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University of Idaho
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Observed Trends in Agriculturally Relevant Climate Metrics In the Pacific Northwest

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USDA

Motivation

Observed changes in climate over the past half century have been noted across various spatial scales and diverse indicators. In the Pacific Northwest, widespread decreases in mountain snowpack and changes in the timing of peak runoff are the hallmark indicators of observed changes in hydrology and downstream water resources that have indirect ramifications for agriculture. This study extends previous observational studies by examining long-term trends in primary climate metrics and a suite of agriculturally relevant metrics using USHCN data to elucidate more direct impacts of changes in climate for agriculture. Observations depict a significant increase in the length of the frost-free season, late-season moisture deficits and reference evapotranspiration concurrent with widespread regional warming trends. In addition, a significant increase has been noted in the median coldest night of the year that is often used in determining cold-hardiness for perennials.

Datasets and Methods

- Daily maximum temperature, minimum temperature and precipitation from United States Historical Climate Network (USHCN, Menne et al., 2009) observations in the Pacific Northwest USA (42-49°N, 110-125°W) was acquired from 1890-2011.
- Daily reference evapotranspiration (ET_o) is derived using the Penman Montieth equation that considers USHCN observations supplemented with monthly mean dewpoint depression from PRISM (Daly et al., 2008) and climatological downward shortwave radiation and wind speeds from NLDAS-2 (Mitchell et al., 2004).
- A modified Thornthwaite water balance model (Willmott, 1985) is run in daily time steps with standard 200mm soil water holding capacity to estimate daily evapotranspiration, soil moisture and moisture deficit.
- A linear least-squares trend is estimated where at least 75% of the annualized time series is complete and satisfies the following criteria:
  - monthly observations missing no more than 5 days per month
  - annual observations not missing any months
  - integrated metrics not missing more than 20 days per year.
- Statistical significance of trends ($p<0.05$) is determined using Mann-Kendall test.
- Unless otherwise shown, trends are only shown for the 62-year period 1950-2011. These trends are supplemented with differential trend analysis for temperature and precipitation across a spectrum of time periods ending in 2011.
- Projected changes in temperature and precipitation from 20 CMIP5 GCMs averaged across the Pacific Northwest are then used to contextualize observed 20th century changes to changes projected over the 21st century for two different representative concentration pathways (RCP).

Spring/Autumn Freeze and Growing Season Length

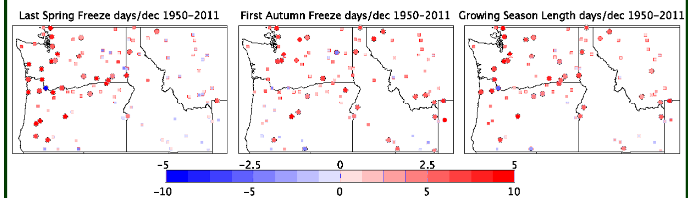

Figure 5: Linear trend (days per decade) in last spring freeze (TMIN<0C), first fall freeze (TMIN<0C) and growing season length (herein defined as freeze-free season). Positive values indicate an advance in the date of the the last spring freeze and delay in the date of the first autumn autumn freeze, respectively.

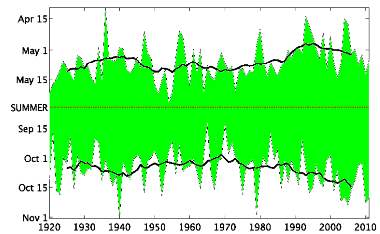

Figure 6: Time series of median last spring freeze date and first autumn freeze date for 10 USHCN stations in the wheat growing region of Washington, Idaho and Oregon that had at least 90% of years with available data. Missing data (<10%) are estimated using regional freeze anomaly dates. The black line depicts the 11-year moving average.

- Warming trends during the shoulder season have increased the freeze-free season by approximately two-to-four weeks over the last 60 years.

Coldest Night and Warmest Day of the Year

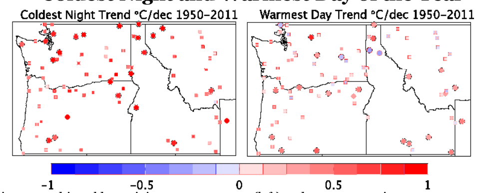

Figure 10 : Linear trend in coldest minimum temperature (left) and warmest maximum temperature observed on a water year and calendar year basis, respectively, from 1950-2011.

- Warming has been particularly acute for the extremes and have resulted in a reorganization of cold hardiness zones including shifts and novel agricultural zones.

Potential Evapotranspiration and Summer Moisture Deficit

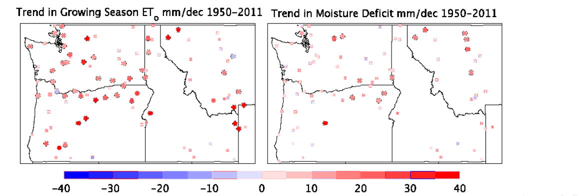

Figure 11 : Linear trend in growing season potential evapotranspiration (left) and growing season moisture deficit (right) calculated over the period 1950-2011. Available water holding capacity at each site is assumed at 200mm.

- Longer growing season coupled with increased potential ET_o have increased later summer moisture deficits and irrigation requirements.

Temperature

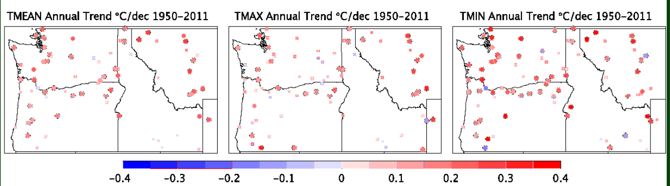

Figure 1: Linear least square trends of maximum (TMAX), minimum (TMAX) and mean (TMEAN) temperature from 1950-2011 from USHCN stations in the PNW. Statistically significant trends ($p<0.05$) are denoted by large circles, insignificant trends denoted as small squares.

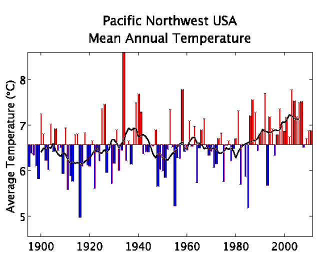

Figure 2: Time series of mean annual temperature averaged over the Pacific Northwest USA (42-49°N, 110-125°W) spatially averaged from PRISM.

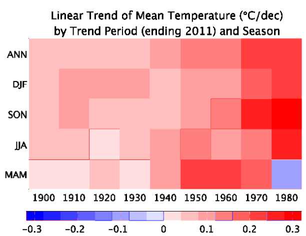

Figure 4: Calculated linear trends in mean temperature using variable starting years (x-axis) and seasonal windows (y-axis) from PRISM.

- Demonstrated acceleration in regional warming, albeit with distinct changes in pace at seasonal and decadal timescales associated with natural variability.

Precipitation

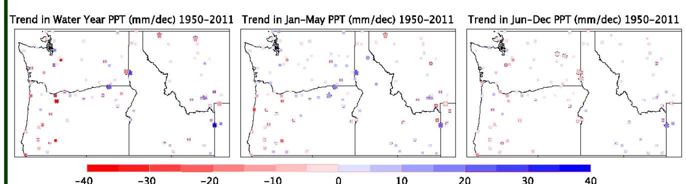

Figure 7: Linear least square trends of year year (Oct-Sep), late winter-spring (Jan-May) and summer thru early winter (Jun-Dec) precipitation.

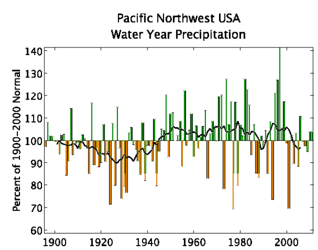

Figure 8: Time series of water year precipitation percent of normal averaged over the Pacific Northwest USA (42-49°N, 110-125°W) spatially averaged from PRISM.

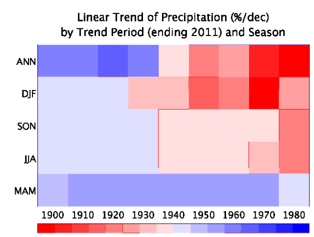

Figure 9: Calculated linear trends in precipitation using variable starting years (x-axis) and seasonal windows (y-axis) from PRISM.

- Precipitation trends have been regionally and seasonally variable with modest increases in spring precipitation and decreases in summer precipitation.

Model Projections

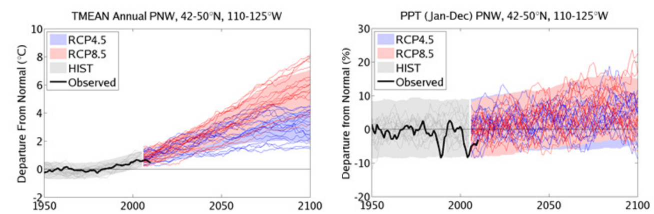

Figure 12 : Modeled simulations of annual mean temperature (left) and precipitation (right) under historical 20th century forcing (grey), RCP4.5 (blue) and RCP8.5 (red) experiments from 20 CMIP5 models. The bold black line shows historic observations from PRISM. Time series have all been smoothed using an 11-year moving average with the shaded areas bounding the 20th - 80th percentile of simulations.

- Amplified warming for the 21st century across the Pacific Northwest, with significant impacts on agriculturally relevant metrics.
- Tendency toward a small increase in total annual precipitation, with increased cool season precipitation and decreased summer precipitation.

Implications

- Strong evidence of widespread trends in temperature sensitive agroclimatic metrics over the past half century in the Pacific Northwest
- Observed trends consistent with those predicted by GCMs under late 20th century forcing
- Projected changes in agriculturally relevant climate metrics over the next half century are likely to outpace observed changes over the last half century.

References

Daly, C.,

Menne M.J., Williams, Jr. C.N., and R. S. Vose, 2010. United States Historical Climatology Network Daily Temperature, Precipitation, and Snow Data. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Mitchell...

Willmott 1985