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Heat Wave Study using Satellite LST and Air Temperature Data over Gujarat Region

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Abstract

Intense, durational, and frequent heat wave becomes a concern in the modern era as they directly effect on human mortality and climate. In this paper, heat wave detection is accomplished through satellite observation and air temperature over the Gujarat region for the period of 15th - 17th March 2022. The Land Surface Temperature (LST) was derived from Indian National Satellite System (INSAT-3D) images for the normal and heat wave year, which indicates severe conditions in some parts of the state. The LST analysis over different land cover types for the year 2019-2022 was observed, which indicates LST intensity on cropland is higher than on other land covers during heat wave. We also qualitatively analyze the correlation between Moderate Resolution Imaging spectroradiometer (MODIS) satellite LST and air temperature over the last 15 years by fitting a linear trend line. It describes the dynamic behavior of land covers over the years. The comparison of an air temperature of normal and heat wave years shows a surge in air temperature during the heat wave in the daytime. This finding shows the potential of satellite remote sensing as it is promising means of accurate study and detection of heat waves from the synoptic view as well as it will help to understand the heat wave pattern.

Keywords: Heat wave, INSAT-3D, Land surface temperature, MODIS, Air temperature.

1. Introduction

The heat wave is a natural hazard and often comes during the summer season which is creating a vulnerable situation for human beings and the natural environment by excessive heat [1]. Since 1980, anthropogenic activities have increases, which contribute an increment in Greenhouse gases [2]. Greenhouse gases play a vital role in the atmosphere to balance the temperature of the earth. Due to fewer plantations, and urbanization, the intensity of heat waves is excessive in urban areas [3]. A heat wave situation is considered if the temperature at any place is higher than the normal maximum temperature by nearly or equal to 5-6 °C in the daytime, and this situation persists for at least 48 hours [4]. Frequent occurrences of Heat waves cause marginally to devastating effects on human mortality, health status, economic impact, vegetation degradation, forest fires as well as negative impact on biodiversity [5] - [7].

Generally, heat waves arrive in India in the summer season between the months of May-June. India has a variety of climates and a large part of India falls under the tropical region. The universal definition of heat waves does not apply as it varies with the people and part of the globe. According to the criteria for declaration of a heat wave given by the Indian Meteorological Department (IMD), a heat wave can be considered only if the temperature of the meteorological station reaches at least 40 °C and 30 °C for plain and hilly areas. It can be classified by an intensity threshold. If the normal Maximum temperature deviates by a value of about 4.5 °C to 6.4 °C it is called a heat wave and if it is greater than 6.4 °C then it is considered to be a severe heat wave. The above criteria should be met at least in 2 meteorological stations for 2 consecutive days. Certain physical parameters are responsible for the onset of heat waves as well as the sustenance of heat waves for prolonged periods. These parameters are mainly, large-scale movement of air and sea surface temperature (SST), anticyclone system, large dry soil area, a small amount of evaporation [8] - [11], etc. It has been predicted that in near future, heat waves will occur frequently, more deadly and longer durational due to an increment in greenhouse gases over the years [12]. Globally, numerous satellites are actively providing direct LST products with different temporal and special resolutions; such are INSAT-3D, MODIS, and Land remote sensing satellite system (LANDSAT) series. In this paper, the INSAT-3D, MODIS satellite, and meteorological air temperature data have been used to observe the heat wave in the Gujarat region from 15th to 17th March of 2022.

2. Study Area & Data Sources

Gujarat is the fifth largest state by size and has the longest coastline in the country, located in western India. The Major landform of Gujarat includes Mountains, Hills, plateaus, and plains, as well as weather is typically hot, cold and dries in summer and winter season, respectively. Here, We have used INSAT-3D Level-2B LST data products at the interval of every half hour, and MODIS/Aqua Land Surface Temperature/Emissivity Daily L3 Global 1km SIN Grid V006 as well

meteorological air temperature data. INSAT-3D is Indian weather satellite positioned at 82° east on the geostationary platform providing data since 2015. The Satellite contains two meteorological payloads such are an imager and a sounder. The imager sensor contains six channels (0.65µm, 1.7µm, 3.9µm, 6.8µm, 10.9µm, 11.9µm) and the sounder has eighteen narrow spectral bands in visible (VIS), shortwave, mid-wave, and thermal infrared (TIR). INSAT-3D satellite uses 10.9 and 11.9 µm TIR channels for measuring LST. MODIS is a NASA's sun-synchronized and polar orbital earth observation satellite which acquiring whole global data since year 2000. MODIS satellite has 36 spectral bands from VIS (0.620µm) to TIR (14.385µm) with different spectral and spatial resolutions. It covers the entire globe within 1-2 days. MODIS uses bands 31 (10.780-11.280 µm) and 32 (11.770-12.270 µm) for measuring LST. These data were downloaded from data archive centers such as Meteorological and Oceanographic Satellite Data Archival Centre (MOSDAC; www.mosdac.gov.in), Application for Extracting and Exploring Analysis Ready Samples (AppEEARS) [13], and The Prediction of Worldwide Energy Resource (POWER) (https://power.larc.nasa.gov/data-access-viewer/).

3. Results and discussion:

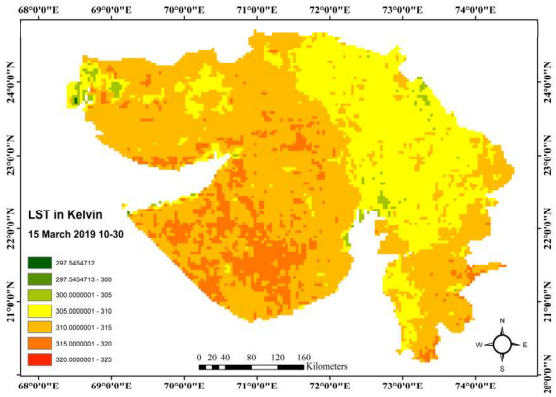

Figure 1. INSAT-3D satellite LST for the normal year of 15th March 2019 at 10:30 IST over Gujarat region.

Figures 1 to 4 represent the derived LST over the Gujarat region for non-heat wave and heat wave years 2019 and 2022 for the days 15th and 17th March 2022, respectively. Figures 1 & 3 show the normal days and 2 & 4show the heat wave days. It is observed that during a non-heat wave year normal maximum temperature lies in the range of 300-310 K whereas, during the heat wave year, the day temperature raises more than 5 K compare to the normal conditions. In some parts of Gujarat, it reached more than 320 K, indicating a severe heat wave condition in 2022. We have selected urban and cropland areas nearby Ahmedabad city as a case study. As per the IMD alert [14], the 15th of March 2022 was considered to be the onset of a heat wave, so, the year- wise comparison of LST for both the areas on 15th March has been shown in Figure 5. Figure 5 shows that there is a steep rise in LST in 2022 as per the IMD alert in both regions. Since the effect of heat waves is more visible in urban areas, this rise of LST due to heat waves is ≥ 5 K. It is also observed that the LST over cropland is 2-3 K higher than urban, which is in agreement with the observations made in other literature [15].

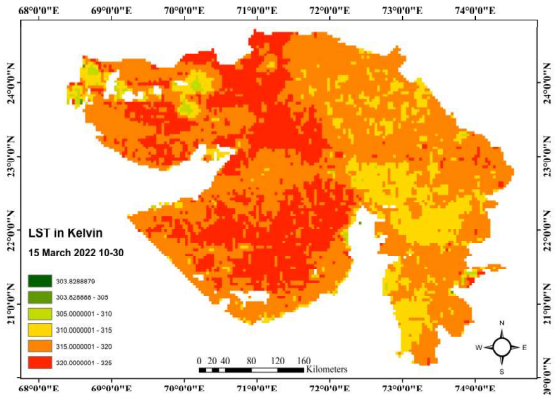

Figure 2. INSAT-3D satellite LST for heat wave year of 15th March 2022 at 10:30 IST over Gujarat region.

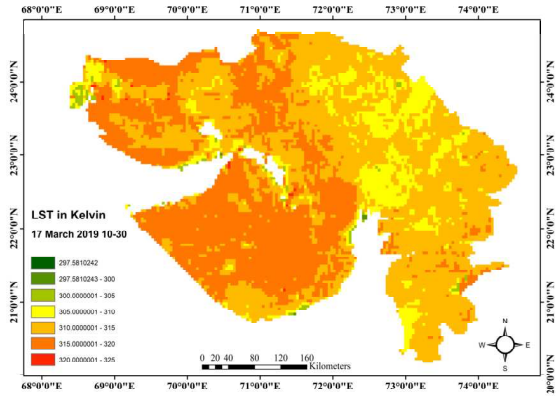

Figure 3. INSAT-3D satellite LST for the normal year of 17th March 2019 at 10:30 IST over Gujarat region.

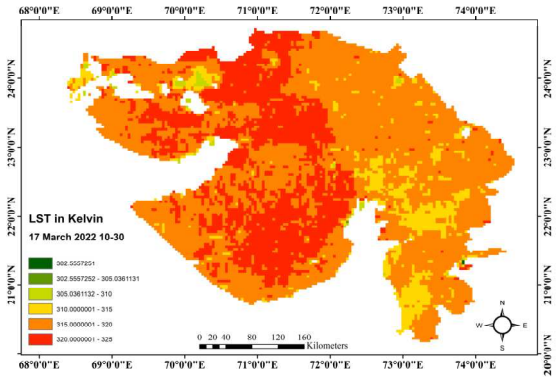

Figure 4. INSAT-3D satellite LST for heat wave year of 17th March 2022 at 10:30 IST over Gujarat region.

The trend of variation of LST in cropland and urban regions can be observed using a time series analysis method. Such analysis may through some light on the correlation between the LST and air temperature and may provide useful information about the different aspects like urban sprawl, urban heat island effects, or the anthropogenic activities in the regions.

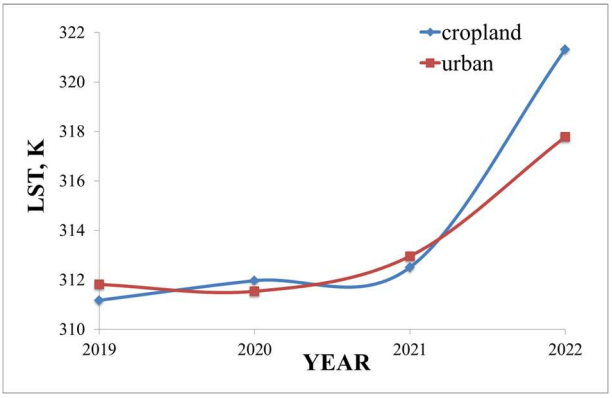

Figure 5. INSAT-3D LST for cropland and urban area of Gujarat region for 15th March 2022.

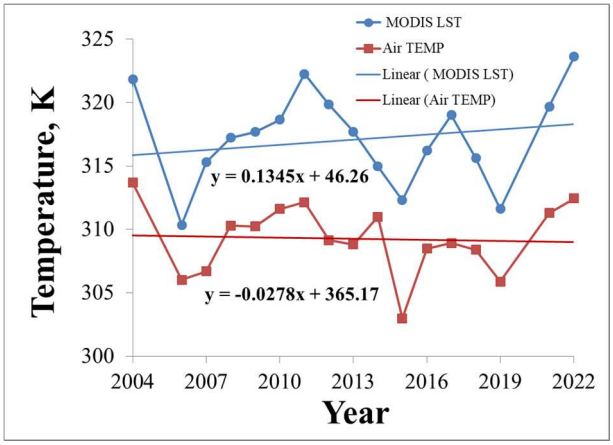

Figure 6. MODIS maximum LST and average Air temperature for cropland area over the central region of Gujarat for 15th March 2022.

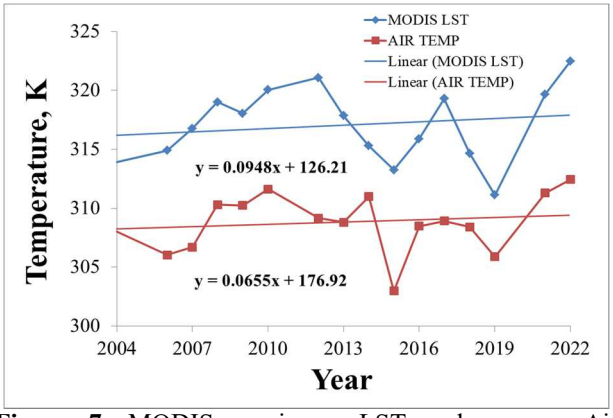

Figure 7. MODIS maximum LST and average Air temperature for an urban area over the central region of Gujarat for 15th March 2022.

It can also give important information regarding the change in energy balance conditions in the regions. So, in order that the present work to become fruitful, we have carried out a time series analysis of MODIS LST and hourly average air temperature data of the last 15 years i.e., from 2004 to 2022, which is shown in Figures 6, 7 for cropland and urban regions, respectively. LST and air temperature has been plotted for cropland and urban areas for the date of 15th March for every year. The first and foremost observation is the rise of LST in both regions over the years. The relation is present that Air temperature and LST are rising respectively. However, some of the data are missing due to inappropriate weather conditions. Here it is also observed that the LST value derived from INSAT-3D, as shown in Figure 5, for the year 2022 for the same day is in excellent agreement with MODIS LST on both the area shown in Figures 6 and 7.

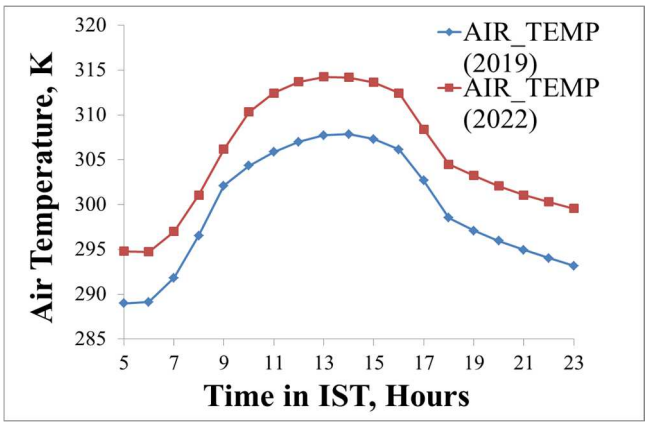

Figure 8. Comparison of an hourly average Air temperature of normal and heat wave year for 15th March over Ahmedabad area.

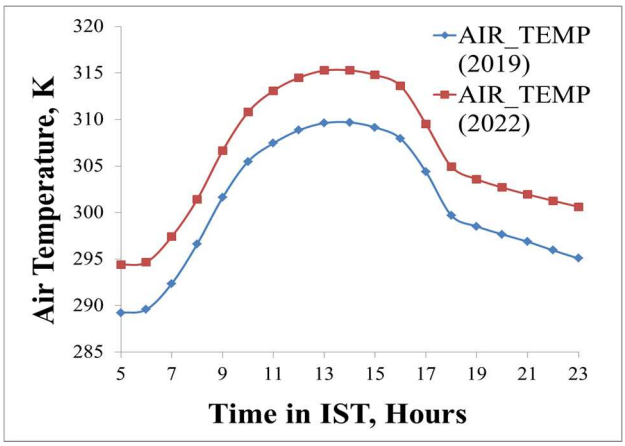

Figure 9. Comparison of an hourly average Air temperature of normal and heat wave year for 17th March over Ahmedabad area.

As we know that air temperature is a clear indicative parameter of heat waves, we have represented the hourly average air temperature data of the normal and heat wave year for the 15th and 17th March in Figures 8 and 9. Here we observe that on the day of the heat wave, the peak temperature is more than 7 K.

4. Conclusion

A heat wave on March 2022 is quite clearly visible in the thermal infrared channel of INSAT-3D. The linear fit to the LST and Air Temperature shown in Figures 6 and 7 indicates the increasing trend in an urban region. However, the trend in the cropland region is quite interesting to analyze since the air temp shows a slightly

decreasing trend over time in contrast to the increasing trend in LST. This aspect may be attributed to the dynamic behavior of land cover changes in cropland degradation near urban regions which may, in turn, lead to a different manifestation of results in the cropland region. Also, this can be attributed to the change in the energy balance of the region due to urbanization on the interface between the two land covers. This is also visible in Figures 6 and 7 that the trends in LST and Air temperature during 2015-2022 are almost similar. As is evident from figures 8 and 9, the average air temperature rise of nearly 7 K at the peak is indicative of a heat wave. The present study also points out at another aspect of heat wave occurrence in the Gujarat region. It is generally observed that the heat waves occur during the May-June months, but the recent heat wave occurred during March. This shift in the month may be attributed to the increasing trend of LST and Air temperature as shown in Figure 7 for the urban region.

5. Acknowledgements

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6. References

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