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Docket Number:	16-IEPR-04
Project Title:	Climate Adaptation and Resiliency
TN #:	211806
Document Title:	Creating Probabilistic Sea Leve Rise Projections
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Filer:	Raquel Kravitz
Organization:	California Energy Commission
Submitter Role:	Commission Staff
Submission Date:	6/14/2016 10:18:24 AM
Docketed Date:	6/14/2016

Creating Probabilistic Sea Level Rise Projections
to support the 4th California Climate Assessment

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06 June, 2016

1. Purpose

We describe new probabilistic sea level rise (SLR) estimates for California to support the 4th Assessment. We take a probabilistic approach, using recent published results on the primary components that contribute to global and regional SLR, along with a model that produces continuous projections of sea level at selected locations along the California coast. The document includes a basic explanation of the components that contribute to SLR, the methods used to develop probabilistic projections of SLR for California under different greenhouse gas emission scenarios and finally the methods used to create hourly seal level rise projections based on the probabilistic projections.

2. Overview

California has over 800 miles of coast and as such the environments, infrastructure and real-estate at or near the coast is vulnerable to SLR. Historically, El Nino has the largest impact on sea level in California on a seasonal to interannual basis. In 2016, during a strong El Nino and high tide, the La Jolla tide gauge in Southern California had the highest sea level in its 92-year record. Northern California is also affected by El Nino events. However, the highest sea levels in Northern California are more often attributed to storm events which cause large storm surges and elevate sea level.

In the future, shorter period sea level extremes associated with Pacific basin, regional and local sea level patterns will be exacerbated by continuing and possibly increasing rates of SLR. In preparing for long-term SLR, California currently uses the National Research Council (NRC) Report (2012) as a guiding document to plan for and protect against future SLR. However, since the NRC Report was published in 2012, a growing body of scientific studies have produced new results describing present and future SLR, including the dynamics of the contributing components, and the methods to estimate regional SLR.

In particular, a recent study that incorporates new dynamics to an ice sheet model that estimates the contributions to global sea level from Antarctica have introduced possible higher global and regional SLR outcomes under higher greenhouse gas emissions scenarios. This document provides updated SLR projections by developing probabilistic SLR projections for California and hourly sea level projections at certain locations along the coast based on the most current research and methods. Also, in addition to developing SLR projections pinned to the conventionally-employed Representative Concentration Pathways (RCP) scenarios, we include regional estimates of SLR that would occur under the Intended Nationally Determined Contributions (INDCs) that arose from the U.N. Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP21) in Paris in December 2015.

3. Global SLR Components and Uncertainty

Global SLR, or eustatic SLR, projections include the contribution from five different components: the thermal expansion of the ocean, melt from glaciers, extraction of surface water and contributions from the large ice sheets on Antarctica and Greenland. Each component of global SLR has a certain amount of uncertainty which is based upon the total amount the component can contribute to SLR as well as how well the response of the component to warming is understood. The ranges of possible contributions to SLR from the extraction (or sequestration) of land surface water is the smallest of the components. Glacial melt will continue to contribute, but will probably decline to very low levels as glaciers disappear during the 21st Century. The thermal expansion of the ocean has, over the 20th Century, been the largest contributor to SLR, and is projected to continue to be a primary contributor through the 21st Century. Greater than the uncertainty of SLR from thermal expansion, is that from the Greenland and Antarctica ice sheets, the two most uncertain components of SLR (Figure 1). The range of possible contributions from ice sheets is large because they have the potential to significantly contribute to SLR in rather large catastrophic episodes or events that are difficult to model in that they have not been commonly observed and they involve ice mass loss dynamics that are complex and probably non-linear (Vaughan and Arthern, 2007).

Of the two ice sheets, the contribution to SLR from Antarctica is more uncertain (and potentially larger) than that from Greenland according to a survey amongst experts (Bamber and Aspinall, 2013). Antarctica is divided into West and East Antarctica by the Transantarctic Mountains. The uncertainty is largely due to the instability of the West Antarctic Ice Sheet (WAIS) and lack of understanding regarding the dynamics and rate of potential ice sheet collapse. The East Antarctic Ice Sheet (EAIS) is not thought to be unstable and is likely the least susceptible to climate change on a centennial time scale. Two studies suggested that the WAIS retreat is unstable (Joughin et al., 2014; Rignot et al., 2014), though both concluded that the contribution to SLR from WAIS would not substantially (>1mm/year) increase until after 2200 (Joughin et al. 2014). However, a recent modeling study by DeConto and Pollard (DeConto and Pollard, 2016), here after DP2016, included new dynamics in an Antarctica ice sheet mass loss that, under higher rates of global warming, would provoke the WAIS to contribute much more significantly to SLR within the latter half of the 21st Century and beyond. The new dynamics included in DP2016 account for atmospheric and oceanic warming, resulting in fracturing within the ice sheet due to the refreezing of water and the collapse of ice shelves. DP2016 validated their model by comparing their results to the paleo record of sea level during two periods of time, the last interglacial (~125,000 years ago) when temperatures are estimated to be 0-2˚C above current temperature and the Pliocene (~3 million years ago) when carbon dioxide concentrations are estimated to be similar to today. The DP2016 results will undoubtedly be followed up by other modeling and observationally based studies, but for now, we feel they must be taken seriously in developing global and regional SLR scenarios. Including DP2016, under the high emission, business as usual scenario (RCP 8.5) contribution from Antarctica to SLR in 2100 range from 0-70 cm (Figure 1).

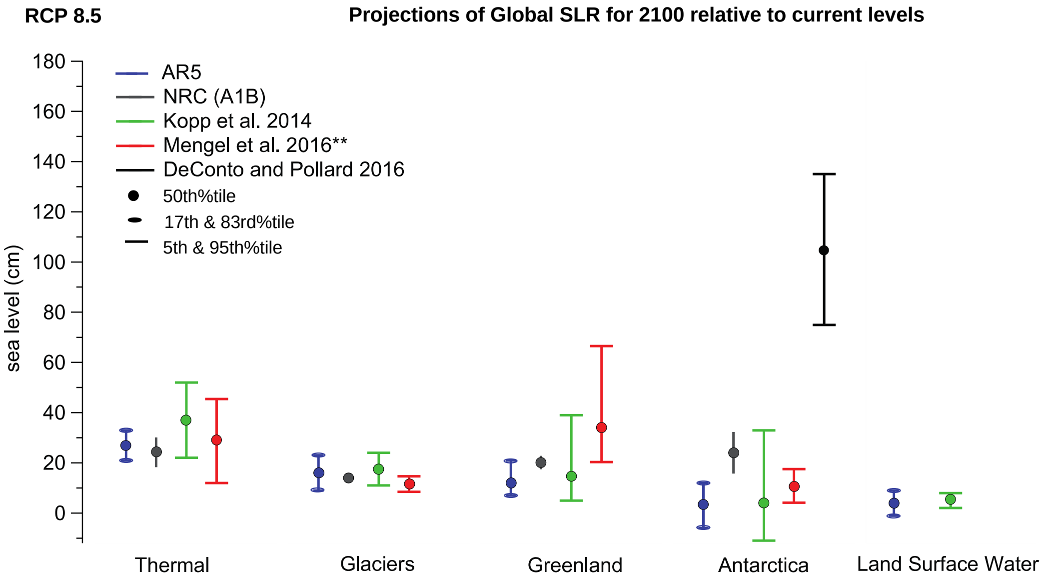


Figure 1. The contribution to global SLR in 2100 by components under the RCP 8.5. The contributions are relative to 2000 levels and shown in cm. The circle represents the 50th percentile for all except the NRC (grey circles), which represent the committee agreed upon value. The range for the IPCC 5th Assessment Report (AR5, blue) represents the likely range (17th-83rd percentiles). The range for the NRC represents the range under different greenhouse gas scenarios. The range for the remaining estimates represents the 5th-95th percentiles. For Greenland and Antarctica, the 5th and 95th range from Mengel et al. (2016) was estimated by combining the 5th and 95th percentile for the surface mass balance and solid ice discharge.

4. Regional Sea Level Rise

Regional SLR includes the global signal as well as the regional effects from ocean dynamics, tectonics and ice sheet finger printing. Changes in the ocean circulation can affect local sea level by causing water to accumulate or disperse along a coast due to winds. For example, in California El Niño events have the largest impact on interannual sea level because wind and ocean circulation changes cause water to accumulate along the coast. For future SLR, global climate models (GCM) are used to project what ocean circulation will be and then the change in local SLR due to ocean dynamics is extracted from these models. Local SLR also includes changes in tectonics. Tectonics include the sinking or uplifting of plates due to plate tectonics and glacial isotactic adjustment, and the rebounding of the Earth's crusts as a result of the removal of the immense weight of the ice sheet. The Earth's crust does not respond uniformly, but rather is more like a mattress rebounding after a person lying on it with some areas sinking and other areas ascending. Currently the Earth is undergoing this process in response to the last ice age (~18,000 years ago) and will in the future as ice sheets melt. Throughout California, regional SLR is relatively similar south of Crescent City, whereas farther north, the SLR is projected to be reduced by ~25 cm (Figure 2). In addition to these large spatial processes, there are very local processes that might cause a specific location to subside or uplift (Simms et al., 2016).

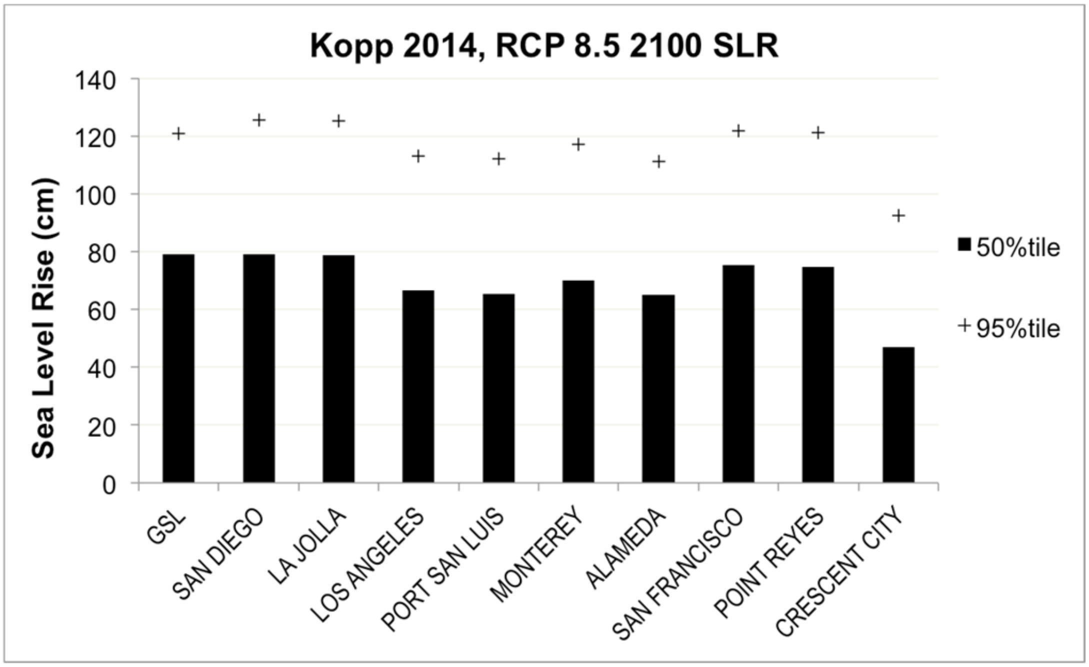


Figure 2. Probabilistic SLR projections in cm relative to 2000 under RCP 8.5 for locations along the coast from Kopp et al. (Kopp et al., 2014). These projections do not include the recent results of DP2016. The solid black bars represent the 50 percentile and the + symbols represent the 95th

5. Probabilistic Sea Level Rise Scenarios

Prior to this analysis, a panel of experts was solicited. The panel, identified in Appendix 2, provided guidance on the method proposed to develop the SLR scenarios and the latest science. The expert panel was composed of 7 experts who provided feedback via teleconference. The panel supported using a probabilistic approach to develop SLR projections and they indicated that the new findings of DP2016 were significant. The panel agreed that although the DP2016 was the first study to include these new dynamics and is still an emerging field, the results were important to include in the probabilistic projections. Key points from the expert panel discussion are summarized in Appendix 2.

Using the input from the expert panel, probabilistic SLR projections were developed based on the methodology of Kopp et al. 2014 with a modification of using the recent results from DP2016 for the contribution from the Antarctic Ice Sheet. The Kopp et al. (2014) method creates a time-dependent probability distribution of the different components and uses a sampling method, Latin hyper-cube, to sample the different components times 10,000 to calculate the SLR probabilities. This process assumes that the components are independent of each other because the response of the different components might not be correlated. For example, 2˚C temperature increase might affect ocean circulation in such a way that SLR is reduced while ice sheet melting might increase.

The estimated probability density functions of each of the five primary global SLR components are developed based on the current research about how the individual components have responded historically to climate variability and are projected to respond to future climate change. The land surface water contribution to SLR is based upon population estimates (Rahmstorf et al., 2012). The projected contribution from glacier and ice caps is based upon regional modeling of the response of glaciers and ice caps to changes in temperature and precipitation (Marzeion et al., 2012). The oceanographic processes, including both thermal expansion and dynamical changes, are based on global climate models. Contribution from Greenland ice sheets are based upon AR5, the most recent Intergovernmental Panel of Climate Change 5th Assessment report, for the median and likely (17-83 percentiles) range and on expert elicitation outside of this range (Bamber and Aspinall, 2013). The Antarctic contribution is based on the DP2016 model developed using estimated Pliocene sea levels above present day between 5-15 meters (m) and without any adjustment to ocean temperature. Local sea level changes from tectonics and glacial isotactic adjustment were extrapolated (by Kopp) from tide gauge data.

The different greenhouse gas emission scenarios do not begin to show a significant difference in SLR until around 2060 (Figure 3). The range of between the 5th and 95th percentile also increases with time, which is primarily due to the large uncertainty in the ice sheet response to climate change. The 99.9th percentile is shown and is currently considered the maximum of what is physically possible (Figure 3). The increase in SLR project is not linear in time, and by 2200, for RCP 8.5 the 50 percentile SLR projection is more than five times the projection at 2100 (Figure 3, small graph). The new probabilistic SLR 50th percentile projections from all RCP greenhouse gas scenarios, are lower than the committee values at both 2030 and 2050, but RCP 8.5 50th percentile value at 2100 is 47cm higher than the NRC committee value (Figure 3, Table 1).

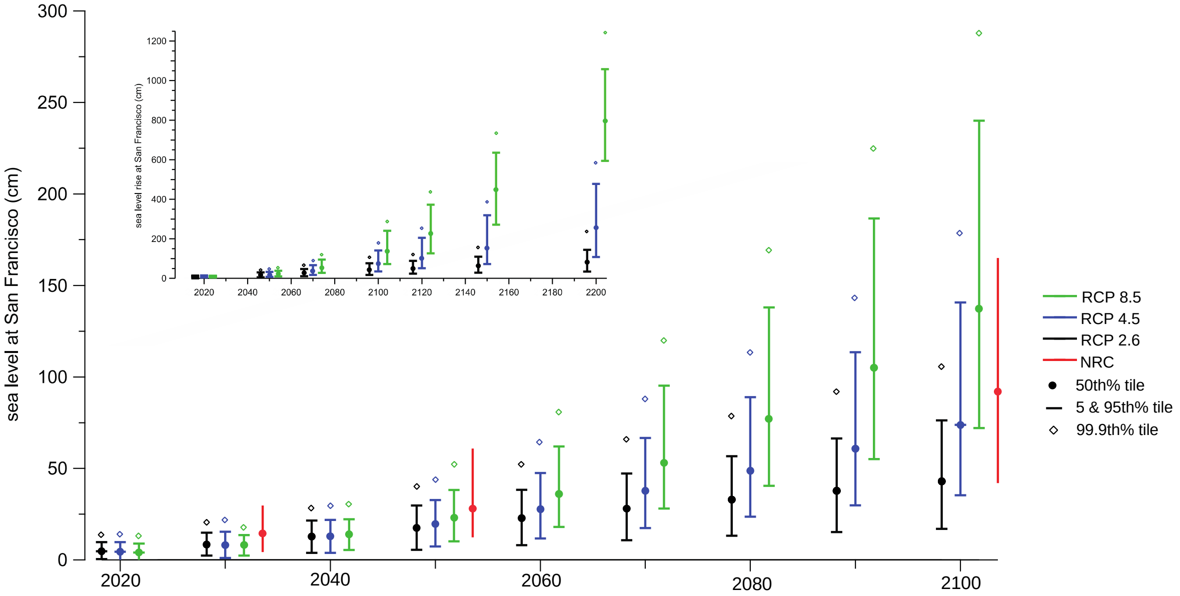


Figure 3. The probabilistic SLR projections for San Francisco using the three different RCP scenarios for each decade from 2020 to 2100. The circle is the 50th percentile value and the dash lines represent the 5th and 95th percentiles. The diamond is the 99.9th percentile and should be considered the maximum that is physically possible. The red circles are the committee values from the NRC report and the line represents the range under different scenarios. The small insert is the same but extends out to 2200. Note the change of scale in the insert. All the values from this graphic can be found in Appendix 1.

6. Emission Scenarios and INDC Estimates

The probabilistic SLR projections were developed in association with 3 different greenhouse gas emission scenarios. First the probabilistic projections were created for RCP 2.6, 4.5, and 8.5 which correspond to an estimated radiative forcing (W/m2) in 2100 and were created for AR5. However, while these emission scenarios are based upon plausible futures, they were not tied to international community commitments to reduce greenhouse gas emissions. The 1992 United Nations Framework Convention on Climate Change (UNFCC) set a goal to diminish greenhouse gas emissions to reduce the likelihood of dangerous interferences with the climatic system. Once a year, nations of the world convene to discuss the implementation of the UNFCC in what is known as the Conference of the Parties (COP). The COP can adopt agreements such as the 1997 Kyoto Protocol and the recent 2015 agreement in Paris at the 21st COP or COP21. The Kyoto Protocol is mainly responsible for the decline in European greenhouse gas emissions by about 19% since 1990, even though Europe's economic output increased by 45% (European Environmental Agency, 2015). The results of COP21 are notable for several reasons, including the fact that 187 countries (including the European Union member states) have submitted pledges to reduce GHG emissions. These nations represent about 95% of the total global emissions and include developed and developing countries. These pledges are known as "Intended Nationally Determined Contributions" (INDC) which will become "Nationally Determined Contributions" when governments formally join the Paris Agreement (Keohane and Victor, 2016). The INDCs represent a new approach because some of them are tied to the local interest of the nations involved, which may increase the likelihood of success. For example, China is concerned about serious air pollution problems in their urban areas and their proposed reductions are strongly tied to their efforts to improve air quality in China, as indicated in China's 13th Five-Year Plan approved in March 2016.

The influence of the INDCs and the subsequent National Determined Contributions would end on 2030 but subsequent COP meetings would establish post COP21 targets. Some research groups are trying to determine the potential climatic consequences, based upon these targets. For example, Figure 4 shows one view of post COP21 commitments. Figure 4 has two potential scenarios: Paris-Continued and Paris-Increased ambition. The first scenario assumes that after 2030, CO_2 emissions per GDP decreases at a 2% annual rate, which results in almost flat global emissions after 2030. The Paris-Increased ambition assumes that countries implement a minimum of 5% per year decarbonization rate, which is the average de-carbonization rate required by the EU and the U.S. to achieve their INDCs from 2020 to 2030 (Fawcett et al., 2015). Figure 4 also shows the emissions associated with the RCPs.

In the U.S. there are presently two main drivers that would strongly influence future emissions. The first is the proposed regulations of the U.S. Clean Power Plan that would limit GHG emissions from power plants. The second is the U.S. INDC submitted on March 31, 2025 pledging to reduce GHG emissions by 26% to 28% in 2025 in relation to U.S. emissions in 2005. The Clean Power Plan proposed rule is an instrumental part of the INDC put forward by the Obama Administration because power plants in the U.S. contribute about 40% of the total GHG emissions. The negative trend in GHG emissions in recent years is due, in part, to the switch from coal to natural gas in power plants for economic reasons.

At the subnational level, California and others are taking the lead in the U.S. by pledging to reduce GHG emissions with the goal of limiting planetary warming below 2°C (3.6 °F) above preindustrial levels. The Under 2 MOU has a goal of limiting GHG emissions to 2 tons per capita or 80-95% below 1990 level by 2050. As of April 2016, a total of 128 subnational entities representing 28 countries and six continents have signed or endorsed the Under 2 MOU. They represent more than a quarter of the global economy.

The RCPs were developed several years ago and, for this reason, emissions after 2005 are projections that can be compared with actual historical global emissions after 2005. Actual historical emissions are following the high emission scenario known as RCP8.5 and this was reflected in the preparation of the INDCs commitments. The probabilistic projections were developed for the RCP scenarios in the manner described above, however, none of these emission scenarios align with the new international agreement, COP-21. Using the probabilistic scenarios that were developed for RCP 2.6, 4.5. and 8.5, and total greenhouse gas emissions and time, we estimate the SLR for two new greenhouse gas emission scenarios, INDC+ and INDC++ using a best fit line. The authors thought it was important to estimate how the new greenhouse gas scenarios might impact SLR scenarios given the new compromise by the international community. The INDC SLR projections scenarios were not generated using the same SLR component estimation process that was employed to develop the time dependent probability density function for each component because these emission scenarios are too recent to have the research needed to develop the probability density function for each component. The SLR estimates for the two INDC scenarios presented (Table 1 and Appendix 1) are estimates until the research is available to provide more rigorously developed SLR probabilities with these new greenhouse gas scenarios. The hourly SLR projections (discussed below) are only developed for RCP 4.5 and RCP 8.5 because the hourly SLR rely on downscaled data from global climate models, which are available for RCP 4.5 and RCP 8.5, but have not been developed for RCP 2.6 nor for INDC+ and INDC++.

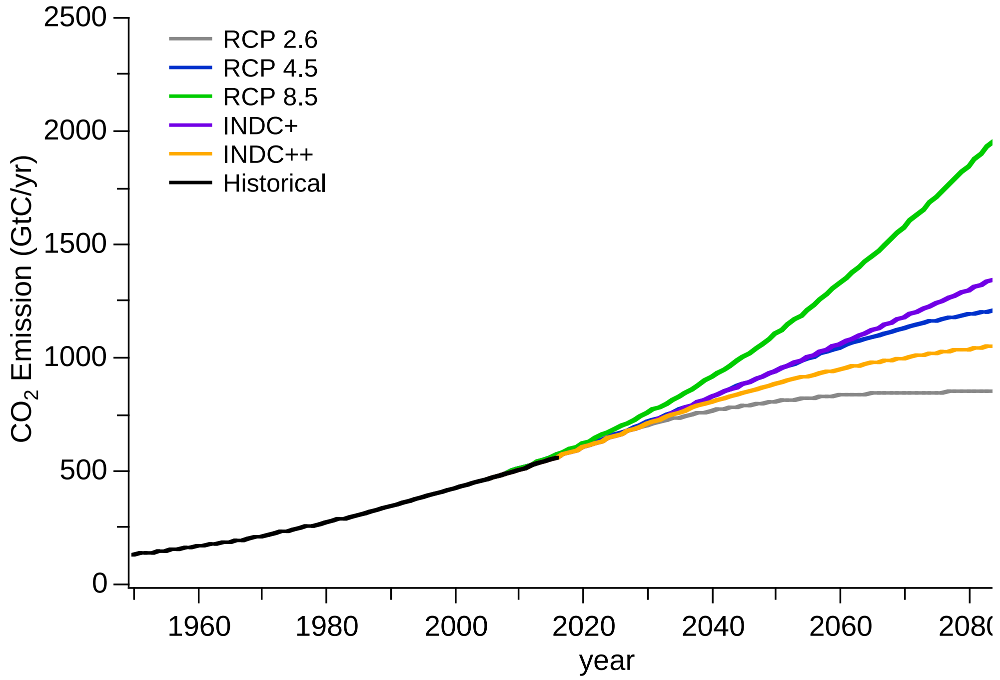


Figure 4. Historical and future cumulative CO_2 emissions from fossil fuels and cement production under the different scenarios. The INDC scenarios are estimates of future emissions based on the recent international agreement, COP-21 (Fawcett et al. 2015).

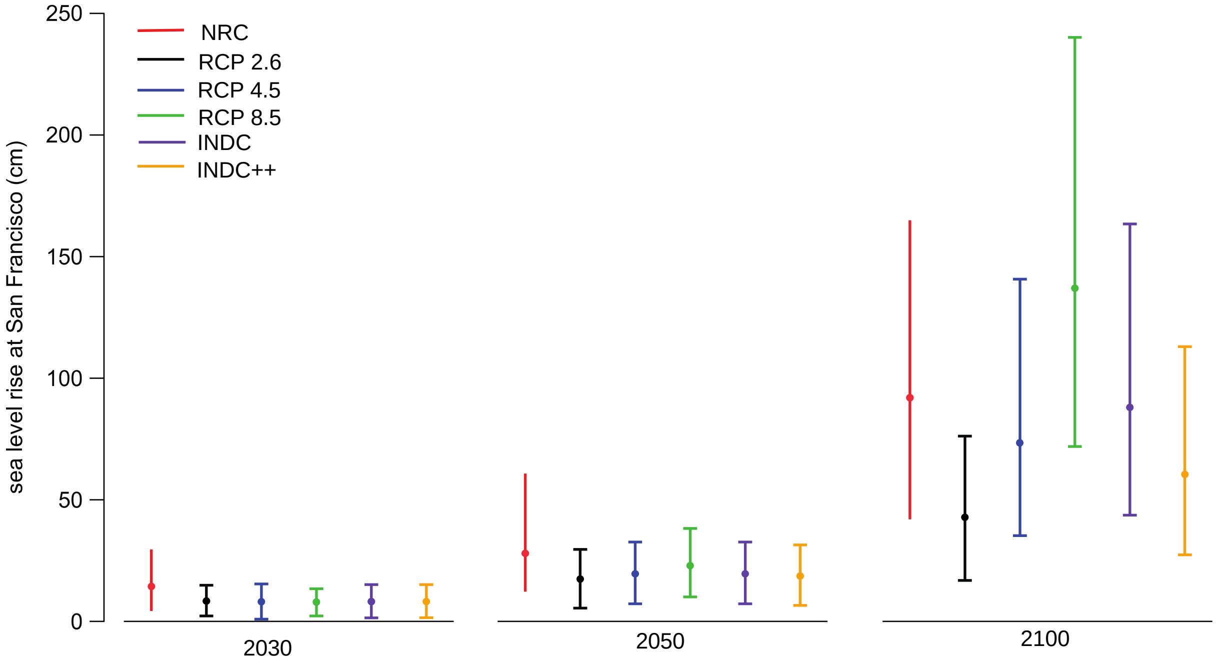
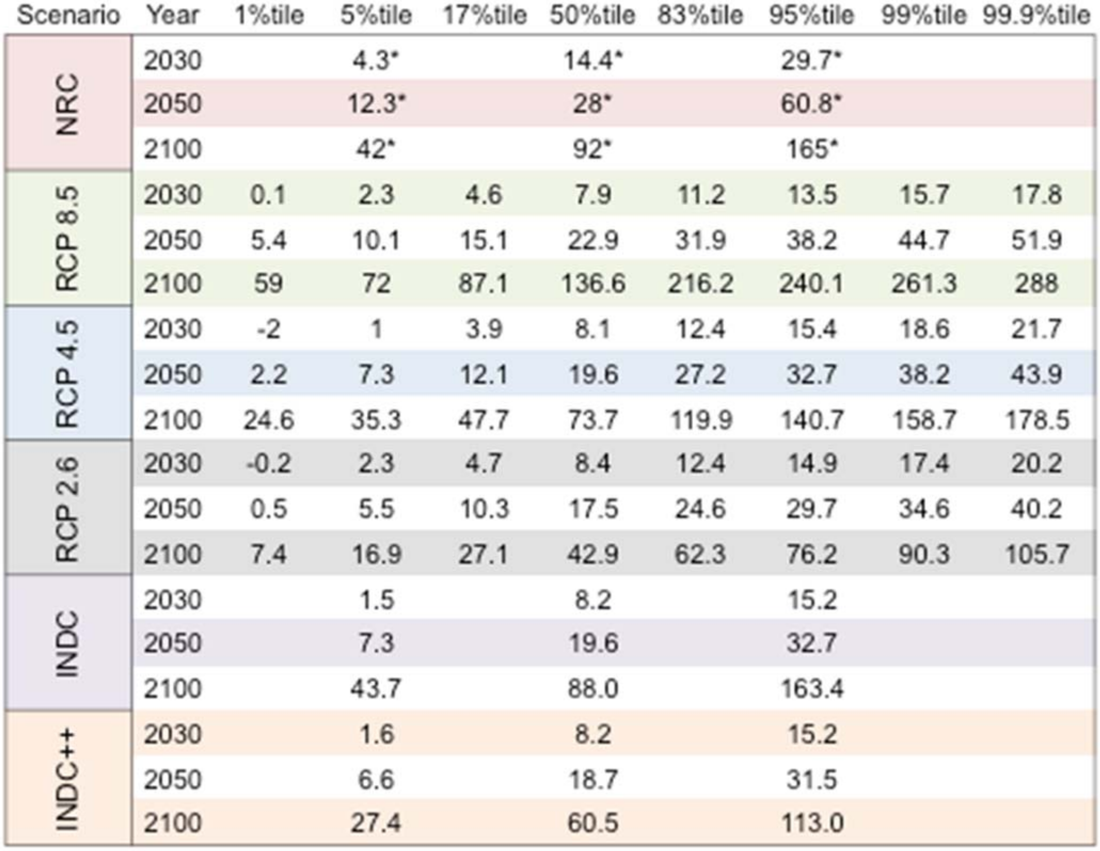


Figure 5. The 50th percentile (circle), 5th percentile and 95th percentile for projected SLR at San Francisco in cm relative to 2000 are shown. The NRC line shows the low to high range estimates with the committee value as the circle. The RCP are probabilistic projections, while the INDC developed using a best fit using the year, cumulative CO_2 emission, and SLR for each RCP at the different percentiles.

Table 1. The SLR (cm) relative to 2000 for the NRC, RCP and INDC scenarios. The values for the RCP and INDC scenarios are for San Francisco. The asterix by the NRC values are because they are not percentiles, but rather the agreed upon committee value (50th percentile) and the low (5th percentile) and high (95th percentile) range of the projections.



Scenario	Year	1%tile	5%tile	17%tile	50%tile	83%tile	95%tile	99%tile	99.9%tile
NRC	2030		4.3*		14.4*		29.7*		
	2050		12.3*		28*		60.8*		
	2100		42*		92*		165*		
RCP 8.5	2030	0.1	2.3	4.6	7.9	11.2	13.5	15.7	17.8
	2050	5.4	10.1	15.1	22.9	31.9	38.2	44.7	51.9
	2100	59	72	87.1	136.6	216.2	240.1	261.3	288
RCP 4.5	2030	-2	1	3.9	8.1	12.4	15.4	18.6	21.7
	2050	2.2	7.3	12.1	19.6	27.2	32.7	38.2	43.9
	2100	24.6	35.3	47.7	73.7	119.9	140.7	158.7	178.5
RCP 2.6	2030	-0.2	2.3	4.7	8.4	12.4	14.9	17.4	20.2
	2050	0.5	5.5	10.3	17.5	24.6	29.7	34.6	40.2
	2100	7.4	16.9	27.1	42.9	62.3	76.2	90.3	105.7
INDC	2030		1.5		8.2		15.2		
	2050		7.3		19.6		32.7		
	2100		43.7		88.0		163.4		
INDC++	2030		1.6		8.2		15.2		
	2050		6.6		18.7		31.5		
	2100		27.4		60.5		113.0		

7. Hourly SLR along the California Coast

The long term SLR projections developed above establish the base level up upon which operates an envelope of short-term sea level fluctuations. These short-term fluctuations are caused by astronomical tides, storm surges, and El Nino Southern Oscillation events. Open coast tide range in California is up to approximately 3 m from high to low tide. The tidal time scales that are important for California are semi-diurnal, diurnal, semi-monthly, semi-annually and 4.4 years. Tides are the only component of sea level that is accurately predictable. Storm surge is the sea level above the predicted tides that is attributed to low pressure and high winds associated with storms. Storm surge along the California coast rarely exceeds 0.7 m in amplitude when excluding the effects of waves, but can reach over 1.5 m when including wave induced surge (Cayan et al., 2008). As mentioned previously, El Nino events have the largest seasonal to interannual impacts on sea level heights with amplitudes of 10-20 cm.

Following the methods in Cayan et al. (2008), hourly sea level projections using a base line of the probabilistic SLR projections were developed for the 4th Assessment. Hourly projections were made for locations with a reliably continuous coastal tide gauge record that begins before 1984 (Figure 6). The sea level projections were derived from short period climate and weather extracted from a subset of global climate models and various RCP-based SLR scenarios (described above). The modeled sea level includes contributions from astronomical tides, weather influences from wind and barometric pressure, short period climate (e.g. El Nino and other climate patterns), and long period change over the region from global SLR. Eight climate models, selected for California water resource climate planning and assessment by the Climate Change Technical Advisory Committee (CCTAG, 2015) were employed to provide daily estimates of SLP and winds needed to be converted to hourly data. The daily climate and meteorological variables (wind, sea level pressure, ocean temperatures) used to predict local sea level at each of the selected California tide gage stations were extracted from the eight selected global climate models and bias corrected using methods developed for the Scripps Localized Constructed Analogs (LOCA) downscaling procedure. Hourly data is derived using a sampling of an archive of historical observations. The El Nino/Southern Oscillation component was estimated using a regression equation that related the monthly Nino 3.4 sea surface temperatures to the smoothed sea levels at California's tide stations. These components were then combined to synthesize the hourly sea levels based on the probabilistic SLR projections.

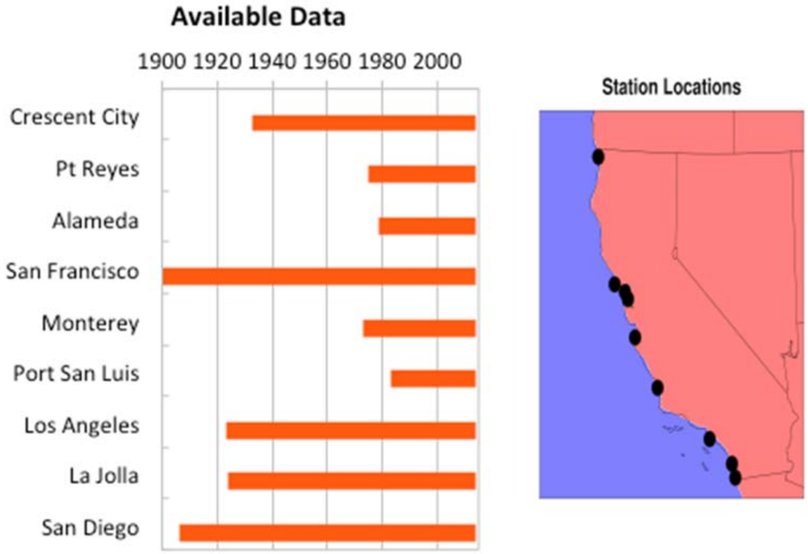


Figure 6. The record length for tide gauge stations in California that are continuous and being before 1984. The map illustrates the location of the tide gauge stations. Hourly sea levels were synthesized for these locations.

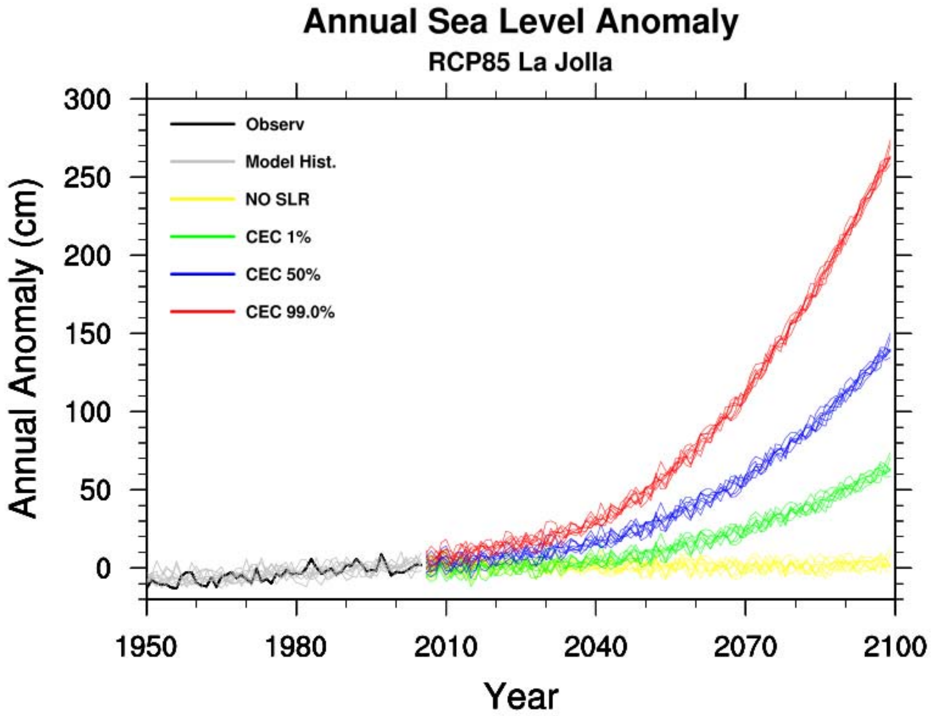


Figure 7. Median (blue), 99th, and 1percentile sea levels projected for La Jolla, California from 8 RCP 8.5 GCM simulations using modified Kopp et al. (2014) with DeConto and Pollard Antarctic ice loss contribution. Yellow lines are sea level projections under present day sea level (no SLR).

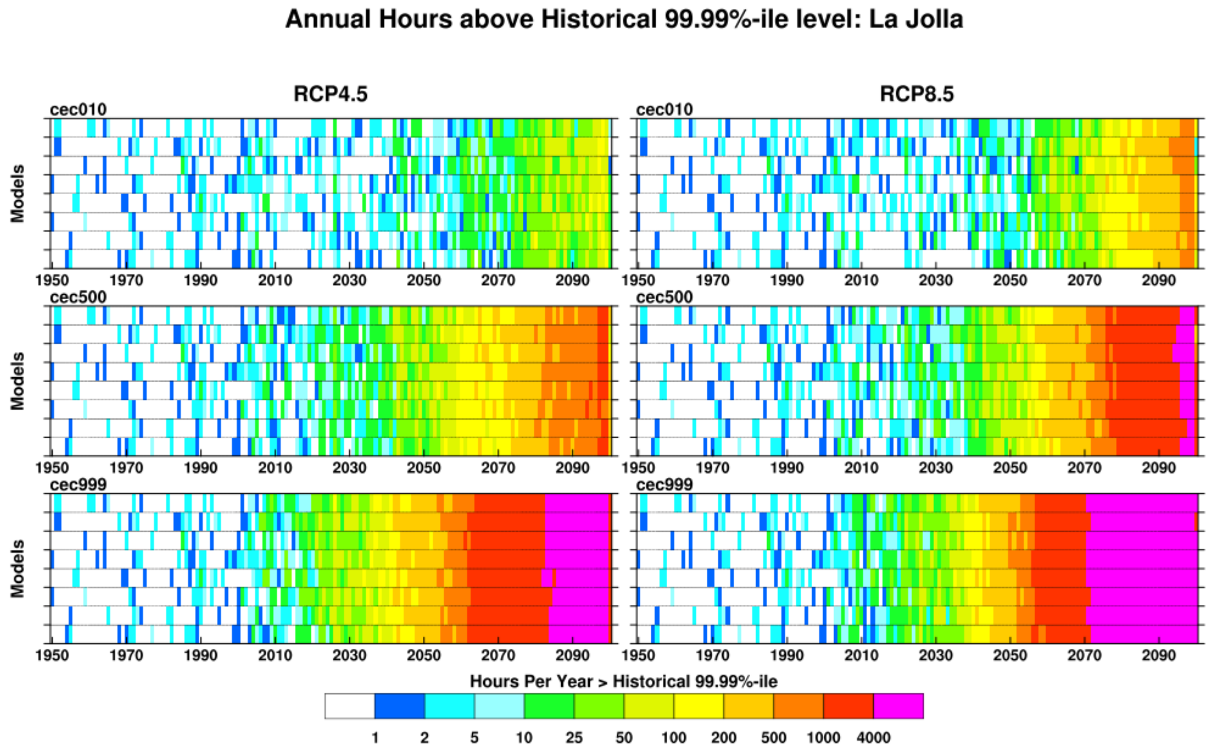


Figure 8. Number of hours of La Jolla, California sea level excess over 99.99% historical level under RCP 4.5 (left) and RCP (right) for three SLR scenarios corresponding to the 1%, 50% and 99% projections shown in Figure 7.

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Appendix 1. SLR projections for in cm above 2000 levels for San Francisco for the different scenarios at decadal time steps.

Scenario	Year	1st%tile	5th%tile	17th%tile	50th%tile	83rd%tile	95th%tile	99th%tile	99.9%tile
RCP 8.5	2010	-2.5	-1.2	-0.1	1.6	3.4	4.6	5.9	7.4
RCP 8.5	2020	-2	-0.2	1.7	4.3	7	8.9	11.1	13
RCP 8.5	2030	0.1	2.3	4.6	7.9	11.2	13.5	15.7	17.8
RCP 8.5	2040	2.2	5.4	8.7	13.7	18.7	22.2	25.9	30.1
RCP 8.5	2050	5.4	10.1	15.1	22.9	31.9	38.2	44.7	51.9
RCP 8.5	2060	12.7	18	24.4	35.8	52.5	62	70.7	80.7
RCP 8.5	2070	21.2	28	35.9	53.3	82.2	95.2	106.2	119.6
RCP 8.5	2080	32.3	40.5	50.2	76.6	121.5	138	151.9	168.8
RCP 8.5	2090	44.9	55	66.9	104.5	166.8	186.6	203.3	225.1
RCP 8.5	2100	59	72	87.1	136.6	216.2	240.1	261.3	288
RCP 8.5	2110	82.9	94.2	109	173.9	269.8	294.1	314.6	345.8
RCP 8.5	2120	111.7	126.1	146.1	227.3	345.5	372.2	396.1	436.9
RCP 8.5	2150	250.5	271.3	316.6	446.8	601.4	635.3	672.8	733.9
RCP 8.5	2200	563	594.4	646.1	796.8	1001.5	1057.9	1127.8	1243.7
RCP 4.5	2010	-1.6	-0.6	0.4	1.8	3.5	4.6	5.7	6.8
RCP 4.5	2020	-2.5	-0.4	1.5	4.4	7.6	9.7	12	14.2
RCP 4.5	2030	-2	1	3.9	8.1	12.4	15.4	18.6	21.7
RCP 4.5	2040	0.1	3.8	7.4	12.9	18.2	21.8	25.5	29.4
RCP 4.5	2050	2.2	7.3	12.1	19.6	27.2	32.7	38.2	43.9

RCP 4.5	2060	5.7	11.7	18.2	27.8	39.1	47.4	55.5	64.3
RCP 4.5	2070	10.4	17.4	25	37.7	55.2	66.6	76.6	87.8
RCP 4.5	2080	15.7	23.6	32.5	48.8	74.5	88.9	100.9	113.8
RCP 4.5	2090	20.9	29.8	40.1	60.8	96.3	113.5	127.9	143
RCP 4.5	2100	24.6	35.3	47.7	73.7	119.9	140.7	158.7	178.5
RCP 4.5	2110	33.3	44.5	57.4	88.1	147.7	171.3	191.7	212.4
RCP 4.5	2120	38.8	50.9	65.5	102.3	177.9	205.2	228.2	252.7
RCP 4.5	2150	56.1	72.1	90.8	151.6	282.9	319.3	349.4	386
RCP 4.5	2200	82.3	107.8	137.5	256.5	427.1	477.3	519	583.3
RCP 2.6	2010	-1.9	-0.7	0.4	2.1	3.9	5.2	6.5	8
RCP 2.6	2020	-1.4	0.5	2.2	4.7	7.7	9.7	11.7	13.7
RCP 2.6	2030	-0.2	2.3	4.7	8.4	12.4	14.9	17.4	20.2
RCP 2.6	2040	0.2	3.8	7.4	12.7	18	21.5	25.1	28.4
RCP 2.6	2050	0.5	5.5	10.3	17.5	24.6	29.7	34.6	40.2
RCP 2.6	2060	2.1	8	14	22.8	31.8	38.3	45	52.1
RCP 2.6	2070	4	10.7	17.6	28	39	47.2	55.7	65.7
RCP 2.6	2080	5.6	13.2	21	32.9	46.5	56.7	67	78.4
RCP 2.6	2090	7	15.1	24.1	37.7	54.2	66.4	78.5	91.8
RCP 2.6	2100	7.4	16.9	27.1	42.9	62.3	76.2	90.3	105.7
RCP 2.6	2110	14.6	22.2	31.2	45.2	66.1	80.4	92.4	106.1
RCP 2.6	2120	15.1	23.6	33.7	49.6	72.8	88.7	102.5	119
RCP 2.6	2150	18.6	28.7	41.7	62.4	90.3	109.2	127.8	155.2
RCP 2.6	2200	19.4	34.6	52.9	82	117.4	144.7	174	236.3
INDC	2020		-0.2		4.6		9.9		
INDC	2030		1.5		8.2		15.2		
INDC	2040		3.8		12.9		21.8		
INDC	2050		7.3		19.6		32.7		
INDC	2060		12.0		28.2		48.1		
INDC	2070		18.7		39.4		69.9		
INDC	2080		26.3		52.9		96.6		
INDC	2090		34.0		68.7		128.6		
INDC	2100		43.7		88.0		163.4		
INDC++	2020		-0.2		4.6		9.9		
INDC++	2030		1.6		8.2		15.2		

INDC++	2040	3.8	12.8	21.7
INDC++	2050	6.6	18.7	31.5
INDC++	2060	10.0	25.5	43.2
INDC++	2070	14.3	33.2	57.6
INDC++	2080	19.0	41.7	74.5
INDC++	2090	23.5	50.9	93.3
INDC++	2100	27.4	60.5	113.0

Appendix 2. Sea Level Rise Expert Panel

Expert Panel on Probabilistic Sea Level Rise for California's 4th Assessment
April 11, 2016 Conference Call

Attendance:
Dan Cayan (organizer, SIO/UCSD)
Julie Kalansky (organizer, SIO/UCSD)
Reinhard (Ron) Flick (expert, California Dept of Parks and Recreation and SIO/UCSD)
Helen Fricker (expert, SIO/UCSD)
Gary Griggs (expert, UCSC)
Robert Kopp (expert, Rutgers Univ.)
Tadd Pfeffer (expert, University of Colorado)
Eric Rignot (expert, UC Irvine)
Jeffrey Severinghaus (expert, SIO/UCSD)

Guido Franco	California Energy Commission
Abe Doherty	California Ocean Protection Council
Lesley Ewing	California Coastal Commission
Michael Anderson	California Department of Water Resources
Louise Bedsworth	Governor's Office of Planning and Research
Susan Wilhelm	California Energy Commission
Jamie Anderson	California Department of Water Resources

Key points

The Experts generally agreed that it is useful for California to construct a bottom-up estimate of sea level rise (SLR) from the major contributing components of SLR in a probabilistic framework.

The consistency between SLR estimates across different studies may be deceptive, because they may rely on the same input data.

The committee viewed the recent DeConto and Pollard (2016) (D&P) Antarctic SLR model projections are viewed as important new results because they are include new physical mechanisms driving ice loss. Nonetheless, these results should be used with caution

Very high percentile (e.g. 99.9%) estimates of global SLR by year 2100 from recent studies are generally thought to conform to physically-possible maximum SLR.

The notion that the contribution of SLR by each of the major components within the present day-year 2100 period will be strongly correlated with that of the other major components (e.g. they co-depend on global temperature change) is a simplification that may not be justified because of the complex physics and mechanics of these processes. Rather, a safer assumption would be that the component-SLR contributions are statistically independent of one another.

Observations from the instrumental and the paleo record are essential in guiding the longer term (centennial) and shorter term (next few decades) projections of SLR.
Regional observations are vital in understanding and modeling local extreme sea levels--in the next few decades, weather and short period climate variability are strongest drivers of extreme high SL's.

The Scenarios Project must be scientifically rigorous and include up-to-date research findings, but-- messages and explanations to decision makers must be clear, simple and assumptions, caveats, constructs need to be clearly explained.