Space-time variability of precipitation and their large-scale drivers in the US Great Plains region

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MOTIVATION

The Great Plains region experiences high variability in precipitation which strongly affects water availability. However, existing research and applications are limited in their ability to robustly predict precipitation on seasonal and longer timescales in this region.

In the face of increasing water demands, growing environmental challenges, and the uncertainties associated with future climate change, advancement in our understanding of large scale atmospheric-ocean processes and teleconnections that drive regional moisture transport is therefore critical to informing preparedness and adaptation in different sectors in this region.

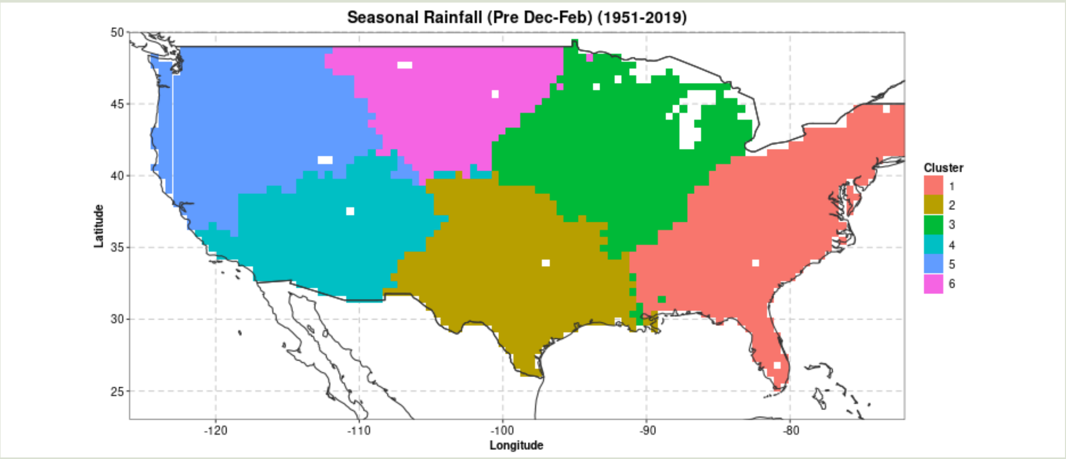
MATERIALS & METHODS

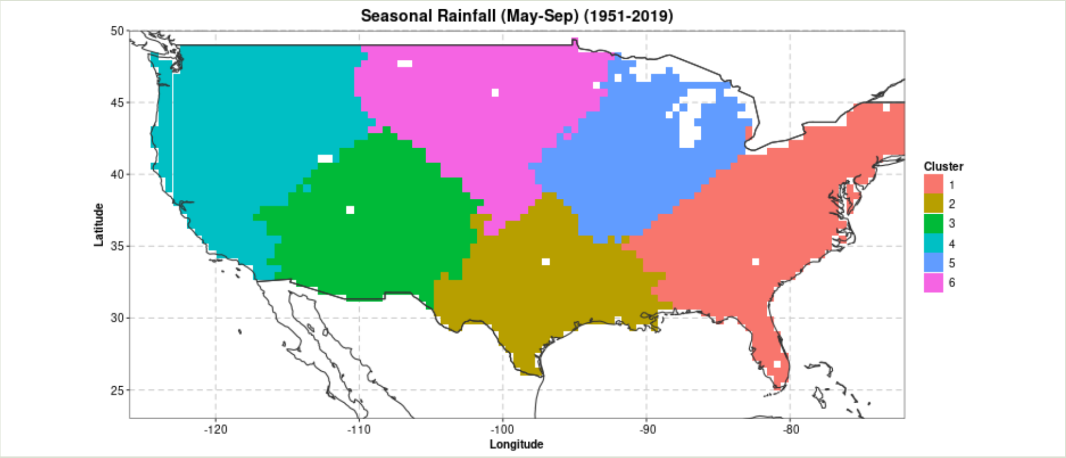
Modified Partitioning around medoids (PAM) clustering technique, developed by - Bracken et al. 2015, and applied on seasonal precipitation over CONUS for cold and warm seasons.

Identified six spatially coherent and homogeneous regions which are similar for both seasons.

Great Plains were captured in two clusters i.e., NGP, SGP for both seasons as shown in figures above.

IVT is computed as proposed by Newell et al. (1992), where it has meridional and zonal components and are shown as vector fields that show the moisture transport direction.





RESULTS

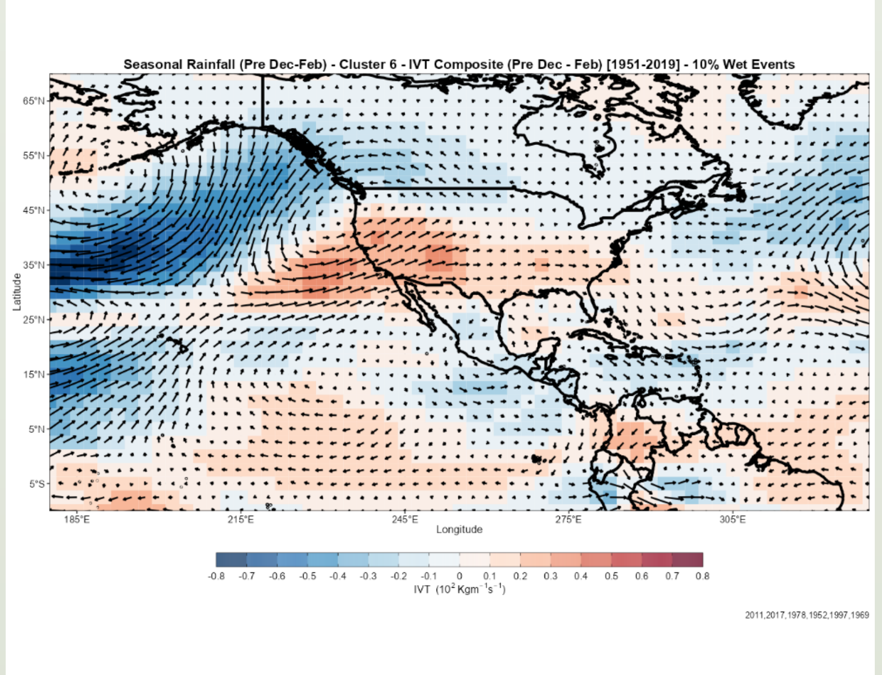
The extreme wet and dry years are obtained as the years as the top and bottom 10% of years from the cluster average precipitation time series, respectively.

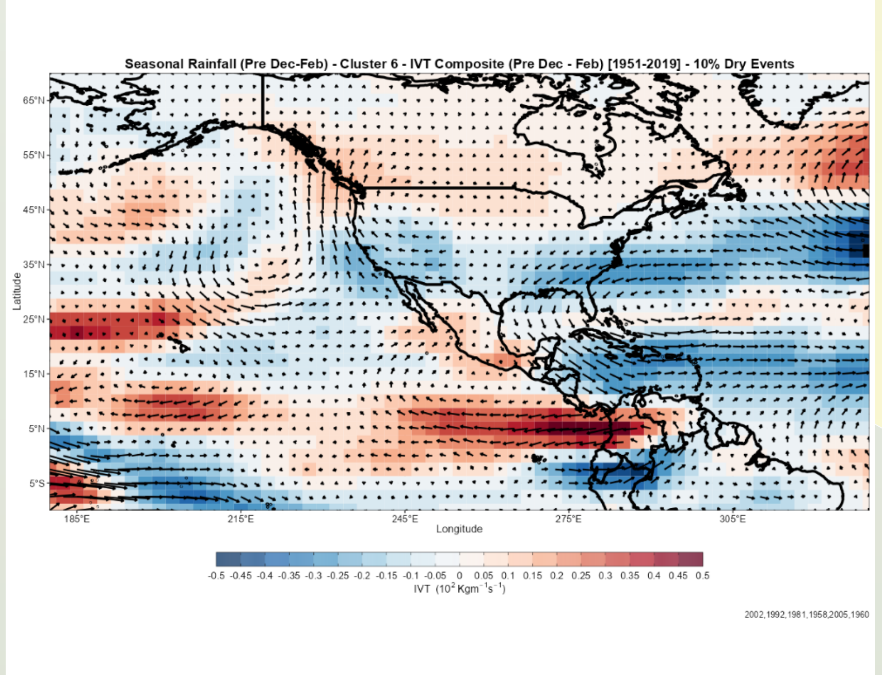
Composite maps of SST and IVT for wet and dry years are obtained by averaging the anomaly detrended SST and IVT at each grid point over the extracted set of years in the wet and dry categories, separately for warm and cold seasons. Similarly, correlation maps of detrended SST with respective cluster average precipitation are generated.

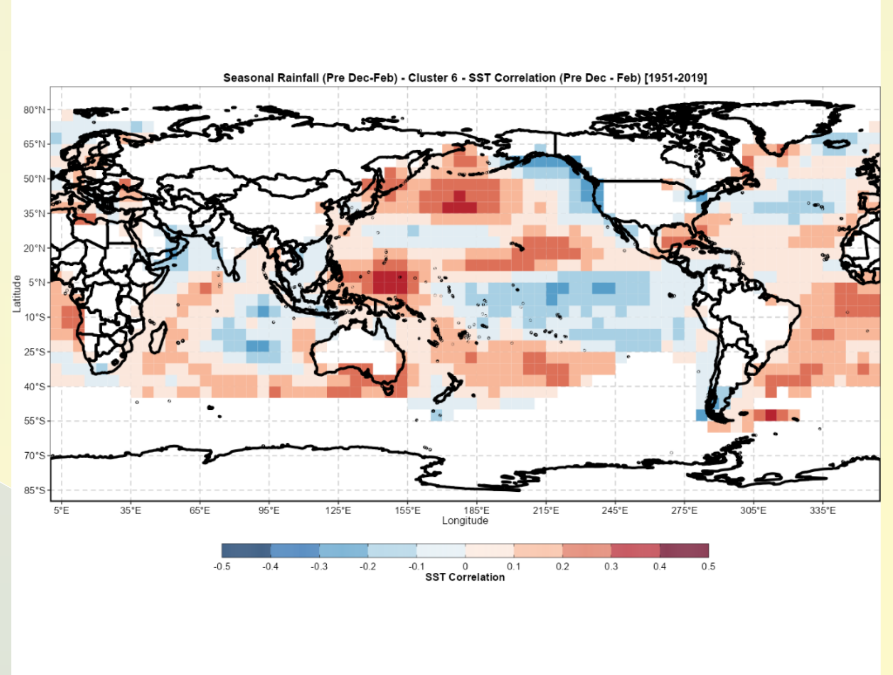
Drivers Influencing Warm Season (May - Sep) Precipitation

NGP cluster shows strong correlation with SSTs in the tropical Pacific (ENSO) and mid-latitude Pacific region (PDO). The composites show that for wet years, warm ENSO (El Niño) and warm PDO conditions are present, whereas for the dry years, cold ENSO (La Niña) and cold PDO conditions can be seen, suggesting a potential for predictability of warm season precipitation based on these teleconnections.

For wet years, there is increased moisture transport from Gulf expectedly facilitated by the Great Plains Low Level Jet (GPLLJ). This GPLLJ, which has often been associated with severe weather events, is well documented in observational studies. For dry years, the anomalous moisture transport is largely opposite of the wet year composite; the anomalous transport is from the land mass to Gulf. From the composite maps of anomalous IVT we can infer that strong convergence of moisture from GPLLJ is crucial for warm season wet years. Weaker or lack of convergence results in dry years.



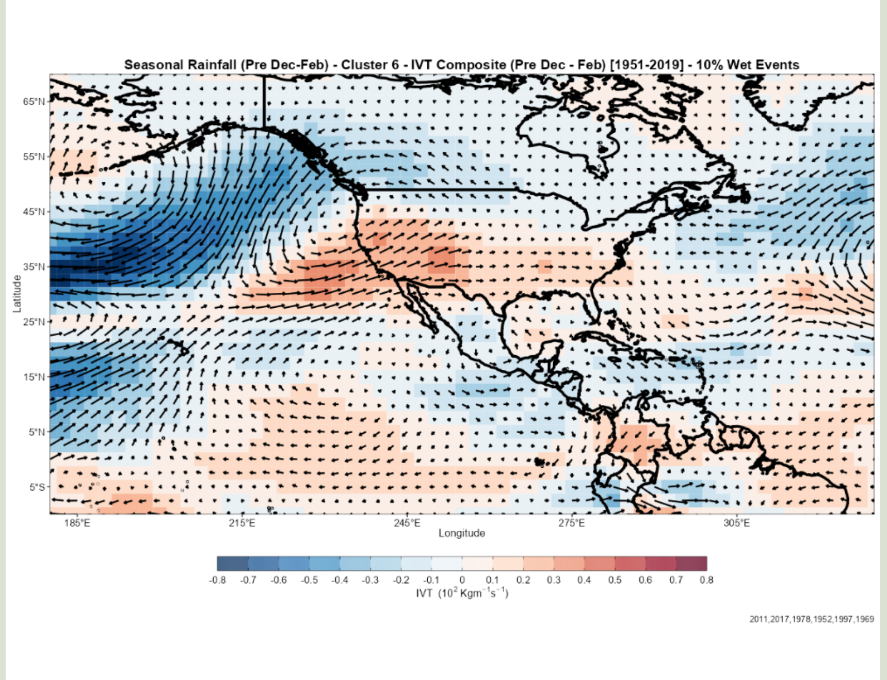


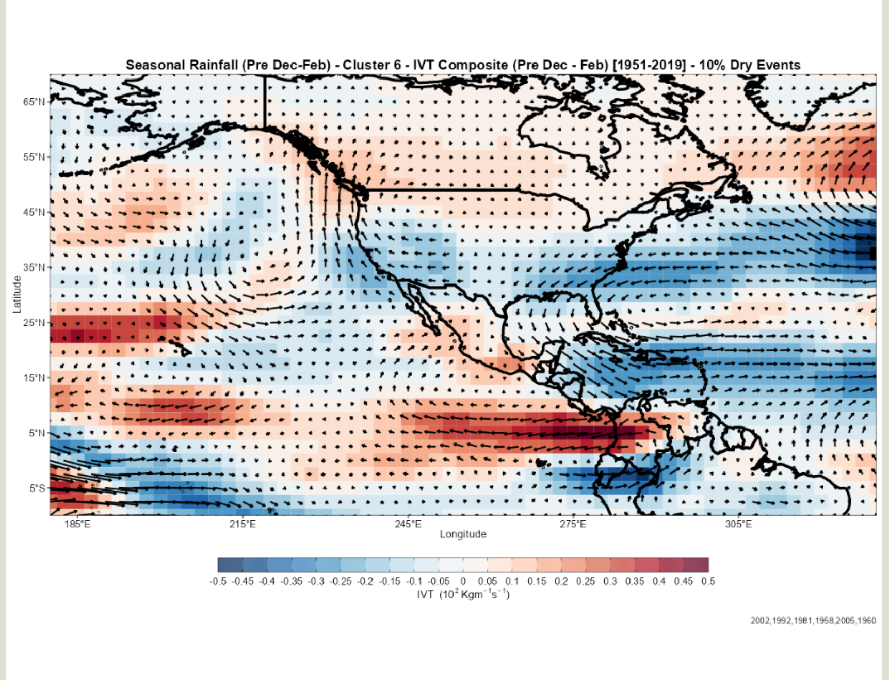


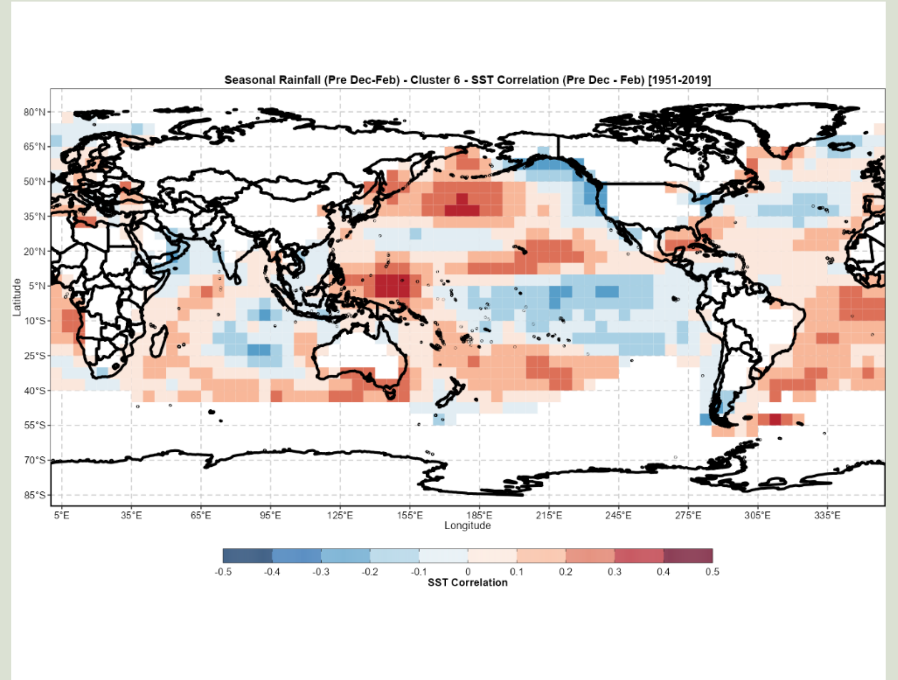
Drivers Influencing Cold Season (Dec - Feb) Precipitation

For wet years, the moisture transport is greater from the Pacific Ocean driven by the Pacific winter jet stream. For dry years, the anomalous moisture transport is largely opposite of the wet year composite; the anomalous transport is from the land mass to Pacific. From the composite maps of anomalous IVT we can infer that strong convergence of moisture from winter jet stream is crucial for above average cold season precipitation. Weaker or lack of convergence results in dry years.

Unlike in the warm season, the NGP cluster does not show a strong correlation with ENSO in the cold season. However, there is some signal in the central mid-latitude Pacific region. The composites show that, for dry years, we observe warmer tropical Pacific compared to the wet years. In the mid-latitudes, we see a contrast in patterns between wet and dry years, where eastern-warmer and western-colder pattern is seen in the dry years and vice versa in the wet years.







CLIMATE MECHANISTIC UNDERSTANDING USING CART

Pluvial (high precipitation) years in the Great Plains (GP) are driven by synoptic-scale (1000s km) processes, with distinct patterns for the southern and northern regions. Pluvials in the southern Great Plains (SGP) are associated with negative height anomalies over the southwestern US, while those in the northern Great Plains (NGP) with negative height anomalies in the northwestern US.

GP precipitation anomalies are influenced by the phase alignment of the Pacific decadal oscillation (PDO) and El Niño–Southern Oscillation (ENSO). Wet periods are enhanced when PDO and ENSO are both in their warm phases, and vice versa for their cold phases while having less connection when in out-of-phase. These connections vary seasonally with spring being the strongest, autumn being the weakest, and summer and winter falling in-between.

FUTURE STEPS

Improved Mechanistic Understanding of Processes: Examine space-time variability of hydroclimate in the region and their connections to regional and global ocean conditions and atmospheric circulation patterns. Analyze the sequence of climate events to understand how they manifest and propagate.

Develop a Predictive Modeling Framework: Develop a robust modeling framework that captures important relationships between the large scale climate drivers and regional scale moisture transport to improve predictions of seasonal (and/or even multi-year) precipitation in the GP region.

Assess Climate Change Impacts: Evaluate current CMIP models' ability to simulate observed climatic patterns and diagnose the causes (i.e., nature of large scale drivers) for projected wetter or drier future.

Scenarios for the Future: Develop more robust scenarios of future water availability to inform adaptation strategies and policy decisions.

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