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Hot Pixel Identification using Satellite Hyper-spectral Data

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Abstract: Remote Sensing using Satellite images has started playing a pivotal role in resource management and planning, dynamic monitoring, disaster management and mitigation and other day to day phenomena. As the field has progressed, hyper-spectral imaging has shown its impact in precise identification and distinction of features owing to the high spectral resolution of these images. This study aims to detect features with marked Temperature difference from their surroundings using their spectral characteristics in certain Short Wave Infra-Red (SWIR) bands. This paper illustrates the effectiveness of this approach in distinguishing hot pixels from various classes namely Vegetation, Water bodies, Urban areas and Clouds by means of their spectral responses. The significance of the research can be well utilized for identification of events/disasters which deals with high temperature phenomena such as active volcanoes, forest fires etc.

***Keywords:** Hyper-spectral, Thermal, Spectral characteristics, Hyperion, Hot Pixels*

1. Introduction

The hyperion imager aboard the Earth Observation-1 (EO-1) spacecraft of NASA is a pushbroom type hyperspectral sensor having a single telescope and two spectrometers operating in Visible/Near Infra-Red (VNIR) and Short Wave Infra-Red (SWIR) region. It stands as the first space imager to cover the electromagenetic spectrum extending from Visible to Shortwave Infra-Red. The instrument images in bands spanning 355.59 to 2577.08 nm with a spectral resolution of 10 nm. The spatial resolution for each of the bands is 30m with a swath width of 7.5km [1][2][3]. At an altitude of 705 km, the instantaneous Field of View (IFOV) of 0.624 degree corresponds to 30m on ground which is equivalent to 60 micron pixels in VNIR (3x3 binning of 20 microns) and SWIR bands. The detectors have 256 pixels in the across track direction while in the spectral direction, VNIR and SWIR possess 70 and 172 array of bands respectively which effectively sums to a total of 242 imaging bands [4]. Hence the imaging data can be represented as a standard imaging cube Hyperion data stretching 19.8 km long in 660 consecutive frames. [1]

Hyperion data has several advantages when compared to traditional multispectral and panchromatic sensors' data because it contains enhanced spectral information of the observed objects [5]. Further, it can also be used for atmospheric correction of images. Different combinations of hyperspectral bands may highlight different features in the image. A wide array of application of hyperspectral images include agricultural applications such as plant health and growth stage identification, mineral identification, water quality monitoring etc.

This paper demonstrates a very effective approach to determine regions with high temperature using its spectral characteristics in certain SWIR bands. The high radiances observed in these bands plays pivotal role in identification of such areas. Our spectral bands of interest lie mainly between Band 180 to 220 (Reasons will become evident later in the section "Hot Pixel Identification"). Following Table summarizes the details of these bands in terms of wavelength [6]:

***Table 1:** Hyperion data details from Band 180-220*

Hyperion Band	Average Wavelength (nm)	Full Width at Half the maximum (nm)
B180	1951.5700	10.9698
B181	1961.6600	10.9508
B182	1971.7600	10.9355
B183	1981.8600	10.9230
B184	1991.9600	10.9139
B185	2002.0600	10.9083
B186	2012.1500	10.9069
B187	2022.2500	10.9057
B188	2032.3500	10.9013
B189	2042.4500	10.8951
B190	2052.4500	10.8854
B191	2062.5500	10.8740
B192	2072.6500	10.8591
B193	2082.7500	10.8429
B194	2092.8400	10.8242
B195	2102.9400	10.8039
B196	2113.0400	10.7820
B197	2123.1400	10.7592
B198	2133.2400	10.7342
B199	2143.3400	10.7092
B200	2153.3400	10.6834
B201	2163.4300	10.6572

B202	2173.5300	10.6312
B203	2183.6300	10.6052
B204	2193.7300	10.5803
B205	2203.8300	10.5560
B206	2213.9300	10.5328
B207	2224.0300	10.5101
B208	2234.1200	10.4904
B209	2244.2200	10.4722
B210	2254.2200	10.4552
B211	2264.3200	10.4408
B212	2274.4200	10.4285
B213	2284.5200	10.4197
B214	2294.6100	10.4129
B215	2304.7100	10.4088
B216	2314.8100	10.4077
B217	2324.9100	10.4077
B218	2335.0100	10.4077
B219	2345.1100	10.4077
B220	2355.2100	10.4077

The regions selected for this study are the Brick Factory in Nellore, Andhra Pradesh, (India) and the Thermal Power station in Raichur, Karnataka (India) which certainly possess extreme thermal reflectance. Comparison of Spectral profiles of other feature class has also been brought out in order to distinguish hot pixel. This study has significant relevance in disaster management scenarios such as forest fires and active volcanoes as these events possess high temperature and thus might be effective for advance predictions.

2. Methodology

2.1 Study Area

As this study concerns the identification and demonstration of the spectral properties of high temperature areas through hyperspectral imaging, it is important to analyse regions having distinct thermal profile. In order to meet such criteria, the following regions have been identified based on the availability of Hyperion images:

1. Nellore, Andhra Pradesh
2. Raichur, Karnataka

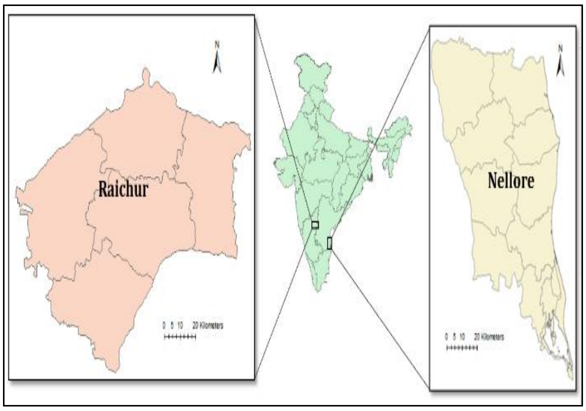

Figure 1 *Study Area Map*

Nellore (14^0 26’ N, 80^0 0’ E) is located in the coastal region of Andhra Pradesh and is bordered by the Bay of Bengal to the east [7]. The city stands as the state’s fourth most populous town and is well known for aquaculture and agriculture. The climate of Nellore is Tropical Maritime climate with hot humid summers and mild winters [8]. It is also home to Shriharikota, the space port of India.

Raichur (16^0 12’ N, 77^0 22’ E) is located at the border of Karnataka and Andhra Pradesh between river Krishna and Tunghabhadra. It is located ~400 km from the Karnataka state capital—Bangalore. Raichur experiences hot and dry climate almost throughout the year except few months of monsoon and winter [9]. It is well known for the first thermal power plant (~1500 MW) to be set up in the state and accounts for 40% of the total power generated in the state [10][11][12].

2.2 Pre-Processing

United States Geological Survey (USGS) provides Earth Observatory – 1 (EO-1) Hyperion data as L1GsT, (GeoTIFF) format individually for each band in WGS84 UTM (zone 43N for Raichur and zone 44N for Nellore) coordinate system. L1GsT data is radiometrically and geometrically corrected using ground control points and digital elevation model for distortions related to the sensor, satellite and Earth [6].

Table 2: *Hyperion Data details*

Path	Row	Acquisition Date	Area
142	051	26-01-2011	Nellore
144	048	26-09-2009	Raichur

The Hyperion Images are converted from Digital Numbers to Radiance. The conversion factor for VNIR (Band 1-70) bands is 1/40 while that for the SWIR (Band 71-242) bands is 1/80 [13]. The data was also atmospherically corrected to remove the effects of atmospheric gases and aerosols by FLAASH method. FLAASH causes suppression in the bands of wavelength 1366.44 to 1396.73 nm and 1830.57 to 1941.56 nm. This method possesses advantage over its counterparts as its suppression band interval is narrower [14].

As mentioned before, the dimension of the Hyperion data is 256x6925x242 where 242 stands for the number of bands. However, only 200 channels out of 242 are calibrated while the rest of the spectra having wavelength 436 nm to 926 nm and 892nm to 2406nm (i.e. band number 1 to 8 and band number 75 to 225) are not calibrated. Unavailability of Bands 1-8 is caused by the fact that detectors do not have sufficient signal or material sensitivity. Similarly, Band 75 to 225 unavailability is attributed to the overlap region between VNIR and SWIR. These uncalibrated bands are set to zero.

Figure 2 shows the Hyperion and the Google Earth Images of the study areas:

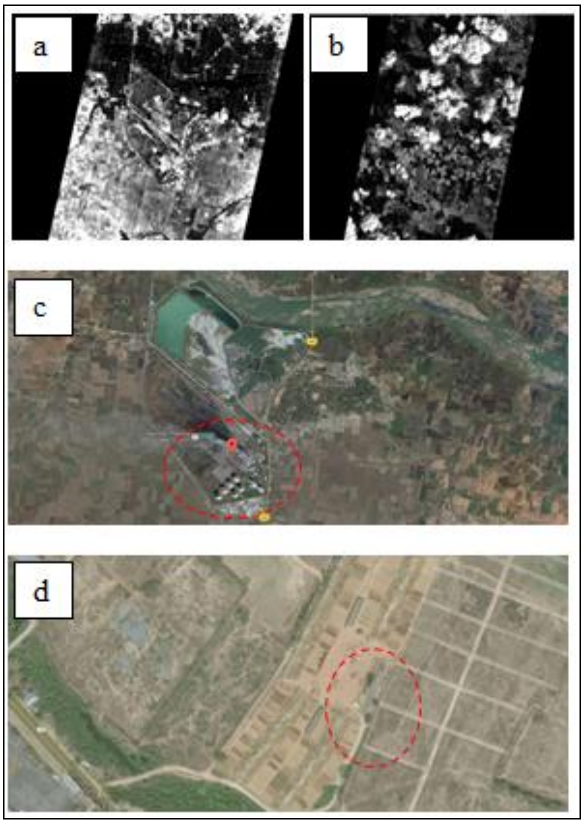

Figure 2 *Hyperion Image over (a) Raichur and (b) Nellore. Google Earth Image of (c) Raichur highlighting the Raichur Thermal Power plant and (d) Brick Factory in the Outskirts of Nellore.*

3. Hot Pixel Identification

The spectral profile for different features like Water, Urban areas, Clouds Vegetation and Areas having distinct elevated temperatures was derived across 242 bands of the Hyperion data. These spectral profile provided some interesting and unique characteristics for the identification of Hot pixels. Hot pixels refer to the radiance of areas which are at considerably higher temperature than their surroundings. The image of Nellore and Raichur provides two such specific cases. The image of outskirts of Nellore captures an operational brick factory with its noticeable chimney due to its high temperatures. Similarly, the thermal power station of Raichur offers very analogous thermal profile based on its temperature.

Hot pixels in such areas produce very high radiance values in certain Infra-Red bands. This characteristic may be exploited to distinguish against feature classes having high reflectance/radiance like clouds, Urban areas. The bands useful for this kind of characterization were found to lie in the Short Wave Infra-Red region specifically in the range of 1951nm to 2355 nm (i.e. Band number 180-220). The spectral profiles for different classes are shown in the following figures and the above mentioned bands are highlighted. Figure 3 shows the Hyperion Image of Vegetation and its spectral profile

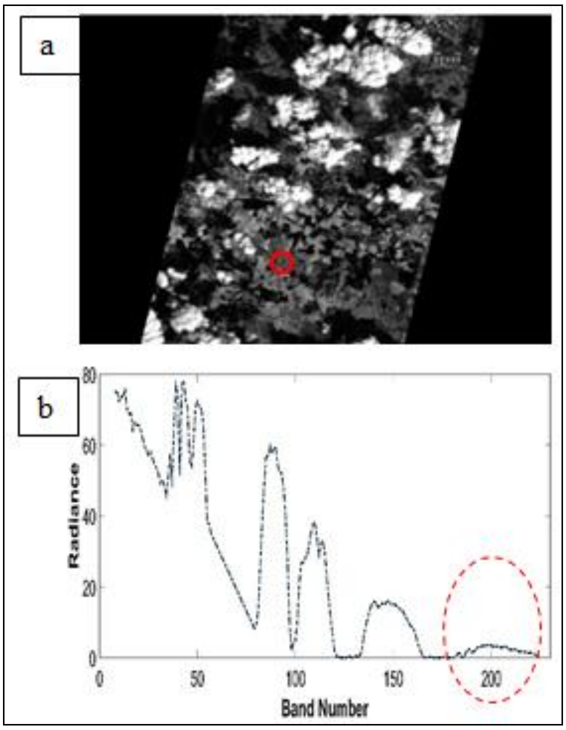

Figure 3 *The Hyperion Image highlighting Vegetation area (a) and its spectral profile (b) across all the bands available in the data*

The Hyperion image in Figure 4 highlights water area and its respective spectral plot

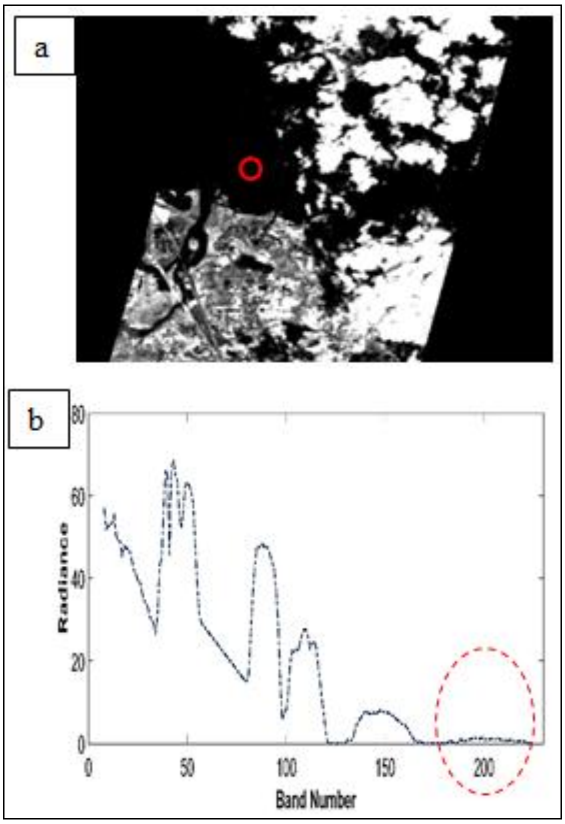

Figure 4 *The Hyperion Image highlighting Water areas (a) and its spectral profile (b) across all the bands available in the data*

The urban areas in the Hyper-spectral image and its corresponding spectral profile are illustrated in Figure 5.

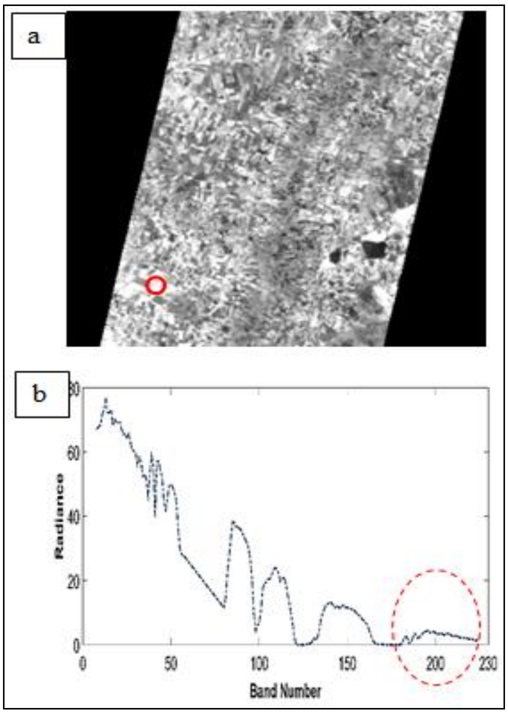

Figure 5 *The Hyperion Image highlighting (a) Urban areas and (b) its spectral profile across all the bands available in the data*

Figure 6 demonstrates the spectral characteristics of clouds which certainly possess high radiance values.

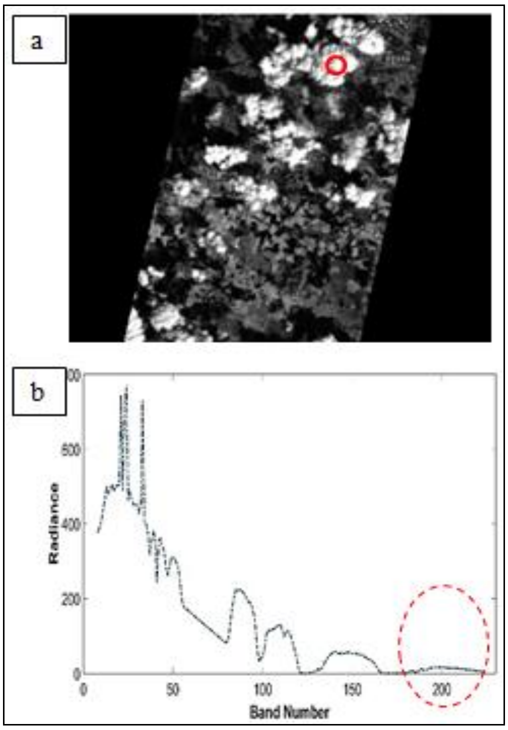

Figure 6 *The Hyperion Image highlighting (a) Clouds and (b) its spectral profile across all the bands available in the data*

Figure 7 and 8 illustrate the spectra of Hot areas of Brick Factory at Nellore and Raichur Thermal Power station respectively.

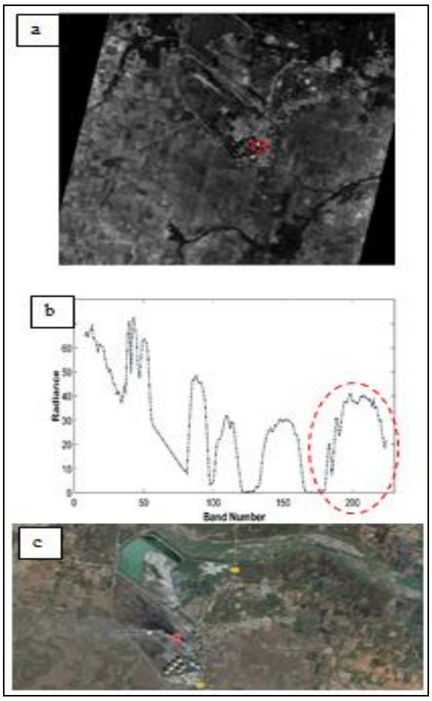

Figure 7 *The Hyperion Image highlighting Hot pixel at (a) Raichur Thermal Power station and (b) its spectral profile across all the bands available in the data. (c) The google earth image is also shown for validation*

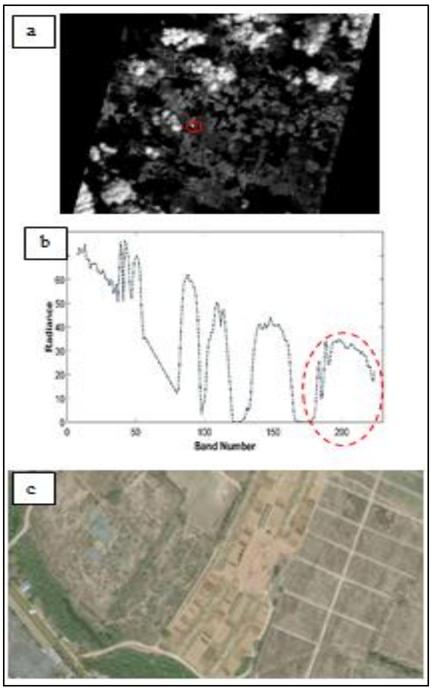

Figure 8 *The Hyperion Image highlighting (a) Hot pixesl of Brick Factory at outskirts of Nellore and (b) its spectral profile across all the bands available in the data. (c) The Google earth image is also shown for validation*

4. Results and Conclusions

The study result shows that areas having very high temperatures reflect exceedingly high in Short Wave Infra-Red region distinctively in the range of 1951nm to 2355 nm (i.e. Band number 180-220). In the above mentioned range of spectrum, the span of radiance value was found to be from 7 to 45 Watt/steradian-m^2. Peak value of the Hot Pixels was observed in electromagnetic wavelength ranging from 2100-2150 nm (which corresponds to Band no. 195-200). It is also noted that Hot pixels can be differentiated from high radiating clouds with the help of its peak radiance value in 2100-2150 nm range. Peak radiance observed in case of hot pixels is around 40 or more while in case of clouds it is about 20.

This study shows the utility of Hyper spectral data in detecting minute but significant features having very high temperatures. The narrow and numerous bands of Hyper spectral Imaging thus have clear advantage over Multispectral Bands. Such study can be more effectively used in identification of hot industrial furnaces/ chimneys, disasters like forest fire and active volcanic eruptions in order to take prior decisions and initiate mitigation steps.

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