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Analysis of Extreme Heat Events and Associated Wind Behaviors over the Pacific North West

Abstract

Heatwaves can have a significant impact on public health and local economies while greatly increasing fire risk. As the global climate warms these heat waves are projected to happen more often and can be more extreme. Therefore, it is vital to understand the underlying circumstances that lead to these heat events. The goal of this project is to analyze climate models to assess correlations between orographic features and extreme heat events to better understand where, when and why these heat events may take place in the future. Specifically, this research examined wind behavior for correlations with temperature in the Pacific Northwest of the United States.

Introduction

The continuance of anthropogenic climate change and its effect on the global climate has been modeled effectively and shown to be accurate when compared against historical data. While these global climate models can give accurate large-scale predictions, they break down when modeling for regional climates as orographic features have been shown to effect small-scale climate responses. (Salathé et al. 2008) The major contributing features are mountain ranges, landscapes, and their effects on local weather including cloud cover, winds, rainfall and more. Global models typically run at a spatial resolution between 300 and 1000 km. Prior work (Mass et al., 2003) suggests that for the Seattle region a spatial resolution of around 15km is necessary to account for the local orography. To model the pacific northwest at this resolution, an ensemble of 12 different global models from the Climate Model Intercomparison Project (CMIP5) (Taylor et al. 2012) was created using the Weather Research and Forecast (WRF) model (Zhang et al. 2009). This Resolution is especially important when considering the affects the changing climate may have on the occurrences of extreme heat events. Prior work based on global models projects an increase in frequency, intensity, and duration of North American heat waves (Kunkel et al. 2010). Only with models such as the WRF ensemble can the complex terrain features of the coastal region be accounted for to accurately model how the local climate will respond, and therefore how we can expect the behavior of regional heatwaves to change (Brewer and Mass, 2016). The focus of this research was on using the high-resolution modeling of the WRF ensemble to assess the correlation between wind behavior and heat waves.

In coastal climates, the ocean serves as a major heat sink forming an onshore pressure gradient. Because of this, winds tend to be onshore much of the time. This onshore flow of cool ocean air provides a negative feedback, while a wind reversal brings hotter air from inland heating the local area further. In mountainous regions as this air pushes to lower elevations the pressure increases, again increasing the local temperatures. Due to these processes we hypothesized that when analyzing the summer temperatures in the Pacific Northwest, we will see a strong correlation between hot days and wind reversals.

Methods

The WRF model outputs hourly temperature, and wind data from the year 1970-2100 for each geographical location, a 12km grid pixel. We used the WRF data from one location, Seattle, based on one of the global ensemble members, for analysis. The temperatures in Seattle peek around the end of July, so our analysis was narrowed to the months of July and August to ensure similar climate behaviors. With 30-year observational periods; 1980-2009, 2030-2059, and 2070-2099, MATLAB was used to analyze the data. These data were ran to find the max temperature for every day, and the average wind speed, west to east, for all observational periods. We used the historical temperatures to set an extreme heat baseline at the 95th percentile temperature. The average wind for any extreme heat day for all observation periods was then assessed.

Results

We found the average daily temperatures and the number of extreme heat days to drastically increase as shown in the figures below.

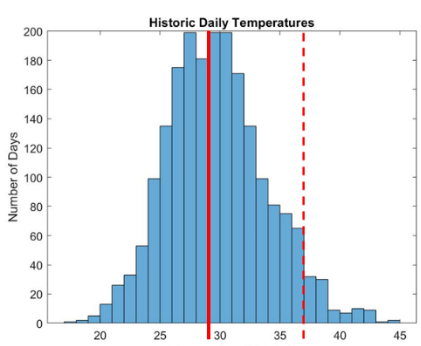

Fig. 2. Max daily temperatures for July-Aug 1980-2009

95th percentile Historic Baseline
37° C
102 Extreme Heat Days

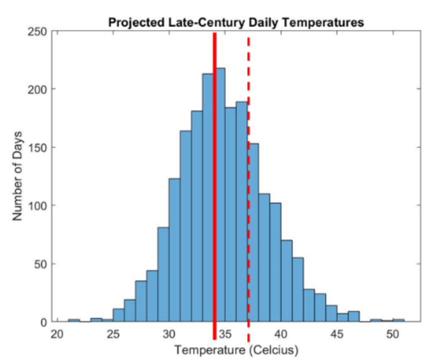

Fig. 3. Max daily temperatures for July-Aug 2070-2099

Extreme Heat Baseline
37° C
577 Extreme Heat Days

There was not much more than a vague hint at a correlation between these extreme heat events and wind reversals. The below figures graph the max temperature for all days versus that days corresponding average wind.

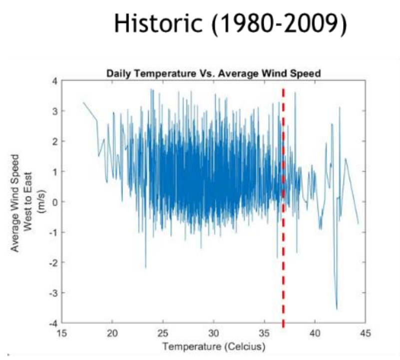

Fig. 3. Temperatures Vs. Wind for July-Aug 1980-2009

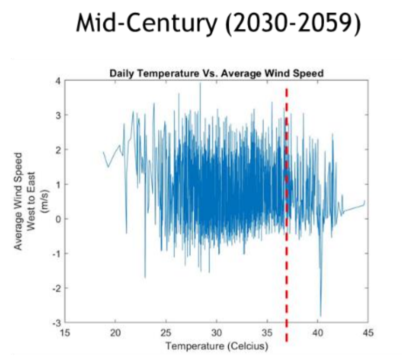

Fig. 4. Temperatures Vs. Wind for July-Aug 2030-2059

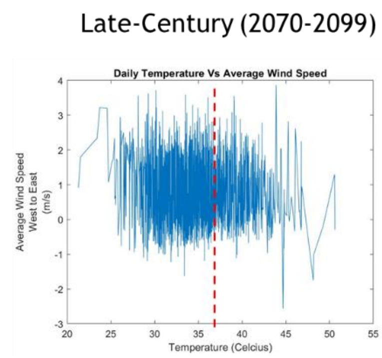

Fig. 5. Temperatures Vs. Wind for July-Aug 2070-2099

After the extreme heat cutoff line, a small trend towards the negative can be observed compared to the relatively flat relationship beforehand.

Conclusion

Due to the fact that this research only covered one physical location and only used a model from one global climate model, no rigorous correlations can be drawn from this analysis. The small suggestive trend can be used to encourage further study into the relationship between wind behavior and extreme heat events. More exploratory analysis needs to be done, varying how the wind associated to these heat events is measured, as an average wind over the full day could be insufficient. A proper error analysis has not yet been able to be formed, as the WRF ensemble needs a larger computing power to perform this.

Once a more thorough investigation is done into the heat, wind relationship, extending the work of Brewer and Mass on projected wind variability and temperature skew could provide insightful results.

References

Brewer, M. C., and C. F. Mass, 2016: Projected changes in heat extremes and associated synoptic- and mesoscale conditions over the Northwest United States. J. Clim., 29, 6383– 6400, doi:10.1175/JCLI-D-15-0641.1.

Kunkel, K. E., X.-Z. Liang, and J. Zhu, 2010: Regional climate model projections and uncertainties of U.S. summer heat waves. J. Climate, 23, 4447–4458, doi:10.1175/2010JCLI3349.1

Mass, C. F., and Coauthors, 2003: Regional environmental prediction over the pacific nothwest. Bull. Am. Meteorol. Soc., 84, 1353-1366+1328, doi:10.1175/BAMS-84-10-1353. http://journals.ametsoc.org/doi/10.1175/BAMS-84-10-1353

Salathé, E. P., R. Steed, C. F. Mass, and P. H. Zahn, 2008: A high-resolution climate model for the U.S. Pacific northwest: Mesoscale feedbacks and local responses to climate change. J. Clim., 21, 5708–5726, doi:10.1175/2008JCLI2090.1.

Taylor, K. E., R. J. Stouffer, and G. A. Meehl, 2012: An overview of CMIP5 and the experiment design. Bull. Amer. Meteor. Soc., 93, 485–498, doi:10.1175/BAMS-D-11-00094.1.

Zhang, Y., V. Duliére, P. W. Mote, and E. P. Salathé, 2009: Evaluation of WRF and HadRM mesoscale climate simulations over the U.S. Pacific Northwest. J. Clim., 22, 5511–5526, doi:10.1175/2009JCLI2875.1.