Summary of Climate-Related Changes in Southern California

Climate variable	Historical changes	Direction and range of projected future change	Seasonal patterns of change	Confidence
Air temperature	Since 1970 in southern California • Average maximum temp increased +0.41°C per decade • Average minimum temperatures increased +0.37°C per decade[1] Between 1950-2010, heat wave activity increased across California • Humid, nighttime events increased more rapidly than daytime events[2] Urban heat island effects have: • Enhanced extreme high temperatures during heat waves • Reduced ameliorating wind events, further exacerbating heat wave events[3]	Most likely projections for statewide temperature changes by 2100 include: • A +5°C increase, but model estimates range between +2.5°C and +9°C[4] • Increased frequency of heat wave events2 above with a greater relative increase in frequency of humid nighttime heat waves ○ Coastal areas will be particularly susceptible[2]	Historically, warming trends are: • Most pronounced during spring (Mar, Apr, May) • Least pronounced during winter (Dec, Jan, Feb)[1]	There is a consensus among downscaled GCM models that the temperature in California will warm in the 21st century[1,4,5] The degree of warming, however, is less certain due to chaotic inputs from the global system and future anthropogenic mitigation measures
Precipitation	Between 1930-2000 in southern California mean annual precipitation declined by as much as 250 mm[6] • The majority of precipitation fell during a few (5-15) wet days per year, resulting in high 3-day storm totals[4] • Higher elevations typically received more precipitation than lower elevations, creating interior rain shadows[7] Between 1950-2009, extreme precipitation events increased slightly, but were variable by location in southern California[8,10]	Overall, precipitation estimates for California are uncertain: • Late century estimates range from substantial declines to increases[9,10] More precipitation will fall as rain rather than snow,[5] especially at lower elevations[11] Mean precipitation shifts by the end of the century will likely be minor compared to the natural inter-annual variability of this study region[9]	There is a consensus across models indicating that winters will experience more rain and summers will be drier[6]	Overall changes in future precipitation are uncertain It is likely that California will be drier irrespective of precipitation patterns due to warmer temperatures, reduced snowpack and earlier snowmelt, and increased evapotranspiration.[12]

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	In general, southern California precipitation experienced large inter-annual variability Precipitation patterns were linked to large-scale climatic forcing systems (e.g., ENSO, PNA, PDO)[4,9]			
Snowpack and snowmelt	Across California: • Snowpack and runoff are declining and snowmelt and runoff are occurring earlier in the spring[6,13] In southern California: • Areas that receive snow have experienced significant declines since 1930[13] Mean April 1st snow-water equivalent (SWE) declined 17% between 1981-2010 compared to the baseline period (1951-1980)[14]	Compared to baseline conditions (1981-2000), "business-as-usual" emission scenarios for the southern California mountains project: • A 30% reduction in snowfall by mid-century (2041-2060) and 50% reduction by (2081-2100) • Snowpack may decline by an additional 15-20 percentage points at low and middle elevations (e.g., 45-50% by 2060), and by 5 percentage points at high elevations • Spring snowmelt will occur 1-3 weeks earlier by mid-century[11]	Temperature increases will drive shifts from snow to rain during winter months, particularly at lower elevations[4,11]	Although there is uncertainty associated with the magnitude of projected snowfall loss due to downscaling of global climate models, this uncertainty generally diminishes with increasing elevation[11]
Stream flows	Between 1951-1980 and 1981-2010, mean runoff decreased by 3% in southwestern California, but increased in central western California (11%), the Mojave Desert (25%), and Sonoran Desert (17%)[14] From 1948-2002, in southern California the onset of snowmelt runoff occurred earlier due to elevated spring temperatures[15] Over the past 100 years, annual runoff has	Although California hydrology models vary by basin, there is an overall consensus among future projections that: • Increasing temperatures driven by climate change will lead to an earlier and shorter spring snowmelt and an increase in winter runoff in California[17]	The greatest impacts on stream flow will likely occur during the spring and late summer season due to earlier snowmelt and runoff and earlier and longer dry periods in the summer[5,12]	Runoff and hydrological projections are highly variable among climate models, creating uncertainty among future runoff projections[12,17,18,19]

Climate variable	Historical changes	Direction and range of projected future change	Seasonal patterns of change	Confidence
	decreased by 19% in the San Joaquin basin due to earlier onset of snowpack melt[16]	Various basins will exhibit increases in storm water volume and peak flows and reductions in flood return intervals[18,19]		
Soil moisture and recharge	Soil moisture recharge is occurring earlier in the spring leading to longer dry periods in the summer[20] In the past 4 years, groundwater declines have reached historical lows[21] Between 1951 and 2010: • Mean climatic water deficit increased by 1-3% in all areas of the study region • Potential evapotranspiration increased 2-3% • Groundwater recharge declined by 5% in southwestern California, but increased in central western California (4%) and the Mojave (26%) and Sonoran Desert regions (35%)[14]	Climatic water deficit will likely increase by the end of the century Groundwater recharge may experience modest increases or significant decreases, depending on regional precipitation[12]	A consensus among models indicates that winters will experience more rain and summers will be drier[6] In areas with snow, lowest climatic water deficits are typically in spring, coinciding with snowmelt[12]	Climatic water deficit is projected to increase under all future precipitation scenarios[12] Recharge projections are more variable, depending on changes in precipitation[12]
Drought	Drought from 2012-2014 broke multiple records for the most severe drought year (2014), lowest accumulated soil moisture, and regionally as the most severe drought in the southern California Central Valley and heavily-populated coastal areas[22,23] High temperatures exacerbated the impact of low precipitation between 2012-2014[22,23] • Anthropogenic warming accounted for 8-27% of 2012-2014 drought, and 5-	Droughts are expected to be more severe than those previously experienced in the state[24] Drought years are twice as likely to occur over the next several decades[25] Between 2050 and 2100, the chance of a drought lasting 10 years or more is 80% under a high-emissions scenario (reduced risk in the moderate-emissions scenario, but	Soil moisture is more likely to be very low in summers following a period of low winter precipitation, increasing the risk of drought	There is uncertainty around precipitation projections, and the metrics used for drought are often not consistent; however, climate models are able to confidently predict longer and more severe drought even when the details are uncertain

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	18% of 2014 year[23] Droughts are common in southern California; the region has experienced 6 since 1900[22] Within the Southwest and Central Plains, mega-droughts occurred that lasted from decades to centuries in the Medieval warm period (between 900 and 1300 CE)[24]	still significant)[24]		
Wildfire	Historically, fires in southern California occurred in lowland shrubland ecosystems at a fire return interval of 60–100 years[26] Currently, the fire return interval in shrubland communities has fallen to 10-20 years or less[27] • Fires have become larger and more severe in these ecosystems, however there is disagreement among the scientific community about whether this is accurate[6] In mid- and high elevation conifer stands, fire suppression efforts have increased fire return intervals, allowing fuels to accumulate and leading to conditions favoring high-intensity, large-scale, stand-replacing fires[6,28]	Warmer temperatures, increased fuel loading, increased human ignitions, and altered Santa Ana winds will lead to increased size, severity, and frequency of fires in the future	Wildfire severity and size will likely increase during the late fire-season period due to increased Santa Ana winds and thunder cell activity[6]	Climate models indicate future conditions will be more conducive to large, more intense wildfires due to: • Increased rate of woody fuels growth (i.e., from more atmospheric CO_2) • Extended late season dry periods • Increased human ignitions[6] By mid-century in California: • 10-35% increase in large fire risk • 2.5X greater area burned in shrublands[29,30]
Vegetation	In the Santa Rosa Mountains, the average	By the end of the century in	None identified	Excluding desert

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shifts	elevation of dominant plant species in 2006-2007 was roughly 65 m higher than in 1977, a shift attributed to regional climate variability[31]	California: • Conifer forest, mixed conifer forest, and shrublands in California are projected to decline, while grasslands may increase[32] • Mixed conifer may displace conifer forest due to increased productivity of hardwoods[32] • Desert vegetation may increase in extent under drier conditions, or decrease in extent under wetter conditions[32]		vegetation, projections regarding the direction of change for every vegetation type were consistent across models, although spatial variations in vegetation occurrence varied between models[32]

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