Analysis of the extreme weather in Southern China

Author: Yabei Zeng
yabei_zeng@ucsb.edu

I. Introduction

In the year 2022, Southern China, specifically the province of Sichuan and the city of Chongqing, was struck with the most severe heat wave of the previous ten years. Extreme temperatures (over 40 degrees Celsius or 104 degrees Fahrenheit) have reportedly affected major cities across sections of "southwest, central, and eastern china" (Chang et al., 2022). Heat waves and extreme temperatures have received a lot of attention in recent years and decades. The study of extreme weather events in Southern China can provide a glimpse into the reasons for the occurrence of extreme heat, further helping understand the possible impacts of heat waves on humans, nature, and factors related to that. According to Zeppetello (2022), short wave radiation, precipitation-induced moisture anomalies in soil, Carbon dioxide concentration, and humidity are some of the many factors that drive and control heat waves. (Zeppetello et al., 2022). Therefore, in this study, the daily temperatures with all other factors will be retrieved from the Weather for 243 Countries of the World (Rp5.Ru) to study the variables with great importance in order to discuss their impacts on heatwaves and vice versa.

II. Methods

A. Variable Correlation

The variable correlations explore the relationship between the variables in the datasets, describing the strength of the association between two variables. (The BMJ, 2020) Normally, the correlation between variable A and variable B is the same as the correlation between variable B and variable A, which is completely symmetrical (The BMJ, 2020). The variable correlation represents the dependence

of one variable on the other, in further, describing the sensitivity of extreme temperature regarding the change of relating factors, such as energy received, humidity, pressure, etc.

B. Linear regression analysis

Linear regression is a simple method to find the linear line between observations by calculating the estimated β_0 and β_i, namely the intercept and the slope, that minimizes the squared error between predicted value and observations. The linear regression analysis used here is to understand the general trend of the temperature as the observation line plot does not show a clear trend of whether the temperature increases or not.

C. Variable Inflation Factor (VIF)

Variable Inflation Factor is a method to find the multicollinearity degree of the variables and is used when the assumption that independences of variables does not hold. The VIF helps to understand the dependence degree between two variables that co-contributes to the change of the extreme temperature and help finding the interaction terms in models.

D. CMIP3 models

The CMIP3 (Coupled Model Intercomparison Project) used by Sherwood et. al (2010) used 18 in total GCMs (General Circulation Model), estimated the average of all the simulations from the GCMs to explore the changes of relative humidity with per kelvin of surface warming. Through the Use of CMIP3, Sherwood et al. (2010) obtained the climate sensitivity of relative humidity by dividing the change

in relative humidity by the change in global mean surface temperature. (Sherwood et al., 2010).

III. Data description

Two datasets (Daily temperatures from 2012 to 2022 in Chongqing and Daily temperatures from 2012 to 2022 in Las Vegas) from Weather for 243 Countries of the World (Rp5.Ru) The las Vegas dataset is used as a comparison to compare the variables importance and temperature changes in different heights and longitudes but approximately same latitudes.

A. Chongqing

* There are in total 19194 observations in this dataset

Name	Variable description	Type
date	The datetime of the date received	Numeric
T	Temperature at the given time	Numeric
Po	Atmospheric pressure at weather station level	Numeric
P	Atmospheric pressure reduced to mean sea level	Numeric
Pa	Pressure tendency	Numeric
U	Relative humidity	Numeric
DD	Mean wind direction	Numeric
Ff	Mean wind speed	Numeric
N	Total cloud cover	Categorical
WW	Present weather reported from a weather station	Numeric
W1	Past weather of observation 1	Categorical
W2	Past weather of observation 2	Categorical
Tn	Minimum air temperature	Numeric
H	Height of the base of the lowest clouds	Numeric
VV	Horizontal visiblity	Categorical
Td	Dewpoint temperature	Numeric
RRR	Amount of precipitation	Numeric
tR	The period of time in precipitation	Numeric

B. Las Vegas Dataset

*There are in total 15848 observations in Las Vegas dataset

Name	Variable description	Type
date	The datetime of the date received	Numeric
T	Temperature at the given time	Numeric
Po	Atmospheric pressure at weather station level	Numeric
P	Atmospheric pressure reduced to mean sea level	Numeric
Pa	Pressure tendency	Numeric
U	Relative humidity	Numeric
DD	Mean wind direction	Numeric
Ff	Mean wind speed	Numeric
N	Total cloud cover	Categorical
WW	Present weather reported from a weather station	Numeric
W1	Past weather of observation 1	Categorical
W2	Past weather of observation 2	Categorical
Tn	Minimum air temperature	Numeric
H	Height of the base of the lowest clouds	Numeric
VV	Horizontal visiblity	Categorical
Td	Dewpoint temperature	Numeric
RRR	Amount of precipitation	Numeric
tR	The period of time in precipitation	Numeric

IV. Results

From the line plots of the daily temperature differences, the differences between Las Vegas daily temperatures are larger than that of Chongqing. (Figure1) However, from figure 2, the daily maximum temperatures between Las Vegas and Chongqing are very close, which represents that the nighttime temperatures of Chongqing are relatively higher than Las Vegas due to the low daily temperature difference in Chongqing. As heatwave's impact humans on only

during daytime but also nighttime, the days with temperatures above 40 degree celsius in Chongqing may have larger impacts on humans and environment compared with that of Las Vegas.

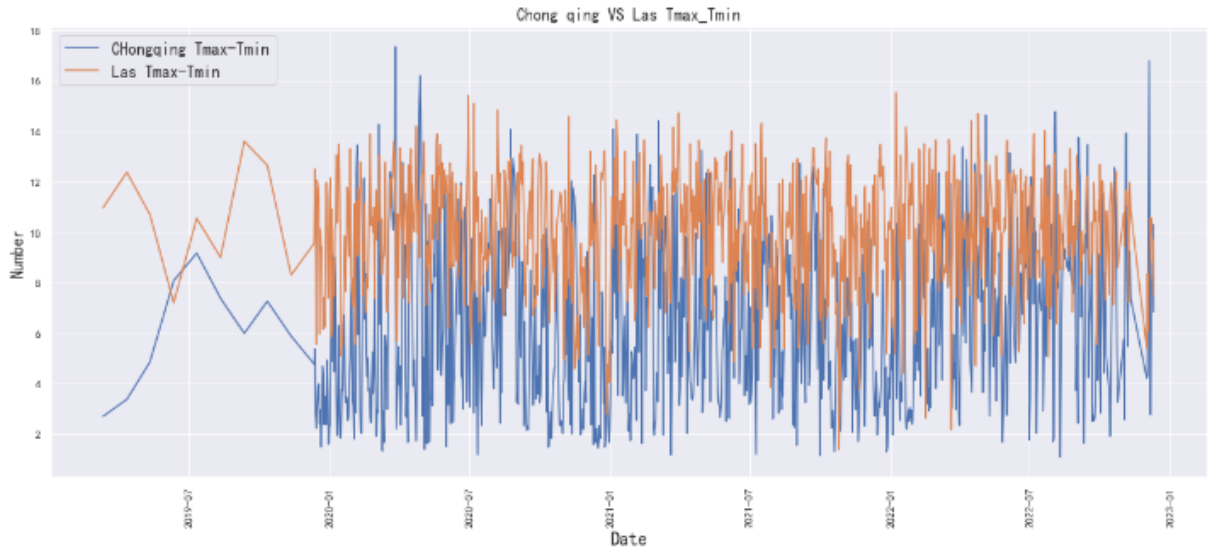


Figure1: daily temperature differences in Las Vegas and Chongqing

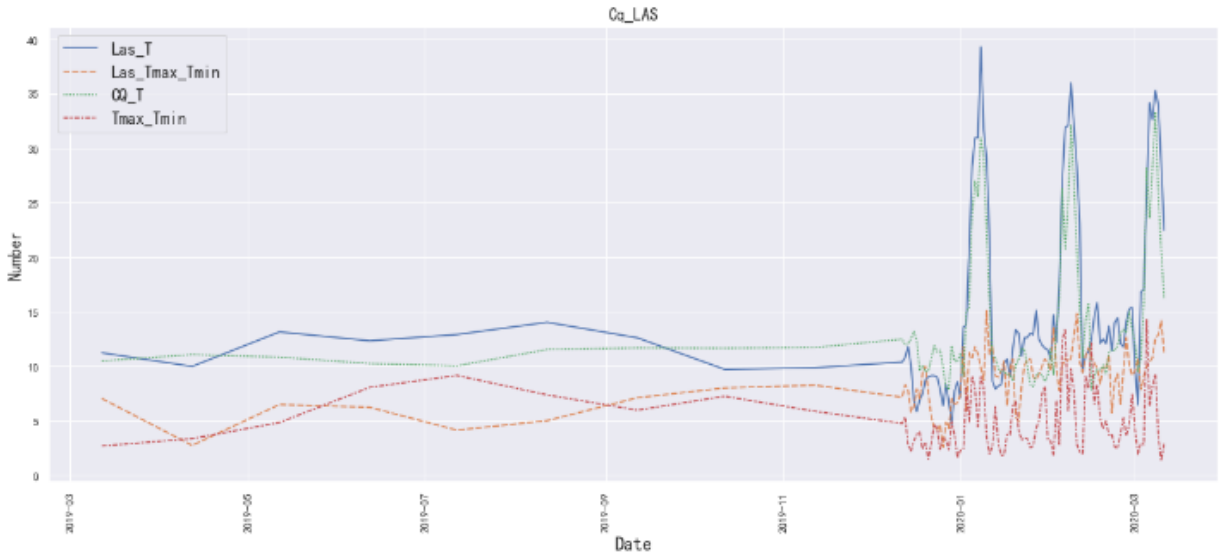
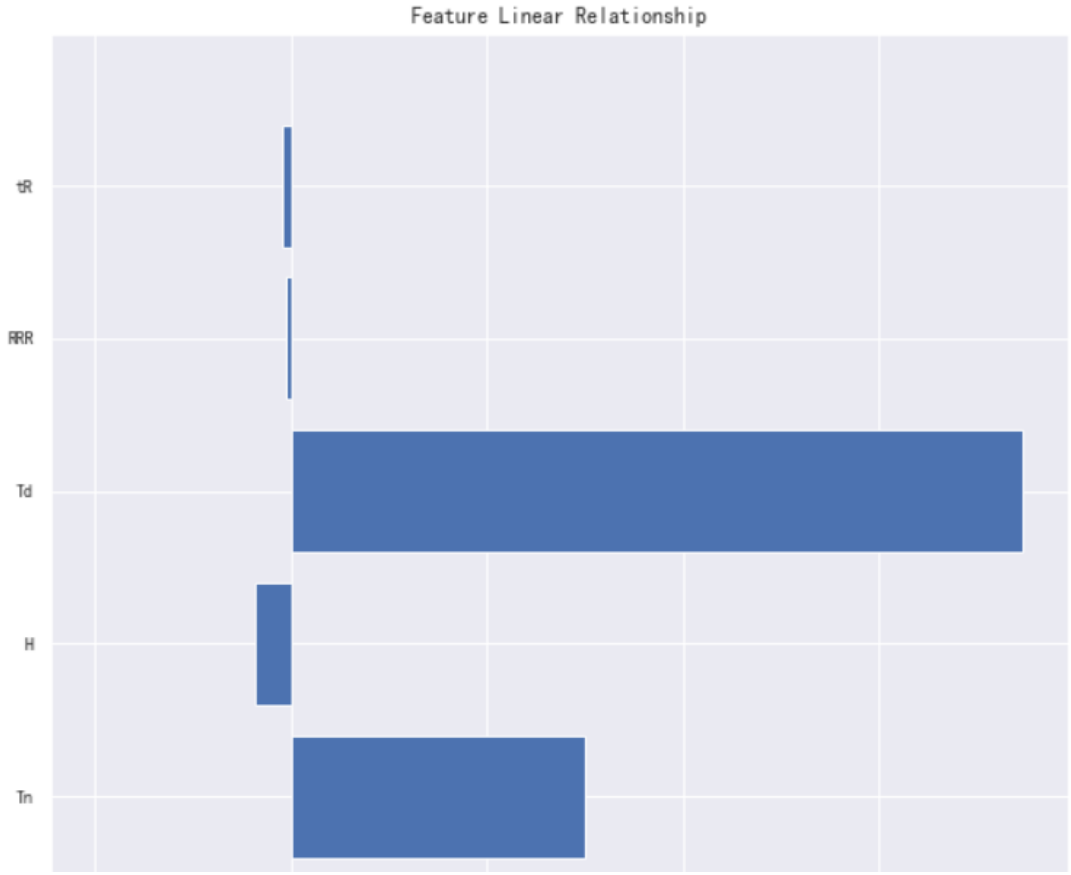


Figure2: multi y plot Las Vegas daily temperatures and Chongqing temperatures

In further study of the factors that contribute to the extreme heat in Chongqing, variables importance calculated from their correlation is presented in figure 3. As the figure showed, Td (dew point temperature, 0.6 weighs), Tn (daily minimum temperature, 0.35 weighs), Ff (Mean wind speed, 0.38 weighs), and U (relative humidity, -0.2 weighs) have relatively large weights among all the features. First, dew point temperature and daily minimum temperature are calculated based on the daily temperatures, therefore they will have large weights and will increase as the temperature increases. Because humidity (including relative humidity and absolute humidity) has the potential effect of aggravating the impacts of heatwave and extreme temperature would affect humidity as well, humidity will be one of the main focus of analyzing the factors importance on temperature increase.



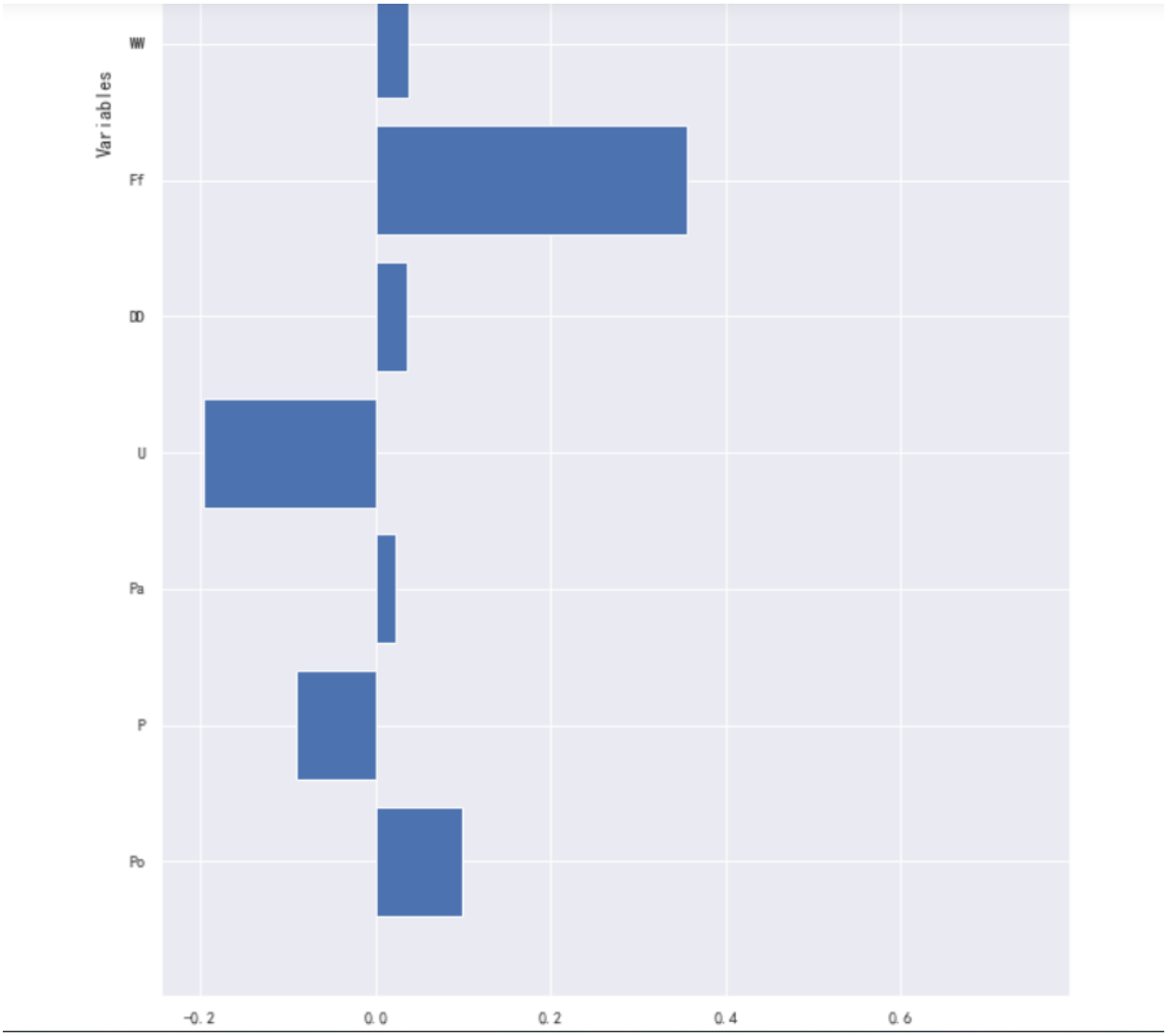


Figure3: feature importance

In the linear regression analysis of the yearly temperature increases in Chongqing (Figure 4), we found that even though the trend of the temperature yearly in Chongqing is increasing, there still exists a large error band, which represents a large variation in such increase especially in the years between 2012 and 2018. Therefore, we calculated the probability density of extreme temperatures with the year from 2018 to 2022. In figure 5, as the density plot showed, from 2018 to 2022, temperatures are generally increasing yearly with 2019 showing the decline of temperatures and 2022 reaching the peak of temperature increase.

Figure 4: linear regression plot of yearly average temperature

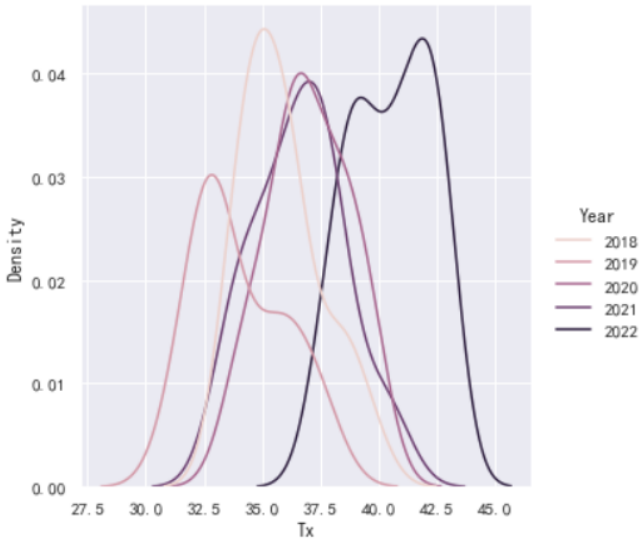


Figure 5: density plot of extreme temperature from 2018 to 2022

From the results above, we explored further into the relationship between humidity and temperature, but found out that the relative humidity and temperature are negatively correlated as

shown in figure 6 , with 2.5 units increase in temperature, the relative humidity decreased by 10 units. In other words, there is larger space for the air to hold water vapor with the temperature increase. However, when we calculated the absolute humidity and found out that it increases with the temperature, the variance inflation factor is up to 24.70214. As the warm temperature tends to hold more water vapor compared to that of the cool air. However, the relative humidity does not show such a linear relationship with temperature in other areas such as in Las Vegas.

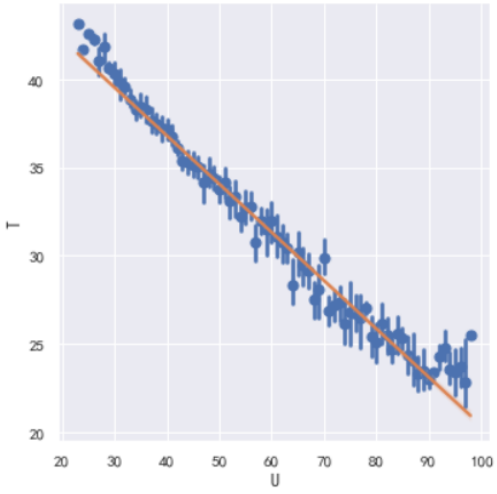


Figure6: linear plot of relative humidity and temperatures

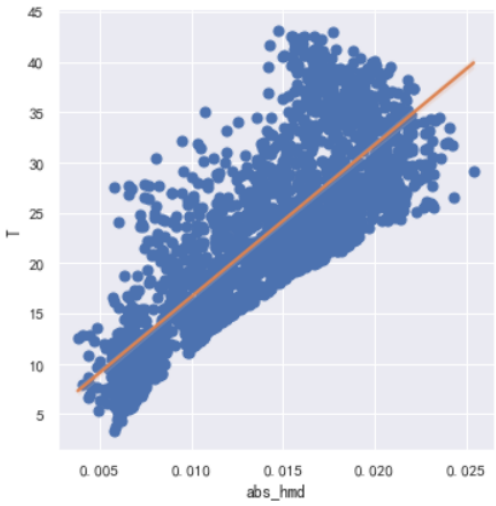


Figure7: linear plot of absolute humidity and temperatures

Therefore, we used the CMIP3 model with 18 GCMs model results from Sherwood el tal. In the CMIP3 model by Sherwood, she examined the average of the relative humidity and climate sensitivity for tropical-lower (from 25 degree South to 25 degree North, pressure between 400 to 900 hPa), tropical-upper (from 25 degree South to 25 degree North, pressure between 175 to 350 hPa), extratropical-lower (from 30 degree to 65 degree in both hemisphere, pressure between 350 to 900 hPa), extratropical-upper (from 40 degree to 90 degree in both hemispheres, pressure between 175 to 300 hPa) regions distinctively. From the model results, the change in relative humidity is increasing (steeper slope) in tropical upper and extratropical upper region (pressure from 0 to 250 hPa), whereas the change in relative humidity per Kelvin is held constant in tropical lower and extratropical lower regions (pressure from 350 - 900 hPa)

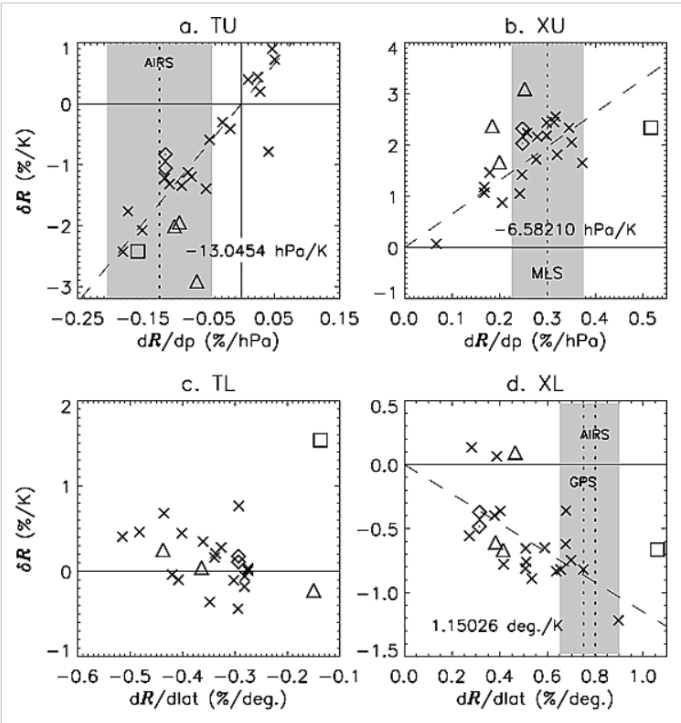


Figure 8: the CMIP3 model results by Sherwood et al.

Chongqing, with the data from Weather for 243 Countries of the World (Rp5.Ru), has the average latitude of 30 degrees North and average pressure of 900 hPa approximately. From the definition of the four regions above, Chongqing is in the tropical lower region, where the relative humidity is held constant or decreasing and matches our data results of relative humidity and temperatures.

V. Conclusion and Discussion

Similar studies have been conducted by Li (2020). Li(2020) compared the temperature difference under wet-bulb (where absolute humidity is high) and dry-bulb (where absolute humidity is low) conditions, concluding that wet-bulb has larger temperature increase compared with the dry-bulb conditions. The results between Li (2020), Sherwood et al. (2010), and our data analysis suggest that the increased temperature and humidity will not exacerbate health problems caused by heat through constraining sweating. However, due to the high absolute humidity results from our analysis, people will feel hotter outside compared to the actual temperature caused alone. Also, as the relative humidity decreases with the temperature increase, from the study of Yuan et al., (2016), the soil moisture has dramatically declined, eroding “the health and productivity of ecosystems, reversing sinks to sources and contributing to positive carbon-climate feedbacks, ” and the reduction of photosynthesis by reduced relative humidity would cancel out the carbon uptake in the warmer springs season, further lower the crop yields. (Yuan et al., 2016) Furthermore, as the absolute humidity increases with the temperature, Southern China would likely experience a decline in tourism during the summer seasons. Therefore, even though the extreme temperature would not have adverse effects on human health, it is likely to cause issues in ecosystems, agriculture, and tourism.

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