Tidal Mixing Sustains a Bottom-trapped River Plume and Buoyant Coastal Current on an Energetic Continental Shelf

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1.Introduction

The Changjiang (Yangtze) River is one of the major river-borne material contributors to the East China Continental Shelf. The river water flows into the Yellow and East China Sea and forms the Changjiang River plume. The plume can extend to three directions, whose southern branch imposes great impacts on the ecosystem and sedimentary system of the Zhejiang-Fujian (Zhe-Min) Coastal Water and drives a buoyant coastal current (Zhe-Min Coastal Current, ZMCC). It was conventionally believed that the ZMCC prevails in winter but vanishes in summer, as controlled by the Eastern Asian Monsoon. However, a down-shelf buoyant coastal current can also be detected in the ZMCW even under upwelling-favorable summer monsoon (Li et al., 2014). The Zhe-Min Coastal Water is energetic with strong tide, shelf currents, winds and buoyancy inflow. In this study, we used a 3-D hydrodynamic numerical model to look into the variations of the Changjiang River plume in such energetic environment, investigate the major driving forcing of the ZMCC, and try to answer why the ZMCC persists against the upwelling-favorable wind in summer.

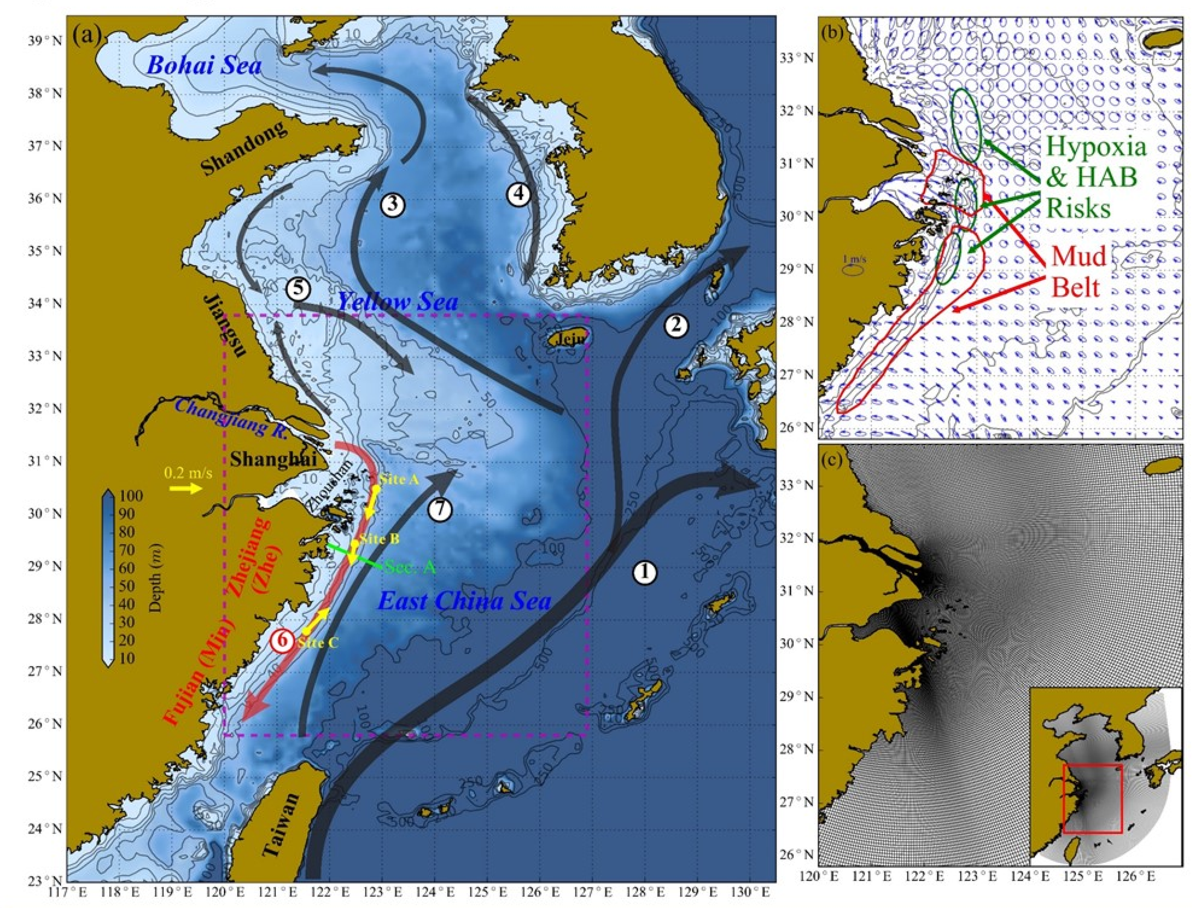


Fig. 1 Map and bathymetry of the East China Continental Shelf (a), observations of summer ZMCC (yellow vectors in (a), Li et al., 2014), Section A (green line in a), locations of the Zhe-Min mud belt and hypoxia and harmful algae bloom (HAB) events (b) and the model domain (c)

2. Methods

The 3-D hydrodynamic numerical model used in the study is developed from ECOM-si. The model covers the entire East China Continental Shelf as well as parts of the Japan Sea and the Northwest Pacific Ocean (Fig. 1c). Tide, shelf current and Changjiang River discharge are included in the simulation. The model has been validated by a series of in-situ data and performed well.

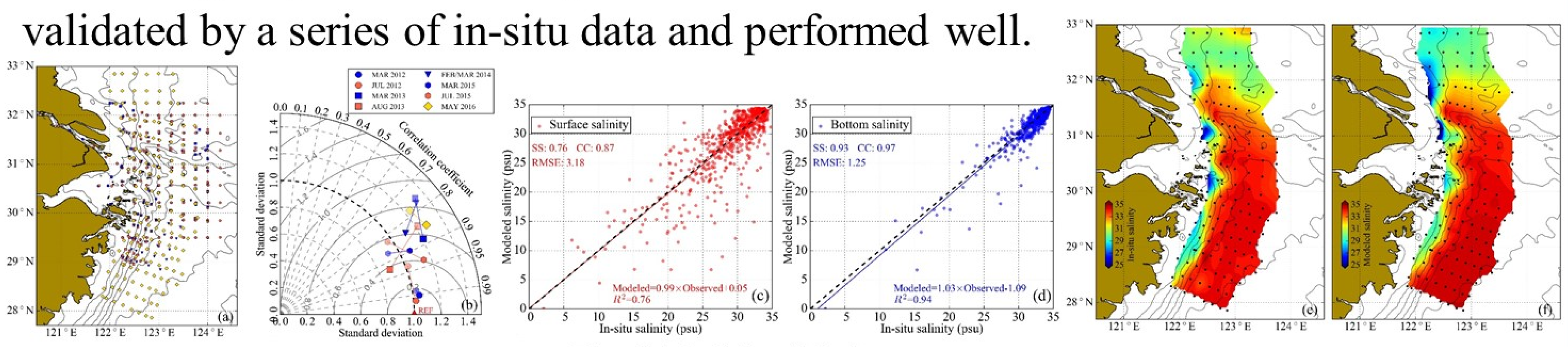


Fig. 2 Model validations

3. The Bottom Plume Front and the ZMCC

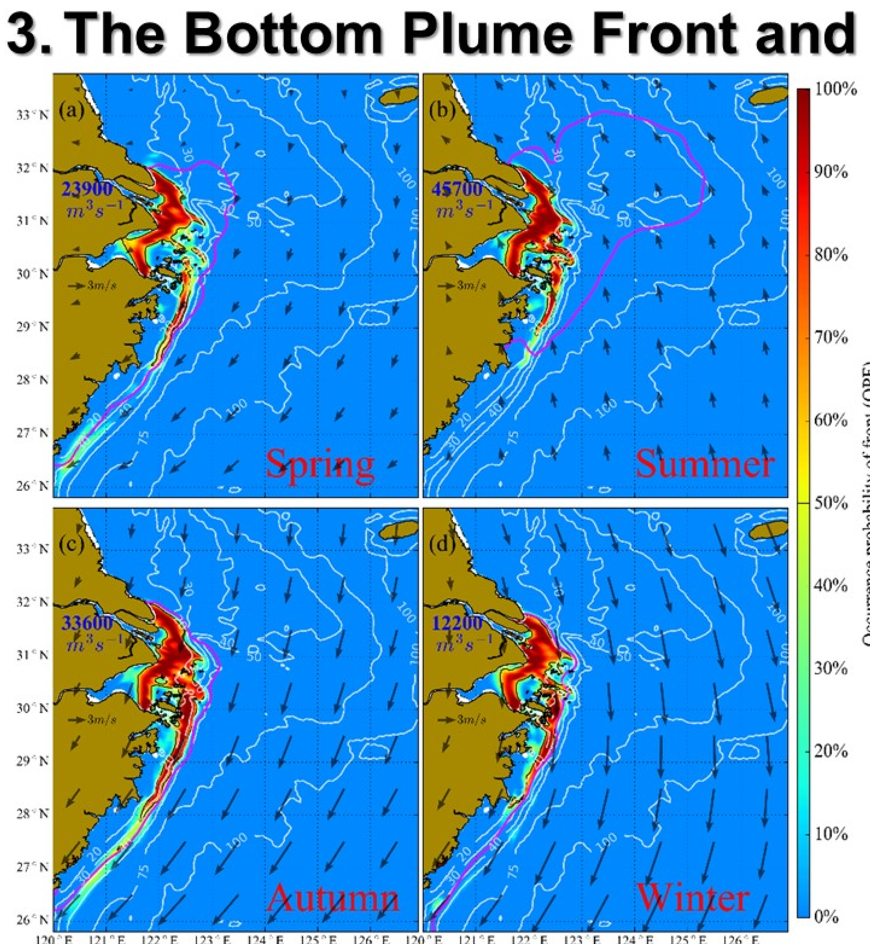


Fig. 3 Climatologically seasonal mean occurrence probability of bottom salinity front (color), surface 30-psu isohaline (purple contours)

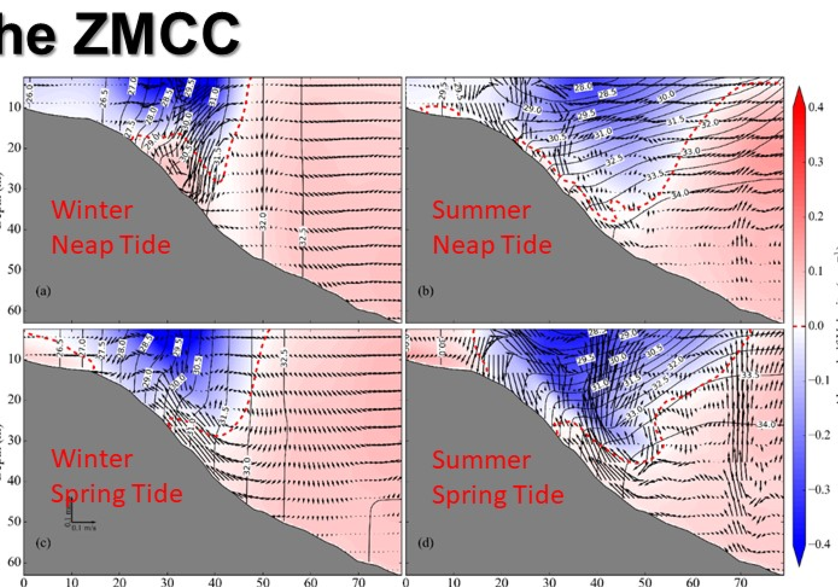


Fig. 4 Profiles of salinity and along-shelf velocity

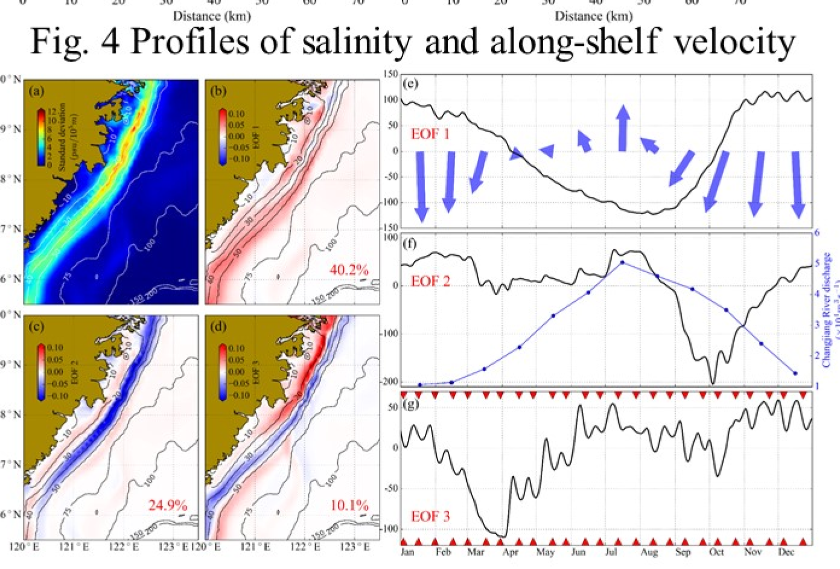


Fig. 5 EOF analysis of bottom salinity gradient

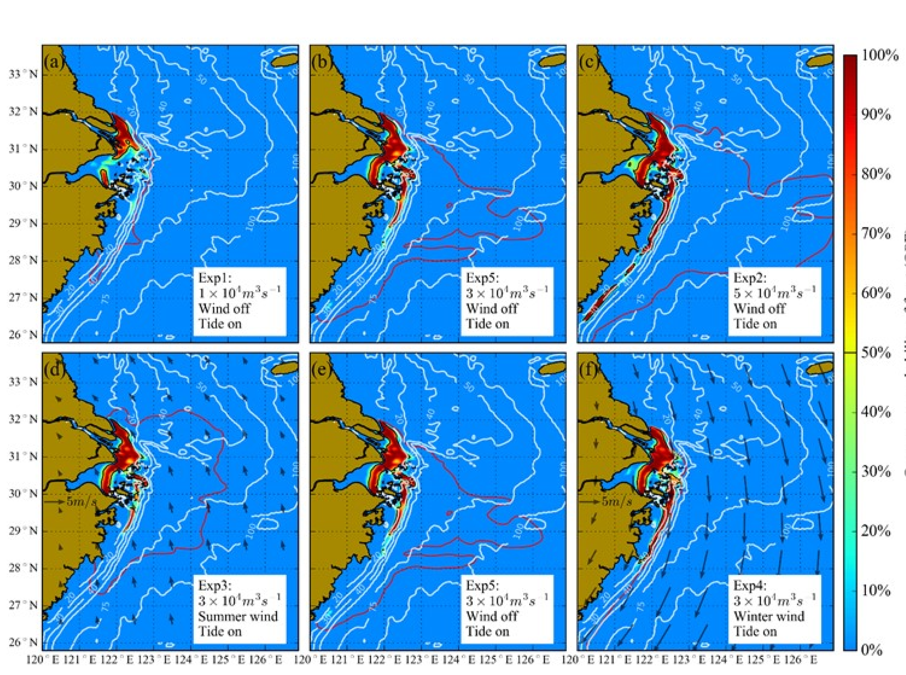


Fig. 6 Diagnostic experiments on response of the Changjiang River plume to different Changjiang River discharge and wind forcing conditions

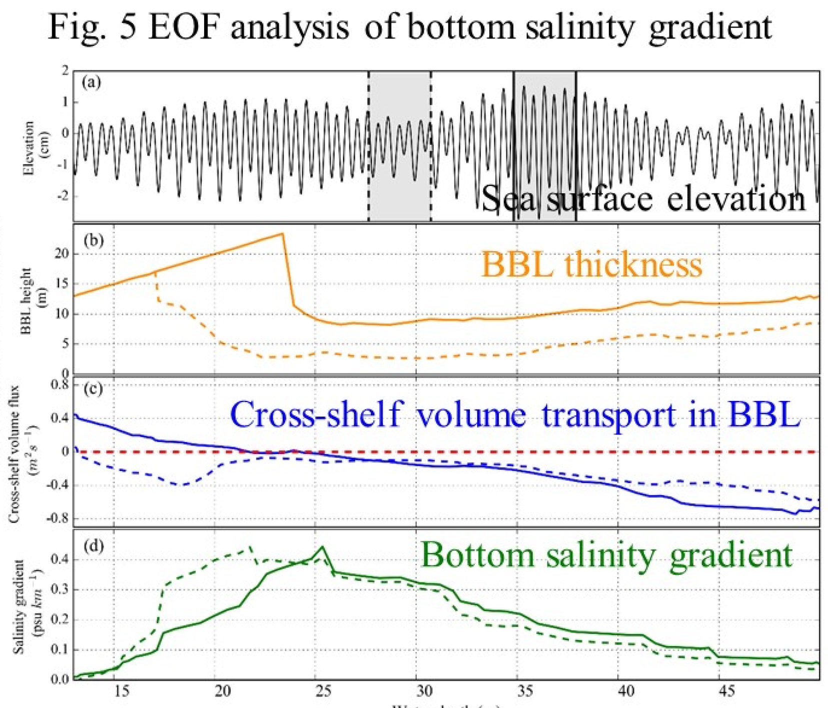


Fig. 7 Response of the Changjiang River plume front to different tidal intensities

4. The Major Driving Force of the ZMCC, Wind or Buoyancy?

- Buoyancy of the plume water is the major direct driving force of the ZMCC.
- The direct contribution of wind is less than 20%. However wind can also significantly modulates the ZMCC by redistributing the plume water.

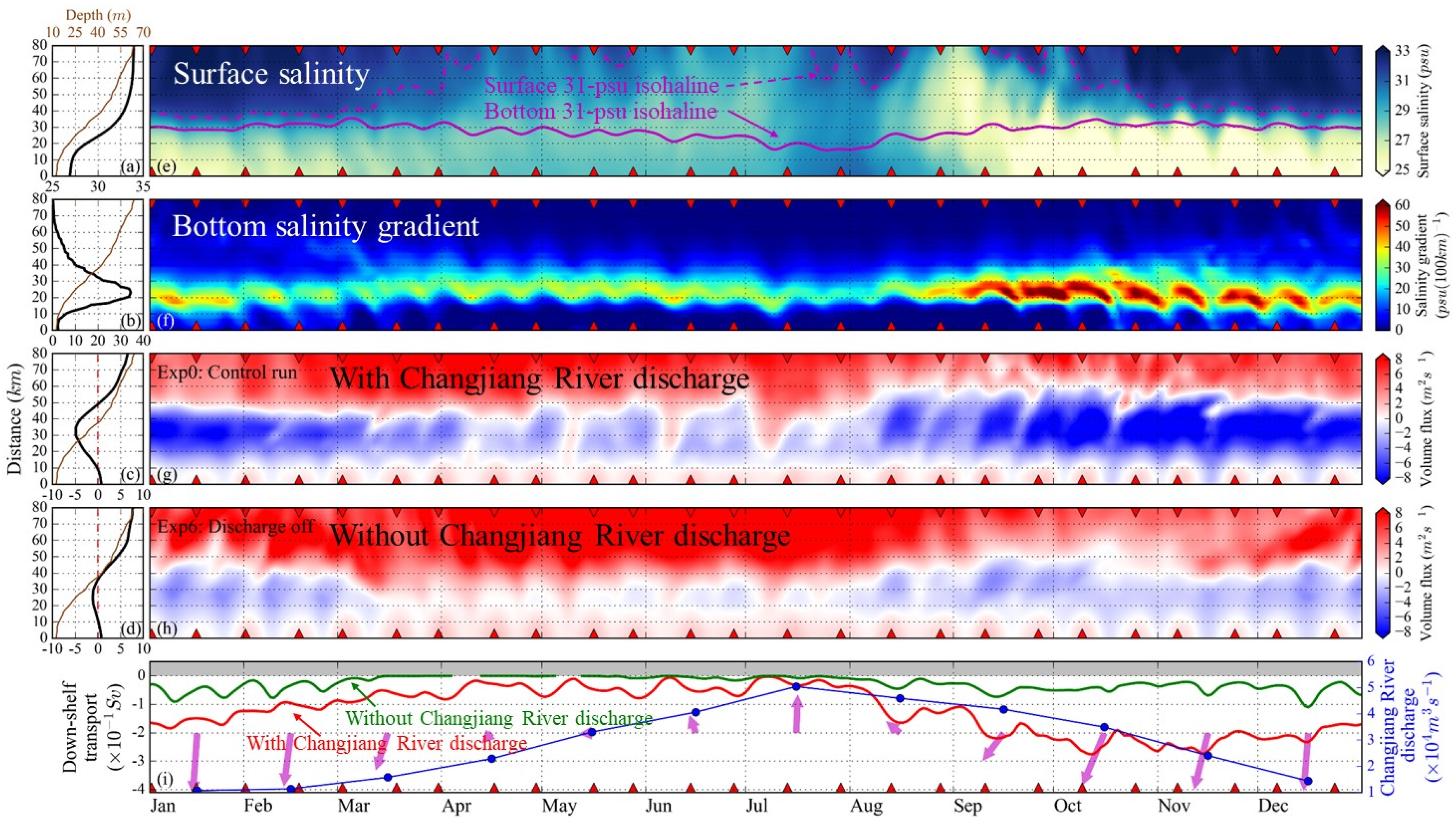


Fig. 8 Annual means and time series of subtidal surface and bottom salinity (a, e), bottom salinity gradient (b, f) and residual volume flux (c, g) from the climatological run, residual volume flux (d, h) from the experiment without Changjiang River discharge (other conditions are same as the climatological run), and total down-shelf volume transport from both experiments (i) in Section A

5. Sustention of the Plume Front and the ZMCC in Summer

- The Changjiang River plume provides vertical stratification in the Zhe-Min Costal Water under upwelling-favorable summer monsoon.
- Tidal mixing induces a plume front along the Zhe-Min Coastal Water under the stratified environment.
- The tidal-induced front drives a down-shelf buoyant coastal current (ZMCC) that flows against the wind.
- The down-shelf current provides plume water to the Zhe-Min Coastal Water and maintains stratification there.

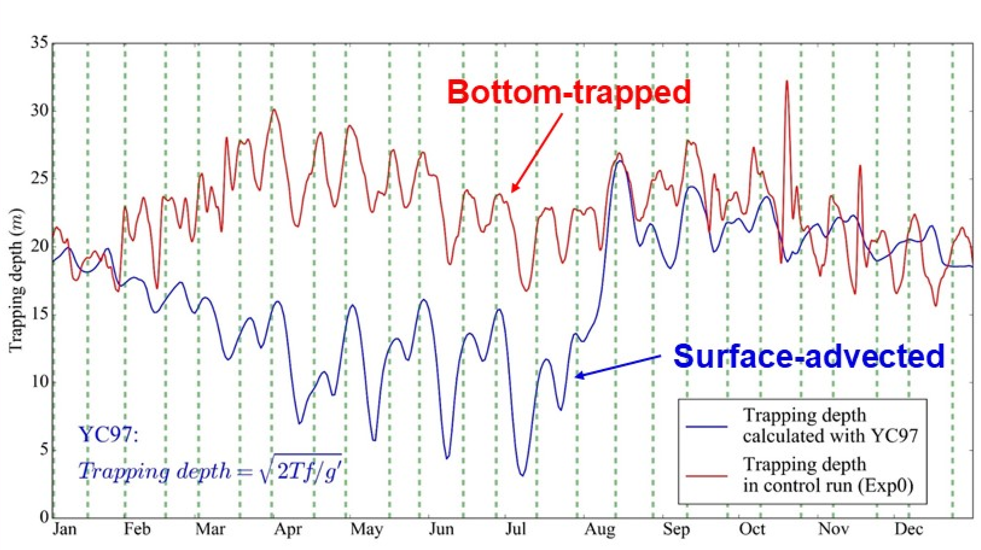
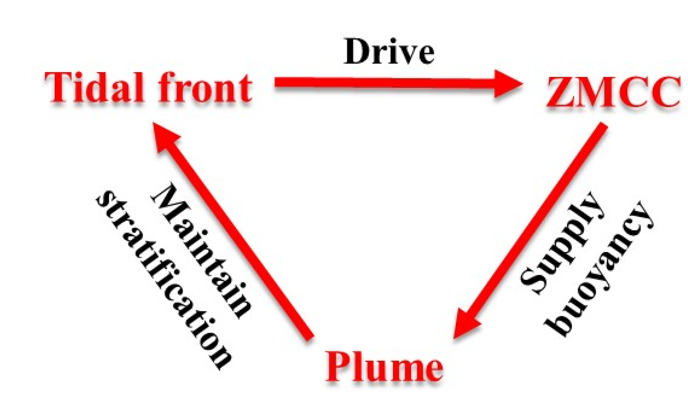


Fig. 9 Comparison of predicted trapping depth calculated with YC97 (blue line) and modeled trapping depth where the maximum bottom salinity gradient took place (red line) in Section A from the climatological run



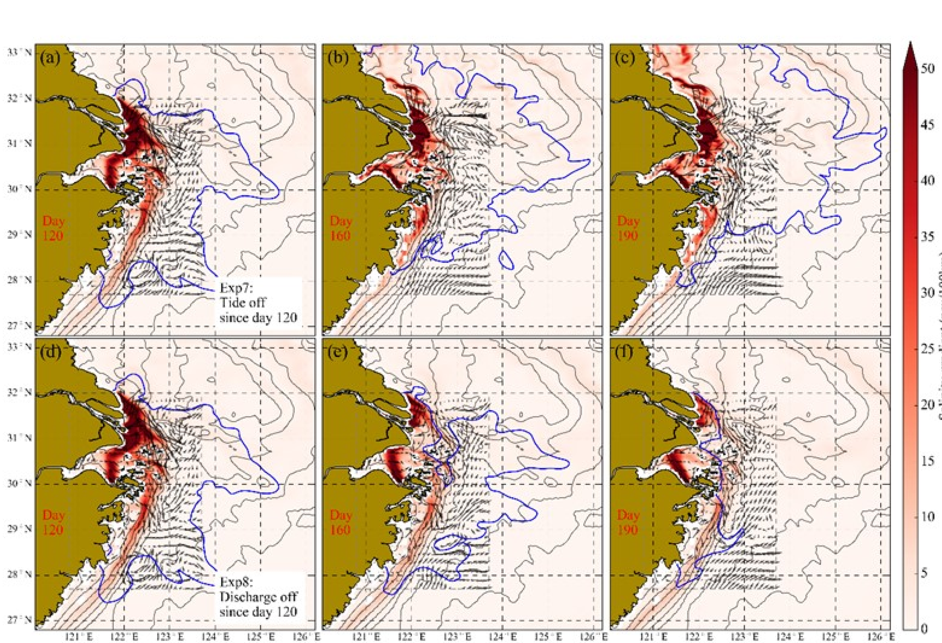


Fig. 10 Response of the Changjiang River plume and residual surface currents after shutting down tide (a-c) and Changjiang River discharge (d-f) under southerly wind

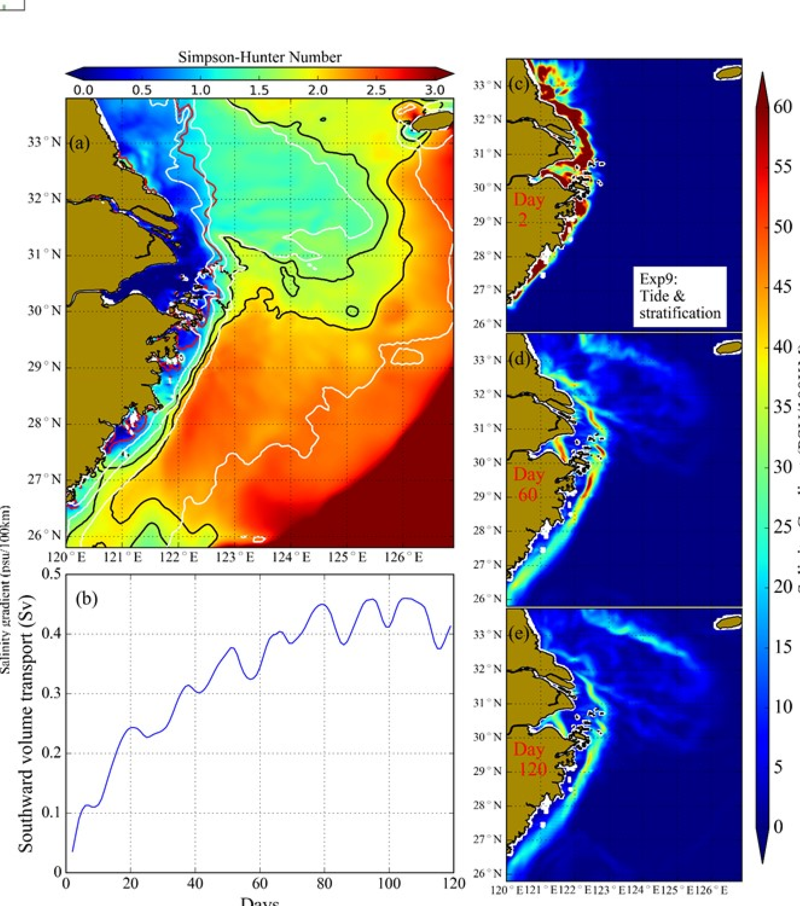


Fig. 11 Simpson-Hunter Number (a), evolutions of down-shelf volume transport and bottom salinity gradient in the “stratification-tide” experiment (b-e)

6. Summary

- The Changjiang River plume along the Zhe-Min Coastal Water persists bottom-trapped and drives a down-shelf buoyant coastal current (ZMCC) throughout the whole year.
- Buoyancy is the major direct driving force of the ZMCC, while wind also significantly modulates the ZMCC by redistributing the buoyancy.
- Tidal-induced front sustains the plume water along the Zhe-Min Coastal Water and the ZMCC under upwelling-favorable summer monsoon.