University of Montana Conference on Undergraduate Research (UMCUR)

Apr 27th, 3:00 PM - 4:00 PM

An Inter-Model Comparison of Gridded Temperature and Precipitation Products in Montana

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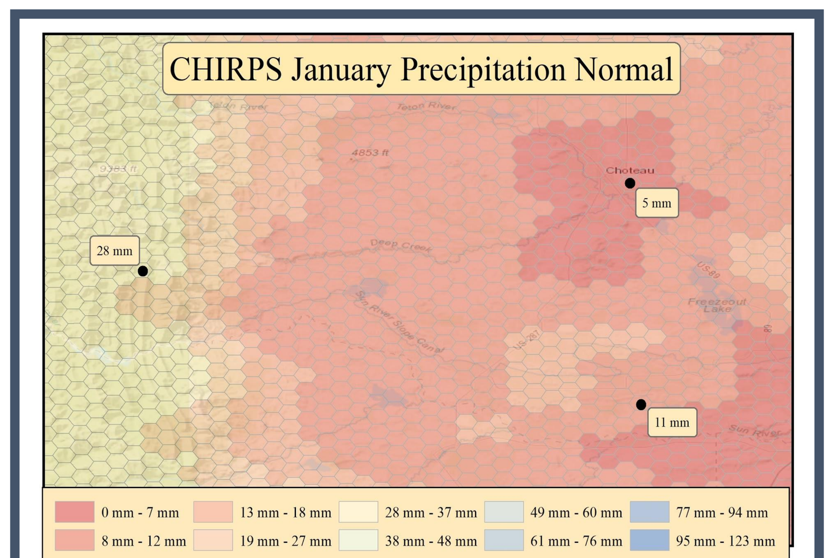
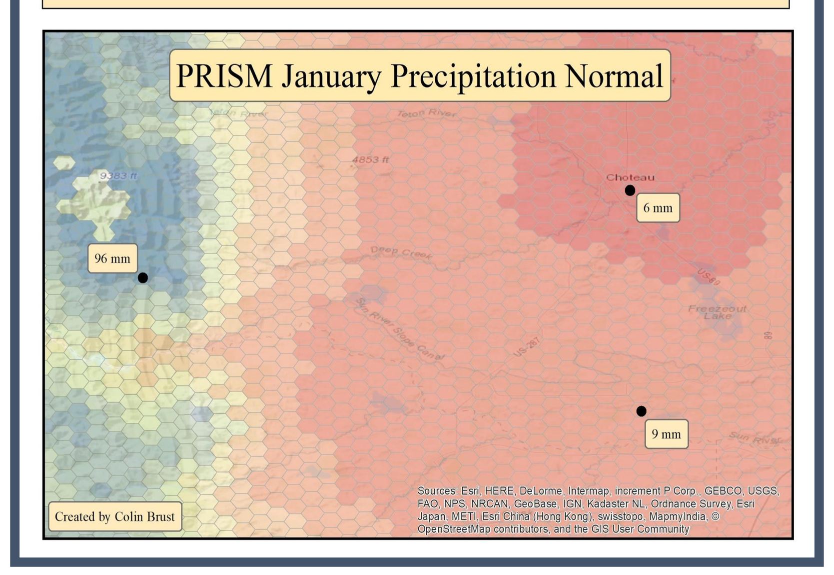
UMCUR 2018

Introduction

Gridded datasets are one of the primary sources of temperature and precipitation data upon which land managers, ranchers and scientists base their decisions. Gridded data are maps that overlay a study area and predict climate variables for every point within it. These datasets use weather station data to interpolate the physical values of climatic variables across the dataset's area of interest. As a result, gridded datasets are powerful tools that estimate climatic variables when physical measurements are unavailable. However, due to differences in calculation methods, interpolation methods and input data, it is unlikely that any two datasets will yield the same result for a given point within a study area. To understand the variability between datasets within Montana, we compared 30 years of data from five gridded datasets that measure maximum temperature (tmax), minimum temperature (tmin), and precipitation (ppt) across the state. This initial analysis provides important insights into the most applicable datasets for decision making across Montana.

Significance





Gridded data are commonly used as substitutes for physical measurements because of their ease of access. Unfortunately, using a dataset that isn't a good fit for your study area could dramatically affect your final decision. The image to the left shows the average January precipitation between 1981 and 2010 for two different gridded precipitation datasets. The leftmost point shows a difference of 68mm between the two datasets. If a local farmer were to irrigate their land assuming it had received 28mm of precipitation when in reality it received 96mm of precipitation, it could significantly affect their crop production. Because of the variability between datasets, it is essential to understand how they compare to one another across Montana.

Datasets Analyzed

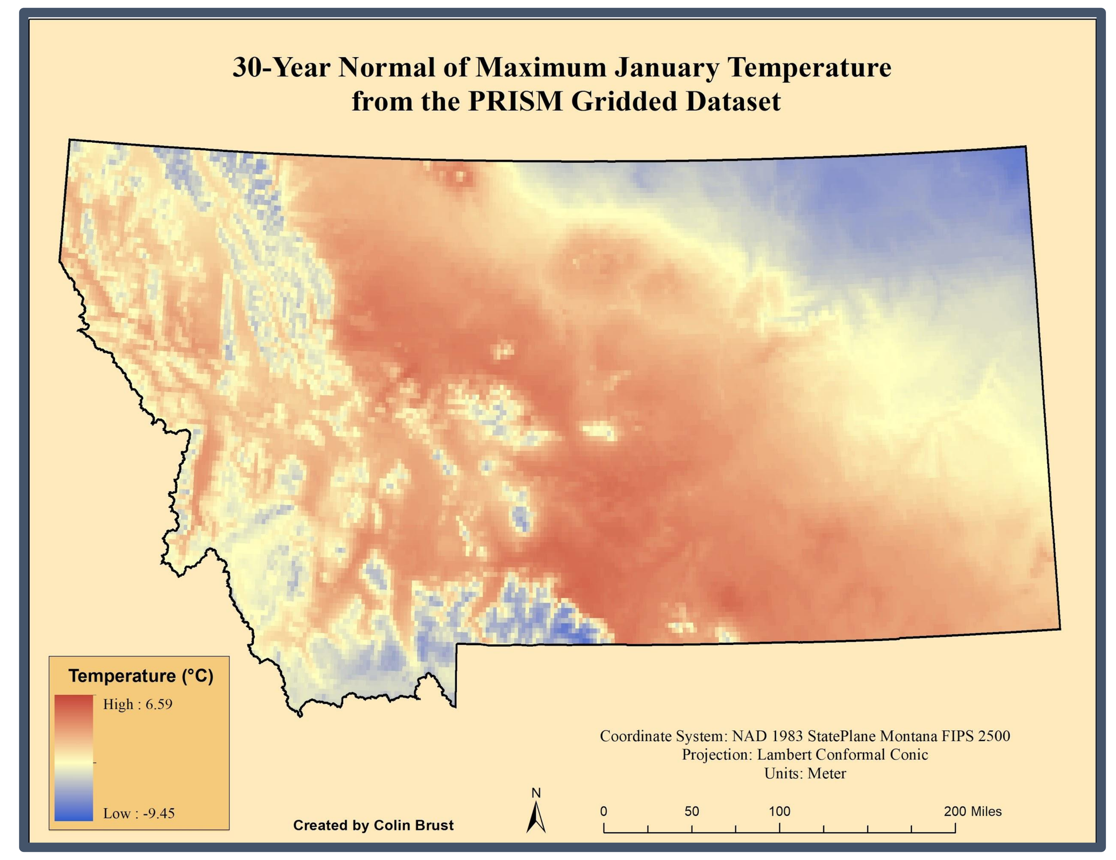
Five different gridded datasets were used for this analysis, each producing daily values for at least one of the climatic variables of interest.

Dataset	tmax	tmin	ppt
CHIRPS			X
Daymet	X	X	X
Gridmet	X	X	X
PRISM	X	X	X
TopoWx	X	X	

To perform a broad scale analysis of these datasets, we did a number of manipulations to the daily data from each dataset:

- Gathered daily data from 1981 - 2010 for each variable produced by each dataset.
- Created 30-year normals (averages) and standard deviations (SD) for each variable of each dataset from the daily data.
  - We did this at seasonal, monthly, and annual timesteps.
- This process yielded 34 maps for each variable of each dataset:
  - 12 maps of monthly normals (January through December)
  - 12 maps of monthly SDs (January through December)
  - 4 maps of seasonal normals (winter through autumn)
  - 4 maps of seasonal SDs (winter through autumn)
  - 1 map of annual normal
  - 1 map of annual SD

Creating Climate Normals



Above is an example of the 1981 - 2010 January normal tmax for the PRISM dataset. To create this 30-year monthly normal:

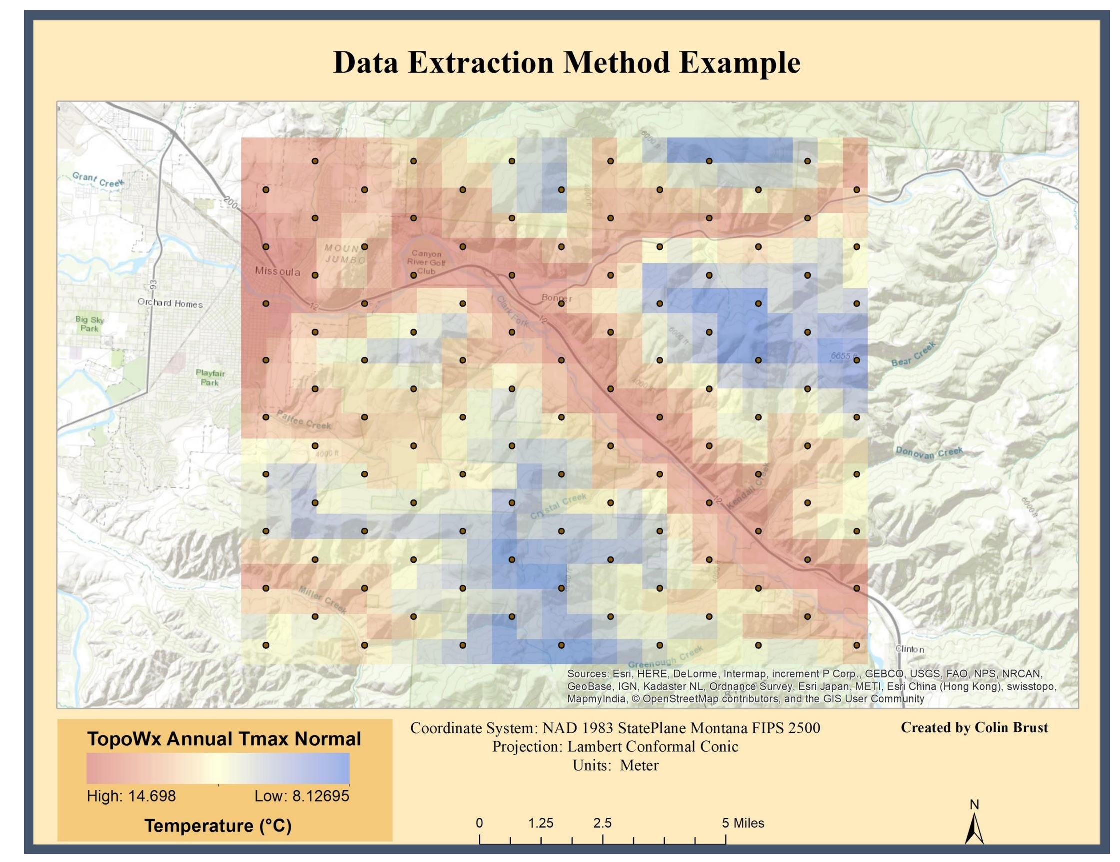
- We gathered PRISM tmax images covering the same spatial extent for every day between 1981 and 2010.
- We then grouped the daily images annually by the time period of interest (i.e. January).
- For each annual group of images, we averaged the tmax pixel values, yielding a map for each year between 1981 - 2010. Each map depicted the average January tmax for each pixel across Montana.
- We repeated the same process of averaging pixel values for the 30 annual images to produce the map seen above.

This process is how we made all of the monthly normals. In the case of ppt data, we summed the daily ppt values to give pixel-wise totals for each time period. We then averaged the annual ppt values as described above. To calculate the SD images, we either averaged or summed the daily images depending on the variable type. We then calculated the pixel-wise SD based on the 30 annual averages.

Comparison Methods

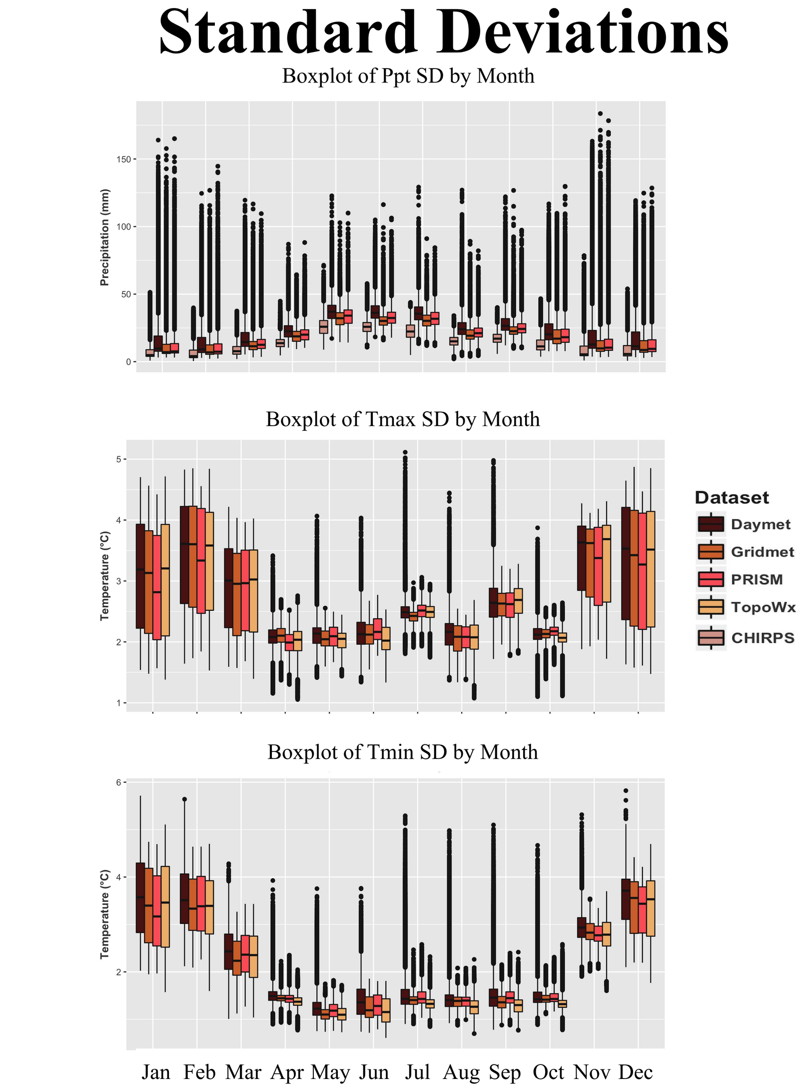
We used a uniform grid of 170,000 points spread across Montana. to compare the 30-year monthly, annual and seasonal normals and SDs to one another:

- For each of the normal and SD maps, we used the grid of points to extract the underlying pixel values.
- This extraction produced a list of 170,000 tmax, tmin, or ppt values for each time period of each dataset.
- We converted each list of values into a boxplot to examine how dataset distributions compared to one another across Montana at different temporal scales.



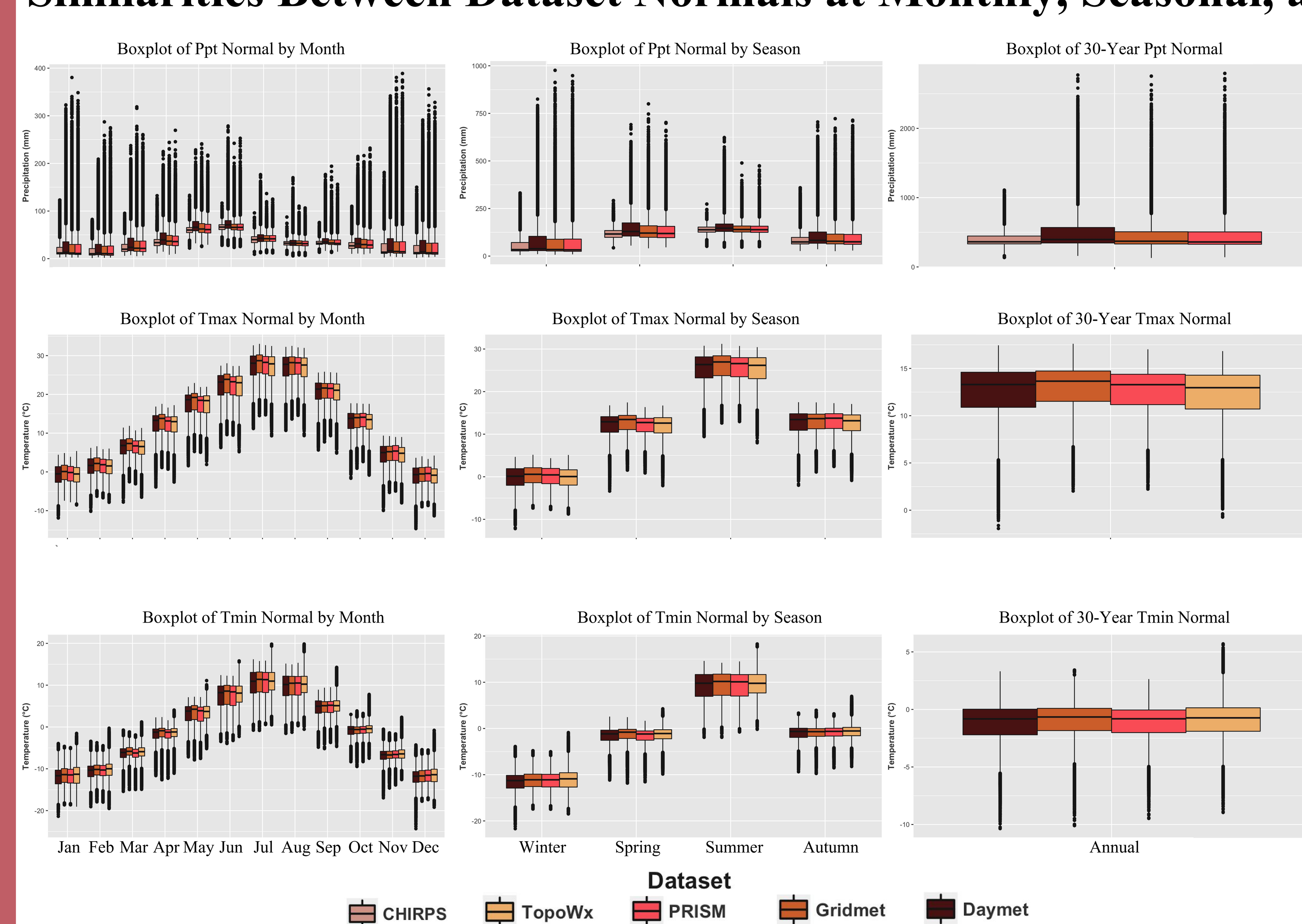
This example map shows the annual tmax normal for the TopoWx dataset and a subset of 117 points from the spatial point grid. Each of the points is sitting on top of one pixel with a specific tmax value. Each of these tmax values are then put into a list containing all of the 117 tmax values for this dataset. This process is repeated with the same point grid for the three remaining tmax normal datasets. The distributions of tmax values are subsumed as box plots to show how the datasets compare to one another across the study area.

Differences Between Dataset Standard Deviations



When using SD as the metric of comparison, there are clear differences between datasets. In the boxplots shown above, CHIRPS is a clear outlier relative to the other precipitation datasets and Daymet has far more extreme values than the other temperature datasets. In this study, SD is essentially a measure of interannual variability between datasets. Therefore, these discrepancies suggest that even at a spatial scale as broad as Montana, datasets such as Daymet and CHIRPS may be less reliable at timescales between a few months and a few years.

Similarities Between Dataset Normals at Monthly, Seasonal, and Annual Time Scales



***Note: Generally, dots above and below box plots represent outliers. However, because this is climate data, the dots in these boxplots likely represent temperature and precipitation extremes (high elevation and topographically varied regions), not unreliable data.*

Across large geographic regions and long temporal scales, all precipitation and temperature datasets produce relatively similar results. As seen in the box plots to the left, there are only minor fluctuations between datasets across all monthly, seasonal and annual timescales. This suggests that if gridded data are being smoothed across large areas (such as the state of Montana) and long time scales (30 years), all gridded climate dataset produce relatively similar results.

It is important to note, however, that even though we created these boxplots from 170,000 points, none of them are exactly the same. One might predict that if there were small differences in temperature or precipitation between datasets, the box plots should look very similar with such a large sample size of points. This suggests that there must be some areas of the state where the temperature and precipitation values predicted by each dataset begin to diverge.

Discussion and Future Work

This analysis shows that at broad temporal and spatial scales, gridded temperature and precipitation datasets produce similar results to one another across Montana. Additionally, it shows that some gridded datasets vary more than others from year to year, suggesting that they may produce unreliable results in high elevations or varied terrain. To further understand these differences between datasets, the next steps of this project will be to:

- Create maps comparing normals and SDs of each dataset (a spatial display of the box plots presented here).
- Compare datasets at smaller spatial scales such as:
  - Elevations > 2000m
  - Rangelands and croplands
  - Valley bottoms and ridge lines
- Write a program that will:
  - Generate normals for new gridded datasets
  - Generate plots and maps comparing gridded dataset normals and specified spatial, temporal, and topographic scales.
- Compare gridded data to independent Montana Mesonet data

Acknowledgements

This research is currently funded by the Montana Space Grant Consortium and is being produced in conjunction with the Montana Climate Office at the University of Montana.