Climate Variable	Trend	Relative Change by 2100	Observed Change	Projected Change	Confidence	Uncertainty (trend direction, magnitude)
Air temperature[1-6]	↑	High	**All Islands** > From 1975-2006, the rate of temperature increases accelerated to 0.29°F/decade (compared to 0.79°F/decade from 1919-2006), with the largest increases in winter low temperatures > Since 1975, higher elevation sites (>800 m) warmed faster (0.49°F/decade) than low elevation sites (0.16°F/decade)	**All Islands** *Mean annual temperature* > By 2021-2050: increase of +1-2°F > By 2041-2070: increase of +1-3°F > By 2070-2100: increase of +2-5°F (up to +6.1-6.3°F in higher elevations, +3.6-4.5°F in lower elevations *Heat waves* > Extreme heat days are expected to become more frequent and more intense	High	> High certainty that temperatures will increase > The amount of increase is somewhat uncertain because global climate models have a wide range of possibilities for this region, and the amount of increase expected depends on which emissions scenario is used
Precipitation (amount and timing)[3,5-6,7-9]	↑↓	Low to High	**All Islands** > Since 1970, downward trend in winter precipitation since 1970 > From 1913-2008, downward trend in dry season (July-Sept) precipitation at high rainfall (>3000 mm) and moderate rainfall (800-3000 mm) stations > La Niña events have historically been correlated with higher precipitation while El Niño events have been correlated with lower precipitation, and correlations have been magnified by changes in the PDO phase; however, in the last decade there has been a decoupling of these modes and precipitation patterns	**O‘ahu** Multiple possibilities for precipitation differ in direction and magnitude of change: > Slight decrease or no change in precipitation by 2071-2099 *(Keener et al. 2013)* > Increased rainfall on windward sides and decreased rainfall on leeward sides by 2099 *(Hamilton 2013)* > Moderate decrease in precipitation *(Timm et al. 2015):* > > By 2041-2071: -14 to -16% (wet season), -14% to -18% (dry season) > > By 2071-2099: -16% to -22% (wet season), -16% to -28% (dry season)	Low	> Precipitation is highly variable depending on location > Studies have made very different projections, disagreeing on both the direction and magnitude of change (e.g., whether precipitation will increase or decrease, and by how much) > Factors such as the emissions scenario and climate models chosen, study methodology, geographic region included, and data resolution all contribute to differences in precipitation projections > > Not all models consider large-scale climate variability (e.g., El Niño) and possible changes in the trade winds > > Models with low resolution may not account for steep island topography

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Climate Variable	Trend	Relative Change by 2100	Observed Change	Projected Change	Confidence	Uncertainty (trend direction, magnitude)
Precipitation (extreme events)[5,10-16]	↑↓	Low to Medium	**All Islands** *Extreme precipitation events* > From 1980-2100, decreased frequency of moderate- and high-intensity extreme events and increased frequency of low-intensity events (compared to 1950-1979) > Trends are likely caused by natural variability associated with El Niño/La Niña events *Tropical cyclones* > 1966-1981: Relatively low activity (mean of 1.88 cyclones/year) > 1982-1994: Increase of 3.45 cyclones/year compared to 1966-1981 (mean of 4.31 cyclones/year) > 1995-2000: Decrease of 2.22 cyclones/year compared to 1982-1994 **Oʻahu** *Extreme precipitation events* > Since 1950, intensity and frequency of extreme events has decreased in recent years > This trend may be reversing direction with more frequent extreme precipitation events occurring in recent years > From 1960-2009, annual maximum 1-day precipitation volume decreased	**All Islands** *Extreme precipitation events* At least two possibilities differ in direction and magnitude of change > Reduced frequency of extreme precipitation events by 2100, with greater reductions in dry areas *(Timm et al. 2011)* > Little change in the frequency of extreme precipitation events *(Takahashi et al. 2011)* *El Niño events* (by 2090) > Slight decrease in the number of El Niño events (compared to 1891-1990) > Extreme El Niño events twice as likely to occur (from one event every 20 years to one event every 10 years) > No change in spatial pattern of El Niño events *Tropical cyclones* > Increased frequency and strength of tropical cyclone activity around the Hawaiian Islands	Low	> Climate models disagree about whether extreme events will become more or less frequent/severe, but most models predict a decrease in frequency and an increase in intensity > Changes may vary by location and the type of event (e.g., tropical cyclone, El Niño event, etc.) > Changes in the frequency/severity of extreme events are heavily impacted by topography, and will likely be impacted by changes in the trade winds > The frequency and severity of extreme precipitation events and tropical cyclones are highly variable, and are influenced strongly by natural climate variability (e.g., cycles of El Niño Southern Oscillation [ENSO] and Pacific Decadal Oscillation [PDO])
Drought[5,12,17]	↑↓	Medium	**All Islands** > Increased drought length in 1980-2011 (compared to 1950-1979) > Drought conditions are usually less prevalent during La Niña years, and more prevalent during El Niño years	**Oʻahu** By 2080-2100: > Increased risk in low-elevation leeward areas > Decreased risk at the highest elevations > No change in risk in other areas	Low	> Drought projections are closely related to those for precipitation, which are very uncertain > Few studies have projected drought risk, and background information is unavailable on the methodology for Keener et al. 2012 and Takahashi et al. 2011

Climate Variable	Trend	Relative Change by 2100	Observed Change	Projected Change	Confidence	Uncertainty (trend direction, magnitude)
Streamflow[7,18-20]	↓	Medium to High	**All Islands** From 1943-2008 (compared to 1913-1943): > 22% decline in streamflow (19% wet season, 27% dry season) > 23% decline in baseflow (22% wet season, 27% dry season) > Increased high-flow variability (especially Jan-March) > Shift towards more days with low-flow conditions and fewer days with high-flow conditions > Jan-March streamflow is typically low following El Niño events, and high following La Niña events; this pattern is enhanced during positive PDO phases	**All Islands** If mean annual rainfall decreases within a given watershed, it is likely that: > Low flows would become lower, and streamflow/baseflow would continue to decline > Flows would become more variable and more unstable ('flashy'), especially in wet years **O'ahu** Leeward coast by 2100 (Makaha watershed study area): > Annual: Decrease of -6.7% to -17.2% > Wet season: Decrease of -9.6% to -21.2% > Dry season: Increase of +1.7% to decrease of -5.3%	Low	> Streamflow is closely related to changes in both precipitation and temperature, but is also impacted by land cover and vegetation composition, substrate, groundwater withdrawals, and management practices > Increases in CO_2 could alter vegetation processes, all of which could also alter streamflow; these include evapotranspiration rates, leaf area, and stomatal conductance
Stream temperature[21-23]	↑	Unknown	**All Islands** > No information is available about stream temperature trends > Stream temperatures are lower in forested areas compared to urban areas > Stream temperatures are lower in the wet season than during the dry season	**All Islands** > No stream temperature projections for this region are available. **United States (mainland only)** > In the contiguous U.S., stream temperatures may increase by an average of 2°–5°C	Low	> No regional studies have been published on the impacts of climate change on stream temperatures, but researchers generally agree that stream temperatures will increase as air temperature increases > Several studies have compared forested vs. urban sites and dry vs. wet seasons > Studies of temperate streams may not be generalizable to tropical Hawaiian streams

Climate Variable	Trend	Relative Change by 2100	Observed Change	Projected Change	Confidence	Uncertainty (trend direction, magnitude)
Sea level rise[24-31]	↑	High	**All Islands** *Extreme sea level events* > Extreme sea level events result from a combination of factors including long-term sea level rise, tides, and storms > Since 1920, extreme SLR events have increased from a frequency of every 20 years to every 5 years **O'ahu** *Sea level rise* > Honolulu station from 1905-2015: Average increase of 1.41 mm/year (+/- 0.21) > Mokuoloe station from 1957-2015: Average increase of 1.13 mm/year (+/- 0.52) *Shoreline change* > Average long-term change was erosion at -0.06 m/year (+/-0.01), with 60% tending towards erosion and 38% towards accretion > Average short-term change was erosion at -0.05 m/year (+/-0.01), with 58% tending towards erosion and 40% towards accretion > 8% of beach length (9 km) was lost to erosion	**O'ahu** *Sea level rise* Multiple possibilities vary in magnitude, depending on which factors they take into account: > By 2100, global sea level rise will likely rise between 0.75 and 1.9 m. *(Vermeer and Rahmstorf 2009)* > Likely Honolulu, HI sea level (90% probability, compared to 2000) *(Kopp et al. 2009)*: > > By 2030: 0.08-0.21 m (95% probability is 0.05-0.25 m) > > By 2050: 0.15-0.44 m (95% probability is 0.08-0.57 m) > > By 2100: 0.26-1.41 m (95% probability is 0.11-2.09 m) *Shoreline change* By 2050 and 2100 (compared to 2005): > Ehukai and Sunset: -8.7 ± 6.2 by 2050, -25.2 ± 10.4 by 2100 (high seasonal variability) > Hauula: -9.0 ± 0.5 by 2050, -24.2 ± 1.0 by 2100 > Kailua: 7.1 ± 3.2 by 2050, 4.9 ± 6.8 by 2100 (only site with shoreline advancement) > Makaha: -6.9 ± 2.4 by 2050, -18.6 ± 3.9 by 2100	Moderate-High	> Although there is widespread agreement that sea level will rise, projections vary widely depending on whether or not they include large-scale climate variability (ENSO, PDO) and the contribution of ice-sheet collapse > It is difficult to predict how ice sheets will respond to increasing temperatures; models are unable to estimate large non-linear changes in ice sheets > The emissions scenario and climate models chosen also contribute to large differences among the available projections > Sea level rise measurements use various baselines, including Mean High Water, Mean Higher High Water, Mean Sea Level, and others > Tidal datums vary from island to island and there is no set standard for which to use and which time period to set as a reference > The Vermeer and Rahmstorf (2009) estimate given here (0.75-1.9 m) incorporates ice-sheet collapse and has been used in studies modeling coastal flooding in Maui

Climate Variable	Trend	Relative Change by 2100	Observed Change	Projected Change	Confidence	Uncertainty (trend direction, magnitude)
Coastal flooding & saltwater intrusion[5,31-36]	↑	High	**All Islands** *Coastal inundation* > Sea level rise has contributed to both marine inundation (flooding in areas with a direct hydrological connection to the ocean) and groundwater inundation (flooding in areas with an indirect hydrological connected due to elevated water tables)	**All Islands** *Saltwater intrusion* There are no projections available for saltwater intrusion (see below for groundwater inundation) > Sea level rise will likely contribute to increased water salinity and higher water tables, especially during storms > Drought conditions also increase groundwater salinity > Increased human populations and associated water withdrawals will contribute to saltwater intrusion into groundwater sources **O'ahu** *Coastal flooding (includes marine and groundwater inundation)* > Within a 1-km shoreline buffer in Honolulu (heavily urbanized): > > If 0.33 m SLR: 0.5% flooded area (51% due to groundwater inundation) > > If 0.66 m SLR: 2.5% flooded area (69% due to groundwater inundation) > > If 1 m SLR: 10% flooded area (58% due to groundwater inundation) > > Flooded area is greater in Waikiki (13.5% flooded area) and Ala Moana (19% flooded area) James Campbell National Wildlife Refuge (north O'ahu) > At 0.3 m (est. by 2057), 0.1% of total area inundated > At 0.74 m (est. by 2100), 2.5% of total area inundated (0.1% of area	Moderate	> Because there are no downscaled sea level rise projections for this region, models of flooding/inundation use set amounts of sea level rise to determine the area flooded (rather than reporting the amount of change by 2050/2100 like many other studies do) > Cooper et al. (2012) based their coastal inundation models on SLR estimates by Vermeer and Rahmstorf (2009) > Kane et al. (2015) based their models on global SLR projections by Church et al. (2013), which do not take melting ice sheets into account > Saltwater intrusion is also impacted by recharge rates and groundwater pumping/withdrawals (withdrawals likely play a larger role in saltwater intrusion than does sea level rise)

Climate Variable	Trend	Relative Change by 2100	Observed Change	Projected Change	Confidence	Uncertainty (trend direction, magnitude)
				flooded by marine inundation, 1.4% by groundwater inundation)		
Wildfire[37-39]	↑	Unknown	**All Islands** > Overall trend towards increases in area burned from 1904-2011, but with high interannual variability > From 1976-1997, large wildfires typically occurred during the spring and summer after an El Niño event > Wildfire frequency in Hawaiian Islands is positively correlated with human activity and population growth **O'ahu** The majority of wildfires occur during summer (June-Aug), when conditions are warm and dry, accounting for 60% of the annual area burned	**All Islands** > There are no regional wildfire projections available > Wildfire will likely increase if drought events increase	Low	> Wildfire is strongly correlated with dry conditions, and precipitation projections are highly uncertain > Increasing temperatures are likely to increase evapotranspiration, and may cause higher climatic water deficits even if precipitation increases slightly
Species distribution[1,40-42]	↑↓	Medium to High	**All Islands** *Mosquito distribution* > Based on precipitation and temperature data from 1971-2000, mosquito habitat expands during increased rainfall years (e.g. La Niña years), with predominant expansions occurring in windward locations and small to moderate increases in habitat area in leeward locations > Mosquito habitat declines under drought conditions (e.g., El Niño years), with core habitat remaining in windward locations	**All Islands** *Forest birds* > By 2100, species richness is expected to decline, with 90% of modeled bird species likely losing >75% of their current range (due to increased temperatures and risk of avian malaria) > Small island endemic species are most vulnerable to climate-driven habitat loss *Native plant species* By 2100: > 39% average reduction in climatically suitable habitat for native plants > 15% of modeled species will likely	Moderate	*Mosquito distribution* > Mosquito expansion is heavily dependent on increasing temperatures (high certainty) and adequate precipitation (low certainty) *Forest birds* > Modeled ranges vary depending on the emissions scenario chosen, and they may end up being smaller than presented in the Fortini et al. 2015 study > Forest bird distribution models did not incorporate potential habitat loss to urban or agricultural development > Additional factors that were not addressed in the models but may impact bird distributions include ecological interactions and non-climate stressors

Climate Variable	Trend	Relative Change by 2100	Observed Change	Projected Change	Confidence	Uncertainty (trend direction, magnitude)
				have no overlap between current and future suitable habitat (i.e., will have to migrate to persist) > 5% of modeled species are projected to lose >99% of their current climate envelope (i.e., these species will "wink-out") > Most vulnerable species include: single island endemics, species with a conservation listing (e.g., endangered), coastal species, monocots, and dry forest-affiliates *Invasive plant species* By 2100: > ~11% increase in land area suitable for invasion (12% increase in critical habitat areas) > All but 4 modeled species are projected to expand > Invasion risk increases at higher elevation locations		*Native plant species* > Modeled changes in plant distribution are dependent on the emissions scenario used, as well as additional factors that affect species distribution and survival, but which were not considered here (e.g., reductions in habitat quality/availability, adaptive capacity traits, disease risk, new invasions) > El Niño events can significantly affect vegetation distribution by altering patterns of precipitation and drought, but projected changes in these factors are poorly understood *Invasive plant species* > Models may under-represent invasive species distribution because the majority of the data was sourced from areas of conservation concern rather than from across the entire landscape > Climatic tolerances of individual species and how they may react to changes are not well-understood > On islands where invasive plants have only recently become established, populations have not reached an equilibrium with the environment and models may predict future distributions less accurately

Climate Variable	Trend	Relative Change by 2100	Observed Change	Projected Change	Confidence	Uncertainty (trend direction, magnitude)
Wind/circulation[3,6,43-44]	↑↓	Low to Medium	**Pacific Ocean** *Trade wind strength/velocity* > Since the 1990s, the Pacific trade winds (both the Walker and Hadley cells) have increased, corresponding with a negative PDO phase > Increased winds are driving an acceleration of shallow overturning cells, which causes subduction of warmed surface waters and upwelling of cooler water (allows greater storage of heat in the ocean) > Accelerated trade winds and resulting ocean heat exchange contributes to a hiatus in global surface air temperature warming since 2001 **All Islands** *Trade wind inversion (TWI) frequency* > ENSO and PDO affects the proportion of days with a TWI (drier days), and so affects the conditions associated with each phase > > During the warm phases of ENSO (El Niño) and PDO, mean TWI frequency is higher during the wet season and lower during the dry season, resulting in winter drought > > During the cool phases of ENSO (La Niña) and PDO, mean TWI frequency is higher during the dry season and lower during the wet season, resulting in drier summers *Trade wind inversion (TWI) height* > From 1990-2009, range of variability for TWI is 1.2-2.5 km for height, most frequently occurring height is 1700-2000m.	**All Islands** *Surface winds* Wind speed (compared to (1976-2005) > By 2026-2045: Sept-Nov wind speed decreases > By 2081-2100: Sept-Nov wind speed decreases strongly; smaller decrease in other seasons Wind direction (compared to 1976-2005) > By 2026-2045: Dec-Feb wind direction rotates by a value of -0.50 to -10.0 degrees > By 2081-2100: No significant changes *Trade wind inversion (TWI) frequency* > By the late 21st century: 8% increase in the proportion of days with a TWI (from 82% to 90%) *Trade wind inversion (TWI) height* > By the late 21st century: 10% decrease in cloud top height on days with a TWI	Moderate	> Trade winds are driven by large-scale atmospheric processes, which are difficult to accurately predict > Trade wind inversion frequency and height are variable, depending on location, time of day, season, and phases of ENSO and PDO > Surface winds are also influenced strongly by oceanic factors

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