Reduced Heat Exposure by Limiting Global Warming to 1.5°C

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The benefits of limiting global warming to the lower Paris Agreement target of 1.5°C are substantial with respect to population exposure to heat, and should impel countries to strive towards greater emissions reductions.

Since the Paris Agreement was reached in December 2015 there has been a drive in the scientific community to understand the impacts of global warming at the target levels of 1.5°C and 2°C¹⁻³. A Special Report on the pathways to limiting global warming to 1.5°C, and associated implications of this target, is being prepared by the Intergovernmental Panel on Climate Change (IPCC).

Research to date has focussed on changes in different types of climate extremes globally^{1,3} or regionally^{2,4}, developing and utilising model experiments to infer differences between the two warming targets⁵, or the emissions and warming trajectories associated with meeting or breaching the 1.5°C target^{6,7}. Here we approach the question of how different a 1.5°C world and a 2°C world are through the lens of human population exposure to historically unprecedented heat extremes, warmer than those observed since 1950, in Europe. We show that the population levels exposed to hot summers above the current record increase dramatically from 1.5°C to 2°C. In the past, record summer heat in Europe has been associated with severe heatwaves resulting in thousands of excess deaths⁸, albeit with high variability in impacts between events, in part due to non-climatic factors. Nonetheless, global warming must be limited to reduce human exposure to historically unprecedented heat.

Warming summers

24 People tend to remember record hot summers⁹, and such extremes are well-observed over a
25 long period in Europe especially, so they provide a useful benchmark for investigating future
26 climate extremes. The warmest observed summers (June-August) in Europe from 1950-2017
27 are associated with average temperatures below 15°C in parts of Scandinavia, Scotland and
28 the Alps, rising to temperatures exceeding 25°C around much of the Mediterranean (Figure
29 1a). Since populations and ecosystems are well-acclimatised to temperature variability in
30 their home locations, summer temperatures exceeding these observed records could have dire
31 consequences even where they may be relatively low in northern Europe compared to Spain
32 and Italy, for example¹⁰.

33 Over the majority of Europe, the hottest summers on record (since 1950) occurred after 2000
34 (Figure 1b) with the summers of 2003 and 2006 being the hottest over much of western
35 Europe^{11,12} while 2010 was the hottest further east. However, there are exceptions, for
36 example, in Central England the hottest summer remains 1976. All the aforementioned
37 summers were associated with shorter spells of record-breaking extreme temperatures and
38 major impacts, such as excess heat-related deaths in western Europe in 2003⁸, wildfires in
39 Russia in 2010, and severe drought in England in 1976.

40 In future 1.5°C and 2°C worlds, represented in bias-adjusted model projections, we find an
41 increase in the likelihood of historically unprecedented hot summers (hereafter used to refer
42 to summer-average temperatures exceeding the observed record summer during 1950-2017 at
43 each location). The probability of a hot summer exceeding the current record is higher across
44 Europe in a 2°C world than in a 1.5°C world, and at least doubles in parts of southern and
45 eastern Europe (Figure 2a). This illustrates the benefit of limited global warming through
46 reduced heat extremes^{4,13}.

47 **Increasing population exposure to summer heat**

48 In each year within each world (“natural”, “current”, “1.5°C” and “2°C”)^{2,4} we aggregate the
49 population (based on 2010 estimates; see Supplementary Information S4) experiencing
50 extreme high summer-average temperature anomalies, temperatures that are unprecedented in
51 the observed record. Figure 2b shows probability distributions of aggregated population totals
52 in Europe exposed to these hot summers in each world. In the current climate most summers
53 see a small proportion of Europe’s overall population exposed to temperatures above the
54 observed record with a median estimate of 45 million (in recent observations, 2003 was an
55 exceptional year when larger numbers of people experienced a new record). The population
56 exposed to summer heat rises for the simulated Paris Agreement target worlds. On average, in
57 the simulated 1.5°C world, 90 million people (or 11% of the estimated 2010 population of the
58 continent) are exposed to hot summers beyond the observed record (i.e. half of summers
59 would have more than 90 million people exposed to historically unprecedented summer-
60 average temperatures). In the simulated 2°C world, on average there are 163 million
61 Europeans (or 20% of the continent’s population) experiencing summer temperatures
62 exceeding the observed 1950-2017 record. That is equivalent to more than ten times the
63 metropolitan population of Western Europe’s largest city, London, and is about twice the
64 population of Germany.

65 Population exposure to historically unprecedented summer heat increases dramatically even
66 at the relatively low global warming levels of the Paris Agreement (Figure 2c). For example,
67 the chance of having a summer with such widespread heat that at least 400 million people (or
68 almost 50% of the continental population) experience a summer temperature exceeding the
69 historical record is negligible in the current climate. In contrast, in the modelled 1.5°C world
70 such an event would occur on average in one-in-18 years (Figure 2c) and in the 2°C world
71 simulations the likelihood rises such that a high exposure event would occur on average once
72 every seven years (Figure 2c). We have already raised the odds in favour of hotter summers

73 and increased population exposure to summer heat, and even under low global warming
74 scenarios associated with the Paris Agreement this effect is exacerbated.

75 **An incentive to strive for a low global warming scenario**

76 As the Earth warms populations will have to cope with more frequent and intense heat
77 extremes^{1,3}. We show that for the densely-populated region of Europe which has previously
78 experienced devastating impacts of severe heat, particularly in 2003^{8,14} and 2010¹¹, there is a
79 substantial benefit, with respect to reduced heat exposure, to limiting global warming to the
80 1.5°C Paris target. This benefit is perceptible even when compared with a 2°C world, let
81 alone higher levels of global warming. This benefit is also likely to extend to other regions of
82 the world¹⁵, although we chose to focus only on the European continent (see Supplementary
83 Information S1, S10 for further discussion).

84 Prior to the Paris Agreement more focus had been placed on 2°C and higher levels of global
85 warming. Only since the end of 2015 has there been a shift in focus in the scientific
86 community towards investigating the implications of lower levels of global warming. While
87 it is recognised that it will be very difficult to meet the aspirational 1.5°C Paris target, the
88 benefits from doing so would be very large with respect to limiting the frequency and
89 intensity of hot extremes and the consequences of these events. This may act as additional
90 motivation for the world to aim for the 1.5°C Paris target and develop an emissions pathway
91 and associated technologies that will increase the likelihood of achieving the target.

92 European countries are among the most ambitious in the world in tackling climate change
93 through with strong intended reductions in greenhouse gas emissions. Here we illustrate that
94 this need not be a selfless act; the countries and peoples of Europe, especially the
95 Mediterranean region which has suffered in recent hot summers, would benefit from a future
96 of relatively fewer hot summers with limited global warming.

97 Regardless of the emissions path the world takes over the next few years, global warming
98 will continue, and heat extremes and associated population exposure will increase. In addition
99 to efforts to limit global warming, strategies to adapt to hotter summers, outside of the
100 observed range we have experienced to date, will be needed to reduce heat-health impacts.

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163 **Author contributions**

A.D.K. had the idea for the study. A.D.K. and M.G.D. developed the methodology. A.D.K. performed the analysis and led the writing of the paper. All authors contributed to the writing of the paper.

Additional information

Supplementary information is available in the online version of the paper.

Figure 1: Across most of Europe the warmest summers occurred in 2003, 2006 or 2010.

Maps showing a) the highest average summer temperatures and b) the decade in which the warmest summer occurred. (See Supplementary Information S1, S2 for details.)

Figure 2: There is a much greater likelihood of, and population exposure to, historically

unprecedented warm summers at 2°C of global warming than 1.5°C. a) best estimate ratio of hot summers exceeding the observed record between a 2°C world and a 1.5°C world. b) the probability of European population numbers exposed to historically unprecedented hot summers for a given year in the current world, a 1.5°C world and a 2°C world. c) likelihoods of population exposure to historically unprecedented hot summers exceeding different thresholds. Best estimates are shown in bold with 90% confidence intervals in parentheses. (See Supplementary Information S3-S5 for details.)

a) Historical record summer temperature

b) Decade of record summer temperature

a) Ratio of unprecedented hot summers (2°C vs. 1.5°C)

b) Population exposure to unprecedented hot summers

c) Chance of high population exposure event per year

POPULATION	NAT	CURRENT	1.5°C	2°C
> 100 million	11% (0-33%)	29% (16-47%)	47% (21-78%)	67% (46-98%)
> 200 million	6% (0-29%)	10% (1-21%)	25% (7-50%)	42% (19-83%)
> 300 million	0% (0-0%)	5% (0-12%)	13% (2-30%)	26% (8-62%)
> 400 million	0% (0-0%)	1% (0-2%)	6% (0-15%)	15% (3-39%)