CHARACTERIZING TEMPERATURE AND PRECIPITATION INTERACTIONS ACROSS IDAHO

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Abstract

This study used growing season mean temperature and sum of precipitation for the years 1980 through 2022 to examine interactive effects. Specifically, this study sought to determine if seasonal minimum temperature (Tmin) and/or seasonal maximum temperature (Tmax) can be treated as a driver variable for precipitation (Precip) in future modeling efforts. These data, spatially stratified as either (1) lower elevation/gentle terrain site (Snake River Plain) or (2) higher elevation/rugged terrain site (High Country) were derived from the Daymet daily surface weather dataset. Using ANOVA and linear regression tests, statistically significant interactive effects were identified. In addition, some interesting relationships were observed and reported in this paper. These relationships can be further explored using a finer, monthly or even weekly temporal scale to better understand weather patterns and future projections.

Keywords: *Idaho, climate, weather*

Introduction

This study builds upon datasets and previous analyses completed by Weber as part of the Idaho Community-Engaged Resilience for Energy-Water Systems (I-CREWS) project (Weber 2025a and Weber 2025b). Specifically, the current study sought to determine if seasonal minimum temperature (Tmin) and/or seasonal maximum temperature (Tmax) acts as a driver variable of precipitation (Precip). The time period of this study spanned 1980-2022 which is a direct result of current weather data availability, continuity, and resolution. The specific dataset identified for this study was derived from the Daymet[1] daily surface weather dataset (Thornton et al 2022) which provided temperature minimum (Tmin in degree Celsius), temperature maximum (Tmax in degree Celsius), and Precipitation (Precip in mm/day).

Weather events vary over space and time. For this reason, an investigation seeking statistically significant weather drivers and interactions across the entire state of Idaho was not pursued. In essence, the variability within any weather parameter (Tmin, Tmax, or Precip) due to geography would overwhelm any chance of detecting relationships or interactions between weather parameters. This is evidenced very well in **Figure 1** which at first glance can be mistaken for a map of elevation when in reality this particular map shows mean Tmax for the 1984 growing season. It goes almost without saying that time also has profound effects on weather and as a result we have all become quite accustom to the seasons (spring, summer, fall, and winter) especially in more northerly regions of the United States where seasonal differences are more pronounced. Thus, an assessment of any relationships and interactions between weather variables is more meaningful within a specific season or shorty

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[1] https://daymet.ornl.gov/

temporal window. To further exemplify this, consider two study sites. One has a constant temperature of 10° C throughout the year and the other exhibits bimodal ambient temperatures of 0° C for half the year and 20° C for the other half of a year. Both sites have a mean temperature of 10° C. We only understand the difference between these sites when the assessment is stratified by time. In this study, two temporal windows were used. The *growing season* was defined as Julian dates 091-273 (April 1st-September 30th) while the *winter season* was defined as Julian dates 244-365 (September 1st-December 31st) for year *Y* in addition to Julian dates 001-120 (January 1st-April 30th) for year *Y+1*.

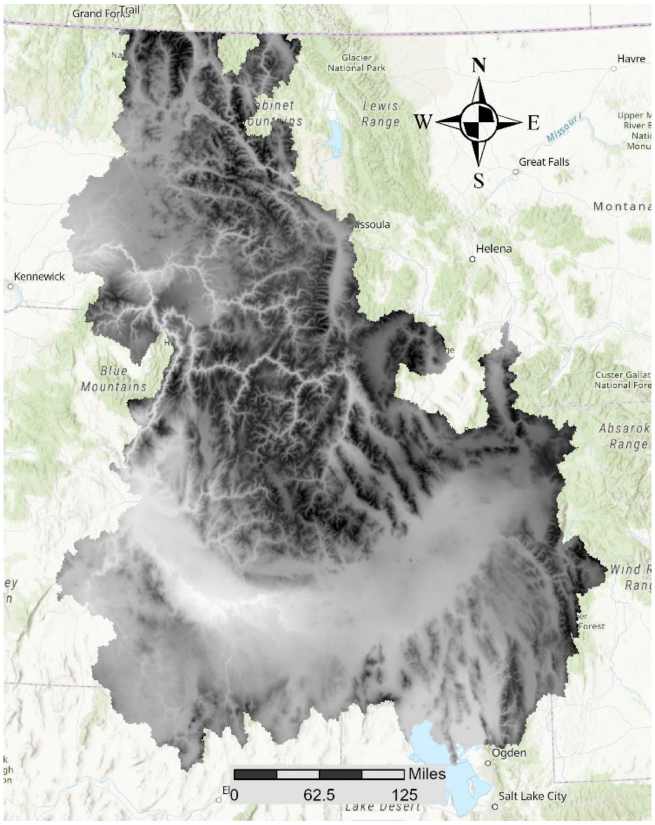

Figure 1. This map of Idaho can be easily mistaken for an elevation map. In reality it shows mean maximum temperature for the 1984 growing season. The terrain has a substantial effect on weather.

The goal of this study was to (1) determine if seasonal Tmin and/or Tmax exhibit significant driver effects on precipitation and (2) quantify the relationship between temperature and precipitation. These results will ideally help inform future modeling efforts within the larger I-CREWS study.

Methods

There are 93 HUC08 watershed basins (polygons) within the study area. This paper selected and reports results for seven of those watersheds; four henceforth referred to as High Country watersheds (totaling 18,451 km^2) and three referred to as Snake River Plain watersheds (totaling 15,708 km^2) (**Figure 2**). These watersheds were selected to represent a (1) contiguous mountainous region and (2) lower elevation region with minimal topographic relief all within eastern Idaho.

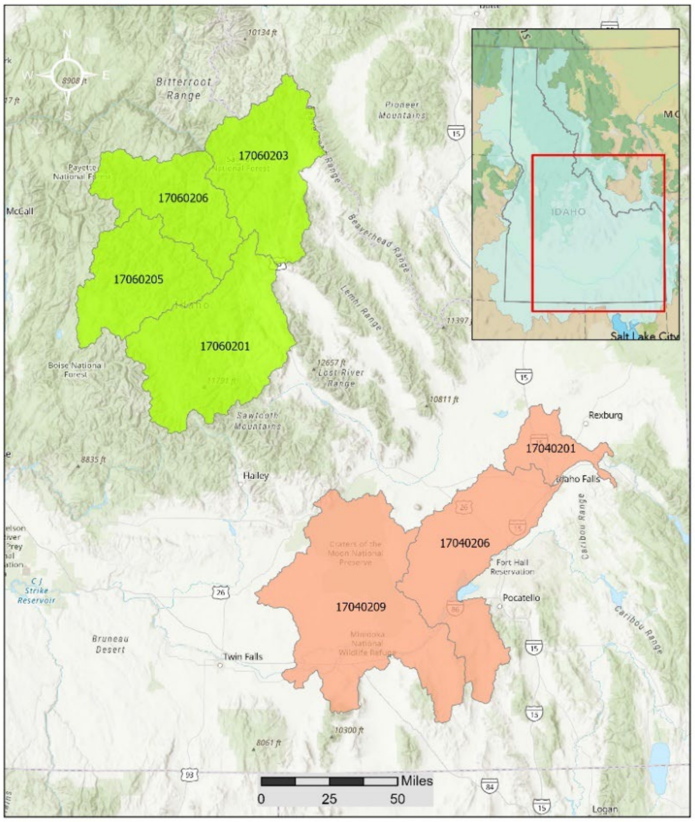

Figure 2. Seven watersheds were selected to serve as case study regions, four were considered high country watersheds (green) and three Snake River Plain watersheds (orange).

Two-factor ANOVA with replication was used to statistically test log transformed temperature and precipitation interactions throughout the growing season within and between the High Country and Snake River Plain regions. In addition, simple regression plots were used to visualize these data.

Results and Discussion

Based on ANOVA results, a difference in Precip, Tmin, and Tmax was identified between *regions* ($P < 0.001$). This was anticipated as weather conditions in these regions are noticeably different even after only casual observation. There was also a difference between *years* within regions ($P < 0.001$). This was also anticipated and is not considered unusual especially in light of the temporal trends described in previous technical reports (Weber 2025b). An interaction effect of Precip, Tmin, and Tmax variables between and within regions was also present ($P < 0.001$) (**Table 1**). This was not necessarily anticipated or expected but rather, was unknown and as noted above, was the primary objective sought by this study. Environmentally and ecologically, this interaction makes sense and agrees with results previously reported in other studies (Madden and Williams 1978, Trenberth and Shea 2005).

Visualizing these data with regression plots provides another insight into how these weather variables interact (**Figure 3**). None of the regressions exhibited a strong correlation ($R^2 < 0.36$). This indicates temperature should not be considered a driver of precipitation but suggests temperature and precipitation should be viewed as covariates. This conclusion is supported by the results of the ANOVA interaction tests. An interesting covariate trend is observed in each of these graphs suggesting as temperature increases, precipitation decreases.

Table 1. Results of ANOVA test for interaction between growing season sum of precipitation (seasonal sum), median temperature minimum, and median temperature maximum within and between two study area sub-regions across the years 1980-2022.

SUMMARY	PRECIP_SUM	TMIN_MEDIAN	TMAX_MEDIAN	Total
High Country				
Count	43	43	43	129
Sum	99.3	44.6	61.6	205.4
Average	2.3	1.0	1.4	1.6
Variance	0.0	0.0	0.0	0.3
Snake River Plain				
Count	43	43	43	129
Sum	94.1	51.6	65.6	211.4
Average	2.2	1.2	1.5	1.6
Variance	0.0	0.0	0.0	0.2
Total				
Count	86	86	86	
Sum	193.4	96.2	127.2	
Average	2.2	1.1	1.5	
Variance	0.0	0.0	0.0	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	0.14	1	0.136	15.123	0.0001	3.879
Columns	57.36	2	28.679	3178.296	0.0000	3.032
Interaction	0.94	2	0.472	52.271	0.0000	3.032
Within	2.27	252	0.009			
Total	60.71	257				

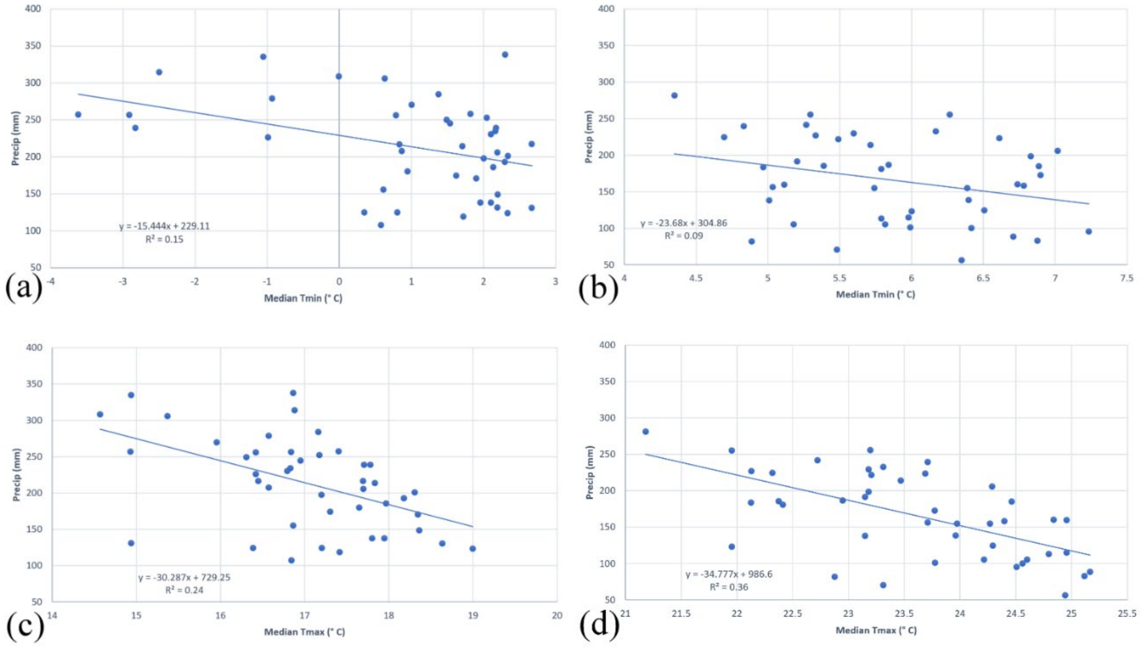

Figure 3. Regression plots for temperature (Tmin a and b; Tmax c and d) and precipitation covariates. An overall trend where precipitation declines as temperature increases is observed across both the High Country (a and c) and Snake River Plain (b and d) regions.

Conclusions

The results of this study agree well with previous studies exploring the spatiotemporal interaction of temperature and precipitation. While an interaction exists ($P < 0.001$), neither temperature or precipitation should be used as a driver variable for the other variable. Instead, both should be correctly considered interacting covariates. An interesting trend was observed between temperature and precipitation across the semiarid study area; as growing season temperature increases, precipitation tends to decrease. These trends conflict with projections given in Peterson et al (2017) where both temperature and precipitation are generally expected to increase concomitantly. However, it is noted that the trends observed in this study characterize past conditions while the trends reported by Peterson forecast future conditions.

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