The Future Is Now

An Update on Climate Change Science, Impacts, and Response Options for California

A report from the California Climate Change Center
California Energy Commission's
Public Interest Energy Research Program

September 2008

California's two-pronged approach to managing its climate risks:

- ***Mitigation*: strengthening its efforts in reducing greenhouse gas emissions to slow down global warming.**
- ***Adaptation*: planning for adaptation to deal with the impacts that are already underway and can no longer be avoided.**

Global warming is no longer a matter of the future or of places far away. Rather, climate change is already evident in the state, and it is happening now. These local changes are consistent with the emerging evidence across the globe and are largely driven by human activities such as the burning of fossil fuels, agriculture, and clearing of forests. They release carbon dioxide (CO_2) and other gases into the atmosphere, changing its composition, and trapping increasing amounts of heat that would otherwise escape into space. If these heat-trapping gas emissions are not curtailed and the related impacts are not reduced, California faces tremendous impacts on its natural resource base, its ecological treasures, and the lives, livelihoods, and wellbeing of its citizens.

Fortunately, the state is exemplary for its commitment to scientifically examine the climate risks it faces and for its wide ranging efforts to confront already apparent and emerging climate challenges. This summary is an interim update that addresses the rapidly evolving science and to further demonstrate the undeniable urgency of the overall problem. It demonstrates the growing need for a two-pronged approach to managing California's climate risks to strengthen its efforts in reducing greenhouse gas emissions to slow down global warming, and to begin planning for adaptation to deal with the impacts that are already underway and can no longer be avoided. Together, mitigation and adaptation will help minimize the potential harm and take advantage of opportunities that may arise as the climate continues to change.

Climate Change Is Here, Now

Already Observed and Accelerating Changes

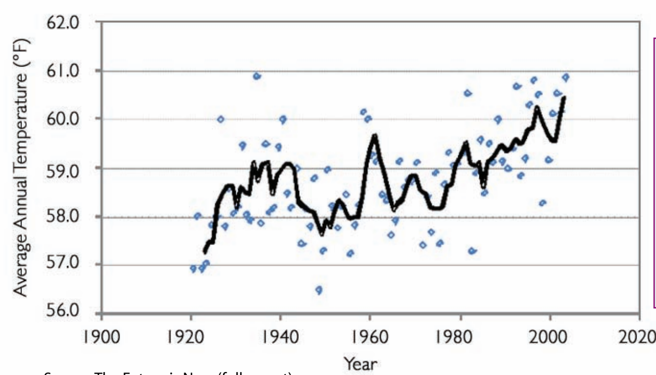
Globally, the current warming trend differs alarmingly from past changes in the Earth's climate because heat-trapping greenhouse gas emissions and atmospheric concentrations are higher, and warming is occurring faster, than at any other time on record within the past 650,000 years. Worldwide, eleven of the last twelve years (1995-2006) rank among the twelve warmest years in the instrumental record of global surface temperature since 1850.

California's Temperatures Are Already Changing. In California, average annual temperatures have been increasing since 1920, but warming has not been uniform across the state. While minimum temperatures (typically occurring at night) are increasing almost everywhere in California, maximum daily temperatures are increasing at a slower rate, with some locations (e.g., the Central Valley) experiencing a small cooling trend in the summer.

To ensure that the observed warming over California is not just a matter of natural climate variability, but driven by human activities, researchers compared eight different sets of observed temperature collected from 1914 to 1999. They found that warming trends among these different datasets were quite consistent, suggesting that they are indeed real, regional trends rather than local or measurement-specific phenomena. Researchers then tried to replicate observed trends in computer models, using different drivers. Only trends including natural and human drivers of change matched the historical trends. The human fingerprint was seen most clearly on warming in late winter and early spring, as well as on the increases in daily minimum (typically nighttime) temperatures from January to September. Summertime warming—especially in the Central Valley—was offset partly by the cooling effect produced by widespread irrigation (acting the same way as evaporative cooler can be used to cool homes in the dry summer months).

The temperature increases and extremes observed in California are consistent with temperature changes observed all over the Western United States.

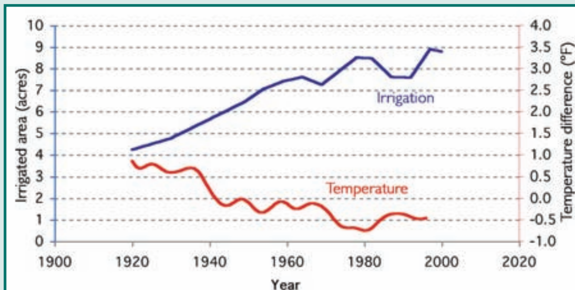
Historical Annual Average Temperature for California



Source: The Future is Now (full report)

Solid line shows the five-year running average trending upwards. Average temperatures are based on data from 54 stations around the state deemed as adequate for trend studies by NOAA.

Impact of Irrigation on Temperatures

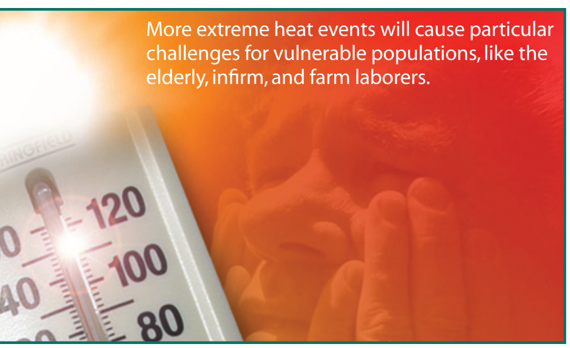


Source: Adapted from Bonfills and Lobell, 2007

Irrigated areas for agricultural use have increased in California since the 1920s (blue line) but appear stabilized in the last two decades. If we calculate the temperature difference every year between areas that are now irrigated and areas that have never been irrigated (red line), we find that differences in temperature have been widening year after year but have also stabilized in the last two decades. This means that areas that are affected now by irrigation have cooled in relation to areas that were never affected by irrigation. Agricultural irrigation has dampened the warming due to climate change, but it will not be able to continue masking the climate change signal in the future. For this reason, the agricultural areas in California may experience a more pronounced warming rate in the future.

Adverse Effects of Climate Change on Public Health. Extremes are also changing. The unusually long heat wave that affected California in July 2006 was the largest heat wave on record since 1948 and led to at least 140 heat-related deaths, mostly in inland, low-lying areas, such as the Imperial Valley, San Bernardino and the San Joaquin Valley.

Extreme heat events such as these are particularly challenging for the elderly, infants, the infirm, and others exposed to relentless heat, such as agricultural laborers or poorer people without access to cooling spaces and air conditioning. In fact, the majority of death in the 2006 heat wave occurred in socioeconomically depressed areas of the state, where many houses lacked air conditioning.



More extreme heat events will cause particular challenges for vulnerable populations, like the elderly, infirm, and farm laborers.

The Changing Water Cycle. Over the past century, rising temperatures over the Sierra Nevada have set in motion critical changes in the water cycle. Like many other states in the American West, California is already observing a decline of total snow accumulation on April 1 (and water content in the snow, especially in lower-elevation areas)—an important measure for water managers. Moreover, spring runoff comes earlier and a decreasing fraction of total runoff occurs in the spring. Over the past 100 years, the fraction of the annual runoff that occurs during April–July has decreased by 23 percent for the Sacramento basin and 19 percent for the San Joaquin basin. This indicates that a greater percentage of the annual runoff is occurring outside the traditional snowmelt season possibly as a result of an earlier onset of the snow melt. If the snowmelt season continues to migrate to earlier times in the year, it would reduce the amount of runoff that could be stored in man-made reservoirs for later use, because runoff would occur during times when flood control requirements mandate release of water from reservoirs during the (wet) winter season.

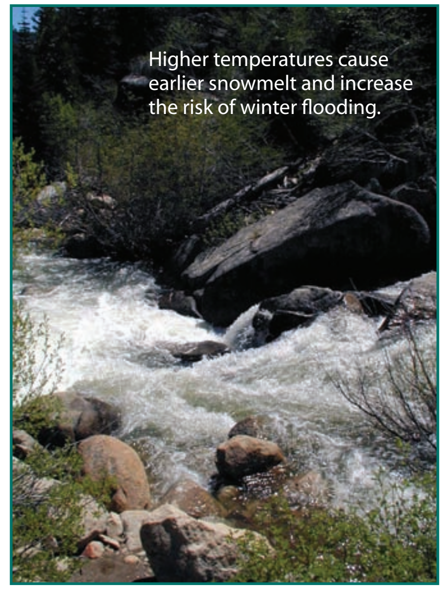
One recent study by Scripps and Lawrence Livermore National Laboratory went further showing that the majority of the observed changes in river flow, winter air temperature, and snow pack from 1950 to 1999 are due to human-caused climate changes.

> **Human-caused climate change is now also detectable in California.**

These changes have already led to challenges for winter reservoir management and to a shortened winter recreation season and earlier low-flow conditions, with potentially severe implications for fish and other aquatic life in addition to those on water supplies.

Growing Stresses in Agriculture. Statewide income from agricultural sales in 2003 was $27.8 billion, or 13 percent of the U.S. total. As the nation's leading producer of 74 different crops, California supplies more than half of all domestic fruit and vegetables. California is also responsible for more than 90 percent of the nation's production of almonds, apricots, raisin grapes, olives, pistachios and walnuts. Many of these crops are sensitive to multiple facets of climate change.

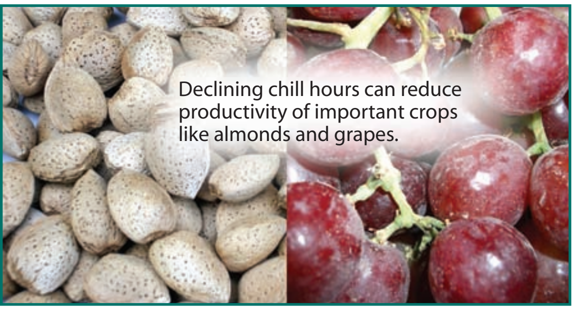
One important facet is the decrease in the number of chill hours. Fruit and nut crops, for example, are especially climate-sensitive and require a certain number of hours of cool temperatures (200 to 1200 chill hours below 45°F, depending


Higher temperatures cause earlier snowmelt and increase the risk of winter flooding.

Credit: Michael Dettinger, U.S. Geological Survey

on the crop) during the winter months to properly set fruit. The number of chill hours, however, has been decreasing since 1950. Failure to meet the minimum requirement of chill hours can cause late or irregular blooming, which decreases fruit quality and economic yield. The greatest rates of change in chill hours are occurring in the Bay Delta region and the mid-Sacramento Valley where grapes and almonds, among other crops, are grown. Unless crop varieties with low chilling requirements can be found to replace existing ones (as is the case, for example, for blueberries), California farmers may face considerable economic losses.

While warmer temperatures have negative impacts on many fruits, nuts, avocados and cotton, it has actually enhanced the production of high-quality wine grapes. In the Napa and Sonoma valleys, warmer winter and spring temperatures have resulted in a longer growing season and more favorable growing conditions. However, as warming continues, conditions will be no longer favorable for certain grape varieties, creating financial risks for growers who make significant upfront investments in crops which take years to provide financial paybacks.



Declining chill hours can reduce productivity of important crops like almonds and grapes.

Credit: California Department of Water Resources

The Deconstruction of California's Ecosystems. As spring begins earlier and autumn arrives later, the change in seasonal timing has serious implications for the life cycles and competitive abilities of numerous plants and animals, on land and in the oceans. Over the course of the past 30 years, researchers have observed budburst, egg laying, and the hatching of caterpillars (among other life cycle events) to occur earlier in the year. For example, 70 percent of 23 California butterfly species studied advanced the date of first spring flights by an average 24 days from 1972 to 2002.

California is also home to dozens of migratory bird species and throughway for millions of birds along the Pacific Flyway. Timing of their migration is essential so that birds can take advantage of favorable weather conditions, find adequate food to sustain them along their flight, and—for spring migrants—to ensure that arrival on the breeding grounds coincides with the flush of spring insects to feed their young. In one recent study, researchers found that most of those migratory species traveling through Northern and Central California that are sensitive to changes in climate now arrive several days per decade earlier in response to the observed regional warming, whereas none of the species that are insensitive to changes in climate shifted their arrival dates.

Climate warming, especially during spring, is the only factor that can explain this consistent shift in the behavior of these climate-sensitive species. Yet different species respond to varying degrees (insects and birds may migrate more quickly than the plants they depend on for food), thus slowly deconstructing the ecosystems common in the state.

Wilson's Warblers have been arriving in California six days earlier per decade due to warming.

Credit: U.S Fish and Wildlife Service

Landscape Shifts and Growing Wildfire Risks. Generally, climatic changes are shifting the suitable range for many plant species to the north and to higher elevations. Such trends are particularly evident in the Sierra Nevada.

In one recent study, researchers found an increase of 5.4ºF in monthly minimum temperatures in the middle elevation Sierra Nevada Mountains over the past 100 years.

This has caused the ponderosa pine forest to move an average of 4.4 miles eastward and upward by more than 630 feet between 1934 and 1996. While the temperature increase alone is unlikely to be responsible for the death of mature pines, which were harvested, the higher temperatures correlate with longer summer drought conditions. They in turn increase drought stress on seedlings which prevents the trees from reestablishing themselves. After areas affected by other factors such as fire, urbanization, and conversion to grassland with competitive nonnative grasses and pressure from cattle grazing were removed from the analysis, climate warming emerged as the most likely driver of the observed eastern and upward retreat of ponderosa pine.

Reduced winter precipitation and earlier spring snowmelt also deplete the moisture in soils and vegetation, leading to longer growing seasons and drought. These increasingly dry conditions are believed to be the main reason for the increased trend in forest wildfire risk because they create more favorable conditions for ignition. Higher temperatures also increase evaporative water loss from vegetation, increasing the risk of rapidly spreading and large fires. In the last three decades the wildfire season in the western U.S. has increased by 78 days, and burn durations of fires greater than 2400 acres in area have increased from 7.5 to 37.1 days, in response to a spring-summer warming of 1.6°F.

Another icon of California's treasured landscapes is Lake Tahoe. The waters of Lake Tahoe are warming at almost twice the rate of the world's oceans. Over the 33-year period from 1969 to 2002, Lake Tahoe's water temperature increased about 0.9°F. Nighttime air temperatures near the lake rose 3.6°F from 1914–2002. The warming of air temperatures is sufficient to explain most of the increase in water temperature. The warming of the surface and deeper layers of the lake is not uniform, causing changes in the ability of higher and lower waters to mix, bring oxygen and nutrients to different layers of the lake and thus support aquatic life and maintain its famous clarity and blue color.

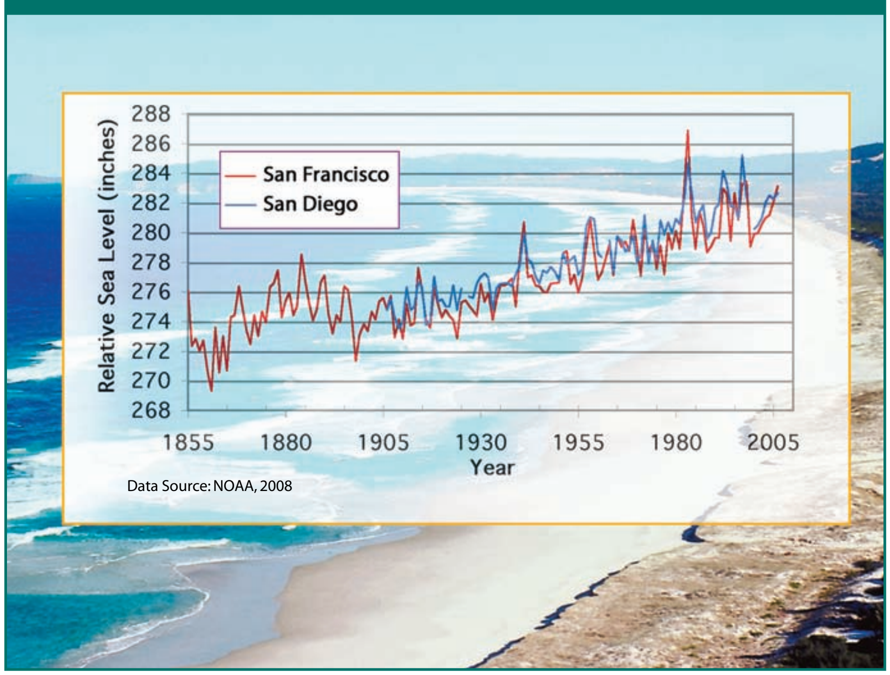
Increasing rate of sea-level rise. Sea level has been rising globally since the end of the last ice age. From 1961 to 2003, global

Credit: California Department of Water Resources

average sea level rose at an average rate of 0.07 inches per year, and at an accelerated average rate of about 0.12 inches per year during the last decade of this period (1993 to 2003). The two primary causes for a global rise in sea level in response to warming are thermal expansion of the ocean water (water expands as it heats up) and the melting of land-based ice (which adds water to the ocean basins).

During the past century, sea levels along California's coast, including the Southern California coast, the Central California open coast, and the San Francisco Bay and upper estuary, have risen about seven inches. The rate of sea-level rise observed at the gauges along the California coast is similar to the estimate for global mean sea level. According to new research by Scripps Institution of Oceanography focused on San Francisco Bay, increases in average sea level is also associated with increases in extreme sea-level events (e.g., surges during storms). Since the 1950s, such extreme sea level stands have become more frequent, and they coincide frequently with high runoff from rivers into San Francisco Bay and the Delta region. This coincidence of extremes places growing burdens on the aging levee structures and increases the risk of catastrophic flooding.

Historical Sea-Level Rise for San Francisco and San Diego



A More Challenging Future

Update on Projected Impacts

What might California look like if the human imprint on its climate were not rapidly minimized? Impact studies using different emissions scenarios allow us to see the benefits of avoiding the more extreme changes in climate associated with higher emissions.

Typically, scientists and the Intergovernmental Panel on Climate Change (IPCC) use a common set of plausible scenarios of how the global population, economy, and technologies might change over the course of the 21st century and feed the resulting emissions along with known natural drivers of change into their climate models. These emissions accumulate in the atmosphere and remain there for decades to centuries, thereby increasing the concentration of greenhouse gases which trap heat and drive the other climatic changes that are observed. The IPCC's projections do not assume climate-specific policy interventions and scientists cannot conclude which climate future is more likely than the other. Considering, in addition, an explicit policy scenario (such as an 80 percent reduction in heat-trapping gases by 2050 from developed countries) shows how some dangers of climate change can be avoided, while others such as sea-level rise must be managed through adaptation.

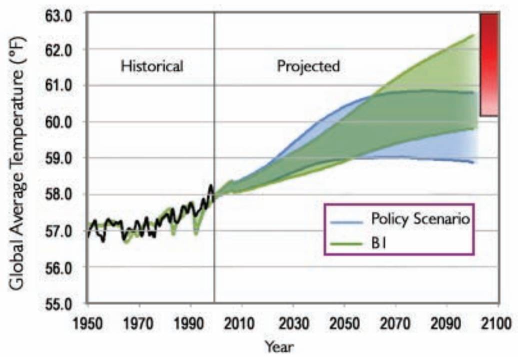
Among the already well established projections for climate change impacts by 2100 in California are the following:

- **Continued warming and more temperature extremes**. Hotter temperatures are expected throughout the state, increasing 3-5.5°F under a lower emissions scenario (B1) and 8-10.5°F under a higher emissions scenario.
- **Severe public health challenges for vulnerable populations**. More extreme heat events increase the risk of heat- and air pollution-related illnesses and deaths.
- **Summertime water scarcity and snowpack reductions**. A relatively dry climate under a medium-high emissions scenario, for example, could raise statewide water scarcity and total operation costs by nearly $500 million per year by 2085.
- **Increasing risks and cost for agriculture**. Higher temperatures, a longer growing season, fewer chill hours, less available water, higher atmospheric carbon dioxide levels, and more pests together will increase the cost of growing crops.
- **Changing landscapes, moving species.** Under pressure from climate change, the habitat for plant and animal species will shift even further northward and upward on land or to cooler depths in the ocean. Species will respond in different ways and their ability to adapt and migrate to a better suited environment depends on the presence of barriers and protected areas.
- **Faster sea-level rise.** California is vulnerable to significant economic impacts resulting from loss of, or damage to, coastal property, infrastructure, recreational beaches, wildlife habitat, and coastal water supplies as sea level rises faster and coastal erosion and flooding increase.
- **Growing energy demand.** With further climate warming, higher costs from increased demand for air conditioning both during heat waves and on a daily basis are expected to outweigh the decreases in heating costs during the cooler seasons.

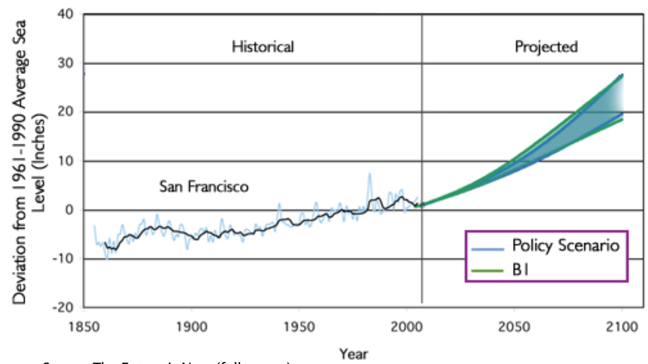
The number of large wildfires could increase by 12–53 percent by the end of the century, depending on the emissions scenario, with larger increases expected in Northern California.

Credit: Federal Emergency Management Agency

Temperature and Sea-Level Rise Projections



Source: The Future is Now (full report)



Source: The Future is Now (full report)

The graphic on the left shows how global average temperature might change under the most optimistic assumption, the lowest emissions scenario (B1, green) and under a scenario with strong policy intervention (Policy Scenario, blue, which assumes that global emissions will be reduced by 80 percent below 2000 levels by 2050 from developed nations with fair contributions from developing nations). There is a 90 percent chance that temperatures will fall within the green shaded area if the world follows the B1 scenario (a 1.7-4.3°F increase above 2005 temperatures by 2100), and a 90 percent change they will fall within the blue shaded area, if the world follows the far more ambitious Policy Scenario (with a 0.8-2.7°F increase by 2100). The benefits of putting in place strong policies to reduce global emissions becomes very clear: even the temperature increases in the optimistic no-policy scenario B1 cannot avoid some of the dangerous impacts of global warming (the red bar on the right indicates growing danger), while they can be mostly avoided if concerted policy efforts are made to keep warming in check.

The graphic on the right shows global average sea level changes over the 21st century. The projected increases are larger than previously reported due to recent improvements in sea-level rise science, though still not accounting for the possibility of rapid ice loss from Greenland and Antarctica. There is almost no difference in the expected range of increase in sea level (about 8 inches higher by 2050 and about 18 inches higher by 2100 above the 1961–1990 average) between the two scenarios. This suggests that even stringent emissions reductions and resulting lower temperature increases—while critically important in limiting other dangers to human health, water resources, food supplies and ecosystems—cannot prevent substantial sea-level rise because ocean waters store heat effectively and will expand for centuries, long after air temperatures have been stabilized. Adaptation is the only way to deal with the long-lasting threat of sea-level rise to coastal areas.

Newer insights from more recent studies suggest an even more complex and challenging future:

- Actual emissions of heat-trapping greenhouse gases are growing more rapidly than the highest emissions scenario used in previous studies.
- Warming in urban areas is greater than the averages projected, with more serious health impacts on more people.
- Due to demographic changes, California is becoming more vulnerable to heat extremes and air pollution, especially the elderly, infirm, socially isolated, poor and outdoor-working populations.
- Overall, projected increases in extreme heat are substantial. Projected increases range from approximately double the historical number of days for inland California cities (such as Sacramento and Fresno) and up to four times present-day levels for previously temperate coastal cities (such as Los Angeles and San Diego), implying that current-day "heat wave" conditions may dominate summer months—and patterns of peak electricity demand—in the future will be challenging to meet. Historically cooler coastal cities (e.g., San Francisco and Los Angeles) are projected to experience greater relative increases in temperature, such that areas which never before relied on air conditioning will experience new cooling demands.
- Climate change impacts on forests will produce changes in stand density, decreased growth, increase tree mortality and susceptibility to disease, and cause complex changes in the interactions among species.

- The number of large wildfires could increase by 12–53 percent statewide by the end of the century depending on the emissions scenario, with larger increases expected in Northern California. Under a higher-emissions scenario, the value of structures lost to fire could increase by as much as 36 percent by 2100. Additional costs and losses related to wildfire stem from its impacts on air pollution, visibility, and human health, ecosystems and wildlife habitat, timber production, the water cycle, flooding and soil erosion.
- Sea-level rise is expected to accelerate and proceed at significantly higher rates than previously thought. Along the California open and Bay coasts sea level could be at least 8 inches higher within 40 years and at least 18 inches higher by 2100 using the lower emissions (B1) scenario or the policy intervention scenario. These lower bound estimates are substantially higher than the 2007 IPCC, yet neither considers the accelerating ice melt observed in the Greenland and West Antarctic ice sheets. These new estimates must be considered conservative. Past economic impact assessments of rising sea levels, using more conservative projections consequently must also be seen as under-representative of the magnitude of costs and adaptive actions needed by state and local decision-makers.

As the frequency of extreme events increases, there is less time between them for recovery. This increases the risk of maladaptations, and some adaptations may become less effective or no longer be feasible.

Interacting Climate Impacts: Multiple Stresses – Multiple Sectors

The Sacramento-San Joaquin Delta, like other regions in California, will face numerous impacts from climate change interacting with each other and with other stresses already evident from urban development, past land use and environmental management practices, and pollution. The resulting combined effects could be larger or smaller than any single projected impact occurring in isolation. Moreover, what happens here will have far-reaching impacts on other regions of the state.

Credit: California Department of Water Resources

For example, land subsidence and rising sea levels together with the growing risk of wintertime flooding are rendering the land behind the levees (especially the western and central Delta with its productive soils) increasingly vulnerable to flooding and saltwater intrusion. As the frequency of extreme events like flooding increases, there is less time between them for recovery. This, in turn, increases the risk of maladaptations, and some adaptations may become less effective or no longer be feasible. In addition, as soils become more saline, economic impacts would be felt by growers, bringing into question the future ability of those regions to sustain irrigated agriculture. Recent research has revealed serious vulnerabilities of growers of corn, grain and hay, alfalfa, tomatoes, asparagus, fruit, safflower, pears, and wine grapes to these combined impacts in the Delta.

Urban development behind the levees would also be affected by increasingly severe floods as sea levels rise faster and runoff in the winter and spring increase. Such floods could seriously impair the proper functioning of much of Northern California's water infrastructure, which is also critical to water supplies in the central and southern part of the state.

Creating Our Future

A Balanced Approach to Managing California's Climate Risks

California must pursue a dual approach to managing its climate risks: reducing the drivers of change on the front end of the problem (mitigation) and minimizing the impacts on the back end (adaptation), with the overall goal of ensuring public safety and welfare, continued economic vitality of the state's climate-sensitive sectors, and a rich and functional natural environment on which people and the economy depend.

Mitigation: Avoiding the Unmanageable Many scientists suggest that the emissions of heat-trapping gasses must be reduced by 80 percent in developed countries below 2000 levels by 2050 with fair contributions from developing nations to keep global warming to a level that would not cause catastrophic consequences for human society and the environment. While there is considerable scientific uncertainty and political debate around this goal, California has been a policy pioneer in the U.S. and the world in committing to this target. Initiated by Governor Schwarzenegger's 2005 Executive Order S-3-05 and then formalized in Assembly Bill 32 (2006), the state is in currently of scoping the strategies and measures to reduce emissions to 1990 levels by 2020 and put California on the path to achieving this ambitious goal.

Every sector of society must be involved and contribute to the overall goal of climate stabilization. If these changes are set in motion and pursued persistently over the course of several decades, innovation and periodic turn-over of infrastructure could be a driver of enormous economic benefits for California, and—if implemented with an eye to social justice and environmental impacts—improved environmental conditions, greater equity, and a better quality of life.

Mitigation efforts must be considered in concert with adaptation strategies since at time they can be mutually reinforcing (e.g., increasing or maintaining tree cover in urban areas provide shade and soak up carbon), and other times undermine each other (e.g., more air conditioning to provide cooling against extreme heat will consume more energy and increase CO_2 emissions).

Adaptation: Managing the Unavoidable. Mitigation alone will not manage California's climate risks and keep impacts to acceptable levels. A wide range of efforts is needed to plan for and deal with the impacts of climate change already set in motion. Such adaptation efforts must be viewed as complementary to and equally necessary as mitigation.

10 Reasons Why California Must Adapt

1. California's climate and ecosystems are already changing, demanding management changes now.
2. Without swift and concerted action, climate change will produce even more severe and costly consequences for California and the world.
3. While mitigation is critical for long-term reduction of global warming, the human impact on the climate is difficult to change because of society's reliance on carbon fuels.
4. Greenhouse gasses currently being emitted remain in the atmosphere for a long time, committing the state for decades to centuries to further warming and impacts that must be managed through adaptation.
5. Changes in the atmosphere, climate and other natural systems are accelerating, increasing the risk of abrupt and dramatic changes for which society is currently unprepared.
6. Climate change together with the additional stresses from rapid growth and development place the state's critical water resources, precious ecosystems, and vulnerable coastlines at growing risk.
7. Decreasing the human footprint on the environment, reducing vulnerability to climate extremes, and planning ahead is smart management even in the absence of climate change.
8. Adaptation may offer important opportunities for California businesses and citizens, e.g., through improvements in infrastructure, building design, smart technologies and a wide range of human services.
9. In the course of adaptation we can improve environmental conditions and economic welfare, enhance social justice, and ensure people's quality of life.
10. Well thought out adaptation plans, implemented over time, are less risky, less costly, and allow Californians to create their future, rather than being compelled later to only cope with it.

California's ability to manage its climate risks through mitigation and adaptation depends on a strong economic resource base, appropriate technologies, adequate infrastructure, institutional support, effective governance, a highly educated and skilled workforce, widespread public awareness, adequate information to support decisions, natural resources and functioning ecosystems, and equity in access to the above resources and institutions. In the future, as the state increases its efforts in mitigation and adaptation, it can bank on existing strengths, but must also increase its response capacity where it may be insufficient.

The Goal of Adaptation: Not "Free from Risk" but "Well Managed Risk". Adapting to climate change does not mean preventing all adverse consequences. Nor does it mean only cleaning up after impacts happen. Rather, the goal of adaptation is to use the best available science to plan ahead, to reduce society's vulnerability, and to help impacted communities, sectors, and ecosystems to recover from the consequences of a variable and changing climate such that they remain within collectively defined and acceptable limits. Ultimately, the goal of adaptation is to enhance society's long-term resilience.

Assessing Adaptation Needs: Weighing Climate Hazards and Societal Vulnerability. Communities, industries, business sectors, and resource managers can assess how much and what kind of adaptation is needed to attain resilience in the face of change by pursuing two lines of inquiry, both with the support of relevant science.

First, it is important to understand what specific hazards climate change may entail. The California Climate Change Center and other researchers are helping to produce and improve "downscaled" and more specific climate change projections relevant to specific locations and sectors (see Examples of Research in Support of Adaptation Planning).

Second, understanding how vulnerable a sector, community, or ecosystem is to the projected climate change is necessary. This entails assessing four aspects:

- The level of exposure to a hazard
- The degree of sensitivity to that hazard
- The ability to respond
- Any barriers to adaptation

Extreme Events


Credit: California Department of Water Resources

Can we ever say that any one extreme event is the result of human-driven global warming? Are heat waves, droughts, or record-breaking floods still purely natural or are they caused by human emissions of greenhouse gases?

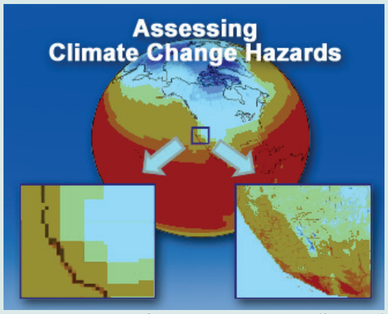
The simple answer is that it is not possible to say that any single extreme event is due to human influence on the climate. But as some scientists have said, "**Humans are loading the die**." Human emissions of heat-trapping gases change the composition of the atmosphere, which increases average temperatures and affects temperature extremes. Climate models project more frequent abnormally hot days and nights and more heat waves with global warming. Cold days and nights are very likely to become much less frequent, as will the number of days below freezing. Droughts are likely to become more frequent and severe in some regions and rainfall is likely to become less frequent but more intense over most regions of the world, increasing the risk of flooding. In short, human activities are changing the climate such that the risk of many extreme events is increasing. This means that the already observed pattern of increases in certain extreme events is consistent with theoretical predictions.

For the future, it is safe to assume that **the trend toward more frequent and, in some cases (such as heat waves) more intense extremes will continue.** This poses growing challenges to hazards managers and society, requiring planning, preparation, and reductions in vulnerability wherever possible. **As extremes occur more often, there is less time in between events to recover and rebuild, and the risk of maladaptations grows.**

Many measures employed to adapt to climate change will have co-benefits because they aim at reducing vulnerability to current climate variability and extremes or improve environmental or social conditions more generally. Policy- and decision-makers must be careful, however, to avoid unintended negative consequences of adaptation for social justice, environmental quality, and other impacts on California's economy and communities. For example, actions that lessen the risk from small or moderate events in the short-term, such as construction of levees, can lead to increases in vulnerability to larger extremes in the long-term, because people may perceive themselves safe and increase development behind the levees (a form of "maladaptation").

Adaptation Planning in California. Climate change impacts must be managed involving private and public sector decision-makers, climate science experts, vulnerability and adaptation analysts, and all affected stakeholders. Actions will need to be coordinated across sectors and levels of government as climate change impacts and many response efforts are not neatly confined in space. Clearly, because climate change impacts will manifest in specific ways at the local level, local governments, businesses and individuals will play a prominent part in minimizing risks and taking advantage of potential opportunities. State and federal-level leadership and guidance, as well as their financial and technical resources will be needed to augment local capacities.

Examples of Research in Support of Adaptation Planning



Source: The Future is Now (full report)

- Further developing methods to downscale global climate model outputs to California.
- Development and refinement tools to assist in impacts and adaptation studies, such as the study and representation of water storage in underground reservoirs, the response of species to warming, or the assessment of increased erosion in response to sea-level rise.
- Using historical analogues (e.g., drought periods, extreme heat events) to better understand the capacities and limits to managing the impacts of a changing climate on water reservoir management.

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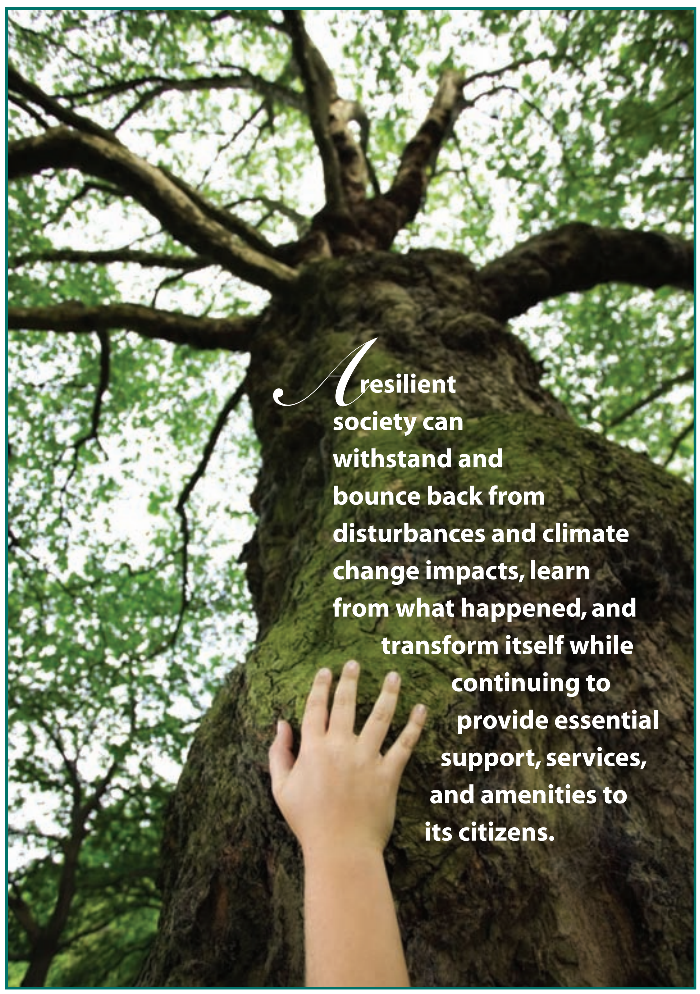
- Vulnerability assessments of various sectors and regions.
- Assessment of different sectors' readiness to plan for, and implement, adaptation actions, including managers' awareness of global warming-related risks, their ability to assess the risks, and the actions anticipated or already taken.
- Assessment of integrated adaptation options across scale.
- In-depth studies of potential social, economic, regulatory, legal and other barriers to adaptation.

The State of California, especially the Resources Agency, has recognized the need for adaptation and in early 2008 began coordinated efforts to develop adaptation plans and strategies across agencies. The goal of this effort, in partnership with the Climate Action Team, is to establish an adaptation planning process in each of the relevant state agencies and a first-order state adaptation plan by the second quarter of 2009. This plan is only the first step in the state's ongoing adaptation efforts needed as long as climate change affects the state.

Taking the Long View. Climate change will affect California and the world for decades to centuries to come. It is being addressed but not easily or quickly resolved. Nevertheless, it holds the opportunity for important changes with multiple environmental and economic co-benefits. The challenges of global warming require the best scientific knowledge, leadership, and societal support. Above all, they require a commitment, vigilance and the ability to learn and adapt quickly, yet thoughtfully, so that we continue to provide for our own needs while not undermining the ability of societies in the far corners of the world nor future generations to meet theirs. That changes how we think about the present and the future: **The future is now.**



Credit: National Renewable Energy Laboratory and California Department of Transportation

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The California Adaptation Strategy (CAS), with the help of sector-focused working groups and in coordination with key state agency stakeholders, will

- synthesize information on anticipated climate change impacts for California policy-makers and resource managers;
- provide strategies to promote resiliency in the face of these impacts; and
- develop implementation plans for short and long term actions.

The CAS process will be guided by peer-reviewed scientific information gathered from scientists, agencies, cities, states, and countries around the world.

For more information on the California Adaptation Strategy, see:
www.climatechange.ca.gov/adaptation

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