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To:
Heather Woods (CP)
Andrea Lustenberger and Rob Rohn (HeliCat Canada)
Joe Obad and Walter Bruns (Canadian Avalanche Association)
Mike Wiegele, Bob Sayer and Elias Ortner (Mike Wiegele Helicopter Skiing)
Gilles Valade and Kevin Seel (Avalanche Canada)
Gord Ritchie and Bruce Jamieson (Avalanche Canada Foundation)

RE: 2017/18 Supporter Update of SFU Avalanche Research Program

1 Purpose of document

The purpose of this document is to inform the supporters of the Simon Fraser University Avalanche Research Program (SARP) including the NSERC Industrial Research Chair in Avalanche Risk Management (IRC) about the activities accomplished between May 1, 2017 and April 30, 2018 and to provide a brief outlook on the planned activities for the next twelve months.

2 Team

Over the last year, the core SARP team consists of the following personnel:

- Dr. Pascal Haegeli (team leader)
- Dr. Simon Horton (postdoctoral fellow, since Sept. 2017)
- Reto Sterchi (PhD student)
- Bret Shandro (MRM student, graduated in Sept. 2017)
- Taylor Clark (MRM student)
- Brendan Wakefield (MRM student)
- Anne St Clair (MRM student, since Sept. 2017)

- Henry Finn (MRM student, since Sept. 2017)
- Moses Towell (MRM student, since Sept. 2017)
- Anna Heuberger (visiting Masters student from Austria, Apr 2018 to Aug 2018)

In addition, SARP includes the following affiliate members:

- Grant Statham, Parks Canada (adjunct professor)
- Dr. James Floyer, Avalanche Canada (adjunct professor)
- Dr. Patrick Mair (research associate, statistics)
- Dr. Robin Gregory (research associate, risk communication)
- Eirik Sharp (external master student collaborating for this thesis project)
- Rosie Longford (undergraduate student)

3 2017/18 Highlights

3.1 Securing of additional research funding

Securing external research funding and getting industry contributions matched remains a primary objective for SARP. In the last 12 months, we have been able to secure an additional $30,000 of new external funding.

- **MITACS**
  We were able to secure MITACS support for two new projects:
  - Perception of avalanche terrain (in partnership with HeliCat Canada):
    $20k for Brendan Wakefield + $10k in expenses (MITACS contribution: $15k)
  - Linking avalanche danger ratings to the conceptual model of avalanche hazard (in partnership with Avalanche Canada):
    $20k for Taylor Clark + $10k in expenses (MITACS contribution: $15k)

We were also able to obtain $36,000 of additional research funding from existing supporters for new research projects.

- **Avalanche Canada**
  The AvID project of Avalanche Canada is providing SARP with an additional $36,000 over two years (Sept. 2017 to Aug. 2019) to support one additional masters student (Henry Finn) working on a project related to avalanche risk communication.

I have also been involved with the **Canadian Mountain Network** (CMN; http://canadianmountainnetwork.ca/)[1] during their preparation of a letter of intent for a **Network of Centres of Excellence (NCE) proposal**. NCE is a federal government program that provides long-term funding (renewable for up to 15 years) for academically led multi-disciplinary research into issues of strategic importance to Canadians. The CMN letter of intent was one of only eleven submissions invited to submit a full application, which is currently in

[1] The Canadian Mountain Network is an alliance of partners from universities, governments, indigenous and non-indigenous communities, businesses and non-for-profit organizations dedicated to the sustainability of mountains across the country,

preparation. SFU's **Centre for Natural Hazard Research**, which SARP is a member of, aims to be the natural hazard hub of the CMN. While no funding has come from these efforts yet, I believe that this is important for the avalanche community to be involved in this initiative early as it has the potential to lead to considerable funding and interesting collaborations.

3.2 Research projects

Over the last 12 months, the research efforts of SARP were focused on seven main projects that can be grouped into three themes.

3.2.1 Decision-making and risk in mechanized skiing

- **Professional terrain preferences for managing the physical risk from avalanche in mechanized backcountry skiing operations (Reto Sterchi)**
  This project uses run list codings and run usage information to better understand how professional guides use terrain to manage the physical risk from avalanches. Reto is currently in the final stages of preparing his first manuscript, which describes our approach for developing customized terrain classifications for mechanized skiing operations. He is currently working on a second manuscript that identifies typical run list types and explores their link to hazard assessments. This provides the foundation for the development of decision aids for run lists.

- **HeliCat Canada sector risk project (Matthias Walcher)**
  The objective of this project was to provide a comprehensive, quantitative perspective on the risks involved in mechanized skiing. The data for this research was collected over the winter 2016/17 and the analysis was completed over the summer. A manuscript about this work has been submitted and is currently under review. To ensure better reporting and an improved understanding of trends in incidents and near misses in the future, SARP has assisted HCC in the development of an online incident and near miss reporting website for the community. The intent is that the website will be fully operational for the 2018/19 winter. The website and underlying database will be hosted by SARP at SFU on behalf of HCC.

- **Terrain perception among ski guides (Brendan Wakefield)**
  An accurate perception of the skiing terrain is critical for making informed decisions about whether it is appropriate to ski a specific run. Existing research on avalanche terrain has primarily focused on simple terrain characteristics (e.g., incline, aspect, vegetation) that can be easily extracted from existing terrain datasets (e.g., TRIM, DEM). However, over their careers, guides develop a much more detailed understanding of the terrain that goes beyond these simple characteristics. Furthermore, in addition to the hazard potential, challenges regarding access and run attributes that determine the value of a run for the skiing program also play an important role when choosing terrain. In collaboration with Roger Atkins and Clair Israelson, we developed a detailed website for working together with interested operations to capture the existing terrain knowledge, make it accessible to their guiding team and exploring differences in perceptions within guiding teams.

3.2.2 Patterns in avalanche hazard and avalanche hazard modelling

- **Examination of seasonal avalanche hazard conditions in Western Canada using the conceptual model of avalanche hazard (Bret Shandro)**
  The objective of this project was to explore avalanche bulletin data from Avalanche Canada and Parks Canada and examine variations in the character of the seasonal avalanche hazard among forecast regions and winter seasons. Bret finished his project in the fall of 2017 and his work has resulted in one publication (Shandro & Haegeli, 2018) and an additional manuscript that is currently in the final stages of being prepared for submission.

- **Snowpack modelling in support of operational decision-making (Simon Horton and Moses Towell)**
  This project is one of the main themes of the IRC, which started in Sept. 2017. The overall objective is to integrate the hazard assessment expertise described in the conceptual model of avalanche hazard (Statham et al., 2018) into the numerical SNOWPACK model. To-date, our work has primarily focused on building the infrastructure to run the SNOWPACK model operationally at a large number of grid points and the development of preliminary visualizations and exploratory analyses. We are now able to start exploring modeling approaches and more meaningful visualizations.

- **Linking the avalanche danger scale to the conceptual model of avalanche hazard (Taylor Clark)**
  While the conceptual model of avalanche hazard (Statham et al., 2018) offers a framework for avalanche hazard assessment, it does not provide public avalanche forecasters with explicit guidance for assigning avalanche danger ratings similar to the Bavarian Matrix used by the European avalanche warning services. Using hazard assessment data from Avalanche Canada and Parks Canada, this project explores the relationship between avalanche hazard assessment and danger ratings. The objective is to extract the rules used by forecasters to assign danger ratings, examine differences between forecast regions and highlight conditions when danger ratings might not be assigned consistently.

3.2.3 Public avalanche risk communication

- **Examining use, comprehension and application of information provided in Canadian avalanche bulletins (Anne St Clair and Henry Finn)**
  This project is part of Avalanche Canada's AvID initiative that aims to develop a new data system for the production and publication of public avalanche bulletins in Canada. The objective of the research project is to better understand how recreationists use, understand and apply the information currently provided in Canadian avalanche bulletins and provide recommendations for presentation alternatives. In Phase 1, we will conduct qualitative interviews with recreationists at different levels of avalanche awareness expertise to better understand how the present avalanche bulletin products are used. The insight gained from these interviews will then be used to develop

information presentation alternatives, whose effectiveness will be explicitly tested in an online survey in Phase 2 of the project.

3.3 Data collection and infrastructure

The collection of research data and the development of the necessary infrastructure continued over the last 12 months. The most important efforts included:

- **Collection of GPS tracks of professional terrain choices**
  To strengthen our ability to conduct research on decision-making in avalanche terrain in the future, SARP purchased a fleet of 100 new GPS units in collaboration with Dr. Reto Rupf at the Zurich University for Applied Science, Wädenswil, Switzerland.

  Our GPS track data collection efforts continued during the 2017/208 winter season. This winter we had 45 GPS units in the field and worked with seven operations:
  - CMH Galena
  - CMH Revelstoke
  - Mike Wiegele Helicopter Skiing
  - Monashee Powder Snowcats
  - Northern Escape Heliskiing
  - Selkirk Tangiers Helicopter Skiing
  - Whistler Heliskiing

  As of April 18, 2018, the complete dataset consists of 6,900 tracked guide days including slightly more than 46,000 ski runs under a wide variety of conditions. Collaborating operations can access their own tracks using an online viewer.

- **Idealized snow profiles**
  In anticipation of the snowpack modelling research objective in the IRC, SARP continued their collaboration with Mike Wiegele Helicopter Skiing to capture and archive their operational idealized snowpack profiles during the 2017/18 winter season.

- **Operational snowpack modelling**
  The evolution of the seasonal snowpack was modelled daily at roughly 7,000 grid points in western Canada using the research computing resources accessible to us from Compute Canada. The modelled grid points were located in areas of upcoming research projects (e.g., Glacier National Park), areas of interest for industrial supporters (e.g., CP Rail, Mike Wiegele Heliskiing, Whistler Heliskiing) and operational needs of Avalanche Canada (e.g., North Rockies). Interested partners are able to access our model runs at https://public.tableau.com/profile/simon.horton#!/vizhome/SNOWPACKAGG/RegionalSnowpackSummary.

3.4 Outreach

3.4.1 Peer-reviewed publications

Six academic peer-reviewed publications were either submitted, revised or published over the last 12 months:

1. Walcher, M., Haegeli, P., and Fuchs, S. (under review). Risk of death and major injury from natural winter hazards in mechanized backcountry skiing in Canada. Submitted to *Wilderness and Environmental Medicine* on April 10, 2018.
2. Rupf, R., Haegeli, P., Karlen, B., and Wyttenbach, M. (under review). Does crowding cause winter backcountry recreationists to displace? Submitted to *Journal of Mountain Research and Development* on February 9, 2018.
3. Haegeli, P., and Strong-Cvetich, L. (accepted). Using discrete choice experiments to examine the stepwise nature of avalanche risk management decisions—An example from mountain snowmobiling. Accepted by *Journal of Outdoor Recreation and Tourism* on January 26, 2018. doi: 10.1016/j.jort.2018.01.007
4. Shandro, B., and Haegeli, P. (2018). Characterizing the nature and variability of avalanche hazard in western Canada. *Natural Hazards and Earth System Sciences*, 18, 1141-1158. doi:10.5194/nhess-18-1141-2018
5. Thumlert, S., and Haegeli, P. (2018). Describing the severity of avalanche terrain numerically using the observed terrain selection practices of professional guides. *Natural Hazards*, 91(1), 89-115. doi:10.1007/s11069-017-3113-y
6. Statham, G., Haegeli, P., Greene, E., Birkeland, K. W., Israelson, C., Tremper, B., . . . Kelly, J. (2018). A conceptual model of avalanche hazard. *Natural Hazards*, 90(2), 663-691. doi:10.1007/s11069-017-3070-5

I also contributed the following paper to the 'State of Mountains Report' initiative of the Canadian Mountain Network.

7. Haegeli, P. (submitted). Snow avalanches. In Hik, D., Parrot, L. and Robinson, Z. (Eds.), *2018 State of the Mountains Report*. Alpine Club of Canada and Canadian Geographical Society. Submitted on October 15, 2017.

3.4.2 Presentations at conferences

I gave **one presentation at the 2017 Annual Meeting of the Society for Risk Analysis** in Arlington:

1. Haegeli, P., Statham, G., Birkeland K., and Greene E. (2017). Untangling the mystery of assessing snow avalanche hazard - a conceptual model. Poster presentation at the 2017 Annual Meeting of the Society for Risk Analysis in Arlington VA, December 10-14, 2017.

I also attended the **Conference on Human Judgement and Decision Making** in Vancouver on Nov. 10-13, 2017. However, I did not present at this conference.

Core SARP members **submitted eight abstracts to the 2018 International Snow Science Workshop** in Innsbruck.

3.4.3 Technology transfer

Over the last 12 months, core SARP members gave **14 presentations at association meetings and early season staff training sessions**. In total, an estimated 400 avalanche professionals were reached with these presentations (1,095 if each presentation is counted individually).

1. Capturing the essence of heli-skiing terrain. Guides' training of Northern Escape Helicopter Skiing in Terrace, BC. January 2, 2018. (size of audience: approx. 15)
2. Linking avalanche hazard in western Canada to climate oscillations. Guides' training of Monashee Powder Snowcats and Canadian Avalanche Association ITP Level 1 course in Cherryville, BC. December 3, 2017. (size of audience: approx. 30).
3. Quantitative Assessment of Risk involved in Mechanized Skiing in Canada. Guides' training of Monashee Powder Snowcats and Canadian Avalanche Association ITP Level 1 course in Cherryville, BC. December 3, 2017. (size of audience: approx. 30).
4. Linking avalanche hazard in western Canada to climate oscillations. Guides' training of Whistler Helicopter Skiing in Whistler, BC. December 3, 2017. (size of audience: approx. 25).
5. Quantitative Assessment of Risk involved in Mechanized Skiing in Canada. Guides' training of Whistler Helicopter Skiing in Whistler, BC. December 3, 2017. (size of audience: approx. 25).
6. Capturing the essence of heli-skiing terrain. Guides' training of Canadian Mountain Holidays in Sun Peaks, BC. November 28, 2017. (size of audience: approx. 120)
7. Linking avalanche hazard in western Canada to climate oscillations. Guides' training of Mike Wiegele Helicopter Skiing in Blue River, BC. November 27, 2017. (size of audience: approx. 40).
8. Quantitative Assessment of Risk involved in Mechanized Skiing in Canada. (presented by Bret Shandro). Guides' training of Mike Wiegele Helicopter Skiing in Blue River, BC. November 27, 2017. (size of audience: approx. 40).
9. Linking avalanche hazard in western Canada to climate oscillations. Forecasters' training of Avalanche Canada in Revelstoke, BC. November 17, 2017. (size of audience: approx. 20).
10. Incorporating avalanche hazard into the concept of avalanche climate. Spring meeting of Canadian Avalanche Association. Penticton, BC. May 5, 2017. (size of audience: approx. 150).
11. The HeliCat Canada sector risk project. Spring meeting of Canadian Avalanche Association. Penticton, BC. May 5, 2017. (size of audience: approx. 150).
12. Identifying patterns in professional terrain choices using self-organizing maps. Spring meeting of Canadian Avalanche Association. Penticton, BC. May 4, 2017. (size of audience: approx. 150).

13. SFU Avalanche Research Program (SARP) – Where we are at and where we are going. Spring meeting of Canadian Avalanche Association. Penticton, BC. May 4, 2017. (size of audience: approx. 150)

14. The HeliCat Canada sector risk project. Spring meeting of HeliCat Canada. Penticton, BC. May 1, 2017. (size of audience: approx. 150).

3.4.4 Public Outreach

Over the last 12 months, core SARP members **participated in two public avalanche awareness events** reaching an estimated 625 recreationists.

1. Shandro, B., and Haegeli, P. (2017). Climate variabilities and avalanche hazard: What can the seasonal ENSO forecast tell us about the nature of the upcoming 2017/18 winter? Vancouver Island Avalanche Bulletin Fundraiser Evening, November 4, 2017 (size of audience: approx. 75).

2. Shandro, B., and Haegeli, P. (2017). Climate variabilities and avalanche hazard: What can the seasonal ENSO forecast tell us about the nature of the upcoming 2017/18 winter? Northwest Snow and Avalanche Workshop in Seattle, WA, October 22, 2017 (size of audience: approx. 550).

I was also scheduled to present research on avalanche airbags and risk compensation at the Northwest Snow and Avalanche Workshop in Seattle but had to cancel due to a family emergency.

During the last year, SARP has also been featured in a number of media stories including:

- November 30, 2017: Canadians at forefront of avalanche-safety awareness. Letter to the editor. Pique News Magazine at https://www.piquenewsmagazine.com/whistler/letters-to-the-editor-for-the-week-of-november-30/;
- January 24, 2018: Can computers forecast avalanches better than humans digging holes? ScienceLine at http://scienceline.org/2018/01/can-computers-forecast-avalanches-better-humans-digging-holes/; and
- February 20, 2018: Avalanche researcher taps commercial guides for expertise. Pique News Magazine at https://www.piquenewsmagazine.com/whistler/avalanche-researcher-taps-commercial-guides-for-expertise/.

3.5 Student training

Since my research program does not have a field program and I am currently not teaching an avalanche risk management course at SFU (scheduled for fall 2019), I am using the following approaches to train my students in addition to the supervision of their personal research projects:

- Organizing visits to collaborating operations;
- Weekly group meetings where we discuss current avalanche conditions (winter only) and research papers on special topics.

Suggestions for how to better train students for industry needs are welcome.

3.6 Other relevant activities

I spent considerable effort **redesigning the SARP website** (www.avalancheresearch.ca) and keeping it up-to-date. This effort paid off as I had a much larger and stronger pool of prospective students applying for the 2018 fall intake.

I continued to serve as co-editor-in-chief of the **Journal of Outdoor Recreation and Tourism** (JORT), a transdisciplinary, academic peer-reviewed journal focusing on any aspect of theory, method, or concept of outdoor recreation research, planning or management. My objective with JORT is to establish a home for publishing interdisciplinary avalanche safety research that does not fit into the traditional outlets for avalanche research (e.g., Cold Regions Science and Technology) and to establish new connections with researchers working in other recreational fields.

I am also directing of SFU's **Centre for Tourism Policy and Research (CTPR)**, a research centre that was established in the late 1980s to support BC's tourism industry with policy relevant research. Due to recent retirements of core faculty members whose research expertise was directly in tourism, we currently have an opportunity to realign the CTPR with current needs of the industry. Last fall, I organized a visioning session with the Adventure Tourism Coalition (ATC) to explore possibilities for how SFU and the CTPR could assist the adventure tourism community. In February, SFU and ATC submitted a proposal to the BC government to fund a part-time managing director for the CTPR for a three-year term. The objective of the managing would be to assist me in administrative duties for the CTPR, strengthen the relationship with adventure tourism sector, co-design and manage relevant research projects that take advantage of the broad research expertise in the CTPR, and develop a long-term strategy for increasing the capacity for tourism-relevant research at SFU.

3.7 Challenges

In my opinion, the biggest challenges for my program are:

- Maintaining a continuous and meaningful connection with supporting organizations and practitioners to ensure the research we work on is meaningful to the community;
- Providing my students with the training they need to allow them to start a promising career in the avalanche community.

Any guidance on these challenges would be welcome.

4 Outlook for next 12 months

4.1 Personnel

The following individuals will be joining the SARP team in the fall of 2018:

- Florian Herla (PhD student; Geography)
- Mike Ward (PhD student; REM)
- Amelie Goulet-Boucher (Masters student; REM thesis stream)

- Katie Fisher (Masters student; REM thesis stream)

4.2 Priorities

SARP has the following priorities for the next 12 months:

4.2.1 Research

- Continue to work on research projects with students:
    - Submit Bret's second paper on the effect of climate oscillations on the nature of avalanche hazard in western Canada;
    - Bring Taylor's project to completion by the end of the summer;
    - Bring Brendan's project to completion by the end of the year;
    - Submit two papers on Reto's terrain research;
    - Conduct and analyze qualitative surveys of AvID project and develop online; survey to test presentation alternatives during 2018/19 winter; and
    - Make substantial progress with research on snowpack modelling.

4.2.2 Funding

- Continue to secure matching funds for unmatched contributions from industry partners (Avalanche Canada) whenever possible:
    - MITACS submissions for Anne St Clair
- I also applied for $5,000 from SFU's Community Engagement Initiative for my students to hold short avalanche awareness seminars to emerging and hard-to-reach user groups in the Lower Mainland.
- If meaningful and sufficient capacity, submit NSERC Discovery grant application on examining the effect of climate change on avalanche hazard in western Canada.

4.2.3 Outreach

- Attending the 2018 ISSW in Innsbruck (Oct.) and the Annual Meeting of the Society for Risk Analysis in New Orleans (Dec.).
- Continue to build research network outside of traditional avalanche research fields within SFU (e.g., big data, visualization) and beyond (e.g., risk communication)
- Strengthen public outreach with social media, practical resources on website, presentations, and articles published in the Avalanche Journal and presentations.
- Since I will not be teaching during the 2019 spring term (Jan to Apr), I am hoping to get the opportunity to visit operations and connect with professionals more frequently.

4.2.4 Student training

- I would like to come up with a better plan for giving students the opportunity to go into the field and connect with collaborating operations and avalanche professionals in a meaningful way.

4.2.5 Anticipated Challenges

- The program has grown tremendously since we started in the fall of 2015 and I am getting concerned about reaching the limit of my capacity. I am not planning to grow the research program any further.

5 Questions

If you have any question about SARP's research activities, please contact me anytime either by email (pascal_haegeli@sfu.ca) or phone (778-782-3579 or 604-773-0854).

6 Thank You

On behalf of my entire research team and SFU, I would like to thank all the supporters and collaborating operations for their support of the SARP research program. Our research would not be possible without your financial support and expert input to guide our program. We are grateful for this support and we are looking forward to a productive and long-term relationship between SARP and the Canadian avalanche community.