Hydrodynamics and Tidal Asymmetry in the Cilacap-Segara Anakan Estuary System

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Abstract

Is the Cilacap mouth flood- or ebb-dominant? Four current stations, from 2 km offshore to 5 km upriver, and a validated MIKE 21 FM model give a clear answer: flood currents peak stronger, while ebb flows occur more often and last longer.

0.25–0.99 velocity skewness: flood-dominant

1.8–2.4 h lag between tide and current peaks

> 1.5 m/s modelled 90th-percentile speed in narrow channels

62% of current events are ebb at C4

Keywords: Estuary, ADCP, Tidal Asymmetry, MIKE 21 FM, Segara Anakan

Introduction

- **Why it matters:** Segara Anakan is Indonesia's largest mangrove lagoon and a key fish nursery, now threatened by rapid sedimentation.
- **Gap:** the tide-dominated eastern inlet (Cilacap) is largely unmeasured.
- **Aim:** map tidal currents and flood–ebb asymmetry from offshore to upriver with field data and a 2D model.

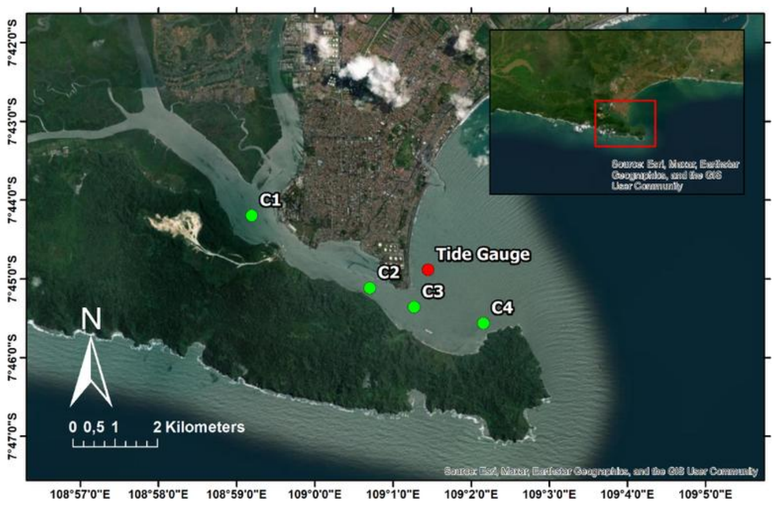

Fig. 1. Study area and observation stations: current stations C1–C4 (green dots) and tide gauge (red dot)

Table 1. Model set-up (DHI MIKE 21 FM).

Parameter	Setting
Software	DHI MIKE 21 Flow Model FM (HD)
Period	1 Jan 2018 – 1 Jan 2019
Time step	600 s
Density	Barotropic
Eddy viscosity	Smagorinsky, 0.28
Bed resistance	Spatially varying Manning
Wind	ERA-Interim, time-varying
Seaward boundary	Tidal parameters
River boundary	Flather (discharge & tide)

Key references
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Method & Observations

- **Measure:** ADCP (C1, C3), AWAC (C2, C4) and tide gauge; 20-min data, Jan–Feb 2019.
- **Analyse:** harmonics, skewness, ebb/flood event counts, cross-correlation.
- **Model:** MIKE 21 FM, validated with r > 0.8 and NRMSE < 20%.

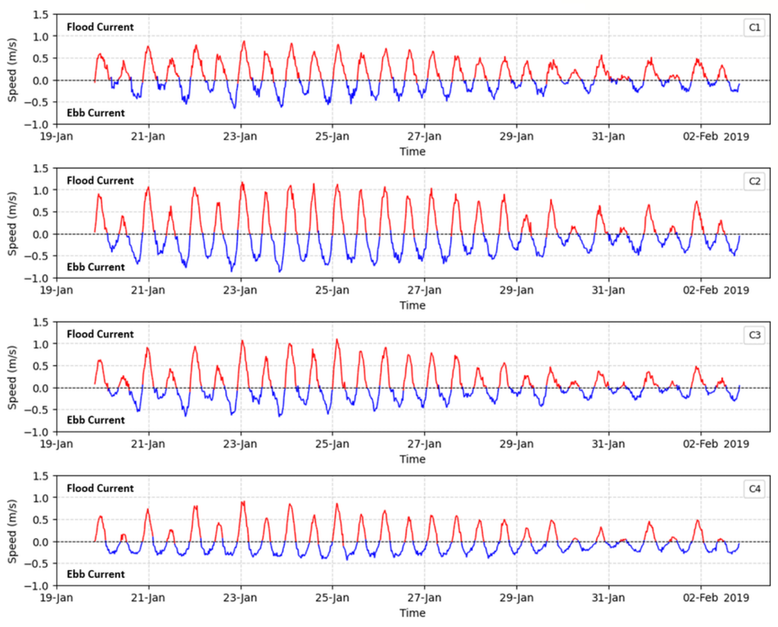

Fig. 2. Principal-axis current speed at C1–C4 (top to bottom), Jan–Feb 2019. Red = flood, blue = ebb

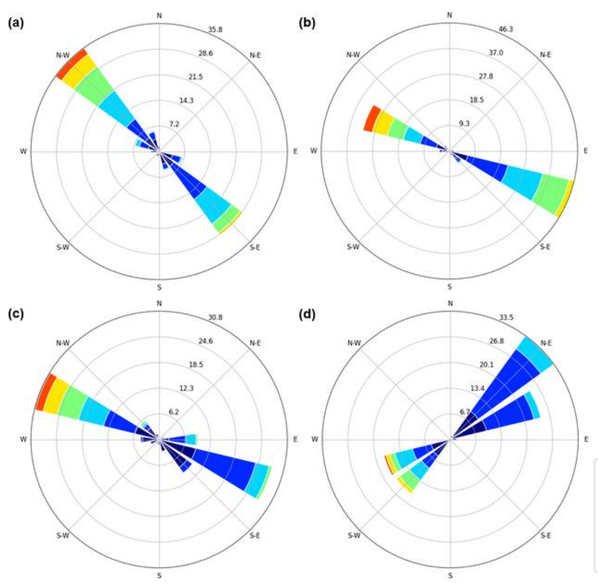

Fig. 3. Current roses at (a) C1, (b) C2, (c) C3 and (d) C4; colours show current speed (m/s)

Flood is stronger, ebb is longer: positive skewness at every station, rising seaward; ebb events dominate at C2–C4 (Table 2).

Table 2. Tidal asymmetry indicators at C1–C4

Station	Skewness	Ebb (%)	Flood (%)	Lag (h)
C1	0.25	44.5	55.5	1.84
C2	0.57	56.4	43.6	2.24
C3	0.75	52.4	47.6	2.08
C4	0.99	62.2	37.8	2.36

Currents lag the tide: peak flow follows peak elevation by 1.8–2.4 h (Fig. 4).

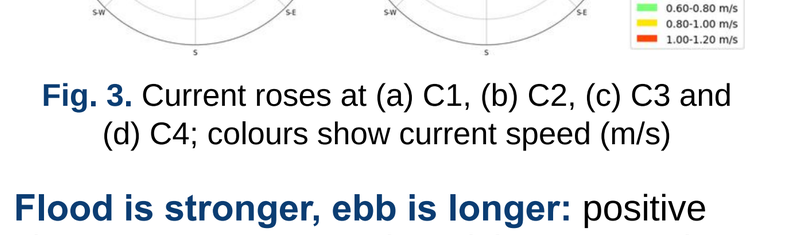

Fig. 4. Elevation–current cross-correlation: (a) C1, C3; (b) C2, C4

Results & Discussion

Mixed semi-diurnal tide: M2 and K1 dominate; M4 and MS4 grow upriver, signalling nonlinear distortion (Table 3).

Table 3. Amplitudes (m) of main tidal constituents

Const.	C1	C2	C3	C4
M2	0.474	0.483	0.473	0.476
K1	0.208	0.212	0.215	0.215
M4	0.024	0.011	0.008	0.004
MS4	0.013	0.005	0.004	0.001

Model hot spots: mean speed 0.25–0.90 m/s along the channel axis; 90th percentile > 1.5 m/s in narrow sections (Fig. 5).

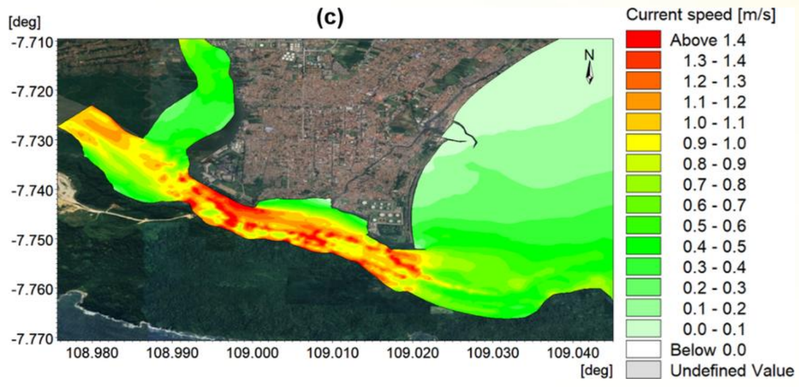

Fig. 5. Modelled 90th-percentile current speed (m/s); highest in the narrow channel

Model confirms flood dominance: skewness is positive everywhere, rising from ~0.3 at C1 to ~0.8 at C4, as observed (Fig. 6).

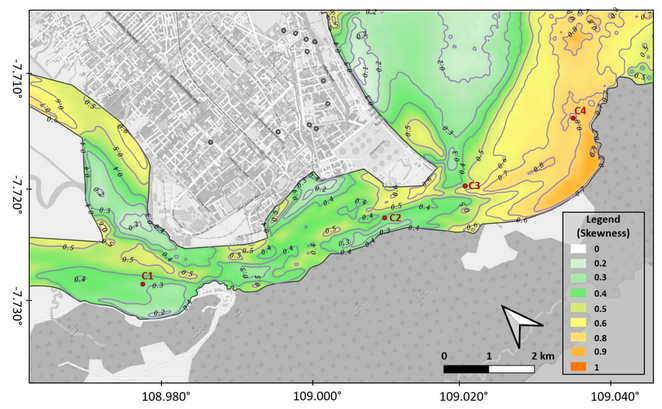

Fig. 6. Modelled velocity skewness

Ebb at the mouth, flood upriver: modelled ebb events prevail at C2–C4 and turn slightly flood-dominant at C1, as observed (Fig. 7).

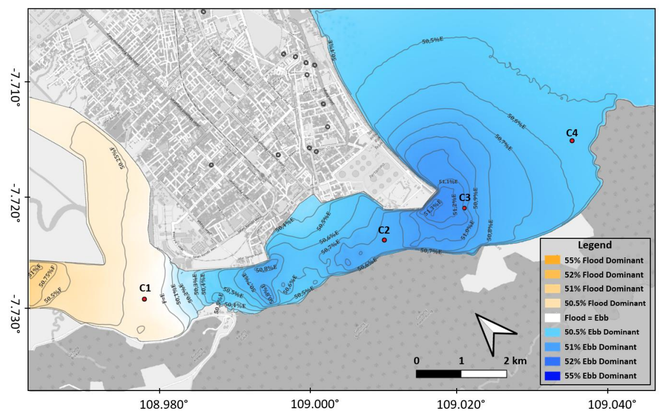

Fig. 7. Modelled percentage of ebb and flood events.

Conclusion

- Mixed semi-diurnal tide; **overtides** amplify upriver.
- Observation x Model → **Flood-dominant:** stronger flood peaks, more frequent ebb.
- Model reproduces observed skewness and ebb-flood patterns.
- Baseline for estuary **sediment management**.
- Future → coupled **Hydrodynamics x Sediment Transport**

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