PREFACE

Remote sensing is the phenomena of sensing the information about the Earths surface features without any physical contact. This process is useful for attaining information over vast area on Earth surface in a shorter time which is considered beneficial for the management of resources. Various satellites have been launched that provides remotely sensed data for attaining information of targets or objects on Earth's surface. Various multispectral scanning systems sense energy in the visible, reflected Infra-red and Thermal Infra-red (TIR) wavelength bands. Optical remote sensing satellite senses energy that is reflected in the visible and reflected infra-red region of electromagnetic spectrum. Thermal remote sensing senses energy that is emitted from the Earth's surface in the TIR region of the electromagnetic spectrum (3 to 15 μm). All the objects with temperature above 0 K emit electromagnetic radiation. The electromagnetic energy emitted from the target materials can be related to temperature as given by Wien's displacement law and Stefan-Boltzmann law. The true surface temperature of a material can be determined by incorporating the approximate emissivity values in the blackbody radiation law. The Earth emits energy at 300 K with dominant wavelength of 9.7 μm. The thermal sensors can detect the thermal radiation from the Earth's surface at all times of the day and night.

Land Surface temperature (LST) information of the Earth surface features can be determined from the satellite data containing thermal sensors. Various satellites consists of thermal sensors like Land Remote-Sensing Satellite System (Landsat), Advanced Spaceborne Thermal Emission and Reflection Radiometer (Aster), Advanced Very High Resolution Radiometer (AVHRR), Moderate Resolution Imaging Spectroradiometer (MODIS) and has been widely used for numerous studies in thermal remote sensing. Thermal remote sensing has been used for various applications like surface temperature detection, surface urban heat island (SUHI) analysis, volcanic activity monitoring, soil moisture estimation, drought monitoring etc. SUHI refers to the urban areas having distinct higher surface and atmospheric temperatures than the surrounding rural areas. This phenomenon mainly occurs due to urbanization because the increase in artificial materials have high heat capacities, increase in anthropogenic heat discharge by industries, vehicles, buildings and also decrease in vegetation and natural pervious surfaces that reduces temperatures through evapotranspiration. Rao (1972) first studied about the SUHI effect from the satellite sensor measurement. Higher urban temperatures have significant negative impact on our environment like raises the pollution levels, increases dryness and also modifies the natural cycle of precipitation. Thus, it is important to study about LST variation in urban areas with different pattern and magnitude and also different land covers for the requirement of urban sustainable planning and environmental protection.

LST acts as an important parameter for the exploration of urban climate as it has the capability to control the biological, chemical and physical processes that occurs on Earth. The spatial and temporal variations of SUHI depend on various factors like landscape structure, impervious surface area, albedo, vegetation cover and climate. In order to understand the interactions between the human activities and the environment, the understanding of LST variation in space and time is important. The urban areas show greater heterogeneity in land cover; hence LST images at fine spatial resolution are required for urban applications. Satellites consisting of thermal sensors and providing thermal images at fine spatial resolution are limited. The increase in urbanization in the last few decades has expanded the city area which shows significant impact on the LST pattern within the city. Therefore, there is an acute requirement to study about the surface urban heat island (SUHI) growth with urban expansion.

The disaggregation of MODIS thermal image based on sensitivity of different SI has been carried out in agricultural region. The downscaling approach found b for agricultural areas may not be suitable for urban regions. The natural land cover surrounding the urban regions may vary for different cities which can influence the result of thermal sharpening. Previous studies on thermal sharpening in urban areas may be suitable for particular cities but not for other cities having different natural surroundings. Thus, it is important to determine downscaling method that should be suitable for most of the urban regions. The relation of LST with different SI has been studied and relations were development using SI in combined form which showed improved relation with LST. However, these studies have been performed for day time but the relations may vary for night time. It is important to analyse the LST relation with different SI both during day and night time to understand the thermal behaviour. Various researchers have also studied the integrated effect of built-ups and bare land in formation of SUHIs. The urbanisation replaces barren or vegetated areas with built-ups. In order to understand the change in SUHI effect with urbanisation, it is important to analyse the independent contribution of built-up land cover on SUHI formation.

This thesis includes new ideas developed for thermal sharpening of satellite based LST images, the relation of day and night LST with spectral indices which can better explain the LST variation and also understand the phenomena of SUHI effect using the satellite derived LST images.

The 1^{st} **chapter** consists of introduction section that discusses about the basics of thermal remote sensing and urban heat island. The literature review is also shown in order to provide an overview of the previous research work performed by various researchers in the field of study on LST variation in urban areas and analysis on phenomena of SUHI effect. Further, the research objectives and motivation of the study performed has been discussed in this chapter of the thesis.

The **2nd chapter** consists of Landsat and MODIS satellite data specifications, the mathematical equations used for calculation of various well known SI used in the study and also, the determination of Impervious surface fraction (ISF) using Normalized Spectral mixture analysis (NSMA) approach are discussed. Further, the estimation of LST using the radiative transfer equation from Landsat 8 thermal image are also presented in this chapter.

The **3rd chapter** discusses about the disaggregation of MODIS LST in urban areas using different regression methods. The performance of six different indices, namely NDVI, EVI, NDBI, UI, NDSI and NDWI were compared for thermal sharpening using Disaggregation of Radiometric Temperature (Distrad) Method over four different cities in India i.e. Bikaner, Hyderabad, Vadodara and Varanasi. The index that performed best among the SI was further used for disaggregation using two robust regression techniques i.e. Least Median Square Regression (LMSR) and Bi-square regression to improve the downscaling result.

The **4th chapter** discusses about the thermal sharpening of MODIS LST using statistical downscaling technique in four urban regions of India i.e. Bikaner, Hyderabad, Vadodara and Varanasi. The performance of nine different SI was compared and various regression techniques were established using combination of SI for thermal sharpening. The best combination of indices was reported and the results were analyzed by comparing for different cities..

The **5th chapter** discusses about the LST behaviour for day and night time of different land covers in two semi-arid cities i.e. Ahmedabad and Gandhinagar. The relation of day and night LST with three independent variables i.e. NDVI, NDBI and ISF were established using Landsat 8 satellite images. The relations of LST with indices were used to develop models from the combination of indices to improve the correlation of LST with the land cover for both day and night time. The developed model was also evaluated using MODIS satellite images for three different seasons i.e. summer, post-monsoon and winter seasons to check the performance of the developed model with changing land covers.

The **6th chapter** discusses about the variation in LST with land cover changes in Varanasi city of India from 1989 to 2018 using Landsat satellite images. A new index named Urban Heat Intensity Ratio Index (UHIRI) was proposed to quantify the urban heat intensity in years 1989, 1997, 2008 and 2018. Further, mean LST of each land cover i.e. water, vegetation, bare land and urban was determined for the years of study and quantitative contribution of each land cover towards SUHI was determined using Land cover contribution index (LCCI).

The **7th chapter** discusses about the determination of SUHI intensity (SUHII) for the monitoring of SUHI growth with increased urbanization. The quantification of SUHI intensity was performed for winter, summer and post-monsoon seasons of the years 2001, 2007, 2013 and 2019 in Varanasi city, India using urban heat index (UHI) obtained from the MODIS LST images. The two parameters i.e. area and the mean UHI value of the region showing SUHI effect was obtained. Then, combining the two parameters quantitative analysis of SUHII was performed for three seasons.

The **8th chapter** provides the overall conclusion of the research work performed and the future work plan.