International Journal of Computer Engineering and Technology (IJCET)
Volume 12, Issue 3, September-December 2021, pp. 8-15, Article ID: IJCET_12_03_002
Available online at https://iaeme.com/Home/issue/IJCET?Volume=12&Issue=3
Journal Impact Factor (2020): 10.8630 (Calculated by GISI) www.jifactor.com
ISSN Print: 0976-6367 and ISSN Online: 0976–6375
DOI: https://doi.org/10.34218/IJCET.12.3.2021.002

SCOPE DATABASE INDEXED

HEATWAVE AI: PREDICTION OF HEAT WAVES IN INDIA USING A DENSE NEURAL NETWORK AND SPATIOTEMPORAL DATA

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ABSTRACT

The increased frequency of heat waves is one of the most dangerous impacts of climate change, seriously negatively impacting human life and agriculture. Using gridded monthly maximum temperature dataset from 1951-2015, I train a Dense Neural Network architecture to predict the occurrence of heat waves over any 1° by 1° geographical co-ordinate over India a month in advance, using monthly maximum temperature data from the 6 months preceding it, to notify people to allow them to take precautions to protect their lives and livelihoods.

Key words: Heat Wave, Deep Learning, Dense Neural Network, Spatiotemporal Prediction

Cite this Article: Vansh Tibrewal, Heatwave AI: Prediction of Heat Waves in India Using a Dense Neural Network and Spatiotemporal Data, *International Journal of Computer Engineering and Technology* 12(3), 2021, pp. 8-15.
https://iaeme.com/Home/issue/IJCET?Volume=12&Issue=3

1. INTRODUCTION

Drought refers to the acute shortage of water and soil moisture caused by a sudden deficiency in precipitation, which results in a scarce supply of water and reduced crop yield. In the Indian Subcontinent, droughts generally occur because of delayed arrival and/or early retreat of the south-west monsoon winds accompanied by poor precipitation [1]. Although inadequate precipitation is a driving force behind droughts, abnormal rises in temperature due to heat waves can also initiate and intensify droughts [2]. Droughts that result from the combined effect of rainfall deficiency and extreme heat are much more severe, and cause greater damage to agriculture, which translates into a significant reduction in crop yield, as was the case in Europe in 2003 [3]. Regions with arid and semi-arid climate are more susceptible to drought since they are more sensitive to rainfall deficiency and temperature extremes. Both rainfall and temperature may play vital roles in drought initiation, development, and persistence, especially for vegetative and agricultural droughts. Heat waves are defined as an abrupt increase in air and land-surface temperature, higher than the normal (long-term average) for several days in succession. Heat waves occur in India during the summer or pre-monsoon (April–May) period, and at the beginning of the rainy season around early June. Such heat waves are generally accompanied by low or lack of precipitation and high moisture deficiency. Rainfall may reduce the intensity of heat waves and thermal stress but seldom occurs during heat wave events. India faces major challenges to increase its food production to feed its ever-growing population. To meet the demand for food from this increased population, the country's farmers need to produce significantly more grains in a short time span. The total gross irrigated area has more than quadrupled from 22.6 million ha in 1950–51 to 99.1 million ha in 2011-2012. Although agriculture contributes only 14% of the Gross Domestic Product (GDP) of India, 64% of the population depends on agriculture for their livelihood. Over the years, the demand for water has increased due to urbanization, increasing population, rapid industrialization, and other developmental initiatives. In addition, changes in cropping and land-use patterns, over-exploitation of groundwater and changes in irrigation and drainage have modified the hydrological cycle in many climate regions and river basins of India. Availability of water is the most important factor in agricultural production.

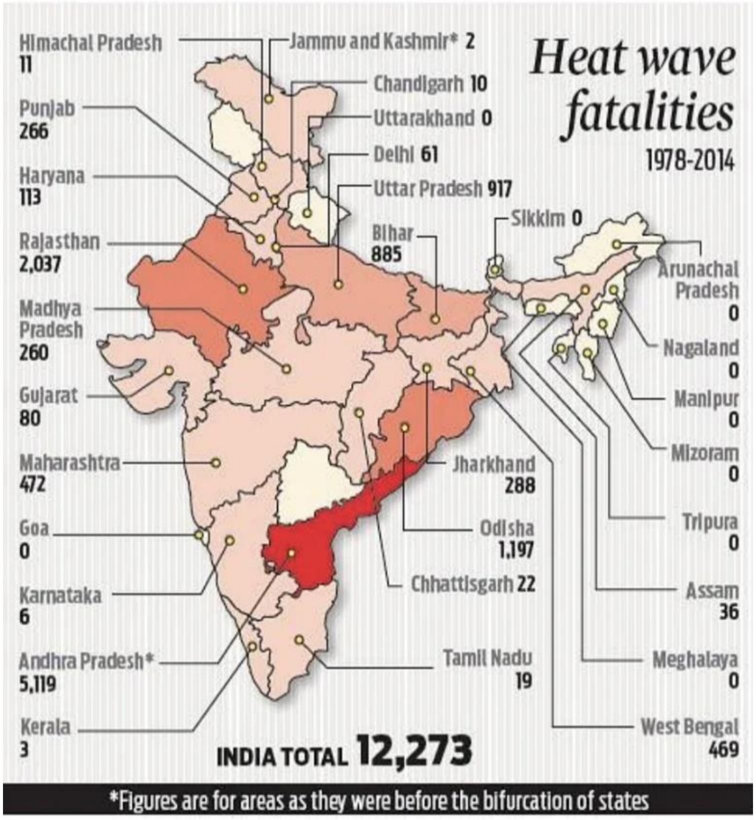
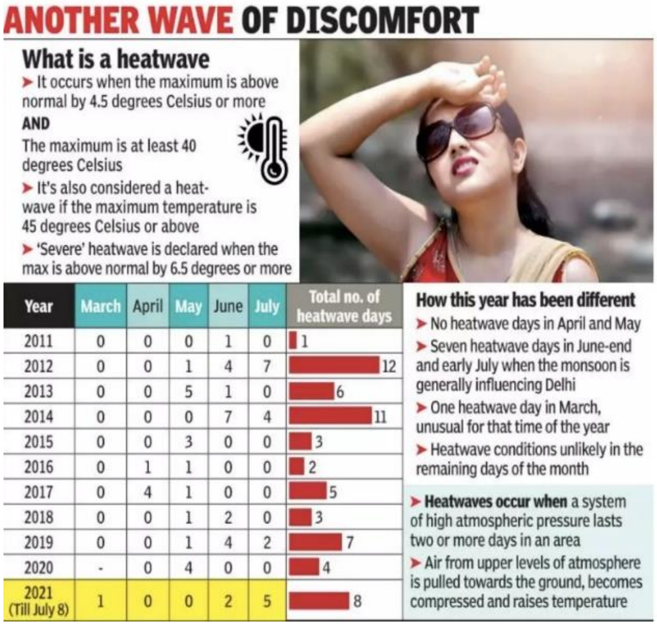


Figure 1 Heat wave fatalities in India

Water quality and quantity are serious constraints for agriculture in most parts of India. Agriculture must adapt to changing climatic conditions by tapping water resources and developing improved water management approaches. Simultaneously, there is also a need to develop and implement technologies and policies which will help in reducing and mitigating greenhouse gas emissions. Therefore, assessment of the availability of water resources is a future national requirement and the expected impact of climate change and its variability is critical for relevant national and regional long-term development strategies for sustainable development. India is home to 16% of the world population, but only 4% of the world's water resources. Agriculture is directly dependent on climate, since temperature, sunlight and water are the main drivers of crop growth. While some aspects of climate change such as longer growing seasons and warmer temperatures may bring benefits in crop growth and yield, there will also be a range of adverse impacts due to reduced water availability and more frequent extreme weather conditions.


ANOTHER WAVE OF DISCOMFORT

What is a heatwave

- It occurs when the maximum is above normal by 4.5 degrees Celsius or more AND The maximum is at least 40 degrees Celsius
- It's also considered a heat-wave if the maximum temperature is 45 degrees Celsius or above
- 'Severe' heatwave is declared when the max is above normal by 6.5 degrees or more

Year	March	April	May	June	July	Total no. of heatwave days
2011	0	0	0	1	0	1
2012	0	0	1	4	7	12
2013	0	0	5	1	0	6
2014	0	0	0	7	4	11
2015	0	0	3	0	0	3
2016	0	1	1	0	0	2
2017	0	4	1	0	0	5
2018	0	0	1	2	0	3
2019	0	0	1	4	2	7
2020	-	0	4	0	0	4
2021 (Till July 8)	1	0	0	2	5	8

How this year has been different

- No heatwave days in April and May
- Seven heatwave days in June-end and early July when the monsoon is generally influencing Delhi
- One heatwave day in March, unusual for that time of the year
- Heatwave conditions unlikely in the remaining days of the month

- Heatwaves occur when a system of high atmospheric pressure lasts two or more days in an area
- Air from upper levels of atmosphere is pulled towards the ground, becomes compressed and raises temperature

Figure 2 Sporadic Heat wave increases signifantly in cities (TOI)

2. LITERATURE REVIEW

These impacts may put agricultural activities at significant risk. Climate change has already caused significant damage to our present crop profile and threatens to bring even more serious consequences in the future. Wheat yields are predicted to fall by 5-10% with every increase of 1°C and overall crop yields could decrease up to 30% in South Asia by the mid-21st century. India could experience a 40% decline in agricultural productivity by the 2080s. [3] Rise in temperatures will affect wheat growing regions, placing hundreds of millions of people at the brink of chronic hunger.

Although deficient rainfall is considered the chief architect of droughts, heat waves and temperature extremes, though underestimated, often play crucial roles in drought development and intensification. [6]

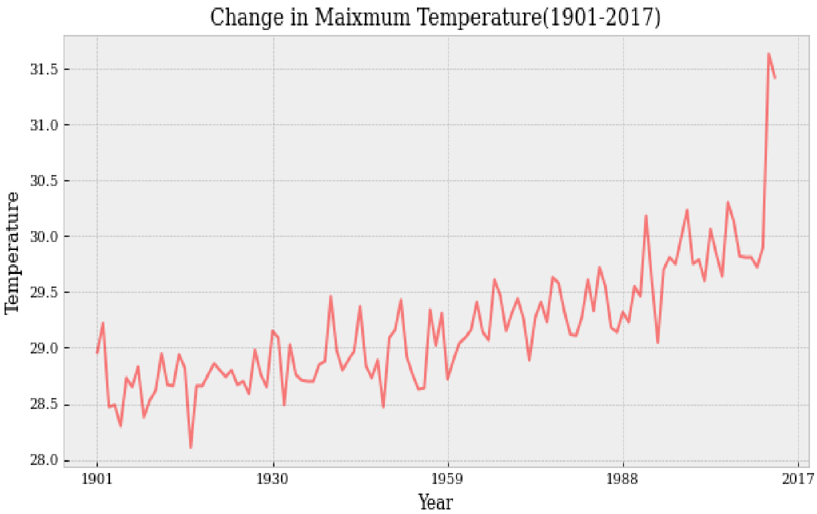


Figure 3 Significant increase in Max Temperature

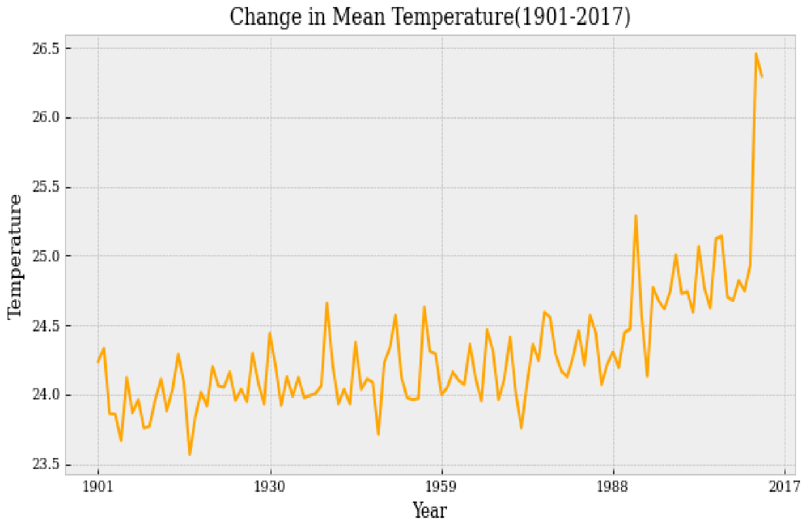


Figure 4 Significant increase in Mean Temperature

High temperatures affect crops in different ways and cause decreased photosynthesis, leaf senescence, decreased pollen production and pollen viability, seed abortion, and consequently lower grain number and grain weight. However, critical temperature thresholds and sensitivities vary between crops, cultivars and phenological development stages resulting in different plant responses. The cultivar diversity and heterogeneity in sowing dates observed under real field conditions is still not reflected in large scale heat stress assessments.

3. BACKGROUND ANALYSIS

I have taken data from 4 cities: Delhi, Mumbai, Chennai, Kolkata. These cities were chosen as they have significant rice production and are geographically diverse.

	A	B	C	D	E
1	MONTH	DAY	YEAR	TEMPERATURE	
2	1	1	1995	72.4	
3	1	2	1995	73.5	
4	1	3	1995	72.6	
5	1	4	1995	75.2	
6	1	5	1995	74.8	
7	1	6	1995	76.4	
8	1	7	1995	78.4	
9	1	8	1995	78.6	
10	1	9	1995	78.1	
11	1	10	1995	79.3	
12	1	11	1995	77.9	
13	1	12	1995	79	
14	1	13	1995	73.4	

Figure 5 Dataset of 4 cities from 1995 to 2019 max temperature

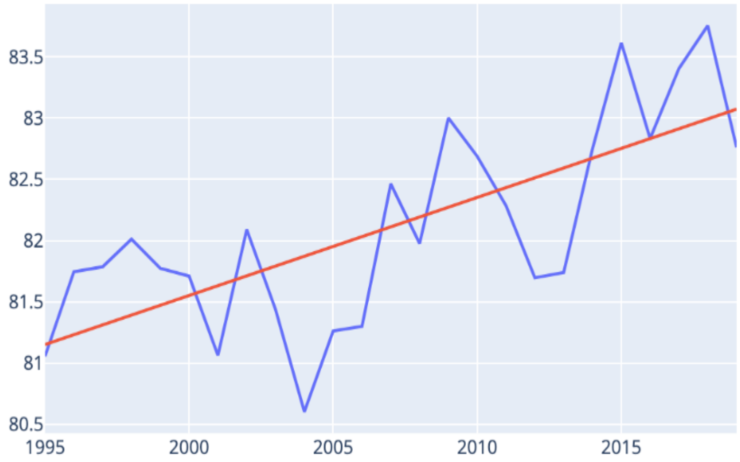


Figure 6 Prediction of increase in temperature in Mumbai city

The temperature analysis shows the long-term increasing trend in temperature month-wise since 1995 to 2020 in Mumbai, showing that heatwaves are an inevitable problem. Similar long-term trends emerged for the other three cities as well.

4. DATA

The present study mainly considers temperature data and precipitation data.

High Resolution Gridded Maximum Temperature Dataset

- Created by the National Oceanic and Atmospheric Administration (NOAA) and Columbia University
- 1° latitude by 1° longitude grid data (high res)
- Highest temperature recorded for each month from 1955-2019
- Based on satellite thermal infrared observations and 15,000 meteorological stations globally
- Accounts for more variance in data than previous existing datasets by up to 51% for the India region
- Dataset has been created by researchers for climate extreme analyses and early warning applications, which is exactly what this project aims to do by creating an early warning system for extreme high temperatures over India in the form of heatwaves

Standardized Precipitation-Evapotranspiration Index

- Multiscalar drought index created to quantify the characteristics of drought episodes in terms of their intensity, magnitude, duration and spatial extent
- Accounts for various meteorological factors relevant to measuring drought including weekly precipitation data
- 1° latitude by 1° longitude grid data (high res)

- Monthly average SPEI index data from 1955-2019
- Analysis shows that the Standardized Precipitation-Evapotranspiration Index is more accurate at tracking drought than the widespread Standardized Precipitation Index, specifically in light of climate change, making it a better dataset for the long-term climate mitigation aim of this project

5. METHODOLOGY

While both the above datasets were tested in combination, the SPEI index seemed to not improve the performance of the neural network significantly, and thus the final neural network used was trained on solely the high resolution gridded monthly maximum temperature dataset.

5.1. Input Parameters

The neural network used the monthly maximum temperature for the current grid(X) and the 12 neighboring grids(o) as seen in Figure 7.

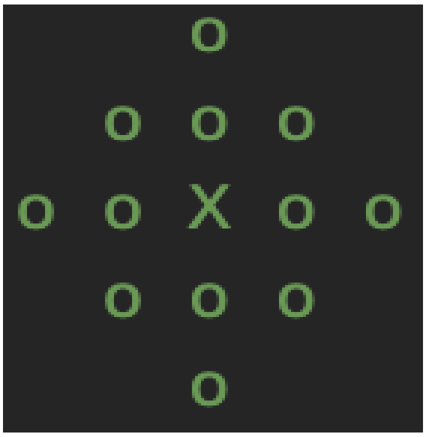


Figure 7 Grid system

The monthly maximum temperature for all 13 of these grids was taken for the current month as well as the past 6 months. A total of 91 input parameters were chosen, 13 grids x 7 months.

Thus, the input parameter choice accounts for spatial and temporal information, allowing effective prediction of temperature trends.

When the input parameters were extracted from the NOAA high resolution gridded max temp dataset, the data samples which had null values in any of the current or neighboring grids were removed. In the end, a dataset of over 400,000 samples was extracted.

5.2. Architecture

A fully connected dense neural network architecture was used, with 91 input nodes, 12 nodes in the first layer, 8 nodes in the second layer, and 1 output node.

ReLU activation was used for nodes of all layers except the final layer, which had linear activation, to allow for accurate temperature prediction.

A visual representation of the architecture can be seen in Figure 8.

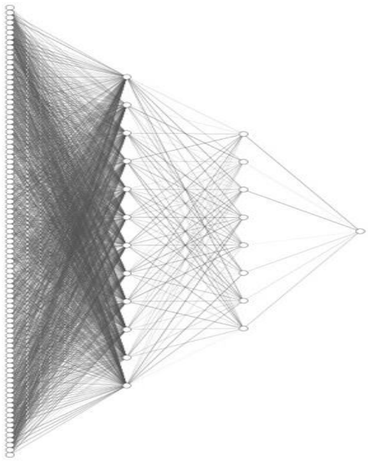


Figure 8 Dense neural network architecture, with the graph weights represented by width of edges

5.3. Output Parameter

The output to be predicted is the maximum recorded temperature in the current grid(X) for the next month.

Since the maximum temperature is being predicted, it identifies whether a heat wave occurs or not depending on how much higher it is than the normal temperature, which can be determined best by the individual judgements of farmers and users using the model for their geographical co-ordinates.

6. CONCLUSION

The 400,000 samples were split 60:20:20 for the training and testing datasets.

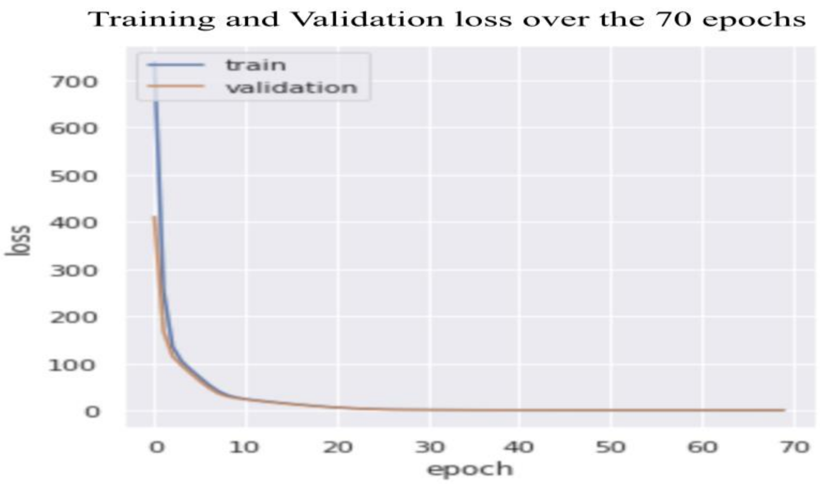


Figure 8 Training and Validation loss graph

The metrics of the trained model on the test dataset:

- Mean Squared Error: 1.4 °C
- Mean Absolute Error: 0.92 °C
- R^2 score: 91.10%
- Mean Absolute Percentage Error: 2.96%
- Mean Accuracy: 97.04%

The high accuracy of the project can be attributed to the parameter choice, accounting for spatial and temporal variation, the large sample set, over 400,000 samples, and the dense neural network architecture, allowing for complex relationships between the 91 spatiotemporal input parameters to be identified.

Thus, this project predicts with 97% accuracy the highest temperature that will be recorded in the next month in a specific 1° latitude by 1° longitude grid, based on the highest recorded temperatures of each of the past 7 months for the same grid and 12 neighboring grids. This prediction will enable farmers to identify when a spike in temperatures and heatwave is coming with a high accuracy, a month in advance and make the appropriate preparations to protect their crops. This research will be extended to create a live website display of the model that will allow farmers to easily access the specific heat wave/temperature prediction for next month for their location with one click. This project will further be extended, as the same neural network used to predict heat waves a month in advance can be reapplied to predict heat waves up to even a year in advance, repeatedly applying the model to predict the subsequent month's temperature based on given month's predicted temperature. Due to the nature of datasets utilized for this project, it can be expanded to help farmers globally, at any location near to the Tropic of Cancer, as they would have similar climatic conditions as those of India.

REFERENCES

[1] L. m. l. t. d. i. India, "NOAA," no. https://www.climate.gov/news-features/climatecurrent, 2012.

[2] V.L.A.S.S.L.I.A.M.H.B.B.C.G.T.H.S.U. Teuling AJ, " Evapotranspiration amplifies European summer drought. Geophys Res Lett," 2013.

[3] R.M.V.N.G.A.O.J.A.V.A.M.B.N.B.C.A.C.F.N.N.F.A.F.P.G.T.H.B.K.K.A.K.G.L.D.M.G.M. G.M. Ciais P, "Europe-wide reduction in primary productivity caused by the heat and drought in 2003," no. Nature, pp. 529-533, 2005.

[4] S.A.M. a. L.D.B. Gourdji SM, "Global crop exposure to critical high temperatures in the reproductive period: historical trends and future projections," vol. Environ. Res. Lett. 8 024041, 2013.

[5] D.A.a.d.J.v.L.Q, "Canopy temperature versus soil water pressure head for the prediction of crop water stress," vol. Agric. Water Manag, no. 127, pp. 1-6, 2013.

[6] "Times of India," [Online]. Available: https://www.independent.co.uk/climate-change/news/india-heatwave-farmers-suicide-killing-themselves-51-record-temperature-climate-change-global-warming-a7039841.html .

[7] E. F. e. al, "Effects of elevated CO2 and drought on wheat: testing crop simulation models," vol. 93, pp. 246-66, 2002.

[8] F. I. a. T. N. C. Asseng S, "`The impact of temperature variability on wheat yields," no. Glob. Change Biol. 17, p. 997–1012, 2011.

[9] "Downtoearth," [Online]. Available: https://www.downtoearth.org.in/news/climate-change/global-warming-can-put-billions-at-risk-of-malaria-dengue-study-77882.

Author Details

Vansh Tibrewal is a machine learning researcher and programmer who has been a research assistant at Harvard and the Georgia Institute of Technology, worked as a programmer at multiple software development companies and founded his own tech startup named Lumos.