USGS

WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Spatial and Temporal Characteristics of Winter Precipitation Variation Over Idaho and Their Association with Pacific Sea Surface Temperature Anomalies

Focus Categories: CP, WS, and HYDROL

Keywords: Climate Variability, Rainfall, and Snow

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Congressional District: First

Statement of Critical Regional or State Water Problems

Winter precipitation in Idaho has experienced large variations and trends in recent decades. Sea surface temperature (SST) anomaly over the eastern tropical Pacific Ocean, the El Nino condition, has been found to significantly influence Idaho winter precipitation. In addition, recent studies suggest that SSTs over the northern Pacific are also closely associated with surface climate over the Pacific Northwest. El Nino occurs every two to seven years while the northern Pacific SST anomaly exhibits decadal time scale variations. Idaho has a diversity of climate regimes and regional variation patterns. Each region is thought to have a unique connection to each of these two Pacific SST variations. However, the regional patterns and time scales of the connections between precipitation in Idaho and Pacific SST conditions have not been researched.

A large part of Idaho's precipitation falls in winter. Farmers, ranchers, ski resort managers, fishermen, transportation departments, and electric utility companies need realistic predictions of seasonal precipitation to make accurate plans and financial forecasts. Given the fact that El Nino can be predicted with a fair degree of accuracy, it would be possible to more accurately predict winter precipitation if relationships between Idaho's precipitation and Pacific SST anomalies were established. Idaho's economy would benefit greatly from improved precipitation prediction.

Statement of Results or Benefits

The purpose of the proposed study is to examine regional patterns, oscillatory characteristics, and trends of winter precipitation across Idaho, and their associations with the two major variation modes of Pacific SST. In addition, atmospheric circulation patterns bridging the connection will be examined to enhance the understanding of relevant atmospheric mechanisms. This study will provide (1) comprehensive knowledge of precipitation variability and trends during the past few decades in 10 major drainage basins covering most of Idaho; (2) the statistical linkages between Pacific SSTs and precipitation over each drainage basin and thus the potential predictability of winter precipitation in Idaho; and (3) a better understanding of the major atmospheric circulation patterns that are critical to precipitation anomalies over Idaho during the winter season.

Nature, Scope and Objectives of the Research

Idaho's water resources rely heavily on winter precipitation, not only because most of Idaho's precipitation falls in the winter but also because a large portion of water is stored as snow at high elevations. The magnitude and timing of the snow melt affects hydropower generation, salmon migration, irrigation, and navigation, thereby impacting all of the state's major industries.

Large interannual variations in winter precipitation have been noted in Idaho, especially in recent decades as El Nino has become more frequent. The Pacific Northwest is one of the most sensitive regions in North America to El Nino, which is characterized by an abnormally high sea surface temperature (SST) over the eastern tropical Pacific (Ropelewski and Halpert 1986; 1996). The El Nino condition has been used to predict winter precipitation over the entire region. For example, a mild and dry winter is thought to be associated with an El Nino year and the opposite condition with a La Nino year. These ideas are based on a general statistical association between El Nino and Pacific Northwest climate parameters derived from about 30 years of data records (Ropelewski and Halpert 1986; 1996). However, Idaho has 10 climate regimes based on Koppen's classification system and is further divided into 16 distinct climate zones based on more recent climatic data and native vegetation distributions (Godfrey, 1999). Two distinct seasonal precipitation patterns are observed: one peak of wet winter climate in the north and two peaks in early fall and late spring in the south (Abramoich et al. 1998). Various weather processes are responsible for regional precipitation. The dominant weather pattern over northern Idaho is the strong westerly that brings mild and moist Pacific air, especially during winter. Southern Idaho is dominated by systems moving from the southwestern United States. Idaho's topography further complicates its diverse regional precipitation characteristics. Better predictions require detailed knowledge of regional connection patterns between winter precipitation and Pacific SSTs.

The reason that the Pacific Northwest is very sensitive to Pacific SSTs is that it is located under one of three anomaly centers of a major atmospheric circulation pattern over North America, the Pacific North American pattern (PNA; Barnett and Livezey 1987; Wallace and Gutzler 1981). The other two centers are located over the northern Pacific and the southeastern United States. When abnormal SST occurs, it directly affects the atmospheric anomaly over the northern Pacific center. Then the atmosphere readjusts its circulation and modifies the other two centers downstream. Thus, this circulation pattern is closely related to Pacific SST and controls surface climate over much of the United States. The PNA pattern has been increasing in intensity in recent decades, possibly as a result of anthropogenic causes (Leather and Palecki 1992). This suggests that precipitation patterns in Idaho may be changing. Statistically significant increasing trends in precipitation have been detected at some weather stations in Idaho during the past few decades (as exercise results by students in PI's climatology class have shown). A more thorough investigation is needed to fully understand this issue.

Recent studies have found that SSTs over the northern Pacific influence mid- and high-latitude climates more than El Nino (Ting and Wang 1997; Wallace et al. 1990). Furthermore, a significant decadal time scale variation of about 20 years is found in northern Pacific SST variations (Latif and Barnett 1996; Trenberth and Hurrell 1994; Ye's ongoing research). The atmospheric circulation patterns associated with this decadal variation is found to be very different from those related to El Nino (Kushnir and Lau 1992; Yamagata and Masumoto 1992). Two recent studies further support the idea that the northern Pacific decadal variation has a significant influence on surface climate over the Northwest. These studies reveal that salmon population and glacier mass balance over the Pacific Northwest are significantly associated with the decadal time scale variation of the northern Pacific SST anomaly (Bitz and Battisti 1999; Mantua et al. 1997). This northern Pacific SST pattern definitely modifies the impact of El Nino on surface climate parameters revealed in earlier studies. A comprehensive examination of the relative contributions of these two different SST anomaly patterns to Idaho's precipitation and the associated different time scales is needed in order to better understand Idaho's precipitation variability.

The goal of the proposed study is to examine and quantify the spatial and temporal characteristics of the teleconnection between Pacific SST anomalies and Idaho's regional precipitation during the winter season by using GIS and advanced statistical methods. In addition, the potential atmospheric circulation patterns that bridge this teleconnection will be examined.

Methods, Procedures and Facilities

Precipitation records from the State Climate Office gathered from weather stations across Idaho during the time period from 1917-96 will be used. Since there are missing values in some stations, selection procedures will be designed and interpolation will be used to maximize station usage and data length. First, the missing value of a single month will be interpolated from nearby months. Winter season precipitation will be based on the total of three monthly means of December, January, and February. If more than one month is missing, the entire season will be considered as missing. Ten major drainage basins (based on a 6-digit classification system) covering the majority of Idaho will be selected to represent different geographical regions. The specific study time period for each drainage basin will be determined to achieve the best spatial station coverage and the longest records. Then station history will be examined to eliminate those that were relocated during the selected study time period. Communication with Dr. Myron Molnau of the State Climate Office reveals that more than 50 stations have data back to 1917 and over 100 stations have data starting in 1960. So, there will be at least 5 to 10 stations for each drainage basin. PI is confident that data coverage for the proposed project is adequate.

Pacific sea surface temperature (SST) data will be derived from the Reynolds Reconstruction of the Comprehensive Ocean-Atmosphere Data Set (COADS) SST covering the time period of 1950-92, described by Smith et al. (1996). The SST anomalies were reconstructed based on the dominant empirical orthogonal function modes derived from the more recent period of 1982-93. These SST data have a resolution of 2° latitude by 2° longitude. Grid points over the Pacific Ocean between 20°S and 70°N will be selected for the study. The cut off at 20°S is designed to avoid unreliable seasonal mean SSTs caused by low-density station distribution south of that latitude (Hurrell and Trenberth 1999). The selected region covers both tropical (El Nino related) and northern Pacific SST (North Pacific) anomaly patterns that are believed to be the major features of Pacific SST variations. The winter SST anomalies will be derived by subtracting the 43-year average winter SST (Dec., Jan., and Feb) from each winter's mean value in each grid point. Then the winter SST anomaly will be standardized before analyses to insure that each grid point is weighted equally.

Monthly mean 500mb height data will be taken from NCEP Grid Point Data Set: Version III which is an update and extension of the NMC Grid Point CDROM produced in 1990. The Northern Hemisphere octagonal grid points comprised of 1,977 equally spaced points in a 47 by 51 array will be used (Jenne 1975). The time period overlapping the SST data will be selected for analysis. In addition, the 500mb data from the National Center for Environmental Prediction (NCEP)'s forty-year analysis (Kalnay et al. 1996) will also be used to insure that the results are not sensitive to the particular data products used.

The GIS software, ArcView 3.2, will be used to process station data and derive yearly area-weighted averages of winter precipitation for the 10 major drainage basins over Idaho. The area-weighted average is a standard method to derive average values over a geographic region to avoid biases caused by non-uniform station distributions. ArcView can convert station data into grid points, and then calculate averages of the gridded precipitation to derive area-weighted averages. The resulting average value represents winter surface water supply for each of the selected drainage basins. As a result, there will be 10 time series of winter precipitation corresponding to the 10 major drainage basins across Idaho.

Potential trends in precipitation will be examined using linear least-square regression analysis for each time series. The oscillatory variation characteristics of winter precipitation on interannual and decadal time scales at each drainage basin will be examined by using singular spectrum analysis (SSA). SSA is a novel and powerful tool for time series analysis that can identify intermittent oscillation spells in short, noise time series such as precipitation (Vautard et al. 1992). The basic oscillations into which a time series decomposes are not functions of prescribed, harmonic form. Instead, their shapes are determined from the time series itself. SSA has been used in many geophysical and climatological studies to reveal and predict periodic activities (Ghil and Vautard 1991; Ghil and Mo 1991; Plaut and Vautard 1994; Ye and Cho 1999; Ye 1999). In addition, the time evolution of each identified oscillation component will be extracted from the original time series based on the reconstruction technique developed by Plaut and Vautard (1994). The reconstructed time series will clearly show the amplitude and phases of low-frequency variation imbedded in the original precipitation time series.

Principal component analysis (PCA) will be applied to Pacific SST anomalies. Major SST variation patterns, the El Nino-related eastern tropical and northern Pacific patterns, will be revealed. The resulting time evolutions of these two major SST patterns are called time series of principal components (PCs). Each PC will be correlated with each of the 10 drainage precipitation time series. Significant correlations among the time series will reveal the connections between Idaho precipitation and Pacific SSTs at interannual time scale.

SSA will also be applied to these SST PCs to reveal low-frequency time scale variations. The reconstructed time series of low-frequency variation components of the Pacific SSTs will be compared to those of precipitation to examine potential connections at decadal time scales.

A cross-correlation coefficients map of the correlation between SST at each grid point and the time series of precipitation for each drainage basin will be calculated to verify those SST regions that are significantly related to precipitation. Furthermore, another cross-correlation coefficients map of the correlation between SST at each grid point and each of the reconstructed time series of the low-frequency variation component of precipitation will also be produced to further test the significance of the teleconnections at low-frequency modes.

Correlation coefficients between grid points of 500mb geopotential height and the time series of precipitation of each drainage basin will be calculated to reveal significant circulation anomaly regions that are related to precipitation variation. These correlation coefficients maps will be compared to those correlating 500mb height and SST PCs to reveal common significant regions in atmospheric circulation. Thus, the key atmospheric circulation anomaly patterns that bridge the connection between Pacific SST and Idaho precipitation will be revealed.

This proposed research aims to examine the variability and predictability of winter surface water supply for 10 major drainage basins at interannual and decadal time scales. The study will provide (1) comprehensive knowledge of precipitation variability and trends during the past few decades across different regions of Idaho; (2) the statistical linkages between Pacific SST and mean winter precipitation over each of 10 major drainage basins and thus the predictability of winter surface water supply in Idaho; and (3) a better understanding of the major mid-tropospheric circulation patterns that are critical to precipitation anomalies over Idaho during the winter season.

National Oceanic and Atmospheric Administration (NOAA) provides eastern tropical SST (El Nino) prediction up to one year ahead. Based on the results of this study, it would be possible to use NOAA's SST predictions to predict regional winter precipitation anomalies over Idaho where statistically significant connections are revealed. Thus many people could utilize this information to estimate potential anomalies of snow accumulation over high elevations and spring runoff for planning. These users might include farmers, cattle ranchers, ski resort managers, fisherman, companies that rely on the Snake River for transportation of goods, electrical utility companies using hydropower, transportation departments, and other citizens and organizations.

The research results will be presented in a regional or national conference and submitted for publication in a peer-reviewed journal. In addition, PI plans to post the findings from this research on the internet for public access.

Dr. Karl Chang in the Department of Geography will help PI with data processing using GIS in the early stages of the project. PI will also consult with Dr. Myron Molnau, the former Idaho State Climatologist, for local climate data quality and selection. PI will supervise one graduate student's participation in this research project.

Related Research

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