



Evolving Assessments of Human and Natural Contributions to Climate Change

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Introduction

As Congress continues to deliberate whether and how to address climate change, a key question has been the degree to which humans and natural factors have influenced observed global climate change.¹ Members of Congress sometimes stress that policies or actions “must be based on sound science.”² Officials in the Trump Administration have expressed uncertainty about the human influence, and some have called for public debate on the topic.³

To help inform policymaking, researchers and major scientific assessment processes have analyzed the attribution of observed climate change to various possible causes. Scientific assessments of both climate change and the extent to which humans have influenced it have varied in expressed confidence over time but have achieved greater scientific consensus. The latest major U.S. assessment, the Climate Science Special Report (CSSR), was released in October 2017 by the U.S. Global Change Research Program (USGCRP). It stated

It is extremely likely [$>95\%$ likelihood] that human influence has been the dominant cause of the observed warming since the mid-20th Century. For the warming over the last century, there is no convincing alternative explanation supported by the extent of the observational evidence.⁴

This CRS report provides context for the CSSR’s statement by tracing the evolution of scientific understanding and confidence regarding the drivers of recent global climate change.⁵

Conclusions

Many factors have contributed to increased scientific confidence in quantifying the human and natural contributions to climate change. Longer records of observational data have provided more evidence of the concordance between higher GHG levels and temperature increases. Satellites have provided important observations of temperatures; atmospheric pollution; and land, snow, and ice cover beginning in the late 1970s. Additionally, improved scientific understanding of atmospheric physics, together with vastly more powerful computers, has led to climate models that better simulate atmospheric and oceanic conditions. Uncertainties in the models remain on how they simulate the effects of clouds, for example, and the model simulations are at smaller scales of space and time. Despite these uncertainties, current climate scientific assessment states high confidence (extremely likely) that human influence is the dominant cause of the observed warming over the past half-century. While the near consensus has developed relatively recently, it has evolved based on increasing confidence through research on scientific concepts established as early as 200 years ago. Future climate outcomes depend on many additional factors, such as the future rates and character of socio-economic development and efforts to curtail the growth of GHG emissions.



RESEARCH PAPER

Evaluating species-specific changes in hydrologic regimes: an iterative approach for salmonids in the Greater Yellowstone Area (USA)

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Abstract Despite the importance of hydrologic regimes to the phenology, demography, and abundance of fishes such as salmonids, there have been surprisingly few syntheses that holistically assess regional, species-specific trends in hydrologic regimes within a framework of climate change. Here, we consider hydrologic regimes within the Greater Yellowstone Area in the Rocky Mountains of western North America to evaluate changes in hydrologic metrics anticipated to affect salmonids, a group of fishes with high regional ecological and socio-economic value. Our analyses assessed trends across different sites and time periods (1930–, 1950–, and 1970–2015) as means to evaluate spatial and temporal shifts. Consistent patterns emerged from our analyses

indicating substantial shifts to (1) earlier peak discharge events; (2) reductions of summer minimum streamflows; (3) declines in the duration of river ice; and (4) decreases in total volume of water. We found accelerated trends in hydrologic change for the 1970–2015 period, with an average peak discharge 7.5 days earlier, 27.5% decline in summer minimum streamflows, and a 15.6% decline in the annual total volume of water (1 October–September 30) across sites. We did observe considerable variability in magnitude of change across sites, suggesting different levels of vulnerability to a changing climate. Our analyses provide an iterative means for assessing climate predictions and an important step in identifying the climate resilience of landscapes.

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Keywords Climate change · Hydrologic regimes · Trout · Vulnerability

Introduction

Hydrologic regimes act as a template for biological processes and a filter for the composition of aquatic communities (Poff et al. 1997; Poff and Ward 1989). For riverine fishes, the timing and magnitude of discharge directly affect behavioral and life-history patterns (Mims and Olden 2012; Schlosser 1985) while also serving as a strong control on abundance and demographic rates (e.g., Gido and Propst 2012;

RESEARCH ARTICLE

The Shifting Climate Portfolio of the Greater Yellowstone Area

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Abstract

Knowledge of climatic variability at small spatial extents (< 50 km) is needed to assess vulnerabilities of biological reserves to climate change. We used empirical and modeled weather station data to test if climate change has increased the synchrony of surface air temperatures among 50 sites within the Greater Yellowstone Area (GYA) of the interior western United States. This important biological reserve is the largest protected area in the Lower 48 states and provides critical habitat for some of the world's most iconic wildlife. We focused our analyses on temporal shifts and shape changes in the annual distributions of seasonal minimum and maximum air temperatures among valley-bottom and higher elevation sites from 1948–2012. We documented consistent patterns of warming since 1948 at all 50 sites, with the most pronounced changes occurring during the Winter and Summer when minimum and maximum temperature distributions increased. These shifts indicate more hot temperatures and less cold temperatures would be expected across the GYA. Though the shifting statistical distributions indicate warming, little change in the shape of the temperature distributions across sites since 1948 suggest the GYA has maintained a diverse portfolio of temperatures within a year. Spatial heterogeneity in temperatures is likely maintained by the GYA's physiographic complexity and its large size, which encompasses multiple climate zones that respond differently to synoptic drivers. Having a diverse portfolio of temperatures may help biological reserves spread the extinction risk posed by climate change.

Introduction

Climate is a major factor driving the ecosystem processes that affect the distribution, interactions, phenology and life-history of species [1, 2]. Rapid changes in climate over the past 50 years have altered species distributions and food-web structure, induced phenological

RESEARCH ARTICLE

Forecasts of 21st Century Snowpack and Implications for Snowmobile and Snowcoach Use in Yellowstone National Park

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Abstract

Climate models project a general decline in western US snowpack throughout the 21st century, but long-term, spatially fine-grained, management-relevant projections of snowpack are not available for Yellowstone National Park. We focus on the implications that future snow declines may have for oversnow vehicle (snowmobile and snowcoach) use because oversnow tourism is critical to the local economy and has been a contentious issue in the park for more than 30 years. Using temperature-indexed snow melt and accumulation equations with temperature and precipitation data from downscaled global climate models, we forecast the number of days that will be suitable for oversnow travel on each Yellowstone road segment during the mid- and late-21st century. The west entrance road was forecast to be the least suitable for oversnow use in the future while the south entrance road was forecast to remain at near historical levels of driveability. The greatest snow losses were forecast for the west entrance road where as little as 29% of the December–March oversnow season was forecast to be driveable by late century. The climatic conditions that allow oversnow vehicle use in Yellowstone are forecast by our methods to deteriorate significantly in the future. At some point it may be prudent to consider plowing the roads that experience the greatest snow losses.

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ARTICLES

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nature
climate change

Slower snowmelt in a warmer world

Keith N. Musselman*, Martyn P. Clark, Changhai Liu, Kyoko Ikeda and Roy Rasmussen

There is general consensus that projected warming will cause earlier snowmelt, but how snowmelt rates will respond to climate change is poorly known. We present snowpack observations from western North America illustrating that shallower snowpack melts earlier, and at lower rates, than deeper, later-lying snow-cover. The observations provide the context for a hypothesis of slower snowmelt in a warmer world. We test this hypothesis using climate model simulations for both a control time period and re-run with a future climate scenario, and find that the fraction of meltwater volume produced at high snowmelt rates is greatly reduced in a warmer climate. The reduction is caused by a contraction of the snowmelt season to a time of lower available energy, reducing by as much as 64% the snow-covered area exposed to energy sufficient to drive high snowmelt rates. These results have unresolved implications on soil moisture deficits, vegetation stress, and streamflow declines.

Science*express*

Report

The Unusual Nature of Recent Snowpack Declines in the North American Cordillera

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In western North America snowpack has declined in recent decades, and further losses are projected through the 21st century. Here we evaluate the uniqueness of recent declines using snowpack reconstructions from 66 tree-ring chronologies in key runoff generating areas of the Colorado, Columbia and Missouri River drainages. Over the past millennium, late-20th century snowpack reductions are almost unprecedented in magnitude across the northern Rocky Mountains, and in their north-south synchrony across the cordillera. Both the snowpack declines and their synchrony result from unparalleled springtime warming due to positive reinforcement of the anthropogenic warming by decadal variability. The increasing role of warming on large-scale snowpack variability and trends foreshadows fundamental impacts on streamflow and water supplies across the western USA.

ARTICLE **OPEN**

Dramatic declines in snowpack in the western US

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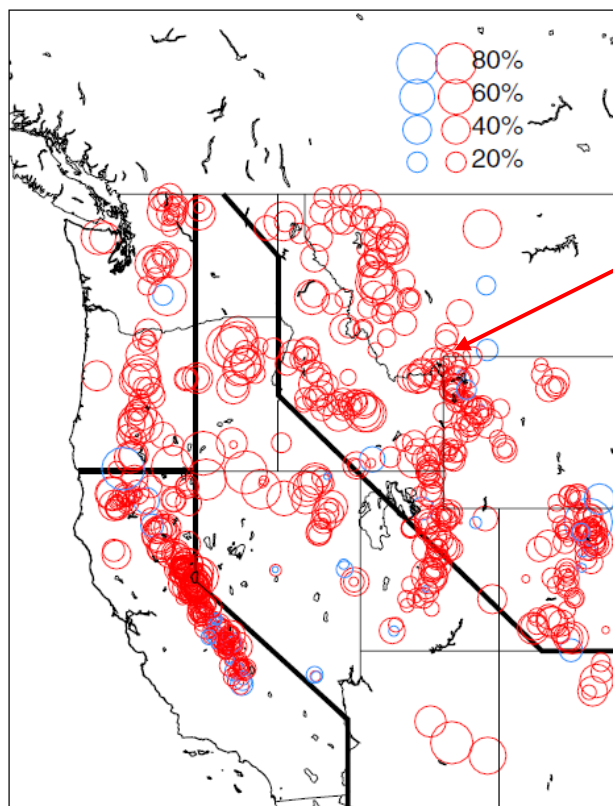
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Mountain snowpack stores a significant quantity of water in the western US, accumulating during the wet season and melting during the dry summers and supplying much of the water used for irrigated agriculture, and municipal and industrial uses.

Updating our earlier work published in 2005, we find that with 14 additional years of data, over 90% of snow monitoring sites with long records across the western US now show declines, of which 33% are significant (vs. 5% expected by chance) and 2% are significant and positive (vs. 5% expected by chance). Declining trends are observed across all months, states, and climates, but are largest in spring, in the Pacific states, and in locations with mild winter climate. We corroborate and extend these observations using a gridded hydrology model, which also allows a robust estimate of total western snowpack and its decline. We find a large increase in the fraction of locations that posted decreasing trends, and averaged across the western US, the decline in average April 1 snow water equivalent since mid-century is roughly 15–30% or 25–50 km³, comparable in volume to the West's largest man-made reservoir, Lake Mead.

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a) April 1 Observed SWE Trends 1955-2016



Upper Yellowstone

Fig. 1 Linear trends in 1 Apr SWE relative to the starting value for the linear fit (i.e., the 1955 value for the best-fit line): (a) at 699 snow course locations in the western United States for the period 1955–2016, with negative trends shown by red circles and positive by blue circles; (b)

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Impacts of climate change on August stream discharge in the Central-Rocky Mountains

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Abstract In the snowmelt dominated hydrology of arid western US landscapes, late summer low streamflow is the most vulnerable period for aquatic ecosystem habitats and trout populations. This study analyzes mean August discharge at 153 streams throughout the Central Rocky Mountains of North America (CRMs) for changes in discharge from 1950–2008. The purpose of this study was to determine if: (1) Mean August stream discharge values have decreased over the last half-century; (2) Low discharge values are occurring more frequently; (3) Climatic variables are influencing August discharge trends. Here we use a strict selection process to characterize gauging stations based on amount of anthropogenic impact in order to identify heavily impacted rivers and understand the relationship between climatic variables and discharge trends. Using historic United States Geologic Survey discharge data, we analyzed data for trends of 40–59 years. Combining of these records along with aerial photos and water rights records we selected gauging stations based on the length and continuity of discharge records and categorized each based on the amount of diversion. Variables that could potentially influence discharge such as change in vegetation and Pacific Decadal Oscillation (PDO) were examined, but we found that both did not significantly influence August discharge patterns. Our analyses indicate that non-regulated watersheds are experiencing substantial declines in stream discharge and we have found that 89% of all non-regulated stations exhibit a declining slope. Additionally our results here indicate a significant ($\alpha \leq 0.10$) decline in discharge from 1951–2008 for the CRMs. Correlations results at our pristine sites show a negative relationship between air temperatures and discharge and these results coupled with increasing air temperature trends pose serious concern for aquatic ecosystems in CRMs.

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Impact of anthropogenic climate change on wildfire across western US forests

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Increased forest fire activity across the western continental United States (US) in recent decades has likely been enabled by a number of factors, including the legacy of fire suppression and human settlement, natural climate variability, and human-caused climate change. We use modeled climate projections to estimate the contribution of anthropogenic climate change to observed increases in eight fuel aridity metrics and forest fire area across the western United States. Anthropogenic increases in temperature and vapor pressure deficit significantly enhanced fuel aridity across western US forests over the past several decades and, during 2000–2015, contributed to 75% more forested area experiencing high ($>1\sigma$) fire-season fuel aridity and an average of nine additional days per year of high fire potential. Anthropogenic climate change accounted for ~55% of observed increases in fuel aridity from 1979 to 2015 across western US forests, highlighting both anthropogenic climate change and natural climate variability as important contributors to increased wildfire potential in recent decades. We estimate that human-caused climate change contributed to an additional 4.2 million ha of forest fire area during 1984–2015, nearly doubling the forest fire area expected in its absence. Natural climate variability will continue to alternate between modulating and compounding anthropogenic increases in fuel aridity, but anthropogenic climate change has emerged as a driver of increased forest fire activity and should continue to do so while fuels are not limiting.

Decreasing fire season precipitation increased recent western US forest wildfire activity

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Data deposition: Annual forest wildfire area-burned data with snow, VPD, and precipitation data and R code for accessing the file have been deposited on Topofire, https://topofire.dbs.umt.edu/public_data/helmsdeep1/fire_climate/.

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Significance

Wildfires have profound impacts on forested ecosystems and rural communities. Increases in area burned by wildfires in the western United States have been widely attributed to reduced winter snowpack or increased summer temperatures. Trends in precipitation have previously been dismissed as has their feedback to regional temperature trends. We show that declines in summer precipitation and wetting rain days have likely been a primary driver of increases in wildfire area burned. Understanding the climatic drivers of fire activity is important for informing forest management. Our findings are consistent with future climate projections, which predict further decreases in summer precipitation and longer dry periods between rain events across much of the West.