Projecting Future Extreme Precipitation Pattern in Ohio Using NARCCAP Regional Climate Models

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Abstract

Global warming has the potential to intensify hydrological cycle, hence causing more frequent extreme precipitation events. This study aims to project future changes in precipitation pattern in Ohio. We first compared the daily precipitation data output from 20th century runs of regional climate models (RCMs) with the historical observations from climate stations within Ohio to evaluate the accuracy of the models and identify the biases. We then apply the bias correction to the 21st century runs of climate models for daily precipitation to make projections on future precipitation patterns for Ohio. Initial results suggest that the bias correction based on probability mapping applied to RCM output was reasonably successful in reproducing the main features of the observed hydrometeorology from the retrospective climate simulations. By applying this method to future simulations, we find that: (a) annual precipitation is going to increase slightly for Ohio; such increase will be more in northeast and less in southwest; (2) seasonally, total precipitation will increase most in winter and will decrease in summer; (3) the magnitudes of extreme precipitation are likely to increase, and the increase will be more significant for more extreme events. Northern Ohio is likely to see more increase in the magnitudes of extreme storms.

Objectives

(1) Identify past trends of precipitation pattern in Ohio
- (i) Annual precipitation totals
- (ii) Number of wet days
- (iii) Average wet day precipitation

(2) Project future precipitation pattern in Ohio
- (i) Annual precipitation totals
- (ii) Number of wet days, wet day precipitation,
- (iii) Seasonal changes
- (iv) Extreme precipitation magnitude

Great Dayton Flood 1913, Dayton, Ohio

Data and Methodology

(1) Trend detection

Data: 41 stations in US Historical Climatology Network in and near Ohio
- Daily precipitation with records 1900-2008
- Only years with more than 350 days of records are used
  Number of years used: 63-108, average 90 years
- Data trimmed to correct instrumental bias:
  Days with lower than 0.05 inch/day are treated as dry

Trend detection method: Nonparametric Kendall's Tau, Significance level $\alpha < 0.1$

Spatial interpolation method: Regularized spline with tension

(2) Future Projection

Baseline data: USHCN 41 stations daily precipitation data 1971-2000

Model Data: daily precipitation from CRCM driven by CGCM3 under A2 scenario
- 20th century model run for 1971-2000
- 21st century model run for 2041-2070

(3) Statistical bias correction

(i) Fit a theoretical distribution for the following data series:
- Observed daily precipitation series (1971-2000) – $F_{obs}(x_{obs})$
- RCM simulated daily precipitation (1971-2000) – $F_{RCM20}(x_{RCM20})$
- RCM simulated daily precipitation (2041-2070) – $F_{RCM21}(x_{RCM21})$

(ii) Map the RCM value to the observed distribution

$$x_{RCM\,20_{corrected}} = F_{obs}^{-1}(F_{RCM\,20}(x_{RCM\,20}))$$

(iii) Correct the future RCM output with the scale of corrected/raw RCM

$$x_{RCM\,21_{corrected}} = x_{RCM\,21} \times \frac{F_{obs}^{-1}(F_{RCM\,21}(x_{RCM\,21}))}{F_{RCM\,20}^{-1}(x_{RCM\,21}))}$$

(4) Probability modeling for daily precipitation

A mixed probability model is used to link magnitude and frequency of extreme precipitation events: $F(x) = P(X \le x) = (1 - P_{pr}) + P_{pr}\int_0^x f(t)dt$

(5) Method for selecting distributions

- (i) L-moment diagrams
- (ii) Goodness of fit tests: Chi-square, Kolmogorov-Smirnov test, Anderson-Darling test, P-P plot and Q-Q plot
- (iii) 3-parameter Gamma distribution is selected

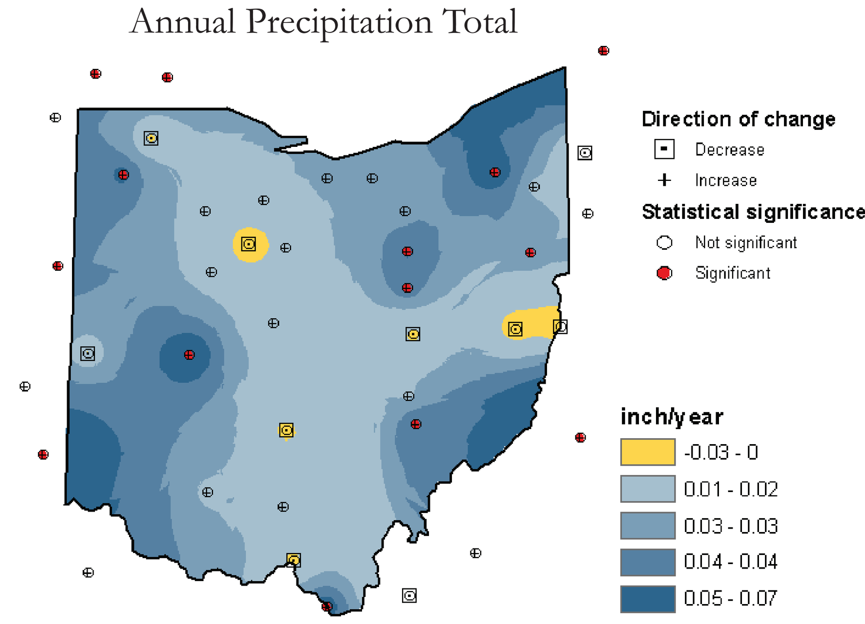
Results

(1) Historical trends of precipitation pattern in Ohio

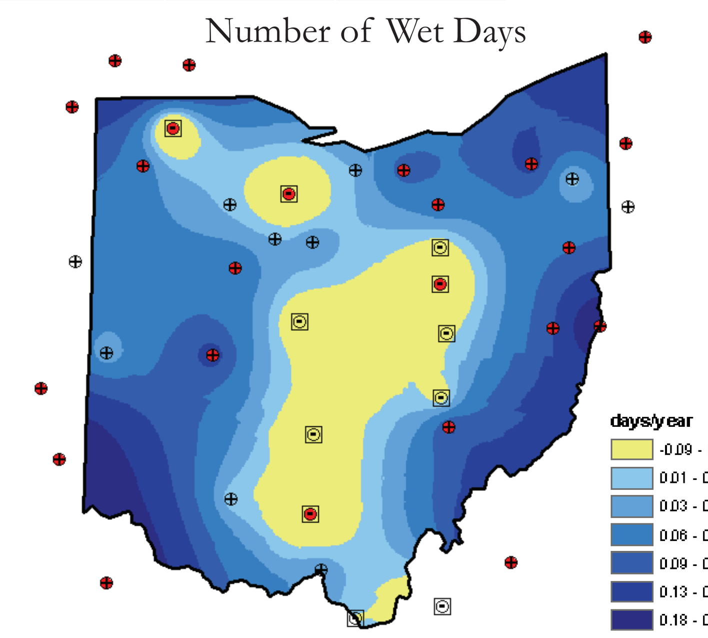
Table 1: Number of station showing increasing/decreasing trends in study area

	Increase		Decrease	
	Total	Significant	Total	Significant
Annual precipitation total	31	14	10	0
Number of wet days	30	19	11	4
Average wet day precipitation	22	6	19	1

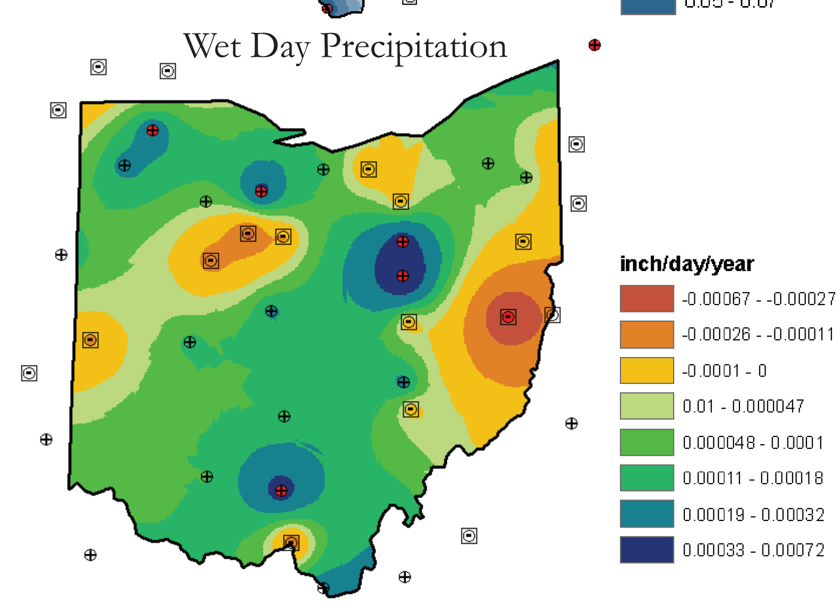
Annual Precipitation Total



Number of Wet Days



Wet Day Precipitation



State average:

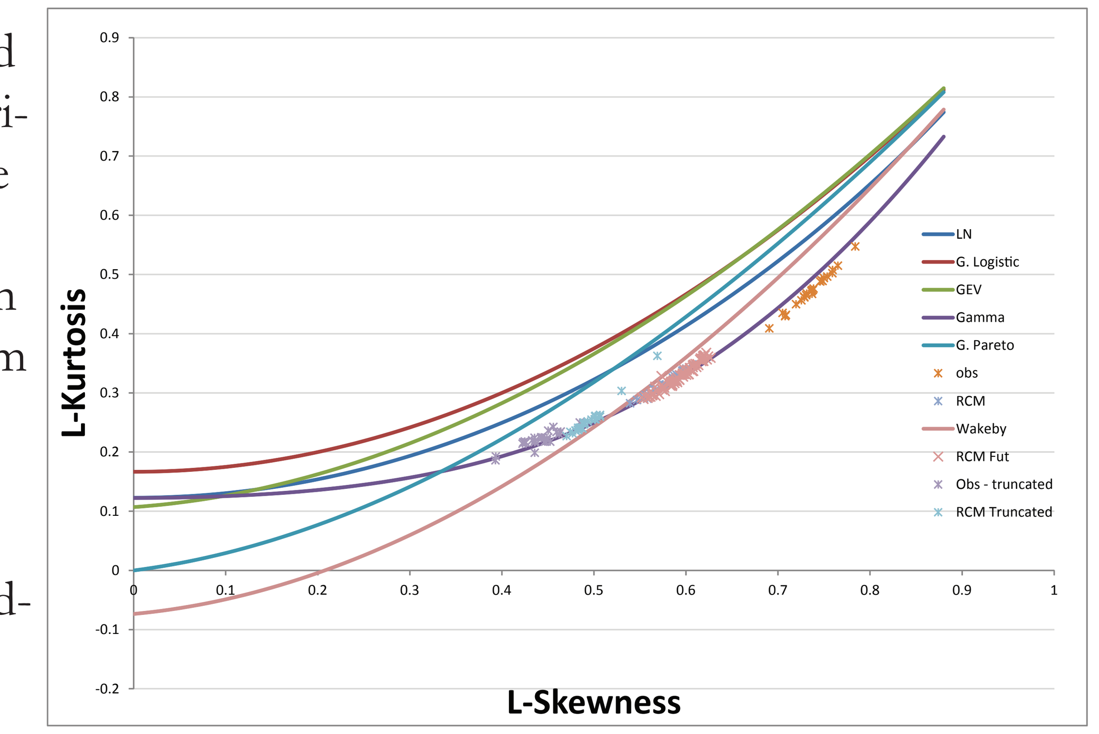
Annual precipitation total:
- Increased 0.025 inch per year
- 2.5 inch (6.5%) over 20th century

Number of wet days
- Increased 0.08 day per year
- 8 (6%) days over 20th century

Wet day precipitation
- Increase 0.005 inch/day
- 0.5 inch (1.8%) over 20th century

(2) Selection of distributions based on L-moment ratios

Based on the L-skewness and L-kurtosis ratios, Gamma distribution is deemed most suitable for estimating both observed and modeled daily precipitation series. However, it is clear from the fiture, that observed and moded data distributions have different shape, therefore, bias correction described in methodology step (3) is necessary.



(3) Future changes in precipitation pattern in Ohio

Table 2: Future changes in precipitation pattern in Ohio

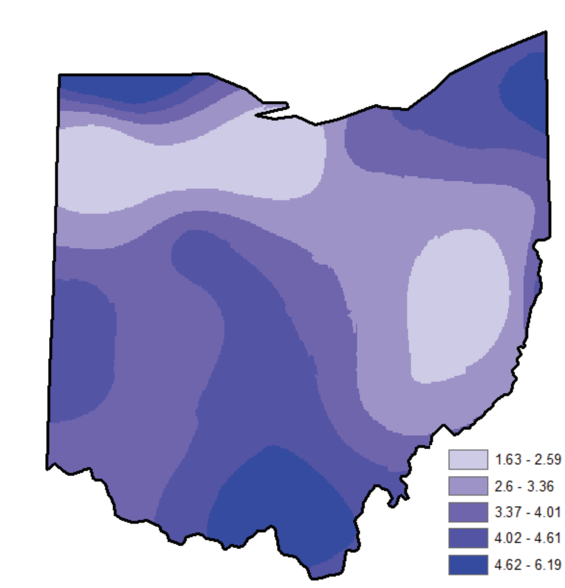
	1971-2000	2041-2070	Change	% change
Annual precipitation (inch)	38.50	39.83	1.33	3.45
Number of wet days	129	125	-4	-3.10
Wet day precipitation	0.30	0.32	0.02	6.51
Seasonal change				
Spring	10.52	11.32	0.80	7.59
Summer	11.33	10.55	-0.78	-6.90
Fall	8.35	8.59	0.24	2.85
Winter	7.79	8.72	0.93	11.89

Table 3: Future changes in extreme precipitation in Ohio

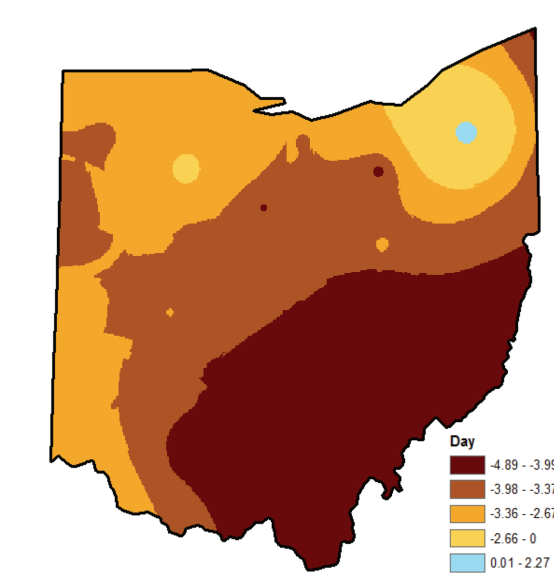
Return Interval	1971-2000	2041-2070	Change	% change
1 year	1.92	2.06	0.14	7.34
2 year	2.28	2.40	0.12	5.21
5 year	2.84	3.05	0.22	7.68
10 year	3.26	3.56	0.30	9.24
15 year	3.47	3.84	0.36	10.43
20 year	3.65	4.13	0.47	12.89
25 year	3.76	4.30	0.54	14.38

Spatial variations of future changes in precipitation pattern in Ohio

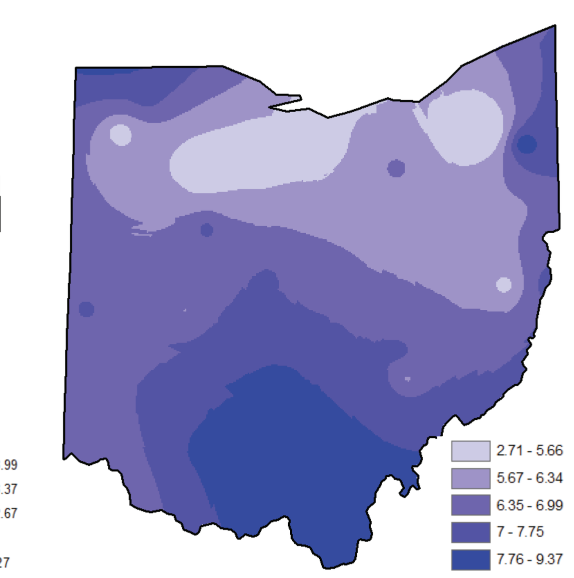
Annual mean precipitation change (%)



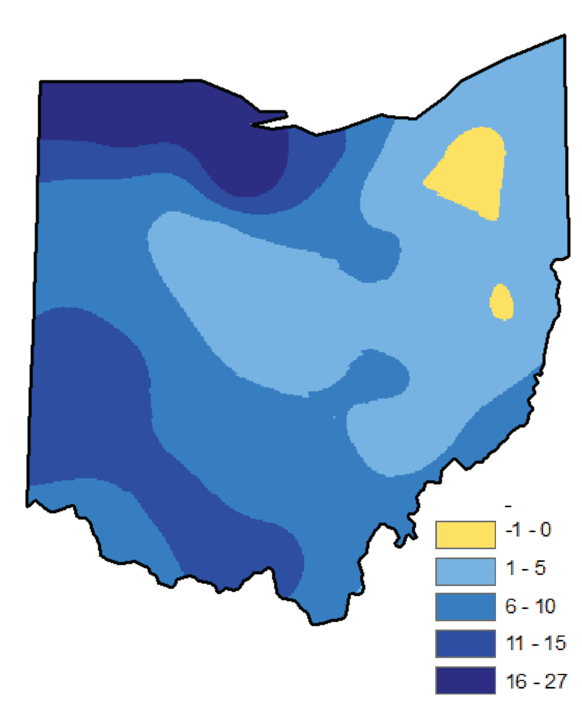
Number of wet days change (days)



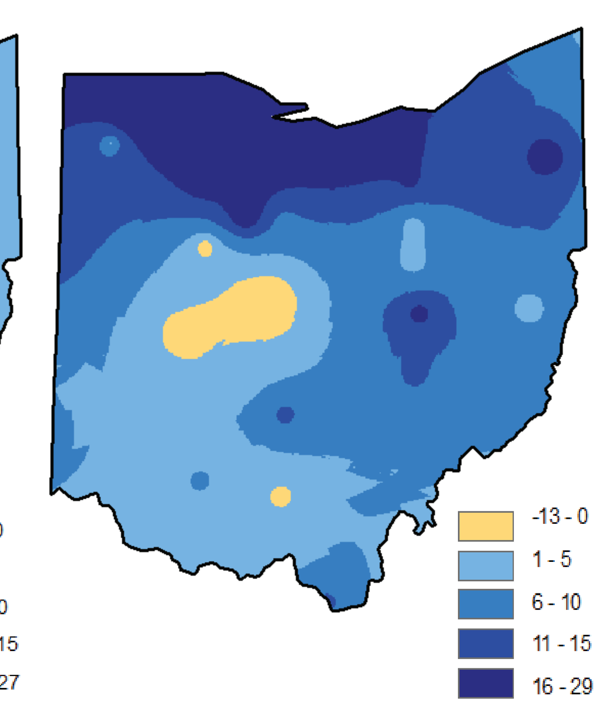
Wet day precipitation change (%)



Changes in 1-year storm (%)



Changes in 10-year storm (%)



Changes in 25-year storm (%)