LA County Climate Vulnerability Assessment

Climate Hazard Assessment

October 2021

Los Angeles County Climate Hazard Assessment

ICF analyzed climate hazards for Los Angeles County's Climate Vulnerability Assessment. Methods, analysis, and results are presented here.

Introduction

Los Angeles County faces challenges driven by a rapidly changing climate. The County and its surrounding region sit at the confluence of a range of climate hazards, including extreme heat and precipitation, wildfires, coastal and inland flooding, and drought. Both at present and in the future, these hazards pose risks to communities, infrastructure, and natural systems within LA County.

Climate change is already impacting LA County. Seven of the ten largest wildfires in California's history have occurred since the start of 2017 (Cal Fire, 2020). LA County experienced its hottest temperature ever recorded during the September 2020 heat wave (Los Angeles Times, 2020). In addition, the extremely wet 2016-2017 winter following the 2011-2017 drought signaled increasing volatility of climate hazards that are impacting the region.

In addition to presenting inherent risks, climate hazards worsen existing environmental conditions and drive secondary impacts to human and natural systems within LA County. For example, extreme precipitation that followed the 2017 wildfires triggered deadly mudslides around Santa Barbara County (Tiwari et al, 2020). The 2011-2017 drought also had major impacts on state water resources, such as permanently reducing groundwater capacity due to land subsidence (Lund et al, 2018). Climate hazards worsen air quality, increase the transmission of vector-borne diseases, and reduce biodiversity. These impacts are projected to increase in frequency and severity due to climate change.

LA County has undertaken a climate hazard assessment to address these risks. The assessment uses best available science to understand localized, decision-relevant climate hazards, as well as their potential impact on environmental conditions in the County. The assessment considers both mid- and late-century time horizons to inform a range of planning scenarios. Furthermore, the assessment considers multiple scientifically plausible greenhouse gas (GHG) concentration scenarios to evaluate a range of climate change outcomes in the region. The results of this climate hazard assessment are intended to inform a companion vulnerability assessment of communities and physical infrastructure in the County and adaptation and resilience efforts.

Present and Future Climate Hazards

The County evaluated the following six climate hazards that are projected to increase in frequency and/or severity due to climate change:

- Extreme heat
- Extreme precipitation
- Wildfire
- Coastal flooding
- Inland flooding
- Drought

This section of the report evaluates these hazards and how they are projected to evolve with climate change through mid- and late-century. In turn, the analysis of climate hazards provides critical information and context to guide effective adaptation and resilience planning. Later sections in this report evaluate the potential impact of climate hazards on environmental conditions in the County.

The LA County Climate Hazard Assessment evaluates hazards already present in the County, such as extreme heat, wildfires, and drought. While climate change may worsen the severity of these hazards in the future, climate hazards already present risks to the County. The assessment facilitates planning for the kinds of climate impacts that LA County already experiences and contends with. Actions taken to increase adaptive capacity to climate hazards increase resiliency, economic vitality, and community wellbeing in both the present and future.

To understand future climate hazards, the County used current climate projections and datasets, many of which were prepared in support of the State of California's Fourth Climate Change Assessment. Temperature and precipitation projections focus on climate change from a recent baseline time period (1976 to 2005) to mid-century (2036 to 2065) and late-century (2066 to 2095). Projections represent average conditions over 30-year periods in order to minimize the influence of inter-annual climate variance (e.g., the impact of an El Niño event on temperature anomalies). This assessment uses the ensemble mean of the 10 priority Global Climate Models (GCMs) identified by the State's Fourth Climate Assessment to best represent California's climate variability and a range of plausible climate outcomes.[1] Daily GCM outputs were downscaled using the Localized Constructed Analogs (LOCA) method to a 6 km resolution compatible with regional and local planning. Models were driven by Representative Concentration Pathway (RCP) 4.5 and 8.5 to evaluate a range of future GHG concentrations. RCP 8.5 assumes GHG concentrations continue to rise throughout the 21st century, whereas RCP 4.5 assumes significant reductions in GHGs prior to mid-century. Projections for wildfire use the ensemble mean of four available LOCA-derived GCMs and assume a business-as-usual population growth scenario (Westerling et al., 2018).

These projections were complemented by additional datasets and a literature review in the assessment of other climate hazards. For projections of coastal flooding, the study team used estimates of future sea level rise from California State Sea Level Rise Guidance and the United States Geological Survey (USGS) Coastal Storm Modeling System (CoSMoS) (Barnard et al., 2018). Finally, the study team consulted best-available scientific literature concerning the future frequency and severity of inland flooding and regional drought.

Extreme Heat

LA County climate is characterized by two distinct seasons: a warm, dry spell from April to November, and a cooler, wet period throughout the rest of the year. Additionally, the diverse landscape – including coastal, mountain, desert, and urban environments – drives climatic variance within the region. Seasonal temperatures

[1] The State of California's 10 priority GCMs include ACCESS1-0, CCSM4, CESM1-BGC, CNRM-CM5, CMCC-CMS, CanESM2, GFDL-CM3, HadGEM2-CC, HadGEM2-ES, and MIROC5.

can be most extreme in the high desert areas of the County, with daytime maximum temperatures over 100˚F common during the summer (University of California ANR, N.d.(b)). Due to the Urban Heat Island Effect, urban areas of the County typically experience daytime temperatures 1-6°F hotter (and up to 22°F hotter at nighttime) than adjacent locations (CalEPA, 2020).

Climate change is already driving temperature increases in the County. Annual average temperatures increased by 0.29˚F per decade over the last century, with the most warming occurring in the fall and winter months (Hall et al., 2018). The County has also experienced more frequent, longer, and severe heat waves, which are prolonged periods of excessively hot weather. The San Fernando Valley recorded a temperature of 119˚F during a prolonged July 2006 heat wave, which is the second hottest ever temperature in the County. That same heat wave saw 21 consecutive days over 100˚F, which was the longest stretch of extreme heat ever recorded since records began in the Valley in 1949 (Tamrazian et al., 2008). In September 2020, the County experienced another record-breaking heat wave, with maximum temperatures in the San Fernando Valley reaching an all-time high of 121˚F (LA Almanac, n.d.).

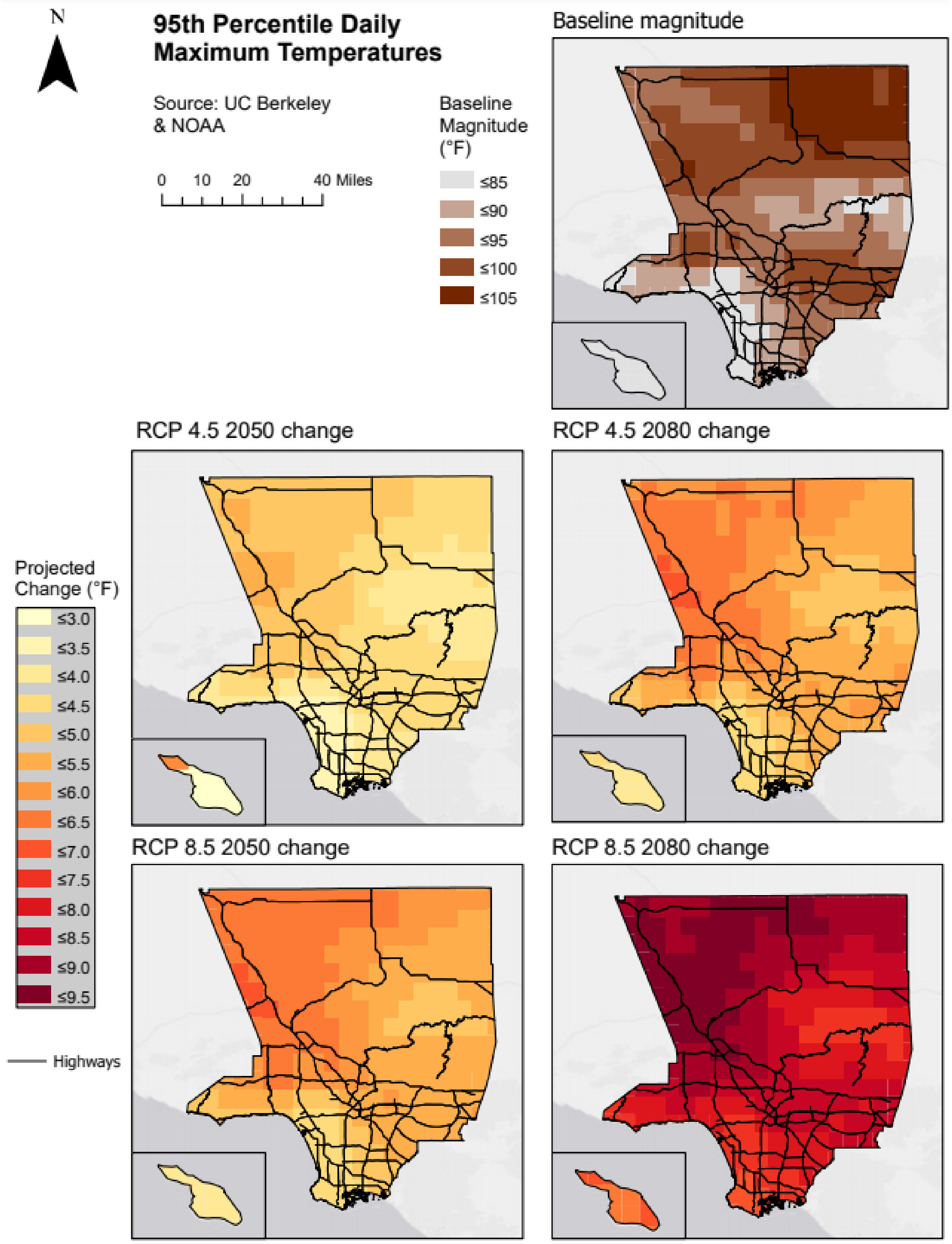

Figure 1. Projected change in the 95th percentile daily maximum temperature within LA County under RCP 4.5 and 8.5 by 2050 and 2080. This refers to the temperature threshold at which 95% of all days in a year have lower temperatures. An increase in this threshold corresponds with an increase in the temperature associated with some of the hottest days of the year. Projected changes are relative to historical baseline conditions (1976–2005).

Extreme temperatures are projected to increase in frequency and severity, with the largest increases occurring in the Santa Clarita and San Fernando Valleys. Figure 1 shows historical baseline and projected 95th percentile daily maximum temperatures – which measure "very hot" temperatures, or the temperature threshold at which 95% of all days in a year have cooler maximum temperatures – under RCP 4.5 and 8.5 scenarios. Using the 95th percentile reveals the relative severity of extreme heat across the County better than raw temperature change; for example, coastal locations of the County experience 95th percentile daily maximum temperatures of 85˚F, while the San Gabriel Valley experiences 95th percentile daily maximum temperatures of 100˚F.

Coinciding with recent warming trends, the entire County is projected to see large increases in extreme heat events through 2080, with more severe warming occurring under the RCP 8.5 scenario. The Santa Clarita Valley and the San Fernando Valley are projected to see increases in "very hot" temperatures of more than 6.5˚F and 9.5˚F (relative to a baseline of 95–100˚F) by 2050 and 2080, respectively, under the RCP 8.5 scenario. In contrast, "very hot" temperatures in coastal locations are projected to increase by approximately 4˚F and 7.5˚F (from a baseline of 85˚F) in 2050 and 2080, respectively, under the RCP 8.5 scenario. Humidity can exacerbate the impact of extreme heat, specifically in coastal locations.

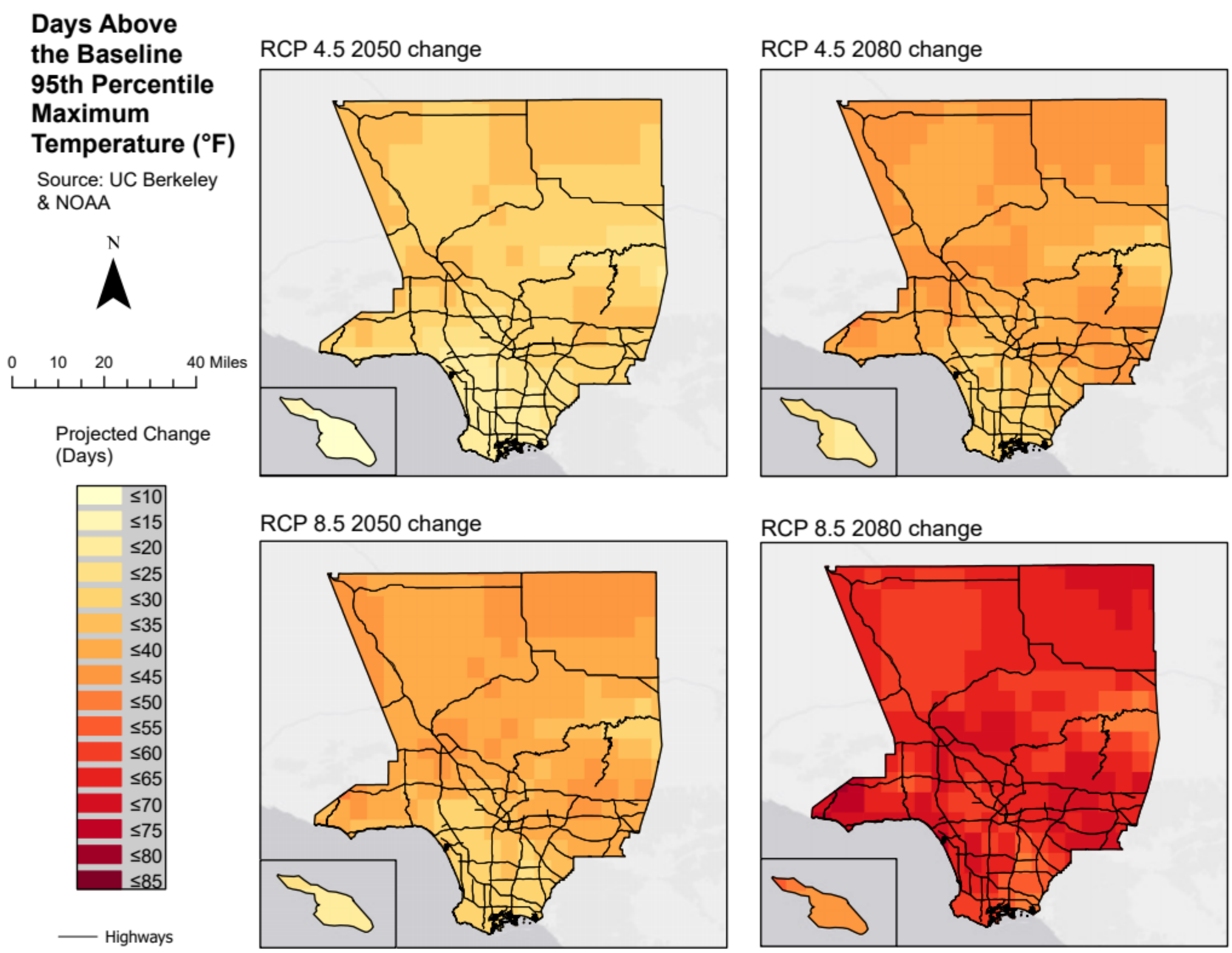

Figure 2. Projected change in the number of days above the baseline 95th percentile daily maximum temperature in LA County, under RCP 4.5 and RCP 8.5, for the years 2050 and 2080. Changes are relative to the historical baseline (1976-2005) value of 18.25 days per year at all locations.

Additionally, the number of days above the baseline 95th percentile temperature is projected to increase dramatically in many parts of the County (Figure 2). Projections reveal the largest increases in the San Fernando

Valley, Santa Clarita Valley, and San Gabriel Valley. By 2080, these locations could experience an additional 80 days per year with "very hot" temperatures. In comparison, the San Gabriel Mountains and coastal areas of the County are projected to see smaller increases.

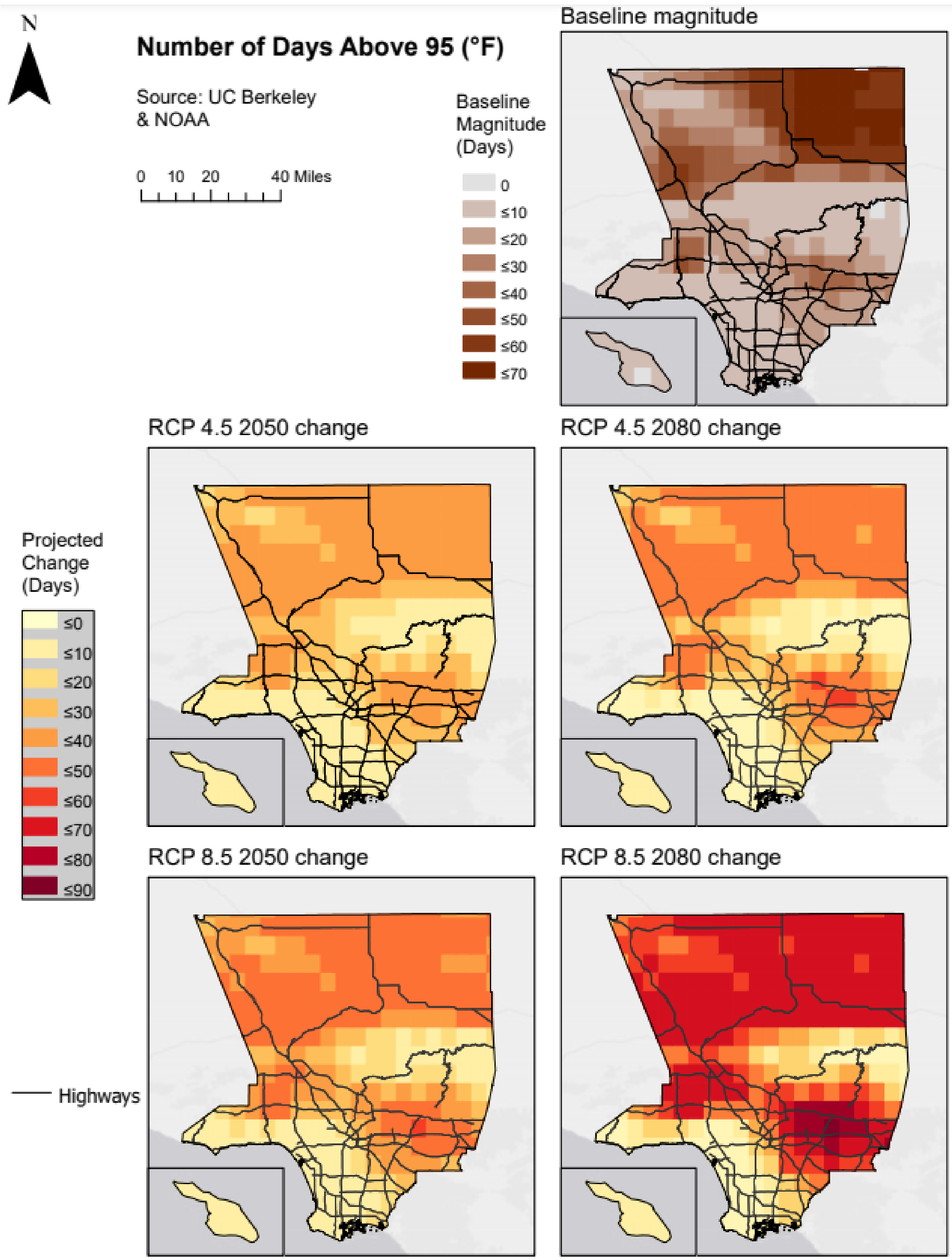

Figure 3. Projected change in the number of days per year above 95˚F in Los Angeles County, under RCP 4.5 and RCP 8.5, by 2050 and 2080. Projected changes are relative to historical baseline conditions (1976–2005).

Many parts of the County are also projected to see a significant increase in the number of days exceeding 95˚F, a temperature at which humans start to experience higher risk of heat illness and thus a common threshold for worker safety rules and determining when to open cooling centers (e.g., Figure 3) (California DIR, N.d.). The largest increases are projected to occur in the Antelope Valley, San Fernando Valley, and San Gabriel Valley. Historically, these locations already experience between 30 and 70 days per year above 95˚F. Projections indicate that by 2080, the Antelope Valley, San Fernando Valley, and San Gabriel Valley could experience between 65 and 85 additional days with temperatures exceeding 95 ˚F, resulting in more than 95 to 155 days per year with temperatures above 95˚F. In comparison, the San Gabriel Mountains and the coastal areas of the County currently experience fewer days above 95˚F and are projected to experience less dramatic increases.

Extreme Cold

Though projections for the Southwest show overall trends towards increasing temperatures, observations show that parts of Los Angeles County, including Antelope Valley and the San Gabriel Mountains, have experienced extremely cold weather in recent decades. This raises the question of whether climate change could increase the frequency or intensity of periods of cold weather, known as cold snaps, through the twenty-first century. Some research shows that California could experience more frequent anticyclone, or “high pressure,” atmospheric conditions because of climate change, which can lead to cold weather outbreaks (Garfin et al., 2013). In addition, other studies suggest that climate change may cause more frequent and persistent cold weather incursions in the northern hemisphere due to weakening polar vortex events, but underlying processes remain uncertain and in need of more research (Kretschmer et al., 2018, Kim et al., 2014). Though polar vortex events could occur anywhere in the continental United States, California is generally less susceptible because the jet stream and other factors typically keep the coldest Arctic air masses east of the state. Overall, occasional extreme cold events are likely to persist even with projected warming (Pierce et al., 2012).

Extreme Precipitation

Although annual total precipitation is not expected to change much in California, rainfall patterns are expected to change in the future, with drier springs and summers and wetter winters throughout the state. Moreover, precipitation may become more concentrated during short time periods, resulting in extreme rain events and heavier rainy seasons that occur after time periods of very dry weather (Swain et al., 2018).

Southern California experiences most extreme precipitation through atmospheric river events, which are streams of high water vapor that travel from the tropics (near Hawaii) to the Pacific Coast. Atmospheric rivers produce topographic-induced precipitation (snow at higher elevations and rain at lower elevations) along California’s mountain ranges that can result in severe flooding. These events typically occur in the winter and spring (November to April), and two to three times per year in the region. In 2016-2017, the County experienced a winter storm that was the strongest in several years, setting an all-time rainfall record at Long Beach Airport of 3.87 inches (Hamilton et al., 2017).

Climate change may increase the frequency, severity, and duration of atmospheric river events and extend their peak season, resulting in a projected 40% increase in precipitation during atmospheric river events by late-century under RCP 8.5 (Hall et al., 2018). The largest relative increases are projected to occur in valleys and mountain lee side (drier sides of mountains where rain does not typically fall) areas (Huang et al., 2020). Warmer temperatures may also mean that more precipitation will fall as rain rather than snow in high elevations, and that accumulated snow may melt faster; meanwhile, individual snow events may produce more snowfall due to more intense snowstorms (Pierce et al., 2018).

In addition, climate models reveal that the region may experience more volatile wet and dry extremes in the future. For example, projections show that the wettest day of the year may become 25-30% more intense under RCP 8.5 by late-century, while extremely dry years may also double in frequency (Hall et al., 2018). Furthermore, projections point to a future characterized by more frequent transitions (i.e., “whiplash”) between extreme dry-to-wet periods (Swain et al., 2018).

The findings in scientific literature discussed above are supported by climate projections developed for this assessment. Projections shown in Figure 4 and Figure 5 indicate that the frequency of heavy precipitation days may not change that much, but the amount of rainfall during those days could increase. It is important to note that there are limitations associated with precipitation projections used in this assessment. It is difficult to capture the full range of changes in precipitation patterns that may occur, since some precipitation-related impacts result from events that occur over sub-daily timescales that are not resolved by the climate models; a half-inch increase in rainfall during a 2-hour period is more significant than the same increase spread out over a 24-hour period. Similarly, consecutive extreme rainfall events are more significant than stand-alone events, as are extreme rainfall events that occur immediately after very dry conditions. Finally, since there is more variation in precipitation projections than for temperature, the averaging of models and years can mute the resolution of extreme values. Still, as shown in Figure 4 and Figure 5 below, the LA County region is projected to experience more severe extreme rainfall events in the future as a result of climate change.

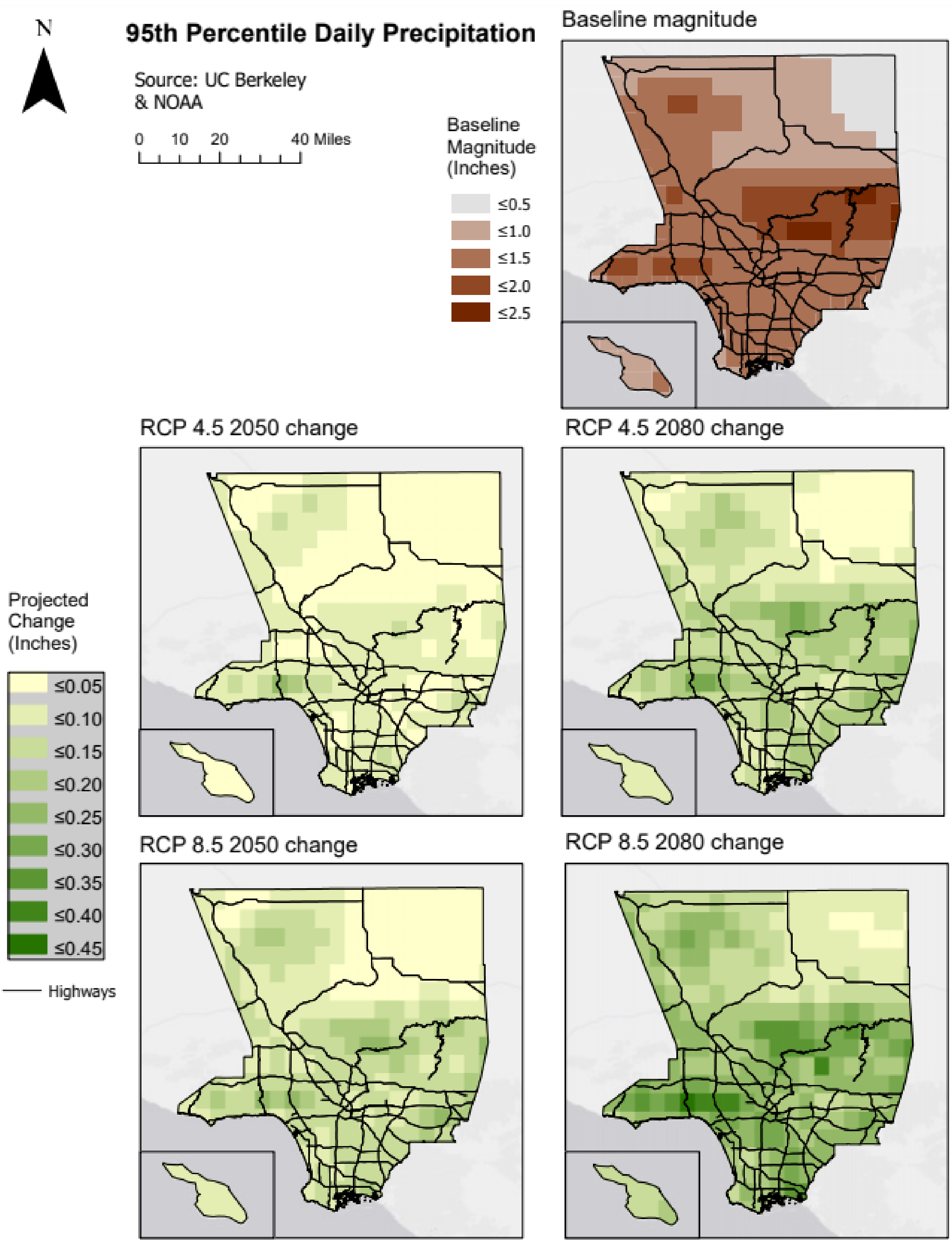

Figure 4: Projected change in the 95th percentile precipitation amount within LA County under RCP 4.5 and 8.5 by 2050 and 2080. This refers to the rainfall threshold at which 95% of all rain days in a year have smaller amounts of precipitation. An increase in this threshold corresponds with an increase in the amount of rain associated with some of the wettest days of the year. Projected changes are relative to historical baseline conditions (1976–2005).

Figure 4 shows historical baseline and projected 95th percentile daily precipitation – which measure “very wet” precipitation events, or the precipitation threshold at which 95% of all rain days in a year have smaller amounts of precipitation – under RCP 4.5 and 8.5 scenarios. Historically, mountain areas have received the most rainfall in the County. The San Gabriel Mountains experience nearly 2.7 inches of rainfall during “very wet” events (Figure 4). In comparison, locations within the Santa Monica Mountains, near Castaic Lake, and the central area of the City of Los Angeles receive approximately 1.6 inches during such events, while areas near the City of Lancaster and the City of Palmdale receive less than 0.8 inches.

Similarly, the greatest change in “very wet” precipitation events within the County are projected to occur within the mountains (Figure 4). The Santa Monica and San Gabriel Mountains, as well as the eastern border of the County are projected to experience a 10% increase in the amount of precipitation associated with “very wet” events by 2050 and 2080 under RCP 8.5 and RCP 4.5, respectively. Much of the southern half of the County is projected to experience a 10-15% increase by 2080 under RCP 8.5, with up to a 20% increase in mountains. In comparison, the smallest projected increases are in the areas near the City of Lancaster and the City of Palmdale.

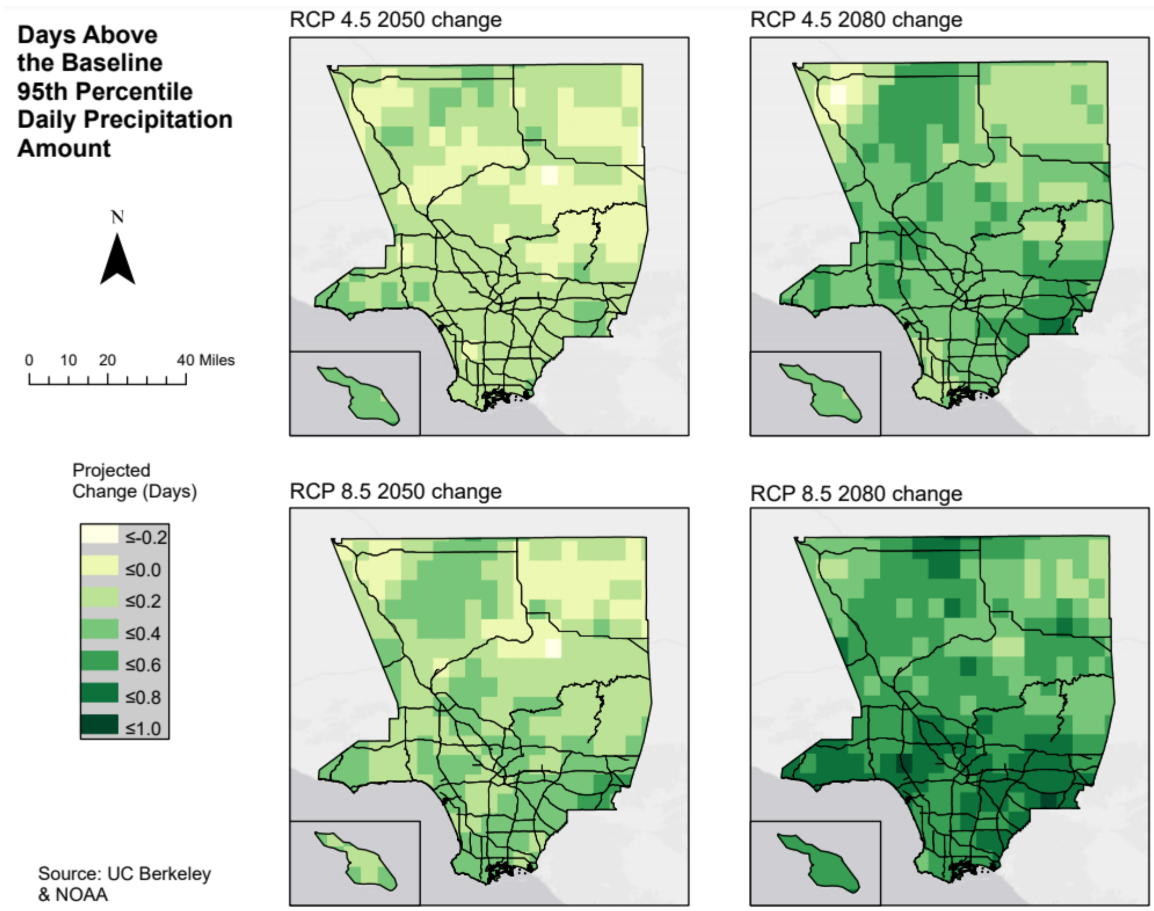

Figure 5: Projected change in the number of rainy days above the baseline 95th percentile precipitation amount, under RCP 4.5 and RCP 8.5, by 2050 and 2080. Changes are relative to the historical baseline (1976-2005); because the number of rainy days varies by location, the baseline value also varies. In LA County the baseline value varies between 2 and 5 days per year.

While the severity of heavy precipitation is projected to increase, there is relatively little change in the frequency of "very wet" days through 2050 under both RCP scenarios (Figure 5). Increases are largest through 2080, although even in that case the County is projected to experience only an additional half-day of heavy rainfall per year under RCP 8.5 relative to the historical baseline.

Wildfire

Hot and dry summer weather in combination with a fire-susceptible landscape often create severe wildfire conditions across the County. The predominant vegetation type across the County is chaparral – an ecological community composed of mostly evergreen shrubs with thick, leathery leaves and stiff branches that are adapted to dry summers and moist winters -and is particularly susceptible to severe wildfires, as the vegetation is highly dense and extremely flammable during dry periods of the year (California Chaparral Institute N.d.). Expanses of chaparral shrub, in conjunction with the build-up of other dry, dead vegetation, serve as reservoirs of wildfire fuel (Hall et al., 2018). The prevalence of wildfire fuel, coupled with past fire suppression efforts, diverse topography, an expansive Wildlife-Urban Interface,[2] and hot, dry summers followed by the low-moisture and strong Santa Ana Winds in the fall, can combine to create severe wildfire conditions across the County (Hall et al., 2018).

The County has recently experienced large and destructive wildfires. The two largest wildfires in Los Angeles County history, the Station Fire (2009) and the Bobcat Fire (2020) (LA Almanac, 2020), occurred in the San Gabriel Mountains and the foothill areas. The Station Fire killed two firefighters, burned 160,557 acres of land – almost 25% of Angeles National Forest – and consumed 89 homes (Thompson et al., n.d.). The Bobcat fire (still ongoing at time of writing) has burnt over 115,000 acres of land and damaged or destroyed over 200 structures (InciWeb, 2020). Other recent fires include the 2018 Woolsey Fire, which burned 96,949 acres and destroyed 1,643 structures (County of Los Angeles, 2019).

[2] The Wildland-Urban Interface refers to the zone between unoccupied wildland and human development, which is particularly vulnerable to impacts from wildfires.

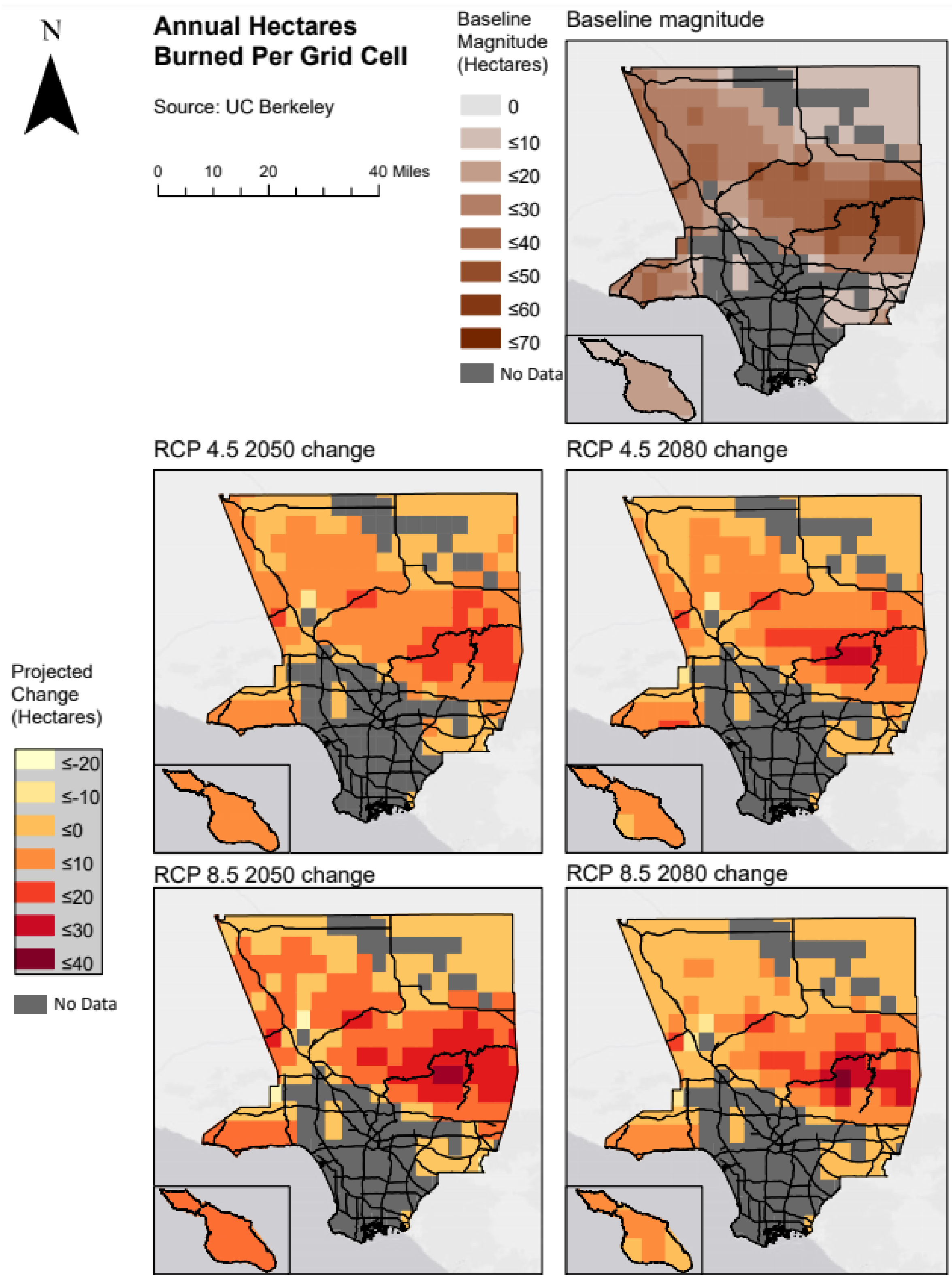

Figure 6. Projected change in annual hectares burned by wildfire per grid cell under RCP 4.5 and 8.5 by 2050 and 2080. Projected changes are relative to historical baseline conditions (1976-2005).

The San Gabriel Mountains, largely covered by the Angeles National Forest, has the highest degree of wildfire risk (Figure 6). In response to warming temperatures and more intense and prolonged periods of drought, this mountain range is projected to see the largest increases in wildfire risk within the County through 2050 and 2080 under both RCP scenarios. On average, the San Gabriel Mountains are projected to experience an increase in wildfire burn area of approximately 40% and 50% in 2050 and 2080, respectively, under the RCP 8.5. The most at-risk locations within the mountain range are projected to experience an increase in burn areas of 50% and 65% in 2050 and 2080, respectively, under the RCP 8.5.

Projections by Jin et al. (2015) also reveal large increases in wildfire occurrence and burned area in the County and greater Southern California (Jin et al., 2015). That study projects an overall increase in burned area of 77% and 64% for Santa Ana Winds-driven fires and non-Santa Ana Winds fires, respectively. Jin et al. (2015) find larger increases compared to other studies in part because it more explicitly resolves wind dynamics, which are important to the development of large wildfires. High winds provide oxygen that fuels rapid wildfire growth and also carry embers far distances, which can ignite surrounding areas. Although their remains a need to improve wildfire modeling, the totality of projections across studies reveals a future defined by considerably larger, more frequent, and destructive wildfires.

Coastal Flooding

Much of the LA County coastline is characterized by wide, sandy beaches and high-rising, steep cliffs (Hall et al., 2018). Sea level rise poses a risk to low-lying areas of the County and exacerbates inundation during high tides and coastal storms. Additionally, sea level rise may result in rising inland water tables (i.e. "shoaling"), especially in areas with shallow groundwater, increasing severity of flooding (Befus et al., 2020). Coastal flooding events may become more frequent and severe even with small increases in sea level.

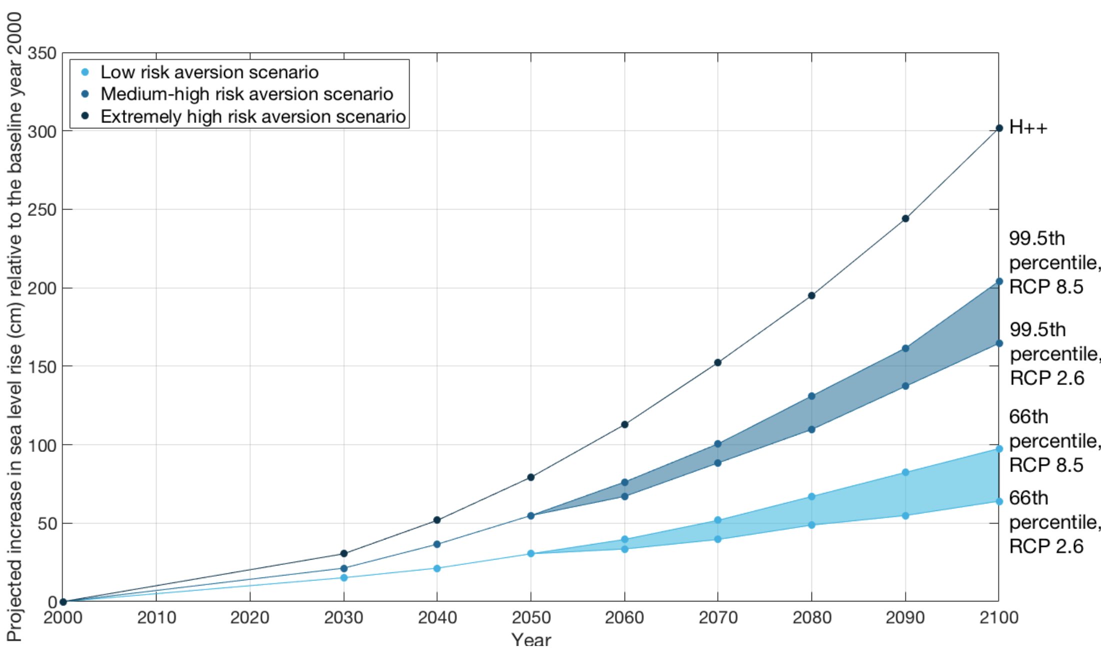

Figure 7. Projected sea level rise in LA County under the low, medium-high, and extremely high-risk aversion scenarios. Projections are quasi-probabilistic across an ensemble of Global Climate Models, with higher percentiles representing larger increases in sea level rise. Projections consider RCP 8.5 and RCP 2.6 to bookend the range of plausible change. Data source: California State Sea Level Rise Guidance

Recent sea level rise in Southern California has occurred at a rate of approximately 2 centimeters (0.8 inch) per decade, which is consistent with increases in Global Mean Sea Level (Cayan et al., 2008). Ocean thermal expansion has been the most prominent contributor to sea level rise, followed closely by mass loss from the Greenland Ice Sheet and the Antarctic Ice Sheets, as well as ice caps and glaciers (Hall et al., 2018).

Sea level rise within the County is projected to accelerate through the 21st century (see Figure 7) (CO-CAT, 2018). Under the State's extreme sea level rise scenario,[3] sea level is projected to rise by approximately 0.75 meter (2.5 feet) and 2 meters (6.6 feet) by 2050 and 2080, respectively, relative to baseline. Projections under the State's medium-high risk aversion scenario are smaller, with sea levels expected to reach 0.5 meter (1.6 feet) and 1.25 meters (4.1 feet) above baseline in 2050 and 2080, respectively, assuming RCP 8.5 (Figure 7).

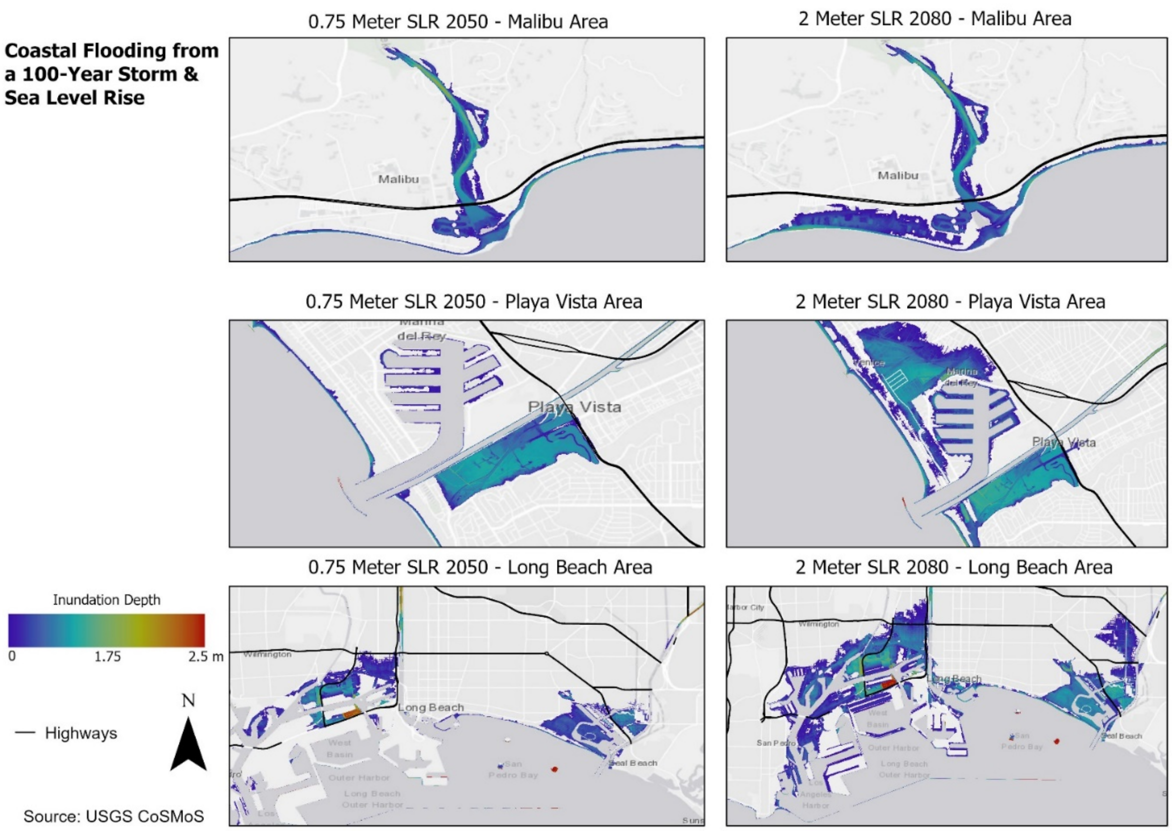

Figure 8. Projected inundation from 0.75 m and 2 m of sea level rise coupled with a 100-year storm event in three high-exposure locations along the LA County coastline. Data Source: USGS Coastal Storm Modeling System (CoSMoS)

Figure 8 displays three communities in the County that are particularly exposed to sea level rise and coastal flooding. The figure shows floodplains associated with 0.75 meter and 2 meters of sea level rise combined with a 100-year storm event as simulated by the USGS Coastal Storm Modeling System (CoSMoS) (Barnard et al., 2018), which integrates dynamic coastal processes with relevant storm physics and projected sea level rise.[4] Under the

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[3] The California State Sea Level Rise Guidance details the H++ scenario, which is an extreme sea level rise scenario that assumes accelerated mass loss from the West Antarctic Ice Sheet over the 21st century.

[4] A 100-year storm event is expected to occur once every 100 years, and thus has a 1% chance of occurring in any given year.

extreme sea level rise scenario combined with a 100-year storm event, communities and infrastructure along Malibu Beach, Malibu Lagoon, and Malibu Creek are projected to experience up to 1 meter (3.3 feet) of inundation in 2080. Under the same scenario, the Playa Vista neighborhood in the City of Los Angeles is projected to experience 1 meter of flooding throughout both the Ballona Wetlands Ecological Reserve and the Venice and Oakwood neighborhoods in the City of Los Angeles. City of Long Beach may see up to 2.5 meters (8.2 feet) of inundation throughout the Long Beach Port, and more than 1 meter of inundation in the southern portions of its Westside neighborhood, as well as the Wilmington neighborhood in the City of Los Angeles.

Inland Flooding

Inland flooding in the County most often occurs due to heavy precipitation events or flash floods caused by intense rainfall after a dry period. Flood-prone zones include low-lying areas where heavy rainfall can collect, areas within river floodplains or adjacent to drainage systems, and areas with inadequate storm drain infrastructure. Flooding in riverine areas occurs when excessive rainfall makes a river exceed its capacity, causing water to overflow and inundate nearby locations. Excessive rainfall in areas with poor drainage may also cause localized flooding. The 2016-2017 winter storms resulted in widespread flooding and a flash flood warning along roads and freeways due to inadequate drainage (Hamilton et al., 2017).

Inland flooding will likely increase in the future as a result of changes in extreme weather, such as heavy precipitation and downpours. Atmospheric river events drive much of the flooding in the region and are projected to produce nearly 40% more rainfall by the end of the 21st century (Espinoza et al., 2018). Models project an increase in high intensity hourly rainfall during extreme atmospheric river events, which are primary drivers of dangerous flash flood events (Huang et al, 2020). In addition, increasing urbanization has already exacerbated flood risk in the County and the continuation of this trend may worsen future floods (Hall et al., 2018).

Projections are not available for inland flooding. As a proxy, the County evaluated current 100- and 500-yr flood zone maps, as defined by the Federal Emergency Management Agency (FEMA) and made available through the Public Works' Flood Zone Determination Website (PW Los Angeles County, 2020.).[5] Although these maps represent present day risks, the flood zones indicate the areas that are most likely to flood first, or more frequently, as the climate changes. Areas outside FEMA flood zones that flood frequently due to poor drainage are also likely to become more frequently flooded in the future.

[5] A 100-year flood is expected to occur once every 100 years, and thus has a 1% chance of occurring in any given year. Similarly, 500-year floods have a 0.2% chance of occurring in any given year and highlight that more extensive flooding is possible during the most extreme flooding events.

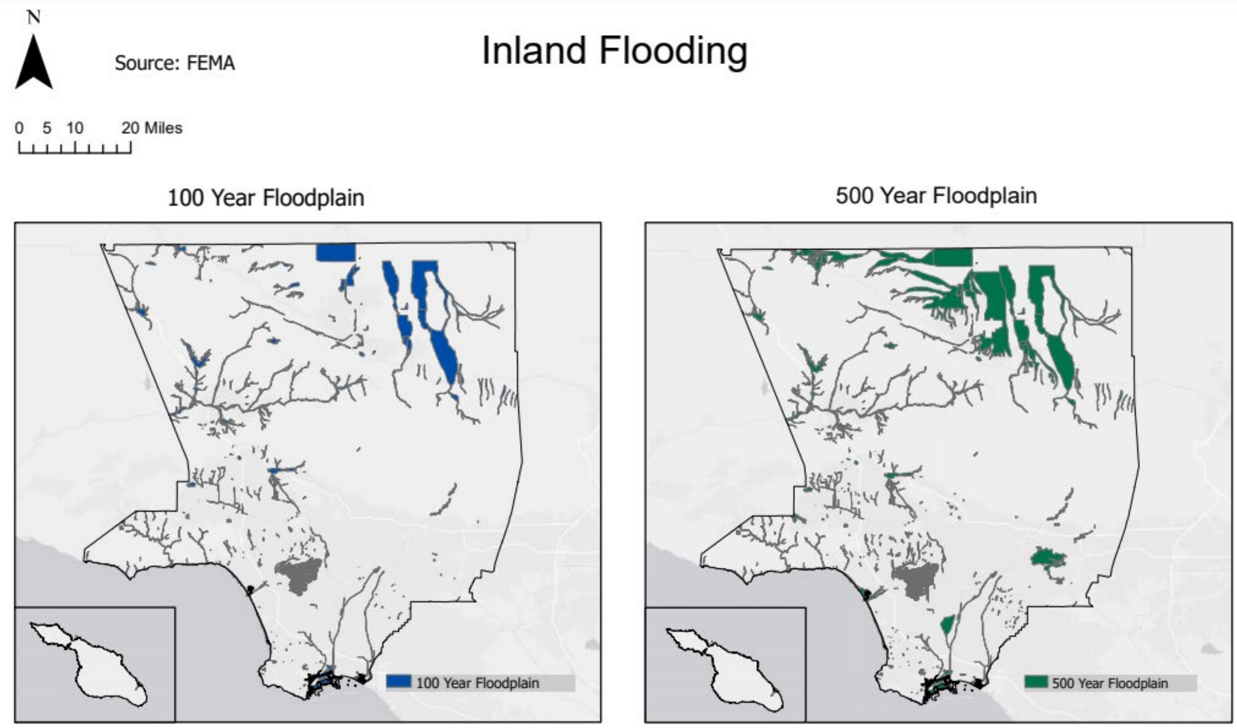

Figure 9: FEMA 100-year (light blue) and 500-year (green) flood zones in LA County. Dark blue outline represents the County boundary. Source: PW Flood Zone Determination Website.

Both 100-year and 500-year flood zones occur sporadically in the central area of the City of Los Angeles and adjacent unincorporated areas and cities, covering much of South Los Angeles and Downtown (Figure 9). 100-year flood zones occur most frequently along rivers and in mountains, with larger zones existing in the areas east and north of the City of Lancaster and the City of Palmdale that don't appear to be associated with a large water body. Also, 500-year flood zones occur along rivers, while larger zones occur within the City of Lancaster and the City of Palmdale and in the northwestern areas of the County.

Drought

Drought is a regional hazard that is projected to occur more frequently and severely, as well as become more prolonged, within the southwestern United States. Climate change is projected to increase the likelihood of coincident low-precipitation and warm years throughout California, which increases the risk of severe droughts (Hall et al., 2018). The most consequential droughts are those that manifest over a prolonged period of time. Over the southwestern United States, climate models project more than a 65% increase in the chance of a multidecadal drought, or a "megadrought," in 2050-2099 relative to the period between 1950-2000 under RCP 8.5 (Cook et al., 2015).

California is projected to see particularly pronounced increases in drought risks. For example, the current 20th and 5th percentile dry years are projected to increase in frequency to occur 22% and 8% of the time, respectively, by 2050 under RCP 4.5. Increases are larger under RCP 8.5, with the 2nd and 1st percentile dry years projected to more than double in frequency to occur about 4% and 3% of the time by 2050 (Pierce et al., 2018).

While average precipitation in California is not projected to change significantly, annual variability is expected to increase, with drier springs and summers and wetter winters. The increase in frequency of both wet and dry extremes results in a projected 25-100% increase in extreme dry-to-wet precipitation events, or precipitation whiplash, making the drought-flood cycle more dramatic (Swain et al., 2018).

Environmental Conditions

This section provides a qualitative assessment of climate change impacts on environmental conditions, which further stress human and natural systems within the County. For this assessment, the County focused on the following primary environmental conditions: air quality, water supply and quality, biodiversity, vectors, mud and landslides, and extreme cold. Many of these environmental conditions have already worsened as a result of climate change. Understanding this and the impacts of climate change that will occur in the future helps guide adaptation and resilience planning.

Air Quality

Climate change is projected to exacerbate poor air quality in the Los Angeles region, which already experiences some of the worst air quality in the country. Ozone and particulate matter are the primary air pollutants in the region. High temperatures increase ozone production and rates of biogenic emissions, which increases ground-level ozone concentrations. Production of ozone is driven by photochemical responses that are sensitive to temperature and which interact with NOx and VOCs; when NOx concentrations are high, ozone concentrations are sensitive to VOCs (Sillman and Samson, 1995; Steiner et al., 2006). The flux of biogenic VOC emissions is determined by biomass as well as light and temperature; some BVOCs increase exponentially with temperature up to about 95-104 degrees F (Steiner et al., 2006). By 2050, ozone concentrations in Los Angeles could increase up to 5-10 parts per billion (ppb), and the number of days with ozone over 90 ppb (which is unhealthy for sensitive populations) could increase to 22-33 days (Hall et al., 2018).

Increases in wildfire activity may also result in higher particulate matter concentrations, particularly PM 2.5 (particulate matter smaller than 2.5 micrometers), which exacerbates human respiratory illnesses (Liu et al., 2018). Wildfire smoke may also affect communities outside of wildfire risk zones as wind helps smoke travel. A study researching wildfires from 2002-2013 found that air quality in urban areas that are 50-100 miles away from fires were often 5-15 times worse than usual (Hall et al., 2018). Thus, while many parts of LA County are not within projected high-risk zones for wildfire, they may still face more severe air quality impacts in the future from wildfires.

Other climate change hazards may have impacts on air quality. Extreme precipitation may lead to excess moisture in homes, potentially worsening indoor air quality through increased mold production. Increasing frequency and severity of drought may also dry out soils and increase dust levels, which can exacerbate human respiratory illnesses (Public Health Institute and Center for Climate Change and Health, 2016).

Water Supply and Quality

Climate change impacts water resources in the County. In 2017, nearly 33% of the County's water was sourced from Metropolitan Water District (MWD)'s imported sources, 32% from local groundwater and surface reservoirs, 9% from local recycled water, and 26% from the Los Angeles Aqueduct, which transports water from the Owens Valley to the City of Los Angeles (UCLA et al., 2018). MWD's imported water comes through two primary sources: the California Aqueduct, which transports water south from Northern California and the San Joaquin Delta, and the Colorado River Aqueduct, which transports water west from Lake Mead (UCLA et al., 2018).

Projected increases in temperatures, drought, and sea level rise present risks to the water supply in the County. Future changes to snowpack in the Sierra Nevada mountains will affect water supply in Southern California as snowmelt is a main contributor to Northern California rivers and the Bay Delta (Hall et al., 2018). Snowpack in the Sierras may largely disappear below 6,000 feet by 2070-2100, particularly in the northern portions of the mountain range, reducing mountain system recharge (Meixner et al., 2016). April snow-water equivalent (SWE), which is an indicator of water resources due to its role as a seasonal storage reservoir, may decrease up to 80% by 2036-2065, with more dramatic changes in the northern mountains (Pierce et al., 2018). Sea level rise may also result in saltwater intrusion in the San Joaquin Delta, reducing freshwater supplies from this water source. In addition, multiple climate hazards are projected to impact reservoirs and rivers that feed into the County's water. For example, increased temperatures may drive evaporation and decrease the amount of water available, extreme precipitation events can bring operational risks, and drought may decrease the amount of overall rainfall that goes into these water resources (UCLA et al., 2018; Hall et al., 2018).

An increased frequency and intensity in drought that reduces the availability of other water resources may increase use of groundwater; if not handled in a sustainable way, this overdraft could permanently reduce groundwater capacity (Stokstad, 2020). Water availability for recharge via spreading grounds may also be impacted by water management responses to reduced water availability.[6] These impacts may threaten the water supply of the 79 community water systems that are 100% dependent on groundwater for drinking water; most (48) of these community water systems are very small (defined as serving 25 to 500 people) (UCLA Luskin Center for Innovation 2015). On the other end of the climate extreme, greater frequency and severity of extreme precipitation may overwhelm stormwater capture systems, which may not have the capacity to manage and capture runoff, resulting in reduced capacity for recharge of groundwater basins. Sea level rise may increase the potential for saltwater intrusion into coastal groundwater basins, including the Santa Monica Basin and West Coast Basin (UCLA et al., 2018).

Climate change may also worsen water quality. Decreases in precipitation from drought could increase the concentration of pollutants and salinity in streams, reservoirs, and groundwater, while extreme precipitation events may result in flooding that could transport more contaminants to surface waters (Smith et al., 2015). More frequent and larger wildfires may increase sediment flows or deposit toxins and suspended particulate matter in surface waterways (Meixner et al., 2004; Smith et al., 2015). Furthermore, higher temperatures in lakes and reservoirs may potentially remove dissolved oxygen, lead to excess nutrients, and alter rates of stratification, as well as change water chemistry and promote the growth of bacteria, algae, and parasites (Melilo et al., 2014; Duran-Encalada et al., 2017; Major et al., 2011).

Biodiversity

The County predominantly features a Mediterranean climate and encompasses a range of ecosystems, including desert, mountain, and coastal zones (University of California ANR, N.d.(a)). There is high biodiversity, with more than 4,200 distinct species (over 1,200 of which are native), and even the most urbanized land types containing over 200 native species (LA County, 2020; NHM and TNC, 2019). The number of bird species is highest in wetlands and urban parks, as well as mountainous areas, which can see up to 97 bird species per 10 by 10 kilometer grid area (NHM and TNC, 2019; UCLA Grand Challenges, 2020). Several parts of the County also have a high urban tree species richness, with 40–60 tree species found in Rancho Palos Verdes, Pasadena, cities surrounding the Santa Monica Mountains, and cities on the northeastern border of the County (UCLA Grand Challenges, 2020). Native plant species like the California poppy and Joshua tree have become iconic parts of the desert in the County's more rural northern half, while residents in the County's more urban or suburban areas may have become more familiar with California ground squirrels and coyotes (UCLA Grand Challenges, 2020). The County already faces some threats to its biodiversity, such as invasive species; the shot hole borer, for example, is responsible for a tree disease that has attacked over 260 tree species and killed hundreds of thousands of trees in Southern California (UCLA Grand Challenges, 2020).

[6] From November 18, 2020 meeting with Department of Public Works for this study

Climate change will increasingly pose risks to the vegetation within the County. Changes in temperature and precipitation could threaten vegetation that is uniquely adapted to this climate, particularly endemic or endangered species, and these changes introduce potentially important consequences for regional fire regimes. Drought has decreased vegetation greenness for chaparral and coastal sage scrub, and this trend will likely continue in the future. Drought also triggers water management strategies that reduce irrigation availability for vegetation. The County's Department of Parks and Recreation has noted extensive loss to trees due to this.[7] An increase in the frequency and intensity of wildfires is also detrimental to vegetation. For example, more frequent fires may cause non-native grasslands to replace native shrubs; these non-native grasses are more efficient wildfire fuel and may further increase fire frequency, in a destructive feedback cycle (Hall et al. 2018). Many native plant and animal species, such as species of California lilac, cypress, pine, and coastal sage scrub, also face threats from overly frequent fires (LA County, 2018).

Endangered and endemic plant species are especially vulnerable to climate change. About two-thirds of California's endemic species may experience more than an 80% reduction in their geographic distribution and almost half of the protected land area currently containing endemic species may be devoid of them by mid-century under RCP 8.5 (Hall et al. 2018). Climate change will also shift many endangered plant habitats northward or to higher elevations, fundamentally shifting the region's biodiversity landscape.

Sea level rise threatens wetlands that serve as spawning and nursery grounds for fish and invertebrates and resting areas for migrating wildfowl. As a result of sea level rise, 12% of vegetated marsh and flats could disappear by 2050, and up to 48% by 2100 (Hall et al. 2018). In addition to serving as habitats for endangered species, wetlands and marshes also provide ecosystem services to humans, such as long-term carbon storage.

In the oceans surrounding the County, increasing temperatures may shift fish populations northward, introducing more subtropical species into the region (Hall et al. 2018). Increased temperatures, ocean acidification, and low-oxygen zones may result in a decline in biodiversity, particularly for mussel beds and rockfish.

Vectors

Climate change will impact the prevalence, seasonality, and geographic distribution of vector-borne illnesses throughout LA County.

Warming temperatures and more intense rainstorms as a result of climate change create conditions conducive to the proliferation of mosquitos, potentially increasing the prevalence of West Nile Virus (WNV) throughout the County (Hall et al., 2018). After the first appearance of WNV in 2003, the County experienced major outbreaks in 2004, 2008, 2014, and 2015, and suffered a record number of fatalities from WNV in 2017 (Kluh et al., 2010; LA County Public Health, 2016). However, the number of WNV cases in people have declined between 2017 and present, and other factors besides climate contribute to WNV infection rates, such as availability of mosquito habitats and immunology of bird populations (Montgomery and Murray, 2015).

Increasing temperatures and precipitation provide favorable conditions for invasive Aedes mosquitos, which are vectors for dengue fever, Zika virus, and chikungunya virus elsewhere in the world, though these viruses are not currently endemic in LA County. Aedes mosquitos first appeared in the County in 2011 (LA County Public Health, 2016; CA Department of Public Health, n.d.) and are now found in most communities. Climate change will likely continue to facilitate the spread of Aedes mosquitos, though it is unclear to what extent this will occur in the Los Angeles region (Campbell et al., 2019).

[7] From November 5, 2020 meeting held with Department of Recreation for this study

Mudslides and Landslides

Southern California has historically been susceptible to large mudslides and landslides. Mudslides are a type of landslide that contain significant amounts of water and rapidly surge down hillsides. These events are sometimes induced by earthquake activity, but are more frequently triggered by extreme precipitation, especially following wildfire events (USGS, n.d.).

Future changes in precipitation patterns, coupled with more frequent and severe wildfires, are projected to increase landslide risks across the County. Climate models indicate that the region will experience more intense and prolonged periods of rainfall in the future, which work to saturate soils and trigger mudslides and landslides (Kirschbaum et al., 2018). These risks are exacerbated by wildfires. Wildfires produce an impermeable layer of ash and hydrophobic soils. Runoff from heavy precipitation in these areas is more likely to flow along the ground, picking up sediment and debris rather than penetrating into the subsurface, contributing to mudslides (USGS, n.d.; Hall et al., 2018). Mudslide and landslide susceptibility is highest within mountainous and high angle terrain of the County.

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