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Numerical study of Jiulongjiang river plume in the wet season 2015

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ABSTRACT

Numerical simulation of the buoyant river plume in the Jiulongjiang River (JR) estuary, China, and its shelf in a wet season, April–September 2015, is constructed and applied to explore the evolution of the JR plume. The model is forced with realistic forcing, including river discharge, tides, wind stress, surface heat flux and freshwater flux, and ocean open boundary conditions. The simulation results agree well with in-situ and satellite observations. A Lagrangian particle tracking method is used to identify the freshwater pathway. It is found that the JR freshwater tends to escape the estuary-shelf system to the north from April to mid-August but to the south since late August. Based on a self-organizing map (SOM) analysis, four major JR patterns are identified. A northeastward plume pattern has the highest frequency of occurrence (44.8%), while a southwestward plume pattern has the second highest frequency of occurrence (33.9%). The other two patterns are transitional. The analysis of the alongshore and cross-shore momentum balances indicates that the JR plume is largely shaped by wind and background alongshore current. Particularly, the background coastal current plays an important role for the JR freshwater escape to the north in the Taiwan Strait.

1. Introduction

Jiulongjiang River (JR), located in the Southeast of China, is one of the largest rivers entering the Taiwan Strait. The climatological annual freshwater discharge is about 1.2×10^{10} m^3, approximately 70% of which occurs from April to September, so called the wet season (Wang et al., 2013a, b). The river runoff enters the Taiwan Strait, affecting shelf circulation, stratification and mixing dynamics. The associated suspended load and dissolved matters of land origin can significantly influence coastal water properties. Thus, the JR plume potentially exerts a large impact on hydrodynamics and ecosystem health in the Taiwan Strait.

River plumes spread variably in different estuary-shelf systems, and individual system may also exhibit markedly different characteristics due to the varied forcing conditions. According to previous studies, river discharge (e.g. Pritchard and Huntley, 2006; MacDonald et al., 2007; Horner-Devine et al., 2009; Hickey et al., 2010; Zhang et al., 2012), local wind (e.g. Chao, 1988; Lentz, 2004; Gan et al., 2009; Liu et al., 2009; Ji et al., 2011; Schiller et al., 2011; Jurisa and Chant, 2013; Zu et al., 2014), coastal currents (e.g. MacCready et al., 2009; Schiller et al., 2011), topography (Schiller et al., 2011; Horner-Devine et al., 2015) and tides (Chao, 1990; Guo and Valle-Levinson, 2007; MacCready et al., 2009; McCabe et al., 2009; Zu et al., 2014; Horner-Devine et al., 2015) are all important factors controlling river plume dynamics.

The JR estuary-shelf system is subject to the strong East Asian monsoon. In general, the northeasterly prevails from September to April and southwesterly prevails from May to August. Off the JR mouth, Yuedong Coastal Currents flow northeastward in summer, and Zhemin Coastal Currents flow southwestward in winter (Hu et al., 2010). The Taiwan Strait currents are closely related to the change of wind (Oey et al., 2014). With no wind conditions, the higher coastal sea level in the South China Sea drives northeastward currents in the strait (Wang et al., 2003). The interaction of the river plume with the coastal current is a crucial dynamic process for nearshore circulation in the Taiwan Strait.

Previous studies of the JR plume mainly relied on in-situ and satellite observations. Wang et al. (2013a, b) revealed the existence of a northeast and a southwest plume pattern, respectively, based on the cruise data in summer 2010. Based on satellite turbidity, Wang et al. (2013a, b) classified the river plume into four patterns during June, July and August from 2003 to 2011. However, due to the environmental complexities, the daily distribution of turbidity is not always available. Modeling studies of the JR plume are required for better understanding the fate and characteristics of

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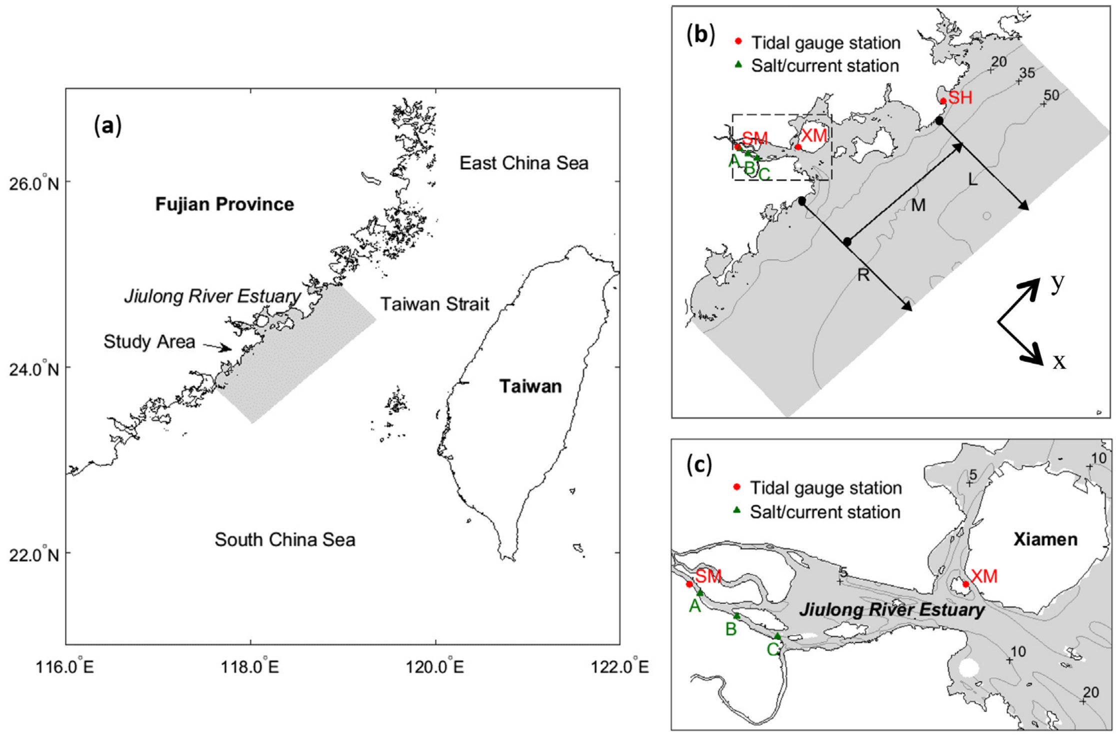

Fig. 1. A map of the study region in the Jiulong River estuary-shelf system (the gray shaded in a) with the 20 m, 35 m and 50 m isobaths, and observation sites (red circle and green triangle in b&c). The three transects (R, L and M in b) are marked to estimate freshwater transport. Black circles and black triangles denote the starting and end points of the along-section distance in Fig. 7. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

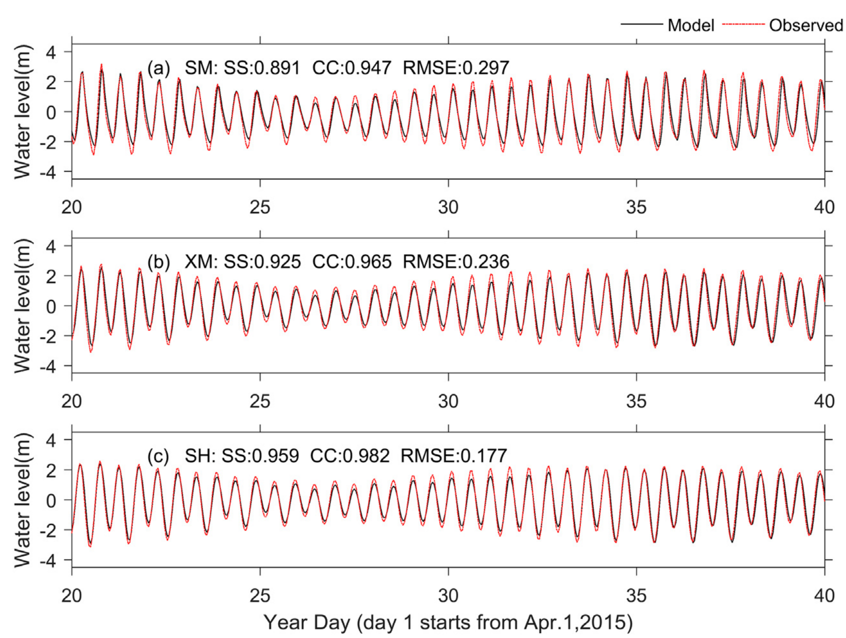

Fig. 2. Time series of modeled (black) and observed (red) free surface elevations (m) at site (a) SM, (b) XM, and (c) SH. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

the plume, as well as the interaction of the plume with the coastal current system. To our knowledge, no modeling studies have been conducted to investigate the JR plume dynamics.

In the study, we aim to capture the major distribution patterns of the JR plume in a wet season and investigate the associated dynamic forcing in the plume-circulation environment via modeling studies. The model is validated with in-situ observations and published river plume patterns based on satellite turbidity in summer. A Self-Organizing Map (SOM) method, widely used for feature extraction and pattern recognition in many fields including physical oceanography (e.g. Liu et al., 2006; Mau et al., 2007; Liu et al. 2008; Huang et al., 2017), is applied to obtain major JR plume patterns from the model output. The influence of river discharge, local wind and background coastal currents on the JR plume spreading is investigated.

The paper is organized as follows. The model configuration and experimental setup are described in Section 2, followed by model validation in Section 3. Section 4 presents the spatial and temporal