Most Americans associate the month of May with warm temperatures, fresh green foliage, and blooming flowers. Indeed, these are the conditions that the five incoming Mount Washington Observatory (MWO) 2013 summer interns (Fig. 1) experienced as they arrived in Pinkham Notch for their first trip up the mountain to start their internships. Upon arrival at the summit of Mount Washington, New Hampshire (KMWN; 1,917 m MSL), however, they were greeted by winter: subfreezing temperatures, snow, rime ice, and hurricane-force winds. It is the allure of the famed extreme weather conditions synonymous with Mount Washington and the desire to become intimately engaged in weather observation, forecasting, and research that attracts many of the 30–50 applicants for the summer internship positions offered each year (C.-M. Briedé, 2013, personal communication with applicants).

Through geoscience research opportunities, such as internships and research experiences for undergraduates, undergraduate students are able to learn the scientific process, develop their scientific research skills, develop methods to overcome obstacles, gain confidence as scientists, improve written and oral communication, and increase their chances of obtaining a graduate degree and employment in the geosciences (National Research Council 2000; Seymour et al. 2004; Lopatto 2007; Thiry et al. 2011). Part of MWO’s mission is to advance understanding of the natural systems that create Earth’s weather and climate through conducting research and educational programs, which include training new atmospheric scientists through MWO internships. Every year, MWO offers unpaid seasonal internship opportunities to increase the number of skilled geoscience professionals through real, impactful atmospheric science activities.
Every summer, the Mount Washington Observatory (MWO) attracts a diverse group of applicants, including recent graduates, undergraduate students or recent graduates, and others with backgrounds in a variety of disciplines such as computer science, physics, and other earth science backgrounds. MWO summer interns are selected based on a combination of academics and experience backgrounds apply. Interns are selected based on responses provided in a two-stage process: typed responses to an online application and a phone interview. About 6-10 applicants will advance to the phone interview stage of the internship program, and critical thinking skills through individual research helps interns apply for graduate school and operate the Sherman Adams building. This summit building, a part of the Mount Washington State Park, contains public space that is open during the warm season (mid-May through early October, weather permitting) and private space that MWO leases from the state year-round. The state constructed the building in 1980 with space specifically designed for MWO: living quarters, a living room, a full kitchen, working space, conference room, a parapet and deck space for instrumentation and research (Fig. 1), and MWO’s Extreme Mount Washington museum.

There are many goals of the MWO summer internship program, including learning how to observe and forecast mountain weather; developing data analysis and critical thinking skills through individual research projects; and living, working, and collaborating effectively with others at a remote mountain-top observatory. To achieve these goals, MWO interns engage in a comprehensive set of meteorological activities designed to inquire further about the applicability of the internship program at achieving its goals.

ABOUT THE INTERNSHIPS. Most applicants are atmospheric science undergraduate students or recent graduates, although students from a variety of disciplines such as computer science, physics, and other earth science backgrounds apply. Interns are selected based on responses provided in a two-stage process: typed responses to an online application and a phone interview. About 6-10 applicants will advance to the phone interview stage of the internship program, and critical thinking skills through individual research helps interns apply for graduate school and operate the Sherman Adams building. This summit building, a part of the Mount Washington State Park, contains public space that is open during the warm season (mid-May through early October, weather permitting) and private space that MWO leases from the state year-round. The state constructed the building in 1980 with space specifically designed for MWO: living quarters, a living room, a full kitchen, working space, conference room, a parapet and deck space for instrumentation and research (Fig. 1), and MWO’s Extreme Mount Washington museum.

Applications arrive from colleges and universities located across the United States (MWO currently does not accept foreign applicants). All MWO internships, including summer (May–August), fall (September–December), and winter (January–April), are unpaid, although food and lodging while interns are on the summit are provided. The summer internship consists of about 7–8 weeks on the summit. The interns work the same shifts as the full-time observers: ascend Mount Washington via the Mount Washington Auto Road on Wednesday morning for an 8-day shift on the summit and then descend the mountain the following Wednesday afternoon after the second group of observers and interns go up the mountain for their 8-day shift. During off weeks, interns typically find local temporary housing for the summer or stay with a nearby relative or friend, while others live close enough to drive to and from home each week. Some interns choose to find paid employment during their off weeks.

INTERNSHIP ACTIVITIES. Every summer, the internship activities designed by MWO are aimed to achieve the internship goals: learn how to observe and forecast mountain weather; develop data analysis and critical thinking skills through individual research projects; and live, work, and collaborate effectively with others at a remote mountain-top observatory. Interns often join the observers on the observation deck (Fig. 1) for the hourly observations to learn how to observe and measure weather variables, such as cloud type, cloud height (above and below summit), visibility using fixed landmarks, and other present weather conditions. Interns learn the method of measuring the dry and wet-bulb temperatures using a sling psychrometer (Fig. 2), the standard measurement method on the summit since 1932, and how to calculate the dewpoint temperature and relative humidity. When wind or glaze ice occurs, interns assist in deicing the Pitot tube anemometer, wind vane, and other instruments mounted on top of the parapet (Fig. 3). Back inside, observers and interns check the digital reading of wind speed and direction that are measured by the Pitot tube anemometer and wind vane located at the top of the parapet (Figs. 1 and 3).

Every afternoon, interns are responsible for making forecasts for the higher summits and valleys for safety procedures and a thorough walkthrough of the Sherman Adams building are reviewed with all new interns upon their arrival.

Fig. 1. On the observation deck of the Sherman Adams building with the Mount Washington Observatory parapet in the background. (left to right) Eric Kelsey (MWO Director of Research), Luke Davis (intern), Tom Padham (intern), Matthew Cann (research intern), Kaitlyn O’Brien (intern), Alex Carne (intern), and Cyrena Briedé (MWO Director of Summit Operations).

Fig. 2. Intern Matthew Cann on the observatory deck using a sling psychrometer to measure the dry and wet-bulb temperature in August 2013.
because of the unobstructed exposure of the anemometer and northwest have the lowest gust factors (1.10–1.12) and south and southwest have the highest mean gust factors (1.10–1.13). Gust variability may be a dominant cause of gust variability; winds from the east were predominant, which is consistent with the large volume of air deeper, likely because of the larger volume of air cooled during the longer nights. The inversion tops were found at about the same elevation as the lowest surrounding ridges, suggesting that the valley filled with radiatively cooled air (Doran et al. 1990). Full inversions are slightly deeper, likely because of the larger volume of air cooled during the longer nights. Canн quantified the WRF Model forecast skill for a 24–25 February 2012 snowstorm in the White Mountain National Forest using the 18 WMO mesonet stations. Plymouth State University and New Hampshire Department of Transportation (DOT) weather stations, and other nearby Automated Surface Observing System (ASOS)/Automated Weather Observing System (AWOS) weather stations. The Advanced Research version of WRF (ARW) was run at 20-km horizontal resolution with two-way nested grids of 4- and 0.8-km resolution centered over the White Mountain National Forest. Five microphysics (Eta, WRF single-moment 6-class, New Thompson et al., Milbrandt–Yau double-moment microphysics schemes and two boundary layer (Yonsei University and Mellor–Yamada–Janjic) parameterization schemes were tested for a total of 10 ensemble members: ENS01 to ENS10. The New Thompson, Milbrandt–Yau, and Morrison double-moment microphysics scheme members run with the Yonsei University boundary layer scheme produced the most accurate 2-m temperature [mean absolute error (MAE) = 0.89–0.93] and 2-m relative humidity (MAE = 8.89–9.22). Wind speed was overforecast by an average of 2.42 m s⁻¹ at all stations with the exception of Mount Washington, which was underforecast by 17.82 m s⁻¹, suggesting overmixing of the boundary layer by the boundary layer scheme, especially during nighttime (Hu et al. 2010; Draxl et al. 2014). The Morrison double-moment microphysics and Yonsei University boundary layer scheme member (ENS10 in Fig. SB3) produced the best precipitation forecast (MAE = 1.85 mm; a 14.7% difference from a 12.55-mm mean observed water equivalent. Future work entails performing similar skill analyses for other air mass types and a broader variety of atmospheric patterns during all seasons. Carne and Davis examined how weather conditions above and near the base of Tuckerman Ravine impacted snowpack conditions relevant for avalanches. Hourly summit observations, weather observations at the Forest Service ranger station 400 m downslope of the base of Tuckerman Ravine, and snowpack measurements taken near the ranger station were analyzed. Wind is important in transporting snow into the ravine from the alpine zone above the ravine rim and in producing wind slabs. Being able to estimate wind speeds above the ravine by using the wind speed at the ranger station or summit can help rangers predict the likelihood of wind slab formation. Carne and Davis calculated that the ranger station mean daily wind speed was 28% of the summit wind speed on average (Fig. SB4). They also examined the snowpack temperature gradient because of its role in the formation of depth and surface hoar. They found a...
local radio stations. Interns use observations, gridded model forecast data, and model output statistics to formulate a 48-h forecast. Interns discuss and defend their forecasts with an observer. The observer shares their mountain forecasting expertise for the anticipated atmospheric conditions and discusses if and how the forecast could be improved. Finally, interns record their refined forecast to be aired on a local radio station.

During the 2013 summer internships, each intern was assigned a research question and tasked to perform original research over the course of the summer to address the question. They were asked to write a scientific research paper summarizing motivation, methods, results, and conclusions by the end of their internship and present their results during a summit meeting at the end of the internships. These research projects were chosen and assigned by the Director of Research Dr. Eric Kelsey and the Director of Summit Operations Cyrena-Marie Briède and relate to local atmospheric and/or environmental phenomena (see the “Intern research” sidebar that describes each intern project and their results). The practice of many research skills were emphasized: practicing the scientific method, developing computer software skills, practicing data acquisition and quality assurance, analyzing datasets, thinking critically, and gaining experience presenting scientific research to an audience. To maximize the likelihood that each intern would produce meaningful research results, the incoming skill sets, meteorological interests, and education level of the interns were used to assign their projects. Indeed, all interns were able to complete their objectives that they set early in the internships and each produced meaningful results (see the sidebar).

To begin their research projects, interns performed a basic literature review of their research topic and presented what they learned to the other interns and Kelsey. This exercise helped the interns develop specific objectives for their research. Observers and Kelsey helped the interns navigate the MWO servers to access and analyze data through various computer software and programming languages, such as Microsoft Office, MySQL, and UNIX. The scientific papers provided an opportunity for interns to gain scientific and technical writing experience. These papers serve as a record of their work so that MWO scientists and future interns can build upon the work performed by the interns.

Group research meetings occurred every Wednesday morning when all five interns were together on the summit for the weekly shift change. The upcoming shift of interns, observers, and volunteers met Kelsey and Briède at the base of the Mount Washington Auto Road at 0815 LT. They traveled the 12-km Auto Road to the summit in the MWO van, unloaded the van of personal gear and food for the week, and then repacked the van with personal gear of the downgoing shift. Then, all five interns and Kelsey met for their weekly group research meeting. The downgoing interns began the meeting sharing methods, data, and figures summarizing their research progress, typically with informal PowerPoint presentations. The other interns and Kelsey critiqued their results, asked questions, and provided feedback on their presentation style, content, and research methodology. The meeting concluded with the interns discussing their next objectives and methodologies.

In addition to the research responsibilities, the interns assisted the observers with many other tasks critical for operating a continuously staffed mountain-top observatory. When instrumentation or other equipment needed
After the summer internships ended, the interns were encoding scientific results. They were provided an additional outreach and public speaking opportunity to develop their skills in communication and answering questions from the audience. These presentations included scientific presentations followed by 10 min for research. On 17 August 2013, the two interns presented their last day on the summit (Fig. 5). Beforehand, interns helped staff the MWO Extreme Mountain Observatory (MWO) summit volunteers. Dinner time was an important time to share stories from the day, discuss problems that arose, debate strategies to resolve them, and reflect on living and working in a remote environment where the weather is constantly changing, inspiring, and exhilarating. Dinner time and the other collaborative projects are important activities for the team of MWO staff, interns, and volunteers to develop camaraderie and trust, which are critical for a well-functioning remote mountain observatory.

**RESEARCH PRESENTATIONS.** In mid-August, each intern concluded their MWO summer internship with a 15-min research presentation on their last day on the summit (Fig. 5). Beforehand, Kelsey discussed effective presentation methods with the interns and the interns practiced their presentations in front of volunteers and observers. The audience of their final presentations consisted of both shifts of observers, MWO staff members, MWO volunteers, and other MWO guests. Because of the exceptional quality of the results by two interns, MWO held a special event to highlight their research. On 17 August 2013, the two interns presented their research results at the MWO Weather Discovery Center in Conway to MWO members. The presentations were structured as 20-min scientific presentations followed by 10 min for questions from the audience. These presentations provided an additional outreach and public speaking opportunity to develop their skills in communicating scientific results.

**ASSESSING INTERNSHIP OUTCOMES.** After the summer internships ended, the interns were asked to complete a survey to assess the effectiveness of the internship at achieving its goals. The questions were as follows:

1) One goal of the internship is for interns to learn how to observe and report mountain weather. How effective was the internship at meeting this goal? Please provide a number between 0 and 4, where 0 = “I did not learn anything” and 4 = “the internship was highly effective at increasing my knowledge of observing and reporting mountain weather.” What was effective? What can be improved?

2) One goal of the internship is for interns to learn how to forecast short-term mountain weather. How effective was the internship at meeting this goal? Please provide a number between 0 and 4, where 0 = “I did not learn anything” and 4 = “the internship was highly effective at developing my data analysis skills.” What was effective? What can be improved?

3) One goal of the internship is for interns to develop data analysis skills through a research project. How effective was the internship at meeting this goal? Please provide a number between 0 and 4, where 0 = “I did not learn anything” and 4 = “the internship was highly effective at developing my critical thinking skills.” What was effective? What can be improved?

4) One goal of the internship is for interns to develop critical thinking skills through a research project. How effective was the internship at meeting this goal? Please provide a number between 0 and 4, where 0 = “I did not learn anything” and 4 = “the internship was highly effective at increasing my knowledge of short-term mountain weather forecasting.” What was effective? What can be improved?

5) One goal of the internship is for interns to learn how to live, work, and collaborate effectively with others at a remote mountain-top observatory. How effective was the internship at meeting this goal? Please provide a number between 0 and 4, where 0 = “I did not learn anything” and 4 = “I learned how to live, work, and collaborate with others.” What was effective? What can be improved?

6) What did you find beneficial about providing observational tours to MWO members and guests? What was not beneficial to you about providing tours?

7) How did the internship impact your career and/or graduate school decisions? Four out of the five interns completed and returned the survey. Overall, the results indicate that the goals of the internship were met and achieved effectively. The quantitative responses for questions 1–5 were all fours (even a few fives) with only one three (still a positive response). For question 1, interns found that frequent shadowing of the observers taking hourly observations during a variety of weather conditions, day and night, was highly effective. Interns were able to ask questions and practice some observational methods, such as using the sling psychrometer (Fig. 2), taking rain and snowfall observations, measuring visibility using known landmarks, describing cloud types, and estimating sky cover. One intern noted the “vast knowledge” learned about aviation routine weather reports (METARs) when the observers translated the observations into METAR code.

For question 2, interns learned a lot from the process of creating their own forecasts and recording them for radio stations. One intern noted that creating forecasts “offered a sense of confidence as a meteorologist.” All four responses highlighted the value of discussing their forecasts with an on-staff meteorologist (at least one of the three observers on each shift has a bachelor’s degree in meteorology). One intern suggested more frequent discussions with the staff meteorologist and other opportunities to learn more about mountain weather forecasting. The types of research projects varied for each intern (see the sidebar), which is reflected in the responses for question 3. Interns learned “a lot” about literature review, data analysis, quality assurance, data analysis, and how to use the Weather Research and Forecasting (WRF) Model. One intern learned how to use MySQL and thought the research project allowed the application of knowledge gained in the classroom to the weather occurring on the mountain.

Two responses recommend that more guidance on data analysis be provided. One intern felt the internship did not provide enough time to work on the research project. During informal conversation during weekly team meetings, the interns mentioned the structure of researching every other week for only 7–8 weeks is a time limitation that challenged them. Interns mentioned the week-long break in between shifts broke their momentum at times but, overall, did not result in any serious challenges.

For question 4, all interns felt they regularly applied critical thinking skills throughout the research project. One intern was “happy” that the assigned project was relatively open-ended because it gave “freedom to pursue how” to perform the research. Another intern felt the weekly group meetings and independent work were beneficial to the development of critical thinking skills and suggested longer meetings and/or more frequent meetings would be beneficial. One intern stated that sharing ideas and methods during the group meetings stimulated new ideas for their own research.
Regarding question 5, all interns commented positively about the development of community among the interns and volunteers. One intern expressed that the sharing of common goals and frequent collaborative work was a key catalyst for the development of community. Another intern commented that the internship allowed significant growth “on an interpersonal level.”

For question 6, all interns learned a wealth of information about the history of MWO and the mountain by giving observatory tours. Three interns mentioned some degree of enjoyment, and the other two interns did not offer comments on how they felt giving tours. Other benefits that were mentioned include gaining experience and confidence with public speaking, engaging with other weather enthusiasts and supporters of the observatory, and being inspired to learn more about the history of Mount Washington. Two interns noted that productivity of other work was reduced during busy days when they gave several tours.

Last, all four responses to question 7 noted positive impacts on their career and/or decision to go to graduate school. The internship provided a new perspective on meteorology careers for one intern who still had two more years in his college program. For another intern, it reinforced a tentative decision to apply for graduate school during the fall of 2013; the internship taught the intern something “completely new about meteorology” and that graduate school is needed to “improve understanding of meteorology” and research skills.

INTERNSHIP CONCLUSIONS. The MWO internship format of learning from human weather observers how to observe, measure, and document a wide variety of atmospheric variables, combined with weather forecasting, public speaking, instrument maintenance, and scientific research provided a unique, comprehensive meteorology internship opportunity for aspiring atmospheric scientists. Closely working with observers on a variety of scientific, technical, and mechanical tasks helped build community and trust, which is essential to be an effective team member. Receiving intern survey responses elicited valuable input, identifying aspects of the program that were effective and those that can be made even better. The dominantly positive survey responses indicate that the goals of the MWO summer internship program were achieved. Interns gained or improved several career skills through experiential learning, including weather observing, weather forecasting in complex terrain, the scientific process, data analysis, critical thinking, public speaking, presenting scientific information, and working collaboratively.

The successful development of these skills and exceptional work by two interns resulted in their hiring as full-time paid observers when they applied for new observer positions during the subsequent months. One intern was hired less than one month after the end of the internship when an observer position opened. The other intern worked for a private meteorological company in Oklahoma before being hired as a MWO observer in March 2014. It is relatively common for former interns to be hired at MWO as full-time observers because of their high familiarity with the job and known ability to work collaboratively on a remote mountain summit for a week at a time; a majority of observers hired over the past decade were previously interns. As previously mentioned, one intern’s decision to apply for graduate school was solidified as a result of the internship experience and is currently a graduate student at Plymouth State University with Kelsey as his advisor. The other two interns recently graduated from their respective undergraduate meteorology programs. The interns were pleased with the internship program, and they offered some suggestions to make it even better in the future. Many suggestions related to wanting to spend more time with MWO staff to discuss mountain weather forecasting and their research during the summer. These improvements from a three-year study. Sci. Educ., 88, 493–534, doi:10.1002/see.10131. Thiry, H., S. L. Laursen, and A. B. Hunter, 2011: What experiences help students become scientists? A comparative study of research and other sources of personal and professional gains for STEM undergraduates. J. Higher Educ., 82, 357–388, doi:10.1080/00221546.2011.10223.
ABSTRACT

With extreme winds, rapidly changing weather, and a myriad of weather conditions during any given month, Mount Washington, New Hampshire (1,917 m MSL), is an ideal location to observe and learn about atmospheric sciences. During the summer of 2013, Mount Washington Observatory (MWO) welcomed a select group of interns to experience life at the "Home of the World's Worst Weather" and develop scientific and meteorological skills. The goals of the internship program are to learn how to observe and forecast mountain weather; develop data analysis and critical thinking skills through individual research projects; and live, work, and collaborate effectively with others at a remote mountain-top observatory. Interns are typically undergraduate students or recent graduates of atmospheric science programs and are selected from a highly competitive field of applicants.

The summer 2013 interns worked on a variety of research projects, ranging from developing a forecast tool for the gustiness of wind at the summit to understanding the evolution of atmospheric and environmental conditions that lead to avalanches in nearby Tuckerman Ravine. To accomplish their research projects, the interns learned how hourly weather observations are made, used data analysis software, and practiced critical thinking about their methods and results. Weekly meetings with the interns and the MWO Director of Research allowed for the sharing of research progress, peer feedback, and practice presenting scientific results. The internships ended with presentations of their scientific research to MWO observers, staff, and observatory members. Post-internship survey responses revealed the program was highly effective at meeting its goals and provided constructive suggestions for future internship programs.