An undergraduate research lab for optical glacier monitoring

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Abstract

Water resources in Lane County and Oregon at large depend on rain fall, snow melt and glacier melt. Availability of those resources throughout the year are essential for providing fresh water as well as hydroelectric power, which is the central pillar of renewable, green energy for Lane County and the entire Pacific Northwest. During the summer months, snow and glacier melt play an important role that cannot be overstated. As there is little precipitation throughout the summer, melting snow and ice act as a buffer for streamflow for Oregon's mountain rivers, usurping ground water in many regions. Without this important buffer, mountain rivers run dry in the late summer. Glaciers provide steady cold water, which can make up a significant portion of the overall amount of water available and is crucial for sustaining river habitats. As glaciers shrink, this reservoir will dwindle, threatening river habitats, wildfire resilience and water resource availability. The precise pace and magnitude of this evolution is unknown to scientists, policy makers and the public, as are the attendant consequences of these changes.

Collier glacier seen from North Sister

Amid climate change, the transition to clean energy, and rising energy demand, we see education and research at a local level in a crucial role. The years to come will require mindfulness for the natural resources, a scientific effort tailored to the circumstances of the Oregon Cascades, and an educated workforce that can spearhead the transition to clean energy. For this purpose, this project brings together researchers and educators from the University of Oregon (UO), the Central Oregon Community College (COCC) and the Oregon Glacier Institute (OGI) to build a program that provides glacier monitoring and water resource research, implement it at an undergraduate research level and promote scientific community outreach. Markus Allgaier, a physicist at UO, develops optical instrumentation tailored to glacier monitoring in the Cascades: lightweight, compact and affordable, for easy use in wilderness areas accessible only on foot. Anders Carlson is the founder and president of OGI, which is reviving the monitoring of Oregon's glaciers and engaging and educating citizen scientists and the public. Hal Wershow, assistant professor of geology at COCC, teaches Earth Science with a strong focus on sustainability, field experiences and accessibility. During the pandemic, he turned field-based courses such as "Cascade Volcanoes" into virtual experiences that still demanded students to explore their environment. As field-based learning returns, COCC Geology students still have the option of virtually experiencing the field, thereby eliminating one of the most persistent barriers in the Earth Sciences. Wershow has a history of successful undergraduate research projects, including an ongoing collaboration with the USGS and The Nature Conservancy to monitor springs and their response to climate change in the Cascades and Ochocos.

We propose to adopt the newly developed optical instrumentation for the use in undergraduate research, recruit students from UO and COCC for summer research projects and have them take part in OGI's glacier monitoring program in the Three Sisters Wilderness throughout field seasons 2021 and 2022. On OGI's newly set up mass-balance site on Collier Glacier, the true headwater of the McKenzie River given the extremely short regional groundwater-residence time, students can make contributions to evaluate the resilience of our local water resources and receive training on state-of-the art optical instrumentation.

1. Background

University of Oregon

Nestled in the Willamette Valley, within an easy drive to both the Pacific Ocean and the Cascade Mountains, the University of Oregon is renowned for its research prowess and commitment to teaching. As the number 1 public university in the state, UO offers 331 degree and certificate programs to its 21,800 students.

The University of Oregon is a comprehensive public research university committed to exceptional teaching, discovery, and service. UO helps individuals question critically, think logically, reason effectively, communicate clearly, act creatively, and live ethically. University of Oregon aspires to be a preeminent and innovative public research university encompassing the humanities and arts, the natural and social sciences, and the professions. The UO community seeks to enrich the human condition through collaboration, teaching, mentoring, scholarship, experiential learning, creative inquiry, scientific discovery, outreach, and public service.

The Oregon Center for Optical, Molecular, and Quantum Science (OMQ) seeks to promote and facilitate research and education in the sciences wherever optics, spectroscopy, quantum science and the physical investigation of atomic and molecular processes are involved — in either fundamental aspects or technological applications. Students—undergraduate, Master's and PhD—are involved in all aspects of research at the center.

Oregon Glacier Institute

Mission. The Oregon Glaciers Institute documents the health of Oregon's glaciers and their responses to climate change to determine their future viability and to educate communities on the role glaciers play in Oregon's environment and economy.

Needs. OGI is filling the pressing need to monitor changes in Oregon's natural, frozen freshwater reservoirs in the high alpine zone. Oregon's glaciers supply meltwater to streams and rivers. This meltwater is directly used as drinking water in many communities, such as Eugene and Bend, and as an irrigation source, particularly in the late summer when glacier melt can constitute 70% of streamflow. Glacial meltwater also cools streams to sustain salmon and trout habitat. Cooler streams cool forests and reduce fire risk and severity. Thus, water-use planning and fire resiliency preparation require data on the seasonal contribution of glaciers to streamflow and how this will change in the future. However, no agency was monitoring the changes in this natural resource. OGI is meeting this need to aid ecosystems and communities that depend on glaciers and their meltwater.

Programs. OGI has four main programs:

1) Glacier surface mass balance. This program is measuring the seasonal health of glaciers in Oregon. OGI conducts detailed measurements of winter snow accumulation and summer melt on benchmark glaciers in the Cascades to determine how seasonal weather is driving larger scale glacier change. This program documents the volume of glacier melt supplied to streams each summer and how that contribution is changing.

2) Glacier change. This program is to measure multi-year changes in glacier area and volume. This is the measure of how much ice remains in the high alpine zone and how it has changed over the past century. Historical photographs and field mapping delineate past changes in Oregon's glacier extents. Biennial mapping documents modern area change. Using optical techniques, glacier volume is determined and thus the change in the size of Oregon's frozen freshwater reservoir. Evolving geohazards are documented and reported. These include debris flow potential and the development of proglacial lakes that can catastrophically drain.

3) Glacier future. This program utilizes data from the surface mass balance and area/volume programs to build numerical models of glacier responses to climate. With these models, OGI can project future glacier changes, meltwater runoff and ultimate viability for the different carbon emission pathways and climate responses determined the United Nations Intergovernmental Panel on Climate Change (IPCC).

4) Glacier education. Glaciers are not just pretty things to marvel over while on vacation, but integral parts of Oregon's economies and ecosystems. OGI performs outreach and educational activities to inform Oregonians about this important and unique resource. Glacier loss is the strongest indicators of climate change's impacts on Oregon. OGI believes that glacier preservation will only come through glacier education.

Budget. OGI is currently a two-person, part-time team. It's annual operating budget is ~$185,000 to conduct the four programs. OGI utilizes citizen scientists for additional field support and data collection. The two-person, part-time salary (FTE=0.75) and benefits total ~$162,000/year. Operating costs are ~$9,000/year for web infrastructure, computing, insurance, and publishing. Field costs are also ~$11,000/year for mileage, per diem and occasional lodging. Meeting attendance is ~$3,000/year.

Central Oregon Community College

The COCC Geology program serves the community of Central Oregon by:

1) Promoting Earth Science literacy amongst the people of Central Oregon. In practice, this means
   a) Educating people about the risks of geohazards and how to avoid becoming victims
   b) Helping people connect our present and future prosperity to the sustainable management of earth resources and geologic systems
   c) Connecting people to their local landscape
2) Preparing Geology majors for a successful career with high-impact educational practices. In practice, this means
   a) Introducing majors to authentic research experiences early in their careers
   b) Bringing the classroom to the field with frequent field trips
   c) Implementing active learning techniques in the classroom
3) Serving all communities through an equity-based framework. In practice, this means
   a) Welcoming every member of our community with inclusive practices
   b) Reaching out to community members who have been traditionally under-represented in the Earth Sciences

This project directly addresses our second mission by connecting Geology majors to a research project. Furthermore, it exposes these students to the messy reality of field science (2a). Students will be expected to present their findings to the Central Oregon community, thereby promoting Earth Science literacy with a focus on our freshwater resources and their green energy potential (1b). We will use this experience to develop a virtual field trip to the Collier Glacier as well, thus creating an experience that is accessible for any member of our community (3a).

For many undergraduates, a research experience is a trade-off with their income, which is often supporting a family. Therefore, even when an opportunity such as glacier monitoring presents itself, they are forced to decline because they cannot afford to not be working. To ensure the successful recruitment of COCC students, we need to offer them fair compensation for their time.

2. Project description

Research background

In Western and Central Oregon, hydroelectric power is the essential source of green energy. It will become even more important as we combat climate change[1]. The rivers in the region are fed by rainfall, snow and glacier melt water. With rising temperatures, snow will play a smaller role in the future, shifting run-off to the winter months,

[1] Farinotti et al., 2019, Large hydropower and water-storage potential in future glacier-free basins, Nature, 575, 341-344

leaving it to ground water and glaciers to buffer river flow in summer[2]. For the watersheds bordering the Central Oregon Cascades, i.e. the McKenzie and Deschutes rivers, it is unknown exactly how much glaciers contribute to water resources as such studies have never been conducted despite the clear role that glaciers play in the watersheds (for an example of what can be determined by actual concerted research that has been lacking so far in the United States, see Anderson & Radić[3] for what impacts glacier change will have on all communities east of the Canadian Rockies on the plains of Alberta). However, a recent study of the Hood River watershed revealed that water availability in the summer months could drop by as much as 78% during the late summer[4] when glacier meltwater can constitute more than 70% of streamflow[5]. Likewise, glaciated regions constitute important and largely untapped sources of hydroelectric power in Oregon. For instance, half of Switzerland's hydroelectric power is generated by glaciers, 4% of all France's and 15% of all Norway's electricity comes from glacier-based hydroelectric power. In the late summer, half of British Columbia's hydroelectric power is generated by glaciers. Oregon's glaciers thus hold unrealized green-power generating capabilities.

What is clearly needed to address both the water resources and green-power generation potentials of Oregon's glaciers is actual data on the volume of water stored in these glaciers, when and how this water is released and how this reservoir is changing in response to climate change. This project will address generating data on glacier volume and educating undergraduate students and the public at large in the process.

In the Pacific Northwest, glacier volume and its evolution over time provides critical information in terms of water resources, fisheries and geohazards [6,7]. Glacier volume requires two metrics: area and thickness[8]. Glacier area is readily determined by remote sensing and field mapping, the most recent of which for Oregon was completed last summer by OGI. Glacier thickness is more difficult to measure. Indeed, the last (and only) ice thickness measurements made in Oregon date to 1981 when the recent eruption of Mt. St. Helens and attendant lahars created concern over the geohazards posed by heavily glaciated active volcanos [9]. This 1981 study was, however, selective in its glacier measurements, excluding many glaciated regions of the Pacific Northwest, particularly those in steep terrain. Furthermore, significant glacier retreat and disappearance in the last 40 years has made these measurements obsolete[10,11].

A large quantity of glacier thickness measurements is needed to document the volume of ice remaining in the high alpine zone and how it is changing as the climate warms[12]. This requires inexpensive, easy-to-use, and transportable instrumentation to measure ice thickness on many glaciers. The glaciers of the contiguous United States are thin, which means that means optical methods (i.e., lasers) can measure ice thickness, fulfilling the need to increase the number of glacier thickness observations. As such instrumentation is much easier to use than traditional geophysical methods such as ground-penetrating radar, a larger number of helping hands can be recruited and quickly trained among undergraduate students, enabling a plethora of observations per field work

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[2] Huss & Hock, 2018, Global-scale hydrological response to future glacier mass loss, Nature Climate Change 8, 135-140
[3] Anderson & Radic, 2020, Identification of local water resource vulnerability to rapid deglaciation in Alberta, Nature Climate Change 10, 933-938
[4] Frans et al., 2016, Implications of decadal to century scale glacio-hydrological change for water resources of the Hood River basin, OR, USA, Hydrological Processes 30(23), 4314-4329
[5] Nolin et al., 2010. Present-day and future contributions of glacier runoff to summertime flows in a Pacific Northwest watershed: Implications for water resources. Water Resources Research 46, W12509
[6] Pitman et al., 2020. Glacier retreat and Pacific Salmon. BioScience 70, 220-236.
[7] Hock et al., 2019. High Mountain Areas, in IPCC Special Report on the Ocean and Cryosphere in a Changing Climate, 131-202.
[8] Bahr et al., 2015. A review of volume-area scaling of glaciers. Reviews of Geophysics 53, 95-140
[9] Driedger & Kennard, 1986. Ice volumes on Cascade volcanoes: Mount Rainier, Mount Hood, Three Sisters, and Mount Shasta. USGS Professional Paper 1365.
[10] Roe et al., 2016. Centennial glacier retreat as categorical evidence of regional climate change. Nature Geoscience 10, 95-99.
[11] Hartz & Carlson, 2020. Glacier disappearance in the high alpine of Oregon, U.S.A. American Geophysical Union Fall Meeting.
[12] Farinotti et al., 2017. How accurate are estimate of glacier ice thickness? Results from ITMIX, the Ice Thickness Models Intercomparison eXperiment. The Cryosphere 11, 949-970.

season. The feasibility of an optical, laser-based instrument for glacier monitoring has recently been demonstrated by UO[13], where a prototype is currently being built.

An additional metric measured by this method is the scattering and absorption coefficient of ice. One means of measuring ice-volume change (not actual ice volume) is satellite and airborne laser altimetry, which can provide global records of glacier volume change and water resource availability. However, these laser data require knowledge of how reflective the ice is, measurements of which are highly limited[14]. The laser-based instrument proposed here would provide the necessary parameters to accurately model reflectivity and sub-surface scattering, greatly increasing the number of observations for calibrating remote-sensed laser altimetry.

The involvement of undergraduate researchers will help train a work force that can combat climate change in the years to come and make an extraordinary contribution to higher education in the region by offering the opportunity for a variety of field research opportunities. We believe that our newly developed optical instrumentation is well suited for this task, as it is simple to use and does not require a geophysical expert.

The Oregon high Cascades provide excellent opportunities for field research. Numerous glaciers flow on the peaks of the Cascades, with the best studied glacier being Collier Glacier on the west flank of North Sister where it constitutes the true headwater of the McKenzie River, which it feeds via springs after as little as a 3-year residence time in the highly porous volcanic groundwater network[15]. The U.S.G.S. measured the thickness of this glacier in 1981 as part of the Pacific Northwest survey and documented its change in area since the end of the Little Ice Age up to the early 1990s[16]. Mass balance measurements were made on the glacier up to 1994[17]. Supported by the Mazama Mountaineering Club, OGI is resuming these area and mass balance measurements in the summer of 2021, with data collection ideally continuing in perpetuity. OGI has obtained permits from the Willamette National Forest to conduct research on this glacier that resides within the Three Sisters Wilderness Area. By collaborating with OGI, undergraduate students recruited at UO and COCC can participate in field work over the next two seasons, making use of this well studies glacier as a test bed for the new methods and without the need of obtaining additional permits.

We believe that by performing this research we can make a crucial contribution to natural resource conservation in the Central Oregon Cascades and throughout the region where these resources are used for fresh water, irrigation and hydroelectric power.

Accessible Instrumentation

Oregon is not the Arctic. U.S. climate research and glacier monitoring in the Northern Hemisphere has largely focused on the changes happening in the Arctic regions. There, glaciers are massive, access requires helicopters and snowmobiles, and many observations are done using extremely expensive and difficult to use instrumentation such as ground-penetrating radars. In the Pacific Northwest, glaciers are much smaller and thinner. With the added difficulty of access in wilderness areas, different instrumentation is necessary. Working around these constraints, many observations using optical measurements are possible in Oregon. Such instrumentation is more affordable, easy to use with minimal training, and can be built to fit in a backpack.

[13] Allgaier & Smith, 2021, Diffuse optics for glaciology, Optics Express 29(12), 18845-18864

[14] Zemp et al., 2019. Global glacier mass changes and their contributions to sea-level rise from 1961 to 2016. Nature 568, 382-386.

[15] Jefferson et al., 2006. Influence of volcanic history on groundwater patterns on the west slope of the Oregon High Cascades. Water Resources Research 42, W12411

[16] O'Connor et al., 2001. Debris flows from failures of Neoglacial-age moraine dams in the Three Sisters and Mount Jefferson wilderness areas, Oregon. USGS professional paper 1606.

[17] Clark, 1993. Mass balance study of the Collier Glacier, Three Sisters Area, Cascade Range, Oregon. Oregon Water Resources Research Institute, WRRI-114.

Left: A miniature spectrometer for measuring background light, packaged for work in the field, is one example for portable, optical instrumentation that can easily be transported on foot (Quarter for scale). *Right:* Prototype of the optical detector in the lab. After injecting light from a laser into glacier ice, its propagation pattern and timing can be measured with a photon counting detector even for the faintest signals, enabling measurement of optical properties, thickness and ice flow direction. The sealed, temperature-controlled detector is well suited for outdoors work, optics (lenses and spectral filters) are packaged in a lens tube and do not require alignment in the field. The detector can be powered for several hours directly using a compact 12V battery, with no need for mains power or inverter. With the mount disassembled, this entire system fits in a briefcase.

Access to field observations. One additional hurdle for undergraduate research, especially at community colleges, is the lack of research opportunities in the field. We hope to remedy this by providing students with access to field work, instrumentation, know-how and research permits under the umbrella of the participating institutions.

Where we stand. A prototype of the new instrument or optical glacier ice characterization is already set at UO, ready to be used in field this summer. The instrument is easy to use through a simple computer interface. OGI has secured a research permit from the Willamette National Forest and spent the summer of 2020 surveying all of Oregon's glaciers to select appropriate field sites. In 2021, OGI will commence mass-balance measurements on Collier Glacier. In addition, NASA's satellite-based laser altimeter (ICESat-2) provides regular elevation data for several glacier in the Three Sisters wilderness (Collier, Hayden, Crook and Bend Glacier).

Community Science education

Undergraduate research. It has been shown that the undergraduate research programs have a lasting positive influence on preparing students for professional service, honing independent critical thinking and communication skills, and aiding institutions of higher education by increasing visibility[18]. Enrolling students in research project early on offers an outlook of career opportunities, and even motivate them to pursue a career in research[19]. Especially in environmental and earth science programs, undergraduate research opportunities involving extensive field work are rare, but would undoubtably have a lasting effect on someone. Particularly at community colleges, undergraduate research is often a privilege, contrary to the fact that a large portion of science majors at UO start their education at a community college.

Outreach. In times where climate change skepticism soars, trust in science is in decline, and the task of combating climate change lies ahead, scientific outreach is more important than ever. Generally, scientific topics are oversimplified in the media, just to name one of the reasons why there is a disconnect between scientists and the public[20]. We see scientific outreach at the core of any research or educational activity that deals with climate

[18] Petrella & Jung, 2008, Undergraduate Research: Importance, Benefits, and Challenges, Int J Exerc Sci. 1(3): 91–95
[19] Webb, 2007, The Importance of Undergraduate Research, Science Mag, doi:10.1126/science.caredit.a0700095
[20] Pham, 2016, Public engagement is key for the future of science research, npj Science Learn 1, 16010

change. Since its inception in early 2020, OGI has spearheaded a public outreach campaign that put glacier monitoring and water resource conservation in Oregon on the map, appearing on virtual talks, the Bend bulletin, Channel 21, OPB, Backcountry Magazine and The Guardian as a few examples. This project will continue the momentum of that campaign and communicate new results. We will use opportunities at UO to address the scientifically interested public in Eugene, such as the undergraduate research symposium.

Approachable science. Climate research is a particularly hard sell for the public, as studies mostly look at Antarctic or Greenland ice sheet, places utterly inaccessibly to the non-expert, literally and figuratively. In contrast, everyone can marvel at the Collier Glacier from afar on a drive over Highway 242 or camp alongside the moraines of the now-gone “Jack” glacier on Three Fingered Jack (a glacier never officially named or put on federal maps, highlighting how little is known about Oregon’s glaciers and why this project is needed to address this large gap in knowledge over Oregon’s full water cycle and resources). Local glacier enables approachable scientific communication about places familiar to the community

Project purpose and EWEB’s mission

Our proposed project serves the purpose of evaluation, monitoring and forecasting of water provided by Oregon’s glaciers. We integrate this goal with an effort to promote undergraduate science and contribute to workforce education. The project is embedded in the local communities through outreach. We believe that these goals align with several core values of EWEB:

Reliability. EWEB values continuous, on-demand delivery of quality drinking water and electricity. Climate change and its impact on our glaciers and snowpack affect this pledge in a profound way by potentially reducing the availability of water. This project will help inform about these upcoming challenges and aid EWEB in making decisions that ensure continuous water availability in the future.

Responsibility. Prudent and sustainable stewardship of natural resources as well as reduction of greenhouse gases are key values of EWEB. As hydroelectric power plays a central role in green energy in the region, there is a crucial interconnect between watershed stewardship and reduction of greenhouse gases. Monitoring the glaciers at the McKenzie headwaters helps implement stewardship of the McKenzie River, helps sustain a healthy watershed and helps anticipate changes caused by climate change. Likewise, in developing new green energy, glaciers and their stored energy potential need to be assessed as they have proven to be excellent and reliable energy sources in other glaciated countries.

Community. Our project serves local communities by informing them of the state and sustainability of their natural resources and train a workforce that can carry on this task in years to come. We will perform this service in a transparent way by providing all results free of charge in open-access journals, and engage with the community directly through outreach and in higher education both at UO and COCC.

Population Served

Undergraduate students. Undergraduate studies in environmental and earth sciences are tantamount for climate change resilience, as those programs train the next generation of the workforce for natural resource utilization and conservation. Especially at the undergraduate level in rural areas served by community colleges, the barrier to conduct meaningful research projects and obtain funding is high. Our project addresses this need to engage with the local undergraduate students and engage them in research.

Lane and Deschutes County. Our project serves the population of Lane and Deschutes Counties by addressing the challenges regarding our natural resources, especially water. These communities rely on the high alpine environment for water in a unique way.

Pacific Northwest. While the research conducted within this project is of special importance to local resource availability, the McKenzie watershed is one of many in the Northwest impacted by climate change. The research results we hope to obtain can be applied to other watersheds in Oregon and the Pacific Northwest at large.

3. Project evaluation

The three pillars of the project directly translate into the project goals, which in turn define our success criteria. As this is primarily a research development training project, the main measure of success for each individual pillar is scientific publication and dissemination.

Scientific Deliverables.
- Measure glacier thickness to determine glacier volume and thus the stored freshwater and green energy potential of glaciers in the McKenzie River watershed.
- Measure optical properties of glacier ice and snow to improve glacier remote sensing methods used for global glacier change measurements.

Educational Deliverables.
- Train undergraduate students in glacial field methods and optical physics laboratory methods.
- Expose undergraduate students to the scientific method where they develop and test their own hypotheses on real-world environmental and green-energy problems
- Provide a unique educational experience that will result in student first-authored publications, which will increase future academic and employment success of the students.

Pillars	Accessible Instrumentation	Undergraduate Research	Glacier Monitoring and Climate Research in the Oregon Cascades
Goals	Demonstrate an optical instrument that: - Is affordable and portable - Can measure optical scattering and absorption coefficients of ice and snow - Requires minimal training - Can be used by undergraduate researchers	- Recruit undergraduate students - Assist them in choosing suitable summer research projects - Train them in using optical measurement instruments - Enable them to perform field work	Improve scientific understanding of the impact of climate change on glaciers and hydrology in the Central Oregon Cascades, such as - Mass balance - Glacier melt run-off - Water resource availability - Viability of remote sensing - Impact of wildfires
Success Criteria	Deploy the developed instrument on glaciers in the Oregon Cascades and have students use it to perform measurements for their research projects	Complete several exciting undergraduate research projects that present a real scientific impact and present and publish the results	Make quantitative observations of state and decay of our glaciers, evolution of water resources, and implement remote sensing monitoring
Success Metrics	Publication of an article about the instrument in an open-access, peer-reviewed journal with a focus on optical instrumentation, such as *Applied Optics* (Optical Society of America)	- Participation at UO undergraduate research symposia - Present at regional meetings such as and Northwest Climate conferences - Publish each undergraduate projects in peer-reviewed undergraduate or geophysical journals	- Publication of results in in peer-reviewed journals on glaciology and hydrology - Dissemination in several scientific and public talks: OMQ symposium (fall 2021), physics colloquium, OGI talks - Create interactive website - Public lab tours at UO

4. Budget

To facilitate the project, all three parties need financial support to support the participating educators and researchers for the durations of field work and student training. In addition, support is required for transportation and rental equipment for students to avoid any financial burden that might stop students from participating. Part of the budget will be needed to maintain and improve the instrumentation for field work and laboratory demonstrations. Project administration will rest with UO, with the other parties as subrecipients.

University of Oregon (OGI)

Category	*2021*	*2022*	
Salary			
Markus Allgaier (0.083FTE)	2281	2281	
OPE rate (51.8%)	1182	1182	
Total	*3463*	*3463*	
Travel	400	400	
Equipment			
Laser diode module 405nm	652		
Laser diode module 520nm	412		
Laser diode module 635nm	535		
Supplies for scale models	300		
Optomechanics & electronics	1035		
TOTAL UO	6797	3863	10660

Oregon Glacier Institute (OGI)

Category	*2021*	*2022*	
Salary			
Anders Carlson	3500	4000	
Aaron Hartz	3500	4000	
total	7000	8000	
Fringe @ 7.65%	536	612	
Total	*7536*	*8612*	
Travel			
Mileage @ $0.56/mile	224	224	
Per Diem @ $55/day	550	550	
Total	*774*	*774*	
Total OGI	8310	9386	17696

Central Oregon Community College (COCC)

Category	2021	2022
Salary		
Hal Wershow	2400	2400
COCC Benefits (38.4%)	922	922

total	3322	3322	
Student researcher support (3 students / year)	7500	7500	
Total COCC	14144	14144	21644
<u>Project total</u>	<u>25929</u>	<u>24071</u>	<u>50000</u>

5. Timeline

Task	Q3 '21			Q4 '21			Q1 '22			Q2 '22			Q3 '22			Q4 '22		
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Student recruiting and training	■	■								■	■	■	■					
Field work			■											■	■			
Data evaluation				■	■	■										■	■	■
Improving instrumentation	■	■					■	■	■									
Undergraduate publication					■	■											■	■
Scientific publication							■	■	■							■	■	■
Dissemination and outreach							■	■	■	■	■	■	■			■	■	■

Q3 2021. The first field work season in September 2021 will be a smaller scale test run as there is not much time between project kick-off and field work. We will recruit 2-3 undergraduate students, give the final finishing touches to our instrumentation, train students in the lab at UO by imaging the prepared scattering phantoms, and commence field work on Collier Glacier by early September, where we typically find a 3-4 week window where bare ice can be found.

Q4 2021. After completed field work, we will assist students in data analysis and evaluation, put the results into context corresponding to each research project, and start writing and submission of their independent publications to an undergraduate research journal.

Q1 2022. Starting in 2022 we will pool the results from the first field work season and the individual undergraduate projects and evaluate them. This will allow us to draw more far-reaching conclusions about the state and properties of the Collier Glacier. We will prepare these results as a scientific publication and begin our larger outreach activities. In addition, we will spend the winter to improve our instrumentation as needed to address any issues that arise during the first field work season.

Q2 2022. As we have more time to prepare for the second field work season, we can recruit more students and plan follow-up projects for returning students. As our outreach activities continue with talks and lab tours, students who participated in the first field work season will have the opportunity to present their research at the UO undergraduate research symposium in May.

Q3 2022. August and September 2022 will allow for an extended field work period as we can draw from the experience of the first season, work with more experienced students, and having had more time to prepare and plan students' projects. Here, we may be able to cover more field sites than just Collier Glacier, potentially expanding our effort to monitoring more glaciers in the region.

Q4 2022. The last quarter of the project will contain the bulk of data analysis and publication preparation as we can compare two field seasons, expand on the previous year's results, and pool all project results into a final publication, accompanied once again by the individual undergraduate researcher's publications. At this stage, we will benefit these combined results to the public.

Attachments

Proof of non-profit status, OGI

INTERNAL REVENUE SERVICE
P. O. BOX 2508
CINCINNATI, OH 45201

DEPARTMENT OF THE TREASURY

Date: JUN 19 2020

OREGON GLACIERS INSTITUTE
6025 NW ROSEWOOD DRIVE
CORVALLIS, OR 97330-9567

Employer Identification Number:
85-1147710
DLN:
26053567001230
Contact Person:
CUSTOMER SERVICE ID# 31954
Contact Telephone Number:
(877) 829-5500
Accounting Period Ending:
May 31
Public Charity Status:
170(b)(1)(A)(vi)
Form 990/990-EZ/990-N Required:
Yes
Effective Date of Exemption:
May 21, 2020
Contribution Deductibility:
Yes
Addendum Applies:
No

Dear Applicant:

We're pleased to tell you we determined you're exempt from federal income tax under Internal Revenue Code (IRC) Section 501(c)(3). Donors can deduct contributions they make to you under IRC Section 170. You're also qualified to receive tax deductible bequests, devises, transfers or gifts under Section 2055, 2106, or 2522. This letter could help resolve questions on your exempt status. Please keep it for your records.

Organizations exempt under IRC Section 501(c)(3) are further classified as either public charities or private foundations. We determined you're a public charity under the IRC Section listed at the top of this letter.

If we indicated at the top of this letter that you're required to file Form 990/990-EZ/990-N, our records show you're required to file an annual information return (Form 990 or Form 990-EZ) or electronic notice (Form 990-N, the e-Postcard). If you don't file a required return or notice for three consecutive years, your exempt status will be automatically revoked.

If we indicated at the top of this letter that an addendum applies, the enclosed addendum is an integral part of this letter.

For important information about your responsibilities as a tax-exempt organization, go to www.irs.gov/charities. Enter "4221-PC" in the search bar to view Publication 4221-PC, Compliance Guide for 501(c)(3) Public Charities, which describes your recordkeeping, reporting, and disclosure requirements.

Letter 947

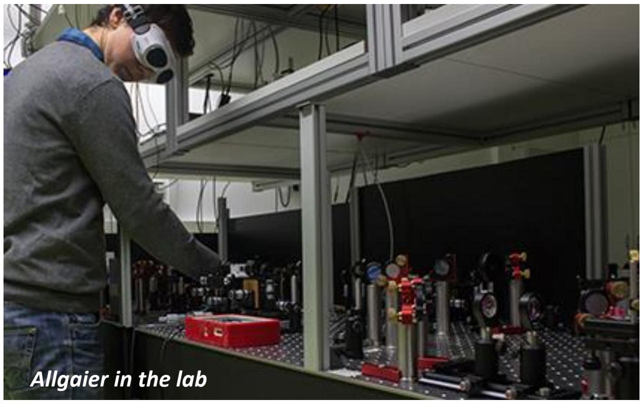
List of board of directors, OGI

As OGI is a small 501-c-3. Following with federal guidelines, the board currently consists of three members, one of which is also the OGI Executive Director/President; this is typical for a small 501-c-3.

- Board President – Mr. Graham Zimmerman, Professional Alpinist & Bedrock Film Works
- Board Secretary – Dr. Faron Anslow, Pacific Climate Impacts Consortium
- Board Member – Dr. Anders Carlson, Oregon Glaciers Institute

Staff resumes

UO – Markus Allgaier, Ph.D.



Allgaier in the lab

Allgaier grew up in the northern Alps in Germany. He received a B.S. in physics and materials science as well as a M.S. in physics from Philipps-University Marburg, Germany. During his masters program he spent 5 months in Nice, France, for a research internship studying chaotic scattering of light. He received his Ph.D. in applied physics from University Paderborn, Germany. There, he engaged in outreach and communication activities, organizing a graduate student workshop on novel photonic devices, supervised high school interns and planned and led a workshop on quantum optics for girls at the high school level interested in STEM research. During his research in Paderborn, Allgaier focused on developing novel experimental methods for high-resolution time-resolved detection of single photons and weak pulses of light, which is published in leading scientific journals such as *Nature Communications*, *Applied Physics Letters* and *Quantum Science and Technology*. After moving to Eugene, OR, to take a postdoctoral research position in the research group of Dr. Brian Smith at the Oregon Center for Optical, Molecular and Quantum Science, he started combining his experience in scattering systems and quantum sensing to develop optical sensors for glaciology and environmental sensing.

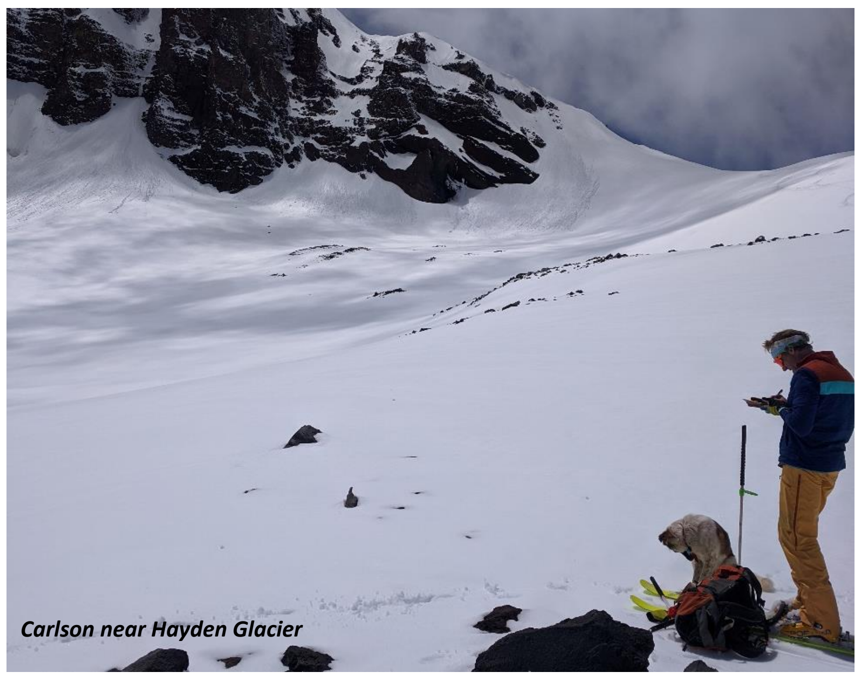
COCC – Hal Wershow, M.S.

Wershow at Railroad Grade moraine (Mt. Baker)

Wershow grew up backpacking in the North Cascades, and quickly tracked onto Geology as an undergraduate at Pomona College. Research projects took him to Peru, where he investigated impacts on water quality on the Rio Ramos, and then Hawaii, where he interned with the Hawaiian Volcanoes Observatory. Before returning to school for a M.S. in Geology at Western Washington University, he spent three years working as a project geologist at Los Alamos National Laboratory. At WWU, his research took him back into the North Cascades, where he reconstructed the recent history of glacial fluctuations. Meanwhile, his interests turned to teaching, including positions at WWU, Whatcom Community College, Everett Community College, and now Central Oregon Community College. Since beginning at COCC in the Fall term of 2018, Hal is focused on incorporating sustainability into the Geology curriculum, creating a welcoming environment for students who have not traditionally found themselves in a Geology career, and developing undergraduate research experiences. Students have already investigated inclusions in cinder cones, reconstructed paleo-lakes created by lava dams, and are part of an ongoing spring monitoring effort to better understand how springs respond to climate change.

OGI - Anders E. Carlson, Ph.D.

Carlson began studying glaciers as an undergraduate student while conducting research at Matanuska Glacier in Alaska. After receiving his B.A. in Geology and German from Augustana College, IL, he earned a M.S. at the University of Wisconsin-Madison and a Ph.D. at Oregon State University in glacial geology. Following a postdoctoral scholarship at Woods Hole Oceanographic Institution, MA where he studied climate change impacts, he was a professor at the University of Wisconsin-Madison and then Oregon State University before co-founding the Oregon Glaciers Institute. With ~3.6 million dollars in federal funding as an academic, Carlson studied glacier-climate change in the contiguous United States, Alaska, Canada, Greenland, Svalbard, Scandinavia, Patagonia, and Antarctica. He has published more than 70 peer-reviewed papers on this topic, including the leading international journals *Science* and *Nature*. His findings have garnered international coverage from the *New York Times* to Dubai's leading newspaper. Carlson led United Nations scientific groups focused on the issue of glacier retreat and sea-level rise, served the U.S. National Academies of Sciences for two terms, and was the Vice President of the International Union for Quaternary Research working group on sea level-glacier change. He now focuses his expertise on glacier change in Oregon.



Carlson near Hayden Glacier

OGI - Aaron J. Hartz, M.S.


Hartz measuring snow depth on Collier Glacier

Hartz grew up skiing in the Cascade Mountains of Oregon and developed a deep appreciation for the mountain environment. He went on to earn a B.S. degree in environmental science from Oregon State University, a M.S. from Nova Southeastern University, FL in biological sciences, and a M.S. degree in oceanography from Oregon State University. For the past decade he has worked as a professional ski and climbing guide and is a certified ski mountaineering guide through the American Mountain Guides Association. Aaron co-founded the Oregon Glaciers Institute and operates a freelance scientific fieldwork business: Hartz Science Explorations. He is also the lead avalanche forecaster with the Central Oregon Avalanche Center.