10/04/2016

Integrated Climate Change Analysis

Modeling Workgroup Quarterly Meeting

Kyle Hinson[1] and Gopal Bhatt[2]

[1] Chesapeake Research Consortium, [2] Penn State University

Presentation Outline

- Catalog of climate change scenarios
- Rainfall inputs for the year 2025
- Long-term rainfall trend analysis
- 32 member ensemble of downscaled GCMs
  - US Climate Resilience Toolkit
- Spatial and seasonal change in rainfall and temperature
- Model simulation and results

Year 2025

- PRISM Rainfall Trends - EQ
- PRISM Rainfall Trends - KK

RCP 4.5 P50

CO_2 Correction 427 ppm

Year 2050 *RCP 4.5*

- RCP 4.5 P90 - EQ
- RCP 4.5 P90 - KK
- RCP 4.5 P50 - EQ
- RCP 4.5 P50 - KK
- RCP 4.5 P10 - EQ
- RCP 4.5 P10 - KK

RCP 4.5 P50

CO_2 Correction 487 ppm

Year 2050 *RCP 8.5*

- RCP 8.5 P90 - EQ
- RCP 8.5 P90 - KK
- RCP 8.5 P50 - EQ
- RCP 8.5 P50 - KK
- RCP 8.5 P10 - EQ
- RCP 8.5 P10 - KK

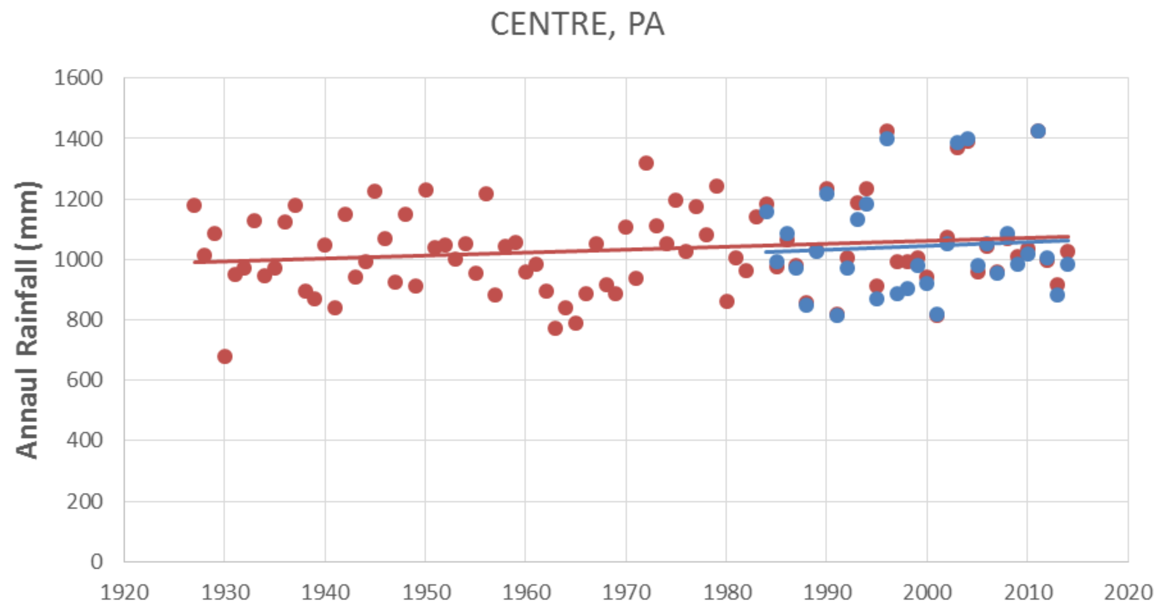
RCP 8.5 P50

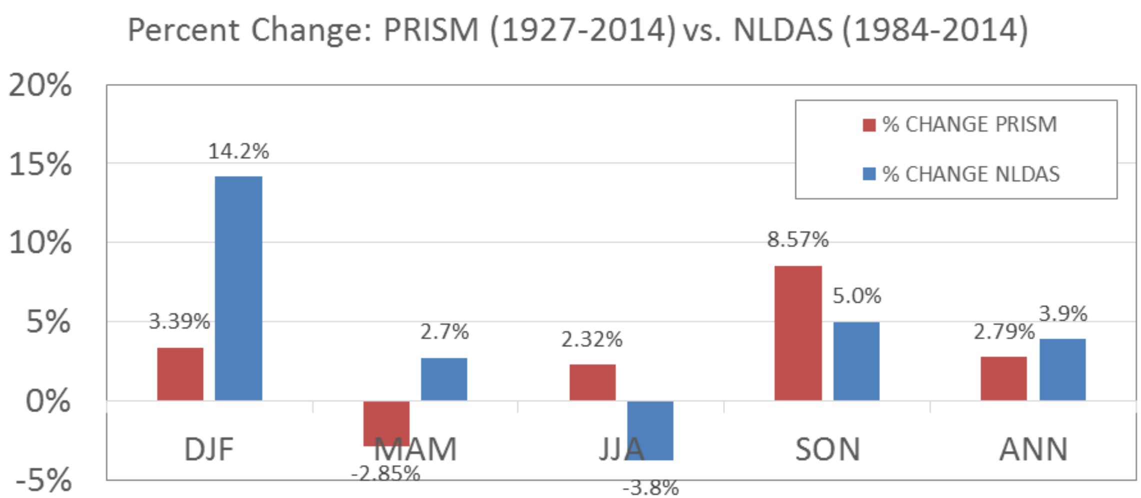
CO_2 Correction 487 ppm

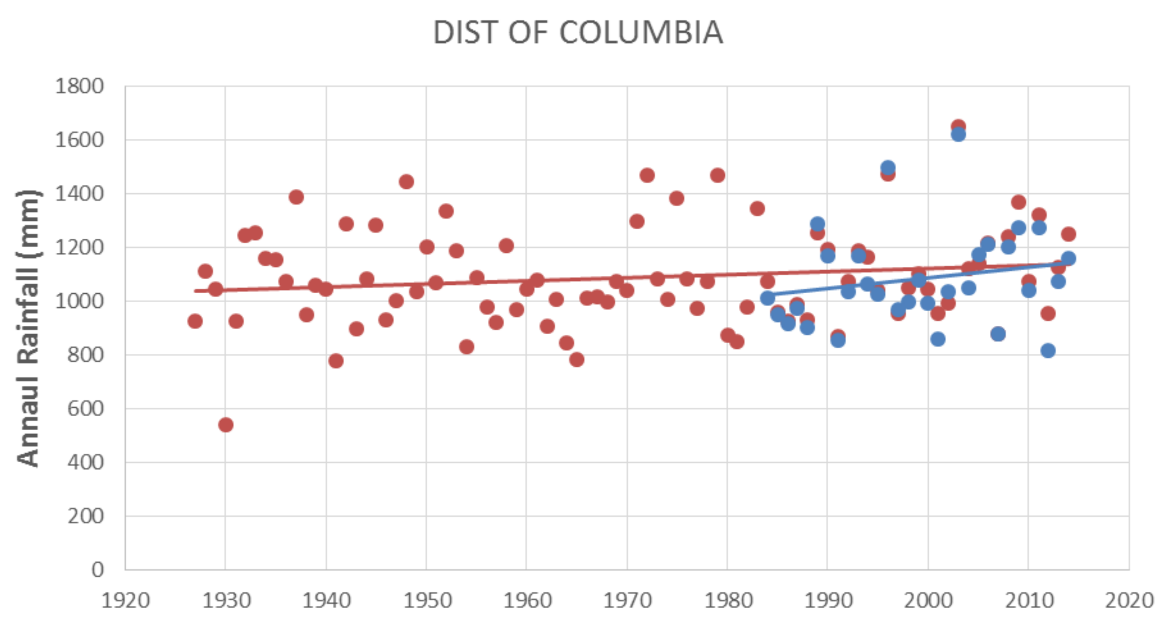
a total of 14 integrated scenarios.

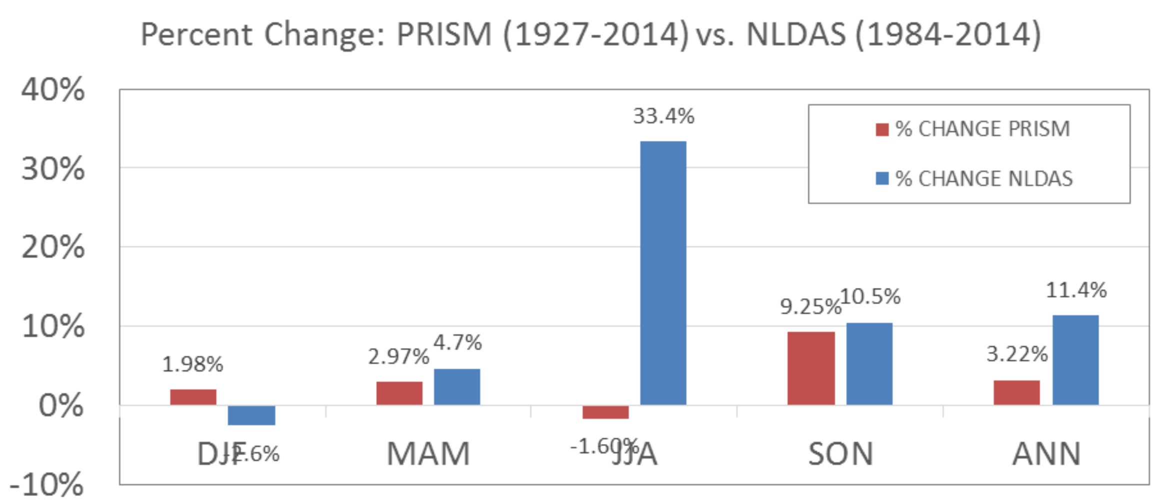
2025 rainfall based on long term trends

- *STAC has recommended use of long-term trends for estimating 2025 rainfall projections.*
- Monthly PRISM data is a reliable source of rainfall data.
- Aaron Mills (USGS) and Karen Rice (USGS) recommended using trends on annual PRISM data.
- 32 member ensemble (P50 median) was recommended for temperature projections.


CENTRE, PA
Annaul Rainfall (mm)
1600
1400
1200
1000
800
600
400
200
0
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020

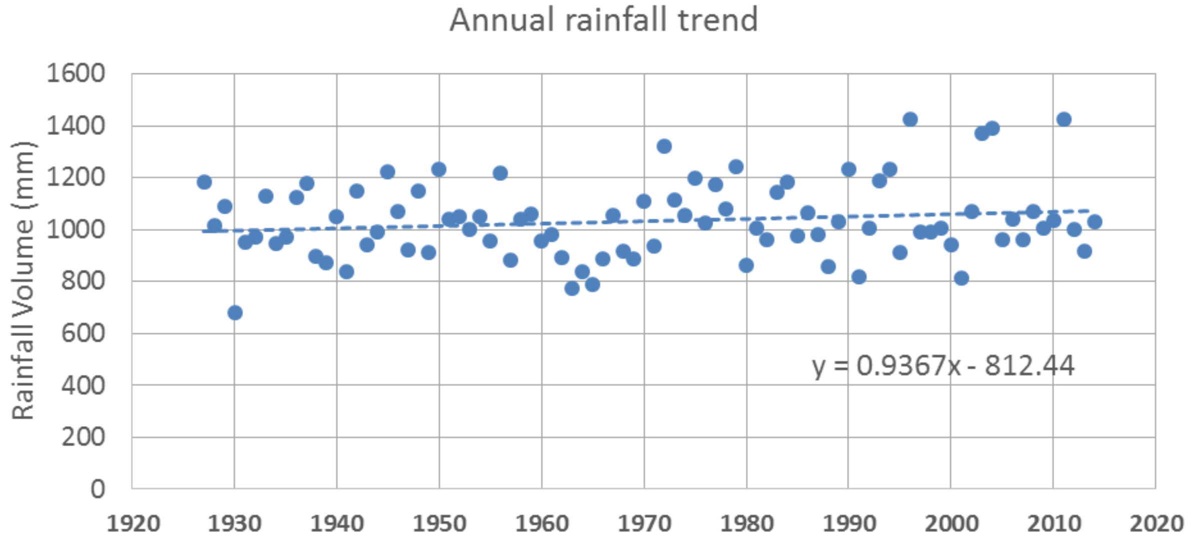

Percent Change: PRISM (1927-2014) vs. NLDAS (1984-2014)
% CHANGE PRISM
% CHANGE NLDAS
20%
15%
10%
5%
0%
-5%
3.39%
14.2%
-2.85%
2.7%
2.32%
-3.8%
8.57%
5.0%
2.79%
3.9%
DJF
MAM
JJA
SON
ANN

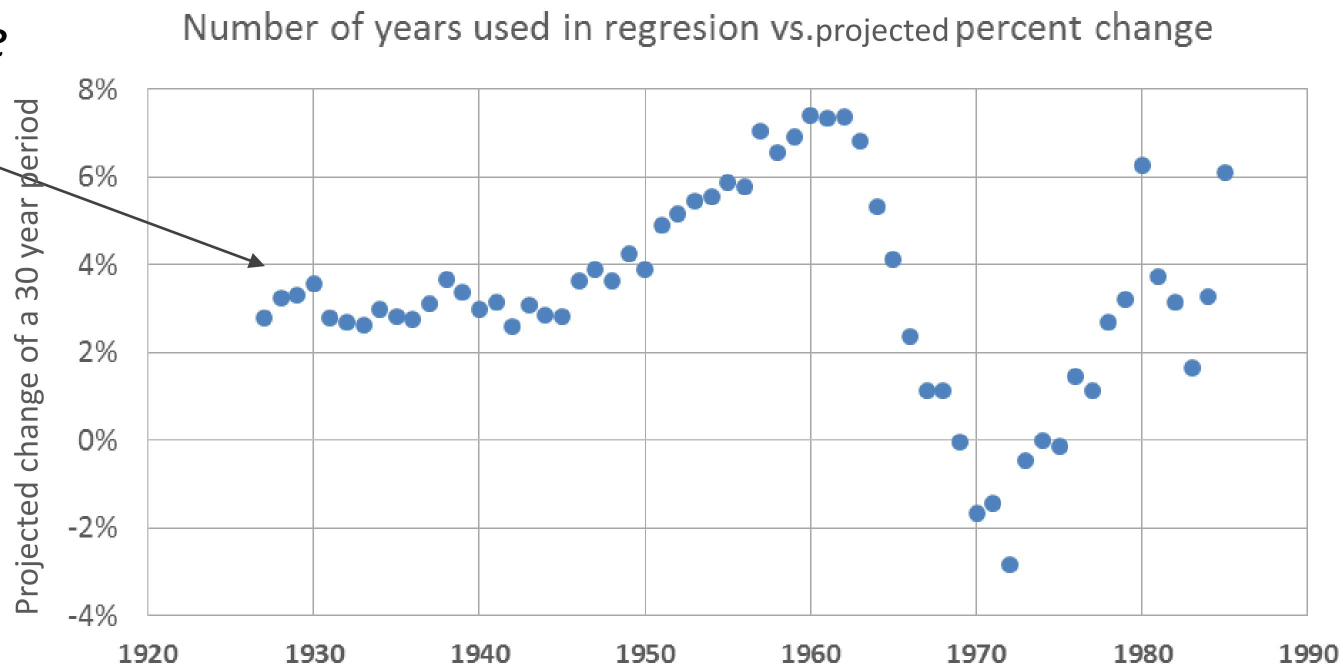

DIST OF COLUMBIA
Annaul Rainfall (mm)
1800
1600
1400
1200
1000
800
600
400
200
0
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020


Percent Change: PRISM (1927-2014) vs. NLDAS (1984-2014)
40%
30%
20%
10%
0%
-10%
% CHANGE PRISM
% CHANGE NLDAS
1.98%
-2.6%
2.97%
4.7%
-1.60%
33.4%
9.25%
10.5%
3.22%
11.4%
DJF
MAM
JJA
SON
ANN

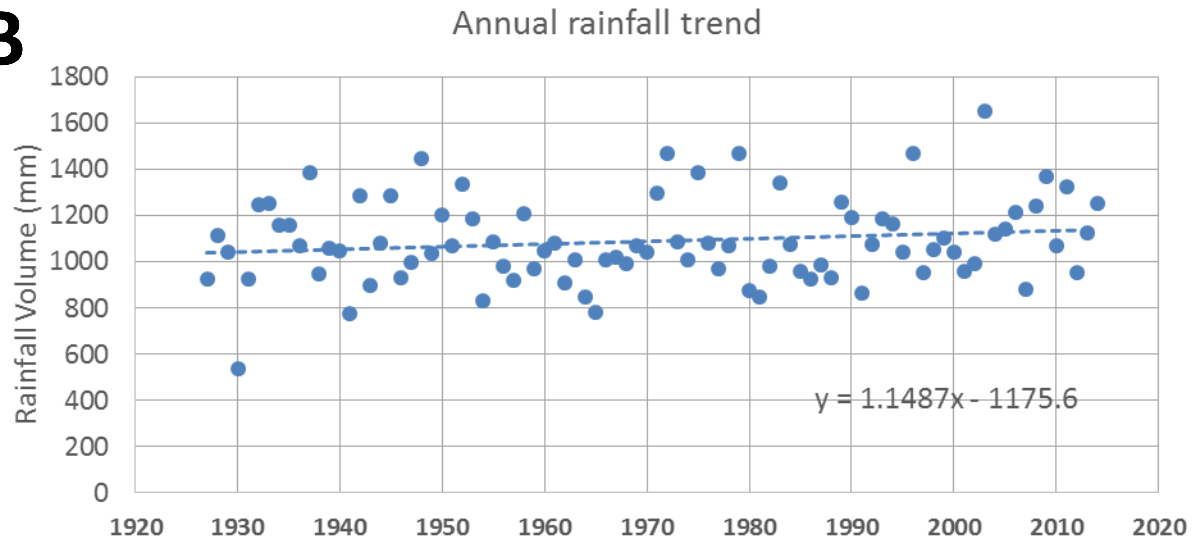
County A

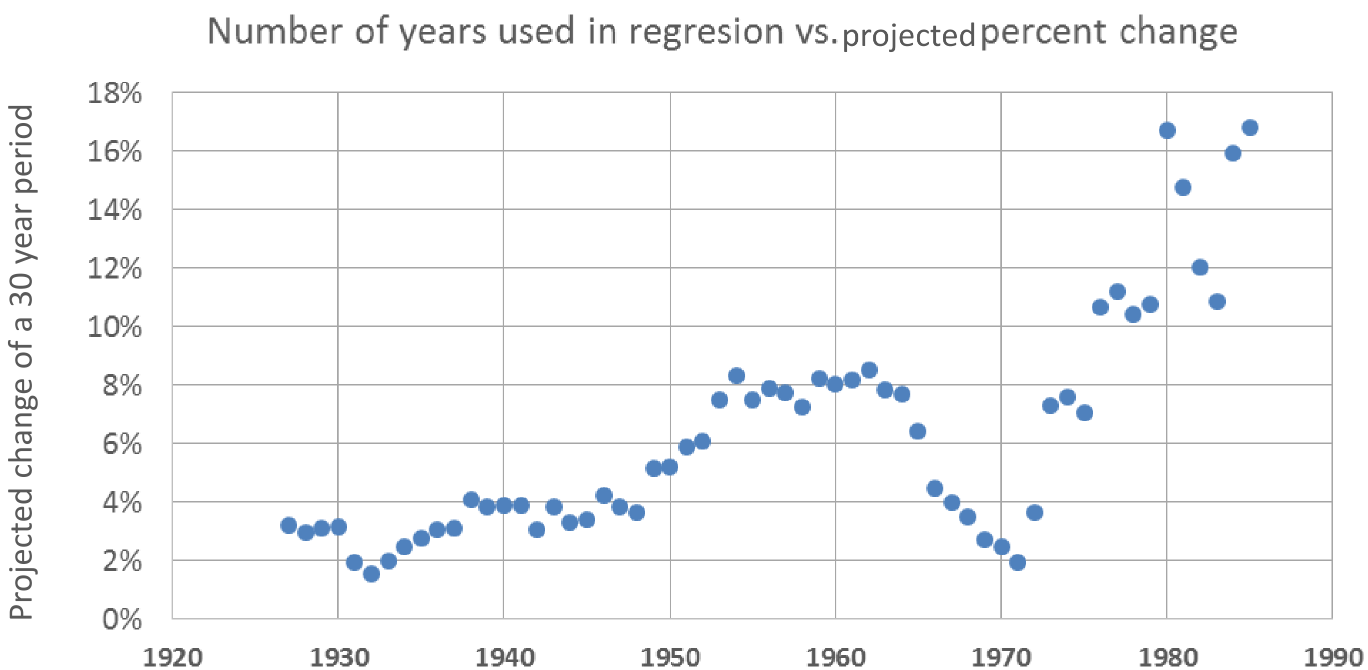
Projected rainfall change varied significantly depending on the numbers of years included in the regression.





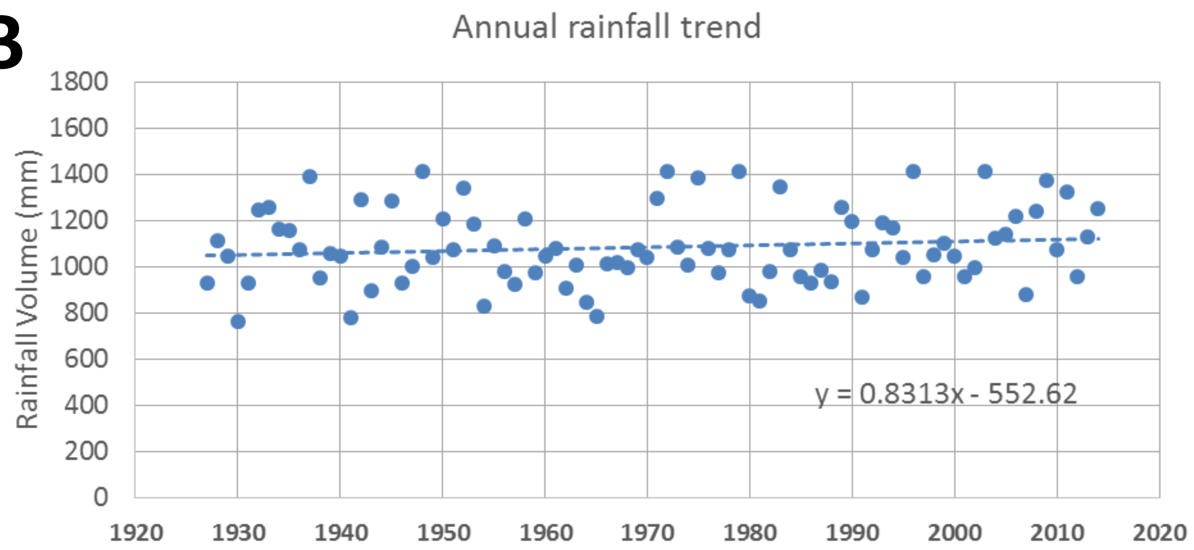
County B

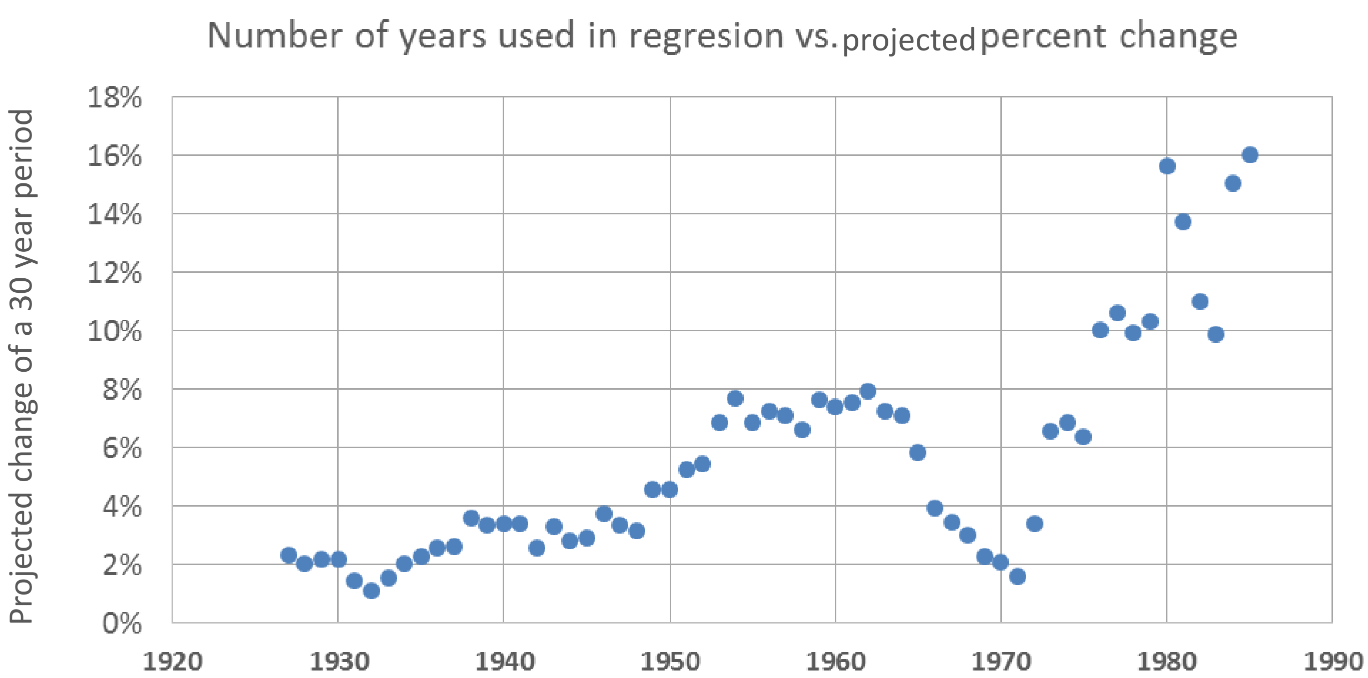

Annual rainfall trend
Rainfall Volume (mm)
1800
1600
1400
1200
1000
800
600
400
200
0
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
y = 1.1487x - 1175.6


Number of years used in regresion vs. projected percent change
Projected change of a 30 year period
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
1920
1930
1940
1950
1960
1970
1980
1990

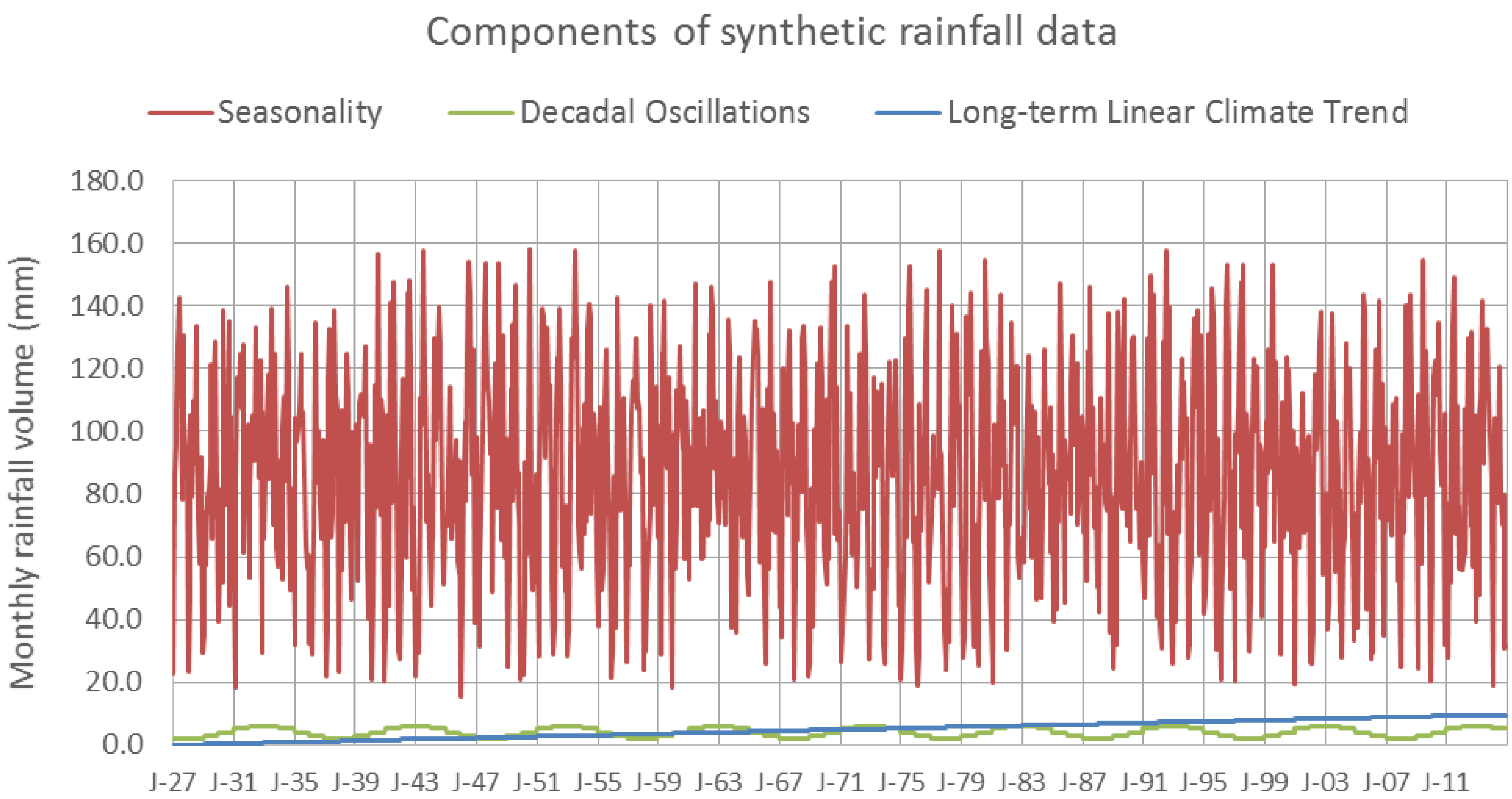
County B

with constrained extreme (wet/dry) years

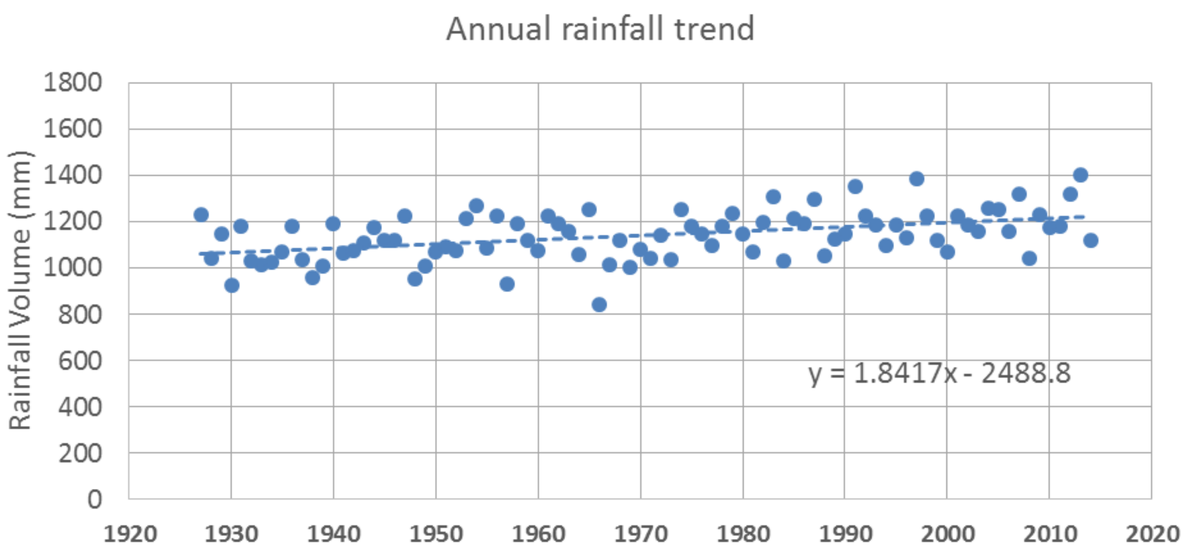




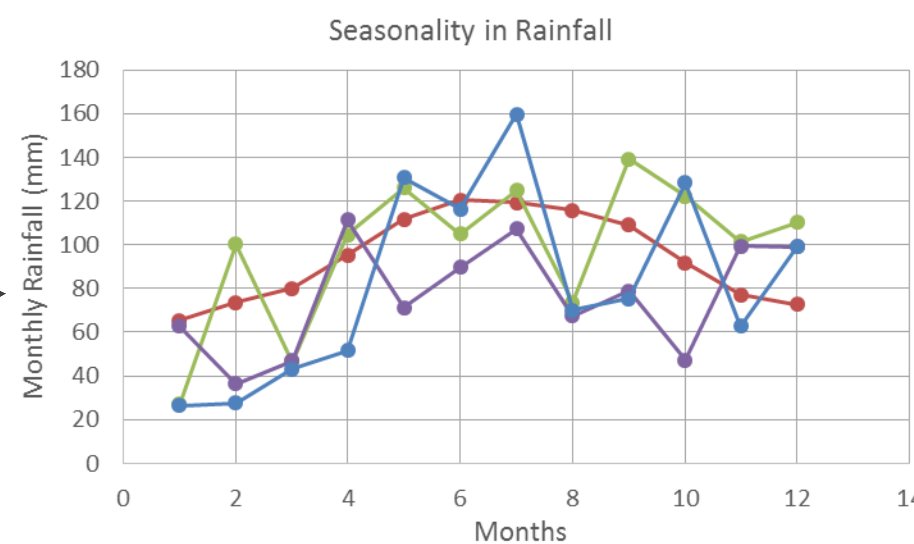
An investigation using synthetic rainfall data



Here a known long term ***linear*** *climate trend is embedded in the synthetic rainfall data.*

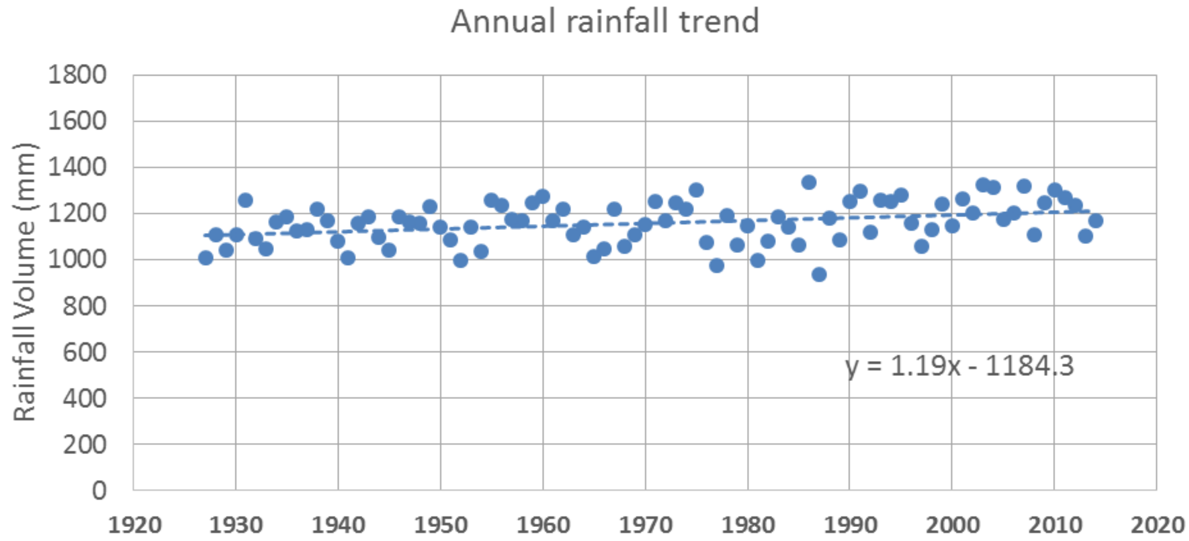


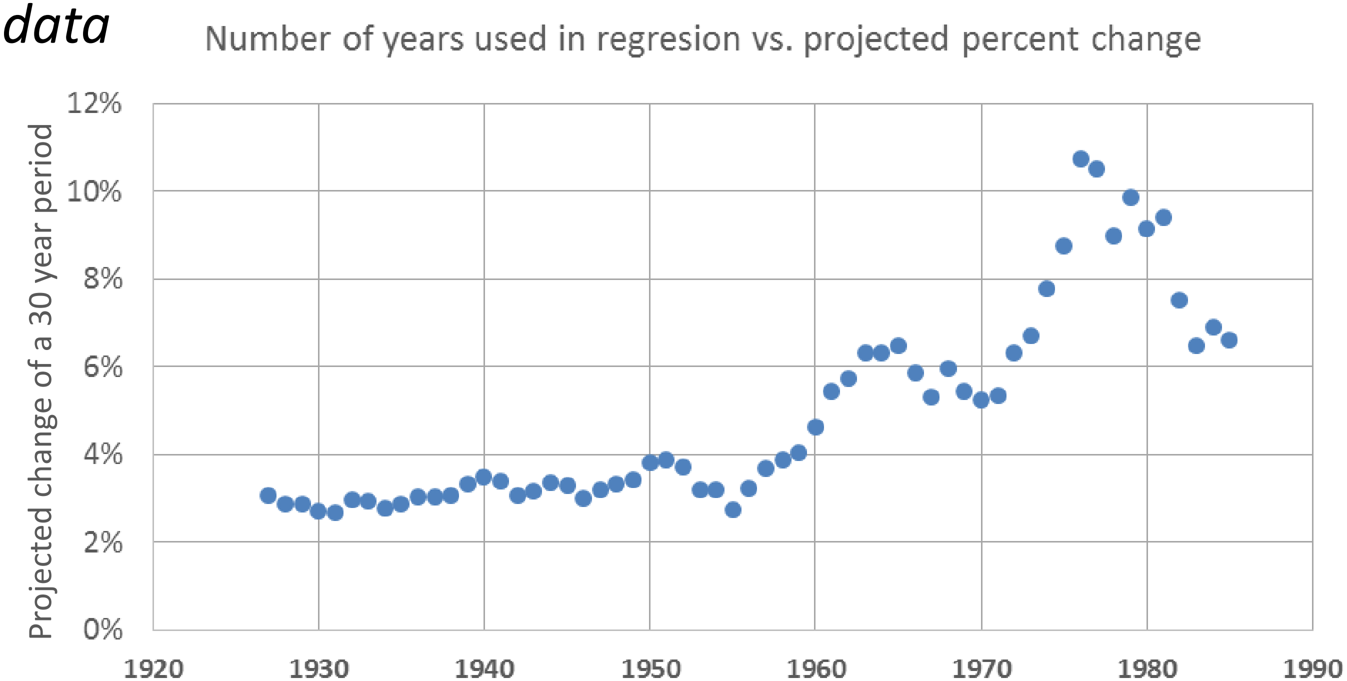
The synthetic rainfall data was created to reflect some of the key characteristics of the rainfall data in the region.

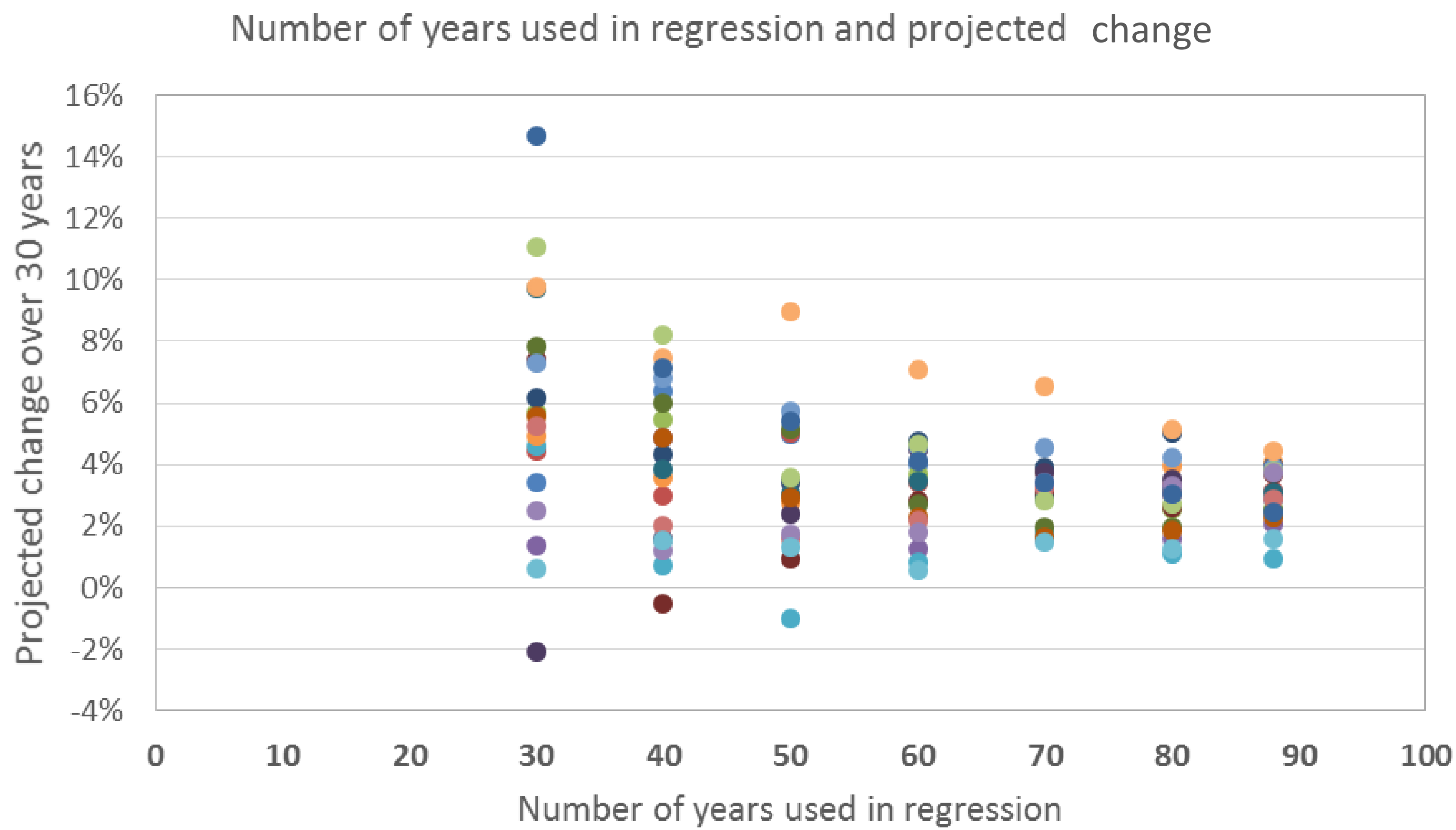


Synthetic rainfall

Here we also see similar behavior to that of the observed (PRISM) data



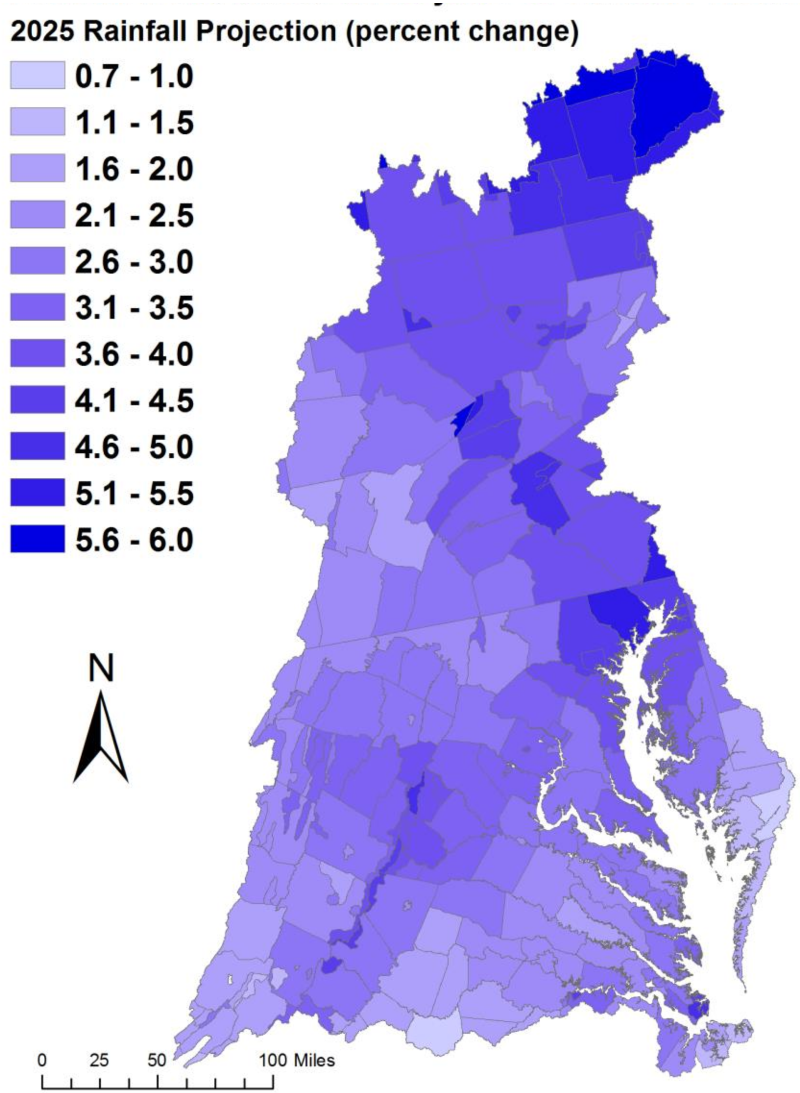




Linear increase corresponds to a 3.5% increase over a 30-year period.

Error in estimation of a ***linear*** *trend decreases with an increasing number of years.*

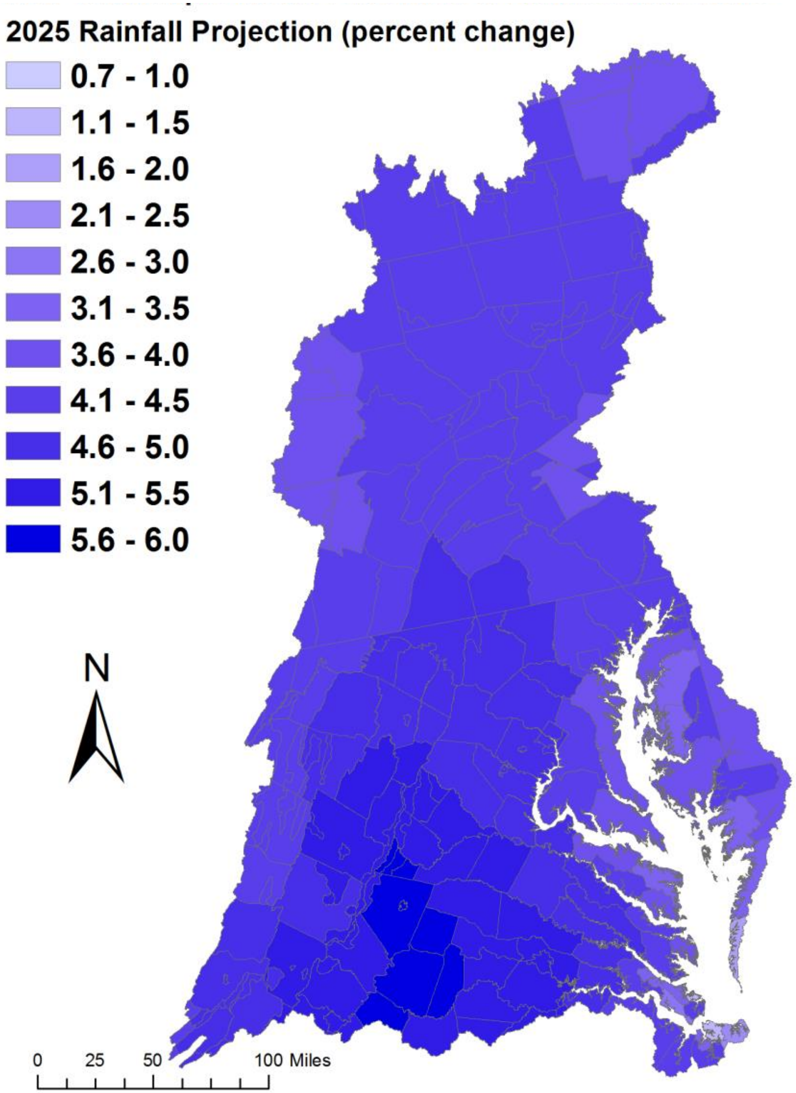
Change in Rainfall using Annual Trend in PRISM data (88 Years)



Change in Rainfall Volume 2021-2030 vs. 1991-2000

Major Basins	PRISM Trend
Youghiogheny River	2.1%
Patuxent River Basin	3.3%
Western Shore	4.1%
Rappahannock River Basin	3.2%
York River Basin	2.6%
Eastern Shore	2.5%
James River Basin	2.2%
Potomac River Basin	2.8%
Susquehanna River Basin	3.7%
Chesapeake Bay Watershed	**3.1%**

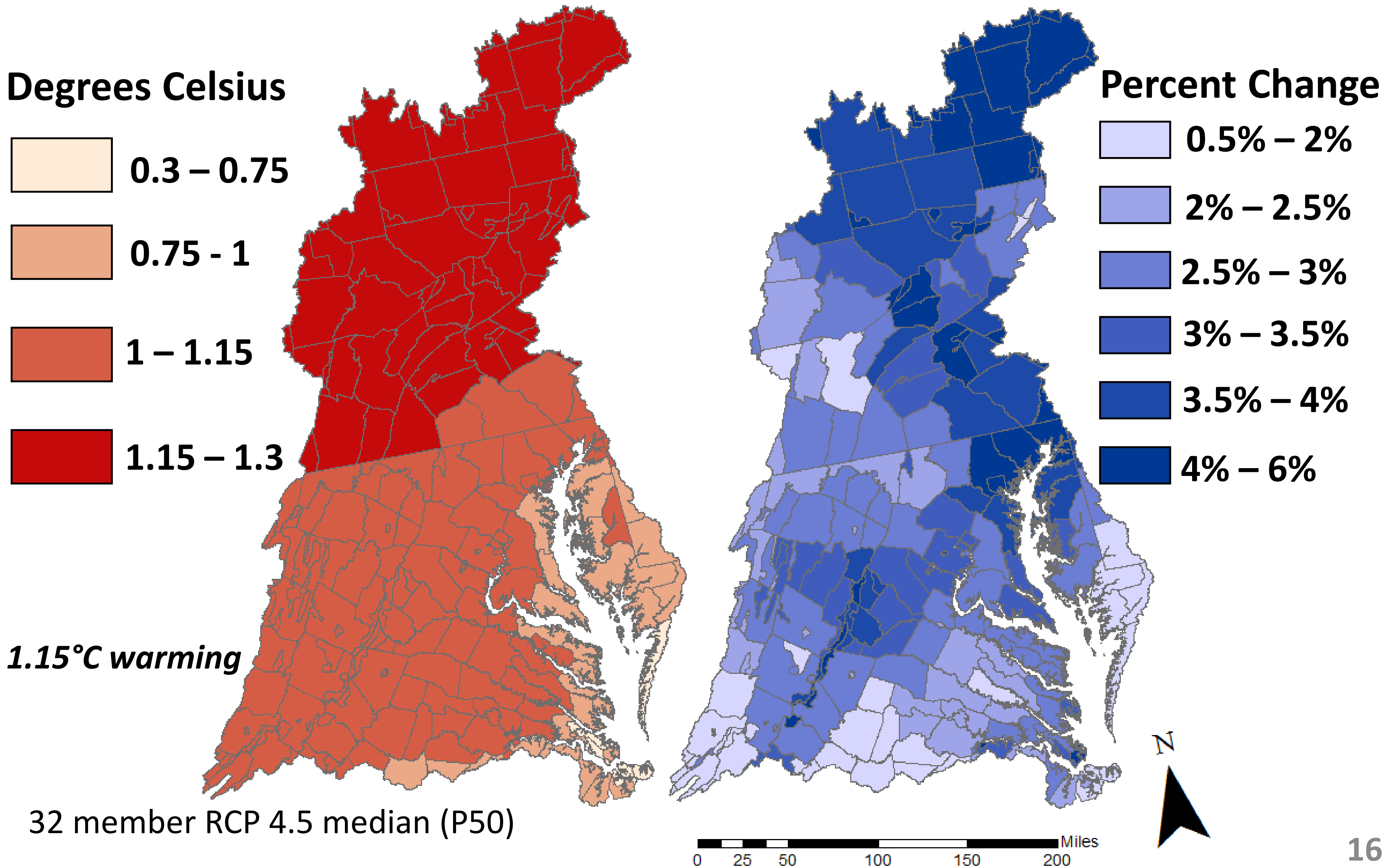
Change in Rainfall using Multiple Model Ensemble of Downscaled GCMs (RCP 4.5)



Change in Rainfall Volume 2021-2030 vs. 1991-2000

Major Basins	CMIP5
Youghiogheny River	4.1%
Patuxent River Basin	4.2%
Western Shore	4.2%
Rappahannock River Basin	4.9%
York River Basin	4.7%
Eastern Shore	3.7%
James River Basin	5.0%
Potomac River Basin	4.7%
Susquehanna River Basin	4.1%
Chesapeake Bay Watershed	**4.4%**

Year 2025: Changes in Temperature* and Precipitation



32 member RCP 4.5 median (P50)

Incorporation of PRISM trends to baseline rainfall data

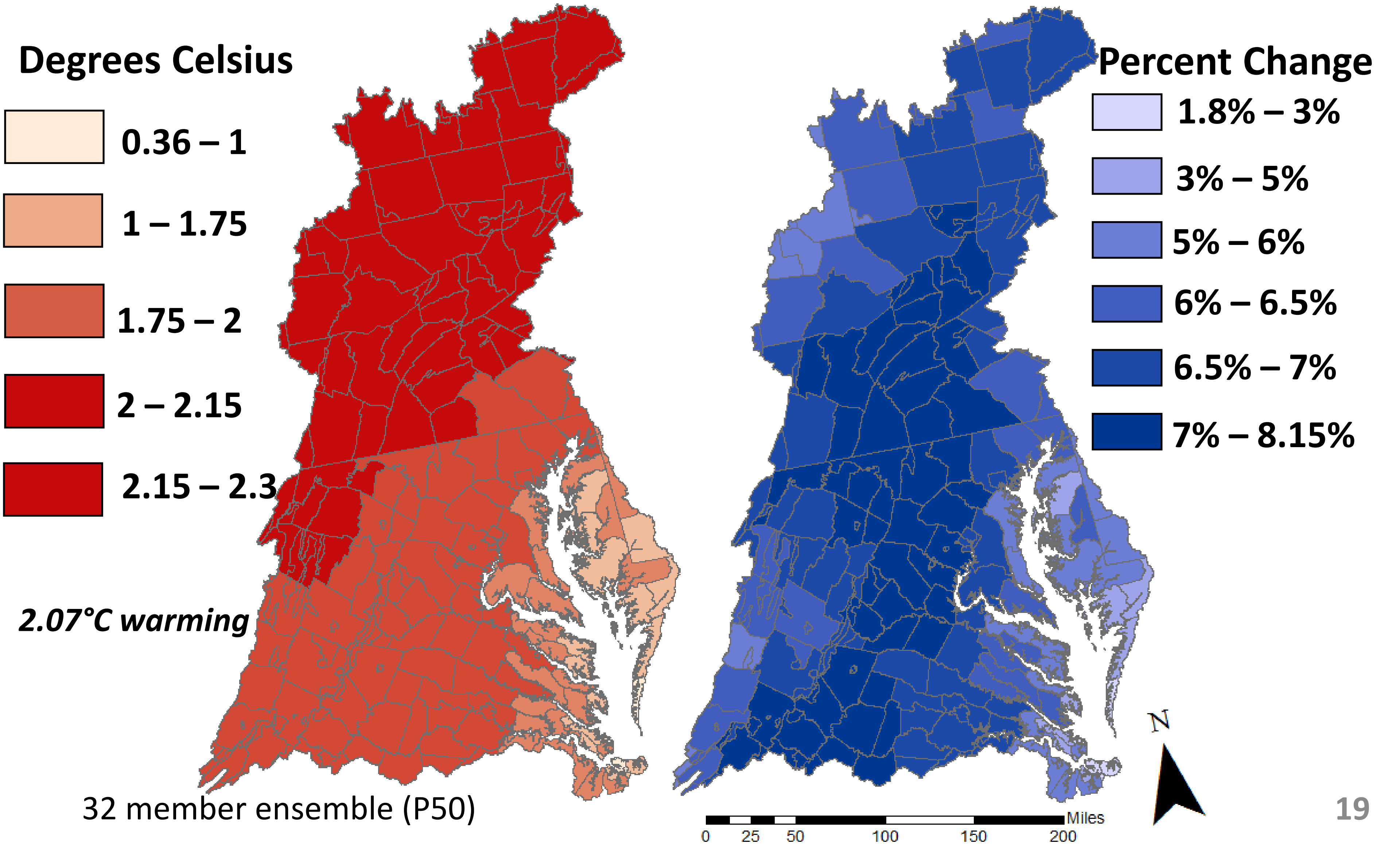
- Annual change from long term PRISM trends were applied to each month.
- Two rainfall scenarios were developed:
  - equal split of volume across intensity deciles (**EQ**)
  - relative trends in rainfall intensity using Karl & Knight (**KK**)

2050 rainfall and temperature projections

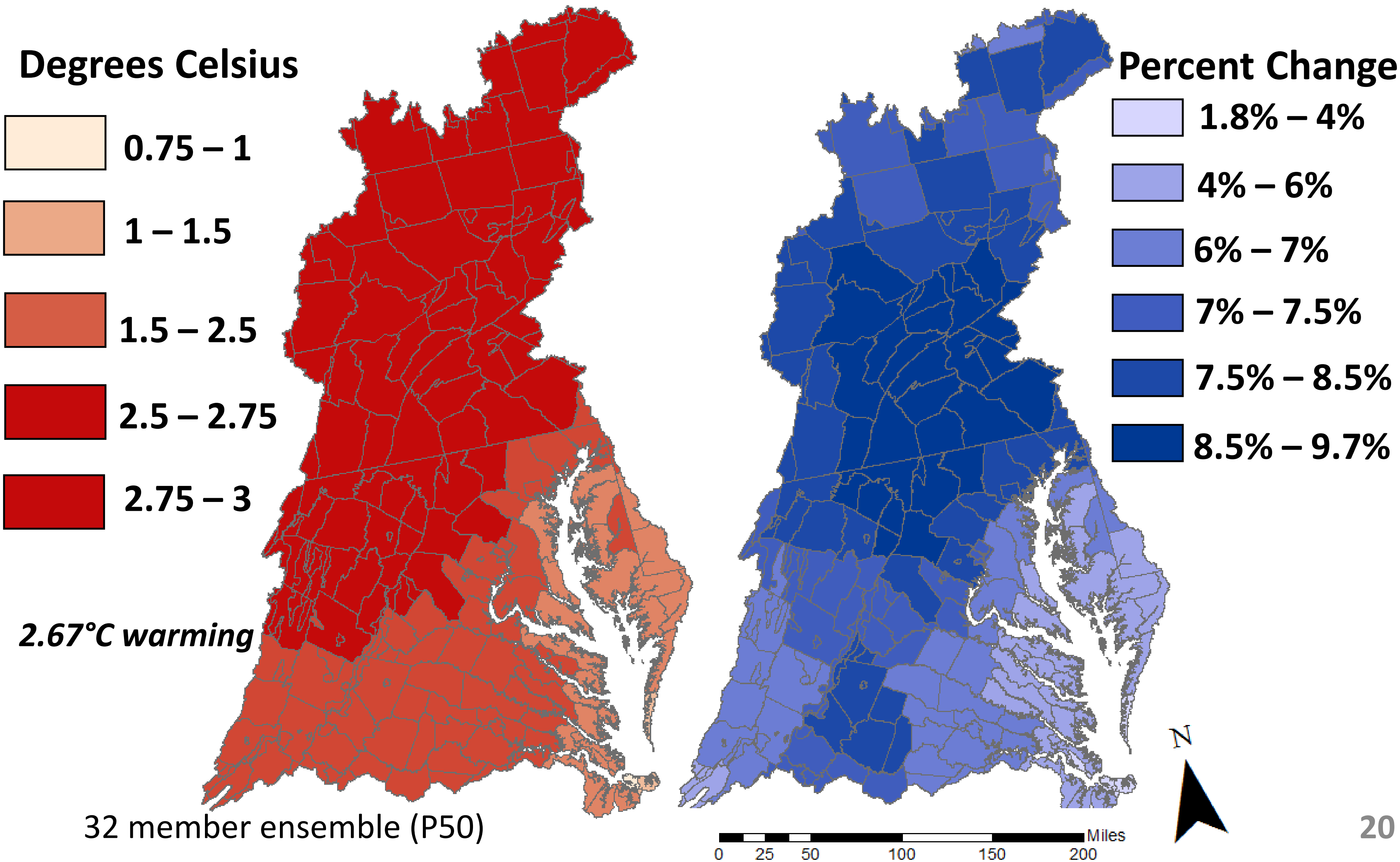
- *STAC has recommended use of downscaled climate models for rainfall and temperature projections.*

- 32 members ensembles are being used for the preparation of input rainfall and temperature dataset.
- Use of RCP 4.5 and 8.5 has been recommended.
- For rainfall, ***P50 (median), P90 and P10 (90 and 10% bounds)*** have been recommended.
- For temperature P50 (median) has been recommended.

Year 2050: Changes in Temperature and Precipitation – RCP 4.5



Year 2050: Changes in Temperature and Precipitation – RCP 8.5



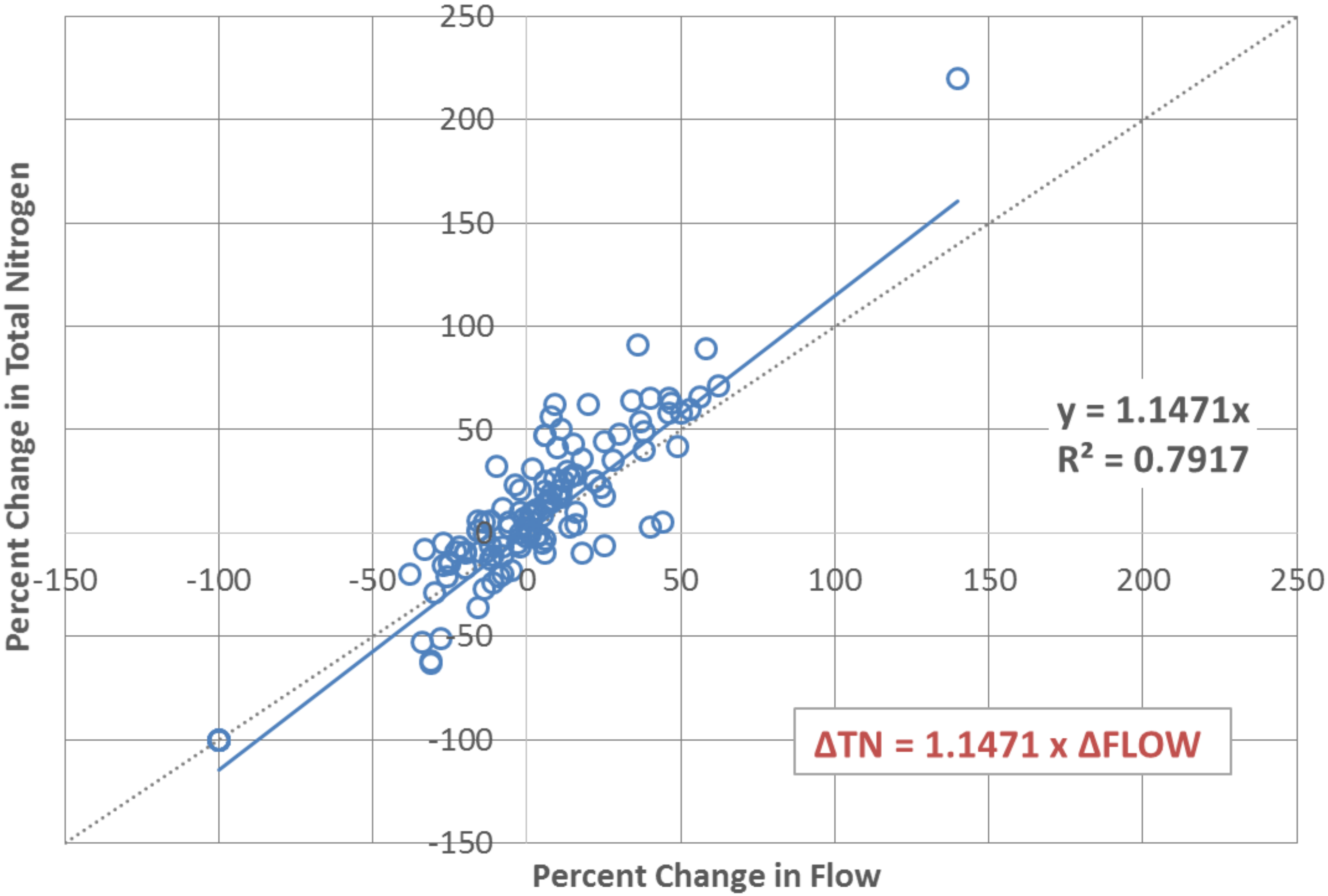
32 member ensemble (P50)

Simulation of climate change scenarios

- Phase 6 Beta 3 model was used for the simulation of climate change scenarios.
- Phase 6 has a *process-based* simulation of hydrology and sediment transport.
- Nutrient simulation is deterministic based on *Phase 6 sensitivities*:
  - For phosphorus sensitives are available for changes in flow, sediment (APLE).
  - For nitrogen, sensitivities for flow have not been incorporated in the model yet.

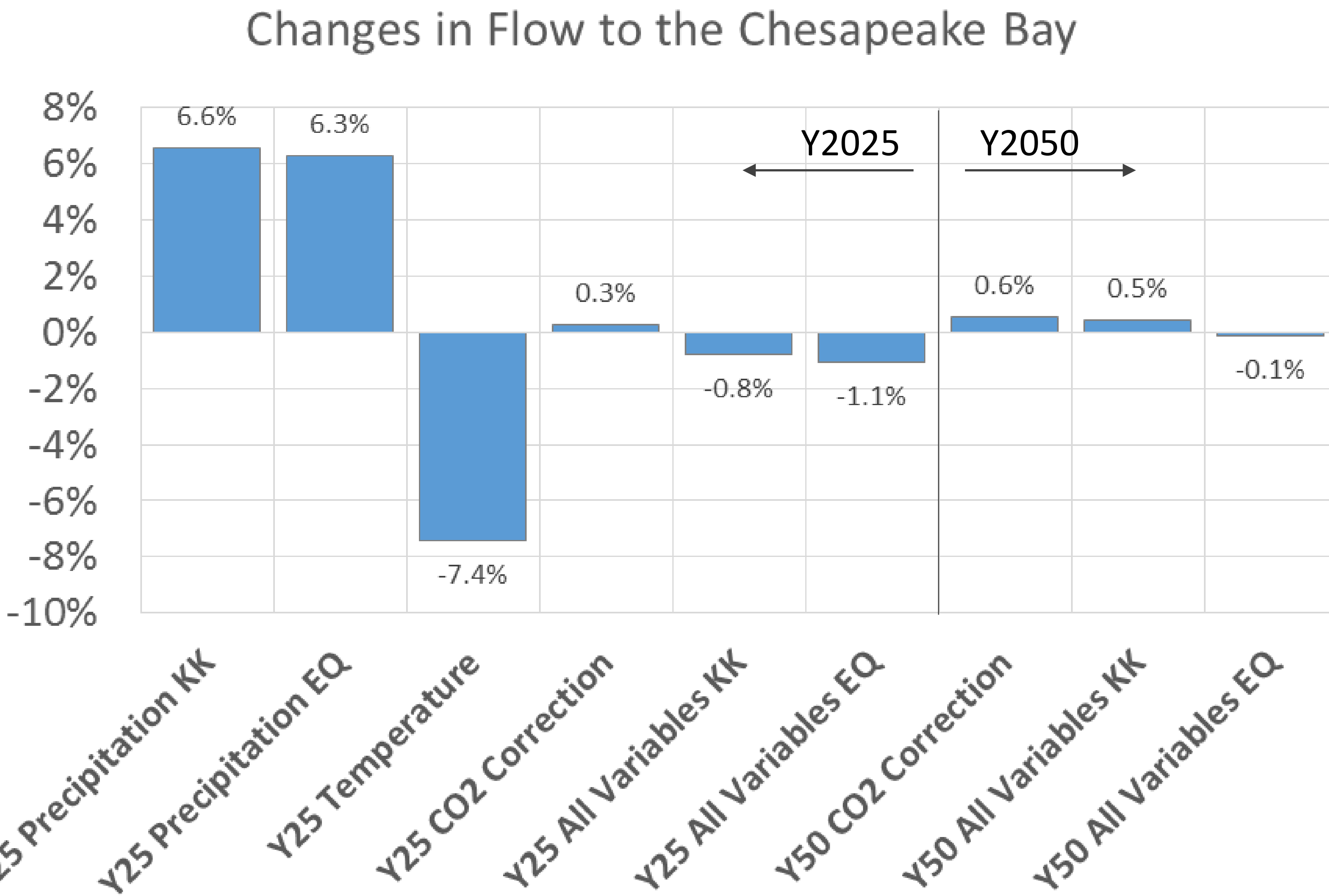
Nitrogen sensitivity to flow

- 20 Watershed study (Butcher et al. 2013, EPA/600/R12/058A) provides nitrogen sensitivity using SWAT.

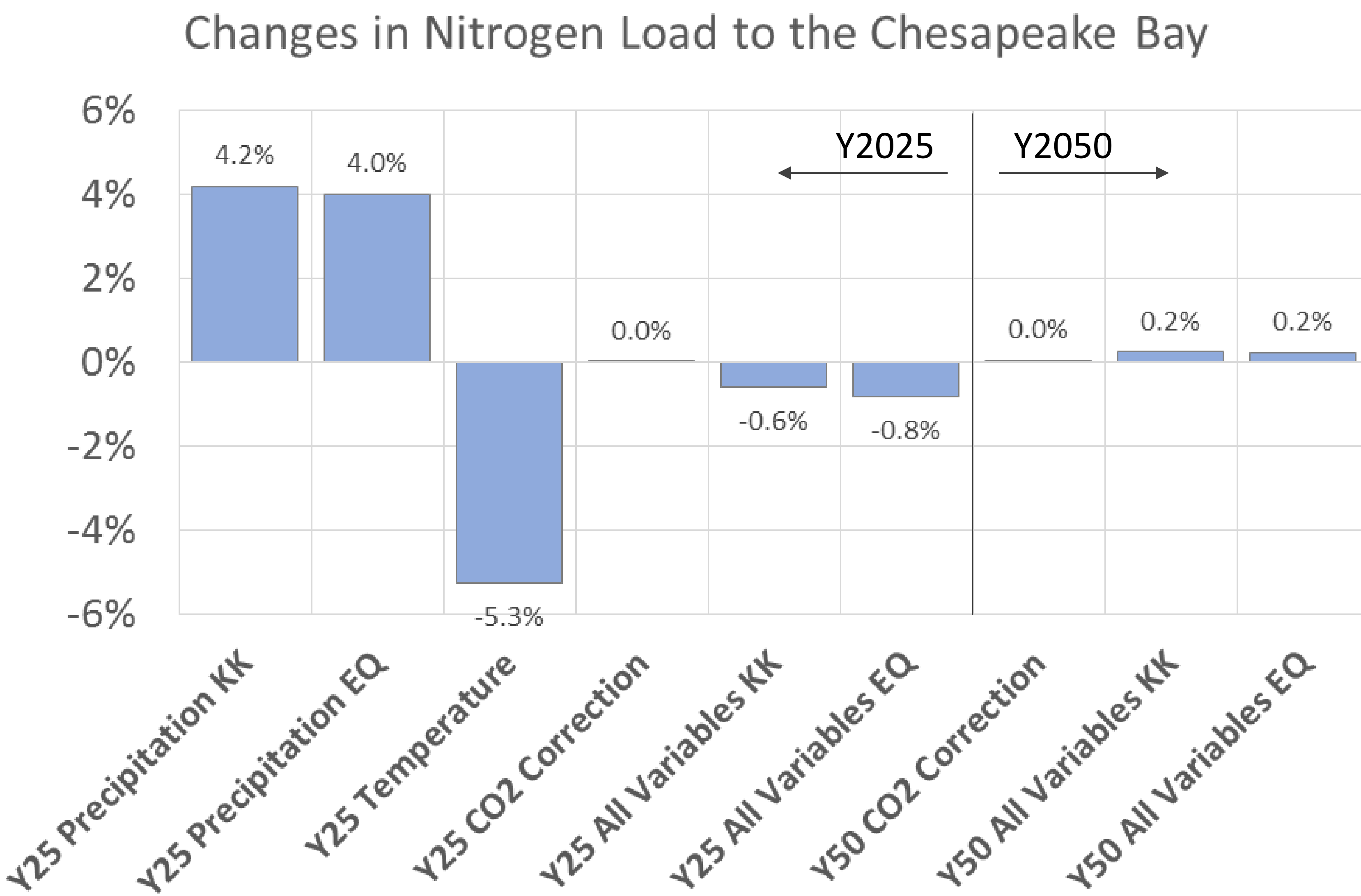


For the analysis, a conservative estimate of 1.0 was selected for the sensitivity.

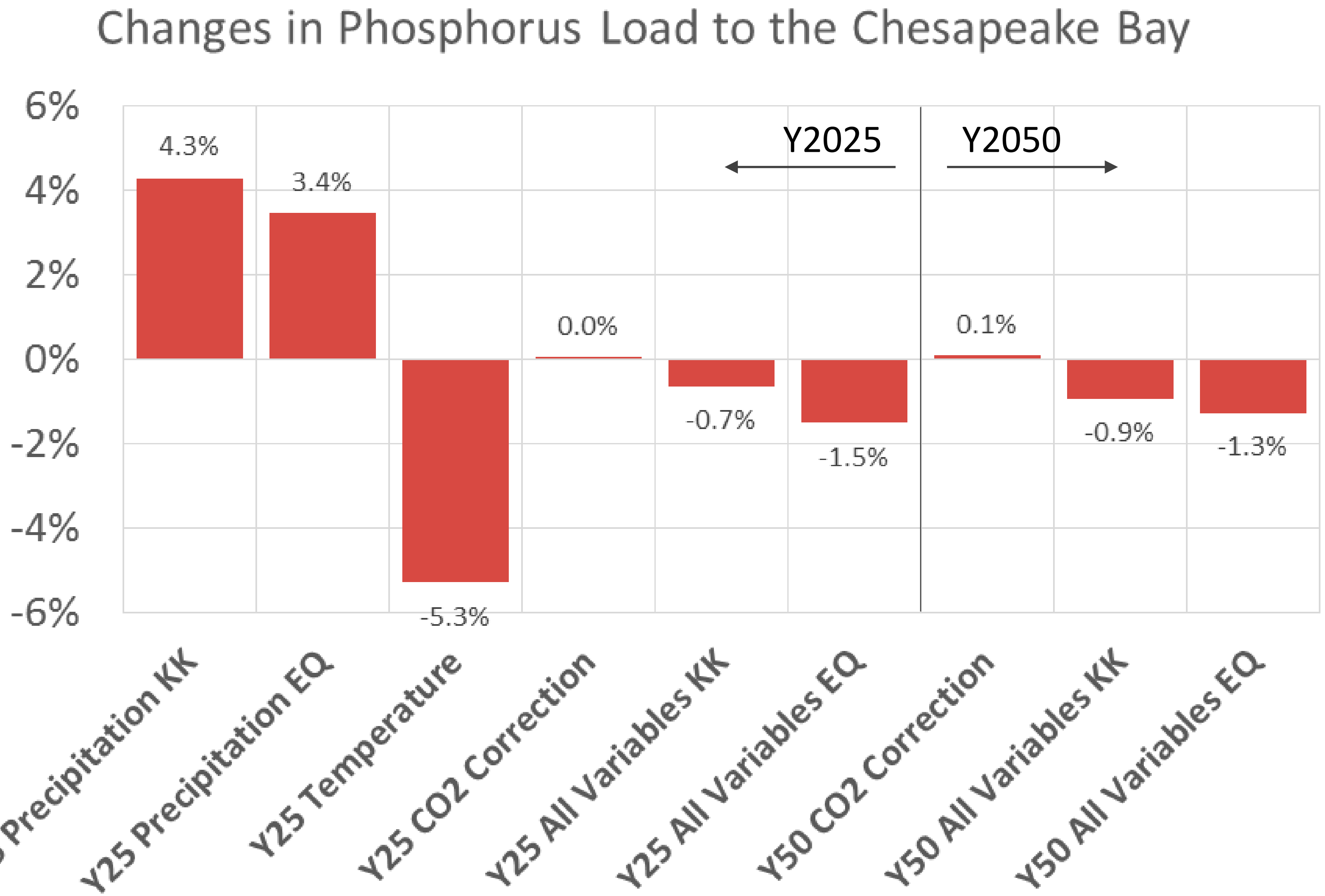
Model results



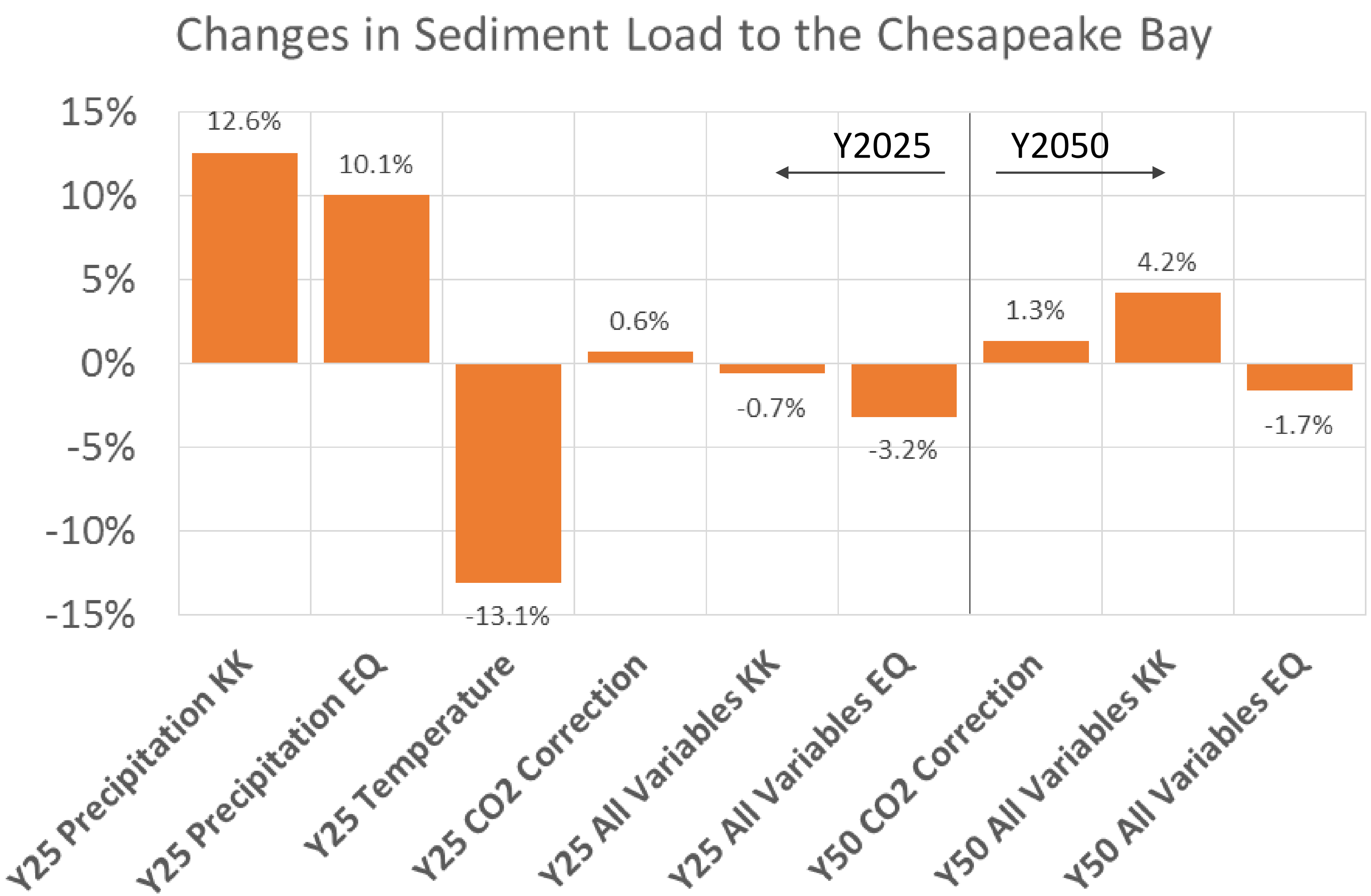
Model results



Model results



Model results



Next Steps…

- Complete simulation of remaining climate change scenarios.
- Investigate any potential issues.
- Prepare input loads for the Water Quality and Sediment Transport Model.

"To assess the sensitivity of model results, we performed sets of SWAT simulations with and without increased atmospheric CO2 for all five study areas using the six NARCCAP dynamically downscaled climate scenarios, which provide internally consistent, downscaled time series of all meteorological variables (the available BCSD scenarios did not include downscaled estimates of relative humidity, solar radiation, or wind). Fig. 3 shows selected flow and water quality endpoints simulated with and without effects of CO2 con- centration changes (see USEPA, 2013 for details). When representing response to increased CO2 concentrations, the model predicts increased annual streamflow, with median increases by station ranging from 3% to 38%, and an overall median increase of 11%. The overall increase is in the same range as the experimental ecosystem observations summarized by Leakey et al. (2009)."

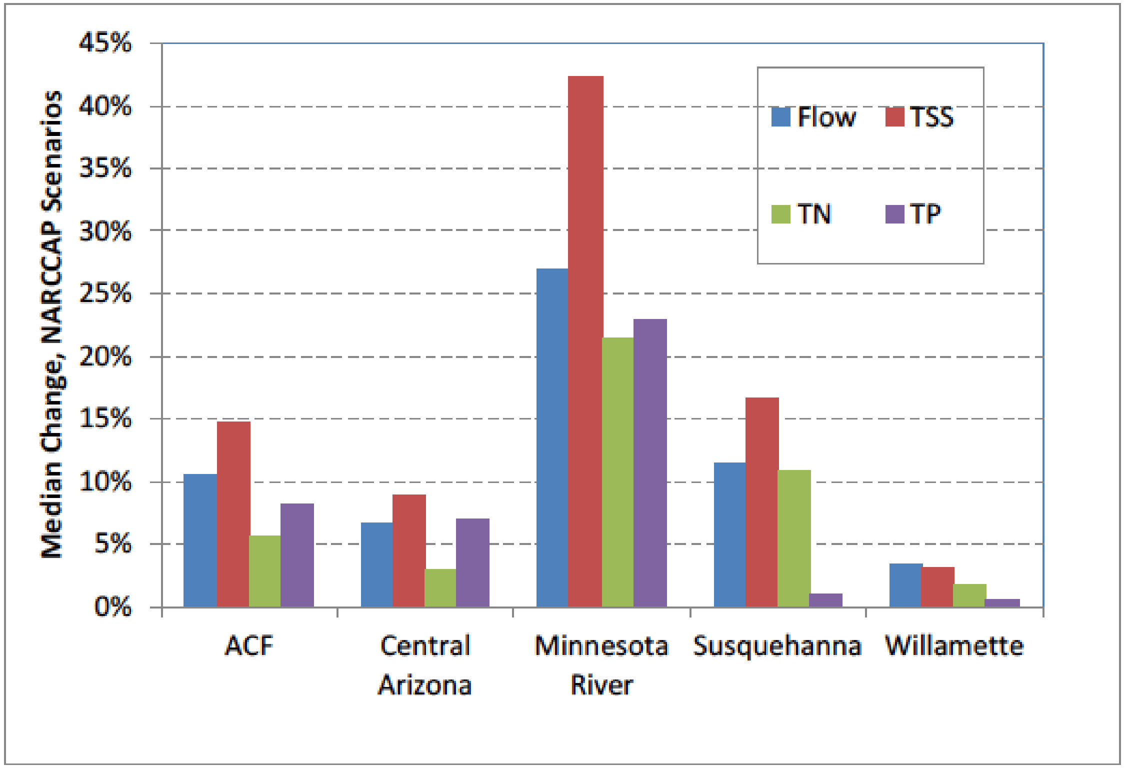


Figure 6-11. Differences between SWAT projections of mid-21st century streamflow and water quality (median across six NARCCAP scenarios) with and without representation of increased atmospheric CO_2.