Regime shift of the tidal channel morphodynamics and its underlying mechanism in the Pearl River Delta, China

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1. Background

- Tidal channels are ubiquitous features in estuarine and coastal areas. Understanding the tidal channel morphodynamics evolution is essential for the transports of water, sediment and nutrients and the related water resources management (e.g., flood control and salt intrusion) in river deltas.
- The evolution of tidal channel morphology and quantifying the potential impacts of human interventions on the regime shift of tidal channel morphodynamics are receiving increasing attention.
- Less attention has been paid to the evolution and the resilience of Shiziyang tidal channel, ignoring the interaction between outer bay and channel networks.
- The results can provide scientific supports for the channel regulation, embankment protection and water security assurance of the Pearl River Delta.

2. Coupling Approaches

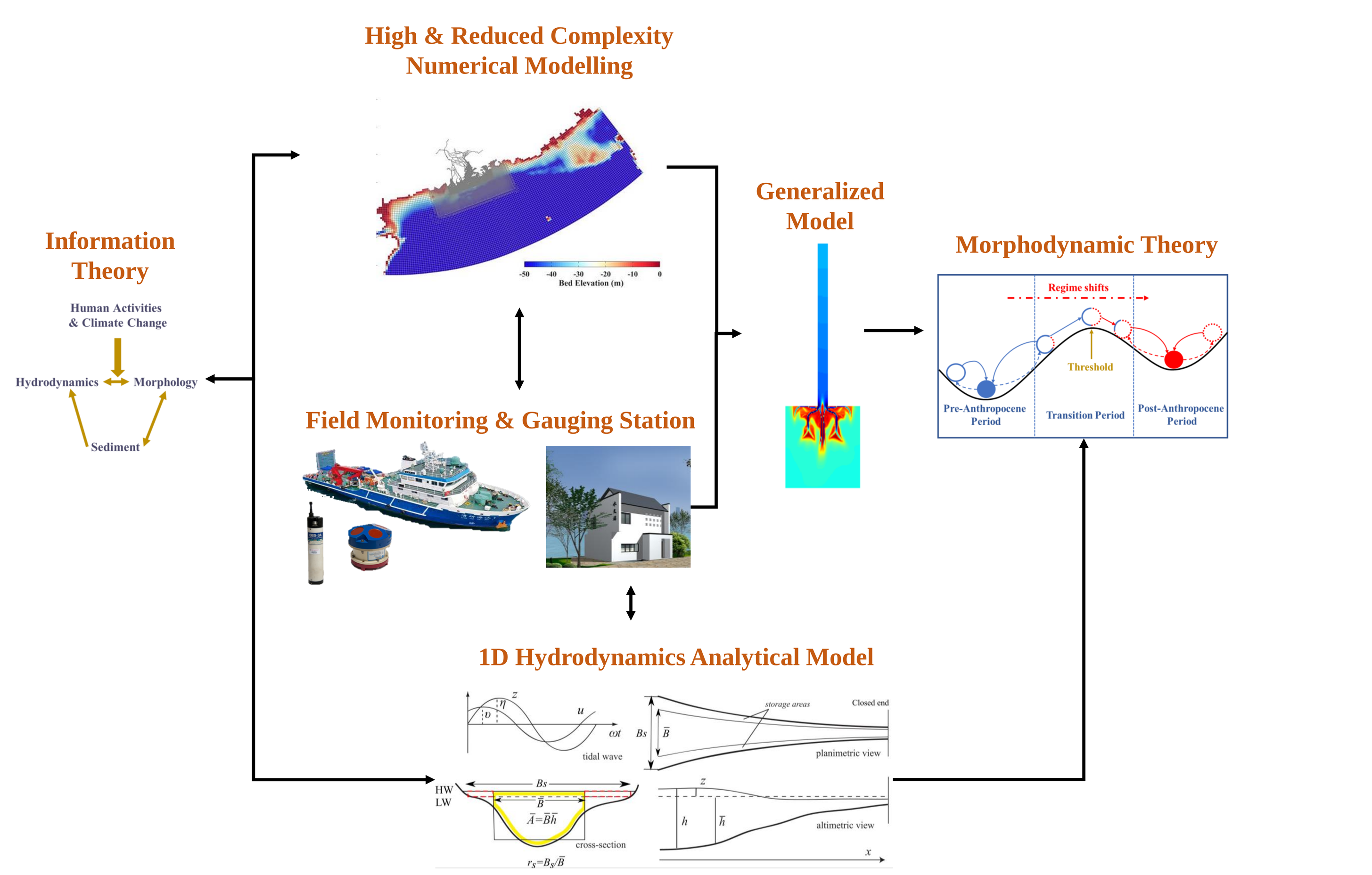

Figure 1. Coupling approaches combining the information theory, filed monitoring, numerical model and analytical model (modified from Hoitink, et al., 2020).

Based on the information theory, combined with the filed monitoring, historical data from gauging stations, Numerical model and 1D Hydrodynamics Analytical Model, the morphodynamic theory is summarized.

3.1 Regime Shift-Morphology

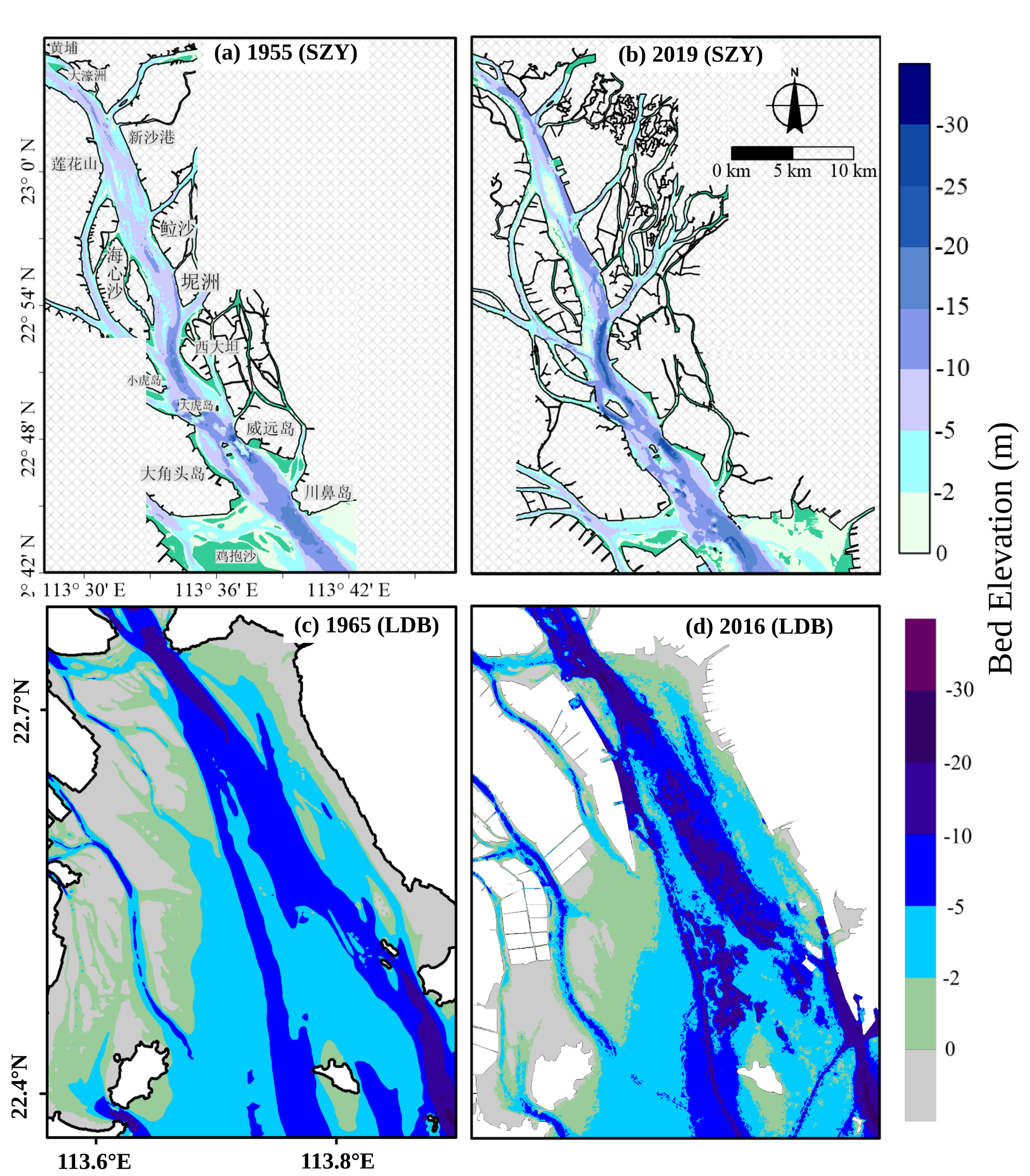

Figure 2. Bathymetric maps of Shiziyang Tidal Channel in 1955 (a), 2019 (b) and Lingdingyang Bay in 1965 (c), and 2016 (d)

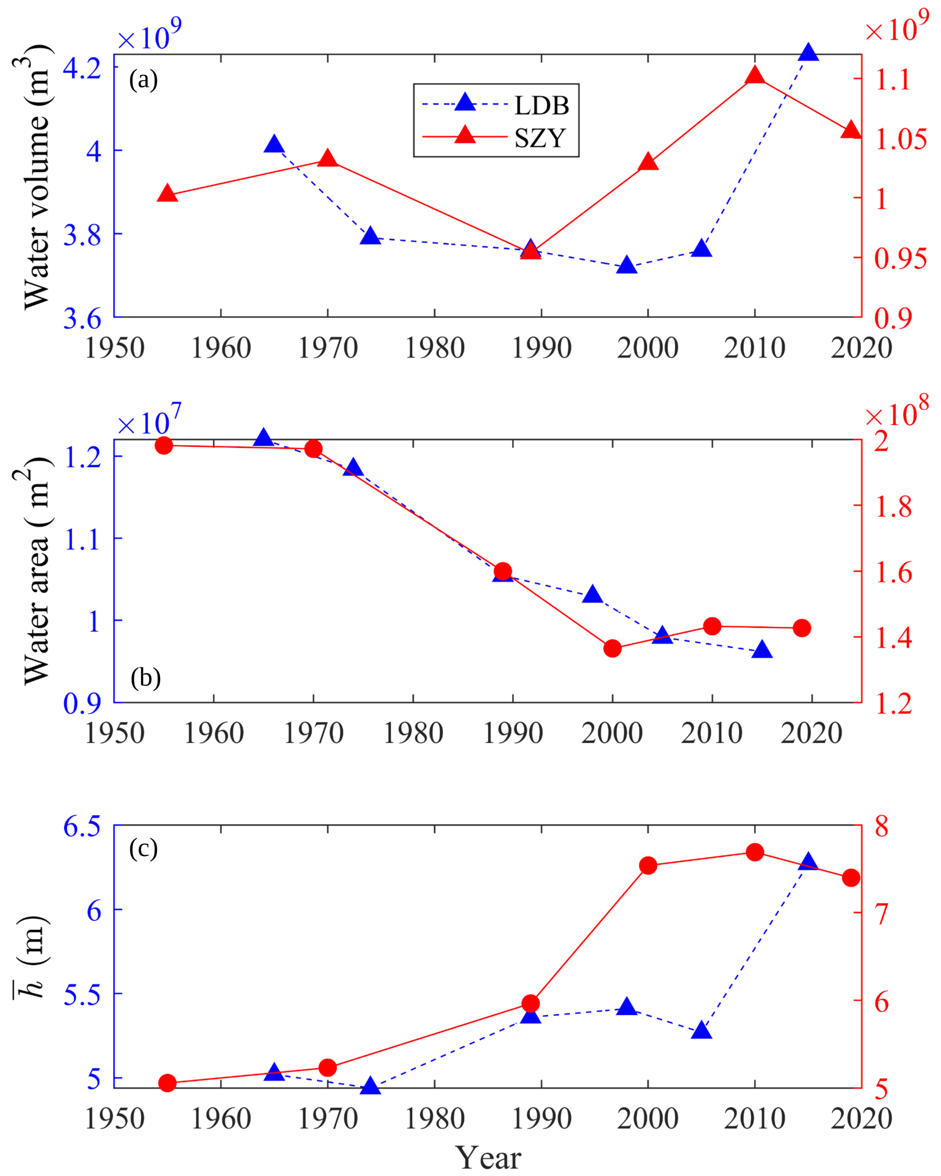

Figure 3. Temporal variations of water volume (a) and surface area (b) and average water depth (c)

✓**The tidal channel deepened and narrowed with stepwise alterations due to human interventions.**

3.2 Regime Shift-Tidal hydrodynamics

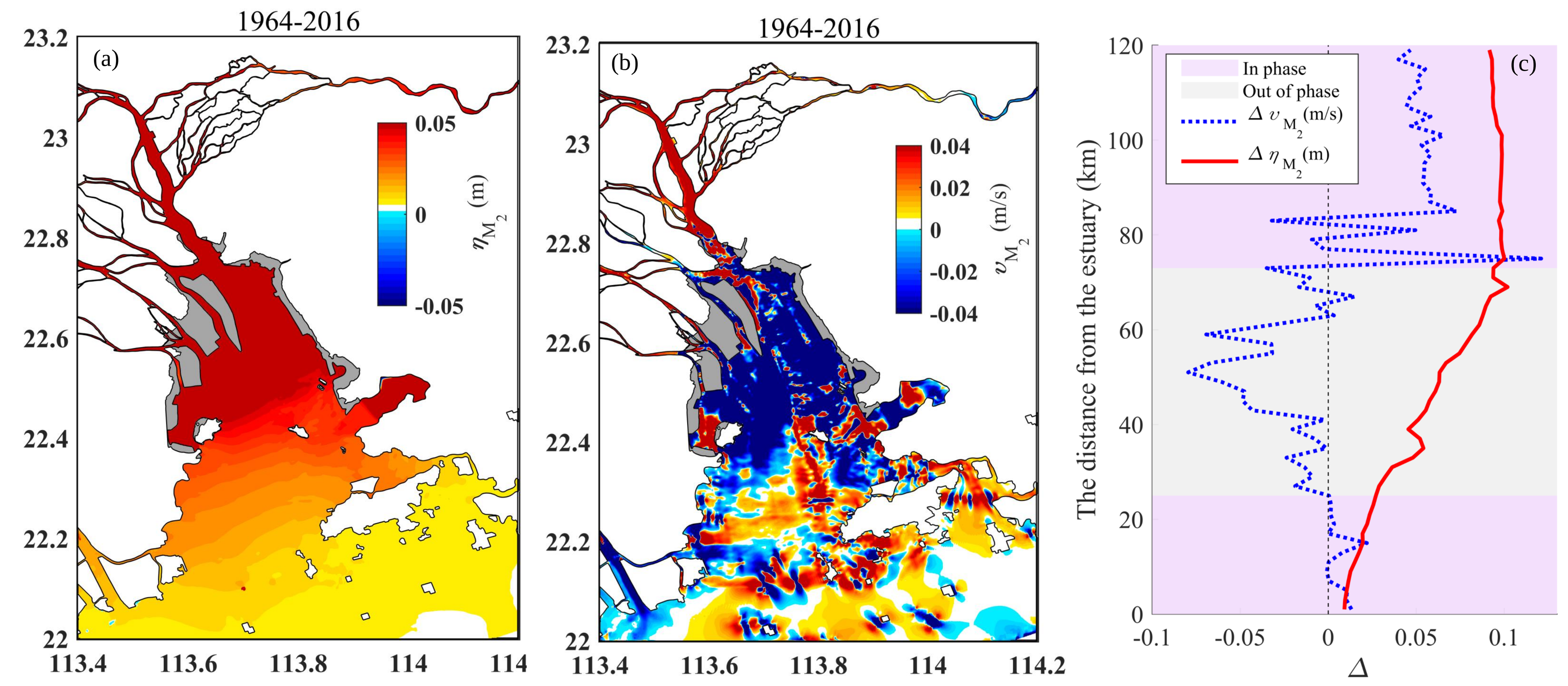

Figure 4. Spatio-temporal variations of tidal amplitude η (a) and velocity amplitude υ (b) from 1965 to 2016 and their variations along the tidal channel (c)

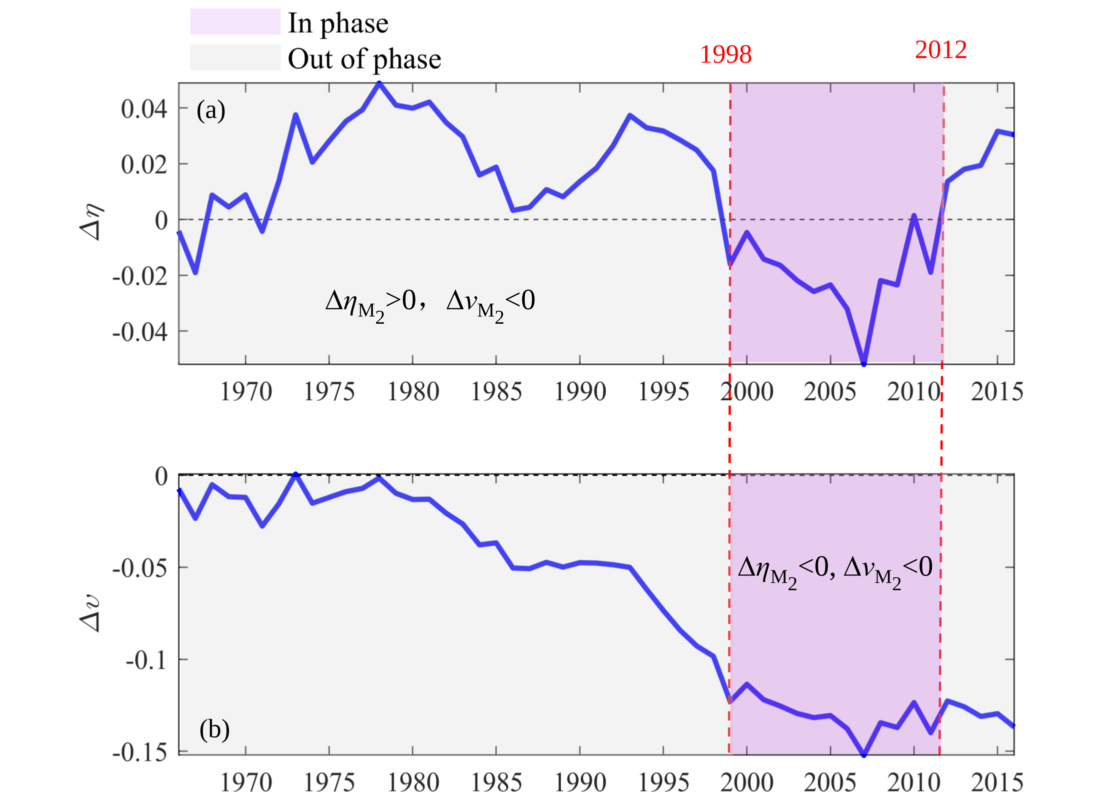

Figure 5. Stepwise variation of the change of tidal amplitude η (a) and velocity amplitude υ (b) from 1965 to 2016 reproduced by 1D analytical model

✓**Stepwise alteration of the relationship between $\Delta\eta$ and $\Delta\upsilon$: out of phase → in phase→ out of phase.**

4 Underlying Mechanism

Sensitivity Analysis

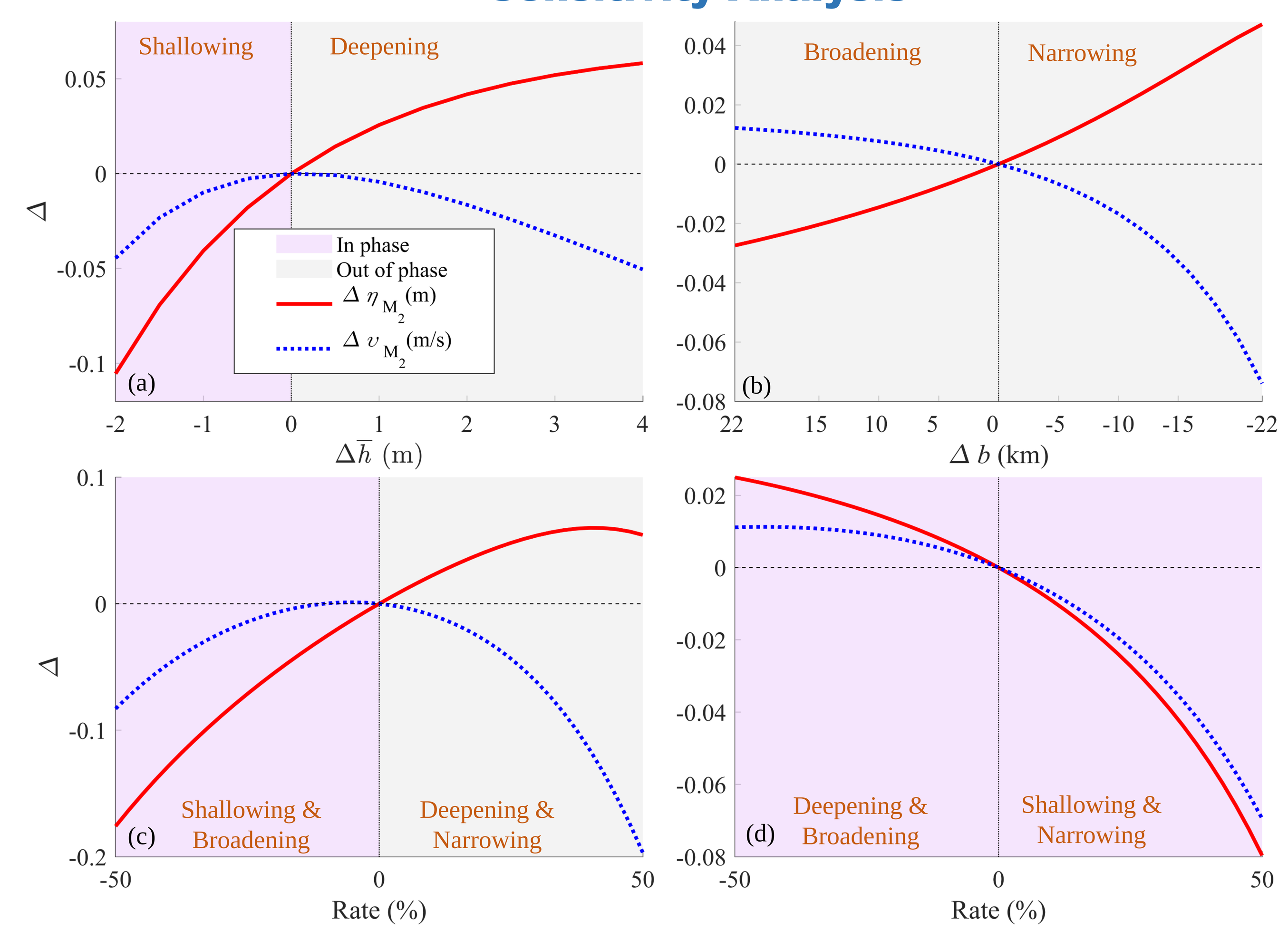

Figure 6. Variations of tidal amplitude η and velocity amplitude υ with alterations in spatially averaged water depth $\Delta\bar{h}$ (a), width convergence length Δb and both (c,d) for given actual parameters observed in 2016 predicted by 1D analytical model.

✓**Geometric Characteristics impact the pattern;**

✓**Channel deepening plays a more important role.**

Qualification of human-induced and natural impacts

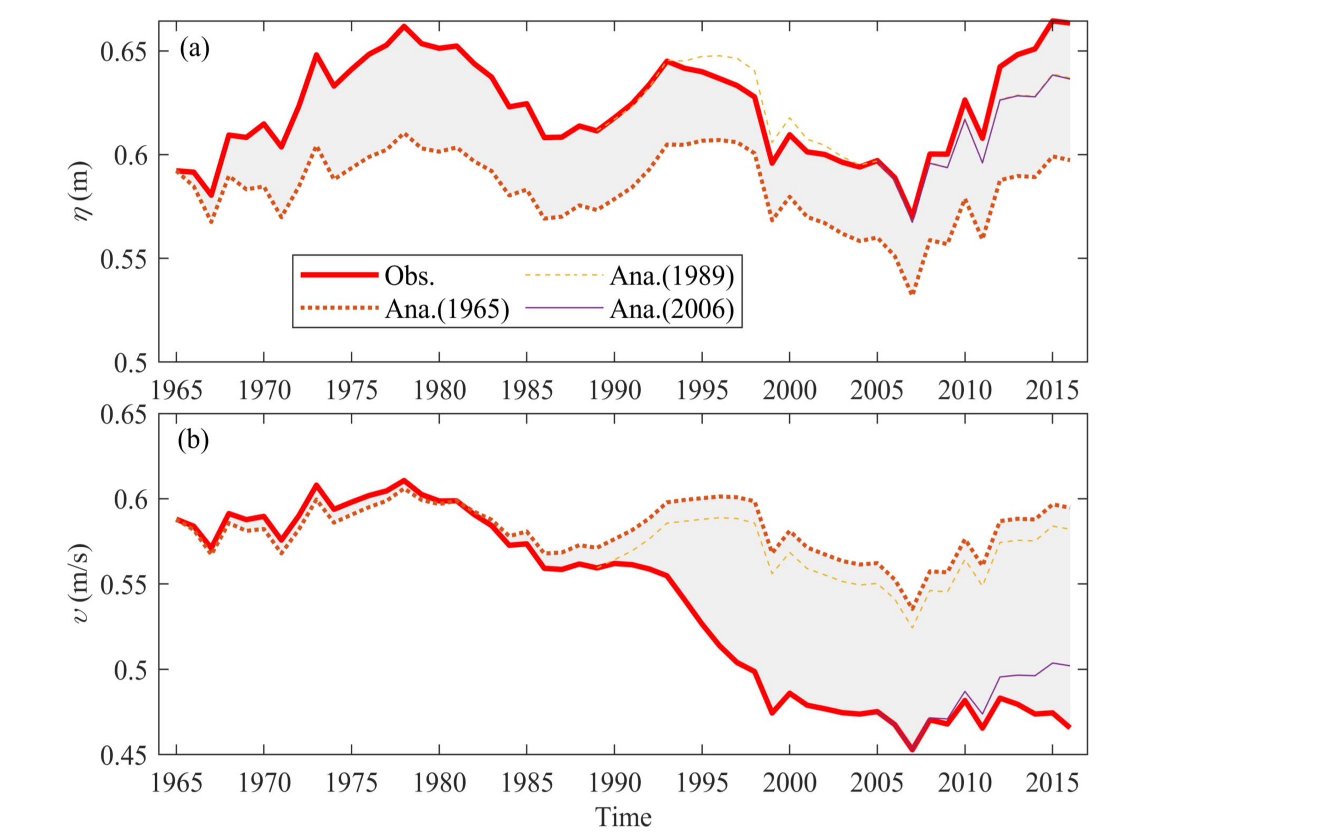

Figure 7. Observations of tidal amplitude η (a) and velocity amplitude υ (b) and their analytical results derived on the basis of the data in dynamic equilibrium period (1965, 1989, 2006) by means of the 1D analytical model (the grey area indicates the difference between observation and that would have occurred without human-induced and natural impacts).

✓**Human-induced (deepening and narrowing) and natural impacts resulted in increasing η (0.0393 m) and decreasing υ (0.0432 m/s).**

5 References

[1] Cai, H., Toffolon, M., Savenije, H.H.G., et, al, 2018. Frictional interactions between tidal constituents in tide-dominated estuaries. Ocean Sci. 14, 769–782.

[2] Hoitink, A.J.F., Nittrouer, J.A., Passalacqua, P., et al., 2020. Resilience of River Deltas in the Anthropocene. Journal of Geophysical Research: Earth Surface 125, e2019JF005201.

[3] Zhang, P., Yang, Q., Wang, H., et al., 2021. Stepwise alterations in tidal hydrodynamics in a highly human-modified estuary: The roles of channel deepening and narrowing. Journal of Hydrology 597, 126153