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Case report

Convergence of climate-driven hurricanes and COVID-19: The impact of 2020 hurricanes Eta and Iota on Nicaragua

James M. Shultz[a,*], Ryan C. Berg[b], James P. Kossin[c], Frederick Burkle Jr[d], Alessandra Maggioni[e], Victoria A. Pinilla Escobar[e], Melissa Nicole Castillo[e], Zelde Espinel[f], Sandro Galea[g]

[a] Center for Disaster & Extreme Event Preparedness (DEEP Center), Department of Public Health Sciences, University of Miami Miller School of Medicine, Miami, FL 33136, USA
[b] Senior Fellow, Americas Program, Center for Strategic and International Studies (CSIS), Washington, DC 20036, USA
[c] Climate Science and Services Division, NOAA's National Centers for Environmental Information (NCEI), Madison, WI 53706, USA. Current affiliation: The Climate Service, Durham, NC 27701, USA
[d] Harvard Humanitarian Initiative, Harvard University & T.H. Chan School of Public Health, Senior International Public Policy Scholar, Woodrow Wilson International Center for Scholars, USA
[e] Department of Public Health Sciences, University of Miami Miller School of Medicine, Miami, FL 33136, USA
[f] Sylvester Comprehensive Cancer Center, Department of Psychiatry and Behavioral Sciences, University of Miami Miller School of Medicine, Miami, FL 33136, USA
[g] Robert A Knox Professor, School of Public Health, Boston University, 715 Albany Street - Talbot 301, Boston, MA 02118, USA

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ABSTRACT

The 2020 Atlantic hurricane season was notable for a record-setting 30 named storms while, contemporaneously, the COVID-19 pandemic was circumnavigating the globe. The active spread of COVID-19 complicated disaster preparedness and response actions to safeguard coastal and island populations from hurricane hazards. Major hurricanes Eta and Iota, the most powerful storms of the 2020 Atlantic season, made November landfalls just two weeks apart, both coming ashore along the Miskito Coast in Nicaragua's North Caribbean Coast Autonomous Region. Eta and Iota bore the hallmarks of climate-driven storms, including rapid intensification, high peak wind speeds, and decelerating forward motion prior to landfall. Hurricane warning systems, combined with timely evacuation and sheltering procedures, minimized loss of life during hurricane impact. Yet these protective actions potentially elevated risks for COVID-19 transmission for citizens sharing congregate shelters during the storms and for survivors who were displaced post-impact due to severe damage to their homes and communities. International border closures and travel restrictions that were in force to slow the spread of COVID-19 diminished the scope, timeliness, and effectiveness of the humanitarian response for survivors of Eta and Iota. Taken together, the extreme impacts from hurricanes Eta and Iota, compounded by the ubiquitous threat of COVID-19 transmission, and the impediments to international humanitarian response associated with movement restrictions during the pandemic, acted to exacerbate harms to population health for the citizens of Nicaragua.
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Introduction

Our interdisciplinary team of collaborators has been writing regularly about climate change effects on hurricane hazards and associated population health consequences. Throughout 2020, we extended our writing to describe the superimposed risks to public health associated with climate-driven tropical cyclones striking populations worldwide just as COVID-19 was sweeping the globe [1-4]. Here we describe the impacts of the Atlantic season's two strongest hurricanes, Eta and Iota, coming ashore in Nicaragua in rapid succession.

The hyperactive 2020 Atlantic hurricane season produced an unprecedented 30 named storms, concluding with Hurricanes Eta and Iota, storms 28 and 30, that devastated portions of Central America. Just 13 days and two dozen kilometers apart, Eta and Iota both made landfall near Puerto Cabezas, Nicaragua, pounding the coastline with towering storm surge, pummeling settlements with 140 mph and 155 mph eyewall wind speeds, and inundating the interior with torrential rains that triggered flooding (Figure 1). Beyond the direct exposure of the Nicaraguan population to Eta's and Iota's wind and water hazards, threats to population health were complicated by

* Corresponding author.
E-mail addresses: jshultz1@med.miami.edu (J.M. Shultz), RBerg@csis.org (R.C. Berg), jkossin@theclimateservice.com (J.P. Kossin), Skipmd77@aol.com (F. Burkle Jr), axm2161@miami.edu (A. Maggioni), v.pinillaescobar@med.miami.edu (V.A. Pinilla Escobar), mnc22@miami.edu (M.N. Castillo), z.espinel@miami.edu (Z. Espinel), sgalea@bu.edu (S. Galea).

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Fig. 1. Trajectories of 2020 Hurricane Eta and 2020 Hurricane Iota moving across Central America

multiple interrelated factors: 1) the effects of climate change on the behavior of Atlantic tropical cyclones, 2) the overlay of active COVID-19 transmission risks among hurricane survivors during the pre-vaccine era, and 3) worldwide border closures and travel restrictions that impeded the humanitarian response.

With our co-authors providing expertise from the fields of atmospheric science, population health science, Latin American studies, humanitarian disaster response, and global mental health, we discuss, in sequence: how climate change is making tropical cyclones more dangerous, defining features of the Eta and Iota hurricane strikes, how the COVID-19 pandemic interacted with hurricane mitigation procedures and hindered the international response, and considerations for dealing with future compound disaster scenarios. Our team actively monitored the intersection of emergency response to tropical cyclones worldwide throughout 2020 as COVID-19 circumnavigated the globe [1-4].

Climate change is making Atlantic hurricanes more dangerous and damaging

Hurricanes Eta and Iota were the third and second strongest November storms on record in the Atlantic, respectively, reaching peak wind speeds and low central pressures of 150 mph (923 mbar) and 160 mph (917 mbar). No previous Atlantic season has seen two major (Category 3 or higher) hurricanes in November.

Eta and Iota made meteorological history; never before had two storms made landfall so close in time and place at Category 4 intensity [5]. Iota had ramped up to Category 5 wind speeds shortly before reaching the coast [6,7]. When Iota, the very last storm of the season, reached Category 5 winds speeds, the number of consecutive Atlantic hurricane seasons with one or more Category 5 storms was extended to five years.

Climate change appears to be modifying the hazard properties and potential destructiveness of tropical cyclones, partly explained by the production of anomalously warm ocean and air temperatures [8]. Indeed, seven consecutive years, 2014 through 2020, have been the hottest years on record [9,10]. The year 2020, the focus of our discussion, and the year 2016, have been the warmest ever. NASA declared a tie, [11] while NOAA estimated that 2016 was fractionally warmer by hundredths of a degree [12].

Atmospheric scientists have demonstrated that, over a period of decades, Atlantic hurricanes are becoming stronger and wetter, frequently coupled with decelerating translational (forward motion) speed as these storms approach coastlines and make landfall [8,13-21]. Eta and Iota are exemplars of these stronger, wetter, slower-moving attributes that increasingly distinguish Atlantic tropical cyclones under the influence of climate change.

Regarding “stronger” storms, climate scientists have previously observed an increase in the rotational wind speeds of the strongest tropical systems, likely attributable to climate change [15]. Research suggests that the likelihood of an Atlantic storm intensifying to become a major hurricane (Category 3, 4, or 5 on the Saffir-Simpson Hurricane Wind Scale) has increased by about eight percent per decade over the past four decades [16,17,22].

In addition to the increasing proportion of major hurricanes, and the considerable frequency with which storms attain very high peak wind speeds, another feature of stronger climate-driven storms is rapid intensification. Rapid intensification is defined as an increase in rotational wind speeds of 35 mph—or more—within a 24-hour period [23-25]. Ten of the 2020 Atlantic season’s 30 named storms met this criterion. Eta and Iota both intensified in the anomalously warm Western Caribbean waters that lingered late into the season, the 9th and 10th storms of 2020 to do so [23-25]. Eta’s intensification rate was particularly exceptional with wind speeds accelerating upward by 75 mph in 24 h, and by an astonishing 105 mph within 36 h, just prior to moving onshore [24].

Moreover, consistent with what is known about climate change transforming the hazard properties of Atlantic tropical cyclones, for

both Eta and Iota, the translational speed of both systems decreased on approach to Nicaragua's eastern flank. This deceleration effect increased the length of time when spiraling rainbands were producing heavy thunderstorm activity over Nicaragua and Honduras and strong wave action was battering the east coast of Nicaragua. The destructiveness of these water hazards was amplified by another climate effect, sea level rise.

Climate-driven hurricanes Eta and Iota created severe consequences for population health

Hurricane Eta impact. In preparation for Eta's two-story storm surge, Nicaraguan President Daniel Ortega issued a red alert for the North Caribbean Coast Autonomous Region (abbreviated RACCN in Spanish), encouraging citizens to evacuate. The government prestaged 88 tons of food and supplies, including hygiene kits, in Puerto Cabezas, close to the anticipated point of impact [26]. An estimated 10,000 citizens sheltered as Eta moved onshore. Eta caused extensive flooding, roof damage, and power outages throughout the RACCN, and disabled communications. Damages were estimated at $178 million (USD). In Nicaragua, two deaths were blamed on a landslide triggered by Eta. The International Federation of Red Cross and Red Crescent Societies (IFRC) initiated a "massive, multi-country operation" to respond to the Central American countries affected by Eta; other humanitarian response agencies coordinated their efforts through the IFRC [27].

Hurricane Iota impact. The second and more devastating salvo came with the arrival of Iota two weeks later. Iota was the strongest hurricane in history to make landfall in Nicaragua. On approach to the Nicaraguan coastline, Iota's eyewall was producing a spectacle of lightning strikes and hail. Iota's massive storm surge set off flash flooding along the coast, compounded by pelting rains that enlarged the geographic expanse of inundation. Despite the immense strength at initial impact, Iota's winds rapidly diminished from major hurricane to a tropical depression and then to a remnant low as the storm encountered Nicaragua's rugged mountainous topography, closely mimicking what had happened with Eta two weeks earlier.

The Nicaraguan government's tally of casualties in the first weeks following Iota's impact included 28 deaths and 29 persons missing and unaccounted. Mortality from both Eta an Iota was modest, as has been the case with the four hurricanes that previously struck Nicaragua during the 2000s (e.g. 2005 Hurricane Beta: 6 deaths; 2007 Hurricane Felix: 130 deaths). None compare to the deadliest hurricane in Nicaraguan history, 1998 Hurricane Mitch, that resulted in 3800 deaths as torrential rains caused the flank of the Casita volcano to fail, producing a massive mudslide that buried entire communities.

Nicaragua estimated damages from Iota at $564 million (USD). Government relief efforts focused on placing tents, erecting temporary medical facilities, and bringing supplies of food and water to the ravaged RACCN. Debris remaining from Eta, as well as fresh destruction from Iota, hampered the rescue efforts. Food insecurity was widespread, a consequence of extensive crop damage from Eta's landfall, later exacerbated by Iota's nearly identical east-to-west trajectory through Nicaragua. Taiwan provided critical emergency food relief, quickly responding with a donation of 800 tons of rice.

Eta and Iota response. The United Nations Office for the Coordination of Humanitarian Affairs (OCHA) summarized the humanitarian crisis in the near-term aftermath [28,29]. Flooding from Iota extended across the entire Nicaraguan isthmus from the Caribbean Miskito Coast to the Pacific shores. As a critical case in point, the hard-hit municipality of Puerto Cabezas was cut off by a combination of flooded roads, and near-total destruction of the two primary markets and the seaport [28]. This created major logistical challenges because Puerto Cabezas, the gateway to the RACCN, was ground zero for the impact of both Eta and Iota. Puerto Cabezas was not a singular case; the Nicaraguan government reported disruption of infrastructure in 56 municipalities with 98 percent of roadways damaged or submerged [29].

An estimated 43,000 homes were severely damaged or destroyed, creating significant displacement [29]. Three days post-impact, an estimated 50,700 citizens—in need of food, medical attention, and psychosocial evaluation and support—were distributed among 1195 active shelters [28]. Just one week later, OCHA estimated a much larger number of storm-displaced survivors—190,000—housed in "shelters and temporary accommodations," based on data from the International Organization for Migration (IOM) [29].

A total of 81 health care facilities (including 11 hospitals, 15 health centers, 42 primary health centers, and 5 maternity care facilities) were damaged in the storms and the government estimated almost $13 million in damages to the national public health system [29]. Flooding of medical facilities disrupted operations due to electrical power outages, destroyed medical equipment, and water-soaked medications. A variety of infectious diseases were spreading in the aftermath of the Eta and Iota impacts. UNICEF reported several hundred cases of malaria erupting in community and shelter facilities, likely due to increased mosquito breeding in stagnant water following storm-associated flooding. Several cases of leptospirosis were detected. Both HIV and tuberculosis rates were elevated, compared to national averages, in the community of Wapum in the RACCN, possibly related to the storms [29].

Notably, but not surprisingly, information on COVID-19 cases in storm-affected regions was not reported; Nicaragua's COVID-19 case counts had been consistently underreported since the arrival of the pandemic in Central America [30]. The substantial undercounting was confirmed in a discussion between author RCB and the former Nicaraguan ambassador to the US. The fact that Eta and Iota primarily impacted sparsely-populated rural areas with low COVID-19 prevalence rates diminished the risk of storm-associated transmission. Encouragingly, neighboring Honduras and Guatemala, nations that were also severely impacted by both storms, did not see a spike in COVID-19 cases following Eta and Iota, and both countries maintain robust COVID-19 surveillance systems.

Immediately post-impact, power outages were widespread and telecommunications were disabled over large areas. The Nicaraguan power company, Enatrel, sent brigades of electrical technicians to the coast, restoring electrical service to half of the 160,000 households that initially lost power within several days. A total of 53,000 families lost access to clean water in the aftermath of the two storms. Seventy-six schools were initially closed due to damages sustained.

Revised estimates from the Nicaraguan government placed total damages across both storms at $617 million (USD) and economic losses at $121 million (USD) [29]. Adding response expenditures to this sum, Nicaragua estimated that total storm costs would be equivalent to six percent of the nation's Gross Domestic Product (GDP).

Multiple UN "agencies, funds, and programs (AFPs)" and international non-governmental organizations (INGOs) participated in the response. For tens of thousands who were sheltering, Save the Children, Plan International, IOM, UNICEF, and World Food Program (WFP) provided food and basic needs items, while the government focused on returning families safely to their homesites. WFP and UNICEF were providing food assistance to the general populations of the most impacted municipalities. Much of the work of WFP, including logistics planning, was conducted in conjunction of the Sistema Nacional para la Prevención, Mitigación y Atención de Desastres (SINAPRED), the Nicaraguan government's disaster response agency.

UNICEF was distributing special nutritional supply kits and providing educational sessions for pregnant and breastfeeding women and family caregivers. Given the severe storm damage to water supplies, multiple INGOs were providing chlorine, hygiene kits, water filters, and educational workshops to help decrease risks for waterborne disease outbreaks.

Health care personnel, working long hours in damaged facilities, were experiencing burnout. Identified needs for surge personnel and for mental health and psychosocial support (MHPSS) were not being adequately met.

To address this multiplicity of impacts on the health system, The Nicaraguan Ministry of Health dispatched emergency brigades, medical teams, and mobile medical clinics to the worst-hit areas. Save the Children initiated a health communications campaign aimed at reducing transmission risks for COVID-19 and water-borne diseases. UNICEF procured personal protective equipment (PPE) for 1000 health workers. PAHO brought in almost 20 medical teams for deployment in Puerto Cabezas and surrounding municipalities. Prophylactic treatment for leptospirosis was being provided to large numbers of sheltering persons.

Superimposed risks for COVID-19 transmission among sheltered residents and storm survivors

Throughout 2020, the COVID-19 pandemic produced widespread illness and mortality worldwide. Globally, 2020 was characterized by population-wide susceptibility to COVID-19 in the absence of effective treatments and efficacious vaccines. Multiple climate-driven 2020 Atlantic hurricanes resulted in devastation of island and coastal populations where COVID-19 was actively circulating. Time-tested actions—warning, evacuating, sheltering—have historically proven effective for safeguarding populations from hurricane hazards. These actions move people together, packing them into durable home and community structures away from coastlines prior to impact and throughout the duration of the storm. Indeed, the death tolls from Eta and Iota in Nicaragua were modest because evacuation and sheltering saved lives.

Yet, in 2020, actions to protect populations from hurricanes also increased the threat for COVID-19 transmission. Protective measures to safeguard populations from hurricane hazards run counter to COVID-19 community mitigation approaches—physical distancing, closures, shutdowns, and prohibitions on mass gatherings—that intentionally space people apart [1-4].

Research throughout the pandemic's first year has readily demonstrated COVID-19′s ease of transmissibility. COVID-19 can spread via large droplets expelled when someone coughs or sneezes, but equally well by the airborne diffusion of aerosols comprised of tiny particles that hover in the air, especially in enclosed spaces [31]. Sharing crowded spaces for periods of hours or days amplifies risks for airborne spread. As many as 40 percent of persons infected with COVID-19 experience no illness symptoms, yet these persons with outwardly undetectable infection can shed COVID-19 and infect others [32]. Super spreader events account for high proportions of cases [33]. Each of these mechanisms may play a role in amplifying community spread, especially when local residents are crowded into shelter environments during and after the storm.

The population burden of COVID-19 in Nicaragua has been underreported, with more widespread infection, illness, and death than official counts indicate. With an estimated 190,000 storm survivors placed in community shelter environments one month following impact,[29] and others doubled up in homes with family and friends, the risk for COVID-19 spread was increased. For example, Plan International surveyed shelters in one region and found the facilities in acute need of food, water, sanitation, and personal protective equipment (PPE). Post storm adversities, lack of sanitation and hygiene, and crowding of survivors preclude many survivors from practicing behaviors that limit COVID-19 infection risks: physical distancing, limiting the size of gatherings, COVID-19 testing, and wearing masks.

On a global scale, COVID-19 also severely impeded the timely arrival of humanitarian actors and relief supplies due to border closures, transportation shutdowns, and mandatory quarantines for arriving teams [34]. The situation was complicated by Nicaraguan government policies that limit the operations of international response agencies and the distribution of aid.

Distinguishing vulnerabilities of the Nicaraguan population

The hurricanes slammed part of the Miskito Coast, a historically autonomous region of Nicaragua populated by the indigenous Miskito people. Infrastructure in this region of Nicaragua is substandard, which likely contributed to the hurricanes' profound devastation, with 43,000 structures damaged or destroyed. Since 2007, the budget for SINAPRED, Nicaragua's disaster response agency, has been reduced by 58% to offset the government's priority expenditures for the military and the police. Therefore, in the aftermath of Eta and Iota, the humanitarian response had to unfold in a region of the country where government services were notably lacking, and mistrust of government—including entities participating in the disaster response—was entrenched and longstanding.

Concluding comments

In January 2021, United Nations (UN) agencies and INGO partners released highlights of their Plan of Action for Nicaragua, summarizing the ongoing crisis following the twin strikes of Eta and Iota that affected 60% of the country, but the RACCN most severely [35]. UN partners identified a total of 731,000 persons in need, including one-half million persons with inadequate access to basic health services, 490,000 lacking access to clean water supplies, 300,000 facing food insecurity, and 230,000 dealing with structural damages to their households caused by the storms [35]. Meanwhile, in the first quarter of 2021, Nicaragua was negotiating with Russia to procure quantities of its Sputnik V COVID-19 vaccine with the intention to initially vaccine 3.7 million persons (approximately 12% of the national population); the population was almost universally unprotected during early 2021.

Key lessons learned included powerful reinforcement for the notion, grounded on science, that climate change is demonstrably transforming the hazard properties of tropical cyclones worldwide, including Atlantic hurricanes. The overlay of pandemic risks on top of climate-driven extreme storm threats has signaled the need to prioritize surveillance of COVID-19 specifically, and airborne pathogens generally, when upgrading disaster preparedness and response plans. As one component of this approach, in the aftermath of Eta and Iota, PAHO/WHO donated 40,000 antigen tests and 300,000 PCR tests to bolster early COVID-19 detection at hurricane shelters in neighboring Honduras. A related element is to accelerate programs to vaccinate coastal and island populations against COVID-19 prior to the upcoming 2021—and future—hurricane seasons. This will diminish the preventable infectious disease burden following hurricane impact.

Taken together, the Eta/Iota experience in Nicaragua represents a consequential example of a complex threat to population health involving the superimposed risks of climate-driven hurricanes intersecting with the COVID-19 pandemic.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. All will complete an ICMJE form regarding COI if requested.

References

[1] Salas RN, Shultz JM, Solomon CG. The climate crisis and COVID-19 - a major threat to pandemic response. N Engl J Med 2020;383(11):e70. doi: 10.1056/NEJMp2022011.
[2] Shultz JM, Fugate C, Galea S. Cascading risks of COVID-19 resurgence during an active 2020 Atlantic hurricane season. JAMA 2020;324(10):935–6. doi: 10.1001/jama.2020.15398.

[3] Shultz JM, Kossin JP, Ali A, Borowy V, Fugate C, Espinel Z, Galea S. Superimposed threats to population health from tropical cyclones in the prevaccine era of COVID-19. Lancet Planetary Health 2020;4(11):e506–8. doi: 10.1016/S2542-5196(20)30250-3.
[4] Shultz JM, Kossin JP, Hertelendy AJ, Burkle F, Fugate C, Sherman R, Bakalar J, Berg K, Maggioni A, Sands DE, Espinel Z, Salas RN, Galea S. Mitigating the twin threats of climate-driven Atlantic hurricanes and COVID-19 transmission. Disaster Med Public Health Prep 2020;14:1–10. doi: 10.1017/dmp.2020.243.
[5] Cappucci M. Two Category 4 hurricanes hit the same place in two weeks. That's unheard of. Disaster struck twice in two weeks in Nicaragua. Washington Post—Capital Weather Gang, 2020. https://www.washingtonpost.com/weather/2020/11/17/nicaragua-eta-iota-landfalls/.
[6] Center for Disaster Philanthropy. 2020 Atlantic Hurricane Season. November 24, 2020. https://disasterphilanthropy.org/disaster/2020-atlantic-hurricane-season/
[7] National Hurricane Center. Hurricane Iota Discussion Number 13. November 16, 2020. https://www.nhc.noaa.gov/archive/2020/al31/al312020.discus.013.shtml
[8] Kossin J.P., Hall T., Knutson K.E., et al. Extreme storms. In: Wuebbles DJ, Fahey DW, Hibbard KA, et al., editors Climate Science Special Report: fourth National Climate Assessment, Volume I, Washington, DC: U.S. Global Change Research Program; 2017:257–76. https://science2017.globalchange.gov/chapter/9/
[9] Neukom Raphael, Steiger Nathan, Gómez-Navarro Juan José, Wang Jianghao, Werner Johannes P. No evidence for globally coherent warm and cold periods over the preindustrial common era. Nature 2019;571:550–4. doi: 10.1038/s41586-019-1401-2.
[10] World Meteorological Organization (WHO). 2020. State of the global climate 2020: provisional report. December 2, 2020. https://reliefweb.int/report/world/wmo-provisional-report-state-global-climate-2020
[11] NASA. 2020. Tied for Warmest Year on Record. NASA Analysis Shows 2020 January 14, 2020 https://www.nasa.gov/press-release/2020-tied-for-warmest-year-on-record-nasa-analysis-shows.
[12] NOAA. 2020. 2020 was Earth's Second Hottest Year, Just Behind 2016. January 14, 2020. https://www.noaa.gov/news/2020-was-earth-s-2nd-hottest-year-just-behind-2016
[13] Knutson T, Camargo SJ, Chan JCL, et al. Tropical cyclones and climate change assessment: part I: detection and attribution. Bull Am Meteor Soc 2019;100(10):1987–2007. doi: 10.1175/BAMS-D-18-0189.1.
[14] Knutson T, Camargo SJ, Chan JC, et al. Tropical cyclones and climate change assessment: part II: projected response to anthropogenic warming. Bull Am Meteor Soc 2020;101(3):E303–22 https://journals.ametsoc.org/doi/10.1175/BAMS-.
[15] Elsner JB, Kossin JP, Jagger TH. The increasing intensity of the strongest tropical cyclones. Nature 2008;455(7209):92–5 55. doi: 10.1038/nature07234.
[16] Bhatia KT, Vecchi GA, Knutson TR, Murakami H, Kossin J, Dixon KW, Whitlock CE. Recent increases in tropical cyclone intensification rates. Nat Commun 2019;10:635. doi: 10.1038/s41467-019-08471-z.
[17] Kossin JP, Knapp KR, Olander TL, Velden CS. Global increase in major tropical cyclone exceedance probability over the past four decades. Proc Natl Acad Sci USA 2020;117(22):11975–80. doi: 10.1073/pnas.1920849117.
[18] Hall TM, Kossin JP. Hurricane stalling along the North American coast and implications for rainfall. npj Clim Atmos Sci 2019;2:17. doi: 10.1038/s41612-019-0074-8.
[19] Kossin JP. A global slowdown of tropical-cyclone translation speed. Nature 2018;558(7708):104–7. doi: 10.1038/s41586-018-0158-3.
[20] Kossin JP. Reply to: moon, I-J et al.; Lanzante, JR. Nature 2019;570:E16–22. doi: 10.1038/s41586-019-1224-1.
[21] Patricola CM, Wehner MF. Anthropogenic influences on major tropical cyclone events. Nature 2018;563(7731):339–46. doi: 10.1038/s41586-018-0673-2.
[22] Freedman A, Samenow J. The strongest, most dangerous hurricanes are now far more likely because of climate change, study shows. Washington Post—Capital Weather Gang 2020. https://www.washingtonpost.com/weather/2020/05/18/hurricanes-stronger-climate-change/.
[23] Cappucci M. Hurricane Eta exploded before hitting Nicaragua, but we may never know how strong it was. Washington Post—Capital Weather Gang 2020. https://www.newsbreak.com/news/2096817842953/hurricane-eta-exploded-before-hitting-nicaragua-but-we-may-never-know-how-strong-it-was.
[24] Samenow J, Freedman A, Cappucci M. Atlantic hurricane season breaks all-time record while leaving Gulf Coast battered. Washington Post—Capital Weather Gang 2020. https://www.washingtonpost.com/weather/2020/11/10/record-hurricane-season-atlantic/.
[25] Freedman A. Slew of rapidly intensifying hurricanes portends trouble in a warming world. Washington Post—Capital Weather Gang. 2020 https://www.seattletimes.com/nation-world/slew-of-rapidly-intensifying-hurricanes-portends-trouble-in-a-warming-world/.
[26] Brackett R. Hurricane Eta Forces Red Alerts, Evacuations in Nicaragua and Honduras. 2020. https://weather.com/news/news/2020-11-02-hurricane-eta-nicaragua-honduras-evacuations-red-alerts.
[27] I. nternational Federation of Red Cross and Red Crescent Societies (IFRC). Red Cross launches massive, multi-country operation as horror of Hurricane Eta emerges. 2020. https://media.ifrc.org/ifrc/press-release/red-cross-launches-massive-multi-country-operation-horror-hurricane-eta-emerges/
[28] United Nations Office for the Coordination of Humanitarian Affairs. Latin America & The Caribbean: 2020 Hurricane Season—Situation Report No. 4. 2020. https://reliefweb.int/sites/reliefweb.int/files/resources/20201120_CA%20Eta%20SitRep%204%20ENG.pdf.
[29] United Nations Office for the Coordination of Humanitarian Affairs. Central America & Mexico: 2020 Hurricane Season—Situation Report No. 5. 2020. https://reliefweb.int/sites/reliefweb.int/files/resources/20201126%20CA%20Eta%20SitRep%205%20%28ENG%29.pdf.
[30] Salazar Mather TP, Gallo Marin B, Medina Perez G, Christophers B, Paiva ML, Oliva R, Hijaz BA, Prado AM, Jarquín MC, Moretti K, González Marqués C, Murillo A, Tobin-Tyler E. Love in the time of COVID-19: negligence in the Nicaraguan response. Lancet Glob Health 2020;8(6):e773. https://www.thelancet.com/pdfs/journals/langlo/PIIS2214-109X(20)30131-5.pdf.
[31] Morawska L, Milton DK. It is Time to Address Airborne Transmission of COVID-19 [published online ahead of print, 2020 Jul 6]. Clin Infect Dis 2020:ciaa939.
[32] Oran DP, Topol EJ. Prevalence of Asymptomatic SARS-CoV-2 Infection: a Narrative Review. Ann Intern Med 2020;173(5):362–7.
[33] Kwok KO, Chan HHH, Huang Y, et al. Inferring super-spreading from transmission clusters of COVID-19 in Hong Kong, Japan, and Singapore. J Hosp Infect 2020;105(4):682–5.
[34] Hsiang S, Allen D, Annan-Phan S, et al. The effect of large-scale anti-contagion policies on the COVID-19 pandemic. Nature 2020 . doi: 10.1038/s41586-020-2404-8.
[35] United Nations agencies and Government of Nicaragua. Nicaragua Plan of Action: hurricanes Eta and Iota. 2021. https://reliefweb.int/report/nicaragua/nicaragua-plan-action-hurricanes-eta-and-iota-january-2021-one-pager.