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SPECTRA OF THE MONTH

EXPLORING SNOW ALBEDO THROUGH SPECTROSCOPIC ANALYSIS

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INTRO

BACKGROUND OF APPLICATION

During the summer months, we are often cautioned to prevent the harmful effects of overexposure to UV rays by wearing sunscreen to protect our skin, hats to protect our head, neck, and scalp, and sunglasses to protect our eyes. These precautions do not usually carry over to winter, where the greater concern is keeping our bodies warm and retaining heat in the much colder weather. Despite this, a similar damaging condition can occur during both seasons: photokeratitis, or sunburned eyes. While this is caused by longer daytimes during the summer, the condition can be caused during the winter by prolonged exposure to light from highly reflective snow. This reflective property is quantified as albedo, which is specifically a ratio of irradiance to radiosity or radiant flux. This term has a range of 0 to 1, with 0 being a surface that absorbs all incident radiation and 1 being a surface that reflects all incident radiation. For reference, Earth as a whole has an average albedo measurement around 0.3, while the Moon has an average albedo of 0.12. The albedo of snow can be highly variable, with values as high as 0.9 for fresh snow and as low as 0.2 for dirty snow. This value, along with peaks in the measured spectra, can be used to determine the age of snow, if it is melting, and if other particles and molecules are present. Such results are particularly useful when studying polar ice caps for effects from climate change.

This experiment aims to measure the albedo of snow utilizing our spectrometers. To obtain this value, we measured irradiance and radiant flux of the sample, which were used to calculate albedo. For comparison, we also performed pure reflectance measurements to see how closely they resembled the final albedo values. Because the typical albedo measurements cover a wavelength range of 300-3000 nm, we utilized both a UV/VIS and NIR spectrometer for these measurements. All snow measurements were performed just outside our office a day after moderate snowfall.

DESCRIPTION OF SPECTROSCOPY SETUP

The setup for this experiment (Figure 1) utilized two of our spectrometers, the first of which was our NIR512-2.5-HSC-EVO. Specifically for measurements in the NIR range up to 2.5 µm, this model pairs our high-sensitivity optical bench with next generation electronics for exceptional performance, including 0.54 ms/scan sample speed and integration times as fast as 10 µs. The AvaSpec-NIR512-2.5-EVO is equipped with our trusted InGaAs (Indium-Gallium-Arsenide) array detector and our ultra low-noise electronics board with both USB3.0 and Giga-Ethernet connection ports onboard. Additional features include multiple grating and replaceable slit options, as well as digital and analog I/O ports, which can be used to control the shutter or pulse of connected light sources and the gain setting of the spectrometer, with either High Sensitivity or Low Noise. The instrument used in this experiment had a wavelength range of 1000-2500 nm and a 25-micron slit installed.

FIGURE #1 Experimental setup for snow sample measurements. Each spectrometer was irradiance calibrated with the attached fiber and cosine corrector. During the measurements, the fiber was pointed at the snow samples at an angle to measurement incident reflectance.

The second instrument used was our AvaSpec-NXS2048CL, more commonly known as the NEXOS™. This compact instrument is the next-generation photonics backbone spectrometer, designed to empower a wide range of applications in various industries. This device is built using our new semi-automated manufacturing technique that ensures higher levels of consistency and reproducibility unit-to-unit. The Nexos offers USB2.0 communication as well as RS232 and SPI communication protocols, a CMOS linear array detector, ultra-low stray light as low as 0.1%, and a signal/noise ratio of 375:1. Furthermore, this spectrometer can be customized with a wide range of gratings (13 total available) and the replaceable slit option is now standard for non-OEM units, which provides even more flexibility for a variety of application needs. The unit used in this experiment was optimized for the UV and visible range with a 200-1100 nm wavelength range.

Because the measurements were performed outside using the Sun as a light source, no additional light source was needed. Other accessories used for this experiment included two 600-micron core fiber optic cables and two cosine correctors, one of each for each spectrometer.

DESCRIPTION OF METHODOLOGY

Because of a recent snowfall in our neighborhood, we were able to measure the snow outside of our office that had accumulated. Measurements were taken at an angle and care was taken to avoid any shadows in the measurements. A laptop was used to take the measurements outside in a more portable manner, though a long extension cord was needed to power the NIR512-2.5-HSC-EVO. Two sample spots were measured using both the Nexos and NIR512-2.5-HSC-EVO, and two additional sample spots were measured with the Nexos alone due to ease of measurement with this instrument.

For data collection and analysis, we used two modes in AvaSoft, our proprietary software package. The first mode used was Reflectance mode. This mode is designed for reflection applications, where the reference measurement will report 100% and the dark measurement will report 0%. In this experiment, the Sun was measured and used as the reference. The second mode used was our Irradiance module, which is included in AvaSoft-All or available as a single add-on module. This mode was used to collect radiometric values including irradiance and radiant flux, and can also be used to measure photometric values, color, and spectral peak values. Because radiant flux in AvaSoft is reported in µWatts rather than µWatts/cm2, an additional calculation was implemented to to convert the value by dividing by the area of the cosine corrector (1.952/π). For the NEXOS, we used an integration time of 25 ms and set averaging to 21. For the NIR512-2.5-HSC, we used an integration time of 125 ms and set averaging to 7. Integration time can be adjusted to increase or decrease the amount of light being measured at one time and affects the overall magnitude of the reported spectrum, and higher averaging provides more consistency between scans.

TEST DATA AND RESULTS

Displayed below are the reflectance spectra of the snow samples, along with a table of irradiance and radiant flux measurements with calculated albedo values. The UV/VIS and NIR measurements, while taken with two separate spectrometers, are color-matched for each sample spot for easier comparison between sample spots.

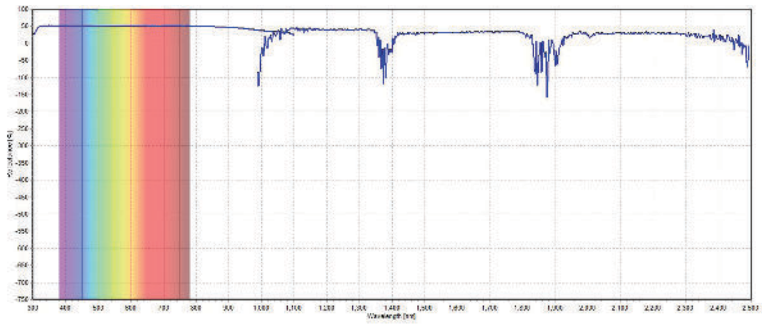

FIGURE #2: Reflectance spectra of Sample Spot 1.

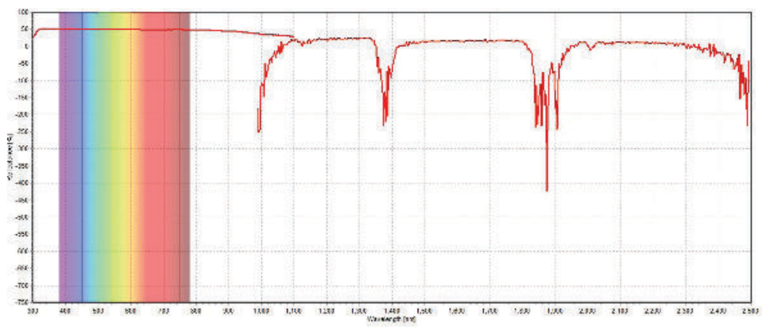

FIGURE #3: Reflectance spectra of Sample Spot 2.

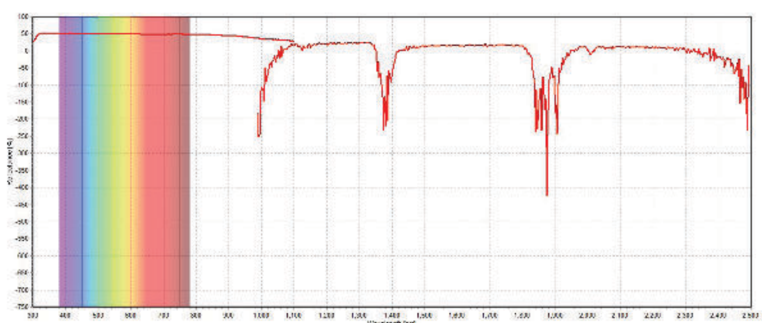

FIGURE #4: Reflectance spectra of Sample Spot 3

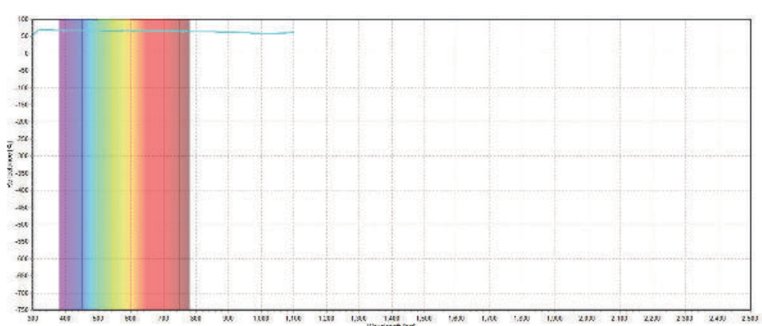

FIGURE #5: Reflectance spectra of Sample Spot 4.

TEST DATA AND RESULTS

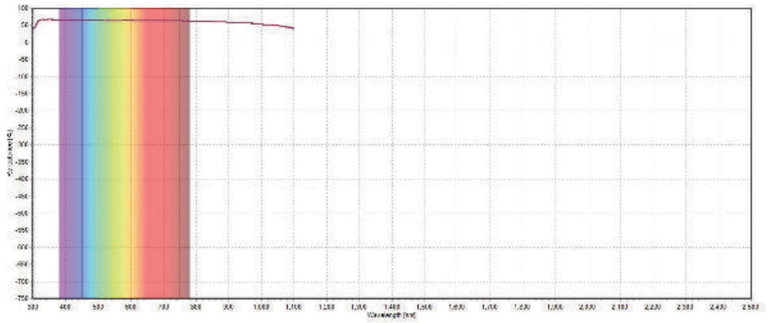

FIGURE #6: Reflectance spectra of Sample Spot 5.

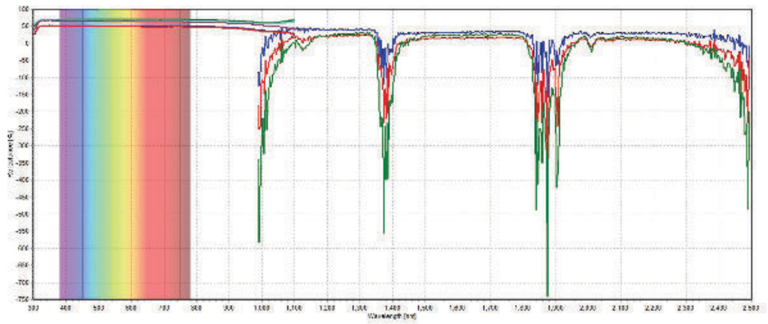

FIGURE #7: Reflectance spectra of all Sample Spots, shown together for comparison.

TABLE 1: RADIOMETRIC MEASUREMENTS OF EACH SAMPLE SPOT WITH CALCULATED ALBEDO:

Sample Spot	Irradiance (µWatt/cm^2)	Radiant Flux (µWatt/cm^2)	Albedo
UV/VIS Spot 1	46921.1470	49356.7529	0.9507
NIR Spot 1	2448.3980	2541.9074	0.9632
UV/VIS Spot 2	43817.7739	45491.2652	0.9632
NIR Spot 2	881.9700	915.6543	0.9632
UV/VIS Spot 3	64179.0401	66630.1702	0.9632
NIR Spot 3	12019.1051	12478.1395	0.9632
UV/VIS Spot 4	66288.2740	68819.9601	0.9632
UV/VIS Spot 5	60706.1581	63024.6517	0.9632

ANALYSIS

Analyzing the spectra, it seems that the UV/VIS range is relatively flat for all the measured spots. The upper end of this range (i.e., 1050-1100 nm) curved slightly down for Sample Spots 1 (Figure 2), 2 (Figure 3), and 5 (Figure 6), and curved slightly up for Sample Spots 3 (Figure 4) and 4 (Figure 5). Sample Spots 3, 4, and 5 showed overall higher reflectance compared to Sample Spots 1 and 2. Both of these differences correlated with higher total irradiance values, which makes sense due to the increased light. This did not, however, lead to an increased albedo value, as the radiant flux increased proportionally.

The NIR measurements did not show the same flat spectra. These spectra showed consistent valleys, or negative peaks, at wavelengths around 992 nm, 1380 nm, 1874 nm, and 2500 nm. While the locations were consistent, the magnitudes varied considerably, with Sample Spot 3 showing a valley with a reflectance value of -750% where Sample Spot 1 had a reflectance value around -150% at the same valley. While these differences once again did not correlate to a difference in albedo due to the proportional change in irradiance and radiant flux, there seemed to be a loose correlation between an increased total reflectance of the UV/VIS spectra and a decrease in the valley reflectance values of the NIR spectra. Further measurements would have to be taken to strengthen this relation. A graph of all the spectra together is included for comparison of all samples (Figure 7).

CONCLUSION

In conclusion, the present experiment highlights the use of spectroscopic analysis in determining the albedo of snow. Surprisingly, higher overall reflectance in the UV/VIS spectrum seemed to correlate with lower reflectance in the NIR spectrum, specifically at the valleys seen around 992 nm, 1380 nm, 1874 nm, and 2500 nm. The radiometric values showed almost identical albedo measurements for each sample spot, all measuring about 0.96 except for Sample Spot 1 in the UV/VIS range, which measured around 0.95. The AvaSpec-NIR512-2.5-EVO is a highly versatile NIR spectrometer with plenty of available options to match the bandwidth and requirements fitting your application. The AvaSpec-NXS2048CL is an ideal solution for OEM applications or for any measurements where a smaller instrument is preferred, such as the field work we performed for this study. Please contact Avantes for more information on the configuration that is best suited for your data collection.

CONTACT

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