INVESTIGATING THE POTENTIAL CLIMATE CHANGE IMPACTS ON MARITIME OPERATIONS AROUND THE SOUTHERN AFRICAN COAST

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ABSTRACT

This paper gives an overview of the present investigation on the wave climate around the South African coast and possible trends therein, due to climate change effects on the oceans. Preliminary findings indicate that there may be long-term trends in the regional metocean climate, while sea level rise alone will greatly increase the risks and impacts associated with extreme sea-storm events. The paper aims to contribute towards determining some of these risks to the port and maritime operations associated with climate change effects in the Southern African marine and coastal region.

1. INTRODUCTION

The southern African coast plays host to wide range of activities, which include the maritime transport around the coast, fishing, and imports/exports through ports. More than 30% of South Africa's population and about 60% of Mozambique's population currently live at the coast. Furthermore, over 80 % of world trade is transported by sea-going vessels. Therefore, the effects of Climate Change should be a concern to the maritime industry and the coastal communities.

Figure 1 presents the outline of the southern African coast showing the major ports. The South African (SA) coastline covers a distance of about 3 000 km. There are seven commercial ports of which four are major ports, with three smaller ports (see Table 1). There are also a number of small fishing harbours along the SA coast. On the western side of southern Africa, along the Nambian coast, there is one major port and one smaller commercial port. The Mozambican coast on the eastern side has two major ports.

Table 1: Summary of ports around southern Africa

Country	**Port**	**Main functions**	**Export/Import Volumes p.a. (2007)**
Namibia	Walvis Bay	Containers & fishing	3.9 Mt (0.13 MTEU)
	Lüderitz	Fishing & zinc export	0.5 Mt (0.01 MTEU)
South Africa	Saldanha Bay	Iron ore export	43.7 Mt
	Cape Town	Containers, fishing & repair works	4.1 Mt (0.76 MTEU)
	Mossel Bay	Fishing & export of oil products	1.8 Mt
	Port Elizabeth	Containers, cars & fishing	5.5 Mt (0.42 MTEU)
	East London	Cars & containers	1.8 Mt (0.04 MTEU)
	Durban	Containers & cars, oil import & food	41.9 Mt (2.48 MTEU)
	Richards Bay	Coal export	84.5 Mt
Mozambique	Maputo	Coal, containers & sugar	6.3 Mt (0.10 MTEU)
	Beira	Containers, oil import & fishing	N/A

Mt: Mega-tonnes; MTEU: Million Twenty-foot Equivalent Units

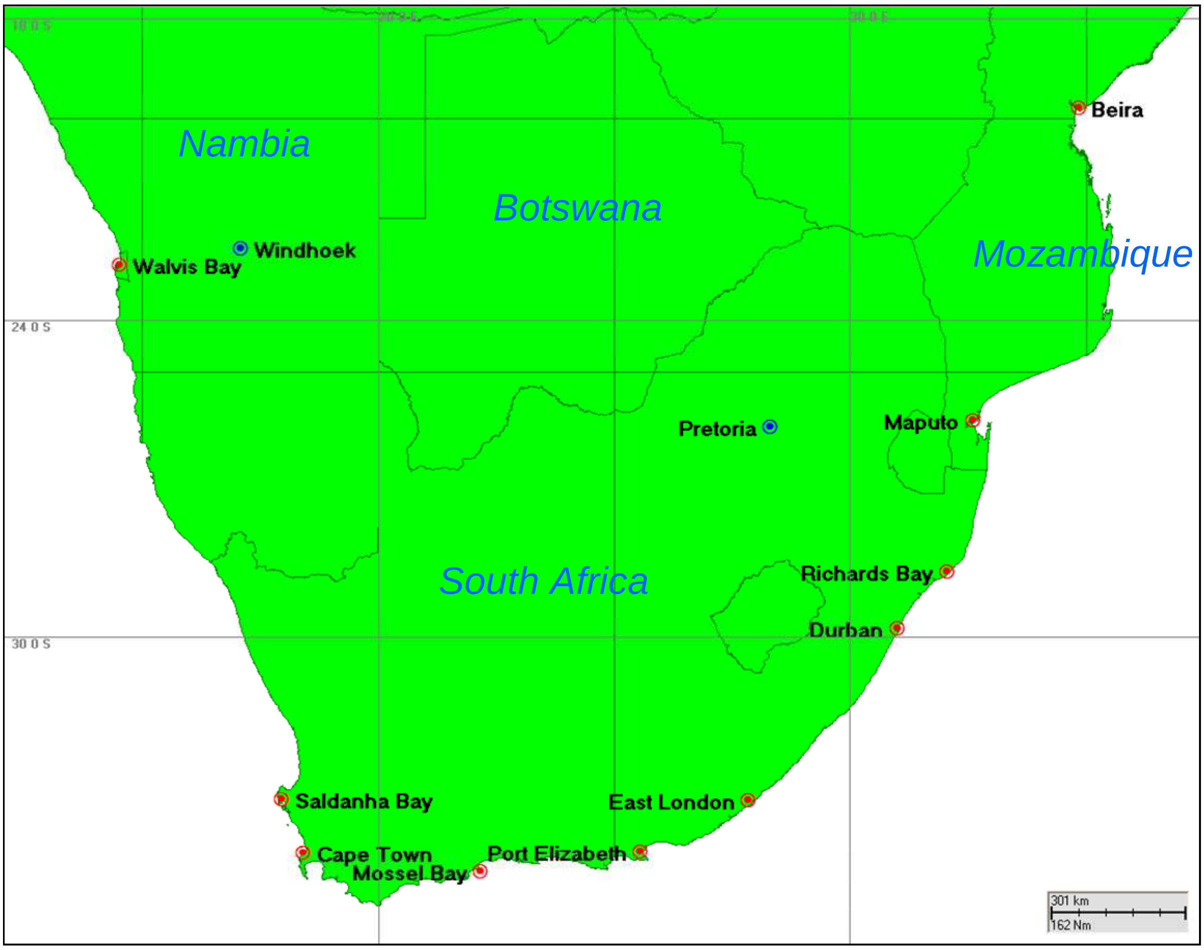

Figure 1: Map of southern Africa showing locations of major ports

2. GENERAL WAVE CLIMATE OF THE SOUTHERN AFRICAN COAST

The general weather climate of southern African is influenced by different types of synoptic patterns (MacHutchon, 2006). Waves significantly affecting maritime activities are generated mainly by passing frontal systems from the southern Atlantic, cut-off low systems along the SA southern to eastern coast and occasionally by tropical cyclones moving down the Mozambican channel.

The wave climate around the SA coast shows clear seasonality and varies in intensity and directionality around the coast. An overview of the annual variation in wave height and period is given in Figure 2, as based on the NCEP model data.

The most severe wave conditions occur on the SA South-west and the south coasts but decreases in magnitude along the west and east coasts. The distribution of wave period remains fairly constant, due to the swell propagating northwards. Wave directions are predominantly south-west but swing more toward a south-south-westerly direction on the east coast.

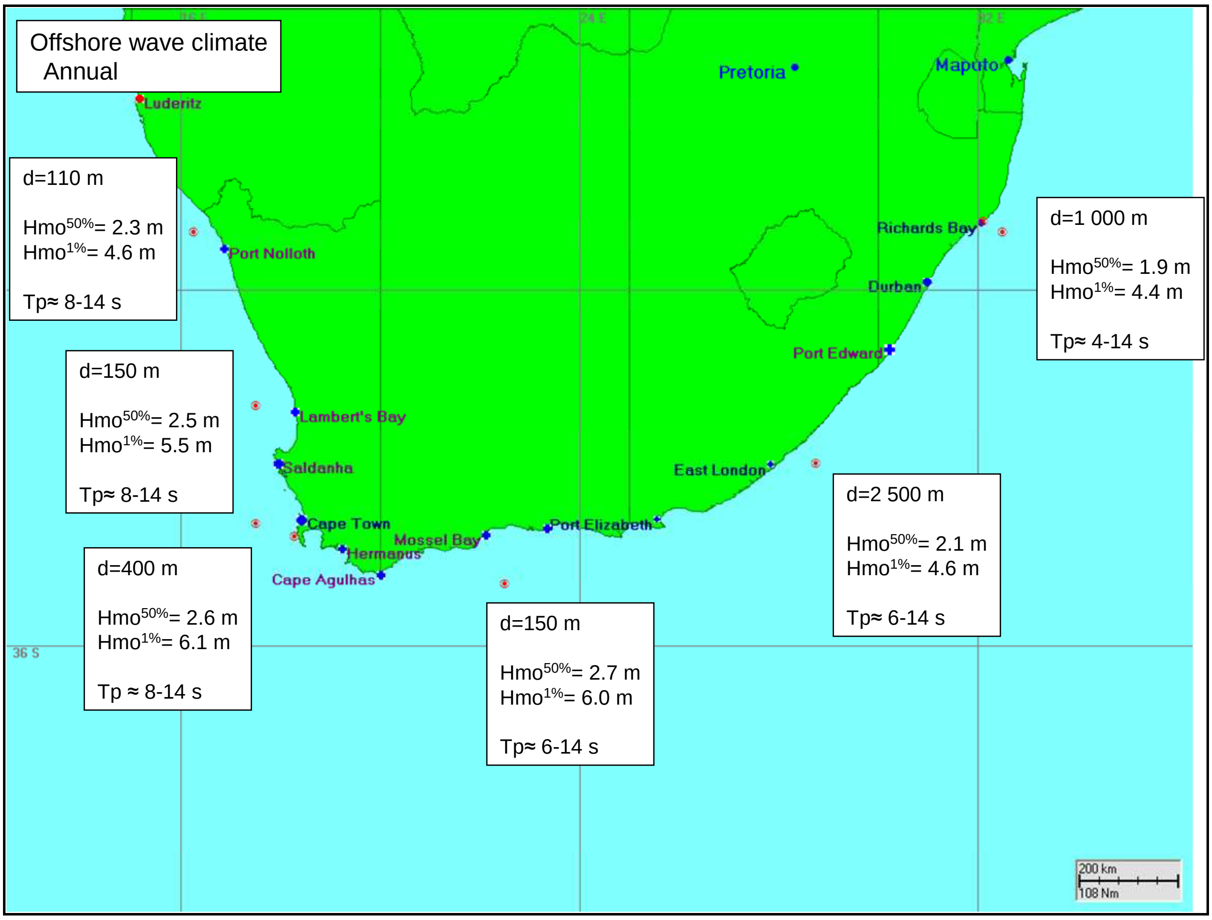

Figure 2: Overview of wave height and period distribution around SA coast

3. VULNERABILITY: MARINE WEATHER AND CLIMATE CHANGE EFFECTS

The aspects further discussed with regard to the impact of climate change on the port and maritime transport operations are presented below.

3.1 <u>Shipping around the SA coast</u>

The type and number of vessels calling at South African ports on an annual basis are summarised in Table 2. Note that many more vessels pass the South African coast on the shipping route between America and Asia.

Table 2: Summary of large vessels calling at South African ports (2007)

Type of vessel	Number	Main ports
Bulk carriers	2470	Richards Bay, Durban, Saldanha Bay
Oil tankers	1120	Durban
General cargo ships	1350	Durban
Container carriers	3396	Durban, Cape Town, Port Elizabeth
Car carriers	616	Durban, Port Elizabeth, East-London
Fishing trawlers	2985	Mossel Bay, Cape Town

Although ships are generally well-equipped for the severe wave conditions of the southern Atlantic, damage to ships does occur, especially on the south-east coast where the south-westerly waves interact with the strong, opposing, south-west flowing Agulhas current (Figure 3). The wave-current interaction result in an amplification of the waves, which infrequently lead to the creation of a gigantic or freak wave. This wave consists of a long trough, followed by a steep wave front, which can damage vessels severely. From the available literature it appears uncertain whether climate change effects will significantly strengthen or reduce the Agulhas current (or increase storminess off the SA south-east coast), and thereby reduce or increase the risk "freak" waves pose to shipping.

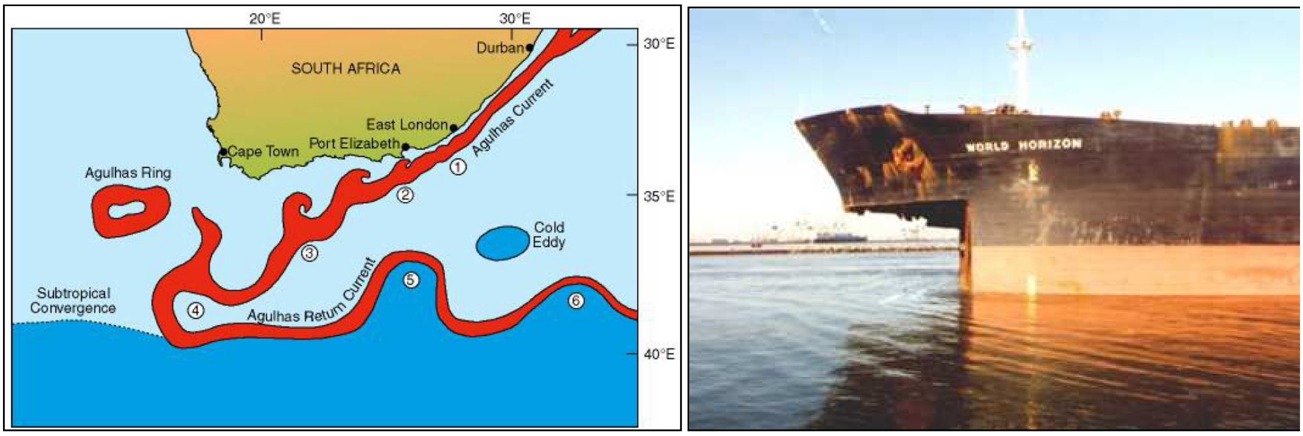

Figure 3: Diagram showing the large scale circulation of the Agulhas current (Lutjeharms and Van Ballegooyen, 1994), and damage to tanker by giant waves off the SE coast

Small vessels such as fishing vessels may be subjected to lesser extreme conditions, but with a greater chance of loss of life. Damage to these vessels is also more frequent. The statistics on casualties for the period 2003 to 2004 are presented in Table 3. During this period, casualties to and on board vessels resulted in 28 deaths of which 20 are linked to small vessels.

Table 3: Statistics on casualties to ships for the period 2003/2004 (SAMSA)

Type of vessel	Fire	Capsize	Grounding	Collision	Vessel sank	Equipment failure	Total
Small vessels	**1**	**10**	**1**	**6**	**4**	**1**	**23**
			SOUTH AFRICAN				
Passenger							
Mining	**1**		**1**				**2**
Harbour Craft			**1**	**1**			**2**
Fishing	**4**		**1**	**3**	**1**	**6**	**15**
			FOREIGN				
Cargo	**3**		**1**	**12**			**16**
TOTAL	**9**	**10**	**5**	**22**	**6**	**7**	**59**

SAMSA: South African Maritime Safety Authority

3.2 Port operations

Daily port operations can be directly influenced by adverse wave conditions, which may lead to port closure. Conditions inside a harbour can also become unbearable for large vessels due to the presence of long period waves (wave periods > 100 s), which are generated by the groupiness effect/phenomenon of swell waves. Mooring lines are placed under extreme loading and in some cases vessels have to leave the port. Thus, the issue of down-time is of concern. Studies are currently being conducted to estimate potential changes and trends due to climate change.

A different example is the Port of Walvis Bay, Namibia (Figure 4). Namibia's main harbour and only deewater port, located at Walvis Bay, is an important national economic hub and regional import/export freight access point for landlocked countries such as Botswana. During seasonal storms, waves wash over the major peninsular sand spit protecting the Port of Walvis Bay. At Baia dos Tigres in southern Angola, natural breaching of a 41 km long sand spit occurred, leaving an 11 km wide gap in the spit, thereby forming an island and destroying safe anchorage. Breaching of the Walvis Peninsula by the sea poses a real threat because the peninsula is so low-lying. Both sea level rise (SLR) and increased sea storminess could greatly increase this risk. A large breach of the Walvis peninsula would have similar disastrous consequences as the Baia dos Tigres breaching.

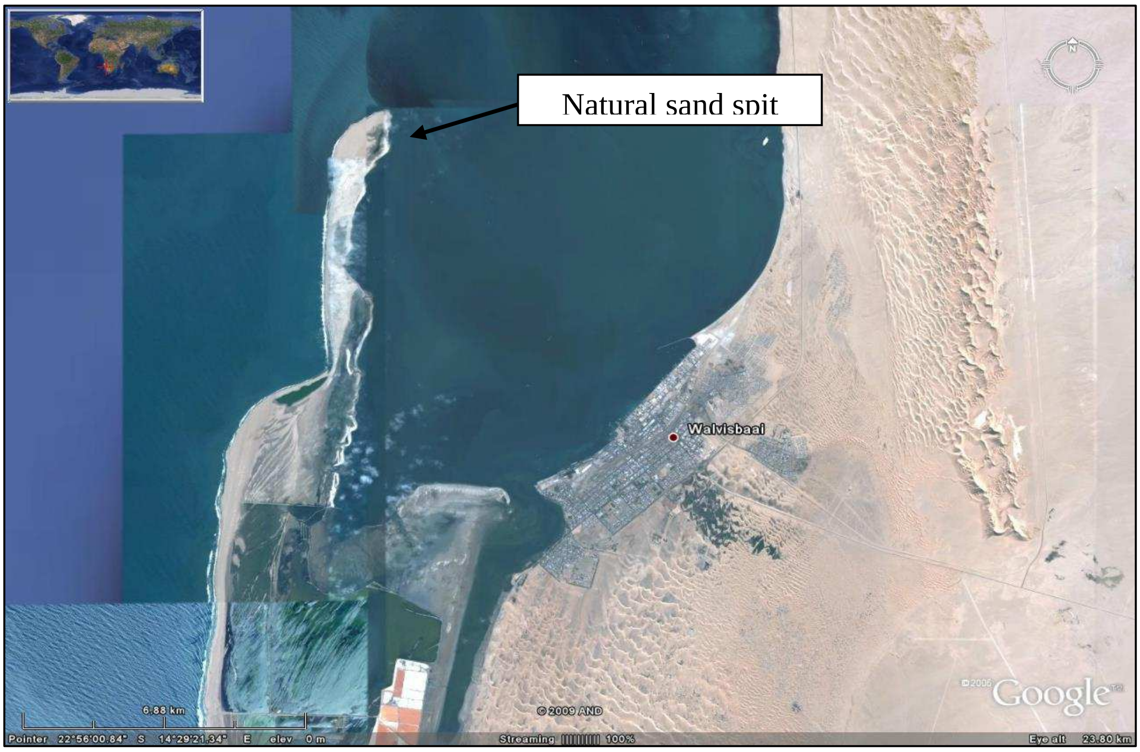

Figure 4: The vulnerable sandspit that protects the Port of Walvis Bay, Nambia

3.3 Ports and transport infrastructure

3.3.1 *Mozambique*

Mozambique's main harbours are located at Maputo and Beira, both major sources of income for the government. Statistical analyses of available seawater levels recorded at Maputo and Beira indicate that present annual maximum recorded seawater levels approximately reach the crest of many protective seawalls and revetments. In addition many of these ageing structures are in a state of poor repair. Therefore, these port cities could become problematic areas in Mozambique from a climate change perspective. Appropriate local planning and adaptation measures should be initiated in the short-term.

Tropical cyclones are another major threat along the Mozambican coast. About 2 cyclones per year enter the Mozambique channel, while about 1 cyclone per year makes landfall in Mozambique. Strong cyclones, even those that do not make landfall, generate large waves that could potentially impact the local coastline. Climate change projections indicate that cyclones may become more intense. A third-world country such as Mozambique can certainly not afford traditional engineering solutions to wide-scale cyclone or coastal climate change impacts.

3.3.2 *South Africa*

It is predicted that, due to climate change effects, breakwaters, revetments and sea walls, which protect infrastructure such as roads and harbours (e.g. Figure 5) from direct wave action and under-scouring, will require more maintenance. The longevity of such structures and facilities will also be reduced due to SLR and potential increases in storminess.

Figure 5: Storm breaching a seawall and overtopping (Cape storm: Sept'08) - examples of existing problems likely to worsen due to climate change (Photos: A Theron)

In some instances, roads and railway lines have been located too close to the sea (Figure 6). The foundations of such structures could be under-scoured due to the combined impacts of sea level rise and increased sea storms, resulting in structural damage and potentially fatal accidents if not rectified.

Taking into account that about 80 % of the southern African coastline comprises sandy shores, erosion is a major area of concern. Extreme storm events combined with sea level rise will pose an ever increasing threat to the natural coastline and coastal structures.

Figure 6: Present SA example of railway line located too close to sea (Photo: A Theron)

4. CLIMATE CHANGE: PRESENT STUDIES ON SA WAVE CLIMATE

It is clear from the previous section that a more severe wave climate and even wind climate will impact negatively on the coast and maritime transport and port activities, leading to a necessity to predict the future trends in the wave climate. The CSIR is currently involved in studying the effect of climate change on a number of physical and biological aspects in and around South Africa. As part of the study, the wave climate is being evaluated.

The annual mean significant wave height (Hmo) and corresponding standard deviation for the wave data set collected off Richards Bay and the annual mean wave height (Hmo) for the long-term data set, collected offshore of Cape Town, indicate no real increase in severity. This may appear to contradict the findings of the IPCC as presented in PIANC (2008). However, these results may reflect a regional aspect of the impact of climate change.

Although the averages appear to remain constant, there seems to be some change in the individual storms. For example, considering the peaks of individual storms during the more extreme winter period (June to August), an increasing trend of about 0.5 m over 14 years is observed (Figure 7). The trend may be indicative of a significant increase in the storminess over the next few decades. It is also worth noting that the opposite occurs during summer. There is a general decreasing trend over the last 14 years, with regard to individual storms.

If the winter trend is indeed true, storminess with regard to intensity may be on the increase. There are, however, a number of aspects that need further attention. These include:

(i) collation and analyses of longer alternative time-series data to verify trends,
(ii) evaluating similar trends around the entire southern African coastline,
(iii) consider not just the trends in magnitude/intensity but also in frequency of events,

(iv) consider the persistence of these events, i.e. are the duration of storm events increasing or decreasing,
(v) review the occurrence of cyclones along the SA East coast,
(vi) review the trends in energy flux and not just the wave height

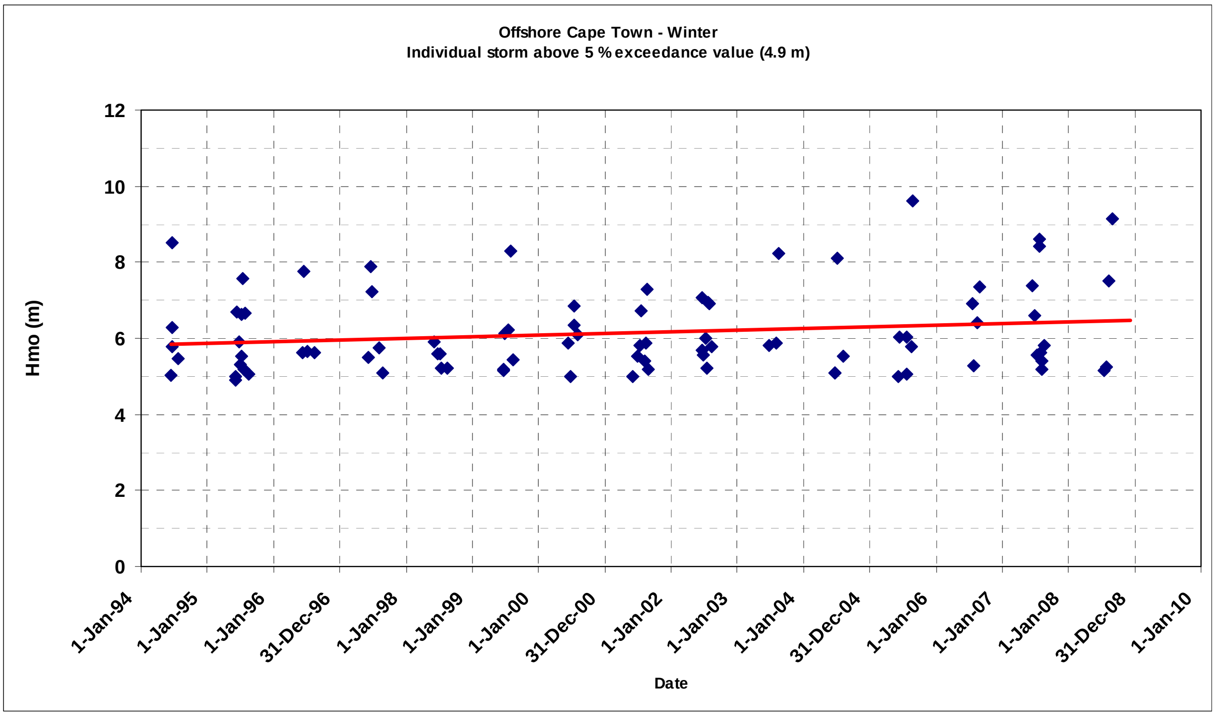

Figure 7: Peaks of individual storms over 14 year-period – offshore Cape Town.

The evaluation of these aspects need to be combined with the present estimates of the sea level rise, which will lead to a better understanding of the potential risk of the issues raised in Section 3.

5. POTENTIAL IMPLICATIONS AND POSSIBLE ADAPTATION MEASURES FOR SA MARINE REGION

The IPCC Fourth Assessment Report (“AR4 Report”, IPCC 2007) predicts that the rise of global average sea level (SLR) by 2100 will be in the range from 0.18 to 0.59 m depending on the emissions scenario. The mean value of the 2007 IPPC SLR predictions is thus about 0.4 m by 2100.

The probability of accelerated sea level rise (potentially up to several metres) due to catastrophic failure of large ice-shelves was recently still considered unlikely this century, but events in Greenland and Antarctica have led to several re-evaluations of that assessment. Such studies have predicted a much wider range of SLR by 2100, but the majority lie in the 0.5 m to 2 m band.

Taking SLR and the potential effect on the wave climate into account, the United Nations Conference on Trade and Development (UNCTAD), listed some potential impacts and adaptation measures (UNCTAD, 2008). This list is presented in Table 4. Additional items considered relevant to the southern African region have been included in this table.

Table 4: Potential impacts & possible adaptation measures for the maritime transport sector (from UNCTAD, 2008)

Climate change factor	Potential implications	Adaptation measure
Rising temperatures • High temperatures • Melting ice • Large variations (spatial and temporal) • Frequent freeze and thaw cycles	• Shorter distance for Asia–Europe trade and less fuel consumption • Competition, lower passage tolls and reduced transport costs • New trade, diversion of existing trade, structure and direction of trade (indirectly through impact on agriculture, fishing and energy) • Damage to infrastructure, equipment and cargo • Increased construction and maintenance costs; new ship design and strengthened hulls; environmental, social, ecosystem related and political considerations • Higher energy consumption in ports • Variation in demand for and supply of shipping and port services • Challenge to service reliability	• Heat-resistant construction and materials • Continuous inspection, repair and maintenance • Monitoring of infrastructure temperatures • Reduced cargo loads, speed and frequency of service • Refrigeration, cooling and ventilation systems • Insulation and refrigeration • Modal shift • Transit management scheme and regulation of navigation in northern regions • Ship design, skilled labour and training requirements
Rising sea levels • Flooding and inundation • Erosion of coastal areas	• Damage to infrastructure, equipment and cargo (coastal infrastructure, port-related structures, hinterland connections) • Increased construction and maintenance costs, erosion and sedimentation • Relocation and migration of people and business, labour shortage and shipyard closure • Variation in demand for and supply of shipping and port services (e.g. relocating), modal shift • Structure and direction of trade (indirectly through impact on agriculture, fishing, energy) • Challenge to service reliability and **increased** dredging, reduced safety and sailing conditions **• Changes in water levels in harbours**	• Relocation, redesign and construction of coastal protection schemes (e.g. levees, seawalls, dikes, infrastructure elevation) • Migration • Insurance
Extreme weather conditions • Tropical cyclones • Storms • Floods • Increased/decreased precipitation • Wind	• Damage to infrastructure, equipment and cargo (coastal infrastructure, port-related structures, hinterland connections) **• Increased damage to ships as a result of wave-current interaction** • Erosion and sedimentation, subsidence and landslide • Damage to infrastructure, equipment, cargo • Relocation and migration of people and business • Labour shortage and shipyard closure • Reduced safety and sailing conditions, challenge to service reliability • Modal shift, variation in demand for and supply of shipping and port services • Change in trade structure and direction • Change in wave climate (swell and long period waves) in harbours	• Integrate emergency evacuation procedures into operations • Set up barriers and protection structures • Relocate infrastructure, ensure the functioning of alternatives routes **• Raising of existing breakwater-structure to counter additional overtopping** • Increase monitoring of infrastructure Conditions – **e.g. CSIR breakwater monitoring programmes** • Restrict development and settlement in low-lying areas • Construct slope-retention structures • Prepare for service delays or cancellations • Strengthen foundations, raising dock and wharf levels **– redevelopment programmes** • Smart technologies for abnormal events detection • New design for sturdier ship **• Redesigning new ports** **• Revising dredging maintenance programmes** • **Amended beach nourishment programmes** **• Revision of pilot-transfer operations** **• Revision in ship mooring operations and equipment in ports** **• Alterations to ports to compensate for additional wave action (swell induced or long period waves)**

Note, in the above table, the items in bold have been added by the authors; these are deemed to be some of the additional aspects relevant to the southern African region.

Table 4 presents a range of impacts due to climate change, the potential implications of these factors as well as some possible adaptation measures or solutions. For example, an increase in storminess ("Climate change factor") could lead to additional erosion and increased sediment transport in and around ports ("Potential implications"). "Adaptation measures" to mitigate this problem would, for example, include a revision of the maintenance dredging programmes.

It would, therefore, be necessary to study and determine, in more detail, the potential implications of the impact of climate change on the SA coast, and to design and implement proper adaptation measures.

6. CONCLUSIONS

This paper includes a brief review of some of the likely physical port and maritime operations related impacts due to expected climate change around the southern African coast. To mitigate these detrimental impacts, research is and should increasingly be directed at an improved understanding of what is happening to our coastline and what is likely to happen as climate change intensifies. Locally applicable methods have to be developed urgently to quantify realistically the impacts of climate change.

To mitigate these impacts, we have to understand the adaptation options available to southern African society, which is considerably different from first world approaches, and still largely undefined. Quantitative information is only starting to become available, and the resulting somewhat speculative discussions and predictions presented here are uncertain. Some important potential consequences of global warming on the southern African coast are highlighted, and there is presently a clear and urgent need for improved understanding of these issues and, especially, predictive capabilities.

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