Cyclone-Driven Sediment Loads in a Tropical Mega-River

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A Role for Tropical Cyclones in Global Sediment Flux?

Sources:
Sediment flux data from Milliman and Farnsworth (2011)
Tropical cyclone frequency from IBTRACS
Methods

- Derive sediment ratings at stations along ~1400 km of the Lower Mekong in Laos & Cambodia
- Use the sediment ratings to estimate sediment loads from modelled flow data (with and without TCs)
- Sediment rating curves were derived from:
  - (Sporadic) historical SSC measurements in Laos
  - Post-hoc retrieval of SSC from acoustic backscatter returns of ADCP gaugings in Cambodia
Data Collection

\[ \text{SSC} = 4.245 \times 10^{-23} (\text{ABS}^{12.62}) \]

\[ r^2 = 0.94, \quad p < 0.001, \quad n = 54 \]
Results: Sediment Rating at Kratie

\[ Q_s = 1.298 \times 10^{-4} (Q^{1.763}) \]

\[ r^2 = 0.85, \ p < 0.001, \ n = 140 \]
## Results: Mekong Sediment Rating Curves

### Table: LMR Rating curves (of form $Q_s = aQ^b$)

<table>
<thead>
<tr>
<th>Station</th>
<th>$a$</th>
<th>$b$</th>
<th>$r^2$</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luang Prabang</td>
<td>0.0551</td>
<td>1.318</td>
<td>0.68</td>
<td>$n = 208$; 1962, 1986-88, 1992, 1998-2000, 2002; MRC</td>
</tr>
<tr>
<td>Pakse</td>
<td>0.0166</td>
<td>1.338</td>
<td>0.69</td>
<td>$n = 94$; 1962, 1999-2002; MRC</td>
</tr>
<tr>
<td>Stung Treng*</td>
<td>$4.724 \times 10^{-10}$</td>
<td>2.964</td>
<td>0.90</td>
<td>$n = 96$; 2009-2012; ADCP</td>
</tr>
<tr>
<td>Kratie*</td>
<td>$1.298 \times 10^{-4}$</td>
<td>1.763</td>
<td>0.85</td>
<td>$n = 140$; 2009-2013; ADCP</td>
</tr>
</tbody>
</table>

* Cambodian stations with SSC data retrieved from ADCP surveys
Isolating the TC contribution to runoff

Implementing on a 5km model grid for the Mekong, with topography from SRTM DEM

**DATA**
- **Soils**: FAO soil map
- **Landuse**: GLC2000
- **Climate**: 151 precipitation + 61 temp. stations
Isolating the TC contribution to runoff

- The contribution of precipitation associated with TCs (~5% of annual precip.) to LMR runoff is isolated by comparing Vmod outputs for:
  - A ‘baseline’ scenario: “reality”, forced by observed climatological data for the period 1981-2005
  - A scenario in which TC contributions to daily precipitation are identified and removed from the baseline scenario
  - The TC contributions to precipitation are estimated by using TC track data (IBTRACS; Knapp et al., 2010) to calculate precipitation anomalies within a 500 km search radius of the TC centroid (Darby et al., 2013, WRR).
Results: Runoff Simulations

A: LUANG PRABANG

\[ Q_s = 0.0551 \cdot Q^{1.318} \]

B: PAKSE

\[ Q_s = 0.0166 \cdot Q^{1.338} \]

C: KRATIE

\[ Q_s = 0.0001 \cdot Q^{1.763} \]
Results: Sediment Load Estimates

- **Sediment Load**
- **% Forced by TCs**

Station ID: LP, MK, PX, ST, KT

Proportion of Flux Forced by TCs (%)

- LP: 76.7
- MK: 75.6
- PX: 79.7
- ST: 74.2
- KT: 89.9

'S3' Basin Inputs
Contribution of TCs to Sediment Flux

Luang Prabang: 16.4% (of 76.7 Mt/yr)
Mukdahan: 27.4% (of 75.6 Mt/yr)
Pakse: 13.1% (of 79.7 Mt/yr)
Stung Treng: 63.3% (of 74.2 Mt/yr)
Kratie: 46.3% (of 89.9 Mt/yr)
Implications: Future TC track shifts

Implications: A Delta in (Greater) Peril?

\[ Q_s \sim 90 \text{ Mt/yr} \]
\[ (~41 \text{ Mt/yr from TCs}) \]

Potential Deposition
(if all retained!)
\[ < 2 \text{ mm/yr} \]

SL Rise \sim 9 \text{ mm/yr}
Conclusions

- Tropical cyclones force a significant proportion of the Mekong’s suspended sediment load; that contribution becoming dominant (~45 to 60% of the total load) in the lower reaches.

- Specifically, the TC-induced contribution to the mean annual load is >40 Mt/yr at Kratie, the apex of the Mekong delta.

- Changes in TC track location, frequency and intensity may, therefore, exert a significant control on sediment delivery to coastal sinks.

- Future declines in the sediment load reaching the Mekong delta apex may be anticipated.
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