AVIRIS OBSERVATION OF NOCTURNAL LIGHTING

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1. INTRODUCTION

Since the electric light was first commercialized in 1879 by Thomas Edison, utilization of exterior lighting of streets and buildings has expanded to become the normal practice in virtually every part of the world. Today the typical commercial center is bathed in continuous lighting and pockets of nocturnal illumination (e.g. street lights) extend to the very edges of human settlements. Elvidge et al. (1997a, 1997b, 1999) developed methods to locate and define the areal extent of nocturnal lighting across large land areas using data from the Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS). This sensor has a unique capability to detect low levels of visible - near infrared radiance at night. The primary function of the DMSP-OLS is to provide global imagery of cloud cover. At night the observed visible - near infrared (VNIR) radiance is intensified, for the purpose of cloud detection using moonlight. In addition to moonlit clouds, the light intensification makes it possible to detect VNIR emissions emanating from the earth's surface, from cities, towns, industrial sites, gas flares, and ephemeral events such as fires.

The spatial linkage between nocturnal lighting and the locations of concentrated human activity has lead to a series of applications for the DMSP nighttime lights data including: 1) spatially explicit estimates population numbers (Sutton et al., 1997), 2) heat island effects on meteorological records (Owen et al., 1998), 3) urban sprawl impacts on agriculture (Imhoff et al., 1997), and 4) greenhouse gas emissions (Saxon et al. 1997).

As part of our effort to further explore the remote sensing of nocturnal lighting, a request was made for a nighttime AVIRIS data acquisition over an urban center. This request was fulfilled with the acquisition of low altitude nighttime AVIRIS data over Las Vegas, Nevada. This paper describes our initial findings from an examination of this unique AVIRIS data set. In addition, we offer several ideas for scientific applications for high spectral resolution nocturnal imaging of the earth.

2. Data Acquisition

Low altitude AVIRIS data was acquired over the central area of Las Vegas, Nevada at approximately 6:35 pm the night of October 4, 1998. The AVIRIS was flying on a NOAA Twin Otter aircraft, acquiring data at an altitude of 12,500 ft ASL, resulting in data with approximately 3 meter spatial resolution. The AVIRIS data that we analyzed had been radiometrically corrected, but had not been geometrically corrected.

3. Results

Figure 1 shows a sampling of the spectra found in the Las Vegas data. Note that most of the spectra contain narrow emission lines, characteristic of vapor lamps, which emit light based on the excitation of electrons in specific elements. Light is emitted at specific sets of lines when the excited electrons relax to less energetic orbits. Mercury and sodium vapor lamps are the primary type of street lighting in many parts of the world. The lights observed at Las Vegas exhibit mercury and sodium emission features, plus a number of other more exotic elements associate with specialty lighting. The spectrum in the lower right hand corner shows a blackbody curve and is probably an incandescent light source.

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4. Conclusion

The high spectral resolution observations made of nocturnal lighting reveal a wealth of spectral information. The current satellite based nighttime lights products being made with DMSP data rely on image time series to distinguish biomass burning (e.g. wildfires) from permanent light sources and inferences to distinguish city light from gas flares. With additional spectral resolution it would be possible to distinguish biomass burning, city lights, and gas flares based on their unique spectral signatures. The evidence from AVIRIS indicates that it may be possible to map spectral patterns in cities associated with commercial, industrial, and residential land use. There may be ways to use the high spectral resolution features present in vapor lamp sources to perform in-flight wavelength calibration for airborne or satellite imaging spectrometers. If these emission lines coincide with absorption present in atmospheric gases, it may be possible to relate relative differences in the magnitude of the emission lines to the concentration of atmospheric gases. These and other potential applications await further analysis and experimentation made with high spectral resolution at night.

5. References

Elvidge, C.D., Baugh, K.E., Dietz, J., Bland, T., Sutton, P.C., Kroehl, H.W, 1999, Radiance calibration of DMSP-OLS low-light imaging data of human settlements. Remote Sensing of Environment (In Press).

Owen, T.W., Gallo, K.P., Elvidge, C.D., Baugh, K.E., 1998, Using DMSP-OLS light frequency data to catagorize urban environments associated with US climate observing stations, International Journal of Remote Sensing, v. 19, no. 17, p. 3451-3456.

Saxon, E.C., Parris, T. and Elvidge, C.D., 1997, Satellite Surveillance of National CO2 Emissions From Fossil Fuels. Harvard Institute for International Development (Harvard University), Development Discussion Paper No. 608.

Elvidge, C.D., Baugh, K.E., Kihn, E.A., Kroehl, H.W, Davis, E.R, Davis, C., 1997a, Relation between satellite observed visible - near infrared emissions, population, and energy consumption. International Journal of Remote Sensing, v. 18, p. 1373-1379.

Elvidge, C.D., Baugh, K.E., Kihn, E.A., Kroehl, H.W, Davis, E.R, 1997b, Mapping of city lights using DMSP Operational Linescan System data. Photogrammetric Engineering and Remote Sensing, v. 63, p. 727-734.

Sutton, P., D. Roberts, C. Elvidge, and H. Meij, 1997, A Comparison of Nighttime Satellite Imagery and Population Density for the Continental United States. Photogrammetric Engineering and Remote Sensing, vol. 63, p. 1303-1313.

Imhoff, M.L., Lawrence, W.T., Elvidge, C., Paul, T., Levine, E., Prevalsky, M. and Brown, V., 1997, Using nighttime DMSP/OLS images of city lights to estimate the impact of urban land use on soil resources in the U.S. Remote Sensing of Environment , v .59, p. 105-117.

Figure 1. AVIRIS spectra of nocturnal lighting in Las Vegas, Nevada, October 4, 1998. Center panel shows AVIRIS scene with light sources indicated as black.