A Comparative Analysis of Microplastic Distribution in Snowfall

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Abstract

Climate change is affecting temperatures around the world and our environment is polluted with plastics. Combining snow and microplastic observations from an urban area and forest preserve help us understand how snow, a crucial element of our climate and environmental systems, is changing and being polluted. Specifically, we want to know how much plastic there is in our snow, and the density and location of the snowpack. Scientists can study snow from space with satellites or using models but data collected on the ground is still fundamental to study what environmental impacts. Over the 2018-2019, 2019-2020 and 2020-2021 winter seasons, snow properties, meteorological data, and microplastic data were collected to analyze microplastic distribution in the snowfall in a developed plot and a remote plot. Lack of snowfall for the 2019-2020 season made large scale snow and microplastic data collection impossible.

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Key Words

- Snow Water Equivalent (SWE): A measure of snow density
- Snowpack: Lasting snow in an area
- Rain on Snow Event (ROS): When it rains on a snowpack
- Peak Streamflow: The maximum streamflow values recorded at a site
- Meteorological Conditions: The processes and phenomena of the atmosphere, especially as a means of forecasting the weather
- Microplastics (MP): a plastic particle less than 5mm in size, can come in many different forms
- Atmospheric transport: movement of pollutants in the atmosphere caused by wind flow

Introduction

In the 2020 study by Bellasi, Binda Et al the conclusion was drawn that microplastic (MP) particles are one of the greatest threats as a pollutant to freshwater and saltwater environments. These microplastics can have a plethora of different possible sources: synthetic fibers from fabrics, and home and industrial dryers, degradation of macro plastics such as discarded plastic bags, or plastic containers, particulates from car tyres along roadways, broken down particulates from landfills and waste incineration. The same study noted that the potential toxicological effects on aquatic ecosystems are not yet known (1).

A 2017 study by Gyer, Jambeck and Law which was the first ever global account of the production, use, and end-of-life fate of all plastics found as of 2015, approximately 6300 Megatons of plastic waste had been generated, around 9% of which had been recycled, 12% was incinerated, and 79% was accumulated in landfills or the natural environment. It was also stated that poor end of life management of plastic materials is a great contribution to environmental plastic pollution (2).

Microplastics are classified as plastic particles smaller than 5 mm in size(1). Studies on MPs in snow are few and far between, groundbreaking findings by Allen and Phoenix Et al in 2019, introduced the factor of atmospheric transport. Through an air mass trajectory analysis they found microplastic transport through the atmosphere over a distance of up to 95 km. They suggest that microplastics can reach and affect remote, sparsely inhabited areas through atmospheric transport (3).

The presence of this atmospheric factor makes it very likely that water vapor can bind to these MP particles. In the 2019 study White and wonderful? Microplastics prevail in snow from the Alps to the Arctic by Bergman, Mutzel Et al, considerable quantities of MP particles are found in the Arctic; however, there are large knowledge gaps regarding their pathways to the North. By analyzing MP distribution in arctic ice flows and and snow samples from the remote Alps they concluded that atmospheric transport and deposition can be notable pathways for MPs. They also found most particles were in the smallest size range indicating large numbers of particles may be below the smallest detectable size of 11 micrometers (µm)(4).

MP particles have even been found in snow and streamwater samples on the slopes of Mount Everest by researchers in 2020. This research aimed to identify and characterize MP pollution near the top of the highest mountain on Earth, and illustrates the implications and impacts on the environment and the people living below (5).

Evangelu, Hayes and Kilmont's 2020 study concluded that Atmospheric transport is a major pathway of microplastics to remote regions. It is also stated that marine, freshwater and terrestrial MP pollution has been discussed extensively, whereas atmospheric microplastic transport has been largely overlooked (6).

The movement of pollutants in the atmosphere is caused by transport, dispersion, and deposition. The Microplastic deposition processes, including precipitation, causes downward movement of pollutants in the atmosphere, which ultimately move the pollutants to the ground surface (7).

Hypothesis

Microplastic distribution will be very similar between Developed and Remote sites, due to the atmospheric transportation of Microplastic particles. Snow depth can be used as a predictor of Microplastic distribution when SWE is accounted for.

Methodology

SNOW DATA

The developed plot on the New Paltz High School grounds located New Paltz, New York Fig. 1 is used to gather snow depth, SWE, and microplastic samples. Another remote site is prepared in the Catskill Mountain region of Ulster County, New York Fig. 2 . This site is located within the Ashokan watershed Fig. 2 with an ideal open space to allow us to take in-situ snow measurements and collect drone photography. Sites were chosen based on 1. Level of surrounding development 2. Accessibility 3. Proximity to possible human disturbance. SWE is calculated by multiplying the average snow density by the snow depth. It is collected with the use of a scale and a volume measurement of snow. Regular sampling was proposed; however, lack of sufficient snowfall for sampling, resulted in irregular sampling intervals. Depth data was recorded with the use of a metric ruler and GPS device to label exact sampling coordinates. Not disturbing the surrounding snow was of utmost priority.

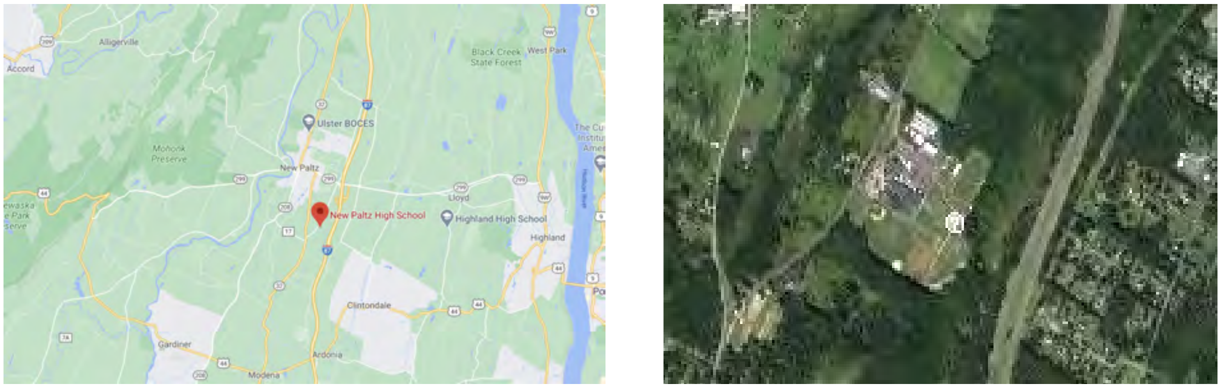

Figure 1. Location of the urban sampling plot at the New Paltz High School

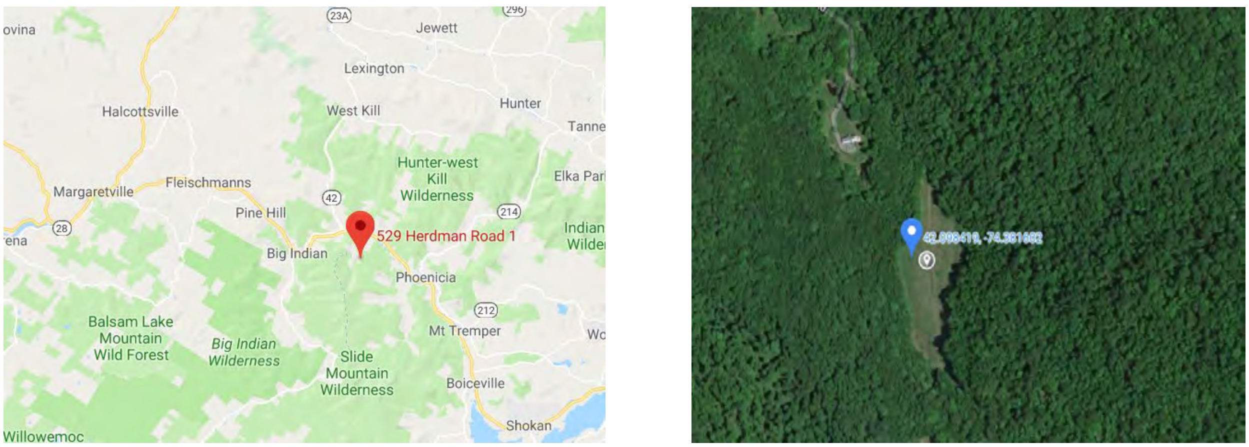

Figure 2. Location of the remote Catskill sampling plot

Figure 3.

Snow depth measurement

MICROPLASTICS

Snow samples are collected in glass jars so as not to contaminate samples, to be analyzed for MP contaminants and stored until analysis is conducted at the end of the winter season. The microplastic analysis technique from Shim, Song Et al, in Identification and quantification of microplastics using Nile Red staining is used. The snow is melted and then a Nile Red (NR), a fluorescent dye is added to the sample (8). The samples are then strained through varying sized sieves to isolate MP particulates. The MP samples can then be counted under with the use of a compound light microscope with a NIGHTSEA Stereo Microscope Fluorescence Adapter. The objective of observing the atmospheric MP deposition was to identify if MPs are present in the atmospheric fallout in the remote, and developed site, if MPs are present, what quantity, size, and shape are deposited?

Figure 4. A sample of MP particles in streamwater

Figure 5. An example of glass jars used in snow MP collection

METEOROLOGICAL DATA

Historical and Current Wind speed and direction data are compiled to analyze how MP particles are distributed in the atmosphere. Current satellite and locally collected snow data are compiled for later SWE and depth analysis. Weather data for the remote site was collected at the Shandaken Highway weather station (ID KNYSHAND3). This station is approximately 2 miles from the sampling site, since on site data collection was not possible at the time. The urban plot collected data from the Zimmerman farm Weather station (ID KNYHIGHL25) which is approximately 1.5 miles from the sampling site. Temperature, precipitation, humidity, wind speed and direction were recorded.

DRONE SPATIAL ANALYSIS

A method using drone imaging will be used to calculate the average total snowfall over a large open field area during the winter season. The drone is a DJI Phantom 4 Pro equipped with a 4k camera and other Infrared and thermal camera mounting capabilities Fig. 6. The drone is programmed to take a photograph every two seconds with a GPS reading taken with each photograph. Later the photographs will be compiled and made into a 3-dimensional Structure from Motion (SFM) file depicting the ground pre snowfall. When the drone is later flown during times of snow cover the process is completed again and an ultra-high-resolution digital elevation model (DEM) using Structure-from-Motion techniques depicting accurate snow depth is made. The new Model is overlaid on the original model to accurately measure the snow depth over a large area. A series of photographs are taken by the drone in a circular pattern surrounding the measurement site, at several different elevations above the surface and a DEM is generated Fig.7. This DEM provides important information for snow depth by applying photogrammetric methods to drone photos taken at certain heights.

Figure 6. DJI Phantom 4 Drone used for large scale snow depth measurement

Figure 7. Aerial Photography of the remote site from the drone

Results

Snow Data

The 2019-2020 winter season was interesting due to the lack of sufficient snowfall for microplastic data collection. We were able to make very interesting observations from the drone spatial analysis data. On February 6th 2019 snow data was collected from the remote site in the central Catskill Mountains of Ulster County, New York. The plot is an approximately 6 acre field area shaded on the South, East and West sides by ridgelines. On the day of sampling there was a nightly temperature of 24.5 degrees and daily high temperature of 38 degrees, with a North, Northwesterly wind.

The measurements of snow depth were taken at sampling points separated by roughly 2 meters, and measurements were taken in a “zigzag” pattern to maximize coverage and to minimize snow disturbance. A driveway running through the center of the site had been plowed and were not sampled to avoid introducing biases in the measurements. Nicholas Frearson operated the drone and collected the drone photographs for DEM reconstruction. A difference map of the DEM taken with and without snow cover will be used to estimate snow depth, which will subsequently be compared with the in person point measurements from the same day for validation.

As indicated in Figure 8, a large range of snow depths was observed at the sampling site. 180 depth measurements were collected. These ranged from roughly 3 cm to 25 cm, with an average depth of 16 cm and a median depth of 17 cm. The drone imagery also suggests that snow depths are lower in the surrounding forested areas.

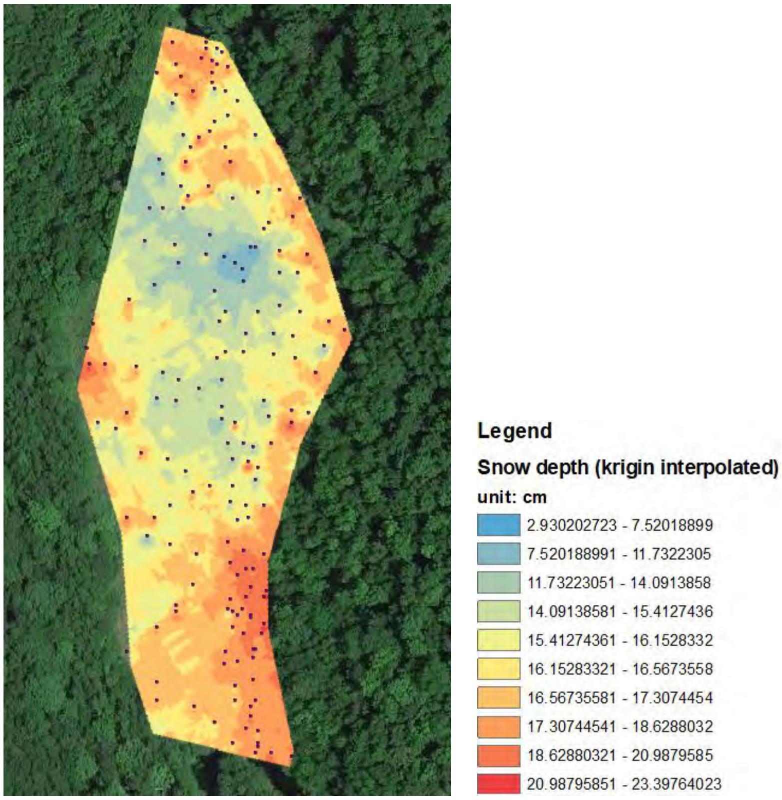

Figure 8. In person snow measurements (cm)

Meteorological Data

The data from February 2019 highlights the unpredictability of the weather. Being only approximately 40 miles each other both sites had significantly different high and low temperatures. The developed site Fig. 10 had a significantly higher maximum recorded temperature at 62.4 Degrees F, and a significantly lower minimum recorded temperature than the remote plot at -8.0 degrees. At the remote site Fig. 9 the monthly maximum temperature was recorded at 32.7 degrees and the minimum at 25.0 degrees. Interestingly for the same month both sites had almost the same average temperature at 29.2 degrees for the remote site and 29.8 degrees for the developed site. The developed site also had a much higher maximum and average wind speed at 28.0 mph for the maximum and an average southerly wind at 2.9 mph. Both sites recorded an average southerly wind direction for the month.

Summary
February 1, 2019 - February 28, 2019

	High	Low	Average		High	Low	Average
Temperature	32.7 °F	25.0 °F	29.2 °F	Wind Speed	11.4 mph	0.0 mph	1.6 mph
Dew Point	29.8 °F	20.1 °F	24.4 °F	Wind Gust	14.8 mph	--	2.3 mph
Humidity	93 %	76 %	82 %	Wind Direction	--	--	South

Figure 9. Meteorological Data for the Remote Catskill site, Feb 2019

Summary
February 1, 2019 - February 28, 2019

	High	Low	Average		High	Low	Average
Temperature	62.4 °F	-8.0 °F	29.8 °F	Wind Speed	28.0 mph	0.0 mph	2.9 mph
Dew Point	45.9 °F	-13.9 °F	20.5 °F	Wind Gust	34.0 mph	--	5.3 mph
Humidity	97 %	30 %	70 %	Wind Direction	--	--	South

Figure 10. Meteorological for the Developed New Paltz site, Feb 2019

Drone Data

The drone collected photographs from a circular flight path encompassing the perimeter of the field site The photographs were processed using the PhotoScan software to produce a digital elevation model of the field site Fig. 11. The DEM successfully captures the building, the field area, and surrounding vegetation, and snow piles. This data is used to validate the snow depth data collected at both the Developed and Remote sites.

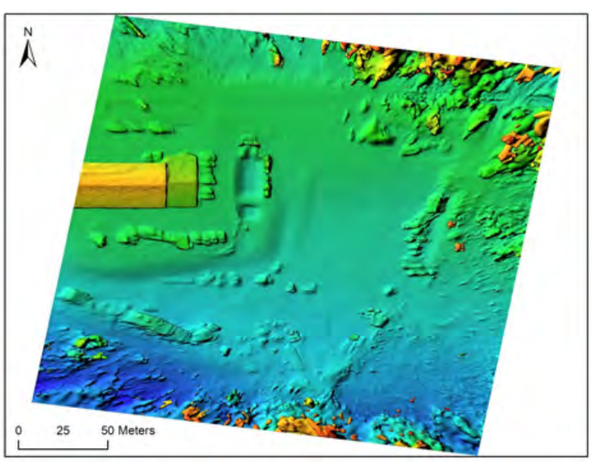

Figure 11. The DEM model of the remote site

Discussion

Analysis of snow data at the remote site in the Catskill Mountains Fig. 2 Shallower depths were observed near the center of the sampling site, while deeper depths can be observed close to the edges of the open area. This variability in snow depth likely results from the topographic variability and wind redistribution, as the edges of the open area are slightly lower in elevation than the center, and adjacent to trees. Drifting snow easily collects in these lower areas, while it is eroded from the higher elevation areas at the center of the site. Snow depth is also lower close to the lone tree in the center of the open area, possibly due to interception of falling snow close to the tree Fig. 8.

The total snowfall in New York State for the 2019-2020 winter season was only 2 inches more than their recorded lowest season snowfall. On average Ulster county, New York, in which both plots are located receives on average 63-125 centimeters of snow each season Fig. 12. In February 2019 there was a vast difference in the meteorological data collected between both sites. This may result from the developed site being influenced by more coastal storms than the remote site. Interestingly the remote site had more stable temperatures, which may result from its sheltered nature in the central Catskill Mountains. On the other hand great temperature fluctuation was observed throughout the month. This extreme fluctuation makes it very difficult for a sustainable snowpack to develop. This fact is quite concerning considering the great impact snow has on the environment, and may be a factor in more severe distribution of MP particles in freshwater bodies of water. More stable temperatures at the remote site allow for a longer lasting snowpack which aides in snow and MP sampling. Upon reviewing past work it is possible to conclude that snow depth and SWE can be a predictor for distribution of MP particles due to the fact that microplastics can reach and affect remote, sparsely inhabited areas through large scale atmospheric transport and deposition. This supports the suggestion by Allen Et al (3) that precipitation events are a positive driver in atmospheric MP deposition.

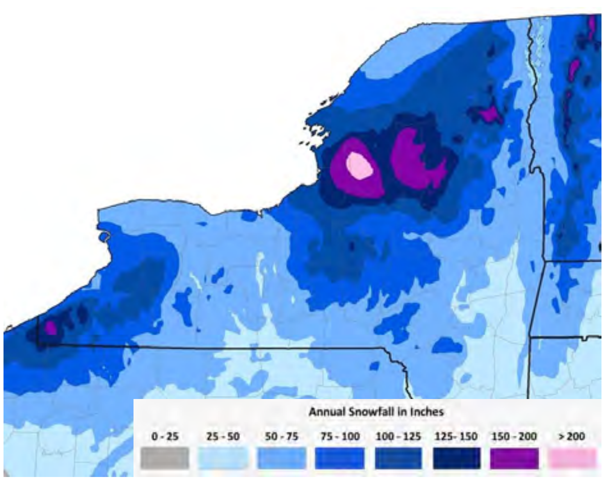

Figure 12. 2018-2019 total winter snow accumulation

Future Work

During the 2020-2021 winter season, we will continue collecting on site and drone-derived measurements over the urban and remote field sites. We hope to add additional instrumentation so as to establish a semi-permanent field station capable of collecting atmospheric and snowpack measurements automatically at the remote site. More frequent snow and meteorological measurements will help us understand snowpack evolution over time. MP sampling of the 2020-2021 snowpack at both the Remote and Developed sites have begun. Analysis of this MP data along with the Snow and meteorological data will be used to aid in MP snow distribution analysis.

Acknowledgments

I would like to thank my mentors Marco Tedesco, and Nickolas Frearson of the Lamont Doherty Earth Observatory (LDEO). I would also like thank Patrick Alexander of the LDEO for aiding me with my project. I would also like to thank my course instructor, Mr. Seweryn for all of his help. And the New Paltz High School for authorizing data collection on their property.

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SCIENTIST MENTOR

Certification

The Student, Teacher and Scientist Certifications are the last pages of the research paper.

Student Name: Diego Schillaci

School Name: New Paltz High School

Your sharing of information reflects strongly on the student's performance.

1. State the origin of the project idea: Was it an assignment, chosen from a list of possibilities, the student's suggestion, or did it arise from discussion, continuation of previous work?

The project idea arose from discussion between Diego and mentors at the Lamont Doherty Earth Observatory (LDEO). Diego found out about the work being done to study microplastics in snow, and proposed looking into the effect of the urban environment on snow and microplastics.

2. Did the student work on the project as a team member? If yes, please state the make-up of the team; i.e., whether they were students, professional researchers, etc. Please describe the student's role on the team.

Diego took the lead on measurements at the school. Other team members (Professor Tedesco, Engineer Nick Frearson, Postdocs and Graduate Students) assisted and collected measurements.

3. Estimate the student's level of dependence (0%) versus independence (100%) on each part of the project listed below. Example: For a student on a three member team who worked as a fully participating member, the answer would be 30-35%.

Experimental design	90	%	Gathering data	30	%
Choice of techniques	90	%	Evaluation of data	60	%
Use of special equipment	20	%	Results/discussion	85	%
Construction of equipment	N/A	%			

4. How many weeks was the student's research project at your institution? 3

5. Indicate whether or not the student received a salary or other compensation for this research

☐ yes ☑ no If yes - dollar amount

6. Other comments

Diego would have collected and analyzed most of the measurements but was hindered during the 2019-2020 winter due to lack of snowfall, and during most of 2020 due to COVID-19.

Supervising Scientist: Marco Tedesco Email: mtedesco@ldeo.columbia.edu

Affiliation: Lamont-Doherty Earth Observatory, Columbia Phone: 202-375-4884

Signature (hand-written): Date: January 7, 2021

STUDENT

Certification

The Student, Teacher and Scientist Certifications are the last pages of the research paper.

Student Name: Diego Schillaci

School Name: New Paltz High School

Please be as specific as possible in answering the following questions.

1. What steps led you to your hypothesis (where did you get the idea for your research)?

   Reviewing past research on atmospheric microplasic distribution.

2. Where did you conduct the major part of your work (home, school, other institutional setting, university lab, medical center, etc.)?

   Home, and outdoors collecting data.

3. If you worked in an institutional setting, did you work on your project as part of a team/group? If YES, who was on the team (students, adult researchers, etc.) and what was your role?

   I did work with Columbia's Lamont Earth Observitory collecting snow data.

4. Describe the parts of the research you did on your own and where you received help (literature search, hypothesis, experimental design, use of special equipment, gathering data, evaluation of data, statistical analysis, conclusions and preparation of written report (abstract and/or paper).

   I recieved help with my experamental design, collection, and evaluation of data.

5. If this is a continuation of an investigation that was previously submitted to a Sub-Regional JSHS describe how you have expanded your investigation?

   NO

Student Signature (hand written)

Date 1/6/21