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Future Heatwaves in Pakistan under IPCC's AR5 climate change scenario

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Acronyms

ESMs	Earth System Models
GCMs	Global Climate Models
IPCC	Intergovernmental Panel on Climate Change
NDMA	National Disaster Management Committee
PMD	Meteorological Department
RCMs	Regional Climate Models

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Introduction

Heatwaves occupy an important class of climate-related disasters with a history of causing large scale mortalities. Most of the people do not realize how deadly a heatwave can be because in contrast to the visible and destructive nature of floods, heatwaves are regarded as “silent killers”. With all its fury and destruction, the heatwaves in France in 2003 resulted in 15,000 death (Poumad`ere et al. 2005). At a time when Pakistan was facing the worst flooding of its history in 2010, a heatwave in Moscow caused the death of 11,000 people (Shaposhnikov et al. 2014). Very recently, another deadliest heatwave caused around 2,300 casualties in India and a few weeks later, Pakistan had to face this havoc, which claimed 1,200 human lives.

The recent heatwaves in India and Pakistan can be attributed to climate change (Khan 2014). Intergovernmental Panel on Climate Change (IPCC), in its series of assessment reports, has been continuously warning about an increase in duration, intensity and magnitude of future heatwaves due to global warming (IPCC 2013). Since IPCC does not do its own research, its findings are based on the published literature, generally in impact factor journals. The technique, which is mostly adopted in such studies, is largely based on climate modeling.

Today climate models or more specifically the Global Climate Models (GCMs) are considered to be the most sophisticated numerical tools to carry out global climate simulations. However, the resolution of these GCMs is coarse and is typically of the order of 250 km. Hence, many regional-scale climatic features go beyond the scope of ESMs. Therefore, it led to the development of regional climate modeling technique in order to downscale the coarse GCMs to the regional scale at a typical resolution of 10 to 50km. These models are named Regional Climate Models (RCMs) (Saeed et al. 2009).

In a recently published study in 2015, the authors used the data of seven GCMs and claimed it to be the “first projection of future heatwaves in India” (Murari et al. 2015). In the present study, we have gone one step further while using the data of three RCMs (having much higher resolution than GCMs) to present a first projection of future heatwaves in Pakistan. This paper is structured as follows: section 2 provides the details of ‘Data and Methodology’ followed by ‘Results’ section. Section 4 presents the critical analysis of “2015 heatwave in Pakistan” followed by the ‘Recommendation’ section at the end.

Data and Methodology

As mentioned earlier, we have used the data of three different RCMs, forced with three different GCMs at a resolution of 0.44° (~ 50km). The models runs are executed under CORDEX (Coordinated Regional climate Downscaling Experiment) initiative for South Asia domain. It is important to mention here that CORDEX is an initiative by World Climate Research Project to downscale CMIP5 (Coupled Model’s Intercomparison Project phase 5) simulations using different RCMs over different domains around the globe. The details of the model matrix for this study can be seen from Table 1. We used data of control (1976-2000) as well as future period (2026-2100) by dividing it into three sub-periods which are 2026-2050, 2051-2075, and 2076-2100. All these simulations are conducted using RCP8.5 concentration

scenario which is also called “business as usual” scenario (Riahi et al. 2011). The data is obtained from Center for Climate Change Research, Indian Institute of Tropical Meteorology, Pune’s database1.

Table 1: Matrix showing names of Regional Climate Models (RCM's) and their forcing Global Climate Models (GCMs) along with their respective institutes.

RCM	RCM’s Institute	GCM	GCM’s Institute
CSIRO	CSIRO, Australia	CCSM	NCAR, USA
RCA4	Rossby Centre, Sweden	EC-EARTH	Rossby Centre, Sweden
REMO_2009	Climate Service Center, Germany	MPI-ESM	Max Planck Institute for Meteorology, Germany

For defining a heatwave, we followed a criterion that is also used by Zahid and Rasul (2012), that if the daily maximum temperature remains 45°C centigrade or more at a continuous stretch of five days, then it will be considered as one heatwave. We applied this criterion on the data of all the three models on control as well as three future sub-periods. It is important to note that the results presented in the proceeding section are the difference of number of heatwaves events between the future and control period for the whole 25 year period. This implies that increase in the number of heatwave events of 50 in a particular grid-box would mean 50 events in 25 years with an average increase of 2 events per year.

Results

The process of future climate change modeling is characterized by many types of uncertainties. In order to cater for these uncertainties, the popular approach which is adopted in climate science is called as multi-model ensemble approach (Haensler et al. 2013). Therefore, the results presented in Figure 1 show the average of the three RCMs at each grid-box for the respective time period.

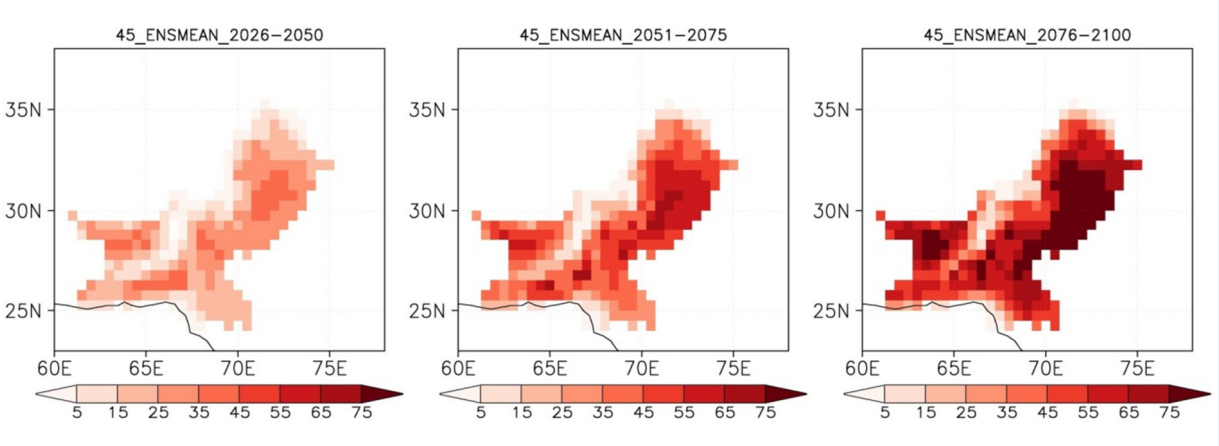

Figure 1: Difference in number of heatwave events between control and three sub-periods 2026-2050 (left), 2051-2075 (middle), 2076-2100 (right). The data presented in these plots is the ensemble average of all the three RCMs.

[1] http://cccr.tropmet.res.in/cordex/files/downloads.jsp.

A consistent increase in the number of heatwave events is obvious from Figure 1. It is worth-mentioning that Figure 1 does not show anything over the northern areas of Pakistan. This is because of our heatwave definition, which sets the threshold at 45°C. The northern areas, which are characterized by low temperatures due to their higher topographic extent, did not achieve such a high temperature. However, in the southern Pakistan, which is characterized by hyper arid and arid to semi-arid region, there is an obvious increase in the number of heatwave events even in the near future i.e. 2026-2050. This trend keeps on increasing in the middle (2051-2075) as well as in the end of century (2076-2100).

Interestingly, increase in the number of heatwave events towards the end of the century are also likely to happen in the provinces of Balochistan and Sindh, however increase in heatwaves is most pronounced over the Punjab plains. In the period between 2076-2100, the increase in the number of heatwave becomes more than 75 over Punjab, implying an average increase of 3 events per year as compared to control period. Considering a high population density in the Punjab, this alarming increase in heatwave will pose a serious concern not only for far future but also for the near future. Moreover, densely populated cities like Lahore, Faisalabad, Rawalpindi, Multan, Gujranwala, Sargodha, and Sialkot are all located in this region, which are more susceptible to the negative impact of heatwaves as compared to the rural areas because of the phenomenon called “urban heat island effect”.

The urban heat island effect can be understood by considering that as the urban areas develop, changes occur in its landscape. Infrastructure such as building, roads, etc. replace open land and vegetation and converts the surfaces once permeable and moist to impermeable and dry. Hence, these changes cause warming of ubran regions as compared to their rural surroundings, hence forming islands of high temperature. This phenomenon is better illustrated in Figure 2 which shows a temperature difference of 4°C between a city’s downtown and its surrounding rural areas.

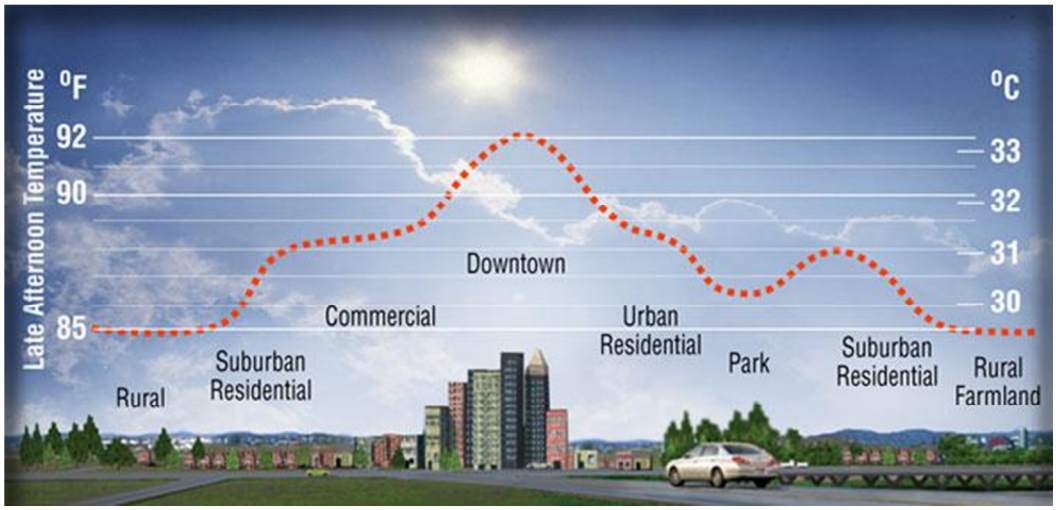

Figure 2: Illustration of Urban Heat Island Effect. The image is obtained from https://heatisland.lbl.gov/

2015 Heatwave in Pakistan

The deadly heatwave hit southern Pakistan in 2015 when temperatures peaked from June 18 to June 23. During this span, additionally from the urban heat island effect, temperatures in Karachi remained above 38°C with June 20 recording the hottest day with a maximum temperature of 45°C. Normally during this time of year, the temperature remains in the range of 33°C to 35°C, thanks to the relatively cool sea breeze blowing towards land that keeps the temperature of Karachi under check from getting hot. However, during this episode, a low pressure was developed over the sea which reversed the direction of wind, i.e. from land to ocean. This resulted in the subsidence of air from aloft, hence causing high humidity. Because of this high humidity, the maximum temperature remained in early 40°C, but the 'feel like' temperatures went as high as 50°C. This particular event, i.e. development of low pressure over the Arabian Sea may be attributed to the presence of a strong positive phase of ENSO (El Nino Souther Oscillation) this year over the Southern Pacific Ocean (By Zolfagharifard & Prigg , 2015).

Besides the climatic factors, there are many other factors, which exacerbated the impact of this particular event. First of all, Pakistan Meteorological Department (PMD) remained unable to forecast this event, therefore, failed to give the relevant authorities to act in time. National Disaster Management Committee (NDMA) also played a passive role initially and towards the end of the heatwave spell, managed to respond after the directions of Prime Minister (Haider M, 2015). The coordination between PMD and NDMA was also criticized during the flooding of 2014 in Pakistan as well (Saeed et al. 2014).

Power and water shortages were also amongst the major reasons resulting in the worsening of matters. K-electric, which is responsible authority in providing the electricity to most of the Karachi, remained unable to meet the demands of public, hence there were long hours of of load-shedding. This initiated a debate in print and electronic media among political parties as to whose responsibility is to ensure the provision of electricity in Karachi. Instead of putting their energies in giving relief to the affected people, the political parties at national and provincial level fell into a 'blame game'. Therefore, instead of educating people on how to cope with the ongoing heatwave, the major time and space of electronic and print media went to the coverage of this 'blame game'. Dehydration caused by fasting during the holy month of Ramadan was also one of the reasons that people, especially the elderly fell prey to heatstrokes.

Recommendation

Based on the analysis presented above, we propose the following recommendations;

- Considering an increase in future heatwave frequencies presented in Figure 1, there is a dire need to improve the capacity of PMD in forecasting such events at a reasonable lag-time. Similarly, the capacities of disaster management authorities should be enhanced to address such calamities in future. Moreover, a better coordination between PMD and National/Provisional disaster management authorities (NDMA/PDMA) should be ensured, especially in the Punjab where the heatwaves are projected to increase the most.
- During the times of heatwaves, the provision of facilities which reduces the impact of heat such as water and power in affected areas, should be made available. Moreover, emergency should be called in hospitals for timely delivery of health care facilities to the victims of heatstrokes.
- The use of electronic and print media should be employed to sensitize people in the times of such extremes. This includes the education of people in terms of maintaining adequate level of hydration by consuming extra water, avoiding large protein rich meals that can result in increased metabolic heat and warm the body avoiding unnecessary visits in the sun, etc.
- Information regarding heatwaves should be passed on to schools to take necessary measures and also to consider potential change in summer holiday schedule.
- Establishment of makeshift “cooling centers” by declaring mosques, libraries, parks, zoo, swimming pools, etc. as cooling centers can also be employed in order to beat the heat.

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