Abstract of Dissertation

題　目 Investigating hydrodynamics of a mesotidal delta channel network using advanced hydro acoustic systems

（高度水中音響システムを用いた中規模デルタ河川ネットワークの流体力学に関する調査研究）

氏　名　XIAO CONG

Investigating the hydrodynamics of tide and river flow is important to provide the best management practices for delta channels and estuarine ecosystems and understand the alteration processes of morphodynamic environments in tidal rivers, as well. This dissertation investigated the spatiotemporal variations in sediment, tidal currents and salinity, aiming to provide a clear understanding of the hydrodynamics between river flow and tides in the Ota River network system. The findings can facilitate the management of small and shallow multi-channel estuarine systems. This work is divided into two main themes: (i) sediment dynamics at a tidal controlled channel, and (ii) flow and salinity patterns at the tidal junction.

The purpose of the first theme was to investigate the behavior of suspended particulate matter concentration (SPMC) variability toward different external forcings in the tide controlled Otagawa floodway. In this study, the relative contributions of external forcings to SPMC were quantified using singular spectrum analysis (SSA). The main environmental features affecting SPMC were identified as i) spring-neap tidal oscillation, ii) ebb/flood velocities, and iii) tidal straining. Large SPMC fluctuations occurred within strong mixing and were directly related to the sediment resuspension stirred up by spring-neap tidal cycles (73.6%–81.9% contributions on SPMC variations) and ebb/flood velocities (9.6%–19.5% contributions on SPMC variations). On the seasonal scale, the river discharge is a key variable that explains the downstream flushing and promoting the occurrence of a convergence zone at the floodway. At the upstream, the spring-neap tidal oscillation dominated the mobility of suspended particulate matter (SPM) under low river discharge. Two interesting findings were revealed in this study: (i) the SPMC and SPM-transport variation responses to tidal forcing (tidal asymmetry) were dominated and modified by river discharge and (ii) the effect of river discharge on the SPMC and SPM transport did not result in a uniform state along the floodway. It is believed that these findings provide further understanding of the dynamics of suspended sediments in shallow tidal systems.

The second part of this thesis highlighted the application the fluvial acoustic tomography system (FATs) to shallow tidal junctions for studying the flow division and spatiotemporal difference of velocity and salinity are vital to understand the hydrodynamics in multi-channel networks. Therefore, in the second theme, this study aimed to observe continuous 2D current and salinity distributions at a shallow tidal junction using six FATs for ~34.4 days. The horizontal distribution and spatiotemporal variations in the currents and salinity were efficiently estimated by the inverse method. The reciprocating patterns of salinity during the spring tide at the junction well respond with the tide. Due to the density-driven current mechanism, the

salinity pattern at the junction revealed that the maximum salinity during neap tide is higher than that during the spring tide. The asymmetry geometrical shape of the junctions modified the density current and salinity behaviors, the shallower side weakened the tide velocities, the wider side prompted more flow into the shallower side, and thereby increased the amount of salinity at the wider side (higher density). The tidal velocity amplitude and the outflow velocity associated the river discharge basically controlled the recovery of salinity at the junction.

For spring tides, high salinity occurred around high water, whereas salinity was negligible at low water. During flood tides, significant landward currents flowed with the maximum speed of ~0.4 m/s at the downstream of the junction near station S4, and significant seaward currents with the maximum speed of ~0.55 m/s occurred during ebb tides at the upstream of the junction near station S3. For neap tides, the salinity pattern began to develop landward from the low water and reached the maximum salinity around the high water; salinity at the ebb slack remained high. Inverted results of FATs indicated a counter-clockwise circulation at the center of the tomography area around the low water during neap tide; some of the currents continuously flowed landward at the downstream of the junction, whereas the western branch river (Tenma River) continuously flowed with seaward currents. The behaviors of the currents did not vary considerably over the neap tidal cycle. The freshwater discharge at the junction was ~29.2% of the tidal discharge during the observation period, induced a certain extent increment and decrement of ebb and flood velocities, respectively. Furthermore, tidal harmonic analyses of the reconstructed currents were performed to clarify the interactions between river flow and tides at the tidal junction. The results reflected the increased tidal wave deformation that occurred with the gradually increasing tidal range and demonstrated the role of the limited river flow on the tidal asymmetry at this tidal junction. These studies advance the understanding of river flow and tidal dynamics in shallow tidal junction systems.