Ensemble-Based Risk Assessment Model of Projected Precipitation Changes in Mexico

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Hydroclimatic Changes in Mexico

Over the past decades, Mexico has observed a consistent increase in average temperatures, while precipitation trends exhibit significant regional variability. Drought conditions have intensified, particularly in arid and semi-arid regions such as northern regions, while southern parts have experienced more frequent and extreme rainfall events, leading to flooding.

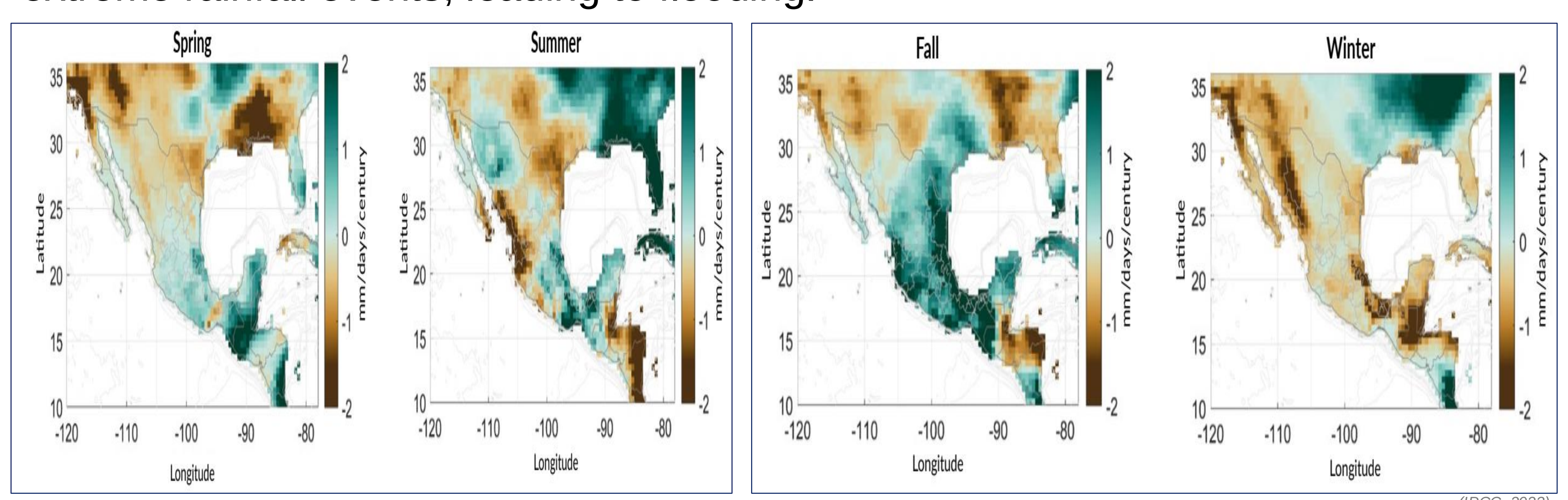

Figure 1. *Mean Annual Precipitation Change (IPCC)*

As regional climate projections indicate, Mexico is expected to face a dual challenge of increasing droughts and floods over the coming decades.

How Can Changing Precipitation in Mexico Be Managed with More Resilient Strategies?

We have focused our analysis on 12 key mining stations in Fresnillo, one of Mexico's largest mining regions, facing concerns with shifts in water availability. Better understanding precipitation variability and its direct impact on water availability requires the development of a flexible, multi-site risk assessment tool capable of capturing the stochastic nature of precipitation patterns while addressing uncertainties in climate projections.

Figure 2. *Mexico's chronic water crisis and spatial distributions of mining stations*
Note: Station names are not displayed on the map due to privacy agreements.

Stochastic Weather Generator for Projections

This methodology integrates observed precipitation data with regionally downscaled projections to generate realistic future time series. First, a stochastic weather generator with Markov chains simulates transition states and precipitation magnitudes, accounting for station-specific seasonal wetness.

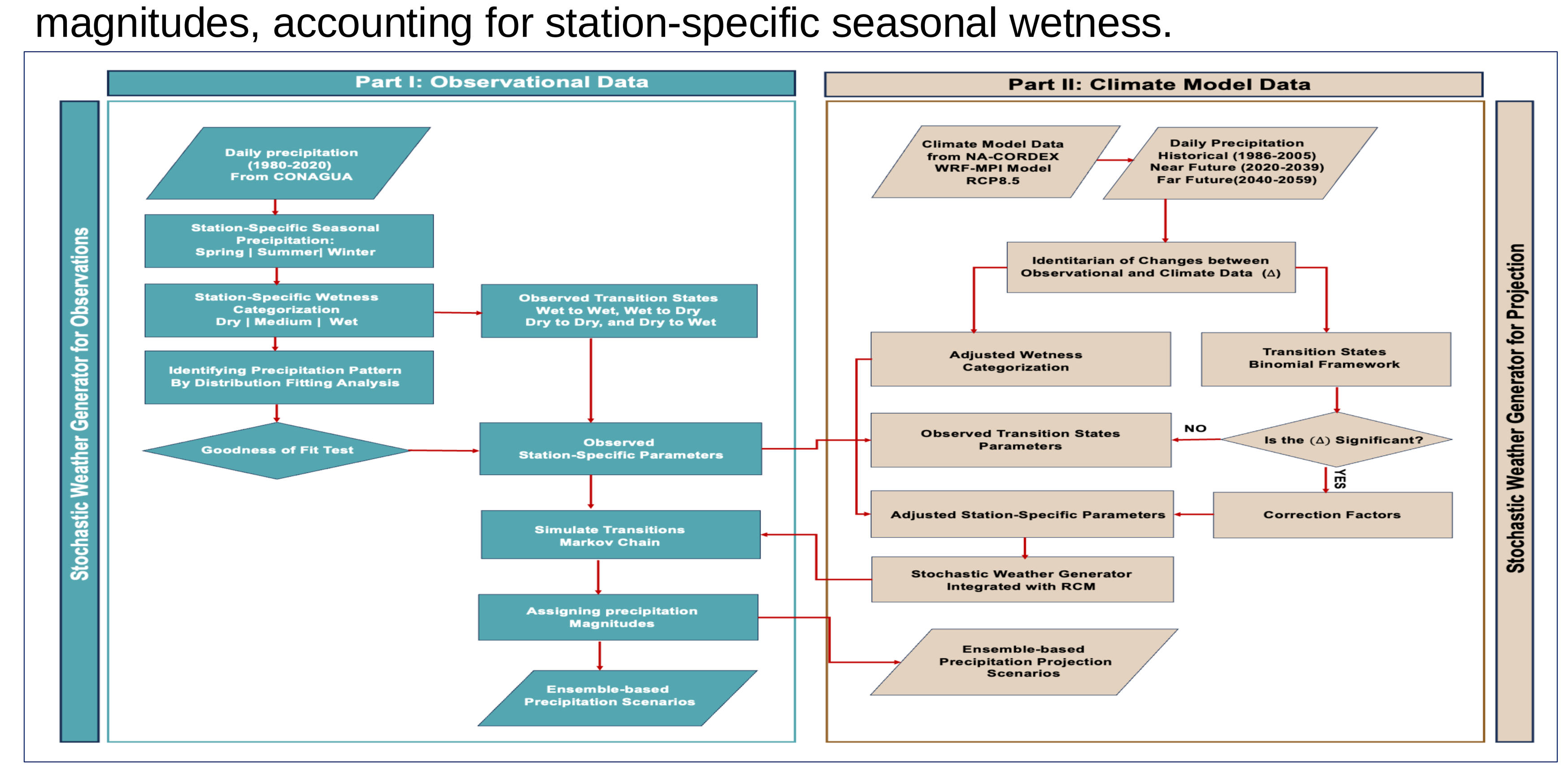

Figure 3. *Development of Weather generator for climate projection data*

Likely-to-Occur Precipitation Timeseries

Second, differences between observations and MPI-WRF climate data are identified, adjusted, and incorporated into the weather generator, enhancing the accuracy of future precipitation projections. The performance of the model validated using synthetic time series (grey) aligning well with the observations (red).

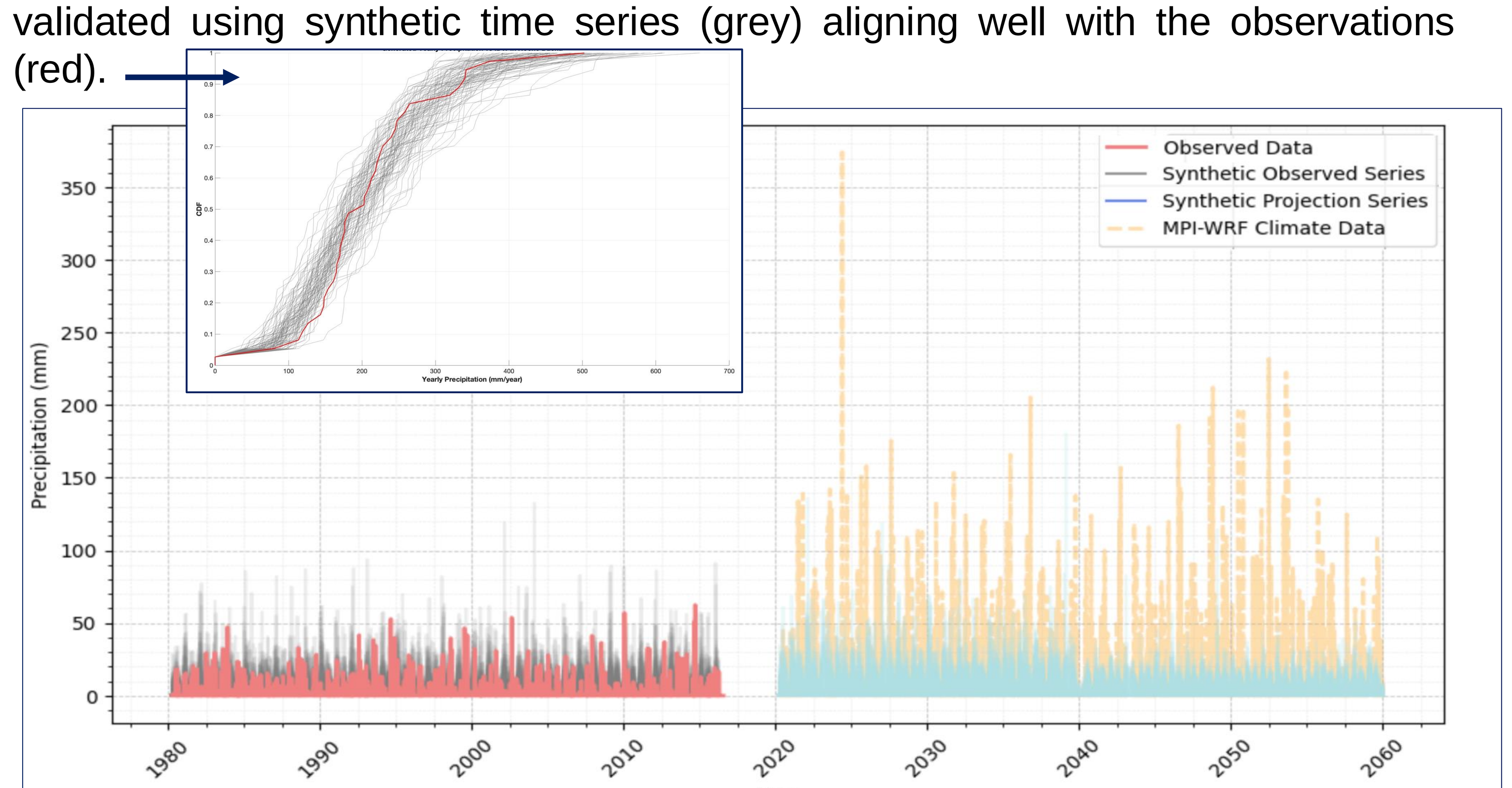

Figure 4. *Differences in Observed, MPI-WRF model data and their Synthetic series*

Projected Precipitation Change over Mexico

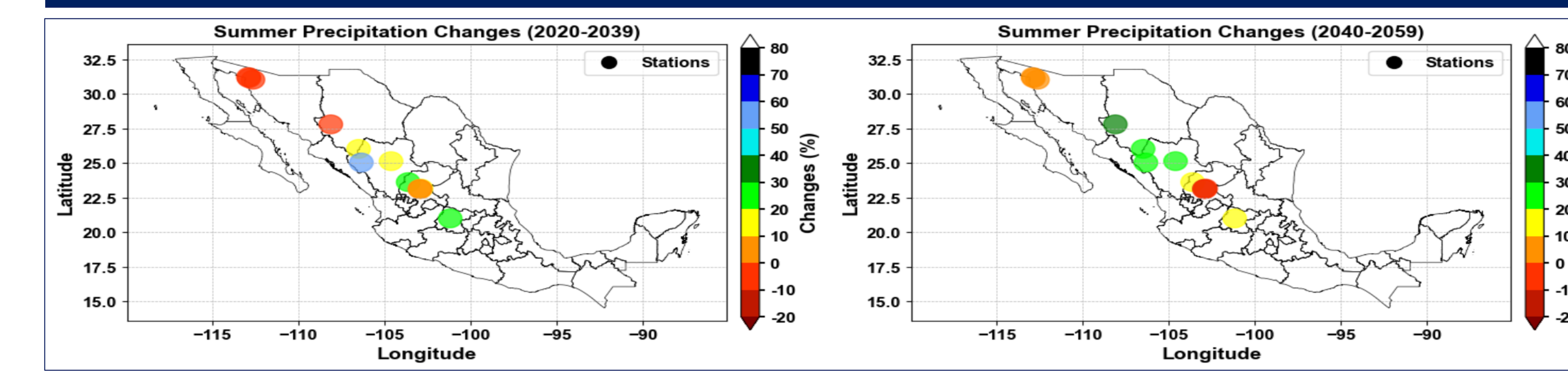

Figure 5. *Summer ensemble mean precipitation changes*

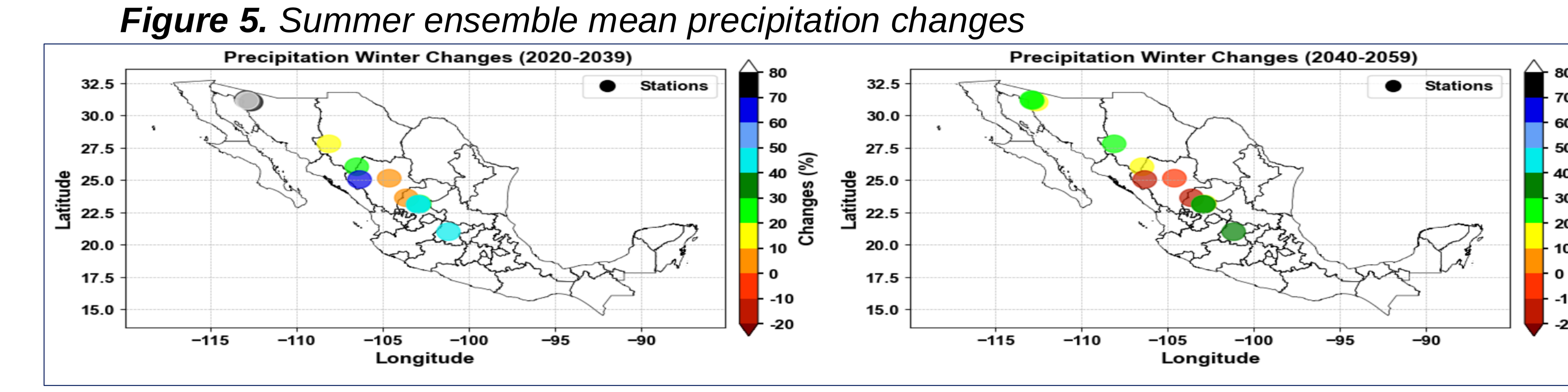

Figure 6. *Winter ensemble mean precipitation changes*

- Study areas in central Mexico, generally located in 2000 (m) above sea level, have higher precipitation increases than other regions.
- Winter has the highest changes in magnitude, particularly in the northern regions.

Applicable Ensemble-Based Risk Assessment

- The assessment indicates an increasing trend towards more pronounced extremes in weather for the stations.
- The seasonal changes in dry spells and rainy days are threshold-dependent, emphasizing the complex nature of hydroclimatic variability.
- Spatial and temporal variabilities highlights the necessity of location-specific climate evaluations to support effective climate adaptation planning.

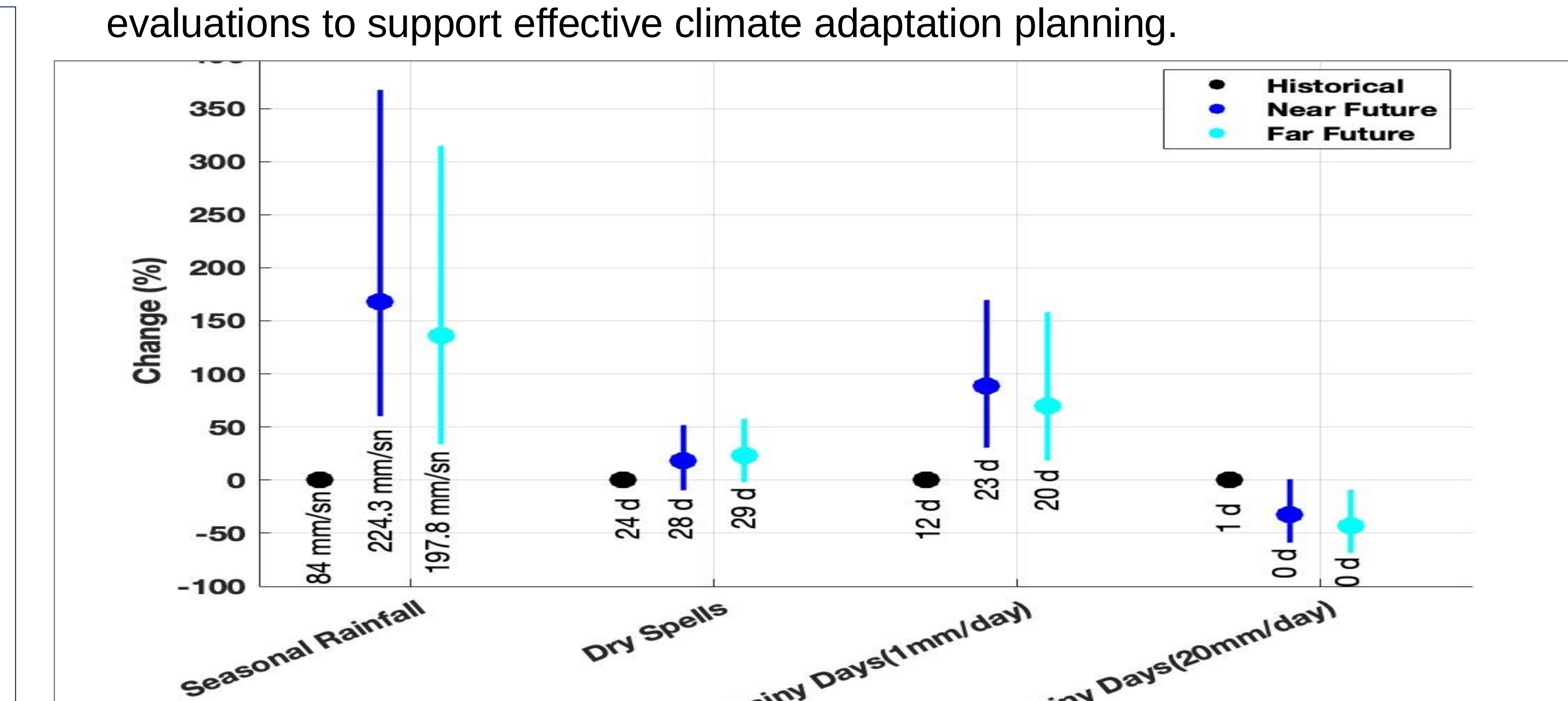

Figure 7. *Frequency-Duration metrics on 400 relative changes in winter on projection time series*