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Climate Change and Pregnancy: Risks, Mitigation, Adaptation, & Resilience

Winnie Fan, Sc.B. [Medical Student],
School of Medicine, University of California San Francisco

Marya G. Zlatnik, M.D., M.M.S. [Professor]
Maternal Fetal Medicine, Program on Reproductive Health and the Environment, Department of Obstetrics, Gynecology, & Reproductive Sciences, Western States Pediatric Environmental Health Specialty Unit, UCSF, University of California San Francisco

Abstract

Importance: Climate change is affecting the earth, resulting in more extreme temperatures and weather, rising sea levels, more frequent natural disasters, and displacement of populations of plants and animals, including people and insects. These changes affect food and housing security, vector-borne illnesses, and access to clean air and water, all of which influence human health.

Evidence and results: There are a number of adverse health outcomes linked to heat, air pollution from wildfires, stress from natural disasters, and other elements of climate change. Pregnant people are especially vulnerable to the health harms resulting from climate change, namely preterm birth, small for gestational age, hypertensive disorders of pregnancy, and other adverse reproductive health and birth outcomes. Strategies to minimize these harms include mitigation and adaptation.

Conclusions and Relevance: Physicians are in a unique position to protect the health of pregnant persons and children by advocating for policy changes that address climate change and providing clinical recommendations for patients to protect themselves from the health impacts of climate hazards.

Introduction: Why is climate change a problem for health?

Climate change is affecting the earth. We are now seeing more extreme weather and temperatures, rising sea levels, more frequent natural disasters (including wildfires, hurricanes, droughts, and flooding), and displacement of people, animals, insects, and plants around the world [1] [2] [3] [4]. We are seeing a record number of climate-related disasters, with over 22,000 disasters in the past 50 years, accounting for 45% of disaster-related deaths and 74% of economic losses [5]. Of the natural disasters, droughts, storms, floods, and extreme weather have led to the highest human losses. Climate change also affects food

Correspondence: Marya G. Zlatnik, MD, MMS, Box 10132, Department of Obstetrics, Gynecology, & Reproductive Sciences, University of California San Francisco, 490 Illinois St., 10th floor, San Francisco, CA 94143, 415-514-2167 (office), 415-476-1811 (fax), Marya.zlatnik@ucsf.edu.

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Target Audience: Obstetricians and gynecologists, family physicians

and housing security, vector-borne illness, and access to clean air and water, all of which influence human health [6]. High heat alone is linked to several adverse health outcomes, including stroke, exhaustion, faints, cramps, and, in severe heat, multi-organ dysfunction [7].

Our climate is warming mostly because of the combustion of fossil fuels and increased carbon dioxide (CO_2) levels in the atmosphere [8] [9]. CO_2, which is the gas that we exhale, is also the by-product of the use of coal, gasoline, natural gas, and other petrochemicals; it is called a greenhouse gas because of its ability to trap heat in the atmosphere [10] [11]. There are other greenhouse gases, such as methane (i.e., natural gas), halocarbons (e.g., chlorofluorocarbons) and some anesthetic gases (e.g., desflurane), which are all important contributors to global warming because they are long-lasting or highly effective at trapping heat [11]. However, CO_2 is the most prevalent gas that drives climate change [10].

The recommended approaches to climate change by the Intergovernmental Panel on Climate Change include mitigation, adaptation, and resilience [12]. Mitigation involves steps to decrease CO_2 and other greenhouse gas levels to minimize the change in climate, whereas adaption refers to employing strategies that deal with a climate that is hotter and stormier such as installing air conditioning units in homes [12]. Lastly, resilience, achieved through sustainable development (ideally, in a just and equitable manner), is an important concept for our society to anticipate and to recover from future climate stressors [13].

Climate change results in a spiral of environmental and health impacts

The warming of the atmosphere and the oceans is changing weather patterns. Analysis of over 400 peer-reviewed studies on weather extremes found some areas of the world have prolonged and more intense droughts, whereas other areas are experiencing more flooding, a result of more intense rains [14]. Higher water temperatures have decreased the ocean's ability to hold CO_2 and are melting the Artic Sea ice, glaciers, and the Greenland ice sheet, releasing legacy stores of CO_2 [10]. In addition, the increase in ocean temperatures leads to a moister atmosphere that produces powerful hurricanes with heavy rainfall [15]. This, in combination with rising seawater levels, can cause destructive storms and flooding. Increased ocean temperatures are also changing the global patterns of weather circulation, exacerbating the disparities of rainfall between wetter and drier areas of the world [16].

Warming of the atmosphere is making air pollution worse

Air pollution and climate change are closely linked. Global warming makes air pollution worse by increasing smog (i.e., ground level ozone) and causing extreme heat and drought events that lead to forest fires and widespread smoke [17]. There is also growing evidence suggesting that wind patterns are changing due to increase in droughts and aridity from climate change, potentially creating dust-bowl-type storms in the American Southwest and leading to higher amounts of particulate matter (PM) in the air [18]. Importantly, air pollution increases the trapping of heat from the sun, worsening climate change through a vicious cycle (figure 1) [19].

One of the most significant sources of air pollution is burning fossil fuels in coal- and natural gas-fired power plants, gasoline-powered cars, and diesel trucks [20] [21]. Burning

fossil fuels emits mercury, organic air toxics, toxic metals, methane, nitrous oxide, and CO_2- the main culprit causing overall warming of the Earth's atmosphere [20] [21]. Other common air pollutants include fine inhalable $PM_{2.5}$ from fire and construction sites and vapor organic compounds (VOCs) from paint and refrigerators [22] [23].

How do climate change & air pollution affect pregnancy & human development?

Climate change is impacting human health now, exacerbating existing health stressors (e.g., vector-borne illnesses), and affecting social determinants of health (e.g., food/housing security) [24] [25] [26]. Women often bear the brunt of the health harms from climate disasters and forced migration due to climate change-related civil unrest, food insecurity, and gender inequality [27] [28]. A geospatial analysis of data from the United Nations High Commissioner for Refugees and the Internal Displacement Monitoring Centre databases estimated that 16 million women were refugees in 2017, with an additional 265 million women living within 50 km of armed conflict [29]. Worldwide, it is difficult to assess the degree of armed conflict due to climate change, but researchers have estimated that a 54% increase in armed conflict may be seen in Africa by the year 2030 [30]. In the 1991 cyclones that killed over 100,000 people in Bangladesh, 90% of victims were women, and the death rate among young adults (ages 20–44 years) was 71 per 1000 for women, compared with 15 per 1000 men [31]. In another example, qualitative research reported a dramatic increase in domestic violence after the Australian bushfires in 2009 [32].

Importantly, climate change is associated with poor pregnancy outcomes that can have lasting effects on offspring and the health of subsequent generations [6] [26]. Pregnant people have special vulnerabilities to certain environmental exposures because of their unique physiology. Specifically, the normal physiological changes of pregnancy, including a 20% increase in oxygen consumption, 40–50% increase in minute ventilation, and a 40% increase in cardiac output, make pregnant people particularly vulnerable to air pollution and heat stress [33]. Pregnancy is also a time of susceptibility to hypertension, including preeclampsia and gestational hypertension, which can affect both the pregnant individual and fetus [34].

In addition to these physiologic changes, dependence on functional transportation systems and health care institutions also makes pregnancy a particularly vulnerable period to climate changes. Most women require inpatient medical care at least once during their pregnancy, and as such, disrupted healthcare access due to natural disasters can pose a threat to the health of the pregnant person and fetus. For instance, in areas affected by Hurricane Katrina, pregnant women were reported to have greater risks for adverse pregnancy and infant outcomes, potentially due to stress, high heat, and inadequate access to reproductive health care, electricity, clean water and food, and other clinical infrastructures [35]. A prospective cohort study of women delivering at two hospitals in Louisiana after Hurricane Katrina found an association between intensity of hurricane exposure (high exposure was defined as having 3 or more severe experiences of the following: feeling that one's life was in danger, experiencing illness or injury to self or a family member, walking through floodwaters,

significant home damage, not having electricity for more than 1 week, having someone close die, or seeing someone die) and birth outcomes, with high hurricane exposure being associated with a more than three-fold increased risk of having low birth weight infants, which persisted after adjustment for confounding variables (adjusted odds ratio (aOR) 3.3 (95% confidence interval (CI): 1.13 – 9.89) compared to women with 0 or 1 severe experience as defined above. The adjusted odds ratio having a preterm birth was doubled in women with high hurricane exposure compared to women with 0 severe experiences, although this was not statistically significant (aOR: 2.3, 95% CI: 0.82 – 6.38) [36].

Similarly, children have physical attributes that make them more susceptible to harm from climate change. Infants and children have greater surface area to body mass ratio than adults, which makes them more susceptible to water loss from skin, increasing the risk for heat related illnesses (e.g., heat stroke and heat cramps) [37]. Additionally, they are more sensitive to air pollutants than adults due to 1) immature lung and immune functions, 2) more exposures from outdoor activities, 3) higher minute ventilation rate, and 4) frequent mouth breathing [38]. A prospective birth cohort study of approximately 4000 children found that the adjusted odds ratio per interquartile pollution range were 1.2 for wheeze, 1.3 for doctor-diagnosed asthma, 1.2 for ear/nose/throat infections, and 1.2 for flu/serious colds during first 4 years of life, suggesting that traffic-related pollution adversely impacts respiratory outcomes of children [39].

Children also more frequently experience serious complications from a variety of infectious diseases, including vector-, water-, and food-borne diseases [40]. Outbreaks of these diseases often increase with extreme weather events [41]. In addition to their physiology, children are particularly vulnerable to climate change due to their dependence on caregivers for basic health needs and safety. For instance, in a study examining posttraumatic stress disorder (PTSD) in children in the year after Hurricane Katrina found that children's new PTSD symptoms strongly correlated with caregivers with new PTSD symptoms, highlighting the impact of caregiver-children relationship following trauma [42].

Air pollution increases risks to reproductive health and human development

Prenatal exposure to air pollution, including $PM_{2.5}$ and ozone, contributes to adverse pregnancy outcomes, including preterm birth [43] [44] [45], low birthweight [44] [45] [46] [47], and stillbirth [48] [49]. Meta-analyses have found that over 3% of preterm births in the United States and 18% of preterm births globally could be attributed to $PM_{2.5}$ exposure [50] [51]. These harms were often greater for vulnerable populations, including people of color and those with asthma [51] [52]. In addition to impacting birth outcomes, exposure to pollutants during prenatal life can have postnatal impacts. For example, exposure to air pollution (including $PM_{2.5}$, polycyclic aromatic hydrocarbons, and metals) during fetal life has been directly associated with abnormal neurodevelopment [53] [54]. Air pollution also increases health risks for pregnant individuals by increasing the risk of hypertensive disorders of pregnancy, which are major contributors to maternal morbidity and mortality in the United States [34] [55] [56].

Climate change increases the risk of wildfires through longer and more intense droughts as well as higher temperatures [57, 58]. The extent to which wildfire smoke impacts health is greater than that of ambient air pollution from sources such as motor vehicles and factories. A recent study found that wildfire $PM_{2.5}$ was up to 10 times more harmful than equal doses of ambient $PM_{2.5}$ and led to more respiratory hospitalizations in Southern California [59]. A small but growing body of evidence links exposure to wildfire smoke in pregnancy with adverse pregnancy outcomes, including preterm birth [60] [61]. Analysis of smoke plume and birth data from California during 2006–2012 suggested that each day of exposure to wildfire smoke during pregnancy was associated with a 0.49 % increase in risk of preterm birth [62]. The authors estimated nearly 7000 excess preterm births were attributable to wildfire smoke exposure, accounting for 3.7 % of observed California preterm births during that period.

Health risks from high heat during pregnancy

Global warming increases extreme heat and the number of hot days, which are associated with many adverse pregnancy complications and birth outcomes. For instance, in a case-crossover analysis using province-wide discharge data of over 17,000 births from Canada, high heat exposure (maximum temperature of 86°F compared to a referent of 59°F) during pregnancy was observed to be associated with increased abruption at term (aOR 1.12, 95% CI 1.02–1.24) [63]. Higher heat during pregnancy was also linked to increased risk of gestational diabetes in several studies, as summarized in a systematic review [64]. Other adverse pregnancy outcomes such as preterm birth, low birthweight, and stillbirth were found in studies across the world to be associated with high temperatures [65] [66] [67] [68] [69] [70] [71] [72] [73]. Of note, in several of these studies, the relative heat, rather than the absolute temperature, was significant[66] [67] [73]; this may reflect either structural adaptations (e.g., home air conditioning) or acclimatization. Mechanisms by which high ambient heat may lead to these birth outcomes include dehydration, altered blood viscosity, impaired thermoregulation triggering rupture of membranes, reduced uterine blood flow, and lowered amniotic fluid volume [66] [68] [69] [70] [71].

Pregnant persons are at greater risk for heat exhaustion and heat stroke than non-pregnant persons, a serious concern for those who work outdoors, or in kitchens, manufacturing, and other places with excess heat exposures [74]. This risk is due to inefficient thermoregulation due to physiologic changes of pregnancy, including an increased plasma volume that allows for greater heat storage [75]. Additionally, a pregnant person’s core temperature increases because of metabolic and hormonal changes and heat dissipation by the fetus [75]. Certain co-morbidities and socioeconomic factors in pregnant people may further increase their risk of heat-related illnesses. In a case-crossover analysis of 14,466 pregnant people in Northern California, the risk of preterm birth related to high ambient heat was found to increase particularly in those with underlying diabetes, hypertension, or pre-eclampsia [76]. The authors also observed that individuals who are younger, black, Hispanic, and underweight are at higher risk of preterm birth during warmer seasons [76].

Vector ecology and pregnancy

Vector-borne diseases are infections in humans or animals transmitted by vectors such as mosquitos, ticks, and lice. Examples of vector-borne diseases include Dengue virus carried by mosquitoes and Lyme disease carried by ticks [77]. Global warming and climate change can impact the geographic range of vector-borne diseases by changing local temperatures and rainfall, altering ecosystems, and changing human activities [26]. As spring and summer become longer in the United States, Dengue fever and Lyme disease are becoming more prevalent due to abundance of vectors during these seasons [26]. However, because vector ecology is complex and dependent on multiple factors, climate change may not increase the spread of all vector-borne illnesses, though any disease new to an area carries risk of impacting people with no prior immunity.

Pregnant people are at risk of vector-borne infections due to suppressed immunity, and such infections have the potential of impacting fetal outcomes [78]. Well-known adverse events in pregnancy from vector-borne diseases such as malaria and Zika include pre-eclampsia, HELLP syndrome, preterm birth, low fetal birth weight, mother to child transmission, and fetal congenital malformations [78] [79] [80]. Cases of coccidioidomycosis, a fungal disease that pregnant people may be more susceptible to, have been reported to have increased in California in response to increased land aridity [81] [82]. Many treatment options that are used for vector-borne diseases, such as doxycycline and chloramphenicol, are avoided in pregnancy due to side effects that could affect the fetus, further compounding this population’s sensitivity towards infectious diseases [78].

Water salinity and pregnancy

Global warming and increased ocean heat content have led to the rise of sea levels. Rising sea level intrudes inland into local water sources and increases the salinity of both surface and ground water. Some regions in the US (including the Mississippi River and Sacramento River deltas) are at risk for increased water salinity from climate change, drought, and other causes such as dams, diversions, and groundwater extraction [83] [84]. A case-control study of 202 pregnant women observed that drinking water from sources with high sodium levels was associated with increased risks for both gestational hypertension and preeclampsia [85]. In this study, the risk of hypertensive disorders of pregnancy increased in a dose-response manner for increasing sodium concentrations (<300 mg/L (referent), 300.01–600 mg/L, 600.1–900 mg/L, >900.01 mg/L) in drinking water, with aORs of 3.30 [95% CI 2.00–5.51], 4.40 [2.70–7.25] and 5.48 [3.30–9.11]) respectively. Notably, gestational hypertensive disorders are a leading cause of death of pregnant people globally; they are linked to cardiovascular complications and development of hypertension later in life [86] [87]. Additionally, in infants, high salt intake is associated with higher systolic blood pressure [88]. Prevention of excess salt intake from water with increased salinity is therefore critical to protect the health of pregnant people and children.

Natural disasters (hurricanes, floods, fires, and others) and pregnancy

Global warming and climate change result in more extreme weather events, increased frequency of precipitation, intensity of wind, and occurrence of droughts [3]. Consequently, natural disasters such as storms, monsoons, floods, tropical cyclones, landslides, avalanches, and heatwaves are becoming more common [5]. These climate-induced natural disasters can be major stressors for pregnant people and prevent their access to basic necessities and healthcare facilities, thereby adversely impact their health and wellbeing [31].

Floods and pregnancy

Several studies have looked at the impact of pregnant individuals' exposure to flooding during pregnancy and birth outcomes and/or neurodevelopment of offspring. A study analyzing exposure to the Red River Flood in North Dakota in 2009 showed a decrease in birth weight for those women living closest to the flooding early in pregnancy [89]. After the 2008 severe flooding in Iowa, a cohort study found that maternal stress, as opposed to objective hardship, adversely impacted neurodevelopment of toddlers [90]. A recent study examined the impact of exposure to the devastating 1998 Yangtze River flood in China during pregnancy on offspring's cognitive development [91]. In this study, greater risks of adverse effects were associated with longer period of flood exposure (3 months) and earlier pregnancy exposure (first trimester). The findings from Yangtze River study support those from the aforementioned North Dakota and Iowa studies.

After Hurricane Harvey, gravidas in the Houston area had a 27% increase in composite maternal morbidity when compared to a cohort of women delivering prior to the storm [92]. Additionally, composite neonatal morbidity increased by 50% in the hurricane-exposed pregnancies [92]. The authors postulated that in addition to prenatal stress, chemical and environmental pollutants resulting from hurricane's flooding and wind damage may had contributed to risks for maternal and neonatal morbidity. Interestingly, women in neighborhoods with a decrease in soil burden of lead after flooding from Hurricanes Katrina and Rita had a lower risk of preeclampsia [93].

Wildfires and pregnancy

Review of the limited but rapidly growing literature examining wildfire exposure (smoke and stress) during pregnancy show an increased risk of fetal growth restriction and preterm birth with exposure during the last trimester [60] [62] [94]. A 2019 study used birth certificate data from Colorado and ground PM2.5 monitors as well as NOAA estimates of daily smoke exposure to assess the impact of wildfire smoke on low birth weight and preterm birth in Colorado from 2007–2015. The authors found exposure to wildfire smoke PM2.5 during the second trimester was significantly associated with preterm birth (aOR = 1.132 $(\mu g/m^3)^{-1}$ [95% CI 1.088– 1.178]) after adjusting for co-exposures and known risk factors for preterm birth. Exposure over the entire pregnancy was significantly associated with preterm birth (aOR = 1.076 $(\mu g/m^3)^{-1}$ [95% CI 1.016–1.139]) [95]. Exposure to a wildfire more directly, including emergency evacuation, may increase pregnancy risks further through stress-related mechanisms [57] [94]. Moreover, burns and inhalational

injuries resulting from wildfires can have serious consequences in pregnancy and may lead to parental and fetal death [96].

Natural disaster and mental health

In the general population, direct exposure to wildfires, hurricanes, and flooding has been associated with increased risk for mental health disorders, particularly post-traumatic stress disorder (PTSD) and depression [97] [98] [99] [100]. Impacts are particularly severe in those experiencing a loss of place, home, and social capital during these disasters [101]. Increases in reported sleep disturbance and generalized anxiety disorder were noted in those experiencing wildfires [97]. Atypically high nighttime temperatures combined with high humidity, which will become more common with climate change, have been associated with insufficient sleep, a risk factor for several mental health outcomes [102]. In a statewide study of California emergency department visits, increased mean apparent temperatures were found to have acute associations with mental health outcomes, including suicide, and intentional injuries [103]. In a survey study of over 96,000 Puerto Rican youths several months after Hurricane Maria, a majority were found to have experienced significant exposure to stressful events from disaster, including witnessing homes being damaged, being forced to evacuate, or having a close one experience injury or death [104]. At the time of the assessment, 7.2% of these youths were likely to have a diagnosis of PTSD based on survey results [104].

Effective clinical interventions and psycho-social education before, during, and after disasters can increase individual resilience and empower community, thereby improving the adverse mental health effects from disasters [105]. In a study of pregnant people following a large wildfire in Canada, satisfaction with social support moderated the impact of peritraumatic stress on PTSD-like symptoms [106]. Better sleep quality, physical exercise, and emotional support contribute to resiliency in the face of the increases in stressful events associated with climate change [97].

Environmental justice is an important consideration

Many of the harms from climate change have a disproportionate impact on otherwise vulnerable communities [52], [107], [108]. These communities may have exposures to other forms of air pollution that impact pregnancy outcomes, higher risk of flooding during severe weather events, or more susceptibility to heat waves [109] [110] [111]. Communities of color are more likely to live in “heat islands,” urban areas with less tree canopy cover, which retain heat, raising health risks during heat waves [111]. Moreover, coping resources are often less accessible to these vulnerable communities [112] [113]. Hence, it is imperative to prioritize supporting vulnerable populations in their adaptation to climate change, providing necessary resources to prevent adverse health effects from natural disasters, and increasing resilience of these communities [13].

Further information about climate change and reproductive justice is provided by Human Rights Watch: https://www.hrw.org/sites/default/files/media_2020/10/climatecrisis-reproductivejustice-US_1020_web.pdf].

What can clinicians do to mitigate these health harms?

Protective public policies are essential for health

Advocating for public policies that promote clean air and prevent climate change is vital. Policy changes are important for both mitigation and adaptation. An example of a mitigation strategy is transitioning from a coal-fired power plant to solar or wind power, whereas adaptation strategies include installing air conditioning and filtration systems in schools. A society's resilience is increased by both mitigation and most adaptation strategies, as well as by efforts to improve the physical, emotional, and financial support of its people [106].

Health care providers are a trusted voice at the policy level.

Health care providers are especially effective at advocating for public policies that protect patients and communities by reducing pollutants and global warming and building resilience in the health care sector [114] [115]. Because of the importance of climate change on human health and safety, several physician organizations have published recommendations for providers, the health sector, and the government to take actions towards mitigating and adapting to climate change. For instance, the American Academy of Pediatrics has recommended several social policies to protect the health of future children from climate change, which include promoting environmental education and reducing carbon footprints of health centers [116].

Overall, policy interventions that reduce prenatal exposure to particulate matter, reduce global CO_2 emissions, and divest from fossil fuels are of utmost importance to halt climate change and help ensure the health of everyone, especially pregnant people and children [116]. (see figure 2). Policy interventions that decrease the combustion of fossil fuels are expected to have benefits both with respect to climate change and atmospheric warming as well as decreasing air pollution and its' health harms. A California study of birth records and US Energy Information Administration data found that local power plant retirements were associated with a decrease in the proportion of preterm birth within 5 km (−0.019, 95% CI: −0.031, −0.008) and 5–10 km (−0.015, 95% CI: −0.024, −0.007), compared to those living 10–20 km away. For pregnancies in the immediate area (0–5-km from the power plant), this corresponded to a reduction in preterm birth from 7.0% to 5.1% [117].

In addressing global environmental change, preventing wildfire is critical in reducing the release of substantial greenhouse gas [118]. For wildfire smoke prevention and mitigation, some policy considerations and mitigation strategies include: 1) decreasing greenhouse gas emissions; 2) establishing local, federal, or multinational initiatives (e.g., the Paris Agreement); 3) investing in renewable energy; 4) establishing economic incentives for reducing emissions (e.g., Cap and Trade); and 5) increasing funding for research to predict high risk areas and behaviors of wildfire.

On the infrastructure level, air filtration should be standardized across public buildings, including schools and hospitals, and administrators should consider air quality recommendations from national or regional guidelines (e.g., https://doh.wa.gov/community-and-environment/air-quality). Funding is particularly important for hardening state and local infrastructures. Equally, indoor air pollution monitoring and establishing standards

for public spaces warrant funding and research. To prevent damages from wildfire, health experts should be consulted as air resource advisors and help modify the fire incidence team protocols. Communities should assess their infrastructure resources needed to address disasters, including cooling centers, disaster response teams, and flood mitigation measures.

Another aspect to consider in preventing wildfire is forest management. Federal and state levels should invest in sustainable forest maintenance initiatives, including mechanical clearing and prescribed burns [57]. Allocating funding to allow for more focus on prevention (e.g., The Fire Funding Fix) is also critical. Defensible space programs, such as reduction of building expansion adjacent to wooded areas, can prevent ignition of wildfire from human activities as well as mitigate damages from wildfire spreading into residential areas. Health systems should consider the future risk of wildfires and other disasters when siting new hospitals, especially those that provide pregnancy or pediatric care [57].

As individuals, we can all do our part to reduce carbon emissions and air pollution and stop the climate crisis. This includes walking, biking, carpooling, and using public transportation when possible. We can conserve energy by supporting renewable energy (solar, wind) [52] [57]. We can all shut off lights when not in use at home or work and buy energy efficient appliances where available. Stop the use of aerosol sprays; instead, use cleaning products and paints that are environmentally safe. Advocate for the government to address fossil fuel combustion, expand renewable energy, improve efficiency and cost through research and technology, and increase accessibility to resources [57].

Clinicians can impact the carbon footprint of health care.

Healthcare accounts for 10% of US greenhouse gas emissions [119]. Clinicians can limit their carbon footprint by engaging in evidence-based care which foregoes unnecessary tests and procedures as exemplified by the Choosing Wisely campaign (https://www.choosingwisely.org/). Clinicians can advocate for hospitals and centers to achieve the following: 1) use clean, renewable energy and work towards carbon neutrality, 2) reduce energy use for heating, humidity, air conditioning, light, ventilation and other clinical processes with high energy consumption by adopting conservative measures, and 3) cut waste through purchasing items with minimum packaging, using reusable items, recycling, composting, and proper disposing [120] [121]. A recent study compared the carbon footprint of metal and disposable specula, with greenhouse gas emissions decreased by ~75% with stainless specula, with a significant decline in end-of-life solid waste generation as well [122]. In the US, cesarean birth is estimated to have double the carbon footprint as compared to vaginal birth, largely due to disposable items used in the OR [123]. An individual clinician may not have choices around some aspects of their own clinical carbon footprint but having an awareness of these issues is important.

Clinical evidence base for managing climate change

The evidence base to guide clinicians' responses specifically to climate change is in its infancy [57] [124]. There are, however, some evidence-based interventions that speak to individual elements of the health risks associated with climate change. For example,

measures to deal with air pollution and wildfire smoke include wearing surgical masks and respirators during wildfire events, improving filtrating indoors, using particulate sensors, and limiting physical activities [57] [125] [126] [127].

Several methods have also been used to mitigate the impacts of heat waves, including cooling centers, which can decrease mortality during excessive heat [128]. For situations where cooling centers are not available locally, or when conditions such as power outages, civil unrest, or pandemics make them potentially unsafe, fans may be used to increase comfort during high heat. However, whether fans decrease mortality during heat waves is controversial [129]. A 2012 Cochrane review, which was published again as stable in 2017, concluded that there was insufficient research to answer this question [130]. Some public health authorities have recommended against their use [131]. It has been suggested that at air temperatures over 35 degrees Celsius (95F), the convective heat gain from fanning may outweigh the evaporative heat loss [132]. If the temperature/humidity matrix indicates that fans may not lower body heat [133] [134], misting or sponging water can be combined with fans to increase cooling [135]. In a study of elderly population, the use of water-soaked T-shirts was observed to be more effective than fans as a method to reduce body temperature during high heat [132].

Regarding vector borne diseases, effective approaches to prevention include both vector control by environmental management and personal protection/prevention strategies [136]. For example, malaria is a parasitic infection transmitted by mosquitoes that are active at night and breed in water bodies. Evidence-based interventions to combat malaria in endemic regions thus include draining of water sources where mosquitoes breed, using insecticide-treated mosquitos nets indoors, and providing preventive treatment to pregnant people and infants [137]. Though vaccines are effective measures for infectious diseases, emerging vector-borne diseases such as Zika, West Nile, and Chikungunya diseases do not have available vaccines [138]. Thus, it is recommended, based on expert opinion only, that pregnant people should avoid traveling to Zika outbreak areas and undergo fetal ultrasound and viral testing if returned from traveling to these areas [138]. Personal protections, including wearing long-sleeved shirts and long trousers and checking one’s body regularly for ticks, are also recommended for those travelling to or living in at-risk areas for vector-borne diseases [77]. The use of pesticides indoors should be avoided around pregnant people when possible due to their well-studied impacts on neurodevelopment, childhood cancer, and other important health outcomes [139].

In addition to advice regarding mitigation of health impacts, clinicians can also serve as educators regarding health hazards. A recent randomly controlled trial investigated the use of a story-telling comic book in comparison to a didactic brochure in educating pregnant people on climate change; the narrative format was found to be more effective in improving knowledge as well as increasing information-seeking and risk-reducing behaviors [140]. Many pregnant people receive some or all of their pregnancy care and education from midwives, doulas, and community health workers. These providers, as well as pregnant people, their families, and communities, should be informed about climate-related issues. Group prenatal care programs that foster relationship-building and health knowledge have

shown some success in reducing some pregnancy complications [141]. These programs may mediate some disaster-related pregnancy risks [142].

Advice to patients and communities

When counseling patients on mitigating risks of exposure to climate disasters, air pollution, and heat, consider the following:

1. **Assess what risks are important where you live**: air pollution (including pollution in urban areas, near roadways, from industrial facilities, wildfires, etc.), high heat (even unusually hot days in temperate climates can have health effects), flooding (from heavy rain, hurricanes, or sea level rise), other severe weather including tornadoes or blizzards (see figure 3).

2. **Access local resources** to get advice on planning ahead (e.g., https://www.readyforwildfire.org/, https://www.ready.gov/hurricanes, https://www.redcross.org/get-help/how-to-prepare-for-emergencies.html, https://wspehsu.ucsf.edu/main-resources/). The CDC provides resources specific to pregnant and breastfeeding people regarding preparing for disasters (https://www.cdc.gov/reproductivehealth/emergency/safety-messages.htm?CDC_AA_refVal=https://www.cdc.gov/reproductivehealth/emergency/wildfires.htm).

3. Prepare an **"emergency go-bag**," which might be the same bag packed in anticipation of going to the hospital for birth or a separate emergency kit. Items to include a battery-powered radio, medications, maps, hand sanitizer, masks. See https://www.ready.gov/kit for more information.

4. Pregnant people should be **educated about symptoms** of preterm labor and hypertensive disorders of pregnancy, include abdominal pain or contractions, bleeding or leaking of fluid vaginally, headache, visual changes, and decreased fetal movement, during the latter portion of their pregnancy,

5. **For vector-borne disease:** If you live in an area that now has the mosquitos that carry Zika or other viruses that can harm pregnancy (https://wwwnc.cdc.gov/travel/page/zika-information) [114], be sure to follow the CDC's advice to avoid insect bites, including wearing bug spray. (https://www.cdc.gov/pregnancy/zika/pregnancy.html)

6. Strategies to **increase mental health resilience** can help with recovery from disasters. Group prenatal care programs can foster relationship-building and health knowledge. The American Psychological Association has published tips to support individuals' climate resilience [143], including:

    - Build belief in one's own resilience.
    - Foster optimism.
    - Boost personal preparedness.
    - Cultivate active coping and self-regulation skills.

- Maintain practices that help to provide a sense of meaning.
- Promote connectedness to family, place, culture, and community.
- Care for oneself through healthy habits.

7. For air pollution:

- Avoid outdoor activities on high pollution days and monitor the Air Quality Index in your area. (https://fire.airnow.gov/).
- Wear an N95 mask if you must be outdoors when the air quality is poor.
- Close your windows on high pollution days.
- Consider investing in an air purifier or home air filter if you live in an area with air pollution or wildfire risk. Alternatively, a low cost DIY air cleaner can be made following instructions here: https://www.epa.gov/system/files/documents/2021-09/diy-air-purifier-infographic_final.pdf/.
- When exercising, avoid being within 300 meters of high-traffic areas.
- Keep the indoor air as clean as possible:
  - Avoid smoking and vaping
  - Avoid using gas, propane, or wood-burning stoves, fireplaces, or candles.
  - Avoid ozone-generating air cleaners.
  - Avoid natural gas or gasoline-powered generators indoors.
  - Avoid using unnecessary chemical products.
  - Avoid frying or broiling meat
  - Avoid vacuuming (unless vacuum has a HEPA filter).

8. For wildfires (recommend air pollution steps in addition):

- Wildfire evacuation checklist: https://ucanr.edu/sites/fire/files/294649.pdf
- Wildfire smoke and pregnancy advice from the CDC: https://www.cdc.gov/air/wildfire-smoke/pregnancy.htm
- Consider steps to harden the home against wildfires

9. For high heat and heat waves:

- Educate your patients on signs and symptoms of dehydration.
- During extreme heat, limit outdoor activities to cooler times of day (morning or evening).
- Avoid being in the sun for long periods and seek shade, take breaks, and drink water regularly.

- Access air conditioning, if possible, to reduce risk for heatstroke or heat-related mortality. Many communities open cooling shelters on very hot days.
- Fans should vent warmer air outdoors or bring cooler air into a room. Keep in mind: Electric fans may provide comfort, but when the temperature is in the high 90s, they will not prevent heat-related illness. Taking a cool shower or bath or moving to an air-conditioned place is a much better way to cool off. https://www.cdc.gov/disasters/extremeheat/heattips.html
- Check Current Temperature Probability Outlook or Current Heat Index Outlook at https://www.heat.gov/ to assess risk of extreme heat in your area. This new National Integrated Heat Health Information System site has many useful resources for education, planning and heatwave prediction.

10. For tornadoes:

- Pregnant people living in regions potentially impacted by tornadoes should prepare ahead of time with an emergency go-bag located in a safe area of the house or easily accessible.
- Safer areas include the basement or a windowless room in the center of the house.
- For added protection get under something sturdy (a heavy table or workbench).
- Cover your body with a blanket, sleeping bag or mattress. Protect your head with anything available.
- Do not stay in a mobile home. If you are outside or in a mobile home, find a nearby building preferably with a basement. If you are in a car, do not try to outrun a tornado but instead find the nearest sturdy building.
- During storms, use a battery-operated radio to listen to weather updates and instructions from local officials.
- Be aware of tornado warning signs, including dark or greenish skies; large, dark, low-lying clouds; a loud roar; large hail; or a visible, rotating funnel.
- Emergency preparedness information from the CDC (https://www.cdc.gov/nceh/features/tornadosafety/index.html) and the American Public Health association (http://www.getreadyforflu.org/Resources/Fact-Sheets/Family-Tornadoes) provides more recommendations.

11. For floods:

Before pregnant people and their families return to an area impacted by flooding or other disasters, the following utilities and public services should be functional:

- The water supply is re-established, and water for drinking and bathing must meet applicable existing standards for biological, chemical, and mineral contaminants.
- The supply of electricity and gas is restored and damage to the transmission system or gas pipes is repaired.
- A reliable food supply is re-established, and appropriate food storage is available.
- The sanitation system (including sewage) is functional, and debris and regular trash collection is re-established.
- The communication system including 911 access is restored, reliable, and readily accessible.
- Healthcare services, including mental health services, are available and accessible.
- Families returning know the location and status of their nearest hospital that provides obstetrical care, and the route to reach it is open and passable.
- Emergency services are functional.
- Medications and medical supplies are readily accessible.
- Buildings are appraised for damage and, if damaged, a decision has been made to either destroy, rebuild, or repair.
- If renovating, all flood hazards are addressed by properly trained experts. Pregnant people should avoid entering areas that have not been cleaned and made safe. The CDC has guidance for returning to a home impacted by mold here: https://www.cdc.gov/disasters/mold/index.html

Conclusions

Climate change can lead to adverse health outcomes due to heat, air pollution from wildfires, and stress from natural disasters. Pregnant individuals are especially vulnerable to these health harms resulting from climate change, with elevated risks of preterm birth, small for gestational age, hypertensive disorders of pregnancy, and other adverse reproductive health and birth outcomes. Obstetrician-gynecologists and other prenatal care providers are in a unique position to protect the health of pregnant persons and children by advocating for policy changes that address climate change and providing clinical recommendations for patients to protect themselves from the health impacts of climate hazards.

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Learning objectives

After participating in this activity, physicians should be better able to

1. Describe the adverse health effects and pregnancy outcomes associated with elements of climate change.
2. Identify strategies for patients to minimize the health harms from climate change, including mitigation, adaptations, and building resilience.

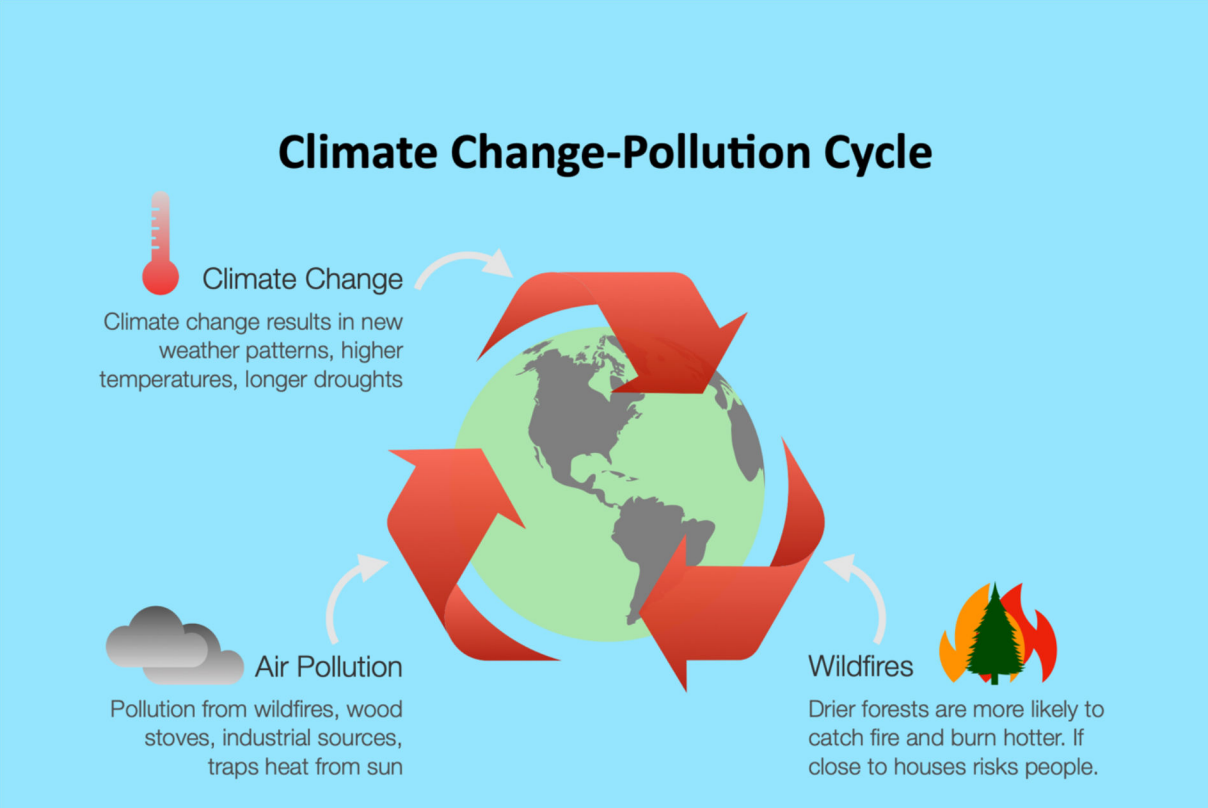

Figure 1:
Climate Change-Air Pollution Cycle. Air pollution increases the trapping of heat from the sun, worsening climate change through a vicious cycle.

Figure 2:

Pregnancy and Climate Change: OBGYN clinicians can act by advocating for healthsparing policies. (Adapted with permission from Kiana Nguyen, Annemarie Charlesworth, Marya Zlatnik, Tracey J. Woodruff, UCSF Program on Reproductive Health and the Environment & EaRTH Center, Genon K. Jensen, Vlatka Matkovic Puljic, Health and Environment Alliance (HEAL), and Patricia D. Koman)

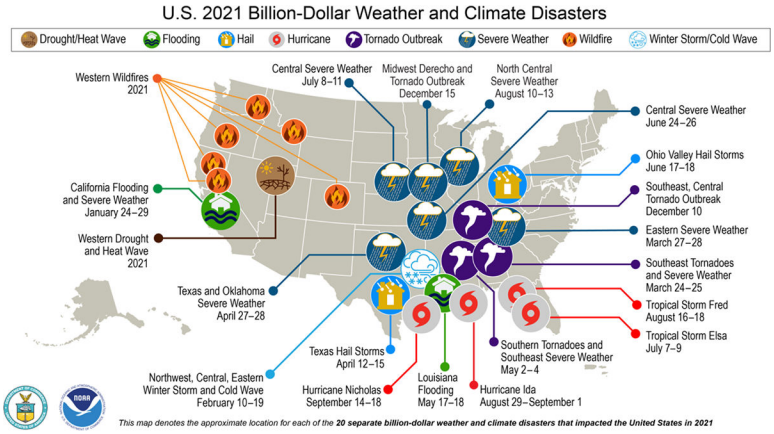

Figure 3:

U.S. 2021 Billion-Dollar Weather and Climate Disasters. Climate-change-related disasters are occurring throughout the United States. Smith, Adam: 2021 U.S. billion-dollar weather and climate disasters in historical context, Climate.gov Technical Report. 2022. Available at: https://www.climate.gov/news-features/blogs/beyond-data/2021-us-billion-dollar-weatherand-climate-disasters-historical, Accessed 1 June 2022.