Title
Rising Tensions: The impact of Sea Level Rise on Maritime Zones

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Rising Tensions: The impact of Sea Level Rise on Maritime Zones

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Abstract:

Sea Level Rise will result in a variety of impacts by 2100. One of these will be changing coastlines around the world as land is inundated by the ocean. Currently, the mean low-water lines around the world are used as baselines for maritime zones under the United Nations Convention on the Law Of the Sea. These physical points will change in the future and UNCLOS does not explicitly state what this means for maritime zones. In some cases the Vienna Convention on the Law of International Treaties can be applied to fix zones defined under bilateral treaties. However, for zones not defined in a bilateral treaty, the future is more uncertain. The future of these zones is likely to be up to the discretion of courts and tribunals with jurisdiction over UNCLOS or rely on updates to the convention.

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List of Acronyms:

AIS	Antarctic Ice Sheet
EEZ	Exclusive Economic Zone
ESL	Extreme Sea Level
GHG	Greenhouse Gas
GIS	Greenland Ice Sheet
GMSL	Global Mean Sea Level
IPCC	Intergovernmental Panel on Climate Change
MISI	Marine Ice Sheet Instability
Ppm	Parts Per Million
RCP	Representative Concentration Pathway
SLR	Sea Level Rise
SMB	Surface Mass Balance
UNCLOS	United Nations Convention on the Law Of the Sea

1. Introduction

How sea level will respond to a changing climate is topic that attracts much attention. This work generally focuses on Global Mean Sea Level (GMSL) changes, regional sea levels, and the cost of Sea Level Rise (SLR) on communities projected to be impacted by it (Church *et* al. 2013). Study of these topics allows for the development of the best possible projections for future GMSL and regional sea level, whilst also addressing the most immediate consequences of Sea Level Rise. The question of how SLR will fit into the United Nations Convention on the Law Of the Sea (UNCLOS) and the maritime zones prescribed by the convention is an important area of research as the world attempts to mitigate and adapt to climate change impacts. Maritime zones prescribed by UNCLOS are already contentious issues in many cases, such as the South and East China seas (Feng 2017 and Jash 2018). As physical baselines currently used by UNCLOS, change, it is likely that deliberations on what different states claim to be areas within which they have the rights to the resources will become more tense.

Issues surrounding UNCLOS and its lack of consideration for SLR are a attributable to the time it was written (Lisztwan 2012). It was signed in 1982 before becoming active in 1994 (United Nations 2012). Sea level rise was not such a widely considered feature of climate change in the 1980s, so the lack of coverage for potential SLR scenarios in UNCLOS is understandable. In 1981 a paper was published referring to potential levels of SLR in the future (Hansen *et* al. 1981). Prior to this, SLR was not a widely researched area of science (Lisztwan 2012).

Since the 1980s, climate science and SLR science have progressed significantly, with our understanding of which places are going to be impacted, by how much and when, all developing tremendously. Therefore, it seems appropriate to be using this developing knowledge to address policy gaps in existing treaties, such as UNCLOS. Development in two of the three major fields has made this research possible. These are sea level rise projections and modelling of SLR.

A better understanding of coastal elevation and the ability to model SLR on more accurate Digital Elevation Models (DEMs) means that projections for the coastal impacts of GMSL rise are more accurate than before, certainly than in the 1980s (Kulp and Strauss 2019). This can be coupled with developments in the understanding and projections of how major ice sheets, a major contributor to SLR, will respond to warming by 2100 (Oppenheimer *et* al. 2019).

This research aims to use up to date projections for GMSL by 2100, in conjunction with the most up to date DEM available, to project how much coastlines of the world are likely to change by 2100. It then aims to consider these changes to support the idea that UNCLOS must be updated, in order to address scenarios in which SLR results in changing baselines for maritime zones by 2100.

2. Background

Sea Level Rise

Throughout the 20th century the dominant drivers of SLR have been the thermal expansion of the oceans and melting of terrestrial ice sheets and glaciers (Church *et* al. 2013). In the past, glacial and interglacial cycles have driven huge fluctuations in Global Mean Sea Level (Lambeck and Chappell 2001). These cycles are largely controlled by eccentricity, one of the three Milankovitch cycles. Changes in eccentricity alter seasonal variation in insolation (Maslin et al. 2001: 40). Currently, eccentricity is at a stage of a weak minimum in summer insolation, with the growth in ice sheets pushing the earth towards a glacial period thought to require CO_2 concentrations below 280ppm. As humans continue to emit CO_2 and have already driven atmospheric concentrations above 400ppm, no glacial inception is projected (Tzedakis et al. 2012). If greenhouse gas emissions continue to grow, the next ice age may be delayed by more than 500,000 years (Archer and Ganopolski 2005). Both of the earth's major ice sheets are also currently losing mass (Vaughan *et* al. 2013). Observations also show mountain glaciers losing mass at a rate unprecedented in recorded history (Zemp *et*. al 2015). As a result it is thought that global warming results in ice sheets and mountain glaciers losing mass and sea levels rising. Global warming also results in the thermal expansion of water in the oceans, the other major driver of sea level rise projections (Church *et* al. 2013).

Projections of SLR depend largely on the Representative Concentration Pathway (RCP) used. The different RCPs are distinguished by their level of radiative forcing in 2100, relative to 1750. RCP 8.5 has the highest emissions of the scenarios and RCP2.6 the lowest (IPCC 2013). The importance of the RCP scenario used is due to the connection between greenhouse gases (GHGs) in the atmosphere and rising temperatures. Rising temperatures then have an impact on both thermosteric and mass change drivers of SLR. Warmer temperatures see surface melting and lubrication of the ice sheet base, accelerating ice discharge into the ocean from land. As the surface mass balance (SMB) of the Greenland Ice Sheet has been decreasing, sea level rise contribution has increased and future contributions are expected to be increasingly positive. Melting of the Greenland Ice Sheet (GIS) is projected to be non-linear, operating as a self-amplifying feedback. Ice melts due to warmer temperatures and the thinner, lower elevation ice sheet melts further (Vaughan *et* al. 2013: 1169).

Most ice loss in Antarctica occurs due to ice discharge into the ocean. Precipitation increases with a warming atmosphere suggest a negative influence on sea level as a result of Antarctic Ice Sheet (AIS) SMB changes. However, relative to the discharge of ice into the ocean this impact is small and total contribution to SLR is expected to increase. Additional precipitation on the edge of ice sheets may actually increase ice flow into the ocean (Church *et* al. 2013).

Modelling limitations on the dynamics of the AIS make it difficult to project the influence of the AIS on future sea level. Due to the low lying bedrock on Western Antarctica, Marine Ice Sheet Instability (MISI) is expected to occur here and could see rapid, significant contributions to sea level (Ritz *et* al. 2015). However large uncertainties exist around this process due to limited observations and modelling proficiency of MISI in Western Antarctica

(Shepard *et* al. 2018). It has not yet been possible to quantify the timing of MISI onset or the magnitude of its contribution to SLR (Ritz *et* al. 2015).

There is uncertainty around projections of SLR due to not knowing which RCP scenario humanity is likely to be closest to, and how ice sheets will respond to the emissions associated with each scenario. This is largely focused on the AIS as it holds enough ice to raise sea levels close to 58m. There is much more potential for different levels of SLR depending on how the AIS responds to warming temperatures (Morlighem *et* al. 2020).

Figure 1 shows the projections for sea level rise by 2100 from the IPCC's Assessment Report 5 and the IPCC Special Report on Ocean and Cryosphere in a Changing Climate. The top of the likely range for RCP 2.6 reaches just over 0.5m and for RCP 8.5 the likely range for an increase in Global Mean Sea Level (GMSL) has a maximum of just over 1m (Oppenheimer *et* al. 2019).

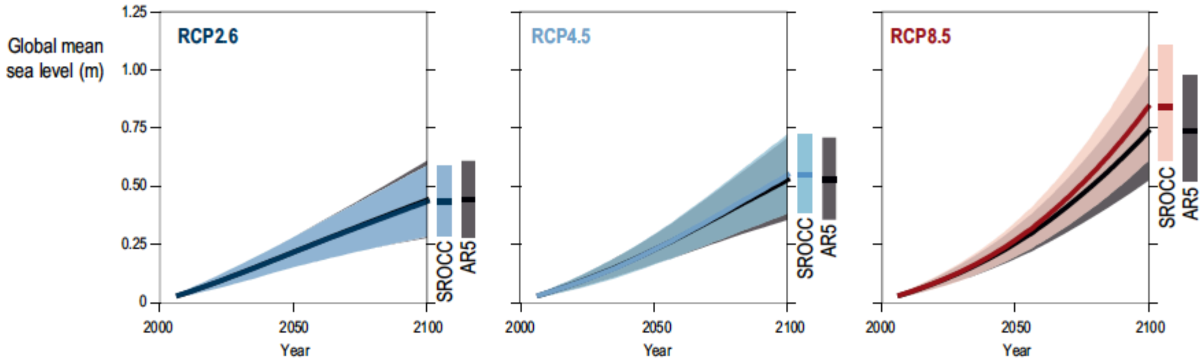

Figure 1 GMSL projections until 2100, shaded areas show likely range and solid lines the median values (Oppenheimer *et* al. 2019: 352).

Despite these projections for changes in GMSL more extreme scenarios should not be ruled out. The uncertainty around the response of both the GIS and more importantly the AIS result in the possibility that even with emissions no greater than under RCP 8.5 much greater levels of SLR could occur by 2100.

One scenario in which SLR by 2100 is more extreme is referred to as H++ (Griggs *et* al. 2017). This scenario is shown in Figure 2, with GMSL rise reaching 2.5m by 2100. This scenario has been developed from a high emissions scenario (RCP 8.5) and high rates of ice loss from the West Antarctic Ice Sheet. Studies have modelled physical processes not seen by humans before that result in high rates of ice discharge into the ocean. This has led to a more extreme 'worst-case' scenario for GMSL by 2100 (Sweet *et* al. 2017). These studies explore processes not yet seen in Antarctica and require further modelling and observations to properly consider the likelihood of them occurring (Griggs *et* al. 2017). However they do also support the inclusion of more extreme scenarios in SLR projections. Therefore, the potential for extreme scenarios should not be ignored when policy making decisions (Griggs *et* al. 2017). Even if H++ ends up not being policy relevant by 2100, it may well be by 2200 so its inclusion has that value also. The use of this scenario is also more likely to provide a stronger signal in the results. This can result in a better understanding of mechanisms and/or regions that will be impacted significantly to focus on under more likely, less extreme scenarios.

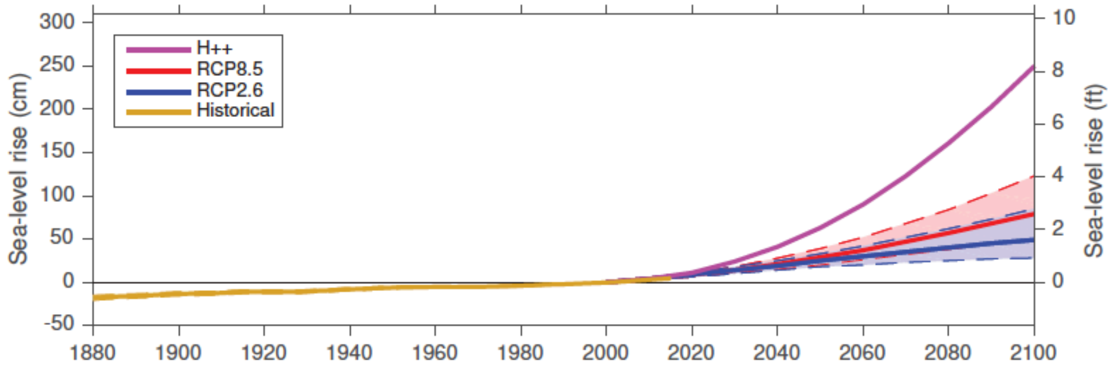

Figure 2 GMSL projections including the H++ scenario (Griggs *et* al. 2017).

The major focus of work surrounding sea level rise impacts on society has been on threats to local areas and has been largely dependent on regional sea level calculations. This work frequently considers the impact of Extreme Sea Level (ESL) events, flooding, salinization and erosion (Oppenheimer *et* al. 2019). However, when considering the laws of the sea as defined in UNCLOS, sea level rise is not addressed as a threat to the future of existing maritime zones.

<u>United Nations Convention on the Law Of the Sea</u>

The existing framework for the governance of the ocean comes from UNCLOS. However it does not provide the first example of territorial claims of the seas. There is evidence of this practice dating back to ancient Greece, where Athenians claimed legal ownership of coasts and bays. This society also established walls of ships in the Aegean sea to ensure their exclusive usage of the area, much like an Exclusive Economic Zone (EEZ) aims to today (Ryan 2019). The major difference between historical governance of the oceans and the contemporary framework is found in the types of regimes that exist.

UNCLOS has created a system of governance of the oceans based on international agreements. This system is based in law and diplomacy as opposed to historical sovereign claims based on military dominium. The last military dominated control of the oceans arguably came through British imperial order in the 18th century (Ryan 2019). Here, security at sea was based upon military or naval power. Now even small island nations without a strong military presence at sea have the rights, under UNCLOS, to an EEZ in the same way the most powerful naval nations do.

UNCLOS is the regime developed by the United Nations in response to more recent proclamations from coastal states such as Chile and Peru. These claimed national sovereignty over marine and submarine areas up to 200 nautical miles from their coastlines. This was done in an effort to control fish stocks in the sea adjacent to their land masses. These declarations came after the United States announced the extension of U.S.

jurisdiction over all resources on their continental shelf in 1945. These were the first major movements towards governance of maritime resources as technology allowed for further exploitation of natural resources. These claims, which were followed around the world by other states with their own claims, counterclaims and sovereignty disputes, created a need for a regime to address the arising issues. This came through the United Nations Conference on the Law of the Sea and the international regime it created (United Nations 2012).

UNCLOS was signed in 1982 and became effective in 1994 after ratification by its 60th party (United Nations 2012). It has now been recognised by 168 parties, with others, including the US, recognising it as general international law, despite not being signatories (UNTC 2020 and Coleman 2012). This convention defines the rights and responsibilities of nations with respect to their use of the world's oceans. The convention also defines the procedures to be followed in a dispute, first requiring efforts to settle disputes by peaceful means under article 279. Article 287 then provides guidelines on the courts and tribunals that have jurisdiction over disputes regarding the convention (United Nations 1982).

The baselines for both the territorial seas and EEZs are defined in article five of UNCLOS as low-water lines marked on large-scale charts officially recognised by the coastal state (United Nations 1982). Territorial seas are the maritime area up to twelve nautical miles from the low-water line (United Nations 1982: 27). The EEZ extends 200 nautical miles from the same baseline (United Nations 1982: 44). It has been suggested that If SLR alters the shape of existing coastlines or submerges land to the point where the low-water line is altered, the outer boundary of a state's maritime area, or its EEZ, must also change (Vidas *et* al. 2019). However, UNCLOS and existing laws do not specifically define a policy solution to baselines moving landward due to SLR (Hioureas 2017).

<u>The future of UNCLOS considering SLR projections</u>

This has resulted in consideration of what changes could be made to UNCLOS. In response to rising sea levels, baselines and/or outer-limits could be fixed, or allowed to change. Depending on the policy decisions made at this stage, the impacts will vary significantly. This results in arguments for and against each policy decision which have been considered by the International Law Association (Vidas *et* al. 2019).

If baselines were to be fixed in their current position, coastal charts would not need to be redrawn. Baselines could be fixed and defined by coordinates, not nautical charts. It would also ensure that states retain their entitlements to the current maritime zones with widths prescribed by UNCLOS. These zones would remain the same size, and the total area of a state's territory would not change, only the proportion of land to maritime territory would change. Any attempts to artificially preserve physical baselines would not be required. Coastal states and Small Island Developing States (SIDS) would not suffer as a result of losing maritime area (Vidas *et* al. 2019).

However, fixing baselines through updating the law of the sea does not come without problems. Maintaining charts that show baselines that are not physically present would result in a legal fiction. The charts would not reflect the actual baseline, as these charts would be out of date. Furthermore, the charts would still need to be updated in the interest of safety for mariners operating within the state's zone. Coastal states may also end up with EEZs and territorial seas based on physical features which no longer constitute an 'island' under article 121(1) of UNCLOS. Finally, if baselines were to be fixed in place, and outer limits as a result of this, then the high seas would be prevented from expanding as they currently might under UNCLOS (Vidas *et* al. 2019).

If the approach of fixing outer limits were taken, coastal states would keep the existing maritime zones and claims to maritime areas beyond territorial seas. This would also allow the baseline to remain the low-water line and reflect the physical reality of sea level rise. Coastal charts would reflect the physical reality of the coastline. Any attempts to artificially preserve physical features in order to maintain existing maritime zones would not be encouraged. Finally, again, coastal states' rights to the ocean would be protected from change as a result of climate change (Vidas *et* al. 2019).

Arguments against such action include: the fact that fixing outer limits could mean countries claiming EEZs larger than 200nm, the limits of the territorial sea would not be fixed and would still change relative to the new baselines, mariners would need to be kept aware of the changing position of the territorial sea, and finally, it would again prevent the expansion of international waters (Vidas *et* al. 2019).

The work by the International Law Association has focused around three objectives (Vidas *et* al. 2019). These are: minimising changes to existing law, facilitating legal certainty into the future and preventing conflict between states (Vidas *et* al. 2019). These objectives do not include any reference to climate justice, or protection of SIDS. These states have contributed relatively little to climate change, but in many cases, including when there are changes to maritime zones, are set to suffer first and worst.

Small Islands are particularly vulnerable to SLR. Limited relocation opportunities and disproportionally coastal settlements are cause for concern here. SLR creates increased risk of storm surges, storm waves, deep ocean swell and tidal cycles (Nurse *et* al. 2014). The Indian Ocean and tropical Pacific, home to many small island nations, see SLR rates significantly higher than global averages (Meyssignac *et* al. 2012) . Should ice sheet discharge raise sea levels, small islands are likely to be the first and worst hit. This is due to the position of many small islands across the globe being connected to natural cycling climate modes that can further exacerbate SLR (Nurse *et* al. 2014 and Fasullo and Nerem 2018). For example, the capital of Tuvalu, the atoll of Funafuti, saw relative SLR increasing at rates three times greater than the global average (Becker *et* al. 2012). SLR is also expected to have an impact on erosion of beaches and coastlines. It is predicted that rising sea levels will result in increasing rates of erosion, further exacerbating the issues facing small island nations around the world (Nurse *et* al, 2014).

Linked to far more significant impacts of SLR, where island nations are entirely submerged the issue appears again. If a state's population and government are left in exile then what happens to the state's EEZ? Fixing the EEZ by marking it with geographic coordinates would result in the stability of currently recognised zones. Here, provided the state can continue to be recognised as a state once all its natural terrestrial territory has been submerged, it could maintain access and rights to its EEZ.

Whether the state would still be recognised is another question. The Montevideo Convention, ratified by the majority of American states in 1933, requires a state to possess: a permanent population; a defined territory; government and the capacity to enter into relations with other states (League of Nations 1936). However, the United Nations does not define the term “statehood” or “states” in the Membership Provisions of the United Nations Charter (Chen 2001).

The criteria listed in the Montevideo Convention are interdependent. For example, it is not possible to have a government if there is no population to govern, or a permanent population without territory for them to live on (Hestetune 2010). Therefore, if SLR removes the territory of an island state such as the Maldives, then their ability to continue to claim an EEZ under UNCLOS may be compromised without them knowing if they will or will not be recognised as a state anymore.

Article 305 of UNCLOS determines who is able to become a party to the convention (United Nations 1982: 139). Provided the party is recognised by the United Nations as eligible to sign the convention, they are entitled to the rights prescribed by all other parties in and by the convention. If the Maldives is completely submerged, then they may no longer be party to the convention and therefore not have the rights to their EEZ under UNCLOS. Furthermore, article 121 defines an island as “a naturally formed area of land, surrounded by water, which is above water at high tide.” (United Nations 1982: 66). The Maldives have attempted to combat climate change and SLR by building artificial island structures (Hestetune 2010). Article 60 of UNCLOS states that an artificial island cannot generate a maritime zone (United Nations 1982: 45). Put simply, according to this, if the Maldives were to be submerged, but its artificial island remained, along with its statehood and position as a party of UNCLOS, its existing EEZ could still be questioned.

3. Methods

The data analysed in this project was provided by Climate Central, an independent non-profit research group based in Princeton New Jersey (Climate Central 2020). The data was received after applying to use it online and signing a non-commercial licensing agreement. The data received makes up a Digital Elevation Model with a 3 arcsecond (~90 meter) horizontal resolution called ‘CoastalDEM90®’ (v1.1). The tile dimensions of the DEM are 1x1 degrees, using the horizontal and vertical datums of WGS84 and EGM96. The files cover 3.5 million km^2 between latitudes 60 degrees north and 56 degrees south (Kulp and Strauss 2018). ArcGIS Pro version 2.5 was the software used to analyse the data, run SLR projections and produce the results.

The DEM was loaded into ArcGIS Pro before being reclassified to show different projections for SLR by 2100. Each of the 5458 individual 1x1 degree DEMs were initially merged together using the Mosaic to New Raster geoprocessing tool in ArcGIS Pro. This allowed for the global DEM file (Figure 3) to be reclassified using the Reclassify geoprocessing tool to show 0.5, 1 and 2.5m of SLR across the globe.

This analysis used GMSL, neglecting regional variations in projected SLR at any specific date. This study prioritised addressing what coastlines will look like at a given projected level, while acknowledging that the target projected level will occur at different times in different regions.

Figure 3 CoastalDEM90® tiles merged into a global DEM file.

The reclassifications were used to determine regional areas of interest for the project, which are Southeast Asia and the Mozambique Channel. In order to reduce processing time, files were created using only tiles from the original DEM that covered the coordinates of the regions of interest. These tiles were then merged together using the Mosaic to New Raster geoprocessing tool to produce regional DEMs for Southeast Asian coasts and the Mozambique Channel's coasts (Figure 4).

Figure 4 Southeast Asia DEM after merging CoastalDEM90® tiles of appropriate coordinates.

Figure 5 Mozambique Channel DEM after merging CoastalDEM90® tiles of appropriate coordinates.

The regional DEMs were used to create projections of coastlines under different SLR scenarios for the year 2100. The regional DEMs were reclassified to display all elevations larger than 50m as 50m. This was done in order to reduce processing times for the large files being analysed. Following the reclassification, contours were produced for the regional DEMs.

The contour interval was 0.5m, producing contours from 0 to 50m with a z-factor of 1. The contours with the values of 0.5, 1 and 2.5m were then selected to represent GMSL rise under each scenario's projections, new GIS layers were produced for each region and SLR scenario to display only the contours with the relevant values (Figure 6). The seaward contours for each land mass in the regions were selected to represent the new coastlines created under each scenario's GMSL rise.

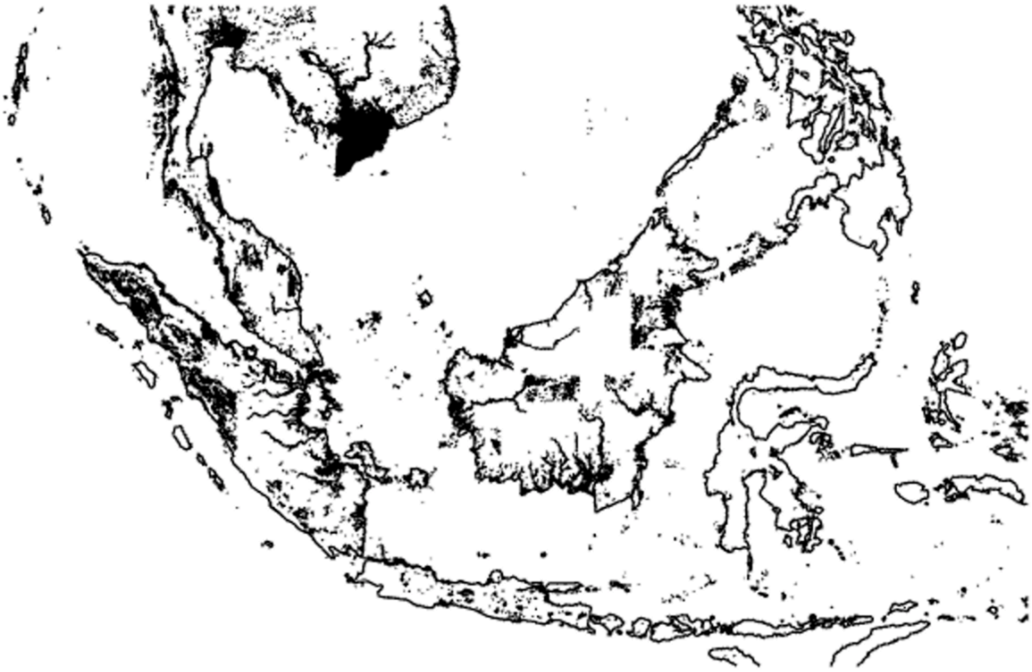

Figure 6 0m Contour lines from the Southeast Asia DEM before only seaward contours displayed.

In order to allow for better visualisation, all contour lines created from the DEM that represented topographic features away from the scenario's new seaward contours were selected and removed from the layers showing the 2100 projected coastlines. The projected coastlines were then compared to the 0m contour lines, created from the same DEMs using the same methods as described above, to show how much change coastlines in each region experience under each scenario (Figure 7).

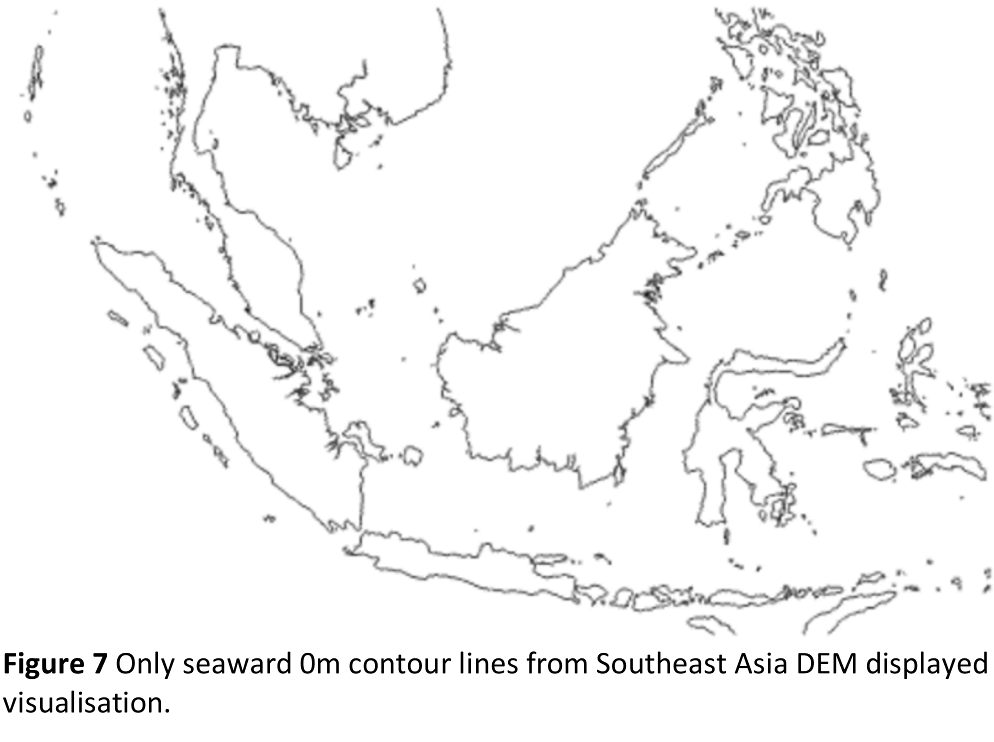

Figure 7 Only seaward 0m contour lines from Southeast Asia DEM displayed for better visualisation.

4. Results

Mozambique Channel

With 0.5m of SLR (Figure 8) the coastline of Mozambique does not change dramatically. The coastlines projected from contours on the CoastalDEM90 model show only two areas where more than a mile of retreat occurs. The first is at 16.5°S, 40°E, where around 10 miles of land is projected to be lost by 2100 with 0.5m of GMSL rise. The other area where the coastline is projected to change significantly is at 12.5°S, 40.5° E, where around 5 miles of retreat occurs on a peninsula. Madagascar sees little to no change under this scenario, certainly nothing that would result in major implications for maritime zones (Figure 8).

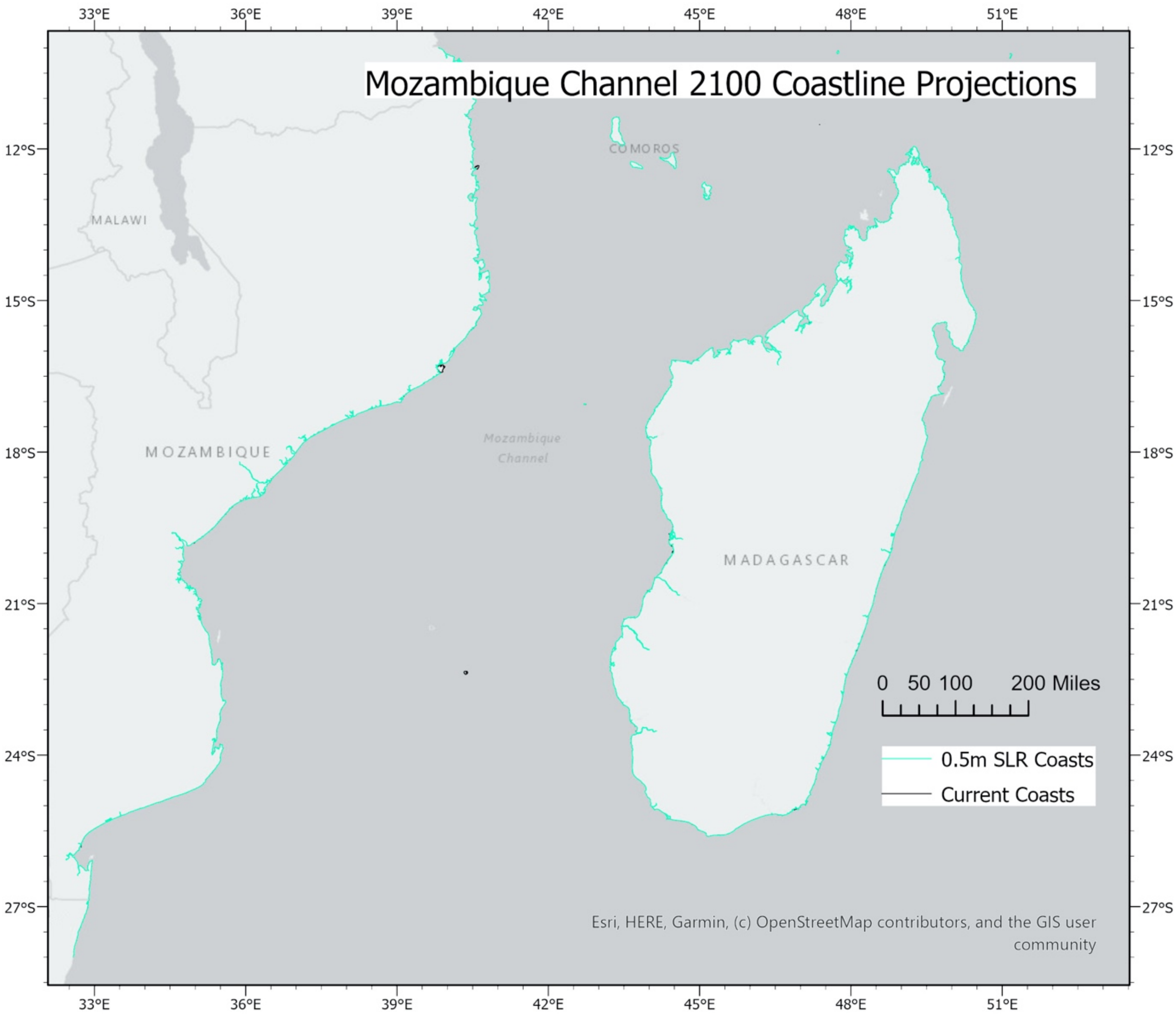

Figure 8 Coastline projections for the Mozambique Channel with 0.5m of GMSL rise by 2100.

The middle scenario of 1m of SLR by 2100 (Figure 9) shows the same areas changing as with 0.5m of SLR, along with two areas at 18°S, 36°E and 21°S, 35°E showing less significant change (Figure 9). At 1m Madagascar's coastline is still projected to not change much, however a portion of the coastline stretching from 20°S, 44.5°E does start to show slight retreat, all less than 5 miles (Figure 9).

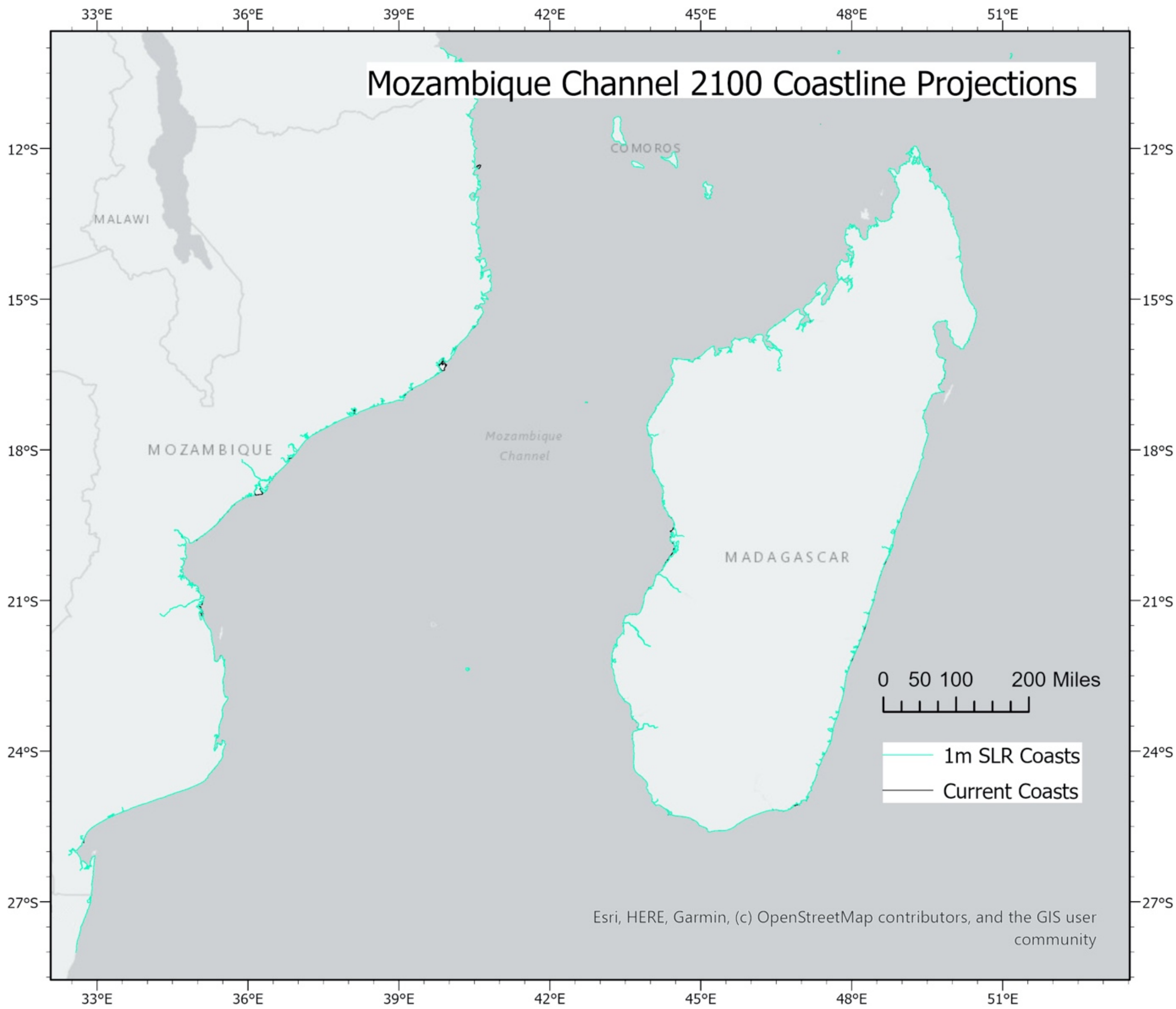

Figure 9 Coastline projections for the Mozambique Channel with 1m of GMSL rise by 2100.

Under the 2.5m of GMSL rise projected with the H++ scenario (Figure 10) coastal retreat is more widespread and significant, but the west coast of Madagascar still shows significantly less retreat than on the coast of Mozambique. The stretch of coast from 19.5°S, 35.5°E to 18°S, 37.4°E sees the most extreme retreat. The locations showing the most retreat here are projected to lose more than 25 miles of land to SLR (Figure 10). Under this scenario the same regions on the coast of Madagascar retreating under 1m of SLR begin to show more significant retreat (Figure 10).

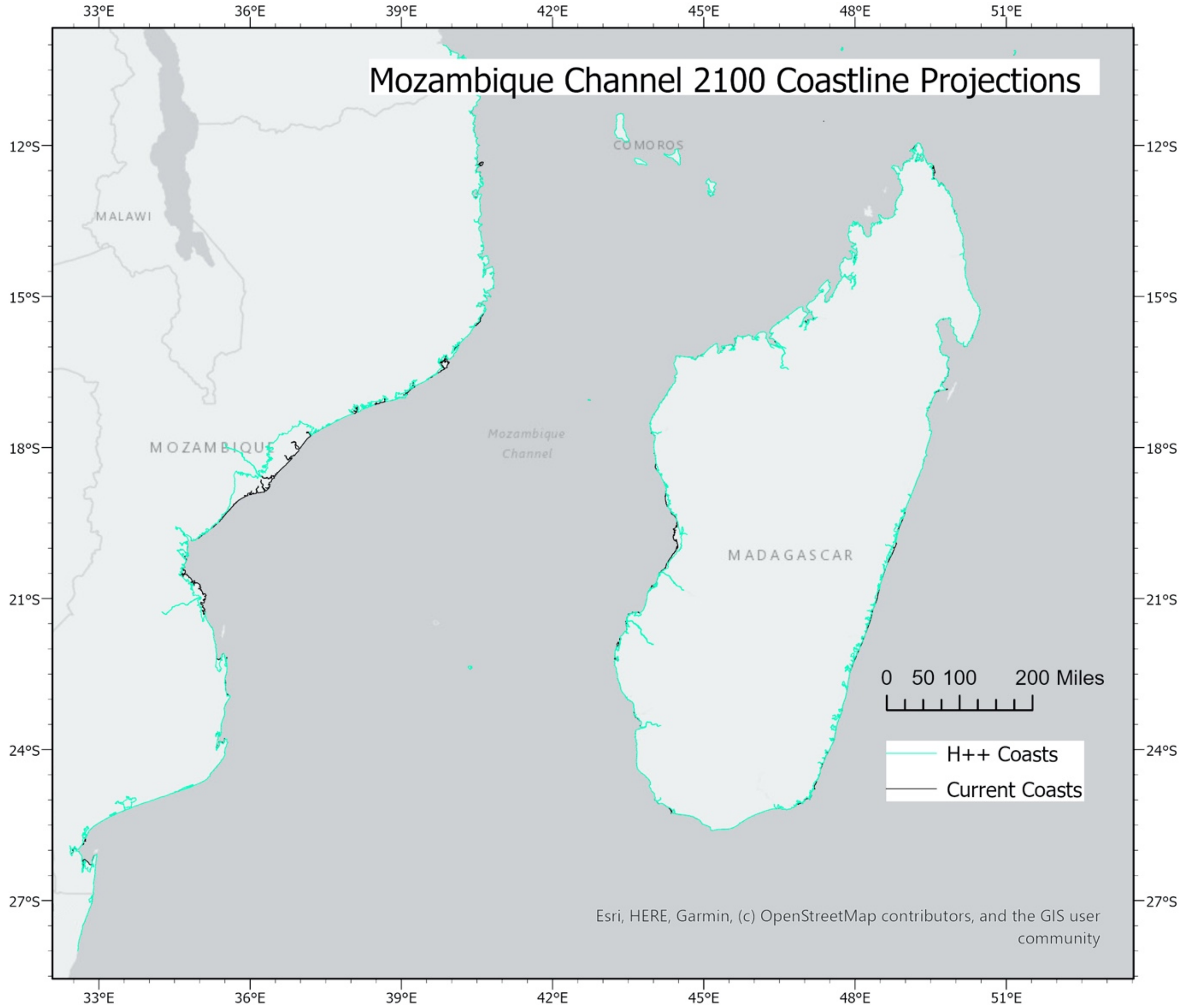

Figure 10 Coastline projections for the Mozambique Channel with 2.5m of GMSL rise by 2100.

Southeast Asia

The other region of interest in this project, southeast Asia, shows significantly more coastal retreat under all SLR scenarios, in a region with more EEZs bordering EEZs of other states.

At 0.5m of SLR (Figure 11) the coastlines around the gulf of Thailand, belonging to Thailand and Cambodia, see land lost in multiple locations, but these are not hugely significant amounts of coastal retreat. Malaysia also sees numerous spots of slight retreat but not on scales significant to maritime zones. Indonesia is more significantly affected.

Peninsulas and islands on the border of the Celebes Sea can be seen in figure 11, where the 0.5m SLR coasts are not on top of the current coasts near the northern border of Indonesia with Malaysia. Other Indonesian islands, along with the Philippines, are largely unchanged by 0.5m of SLR by 2100 (Figure 11).

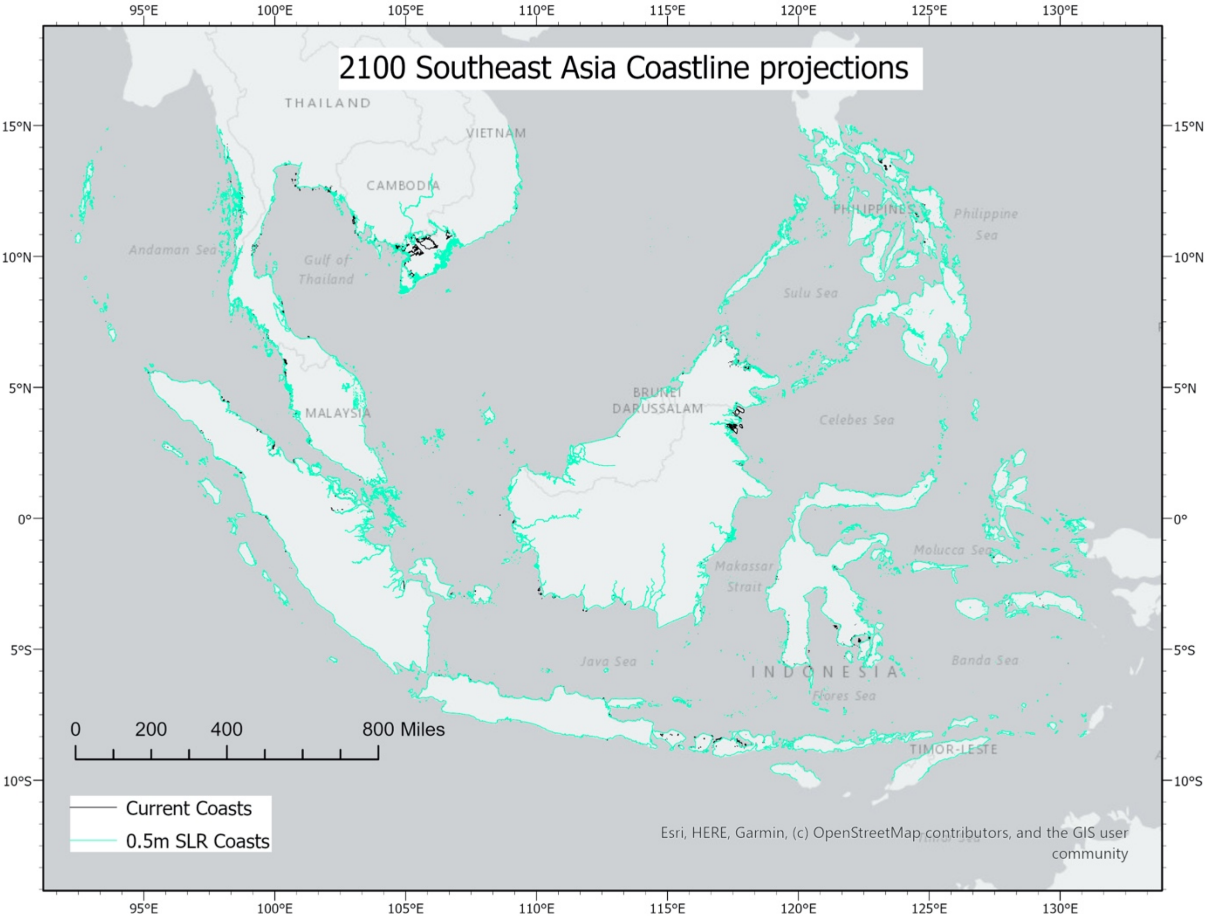

Figure 11 Coastline projections for Southeast Asia with 0.5m of SLR by 2100.

Under the 1m of SLR (Figure 12) the changes are largely the same, with each of the locations impacted at 0.5m seeing slightly more significant impacts. At 1m new areas of land lost also appear. Some of the coastal islands belonging to Burma in the Andaman Sea are lost with 1m of GMSL rise. Projections for Malaysia show the same locations, with more retreat occurring than under 0.5m, along with areas not affected at 0.5m. One such location is a delta region at 2°N, 112°E where the current coastline will have retreated around 50 miles by 2100 with 1m of SLR (Figure 12).

The impacts in Indonesia are also more widespread with 1m than 0.5m of SLR. The coast of Sumatra bordering the Andaman Sea has various locations where retreat is projected to occur. On Kalimantan, another delta region is heavily impacted with Indonesian coastal islands submerged in the Makassar Strait. The Philippines remains largely unaffected at 1m of SLR (Figure 12).

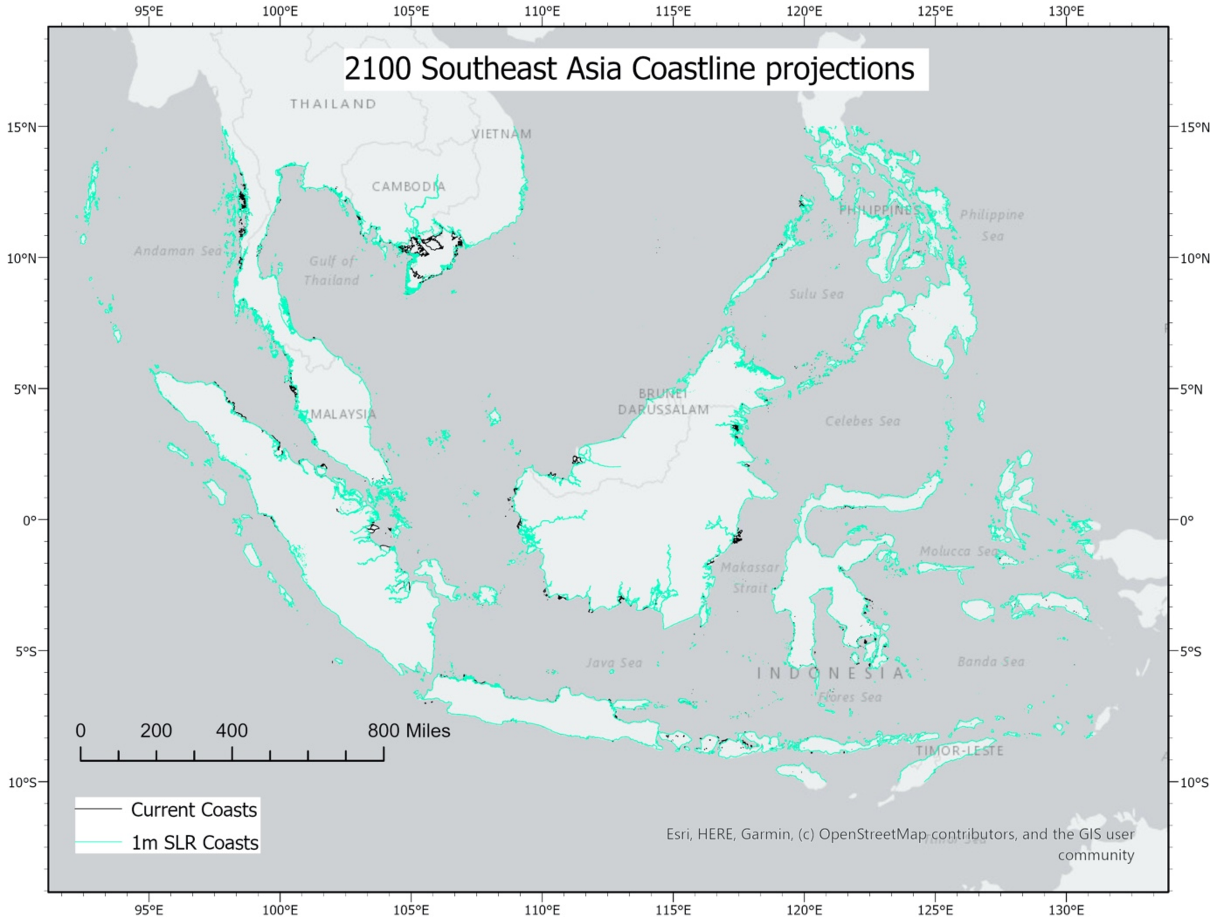

Figure 12 Coastline projections for Southeast Asia with 1m of SLR by 2100.

In southeast Asia the H++ scenario, projecting 2.5m of SLR, produces the most dramatic results of all the regions studied in this paper. Here, almost the entire Mekong delta is submerged, with Vietnam's coastline retreating around 200 miles (Figure 13). This region is one of low lying land, in a marshy delta region, totally inundated by the ocean under 2.5m of SLR (Figure 13).

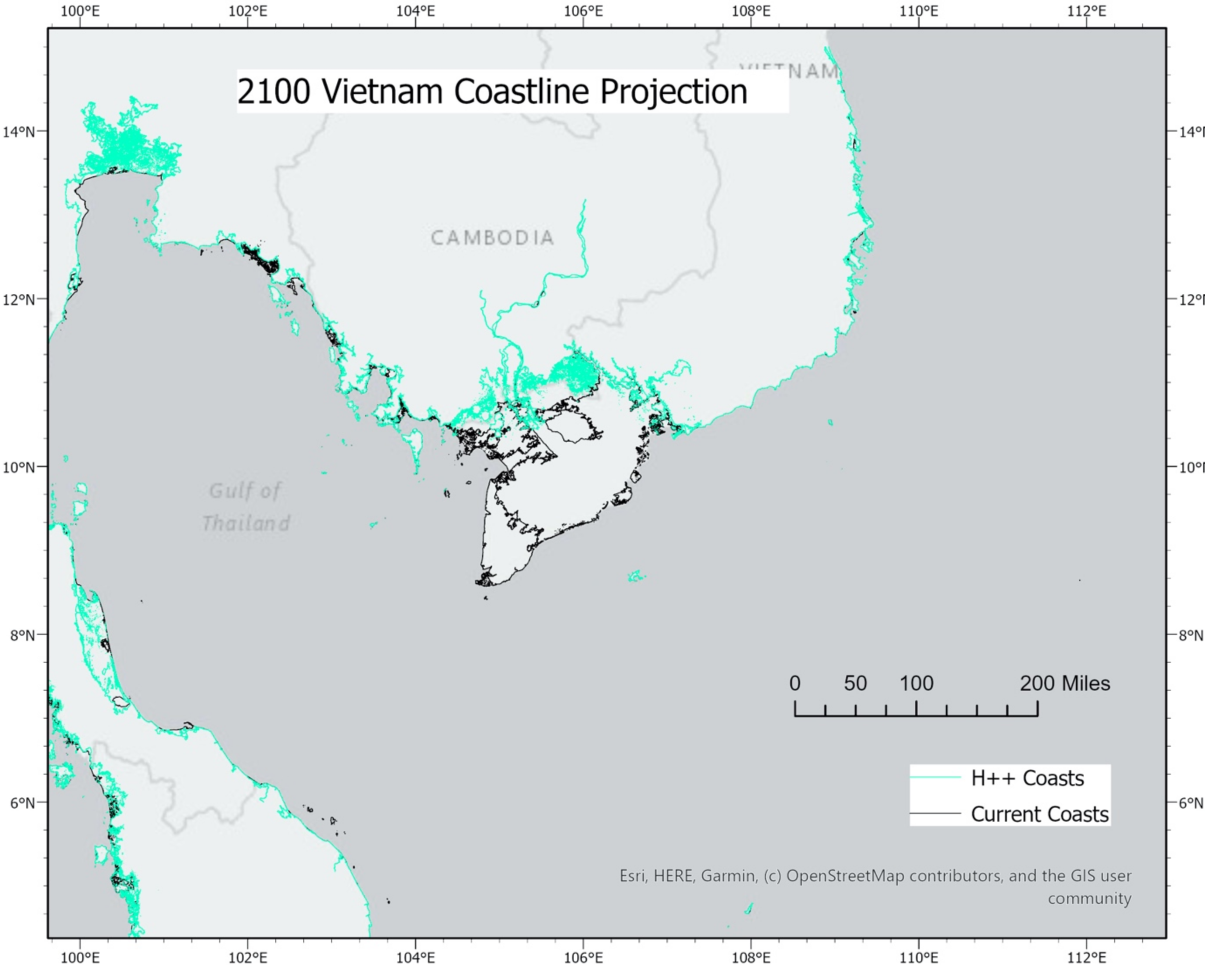

Figure 13 Coastline projections for Vietnam for 2.5m of SLR by 2100.

The projections for Thailand and Burma show the same locations at risk but losing more land. Projections for Malaysia also show largely the same locations losing more terrestrial area. Indonesia loses significant area on Kalimantan, with a delta region in the south of the Island seeing the coastline retreat around 100 miles and more significant land lost on the Celebes Sea on by the border with Malaysia. Undoubtedly the H++ scenario results in the most dramatic coastal changes from the projections, with the southeast Asian area, with lots of low lying islands and coastlines also being the study region with the most change projected (Figure 14).

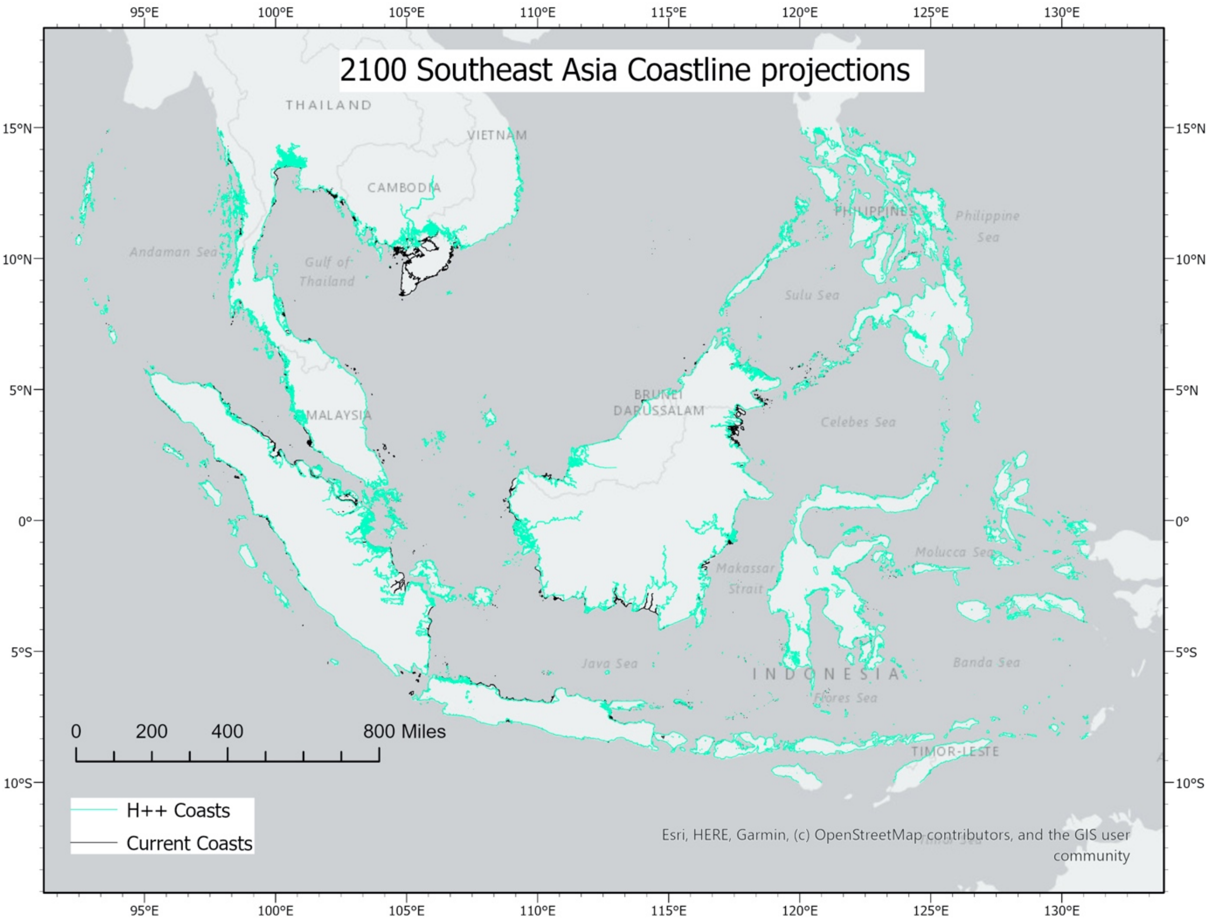

Figure 14 Coastline projections for Southeast Asia with 2.5m of SLR by 2100.

5. Discussion

It is unsurprising that the coastal areas displaying the most change under all scenarios are delta regions. These regions, such as the Mekong delta in the south of Vietnam, show themselves to be at high risk under all scenarios, with the low lying land at risk of inundation and sediments also potentially subsiding as they become more compact (Anthony *et* al. 2015). The computer projections in this paper do not consider isostatic changes and their impact on GMSL. However, when this is added into the calculations for GMSL change in delta regions, already shown to be at risk due to eustatic change, delta regions may be facing even more than the projections in this paper show (Anthony *et* al. 2015).

The coastline projections also show the extreme scenarios having a more dramatic impact on projections for coastal retreat by 2100. However, all SLR scenarios show changes that could raise issues surrounding UNCLOS and maritime zones, even at 0.5m of SLR, a low level estimate for 2100. Therefore, it seems clear that SLR is going to result in coastal changes that UNCLOS is not currently prepared to deal with.

The physical baselines defined in article 5 of UNCLOS are set to change as sea levels rise this century. UNCLOS does not currently guide states set to experience coastal retreat on how to determine their maritime zones as the baselines change. Allowing the definition of baselines to remain the same in the text of UNCLOS could result in ambulatory baselines. If the normal baseline definition in article 5 were to stay the same, they would change as often as charts were updated. However, this is not clear in the text of UNCLOS, as it seems that it was assumed that the baselines, or mean low water marks, were not going to be changing. Updating the baselines and charts periodically would be necessary in order to ensure that the charts used for baseline setting represent the physical reality on the coast.

However, the above policy scenario would result in EEZs changing on a continuous basis as sea level rises. This would be problematic for many reasons, one of which is the negotiation and allocation of fishing quotas. For example, China currently has a 10-year agreement with Madagascar to allow 330 Chinese boats to fish within the Malagasy EEZ (CFFA – CAPE 2018). These types of agreements are common all over the world. In 2013 China had over 1,900 boats operating in the waters of 35 countries around the world (Mallory 2013). International fishing agreements could be complicated by EEZs being re-evaluated and changing periodically. If the state offering a quota to another state to fish in its waters has an EEZ that changes while the agreement is active, this would be problematic. The country that paid to fish in the waters of the state with a changing EEZ would potentially have paid for to fish in an area the host country no-longer has the rights to sell access to.

The issue of international agreements to fish in a state's EEZ do not only exist for fisheries. Article 56 of UNCLOS provides the coastal state with the sovereign rights to exploit, conserve and manage natural resources within the water, seabed and subsoil and to produce energy from the water, currents and winds in the EEZ. Therefore, it is likely that the potential issues described above for fisheries could be expanded into other resources such as mining and oil and gas extraction also (United Nations 1982).

Furthermore, in regions where the EEZ of one state borders the EEZ of another, such as at 16°S in figure 10 between Mozambique and Madagascar, and only one of the two state's sees significant coastal retreat, states may enter into a dispute over ceding part of their EEZ to the state whose coast did not retreat as much. This is also likely to be an issue in southeast Asia with lots of states' waters bordering another states' waters and significant changes to coastlines projected. Under article 74 of UNCLOS, where there is not space for both states to have a 200nm EEZ, the states on opposite or adjacent coasts must come to an agreement on the delimitation. If they cannot come to an agreement, they must follow the procedures of Part XV of UNCLOS referring to the settlement of disputes (United Nations 1982). Here the Vienna Convention for the law of Treaties must be referenced. Article 62 of the Vienna Convention refers to a fundamental change of circumstances. If a fundamental change of circumstances occurs, which was not foreseen by the parties to an agreement, a state may unilaterally terminate an agreement (United Nations 1980). However, a change of circumstances may not be invoked as a ground for terminating or withdrawing from a treaty if the treaty establishes a boundary (United Nations 1980). This suggests that boundary agreements would remain in place under international law, despite a change in coastline (Sefrioui 2017).

The Vienna convention effectively fixes boundaries in place for the duration of the agreement between two countries. However, where an EEZ borders international water, the Vienna convention cannot be relied upon to provide stability of maritime zones. One solution to the potential loss of seaward sections of EEZs would be to allow baselines to remain the mean low water line on charts officially recognised by the coastal state, but to fix the outer limits in place, without requiring bilateral agreements. This would prevent states having signed agreements to access areas that a state no longer has the right to sell access to when SLR results in coastal retreat. However, this would result in EEZs being larger than 200nm in areas where they currently extend 200nm (Vidas *et* al. 2019). In order for this to occur the text of UNCLOS would have to change as it currently does not provide for such a scenario.

Considering the above discussion on problems likely to arise with the proposed solutions, another policy scenario must be considered. This is fixing baselines, and the zones themselves, based on geographic coordinates, instead of the low water line on charts officially recognised by the coastal state. This would reduce the impact of SLR on coastal states, reduce the likelihood of further international relations issues arising and ensure the temporal stability of maritime zones.

Fixing maritime zones as they are currently, based on geographic coordinates would result in EEZs covering more than 200nm offshore. However, this is arguably less troublesome for coastal states than EEZs migrating landwards, replacing outer areas of the EEZ with newly submerged coastal land, which is likely to be far less productive and bountiful than longstanding ocean area. A scenario in which both baselines and outer limits are ambulatory would result in states suffering the costs of losing often valuable and densely populated, developed coastal land, and areas of more productive fisheries and national waters being replaced by newly submerged territory. This would be in order to not exceed a 200nm limit on the size of EEZs under UNCLOS. If outer limits were fixed with coordinates and therefore didn't move as the coastline did, nations would only be suffering the costs of the land lost, not land lost and sovereign waters lost.

Furthermore, in regions of the world where island states may lose most or all of their terrestrial territory, they would maintain the rights to and associated income from their maritime territory. The Maldives may be largely submerged by rising seas this century (Brown *et* al. 2020). With fixed EEZs there would not be a double blow of losing their land masses and also their rights to the water around them. Fixing the boundaries to geographic coordinates would also allow for artificial islands to exist, with the EEZ of the once naturally present islands. Construction of artificial islands has been one of the approaches to SLR used by the Maldives in the 21st century, constructing an island called Hulhumalé, 60cm higher than the average elevation of islands in the Maldives, 1.5m (Oppenheimer 2019 and Hinkel *et* al. 2019). Fixing boundaries of maritime zones based on coordinates would allow for island states such as the Maldives to continue to exist in their current position as artificial islands, without losing the rights to their EEZs.

The impact of sea level is rise is projected to be extreme for small island states, as these regions are often densely populated, without relocation options, or funds for hard protection (Oppenheimer *et* al. 2019). When climate justice is also considered and it becomes clear that SIDS represent states that are relatively less responsible for the emissions that are behind SLR, yet are likely to be more significantly impacted than other regions (Oppenheimer 2019). Fixing maritime zones based on coordinates would provide the best situation for SIDS bar no SLR occurring. It protects them from losing access to valuable maritime resources, as a result of SLR enhanced by emissions they are largely not responsible for.

However, changing UNCLOS to fix EEZs and maritime zones in their current positions based on geographic coordinates would not be an easy fix. UNCLOS is a convention that is frequently the subject of international disputes, without sea level rise entering into the equation. While the fixing of zones based on coordinates may be a policy solution that minimises the negative impacts on SIDS, there are bound to be states that do not support such a decision. The South China Sea has been an area full of disputed territory for over a decade now, an issue which is still not officially settled (Feng 2017). China has been arguing that it has "historic title" over the areas it is claiming, which at some points stretch up to 800nm from the normal baselines. The line China uses to determine the breadth of its perceived maritime zone is referred to as the nine-dash line (Korkut and Kang 2017).

Historic title has been referred to in disputes over territorial sovereignty under the United Nations (United Nations 2006). A case between Eritrea and Yemen in 1998 resulted in the implication that historic titles must be commonly recognised (Korkut and Kang 2017). The evidence presented by China when making a claim of historic title over the area within the nine-dash line has been exclusively Chinese government materials. These materials do not show the common perception of other states recognising the area in question as Chinese (Korkut and Kang 2017). Furthermore, the materials being submitted by China in support of their claims are not consistent on the area being claimed. An atlas published in 1948 differs from the area behind the nine-dash line claimed in 2009 (Korkut and Kang 2017). These details are some of the flaws in the Chinese claim for an EEZ beyond 200nm wide based on historic title. Here, the complexity and slow process of settling disputes encompassing international law must be recognised. If UNCLOS is to be updated to reflect advances in SLR science and projections since the time when it was written, it is unlikely to be a straightforward process.

Assuming states party to UNCLOS agree to fixing boundaries of EEZs as they are now, using coordinates, currently disputed areas such as the South China Sea and the East China Sea would need to be agreed upon. Japan and China currently have disputed claims over their rights to EEZs of certain sizes in the East China Sea (Jash 2017). Until states party to UNCLOS can determine who gets what currently, the process of determining what the EEZs are going to be and which states have sovereignty over them is not possible.

In addition, if states are able to come to an agreement on what each state's maritime claims should look like currently, another agreement would need to be made to edit the UNCLOS document to include fixing maritime zones based on coordinates, not the mean low water line, on charts officially recognised by the coastal state.

6. Conclusions

According to current projections for GMSL change by 2100, it is clear that coastlines around the world will be in different positions to where they are today. How much change and where it happens are still uncertain, however it is clear there will be change. Therefore, UNCLOS is in need of changes to the way in which it determines what a state is able to claim as its EEZ. There are a number of paths that could be taken to address this policy problem. It seems that fixing EEZs as they currently are would provide the most protection to SIDS, who are set to face the worst impacts of SLR. This would prevent changes to the area currently covered, providing long-term stability of their EEZs, which is important when making policy decisions regarding resource use and security. It also reduces the potential for tension between states with EEZs that border another state's EEZ. Climate change and SLR are an issue that SIDS contributed less to through greenhouse gas emissions than many states who will either not be impacted by SLR or are in a less perilous position.

Therefore, considering that the various policy options and the fact that UNCLOS is not equipped to clearly deal to deal with changing coastlines, fixing the zones based on their current position, with coordinates, ensures the best solution for SIDS and island nations who may only be able to exist through artificial islands in the future. However, it may be difficult to achieve through explicitly changing the convention and searching for an agreement on a new convention.

Unfortunately, considering the current disputes that exist surrounding UNCLOS issues, particularly in the South and East China seas, any agreement on EEZ rules and maritime zones stretching well into the future seems rather unlikely. However, it may be possible to achieve this without rewriting the convention. In a case where states with coastlines opposite one another have an agreement in place, the Vienna Convention ensures that this agreement stands, regardless of coastal change. This effectively fixes the maritime zones in question. However, for island states, they may see baselines erased by SLR, not just moved, and for states with EEZs bordering international waters there is no bilateral agreement in place. Without a bilateral agreement for the delimitation of maritime zones the decision is likely to come down to the dispute settlement procedures in part XV of UNCLOS. This would rely on a judicial interpretation of UNCLOS. Considering the stability of agreements made between states regarding maritime boundaries, the stability of EEZs that border international waters, or whose baselines may be erased, is a matter that so far appears open to interpretation.

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