Appendix 2.C

Climate Change Implications and Assumptions

Contents

Table

Figures

Acronyms and Abbreviations

°F	degrees Fahrenheit
Bay-Delta	San Francisco Bay/Sacramento–San Joaquin River Delta
CALFED	CALFED Bay-Delta Program
CH_4	methane
CO_2	carbon dioxide
Delta	Sacramento–San Joaquin Delta
DWR	California Department of Water Resources
ENSO	El Niño Southern Oscillation
GCM	Global Circulation Model
GHGs	greenhouse gases
H_2O	water vapor
IPCC	Intergovernmental Panel on Climate Change
N_2O	nitrous oxide
NRC	National Research Council
O_3	ozone
PDO	Pacific Decadal Oscillation
SRES	Special Report on Emissions Scenarios

Appendix 2.C
Climate Change Implications and Assumptions

Observations from around the world demonstrate that the Earth is undergoing climate change much more quickly than would be expected from natural variation. In its most recent assessment of climate change, the Intergovernmental Panel on Climate Change, an international body made up of scientists from around the world, stated that, “Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level” (Intergovernmental Panel on Climate Change 2007). The Intergovernmental Panel on Climate Change concluded that, “At continental, regional and ocean basin scales, numerous long-term changes in climate have been observed. These include changes in arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones” (Intergovernmental Panel on Climate Change 2007). In a 2010 report, the National Research Council (NRC) concluded that, “There is a strong, credible body of evidence, based on multiple lines of research, documenting that climate is changing and these changes are in large part caused by human activities” (National Research Council 2010).

This appendix provides an overview of scientific understanding of climate change and observed and projected changes in California and the Plan Area. The focus is on the physical basis of climate change. Subsequent appendices discuss the ecological implications of these changes.

2.C.1 Global Climate Change

2.C.1.1 What Is Climate Change?

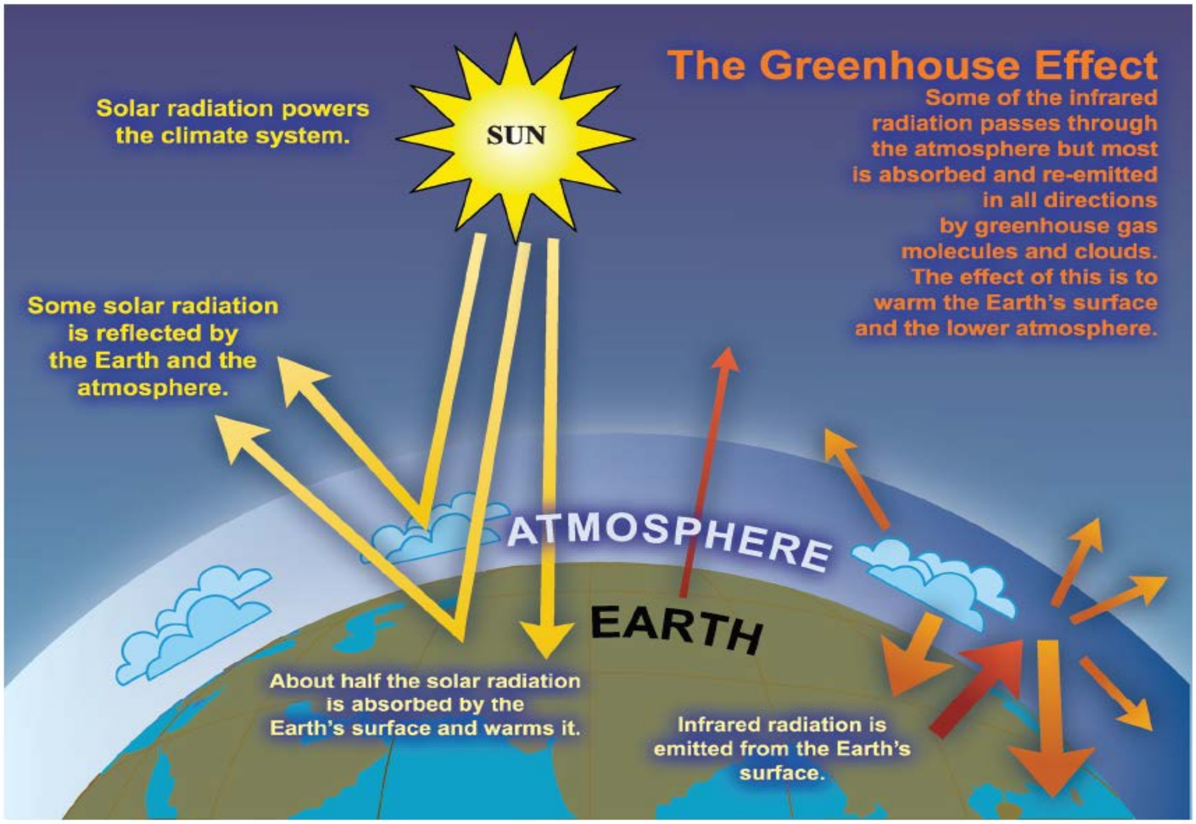
Climate is the average weather over a specific region over many years, measured most often in terms of temperature and precipitation. *Climate change* refers to a statistically significant change in the state of the climate or its variability that persists for an extended period (typically decades or longer). An individual year that is drier or hotter than average would indicate *climate variability* but might not indicate climate change, which is a large-scale shift or trend in the average weather that a region experiences.

The climate changes over many temporal and spatial scales as a result of meteorological processes such as variations in atmospheric circulation patterns. These changes may be due to natural processes or to anthropogenic factors that affect the composition of the atmosphere. Although the climate has changed in the past in response to natural drivers, recent climate change has been linked unequivocally to increasing concentrations of greenhouse gases (GHGs) in the Earth’s lower atmosphere, largely as a result of the burning of fossil fuels since the beginning of the industrial revolution (Intergovernmental Panel on Climate Change 2007).

2.C.1.2 What Causes Climate Change?

Higher concentrations of heat-trapping GHGs in the atmosphere, as well as modifications to the land surface, alter the energy balance of the climate system, increasing the Earth's temperature and thus influencing climate. The so-called "greenhouse effect" is a natural phenomenon in which GHGs—primarily water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3)—allow solar radiation to pass through the atmosphere and warm the Earth's surface (Figure 2.C-1). As the Earth's surface warms, infrared radiation is emitted back to the atmosphere, where GHGs absorb some of the radiation and re-emit it back to Earth, causing the surface to gain more heat (National Academy of Sciences 2006).

This warming of the Earth's surface has been increasing rapidly as levels of atmospheric CO_2 have increased since the onset of the Industrial Revolution, rising by about 30%, since the late 1800s. The atmospheric concentration of CO_2 is now higher than it has been for many millennia. Observations show that the global average surface temperature is rising at an increasing rate, with the decades from 1970 to 2009 being progressively warmer than prior decades (Arndt et al. 2010). Of the 10 warmest years on record, 9 have occurred since 2001 (National Climatic Data Center 2011). Based on the current trajectory, the Intergovernmental Panel on Climate Change projects that atmospheric CO_2 concentrations could rise to more than three times preindustrial levels by the end of this century (Intergovernmental Panel on Climate Change 2007).



Source: Intergovernmental Panel on Climate Change 2007:115

Figure 2.C-1. The Greenhouse Effect

2.C.1.3 What Global Climate Changes Have Been Observed?

Key evidence of long-term changes in climate over the twentieth century includes the following documented changes (Intergovernmental Panel on Climate Change 2007, 2012; National Research Council 2010).

- An increase of 1.3 degrees Fahrenheit (°F) in the Earth's global average surface temperature.
- An increase of 6.7 inches in the global average sea level.
- A decrease in arctic sea-ice cover at a rate of approximately 4.1% per decade since 1979, with faster decreases of 7.4% per decade in summer.
- Decreases in the extent and volume of mountain glaciers and snow cover.
- A shift of cold-dependent habitats to higher altitudes and latitudes.
- Longer growing seasons.
- A decrease in the number of unusually cold days and nights and in periods of extreme cold weather.
- More frequent weather extremes such as droughts, floods, severe storms, and heat waves.

2.C.1.4 How is Global Climate Expected to Change?

Global circulation models (GCMs) are used to project future climate change based on assumptions about future emissions of GHGs. The Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios (SRES) presented a range of possible future GHG emission scenarios based on assumptions about potential future fossil fuel use, regional political and social conditions, technologies, population, and governance (Intergovernmental Panel on Climate Change 2000). Based on a number of the SRES emissions scenarios, the Intergovernmental Panel on Climate Change projected an average increase in surface temperatures of 3.2 to 7.2°F by 2100 compared to 1980 through 1999 levels, with a likely increase in the range of 2.0 to 11.5°F when accounting for the uncertainty in climate science (Intergovernmental Panel on Climate Change 2007). Moreover, temperatures are rising at an increasing rate. The average rate of increase over the past century was 0.13°F per decade. Over the past 50 years, temperatures have been rising at nearly twice that average rate, reaching 0.23°F per decade (Intergovernmental Panel on Climate Change 2007). Over the past 30 years, the average global temperature has risen even faster, at an average of 0.29°F per decade (National Oceanic and Atmospheric Administration 2009).

Similar to the global trend, the United States average temperature is now 1.25°F warmer than at the beginning of the 20th century, with an average warming of 0.13°F per decade from 1895 through 2008. This rate of warming is increasing, and over the past decade, the average temperature for the contiguous United States has increased at a rate of 0.58°F per decade (National Oceanic and Atmospheric Administration 2009).

It is noteworthy that even if atmospheric CO_2 concentrations were stabilized or decreased immediately, the current elevated global average temperatures could persist for hundreds of years. This is because temperatures will not drop until the ocean has reached thermal equilibrium with the atmosphere, which would likely take centuries due to the heat capacity of the ocean (Matthews and Caldeira 2008). One study found that up to two-thirds of the maximum increase in global average temperature could persist for centuries (Eby et al. 2009).

2.C.2 Climate Change in California and the Plan Area

2.C.2.1 Current Climate

The climate in the Sacramento–San Joaquin Delta (Delta) region is generally characterized as Mediterranean (Köppen climate classification), meaning that it has hot, dry summers and cool, rainy winters (Bureau of Reclamation 2011). From 1981 to 2010, average monthly temperatures in Sacramento ranged from 41.0°F in December and January to 94.1°F in July, with average monthly rainfall ranging from a low of 0.02 inches in July to a high of 3.90 inches in February (Western Regional Climate Center 2012).

Heat waves are common in summer months, during which temperatures can reach triple digits on consecutive days. Average air temperatures in the mountainous regions of the watershed are typically 5 to 10 degrees lower than temperatures on the valley floor. Periodically, a "Delta breeze" of cool and humid air from the ocean moves onshore and cools the Central Valley in the vicinity of the Delta by up to 7°F (Pierce and Gaushell 2005).

2.C.2.2 Surface Temperature

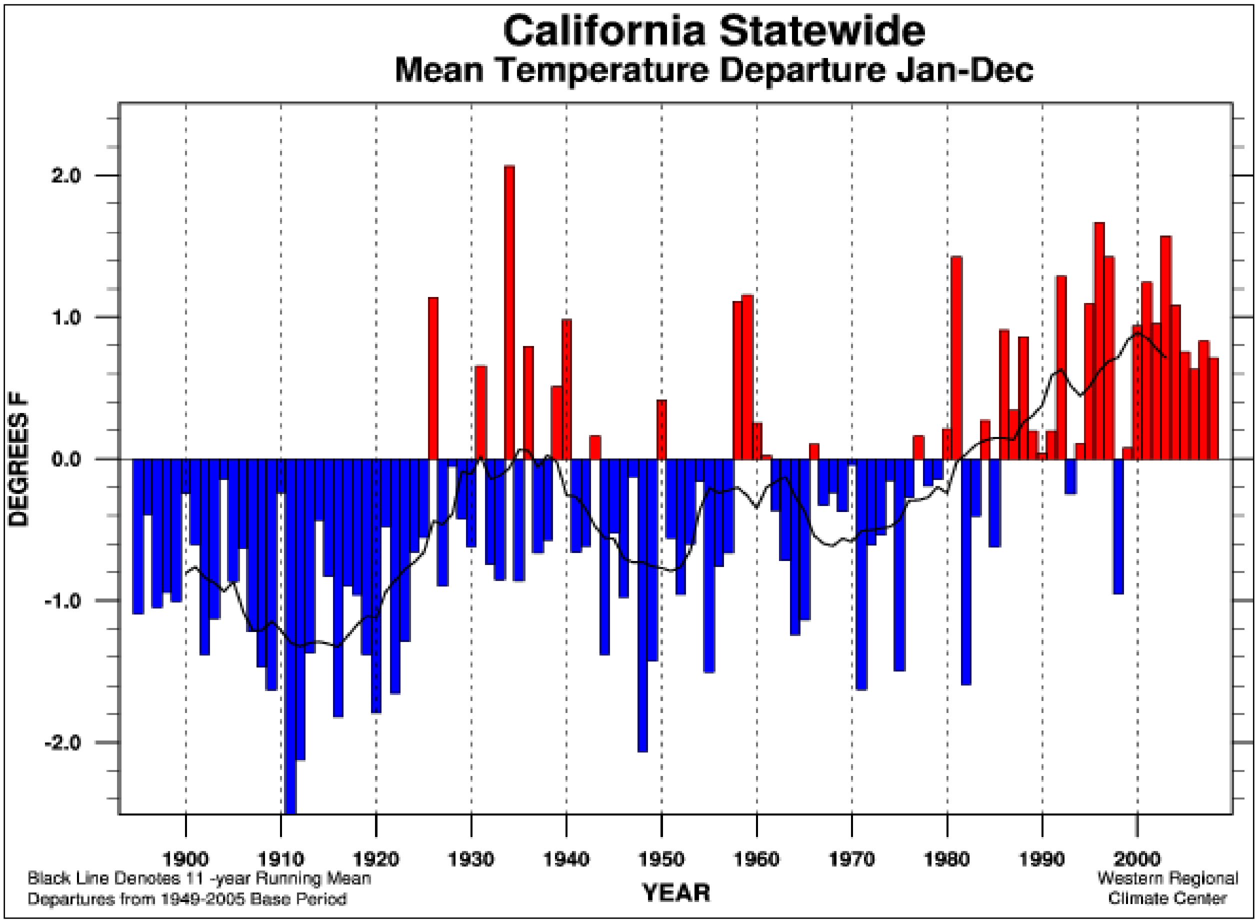
2.C.2.2.1 Observed

Figure 2.C-2 shows historical California statewide mean annual temperature departures during the 20th century, indicating the warming that has occurred in recent decades. During the 20th century, warming increased by about 3°F over the Sacramento and San Joaquin River basins. (Bureau of Reclamation 2011).

2.C.2.2.2 Projected

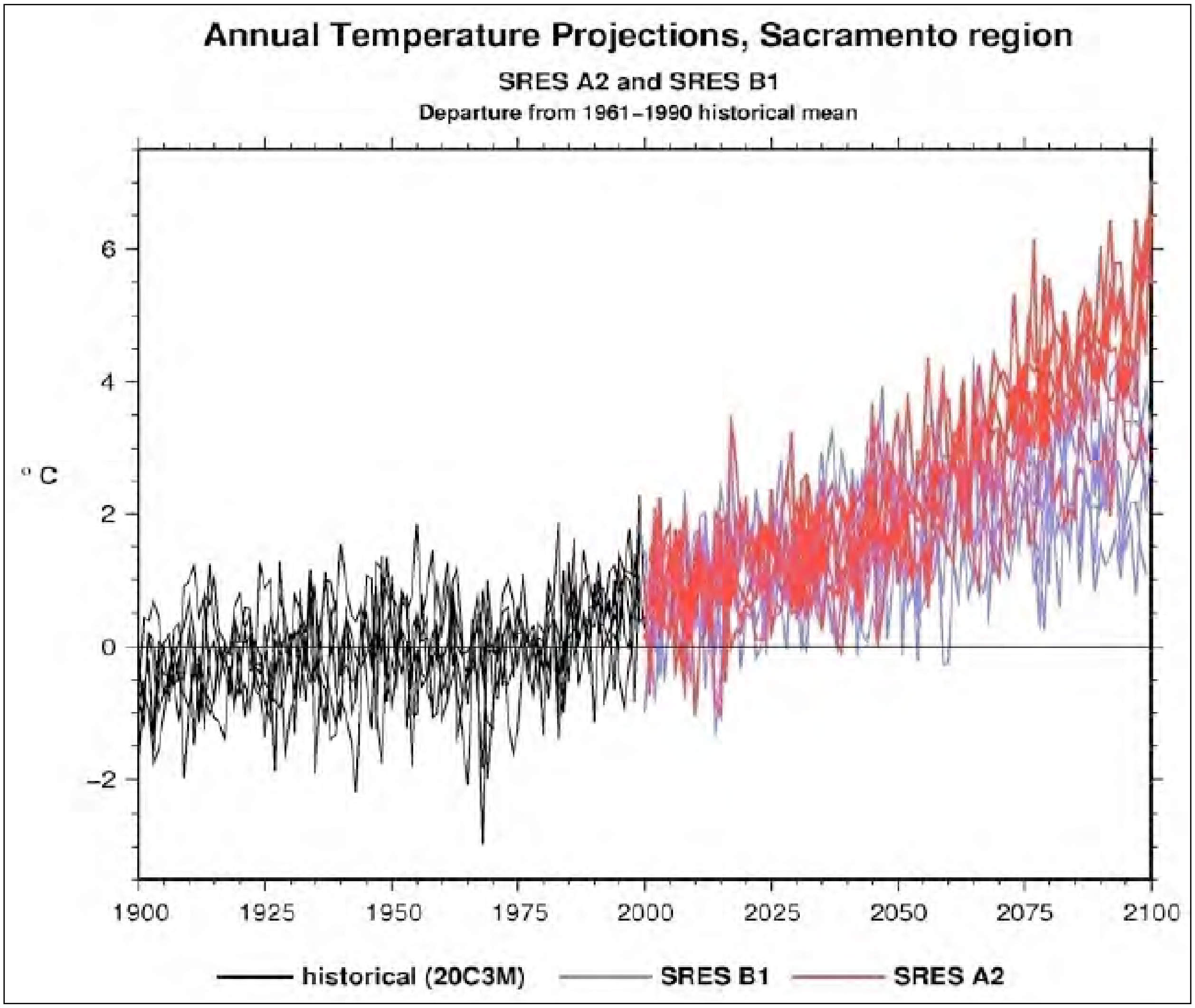
Six GCMs and two of the Intergovernmental Panel on Climate Change SRES emissions scenarios were selected by the California Climate Action Team for their Scenarios Project, resulting in a total of 12 climate change model simulations (Cayan et al. 2009). The scenarios included a high emissions scenario (SRES A2) and a low emissions scenario (SRES B1), Model simulations indicated a midcentury temperature increase in California of about 1.8 to 5.4°F and an end-of-century increase from 3.6 to 9°F, although the warming will not be uniform across California. All climate models projected a greater amount of warming during summer months, during nighttime, and in the interior regions of California (Cayan et al. 2009).

The average mean annual temperature in the Sacramento–San Joaquin basin is projected to increase by 5 to 6°F during this century, though with substantial variability in warming in the Central Valley (Bureau of Reclamation 2011). In addition, the duration of extreme warm temperatures is expected to increase from 2 months (July and August) to four months (June through September) (Climate Action Team 2010). In the early part of the 21st century, the amount of warming in the Sacramento region produced by the SRES A2 high emissions scenario is not very different from the SRES B1 low emissions scenario, but warming becomes increasingly greater through the middle and especially the latter part of the century (Figure 2.C-3).



Source: Western Regional Climate Center 2009

Figure 2.C-2. Historical Observed California Statewide Mean Annual Temperature Departure



Source: Cayan et al. 2009

Figure 2.C-3. Simulated Historical and Future Annual Temperature Projections for the Sacramento Region

2.C.2.3 Water Temperature

Cloern et al. (2011) linked a series of models to evaluate the entire San Francisco estuary-watershed system under two contrasting emissions scenarios. Projections for the period 2010 to 2099 indicated significant increases in water temperatures in both the Sacramento River and the Delta under both the B1 (low) and A2 (high) emissions scenarios. Temperatures in the Sacramento River responded to both increasing air temperature and decreasing snowmelt runoff, which reduce the amount of cold water in the upstream reservoirs that is available to cool waters downstream. By contrast, the temperature of Delta waters responded primarily to air temperature. The authors observed that the projected increases in water temperatures, if realized, would have serious implications for the Delta's native fishes. The frequency of projected water temperatures in the Delta above the thermal threshold for delta smelt (25°C) rose gradually under the B1 scenario but rapidly under the A2 scenario. Water temperatures above the threshold for Chinook salmon (16°C) increased at a modest rate under the B1 scenario, but river temperatures above the threshold were common after 2080 under the A2 scenario.

2.C.2.4 Precipitation

2.C.2.4.1 Observed

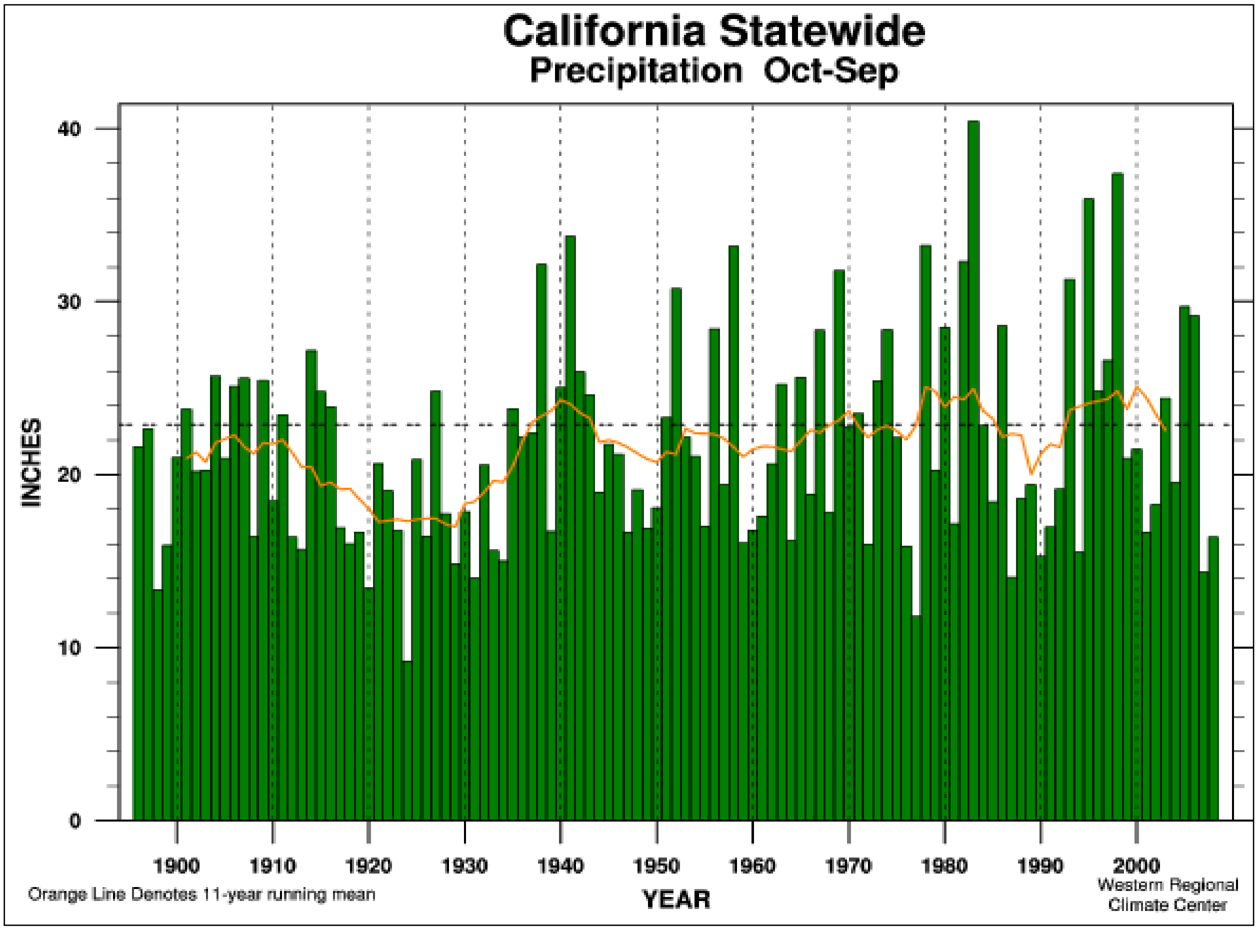
On average, total annual precipitation across the United States increased approximately 6% from 1901 to 2005 (Intergovernmental Panel on Climate Change 2007). In California, precipitation is extremely variable at seasonal, annual, and decadal time scales (Figure 2.C-4).

In the Sacramento River watershed, average annual precipitation ranges from 80 to 90 inches, primarily as snow in the mountainous regions, to 41 and 19 inches of rain in Redding and in Sacramento, respectively. Average annual precipitation for the entire watershed is approximately 36 inches. Most precipitation occurs between November and April, with little or no precipitation falling between May and October. The primary origin of precipitation is the seasonal arrival of low-pressure systems from the Pacific Ocean (CALFED Bay-Delta Program 2000).

The warming trend in the Sacramento River basin has been accompanied by a gradual trend toward increasing precipitation, starting in the 1930s. However, a similar precipitation trend is not evident in the San Joaquin River basin (Bureau of Reclamation 2011).

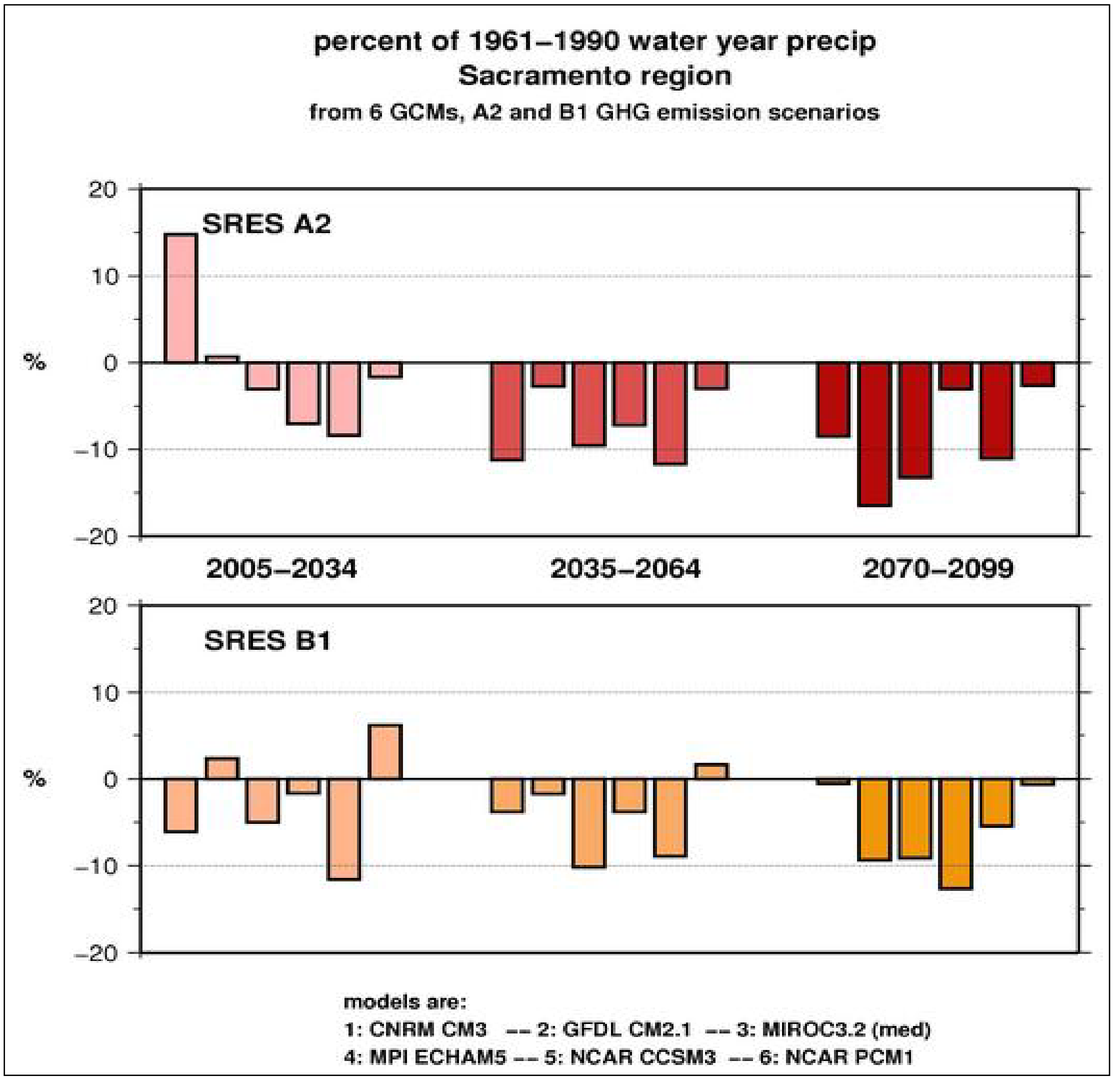
2.C.2.4.2 Projected

Projections of future precipitation are more uncertain than those of temperature (Chung et al. 2009). While it is difficult to discern strong trends from the full range of climate projections, one recent analysis generally indicated a drying trend in California during the 21st century (Cayan et al. 2009). According to this analysis, some areas in northern California may experience higher annual rainfall amounts and potentially larger storm events, but California as a whole, particularly southern California, will be 15 to 35% drier by 2100 (Cayan et al. 2009). Simulated future changes in precipitation for the Sacramento region under the Intergovernmental Panel on Climate Change A2 (high) and B1 (low) emissions scenarios indicate declines in the region's precipitation during the 21st century (Figure 2.C-5), particularly during the second half of the century (Cayan et al. 2009; Bureau of Reclamation 2011).



Source: Western Regional Climate Center 2009.

Figure 2.C-4. Historical Observed California Statewide Water Year Precipitation



Source: Cayan et al. 2009

Figure 2.C-5. Simulated Future Water Year Change in Precipitation for the Intergovernmental Panel on Climate Change A2 and B1 Scenarios for the Sacramento Region

2.C.2.5 Snowpack and Runoff

2.C.2.5.1 Observed

Historically, most of California's precipitation fell during winter as snow along the Sierra Nevada mountain range, which serves as a natural reservoir holding the fallen snow. However, temperatures over the Sierra Nevada have increased during the past 100 years, resulting in less snowfall (and more rainfall) and an earlier snowmelt. As a result, there is less snowmelt to sustain runoff during the warm, dry conditions of summer and fall (Knowles et al. 2006; Cayan et al. 2009; Moser et al. 2009).

2.C.2.5.2 Projected

Climate models project that snowpack will continue to decrease in California, with more precipitation falling as rain (Moser et al. 2009). As a result, cool-season runoff will increase during the 21st century in the Sacramento River and San Joaquin River basins, while warm-season runoff is projected to show significant declines (Bureau of Reclamation 2011).

Hydrologic model simulations indicate that even if mean precipitation remains unchanged, there will be large impacts on snowpack accumulation, runoff, and soil moisture, with a significant change in the timing and magnitude of flows in the tributary rivers of the San Francisco Bay and Sacramento–San Joaquin River Delta (Bay-Delta) (Bureau of Reclamation 2011). Modeling based on results of the GFDL CM2.1 model (NOAA Geophysical Dynamics Laboratory, Princeton, NJ) for a high emissions scenario indicated a 22% decline in flows to the Sacramento Valley during this century as a result of reduced snow accumulation (Medellín-Azuara et al. 2008).

An increase in flows in winter is likely to result in increased flooding, while the decline in spring snowmelt will reduce late summer flows (Cayan et al. 2009). These changes have important implications for California's water supply system, which is dependent on snowpack storage in the Sierra Nevada. The average early spring snowpack decreased by about 10% during the last century, resulting in a loss of 1.5 million acre-feet of snowpack storage (California Department of Water Resources 2008). Snowpack volumes are expected to decline 25% by 2050 (California Department of Water Resources 2010). Results of modeling by Rauscher et al. (2008) indicate that runoff could occur as much as 2 months earlier than at present.

2.C.2.6 Sea Level Rise

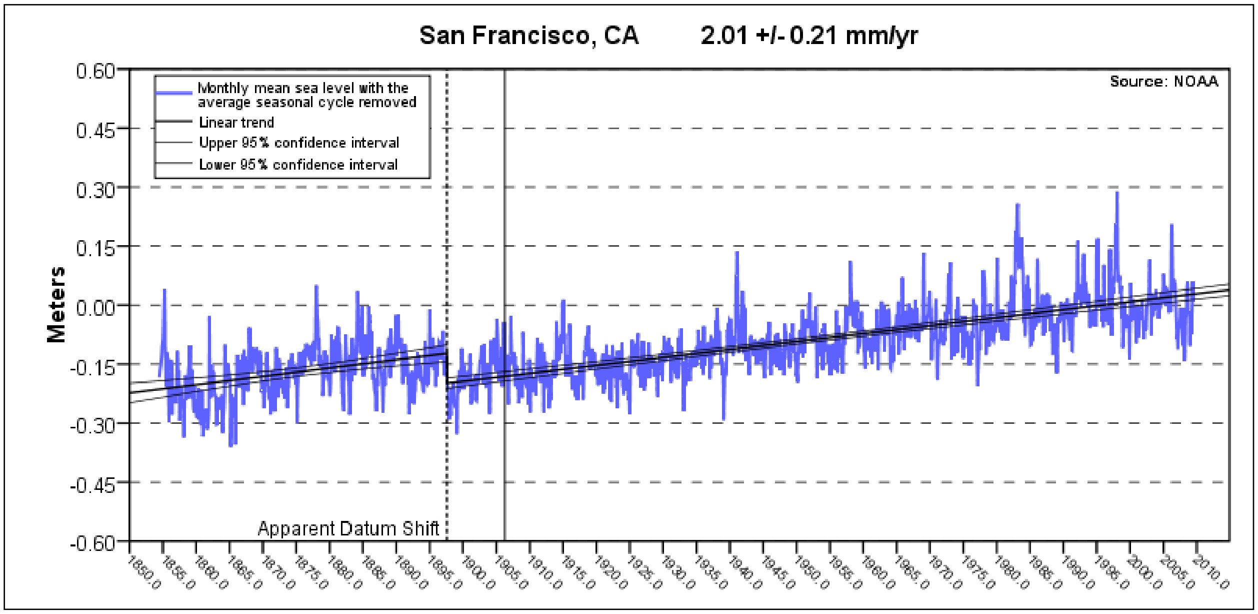
2.C.2.6.1 Observed

Global average sea level has been gradually rising, increasing by about 6.7 inches during the 20th century (Intergovernmental Panel on Climate Change 2007). Consistent with the global trend, sea level measured at tide gages along the California coast over the past several decades has risen at rate of about 6.7 to 7.9 inches per century (Cayan et al. 2009). While there is considerable variability among the gages, primarily reflecting local differences in vertical movement of the land and length of gage record, this observed rate of change in mean sea level is similar to the global mean trend (National Oceanic and Atmospheric Administration 2009).

Sea level has been measured at a tide gage near the Golden Gate since 1897. Based on monthly mean sea-level data from this gage, the mean sea-level increase for San Francisco between 1897 and 2006 was 8.0 inches per century (National Oceanic and Atmospheric Administration 2009).

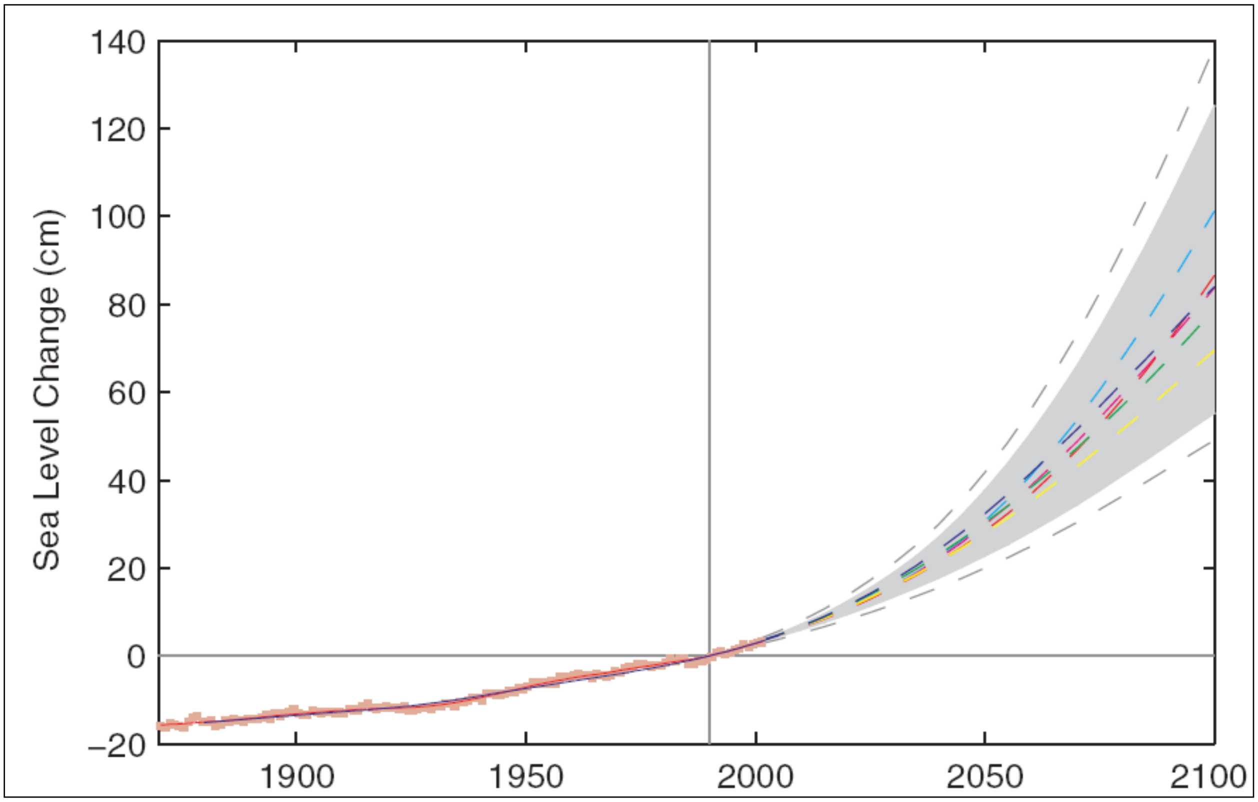
2.C.2.6.2 Projected

Global and regional sea levels have been increasing steadily over the past century, and are projected to increase at a more rapid rate in the future because of the increased thermal expansion of water in the oceans caused by global warming, changes in freshwater inputs to the oceans from melting glaciers and ice sheets, and changes in water storage on land. In 2007, the Intergovernmental Panel on Climate Change estimated a rise in sea level of 0.6 to 1.9 feet by 2100 (Intergovernmental Panel on Climate Change 2007). However, more recent estimates suggest an even greater rise, particularly if melting of the Greenland and Antarctic ice sheets accelerates, as suggested by recent satellite observations. Rahmstorf (2007) used a semi-empirical approach to project future sea level rise, yielding a projected sea level rise of 1.6 to 4.6 feet above 1990 levels by 2100 when applying the Third Assessment Report warming scenarios. Other recent estimates indicate global increases by 2100 of 1.6 to 3.3 feet (National Research Council 2010), 2.6 to 6.6 feet (Pfeffer et al. 2008) and 3.2 to 5.1 feet (Vermeer and Rahmstorf 2009) (Figure 2.C-6 and Figure 2.C-7).



Source: National Oceanic and Atmospheric Administration 2009

Figure 2.C-6. Observed Mean Sea Level Trend for the San Francisco Tide Gage near the Golden Gate



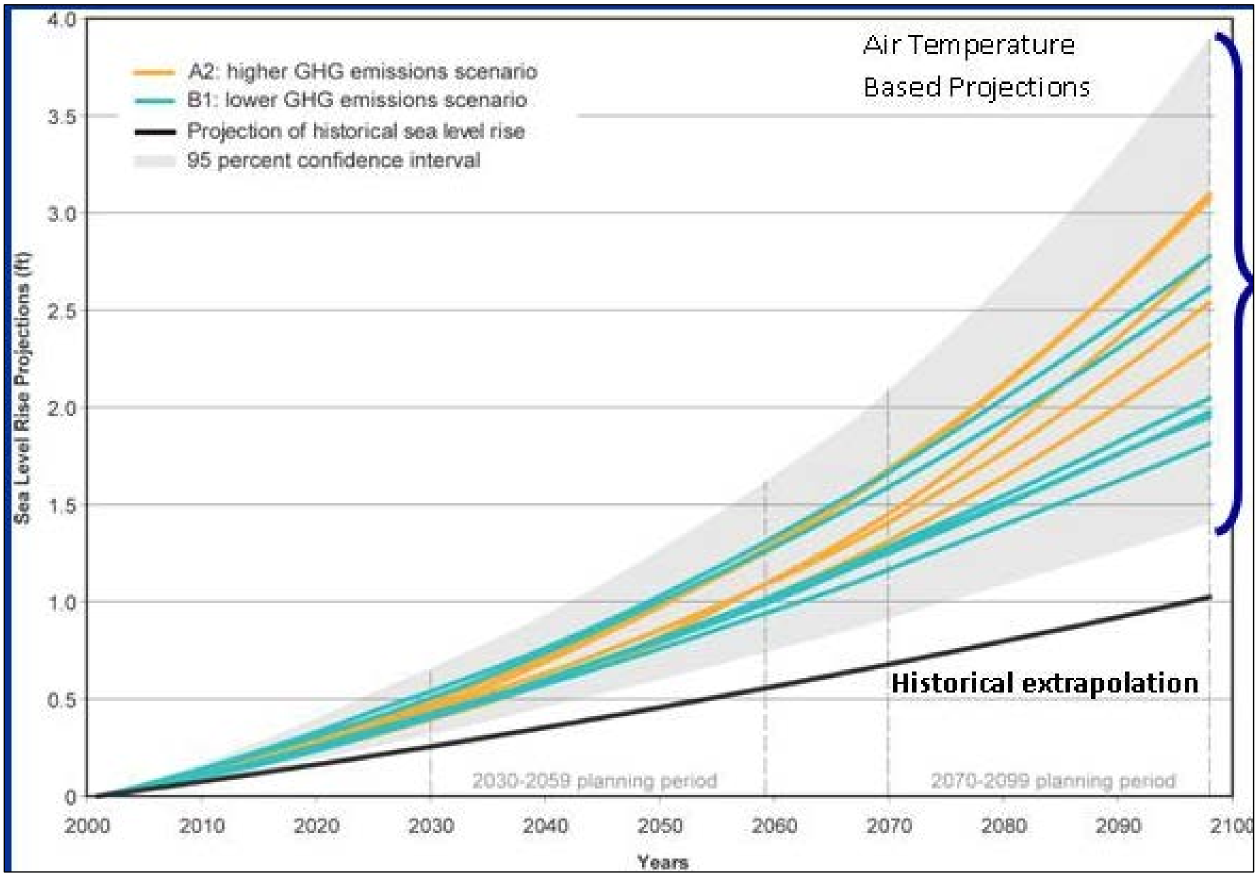
Source: Rahmstorf 2007

Figure 2.C-7. Past Global Mean Sea Level and Future Mean Sea Level Based on Global Mean Temperature Projections

Using the Rahmstorf (2007) method, the CALFED Bay-Delta Program (CALFED) Independent Science Board estimated ranges of sea level rise of 2.3 to 3.3 feet at midcentury and of 1.6 to 4.6 feet by the end of the century (CALFED Independent Science Board 2007). Some tidal gage and satellite data indicate that rates of sea level rise are increasing (Church and White 2006; Beckley et al. 2007). Scenarios modeled by the California Climate Action Team projected sea level rise increases along the California coast of 1.0 to 1.5 feet above 2000 levels by 2050 and 1.8 to 4.6 feet by 2100 (Cayan et al. 2009). However, if California's sea level continues to mirror global trends, increases in sea level during this century could be considerably greater. Increasing sea levels will seriously threaten the integrity of the Delta's levees and conveyance of water supplies through the Delta (Florsheim and Dettinger 2007).

For water planning purposes, the California Department of Water Resources (DWR) estimated sea level rise over the 21st century using the method of Rahmstorf (2007) and 12 climate projections selected by the California Climate Action Team (Chung et al. 2009). The historical 95% confidence interval was extrapolated to estimate the uncertainties in the future projections (Figure 2.C-8). Midcentury sea level rise projections ranged from 0.8 to 1.0 foot, with an uncertainty range spanning 0.5 to 1.2 feet. End-of-century projections ranged from 1.8 to 3.1 feet, with an uncertainty range of 1.0 to 3.9 feet. These estimates are slightly lower than those of Rahmstorf (2007) because DWR used a more limited ensemble of climate projections that did not include the highest projections of temperature increases (Chung et al. 2009).

Parker et al. (2011) observed that, in the Bay-Delta, other factors complicate sea level rise projections, including the Pacific Decadal Oscillation (PDO) and El Niño Southern Oscillation (ENSO) events. The PDO is characterized by cool or warm phase shifts in North Pacific sea surface temperatures that commonly persist for 20 to 30 years. Superimposed on the PDO cycles are smaller-scaled El Niño and La Niña events that persist for about a year. Climatic impacts associated with La Niña events are similar to those tied to the cool PDO phases, and climate conditions related to El Niño episodes parallel those of warm PDO phases. Parker et al. (2011) observed that rates of sea level rise slow during the negative (cool) phase and increase during the positive (warm) phase. They also noted that fluctuations in sea level rise, when combined with processes such as ENSO events, may have a greater effect on wetlands than a steady increase.



Source: Chung et al. 2009.

Figure 2.C-8. DWR-Generated Future Sea Level Rise Projections for the Bay Delta Using the Rahmstorf Method and Regionally Downscaled Data

2.C.2.7 Ocean Conditions

2.C.2.7.1 Observed

Global ocean temperatures are also increasing. Between 1961 and 2003, global ocean temperatures increased about 0.18°F from the surface to a depth of about 2,270 feet (Intergovernmental Panel on Climate Change 2007). In summer 2009, sea surface temperatures were 1.04°F above the average global temperature recorded for the entire 20th century (Hoegh-Guldberg and Bruno 2010), and the global ocean surface temperature for January 2010 was the second warmest January on record.

Another consequence of rising atmospheric concentrations of CO_2 is an increase in the acidity of the oceans as a result of increasing absorption of CO_2 by ocean waters. Recent evidence suggests that oceans have become 30% more acidic since the Industrial Revolution, with severe consequences for marine life (Doney et al. 2009).

In the past, ocean productivity has generally adjusted to natural variations in ocean climate. However, present climate trends are outside the bounds of historical variability, and changes in productivity are increasingly apparent. Three factors are likely to affect ocean productivity in response to climate change: temperature, light (as determined by ice cover, cloudiness, and mixed layer thickness), and nutrient availability, with warming temperatures potentially the largest single factor affecting productivity. In the northern high latitudes, reductions in productivity correspond in part to increases in sea surface temperatures. The low latitudes have generally experienced an increase in ocean primary productivity (Brander 2010).

2.C.2.7.2 Projected

Osgood (2008) identified five major climate change effects on the California system of currents.

- Increased variability in climate forcing.
- Changes to the magnitude and timing of freshwater inputs.
- Changes in the timing and strength of the spring transition.
- Ocean warming and increased stratification.
- Changes in ocean circulation.

More extreme precipitation events and years will affect coastal circulation and stratification. Climate models project greater annual precipitation for northern California but lower streamflow in the 21st century, with a more rapid spring melt leading to a shorter, more intense spring period of river flow and freshwater discharge. This will greatly alter coastal stratification and mixing, and riverine plume formation and evolution.

Although upwelling along the California coast has increased over the past 30 years and these increases are expected to continue (Snyder et al. 2003), greater thermal stratification and a deepening of the thermocline could reduce upwelling, decreasing nearshore productivity (Roemmich and McGowan 1995). The vertical gradient in ocean temperature off California has intensified over the past several decades (Palacios et al. 2004). Regional climate models suggest that winds favorable for upwelling will be stronger in summer, but the peak in seasonal upwelling will occur later. If upwelling strengthens as a result of global climate change, cold-water species will be favored in the coastal upwelling zones (Snyder et al. 2003).

The frequency of large coastal storms and heavy precipitation events is not projected to change significantly over this century (Dettinger et al. 2009). However, the storms that do occur are likely to have significant effects. Increases in the duration of high storm-forced sea levels increases the likelihood that storms will occur during high tides, and higher sea levels combined with severe winter storms and high tides will result in higher storm surges and more severe coastal erosion (Cayan et al. 2009).

2.C.2.8 Extreme Weather Events

2.C.2.8.1 Observed

Extreme temperatures have changed significantly throughout the world over the past 50 years. Hot days, hot nights, and heat waves have become more frequent; cold days, cold nights, and frost have become less frequent (Intergovernmental Panel on Climate Change 2007). Since 1950, the frequency of heat waves experienced in the United States has increased, although in many regions the heat waves recorded in the 1930s remain the most severe on record. Also, fewer unusually cold days occurred globally in the past few decades, with fewer severe cold waves for the most recent 10-year period in the record (Intergovernmental Panel on Climate Change 2012). Daytime and nighttime heat wave events throughout California have increased in intensity, particularly nighttime events (Moser et al. 2009).

Heavy precipitation events have increased in the United States, primarily during the last 3 decades of the 20th century, and mainly over eastern regions (U.S. Global Change Research Program 2009). A recent analysis found that 8 of the top 10 years with extreme 1-day precipitation events occurred between 1990 and 2010 (U.S. Environmental Protection Agency 2010).

Globally, longer, more intense droughts have occurred since the 1970s in some regions as a result of higher temperatures and decreased precipitation, particularly in the tropics and subtropics. Changes in sea surface temperatures, wind patterns, and decreased snowpack and snow cover have also been linked to droughts (Intergovernmental Panel on Climate Change 2007). It is estimated that from 2001 through 2009, 30 to 60% of the land area in the United States experienced drought conditions at any given time (U.S. Environmental Protection Agency 2010).

2.C.2.8.2 Projected

Significant increases in the frequency and magnitude of high temperature extremes are expected in many parts of California. Under the B1 (low) emissions scenario, there is a projected ten-fold increase in extreme temperatures that currently occur only once every 100 years. Under the A2 (high) emissions scenario, these extremes could occur every year (Mastrandrea et al. 2009).

Projections of precipitation extremes are highly variable across the state, depending on the model and downscaling method used. However, in general, projections indicate that longer dry spells will become more common, punctuated by occasional intense rainfall events (Mastrandrea et al. 2009).

Using a regional climate model, Bell et al. (2004) projected that there will be important changes in in some extreme events in the Delta region. The frequency of extremely hot days (exceeding the long-term 95th percentile value and prolonged (7-day) hot spells are projected to increase in both the San Joaquin River Basin and the Sacramento River Basin (Table 2.C-1).

The frost-free growing season was projected to begin earlier and last longer. The models projected fewer days of extreme cold and fewer days below freezing. Prolonged (7-day) cold spells and the duration of cold spells also were projected to decrease.

Table 2.C-1. Projected Weather Extremes in the Delta

Change Per Year	San Joaquin River Basin[a]	Sacramento River Basin[a]
Increased No. Hot Days	11.2	32.1
Increased No. Hot Events	1.6	1.5
Increased Days Frost-Free Season	40.1	30.8
Decreased Days Extreme Cold	- 34.9	- 35.5
Decreased Days Below Freezing	- 36	- 47.4
Decreased No. of Prolonged (7-day) Cold Spells	-1.2	-1.8
Decreased Days of Cold Spells	-3.2	-0.5

[a] as defined by DWR

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