NADP TDEP Fall Meeting 2024

TDep 2024 Fall Meeting Agenda
9:00AM – 12:00PM CT on November 5, 2024

Agenda

9:00	Housekeeping and Introductions
9:15	Recap of Spring 2024 (*Amanda Cole, ECCC*)
9:20	Measurement Workgroup Update (*Bret Schichtel, NPS; Kristi Morris, NPS*)
9:50	Presentation: Total Water Soluble Organic Nitrogen and Sulfur measured in Chemical Speciation Network (CSN) and Interagency Monitoring of Protected Visual Environment Network (IMPROVE) Fine Particulate Samples (*Tracy Dombek, RTI*)
10:05	Presentation: N deposition in complex terrain: New monitoring site installation and modelling research (*Christine Braban, CEH*)
10:25	Update from CLAD ozone WG (*Kris Novak, EPA*)
10:30	BREAK
10:45	Stakeholders Workgroup Update (*Ian Rumsey, EPA*)
10:55	Measurement Model Fusion (MMF) Workgroup Update (*Greg Beachley, EPA*)
11:15	Presentation: Update on Canada's ADAGIO project (*Irene Cheng, ECCC*)
11:30	Updates from EOS (*Chris Rogers, WSP*)
11:35	Discussion: Current WMO GAW activities and how infrastructure could be leveraged (*John Walker, USDA; Amanda Cole, ECCC*)
11:55	Nomination and election of TDep secretary
12:00	CLOSE

Attendance list and slide presentations are included at the end of this document.

Notes

Spring 2024 TDep Meeting Highlights (Amanda Cole, ECCC)

- Spring 2024 TDep Meeting minutes: https://nadp.slh.wisc.edu/wp-content/uploads/2024/06/tdep2024spr.pdf
- Virtual meeting limited to general and workgroup updates, round table of research updates
- MMF WG update:
    - New TDep maps version 2023.01 published
    - Decision to pursue 1-year graduate student APHL fellowship with UW
    - Separation of TDep *trends* vs. *research* products
    - Version comparison and uncertainty
- Measurements WG:
    - Hosted deposition monitoring workshop

- Stakeholders WG:
    - Provided details of fall 2024 Agricultural Stakeholders webinar series
- EOS update:
    - Shifting focus away from social media
    - Aiming to release updated TDep Fact Sheet by Fall Meeting
    - Exploring additional fact sheets for specific topics, generic slides on NADP for wider use
- Updates since Spring Meeting
    - TDep Charter renewal
        - Motion to renew was approved at Executive meeting May 3
        - TDep will next be up for renewal in Spring 2028
    - Website updates (https://nadp.slh.wisc.edu/committees/tdep/:
        - 2024 Spring meeting minutes posted
        - 2023 Annual report posted
        - Stakeholders Workgroup – first webinar recording
    - NADP Newsletter
        - New product to update the community between meetings
        - TDep content highlighted white paper on measurements workshop and stakeholder workgroup webinars

Measurement Workgroup (Bret Schichtel, NPS; Kristi Morris, NPS)

- **See slides at the end of this document.**
- 2024 Activities (from slide deck)
    - SNiPiT (measure total N and P) evaluation study
    - Measurement of smoke tracers (BC, Levoglucosan) in wet deposition samples
    - Southeastern US winter nitrate study
    - Workshop on Nitrogen and Phosphorous Measurement
- Questions
    - Melissa – are the two sites for the SE intensive study included in Katie's study to evaluate Alpha vs. Radiello samplers at a few collocated sites? Katie does not think so. SE will have the continuous NH3, could add some passives if needed since that would be easy. There has been an AMON site at the Great Smoky Mountains NP since 2011.
    - Question about measuring BC and levoglucosan to relate to smoke impacts --Are there plans to incorporate other monitoring data, satellite data, and modeling to help understand smoke contributions that are represented in these measurements? Satellite could be used to get better information about smoke events.
        - John Walker – Yes other monitoring data will be used because measuring smoke impacts on wet deposition samples is difficult. We will look at IMPROVE and CASTNET speciated data to identify smoke events. Will be Using NOAA smoke product and co-located PM data to know which NADP samples were smoke impacted. In terms of satellite that is not a focus of the effort at this point. We could look at emissions inventories for information on trends in fire emissions over time and if those trends can be linked to trends in fire impact on wet deposition.
    - Stu Weiss

- Recommend looking at Sommer et al., 1991 publication as a method for validating modeling of ammonia. Found Rye grass canopy has 0 surface resistance. NH3 gets absorbed right into the stomata. (Sommer, S.G. and Jensen, E.S., 1991. *Foliar absorption of atmospheric ammonia by ryegrass in the field* (Vol. 20, No. 1, pp. 153-156). American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America. https://doi.org/10.2134/jeq1991.00472425002000010024x)
- A good case study to demonstrate importance of deposition measurements is grass allergy problem in CA. Greater biomass means greater pollen. Even if water limited, the grasses use the excess N to produce more pollen. Million-billion dollar and misery impact.
- Urban ammonia from light duty vehicles needs a lot more resolution. Urban ammonia measurements would be useful b/c being underestimated in emissions inventories.

Presentation: Total Water Soluble Organic Nitrogen and Sulfur measured in Chemical Speciation Network (CSN) and Interagency Monitoring of Protected Visual Environment Network (IMPROVE) Fine Particulate Samples (*Tracy Dombek, RTI*)

- **See slides at the end of this document.**

- Conclusions (from slide deck):
    1. Measurements of Total Water Soluble Organic Nitrogen (TWSON) are possible in IMPROVE and CSN samples with a background subtraction
    2. There will be geographic differences depending upon the source, further work is needed to explore seasonality and geographic trends in the data.
    3. The simultaneous analysis of Total Water Soluble Nitrogen (TWSN), NOx and Ammonium are important as we can experience losses of nitrogen in samples and this method provides a TWSON fraction that is not biased by analysis conducted on different days.
- Questions
    1. Are these additional N measurements rather than what you were initial measuring?
        a) Yes, these samples were taken in one day, they are not compared to the routine NH4+ and NO3- data. Did compare them internally and the compared pretty well.

Presentation: N deposition in complex terrain: New monitoring site installation and modelling research (*Christine Braban, CEH*)

- **See slides at the end of this document.**

- Summary and next steps (from slide deck):
    1. We have applied a fog deposition parametrisation and calculated fog deposition of pollutants from EMEP4UK output for 2021 which is a solid foundation for future improvements. The fog parametrisation can be applied to any wet depositing pollutant modelled in EMEP and for any year.

2. In the next steps of the project, we will examine possible improvements to the fog deposition scheme (specifically the application of Henry's law).
3. We will also run EMEP4UK with 2024 meteorology at the higher resolution of 1 km x 1 km around the new measurement sites to match the measurements collected by the sites set up in our parallel project.
4. The chemical analysis of rain and fog samples collected at the newly set up sites will allow us to assess if the assumptions made for the ratio between rain and fog ion concentration in the CBED parametrisation are valid for current UK conditions.
5. We will develop series of recommendations for the model investigated in this study and more general scientific evidence and model process development requirements needed in future to accurately model fog chemistry and fog-driven occult deposition in the UK.
6. It is becoming evident that a new focus on hourly and daily resolution of pollution deposition is needed to underpinning methods to mitigate annual deposition levels.
7. Progress in this area will lead to a step change in capability to identify and change drivers of N-deposition in complex terrain.

- Questions
    1. Mike Bell – Do you have any bio monitors of lichen or mosses in this complex terrain to capture some of the more locale changes and uptake by the ecosystem?
        a) Not in this project. Do have several moorlands which are rain fed. We are looking at lichen diversity as you go across the N deposition gradient. It should be looked at. One of the reasons we've gone to Enerdale is because it is seen as the most pristine ecosystems in England and local officers are reporting that they are seeing species change but they do not have deposition monitoring there. Hopefully in a year will be able to link across the biodiversity indicators up the slope as well, and across some of the elevated moorlands, which should, in theory, be away from direct agricultural deposition. Even in our national parks there is a lot of agriculture, of different intensity. Separating out local deposition impacts on lichen biodiversity and grass inclusion will be interesting. We're staring to look at diversity of algae on some of these atmospheric fed ecosystems to understand what is 'normal' and what indicates that the N balance is out of sync.
    2. What is the timeframe for the measurements, is this a short or long-term effort?
        a) The aim is to keep them running for all of 2025 and then decide whether we will extend the measurements in the medium term using the original monitoring set up or shift to a long-term monitoring plans where we align with national monitoring networks. Will have to make this decision in 9 months and then request for funding as needed.

Update from CLAD ozone WG (*Kris Novak, EPA*)

- Project to look at Forest Inventory and Analysis (FIA) data in relation to the analysis by Horn et al. (https://doi.org/10.1371/journal.pone.0205296) and do a similar analysis for ozone to tease out ozone effects on tree species across the US. This analysis requires interpolated ozone data to get W126 values at all locations.

- Another effort by Jason Lynch has a similar approach of trying to apply some of the growth reduction and exposure response information from recent studies to look at ozone risk in the eastern US, as it relates to emissions reductions.

- The Ozone Garden Network is a collaboration between NOAA and NASA that supports community science efforts to observe and track leaf damage https://www.cgd.ucar.edu/research/ozone-garden/). Will be expanding thanks to additional funding.
- NAAQS ozone review has started. In early stages of that review; no deadlines yet. Will continue to share updates as the review progresses.
- Ozone in national parks and work there that Emmi and others have been doing considering W126 and NLCD40 and ozone flux measurements.
- Any additional questions reach out to Kris Novak or Emmi Felker-Quinn.

Stakeholders Workgroup Update (*Ian Rumsey, EPA*)

- Workgroup Members:
  Ian Rumsey, John Walker, Greg Beachley, Anne Rea (EPA)
  Greg Zwicke, Peter Vadas, Allison Costa (USDA)
  Kristi Morris (NPS)
- Agricultural Stakeholders Webinar Series: ***Atmospheric Nitrogen Deposition: Sources, Impacts, and Management***
  - Agricultural stakeholders' webinar series was linked to a preceding Livestock & Poultry Environmental Learning Community (LPELC) webinar on the role of agriculture in nitrogen deposition.
  - LPELC webinar was held on September 20th (see webinar flyer on slide 2)
  - Opportunity to reach out to stakeholders we might not typically engage with
  - Introduced stakeholders to the topics that will be expanded upon in the NADP-TDEP Ag. Stakeholders Webinar Series, thus promoting our own webinar series.
- Agricultural Stakeholders Webinar Series: ***Atmospheric Nitrogen Deposition: Sources, Impacts, and Management***
  - First webinar was on October 9th and recording is available here: https://nadp.slh.wisc.edu/tdep-ag-stakeholder-1/
  - Diversity in stakeholders that registered for the first webinar
  - Second webinar will be on Wednesday November 20th at 2-3pm ET: https://nadp.slh.wisc.edu/tdep-webinar/
    - Charles Driscoll will present material from his recent publication with a focus on critical loads ("Atmospheric Reduced Nitrogen: Sources, Transformations, Effects, and Management")
  - Third webinar on the management of ammonia emissions and deposition in January 2025
    - Greg Zwicke from USDA-NRCS

Discussion

- Ian: We plan to send out more reminders of the webinars the week/day before to help increase attendance. Oct webinar had over 50 registered but only about 20 attended. Expect better attendance next time when reminders are sent out. Main goal is to reach non-NADP stakeholders.
- Stu Weiss: We are doing a session at AGU in December A21B and A33E Air pollution from Agriculture and Bio-atmospheric N Cycle, Charles Driscoll is one of our invited speakers so you can see him in person.

Measurement Model Fusion (MMF) Workgroup (Greg Beachley, EPA)

- **See slides at the end of this document.**
- Outline (from slide deck)
  1. Recap from Spring TDep MMFWG and Progress on Version status
  2. Results from 2023 data
  3. Weekly Wet Deposition
  4. UW APHL Fellow progress
  5. Wildfire Deposition
  6. IMPROVE and CSN Sulfate
  7. Deposition Uncertainty
- Current TDep MMF Project Prioritization (from slide deck)
  1. Incorporating weekly PRISM precipitation data and CMAQ wet deposition
  2. Development of a protocol for replacement of missing observation data using spatial and temporal statistical analyses of past trends ***Potential APHL project
     a) May extend this to discontinuing sampling and monitoring sites (e.g. Bias adjustment)
  3. Extending the framework and capability of TDep MMF to utilize more measurement data
     a) AMoN NH3 concentrations coupled with method for incorporating bi-directional modeled dry deposition fluxes
     b) Concentration measurements from long-term nationally distributed networks (CSN, IMPROVE, SLAMS NO2)
     c) Concentration and direct flux measurements from local intensive studies (e.g. Urban, Throughfall, lichens, COTAG)
     d) New concentration measurements (e.g. wet soluble organic N)
     e) relative spatial concentration gradients from satellite data
  4. Analysis of concentration samples impacted from smoke- events to estimate excess deposition fluxes from wildfires
     a) Building on an existing EPA ROAR project
  5. Conduct statistical analyses to roughly quantify areas of high uncertainty in deposition fluxes Building a base understanding of sources of uncertainty, and their relative magnitudes
     a) Using current capabilities and resources to run a 'Leave One Out' analyses on TDep MMF
- Request for TDep MMF data accessibility using an on-line access tool
- Questions
  - Amanda – [In reference to issue of loss of CASTNET sites impacting bias adjustment field] Have you considered using SO2 from AQS urban sites to see if this would resolve the bias issues cropping up?
    - Greg will check to see what measurements are available.
    - Amanda says AQS SO2 measurements are used in Adagio.
  - Yong – [In reference to slides showing percent difference of 2023 SO2 deposition flux minus 2020-2022 averages] 2023 is quieter for wildfires in US but there are some big fires in the previous 3 years. Do you think that smoke impact on total deposition is minor or not yet capturing this impact.
    - Greg: Wildfires could be a big impact in comparing 2023 to 2020-2022 average. We have different sampling conditions but we are using the same modeling year. This

means all the differences are all coming from measurements and those measurements for 2023 are definitely different from the 3-year average. Wildfire could be a driver of differences but would need to look to see where on the map are the differences and are they consistent with a wildfire signature.

- From the chat:
    - Colleen: I'm curious about the update to the interpolation radius (may be a question for Kristen). Is that using the same method as in Schwede & Lear 2014, based on CMAQ spatial covariances (I assume for more recent years)? Are the updated radii based on a specific year?
        - Kristen: I am still working on this but I have it coded to find the radius by year and season for the entire EQUATES timeseries so we can see how much these changes across time before deciding on what radius to use. And yes, it is based on fitting the sample correlogram and finding the distance at which the data reach a certain correlation level.
        - Greg - Hi Colleen, the update to the interpolation radius is the same as Schwede & Lear. I believe that we are considering seasons for all years.
    - Stu Weiss - There are obvious footprints of fires - remote areas in CA have high deposition for single years that carry over into the three-year averages
    - Stu Weiss - Sorry to keep bringing this up, but is there an accepted correction for underestimation of vehicular ammonia emissions?
        - Greg: TDep does not use any correction to the underestimation of vehicular emissions. I am unsure if this included in EQUATES dataset that we are using
        - Kristen: The EQUATES CMAQ simulations used in TDEP used onroad mobile emissions from the Motor Vehicle Emissions Simulator version 3 (MOVES3). Since the completion of the EQUATES project a new MOVES version is now available, MOVES version 4. Improvements in MOVES4 include a substantial increase in ammonia (NH_3) emissions from onroad gasoline and diesel vehicles that have a notable impact on PM emissions (Sonntag et al., 2021). So the punchline is that the current EQUATES-based TDEP products did not use a correction for vehicular ammonia emissions, but more recent simulations of CMAQ do have this correction included.

Presentation: Update on Canada's ADAGIO project (*Irene Cheng, ECCC*)

- **See slides at the end of this document.**
- Major ADAGIO Updates (from slide deck)
    - ADAGIO methods manuscript – Part 1 focuses on general methodology and wet deposition MMF (under review[1])
        - 3 papers planned (Atmospheric Environment)
    - Ongoing development of a routine ADAGIO product – produce high-resolution total S and total N deposition maps on annual basis
- ADAGIO Applications (from slide deck)
    - Reporting on Canadian Ecosystem Health Indicator: estimate critical loads exceedance using ADAGIO and track changes over time to assess changes in ecosystem health (first goal is to derive a baseline CL exceedance value to compare against future values)
    - Provide annual total deposition maps for the scientific community and supporting policy development

- Produce historical ADAGIO using GEM-MACH reanalysis (1990-2019)
- Improve GEM-MACH model through mapping of analysis increments

EOS (Chris Rogers, WSP)

- Updated TDEP fact sheet is now available on the website: https://nadp.slh.wisc.edu/wp-content/uploads/2024/11/TDep_Factsheet_2024.pdf
- Great job everyone on providing information for the new newsletter: https://nadp.slh.wisc.edu/filelib/eos/eos-newsletter-fall2024.html
- There will be another opportunity to include TDEP updates the next Newsletter in February.

Discussion: Current WMO GAW activities and how infrastructure could be leveraged (*John Walker, USDA; Amanda Cole, ECCC*)

Update on GAW's Measurement-Model Fusion for Global Total Atmospheric Deposition (MMF-GTAD) Initiative - Amanda Cole

- **See slides at the end of this document for additional details.**
- MMF-GTAD current activities
    - Evaluation of routine global AQ models (ECMWF-CAMS and GEOS-CF) for (a) deposition accuracy and (b) suitability for routine MMF
    - Development of an ozone deposition tool with options for different land cover, meteorology, dry deposition schemes – exploring sensitivity to some of these options. Would like to extend to calculating metrics but project is not yet funded.
    - Exploration of AI methods for MMF
    - Long-term vision document laying out Initiative structure, activities and budgets for next 5-6 years
    - Production of Case for Support and "market research" interviews with outside contacts to develop a fundraising package and strategy (contractor)
    - Adding global precipitation chemistry data to GHOST database (BSC): single source of data for wet and dry global atmospheric deposition calculations
    - Collaboration with GESAMP on deposition to oceans and coastal areas research planning (2025 workshop)
    - Meeting next week to plan 2025 and 2026 activities

World Meteorological Organization Global Atmosphere Watch Science Advisory Group for Total Atmospheric Deposition (SAG-TAD) – John Walker

- **See slides at the end of this document for additional details.**
- SAG-TAD
    1. Facilitate research related to the total atmospheric deposition working closely with the relevant international programs and projects, as well as joint activities with other major environmental science activities including ambient aerosol and gas monitoring, atmospheric modelling, ecosystem effects research, climate research, etc.;

2. Coordinate work related to quantification of the patterns and trends of the composition of precipitation and total deposition on global and regional scales and produce regular assessments;
3. Provide guidance on the development of the methods for the estimation of the total atmospheric deposition with a specific focus on dry deposition and feed those scientific developments to MMF-GTAD initiative;
4. Improve understanding of atmospheric deposition of chemical species of existing or emerging interest
5. Promote the establishment of the new sites, field laboratory and data management operations.

- Development of WMO Guidance for Measuring and Modeling Dry Deposition
    1. SAG-TAD has had a historical focus on wet deposition (interlaboratory comparisons, assessments).
    2. Dry deposition becoming more of a focus
    3. A subset of members are developing a paper to serve as the basis for a more detailed set of WMO guidance
    4. John Walker, Marsailidh Twigg, Chris Flechard, Christian Brümmer, Jianlin Shen, Da Pan
    5. Timeline is to have manuscript drafted by April, 2025
- Strategy for Measurements and Inferential Modeling to Improve Understanding of Ozone, Reactive Nitrogen and Sulfur Dry Deposition at the Global Scale
    1. Review of flux measurement methods
        a) Recommendations on standardization of flux data processing and QA/QC reporting
    2. Review of inferential modeling approaches
        a) Requirements (measurements) for:
            - Atmospheric composition
            - Meteorology
            - Turbulence and energy balance
            - Ecosystem characteristics
        b) Decision framework for modeling strategy
    3. Review of regional and global networks that may be leveraged for inferential modeling and new flux measurements:
        a) Atmospheric composition
        b) Wet deposition
        c) Biometeorology
        d) Carbon, water, energy fluxes
    4. Description of tiered monitoring approach
        a) Tier 1 – High resolution continuous flux measurements
            - Small number of super sites in select locations
            - Provide data for improving process-level understanding of bi-directional exchange and models
        b) Tier 2 – Low-cost direct flux measurements (e.g., COTAG)
            - Intermediate number of sites in select locations

  - Lower time resolution data to characterize deposition budgets and spatiotemporal patterns.
   c) Tier 3 – Air concentration and supporting measurements for inferential modeling of bi-directional exchange
      - Large number of sites
      - Fill geographical gaps in flux measurements to help characterize spatiotemporal patterns
      - To be validated at Tier 1 sites
   d) Goals:
      - Introduce concept of tiered strategy
      - Identify current relevant infrastructure and opportunities for collocation
      - Identify capacity needs (e.g., geographical gaps, need for new monitoring (NH_3), etc)
5. Outcomes
   a) Establish groundwork for more detailed WMO documentation/guidelines for measuring and modeling dry deposition
   b) Justify and demonstrate need and feasibility for tiered monitoring strategy for dry deposition
      - Proposal development
      - Cross-network cooperation
   c) Engage with Science Advisory Groups for Aerosols and Reactive Gases to identify candidate GAW sites (fluxes and inferential modeling)
   d) Support MMF-GTAD
      - Develop info on availability of reactive gases datasets for MMF-GTAD initiative
      - Opportunity for MMF users to inform capacity needs
      - Motivate development of new flux datasets for CTM evaluation

Nomination and election of TDep secretary

- Amanda Cole (ECCC) is rotating off as co-chair – Thank you, Amanda, for your service!!
- Colleen Baublitz (EPA) and Kristen Foley (EPA) will be co-chairs for the upcoming year.
- Colleen nominated Dr. Da Pan for TDEP Secretary
  1. Dr. Da Pan is an Assistant Professor in the School of Civil and Environmental Engineering, Georgia Institute of Technology. He completed his B.S. at Peking University, where he studied the impacts of international trade on redistributing air pollutants. The work received the Cozzarelli Prize (the Paper of the Year Prize) from PNAS. He received his Ph.D. in Civil and Environmental Engineering from Princeton University. His Ph.D. focused on instrument development and field observations of air pollutants and greenhouse gases. He also obtained a Science, Technology, and Environmental Policy Certificate from the School of Public and International Affairs at Princeton University. Dr. Pan later became a postdoctoral fellow and research scientist in the Department of Atmospheric Science, Colorado State University, where he continued his work on air pollution and nitrogen deposition. His current research at Georgia Tech focus effectively managing

atmospheric carbon and nitrogen cycles and reducing air pollution that harms human and ecosystem health.

- The nomination was approved by the TDEP committee. Welcome, Da!

Attendees (31 in person; 31 online)

Amanda Cole (Co-Chair)
Colleen Baublitz (Co-Chair)
Kristen Foley (Secretary)
Amy Mager
Annareli Morales
Anne Marie Macdonald
Beck Dalton
Bret Schichtel
C Collins
Chris Florian
Chris Rogers
Christine Braban
Courtney Stanley
Da Pan
Dakota DeLong-Maxey
Doug Burns
Eladio Knipping
Gary Yip
Georgia Murray
Ginger Tennant
Greg Beachley
Hazel Cathcart
Ian Rumsey
Irene Cheng
Jason lynch
Jason O'Brien
Jayde Alderman
Jean Steele
Jeff Collett
Jesse Bash
Jim Renfro
John Walker
Justin Coughlin
Kat McKinnon
Katherine Ko
Katie Blaydes
Kayla Wilkins
Kenneth Brice

Kevin Mishoe
Kristi Morris
Kristopher Novak
Kulbir Banwait
Lourdes Pineda
Mark Kuether
Melissa Puchalski
Michael Barna
Mike Bell
Mike McHale
Naomi Tam
Nate Topie
Noel Deyette
Ryan McCammon
Sam Simkin
Selma Isil
Stacy Knapp
Stu Weiss
Tracy Dombek
Vincent Vetro
Weiti Tseng
Yayne Aklilu
Yongqiang Liu
Yuan You

TOTAL DEPOSITION MEASUREMENT SUB COMMITTEE REPORT OUT

Bret Schichtel and Kristi Morris

National Park Service – Air Resource Division

2024 Fall TDEP Meeting, Duluth, MN

2024 Activities

- SNiPiT (measure total N and P) evaluation study
- Measurement of smoke tracers (BC, Levoglucosan) in wet deposition samples
- Southeastern US winter nitrate study
- Workshop on Nitrogen and Phosphorous Measurement
- Others?

Wet Deposition Sampler for Nitrogen and Phosphorus in Total (SNiPiT) Evaluation Study

- **Objective**
  - Assess measurement uncertainty and biases
  - Optimize sampling protocols for use in remote and high alpine environments
- **Location(s) and Time**
  - CSU Christman field and Duke Forest, NC and or Coweeta, NC
  - 5-6 months spanning spring and summer, e.g. March – August 202~~4~~ 5
- **Sampling**
  - 4 collocated NCON wet deposition monitors outfitted with SNiPiTs collecting weekly samples in bags and following the NADP protocols.
  - 1 collocated NCON wet deposition monitor for event-based sampling
- **Analysis**:
  - All bucket samples analyzed for total N and P and standard NADP constituents
  - SNiPiT samples analyzed for N and P

SNiPiT Evaluation

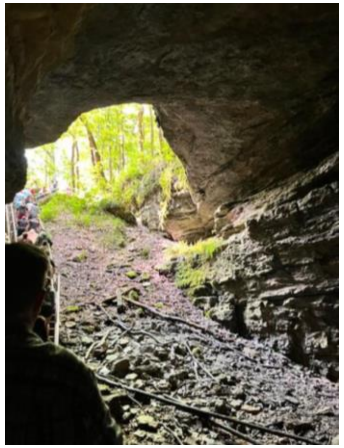
- **Laboratories**
  - CSU: analyze weekly NCON + SNiPiT and event-based samples.
  - Wisconsin: analyze weekly NCON + SNiPiT samples.
  - RTI may analyze some samples
- **Data Analyses**
  - Replicate samples would be used to assess the data uncertainty
  - Cross-laboratory results would help to identify potential biases
  - Event sampling results would serve as a check on the NCON+SNiPiT data
  - Duplicate analyzes in NCON and SNiPiT, e.g. total N and P, would serve as an additional check on the SNiPiT data

SNiPiT Evaluation - Status

- Sampling was delayed and will now wait to Spring/Summer 2025
- CSU
  - Purchased a new P & N analyzer which is now installed
    - Skalar continuous flow analyzer to measure low level phosphate
  - This winter CSU will test the sampling and analysis protocols and refine as needed
  - Deploy an NCON and SNiPiT sampler at MACA, KY during the winter nitrate study (maybe)
- Wisconsin, continued to test and refine analysis protocols
  - Decreased sulfuric acid for preservation in the field for improved total N measurements
    - allows for a lower minimum volume of sample required, i.e. only 20 mL of sample.
  - Issue for total P remained, so switched to ICP-OES. Initial data looks promising.
    - See Kat McKinnon meeting poster on the work to date
- NADP has purchased and received all needed SNiPiT samplers
- Meeting today at lunch to discuss status and logistics

Smoke Tracers in Wet Deposition Samples

- EPA ROAR Project led by John Walker and EPA Region 8
  - Ryan Fulghram has assumed the lead and John will continue to participate
  - Other participants: EPA: Mat Lang Rebecca Perrin, Melissa Puchalski,; CSU Jeff Collett, Amy Sullivan; WI: Ross Edwards; WSP: Chris Rodgers, WSP; Jayd Alderman; NPS: Schichtel
- Objectives and Planned Activates
  - Can we measure smoke marker species in wet deposition samples
    - Analysis of precipitation samples for black carbon at 12 western US sites during the 2024 and 2025 fire seasons.
    - Samples from three sites and other high BC samples will be analyzed for Levoglucosan
  - Determine if fire is a significant contributor to N deposition and trends
    - The second phase will include a statistical analysis to evaluate relationships between chemical species for CASTNET, IMPROVE and NTN.
- Status: Analysis of samples for BC and levoglucosan are underway.

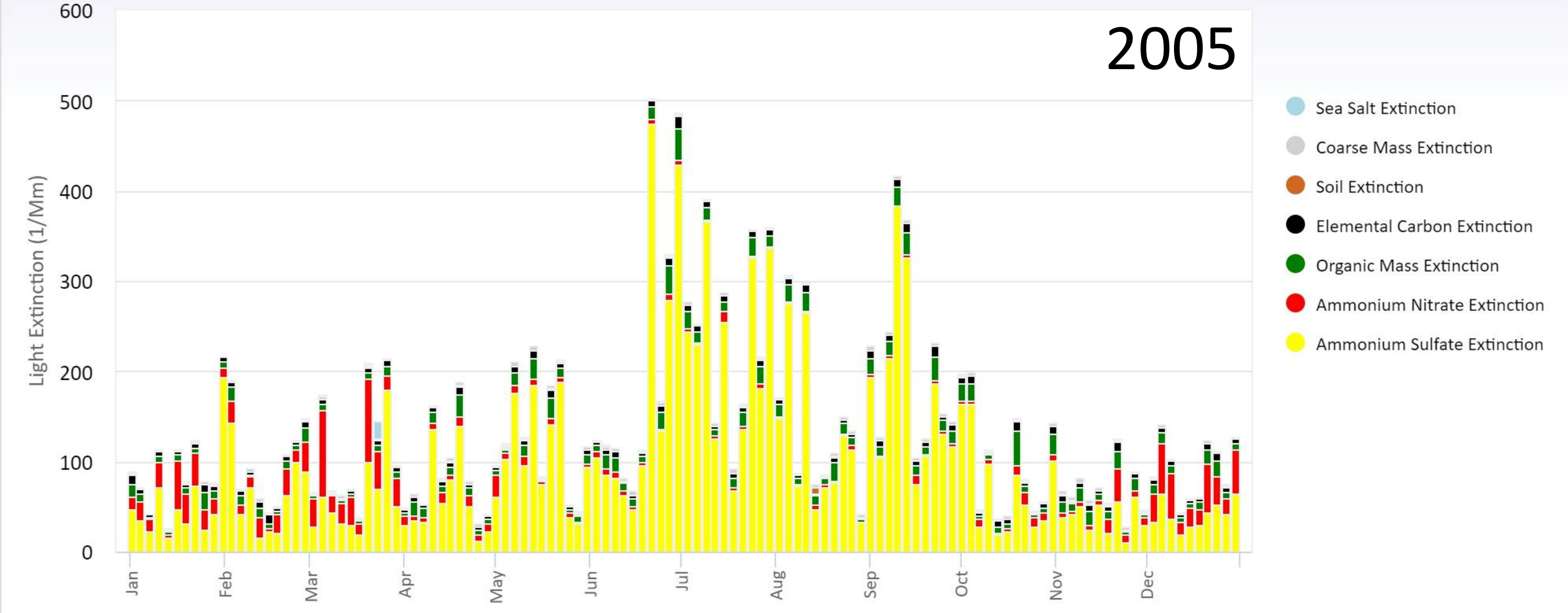



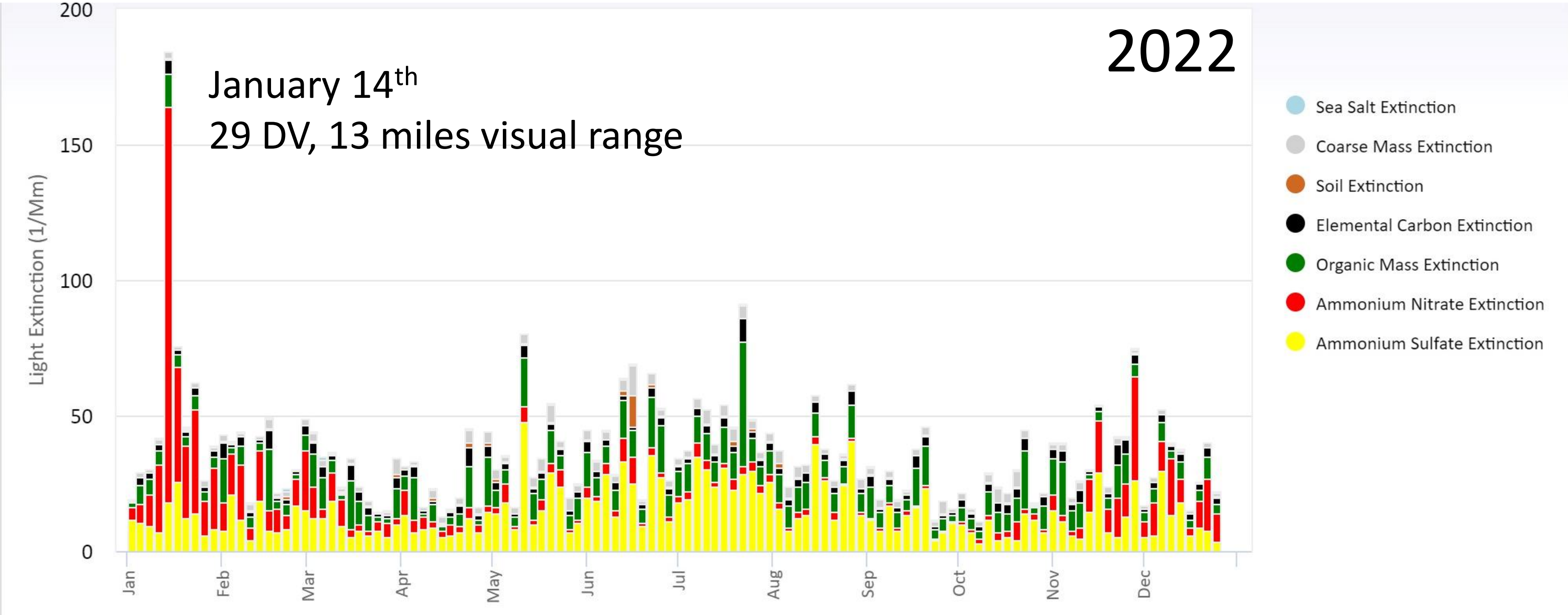

Southeastern US Winter Particle Nitrate Study

Continuing Progress Towards Natural Visibility Conditions



Mammoth Cave Daily Haze Budgets





Note:

- large decreases in summer haze
- Smaller decreases in winter haze
- Winter episodes are similar between years

Shift in Secondary Inorganic Aerosol Formation in the Rural CONUS from 2011-2020

Is particulate nitrate formation NH_3, NOx limited or both?

Da Pan, Denise L. Mauzerall, Lillian E. Naimie, John T. Walker, Amy P. Sullivan, Aleksandra Djurkovic, Rui Wang, Xuehui Guo, Melissa Puchalski, Bret A. Schichtel, Mark A. Zondlo, Jeffrey L. Collett Jr.

Da et al., (2023) Nature Geoscience

NATIONAL PARK SERVICE

NSF | neon Operated by Battelle

Colorado State University

Southeastern US Nitrate Pilot Field Study

Primary Objective:

- Assess the sensitivity of particulate matter, haze and reactive nitrogen to changes ambient concentrations of NH_3 + NH_4, HNO_3 + pNO_3 at Southeastern NP
- Assess the sensitivity of ammonium nitrate to the total regional NO_x and NH_3 emissions and, where possible, to point, mobile, and agricultural sources

Other Objectives

- Assess the changes in aerosol hygroscopicity and affect on haze
- Assess the impact of changing emissions on nitrogen chemistry and reactive nitrogen deposition
  - Reduction in ammonium sulfate and nitrate will redistribute the deposition of reduced and oxidized N

Southeaster US Winter Nitrate Pilot Field Study

Field study Monitoring sites

- Mammoth Cave, KY will be the primary monitoring site
  - Deploy the mobile monitoring lab at the Mammoth Cave Air Quality Site
- Great Smoky Mountain, TN will be the secondary site
  - Look Rock air quality sites

Deployment: January 8th to February 14th 2025

Current Measurements

Mammoth Cave Houchin Meadow Site

- NADP mercury in litterfall sampling
- **NADP NTN and MDN**
- Nephelometer
- **IMPROVE**
- Ozone
- **CASTNET**
- RAWS fire weather
- National Park Service meteorology
- National Park Service all-in-one meteorology
- NASA AERONET
- PM sampling using Purple Air and QuantAQ devices

Other monitoring in Mammoth Cave

- Visibility camera
- NOAA Climate Reference Network
- Soil Climate Analysis Network

Great Smoky Mtns Look Rock Site

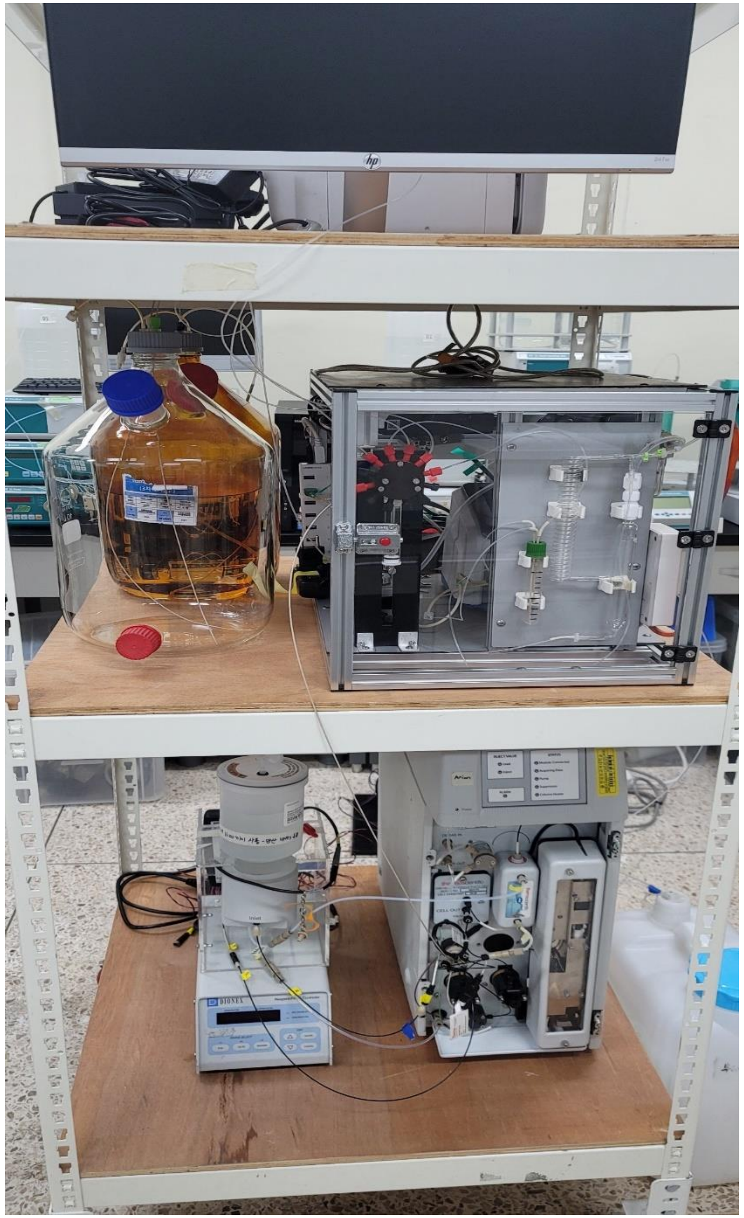
- Same as MACA, including
  - NADP NTN and MDN
  - IMPROVE
  - CASTNET
  - NPS GPMP – ozone and NOx
- NADP-AMON (2-week passive NH_3)
- ASCENT
  - Monitoring site with detailed high time resolution aerosol physical and chemical monitoring
- National Ecological Observatory Network (NEON)
- Ncore

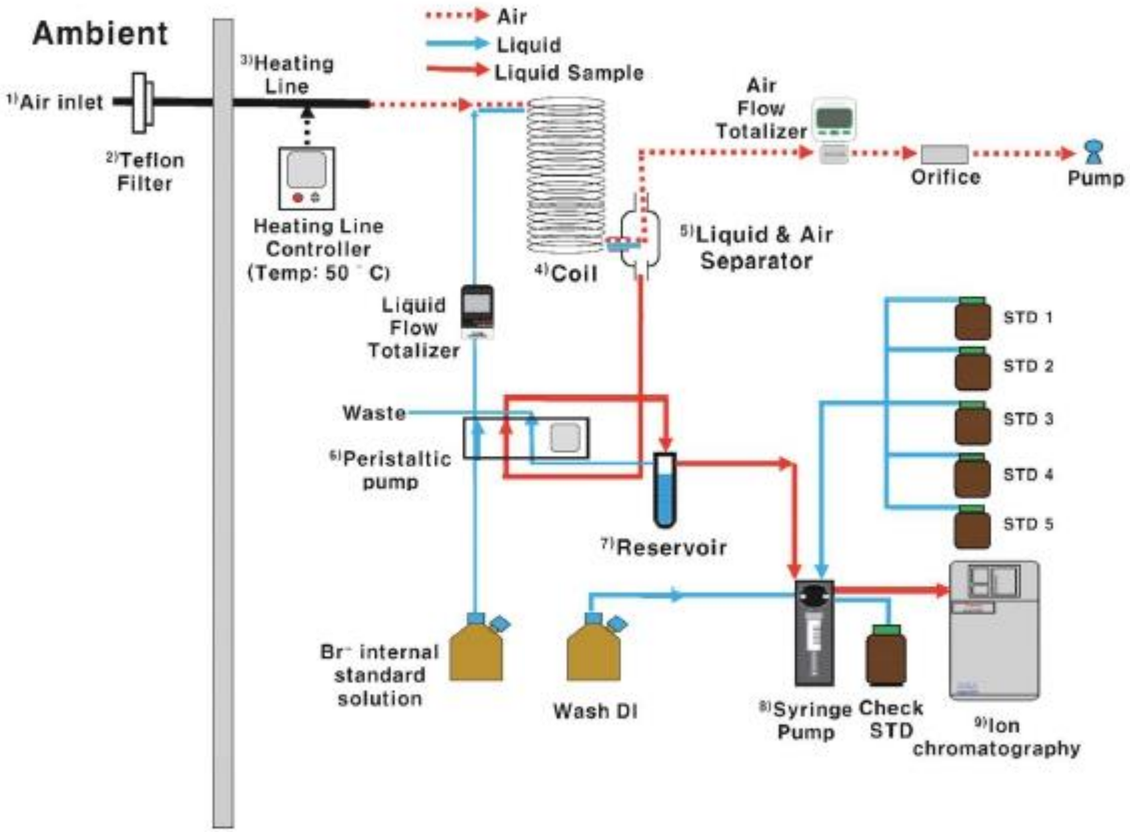
New Measurements

- Mammoth Cave
  - PILS – 15-minute particulate ions, e.g. sulfate and nitrate
  - URG – 24-hr gaseous and particulate concentrations
    - Ammonia, ammonium, nitric acid, nitrate, sulfur dioxide, sulfate
  - NOx
  - Continuous nitric acid (HNO_3)
    - wet scrubber (Taehyoung Lee's group)
  - Continuous ammonia
    - Air Sentry or Picarro instrument

- Great Smoky Mountains
  - URG – 24-hr gaseous and particulate concentrations, 4 days a week
  - Continuous ammonia
  - Continuous nitric acid

Nitric Acid Wet Scrubber





Lee et al.,

Analyses

- Standard data analyses
    - explore known and unknown relationships
- High time resolution thermodynamic modeling, similar to Da Pan’s work
    - Assess the sensitivity of particulate nitrate formation to ammonia and oxidized N availability
- Back trajectory analyses
    - Link sources to the measured concentrations and look for relationship in nitrate formation
        - urban areas
        - agricultural activities
        - Industrial activities
- Potential for using chemical transport model’s, e.g. CAMx and CMAQ in diagnostic data assessments

Collaboration and Sharing of Results

- Data and interpretations will be made available to the regulatory and scientific community
- Collaborations welcomed
    - Will not address all important questions, e.g. particle nitrate formation in urban settings
- Depending on results a larger scale collaborative study could be conducted in following years.

TDEP MEASUREMENT WORKSHOP

April 29, 2024, Spring NADP Meeting

Madison, WI

Goals of the Workshop

- To review the regulatory and scientific needs for reactive nitrogen and phosphorous monitoring
- Review the state of routine N and P monitoring in the United States
- Discuss the state of the science of monitoring methods and how to evolve and refine the US monitoring networks to address current and emerging needs.
- Specifically
    (1) fill monitoring gaps
    (2) help routine networks evolve to address these monitoring gaps, with the overall goal to
    (3) improve total deposition estimates for critical loads assessments.

Commencement

8:30-8:40 Welcome & Introductions by Kristi Morris (NPS)

8:40-9:20 Keynote Address: Atmospheric reduced nitrogen: sources, transformations, effects, and management - Charles Driscoll (Syracuse University)

9:20-9:35 TDEP reactive N total deposition products – data gaps and needs – Greg Beachley (EPA)

Panel 1: Reduced Nitrogen Ambient and Dry Deposition Measurements

Discuss the state of the science of reduced N measurements; monitoring gaps and priorities and needs for development and implementation of these methods.

9:35-9:55	Panel overview: regulatory and scientific needs for NH3 measurements	Bret Schichtel (NPS)
9:55-10:10	Break with coffee provided	
10:10-10:30	Ground-based reduced nitrogen (NH_x, NH_3, NH_4) monitoring, passives, filter-based, and continuous	Jason O'Brien (ECCC)
10:30-10:50	Satellite measurements of ammonia	Rui Wang (Princeton)
10:50-11:10	Process-level high-resolution deposition measurements	Da Pan (CSU) & Vladislav I. Sevostianov (Princeton)
11:10-11:30	Low-cost dry deposition measurements	John Walker (EPA) Additional panelist: Mike Bell (NPS)
11:30-12:15	Discussion facilitated by Bret Schichtel • What are the primary monitoring gaps? • How can current national networks evolve to address these gaps? • How can the new/refined monitoring be used to improve the TDEP maps for critical loads assessments?	

Panel 2: Total Nitrogen (N) & Phosphorous (P) Measurements

Discuss the needs for additional and refined total N and P measurements and monitoring gaps and priorities. Measuring the missing and poorly quantified components, e.g. organic N

1:30-1:50	**Panel overview: regulatory and scientific needs for total N & P measurements**	**Mike Bell and Emmi Felker Quinn (NPS)**
1:50-2:05	NADP total wet N & P (SNIPET)	David Gay (NADP)
2:05-2:25	Organic N ambient and deposition measurements	Nate Topie (WSP) & Ryan Fulgham (EPA)
2:25-2:45	Reactive nitrogen in wildfire plumes: observation capabilities and challenges	Emily Fischer (CSU)
2:45-3:05	P deposition measurements - virtual	Janice Brahney (Utah State)
3:05-3:25	Ambient P measurements, leveraging routine monitoring programs	Nicole Hyslop (UC Davis)
3:25 - 3:55	Break with beverages & refreshments	
3:55-4:40	Discussion facilitated by Mike Bell (NPS) • What are the primary monitoring gaps? • How can current national networks evolve to address these gaps? • How can the new/refined monitoring be used to improve the TDEP maps for critical loads assessments?	

Main Take Away Messages

- Need for more monitoring (reduced N, total N & total P) while agency budgets for monitoring are declining
  - **NH_3 flux measurements**
- Messaging and communication are important!
  - For EPA, it's a human health issue (NH_3 and $PM_{2.5}$); ecosystem protection is secondary
  - Target connections to climate, EJ, C cycling, H_2S, methane issues for funding opportunities
    - i.e. dust and wildfire increase due to changing climate
- Tiered monitoring approach for total deposition
  - 3-4 multi-organizational supersites, with common measurements and protocols, building on existing infrastructure where possible
  - Lower cost regional sites
  - ***While sustaining current long-term sites***

Workshop Products

- Workshop Report
  - Summary of presentations
  - Panel discussion topics
- White paper
  - Need for additional N & P monitoring
  - Propose framework for tiered monitoring approach for new funding
  - Schichtel, Walker, Fisher, Collett, Florian, Pina, Beachley, Puchalski, Cole, Morris, Others?

Questions

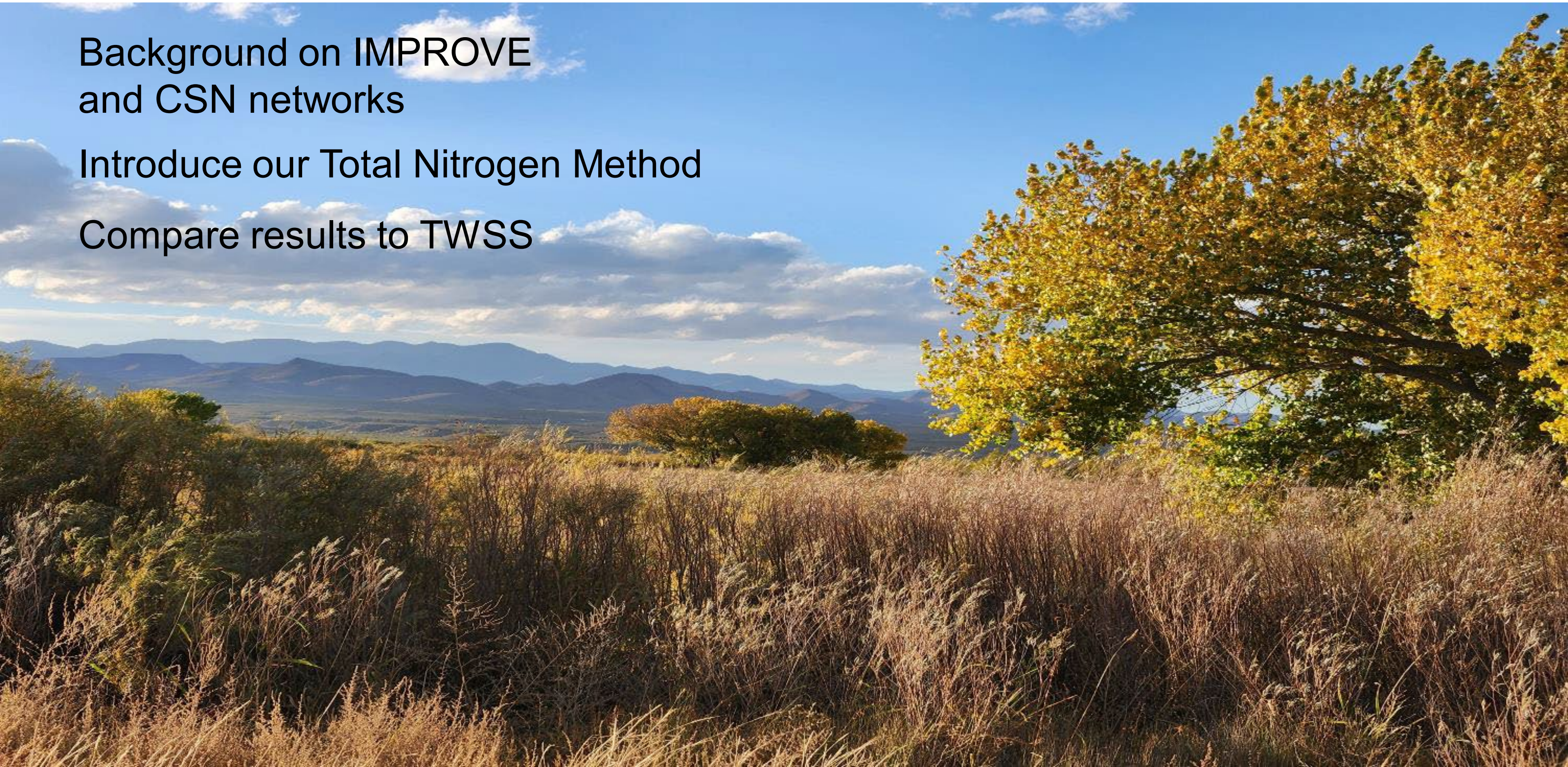
Total Water Soluble Organic Nitrogen and Sulfur measured in Chemical Speciation Network (CSN) and Interagency Monitoring of Protected Visual Environment Network (IMPROVE) Fine Particulate Samples

Tracy Dombek, RTI

Background on IMPROVE and CSN networks

Introduce our Total Nitrogen Method

Compare results to TWSS

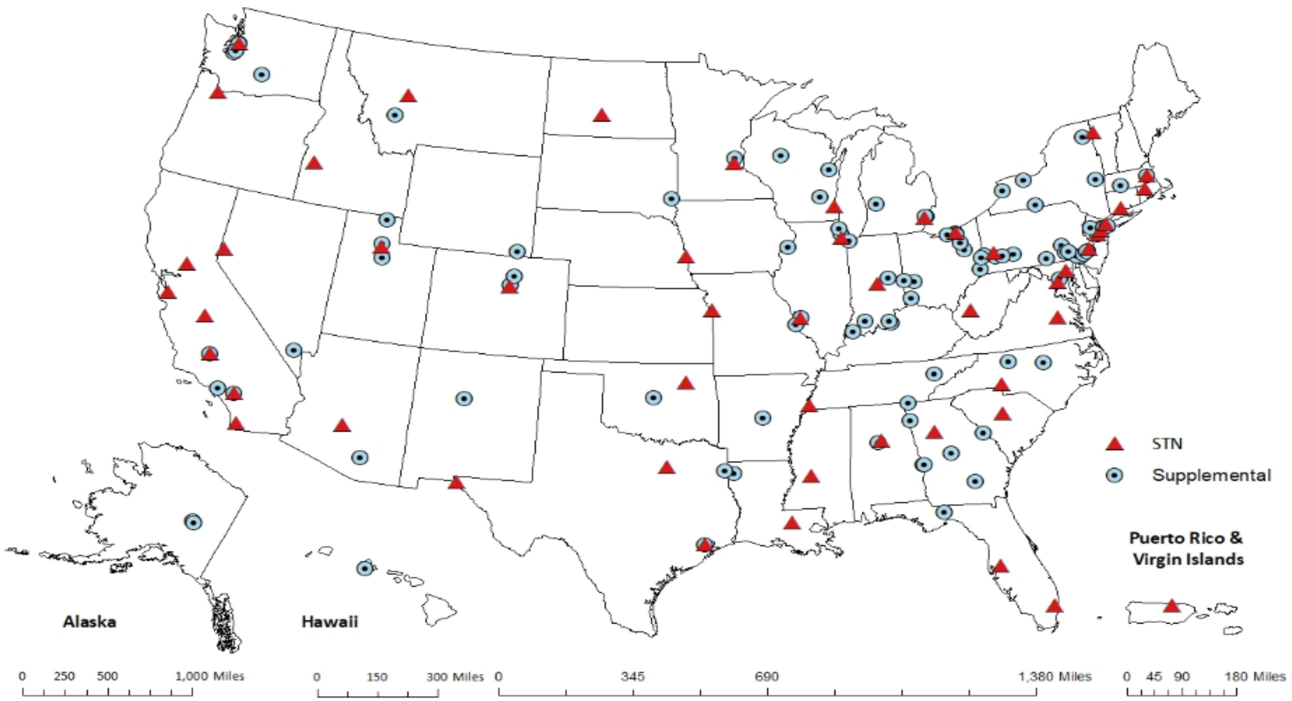


IMPROVE Network

https://aqrc.ucdavis.edu/field-site-reports

- Air Quality monitoring Network of approx. 160 sites in the Network with about 100 these sites located in Class 1 areas throughout the U.S. and about 60 sites in non Class 1 areas.
- 1 in 3 day 24 hour sampling periods capture $PM_{2.5}$ and PM_{10}
- RTI receives and extracts the nylon filters in deionized water and measures SO_4^{2-}, NO_2^-, NO_3^-, and Cl^- by Ion Chromatography.

Chemical Speciation Network

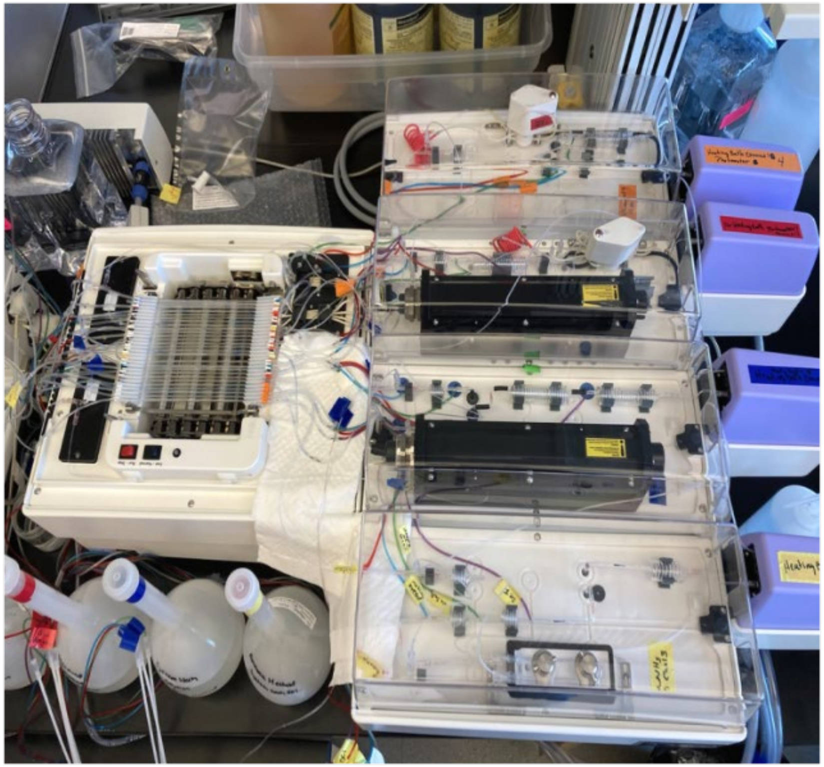


- Air Quality monitoring Network of approx. 50 Speciation Trends Network (STN) sites and about 100 State and Local Air Monitoring Stations (SLAMS)
- STN sample for 24 hour 1 in 3 day while most of SLAMS sample for 24 hour 1 in 6 day periods to capture $PM_{2.5}$
- RTI receives and extracts the nylon filter and measures SO_4^{2-},NO_3^-, Cl^-, Na^+, K^+, and NH_4^+ by ion chromatography.

Total Nitrogen Research

NO_3^- is routinely measured by Ion Chromatography
Segmented Flow Colorimetric measurement

- NH_4^+
- $NO_x = NO_2^- + NO_3^-$
- Total Nitrogen inline persulfate/UV digestion)

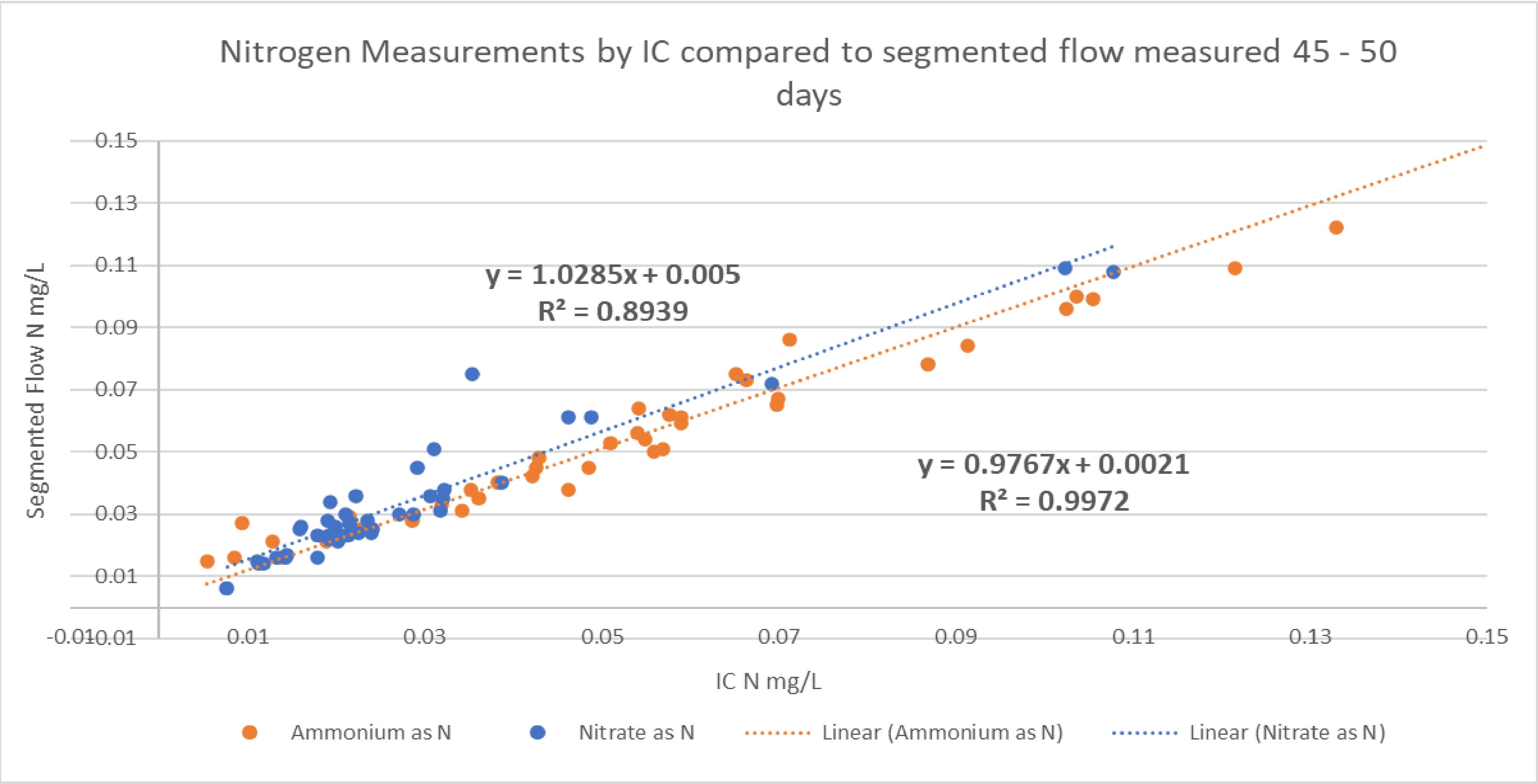


Total Water Soluble Nitrogen (TWSN)
Total Water Soluble Organic Nitrogen (TWSON)
$TWSON = TWSN – (NH_4 + NO_x)$

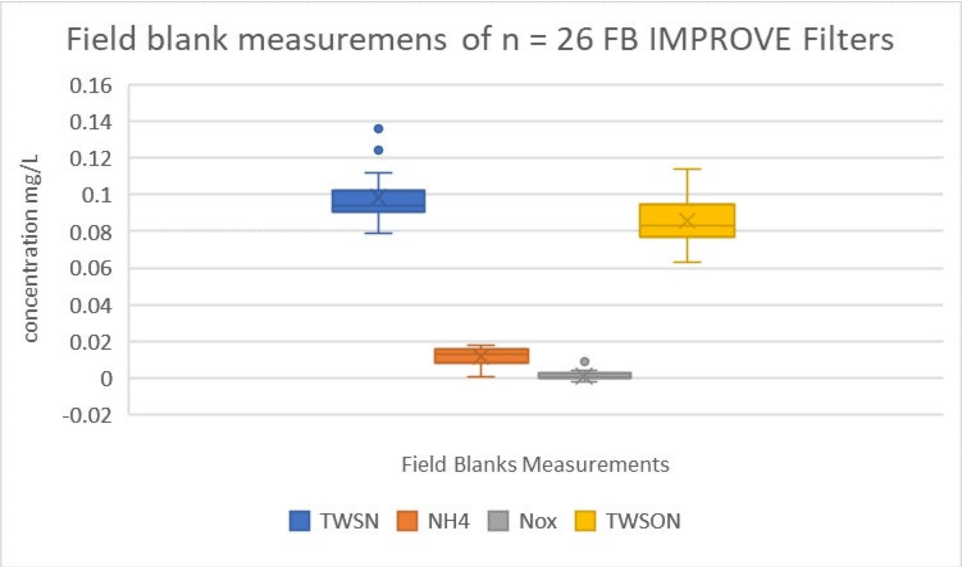
RTI International

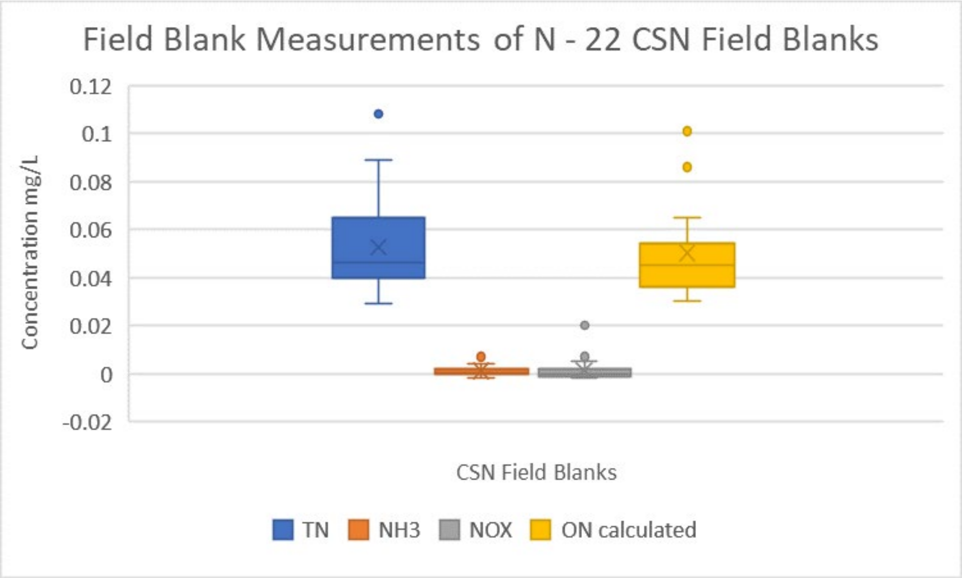
Preliminary Data

TWSN	NH4	NO3	TWSON
0.025 mg/L	0.017 mg/L	0.003 mg/L	0.045 mg/L



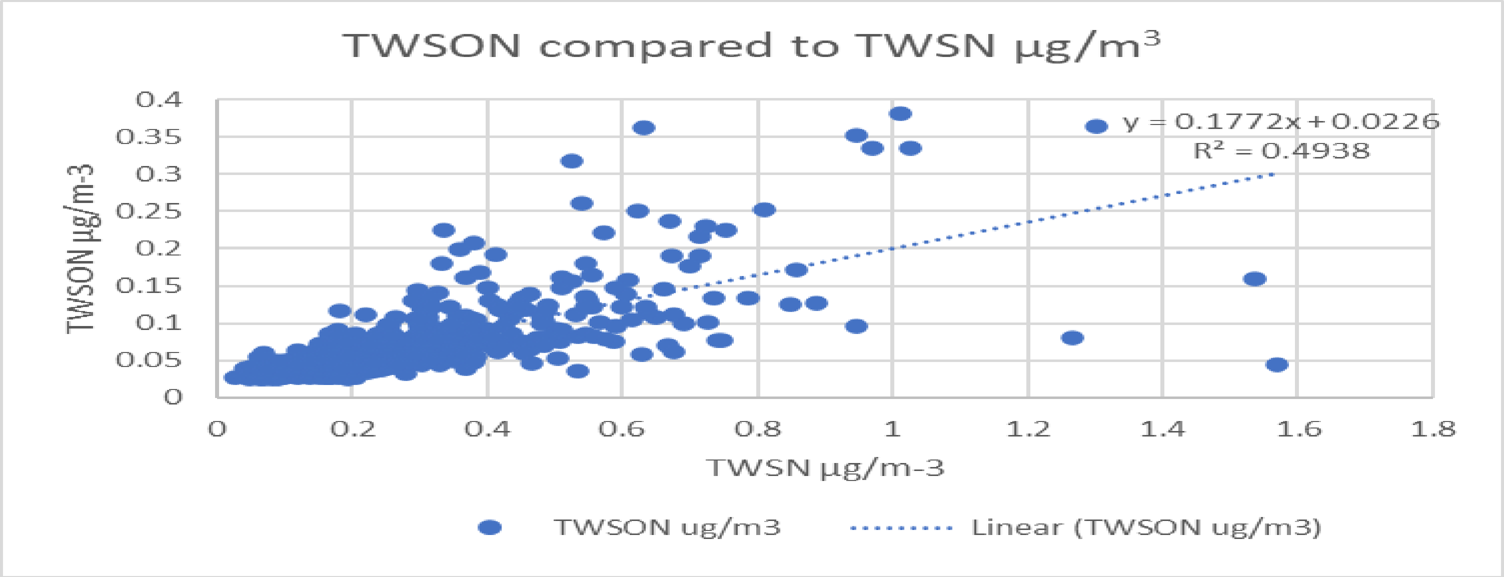
Field Blank Data

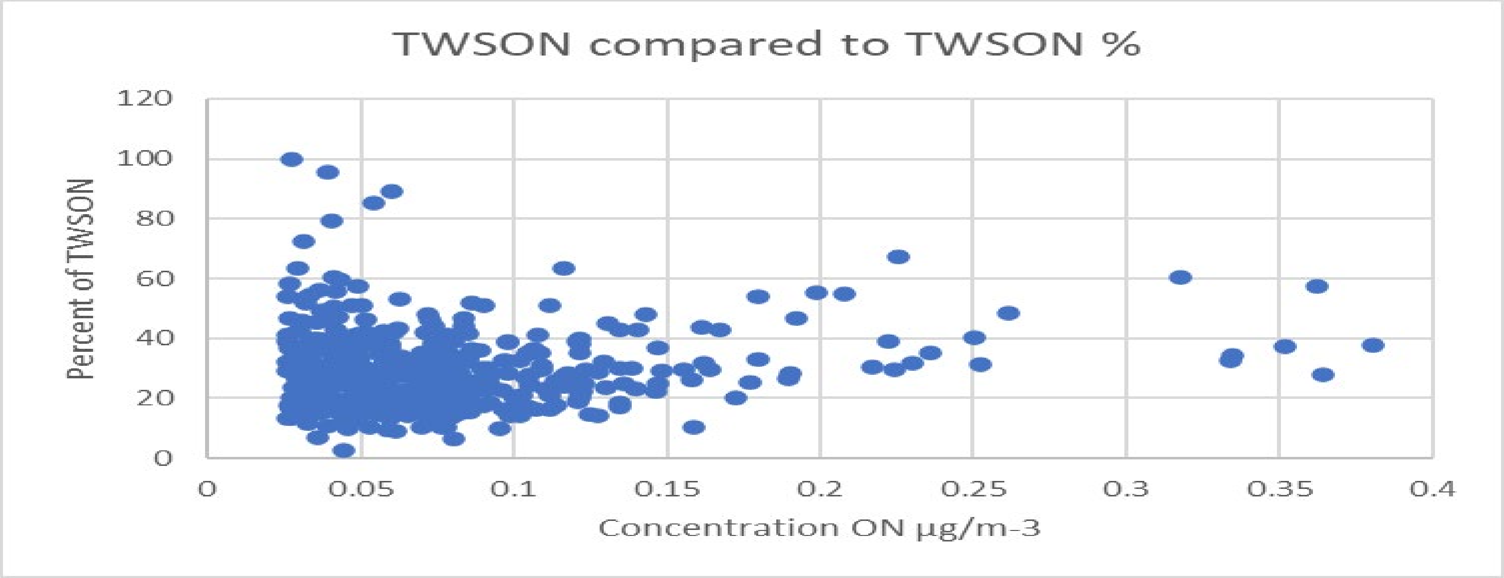




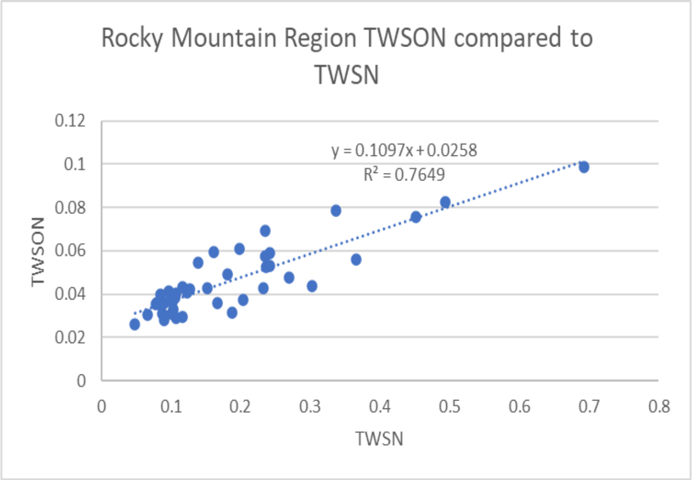
Comparability between IMPROVE and CSN Sites

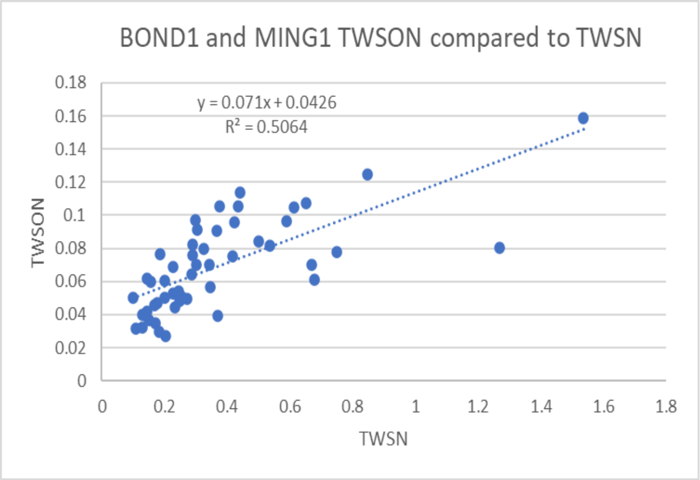
Site	Average % TWSON:TWSN	TWSON $\mu g/m^3$ average
Adam's County: Birch Street (CO)	37	0.145
La Casa (CO)	38	0.088
White Pass (WHPA1)	49	0.033
Yakima: 4th Ave (WA)	50	0.095
Fresno (FRES1)	24	0.102
Fresno-Garland(CA)	25	0.119
Aqua Tibia (AGTI1)	16	0.074
El Cajon: Lexington Elementary (CA)	11	0.086
Everglades NP (EVER1)	47	0.126
Broward County Ncore (FL)	67	0.138
Breton Island (BRIS1)	37	0.119
Capitol (LA)	37	0.122
BIRM1	33	0.110
Birmingham: North Birmingham (AL)	35	0.106

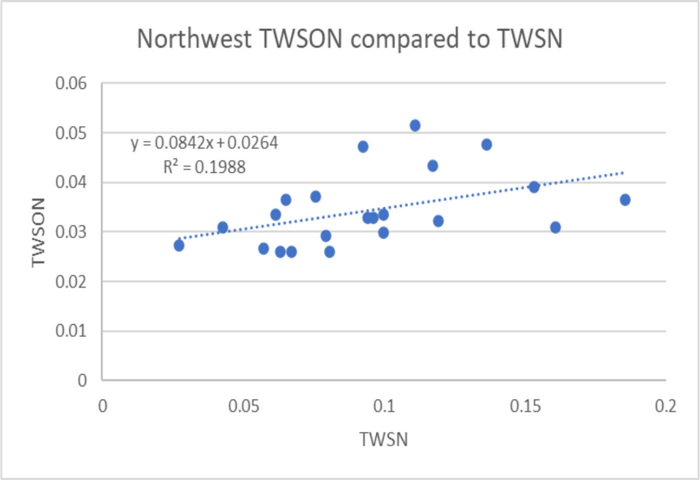

TWSON compared to TWSN µg/m3
y = 0.1772x + 0.0226
R² = 0.4938
TWSON µg/m-3
TWSN µg/m-3
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
TWSON ug/m3
Linear (TWSON ug/m3)

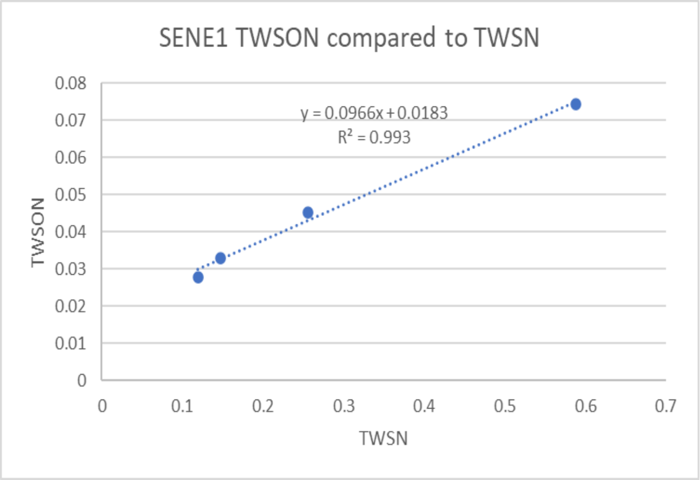

TWSON compared to TWSON %
Percent of TWSON
Concentration ON µg/m-3
120
100
80
60
40
20
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4

Linear regression Analysis TWSON and TWSN

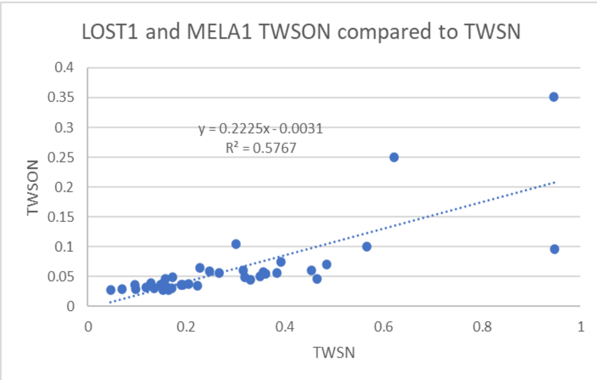


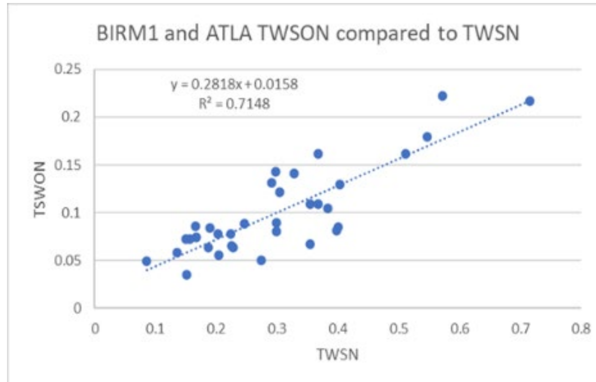


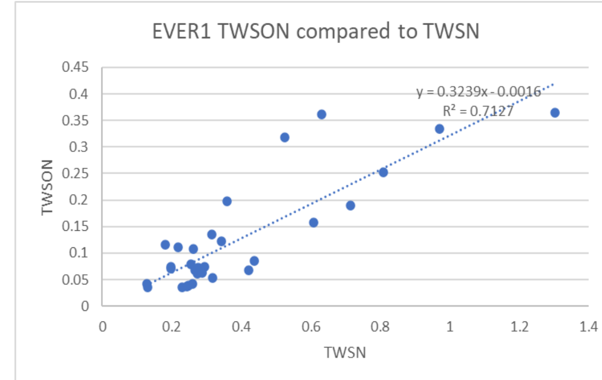


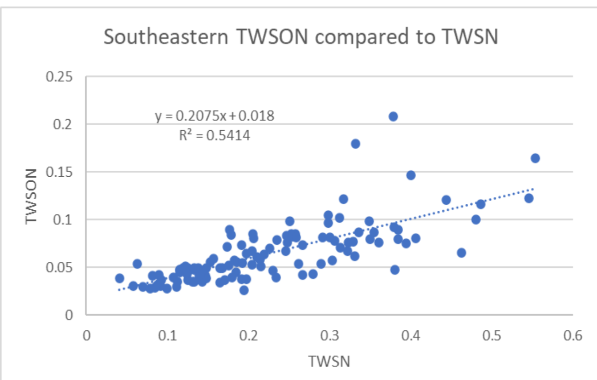


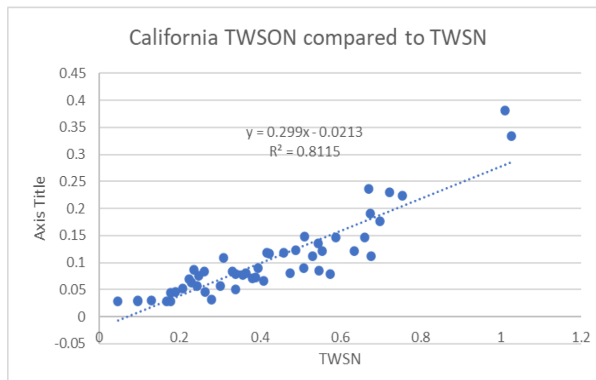
Linear regression

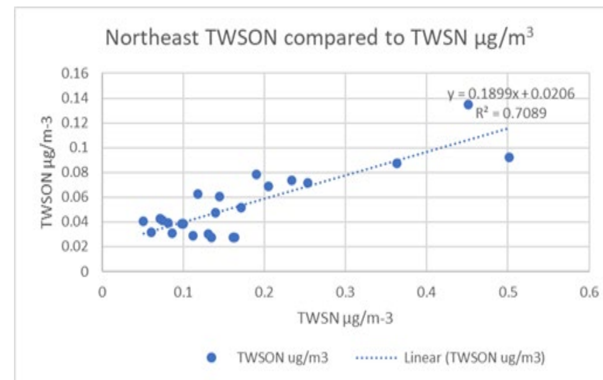








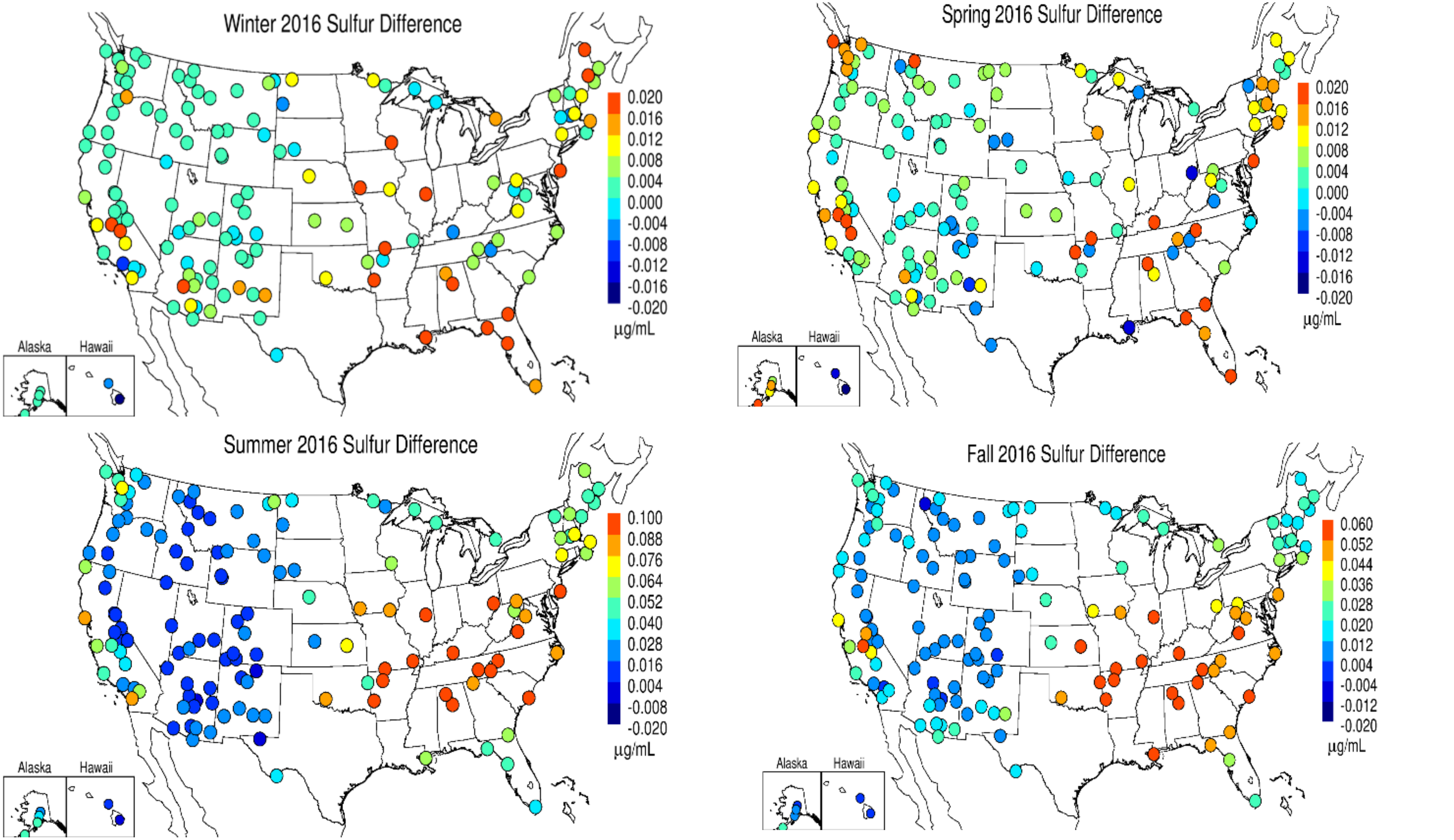




Total Sulfur Analysis

- SO_4^{2-} is routinely measured by Ion Chromatography in both CSN and IMPROVE samples
- The same water extracts were measured for IMPROVE samples collected during 2016 by ICP-OES to evaluate water soluble organic sulfur (WSOrgS).
- Inorganic SO_4^{2-} - Total Water Soluble Sulfur (TWSS) = WSOrgS

Seasonal differences between Sulfur and Sulfate



Conclusions

- Measurements of TWSON are possible in IMPROVE and CSN samples with a background subtraction
- There will be geographic differences depending upon the source, further work is needed to explore seasonality and geographic trends in the data.
- The simultaneous analysis of TWSN, NOx and Ammonium are important as we can experience losses of nitrogen in samples and this method provides a TWSON fraction that is not biased by analysis conducted on different days.

Acknowledgements

- Kat Lindskog, Adam Conway Total Nitrogen analyses
- Eric Poitras, Miranda DeBoskey, Doug Burnette Yuzhi Chen, Jason Surratt Total S work

- RTI for continued research funding

delivering **the promise of science** for global good

RTI INTERNATIONAL

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N deposition in complex terrain: New monitoring site installation and modelling research

A.G. Deshpande, D. Harvey, R. Nicoll, M.R. Jones, I. Simmons, M. Vieno, J Scheffler, R. Hill, G. Lloyd, S. Smith, M. Flynn, T. Jackson, K. Vincent, C. Conolly, E. Nemitz and C. F. Braban

11.05.2024

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Deposition processes and their uncertainties

Wet deposition *(washout by precipitation)*

- Uncertainties associated with orographic rainfall enhancement / precipitation amount at high elevation sites (difficult to model or measure)
- Uncertainties associated with seeder-feeder effect
- Measurement challenges: dry deposition impact on bulk deposition gauges; rain detection on wet-only collectors

Dry deposition (*Deposition of pollutants due to uptake of gases and aerosol by vegetation and surface elements in the absence of precipitation*)

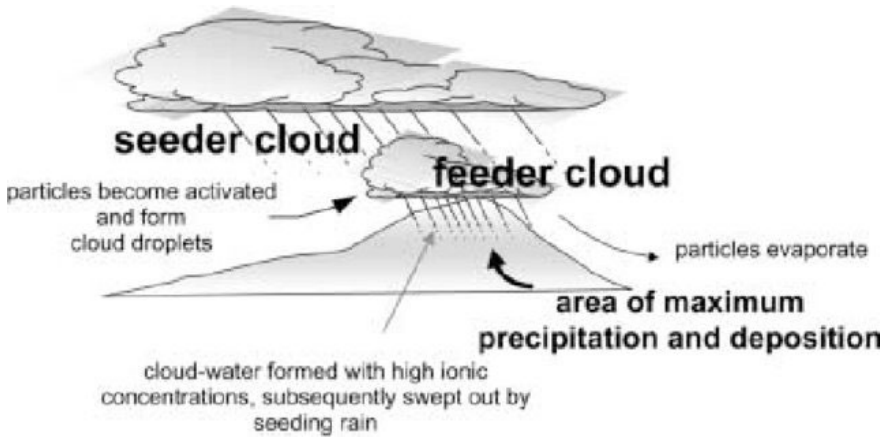
- Dry deposition routines derived for homogeneous, flat-Earth condition
- Complexity of modelling NH_3 transport up agricultural valleys
- Lack of concentration measurements at remote / higher altitude sites

Occult deposition *(via fog droplets)*

- Not included in most Atmospheric Chemistry & Transport Models (ACTMs)
- Fog occurrence / amount difficult to predict / measure
- Fog droplet deposition rates in complex terrain

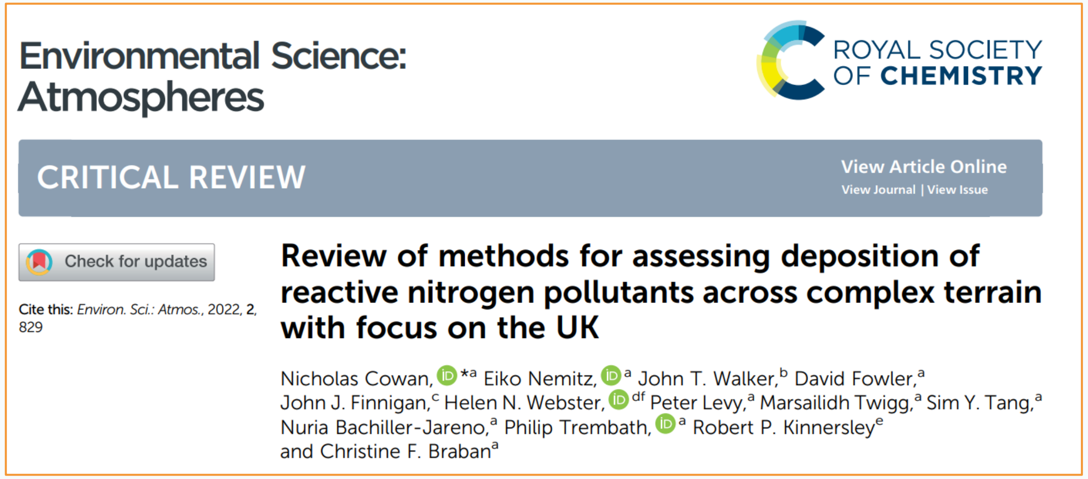
→ Lack of measurements in complex terrain for model validation

→ Reliance on extrapolation



Why are we concerned about N deposition in complex terrain?

- Large uncertainties & most processes likely increasing deposition in complex terrain compared to flat, homogeneous terrain (by factor 1.4 to 3.6).
- Initial assessment suggests this increase could relate to an additional cost for Ecosystem Services of £0.5 billion (fresh water quality, biodiversity, N_2O emissions)
- Impacts our assessment of exceedances of Critical Loads of N and its response to emission changes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Cite this: Environ. Sci.: Atmos., 2022, 2, 829

Review of methods for assessing deposition of reactive nitrogen pollutants across complex terrain with focus on the UK

Nicholas Cowan, *[a] Eiko Nemitz,[a] John T. Walker,[b] David Fowler,[a] John J. Finnigan,[c] Helen N. Webster,[df] Peter Levy,[a] Marsailidh Twigg,[a] Sim Y. Tang,[a] Nuria Bachiller-Jareno,[a] Philip Trembath,[a] Robert P. Kinnersley[e] and Christine F. Braban[a]

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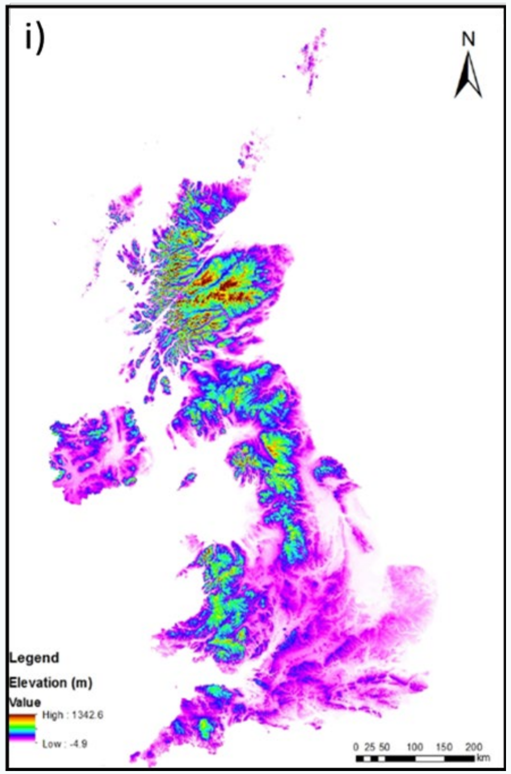
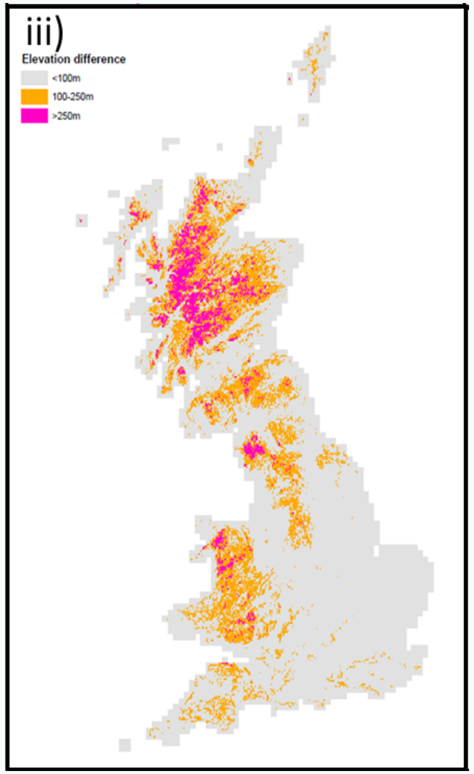
Definition of ‘complex terrain’

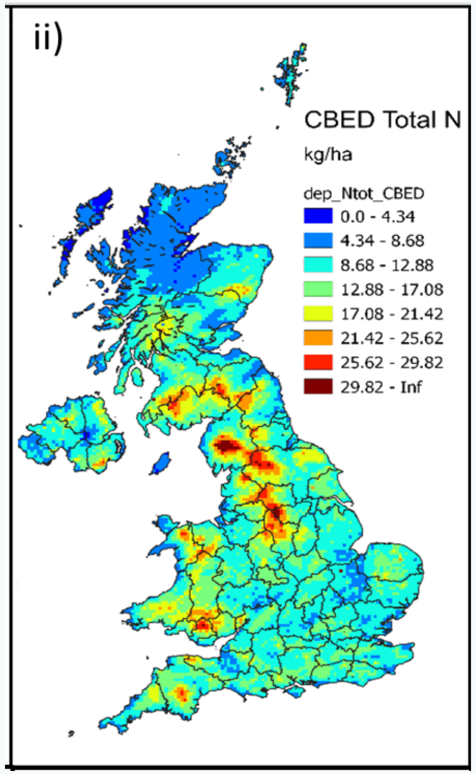
Elevation map



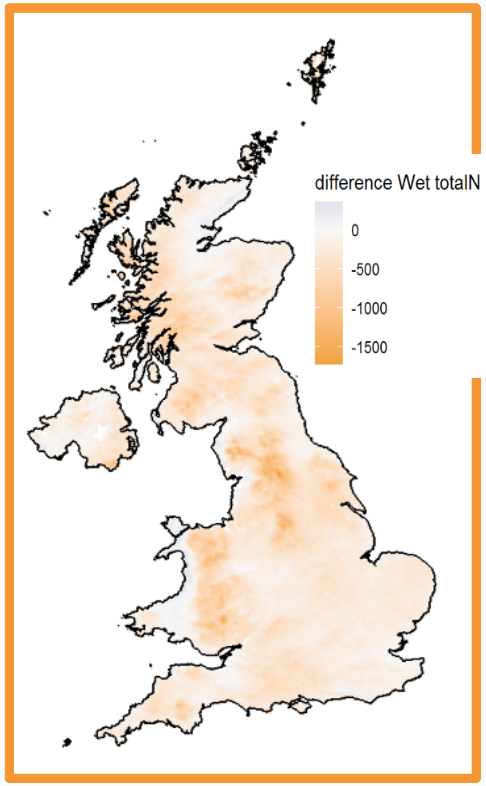
Elevation variability



Total N dep in CBED



Diff EMEP-CBED Ndep wet



- No agreed definition
- Irregular topography such as mountains
- Variations in land cover / land use

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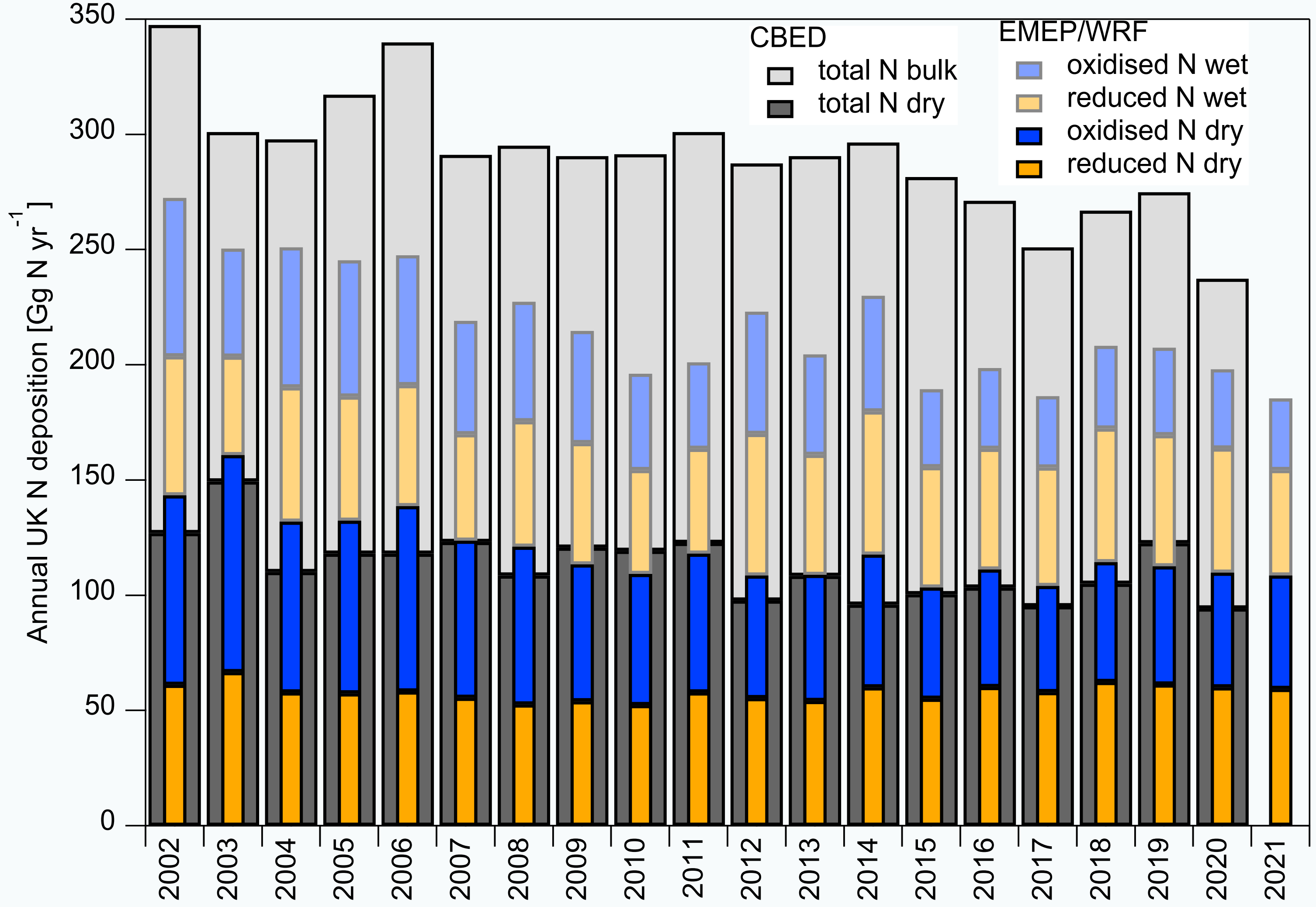
Comparison EMEP4UK vs CBED – overview (wet includes fog)



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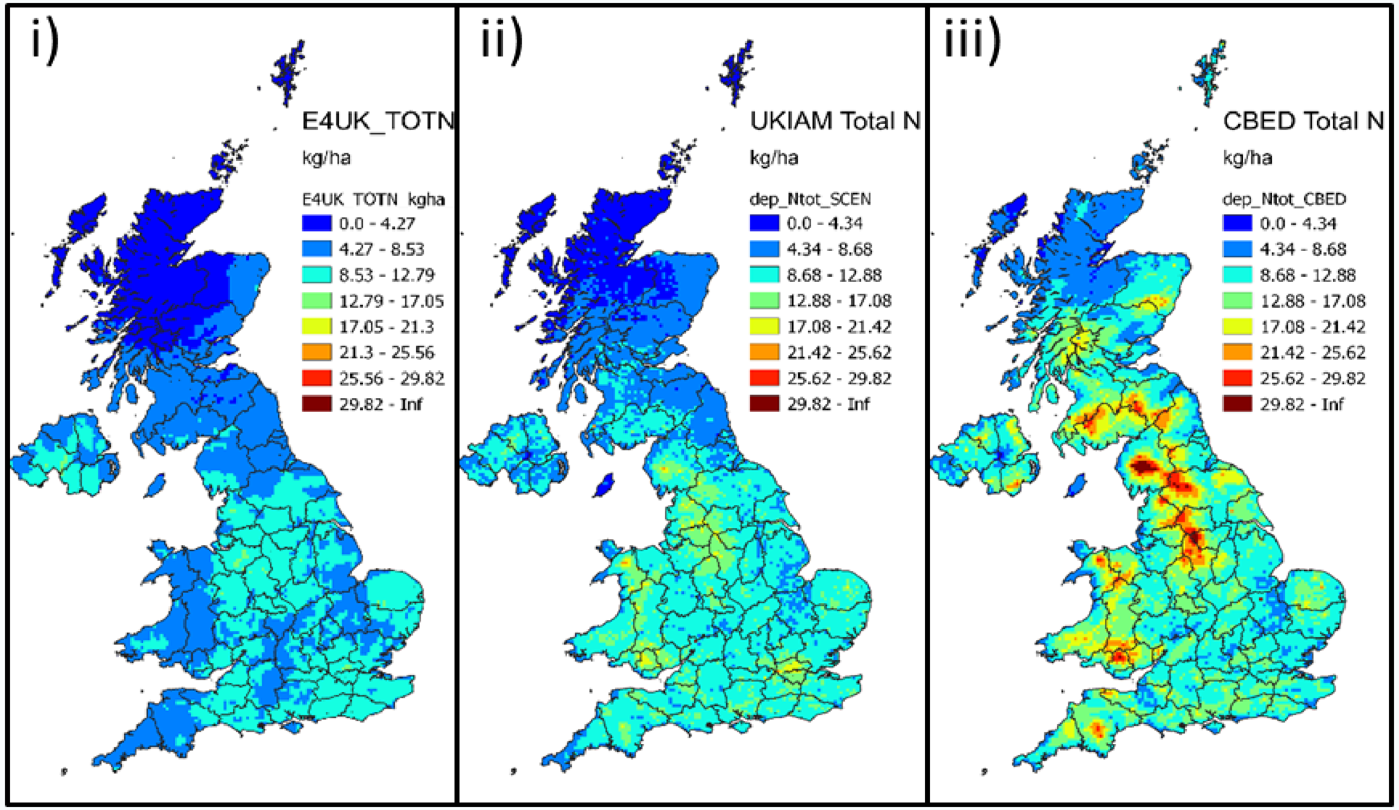
Model comparison can highlight SOME uncertainties

i) WRF-EMEP4UK Atmospheric Chemistry & Transport Model at 5 km x 5 km (starting with emissions)
ii) UKIAM Integrated Assessment Model, simplified, parameterised model combining various ACTM outputs
iii) CBED (Concentration Based Estimate of Deposition), inferential model based on interpolated map of measured concentrations



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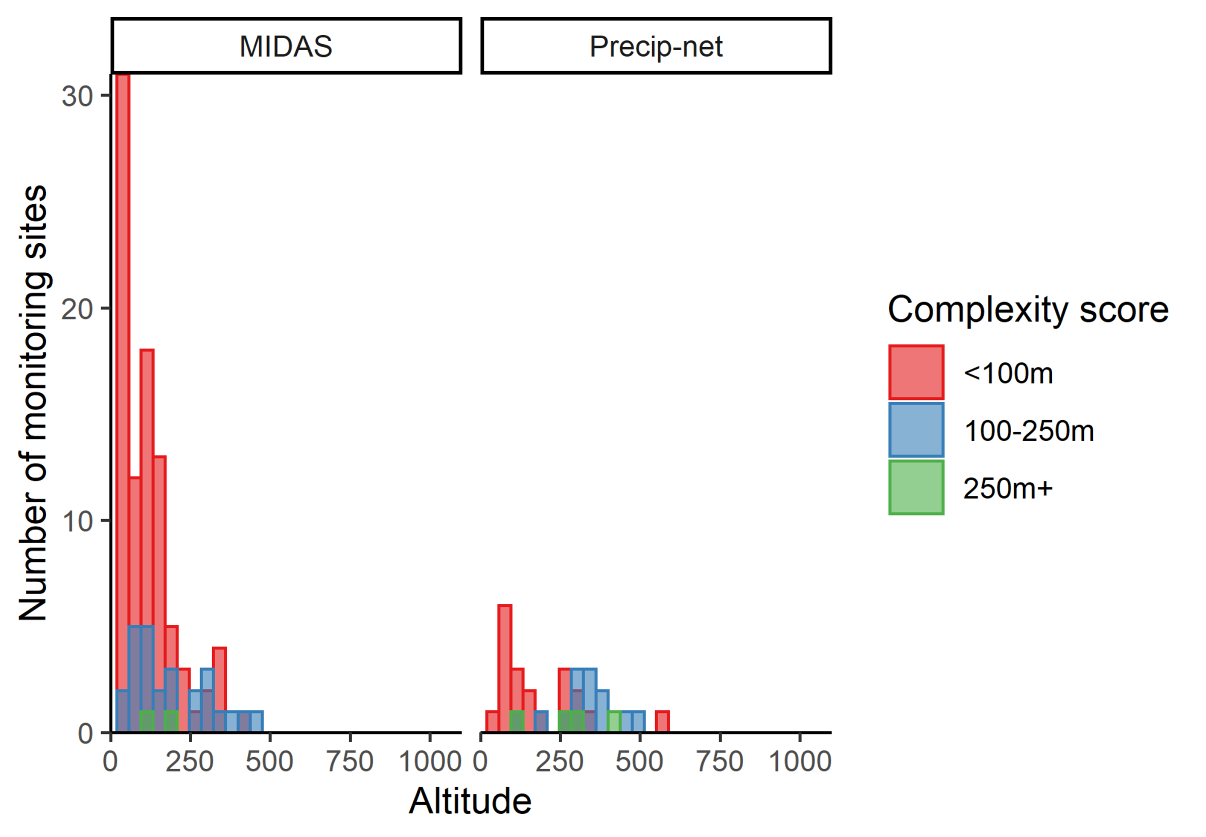
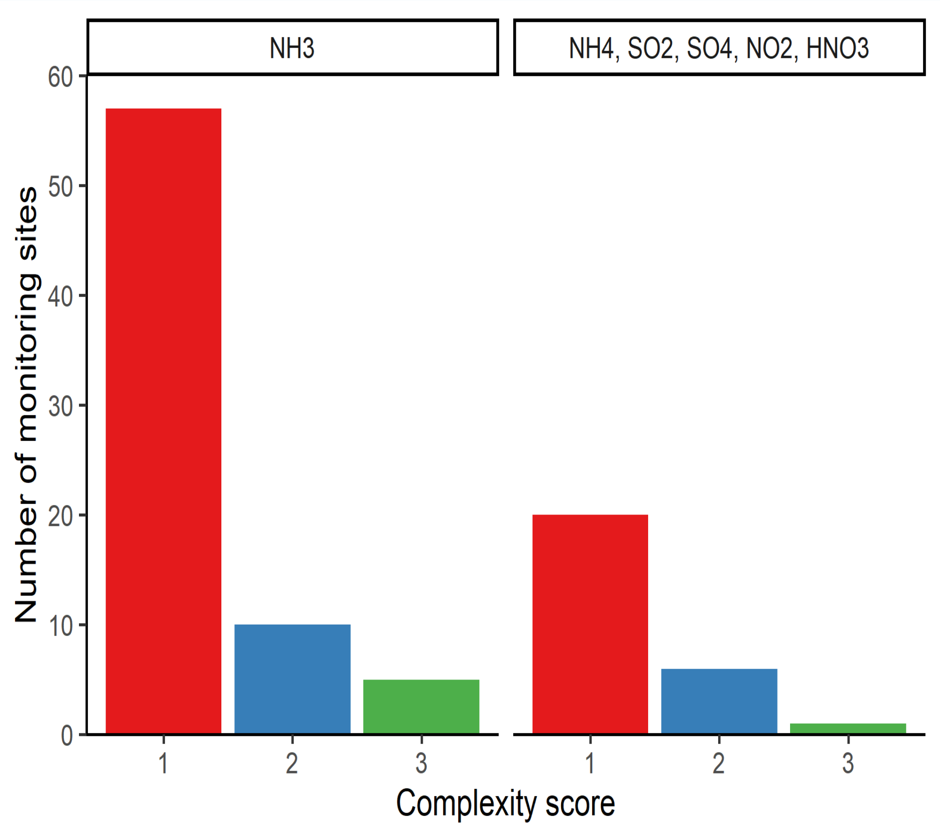
Note: not fully independent, e.g. all dry deposition routines assume flat-earth conditions

Lack of measurements in complex terrain to constrain model estimates





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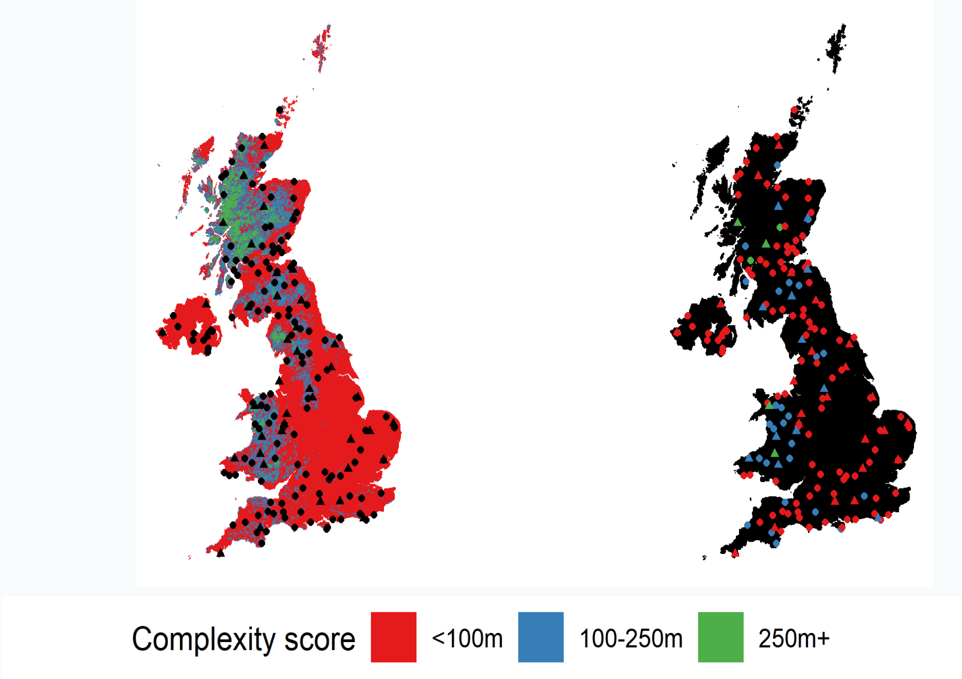
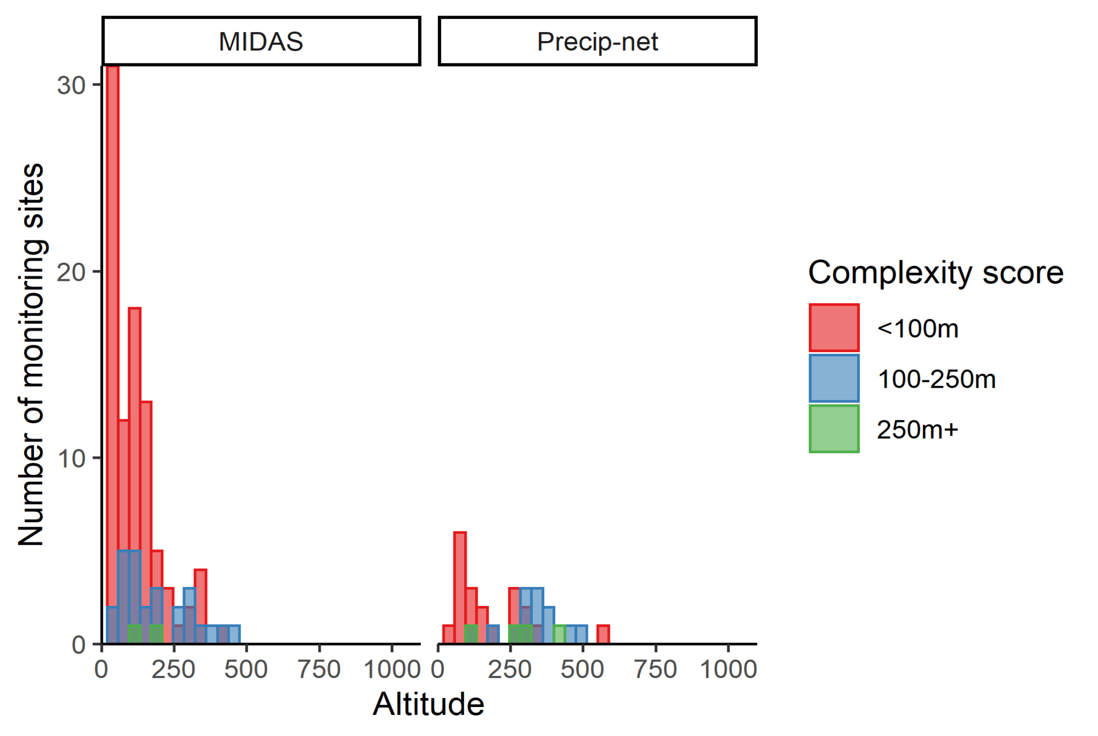
Location respective to existing monitoring sites and networks
Nemitz et al. (2022) evaluated both the locations of the Environment Agency's precipitation network (Precip-Net), which reports both volume and chemical information of precipitation, and the Met Office Integrated Data Archive System (MIDAS), which archives meteorological measurements including precipitation data.



Location of MIDAS (circles) and Precip-net (triangles) monitoring sites based on map of complexity (left) and coloured by complexity score at site (right).



Histogram of the distribution of monitoring sites by altitude and complexity score (X axis range shows range of altitudes in the UK).

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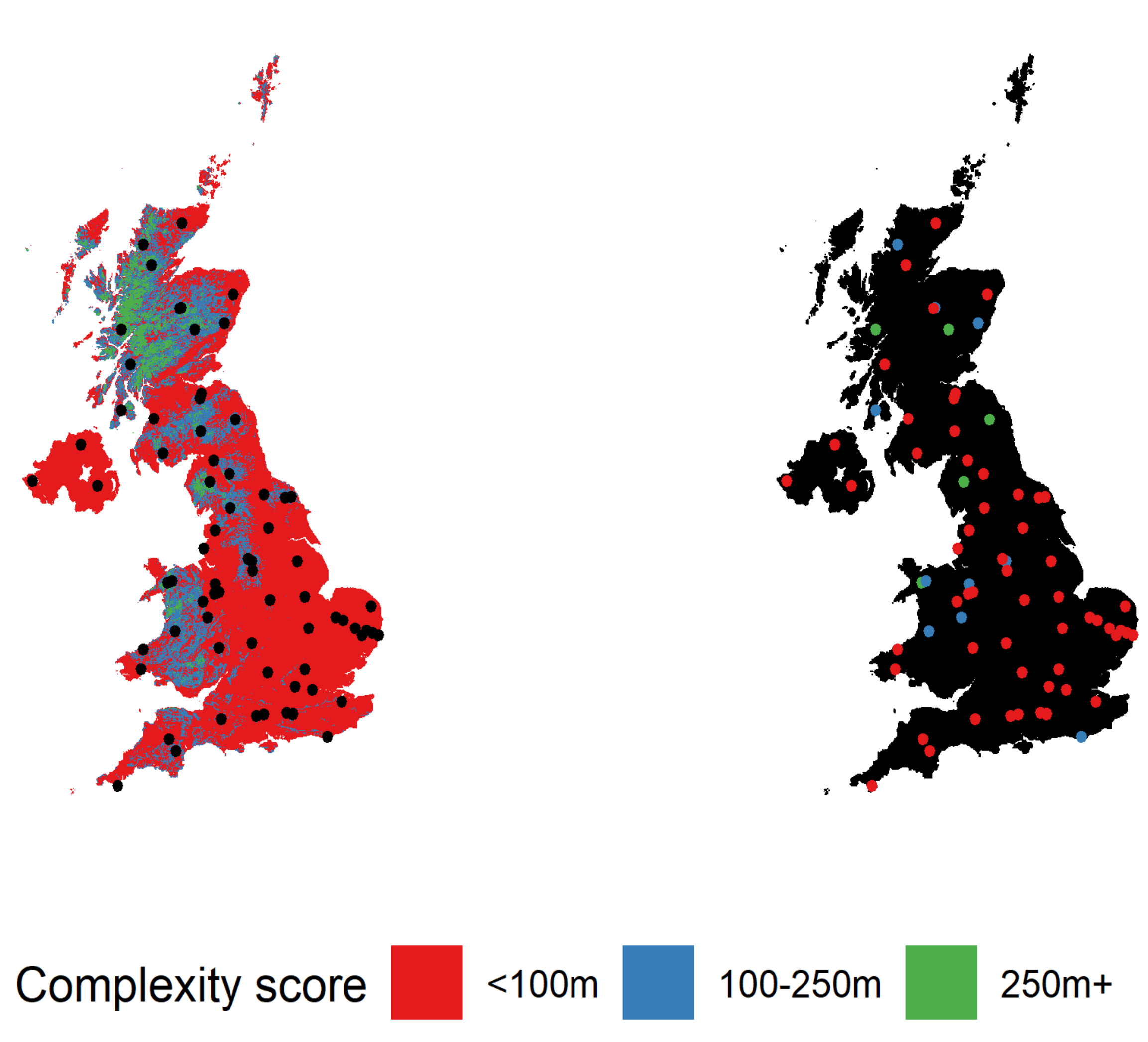
- very few sites located in England (Figures 3 and 4) which would be classified as being within complex terrain
- for both networks, there were no measurements above 600 m.

Map of complexity score and NAMN ammonia monitoring network sites (left) and complexity score per monitoring site (right).



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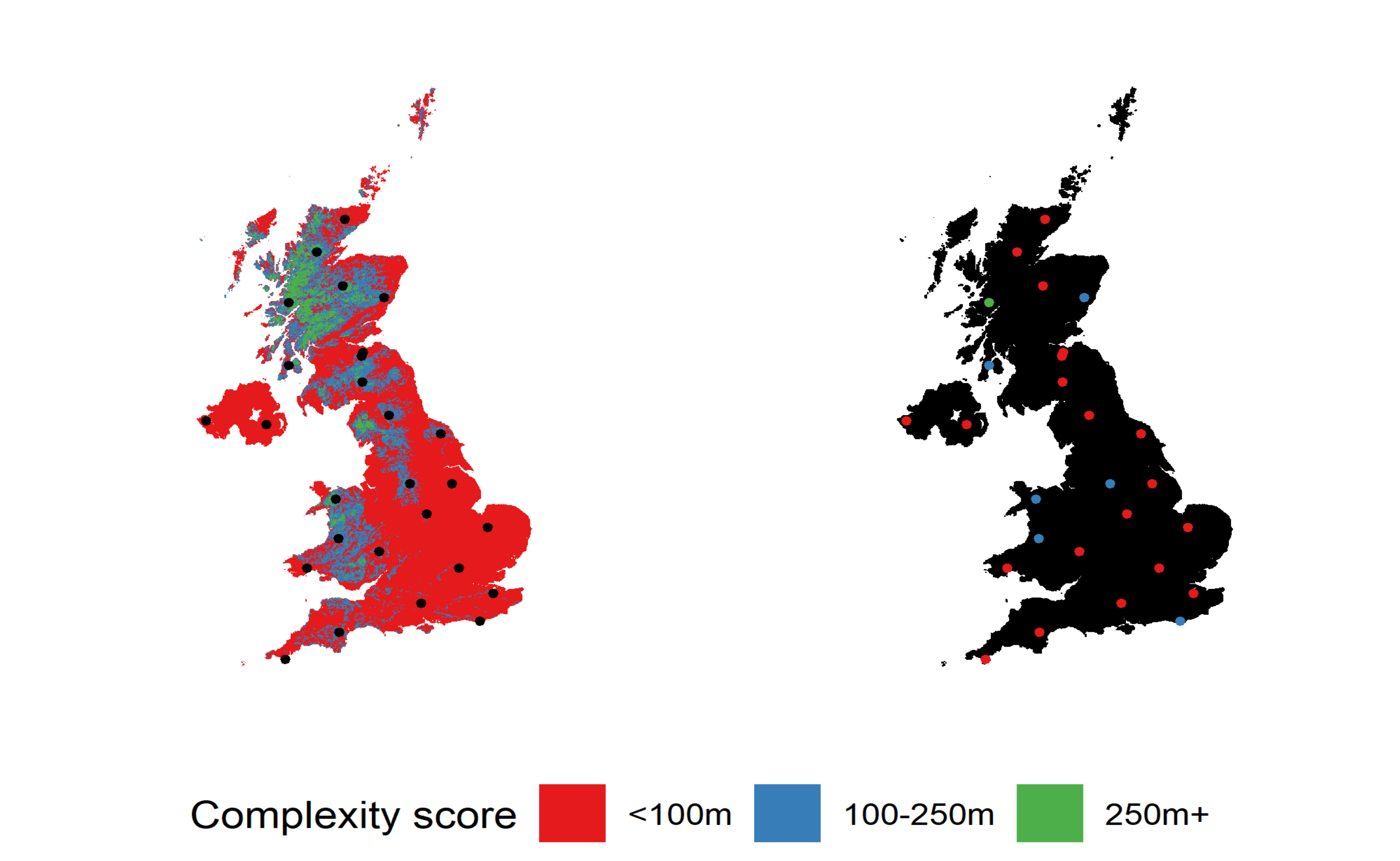
Map of complexity score AGANet network (excl. NH_3) (left) and complexity score per monitoring site (right)



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Gap analysis

Measurement sites in complex terrain (precipitation, wet deposition, concentration, dry deposition, fog occurrence)

Measurement technology suitable for deployment at complex, foggy, windy sites

Process understanding of orographic precipitation, washout, dry / fog deposition in complex landscapes

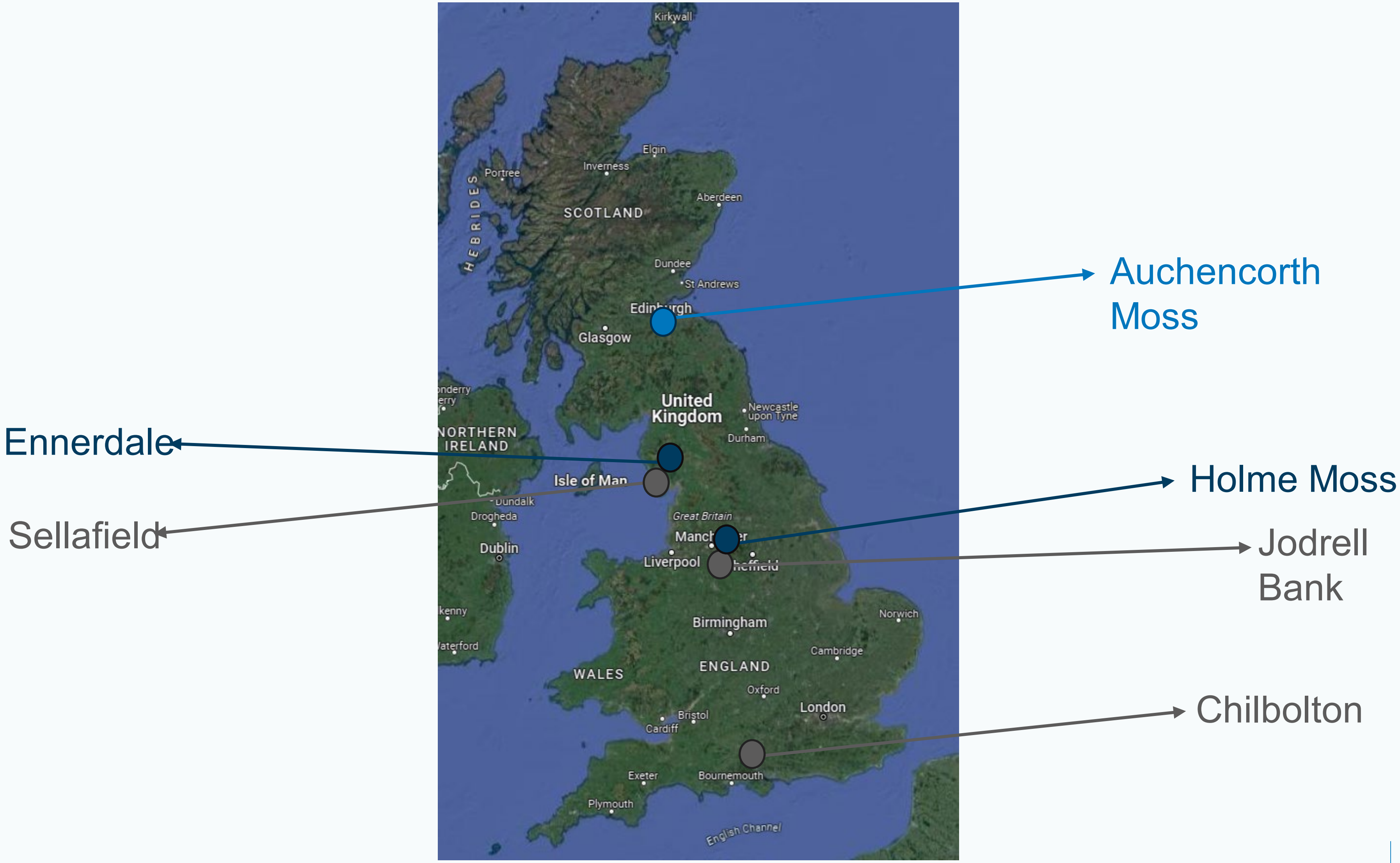
Site	Location	Terrain	Operated by	Installation date	Weeks of data collected
Auchencorth Moss	Midlothian	Elevated, not complex	UKCEH	6th June 2024	15
Chilbolton Observatory	Hampshire	Lowland, not complex	Ricardo/STFC	28th August 2024	3
Holme Moss Observatory	Peak District	Elevated complex	University of Manchester	18th July 2024	10
Jodrell Bank Observatory	Cheshire	Lowland, not complex	University of Manchester	22nd August 2024	4
Sellafield	Cumbria	Lowland, not complex	Sellafield Ltd	30th July 2024	8
Ennerdale	Cumbria	Elevated, complex	Low Gillerthwaite Field Centre	TBC	-

Study sites

Complex terrain sites:
Holmes Moss
Ennerdale

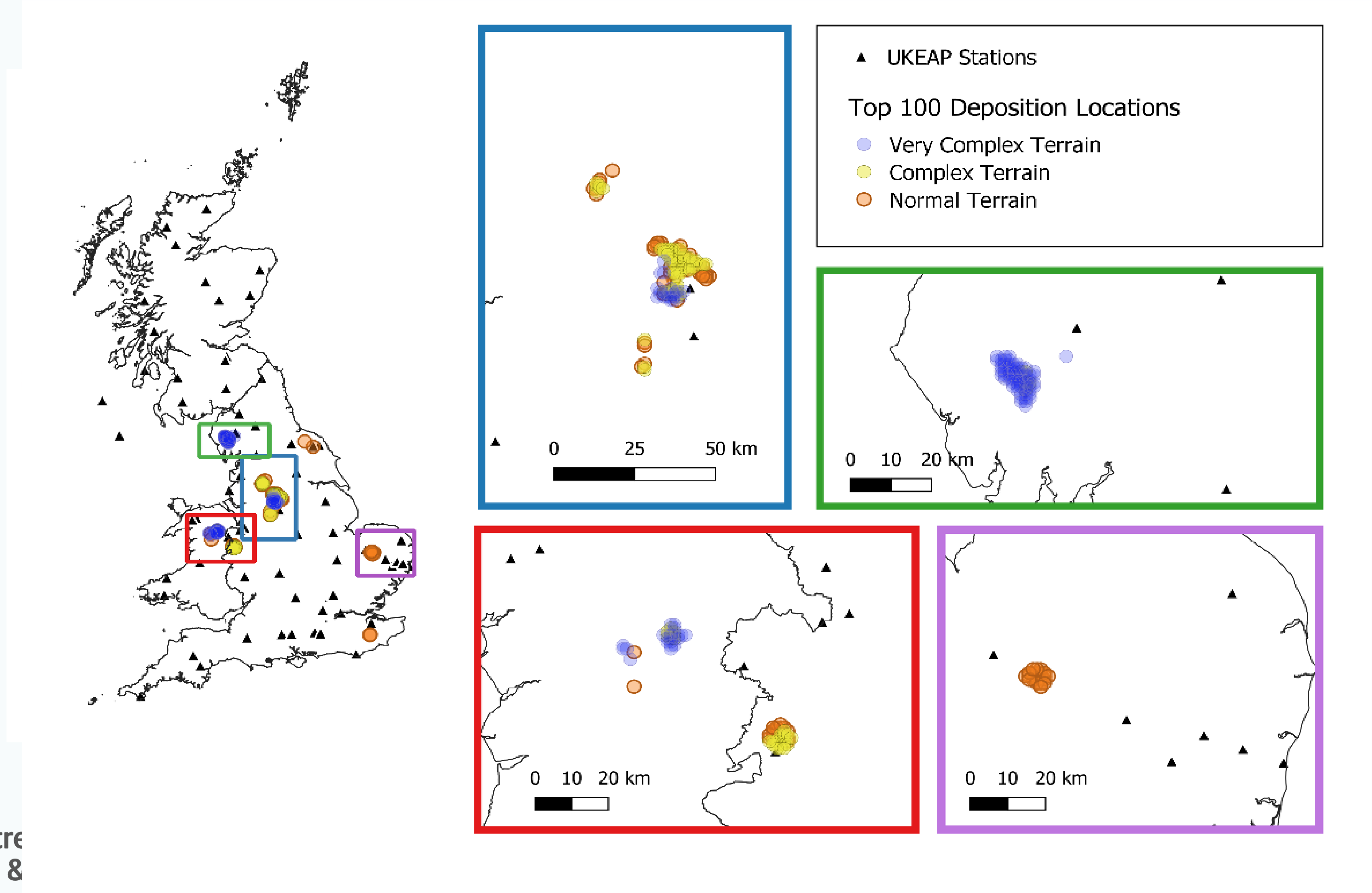
Elevated site:
Auchencorth Moss

Flat terrain sites:
Jodrell Bank
Chilbolton
Sellafield



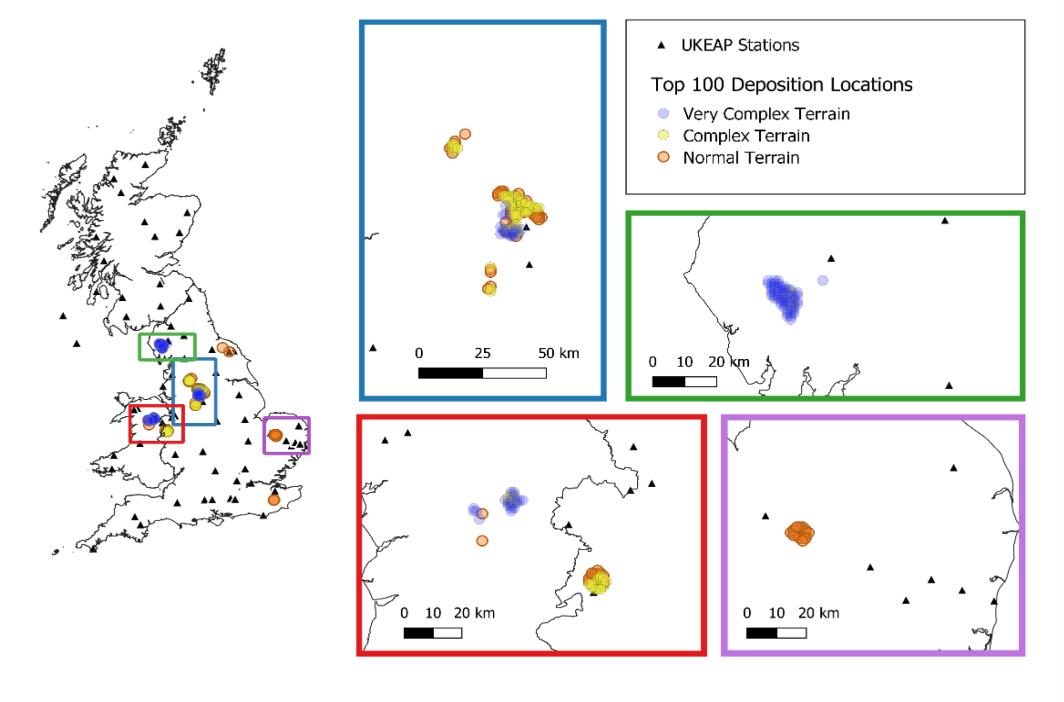
UK Centre for Ecology & Hydrology

Rationale



UK Centre
Ecology &

Problem-3: Monitoring biased towards flat terrain regions and current techniques not adapted to operation in mountains

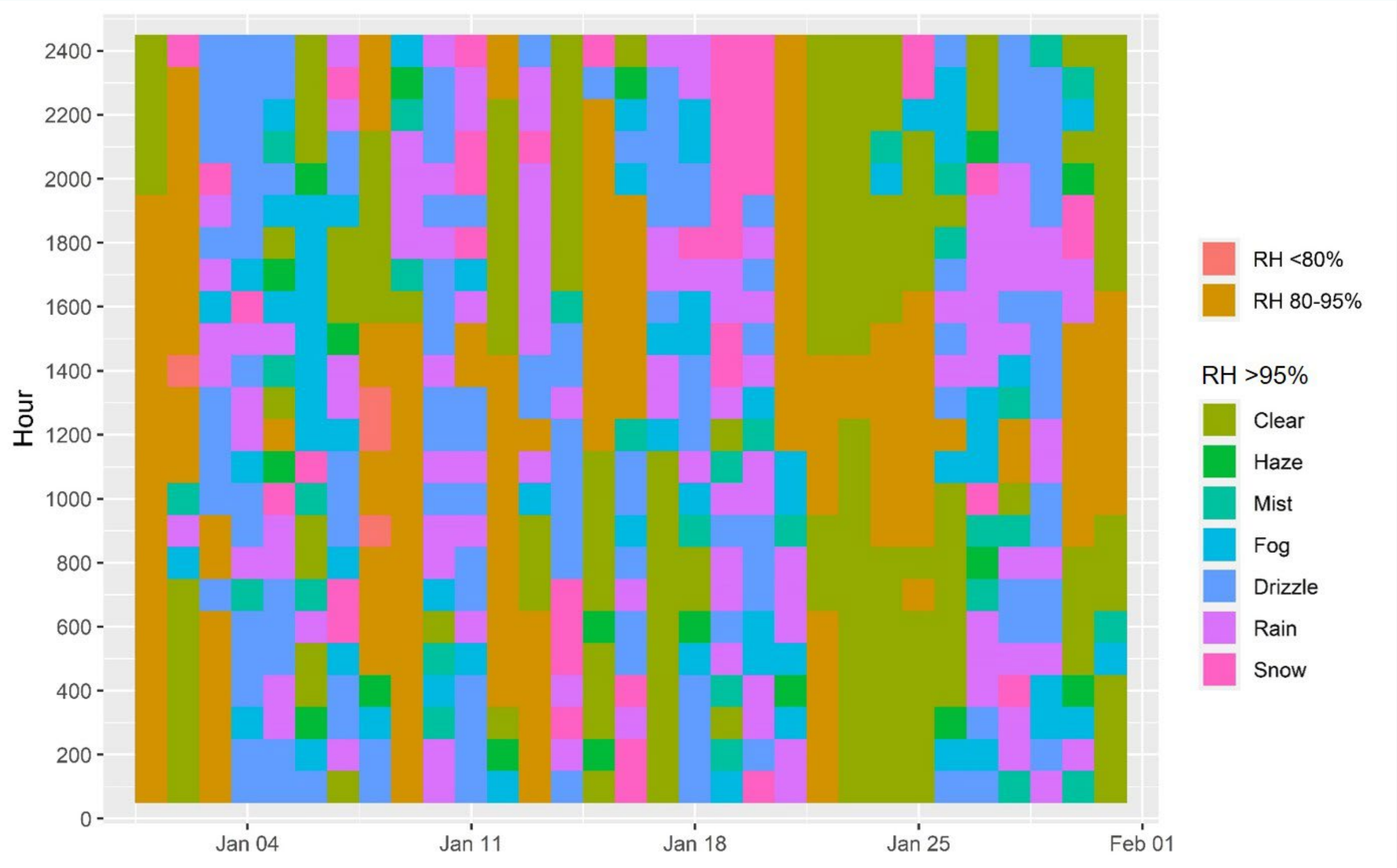


Problem-4: High elevation regions have sensitive species, freshwater reserves and high associated mitigation costs

£880m

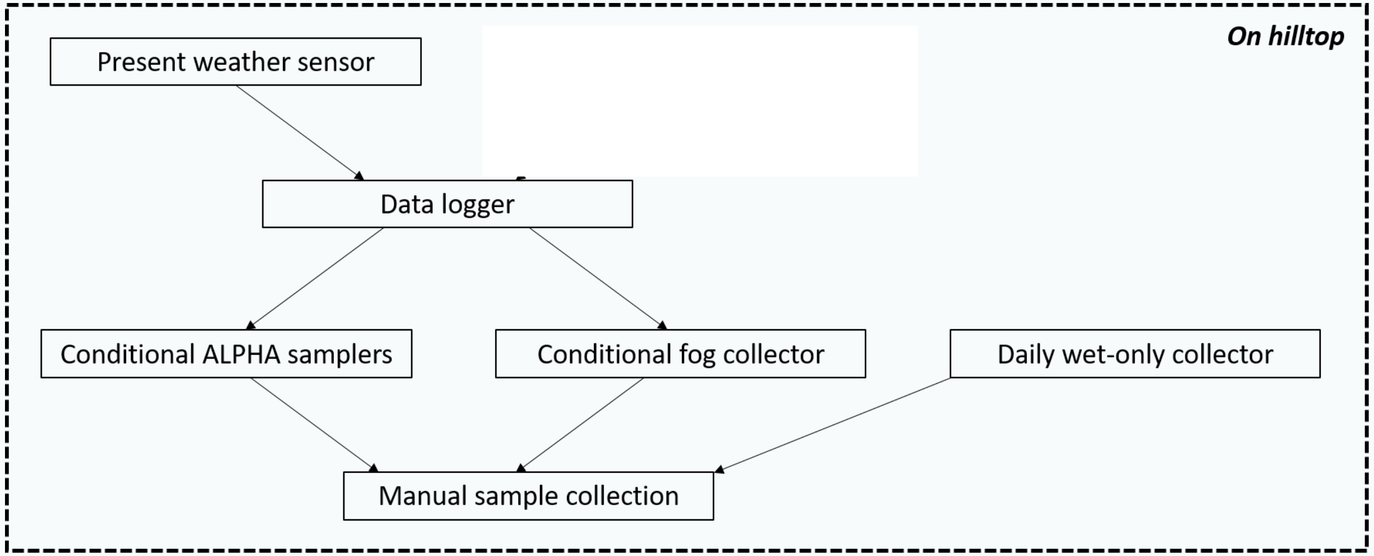
The estimated economic impact on natural capital and ecosystem services from N_r deposition over UK complex terrain annually.

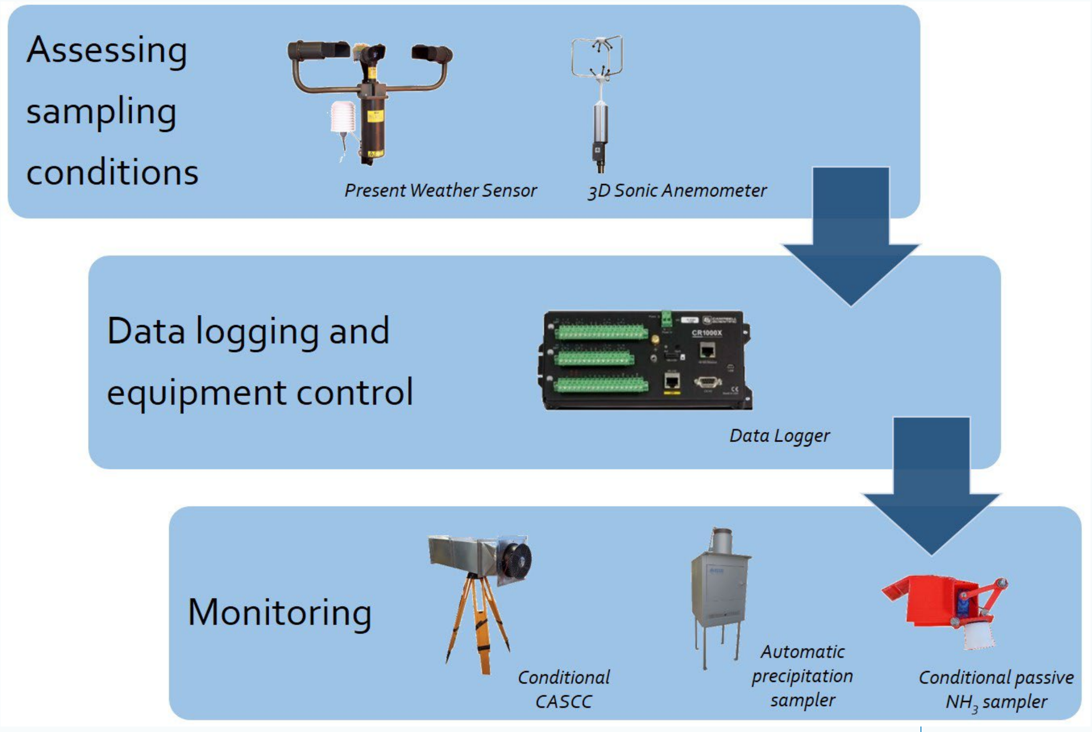
UK Centre for Ecology & Hydrology



Prevalent hourly weather conditions based on relative humidity and visibility at the Auchencorth Moss supersite in January 2021 measured using a Biral VPF-750 Visibility and Present Weather sensor

Instrumentation





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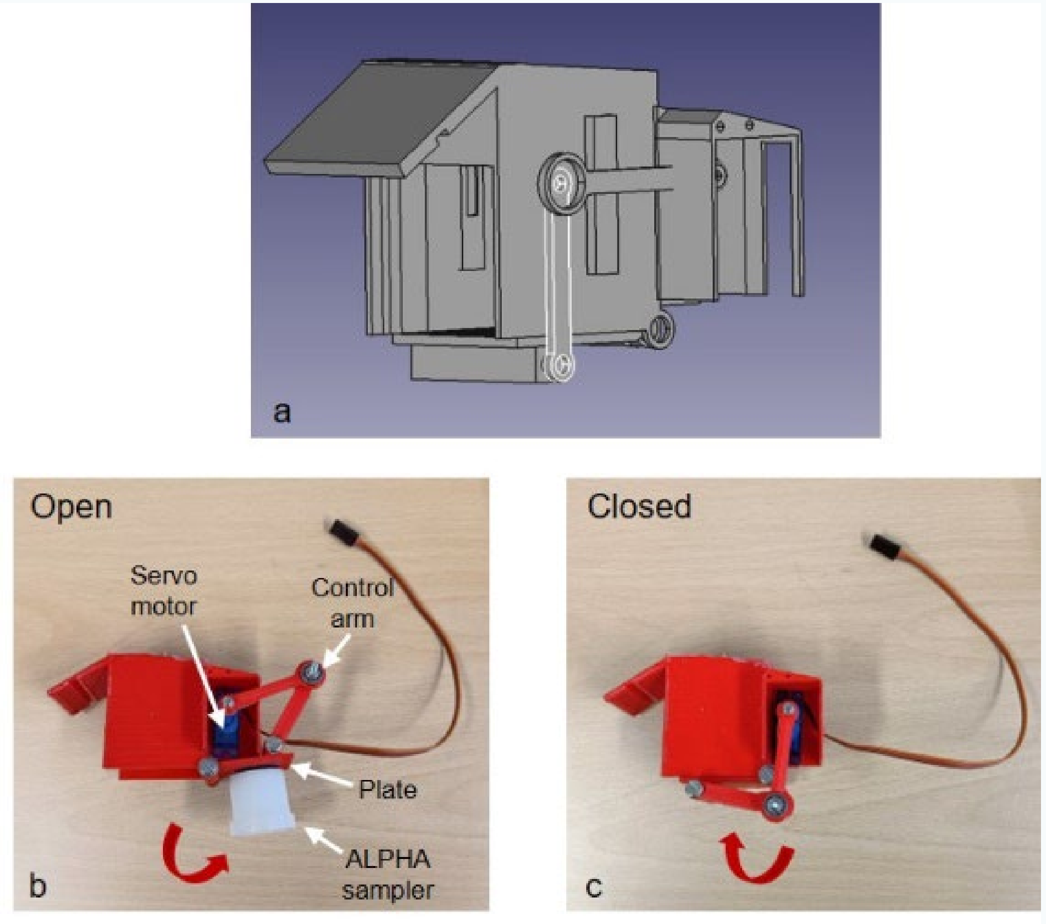
Conditional ALPHAs



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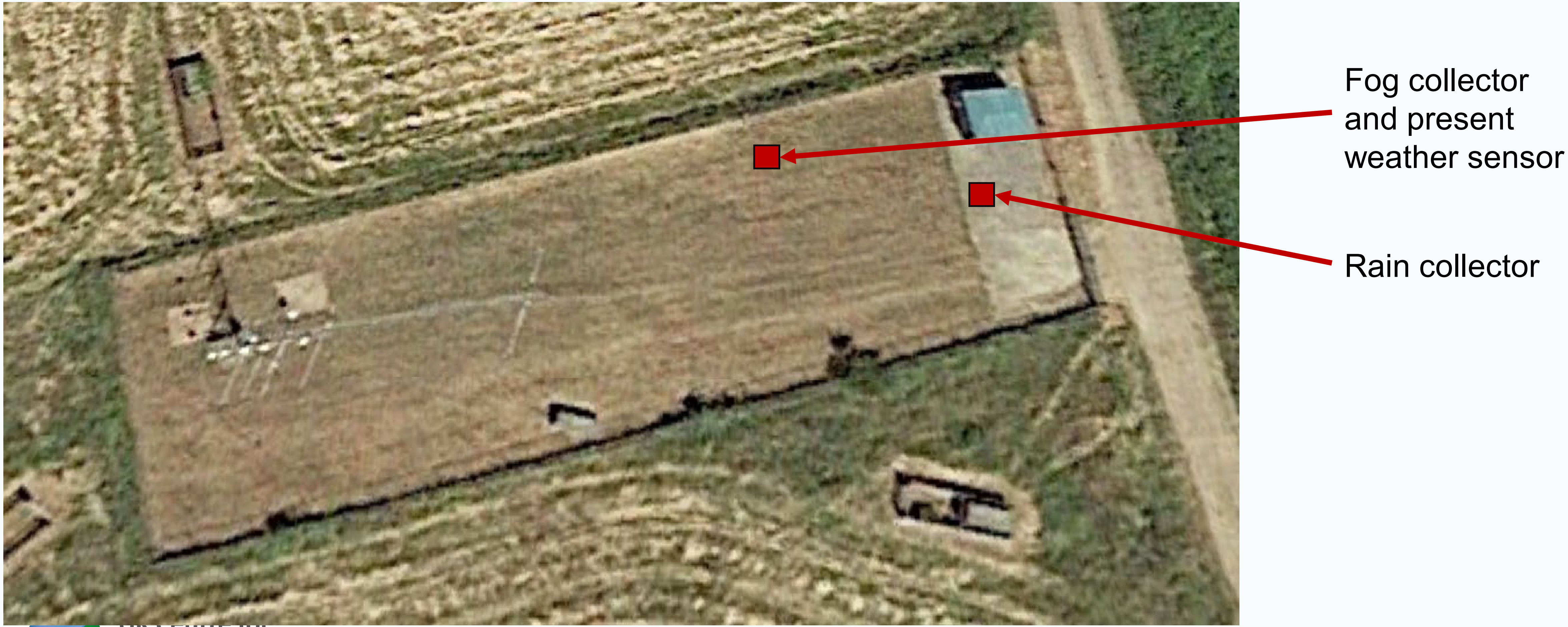
Research equipment set up

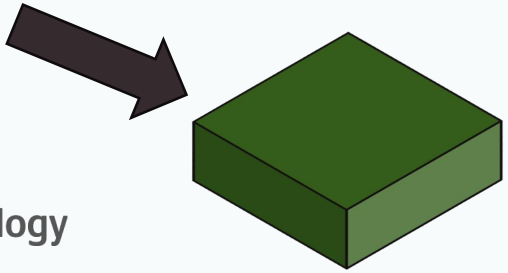


Research equipment

1. Automatic Rain Sampler (Digitel DRA-12)

Sampler dimensions:
65 cm long x 65 cm wide x 150 cm tall

Placed on a concrete slab and legs bolted down to the slab



Concrete slab dimensions:
100 cm x 100 cm

Reference photo of a DRA-12 installed on a concrete slab

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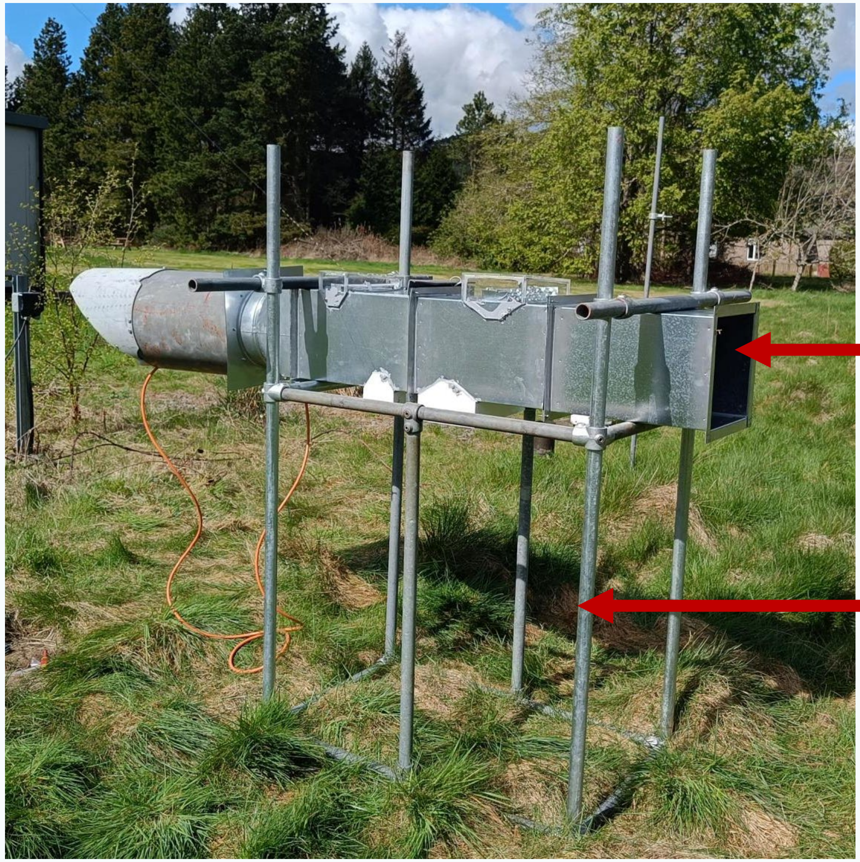
Research equipment

2. Fog collector



Fog collector

Mounting frame

Reference photo of a fog collector from a site in Edinburgh

The fog collector will be mounted on a frame made of scaffolding poles

Dimensions of the fog collector:
30 cm wide x 30 cm tall x 150 cm long

Dimensions of the mounting frame:
60 cm wide x 100 cm tall x 100 cm long

The scaffolding poles will be pushed
50 cm into the ground

Fog modelling

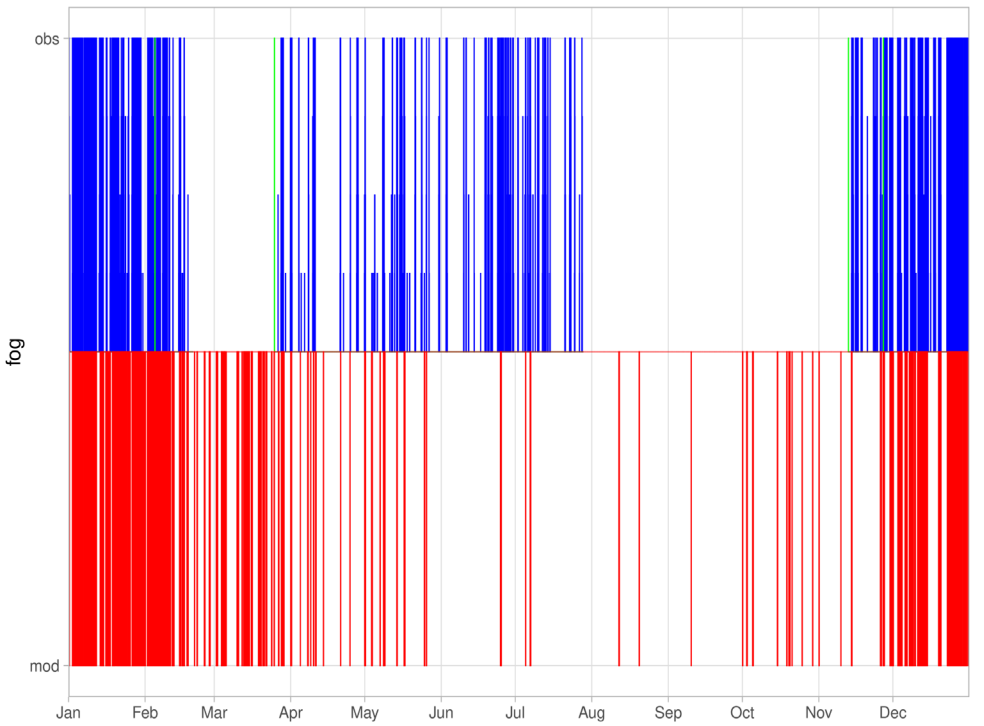


Figure 5 2021 Presence/absence of fog within 15 minute increments at Holme Moss observed (top) and modelled (bottom). Green bars represent missing data within the hour.

Summary and next steps

We have applied a fog deposition parametrisation and calculated fog deposition of pollutants from EMEP4UK output for 2021 which is a solid foundation for future improvements. The fog parametrisation can be applied to any wet depositing pollutant modelled in EMEP and for any year.

In the next steps of the project, we will examine possible improvements to the fog deposition scheme (specifically the application of Henry's law).

We will also run EMEP4UK with 2024 meteorology at the higher resolution of 1 km x 1 km around the new measurement sites to match the measurements collected by the sites set up in our parallel project.

The chemical analysis of rain and fog samples collected at the newly set up sites will allow us to assess if the assumptions made for the ratio between rain and fog ion concentration in the CBED parametrisation are valid for current UK conditions.

We will develop series of recommendations for the model investigated in this study and more general scientific evidence and model process development requirements needed in future to accurately model fog chemistry and fog-driven occult deposition in the UK.

It is becoming evident that a new focus on hourly and daily resolution of pollution deposition is needed to underpinning methods to mitigate annual deposition levels.

Progress in this area will lead to a step change in capability to identify and change drivers of N-deposition in complex terrain.

Thank You

For more information please contact:

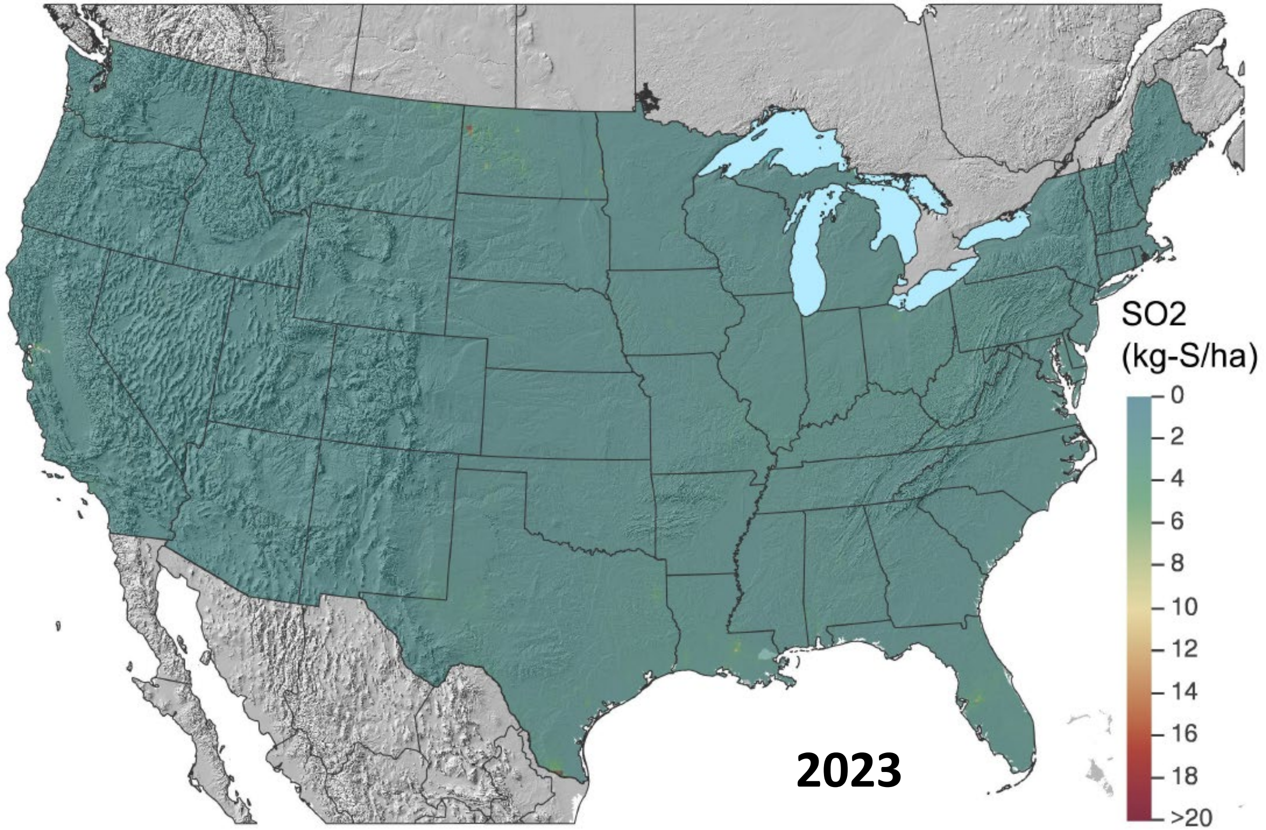
enquiries@ceh.ac.uk

@UK_CEH

ceh.ac.uk

UK Centre for Ecology & Hydrology

TDep Measurement Model Fusion Workgroup Update



TDep Committee Fall 2024 meeting

Nov. 5, 2024

U.S. ENVIRONMENTAL PROTECTION AGENCY

Disclaimer:

The views expressed in this presentation are those of the authors and do not necessarily reflect the views or policies of the U.S. EPA

Outline

1. Recap from Spring TDep MMFWG and Progress on Version status
2. Results from 2023 data
3. Weekly Wet Deposition
4. UW APHL Fellow progress
5. Wildfire Deposition
6. IMPROVE and CSN Sulfate
7. Deposition Uncertainty

1. Recap from Spring TDep MMFWG and Progress on Version status

Running Action Items and Progress since Spring meeting:

- TDep Script Conversion Manuscript being resubmitted to *Environmental Modelling & Software*
- TDep MMF Fact Sheet reviewed by TDep, EOS and ready to publish
- Provide citable material for changes to TDep MMF (bias adjustment)
  - Current explanations in TDep documentation (online); TDep presentation from Fall 2023 (upon request)
  - Plan to discuss bias adjustment along with trends from other versions after weekly wet deposition with CMAQ fusion is completed
- Is there still a need for archived v2018.02 grids (using ArcMap)?
- Current policy is to remove previous versions (still available upon request) from web when new versions are produced

National Atmospheric Deposition Program

Measurement Model Fusion Approach for Estimating Total Deposition

Total Deposition Science Committee

The mission of the Total Deposition Science Committee (TDep) is to improve estimates of atmospheric deposition by advancing the science of measuring and modeling atmospheric wet, dry, and total deposition of nitrogen and sulfur species. TDep provides a forum for the exchange of information on current and emerging issues within a broad multi-organization context including atmospheric scientists, ecosystem scientists, resource managers, and policy makers. Specific charges of the committee and more information and resources can be found on the NADP website at http://nadp.slh.wisc.edu/committees/tdep.

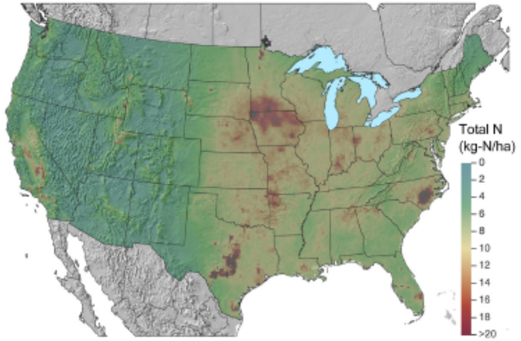


Figure 1. Map of Total Nitrogen Deposition for a 3-year average of 2019 to 2021

A goal of TDep is to provide estimates of total nitrogen and sulfur deposition fluxes (Figure 1) across the U.S. for use in critical loads and other ecological assessments, particularly where loading results in the acidification and eutrophication of ecosystems. Total deposition flux estimates are derived from summing contributions from wet and dry deposition. Members of the TDep committee developed and now maintain a measurement-model fusion approach (herein TDep MMF) to map total deposition that combines measured and modeled values. This provides a product that utilizes both the accuracy of the measurements and the spatial continuity of modeled estimates.

In the TDep MMF, measured values are given more weight at the monitor locations, while modeled data are used to fill in spatial gaps and provide information on chemical species that are not measured by routine monitoring networks. One of the main advantages to this approach is that it provides continuous spatial and temporal coverage of total deposition estimates in the U.S. (beginning in 2000). This allows the analysis of trends over time for any location. Figure 2 illustrates changes in the mean deposition fluxes for total N, oxidized N, and reduced N over the contiguous U.S. since 2000. While fluxes of oxidized N—generally stemming from combustion emissions—have decreased due to regulations on air pollution, fluxes of reduced N—mostly contributed by agricultural emissions—have grown. This has led to an overall slight decrease in total N, with a flatter trajectory in recent years.

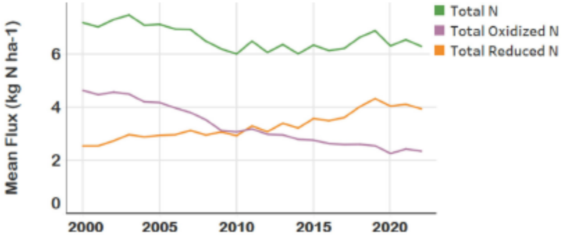


Figure 2. Trends in mean deposition fluxes of total N, oxidized N, and reduced N over the contiguous U.S. from 2000 to 2022.

Thank you to Anna Hyland for formatting. Vetted by TDep and EOS committees

https://nadp.slh.wisc.edu/committees/tdep/

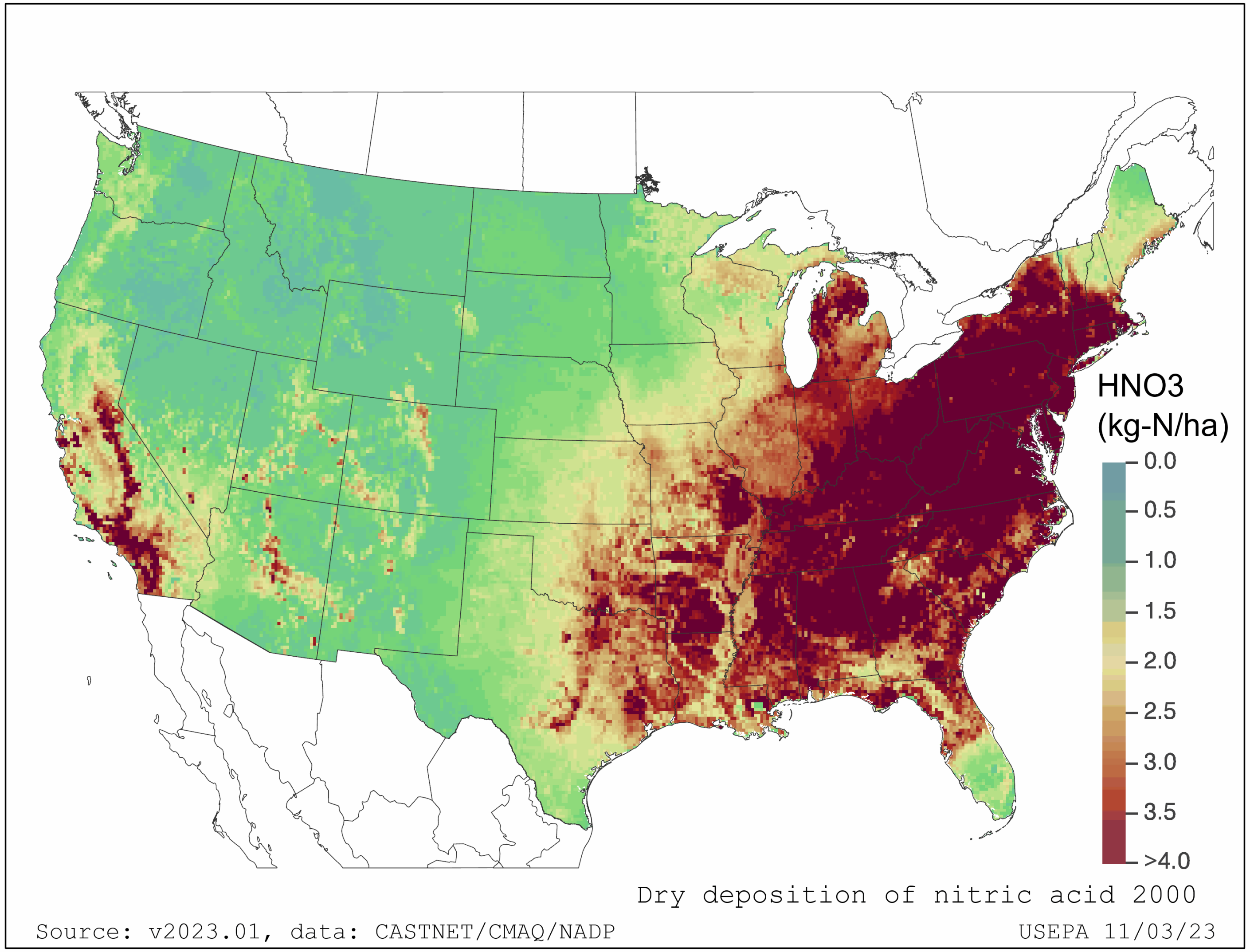
- Total Deposition Map Fact Sheet

1. Recap from Spring TDep MMFWG and Progress on Version status

TDep MMF Versions and run status:

- **2023 data available!** on TDep website (run using last year's v2023.01)
  - Images, Image Summary PDFs
  - Grids, Extended Coastline Grids
  - Image movie GIFs
- **Planned updates:**
  - ***v2025.01:***
    - Will include weekly PRISM and NTN concentrations and precipitation
    - Update IDW interpolation distances

      Thank you to Kristen Foley
  - ***v2025.02:***
    - will include weekly EQUATES wet deposition data fusion
    - Missing data substitution.
- May incorporate both upgrades into a single version with intermediate checks on impacts to deposition estimates for each step.

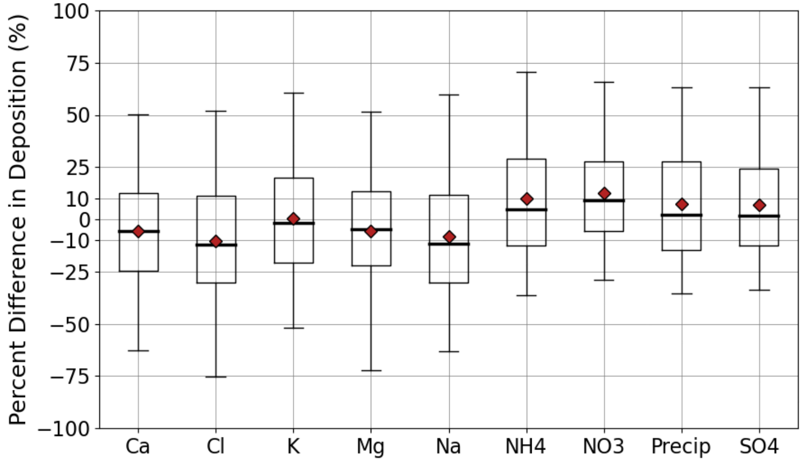


v2023.01 Image movie GIF for HNO_3

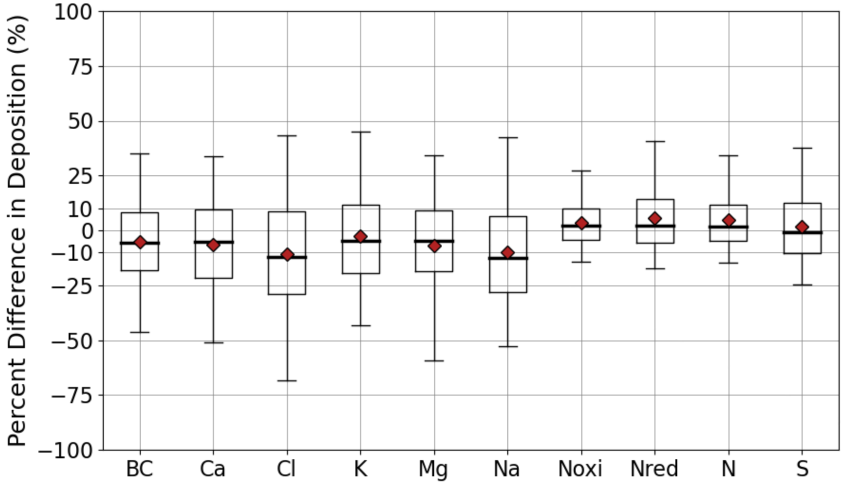
2. Results from 2023 using v2023.01

Percent differences for 2023 minus '2020 to 2022 average'

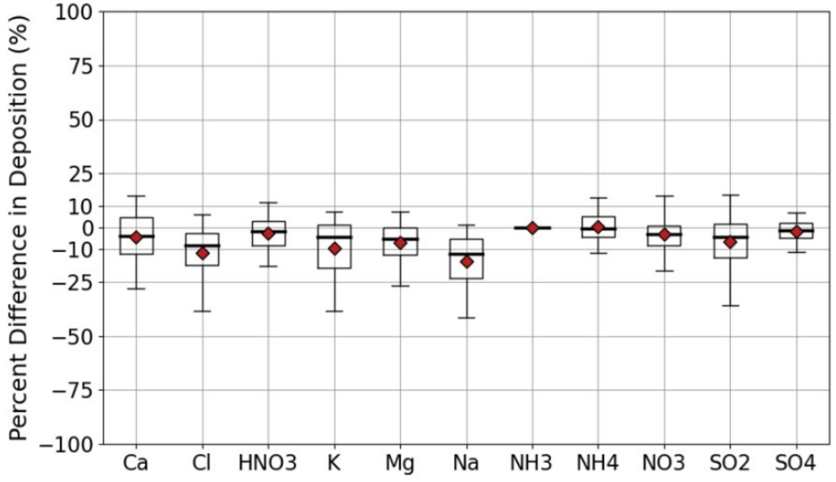
Wet deposition



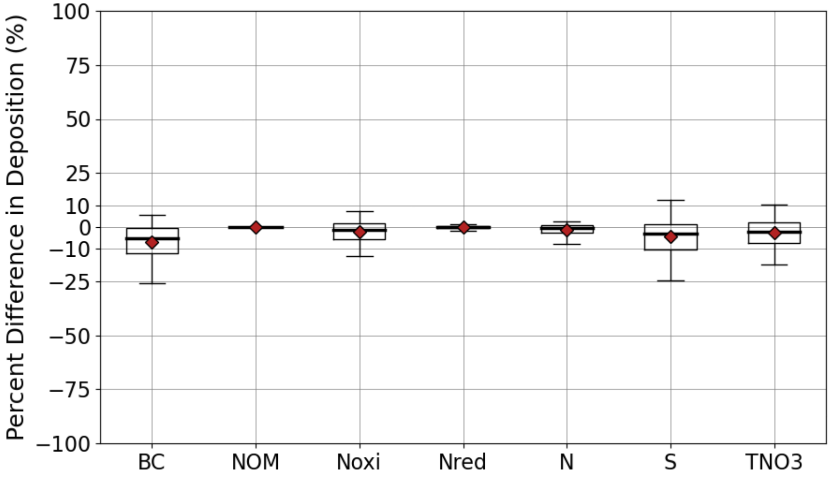
Total deposition



Dry deposition



Dry Sums Deposition



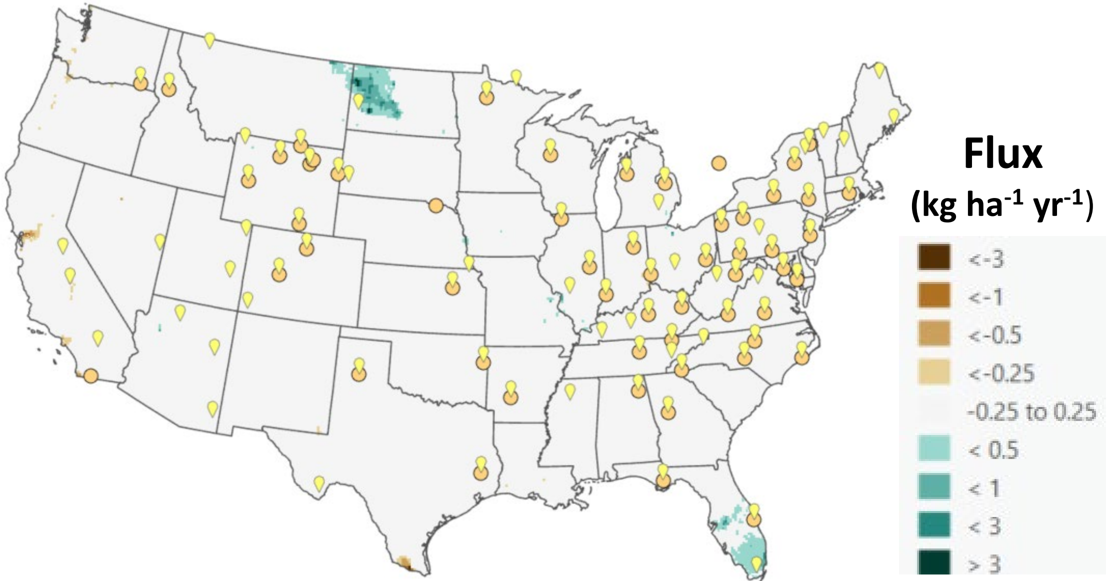
v2023.01: Impacts of NPS discontinuation on SO_2

- CASTNET discontinued SO_2 analysis
  - at NPS-managed sites after July, 2023
  - at all sites after July, 2024
- Less impact than expected in TDep MMF flux estimates
  - Result of LWMA bias adjustment approach

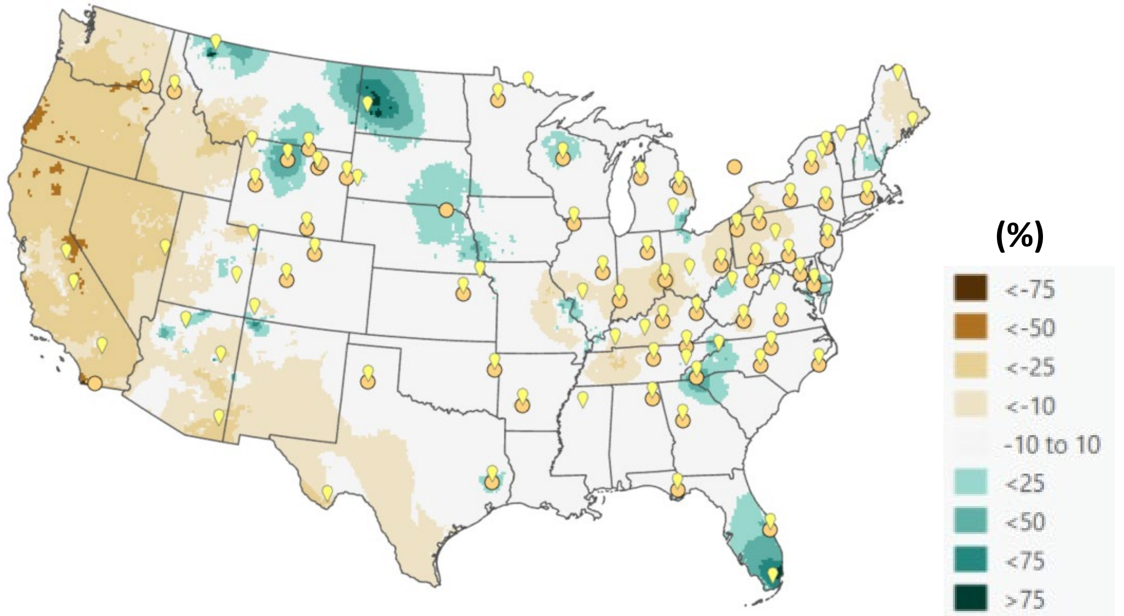
Reduction in SO_2 sites from 2022 to 2023

CASTNET Spring 2022 (week 18); IDW (black)
CASTNET Fall 2023 (week 47), IDW (blue)

Difference in SO_2 deposition flux (2023 minus 2020-22)

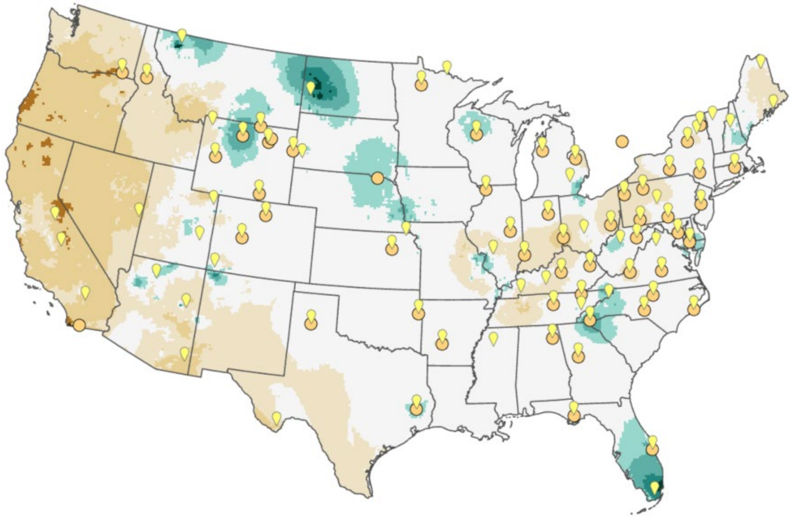


Percent Diff. in SO_2 deposition flux (2023 minus 2020-22)

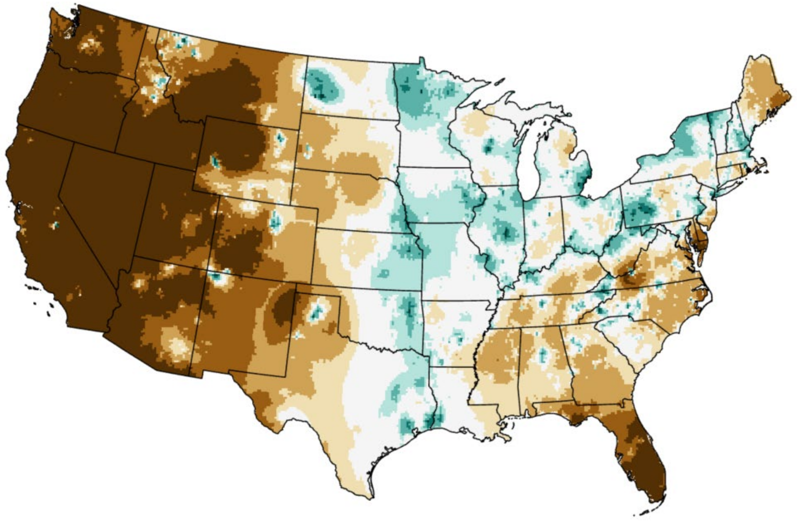


v2023.01: Importance of Bias adjustment of SO_2

% Diff. in SO_2 deposition flux (2023 minus 2020-22)



Scenario with no Bias adjustment (2017): Estimated % Diff. SO_2 deposition flux



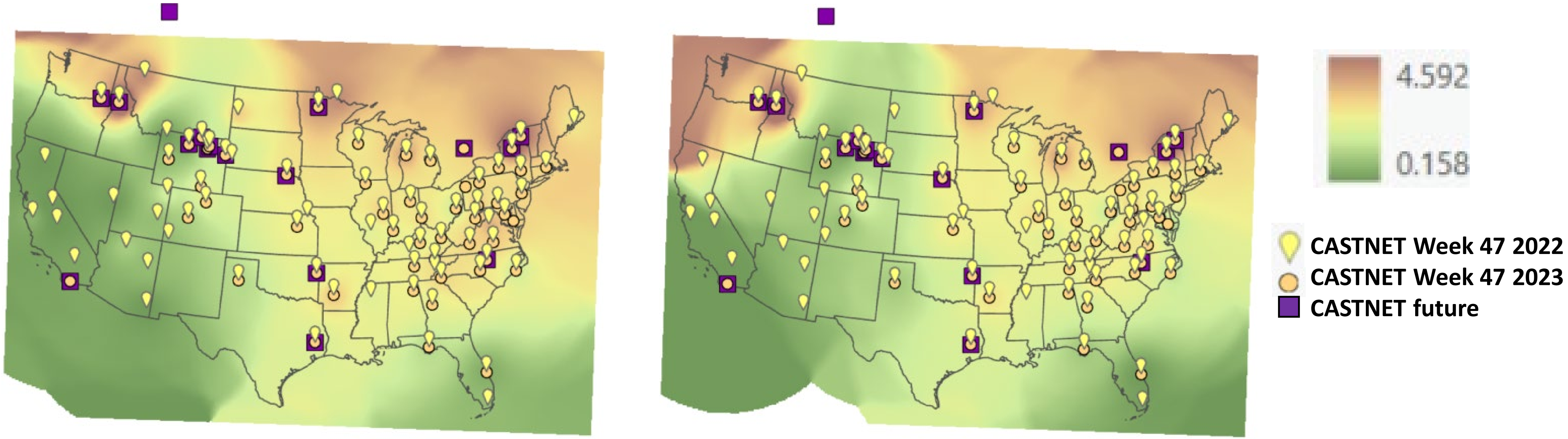
% Difference

- Bias adjustment is important for SO_2
  - Impact of loss of large number of sites is reduced by bias adjustment protocol
  - Scenario without any bias adjustment has larger impacts

Year	Start	End	Nyrs
2013	2011	2015	5
2014	2012	2016	5
2015	2013	2017	5
2016	2014	2018	5
2017	2015	2019	5
2018	2016	2019	4
2019	2017	2019	3
2020	2017	2020	4
2021	2017	2021	5
2022	2018	2022	5
2023	2018	2023	6

- Current Bias adjustment protocol
  - Uses linear-weighted moving average of lead/lag weeks (Week# ± 2) over the most recent years (± 2)
  - Protocol deviates after last modeled year (2019):
    - preserve min of 3 years
    - preserve min of 2 non-mismatched measurement/model years

Options for SO_2 bias moving forward



SO_2 Bias Week 47 2022 (yellow pins) **SO_2 Bias Week 47 2023 (orange circles)**

- Options moving forward:
  - Pretty similar bias (CMAQ / $CASTNET_{Obs}$) rasters for 2022 and 2023
    - Changes are masked with multiple years
  - At some point, loss of sites for bias adjustment will make difference
    - Post-2024, 17 CASTNET sites will continue sampling SO_2 data moving forward (**purple boxes**)
  - How do we want to implement this change?

3. Status of v2025.01: Weekly Wet deposition

Objectives

- Preserve current NTN methods for reported ***annual concentrations and deposition***
- Include NTN weekly concentrations and precipitation to have ***weekly wet deposition estimates***

Coding Complexities and Model Uncertainties

- Cannot simply sum these to different intervals using the same approach as dry
- Reproducing NTN method for estimating ***wet deposition at different averaging intervals*** (e.g. seasons, water years, multiple years) introduces some coding complexities
    - Differences in sampling schedule and existing "idealized" Tues to Tues intervals used for dry and modeled
        - Precip events outside of Tues to Tues schedule
- How to handle invalid concentrations and low precip events used for Total Precipitation (TP)?
- ***How does MMF on a weekly basis reconcile with NADP approach?***

Current NADP Approach to aggregate wet deposition to different intervals

$$PWM = \frac{\left(\sum_{i=1}^{N_v}(C_i * P_i)\right)}{\sum_{i=1}^{N_v} P_i}$$

1. Calculate Precipitation-weighted mean (PWM) concentration using valid precipitation samples

$$PT = \sum_{i=1}^{N_t} P_i$$

2. Calculate total precipitation (PT) using all samples at site

$$DEP = PWM * PT \div 100$$

*3. Deposition is the PWM * PT with a unit conversion factor*

Thank you to Mark Kuether, David Gay for input on NADP calculation and QA approach.

- PRISM modeling differences including use of radar between daily and monthly (used for annual) modeling
- PRISM Daily mismatch with "ideal" sampling schedule (9am to 8 am LT on/off times)
- Additional NADP NTN sampling QA and data handling (long exposure periods, annual concentrations substituted for flags for dry and trace)

Because of uncertainties, we will keep this as a "Research Product" until thorough comparison can be made with v2023.01 and revisit then.

4. Update on UW APHL Fellow

- Application submitted, looking for a start date near *Jan. 1*
- Potential fellow would have project time split between the NADP Lab Operations and TDep MMF script updates
  - A. Mager will replace D. Gay as the UW mentor.
  - G. Beachley will still lead the TDep MMF portion with remote check-ins
- Expect that early portion of the fellowship will be focus on familiarization with TDep MMF:
  - Focus project candidate is to '*Development of a protocol for replacement of missing observation data using spatial and temporal statistical analyses of past trends*'

Thank you to Amy Mager, Katie Blaydes, Zac Najacht, David Gay for efforts on this!

5. Wildfire Deposition

- **EPA ROAR Project:** using NOAA Hazard Mapping System to qualitatively identify NADP and CASTNET samples that are likely wildfire impacted
  - TDep MMF included as a product-user for this dataset
- Small CASTNET Task is in place to build on these datasets to see if we can quantify wildfire contributions to deposition for these periods.
- Included TDep MMF as part of unsuccessful *NASA ROSES proposal* for looking at Wildfire deposition impacts … hopeful to submit to other proposal calls

6. Inclusion of CSN (urban) and IMPROVE data into TDep MMF

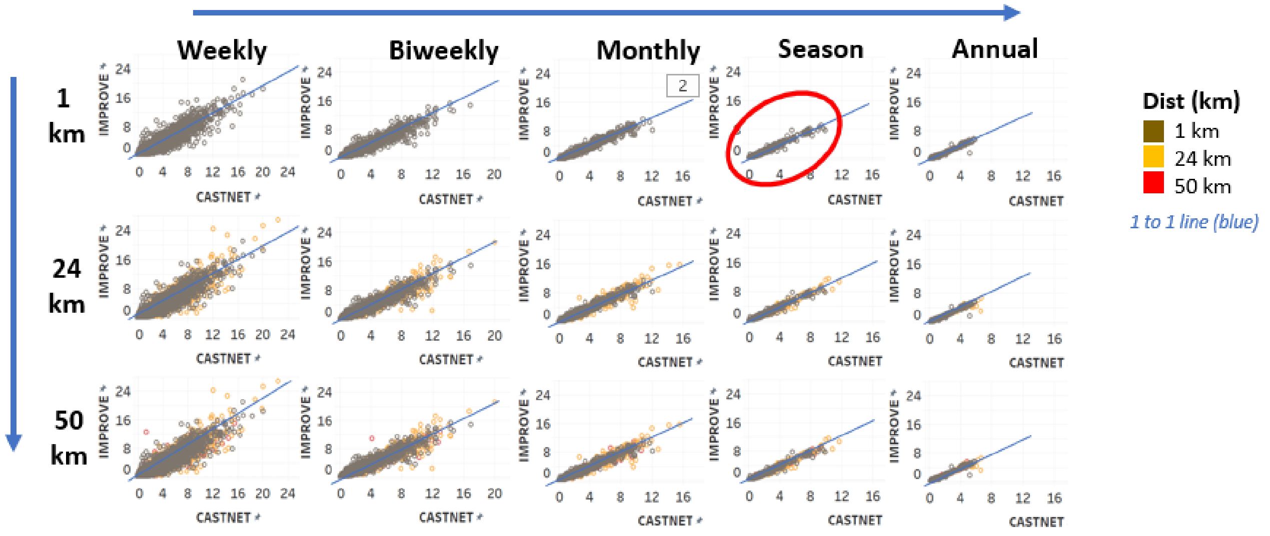
- Analysis of co-located SO_4 measurements found that network sampling frequency differences averaged out over ***seasonal to annual*** periods.
- Consistent with Literature
- Nitrate and Ammonium analyses are still pending
- Plan to include these sites in TDep MMF at seasonal level
    - Working out coding logistics
    - Urban CSN sites will help with known TDep MMF rural measurement bias

EXAMPLE: Collocated Data Comparison

Comparisons for IMPROVE to CASTNET SO_4 (1990 to 2022)

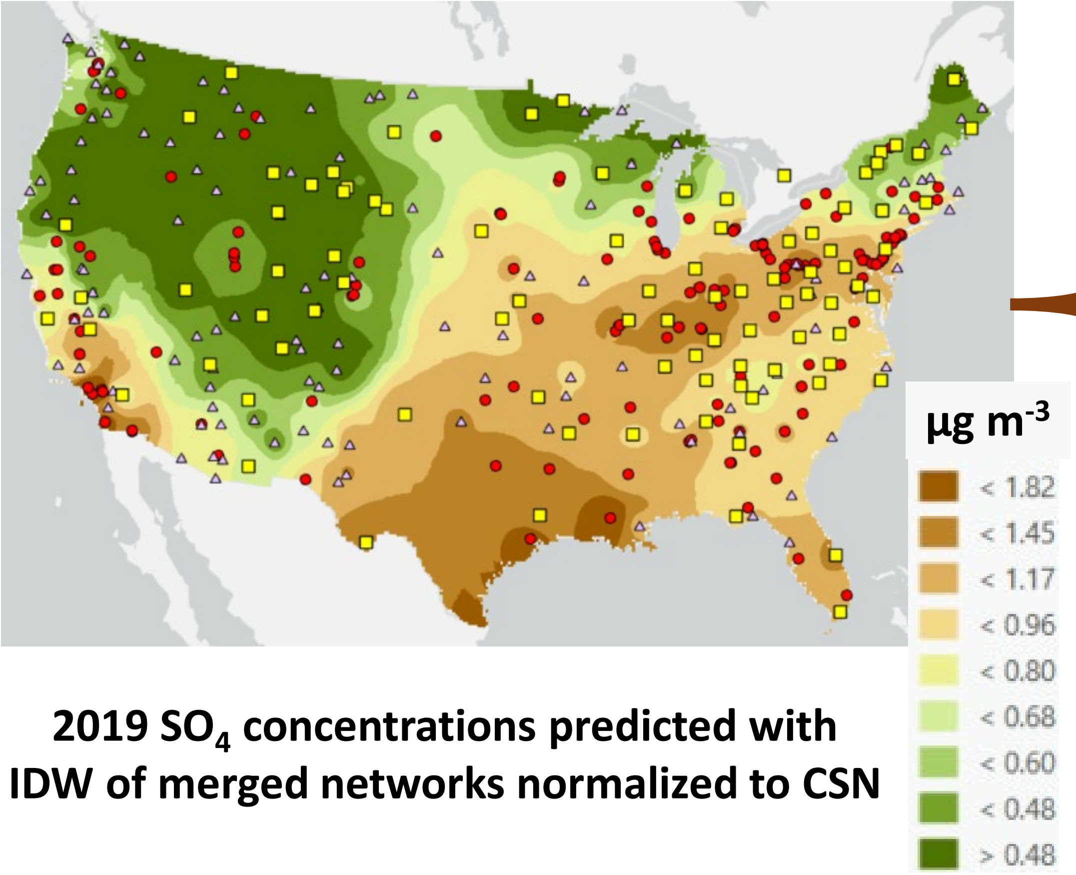
- Increasing aggregation interval length
- Decreasing outliers

- Increasing co-location site distance
- Increasing N
- Increasing spatial variability and outliers



- also run for IMPROVE to CSN and CASTNET to CSN site co-locations with consistent results

Utilize adjusted datasets to Create SO_4 Concentration Maps: e.g. Summer 2019

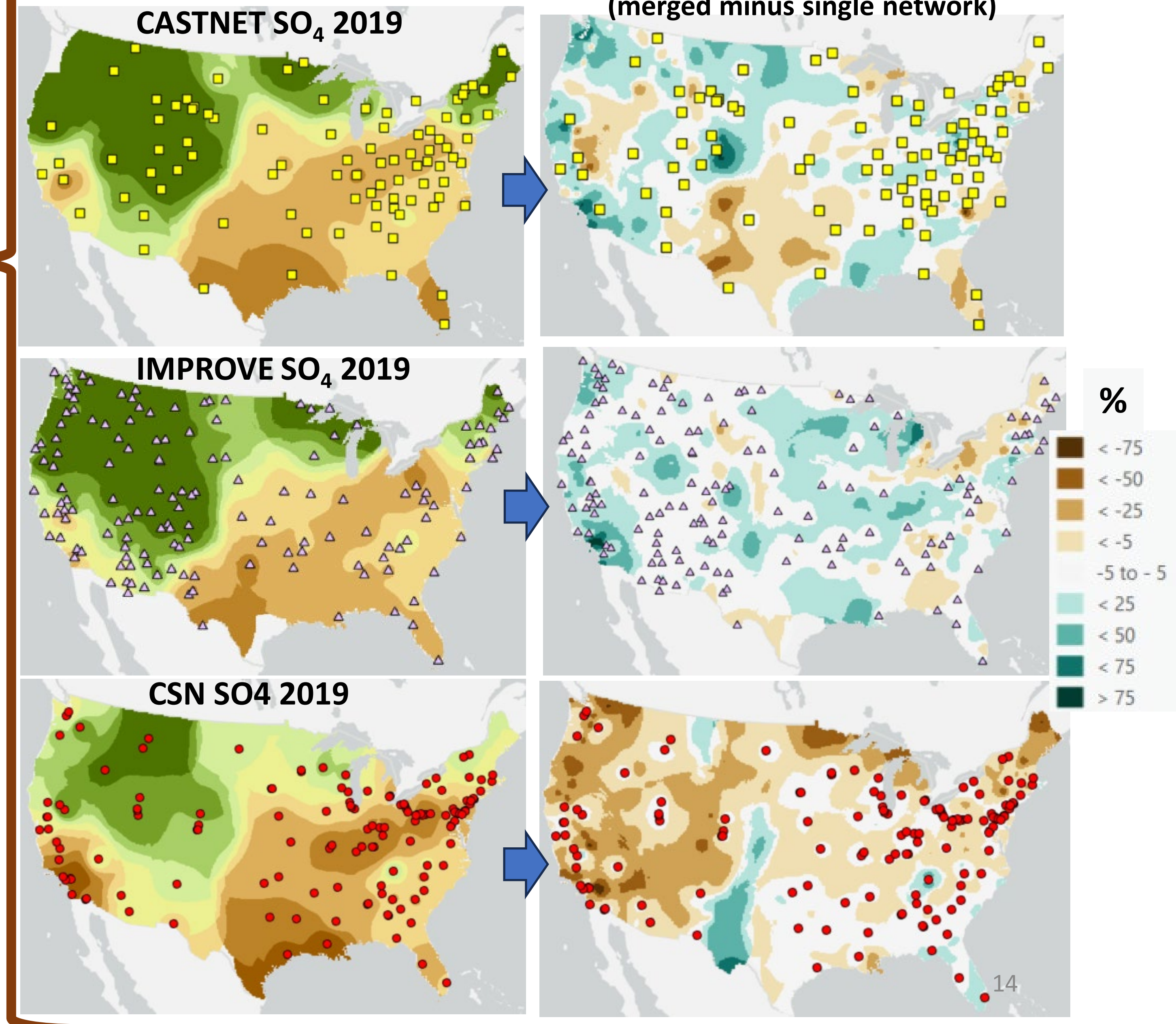


2019 SO_4 concentrations predicted with IDW of merged networks normalized to CSN

- Created multi-network maps from adjusted datasets (based on co-located relationships) to seasonal level
- CSN measurements may help address rural TDep MMF bias

Single network maps:

Percent Difference Maps:
(merged minus single network)



NOTE: Seasonal IDW distance from Variogram of EQUATES seasonal concentrations

7. Deposition Uncertainty Status

- Effort to build an analysis for a framework to quantify Deposition Uncertainty
  - Considered a Leave One Out and Monte Carlo strategies, but were historically hampered with budget constraints
  - New Leave One Out analyses at site locations and interpolated areas underway this winter to be led by Justin Coughlin at USDA
- Update the WDUM metric (*Walker et al., 2019*) for model version and incorporate qualitative factors such as elevation and land-use

Current TDep MMF Project Prioritization

1. *Incorporating weekly PRISM precipitation data and CMAQ wet deposition*
2. *Development of a protocol for replacement of missing observation data using spatial and temporal statistical analyses of past trends* ***Potential APHL project
   - *May extend this to discontinuing sampling and monitoring sites (e.g. Bias adjustment)*
3. Extending the framework and capability of TDep MMF to utilize more measurement data
   A. AMoN NH_3 concentrations coupled with method for incorporating bi-directional modeled dry deposition fluxes
   B. *Concentration measurements from long-term nationally distributed networks (CSN, IMPROVE, SLAMS NO_2)*
   C. Concentration and direct flux measurements from local intensive studies (e.g. Urban, Throughfall, lichens, COTAG)
   D. New concentration measurements (e.g. wet soluble organic N)
   E. relative spatial concentration gradients from satellite data
4. *Analysis of concentration samples impacted from smoke- events to estimate excess deposition fluxes from wildfires*
   - *Building on an existing EPA ROAR project*
5. Conduct statistical analyses to roughly quantify areas of high uncertainty in deposition fluxes Building a base understanding of sources of uncertainty, and their relative magnitudes
   - *Using current capabilities and resources to run a 'Leave One Out' analyses on TDep MMF*

Request for TDep MMF data accessibility using an on-line access tool

Environment and Climate Change Canada / Environnement et Changement climatique Canada

ADADIO

A measurement-model fusion product for atmospheric deposition

NADP TDEP Fall Meeting

November 5, 2024

Irene Cheng, Amanda Cole, Alain Robichaud,
Jian Feng, Hazel Cathcart, Amy Hou, Jason Chiu, Bill Sukloff
Air Quality Research Division
Environment and Climate Change Canada

Canada

DEVELOPMENT TEAM

Alain Robichaud, Amanda Cole	original research and development; data assimilation and measurement data leads
Irene Cheng	project management
Jian Feng, Hazel Cathcart	preparing modeled data, testing/modifying scripts on the supercomputer (Linux system)
Amy Hou	preparing measurement data
Jason Chiu, Bill Sukloff	testing/modifying scripts using SAS software; recoding of programs to R

MAJOR UPDATES

- ADAGIO methods manuscript – Part 1 focuses on general methodology and wet deposition MMF (under review[1])
  - 3 papers planned (Atmospheric Environment)

- Ongoing development of a routine ADAGIO product – produce high-resolution total S and total N deposition maps on annual basis

[1] Robichaud, A., Cole, A., Cheng, I., Cathcart, H., Feng, J., and Hou, A., 2024. Data fusion of modelled and measured deposition in the U.S. and Canada, Part I: description of methodology and validation of wet deposition of sulfur and nitrogen. In review.

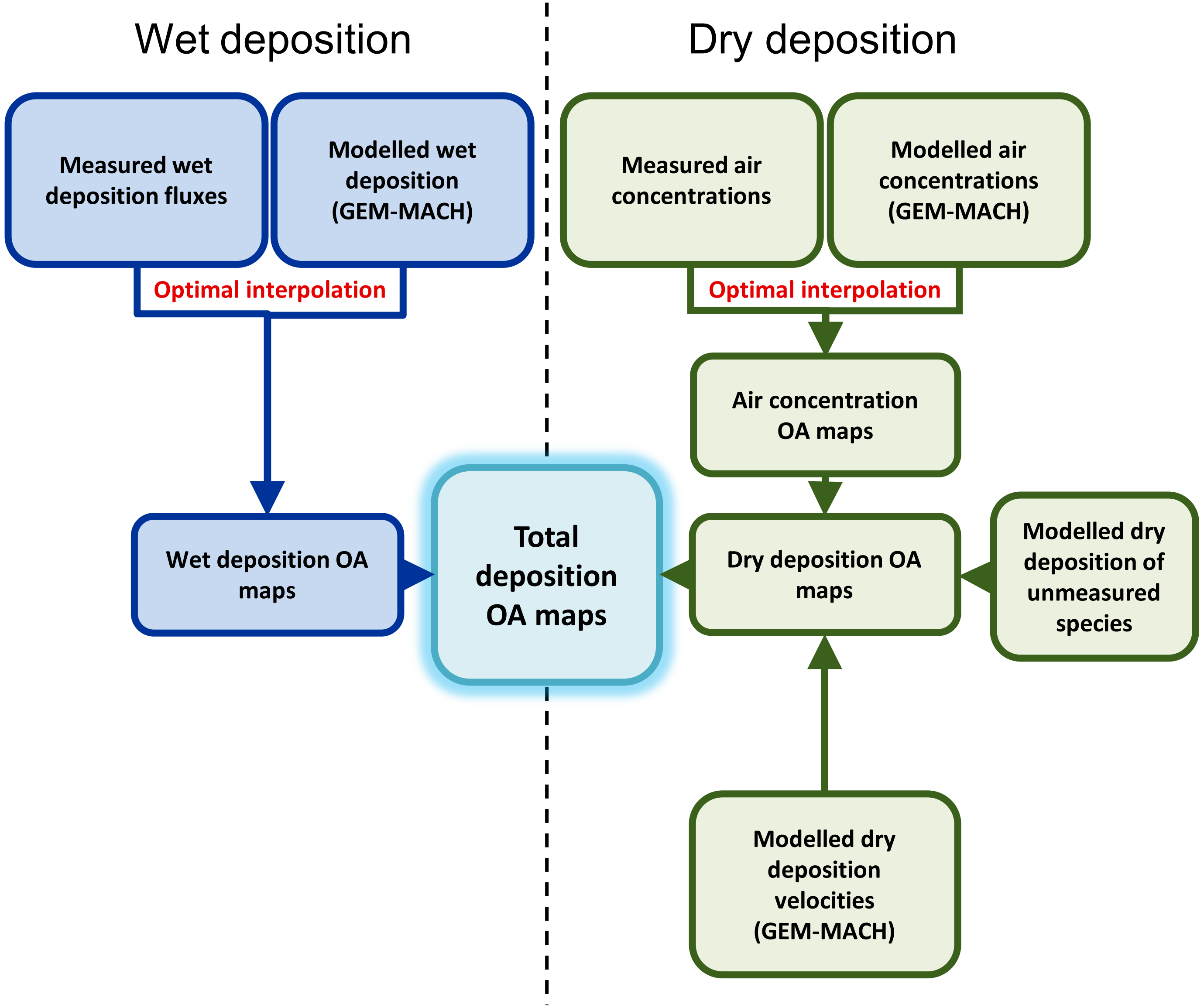
ADAGIO METHODS PAPER (PART 1)

ADAGIO: Atmospheric Deposition Analysis Generated by Integrating Observations into model

Method overview for wet deposition MMF:

- Domain: Canada, USA and Northern Mexico
- Resolution: 10 km
- Measurement data (at regionally representative stations): (1) NADP National Trends Network (NTN) & AIRMoN, (2) ECCC Canadian Air and Precipitation Monitoring Network (CAPMoN), (3) provincial data
- Modeled data: ECCC GEM-MACH (Global Environmental Multiscale - Modelling Air Quality and Chemistry)/RAQDPS (GEM-MACH operational model)
- MMF method uses Optimal Interpolation technique (Robichaud & Ménard, 2014; Robichaud et al., 2016) and additional approaches

ADAGIO Data Flow Diagram



- Fusion of measurement and model is called Objective Analysis (OA)

  OA = Model + Analysis Increment
- We produce seasonal OAs
  - 3 wet deposited species
  - 9 gases and particles (dry)

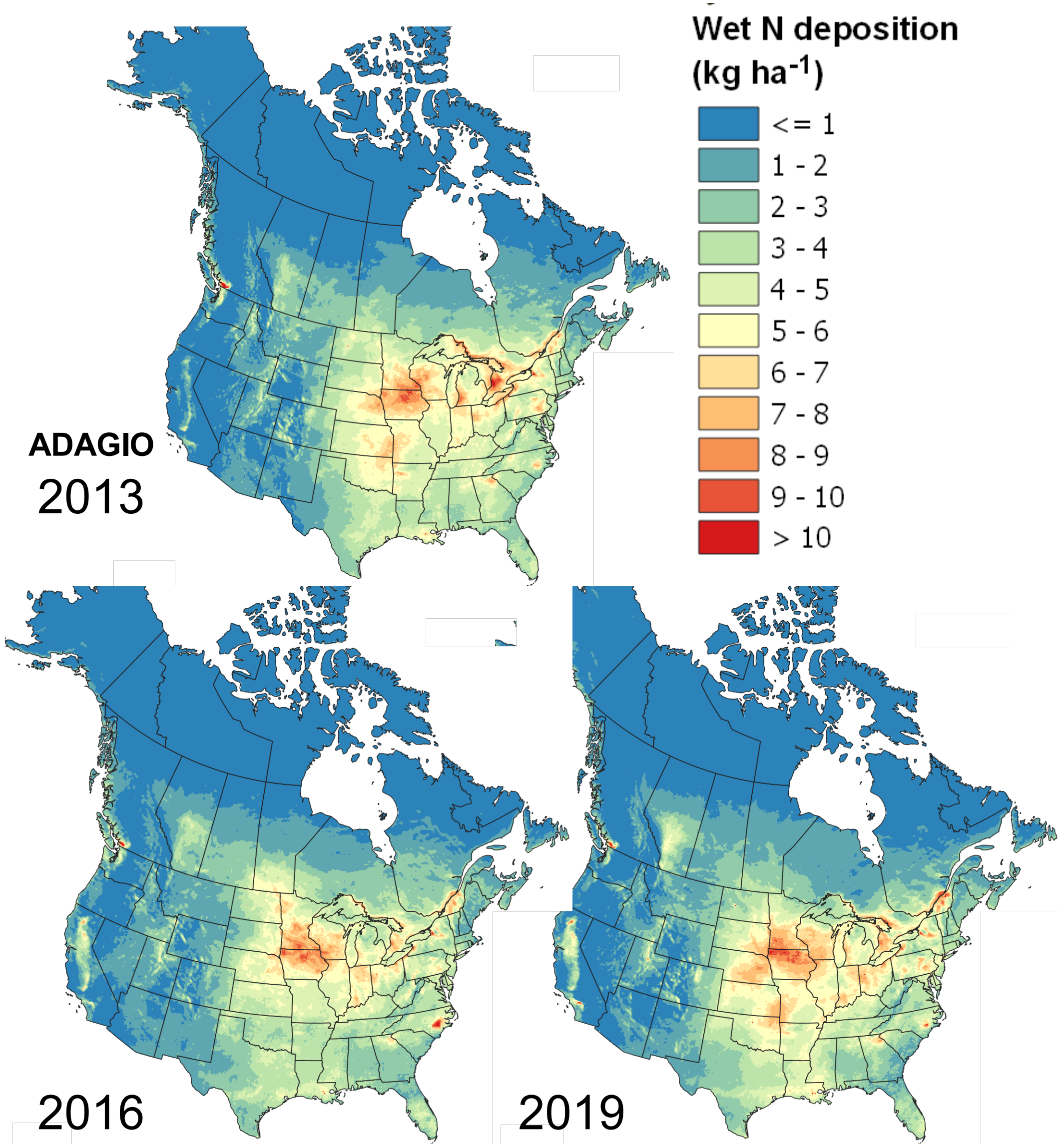
- Optimal interpolation
  - Compute O-P at observation sites
  - Sensitivity tests to determine optimal correlation length
  - Compute error statistics and check against ref. values
  - Compute analysis increment and OA
  - Validation of OA and model

MAJOR RESULTS

- Wet deposition maps for N and S were produced using OI MMF for 6 years (2010, 2013-2016, 2019)
- An empirical equation was derived to estimate correlation length – mainly dependent on network density for wet deposition
- OA-model discrepancies highlight areas where model improvements are needed, e.g. underestimated agricultural NH_3 emissions, sulfur emissions, missing chemistry?
- Good agreement with TDEP maps, though sharper gradients seen in ADAGIO maps for some areas

- Key advantages of ADAGIO:

1. Account for error variances of both model and observations in fusion technique
2. Mapping of analysis increment (model corrections applied)
3. Capture seasonal variability and species dependency in error statistics



Robichaud, A., et al., 2024. Data fusion of modelled and measured deposition in the U.S. and Canada, Part I: description of methodology and validation of wet deposition of sulfur and nitrogen. In review.

ADAGIO - ROUTINE PRODUCT

- Similar to TDEP, we are working towards producing ADAGIO annually and making this product publicly available on a routine basis; starting with year 2019

Development timeline:

- Transfer of knowledge and scripts (Jan 2023 – ongoing)
  - Transfer of shell, Tcl, Fortran, SAS scripts
  - Walkthrough of scripts and algorithms
  - Discussion of research applications & planned papers

- Prepare modeled data (Sep 2023 – Dec 2023)
  - De-archive model output: 1) RAQDPS, 2) FireWork (with wildfire emissions)
  - Extract relevant model fields: gridded concentrations and deposition
  - Process model fields: seasonal averaging, unit conversions, formatting, interpolating to the ADAGIO grid

ADAGIO - ROUTINE PRODUCT

- Prepare measurement data (Jan 2024 – ongoing)
  - Retrieve monitoring data from Canada and U.S. networks
  - Process data and compute seasonal means (SAS-based system)
  - Ongoing work to apply travel blank, pressure, and temperature corrections to passive AMoN (NH_3) data at U.S. sites

- Testing of scripts to produce wet deposition seasonal OA (Jan - Jul 2024)
  - Compute error statistics for wet deposition
  - Validate OA: check χ^2 (chi-squared) statistic, error stats, correlation analysis (OA vs. obs, model vs. obs), frequency distributions
  - **Testing of wet deposition fusion scripts completed**
  - **Seasonal 4-panel maps created successfully, ADAGIO wet deposition is operational**

Working alongside with Alain to ensure results are reproducible

ADAGIO - ROUTINE PRODUCT

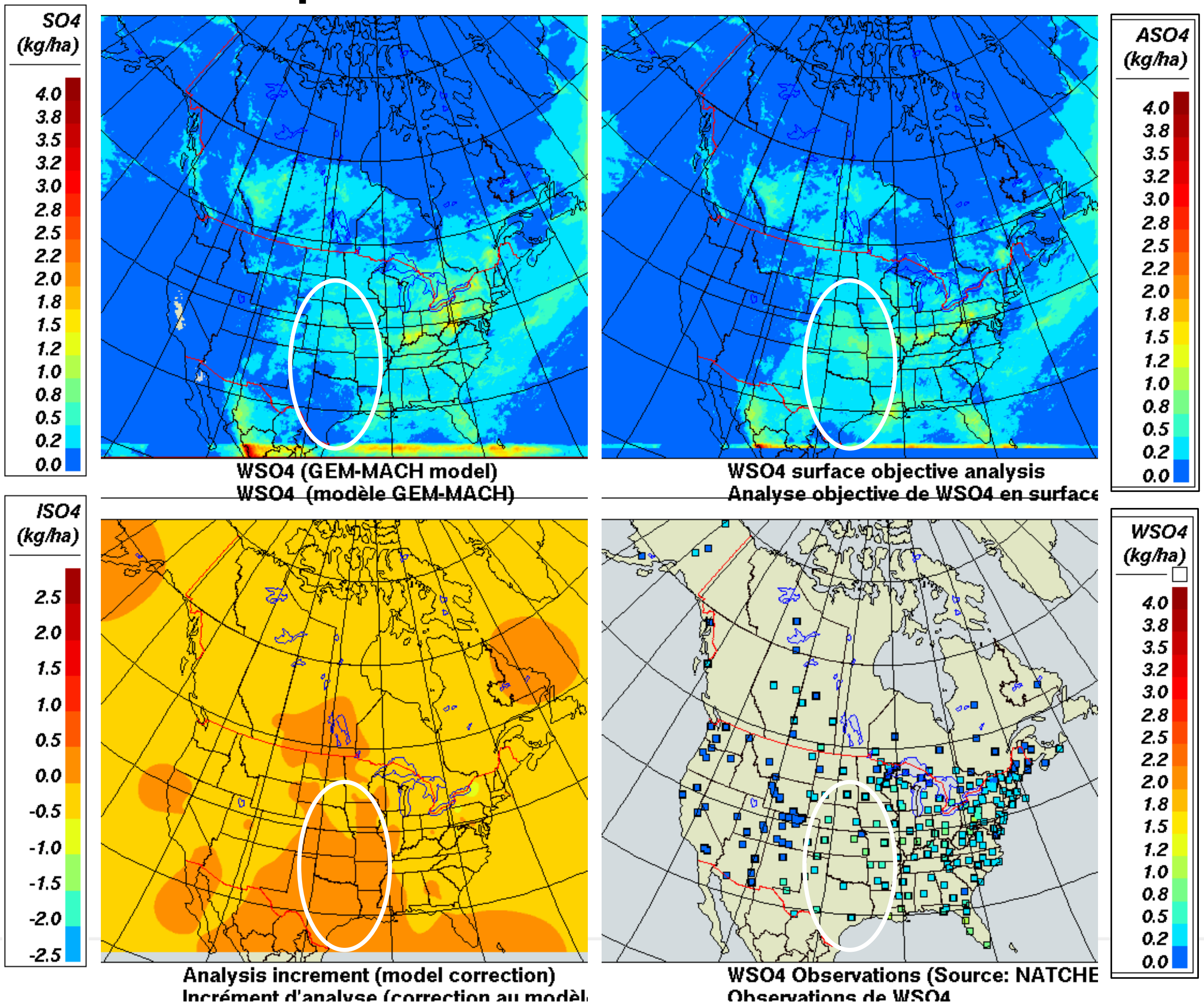
- Unify data processing system & improve automation (May 2024 – ongoing)
  - Part 1 paper: simplified multivariate techniques tested successfully to predict weighting function and error statistics (replacing onerous sensitivity tests)
  - Conversion of SAS programs to R and transfer of all data storage and processing to the Linux system
  - Writing scripts to improve automation
  - File and directory management

- Next steps
  - Testing of error statistics program for gases and particles and the OA dry deposition
  - ADAGIO total dep products 2019, 2020 and 2021 based on RAQDPS-FireWork model

WET SO_4^{2-} DEPOSITION (SUMMER 2019)

1. MODEL

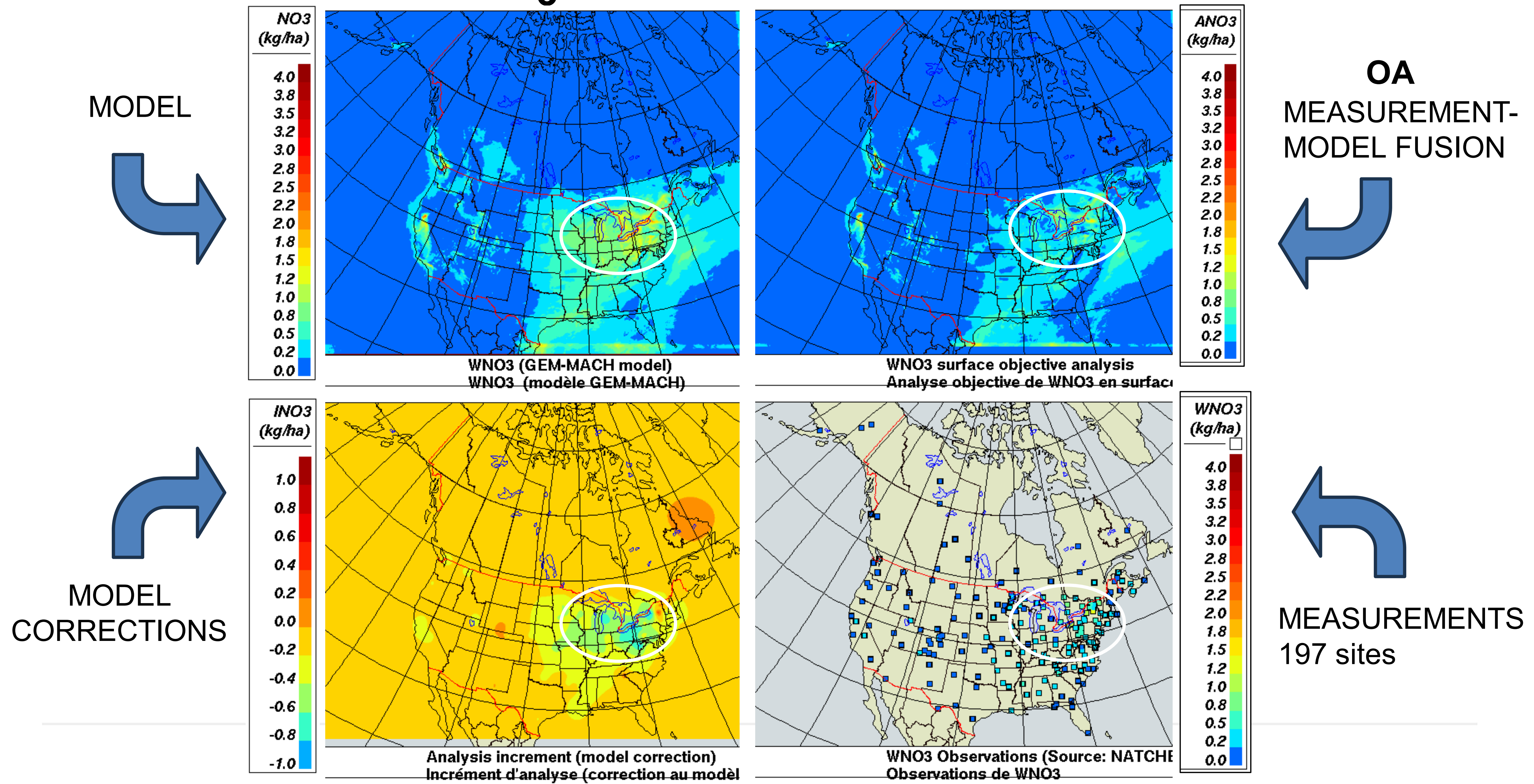
2. OA
MEASUREMENT-MODEL FUSION



3. MODEL CORRECTIONS

4. MEASUREMENTS
244 sites

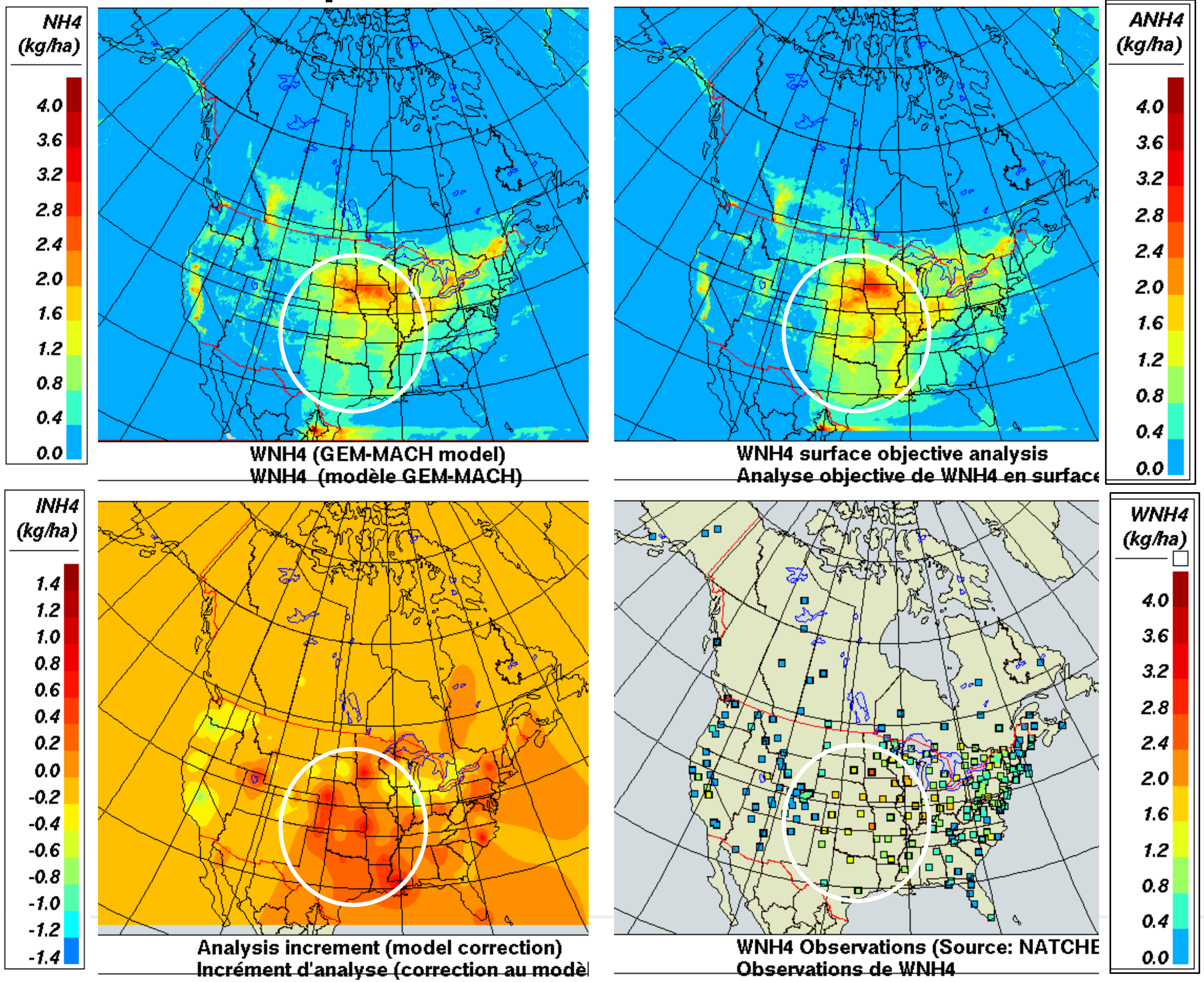
WET NO_3^- DEPOSITION (WINTER 2019)



WET NH_4^+ DEPOSITION (SPRING 2019)

MODEL

OA
MEASUREMENT-MODEL FUSION



MODEL CORRECTIONS

MEASUREMENTS
230 sites

ADAGIO APPLICATIONS

- Reporting on Canadian Ecosystem Health Indicator: estimate critical loads exceedance using ADAGIO and track changes over time to assess changes in ecosystem health (first goal is to derive a baseline CL exceedance value to compare against future values)
- Provide annual total deposition maps for the scientific community and supporting policy development
- Produce historical ADAGIO using GEM-MACH reanalysis (1990-2019)
- Improve GEM-MACH model through mapping of analysis increments

Contact Info: irene.cheng@ec.gc.ca, amanda.cole@ec.gc.ca

Update on GAW's Measurement-Model Fusion for Global Total Atmospheric Deposition (MMF-GTAD) Initiative

WEATHER CLIMATE WATER
TEMPS CLIMAT EAU

WMO OMM

World Meteorological Organization
Organisation météorologique mondiale

Amanda Cole (amanda.cole@canada.ca)
MMF-GTAD Initiative Steering Committee

National Atmospheric Deposition Program
Total Deposition Science Committee Meeting
19 April 2022

What is MMF-GTAD?

- One of three GAW "Science-for-services" initiatives
- Goal is TDep-like products but on a global scale
  - Initial focus on N, S and O_3
  - Potential for expansion to other species
- Client-focused

MMF-GTAD Steering Committee

GAW

- Amanda Cole, Environment and Climate Change Canada, Canada
- Joshua Fu, University of Tennessee, USA
- Lorenzo Labrador, GAW Secretariat
- Wenche Aas, NILU – Norwegian Institute for Air Research, Norway
- Camilla Andersson, Swedish Meteorological and Hydrological Institute, Sweden
- Greg Beachley, US Environmental Protection Agency, USA
- Frank Dentener, European Commission
- Corinne Galy-Lacaux, CNRS, France
- Jeffrey Geddes, Boston University, USA
- Maria Kanakidou, University of Crete, Greece
- Fabien Paulot, NOAA, USA
- Robert Vet, Retired from ECCC, Canada

MMF-GTAD current activities

GAW

- Evaluation of routine global AQ models (ECMWF-CAMS and GEOS-CF) for (a) deposition accuracy and (b) suitability for routine MMF
- Development of an ozone deposition tool with options for different land cover, meteorology, dry deposition schemes – exploring sensitivity to some of these options. Would like to extend to calculating metrics but project is not yet funded.
- Exploration of AI methods for MMF
- Long-term vision document laying out Initiative structure, activities and budgets for next 5-6 years

MMF-GTAD current activities

GAW

- Production of Case for Support and “market research” interviews with outside contacts to develop a fundraising package and strategy (contractor)
- Adding global precipitation chemistry data to GHOST database (BSC): single source of data for wet and dry global atmospheric deposition calculations
- Collaboration with GESAMP on deposition to oceans and coastal areas research planning (2025 workshop)
- Meeting next week to plan 2025 and 2026 activities

World Meteorological Organization
Global Atmosphere Watch
Science Advisory Group for Total Atmospheric Deposition

Update on recent activities for NADP/TDep

John T. Walker
USDA Forest Service
November 5, 2024

WMO OMM

Science Advisory Group for Total Atmospheric Deposition (SAG-TAD)

● **Facilitate** research related to the total atmospheric deposition working closely with the relevant international programs and projects, as well as joint activities with other major environmental science activities including ambient aerosol and gas monitoring, atmospheric modelling, ecosystem effects research, climate research, etc.;

● **Coordinate** work related to quantification of the patterns and trends of the composition of precipitation and total deposition on global and regional scales and produce regular assessments;

● Provide **guidance** on the development of the methods for the estimation of the total atmospheric deposition with a specific focus on dry deposition and feed those scientific developments to MMF-GTAD initiative;

● **Improve understanding** of atmospheric deposition of chemical species of existing or emerging interest

● **Promote** the establishment of the new sites, field laboratory and data management operations;

Science Advisory Group for Total Atmospheric Deposition (SAG-TAD)

- John T. Walker - Co-chair- (United States of America)
- LaToya Myles - Co-chair- (United States of America)
- Amanda Cole - (Canada)
- Christian Brümmer - (Germany)
- Christophe R. Flechard - (France)
- Christopher Lehmann (United States of America)
- Corinne Galy-Lacaux - (France)
- Marsailidh Twigg - (United Kingdom of Great Britain and Northern Ireland)
- Robert Vet - (Canada)
- Wenche Aas - (Norway)
- Van C. Bowersox - (United States of America)
- Jianlin Shen – (China)
- Rick Artz – (United States of America)
- Lorenzo Labrador - Secretariat- (WMO Secretariat)

Development of WMO Guidance for Measuring and Modeling Dry Deposition

- SAG-TAD has had a historical focus on wet deposition (interlaboratory comparisons, assessments).
- Dry deposition becoming more of a focus
- A subset of members are developing a paper to serve as the basis for a more detailed set of WMO guidance
  - John Walker, Marsailidh Twigg, Chris Flechard, Christian Brümmer, Jianlin Shen, Da Pan
- Timeline is to have manuscript drafted by April, 2025

ELSEVIER

Atmospheric Environment

Volume 93, August 2014, Pages 3-100

ATMOSPHERIC ENVIRONMENT

A global assessment of precipitation chemistry and deposition of sulfur, nitrogen, sea salt, base cations, organic acids, acidity and pH, and phosphorus

Robert Vet [a], Richard S. Artz [b], Silvina Carou [a], Mike Shaw [a], Chul-Un Ro [a], Wenche Aas [c], Alex Baker [d], Van C. Bowersox [e], Frank Dentener [f], Corinne Galy-Lacaux [g], Amy Hou [a], Jacobus J. Pienaar [h], Robert Gillett [i], M. Cristina Forti [j], Sergey Gromov [k], Hiroshi Hara [l], Tamara Khodzher [m],

WMO OMM

Strategy for Measurements and Inferential Modeling to Improve Understanding of Ozone, Reactive Nitrogen and Sulfur Dry Deposition at the Global Scale

- Review of flux measurement methods
- Recommendations on standardization of flux data processing and QA/QC reporting

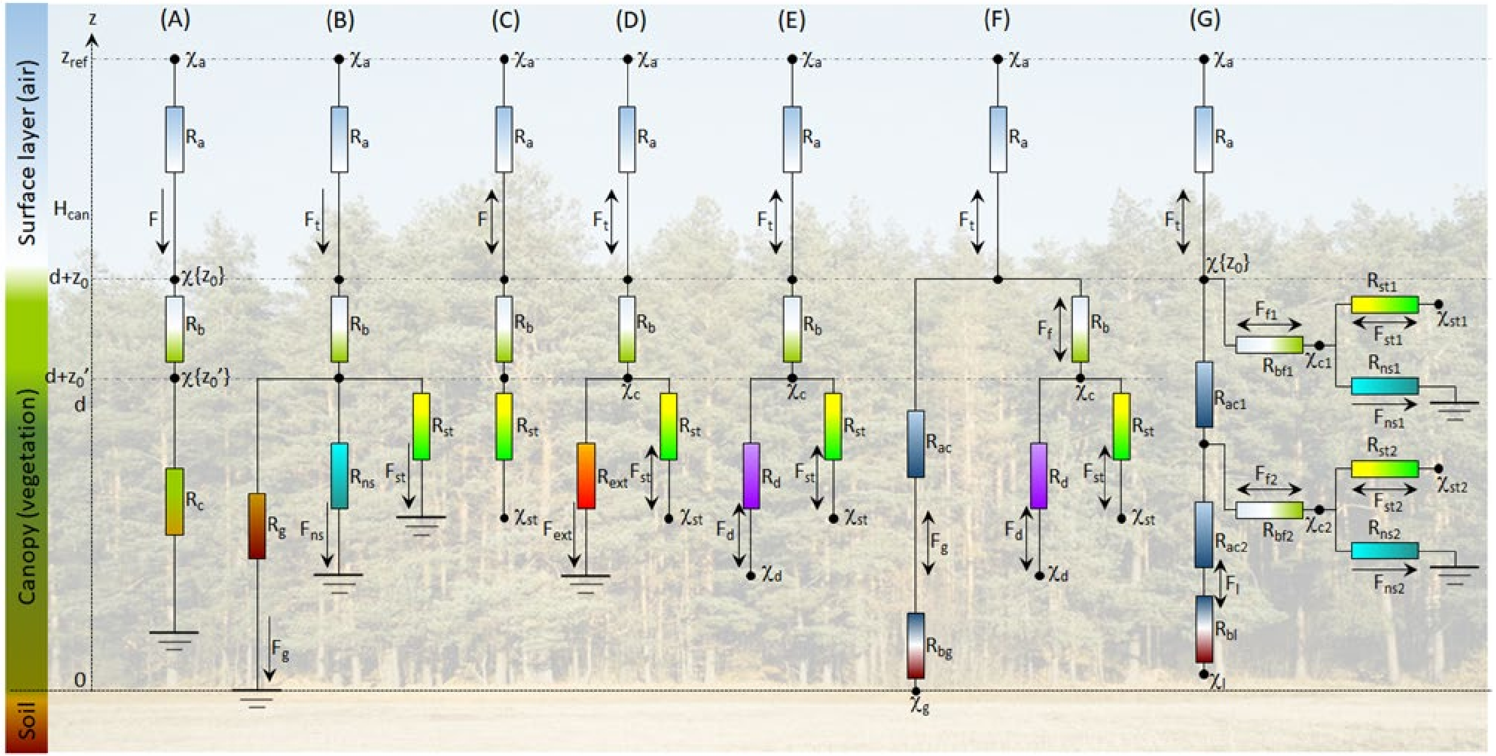
	Species	Analytical Technique	Cost	Maturity of Method	Knowledge of Uncertainties	Standardization of data processing	Suitability for long-term deployment
Eddy Covariance	O_3	CL	Low	High	High	High	High
	NH_3	QCL	High	Medium	Medium	High	Medium
	HNO_3	CIMS	High	Medium	Medium	Low	Low
	NO_2	CL	Medium	High	High	High	High
	Total NO_y	CL	Medium	High	High	High	High
	Total N_r	CL	Medium	High	High	High	High
	NH_4^+	AMS	High	Medium	Low	Low	Low
	NO_3^-	AMS	High	Medium	Low	Low	Low
	SO_4^{2-}	AMS	High	Medium	Low	Low	Low
Gradient	O_3	CL	Low	Medium	Medium	Medium	High
	NH_3	WD-OA	High	High	Medium	Low	Medium
	HNO_3	WD-OA	High	High	Medium	Low	Medium

WMO OMM

Strategy for Measurements and Inferential Modeling to Improve Understanding of Ozone, Reactive Nitrogen and Sulfur Dry Deposition at the Global Scale

- Review of inferential modeling approaches

- Requirements (measurements) for:
  - Atmospheric composition
  - Meteorology
  - Turbulence and energy balance
  - Ecosystem characteristics
- Decision framework for modeling strategy



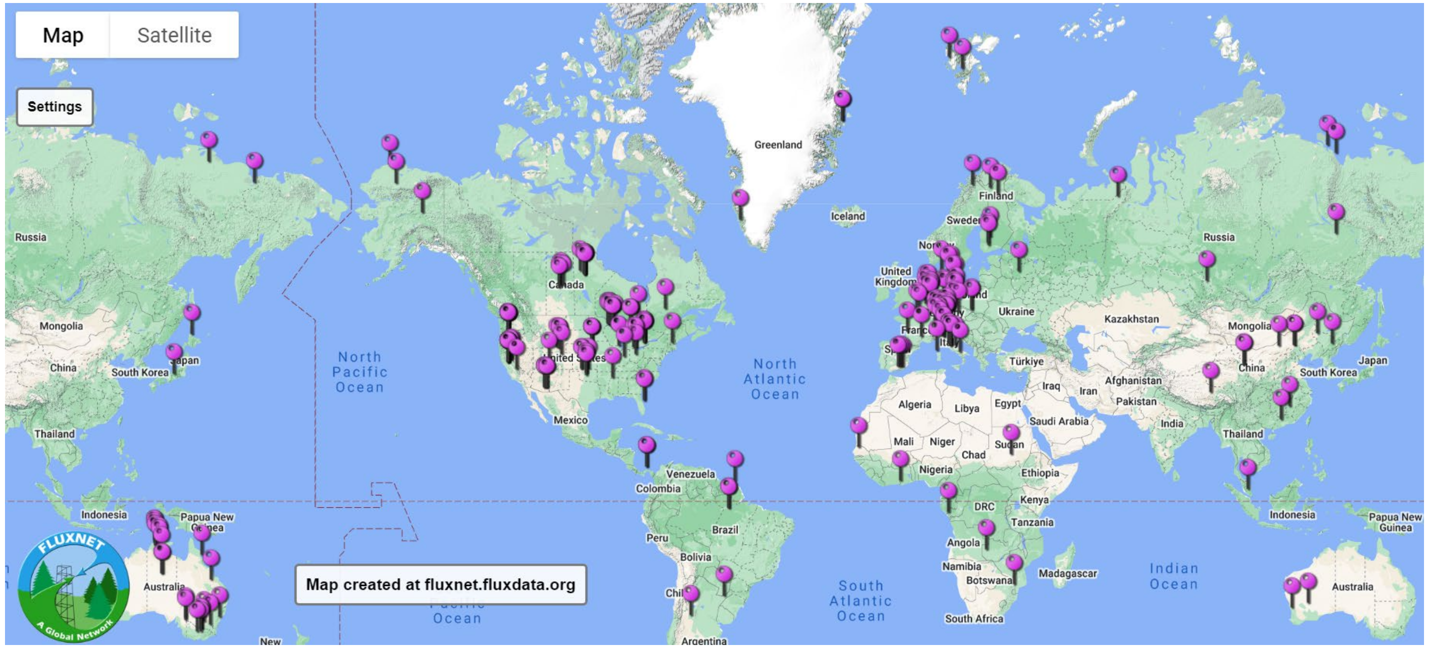
Surface/atmosphere exchange modelling schemes (C. Flechard)

Strategy for Measurements and Inferential Modeling to Improve Understanding of Ozone, Reactive Nitrogen and Sulfur Dry Deposition at the Global Scale

- Review of regional and global networks that may be leveraged for inferential modeling and new flux measurements:
  - Atmospheric composition
  - Wet deposition
  - Biometeorology
    - Carbon, water, energy fluxes

FLUXNET
The Data Portal serving the FLUXNET community

[Regional Networks - FLUXNET]



Carbon, water, energy fluxes

WMO OMM

Strategy for Measurements and Inferential Modeling to Improve Understanding of Ozone, Reactive Nitrogen and Sulfur Dry Deposition at the Global Scale

- Description of tiered monitoring approach
  - Tier 1 – High resolution continuous flux measurements
    - Small number of super sites in select locations
    - Provide data for improving process-level understanding of bi-directional exchange and models
  - Tier 2 – Low-cost direct flux measurements (e.g., COTAG)
    - Intermediate number of sites in select locations
    - Lower time resolution data to characterize deposition budgets and spatiotemporal patterns.
  - Tier 3 – Air concentration and supporting measurements for inferential modeling of bi-directional exchange
    - Large number of sites
    - Fill geographical gaps in flux measurements to help characterize spatiotemporal patterns
    - To be validated at Tier 1 sites

- Goals:
  - Introduce concept of tiered strategy
  - Identify current relevant infrastructure and opportunities for collocation
  - Identify capacity needs (e.g., geographical gaps, need for new monitoring (NH_3), etc)

Strategy for Measurements and Inferential Modeling to Improve Understanding of Ozone, Reactive Nitrogen and Sulfur Dry Deposition at the Global Scale

- Outcomes
  - Establish groundwork for more detailed WMO documentation/guidelines for measuring and modeling dry deposition
  - Justify and demonstrate need and feasibility for tiered monitoring strategy for dry deposition
    - Proposal development
    - Cross-network cooperation
  - Engage with Science Advisory Groups for Aerosols and Reactive Gases to identify candidate GAW sites (fluxes and inferential modeling)
  - Support MMF-GTAD
    - Develop info on availability of reactive gases datasets for MMF-GTAD initiative
    - Opportunity for MMF users to inform capacity needs
    - Motivate development of new flux datasets for CTM evaluation