The Paris Agreement and climate justice: inequitable impacts of sea level rise associated with temperature targets

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Abstract

Anthropogenic greenhouse gas emissions are causing unprecedented changes to the climate. In 2015, at the United Nations (UN) Conference of the Parties in Paris, France, countries agreed to limit the global mean surface temperature (GMST) increase to 2°C above preindustrial levels, and to pursue efforts to limit warming to 1.5°C. Due to the long-term irreversibility of sea level rise (SLR), risks to island and coastal populations are not well encapsulated by the goal of limiting GMST warming by 2100. This paper reviews and synthesizes the climate justice implications of temperature targets in light of our increasing understanding of the spatially variable impact and long temporal commitment to rising seas. In particular we highlight the impact that SLR will have on island states and the role of the Alliance of Small Island States (AOSIS) in UN climate negotiations. As a case study we review dual impacts from the Antarctic Ice Sheet (AIS) under a changing climate: 1) recent climate and ice sheet modeling shows that Antarctic melt has the potential to cause rapid SLR with a distinct spatial pattern leading to AOSIS nations experiencing SLR at least 11% higher than the global average and up to 33% higher; and 2) future ice sheet melt will result in a negative feedback on GMST, thus delaying temperature rise. When considering these impacts in conjunction, justice concerns associated with the Paris Agreement are exacerbated. This case study demonstrates that mitigation policies should consider climate impacts in addition to GMST, particularly sea level rise.

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9	Rey Points:
10	 Temperature targets in 2100 do not rully capture other enects of climate destabilization, particularly sea level rise.
12	 The temperature target metric has significant climate justice implications for Island
13	Nations disproportionately impacted by sea level rise.
14	 Modeling of Antarctic ice sheet melt indicates sea levels may rise while temperature
15	increase slows, exacerbating justice concerns.
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- 52 policies should consider climate impacts in addition to GMST, particularly sea level rise.
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54 Plain Language Summary

55 At the Paris Climate Agreement in 2015, countries adopted a target for stabilizing climate 56 change defined by how the rise in global average air temperature has increased relative to a 57 pre-industrial baseline. Prior research has identified numerous climate justice implications 58 associated with this approach. This study reviews climate justice issues associated with Paris 59 Agreement temperature targets, finding that using air temperature by 2100 as the main metric 60 does not adequately capture other climate risks, particularly sea level rise faced by island and 61 coastal communities. We introduce a new climate justice consideration based on the 62 simultaneous impacts of sea level rise and slowed warming caused by ice loss on Antarctica. 63 Slowed warming might appear to delay the need for climate action, but a focus on temperature 64 alone misses the impacts of accelerating sea level rise.

65 1 Introduction

66 Climate change impacts all parts of the Earth system, and the degree and nature of these

67 impacts vary spatially and temporally. Sea level rise (SLR) presents a distinct threat to coastal 68 communities and island nations (Magnan et al., 2019; Nurse et al., 2014). Global mean sea 69 level (GMSL) has increased by 0.2 m since 1901, accelerating in recent decades to the current 70 (2006-2018) rate of about 3.7 mm/yr (Fox-Kemper et al., 2021). The rate of SLR will increase by 71 the end of the century even under low emissions scenarios. Sea levels will continue to rise for 72 centuries after 2100, regardless of emissions trajectories or overall warming, and will remain 73 elevated for millenia (Clark et al., 2016; Fox-Kemper et al., 2021; Oppenheimer et al., 2019). 74 Sea level rise also has substantial regional variations, the impacts of which depend on 75 geomorphological and sociopolitical considerations at the local scale. In some places SLR may 76 cause islands to be rendered uninhabitable due to submersion, salt water intrusion into 77 groundwater, storm surge, and other factors (Magnan et al., 2019; Oppenheimer et al., 2019). 78 79 Since the 1980s, a focal point of international negotiations has been to establish a common

80 target in the form of a Long Term Global Goal (LTGG) for action to address climate change, yet 81 the metric used for the LTGG does not explicitly consider sea level rise. In 2015, these 82 negotiations led to the adoption of the Paris Agreement which framed the LTGG in terms of a 83 temperature target. This temperature target become the quantitative expression of the United 84 Nations Framework for the Convention on Climate Change (UNFCCC) Article 2 objective of 85 "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent 86 dangerous anthropogenic interference [DAI] with the climate system" (UNFCCC, 1992 p9). 87 According to the Paris Agreement (2015), countries agreed to limit global mean surface 88 temperature (GMST) rise to "well below 2°C above pre-industrial levels and pursue efforts to 89 limit the temperature increase to 1.5°C". As of 2021, the average surface temperature is 1.1°C 90 warmer than preindustrial, currently increasing at a rate of ~0.2°C per decade as greenhouse 91 gas emissions rise at a rate of 59.1 gigatons of CO_2 equivalent per year (Gulev et al., 2021; 92 Hoegh-Guldberg et al., 2018; UNEP, 2020).

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This temperature target, as it is currently framed, poses several challenges which can give rise to multiple sources of climate injustice. First, the temperature target is generally considered to be in reference to the year 2100 however unlike GMST, sea level rise following greenhouse gas emissions evolves over centuries due to complex processes and feedbacks meaning that the full multi-century response is currently unaccounted for (Clark et al., 2016; Li et al., 2013, Mengel et al., 2018). Surface temperature depends mainly on cumulative emissions, thus temperature is expected to stabilize if CO₂ emissions reach net zero. However the thermal

101 expansion component of SLR, which occurs as water warms and expands, will continue for 102 centuries even after emissions stop (Bouttes et al., 2013; Meehl et al., 2012; Zanna et al., 103 2019). Specifically, higher emission rates at earlier times lead to higher SLR for the same 104 cumulative emissions, which has implications for policy proposals if sea level were to be 105 considered as a metric instead of or in addition to GMST (Bouttes et al., 2013; Li et al., 2020). 106 While the rate of SLR from thermal expansion will likely decline as temperatures decline, 107 dynamical contributions from ice sheets will dominate in the long-term with sea levels continuing 108 to rise for hundreds of years even after temperatures stabilize (Wigley, 2018). This occurs even 109 if speculative technologies to remove CO₂ from the atmosphere are deployed (DeConto et al., 110 2021).

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112 Second, by adopting GMST as the metric for international climate action, the conversation 113 around risk and impact has been skewed toward a globally averaged version of a single 114 environmental stressor. This approach fails to convey the breadth of impacts which will vary 115 geographically and over time. Following from this, there is significant discrepancy between 116 'danger as defined' by scientific assessments and 'danger as experienced' by communities on 117 the frontlines of a changing climate (Dessai et al., 2004 p21). While climate change is a global 118 risk, vulnerability is a locally experienced phenomena (Ayers, 2011; Tschakert, 2015). Systems 119 of power and privilege impact the decision-making process regarding what is deemed an 120 acceptable level of damage and risk, often disadvantaging those with less privilege (Dessai et 121 al., 2004; Seager, 2009).

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123 Third, and finally, "acceptable risk" is an ambiguous term with respect to the concept of DAI 124 written into the UNFCCC. This is compounded by the vague language in the Paris Agreement 125 that recommends a target of "well below" 2°C. In what has been termed "the political economy 126 of delay" (Carton, 2019), these ambiguities have jointly enabled a delay in action to reduce 127 carbon emissions by parties more concerned with near-term economic profit than ongoing and 128 long-term environmental and societal harm. Because the Paris Agreement does not directly 129 connect temperature to greenhouse gas emissions regulation, it moves the conversation away 130 from the causes of climate change (increasing greenhouse gas emissions and systems of 131 oppression which drive them). The ambiguities of the UNFCCC and Paris Agreement embody 132 the status quo over principles of egalitarian justice (Morgan, 2016; Morseletto et al., 2017; 133 Okereke, 2006; Tschakert, 2015). Indeed, while countries submit Nationally Determined 134 Contributions (NDCs) to achieve Paris goals, emissions levels have not declined to meet them, 135 and parties are not legally bound to enact them. Moreover, the temperature target has been

136 interpreted as leaving room for overshooting in the coming decades with the promise of

reaching it by 2100 (Rogelj et al., 2018), despite the risk of triggering rapid SLR.

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139 Given these challenges posed by the GMST target, we argue that it is crucial to understand the 140 target's origins in the context of broader inequalities that characterize the global climate 141 negotiation process. The GMST target has its origins in scientific research, which informs policy 142 processes. Predictive modeling plays an important role in negotiations by characterizing climate 143 system changes of interest to policymakers and the public, and constraining potential future 144 trajectories. Issues of justice are crucial in understanding impacts of climate policy (Klinsky et 145 al., 2016), yet science is limited in its ability to answer questions about justice (Okereke; 2006; 146 Oppenheimer, 2005). In scientific assessments there is a tendency for climate change to be framed as an environmental issue with social ramifications, as opposed to a social issue with 147 148 environmental ramifications (Barnett & Campbell, 2011). This approach obscures the nuances 149 of how social systems interface with vulnerability (Liverman, 2009). An interdisciplinary 150 interpretation of scientific results allows for greater understanding of justice concerns (Colven & 151 Thomson, 2019).

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153 In this paper, we focus on three components of justice theory as they relate to the Alliance of 154 Small Island States (AOSIS), an organization formed to amplify the needs of states particularly 155 concerned with the impacts of sea level rise (Heileman, 1993; Liburd, 2021): 1) procedural 156 justice, which notes that fair outcomes require equity throughout the decision making process, 157 2) distributive justice relating to how impacts vary spatially and temporally and are often uneven 158 with respect to emissions contribution, and 3) recognition justice relating to the existence rights 159 of cultural and social groups (Burnham et al., 2013a; Fraser, 1997; Rawls, 1971). We frame 160 each justice consideration centering on AOSIS nations, negotiators, and inhabitants due to the 161 geographic vulnerability of many AOSIS nations to sea level rise, the centrality of this in their 162 negotiating positions, and their strong and ongoing history of advocacy within the UNFCCC. 163 AOSIS statements and NDCs of member nations stress SLR as a threat to their existence 164 (AOSIS, 2009; AOSIS and the LDC Group, 2020; Mills-Novoa & Liverman, 2019; Thomas & 165 Benjamin, 2018c). Interviews with the AOSIS chair and negotiators from member countries note 166 that loss and damage from extreme events had already been witnessed by all of them, and 167 while direct impacts occurred in coastal communities, there were ramifications for the whole 168 country (Thomas & Benjamin, 2018). Under 2°C, lands in island nations inhabited by half a

million people could become permanently submerged (Storlazzi, 2015), though limiting warming
can reduce risks (Hoegh-Guldberg et al., 2018; Hoegh-Guldberg et al., 2019).

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172 Here, we leverage a range of scientific and sociopolitical research to explore the climate justice 173 implications of defining the LTGG according to GMST, interpreted as being by 2100. By bridging 174 physical and social sciences literatures we are able to consider physical earth system changes, 175 while incorporating the sociopolitical context of climate change drivers, responses, and impacts. 176 Scientific research is used to inform international negotiations yet can become detached from 177 the lived experiences of people experiencing SLR (Abbott & Wilson, 2015). In order to 178 understand the policy landscape as well as the experiences of people on the ground we bring 179 together historical, sociological, geographic, and political research to contextualize scientific 180 findings with human interactions and experiences.

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182 First, we review and synthesize documents from United Nations (UN) archives and literature 183 pertaining to three aspects of climate justice. We find that 1) power dynamics influenced the 184 decision to adopt the GMST target, and while AOSIS nations had substantial achievements 185 ultimately a weaker global metric was adopted, 2) vulnerability to SLR varies based on a wide 186 range of climate system, historical, and political factors with some AOSIS islands in danger of 187 being submerged and 3) the long time commitment of rising seas is particularly dangerous for 188 AOSIS countries given the normalization of overshoot pathways that GMST targets have 189 allowed for. This normalization increases the risk of more severe long term SLR commitments. 190 Following this review we then turn to a case study of the projected impacts of Antarctic Ice 191 Sheet melt on SLR, GMST, and AOSIS countries. We assess the spatial variability of the 192 Antarctic SLR component in comparison to the global mean and find that AOSIS nations are 193 disproportionately impacted relative to their emissions contribution (see Methods). This case 194 study illuminates 1) the potential of negative feedbacks to justify increasing allowable emissions 195 budgets while sea levels simultaneously rise and 2) the possibility that overshooting the Paris 196 Agreement goals could further exacerbate climate justice inequities since Antarctic instability 197 points lie near 2°C. The conclusion considers the broader climate justice implications of defining 198 the LTGG according to GMST by 2100.

2 Temperature Targets: A Procedural JusticeCritique

201 Procedural justice considers equity in decision making processes. While temperature targets 202 have become a fixture of climate negotiations, the use of GMST as the LTGG was not 203 inevitable. A complex multi-decade negotiating process embedded in international power 204 dynamics led to the adoption of GMST (see Figure 1a for a timeline). GMST does not 205 adequately capture all dangerous climate risks, particularly SLR, and moves the metric for 206 action away from the causes of climate change, i.e. greenhouse gas emissions. AOSIS has 207 played a prominent role in negotiations since their inception. Their initial advocacy was for 208 binding emissions reductions, and they were instrumental in later reorienting discussions from 209 2°C to 1.5°C as negotiations solidified around temperature as the LTGG. 210



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212 Figure 1. Emissions over time and major historical events. a) timeline of major historical events,

213 statements, and publications shows UNFCCC proceedings (orange), AOSIS statements

214 (purple), and IPCC and other scientific reports (blue). b) A comparison of global greenhouse gas

emissions from 1990-2018 shows the low emissions contribution of AOSIS nations (blue) and

216 increasing levels of total global emissions (red).

217 2.1 Early negotiations and potential targets

218 Beginning in the late 1980s, climate scientists held meetings to discuss options for climate

219 targets. These focused on environmental indicators of change including stabilized atmospheric 220 greenhouse gas concentrations (in CO_2 equivalent), and rates and magnitudes of GMST and 221 SLR. These indicators were intended to be used to define quantitative targets with the possibility 222 of combining several environmental indicators to be translated into emissions targets for 223 regulatory policies (Jaeger, 1988; Rijsberman & Swart, 1990; Vellinga & Swart, 1991). They 224 were also envisioned to serve as both evidence of the extent of the changes occurring and to 225 monitor progress on policy implementation (Rijsberman & Swart, 1990). The rate-limit of 226 temperature change was based on rates of past change that ecosystems adapted to, however 227 this metric was abandoned because natural variability could produce rates higher than the 228 proposed values (Randalls, 2010). The rate of change of sea level rise, with a cap on overall 229 magnitude, was an early favorite among scientists, however lags in response times and ongoing 230 uncertainty in SLR projections complicated the metric and it was rarely mentioned in the political 231 arena (Rijsberman & Swart, 1990). Another reason could have been that SLR would mainly 232 impact coastal communities and therefore may not have been as motivational to some 233 countries. For instance Rijsbersman & Swart (1990, p.54) notes "For example, it is likely that the 234 Maldives in the Indian Ocean would be devastated by a sea-level rise of only one meter. An 235 absolute limit below this level would therefore be required if saving the Maldives from 236 destruction were a societal goal' [emphasis added]. For GMST targets the rate of rise 237 (0.1°C/decade) was suggested alongside a cap on the overall extent of the change. Suggested 238 caps were 1°C, based on past ecosystem adaptation, and 2°C which was put forth as a hard 239 upper limit beyond which climate responses could become nonlinear (Rijsberman & Swart, 240 1990).

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242 International negotiations to confront climate change and establish an LTGG became 243 centralized with the 1992 establishment of the UNFCCC. Annual negotiations, termed the 244 Conference of the Parties (COP), began in 1995. Within the UNFCCC, the idea of equity is 245 characterized through "common but differentiated responsibilities" (CBDR) and redistribution of 246 wealth through financial aid and technology transfers (Hurrell & Sengupta, 2012; UN, 1992). 247 CBDR is important since countries of the Global North [defined in the study as the USA, 248 Canada, Europe, Israel, Australia, New Zealand, & Japan] are responsible for the largest share 249 of historic greenhouse gas emissions (Hickel, 2020). The long residence time of greenhouse 250 gases in the atmosphere, the lag time it takes to realize changes to the climate system 251 (Liverman, 2009) and the fact that cumulative emissions determine the extent of climate 252 damages make historical emissions relevant (Hickel, 2020). Equity and CBDR are key

considerations of AOSIS, who have some of the lowest current and historic greenhouse gas
emissions and are simultaneously among the most impacted, especially by SLR (Figure 1b)
(Betzold, 2010).

256 2.2 AOSIS formation and binding emissions reductions

257 In 1990, following the first international conference on sea level rise hosted by the Maldives, the 258 Alliance of Small Island States (AOSIS) was formed to increase the negotiating prominence of 259 island nations and others sharing their concerns (Betzold et al., 2012; Ourbak & Magnan, 2018; 260 Republic of Maldives, 1989; Shibuya, 1997). AOSIS represents 20% of the UN member states. 261 Member nations are geographically widespread (AOSIS, 2021). They have varying interests, but 262 are united in backing strong climate action (Kelman & West, 2009). Their joint efforts have 263 impacted climate negotiations to a greater extent than possible individually. In the leadup to the 264 establishment of the UNFCCC, they pushed for setting a binding emissions reduction target in which developed nations would stabilize their emissions at 1990 levels by 1995 (Ashe et al., 265 266 1999; Vanuatu, 1991). While wording related to stabilization of atmospheric greenhouse gas 267 concentrations was included in the UNFCCC, a specific limit was not (Ashe et al., 1999). As 268 noted by the AOSIS Chair and others: "AOSIS, whose member states are most vulnerable to 269 the possible adverse effects of climate change, was particularly concerned about those provisions of the UNFCCC that were either watered-down significantly, made largely 270 271 meaningless or excluded altogether. These include: the absence of definite targets or specific 272 timetables, for the significant reduction of carbon dioxide by the industrialized countries of the 273 North" (Ashe et al., 1999 p1). Subsequent AOSIS proposals at COP1 requested implementing 274 UNFCCC Article 2 by requiring developed countries to reduce their 1990-level CO2 emissions 275 by 20% by 2005 and to develop targets for other greenhouse gases (AOSIS, 1994). The United 276 States and other countries, whose economies were based largely on fossil fuels, rejected this 277 (Shibuya, 1997; UNFCCC, 1995).

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In 1997 at COP3 the Kyoto Protocol set a target of legally binding emissions reductions (5%
below 1990 levels) for developed nations (UNFCCC, 1997). However the agreement was not
universally adopted by high emitters and emissions continued to rise globally at the end of the
first commitment period in 2012 (Hurrell & Sengupta, 2012; UNEP, 2012). The US, the world's
largest historic emitter, didn't ratify the Protocol (Gardiner, 2004) for several reasons: lobbying
of Congress and the Bush administration by corporations and conservative think tanks,

285 including those related to the fossil fuel industry (Brulle, 2014; Frumhoff et al., 2015; Supran & 286 Oreskes, 2017), the rise of climate denialism, and the passage of a Congressional resolution 287 prohibiting the US from signing onto a treaty that did not require developing countries to 288 participate (McCright & Dunlap, 2003; Roberts, 2018). Fossil fuel industry lobbying was based 289 on the economic interest of not devaluing their products and preference for keeping regulatory 290 measures related to fossil fuel production at the national level and out of international treaties 291 (Levy & Egan, 1998). These factors made the setting of binding emissions reduction targets 292 virtually impossible and solidified the turn away from these targets and towards nationally 293 determined pledges with a GMST target (Wewerinke-Singh & Doebbler, 2016).

294 2.3 Solidification of temperature targets

295 After Kyoto the 2°C temperature target rapidly gained prominence and solidified as the preferred 296 LTGG within Europe. This was driven by many factors including the 2005 publication of a European Commission report determining 2°C the point at which the benefits of mitigation offset 297 298 costs, and support for this metric at a number of high level European meetings including the G8 299 (Gao et al., 2017, Morseletto et al., 2017; Randalls, 2010). In opposition, AOSIS began formally 300 advocating for a lower temperature target in 2008 using the phrase "1.5 to stay alive" (Benjamin 301 & Thomas, 2016). COP negotiations became characterized by tension between those who 302 wanted a 1.5°C target and those who wanted a 2°C target (Leemans & Vellinga, 2017; 303 Morseletto et al., 2017).

304

305 Prior to COP15, AOSIS released their Declaration on Climate Change (2009) calling for the 306 meeting outcome to include multiple interlocking targets including stabilization of atmospheric 307 greenhouse gas concentrations at "well below 350 CO₂ -equivalent levels [meaning 308 atmospheric greenhouse gas concentrations equivalent to 350 parts per million CO₂]", GMST 309 rise below 1.5°C, and emissions reductions of developed countries by 45% below 1990 levels 310 by 2020. These calls did not gain traction and 2°C was written into the Copenhagen Accord with 311 the intention of making it the LTGG, which was considered a "grave disappointment" to AOSIS 312 negotiators (Liburd, 2021). However, the accord was not adopted, in part due to the objections 313 of developing states over the lack of inclusion of 1.5°C (Benjamin, 2010; UNFCCC, 2009; Wewerinke-Singh & Doebbler, 2016). Farbotko and McGregor (2010, p.162) found that "The 314 315 issue of a maximum 1.5°C temperature increase was pitched directly against the cost of 316 reducing fossil fuel use before and during the Copenhagen COP. For Australia, the EU, China,

- 317 India, the USA and many other states with fossil-fuel-dependent economies, reducing
- 318 greenhouse gas emissions so significantly under the 1.5°C target was unpalatable at
- 319 Copenhagen. The 1.5°C target advocated by [AOSIS nation] Tuvalu represented a significant
- 320 void between its geographic vulnerability and financial interests elsewhere."
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322 At COP16 in 2010, a coalition of middle and high income countries continued advocating for 323 2°C. Opposing them were a majority coalition of AOSIS and over 100 other countries that 324 objected, arguing 2°C would put their survival at risk (Tschakert, 2015). They pushed for 1.5°C 325 while acknowledging that no level of warming is safe (Knutti et al., 2016; Randalls, 2010; 326 Seager, 2009; Tschakert, 2015). The compromise reached at COP16 was that 2°C would be the 327 LTGG, necessitating deep near-term emissions cuts, but that it should be reviewed for 328 adequacy with respect to UNFCCC Article 2 (UNFCCC, 2010). AOSIS's insistence on 1.5°C led to the UNFCCC Structured Expert Dialogue (SED), a review of the scientific knowledge relating 329 330 to the LTGG, which led to the inclusion of 1.5°C in the Paris Agreement.

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332 The SED occurred from 2013-2015 to assess the adequacy of 2°C, the merit of strengthening 333 the goal, and progress towards it (Benjamin & Thomas 2016; UNFCCC, 2015b). During the 334 SED, Dr. Leonard Nurse noted that while islands in the Caribbean were experiencing 335 temperature trends in line with the global average, they were experiencing higher than average 336 SLR, while tropical western Pacific islands and locations in the Indian ocean were experiencing 337 even higher rates (UNFCCC SBSTA, 2015a). SED participants noted that 'danger' is subjective 338 and while fear of climate impacts united the parties, UNFCCC Article 2 divided them due to their 339 disparate perceptions of acceptable risk (UNFCCC SBSTA, 2015a p64). The SED concluded 340 that GMST was an adequate metric despite not encompassing all risks since other targets, or 341 multiple metrics, would only reiterate the primary conclusion necessitating urgent near-term 342 action. SLR was noted as being not well encapsulated by temperature targets. This is because 343 the rate of mean SLR depends on CO_2 emissions paths (Mengel et al., 2018; DeConto et al., 344 2021), so if emissions reductions occur at an earlier time, long-term SLR responses are lower. 345 This is unlike GMST which responds to cumulative emissions and is less dependent on 346 emission times (UNFCCC SBSTA, 2015b). An IPCC author at SED wrote "the unevenness of the political landscape in discussions around 1.5°C/2°C as well as loss and damage is 347 348 staggering...this unevenness epitomizes geographies of privilege, power, and inequality" 349 (Tschakert, 2015, p.10).

350 2.4 The Paris Agreement

351 Preceding COP21 in 2015, AOSIS released a statement saying that 2°C is unsafe according to 352 the SED outcome and requested that the Paris Agreement contain legally binding commitments 353 compliant with 1.5°C pathways (AOSIS, 2015). They asked for SED results to be included at the 354 COP, however objections from Saudi Arabia, China and other countries prevented this until the 355 final days of negotiations (Benjamin & Thomas, 2016; Wewerinke-Singh & Doebbler, 2016). 356 While 1.5°C was favored by a majority of parties, opposition came from countries with higher 357 levels of historic emissions who opposed a stronger goal in part due to their potential culpability 358 to loss and damage (Burkett, 2016; Hoad, 2016; Okereke & Coventry, 2016). AOSIS advocated for a legally binding protocol with firm emissions reduction commitments, but this was blocked 359 360 by the US (Fry, 2016; Wewerinke-Singh & Doebbler, 2016). Instead, the 2°C target was formally 361 adopted within the Paris Agreement, with the compromise language of pursuing efforts toward 362 1.5°C (UNFCCC, 2015). As a framework for achieving this, the agreement includes 363 mechanisms for strengthening the global response through periodically revised NDCs and 364 global stocktakes. The process outlined in the agreement is legally binding, though countries 365 are not legally required to reduce emissions or achieve the proposals they include in their NDCs 366 (Clémencon, 2016; UNFCCC, 2015; Wewerinke-Singh & Doebbler, 2016). Language on equity 367 is included only in the preamble (in reference to the UNFCCC), and in Articles 2 and 4 in 368 relation to CBDR and reducing emissions in the context of sustainable development (Klinsky et 369 al., 2016; UNFCCC, 2015). Climate justice is only mentioned once in the preamble, where it 370 states "noting the importance for some of the concept of 'climate justice' when taking action to 371 address climate change" (UNFCCC, 2015).

372 2.5 Post-Paris

373 As of 2021, six years post-Paris, NDCs are insufficient to stay below a 2°CGMST rise (Climate 374 Action Tracker, 2021; UNFCCC, 2021) and 1.5°C may no longer be achievable (Schleussner et 375 al., 2016; Warszawski et al., 2021; Zhou et al., 2021). Content analysis of NDCs show a 376 continuation of the "divergent climate priorities that have existed within the UNFCCC for decades" (Stephenson et al., 2019 p1258). NDCs from AOSIS nations emphasize vulnerability 377 378 and equity, while those of the US and EU nations demonstrate a lack of ambition on mitigation 379 and a deprioritization of climate action in favor of economic priorities (Mills-Novoa & Liverman, 380 2019; Stephenson et al., 2019). The gap between rhetoric on climate and action specified in the NDCs reveals the dichotomy between justice and economic and political power (Okereke &Coventry, 2016).

383

384 In summary, not all early target proposals (SLR, atmospheric greenhouse gas concentrations, 385 temperature) put forth by the scientific community were given full consideration in negotiations. 386 While the UNFCCC contains language on stabilizing atmospheric greenhouse gas 387 concentrations, the Paris Agreement adopted GMST and moved away from emissions and 388 concentration targets. While lower-emitting countries advocated for binding emissions targets on 389 the basis of equity, higher emitting countries ultimately prevailed in achieving non-binding 390 contributions. AOSIS advocated for binding emissions reductions targets, multiple metrics, and 391 a lower temperature goal. Their negotiating position emphasized the uneven distribution of 392 emissions versus impacts, noting that countries with high (low) emissions were among the least 393 (most) impacted by climatic changes. However, despite the advocacy of AOSIS and others, 394 non-binding pledges with temperature targets prevailed, in part due to power dynamics that 395 privileged high-emitting nations. The negotiating position of AOSIS centered on their geographic 396 vulnerability and the existential threat of sea level rise. To consider this we next turn to 397 recognition justice.

³⁹⁸ 3 Recognition justice - Adaptation, Displacement ³⁹⁹ and Migration

400 AOSIS negotiators have always centered the current and future impacts of sea level rise in their 401 negotiating positions. Recognition justice, recognizing differences in cultural and social groups 402 and seeking to address injustices and systemic disadvantages between cultural groups (Fraser, 403 1997), is an under-researched topic in climate justice (Burnham et al., 2013a; Burnham et al., 404 2013b; Thomas et al., 2020). Long before the 2°C target was set, scientists predicted some 405 islands could be pushed past adaptive limits due to inundation and saltwater intrusion into 406 aquifers and atoll freshwater lenses, potentially rendering them uninhabitable (Pernetta & 407 Hughes, 1990). This point is made often in AOSIS statements. Yet in the political realm, a goal 408 that could ensure continued existence of all parties was not taken as a baseline need for an 409 LTGG (Hoad, 2016). AOSIS leaders and the citizens of AOSIS nations often attribute their 410 vulnerability to sea level rise to colonial history and ongoing aid dependence. The voices of 411 people at the local and subnational levels experiencing SLR impacts are often left out of high

level policy conversations and the physical sciences literature. This section reviews literature on
how people in AOSIS nations perceive of and experience SLR, to motivate how this influences
their negotiating position in international negotiations and their perspectives on climate justice
more broadly.

416 3.1 Habitability, statehood, and exclusive economic zones

417 Especially in regards to atoll states, questions have been raised related to whether island states 418 could lose statehood if their territories are submerged. Under international law expressed in the 419 Convention on Rights and Duties of States (1933) a state must have "a defined territory". 420 However legal scholars have suggested this pertains more to the formation of a state than its 421 dissolution and have posited multiple ways statehoods could be maintained if territory is lost 422 (Yamamoto & Esteban, 2014), such as expanding the definition of statehood to include 423 recognition of states constituted by people in diaspora (Burkett, 2011). Despite this, the 424 uncertainty of the legal status is a concern in AOSIS nations. For example in this statement from 425 the 2020 Thimphu Ambition Summit: "High on the minds of representatives was the sobering 426 reflection that in another 75 years many of their members may no longer hold seats at the 427 United Nations if the world continues on its present course and average warming exceeds 428 1.5°C" (AOSIS and LDC Group, 2020). Habitability questions will arise before submersion 429 occurs, and will need to be ultimately decided by residents themselves (Liburd, 2021b). In 430 addition to the issues related to the loss of habited locations, the submergence of uninhabited 431 islands has potential ramifications for legal boundaries of Exclusive Economic Zones. EEZs 432 define the boundaries within which a country has exclusive economic rights to resources as 433 being within 200 nautical miles of the coast so loss of EEZ territory could lead to loss of 434 resources and income (Yamamoto & Esteban, 2014). However the Pacific Islands Forum has 435 declared that "our maritime zones, as established in accordance with the Convention [on the 436 Law of the Seal.... shall continue to apply, without reduction, notwithstanding any physical 437 changes connected to climate change-related sea-level rise" (Pacific Islands Forum, 2021).

438 3.2 Migration: discourses and perspectives

Island studies scholars have stressed that nuance, local perspectives, and historical grounding
are needed in conversations on SLR and migration. AOSIS nations vary widely in terms of
geomorphology, social and cultural makeup, and history (Barnett & Campbell, 2011; Bouchard,
2001; Perumal, 2018; UNDP, 2010), yet there is a tendency to view island nations as

443 homogeneous and universally vulnerable (Kelman, 2018). While loss of land is referenced often 444 in official statements, both negotiators and the general population in most states reject the 445 narrative of inevitable climate refugees and emphasize their preference for mitigation and aid 446 sufficient to allow for them to adapt in place (Corendea, 2016; Farbotko & Lazarus, 2010; 447 McNamera & Gibson, 2009; Perumal, 2018; Thomas & Benjamin, 2018). Given uncertainties in 448 the science and in the limits of adaptation, framings of inevitable loss of islands, which are 449 common in the media, can normalize conditions that AOSIS residents are seeking to avoid (Barnett, 2017; Perumal, 2018). The discourse surrounding migration also presents narratives of 450 451 climate refugees that promote victimization and lack of agency which can increase their 452 marginalization while being at odds with how people in island nations see themselves and their 453 own relationships to migration (Kelman, 2018; Kelman, 2020). Media narratives presenting 454 island populations as inevitable refugees, or the loss of islands as 'canaries in the coalmine', 455 have been criticized as falling into what has been termed the 'eco-colonial gaze' (Farbotko, 456 2010). Narratives of climate refugees are not always accurate as relocations have many 457 underlying factors, and these narratives can have negative ramifications on how islanders view 458 their environment (Siméoni & Ballu, 2012). Pacific scholars have put forth that imperialism 459 created the view of islands as small, poor, and isolated, but that this contrasts with the 460 expansive view islanders hold of an ocean of connected islands inhabited by resilient people 461 who constantly adapt to ocean changes (Hau'ofa, 1994). In light of this, the term "large ocean 462 states", emphasizing the reach of their ocean-based territory is often preferred to the more 463 common "small island developing states" (Chan, 2018).

464

465 Even if states are not fully lost to sea level rise issues of recognition relating to SLR remain. 466 Social values and identities of island populations are tied to physical place, but the physical changes SLR causes, and the adaptation measures used to confront them, pose risks to 467 468 cultural heritage sites, burial grounds, and long-term habitability (Graham et al., 2013; Marzeion 469 & Levermann, 2014; Mueller & Meindl, 2017; Oppenheimer et al., 2019). The UN Special 470 Rapporteur on cultural rights has noted that "While most human rights are affected by climate 471 change, cultural rights are particularly drastically affected, in that they risk being simply wiped 472 out in many cases", highlighting SLR as an example (UNGA, 2020). Due to these factors, 473 instances of relocation, regardless of statehood status, impact recognition justice (Robinson, 2020; Yamamoto & Esteban, 2014). In some Pacific and Caribbean island communities 474 475 relocation due to environmental hazards has occurred, though few countries have national 476 policies for this (Thomas & Benjamin, 2018c). Kiribati is the only country with a plan for

477 international migration, as they have purchased land in Fiji (Corendea, 2016; Thomas & 478 Benjamin, 2018c). In interviews, residents of villages in Fiji and Tuvalu note that people already 479 view SLR as impacting their lives and expect that trend to continue (Martin et al., 2018; 480 McMichael et al., 2021; Piggot-McKeller et al., 2021). Incremental retreat, which has already 481 occurred in some villages in Fiji, where new construction must take place on higher ground, can 482 be a way for people to maintain their place-based grounding to an extent (Piggot-McKeller et al., 483 2021). However preferences around relocation and adaptation responses vary between 484 individuals and can be characterized by generational differences. Short distance relocation is 485 not the preference of all community members (Martin et al., 2018; McMichael et al., 2021; 486 Piggot-McKeller et al., 2021). Binary and linear discourses on remaining or leaving is in contrast 487 to lived experiences of island residents (McMichael et al., 2021). Placed-based cultural 488 connections are often very strong such that even when residents expressed seeing graves and 489 homes wash away they express a strong desire to stay and retain their culture (McMichael et 490 al., 2021).

491 3.3 Legacies of colonization

492 AOSIS states have traditionally had high adaptive capacity for environmental change, however 493 these capacities were reduced in many places due to colonization and globalization (Barnett, 494 2001; Barnett & Campbell, 2011; Bordner et al., 2020; Douglass & Cooper, 2020; Nunn & 495 Campbell, 2020). Almost all AOSIS nations have histories of being colonized, and the majority 496 gained independence within the past century (United Nations, 2021). Legacies of resource 497 extraction, colonial occupation, genocide, and forced migration increase vulnerability to SLR 498 and other climate impacts, a situation that scholars are increasingly calling for recognition of 499 (Baptiste, 2016; Barnett & Campbell, 2011; Bordner, 2020; Corendea, 2016; Douglass & 500 Cooper, 2020; Hau'ofa, 1994; Kelman, 2018). Anthropological and paleoecological research 501 demonstrates that in the Caribbean, for example, genocide in the 16th century carried out by 502 Europeans led to loss of the traditional ecological knowledge of past adaptation strategies and 503 introduced more vulnerable infrastructure and settlement patterns (Douglass & Cooper, 2020). 504 The introduction of new settlement patterns, loss of traditional ecological knowledge, and 505 removal of mangrove forests following European colonization is also implicated in increased 506 vulnerability of Pacific volcanic islands (Nunn & Campbell, 2020). In the Indian Ocean political 507 and economic marginalization from past colonization, as well as current economic reliance on 508 extractive industries and tourism increase vulnerability (Bouchard, 2008; Douglass & Cooper,

2020). In the Marshall Islands narratives of sea level rise leading to unavoidable migration can
activate collective trauma from their history of forced migration to escape nuclear contamination
following US nuclear weapons testing on their islands (Bordner et al., 2020). While different
islands have different histories, geomorphologies, and current socioeconomic conditions, this
history shapes AOSIS states today.

514

515 Colonization was in part motivated by extraction of wealth which paved the way for

516 industrialization that released fossil greenhouse gas emissions (Sealey-Huggins, 2017).

517 Contemporary climate change is tied to global power and inequity, which is in turn tied to

518 economic development (Hurrell & Sengupta, 2012). Colonial legacies are a key factor in the

519 creation of these gradients of power and wealth, and the resulting systems of dependency in

520 terms of debt, aid, and international political power (Barnett & Campbell, 2011; Bordner et al.,

521 2020; Sealey-Huggins, 2017). Several high-emitting countries, such as the US, Australia, and

522 European nations who advocated for 2°C were colonizing nations whose actions reduced the

523 natural adaptive capacities that island nations traditionally had (Barnett, 2001; Barnett &

524 Campbell, 2011; Bordner et al., 2020; Douglass & Cooper, 2020; Nunn & Campbell, 2020). 525

526 These historical dynamics between industrialized high emitters and more vulnerable states 527 come into UNFCCC negotiations through mechanisms to address loss and damage. One 528 concrete approach is to allocate financial aid, leading to questions about who qualifies, how this 529 will be determined, and who pays (Klein & Möhner, 2011). Yet in later negotiations and within 530 the Paris Agreement, there has been a shift away from financial reparations for loss and 531 damage on the part of countries with larger historical emissions, higher wealth, and colonial 532 histories (Morgan, 2016; Okereke & Coventry, 2016). Instead, places with higher vulnerabilities 533 become reliant on international financial aid for adaptation projects. Developed countries had 534 agreed to provide \$100 billion per year in financial assistance to developing nations however 535 currently nations have provided far less, much in the form of loans, and only 3% of the total has 536 gone to small island developing states [most SIDS are AOSIS members, but not all] (Oxfam, 537 2020; Virtual Island Summit, 2021). Aid providers who view migration as unavoidable don't 538 provide adequate funding for the extent of adaptation islanders see as necessary to achieve 539 their goal of adapting in place (Bordner et al., 2020). Moreover, there is also no mechanism of 540 accountability of multinational corporations who are responsible for the majority of industrial 541 emissions (Frumhoff, 2015; Heede, 2014). Scientific research has attributed 50% of the rise in 542 GMST and 32% of the current sea level rise to emissions from industrial producers over the full

historical period (1880-2010). A substantial portion of this contribution is from recent decades
(1980-2010) where 35% of the GMST rise and 14% of the GMSL rise are attributed to the top
90 industrial producers (Ekwurzel et al., 2017).

546 3.4 Inclusion

547 Recognition justice would also entail increased consideration of local perspectives and support for AOSIS researchers in the scientific community. This would yield a wider reach in regards to 548 549 policy influence and a greater understanding of the nuances of SLR impacts. AOSIS nations are 550 very supportive of the work of the IPCC and reference its reports often, however their 551 researchers are significantly underrepresented on IPCC author teams (Barnett & Campbell, 2011: Livingston & Rummukainen, 2020; McSweeney, 2018; O'Reilly, 2012; Walshe, 2018). 552 553 Following the publication of IPCC AR5 in 2014 there was an expanded interest in issues of 554 justice and migration, however scholarship on this has been dominated by developed nations (Robinson, 2020). Determining the impact that SLR will have locally will require more detailed 555 556 regional studies and increased research funding (Robinson, 2020). Most current research 557 focuses on the Pacific, with Caribbean, Indian, African, and South China Sea regions 558 understudied (Douglass & Cooper, 2020; Robinson, 2020). In NDCs several AOSIS nations 559 noted wanting to collect "geospatial, migration and displacement data...but lack the financial 560 resources to do so" (Thomas & Benjamin, 2018c p95). In policy discussions and scientific 561 research there is also a lack of local community perspectives (Baptiste, 2016; Barnett, 2017; 562 Klinsky & Dowlatabadi, 2009; Perumal, 2018; Thomas & Benjamin 2018b) and traditional 563 Indigenous knowledge and other local knowledges (David-Chavez & Gavin, 2018; Kelman & 564 West, 2012). This is reflected in the words of Marshallese poet Kathy Jetñil-Kijiner reflecting on 565 her time speaking at COP negotiations "I was told to perform my poem and then sit down while 566 the professionals spoke" (Jetñil-Kijiner, 2021). Science relevant to island nations is also lacking 567 from a modeling standpoint since the resolution of global climate models used for future 568 assessments is too coarse to capture most islands and downscaling or aggregation by region 569 can obscure them (Kelman & West, 2012; Nurse et al, 2014). Bridging diverse assessments of 570 SLR, including scientific assessments, local, and Indigenous knowledge systems will aid 571 understanding of SLR impacts and responses (McMichael et al., 2021).

572

573 In sum, while SLR could potentially lead to loss of territory and migration in some places,

574 islanders have repeatedly emphasized the desire to adapt in place and not allow discourses of

575 inevitable migration to limit adaptation possibilities. In the literature there is a tendency to 576 homogenize island nations rather than gain a deeper understanding of their diverse 577 perspectives. The diversity between places means that SLR impacts will be widely varying as well. The greatest potential habitability impacts are in atolls, but even at higher elevations the 578 579 long-term SLR commitment will alter coastlines and impact populations for generations to come. 580 The extent of multigenerational recognition justice remains to be seen and will be determined by 581 nearterm policy and emissions. Increased recognition of local perspectives and further studies 582 at the regional level are needed to guide adaptation planning. As historical oppression impacts 583 adaptive capacity, recognition of this, and financial compensation, are key to any consideration 584 of climate justice. Recognition justice and the continued existence of islanders in their homes, 585 especially across generations, will be in part determined by the temporal and spatial distribution of sea level rise, which we turn to next. 586

587 4 Distributive justice

588 Distributive justice relates to addressing spatial and temporal variability of climate impacts, 589 particularly with respect to uneven contribution to the causes of climate change. Distributive 590 justice is tied to recognition justice as differences in distribution of resources and impacts are 591 often related to hierarchies in cultural, political, and social groups (Fraser, 1997). The spatial 592 and temporal distribution of sea level rise impacts are unaccounted for in GMST targets. Many 593 AOSIS nations already experience SLR rates higher than the global average, but have had very 594 low contributions to the greenhouse gas emissions driving it. This mismatch has been shown to 595 be a source of inequity (Althor et al., 2016). Moreover, higher sea levels will persist for centuries 596 to millennia, with the exact time profile to be determined by emissions pathways (Mengel et al., 597 2018). Finally, overshoot pathways, a feature of temperature targets, have become normalized 598 via integrated assessment modeling, even though overshoot pathways increase the risk of SLR 599 (DeConto et al., 2021).

600 4.1 Regional sea level rise

Regional SLR is projected to differ from GMSL (Clark & Lingle, 1977; Gomez et al., 2010;
Hamlington, 2020; Nurse et al., 2014; Oppenheimer et al., 2019). Impacts vary spatially due to
thermal expansion, gravitational, and Earth rotational effects from changing land ice storage,
glacial isostatic rebound, land subsidence, and other factors. Gravitational, Earth rotational, and

605 deformational (GRD) effects associated with ice sheet mass loss have been shown to explain 606 variations in regional sea level observed in tide gauges (Farrel & Clark, 1976; Mitrovica et al., 607 2001). Current sea level trends show high SLR rates at many AOSIS locations, though analysis 608 is complicated by sparse tide gauge locations and short observation periods (Holgate et al, 609 2013; Palanisamy et al. 2012; Hsu & Velicogna, 2017). In the Caribbean basin, the average 610 SLR is in line with the global mean (Jevrejeva et al., 2020; Palanisamy et al. 2012), however 611 small scale regional variability is large with some places experiencing substantially higher rates 612 (up to 5.3 mm/yr) (Torres & Tsimplis, 2013) and a recent rapid rise was detected (Ibrahim & 613 Sun, 2020). In the western tropical Pacific SLR rates are up to 4 times the global average 614 (Hamlington, 2020; Nurse et al., 2014). At Funafuti in Tuvalu, rates are significantly higher than 615 the global mean (5 mm/yr) with the island experiencing 30 cm of SLR over the past 60 years 616 (Becker et al., 2012). In the Indian Ocean SLR is occurring 37% faster than the global average and can differ regionally from expected rates. For instance in the Seychelles the expected rate 617 618 is 2.21 mm/yr while the actual rate is 5.19 mm/yr (Jyoti et al., 2018). 619

620 While there are regional differences, local-scale physical geographic features will also 621 determine impact (Mycoo, 2018; Simpson et al., 2010). For example, islands situated on atolls 622 and reefs typically have maximum elevations around 3 meters while volcanic islands have 623 higher elevations (Kumar & Taylor, 2015; Mimura, 1999; Nurse et al., 2014). Island nations 624 often have population centers and built infrastructure proximal to the land-ocean interface in 625 regions that already experience flooding and erosion (Magnan et al., 2019). Most Pacific island 626 nations have the majority of infrastructure within 500 m of the coast, while Tuvalu, the Marshall 627 Islands, and Kiribati have 95% of infrastructure within that distance (Kumar & Taylor, 2015). 628

629 Damage from SLR is often due to extreme sea level events arising from storm surge, cyclones, 630 wave propagation or other factors. Tropical storms lead to the largest sea level extremes in the 631 South Pacific and northern Caribbean. The severity and frequency of these events is intensified 632 by climate warming in a number of ways, including through sea level rise. Tropical storms have 633 caused damage to island nations in recent years, a trend projected to worsen, even under low 634 emissions (Hoegh-Guldberg et al., 2018; Magnan et al., 2019). In many locations, flood events 635 that historically occurred once every hundred years are projected to become annual in the coming decades even under RCP2.6 (Oppenheimer et al., 2019). Modeling work in Fiji has 636 637 shown that local inundation impacts will vary based on topography, bathymetry, and wind 638 conditions (Sabūnas et al., 2020). The impact of waves in addition to SLR can double flood

639 heights during extreme events (Arns et al., 2017; Biondi & Guannel, 2018). Wave impacts can 640 also double the inundation area, which could make some atolls uninhabitable within decades 641 (Storlazzi et al., 2015). A study considering nonlinear interactions between SLR and wave 642 induced overwash finds two tipping points for atoll islands by mid-century under Paris compliant 643 pathways- a lack of potable drinking water due to salinization and the time at which more than 644 half of the island could experience annual flooding (Storlazzi et al., 2018). Using an updated 645 methodology for assessing elevation it was found that 1 million people in the Caribbean live less 646 than 1 m above local high tide while 600,000 less than 0.5 m above tides. Flooding of 0.5 m 647 above high tide could be common within decades with floods above 1 m occurring by 2100 648 (Strauss, & Kulp, 2018). Assessments of atoll habitability will need to consider multiple 649 interlocking risk factors to understand how risk varies in different locations (Duvat et al., 2021). 650 Due to these complicating factors local scale impacts in island nations can be substantial, and 651 are worsened by warming above 1.5°C (Hoegh-Guldberg et al., 2019).

652 4.2 Temporal justice

SLR is a slow onset event which presents intergenerational equity concerns. Temporal justice is a guiding principle stated in Article 3 of the UNFCCC: "the Parties should protect the climate system for the benefit of current and future generations" (UN, 1992). Paris Agreement Article 8 states "the importance of averting, minimizing and addressing loss and damage associated with the adverse effects of climate change, including...slow onset events." SLR is a slow onset event which presents intergenerational equity concerns.

659

660 Sea level rise will increase over time, therefore assessing the climate justice implications of 661 temperature targets necessitates a consideration of distributive impacts over the long-term. The 662 year 2100, while not directly mentioned within the Paris Agreement, is the main point of 663 temporal reference generally associated with it. While policy discussions focus primarily on the 664 current century, many predicted changes to the Earth system, including SLR, are irreversible. 665 The implications for intergenerational equity are vast considering sea levels are projected to 666 continue to rise for thousands of years, with no hope of returning to present values for the 667 foreseeable future (Clark et al., 2016; DeConto et al., 2021; Oppenheimer et al., 2019). The long-term SLR committed by the NDCs is at least 1 m by 2300 and higher thereafter unless the 668 world stays below 1.5°C (DeConto et al., 2021; Fox-Kemper et al., 2021; Nauels et al., 2019). 669 670 Even if a 1.5°C temperature target is achieved, SLR could still rise by 2.3-3.1 m over 2000 years

- and 6-7 m over 10,000 years. Under 2°C the commitment would be 2-6 m and 8-13 m,
- 672 respectively (Clark et al., 2016; Fox-Kemper et al., 2021).
- 673

Past inaction suggests that these temporal justice concerns may accelerate in the future. It took 23 years from the UNFCCC establishment to the creation of the Paris Agreement, while emissions continued to increase (Figure 1b). Emissions released over that time have increased the long-term SLR commitment. An analysis of this commitment shows that emissions that occured between 1991-2016 will lead to 12 cm more SLR by 2100 and 25 cm more by 2300. Of these values, emissions from the top 5 highest emitters during that time period (China, US, EU, Russia, India) are responsible for 7 cm by 2100 and 14.4 cm by 2300 (Nauels et al., 2019).

4.3 Overshoot pathways and integrated assessment modeling

682 Spatial and temporal justice concerns are magnified by the current trend in the acceptance of 683 overshoot pathways. Overshoot pathways allow for the temporary exceedance of the 684 temperature target if it can be returned to at a later time, for example, by using negative 685 emissions technologies such as carbon capture to reduce atmospheric greenhouse gas 686 concentrations and GMST (Rogelj et al., 2018). The Paris Agreement came with an invitation for 687 the IPCC to compile a Special Report assessing pathways by which the goals were achievable 688 and highlighting differences in impact and risk between 1.5-2°C (Ourbak & Tubiana, 2017; 689 UNFCCC, 2016). This invitation represented a shift in interaction between scientists and policy 690 as it was the first time the IPCC directly engaged with the question of the temperature targets 691 which were formerly thought to be too political and thus not in line with the IPCC mandate to be 692 policy relevant but not policy prescriptive (Livingston & Rummukainen, 2020). The report 693 showed substantial differences in risk between the two temperature goals and found that the 694 majority of 1.5°C-compliant emissions pathways required temperature overshoot (Rogelj et al., 695 2018).

696

Integrated assessment models (IAMs) used to produce the pathways are optimization models operating under neoclassical economic assumptions (Carton, 2019) which rely on "minimization of mitigation expenditures, but not climate-related damages" (Rogelj et al., 2018 p98). In other words, while they model the costs and feasibility of different scenarios, they do not consider the cost of climate damages. Specifically, when IAMs contain overshoot pathways there is no accounting for irreversible climate damages incurred during an overshoot period which would

703 not have happened in the absence of overshoot (Tavoni & Socolow, 2013). Modelled pathways 704 from IPCC AR4, released in 2007, primarily assessed scenarios with atmospheric CO₂ 705 concentrations of 550-650 ppm. The few IAMs that considered a lower 450 ppm concentration 706 broadly consistent with 2°C targets incorporated overshoot and drawdown with carbon dioxide 707 removal, a new modeling development at the time. This dramatically underestimated the cost, 708 making those scenarios look more feasible (Tavoni & Tol, 2010). At that time European nations 709 were consolidating around support for 2°C, modelers were asked to further assess these more 710 stringent pathways for IPCC AR5 (Randalls, 2010; Tavoni & Socolow, 2013). This required 711 expanding use of overshoot pathways to be achievable (Tavoni & Socolow, 2013). The 712 normalization of overshoot pathways, thus, serves to allow the continuation of the status quo 713 fossil fuel-based emissions and in turn helps to justify delays in mitigation during international 714 climate negotiations. This process has been termed the "political economy of delay" (Carton. 715 2019). Since IAMs rely on cost-minimization, anticipating negative emissions becomes a 716 substitute for near-term emissions reductions. However negative emissions technologies are 717 unproven and one analysis determined that if they fail to deliver the stated reductions or come 718 with side effects, they could increase overshoot by up to 1.4°C (McLaren, 2020). Distributive 719 justice issues inherent in integrated assessment modeling have only recently been 720 acknowledged within the modeling community (Jafino et al., 2021).

721

722 The distributive implications of climate policy are key for assessing justice (Klinsky & 723 Dowlatabadi, 2009) and the additive sea level impacts caused by overshoot presents a key 724 challenge to distributive justice. Framing overshoot pathways as acceptable under the Paris 725 Agreement simultaneously justifies the targets as achievable, while legitimizing the lack of 726 action likely to render them unachievable. If the $>2^{\circ}C$ pathway implied by the NDCs is followed, 727 implementing carbon dioxide removal after 2060 in hopes of meeting the Paris Agreement goal 728 will likely be too late to prevent a sharp jump in SLR. Every decade of delay thereafter comes 729 with a commitment to higher, long-term SLR despite reductions in GMST (DeConto et al., 2021). 730 If the commitments to future SLR are locked in, then the inclusion of pathways that allow for an 731 overshoot exacerbate the distributive climate justice issues brought about by insufficient global 732 climate action.

733

In sum, overshoot pathways have been used to justify nearterm delays in emissions reductions.

735 Their normalization within the global climate and policy spheres, will exacerbate pre-existing

736 justice issues for communities confronting sea level rise. AOSIS nations are already

experiencing higher than average rates of SLR in many locations. Given their small contribution
to emissions, the impacts of sea level rise present a distributive injustice. As discussed next,
this trend of higher impacts from SLR will become more severe if Antarctic instability thresholds
are breached.

741

742 The preceding three sections have looked into procedural, recognition, and distributive justice 743 considerations of using GMST, normatively framed as being by 2100, as the international metric 744 for climate action. We have found that procedural power dynamics between negotiating parties 745 solidified the GMST target as opposed to a target like binding emissions reductions initially 746 advocated by AOSIS negotiators. Furthermore, sea level rise has an uneven spatial footprint, 747 long term irreversible impact, and can become exacerbated by the overshoot pathways 748 normalized by temperature targets. The impacts of sea level rise have long been a concern to 749 AOSIS nations as they threaten the physical spaces and cultural practices of these nations. We 750 now turn to highlighting the complexities of the Earth system processes that contribute to future 751 SLR and the implications of these complexities for AOSIS nations through a case study of the 752 Antarctic Ice Sheet (AIS) component of SLR.

753 5 Antarctic case study

754 The Antarctic Ice Sheet is the biggest wildcard in SLR projections and has the potential to 755 dominate the long-term response. Scientific knowledge of Antarctica and its contribution to SLR 756 has expanded greatly in the past few decades. The Antarctic component of SLR will exacerbate 757 the uneven impacts for AOSIS nations and others over the coming centuries (Figure 2). AIS 758 melt could also lead to negative feedbacks on GMST rise (Golledge et al., 2019; Sadai et al., 759 2020), which could potentially be used to justify the increase in allowable carbon budgets further 760 enabling the political economy of delay. It is crucial to understand that any negative feedbacks 761 on GMST resulting from AIS melt would occur in conjunction with SLR and would therefore be 762 at the expense of AOSIS nations and coastal communities, exacerbating climate injustice.

763 5.1 Historical and current Antarctic science

The AIS stores the largest potential reservoir of freshwater, with a GMSL equivalent of 58
meters (Morlighem et al., 2020), and the current science projects it could become the largest
contributor to long-term SLR (Clark et al., 2016; DeConto et al., 2021; Fox-Kemper et al., 2021;

767 Golledge et al., 2015; Rintoul et al., 2018). Antarctica has a unique bed configuration in which 768 substantial regions of the ice sheet are in direct contact with the ocean and lie on bedrock below 769 sea level (Morlighem, 2020) making it vulnerable to instabilities. This has been a cause for 770 concern since the 1970s (Mercer, 1978; Oppenheimer & Alley, 2005; Weertmen, 1974). While 771 the combined melting of land ice (Antarctica, Greenland, and all glaciers) is already the 772 dominant component of SLR, exceeding the rate of thermal expansion (Oppenheimer et al., 773 2019), Antarctica could become the primary contributor under high emissions scenarios leading to non-linearly increasing SLR (Rintoul et al., 2018). Under such circumstances the current rate 774 775 of global mean SLR of ~3.6 mm/yr (2006-2015) could increase by an order of magnitude to 776 rates of centimeters per year (Oppenheimer et al, 2019).

777

The science of the Antarctic contribution to SLR has advanced significantly over the past 778 decades, as has modeling showing the projected climatic impacts. While portions of the AIS 779 780 were known since the 1970's to be vulnerable to destabilization, throughout the 90s and into the 781 2000s the first, second, and third Intergovernmental Panel on Climate Change (IPCC) reports 782 reflected the scientific consensus at the time which was that AIS would almost certainly have a 783 net gain of mass through 2100 (Figure 1a). This is due to higher snowfall in a warming 784 atmosphere, the result being AIS contributing to a sea level fall instead of rise (Church et al., 785 2001; Warrick & Oerlemans, 1990; Warrick, et al. 1996). Models used for projections in the 786 IPCC Third Assessment Report (TAR) in 2001 had ruled out dynamical processes occurring in 787 the 21st century which could result in larger SLR from AIS instability as these were assumed to 788 only be possibly on longer multi-century timescales with warming of a few degrees (Church et 789 al., 2001), however scientific advancements following its publication suggested that threat was 790 likely underestimated (O'Reilly et. al, 2012; Rapley, 2006). Shortly before the publication of 791 IPCC Assessment Report 4 (AR4) in 2007, observational evidence showed that rapid ice loss 792 was already occurring in sensitive regions of the West Antarctic Ice Sheet. These results were 793 discovered too late to be included in the report, though were noted by the author team (IPCC, 794 2007; O'Reilly, 2012).

795

By the time of IPCC Assessment Report 5 (AR5) in 2014, physics based models had advanced
significantly and showed the potential for larger Antarctic SLR contributions (Church, 2013;
O'Reilly, 2012). The ice sheet modeling community was increasingly recognizing that marine
based sectors of the AIS were vulnerable to instability. This was recognized within AR5 where it
states "Only the collapse of the marine-based sectors of the Antarctic ice sheet, if initiated,

801 could cause GMSL to rise substantially above the likely range during the 21st century. This 802 potential additional contribution cannot be precisely quantified but there is medium confidence 803 that it would not exceed several tenths of a meter" (Church, 2013, p. 1140). This led to 804 expanded research into instability points following the release of this report. At present, 805 observation evidence shows an increasing SLR contribution (Shepherd et al, 2018). Modeling 806 developments are showing the potential for even greater Antarctic ice loss than previously 807 projected mainly as a result of brittle glaciological processes including meltwater-enhanced 808 break up of ice shelves and rapid calving at tall ice cliffs, not included in previous modeling 809 studies. Yet despite observational evidence of these processes in nature there is ongoing 810 debate regarding their validity and their application to Antarctica (DeConto & Pollard, 2016; 811 DeConto et al., 2021; Edwards et al., 2019; Fox-Kemper et al., 2021). There is a long-standing 812 documented tendency for scientists to err on the side of more conservative estimates, which 813 contributed in the past to the lower AIS SLR estimates seen in TAR and AR4 (Brysse, 2013). 814 Yet erring on the side of conservative estimates can work in opposition to the precautionary 815 principle enshrined in the UNFCCC as policymakers are generally not preparing for the worst 816 case scenarios (Brysse, 2013).

817

818 Today, much of the Antarctic continent is fringed by buttressing ice shelves that slow the 819 seaward flow of the ice sheet (Fürst et al., 2016). The loss of these ice shelves can trigger 820 dynamic instabilities in the ice sheet, with the potential to produce rapid sea level rise 821 (Oppenheimer et al., 2019). Recent work suggests the global warming threshold for the onset of 822 widespread ice-shelf loss could be as low as 1.5-3°C (DeConto et al., 2021; Fox-Kemper et al., 823 2021; Hoegh-Guldberg et al., 2018). One recent modeling study showed that with global mean 824 warming limited to less than 2°C, SLR from Antarctica will likely remain modest within the 825 current century but could rise to 1-2 m on multi-century timescales (DeConto et al., 2021; Fox-826 Kemper et al., 2021). Given that Paris Agreement aspirations are not currently being met, it 827 remains prudent to consider the implications of temperatures exceeding 2°C this century. With 828 3°C warming committed by the current NDCs, sea levels are projected to rise up to 0.2 m this 829 century, and 1.5 m by 2300 from the AIS contribution alone (DeConto et al., 2021). 830 Temperatures beyond 3°C could lead to substantial disintegration of the marine-based sectors 831 of the ice sheet (Fox-Kemper et al., 2021). Once ice shelves are lost and instabilities are 832 triggered, the long thermal memory of the ocean will impede the re-growth of the ice sheet, 833 leading to centuries of ongoing SLR even if carbon dioxide is removed from the atmosphere 834 (DeConto et al., 2021).

5.2 Projections of AIS SLR for AOSIS locations

836 As the ice sheet loses mass, reduced gravitational attraction between ice and water leads to a 837 draw down of the sea surface resulting in sea levels falling within ~2000 km of the melting ice 838 sheet, while sea level rises outside this zone increasing with distance from the location of ice 839 loss. Uplift of the solid Earth beneath retreating marine sectors of the AIS reduces water 840 accommodation space and expels water out into the global ocean, amplifying the SLR away 841 from Antarctica (Gomez et al., 2010; Pan et al., 2021). A shift of the Earth's rotation axis 842 towards the missing ice mass, and Earth deformation associated with water loading across the 843 global ocean both contribute further geographic variability in the far field sea level rise. 844

845 The maps showing spatial heterogeneity of SLR produced by Antarctic ice loss in Figure 2 846 indicate that regions in the Atlantic, Pacific, and Indian ocean basins are at disproportionate risk 847 from the AIS component of SLR (Gomez, et al., 2010; Mitrovica et al., 2011). These maps show 848 how much regional sea level would differ from the global mean for each of the 38 AOSIS 849 member nations. We find that all AOSIS countries will experience SLR from Antarctica that is at 850 least 11.6% higher than the global mean and that the majority (22-32 countries, depending on 851 scenario) will experience an average SLR more than 20% higher than the global mean, with 852 some up to 33% higher (Table 1, Figure 2). This remains true regardless of emissions 853 trajectories (medium-high emissions) or time periods considered (2100-2300) (see Methods). 854 Under high emissions simulations where the ice sheet includes marine ice cliff instability (MICI) 855 in addition to marine ice sheet instability (MISI) the spatial pattern changes slightly. MISI occurs 856 when buttressing support from fringing ice shelves is lost in sections where the bed deepens 857 upstream, leading to runaway retreat of the grounding line. MICI is theorized to occur when 858 fringing ice shelves are lost, leading to the exposure of ice cliffs at thick ice margins, which are 859 vulnerable to collapse if they exceed a critical height and lose structural integrity (DeConto & 860 Pollard, 2016; Pattyn et al., 2018).

861

Due to GRD effects, the spatial pattern of Antarctic-driven SLR shows the largest amplification
occurring near the center of ocean basins, with values tapering by coastlines (Gomez et al.,
2010; Figure 2). As a result, Mauritius (near the center of the Indian Ocean) experiences the
highest SLR of all AOSIS nations. The countries experiencing the second and third highest SLR
are the Bahamas and Cuba due to their positioning within a North Atlantic basin sea level bulge.
This pattern holds across both emissions scenarios and all time periods where the ice model

868 only considers MISI processes. In the case where both MISI and MICI processes are included 869 the sea level bulge over the Pacific Ocean is more centered over the basin leading to the 870 western Pacific experiencing the highest AIS-sourced SLR. The most impacted nations under 871 this scenario are the Marshall Islands, Kiribati, Nauru, the Federated States of Micronesia, 872 Tuvalu, and Palau. In either scenario the Cook Islands, Guyana, Suriname, Guinea-Bissau, and São Tomé and Príncipe consistently see the least amplification of SLR, though importantly it 873 874 remains 12-17% above the global mean. This is due to their geographic placement. The Cook Islands are the southernmost islands of Oceania, closest to the Antarctic Ice Sheet and the 875 876 delineation between sea level rise and sea level fall. The remaining countries with lower impact 877 lie in regions of tapering sea level impact along continental margins: São Tomé and Príncipe are the largest islands of archipelagos close to the western equatorial coast of Africa, Guyana and 878 879 Suriname are continental lying on the northern coast of South America, while Guinea-Bissau is 880 on the northwest coast of Africa.

881

	RCP45 MISI 2100 PAGM	RCP45MISI 2200 PAGM	RCP45 MISI 2300 PAGM	RCP45 MISI 2100 MEAN SLR (m)	RCP45 MISI 2200 MEAN SLR (m)	RCP45 MISI 2300 MEAN SLR (m)	RCP85MISI 2100 PAGM	RCP85MISI 2200 PAGM	RCP85 MISI 2300 PAGM	RCP85MISI 2100 MEAN SLR (m)	RCP85MISI 2200 MEAN SLR (m)	RCP85 MISI 2300 MEAN SLR (m)	RCP85MICI 2100 PAGM	RCP85MICI 2200 PAGM	RCP85MICI 2300 PAGM	RCP85 MICI 2100 MEAN SLR (m)	RCP85 MICI 2200 MEAN SLR (m)	RCP85 MICI 2300 MEAN SLR (m)
Antigua and Barbuda	28.84	27.24	27.32	0.073	0.24	0.462	30.03	27.89	28.59	0.043	0.487	1.654	22.88	23.19	21.81	0.418	6.566	11.657
Bahamas	30.99	29.31	29.44	0.075	0.244	0.47	32.66	30.4	30.95	0.044	0.497	1.684	23.1	23.53	21.64	0.419	6.584	11.641
Barbados	25.76	24.22	24.34	0.072	0.234	0.451	26.58	24.66	25.56	0.042	0.475	1.615	20.91	21.6	20.67	0.411	6.481	11.548
Belize	25.21	23.36	23.55	0.071	0.233	0.448	26.22	24.44	25.28	0.042	0.474	1.611	19.28	20.38	18.99	0.406	6.416	11.388
Comoros	22.59	21.19	21.58	0.07	0.229	0.441	23.27	21.58	22.94	0.041	0.463	1.581	14.58	17.71	17.41	0.39	6.274	11.236
Cook Islands	14.29	13.4	12.81	0.065	0.214	0.41	14.03	12.24	12.85	0.038	0.428	1.451	17.06	15.86	16.17	0.398	6.176	11.117
Cuba	29.64	27.96	28.11	0.074	0.242	0.465	31.11	28.98	29.65	0.043	0.491	1.667	22.31	23.01	21.33	0.416	6.556	11.611
Dominica	27.59	26.02	26.12	0.073	0.238	0.458	28.62	26.57	27.36	0.042	0.482	1.638	22.07	22.55	21.36	0.415	6.532	11.614
Dominican Republic	28.77	27.1	27.21	0.073	0.24	0.462	30.08	27.96	28.62	0.043	0.488	1.654	22.25	22.65	21.06	0.416	6.537	11.586
Federated States of																		
Micronesia	26.54	24.71	25.1	0.072	0.236	0.454	26.14	24.82	26.5	0.042	0.476	1.627	24.94	26.95	27.39	0.425	6.766	12.191
Fiji	22.3	21.14	20.69	0.07	0.229	0.438	23.18	20.74	20.95	0.041	0.46	1.555	20.52	18.52	17.29	0.41	6.317	11.225
Grenada	23.99	22.43	22.57	0.071	0.231	0.445	24.71	22.88	23.84	0.041	0.468	1.593	19.44	20.33	19.49	0.406	6.414	11.435
Guinea-Bissau	16.67	15.09	15.1	0.067	0.218	0.418	16.94	15.42	16.34	0.039	0.44	1.496	14.51	14.96	14.35	0.389	6.127	10.944
Guyana	13.66	12.02	12.21	0.065	0.212	0.407	13.6	12.37	13.63	0.037	0.428	1.461	11.65	13.17	12.93	0.38	6.032	10.807
Haiti	28.72	27.04	27.16	0.073	0.24	0.462	30.02	27.92	28.6	0.043	0.487	1.654	22.14	22.63	21.06	0.415	6.536	11.585
Jamaica	28.66	27.02	27.17	0.073	0.24	0.462	29.89	27.84	28.63	0.043	0.487	1.654	22.12	22.89	21.48	0.415	6.55	11.626
Kiribati	28.44	26.73	26.93	0.073	0.24	0.461	28.41	26.78	28.11	0.042	0.483	1.648	26.59	27.73	27.76	0.43	6.808	12.227
Maldives	20.91	19.31	19.54	0.069	0.236	0.434	20.76	19.35	20.77	0.04	0.455	1.553	18.34	20.23	20.51	0.402	6.408	11.533
Marshall Islands	28.92	27.06	27.46	0.073	0.24	0.463	28.65	27.22	28.85	0.042	0.485	1.657	26.93	28.86	29.18	0.432	6.868	12.362
Mauritius	32.13	30.65	31.07	0.075	0.247	0.476	33.99	31.64	32.61	0.044	0.502	1.705	18.58	21.94	20.53	0.403	6.5	11.534
Nauru	27.95	26.24	26.42	0.073	0.239	0.459	28.1	26.36	27.58	0.042	0.481	1.641	25.58	26.41	26.17	0.427	6.738	12.075
Niue	19	17.98	17.45	0.068	0.223	0.426	19.38	17.18	17.54	0.039	0.446	1.512	19.34	17.61	17.07	0.406	6.268	11.203
Palau	22.71	20.96	21.33	0.07	0.229	0.44	22.19	21	22.72	0.04	0.461	1.578	21.46	23.58	24.17	0.413	6.587	11.883
Papua New Guinea Republic of Cabo	22.09	20.38	20.41	0.07	0.228	0.437	22.85	20.99	21.71	0.041	0.461	1.565	18.17	18.35	17.16	0.402	6.308	11.212
Verde	24.58	23.08	23.05	0.071	0.233	0.447	25.26	23.32	24.09	0.041	0.47	1.596	21.17	21.15	20.28	0.412	6.457	11.51
Saint Kitts and Nevis	28.79	27.19	27.28	0.073	0.24	0.462	29.98	27.85	28.55	0.043	0.487	1.653	22.8	23.12	21.74	0.418	6.562	11.65
Saint Lucia	26.27	24.72	24.84	0.072	0.236	0.453	27.16	25.2	26.07	0.042	0.477	1.621	21.18	21.81	20.79	0.412	6.492	11.56
Saint Vincent and the																		
Grenadines	25.48	23.93	24.05	0.072	0.234	0.45	26.3	24.39	25.29	0.042	0.474	1.611	20.58	21.3	20.36	0.41	6.465	11.518
Samoa	22.73	21.47	21.16	0.07	0.23	0.44	23.07	20.99	21.61	0.041	0.461	1.564	22.19	21.22	20.74	0.415	6.461	11.555
São Tomé and																		
Principe	15.16	13.83	14.1	0.066	0.215	0.414	14.89	13.69	15.24	0.038	0.433	1.482	12.68	14.79	15.2	0.383	6.118	11.025
Seychelles	23.86	22.37	22.68	0.071	0.231	0.445	24.38	22.68	23.99	0.041	0.467	1.595	17.41	19.93	19.69	0.399	6.392	11.454
Singapore	18.96	17.19	17.44	0.068	0.221	0.426	19.04	17.71	18.99	0.039	0.448	1.53	15.95	17.77	17.62	0.394	6.277	11.256
Solomon Islands	26.31	24.81	24.74	0.072	0.236	0.453	27.16	25	25.63	0.042	0.476	1.616	22.69	22.06	20.89	0.417	6.506	11.569
Suriname	13.91	12.28	12.49	0.065	0.212	0.408	13.79	12.57	13.88	0.038	0.429	1.465	12.05	13.62	13.48	0.381	6.056	10.86
Timor-Leste	24.67	23.12	23.2	0.071	0.233	0.447	25.89	23.83	24.5	0.042	0.472	1.601	18.36	18.44	16.9	0.402	6.313	11.187
Tonga	19.6	18.59	18.02	0.068	0.224	0.428	20.26	17.87	18.05	0.04	0.449	1.518	19.1	16.93	16	0.405	6.232	11.102
Trinidad and Tobago	21.41	19.82	19.97	0.069	0.226	0.435	21.95	20.28	21.3	0.04	0.458	1.56	17.48	18.63	17.95	0.399	6.323	11.288
Tuvalu	25.84	24.39	24.26	0.072	0.235	0.451	26.27	24.21	24.97	0.042	0.473	1.607	24.09	23.59	22.99	0.422	6.587	11.77
Vanuatu	21.78	23.26	22.9	0.071	0.233	0.446	25.75	23.19	23.33	0.041	0.469	1.586	21.01	18.98	17.29	0.411	6.342	11.224
GMSL				0.057	0.189	0.363				0.033	0.381	1.286				0.34	5.33	9.57
	Note: PAGM stands for percentage above global mean																	

882

883

Table 1. Projected Antarctic contribution to sea level rise at AOSIS member locations. Values

885 are given for percentage above global mean (PAGM), and for absolute sea level rise for three

time periods (2100, 2200, 2300) and three scenarios- RCP4.5 with only MISI dynamics, RCP8.5

887 with only MISI dynamics, and RCP8.5 with both MISI and MICI dynamics. Values for global

888 mean sea level under each scenario are provided in bold for comparison.



≤0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 0.1 1 0.5 0.5 1.1 0.1 1.2 0.1 1.2 0.1 1.2 0.1 1.3 0.1 1

Regional sea level rise compared to the global mean





890 **Figure 2.** Sea level rise predictions normalized by global mean sea level rise. a) The spatial

distribution of the Antarctic contribution to sea level rise at 2100 (relative to 2000) under an

892 RCP4.5 emissions scenario (without MICI) demonstrates that AOSIS members are highly

893 impacted. The purple line indicates where SLR values are equal to GMSL. Closer sections are

shown for b) the Indian Ocean c) the Caribbean and Atlantic, and d) Oceania.

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897 While these sea level calculations provide a regional perspective on the distribution of SLR from 898 Antarctic ice loss, the actual impacts felt in these countries are highly variable at the local level 899 and influenced by socio-political factors in addition to physical impacts. Across all the scenarios, 900 sea level continues to rise for centuries (Table 1). Values in this table are a lower bound as they 901 only reflect the AIS contribution to SLR and not the components from thermal expansion, Greenland mass loss, and other factors. AOSIS nations are not the only ones to experience an 902 903 Antarctic contribution to SLR above the global mean, but we stress the distributive justice issues 904 in relation to their advocacy for more stringent climate targets, the inherent vulnerability many 905 have to SLR, and their extremely low contribution to greenhouse gas emissions (Figure 1b).

906 5.3 Impacts of Antarctic ice loss on climate

In addition to SLR, AIS melt impacts the global climate system in complex ways. These
interconnections have been difficult to constrain, because most global climate models (GCMs)
used to predict future climate impacts and inform policy, don't include dynamic, interactive icesheet components in part due to the complexity of modeling the two-way interactions between a
changing ice sheet with the surrounding ocean and overlying atmosphere (Meijers, 2014).

913 Recent modeling incorporating ice-ocean-atmosphere interactions have demonstrated that 914 freshwater and ice discharged from the AIScan have a negative feedback on GMST- delaying 915 the rise in air temperature while simultaneously raising global sea levels (Bronselear, 2018; 916 Golledge, 2019; Sadai et al, 2020; Schloesser, 2019). Model responses show a decrease in 917 salinity induced by freshwater input into the saline Southern Ocean which raises the freezing 918 temperature of the water while increasing stratification. Expanded sea-ice and stratification 919 stabilizes the water column, inhibiting the normal vertical mixing that is important for distributing 920 heat. This stratification results in the accumulation of heat in subsurface layers, warming the 921 ocean at intermediate depths around Antarctica, a process that can increase melting at the base 922 of the ice shelves that fringe the continent. At the same time, freshwater induced expansion and 923 thickening of perennial sea-ice around the continental margin increases albedo, reflecting more 924 solar radiation to space. This negative sea-ice-albedo feedback slows the pace of warming 925 around and over Antarctica and the cooling feedback is felt globally. Overall, model simulations 926 show GMST values 0.3-1°C lower at the end of the 21st century under high emissions scenarios 927 when meltwater impact is considered (Bronselear et al., 2018; Golledge et al., 2019; Sadai, 928 2020). Looking beyond the current century, model results indicate that this meltwater feedback 929 reduces the amount of global warming by up to 2.5°C during peak ice loss under RCP8.5 930 (around the year 2120, Figure 3) and up to 1°C under RCP4.5 (by mid 22nd century) (Sadai et 931 al., 2020).



933

934 Figure 3. Sea level rise and negative feedbacks on GMST. Under an RCP8.5 emissions 935 scenario one climate model predicted GMST response to meltwater could be over 2°C lower at 936 peak ice sheet collapse. When driven with these climatologies, an ice sheet model predicts that 937 meltwater delays ice sheet loss but that up to 7 m of sea level rise is still locked in over the

- 938 coming centuries.
- 939

940 This negative feedback on GMST rise impacts the ice sheet's stability and contribution to SLR.

941 First, increased subsurface warming could accelerate the melting of buttressing ice shelves that 942 could lead to faster SLR (Golledge et al., 2019). However, in models that consider the effect of 943 atmospheric warming and meltwater on ice shelf surfaces, the albedo cooling feedback slows 944 the pace of ice loss despite the warmer sub-surface ocean (DeConto et al., 2021). Although, 945 even in the high emissions RCP8.5 scenario in which negative feedbacks can substantially 946 lower GMST during peak ice loss, model projections still yield ~0.5 m of SLR from Antarctica 947 alone by mid-century and 7 m by 2250 (Figure 3) (DeConto et al., 2021; Sadai et al., 2020). In a 948 scenario in line with a 1.5-2°C Paris GMST target, these ice-sheet induced negative feedbacks 949 on GMST would be small, the risk of triggering widespread ice sheet instabilities in Antarctica 950 would be small, and the rate of SLR would remain similar to today throughout the 21st century 951 (DeConto et al., 2021), giving island nations and coastal communities a better chance at adapting in place. However, as of 2021, submitted NDCs commit ~2.7°C warming (UNFCCC, 952 953 2021), and current policies would lead to 2.9°C warming (Climate Action Tracker, 2021). In this scenario, SLR rates and magnitudes will be much higher, and pose much larger threats during 954 955 this century (DeConto et al., 2021) while at the same time triggering larger negative feedbacks 956 on GMST.

957 5.4 Negative ice-loss feedbacks and carbon budgets

958 While the combined effect of all known climate feedbacks is thought to be positive (Forster et 959 al., 2019), the existence of negative feedbacks, particularly when they are correlated with 960 climate impacts that enhance vulnerability of specific populations (in this case AOSIS nations), 961 are critical components to assessing the justice implications of temperature targets. Carbon 962 budgets, which predict the remaining emissions before a given temperature is exceeded, can be 963 calculated in a variety of ways (Rogelj et al, 2016). Current estimates of the remaining carbon 964 budget generally do not account for feedbacks within the climate system, including the strong 965 Antarctic ice loss-cooling feedback described here. Attempts to estimate the impact of these 966 feedbacks yields a low probability that they will increase the remaining budget and a high 967 probability that they will lower it, primarily due to the large additional warming contribution from 968 permafrost melt (Lowe & Bernie, 2018). A framework for standardizing the way carbon budgets 969 are calculated has called for the inclusion of feedbacks into budget calculations (Rogeli et al., 970 2019). To our knowledge the impact that negative feedbacks resulting from AIS discharge would 971 have on carbon budgets has never been estimated. Given that the feedback is negative, on its 972 own it would raise the remaining allowable emissions, however it remains unclear how this 973 would interface with other positive feedback mechanisms like permafrost melt. Furthermore and

974 crucially, any reduction in GMST resulting from Antarctic ice loss would come at the expense of 975 flooded coastlines in AOSIS countries and around the world. If emissions budget estimates are 976 raised, and high emitters use it as justification for delaying mitigation, this could lead to greater 977 long-term SLR. This scenario would exacerbate already existing trends that disadvantage island 978 nations and other coastal communities. With the low remaining carbon budgets for the Paris 979 goals, it is possible that the impact of feedbacks on policy will be small. However if temperature 980 continues to be used as an LTGG during future negotiations, particularly on post-2100 981 timescales, the inclusion of negative feedbacks could become more relevant. In this eventuality, 982 negative feedbacks entangled with SLR will be a key component in assessing the climate justice 983 impacts of policy decisions.

984 Conclusions

The adoption of global mean surface temperature as a target for climate action has significant
procedural, recognition, and distributive justice issues when considering the effects of sea level
rise. Physical sciences alone are inadequate to fully assess climate justice considerations.
Here, we integrate the historical legacy of policy decisions and key findings from the physical
and social sciences to gain a greater understanding of how climate justice interfaces with SLR
and temperature targets.

991

992 Within the framework of the UNFCCC climate negotiations the Alliance of Small Island States 993 has been pivotal in bringing to the forefront the needs of countries most concerned with the 994 impacts of sea level rise. AOSIS countries have had many successes in UNFCCC negotiations 995 and were instrumental in gaining the inclusion of the lower 1.5°C temperature target into the 996 Paris Agreement following unification of the international community around temperature 997 targets. However, uneven power divisions within the negotiating landscape favored high carbon-998 emitting nations and led to a weak and disembedded LTGG lacking enforcement mechanisms. 999 As a metric, global mean surface temperature by 2100 fails to fully encompass the UNFCCC 1000 Article 2 goal of avoiding dangerous anthropogenic interference in the climate system when 1001 considering the regional and temporal variations of rising sea levels. The adoption of a GMST 1002 target led to the normalization of overshoot pathways via integrated assessment modeling. 1003 These pathways enable the political economy of delay that is used to justify a lack of nearterm 1004 emissions reductions. As climate damages incurred during an overshoot are not accounted for, 1005 the use of these pathways can increase vulnerability to sea level rise. Vulnerability is shaped by

a variety of physical and sociopolitical factors and will vary at the regional, national, and local
scales. Recognition of historical factors impacting ongoing vulnerability, such as colonization, as
well as considering how migration and displacement are discussed, will be key factors in
assessing climate justice implications of SLR. Greater inclusion of the voices of island
inhabitants is needed in the scientific and policy spheres; social sciences and humanities work
has focused on this, which we have highlighted here.

1012

1013 The complications presented by the entangled climate impacts from sea level rise and negative 1014 feedbacks on GMST arising from Antarctic Ice Sheet destabilization provide a case study for 1015 assessing climate justice. These dual AIS impacts exacerbate climate inequities inherent in 1016 GMST targets. This is seen in 1) the disproportionate impact of the Antarctic contribution to sea 1017 level rise on island nations relative to their emissions, 2) the possibility for AIS to become the 1018 dominant contributor to SLR exacerbating the long-term and irreversible commitment to rising 1019 seas and its associated multigenerational recognition justice issues, and 3) the potential for 1020 islands to be pushed past adaptation limits, while at the same time the threat of extreme 1021 warming is reduced. As recent modeling developments demonstrate negative feedbacks on 1022 GMST arising from ice sheet loss, these findings could lead to higher allowable carbon budgets 1023 under the Paris Agreement goals. The potential for higher carbon budgets and emissions could 1024 further entrench the political economy of delay, thus slowing emissions reductions while further 1025 impacting communities vulnerable to sea level rise. The long-term commitment to rising seas, 1026 potential impacts of AIS melt on carbon budgets, and the historical injustices that increase 1027 vulnerability and exacerbate recognition justice issues are areas needing further study. Future 1028 work should investigate other ways climate system feedbacks on GMST could have 1029 ramifications for vulnerable communities and climate justice.

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1035

1036 Open Research

1037 Literature review- A search was conducted across multiple databases including Directory of 1038 Open Access Journals, Gale, ERIC, and Academic Search Premier for combinations of search 1039 terms- climate justice, recognition justice, distributive justice, procedural justice, sea level rise, 1040 AOSIS, Caribbean, Indian Ocean, Pacific, temperature targets. Back searches were done on 1041 included references as needed. In addition to the database search the Journal of Island Studies 1042 was searched for sea level, AOSIS, UNFCCC, and climate justice. The United Nations archive 1043 was utilized for documents written by AOSIS and member states, proceedings and decisions 1044 from major COP meetings, and materials related to the 2013-2015 Structured Expert Dialogue. 1045

Emissions data (Figure 1) - Data were obtained from Climate Watch Historical GHG
Emissions data archive and include emissions from fossil fuel combustion as well as Land-Use
Change and Forestry or Agriculture. Data sources are FAO 2020, FAOSTAT Emissions
Database, CO2 Emissions from Fuel Combustion, OECD/IEA, 2020. Data were summed across
all countries for the 'World' values and across AOSIS nations for the 'AOSIS' values.

1052 Sea level rise data (Figure 2)- Sea level predictions were computed with the pseudo-spectral, 1053 gravitationally self-consistent sea level model described in Gomez et al. (2010) that includes 1054 gravitational and rotational effects associated with surface ice and water mass redistribution. 1055 viscoelastic deformation of the solid Earth and migrating shorelines. The Earth rheological 1056 structure in the model varies radially, with elastic and density structure given by the Preliminary 1057 Reference Earth Model, lithospheric thickness of 120 km, and upper and lower mantle 1058 viscosities of 0.5 and 5 x10²¹ Pa s, respectively. Global sea level changes were computed 1059 relative to 2000 using the coupled Earth-ice sheet simulations from DeConto et al. (2021) in 1060 which the Penn State University ice sheet model was coupled to a high viscosity viscoelastic 1061 Earth model and run under RCP4.5 and 8.5 emissions scenarios, with and without the inclusion 1062 of brittle ice processes (MICI dynamics). Values were normalized by the global mean sea level 1063 equivalent change (termed the "effective eustatic value") in Gomez et al., 2010, computed by 1064 filling areas freed of marine based ice with water and spreading the rest of the water evenly 1065 across the modern ocean area. Plotting was done using ArcGIS following the methodology of 1066 Gosling-Goldsmith, Ricker, and Jan Kraak (2020) to highlight AOSIS locations. Country 1067 polygons were obtained from the following Natural Earth shapefiles: Pacific groupings, 1:10 m 1068 countries, 1:50 m Tiny Country Points. Spatial statistics of sea level values at AOSIS locations

- 1069 were calculated in ArcGIS for years 2100, 2200, and 2300 under RCP4.5 and for RCP8.5. For
- 1070 the RCP8.5 case a scenario that includes marine ice cliff instability and a scenario that only
- 1071 includes marine ice sheet instability were both used.
- 1072

Sea level and GMST data (Figure 3)- GMST values under RCP8.5 showing the meltwater
induced negative feedback values were from Sadai et al., 2020. Sea level rise estimates were
from DeConto et al., 2021, in which the Penn State University ice sheet model was driven by
meltwater perturbed climatology data from Sadai et al., 2020.

- 1077
- 1078 Data Availability- The emissions data used in Figure 1 is available at
- 1079 <u>https://www.climatewatchdata.org/ghg-emissions</u>. The data used for the negative feedback
- 1080 shown in Figure 3 from Sadai et al., 2020 are available at the US Antarctic Program Data Center,
- 1081 cited below as Condron, 2021 and downloadable here <u>https://doi.org/10.15784/601449</u>. The data
- 1082 used for Figure 2 and Table 1, as well as the sea level rise estimate in Figure 3 will be available
- 1083 through the UMass ScholarWorks website at publication and are available for peer review at this
- 1084 share link: <u>https://drive.google.com/drive/folders/1CWqi-</u>
- 1085 <u>Dv9JHCnCOGlvT7ygmXrgQGYSkV6?usp=sharing</u>. The sea level code used to generate this
- 1086 data will be published in association with Han et al. (in review) and is viewable here:
- 1087 <u>https://osf.io/8ptfm/</u>. Natural Earth shapefiles used in Figure 2 are available at
- 1088 <u>https://www.naturalearthdata.com/downloads/</u>.

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