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Key Points:

- This review considers the Paris Agreement temperature target in the context of long-term, spatially variable sea level rise
- We interpret reviewed literature through theories of climate justice, assessing impact to members of the Alliance of Small Island States
- Modeling of Antarctic melt indicates sea levels rise while temperature increase slows, complicating use of temperature targets post-2100

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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 temperature (GMT) 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 GMT warming by 2100. This review article investigates 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 under a changing climate: (a) 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 (b) future ice sheet melt will result in a negative feedback on GMT, thus delaying temperature rise. When considering these impacts in conjunction, justice concerns associated with the Paris Agreement are exacerbated.

Plain Language Summary At the Paris Climate Agreement in 2015, countries adopted a target for stabilizing climate change defined by how the rise in global average air temperature has increased relative to a pre-industrial baseline (1850–1900). Prior research has identified numerous climate justice implications associated with this approach. This study reviews climate justice issues associated with Paris Agreement temperature targets, finding that using air temperature by 2100 as the main metric does not adequately capture other climate risks, particularly sea level rise (SLR) faced by island and coastal communities. We introduce a new climate justice consideration based on the simultaneous impacts of SLR and slowed warming caused by ice loss on Antarctica. Slowed warming might appear to delay the need for climate action, but a focus on end-of-century temperature misses the impacts of long-term accelerating SLR.

1. Introduction

Climate change impacts all parts of the Earth system, and the degree and nature of these impacts vary spatially and temporally. Sea level rise (SLR) presents a distinct threat to coastal communities and island nations (Magnan et al., 2019; Nurse et al., 2014). Global mean sea level has increased by 0.2 m since 1901, accelerating in recent decades to the current (2006–2018) rate of about 3.7 mm/yr (Fox-Kemper et al., 2021). The rate of SLR will increase by the end of the century even under low emissions scenarios (Fox-Kemper et al., 2021). Sea levels will continue to rise for centuries after 2100, regardless of emissions trajectories or overall warming, and will remain elevated for millenia (Clark et al., 2016; Fox-Kemper et al., 2021; Oppenheimer et al., 2019). SLR also has substantial regional variations, the impacts of which depend on geomorphological and sociopolitical considerations at the local scale. In some places SLR may cause islands to be rendered uninhabitable due to submersion, saltwater intrusion into groundwater, storm surge, and other factors (Magnan et al., 2019; Oppenheimer et al., 2019).

Since the 1980s, a focal point of international negotiations has been to establish a common target in the form of a long-term global goal (LTGG) for action to address climate change. In 2015, these negotiations led to the adoption of the Paris Agreement (UNFCCC, 2016a). The LTGG (UNFCCC, 2016b, 10/CP.21 para 4) contains a temperature target referred to as the long-term temperature goal (LTTG) (UNFCCC, 2016a, 1/CP.21 Article 2.1a). This temperature target becomes the quantitative expression of the United Nations Framework for the

Convention on Climate Change (UNFCCC) Article 2 objective of "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference [DAI] with the climate system" (UNFCCC, 1992, p. 9). As stated in the Paris Agreement, countries agreed to hold "the increase in the global average temperature to well below 2°C above pre-industrial levels and pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change" (UNFCCC, 2016a). The LTTG metric is interpreted as long-term anthropogenic global mean temperature (GMT) change, excluding natural variability (Rogelj et al., 2017). As of 2021, the average surface temperature is 1.1°C warmer than preindustrial (1850–1900), currently increasing at a rate of ~0.2°C per decade as greenhouse gas emissions rise at a rate of 59.1 gigatons of CO_2 equivalent per year (Gulev et al., 2021; Hoegh-Guldberg et al., 2018; UNEP, 2021).

In this Review, we ask how the LTTG was developed; what the justice implications of that target are particularly when considering SLR; and how projections of Antarctic Ice Sheet (AIS) melt impact both GMT and SLR with implications for justice and policy. The LTTG poses several challenges which can give rise to multiple sources of climate injustice. First, it is generally considered to be in reference to the year 2100. This is due to Article 4 of the Paris Agreement, which connects the LTTG to mitigation stating "In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible…so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century." However, unlike GMT, SLR 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 CO_2 emissions reach net zero (Rogelj et al., 2018). However the thermal expansion component of SLR, which occurs as water warms and expands, will continue for centuries even after emissions stop (Bouttes et al., 2013; Meehl et al., 2012; Zanna et al., 2019). Specifically, higher emission rates at earlier times lead to higher SLR for the same cumulative emissions, which has implications for policy proposals if sea level were to be considered as a metric instead of or in addition to GMT (Bouttes et al., 2013; Li et al., 2020). While the rate of SLR from thermal expansion will likely decline as temperatures decline, dynamical contributions from ice sheets will dominate in the long-term with sea levels continuing to rise for hundreds of years even after temperatures stabilize (Wigley, 2018). This occurs even if speculative technologies to remove CO_2 from the atmosphere are deployed (DeConto et al., 2021).

Second, by adopting GMT as the metric for international climate action, the conversation around risk and impact has been skewed toward a globally averaged version of a single environmental stressor. While the LTTG is backed by scientific knowledge linking temperature and other climate impacts this approach of using one globally averaged metric doesn't account for the breadth of "dangerous" impacts which will vary geographically and over time (Hoegh-Guldberg et al., 2018; UNFCCC SBSTA, 2015). Following from this, there is significant discrepancy between "danger as defined" by scientific assessments and "danger as experienced" by communities on the frontlines of a changing climate (Dessai et al., 2004, p. 21). While climate change is a global risk, climate impacts are locally experienced phenomena (Ayers, 2011; Tschakert, 2015). Systems of power and privilege impact the decision-making process regarding what is deemed an acceptable level of damage and risk, often disadvantaging those with less privilege (Dessai et al., 2004; Seager, 2009).

Third, and finally, acceptable risks are ambiguous with respect to the concept of DAI written into the UNFCCC. This is compounded by the vague language in the Paris Agreement that recommends a target of "well below" 2°C. In what has been termed "the political economy of delay" (Carton, 2019), these ambiguities have jointly enabled a delay in action to reduce carbon emissions by parties more concerned with near-term economic profit than ongoing and long-term environmental and societal harm. The ambiguities of the UNFCCC and Paris Agreement embody the status quo over principles of justice (Morgan, 2016; Morseletto et al., 2017; Okereke, 2006; Tschakert, 2015). Indeed, while countries submit Nationally Determined Contributions (NDCs) to achieve Paris goals, emissions levels have not declined to meet them, and parties are not legally bound to enact them (UNEP, 2021; Wewerinke-Singh & Doebbler, 2016). Moreover, the temperature target has been interpreted as leaving room for exceeding the temperature threshold in the coming decades with the promise of reaching it by 2100 (Rogelj et al., 2018), despite the risk of triggering rapid SLR (DeConto et al., 2021).

Given these challenges posed by the LTTG, we argue that it is crucial to understand the target's origins in the context of broader inequalities that characterize the global climate negotiation process. The GMT target has origins in scientific research, which informs policy. Scientific research, such as predictive modeling, plays an important role in negotiations by characterizing climate system changes of interest to policymakers and the public, and constraining potential future trajectories. Issues of justice are crucial in understanding impacts of climate policy (Klinsky et al., 2017), yet science is limited in its ability to answer questions about justice (Okereke, 2006; 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 environmental ramifications (Barnett & Campbell, 2011). This approach obscures the nuances of how social systems interface with vulnerability (Liverman, 2009) and can become detached from the lived experiences of people experiencing SLR (Abbott & Wilson, 2015). An interdisciplinary interpretation of scientific results allows for greater understanding of justice concerns (Colven & Thomson, 2019). The discipline of critical physical geography emphasizes interdisciplinary work combining physical and social sciences to understand how power relations and political dynamics shape biophysical systems (Lave et al., 2018). Colven and Thomson (2019) suggest critical physical geography interpretations of climate modeling results as an avenue for exploring justice and producing socially relevant climate knowledge. We answer that call in this review by assessing how climate and SLR modeling interface with the political process and the implications this has for climate justice.

In this paper, we review a range of scientific and sociopolitical literature to understand how the LTTG, interpreted as being by 2100, impacts communities and societies disproportionately impacted by SLR. We focus on three components of justice theory which originate from philosophy and have in recent years been increasingly applied to climate and environmental concerns (Burnham et al., 2013a, 2013b; Schlosberg, 2004). Applications of justice theory to the LTTG and SLR are assessed as they relate to the Alliance of Small Island States (AOSIS), an organization formed to amplify the needs of states particularly concerned with the impacts of SLR (Heileman, 1993; Liburd, 2021b). We frame each justice consideration centering on AOSIS nations, negotiators, and inhabitants due to the geographic vulnerability of many AOSIS nations to SLR, the centrality of this in their negotiating positions, and their strong and ongoing history of advocacy within the UNFCCC. We begin in Section 2 tracing the development of the LTTG, assessing it from the perspective of procedural justice (Fraser, 1997; Young, 1990), by reviewing documents from United Nations (UN) archives and historical literature. In Section 3 we review SLR-related concerns expressed in AOSIS statements assessing them through the lens of recognition justice, which relates to the existence rights of cultural and social groups (Fraser, 1997; Young, 1990). In Section 4 we review how SLR impacts vary spatially and temporally and are often uneven with respect to emissions contribution, assessing this with respect to distributive justice (Burnham et al., 2013a; Rawls, 1971). Finally, in Section 5 we turn to a case study of the AIS reviewing the projected impacts of Antarctic melt on SLR and GMT. As Antarctica is projected to potentially become the main driver of SLR in the long-term and Antarctic-sourced meltwater also has the potential to delay GMT rise, this is an important case study for considering the intersection between the LTTG and SLR. We assess the projected impact of the Antarctic SLR contribution on AOSIS nations and find that they will experience SLR from Antarctica at levels higher than the global mean and are disproportionately impacted relative to their emissions contribution (see Data Availability Statement). Our objective in this review is not to be policy prescriptive regarding a new or strengthened target metric, but rather to understand the justice concerns present in the current metric, particularly over the long-term and as they apply to those disproportionately impacted by SLR.

2. Temperature Target Development and Procedural Justice

Theories of justice began at considering uneven distributions and were expanded to encompass the underlying causes of distributional inequity by analyzing recognition of social hierarchies and political participation (Fraser, 1997; Rawls, 1971; Schlosberg, 2004; Young, 1990). Procedural justice considers political participation and the role of structural power in the decision-making process (Young, 1990). Here we begin with procedural justice to understand the decision-making processes that led to the development of the LTTG. While temperature targets have become a fixture of climate negotiations, the use of GMT as a target metric was not inevitable. Rather, it was a result of a complex multi-decade negotiating process embedded in international geopolitical power dynamics (see Figure 1a for a timeline).

UNFCCC negotiations evolve based on the work of delegations and the negotiators within them. As the UNFCCC grew from the UN, which was formed largely before the decolonization that occurred in the latter half of the 20th century, global hierarchies are institutionalized within it (Falzon, 2021). These hierarchies privilege large

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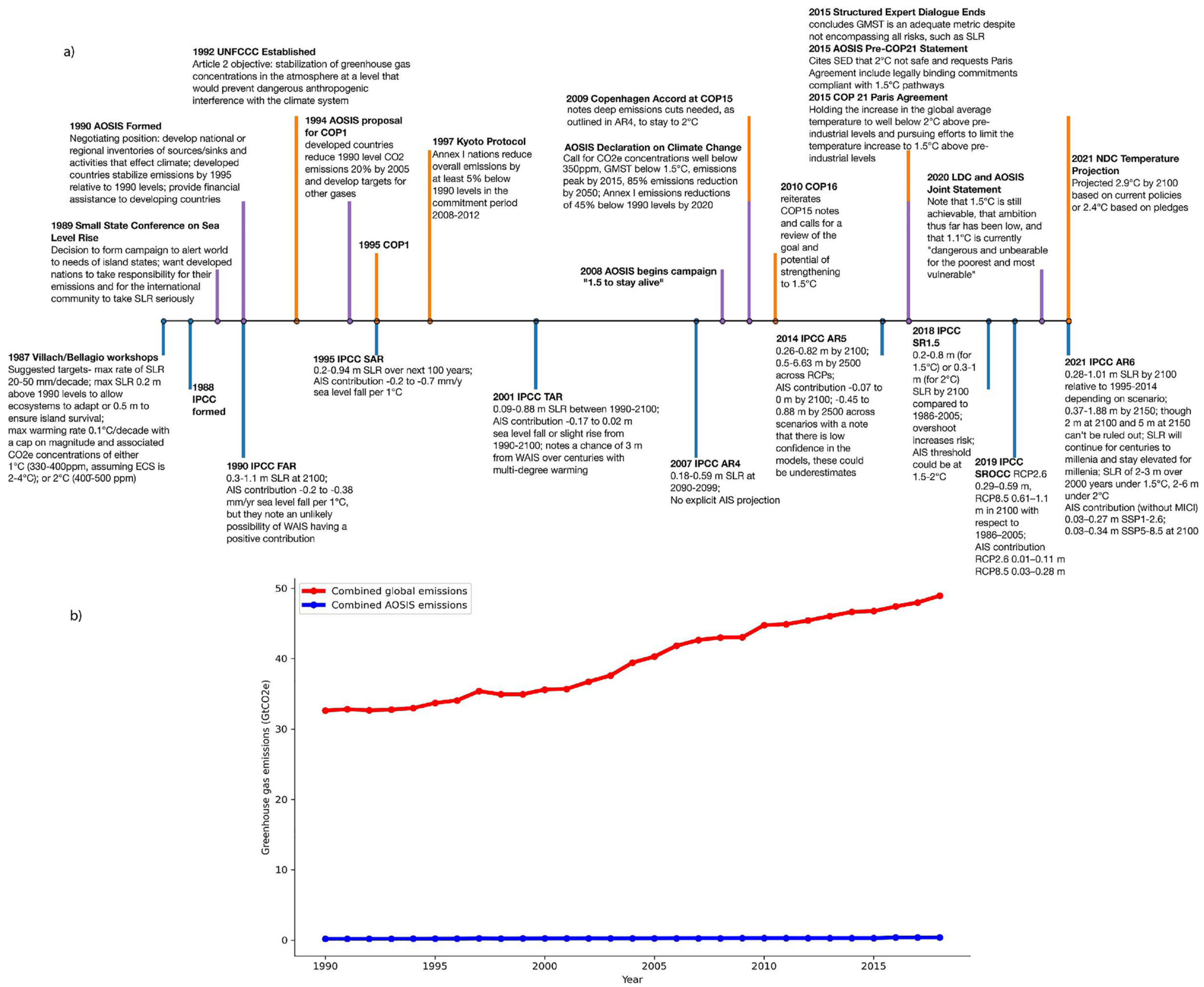

Figure 1. Emissions over time and major historical events. (a) timeline of major historical events, statements, and publications shows United Nations Framework for the Convention on Climate Change proceedings (orange), Alliance of Small Island States (AOSIS) statements (purple), and Intergovernmental Panel on Climate Change and other scientific reports (blue). (b) A comparison of global greenhouse gas emissions from 1990 to 2018 shows the low emissions contribution of AOSIS nations (blue) and increasing levels of total global emissions (red).

delegations with Western scientific and legal expertise, such as those from countries that caused rapid increases in emissions (Falzon, 2021). Interviews with negotiators from AOSIS show that these hierarchies cause difficulties for smaller delegations with fewer resources (Falzon, 2021), which itself is a source of procedural injustice.

2.1. Early Negotiations and Potential Targets

Beginning in the late 1980s, scientists held meetings to discuss options for climate targets. These focused on environmental indicators of change including stabilized atmospheric greenhouse gas concentrations (in CO_2 equivalent), and rates and magnitudes of GMT and SLR. These indicators were intended to be used to define quantitative targets with the possibility of combining several environmental indicators to be translated into emissions targets for regulatory policies (Jaeger, 1988; Rijsberman & Swart, 1990; Vellinga & Swart, 1991). They were envisioned to serve as both evidence of the extent of the changes occurring and to monitor progress on policy implementation (Rijsberman & Swart, 1990). The rate-limit of temperature change was based on rates of past change that ecosystems adapted to, however this metric was abandoned because natural variability could produce rates higher than the proposed values (Randalls, 2010). The rate of change of SLR, with a cap on overall

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magnitude, was an early favorite among scientists, however lags in response times and ongoing uncertainty in SLR projections complicated the metric and it was rarely mentioned in the political arena (Rijsberman & Swart, 1990). Another reason could have been that SLR would mainly impact coastal communities and therefore may not have been as motivational to some countries. For instance, Rijsberman and Swart (1990), p.54 notes "For example, it is likely that the Maldives in the Indian Ocean would be devastated by a sea level rise of only one meter. An absolute limit below this level would therefore be required *if saving the Maldives from destruction were a societal goal*" (emphasis added). For GMT targets the rate of rise (0.1°C/decade) was suggested alongside a cap on the overall extent of the change. Suggested caps were 1°C, based on past ecosystem adaptation, and 2°C which was put forth as a hard upper limit beyond which climate responses could become nonlinear (Rijsberman & Swart, 1990).

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

2.2. AOSIS Formation and Binding Emissions Reductions

In 1990, following the first international conference on SLR hosted by the Maldives, the AOSIS was formed to increase the negotiating prominence of island nations and others sharing their concerns (Betzold et al., 2012; Ourbak & Magnan, 2018; Republic of Maldives, 1989; Shibuya, 1997). AOSIS represents 20% of the UN member states. Member nations are geographically widespread across the Caribbean, Indian Ocean, Oceania, and along the western coast of Africa (AOSIS, 2021; see map in Figure 2). They have varying interests but are united in backing strong climate action (Heileman, 1993; Kelman & West, 2009). In the leadup to the 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 (AOSIS, 1991; Ashe et al., 1999). While wording related to stabilization of atmospheric greenhouse gas concentrations was included in the UNFCCC, a specific limit was not (Ashe et al., 1999). As noted by the AOSIS Chair and others: "AOSIS, whose member states are most vulnerable to the possible adverse effects of climate change, was particularly concerned about those provisions of the UNFCCC that were either watered-down significantly, made largely meaningless or excluded altogether. These include: the absence of definite targets or specific timetables, for the significant reduction of carbon dioxide by the industrialized countries of the North" (Ashe et al., 1999, p. 1). Subsequent AOSIS proposals at COP1 requested implementing UNFCCC Article 2 by requiring developed countries to reduce their 1990 level CO_2 emissions by 20% by 2005 and to develop targets for other greenhouse gases (AOSIS, 1994). The United States and other countries, whose economies were based largely on fossil fuels, rejected this (Shibuya, 1997; UNFCCC, 1995).

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, including those related to the fossil fuel industry (Brulle, 2014; Frumhoff et al., 2015; Supran & Oreskes, 2017), the rise of climate denialism, and the passage of a Congressional resolution prohibiting the US from signing onto a treaty that did not require developing countries to participate (McCright & Dunlap, 2003; Roberts, 2018). Fossil fuel industry lobbying was based on the economic interest of not devaluing their products and preference for keeping regulatory measures related to fossil fuel production at the national level and out of international treaties (Levy & Egan, 1998). These factors made the setting of binding emissions reduction targets virtually impossible

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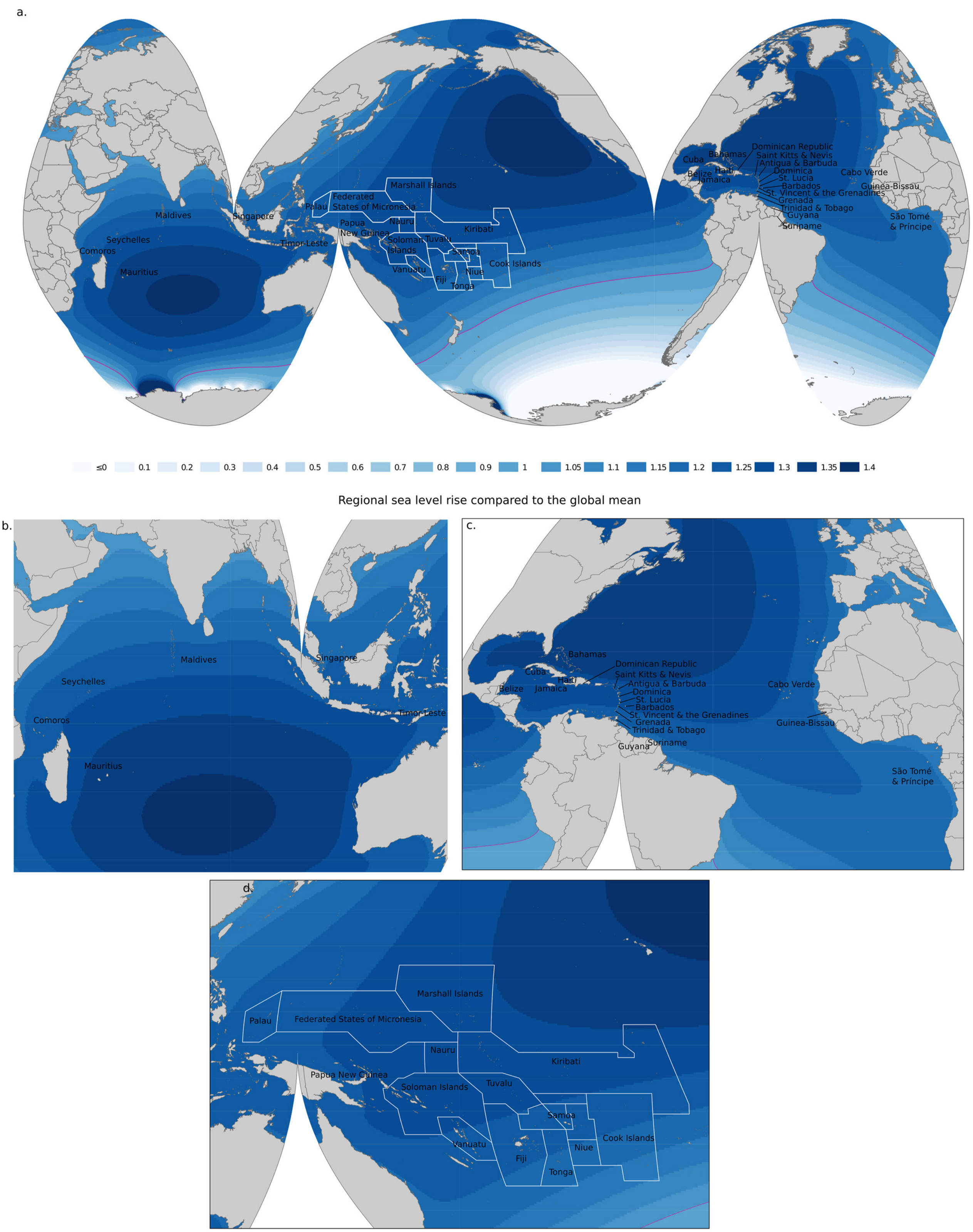

Figure 2.

and solidified the turn away from these targets and toward nationally determined pledges with a GMT target (Wewerinke-Singh & Doebbler, 2016).

2.3. Solidification of Temperature Targets

After Kyoto the 2°C temperature target rapidly gained prominence and solidified as the preferred metric within Europe (Morseletto et al., 2017). 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 costs, and support for this metric at a number of high-level European meetings (Gao et al., 2017; Morseletto et al., 2017; Randalls, 2010). In opposition, AOSIS began formally advocating for a lower temperature target in 2008 using the phrase "1.5 to stay alive" (Benjamin & Thomas, 2016). COP negotiations became characterized by tension between those who wanted a 1.5°C target and those who wanted a 2°C target (Leemans & Vellinga, 2017; Morseletto et al., 2017).

Prior to COP15, AOSIS released their Declaration on Climate Change (2009) calling for the meeting outcome to include multiple interlocking targets including stabilization of atmospheric greenhouse gas concentrations at "well below 350 CO_2 -equivalent levels," GMT rise below 1.5°C, and emissions reductions of developed countries by 45% below 1990 levels by 2020. These calls did not gain traction and 2°C was written into the Copenhagen Accord with the intention of making it the LTGG, which was considered a "grave disappointment" to AOSIS negotiators (Liburd, 2021b). However, the accord was not adopted, in part due to the objections 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 issue of a maximum 1.5°C temperature increase was pitched directly against the cost of reducing fossil fuel use before and during the Copenhagen COP. For Australia, the EU, China, India, the USA and many other states with fossil-fuel-dependent economies, reducing greenhouse gas emissions so significantly under the 1.5°C target was unpalatable at Copenhagen. The 1.5°C target advocated by [AOSIS nation] Tuvalu represented a significant void between its geographic vulnerability and financial interests elsewhere."

At COP16 in 2010, a coalition of middle and high income countries continued advocating for 2°C. Opposing them were a majority coalition of AOSIS and over 100 other countries that objected, arguing 2°C would put their survival at risk (Tschakert, 2015). They pushed for 1.5°C, recognizing that this lower goal would reduce climate impacts, while acknowledging that no level of warming is safe (Knutti et al., 2016; Randalls, 2010; Seager, 2009; Tschakert, 2015). The compromise reached at COP16 was that 2°C would be a component of the broader LTGG, necessitating deep near-term emissions cuts, but that it should be reviewed for 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 to the LTGG, which led to the inclusion of 1.5°C in the Paris Agreement (Benjamin & Thomas, 2016).

The SED occurred from 2013 to 2015 to assess the adequacy of 2°C, the merit of strengthening the goal, and progress toward it (UNFCCC SBSTA, 2015). During the SED, Dr. Leonard Nurse noted that while islands in the Caribbean were experiencing temperature trends in line with the global average, they were experiencing higher than average SLR, while tropical western Pacific islands and locations in the Indian Ocean were experiencing even higher rates (UNFCCC SBSTA, 2015). SED participants noted that "danger" is subjective and while fear of climate impacts united the parties, UNFCCC Article 2 divided them due to their disparate perceptions of acceptable risk (UNFCCC SBSTA, 2015, p. 179). The SED concluded that GMT was an adequate metric despite not encompassing all risks since other targets, or multiple metrics, would only reiterate the primary conclusion necessitating urgent near-term action (UNFCCC SBSTA, 2015). This conclusion noted "a temperature-only target will not capture all changes in the climate system that follow from GHGs emissions and may thus lead to other changes being overlooked…including…sea level rise" (UNFCCC SBSTA, 2015, p. 8). This is because the rate of mean SLR depends on CO_2 emissions paths (DeConto et al., 2021; Mengel et al., 2018), so if emissions reductions occur at an earlier time, long-term SLR responses are lower. This is unlike GMT which responds to cumulative emissions and is less dependent on emission times (UNFCCC SBSTA, 2015). An Intergovernmental

Figure 2. Sea level rise (SLR) projections normalized relative to global mean SLR. (a) The spatial distribution of the Antarctic contribution to SLR at 2100 (relative to 2000) under an RCP4.5 emissions scenario (without MICI; see Data Availability Statement) demonstrates that Alliance of Small Island States members are disproportionately impacted. Numbers shown in the map legend are factors in comparison to global mean sea level, for instance a factor of 1.2 indicates that location experiences SLR 1.2 times the global mean value. The purple line indicates where SLR values are equal to the global mean value. More detail is shown for (b) the Indian Ocean (c) the Caribbean and Atlantic, and (d) Oceania.

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Panel on Climate Change (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 staggering…this unevenness epitomizes geographies of privilege, power, and inequality" (Tschakert, 2015, p.10).

2.4. The Paris Agreement

Preceding COP21 in 2015, AOSIS released a statement saying that 2°C is unsafe according to the SED outcome and requested that the Paris Agreement contain legally binding commitments compliant with 1.5°C pathways (AOSIS, 2015). They asked for SED results to be included at the COP, however objections from Saudi Arabia, China, and other countries prevented this until the final days of negotiations (Benjamin & Thomas, 2016; Wewerinke-Singh & Doebbler, 2016). While 1.5°C was favored by a majority of parties, opposition came from countries with higher levels of historic emissions who opposed a stronger goal in part due to their potential culpability 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 by the US (Fry, 2016; Wewerinke-Singh & Doebbler, 2016). Instead, the 2°C target was formally adopted within the Paris Agreement, with the compromise language of pursuing efforts toward 1.5°C (UNFCCC, 2016a). As a framework for achieving this, the agreement includes mechanisms for strengthening the global response through periodically revised NDCs and global stocktakes (UNFCCC, 2016a). The process outlined in the agreement is legally binding, though countries are not legally required to reduce emissions or achieve the proposals they include in their NDCs (Clémençon, 2016; UNFCCC, 2016a; Wewerinke-Singh & Doebbler, 2016). Language on equity is included only in the preamble (in reference to the UNFCCC), and in Articles 2 and 4 in relation to "common but differentiated responsibilities" and reducing emissions in the context of sustainable development (UNFCCC, 2016a). Climate justice is only mentioned once in the preamble, where it states "noting the importance for some of the concept of 'climate justice' when taking action to address climate change" (UNFCCC, 2016a).

2.5. Post-Paris

As of 2021, 6 years post-Paris, NDCs are insufficient to stay below a 2°C GMT rise (Climate Action Tracker, 2021; UNFCCC, 2021) and 1.5°C will no longer be achievable without substantially strengthened mitigation efforts that would around halve global emission by 2030 (Schleussner et al., 2016; Warszawski et al., 2021; Zhou et al., 2021). Content analysis of NDCs show a continuation of the "divergent climate priorities that have existed within the UNFCCC for decades" (Stephenson et al., 2019, p. 1258). NDCs from AOSIS nations emphasize vulnerability and equity, while those of historic high-emitters including the US and EU nations demonstrate a lack of ambition on mitigation and a deprioritization of climate action in favor of economic priorities (Mills-Novoa & Liverman, 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).

Recent work has revisited the idea of other target metrics. Clark et al. (2018) suggests using the long-term commitment of SLR as a factor in assessing emissions quotas. Another study suggests SLR targets as a reinterpretation of temperature targets by estimating the SLR corresponding to a given temperature target (Li et al., 2020). Using multiple targets including temperature, SLR, food production, ecosystem impacts, ocean acidification, and aragonite saturation is another option which leads to lower allowable emissions, in line with SED findings (Steinacher et al., 2013; UNFCCC SBSTA, 2015). The idea of multiple interlocking target. aligns with work by Morseletto et al. (2017) which described the LTTG as encapsulating "reducio ad anum", the consolidation of a complex multifaceted issue into a single element which has become disembedded from the people and ecosystems that inhabit the Earth. Linking the LTTG to other human or environmental targets could potentially be beneficial but would be a procedural challenge. Furthermore, the second periodic review of the adequacy of the LTGG, taking place from 2020 to 2022, "will not result in an alteration or redefinition of the long-term global goal stated in decision 10/CP.21" (UNFCCC, 2019).

In summary, early target proposals put forth by the scientific community included metrics based on SLR, atmospheric greenhouse gas concentrations, and temperature. While the UNFCCC contains language on stabilizing atmospheric greenhouse gas concentrations, COP negotiations moved away from emissions and concentration targets toward a GMT target. AOSIS initially advocated for binding emissions reductions targets and multiple metrics, and they were instrumental in later reorienting discussions from 2°C to 1.5°C as negotiations solidified around temperature metrics. However, despite the advocacy of AOSIS and others, non-binding pledges with temperature targets prevailed, in part due to power dynamics that privileged high-emitting nations. Interpreted through justice theory, these systemic inequities can be seen as procedural injustices. As discussed in the following section, the negotiating positions of AOSIS and other low-emitting nations emphasize the uneven distribution of emissions versus impacts, noting that countries with high (low) emissions were among the least (most) impacted by climatic changes.

3. Recognition Justice—Adaptation, Displacement and Migration

Recognition justice, recognizing differences in cultural and social groups and seeking to address injustices and systemic disadvantages between them (Fraser, 1997; Young, 1990), is an under-researched topic in climate justice (Burnham et al., 2013a, 2013b; Thomas et al., 2020). In their negotiating positions, AOSIS representatives have always centered the current and future impacts of SLR, and how these impacts directly relate to recognition and preservation of their cultures and the physical spaces that shape those cultures. This section reviews literature on how people in AOSIS nations perceive and experience SLR, to motivate how this influences their negotiating positions and perspectives on climate justice.

3.1. Habitability, Statehood, and Exclusive Economic Zones

Long before the 2°C target was set, scientists predicted some islands could be pushed past adaptive limits due to inundation and saltwater intrusion into aquifers and atoll freshwater lenses, potentially rendering them uninhabitable (UNEP, 1990). AOSIS statements and NDCs of member nations stress SLR as a threat to their existence (AOSIS, 2009; AOSIS and the LDC Group, 2020; Mills-Novoa & Liverman, 2019; Thomas & Benjamin, 2018c). Interviews with the AOSIS chair and negotiators from member countries note that loss and damage from extreme events had already been witnessed by all of them, and while direct impacts occurred in coastal communities, there were ramifications for the whole country (Thomas & Benjamin, 2018a). Under 2°C, atoll islands inhabited by half a million people could become permanently submerged (Storlazzi et al., 2015), though limiting warming can reduce risks (Hoegh-Guldberg et al., 2018, 2019). Habitability questions will arise before submersion occurs and will need to be ultimately decided by residents themselves (Liburd, 2021a).

Due to these factors, questions have been raised related to whether island states could lose statehood if their territories are submerged. Under international law expressed in the Convention on Rights and Duties of States (1933) a state must have "a defined territory." However legal scholars have suggested this pertains more to the formation of a state than its dissolution and have posited multiple ways statehoods could be maintained if territory is lost (Yamamoto & Esteban, 2014), such as expanding the definition of statehood to include recognition of states constituted by people in diaspora (Burkett, 2011). Despite this, the uncertainty of the legal status is a concern in AOSIS nations. For example, in this statement from the 2020 Thimphu Ambition Summit: "High on the minds of representatives was the sobering reflection that in another 75 years many of their members may no longer hold seats at the United Nations if the world continues on its present course and average warming exceeds 1.5°C" (AOSIS and LDC Group, 2020). In addition to the issues related to the loss of habited locations, the submergence of uninhabited islands has potential ramifications for legal boundaries of Exclusive Economic Zones (EEZ). EEZs define the boundaries within which a country has exclusive economic rights to resources (within 200 nautical miles of the coast) so loss of EEZ territory could lead to loss of resources and income (Yamamoto & Esteban, 2014). Multiple options have been proposed for updating boundary definitions in the face of SLR, with justice implications (Armstrong & Corbett, 2021). The Pacific Islands Forum has declared that "our maritime zones, as established in accordance with the Convention [on the Law of the Sea]… shall continue to apply, without reduction, notwithstanding any physical changes connected to climate change-related sea-level rise" (Pacific Islands Forum, 2021).

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, 2008; Perumal, 2018; Simpson et al., 2010), yet there is a tendency to view island nations as homogeneous and universally vulnerable (Kelman, 2018). While loss of land is referenced often in official statements, both negotiators and the general population in most states reject the narrative of inevitable climate refugees and emphasize their preference for mitigation and aid sufficient to allow for them to adapt in place (Corendea, 2016; Farbotko & Lazrus, 2012; McNamara & Gibson, 2009; Perumal, 2018; Thomas & Benjamin, 2018a). Given uncertainties in the science and in the limits of adaptation, framings of inevitable loss of islands, which are 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 climate refugees that promote victimization and lack of agency which can increase their marginalization while being at odds with how people in island nations see themselves and their own relationships to migration (Kelman, 2018; Kelman & Stojanov, 2020). Media narratives presenting island populations as inevitable refugees, or the loss of islands as "canaries in the coalmine", have been criticized as falling into what has been termed the "eco-colonial gaze" (Farbotko, 2010). Narratives of climate refugees are not always accurate as relocations have many underlying factors, and these narratives can have negative ramifications on how islanders view their environment (Siméoni & Ballu, 2012). Pacific scholars have put forth that imperialism created the view of islands as small, poor, and isolated, but that this contrasts with the expansive view islanders hold of an ocean of connected islands inhabited by people who constantly adapt to ocean changes (Hau'ofa, 1994). In light of this, the term "large ocean states," emphasizing the reach of their ocean-based territory is often preferred to the more common "small island developing states" (Chan, 2018).

Even if states are not fully lost to SLR, issues of recognition relating to SLR remain. 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 cultural heritage sites, burial grounds, and long-term habitability (Graham et al., 2013; Martyr-Koller et al., 2021; Marzeion & Levermann, 2014; Mueller & Meindl, 2017; Oppenheimer et al., 2019). The UN Special Rapporteur on cultural rights has noted that "While most human rights are affected by climate change, cultural rights are particularly drastically affected, in that they risk being simply wiped out in many cases," highlighting SLR as an example (UNGA, 2020). Due to these factors, instances of relocation, regardless of statehood status, impact recognition justice (Robinson, 2020; Yamamoto & Esteban, 2014). In some Pacific and Caribbean island communities relocation due to environmental hazards has occurred, though few countries have national policies for this (Thomas & Benjamin, 2018c). Kiribati is the only country with a plan for international migration, as they have purchased land in Fiji (Corendea, 2016; Thomas & Benjamin, 2018c). In interviews, residents of villages in Fiji and Tuvalu note that people already view SLR as impacting their lives and expect that trend to continue (Martin et al., 2018; McMichael et al., 2021; Piggot-McKeller et al., 2021). Incremental retreat, which has already occurred in some villages in Fiji, where new construction must take place on higher ground, can be a way for people to maintain their place-based grounding to an extent (Piggot-McKeller et al., 2021). However preferences around relocation and adaptation responses vary between individuals and can be characterized by generational differences; short distance relocation is not the preference of all community members (Martin et al., 2018; McMichael et al., 2021; Piggot-McKeller et al., 2021). Binary and linear discourses on remaining or leaving is in contrast to lived experiences of island residents (McMichael et al., 2021). Place-based cultural connections are often very strong such that even when residents recount seeing graves and homes wash away they express a strong desire to stay and retain their culture (McMichael et al., 2021).

3.3. Legacies of Colonization

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

Colonization was in part motivated by extraction of wealth which paved the way for industrialization that released fossil greenhouse gas emissions (Sealey-Huggins, 2017). Contemporary climate change is tied to global power and inequity, which is in turn tied to economic development (Hurrell & Sengupta, 2012). Colonial legacies are a key factor in the creation of gradients of power and wealth between nations, and the resulting systems of dependency in terms of debt, aid, and international political power (Barnett & Campbell, 2011; Bordner et al., 2020; Sealey-Huggins, 2017). Several high-emitting countries, such as the US, Australia, and European nations who advocated for 2°C were colonizing nations whose actions reduced the natural adaptive capacities that island nations traditionally had (Barnett, 2001; Barnett & Campbell, 2011; Bordner et al., 2020; Douglass & Cooper, 2020; Nunn & Campbell, 2020).

These historical dynamics between industrialized high emitters and more vulnerable states come into UNFCCC negotiations through mechanisms to address loss and damage (Khan et al., 2019). One concrete approach is to allocate financial aid, leading to questions about who qualifies, how this will be determined, and who pays (Klein & Möhner, 2011). Yet in later negotiations and within the Paris Agreement, there has been a shift away from financial reparations for loss and damage on the part of countries with larger historical emissions, higher wealth, and colonial histories (Morgan, 2016; Okereke & Coventry, 2016). Instead, places with higher vulnerabilities become reliant on international financial aid for adaptation projects. Developed countries had agreed to provide $100 billion per year in climate finance assistance to developing nations however currently nations have provided far less, much in the form of loans, and only 3% of the total has gone to small island states (Oxfam, 2020; Virtual Island Summit, 2021). Aid providers who view migration as unavoidable don't provide adequate funding to the extent of adaptation islanders see as necessary to achieve their goal of adapting in place (Bordner et al., 2020). Moreover, there is also no mechanism of accountability of multinational corporations who are responsible for the majority of industrial emissions (Frumhoff et al., 2015; Heede, 2014). Scientific research has attributed 50% of the rise in GMT and 32% of the current SLR 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 GMT rise and 14% of the global mean SLR are attributed to the top 90 industrial producers (Ekwurzel et al., 2017).

3.4. Inclusion

Scholars working at the intersection of anti-colonial methodology and knowledge production have emphasized the importance of recognizing local and Indigenous knowledges (David-Chavez & Gavin, 2018; Kelman & West, 2009). In policy discussions and scientific research there is a lack of local community and Indigenous perspectives (Baptiste & Rhiney, 2016; Barnett, 2017; David-Chavez & Gavin, 2018; Kelman & West, 2009; Klinsky & Dowlatabadi, 2009; Perumal, 2018; Thomas & Benjamin, 2018b). This is reflected in the words of Marshallese poet Kathy Jetñil-Kijiner reflecting on her time speaking at COP negotiations "I was told to perform my poem and then sit down while the professionals spoke" (Jetñil-Kijiner, 2021). AOSIS nations are very supportive of the work of the IPCC and reference its reports often, however their researchers are significantly underrepresented on IPCC author teams (Barnett & Campbell, 2011; Livingston & Rummukainen, 2020; McSweeney, 2018; O'Reilly et al., 2012; Walshe & Stancioff, 2018). Following the publication of IPCC Assessment Report 5 in 2014 there was an expanded interest in issues of 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 regional studies and increased research funding (Robinson, 2020). Most current research focuses on the Pacific, with Caribbean, Indian, African, and South China Sea regions understudied (Douglass & Cooper, 2020; Robinson, 2020). In NDCs several AOSIS nations noted wanting to collect "geospatial, migration and displacement data…but lack the financial resources to do so" (Thomas & Benjamin, 2018c, p. 95). Science relevant to island nations is also lacking from a modeling standpoint since the resolution of global climate models used for future assessments is too coarse to capture most islands and downscaling or aggregation by region can obscure them (Kelman & West, 2009; Nurse et al., 2014). Bridging diverse assessments of SLR, including scientific assessments, local, and Indigenous knowledge systems will aid understanding of SLR impacts and responses (McMichael et al., 2021).

In sum, within justice theory recognition is needed across cultural, social, political, and institutional spaces (Young, 1990). Islands nations and the people that comprise them are diverse with cultures shaped by the physical spaces they inhabit. Yet rather than gaining a deeper understanding of their diversity, media and political narratives tend to homogenize them. Historical oppression impacts modern adaptive capacity and aid dependence, yet this is not widely recognized within climate negotiations despite being a key climate justice consideration. The voices of people at the local and subnational levels experiencing SLR impacts are often left out of high-level policy conversations and the physical sciences literature which guides these discussions. Recognition justice thus entails increased recognition and inclusion of local perspectives within the UNFCCC framework, and support for researchers from AOSIS nations in the scientific community. While SLR could potentially lead to loss of territory and migration in some places, AOSIS statements have repeatedly emphasized the desire to adapt in place and not allow discourses of inevitable migration to limit adaptation possibilities. The greatest potential habitability impacts are in atolls, but even at higher elevations the long-term SLR commitment will alter coastlines and impact populations for generations to come. Recognition justice and the continued existence of islanders in their homes, especially across generations, will be in part determined by the temporal and spatial distribution of SLR, which we turn to next.

4. Sea Level Rise Distributions and Distributive Justice

Distributive justice was first introduced in relation to equitable distributions of material goods (Rawls, 1971). Within the context of climate change distributive justice has been discussed as the dichotomy between states who most contributed to greenhouse gas emissions versus those who are most negatively impacted by the risks of climate change (Babatunde, 2020). In the geographic literature distributive justice is further reconceptualized to encompass the spatial and temporal variability of climate impacts, particularly with respect to uneven contribution to the causes of climate change (Burnham et al., 2013a). As theories of justice expanded, distributive justice was tied to recognition justice as inequities in distribution are often related to hierarchies in cultural, political, and social groups (Fraser, 1997). In this section we consider distributive justice with respect to the spatial and temporal distribution of SLR impacts, which are unaccounted for in temperature targets, particularly when focusing solely on the current century.

4.1. Regional Sea Level Rise

Regional SLR differs from the global mean (Clark & Lingle, 1977; Gomez et al., 2010; Hamlington et al., 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 deformational effects associated with ice sheet mass loss have been shown to explain variations in regional sea level observed in tide gauges (Farrell & Clark, 1976; Mitrovica et al., 2001). Many AOSIS nations already experience SLR rates higher than the global average, but have had very low contributions to the greenhouse gas emissions driving it. This mismatch has been shown to be a source of inequity (Althor et al., 2016). Analysis of current SLR trends is complicated by sparse tide gauge locations and short observation periods (Holgate et al., 2013; Hsu & Velicogna, 2017; Palanisamy et al., 2012). In the Caribbean basin, the average SLR is in line with the global mean (Jevrejeva et al., 2020; Palanisamy et al., 2012), however regional variability is large with some places experiencing substantially higher rates (up to 5.3 mm/yr) (Torres & Tsimplis, 2013) and a recent rapid rise was detected (Ibrahim & Sun, 2020). In the western tropical Pacific SLR rates are up to 4 times the global average (Hamlington et al., 2020; Nurse et al., 2014). At Funafuti in Tuvalu, rates are significantly higher than the global mean (5 mm/yr) with the island experiencing 30 cm of SLR over the past 60 years (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 is 2.21 mm/yr while the actual rate is 5.19 mm/yr (Jyoti et al., 2019).

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

Damage from SLR is often due to extreme sea level events arising from storm surge, cyclones, wave propagation or other factors. Tropical storms lead to the largest sea level extremes in the South Pacific and northern Caribbean. The severity and frequency of these events is intensified by climate warming in several ways, including through SLR. Tropical storms have caused damage to island nations in recent years, a trend projected to worsen, even under low emissions (Hoegh-Guldberg et al., 2018; Magnan et al., 2019). In some locations, flood events 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 shown that local inundation impacts will vary based on topography, bathymetry, and wind conditions (Sabūnas et al., 2020). The impact of waves in addition to SLR can double flood heights during extreme events (Arns et al., 2017; Biondi & Guannel, 2018). Wave impacts can also double the inundation area, which could make some atolls uninhabitable within decades (Storlazzi et al., 2015). A study considering nonlinear interactions between SLR and wave induced overwash finds two tipping points for atoll islands by mid-century under Paris-compliant pathways: a lack of potable drinking water due to salinization and the time at which more than half of the island could experience annual flooding (Storlazzi et al., 2018). Using an updated methodology for assessing elevation it was found that 1 million people in the Caribbean live less than 1 m above local high tide, and 600,000 of them live less than 0.5 m above local high tide (Strauss & Kulp, 2018). Floods 0.5 m above high tide will likely be common within decades while floods above 1 m would be likely by 2100 under scenarios with high AIS melt (Strauss & Kulp, 2018). Assessments of atoll habitability will need to consider multiple interlocking risk factors to understand how risk varies in different locations (Duvat et al., 2021). Due to these complicating factors local scale impacts in island nations can be substantial and are worsened by warming above 1.5°C (Hoegh-Guldberg et al., 2019).

4.2. Temporal Justice

The evolution of climate impacts over time is a concern 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 builds on this stating "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, which is relevant to temporal distributive justice (Martyr-Koller et al., 2021).

Sea levels will continue to increase over time, therefore assessing the climate justice implications of the LTTG necessitates a consideration of distributive impacts over the long-term. The year 2100, while not directly mentioned within the Paris Agreement, is the main point of temporal reference generally associated with it. While policy discussions focus primarily on the current century, many predicted changes to the Earth system, including SLR, are irreversible. The implications for intergenerational justice are vast considering sea levels are projected to continue to rise for thousands of years, with no hope of returning to present values for the foreseeable future (Clark et al., 2016; DeConto et al., 2021; Oppenheimer et al., 2019). If countries follow the NDCs they have submitted under the Paris Agreement research suggests that the long-term SLR committed under those policies would be at least 1 m by 2300 and higher thereafter unless the world stays below 1.5°C (DeConto et al., 2021; Fox-Kemper et al., 2021; Nauels et al., 2019). Even if a 1.5°C temperature target is achieved, sea levels 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, respectively (Clark et al., 2016; Fox-Kemper et al., 2021).

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 occurred between 1991 and 2016 will lead to 12 cm more SLR by 2100 and 25 cm more by 2300 (Nauels et al., 2019). 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

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

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, p. 98). In other words, while they model the costs and feasibility of different scenarios, they do not consider the human or financial 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 not have happened in the absence of overshoot (Tavoni & Socolow, 2013). Modeled pathways from IPCC Assessment Report 4, released in 2007, primarily assessed scenarios with atmospheric CO_2 concentrations of 550–650 ppm. The few IAMs that considered a lower 450 ppm concentration broadly consistent with 2°C targets incorporated overshoot and drawdown with carbon dioxide removal, a new modeling development at the time. This dramatically underestimated the cost, making those scenarios look more feasible (Tavoni & Tol, 2010). At that time European nations were consolidating around support for 2°C and modelers were asked to further assess these more stringent pathways for IPCC Assessment Report 5 (Randalls, 2010; Tavoni & Socolow, 2013). This required expanding use of overshoot pathways to be achievable (Tavoni & Socolow, 2013). The normalization of overshoot pathways, thus, serves to allow the continuation of the status quo fossil fuel-based emissions and in turn helps to justify delays in mitigation, a process that has been termed the "political economy of delay" (Carton, 2019). Since IAMs rely on cost-minimization, anticipating negative emissions becomes a substitute for near-term emissions reductions (Carton, 2019). However negative emissions technologies are unproven and one analysis determined that if they fail to deliver the stated reductions or come with side effects, they could increase overshoot by up to 1.4°C (McLaren, 2020). Distributive justice issues inherent in integrated assessment modeling have only recently been acknowledged within the modeling community (Jafino et al., 2021).

The distributive implications of climate policy are key for assessing justice (Klinsky & Dowlatabadi, 2009) and the additive sea level impacts caused by overshoot presents a key challenge to distributive justice. Framing overshoot pathways as acceptable under the Paris Agreement simultaneously justifies the targets as achievable, while legitimizing the lack of action likely to render them unachievable. If the >2°C pathway implied by the NDCs is followed, implementing carbon dioxide removal after 2060 in hopes of meeting the Paris Agreement goal will likely be too late to prevent a sharp jump in SLR, and every decade of delay thereafter comes with a commitment to higher, long-term SLR despite reductions in GMT (DeConto et al., 2021). If the commitments to future SLR are locked in due to the triggering of self-sustaining ice sheet instabilities, then the inclusion of pathways that allow for an overshoot exacerbate the distributive climate justice issues brought about by insufficient global mitigation action.

In sum, AOSIS nations are already experiencing higher than average rates of SLR in many locations. Given their small contribution to emissions, the impacts of SLR present a distributive injustice. Higher sea levels will persist for centuries to millennia, with the exact time profile to be determined by emissions pathways (Mengel et al., 2018). The long-term commitment to higher sea levels and coastal inundation is a concern of temporal distributive injustice, particularly intergenerationally as people born long after the emissions that caused SLR will be experiencing its irreversible effects. Finally, overshoot pathways have become a feature of temperature targets, normalized via integrated assessment modeling. These pathways have the effect of justifying near-term delays in emissions reductions. As overshoot pathways increase SLR their normalization within the global climate and policy spheres, will exacerbate pre-existing justice issues for communities confronting SLR. As discussed next, this trend of higher impacts from SLR will become more severe if Antarctic instability thresholds are breached.

5. Antarctic Case Study

The preceding three sections have reviewed a range of literature to assess procedural, recognition, and distributive justice considerations of using GMT, normatively framed as being by 2100, as the international metric for climate action. We have found that procedural power dynamics between negotiating parties solidified the GMT target as opposed to a target like binding emissions reductions initially advocated by AOSIS negotiators. Furthermore, SLR has an uneven spatial footprint, long-term irreversible impact, and can become exacerbated by the overshoot pathways normalized by temperature targets. The impacts of SLR have long been a concern to AOSIS nations as they threaten the physical spaces and cultural practices of these nations, and therefore human wellbeing. In the concluding section of the paper we turn to a case study of the AIS component of SLR. The case study is intended to highlight the complexities of the Earth system processes that contribute to future SLR and the justice implications for AOSIS nations, particularly in terms of distributive and recognition justice. As projections of the impact of AIS melt show the potential for slowing GMT rise while raising global sea levels, this case study presents a unique consideration on the question of how GMT targets interface with climate justice and SLR.

5.1. Historical and Current Antarctic Science

The AIS stores the largest potential reservoir of freshwater, with a global mean sea level equivalent of 58 m (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; Golledge et al., 2015; Rintoul et al., 2018). While the combined melting of land ice (Antarctica, Greenland, and all glaciers) is already the dominant component of SLR, exceeding the rate of thermal expansion (Oppenheimer et al., 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 of global mean SLR of ~3.6 mm/yr (2006–2015) could increase by an order of magnitude to rates of centimeters per year (Oppenheimer et al., 2019).

The science of the Antarctic contribution to SLR has advanced significantly over the past decades, as has modeling showing the projected climatic impacts. Antarctica has a unique bed configuration in which substantial regions of the ice sheet are in direct contact with the ocean and lie on bedrock below sea level (Morlighem et al., 2020) making it vulnerable to instabilities. This has been a cause for concern since the 1970s (Mercer, 1978; Oppenheimer & Alley, 2005; Weertman, 1974). Throughout the 90s and into the 2000s the first, second, and third IPCC reports reflected the scientific consensus at the time which was that AIS would almost certainly have a net gain of mass through 2100 (Figure 1a). This is due to higher snowfall in a warming atmosphere, the result being AIS contributing to a sea level fall instead of rise (Church et al., 2001; Warrick & Oerlemans, 1990; Warrick et al., 1996). Models used for projections in the IPCC Third Assessment Report in 2001 had ruled out dynamical processes occurring in the 21st century which could result in larger SLR from AIS instability as these were assumed to only be possible on longer multi-century timescales with warming of a few degrees (Church et al., 2001), however scientific advancements following its publication suggested that threat was likely underestimated (O'Reilly et al., 2012; Rapley, 2006). Shortly before the publication of IPCC Assessment Report 4 in 2007, observational evidence showed that rapid ice loss was already occurring in sensitive regions of the West Antarctic Ice Sheet. These results were discovered too late to be included in the report, though were noted by the author team (IPCC, 2007; O'Reilly et al., 2012). The lower AIS SLR estimates seen in the third and fourth Assessment Reports can be discussed in the context of a documented tendency for scientists to err on the side of more conservative estimates (Brysse et al., 2013).

The ice sheet modeling community was increasingly recognizing that marine-based sectors of the AIS, which rest on bedrock below sea level, were vulnerable to instability. By the time of IPCC Assessment Report 5 in 2014, physics-based models had advanced significantly and showed the potential for larger Antarctic SLR contributions (Church et al., 2013; O'Reilly et al., 2012). This led to expanded research into instability points following the release of this report. At present, observational evidence shows an increasing SLR contribution (Shepherd et al., 2018). Modeling developments are showing the potential for greater Antarctic ice loss than previously projected mainly as a result of brittle glaciological processes including meltwater-enhanced break up of ice shelves and rapid calving at tall ice cliffs, not included in earlier modeling studies (DeConto & Pollard, 2016; DeConto et al., 2021). Yet despite observational evidence of these processes in nature there is ongoing debate regarding their validity and their application to Antarctica (DeConto & Pollard, 2016; DeConto et al., 2021; Edwards et al., 2021; Fox-Kemper et al., 2021).

Today, much of the Antarctic continent is fringed by buttressing ice shelves that slow the seaward flow of the ice sheet (Fürst et al., 2016). The loss of these ice shelves can trigger dynamic instabilities in the ice sheet, with the potential to produce rapid SLR (Oppenheimer et al., 2019). Recent work suggests the global warming threshold for the onset of widespread ice-shelf loss could be as low as 1.5°C–3°C (DeConto et al., 2021; Fox-Kemper et al., 2021; Hoegh-Guldberg et al., 2018). With warming limited to less than 2°C, SLR from Antarctica will likely remain modest within the current century, but could rise 1–2 m on multi-century timescales (DeConto et al., 2021; Fox-Kemper et al., 2021). Given that Paris Agreement aspirations are not currently being met, it remains prudent to consider the implications of temperatures exceeding 2°C this century. With 3°C warming committed by the current NDCs, sea levels are projected to rise up to 0.2 m this century, and 1.5 m by 2300 from the AIS contribution alone (DeConto et al., 2021). Temperatures beyond 3°C could lead to substantial disintegration of the marine-based sectors of the ice sheet (Fox-Kemper et al., 2021). Once ice shelves are lost and instabilities are triggered, the long thermal memory of the ocean will impede the re-growth of the ice sheet, leading to centuries of ongoing SLR even if carbon dioxide is removed from the atmosphere (DeConto et al., 2021). Due to the limited knowledge of Antarctic instability thresholds during the early years of UNFCCC negotiations, information on the extent of the threat of AIS instability to long-term SLR could not be fully considered in the procedural political process as potential targets, including ones based around SLR, were discussed.

5.2. Projections of AIS SLR for AOSIS Locations

As the ice sheet loses mass, reduced gravitational attraction between ice and water leads to a drawdown of the sea surface resulting in sea levels falling near the melting ice sheet, while SLR increases with distance from the location of ice loss. Uplift of the solid Earth beneath retreating marine sectors of the AIS reduces water accommodation space and expels water out into the global ocean, amplifying the SLR away from Antarctica (Gomez et al., 2010; Pan et al., 2021). A shift of the Earth's rotation axis toward the missing ice mass, and Earth deformation associated with water loading across the global ocean both contribute further geographic variability in the far field SLR (Gomez et al., 2010; Mitrovica et al., 2011). Together, these effects produce uneven spatial fingerprints of Antarctic-sourced SLR that exacerbate impacts to AOSIS nations.

To explore possible AIS-sourced SLR impacts at AOSIS locations, we provide new SLR fingerprints under two emissions scenarios spanning three centuries (see Data Availability Statement). Sea level fingerprints associated with a recent projection of the AIS from DeConto et al. (2021) are generated using a gravitationally self-consistent sea level model that includes viscoelastic deformation, Earth rotational effects and migrating shorelines (Gomez et al., 2010; Han et al., 2022). Sea level predictions are normalized by the global mean sea level equivalent change calculated as in Gomez et al. (2010) by distributing meltwater evenly over modern global topography (NOAA, 2009), and allowing for water to inundate areas freed of marine ice. These new fingerprint maps illustrate the spatial heterogeneity of SLR produced by Antarctic ice loss (Figure 2; see Data Availability Statement). We find that regions in the Atlantic, Pacific, and Indian ocean basins are at disproportionate risk from the AIS component of SLR. These findings are in agreement with previous studies projecting the sea level changes associated with AIS melt (Bamber et al., 2009; Gomez et al., 2010; Mitrovica et al., 2009, 2011; Pan et al., 2021; Yousefi et al., 2022). This is due to the dependence of the spatial pattern of AIS-sourced SLR on the location of ice loss which is concentrated in West Antarctica in most ice sheet modeling studies of the next few centuries (Seroussi et al., 2020). When a low viscosity mantle is included beneath areas of the WAIS in the sea level modeling rapid bedrock uplift following ice sheet retreat, and induced meltwater expulsion, can increase SLR relative to the projections shown here (Pan et al., 2021; Yousefi et al., 2022). AOSIS nations will be impacted by AIS-sourced SLR following these patterns with uncertainty being mainly due to the magnitude of SLR by a given time, which will be determined by emissions pathways.

The maps (Figure 2) show how much regional sea level would differ from the global mean for each of the AOSIS member nations. We find that all AOSIS countries will experience SLR from Antarctica that is at least 11.6% higher than the global mean and that the majority (22–32 countries, depending on scenario) will experience an average SLR more than 20% higher than the global mean, with some up to 33% higher (Table 1, Figure 2).

Table 1
Projected Antarctic Contribution to Sea Level Rise at Alliance of Small Island States Member Locations

	RCP45 MISI 2100 PAGM	RCP45 MISI 2200 PAGM	RCP45 MISI 2300 PAGM	RCP85 MISI 2100 PAGM	RCP85 MISI 2200 PAGM	RCP85 MISI 2300 PAGM	RCP85 MICI 2100 PAGM	RCP85 MICI 2200 PAGM	RCP85 MICI 2300 PAGM
Antigua and Barbuda	28.84	27.24	27.32	30.03	27.89	28.59	22.88	23.19	21.81
Bahamas	30.99	29.31	29.44	32.66	30.4	30.95	23.1	23.53	21.64
Barbados	25.76	24.22	24.34	26.58	24.66	25.56	20.91	21.6	20.67
Belize	25.21	23.36	23.55	26.22	24.44	25.28	19.28	20.38	18.99
Comoros	22.59	21.19	21.58	23.27	21.58	22.94	14.58	17.71	17.41
Cook Islands	14.29	13.4	12.81	14.03	12.24	12.85	17.06	15.86	16.17
Cuba	29.64	27.96	28.11	31.11	28.98	29.65	22.31	23.01	21.33
Dominica	27.59	26.02	26.12	28.62	26.57	27.36	22.07	22.55	21.36
Dominican Republic	28.77	27.1	27.21	30.08	27.96	28.62	22.25	22.65	21.06
Federated States of Micronesia	26.54	24.71	25.1	26.14	24.82	26.5	24.94	26.95	27.39
Fiji	22.3	21.14	20.69	23.18	20.74	20.95	20.52	18.52	17.29
Grenada	23.99	22.43	22.57	24.71	22.88	23.84	19.44	20.33	19.49
Guinea-Bissau	16.67	15.09	15.1	16.94	15.42	16.34	14.51	14.96	14.35
Guyana	13.66	12.02	12.21	13.6	12.37	13.63	11.65	13.17	12.93
Haiti	28.72	27.04	27.16	30.02	27.92	28.6	22.14	22.63	21.06
Jamaica	28.66	27.02	27.17	29.89	27.84	28.63	22.12	22.89	21.48
Kiribati	28.44	26.73	26.93	28.41	26.78	28.11	26.59	27.73	27.76
Maldives	20.91	19.31	19.54	20.76	19.35	20.77	18.34	20.23	20.51
Marshall Islands	28.92	27.06	27.46	28.65	27.22	28.85	26.93	28.86	29.18
Mauritius	32.13	30.65	31.07	33.99	31.64	32.61	18.58	21.94	20.53
Nauru	27.95	26.24	26.42	28.1	26.36	27.58	25.58	26.41	26.17
Niue	19	17.98	17.45	19.38	17.18	17.54	19.34	17.61	17.07
Palau	22.71	20.96	21.33	22.19	21	22.72	21.46	23.58	24.17
Papua New Guinea	22.09	20.38	20.41	22.85	20.99	21.71	18.17	18.35	17.16
Republic of Cabo Verde	24.58	23.08	23.05	25.26	23.32	24.09	21.17	21.15	20.28
Saint Kitts and Nevis	28.79	27.19	27.28	29.98	27.85	28.55	22.8	23.12	21.74
Saint Lucia	26.27	24.72	24.84	27.16	25.2	26.07	21.18	21.81	20.79
Saint Vincent and the Grenadines	25.48	23.93	24.05	26.3	24.39	25.29	20.58	21.3	20.36
Samoa	22.73	21.47	21.16	23.07	20.99	21.61	22.19	21.22	20.74
São Tomé and Principe	15.16	13.83	14.1	14.89	13.69	15.24	12.68	14.79	15.2
Seychelles	23.86	22.37	22.68	24.38	22.68	23.99	17.41	19.93	19.69
Singapore	18.96	17.19	17.44	19.04	17.71	18.99	15.95	17.77	17.62
Solomon Islands	26.31	24.81	24.74	27.16	25	25.63	22.69	22.06	20.89
Suriname	13.91	12.28	12.49	13.79	12.57	13.88	12.05	13.62	13.48
Timor-Leste	24.67	23.12	23.2	25.89	23.83	24.5	18.36	18.44	16.9
Tonga	19.6	18.59	18.02	20.26	17.87	18.05	19.1	16.93	16
Trinidad and Tobago	21.41	19.82	19.97	21.95	20.28	21.3	17.48	18.63	17.95
Tuvalu	25.84	24.39	24.26	26.27	24.21	24.97	24.09	23.59	22.99
Vanuatu	21.78	23.26	22.9	25.75	23.19	23.33	21.01	18.98	17.29

Note. Values are given for PAGM for three time periods (2100, 2200, 2300) and three scenarios-RCP4.5 with only MISI dynamics, RCP8.5 with only MISI dynamics, and RCP8.5 with both MISI and MICI dynamics (see Data Availability Statement). PAGM stands for percentage above global mean; MICI, marine ice cliff instability; MISI, marine ice sheet instability.

This remains true regardless of emissions trajectories (medium-high emissions) or time periods considered (2100–2300) (see Tables 1 and 2). As the AIS SLR contribution to the global total SLR differs very little between RCP2.6 and RCP4.5 (DeConto et al., 2021) and the magnitude of impact at AOSIS locations is consistent across MISI scenarios (Table 1) we do not include further calculations under RCP2.6. Under high emissions simulations where the ice sheet includes marine ice cliff instability (MICI) in addition to marine ice sheet instability (MISI) the spatial pattern changes slightly. MISI occurs when buttressing support from fringing ice shelves is lost in sectors of the ice margin where the bed deepens upstream, leading to runaway retreat of the grounding line. MICI is theorized to occur when fringing ice shelves are lost, leading to the exposure of ice cliffs at thick ice margins, which are vulnerable to collapse if they exceed a critical height and lose structural integrity (Bassis & Walker, 2012; DeConto & Pollard, 2016). Antarctic sea level contributions in MISI-only projections are in line with those from other models and statistical techniques, while projections including MICI are generally higher (Edwards et al., 2021; Fox-Kemper et al., 2021; Seroussi et al., 2020). Figure 2 shows projections only including MISI while MICI projections for the high-end scenario can be found in Tables 1 and 2.

Due to gravitational, Earth rotational, and deformational effects, the spatial pattern of Antarctic-driven SLR in our simulations shows the largest amplification occurring near the center of ocean basins, with values tapering closer to coastlines (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 maximum. This pattern holds across both emissions scenarios and all time periods where the ice model only considers MISI processes. In the case where both MISI and MICI processes are included, the sea level bulge over the Pacific Ocean is more centered over the basin leading to the western Pacific experiencing the highest AIS-sourced SLR. The most impacted nations under this scenario are the Marshall Islands, Kiribati, Nauru, the Federated States of Micronesia, Tuvalu, and Palau. In either scenario the Cook Islands, Guyana, Suriname, Guinea-Bissau, and São Tomé and Príncipe consistently experience the least amplification of SLR, though it still remains 12%–17% above the global mean. The Cook Islands are the southernmost islands of Oceania, closest to the AIS. The remaining countries with lower impact lie in regions of tapering sea level gradients along continental margins: São Tomé and Príncipe are the largest islands of archipelagos close to the western equatorial coast of Africa, Guyana and Suriname are continental, lying on the northern coast of South America, while Guinea-Bissau is on the northwest coast of Africa. While Guyana and Suriname experience some of the lowest SLR amplification, they are also identified as places in the Caribbean with the highest population below 0.5 m elevation (Strauss & Kulp, 2018).

Across all the scenarios, sea level continues to rise for centuries (Table 2). Values in this table are generally a lower bound as they only reflect the AIS contribution, however the overall SLR fingerprint at any given place and time will be influenced by an array of factors including the spatial patterns resulting from Greenland ice loss, glaciers, increasing ocean heat content, and other factors. If fingerprints from Greenland mass loss were considered in addition to those from Antarctica the combined impact at many AOSIS locations, particularly in the Pacific and Indian ocean basins would be amplified, though a slight counteracting effect could occur in the Caribbean and along the west African coast (Golledge et al., 2019). Our intention here is not to provide an assessment of the exact amount of SLR that will be felt but rather to consider how spatial variation interfaces with climate justice using the Antarctic contribution to SLR as a case study. Uncertainty in SLR increases the farther out projections look and there are many factors that could alter the eventual SLR centuries in the future, however we choose to include projections until 2300 as we want to emphasize the importance of thinking long-term as a component of considering intergenerational recognition justice and temporal distributive justice. While these sea level calculations provide a regional perspective on the distribution of SLR from Antarctic ice loss, the actual impacts felt are highly variable at the local level and influenced by socio-political factors in addition to physical impacts. Furthermore, we note that even in absence of large-scale mass loss from Antarctica the climate justice implications of temperature targets and SLR discussed in Sections 2–4 remain highly relevant. AOSIS nations are not the only ones to experience an Antarctic contribution to SLR above the global mean, but we stress the distributive justice issues in relation to their advocacy for more stringent climate targets, the inherent vulnerability many have to SLR, and their extremely low contribution to greenhouse gas emissions (Figure 1b).

Table 2
Projected Antarctic Contribution to Sea Level Rise in Meters at Alliance of Small Island States Member Locations

	RCP45 MISI 2100 mean SLR (m)	RCP45 MISI 2200 mean SLR (m)	RCP45 MISI 2300 mean SLR (m)	RCP85 MISI 2100 mean SLR (m)	RCP85 MISI 2200 mean SLR (m)	RCP85 MISI 2300 mean SLR (m)	RCP85 MICI 2100 mean SLR (m)	RCP85 MICI 2200 mean SLR (m)	RCP85 MICI 2300 mean SLR (m)
Antigua and Barbuda	0.073	0.24	0.462	0.043	0.487	1.654	0.418	6.566	11.657
Bahamas	0.075	0.244	0.47	0.044	0.497	1.684	0.419	6.584	11.641
Barbados	0.072	0.234	0.451	0.042	0.475	1.615	0.411	6.481	11.548
Belize	0.071	0.233	0.448	0.042	0.474	1.611	0.406	6.416	11.388
Comoros	0.07	0.229	0.441	0.041	0.463	1.581	0.39	6.274	11.236
Cook Islands	0.065	0.214	0.41	0.038	0.428	1.451	0.398	6.176	11.117
Cuba	0.074	0.242	0.465	0.043	0.491	1.667	0.416	6.556	11.611
Dominica	0.073	0.238	0.458	0.042	0.482	1.638	0.415	6.532	11.614
Dominican Republic	0.073	0.24	0.462	0.043	0.488	1.654	0.416	6.537	11.586
Federated States of Micronesia	0.072	0.236	0.454	0.042	0.476	1.627	0.425	6.766	12.191
Fiji	0.07	0.229	0.438	0.041	0.46	1.555	0.41	6.317	11.225
Grenada	0.071	0.231	0.445	0.041	0.468	1.593	0.406	6.414	11.435
Guinea-Bissau	0.067	0.218	0.418	0.039	0.44	1.496	0.389	6.127	10.944
Guyana	0.065	0.212	0.407	0.037	0.428	1.461	0.38	6.032	10.807
Haiti	0.073	0.24	0.462	0.043	0.487	1.654	0.415	6.536	11.585
Jamaica	0.073	0.24	0.462	0.043	0.487	1.654	0.415	6.55	11.626
Kiribati	0.073	0.24	0.461	0.042	0.483	1.648	0.43	6.808	12.227
Maldives	0.069	0.236	0.434	0.04	0.455	1.553	0.402	6.408	11.533
Marshall Islands	0.073	0.24	0.463	0.042	0.485	1.657	0.432	6.868	12.362
Mauritius	0.075	0.247	0.476	0.044	0.502	1.705	0.403	6.5	11.534
Nauru	0.073	0.239	0.459	0.042	0.481	1.641	0.427	6.738	12.075
Niue	0.068	0.223	0.426	0.039	0.446	1.512	0.406	6.268	11.203
Palau	0.07	0.229	0.44	0.04	0.461	1.578	0.413	6.587	11.883
Papua New Guinea	0.07	0.228	0.437	0.041	0.461	1.565	0.402	6.308	11.212
Republic of Cabo Verde	0.071	0.233	0.447	0.041	0.47	1.596	0.412	6.457	11.51
Saint Kitts and Nevis	0.073	0.24	0.462	0.043	0.487	1.653	0.418	6.562	11.65
Saint Lucia	0.072	0.236	0.453	0.042	0.477	1.621	0.412	6.492	11.56
Saint Vincent and the Grenadines	0.072	0.234	0.45	0.042	0.474	1.611	0.41	6.465	11.518
Samoa	0.07	0.23	0.44	0.041	0.461	1.564	0.415	6.461	11.555
São Tomé and Principe	0.066	0.215	0.414	0.038	0.433	1.482	0.383	6.118	11.025
Seychelles	0.071	0.231	0.445	0.041	0.467	1.595	0.399	6.392	11.454
Singapore	0.068	0.221	0.426	0.039	0.448	1.53	0.394	6.277	11.256
Solomon Islands	0.072	0.236	0.453	0.042	0.476	1.616	0.417	6.506	11.569
Suriname	0.065	0.212	0.408	0.038	0.429	1.465	0.381	6.056	10.86
Timor-Leste	0.071	0.233	0.447	0.042	0.472	1.601	0.402	6.313	11.187
Tonga	0.068	0.224	0.428	0.04	0.449	1.518	0.405	6.232	11.102
Trinidad and Tobago	0.069	0.226	0.435	0.04	0.458	1.56	0.399	6.323	11.288
Tuvalu	0.072	0.235	0.451	0.042	0.473	1.607	0.422	6.587	11.77

Table 2
Continued

	RCP45 MISI 2100 mean SLR (m)	RCP45 MISI 2200 mean SLR (m)	RCP45 MISI 2300 mean SLR (m)	RCP85 MISI 2100 mean SLR (m)	RCP85 MISI 2200 mean SLR (m)	RCP85 MISI 2300 mean SLR (m)	RCP85 MICI 2100 mean SLR (m)	RCP85 MICI 2200 mean SLR (m)	RCP85 MICI 2300 mean SLR (m)
Vanuatu	0.071	0.233	0.446	0.041	0.469	1.586	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. Values are given for three time periods (2100, 2200, 2300) and three scenarios-RCP4.5 with only MISI dynamics, RCP8.5 with only MISI dynamics, and RCP8.5 with both MISI and MICI dynamics. Values for global mean sea level (GMSL, in meters) shown in bold are from DeConto et al., 2021 are provided for comparison (see Data Availability Statement). MICI, marine ice cliff instability; MISI, marine ice sheet instability.

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 ice sheet components (Meijers, 2014).

Recent modeling incorporating ice-ocean-atmosphere interactions have demonstrated that freshwater and ice discharged from the AIS can have a negative feedback on GMT-delaying the rise in air temperature while simultaneously raising global sea levels (Bronselaer et al., 2018; Golledge et al., 2019; Sadai et al., 2020; Schloesser et al., 2019). This effect is due to freshwater induced sea ice expansion around the continent which increases albedo, reflecting more solar radiation to space. This negative sea-ice-albedo feedback slows the pace of warming around and over Antarctica and the cooling feedback is reflected in GMT. Overall, model simulations show GMT values 0.3°C–1°C lower at the end of the 21st century under high emissions scenarios as compared to projections that don't include meltwater impact (Bronselaer et al., 2018; Golledge et al., 2019; Sadai et al., 2020; Schloesser et al., 2019). Beyond the current century, meltwater feedback can reduce GMT projections by up to 2.5°C during peak ice loss under RCP8.5 (around the year 2120, Figure 3) and up to 1°C under RCP4.5 (by mid-22nd century) (Sadai et al., 2020). All temperature values reported here ignore natural climate variability and thus provide a general idea of the current modeling assessments of freshwater impact on GMT but would need to be reassessed for the anthropogenic component to be directly relevant to the LTTG (Rogelj et al., 2017).

This negative feedback on GMT rise impacts the ice sheet's stability and contribution to SLR. First, increased subsurface warming induced by the fresh meltwater inhibiting vertical circulation could accelerate the melting of buttressing ice shelves, leading to faster SLR (Golledge et al., 2019). However, in models that consider the effect of atmospheric warming and meltwater on ice shelf surfaces, the albedo cooling feedback slows the pace of ice loss (DeConto et al., 2021). In the high emissions RCP8.5 scenario in which negative feedbacks can substantially delay greenhouse gas-forced GMT rise during peak ice loss, model projections still yield ~0.5 m of SLR from Antarctica alone by mid-century and 7 m by 2250 (Figure 3) (DeConto et al., 2021; Sadai et al., 2020). This scenario reflects the low-likelihood, high-impact scenario of a world where the goals of the Paris Agreement are far exceeded (Fox-Kemper et al., 2021). In a scenario in line with the 1.5°C–2°C LTTG, these ice sheet induced negative feedbacks on GMT and the risk of triggering widespread ice sheet instabilities in Antarctica would be small, with the rate of SLR remaining similar to today throughout the 21st century (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 in 2100 (UNFCCC, 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 larger threats during this century (DeConto et al., 2021) while at the same time triggering larger negative feedbacks on GMT. It is crucial to understand that any negative feedbacks on GMT resulting from AIS melt would occur in conjunction with SLR and would therefore be at the expense of AOSIS nations and coastal communities, exacerbating climate injustice. Limited studies have explored these ice sheet-climate feedbacks, and this Review paper is the first to point out the climate justice implications in the context of the LTTG, thus further study is needed.

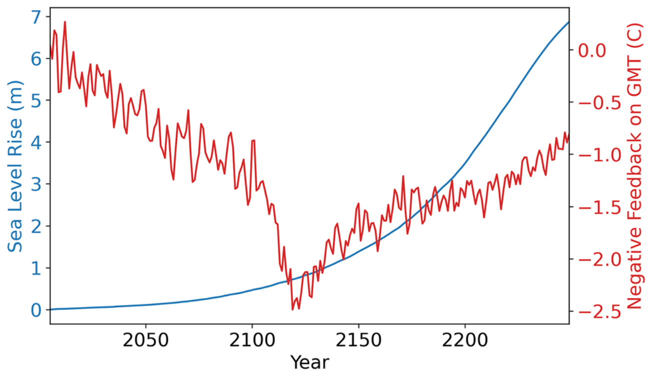

Figure 3. Global mean sea level rise (SLR) and negative feedbacks on global mean temperature (GMT). Under an RCP8.5 emissions scenario one climate model projected GMT response to meltwater could be over 2°C lower at peak ice sheet collapse (Sadai et al., 2020). When driven with these climatologies, an ice sheet model projected that meltwater delays ice sheet loss but that up to 7 m of SLR is still locked in over the coming centuries due to the triggering of self-sustaining instabilities in the ice sheet (DeConto et al., 2021).

5.4. Negative Ice-Loss Feedbacks and Carbon Budgets

While the combined effect of all known climate feedbacks is thought to be positive (Forster et al., 2021), the existence of negative feedbacks, particularly when they are correlated with climate impacts that enhance vulnerability of specific populations (such as AOSIS nations), are critical components to assessing the justice implications of the LTTG. Carbon budgets, which predict the remaining emissions before a given temperature is exceeded, can be calculated in a variety of ways (Rogelj et al., 2016). Current estimates of the remaining carbon budget generally do not account for feedbacks within the climate system, including the strong Antarctic ice loss-cooling feedback described here. Attempts to estimate the impact of feedbacks yields a low probability that they will increase the remaining budget and a high probability that they will lower it, primarily due to the large additional warming contribution from permafrost melt (Lowe & Bernie, 2018). A framework for standardizing the way carbon budgets are calculated has called for the inclusion of feedbacks into budget calculations (Rogelj et al., 2019). To our knowledge the impact that negative feedbacks resulting from AIS melt would have on carbon budgets has never been estimated. Given that the feedback is negative, on its own it would raise the remaining allowable emissions, however it remains unclear how this would interface with other positive feedback mechanisms like permafrost melt. Furthermore, and crucially, any reduction in GMT resulting from Antarctic ice loss would come at the expense of flooded coastlines in AOSIS countries and around the world. If emissions budget estimates are raised, and high emitters use it as justification for delaying mitigation, this could lead to greater long-term SLR. This scenario would exacerbate already existing trends that disadvantage island nations and other coastal communities. With the low remaining carbon budgets for the Paris goals, it is possible that the impact of feedbacks on policy will be small. However if the LTTG continues to be used, particularly on post-2100 timescales, the inclusion of negative feedbacks could become more relevant. In this eventuality, negative feedbacks entangled with SLR will be a key component in assessing the climate justice impacts of policy decisions.

6. Conclusions

The adoption of GMT as a target metric for international climate action fails to fully encompass the UNFCCC Article 2 goal of avoiding dangerous anthropogenic interference in the climate system when considering the regional and temporal variations of rising sea levels. Within the framework of the UNFCCC climate negotiations, the AOSIS has been pivotal in bringing to the forefront the needs of countries most concerned with the impacts of SLR. We use justice theory to understand how the LTTG has procedural, recognition, and distributive justice implications for the AOSIS when considering the effects of SLR.

We find that through the lens of procedural justice, political dynamics influenced the decision to adopt the GMT target. While AOSIS was instrumental in gaining the inclusion of the lower 1.5°C temperature target into the Paris Agreement following unification of the international community around temperature targets, their preferred initial metric of binding emissions reductions was not adopted largely due to uneven power divisions within the negotiating landscape which favored high carbon-emitting nations. Through the lens of recognition justice we show that cultural connection is tied to physical spaces, with SLR threatening this connection, particularly across generations. The diversity of local perspectives and consideration of intergenerational recognition justice are underrepresented in international negotiations. We have found that the social sciences and humanities have begun to center the voices and experiences of island inhabitants and argue for greater inclusion of these voices in the scientific and policy spheres. Finally, as a metric, GMT rise by 2100 fails to fully encompass the UNFCCC Article 2 goal of avoiding dangerous anthropogenic interference in the climate system when considering the distributive injustices associated with the long time commitment and uneven spatial pattern of rising seas across regional, national and local scales. This is particularly dangerous for AOSIS countries given the normalization of overshoot pathways that GMT targets have allowed for. This normalization enables the political economy of delay that is used to justify a lack of near-term emissions reductions and increases the risk of more severe long-term SLR commitments incurred during the overshoot period.

The Antarctic case study illuminates how rising seas can co-exist with delays in GMT rise, a situation which amplifies the justice issues of the LTTG. The spatial fingerprint of the Antarctic contribution to SLR disproportionately impacts AOSIS nations relative to their emissions, a distributive injustice. If Antarctica becomes the dominant contributor to SLR it will exacerbate the long-term and irreversible commitment to rising seas and its associated temporal distributive injustices and multigenerational recognition injustices. Overshooting the Paris Agreement goals could further exacerbate climate injustice since Antarctic instability points lie near 2°C. As recent modeling developments demonstrate negative feedbacks on GMT arising from AIS melt, this is a key consideration for the climate justice implications of the LTTG, but the current literature is limited in terms of scenarios, models, quantification of feedbacks, and post-2100 impact. Further work is needed to explore the intersection of meltwater feedbacks and temperature targets, as well as on how these feedbacks could alter emissions budgets. The potential for higher carbon budgets and emissions could further entrench the political economy of delay, thus slowing emissions reductions while further impacting communities vulnerable to SLR. Future work could investigate other ways climate system feedbacks on GMT could have ramifications for specific communities and climate justice.

Conflict of Interest

The authors declare no conflicts of interest relevant to this study.

Data Availability Statement

Literature review: This paper is a traditional review (Jesson et al., 2011) of existing literature with critical interpretation through the lens of justice theory. It follows a disciplinary framework from critical physical geography, a discipline noting the importance of integrating work across both physical and social sciences (Colven & Thomson, 2019; Lave et al., 2018). To find the range of articles from different disciplinary perspectives, including from the social sciences, history, legal studies, and natural sciences, we conducted a search of multiple databases including Directory of Open Access Journals, Gale, ERIC, and Academic Search Premier for combinations of search terms-climate justice, recognition justice, distributive justice, procedural justice, sea level rise, AOSIS, Caribbean, Indian Ocean, Pacific, Paris Agreement, temperature targets. Back searches were done on included references as needed. In addition to the database search the *Journal of Island Studies* was searched for sea level, AOSIS, UNFCCC, and climate justice. The UN archive was utilized for documents written by AOSIS and member states, proceedings and decisions from major COP meetings, and materials related to the 2013–2015 SED. A concerted effort was made to identify papers written by AOSIS representatives and citizens of AOSIS nations, and papers written by scholars who directly interviewed or collaborated with AOSIS scholars and citizens.

Emissions data (Figure 1): Data were obtained from Climate Watch Historical GHG Emissions (2021) data archive and include emissions from fossil fuel combustion as well as Land-Use Change and Forestry or Agriculture (Climate Watch Historical GHG Emissions, 2021). Data were summed across all countries for the "world" values and across AOSIS nations for the "AOSIS" values.

Sea level rise data (Figure 2; Tables 1 and 2): Sea level predictions were computed with the pseudo-spectral, gravitationally self-consistent sea level model described in Gomez et al. (2010) that includes gravitational and rotational effects associated with surface ice and water mass redistribution, viscoelastic deformation of the solid Earth and migrating shorelines. The Earth rheological structure in the model varies radially, with elastic and density structure given by the Preliminary Reference Earth Model, lithospheric thickness of 120 km and upper and lower mantle viscosities of 0.5 and 5×10^{21} Pa s, respectively. Global sea level fingerprints were computed relative to 2000 using sea level magnitude values from the coupled Earth-ice sheet simulations from DeConto et al. (2021) in which the Penn State University ice sheet model was coupled to a high viscosity viscoelastic Earth model and run under RCP4.5 and 8.5 emissions scenarios, with and without the inclusion of brittle ice processes (MICI dynamics). Values were normalized by the global mean sea level equivalent change (termed the "effective eustatic value" in Gomez et al., 2010) computed by filling areas freed of marine-based ice with water and spreading the rest of the water evenly across the modern ocean area with ocean topography from ETOPO1 (NOAA, 2009). We then used ArcGIS following the cartographic methodology of Gosling-Goldsmith et al. (2020) to highlight AOSIS locations. Country polygons were obtained from the following Natural Earth shapefiles: *Pacific groupings, 1:10 m countries, 1:50 m Tiny Country Points*. We calculated spatial statistics in

ArcGIS to assess values at AOSIS locations. Mean sea level values were calculated at 2100, 2200, and 2300 under RCP4.5 and RCP8.5. For RCP8.5 we use a scenario that includes MISI only and a scenario that includes MICI. Uncertainties in the sea level magnitude values for MICI are in Table 1 of DeConto et al. (2021). MISI magnitude values were from single model simulations rather than ensembles and can be found in the supplementary material for DeConto et al. (2021).

Sea level and GMT data (Figure 3): GMT values under RCP8.5 showing the meltwater induced negative feedback values were obtained from Sadai et al. (2020). Sea level rise estimates were obtained 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). Ensembles were not available for these studies and thus uncertainty can't be directly quantified. For a general understanding of uncertainty in CESM1.2 see Tsai et al. (2020) and for an understanding of uncertainty in PSU3D see DeConto et al. (2021).

Data Availability: The emissions data used in Figure 1 is available at https://www.climatewatchdata.org/ghg-emissions. The data used for the negative feedback shown in Figure 3 from Sadai et al., 2020 is available at the U.S. Antarctic Program Data Center, cited below as Condron (2021) and downloadable here https://doi.org/10.15784/601449. The data used in Figure 2, Tables 1 and 2, and for the sea level rise estimate in Figure 3 is available here https://doi.org/10.7275/bshp-wq34. The sea level code used to generate this data is published in association with Han et al. (2022). Natural Earth country polygons and Pacific boundaries data are available at www.naturalearthdata.com.

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