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Evaluating Temperature trends with self-engineered data logging thermometer: Is July 2021 in Jaipur warmer than average.

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Abstract

In the last 10 years, the global surface temperature has risen 0.2°C, which is similar to the warming rate anticipated in the 1980s by early global climate model simulations with transient greenhouse gas changes. It is difficult to detect global warming directly because most people experience changes only in local weather patterns, which are highly variable and may not reflect long-term global climate trend. However, experience with local weather may also influence global warming beliefs (33,34). As global climate change intensifies, changes in local temperatures and weather patterns may be increasingly detected by the global public. Here we examine the extent to which there is an increase in the average temperature of Jaipur over 2 weeks in July. We gather primary research by measureingthe daily average temperature with a self-engineered arduino based thermometer and data logger and then use that data to calculate the discrepancy compared to the last decade. We demonstrate that even though there has been a consistent increase in temperature in Jaipur for several decades, there is a decrease this year post the pandemic. These findings, although, suggest the difference for a month whereas the overall temperature for the year may give the analysis a different direction. It may also lead us to the increase in aerosols that may have caused the cooling effect in a month before the monsoon season.

Introduction

Scientific evidence has demonstrated that earth's climate is warming (IPCC 2018, 23, 1, 2). Global temperature has increased 2006-2015 was 1.58 ◦C higher than for the period 1850-1900, and 0.66◦C larger than the equivalent global mean temperature change. Additionally, the planet's average surface temperature has risen about 1.18 ◦C since late 19th century(NASA,7,8) Overwhelming evidence for the warming planet can be drawn from integrative indicators including changes in sea level (ocean warming + land ice melt), in ocean acidification (ocean uptake of CO2) and in the amount of ice on ocean and land (temperature and hydrological changes). (IPCC, 2018, IPCC, 2013*;24)*

The environment has already been affected by global climate change. Glaciers have diminished, ice on rivers and lakes has thawed up earlier, plant and animal ranges have changed, and trees have begun to bloom earlier. Sea ice loss, rapid sea level rise, and longer, more intense heat waves are all effects that experts anticipated would occur as a result of global climate change in the past.(3,4,5)

Climate Change in India

Between 1901 and 2020, India's average temperature increased by about 0.7°C. This increase in temperature is mostly due to GHG-induced warming, which is slightly countered by anthropogenic aerosol forcing and changes in LULC. Under the RCP8.5 scenario, the average temperature over India is expected to climb by around 4.4°C by the end of the twenty-first century, compared to the recent past (1976–2005 average) (Fig. 1). (see Box 1). Temperatures of the warmest day and coldest night of the year have risen by around 0.63°C and 0.4°C over the last 30 years (1986–2015). (4,5) Under the RCP8.5 scenario, these temperatures are expected to climb by around 4.7°C and 5.5°C by the end of the twenty-first century, respectively, compared to the corresponding temperatures in the recent past (1976–2005 average). (5,8,9) In the RCP8.5 scenario, the frequency of summer heat waves across India is anticipated to be 3 to 4 times greater by the end of the twenty-first century, compared to the 1976–2005 baseline period. The average duration of heat waves is also expected to nearly double, however, there is a wide range of projections. Heat stress is anticipated to worsen across India as a result of the simultaneous rise in surface temperature and humidity, notably in the Indo-Gangetic and Indus river basins.

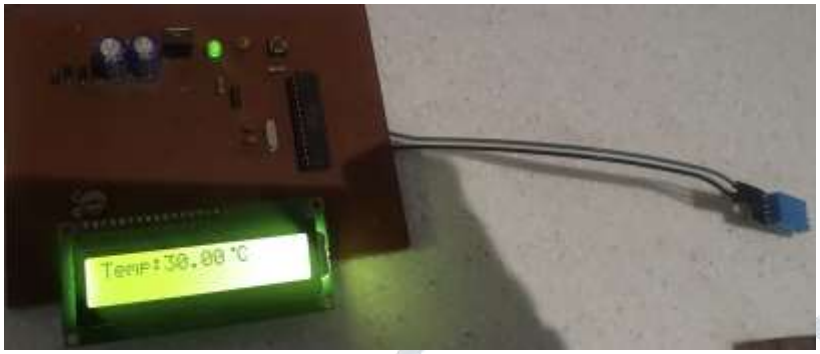
According to a report released on Tuesday by the London-based global think tank Overseas Development Institute, India might lose anywhere between 3 and 10% of its GDP yearly by 2100, and its poverty rate could grow by 3.5 per cent by 2040 as a result of climate change. In India, climate change is indeed delaying poverty reduction and increasing inequality. The fastest-warming districts all had their gross domestic product increase at a cagr of 56 per cent less than the slowest-warming districts. Rising average temperatures may erase recent development achievements if global action to curb greenhouse gas emissions is not taken quickly. According to the analysis, even if global temperatures are kept below two degrees Celsius, India will lose 2.6 per cent of its GDP year, and if global temperatures rise to three degrees Celsius, this loss will climb to 13.4% annually.

In Rajasthan, where water is scarce, climate change is a concern. In comparison to the rest of the country, the state contains a substantial portion of the desert or arid land (58 per cent of total geographical area) and limited water resources(Kates et al. 1985)Summers in Jaipur are tremendously hot, while winters are brutally cold. In May, maximum temperatures range from 40 to 47 degrees Celsius. For a few days of the season, a heat wave occurs, with daytime temperatures rising to 4–6 degrees Celsius above usual. Minimum temperatures in the winter range from 4 to 9 degrees Celsius and rarely drop below 0 degrees. So it is when a chilly (northerly) wind blows from the Himalayan region. The heavy rainfall months are July and August. Rainfall decreased in the months of October and November. These months are called the transition period. After the passage of western disturbances, mist and fog appear in the morning hours. On the 16th of January, 1964, and the 31st of January, 1905, temperatures as low as -2.2 °C were recorded.

To our knowledge, little literature has been developed for the temperature model of Jaipur, which is the most important city of the desert state Rajasthan in India. In order to calculate the discrepancy lies in the primary data compared to the secondary data we get from the weather station in Jaipur, our main objective of the research is to study and assess if the average temperature of the

day in Jaipur () from July 17 - July 31st higher or lower than the temperature at the weather station since 2009?

Methodology



A self-made thermometer is used to measure the daily high and low temperatures from 17th to the 31st of July and that data is then compared with the daily average temperature from 17th to the 31st of July from 2009 to 2020. The daily average temperature of the previous years is taken from the website (20,21) that is linked to the weather station in Sanganer, Jaipur.

The thermometer is made by assembling and designing a temperature sensor and data logger on a printed circuit board. An Arduino integrated circuit is used with a lcd display, sd card and temperature sensor to measure the temperature at a 1 second interval daily from 17th to the 31st of July. If the parts aren't easily available then one can also opt for the velveeta air thermometer that is easily available on amazon(22). To ensure that the thermometer that I am using gives accurate readings, I placed it just near the Indian meteorological centre in jaipur for 7 days before the trial. I then logged in the data on my computer and compared the daily high and low temperatures given by both- the self-made thermometer and the weather station. For all 7 days, the maximum discrepancy that occurred was .1 degrees celsius. Considering that to be negligible when calculating the average, I decided to proceed with my device.

The daily average temperature is computed by taking the maximum and minimum temperatures for each day from midnight to midnight and averaging them. Let us note the maximum and minimum temperatures measured in a single day if we have a weather station. The day's average temperature is calculated as follows:

(□□□□ + □□□□)/2= T a

T a= Average temperature of the day

For Jaipur, an 11-year-long time series of daily mean temperature grids in the month of July was created and recorded in a spreadsheet. Homogenized station values of daily mean temperature from Jaipur weather station as well as from a self-engineered thermometer were measured and recorded. Spatial interpolation was used to calculate the estimated temperature at certain time periods and the average temperature of each day from 17th to 31st July was calculated. For each respective year from 2009 to 2021, The average of the last 2 weeks of July is calculated to assess the difference between each successive year and it's reasons. By using a simple spreadsheet, we can present the data in a tabular and graphical format.

Results

Year	Average temperature(°c) from 17th to 31st (July)
2009	30.33333333
2010	31.7
2011	31.4
2012	33.26666667
2013	32.9
2014	32.83333333
2015	31.3
2016	30.73333333
2017	31.73333333
2018	30.166666670
2019	31.46666667
2020	32.16666667
2021	29.3

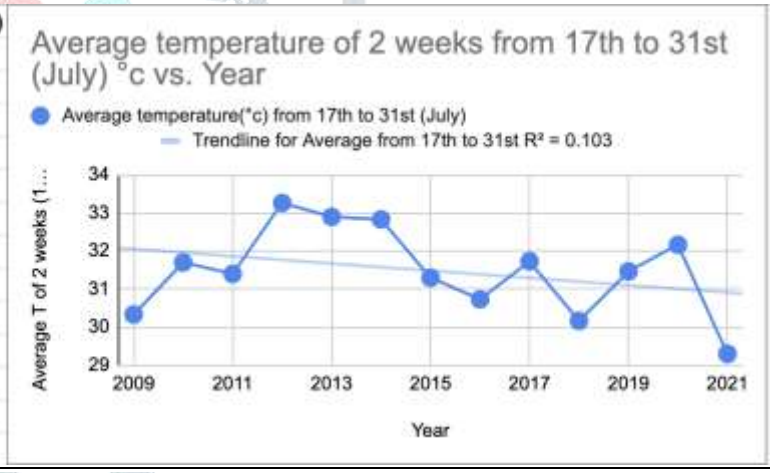


Table 1.1 and Figure 1.1

The 2 week average from 17th to 31st July of all years from 2009 to 2021 are displayed above in a tabular and graphical format. (See figure 1.1 and table 1.1). The highest average temperature of the two weeks occurred in 2012 and the lowest temperature occurred in 2021. The trendline would have been flatter without the 2021 datapoint as it brings the sudden decline in temperature causing a

more sloped trendline with a R^2 value of 0.103. The only 2 week tenure with an average temperature lesser than 30 degrees celsius is in 2021.

Day (July)	Average Temperature (°c)(2009-2020)	Average Temperature (2021)
17	32.7	33
18	33.4	29
19	32.9	27
20	32.7	29.5
21	32.3	31.5
22	31.9	30.5
23	32.2	29.5
24	31.6	31
25	31.3	32.5
26	31.4	31
27	30.7	27.5
28	30.25	27
29	30.7	27.5
30	31	28
31	31.2	25

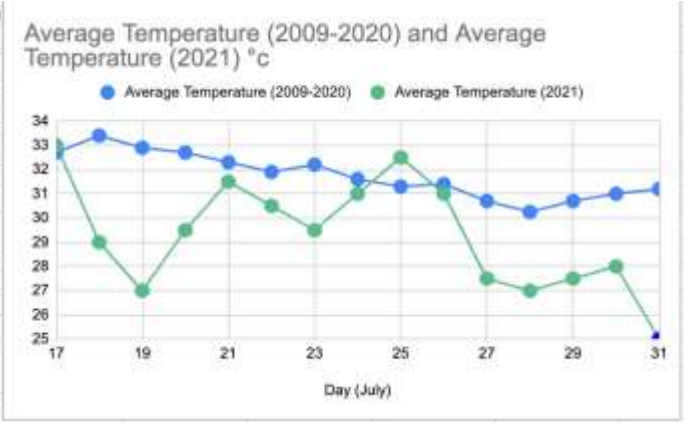


Table 1.2 and Figure 1.2

The Average Temperature for each day from 2009 to 2020 and 2021 has been displayed above in a tabular and graphical format. (See figure 1.2 and table 1.2). For the majority of cases, the average temperature before 2021 has been higher than 2021. The temperature has remained constant for most days from 2009-2020 but it has not been the same for 2021. After the 26th of July, the average temperature takes a sudden decline and continues to decrease. There is a linear pattern noticeable in the line graph of 2009-2020 but the line graph of 2021 has no order or consistency to it's readings. Excluding the 17th of July and 25th, all days of 2021 in the 2 week period have been comparatively cooler.

Discussion

	Treatments					
	1	2	3	4	5	Total
N	15	15				30
∑X	476.25	439.5				915.75
Mean	31.75	29.3				30.525
$\sum X^2$	15132.9825	12950.75				28083.7325
Std.Dev.	0.9276	2.2897				2.121

In a one way analysis of variance test, we computed the results of the average temperature of the daily average temperature from 2009-2020 and 2021 in two different treatments. The first treatment covered the 2009-2020 batch whereas the second covered the 2021 set. The standard deviation clearly indicates the high variance in the 2nd set compared to the first one. Also another thing to be noticed is the difference in mean value which suggests the low temperature during the two weeks compared to the previous 11 years. The p value is 0.00643 and f ratio value is 14.75247. The p value indicates the 99.357% confident that the two values are different. The f ratio value also suggests that the variation among the 2 groups is more than you'd expect to see by chance.

The average temperature in Jaipur was lower in the last 2 weeks of July because of the increase in precipitation during those days this year. (citation) The trendline would have a R^2 value of 0.064 if it hadn't been for the sudden decrease in average temperature brought by the 2021 datapoint; increasing the variation in temperature from 2009-2021. The 14 measurements taken for the 2 week analysis are not sufficient to extrapolate the average temperature and comment upon the temperature in Jaipur for 2021 due to the presence of numerous factors. If the year is observed as a whole, the temperature has supposedly increased.

The average temperature from July 17 to July 31st, 2021, shows a decreasing tendency, similar to the average temperature from July 14 to July 31st, 2009 to July 2020. Ross et al. (2018) found a pattern consisting of two warming regions over India, one to the northwest and one to the south, as well as a region of reduced warming, centred in northeastern India but extending southwestward into central India.

Despite the fact that the IPCC report from 2014 suggested that the warming trend is observed in Northwest and Southern India, with the greatest warming in the Northwest, and several studies have shown that global warming is occurring on the planet (IPCC 5th assessment report, NASAEvidence I Facts — Climate Change: Vital Signs of the Planet (nasa.gov);NOAA Global climate change indicators,NASA GISTEMPv4,Temperature. The subject of why there is a break in the temperature trend in India is raised.

Although a noticeable warming trend in Northwestern India (beginning in the 1970s and accelerating in the 2000s and 2010s) and maximum temperatures observed during the warm pre-monsoon season with an exponential rate, particularly in the last two decades, the pattern in India is disrupted by a broad cooling pattern extending from northeast to southwestward (Ross et a1,2018; Krishnan et al.2002).

Future Research

The model forementioned focuses on a small area in a city in the country thus it lacks the ability to massively contribute to the reasoning behind the ongoing climate change. While researching for the change in temperature over a set period of time, a larger geographical area is beneficial as it provides more generic information and adds highly to the broader context. Multiple cities throughout the country will allow the researches to imply the impact of climate change in the country.

Another way the research can be included in a broader context and have more reliable information to interpret is that if measurements are recorded for a longer period of time. Daily measurements for a year will clearly indicate the overall increase or decrease in temperature when compared to the previous decade which will then also elaborate upon the impact of aerosols more evidently.

To verify that the temperature decrease during July is due to the increase of anthropogenic aerosols, a researcher can incorporate an aerosol monitoring device. The device can be used to measure the amount of aerosols or particulate matter in the area where he or she is recording the temperature. They can then use that as a factor and delve deeper into the mechanics of the impact of aerosols on the change in temperature and the particulate content in that locality.

Solutions

Anthropogenic global warming is unquestionably one of the most pressing issues we face today. Over the last 150 years, human activities such as the burning of fossil fuels and deforestation have resulted in significant emissions of greenhouse gases (eg carbon dioxide and methane). These gases are increasing the amount of heat trapped in the atmosphere, causing climate change faster than it has ever been since the last 10,000 years ago.(25) Removal of greenhouse gases is considered the most efficient way to tackle climate change. Because so many human activities contribute to greenhouse gas (GHG) emissions, there are numerous options for reducing them.

Geoengineering refers to a set of emerging technologies that could manipulate the environment and partially offset some of the impacts of climate change. Carbon geoengineering, also known as carbon dioxide removal, is the first of two widely used categories in geoengineering (cdr). Solar geoengineering, also known as solar radiation management (srm), albedo modification, or sunlight reflection, is the other.

To reduce carbon emissions, energy production can be altered in a variety of ways. For starters, we can move from coal and oil to gas, which generates half as much CO2 as coal and two-thirds as much CO2 as oil per joule of energy utilised. Expanding the utilisation of Combined Heat and Power (CHP or cogeneration) plants is another option. These facilities use waste heat from energy production to offer space heating or hot water to buildings nearby. The most effective improvement in energy production would be to adopt renewable energy sources that produce no GHGs during operation. However, some renewable energy sources have the drawback of being intermittent.

Bioenergy with Carbon Capture and Storage is another option (BECCS). Carbon Capture and Storage in Bioenergy (BECCS). This method takes advantage of the carbon that plants naturally store during photosynthesis. BECCS eliminates carbon dioxide from the environment by burning biomass to generate energy before it decomposes and releases its abundance of carbon, and then capturing and storing the carbon released during biomass combustion underground. Biological Carbon Sequestration can help with this strategy. These technologies modify the biological building blocks of plants and other systems to absorb more CO2, lowering atmospheric levels.

Several solar geoengineering systems have been proposed. Marine cloud brightening, cirrus cloud thinning, space-based approaches, and stratospheric aerosol scattering are some of the techniques used. Maritime cloud brightening aims to brighten marine clouds so that more light is reflected back into space. Cirrus cloud thinning aims to minimise the thin, high-altitude cirrus clouds, allowing the planet to release more long-wave radiation into space. By deploying sun shields in space, space-based devices would aim to reflect a small fraction of sunlight away from the earth. Finally, stratospheric aerosol scattering would introduce small reflective particles like sulphate aerosols into the atmosphere.

Given the existing inequities in climate change, any proposed climate engineering strategy to solve the climate problem must meet a high threshold for justice. Geoengineering carries ‘large risks’ for the natural world. The conversion of current land to BECCS plantations on a broad scale could result in a 10% reduction in global forest cover and a 7% reduction in biodiversity "intactness." According to a second study, the use of solar geoengineering could endanger biodiversity. According to new research, deploying – and then failing to maintain – such technology might lead global temperatures to swiftly rebound, leaving many species unable to deal with the abrupt change in conditions.

It's all too simple to wish climate change away by dismissing the science or claiming that a quick transition to new clean energy sources will solve the problem. The science of climate danger is strong, and the carbon cycle's inertia, along with the world's economy, means that attempts to reduce emissions will only mitigate (not reverse) climate change this century.

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