# Sensitivity of projected Chesapeake Bay hypoxia to climate model, downscaling model, and watershed model

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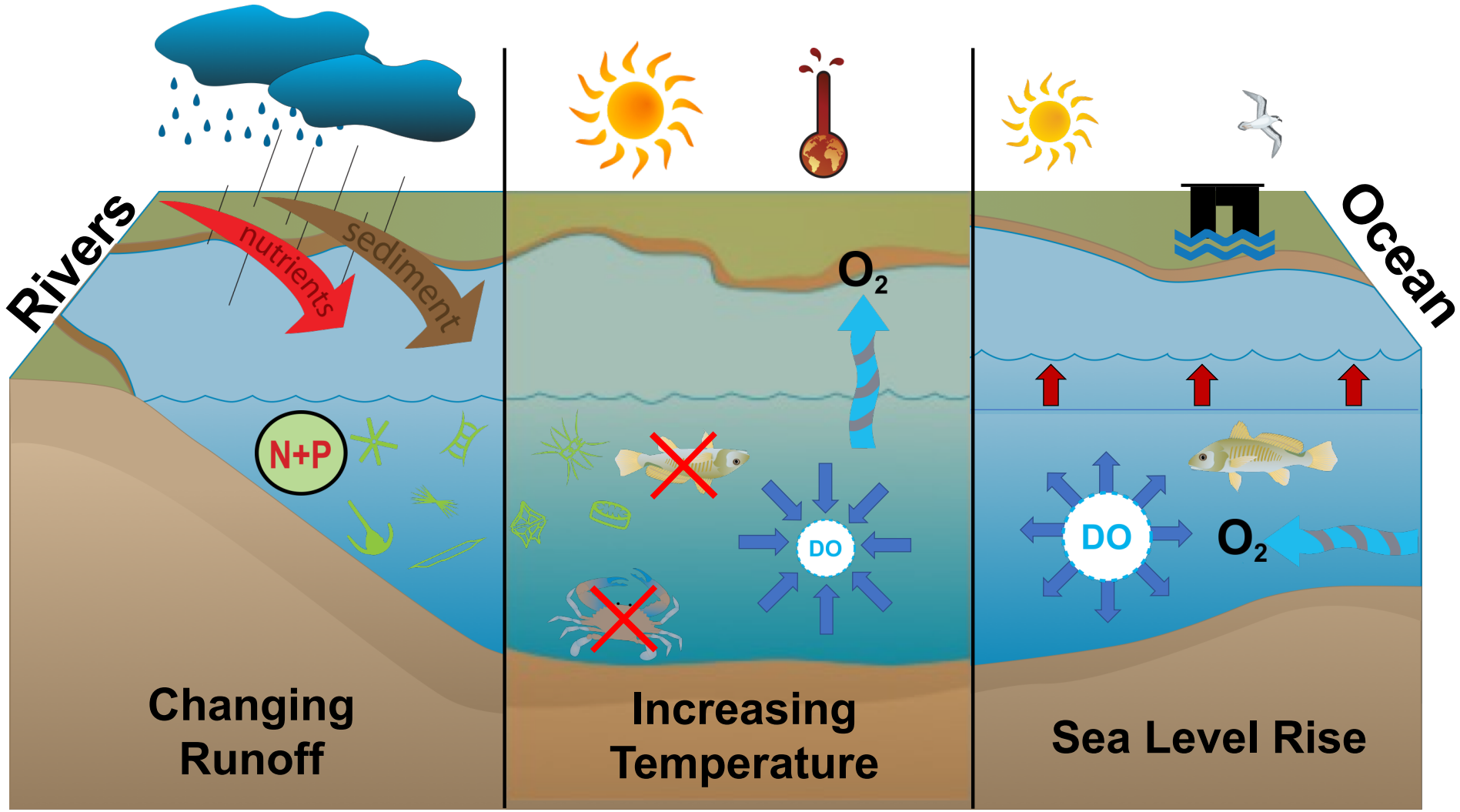
**4**. Auburn University

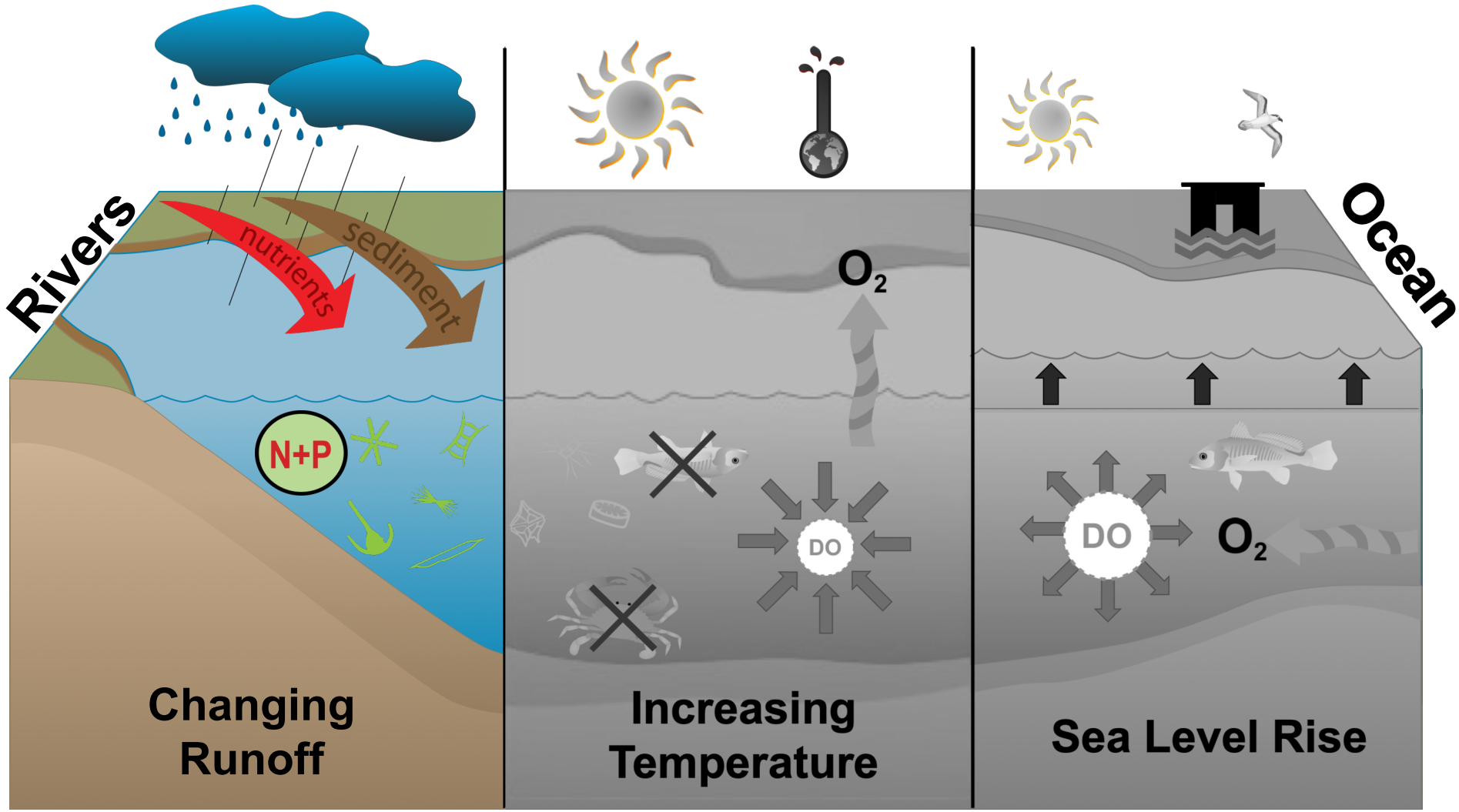
VIMS | William & Mary
Virginia Institute of Marine Science

# Climate change has multiple impacts on Chesapeake Bay oxygen

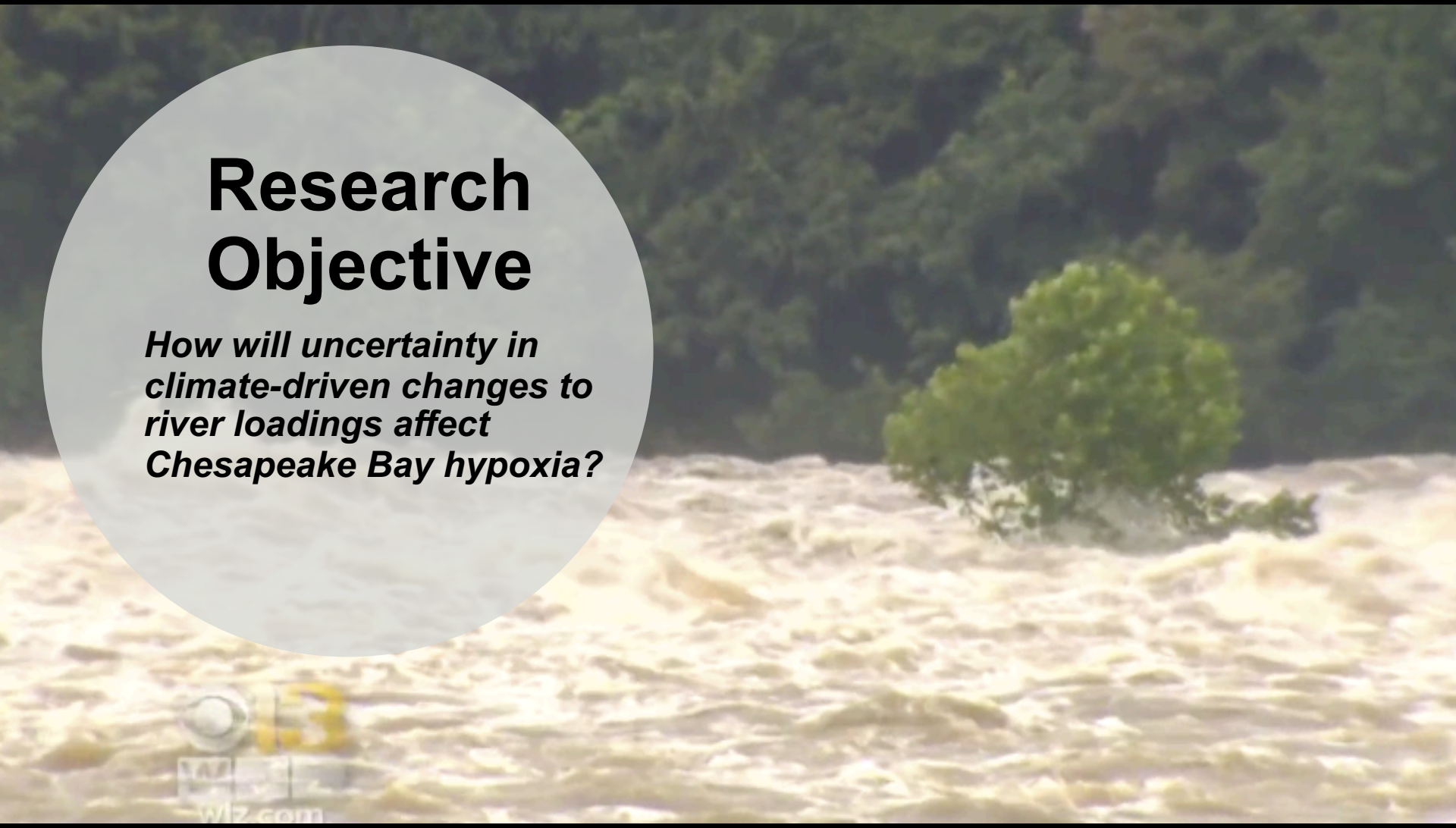



Irby et al., 2018

# Here we examine only the effect of changing river runoff




Irby et al., 2018



# Research Objective

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

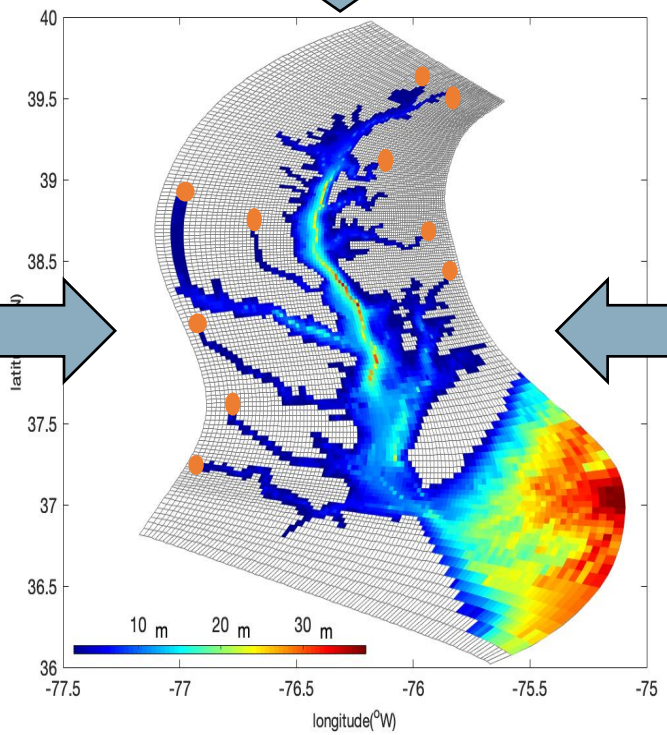
# Methods: Modeling Framework

**Atmospheric Forcing**

**Hindcast Weather Data**

**Riverine Inputs**

**Terrestrial Models:**
**Phase 6: 1984-2014**
**DLEM: 1900-2015**



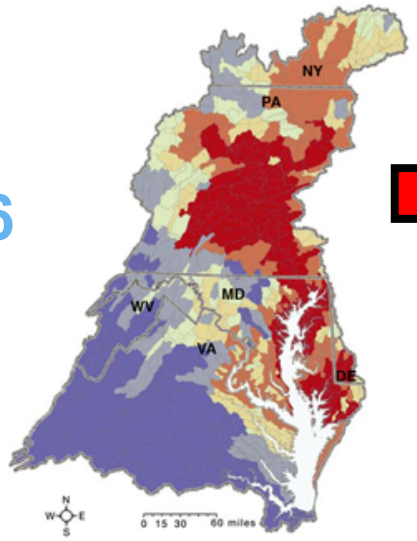

**Coastal Fluxes**

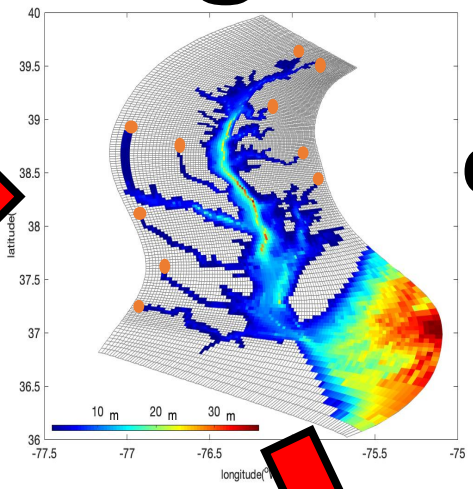
**Climatological Data**

**ChesROMS-ECB**

# Methods: Modeling Framework

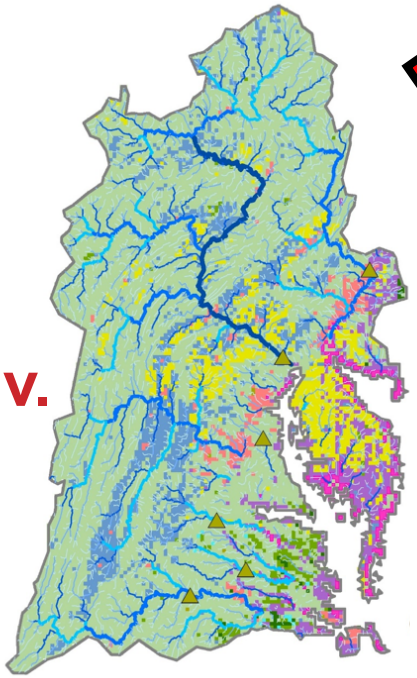
Phase 6
CBP



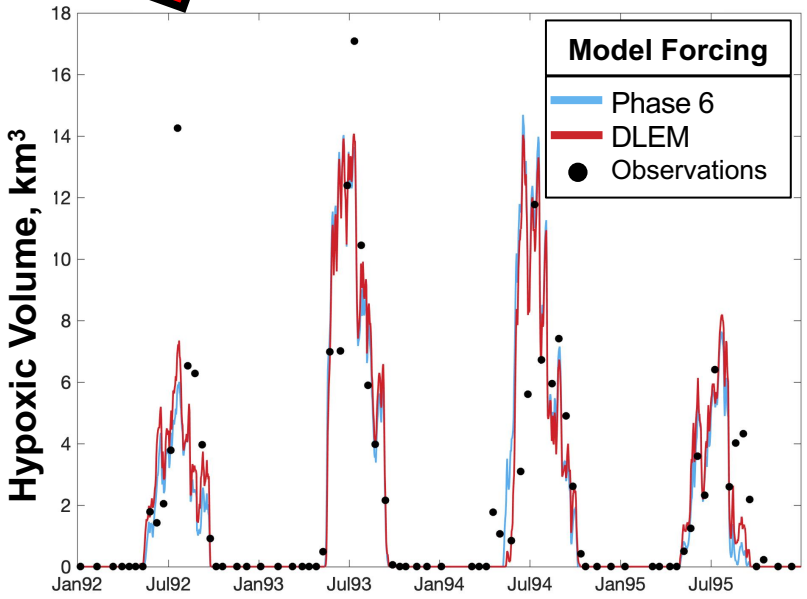




ChesROMS-ECB

DLEM
Auburn Univ.



Hypoxia

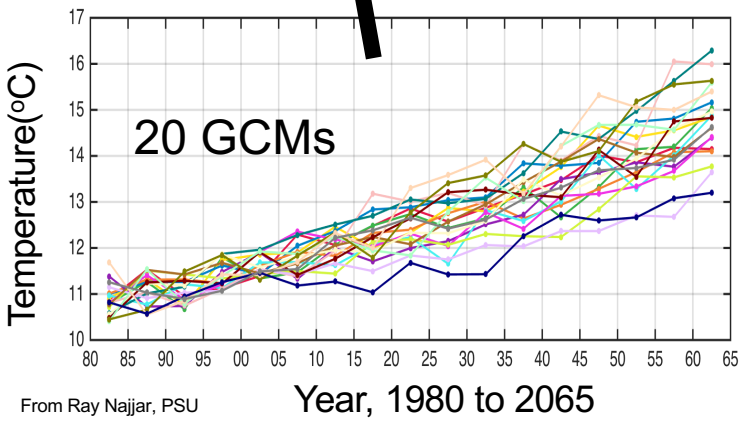


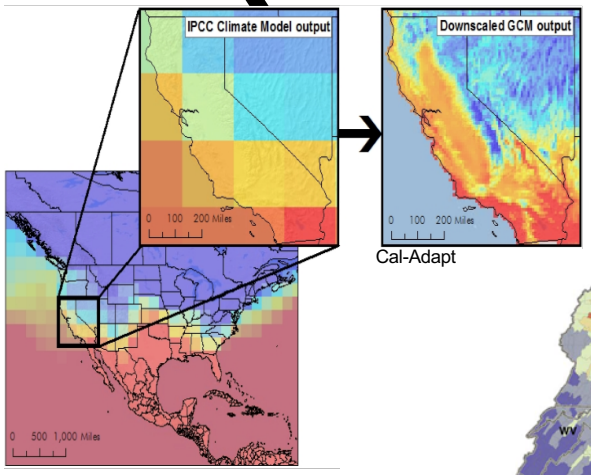
Climate Model | Downscaling Model | Watershed Model

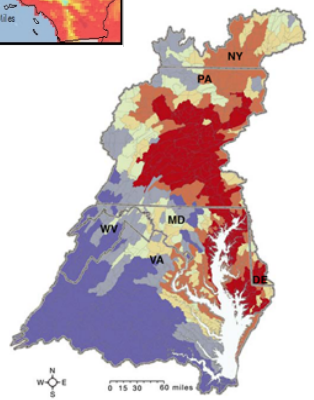
GCM 1
GCM 2
GCM 3
GCM 4
GCM 5...

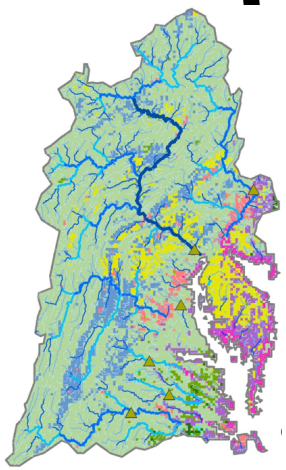
MACA
BCSD

DLEM
P6 WSM



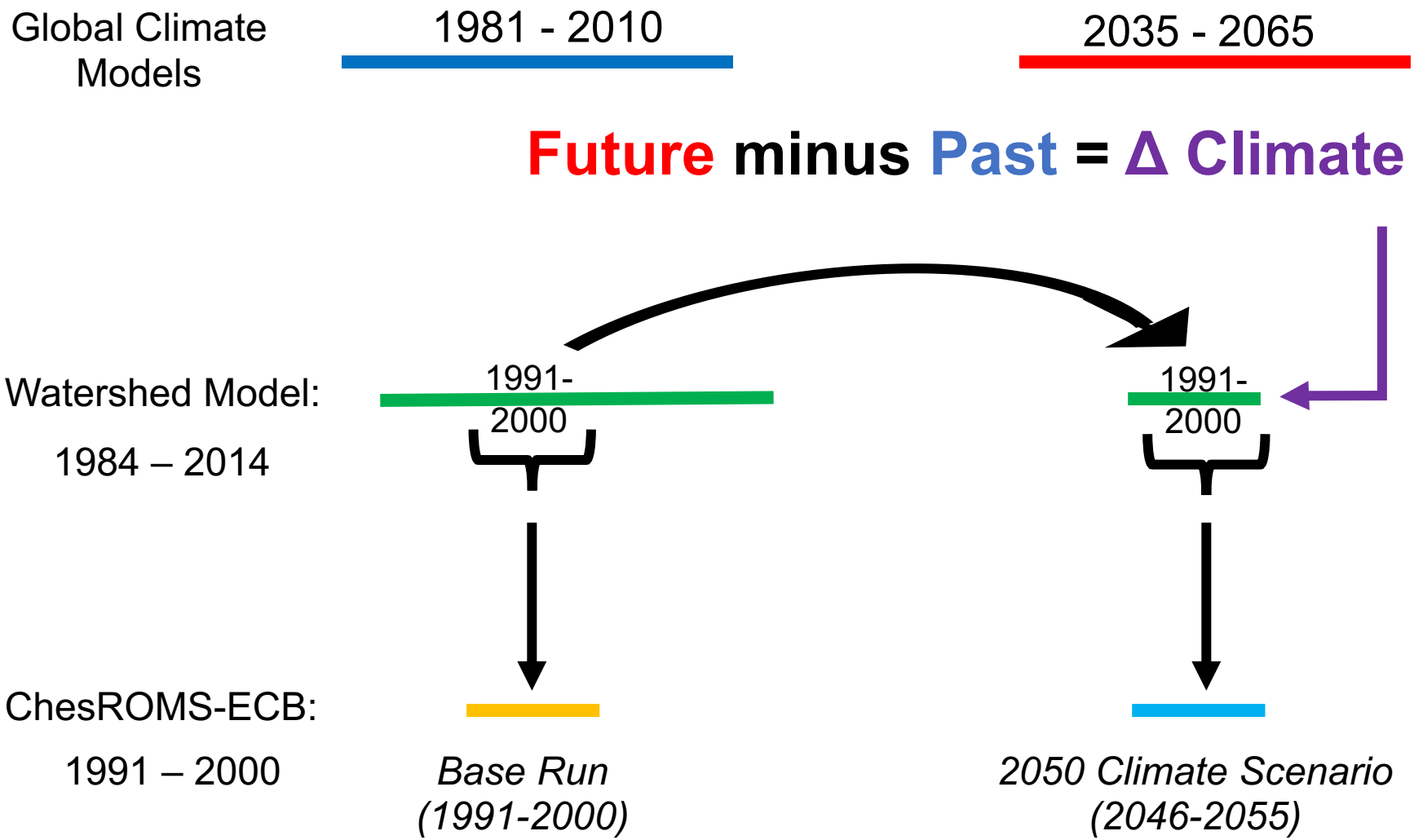



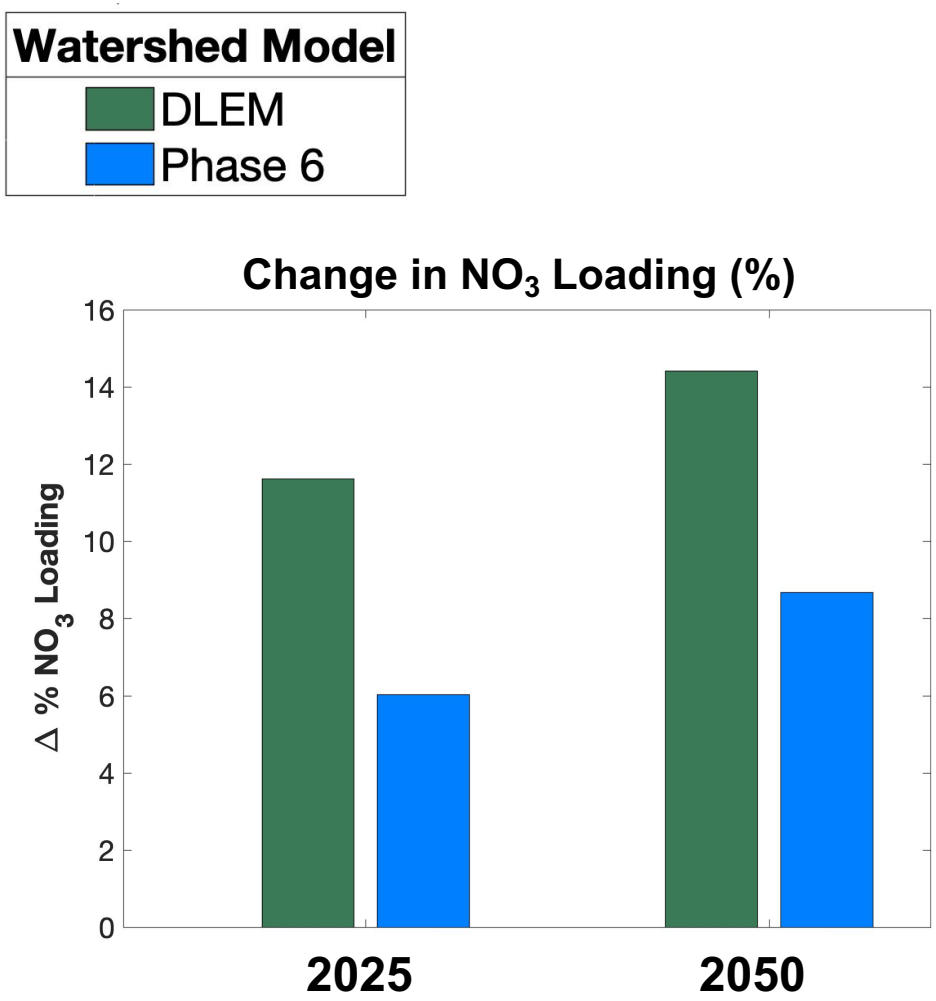
Multiple sources of uncertainty exist for climate forcings

# Climate Forcing Method

- Delta approach is applied:

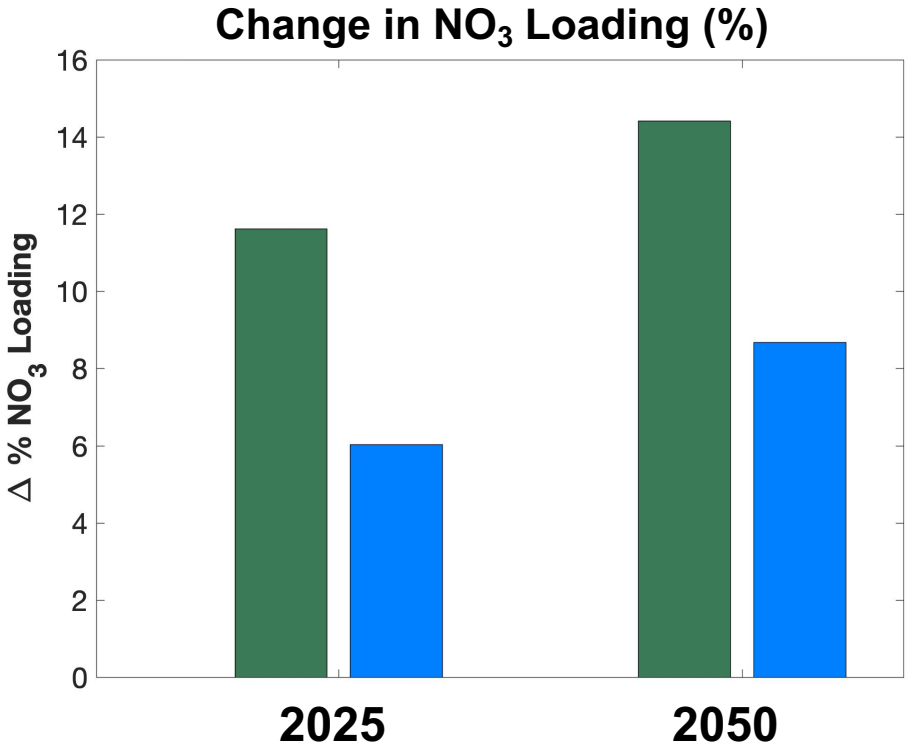


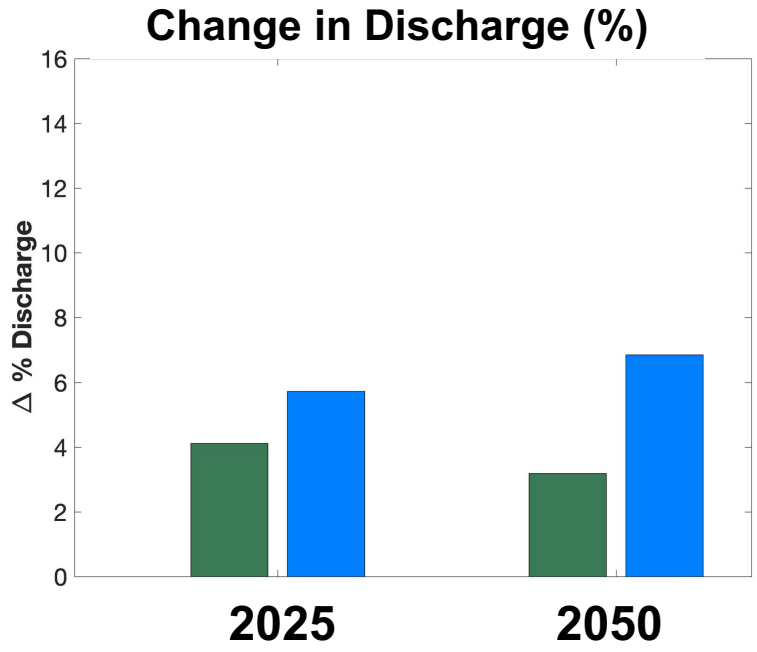
# How does climate affect $NO_3$ loading?

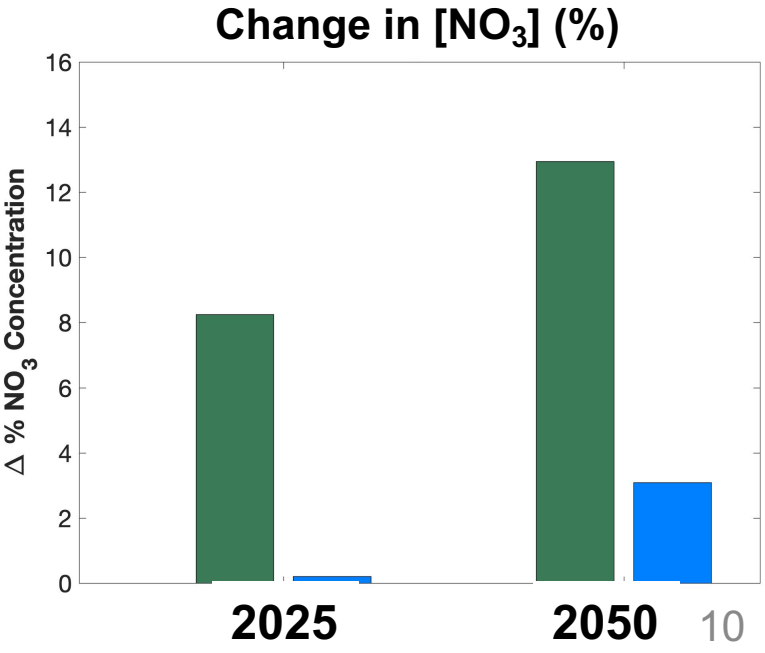



- Both watershed models show increases in $NO_3$ loading due to climate change
- Similar relationship exists between watershed models in 2025 and 2050

# What causes these changes in $NO_3$ loading?

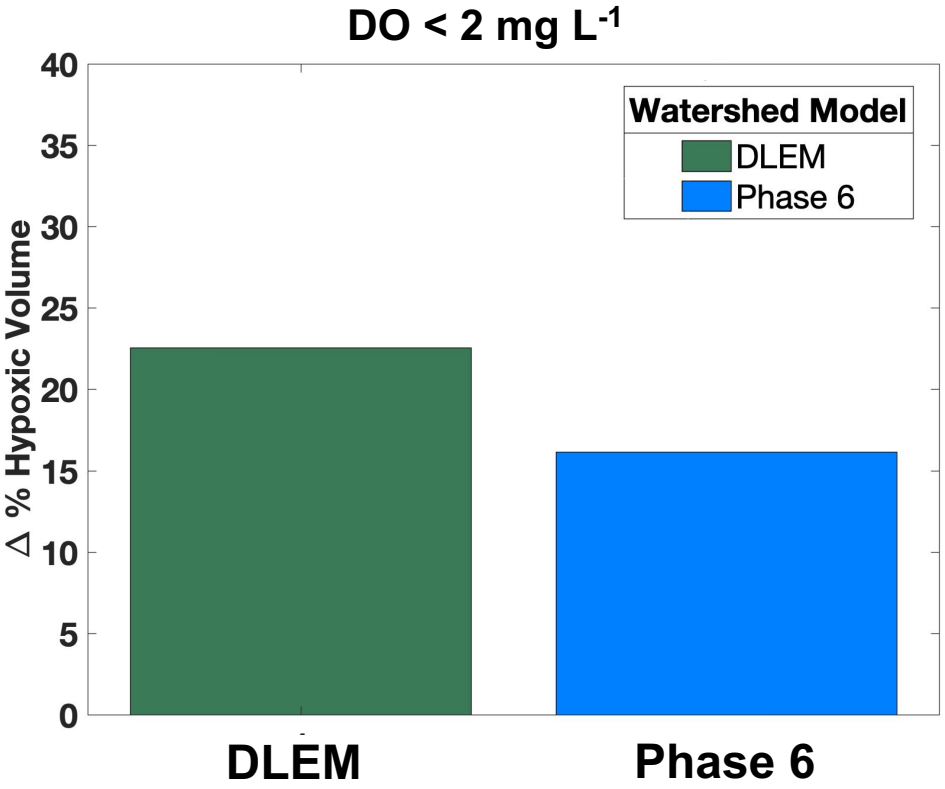




- Increases in $NO_3$ loadings can be attributed to:
  - In DLEM → discharge & [ $NO_3$ ]
  - In Phase 6 → mostly discharge

# Which uncertainty is greatest in 2025?

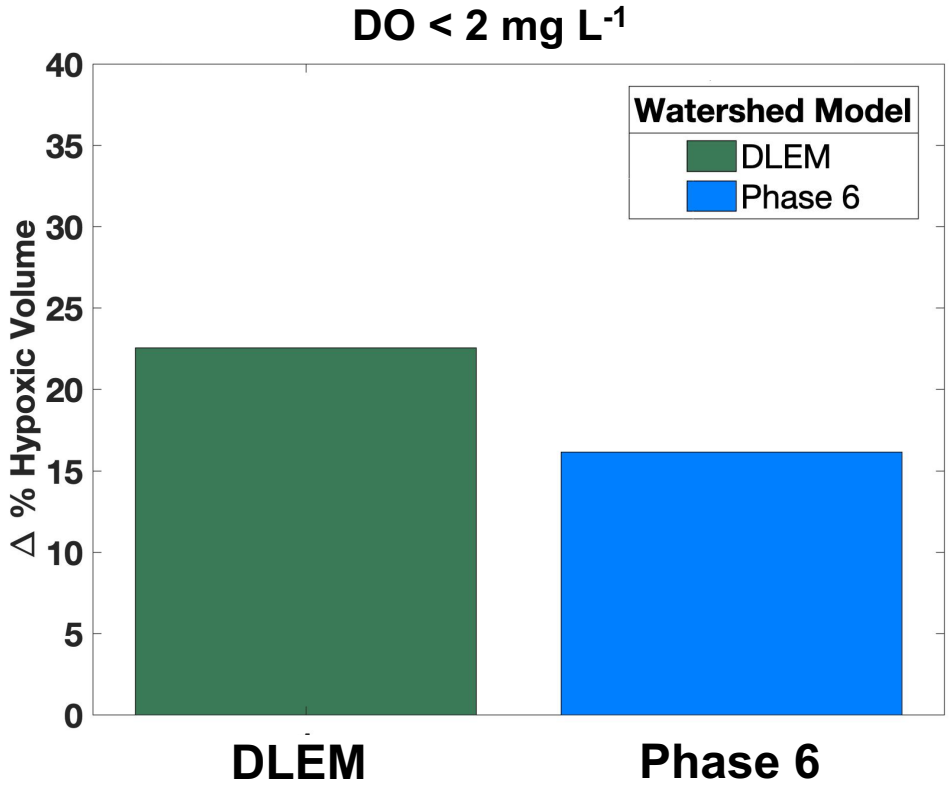
## Watershed Model



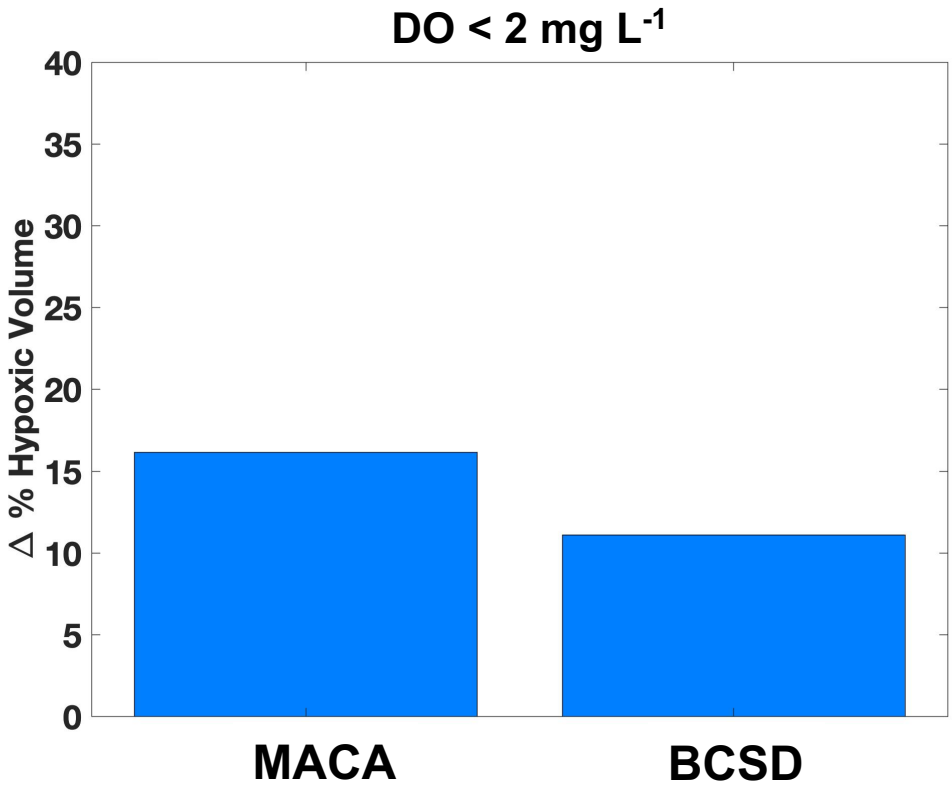

- Climate scenarios show an increase in hypoxia
- There is uncertainty due to watershed model choice

# Which uncertainty is greatest in 2025?

## Watershed Model

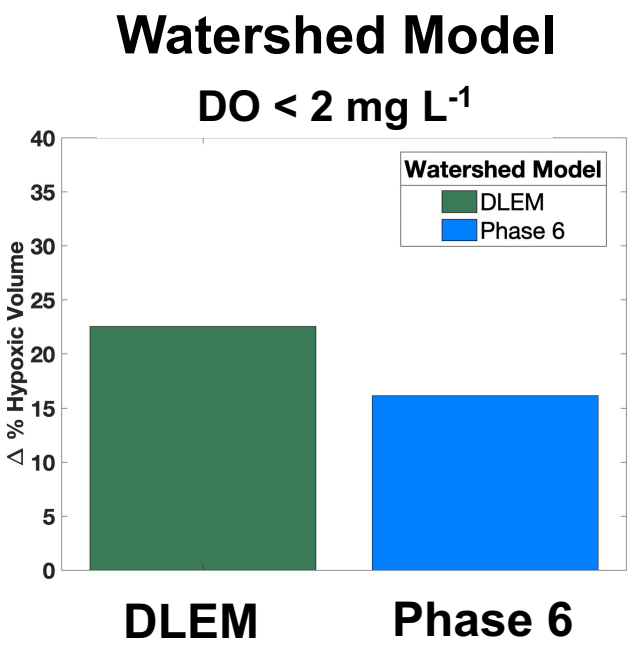


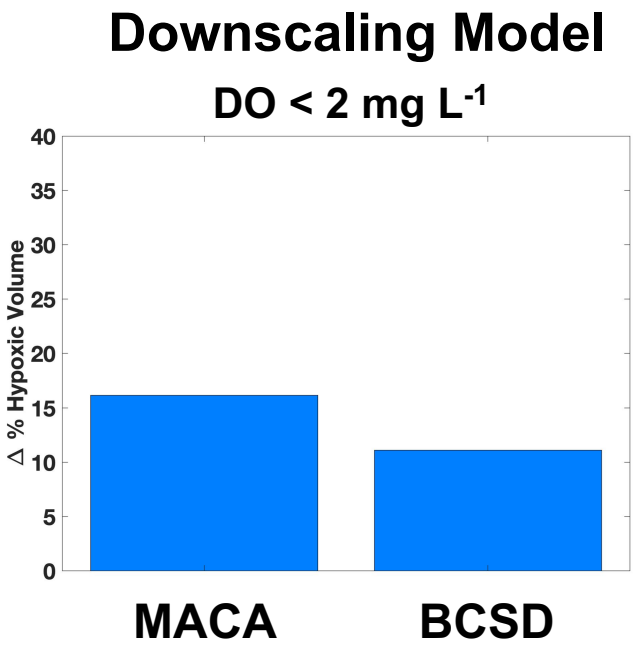

## Downscaling Model

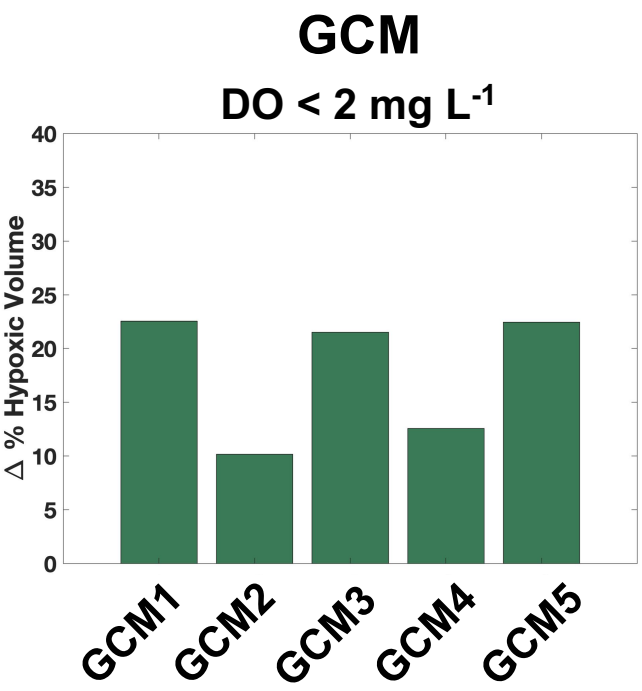



- The downscaling model produces a similar amount of uncertainty as choice of watershed model

# Which uncertainty is greatest in 2025?



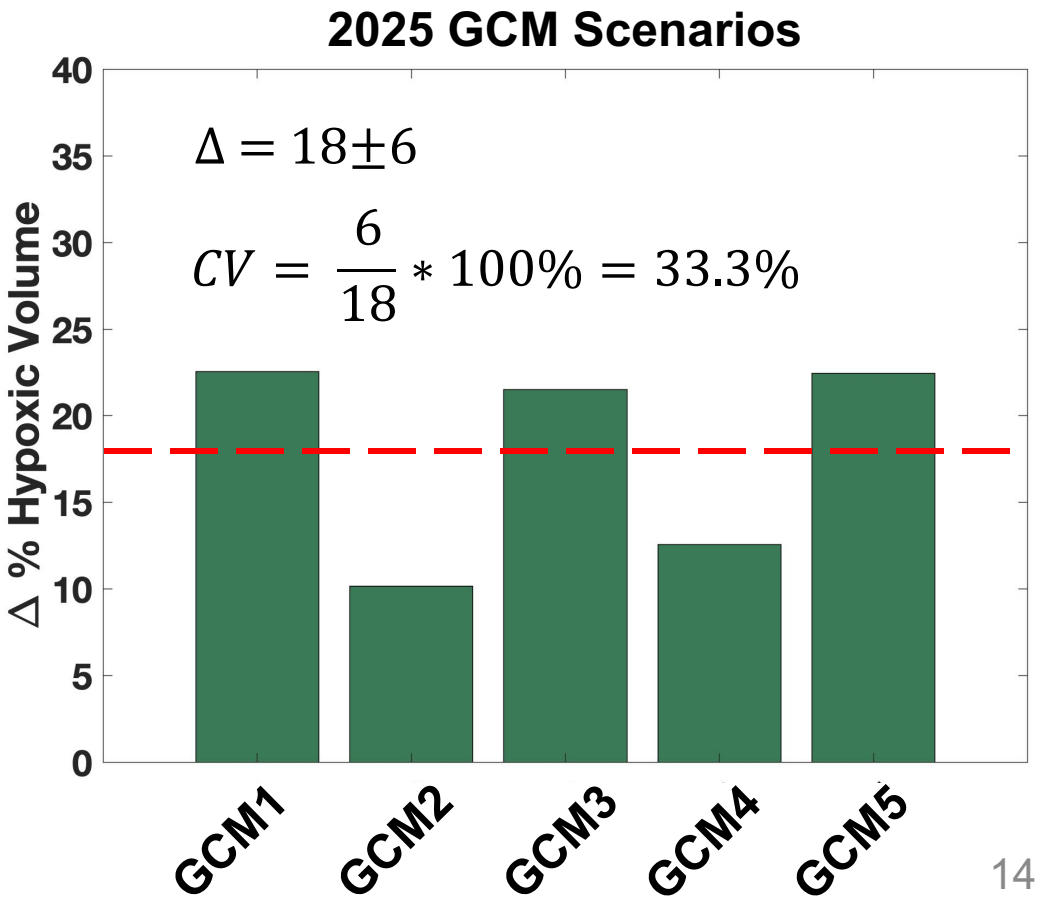




- GCM uncertainty slightly greater than others
- At low oxygen levels, uncertainty from the watershed model, downscaling model, and global climate model are all similar

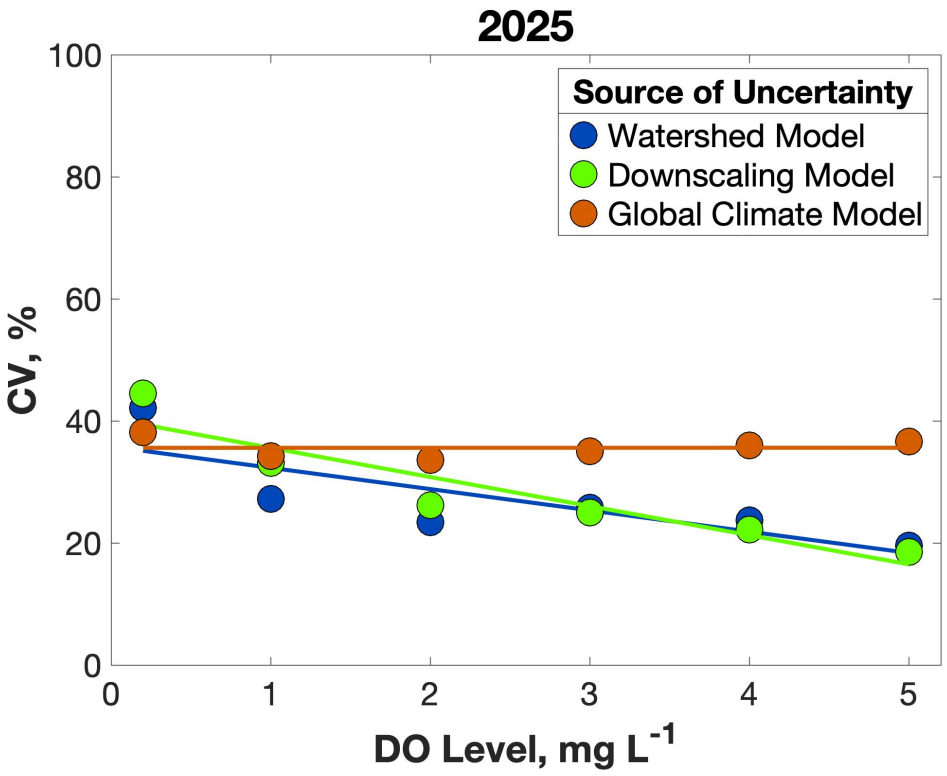
# Comparing Uncertainties: Coefficient of Variation

- The metric that we use to compare 3 sources of uncertainties is the coefficient of variation (CV)

$$CV = \frac{Standard\ Deviation}{Mean} * 100\%$$

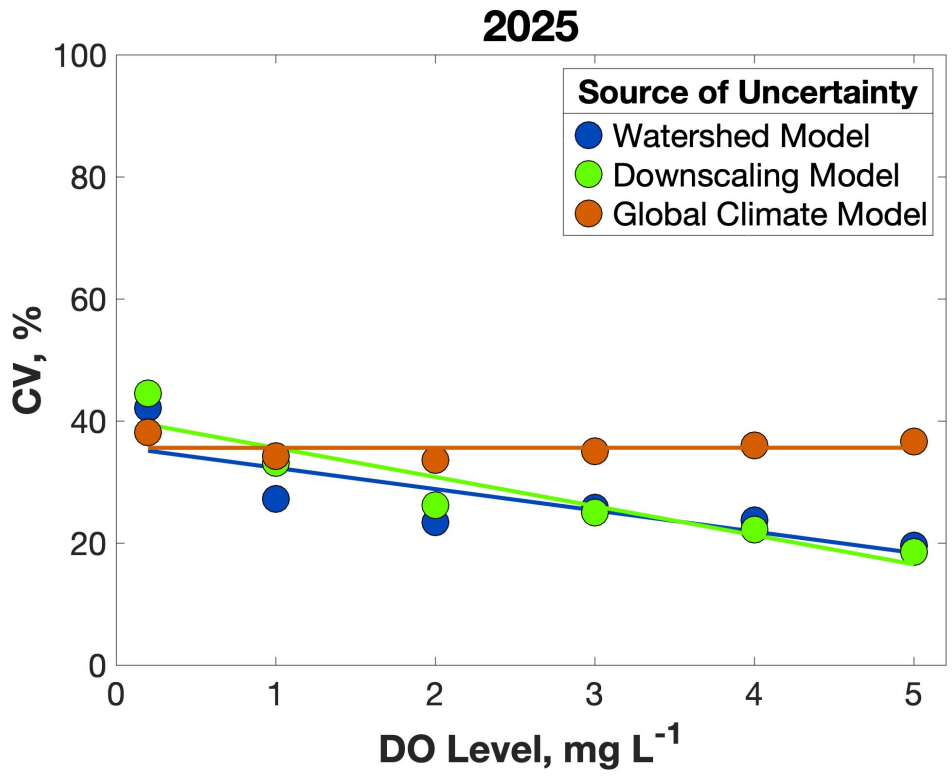


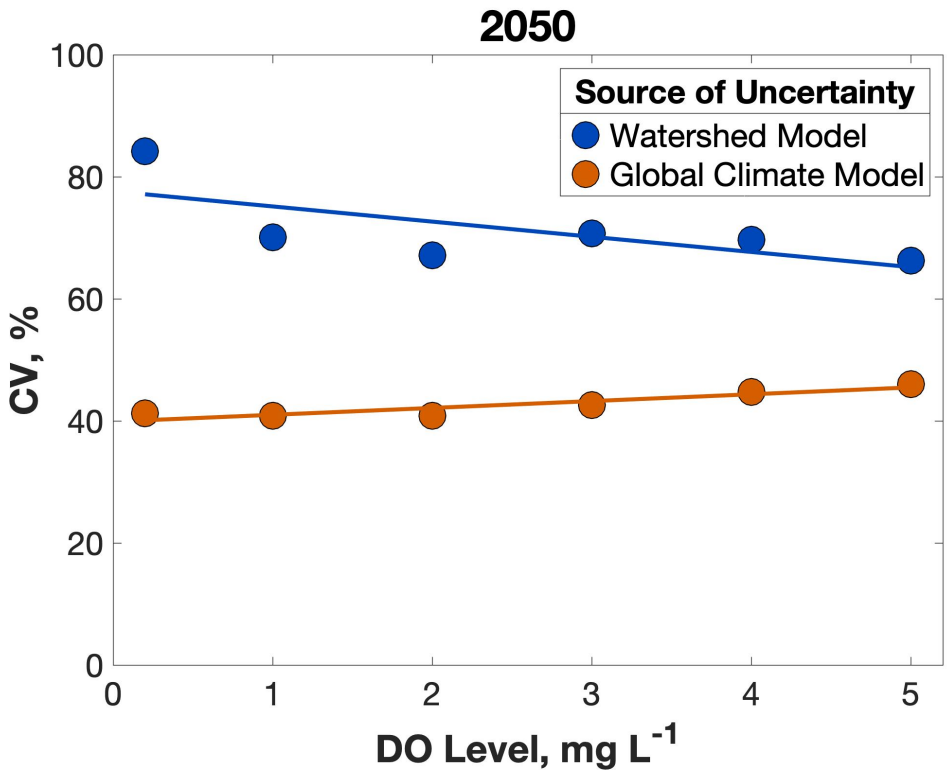
# Comparing Uncertainties




- For 2025 scenarios
  - Downscaling and watershed model uncertainty ↓ as hypoxia thresholds ↑
  - Climate model uncertainty > downscaling and watershed model uncertainty as hypoxia thresholds ↑

# Comparing Uncertainties




- 2050 scenario uncertainty > 2025 scenario uncertainty
- In 2050, watershed model uncertainty > climate model uncertainty

# Comparing Uncertainties

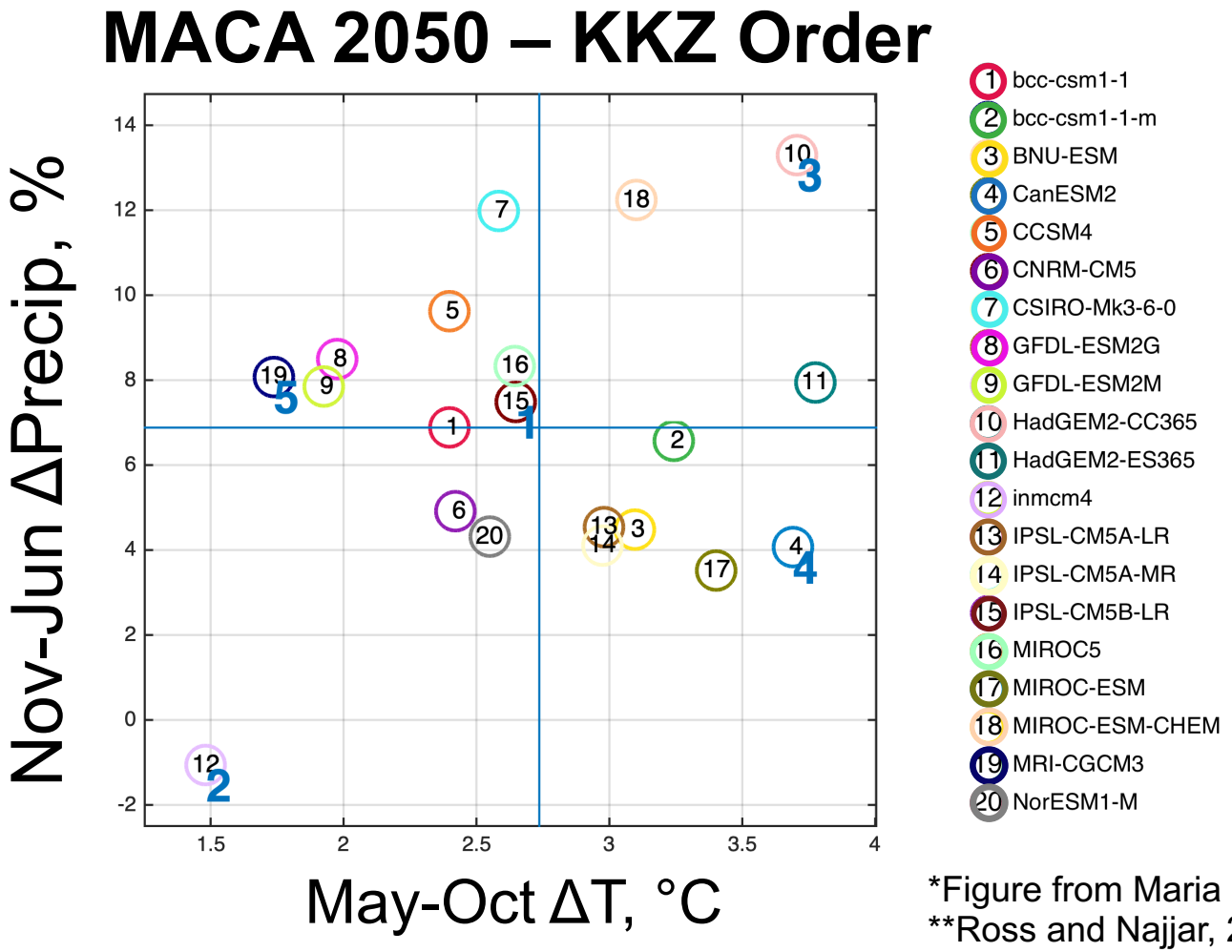
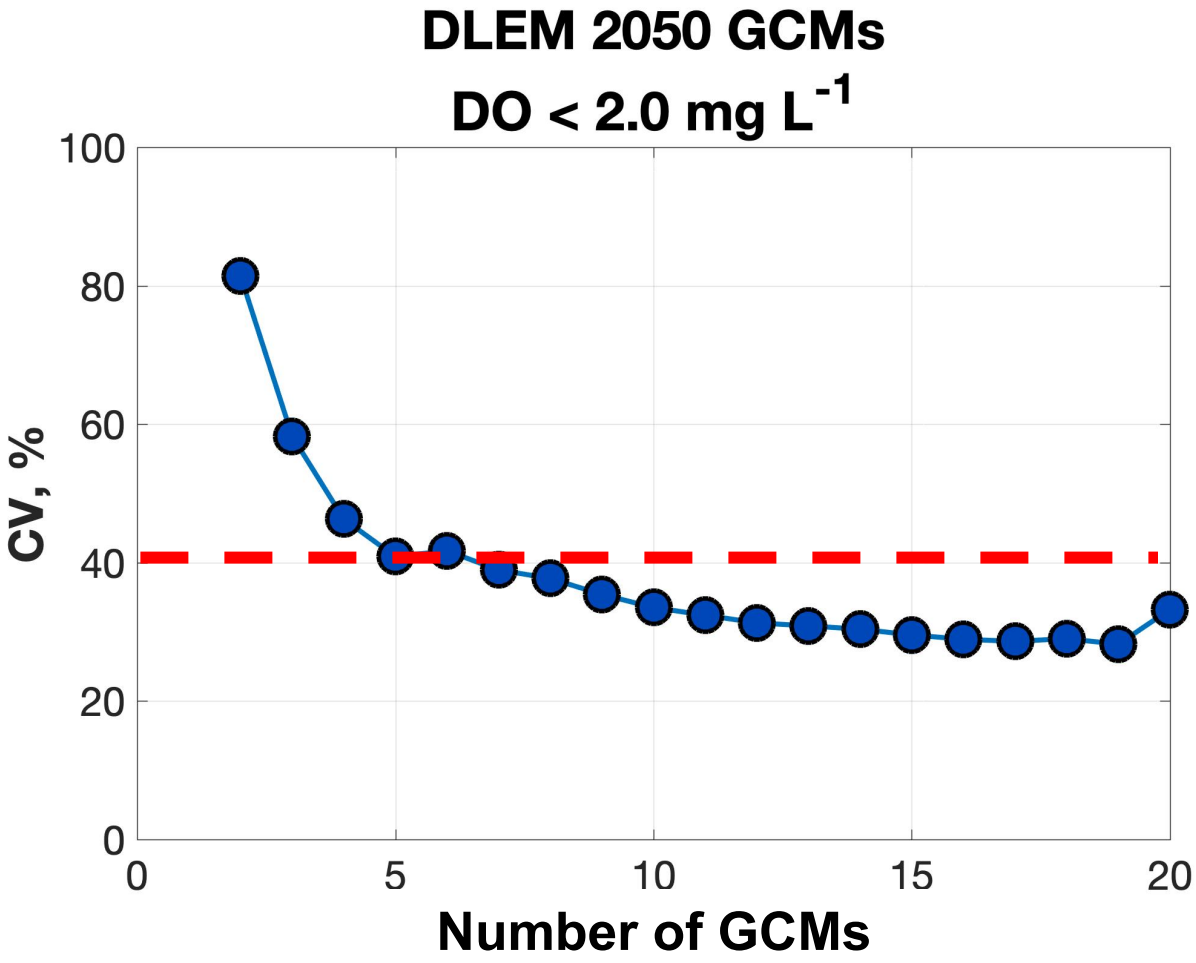



*Figure from Maria Hermann
**Ross and Najjar, 2019 (link)

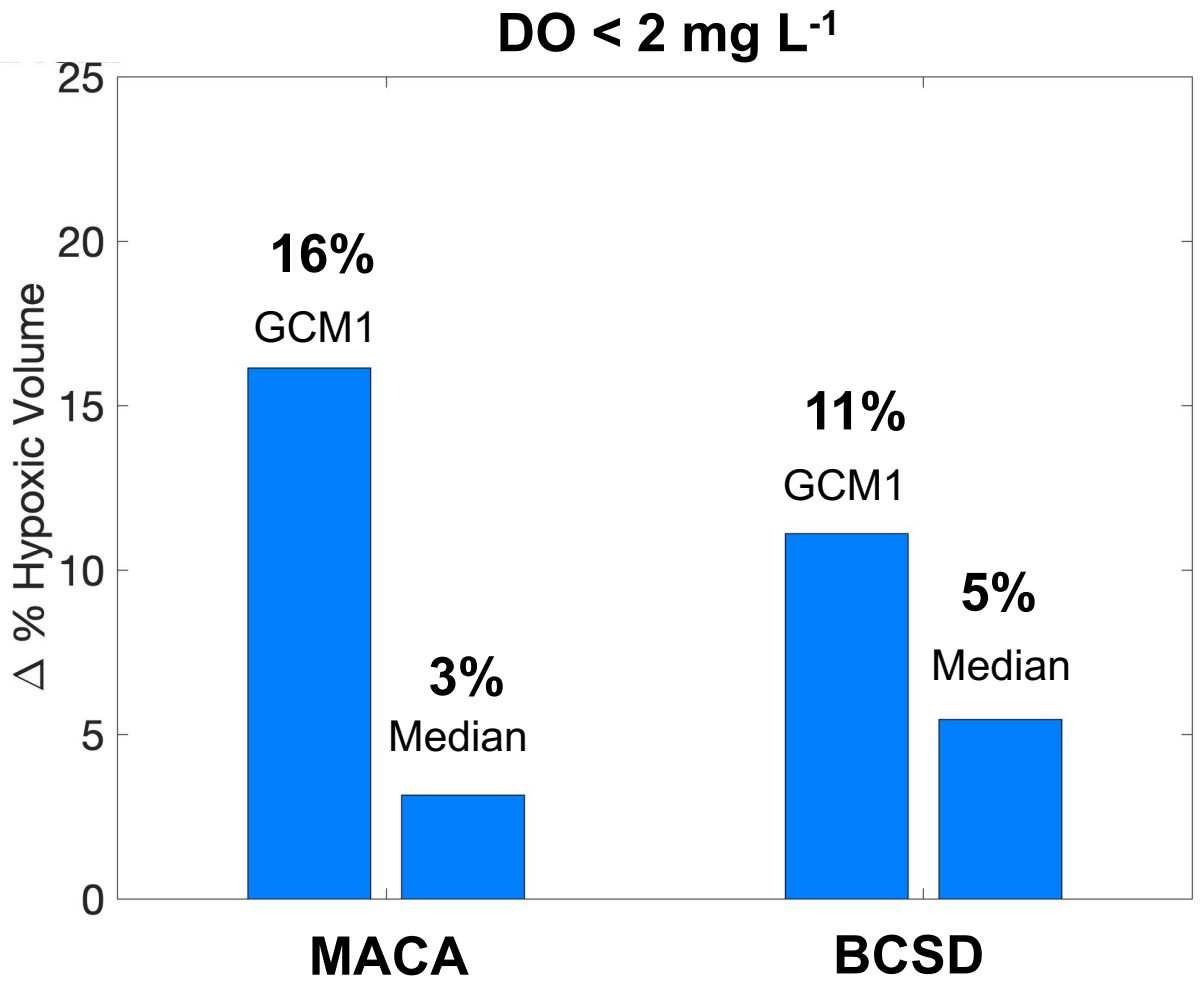
- 5 GCMs were chosen to reduce computational effort
- How can our uncertainty change if we use one GCM? Or 20?

# Comparing Uncertainties




- GCM uncertainty ↓ as model outputs ↑
- Standard deviation (and CV) decrease as *n* ↑
- Tradeoff between greater certainty and computational time

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




- In 2025, the median method results in climate change impacts 50-80% smaller than the “median” GCM

# Conclusions

- Climate change scenarios show an increase in hypoxia and anoxia
  → Uncertainty does not affect direction of trends
- In 2025:
  - At low oxygen levels, uncertainty from watershed model, downscaling model, and global climate model are similar
  - At mid-oxygen levels, climate model uncertainty is greatest
- In 2050:
  - Uncertainty is greatest for watershed model choice

→Therefore, the relative sources of uncertainty for climate scenarios could be ordered as:

**2025: GCM > Watershed Model ≈ Downscaling Model**

**2050: Watershed Model > GCM**

# Recommendations for the Modeling WG from the CHAMP PIs

1. Compare current results with outputs from latest model version
2. Use an individual GCM rather than the median method to avoid producing artificially low estimates of climate impacts.
3. Use multiple GCMs (rather than just one) to reduce uncertainty associated with climate change impacts.