Web-based Integrated Drought Monitoring and Analysis with Copula Models

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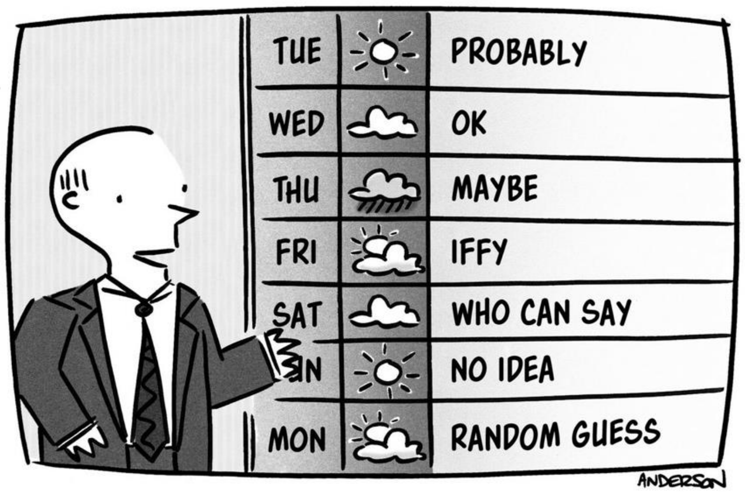
Introduction

- Drought monitoring and prediction is complex
- Unprecedented droughts may lead to famine, loss of lives, and economic slowdowns further enhanced by changing climate and increasing occurrences of extreme events.
- Multiple data sources, applied indices, and other components drought risk also introduce considerable uncertainty.
- Integrated data sources in the HydroLang framework offer new opportunities to monitor 'moisture' 'fluxes within a region of interest.

Motivation

- Existing models have various limitations.
- Critical need for a proactive approach to understand and predict droughts
- Droughts, as a significant natural hazard, have substantial impacts that can potentially be mitigated through early warning systems.

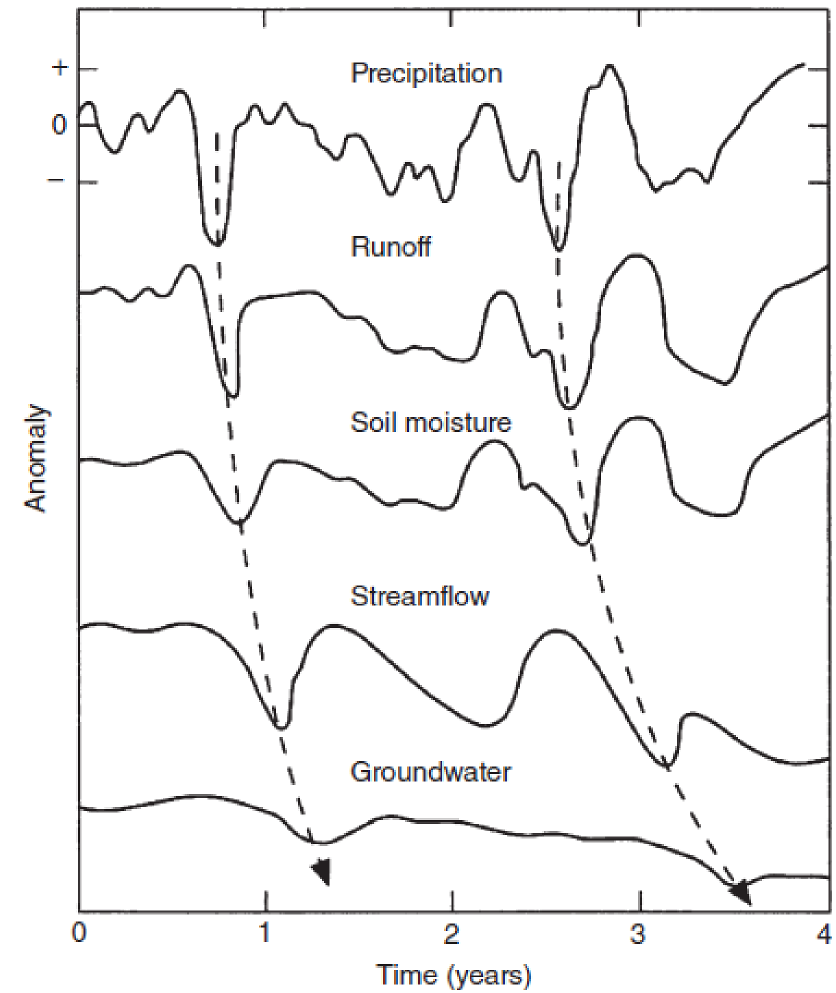


"And now the 7-day forecast..."

Problem Statement

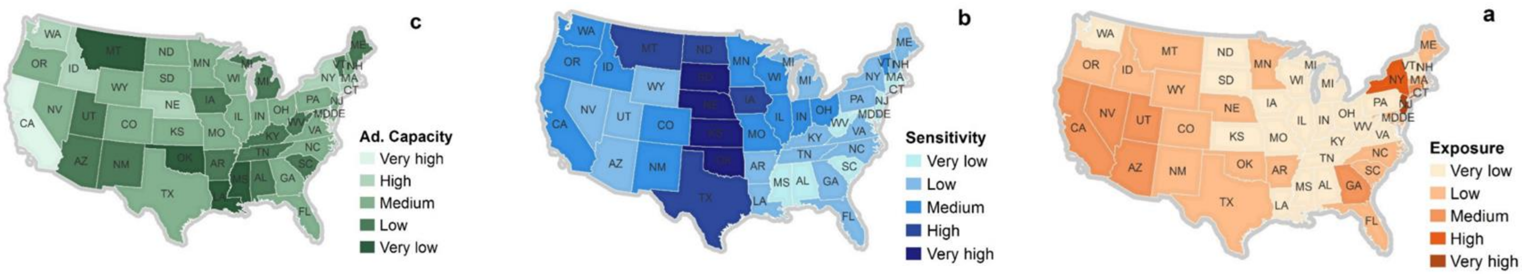
- Variability in how meteorological droughts transition into hydrological droughts.
- Complexity with diverse origins and occurrence at multiple time scales
- Lack of universal thresholds for predicting drought propagation with large scale uncertainties.
- Reactive drought response.

Initial trigger > Propagation > Persistence



Literature Review / Background

- Engström et al., 2020 studied Drought Vulnerability in the U.S. using three main factors: sensitivity, exposure, and adaptive capacity using a DVI.



- Rajsekhar et al.,2015 studied drought causality, hazard, and vulnerability assessment using the Multivariate Drought Index.
- Drought properties are expected to increase due to climate change.
- Significant regional variability in drought vulnerability and hazard levels.

Objectives

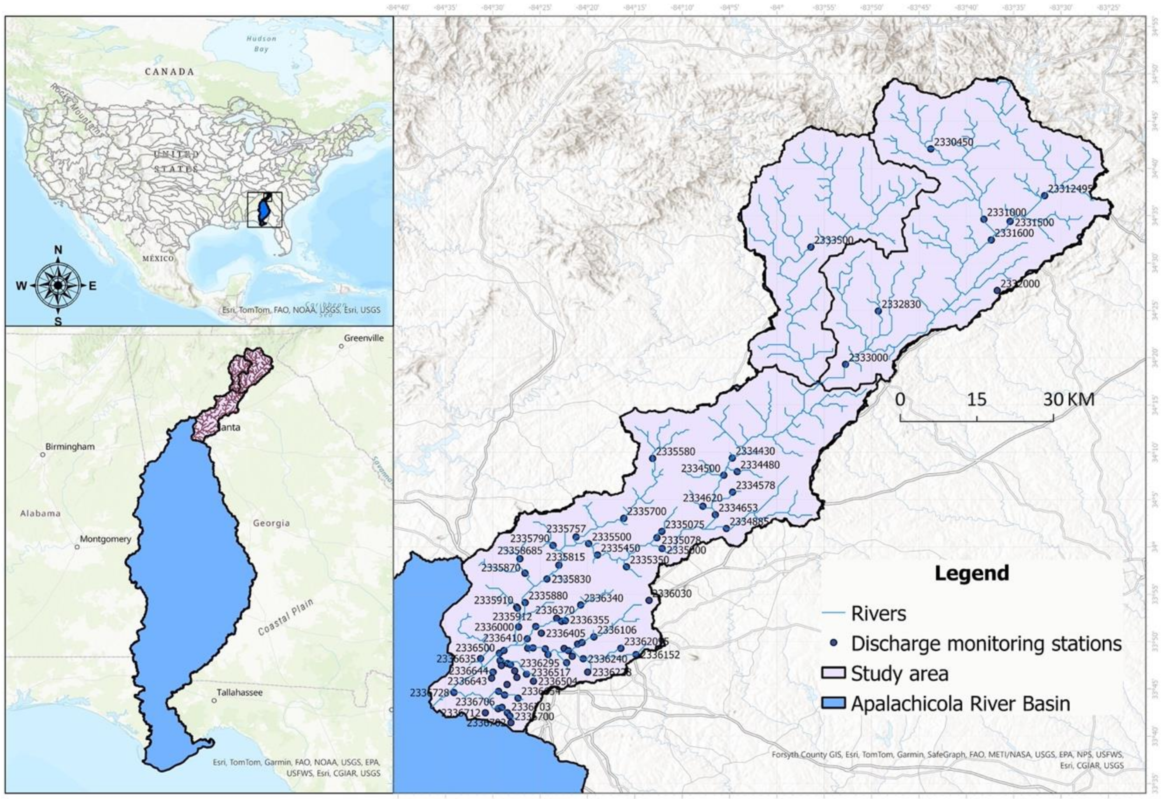
- Examine the propagation of precipitation droughts into streamflow/hydrological droughts.

Key questions:

1. What is the likelihood of hydrological drought given a meteorological drought?
2. What is the probability of both hydrological and meteorological droughts occurring simultaneously?

Study Area

- Alabama Coosa-Tallapoosa (ACT) River Basin
- Covering northeastern and east-central sections of Alabama, Northwestern Georgia and part of Tennessee.
- Approximate area of 59,100 km^2 with 14 US Hydrologic Subbasins (HUC08s).



Data

Data Source: USGS National Water Information System (1990-2023, daily time step).

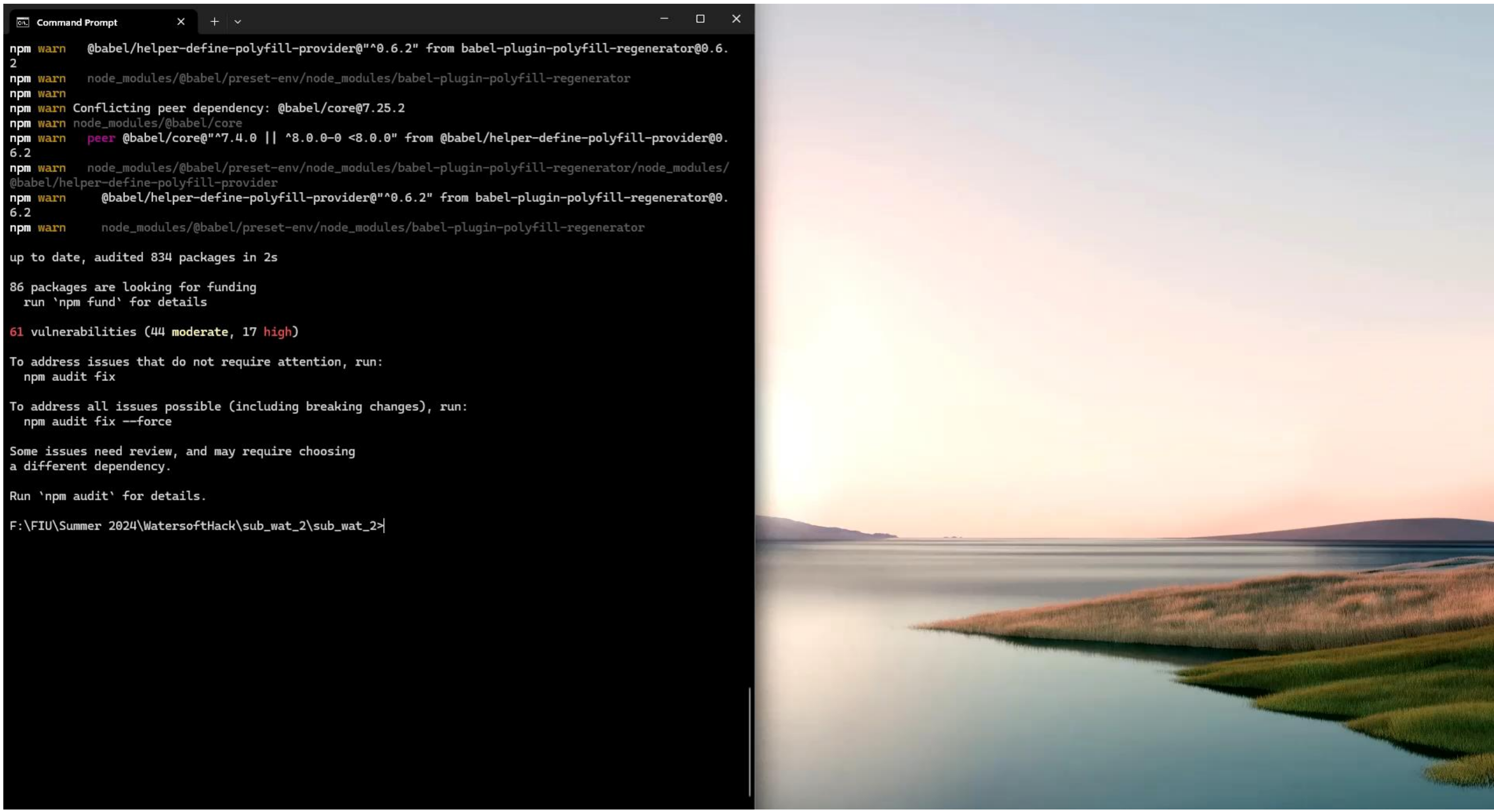
Tool: HydroLang framework for data visualization and interaction.

Key Functions:

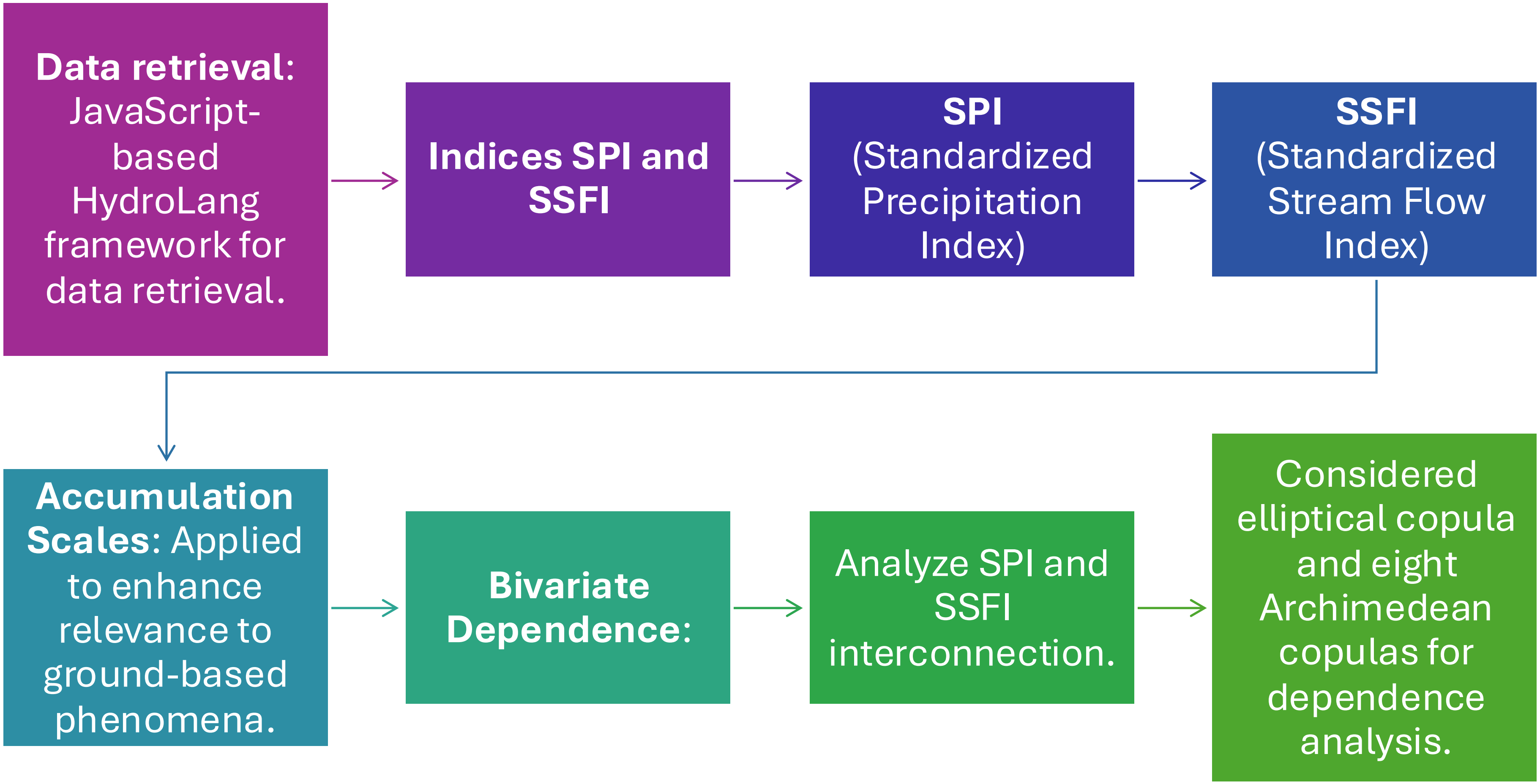
- **Initialization**: Set up Hydrolang object and global variables.
- **Polygon Layer Loading**: Loaded and displayed GeoJSON boundary data.
- **Data Retrieval**: Accessed USGS WaterOneFlow API, transformed data for processing.
- **Data Filtering and Mapping**: Filtered and displayed data on a map with interactive details.
- **Visualization and Download**: Enabled chart visualization and CSV downloads.

Data Processing: Rescaled daily data to monthly using Python for further analysis.

Data Retrieval

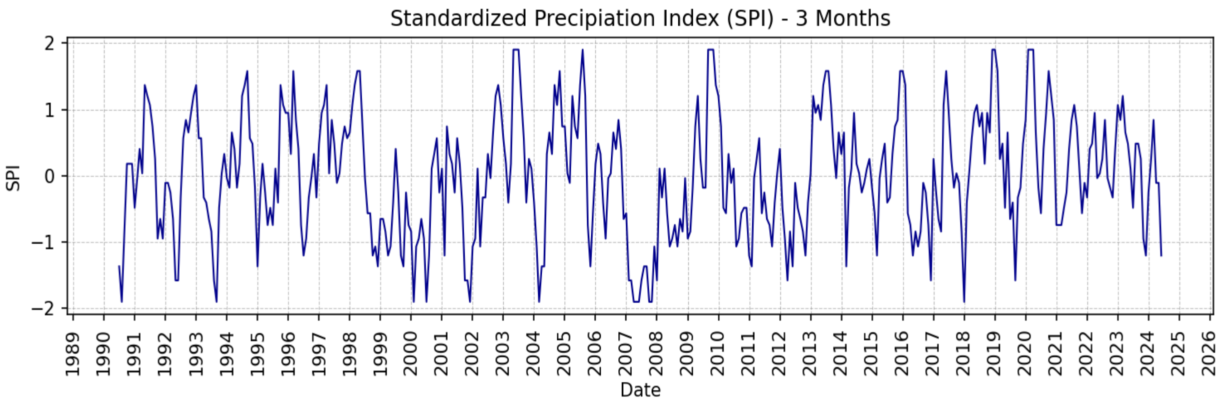


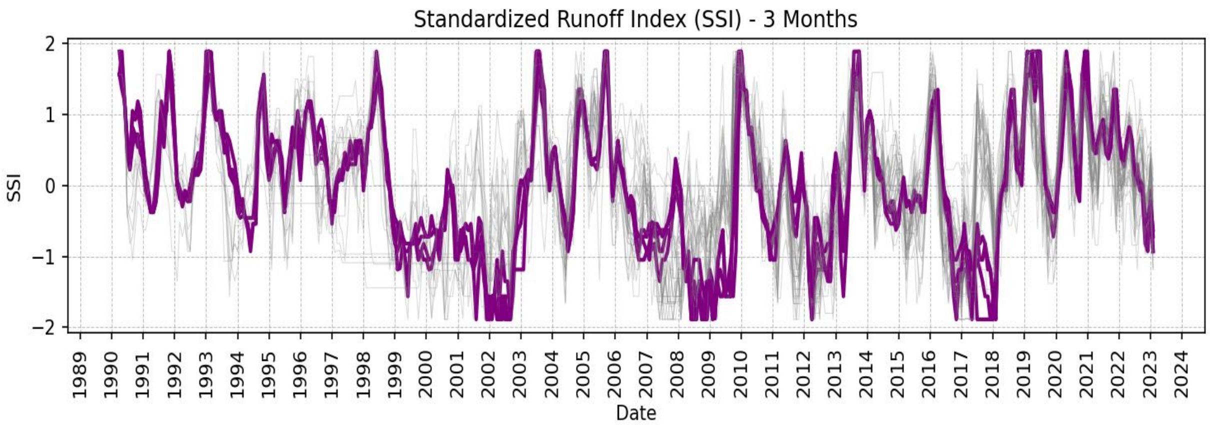
Model / Analysis



Results – Drought Indices

- Seasonal droughts captured using the 3-month SPI
- Intra-annual & Annual Events: Highlighted by 6 and 12-month SPI respectively.
- Significant deficits in 1999/2000, 2008, 2013, and 2017 (SPI < -1).
- Deficits in 2002/03, 2008/09, 2012/13, and 2017/18 (SSI < -1).

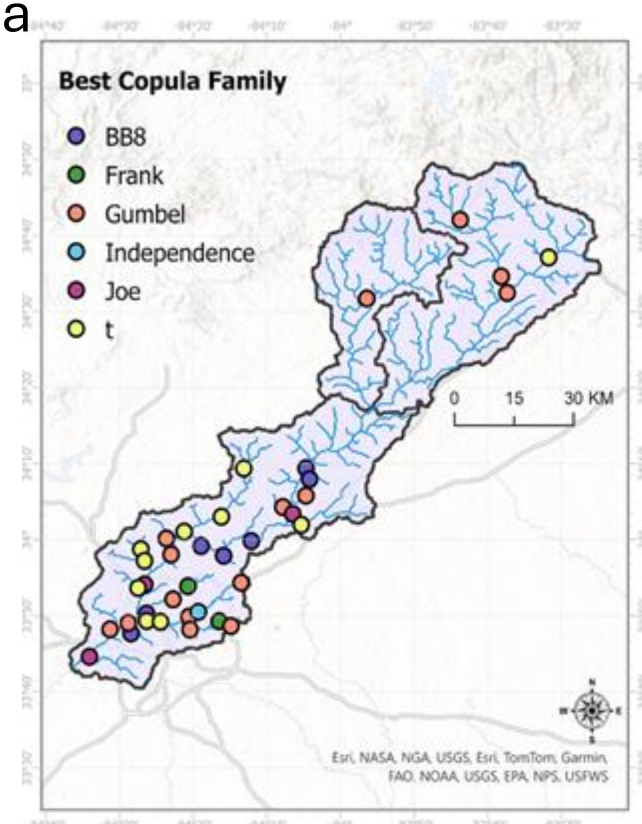




Results – Best fit Copula family

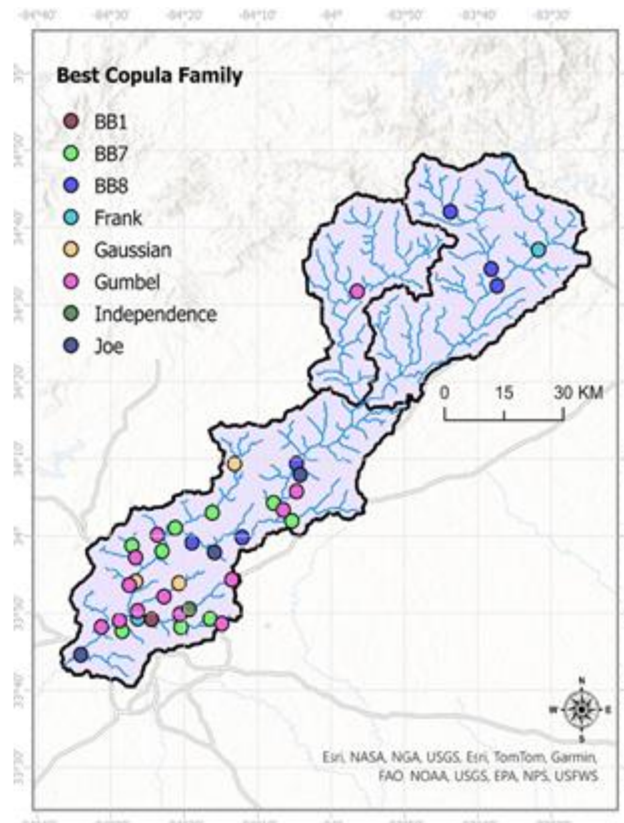
1 - Month

a



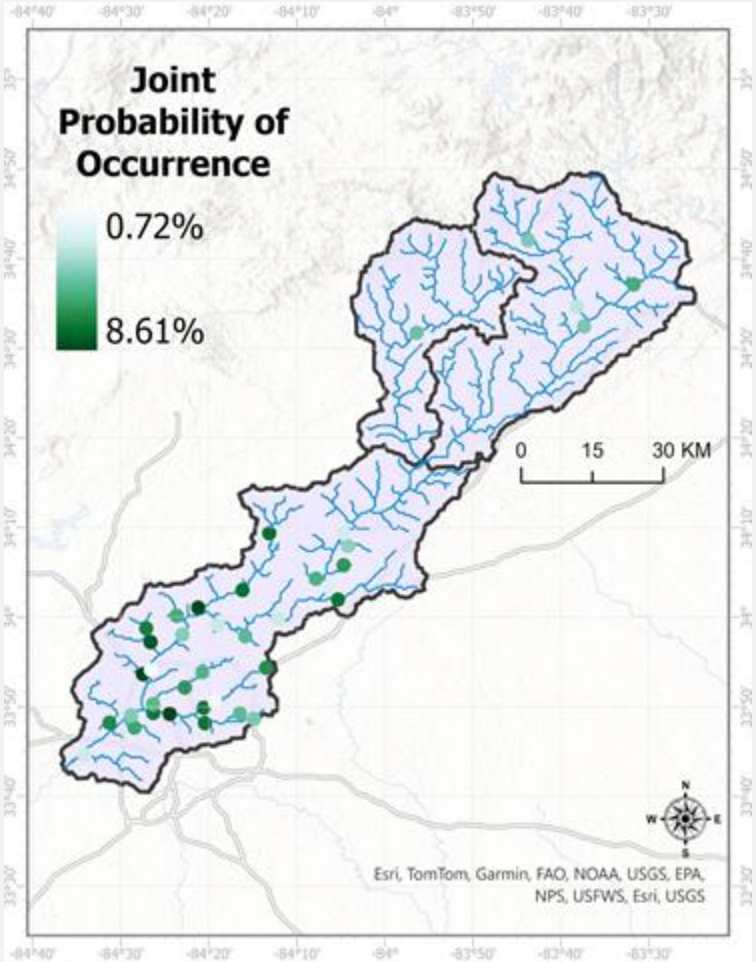
3 - Month

b

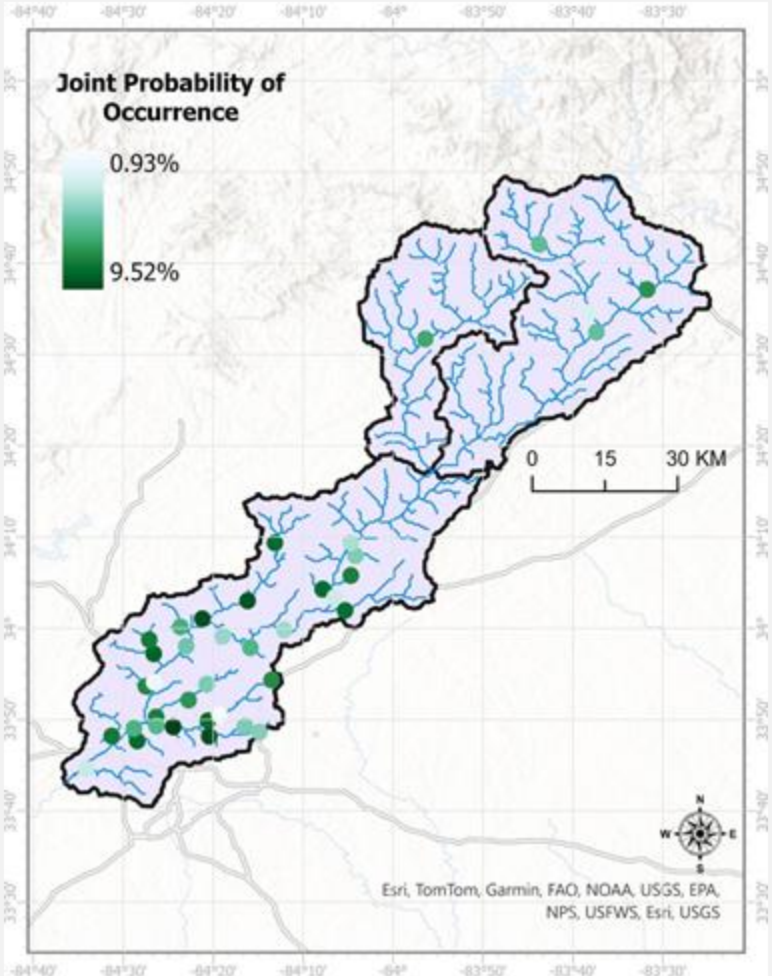


Results – Joint Probability of Occurrence

1 - Month

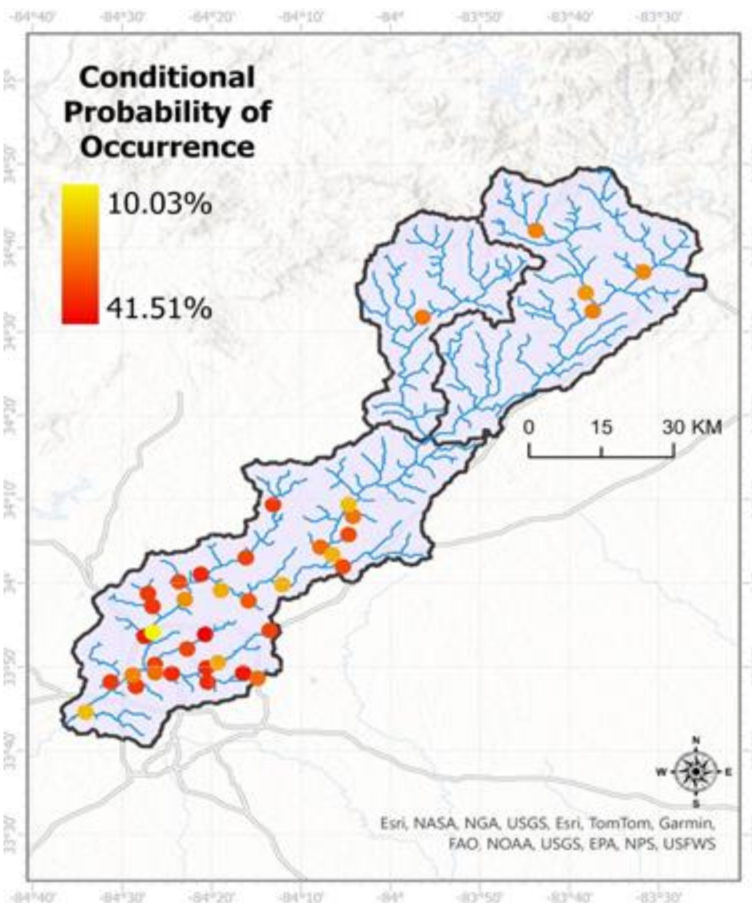


3 - Month

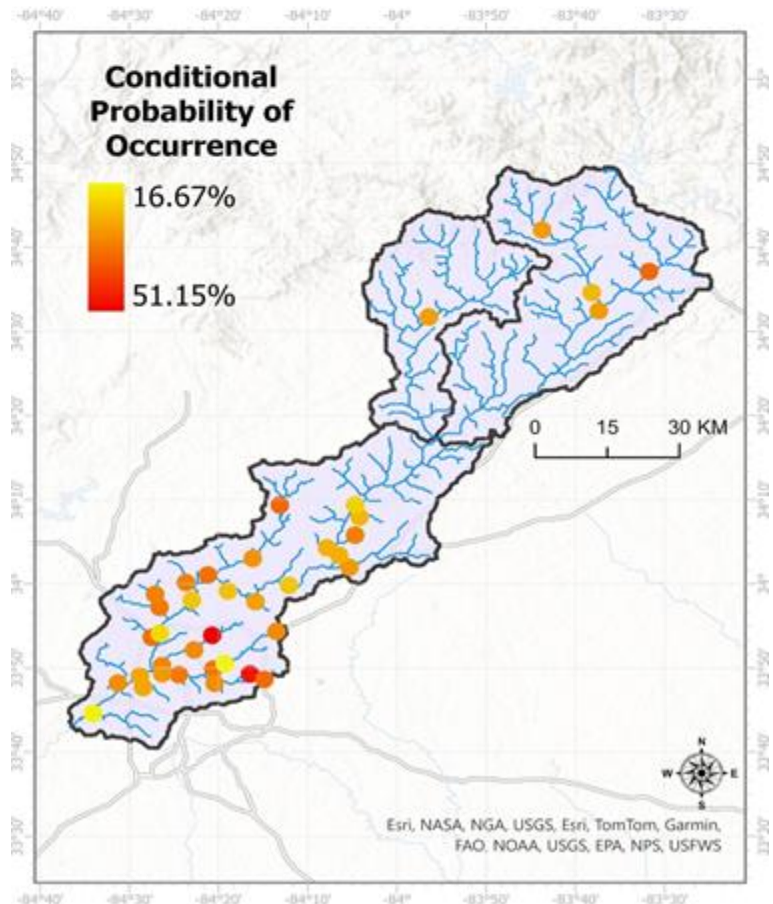


Results – Conditional Probability of Occurrence

1 - Month



3 - Month



Limitations and future directions

- Currently our portal provides capabilities of bivariate modelling but limited to streamflow and precipitation.
- For a more holistic examination we intend to include more variables available within the HydroLang framework. Users can then specify and see occurrence/conditional probabilities of different forms of droughts. For e.g. (SPEI: For atmospheric water deficit, NDVI: for plant stress)
- Include more precipitation data sources and thiessen polygon to extract rainfall for basins- basically use drainage areas delineated using StreamStats API and Hydrolang.
- Expand this portal over more regions, with ability to forecast risks based on historically fit climatologies.

Conclusion

- Simultaneous occurrence of meteorological and hydrological droughts
- The conditional probability that a hydrological drought occurs given a meteorological drought.
- Developed a web-based tool that extracts precipitation and discharge data from large-scale services.
- Highlights the importance of understanding how precipitation deficits translate into streamflow deficits.
- Future studies should consider applying the copula model to a global scale to assess their effectiveness in various climatic and hydrological contexts.

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Thank you.