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Heat Stress and Heat Waves

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According to WGI, it is *very likely* that the number and intensity of hot days have increased markedly in the last three decades and *virtually certain* that this increase will continue into the late 21st century. In addition, it is *likely* (*medium confidence*) that the occurrence of heat waves (multiple days of hot weather in a row) has more than doubled in some locations, but *very likely* that there will be more frequent heat waves over most land areas after mid-century. Under a medium warming scenario, Coumou et al. (2013) predicted that the number of monthly heat records will be more than 12 times more common by the 2040s compared to a non-warming world. In a longer time perspective, if the global mean temperature increases to +7°C or more, the habitability of parts of the tropics and mid-latitudes will be at risk (Sherwood and Huber, 2010). Heat waves affect natural and human systems directly, often with severe losses of lives and assets as a result, and may act as triggers of tipping points (Hughes et al., 2013). Consequently, heat stress plays an important role in several key risks noted in Chapter 19 and CC-KR.

Economy and Society (Chapters 10, 11, 12, 13)

Environmental heat stress has already reduced the global labor capacity to 90% in peak months with a further predicted reduction to 80% in peak months by 2050. Under a high warming scenario (RCP8.5), labor capacity is expected to be less than 40% of present-day conditions in peak months by 2200 (Dunne et al., 2013). Adaptation costs for securing cooling capacities and emergency shelters during heat waves will be substantial.

Heat waves are associated with social predicaments such as increasing violence (Anderson, 2012) as well as overall health and psychological distress and low life satisfaction (Tawatsupa et al., 2012). Impacts are highly differential with disproportional burdens on poor people, elderly people, and those who are marginalized (Wilhelmi et al., 2012). Urban areas are expected to suffer more due to the combined effect of climate and the urban heat island effect (Fischer et al., 2012; see also Section 8.2.3.1). In low- and medium-income countries, adaptation to heat stress is severely restricted for most people in poverty and particularly those who are dependent on working outdoors in agriculture, fisheries, and construction. In small-scale agriculture, women and children are particularly at risk due to the gendered division of labor (Croppenstedt et al., 2013). The expected increase in wildfires as a result of heat waves (Pechony and Shindell, 2010) is a concern for human security, health, and ecosystems. Air pollution from wildfires already causes an estimated 339,000 premature deaths per year worldwide (Johnston et al., 2012).

Human Health (Chapter 11)

Morbidity and mortality due to heat stress is now common all over the world (Barriopedro et al., 2011; Nitschke et al., 2011; Rahmstorf and Coumou, 2011; Diboulo et al., 2012; Hansen et al., 2012). Elderly people and people with circulatory and respiratory diseases are also vulnerable even in developed countries; they can become victims even inside their own houses (Honda et al., 2011). People in physical work are at particular risk as such work produces substantial heat within the body, which cannot be released if the outside temperature and humidity is above certain limits (Kjellstrom et al., 2009). The risk of non-melanoma skin cancer from exposure to UV radiation during summer months increases with temperature (van der Leun, et al., 2008). High temperatures are also associated with an increase in air-borne allergens acting as triggers for respiratory illnesses such as asthma, allergic rhinitis, conjunctivitis, and dermatitis (Beggs, 2010).

Ecosystems (Chapters 4, 5, 6, 30)

Tree mortality is increasing globally (Williams et al., 2013) and can be linked to climate impacts, especially heat and drought (Reichstein et al., 2013), even though attribution to climate change is difficult owing to lack of time series and confounding factors. In the Mediterranean region, higher fire risk, longer fire season, and more frequent large, severe fires are expected as a result of increasing heat waves in combination with drought (Duguy et al., 2013; see also Box 4.2).

Marine ecosystem shifts attributed to climate change are often caused by temperature extremes rather than changes in the average (Pörtner and Knust, 2007). During heat exposure near biogeographical limits, even small (<0.5°C) shifts in temperature extremes can have large effects, often exacerbated by concomitant exposures to hypoxia and/or elevated CO_2 levels and associated acidification (*medium confidence*; Hoegh-Guldberg et al., 2007; see also Figure 6-5; Sections 6.3.1, 6.3.5, 30.4, 30.5; CC-MB).

Most coral reefs have experienced heat stress sufficient to cause frequent mass coral bleaching events in the last 30 years, sometimes followed by mass mortality (Baker et al., 2008). The interaction of acidification and warming exacerbates coral bleaching and mortality (*very high confidence*).Temperate seagrass and kelp ecosystems will decline with the increased frequency of heat waves and through the impact of invasive subtropical species (*high confidence*; Sections 5, 6, 30.4, 30.5, CC-CR, CC-MB).

Agriculture (Chapter 7)

Excessive heat interacts with key physiological processes in crops. Negative yield impacts for all crops past +3°C of local warming without adaptation, even with benefits of higher CO_2 and rainfall, are expected even in cool environments (Teixeira et al., 2013). For tropical systems where moisture availability or extreme heat limits the length of the growing season, there is a high potential for a decline in the length of the growing season and suitability for crops (*medium evidence*, *medium agreement*; Jones and Thornton, 2009). For example, half of the wheat-growing area of the Indo-Gangetic Plains could become significantly heat-stressed by the 2050s.

There is *high confidence* that high temperatures reduce animal feeding and growth rates (Thornton et al., 2009). Heat stress reduces reproductive rates of livestock (Hansen, 2009), weakens their overall performance (Henry et al., 2012), and may cause mass mortality of animals in feedlots during heat waves (Polley et al., 2013). In the USA, current economic losses due to heat stress of livestock are estimated at several billion US$ annually (St-Pierre et al., 2003).

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