office of Air and Radiation; OAR), and Katie Benedict (Los Alamos National Laboratory). Ryan Fulgham (EPA/Office of Research and Development; ORD) is the TDep **Secretary**. The TDep Steering Committee meets bi-monthly to establish meeting agendas, share information on upcoming opportunities for outreach, and identify project priorities. The **Steering Committee** is made up of past Co-chairs, Working Group leaders, and federal agency representatives. Steering Committee members include: Greg Beachley, Katie Benedict, Ryan Fulgham, Mike Bell (National Park Service; NPS), Amanda Cole (Environment Climate Change Canada; ECCC), Selma Isil (Wood), Chris Rogers (Wood), Kristi Morris (NPS), Melissa Puchalski (EPA/OAR), Bret Schichtel (NPS), David Schmeltz (EPA/OAR), Donna Schwede (EPA/ORD), John Walker (EPA/ORD), and Greg Wetherbee (U.S. Geological Survey; USGS).

TDep is organized into a workgroup format to provide structure and organization within the committee. This format helps to distribute workloads, provide more accessibility of projects and opportunities to committee members and promote more collaborative work. Descriptions and updates from these workgroups are included herein.

This annual report serves as a summary and quick reference for the activity, progress, and accomplishments of TDep over the course of 2020. It contains links to the biannual meeting notes, updates from each of the TDep workgroups, and descriptions and status updates on TDep-related products and research.

Annual Summary of TDep Accomplishments

It was another productive year for TDep. Below is a snapshot of the 2020 accomplishments.

The Science Committee charter was renewed by the Executive Committee in May 2020.

A Virtual Special Issue of Science of the Total Environment (STOTEN) on Reactive Nitrogen Deposition was published (<https://www.sciencedirect.com/journal/science-of-the-total-environment/special-issue/10L3T8MRVHD>) that included nine peer-reviewed articles that were related to the TDep White Paper. Co-chairs John Walker and Greg Beachley were guest editors for this issue. Specific references are listed in the Publications section of this report. The papers from the special issue can be found on the NADP website (<http://nadp.slh.wisc.edu/committees/tdep/reports/stoten/>).

The TDep White paper monthly webinar series was completed in 2020. This webinar was organized by the National Park Service (Mike Bell, Kristi Morris). Lead authors from the White Paper presented a summary of the current state of the science and research needs covered in their chapter. The webinars are recorded and can be found on the TDep website (<https://nadp.slh.wisc.edu/committees/TDep/webinars/>).

A summary of the presentations and proceedings of the 2019 TDep Workshop ‘*Connecting Stakeholder and Science Perspectives to Better Understand the Linkages Between Agriculture and Reactive Nitrogen Deposition*’ was authored by John Walker, Greg Beachley, and Selma Isil (https://nadp.slh.wisc.edu/committees/tdep/reports/2019tdepagworkshop/TDep_ag_Workshop_summary.pdf). In addition, the summary document lists key points from each session and a section on next steps for the Stakeholder Workgroup to further engage with the agricultural community.

General Updates

Katie Benedict was elected as TDep Co-chair at the Spring 2020 virtual TDep meeting.

Ryan Fulgham was elected as TDep secretary at the Fall 2020 virtual TDep meeting.

The Education and Outreach Subcommittee (EOS) enacted guidance that biannual meeting notes for each committee should be approved electronically approximately 6 weeks after convening to help meet committee objectives more effectively between each meeting.

Due to the pandemic, TDep held virtual meetings for the Spring and Fall 2020. Feedback was largely positive on the meetings. We hope to incorporate some level of remote broadcasting when in-person meetings are able to resume.

TDep Workgroup Updates

In 2019, TDep adopted a Workgroup structure in order to increase structure and organization, and to promote collaborative work. It is hoped that the new format will help to distribute workloads, make projects more accessible to a broader audience, and advance research between the spring and fall meetings.

The current workgroups include:

- Stakeholder Workgroup (Lead: John Walker)
- Measurement Model Fusion (MMF) Workgroup (Lead: Greg Beachley)
- Deposition Uncertainty Workgroup (Lead: Mike Bell)

TDep also hosted the Urban Deposition Science Committee (CityDep) chaired by Greg Wetherbee (US Geological Survey; USGS) at our biannual meetings. There are many overlapping objectives between CityDep and TDep, particularly in understanding urban deposition and its spatial variability to better represent urban deposition in the TDep maps.

Stakeholder Workgroup *Lead:* John Walker, EPA (walker.johnt@epa.gov)

Workgroup Objectives:

- Increase communication across scientific communities (i.e., atmospheric chemistry, ecology)
- Create new opportunities for collaborative research by promoting the inclusion of deposition science in grant programs
- Advance the integration of TDep science needs into existing research programs across stakeholder groups
- Facilitate communication among program managers within stakeholder Agencies and user groups

Examples of Current Projects (Project descriptions listed in TDep Project Tracker):

- Development of outputs from Fall 2019 TDep Workshop ‘Connecting Stakeholder and Science Perspectives to Better Understand the Linkages Between Agriculture and Reactive Nitrogen Deposition’ (<https://nadp.slh.wisc.edu/nadp2019/TDepworkshop.asp>). In addition to the workshop summary report mentioned above, a TDep agricultural stakeholder outreach plan is being developed and potentially a communication piece for an agricultural journal or trade magazine.
- Participation in USDA North Central Regional Development Committee Project developed by Rich Grant (Purdue University) and colleagues: ‘NCDC233 Sources and Fate of NH₃ Across the Region’.

Measurement Model Fusion Workgroup *Lead:* Greg Beachley, EPA (beachley.gregory@epa.gov)

The objective of this workgroup is to be the caretakers of the TDep MMF grids and product output. Workgroup members will conduct research and have discussions to ensure that the TDep MMF stays

current with the state of deposition science. The group will respond to any questions and requests involving the TDep MMF products. The workgroup will meet quarterly.

In 2020, the annual maps were produced using the 2019 measurement data (version 2018.02). This version still uses the 2002 to 2012 CMAQ v5.0.2 modeled time series. The grids and images are available at <https://nadp.slh.wisc.edu/committees/tdep/tdepmaps/>.

Examples of Current Projects (Project descriptions listed in TDep Project Tracker):

- Script transcription and modernization and transcription of the TDep Measurement Model Fusion (MMF).
- Incorporation of new CMAQ v5.3 time-series (2002 to 2017) into the updated TDep MMF scripts.
- A publication focusing on deposition trends estimated from the AML TDep MMF method for 2000 to 2018 is in preparation.

Deposition Uncertainty Workgroup

Lead: Mike Bell, NPS (michael_d_bell@nps.gov)

Workgroup Objectives:

- Evaluate the differences in deposition model outputs, deposition measurements, and actual deposition rates and how these vary along environmental gradients and across ecosystems.
- Assess deposition measurement methods (bulk precipitation collectors, ion exchange resin (IER) columns, snowpack, and lichen tissue) in comparison to modeled values.
- Evaluate deposition model estimates (CMAQ, TDep, CAMx, and ADAGIO) and compare to measurements to assess the spatial variability of uncertainty.
- Develop a framework to identify impacts of evaluating critical load (CLs) exceedances with a single deposition model when CLs were developed from different data sources.

Examples of Current Projects:

- Evaluation of how using different models (CMAQ, TDep, CAMx, and ADAGIO) impacts the exceedance of CLs in Class I areas (NPS-led).
- Downscaling deposition model data to land use type to develop more spatially explicit deposition data (EPA-led)

TDep Project Tracker

TDep uses the annual report to communicate a “TDep Project Tracker”. The objectives of the project tracker are to 1) allow TDep members to highlight research and products motivated by the TDep mission and 2) log ideas that cannot be currently acted on so that they are not lost. The TDep Project Tracker will be included in each year’s annual report and will be presented and discussed at biannual TDep meetings to solicit audience feedback and endorsement.

Research and products motivated by the TDep mission

- **AMoN Flux Characterization Pilot Study update**

A project is currently underway (EPA/Wood) to develop a methodology to estimate net and component NH_3 fluxes using two-week integrated NH_3 concentrations at AMoN sites. An EPA report is near completion (Spring 2021) that describes the Phase I measurements of micrometeorology, biogeochemistry, and canopy physical characteristics at three AMoN pilot sites: Duke Forest, NC; Bondville, IL; and Chiricahua National Monument, AZ. Phase II of the project is progressing, where Phase I measurements will be used to parameterize a bidirectional NH_3 model for implementation across the AMoN network, including assessment of uncertainties associated with the use of time-integrated concentration measurements, use of modeled meteorological inputs, and parameterizations of soil and vegetation emission potentials.

- **Reactive N flux measurements by eddy covariance**

Thermal and photolytic converter methods can be combined with fast nitric oxide chemiluminescence detection to quantify canopy-scale fluxes of reactive N by eddy covariance. A project is underway (EPA/Wood) to develop an inlet system for a two-channel chemiluminescence instrument for deployment at Duke Forest. The inlet system will include a photolytic converter for NO_2 , a heated molybdenum converter for total NO_y , and a heated stainless-steel converter for total reactive N. By employing dual chemiluminescence reaction cells, fluxes can be measured in one of two modes for continuous concurrent flux measurements of (Mode 1) NO_2 and total NO_y or (Mode 2) total NO_y and total reactive N. This combination of fluxes allows for assessment of the contribution of NO_2 to total NO_y fluxes and, by comparing total NO_y and total reactive N, the relative fractions of reduced versus oxidized forms of reactive N dry deposition. The Total N, NO_y , NO_2 converter/inlet system is undergoing laboratory testing at EPA with deployment at Duke Forest hardwood tower in Spring 2021.

- **Low-cost dry deposition system**

Datasets of dry deposition of reactive nitrogen are lacking due to the cost and complexity of online micrometeorological flux measurements. A low-cost dry deposition measurement system suitable for routine network operation is needed. EPA has constructed and is testing a conditional time-averaged gradient (COTAG) system for measurement of speciated dry deposition of reactive N (NH_3 , HNO_3 , HONO , NO_3^- , NH_4^+) on weekly to monthly time-scales. One COTAG system is currently deployed in Idaho. A second system with improved flow monitoring is complete and undergoing testing at EPA. It is planned to be sent to ID to replace the first system will return to EPA for flow component upgrades. Once completed, the system will be returned to ID. A third system will be constructed and deployed at Duke Forest in summer 2021. The design package for the EPA COTAG, including mechanical drawings, wiring schematics, field and lab SOPs, etc. is an official EPA deliverable with a due date of March 31, 2021. This package is for other groups interested in constructing and operating the COTAG. One of the systems will be used on the NCDC233 project starting in 2022.

- **Water soluble organic nitrogen aerosol pilot study status**

EPA and Wood are conducting a special study using data collected from five CASTNET sites: Great Smoky Mountain National Park, TN; Kickapoo Tribe in Kansas, KS; Rocky Mountain National Park, CO; Salamonie Reservoir, IN; and Washington Crossing State Park, NJ. The study involves analyzing the Teflon filter extracts (which captures particles) for total nitrogen. The Teflon filter is the first of three filters in the CASTNET filter pack's standard configuration. During 2019, methods were developed, and a Shimadzu total carbon/total nitrogen instrument was installed in Wood's Gainesville, FL laboratory. In early 2020, Wood analyzed samples measured between January through March. Water soluble organic nitrogen (WSO_N) is calculated as the difference between the total nitrogen measured by the Shimadzu and the particulate NO₃⁻ and NH₄⁺ measured using standard CASTNET methods. Currently, a 12-week study of more comprehensive testing of sample transport and storage effects on WSO_N is being conducted. Potential ways to characterize measurement bias due to volatility effects is also being researched.

- **Flux metadatabase**

TDep developed a questionnaire requesting input from scientists around the world regarding completed flux measurement campaigns. The goal of this effort was to collect metadata for different studies including Principal Investigator, location, parameters measured, land use and cover, relevant publications, etc. John Walker distributed the questionnaire to his list of colleagues and multiple responses were received. Outreach continued during 2020 and to-date there are 14 studies included in the metadata database. The questionnaire will be published on the NADP TDep website along with an online questionnaire that will make it easier for future entries to be included.

- **Improving characterization of reduced nitrogen at IMPROVE and CSN monitoring sites**

The goal of increasing reduced nitrogen measurements remains important for the TDep community and is shared by other monitoring groups and existing networks. There has been interest over the years in exploring the use of acid-impregnated filters that could be added to sites in existing networks such as IMPROVE and CSN. Chen et al. (2014) used acid-impregnated filters deployed as part of the IMPROVE at sites primarily in Colorado and other western states. EPA, NPS, and Wood collaborated to run a similar set up for IMPROVE equipment plus a CSN module with an impregnated filter during the 2017 warm season at two sites in the southeastern United States (Duke Forest, NC and Gainesville, FL). Data analysis occurred during late 2017 and 2018, and a summary report was completed during 2019 (<https://www.epa.gov/castnet/castnet-special-studies>). Additional testing of the cellulose filters is needed to identify if there are biases introduced caused by the filter ratings, but due to the pandemic the EPA laboratory is not fully staffed. Evaluation of the filters will resume at a future date.

- **Developing Fact Sheet on White Paper**

Current effort to highlight the TDep White Paper in a 1-page fact sheet is completed and was led by Kristi Morris. The fact sheet focuses on visuals and discussion of research areas and projects that will address key scientific knowledge gaps that will require collaborative efforts between multiple agencies and scientific groups. This material is discussed in more detail in the White Paper section 4 "Enhanced Coordination to Address Stakeholder Issues and Resource Needs".

- **WMO Measurement-Model Fusion for Global Total Atmospheric Deposition Initiative**

TDep members Amanda Cole and Donna Schwede are members of a steering committee for the WMO initiative MMF-GTAD. The long-term goal of this initiative is to produce high-quality maps and estimates of fluxes of atmospheric pollutants on a global scale in a semi-operational manner, drawing from the methods and expertise of TDep and other regional MMF deposition products. Short-term projects include an overview paper, an initial proof-of-concept set of maps for a single year, and extension of a Swedish MMF product over Europe. The overview paper was submitted in early 2021 to Environmental Science and Technology. A formal project implementation plan was drafted and will be published by WMO in early 2021. Work on the global proof-of-concept maps has begun under the leadership of Jeff Geddes (Boston University), with products expected in 2022.

- **Nitrogen deposition from Agricultural sources and development of Stakeholder engagement plan (Stakeholder Workgroup)**

An outcome from the Fall 2019 TDep Workshop ‘Connecting Stakeholder and Science Perspectives to Better Understand the Linkages Between Agriculture and Reactive Nitrogen Deposition’ was for the development of a Stakeholder engagement plan. Some background information and some early progress was presented at the 2020 Fall meeting by Anne Rea, EPA. The initial focus will be on closer engagement with the agricultural community.

- **Script transcription and modernization and transcription of the TDep Measurement Model Fusion (MMF) (Measurement Model Fusion Workgroup)**

The TDep MMF script conversion project is nearing completion. The work was included in EPA’s Clean Air Status and Trends Network (CASTNET) Operations contract with Wood using Sonoma Technology, Inc. (STI) as a subcontractor. The new code is written in Python and ArcPy and requires ArcGISPro 2.4 or higher. The scripts are currently under revision for accuracy compared with the 2010 AML output and will be posted to the TDep website after they are assigned a DOI. A document identifying differences in the methods due to improvements (e.g. a correction to handling of the CMAQ datum, and a new standardized grid size of 4 km²) in the method is in preparation. Due to the adjustments, the archived AML grids will still be made available on the TDep website. The work was summarized in a presentation by Changsy Chang (STI) at the 2020 Fall Science Symposium.

- **Measurements of NH₃ and other reactive N dry deposition fluxes in Rocky Mountain National Park (RMNP)**

A new project funded through a Regional Applied Research Effort (RARE) grant is beginning between EPA ORD, EPA Region 8, NPS and Colorado State University (CSU) to measure NH₃ and other reactive N dry deposition fluxes in RMNP and along the NH₃ transport path from agricultural sources on the Front Range to the Park. Measurements to begin Spring 2021.

- **Use of TDep MMF in estimating N loads from urban environments (Greg Wetherbee, USGS, CityDep)**

Measured urban deposition data collected in the South Platte River area was used in combination with TDep MMF estimated deposition data. The data was input into the SPARROW model to

estimate urban fractions of N deposition to the South Platte River watershed. Preliminary results were presented at the 2020 TDep Fall meeting.

- **Sensitivity of critical loads to modeled deposition estimates (Mike Bell, NPS; Deposition Uncertainty Workgroup)**

A new project from the NPS (Mike Bell), US Forest Service (Mark Fenn), and San Francisco State University (Leora Nanus) comparing measured values of N and S throughfall to TDep model outputs from corresponding years. The initial phase of the study is will compare deposition measurements from IER columns in the western US to modeled data. Researchers will assess conditions on where measurements align best in hopes of advancing our understanding of model uncertainty.

- **Using epiphytic lichen tissue nitrogen content to understand TDep uncertainty in the Pacific Northwest (Deposition Uncertainty Workgroup)**

A new project with the NPS (Mike Bell), US Forest Service (Linda Geiser), and Washington State University (Dave Evans/Meaghan Petix) using tissue nitrogen concentrations from epiphytic lichen species as bioindicators of deposition. Developing relationships between tissue N, tissue isotopic concentration, and deposition values should allow researchers to assess consistency of tissue to model values and better understand deposition patterns on a fine scale.

- **Using downscaled N deposition model estimates to evaluate critical loads (Deposition Uncertainty Workgroup)**

A new project with the NPS (Mike Bell) and the EPA/ORD (Jesse Bash/John Walker) to assess differences in critical load exceedances based on the scale at which deposition is modeled. Phase I of this project will use land-use specific dry deposition estimates at a 500m scale developed for the Chesapeake Bay to assess changes to critical loads exceedances at Shenandoah National Park and the George Washington-Jefferson National Forest. Exceedances will be compared to TDep total N estimates. Depending on results additional analyses will be performed in areas with more variable land use and different dominant tree species.

Outlook for 2021 research and products motivated by TDep mission

- **Testing of the NADP total N / total P wet deposition sampler**

The Wisconsin State Laboratory of Hygiene (WSLH) is developing a collector and analytical methods for measurement of total water soluble nitrogen (WSON) and phosphorous (P) in precipitation. The prototype collector fits on the outside of the NTN bucket and is pre-charged with acid to avoid microbial processing of N and P.

- **Incorporation of new CMAQ v5.3 time-series (2002 to 2017) into the updated TDep MMF scripts (Measurement Model Fusion Workgroup)**

Kristen Foley (EPA/ORD) is leading the EPA's Air QUALity Time Series Project (EQUATES) which will provide a CMAQ v5.3 time-series (2002 to 2017) dataset of concentration and deposition data over the contiguous US for incorporation into the TDep measurement model fusion (MMF) product. Kristen

provided a project overview at the Spring TDep biannual meeting. An “anchor year” of 2010 dataset was provided in Q1 of 2021 and will be used to quantify any changes that result from the new dataset.

Project ideas that maybe investigated for TDep in the future

- **Incorporation of CMAQ wet deposition data into the TDep MMF model (Measurement Model Fusion Workgroup)**
- **Investigation of measurement bias in the NCON precipitation collector (Greg Wetherbee, USGS)**
- **Incorporation of measurement data from intensive studies into TDep MMF model estimates (Measurement Model Fusion Workgroup)**

Initial ideas for inclusion of NO₂ data from SLAMS, measurements of passive NH₃ in the Greeley, CO area, throughfall measurements, and deposition in urban areas.

- **NSF RCN proposal (Leora Nanus, Alexandra Ponette, and Pam Templar; CityDep)**

TDep 2020 Publications

References for Virtual Special Issue of Science of the Total Environment

(<https://www.sciencedirect.com/journal/science-of-the-total-environment/special-issue/10L3T8MRVHD>) are listed below for papers with a publication date of 2020:

- John T. Walker, Gregory Beachley, Leiming Zhang, Katherine B. Benedict, Barkley C. Sive, Donna B. Schwede. 2020. A review of measurements of air-surface exchange of reactive nitrogen in natural ecosystems across North America. *Sci. Tot. Environ.* 698. 133975. <https://doi.org/10.1016/j.scitotenv.2019.133975>
- Rodolfo Sosa Echeverria, Ana Luisa Alarcón Jimenez, María del Carmen Torres Barrera, Pablo Sánchez Alvarez, Monica Jaimes Palomera, Elias Granados Hernandez, David Gay. 2020. Sulfur and nitrogen compounds in wet atmospheric deposition on the coast of the Gulf of Mexico from 2003 to 2015. *Sci. Tot. Environ.* 700. 134419. <https://doi.org/10.1016/j.scitotenv.2019.134419>
- Jordan Baker, William H. Battye, Wayne Robarge, S. Pal Arya, Viney P. Aneja. 2020. Modeling and measurements of ammonia from poultry operations: Their emissions, transport, and deposition in the Chesapeake Bay. *Sci. Tot. Environ.* 706. 135290 <https://doi.org/10.1016/j.scitotenv.2019.135290>