Sensitivity of tides and net water transport in an estuarine network to sea level rise

Jinyang Wang and Huib de Swart

Feedback by readers is highly appreciated
Estuarine networks: bodies of water that consist of multiple channels and in which water motion is drive by tides and river discharge.
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**Example 1: The Berau Delta (Indonesia)**
Estuarine networks: bodies of water that consist of multiple channels and in which water motion is driven by tides and river discharge.

Example 2: The Pearl River Delta (China)
Sensitivity of tides and net water transport in an estuarine network to sea level rise

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Main messages:
1. Tides are sensitive to sea level rise.
2. Water transport is less sensitive to sea level rise.
Research question

How will tide and net water transport in the estuarine network respond to sea level rise (SLR)?

Net water transport: tidally averaged integral of velocity over cross-section.

Tide \{ surface elevation current \}

Water transport induced by \{ river discharge density gradient other nonlinear effects… \}
2DV idealised channel network

A scheme of model domain near one branching point
2DV idealised channel network

Prescribed river discharge

Mass and energy conservation

A scheme of model domain near one branching point

Prescribed semi-diurnal tide

Intro  Method  Results  Conclusions
Expected sea level rise in a century
1-2 m (Kuang et al, 2017)
Tidal range ~ 2m (mainly $M_2$)
River discharge $10^4$ m$^3$/s (dry season)
Expected sea level rise in a century
1-2 m (Kuang et al, 2017)
Tidal range ~ 2m (mainly M\textsubscript{2})
River discharge 10^4 m\textsuperscript{3}/s (dry season)
**Default settings: 2014**

**Dry season**

**Monthly averaged tidal forcing**

**Solid lines: modelled tide**

**Dots: observed tide**
**Default settings: 2014**

- **Dry season**
- **Monthly averaged tidal forcing**
- **Solid lines: modelled tide**
- **Dots: observed tide**
- **Model is reliable**

**Time of high water relative to that at sea**

**Tidal elevation amplitudes**

- **Intro**
- **Method**
- **Results**
- **Conclusions**
Vertical structure of tidal current

**North Passage**

**South Passage**

**South Channel**

Maximum tidal current at the surface.
Strong current in the SP due to channel convergence.
Water transport

River water transport (m$^3$/s)

<table>
<thead>
<tr>
<th>Value</th>
<th>Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>10000</td>
<td>←</td>
</tr>
</tbody>
</table>
| 9307  | ← 692
| 4537  | ← 4770
| 2175  | → 2361 |

Net water transport (m$^3$/s)

<table>
<thead>
<tr>
<th>Value</th>
<th>Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>10000</td>
<td>←</td>
</tr>
</tbody>
</table>
| 9423  | ← 576
| 4268  | ← 5155
| 751   | → 3516 |

Different from 1D model of Alebregtse and de Swart (2016) due to two additional subtidal components in this 2DV model:

1. baroclinic pressure/density driven flow
2. excess mass transport due to free surface variation.
Sensitivity of tides to SLR

Tides become stronger and propagate faster if sea level rises.
Sensitivity of tides to SLR

Tides become stronger and propagate faster if sea level rises

Reasons:
- Increasing water depth
- Less friction
- Weaker river flow
- Slower decay
- Tides propagate faster
- Convergence wins
Response of tidal current to 2m SLR

Reason for the changes:

Tidal current is proportional to local pressure gradient

\[ \zeta = \frac{z}{H} \]
Sensitivity of water transport to SLR

River water transport is hardly affected.
Sensitivity of water transport to SLR

River water transport is hardly affected.

Difference in net water transport after 2m sea level rise (m³/s)

<table>
<thead>
<tr>
<th>Sea Level Rise (m)</th>
<th>Net Water Transport (10⁴ m³/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.4</td>
</tr>
<tr>
<td>0.25</td>
<td>0.4</td>
</tr>
<tr>
<td>0.5</td>
<td>0.4</td>
</tr>
<tr>
<td>0.75</td>
<td>0.4</td>
</tr>
<tr>
<td>1</td>
<td>0.4</td>
</tr>
<tr>
<td>1.25</td>
<td>0.4</td>
</tr>
<tr>
<td>1.5</td>
<td>0.4</td>
</tr>
<tr>
<td>1.75</td>
<td>0.4</td>
</tr>
<tr>
<td>2</td>
<td>0.4</td>
</tr>
</tbody>
</table>

- River water transport: $Q_{river}$
- Net water transport: $Q_{net}$

**Results**

- The sensitivity of water transport to SLR is evaluated.
- River water transport ($Q_{river}$) is nearly unaffected by SLR.
- The net water transport ($Q_{net}$) shows a minimal change after a 2m sea level rise.

**Conclusions**

- The system is resilient to SLR impacts on river water transport.
- Further studies could explore the impact on other water transport systems.

**Method**

- The sensitivity analysis was conducted for various sea level rise scenarios.
- Graphs illustrate the change in net water transport under different SLR conditions.
Sensitivity of water transport to SLR

River water transport is hardly affected.

Difference in net water transport after 2m sea level rise (m$^3$/s)

Most important contribution: density driven flow
Conclusions

Impacts of 2 metre sea level rise on Tides

1. Tidal amplitudes increase due to weaker exponential decay of tidal wave.
2. Tidal waves travel faster due to less friction and weaker river flow.

Net water transport

1. River water transport is almost unaffected by SLR.
2. Subtidal transports due to baroclinic pressure, advection and dynamic pressure might be important.

Questions? Feedback?
References
