05/07/2024

Application of Climate Data and Global Climate Models in Chesapeake Bay Program's Phase 6 Models

STAC Workshop on CBP Climate Change Modeling III: Post-2025 decisions

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Motivation

- Assessment of 2025 climate change effects was made as compared to the 1993–1995 Chesapeake Bay TMDL critical period and 1991–2000 average hydrology period.

- Precipitation and meteorological inputs for 2025, 2035, 2045, and 2055, representing a change of 30, 40, 50, and 60-years as compared to the 1993–1995 *critical period* and 1991–2000 *average hydrology period* were developed to examine the expected effects of climate change.

Approach

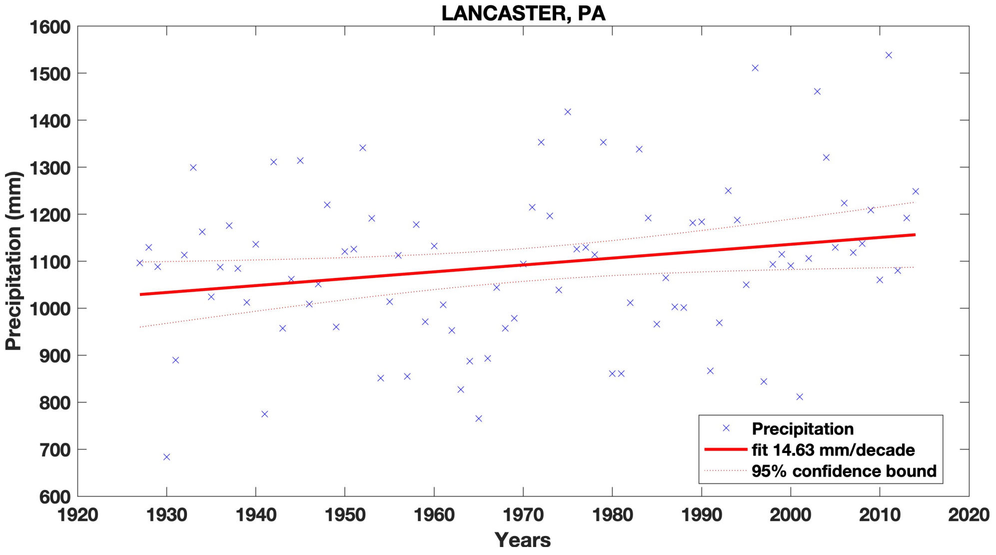
- As per STAC (2016)[1] and CBP Climate Resiliency Workgroup recommendations, expected change in 2025 precipitation was developed based on long-term trends in historical observations, and an ensemble of climate models for 2050 and beyond.

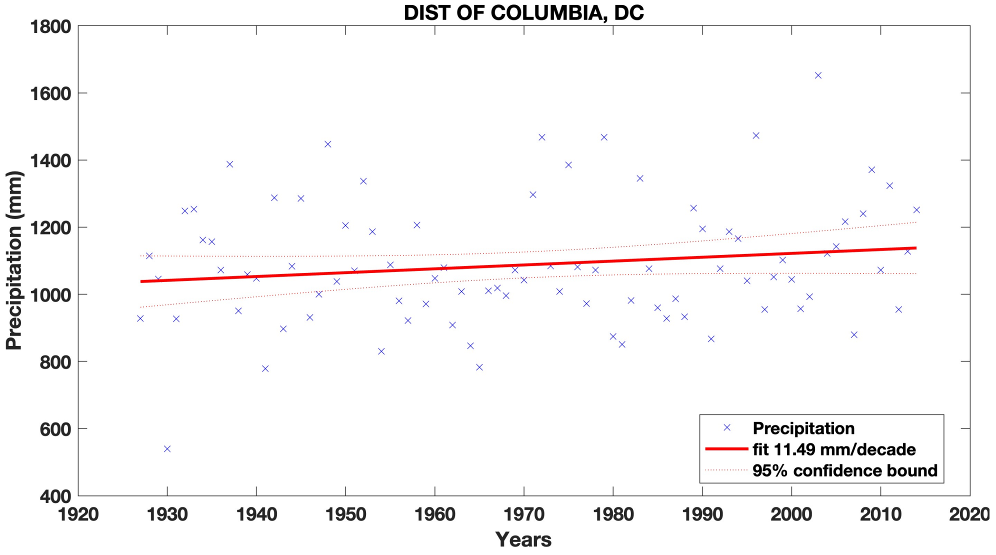
- Modeling workgroup in September 2018[2] recommended combining the two approaches for the periods between 2025 and 2050 (i.e., 2035 and 2045).

[1] Johnson et al., 2016 STAC Workshop Report – http://www.chesapeake.org/pubs/360_Johnson2016.pdf
[2] https://www.chesapeakebay.net/channel_files/26032/20180911b_-_bhatt_-_mwcc_-_application_of_phase_6_watershed_model_to_climate_change_assessment.pdf

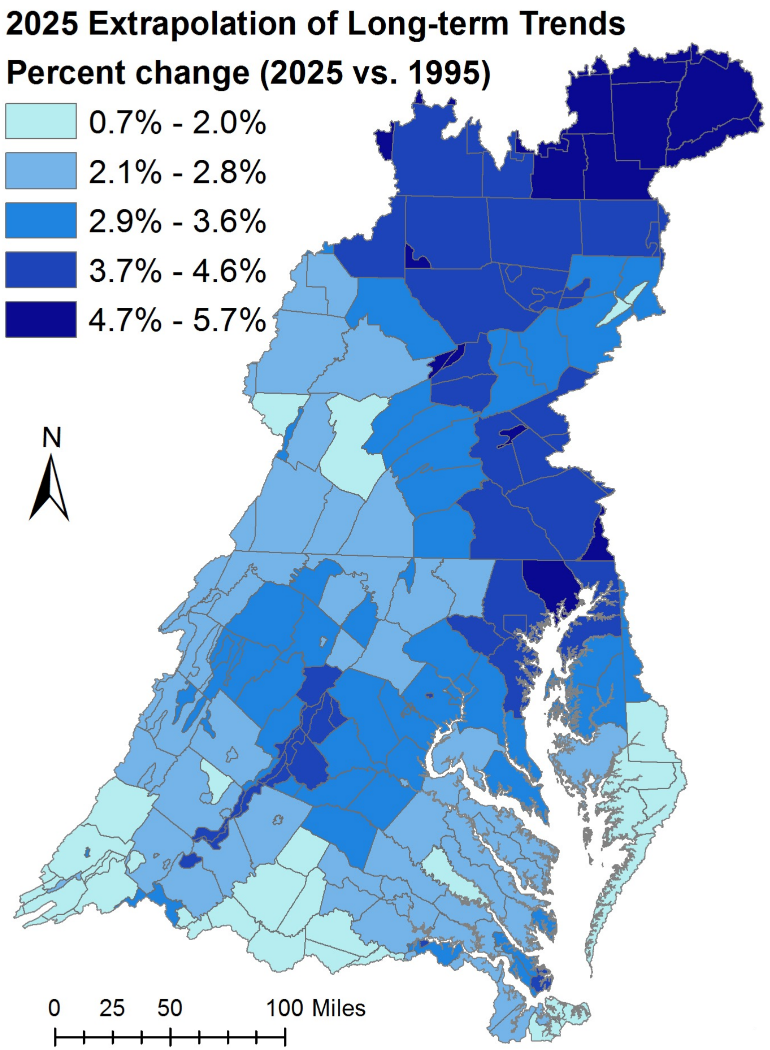
Long-term trends in historical observations

1. Linear trend analysis of county scale 1927-2014 (88-years) historical observations





2. Estimated 30-year change for the counties



3. Estimated change spatially aggregated for the river basins

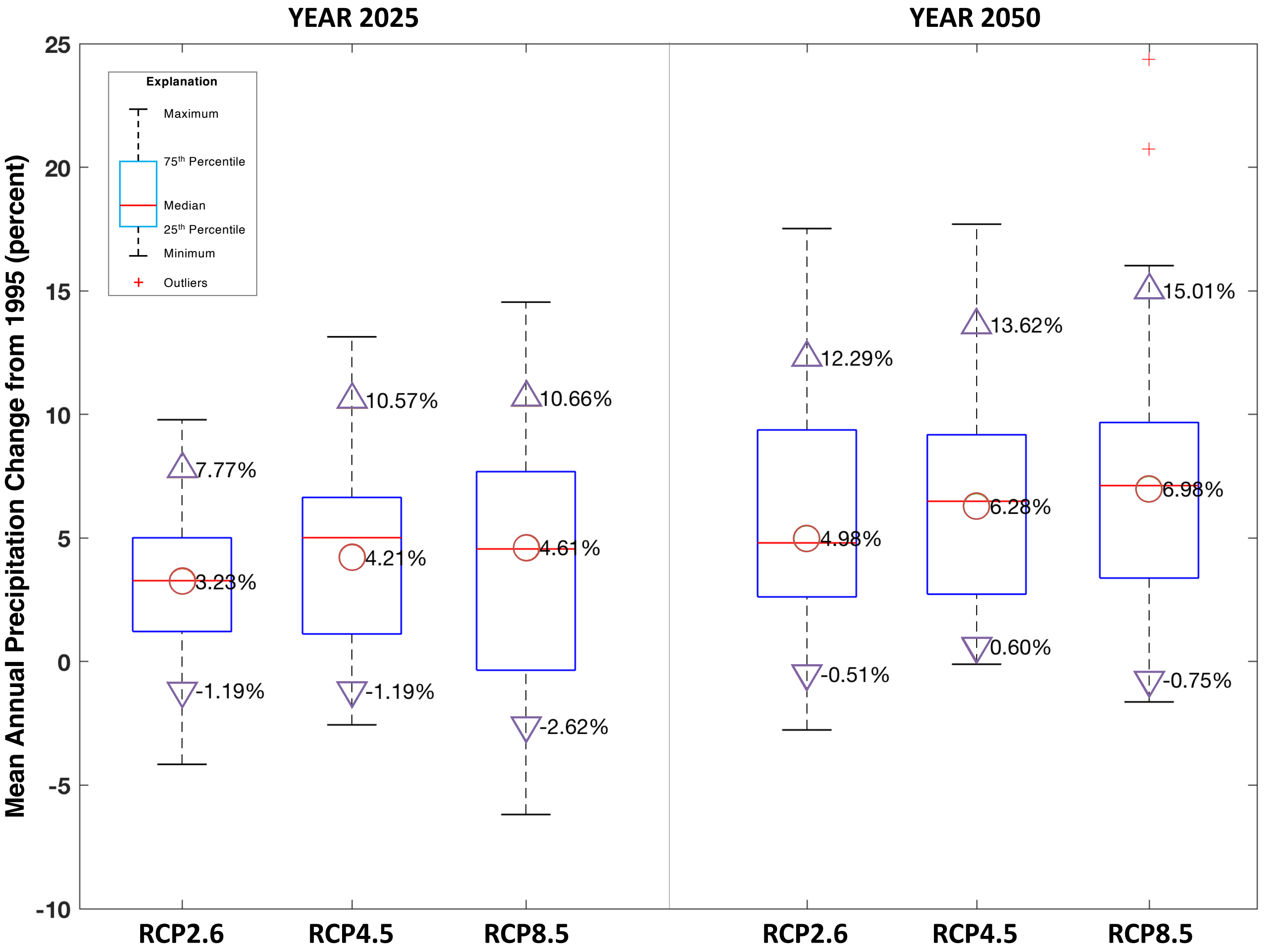
Major Basins	Change
Youghiogheny River	2.1%
Patuxent River Basin	3.3%
Western Shore	4.1%
Rappahannock River Basin	3.2%
York River Basin	2.6%
Eastern Shore	2.5%
James River Basin	2.2%
Potomac River Basin	2.8%
Susquehanna River Basin	3.7%
Chesapeake Bay Watershed	**3.1%**

Global Climate Models (GCMs)

- General circulation models included in then most recently completed Coupled Model Intercomparison Project Phase 5, CMIP5 (Taylor et al. 2012) were used for the precipitation and temperature projections.

- The GCMs utilize forcings based on potential future socio-economic and natural scenarios defined as Representative Concentration Pathways (RCPs).

Δ Mean annual precipitation using ensemble of 31 GCM projections



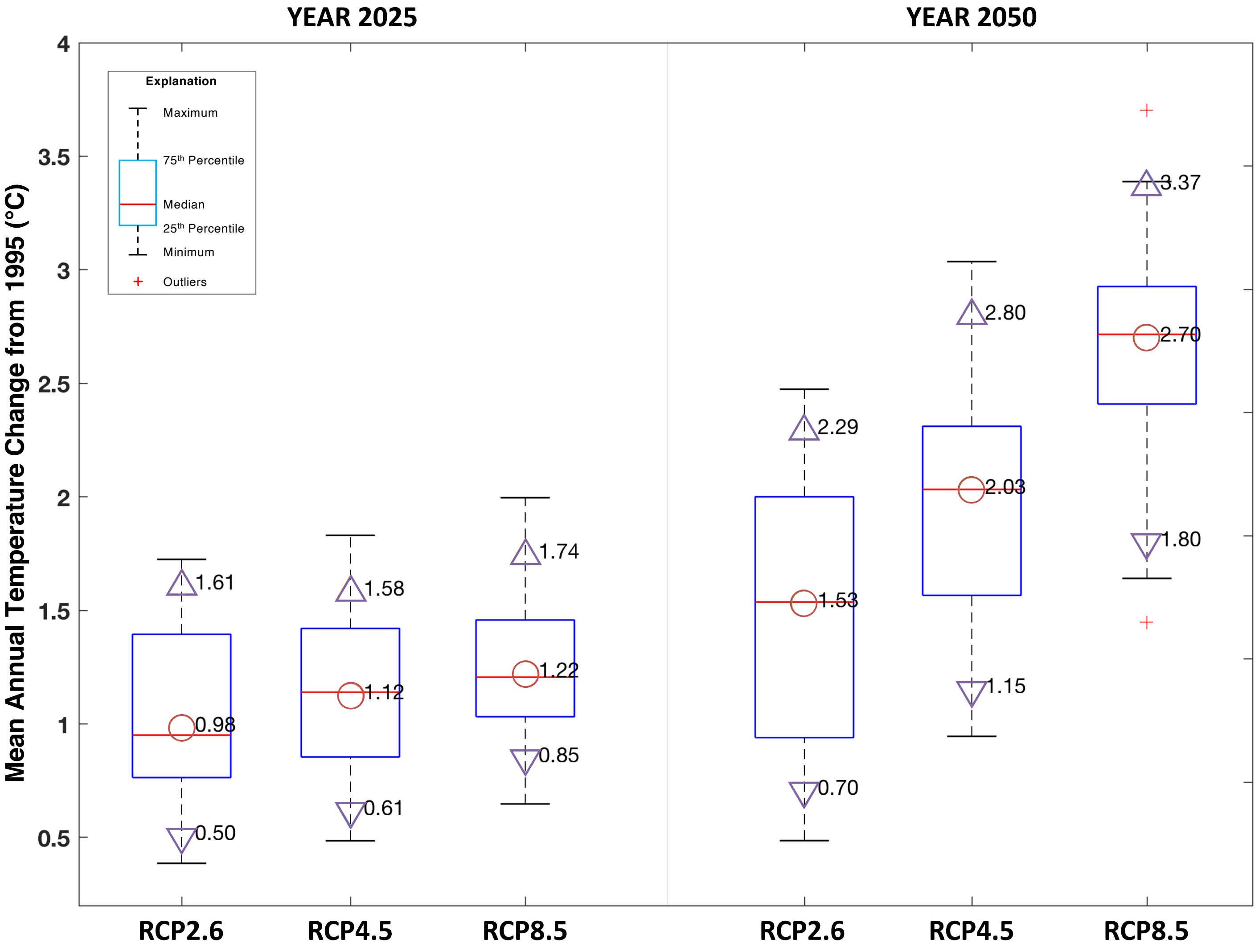
Ensemble median (circles) and 10th and 90th percentile (triangles) ranges are shown.

Taylor, K.E., R.J. Stouffer, and G.A. Meehl. 2012. "An Overview of CMIP5 and the Experiment Design." Bulletin of the American meteorological Society 93(4): 485–498

Global Climate Models (GCMs)

- Statistically downscaled data for climate models and corresponding realizations were retrieved from an online archive accessed through the Geo Data Portal (Bureau of Reclamation, 2013). The decision to use an existent downscaled dataset rather than either developing or applying a tailored statistical climate downscaling process was based upon the recommendations of the STAC (Johnson et al. 2016).

Δ Mean annual temperature using ensemble of 31 GCM projections

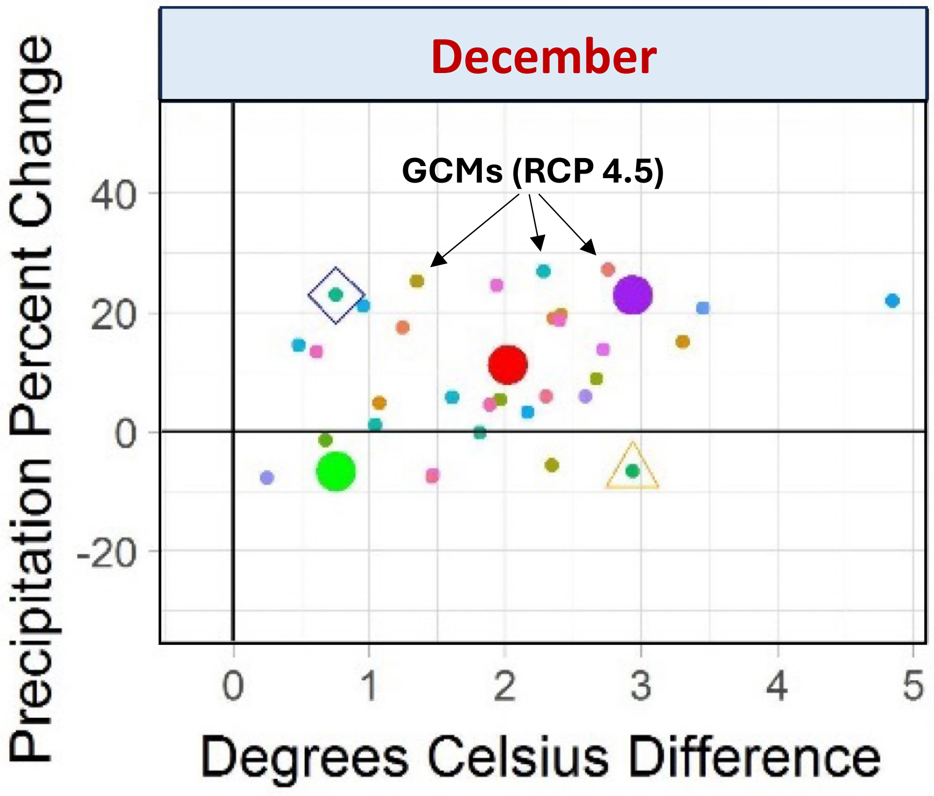


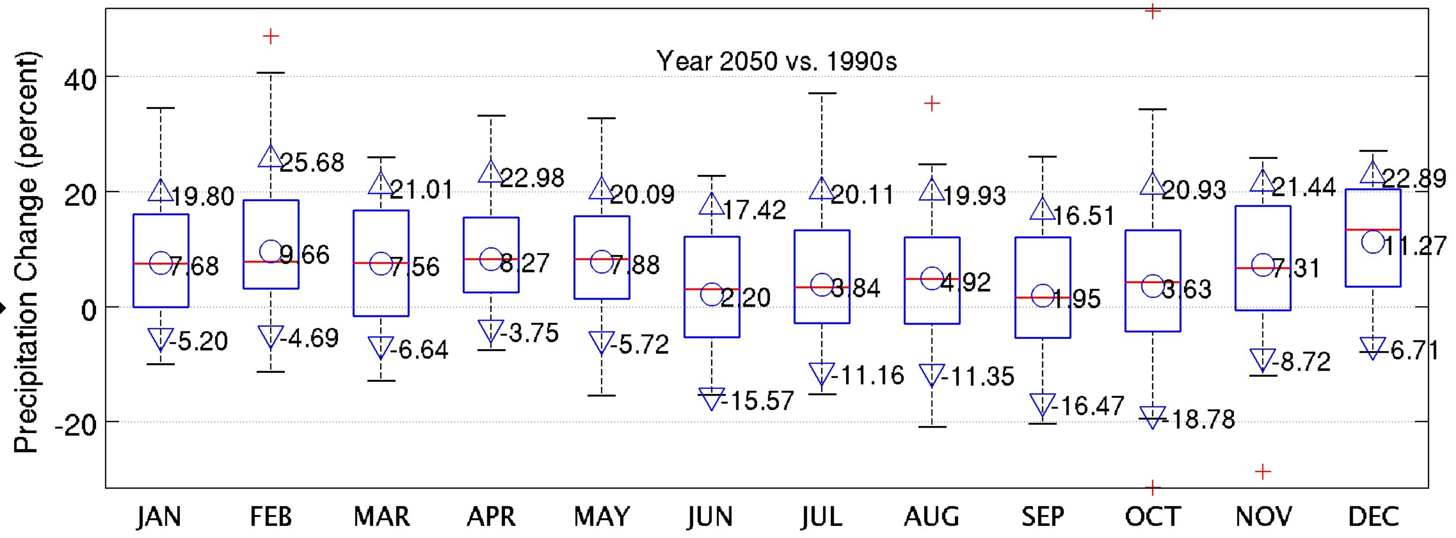
Ensemble median (circles) and 10th and 90th percentile (triangles) ranges are shown.

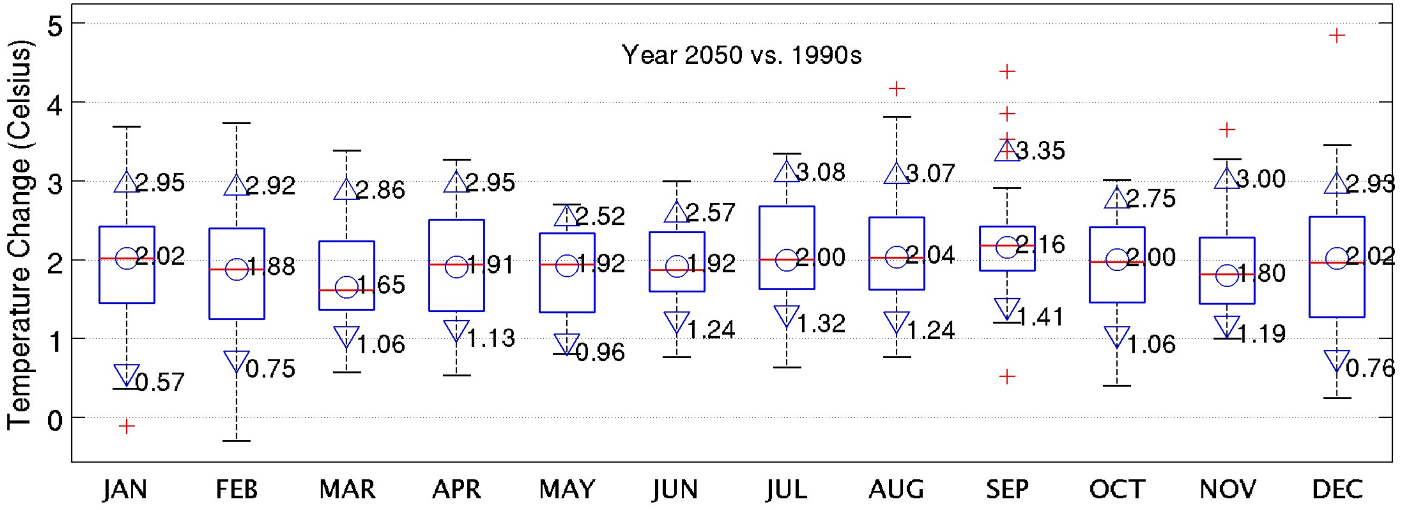
Bureau of Reclamation. 2013. Downscaled CMIP3 and CMIP5 Climate Projections: Release of Downscaled CMIP5 Climate Projections, 116 p. https://gdo-dcp.ucllnl.org/downscaled_cmip_projections/techmemo/downscaled_climate.pdf
Johnson et al., 2016 STAC Workshop Report – http://www.chesapeake.org/pubs/360_Johnson2016.pdf

Ensemble median of monthly change (seasonality)

Monthly ensemble analyses for each county

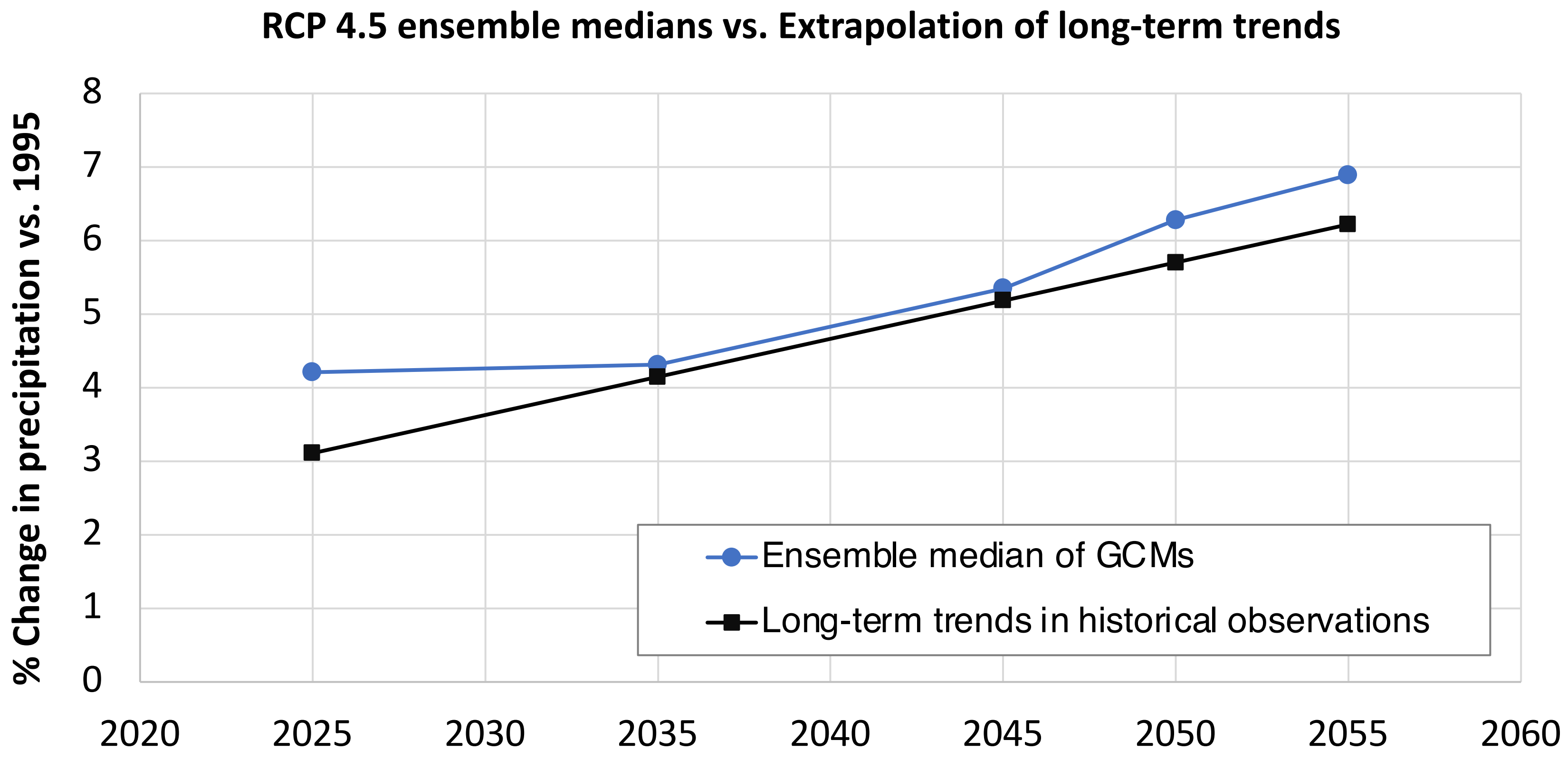






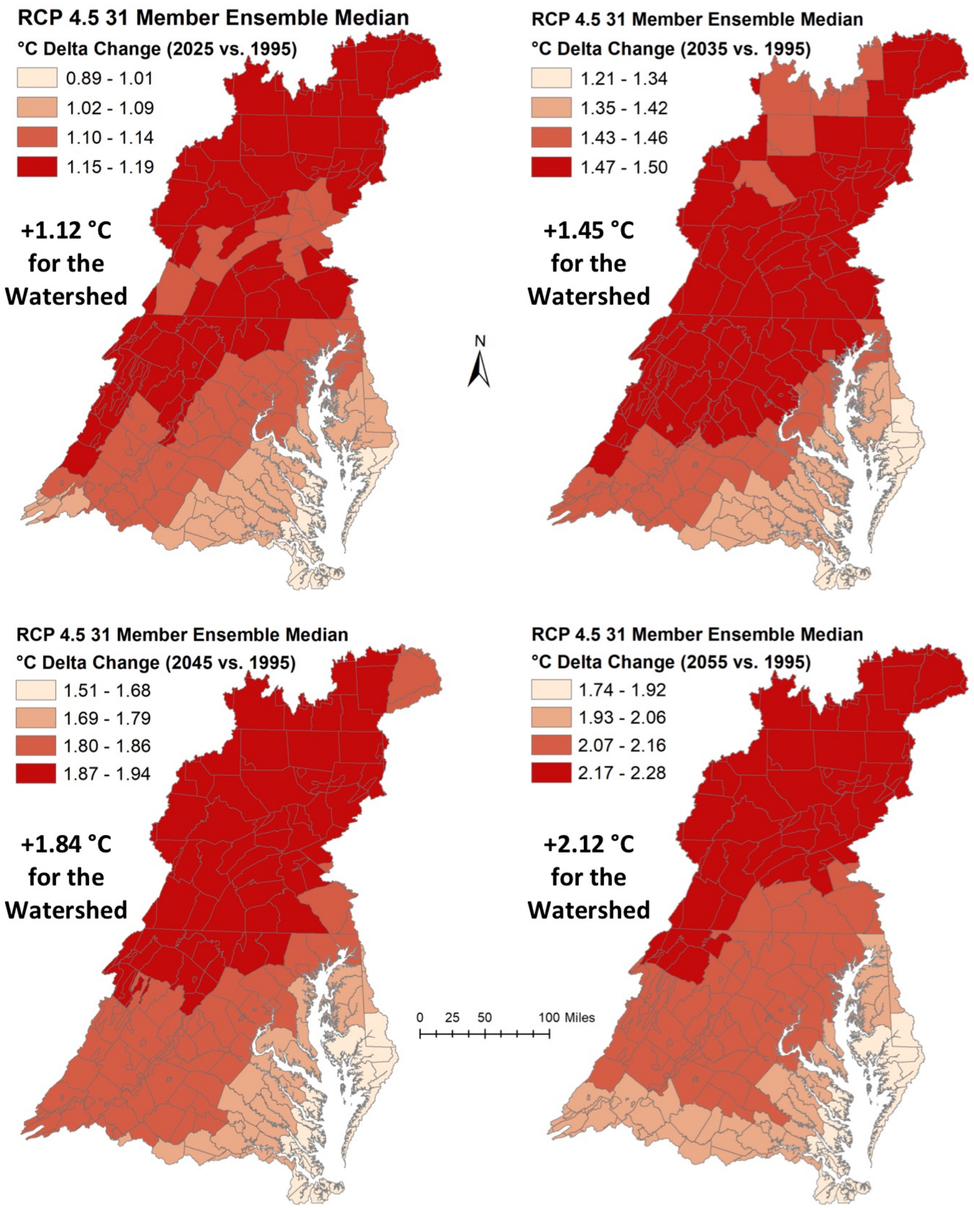
Ensemble median (circles) and 10th and 90th percentile (triangles) ranges are shown.

Ensemble medians vs. long-term trends in historical observations

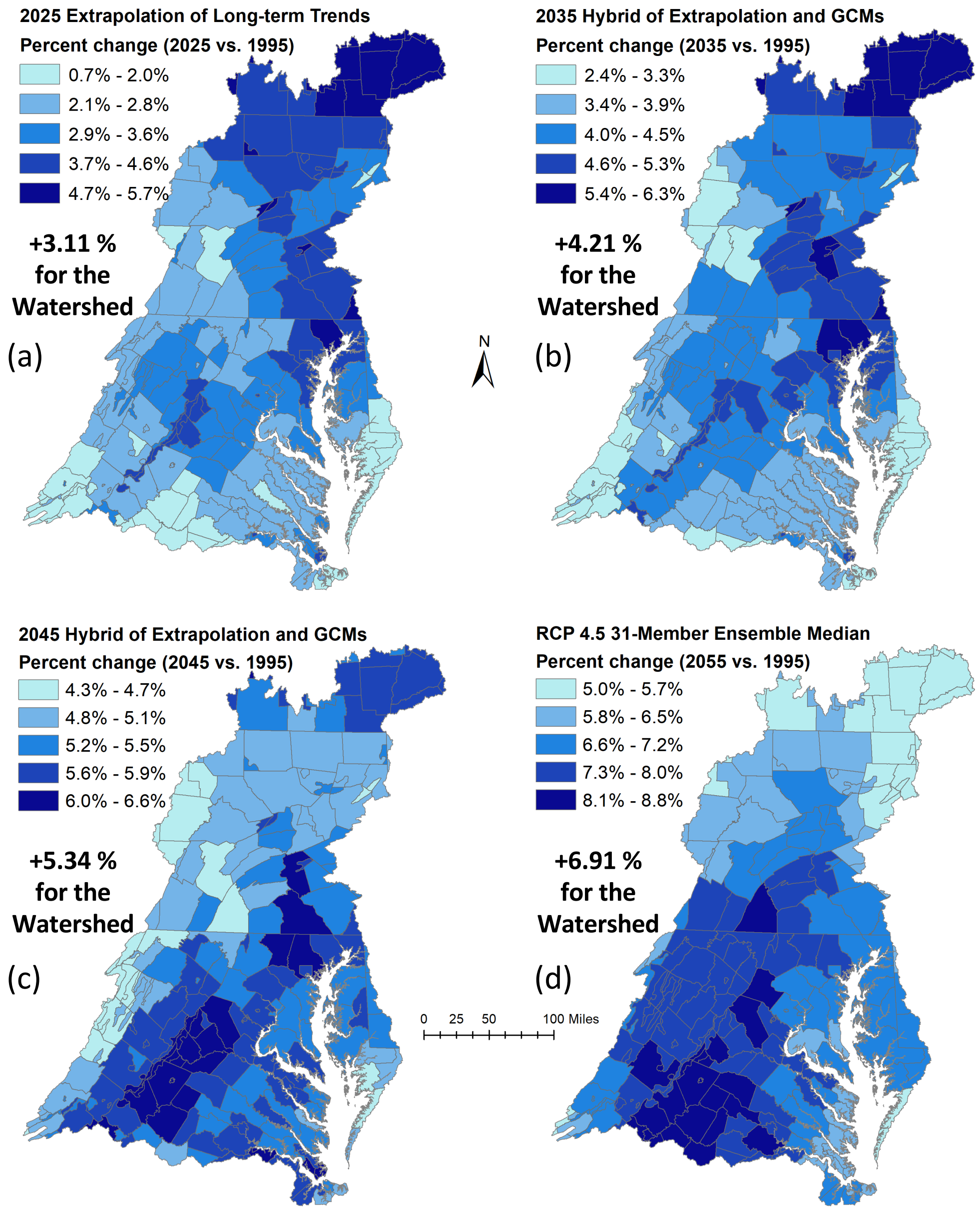


Estimated change for 2025, 2035, 2045, and 2055 (vs. 1995)

Estimated change in mean annual temperature



Estimated change in mean annual precipitation volume



Precipitation intensity

- Analyses of daily precipitation by Karl and Knight (1998) and Groisman et al. (2004) provide estimates of changes in rainfall intensity classes.
- Such analysis was based on approximately 6000 stations for the period in each region that has a sufficient amount of long-term daily precipitation time series.

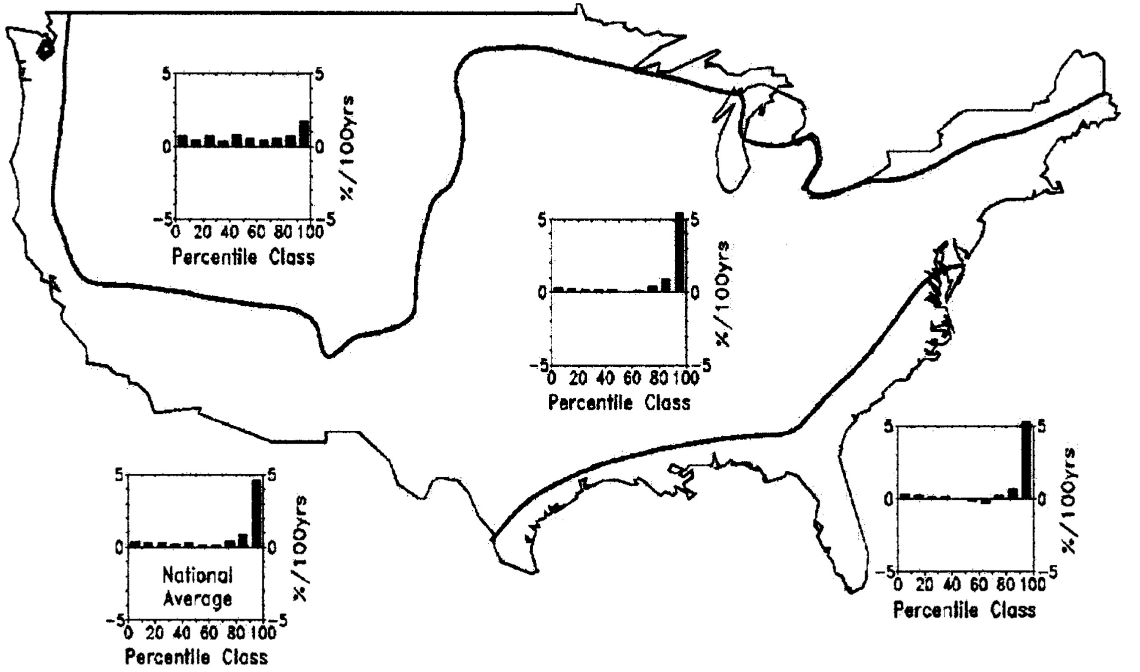


FIG. 10. Data are partitioned by three megaregions: one in which rainfall is strongly influenced by tropical cyclones, one in which more than 20% of precipitation falls in frozen form, and an intermediate region (Groisman et al. 2001c). For these regions and nationwide (shown in low left corner), the contribution of various parts of daily precipitation distribution to the linear trend of the total annual precipitation [% (100 yr)$^{-1}$] for the 1908–2002 period is shown. Trends are partitioned by 10th-percentile rainfall intensity classes. Linear trends for the upper 10% class in the intermediate region and nationwide are statistically significant at the 0.05 level. The intermediate region occupies 60% of the contiguous United States and is dubbed in Fig. 9 as the major part of the country.

Groisman et al. (2004)

Karl, T.R., and R.W. Knight. 1998. "Secular Trends of Precipitation Amount, Frequency, and Intensity in the United States." Bulletin of the American Meteorological Society 79(2): 231–42.
Groisman, P.Y., R.W. Knight, T.R. Karl, et al. 2004. "Contemporary Changes of the Hydrological Cycle over the Contiguous United States: Trends Derived from In Situ Observations." Journal of hydrometeorology 5(1): 64–85.

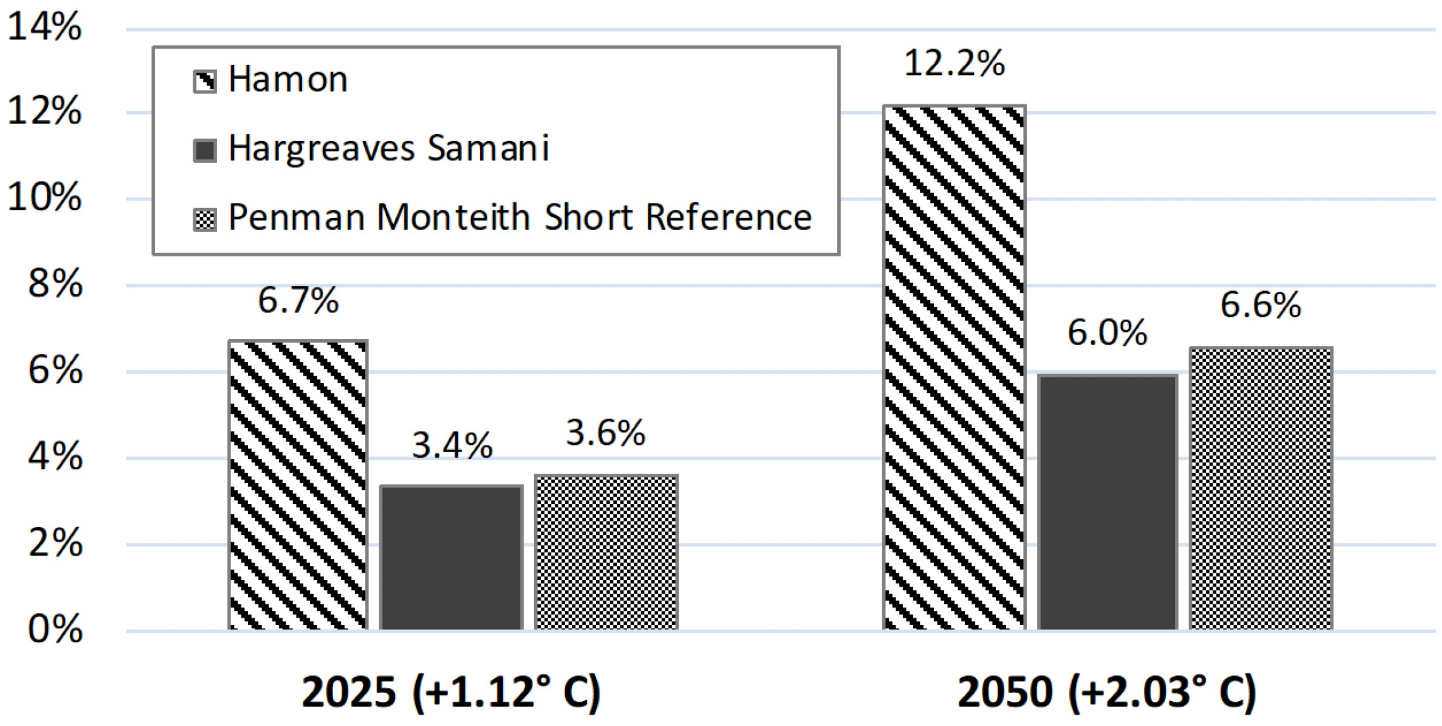
Mean monthly change to hourly model inputs

- The Phase 6 Watershed Model was calibrated to the precipitation and meteorological data obtained from NLDAS-2.
- For the time-disaggregation of mean monthly change in precipitation, monthly volume change was first divided into 10 precipitation intensity deciles using a-priori distribution.
- The volume change for intensity deciles were applied as monthly factors to hourly precipitation events of the decile.
- Mean monthly change in air temperatures were applied as monthly additive values.
- This method did not change the frequency of precipitation.

Potential Evapotranspiration (PET)

- Hamon and Hargreaves-Samani PET methods were evaluated for estimating change in potential evapotranspiration (PET).

- Due to the similarities between estimated changes produced by the Hargreaves-Samani and Penman-Monteith methods, along with guidance provided by CBP STAC and the recommendation of the CBP Modeling Workgroup, Hargreaves-Samani was used.

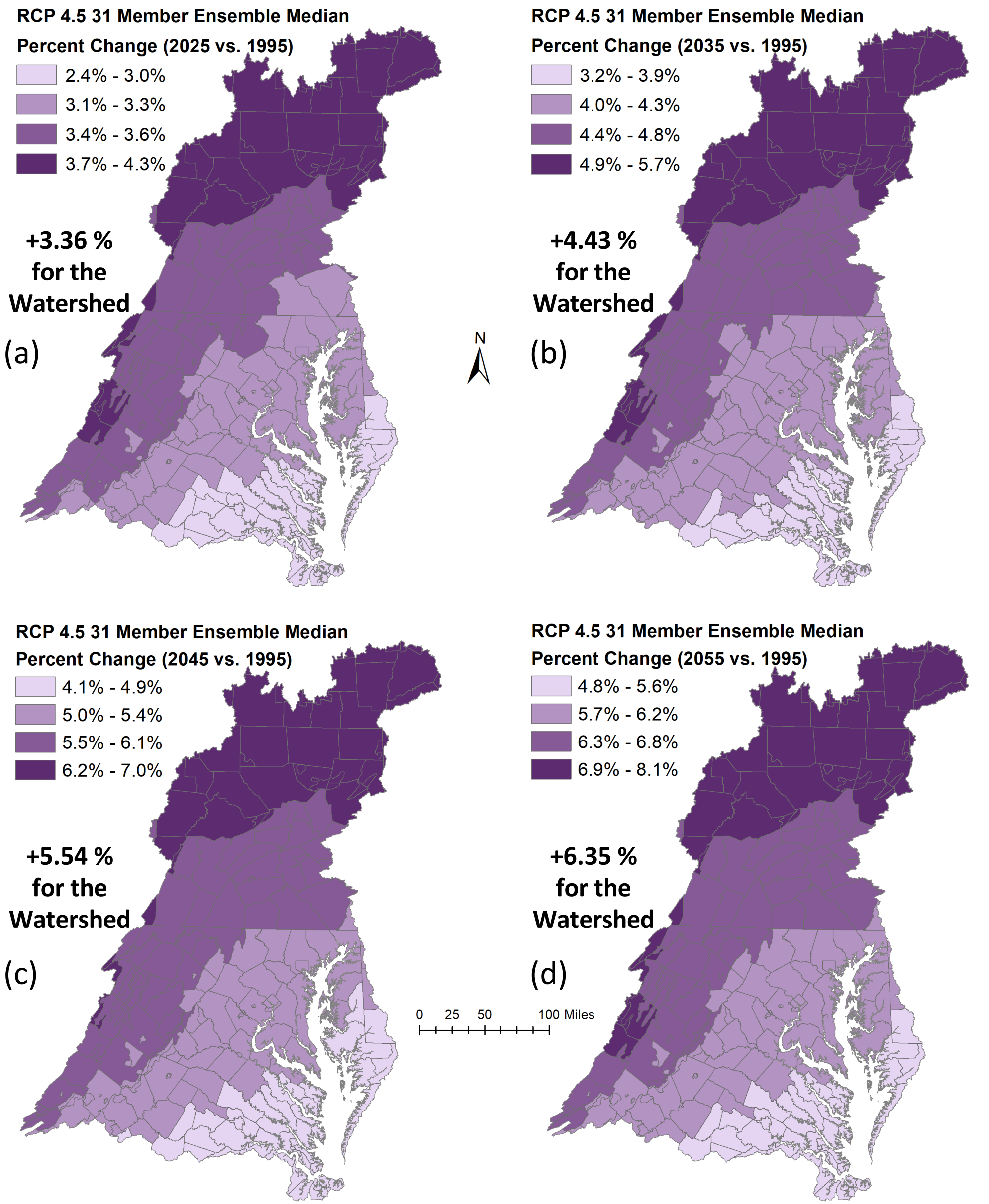


Shenk et al. 2021

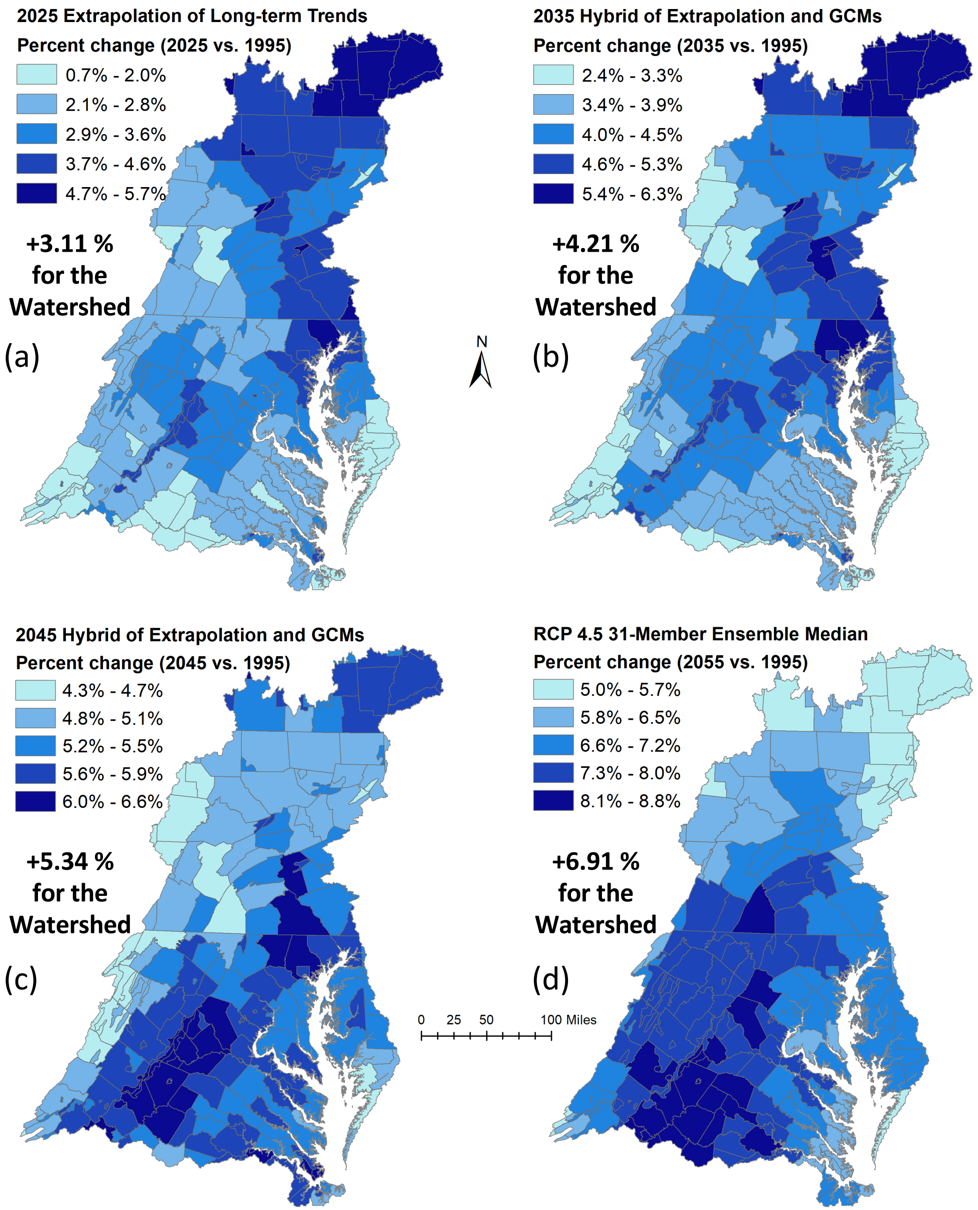
Hargreaves, G.H., and Z.A. Samani. 1985. "Reference Crop Evapotranspiration from Temperature." Applied Engineering in Agriculture. 1(2): 96–99.
Shenk, G.W., G. Bhatt, R. Tian, C.F. Cerco, I. Bertani, and L.C. Linker. 2021. "Modeling Climate Change Effects on Chesapeake Water Quality Standards and Development of 2025 Planning Targets to Address Climate Change." CBPO Publication 328–21, Annapolis, MD, 145 pp.

Estimated change for 2025, 2035, 2045, and 2055 (vs. 1995)

Estimated change in mean annual potential evapotranspiration



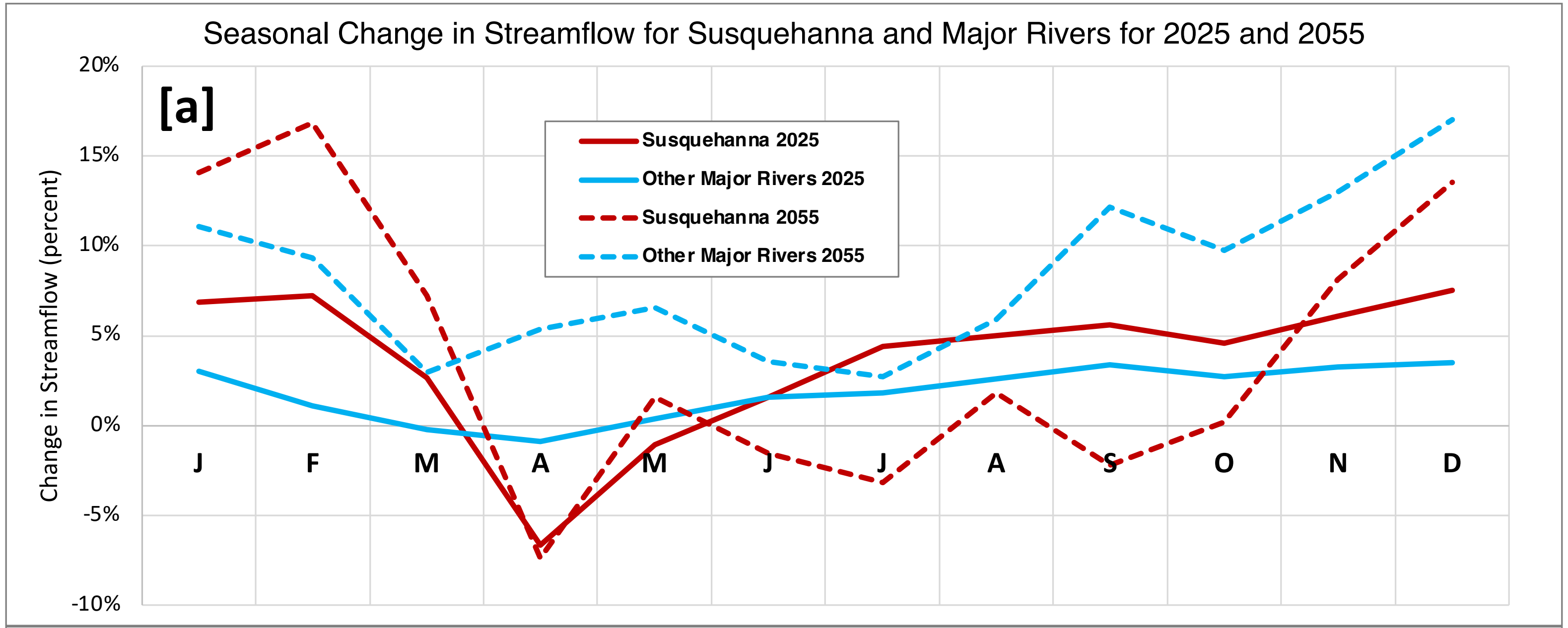
Estimated change in mean annual precipitation volume

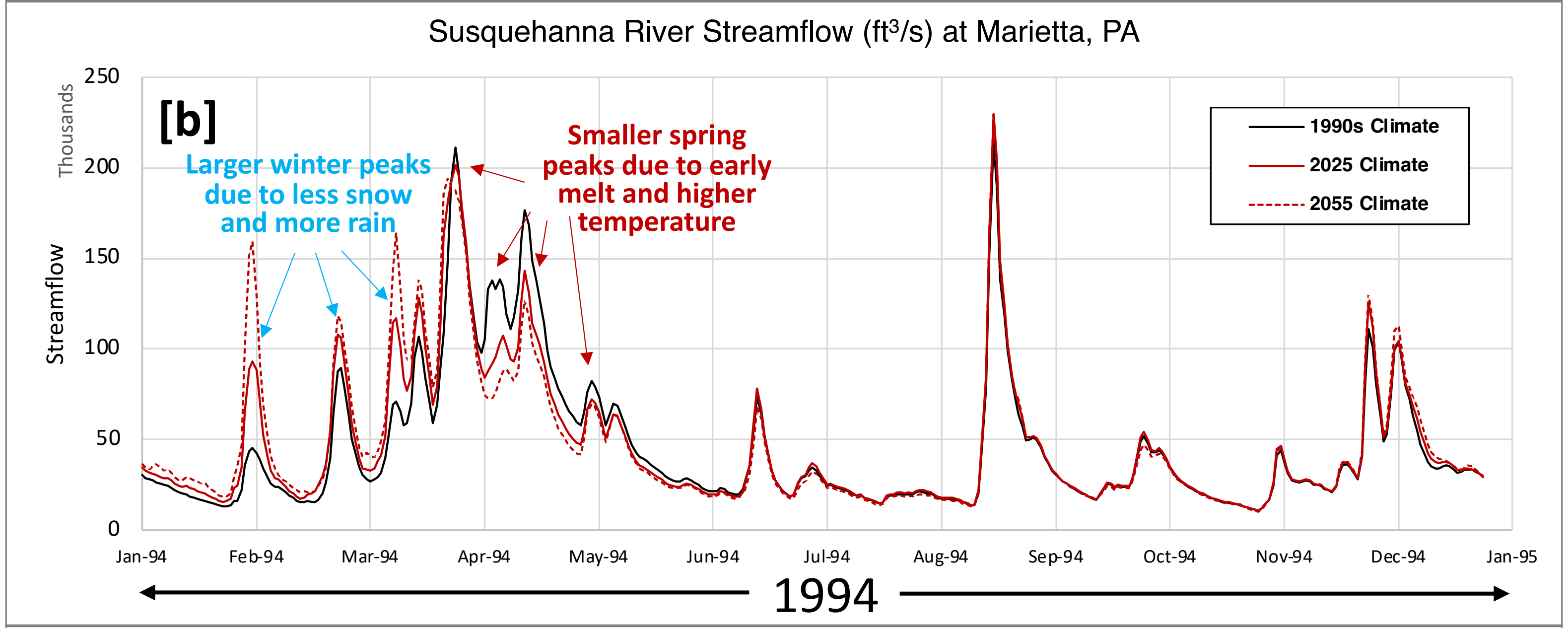


Summary

- Statistically downscaled data for climate models included in CMIP5 were used.
- Expected change in 2025 precipitation was developed based on long-term trends in historical observations, and an ensemble of GCMs for 2050 and beyond.
- We used GCMs for temperature and Hargreaves-Samani method for estimating change in PET.
- Mean monthly change was applied using delta method to adjust hourly 1991-2000 NLDAS-2 precipitation and meteorological data.

CBP 2021 Climate Change Assessment





- Model results provide: **[a]** estimate of seasonal change due to 30 to 60 years of climate change, and **[b]** underlying event scale changes in the streamflow (showing Year 1994 as an example).