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Incremental improvements of 2030 targets insufficient to achieve the Paris Agreement goals

Andreas Geiges[1], Paola Yanguas Parra[1], Marina Andrijevic[1,2], William Hare[1], Alexander Nauels[1], Peter Pfleiderer[1,2,3], Michiel Schaeffer[1,4], and Carl-Friedrich Schleussner[1,2,3]

[1]Climate Analytics, 10961 Berlin, Germany
[2]IRITHESys, Humboldt University, 10117 Berlin, Germany
[3]Potsdam Institute for Climate Impact Research, 14473 Potsdam, Germany
[4]Department of Environmental Sciences, Wageningen University and Research Centre, 6700 AA Wageningen, The Netherlands

Correspondence: Andreas Geiges (andreas.geiges@climateanalytics.org)

Abstract. Current global mitigation ambition as under the Paris Agreement as reflected in the National Determined Contributions (NDCs) up to 2030 is insufficient to achieve the Agreement's 1.5°C long term temperature limit. As governments are preparing new and updated NDCs for 2020, the question as to how much collective improvement is achieved is a pivotal one for the credibility of the international climate regime. The recent Special Report of the Intergovernmental Panel of Climate Change on Global Warming of 1.5°C has assessed a wide range of scenarios that achieve the 1.5°C limit. Those pathways are characterized by a substantial increase in near-term action and total greenhouse gas (GHG) emission levels about 50% lower than what is implied by current NDCs. Here we assess the outcomes of different scenarios of NDC updating that fall short of achieving this 1.5°C benchmark. We find that incremental improvements in reduction targets even if achieved globally, are insufficient to align collective ambition with the goals of the Paris Agreement. We provide estimates for global mean temperature increase by 2100 for different incremental NDC update scenarios and illustrate climate impacts under those scenarios including for extreme temperature, long-term sea level rise and economic damages for the most vulnerable countries. Under the assumption of maintaining ambition as reflected in current NDCs up to 2100 and beyond, we project a reduction in the Gross Domestic Product (GDP) in tropical countries of about 50-60% compared to a no-climate change scenario and long-term sea-level rise of close to 2m in 2300. About half of these impacts can be avoided by limiting warming to 1.5°C, or below. Scenarios of more incremental NDC improvements do not lead to comparable reductions in climate impacts. An increase in 2030 of the aggregated NDC ambition of big emitters by 33% does not deliver more than about half the potential reduction in climate impacts compared to limiting warming to 1.5°C. Our results underscore that a transformational increase in 2030 ambition is required to achieve the goals of the Paris Agreement and avoid the worst impacts of climate change.

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1 Introduction

Under the Paris Agreement of the United Nations Framework Convention on Climate Change (UNFCCC), governments have committed to holding temperature increase well below 2°C above pre-industrial levels and to pursue efforts to limit this to 1.5°C (UNFCCC, 2015). However, current efforts and targets globally are by far insufficient: aggregate mitigation targets under the Nationally Determined Contributions (NDCs), result in global warming of about 3°C (Climate Action Tracker, 2018; United Nations Environment Programme (UNEP), 2017; Climate Analytics, 2018).

The special report on Global Warming of 1.5°C of the Intergovernmental Panel on Climate Change (IPCC) has emphasised the importance of near term emission reductions to achieve the goals of the Paris Agreement (Masson-Delmotte et al., 2018). Pathways that achieve limiting warming to 1.5°C with no or limited overshoot require total greenhouse gas emission levels of 25-30 Gt CO_2eq /yr in 2030, about half of the 52-58 Gt CO_2eq / yr implied by current NDCs (Rogelj et al., 2018b). The IPCC further stressed that " rapid and far-reaching transitions" are required to achieve those emissions reductions and highlighted the importance of "fundamental societal and systems transitions and transformations" in helping to achieve the 1.5°C limit. In this context, it is important to highlight the scientific underpinning of the Paris Agreement temperature goal linked to robust assessments of the risks and impacts of climate change that would be avoided by achieving it (Schleussner et al., 2016b; Pfleiderer et al., 2018).

The IPCC special report further has provided comprehensive evidence on the impacts at global warming of 1.5°C and the impacts avoided compared to higher levels (Ove Hoegh-Guldberg et al., 2018) . Those include substantially lower impacts including for extreme weather events (Seneviratne et al., 2018) , water availability, and regionally specific drought or flooding risks (Döll et al., 2018; Karnauskas et al., 2018; ul Hasson et al., 2019), crop production in particular in tropical regions (Faye et al., 2018; Schleussner et al., 2018b), circulation changes including extreme El Niño, persistence of weather patterns and tropical rainy season changes (Pfleiderer et al., 2019; Saeed et al., 2018; Wang et al., 2017) , land and marine ecosystems (Warren et al., 2018; Schleussner et al., 2016a; Cheung et al., 2016), cryosphere changes including glacier and sea-ice loss (Laura and Dirk, 2018; Kraaijenbrink et al., 2017), (extreme) sea-level rise in particular beyond 2100 (Mengel et al., 2018; Schleussner et al., 2018a; Rasmussen et al., 2018), as well as economic damages (Burke et al., 2018; Pretis et al., 2018) and a wide range of other sectoral impacts (Arnell et al., 2018).

The findings of the IPCC have a key source of input into the Talanoa Dialogue process under the UNFCCC that has resulted in a "Call for Action" emphasising the need for increased near term ambition (UNFCCC, 2018). However, the window for strengthening the NDCs is closing quickly. By 2020 countries are required to come forward with new or updated NDCs over the time frame up to 2030 (UNFCCC, 2015).

Despite the scientific evidence for the need of profound increases in near-term ambition, it is far from certain that those may materialise in the near term. Although governments may come forward with improvements of their commitments in their new or updated NDCs, those improvements may fall short to deliver the emissions reductions required on the global scale, but rather resemble gradual improvements to collective emission reductions efforts in 2030.

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In the following, we explore different incremental global NDC update scenarios for 2030 and the implied global mean temperature increase up to the end of the century if proportional level of effort was to continue throughout the century. We provide projections for selected climate impacts (extreme temperatures, sea-level rise and economic damages) for current NDCs and gradual reduction pathways in comparison with a 1.5°C pathway. We are thereby linking near-term mitigation efforts directly to climate impact projections up to 2100 and beyond.

2 Methods

The analysis presented here combines a range of different approaches and methodologies ranging from an in-depth analysis of mitigation targets by big emitters to climate impacts projections. Those will be detailed out in the following.

2.1 NDC pathways

The analysis of emission pathways builds on the methodology of Climate Action Tracker (CAT), which estimates the collective result of current NDCs in global emissions, and the temperature implications of this pathway until the end of the century, if the same level of effort was kept after 2030 (Climate Action Tracker, 2015). Specifically, the CAT provides detailed assessments of pledges and policies of greenhouse gas (GHG) emission reductions by the Group of 20 (G20) plus a representative selection of minor emitters. Together the CAT countries[1] comprise about 80% of global emissions and 70% of total population (4,7 Billion in 2018). Although the list of CAT countries also includes a few minor emitters, the vast majority of the emissions from this group comes from the G20 [2],. Therefore, in the following we use the combined emission reduction efforts derived from the CAT countries as a proxy for emissions reduction efforts by political group of the G20. The extension to the global scale is then done following assumptions about the emission trajectories by all other countries globally. For non-CAT countries, we currently assume that the emissions of these countries will either follow the countries Kyoto Protocol commitments (as applicable e.g. for Iceland) or a 'business-as-usual' (BAU) pathway or The BAU pathways used in this analysis are from the PRIMAP4 (Gütschow et al., 2016) baseline.

Based on this analysis, 2030 global emission levels based on the CAT assessment of current pledges (53 Gt CO_2eq, National emissions, excluding LULUCF, aviation and marine emissions) and policies can be estimated. In order to relate the ambition reflected in the assessed NDCs in 2030 with the temperature goal of the Paris Agreement, an extension into emission scenarios until 2100 is required. This is done using the "Constant quantile extension" method (Gütschow et al., 2018) that is based on the assumption that the relative ambition level of climate policy is kept constant after the end of the NDC pathway. The extension is done using a database of emissions scenarios by Integrated Assessment Models (IAMs) included in the AR5 (Clarke et al., 2014). The ambition level implied by the NDC, or any other level of GHG emissions in 2030, is reflected by the quantile of scenarios above and below the value implied by the NDCs. This emission value in 2030 defines the implicit selection of

[1] Argentina, Australia, Bhutan, Brazil, Canada, Chile, China, Costa Rica, Ethiopia, EU, Gambia, India, Indonesia, Japan, Kazakhstan, Mexico, Morocco, Nepal, New Zealand, Norway, Peru, Philippines, Russia, Saudi Arabia, Singapore, South Africa, South Korea, Switzerland, Turkey, United Arab Emirates, Ukraine, and the United States.

[2] PRIMAP 2018 for national total excluding LULUCF reports for G20 countries 38.3Gt CO_2eq and CAT countries: 40.3 Gt CO_2eq (Gütschow et al., 2016)

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IAM scenarios which are extend the pathway throughout the 21st century, while maintaining the same level of ambition. This methodology ensures that the long-term projection is as consistent as possible with shorter-term action or pledges by accounting for the inertia of near-term actions.

2.2 Scenarios of incremental NDC improvements

Our "current NDC" ambition reference scenario corresponds to a modified version of the 2018 *CAT Pledges & Targets* pathway, which estimates global emissions levels implied by current NDCs. This CAT pathway accounts for all national emission as aggregate Kyoto gas pathways excluding marine, aviation and LULUCF. In order to obtain global emissions pathways, marine emission are included based on ranges from RCP6.0, aviation emissions are included and based on data from (Owen et al., 2010) and LULUCF emission are based on the median of baseline scenarios of land-use emissions from the LIMITS project (Kriegler et al., 2014). The 2018 CAT *Pledges & Targets* global emissions pathway would lead a temperature increase of about 3°C in 2100.

To create a "current NDC" ambition reference scenario for our analysis of increased ambition beyond current NDCs, we modify the CAT scenario by assuming for all countries that they will reach the lowest emissions level implied by their current NDC targets (when multiple or a range) or projections of planned policies as estimated by the CAT (when these are lower than the country's NDC). Taking into account the fact that some countries are on track to overachieve their current NDC targets (e.g. India, Russia, Indonesia), as well as the conditionality on some NDC targets (e.g. The Philippines, Peru, Kazakhstan), 2030 total GHG emission levels implied by our reference scenario are 1.5 Gt CO_2eq lower than the 2018 *CAT Pledges & Targets* pathway (Climate Action Tracker 2018). Based on the pathway extension, our "current NDC" ambition reference scenario would lead to a global warming of 2.8°C in 2100.

Starting from this "current NDC" ambition baseline that we define as the world's current highest ambition level, we create a number of NDC update scenarios, which are meant to represent different increments of improvement in ambition. Specifically, we assume a 5%, 10%, 25% and 33% reduction in global GHG emission levels by 2030 below "current NDC" reference pathway. We apply these reduction levels either to the CAT countries only (as the representatives of the largest emitters or G20 group) as well as to all countries globally. Comparing scenarios for big emitters and all countries will highlight the importance of the big emitters' reductions for the collective ambition reflected in the aggregated emission levels. In addition, for consistency, for each scenario the same reduction factors were applied to marine, aviation and positive LULUCF emission in 2030. We extend these incrementally strengthened NDC scenarios into pathways until 2100 following the constant quantile extension introduced above which is used for the reference scenario. This allows for an assessment of the implications of the gradual reductions for long-term temperature levels.

2.3 Deriving global mean temperature trajectories

The constructed GHG(following AR4 global warming potential) emission pathways are then used to derive probabilistic temperature projections (median GMT increase) with the reduced complexity carbon cycle and climate model MAGICC6 (Meinshausen et al., 2011), reflecting both the climate sensitivity range assessed by IPCC AR5 (Rogelj et al., 2014) and the

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C4MIP carbon cycle response range (Friedlingstein et al., 2014). To allow comparison with a representative 1.5˚C consistent pathway, MAGICC6 is also forced with SSP1 RCP1.9 type emissions (Rogelj et al., 2018a) normalized to the year 2010 emissions of the CAT pathways to ensure a consistent experimental setup. The MAGICC model is run from 1750 to 2300 to also shed light on longer-term impacts like global mean sea-level rise. It is important to stress that for this longer-term outlook radiative forcing levels for the 22nd and 23rdcenturies are held constant on 2100 levels for all pathways, making the post-2100 model responses more stylized than for the 21st century.

2.4 Climate Impacts

In order to illustrate the implications of different temperature trajectories, we extend our analysis with additional climate impacts of three selected pathways: the current NDC pathway as reference (**NDC**), a selected gradual improvement scenario for the big emitters (CAT countries) with a reduction of 33% (**BE33**) and a 1.5°C scenario SSP1-RCP1.9 from (Rogelj et al., 2018b) (**1.5°C**).

2.4.1 Long-term sea-level rise

Global mean sea-level rise (GMSLR) projections are generated with the MAGICC sea-level model (Nauels et al., 2017). For the period 1850 to 2300, the model emulates IPCC AR5 consistent process-based model projections for thermal expansion, glacier mass loss, Greenland and Antarctic ice sheet contributions, and also includes a land water storage estimate which is independent from the climate change signal. While the Antarctic sea level component accounts for rapid dynamics captured by (Levermann et al., 2014), it does not reflect the proposed process of marine ice cliff stability (Deconto and Pollard, 2016), that could increase sea level estimates for high emission scenarios but is scientifically debated still (Edwards et al., 2019; Golledge et al., 2019). To this end, the provided sea level projections can be interpreted as conservative estimates for the longer-term sea-level response.

2.4.2 Extreme temperature

We present changes in hot extremes as land fraction distributions of changes in the intensity of the hottest day in a year (TXx) following the method introduced by (Fischer et al., 2013). This analysis is based on the time-slicing approach in which for each model a 21-year time period is selected for which the averaged global warming corresponds to the end-of-century GMT increase given by the respective scenarios (see Table S1). At each grid-cell the hottest days of a year (TXx) is averaged over the selected 21-year period and these averages of all selected CMIP5 runs are merged into one TXx change distribution per scenario and per region. Weighting the grid-cells by their area, a land fraction distribution is calculated for each region (as shown in Fig. 2). For each model we selected a run in the lowest emission scenario for which the desired GMT value is reached. Doing so, we assure that the warming during a 21-year period is minimal and that all models have an equal contribution the result.

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2.4.3 Economic damages

Expressed in terms of the gross domestic product (GDP), economic damages are calculated based on the methodology of (Burke et al., 2018). The method combines the estimates obtained from the historical relationship between GDP growth and temperature variability, and projected future temperature changes. With our own temperature pathways, GDP is estimated at the degrees of warming reached with the current NDCs, BE33, and a 1.5°C pathway, and then compared to the GDP in a counterfactual scenario without climate change. The impacts are calculated for the mid-century (2046-2065) and end-of-century (2081 - 2100).

To downscale GMT differences to gridded change patterns in annual mean temperature, we calculate downscaling factors for each model based on differences in annual mean temperature between two 20-year periods (2046-2065 and 2081-2100) and a reference period (1986-2005) for the three scenarios. Then we apply the median downscaling factor of each model (see Fig. S1) to the GMT differences of the selected scenarios to get local changes in GMT.

3 Results

The ambition reflected in current NDCs as assessed in the 2018 *CAT Pledges & Targets* pathway would put us on track for about 3°C temperature increase in 2100 (see Table 1). Our slightly more optimistic "current NDC" reference scenarios used here would lead to a reduced warming by about 0.2°C, implied by a reduction in 2030 GHG emission levels of about 1.5 Gt CO_2eq compared to the 2018 CAT pathway.

None of the pathways considered here limit median warming by 2100 to 1.5°C, which would require a reduction in 2030 NDC GHG levels of about 50% (Masson-Delmotte et al., 2018). Only the 25% and 33% reduction scenario for all countries limit median warming to under 2°C (see Table 1 and Figure 1). A median estimate of less than 2°C does however not imply that such pathways are in line with the "well below 2°C" limit set out in the long-term temperature goal of the Paris Agreement (Schleussner et al., 2016b). Smaller incremental improvements of a 5 or 10% increase in ambition would not bring median estimates for GMT increase close to 2°C. Emission reductions were limited to big emitters only lead to higher temperature outcomes. The temperature outcomes for the smallest ambition increase scenarios studied (5% and 10%) are very close, indicating that the impact of NDCs ambition increase by small emitters is very limited at the global level if bigger emitters do not increase ambition at least proportionally. For larger increases in NDC ambition (25% and 33%) the difference in implied 2100 GMT increase between the big emitter and all country scenario increases (see Table 1). Conditional on big emitters leading the way, the importance of the contribution of relatively small emitters thereby increases under scenarios of more ambitious global ambition. This result demonstrates that getting close to the Paris Agreement's long-term temperature goal will require comparable levels of action by all emitters, not just the largest.

Based on warming trajectories over the 21st century, assessments of differential climate impacts are provided. These are analyzed in the following for the "current NDC" ambition reference pathway and a 33% NDC improvement scenario - 33% reduction below the 2030 emissions of the "current NDC" ambition pathway for big emitters (BE33), compared to the effects

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Scenario	Big emitters (BE)		All countries (ALL)	
	Emissions 2030 [CO_2eq]	GMT 2100	Emissions 2030 [CO_2eq]	GMT 2100
High CAT Pledges & Targets pathway (as reference)	56.2 Gt	3.0 °C		
NDC reference scenario (this study)	54.8 Gt	2.8 °C		
NDC ambition 5% emission reduction	52.7 Gt	2.56 °C	52.2 Gt	2.52 °C
NDC ambition 10% emission reduction	50.6 Gt	2.43 °C	49.6 Gt	2.35 °C
NDC ambition 25% emission reduction	44.3 Gt	2.1 °C	41.8 Gt	2.0 °C
NDC ambition 33% emission reduction	41.0 Gt	1.9 °C	37.75 Gt	1.75 °C

Table 1. Overview about evaluated scenarios including the global emission in 2030 and the increase of the GMT for the year 2100. The references reduction levels (x%) in 2030 are applied to either only big emitters (BE) or all countries (ALL)

of a 1.5°C pathway. This allows assessment of the additional impacts implied by such pathways in comparison to achieving the 1.5°C limit.

3.1 Long-term sea-level rise

2100 GMSLR projections under the NDC reference scenario yield a median of around 64 cm (66% model range: 50 to 81 cm) (Figure 2). If major emitters increased their NDC ambition by 33% (BE33), 2100 GMSLR would be around 10 cm lower, namely 54 cm (43 to 68 cm). With projected GMSLR of 45 cm (36 to 57 cm) in 2100, a further reduction of around 10 cm would result from implementing a 1.5˚C consistent pathway. When looking beyond 2100, the sea-level rise implications of the selected scenarios become more pronounced. For 2300, the stylised pathway extensions yield around 1.9 m (1.4 to 2.5 m) of GMSLR under the NDC reference scenario, 1.4 m (1.1 to 1.8 m) for the BE33 case, and around 1 m (0.8 to 1.3m) for the 1.5˚C consistent pathway.

3.2 Extreme temperature

Figure 2 shows the changes in the hottest day in a year (TXx) with respect to 1986-2005 levels for each scenario globally (most left panel) and for SREX regions used in IPCC reports. In all regions, the differences between no increase in ambition, a 33% increase in ambition and a 1.5°C scenario are clearly distinguishable. Under a 1.5°C scenario (around 0.9°C above the 1986-2005 level), for 50% of the land area TXx would increase by at least 1.1°C (compared to current conditions). At the same time, the 1.5°C distribution is the narrowest showing more uniform increases across the regions and limited increase in the very high temperature tail of the distribution compared to higher levels of warming. As a result, only few places would experience increases as high as 3°C in TXx. For the BE33 scenario, half of the land area would experience an increase in TXx of at least 1.8°C. In this scenario, for 10% of the land area a 3°C increase in TXx is projected whereas in the 1.5°C scenario the 10% strongest increases would be about 2°C.

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Climate Impact	**Year**	**NDC reference scenario**	**%33% ambition increase for big emitters**	**1.5°C scenario**
Median increase in annual maximum temperature (TXx) relative to 1986-2005	2100	+2.7°C	+1.8°C	+1.1°C
Sea level rise relative to average between 1986-2005	2100	64 (50-81) cm	54 (43 -68) cm	45 (36-57) cm
	2300	190 (140-250)cm	140 (110-180) cm	100 (80-130) cm
GDP reductions relative to a no-climate %change scenario for LDC countries	2050	-20%	-17%	-14%
	2100	-63%	-48%	-34%

Table 2. Selected Climate Impacts under different scenarios of mitigation ambition. Where available, the 66% likely range is given in parenthesis.

Under the NDC scenario, changes in TXx would be most pronounced. The global median increase of TXx under this scenario is projected to be 2.7°C above the 1986-2005 level. The increase in the high-end tail is most pronounced under this scenario with 10% of the land area experiencing increases of over 4°C above the 1986-2005 levels.

3.3 Economic damages

In line with previous assessments (Diffenbaugh and Burke, 2019; Burke et al., 2018), most countries and in particular those in tropical regions are projected to experience economic damages from temperature increase under all scenarios. Note that the model does not consider the effects of sea-level rise, extreme weather events, or other non-linear trends that would likely exacerbate the current estimates. Figure 3 shows economic damages for selected vulnerable country regions, grouped in four categories based on their geographical region or level of development: Latin America, South Asia, Least Developed Countries (LDCs) and Small Island Developing States (SIDS).

Compared to a no climate change scenario, estimated reduction in GDP per capita around 2050 ranges between 11% and 14% for the 1.5°C pathway, 13% and 17% for the BE33 scenario (33% increase in NDC ambition), and between 16% and 20% reduction for the baseline pathway of the current NDCs. Variations between the country groups are small, though they are consistently highest for the LDCs. The differences between the scenarios increase further towards the end of the projection period. In 2100, the damages to GDP per capita range between 27% and 34% for the 1.5°C pathway, 39% and 48% for the 33% increase in NDCs, and between 51% and 63% reduction for no change from the current NDCs indicating profound economic risks for developing countries under scenarios of current ambition. Economic impacts can be halved by achieving a 1.5°C scenario.

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4 Discussion and conclusions

We have provided a detailed updated analysis of the implied consequences of present day NDC ambition levels as well as incremental improvement scenarios up to a 33% reduction relative to present day NDCs emission levels in 2030. In line with the 1.5°C special report (Masson-Delmotte et al., 2018), we find that that such gradual improvements are insufficient to achieve the 1.5°C limit, which would require 2030 GHG emission levels to be about halved compared to current NDCs. While improvements of big emitters have the biggest effect, the lower the overall warming level becomes, the more important become the ambition of all countries. The increasing differences in temperature outcomes between scenarios considering strengthened NDCs for big emitters only vs. all countries (compare *Table 1*) show that with increasing ambition the relative importance of the contributions by small emitters grows. This has important implications for climate policy as it underscores that big emitters need to spearhead global efforts, but that in order to achieve the goals of the Paris Agreement no country can stay behind and all are needed to improve collective ambition sufficiently to limit warming to 1.5°C.

Our estimates of selected climate impacts relating to current NDCs point to substantial additional impacts implied by current trajectories. Even if big emitters increase their ambition level by a third, this will only reduce about half the inferred impacts including for sea level rise, extreme temperatures and economic damages compared to what can be achieved by limiting warming to 1.5°C.

The consequences for affected population around the globe and specifically vulnerable regions such as least developed countries or small islands states will be profound (Schleussner et al., 2018a). Our findings are in line with other studies reporting substantial impact reduction potential at 1.5°C compared to higher levels of warming (Arnell et al., 2018). The implications of a lack of ambition towards achieving beyond gradual improvements will therefore manifest itself in a broad range of impacts beyond the limited set studied here. It will also increase the risks of potentially exceeding tipping points of the earth system going forward (Schellnhuber, H. J. Rahmstorf and Winkelmann, 2016)).

Our analysis does not aim at deriving conclusions about the global impact of *individual* proposed NDC updates, but rather to inform about the overall *collective aggregate ambition* increase that is needed in the short term to keep the door open for ambitious emissions reductions in the long-term. This means that the reduction numbers cannot be to easily extrapolated to individual NDCs of countries. First and foremost, actual domestic emissions reductions will differentiate strongly among countries, depending on technically and economically feasible reduction potentials. In addition, the additional emissions reductions to be achieved elsewhere via contributions to e.g. international climate finance, as well as international finance received by countries, may depend on assumptions of fair share and equity that need to be considered carefully (Robiou Du Pont et al., 2017).

Furthermore, individual NDCs may have very different types of targets, with mixed coverage of sectors and different levels of uncertainty around the emission levels implied by the targets included the NDC. The overall percent reductions presented here, therefore needs to be translated back to each country specific NDC "language" to understand how the NDC update announcements compare to the different levels of ambition described. For countries where current policies indicate an over-

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achievement of their NDC targets, the percent improvement presented here refers to emissions levels in line with these current policies projections (see above) and thus translates to a higher percent improvement from the current NDC target.

Furthermore, our "current NDC" ambition baseline NDC pathway refers to emissions excluding Land use, land use change, and forestry (LULUCF) activities, and by reducing this, as well as the LULUCF global pathway by the same percentage we are indirectly assuming that the contribution to the NDC enhancement will be equal for LULUCF and no-LULUCF sectors. It is to be expected, however, that for a big number of countries the contributions to a more ambitious NDC would come more than proportionally from the LULUCF sector. These considerations should be carefully examined when judging the ambition improvements of individual NDCs, in particular given issues regarding transparency and ambiguity of the treatment of LULUCF in the current NDCs. The ambiguity land use mitigation targets, provided by most countries results in an uncertainty of about ~3 GtCO2/year in global land use emissions in 2030 (Fyson and Jeffery, 2019) .

Our results provide clear evidence of the need of a transformational increase in 2030 ambition by countries to achieve the 1.5°C limit and to avoid the impacts of exceeding this level of warming. While it is necessary – and essential – that these ambition increases need to spear-headed by the big emitters, it also clear that this is not sufficient and hence all countries need to contribute their fair share reflected in their 2020 NDCs in order to achieve the transformational change in near term ambition required to meet the Paris Agreement's long term temperature goal.

Author contributions. AG, PP WH and MS designed the scenarios, AG computed the emission pathways, AN and AG provided the temperature projections. AN provided the sea level projections, PP the temperature extremes and MA the economic damages. CFS lead the writing of the manuscript with contributions of all authors.

Competing interests. The authors declare that they have no conflict of interest

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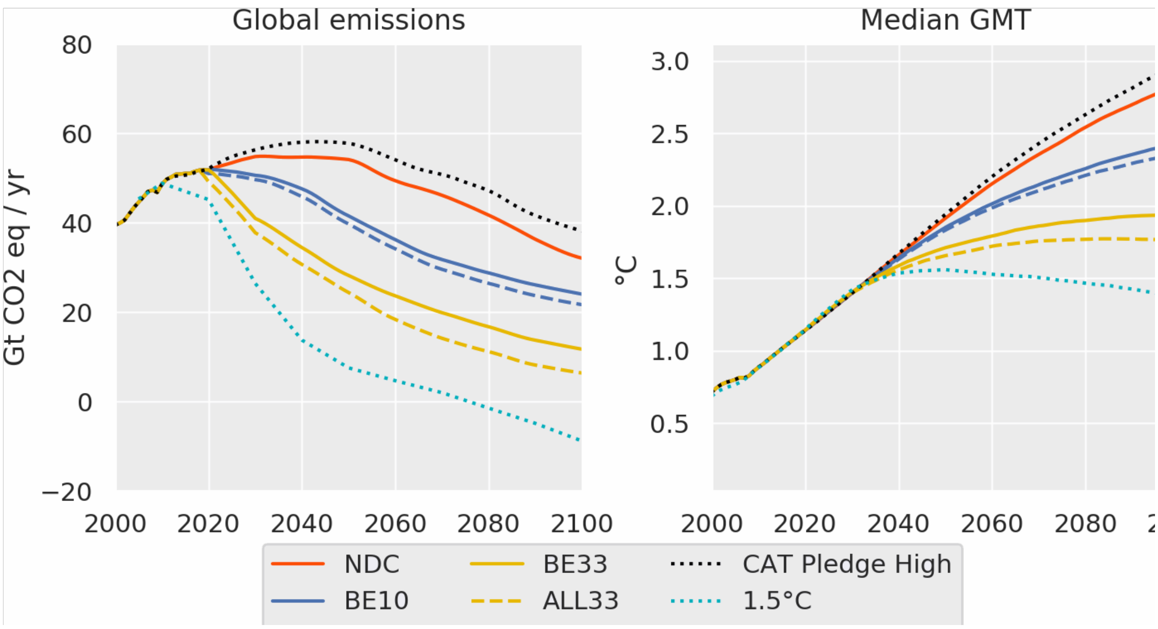

Figure 1. Global GHG emission trajectories for the NDC reference scenario and several NDC improvement scenarios ranging from 10 to 33% reduction of 2030 emission levels relative to the NDC reference. Scenario for Big Emitters are indicated by "BE" and scenarios for all countries by "ALL"

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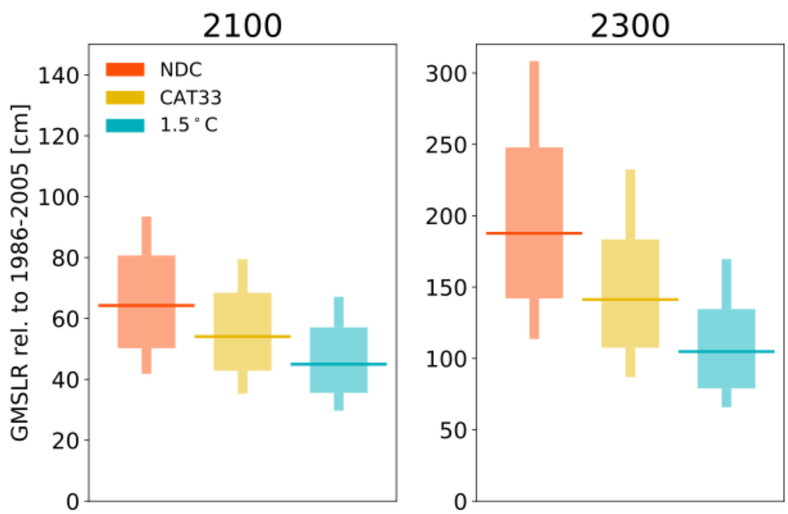

Figure 2. Global mean sea-level rise (GMSLR) projections under the NDC reference scenario (NDC), the CAT-based scenario for a 33% increase in NDC ambition of big emitters (BE33), and a scenario consistent with limiting 21st century warming to 1.5 ˚C (1.5 ˚C) for the years 2100 and 2300, relative to the IPCC AR5 reference period 1986-2005 in centimetres. Median values (thin horizontal lines) are provided together with the 66% model ranges (boxes) and 95% model ranges (whiskers). Please note the different y-axis scales.

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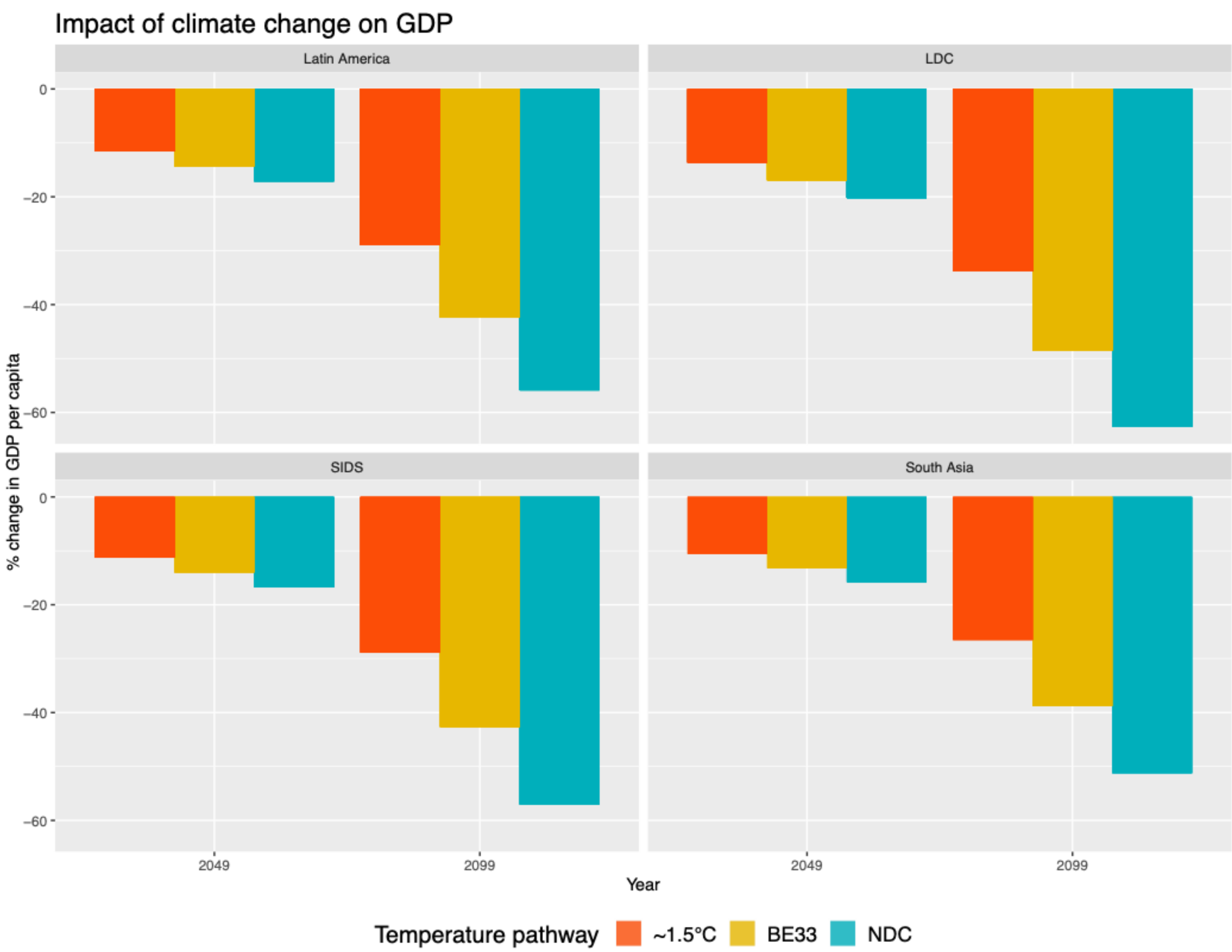

Figure 3. Economic damages under different scenarios of GMT increase. The bars show the percentage difference between GDP per capita under selected temperature pathways (no change in current NDCs, BE33 scenario resembling a 33% change in NDCs of big emitters and a 1.5°C pathway) and GDP per capita under a no climate change scenario. Estimates are given for mid-century (2046-2065) and end-of-century (2081-2100). Countries are grouped by either geographical regions (South Asia and Latin America) or political groupings following the UN classifications (Small Island Development States, SIDS and Least Developed Countries, LDCs).

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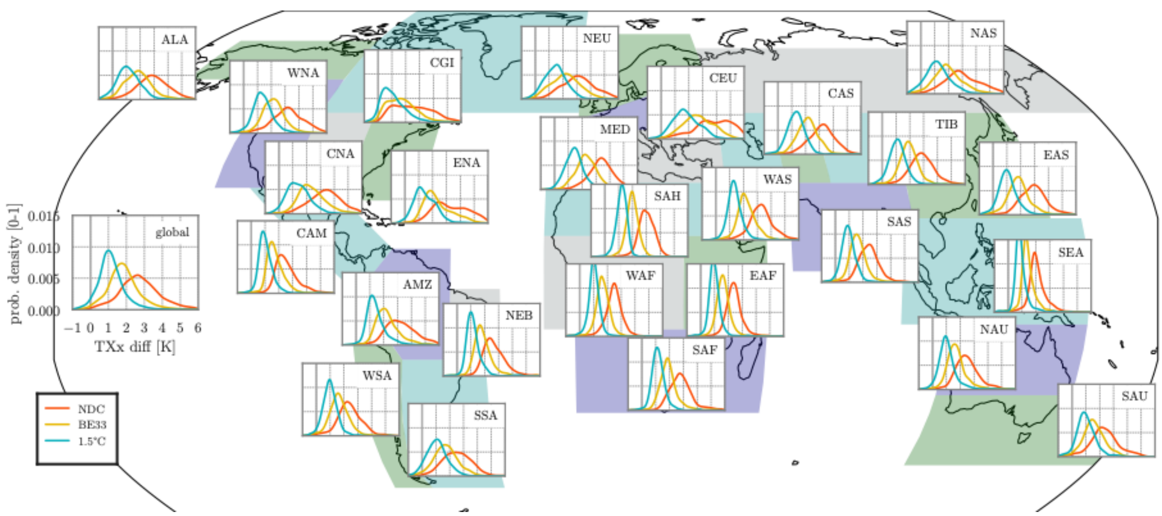

Figure 4. Probability density functions for area-aggregated changes in TXx (x-axes) globally and for individual world regions. Changes are presented relative to the 1986-2006 period for the NDC scenario (red), the BE33 scenario (yellow) and the 1.5°C scenario (cyan). Distributions are based on an area weighted aggregation of all TXx change values projected at grid-cells within a region and across climate models.