CLIMATE EXTREMES

The worst heat waves to come

The combination of high temperatures and humidity could, within just a century, result in extreme conditions around the Persian Gulf that are intolerable to humans, if climate change continues unabated.

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Recent work has established that there is a robust upper limit to the human body's ability to adapt to heat and humidity stress[1]. If people are exposed to the combination of temperature and humidity above this level over extended periods, hyperthermia and ultimately death will result, because dissipation of heat from the body becomes physically impossible. Using global climate models, Sherwood and Huber[1] had estimated that this limit will become important in the distant future, if a 7 °C increase in the global mean temperature is reached. Now, writing in *Nature Climate Change*, Pal and Eltahir[2] use a high-resolution regional climate model to provide evidence that such conditions could occur much earlier. The study pinpoints the Persian Gulf (also known as the Arabian Gulf, referred to here as the Gulf) as a region where heat waves are likely to exceed this critical threshold in the course of the current century, assuming that climate change proceeds unabated and reaches a global temperature increase of around 4 °C.

The consequences of major heat waves for human health has become apparent from the death toll of recent events such as those in Chicago in 1995, Europe in 2003 and Russia in 2010[3–5]. During these heat waves, mostly elderly and ill individuals were at risk, as well as people who did not take appropriate precautions. The focus of the Pal and Eltahir[2] study concerns another category of heat waves — one that may be fatal to everybody affected, even young and fit individuals under shaded and well-ventilated outdoor conditions.

Our bodies cool by ventilation (exchange of heat) and sweating (evaporation of water). However, these processes have physical limits that are expressed by the concept of wet-bulb temperature (*TW*), which represents the temperature to which an object may be cooled by ventilation and evaporation. If *TW* approaches or exceeds body temperature (i.e. *TW* > 35 °C), then the body's natural cooling system is disabled and people exposed to such conditions, in the absence of external cooling aids (such as air conditioning), are at high risk.

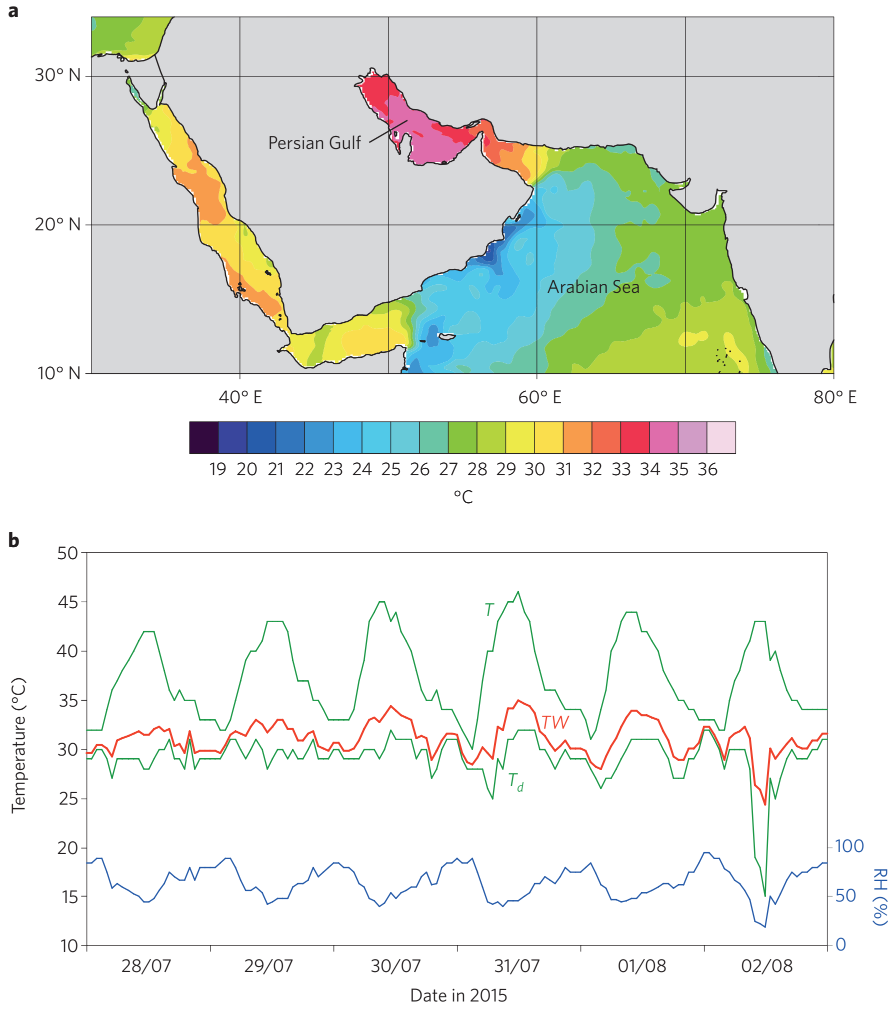

Figure 1 | The heat wave of July 2015 in the Persian Gulf. **a**, Sea surface temperature in the Arabian Sea and the Gulf on 31 July 2015. Note the high temperatures in the Gulf. **b**, Temperature and humidity conditions at the airport of Bandar Mahshahr, Iran, from 28 July to 2 August 2015. The curves show temperature (*T*) and dewpoint temperature (T_d) (both in green), relative humidity (RH, blue) and wet-bulb temperature (*TW*, red). Note how *TW* peaks above 34 °C on 31 July.

The study of Pal and Eltahir shows that these dangerous heat waves may occur in the course of this century in the vicinity of the Arabian Peninsula. They employ an ensemble of regional climate model simulations at 25 km horizontal resolution and consider control (1976–2005) and scenario (2071–2100) conditions using two greenhouse gas emission scenarios (RCP8.5 and RCP4.5) that represent business-as-usual and mitigation pathways.

Although *TW* = 35 °C is never reached under current climatic conditions in their simulations, it is projected to be reached several times in the business-as-usual 30-year scenario period in Bandar Mahshahr and Bandar Abbas (Iran), Dhahran (Saudia Arabia), Doha (Qatar), Dubai and Abu Dhabi (United Arab Emirates), and probably in additional locations along the Gulf that have not been specifically investigated. Furthermore, temperatures are projected to reach unacceptable levels; for instance, in some years of the scenario period $T = 60$ °C will be exceeded in Kuwait City. The rise in temperature and humidity would thus be likely to constrain development along the shores of the Gulf. The study also shows that global mitigation efforts consistent with the RCP4.5 scenario would be of significant benefit in the Gulf region.

Why is this effect so severe around the Gulf (and to some lesser extent the Red Sea)? This region is well known for its extremely warm sea surface. These conditions owe their existence to the shallow depth of the Gulf, which implies that in response to the seasonal cycle it warms much more than the Arabian Sea (Fig.1a). There is also evidence of a significant warming of the Gulf during the past 60 years[6], which was most pronounced in the period 1990–2010 with a trend of a 0.47 °C increase per decade. Again, this warming was significantly larger in the Gulf than in the Arabian Sea.

Although the control simulations credibly represent the current climate, and the authors provide a process-based interpretation of their results, there are some significant uncertainties. In particular, the employed modelling framework uses high computational resolution (25 km) in the atmosphere, but future oceanic conditions are taken from lower-resolution global climate models. This simplification may be justified due to the shallow depth of the Gulf, but the results will require corroboration using fully coupled atmosphere–ocean models[7].

There is also support for the study from recent observations. Moist heat waves are characteristic for the climatology of the Gulf region, such as the dramatic event that occurred towards the end of July 2015. In terms of *TW*, it was one of the worst heat waves ever recorded. Over much of the Gulf, sea surface temperatures were above 34 °C (Fig. 1a), and relative humidity was close to saturation. To the north of the Gulf, dry and hot desert conditions persisted, with diurnal temperature variations peaking at $T = 48–51$ °C in Basrah (Iraq) and Omidiyeh (Iran). The worst of the heat wave, however, developed in between the hot and dry conditions over land, and the warm and moist conditions over the Gulf, when humid air was advected towards land with southeasterly winds. Figure 1b shows surface data from Bandar Mahshahr (Iran), about 30 km inland. For a whole week, maximum daytime temperatures rose above $T = 40$ °C and night temperatures stayed above 30 °C. The worst, however, was the combination of heat and humidity. The heat wave peaked on 31 July around 12:00 UT (16:30 IRDT) with temperatures of $T = 46$ °C and a relative humidity of 49%. These conditions correspond to a wet-bulb temperature of 34.6 °C (red curve in Fig.1b), only slightly below the critical *TW* threshold.

The occurrence of such an event lends support to the results of Pal and Eltahir[2]. If *TW* can rise to above 34 °C in the current climate, it is credible that it will sometimes rise above 35 °C within this century, as regional warming is projected to amount to 2–3 °C with the RCP8.5 scenario[8]. The new study thus shows that the threats to human health may be much more severe than previously thought, and may occur in the current century. The study also indicates that mitigation measures (reducing global greenhouse gas emissions) and adaptation efforts (protecting against heat waves) are essential for the inhabitants of the Gulf and Red Sea regions. ❐

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Acknowledgements

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