Assessing Water Quality Sensitivity to Decadal Climate Variability in the Missouri River Basin based on SWAT Simulations

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Outline

- Overview of decadal climate variability impacts project focusing on the Missouri River Basin (MRB)

- Preliminary analysis of decadal variability impacts on nutrient (Nitrogen and Phosphorous) transport over MRB that can potentially influence water quality in the MRB region
Decadal Climate Variability
(Variability with 8-12 year time scale)

Interactions between ocean and atmosphere give rise to natural decadal climate variability (DCV)

Well-known DVC phenomena are:

- Pacific Decadal Oscillation (PDO)
- Tropical Atlantic sea-surface temperature (SST) gradient variability (TAG)
- West Pacific warm pool (WPWP) SST variability

Observations have shown that DCV impacts regional hydrologic conditions in many parts of the world
The Center for Research on the Changing Earth System (CRCES), in collaboration with Texas A & M University (Texas A&M) and NASA-UMBC-Joint Center for Earth Systems Technology (JCET), is leading a project to assess impacts of natural decadal climate variability on water and crop yields in the Missouri River Basin (MRB).

MRB is the largest river basin in the US, covers more than 500,000 square miles (~1,280,000 sq. km), a major crop producing region, dependent mostly in seasonal precipitation (non-irrigated agricultural practice), vulnerable to climate variability and change.
Impacts Assessment of Decadal Climate Variability on Water and Crop Yields in the Missouri River Basin (MRB)

- Temperature and Precipitation Observations (12 km Resolution) (1950-2012) Over MRB
- Soil and Water Assessment Tool (SWAT) Simulations over MRB
- Water and Agricultural Yields Analysis
- Economic impact assessment over MRB
- Development of management strategy over MRB
SWAT was calibrated over 14,000 sub-basins covering MRB

SWAT simulations were conducted over these sub-basins using observed temperature and precipitation from 1950-2012

SWAT simulations were also conducted for various DCV scenarios (PDO, TAG, and WPWP in positive and negative phases)

SWAT simulations used auto-fertilization practice based on nitrogen and phosphorous stress conditions
Analysis of the multi-decadal SWAT simulations show that overall water yield and streamflow in MRB increase by 80% during the positive phase of PDO and negative phase of TAG compared to average condition (Similar deficit was found during the opposite phases of PDO and TAG)

SWAT simulations also showed significant DCV impact on winter and spring wheat
Our hypothesis is that the DCV impact on water yield, subsequent impact on total sediments, and crop yields would result in DCV of nutrient transport (N and P) with potential of significant impact on water quality (e.g. algal bloom, dissolved oxygen) in the MRB region.
SWAT Simulations of N and P Transport over MRB

10-year Climatology

Nitrate

Organic Nitrogen

Soluble Phosphorus

Organic Phosphorus

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SWAT Meeting, June 24-26, 2015
SWAT Simulation of Water and Sediment Yields over MRB

Water Yield

10-Year 1990-1999 Climatology SWAT Output (mm)

Sediment

10-Year Climatology SWAT Output

10-Year Climatology SWAT Output

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Spatially coherent impact over southern South Dakota and central/northern Nebraska
SWAT-Simulated DCV of Water Yield and Sediment Associated with PDO

Per Cent Change from Climatology

Water Yield

PDO+

 PDO-

Sediment

PDO+

 PDO-

Figure 4: SWAT-simulated annual-average water yield (% change from climatology) in the Missouri River Basin in (a) PDO+ and (b) PDO- phases. Black dots show locations of 95% significance.
SWAT-Simulated DCV of N and P Associated with PDO

![Graphs showing relationships between sediment yield, organic nitrogen, and nitrate percentages.](image-url)
SWAT-Simulated DCV of N and P Associated with PDO

![Graphs showing SWAT Sediment % Change from Climatology from PDO+ Compared with Water Yield % Change from Climatology](image1)

![Graphs showing SWAT Nitrate % Change from Climatology Compared with Water Yield % Change from Climatology in 1014, 1015, 1020, and 1021](image2)
Many SWAT-based studies focus on nutrient transport and water quality issues, the present study focuses on sensitivity of nutrient transports associated with natural DCV over such a large river basin.

Mean N and P transports are much larger in the lower MRB where water yields and sediment output are also large.

Decadal variability of N and P is primarily influenced by PDO phases and show spatially coherent variability in Nebraska and South Dakota – 40-60% change from PDO⁺ to PDO⁻.

Larger variability is found in organic N and P components and appear to be related primarily to sediment variability -- positive (negative) anomaly during PDO⁺ (PDO⁻).
On-going Analysis

- Detailed analysis of: i) land use and crop simulations and ii) water stress and nutrient stress
- Focus on upper and middle MRB to understand spatial pattern of DCV variability
Thank You!