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HEAT WAVE ANALYSIS FOR THE REGION OF PUDUCHERRY AND KARAIKAL IN THE U.T. OF PUDUCHERRY

1. Heat wave is a period of abnormally high temperature more than the normal maximum temperature that occurs during the summer season typically from March to June. Heat wave occurrence and severity are predicted to be increasing rapidly in the recent decades due to the global warming and associated climate change and has become a serious concern because of its severe impacts on human health and ecosystem. The Intergovernmental Panel on Climate Change (IPCC) 2018 report indicates that human induced global warming has already caused multiple observed changes in the climate system which include increases in both land and ocean temperatures, as well as more frequent heat waves in most land regions. Studies have indicated that global warming will drive local average temperatures upwards and increase the frequency, intensity, and duration of heat waves leading to increase in heat related morbidity and mortality (Perkins *et al.*, 2012; Mishra *et al.*, 2017; IPCC, 2018).

For India, several studies have indicated that significant increase in heat wave and severe heat wave events has occurred in the last three decades from 1991 and such events are projected to become more frequent due to rising global temperature (Srivastava *et al.*, 2001; Pai *et al.*, 2004; Pai *et al.*, 2013; Mishra *et al.*, 2017). A recent study by Singh *et al.* (2021) reveals that the characteristics of heat wave events in India have changed over the years becoming more frequent and expanding in areas where previously there were no or very less heat wave events. The study shows that during the recent decades 2010 to 2016, heat waves have emerged in southern states like Karnataka and Tamil Nadu, which had previously not experienced such events. However, specific study on the occurrence of heat wave events in the Union Territory of Puducherry have not been carried out so far. The present study is carried out to assess the frequency and patterns of Heat wave events in the two coastal regions of the Union Territory of Puducherry namely Puducherry and Karaikal by analyzing maximum temperature data of 40 years from 1981 to 2020.

2. *Definition* : According to the World Meteorological Organization definition, heat wave is a period of abnormally hot weather, spanning at least five consecutive days during which the daily maximum temperature exceeds the average maximum temperature by 5 °C or more. However, temperature based extreme weather events like heat waves vary largely based on the

geographical and meteorological factors of the region. Hence, different countries define heat wave differently in context of their local conditions. In India, as per the criteria laid down by the Indian Meteorological Department (IMD, 2020) heat wave is considered if the maximum temperature reaches at least 40 °C or more for plains, 37 °C or more for coastal areas and at least 30 °C or more for hilly regions. Following criteria are used to declare a heat wave:

(i) Based on Departure from Normal:

Heat Wave : Departure from Normal is 4.5 °C to 6.4 °C

Severe Heat Wave : Departure from normal is > 6.4 °C

(ii) Based on Actual Maximum Temperature (for plains only)

Heat Wave : When actual Maximum Temperature >45 °C.

Severe Heat Wave : When actual maximum temperature >= 47 °C.

3. *Data and Methodology* : The study area, Union Territory of Puducherry comprises of four coastal enclaves, viz., Puducherry, Karaikal, Mahe and Yanam. The Puducherry and Karaikal regions are located along Bay of Bengal and surrounded by the state of Tamil Nadu. Mahe and Yanam are smaller regions of the Union Territory located in the state of Kerala and Andhra Pradesh respectively. In this study, heat wave analysis is carried out for the data collected at the IMD stations at Puducherry and Karaikal in U.T. of Puducherry for a period of 40 years from 1981 to 2020. The regions are two discontinuous coastal enclaves separated by a distance of about 132 kms from each other.

The IMD station data with respect to maximum temperature recorded in Puducherry and Karaikal are used in the present study. Since, both the study areas are coastal regions, criteria prescribed by IMD for a “coastal station” is used for identifying the heat wave days, *i.e.*, when actual maximum temperature reaches 37 °C or more, and if departure of maximum temperature from normal is 4.5 °C to 6.4 °C heat wave condition is considered; if departure of maximum temperature from normal is > 6.4 °C severe heat wave condition is considered. Heat wave spell is declared if the above criteria is met for at least two consecutive days (IMD, 2020).

Accordingly, from the daily maximum temperature data for the study period 1981 to 2020, days experiencing

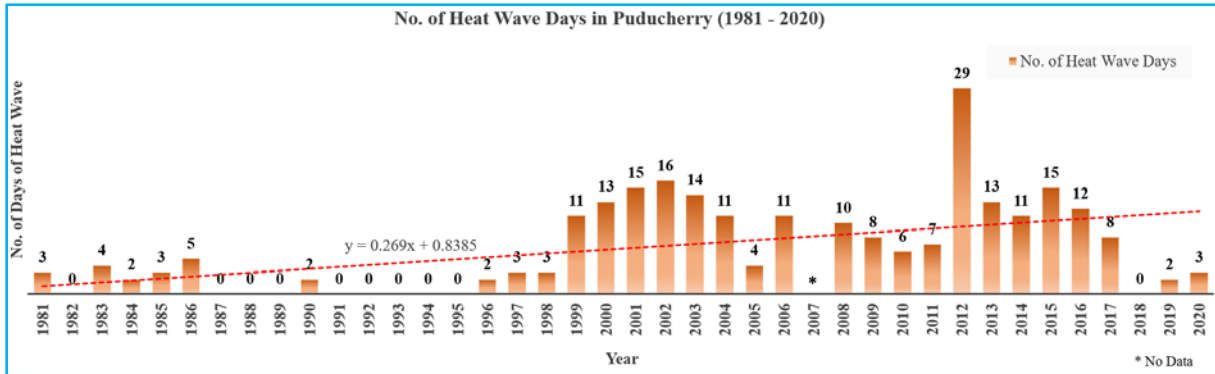


Fig. 1. Heat wave days in Puducherry from 1981 to 2020

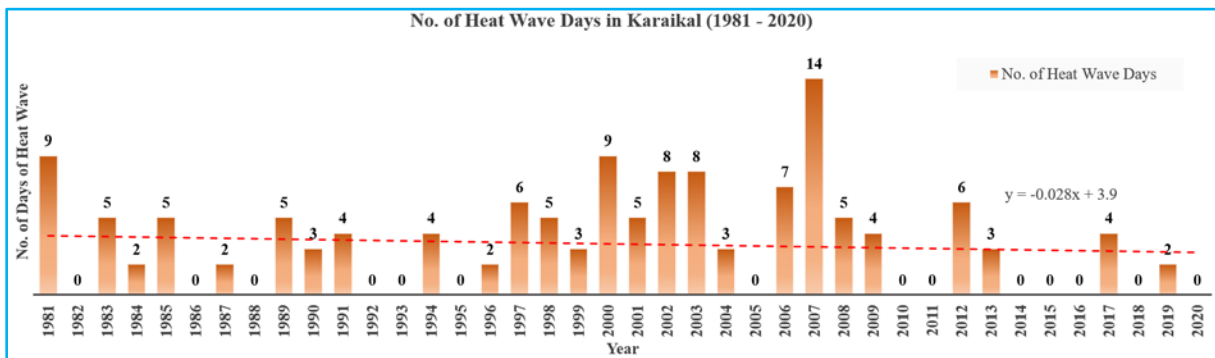


Fig. 2. Heat wave days in Karaikal from 1981 to 2020

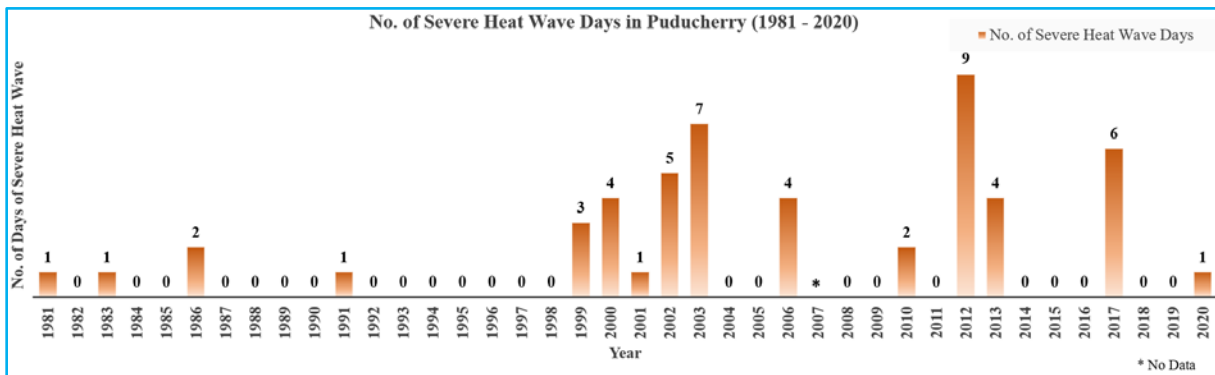


Fig. 3. Severe heat wave days in Puducherry from 1981 to 2020

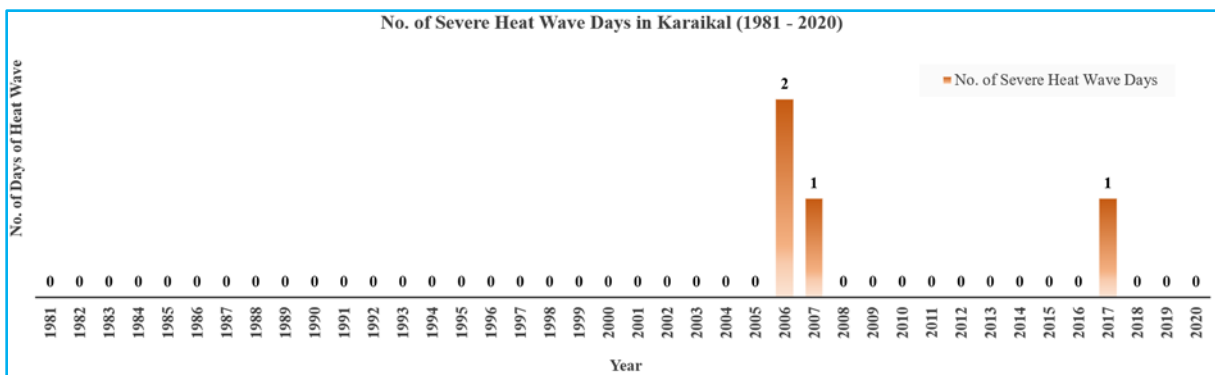


Fig. 4. Severe heat wave days in Karaikal from 1981 to 2020

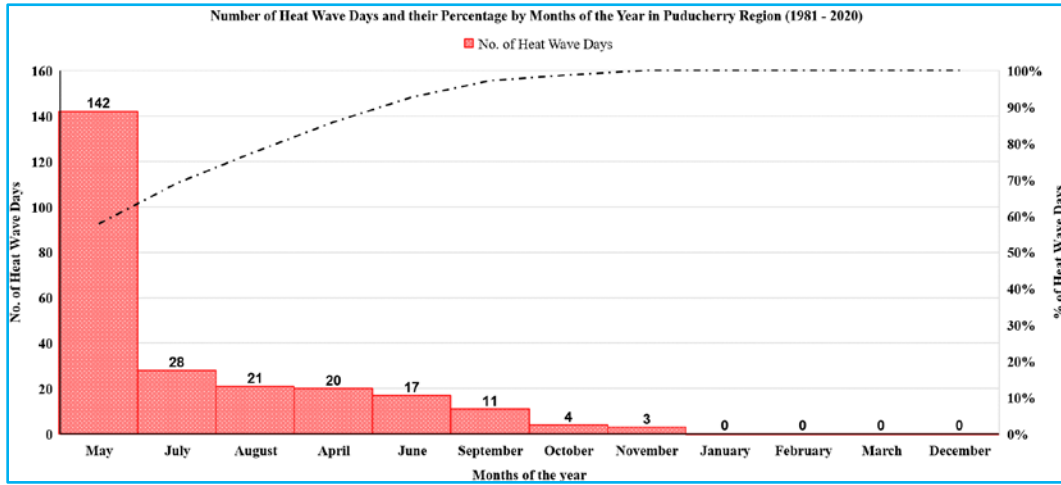


Fig. 5. Number of heat wave days and their percentage by months of the year in Puducherry (1981-2020)

maximum temperature of 37 °C or more are identified, following which they are checked if their departure from normal maximum temperature is from 4.5 °C to 6.4 °C for a heat wave day and greater than 6.4 °C for a severe heat wave day. The following normal maximum temperature data for Puducherry and Karaikal region obtained from IMD (<https://www.imdpune.gov.in/hydrology/normal/norclim.html>) is used to identify the departure from normal:

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Temp.	29.6	30.5	31.7	33.1	34.7	36	34.6	34	33.4	32	30.1	29.6

4. **Results and discussion** : The daily maximum temperature data of Puducherry and Karaikal IMD stations for the period 1981 to 2020 are analysed and their results are discussed below:

Figs. 1&2 show the number of heat wave days for four decades from 1981 to 2020 in the Puducherry and Karaikal IMD stations. Decadal analysis of heat wave frequency indicates an increasing trend in annual number of heat wave days for Puducherry station while no substantial increasing or decreasing trend is seen in Karaikal station. It is observed that, during the last four decades, Puducherry has experienced 246 heat wave days and Karaikal has experienced 133 heat wave days. The number of heat wave days were maximum in Puducherry during the last two decades and a maximum of 29 heat wave days was experienced in the year 2012. It is also observed that heat wave condition had prevailed in Puducherry during all the years in the last two decades, except for the year 2018. In Karaikal, it is observed that the number of heat wave days were more during the decade 2001-2010 with a maximum of 14 heat wave days in 2007.

Figs. 3&4 depict the severe heat wave spells that prevailed in the region of Puducherry and Karaikal respectively from the year 1981 to 2020. It is observed that the region of Puducherry has had 51 days of severe heat wave spell, while Karaikal had only 4 days of severe heat wave spell during the same period.

From the analysis of 40 years temperature data, it is observed that the longest spell of heat wave days was observed in Puducherry station during 17th March to 31st May 2012 when temperatures higher than the normal maximum were recorded for 15 consecutive days. During this period severe heat waves were experienced on 8 days with maximum temperature of 43 °C recorded on 18th May 2012 which is the highest temperature experienced in the region during the study period. Also, a record number of 6 heat wave spells were observed in Puducherry region during this year. It is relevant to note that, in a study carried out by Mishra *et al.* (2017) the magnitude of the heat waves that occurred in India for the period 1951-2015 was measured and it was observed that the year 2012 is one of the top three heat year in the country.

For Karaikal region, the longest spell of heat wave was recorded during 15th to 22nd May 2007 for a continuous period of 8 days. Also, a severe heat wave condition is observed on 12th May, 2007 when temperature had reached a maximum of 41.3 °C.

In Figs. 5&6, the annual pattern of heat wave occurrence is depicted by showing their percentage of occurrence during each month in the last four decades. In India, heat waves typically occur during hot weather season from March to June and sometimes extend till July. The peak month of the heat wave over India is May. From the analysis of the heat wave spells on monthly basis for

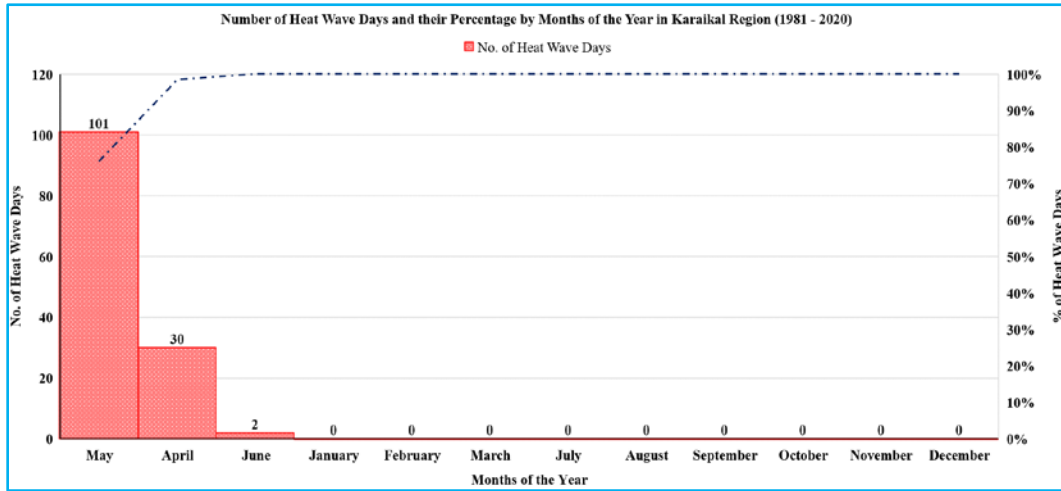


Fig. 6. Number of heat wave days and their percentage by months of the year in Karaikal (1981-2020)

Puducherry region shown in Fig. 5, it is observed that the heat wave spells have occurred during the summer months of April to June with about 58% of the total heat wave days in Puducherry (142 days) occurring in the month of May as observed in other parts of the country. Heat wave days are also observed in the months from July to November on certain years of the study period. These are mostly short spell *in-situ* heat wave, which may be attributed to synoptic conditions like movement of the tropical cyclones formed in Bay of Bengal or other favourable atmospheric conditions that prevailed in the region coupled with urban heat island effect. From Fig. 6, it is observed that, in the Karaikal region, almost all the heat wave spells have occurred during April and May, with just one heat wave spell in the month of June. No heat wave days are observed during other months. About 76% of the total heat wave days (101 days) are in the month of May.

The region of Puducherry and Karaikal are coastal plains whose meteorological conditions are largely impacted by the sea surface temperature of the adjoining Bay of Bengal. In general, the average maximum temperatures along the coast are lower than inland area. This is due to the cooling effect brought about by sea breeze that sets in at the coastal places in the forenoon or early afternoon. When the sea breeze is delayed or if the sea breeze does not set in, higher maximum temperatures are recorded at the coastal stations, the coastal stations experience very high maximum temperature as the inland stations, and many a time experience occasional / long spells of severe heat wave condition (Pai *et al.*, 2013). Heat waves generally occur in regions with temperature extremities coupled with quasi-stationary anti-cyclonic effects (atmosphere blocking) that stalls air in the upper

atmosphere over a landmass causing the air in the near land surfaces to warm up to extreme temperatures (IPCC, 2012).

Singh and Kumar (2018) analysed the meteorological conditions which led to severe heat wave spell in coastal Andhra Pradesh and Telangana in May 2015 and found that synoptic conditions like advection of dry air from northwest over a prolonged period of time, absence of sea breeze or late setting of sea breeze and dynamic conditions like high insolation and cloud - free atmosphere are the causes of such a long spell of severe heat wave.

Jenamani (2012) revealed that several heat waves occurring in eastern coast of India were caused by sea breeze cutoff due to the re-curving tropical cyclones in the Bay of Bengal, coupled with prevalence of much stronger and persistent dry continental westerly winds. Ratnam *et al.* (2016) pointed out that heat waves occurring over the east coast of India are caused by anomalous cooling over central and east equatorial Pacific which generates northwesterly anomalies over the landmass reducing the land-sea breeze. Rohini *et al.* (2016) indicated that the variability of heat waves over India is influenced by the sea surface temperature anomalies in tropical Indian Ocean and central Pacific and El Nino events.

From the decadal analysis of maximum temperature data for 40 years, it is observed that Puducherry has experienced almost twice the number of heat wave days than Karaikal during the study period despite their geographical proximity and similarity which may be attributed to the more urbanized landscape of Puducherry region and associated heat island effect. However, further

detailed study needs to be carried out to understand the various synoptic and dynamic meteorological conditions responsible for causing severe heat wave over the study regions.

5. *Conclusions* : The region of Puducherry and Karaikal has experienced 246 days and 133 days of heat wave spells respectively during the study period of 40 years from 1981 to 2020. Higher number of heat wave spells were identified to be occurring in Puducherry region when compared to Karaikal region during the study period, which may be attributed to the urbanized landscape of Puducherry with more concrete infrastructure, higher residential and institutional setups, higher vehicular population, relatively higher number of industries, and comparatively lesser green-cover. Risks due to heat stress and heat stroke during heat waves are higher in coastal cities and towns because of the higher relative humidity. Hence, improving the adaptive capacity of the vulnerable population in coastal areas through development of heat wave action plan, increasing the green-cover, improving the resilience of the habitants by adopting measures like “Cool Roof Programmes” already practiced in several Indian cities, the “Cool Pavement Programmes” initiated in major cities of the world and in India are ideas that could combat heat impacts in the region.

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Disclaimer : The contents and views expressed in this study are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

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