The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLVIII-M-3-2023
ASPRS 2023 Annual Conference, 13–15 February & 12–15 June 2023, Denver, Colorado, USA & virtual

INFLUENCE OF LINEAR MIXING ON CONTAMINATED SNOW SPECTRAL SIGNATURES

Balla Vivek, P.K. Garg

Civil Engineering Dept., Geomatics Engineering, IIT Roorkee, Uttarakhand, India - b_vivek@ce.iitr.ac.in, p.garg@ce.iitr.ac.in

KEY WORDS: Field spectro-radiometer, Snow Contamination, Linear Spectral Mixing, Hyperspectral analysis.

ABSTRACT:

Experiments using an SVC spectroradiometer ranging from 0.35 to 2.5 µm are being conducted in the field as part of the current research in order to gain a better understanding of how contamination affects spectral characteristics. Utilizing a spectroradiometer (0.35–2.5 µm), studies were carried out in the field to determine the linear mixing of snow pollutants (such as coal, ash, wood, and soil) with snow in terms of concentration of contaminants in order to simulate and comprehend the spectrum response of real-world scenarios. Present studies contribute to mapping snow and contaminated snow pixels in remote sensing RS data based on of linear mixing, and to identifying and discriminating between different types of snow contaminants in respect of linear mixing manner, via appropriate wavelength selections for future studies.

1. INTRODUCTION

Generally, the snow cover has a great influence on the hydrological cycle and global climatic change. In addition, it is considered as a significant component of the cryosphere and also indispensable variable in the field of hydrological science. The melting and accumulation of snow is quite responsible for redistribution of water resources. Additionally, it contributes to the freshwater resources in the area of semi-arid and arid region. The characteristic of snow reflectance is used in the simulation of hydrological and climatic characteristics. It also plays a vital role in the detection of flood and drought, snowmelt runoff simulation and forecasting of weather. Himalaya, the home of India's main river sources and the nation's source of sustenance, is experiencing a steady decline in glaciers, resulting in a scarcity of freshwater. The Himalayan mountains are home to significant natural resources of frozen fresh water; these resources are found in the form of snow. The tropics, mountainous regions, and valley types predominate among these snow-covered places, and many of them are cluttered with debris. Seasonal snow cover is an important factor in the production of hydropower, the storage of water, the conduct of weather research, the prediction of avalanches and floods, and a great number of other activities that make a contribution to the economy of the nation (Negi et al. 2006). Because the mountains that produce snow are subject to the severe wrath of nature, such as frequent forest fires, storms, and blizzards, and especially atmospheric aerosols, such as haze, dust, and industrial pollutant due to this snow is becoming contaminated with ash, coal, wood, dirt, and other impurities as a result, if these contaminants are mixed with the ice grains, they will be more effective in reducing the snow's albedo. A small amount of contamination in the snow cover that is disseminated linearly through larger particle sizes can have a significant impact on the albedo of the snow (Balla et. al., 2023). With its increased concentration of contaminants, snowmelt has been shown to have a negative impact on water quality. For the study and prediction of contaminants in snow cover, it is important to know how the snow is managed and what kinds of contaminants are in it. The melting of snow is an important source of freshwater in many parts of the world, notably in mountainous regions and places that are located at high latitudes. When snowfall accumulates over the course of the winter months, it serves as a natural reservoir by holding water. This water can be released when the snow melts in the spring and summer months. This snowmelt is needed for irrigation, energy, and drinking water for homes. Since snowmelt is a crucial source of freshwater for many places, contaminants in snow can have a major effect on water quality and availability. Due to presence of contaminants in snow, when snow melts, it can release toxins into streams, rivers, and lakes, where they could pose a threat to aquatic life and human health. The toxins that are present in these places have the potential to be carried downstream in a short amount of time, thereby contaminating a broad area. Therefore, it is essential to gain a better understanding of what types of contaminants present in snow. The spectral features of snow can provide useful information on the snow's physical and chemical properties, which can help in understanding the rate of snow melts and type of contaminant in it. Snow's unique diagnostics characteristics between spectral ranges (0.35-2.5 µm) (Negi et al., 2006) make hyperspectral remote sensing vital to monitoring Himalayan snow cover. In most cases, these diagnostic features have the impression of having a relatively narrow spectral range. In the visible section of the electromagnetic spectrum, fresh snow reflects around 80-90% of the incoming sunlight (Singh et. al., 2010); this percentage of reflection decreases as the wavelength of the incident light becomes longer. In comparison to the reflectance properties exhibited by fresh snow, snow that has been contaminated with substances such as ash, coal, wood and soil demonstrates a reduction in reflectance primarily in the visible region of the electromagnetic spectrum (Garg et. al., 2020). However, this contamination has a comparatively lesser impact on the longer region.

2. STUDY AREA

This research will focus on the Koti, Sissu, and Manali regions of the lower Himalayas because contaminated snow is prevalent in the lower Himalayas due to the moderate temperature (in comparison to the upper Himalayas).

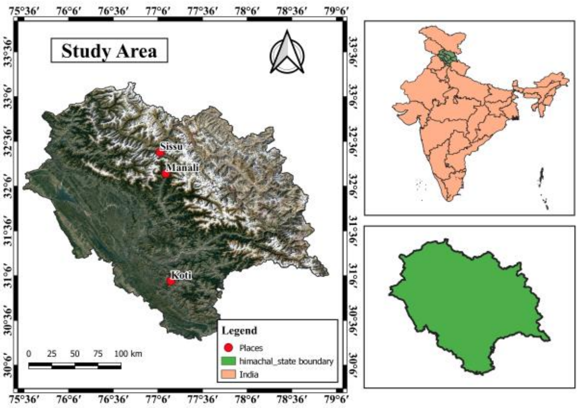

Figure 1. Study Area

The Manali, Koti, and Sissu regions of Himachal Pradesh (India) were visited in February 2022 to collect the reflectance of pure snow and contaminated snow spectra using a svc Spectro-radiometer.

3. METHODOLOGY

The spectral signature over the target of interest is collected using a fibre optic cable assembly spectral-radiometer of approximately 1.5 m in length keeping FOV (Field of view) of 25^0 and viewing zenith angle of 0^0. For this experiment, the distance of the optical fibre from the snow surface was held constant at 51 cm, yielding an area of field of view (FOV) of approximately 401 cm^2 that makes a circle of diameter of 22.6 cm.

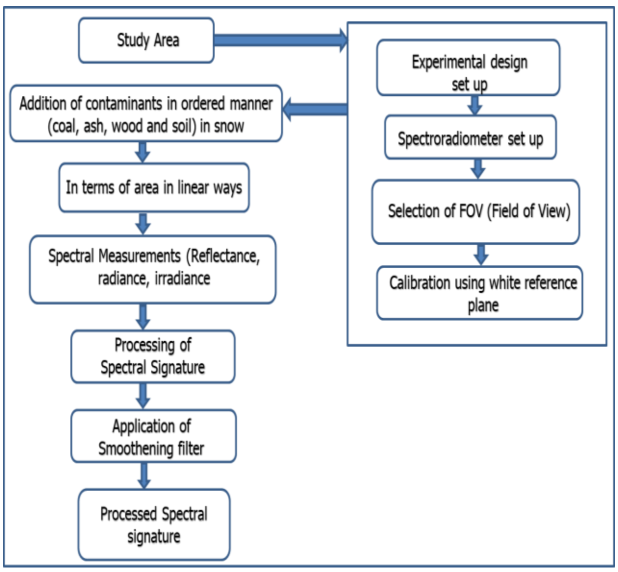

Figure 2. Methodology

After that reflectance and radiance readings were calibrated with the white reference panel which aids in the avoidance of saturation in the signature problem (Shekhar et al., 2019). The area of the FOV on the snow surface was divided into 25% areal pieces and 2.5 gm of contaminant was distributed over the area and spectra is collected, Similarly, the contaminant was gradually spread into these areas until 100% of the FOV area was covered, and spectral measurements were taken in the linear ways as per the definition of Van der Meer and De Jong, 2011 (a mixture is linear if the materials in the field of view are optically split in a way that prevents multiple scattering between the components, photons that reach the sensor only interact with one substance).

The instrument is controlled by a PDA that remotely links the SVC Spectro-radiometer, and displays and stores data. In order to decrease the influence of other parameters, this experiments were conducted at the same time and location under a clear sky. Each experiment was conducted four to five times. The experiments were conducted on level ground, and each set of observations lasted around 3 minutes. For the contaminated-snow reflectance, soil, ash, and wood and coal contamination were measured respectively.

.

4. RESULTS & DISCUSSIONS

From figure 3. in the visible portion of the electromagnetic spectrum, snow reflects approximately 96%–98% of the total electromagnetic energy that is incident on it. When moving from the visible portion of the spectrum to the infrared region, the reflection from snow becomes less obvious as one gets further away from the visible zone. In a snow spectrum, it is seen that the values of

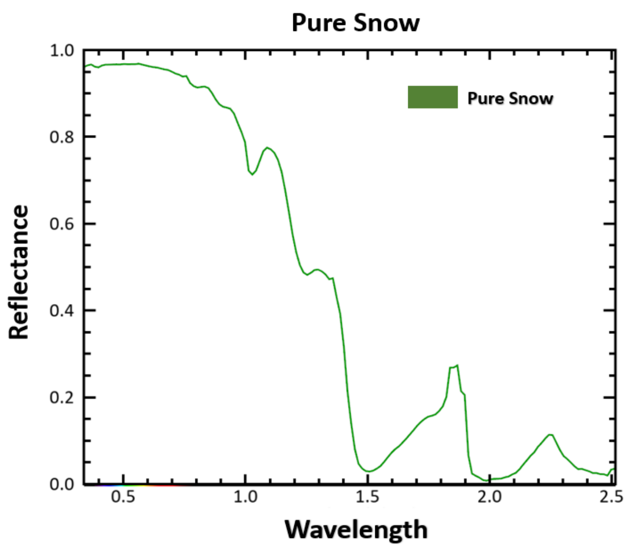

Figure 3. Spectra of pure snow

reflectance is frequently quite high in the visible portion of the spectrum, with the maximum values occurring between 0.50 and 0.53 µm, which is where the reflectance varies from 96 to

100% of the total incident electromagnetic radiation on snow. Moreover, several peaks can be seen between 1.8 and 2.25 µm in the spectra and it follows a declining pattern in the near-infrared, with the steepest slope between 1.2 and 1.5 µm. Absorption bands in snow can be divided into two categories: main absorption bands, which occur near wavelengths of 1.0, 1.5, 2.0, and 2.5µm and minor absorption bands occur near to wavelengths of 0.8 and 0.9 µm and these absorption bands occurrence is mainly due to liquid water and water vapor.

Liquid water has relatively high absorption at near-infrared wavelengths, typically between 1 and 1.4 µm, and is responsible for the majority of the primary absorption bands. The presence of liquid water in the snowpack causes it to absorb a substantial quantity of near-infrared light, which leads to decreased reflectance in this wavelength band and influences the reflectance spectra in the region of the shortwave infrared spectrum, which is typically located between 1.4 and 2.5 µm because of its molecular vibrational patterns liquid water shows strong absorption bands in this region and radiation in these bands is also absorbed by water vapour in the atmosphere. This can cause dips in absorption or less reflection in the NIR and SWIR regions of the snow reflectance spectrum, as well as in the minor absorption bands near 0.8 and 0.9 µm. So, both sorts of bands have the effect of reducing the amount of light that snow reflects. It is also noted that the wavelength ranges from 0.3 to 0.9 µm, 1.1 to 1.4 µm, 1.6 to 1.9 µm, and 2.1 to 2.4 µm are the "atmospheric windows" that are not influenced by the absorption.

From figure 4, it is observed that when snow is contaminated with ash the reflectance decreases across the whole electromagnetic spectrum and the peak in the reflectance was found to have moved to longer wavelengths, which appeared initially in the visible region for the pure snow spectra. When compared with spectra of pure snow, the decrease in spectral reflectance that occurs when 100% of an area is contaminated with ash is more pronounced (0–87%) in the visible wavelengths at 0.35µm, despite the fact that these decreases occur at the different magnitude, nonetheless, an increase in reflect-

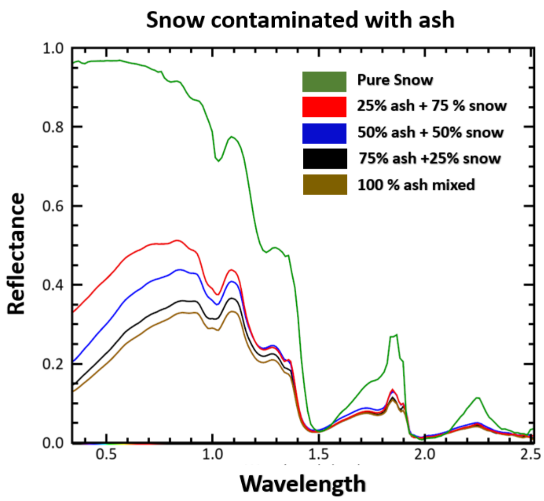

Figure 4. Spectra of Snow contaminated with ash

ance was seen at 1.1 µm for areas 100 % area contaminated with ash than 75% area contaminated with ash spectra.

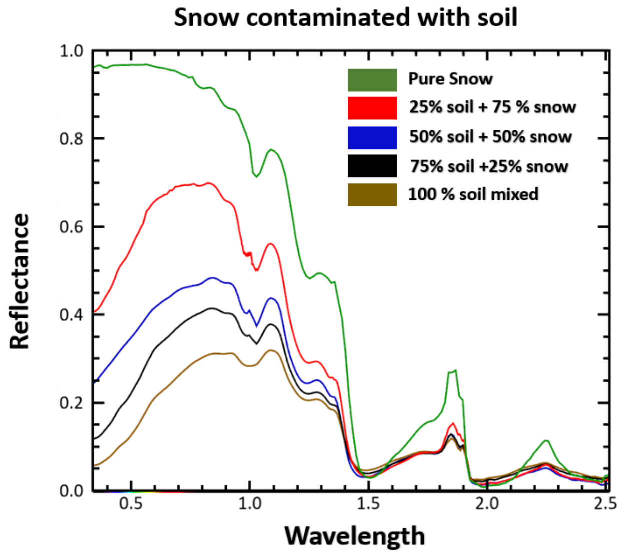

Figure 5. Spectra of Snow contaminated with soil

From figure 5, in the event of soil contamination with soil, the reflectance of the soil component is greater than that of snow for wavelengths from around 1.45 µm onwards and also the peak in the reflectance of the soil contaminated snow was found to have moved to longer wavelengths, which appeared initially in the visible region for the pure snow spectra. When spectra of pure snow are compared to spectra of soil-contaminated snow, the drop in spectral reflectance (0–96%) is more noticeable at 0.35µm, where 100% of an area is contaminated with soil. The visible region experiences the greatest decrease in reflectance as the proportion of snow decreases from 100 to 50 %. After 50 %, an increase in soil area has a negligible effect on reflectance.

From figure 6, it was noticed that in the visible part the peak is almost flattened as coal contamination dominates over the snow and it was discovered that the peak in the reflectance of coal contaminated snow had shifted to longer wavelengths, which initially appeared in the visible region for pristine snow spectra and the decrease in spectral reflectance (0–87%) is more evident at 0.35 µm when an area is contaminated with coal to a hundred percent.

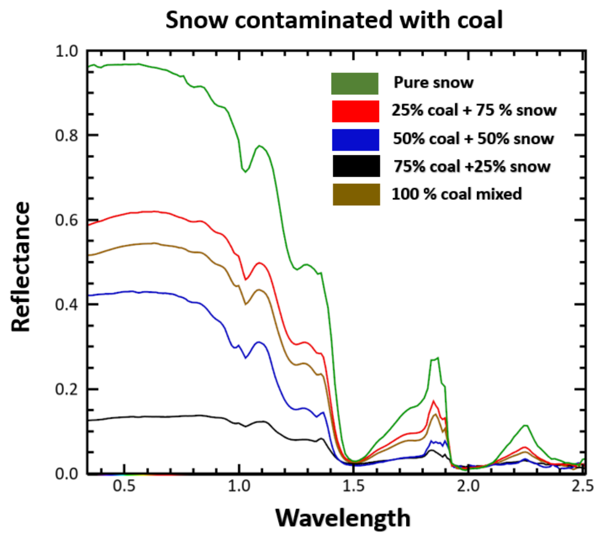

Figure 6 . Spectra of Snow contaminated with coal

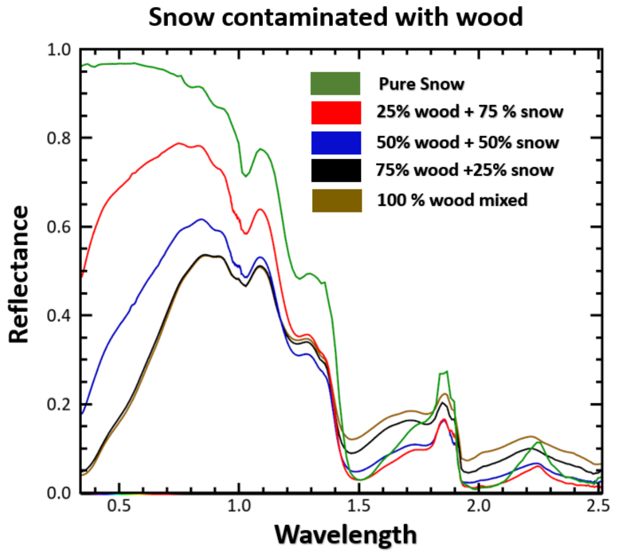

Figure 7. Spectra of Snow contaminated with coal

From Figure 7. it is observed that reflectance increases in the SWIR region as the wood area increases from 0 to 100%. When pure snow spectra are compared to wood contaminated snow spectra, the decline in spectral reflectance (0-96%) is more and the peak in reflectance, originally seen in the visible region for pure snow spectra, was found to have moved to longer wavelengths in wood-contaminated snow also.

Table 1. % drop in reflectance as the contaminants(ash & coal) increases

S.no	% Area of contamination (22.6 cm diameter)			Reflectance peak at 0.35µm.	% drop in Reflectance at 0.35µm
	Snow	ash	coal		
1.	100	-	-	0.990	0%
	75	25	-	0.337	65%
	50	50	-	0.213	78%
	25	75	-	0.135	86%
	-	100	-	0.122	87%
2.	100	-	-	0.990	0%
	75	-	25	0.590	40%
	50	-	50	0.517	48%
	25	-	75	0.421	57%
	-	-	100	0.126	87%

Table 2. % drop in reflectance as the contaminants(soil & wood) increases

S. no	% Area of contamination (22.6 cm diameter)			Reflectance peak at 0.35µm.	% drop in Reflectance at 0.35µm
	Snow	soil	wood		
1.	100	-	-	0.990	0%
	75	25	-	0.412	58%
	50	50	-	0.252	74%
	25	75	-	0.121	87%
	-	100	-	0.059	94%
2.	100	-	-	0.990	0%
	75	-	25	0.513	48%
	50	-	50	0.194	80%
	25	-	75	0.050	95%
	-	-	100	0.042	96%

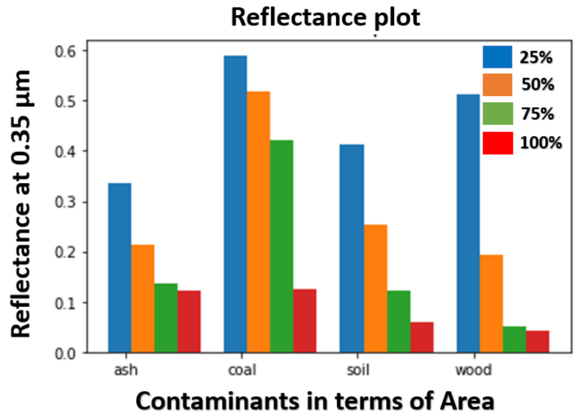

Figure 8. Variation in reflectance values as contamination increases at 0.35 µm.

Table 1 & 2 shows how the % drop in reflectance in the visible region, mostly at 0. 35 µm, is decreasing as the contamination in the snow increases. And from figure8. Showing how the reflectance values of snow contaminated with ash, coal, soil, and wood decreases as the percentage of the contaminated area increases.

5. CONCLUSION & FUTURE SCOPE

The study found that when coal, wood, ash, and soil are mixed with snow, the reflectance drops by a lot, and the peak of the highest reflectance changes from the visible spectrum to the NIR spectrum. But when contaminants like wood are present, the reflectance goes up in the SWIR region as the amount of wood contamination goes up. In the visible part, the peak almost flattens as coal contamination takes over the snow surface, and the reflectance goes up at 1.1 µm when 100% of the area is covered with ash instead of 75%. Also, the Spectral Library for new snow, snow with wood, snow with coal, snow with ash, and snow with soil is done.

This study helps mapping snow in remote sensing data based on linear mixing using hyperspectral images for researchers and also water managers can manage and protect water resources by monitoring and analyzing these spectral features.

REFERENCES

Balla, V., & Garg, P. K., (2023). "Emerging Trends in the Mapping of Contaminated Snow Using Hyperspectral Images and Field Spectra". , Emerging Trends, Techniques, and Applications in Geospatial Data Science (pp. 220-243). IGI Global. https://doi.org/10.4018/978-1-6684-7319-1.ch011

Chander shekhar., Sunita, S., Negi, Akshay, G., Snehmani., (2019) "Effect of linear and non-linear mixing on hyper-spectral signatures of snow in the optical region (350–2500 nm)", Geocarto international, 34:6, 644-663, DOI: 10.1080/10106049.2018.1434683.

Garg, P.K., "effect of contamination and adjacency factors on snow using spectroradiometer and hyperspectral images", hyperspectral remote sensing theory and applications, 2020, pp. 167–196.

Kulkarni, A.V., Srinivasulu, J., Manjul, S.S., And mathur, P., 2002a, "field based spectral reflectance to develop NDSI method for the snow cover", journal of indian society of remote sensing, 30, pp. 73–80.

Negi, HS., Thakur, N.K., Ganju, A., Snehamani, "monitoring of gangotri glacier using remote sensing and ground observations", journal of earth system science, 121, pages855–866 (2012).

Negi, H.S., Kulkarni, A.V., Prajapati, R.P., Singh, S.K. and Sharma, J.K., 2006, "Effect of contamination and mixed objects on snow reflectance using spectroradiometer".

Singh S.K., Chaudhary B.S., Kulkarni A. V., "Hyperspectral analysis of snow reflectance to understand the effects of contamination and grain size", Annals of Glaciology, May 2010.

Van der Meer, FD., De Jong, SM., 2011. "Imaging spectrometry: basic principles and prospective applications". Dordrecht: Springer Science & Business Media.