Potential Impacts of Climate Change on Southern African Ports and Coast

by
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Outline of presentation

• Climate Change and Drivers of CC Impacts in South Africa

• Vulnerability of maritime activities to Climate Change effects

• Overview of some CC impacts on SA ports and the coast
Climate Change in South Africa

Climate Change refers to the change in the global temperature (global warming) and the resultant effect on the environment, which includes the marine environment.

The cause (anthropogenic):

the effect of human activities, e.g. burning of fossil fuels (coal, oil & gas) and large-scale de-forestation.

The result:

- Emission of Green House Gasses (GHG) - mainly CO₂
- GHG are trapped in atmosphere which leads to a general increase in atmospheric and water temperatures
- Sea Level Rise (SLR) as a result of expanding water mass, and melting ice masses: present estimates 0.5 - 2 m by 2100 (1 m used for design in SA).
- Change in the global weather climate – change in marine environment
Impacts of Climate Change

- atmospheric and water temperatures
- winds
- ocean waves (incl. long waves)
- rise in sea level
- ocean currents
- rainfall

Strand Sept'08

Coega 2013
Southern African coast
- 8 major ports
- 3 000 km coast (mostly sand)

Over 80% of world trade is transported by sea-going vessels.

Therefore, the effect of Climate Change should be a concern to the maritime industry.

<table>
<thead>
<tr>
<th>Country</th>
<th>Port</th>
<th>Main functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Namibia</td>
<td>Walvis Bay</td>
<td>Containers &amp; fishing</td>
</tr>
<tr>
<td></td>
<td>Lüderitz</td>
<td>Fishing &amp; zinc export</td>
</tr>
<tr>
<td>South Africa</td>
<td>Saldanha Bay</td>
<td>Iron ore export</td>
</tr>
<tr>
<td></td>
<td>Cape Town</td>
<td>Containers, fishing &amp; repair works</td>
</tr>
<tr>
<td></td>
<td>Mossel Bay</td>
<td>Fishing &amp; export of oil products</td>
</tr>
<tr>
<td></td>
<td>Port Elizabeth</td>
<td>Containers, vehicles &amp; fishing</td>
</tr>
<tr>
<td></td>
<td>East London</td>
<td>Vehicles &amp; containers</td>
</tr>
<tr>
<td></td>
<td>Ngqura</td>
<td>Containers</td>
</tr>
<tr>
<td></td>
<td>Durban</td>
<td>Containers, oil import &amp; food</td>
</tr>
<tr>
<td></td>
<td>Richards Bay</td>
<td>Coal export</td>
</tr>
<tr>
<td>Mozambique</td>
<td>Maputo</td>
<td>Coal, containers &amp; sugar</td>
</tr>
<tr>
<td></td>
<td>Beira</td>
<td>Containers, oil import &amp; fishing</td>
</tr>
</tbody>
</table>
Vulnerability of Maritime Transport to Climate Change effects

(i) Shipping around the SA coast
(Navigation aspects)

- Severe weather conditions
  - potential delays at ports
  - impact on tow-operations
  - anchorage / sailing

- Getting worse due to CC?
(ii) Ports and infrastructure

Richards Bay: storm surge and spring tide

- Present problems may increase due to CC (e.g. SLR, storminess)
- Need to quantify how much worse it will get due to Climate Change

Gordons Bay: overtopping of breakwater
STORMS: Wave climate extreme analyses

Current trends in wave climate?
- Insufficient data

Waves for future ~100 year period: increase +6% to +10%

Potential changes in local wave regime:
Climate Change: winds + 10%
- wave height + 26% !
- potential sediment transport rates +40 to100% !!!
Port of Richards Bay: Evaluating repair works for South Breakwater

**Design conditions:**
- Wave height: 1:100 yr + 10%
- Water level
  - Astronomical tides
  - Storm surge
    - (i) Wave set-up: waves approaching the shore
    - (ii) Pressure set-up: local atmospheric pressure
    - (iii) Wind set-up: local winds affect the water elevation
  - Sea Level Rise (several future scenarios)

- Two rubble mound breakwaters completed in 1976
- Several extreme storms
- 2 major repairs (1987 and 1996)
- Waves – main forcing mechanism: Impact of CC?
Port of Richards Bay: Evaluating repair works for South Breakwater

Physical model study: Test extreme wave conditions – stability of structures

Potential CC effects were evaluated by way of a physical model – where predicted future wave conditions and water levels at the turn of century (2100) are tested.
(iii) Port operations – impact of long waves

Saldanha Bay and Ngqura: excessive ship-motion impacting on mooring-lines due to long-waves & winds – likely to increase due to increase in storminess & SLR
(iv) Impact on coastlines adjacent to ports

Changing wave & current patterns: potential impact on dredging operations

Quantify Climate Change effects on Sediment budgets and harbour dredging/bypassing rates

Walvis Bay: breaching of protective sand-spit (natural breakwater)
Increased risk due to SLR and increasing storminess
KwaZulu-Natal coast: Impact of March 2007 storm

(iv) Impact on coastlines adjacent to ports

Develop setback lines – for safety and to protect property from physical coastal/marine processes impacts
<table>
<thead>
<tr>
<th>Drivers (change in regime or extremes)</th>
<th>Breakwater (Harbour protection)</th>
<th>Harbour entrance (channel)</th>
<th>Navigation (inside/anchoring areas - port limits)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waves: short period (3 - 25 s)</td>
<td>Major impact of lifetime of structure; need to revise maintenance programme &amp; design criteria; wave height and direction play a role; effects of changing frequency and duration of storms, and of wave direction</td>
<td>Wave and direction may affect the levels of wave energy prevailing in channel - impact of vessel motions inside channel; may impact on maximum allowable drafts; need to revise revetment/groyne protection inside channel; increase in wave penetration, may affect max allowable draught</td>
<td>Vessel motions are affected by short and long waves; more energy penetrating may lead to excessive vessel motions; increase in waves may impact on anchoring of vessels waiting to enter ports - time delays and risk to ship safety; more port closures; potential harbour resonance issues. Storm waves may cause anchor lifting / dragging.</td>
</tr>
<tr>
<td>Waves: long period (25 - 300 s)</td>
<td>N/A</td>
<td>Long wave effects are included in short waves (see above)</td>
<td></td>
</tr>
<tr>
<td>Wind</td>
<td>Potential impact of water spray - reduce visibility; potential increase in storm surge; cyclone patterns</td>
<td>Pilot operations; potential increase in storm surge</td>
<td>Wind affect; Piloting and Tug operations; Helicopter operations; cyclone pattern / tracks change</td>
</tr>
<tr>
<td>Large scale ocean currents (Agulhas current) and long-shore currents driven by waves</td>
<td>N/A</td>
<td>Safe shipping requirements in entrance channels may be affected by increased currents which could result in wider approach and entrance channels</td>
<td>Current is a major force on vessel; wave-current interaction in open sea may lead to excess wave action, e.g. freak waves</td>
</tr>
<tr>
<td>SLR</td>
<td>Potential impact of wave attack &amp; overtopping: significant rise in water level will increase the level of wave energy reaching the structure. Depth limited waves may be larger.</td>
<td>More wave energy may reach inside of channel</td>
<td>More wave energy may reach inside of channel; vessels need to take into account during manouvering operations; mooring-line modifications; proclaimed depth changes - bathy charts</td>
</tr>
<tr>
<td>Sediment transport</td>
<td>May alter bathymetry near &amp; next to structures; currents may also have an impact; erosion (scouring) or deposition at the structure or adjacent to structure</td>
<td>May alter channel depth; impact on shipping; sand trap and maintenance dredging programme to be revised</td>
<td>May alter channel depth; impact on shipping; underkeel clearance issues</td>
</tr>
<tr>
<td>Temperature</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Rainfall/fog visibility</td>
<td>N/A</td>
<td>Higher risk of accidents. Need for navigation aids</td>
<td>Severe rain/fog events may lead to visibility issues, resulting in increased risks</td>
</tr>
<tr>
<td>Drivers (change in regime or extremes)</td>
<td>Ship maneuvring (in harbour) including berthing / unberthing</td>
<td>Moored ships, cargo handling, containering</td>
<td>Storage area</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>---------------------------------------------------------</td>
<td>----------------------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Waves: short period (3 - 25 s) (wind waves and swell)</td>
<td>Less of an issue inside harbour</td>
<td>Less of an issue inside harbour, but delays in on- and offloading and transport operations will occur</td>
<td>N/A</td>
</tr>
<tr>
<td>Waves: long period (25 - 300 s)</td>
<td>Long waves a function of short waves; will impact on moored vessels</td>
<td>Container operations may be delayed due to excess ship motions</td>
<td>N/A</td>
</tr>
<tr>
<td>Wind</td>
<td>May impact on moored vessels and in process of berthing (Piloting and Tugs)</td>
<td>Container operations may be delayed due to excess ship motions; delays in crane and RTG operations</td>
<td>requirement for more secure structures; Increase dust issues</td>
</tr>
<tr>
<td>Large scale ocean currents (Agulhas current) and long-shore currents driven by waves</td>
<td>Less of concern inside harbour; may potentially effect circulation in harbour area - impacting on water quality (e.g. ballast water issues)</td>
<td>Less of concern inside harbour</td>
<td>N/A</td>
</tr>
<tr>
<td>SLR</td>
<td>Cope/Quay levels have to be revised. Bollards for moored vessels and possibly fixed fenders to be revised; More wave energy may reach inside of channel; vessels need to take into account during maneuvring operations; mooring-line modifications; proclaimed depth changes - bathy charts</td>
<td>See previous column</td>
<td>Improved storm water drainage and revising of cope levels</td>
</tr>
<tr>
<td>Sediment transport</td>
<td>In conjunction with rainfall, sedimentation or siltation could impact on dredging programme</td>
<td>Delays in container operations</td>
<td>N/A</td>
</tr>
<tr>
<td>Temperature</td>
<td>N/A</td>
<td>Potential increasing in electricity use - air-conditioning</td>
<td>Need to revise refrigeration systems &amp; cold storage facilities</td>
</tr>
<tr>
<td>Rainfall/fog visibility</td>
<td>Severe rain/fog events may lead to visibility issues</td>
<td>Less of concern inside harbour; potential increase in downtime - flooding</td>
<td>Secondary operations/services to be revised; eg water drainage; less rain - more water required for dust containment/management</td>
</tr>
<tr>
<td>Drivers (change in regime or extremes)</td>
<td>Adjacent coastal zone/shore and sandy shoreline within port</td>
<td>General Port operations/infrastructure</td>
<td>Other</td>
</tr>
<tr>
<td>--------------------------------------</td>
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</tr>
<tr>
<td>Waves: short period (3 - 25 s) (wind waves and swell)</td>
<td>Potential erosion of shorelines next to breakwaters, entrance channels and spending beaches in the port</td>
<td>Delays in marine construction</td>
<td>Disasters outside ports may increase search and rescue readiness. There may be increased shipping and larger ships.</td>
</tr>
<tr>
<td>Waves: long period (25 - 300 s)</td>
<td>Modified shorelines may alter/increase reflected long wave energy</td>
<td>N/A</td>
<td>Changes to type of cargo; impact on fishing patterns; ballast water issues; change in corrosion characteristics; new shipping trade routes (e.g. new North-west passage route)</td>
</tr>
<tr>
<td>Wind</td>
<td>Increased wind-blown (aeolian) transport; changing transport patterns</td>
<td>Opportunity for wind power, but gustiness may be worse</td>
<td></td>
</tr>
<tr>
<td>Large scale ocean currents (Agulhas current) and long-shore currents driven by waves</td>
<td>Increased erosion</td>
<td>N/A</td>
<td>Oil Spill control measures might become more necessary.</td>
</tr>
<tr>
<td>SLR</td>
<td>Increased erosion; setback line issues - setback lines to be revised</td>
<td>Setback line issues; flooding of low-lying infrastructure</td>
<td></td>
</tr>
<tr>
<td>Sediment transport</td>
<td>Increased erosion/accretion</td>
<td>N/A</td>
<td>Alternate forms of energy will be needed. Move to &quot;green&quot; ports</td>
</tr>
<tr>
<td>Temperature</td>
<td>N/A</td>
<td>Increased electricity use; for cooling and refrigeration for shipping and onland facilities</td>
<td></td>
</tr>
<tr>
<td>Rainfall/fog visibility</td>
<td>Erosion/runoff increase</td>
<td>Flooding; delays to civil works; water scarcity - demand on shipping and general port operations; potential increase in salinity - impacting on ecology of area; change in hydrology may affect river ports (e.g. Port of East London)</td>
<td></td>
</tr>
</tbody>
</table>
Purpose & Approach to Adaptation Measures

• Conservative / precautionary principle
  ▪ Authorities: pro-active approach to protect lives, livelihoods and infrastructure
    (Prevention is better than Cure)

• Sustainable solutions
  ▪ Durable and low cost to the Municipality and / or State
Many useful publications:
Potential Implications & Adaptation Measures, e.g. UNCTAD, 2008
However, Southern African states: little adaptive capacity + ability to halt coastal impacts on a large scale virtually non-existent.
Adaptation would reduce impacts by factor 10 to 100 - minor cost compared to damage avoided.
Set & implement adaptation measures sooner rather than later!
To mitigate detrimental impacts of climate change:
understand adaptation options available to South African society – probably different from 1st world approaches.
Potential adaptation measures /coastal protection options

A “Management options”
A1 “Accept and retreat”: repositioning infrastructure at risk; zoning, set-back lines, resettlement, etc.
A2 “Abstention” involves the ‘do nothing’ option, if the risk of loss of property or human life is very minimal.
A3 “Alternative” coastal developments: develop “safe” alternative coastal areas including services.
A4 “Accommodation”: increase resilience, accommodate impacts on infrastructure e.g. raising property.

B “Soft engineering” or Restoration (“semi-natural” interventions in the littoral zone)
B1 Sand nourishment: pump extra sand onto the beach to build it up and reduce wave impacts & flooding.
B2 Managed (vegetated and/or reinforced) dune: construct/reinstate and/or manage vegetated dune.
B3 Managed/rehabilitated mangrove/wetland/coral areas: construct/reinstate &/or manage these natural protections

C “Hard engineering” & armouring (construct shore protection measures)
C1 Seawalls & revetments: sloping, vertical or curved concrete/rock structures.
C2 Dikes: massive sloped (landscaped and vegetated) loose standing sand/ earthen mound.
C3 Perched beach structures: artificially keep the upper part of the beach profile in place.
C4 Shore-parallel structures (e.g. artificial surf zone reefs, detached breakwaters, rock berms, etc.).
C5 Groynes (straight, curved, T, L etc.): perpendicular or at angle to shoreline, can trap sediment.
C6 Spending beach of very coarse sand, gravel or cobbles: dissipates wave energy & erosion.
C7 Beach (and dune) dewatering mechanism. Sediment “stability” can theoretically be increased.
C8 Coastal flood control gates in “enclosed” areas (e.g. river mouths, small bays).

In low to moderate wave energy environments:
C9 Closely spaced piles or wave fences: to dissipate wave energy.
C10 Floating moored “breakwater” type structures.
C11 “Geotextile” shore protection, usually sand filled geotextile containers.
C12 Gabions and/or rock filled wire basket & mattress structures.

D Combined options
Adaptation measures - “Management option A1”

“Accept and retreat”: repositioning infrastructure at risk; zoning/set-back lines, resettlement…

Natures Valley, an excellent example of an appropriate development setback landward of a well-maintained natural foredune functioning as an effective buffer dune system (DEA, 2009)
B1  Sand nourishment: Pump sand onto beach to build it up

B2  Managed dune (vegetated and/or reinforced)

C1  Revetments

C1  Seawalls

Adaptation/protection options
Adaptation/protection options

C5 Groynes can trap sediment

C12 Gabions rock filled wire basket & mattress

C11 Geotextile shore protection in low to moderate wave energy environments

» D Combined options
Mozambique example:
Responding to CC

Site specific analysis
and
recommended prioritized
adaptation actions
Mozambique example: adaptation /coastal protection options based on general criteria, local site characteristics, current use/"value"

**KEY: Adaptation measures**

- **A** “Management options”
  - A1 “Accept & retreat”: zoning, etc.
  - A2 “Abstention” ‘do nothing’
  - A3 “Alternative” developments in safe areas
  - A4 “Accommodation” e.g. raising property

- **B** “Soft engineering” /Restoration
  - B1 Sand nourishment
  - B2 Managed (vegetated &/ reinforced) dune
  - B3 Managed/rehabilitated mangrove/wetland areas

- **C** “Hard engineering” & armouring
  - C1s Seawalls (vertical / curved concrete)
  - C1r Revetments (sloping rock)
  - C2 Dikes (sand/ earthen mound)
  - C5 Groynes (rock/concrete)

  Low/ moderate wave energy:
  - C11 “Geotextiles” sand filled
  - C12 Gabions & mattresses
Beira adaptation / coastal protection options

Priority 1

In wetland area:
A3 “Alternative” developments in safe areas
A1 “Accept & retreat”: zoning, etc.

Construct 1.9 km of
C1s Seawalls (concrete)
/ C1r Revetments (sloping rock)
/ C11 “Geotextiles” sand filled
/ C12 Gabions & mattresses

Construct 3.5km C1s Seawalls (concrete) +
A4 “Accommodation” raise quay walls, warfs, etc
**DETAIL:** Beira preliminary adaptation /coastal protection options based on general criteria, local site characteristics, current use/”value”

The red numbers indicate order of implementation

- Construct 3.5km C1s Seawalls (concrete) + A4 “Accommodation” raise quay walls, warfs, etc
- Construct > 2km of C1s Seawalls (concrete) / C1r Revetments (sloping rock) / C11 “Geotextiles” sand filled / C12 Gabions & mattresses
- A4 “Accommodation” raise jetty/pier & access + add culverts +
- A2 “Abstention” ’do nothing’ in wetland area; OR
- B3 Managed/rehabilitated mangrove/wetland areas
Conclusions

• Climate Change is *already* impacting on SA coast and maritime operations.

• To mitigate these impacts, research should be directed at improving data / understanding of what is happening and what is likely to happen in future.

• To mitigate these impacts, we have to research the adaptation options available to Southern African society, which may be different from first world.

• Changes in design in the long term, but improved forecasting and installing early warning systems are reducing impacts of climate change.
Thank You