Task 2: Report and Recommendations
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Utah Lake Area Site Visits and Meetings, December 17-20, 2019

The following report is a summary of my recommendations to improve the atmospheric deposition sampling project for Utah Lake, as requested by Leland Myers.

On December 17, 2019, I flew out to Salt Lake City, Utah. Over the next several days, Leland Myers, Dr. Theron Miller and I toured several of the deposition sites at Utah Lake and several measurement locations around the Great Salt Lake, met with several researchers from Brigham Young University (Wednesday, Drs. Miller, Merritt, Williams, S. Barrus, and several other members of the local sewer district), and held other meetings on Thursday with E. Gaddis, M. Hogsett, and others. I returned to Champaign on Friday, December 20.

General Comments

Overall, going out to the site has increased my understanding of the difficulty involved in this overall project. Quite a bit of great work has been done to date, and there are many very talented people involved. I said during the meeting--and continue to believe--that with appropriate changes to the measurements and project, you can achieve the goal of making measurements (and/or estimates) of wet and dry deposition that other scientists and policy professionals will have confidence in, and can be confidently used for future larger project needs.

Field Method Recommendations

1. It is important to have a written field SOP (this is currently being developed). This should include everything that the field techs will do, for all analytes (N and P). That way, you have a document to point to that says this is exactly how we did every step of the project.

2. Sampling Time: three years or more. This will allow you to estimate the amount of variation with season and changing precipitation/dry conditions. This is, of course, if

funds are available. If snow problems can be overcome, sample all weeks and months of the year. Additionally, retain a weekly sample schedule.

3. Sampler Design Changes
    a. Reduce the "table" surface area to decrease possible bounce of wet and dry deposition.
    b. Move the solar collector away from the sampler (5 meters or more is best).
    c. Record the opening closing/times digitally (if possible) to pair with a digital precipitation record. This will tell you how well the sampler and sensor are working for wet and dry deposition.
    d. Increase the bucket opening height to between 1.5 and 2.0 meters, to meet NADP guidelines. This should also reduce the amount of plant matter in samples.
    e. Move bucket tops/openings higher from the table surface (unlikely to be able to do this). This would reduce any bounce issues.
    f. Provide a heat source for the sensor, to require additional precipitation to continually activate the collector. This will reduce dry exposure to the wet sample after precipitation is complete. We also discussed the option of changing the sensor to the NADP approved sensor (Thies, https://www.thiesclima.com/en/Products/Precipitation-Electrical-devices/?art=791).
    g. Regularly reduce the height of the grass around the sampler ("weed-eat" between bucket changes).
    h. Wipe down the sampler surfaces with water and Kemwipes (or similar) weekly.

4. Use gloves. I think that you use gloves currently, but if you are not, then do for all sample handling. Also have two or three glove blanks run by the laboratory to show that there is no N or P on the gloves or the powder in the gloves (if applicable).

Quality Assurance Recommendations

5. Sample Screening: It seemed to be the consensus of all the groups that insects be excluded from the wet deposition samples and internal/external cycling of these insect analytes be treated separately. This idea was further discussed in the Dr. M. Hogsett meeting. My opinion is that there are four options to keeping insects out/reduce insect contamination in the sample. These include 1) using screens over

the buckets, 2) moving the sampler to a higher level above the ground (Pollman sampled at 15 meters), 3) move the sampler to an area with fewer bugs, or 4) subtract average insect contamination from the sample (tare concentration). All of these actions have drawbacks, but I would recommend using a screen over both the wet and dry buckets. Screen size should have openings as large as possible while still excluding insects. I would hope that this opening size would be at least the size of a typical "BB" [4.3 to 4.4 mm (0.171 to 0.173 in)] to allow large particles to move into the sampler with little restriction. These screens will lead to some missed sample due to bounce, but I think this option is better than the other three. I would also recommend that these screens be hung/fixed lower into the bucket (perhaps halfway down?) rather than on the top of the bucket to reduce the bounce issue. (Note that an official NADP site will not allow for this screen on the NADP sample, if an NADP sampler is established.)

Be very careful with using screens over the sampler buckets for deposition. For wet deposition, the worry is that when the precipitation droplets hit the screen, some will bounce off and out of the sample bucket leading to bias. For dry deposition, the screen could lead to particle bounce off the screen and not into the bucket.

6. Bag Sampling: As discussed, NADP is moving to bag samples rather than cleaned buckets to collect samples. Assuming that the laboratory can handle bag samples, I can provide the bag supplier that NADP uses. As discussed, this will provide many benefits including reduced cost, and likely better-quality assurance and blanks. This has been shown by NADP for nitrate and ammonium and ortho-phosphate. I would expect that there is some public report on this change, which provides scientific backing for this decision. I can, if you wish, search for this document if you think it is necessary. With this switch, I would also recommend some quality assurance tests on the bags be ordered from the laboratory. The specific recommendation here would be analytical tests on the bags to assure that no phosphate is lost/adhered to the bag at sample pour-off. (i.e. P is adhered to the bag and remaining with the bag during the liquid removal which would lead to a low bias.)

   This change would remove the bucket washing and leaching, the chemicals necessary for this, the bucket side scrubbing before sample removal (and the potential contamination from the same), the cost of purchasing sample bottles, etc.

   I am also recommend considering using bags for the dry side bucket, so that these

buckets also do not have to be cleaned. I am not certain how this could affect the water-based dry deposition sampling, so if would depend on whether this can be done simply and easily without changing the sampling characteristics.

7. Consider starting an official NADP site near Utah Lake. This will provide many benefits, if funds are available. An official site will require a digital rain gage, a NADP approved bucket collector (www.n-con.com/Products/ads.html), and the annual cost for NADP. However, this will provide an independent validation of all of your wet deposition Nitrogen measurements, and ortho-phosphate measurements. Consider asking the NADP lab for an additional test of total P in many or all samples. Please note that NADP filters samples free of suspended solids, which is not occurring (appropriately) in this project. The benefit will be completely independent comparison of your wet deposition values, and all of the scientific validity that will flow from that. I would site the sampler next to one of the Utah sampler locations, likely at where you expect to measure the highest concentrations of N and P. I would not put the NADP sampler at the location consistently high in insect collection, so that the NADP results are most comparable.

8. Following this NCON recommendation, consider asking Dr. Brahney to collocate one of her total P dry deposition collection systems with one site where you are measuring/estimating dry deposition of P. As noted previously, measuring dry deposition is very problematic. Basically, there are several methods for measuring dry deposition, and Dr. Brahney's newer method (baffling within buckets) and other methods have promise, but there is no universally agreed upon method to measure dry deposition that is scientifically valid. In general, the criticism focuses on the issues of the texture of the sampler not resembling the natural environment, inconsistent aerodynamics, loss of sample after collection over time, and other things similar to these. However, a measurement approach is much more viable for TP, since there are no atmospheric phosphorus gases. If the collocated measurements are correlated are supportive of each other while measured with different methods, then this will provide scientific support for the measurements overall.

9. As detailed in my review of the sampling plan, I would recommend an organized and repetitive quality assurance plan for the project, that includes the items listed below, is present in any QA plan documents, and reported in all reports. You want to provide information on how the QA was done, and any laboratory results.

    a) Blank samples on the DI water used for cleaning (perhaps monthly)

b) Blanks on clean buckets (perhaps monthly)
c) Field blanks, after dry weeks (perhaps monthly)
d) Analytical quality assurance information from the Laboratory:
    i. Analytical blank records (every analysis run)
    ii. Analytical calibration records (every batch, or daily)
    iii. Spike samples (weekly, or every batch)
    iv. Listing of standards used by the laboratory
    v. Description of how the laboratory will determine the reporting limit and detection limit, and records of RL and DL
    vi. If the laboratory is NELAC approved, etc., statement of this
    vii. Document the analysis method, detection limits, etc. of the laboratory for all analytes.
e) Unknowns: Consider sending the laboratory sample unknowns. I would purchase a standard, and using DI water, produce several known concentration samples, and send these to the laboratory in a standard sample bag made to look just like a real sample (a true unknown to the lab), and repeat this often until you are convinced that the laboratory is providing you with accurate results. I would probably do this three times per season when they are getting the result correct, and more often if they are not. Consider this for Total N, Total P, ortho-phosphate and any other important analyte (such as organic P) as needed. I would suggest perhaps 4 to 5 of these per year.

10. Birds and Feces: To try and reduce the occurrence of bird feces in the sample and the associated contamination, keeping birds off of the sampler is important. I don't remember that the different groups came to any conclusions about this topic in general, but Dr. T. Miller and I did discuss it some. My recommendation is to first try plastic owl and or raptor figures at the sites. These have been used at some NADP sites and worked to some degree. Alternatives could be regular startling sounds that would frighten away any birds, some type of moving objects designed to scare any birds away, etc. Any option like this is a possible solution. If this does not work, then spikes around the buckets (wet and dry) can be used. However, these would provide additional contamination points for the samples. Additionally, reject any sample with obvious bird feces contamination, given that the project will attempt to determine the flux from the large bird population separately.

11. Plant Matter in the Sample: I don't remember that the group came to any conclusion about how to approach this, but I do remember that trying to keep out plant matter

(from around the sampler) was brought up briefly. I think increasing the height of the bucket opening will help tremendously, as will reducing the height of the grass relative to the sampler. Screening for insects may also be beneficial. Remember that if we successfully keep plant matter out of the deposition sample, this likely remains and important source of N and P to the lake, and needs to be addressed by the overall project in some form.

Project Recommendations

12. Meteorological Measurements: Most, if not all, project scientists are certain that the southwesterly flow, particularly in the spring period, drive large and important aeolian dust events from dry lakebed sources to the south and west (for example, Goodman et al., 2019). You will need to justify/measure the southwesterly component of this wind, and that the local hourly observations at the Provo Airport do not show this southwest component (i.e. a NW and SE dominance), I would strongly recommend this step. This will provide you with a complete record of when the surface wind is from this direction. Use a digital gage, averaged to the hour for wind direction and windspeed, all recorded digitally. If you do any complicated modeling, they will also want 3-d wind direction and winds at two levels. I don't think that this is necessary; horizontal wind and wind speed at 2 meters should be fine. Start this record and collect this data throughout the project. What this will enable you to do is capture a high deposition sample that corresponds directly with measured southwest winds. I would locate this system in the west or southwest part of the lake. You can also supplement this data record with wind measurements to the west and south of the metro area with additional meteorological measurement, if found.

13. Triplicate samples at one sampling location: Assuming that the wet/dry sampler is significantly changed following these recommendations, it may be important to collocate the original sampler design (pre 2020 design) next to the updated/new sampler design (post 2019 design). If this is the case, I would further recommend that the original and new Utah designs be collocated with the NADP site, as recommended previously. Think of this as a QA site for the sampling methods, with three samplers operating. Operation of the original design will show any improvement of the sampler design (statistical differences vs new design), and defines any bias between the new sampler design vs the older design to keep early

measurements useful for the future measurements. The number of samples collocated and analyzed can be determined in part by available funding.

14. Consider measuring atmospheric concentrations of particulates as a second method of determining dry deposition. Following NADP and Clean Air Status and Trends Network, measuring atmospheric concentrations of pollutants and modeling deposition velocity is an alternative approach. If project funds are available, this type of measurement would provide scientific support for dry deposition measurements, if the results are similar. Alternatively, distinct differences between results will signal more work needs to be done on one or the other method.

15. Annual/Final Project Reporting: I realize that student involvement in the project is essential and will continue, and I would argue that their contributions are valuable for both the project and the students. However, I would recommend that annual/final project reports be written in the future rather than relying on theses/dissertations to sum up the project year. Theses/Dissertations are written for a slightly different purpose, and will be completed on the student timetable. With specific project reports, additional material can be included that is important to the project, but would not necessarily be added in an academic document. I would include all quality assurance information (organized into tables), all weekly sample results, etc. so that all can analyses the results of the project. Consider annual release of these results. I would also encourage continued use of graduate students, theses and dissertation projects, and journal articles on aspects of the project.

<u>Other Recommendations and Comments</u>

16. I am going to provide Dr. T. Miller with a copy of a journal article by Pollman et. al., 2002 (see references) where AD measurements were made for phosphorus in Florida. I know Dr. C. Pollman, who is a specialist in metals deposition, has some ideas on exactly how to make phosphorus AD measurements. I would particularly note his field and laboratory methods, and his attempt to remove insects from the wet deposition samples. The authors only made wet deposition measurements. Note that Dr. Pollman elevated the samplers to avoid insects in the sample. He took extreme measures, but it is an additional approach.

17. I would recommend that Dr. T. Miller consider attending NADP's Fall 2020 Meeting, which will be held in Knoxville, TN. Although the specifics of the meeting will likely

not be available till the summer, the meeting will be held on November 2-6, 2020 (nadp.slh.wisc.edu/nadp2020meetings.pdf). The advantage is that there will be a large number of scientists at the meeting that will know a tremendous amount about wet and dry deposition projects. I would also recommend that he attend any TDEP subcommittee meetings (nadp.slh.wisc.edu/committees/tdep/) on Monday or Tuesday of that week), where a specific discussion will be directed towards modeling efforts of dry deposition. Any CLAD subcommittee meetings (Critical Loads Atmospheric Deposition) be considered also (nadp.slh.wisc.edu/committees/clad/).

18. Bulk sampling (requested by L.M.). Although I think that bulk atmospheric sampling is valuable for many projects, particularly when power is not available. However, it is somewhat complicated to analyze the results. My general recommendation not to use bulk sampling is based on two particular issues:
    a. It is not typically a good collector of dry deposition, particularly for gaseous measurements.
    b. It is wet deposition plus *a part* of dry deposition, and generally an unknown portion of dry deposition, which can change weekly.

    If you try to measure dry deposition separately from wet deposition, it is a much easier to understand and use the results. Additionally, I think it is easier to clarify any issues with measurement when separate wet and dry measurements are made. However, if there is no power option, bulk deposition is much better than no sample at all. Also, if the collector was clearly and cleanly measuring dry deposition along with wet deposition, then I would have no problem making bulk deposition measurements. But given the issues with dry deposition measurement, and the resulting uncertainty associated with this measurement, I would recommend going with a separate wet and dry measurement.

19. Lake Freezing: I understand that during many years Utah Lake freezes over somewhat or in total. I just wanted to note that when ice is present, then atmospheric deposition (wet and dry) will collect onto the ice for the days/months while ice is in place. Once the ice melts, likely over several days, the net deposition will move into the lake in a large "slug" of deposition. This may or may not be important to the question of AD to the lake and the results of the same. Additionally, if a square of ice can be collected before thaw, then this could be a very nice estimate of total net deposition from the lake for the freeze-over period. It

would be bulk deposition and could potentially contain some insects, but it would be a very interesting result. Additionally, multiple sections would be a nice addition.

20. By raising the sampler height, the large particles rolling along the surface (i.e. saltation) aren't likely to be in the deposition sample, if they ever were. It is possible that this is occurring along the lake sure and this source of N/P may need to be accounted for.

21. I would take advantage of any equipment, data, and knowledge of the State of Utah Air Quality Department. I think a few meetings in the next few weeks would be advantageous. I would hope that they would be able to help with meteorological equipment, and perhaps some sampling equipment in the future.

Attachments:

Pollman et al., 2002.

References

Goodman, M. M., Carling, G. T., Fernandez, D. P., Rey, K. A., Hale, C. A., Bickmore, B. R., ... & Munroe, J. S. (2019). Trace element chemistry of atmospheric deposition along the Wasatch Front (Utah, USA) reflects regional playa dust and local urban aerosols. *Chemical Geology*, *530*, 119317, doi.org/10.1016/j.chemgeo.2019.119317.

Pollman, C. D., Landing, W. M., Perry Jr, J. J., & Fitzpatrick, T. (2002). Wet deposition of phosphorus in Florida. *Atmospheric Environment*, 36(14), 2309-2318.