No. 18-16663

IN THE UNITED STATES COURT OF APPEALS FOR THE NINTH CIRCUIT

CITY OF OAKLAND, a Municipal Corporation, and The People of the State of California, acting by and through the Oakland City Attorney Barbara J. Parker; CITY AND COUNTY OF SAN FRANCISCO, a Municipal Corporation, and The People of the State of California, acting by and through the San Francisco City Attorney Dennis J. Herrera,

Plaintiffs-Appellants,

v.

B.P. P.L.C., a public limited company of England and Wales; CHEVRON CORPORATION, a Delaware Corporation; CONOCOPHILLIPS, a Delaware corporation; EXXON MOBIL CORPORATION, a New Jersey Corporation; ROYAL DUTCH SHELL PLC, a public limited company of England and Wales; and DOES 1 through 10,

Defendants-Appellees.

On Appeal From The United States District Court, Northern District of California
Case Nos. 3:17-cv-06011-WHA, 3:17-cv-06012-WHA (Hon. William H. Alsup)

BRIEF OF AMICUS CURIAE MARIO J. MOLINA, MICHAEL OPPENHEIMER, BOB KOPP, FRIEDERIKE OTTO, SUSANNE C. MOSER, DONALD J. WUEBBLES, GARY GRIGGS, PETER C. FRUMHOFF AND KRISTINA DAHL IN SUPPORT OF APPELLANTS AND REVERSAL

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CORPORATE DISCLOSURE STATEMENT

Pursuant to Fed. R. App. P. 26.1, amicus curiae Mario J. Molina, Michael Oppenheimer, Bob Kopp, Friederike Otto, Susanne C. Moser, Donald J. Wuebbles, Gary Griggs, Peter C. Frumhoff, and Kristina Dahl certify that they are individuals, not corporations.

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AMICUS CURIAE'S IDENTITY, INTEREST AND AUTHORITY TO FILE

Amicus curiae, as scientists and scholars, have devoted much of their professional life to studying, writing, and teaching one or more aspects of climate science, including sea level rise and its impacts on coastal communities.

Mario J. Molina received the 1995 Nobel Prize in Chemistry (with F. Sherwood Rowland and Paul Crutzen) for his "work on atmospheric chemistry, particularly concerning the formation and decomposition of ozone." He currently serves as a Professor at the University of California, San Diego (UCSD), with a joint appointment in the Department of Chemistry and Biochemistry and the Scripps Institution of Oceanography. **Michael Oppenheimer** is the Albert G. Milbank Professor of Geosciences and International Affairs at Princeton University. He is a coordinating lead author on the Intergovernmental Panel on Climate Change's Special Report on Oceans, Cryosphere and Climate Change and is coeditor-in-chief of the journal *Climatic Change*. He is also the Director of the Center for Policy Research on Energy and the Environment at Princeton's Woodrow Wilson School and the Kravis Senior Contributing Scientist at the Environmental Defense Fund. **Bob Kopp** is the Director of the Institute of Earth, Ocean, and Atmospheric Sciences and co-directs the Coastal Climate Risk &

Resilience Initiative at Rutgers University as well as the Climate Impact Lab. He is a lead author of the U.S. Global Change Research Program's 2017 Climate Science Special Report and was a contributing author to the Intergovernmental Panel on Climate Change's Fifth Assessment Report. Prof. Kopp is a recipient of the American Geophysical Union's James B. Macelwane and William Gilbert Medals and the International Union for Quaternary Research's Sir Nicolas Shackleton Medal. **Friederike Otto** is the Acting Director of the Environmental Change Institute and an Associate Professor in the Global Climate Science Programme at the University of Oxford. She is a lead author on the Intergovernmental Panel on Climate Change's Sixth Assessment Report, contributing to the chapter *Weather and Climate Extreme Events in a Changing Climate*, and a co-investigator on the International World Weather Attribution Project, providing an assessment of the human-influence on extreme weather in the immediate aftermath of the event. **Susanne C. Moser** is on the Research Faculty in the Environmental Studies Department of Antioch University New England. With more than 120 publications, Dr. Moser is an expert on adaptation to sea level rise. She has advised states and local communities (including in California) on how to advance coastal adaptation. **Donald J. Wuebbles** is The Harry E. Preble Professor of Atmospheric Sciences in the School of Earth, Society, and

Environment, Department of Atmospheric Sciences at the University of Illinois at Urbana-Champaign. Dr. Wuebbles is an expert in atmospheric physics and chemistry, with over 500 scientific publications related to the Earth's climate, air quality, and the stratospheric ozone layer. He was a co-author on the 2013 Intergovernmental Panel on Climate Change, as well as the 2014, 2017, and 2018 U.S. National Climate Assessments. **Gary Griggs** is Professor of Earth & Planetary Sciences at the University of California Santa Cruz, where he also served as Director of the Institute of Marine Sciences for 26 years. He is an expert on sea level rise, publishing over 180 articles in scientific journals and book chapters, and has written 11 books. He was a member of the National Academy of Sciences committee that prepared the report: Sea-Level Rise for the Coasts of California, Oregon and Washington (2012). **Peter C. Frumhoff** is Director of Science and Policy and Chief Climate Scientist at the Union of Concerned Scientists (UCS). A global change ecologist, Dr. Frumhoff has published widely at the nexus of climate science and policy, including on the climate responsibilities of fossil fuel companies and the attribution of extreme events to climate change researchers. He currently serves on the US National Academy of Sciences' Board on Atmospheric Sciences and Climate. He was lead author of the Fourth Assessment Report of the Intergovernmental Panel on Climate

Change. **Kristina Dahl** is a Senior Climate Scientist in the Climate and Energy program at the Union of Concerned Scientists. Dr. Dahl's research focuses on the impact of climate change, particularly sea level rise, on people and places. She was the lead analyst and co-lead author on UCS's report that quantified the risks of sea level rise for communities and real estate in the contiguous United States and has performed detailed GIS analyses showing the projected extent of sea level rise and chronic flooding along the U.S. coasts.

As courts address cases involving the damage to coastal communities caused by climate change and ongoing sea level rise, we feel it is essential for judicial decisions to be based on an understanding of the relevant science and the ***inevitable*** adaptation expenses these communities are facing. We submit this *amicus* brief in order to assist the Court in that regard.

All parties have consented to the filing of this brief. No party's counsel authored the brief in whole or in part, no party or party's counsel contributed money that was intended to fund preparing or submitting the brief, and no person other than counsel for amici contributed money that was intended to fund preparing or submitting the brief.

SUMMARY OF ARGUMENT

There is broad consensus within the community of climate scientists that the impacts of global warming, including rising seas, are accelerating. Carbon dioxide (CO_2) from combustion of fossil fuels—of which the Defendant-Appellant oil companies' products are a primary source—are the largest single contributor to this warming. Global warming has produced a well-documented rise in the world's sea levels through thermal expansion of ocean water, the melting of mountain glaciers, and losses of ice from the Greenland and Antarctic ice sheets.

The coastal cities that filed these lawsuits are facing the daunting and expensive challenge of protecting their citizens and their infrastructure – roads, bridges, airports, rail lines, port facilities, sewage treatments systems, drinking water supply systems, storm drainage systems, and public utilities—from these rising sea levels now and for decades to come.

Even if there were huge reductions in fossil fuel use and CO_2 emissions, the ocean will continue to rise because of the slow nature of the processes governing sea level rise.

Despite the recent United Nations Paris Agreement, by which 195 governments agreed to reduce global emissions in order to keep global warming from progressing to dangerous levels, global CO_2 emissions grew to record levels in 2017 (1.6% increase) and were projected to grow again in 2018 (between 1.8% to 3.7% projected increase).[1] Continued production, marketing, and combustion of fossil fuels on this high emission path would likely result in at least 2 feet of mean global sea-level rise by the end of the century[2], and there is a small but very real possibility that collapse of parts of the Antarctic ice sheet could result in 10 feet of sea level rise in the San Francisco Bay Area by the year 2100.[3] Even the most aggressive emissions reduction scenarios contemplated by any recognized international or national authority would result in at least one foot of mean global sea level rise this century[4,5], and these scenarios are generally recognized as well beyond the reach of current policies.

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[1] Le Quéré, C., et al., "Global Carbon Budget 2018", *Earth System Science Data*, *10*, 405-448 (2018).

[2] About 85% probability according to Kopp, R. E., et al., "Probabilistic 21st and 22nd Century Sea-Level Projections at a Global Network of Tide-Gauge Sites", *Earth's Future*, *2*, 383–406 (2014).

[3] Griggs, G, et al., "Rising Seas in California: An Update on Sea-Level Rise Science", *California Ocean Science Trust,* http://www.opc.ca.gov/webmaster/ftp/pdf/docs/rising-seas-in-california-an-update-on-sea-level-rise-science.pdf

[4] About 92% probability according to Kopp, R. E., et al., "Probabilistic 21st and 22nd Century Sea-Level Projections at a Global Network of Tide-Gauge Sites", *Earth's Future*, *2*, 383–406 (2014).

[5] Sweet, W.V., et al., "Global and Regional Sea Level Rise Scenarios for the United States", *Climate Science Special Report* (2017).

These predictions mean that the types of damage already caused by coastal flooding and inundation will inevitably increase as global warming causes sea levels to rise further. This will require coastal communities to take costly remedial steps to harden infrastructure so they can either withstand such flooding or people and communities will have to retreat from coastal locations.

The lawsuits filed by the Plaintiff cities seek to recover from the oil companies, whose products are the primary source of the greenhouse gases causing global warming and the sea level rise that threatens them, a fair share of the cost of adapting their coastal infrastructure to these rising seas.

We detail below the scientific evidence showing that fossil fuels are a primary cause of the global warming and the sea level rise affecting the cities who have brought suit in their state courts. We also show there is evidence establishing the relative contribution of each individual oil company to the total greenhouse gases in the atmosphere, including the Defendant oil companies named herein, which would provide a reasonable basis for allocating the cost of adaptation.

ARGUMENT

I. Advances In Climate Science Have Shown That During The Period of Human Civilization Stable Levels of Atmospheric Carbon Dioxide and Relatively Stable Global Temperatures And Sea Level Permitted Civilization To Flourish.

The foundation of modern climate science can be traced back to the 19th century. In 1824, Joseph Fourier proposed that Earth's atmosphere acts to raise the planet's temperature. Fourier wondered how Earth could be so warm as it was so far from the sun. Fourier knew that energy from the sun was reflecting off Earth and escaping back to space, and he hypothesized that the atmosphere must capture some of that radiation, otherwise the planet would be significantly cooler. Fourier was the first to describe what would become known as "the greenhouse effect."[6]

In 1856, Eunice Foote was the first person to demonstrate experimentally that the presence of CO_2 in the atmosphere causes the sun to heat the air to a higher temperature compared to atmosphere without CO_2.[7] Soon after, in 1861, John Tyndall expanded on Foote's discovery by

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[6] Fourier, J., "General Remarks on the Temperature of the Earth and Outer Space", *American Journal of Science, 32,* 1-20 (1824), Translation by Ebeneser Burgess.

[7] Foote, E. (1856), "Circumstances Affecting the Heat of the Sun's Rays", *The American Journal of Science and Arts,* 46, 383–384.

studying the amount of infrared energy absorbed by different gas molecules, including CO_2.[8] In 1896, Svante Arrhenius used principles of physical chemistry to calculate estimates of the extent to which increases in atmospheric CO_2 would increase Earth's surface temperature through the greenhouse effect. Arrhenius calculated that a doubling of CO_2 in the atmosphere would increase surface temperatures of the Earth by 4 degrees Celsius (4˚C), which remains within the range of today's state-of-the-art climate model predictions.[9,10]

The greenhouse effect is an atmospheric process that warms Earth's surface. The sun provides energy primarily in the form of visible light and ultraviolet radiation. Though some of that energy is reflected back to space (by snow, clouds, etc.), most is absorbed by Earth's surface. The planet's surface then emits infrared radiation back toward space. Greenhouse gases in the atmosphere, such as CO_2, absorb this emitted infrared radiation; this energy is then re-emitted in all directions in the form of infrared radiation, roughly half upwards towards space and half back down to Earth.

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[8] Tyndall, J. (1861), "On the Absorption and Radiation of Heat by Gases and Vapours, and on the Physical Connexion of Radiation, Absorption, and Conduction", *Philosophical Magazine*, *22*, 169-94.
[9] Arrhenius, S. (1896), "On the Influence of Carbonic Acid in the Air Upon the Temperature of the Ground", *Philosophical Magazine*, *41*, 237-76.
[10] Stocker., et al. (2013), Technical Summary, in *Climate Change 2013: The Physical Science Basis*.

Carbon dioxide is the most important greenhouse gas due to its potency, longevity, and abundance in the atmosphere. Water vapor is the most abundant greenhouse gas and plays an important role in regulating Earth's temperature. The amount of water vapor in the atmosphere is modulated by air temperature; warmer conditions cause liquid water to evaporate, and warm air can hold more water vapor than cold air. Rising CO_2 leads to an increase in temperature, which in turn leads to increased water vapor in the atmosphere. This feedback loop amplifies the warming effect CO_2 has on the planet.[11] Without CO_2, water vapor, and other greenhouse gases in the atmosphere, the mean surface temperature of Earth would be 33˚C (60˚F) cooler than it currently is.[12,13]

Earth's history is punctuated by naturally driven climate change events. Large continental ice sheets in the northern hemisphere have advanced and retreated many times during the last 2.6 million years; periods with large ice sheets are called *glacial periods* or *ice ages*, and those without

[11] Solomon, S., et al., "Contributions of Stratospheric Water Vapor to Decadal Changes in the Rate of Global Warming", *Science*, *327*, 1219-1223 (2010).
[12] Schneider, S., "The Greenhouse Effect: Science and Policy", *Science*, *243*, 771-81 (1989).
[13] Collins, M., et al., Chap. 12: "Long-Term Climate Change: Projections, Commitments and Irreversibility", *Climate Change 2013*: *The Physical Science Basis* (2013).

are known as *interglacial periods*. This pattern of climate change was driven primarily by changes in incoming solar radiation due to variations in Earth's orbit. For the last eight hundred thousand years, glacial periods have lasted around 100,000 years and have been separated by relatively warm interglacial periods that lasted between 10,000 to 30,000 years. The most recent glacial period occurred between 11,500 and 116,000 years ago. Since then, Earth has been in an interglacial period called the Holocene Epoch.[14]

At the end of the last glacial period (during a 12,000-year span beginning around 20,000 years ago), global mean sea level rose approximately 400–450 feet at an average rate of 0.4 inches per year.[15] However, this deglaciation was punctuated by episodes of very rapid sea level rise. For example, 14,000 years ago, sea level rose between 28–48 feet over 350 years.[16] Around 7,000 years ago, in the midst of the subsequent interglacial period (the Holocene), the rate of sea level rise markedly decreased. Between 6,700 and 4,200 years ago, sea level rose about 10 feet, at a rate of about 0.05 inches per year. Sea level rose no more than about 3

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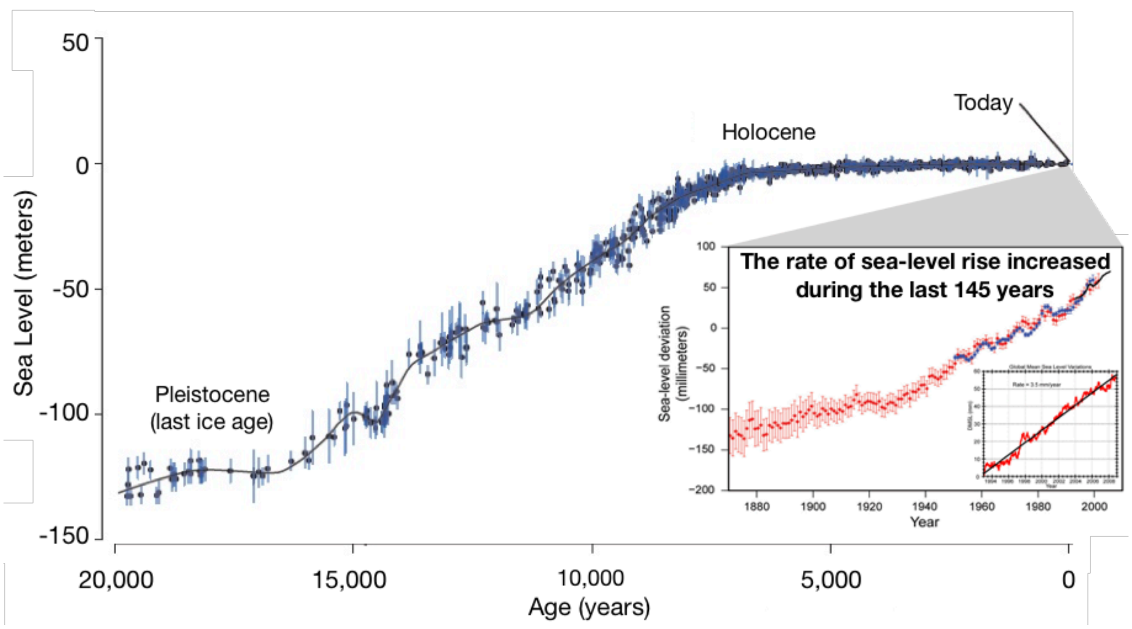
[14] Masson-Delmotte, V., et al., Chap. 5: "Information from Paleoclimate Archives", *Climate Change 2013*: *The Physical Science Basis* (2013).
[15] Masson-Delmotte, V., et al., Chap. 5: "Information from Paleoclimate Archives", *Climate Change 2013: The Physical Science Basis* (2013).
[16] Liu, J., et al., "Sea Level Constraints on the Amplitude and Source Distribution of Meltwater Pulse 1A", *Nature Geoscience*, *9*, 130-134 (2016).

feet between 4,200 years ago and the time of onset of recent sea-level rise (about 150 years ago),[17] or less than approximately 0.01 inches per year.[18] Human civilization has flourished during the Holocene period of sea level stability and has never had to deal with rapid changes in sea level (Figure 1).[19]

Figure 1. Global mean sea level over the last 20,000 years. During the termination of the last ice age, massive continental ice loss led to 120–135 m (400–450 feet) of sea level rise. Around 7,000 years ago, the rate of sea level rise dropped to a "pre-industrial" rate of <1 mm per year. Figure inset depicts estimated sea level change (mm) since 1870. Global mean sea level has been rising at an average rate of 1.7 mm per year over the past 100 years. Since 1993, the rate increased to about 3.5 mm per year. Red: sea level since 1870. Blue: tide-gauge data. Black: satellite observations. Figures modified from: Clark, P., et al. (2016). Consequences of twenty-first-century policy for multi-millennial climate and sea level change, *Nature Climate Change*, *6*, 360-369, and NOAA https://www.ncdc.noaa.gov/monitoring-references/faq/indicators.php.



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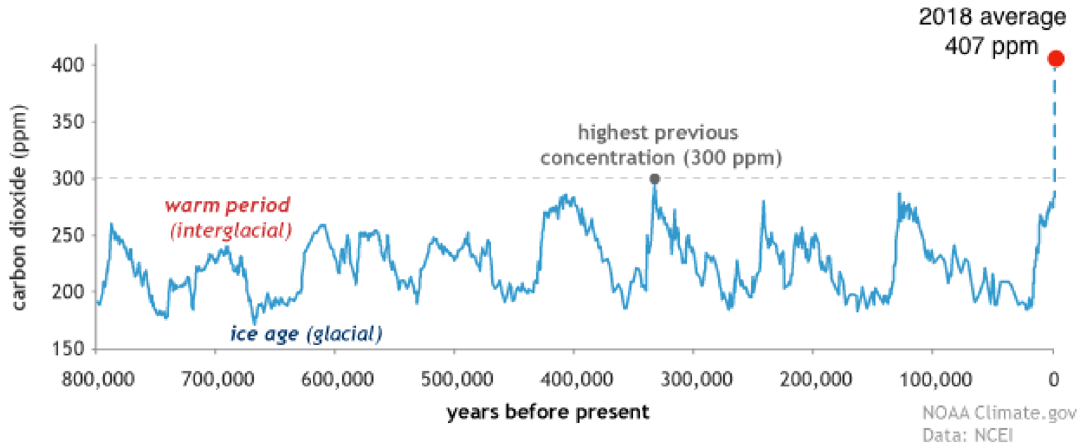
[17] Kopp, R., et al., "Temperature-Driven Global Sea-Level Variability in the Common Era", *PNAS*, E1434-E1441 (2016).
[18] Lambeck, K., et al., "Sea Level and Global Ice Volumes From the Last Glacial Maximum to the Holocene", *PNAS*, *111*(43), 15296-15303 (2014).
[19] Masson-Delmotte, V., et al., Chap. 5: "Information from Paleoclimate Archives", *Climate Change 2013: The Physical Science Basis* (2013).

II. With the Commencement of the Industrial Revolution, Previously Stable Atmospheric Carbon Dioxide Levels Began Increasing, Causing Rising Atmospheric and Ocean Temperatures and Sea Level Rise That Is Unprecedented In the History of Human Civilization.

For most of the history of human civilization the amount of CO_2 in the Earth's atmosphere remained in a stable range between 260–280 parts per million (ppm).[20] During the past 200 years, commencing with the Industrial Revolution (1720–1800 CE), increased combustion of fossil fuels, cement production, and deforestation[21] have raised the average concentration of CO_2 in the atmosphere to greater than 410 ppm[22] – higher than any time in at least 800,000 years (Figure 2).[23] Most critically, however, more than half of all industrial emissions of CO_2 have occurred since 1988.[24]

[20] Lourantou, A., et al., "Changes in Atmospheric CO_2 and Its Carbon Isotopic Ratio During the Penultimate Deglaciation", *Quaternary Science Reviews*, *29*, 1983-1992 (2010).
[21] Le Quéré, C., et al., "Global Carbon Budget 2018", *Earth System Science Data*, *10*, 2141-2194 (2018).
[22] Dlugokencky, Ed and Trans, Pieter, *NOAA/ESRL (www.esrl.noaa.gov/gmd/ccgg/trends/)*
[23] Masson-Delmotte, V., et al., Chap. 5: "Information from Paleoclimate Archives", *Climate Change 2013*: *The Physical Science Basis* (2013).
[24] Frumhoff, P., et al., "The Climate Responsibilities of Industrial Carbon Producers", *Climatic Change*, *132*, 157-171 (2015).

Figure 2. Changes in atmospheric CO_2 concentrations over the last 800,000 years. Historic CO_2 levels are from ice core data, and current data are from the Mauna Loa Observatory. Average 2018 concentration indicated by red dot. Figure modified from NOAA.



Due primarily to the increased concentration of anthropogenic CO_2 from fossil fuel combustion, the mean surface temperature[25] of Earth has increased by 1˚C (1.8˚F) since the late nineteenth century.[26,27,28] One way to conceptualize the immense amount of heat that Earth is absorbing is to combine measurements of ocean, land, atmosphere, and ice heating. Based on these data, over the last two decades Earth's climate system has been

[25] *Global mean surface temperature* is calculated by combining measurements from the air above land and the ocean surface.
[26] Hawkins, E., et al., "Estimating Changes in Global Temperature Since the Preindustrial Period", *Bulletin of the American Meteorological Society*, *98*(9), 1841-1856 (2017).
[27] These facts were also agreed to by the defendant corporations in a tutorial before Judge William Alsup, in federal district court in the 9th circuit, in March 2018.
[28] IPCC, "Summary for Policymakers", *Global warming of 1.5°C* (2018).

absorbing the heat equivalent, in joules, of detonating four Hiroshima atomic bombs per second, or nearly 400,000 Hiroshima A-bombs per day.[29,30]

If there is no significant global effort to limit fossil fuel combustion and the resultant CO_2 emissions, by the end of the century global mean surface temperature is projected to increase by between 3.6–5.8˚C above pre-industrial temperature.[31] The last time global mean surface temperature was comparable to today,[32,33] global mean sea level was 20–30 feet higher than modern sea level.[34]

Global warming contributes to sea level rise in multiple ways. As the ocean warms from climate change, seawater expands, takes up more space, and the oceans rise to accommodate this basic physical expansion. This process is known as *ocean thermal expansion*. Ocean thermal expansion

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[29] Church, J. A., et al., "Revisiting the Earth's Sea-Level and Energy Budgets From 1961 to 2008", *Geophysical Research Letters*, *38*, L18601 (2011).
[30] Nuccitelli, D., et al., "Comment on Ocean Heat Content and Earth's Radiation Imbalance II, Relation to Climate Shifts", *Physics Letters A*, *376*(45), 3466-3468 (2012).
[31] Collins, M., et al., Chap. 12: "Long-term Climate Change: Projections, Commitments and Irreversibility", *Climate Change 2013*: *The Physical Science Basis* (2013).
[32] The Last Interglacial, 130,000–115,000 years ago.
[33] Hoffman, J., et al., "Regional and Global Sea-Surface Temperatures During the Last Interglaciation", *Science*, *355*, 276-279 (2017).
[34] Dutton, A., et al., "Sea Level Rise Due to Polar Ice-Sheet Mass Loss During Past Warm Periods", *Science*, *349*(6244), aaa4019 (2015).

accounts for about 50% of the increased volume of the world's oceans in the past 100 years. The remaining sea level rise of the past century has been largely due to melting mountain glaciers (about 25%) and Antarctic and Greenland ice sheet loss (about 25%).[35,36]

III. Even If All Carbon Dioxide Emissions Were To Cease Immediately, Sea Levels Would Continue To Rise For The Rest Of The Century Because Of The Additional Global Warming That Is Locked In By Cumulative Past Emissions.

There is a delay between rising air temperatures and sea level rise. Ocean thermal expansion and ice loss occur on timescales slower than the rate at which air temperature increases in response to increasing atmospheric CO_2 concentrations. It can take over a thousand years for ocean thermal expansion to equilibrate with warmer air temperatures.[37]

Since 1900, global mean sea level rose about 8 inches[38], but it was not a steady progression. The rate of sea level rise is dramatically increasing.

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[35] Griggs, G, et al., "Rising Seas in California: An Update on Sea-Level Rise Science", *California Ocean Science Trust*, http://www.opc.ca.gov/webmaster/ftp/pdf/docs/rising-seas-in-california-an-update-on-sea-level-rise-science.pdf

[36] Church, J. A., et al., Chap. 13: "Sea Level Change", *Climate Change 2013: The Physical Science Basis* (2013).

[37] Levermann, A., et al., "The Multimillennial Sea-Level Commitment of Global Warming", *Proceedings of the National Academy of Sciences*, 110(34), 13745-13750 (2013).

[38] Church, J., White, N., "Sea Level Rise From the Late 19th to Early 21st Century", *Surveys in Geophysics, 32*, 4-5, 585-602 (2011).

Since 1990, the rate of sea rise increased about twice the rate of the last century and the rate of sea rise is continuing to accelerate.[39,40] This sea level rise can increase damages from daily tides, king tides, and extreme weather events. In superstorm Sandy, sea level rise was estimated to have inflicted an additional $2 billion in flooding damage.[41] A report published in March 2018 by San Mateo County found that "*the assessed value of parcels exposed to near-term (present-day) flooding exceeds $1 billion*."[42]

Current atmospheric CO_2 concentrations have committed the world to significant levels of sea level rise for centuries to come. There is no feasible combination of emissions reductions, no matter how aggressive, that can prevent the now inevitable rise of seas over the next one hundred years or more. The recently published Fourth National Climate Assessment warns that:

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[39] Nerem, R. S., et al., "Climate-Change-Driven Accelerated Sea-Level Rise Detected in the Altimeter Era", *Proceedings of the National Academy of Sciences of the United States of America*, *115*(9), 2022-2025 (2018).

[40] Griggs, G, et al., "Rising Seas in California: An Update on Sea-Level Rise Science", California Ocean Science Trust (2017). http://www.opc.ca.gov/webmaster/ftp/pdf/docs/rising-seas-in-california-an-update-on-sea-level-rise-science.pdf

[41] Leifert, H., "Sea Level Rise Added $2 Billion to Sandy's Toll in New York City", *Eos*, *96*, 16 (2015).

[42] County of San Mateo Sea Level Rise Vulnerability Assessment (2018), https://seachangesmc.org/wp-content/uploads/2018/03/2018-03-12_SLR_VA_Report_2.2018_WEB_FINAL.pdf

> Even if significant emissions reductions occur, many of the effects from sea level rise over this century (and particularly through mid-century) are already locked in due to historical emissions, and many communities are already dealing with the consequences. Actions to plan for and adapt to more frequent, widespread, and severe coastal flooding, such as shoreline protection and conservation of coastal ecosystems, would decrease direct losses and cascading impacts on other sectors and parts of the country.[43]

The Intergovernmental Panel on Climate Change (IPCC), a body of the United Nations, is the internationally accepted authority on climate change science. The IPCC issues global consensus scientific assessment reports every five to seven years reviewing the state of climate science. The IPCC's Fifth Assessment Report utilizes a set of future scenarios, known as Representative Concentration Pathways (RCPs) (Figure 3)[44] to help policy makers understand the impact of policies designed to reduce emissions.

The four RCPs describe scenarios based on different assumptions about energy consumption, energy sources, land use change, economic growth, and population. At one end of the spectrum, RCP 2.6 represents a suite of extremely aggressive reduction scenarios which require that CO_2 emissions worldwide plateau by 2020, just one year from now, and are

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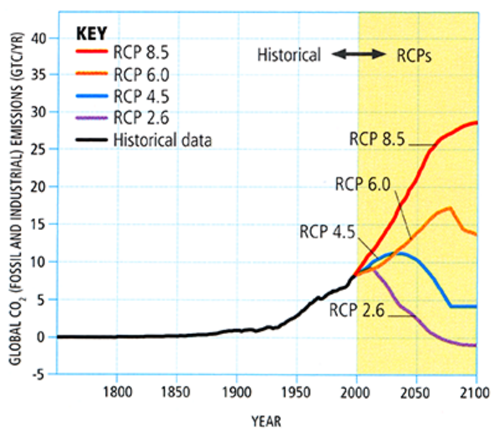
[43] Fourth National Climate Assessment (2018), Vol. II, "Summary Findings", https://nca2018.globalchange.gov/#sf-12

[44] RCPs are named for the associated radiative forcing level in watts per square meter (the difference between sunlight absorbed by Earth and energy radiated back to space) by the year 2100 relative to pre-industrial values.

reduced by 50% by 2050.[45,46] At the other end, RCP 8.5 represents a future in which there is no significant global effort to limit greenhouse gas emissions. Each RCP represents a family of climate outcomes, including temperature and sea level rise.[47]

Figure 3. Observed and predicted projected CO_2 emissions. Current rate of annual carbon emissions in gigatons (black line) compared to IPCC projected scenarios. Figure source: Mann & Kump, Dire Predictions: Understanding Climate Change, 2nd Edition © 2015 Dorling Kindersley Limited.



Under RCP 2.6, the Intergovernmental Panel on Climate Change's Fifth Assessment Report projects that global mean sea level will likely rise

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45 Compared to 1990 CO_2 emissions.

46 Jones, C., et al., "Twenty-First-Century Compatible CO_2 Emissions and Airborne Fraction Simulated by CMIP5 Earth System Models Under Four Representative Concentration Pathways", *Journal of Climate*, *26*, 4398-4413 (2013).

47 Collins, M., et al., Chap. 12: "Long-term Climate Change: Projections, Commitments and Irreversibility", *Climate Change 2013*: *The Physical Science Basis (2013)*.

11–24 inches by 2100.[48,49] Under RCPs 4.5, 6.0, and 8.5, which are more plausible paths based on current policies, sea level is projected to likely rise 14–28 inches, 15–29 inches, and 20–39 inches, respectively, by 2100. [50,51] Projections of sea level rise that rely on these RCP scenarios generally provide conservative estimates because they do not account for the possibility that changing Antarctic ice sheet dynamics could dramatically increase sea levels by the end of the century.[52,53]

A fifth sea level rise scenario included in the California Ocean Science Trust's projections of sea-level rise in California, named H++, represents the maximum physically plausible global mean sea level rise that could result from exceedingly rapid Antarctic ice sheet loss during the latter

[48] At least about 66% probability, according to Church, J. A., et al., Chap. 13: "Sea Level Change", *Climate Change 2013: The Physical Science Basis* (2013).
[49] Relative to global mean sea level over 1986–2005.
[50] At least about 66% probability, according to Church, J. A., et al., Chap. 13: "Sea Level Change", *Climate Change 2013: The Physical Science Basis* (2013).
[51] Church, J. A., et al., Chap. 13: "Sea Level Change", *Climate Change 2013: The Physical Science Basis* (2013).
[52] DeConto, R. & Pollard, D., "Contribution of Antarctica to Past and Future Sea-Level Rise", *Nature*, *531*(7596): 591-597 (2016).
[53] Shepherd, A., et al., "Mass Balance of the Antarctic Ice Sheet From 1992 to 2017, *Nature*, *556*, 219-222 (2018).

half of this century.[54] This scenario projects an 8-foot rise in global mean sea level. The H++ scenario represents extreme sea level rise, the probability of which is currently unknown due to our limited understanding of the dynamics governing the magnitude and timing of Antarctic ice sheet loss.

In October of 2018, the IPCC issued a special report assessing: 1) the possibility of restricting global warming to 1.5˚C above pre-industrial temperatures, and 2) what the avoided damages might be between 1.5˚C and 2˚C warming, the two goals adopted at the 2016 Paris Climate Summit.[55,56]

Capping global warming at 1.5˚C would require exceptional measures, even more aggressive than those contemplated in the IPCC's RCP 2.6 scenario, which was the most aggressive emissions reduction pathway previously assessed by the group. To prevent the world from warming more than 1.5˚C above pre-industrial levels, global CO_2 emissions would need to decline about 45% by 2030 and reach net zero emissions globally by

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[54] Griggs, G, et al., "Rising Seas in California: An Update on Sea-Level Rise Science", *California Ocean Science Trust* (2017). http://www.opc.ca.gov/webmaster/ftp/pdf/docs/rising-seas-in-california-an-update-on-sea-level-rise-science.pdf

[55] Intergovernmental Panel on Climate Change, " Summary for Policymakers", *Global warming of 1.5°C* (2018).

[56] The UN Paris Agreement, https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

2050.[57] Given the current trajectory of global economic development and the weak voluntary commitments of the world's nations to curbing the problem (discussed below) coast cities like Plaintiffs faced with increasingly severe climate change impacts cannot rely on this level of emissions reductions being achieved. Indeed, between 2017 and 2018, global energy-related CO_2 emissions *increased* by +2.7% (range of +1.8% to +3.7%).[58,59] And even if net emissions were cut to zero globally by 2050, the seas would continue to rise over at least the next few centuries to levels that would threaten billions of dollars of property and infrastructure in California and beyond.

Local sea level may differ from global mean sea level due to a number of factors.

a. Large ice sheets exert a gravitational pull on the nearby ocean, drawing water towards it. If that ice melts, this gravitational force weakens, causing a lowering of sea level near the ice sheet and an enhanced sea-level rise further away. Consequentially, the loss of Antarctic ice generally has an enhanced effect on Northern

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[57] Intergovernmental Panel on Climate Change, "Summary for Policymakers", *Global warming of 1.5°C* (2018).
[58] Le Quéré, C., et al., "Global Carbon Budget 2018", *Earth System Science Data*, *10*, 2141-2194 (2018).
[59] International Energy Agency, "Global Energy and CO2 Status Report", https://www.iea.org/geco/emissions/

Hemisphere sea level rise, while the loss of Greenland ice generally has an enhanced effect on Southern Hemisphere sea level rise.[60,61]

b. Regions near the centers of ice sheets of the last ice age may experience post-glacial rebound, which is the rise of land masses that were depressed by massive ice sheets during the last ice age. Conversely, land pushed up during the building of ice sheets in the last ice age ("the forebulge") may now be sinking (e.g. Chesapeake Bay).[62]

c. Prevailing winds can push water across oceans. For example, the Trade Winds in the Pacific blow water westward, increasing sea level in the western Pacific (e.g. the Philippines) by about 24 inches, and decreasing sea level in the eastern Pacific (e.g. northern South America). In the long term, global wind patterns

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[60] Mitrovica, J. X., et al., "On the Robustness of Predictions of Sea Level Fingerprints", *Geophysical Journal International*, *187*, 729–742 (2011).

[61] Griggs, G, et al., "Rising Seas in California: An Update on Sea-Level Rise Science", *California Ocean Science Trust* (2017), http://www.opc.ca.gov/webmaster/ftp/pdf/docs/rising-seas-in-california-an-update-on-sea-level-rise-science.pdf

[62] DeJong, B., et al., "Pleistocene Relative Sea Levels in the Chesapeake Bay Region and Their Implications for the Next Century", *GSA Today*, *25*(8), 4–10 (2015).

change as climate changes, geographically re-allocating mounds of sea water. Short term changes in winds, such as those associated with El Niño events, can have large effects on local sea level. During the El Niño winters of 1940–41, 1982–83, and 1997–98, San Francisco Bay sea level rose 8–12 inches for several months at a time.[63]

d. In addition to ocean currents generated by surface wind, currents that are driven by differences in water density due to temperature and salinity variations in different parts of the ocean (*thermohaline circulation*) can have large effects on local sea level.[64]

e. Localized processes such as plate tectonics and sediment compaction can cause land masses to fall or rise.[65]

[63] Griggs, G, et al., "Rising Seas in California: An Update on Sea-Level Rise Science", *California Ocean Science Trust* (2017).
[64] Levermann, A. et al., "Dynamic Sea Level Changes Following Changes in the Thermohaline Circulation", *Climate Dynamics*, *24*(4), 347-354 (2005).
[65] Griggs, G, et al., "Rising Seas in California: An Update on Sea-Level Rise Science", *California Ocean Science Trust* (2017), http://www.opc.ca.gov/webmaster/ftp/pdf/docs/rising-seas-in-california-an-update-on-sea-level-rise-science.pdf

f. Oil and gas extraction, as well as groundwater withdrawal can cause the continental shelf to "deflate," raising sea level at coastal deltas (e.g. Louisiana).[66,67,68]

At the Golden Gate Bridge in San Francisco, sea level rose 9 inches between 1854 and 2016.[69] Under RCP 2.6, an extremely aggressive emissions reduction scenario, the San Francisco Bay is expected to rise roughly another 19 inches by 2100[70], at a rate more than double that of the past 20 years (Figures 4–6).[71,72,73]

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[66] Nienhuis, J. H., et al., "A New Subsidence Map for Coastal Louisiana", *GSA Today, 27* (2017).

[67] Griggs, G, et al., "Rising Seas in California: An Update on Sea-Level Rise Science", *California Ocean Science Trust* (2017), http://www.opc.ca.gov/webmaster/ftp/pdf/docs/rising-seas-in-california-an-update-on-sea-level-rise-science.pdf

[68] Kopp, R. E., et al., "Probabilistic 21st and 22nd Century Sea-Level Projections at a Global Network of Tide-Gauge Sites", *Earth's Future, 2*, 383–406 (2014).

[69] Fourth National Climate Assessment (2018), Vol. II, Chap. 25: "Southwest", https://nca2018.globalchange.gov/chapter/25/#section-kf-key-message-3

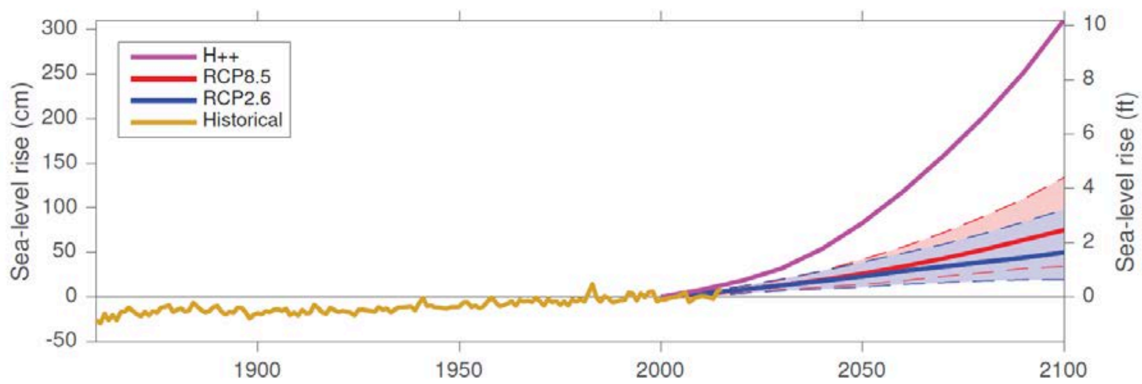
[70] 19 inches is a median value and has a 67% probability range of 12–29 inches, with a 1-in-20 chance of exceeding 38 inches.

[71] Relative to mean sea level between 1991–2009.

[72] Griggs, G, et al., "Rising Seas in California: An Update on Sea-Level Rise Science", *California Ocean Science Trust* (2017), http://www.opc.ca.gov/webmaster/ftp/pdf/docs/rising-seas-in-california-an-update-on-sea-level-rise-science.pdf

[73] Kopp, R. E., et al., "Probabilistic 21st and 22nd Century Sea-Level Projections at a Global Network of Tide-Gauge Sites", *Earth's Future, 2*, 383–406 (2014).

Figure 4. Past and future sea level change in San Francisco. Historical sea level in San Francisco Bay and sea level rise projections for RCP 2.6, RCP 8.5, and the H++ scenarios. The shaded areas bounded by the dashed lines represent the 5th and 95th percentiles. Figure source: Griggs, G, et al. (2017).



Under RCP 8.5, a scenario that assumes more or less unabated emissions, local sea level is most likely to rise roughly 30 inches by 2100,[74] at nearly four times the rate of current sea level rise (Figure 6). [75,76,77] If

[74] 30 inches is a median value and has a 67% probable range of 19–41 inches, with a 1-in-20 chance of exceeding 53 inches.
[75] Relative to mean sea level between 1991–2009.
[76] Griggs, G, et al., "Rising Seas in California: An Update on Sea-Level Rise Science", *California Ocean Science Trust (2017),* http://www.opc.ca.gov/webmaster/ftp/pdf/docs/rising-seas-in-california-an-update-on-sea-level-rise-science.pdf
[77] Kopp, R. E., et al., "Probabilistic 21st and 22nd Century Sea-Level Projections at a Global Network of Tide-Gauge Sites", *Earth's Future, 2,* 383–406 (2014).

warming triggers the rapid decay of the Antarctic ice sheet (H++ scenario), local sea level rise could be as high as 10 feet.[78,79]

IV. Combining Climate Science Predictions of Sea Level Rise with Engineering Assessment of the Vulnerability of Specific Coastal Cities, Such As These Appellants, Shows That They Are Facing Unavoidable and Costly Infrastructure Damage From Flooding Due To Rising Sea Levels That Will Worsen As Sea Levels Inevitably Continue To Rise.

Both of the Appellant cities and other San Francisco Bay communities have general and locally specific vulnerability to sea level rise. With the current state of climate science and engineering assessments, the extent of that vulnerability can be reliably predicted. For example, San Francisco Baykeeper generated cost estimates of damages for future flood scenarios using FEMA's Hazus[80] model and the US Geological Survey's sea level rise model.[81] They found that under 3.3 additional feet of sea level rise and a 100-year flood, San Francisco will sustain $1,392 million in structure and content loss, and Oakland will sustain $213 million in structure and content

[78] Griggs, G, et al., "Rising Seas in California: An Update on Sea-Level Rise Science," *California Ocean Science Trust* (2017), http://www.opc.ca.gov/webmaster/ftp/pdf/docs/rising-seas-in-california-an-update-on-sea-level-rise-science.pdf
[79] Sweet, W.V., et al., "Global and Regional Sea Level Rise Scenarios for the United States" (2017).
[80] https://www.fema.gov/hazus
[81] http://data.pointblue.org/apps/ocof/cms/index.php?page=users

loss.[82] Studies conducted by the Pacific Institute, the U.S. Army Corps of Engineers, and the California Department of Water Resources found that nearby San Mateo County is one of the most vulnerable counties in California to the impacts of flooding,[83] with the assessed property value exposed to present-day coastal flooding exceeding $1 billion.[84,85,86] If San Mateo County were to experience a 100-year coastal flood[87] today, the county would sustain $3.6 billion dollars of damage to property due to flooding. With 3.3 additional feet of sea level rise (at the high end of the RCP 8.5 scenario for 2100) and a 100-year flood, damage due to flooding in San Mateo County increases to $34 billion, with the inundation of: 30,000 residential parcels, 2,200 commercial parcels, 34 schools, 23 medical

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[82] "The Economic Cost of Sea Level in the Bay Area" https://baykeeper.org/shoreview/economic-loss.html#

[83] California Department of Water Resources (2013), "California Water Plan Update", https://water.ca.gov/Programs/California-Water-Plan/Water-Plan-Updates

[84] Pacific Institute, "The Impacts of Sea Level Rise on the San Francisco Bay" (2012), http://www.energy.ca.gov/2012publications/CEC-500-2012-014/CEC-500-2012-014.pdf

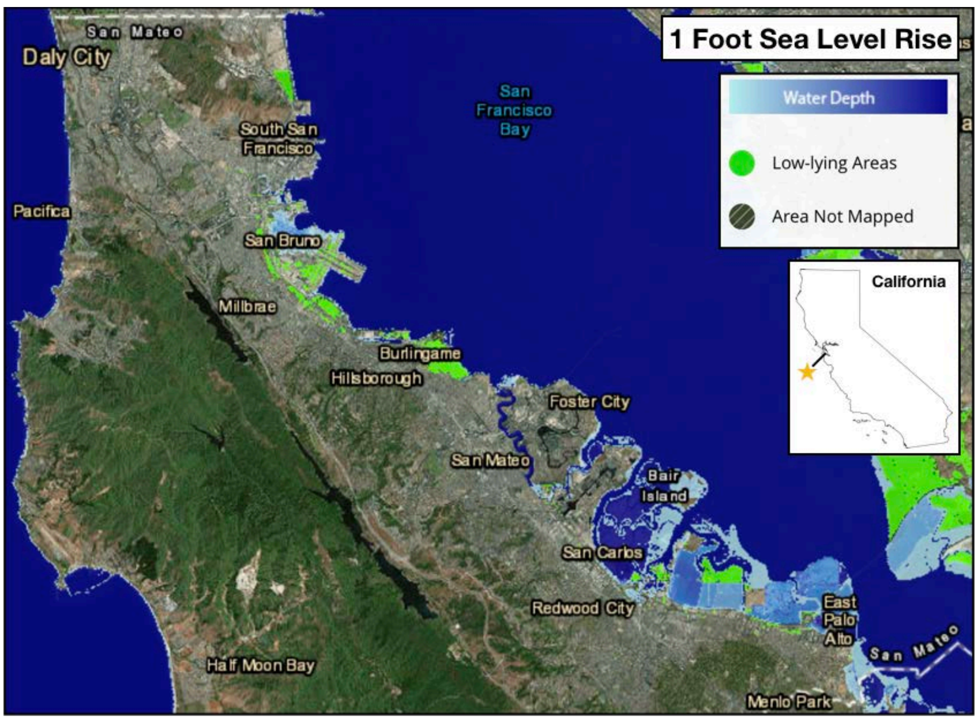
[85] U.S. Army Corps of Engineers, "North Atlantic Coast Comprehensive Study Report" (2014), http://www.nad.usace.army.mil/CompStudy/

[86] County of San Mateo Sea Level Rise Vulnerability Assessment (2018), https://seachangesmc.org/wp-content/uploads/2018/03/2018-03-12_SLR_VA_Report_2.2018_WEB_FINAL.pdf

[87] A flood that has a 1% chance of occurring in any given year. In the SF Bay Area, this is equal to a 3.5 ft storm surge.

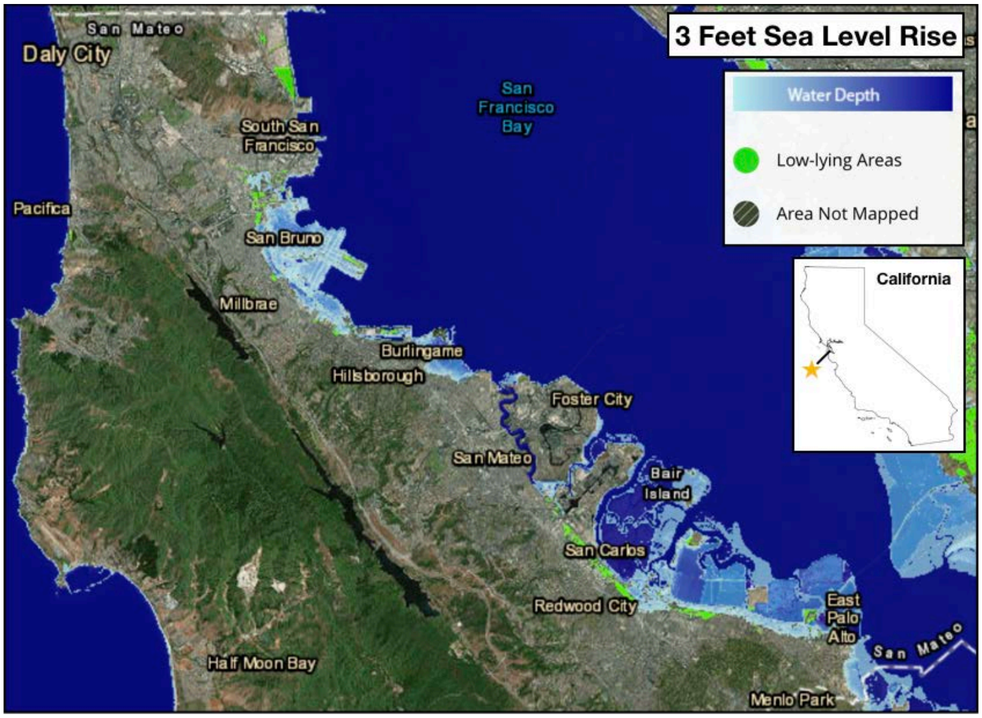
facilities, 3 police stations, 8 fire stations, 2 airports (including San Francisco International Airport, which would be inundated by 2 feet of sea level rise), and 12 electrical substations.[88]

Figure 5. One foot of sea level rise in San Mateo County, California. Water levels are relative to Mean Higher High Water Datum (the average of the higher high-tide height for each tidal day over a designated 19 year period). Blue shading indicates areas below water level. Green shading represents areas below water level but not connected to the ocean, due to natural or built breaks such as levees. Figure source: NOAA Sea Level Rise Viewer.



[88] County of San Mateo Sea Level Rise Vulnerability Assessment (2018), https://seachangesmc.org/wp-content/uploads/2018/03/2018-03-12_SLR_VA_Report_2.2018_WEB_FINAL.pdf

Figure 6. Three feet of sea level rise in San Mateo County, California. Water levels are relative to Mean Higher High Water Datum (the average of the higher high-tide height for each tidal day over a designated 19 year period). Blue shading indicates areas below water level. Green shading represents areas below water level but not connected to the ocean, due to natural or built breaks such as levees. Figure source: NOAA Sea Level Rise Viewer.



In 2015, the nations of the world, including the United States, signed the Paris Climate Agreement, committing to put forward their best efforts to reduce greenhouse gas emissions in line with a goal of keeping global temperature rise to well below 2˚C over pre-industrial levels (roughly equivalent to RCP 2.6). Current national plans (nationally determined contributions, NDCs) fall far short of this goal and would lead to about a 3˚C temperature increase by 2100.[89] In the U.S., the Trump Administration has stated its intention to withdraw from the Paris Agreement.

As a consequence, responsible local governments must prepare for the consequences of global warming at least 2˚C above pre-industrial levels. For the California cities in this litigation, 2˚C global warming translates to a median estimate of 9 inches of sea level rise by 2050 - more than the past 100 years of sea level rise in just 30 years - and 21 inches of sea level rise by 2100.[90]

Even under the most ambitious emissions reductions scenario, the world's oceans will continue to rise as the climate system comes into balance with the roughly 50% increase in atmospheric CO_2 concentration since the dawn of the industrial revolution. Given that physical fact, and the Plaintiff cities' vulnerability to sea level rise of just one or two feet, there is no plausible emissions reduction scenario where these cities can avoid the substantial cost of adapting to and protecting themselves from rising seas that result primarily from the combustion of fossil fuels, including the Defendant oil companies' products.

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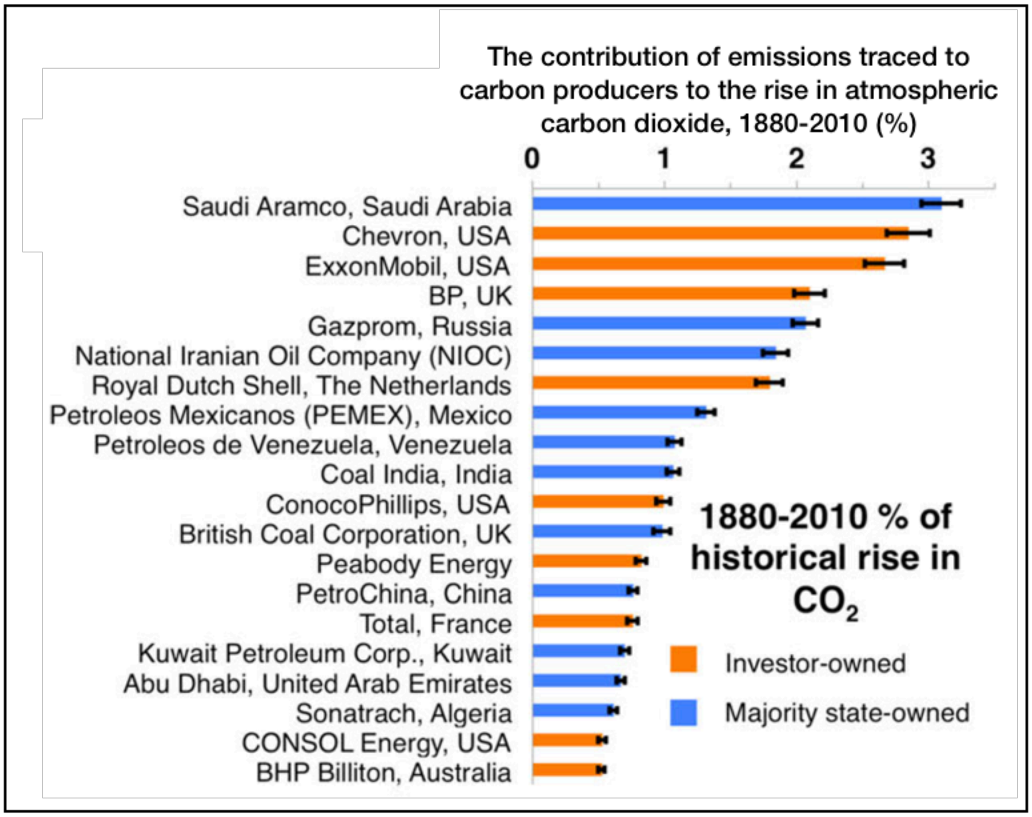
[89] Rogelj, J., et al., "Paris Agreement Climate Proposals Need a Boost to Keep Warming Well Below 2 C", *Nature 534*(7609), 631 (2016).
[90] Rasmussen, D. J., et al., "Extreme Sea Level Implications of 1.5°C, 2.0°C, and 2.5°C Temperature Stabilization Targets in the 21st and 22nd Centuries", *Environmental Research Letters*, *13*, 034040 (2018).

Finally, the portion of total CO_2 in the atmosphere attributable to each oil company's products has been now well established. This work demonstrates that emissions caused by the products of 90 major carbon producers contributed 57 (±2.9)% of the total increased atmospheric CO_2 from 1880 through 2010 (Figure 7).[91] Nearly half of that was attributable to the 20 largest entities. And nearly half of that, in turn, was attributable to Defendant-Appellees in this case. Chevron was the 2nd largest CO_2 producer during that period. ExxonMobil is the 3rd largest, BP is the 4th largest, Shell ranks 7th and ConocoPhillips is 11th. This evidence provides a reasonable basis for allocation of the costs of adaption.

[91] Ekwurzel, B, et al., "The Rise in Global Atmospheric CO_2, Surface Temperature, and Sea Level from Emissions Traced to Major Carbon Producers", *Climatic Change*, *144*, 579-590 (2017).

Figure 7. Top twenty investor- & state-owned entities and attributed CO_2 emissions. Emissions from these companies contributed about 27.2 (±2.9)% of increase in cumulative atmospheric CO_2 between 1880 and 2010. Figure modified from: Ekwurzel, B., et al. (2017).



CONCLUSION

In sum, we know that the present damage and future risk to coastal communities such as the Appellants, posed by rising sea levels, is caused in significant part by global warming. We know that the Defendant-Appellee oil companies' production and marketing of their fossil fuels is a significant cause of that global warming and the sea level rise threatening these cities. We know what portion of CO_2 emissions are associated with each of the oil companies' products and, thus, can attribute a portion of sea level rise to these products. All of these matters can be proven at trial through the introduction of evidence in the form of well-established scientific facts.

We therefore urge the Court to reverse the decisions of the court below.

March 20, 2019

Respectfully submitted,

By /s/ William A. Rossbach

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CERTIFICATE OF SERVICE

I hereby certify that I caused the foregoing to be electronically field with the Clerk of the Court for the United States Court of Appeals for the Ninth Circuit by using the appellate CM/ECF system on March 20, 2019.

I certify that all participants in the case are registered CM/ECF users and that service will be accomplished by the appellate CM/ECF system.

/s/ William A. Rossbach
William A. Rossbach

CERTIFICATE OF COMPLIANCE

Pursuant to Federal Rule of Appellate Procedure 29(a)(4)(g), I certify that:

This Brief complies with Rule 29(a)(5)'s type-volume limitation, because it contains 6,380 words as determined by the Microsoft Word 2016 word-processing system used to prepare the brief, excluding the parts of the brief exempted by Rule 32(a)(7)(B)(iii).

This Brief complies with Rule 32(a)(5)'s typeface requirements, and Rule 32(a)(6)'s type-style requirements because it has been prepared in a proportionately spaced typeface using the 2016 version of Microsoft Word in 14-point Times New Roman font.

/s/ William A. Rossbach
William A. Rossbach

APPENDIX

Amicus **Mario J. Molina** received the 1995 Nobel Prize in Chemistry (with F. Sherwood Rowland and Paul Crutzen) for his "work on atmospheric chemistry, particularly concerning the formation and decomposition of ozone." He was a co-author, with F. Sherwood Rowland, of the seminal 1974 publication in the British journal Nature on the threat to the ozone layer from chlorofluorocarbon (CFC) gases. He currently serves as a Professor at the University of California, San Diego (UCSD), with a joint appointment in the Department of Chemistry and Biochemistry and the Scripps Institution of Oceanography. Prior to joining UCSD he was an Institute Professor at MIT. He received a Ph.D. in Physical Chemistry from the University of California, Berkeley. He has been involved in developing our scientific understanding of the chemistry of the stratospheric ozone layer and its susceptibility to human-made perturbations. He has served on the President's Committee of Advisors in Science and Technology, and on many other advisory boards and panels. He is a member of the NAS, the Institute of Medicine, and the Pontifical Academy of Sciences. He has received numerous awards for his scientific work in addition to the 1995 Nobel Prize in Chemistry, including the Tyler Ecology and Energy Prize in 1983, the

UNEP-Sasakawa Award in 1999, the Heinz Award in the Environment in 2003, and the Presidential Medal of Freedom in 2013.

Amicus **Michael Oppenheimer** is the Albert G. Milbank Professor of Geosciences and International Affairs at Princeton University. He is also the Director of the Center for Policy Research on Energy and the Environment at Princeton's Woodrow Wilson School, and the Kravis Senior Contributing Scientist at the Environmental Defense Fund. Dr. Oppenheimer received a S.B. degree from MIT in Chemistry and a Ph.D. from the University of Chicago in Chemical Physics. He is a long-time participant in the Intergovernmental Panel on Climate Change (IPCC), which won the Nobel Peace Prize in 2007. He now serves as a coordinating lead author on IPCC's Special Report on Oceans, Cryosphere and Climate Change. Dr. Oppenheimer is coeditor-in-chief of the journal *Climatic Change*. He serves on the New York City Panel on Climate Change and is a science advisor to the Environmental Defense Fund. Oppenheimer is a Heinz Award winner and a Fellow of the American Association for the Advancement of Science. His research focuses on sea level rise, migration, and other impacts of climate change from the perspectives of science, adaptation, and risk. He joined the Princeton faculty in 2002 after more than two decades with the Environmental Defense Fund, where he served as chief scientist and manager of the Climate and Air Program. Earlier, he was an Atomic and Molecular Astrophysicist at the Harvard-Smithsonian Center for Astrophysics.

Amicus **Bob Kopp** is the Director of the Institute of Earth, Ocean, and Atmospheric Sciences (EOAS) and a Professor of Earth and Planetary Sciences at Rutgers University. Prof. Kopp received an S.B. in Geophysical Sciences from the University of Chicago and an M.S. and Ph.D. in Geobiology from the California Institute of Technology. Prof. Kopp co-directs the Coastal Climate Risk & Resilience Initiative at Rutgers as well as the Climate Impact Lab. His research focuses on understanding uncertainty in past and future climate change and on the interactions between climate change and the economy. He is a lead author of *Economic Risks of Climate Change: An American Prospectus* (Columbia University Press, 2015) and of the U.S. Global Change Research Program's 2017 Climate Science Special Report, and was a contributing author to the Intergovernmental Panel on Climate Change's Fifth Assessment Report. He has served on the National Academies' Committee on Assessing Approaches to Updating the Social Cost of Carbon and in sea-level rise expert groups for several states and cities. He has authored over sixty scientific papers and several popular articles in venues including the *New York Times*. Prof. Kopp is a recipient of the American Geophysical Union's James B. Macelwane and William Gilbert Medals and the International Union for Quaternary Research's Sir Nicolas Shackleton Medal. *See also* http://www.bobkopp.net/about/

Amicus **Friederike Otto** is the Acting Director of the Environmental Change Institute and an Associate Professor in the Global Climate Science Programme at the University of Oxford. Dr. Otto holds a Diploma in Physics from the University of Potsdam and a Ph.D. in Philosophy of Science from the Free University of Berlin. At Oxford, Dr. Otto leads several projects understanding the impacts of climate change on natural and social systems. Her main research interest is extreme weather events, specifically improving and developing methodologies to understand whether and to what extent external climate drivers alter the likelihood of extreme weather events, as well as the policy implications of this emerging scientific field. She is a lead author on the Intergovernmental Panel on Climate Change's Sixth Assessment Report, contributing to the chapter *Weather and Climate Extreme Events in a Changing Climate*, and a co-investigator on the international World Weather Attribution project, which aims to provide an assessment of the human-influence on extreme weather in the immediate aftermath of the event. *See also* https://www.eci.ox.ac.uk/people/fotto.html. https://de.wikipedia.org/wiki/Friederike_Otto

Amicus **Susanne C. Moser** is Research Faculty in the Environmental Studies Department of Antioch University New England and Director and Principal Research of Susanne Moser Research & Consulting. Dr. Moser received her first M.A. degree in Applied Physical Geography and the Earth Sciences from the University of Trier (Germany), and her second M.A. and Ph.D. in Geography from Clark University. She was a post-doctoral fellow at Harvard's Kennedy School of Government, served as Staff Scientist for Climate Change at the Union of Concerned Scientists, as a Research Scientist at the National Center for Atmospheric Research, and as a Social Science Research Fellow of Stanford University's Woods Institute for the Environment. She was named a Distinguished Adaptation Scholar at the University of Arizona and a Walton Sustainability Solutions Fellow at Arizona State University. Dr. Moser is widely regarded as one of the leading experts on adaptation to sea level rise. She has published more than 120 peer-reviewed journal articles, book chapters, and reports; has made hundreds of presentations before audiences of all kinds; has advised states and local communities (including in California) on how to advance coastal adaptation; and has served as an expert member on numerous international science committees, more than a dozen National Academy committees, and on the Executive Committee of the US National Advisory Committee to the

Third National Climate Assessment, where she also co-led the coastal chapter. A full catalog of her extensive expert work and scientific publications can be found in Dr. Moser's curriculum vitae, which is available online at http://www.susannemoser.com.

Amicus **Donald J. Wuebbles** is The Harry E. Preble Professor of Atmospheric Sciences in the School of Earth, Society, and Environment, Department of Atmospheric Sciences at the University of Illinois at Urbana-Champaign. He was awarded the distinction of University of Illinois Presidential Fellow, with the aim of helping the university system develop new initiatives in urban sustainability. Dr. Wuebbles has two degrees in Electrical Engineering from the University of Illinois (1970, 1972) and a Ph.D. in Atmospheric Sciences from the University of California, Davis (1983). He spent many years as a research scientist and group leader at the Lawrence Livermore National Laboratory before returning to the University of Illinois to be Head of the Department of Atmospheric Sciences in 1994. Within the climate science community Dr. Wuebbles is widely regarded as one of the leading experts in atmospheric physics and chemistry, with over 500 scientific publications related to the Earth's climate, air quality, and the stratospheric ozone layer. He has co-authored a number of national and international scientific assessments, including as a leader in the 2013

Intergovernmental Panel on Climate Change as well as the 2014, 2017, and 2018 U.S. National Climate Assessments that evaluate climate change science as required by the U.S. Congress under the 1990 Global Change Act. From 2015 to early 2017, Dr. Wuebbles was Assistant Director with the Office of Science and Technology Policy at the Executive Office of the President in Washington DC, where he was the White House expert on climate science. He is the recipient of several scientific awards; is a Fellow of three major professional science societies; has made hundreds of presentations before audiences of all kinds; and has served as an expert member of many governmental committees and boards tasked with combatting the effects of climate change. A full catalog of his extensive expert work and scientific publications can be found in Dr. Wuebble's curriculum vitae, which is available online.

Amicus **Gary Griggs** is Professor of Earth & Planetary Sciences at the University of California Santa Cruz, where he also served as Director of the Institute of Marine Sciences for 26 years. Dr. Griggs received his B.S. in Geological Sciences from the University of California Santa Barbara, and his Ph.D. in Oceanography from Oregon State University. He was appointed a Professor at the University of California Santa Cruz in 1968. Within the climate science community, he is widely regarded as one of the leading experts on sea level rise. He has published over 180 articles in scientific journals, book chapters, and elsewhere and has also written 11 books; has made hundreds of presentations before audiences of all kinds; and has served as an expert member of many governmental committees and boards focused on climate change and sea-level rise. He was a member of the National Academy of Sciences Committee that prepared the report: Sea-Level Rise for the Coasts of California, Oregon and Washington (2012). Most recently he chaired the committee requested by Governor Brown to investigate the effects of sea-level rise on California (2017: Rising Seas in California). A full catalog of his extensive expert work and scientific publications can be found in Dr. Griggs' curriculum vitae, which is available online at http://www.aaa/cv.pdf

Amicus **Peter C. Frumhoff** is Director of Science and Policy and Chief Climate Scientist at the Union of Concerned Scientists (UCS). Dr. Frumhoff received his B.A. in Psychology from the University of California at San Diego, and his M.A. in Zoology and his Ph.D. in Ecology from the University of California at Davis. He was the 2014 Cox Visiting Professor in the School of Earth Sciences at Stanford University, taught at Harvard University and the Fletcher School of Law and Diplomacy at Tufts University, and was a Science and Diplomacy Fellow at the US Agency for

International Development. A global change ecologist, Dr. Frumhoff has published widely at the nexus of climate science and policy including on the climate responsibilities of fossil fuel companies, the attribution of extreme events to climate change, the regional impacts of climate change, the role of forests and land use in climate mitigation, and the societal responsibilities of geoengineering researchers. He currently serves on the US National Academy of Sciences' Board on Atmospheric Sciences and Climate, and previously served on the Advisory Committee on Climate Change and Natural Resources Science at the US Department of Interior and was lead author of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Dr. Frumhoff is widely quoted in the media and has made hundreds of presentations before audiences of all kinds, including providing testimony on climate science and climate policy on multiple occasions before House and Senate committees. A list of Dr. Frumhoff's recent publications is available here.

Amicus **Kristina Dahl** is a Senior Climate Scientist in the Climate and Energy program at the Union of Concerned Scientists. Dr. Dahl received her Ph.D. in Paleoclimate from the MIT/Woods Hole Oceanographic Institution Joint Program, and holds a B.A. in Earth Sciences from Boston University. Her research focuses on the impact of climate change, particularly sea level rise, on people and places, and often involves spatial analyses and products. Dr. Dahl has published numerous technical and non-technical articles on sea level rise. She was the lead analyst and co-lead author on UCS's *When Rising Seas Hit Home: What Coastal Communities Can Expect, and When to Expect It* and *Underwater: Rising Seas, Chronic Floods, and the Implications for US Coastal Real Estate* reports, which quantified the risks of sea level rise for communities and real estate in the contiguous United States, and has performed detailed GIS analyses showing the projected extent of sea level rise and chronic flooding along the U.S. coasts. Dr. Dahl was the associate director of a school-wide climate change initiative at Rutgers University, and provided scientific guidance as a course scientist for the American Museum of Natural History's Seminars on Science program. Dr. Dahl makes frequent presentations before audiences of all kinds, and her work has been highlighted in a variety of national and local newspaper, radio, and television outlets.