日米雪崩共同研究招聘研究者等報告書

防災科学技術研究所
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Reports by the Visiting Two American Scientists and Others on US/Japan Snow Avalanche Joint Research Projects Conducted in 1992 and 1993

Edited by

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Abstract

This report contains ten reports in total. Eight reports are bilingual. Therefore six reports are original. The two original reports are written by two American snow avalanche researchers, i.e., by Mr. Bruce Tremper, avalanche forecaster and by Dr. Sue Ferguson, snow avalanche researcher. Mr. Tremper has written another special report for the Tenjin-daira ski fields on Mt. Tanigawadake. Other three original reports explain the activities of the US/Japan snow avalanche joint research projects conducted in 1992 and 1993.

キーワード：雪崩（Snow avalanche），雪崩研究（Research work of snow avalanche）
日米共同雪崩研究（US/Japan joint snow avalanche project）

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発刊に際して

この資料集には、平成3年度（1992年度）と平成4年度（1993年度）にアメリカと共同で行った、雪崩に関する研究の一環として我国に招聘した2人の研究者、即ち、ブルース・トレンパー氏とスー・ファーガソン博士による報告書2編と、この共同研究の骨子に関する報告書2編(日英それぞれ2編計4編)、それにトレンパー氏による谷川岳に関する特別報告書1編、及び出張報告書（平成4年度）など邦文英文併せて計10編を掲載してある。

研究終了後若干の月日が経過したが、今尚、雪崩災害予防・防除に役立つことを信じているので、ここに資料集として印刷公刊するものである。ブルース・トレンパー氏の研究報告書の邦訳は第1研究室の山田穣室長によるものであり、その労を多としたい。同氏の谷川岳についての報告の邦訳は中村による。

尚、B.トレンパー氏及びS.ファーガソン博士御両人の報告書の刊行については、御両人から了承を得ている。

平成7年3月
長岡雪氷防災実験研究所長
中村　勉

目　　次

（様式９　研究報告記載事項）

科学技術振興調整費関係外国人研究者研究報告書

１．招聘研究者氏名・年齢　　ブルース　トレンパー・38才

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３．招聘研究者専門分野　　雪崩予報とコントロール

４．招聘目的（研究課題）　　表層乾雪雪崩の発生、制御ならびに防御手法に関する研究

５．滞在研究期間　　自 平成４年１月２３日 至　平成４年２月１３日

６．受入機関　　防災科学技術研究所

７．日本での研究活動内容（成果）

日本滞在中の旅程（itinerary）は以下の通りである：

－　長岡雪氷防災実験研究所訪問。
－　谷川岳天神平スキー場に４日間滞在し、雪崩発生の可能性（avalanche potential）と可能なスキーコース拡張計画（potential expansion plans）の評価を行った。また、スキーパトロール者ならびに長岡雪氷防災実験研究所の研究者と雪崩情報の交換を行うとともにスノーピット技術（斜面積雪の安定性テスト）と雪崩救助ビーコン使用法を伝授した（添付の報告書参照）。
－　新庄雪氷防災研究支所訪問。
－　黒部渓谷水力発電所を訪問し、そこの雪崩問題を視察しそして（志合谷の）雪崩観測所を訪問した。
－　笹ケ峰を訪問し積雪観測を行う手助けをした。

背景

世界のほとんどすべての山岳積雪地域では、雪崩は人間や構造物にとり危険である。世界各地の地域の人々は、その地域の雪崩危険に様々な方法で適応することを学んできた。この適応は１）地形や気候の性質、２）利用可能な手段、そして３）人々の文化に依存している。

まず、日本、北米およびヨーロッパでの雪崩危険の取扱いにおける違いを比較してみる。これらの３つの地域は、この問題を取り扱うのに十分な手段を持ちうる同レベルの工業化された国であるばかりでなく、各地域は日本と同じような地

形･気候である。例として、アメリカでは、ワシントン州、オレゴン州そしてアラスカ州の沿岸山地では日本の気候と同じである。同様にノルウエーやアルプスの一部は同じ気候である。それ故、これらの地域で雪崩問題を取り扱う最も大きな違いは主に人間の文化の違いによっている。

文化は、無論、歴史に依存する。ヨーロッパの人々は、例えば、日本と同じく数百年間も山地に雪崩に取り囲まれて住んできた。他方、北米では人々はつい最近、多くは1,800年代後半特に1950年以降、雪崩地形に住み始めたにすぎない。ヨーロッパ人はより長く雪崩とともに住んでいたので、北米よりも雪崩死者に対して疲れてるように思われる。例えば、ヨーロッパでは年に100ないし200人が雪崩で死亡している。アメリカ人にとって、彼らの雪崩に対する危険の受容レベルはとても高いように見える。

他方、北米では、比較的最近になって雪崩地形に住むようになってきた。多くの人が山地に移動するまでに、雪崩危険はゾーニング、爆薬によるコントロール、防御工や予報によって大きく軽減された。この結果、アメリカ、カナダ両国の死者数は年に約20人で、ヨーロッパのほぼ十分の一であり、そのほとんどはバックカントリーのリクレーションで発生している。日本では危険の受容レベルは更に低いように見受けられる。1984年以降の日本の死者は年平均９人であるが、この数字は受容されたとは考えられていない。

もう一つの文化の違いは爆薬の使用である。第二次大戦後、日本での爆薬の使用は厳しく制限されているが、一方北米やヨーロッパでは爆薬の使用は極めて広範であり、比較的規制されていない。それ故、北米やヨーロッパでは爆薬は雪崩に数十年にわたって使用されてきたし、ヨーロッパでは第一次大戦後、北米では第二次大戦後に始まっている。このため、雪崩コントロールの技術はヨーロッパや北米ではともに十分に発達してきた。アクティブな雪崩コントロールといえば、雪崩予報のことが自然に思い浮かんでくる。この技術はこれまで世界の他の地域、例えばニュージーランドや南米に広まっている。

他方日本では、雪崩予防工（snow rakes）､スノーシェッド（avalanche sheds）走路上の減勢工（enegy disapaters）そして雪崩地域での建設設計を含む雪崩防御構造物開発の世界のリーダーである。この分野では、北米やヨーロッパはともに日本に学ぶ点がある。日本人は、しかしながら、外国から雪崩予報とアクティブな雪崩コントロールについて知識を得ることができる。協力と情報交換によって、日本と諸外国は互いに、また、ともに学び前進することができる。アメリカ合衆国は雪崩予報とコントロール技術の世界のリーダーである。我々はこの分野の専門的な知識技術を提供することができるし喜んでそうするつもりである。

観察と推奨

３週間の私の短い訪問中の観察から、日本人は特にスキー場（ski resort）、公益事業会社（utility company）ならびに雪崩地形に住む人々や、設置されている構造物の分野で雪崩予報とコントロール技術から利益を得ると思う。例えば、谷川岳の天神平スキー場は明らかに雪崩予報とコントロールから利益を受けうる（添付の報告書参照）。

現時点で日本での爆薬使用はとても困難であることは明確に理解しているが、爆薬は雪崩のトリガーにとても効果的である。これは高価でなく、ポータブルでありいかなる場所にも設置できる。もし可能ならば雪崩コントロール用の爆薬使用に必要なアレンジメントを始めることを強く推奨する。

多分二成分爆薬の法的認可を得ることは日本で可能であろう。なぜなら、この爆薬は二つの成分が混合されたときにのみ爆薬となるからである。このようなわけで、安全に合法的に輸送でき貯蔵できよう。アメリカ合衆国における二成分爆薬のポピュラーな方法は硝酸アンモニウム（普通の肥料）と軽油である。混合することによって、とても廉価であるばかりでなく他の高速二成分爆薬と併用することによって、効果的な雪崩コンコトールに十分な速度を持つとても強力な爆薬となる。

二成分爆薬は、アバランチャー（avalaunchers）にも用いられる。この砲は推進燃料として圧縮窒素を用い、１キロメートル以上の距離まで爆発物を撃ち出せる。アメリカで一種類製造されているが、最良のものはイギリスとフランスで造られている。

これに代わりうる雪崩コントロール方法には最も注目すべきガゼックス（Ga-sex）がある。ガゼックスは（プロパンガスの他には）爆薬を用いないという利点があり、地域の人が望むときにいつでも合法的に操作することができる。それはまた雪崩をトリガーするのにとても効果的な大きな衝撃波を加えることができる。しかしながらこれには、独自の不利な点がある：まず、購入価格と建設費が高価である。ガゼックス１基の購入費と設置費は約1,600万円と理解している。　第二の不利な点はその位置が固定されていることである。この二番目の点は積雪の不安定性は常に同じ領域では形成されないので最大の不利である。雪、風、そして日射の推移パターンはしばしば全く異なった場所に不安定な領域を創り出すものである。雪崩をトリガーするいかなる方法も、変化する状況に適応するよう容易に動かせるようフレキシブルであるべきである。爆薬はこの点に関してとてもうまく機能している。

雪崩コントロールにはまだ試みられていないその他の方法は、圧搾空気衝撃波発生装置（Compressed air shock wave generator）である。これは特に海洋環境における人工地震探査（seismic exploration）に広く用いられている。この装置は、ふつう船舶により水中で曳航され、トリガー時にとても強力な衝撃波を生じる。それはとても強力で、科学者は海底下数百メートルの地層を探知できるほどである。この装置はトリガー砲から耐圧ホース（pressurized hose）を通した高圧空気を用いている。圧縮チェンバー（pressurized chamber）が解放されると、大きな衝撃波を生じるのである。この方法は次の利点を持っている：　１）爆薬を用いないので、ほとんどの場合合法的に操作でき、２）この技術は十分に開発され多くの異なった過酷な環境で完全にテストされており、３）比較的高価でなく、４）砲の位置はた易く変更でき、そして５）いくつかの砲で、砲間に使用者が指定した（user-defined）百万分の一秒の遅延時間で一度に爆破させることが可能である。この砲は雪崩コントロールプログラムでまだテストされてはいないが、今後テストを始めたいと考えている。多分これは日米共同研究の良いプロジェクトである。将来、プロポーザルを提出したいと望んでいる。

現時点で日本では爆薬は可能でないので、雪崩予報は依然として唯一の雪崩に対するアクティブな防御法である。スキー場は特に雪崩予報の発達した技能の利益を受けるが、公益事業会社や雪崩地形でなされるいかなる人間活動についてもそうである。

例えば、黒部峡谷水力発電所訪問の際、作業員はバスに乗り、ついで雪上車（snow cat）に乗って作業場に向かう。バスは３度停まり、その間作業者は下車してようやく人が通れるほどの小さな軽便なコンクリート製のスノーシェッドを歩いて通り抜ける。バスはそれから雪崩道（avalanche path）を通り過ぎ反対側

で作業者を乗せる。それぞれのスノーシェッドは雪崩を防ぐにはしばしば余りに短すぎるように思われた。言いかえると、そのシェッドの両側の地形はシェッド上方の地形と全く同じように危険に見えた。例えば、私が訪れたとき、つい最近湿雪雪崩が流下したケースを二個所観察した。そのどちらもスノーシェッドから全くはずれていた。

道路のこの部分で雪崩危険度（avalanche hazard index）を計算しようとするなら、この道路を襲う雪崩回数に、それぞれの雪崩道の下を通過する時間を掛け合わせればよいであろう。　作業者がバスを離れスノーシェッドに入り、それから再びバスに乗るため、作業者は雪崩にさらされているように私には思えた。作業者全員がこの危険な地域を通過するのに少なくとも１、２分かかる。もしバスが、そうしないで、停まらずに雪崩道の下を素速く通過するならば、さらされる時間はほんの数秒である。さらに、バスとスノーシェッド間の全く防御のないところを横切るよりもバスに乗っている方が雪崩からのより良い防護となる。

雪崩予報はこの状況を大いに手助けするであろう。例えば、ユタ州のリトルコットンウッド渓谷ハイウエーは世界でもっとも雪崩危険度が高い所の一つであるにもかかわらず、約４０年間も死者がない。そこにはスノーシェッドはなく交通はしばしば車のバンパーのふれあうほど混んでいる。道路管理者は雪崩危険度の高い時に、単に道路を閉鎖しあるいは爆薬を用いて雪崩をコントロールする。道路閉鎖時間は一シーズンに合計僅か１日か２日である。

日本ではバックカントリーでの雪崩死者は増加しているようだが、バックカントリーの雪崩予報プログラムを始めることは日本独特な文化の故に困難かも知れない。欧米の文化では、個人の危険を冒す権利は十分に確立し奨励されてさえいる。言いかえると、人々は山に登り危険を冒すことを権利と考えているばかりでなく、積極的にこの活動を追求している。この活動にはロッククライミング、登山、野生の危険な動物と出会う荒野への旅行（wilderness travel）、そして勿論バックカントリーの雪崩地形でのスキーを含んでいる。欧米の文化ではそれは完全に合法的であり、大多数の人々によって広く実行されている。しばしば、危険そのものが魅力である。人々がこの危険を受け入れているので、例え死傷者が発生しても、人々は非難したり訴訟したりはしない。

日本の文化は全く異なり、私のような欧米人は日本の文化を多分決して完全には理解できないけれども、日本でバックカントリーの雪崩予報を出すことはとても難しいと聞いている。まず、雪崩危険の故にバックカントリーは冬季間閉鎖される。第二に、オープンされている間に誰かが死んだならば、政府や自治体の責任である。しかしながら、もし人々がこの閉鎖を意図的に無視しバックカントリーでの雪崩死者が問題化したならば、バックカントリーでの雪崩予報技術は十分に発達しており、いつでも効果を発揮しうる。ワシントン州の雪崩予報センターでは、例えば、日本とほとんど同じような地形、気候と人口規模を取り扱っており、多年にわたり雪崩予報プログラムを成功裏に運営している。

最後に、雪崩予報は山や雪崩に深い関係を持っている地域の人々によって実施されることが絶対必要である。予報者が熟練していなければ、机上での仕事以外の何ものでもなくなる。予報者は常に（regular basis）フィールドに出て雪と接し、その状況に対する感覚を磨かねばならない。多くのパラメータはデータだけによっては伝わらない。最良の雪崩予報は、ギルドのような徒弟制度によって教えられ数年間にわたって仕立てられる。雪崩予報システムを組み立てる時には、地元の知識を使い、固有の雪崩道や気候の特徴の知識のある地元に長年住んでいる住民にコンサルトするか雇うことが重要である。

まとめ

要約すると、外国、特にアメリカ合衆国、は雪崩防御構造物に関する日本の技術から学ぶことが多々ある。また、日本は世界のほとんどの人の住む、あるいは人の入る雪崩頻発地域（avalanche-prone area）の標準的作業手順（oparating procedure）となっている雪崩予報とコントロールの技術を学ぶことにより便益を受けるものと私は信じている。もし我々が技術を分かち合い協力するならば、共に前進することができよう。日本での爆薬使用は困難であろうが、爆薬を用いない十分に作動する他の技術（ガゼックスや地震工学の圧縮空気砲のような）がある。しかしながら、二成分爆薬を含む爆薬の直接使用がよりよく作動する。爆薬を用いない場合でさえも、スキー場や雪崩地形で行動する人々は、十分に発達した雪崩予報技術を学ぶことが絶対必要である。これには二つの方法がある。第一に、芸術の域に達した（state-of-the-art）雪崩予報が行われている北米、ヨーロッパ、あるいはニュージーランドのスキー場で一シーズンを過ごすこと、第二に、コンサルタントを雇い一シーズンを費やしてこの技術を教わること、最後に、雪崩予報プログラムは地元住民と雪崩道や気候の地域の知識もまた絶対必要なことである。雪崩予報はオフィスだけからも出すこともできるかも知れないが、予報者が雪と日頃直接接触することがとても重要である。
私は日米間の協力と交換が継続することを期待する。

8．研究活動の感想

私は、日本での滞在をとても楽しんだ。3週間はすべてを見るには十分な時間ではなかったが、私の受け入れ機関は良い総体的印象（overview）を与えてくれた。

9．日本政府への要望等

私は招聘外国人研究者制度（the visiting scientest exchange program）は両国にとってとても役立つと感じた。私のこの制度を改善するための唯一のサジェスションは、日本語が十分に話せないので言葉では苦労したことである。欧米人にとって日本語を読むことはほとんど不可能であり、看板等がローマ字または英語だった時は大いに助かった。一緒に働いた多くの日本人は英語を話せ、それが手助けになったが、しばしば彼等の英語は、より立ち入ったコミュニケーションには十分でなかった。より詳細な質問をするために、英語をうまく話せる人をいつも探した。これらの役を為し得る通訳がいたら素晴らしかったと思う。しかし予算のしばりでこれが多分許さないであろうことは知っている。

Bruce Tremper （サイン）

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3. Avalanche Forecasting and Control

4. A STUDY ON THE RELEASE, CONTROL AND PROTECTION METHODS OF SURFACE DRY SNOW AVALANCHES

5. Tenure: from January 23, 1992 to February 13, 1992

6. National Research Institute for Earth Science and Disaster Prevention

During my stay in Japan my itinerary was as follows:

- I visited Nagaoka Institute of Snow and Ice Studies.
- I spent 4 days at Tenjin Daira Ski Resort on Tanigawa Dake where I evaluated avalanche potential and potential expansion plans. I also exchanged avalanche information and taught personnel from the ski patrol and from the Nagaoka Institute of Snow and Ice Studies about snowpit techniques and avalanche rescue beacons. (see attached report).
- I visited the main office of the National Research Institute for Earth Science and Disaster Prevention in Tsukuba.
- I visited the Shinjo Branch of Snow and Ice Research Studies.
- I visited Kurobe Canyon Hydroelectric station where I observed some of their avalanche problems and visited the avalanche observation site.
- I visited Sasagamine and helped conduct snow observations.

7. Background

In nearly every mounainous, snowy region of the world, avalanches are a hazard to people and structures. The local people in each part of the world have learned to adapt their local avalanche hazard in different ways. The adaption depends on 1) the nature of the terrain and climate, 2) the resources available, and 3) the culture of the people.

First, I will compare the differences in dealing with avalanche hazards between Japan, North America and Europe. All three areas are not only equally industralized countries with sufficient resources to deal with the problem, but each area also has terrain and climate similar to Japan. For instance, in the U.S., the coastal mountain of Washington, Oregon and Alaska have a similar climate to that of Japan. Likewise, Norway and part of the Alps have a similar climate. Therefore most differences in dealing with avalanche problems in these locations result primarily because of differences in human culture.

Culture, of course, depends on history. In Europe, for instance, people have been living in mountains and around avalanches for hundreds of years, and likewise in Japan. On the other hand, in North America people started living in avalanche terrain only in more recent years, mostly since the late 1800's and especially since 1950. Since Europeans have been living with avalanches for a much longer time, they seem to be more jaded toward avalanche deaths than North Americans. For instance, 100-200 people per year die in avalanches in Europe. To an American, thier acceptable level of risk towards avalanches appears to be quite high.

On the other hand, in North America, people have lived in avalanche terrain only in relatively recent times. By the time most of the people have moved into the mountains, the avalanche hazards were largely mitigated through zoning, control with explosives, defense structures and forecasting. Consequently, the death toll in the U.S. and Canada combined is about 20 people per year--almost ten times less than in Europe--and almost all of them occur to recreationalists in the backcountry. In Japan the acceptable level of risk seems to be even lower. Since 1984 an average of only nine people per year die in avalanches in Japan, and when they do it is not considered acceptable.

Another cultural difference lies in the use of explosives. After World War II, use of explosives in Japan was severely curtailed, while in North America and Europe, explosive use has remained quite widespread and relatively unregulated. Therefore, in North America and Europe, explosives have been used on avalanches for many decades, starting during World War I in Europe and after World War II in North America. Because of this, the technology of avalanche control has become well developed in both Europe and North America. With active avalanche control, avalanche forecasting has naturally followed. This technology has since spread to other areas of the world, for instance, New Zealand and South America.

Japan on the other hand, is a world leader in developing avalanche defence structures including snow rakes, avalanche sheds, energy disapaters in run out zones and designs of buildings in avalanche areas. In this area, both North America and Europe have something to learn from the Japanese. The Japanese, however, can learn about avalanche forecasting and active avalanche control from the rest of the world. With cooperation and information exchange, both Japan and the rest of the world can learn from each other and together we can all move ahead. The U.S. is a world leader in the technology of avalanche forecasting and control. We are willing and able to offer expertise in these areas.

Observations and Recommendations

From my observations during my short three week visit, I think the Japanese can benefit from the technology of avalanche forecasting and control, especially ski resorts, utility companies, or any people or structures existing in avalanche terrain. For instance, the Tenjin Daira Ski Resort at Tanigawa-Dake can clearly benefit from avalanche forecasting and control (see attached report).

I realize that using explosives in Japan is very difficult at this time, but explosives are very effective for triggering avalanches. They are inexpensive, portable and they can be placed in any location. I strongly recommend that, if possible, the necessary arrangements be initiated for the use of explosives for avalanche control.

Perhaps obtaining the legal permit for two-component explosives would be possible in Japan because they form an explosive only when the two components are mixed together. In this way, they can be transported and stored safely and legally. A popular method of two-component explosive in the United States is amonium nitrate (which is a common fertilizer) and diesel fuel. When mixed together, they are not only very inexpensive but when detonated with another high velocity two-component explosive it becomes a very powerful explosive with enough velocity for effective avalanche control.

Two-component explosives can also be used in avalaunchers. These guns use compressed nitrogen as a propellent and can shoot an explosive charge over a kilometer in distance. Although one type is manufactured in the United States, the best ones are made in England and France.

Alternative methods of avalanche control include most notably, Gasex. Gasex has the advantage in that it does not use explosives (other than propane) and they can legally be operated by local people at the time of their choosing. It also delivers a large shock wave which is very effective at triggering avalanches. It has some distinct disadvantages in that: First, it is expensive to purchase and construct. I understand that the Gazex device costs about 16,000,000¥ apiece for purchase and installation. The second disadvantage is that its location is fixed. This second point has the most disadvantages because snow instability does not always form in the same area. Shifting patterns of snow, wind and sun create unstable areas in often very different locations. Any method of triggering avalanches should be quite mobile and flexible to adapt to changing conditions. Explosives work very well in this regard.

Another method which has not yet been tried for avalanche control are compressed air shock wave generators. These have been used extensively in seismic exploration especially in ocean environments. These are commonly trailed in the water behind a ship, and when triggered, they produce a very powerful shock wave. It is so powerful that the scientists can detect geologic layering for many hundreds of meters below the ocean floor. These devices use highly compressed air which travels to the triggering guns via pressurized hoses. When the pressurized chamber is released, it produces a large shock wave. This method has advantages in that: 1) it uses no explosives and thus can be operated legally in most situations, 2) the technology is very well developed and thoroughly tested in many different harsh environments, 3) it is relatively inexpensive, 4) gun positions can easily be changed, and 5) several guns can be detonated at once with user-defined microsecond delays between the various guns. Although these guns have not yet been tested for avalanche control purposes, we would like to begin testing. Perhaps this is a good U.S.- Japan joint project. We hope to submit a proposal in the future.

Since explosives are not possible in Japan at this time, avalanche forecasting remains as the only active defense against avalanches. Ski resorts can especially benefit from developing skills in avalanche forecasting, but so can utility companies or any human activity which occurrs in avalanche terrain.

For instance, on my visit to Kurobe Canyon Hydroelectic Plant, the workers ride a bus, then a snowcat to the site. The busses must stop three times while the workers get out and walk through a small, portable, concrete avalanche shed which is only large enough for people. The bus then drives past the avalanche path and picks up the workers on the other side. Each avalanche shed seemed to be much too short to offer much protection from avalanches. In other words, the terrain on each side of the shed seemed just as hazardous as the terrain above the shed. For instance, on my visit, I observed two cases where recent wet avalanches had come down and both of them entirely missed the avalanche shed.

If one would calcualte an avalanche hazard index for this section of road, one would multiply the number of times avalanches hit the road by the amount of time each person spends beneath each one of the avalanche paths. It seems to me that the workers are very exposed to avalanches as they leave the bus and enter the shed, then again when they leave the shed and enter the bus. It takes at least a minute or two for all the workers to pass this dangerous area. If the bus would, instead, quickly pass under the avalanche path without stopping, then the exposure would be only a few seconds. Additionally, a bus provides much better protection from an avalanche than the crossing between the bus and the avalanche shed--where there's absolutely no protection.

Avalanche forecasting would help this situation a great deal. For instance, Utah's Little Cottonwood Canyon highway has one of the highest avalanche hazard indexes in the world, yet no one has been killed on that road in about 40 years. There are no avalanche sheds and the traffic is often bumper to bumper. They simply close the road during times of high avalanche hazard and control the avalanche paths using explosives. The total road closure time adds up to only a day or two each season.

Although avalanche fatalaties in the backcountry seem to be increasing in Japan, to initiate a backcountry avalanche forecasting program may be difficult because of Japan's unique culture. In Western culture, an individual's right to take risks is well established and even encouraged. In other words, people not only think that it is their right to go into the mountains and take risks, but people actively persue these activities. These include rock climbing, mountaineering, wilderness travel with wild and dangerous animals, and, of course, skiing in backcountry avalanche terrain. In Western culture it perfectly legal and widely practiced by a large segment of the population. Often, the risk itself is the attraction. Since people accept this risk, if any injury or death occurs, people do not tend to blame or file lawsuits.

Japan's culture is quite different, and although a Westerner such as myself can probably never fully understand Japanese culture, I have been told that issuing backcountry avalanche forecasts in Japan would be very difficult. First, the backcountry is closed in winter because of the avalanche hazard. Second, if someone were killed there while it was open, the government would be responsible. However, if people choose to ignore the closure and deaths from backcountry avalanches becomes a problem, backcountry avalanche forecasting technology is well developed and can be implemted at any time. The avalanche forecast center in Washington, for example, deals with terrain, climate, and a population size very similar to Japan and they have operated a very successful avalanche forecasting program for a number of years.

Finally, it is absolutely imperative that avalanche forecasting be done by local people in close relation with the mountains and avalanches. Unless the forecaster is very skilled, it is not something which can be done from the office. One must be out on the snow on a regular basis to develop a feel for the conditions. Many parameters can not be communicated by data alone. The best avalanche forecasting is taught through a master-apprentice relationship and nurtured over several years. When setting up an avalanche forecasting system, it is important to use local knowledge, consult or hire local, long-time residents with knowledge of the characteristics of specific avalanche paths and climate.

Summary

In summary, The rest of the world--especially the United States--can learn much from Japan's technology of avalanche defense structures. Also, I believe that Japan could benefit from learning the technology of avalanche forecasting and control which has become standard operating proceedure in most every other populatd, avalanche-prone area of the world. If we share our technology and cooperate, we can all move forward.

Although using explosives in Japan would be very difficult, there are other technologies which do not use explosives (such as Gasex and seismic compressed air guns) which work quite well. However, the direct use of explosives, including two-component explosives, works much better. Even without using explosives, it is imperative that ski areas and other endevors which operate in avalanche terrain, learn the well develped technology of avalanche forecasting. They can do this in one of two ways: first, they can spend a season at a ski area where state-of-the-art avalanche forecasting is done in North America, Europe, or New Zealand. Second, they can hire a consultant to spend a season and teach them the technology. Finally, it is also imperative that an avalanche forecast program use local residents and local knowledge of avalanche paths and climate. Even though avalanche forecasts can be issued from an office, it is very important that the forecaster have regular direct contact with the snow.

I look forward to continued cooperation and exchange between Japan and the U.S.

8. I enjoyed my stay in Japan very much. Although three weeks was not enough time to see everything, my hosts gave me a good overview.

9. I felt that the visiting scientist exchange program is very helpful to both countries. My only suggestion to improve the system is that since I do not speak Japanese very well, I had a difficult time with the language. Reading Japanese is nearly impossible for a westerner, so when signs were in Romanji or in English, it was a great help. Many of the Japanese people I worked with could speak English which was very helpful, but often their English was not good enough for more detailed communication. I was always looking for people who spoke English very well so I could ask more detailed questions. It would be nice to have an interpreter who could perform these duties, but I know that budgetary constraints will probably not permit this.

Bruce Tremper
Director, Utah Avalanche Forecast Center

谷川岳天神平スキー場における雪崩危険に関する報告

まず最初に、私は、アメリカと日本とでは、雪崩コントロールの方法について、いくつかの違いがあることを議論したいと思います。日本では、大抵の雪崩は、雪崩防止工法と閉鎖によってコントロールされていると思います。しかしながら、アメリカでは、雪崩予報と、爆薬を用いての雪崩コントロールの長い歴史があります。この理由のために、アメリカのやり方で、天神平を考えてみたいと思います。

アメリカでは、雪崩予報とコントロールは約４０年前に始まりまして、現在、大変洗練されたレベルに迄到達しております。最近では、雪崩予報とコントロールが実際行われているアメリカのスキー場で、雪崩で市民が死ぬということはまずありません。爆薬を用いたテストと、それによる斜面の安定化により、斜面勾配がどうであれ、あるいは雪崩の危険性に拘らず殆ど全ての地形に対してスキー場としてオープン出来るようになってきています。毎朝、市民がスキー場へやってくる前に、スキーパトロール員が斜面の安定性を解析し、もし必要ならば、市民が到着する前に雪崩を引き起こすために爆薬を使います。

雪崩については、斜面勾配が、何と言っても雪崩の危険性を判定する最も重要な斜面変数です。例えば、３０度の斜面では、雪崩は殆ど動き出すには到らず、３８度で最大に達します。言い替えますと、３０度と３８度の間の斜面角度が非常に重要です。例えば、３６度と３８度の間の差というのはそれほど大きくは見えませんが、雪崩に対してはこの差はべらぼうに大きな差なのです。天神平では、臨界角度は３５度付近と思われます。言い替えますと、斜面が３５度を越えると、雪崩の発生は急激になると思われます。

私は、提案されている新しいスキーコース（田尻沢・高倉沢スキー滑降コース、すなわち、ロッジから下方のゴンドラ駅までのコース）の安定性について評価してくれるよう依頼されました。これからの議論のために、私はこの地形を２つの部分に分けて考えます。即ち、この谷の上の部分と、その下の谷底の部分です。私はこのスロープを２回滑走し、斜面角度を注意深く測定致しました。斜面角度はコースがこの谷の下部と出会う谷底－ここでは、斜面角度は４０度にまでなっているが－まで、ほとんど、３４度以下と思われます。私の意見では、この部分即ち、提案されているスキーコースが谷底と出会う所が、この新しいスキーコースでは最も危険な所です。また、この谷底は、深いＶ型となっていますが、ここは雪崩斜面地形としては非常に危険な型の所です。なぜならば、ほんの小さい雪崩でさえも、遭難者を非常に非常に深く埋めてしまうからです。

私は、このコースの計画は、スロープの急峻という問題を回避するために、このコースが谷底と交わるところで、その地勢を変化させるという風に理解しています。これは、この交差点でのこの問題を減少させると思いますが、谷底より下の所にはまだ問題が残されています。両岸には４０度に近い急峻な斜面があります。私が拝見した開発計画には北に面する斜面の孤立した斜面にはいくつかのスノーレーキ（雪崩予防柵）がありましたが、南に面する斜面には何もありません。過去の雪崩をみますと、大半は北斜面に発生してはいますが、南向き斜面も同様に急峻であり、そこでも雪崩の発生の危険はあります。特に、太陽による急激な融解の時には危険です。私が思うには、この谷の南側の斜面もそうですが、北側の斜面にもっと多くのスノーレーキ（雪崩予防柵）が必要です。しかし、より大きな問題は、今提案されている田尻沢・高倉沢スキーコースだけが天神平スキー場での危険な所ではありません。とくに、山頂ゴンド

ラ駅の上のリフト（天神峠リフト）で行けるところは危険です。このリフトの両側の何箇所かの斜度を測定したところ、それは３８～４０度ありました。そこは、強い降雪や或いはこれらの斜面で強風が吹けば、雪崩が発生すること間違いありません。いくつかの観点から、これらの地域は今計画中の田尻沢、高倉沢スキーコースよりも、より危険です。なぜならば、これらの斜面は山の稜線の所にあるのでそこでは風は、雪をより低い地形の所まで運びます。降雪があればいつも、特に強風を伴う降雪の後では、スキーパトロールにとって大事なことは雪崩の危険を評価することです。そして、もし必要ならば、この不安定性をコントロールできないときにはスキーコースを閉鎖することが大事なことです。

スキーパトロール者は、降雪や強風の後で雪庇落としをしていると聞いております。この事は良いことです。しかし、もっと重要な事は雪庇の下で発達するウインドスラブ（風によって作られる広い吹き溜まり）をコントロールする事です。一般的に言って、風が強いほどより低い所にウインドスラブが作られます。私は、この部分を安全にするための方法として爆薬を使う事以外の事は知りません。

もう１つの側面として、現在日本のスキーパトロールの人々は、アバランシュレスキュービーコン（雪崩遭難事救助信号発信器）を使っていません。私自身のビーコンを使って、私がここに滞在中、１組のパトロールの人々にその使い方を教えました。しかしながら、私が考えるには、パトロールの人がビーコンを購入し、いつも彼らがそれを使う事が大事だと思います。なぜならばこの方法が、誰か雪崩に埋まったときにその人の命を助ける事が出来る唯一の方法だからです。他の方法では時間がかかりすぎて駄目です。

私が思うには、現在、日本では爆薬を使う事は不可能と思います。しかし乍ら、これを使えるようなアレンジメントを進める事を強く勧めるものです。スキーパトロールの人々も、市民も、爆薬を使える事により、雪崩の危険から大変大きく身を守る事が出来るようになると思います。この場合、たぶん２成分の爆薬を用いる事が最良と思います。その理由は、それは安全に輸送され、貯蔵する事が出来るからです。この爆薬は、２つの成分が混合されたときにのみ、爆発物となります。ダイナマイトの作業はこれよりも良いし、準備時間がかかりませんが、輸送と貯蔵にもっと大きな問題があります。この理由で、２つの成分を混合させる方式のものが恐らく最良でしょう。この２成分爆発物は、空気砲に使われます。それは、約１Kmほどの遠方迄爆薬を飛ばす事が出来ます。

空気砲は、谷川岳の山頂よりも少し下方の斜面をコントロールするのに理想的でしょう。この方法では、スキーパトロールは一降雪毎にいくつかの小さな雪崩を発生させ得ましょう。これにより、大きな雪崩の発生を低くしましょう。例えば、かって塔を破壊したような大きな雪崩を発生しにくくします。更に、田尻沢・高倉沢スキーコースに雪崩がやってくる前にこの谷底に一連の雪崩ダムや、雪崩減勢工を作る事は大きな効果となります。

最後に、殆どの事故は、遭難者自らが雪崩を引き起こすのですが、２番目の問題は自然発生雪崩が上方から来る事です。田尻沢・高倉沢スキーコース計画では、特に谷底で、道の上に急峻なスロープが沢山ある事です。これらの斜面からは、特に大雪や雨の時、そして南向き斜面では強い日射により雪崩が発生します。スキーパトロールとしては、雪崩予測に熟達する必要が絶対あります。そうすれば、彼らは、悪条件の時にはこのコースを閉じる事が出来ます。もし、スキーパトロール隊が、爆薬を使う事が出来れば、雪崩予測をより容易にする事ができますし、又、スキーコースをより安全にする事が出来ます。

結論として、スキーパトロール隊が雪崩予測と、コントロールに熟達する事が絶対的に必要と私は考えます。この方式は世界中のほとんどの山岳地帯で、標準的なやり方となっております。現在、谷川岳で市民に開放されている多くの斜面は数年前に３人が死亡した斜面と同じ危険性を持っています。もしスキーパトロールがこの雪崩方法を会得し、必要な閉鎖或いはアクティブコントロールをしなければより多くの人々が雪崩で死亡する事は時間の問題です。パトロール者は、これらの技術を、アメリカ、ニュージーランド、カナダ或いはヨーロッパで身につける事が出来ます。そして、良い雪崩プログラムについて学んだり、或いは、天神平スキー場で１シーズンコンサルタントを雇うなりして、これを遂行する事が出来ます。もし、パトロールの人がアメリカに行くのであれば、現在最良の所は、アルタまたはスノウバード（ユタ州）あるいはアルパインメドー（カリフォルニア）、クリスタルマウンティン（ワシントン）あるいはブリッジャーボウル（モンタナ）です。

ブルース・トレンパー
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１９９２年2月3日
翻訳：中村　勉

REPORT ON THE AVALANCHE HAZARDS AT TENJIN DAIRA SKI FIELDS ON TANAGAWA-DAKE

3 February, 1992

First, I would like to discuss the differences between the American and Japanese way of controlling avalanches. In Japan, it seems that most avalanches are controlled with avalanche defense structures and with closures. On the other hand, in the United States, we have a long history of controlling avalanches with forecasting and explosives. Consequently, this report will look at Tenjin-Daira with somewhat of an American perspective.

In the United States, avalanche forecasting and control began about fourty years ago and has evolved to a very sophisticated level. In recent years, it has been very rare for any public to be killed in avalanches at an American ski area where avalanche forecasting and control has been practiced. Because of our use of explosives to test and stabilize the slope, it has allowed ski areas to open almost all terrain regardless of its steepness or avalanche hazard. Each morning before the public arrives, the ski patrol analyzes the stability of the slopes and, if necessary, uses explosives to trigger avalanches before the public arrives.

With avalanches, the steepness of the slope is by far the most important terrain variable for judging avalanche danger. For instance, a slope of 30 degrees is barely steep enough to slide but avalanche activity reaches its maximum at 38 degrees. In other words, between 30 and 38 degrees, slope steepness is extremely important. For instance, a difference between 36 and 38 degrees doesn't seem like much to a person, but it makes a huge differnce with respect to avalanche activitly. In the maritime climate of Tenjin-Daira, the critical slope angle seems to be around 35 degrees. In other words, avalanche activity seems to increase dramatically as slopes become steeper than about 35 degrees.

I was asked to evaluate the safety of the proposed new run (Tajirezawa-Takakurazawa ski course) which travels between the lodge down to the bottom of the gondola. For this discussion, I will separate the terrain into two sections: the upper section above the canyon bottom and the lower section in the canyon bottom itself. I skied the run twice and carefully measured the slope angles. On the upper section, most of the slope angles stay under 34 degrees until just above where the run meets the canyon bottom, where the slope steepens briefly to about 40 degrees. Below this the run follows a road which is quite flat but steep slopes of the canyon rise above it on both sides. In my opinion, this canyon bottom is the most dangerous section of the proposed new run. The canyon bottom also forms a deep V shape which is a very dangerous type of avalanche terrain because even a small avalanche can bury a victim very, very deeply.

I understand that the plans for this run include changing the slope configuration where the run intersects the canyon bottom to avoid this problem of slope steepness. This may mitigate the problem at the intersection point but the canyon bottom below the intersection point remains quite hazardous. Steep slopes of close to 40 degrees rise above the canyon bottom on both sides. The development plans I saw called for some snow rakes in isolated areas on the north facing slopes but none on the south facing slopes. Although most of the past avalanches have occurred on the north facing slopes, the south facing slopes are equally steep and they could also produce avalanches, especially in times of strong melting from the sun. I feel there needs to be more snow rakes on the north facing slide of the canyon and snow rakes on the south facing side as well.

But an equally large problem is that the proposed Tajirezawa-Takakurazawa ski course is not the only dangerous avalanche terrain at Tenjin-Daira. Specifically, the area accessed by the top-most lift above the gondola upper terminal (Tenjin Tage Lift). On both sides of the lift, I measured several areas where the slope angle is 38-40 degrees, and I am certain that they produce avalanches when large storms occur or when the wind blows snow onto these slopes. In several respects these areas are more dangerous than the proposed Tajirezawa-Takakurazawa ski course because they lie along a ridgetop where the wind can drift snow onto the downwind terrain. After each storm, and especially after each storm with strong winds, it is important for the ski patrol to evaluate the avalanche hazard and, if necesarry, close the run if they cannot control the instability.

I understand that the ski patrol cuts the cornice there after storms and wind events. This is good, but it is probably more important to control the wind slabs which form below the cornice. In general, the stronger the wind, the lower the wind slabs will form on the slope. I don't know any way to do this safely without using explosives.

As a sidelight, at the present time, the ski patrol does not use avalanche rescue beacons. Using my own beacons, I trained a couple of the patrollers while I was there in the use of beacons. I feel, however, that it is very important for the patrol to purchase their own beacons and use them at all times because it is the only way to save the life of someone buried beneath avalanche debris. All other methods are far too slow.

I realize that using explosives is not presently possible in Japan. However, I strongly recommend that the necessary arrangements be started to use them in the future. I feel that avalanche safety for both the ski patrol and the public will be increased significantly with the use of explosives.

In this case, perhaps two-component explosives work best because they can be transported and stored safely. They form an explosive only when the two components are mixed together. Although dynamite works better and takes less time for preparation, transportation and storage present much greater problems. For these reasons, two component explosives are probably the best choice. Two component explosives can also be used in air guns, which can propel explosives for distances of about a kilometer.

Air guns would be an ideal tool for controlling the slopes below the summit of Tanigawa-Dake. In this way, the ski patrol can make several small avalanches after each storm and thereby reduce the liklihood of large avalanches--for instance, the one which destroyed the lift towers. In addition, a series of dams, or energy disipaters in the bottom of the canyon before the avalanche reaches the Tajirezawa-Takakurezawa ski course would also be an effective method.

Finally, although most avalanche accidents occur when the victim triggers the avalanche, there is the second problem of natural avalanches coming down from above. On the proposed Tajirezawa-Takakurazawa ski course , especially in the canyon bottom, there are a number of steep slopes above the road which can and will produce avalanches especially during times of heavy snowfall, rain, or strong sun on the south facing slopes. It is absolutely necessary for the ski patrol to become skilled at avalanche forecasting technology so they can close this run when conditions become hazardous. If the ski patrol were allowed to use explosives, it would make forecasting much easier and it would make the run much more safe.

In summary, I feel that it is absolutely necessary for the patrol to become skilled in the technology of avalanche forecasting and control, which has become standard operating proceedure im most mountainous areas of the world. Many of the slopes presently open to the public are just as dangerous as the one which killed three people some years ago. Unless the patrol aquires these avalanche skills and performs the necessary closures, or performs active control, then it is only a matter of time before more people are killed. The patrol can aquire these skills either by going to the United States, New Zealand, Canada or Europe and studying with a good avalanche program, or by hiring a consultant to spend a season at the Tenjin-Daira Ski Fields. If a patrol member goes to the United States, I would suggest an area where state-of-the-art avalanche control is currently practiced, such as Alta or Snowbird (in Utah), Alpine Meadows (in California), Crystal Mountain (in Washington) or Bridger Bowl (in Montana).

Bruce Tremper
Director, Utah Avalanche Forecast Center
337 N. 2370 W.
Salt Lake City, Utah, U.S.A.

Visiting Scientist with the Nagaoka Institute of Snow and Ice Studies
Suyoshi, Nagaoka
Niigata 940

（様式1）
平成３年度科学技術振興調整費個別重要国際共同研究成果報告書

1．省庁、機関名	科学技術庁防災科学技術研究所			
2．課題名	乾雪表層雪崩の制御と防御に関する研究			
3．研究参加部室名	長岡雪氷防災実験研究所 第1・第3研究室 新庄雪氷防災研究支所 雪氷防災第1研究室			
4．相手国及び相手側研究機関名	相手国 アメリカ合衆国	研究機関名 ユタ州立大学、USDA Forest Sevrice		
5．３年度予算額（千円）	試験研究費	外国旅費	外国人招聘経費	合　計
	2,350	1,070	672	4,092

6．研究の内容・成果

（1）研究の目的と意義

この研究は日米共同研究の一貫として実施されている研究である。

我国における最近の大きな雪崩災害は大規模な乾雪表層雪崩によるものである。これによる災害を未然に防止するため、アメリカで発達している雪崩発生予知のソフト手法を我国へ導入すると共に、我国で開発されたハードな雪崩制御工法の効果判定を米国で人工雪崩を用いて行い、雪崩による災害の総合的予防研究を行う。

（2）研究方法

研究の目的は乾雪表層雪崩について気象並びに野外積雪断面観測結果に基づき、人工雪崩を発生させる手法の確立を図ること、並びにパイロンにかかる衝撃力を測定し、雪崩減勢工あるいは雪崩防護工の設計基準に役立たせることである。

平成3年度は米国ソルトレークシティ近郊のスキー場で人工雪崩実験を行い、そのビデオ撮影及び積雪観測を実施すると共に衝撃力測定のための予備調査を行う。また、雪崩発生制御に関するアメリカの予知技術を我国で実施し、その我国における適用性を明らかにする。

（3）成果

平成4年2月13日から3月3日まで米国ソルトレークシティ近郊のスキー場に滞在し、米国林野庁およびユタ州立大学等と共同で同地のスキーパトロールが実施している　人工爆破による雪崩コントロールに参加した（写真1）。この間、2度の実験を行い、そのうち1回は大規模な雪崩は発生しなかったが、もう1回は大規模な乾雪表層雪崩が発生し、その模様をビデオ撮影することができた。また、この滞在中，積雪層の観測・解析等を日本から持ち込んだ新たに開発された機器により行うとともに（写真2，図1）、米国側の観測との比較を実施した。

また、平成4年1月28日から2月1日まで谷川岳天神平スキー場に滞在し、米国林野庁と共同観測を行った。この間、米国で実施されている表層崩観測手法の一つである弱層テストが日本でも有効であることが分かった。今後の我国における表層雪崩観測にこのテストが役立つことが期待される。

なお、外国人招聘研究者ブルース・トレンパー氏による「アメリカにおける雪崩予知」と題する講演会を行い、日本の雪崩研究者、気象台関係者、スキー場等の雪崩対策実務者を交え討論を行った。

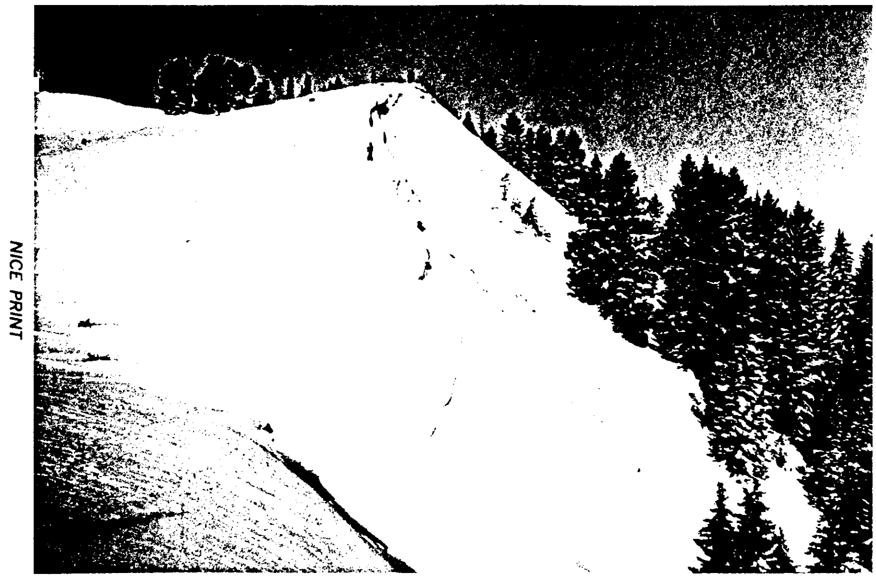

写真1　人口爆破による雪崩コントロール

写真2　複合ゾンデによる測定風景

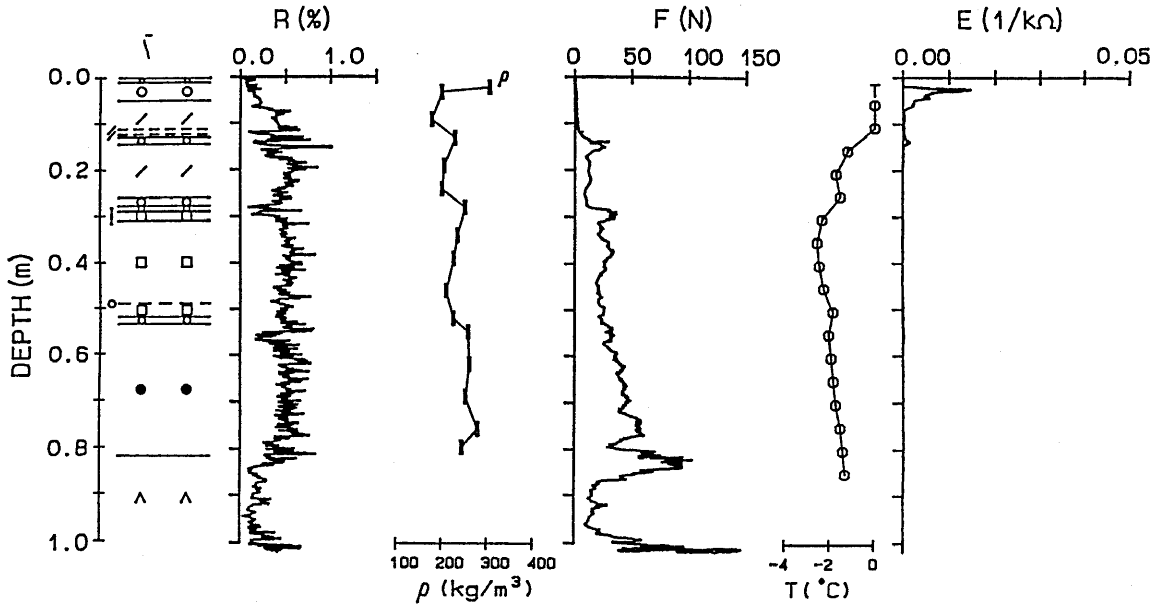

図1　複合ゾンデによる測定結果と断面観測結果の比較

7．その他（今後の課題等）

乾雪表層雪崩の発生予測とその衝撃力についての米国との共同研究を、更に数年継続する必要がある。

8．研究発表等

（1）学会発表（発表者名、発表題名、学会名）

Abe, O., Ikarashi, T., Decker, R., Sensoy, B., Ream, D. & Tremper, B. (1992)：Snow profile observations for avalanche forecasat by new generation ramsonde. Symposium on Snow and Snow-Related phenomena. International Glaciological Society.

Tremper, B. (1992): Avalanche Forecasting in the United States. A Lecture at Hokushin'etsu Branch, Japanese Society of Snow and Ice.

（2）論文等（著者名、題名、発表紙名、巻号名）

Nakamura, T.(1991): Activities of the Japan/US Joint Program under the Snow and Snow Avalanche Management. Japan-US Workshop on Snow Avalanche, Land Slide, Debri Flow Prediction and Control. Organizing Committee of JUSSLDPC.

Tremper, B. (unpublished): Report on the Avalanche Hazard at Tenjin-Daira Ski Area on Tanigawa-dake.

（3）特許等（出願番号、出願年月日、発明の名称、発明者、出願人）

なし

（様式２）

Report of The Bilateral International Joint Research by Special Coordination Funds Promoting for Science and Technology (FY 1991)

1. Research Theme

A study on the release control and the protection method against surface dry snow avalanches

2. Implementing Institutes and Principle Researchers

Japanese Side:
National Research Institute for Earth Science and Disaster Prevention.
Science and Technology Agency
Tsutomu Nakamura

United States of America Side:
The University of Utah
Rand Decker

3. Total Expenditure (Yen)
¥4,092,000

4. Summary

Recent catastrophic avalanche disasters in Japan were caused by surface dry snow avalanches. The final goal of this study is to prevent these disasters. The aims of this study are to establish a method of artificial avalanche control that is based on meteorological and snow cover profile observations being carried out in the US and other countries, and to carry out a preliminary survey on the avalanching snow impact forces on a pylon.

In the fiscal year of 1991, artificially released avalanches were observed at the ski field in the suburbs of Salt Lake City in the U.S.A. from 13 February to 3 March, 1992 and snow avalanche motions were taken in a vidio film. The artificial snow avalanches were released by explosives by the ski patrol people collaborated with the USDA Forest Service and the Utah State University. Furthermore, snow cover observation was conducted by a Japanese newly developed ramsonde and the results were compared with the United States observations' during this stay. A preliminary survey for the impact force measuremonts on to a pylon was made too.

On the other hand from 28 January to 3 Februaly at the Tenjin Daira Ski Field at Tanigawa-dake colloborative observation was conducted. The weak layer test that has been carried out in the U.S.A. as one of the means of surface avalanche prediction was effective in Japan too.

A lecture entitled "Avalanche forecasting in the United States" by an invited foreign researcher Mr. B. Tremper was held through an interpreter Mr. Y. Yamada on January, 1992 at Nagaoka to which about 60 people attended.

5. Publications

Nakamura. T. (1991) Activities of the Japan/US Joint Program under the Snow and Snow Avalanche Management. Japan-US Workshop on Snow Avalanche, Land Slide, Debris Flow Prediction and Control. Organizing Committee of JUSSLDPC.

Abe, O., Ikarashi, T., Decker, R., Sensoy, B., Ream, D. & Tremper, B. (1992): Snow profile observations for avalanche forecast by new generation ramsonde. Symposium on Snow and Snow-Related Problems. International Glaciological Society.

Tremper, B. (unpublished): Report on the Avalanche Hazard at the Tenjin-Daira Ski Area on Tanigawa-dake.

6. Remarks

This study is conducted under The Japan-U.S. Joint Studies, entitled Snow Avalanche Management, Landslide Prediction and Control of Non-Energy Matters.

United States Department of Agriculture
Forest Service
Pacific Northwest Research Station
Forestry Sciences Laboratory
4043 Roosevelt Way NE
Seattle, Washington 98105
USA

February 8, 1992

Tsutomu Nakamura
Director of the Institute
Nagaoka Institute of Snow and Ice Studies
National Research Institute for Earth Science
and Disaster Prevention
Science and Technology Agency
Suyoshi, Nagaoka
Niigata 940
JAPAN

Dear Tom:

Enclosed is my report of activities that you requested. It is quite a bit longer than you probably expected. However, I wanted to illuminate as many opportunities for joint research as I could so that the US government could also see how valuable these joint projects are. Hopefully, we can find the funding to bring Japanese scientists to the United States.

Dr. Nohguchi asked that I prepare a manuscript for my open lecture to publish in the next JSSI journal. I will work on that as soon as possible and hopefully have it to you before the end of March.

Thank-you again for all of your hospitality. I am pleased by the abundant memories I have of my wonderful experiences in Japan.

Regards,

Sue

Sue A. Ferguson, Ph.D.
Atmospheric Scientist

Tel. 206-553-7815
Fax. 206-553-7709

JOINT OBSERVATION OF SNOW AVALANCHES IN JAPAN
REPORT OF ACTIVITIES

1. NAME: Sue A. Ferguson, Ph.D.

2. POSITION: Atmospheric Scientist
   Global Environmental Protection Program
   Pacific Northwest Research Station
   United States Department of Agriculture Forest Service

   ADDRESS: USDA-FS PNW Research Station
   4043 Roosevelt Way Northeast
   Seattle, Washington 98105 USA

3. RESEARCH FIELDS: 1) avalanche and mountain weather prediction; 2) prediction on the effects of climate change on forest and watershed ecosystems

4. PROPOSED SUBJECT OF RESEARCH IN JAPAN: 1) a joint observation of snow avalanches in Japan; 2) test a laser sensor to distinguish snow and rain; 3) present lectures on avalanche problems in Washington State and the use of weather data for predicting snow layering

5. TENURE: January 11-31, 1993

   ITINERARY:

1/11/93	Arrive Narita
1/12	STA Tokyo Headquarters and NIED in Tsukuba
1/13-18	Nagaoka Institute for Snow and Ice Studies
1/19	Niigata University Research Institute for Hazards in Snowy Areas and Niigata meteorological forecast office
1/20-21	Tenjin-taira Ski Field
1/22	Nagaoka Institute for Snow and Ice Studies
1/23	Observed GAZEX experiment at Mt. Ogenashi-yamma
1/24	Visit site of Masaguchi avalanche disaster
1/25	Nagaoka Institute for Snow and Ice Studies and open lecture

1/26-27 Radar site at Sakata and Shinjo branch of NIED
1/28-29 Institute of Low Temperature Science, Hokkaido University
1/31 Depart Narita

6. HOST INSTITUTE: Nagaoka Institute for Snow and Ice Studies
National Institute for Earth Science and Disaster Prevention
Science and Technology Agency

7. REPORT OF RESEARCH:

The snow climate of North America's Pacific coastal region is similar to Japan. The maritime climate in the coast mountains of Washington, Oregon, California, Alaska, and British Columbia is characterized by frequent storms with heavy snowfalls and widely fluctuating freezing levels. This causes a complex pattern of snow stratigraphy that often is remarkably different than snow patterns found in continental-type climates. Therefore, while developing an avalanche forecasting program for Washington, Oregon and southern British Columbia, the USDA-FS Northwest Avalanche Center (NWAC) has found research results from Japan to be of great help. Whereas, research from other study centers like Utah, Colorado, or Switzerland often applies only to continental-type climates and are not useful for forecast and control problems in our maritime region.

Although my stay in Japan was very short, I was fortunate to observe many aspects of snow and avalanches. The following summarizes my observations for each of several different topics.

Avalanche Forecasting: While visiting the Niigata meteorological forecasting office, I learned that avalanche advisories are issued whenever precipitation, temperature, and snow depth reach certain critical levels. The threshold values vary by region and prefecture. I assume that the critical levels were determined by comparing snow and weather data to avalanche activity.

This system of forecasting avalanches is very common throughout the world. In the United States many National Parks employ such a forecasting system to advise skiers and visitors on snow shoes or snow machines of expected avalanche danger. Also, the National Weather Service Juneau, Alaska forecast office uses a similar method to warn residents and highway workers of possible avalanche problems.

Using critical level parameters to determine the potential for widespread avalanching works well for predicting obvious avalanches that release because of direct weather events (e.g., snowpack weakening by rapidly warming temperatures, or rapid loading by heavy snow/rainfall). In addition, snowfall and rainfall often load the snow cover in a way that imparts simple compressive and down-slope forces on buried weak layers.

Unfortunately, there can be several problems with this method. For example, there often are subtle changes in the weather (where snow depth, snowfall, and temperature do not reach critical levels) that can cause isolated releases of dangerous avalanches. Also, many times buried weak layers are stronger than usual and weather reaching critical levels may not cause avalanching. Finally, complex loading patterns from skiers, snow boarders, climbers, snow mobiles, snow shoes, and other disturbances like earthquakes impart a series of stresses that are difficult to quantify.

These subtle weather changes, variations in snow strength, and complex loading patterns are poorly understood by scientists. Only recently have efforts been made to begin building computer models that can help predict the variety of possible avalanche criteria. Despite this difficulty in quantifying avalanche probability, it is possible to combine experience with a basic understanding of the snow's physical properties to develop a qualitative prediction of avalanche occurrence that is much more accurate than the simple weather criteria described above.

In the mid 1970's the United States experienced a dramatic increase in the number of people skiing and climbing in the backcountry (terrain that is away from developed ski areas and roadways). The travellers were adding a variety of loads to the snowpack and causing avalanches in places and at times that could not be predicted by traditional avalanche forecasting methods. This is why many U.S. avalanche forecast programs now rely on experienced mountaineers, who have scientific knowledge of snow physics, to develop avalanche hazard forecasts.

I believe that this type of forecasting, where there is a strong reliance on a forecaster's personal experience, is the most accurate in the world. However, much effort is being made build computer models that can do the same thing. And as computers are becoming powerful enough to accommodate complicated pattern recognition and expert system modelling, then I believe that this effort may be successful within the next 5 to 10 years.

I learned that scientists at Institute for Low Temperature Science (ILTS) are working on a physical model for avalanche forecasting, using detailed weather information along with equations of metamorphism and calculations of strength. This type of work is similar to that recently developed and used by Meteo France for the 1992 Winter Olympic Games in France. It may be a realistic goal to have such a model for the 1998 Winter Olympic Games that will be held in Nagano Prefecture.

Because I am unfamiliar with the pattern of Japan's avalanche accidents, whether they are increasing or decreasing, I cannot suggest which method of forecasting avalanches is best. It is certainly important to continue work on quantitative methods like the physical model being developed at ILTS. Although the snow and avalanche problems in Japan are similar to other maritime climates like Norway, Washington State, and New

Zealand, they are different than those in France and Switzerland where most modelling efforts have evolved. Therefore, I would encourage Japanese scientists to develop avalanche prediction models that will include the unique aspects of maritime weak layers (like graupel, solid shaped depth hoar, and subtle differences in the amount of riming on crystals). Then test their models in Japan and other maritime climates.

In addition, it also would be valuable to improve the critical parameter methods currently used by the Japanese meteorological service. This can be done by comparing more weather variables with more detailed avalanche activity records. Statistical models like "nearest-neighbors" can be employed in areas with sufficient data.

If Japan is interested in developing a forecast methodology like that used in North America, then I would suggest that a tour of each regional forecast program (Washington, British Columbia, Utah, and Colorado) and several local forecast programs (Montana, California, Alaska, Idaho, and Wyoming) would help determine the methodologies best suited for Japan's political and snow climate. Again I would emphasize that the subtle layering found to cause avalanching in maritime climates is poorly understood by scientists and forecasters in continental climates. Below is the address for NWAC where a unique avalanche forecasting program has been developed not only to address problems common to other snow climates, but to additionally recognize and predict avalanches common only to maritime climates.

Mr. Mark Moore
Lead Forecaster
USDA-FS Northwest Avalanche Center
7600 Sandpoint Way NE
Box C-15700
Seattle, Washington 98115 USA

Please be aware that the regional avalanche forecasting programs in the United States are cooperatively supported programs. For example, the Northwest Avalanche Center (NWAC) is administered by the United States Department of Agriculture Forest Service (USDA-FS). Its USDA-FS employed meteorologists work along side of United States Department of Commerce National Weather Service (NWS) meteorologists in the National Oceanographic and Atmospheric Administration (NOAA) Western Regional Headquarters where the NWS Seattle Forecast Office resides. Another large portion of monetary and field observation support comes from the Washington State Department of Transportation. Other government agencies that support NWAC include the United States Department of Interior National Park Service, the Washington State Parks Department, and the British Columbia Ministry of Highways. Private support groups include the Pacific Northwest Ski Area Association, town utility companies, local television stations, and ski schools. I did not see this kind of cooperation in Japan but would recommend it as a way to develop a forecast program that is broadly beneficial.

Another good way to mitigate avalanche problems among backcountry travellers is to teach individuals to predict avalanche potential on their own. I was pleased to hear of many good avalanche training courses in Japan. Although there also are many good avalanche training courses in North America, one stands out as the best (in my opinion) for teaching individuals how to remain safe even while ski touring or climbing in and around avalanche terrain. This is taught by the Alaska Mountain Safety Center, Inc. (AMSC). I would encourage anyone who is interested in learning or teaching about backcountry avalanche safety to participate an AMSC 4 day avalanche courses.

Mr. Doug Fesler and Ms. Jill Fredston
Alaska Mountain Safety Center, Inc.
9140 Brewsters Drive
Anchorage, Alaska 99516 USA

Avalanche Control: I saw many snow sheds over roadways and snow fences in starting zones and runout zones while touring avalanche areas in Japan. This is an excellent method for permanently mitigating avalanche problems; especially on slopes above roadways or in areas that are not used for skiing.

Methods of building permanent avalanche defense structures are rarely used in the United States (for a variety of political and ecological reasons). Instead, US avalanche control workers have developed an intricate system using explosives to release avalanches frequently so that they do not become large enough to be destructive, and at times when roads or ski areas can be closed. Using explosives also is a good way to control the many various steep slopes in and around ski areas that frequently avalanche when loaded by aggressive skiers.

I found a skier in Japan who was so concerned about avalanches that he built a bomb out of solidified CO_2 ("dry ice") that was mixed with 1/3 water and 1/3 air inside of a plastic soft drink container by vigorously shaking. He threw the bottle onto a snow slope and waited (5 to 20 minutes) for it to explode. Although he used a variety of sizes and had great success in low density snow conditions, he found this bomb to be ineffective in dense snow that is common in central Japan.

I watched the use of GAZEX at Ogenashi-yamma. This is an alternative to hand throwing charges or using projectiles to deploy explosive charges. Unfortunately GAZEX must be installed in a permanent location and effective only on nearby slopes. Ski fields that have a large number of avalanche paths will find that other means of control are necessary.

I understand that a compressed air exploder, similar to the type used for ocean seismic exploration is going to be tested. These exploders may work well for the low density snow conditions. However, such an exploder was tested in Washington State (with dense snow conditions similar to central Japan) and it was found that the exploder had to be so large that it became immobile. It was quickly learned that these air exploders are impractical alternatives for avalanche control in maritime climates. For further information on Washington's search and test of alternative avalanche control equipment, contact:

Mr. Marty Schmoker
Statewide Avalanche Coordinator
Washington State Department of Transportation
P.O. Box 98
Wenatchee, WA 98807 USA

Other than these experiments, I saw no use of explosives for avalanche control in Japan. I was told that laws regulating the use of explosives was very strict. However, when these laws were briefly summarized for me, they sounded remarkably similar to those of the United States. Therefore, I have enclosed a sample of our explosive handling laws in Appendix A so that they can be compared with Japanese laws.

There are ways to safely release small avalanches by skiing across suspected slopes (often called ski cutting). This is most safely accomplished by belaying a trained ski patroller with a sturdy rope from a safe spot above the slope, using techniques that can impart sufficient load yet maintain the safety of the ski patroller and belayer. I saw none of these techniques being used in Japan.

Because heavy snowfall is common in the Japanese Alps, I would like to mention at least one of the difficulties in controlling avalanches by the use of explosives or ski cutting. That is, during large storms with heavy snowfalls, almost constant control is necessary (i.e., throughout the day and night) to keep potential avalanches from building to destructive sizes. I do not know if ski areas in Japan are equipped to accommodate this methodology.

The following is a list of avalanche control specialists in North America who I believe have the best experience with control methodologies in heavy, dense snow conditions. Each specialist has several years of experience in controlling deep snow avalanches and wet snow avalanches in the coastal mountains of Alaska, British Columbia, Washington, and/or California. In addition, each of the following specialists are experienced with a variety of avalanche control techniques that may or may not include explosives.

Mr. Reid Bahnson, P.O. Box 416, Girdwood, Alaska 99587 USA
Mr. David Hamre, P.O. Box 11-1492, Anchorage, Alaska 99511 USA
Mr. Chris Stethem, Box 1507, Canmore, Alberta T0L 0M0 Canada
Mr. Alan Dennis, Canadian Avalanche Centre, Box 2759, Revelstoke, British Columbia V0E 2S0 Canada

Mr. Craig Wilbour, WSDOT Avalanche Crew, P.O. Box 1008, Snoqualmie Pass, Washington 98068 USA
Mr. Larry Heywood, P.O. Box 222, Homewood, California 95718 USA

Rain on Snow: Like Japan's Niigata Prefecture, Washington State experiences many mid-winter rain events. In addition, there are some weather patterns that cause snowfall to quickly change to rain, like the passage of a strong warm front or the sudden erosion of a temperature inversion. When this happens, avalanches can occur within minutes after the precipitation type change. If rain continues, large destructive avalanches are possible.

To predict rain-induced avalanches NWAC has developed a weather forecast procedure that can predict the timing of sudden rain events within 60 minutes accuracy, 6 to 12 hours in advance. (Within 24 to 48 hours in advance, prediction accuracy is 3 to 6 hours). Unfortunately, many rain-induced avalanches affect major roadways in Washington, which have no snowshed or other structural protection.[1] It is not acceptable to close these major roadways for more than a few minutes at a time. Therefore, a system of avalanche control was established using explosives to release avalanches at times when the road could be closed safely for a few minutes.

Timing the use of explosives in wet snow is critical because liquid water absorbs the explosive energy quickly. It was found that the best time to initiate avalanches in wet snow is when it is being wetted for the first time. NWAC's rain event forecasts, although a dramatic improvement over other available forecasts, are not accurate enough for this type of control. Therefore, a system of monitoring precipitation type is sought.

Although there are many types of precipitation sensors commercially available in the U.S. and Japan, most are prohibitively expensive for many avalanche monitoring programs. I brought an inexpensive ($2,400/¥310,000) infrared laser sensor with me from the U.S. to test while staying at the Nagaoka Institute for Snow and Ice Studies. Several storms of rain, sleet, graupel, and snow occurred during my visit and useful data was collected. It was discovered that this sensor requires some modification before it can be used in a snow climate like Nagaoka

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[1] Recently a snow shed on the west side of Snoqualmie Pass along Interstate-90 (one of the three main highways that cross the United States from east to west) was removed. The reason for its removal was that more traffic accidents were caused by cars and trucks colliding with the edge of the snowshed or sliding on ice that formed inside the snowshed. In its place, a small retaining wall was built and avalanches are initiated frequently with explosives to keep their size small.

and the mountains of Washington. This study will be completed September 1993. A final report summarizing results will be prepared and a copy will be given to the Nagaoka Institute for Snow and Ice Studies.

During my visit I learned of several other precipitation-type sensors that are used in Japan to assist the automated road clearing systems. To my knowledge, there are no automatic road clearing systems used in the United States. However, many of the roads are in remote areas and roadway conditions must be monitored automatically. Currently, these automatic stations monitor air temperature, road surface temperature, visibility, and precipitation (no discrimination between rain and snow). A sensor to distinguish between rain and snow would greatly improve the U.S. road monitoring program.

In addition to the infrared type sensors like mine, Japanese precipitation identification sensors include heated plates and heated water baths that measure electrical resistance and latent heat exchange. In addition, I learned of efforts at the Nagaoka Institute for Snow and Ice Studies to develop an innovative acoustic sensor that can distinguish between the sounds of falling rain and falling snow. Also, a photographic method is being developed to determine if snowfall is in the shape of graupel or not.

All these sensors could have direct application to predicting the potential for avalanches, determining the timing of avalanche control, and monitoring roadway conditions. It would benefit both countries to share information on developing and using precipitation type sensors. Although many areas throughout the world could benefit from such studies, the problem is most difficult in maritime climates where temperatures are near freezing with many mixed rain and snow events.

The ability to remotely monitor precipitation type is only the first part of the problem in predicting rain-induced avalanches. The next step is to determine how the wetted snow strength will change its ability to avalanche. Most studies on percolating melt-water have been done on homogenous snow to help predict water run-off during spring. Studies are just beginning on melt-water flowing through snow layered with fine and coarse grained ice that can cause wet-snow avalanches during the spring. Very little work has been done to study the effect of rain falling on complex shaped snow crystals that cause dangerous wet-snow avalanches during mid-winter.

NIED's Rainstorm Disaster Prevention Laboratory provides a unique opportunity to investigate rain falling on earth systems. Unfortunately, the Tsukuba laboratory is not in snow country. I have learned that the Japanese are very innovative at designing experiments. It would be worthwhile for US scientists to work with Japanese scientists so that an experiment can be designed to investigate realistic wet-snow avalanche conditions; since these types of avalanches are a major cause of destruction in maritime climates.

Snow Physics: I was encouraged to see that the Japanese are continuing their effort to analyze the physical and mechanical characteristics of individual snow particles and snow layer structures, especially at the Institute for Low Temperature Science. Studies on solid depth hoar crystals that develop under relatively warm temperatures and in dense snow layers have greatly aided efforts to forecast avalanches in maritime and transitional climates.[2] In addition, investigations on the way that graupel interacts with adjoining layers and the role of disordered ice surfaces ("quasi-liquid layer") on snow that is near 0°C have aided in the discovery of other useful tools for avalanche forecasters on the west coasts of the United States and Canada.[3] Finally, on-going research into the role of liquid water in snow is important, not only for springtime avalanches and water runoff forecasts, but also for mid-winter rain on snow events that are common in maritime climates.

I believe that it would be valuable for Japanese scientists to collaborate with field observers in North America -- especially through the intensive observation networks in place at the British Columbia Ministry of Highways Avalanche Section and the Northwest Avalanche Center. This way practical applications of research results can be tested and/or verified. The following are contacts for these observation networks:

Mr. Mark Moore
Lead Forecaster
USDA-FS Northwest Avalanche Center
7600 Sandpoint Way NE
Box C-15700
Seattle, Washington 98115 USA

Mr. Jack Bennetto
Manager, Snow Avalanche Programs
Ministry of Transportation and Highways
940 Blanshard Street
Victoria, British Columbia V8W 3E6 CANADA

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[2]The discovery at ILTS in the mid 1970's that solid depth hoar is an equilibrium form of kinetic growth helped avalanche forecasters learn that these crystal shapes can survive through an entire winter under a deep, heavy snowpack, even when the temperature gradient that helped develop them was removed.

[3]Scientists at ILTS discovered that a disordered surface layer on ice exhibits a dramatic increase in thickness as soon as the temperature warms above -5°C. This has confirmed qualitative observations by Northwest avalanche forecasters that layers of graupel quickly increase their strength if warmer than -5°C.

Avalanche Motion: The study of moving avalanches by Japanese scientists has helped scientists all over the world to better understand this complex motion. I was fortunate to meet many scientists continuing this fine effort (at the Nagaoka and Shinjo Institutes for Snow and Ice Studies and the Niigata University Research Institute for Hazards in Snowy Areas) and to see many experiments designed to measure moving snow in the laboratory, in a controlled outdoor environment, and in natural field settings. The use of inclined chutes and rotating drums with natural snow, fragmented ice particles, and ping pong balls to simulate avalanche motion demonstrates the Japanese creativity in this field.

Now, in addition to the use of radar, stationary load cells, and photography, I learned that Japanese scientists are gaining insight into the use of inexpensive geophones to measure avalanche speeds. This could provide a wealth of new data on avalanche motion since the low cost of monitoring and analyzing seismic signals could allow numerous observations in many parts of the world.

Of special interest is the study of wet snow and slush avalanche motion. No studies of this sort are being conducted in the United States and these type of avalanches pose a serious problem in maritime climates. Obtaining coefficients that describe moist and saturated avalanche motion would help improve existing numerical models of avalanche flow. Perhaps new models could be developed to explicitly describe these unique avalanches.

Again a cooperative effort between Japanese scientists and field observers in North America would help hasten results on avalanche motion modelling that are so desperately needed for avalanche hazard planning.

Snow Climate: As mentioned briefly in the opening paragraph of this section, the snow climate of Japan is very similar to the snow climate of the coastal mountains in Alaska, British Columbia, Washington, Oregon, and California. These similarities are caused by the close proximity to ocean moisture and the steep rise of folded and volcanic mountains.

Accompanying the similarities in snow climate, there also are similarities in avalanche characteristics. Both locations experience frequent wet avalanche cycles. Both locations experience trouble-some weak layers of graupel, solid-type depth hoar, and subtle variations in the amount of riming on individual crystals. Both locations have serious earthquakes that can initiate dramatic avalanching. And both locations have heavy precipitation events that can cause widespread avalanching as well as dramatic flooding. These characteristics are uniquely common features in maritime climates.

During my stay at the Nagaoka Institute for Snow and Ice Studies, I entered nearly 30 years of snow depth data from Nagaoka into my computer to compare with snow depth data from a similar station in Washington (a graph of these data are shown in

Appendix B). It is interesting that people in both areas have remarked that the snow depths have been lower during the last several years than is "normal." However, both areas have experienced periods of even less snow depth in recent history.

There are no obvious correlations in the variation of snow depth between the two stations. This may be because the two stations receive snow in different ways. Snoqualmie Pass is a low elevation station near the crest of the Cascade Mountain Range. It consistently receives snow from orographic induced precipitation as westerly winds are lifted by the surrounding mountains. In addition, a convergence zone often develops in the vicinity of Snoqualmie Pass, causing periods of enhanced convective precipitation. On the other hand, the Nagaoka Institute is in the Shinano River valley near the foothills of the Japanese Alps. Although there is some orographic lifting of prevailing westerly winds, nearly 30% of all precipitation in this area falls as graupel. This indicates that most snow accumulations occur during convective precipitation as cold arctic air from Russia moves over warm ocean currents in the Sea of Japan.

Like other maritime locations, climatic changes cause negligible changes in annual precipitation at Snoqualmie Pass and Nagaoka. However, it appears that the type of precipitation (whether rain or snow, frontal or convective) is influenced by even small changes in climate patterns. It would be interesting to conduct a more detailed analysis of precipitation and snow depth patterns in both locations to determine what effects on snowfall and avalanche occurrence might be caused by future climate changes.

Snow depth in both locations appear to be adversely affected by ENSO events near the equatorial Pacific. However, this correlation has yet to be quantitatively proven. An investigation into tele-connections between ENSO and snowfall in both Japan and Washington could provide valuable insight into the global climate. NIED in Tsukuba has recently installed a super-computer to help couple ocean, land, and atmosphere interactions into unified regional and global models. Similar modelling efforts are underway in the United States. However, US modelers have little connection with avalanche specialists. Since snow and avalanche science are intricate parts of NIED's mission, a unique opportunity is developing in Japan to study the effects of ENSO on snowfall, avalanches, and flooding.

<u>Avalanche Data:</u> Many local ski areas, highway departments, and government avalanche centers in the United States maintain a record of avalanche occurrence in their area of responsibility. In addition, we have a central facility for collecting data on mountain weather and avalanche occurrence. This is the Westwide Mountain Weather and Avalanche Network that is administered by the United States Department of Agriculture Forest Service in Ft. Collins, Colorado. This Network accumulates data from over 50 sites in the United States, stores it on a computer, publishes

monthly summaries of statistics, and prepares a book describing interesting avalanche accidents once every 10 years. To obtain historical information or join the mailing list, contact:

Mr. Knox Williams
Program Administrator
Westwide Mountain Weather and Avalanche Network
USDA Forest Service
240 West Prospect
Ft. Collins, Colorado 80526-2098 USA

While describing avalanche problems to my colleagues in Japan I was able to use data from the Network to show that although the number of reported avalanches is increasing in the United States, the number of accidents causing damage or loss of life is remaining constant in some states and has actually decreased in other states. These data are used to show local, state, and government agencies who finance avalanche mitigation programs that their investment is valuable.

Data from the Network also is valuable for developing avalanche forecasting models. Some areas have enough avalanche occurrence and associated meteorological data to use a statistical avalanche forecasting model that was developed and tested by the Swiss Federal Institute for Snow and Avalanche Research ("nearest neighbors").

While at the Nagaoka Institute for Snow and Ice Studies I was pleased to see that historical avalanche occurrence data are being collected. In addition to archiving historical data, I would encourage this Institute to work with others in developing a systematic way of collecting and analyzing current avalanche occurrence information. This way, the number of avalanche accidents can be viewed over time to see if the problem is becoming worse or better. Also, avalanche data can be combined with meteorological data to improve existing avalanche forecasting methods. ILTS also has compiled a list and map location of avalanche accidents in Hokkaido.

In addition to general location maps of avalanche occurrence I saw a few examples of detailed outlines of past avalanche occurrence on high resolution topographic maps. This information is very valuable. For one thing it provides accurate information on dangerous avalanche areas. However, some avalanche flow models should be used to determine the potential maximum extent of these observed avalanches. In addition to site specific information, if these avalanche path data are available for an entire region then quantitative analysis of the overall hazard can be evaluated. For example, the percentage of avalanches that affect a certain elevation, a certain aspect, or villages and roadways can be evaluated to help design better hazard mitigation programs and to help emergency rescue programs prepare for potential future disaster.

Techniques of avalanche hazard mapping now can use an automatic geographic information system (GIS) to locate potential avalanche starting zones (based on slope angle, slope aspect, and vegetation cover) and calculate potential runout areas. Once this coarse estimation is accomplished on a computer, the output can be verified by ground observations and historical avalanche occurrence records. I believe that these techniques would be very useful in Japan where avalanches can affect so many people in so many different places.

In addition to collecting data on weather and avalanche occurrence, it is also of value to collect data on the structure of deposited snow layers. Such data is being collected on a regular basis by scientists at the Nagaoka and Shinjo Institutes for Snow and Ice Studies. However, I saw no analysis of the data after it was collected by manual observations from snowpits. These data provide a unique opportunity to learn more detail about the snow climate and avalanche occurrence criteria within Niigata and Yamagata Prefectures.

In fact, the snowpit observations conducted by the Nagaoka Institute are done in 4 kilometer increments around the city almost every day. These data have been collected for 15 years and could provide valuable insight into the meso-scale climate of the area. In addition, they offer a unique opportunity to be used as verification data for any meso-scale weather modelling that may be implemented. Such weather models are now being tested for use in avalanche forecasting (Northwest Avalanche Center, Meteo France, Swiss Federal Institute for Snow and Avalanche Research) and could benefit greatly from the Nagaoka's snowpit data set.

Earthquakes: Like Japan, North America's west coast mountains lie over subducting oceanic plates. This causes numerous small earthquakes with the potential for large, destructive tremors. In 1965 a large earthquake (8.2 Richter scale) in Alaska caused hundreds of simultaneous snow avalanches within the first 5 minutes of the initial shock. Many more avalanches shook loose during the 24 hours of after-shocks. In 1980, pre-eruption tremors on Mt St Helens in Washington State caused several large avalanches to release. During March the mountain was closed because of the potential for destructive earthquake-induced avalanches, 2 months prior to the first of a series of major eruptions.

While visiting NIED's earthquake monitoring laboratory in Tsukuba, I saw that earthquake monitoring and location techniques in the United States are very similar to Japan's. In relation to avalanche problems, I was very impressed by NIED's earthquake simulation laboratory and do not know if similar laboratories exist in the United States. Such laboratories offer a unique way to test the effect of ground shaking motion on layered material like seasonal snow. There has been little, if any, research of this type accomplished on material like snow that is distinctly layered and so close to its melting temperature.

An earthquake of the size that is predicted for Washington State by seismologists could release enough snow avalanches to stop trans-continental commerce for several days. Similar earthquake-induced avalanches in Japan could block roadways and destroy villages. A joint study on earthquake-induced avalanches between the Nagaoka Institute for Snow and Ice Studies, NIED Earthquake Precursor Research Laboratory, the University of Washington Seismic Center, and the USDA-FS Pacific Northwest Research Station would benefit both countries.

8. IMPRESSION OF RESEARCH ACTIVITY:

The Nagaoka Institute for Snow and Ice Studies was a perfect place for me to base my observations of precipitation type. It was well equipped with weather and snowfall observations to compare with output from my experimental precipitation identification sensor. All of the scientists and technicians were extremely helpful. Unfortunately, I learned only a little Japanese language during my visit. However, I was very impressed by the number of people at the institute who either spoke fluent English, or who were patient enough to help me communicate with them.

Visits to other institutes and avalanche sites were well organized and very informative. Scientists at each location were very generous to interrupt their work long enough to share with me their methods, observations, and results. They were also very kind to share the social aspects of Japan and I was invited to many wonderful lunches, dinners, and festivals.

In addition to increasing my respect for Japanese scientific progress, I very much enjoyed learning more about the Japanese culture, experiencing the variety of wonderful food, and meeting so many kind and interesting people.

9. RECOMMENDATION FOR JAPANESE GOVERNMENT:

To develop a complete understanding of avalanche problems in Japan, it would be helpful to look beyond the research perspective. For example, to learn more of the political perspective I would have enjoyed meeting government officials who are responsible for the safety of their citizens and have had to respond to avalanche problems in their district or town. In addition, to understand the character of avalanches in Japan, it would have been helpful to spend more time on skis so I could have travelled in and around avalanche terrain to witness its variety and extent. Also, meeting and touring with mountaineering clubs would have helped to understand the avalanche problems encountered in recreational activities. Participation in an avalanche training course also would have helped to see how Japanese are educated to deal with avalanche problems.

Obviously all of the acitivities that I describe above are not possible during a short 3 week tour by a visiting scientist.

However, I believe that much of these interactions between different groups are already accomplished through the Japanese Society for Snow and Ice (JSSI). Therefore, I would encourage the Japanese government to continue its support of JSSI and continue its support of government research institutes (like NIED's Nagaoka and Shinjo Institutes) and educational research institutes (like Hokkaido and Niigata Universities). Also, I believe that it is important to encourage joint projects between agencies and institutions. For example, research and forecast methods developed through the Japanese Meteorological Agency could benefit from research and forecast methods developed at the various snow research institutes.

In addition, because snow and avalanche problems in maritime climates are unique from other, more internationally documented snow climates, I propose that the joint technical agreement between the US and Japan be used to help organize a world-wide seminar on maritime snow and avalanche problems.

Finally, Japan has contributed significantly to the world's understanding of snow and avalanche problems. In order to continue this role, it is important to continue cooperation between Japanese scientists and scientists from other countries. For this reason, I encourage the Japanese government to continue its visiting scientist programs like this one.

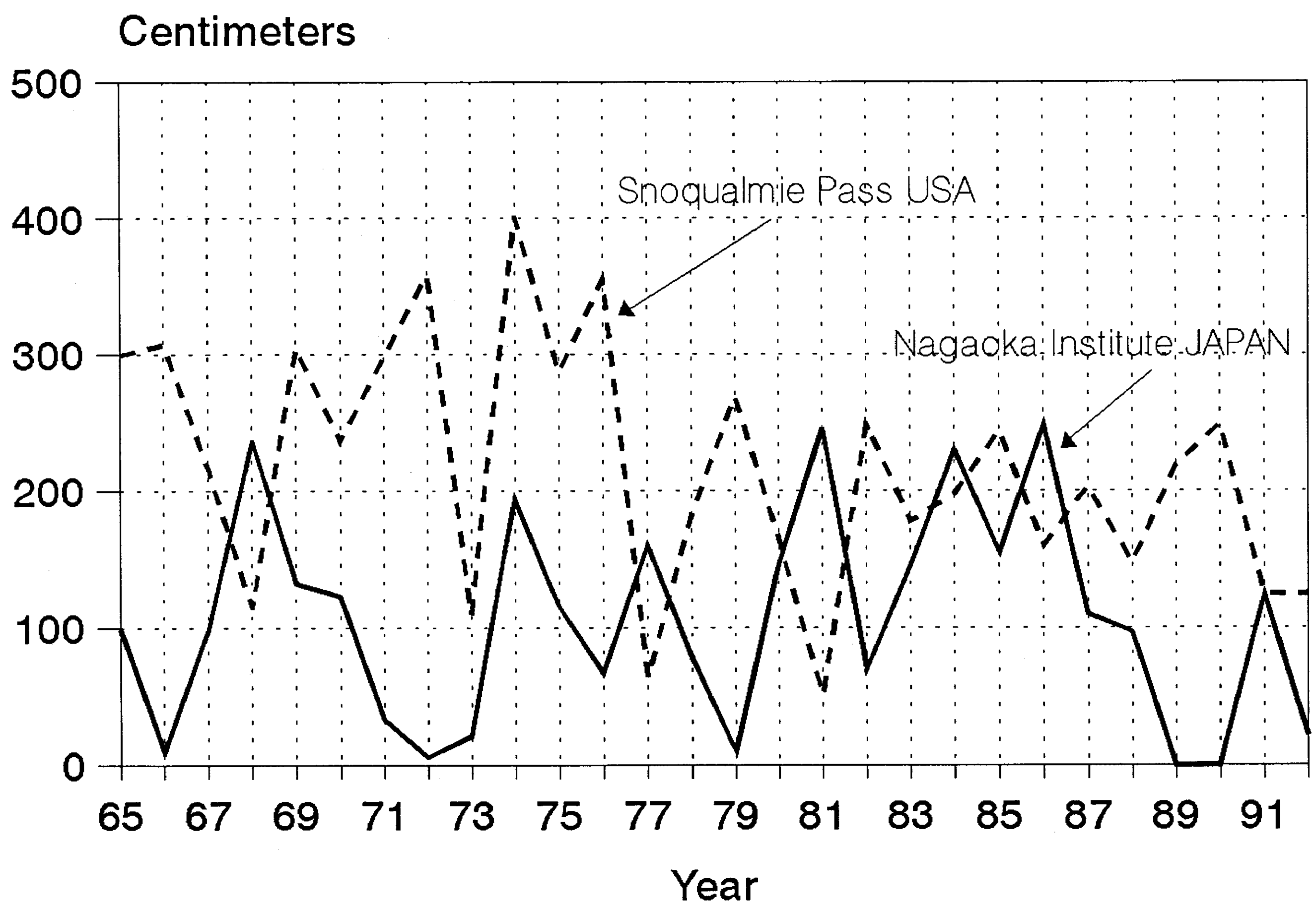
Again, I wish to thank the Japanese Government for supporting my visit through the Nagaoka Institute for Snow and Ice Studies. It was a special opportunity for me and I hope that my visit has somehow enhanced our mutual understanding of snow and avalanches.

Appendix A: State of Washington Department of Labor and Industries, Safety Standards for Possession and Handling of Explosives.

State of Washington Department of Labor and Industries, Safety Standards for Ski Area Facilities and Operations.

Appendix B: Depth of Snow on the Ground

Depth of Snow on the Ground
March 1



（様式１）

平成４年度科学技術振興調整費個別重要国際共同研究成果報告書

<table>
<tr><td>１．省庁、機関名</td><td colspan="4">科学技術庁防災科学技術研究所</td></tr>
<tr><td>２．課題名</td><td colspan="4">乾雪表層雪崩の発生予測とその衝撃力に関する研究</td></tr>
<tr><td>３．研究参加部室名</td><td colspan="4">長岡雪氷防災実験研究所　第１・第３研究室
新庄雪氷防災研究支所　雪氷防災第１研究室</td></tr>
<tr><td>４．相手国及び相手側研究機関名</td><td>相手国
アメリカ合衆国</td><td colspan="3">研究機関名
ユタ州立大学，USDA Forest Service</td></tr>
<tr><td rowspan="2">５．３年度予算額（千円）</td><td>試験研究費</td><td>外国旅費</td><td>外国人招へい経費</td><td>合　計</td></tr>
<tr><td>2,620</td><td>1.660</td><td>667</td><td>4.947</td></tr>
</table>

６．研究の内容・成果

（１）研究の目的と意義

この研究は日米共同研究の一環として実施されている研究である。

我国における最近の大きな雪崩災害は、大規模な乾雪表層雪崩によるものである。これによる災害を未然に防止するため、雪崩発生予知のソフト手法を我国へ導入し、その高度化を図ると共に、パイロンに加わる衝撃力の測定を米国で人工雪崩を用いて行い、雪崩による災害の総合的予防研究を行う。

（２）研究方法

雪崩研究の困難性と進展度の低さの大きな原因は、自然雪崩に遭遇する機会が少ないため、その観察や観測例の少なさと観測時の危険性にある。特に表層雪崩の場合は全層雪崩の比ではない。この困難性の打破と危険性の回避のために、しばしば人工雪崩を発生させて研究を進めるというやり方がとられる。我国では、表層雪崩の人工雪崩研究はアメリカほど進展していない。しかし、衝撃力の解明ではアメリカよりは進んでいる。

このような理由のため、この共同研究では、日米でそれぞれ発達、未発達の分野をお互いに補完し合い研究を進めようというものである。すなわち、米国の乾雪表層雪崩多発地に観測機器を設置し、そこで人工雪崩を発生させて雪崩衝撃力のメカニズム解明を行う。また、米国の研究者を日本へ招へいし、雪崩の発生予知と人工雪崩発生手法の高度化技術を導入する。

（３）成果

1)雪崩の走路上にある人工構造物に加わる雪崩の衝撃力を知り、雪崩の内部構造を探るため、夏の無雪時に設置した計測機器（加速度計、荷重計、圧力計）の作動を改良し、これらが付加されたパイロン（測定用杭）で雪崩の衝撃力の測定及び記録を行った。自然及び人工両方の雪崩による衝撃力のデータを得ることができ、現在解析中である。

2)アメリカ側がヘリコプター上からダイナマイトで発生させた人工雪崩を観察し、ビデオ及びスチールカメラで雪崩の運動を撮影した。

3)自然雪崩による災害家屋及び堆積物の調査を行った。また大規模な人工雪崩跡の調査を撮影等により行った。

4)雪崩の発生条件を考慮した積雪断面観測ならびに発生機構に関わる雪の造粒実験を行った。

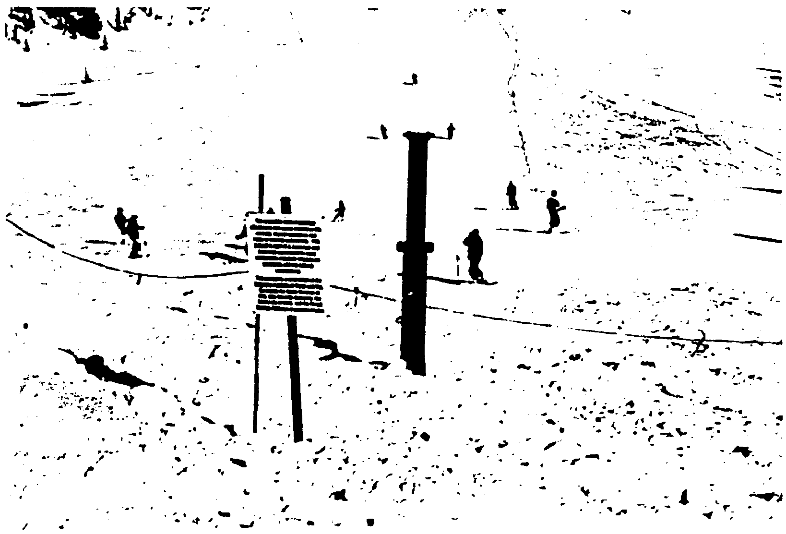


写真.　Baldy山（標高11,068ﾌｨｰﾄ）の主斜面上に設置されたパイロン（衝撃力等の測定杭）．後方にスキーヤーが見える。看板には、この装置は日米共同研究用のものであるのでいたずらをしない様にと書かれている。

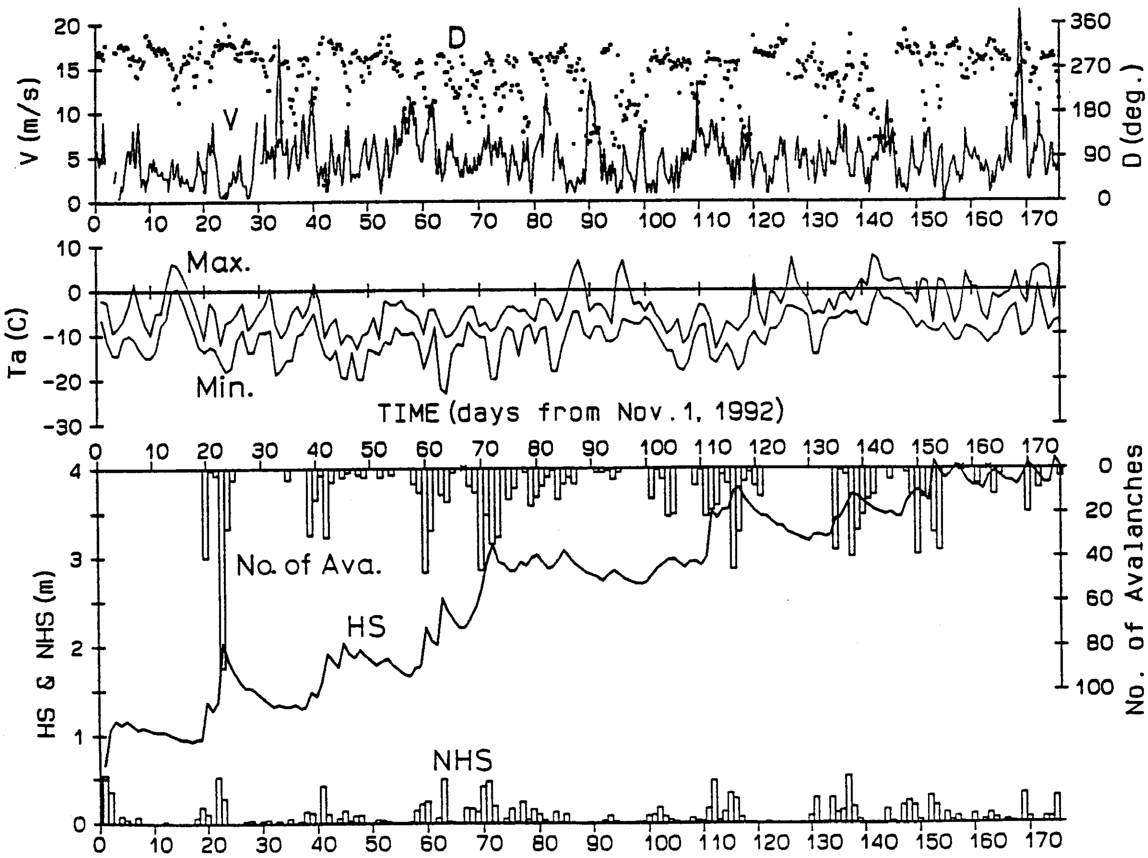


図.　雪崩衝撃力測定地点における気象と降積雪と雪崩の発生数.
V（風速），D（風向），Ta（気温），HS（積雪深），NHS（新積雪深）

5)エアガンを用いた人工雪崩発生装置の実験に参加し、その有効性について議論した。
6)雪崩予報センターを訪問し、雪崩予報のための気象・降積雪データの利用方法、予報の発表方法の説明を受けた。実際に宿舎の端末装置で、この情報を滞在中の日々の行動計画に毎日利用した。
7)ユタ大学のR. Decker助教授、N. Fukuta教授、オハイオ州立大学のJ. G. Lyon助教授と将来の研究について意見交換をした。
8)1993年1月11日から31日までの21日間、アメリカ合衆国、林野庁、森林局太平洋岸北西地区研究所、地球環境保護プログラムグループ所属のSue Ferguson博士を招へいし、雪崩発生予測に関して、新潟県新井市郊外の大毛無山や群馬県谷川岳の天神平の現地において、共に雪崩観測及び現地積雪観測を行うと共に、更に積雪上への降雨によって引き起こされる災害等について意見交換をした。
9)1992年9月長岡で開催された国際雪氷学シンポジウムにおいて、本共同研究によって得られた成果の一部を発表した。

7．その他（今後の課題等）
この種の自然現象解明研究は、長期間行うことが必要である。

8．研究発表等
（1）学会発表（発表者名、発表題名、学会名）
Nohguchi, Y. (1992): Horizontal heterogeneity of snow cover. IGS Symposium held at Nagaoka.

Decker, R., Clayton, A. and Nakamura, T. (1993): The Alta Avalanche Impact Pylon Facility; Installation, Experimental Design and Preliminary Results from the 1992/93 Winter Season. Presented at the MEET'N'93, JOINT ASCE-ASME-SES held on June 6-9, 1993 at the University of Virginia, Charlottesville, Virginia.

（2）論文等（著者名、題名、発表紙名、巻号名）
Nohguchi, Y. (1993): Horizontal heterogeneity of snow cover. Annals of Glaciology, Vol. 18 (in printing)

Ferguson, S. (1992): Joint observation of snow avalanches in Japan (Report of Activities). Report for the STA (pp.1-16). With two appendixes A and B; A: Safety Standards for Possession and Handling of Explosives. Chapter 296-52 WAC. Division of Industrial Safety and Health, Department of Labor and Industries, USA, pp.1-76 (Reference: 88pp.), B: Safety Standards for Ski Area Facilities and Operations. Chapter 296-59 WAC. Division of Industrial Safety and Health, Department of Labor and Industries, USA, 42pp.

Clayton, A., Decker, R., Richardson, C. and Abe, O (1992): Installation Design of the Avalanche Impact Pylon Facility, Alta, Utah. Proceedings of the ISSW Meeting.

（3）特許等（出願番号、出願年月日、発明の名称、発明者、出願人）
なし

（様式２）

Report of The Bilateral International Joint Research by Special Coordination Funds Promoting for Science and Technology (FY 1992)

1．Research Theme

A study on the release prediction and the impact force of surface dry snow avalanches

2．Implementing Institutes and Principle Researchers

Japanese Side:
National Research Institute for Earth Science and Disaster Prevention.
Science and Technology Agency
Tsutomu Nakamura

United States of America Side:
The University of Utah
Rand Decker

3．Total Expenditure (Yen)
¥4,947,000

4．Summary

Recent catastrophic avalanche disasters in Japan were caused by surface dry snow avalanches. The final goal of this study is to prevent these disasters. The aims of this study are to establish a method of artificial avalanche control that is based on meteorological and snow cover profile observations being carried out in the US and other countries, and to carry out a preliminary survey on the avalanching snow impact forces on a pylon.

The joint research products are summarized as follows;

1)Avalanching impact snow forces were measured and recorded on the six pressure sensors and on an accelometor fixed on a pylon, 6 m high. The data will be analyzed to know the interior motion of snow particles of the avalanching snow. The avalanching snow was either naturally released or artificially released. The detailed analyses have been carried on.

2)The movement of a snow avalanche released artificially by the aid of a dynamite thrown from a helicoptor was recorded in a video camera and a still camera.

3)A house destroyed by a natural snow avlanche was surveyed in relation between the avalanche and the structure of the housing, especially in its shape and the degree of fracture, as well as the amount of the debris. The debris of an artificially released snow avlanche was surved, too.

4)Snow pit observations were carried out. Snow-ball making experiments were conducted, too.

5)Experimental tests of an air gun explosion for the release of avalanches were carried out.
6)Part of the analyzed data of the joint researches was presented at the IGS Symposium held at Nagaoka, in 1992.
7)At the Utah-Avalanche Center, the activities of the Center including the usage of the meteorological and snow data, and how to forecast the avalanche danger were introduced, and discussions on them were done between Japan and US researchers. These data were used at an upper guard station for researchers to make an action-plan in each day.
8)Probable "Joint research projects between USA and JAPAN were discussed with Professors R. Decker, N. Fukuta, Utah U., and J. Lyon, Ohio State U.
9)A lecture entitled "Predicting snow stability with weather data" by an invited foreign researcher Dr. Sue Ferguson (stayed Jan. 11 - Jan. 31, 1993) was held on January 25, 1993 at Nagaoka to which about 30 people attended. Two joint observations were carried out at Mts. Ohkenashi and Tanigawa(Tenjin-taira), and "Rain on Snow Disasters" as well as the snow avalanche disaster reduction were discussed among Japanese and the USA researchers.

5. Publications

Nohguchi, Y. (1993): Horizontal heterogeneity of snow cover. Annals of Glaciology, Vol. 18 (in printing)

Ferguson, S. (1992): Joint observation of snow avalanches in Japan (Report of Activities). Report for the STA (pp.1-16). With two appendixes A and B; A: Safety Standards for Possession and Handling of Explosives. Chapter 296-52 WAC. Division of Industrial Safety and Health, Department of Labor and Industries, USA, pp.1-76 (Reference: 88pp.), B: Safety Standards for Ski Area Facilities and Operations. Chapter 296-59 WAC. Division of Industrial Safety and Health, Department of Labor and Industries, USA, 42pp.

Clayton, A., Decker, R., Richardson, C. and Abe, O. (1992): Installation Design of the Avalanche Impact Pylon Facility, Alta, Utah. Proceedings of the ISSW Meeting.

6. Remarks

海外出張報告

①試験研究課題

乾雪表層雪崩の発生予測とその衝撃力に関する研究

（個別重要国際共同研究）

②氏名

中村　勉　（なかむら　つとむ）

阿部　修　（あべ　おさむ）

納口恭明　（のうぐち　やすあき）

岩波　越　（いわなみ　こゆる）

③所属機関名

科学技術庁防災科学技術研究所長岡雪氷防災実験研究所（中村、納口、岩波）

科学技術庁防災科学技術研究所新庄雪氷防災研究支所（阿部）

④滞在期間

平成５年２月　５日～２月２０日（中村）

平成５年２月　５日～２月１３日（阿部）

平成５年２月１４日～３月　６日（納口、岩波）

⑤在外試験研究機関名

アメリカ合衆国農務省林野庁ワサッチ・キャッシュ国立森林公園

国立雪崩センター

National Avalanche Center, Wasatch-Cashe National Forest,

Forest Service, U.S. Department of Agriculture

アメリカ合衆国ユタ大学工学部土木工学科

Department of Civil Engineering, College of Engineering,

University of Utah

⑥実施した試験研究の内容及び成果

１）雪崩の走路上にある人工構造物に加わる雪崩の衝撃力を知り、雪崩の内部構造を探るため、夏の無雪時に設置した計測機器（加速度計、荷重計、圧力計）の作動を改良し、これらが付加されたパイロン（測定用杭）で雪崩の衝撃力の測定及び記録を行った。自然及び人工両方の雪崩による衝撃力のデータを得る

ことができ、現在解析中である。

2）アメリカ側がヘリコプター上からダイナマイトで発生させた人工雪崩を見学し、ビデオ及びスチルカメラで雪崩の運動を撮影した。

3）自然雪崩による災害家屋及び堆積物の調査を行った。また大規模な人工雪崩跡の調査を撮影等により行った。

4）雪崩の発生条件を考慮した積雪断面観測ならびに発生機構に関わる雪の造粒実験を行った。

5）エアガンを用いた人工雪崩発生装置の実験を見学し、その有効性について議論した。

6）雪崩予報センターを見学し、雪崩予報のための気象・降積雪データの利用方法、予報の発表方法の説明を受けた。実際に宿舎の端末装置でこの情報を毎日利用した。

7）ユタ大学の R. Decker助教授、N. Fukuta教授、オハイオ州立大学の J. G. Lyon助教授と将来の研究について意見交換をした。

⑦試験研究に役立った試験研究機関の設備環境等

・宿舎には避難小屋を兼ねている合衆国林野庁のアッパー・ガード・ステーションを利用することができた。集中暖房で常時湯を使えて快適な生活が送れた。

・パイロンを設置したアルタ・スキー場のスキー・パトロール員の皆さんの様々な協力を受けることができた。

⑧所感、今後在外研究を行う者に参考となる事項

・電話回線で雪崩予報センターと結ばれたアッパー・ガード・ステーションのパーソナル・コンピュータで、天気図、天気予報、雪崩予報、降積雪データを見ることができ、非常に役立った。こういった情報の利用が、近い将来日本でも可能になることが期待される。

・野外観測を行ううえで、特に健康に留意すべきであることを痛感した。

海外出張を容易にして下さった関係各位に厚く御礼を申し上げる。