Analysis of Changes in Location-Specific Extreme Precipitation Using an Ensemble of Global Climate Model Output from the Coupled Model Inter-comparison Project, Phase 5 (CMIP5)

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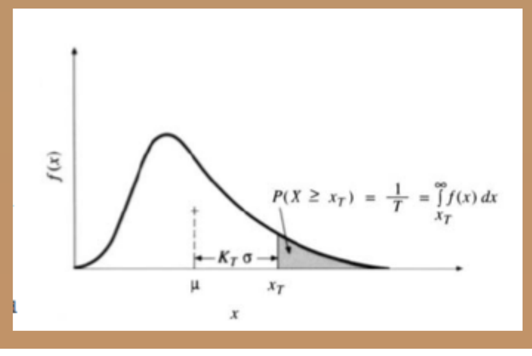
Introduction

Climate models indicate that an increase in global mean temperature will lead to increased frequency and intensity of storms of a variety of types. *Gao et al., 2012* show that Philadelphia, Pennsylvania is expected to experience the greatest increase of precipitation in the United States due to an increase in annual extreme events. We use rain gauge data and high resolution (greater than 1.5º) global climate models from the Coupled Model Inter-comparison Project Phase 5 (CMIP5) to analyze discrepancy between historical and modeled data. We then use this bias and apply it to the historical data in order to forecast precipitation into the future. In order to attain the frequency of extreme precipitation, we analyze the data in a Log Pearson Type III distribution.

Methods & Materials

- Log Pearson Type III (LP3) – Annual Max



$$y = \log x$$

$$w = \left[\ln\left(\frac{1}{p^2}\right)\right]^2 \quad (0 < p \leq 0.5)$$

$$p = 1 - p \quad (p > 0.5)$$

$$z = w - \frac{2.515517 + 0.802853w + 0.010328w^2}{1 + 1.432788w + 0.189269w^2 + 0.001308w^3}$$

$$K_T = z + (z^2 - 1)k + 1/3(z^3 - 6z)k^2 - (z^2 - 1)k^3 + zk^4 + 1/3k^5$$

$$k = \frac{Cs}{6}$$

$$y_T = y_{bar} + K_T s_y$$

$$X_T = 10^{Y_T}$$

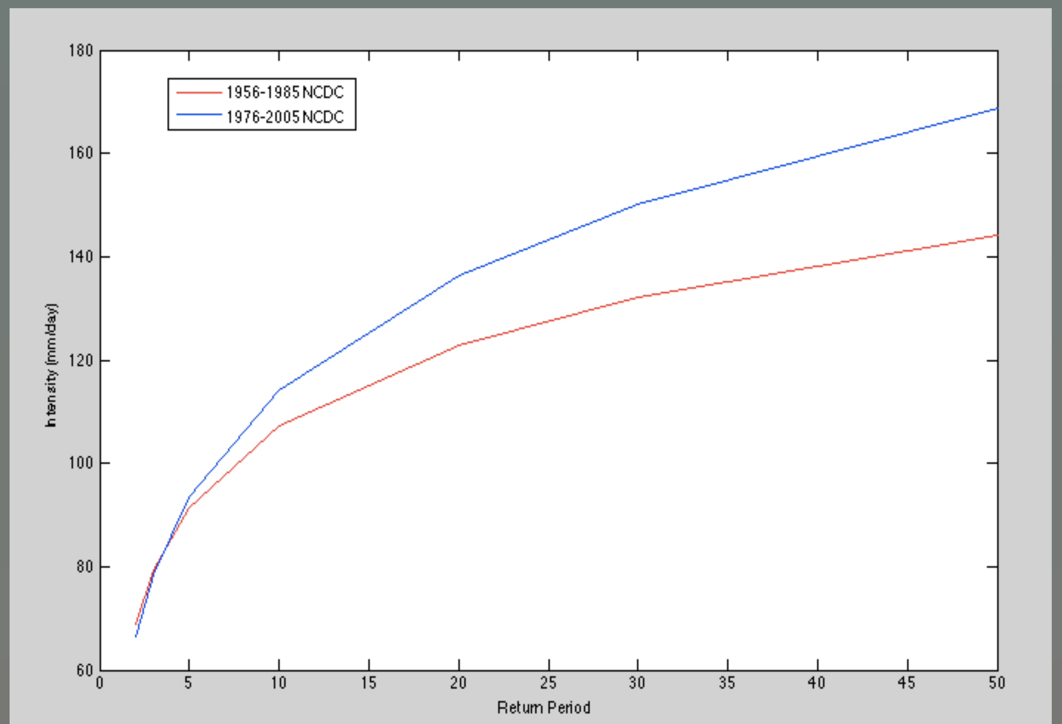
CMIP5 Global Climate Models

- CCSM4
- MIRO5C
- MRI-CGCM3

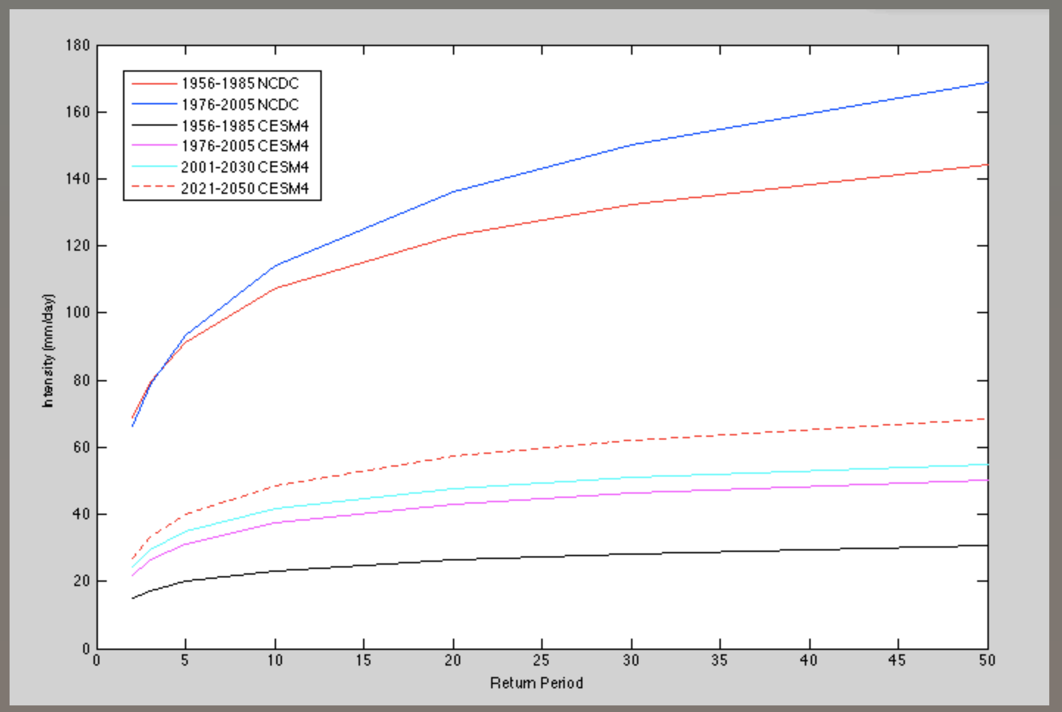
Results

The study conducted on rain gage data from Philadelphia, PA over two thirty year periods, 1956-1985 and 1976-2005 indicates an increase in the frequency of intense precipitation (Figure a) utilizing a LP3 distribution. Increased frequency of intense precipitation agree with previous research findings (*e.g. Frich et al. 2002, Lehtonen et al. 2013, Sun et al. 2007*). LP3 was chosen over Generalized Extreme Value Theory and Generalized Pareto because it is a better choice for urban planning purposes and *Guttman, 1999* determined that LP3 performed the best in calculating the Standardized Precipitation Index. Another finding is that all of the CMIP5 GCMs underestimated precipitation (Figures b-e). GCM results underestimate rainfall due to their inability to capture regional characteristics and climate phenomena (*Lehtonen et al., 2013*). However *Lehtonen et al., 2013* determined that there was no difference between GCMs and RCMs in their tendency towards more extreme precipitation. Therefore, despite its inaccuracy, it is still useful in analyzing trends in extreme precipitation. CCSM4 (Figure b) and MIRO5C (Figure c) performed the best compared to historical data, while MRI-CGCM3 (Figure e) performed the worst. In order to use the trends that the GCMs show, a bias was determined between the historical results and the model results. Each models bias was calculated as the number of times larger the historic data was than the model data. The bias used to extend the historic data was calculated as the average of CCSM4 and MIRO5C biases. *Knutti et al., 2010* states that "there is empirical evidence from various areas of numerical modeling that a multi model average yields better prediction or compares more favorably to observations than a single model." The averaged bias used to forecast the historic data is 4.05. Figure d shows the results of the forecasted historic data for 2001-2021 and 2021-2050. The figure shows that rainfall is expected to increase every 30 year period and that based on the results of these models, as great as a 45% chance of increased precipitation is possible.

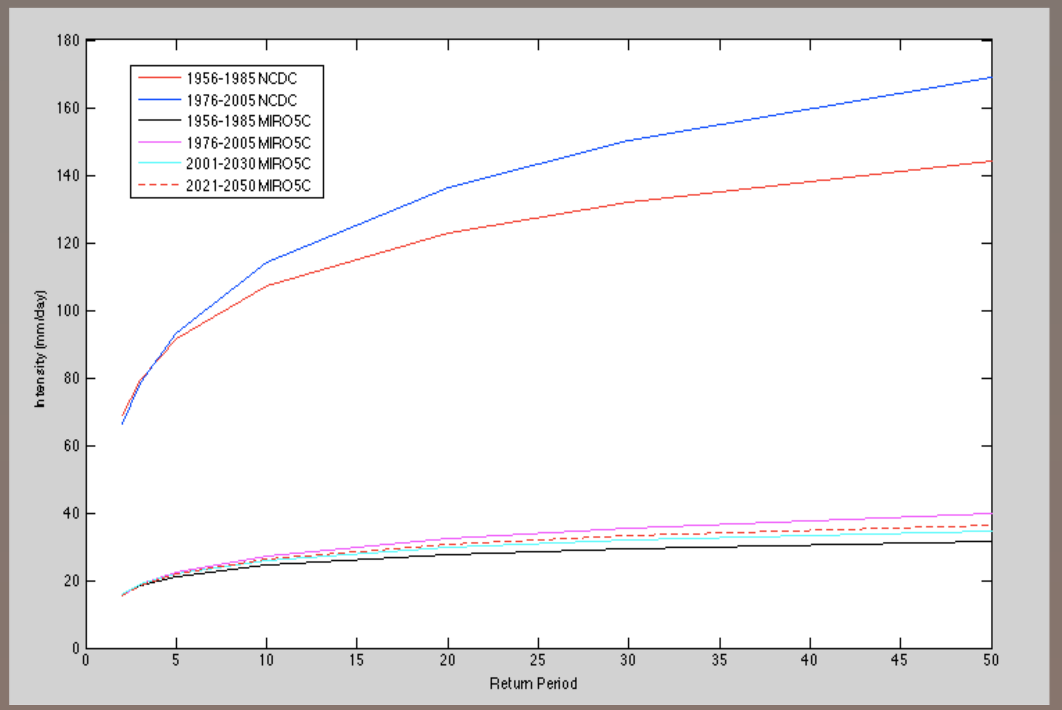
(a)



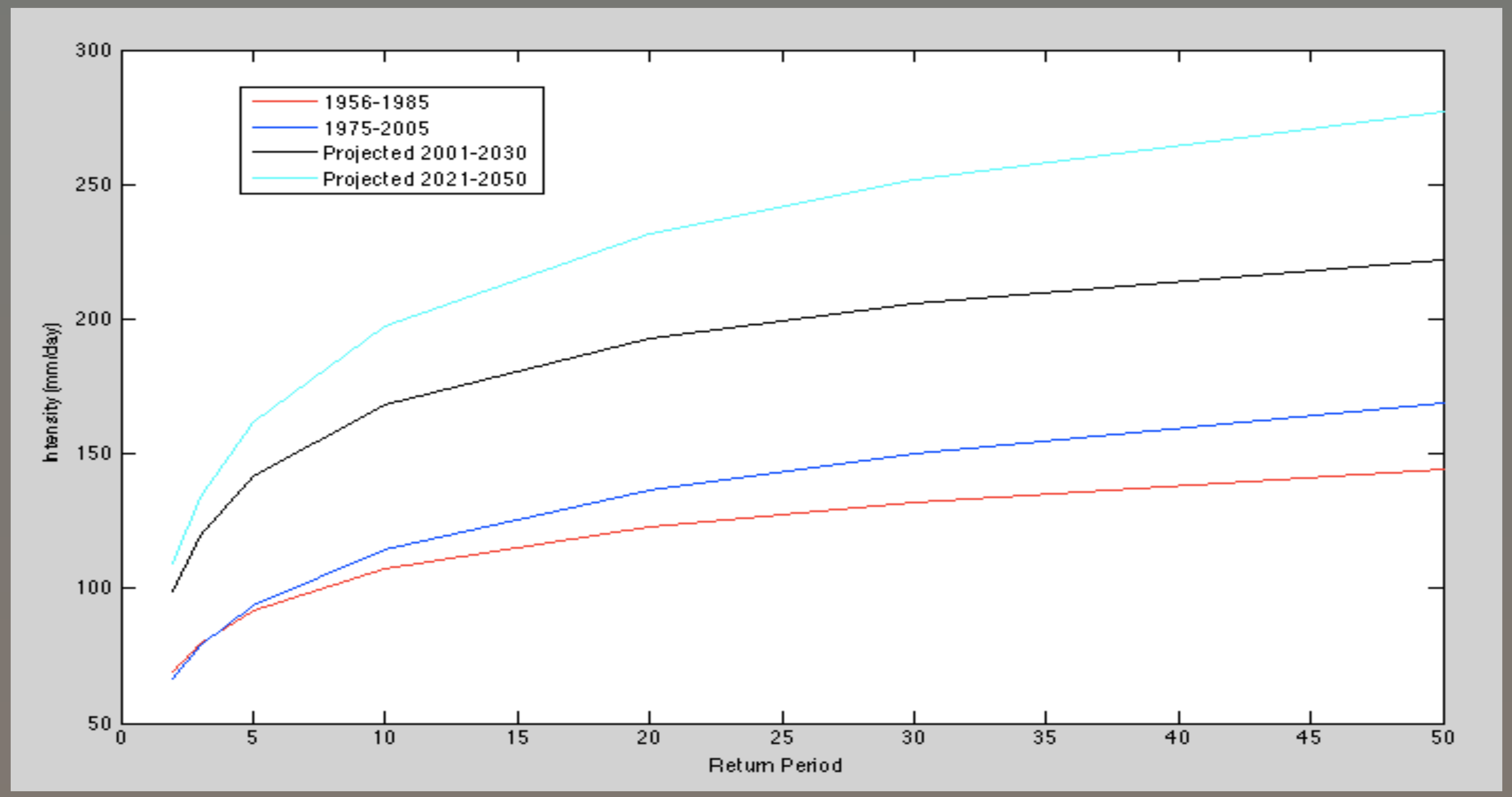
(b)



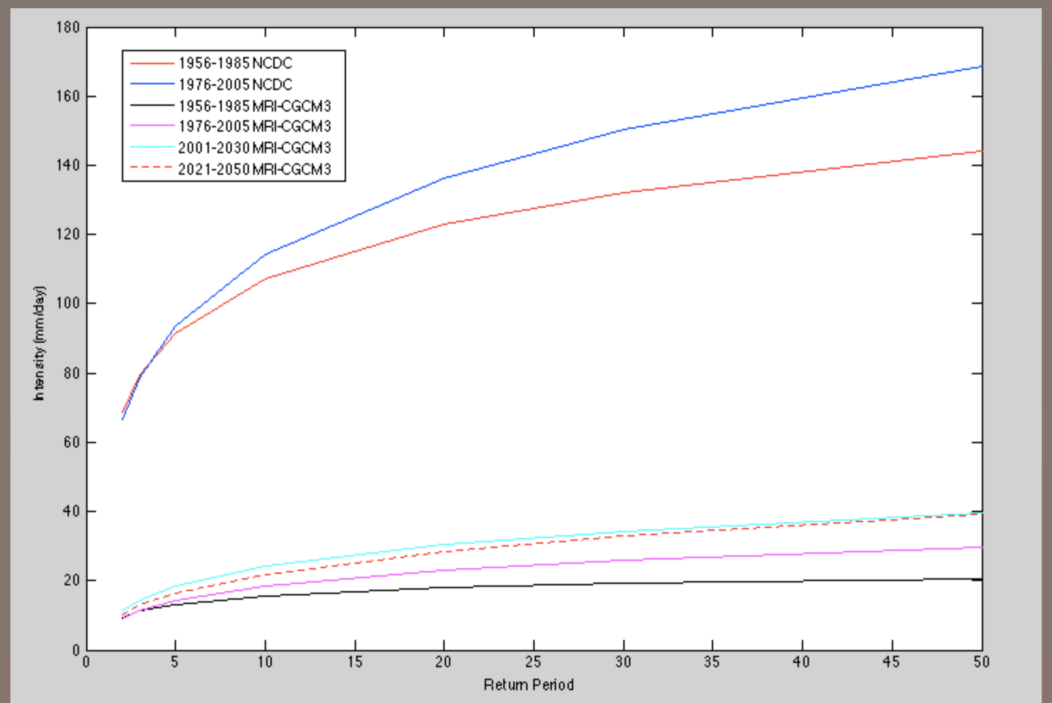
(c)



(d)



(e)



From top to *bottom* LP3 analysis of Philadelphia rain gauge data (Figure a). LP3 analysis of CCSM4 GCM (Figure b). LP3 analysis of MIRO5C (Figure c). LP3 Analysis of Projected Historic Data using 4.05 Averaged Bias (Figure d). LP3 analysis of MRI-CGCM3 (Figure e).

Conclusions

- Frequency of extreme precipitation increased during second thirty year period, 1976-2005
- GCMs severely underestimate extreme precipitation due to their low resolution
- CCSM4 and MIROC5 performed the best compared to historical data. MRI-CGCM3 performed the worst
- 4.05 averaged bias between historical data and GCM data
- As great as a 45% increase in intensity of extreme precipitation events

Continued Research

With rising population and increasing urban density, it is of pivotal importance for urban planners to plan for increasing extreme precipitation events. Analysis of results from CMIP5 has demonstrated that GCMs severely underestimate precipitation. In order to obtain more reliable results, downscaled analysis of Philadelphia, Chicago, and New York will be developed in the Weather and Research Forecasting regional climate model (WRF). We will analyze historical precipitation data and WRF output utilizing a LP3 distribution. We will determine the likelihood of extreme precipitation in the near future and determine the effects on the cost of storm water management for these three cities.

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Acknowledgements

I would like to thank the National Science Foundation, University of Tennessee, and Oak Ridge National Laboratory for their support and use of supercomputers. In addition, I would like to thank the CSURE ,NICS, and JICS programs their support and use of resources.