How will the impact of climate change on riverine nutrient loading impact Chesapeake Bay hypoxia?

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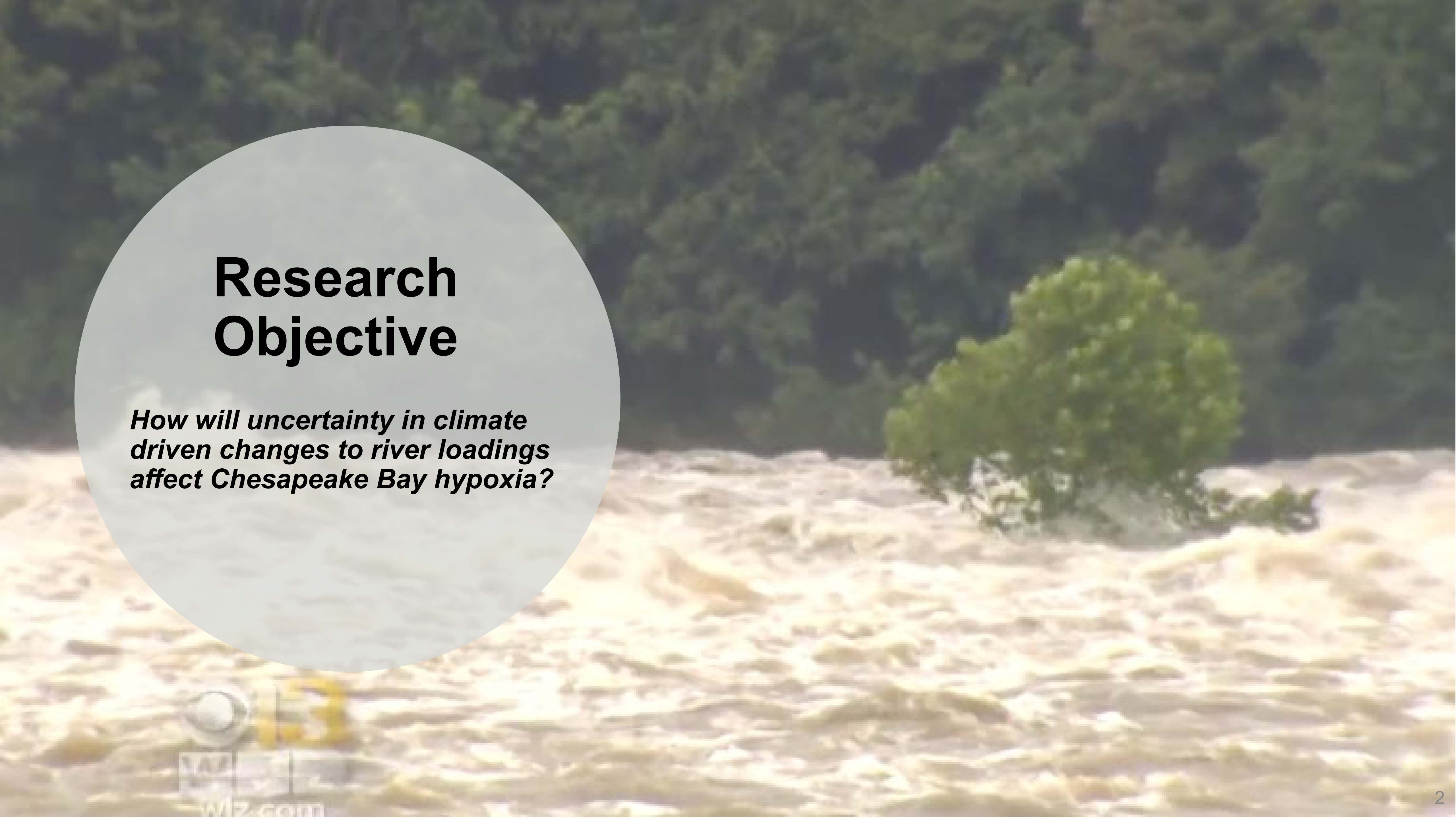


Research Objective

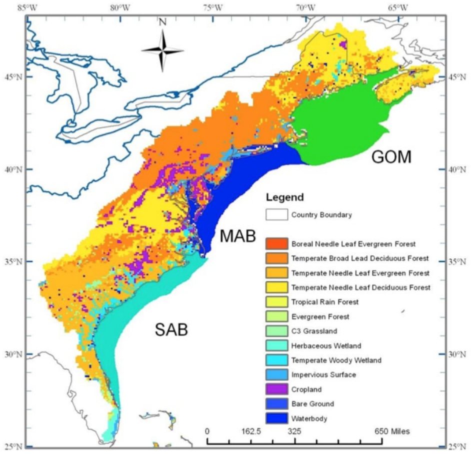
How will uncertainty in climate driven changes to river loadings affect Chesapeake Bay hypoxia?

Outline

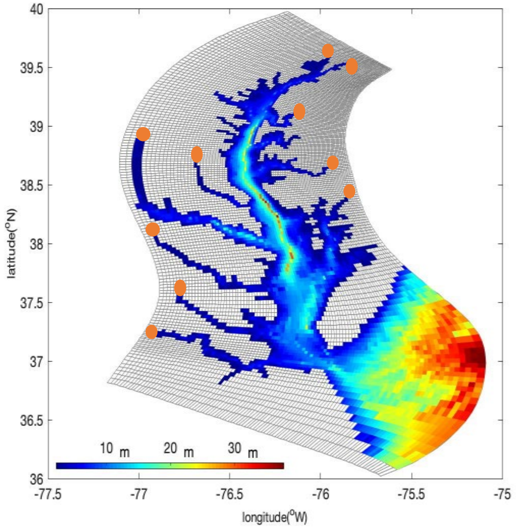
- Methods
  - ChesROMS Reminder
  - Development and Application of Climate Scenarios
- Results
  - Changes in Watershed Nutrient Loading
  - Impact of Loading on Hypoxia
  - Relative Sources of Uncertainty
- Conclusions and Next Steps

Using ChesROMS

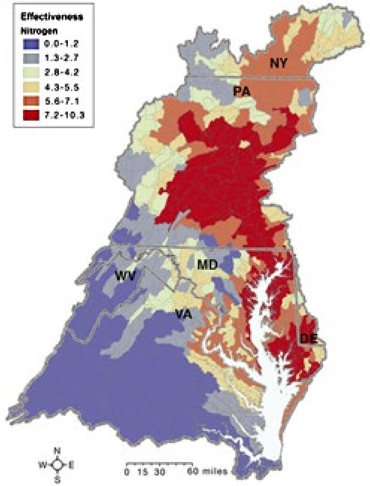
- ChesROMS-ECB is a fully coupled, hydrodynamic-biogeochemical model
  - Resolution ~1 km, 20 depth layers
- Watershed forcings from DLEM (Auburn University) and P6 WSM (USEPA-Chesapeake Bay Program)



DLEM



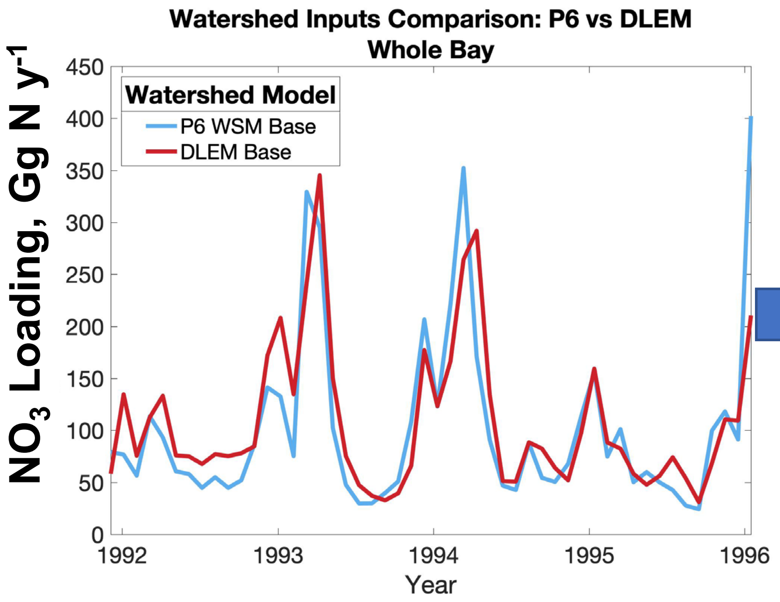
ChesROMS-ECB

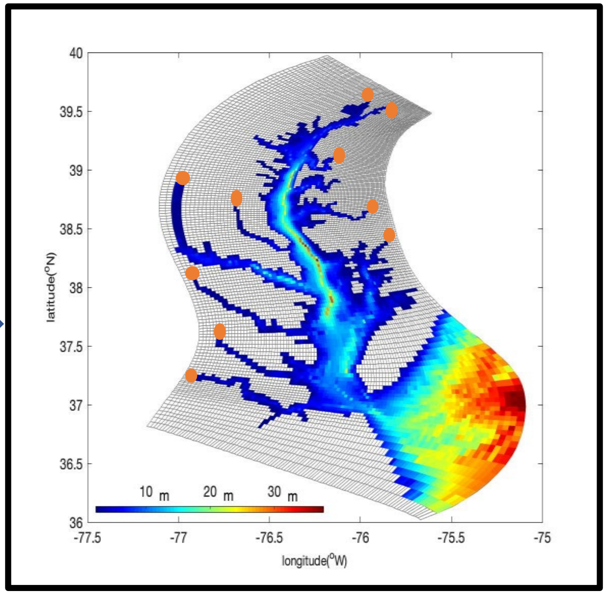


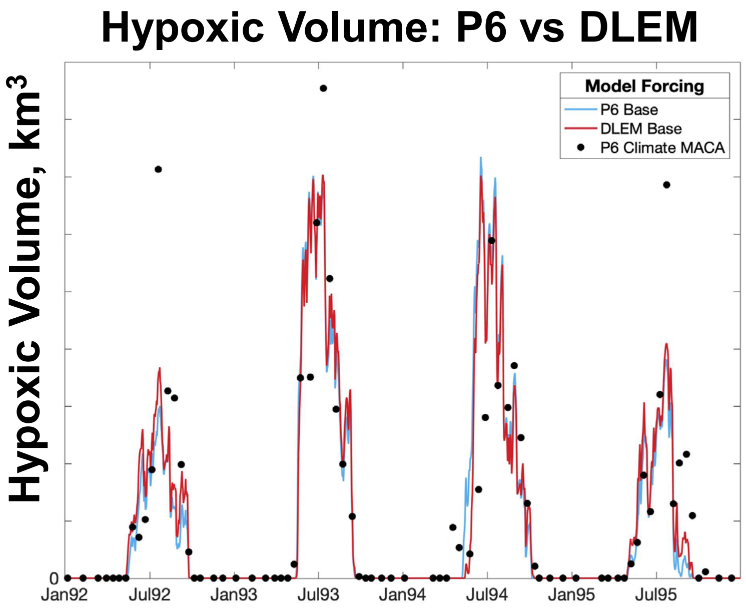
P6 WSM

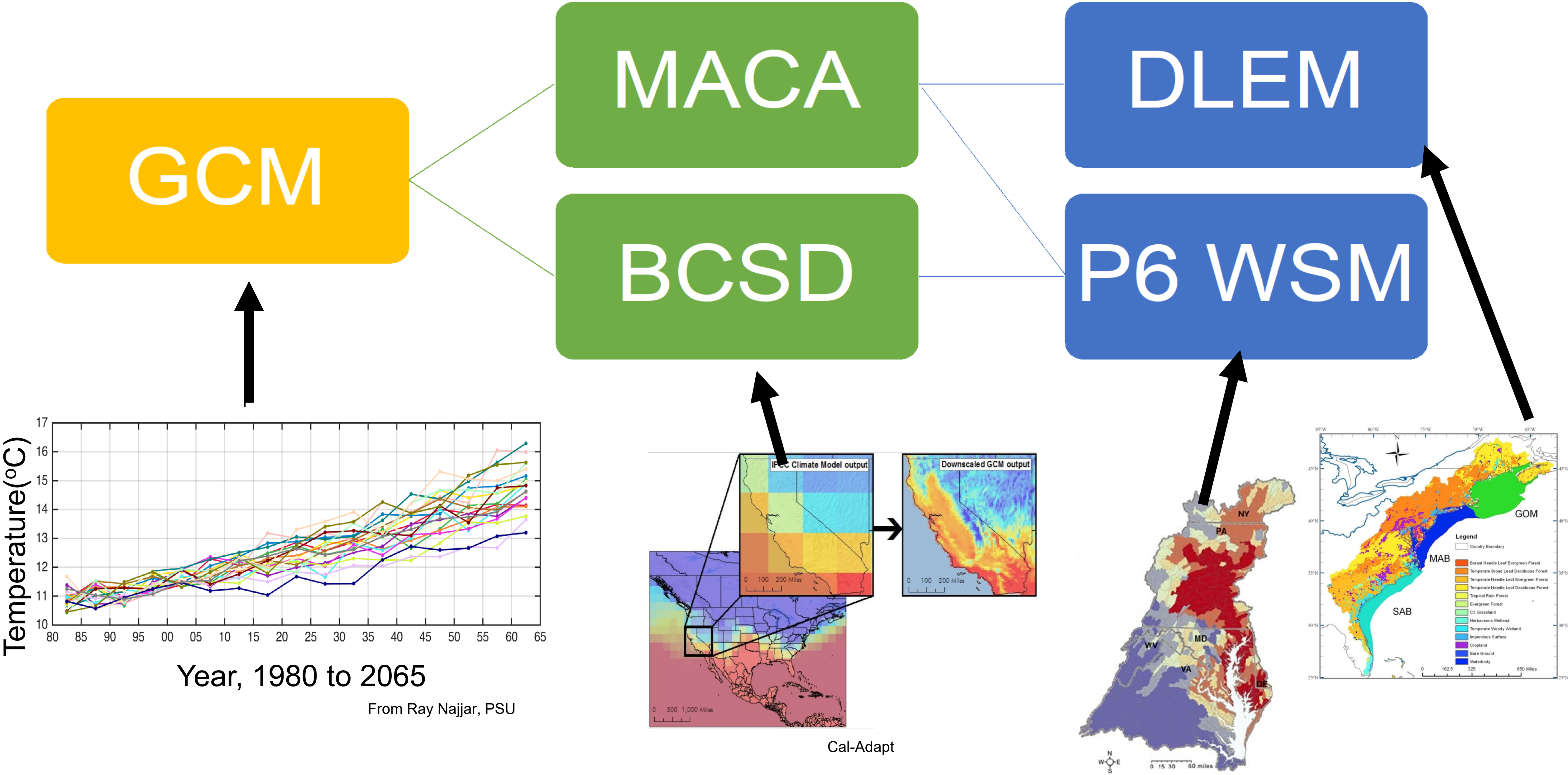
Using ChesROMS

- Two independent watershed models produce similar estimates of NO3 loading
- ChesROMS-ECB produces similar estimates of hypoxic volume for the two watershed models; both align relatively well with cruise observations.



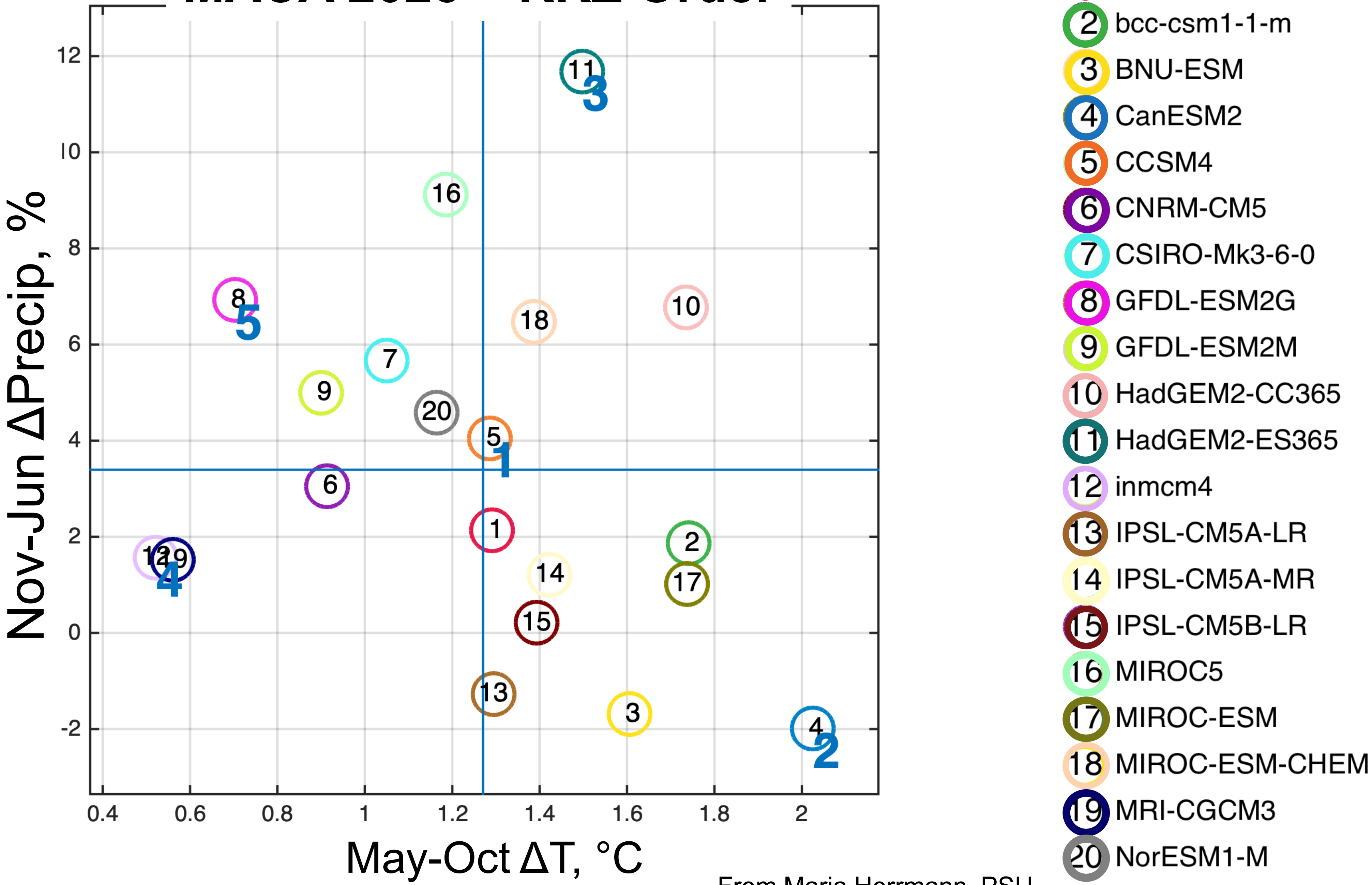






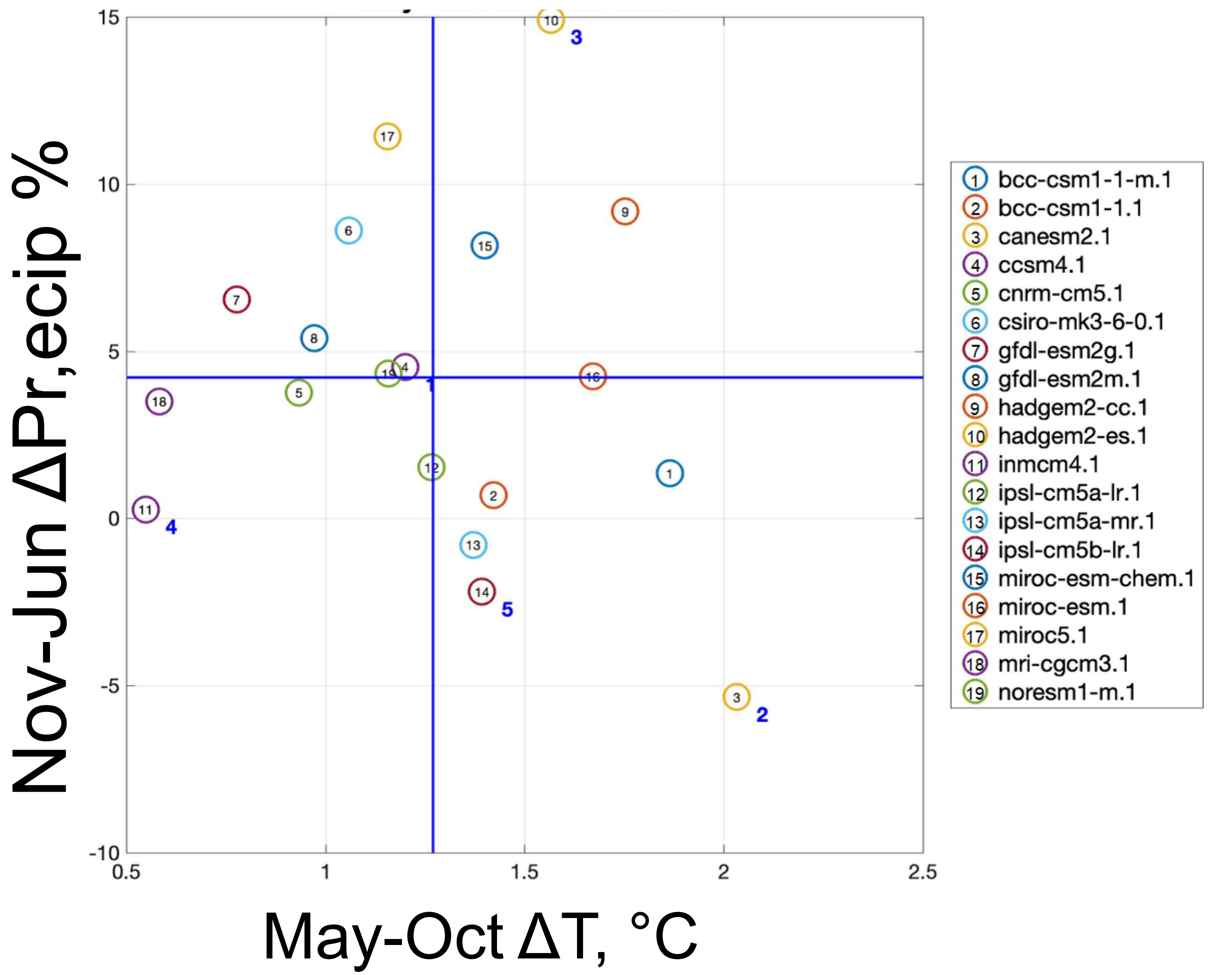
Multiple sources of uncertainty exist for watershed model climate scenarios

MACA 2025 – KKZ Order

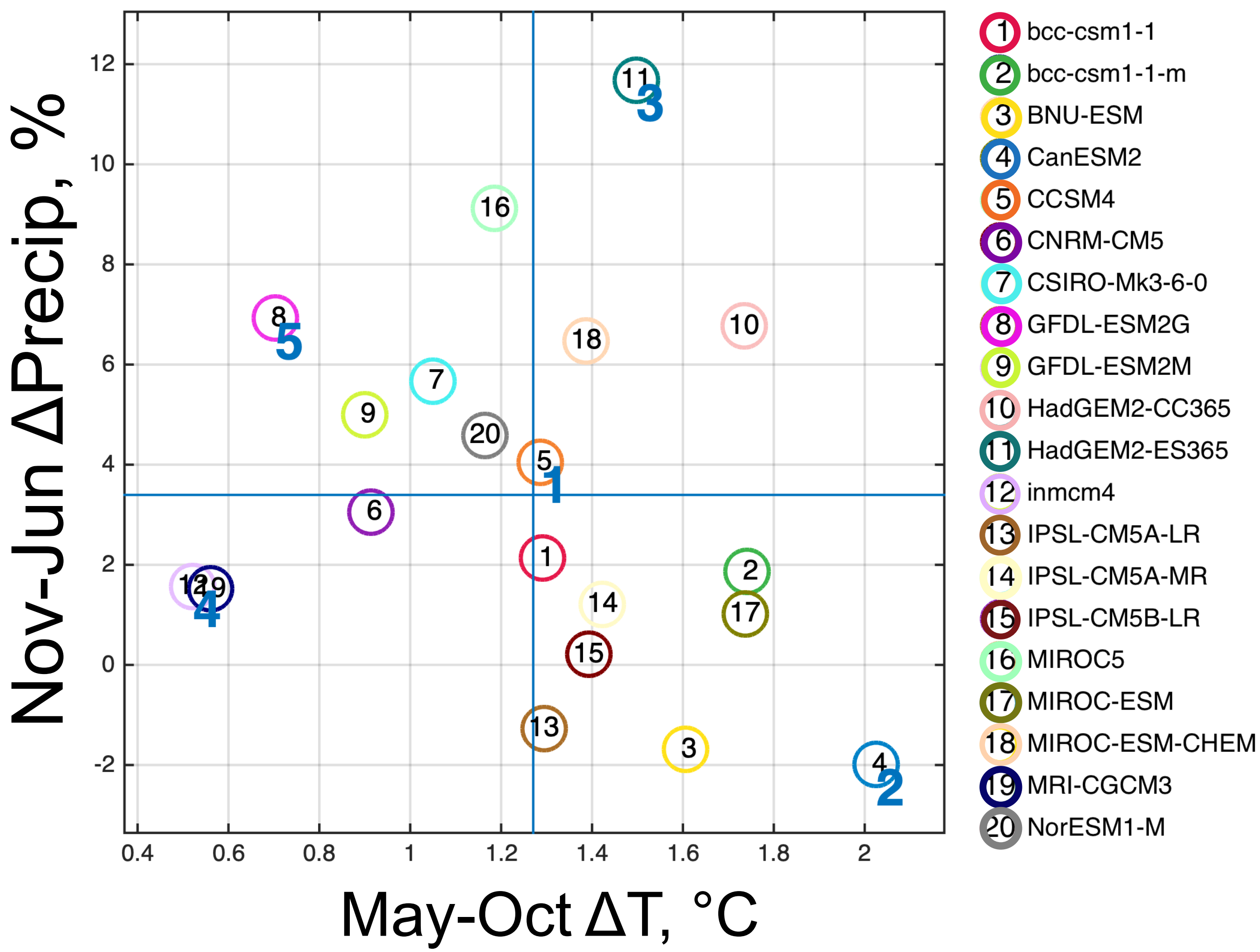


From Maria Herrmann, PSU

BCSD 2025 – KKZ Order



MACA 2025 – KKZ Order



- **Average Δ precipitation for BCSD is ~1% greater than MACA**
- **Approximate change in average Δ temperature is about equal for BCSD and MACA downscaling**

Climate Scenario Methods

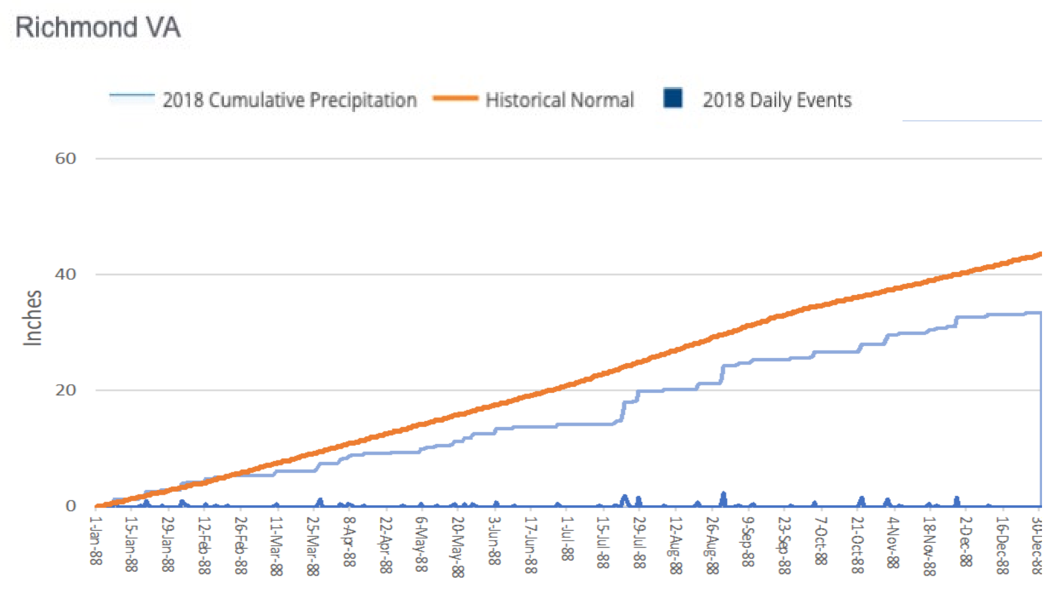
- Delta approach is applied:

Global Climate Models | 1981 - 2010 | 2011 - 2040

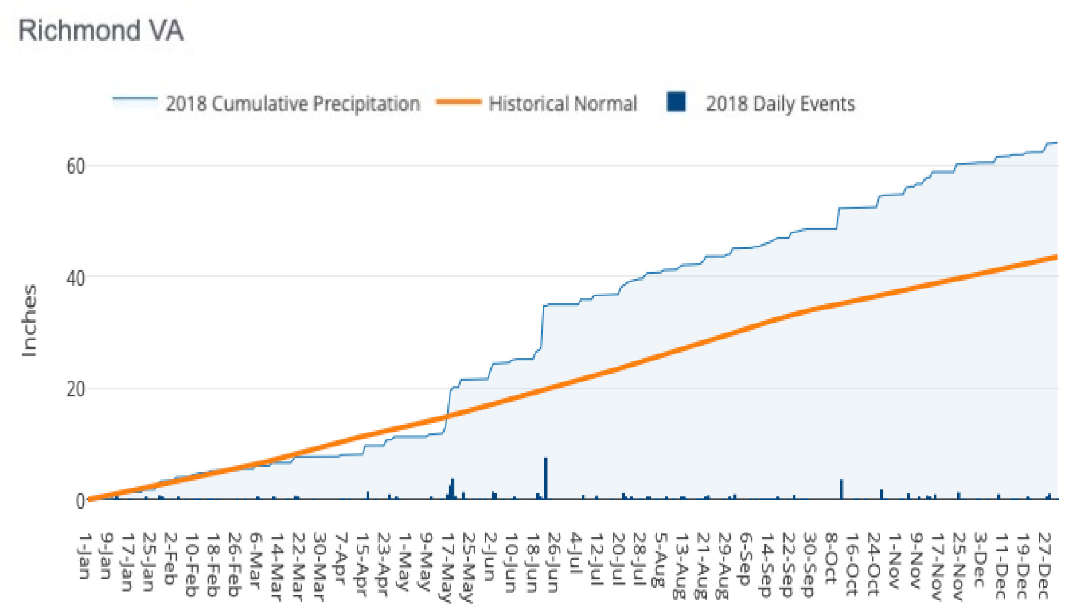
Climate Scenario Methods

- Delta approach is applied:

Global Climate Models — 1981 - 2010 — 2011 - 2040



1988 Precipitation



2018 Precipitation

Climate Scenario Methods

- Delta approach is applied:

Global Climate Models — 1981 - 2010 | 2011 - 2040

Future minus Past = Climate Delta

Climate Scenario Methods

- Delta approach is applied:

Global Climate Models — 1981 - 2010 | 2011 - 2040

Future **minus** **Past** **=** **Climate Delta**

Watershed Model: 1984 – 2014

Climate Scenario Methods

- Delta approach is applied:

Global Climate Models — 1981 - 2010 | 2011 - 2040

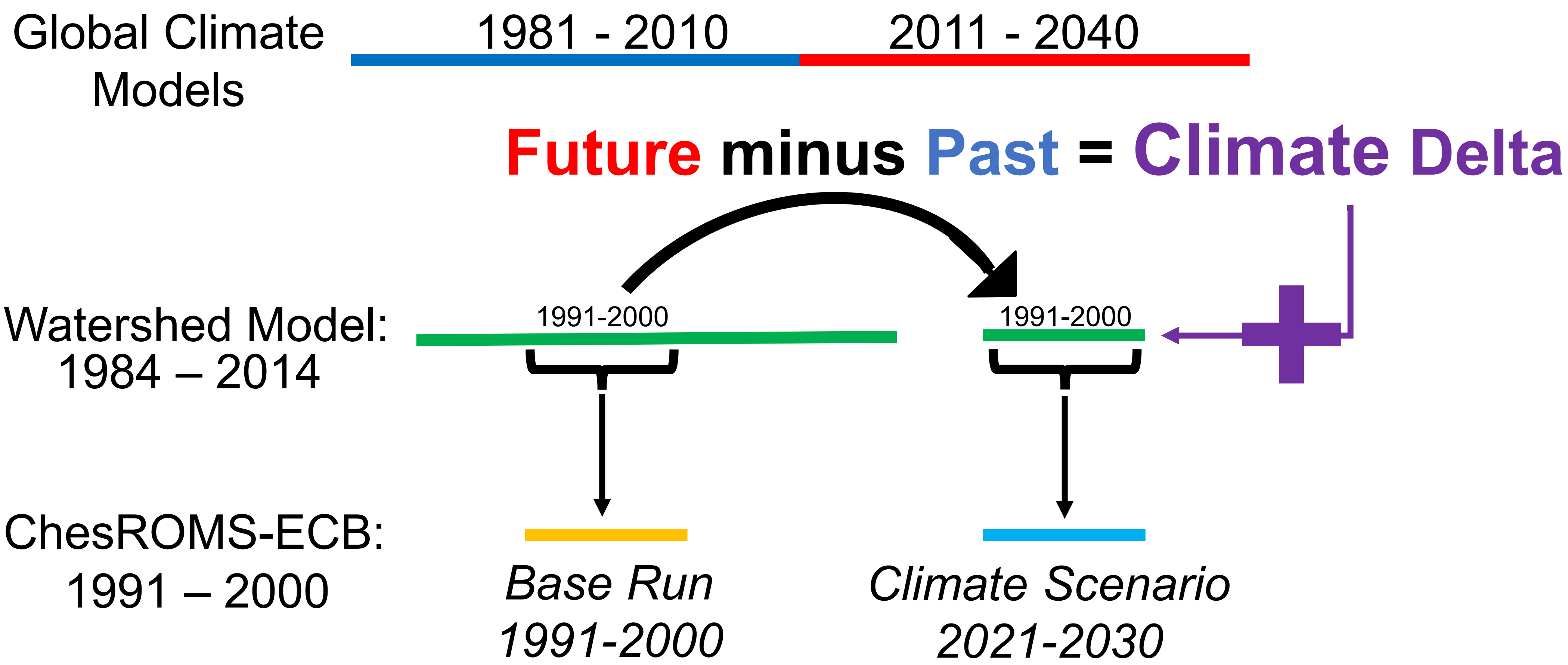
Future **minus** **Past** **=** **Climate Delta**

Watershed Model: 1984 – 2014 — 1991-2000

ChesROMS-ECB: 1991 – 2000 — *Base Run 1991-2000*

Climate Scenario Methods

- Delta approach is applied:



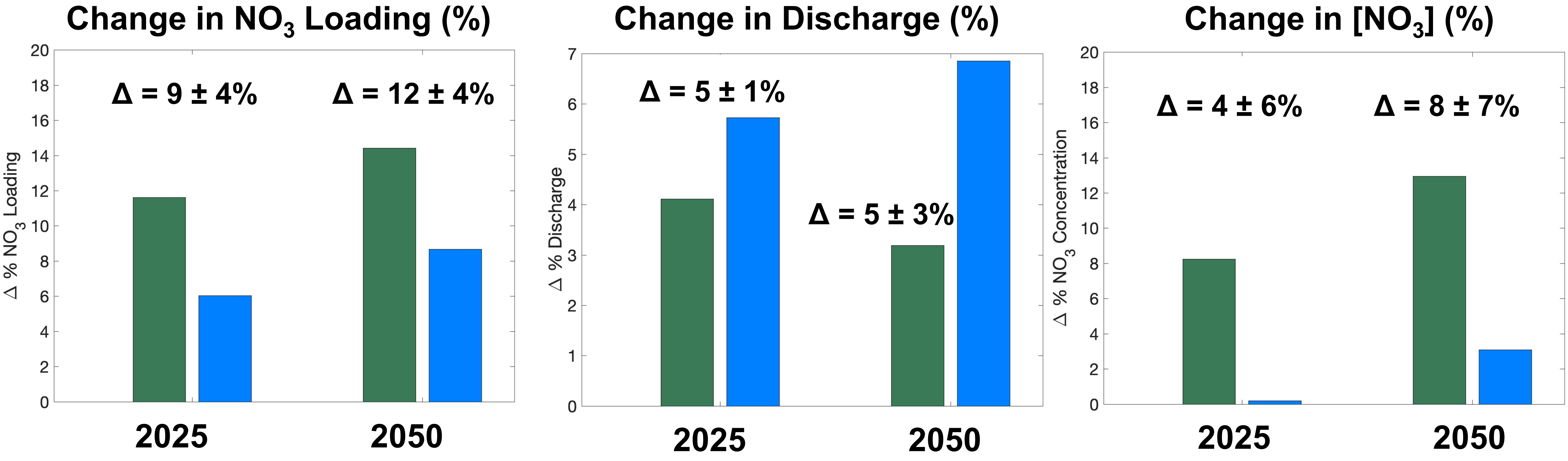
Results

- Changes in watershed nutrient loading
- Impact of changes in loading on hypoxia
- Relative sources of uncertainty

How are changes in NO_3 loading affected in climate scenarios?

- Both watershed models show increases in NO_3 loading due to climate change
- Difference in impact of using two different watershed models is similar in 2025 and 2050 (~4%)
- Is this difference caused by differences in freshwater discharge or NO_3 concentrations?

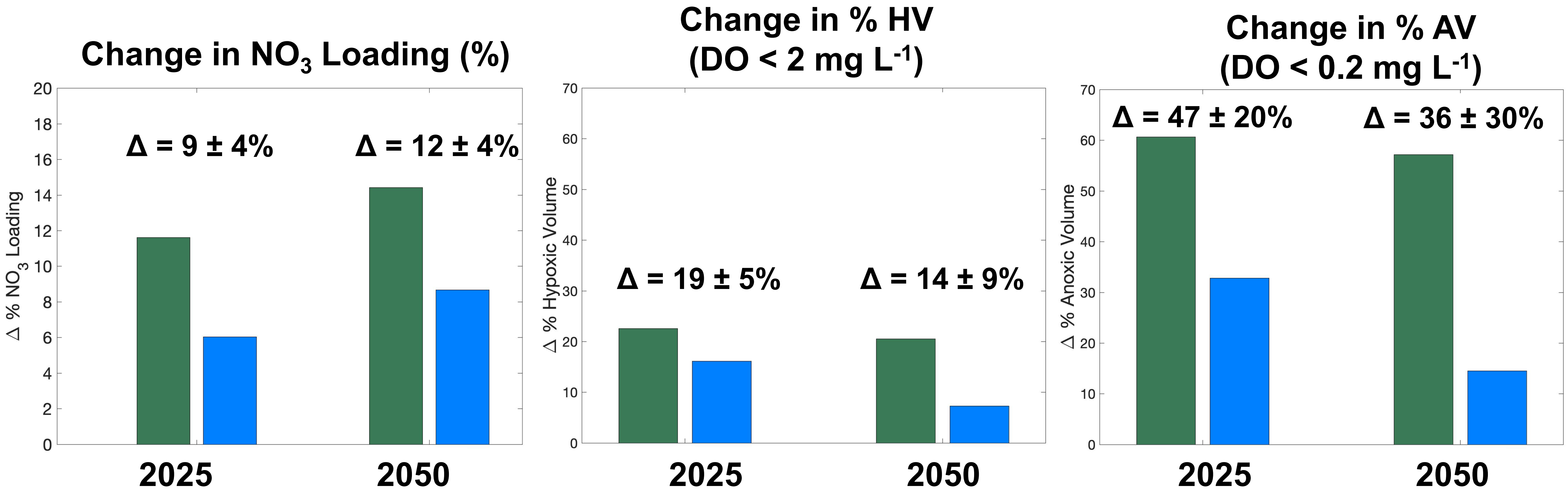
What causes these changes in NO_3 loading?



- Increased in NO_3 loadings can be attributed to:
  In DLEM → discharge & NO_3 concentration
  In Phase 6 → discharge only

Future discussion: Why does Phase 6 result in very small changes in concentration compared to DLEM?

What is the impact of the change in NO_3 loading on hypoxia?



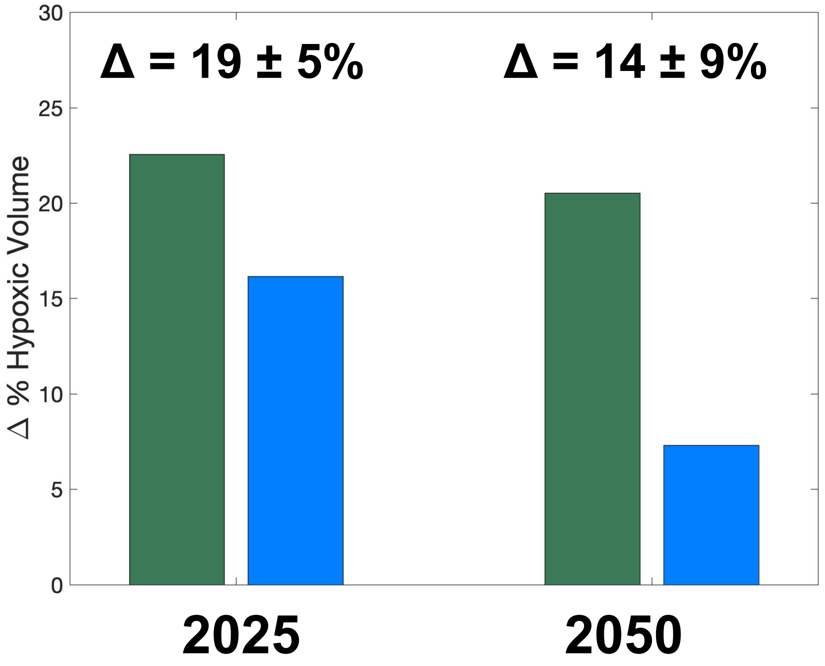
- The choice of watershed model significantly impacts uncertainty in our estimate of loading
- Changes in hypoxia and anoxia largely mirror changes in NO_3 loading for both watershed models
- Differences are magnified for anoxic volume by percent compared to other hypoxia levels

What factor produces the greatest amount of uncertainty in climate scenarios?

Watershed Model
DLEM
Phase 6

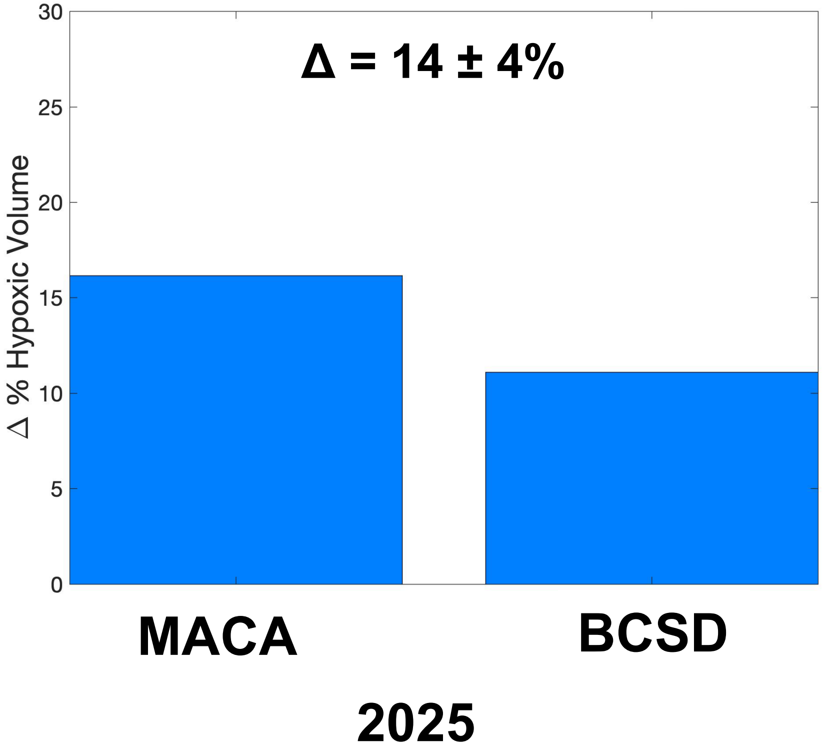
Watershed Model

DO < 2 mg L^{-1}



Downscaling Model

DO < 2 mg L^{-1}



Downscaling Model

DO < 2 mg L^{-1}

?

2050

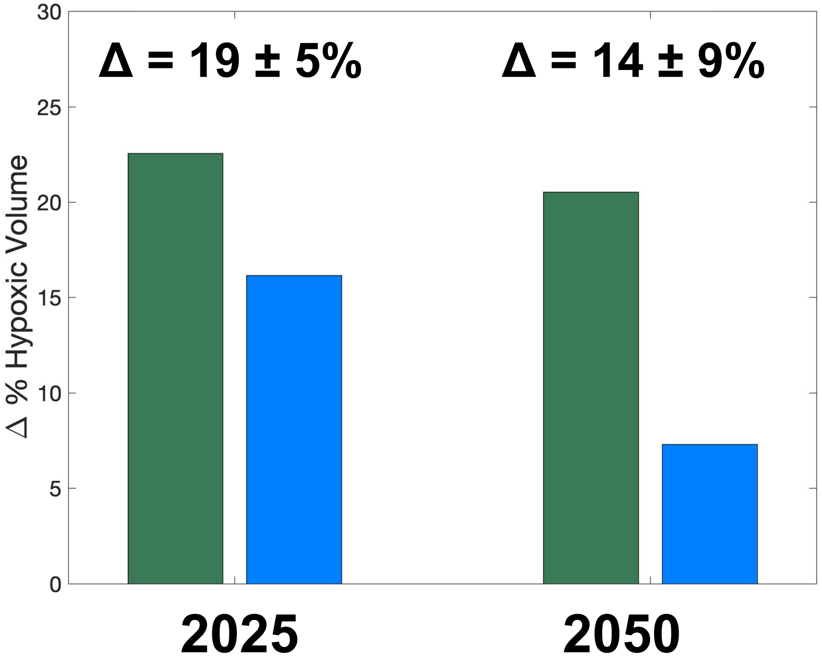
- The choice of downscaling model also produces a significant amount of uncertainty, but slightly less than the choice of watershed model

What factor produces the greatest amount of uncertainty in climate scenarios?

Watershed Model
DLEM
Phase 6

Watershed Model

DO < 2 mg L^{-1}



GCM

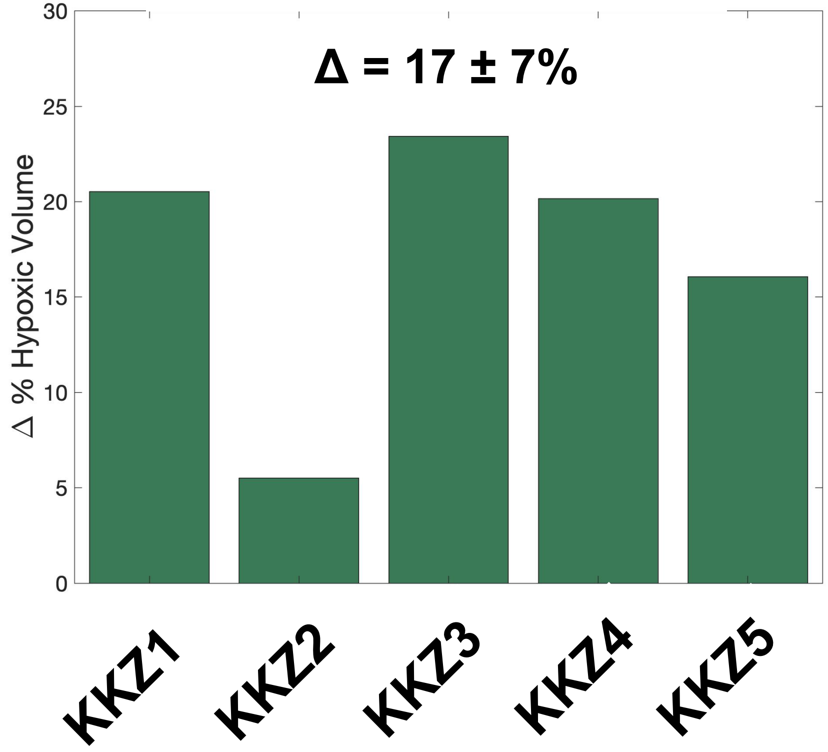
DO < 2 mg L^{-1}

Coming Soon!

2025

GCM

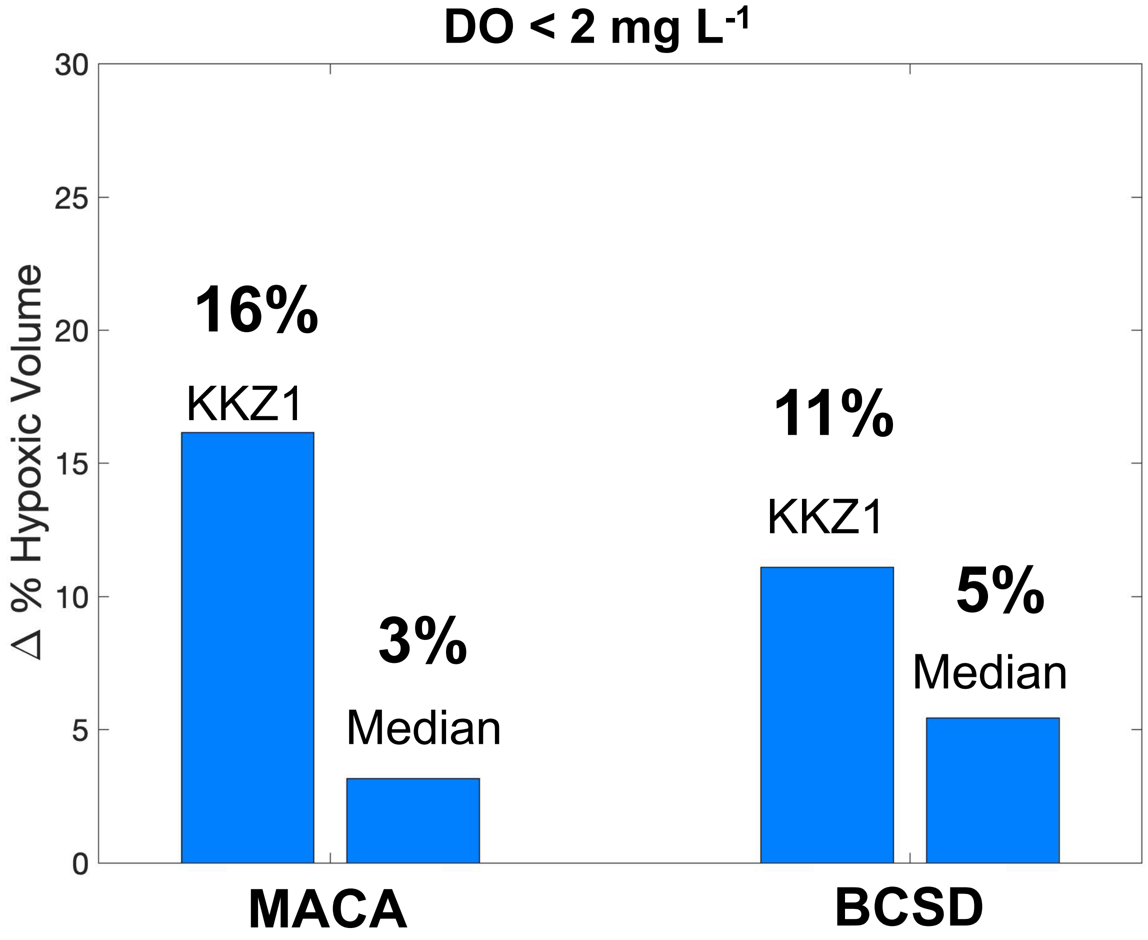
DO < 2 mg L^{-1}



2050

- The choice of GCM produces a significant amount of uncertainty, about the same as the choice of watershed model

Is there a difference between the median method (current CBP approach) and the central (KKZ1) GCM?



- The median method with MACA substantially underestimates the impact of climate change in 2025 (2050?)
- The median method with BCSD slightly underestimates the impact of climate change in 2025 (2050?)

Overall Results

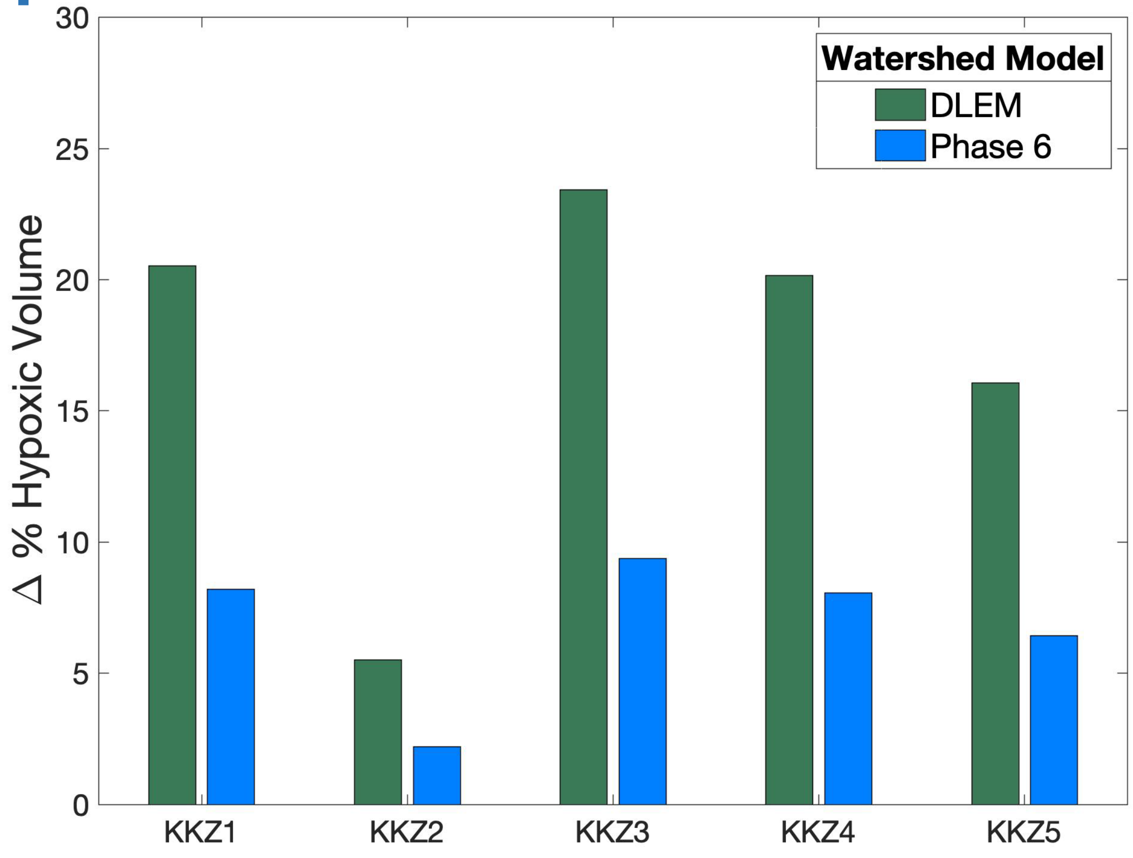
1. **All** climate change scenarios now show an increase in hypoxia and anoxia
2. Differences in Phase 6 and DLEM results are consistent between 2025 and 2050 scenarios
3. The effect of downscaling is relatively small compared to uncertainty due to choice of watershed model and GCM
4. The median of all GCMs produce estimates that **underestimate** outputs from the central GCM selected via the KKZ methodology

   → GCM Median ≠ GCM KKZ1 (especially for MACA in 2025; 2050?)

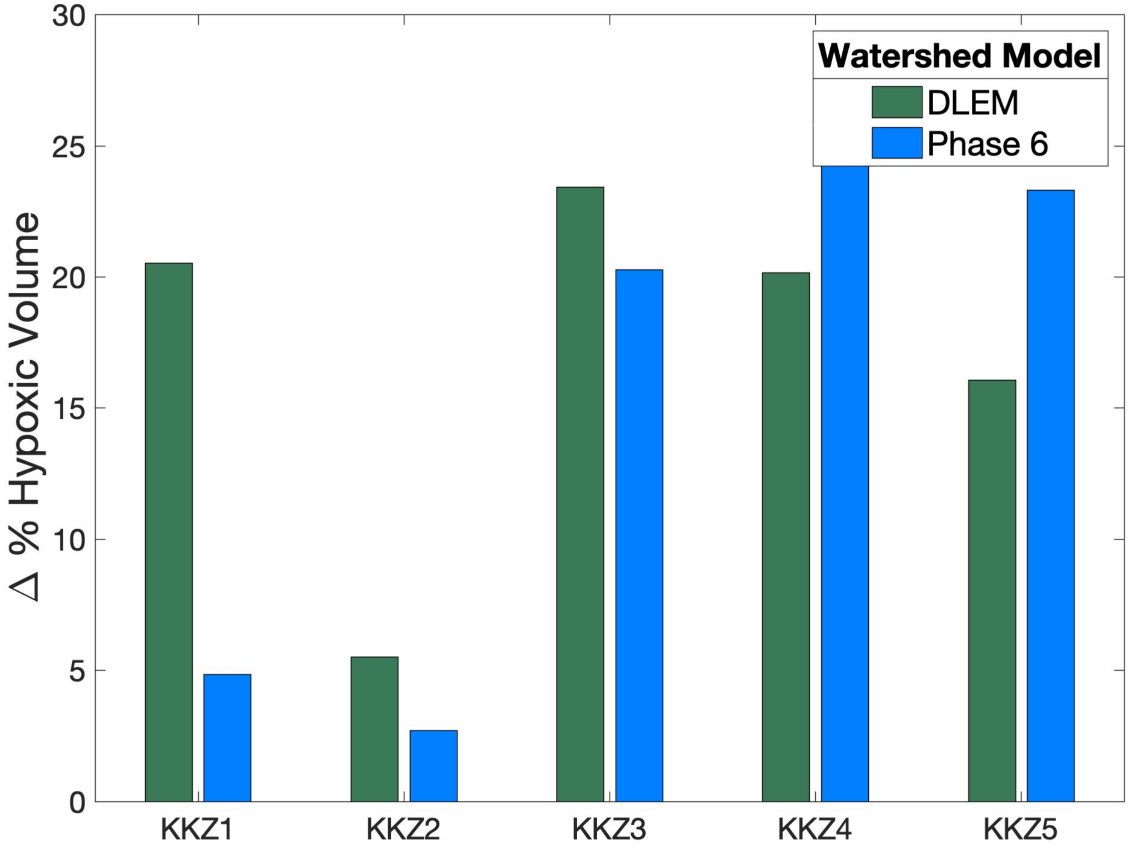
- Therefore, the relative sources of uncertainty for climate scenarios could be ordered as: **GCM & Watershed Model >= Downscaling Method**

Next Steps: How will having more GCM results for Phase 6 compare to DLEM outputs?

Hypothetical results for Phase 6!!!



Will there be a common pattern in differences between DLEM and Phase 6 estimates of changes in hypoxia/anoxia?



Will there be a greater propagation of uncertainty between watershed model estimates of hypoxia/anoxia?