RAPID CLIMATE CHANGE AND THE WEST: SNOWPACKS AND FORESTS AT RISK

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ABSTRACT

There is a growing recognition in the broader scientific community that rapid climate change from the enhanced greenhouse effect is affecting the western United States. This coalescing of opinion has diffused into the policy-making realm, with a number of western states having taken or contemplating actions to address greenhouse gas emissions. The available data indicates rapid warming in the past 3 decades, with an amplification of the warming signal with elevation. Future climate change scenarios developed as part of the Fourth IPCC Assessment Report suggest that the recent warming trends in the West will continue and intensify. The warming alone will induce greater aridity in much of the West, with worst-case scenarios suggesting a significant reduction in stream flow in most western river basins coupled with much higher risks of forest fires. As noted above, the data for the past few decades supports these climate model projections.

An ad-hoc interdisciplinary community of climate scientists—including climatologists, hydrologists, and forest ecologists (The Consortium for Climate Change Research in Western Mountains, CIRMOUNT)—has come into existence in the past three years, with the aim of communicating in plain language the environmental and potential socioeconomic threats facing western society from climate change. This paper will examine some of the evidence for rapid warming in the West in recent decades and describe some of our efforts to communicate key findings by the climate science community about ongoing and expected impacts to western society. Our efforts are also meant to engage and encourage the general public to participate in developing practical solutions to emerging problems arising from climate change.

INTRODUCTION

Mountain regions are uniquely sensitive to changes in climate, and are especially vulnerable to climate effects acting on many biotic systems and the physical settings. Because mountain regions serve as sources of needed natural resources (e.g., water, forests) and they serve as foundations for desired human activities (e.g. tourism, places to live), changes in mountain systems cascade into issues of regional and national concern. Mountains also comprise highly sensitive systems that may act as “canaries in the coal mine” to provide early signals of significant climate-driven changes in many of our valued resources.

There is compelling evidence that changes in large-scale climate patterns in the past thousand years are associated with multi-decadal climate changes in the western United States (Graham et al., 2007). Changes in surface ocean temperatures (SST) in the tropical Indo-Pacific and the North Atlantic have been related to persistent hydrological anomalies throughout the West—long-lived SST anomalies, particularly in the tropical oceans, help to establish, and maintain, atmospheric circulation patterns, which favor prolonged dry conditions over large parts of western North America (Cook et al., 2004). Models of projected future changes in climate associated with higher levels of CO_2 indicate that the region may face very significant secular changes in climate that will be superimposed on natural variability.

Climate change is predicted to alter hydrology in western mountains (Bales et al., 2006), which is likely to result in dramatic changes in landscapes and ecosystems. Changes in temperature and precipitation resulting from global climate change will modify current patterns of vegetation and associated species along elevational gradients. Riparian vegetation along streams that transect upland vegetation zones will also be affected, as the changing climate patterns modify the hydrologic cycle through changes in precipitation, snowpack characteristics, and runoff patterns (Mote, 2003; Walter et al., 2004; Stewart et al., 2005; Knowles et al., 2006).

CLIMATE MONITORING IN THE WEST

About half of the surface area in the West lies above an elevation of ~1,500 m (~5,000 ft). Yet, only about 30%

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of the climate observing sites, and only about 20% of the stream flow gages lie at the higher elevations in the West. Furthermore, the typical snow-rainfall line in much of the West also occurs near the 5,000-ft elevation zone. The implication of increasing temperatures throughout the lower troposphere in the West is a rise of the freezing-level surface (Diaz and Graham, 1996; Diaz et al. 2003), resulting in significant modification of the hydrologic regimes (Stewart et al., 2005; Knowles et al., 2006) and water supplies (Bradley et al., 2006) and on drought, intensified fire regimes and ecological shifts (Breshears et al., 2005; Westerling et al., 2006).

Because of the complex nature of physical, biogeochemical, and human-induced processes in mountain regions, monitoring in mountain regions requires an integrated approach of long-term consistently measured variables (Bradley et al. 2004; Huber et al., 2005). The high terrain in the western United States is particularly poorly sampled. Typically, above 7,000 ft. where most of the seasonal snow pack accumulates, the relative fraction of climate observing stations with respect to the total number of observing sites in the West, is considerably less than the corresponding fraction of western area above this level. Compared to the station density at lower levels (below 5,000 ft), it is only about a third of less in proportional coverage.

OBSERVED CHANGES IN THE LAST 100 YEARS

In the following two examples, I illustrate some of observationally-based climatic changes in the West. Figure 1 gives mean maximum and minimum surface temperature trends for the period 1979–2005 using the PRISM 4-km resolution data set (Daly et al., 2002; Gibson et al., 2002). The period since 1979 is considered here because recent studies have shown that a strong greenhouse-forcing signal on global climate is most evident starting in the late 1970's (IPCC, 2007). The trends are displayed in 250 m elevation bins. The red dots indicate the median of the trend distribution for all 4-km PRISM pixels in each elevation range. The small plus signs denote the spread of the 5% and 95% of the trend values. Temperatures have risen substantially throughout the vertical column, but at substantially greater rates above about 3,000 m.

In Figure 2, I illustrate the changes that have taken place in the past century in the Köppen-Geiger climate classification (Kottek et al., 2006) of the high alpine (tundra) climate in western mountains. The graph shows the areas, using the 4-km PRISM data, which were classified as alpine tundra (Climate Type E) in the period 1901–1930 and during the most recent 20-years (1987–2006). There has been a 73% reduction in the area classified as alpine tundra during the last century.

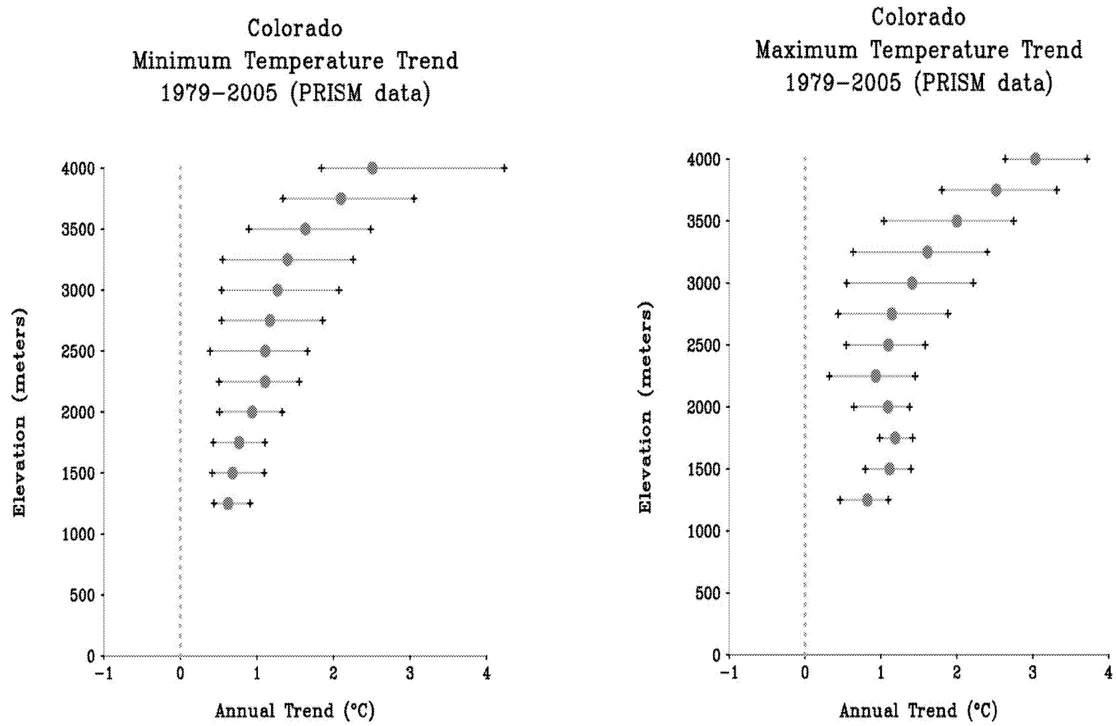

Figure 1. Trends in mean minimum and maximum annual temperature for Colorado. (See text for details).

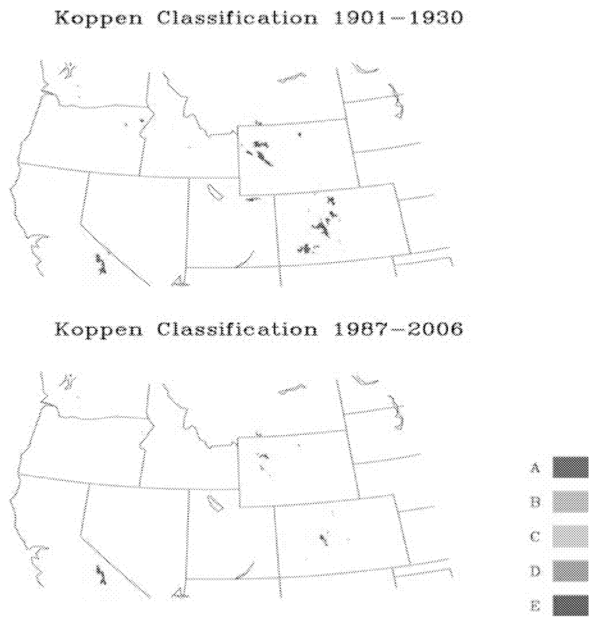

Figure 2. Extent of the alpine tundra (Köppen-Geiger classification type E) in the first 30-years of the 20th century (top map) and in the last 20-years (1987–2006).

SUMMARY

In the mountainous western United States most studies show that during the last few decades, temperature has risen, with greater warming occurring at the higher elevations. Accompanying this warming climate, other studies have documented the occurrence of earlier stream flow peaks in the spring, increasing wildfire areas accompanied by very intense fires, and enormous areas being affected by insect infestations. The most recent severe and sustained western U.S. drought covering the period 2000–2004 averaged about 42% of the western are in extent—the highest multiyear areal coverage of any 5-year interval since 1895. The impact of this drought was measured at Lee Ferry, where the mean flow of the Colorado River was approximately10 MACF—two-thirds of the long-term average.

Although the precise trajectory of climate in the West in the next few decades in response to global warming is uncertain, recent trends point to significant vulnerability for water resources, forests and ecosystems, and therefore, to western society.

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