North Central Climate Adaptation Science Center (NC CASC)

Rapid Climate Assessment Program (RCAP) 2023

Examination of large-scale drivers of water availability in the US Great Plains

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Outline

- Motivation and Study Area
- Methods
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  - Research gaps
  - Analysis
- Tool Developed
- Conclusions
- Future work

Study Area

- The US Great Plains, stretching over 1,300 miles from US-Canada border to Texas, constitutes a crucial and ecologically diverse region in the heart of North America.
- Known for its agricultural productivity and vital ecosystems, this vast expanse plays a significant role in supporting human livelihoods, wildlife, and natural resources.

Great Plains

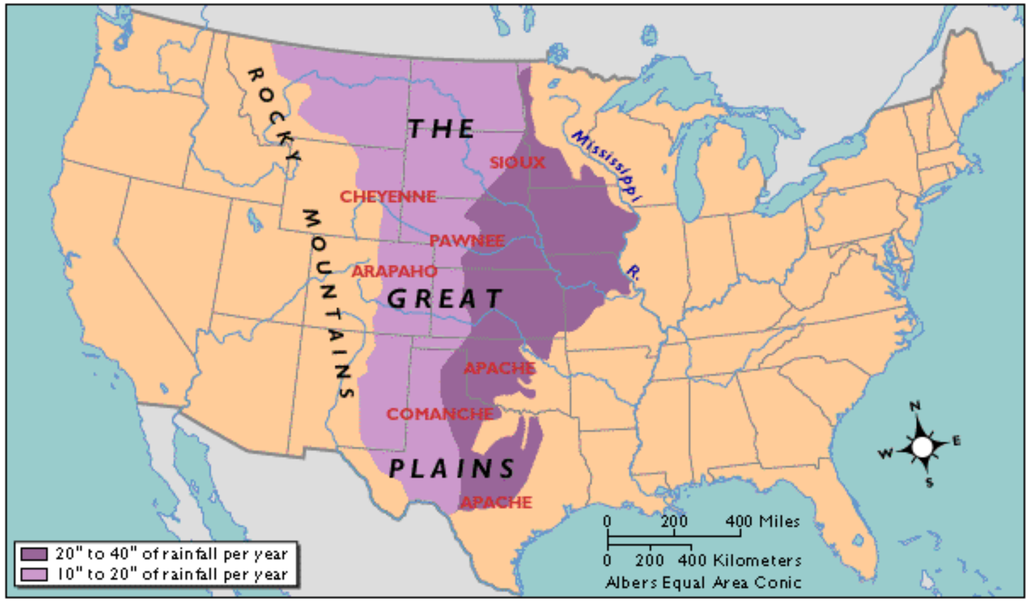


Image from https://my.hrw.com/GoHRW/keywordSearchST9+Great+Plains/index.html

Motivation

- Water availability in the Great Plains governing ecosystem productivity, and Precipitation regime plays a crucial role in this.
- Understanding these processes and their drivers is of paramount importance in the face of increasing water demands, growing environmental challenges, and the uncertainties associated with future climate change.
- Investigating the influence of cold and warm season precipitation and their spatial variation is crucial for comprehending the drivers of water availability and potential climate change impacts.

Image from https://www.google.com/url?sa=i&url=https%3A%2F%2Funsplash.com%2Fs%2Fphotos%2Fgrassland&psig=AOvVaw3qTT5nTZ50ccTI8C9vTSgV&ust=1691164383519000&source=images&cd=vfe&opi=89978449&ved=0CBAQjRxqFwoTCJiulrTswIADFQAAAAAdAAAAABAE

Methods

- Literature Synthesis
  - Precipitation Variability, Teleconnections, Large scale drivers, Climate Change Implications
- Analysis
  - Tool development

Literature synthesis - Results

- Water availability in the Great Plains of the US have identified strong connections with sea surface temperatures (SST) in key oceanic regions. **El Niño and La Niña events play a significant role in modulating precipitation patterns in the region** (*Abel et al. 2022, Anderson et al. 2017, Lau and Weng 2002, Simon Wang et al. 2015, Malloy and Kirtman 2023, Agarwal et al. 2021, Krishnamurthy et al. 2015*).
- Other Teleconnections, such as the Pacific-North American (PNA) pattern and the Atlantic Multidecadal Oscillation (AMO), have also been found to influence precipitation variability in the Great Plains. **These large-scale atmospheric circulation patterns can lead to prolonged periods of drought or increased rainfall** (*Abel et al. 2022, Anderson et al. 2017, Lau and Weng 2002, Harding and Snyder 2015, Castro et al. 2001, Agarwal et al. 2021*).
- In individual extreme precipitation events, large-scale drivers such as atmospheric rivers, low-pressure systems, and strong jet streams have been identified as significant factors. **These drivers can lead to intense rainfall and flooding in specific areas of the Great Plains** (*Flanagan et al. 2018, Polley et al. 2013*).

Literature synthesis - Results

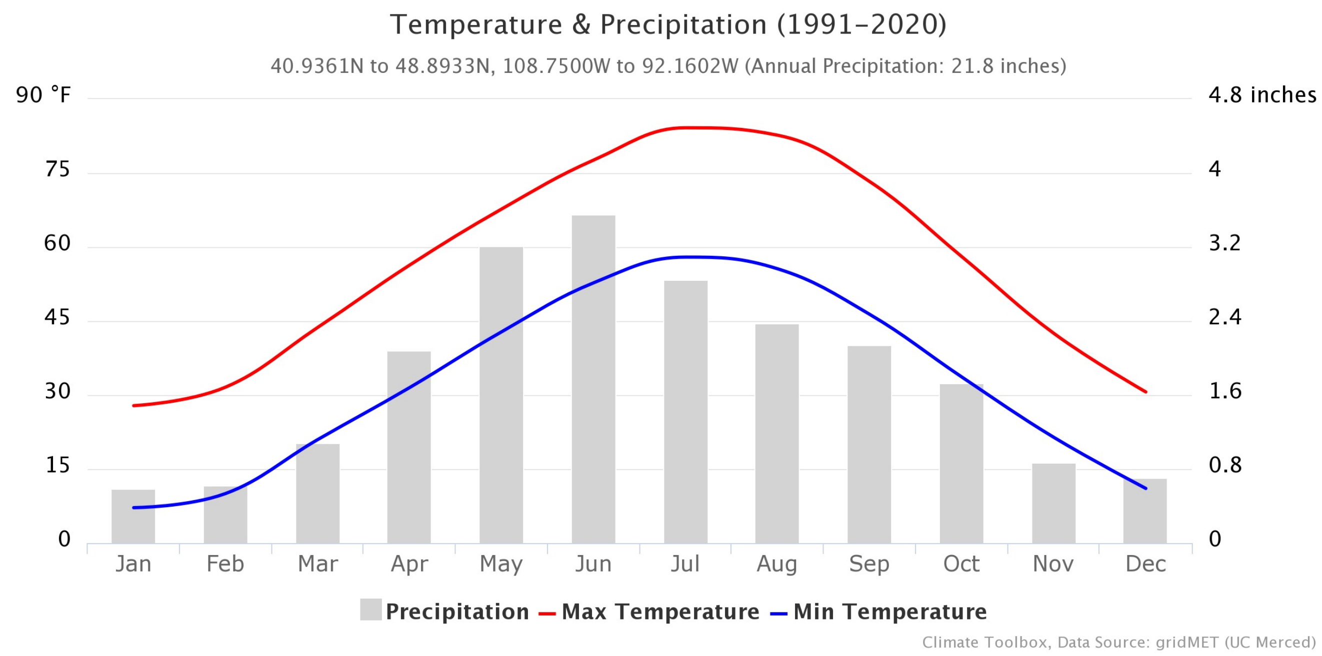
- *Abel et al. 2020* used the HYSPLIT model to track back trajectories of summer precipitation events and found that **land moisture is the primary moisture** source for both rain and extreme events in the Prairie Pothole region.
- The Great Plains Low-Level Jet/Maya Express plays a critical role in moisture transport to the region, impacting both land and Gulf of Mexico (GoM) - sourced events. **GoM is the secondary source of moisture for precipitation events**, with a stronger influence in stations further southeast Prairie Pothole region(*Abel et al. 2020*).
- Impact of climate change on the Great Plains influence precipitation patterns and water availability in the region. **Climate change could exacerbate drought conditions and increase the frequency of extreme weather events** (*Polsky and Easterling 2001, Hoerling et al. 2014, Polley et al. 2013, Ojjima et al. 2021, Krishnamurthy et al. 2015*).

Research Gaps and Objectives

- While existing studies have provided valuable insights, there remains a critical knowledge gap concerning the future hydroclimate of the Great Plains.
- These insights largely focus on individual events/years or on a short duration.
- A systematic examination of Integrated Vapor Transport (IVT) and precipitation across seasons and different regions within the Great Plains is crucial to understanding large scale mechanism.

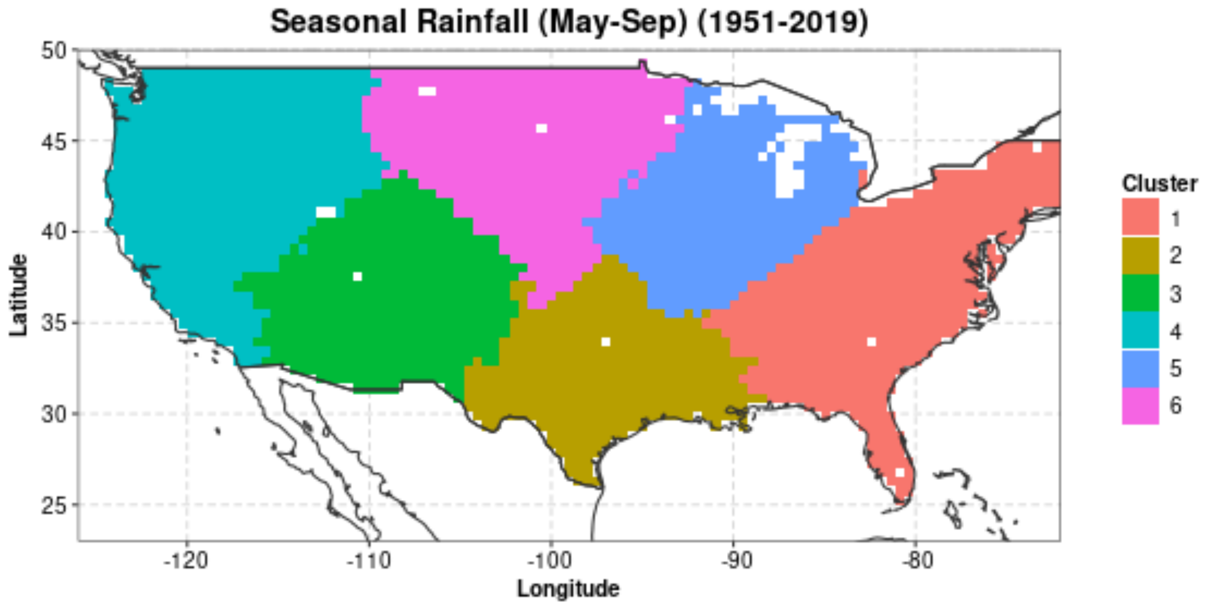
Analysis – Precipitation in Northern Great Plains

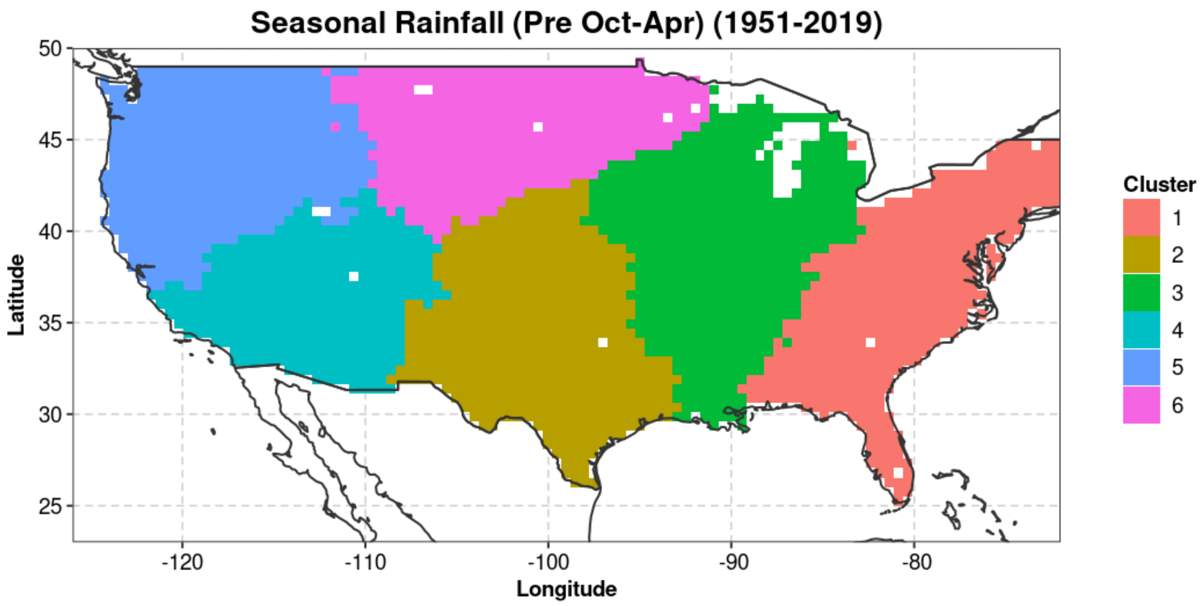
- Summer months (June to August) tend to be the wettest period in the northern Great Plains
- Conversely, winter months (December to February) in the region are typically drier
- Fall (September to November) and spring (March to May) represent transitional seasons.
- In our study, we identified May-Sep as warm season and Oct-Mar as cold season



Analysis – PAM Clustering

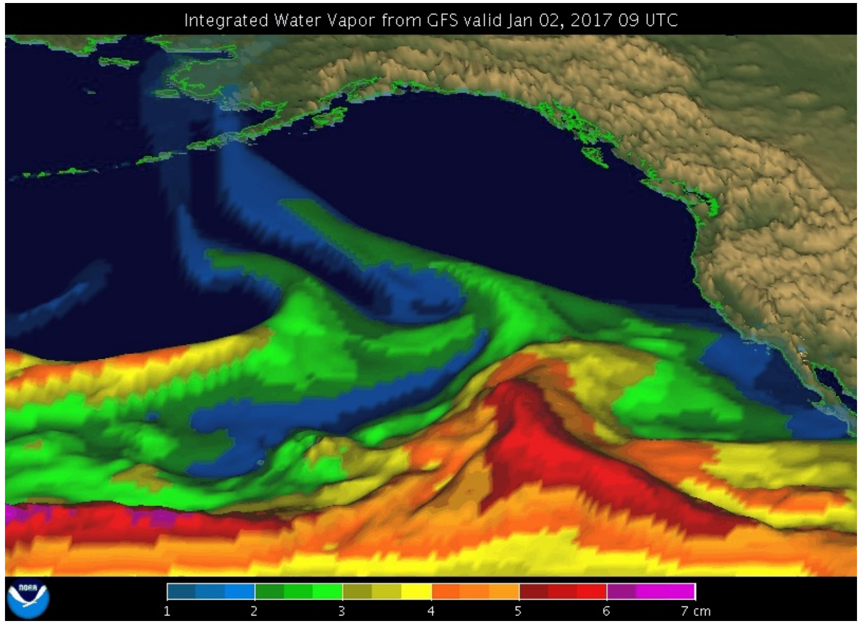
- Modified Partitioning around medoids (PAM) clustering technique developed by Bracken et al. 2015 is applied on seasonal rainfall over CONUS for cold and warm season
- We identified six spatially coherent and homogeneous regions which are similar for both seasons.
- These cluster regions are contiguous in space and consistent with the topography.
- Great Plains were captured in two clusters





Vertically-Integrated Vapor Transport (IVT)

- IVT data helps assess water availability and manage water resources more effectively.
- Atmospheric rivers (ARs) are created as a result of this evaporating water and their transport by the monsoonal winds.
- The computation of IVT as proposed by Newell et al. (1992) is given by the equation below, which we used in this study.



$$IVT = \sqrt{\left(\frac{1}{g}\int_{1000}^{300} qu\,dp\right)^2 + \left(\frac{1}{g}\int_{1000}^{300} qv\,dp\right)^2}$$

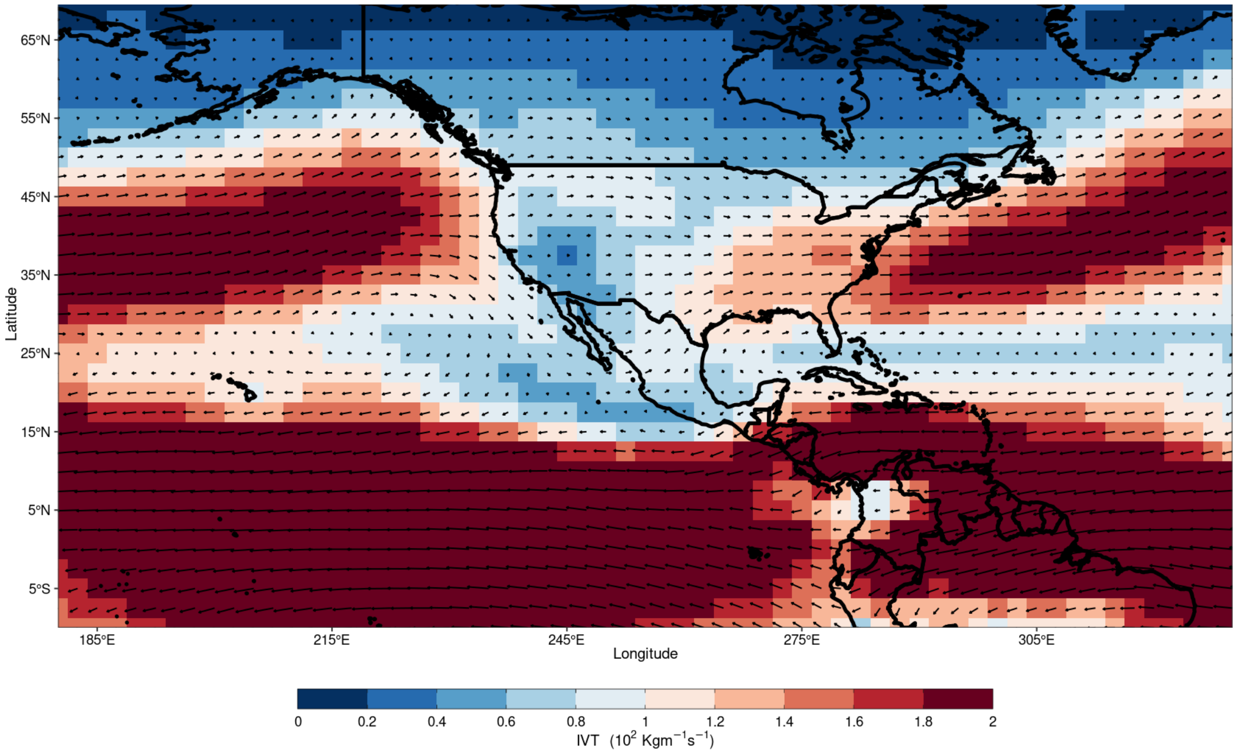
Zonal

Meridional

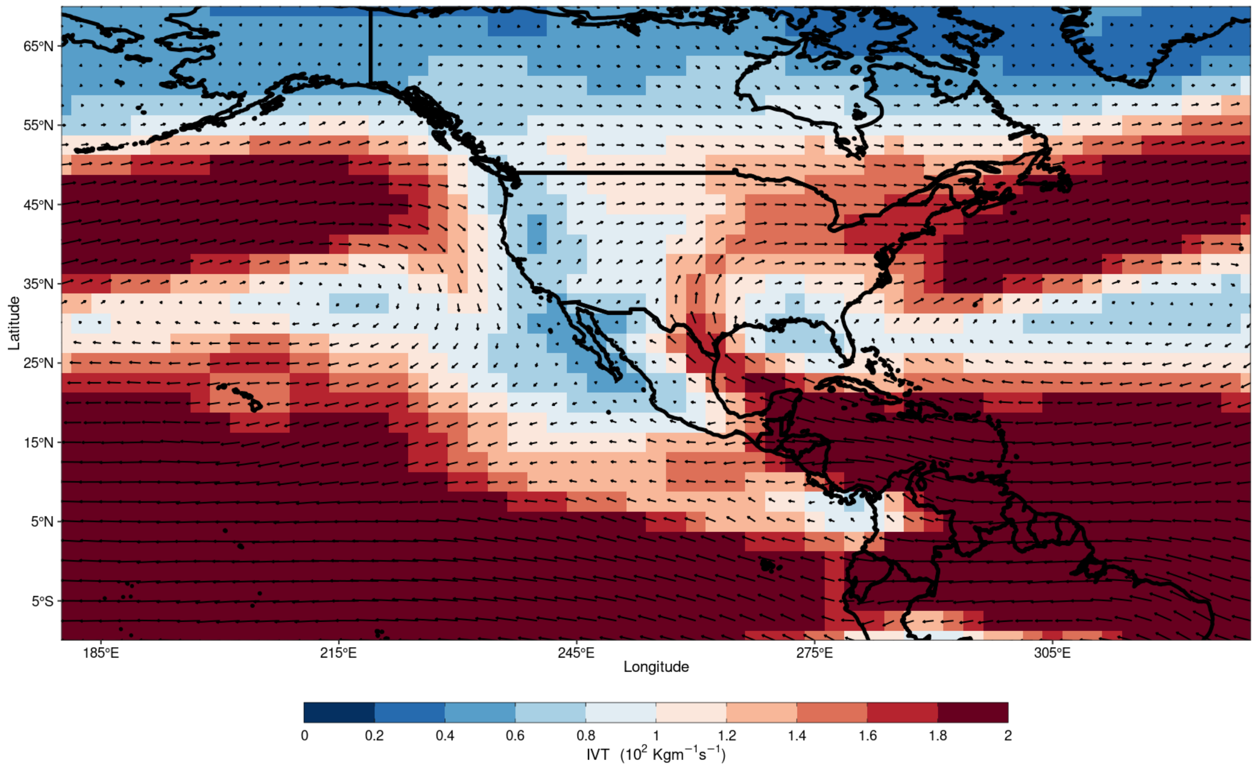
Image from https://www.google.com/url?sa=i&url=https%3A%2F%2Fpsl.noaa.gov%2Farportal%2Fabout%2F&psig=AOvVaw1uZfgrinQDpSbGgMLdHBZ9&ust=1691169652212000&source=images&cd=vfe&opi=89978449&ved=0CBAQjRxqFwoTCOjKvoWAwYADFQAAAAAdAAAAABAE

Analysis – IVT Climatology

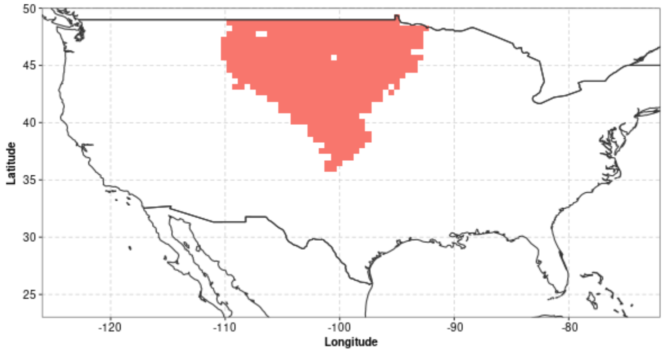
Cold Season (Oct – Apr)



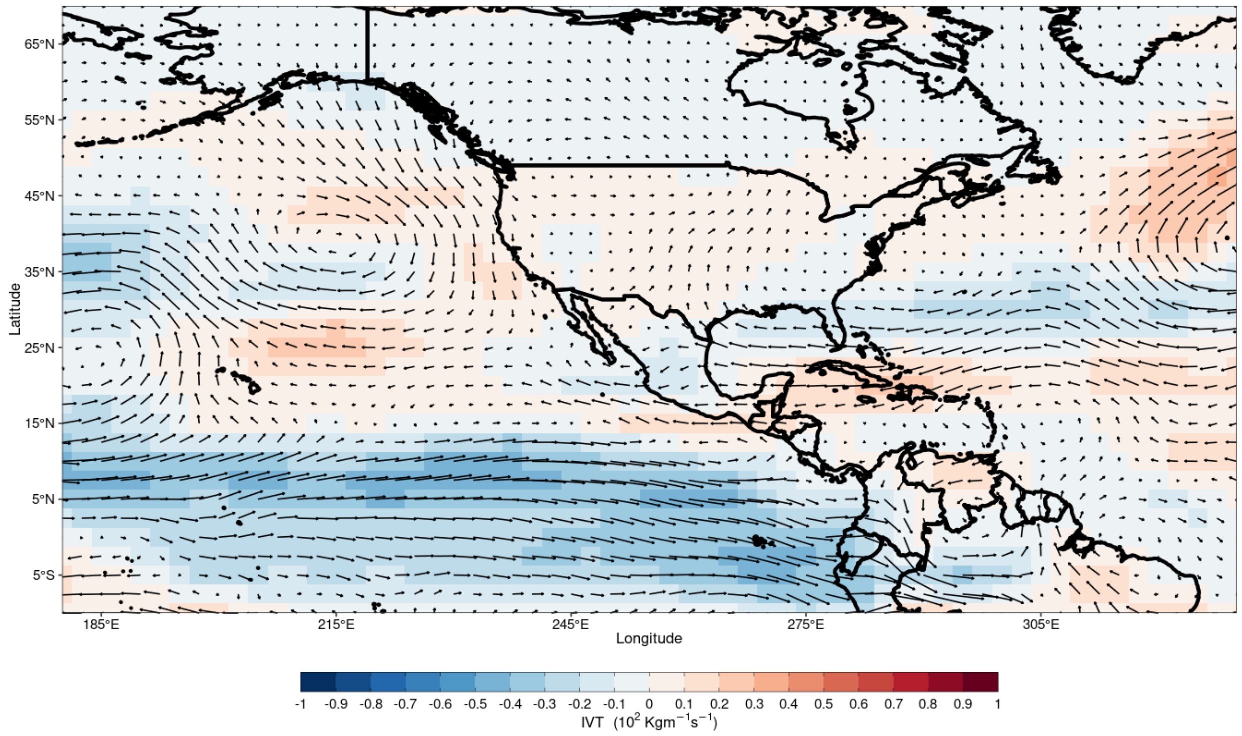
Warm Season (May – Sep)



Analysis – IVT Composites for Wet Years For the Northern Plains Cluster

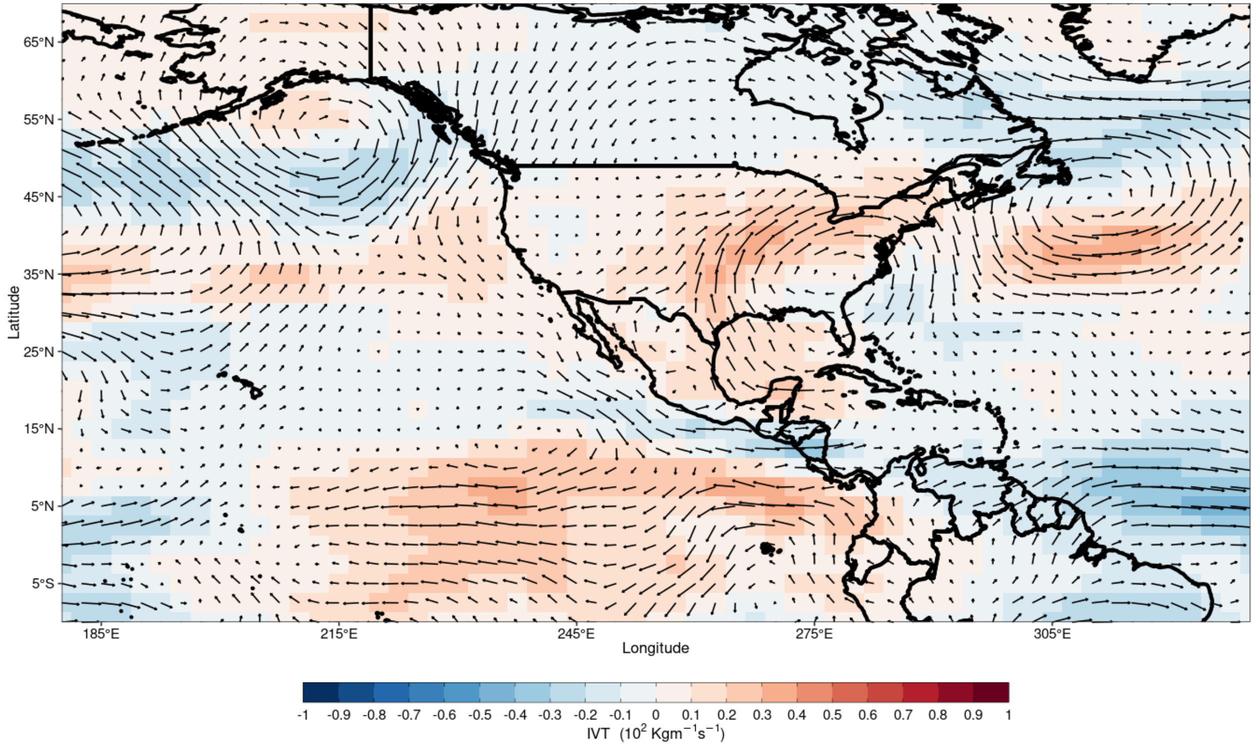


Cold Season Wet Years



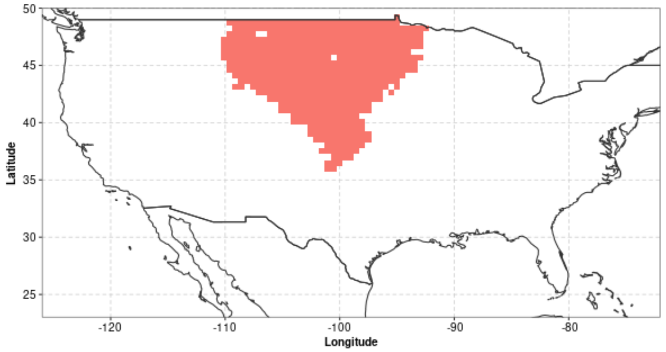
1999,2009,2014,1972,1995,1997

Warm Season Wet Years

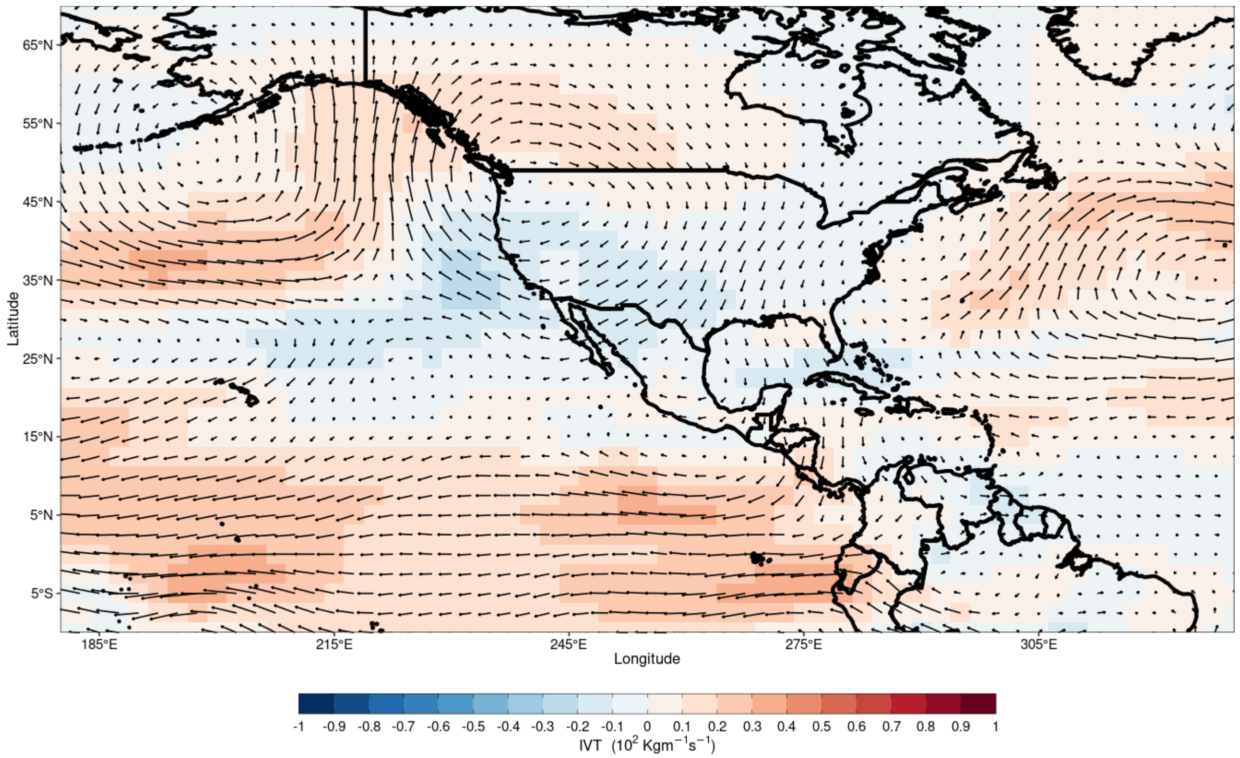


2019,1993,1962,1965,2010,1957

Analysis – IVT Composites for Dry Years For the Northern Plains Cluster

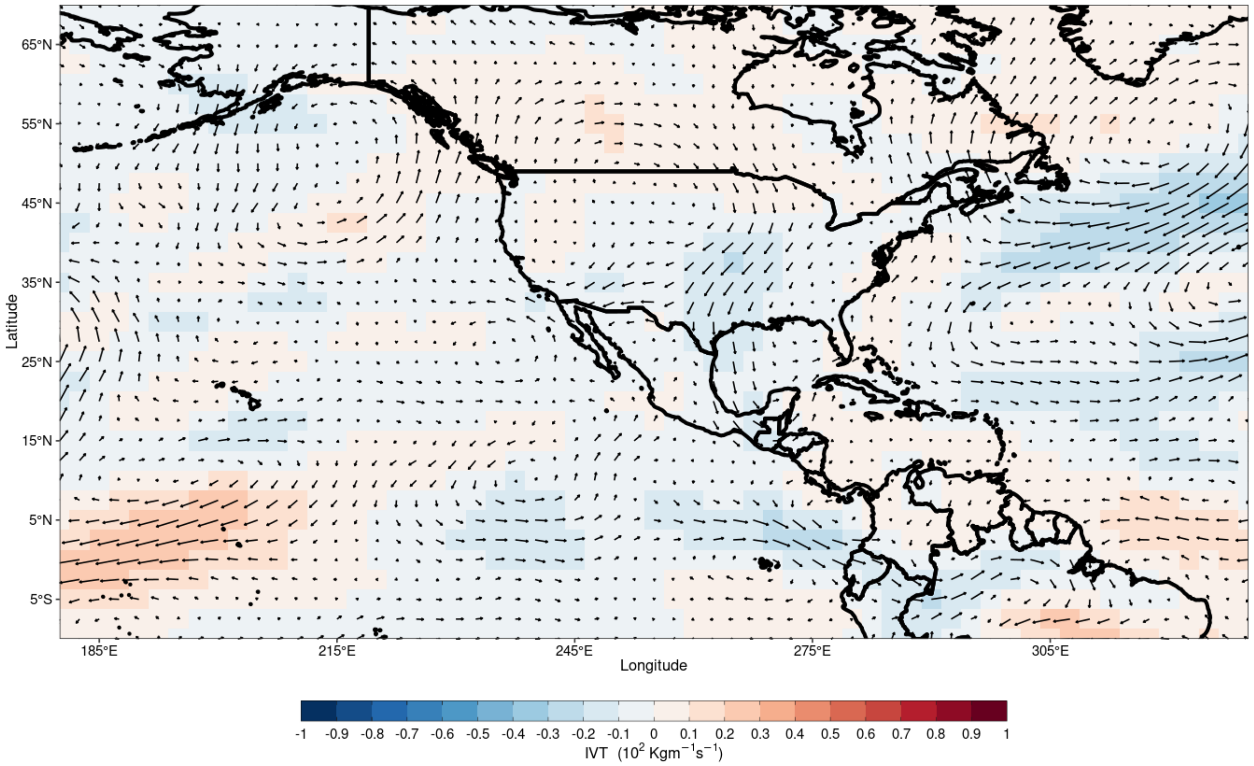


Cold Season Dry Years



1988,2015,1961,2000,1955,1977

Warm Season Dry Years



2012,1976,1952,1984,2006,1974

Conclusions

- This research provides a synthesis of the processes and mechanisms that determine water availability in the US Great Plains region.
- It provides insights on large-scale climatic conditions and processes that control precipitation (both cold and warm season precipitation).
- Moisture from westerlies is the primary source during the cold season whereas Gulf moisture is the primary source during the warm season.
- Provides insights on moisture sources and lack of enough moisture during wet-dry years across seasons.

Tool Developed

- https://nccasc.shinyapps.io/Clustering_CONUS_Gridded_Rainfall_App/
- Allows to do clustering across any user selected season for the selected period of the record
- Looks into Trends
- Teleconnections associated with any cluster
  - SST Correlation
  - SST Composite for wet and dry years
  - IVT Composite for wet and dry years

Future work and potential research questions

- Are global climate models (GCMs) adequately representing the important large-scale processes that deliver warm-season rainfall to the Great Plains? Why do several models project a decreasing precipitation trend during the 21st century?
- What factors (including large-scale climatic conditions and processes) have caused excess warm-season rainfall in the northern grasslands (Northern Great Plains) in recent decades?

Thank you!

Questions and Comments!