沿道環境を考慮した吹雪量推定技術に関する研究

Study on Techniques to Estimate Snow Transport with Consideration to the Environment of Roadside Areas

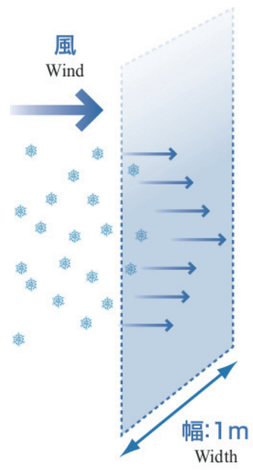
吹雪に起因した立ち往生車両の発生を予防軽減していくためには、道路通行止めの判断や除雪計画などの道路管理をより適切に行って行くことが重要です。このためには道路管理の判断支援に資する、沿道環境（吹走距離）に応じた吹雪量及び吹きだまり予測技術が重要です。本研究では、吹きだまり発生などに大きく寄与すると考えられる、吹雪量の推定技術の高度化を目指しています。

Appropriate road management activities, including timely judgments for road closures and appropriate planning for snow removal, are important for preventing and reducing the number of vehicles stranded in snowstorms. To carry out appropriate road management, it is important to have techniques that support decision-making on road management activities. Such supporting techniques include one for forecasting the snow transport and the amount and distribution of snowdrifts on roads. The fetch, on which the snow transport and the amount and distribution of snowdrifts depend, differs according to the roadside environment. This study aims at greatly improving a technique for estimating snow transport, which is considered to be an important factor contributing to snowdrifts.

吹雪量とは
What is snow transport?

吹雪量（kg/(m･h)）とは、風向に直行する単位幅を単位時間に通過する飛雪粒子の質量と定義されています（図１）。吹雪量は、ネット式吹雪計やスノーパーティクルカウンター(SPC)を用いるなど様々な方法で計測されています（図２、３）。しかし、このような方法で吹雪量を広域で連続計測することは難しいため、気象庁などで全国的に観測されている気温、降水量、風向風速などの気象データとは異なり、一般的には計測が行われていません。

Snow transport (kg/(m·h)) is defined as the mass of snow particles passing a unit width perpendicular to the wind direction per unit time (Fig. 1). Snow transport measurements have been done in various ways, including by net-type blowing-snow trap meters and snow particle counters (SPCs) (Figs. 2 and 3). However, continuously measuring the snow transport in a wide area using these devices is difficult. Therefore, snow transport measurement has not been among the routine measurements of general weather data (e.g., air temperature, precipitation, wind direction, and wind speed) done nationwide by the Japan Meteorological Agency.



▲図1 吹雪量
Fig. 1 Snow transport

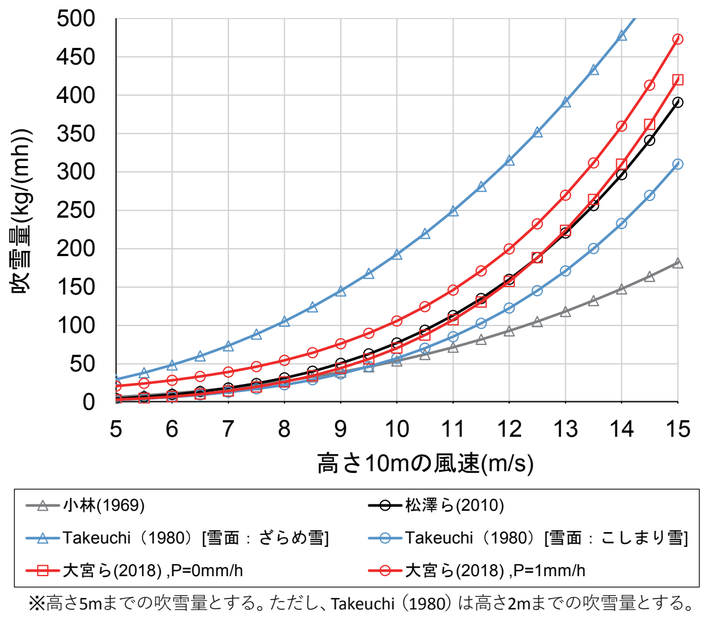
▲図2 ネット式吹雪計による計測状況
Fig. 2 Measurement using a net-type blowing-snow trap meter

▲図3 スノーパーティクルカウンター（SPC）による計測状況
Fig. 3 Measurement setup using an SPC

既往の吹雪量推定手法とその課題
Existing techniques for estimating snow transport, and their problems

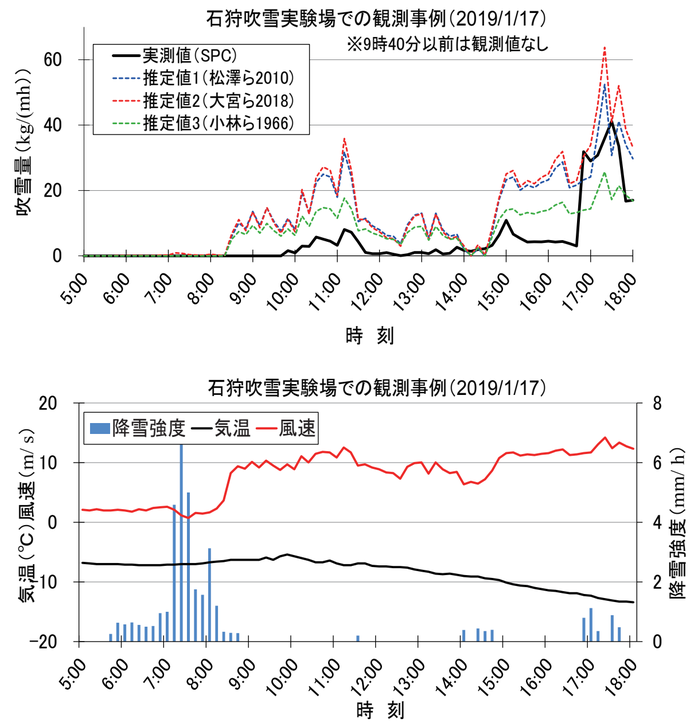
吹雪量は一般的には計測されていないため、気象データから推定されています。これまでに、吹雪量は風速の増加に伴って指数的に増加することが明らかとなっており、実測の吹雪量と風速から求めた経験式が多く提案されています（図４）。しかし、同じ風速であっても経験式の違いによって推定値には大きな差があるほか、実測の吹雪量と乖離が生じる場合があります（図4、５）。

Snow transport is estimated from commonly available weather data because it is not generally measured. It has been clarified that snow transport increases exponentially with increase in wind speed. Many empirical formulas obtained from the measured snow transport and the wind speed have been proposed (Fig. 4). However, the estimated values for a given wind speed differ greatly according to the formula used. The estimated values sometimes deviate from the measured ones (Figs. 4 and 5).



※高さ5mまでの吹雪量とする。ただし、Takeuchi（1980）は高さ2mまでの吹雪量とする。

▲図4 風速と吹雪量の関係（経験式）
Fig. 4 Relationship between wind speed and snow transport (empirical formula)



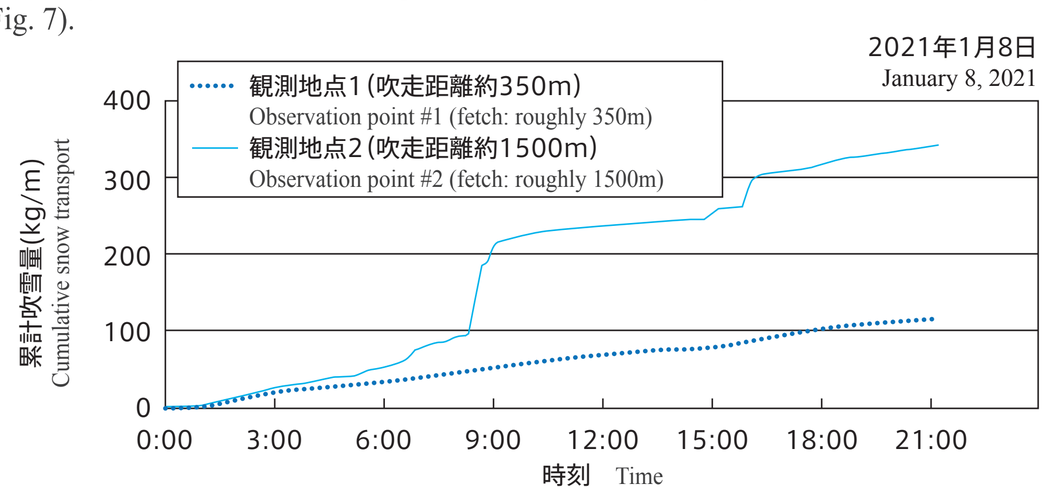
▲図5 吹雪量の実測値と推定値の比較事例
Fig. 5 Example of a comparison between measured and estimated snow transport

吹雪量と吹走距離・気象条件との関係
Relationship between snow transport and the fetch or weather conditions

吹雪量は吹走距離（吹雪の発生地点からの距離）が長くなるとともに増加することが確認されていますが、その関係は明確にされていません。また、吹雪量は風速以外にも降雪量や雪質に影響を及ぼす気温などの条件によっても変化すると考えられますが、その影響は明確にされていません。そこで、吹走距離の異なる地点で吹雪量を実際に観測し、吹雪量と吹走距離及び気象条件との関係について調査を行っています（図６）。2021年1月8日の吹雪時に観測した結果では、風上側の林縁からの吹走距離が約350mの地点に比べ吹走距離約1500mの地点で風速や累計吹雪量が大きい傾向が見られました（図７）。

The snow transport was found to increase with increase in the fetch (a distance from a point at which blowing snow occurs to a point downwind); however, the relationship between these has not been clarified. The snow transport is considered to change according to not only the wind speed but also to other weather conditions, including the air temperature, which affect the snowfall and the snow quality. The relationship between the snow transport and the air temperature has not been clarified, either. We have investigated the relationship between the snow transport and fetch and the weather conditions by observing snow transport at points that differ in fetch (Fig. 6). We conducted these observations during a snowstorm on January 8, 2021. The wind speed and cumulative snow transport tended to be greater at a point with a fetch of roughly 1500m from the windward edge of the woods than at a point with a fetch of roughly 350m from the windward edge of the woods (Fig. 7).

▲図6 吹走距離が異なる地点での吹雪量観測（北海道弟子屈町）
Fig. 6 Snow transport observation at locations with different fetches (Teshikaga Town, Hokkaido Prefecture)



▲図7 吹走距離の異なる地点での累計吹雪量の観測事例
Fig. 7 Observation of cumulative snow transport at locations with different fetches