PNNL-38069

DOE Early Career Project Annual Report

Disentangling the factors controlling the emission of bioparticles that act as ice nucleating particles

August 2025

Principal Investigator: Gavin Cornwell

Award number: 83454
Project period: September 3, 2024–September 2, 2025
Budget period: September 3, 2024–July 25, 2025
gavin.cornwell@pnnl.gov, (509) 375-6364

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

Available to DOE and DOE contractors from
the Office of Scientific and Technical Information,
P.O. Box 62, Oak Ridge, TN 37831-0062
www.osti.gov
ph: (865) 576-8401
fox: (865) 576-5728
email: reports@osti.gov

Available to the public from the National Technical Information Service
5301 Shawnee Rd., Alexandria, VA 22312
ph: (800) 553-NTIS (6847)
or (703) 605-6000
email: info@ntis.gov
Online ordering: http://www.ntis.gov

DOE Early Career Project Annual Report

Disentangling the factors controlling the emission of bioparticles that act as ice nucleating particles

August 2025

Principal Investigator: Gavin Cornwell

Prepared for
the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Pacific Northwest National Laboratory
Richland, Washington 99354

1.0 Introduction

This report describes the accomplishments, progress, and obstacles encountered during the first project year of the U.S. Department of Energy Biological and Environmental Research program Early Career project, “Disentangling the factors controlling the emission of bioparticles that act as ice nucleating particles.”

The project has three main thrusts:

- Thrust 1: Laboratory Measurements of Bioparticle Standards.
- Thrust 2: Collect and Analyze Measurements at ARM Sites.
- Thrust 3: Investigate Relationships Between Environmental Factors and Bioparticle and Bio-INP Emissions.

The structure of this project is very linear, with the success of each aim dependent upon the success of the previous aim. For example, the successes of Thrusts 2 and 3 require a machine learning (ML) classifier to type particles measured by a Wideband Integrated Bioaerosol Sensor (WIBS). Therefore, the focus of the first year has been developing this ML classifier (Thrust 1) while performing some preliminary work on the other two thrusts. Here, I discuss the accomplishments thus far under each project thrust.

2.0 Accomplishments

2.1 Laboratory Measurements of Bioparticle Standards

The primary goal of the laboratory measurements is to develop an ML classifier that can identify fluorescent bioaerosol as belonging to either bacteria, pollen, or fungal spores. This necessitated the purchase of a WIBS from Droplet Measurement Technology, Inc. The WIBS is a fluorescent particle sizer that is used to measure fluorescent bioparticles. It measures particle fluorescence in three channels, along with the optical diameter, and an asymmetry factor that provides a score for the shape of the particle. I have started collecting measurements of bioaerosol samples (and samples that may have similar fluorescent profiles to bioaerosol). So far I have measured approximately 30 samples.

I also purchased a Portable Ice Nucleation Experiment (PINE) from Bilfinger SE, which is a deployable cloud chamber that I will use to measure ice nucleating particle (INP) concentrations at the Bankhead National Forest (BNF). I plan to collect measurements of a subset of bioparticle and ice nucleating standards to characterize the PINE before I ship it to BNF for deployment.

Not in my original proposal, but I decided to purchase a Pollensense, which is a new, low-cost, bioaerosol measurement sensor. It works by collecting ambient aerosol onto tape and collecting microscope images, which it then categorizes into particle types using a library of previously collected standards. An example of this is shown in Figure 1. While it was designed with the goal of quantifying pollen, the developer claims that it has the ability to identify other species such as spores, along with certain non-biological particles. I am interested in the instrument because one of the key issues hindering our ability to model bioaerosol is the lack of distributed measurements of their concentrations. A low-cost sensor like the Pollensense could enable us to assemble broad measurement networks to solve this issue. I will evaluate the Pollensense side by side with the WIBS, as well as collect particles onto substrates for microscopy analysis.

I have also spent project funds on modifying our laboratory space for an inlet that can introduce ambient air to inside instruments. This will allow us to measure ambient air in a test run for deployment to the BNF.

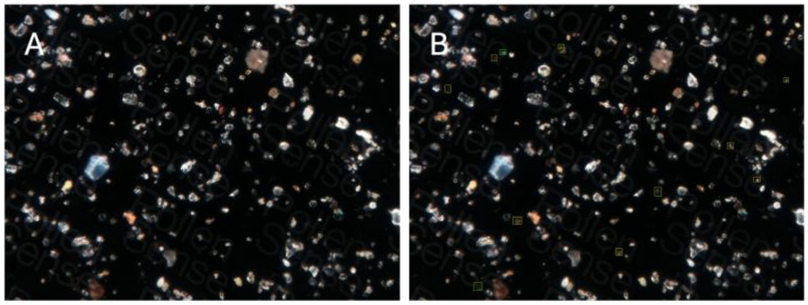

Figure 1. Single images from the Pollensense on 2025-06-18 at 18:03 UTC. Left panel shows all particles collected during the sampling period, while the right panel shows particles identified as Bortyritis spores.

Finally, I submitted a user proposal to the Environmental Molecular Sciences Laboratory (EMSL) to disambiguate the detection of biomass burning and bioaerosol particles emitted from controlled burns. Biomass burning (BB) has been shown to emit both bioaerosol and polyaromatic hydrocarbons (PAHs). These species may fluoresce in overlapping wavelengths, which complicates the detection of either species in atmospheric measurements, and no studies have conclusively determined whether the fluorescent particles emitted from BB are bioaerosol or contain PAHs.

To resolve these uncertainties, I proposed to use custom-made controlled combustion chamber at EMSL that can generate BB using a variety of different fuels, and under different burning regimes (i.e. smoldering or flaming). To determine whether BBA contain PAHs, I will use several EMSL instruments. First, we will measure size-resolved, fluorescent bioaoerosol with the WIBS. Second, we will measure the size-resolved aerosol composition with the miniSPLAT. Finally, we will deposit BBA onto substrates and filters so that we can measure their composition using CCSEM and nanoDESI HRMS. For our offline sampling, we will use an aerosol cycle to collect sub- and super-micron particles separately. This will allow us to evaluate what size ranges bioaerosol and PAHs are detected in.

I submitted the letter of interest for this user proposal in early July, and am waiting to learn whether it will be accepted.

2.2 Collect and Analyze Measurements at Atmospheric Radiation Measurement Sites

This second thrust focuses on collecting measurements at Atmospheric Radiation Measurement (ARM) sites, and in particular those at the BNF site. My work under this thrust has been to (1) prepare for long-term measurements at BNF and (2) perform a preliminary analysis of INP measurements previously collected at ARM sites.

To prepare for the deployment to BNF, I have planned a to conduct a mini-campaign at Pacific Northwest National Laboratory (PNNL) during which I will operate the WIBS and PINE remotely. This will be done to ensure I have the expertise to operate these instruments at BNF, while working remotely. If I have time, I will also collect substrates and filters for measurements and test my ability to make these measurements in subsequent campaigns. I have also made plans to visit BNF to understand the site and facility better.

I have also started on a preliminary analysis of INP measurements from other ARM sites. I have decomposed the INP spectra from the sites using the HUB (heterogeneous underlying-based) model which extracts the underlying distributions from INP spectra. An example of this, from a measurement collected during the Surface Atmosphere Integrated Laboratory (SAIL) campaign is shown in Figure 2.

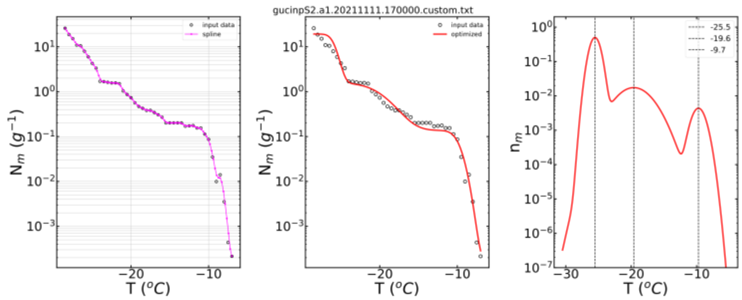

Figure 2. Example of using the HUB (heterogeneous underlying-based) model to determine the underlying distribution of INP populations from a cumulative spectrum. The left panel shows the cumulative spectrum from an ice nucleation sample collected during SAIL, along with a spline fit the model uses in its process. The middle panel shows experimental results and the optimized fit. Finally, the right panel shows the underlying distribution of INP populations. This sample shows a clear population whose peak is at –10 °C, indicative of a biological source of INPs.

I have also run simulations using a Lagrangian transport model, FLEXPART, to calculate source-receptor (SR) footprints. An example footprint is shown in Figure 3. I will use the SR footprints to weight environmental variables, which will enable me to score these variables along the airmass path.

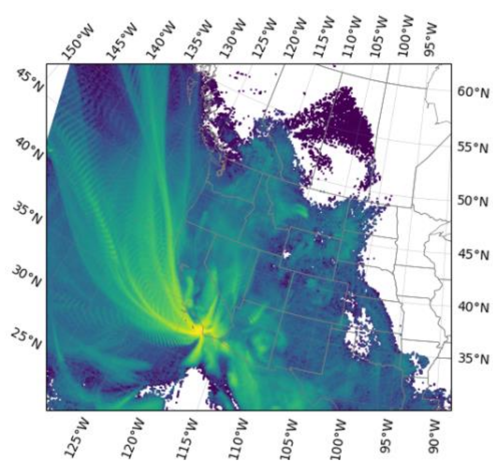

Figure 3. Composite SR footprint from INP samples collected during the SAIL field campaign. The SR footprint is calculated using the 12 km North American Mesoscale Forecast System grid.

2.3 Investigate Relationships Between Environmental Factors and Bioparticle and Bio-INP Emissions

The goal of the third thrust is to derive quantitative relationships between bio-INPs and environmental variables. As mentioned previously, this thrust is contingent upon the previous two, and thus the bulk of the work will be completed during the second half of this project. For the first year, work under this thrust has focused on conducting FLEXPART simulations.

3.0 Training and Dissemination of Results

3.1 Opportunities for Training and Professional Development

I recruited and onboarded a postdoctoral research associate, Shreya Joshi, who began work at PNNL in May 2025. Joshi's background is primarily in aerosol measurements, including extensive work at the Michigan Tech pi cloud chamber. During his time at PNNL, he has been collecting bioaerosol measurements using the WIBS, which he will use to construct the ML classifier to type bioaerosol. Joshi has also been working with the Pollensense and will be evaluating its performance compared to other bioaerosol detection methods.

I meet with Joshi every week for mentorship and to discuss results. To facilitate his training and productivity, Joshi has developed project and professional development goals, which we will review and jointly update every 6 months.

Joshi attended the ARM Summer School at the University of Alabama in May 2025. He gained a comprehensive understanding of the ARM user facility and its data systems, with a particular focus on the BNF campaign. This included a guided visit to the BNF site. They learned about the key instruments deployed at the site, with detailed sessions on in situ aerosol and radar systems and a hands-on training with ARM's JupyterHub and Py-ART tools. The summer school provided Joshi with valuable opportunities to connect with other early-career scientists and experts in the field, explore the field site, and gain practical experience with ARM data products—skills that will directly support our upcoming work at BNF.

3.2 Dissemination of Results to Communities of Interest

This is the first year of the project, and I do not have results that are ready to be disseminated to the research community. Both Joshi and I will be presenting preliminary results at AGU25.

4.0 Plans for Next Reporting Period

Summary of plans for work in the next reporting period, separated by project thrusts.

Thrust 1: Laboratory Measurements of Bioparticle Standards.

- Finish collecting bioparticle standard measurements.
- Collect ambient measurements to test the ability of the WIBS and PINE to be operated autonomously and remotely. We will also collect substrates for analysis by microscopy.
- Write and submit manuscript on ML classifier.

Thrust 2: Collect and Analyze Measurements at ARM Sites.

- Deploy the WIBS and PINE to BNF for long-term measurements.
- Continue with environmental variable analysis for ARM sites.

Thrust 3: Investigate Relationships Between Environmental Factors and Bioparticle and Bio-INP Emissions.

- Continue to run FLEXPART simulations.

5.0 Products

5.1 Simulations

A total of 1401 FLEXPART simulations have been performed so far.

5.2 Presentations

Cornwell, G. C. *Disentangling the factors controlling the emission of bioparticles that act as ice nucleating particles*. PNNL Council of Fellows; 12/19/2024, Richland, WA.

6.0 Participants

Table 1 shows the staff working on the project and their time commitments in Year 1.

Table 1. Project participants (person-months worked from August 1, 2024 to July 24, 2025).

Name	Roles and Tasks	Person Months	International Collaboration and Travel
Gavin Cornwell	Principal investigator.	5.0	Participant at National Science Foundation workshop on bioaerosol.
Shreya Joshi	Postdoc; collects and analyzes bioaerosol experiments with WIBS and PINE.	2.5	Attended ARM 2025 Summer School at University of Alabama in Huntsville.
Support Staff	Financial coordinator; provides support to build and manage budgets; manages procurements and other project-related tasks. Administrator; coordination of travel, reporting of publications, and other project-related tasks. Communications; provides communication support for publications and outreach.	0.05	Nothing to report during this project year.

7.0 Impacts

7.1 Impacts on Development of Human Resources

This project is affecting the development of human resources by:

- Enhancing my experience in project management and mentorship.
- Advancing the experimental expertise of postdoc Shreya Joshi through training on project instrument capabilities, including the WIBS, PINE, and aerosol characterization methods such as microscopy.
- Facilitating the professional development of postdoc Shreya Joshi through attendance at the ARM summer school.

7.2 Impacts on Capabilities

I purchased the WIBS and the PINE to measure bioparticle and INP concentrations, which has improved our capabilities to measure aerosol properties.

7.3 Carryover

As of July 24, 2025, the total carryover for project year 1 is $1,031,971 (Table 2). The project was front funded for Year 1, and Years 2 and 3 have also been funded as of July 25, 2025.

Table 2. Total project carryover.

	Year 1 September 2024 to August 2025*	Total
Funding	$1,764,000	$1,764,000
Cost	$732,029	$732,029
Carryover	$1,031,971	$1,031,971

**as of financial month end processing 7/25/25*

8.0 Changes

Due to ongoing uncertainty about government funding, PNNL decided to retroactively raise the charge-out rates for all staff members by approximately 1%. This change will also affect the charge-out rates for future project years.

Our plans to utilize the PINE have been delayed. PNNL requires all instruments to be Nationally Recognized Testing Laboratory (NRTL) compliant. NRTL is a standard required by Occupational Safety and Health Administration (OSHA), a part of the U.S. government. The PINE was manufactured in Germany, and the manufacturer has thus not gone through the process to ensure that their instrument was NRTL compliant. This necessitated hiring an external contractor (TÜV SÜD) to inspect and modify the instrument, which cost approximately $10,000.