07/10/2018

Application of Phase 6 Watershed Model to Climate Change Assessment

Modeling Workgroup Quarterly Meeting – July 2018

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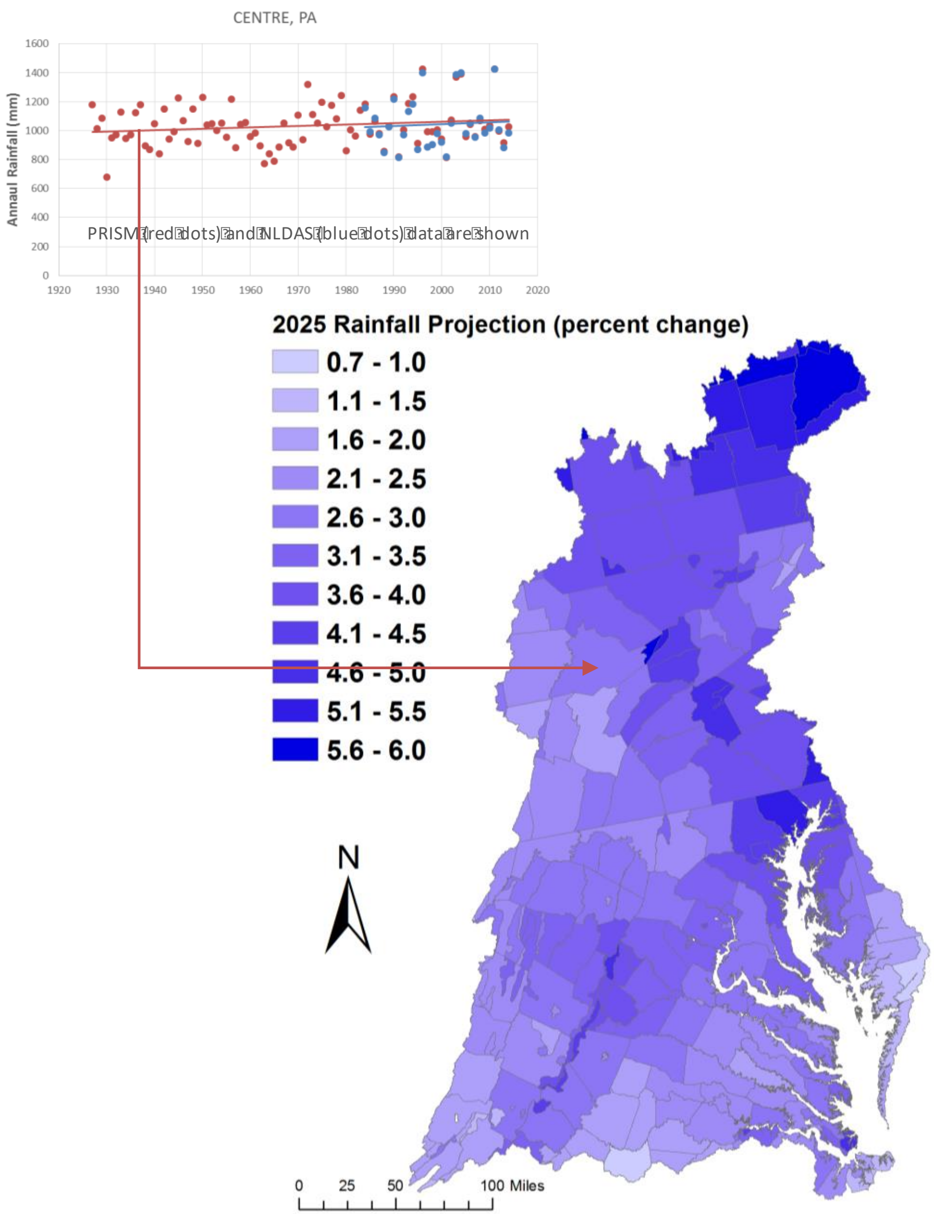
Presentation outline

- Estimated impacts of 2025 and 2050 climate change on the watershed delivery of nutrients and sediment.

- Decadal series of climate change assessments for the years 2025, 2035, 2045, 2055, and 2065.

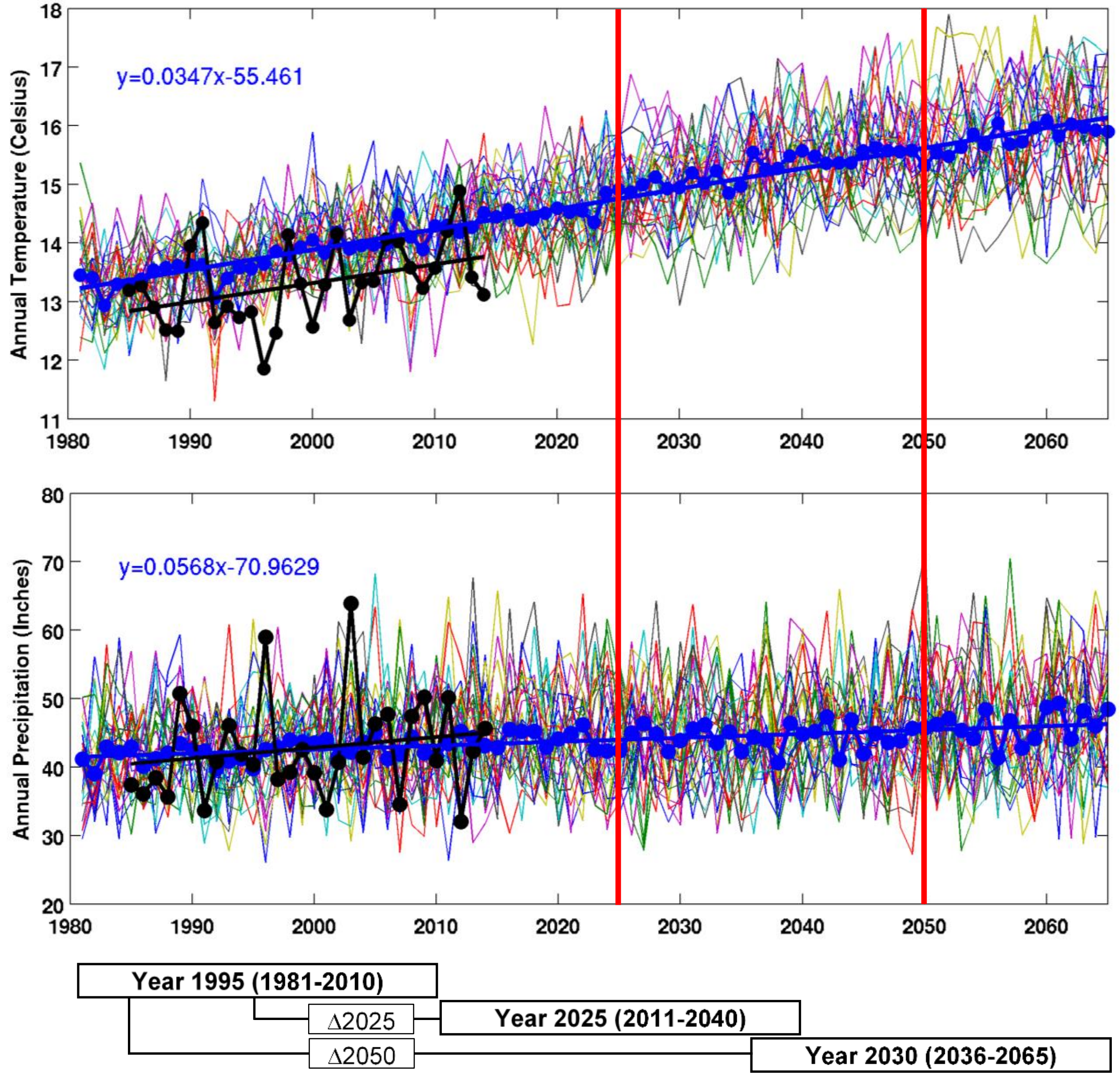
Rainfall projections using 88-years of annual PRISM[1] data trends



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%**

[1] Parameter-elevation Relationships on Independent Slopes Model



Data shown for the District of Columbia for illustration.

Average annual precipitation and temperature from the 31 bias-corrected downscaled global circulation models are shown for a land segment. Shown in blue line is the ensemble median. Data used in model calibration from NLDAS-2 are shown in black

Ensemble analysis of GCM projections – RCP 4.5

- An ensemble analysis of statistically downscaled projections were used from **BCSD CMIP5[1]** dataset.
- Change were calculated as differences in 30-year averages.

ACCESS1-0	FGOALS-g2	IPSL-CM5A-LR
BCC-CSM1-1	FIO-ESM	IPSL-CM5A-MR
BCC-CSM1-1-M	GFDL-CM3	IPSL-CM5B-LR
BNU-ESM	GFDL-ESM2G	MIROC-ESM
CanESM2	GFDL-ESM2M	MIROC-ESM-CHEM
CCSM4	GISS-E2-H-CC	MIROC5
CESM1-BGC	GISS-E2-R	MPI-ESM-LR
CESM1-CAM5	GISS-E2-R-CC	**MPI-ESM-MR**
CMCC-CM	HadGEM2-AO	MRI-CGCM3
CNRM-CM5	HadGEM2-CC	NorESM1-M
CSIRO-MK3-6-0	HadGEM2-ES	
EC-EARTH	INMCM4	

31 member ensemble

Data unavailable

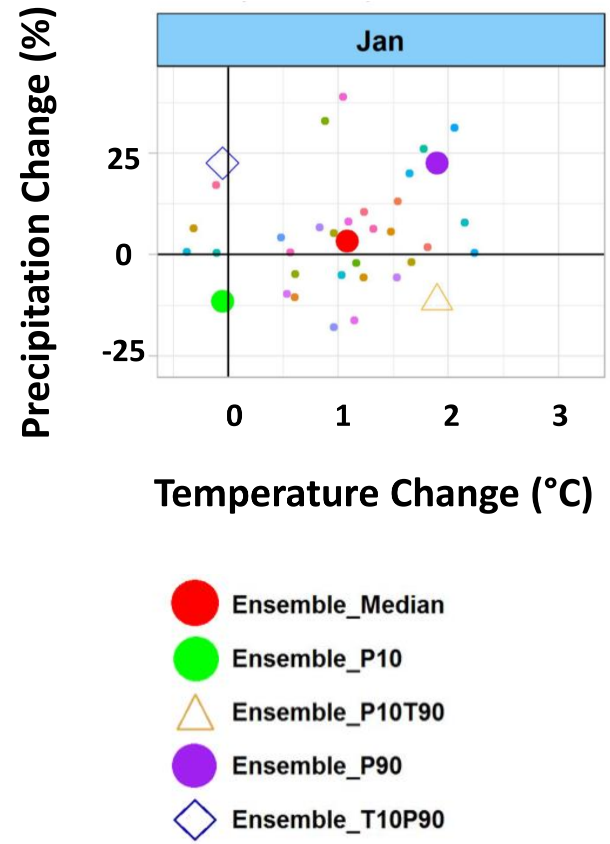
GCM Used

Selection updated

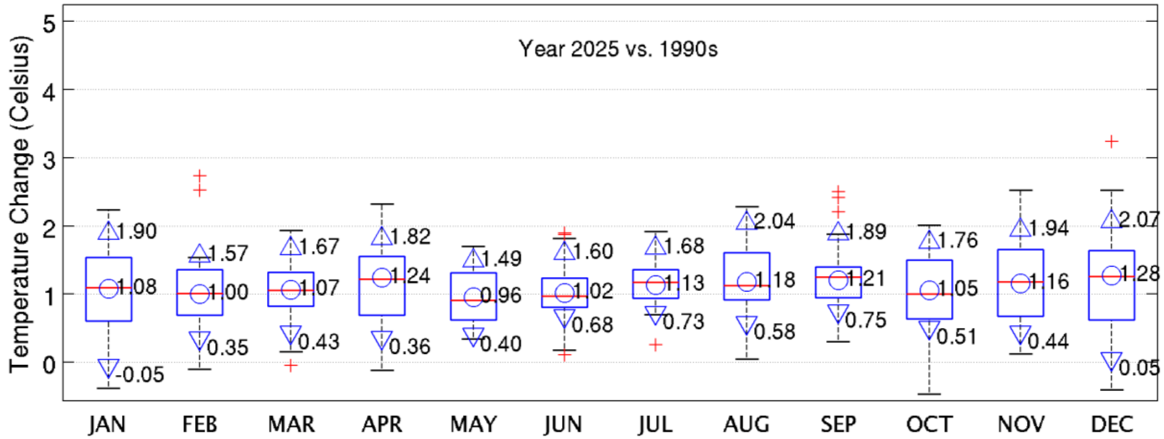
[1] Reclamation, 2013. 'Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections: Release of Downscaled CMIP5 Climate Projections, Comparison with preceding Information, and Summary of User Needs', prepared by the U.S. Department of the Interior, Bureau of Reclamation, Technical Services Center, Denver, Colorado. 47pp.

[1] BCSD – Bias Correction Spatial Disaggregation;
[1] CMIP5 – Coupled Model Intercomparison Project 5

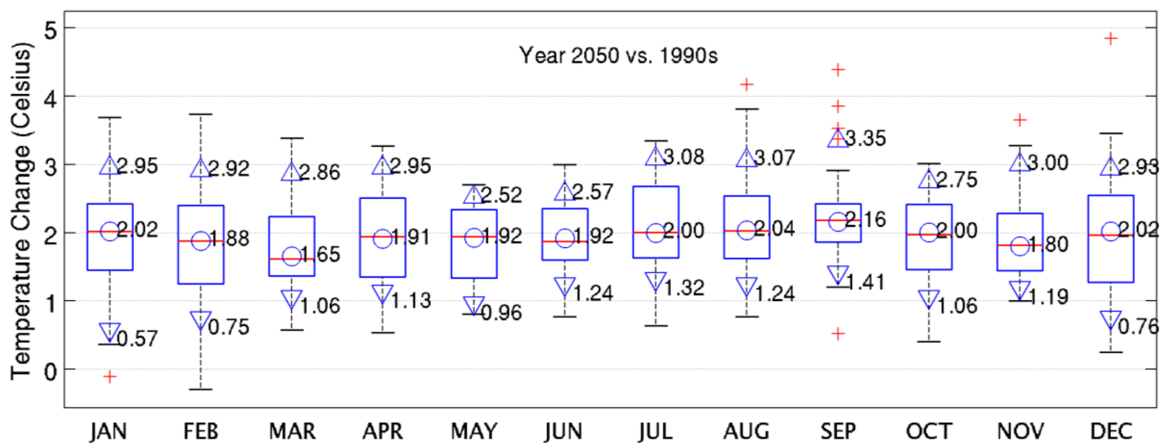
P90 – 90th percentile
P50 – median ensemble
P10 – 10th percentile



Projected changes in temperature (RCP 4.5)



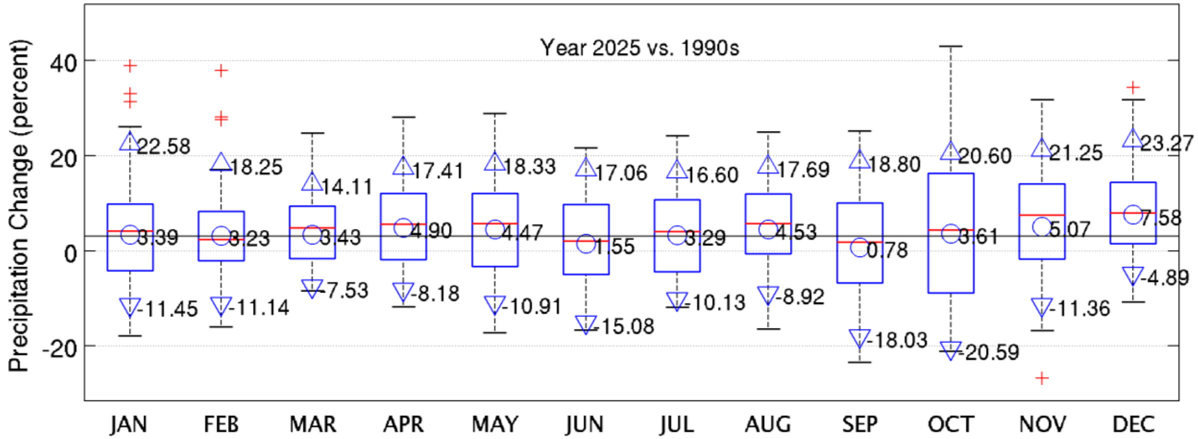
Watershed average of ensemble median is +1.12 ^{o}C



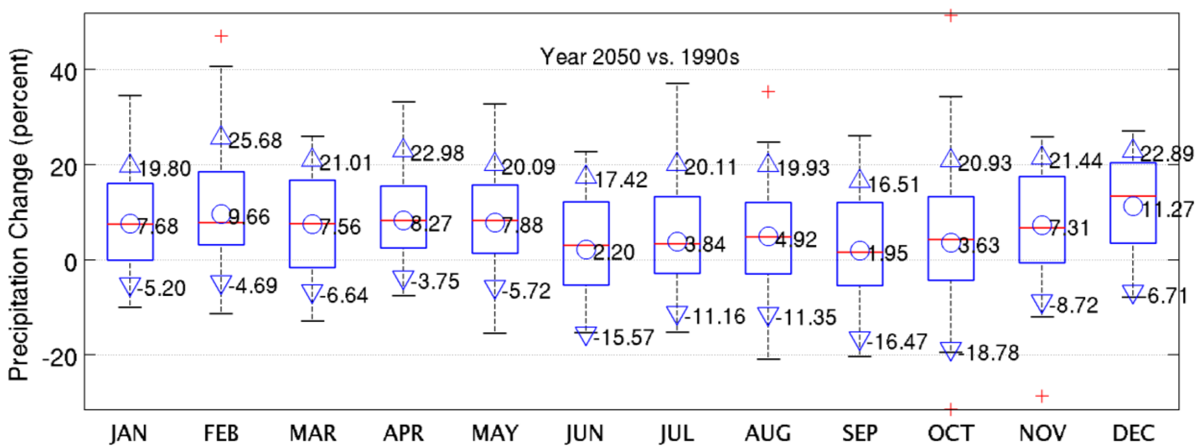
Watershed average of ensemble median is +1.95 ^{o}C

Monthly change in temperature for the Chesapeake Bay Watershed is shown. Box plot shows distribution of projected change based on 31-member ensemble of RCP 4.5 for the years 2025 and 2050. Additional three marker keys show 10th percentile (P10), ensemble median (P50), and 90th percentile (P90) bounds.

Projected changes in precipitation (RCP 4.5)



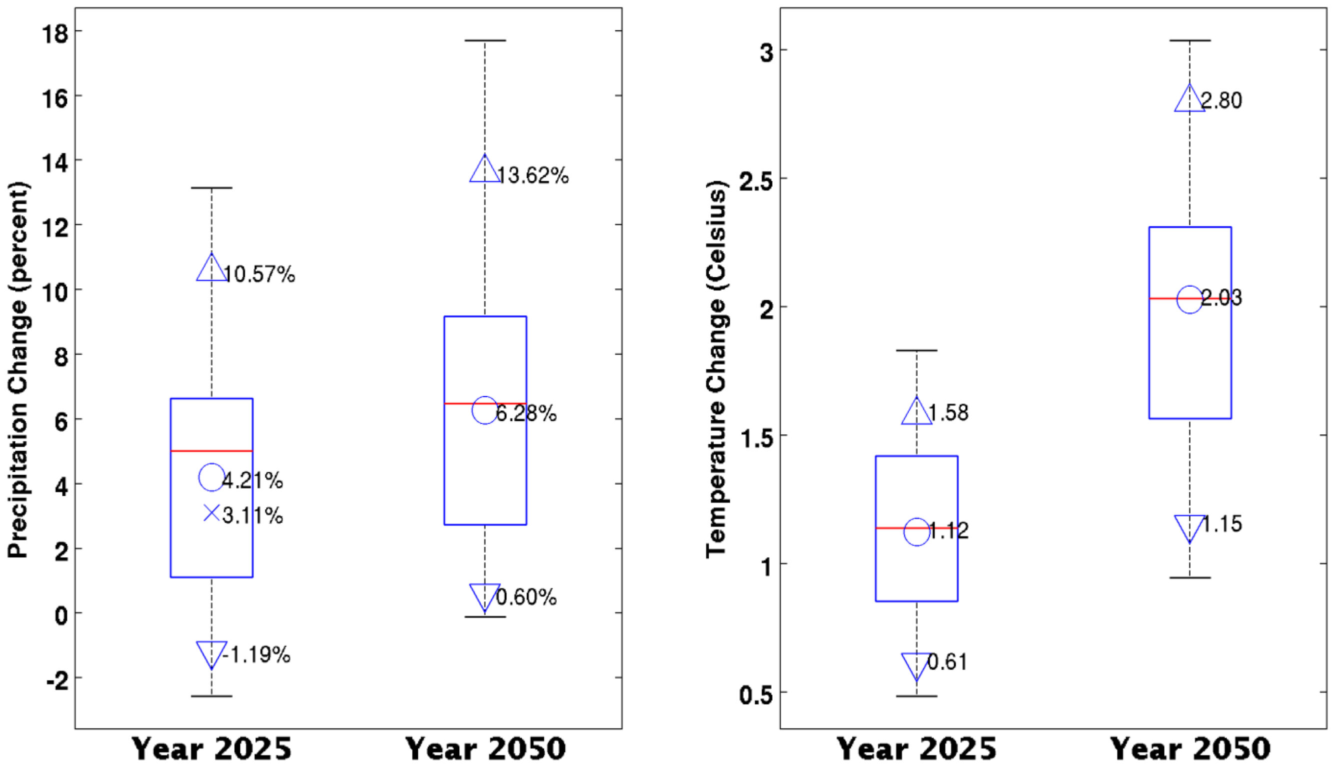
Watershed average of ensemble median is +4.21% (+3.11% estimated using extrapolation of long term trend)



Watershed average of ensemble median is +6.28%

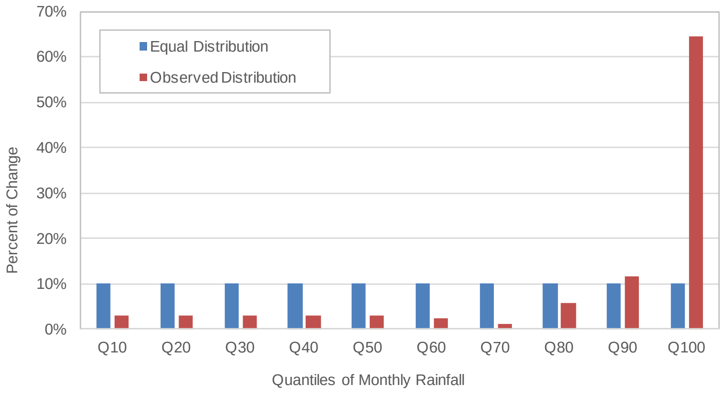
Monthly change in precipitation volume for the Chesapeake Bay Watershed is shown. Box plot shows distribution of projected change based on 31-member ensemble of RCP 4.5 for the years 2025 and 2050. For the year 2025 projected change based on long term trend is shown in black line. Additional three marker keys show 10th percentile (P10), ensemble median (P50), and the 90th percentile (P90) bounds.

Projected changes in precipitation (RCP 4.5)

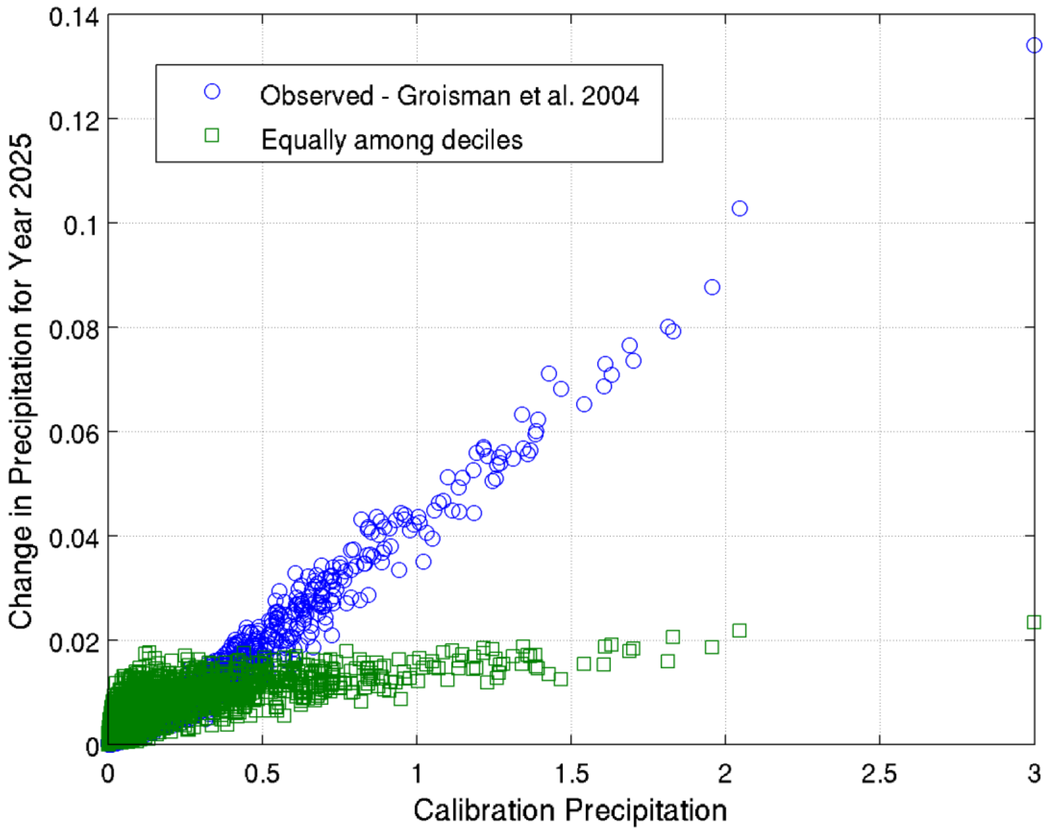


Summary of RCP4.5 average annual rainfall and temperature change for the Chesapeake Bay watershed are shown. Then range for 10th percentile (P10), ensemble median (P50), and 90th percentile (P90) are shown. The estimated change in rainfall volume based on the extrapolation of long-term trends are also shown (with marker symbol x)

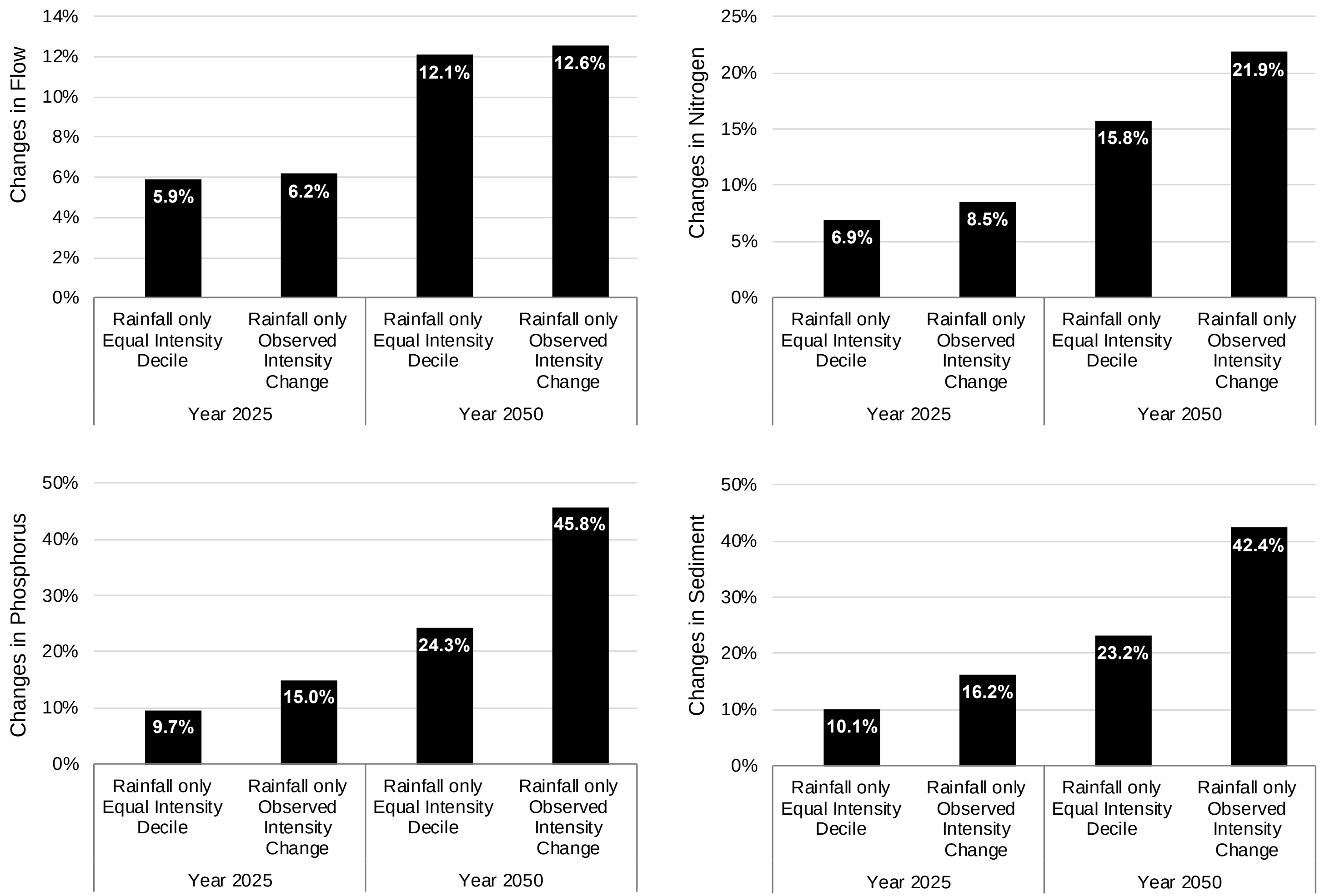
Monthly delta change to hourly events



Observed changes in rainfall intensity over the last century (based on Figure 10 in Groisman et al. 2004). The equal allocation distribution (blue) is contrasted with the distribution obtained based on observed changes (red).

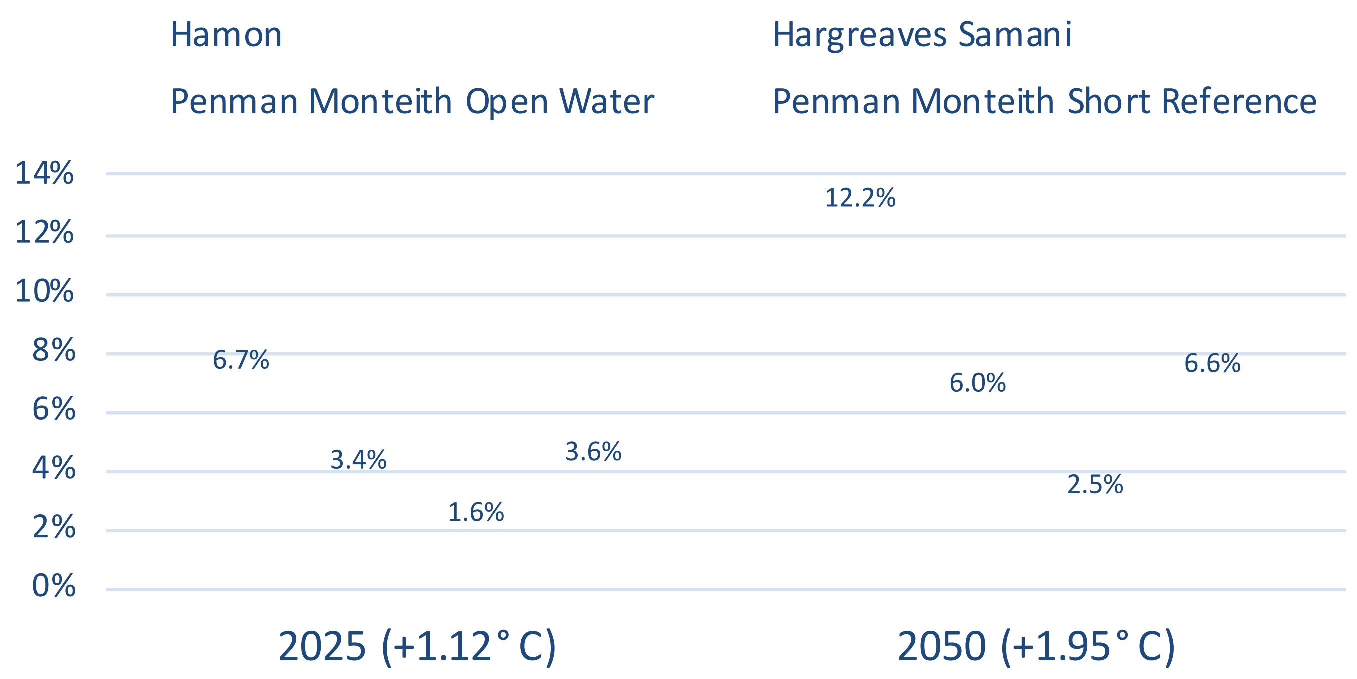


Additional rainfall added to the baseline daily rainfall over the 10-year period for a Phase 6 land segment (Potter, PA) is shown. In the method based on observed intensity trends, (Groisman et al. 2004) more volume is added to 10th decile resulting in higher intensity events become stronger.

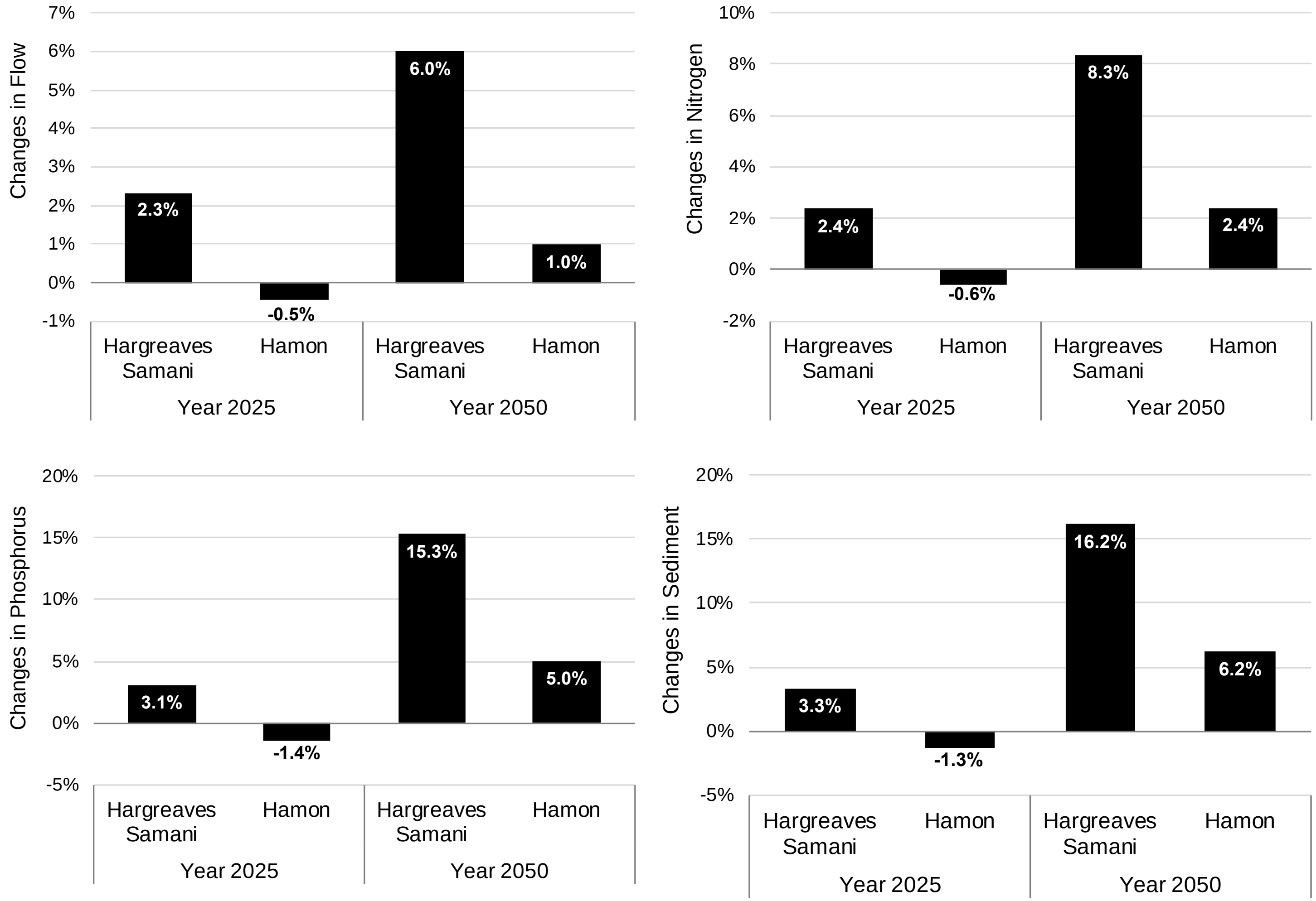


Differences in the watershed delivery of flow, nitrogen, phosphorus, and sediment are shown for the two different methods for downscaling projected changes in monthly rainfall volume for the year 2025 and 2050 to hourly rainfall events.

Estimation of potential evapotranspiration

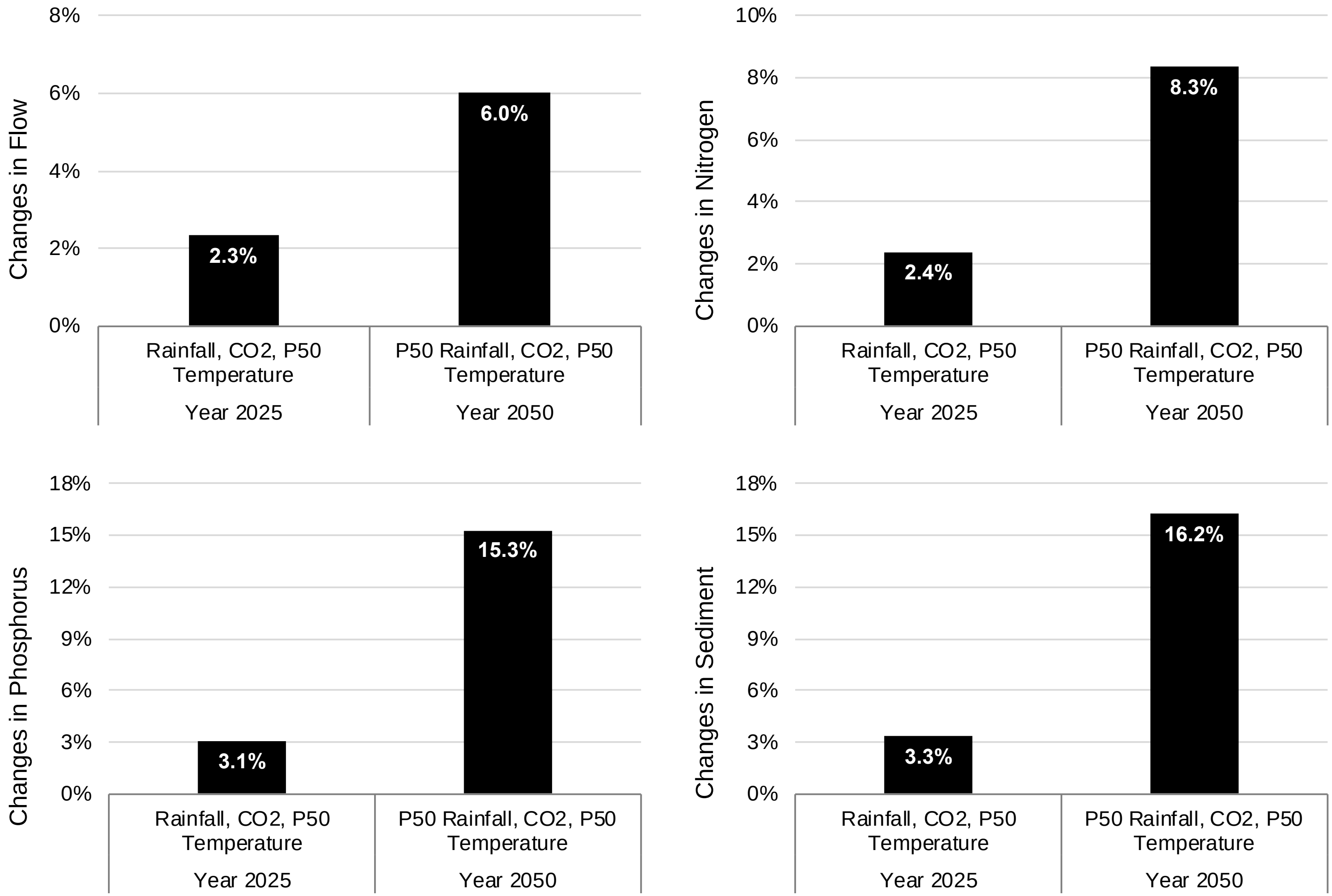


The relative difference in PET produced by using either the Hamon or Hargreaves-Samani methods are shown here. In 2025 projections produced by the WSM, the Hamon method simulated an increase in PET that was 3.36 percent greater than that simulated with the Hargreaves-Samani method. The change was more pronounced in 2050 simulations where the Hamon method outpaced the PET rate of Hargreaves-Samani by 6.26 percent



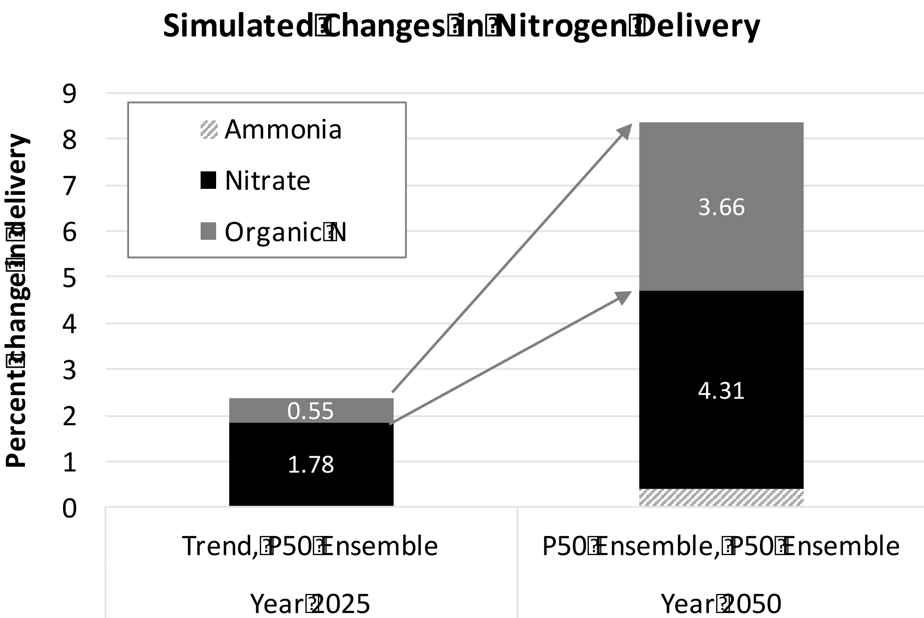
Differences in estimated delivery due to selection method for estimating potential evapotranspiration for 2025 and 2050 are shown. The differences get higher with increase in temperature

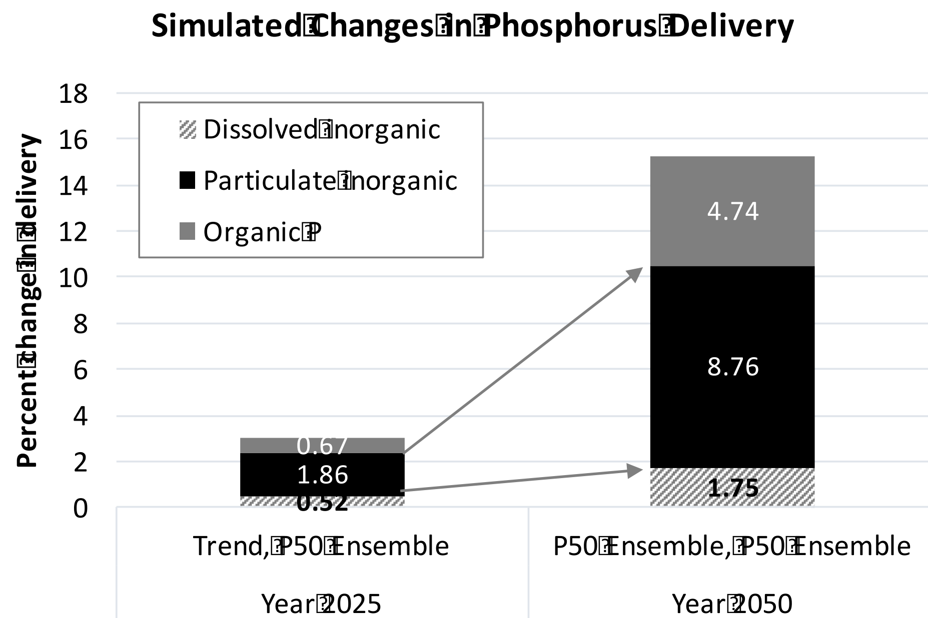
Summary of changes in delivery



Differences due to selection method for estimating potential evapotranspiration for 2025 and 2050 are shown. The differences get higher with increase in temperature

Nitrogen and phosphorus species





Relatively more increase in organic nitrogen as compared to inorganic.

Relatively more increase in inorganic (particulate) phosphorus as compared to organic.

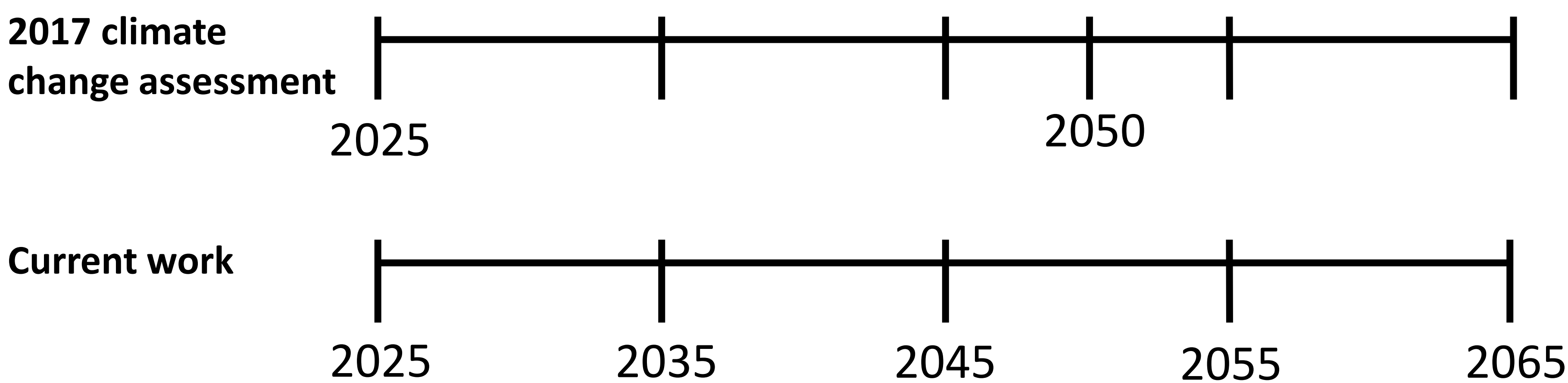
Uncertainty due to rainfall and temperature inputs

Period	Climate Change Scenario	Flow		Nitrogen		Phosphorus		Sediment	
		B ft3	percent	M lbs	percent	M lbs	percent	M tons	percent
Year 2025	Rainfall, CO2, P10 Temperature	124.78	4.8%	13.55	6.9%	1.61	11.6%	1.10	13.1%
	Rainfall, CO2, P50 Temperature	61.16	2.3%	4.68	2.4%	0.43	3.1%	0.28	3.3%
	Rainfall, CO2, P90 Temperature	-0.44	0.0%	-1.24	-0.6%	-0.22	-1.6%	-0.15	-1.8%
Year 2050	P10 Rainfall, CO2, P10 Temperature	-478.34	-18.3%	-36.01	-18.3%	-3.04	-21.9%	-2.15	-25.6%
	P50 Rainfall, CO2, P50 Temperature	157.25	6.0%	16.44	8.3%	2.13	15.3%	1.36	16.2%
	P90 Rainfall, CO2, P90 Temperature	966.74	36.9%	362.81	183.9%	81.80	588.3%	18.41	219.3%

Presentation outline

- Estimated impacts of 2025 and 2050 climate change on the watershed delivery of nutrients and sediment.

- **Decadal series of climate change assessments for the years 2025, 2035, 2045, 2055, and 2065.**



STAC workshop report [1]

Page 6, Paragraph 3 & 4

Workshop participants recommended the use of historical (~100 years) trends to project precipitation to 2025 for purposes of the Midpoint Assessment, as opposed to utilizing an ensemble of future projections from GCMs. Shorter term climate change projections using GCMs have large uncertainties because climate models are structured to look further out and at much larger scales. Participants in the workshop shared varied perspectives on the topic of uncertainty and climate projections. One recurring perspective was that uncertainty in some climate change projections is high, particularly for precipitation volumes and intensities across the Chesapeake watershed. There are inherent limitations in projecting precipitation, particularly its intensity, from existing regional statistical and dynamical downscaling of GCMs because they don't take adequate account of mesoscale processes that are important in water dynamics. Furthermore, extrapolating short term trends in precipitation is particularly risky. There are strong cyclic variations associated with climate models that impact shorter term precipitation trends and make longer term projections difficult.

Participants recommended that for long-term assessments (2050 and beyond) the CBP use an ensemble or multiple global climate model approach, selecting model outputs that bound the range of key climate variables (e.g., temperature, precipitation) for the Chesapeake Bay region. The use of multiple scenarios covering a range of projected emissions (representative concentration pathways (RCP) 4.5 and 8.5, as currently being utilized for Fourth National Climate Assessment) was recommended along with the inclusion of the 2 °C emissions reduction pathway (RCP 2.6). Lastly, participants advised the CBP to use an existing system to access

[1] http://www.chesapeake.org/pubs/360_Johnson2016.pdf

STAC recommendations [1]

Page 8, Recommendations

Recommendations

The workshop culminated with the following specific recommendations related to the selection, use, and application of climate projections and forecasts for the 2017 Midpoint Assessment.

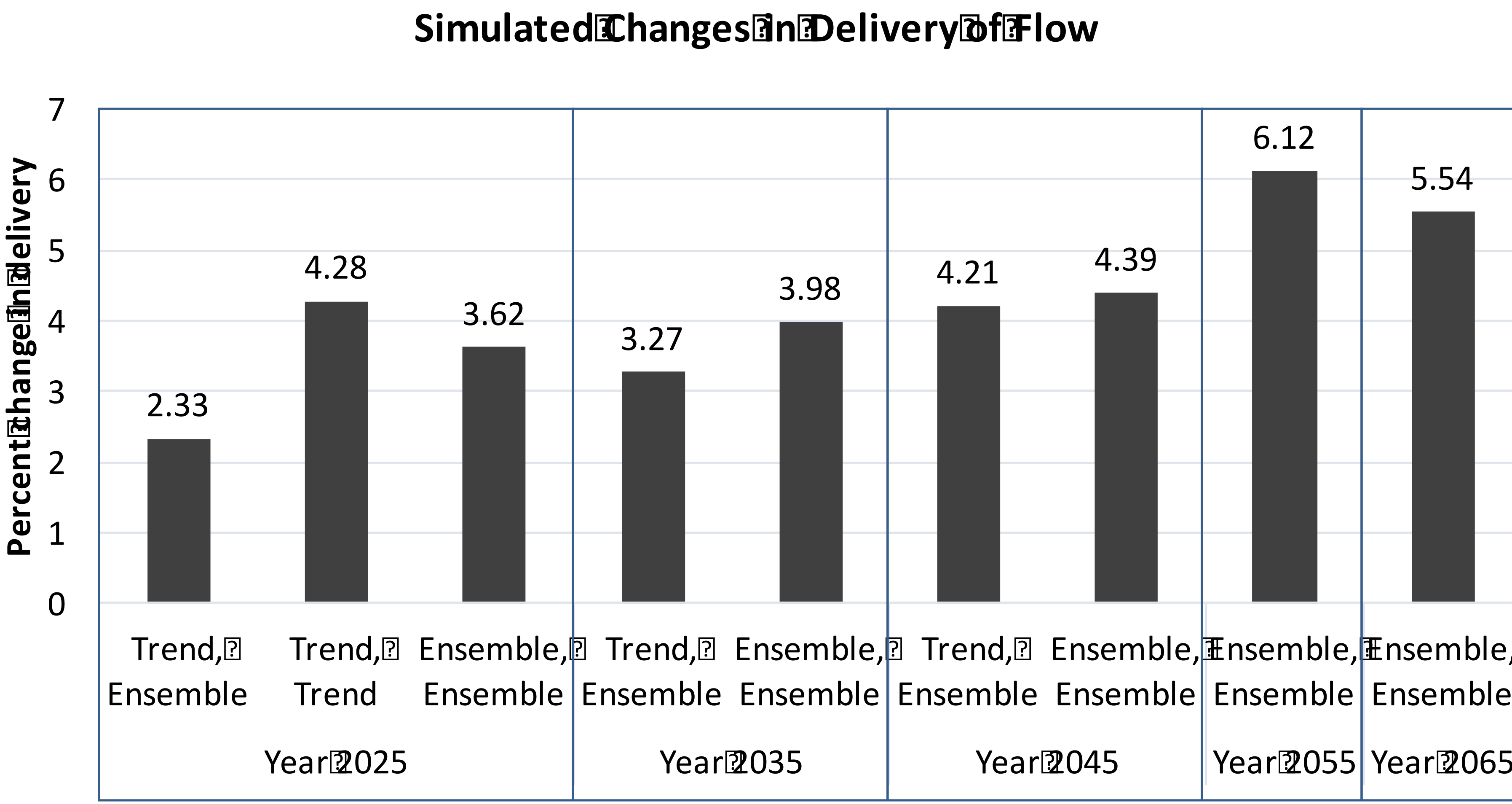
1. The Partnership should seek agreement on the use of consistent climate scenarios for regional projections of Chesapeake Bay condition and the benefits of an integrated source of climate change projection simulation data that all seven jurisdictions could draw from.
2. For the 2017 Midpoint Assessment, use historical (~100 years) trends to project precipitation to 2025 as opposed to utilizing an ensemble of future projections from GCMs. Shorter term climate change projections using GCMs have large uncertainties because climate models are structured to look further out and at much larger scales.
3. The Partnership should carefully consider the representation of evapotranspiration in Watershed Model calibration and scenarios because the calculation method for evapotranspiration has a strong influence on the strength and direction of future water balance change.
4. Looking forward, the 2050 timeframe is more appropriate for selecting and incorporating a suite of global climate scenarios and simulations to provide long-term projections for the management community, and an ongoing adaptive process to incorporate climate change into decision-making as implementation moves forward.

[1] http://www.chesapeake.org/pubs/360_Johnson2016.pdf

Year	Precipitation		Temperature	
	Trend	Ensemble	Trend	Ensemble
2025	**x**	–	–	**x**
2035	**?**	**?**	**?**	**?**
2045	**?**	**?**	**?**	**?**
2050	–	**x**	–	**x**
2055	**?**	**?**	**?**	**?**
2065	**?**	**?**	**?**	**?**

- Highlighted in yellow are the STAC and CBP climate resiliency workgroup recommendations for the 2017 Climate Change assessment, which included years 2025 and 2050.
- For 2035 and 2045 a discussion is needed, leading to perhaps a recommendation for either a specific source or a method for combine the two sources.

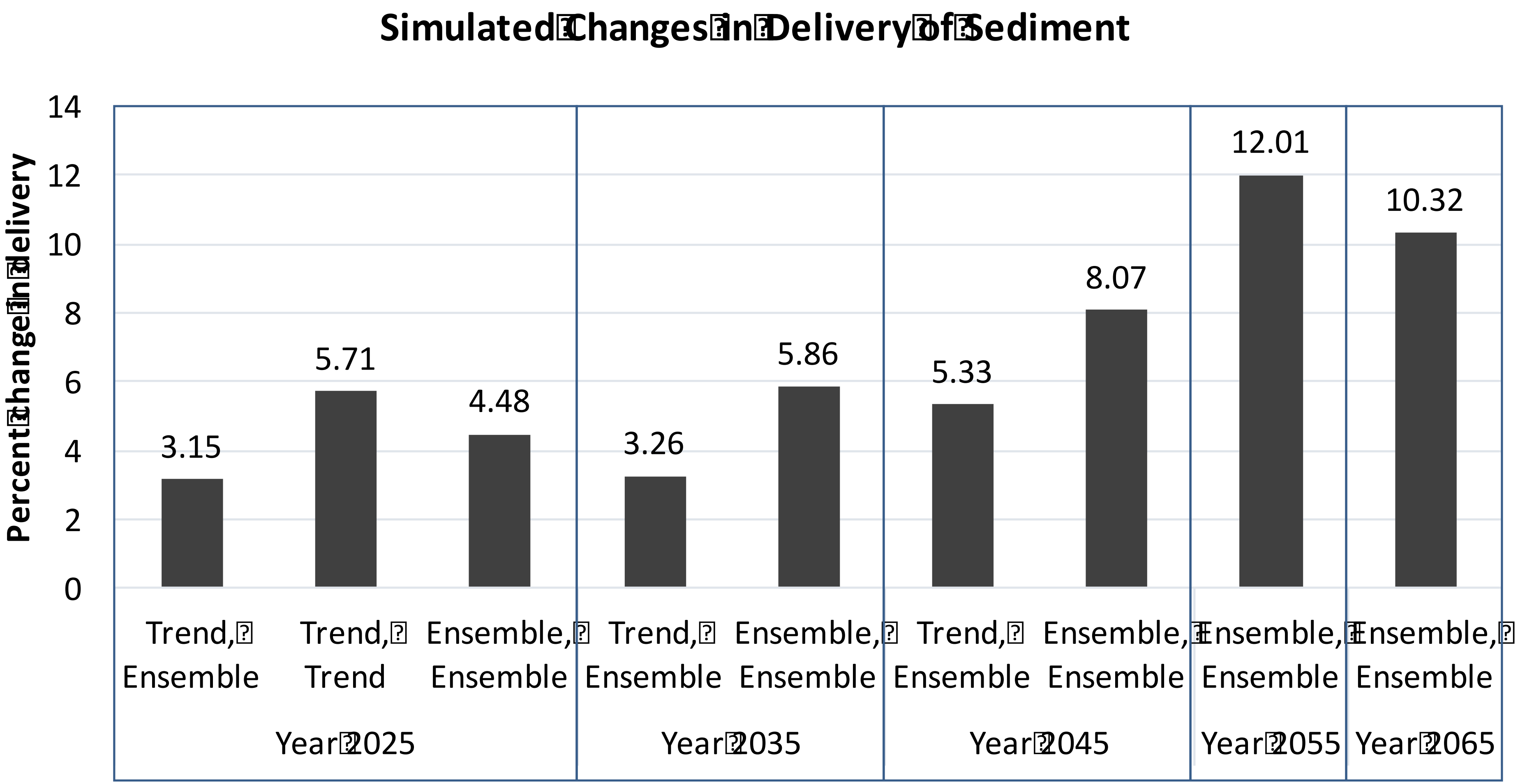
Estimated changes in flow



***Trend**: projection of extrapolation of long-term trends*

***Ensemble**: 31-member ensemble median (P50) of statistically downscaled GCM RCP4.5*

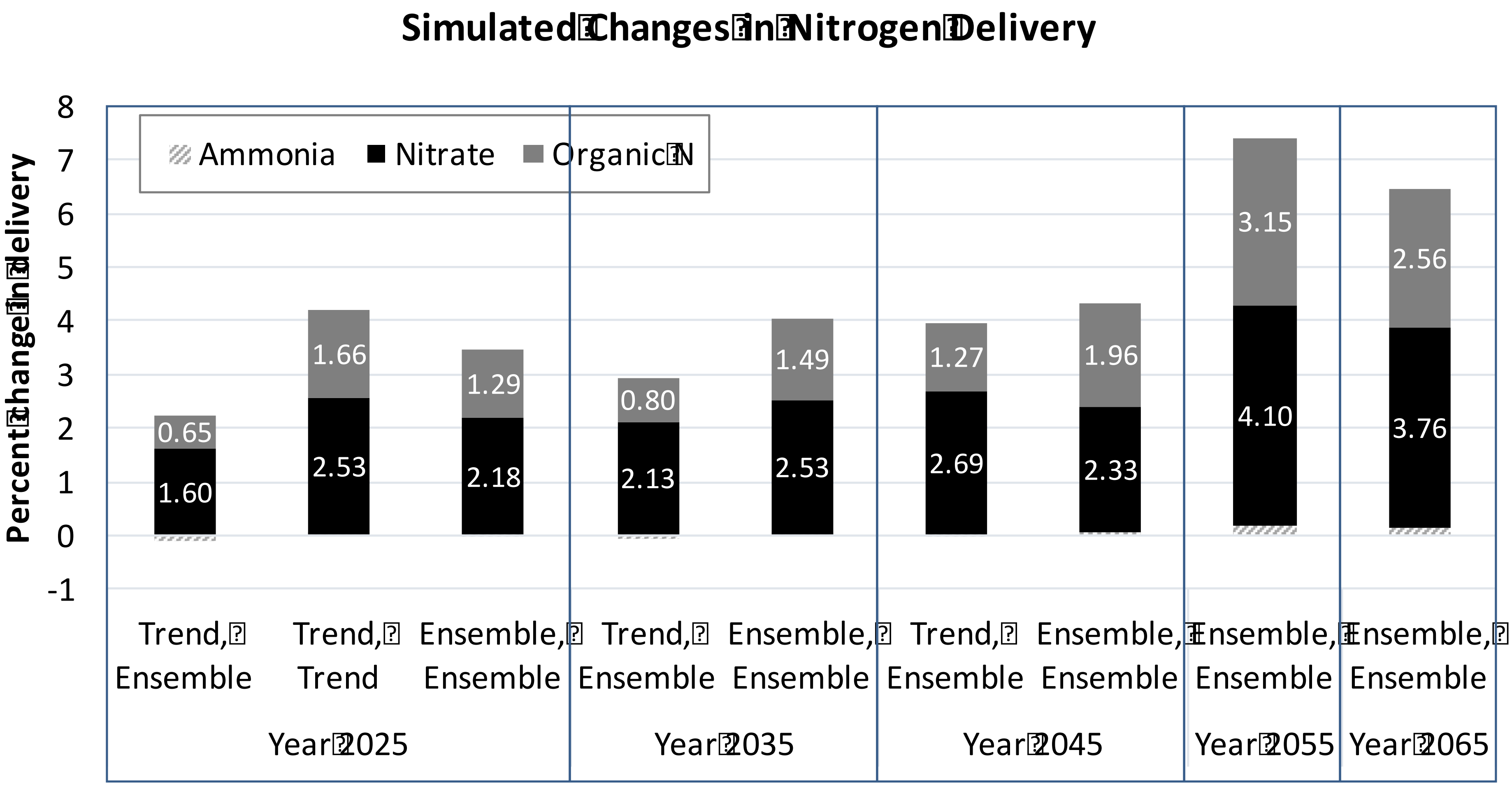
Estimated changes in sediment



***Trend**: projection of extrapolation of long-term trends*

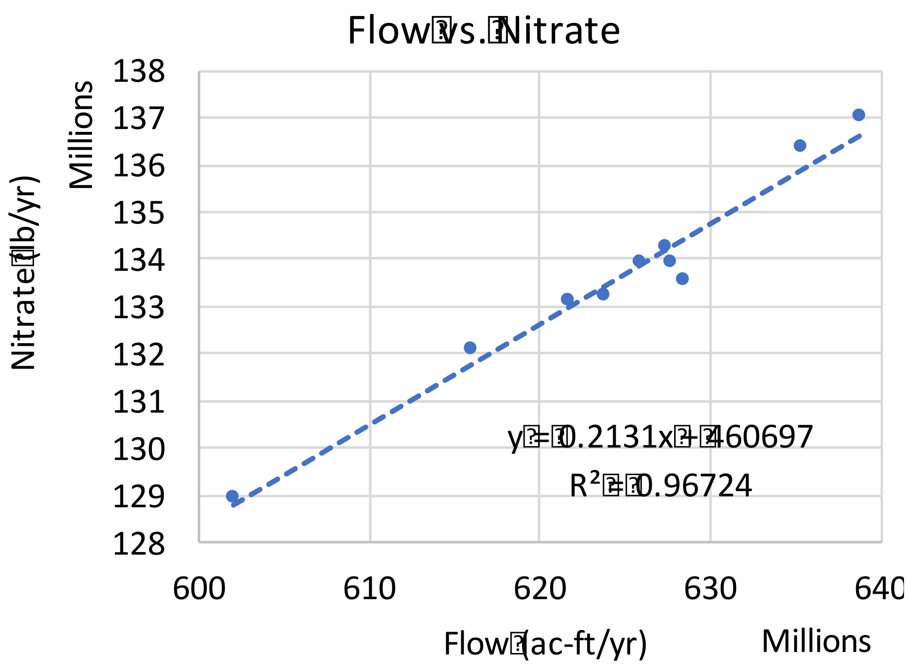
***Ensemble**: 31-member ensemble median (P50) of statistically downscaled GCM RCP4.5*

Estimated changes in nitrogen

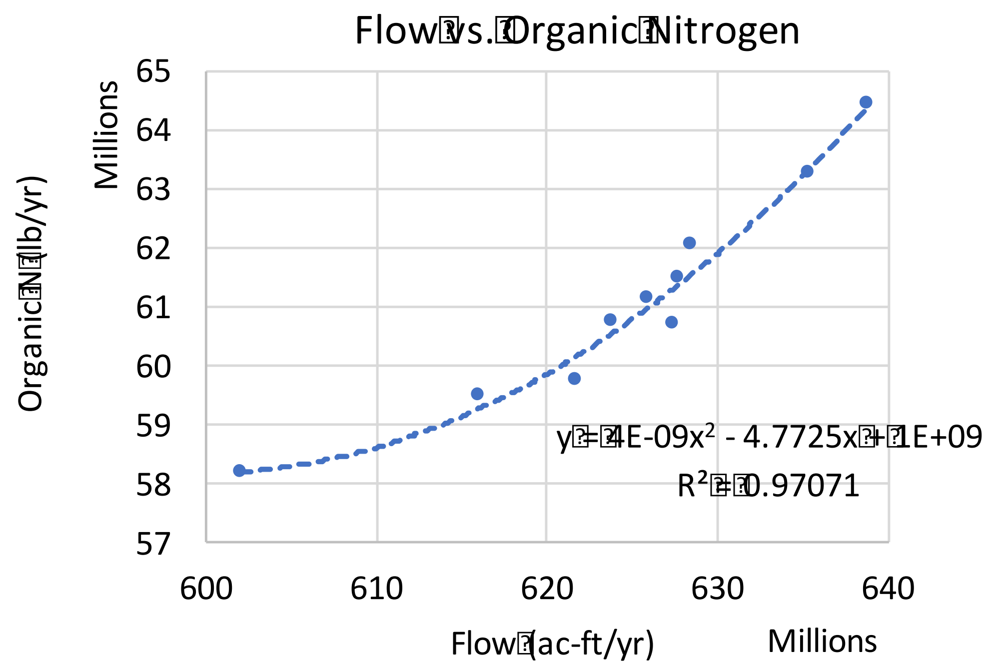


***Trend**: projection of extrapolation of long-term trends*

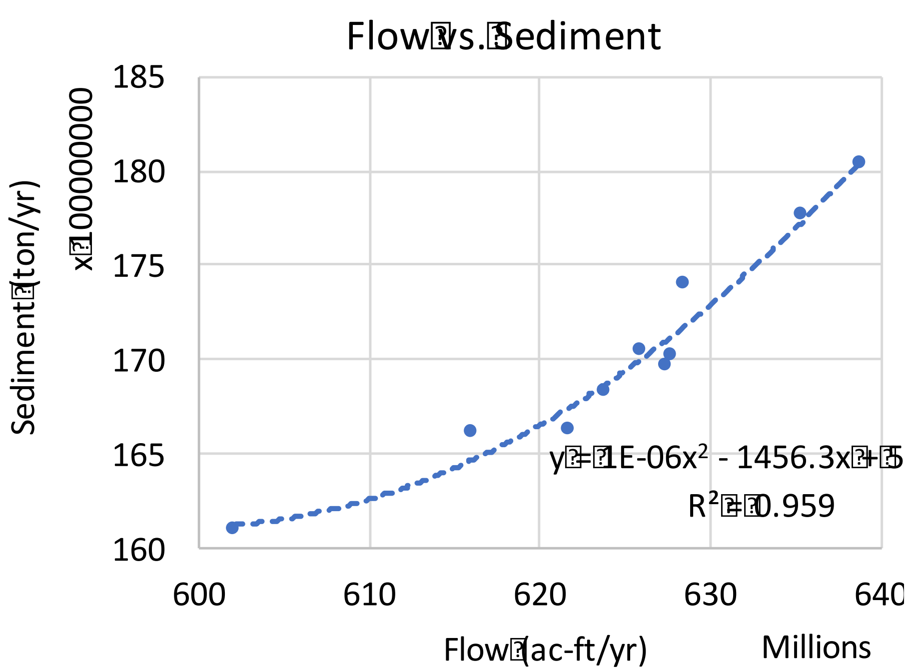
***Ensemble**: 31-member ensemble median (P50) of statistically downscaled GCM RCP4.5*



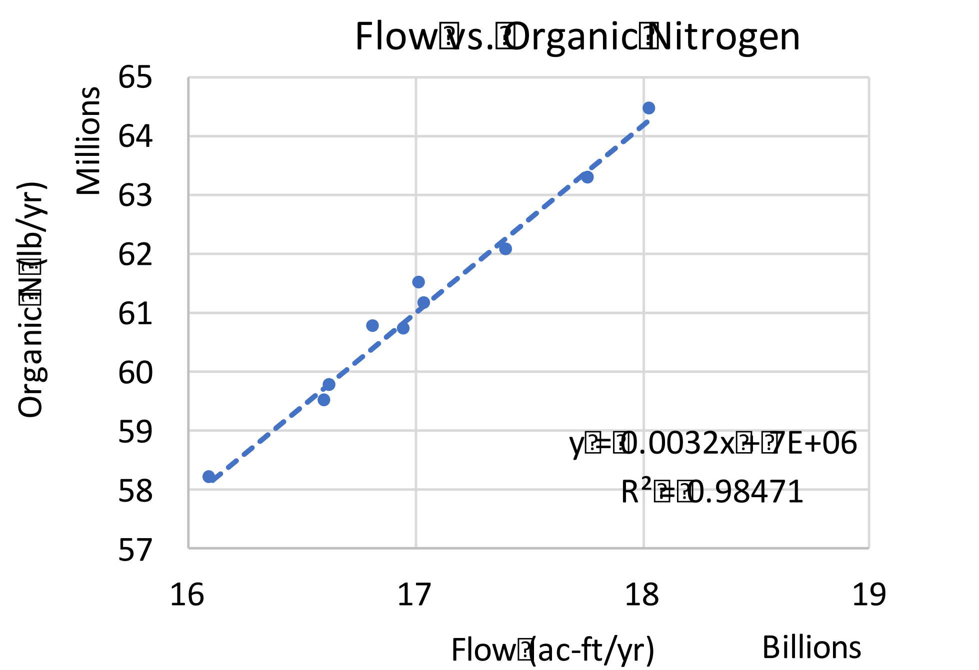
Flow vs. Nitrate
Nitrate (lb/yr)
Millions
138
137
136
135
134
133
132
131
130
129
128
y = 0.2131x + 460697
R² = 0.96724
600
610
620
630
640
Flow (ac-ft/yr)
Millions



Flow vs. Organic Nitrogen
Organic N (lb/yr)
Millions
65
64
63
62
61
60
59
58
57
y = 4E-09x² - 4.7725x + 1E+09
R² = 0.97071
600
610
620
630
640
Flow (ac-ft/yr)
Millions

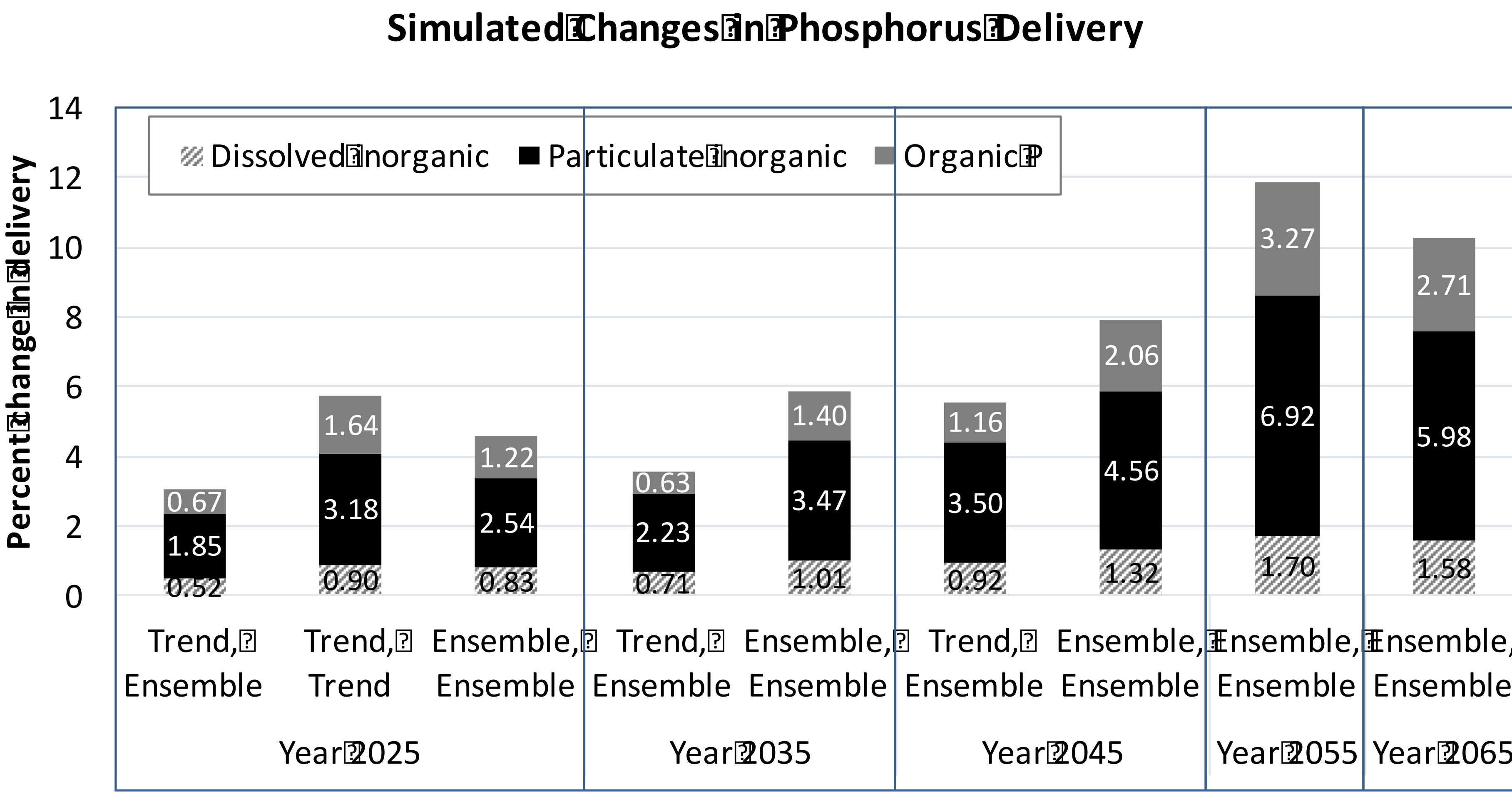


Flow vs. Sediment
Sediment (ton/yr)
x 100000000
185
180
175
170
165
160
y = 1E-06x² - 1456.3x + 5
R² = 0.959
600
610
620
630
640
Flow (ac-ft/yr)
Millions



Flow vs. Organic Nitrogen
Organic N (lb/yr)
Millions
65
64
63
62
61
60
59
58
57
y = 0.0032x + 7E+06
R² = 0.98471
16
17
18
19
Flow (ac-ft/yr)
Billions

Estimated changes in phosphorus



***Trend**: projection of extrapolation of long-term trends*

***Ensemble**: 31-member ensemble median (P50) of statistically downscaled GCM RCP4.5*

Summary and Conclusions

- Estimated impacts of 2025 and 2050 climate change on the watershed delivery of nutrients and sediment were shown.
- Estimated changes in the delivery of flow, nutrients and sediment were shown for decadal series of climate change assessments for the years 2025, 2035, 2045, 2055, and 2065.
- For years 2035 and 2045 both extrapolation of long-term trends and 31-member ensemble medians of downscaled GCMs were used – which will be updated based on specific recommendations from STAC workshop or CBP Climate Resiliency workgroup.