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Towards an Integrated Climate Change Analysis of the Chesapeake Bay Watershed

STAC Workshop on the Development of Climate Projections

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Presentation outline

- A brief overview of climate change simulations
- Climate change projections for the Chesapeake Bay region
- Method: a revised climate change simulation
  - Rainfall inputs
  - Temperature inputs
  - CO_2 and potential evapotranspiration
- A summary of model outputs

CMIP3 – 6 GCMs and 3 Emission Scenarios

Najjar et al. 2009
- End of 21st century
- Mid-Atlantic region, coupled models
- Large variability: ΔQ from -39 to +33 %

Meehl et al. 2007, IPCC 4AR
- End of 21st century
- Coupled models
- 15-model mean projections
- $\Delta Q = +0.1\ \text{mm d}^{-1} = 0.04\ \text{m yr}^{-1}$

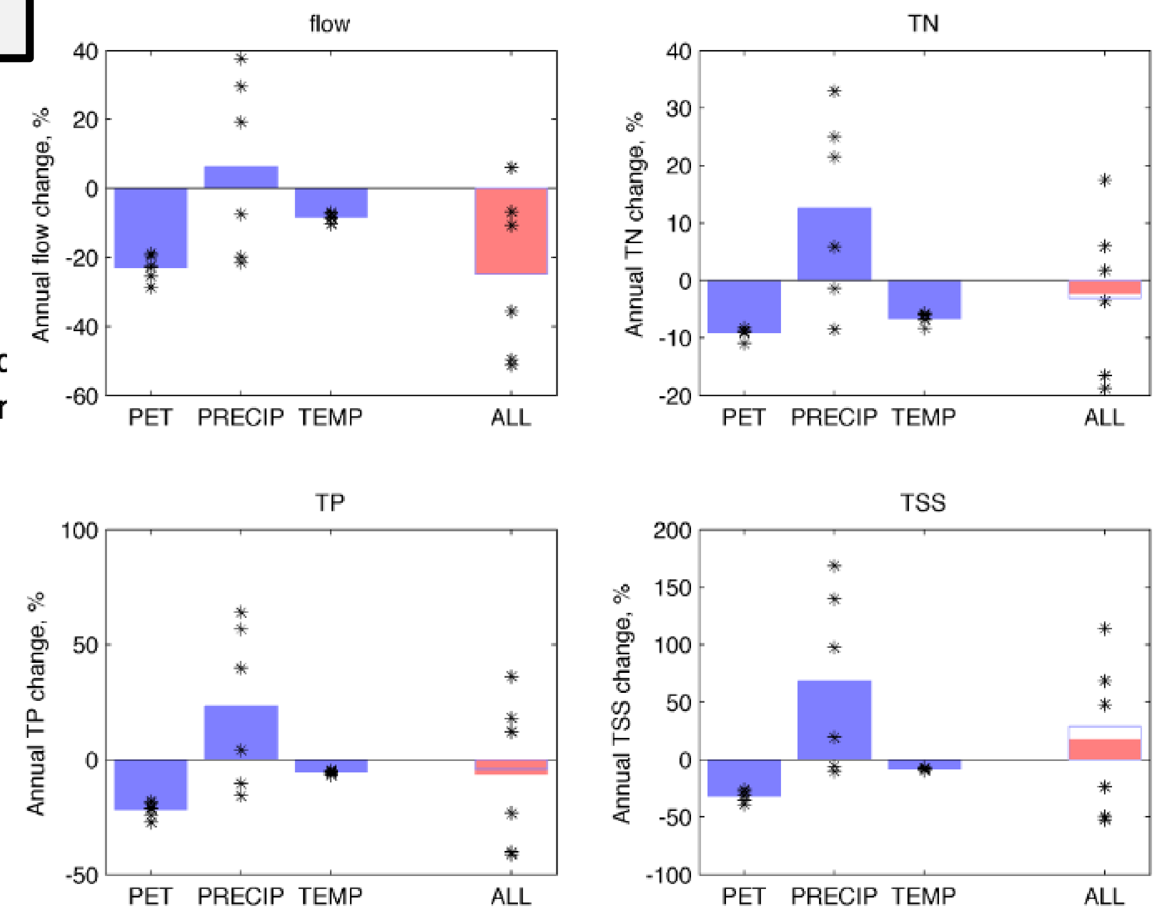
Hay et al. 2011
- End of 21st century projections
- Hydrological models for 14 U.S. watersheds
- ΔQ < 0 for almost all watersheds

Milly and Dunne 2011
- Uncoupled simulations may lead to unrealistically large flow reductions: empirical PET formulations calibratec in the present climate might cause ar overestimation of ET when used for future climate conditions

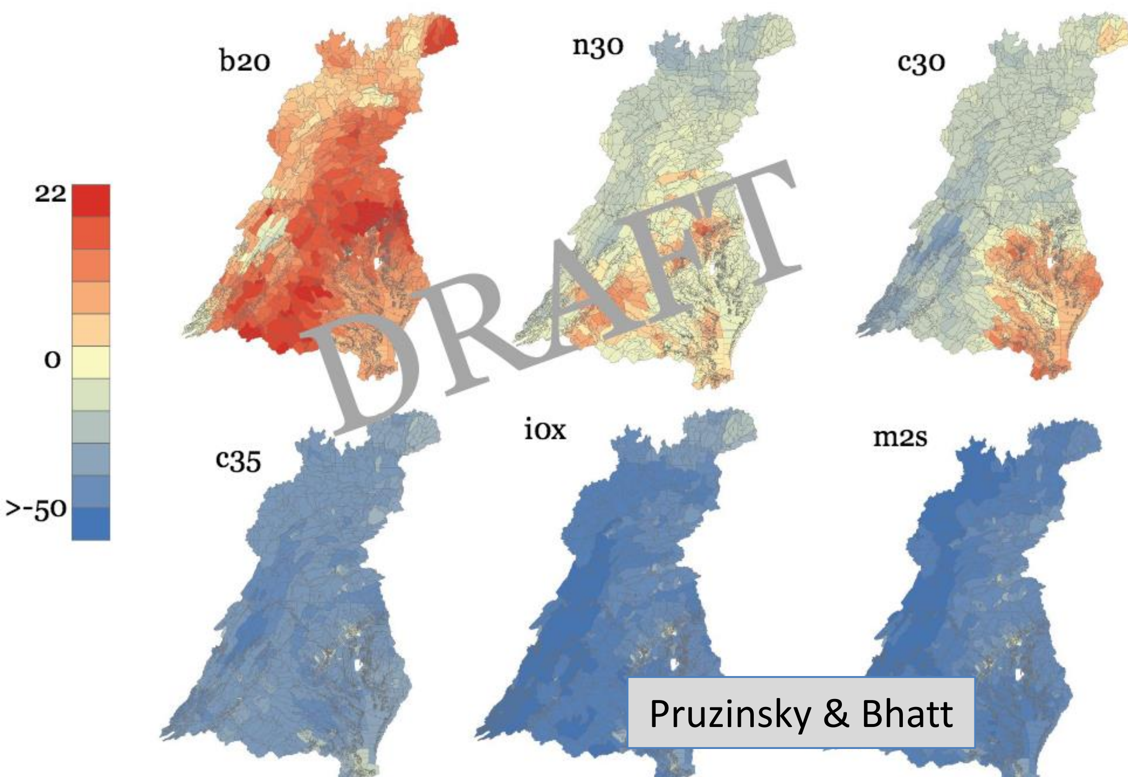
This study

Annual Q summary [m yr^{-1}]	MEAN	STD	MIN	MAX
Baseline average	0.5	0.1	0.3	0.8
HSPF projections	-0.11 (25 %)	0.11 (25 %)	-0.24 (51%)	+0.03 (6 %)

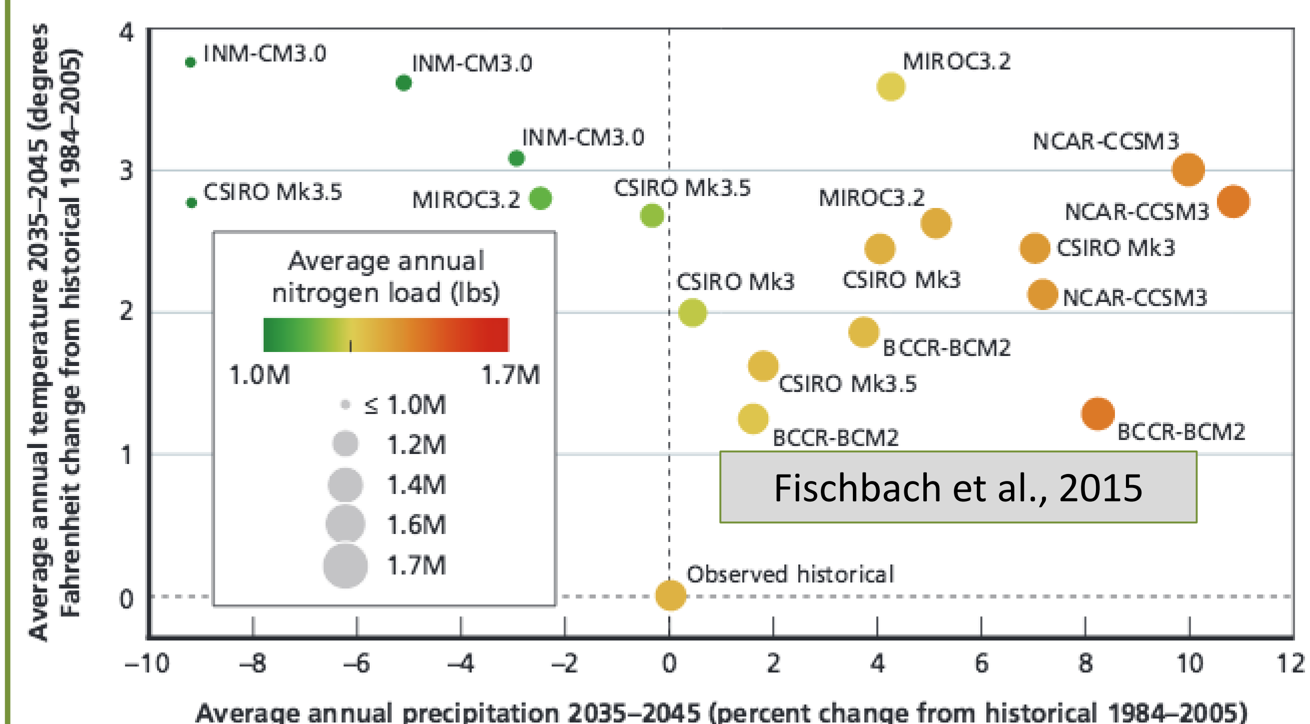
Herrmann & Najjar, 2013



Percent Change in Flow

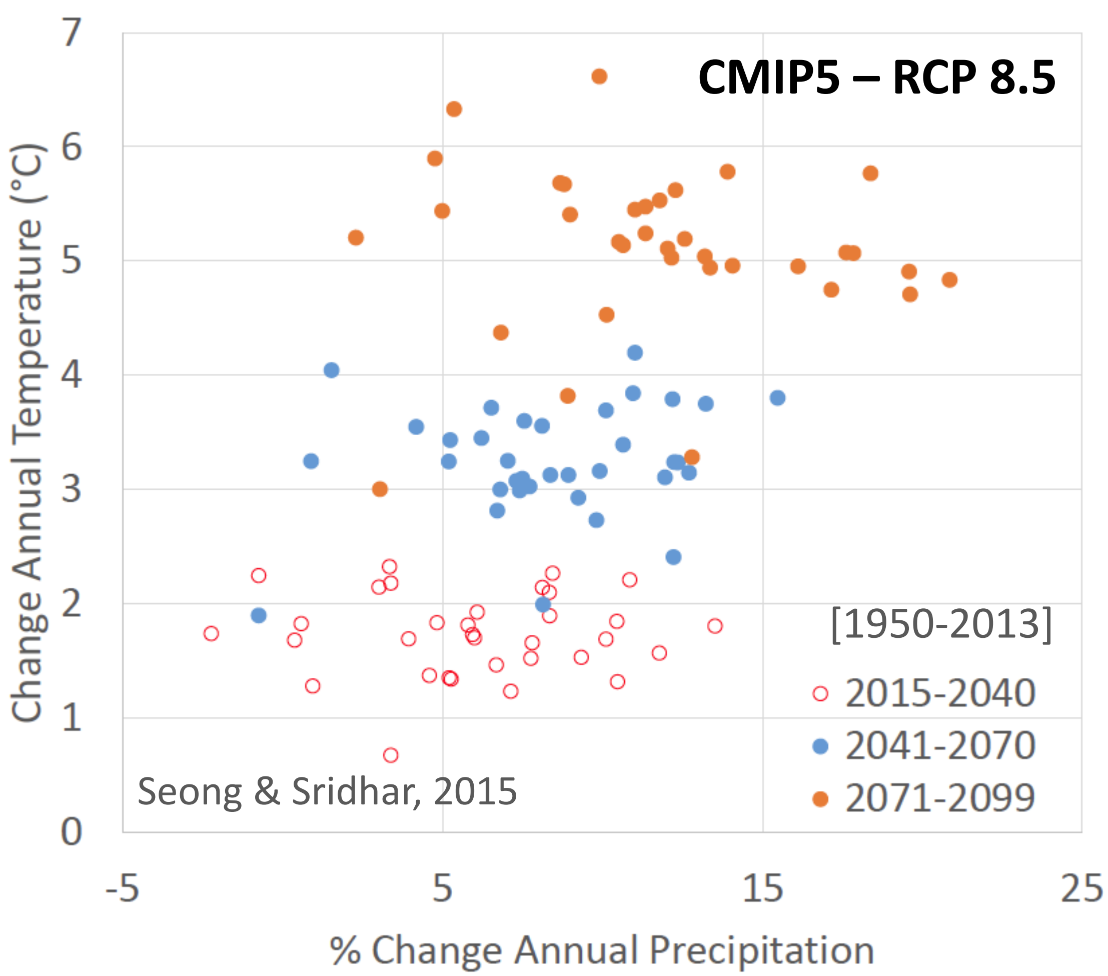


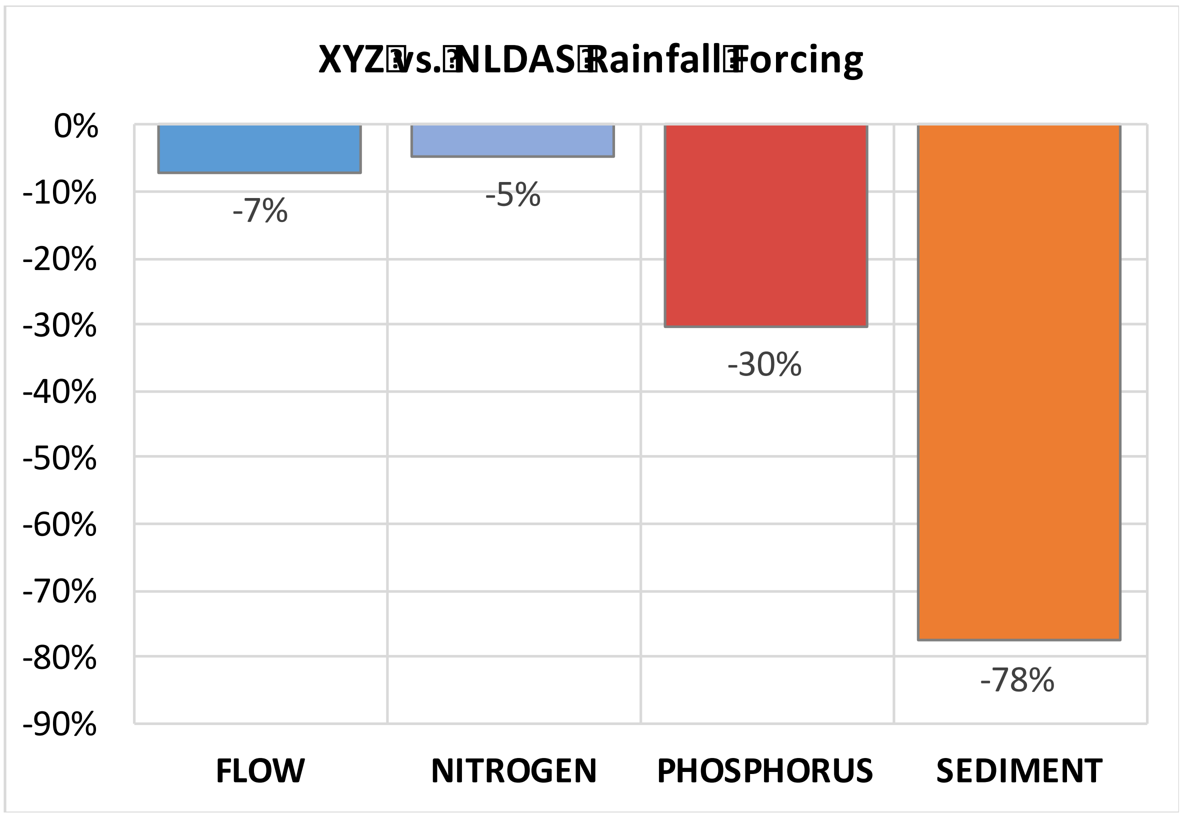
Pruzinsky & Bhatt

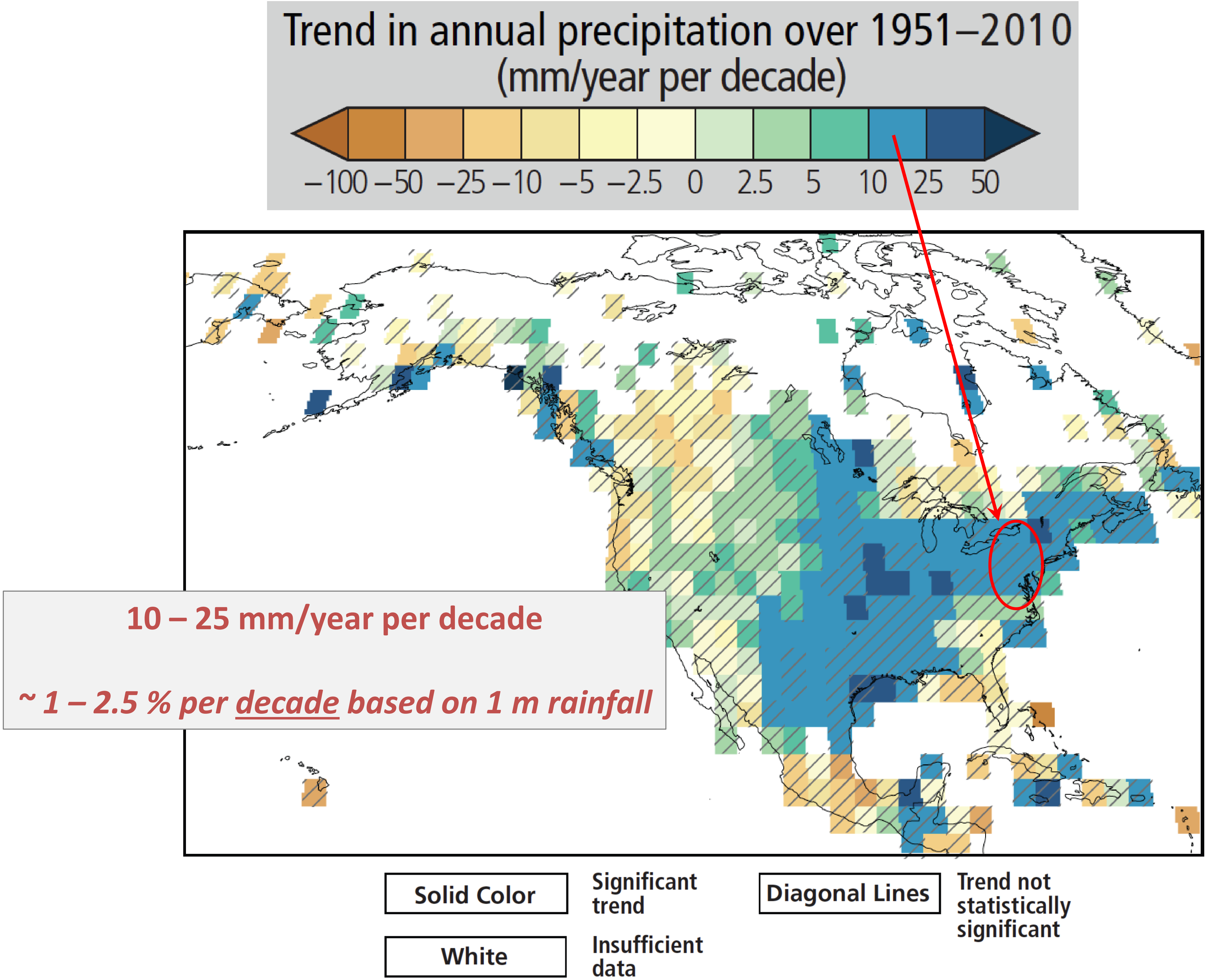


Fischbach et al., 2015

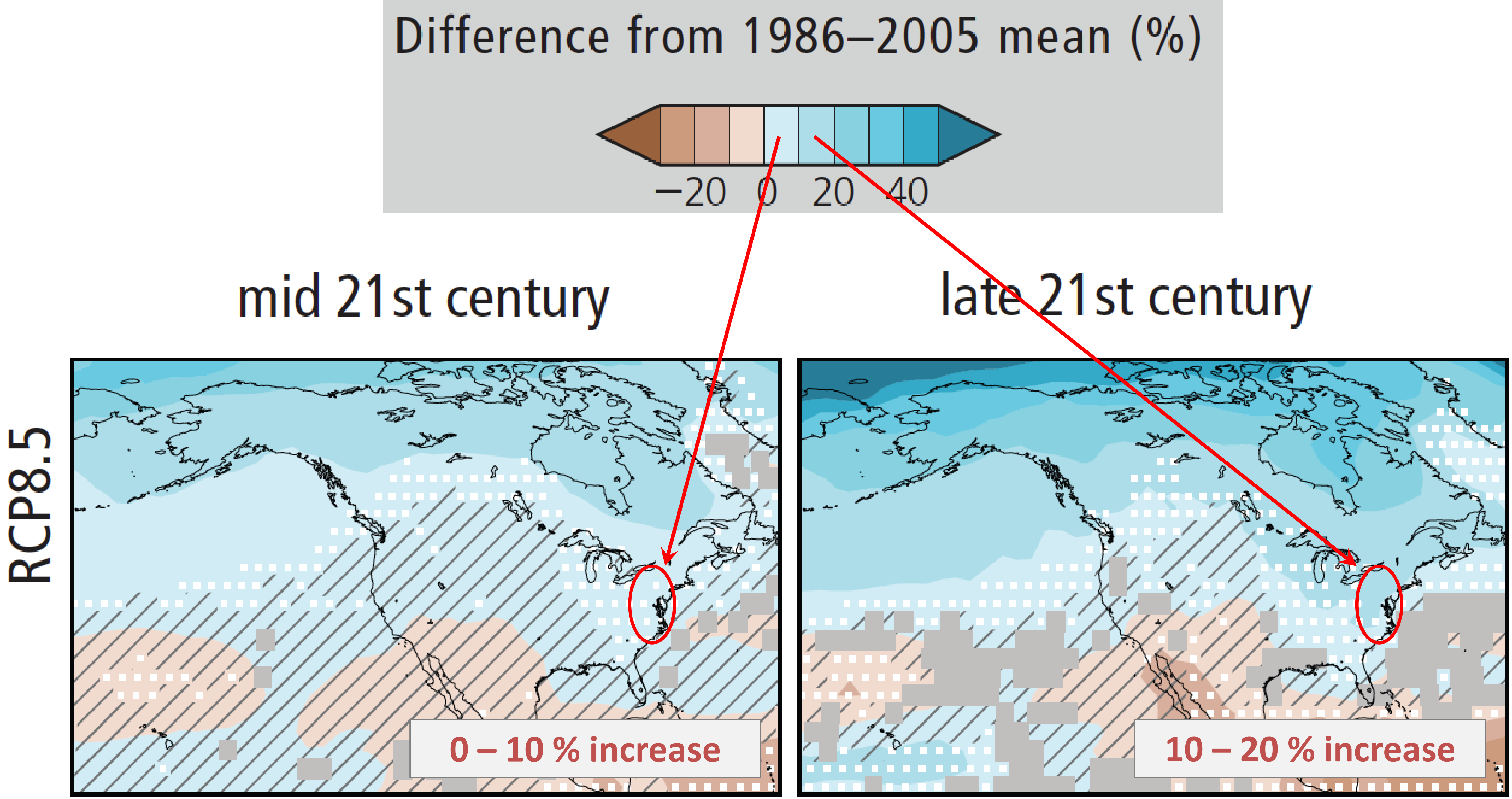
- Climate change analysis show significant variability in flow, nutrient, and sediment delivery to Bay.
- Downscaled rainfall data show extensive variability in rainfall projections from GCMs.
- *Importance of hourly rainfall data as model input.*







Romero-Lankao and others, North America. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B:

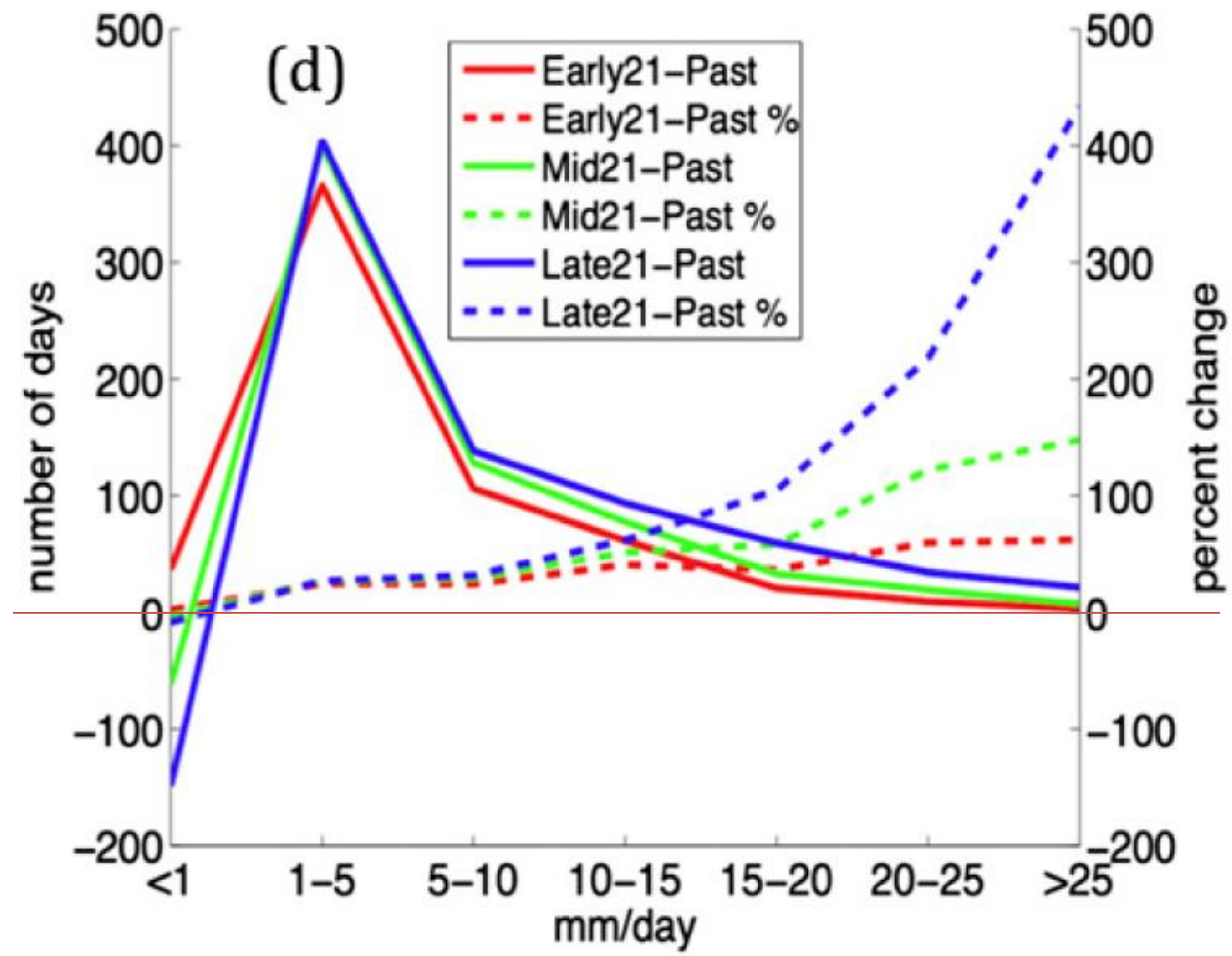


Solid Color	**Very strong agreement** √	**White Dots**	**Strong agreement** √
Gray	**Divergent changes**	**Diagonal Lines**	**Little or no change**

Romero-Lankao and others, North America. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B:

(2069–98) minus historical for these same models. For the early twenty-first century (Fig. 11b), the precipitation increases 5%–10% (10–30 mm) over the northeast United States. Less than a 5% increase occurs over the western Atlantic associated with the midlatitude storm track, while the largest percentage increase is over northeastern Canada (10%–20%). By the late twenty-first century (Fig. 11c), the largest increase of 35%–80% (40–100 mm season^{-1}) occurs in eastern Canada. Over the northeast United States, the mean precipitation increases by 15%–25% by the late twenty-first century. The number of relatively heavy precipitation events (>25 mm day^{-1}) over the northeast United States increases by 50% by the early twenty-first century and increases by 4–5 times by the late twenty-first century (Fig. 11d). These results suggest that the potential exists for a dramatic increase in the number of extreme rainfall events over the northeast United States during the next 50–75 yr.

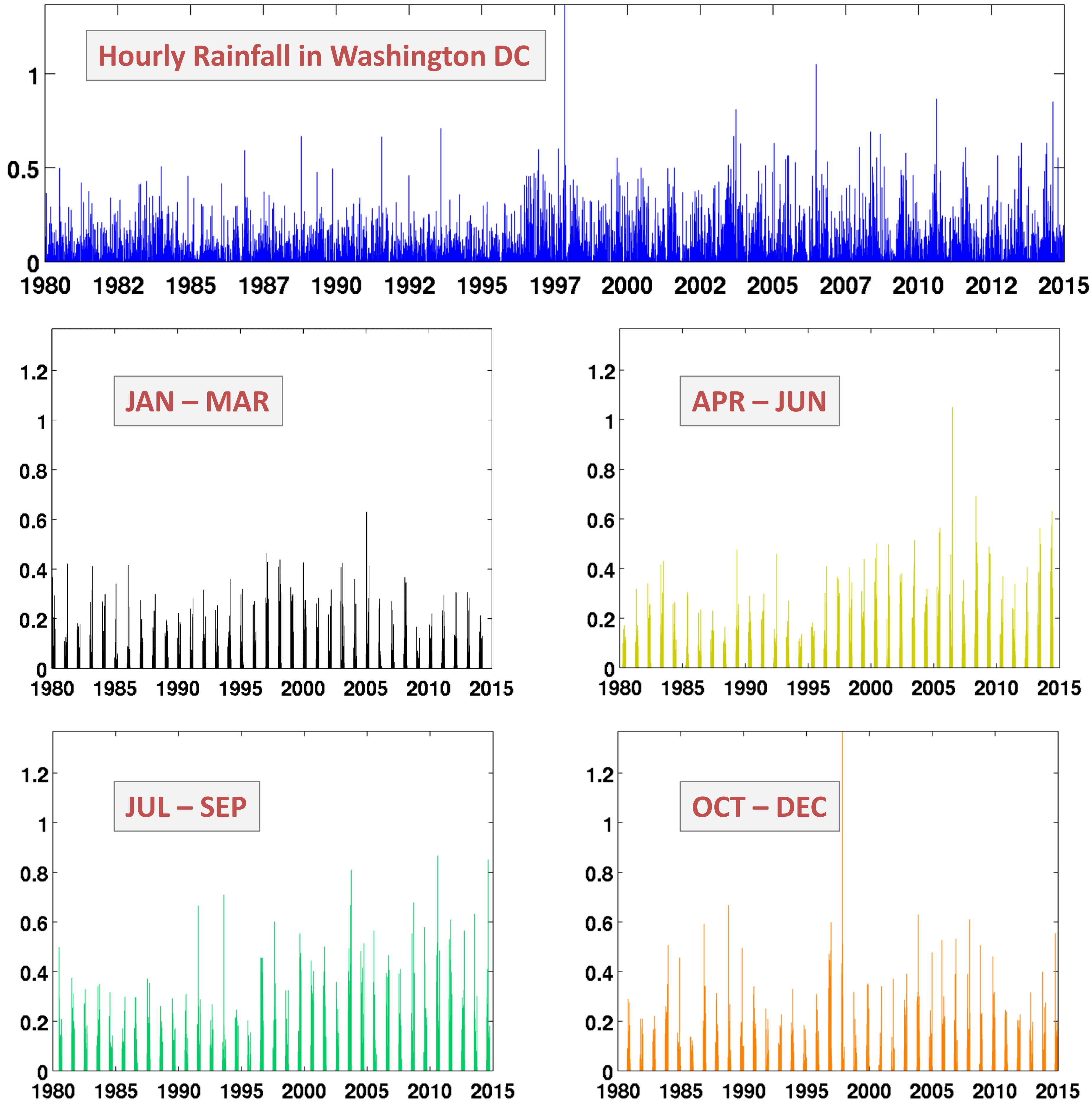
MEM for November to March

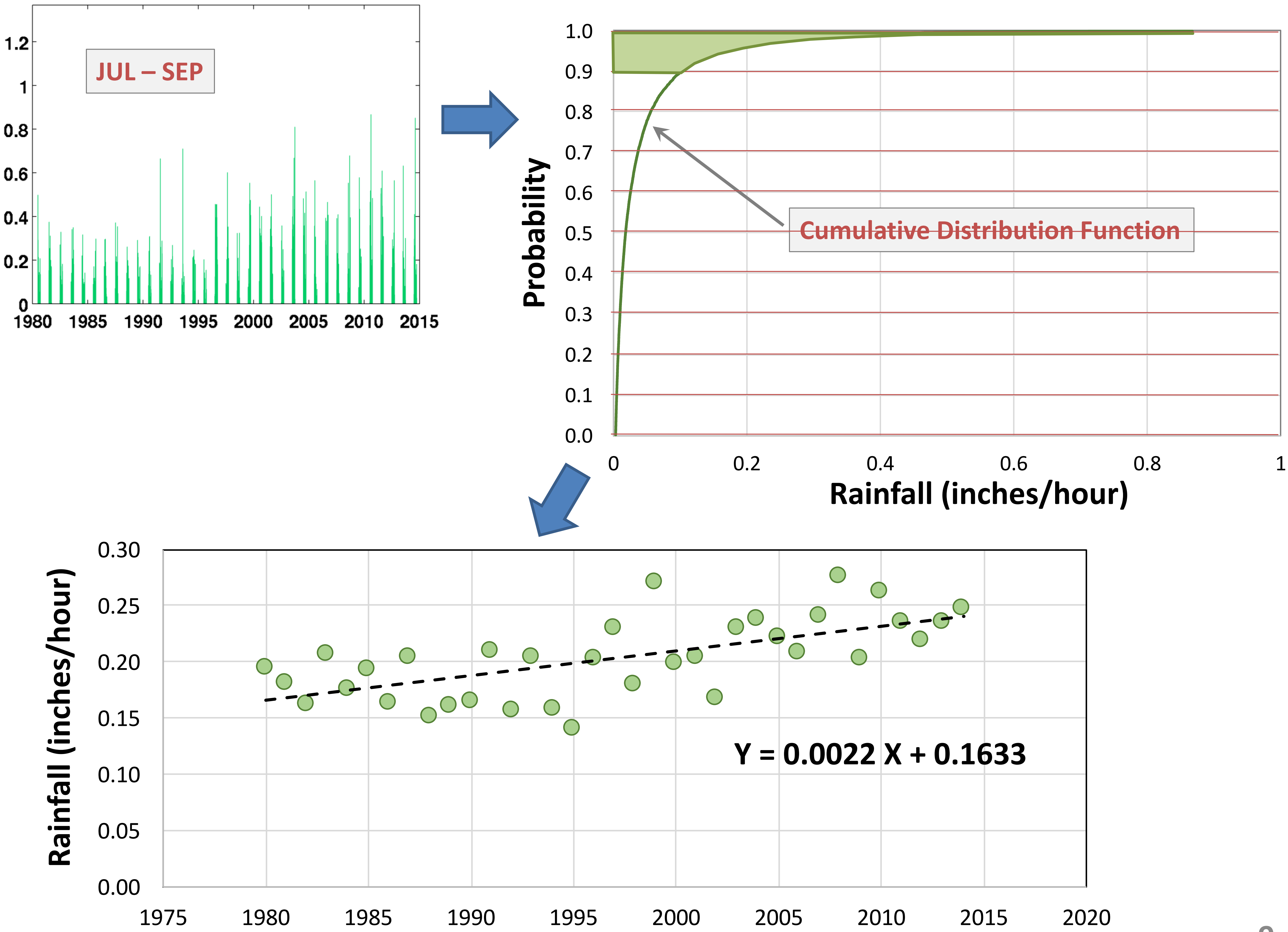


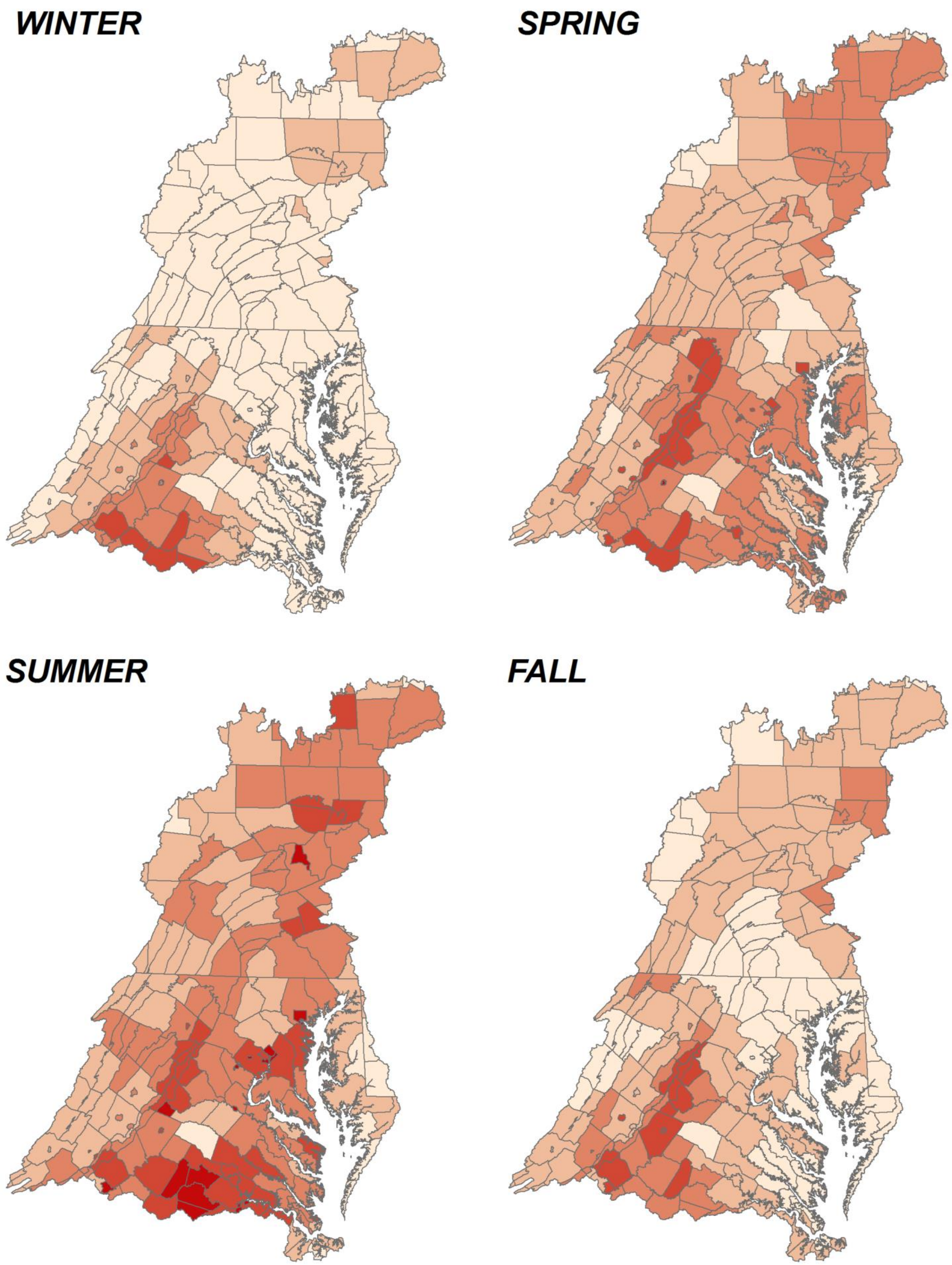
25 mm/day = 1 inch/day

Historical	:	1979-2004
Early 21	:	2009-2038
Mid 21	:	2038-2069
Late 21	:	2069-2098

Maloney and 31 others, 2014: North American Climate in CMIP5 Experiments: Part III


Hourly Rainfall in Washington DC
JAN – MAR
APR – JUN
JUL – SEP
OCT – DEC
0
0.5
1
1980
1982
1985
1987
1990
1992
1995
1997
2000
2002
2005
2007
2010
2012
2015
0
0.2
0.4
0.6
0.8
1
1.2
1980
1985
1990
1995
2000
2005
2010
2015

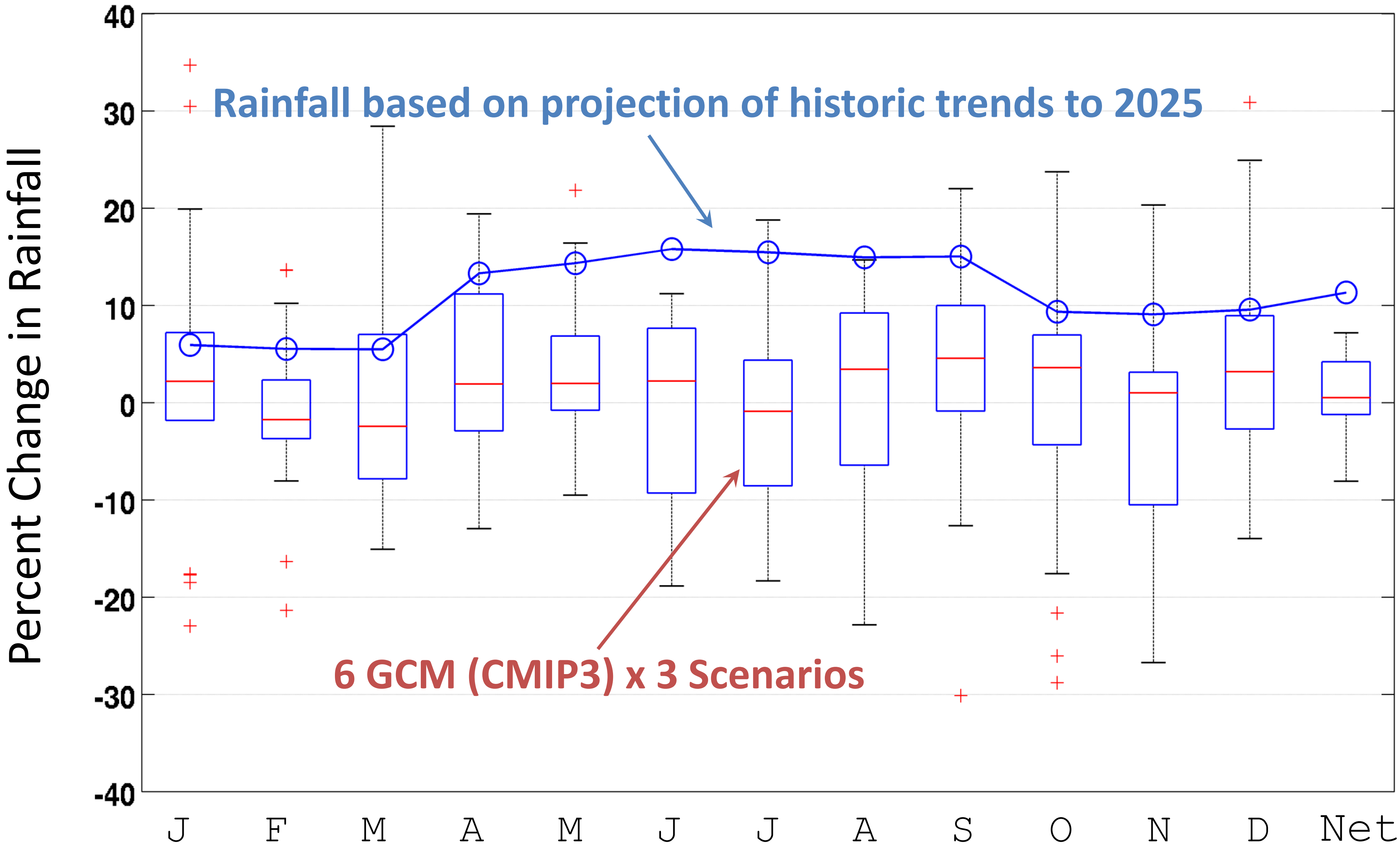

JUL – SEP
1.2
1
0.8
0.6
0.4
0.2
0
1980 1985 1990 1995 2000 2005 2010 2015
Probability
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0 0.2 0.4 0.6 0.8 1
Rainfall (inches/hour)
Cumulative Distribution Function
Rainfall (inches/hour)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1975 1980 1985 1990 1995 2000 2005 2010 2015 2020
Y = 0.0022 X + 0.1633



A slope of 0.002 inches suggest an increase of 0.02 inches in average rainfall intensity over a decade.

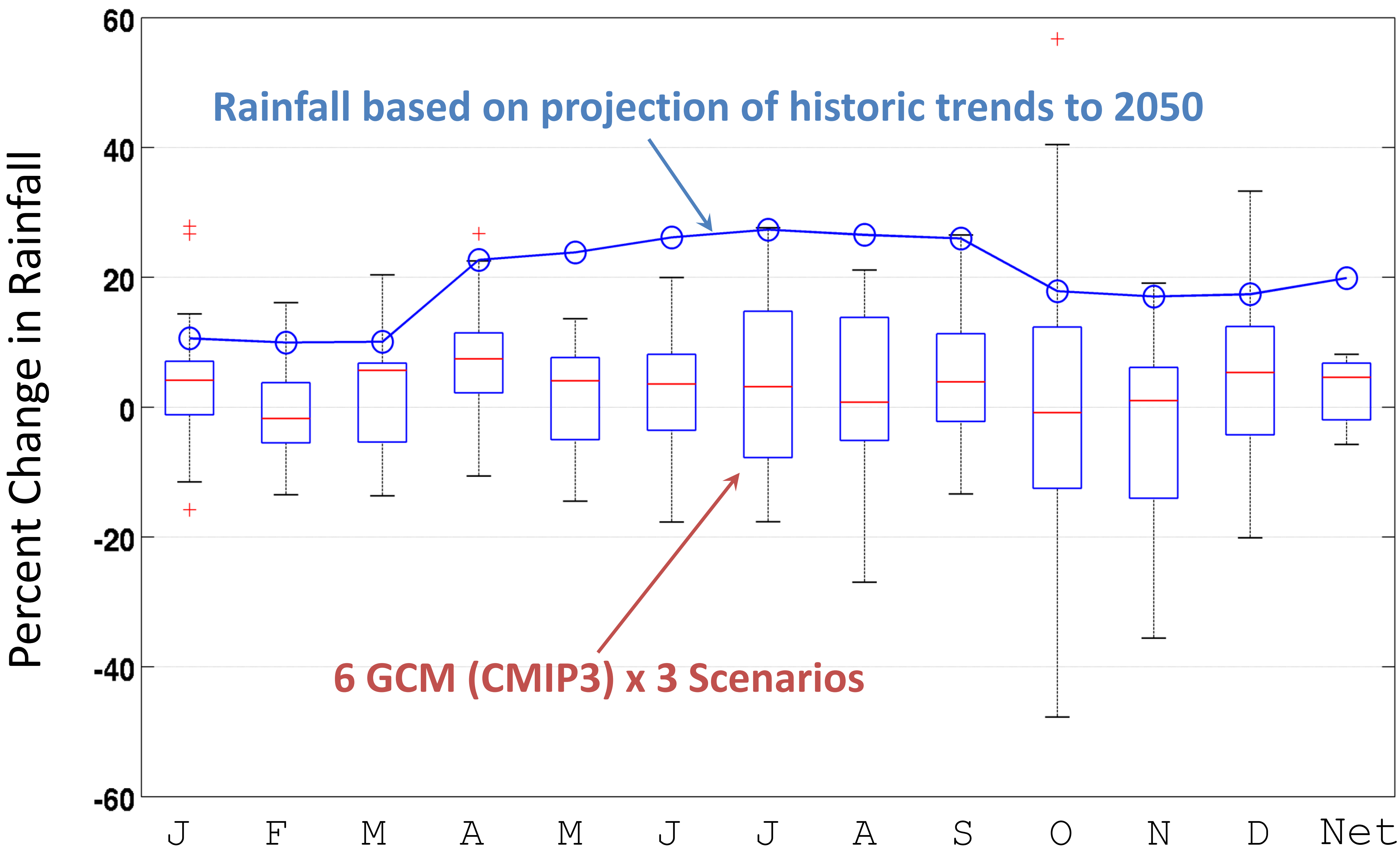
Geographic and Seasonal trends in rainfall based on NLDAS-2 dataset

Monthly Precipitation – Year **2025**



Overall, an increase of **4.93 inches (11.3%)** in average annual rainfall

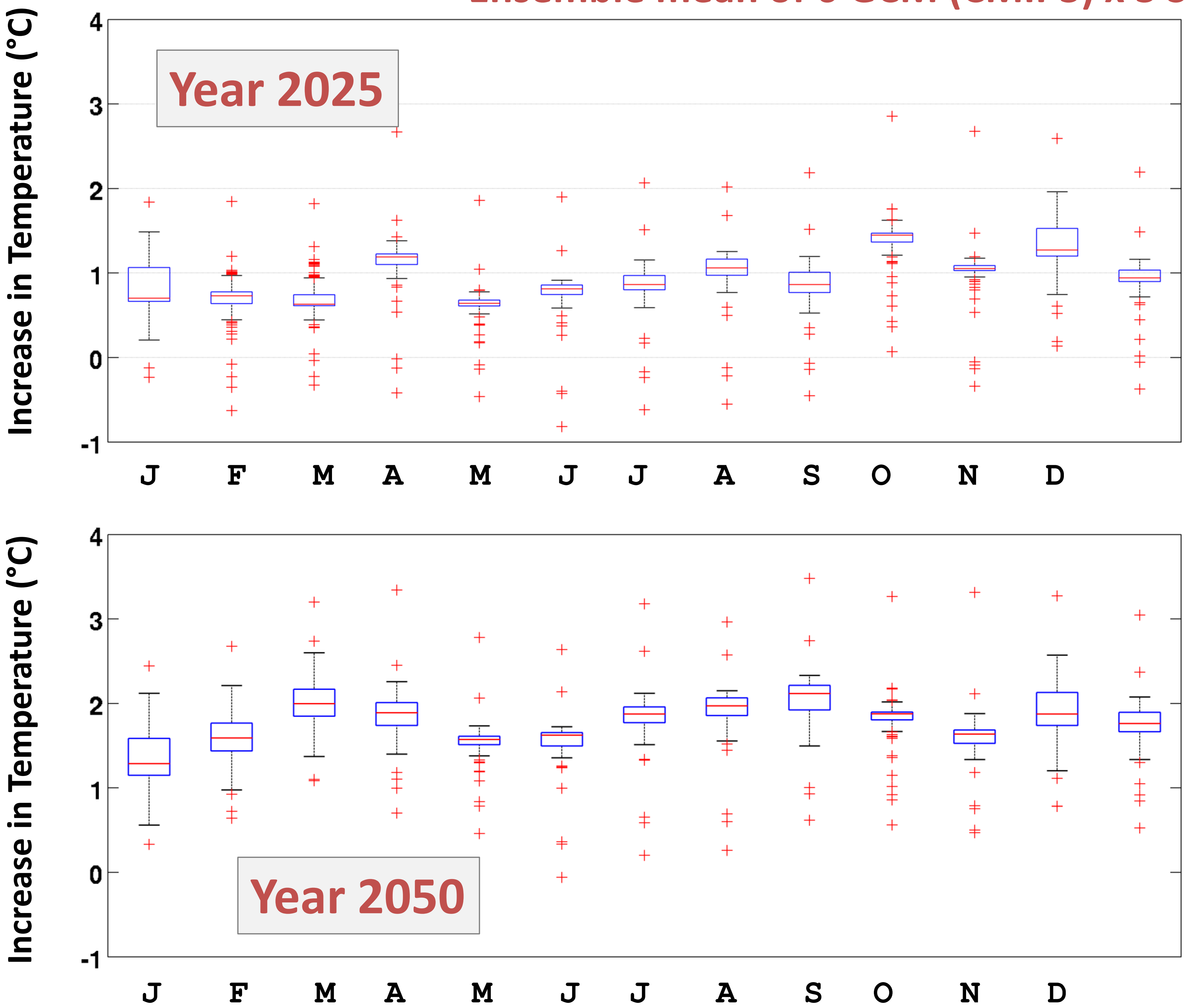
Monthly Precipitation – Year 2050



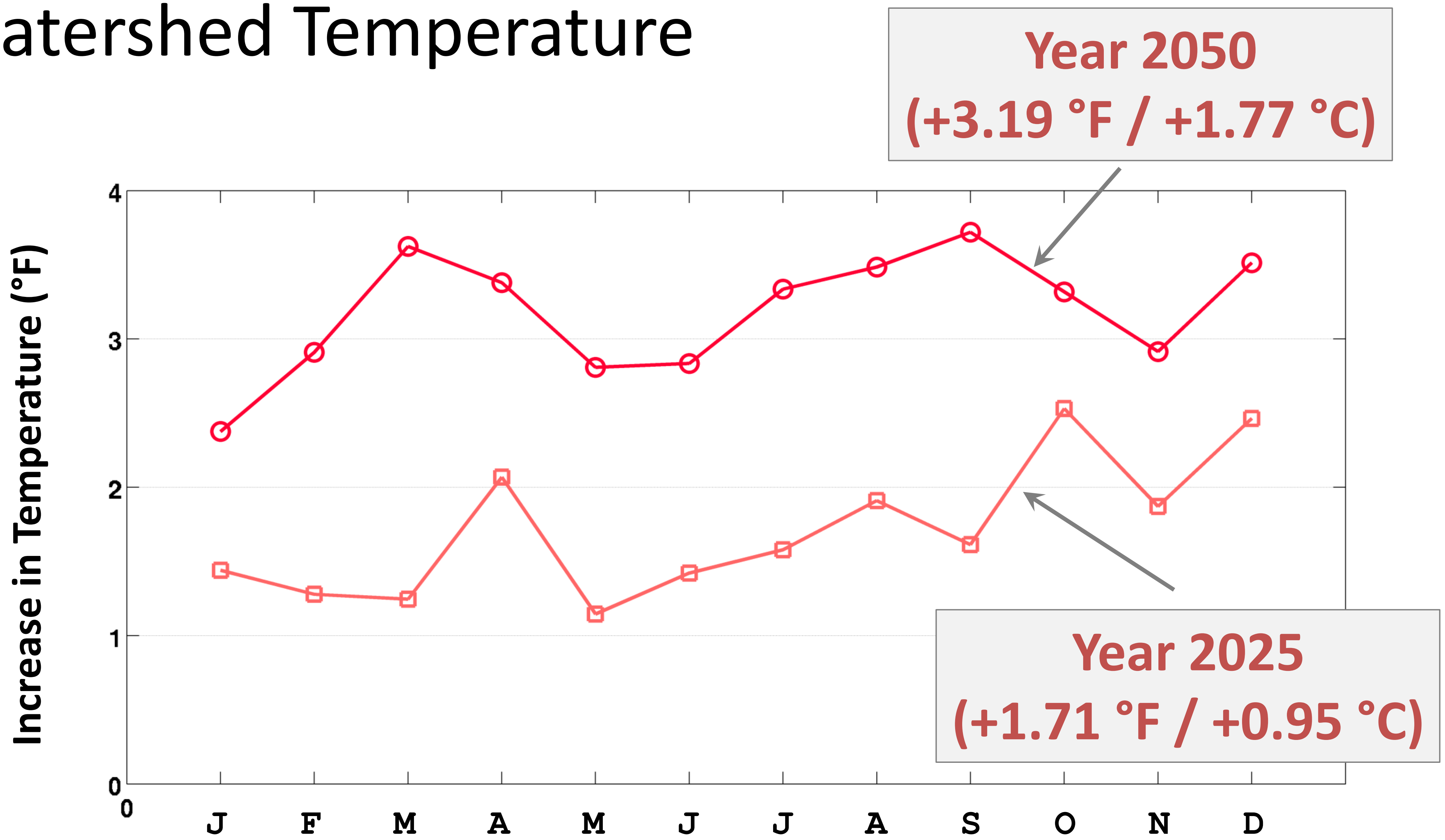
Overall, an increase of **8.67 inches (19.9%)** in average annual rainfall

Monthly Temperature

Ensemble mean of 6 GCM (CMIP3) x 3 Scenarios

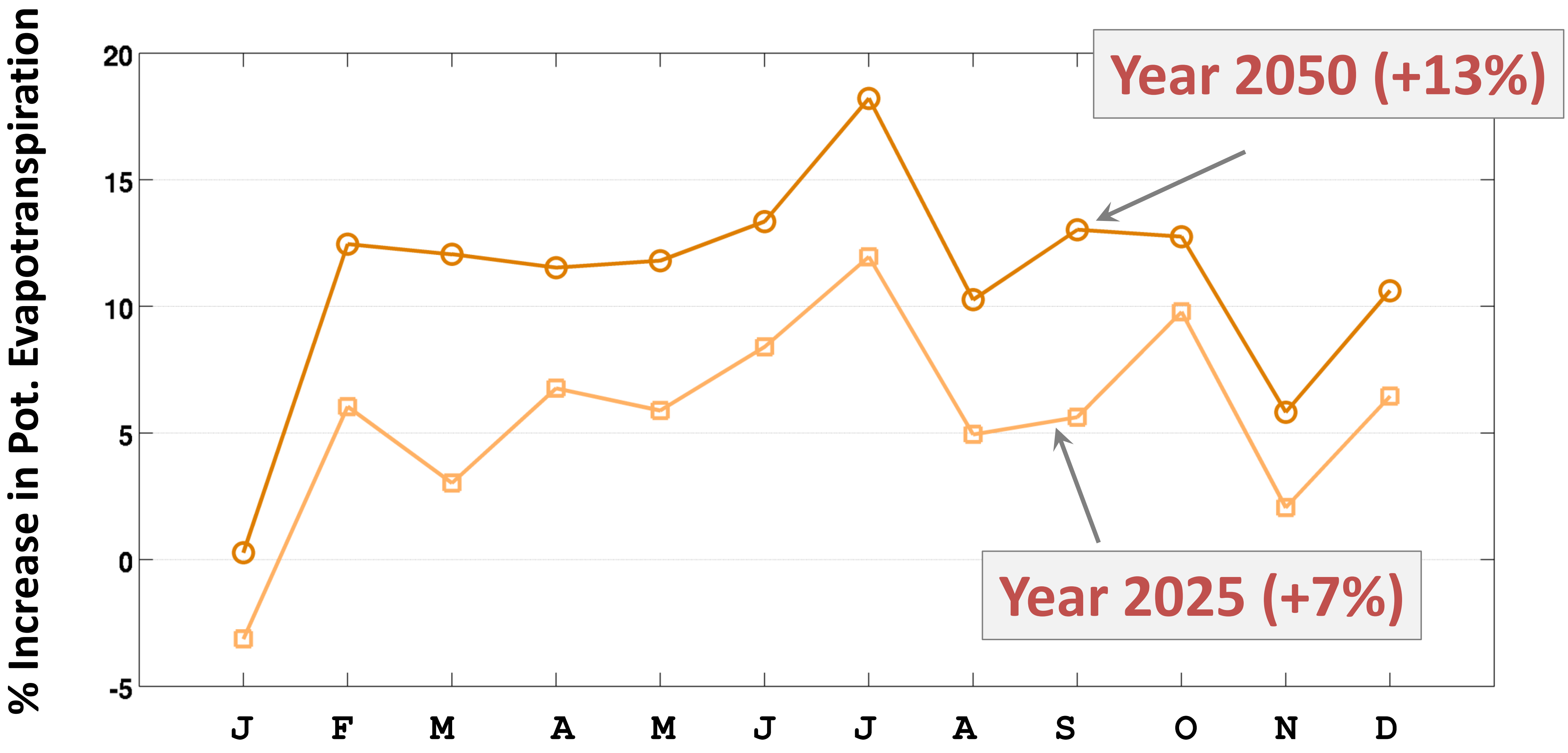


Watershed Temperature

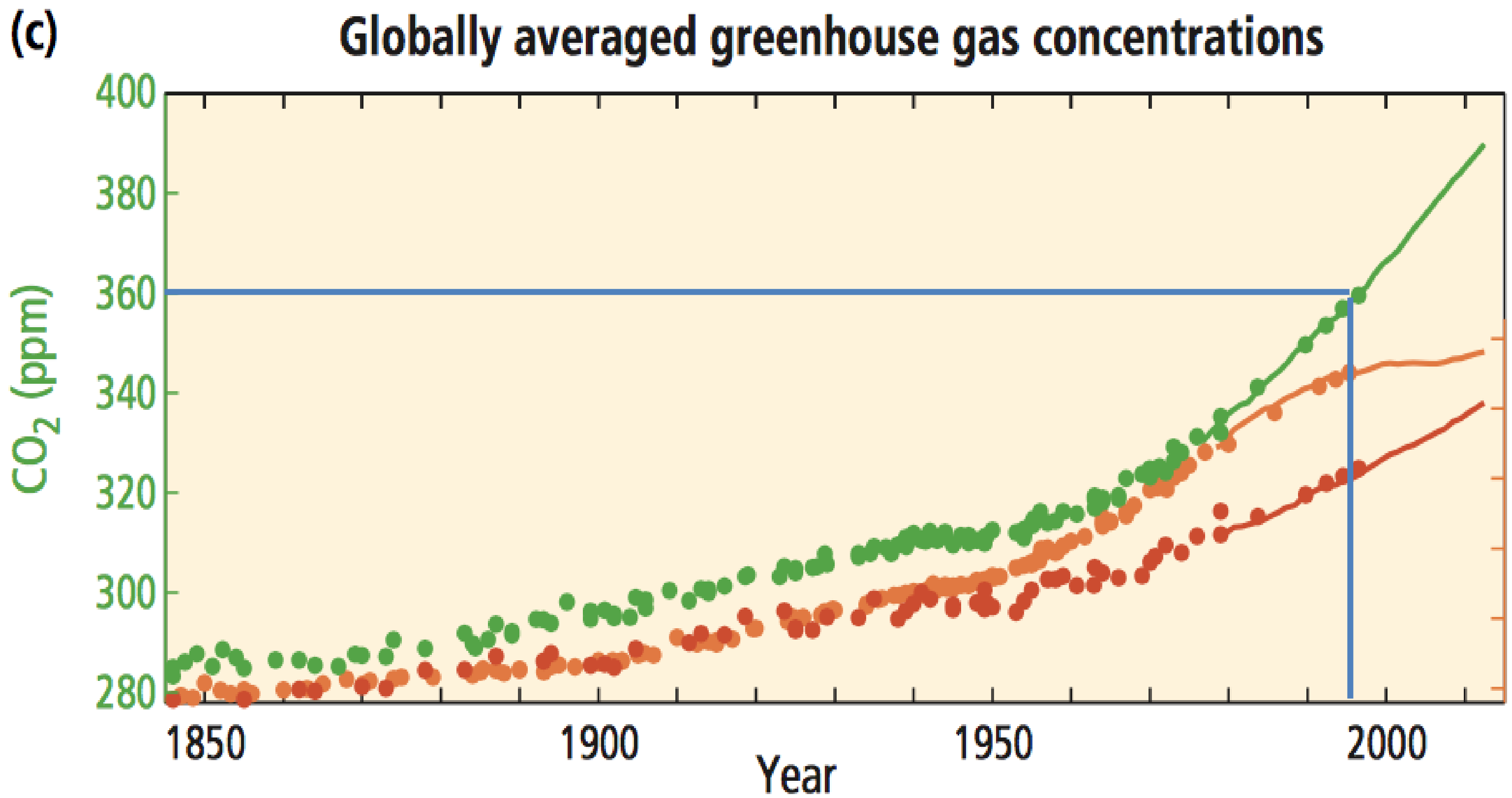


Relative to 1995

Watershed Potential Evapotranspiration



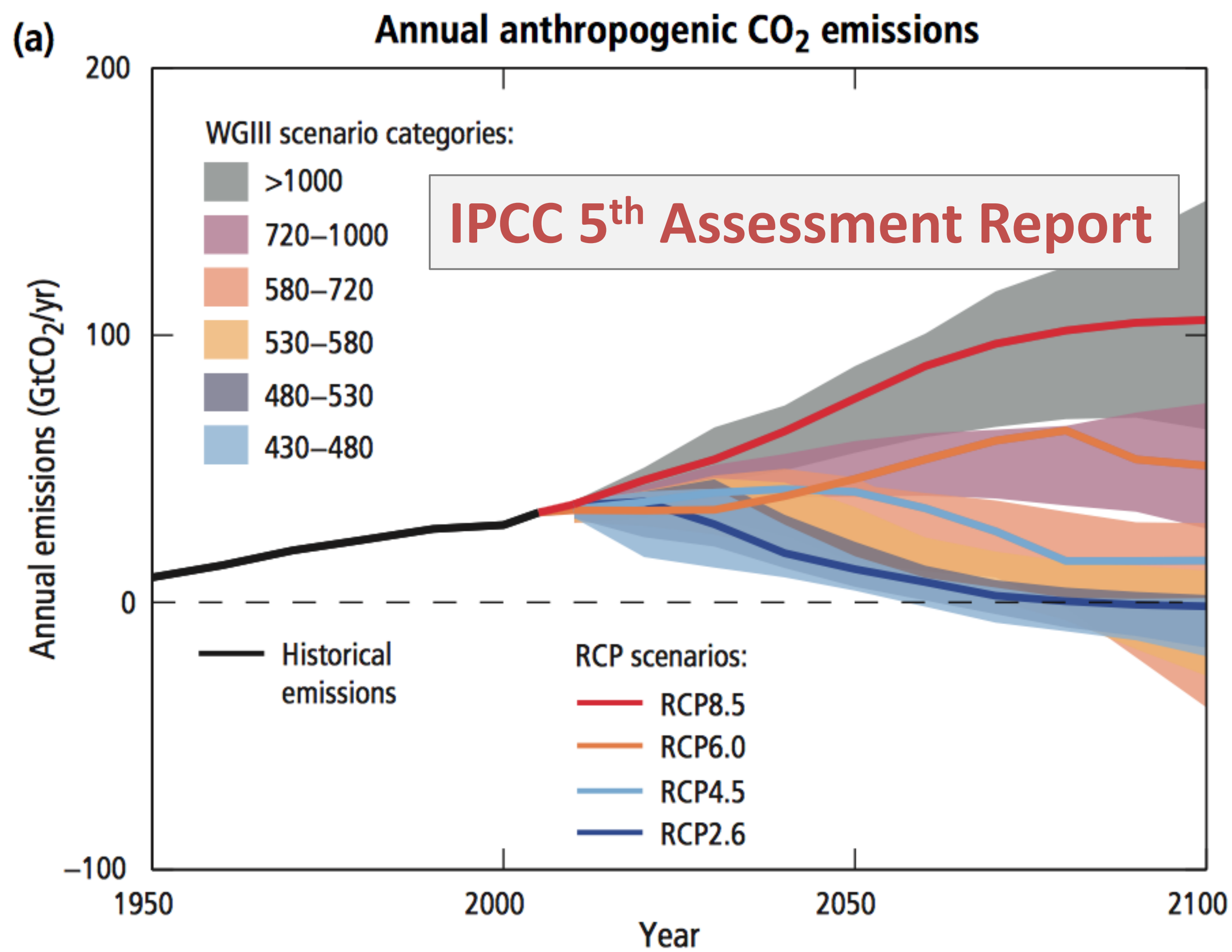
CO_2 Level and Transpiration



Used Butcher et al. 2014 to adjust HSPF (LZETP) parameter

Baseline (1991 - 2000)
CO_2[1] = 363.22ppm

402.8 ppm in 2014



2100 CO_2 for RCP 6.0 = 720 – 1000 ppm

⇒2025 CO_2 = 402.8 + 58.4 = 461.2 ppm

An increase of ~ 98 ppm from 1995

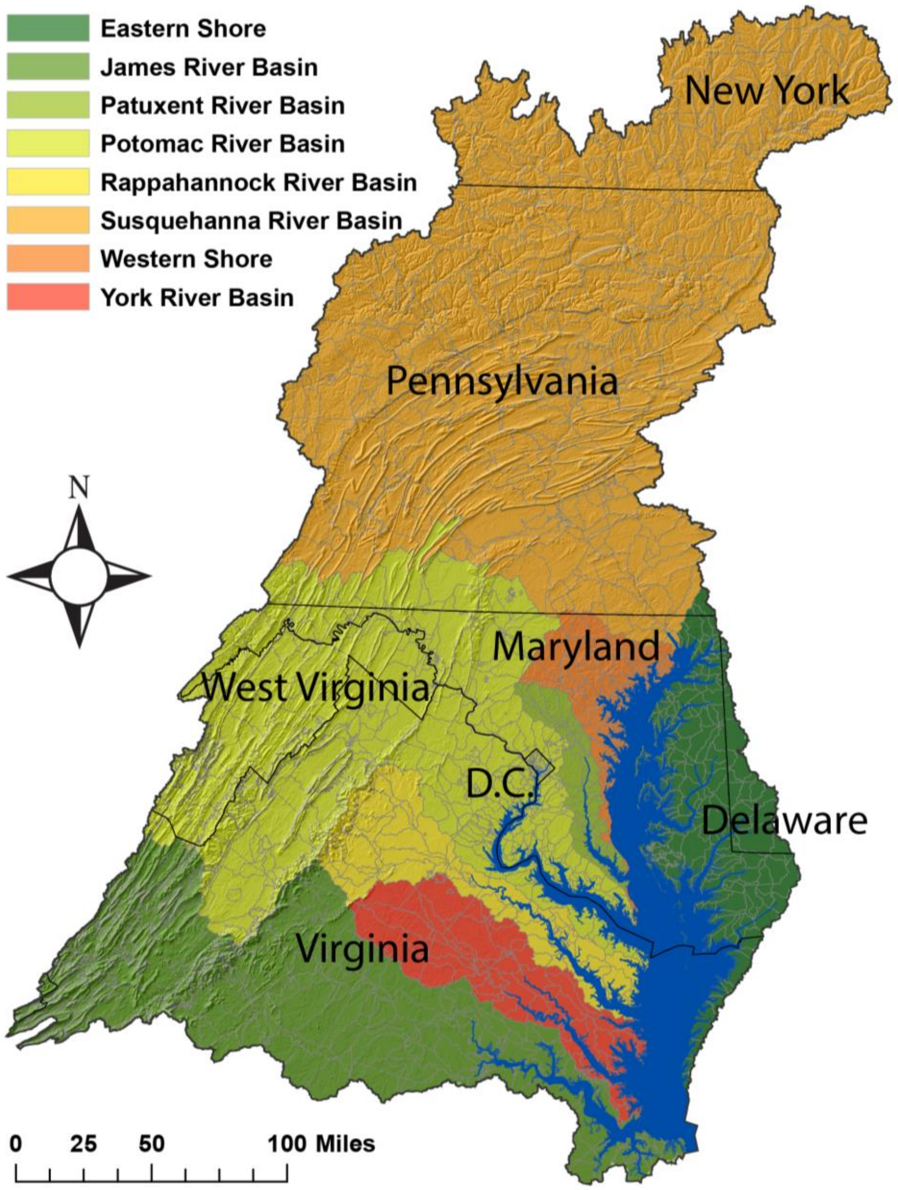
2100 CO_2 for RCP 6.0 = 720 – 1000 ppm

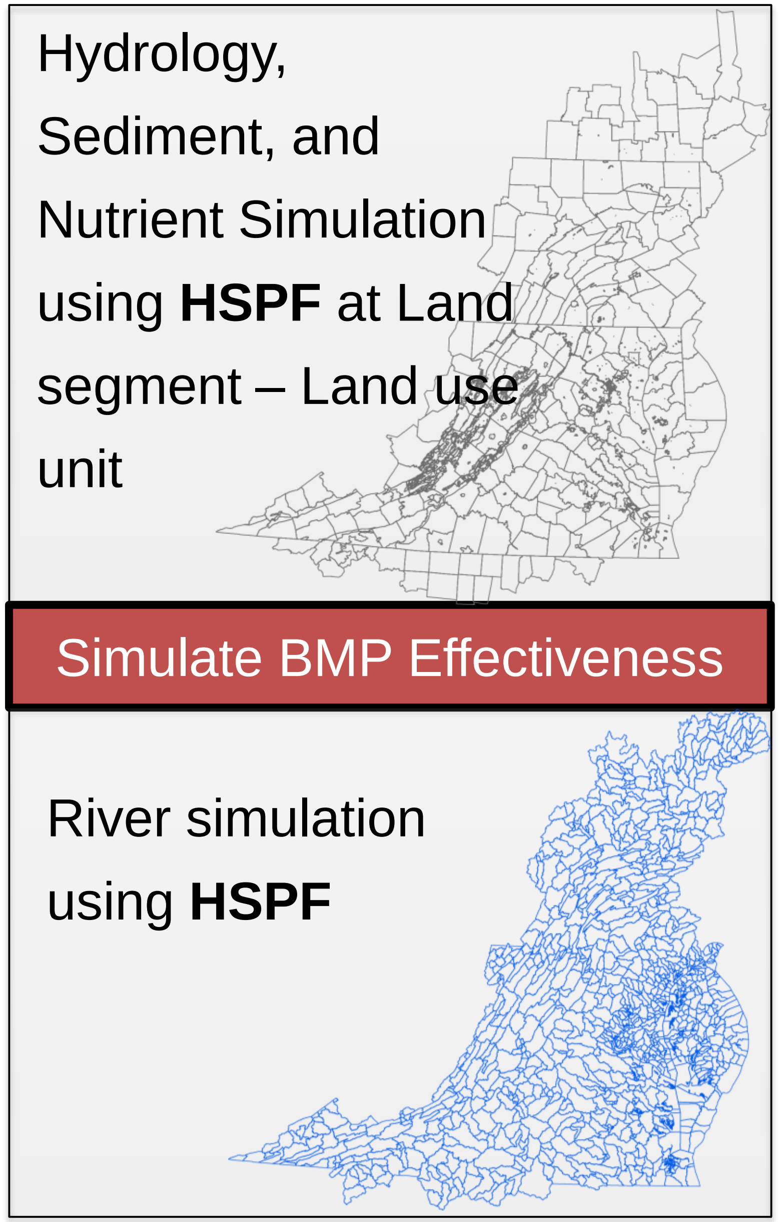
⇒2050 CO_2 = 402.8 + 191.2 = 594 ppm

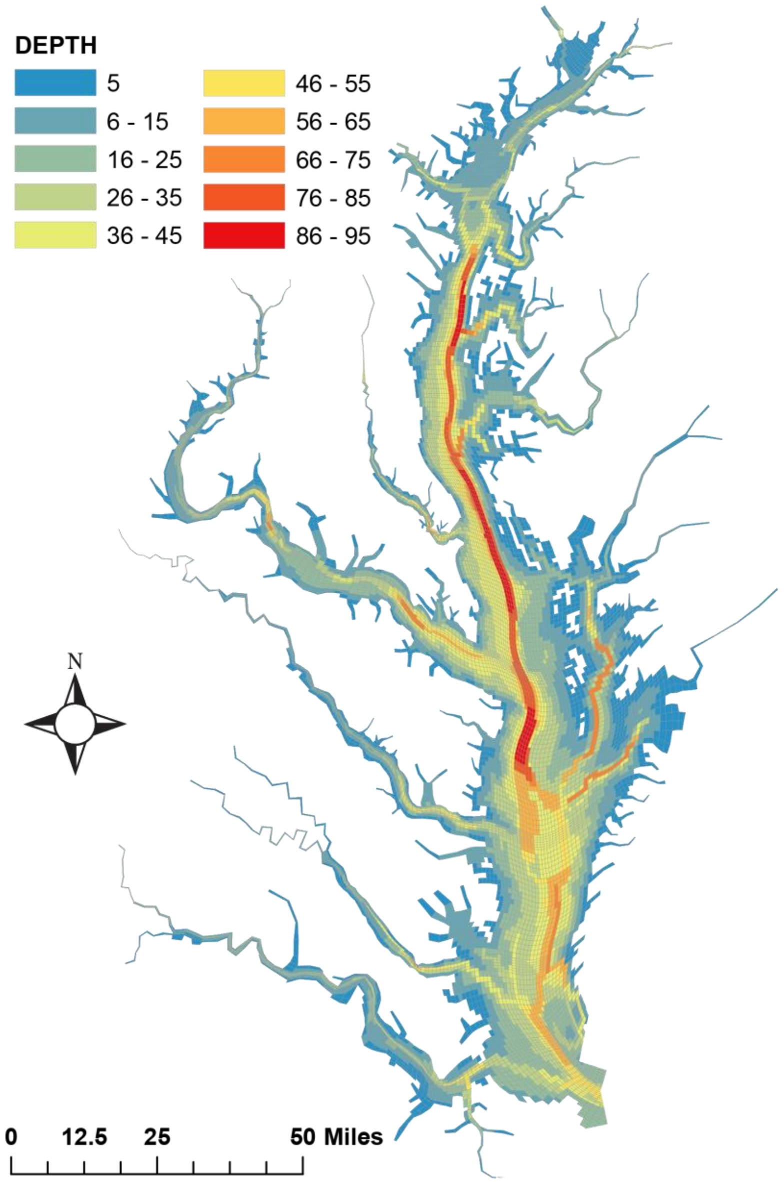
An increase of ~ 230 ppm from 1995

[1] http://www.carbonify.com/carbon-dioxide-levels.htm

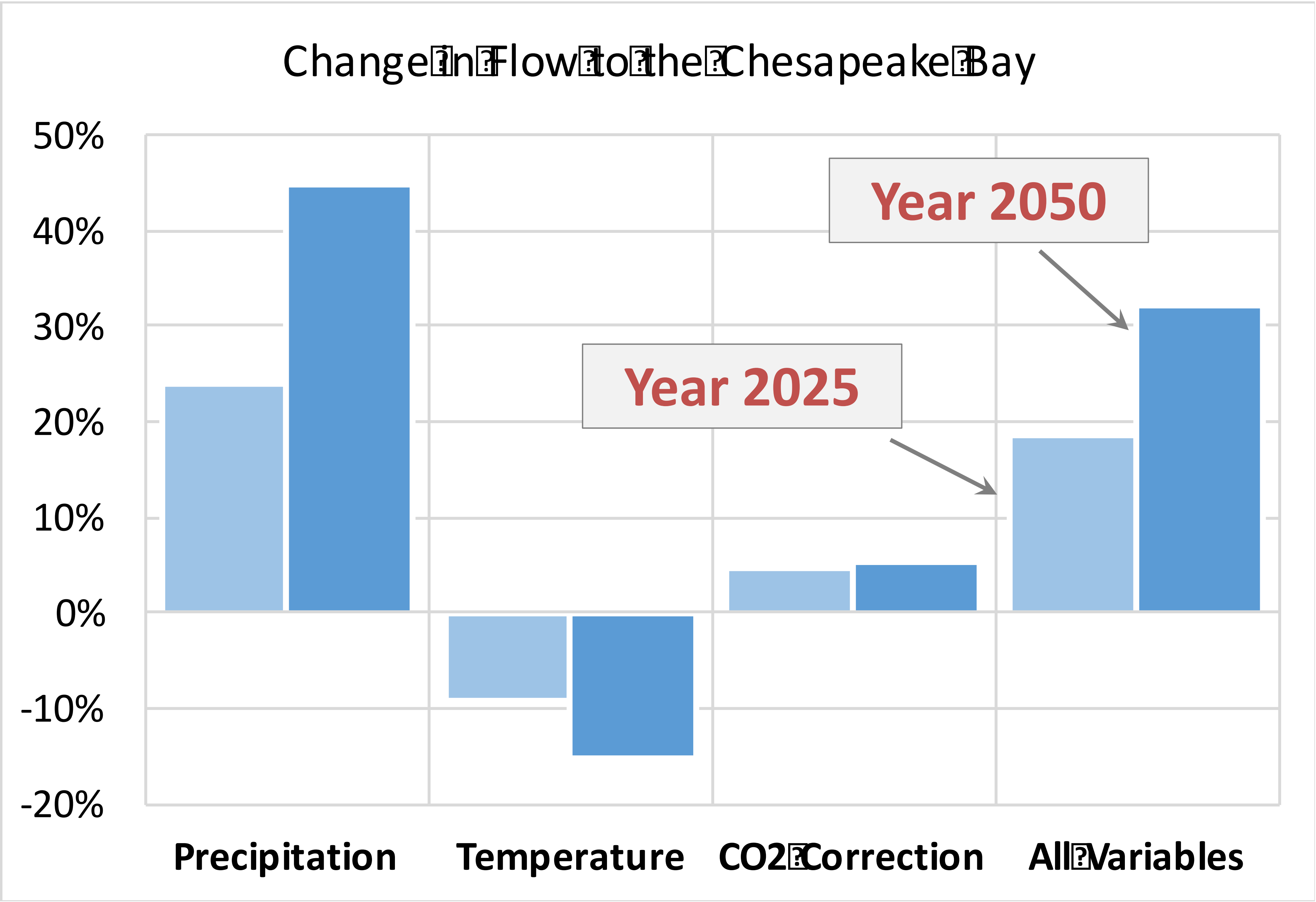
Phase 5.3.2 CBP Watershed Model



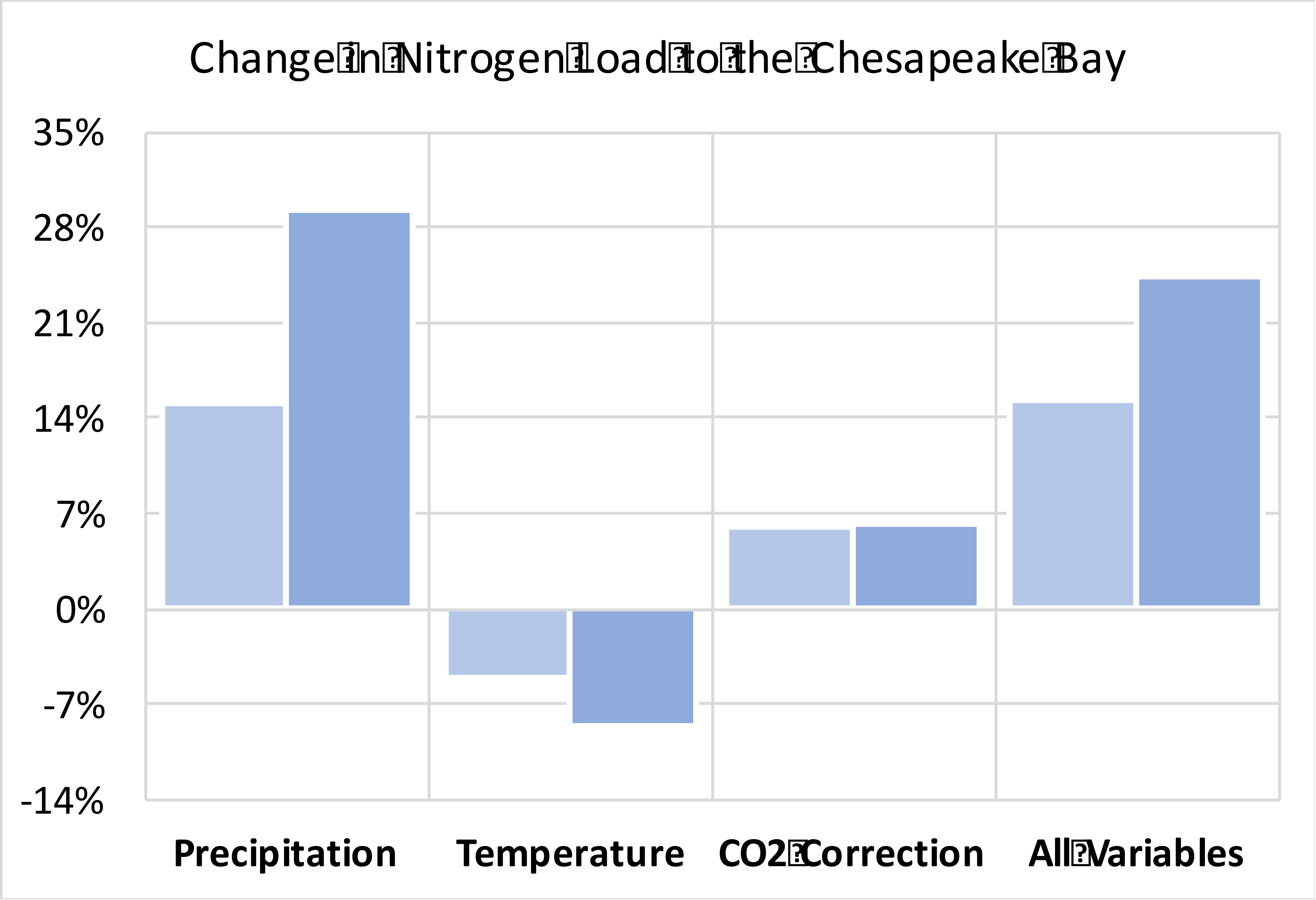


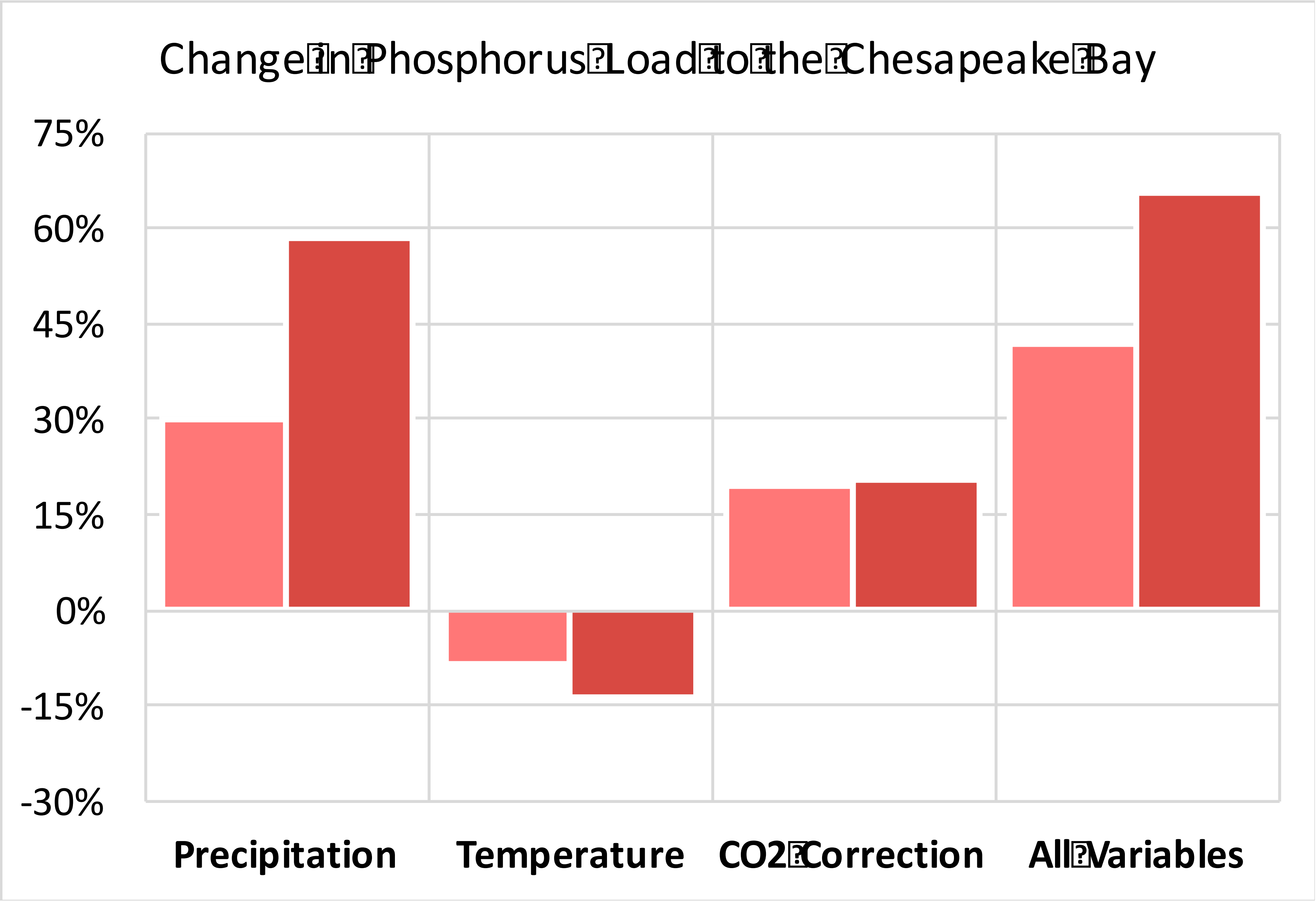


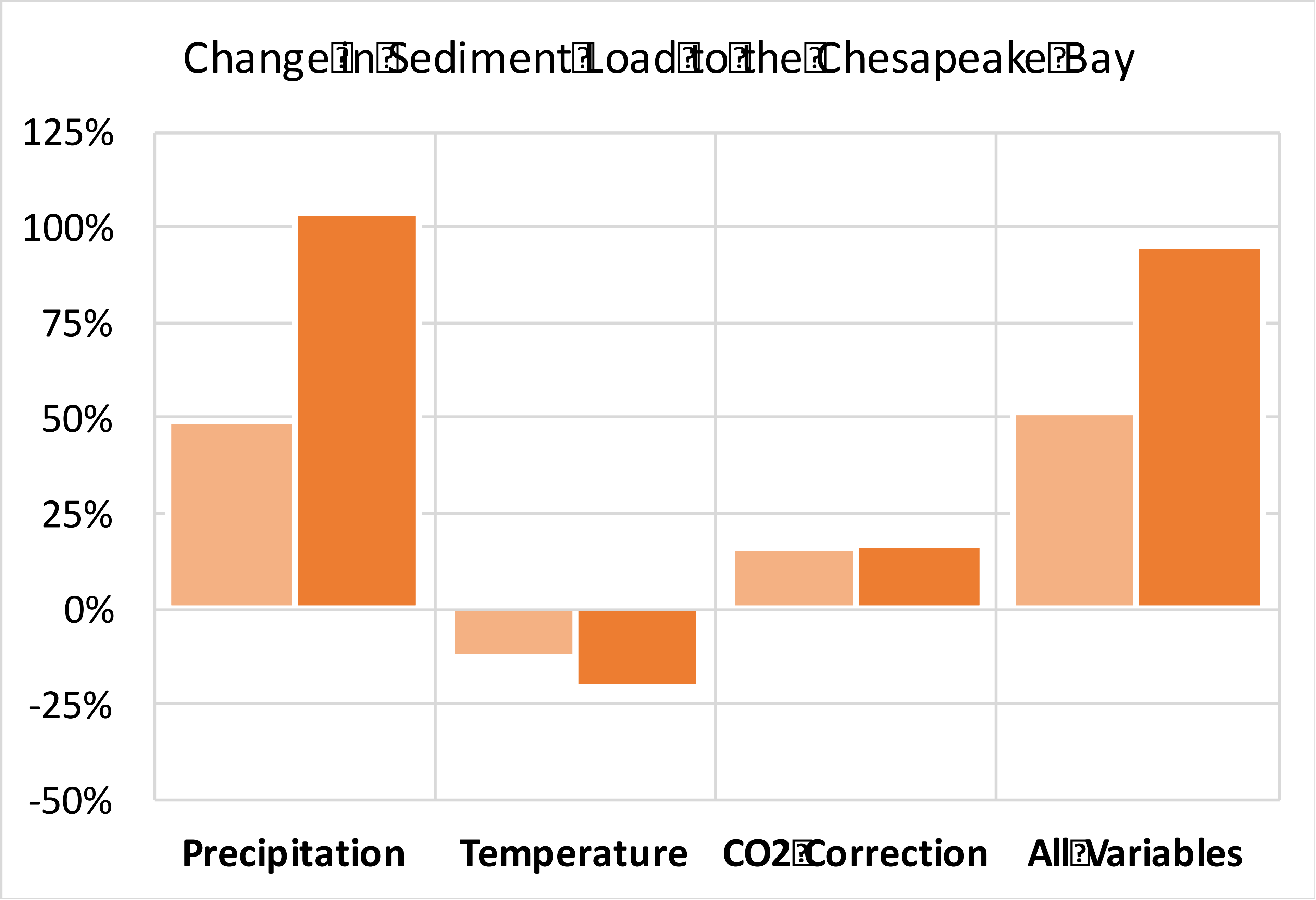
Watershed model was calibrated using observations at several monitoring stations (287 flow stations, 207 nitrogen stations, 249 phosphorus stations, and 239 total suspended solid stations)



… against the 1991-2000 baseline.


Change in Nitrogen Load to the Chesapeake Bay
35%
28%
21%
14%
7%
0%
-7%
-14%
Precipitation
Temperature
CO2 Correction
All Variables


Change in Phosphorus Load to the Chesapeake Bay
75%
60%
45%
30%
15%
0%
-15%
-30%
Precipitation
Temperature
CO2 Correction
All Variables


Change in Sediment Load to the Chesapeake Bay
125%
100%
75%
50%
25%
0%
-25%
-50%
Precipitation
Temperature
CO2 Correction
All Variables

- An alternative to downscaling of rainfall from GCMs that uses baseline rainfall used in model calibration.
- For year 2025 – an increase of 19%, 15%, 42%, and 52% in flow, nitrogen, phosphorus, and sediment loads delivery to bay.
- For year 2050 – an increase of 32%, 24%, 65%, and 95% in flow, nitrogen, phosphorus, and sediment loads delivery to bay.