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On behalf of Climate Central, a non-profit, non-advocacy organization dedicated to researching and communicating climate change impacts and solutions, we are submitting the following comments on the Department of Energy's (DOE) recent report, "A Critical Review of Impacts of Greenhouse Gas Emissions on the U.S. Climate." We appreciate the opportunity to submit comments.

As a science-based organization, we are deeply concerned about the content of this report. The report leaves out major international scientific assessments that synthesize hundreds of studies and selectively ignores major scientific developments from the last two decades. The vast body of work on climate science, built over decades, has led to a clear scientific consensus that climate change is happening, that human activity is the root cause, and that the consequences of continued warming will be very harmful.[1] **The DOE report does not represent the scientific consensus and should not be used as a scientific basis for setting policies.**

Historically, scientific assessments of climate change by the U.S. government have employed the best practices of the scientific enterprise, including transparency, robust multi-author engagement, and peer review. **This report would have benefited by employing the review and engagement process used by the U.S. National Climate Assessments.**

The impacts of climate change are becoming clearer by the season. Wildfires are worsening. Hurricanes are strengthening. Storms are unleashing more rain. Heat waves are hotter, longer, and more frequent. Each of these statements represents decades of climate science research, of careful documentation, of scientific discourse. **Omitting the major findings of climate science harms our collective ability to protect people from the impacts of human-caused climate change.**

Below, we provide detailed comments on several sections of the DOE report where we have particular expertise. This is not a comprehensive review of the entirety of the report. We hope that these comments help to shape a future climate report that truly represents the best available science.

Best Regards,

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Comments on Section 6.2 (Extreme Weather: Hurricanes and tropical cyclones)

It should be noted in this section that tropical cyclone is *not* a synonym with hurricane in the IPCC AR6 report,[2] particularly as there are distinct climate signals between ocean basins. The report should be clear and disambiguate in each instance whether the trends and attributes being discussed are North Atlantic hurricanes or tropical cyclones in other global basins (which are less directly relevant to the United States).

This section of the report places its emphasis on hurricane frequency changes. However, this neglects to speak to how hurricane impacts like extreme rainfall—as was seen in the devastating floods of Hurricanes Harvey or Helene—have changed in a world warmed by climate change. Hurricane frequency changes, while an important factor, are not solely responsible for past and future hurricane activity and impacts.[3 (section 11.7.1)] Ultimately, the report does not cover the actual *impacts* of the storms and how they have changed over time, making it less relevant for the average American facing risks from hurricanes. The report would be enhanced by a full consideration of the characteristics of hurricanes that are changing, and that have and will continue to impact communities in the United States.

The existing literature shows strong links between global climate change and hurricane characteristic changes, such as storm surge, rainfall, and intensity. The report claims that "the relatively small number of hurricanes with varying landfall locations and the complex dynamics associated with each storm preclude meaningful detection of change." This claim is unsupported. In fact, a wide swath of literature including observations, theory, models, and detection and attribution studies have repeatedly shown that hurricane characteristics respond to human-caused climate change. IPCC AR6 findings likewise use stronger confidence statements around these topics than the report acknowledges.[2]

As discussed in the response to Section 7.1-7.3 (below), there is strong confidence that sea levels have already risen and will continue to rise throughout this century in response to human caused climate change.[4,5] As a result, when tropical cyclones make landfall, the storm surge occurs on top of higher baseline water levels, leading to more water coming ashore than there would have been in a world without climate change. This has already been demonstrated with Hurricane Sandy in 2012.[6] Overall, an increase in background sea levels will increase storm surge impacts worldwide.

While there is no trend in the *number* of U.S. landfalling storms,[7] there are still strong, significant trends in the translation speed of tropical cyclones worldwide, with specifically a reduction in

Atlantic hurricane translation speed of 16% over 1949-2016, "consistent with expected changes in atmospheric circulation forced by anthropogenic emissions."[8] Such slowdowns increase coastal and inland flooding damages associated with landfalling storms, increasing their threat and multiplying risks that U.S. communities are facing, even if the number of storms remains unchanged. The IPCC AR6 report communicated the consensus view of this clearly, stating: "It is *likely* that TC [tropical cyclone] translation speed has slowed over the USA since 1900",[3 (section 11.7.1.4)] and "It is more likely than not that the slowdown of TC translation speed over the USA has contributions from anthropogenic forcing".[3 (section 11.7.1.4)]

Hurricane rainfall has likewise already been shown to be linked to anthropogenic climate change. As the climate warms, associated increases in atmospheric moisture increase hurricane precipitation.[3 (section 11.7.1.4)] Multiple studies have shown a consistent fingerprint of human influence on Hurricane Harvey's rainfall.[9,10,11,12,13] Similar results have been shown for Hurricane Florence and entire hurricane seasons.[14,15] The IPCC concluded "There is high confidence that anthropogenic climate change contributed to extreme rainfall amounts during Hurricane Harvey (2017) and other intense TCs.".[3 (section 11.7.1.4)] The report entirely neglects these known and important rainfall influences.

Changes in tropical cyclone intensity are acknowledged in the report as "a slight but insignificant increase in the number of major hurricanes" and an "overall increase in the proportion of major hurricanes." This statement understates the actual pattern: Kossin et al. (2020) found a statistically significant trend in the proportion of Atlantic major hurricanes of about 6% per decade.[16]

Many recent major hurricanes underwent rapid intensification.[17] Studies have consistently shown that hurricane intensification rates and the proportion of storms undergoing rapid intensification is increasing as sea surface temperatures warm in response to climate change.[18,19,20,17,21,22] The AR6 concludes: "It is likely that the global proportion of Category 3–5 tropical cyclone instances and the frequency of rapid intensification events have increased globally over the past 40 years."[3 (section 11.7.1.2)] Despite this clear and human-relevant signal, rapid intensification, its changes, and its impacts are currently left out of the report.

The report concludes, "The relatively short historical record of hurricane activity, and the even shorter record from the satellite era, is not sufficient to assess whether recent hurricane activity is unusual relative to the background natural variability." We note that activity (by definition) is composed of both frequency *and* intensity, and studies have shown that hurricane intensity has evolved and is expected to continue to evolve in response to anthropogenic influences through climate warming. The relatively short record *does not preclude* assessment of hurricane activity. As noted above, the observational record is long enough to detect a significant trend in the proportion of major hurricanes.[16] Hurricane intensity theory and models are in agreement with the observed trends. They show that the upper bound on individual tropical cyclone intensities has increased and will continue to increase in response to human-caused climate warming.[23,24,25,26] Analyses since the AR6—using a suite of observations, modeling, and theory—have found that recent observed hurricanes have higher intensities tied to global climate change.[27,28] As the IPCC AR6 concludes: “it is very likely that the recent active TC seasons in the North Atlantic…cannot be explained without an anthropogenic influence.”[3 (section 11.7.1.4)]

These human-influenced changes in hurricane characteristics contribute to increasing risks and rising damages. The potential damages from storm surge, rainfall-induced floods, and tornadoes scale with wind speed raised to the eighth power, meaning that small increases in intensity can lead to large increases in damages.[29] Hurricanes have been increasing in destructiveness since the 1970s.[30] Coinciding with this, the number of hurricane-related billion-dollar disasters has steadily increased despite little change in the number of hurricane landfalls.[31] Willoughby et al. (2024) concluded that anthropogenic climate change played a role in these increasing damages,[32] and the report should acknowledge this critical trend, as it is particularly relevant for U.S. communities at risk.

In summary: as written, this section of the report does not represent the state of the science on connections between climate change and changes in hurricane characteristics. The preponderance of scientific evidence shows that the prosperity and security of American coastlines and increasingly, inland areas, are at increasing risk from worsening hurricane impacts as human greenhouse gas emissions continue and global climate warms.

Comments on Section 6.3 (Extreme Weather: Temperature extremes)

There are numerous scientific issues that arise in Section 6.3’s attempt to assess the impacts of greenhouse (GHG) gas emissions on extreme temperatures. In particular, this section in the DOE report does not provide sufficient context for the regional variations in hot and cold temperatures across the U.S. relative to the rest of the globe. The report then fails to provide physical explanations and associated references for the extensive amount of research related to the heat of the 1930s and Dust Bowl-era compared to modern day conditions in its text and analysis. The lack of daytime warming in summer in the central U.S. is in fact a well-studied phenomenon in the scientific literature, even frequently nicknamed as the Central U.S. “warming hole”.[33,34] The rest of our comments on this section provide additional needed context for understanding the causes of differing regional changes in U.S. temperature extremes, especially relative to the early/mid-20th century.

Understanding changes in hot extremes in the U.S. since the 1800s is complicated by the intense heat waves and prolonged drought of the 1930s. NCA5 explicitly acknowledges this point in the first sentence of their section on changing temperature extreme risks: “By some measures, the most extreme heatwaves on record in the United States occurred during the Dust Bowl era of the 1930s”.[35] It is important to note that the unusually warm conditions in the U.S. were not representative of global climate conditions in the 1930s, which were on average cooler than today.[36] Focusing on this small regional anomaly without placing it within the broader global context of early 20th-century global temperatures is misleading. These extreme hot and dry conditions during the Dust Bowl were driven in part by natural variability associated with a teleconnection from anomalous tropical Pacific sea surface temperatures and were then further amplified by human-driven land-use and land-cover changes resulting from poor land management practices.[37,38] Cowan et al. (2020) also conclude that the influence of GHG gases on heat waves may have even been detectable as early as the 1930s over North America,[39] which contradicts Section 6.3's focus on the lack of connection between GHG emissions and temperature extremes.

Since the 1930s, both maximum and minimum temperatures have warmed across much of the contiguous United States. The exception is a region from the Central to Southeast U.S. during daytime in the summer season. Recent studies have identified numerous potential contributors to this warming hole pattern, which include human-induced land use change from cropland intensification,[40] emission of anthropogenic aerosols,[41,42] an unusual realization of internal variability,[43] and atmospheric circulation changes amplified partly by externally-forced sea surface temperature trends in the Pacific.[34] In summary, several factors that may have accelerated the hydrologic cycle and, in turn, dampened daytime heat extremes in recent decades across the Central U.S., likely result from human activities. It is therefore crucial for Section 6.3 to document this extensive body of research to understand why this region in this season stands apart from broader national trends.[44] Given that these mechanisms may influence heat extremes in ways that counter the GHG-driven positive trend, without a comprehensive attribution study to control for and disentagle these unique factors, the DOE report's conclusion in Section 6.3 ("For CONUS as a whole, the evidence in this section suggests GHG emissions have had little-to-no effect on heatwaves against the background of urbanization and natural climate variability") is unsupported.

Nevertheless, as previously mentioned, average summer temperatures have warmed significantly for most locations outside of the Central U.S. warming hole when comparing the last two decades with the first half of the 20th century, inclusive of the Dust Bowl era (Figure 2.4 in Marvel et al., 2023).[35] Warming is also found along the highly-populated corridor of the East Coast, strongly shaped by high overnight temperatures. Given the wide spatial coverage of this warming, which includes undeveloped areas and areas that have been highly urbanized throughout the record, it is obvious that the urban heat island effect cannot explain these regional temperature trends. More importantly, to understand the broader climate change context, trends in hot temperature extremes across the U.S. only represent a relatively small fraction of the rest of the globe. Even in a warming world driven by the burning of fossil fuels, there can be large regional differences modulated by internal variability. This variability has been well simulated by state-of-the-art global climate models for several model generations now.[45,46] As demonstrated in Figure SPM3 of IPCC (2021), central and eastern North America are actually two of the only regions that have low confidence in the human contribution to observed changes in hot extremes since the year 1950.[47] Thus, although different observational heat extreme metrics may yield varying results, linking attribution statements to increases in hot extremes for only the contiguous U.S. – as done in the DOE report – fails to provide a complete picture.

Figure 6.3.3 in the DOE report is another attempt to highlight changes in extremes; this time it does so by counting the number of daily high and low temperatures across the U.S. since the late 1800s. However, this approach does not reflect the substantial body of work documenting changes in the ratio of daily highs to record lows within a long-term climate context.[48,49,50] While large interannual variability and a few outlier years occurred during the Dust Bowl era, accounting for decadal averages reveals that by the 2010s the ratio record had again risen to levels comparable to the 1930s and with signs of further warming in the 2020s (Figure 1c in Meehl et al., 2022).[50] This is closely in line with the mean background climate warming driven by external forcing.[51] Recent studies (e.g., McHugh et al., 2023) have also assessed the areal extent of record-breaking temperatures looking forward into the next few decades, and climate model projections forced under a moderate future emissions scenario (SSP2-4.5) show increases across all regions of the U.S.[52] The likelihood of extremes that are projected to surpass Dust Bowl-era levels grows significantly by 2050 (Figure 13 in Eischeid et al., 2023),[34] and thus the prominence of the warming hole temperature pattern is expected to fade with continued global warming.

Comments on Section 6.8 (Extreme Weather: Wildfires)

The DOE report's assessment of trends in wildfire activity and the contribution of climate change to those trends is incomplete and misses a large body of scientific evidence that particularly pertains to wildfire activity in the western United States. The DOE report also lacks nuance with respect to geographies and ecosystems.

Of the many omissions in this section of the report, several regarding western US wildfire activity are particularly noteworthy. Excerpting from Dahl et al., 2023,[53] these include:

1) Multiple metrics that document increases in wildfire activity. As stated in Dahl et al., 2023 and the references therein, "Over the last several decades, the western United States and southwestern Canada have experienced increases in the area burned by wildfires (Abatzoglou and Williams 2016, Hanes *et al* 2019, Balch *et al* 2022), the number of large fires (Dennison *et al* 2014, Westerling 2016), the length of the fire season (Westerling 2016, Kirchmeier-Young *et al* 2017, Goss *et al* 2020), the elevation at which fires burn (Alizadeh *et al* 2021), and the extent of forested lands that burn at high severity (Parks and Abatzoglou 2020)."[54,55,56,57,58,59,60,61,62]

2) Significant portions of many of these trends in wildfire activity have been definitively "attributed to anthropogenic climate change (Abatzoglou and Williams 2016, Kirchmeier-Young *et al* 2017, Williams *et al* 2019, Zhuang *et al* 2021)."[54,59,63,64]

3) It is not only wildfire activity, but wildfire-prone *conditions* that are changing in response to climate change. "Vapor pressure deficit (VPD)—a measure of atmospheric water demand defined as the difference between the amount of water vapor in the air and the amount of water vapor that air would hold at saturation—has emerged as a key metric linking climate change and burned area due to its role in regulating ecosystem water

dynamics (Grossiord *et al* 2020, Clarke *et al* 2022). More than two-thirds of the observed summertime increase in VPD in the western U.S. has been attributed to anthropogenic warming (Zhuang *et al* 2021). In turn, the increase in summertime VPD has driven increases in fuel aridity in the region, resulting in nearly a doubling of burned area in western U.S. forests during 1984–2015 (Abatzoglou and Williams 2016)."[65,66 64,54]

More recently, Abatzoglou et al., 2025, documented that climate change is not only raising the odds of wildfire activity in the western U.S., but in forested areas globally.[67]

The scientific evidence linking climate change to worsening western wildfires is clear. Climate change contributes to drier conditions that increase the size and intensity of fire regardless of ignition source or forestry management. In addition to structural losses from fire, climate change is increasing the risk of mortality from wildfire smoke.[68]

Comments on Sections 7.1-7.3 (Changes in sea level)

We fully incorporate and endorse the comments submitted by Kopp et al., 2025.[69]

The following quotation briefly summarizes the core conclusions of the cited comment, each of which contradicts specific claims made in Sections 7.1-7.3, and each of which is robustly supported by peer-reviewed science, as detailed by the comment:

"Sea-level rise is increasing risk to coastal communities. The rate of global-mean sea-level rise has more than doubled over the last 30 years, from about 0.08 inches/year in 1992 to 0.18 inches/year in 2024, and statistical analysis also reveals sea-level acceleration at many U.S. tide gauges and in contiguous U.S. tide gauges in aggregate. Along parts of the U.S. Atlantic and Gulf coasts, the number of days of coastal flooding per year have increased more than ten-fold since the 1970s as a result of sea-level rise, and relative sea-level rise is projected to increase high-tide flooding by 5-10x on average across the country's coast by 2050."

Here, we draw increased attention to four key points.

(1) The DOE report claims that sea level rise in the U.S. has not accelerated (Section 7.1, p.75), apparently on the basis of graphical presentations of data from four tide gauges selected, without explanation, from out of 140+ U.S. gauges with long-term records. To the contrary, peer-reviewed research indicates substantial acceleration in (a) global sea level rise, (b) sea level rise around the contiguous U.S. as a whole, and (c) sea level rise at the great majority of long-term tide gauges in the U.S., *including the ones highlighted in the DOE report* (we refer to Kopp *et al.*, 2025, above, and the citations therein). The DOE report is silent with respect to the acceleration of global sea level rise, but no wall separates U.S. coasts from the world's one ocean.

(2) The DOE report downplays the importance of the rate of absolute sea level rise by comparing long-term average historical rates of relative sea level rise (over 100+ years) to

vertical land motion rates (Section 7.2, pp. 76-79; Table 7.1; Figures 7.2-7.5). But long-term average rates of sea level rise are far lower than present rates due to the acceleration of absolute sea level rise, so the report's comparison is irrelevant for considering current and future risk. In fact, present rates of absolute sea level rise already outpace the effects of vertical land motion in most places, and this gap will widen as sea level rise continues to accelerate. Figure 1 shows that most of the U.S. Gulf and Atlantic coasts are sinking less than 0.12 inches (3 mm) per year, whereas the global average increase in absolute sea level in the most recent complete year, 2024, has been estimated at 0.18 inches.[70] Sinking land aggravates the threat of sea level rise; the former is not a reason to disregard the latter, as suggested by the DOE report.

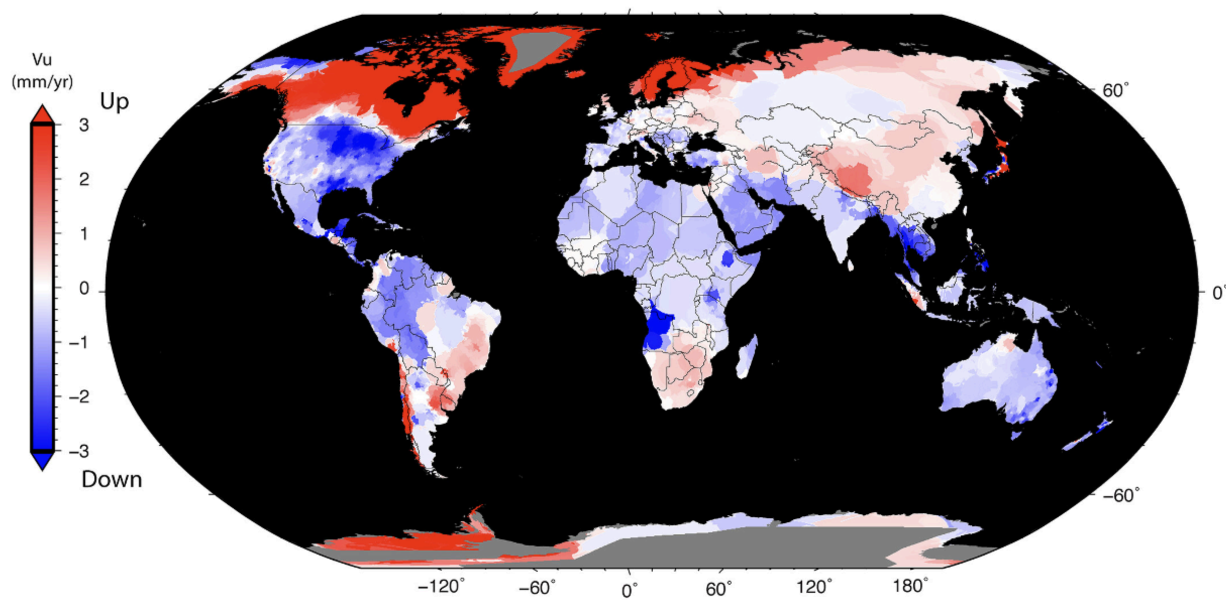

Figure 1. Estimates of vertical land motion for global land areas.[70]

(3) Numerous peer-reviewed projections indicate that absolute sea level could rise by several feet this century, reshaping the nation's coastlines and coastal cities (see Kopp *et al.*, 2025). But the rise over the last century, measured in inches, is already doing meaningful damage. Strauss et al. (2021) found that historical human-caused sea level rise of 2.0-5.2 inches specifically in the New York City area, through 2012, contributed $4.7-14 billion out of the total damages from Superstorm Sandy.[6] That is the imprint for just one storm. Other research has found large increases in the frequency of high-tide flooding around the U.S. over recent decades.[71] There are many other current impacts of sea level rise and projected future ones; Kopp *et al.*, 2025, cited above, gives a brief sketch. The simple greater truth is that every U.S. coastal flood today covers more land, more deeply because of human-caused sea level rise.

The DOE report does not discuss sea level rise impacts (pp. 75-81), despite the report's overall title, "A Critical Review of Impacts of Greenhouse Gas Emissions on the U.S. Climate," and a whole section of the report dedicated to “Impacts on Ecosystems and Society” (Part III, chapters 9-12, pp. 103-131). The term “sea level” does not appear in this section.

(4) The DOE report states, without citing any supporting research, that the current increase in global mean sea level began during 1820-1860 (Section 7.1, p. 76). The authors use this claim to imply that observed rise may be more related to the end of the Little Ice Age near that time than to greenhouse gas emissions, which were relatively modest then. However, evidence indicates that human effects on global sea level began to emerge in the 1860s.[72] Further, Kopp et al. (2016) show a sharp increase in sea level in the 20th century compared to any other century of the last 2000+ years.[73] This increase and its timing parallel a steep climb in global mean temperature well-known to be caused by human activity.

Sea level has risen and fallen with natural changes in climate like the Little Ice Age for millions of years. But this has no bearing on whether human activity is influencing sea level today—just as natural forest fires do not rule out ones started by campfires. Investigators can often discern the difference: did the fire start in a remote area, right after a lightning storm? Or did it start on a clear day near a campsite? Climate scientists conduct analogous investigations related to global warming and sea level rise. A review of past IPCC reports makes it clear: evidence from hundreds of peer-reviewed studies attests that the dominant force driving sea level rise today is human activity.

Comments on Sections 8.1-8.6 (Uncertainties in climate change attribution)

Based on statements quoted from the IPCC’s AR4 (WGI; 2007) and AR5 (WGII; 2014) reports, in Section 8.1 of the report, the authors of the DOE report argue for caution in attributing causes of climate change and climate impacts. This assertion is based on outdated information that has been superseded by more recent assessments and does not reflect the current scientific consensus around the causes of climate change and the contribution of climate change to extreme weather events. This current consensus is described by the IPCC’s most recent report,[2] which the DOE report does not cite in this introduction, instead citing earlier reports. This section of the DOE report also omits the advances in event attribution science that have taken place over the last two decades, including those summarized by an influential 2016 report.[74]

Section 8.3 of the report makes a series of incorrect assertions about the causes of warming. We will focus on one: the claim that there is significant uncertainty about the impact of solar variations and that there is substantial debate regarding the solar contribution. As evidence of these uncertainties, the DOE report points to challenges in measuring total solar irradiation (TSI) as well as potential non-TSI mechanisms by which solar activity could indirectly influence the climate.

These claims are incorrect. The IPCC AR6 report explicitly considers changes in effective radiative forcing due to solar activity in its assessment of the contributions of internal and external drivers of long-term climate change (Figure 2 below).[75]

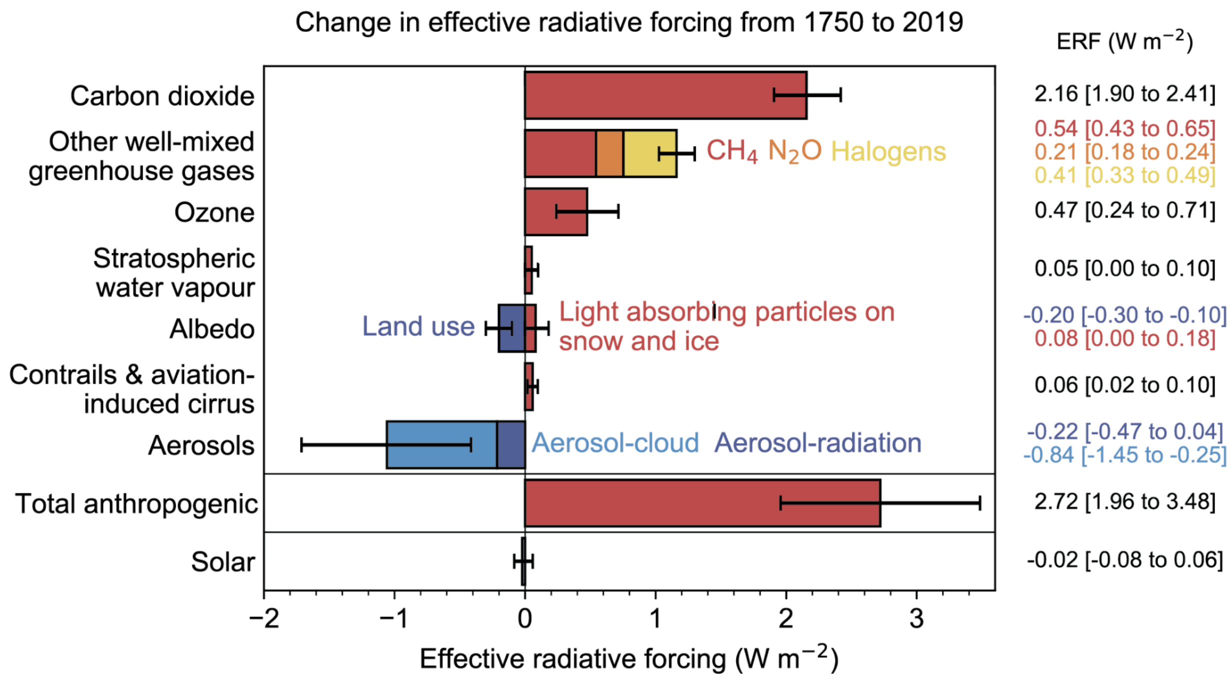

Figure 2. Changes in effective radiative forcing from 1750-2019.[75]

Moreover, changes in Earth's surface energy budget based on multi-decadal records of surface solar radiation records are considered and discussed thoroughly in the same report, concluding that there is evidence for widespread, long-term trends in solar radiation in many locations.[75] As is clear from the evidence compiled in the AR6 report, the effect of these trends on radiative forcing is exceedingly small relative to that of increasing heat-trapping emissions of carbon dioxide and other greenhouse gases.

In short, the IPCC report's conclusions regarding the contribution of solar activity changes to climate change are substantiated by dozens of peer-reviewed studies and are exceedingly clear: changes in solar activity are not a significant contributor to the observed long-term trends in Earth's climate.

In Section 8.5 of the report, the authors use a specific table from the IPCC AR6 report as evidence that an anthropogenic signal in different climate variables has not yet definitely emerged from the noise of natural climate variability. While the DOE report authors accurately reproduce part of the IPCC's table in their report, the high-level nature of this table obscures a wealth of underlying data and studies attributing regional climate trends to climate change. The regionally varying detectability and attributability of trends in hot extremes, heavy precipitation, and drought is summarized well in IPCC AR6 2021 (Figure 3 below).[47] This summary figure, which represents a synthesis of the published literature, makes clear that there are quantifiable trends in major climate hazards in many parts of the world. Moreover, there is medium to high confidence in the human contribution to observed increases in hot extremes in most regions. Figure 3 also transparently shows that there are regions where trends in a climate variable are unclear and that there is greater uncertainty for variables such as heavy precipitation and drought than there is for heat.

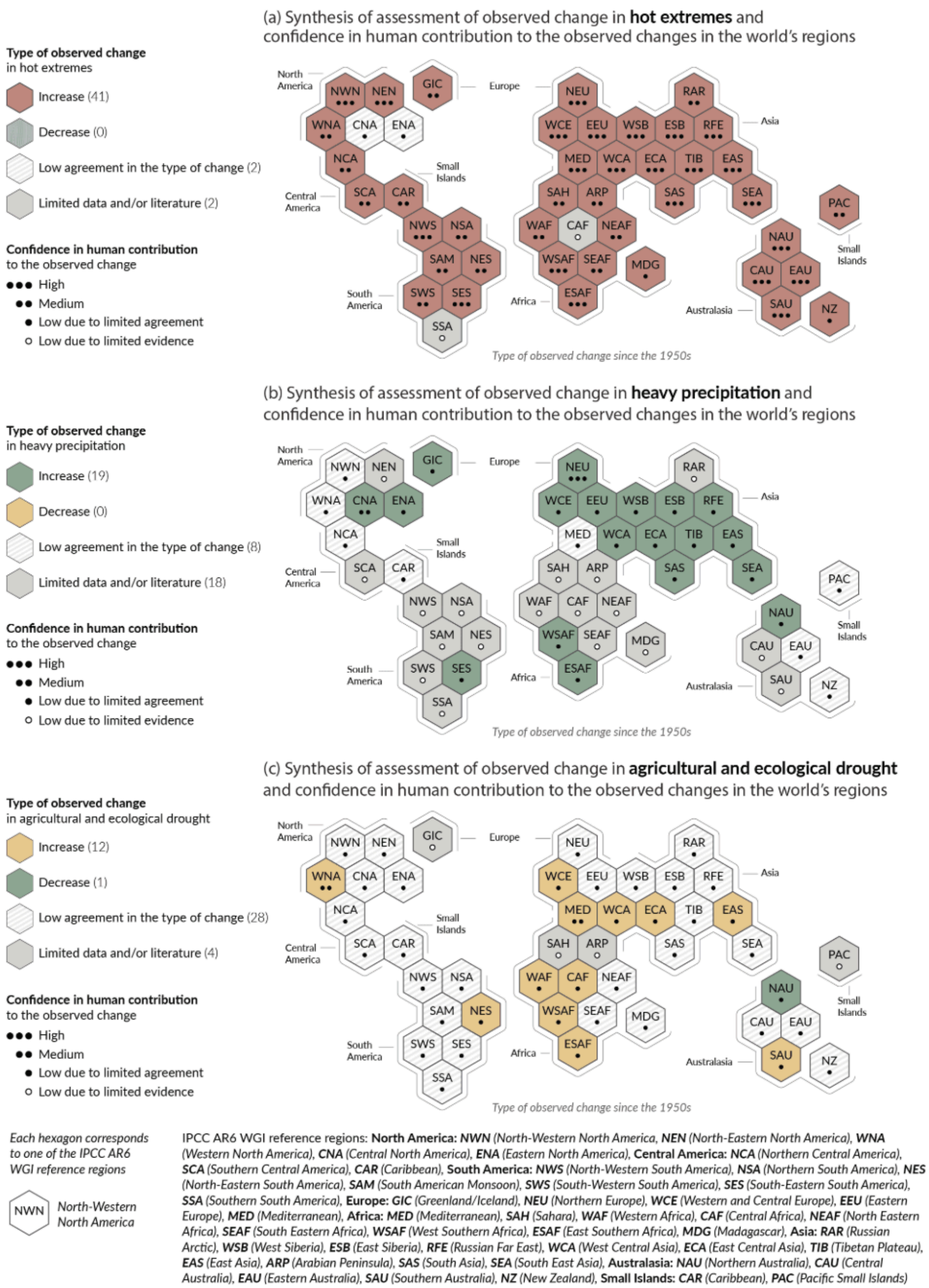

Figure 3. Summary of changes in weather and climate extremes by region.[47]

In Section 8.6, on page 95, the DOE report authors enumerate a number of technical criticisms of World Weather Attribution's (WWA) approaches to extreme event attribution and question the impartiality of their conclusions. In particular, they take issue with the fact that WWA's reports do not undergo formal peer review and they raise concerns about WWA's impartiality.

Regarding criticisms of WWA's extensive promotion of non-peer-reviewed findings, WWA has published more than ten peer-reviewed papers on their methodology, all of which are listed on their website.[76] One of those foundational methodological papers, Philip et al., 2021, has been cited by more than 250 scholarly publications, as the WWA methodology has been widely replicated by other groups.[77] The studies WWA regularly publish on their website and promote to the media utilize the same peer-reviewed methodological foundation. Because of the societal demand and need for attribution studies on the most impactful extreme weather events around the world,[78] the relatively slow (e.g., 6+ month) process of peer review is impractical. This is analogous to how weather forecasts are based on peer-reviewed methodologies, but weather forecasts are not peer reviewed.

Regarding skepticism of the impartiality of WWA's conclusions, WWA finds a clear climate signal for many of the events they study, but this is far from their universal conclusion. Their recent study of a heavy rainfall event in Colombia and Venezuela, for example, found that the rainfall event was not particularly extreme by historical standards for the region.[79] Moreover, high levels of uncertainty and clear disagreement among climate models prevented them from making a clear attribution statement. Such a result is not uncommon among WWA's collection of event attribution studies (see, for example, Kimutai et al., 2023).[80]

The report authors also question how settled EEA methodologies are. While the field of EEA is relatively new, scientists have been conducting EEA studies for more than 20 years (see, for example, Stott et al., 2004),[81] and methodologies have grown stronger and more established over that period of time. Key methodological considerations for EEA studies are laid out clearly in Section 11.2 of IPCC's AR6 WGI report,[3] and best practices have emerged and been vetted in the peer-reviewed literature.[82,77]

To support their critique of EEA, the DOE report cites earlier IPCC reports. In contrast, the IPCC's most recent report (AR6) addresses the many advances in EEA methodologies that occurred between the writing of the AR5 and AR6 reports. Relevant statements from the AR6 report include the following direct quotations:

"Since the IPCC Fifth Assessment Report (AR5), there have been important new developments and knowledge advances on changes in weather and climate extremes, in particular regarding human influence on individual extreme events, on changes in droughts, tropical cyclones, and compound events, and on projections at different global warming levels (1.5°C–4°C)." –AR6 WGI Executive Summary,[47] p. 1517

"Since AR5, the attribution of extreme weather events, or the investigation of changes in the frequency and/or magnitude of individual and local- and regional-scale extreme weather events due to various drivers (Section 11.2.3 and Cross-Working Group Box 1.1) has provided

evidence that greenhouse gases and other external forcings have affected individual extreme weather events." –AR6 WGI, Section 11.1.4,[3] p. 1523

"In AR5, there was an emerging consensus that the role of external drivers of climate change in specific extreme weather events could be estimated and quantified in principle, but related assessments were still confined to particular case studies, often using a single model, and typically focusing on high-impact events with a clear attributable signal. However, since AR5, the attribution of extreme weather events has emerged as a growing field of climate research with an increasing body of literature (see series of supplements to the annual State of the Climate report (Peterson et al., 2012, 2013a; Herring et al., 2014, 2015, 2016, 2018), including the number of approaches to examining extreme events (described in Easterling et al., 2016; Otto, 2017; Stott et al., 2016))." –IPCC AR6 WGI, Section 11.2.3,[3] p. 1540

Comments on Section 10.2 (Managing risks of extreme weather: Data challenges)

The main purpose of section 10.2 is to make the point that the U.S. Billion-Dollar Disasters dataset[31] does not account for GDP growth. It is important to note that this section does not refute that disaster costs are increasing. The section is implying that a) disaster costs are rising due to increasing exposure and not due to any increases in hazards and b) that disaster costs are manageable due to the scale of the U.S. economy represented by GDP. Both of these implications are not supported by any evidence presented in the section.

Over the last ten years (2015-2024), the U.S. has been impacted by 190 separate billion-dollar disasters that have killed more than 6,300 people (direct and indirect fatalities) and cost ~$1.4 trillion in damage.[83] In addition, the U.S. has been impacted by landfalling category 4 or 5 hurricanes in six of the last eight years (Harvey, Irma, Maria, Michael, Laura, Ida, Ian, Helene), which is among the highest frequencies on record.[84] In 2024, the U.S. impacts from Hurricanes Helene and Milton alone were particularly destructive, causing more than $100 billion in combined damage across Florida, Georgia, South Carolina, North Carolina, Tennessee, and Virginia over a two-week period. A number of these hurricanes, notably Ida in 2021 and Helene in 2024, encountered record warm sea surface temperatures, underwent rapid intensification and caused flooding and wind damage many hundreds of miles inland. These storm properties are consistent with peer-reviewed studies linking climate change to more frequent rapid intensification and a farther inland reach of tropical cyclones.[17,85]

Additionally, there were more billion-dollar extreme rainfall-induced flood events from 2010-2024 (26) than in the 1980s, 1990s and 2000s combined (19; all event costs expressed in CPI-adjusted 2024 dollars).[31] While increased development in or near floodplains has contributed to rising flood-related damages,[86] a warming atmosphere– driven by climate change–is also a key factor. Warmer air holds more moisture, which raises the likelihood of extreme precipitation events and severe flooding.[87]

The primary message of Section 10.2 is captured in Figure 10.1 (taken from Pielke, Jr. 2024), which shows a slight decline in “losses per disaster” as a percentage of U.S. GDP (1980-2022) from NOAA’s Billion-dollar disaster dataset.[88] The slight negative trend described by this figure is attributable to the increasing frequency of U.S. billion-dollar disaster events in recent decades, many of which incur comparatively lower economic losses (i.e., in the lower single-digit billions), thereby reducing the annual mean loss per event over time. The time series in Figure 10.1 also excludes data for 2023 and 2024, which have the highest (28) and second highest (27) counts of billion-dollar disasters (inflation-adjusted) on record, respectively.[83]

The presence of a trend in disaster costs as a function of GDP is not evidence against an increase in climate-driven hazards. The report’s statement that “over time, population and wealth have increased dramatically in the U.S., so when an extreme weather or climate event occurs, there is more damage even if there is no underlying trend in the frequency or intensity of extreme weather” is factually correct; however, because there is no discussion of trends in the hazards, either in the section or in Pielke, Jr., both imply that there are no trends in extreme weather.[88] The presence of one trend (rising exposure) is not evidence against the existence of other trends. As discussed above, there are well-documented trends in the intensity of hurricanes, extreme precipitation events, wildfires, and heatwaves that are strongly linked to human caused climate change. Changes in exposure, for example, through more development in higher risk areas, will act synergistically with increases in the hazards to produce costly disasters.

The fact that disaster costs are a small part of GDP is one indication of the adaptive capacity of society, but it is not evidence that adaptation is occurring or that weather and climate disasters are not significant. In fact, inflation-adjusted per capita billion-dollar disaster costs have increased from approximately $90 per person in the 1980s to more than $400 per person in the late 2010s and have remained at a high level in recent years.[83]

The reality of U.S. disaster losses is much more complex and nuanced than implied by Figure 10.1. The frequency and cost of weather and climate disasters are increasing in the United States due to a combination of increased physical exposure, vulnerability, and the fact that climate change is increasing the frequency and intensity of some types of extremes that lead to billion-dollar disasters.

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