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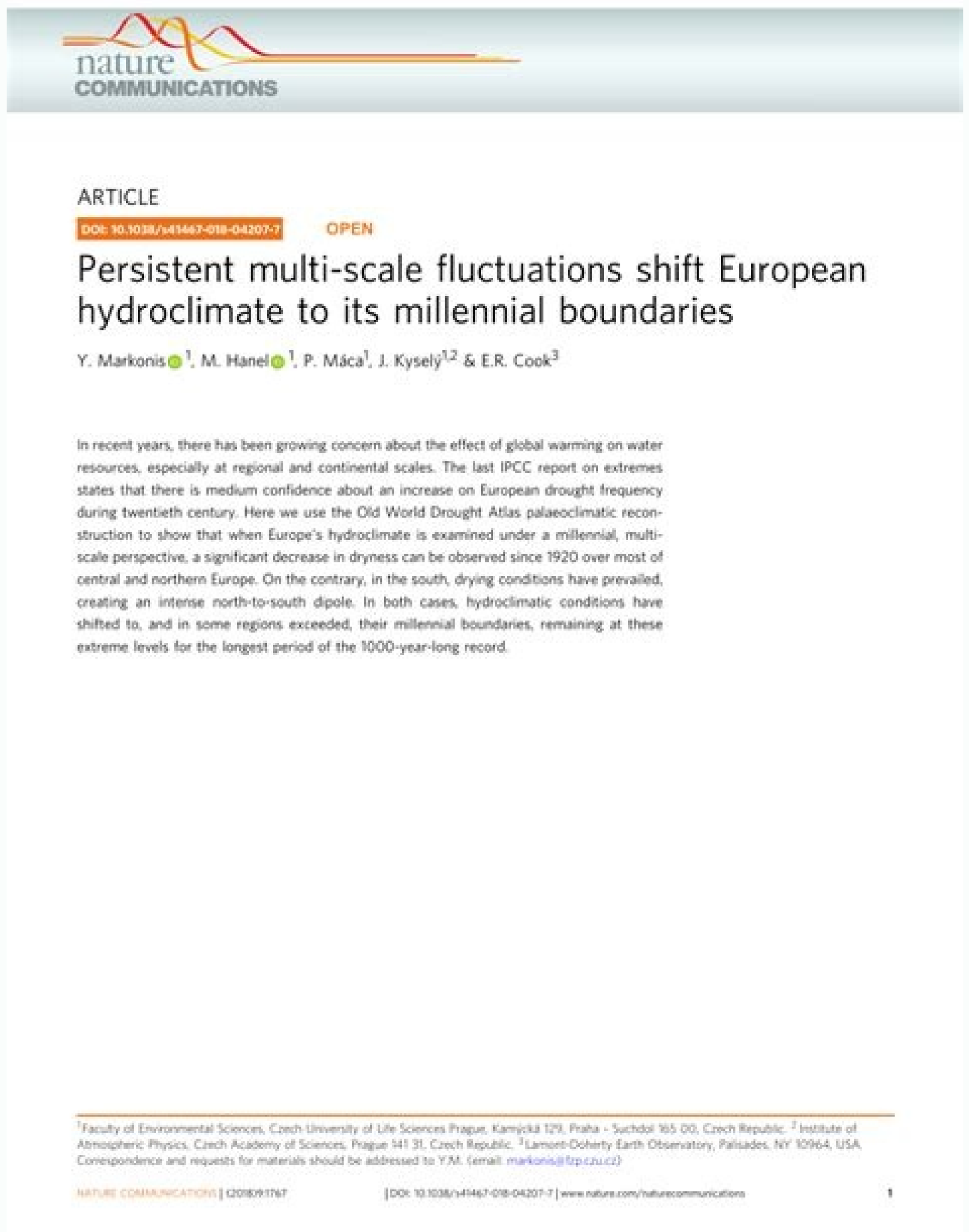

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Persistent multi-scale fluctuations shift European hydroclimate to its millennial boundaries

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In recent years, there has been growing concern about the effect of global warming on water resources, especially at regional and continental scales. The last IPCC report on extremes states that there is medium confidence about an increase on European drought frequency during twentieth century. Here we use the Old World Drought Atlas palaeoclimatic reconstruction to show that when Europe's hydroclimate is examined under a millennial, multi-scale perspective, a significant decrease in dryness can be observed since 1920 over most of central and northern Europe. On the contrary, in the south, drying conditions have prevailed, creating an intense north-to-south dipole. In both cases, hydroclimatic conditions have shifted to, and in some regions exceeded, their millennial boundaries, remaining at these extreme levels for the longest period of the 1000-year-long record.

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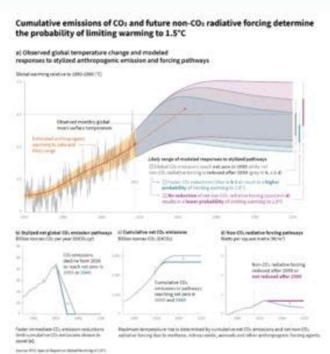

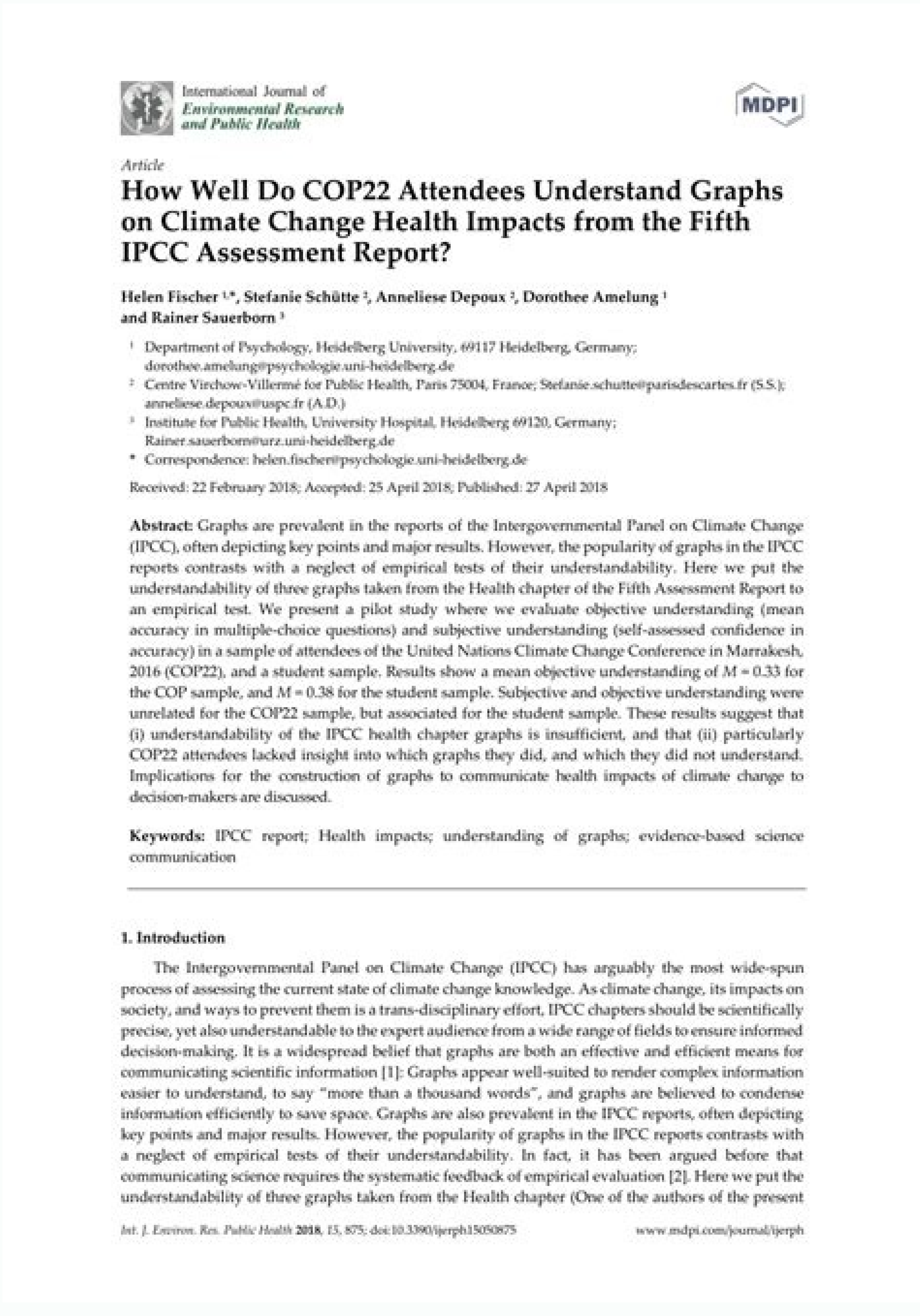

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Article

How Well Do COP22 Attendees Understand Graphs on Climate Change Health Impacts from the Fifth IPCC Assessment Report?

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Abstract: Graphs are prevalent in the reports of the Intergovernmental Panel on Climate Change (IPCC), often depicting key points and major results. However, the popularity of graphs in the IPCC reports contrasts with a neglect of empirical tests of their understandability. Here we put the understandability of three graphs taken from the Health chapter of the Fifth Assessment Report to an empirical test. We present a pilot study where we evaluate objective understanding (mean accuracy in multiple-choice questions) and subjective understanding (self-assessed confidence in accuracy) in a sample of attendees of the United Nations Climate Change Conference in Marrakesh, 2016 (COP22), and a student sample. Results show a mean objective understanding of $M = 0.33$ for the COP sample, and $M = 0.38$ for the student sample. Subjective and objective understanding were unrelated for the COP22 sample, but associated for the student sample. These results suggest that (i) understandability of the IPCC health chapter graphs is insufficient, and that (ii) particularly COP22 attendees lacked insight into which graphs they did, and which they did not understand. Implications for the construction of graphs to communicate health impacts of climate change to decision-makers are discussed.

Keywords: IPCC report; Health impacts; understanding of graphs; evidence-based science communication

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) has arguably the most wide-spun process of assessing the current state of climate change knowledge. As climate change, its impacts on society, and ways to prevent them is a trans-disciplinary effort, IPCC chapters should be scientifically precise, yet also understandable to the expert audience from a wide range of fields to ensure informed decision-making. It is a widespread belief that graphs are both an effective and efficient means for communicating scientific information [1]: Graphs appear well-suited to render complex information easier to understand, to say "more than a thousand words", and graphs are believed to condense information efficiently to save space. Graphs are also prevalent in the IPCC reports, often depicting key points and major results. However, the popularity of graphs in the IPCC reports contrasts with a neglect of empirical tests of their understandability. In fact, it has been argued before that communicating science requires the systematic feedback of empirical evaluation [2]. Here we put the understandability of three graphs taken from the Health chapter (One of the authors of the present

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{3.3.4, 3.3.5, 3.4.2} Risks of water scarcity are projected to be greater at 2°C than at 1.5°C of global warming in some regions (medium confidence). {3.3.10, 3.4.4} Larger risks are expected for many regions and systems for global warming at 1.5°C, as compared to today, with adaptation required now and up to 1.5°C. {3.4.4, Box 3.4} Water Resources The projected frequency and magnitude of floods and droughts in some regions are smaller under 1.5°C than under 2°C of warming (medium confidence). Migration in small islands (internally and internationally) occurs for multiple reasons and purposes, mostly for better livelihood opportunities (high confidence) and increasingly owing to sea level rise (medium confidence). {3.3.2, 3.4.3, 3.4.4} Ocean Ecosystems Ocean ecosystems are already experiencing large-scale changes, and critical thresholds are expected to be reached at 1.5°C and higher levels of global warming (high confidence). There are multiple lines of evidence that ocean warming and acidification corresponding to 1.5°C of global warming would impact a wide range of marine organisms and ecosystems, as well as sectors such as aquaculture and fisheries (high confidence). {3.4.5, 3.4.8} Poverty and disadvantage have increased with recent warming (about 1°C) and are expected to increase for many populations as average global temperatures increase from 1°C to 1.5°C and higher (medium confidence). Above 1.5°C, an expansion of desert terrain and vegetation would occur in the Mediterranean biome (medium confidence), causing changes unparalleled in the last 10,000 years (medium confidence). Urban heat islands often amplify the impacts of heatwaves in cities (high confidence). {3.5} In 'global aggregate impacts' (RFC4) a transition from moderate to high levels of risk is now located between 1.5°C and 2.5°C of global warming, as opposed to at 3.6°C of warming in AR5, owing to new evidence about global aggregate economic impacts and risks to Earth's biodiversity (medium confidence). This assessment is based on several lines of evidence, including attribution studies for changes in extremes since 1950. Outmigration in agricultural- dependent communities is positively and statistically significantly associated with global temperature (medium confidence). Heavy precipitation, when aggregated at a global scale, is projected to be higher at 2°C than at 1.5°C of global warming (medium confidence) {3.3.3, 3.3.6} Limiting global warming to 1.5°C is expected to substantially reduce the probability of extreme drought, precipitation deficits, and risks associated with water availability (i.e., water stress) in some regions (medium confidence). An intermediate temperature overshoot will have no long- term consequences for Arctic sea ice coverage, and hysteresis is not expected (high confidence). The increase in global mean surface temperature (GMST), which reached 0.87°C in 2006–2015 relative to 1850–1900, has increased the frequency and magnitude of impacts (high confidence), strengthening evidence of how an increase in GMST of 1.5°C or more could impact natural and human systems (1.5°C versus 2°C). Robust increases in temperature means and extremes are also projected at 1.5°C compared to present-day values (high confidence) {3.3.1, 3.3.2}. Long-term risks of coastal flooding and impacts on populations, infrastructures and assets (high confidence), freshwater stress (medium confidence), and risks across marine ecosystems (high confidence) and critical sectors (medium confidence) are projected to increase at 1.5°C compared to present-day levels and increase further at 2°C, limiting adaptation opportunities and increasing loss and damage (medium confidence). {3.5.2} The category 'Unique and threatened systems' (RFC1) display a transition from high to very high risk which is now located between 1.5°C and 2°C of global warming as opposed to at 2.6°C of global warming in AR5, owing to new and multiple lines of evidence for changing risks for coral reefs, the Arctic and biodiversity in general (high confidence). {3.3.6, 3.4.4.12, 3.4.9.1, Box 3.4} Small Islands, and Coastal and Low-lying areas Small islands are projected to experience multiple inter- related risks at 1.5°C of global warming that will increase with warming of 2°C and higher levels (high confidence). {3.3.9, 3.4.5, 3.6.3} The ocean has absorbed about 30% of the anthropogenic carbon dioxide, resulting in ocean acidification and changes to carbonate chemistry that are unprecedented for at least the last 65 million years (high confidence). There is also (high confidence) global warming has resulted in an increase in the frequency and duration of marine heatwaves. Overshooting poses large risks for natural and human systems, especially if the temperature at peak warming is high, because some risks may be long-lasting and irreversible, such as the loss of some ecosystems (high confidence). This difference is due to the smaller rates and magnitudes of climate change associated with a 1.5°C temperature increase, including lower frequencies and intensities of temperature-related extremes. Lower risks are projected at 1.5°C than at 2°C for heat-related morbidity and mortality (very high confidence), and for ozone-related mortality if emissions needed for ozone formation remain high (high confidence). The impacts on natural and human systems would be greater if mitigation pathways temporarily overshoot 1.5°C and return to 1.5°C later in the century, as compared to pathways that stabilize at 1.5°C without an overshoot (high confidence). {3.5} Finally, 'large-scale singular events' (RFC5), moderate risk is now located at 1°C of global warming and high risk is located at 2.5°C of global warming, as opposed to at 1.6°C (moderate risk) and around 4°C (high risk) in AR5, because of new observations and models of the West Antarctic ice sheet (medium confidence). Risks for natural and managed ecosystems are higher on drylands compared to humid lands. Regarding hot extremes, the strongest warming is expected to occur at mid-latitudes in the warm season (with increases of up to 3°C for 1.5°C of global warming, i.e., a factor of two) and at high latitudes in the cold season (with increases of up to 4.5°C at 1.5°C of global warming, i.e., a factor of three) (high confidence). Risks will be lower for tourism markets that are less climate sensitive, such as gaming and large hotel-based activities (high confidence). Risks of impacts and decreasing food security are projected to become greater as global warming reaches beyond 1.5°C and both ocean warming and acidification increase, with substantial losses likely for coastal livelihoods and industries (e.g., fisheries and aquaculture) (medium to high confidence). A loss of 7–10% of rangeland livestock globally is projected for approximately 2°C of warming, with considerable economic consequences for many communities and regions (medium confidence). Large, robust and widespread differences are expected for temperature extremes (high confidence). The number of exceptionally hot days are expected to increase the most in the tropics, where interannual temperature variability is lowest; extreme heatwaves are thus projected to emerge earliest in these regions, and they are expected to already become widespread there at 1.5°C global warming (high confidence). The regions with the largest increases in heavy precipitation events for 1.5°C to 2°C global warming include: several high-latitude regions (e.g. Alaska/western Canada, eastern Canada/ Greenland/Iceland, northern Europe and northern Asia); mountainous regions (e.g.,Tibetan Plateau); eastern Asia (including China and Japan); and eastern North America (medium confidence). {3.3.2.2, 3.3.6–9, 3.4.3.2, 3.4.4.2, 3.4.4.5, 3.4.4.12, 3.4.5.3, 3.4.7.1, 3.4.9.1, 3.5.4.9, Box 3.4, Box 3.5} Impacts associated with sea level rise and changes to the salinity of coastal groundwater, increased flooding and damage to infrastructure, are projected to be critically important in vulnerable environments, such as small islands, low-lying coasts and deltas, at global warming of 1.5°C and 2°C (high confidence). {3.3.3, 3.3.4, Box 3.1, Box 3.2} Risks to natural and human systems are expected to be lower at 1.5°C than at 2°C of global warming (high confidence). Countries in the tropics and Southern Hemisphere subtropics are projected to experience the largest impacts on economic growth due to climate change should global warming increase from 1.5°C to 2°C (medium confidence). Incorporating estimates of adaptation into projections reduces the magnitude of risks (high confidence). {Cross-Chapter Box 6 in this chapter} Fisheries and aquaculture are important to global food security but are already facing increasing risks from ocean warming and acidification (medium confidence). Lower risks of undernutrition are projected at 1.5°C than at 2°C (medium confidence). {3.5.2.1} In 'Extreme weather events' (RFC2), the transition from moderate to high risk is now located between 1.0°C and 1.5°C of global warming, which is very similar to the AR5 assessment but is projected with greater confidence (medium confidence). {Cross-Chapter Box 7 in this chapter} Large-scale deployment of BECCS and/or AR would have a far-reaching land and water footprint (high confidence). Chapter 3 explores observed impacts and projected risks to a range of natural and human systems, with a focus on how risk levels change from 1.5°C to 2°C of global warming. Climate models project robust differences in regional climate between present-day and global warming up to 1.5°C, and between 1.5°C and 2°C (high confidence), depending on the variable and region in question (high confidence). The strongest warming of hot extremes is projected to occur in central and eastern North America, central and southern Europe, the Mediterranean region (including southern Europe, northern Africa and the Near East), western and central Asia, and southern Africa (medium confidence). There are decreases in the occurrence of cold extremes, but substantial increases in their temperature, in particular in regions with snow or ice cover (high confidence) {3.3.1}. Whether this footprint would result in adverse impacts, for example on biodiversity or food production, depends on the existence and effectiveness of measures to conserve land carbon stocks, measures to limit agricultural expansion in order to protect natural ecosystems, and the potential to increase agricultural productivity (medium agreement). In particular, risks associated with increases in drought frequency and magnitude are projected to be substantially larger at 2°C than at 1.5°C in the Mediterranean region (including southern Europe, northern Africa and the Near East) and southern Africa (medium confidence). Model simulations suggest that at least one sea-ice-free Arctic summer is expected every 10 years for global warming of 2°C, with the frequency decreasing to one sea-ice-free Arctic summer every 100 years under 1.5°C (medium confidence). Changes include increases in both land and ocean temperatures, as well as more frequent heatwaves in most land regions (high confidence). Risks have been identified for the survival, calcification, growth, development and abundance of a broad range of marine taxonomic groups, ranging from algae to fish, with substantial evidence of predictable trait-based sensitivities (high confidence). Localized subsidence and changes to river discharge can potentially exacerbate these effects. Risks for some vector-borne diseases, such as malaria and dengue fever are projected to increase with warming from 1.5°C to 2°C, including potential shifts in their geographic range (high confidence). The size and duration of an overshoot would also affect future impacts (e.g., irreversible loss of some ecosystems) (high confidence). This suggests a transition from medium to high risk of regionally differentiated impacts on food security between 1.5°C and 2°C (medium confidence). In the transition to 1.5°C of warming, changes to water temperatures are expected to drive some species (e.g., plankton, fish) to relocate to higher latitudes and cause novel ecosystems to assemble (high confidence). {3.3.1, 3.4.5.3, 3.4.5.6, 3.4.11, 3.5.4.9, Box 3.5} Global warming of 2°C would lead to an expansion of areas with significant increases in runoff, as well as those affected by flood hazard, compared to conditions at 1.5°C (medium confidence). For example, multiple lines of evidence indicate that the majority (70–90%) of warm water (tropical) coral reefs that exist today will disappear even if global warming is constrained to 1.5°C (very high confidence). Limiting global warming to 1.5°C instead of 2°C could result in around 420 million fewer people being frequently exposed to extreme heatwaves, and about 65 million fewer people being exposed to exceptional heatwaves, assuming constant vulnerability (medium confidence). {3.4.5.3, 3.4.5.4, 3.4.5.7, 5.4.5.4, Box 3.5} Existing and restored natural coastal ecosystems may be effective in reducing the adverse impacts of rising sea levels and intensifying storms by protecting coastal and deltaic regions (medium confidence). {3.5.2, 3.5.3} The largest reductions in economic growth at 2°C compared to 1.5°C of warming are projected for low- and middle-income countries and regions (the African continent, Southeast Asia, India, Brazil and Mexico) (low to medium confidence). Projected GMSLR for 1.5°C of global warming has an indicative range of 0.26 – 0.77m, relative to 1986–2005, (medium confidence). Human exposure to increased flooding is projected to be substantially lower at 1.5°C compared to 2°C of global warming, although projected changes create regionally differentiated risks (medium confidence). Further, there is substantial evidence that human-induced global warming has led to an increase in the frequency, intensity and/or amount of heavy precipitation events at the global scale (medium confidence), as well as an increased risk of drought in the Mediterranean region (medium confidence). {3.4.4, Box 3.4} Current ecosystem services from the ocean are expected to be reduced at 1.5°C of global warming, with losses being even greater at 2°C of global warming (high confidence). {3.2, 3.3.1, 3.3.2, 3.3.3, 3.3.4} Several regional changes in climate are assessed to occur with global warming up to 1.5°C as compared to pre-industrial levels, including warming of extreme temperatures in many regions (high confidence), increases in frequency, intensity and/or amount of heavy precipitation in several regions (high confidence), and an increase in intensity or frequency of droughts in some regions (medium confidence). Heavy precipitation associated with tropical cyclones is projected to be higher at 2°C compared to 1.5°C of global warming (medium confidence). {3.4.7, 3.4.7.1, 3.4.8, 3.5.5.8} Global warming of 2°C is expected to pose greater risks to urban areas than global warming of 1.5°C (medium confidence). Temperature means and extremes are also projected to be higher at 2°C compared to 1.5°C in most land regions, with increases being 2–3 times greater than the increase in GMST projected for some regions (high confidence). Small-scale fisheries in tropical regions, which are very dependent on habitat provided by coastal ecosystems such as coral reefs, mangroves, seagrass and kelp forests, are expected to face growing risks at 1.5°C of warming because of loss of habitat (medium confidence). However, risks would be larger at 2°C of warming and an even greater effort would be needed for adaptation to a temperature increase of that magnitude (high confidence). Socio-economic drivers, however, are expected to have a greater influence on these risks than the changes in climate (medium confidence). Depending on future socio-economic conditions, limiting global warming to 1.5°C, compared to 2°C, may reduce the proportion of the world population exposed to a climate change-induced increase in water stress by up to 50%, although there is considerable variability between regions (medium confidence). {Cross-Chapter Box 7 in this chapter} Human Health, Well-Being, Cities and Poverty Any increase in global temperature (e.g., +0.5°C) is projected to affect human health, with primarily negative consequences (high confidence). There is (medium confidence) that these instabilities could be triggered at around 1.5°C to 2°C of global warming. Small island states and economically disadvantaged populations are particularly at risk (high confidence). The extent of risk depends on human vulnerability and the effectiveness of adaptation for regions (coastal and non-coastal), informal settlements and infrastructure sectors (such as energy, water and transport) (high confidence). Climate hazards at 1.5°C are projected to be lower compared to those at 2°C (high confidence). In particular, reforestation could be associated with significant co-benefits if implemented in a manner than helps restore natural ecosystems (high confidence). A slower rate of sea level rise enables greater opportunities for adaptation (medium confidence). There is thus low confidence in the level at which global warming could lead to very high risks associated with extreme weather events in the context of this report. {3.4.6, 3.6, Box 3.1, Cross-Chapter Box 6 in this chapter} Reductions in projected food availability are larger at 2°C than at 1.5°C of global warming in the Sahel, southern Africa, the Mediterranean, central Europe and the Amazon (medium confidence). The risks of declining ocean productivity, shifts of species to higher latitudes, damage to ecosystems (e.g., coral reefs, and mangroves, seagrass and other wetland ecosystems), loss of fisheries productivity (at low latitudes), and changes to ocean chemistry (e.g., acidification, hypoxia and dead zones) are projected to be substantially lower when global warming is limited to 1.5°C (high confidence). If overshoot is to be minimized, the remaining equivalent CO_2 budget available for emissions is very small, which implies that large, immediate and unprecedented global efforts to mitigate greenhouse gases are required (high confidence). Overall for vector- borne diseases, whether projections are positive or negative depends on the disease, region and extent of change (high confidence). {3.4, Box 3.4, Box 3.5, Cross-Chapter Box 6 in this chapter} Future risks at 1.5°C of global warming will depend on the mitigation pathway and on the possible occurrence of a transient overshoot (high confidence). For oceans, regional surface temperature means and extremes are projected to be higher at 2°C compared to 1.5°C of global warming (high confidence). {3.3.5} The probability of a sea-ice-free Arctic Ocean during summer is substantially higher at 2°C compared to 1.5°C of global warming (medium confidence). Natural sedimentation rates are expected to be able to offset the effect of rising sea levels, given the slower rates of sea level rise associated with 1.5°C of warming (medium confidence). {3.4.10, 3.4.11, 5.2.2, Table 3.5} Key Economic Sectors and Services Risks to global aggregated economic growth due to climate change impacts are projected to be lower at 1.5°C than at 2°C by the end of this century (medium confidence). {3.2, 3.6.2, Cross-Chapter Box 8 in this chapter} Robust global differences in temperature means and extremes are expected if global warming reaches 1.5°C versus 2°C above the pre-industrial levels (high confidence). {3.3.2.2, 3.4.3.2, 3.4.3.5, 3.4.6.1, 3.5.5.10, Box 4.2} Many impacts are projected to be larger at higher latitudes, owing to mean and cold-season warming rates above the global average (medium confidence). Changes in land use resulting from mitigation choices could have impacts on food production and ecosystem diversity. Constraining warming to 1.5°C would prevent the thawing of an estimated permafrost area of 1.5 to 2.5 million km^2 over centuries compared to thawing under 2°C (medium confidence). The rate of change for several types of risks may also have relevance, with potentially large risks in the case of a rapid rise to overshooting temperatures, even if a decrease to 1.5°C can be achieved at the end of the 21st century or later (medium confidence). The differences in the risks among regions are strongly influenced by local socio-economic conditions (medium confidence). {3.3.8, 3.4.4.7} Global mean sea level rise (GMSLR) is projected to be around 0.1 m (0.04 – 0.16 m) less by the end of the 21st century in a 1.5°C warmer world compared to a 2°C warmer world (medium confidence). The impact literature contains little information about the potential for human society to adapt to extreme weather events, and hence it has not been possible to locate the transition from 'high' to 'very high' risk within the context of assessing impacts at 1.5°C versus 2°C of global warming. The risk transitions by degrees of global warming are now: from high to very high between 1.5°C and 2°C for RFC1 (Unique and threatened systems) (high confidence); from moderate to high risk between 1°C and 1.5°C for RFC2 (Extreme weather events) (medium confidence); from moderate to high risk between 1.5°C and 2°C for RFC3 (Distribution of impacts) (high confidence); from moderate to high risk between 1.5°C and 2.5°C for RFC4 (Global aggregate impacts) (medium confidence); and from moderate to high risk between 1°C and 2.5°C for RFC5 (Large-scale singular events) (medium confidence). {3.3.5, 3.4.2, Box 3.5} Land Use, Food Security and Food Production Systems Limiting global warming to 1.5°C, compared with 2°C, is projected to result in smaller net reductions in yields of maize, rice, wheat, and potentially other cereal crops, particularly in sub-Saharan Africa, Southeast Asia, and Central and South America; and in the CO_2-dependent nutritional quality of rice and wheat (high confidence). {3.5} Global warming has already affected tourism, with increased risks projected under 1.5°C of warming in specific geographic regions and for seasonal tourism including sun, beach and snow sports destinations (very high confidence). There is high confidence that sea level rise will continue beyond 2100. The chapter also revisits major categories of risk (Reasons for Concern, RFC) based on the assessment of new knowledge that has become available since AR5. {3.3.1, 3.3.2, 3.3.3, 3.3.4, Box 3.4} Trends in intensity and frequency of some climate and weather extremes have been detected over time spans during which about 0.5°C of global warming occurred (medium confidence). Regions with particularly large benefits could include the Mediterranean and the Caribbean (medium confidence). {3.3.1, 3.4} Exposure to multiple and compound climate-related risks is projected to increase between 1.5°C and 2°C of global warming with greater proportions of people both exposed and susceptible to poverty in Africa and Asia (high confidence). Adaptation is already happening (high confidence) and will remain important over multi-centennial time scales. {3.4.4, 3.4.5, 3.4.6, Box 3.1, Box 3.4, Box 3.5, Cross-Chapter Box 6 in this chapter} Land use and land-use change emerge as critical features of virtually all mitigation pathways that seek to limit global warming to 1.5°C (high confidence). {3.6.1, 3.6.2, Cross-Chapter Boxes 7 and 8 in this chapter} Climate Change Risks for Natural and Human systems Terrestrial and Wetland Ecosystems Risks of local species losses and, consequently, risks of extinction are much less in a 1.5°C versus a 2°C warmer world (high confidence). This chapter builds on findings of AR5 and assesses new scientific evidence of changes in the climate system and the associated impacts on natural and human systems, with a specific focus on the magnitude and pattern of risks linked for global warming of 1.5°C above temperatures in the pre-industrial period. The global terrestrial land area projected to be affected by ecosystem transformations (13%, interquartile range 8–20%) at 2°C is approximately halved at 1.5°C global warming to 4% (interquartile range 2–7%) (medium confidence). Risks for coastal tourism, particularly in subtropical and tropical regions, will increase with temperature-related degradation (e.g., heat extremes, storms) or loss of beach and coral reef assets (high confidence). Risks associated with other biodiversity-related factors, such as forest fires, extreme weather events, and the spread of invasive species, pests and diseases, would also be lower at 1.5°C than at 2°C of warming (high confidence), supporting a greater persistence of ecosystem services. Future economic and trade environments and their response to changing food availability (medium confidence) are important potential adaptation options for reducing hunger risk in low- and middle-income countries. High-latitude tundra and boreal forest are particularly at risk, and woody shrubs are already encroaching into tundra (high confidence) and will proceed with further warming. 1.5°C and 2°C Warmer Worlds The global climate has changed relative to the pre-industrial period, and there are multiple lines of evidence that these changes have had impacts on organisms and ecosystems, as well as on human systems and well-being (high confidence). Global warming of 1.5°C would also lead to an expansion of the global land area with significant increases in runoff (medium confidence) and an increase in flood hazard in some regions (medium confidence) compared to present-day conditions. Furthermore, there are questions on how the stabilization of an increase in GMST of 1.5°C can be achieved, and how policies might be able to influence the resilience of human and natural systems, and the nature of regional and subregional risks. In addition to the overall increase in GMST, it is important to consider the size and duration of potential overshoots in temperature. Other ecosystems (e.g., kelp forests, coral reefs) are relatively less able to move, however, and are projected to experience high rates of mortality and loss (very high confidence). {3.3.9, 3.5.2, 3.6.3} Our understanding of the links of 1.5°C and 2°C of global warming to human migration are limited and represent an important knowledge gap. {3.4.4.12, 3.4.5.4, 3.4.5.7} Increased Reasons for Concern There are multiple lines of evidence that since AR5 the assessed levels of risk increased for four of the five Reasons for Concern (RFCs) for global warming levels of up to 2°C (high confidence). Other feedbacks, such as landward migration of wetlands and the adaptation of infrastructure, remain important (medium confidence). {3.3.1, 3.3.2, Cross-Chapter Box 8 in this chapter} Limiting global warming to 1.5°C would limit risks of increases in heavy precipitation events on a global scale and in several regions compared to conditions at 2°C global warming (medium confidence). For global warming from 1.5°C to 2°C, risks across energy, food, and water sectors could overlap spatially and temporally, creating new – and exacerbating current – hazards, exposures, and vulnerabilities that could affect increasing numbers of people and regions (medium confidence). Tropical cyclones are projected to decrease in frequency but with an increase in the number of very intense cyclones (limited evidence, low confidence). The number of species projected to lose over half of their climatically determined geographic range at 2°C global warming (18% of insects, 16% of plants, 8% of vertebrates) is projected to be reduced to 6% of insects, 8% of plants and 4% of vertebrates at 1.5°C warming (medium confidence). These risks are projected to increase at 1.5°C of global warming and impact key organisms such as fin fish and bivalves (e.g., oysters), especially at low latitudes (medium confidence). Lower rates of change enhance the ability of natural and human systems to adapt, with substantial benefits for a wide range of terrestrial, freshwater, wetland, coastal and ocean ecosystems (including coral reefs) (high confidence), as well as food production systems, human health, and tourism (medium confidence), together with energy systems and transportation (low confidence). Most least-cost mitigation pathways to limit peak or end-of-century warming to 1.5°C make use of carbon dioxide removal (CDR), predominantly employing significant levels of bioenergy with carbon capture and storage (BECCS) and/or afforestation and reforestation (AR) in their portfolio of mitigation measures (high confidence). A smaller sea level rise could mean that up to 10.4 million fewer people (based on the 2010 global population and assuming no adaptation) would be exposed to the impacts of sea level rise globally in 2100 at 1.5°C compared to at 2°C. {3.3, 3.4, 3.5, 3.6, Cross-Chapter Boxes 6, 7 and 8 in this chapter} Human-induced global warming has already caused multiple observed changes in the climate system (high confidence). {3.4.3, 3.5.2} Constraining global warming to 1.5°C, rather than to 2°C and higher, is projected to have many benefits for terrestrial and wetland ecosystems and for the preservation of their services to humans (high confidence). {3.6.2, Cross-Chapter Boxes 7 and 8 in this chapter} The impacts of large-scale CDR deployment could be greatly reduced if a wider portfolio of CDR options were deployed, if a holistic policy for sustainable land management were adopted, and if increased mitigation efforts were employed to strongly limit the demand for land, energy and material resources, including through lifestyle and dietary changes (medium confidence). {3.5} With respect to the 'Distribution of impacts' (RFC3) a transition from moderate to high risk is now located between 1.5°C and 2°C of global warming, compared with between 1.6°C and 2.6°C global warming in AR5, owing to new evidence about regionally differentiated risks to food security, water resources, drought, heat exposure and coastal submergence (high confidence). In addition, BECCS and/or AR would have substantial direct effects on regional climate through biophysical feedbacks, which are generally not included in Integrated Assessments Models (high confidence). {3.3.1, 3.3.2, 3.3.3, 3.3.4, Table 3.2} There is no single '1.5°C warmer world' (high confidence). Instabilities exist for both the Greenland and Antarctic ice sheets, which could result in multi-meter rises in sea level on time scales of century to millennia.

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