Phase 6 Climate Change Topics for Approval

Gary Shenk and the CBPO modeling team

7/16/19

Presentation to MWG

CBP Climate Basics

- Critical period for dissolved oxygen is 1993-1995
  - Selected as having a return period for wetness of 10 years
- Hydrologic averaging period is 1991-2000
  - Selected as an 'average' 10-year period
- Management questions
  - What would loads look like in a 1991-2000 that was translated through 30 years of climate change to 2025?
  - What would oxygen attainment look like during a 1993-1995 that was translated through 30 years of climate change to 2025?
  - What would loads have to be in 1991-2000 such that standards are attained with a 1993-1995 period translated to 2025?
- Take a first look at 2035, 2045, and 2055

Topics

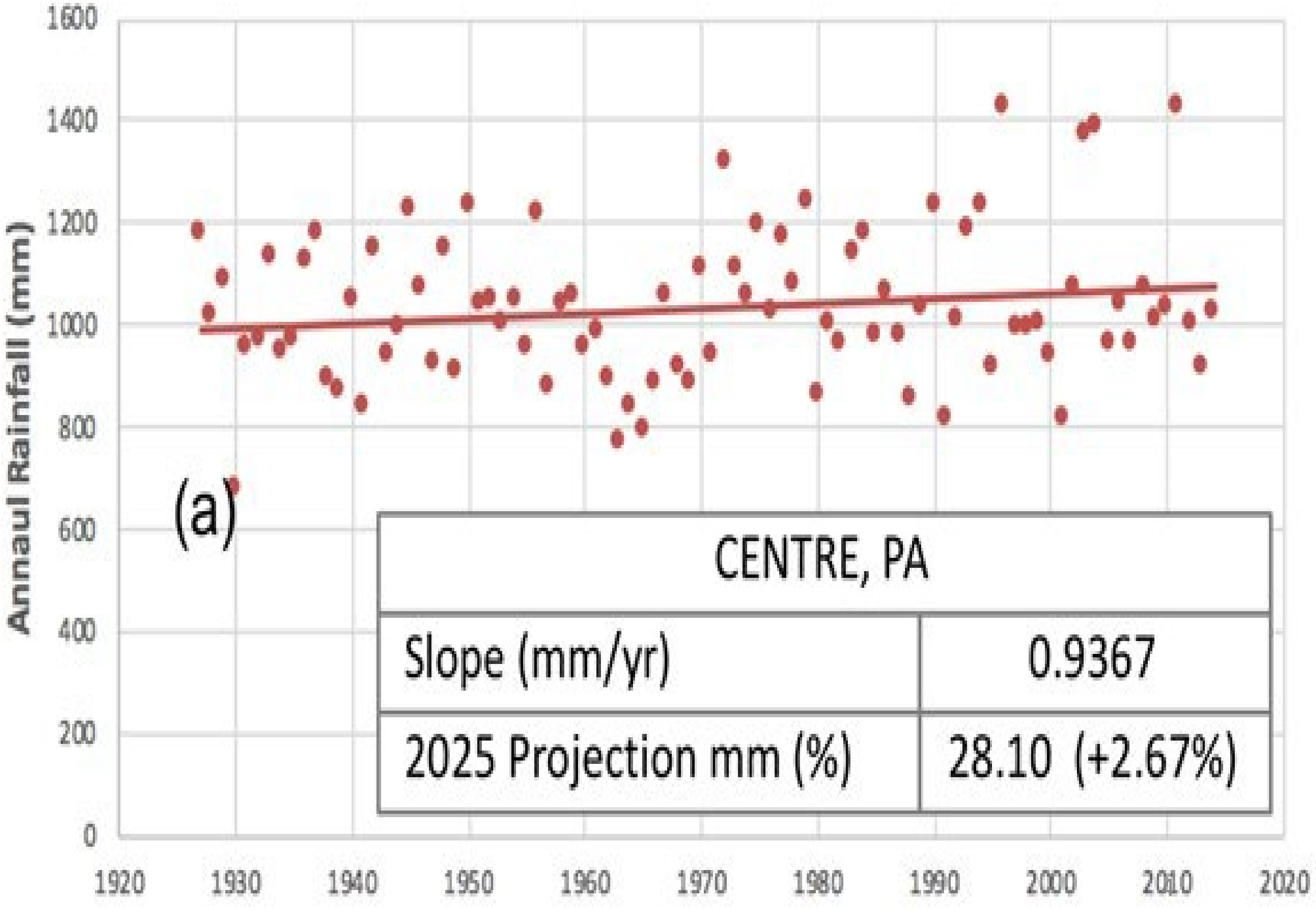
Climate Inputs Section 2
- Precipitation
- Temperature
- Potential Evapotranspiration
- Carbon dioxide

Land use and management Section 3
- Land use
- Agriculture
- WWTP and other direct sources
- Diversions

Simulation Section 4
- Carbon Effect
- Use of HSPF for hydrology
- Use of HSPF for sediment

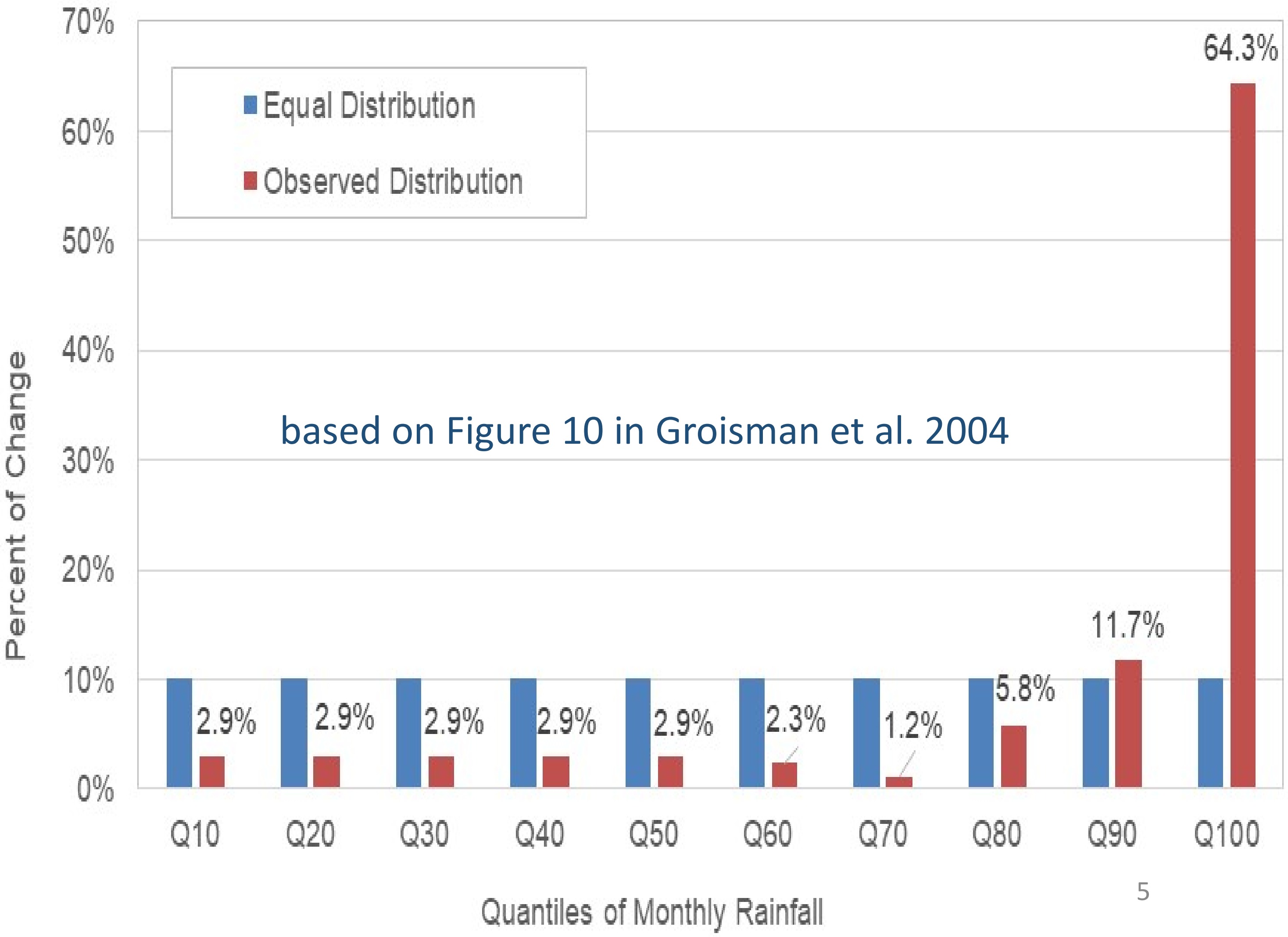
2025 Precipitation – Using observed trends

- PRISM 4-km grid 1927-2014
- OLS regression of annual rainfall
- Use slope X 30 years
- Applied as a percentage change to each month of rainfall



2025 Precipitation – Using observed trends

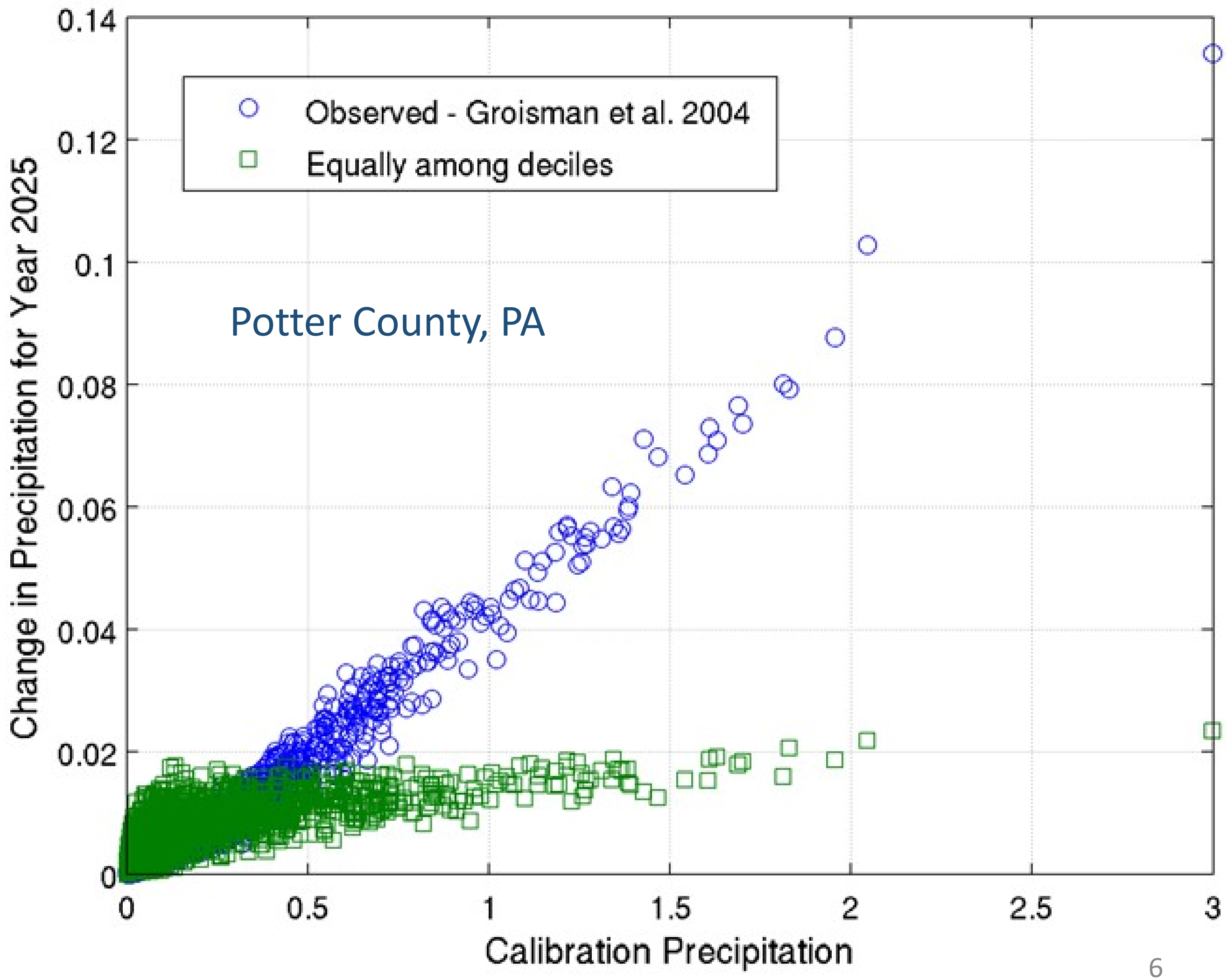
- Within a month
- Applied preferentially to highest quantiles of rainfall
- Applied as a multiplicative factor s.t. these percentages are kept



based on Figure 10 in Groisman et al. 2004

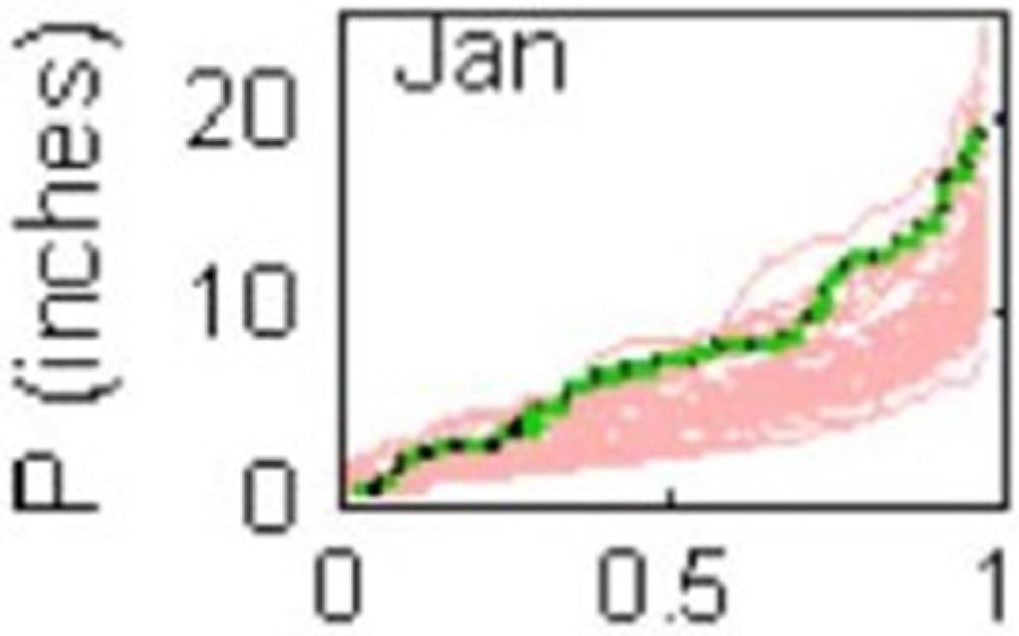
2025 Precipitation – Using observed trends

- Comparison of equal addition of rainfall across deciles and preferentially placed in highest decile



2025 Temperature – Using GCMs

- IPCC CMIP5 models
- Set of models used in NOAA's U.S. Climate Resilience Toolkit

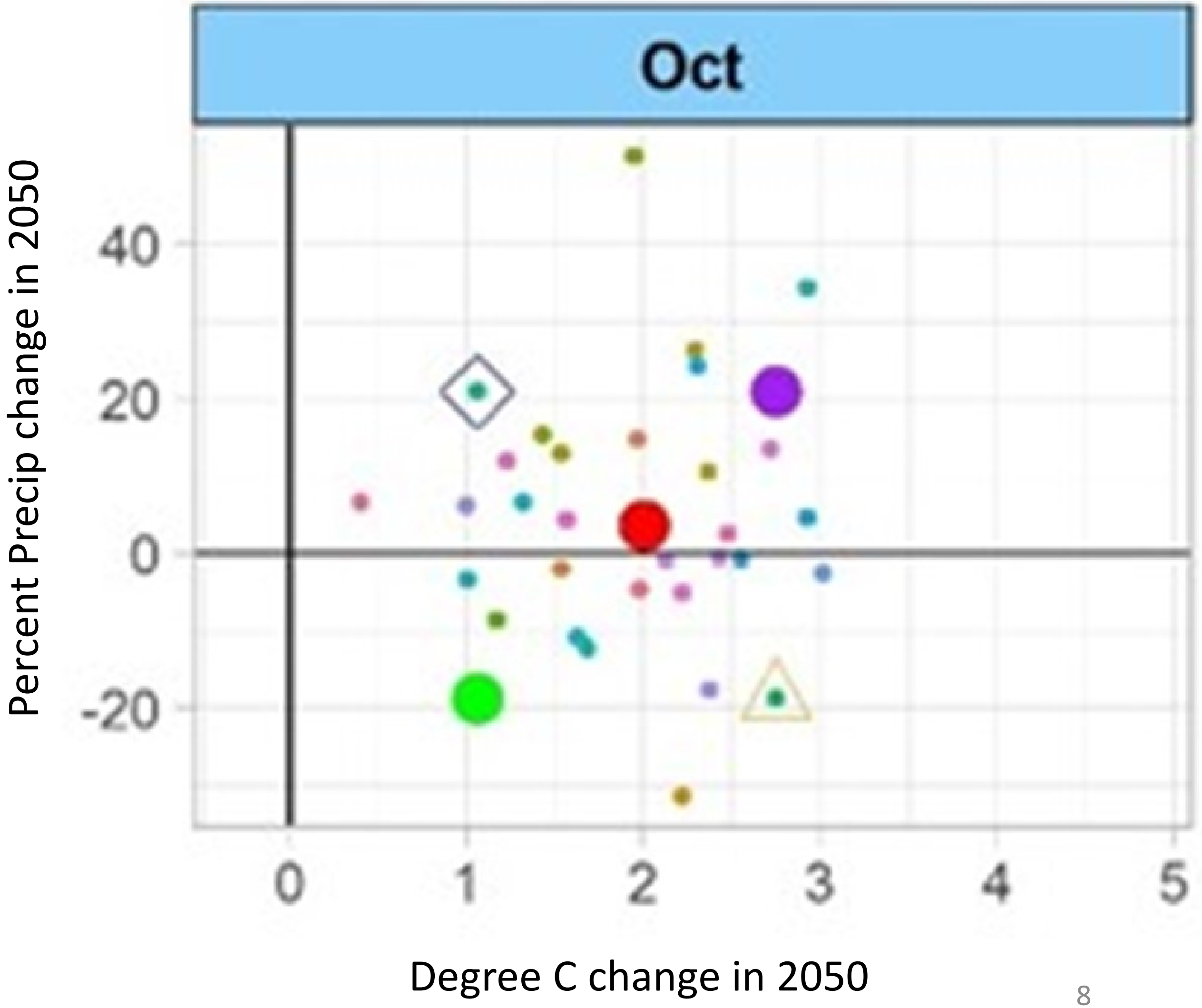


- Bias Corrected Spatial Disaggregation (BCSD) downscaling
  - Available
  - Recommended by data.gov
  - Extensive literature
  - As good as, but different than, MACA or LOCA downscaling
  - Similar to CBP WQSTM criteria attainment method

STAC 2016 CC workshop recommendations

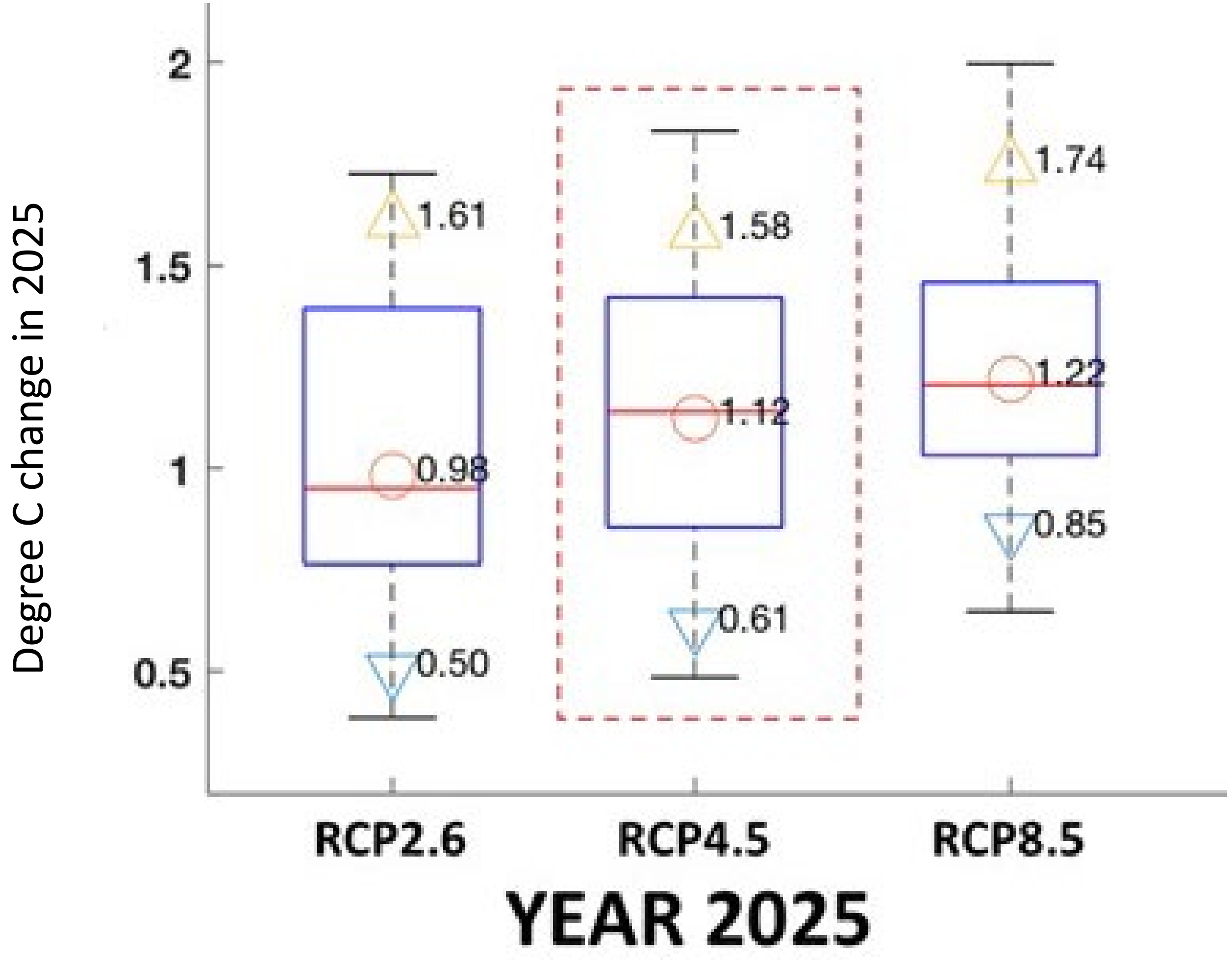
2025 Temperature – Selecting GCMs

- Use a 30-year span
- The chart represents the difference between October temperatures in 1981-2010 and 2036-2065
- Same as 2025 method between 1981-2010 and 2011-2040
- Select median monthly change
- 10th and 90th for uncertainty
- Applied as constant degree addition



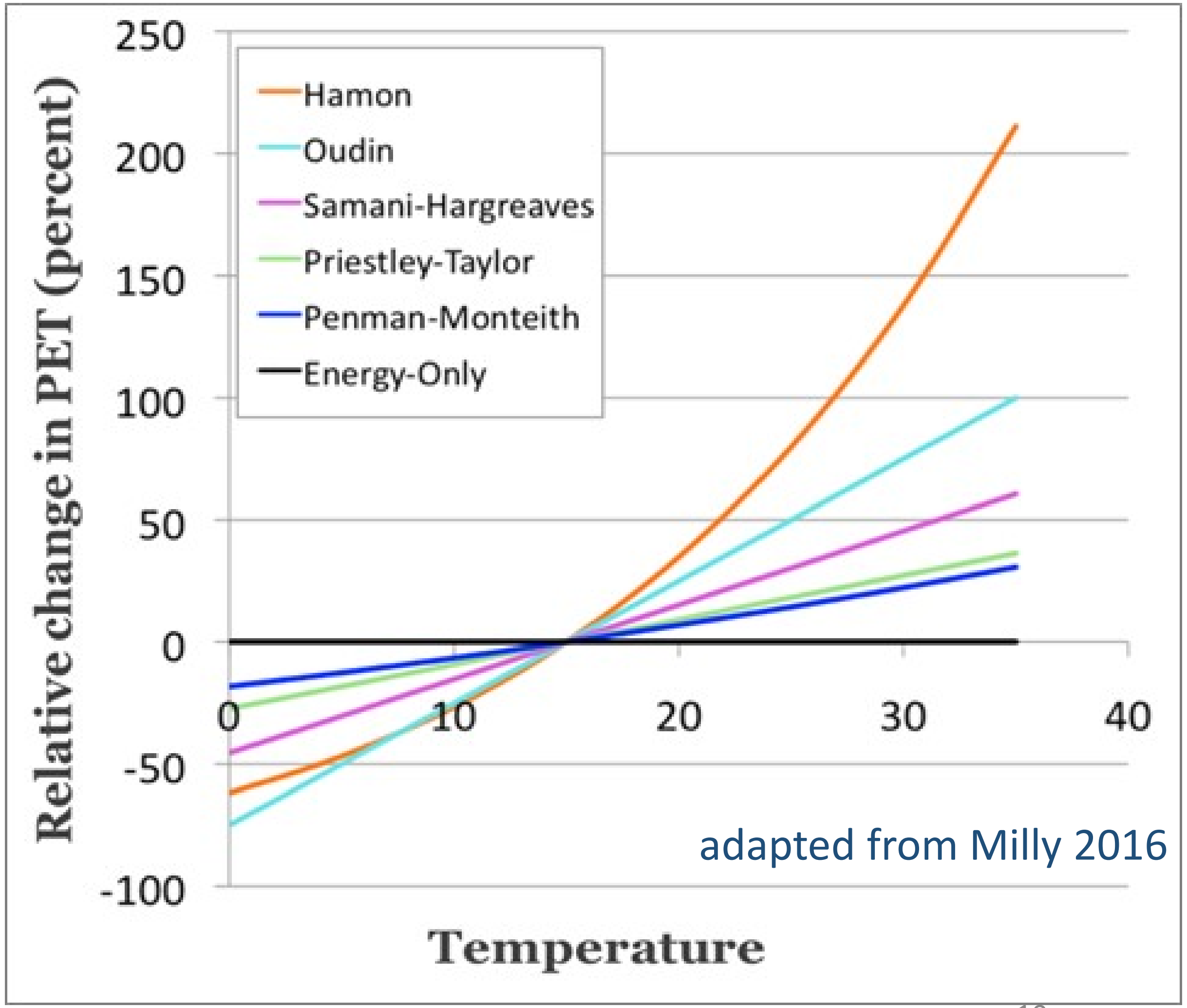
2025 Temperature – Selecting RCP

- Selection of RCP has little effect on 2025 predictions of temperature
- Using RCP 4.5

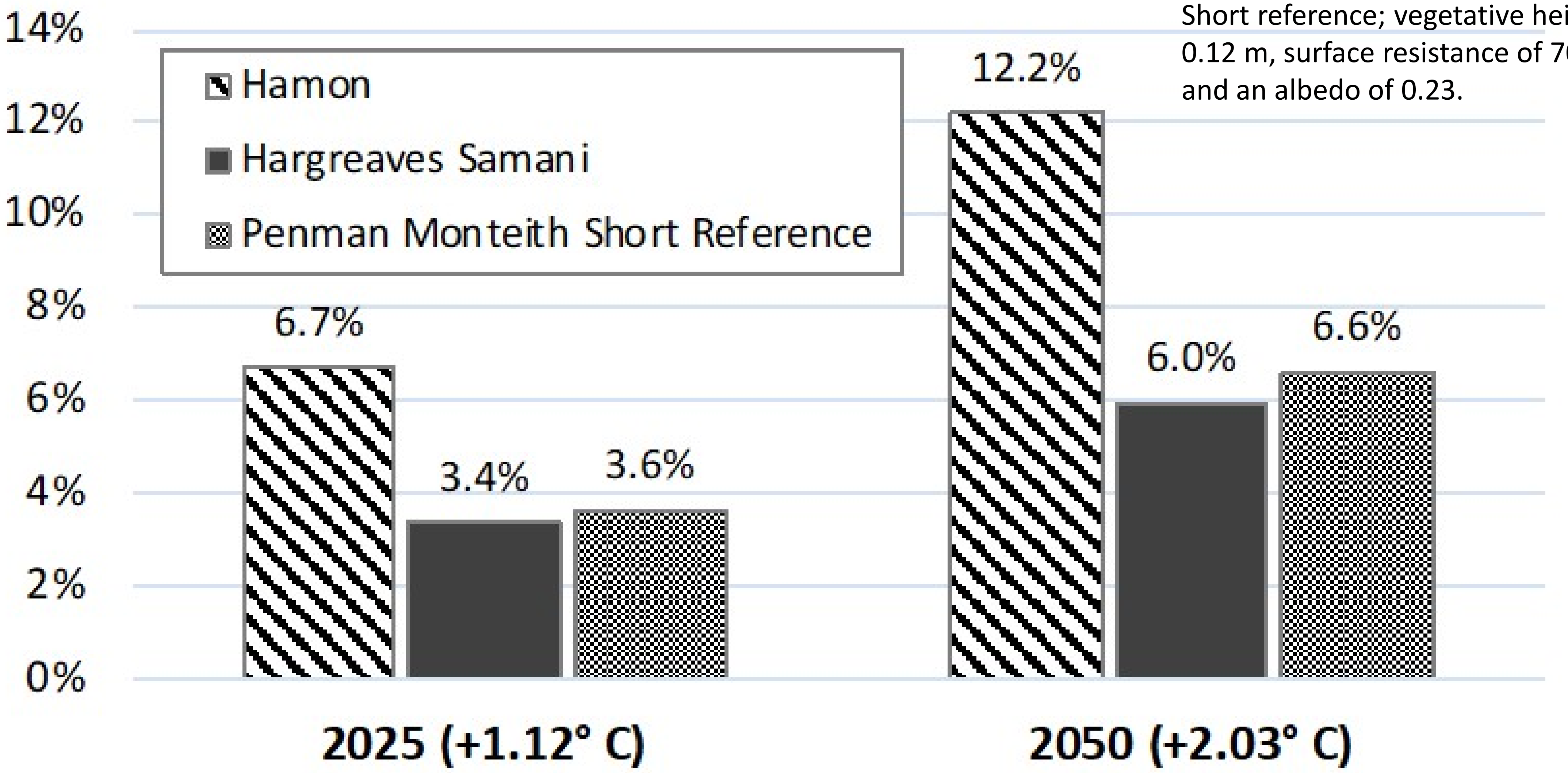


2025 Potential Evapotranspiration

- Hamon method (phase 6 default) not suitable to climate change relative to Penman-Montieth
- P-M and Priestly-Taylor too data-intensive.
- Samani-Hargreaves relies only on extraterrestrial radiation and temperature



2025 Potential Evapotranspiration

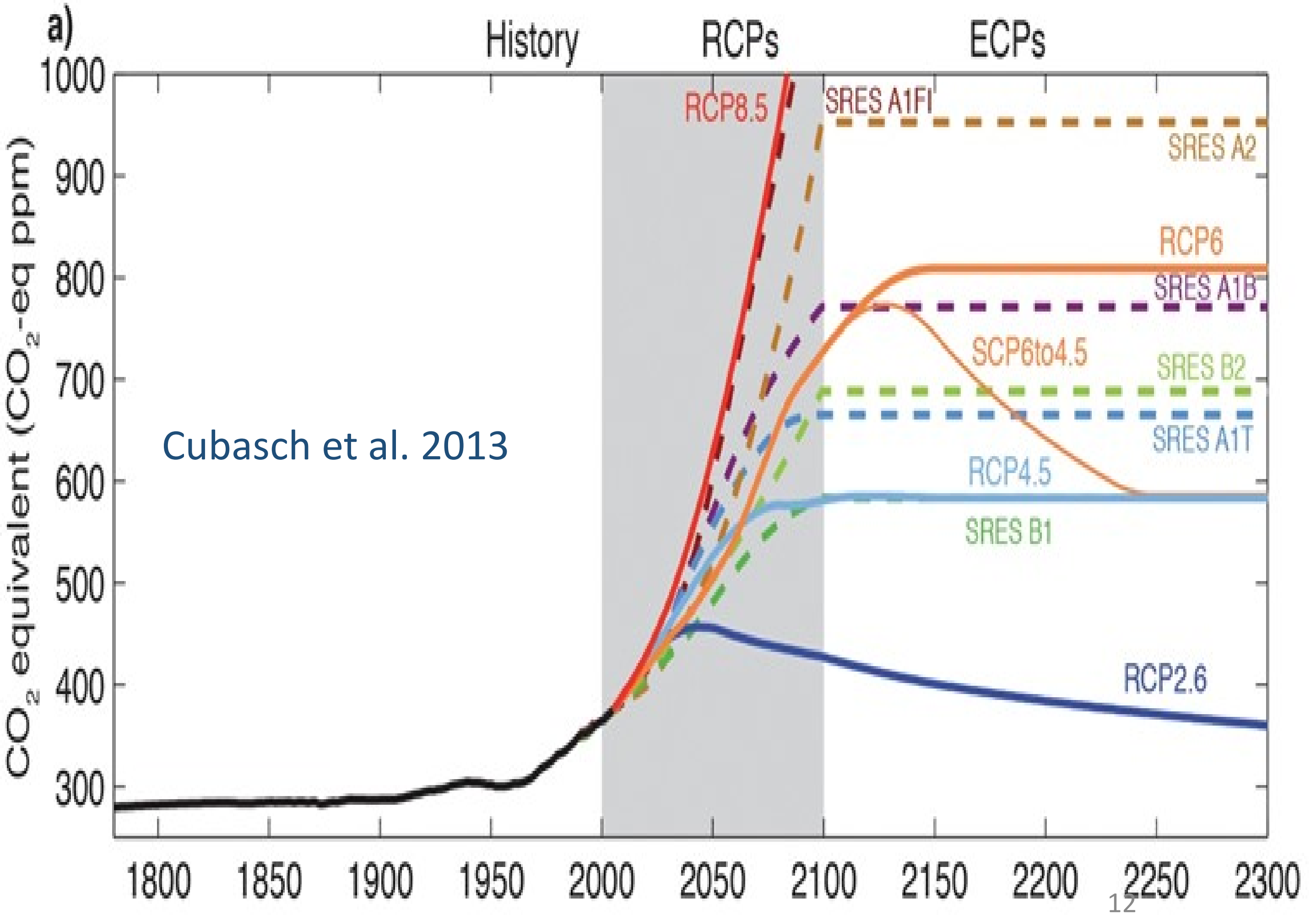


Short reference; vegetative height of 0.12 m, surface resistance of 70 s/m, and an albedo of 0.23.

2025 CO2

- CO2 decreases transpiration due to closing of the stomata.
- Using IPCC-specified values

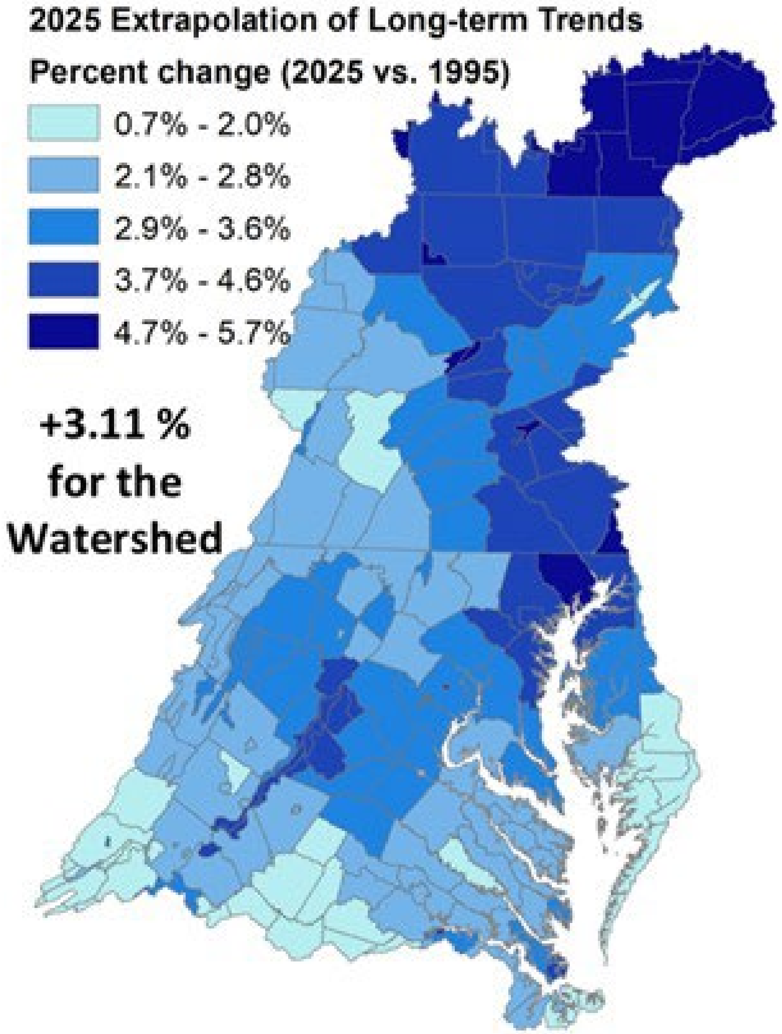
Year	Observed	RCP2.6	RCP4.5	RCP6.0	RCP8.5
PI	***278 ± 2***	***278***	***278***	***278***	***278***
***2011** obs*	***390.5 ± 0.3***				
2000		368.9	368.9	368.9	368.9
2005		378.8	378.8	378.8	378.8
2010		389.3	389.1	389.1	389.3
2020		412.1	411.1	409.4	415.8
2030		430.8	435.0	428.9	448.8
2040		440.2	460.8	450.7	489.4
2050		442.7	486.5	477.7	540.5
2060		441.7	508.9	510.6	603.5
2070		437.5	524.3	549.8	677.1
2080		431.6	531.1	594.3	758.2
2090		426.0	533.7	635.6	844.8
2100		420.9	538.4	669.7	935.9



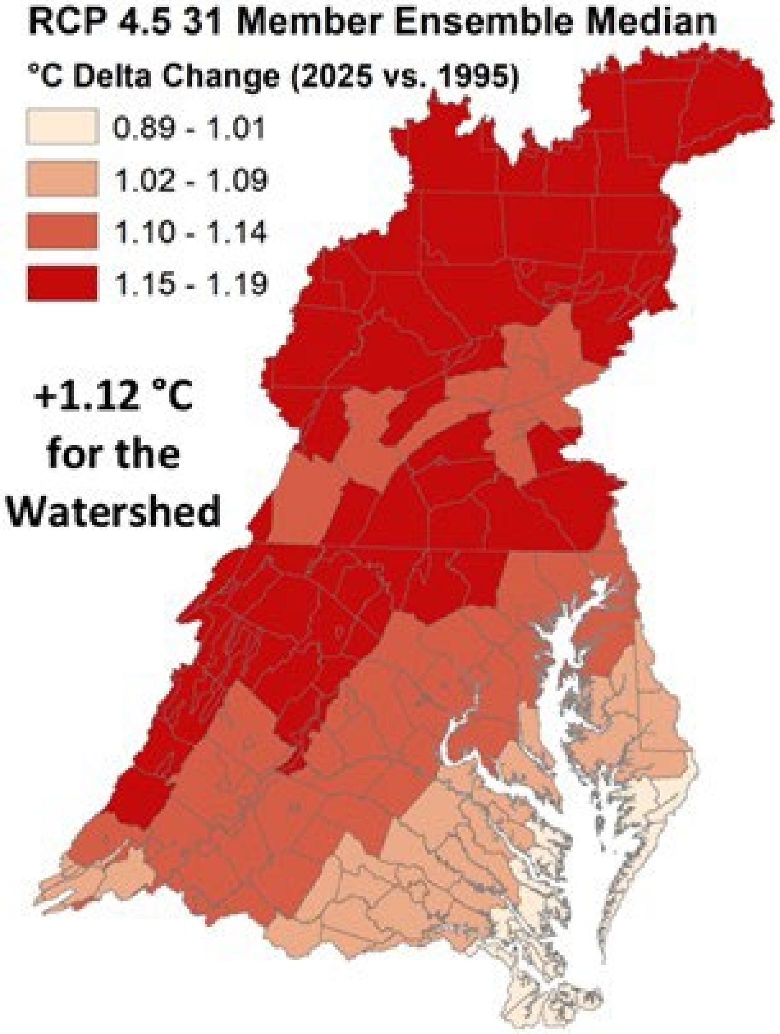
Cubasch et al. 2013

2025 Climate vs 1995 Climate

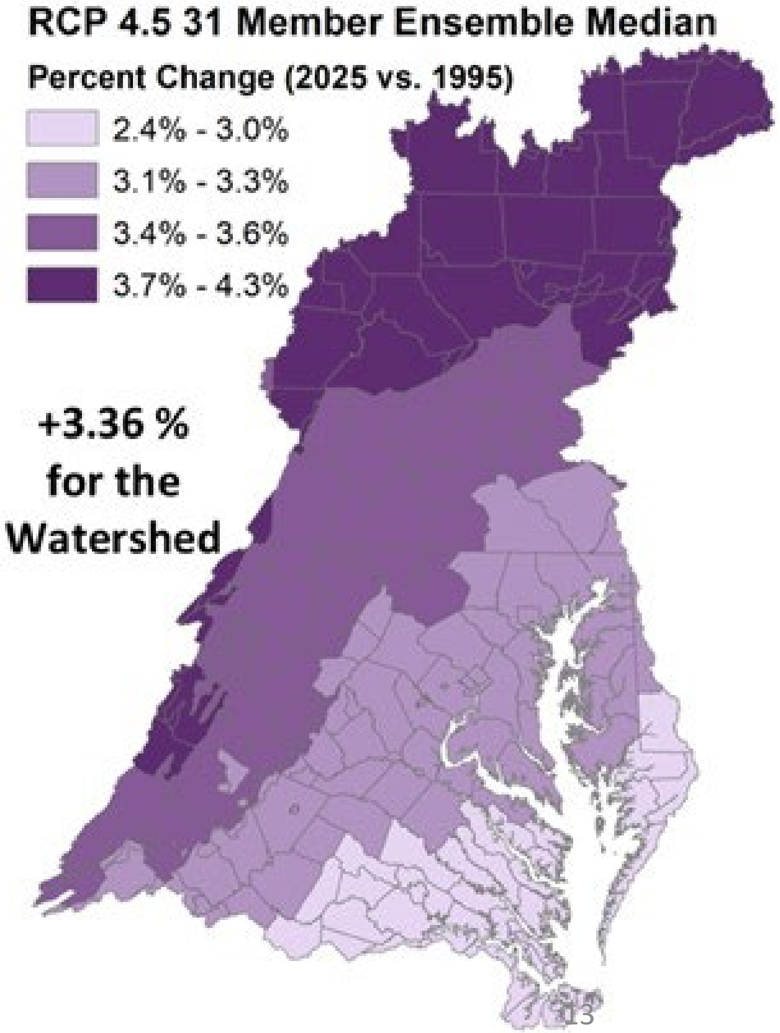
Precipitation



Temperature

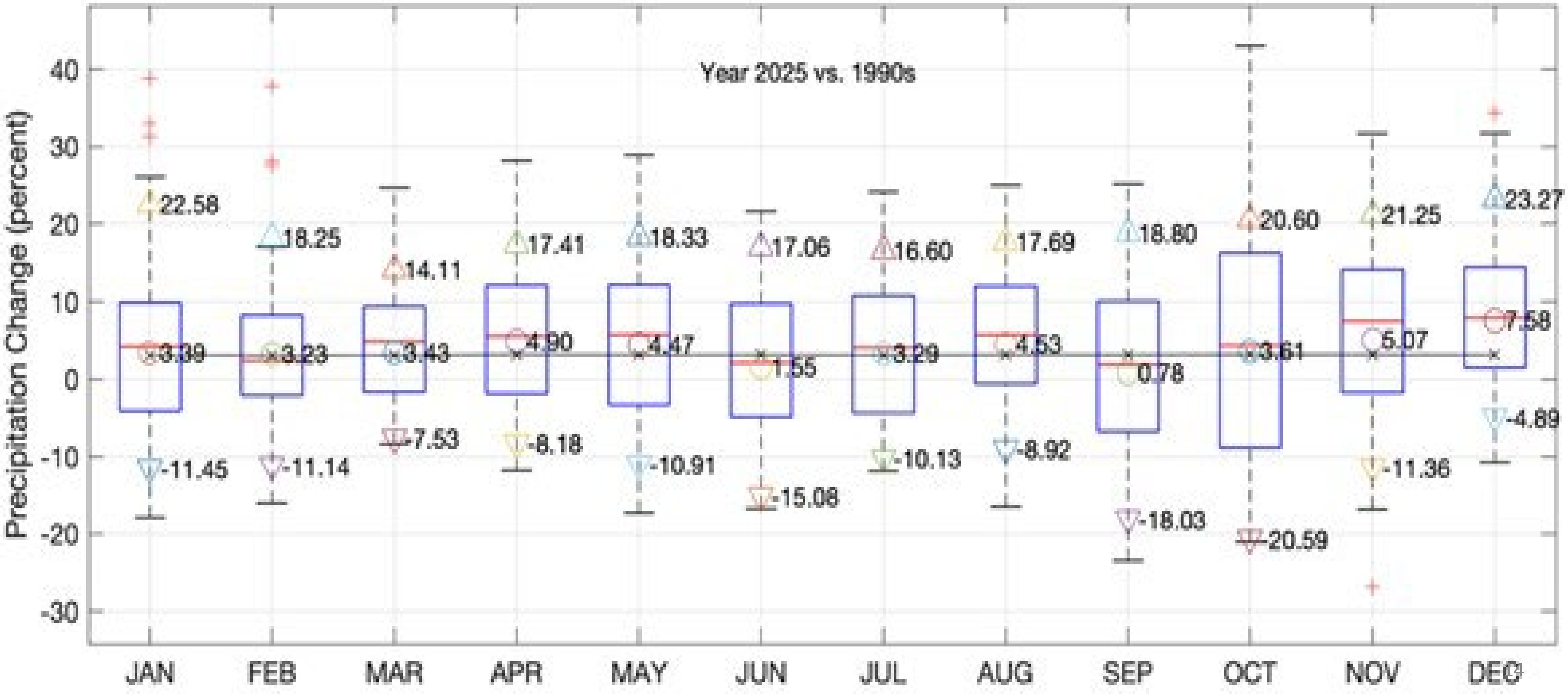


PET



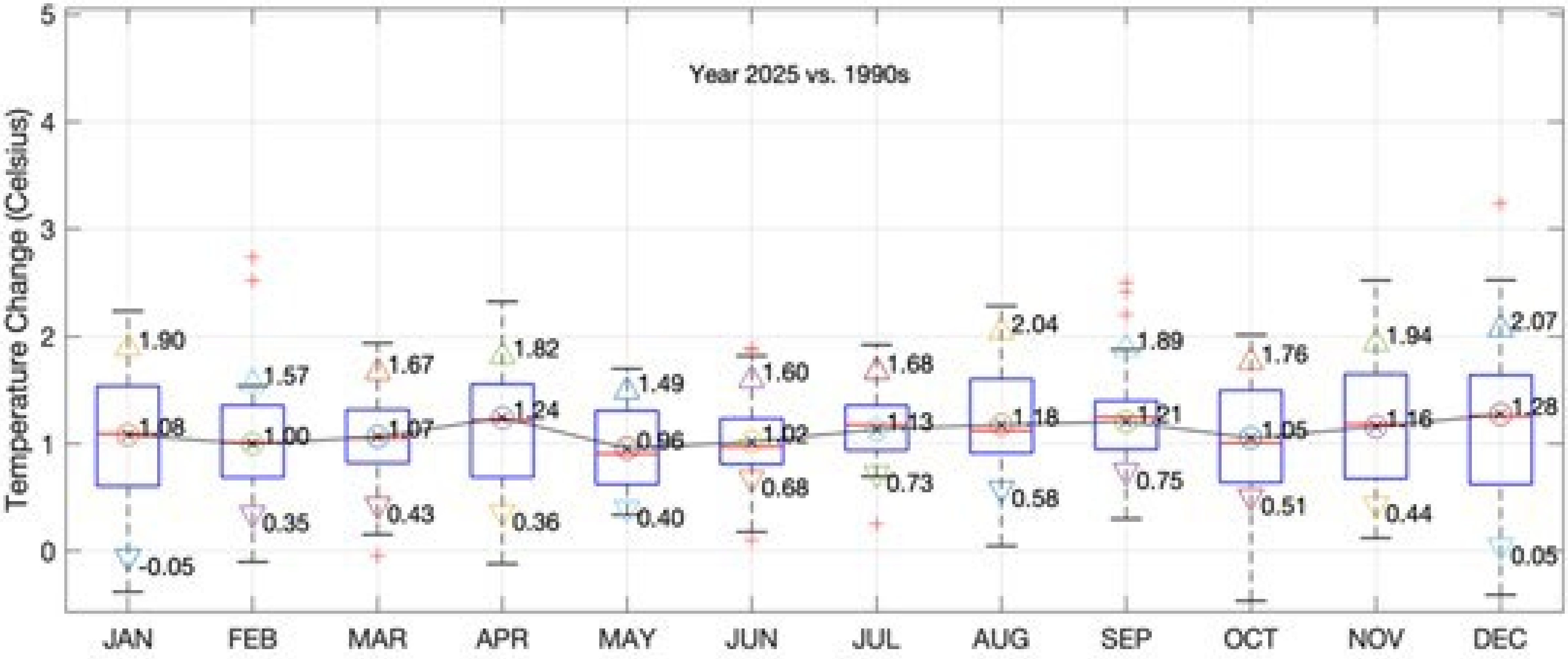
2025 Precipitation

Trend vs Ensemble

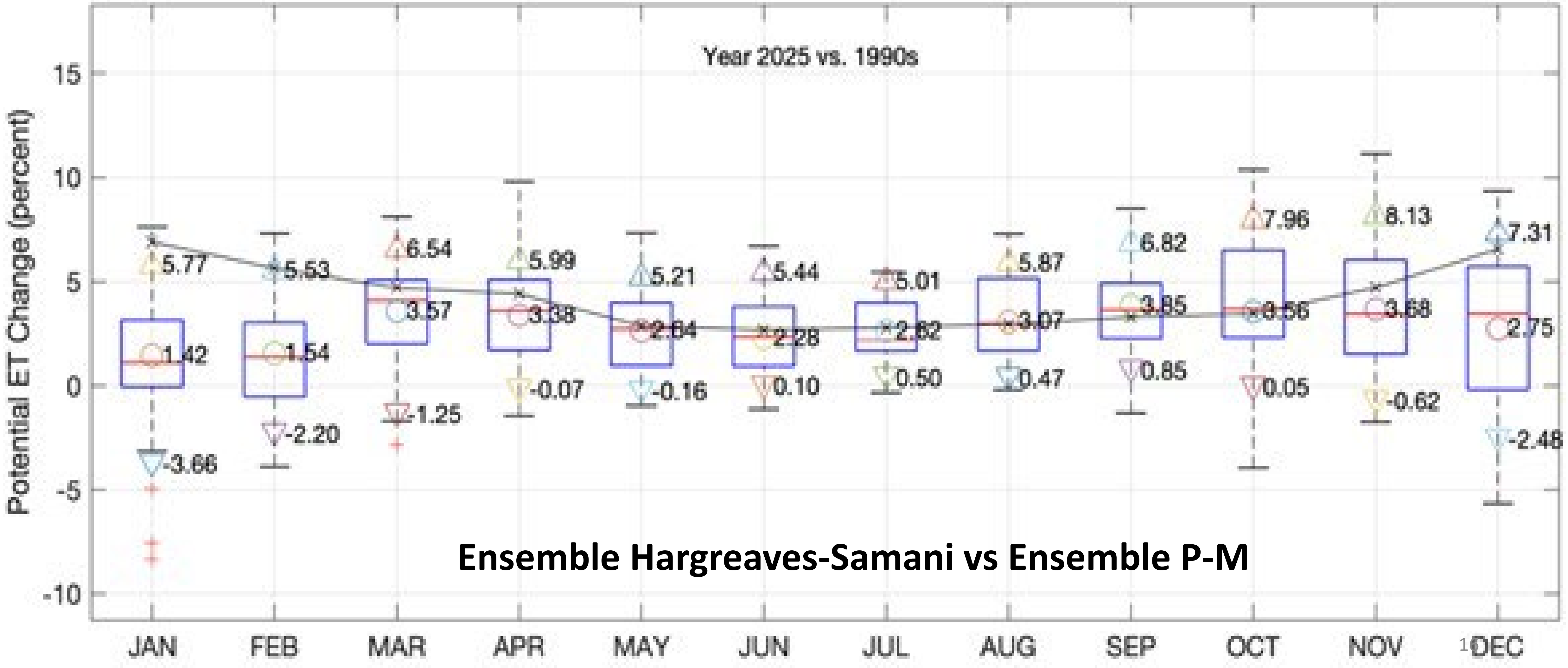


2025 Temperature

Ensemble



2025 Potential Evapotranspiration



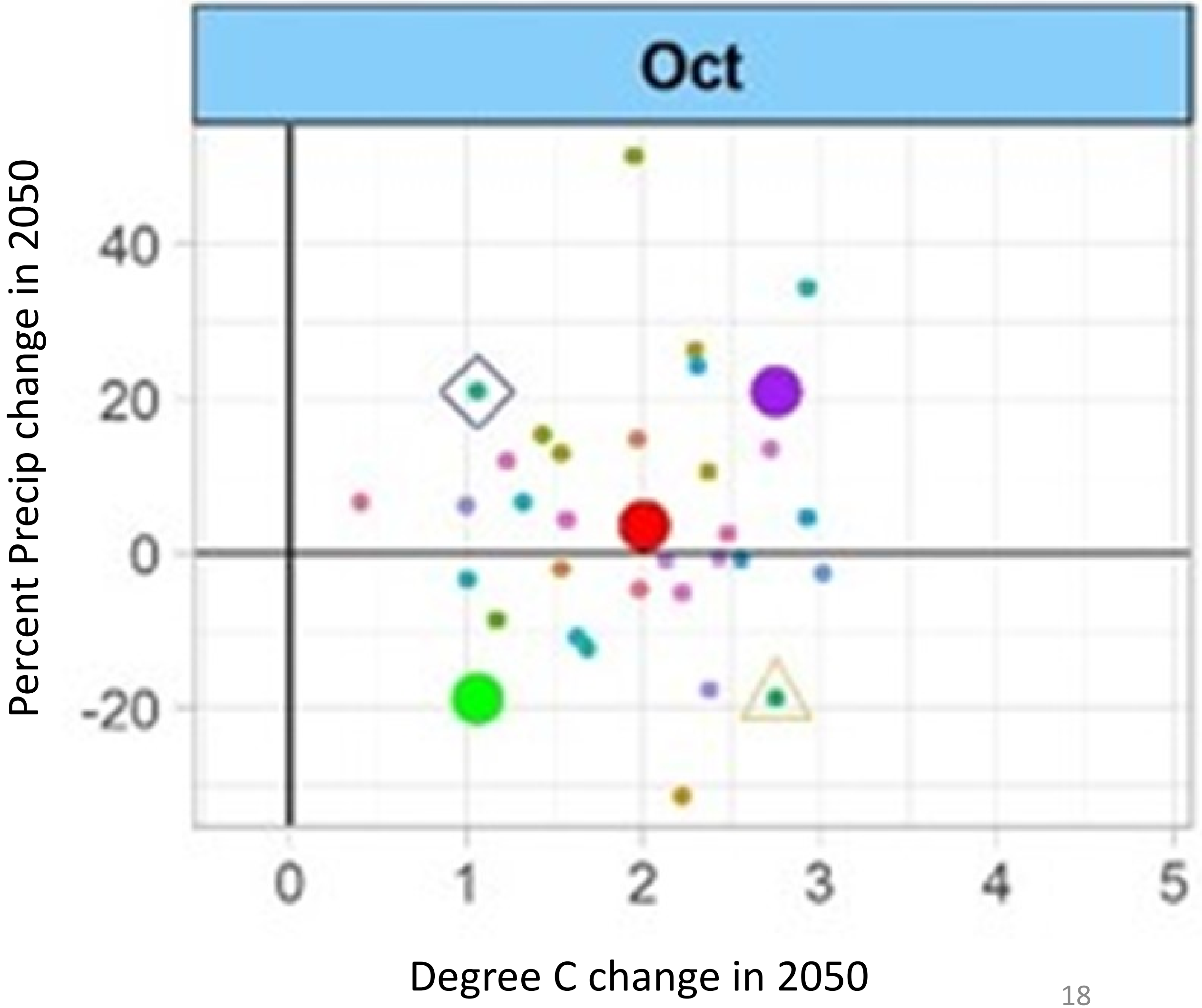
Ensemble Hargreaves-Samani vs Ensemble P-M

2035, 2045, 2055 Climate

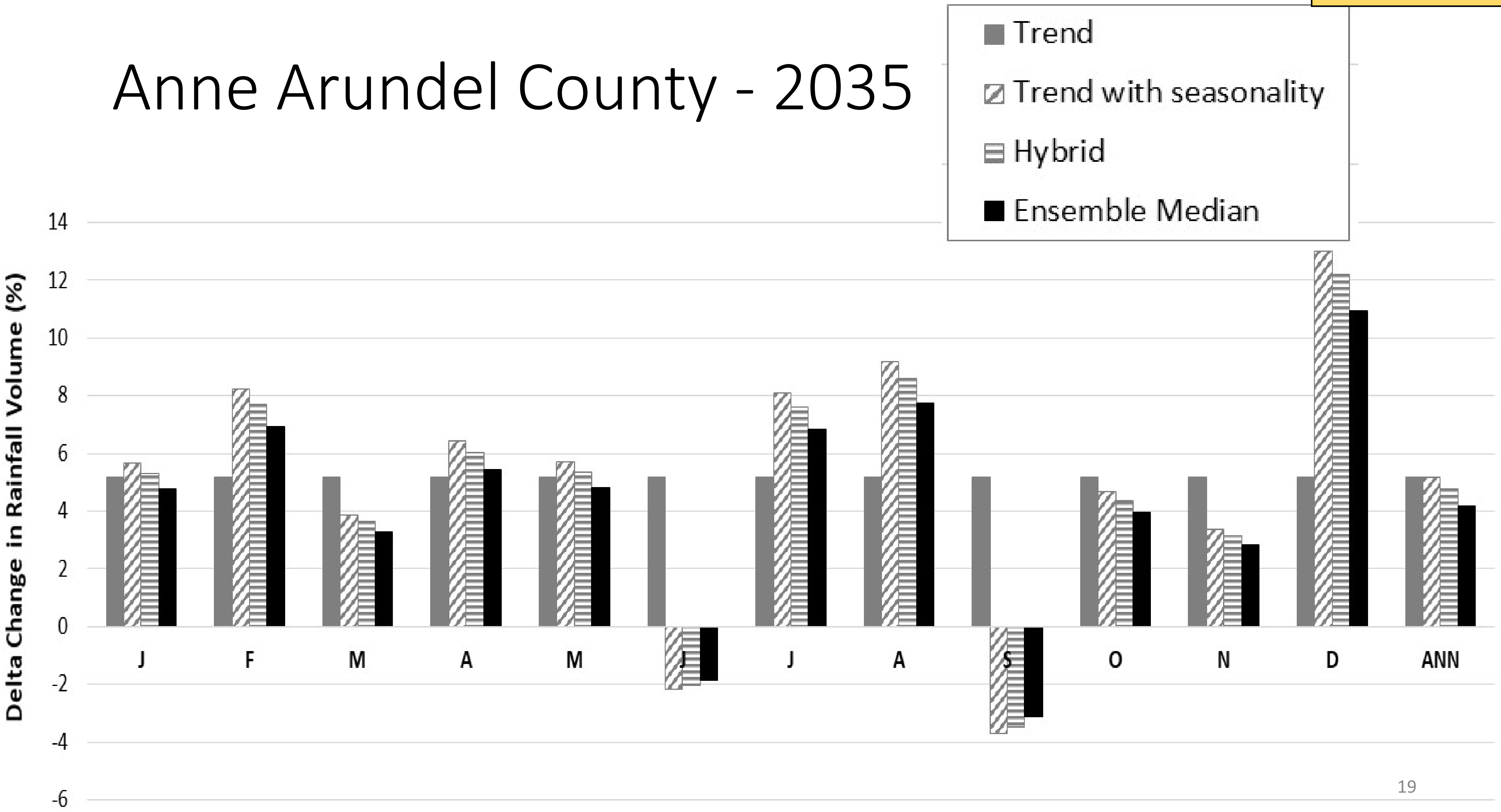
- Temperature, CO_2, and PET follow the same methods as 2025
- Precipitation
  - Decision of MWG to use trend at 2025 and ensemble at 2050
  - 2035 estimate => 60% trend, 40% ensemble
  - 2045 estimate => 20% trend, 80% ensemble
  - 2055 estimate => 100% ensemble

GCM ensemble Precipitation

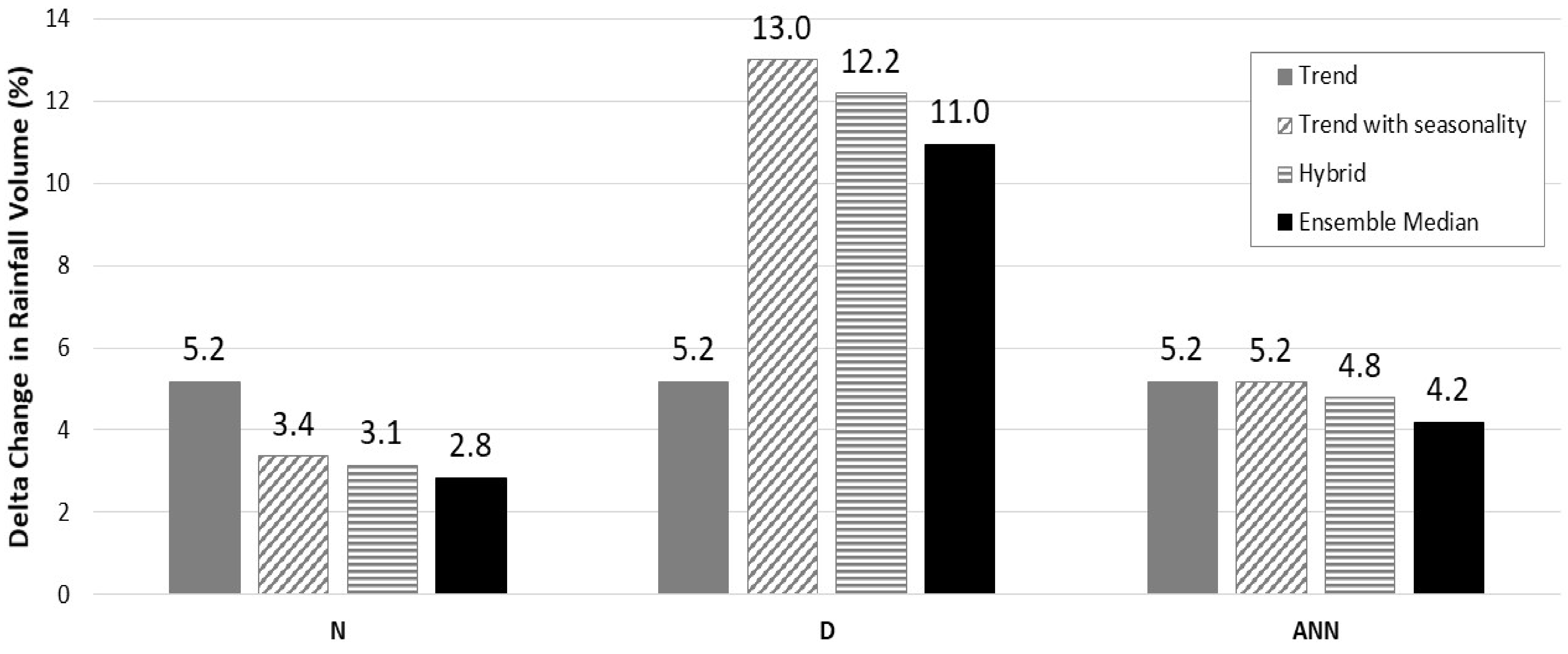
- Same models and downscaling as temperature
- Select median monthly change
- 10th and 90th for uncertainty
- Applied as percent change by month
- Monthly variability applied consistent with GCMs for all years



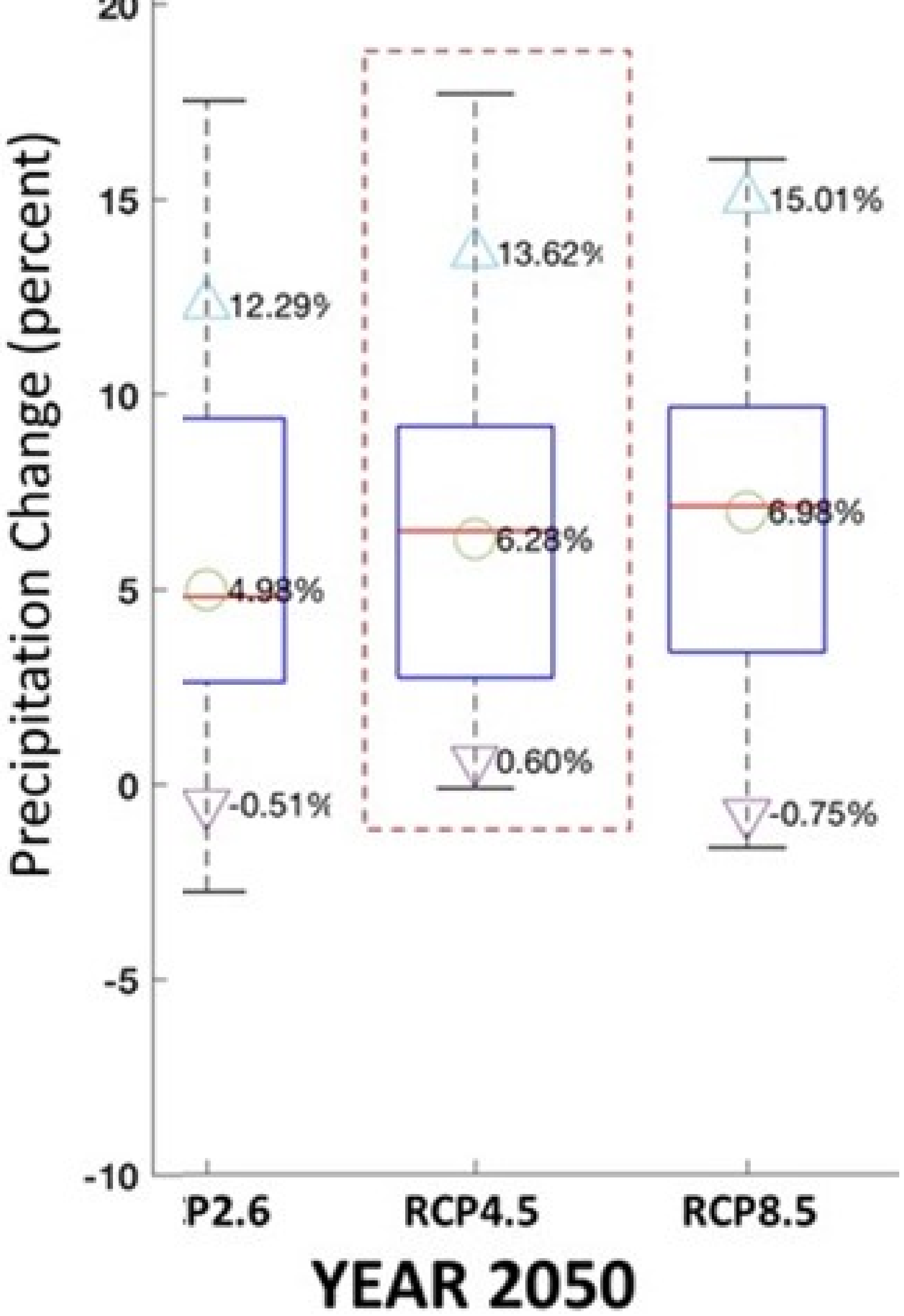
Anne Arundel County - 2035



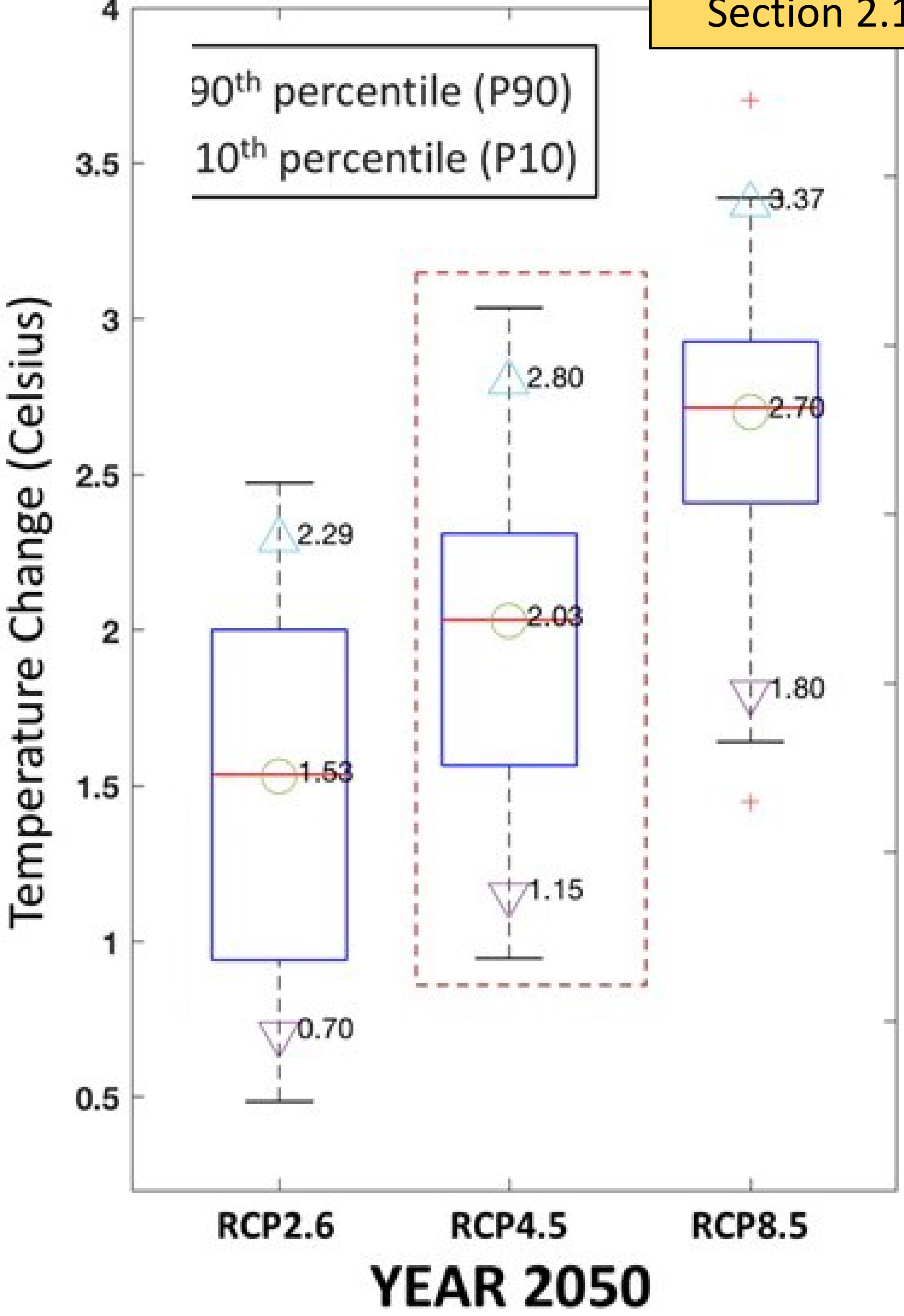
Anne Arundel County - 2035



RCP 4.5



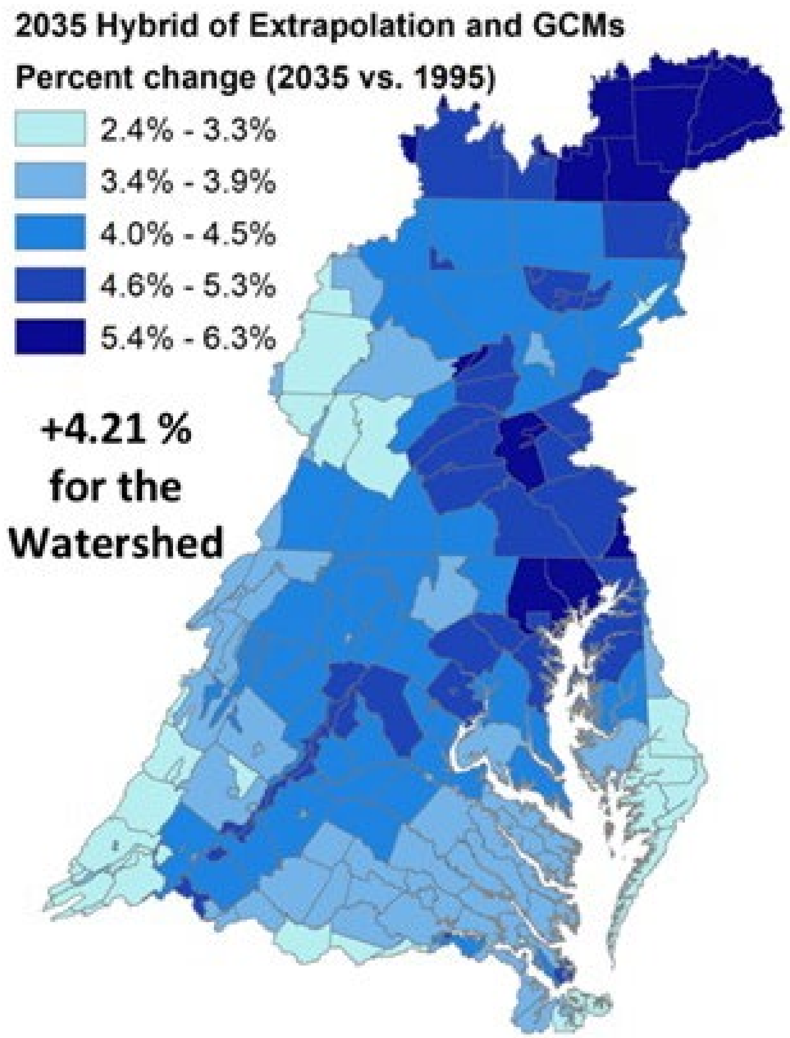
Precipitation Change (percent)
20
15
10
5
0
-5
-10
12.29%
4.98%
-0.51%
13.62%
6.28%
0.60%
15.01%
6.98%
-0.75%
P2.6
RCP4.5
RCP8.5
YEAR 2050



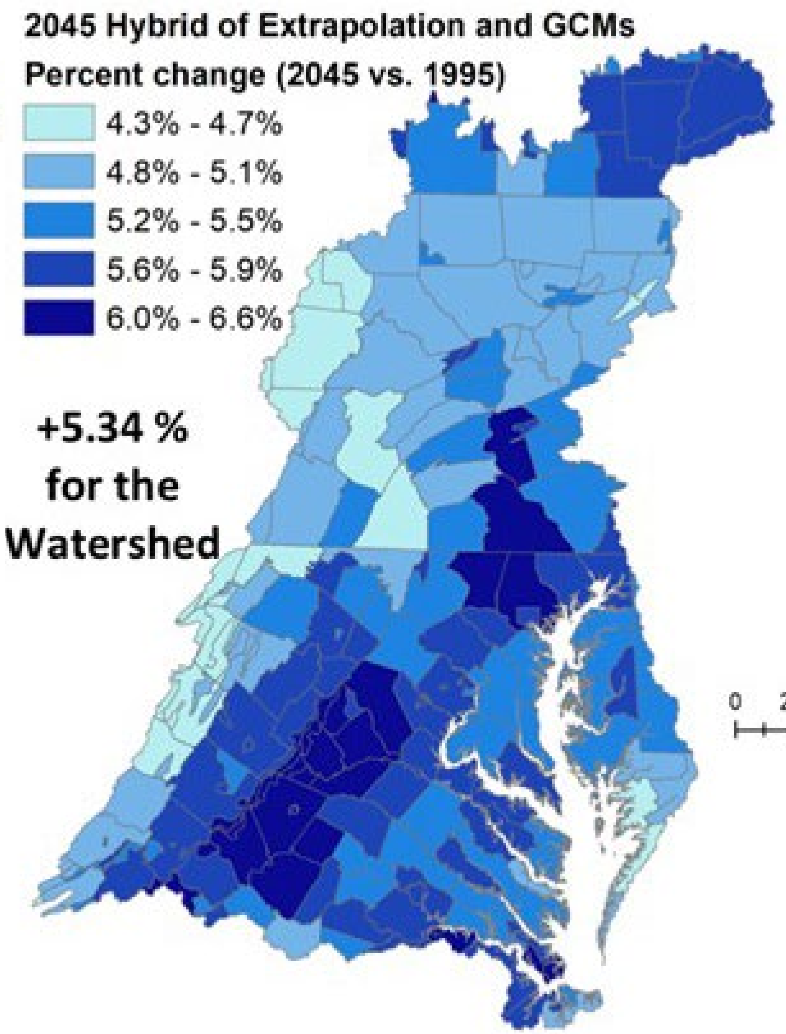
Temperature Change (Celsius)
90th percentile (P90)
10th percentile (P10)
4
3.5
3
2.5
2
1.5
1
0.5
2.29
1.53
0.70
2.80
2.03
1.15
3.37
2.70
1.80
RCP2.6
RCP4.5
RCP8.5
YEAR 2050

Precipitation

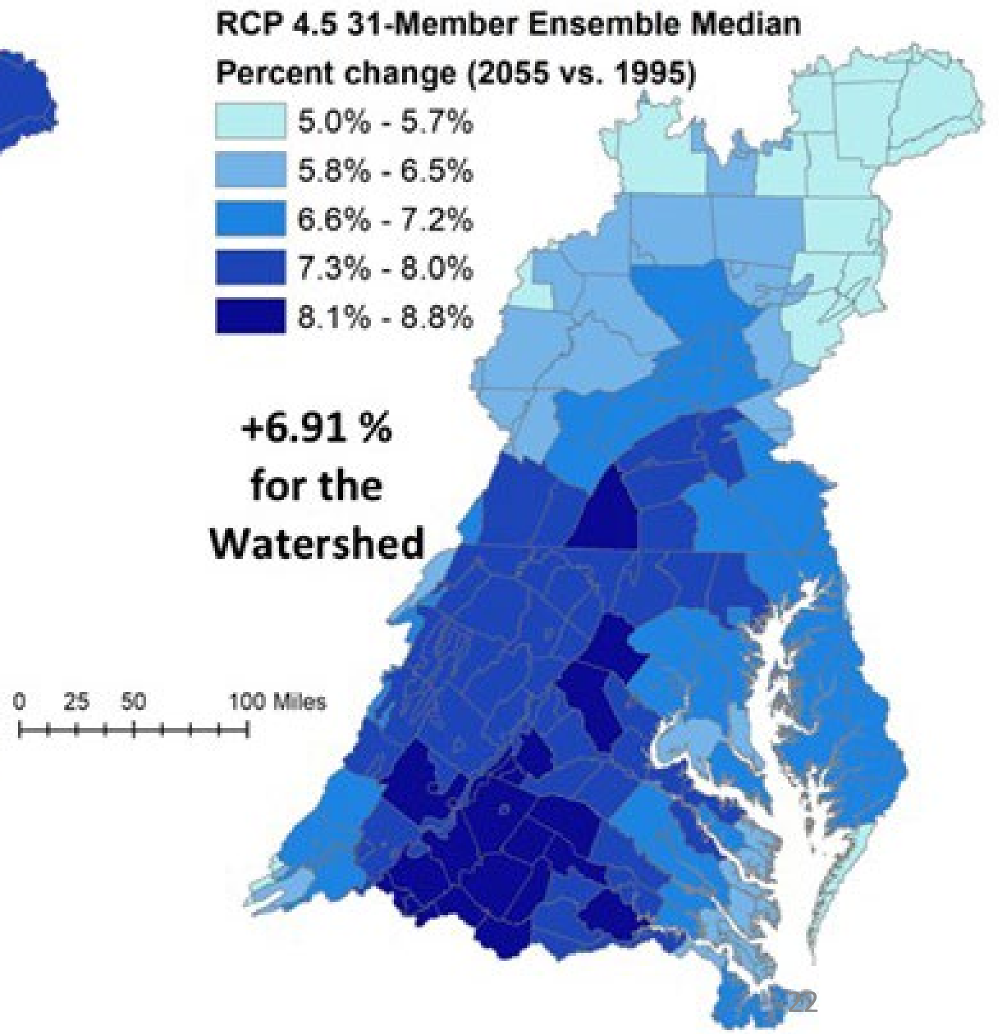
2035



2045

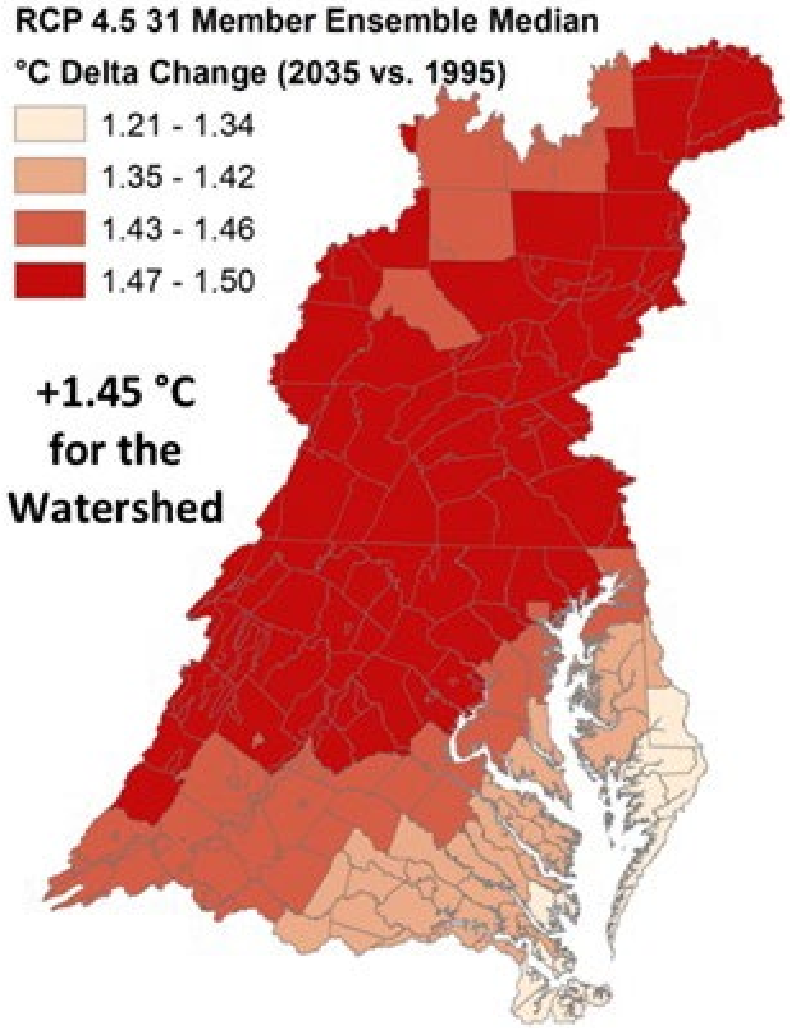


2055

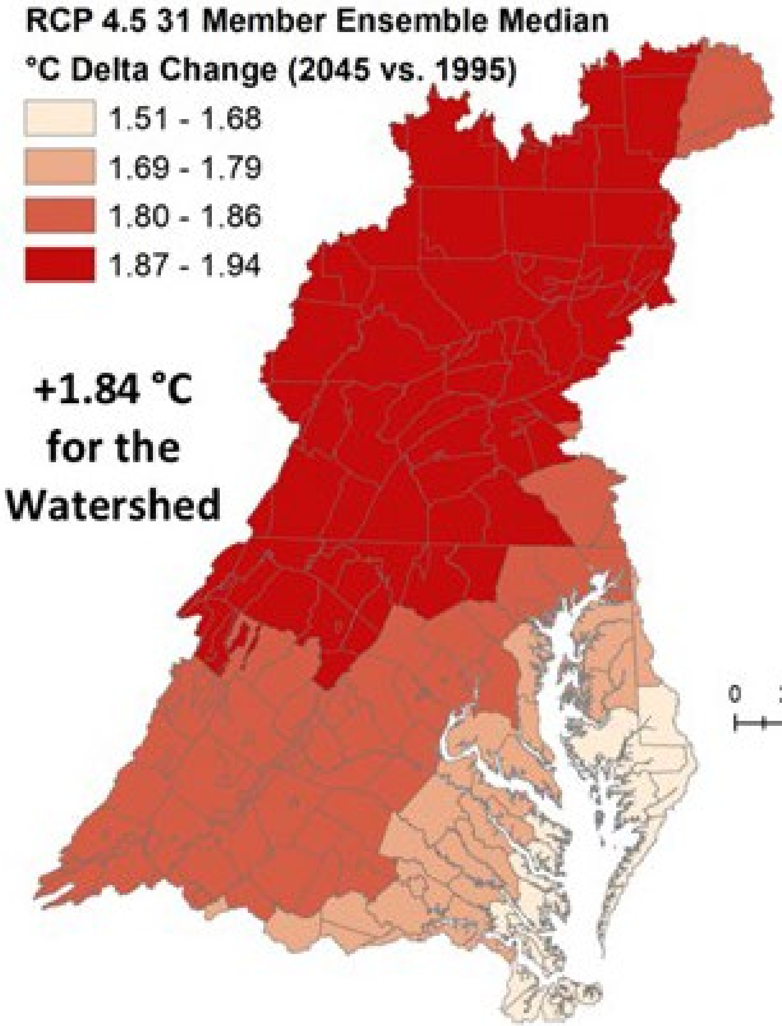


Temperature

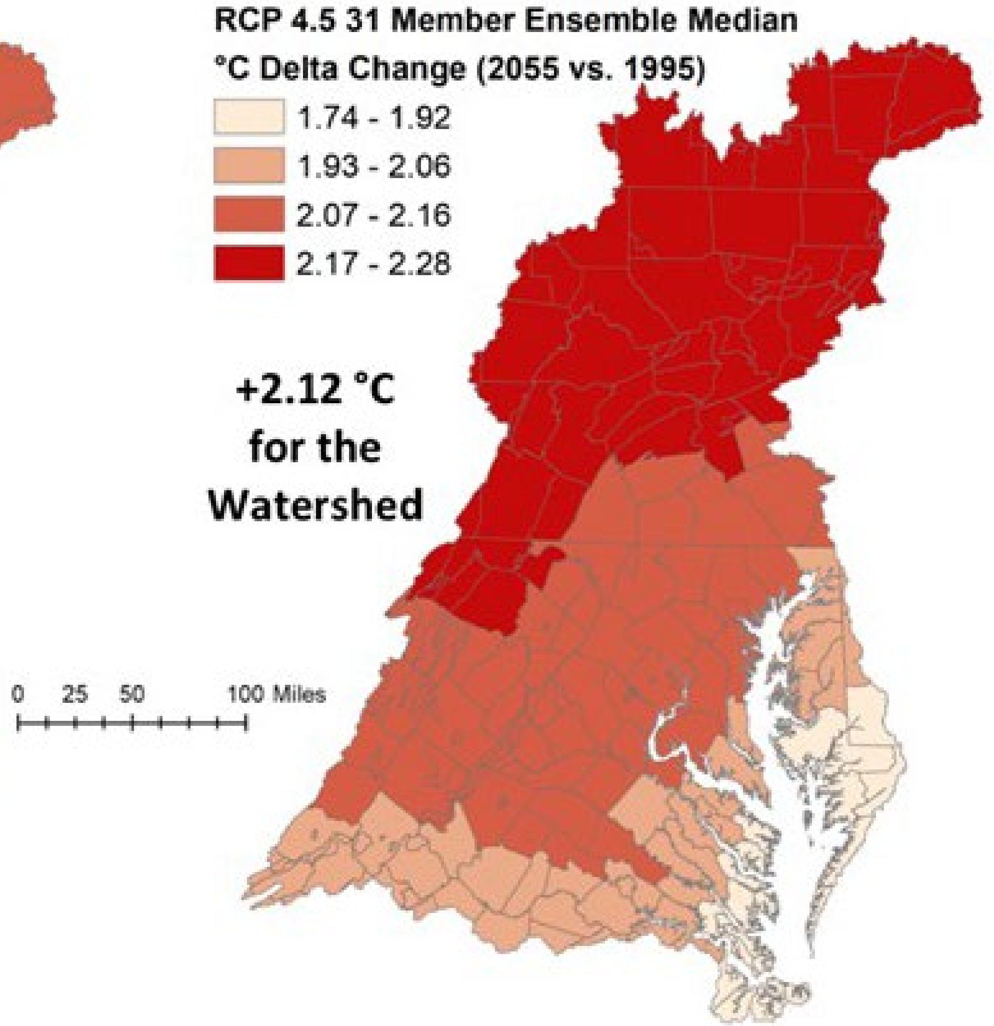
2035



2045

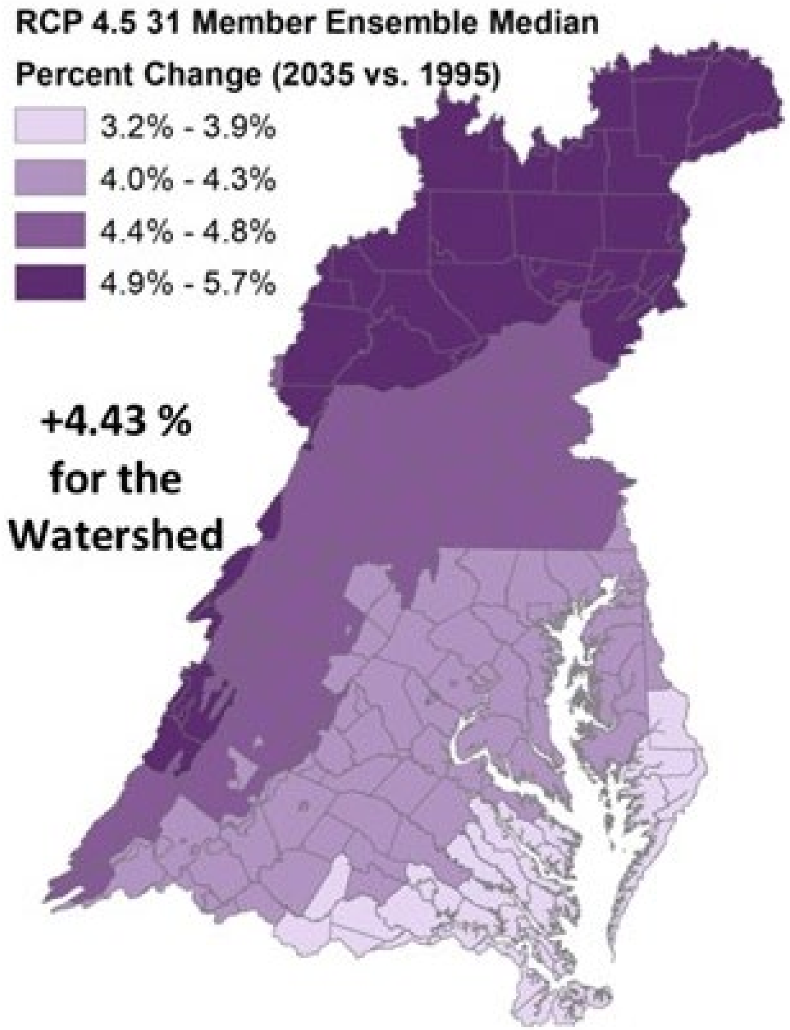


2055

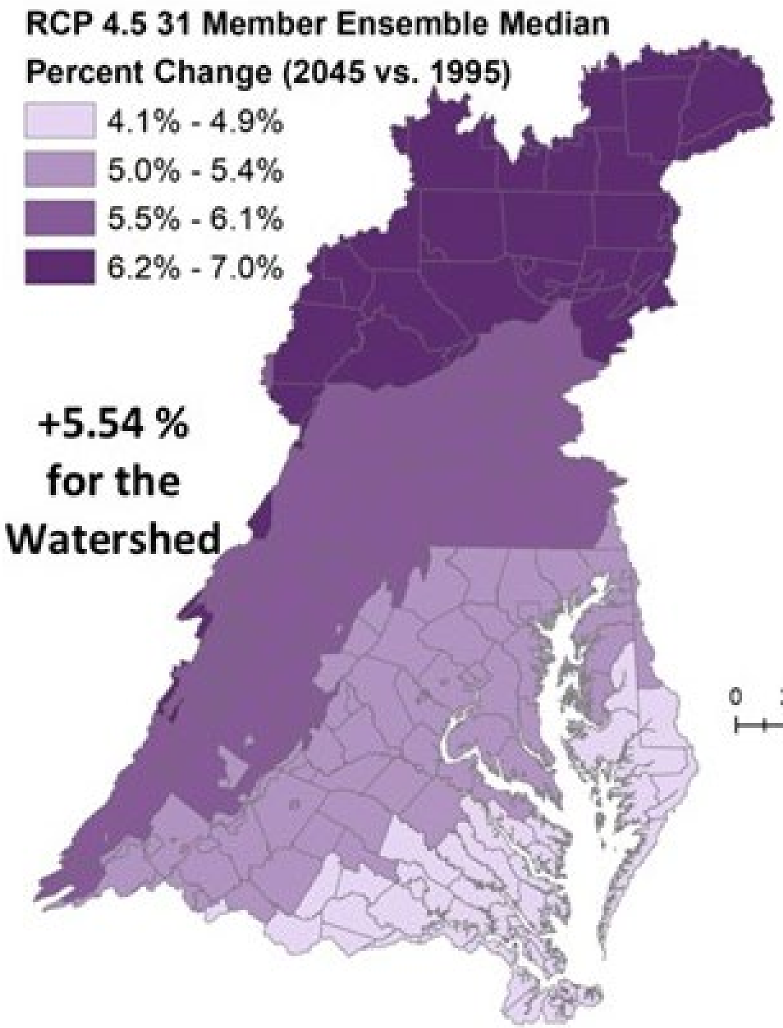


PET

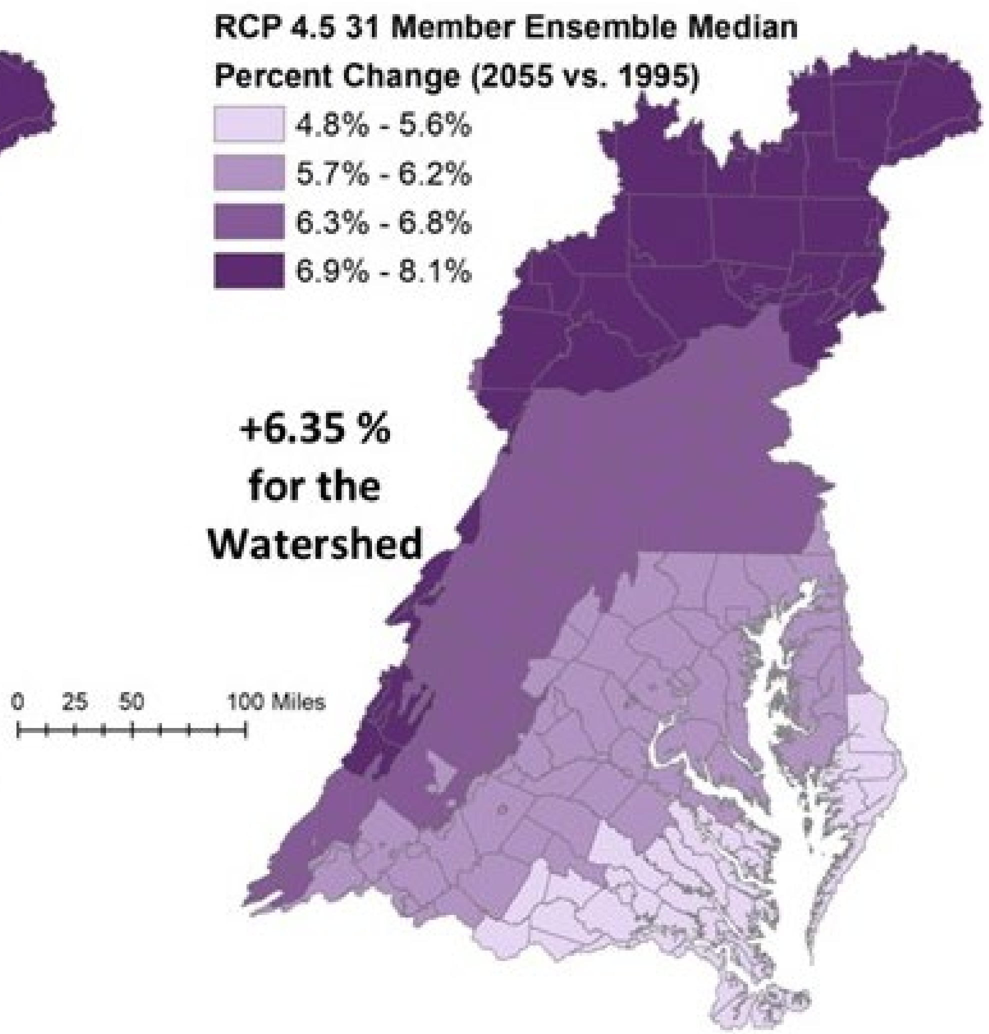
2035



2045



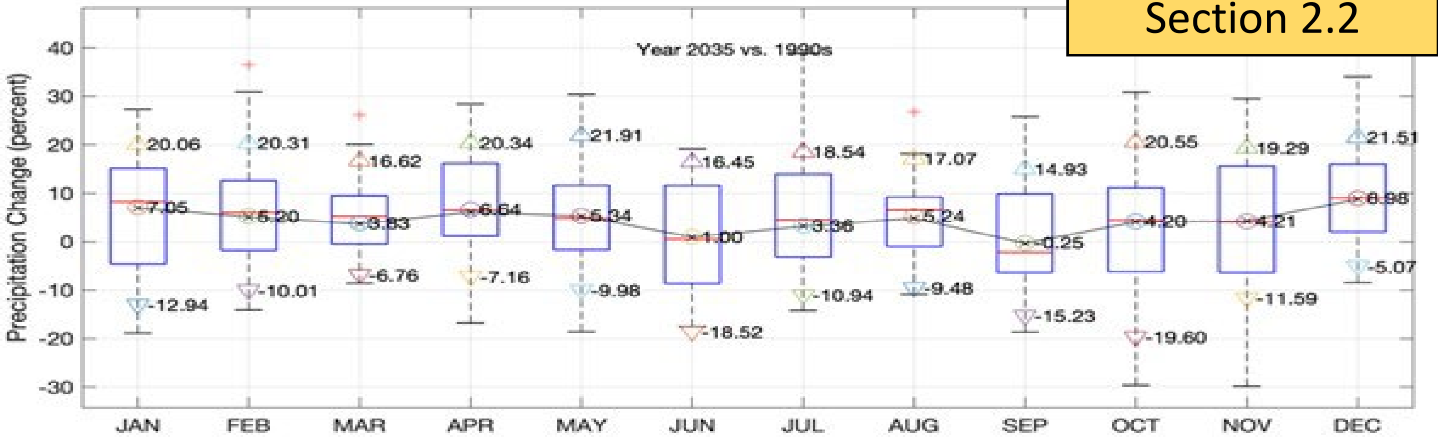
2055



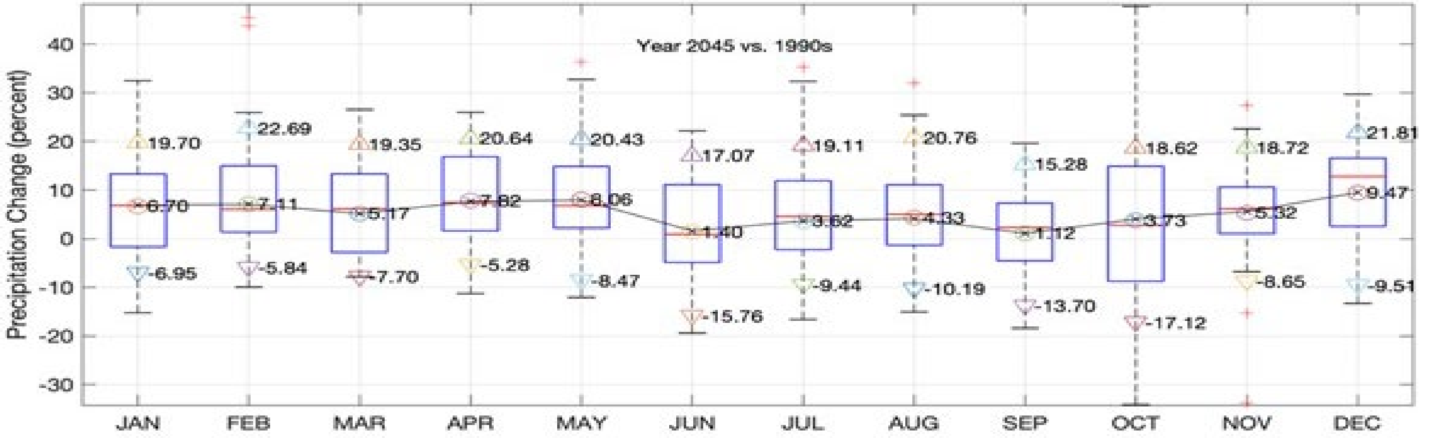
Precipitation

Trend/Ensemble vs Ensemble

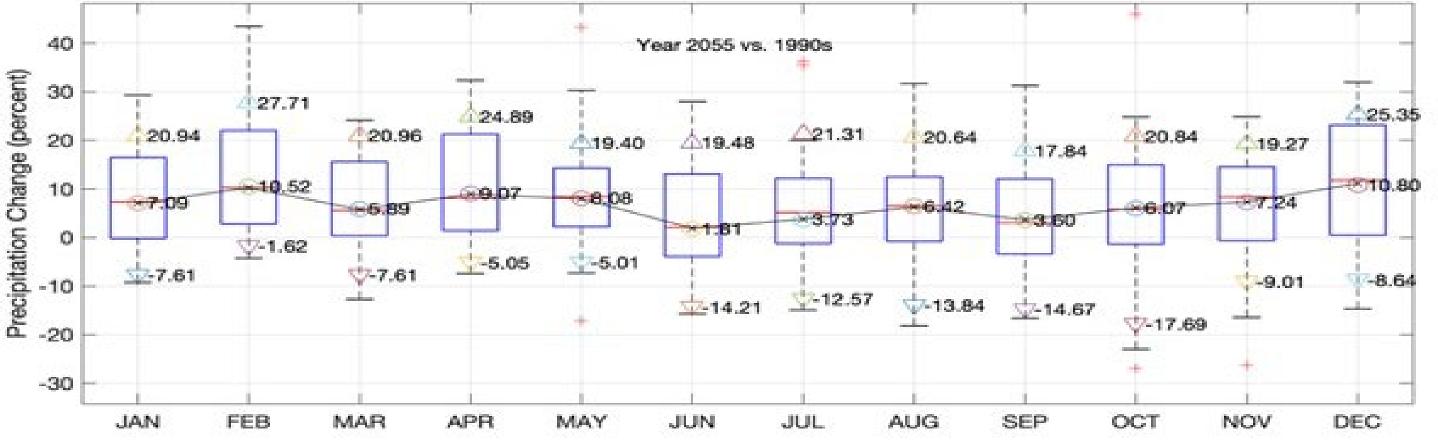
2035



2045



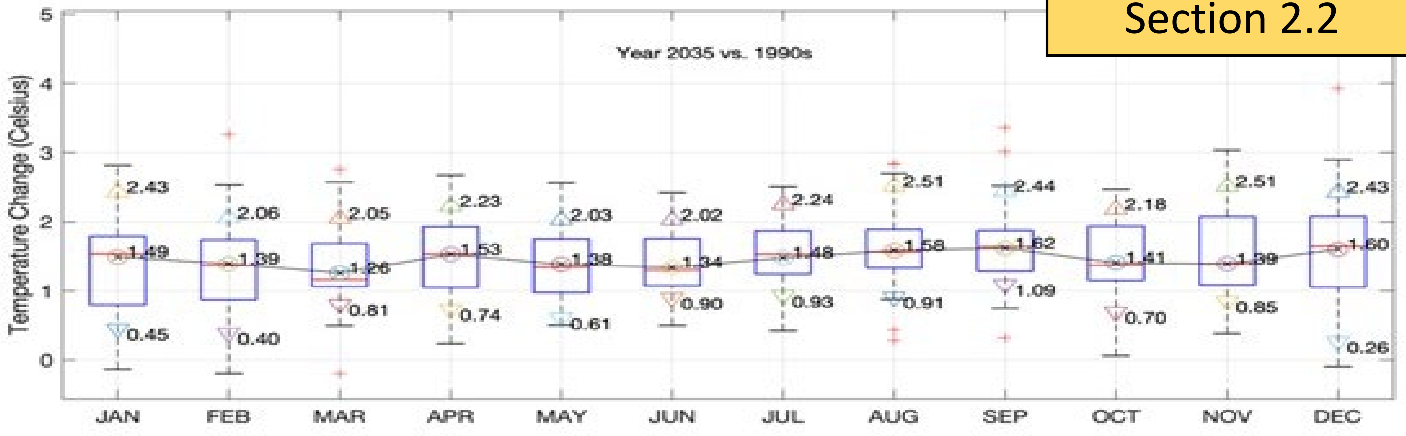
2055



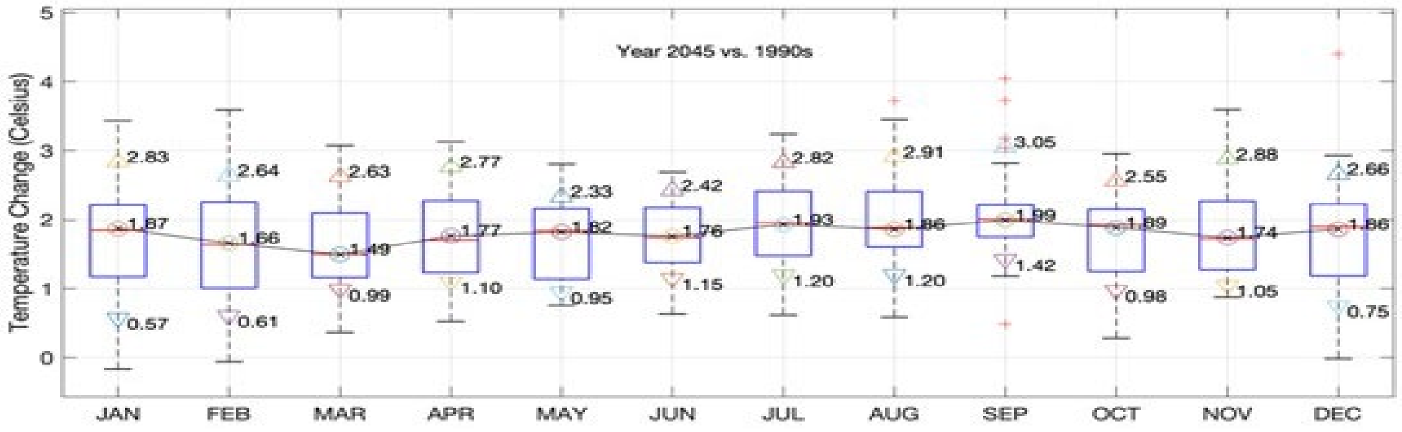
Temperature

Ensemble

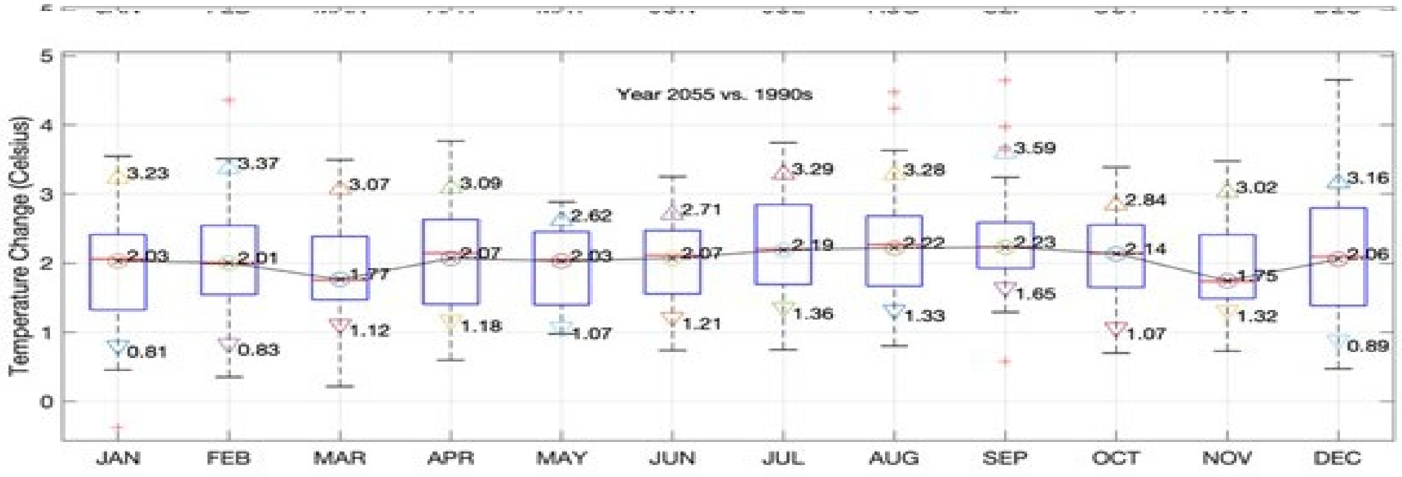
2035



2045

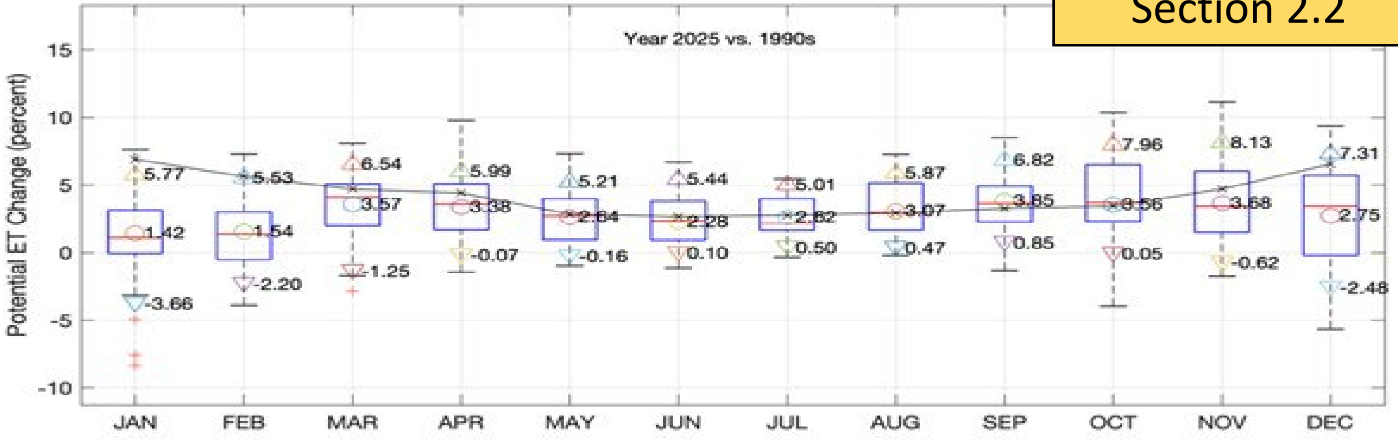


2055

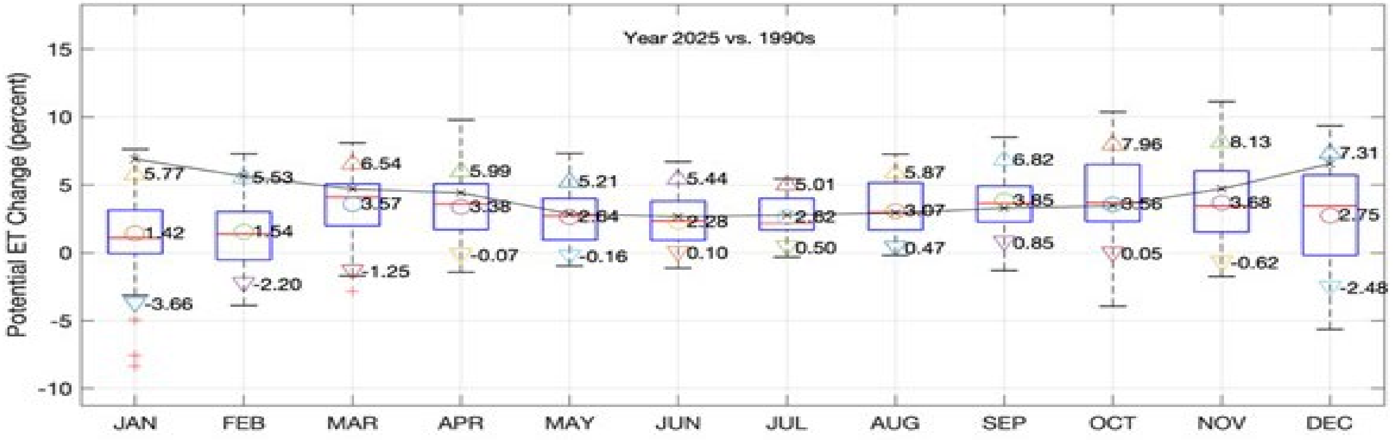


Potential Evapo-transpiration

2035

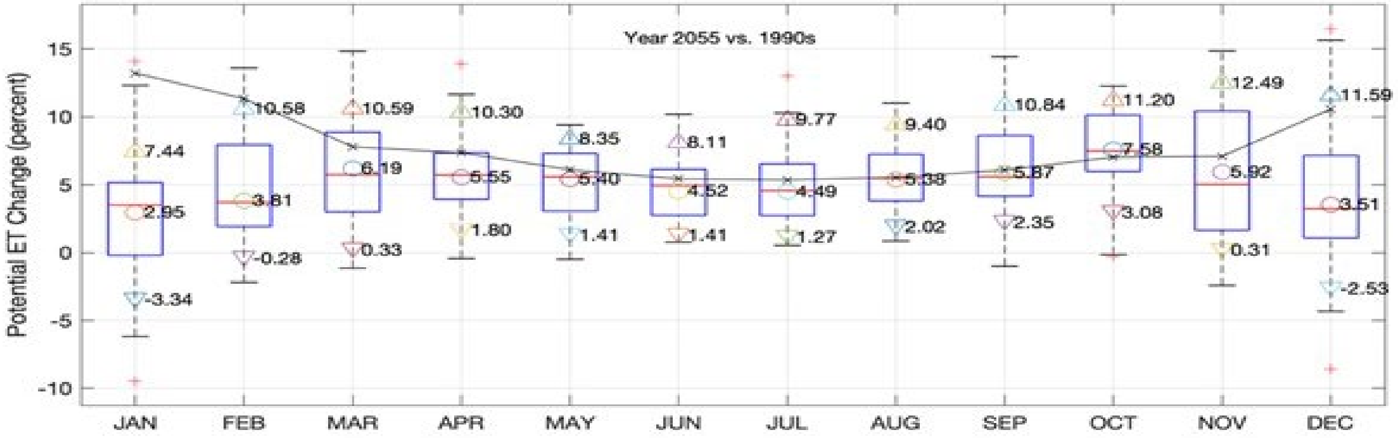


2045



Ensemble Hargreaves-Samani vs Ensemble P-M

2055



Approval – Section 2: Climate Inputs

- Precipitation
- Temperature
- Potential Evapotranspiration
- Carbon dioxide

Subsections of 3 – Nutrient Inputs

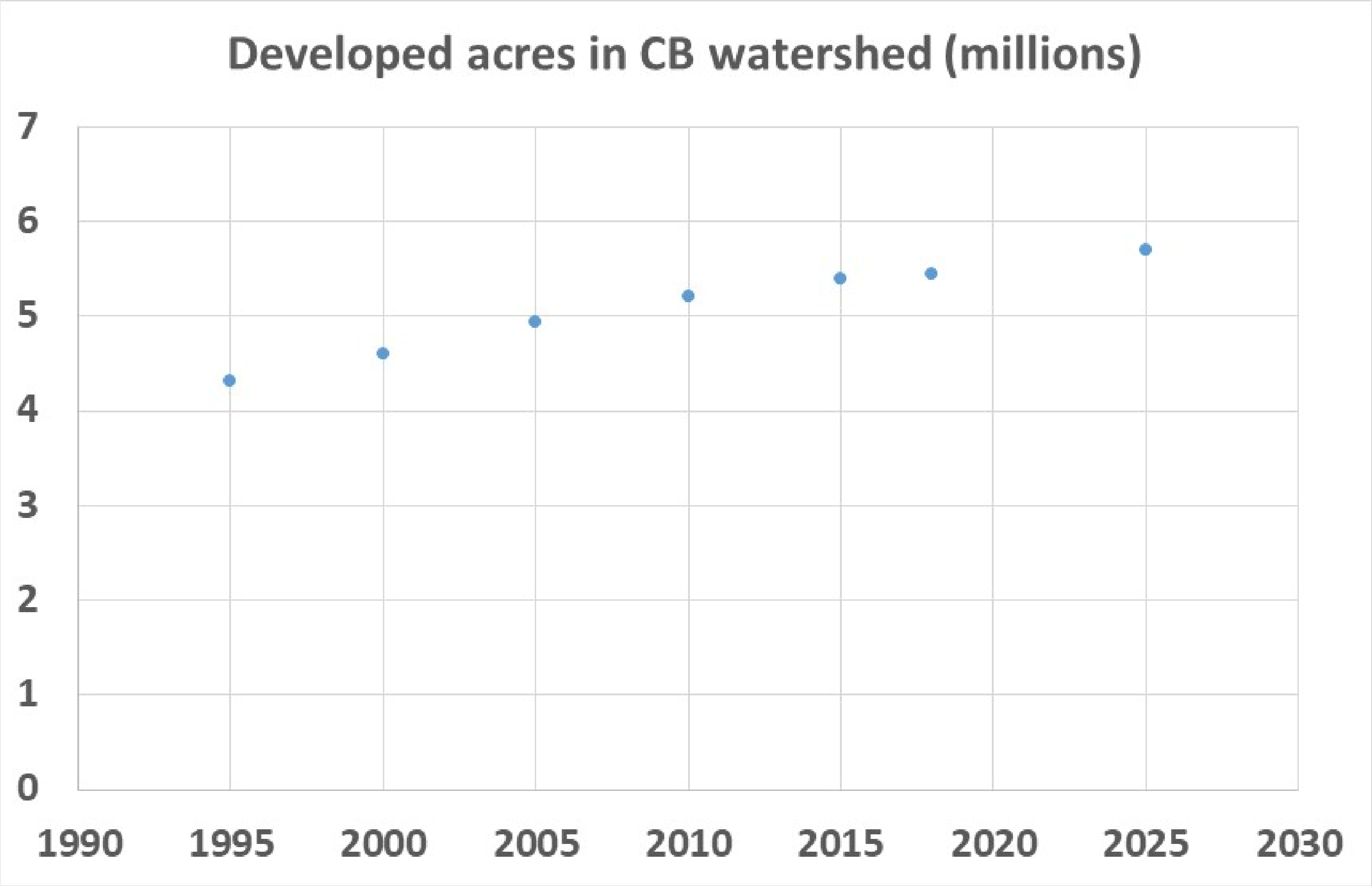
- Looking for climate effects on nutrient inputs

- 3.2 Land use
- 3.3 Agricultural inputs
- 3.4.2 Non-CSO direct loads

- We pretty much know the answer already

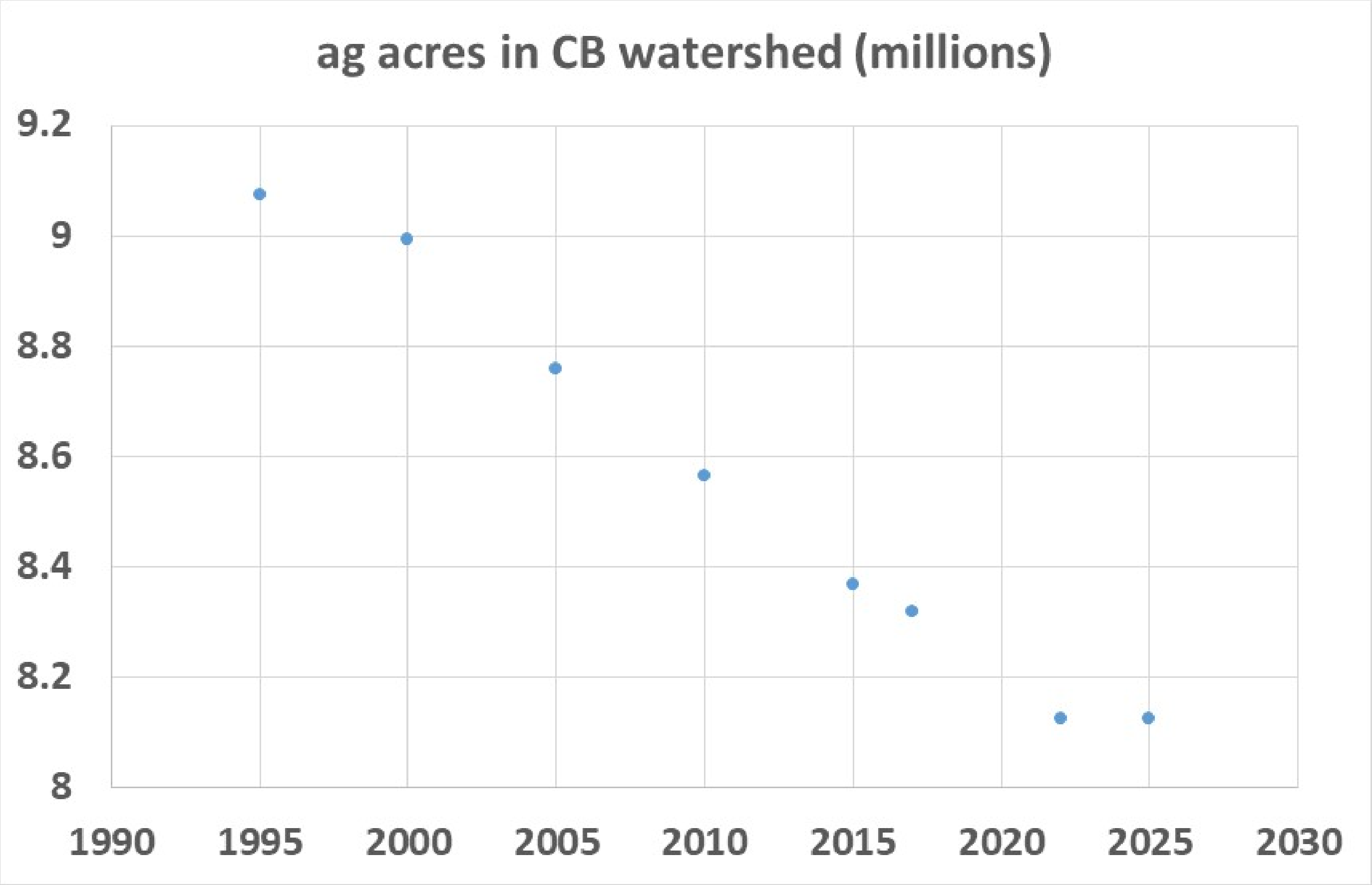
Land use

- Development and agricultural patterns could respond to weather hazards
- Land use is projected through 2050
- Projection is based on observation so includes climate effects
- Not broken out by climate and non-climate effects



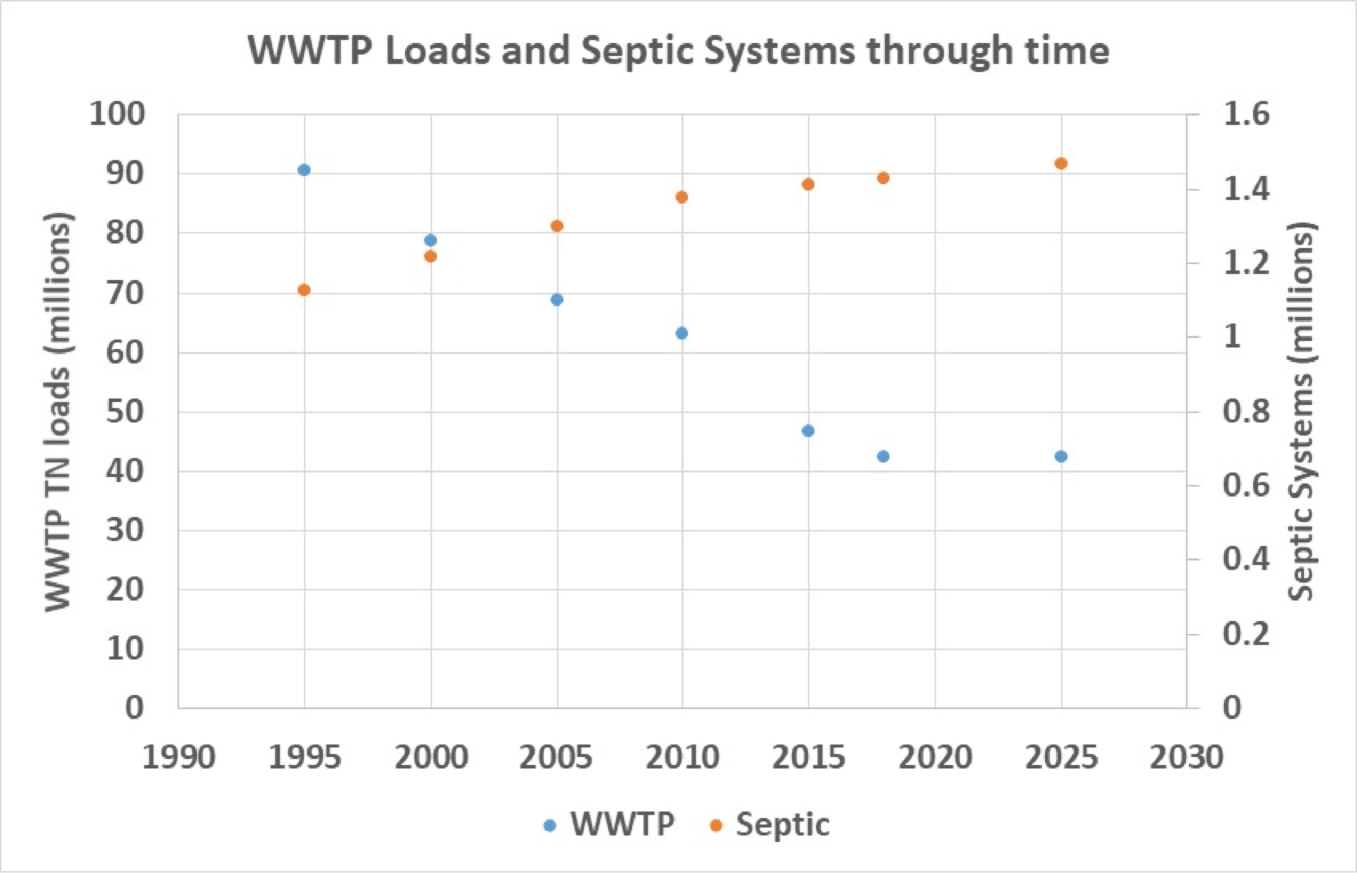
Agriculture

- Climate has a significant effect on the extent, type, and success of agriculture.
- Soon will have 2017 data, which will be projected through 2022, covering 27 of the 30 years.
- Not broken out by climate and non-climate effects
- No method for 2035, 2045, 2055



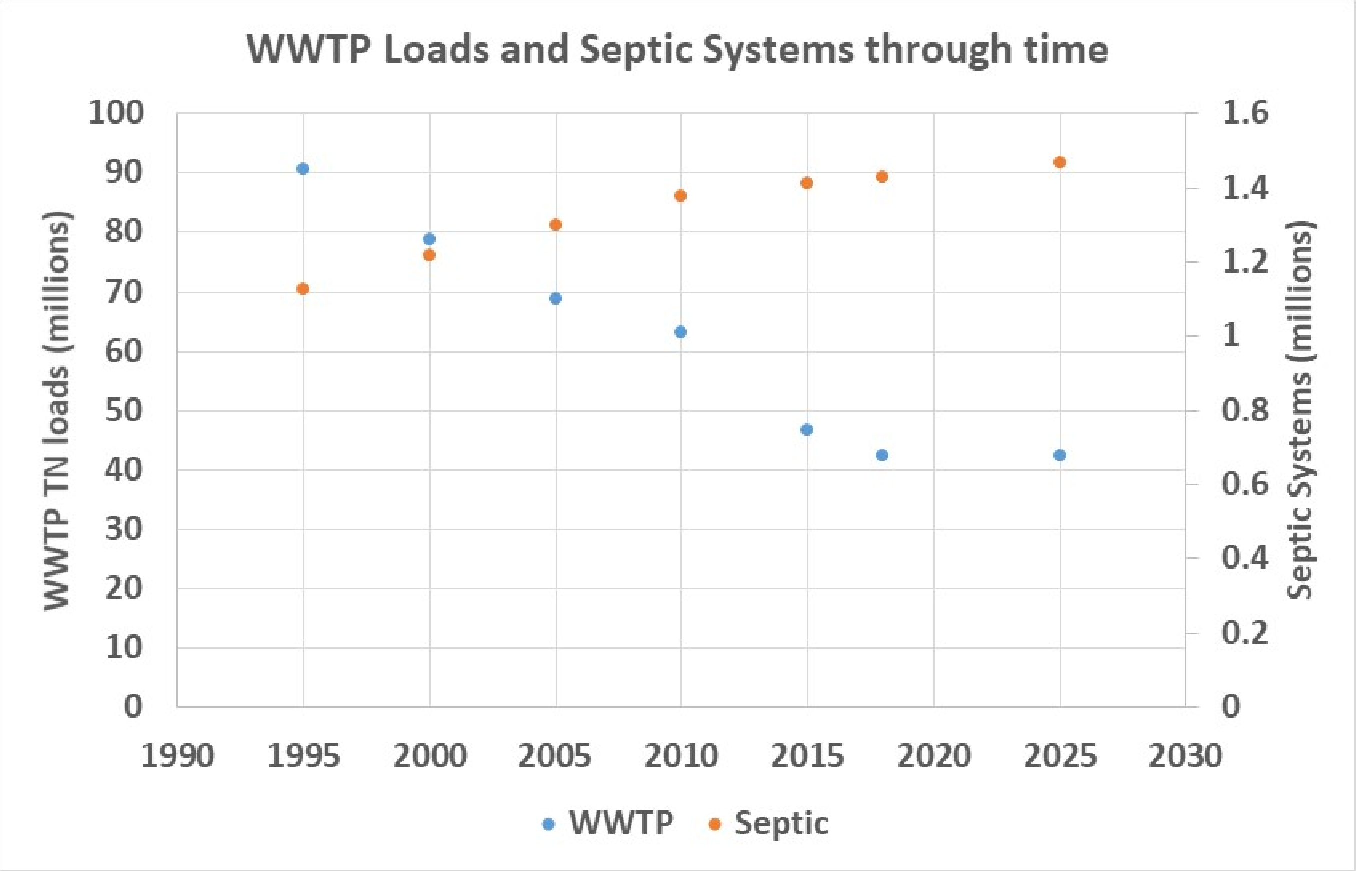
Non-CSO direct loads

- WWTP loads driven by permits, loads would likely remain constant even with changing influent temperature
- Data available through 2018
- Likely to remain at WIP levels



Non-CSO direct loads

- Data also available 1995-2018 on Septic, diversions, and rapid infiltration basins
- Septic projected through 2050
- No projection method for 2035, 2045, 2055 for diversions and RIBs



Approval – Subsections of 3: Nutrient Inputs

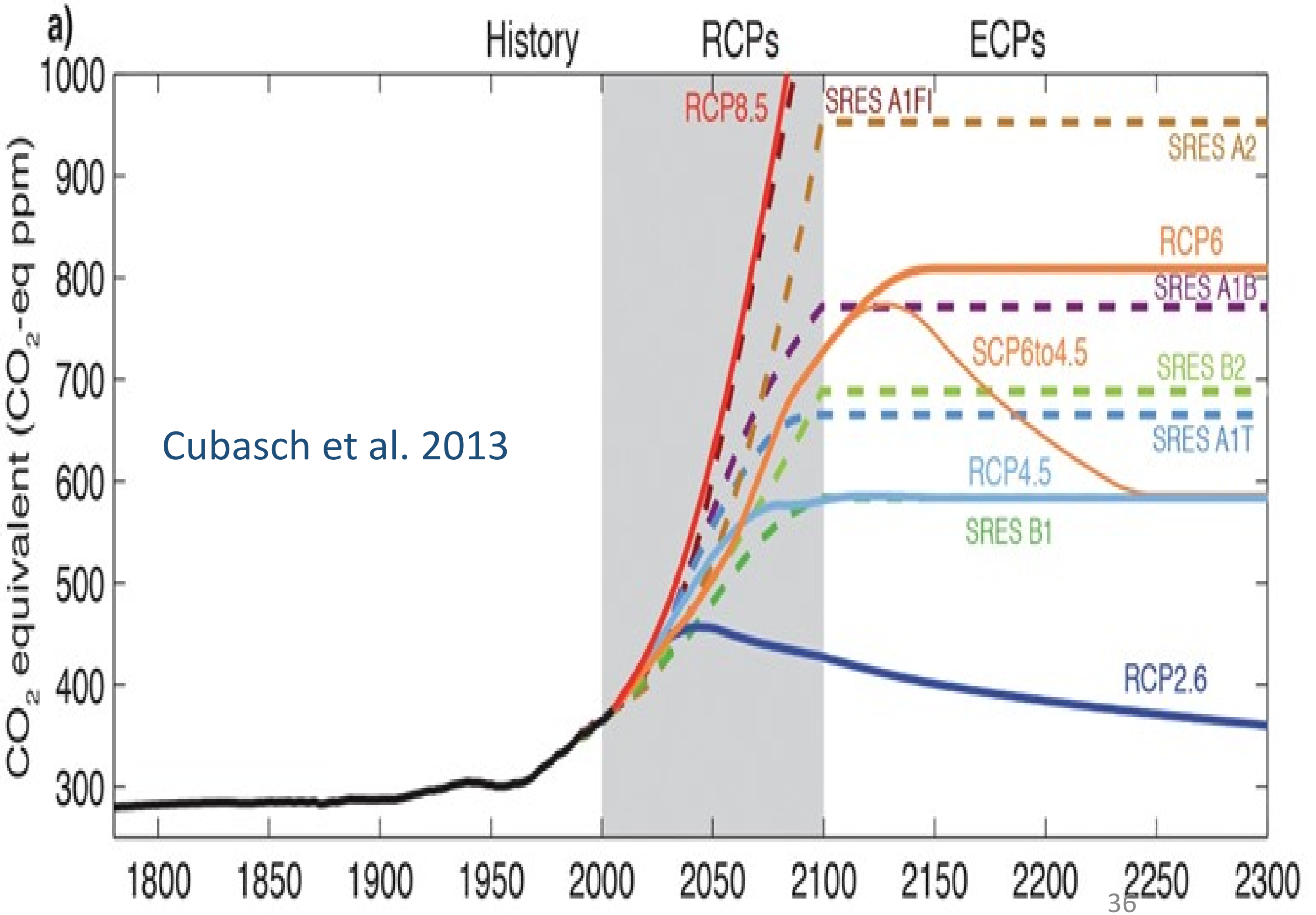
- 3.2 land use
- 3.3 agriculture
- 3.4.2 non-CSO direct loads

Subsections of 4 – Watershed Model Response to Climate Change

- 4.1 response to CO2
- 4.2 hydrology simulation with HSPF
- 4.3 sediment simulation with HSPF
- 4.7.3 groundwater lag

CO2 effect

- CO_2 decreases transpiration due to closing of the stomata.
- Butcher et al. (2014) documents how to simulate this effect in HSPF through decreased vadose zone transpiration
- $\frac{PET_1}{PET_o} = \frac{1/(1-LZETP_1)}{1/(1-LZETP_o)}$

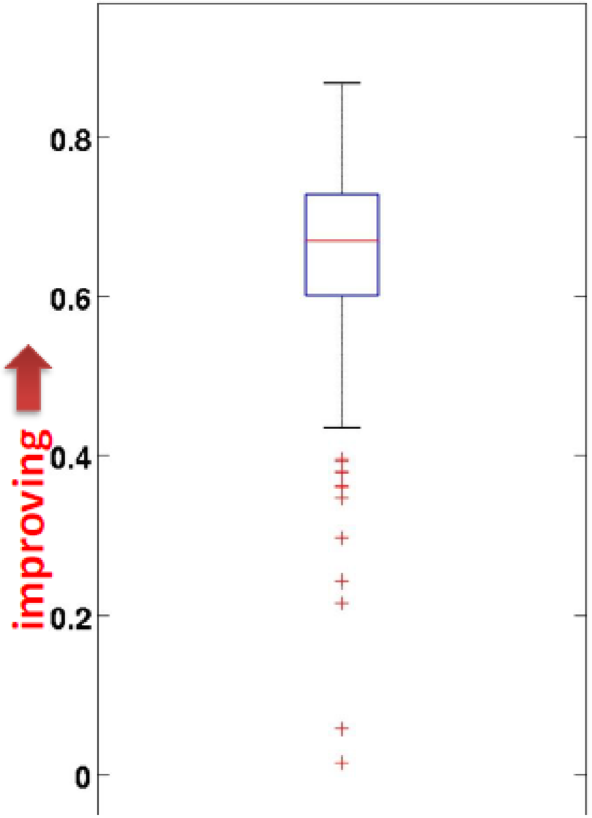


Cubasch et al. 2013

Hydrologic simulation using HSPF

- A process model that is sensitive to the parameters of interest and that can replicate observations
  - Precip volume
  - Precip intensity
  - Temperature - snow
  - PET
  - CO2
  - Antecedent conditions

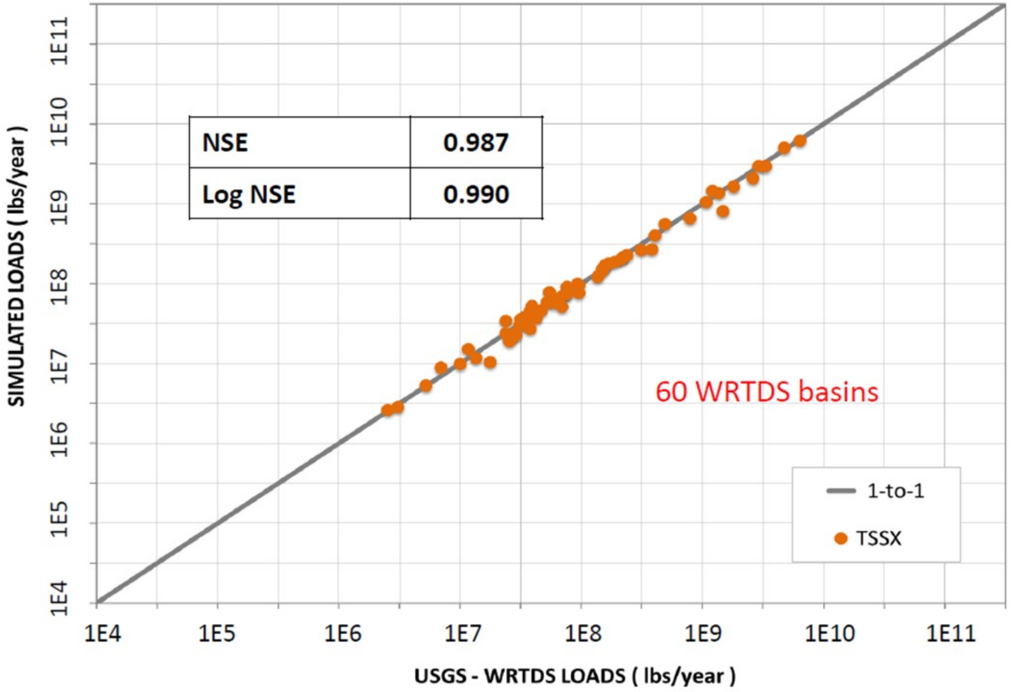
- Distribution of NSE for daily flow at 201 gauges

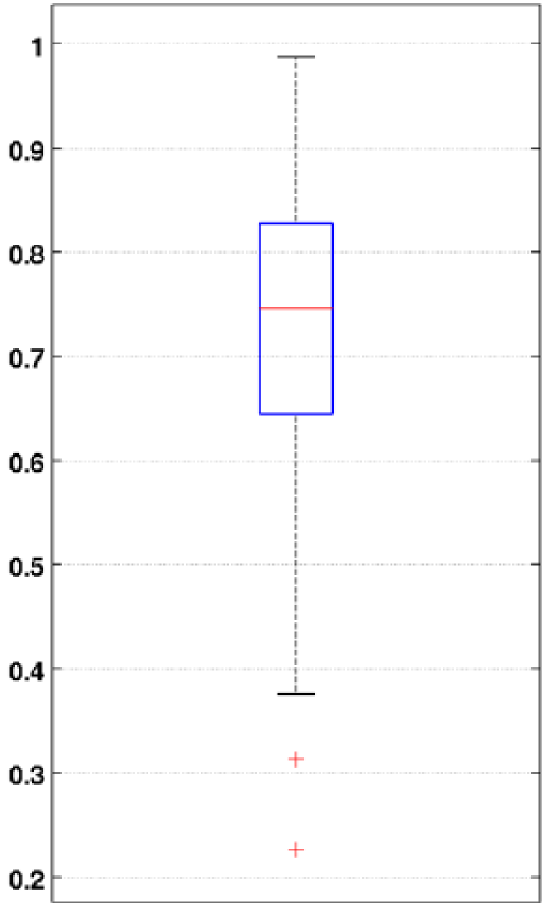


Sediment simulation using HSPF

- A process model that is sensitive to the parameters of interest and that can replicate observations
    - Precip volume
    - Precip intensity
    - Temperature - snow
    - Surface runoff
    - Antecedent conditions

- Agreement with WRDTS per-acre loads





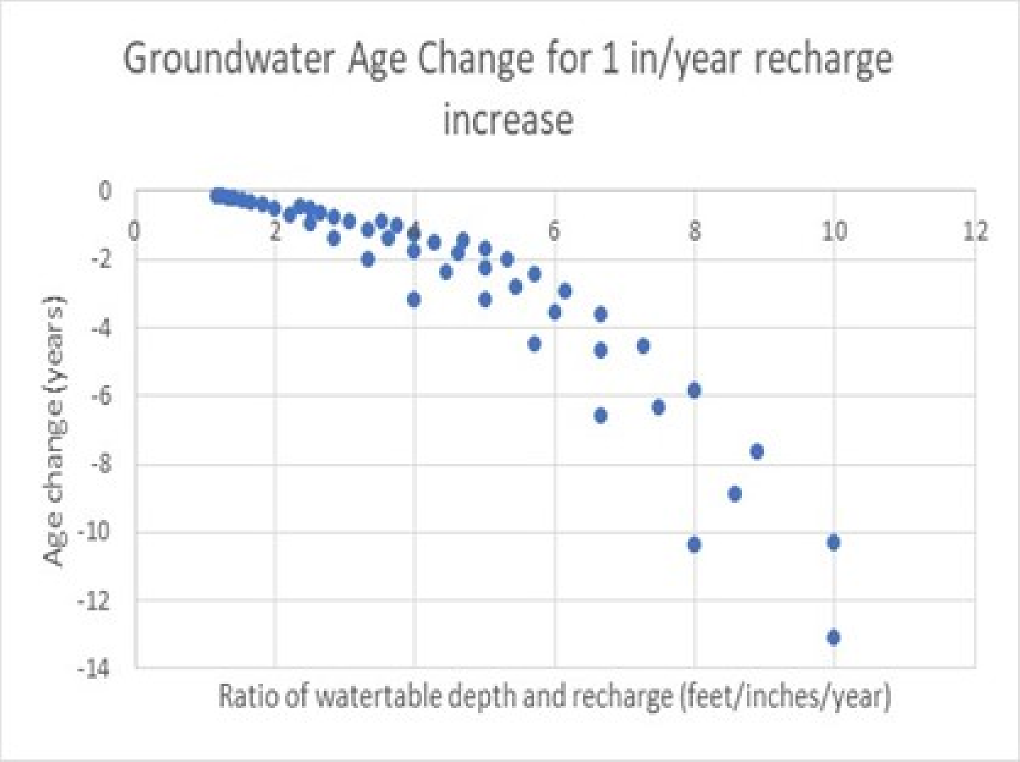
- Distribution of correlation coefficient for monthly WRTDS loads at 60 sites

Groundwater Lag change

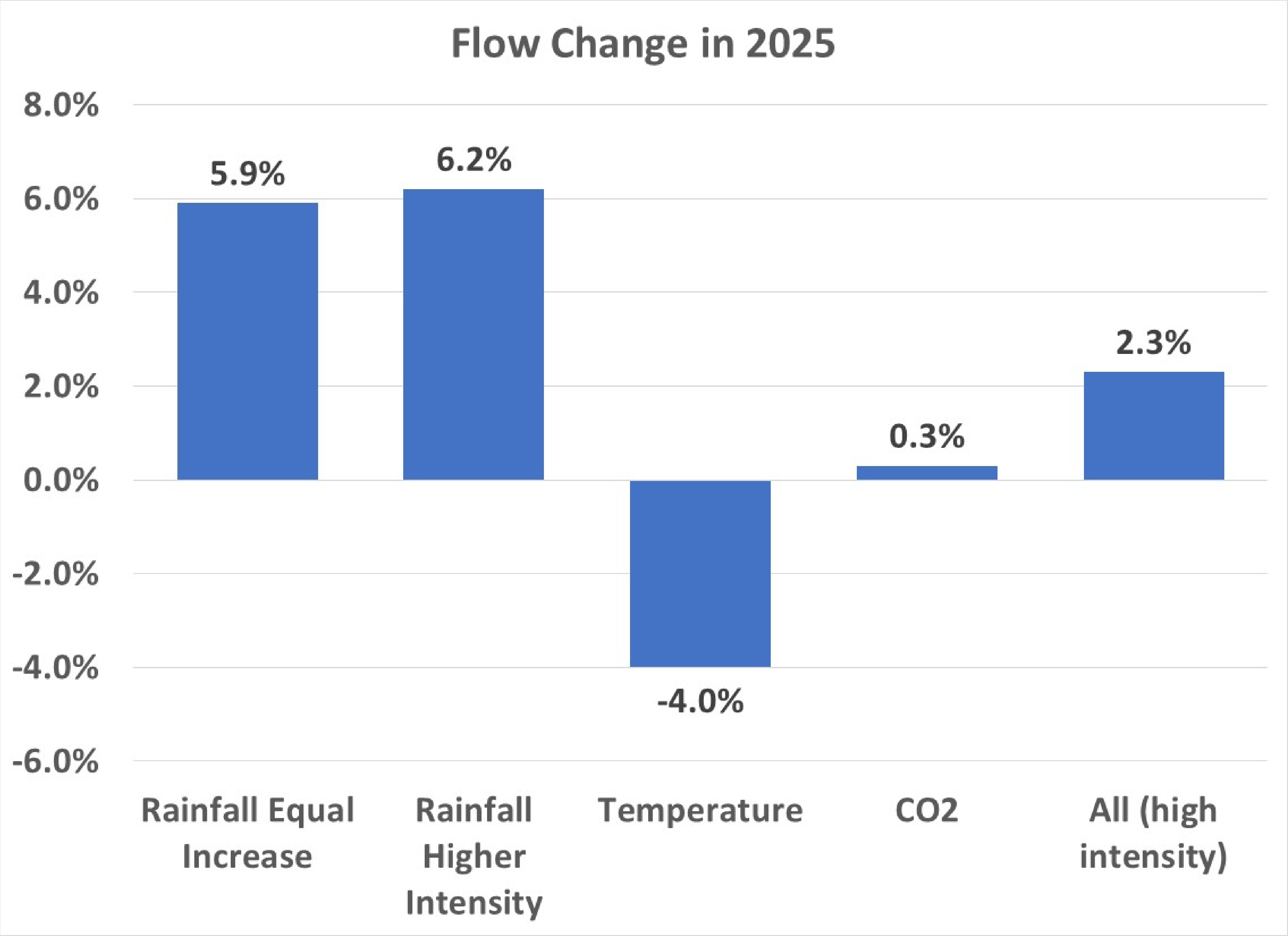
- Not included in CAST or definition of CBP management scenarios

- Dynamic model has lag components
- Non-coastal plain related to recharge
- Coastal plain estimation weakly related to recharge
- Relationships are spatial, not temporal

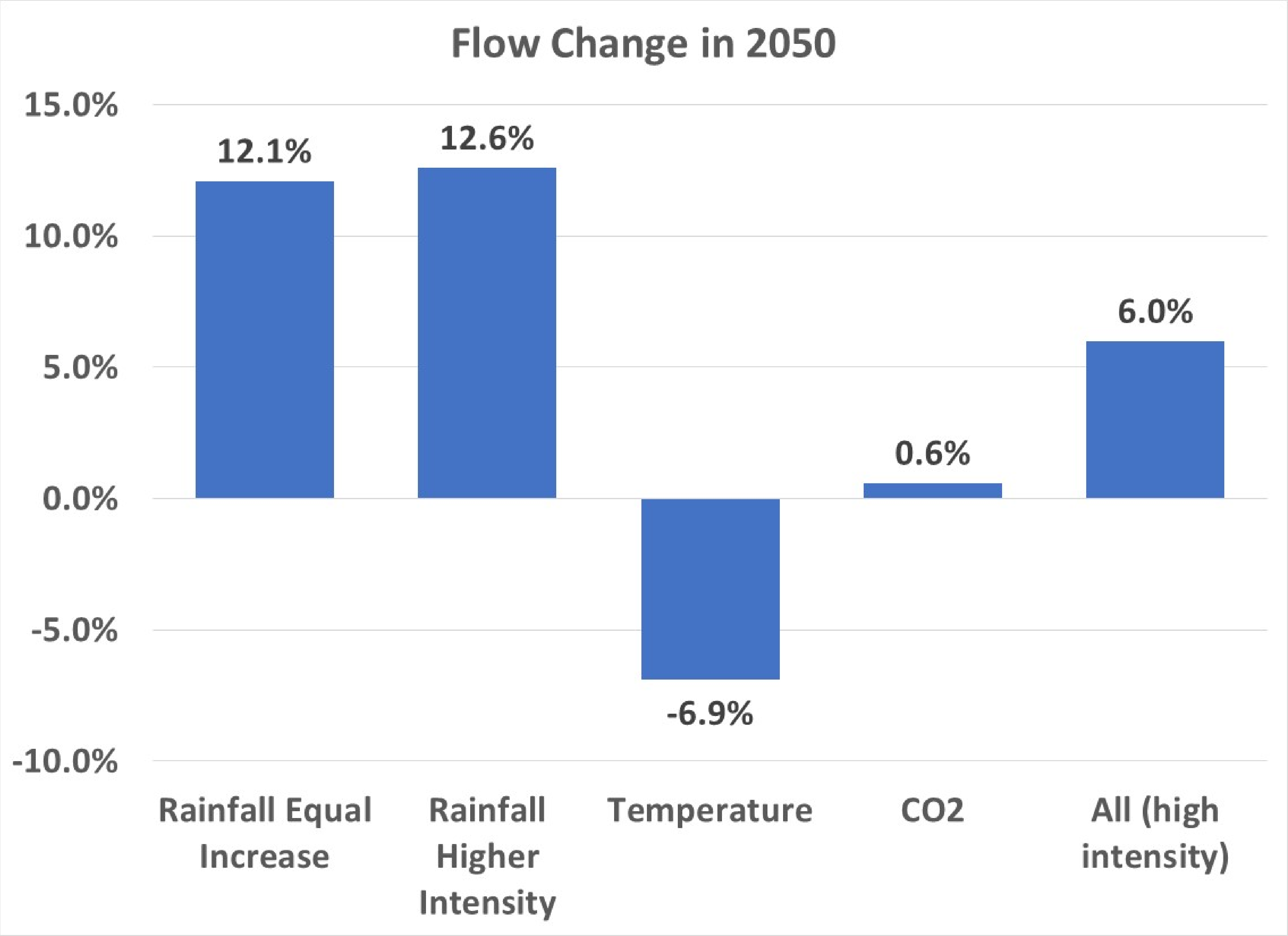
- Recommend ignore lag changes.



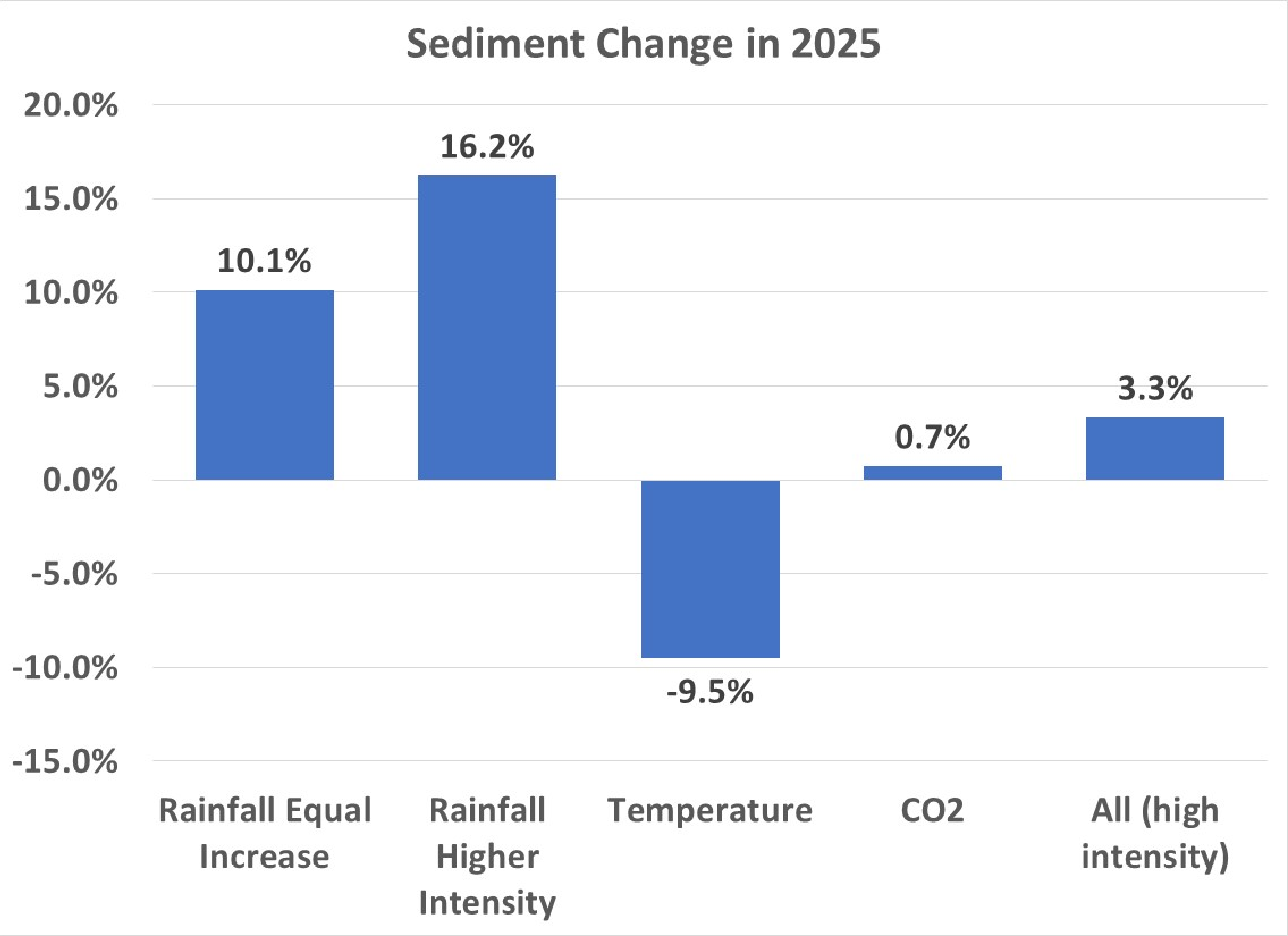
Flow Results



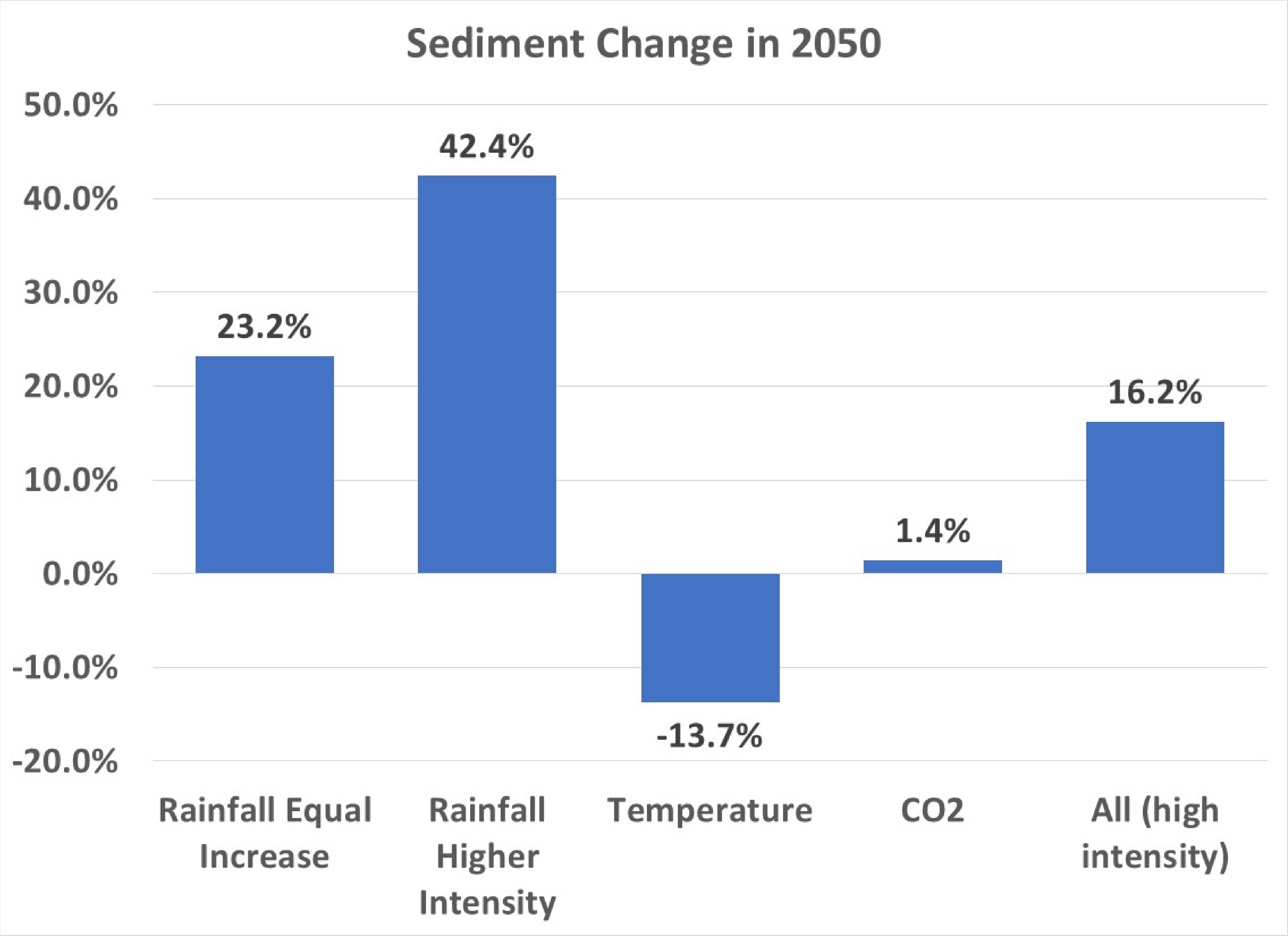
Flow Results



Sediment Results



Sediment Results



Approval of subsections of 4 – Watershed Model Response to Climate Change

- 4.1 response to CO2
- 4.2 hydrology simulation with HSPF
- 4.3 sediment simulation with HSPF
- 4.7.3 groundwater lag