National Aeronautics and Space Administration

FY24 Strategic Initiatives Research and Technology Development (SRTD)

A Golden Era for Hydrology from Space

Principal Investigator: Cedric David (329)**; Co-Investigators:** Elahe Tajfar (329), Madeleine Pascolini-Campbell (329), Maria Hakuba (329), John T. Reager (329), Renato Prata de Moraes Frasson (329), Alexis Bloom (329), Christine Lee (329), Noah Molotch (329), Katherine Chadwick (329), Matthew Bonnema (329)

Strategic Focus Area: A Golden Era for Hydrology from Space **| Strategic Initiative Leader:** Susan E Owen

Objectives: *The overarching goal of this initiative is to strengthen JPL's capabilities for scientific discovery in hydrology and water resources in the upcoming era of satellite remote sensing. Here we address the Decadal Survey question of:* what key Earth System processes drive the joint variability of the water, energy, and carbon cycles?

Background: This research seeks to answer key scientific questions: a) How are water availability and energy distribution changing over time and space?, b) How do water cycles interact with land cover, and influence energy cycles? c) How do different sub-basins of the MRB respond to drought in terms of energy balance components? ?

Approach and Results: a) <u>Water and Energy Cycle Interaction</u>: This research uses a multi-mission approach, investigating interactions between water, energy, and carbon cycles using data from GRACE, GRACE/FO (for hydrology), CERES (for energy), and MODIS (for vegetation). Specifically, we analyze variability in water and energy cycles during severe droughts (2012 and 2022), observing a decreased ratio of precipitation (Pr) to evapotranspiration (ET) and greater sensible heat flux (H) during these periods. **b) <u>Mississippi River Basin Drought Analysis</u>:** The Mississippi River Basin (MRB) spans more than 40% of the U.S. and plays a vital role in the nation's water management and agriculture. This study focuses on how water availability and ET respond to droughts in the MRB, particularly within its sub-basins like the UMRB. Led by E. Tajfar (postdoc), M. Pascolini-Campbell, M. Hakuba.

Table 1. Key attributes of the hydrological, meteorological, and climatic datasets used in this study

Product	Spatial Resolution	Temporal Resolution	Time Period
NOAA ncep reanalysis2: G	2.5°	monthly	1979–present
CERES-EBAF: Rn	1°	monthly	2000–present
GRACE: dS/dt, ET	0.5°	monthly	2003–present
USGS: Q	NA	monthly	2008–2022
MODIS (Terra+Aqua): LCT	0.05°	yearly	2001–2020
MODIS (Aqua): LST	0.05°	monthly	2002–present
GLDAS-NOAH: SM	0.25°	monthly	1948–present
ERA5: VPD, Ta	0.25°	monthly	1940–present

Table 2. Total water storage capacity ($\Delta TWS = TWS_{max}$ - TWS_{min}). The volume of water that the basin can hold between the minimum supply level and full supply level.

Sub-basin	TWS_{min} [mm/month]	TWS_{max} [mm/month]	TWS Capacity [mm/month]
Upper Mississippi	**-213**	**199**	**412**
Missouri	-127	143	270
Ohio	-157	126	283
Arkansas-white-red	-173	131	304

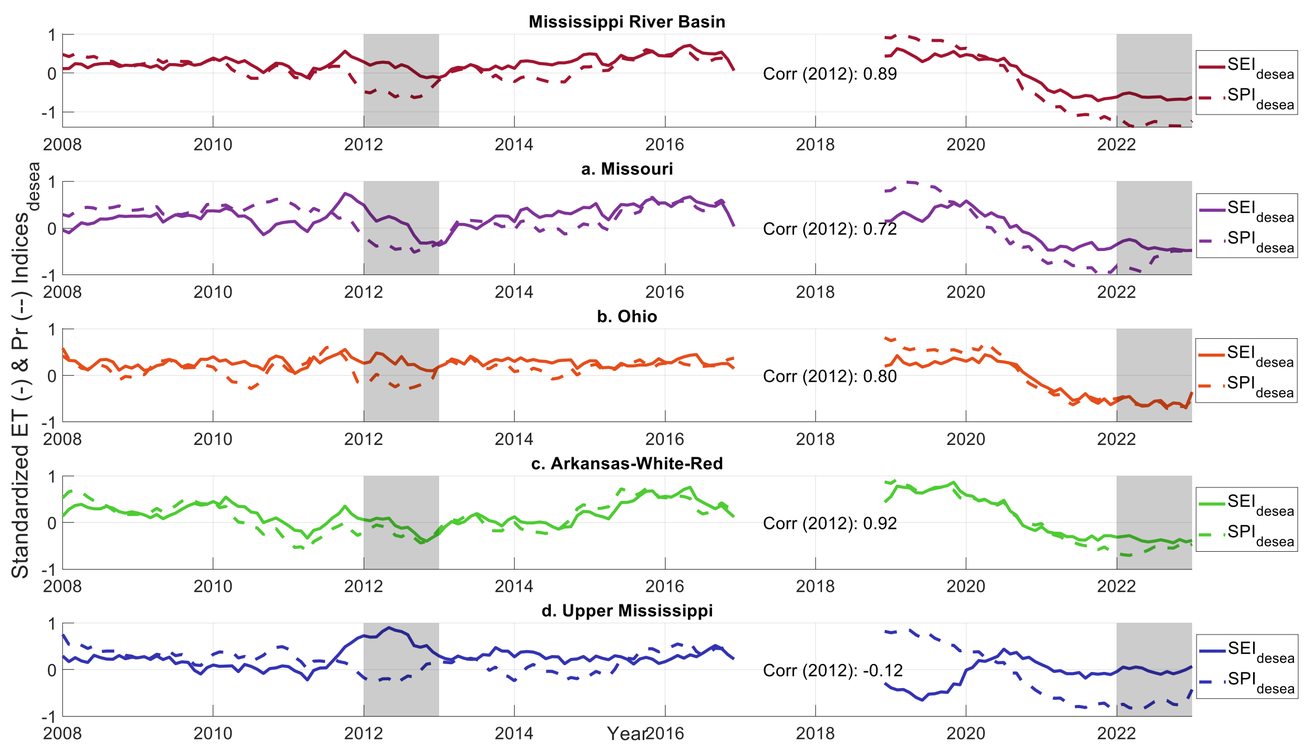

Figure 1. Time-series of drought indices (P & ET) for Mississippi River Basin and its sub-basins. Shaded area show the drought years of 2012 and 2022.

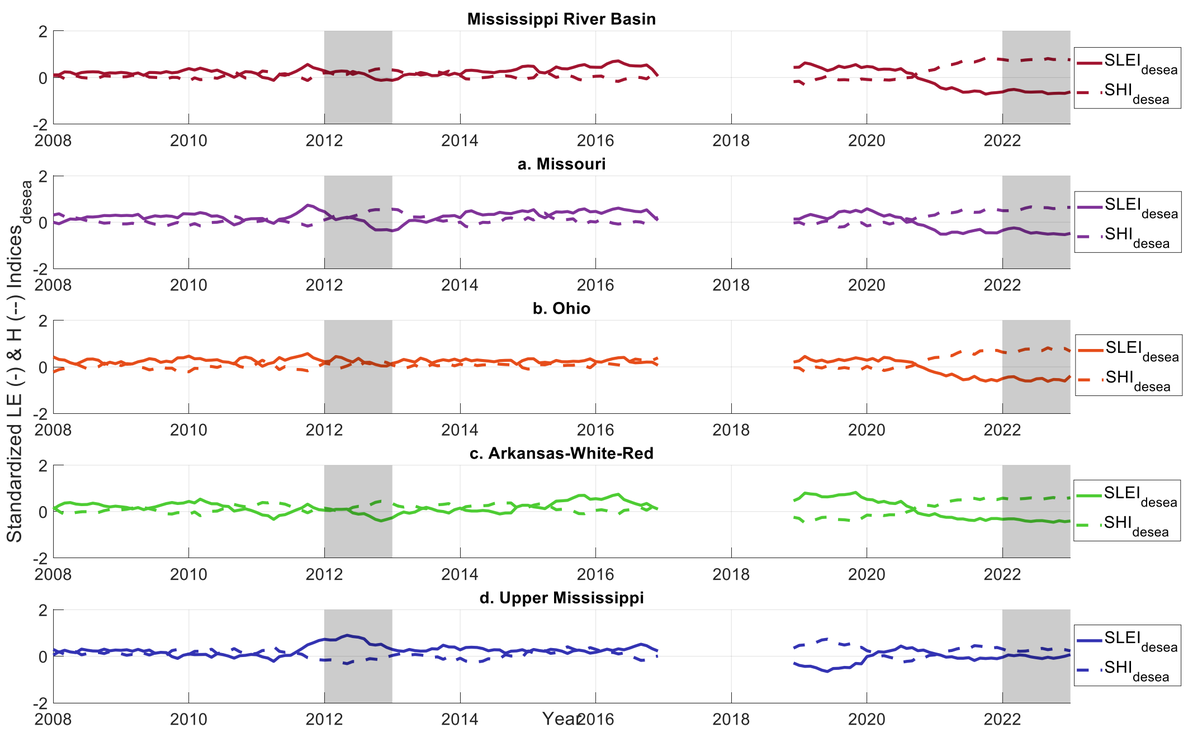

Figure 2. Time-series of energy balance indices (Sensible Heat (H) & latent heat flux (LE)) for Mississippi River Basin and its sub-basins. Shaded area show the drought years of 2012 and 2022.

Key Insight: River basins with higher water storage capacity, like the UMRB, demonstrate resilience during droughts by maintaining higher ET levels. This is due to water released from storage (e.g., soils, groundwater, or snowmelt), resulting in higher latent heat (LE) and a lower Bowen ratio during dry periods.

Significance/ Importance to JPL: This work aligns with the Earth Science Decadal Survey by addressing key questions regarding the changing nature of water and energy fluxes. It will also inform the development of upcoming satellite missions under NASA's Earth System Observatory (ESO), such as the Mass Change and Surface Biology & Geology missions, as well as Libera. By improving our understanding of the relationship between water and energy cycles in both drought and non-drought conditions, this research provides critical insights that can enhance strategies for managing water resources and predicting the impacts of climate variability, particularly in the context of extreme events like drought.

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California
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Publications:

- Pascolini-Campbell, M., & Reager, J. T. (2024). An investigation of the spatial and temporal characteristics of extreme dry and wet events across NLDAS-2 models. *Journal of Hydrometeorology*, *25*(1), 239-255.
- Tajfar, E. et al. Characterizing water and energy cycle changes during droughts in the Mississippi River Basin, Manuscript in prep.
- Tajfar, E. et al. Higher Total Water Storage Capacity Sustains Evapotranspiration During Drought in Mississippi River Sub-Basins, Manuscript in prep.

PI/Task Mgr. Contact Information:

C. David (US 329F) cedric.david@jpl.nasa.gov