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The index contains only those papers or abstracts received in time to be included in the volume. Numbers in parentheses (starting with 77-101) relate the papers in the volume to the order of their presentation and listing in the final program.

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SPECTRAL DIFFERENCES BETWEEN VHRR AND VISSR DATA AND THEIR IMPACT ON ENVIRONMENTAL STUDIES

Stanley R. Schneider
David F. McGinnis Jr.
National Oceanic and Atmospheric Administration
National Environmental Satellite Service
Washington D. C. 20233

BIOGRAPHICAL SKETCHES

Stanley R. Schneider received a B.S. (Cum Laude) in Geology from the City College of New York, subsequently serving on active duty for two years as an officer in the United States Army Corps of Engineers. He has worked for the National Academy of Sciences as an information technician and for the Department of the Navy as a computer programmer. Mr. Schneider is presently a hydrologist with the National Oceanic and Atmospheric Administration specializing in the application of satellite data to the solution of water resource problems. He participates in the United Stated Army Reserves where he is currently Executive Officer of the 955th Engineer Company (TOPO) (CORPS). Mr. Schneider is a member of the American Geophysical Union and the Society of American Military Engineers.

David F. McGinnis Jr. obtained his undergraduate education at the University of Delaware, receiving a Bachelor of Civil Engineering. Graduate work at the Pennsylvania State University led to a Master of Science Degree in Meteorology and a Doctor of Philosophy in Civil Engineering. Since 1971, Dr. McGinnis has been employed by the National Environmental Satellite Service of the United States Department of Commerce, where as a research hydrologist he develops hydrologic uses for environmental satellite data. He is a member of the American Society of Photogrammetry, the American Society of Civil Engineers, the American Meteorological Society and the American Geophysical Union.

ABSTRACT

A comparison is made between visible channel data from sensors on two different satellites, the VISSR on board SMS/GOES and the VHRR on board NOAA-4. The VISSR responds to a larger portion of the spectrum (0.55 - 0.75 um) than the VHRR (0.6 - 0.7 um). Manifestations of this spectral difference were found on imagery from the two sensors. Comparisons with respect to vegetation brightness, metamorphosed snow, water penetration, land-water interface and definition of snowcover on bare rock show that, in all five cases, the VISSR imagery exhibits known characteristics of near infrared imagery.

INTRODUCTION

The National Oceanic and Atmospheric Administration (NOAA) currently operates two different satellite systems, the NOAA system of polar-orbiting satellites and the SMS/GOES system of geostationary satellites. The polar orbiter used in this study is NOAA-4, the third in a series of improved TIROS operational satellites; the first, NOAA-2, was launched on October 15, 1972. The imaging system on NOAA-4 relevant to this study is the Very High Resolution Radiometer (VHRR). It provides daily coverage over the United States in the visible portion of the spectrum and twice daily coverage in the thermal infrared. Spatial resolution for both the visible and thermal infrared data is one kilometer at nadir.

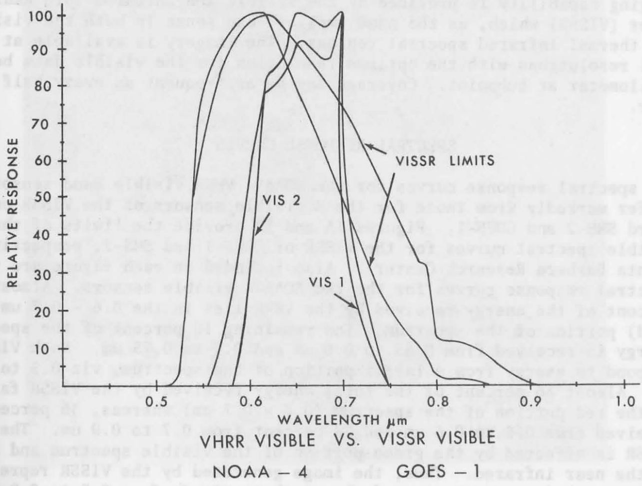

Figure 1a. Spectral response curves for NOAA-4 and GOES-1 VISSR.

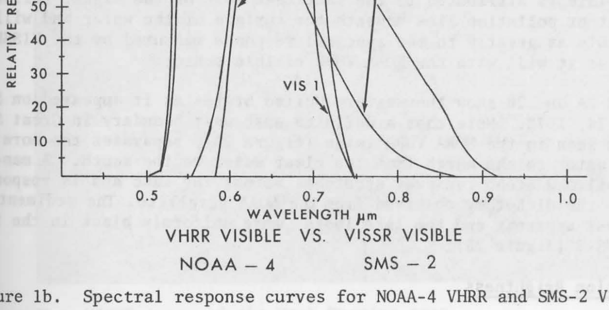

Figure 1b. Spectral response curves for NOAA-4 VHRR and SMS-2 VISSR.

The two SMS/GOES satellites currently operational, GOES-1 and SMS-2, are stationed over the equator at 75°W and 135°W longitude respectively. Imaging capability is provided by the Visible and Infrared Spin Radiometer (VISSR) which, as the name implies, can sense in both the visible and thermal infrared spectral regions. The imagery is available at several resolutions with the optimum resolution for the visible data being 1 kilometer at subpoint. Coverage may be as frequent as every half hour.

SPECTRAL RESPONSE CURVES

The spectral response curves for the NOAA-4 VHRR visible band sensors differ markedly from those for the 8 visible sensors of the VISSR on board SMS-2 and GOES-1. Figures 1A and 1B provide the limits of the visible spectral curves for the VISSR of GOES-1 and SMS-2, respectively (Santa Barbara Research Center). Also included on each figure are the spectral response curves for the two NOAA-4 visible sensors. Almost 90 percent of the energy received by the VHRR lies in the 0.6 - 0.7 um (red) portion of the spectrum. The remaining 10 percent of the spectrum energy is received from 0.55 to 0.6 um and 0.7 to 0.75 um. Both VISSR's respond to energy from a larger portion of the spectrum, viz 0.5 to 0.9 um. Almost 36 percent of the total energy received by the VISSR falls in the red portion of the spectrum (0.6 - 0.7 um) whereas, 36 percent is received from 0.5 to 0.6 um and 28 percent from 0.7 to 0.9 um. The VISSR is affected by the green portion of the visible spectrum and also by the near infrared. Thus, the image generated by the VISSR represents an integrated spectral view of the earth or clouds from 0.5 to 0.9 um.

IMAGE COMPARISONS

Water Penetration

The ability of satellite imagery to detect sediment and/or pollution occuring in water bodies is directly related to wavelength. Specht, et al., (1973) presented data showing the transmittance of various water bodies as a function of wavelength. Transmittance was found to drop precipitously to zero at 0.7 um. Since as much as 30% of the spectral response for VISSR visible imagery lies outside 0.7 um, water bodies will usually appear darker and less reflective in images from the SMS/GOES. This is attributed to the fact that most of the higher reflecting sediment or pollution lies beneath the surface of the water and will not contribute as greatly to the spectral response measured by the VISSR sensor as it will with the NOAA VHRR visible sensor.

Figures 2A and 2B show the western United States as it appeared on September 24, 1975. Note that a definite east-west boundary in Great Salt Lake as seen in the NOAA VHRR image (figure 2A), separates the more turbid water to the north from the clear water to the south. A manmade railroad stone causeway stretches across the lake and is responsible for the dichotomy observed from the NOAA satellite. The sediment is much less apparent and the lake looks more uniformly black in the image from SMS-2 (figure 2B).

Vegetation Brightness

As shown by Hoffer and Johannsen (1969), the spectral response of green vegetation changes abruptly at wavelengths in the range from 0.68 um to

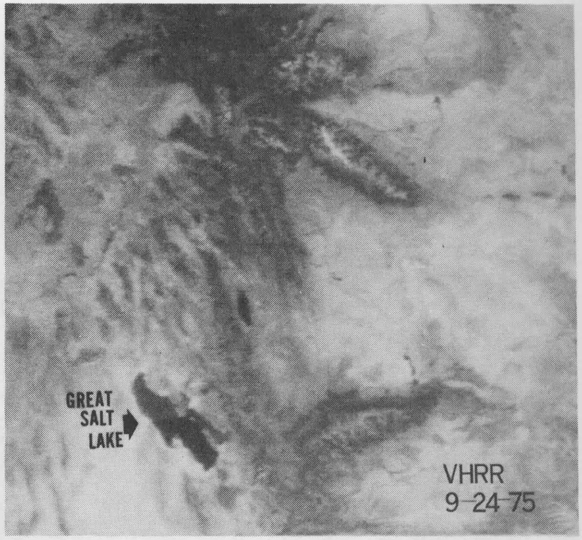

Figure 2a. VHRR image of the Utah-Wyoming area.

Figure 2b. VISSR image of the Utah-Wyoming area.

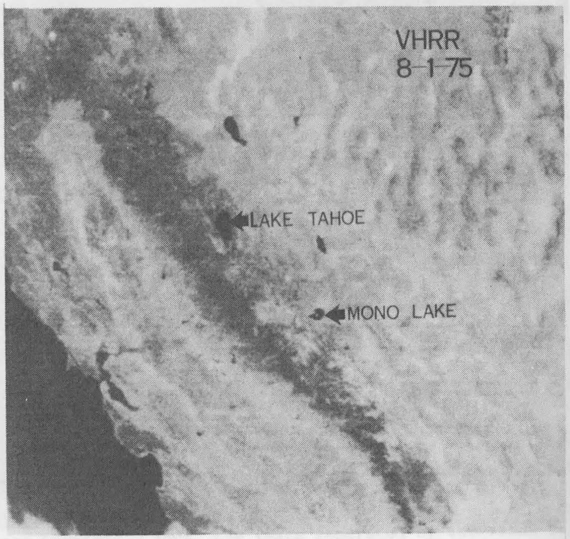

Figure 3a. VHRR image of the Sierra Nevadas.

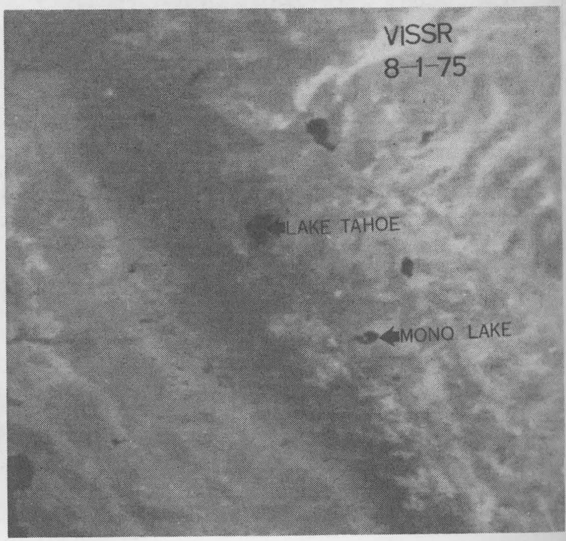

Figure 3b. VISSR image of the Sierra Nevadas.

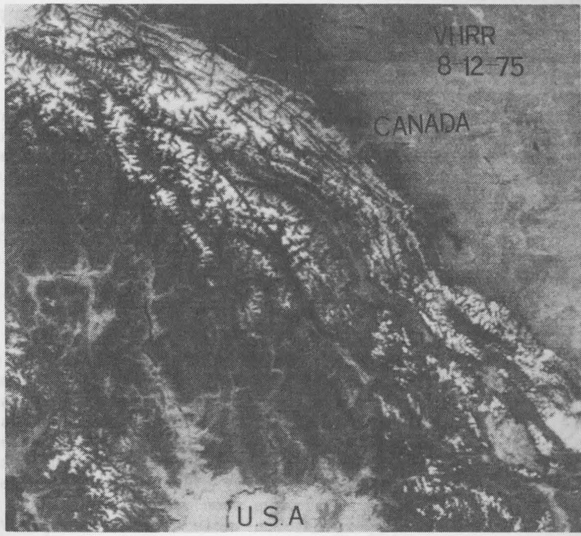

Figure 4a. VHRR image of the Canadian Rockies.

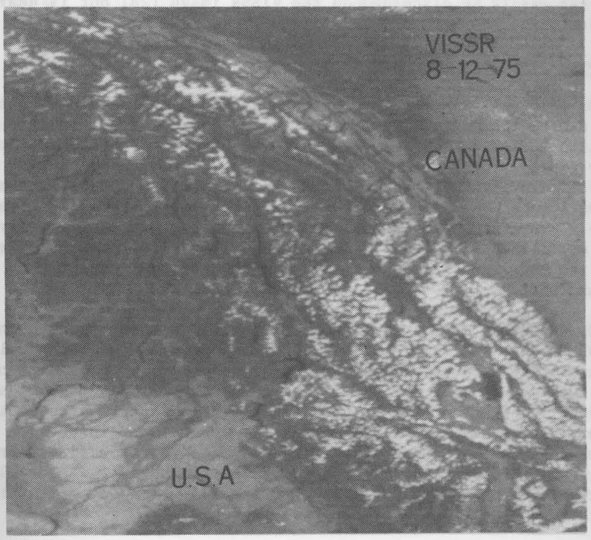

Figure 4b. VISSR image of the Canadian Rockies.

0.72 um. Reflectance values increase from about 10% to 50% in this short range of the spectrum. Since the VISSR receives a greater portion of energy in the near infrared range of 0.75 to 0.90 um than the VHRR, actively growing (green) vegetation will appear brighter (lighter) in SMS/GOES imagery than in NOAA VHRR imagery.

Figures 3A and 3B depict the California-Nevada region as it appeared on August 1, 1975. The dark swath extending from northwest to southeast on each image is the Sierra Nevada Mountains. Lake Tahoe and Mono Lake are labelled for orientation purposes. Notice that on the VHRR image (3A), the forest-covered Sierras show up as very dark in contrast to both the sandy regions in Nevada which are to the east and the cultivated areas of the Sacramento and San Joaquin Valleys which are to the west. However, on the VISSR image (3B), the Sierras are brighter and closer in gray tone to the surrounding areas.

Land-Water Interface

In the previous two sections discussing vegetation and water, it was shown that water appears darker and less reflective and vegetation brighter and more highly reflective in the near infrared and consequently in the VISSR imagery. This combination of darker water bodies and lighter land features also causes an enhancement of the land/water interface and enables us to discern certain water bodies, such as lakes and reservoirs, better in the VISSR imagery. Returning to figure 2B, a series of four small water bodies can be seen aligned in an axis northeast of Great Salt Lake. These features include Blackfoot Reservoir, Palisades Reservoir, Jackson Lake and Yellowstone Lake. It is interesting to note that these same bodies of water appear less distinctly, if at all, in the VHRR images (2A). Utah Lake, southeast of Great Salt Lake, can easily be discerned on the VISSR image (2B) but is nearly invisible on the VHRR image (2A).

Snowcover Definition on Bare Rock

A major complication of late season snowmapping in certain mountainous areas can be the difficulty of distinguishing snow from highly reflective, light-colored rocks, such as granites and limestones. Barnes and Bowley (1974), in observations of the Upper Columbia basin using multispectral data, showed that it was easier to discern snowcovered areas from bare rock when using MSS-6 imagery that is in the near infrared (0.7 - 0.8 um) than when using MSS-5 (or visible) Landsat imagery (0.6 - 0.7 um). They found that there was a marked reduction in reflectivity of the bare rock in the 0.7 - 0.8 um channel thus causing the snow to stand out.

Figures 4A and 4B depict the Canadian Rockies as they appeared on August 12, 1975. This region is located not far from, and is geologically similar to the area observed by Barnes and Bowley in the aforementioned study. As can be seen, it is difficult to discern snowcover from the bare rock in either of the images. In fact, the entire area looks sharper in the VHRR image (4A). However, upon closer inspection it can be seen that the bare rock appears to decrease in reflectivity or "fade away" in the VISSR image (4B). This phenomenon shows that the VISSR imagery exhibits properties similar to the MSS-6 Landsat data which also is in the near infrared spectral region.

Melting Snow

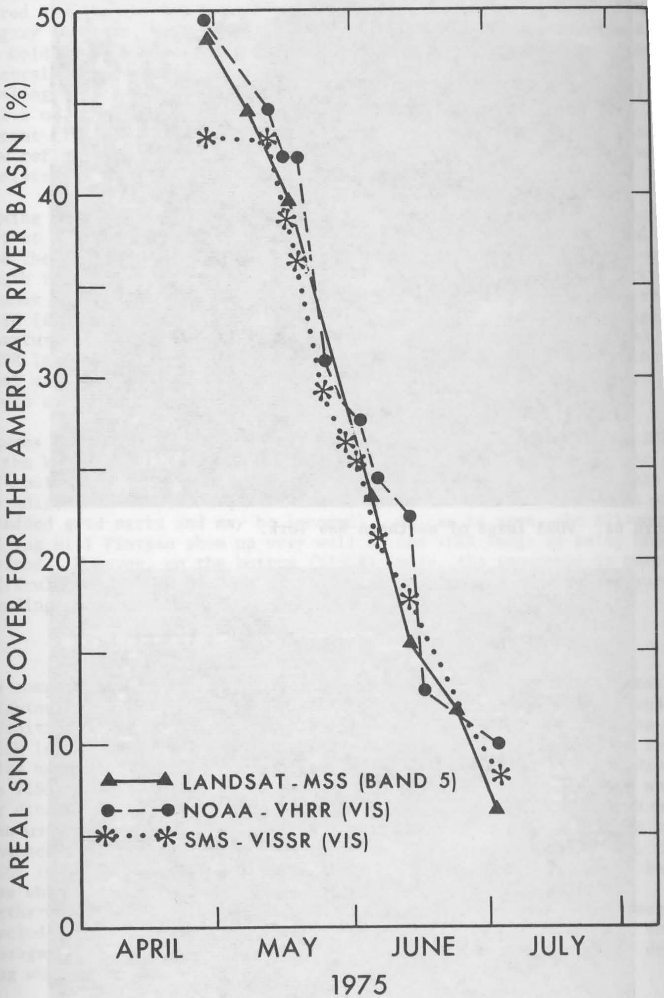

Figure 5. Graph showing depletion of areal snowcover in the American River basin as determined from three different satellites.

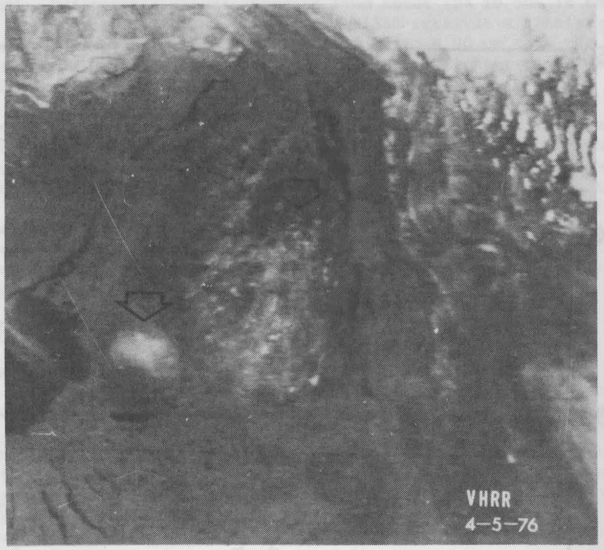

Figure 6a. VHRR image of northern New York.

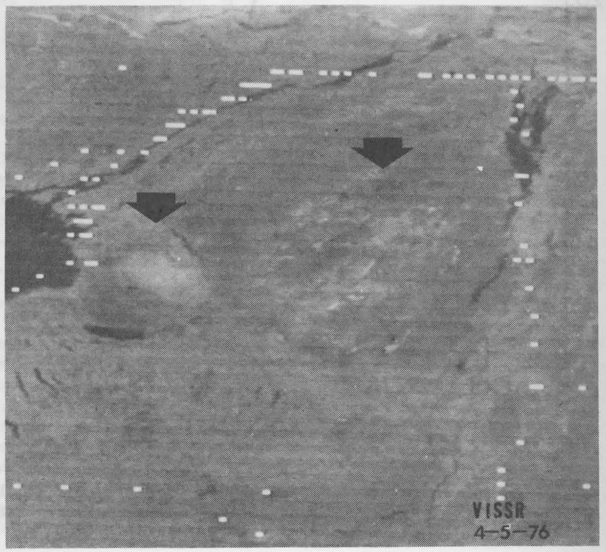

Figure 6b. VISSR image of northern New York.

First observed in Nimbus 3 HRIR satellite images (Strong et al., 1971), the decrease in reflectance of aged or metamorphosed snow in near infrared wavelengths has been documented more recently using Landsat MSS imagery (Wiesnet, McGinnis and McMillan, 1974). A study conducted at the Cold Regions Research and Engineering Laboratory (CRREL) produced spectral curves showing an almost continual decrease in reflectance as wavelength increased from 0.7 um to 1.5 um (O'Brien and Munis, 1975). At 1.5 um, the reflectance of all snow samples tested was less than 5 percent (relative to a $BaSO_4$ standard). This study also showed that snow reflectance in the red portion of the spectrum (0.6 - 0.7 um) was consistently above 80 percent, and often near or above 90 percent.

Viewing snow surfaces from NOAA VHRR and SMS VISSR data has shown a consistent bias between VHRR and VISSR produced snow maps. As expected from the CRREL study, the snow appears less bright in the longer wavelength VISSR imagery and also less extensive substantiating the work of Wiesnet et al. Analysis of snow maps produced for the American River basin (figure 5) for the spring melt season of 1975 showed an average departure of 3% for basin snowcover between maps made using VHRR and VISSR images. The VISSR images, in 9 cases out of 10, gave a smaller areal extent of snowcover. In the other case, both satellite images showed equal amounts of snowcover (Schneider and Forsyth, 1976).

Figures 6A and 6B depict northern New York as reviewed on April 5, 1976, by the VHRR and VISSR respectively. On each image, the arrow on the left points to the Tug Hill Plateau and the arrow on the right points to the Adirondack Mountains (the white dashed lines on the VISSR image are imbedded grid marks and may be ignored). As can be seen, the Adirondacks and Tug Hill Plateau show up very well on the VHRR image as being snow covered. However, on the bottom (VISSR) image, the snowcover is more difficult to discern because of its closeness in gray tone to the surrounding snowfree areas.

CONCLUSIONS

The comparisons of the VISSR and VHRR imagery with respect to vegetation brightness, melting snow, water penetration, land-water interface and definition of snowcover on bare rock show that in all five cases the VISSR imagery exhibits characteristics of near-infrared data. The results have far reaching consequences as concerns environmental studies. The VISSR imagery is preferable for locating small bodies of water and for discerning snowcover from lightly colored bare rock. The VISSR data, when used together with the VHRR data can be used to pinpoint areas of a snowpack that are aged or metamorphosed. However, when used alone, the VISSR imagery can deceive an investigator into thinking an area is snowfree when it is actually covered with an aged or melting snowpack. Furthermore, the lack of water penetration inherent in the VISSR imagery precludes many limnological studies. Investigators are therefore encouraged to consider what use they wish to make of the data before deciding whether to use VHRR or VISSR imagery (or both).

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