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Modeling the mass fluxes and transformations of nutrients in the Pearl River Delta, China

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ABSTRACT

Over recent years, accelerated anthropogenic nutrient discharges have exerted great pressure on the water quality management in the Pearl River Delta (PRD), China. There is a concern about the eutrophication processes and hypoxia in this region. A better understanding of the origins and transport of nutrients is required before accurate prediction of impacts of nutrients on eutrophication and hypoxia in the PRD can be anticipated. Therefore a coupled physical–biological model is developed to simulate the fluxes and transformations of nutrients in the PRD. The coupled model combines a one-dimensional model for the river network (called the RNPRD) and a three-dimensional model for the Pearl River Estuary (PRE), which are both physical–biological models. The model is calibrated and validated to different sets of field data. The model results of water surface elevation, discharges, salinity, suspended sediment and water quality variables are in reasonable agreement with the observational data, suggesting that the model is robust enough to capture the physical and biogeochemical dynamics in the PRD. Also, the fluxes and transformations of carbonaceous biochemical oxygen demand (CBOD), ammonia nitrogen (NH_3), nitrate plus nitrite nitrogen (NO23) and inorganic phosphorus (IP) in July 1999 (wet season) are explored and discussed. Results show that the RNPRD act as a source for NO23, but a sink for CBOD, NH_3 and IP that consumes 50%, 37% and 11% of their external loads, respectively. The riverine fluxes of nutrients exported from the RNPRD to the PRE are generally controlled by high river discharge and significantly contributed by upstream inputs. The riverine fluxes are the largest inputs of nutrients to the PRE. The PRE also behaves as a source for NO23, but a sink for CBOD, NH_3 and IP that consumes 90%, 80% and 16% of their external loads, respectively. The estuarine fluxes of nutrients exported from the PRE to the South China Sea are significantly contributed by the external and internal sources of nutrients in the PRE. In the RNPRD, the transformations of CBOD, NH_3 (also NO23) and IP are dominated by carbonaceous oxidation, nitrification and deposition, respectively. Regarding the PRE, carbonaceous oxidation, nitrification and phytoplankton uptake are identified as the dominant processes with respect to CBOD, NH_3 (also NO23) and IP. Unlike the RNPRD, the phytoplankton dynamics and internal sources of nutrients play an important role in the nutrient budgets in the PRE. Also, seasonal variations of the nutrient budgets in the PRD are discussed. Model results indicate that the dry season and wet season have a similar feature in terms of transformations of nutrients, but show significant seasonal variations in terms of nutrient fluxes. At the same time, the PRE is compared to the Changjiang and Mississippi Rivers with regard to differences in nutrient inputs between these similar river-dominated systems.

1. Introduction

The Pearl River Delta (PRD) is a very complicated large-scale estuarine system in China (Fig. 1a). It consists of a tidal river network (called the River-network in the PRD) and an estuary (called the Pearl River Estuary). In recent years, the PRD region has become one of the most densely populated and economically developed regions in China. Consequently, the water body of the PRD receives a high load of anthropogenic nutrients from increased agricultural activities (Neller and Lam, 1994), fish dike farming (Ruddle and Zhong, 1988) and sewage effluents (Hills et al., 1998). This increase in nutrients is likely to result in serious environmental issues, such as eutrophication, harmful red tides and hypoxia. The water quality has been extensively examined in the Pearl River Estuary (PRE), indicating that the estuary exhibits some symptoms of eutrophication and low dissolved oxygen (Yin et al., 2001; Huang et al., 2003; Tang et al., 2003; Yin et al., 2004a, b; Dai et al., 2006; Harrison et al., 2008). Furthermore, the River-network in the PRD (RNPRD), which is mainly comprised of the Xijiang River, Beijiang River and Dongjiang River (Fig. 1a), is the largest and most complicated tidal river network system in China. A large

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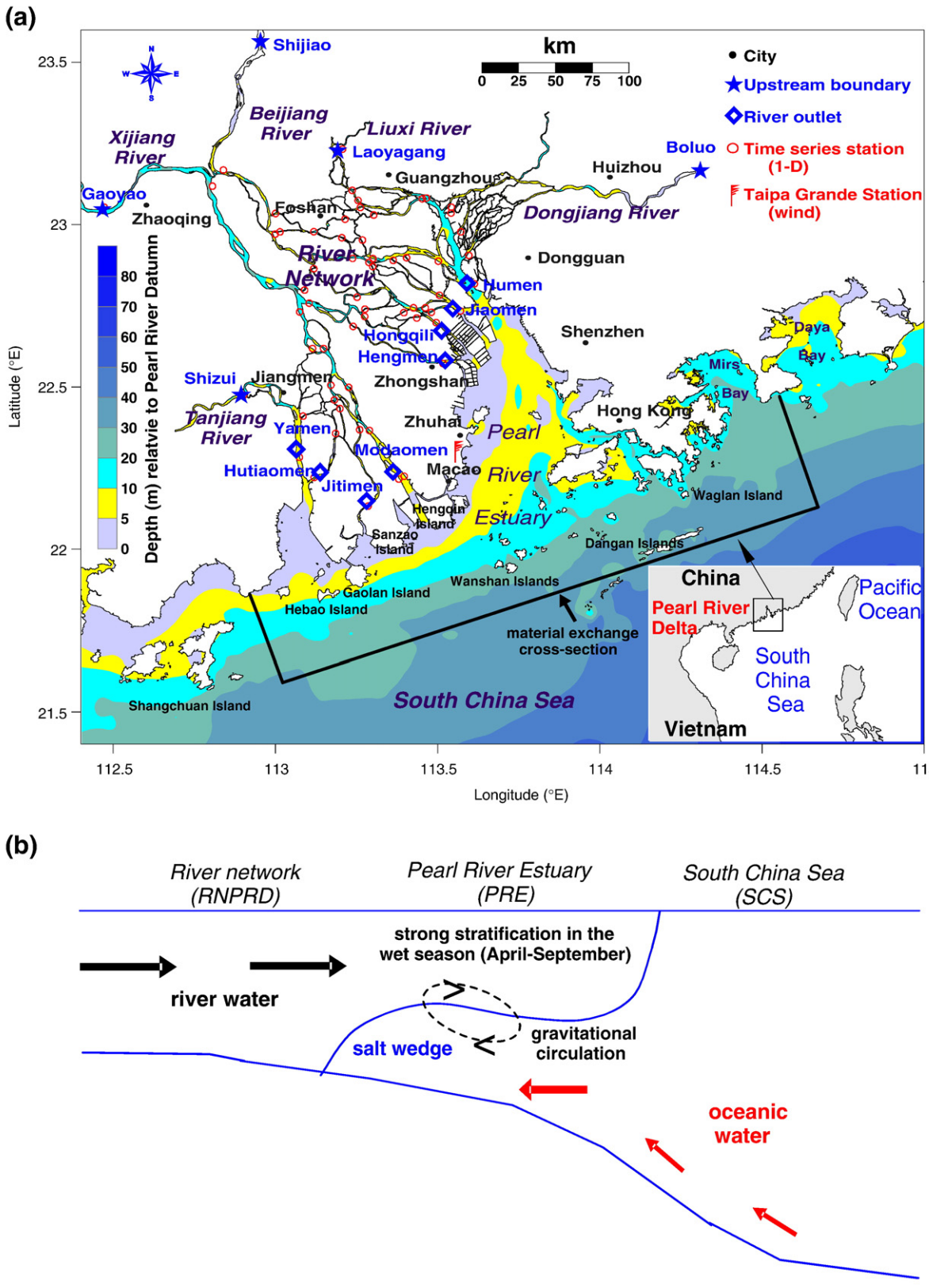

Fig. 1. Maps showing (a) the Pearl River Delta (PRD) coastline, bottom topography, major rivers, major cities and monitoring stations in the river network (RNPRD), and (b) longitudinal circulation in the RNPRD, the Pearl River Estuary (PRE) and the South China Sea (SCS).

amount of nutrients from these rivers and wastewater discharges in the PRD transports through multiple river channels in the RNPRD, passes to the PRE through eight river outlets (Fig. 1a), and ultimately transports to the South China Sea (SCS). The transport of nutrients is controlled by multiple forcing mechanisms including complicated topography, river discharges, monsoon winds, tides and coastal currents (Wong et al., 2003a,b; Dong et al., 2004; Mao et al., 2004), in association with complex biogeochemical processes (Cai et al.,