Source-to-sink transport processes of fluvial sediments in the South China Sea: Progress and prosepect

Zhifei Liu
State Key Laboratory of Marine Geology, Tongji University, Shanghai 200092, China
lzhifei@tongji.edu.cn

The South China Sea is the largest marginal sea in the western Pacific and the largest sink for terrigenous clastic sediments (mainly as fluvial sediments) among enclosed or semi-enclosed oceanic basins worldwide. The South China Sea also has rich surface and deep circulation systems and well-preserved hemipelagic sediments, making it the most suitable marginal sea for the study of source-to-sink transport processes of fluvial sediments. The South China Sea is adjacent to many Southeast Asian countries, including China to the north, the Philippines to the east, Vietnam, Cambodia and Thailand to the west, and Malaysia, Indonesia, Singapore and Brunei to the south, thus becoming an inevitable link for international collaboration in transport processes of fluvial sediments. Therefore, to understand sediment source to sink processes in the South China Sea and to promote cutting-edge research in this field, we have been carrying out substantive cooperation with all countries around the South China Sea since 2008 under the UNESCO Intergovernmental Oceanographic Commission's Sub-Commission for the Western Pacific (IOC/WESTPAC) project "South China Sea Fluvial Sediments and Environmental Changes (FluSed) (2008–2023)". We investigated in detail all 180 major rivers throughout the surrounding area and more than 1100 surface sediment sites on the seafloor of the South China Sea, obtaining important progress in the study of source-to-sink transport processes of fluvial sediments. Based on these advances, we propose prospects for further international cooperation on fluvial sediments of the South China Sea, including terrigenous organic carbon input and marine carbon cycle, in-situ observation of sediment source-to-sink dynamic processes, response of sediment transport processes to rapid or extreme climate change, and relevant theory and application of global change research. This is of great significance for advancing the frontiers of ocean science in the South China Sea, promoting the partnerships for the Belt and Road Initiatives, and realizing the UN Decade of Ocean Science for Sustainable Development.

Incidences of severe coastal erosion on the east coast of Peninsular Malaysia: Case study of Kelantan Delta and Kuala Nerus seaside

Edlic Sathiamurthy
Faculty of Science and Marine Environment, University Malaysia Terengganu
edlic@umt.edu.my

Since the Holocene high-stand (c.a. 4-7 ka BP), sea level had drop from about 5-7 m MSL to present day MSL. This marine regression episode witnessed sea ward progradation and switching of Kelantan Delta and also development of beach ridges and modern day shore ridges. The modern day shore ridges offer protection to back shore environments that have become important human settlements, industrial zones, farming areas and most importantly natural wetlands with their ecosystem services. However, these environments are currently under threats resulting from coastal construction activities coupled with probable climate change induced sea level rise. This paper presents two case studies of severe cases in Peninsular Malaysia east coast, i.e. the coast of wave dominated Kelantan Delta in Kelantan State and Kuala Nerus seaside in Terengganu State. The effects of human activities on coastal processes are very evident in the form of coastline retreat that reached several hundred meters in just under three decades.

Collaboration research on typical tropical river-estuary system in Malaysia

Aijun Wang
Third Institute of Oceanography, Ministry of Natural Resources, China
wangaijun@tio.org.cn

Through the cooperative research of land-ocean interaction in river basin-estuary system in Malaysia, we preliminarily understand the distribution and burial of terrestrial materials derived by a typical small tropical mountainous river into the sea and associated controlled mechanisms in small mountainous river with wide shelf system. It is found that wave action and river plume control the along-shore and offshore transport of terrestrial sediment discharged into the sea. In order to better understand the processes of "source-to-sink" and its ecological effects of the tropical river basin-estuary system, we are carrying out the transport and retention process of pollutants and nutrients from the river basin to the estuary and coastal sea and their impact on the evolution of typical ecosystems in the estuary area, so as to put forward comprehensive management countermeasures suitable for the local actual situation from the perspective of Land-Ocean Integration.

Morphological change in the northern red river delta, under increasing human interferences

BUI Van Vuong
Institutes of Marine Environment and Resources, Vietnam Academy of Science and Technology, Haiphong 18000, Vietnam
geovuonghioimer@gmail.com ; vuongbv@imer.vast.vn

Coastal erosion has become a worldwide concern, typically in the densely populated Asian mega-river deltas. Severe coastal erosion in the southern Red River Delta (RRD) has been intensively studied. Coastal morphological change in the northern RRD was examined in detail through DEM (Digital Elevation Model) analysis based on time series of bathymetrical maps and Landsat images in this study. The results show that the northern RRD is featured by rapid coastal accretion in the past few decades, although suspended sediment flux has dropped by roughly 60% after the completeness of Hoa Binh Dam (HBD) in 1988 and relative sea level rose at 1.9 mm yr^{-1}. However, accretion at the outer part of subtidal shoals and platforms was observed to slow down quickly or even turned into erosion in the last two decades. The resuspended sediments from the erosion zone can be transported landward to replenish the inner coastal zone, keeping the latter accretion in the near future to compensate for the sediment discharge decrease from the river. However, this lag effect should be terminated soon if other adverse effects go worse, e.g., damming rivers, sea-level rising, strengthening storms, land reclamation and other poor-esigned coastal engineering. Coastal planners and managers should pay full attention to these changes.

Coral boulder transport and gravel bar formation by storms in Lumaniag village, Batangas, northwestern Philippines

Fernando P. Siringan
Geological Oceanography Laboratory, Marine Science Institute, University of the Philippines, Diliman, Quezon City 1101, Philippines
fpsiringan@up.edu.ph

The contribution of tropical storms to a carbonate gravel bar formation is presented for Lumaniag village, northwestern Philippines, based on field measurements, high-precision U\Th dating of Porites sp. coral boulders (longest axis>1 m), historical records of tsunamigenic earthquakes and typhoons, and anecdotal accounts. Results of U\Th dating suggest that the events which transported the sampled fully exposed boulders found on the gravel bar occurred during the 1960s to early 1970s; the underlying rubble are presumed to have been deposited by older inundation events. The U\Th ages are consistent with anecdotal accounts and records of typhoon tracks and damage reports from typhoons Dading (international name Winnie; 1964), Welming (international name: Emma; 1967), and several other strong typhoons in early 1970s. Hydrodynamic calculations estimate a minimum flow velocity of 3.2 m/s to initiate translocation of the largest coral boulders in the area. Potential shift in storm frequency and intensity over the next few decades suggests that the gravel bar will further accumulate carbonate sediments. With the mangroves contributing to its stability, the storm-deposited island-like feature contributes to the dissipation of approaching storm waves and provides natural protection for the nearby coastal community. The ridge will likely provide an effective buffer for extreme waves in the term unless destroyed by anthropogenic activities or an oversized extreme event.

Development of Artificial Mangrove belt barrier for alleviating the effects of future sea-level rise in the Upper Gulf of Thailand

Thanawat Jarupongsakul
Department of Geology, Faculty of Science, Chulalongkorn University, Bangkok 10330, Thailand
jthanawat@ymail.com

The upper Gulf of Thailand's coastline, which is 121 kilometer long, is a crucial area for mitigation of coastal erosion in SE. Asia. Approximately 1 kilometer of shoreline retreat and tidal mudflats shrinking of about 5 kilometers wide have been recognized over the last 30 years and the areas in which erosion is occurring have been gradually expanding at the rate of 30 meters per year. It is currently found that the coastal lowland and tidal mudflat areas, which are of five coastal provences of Chachoengsao, Samut Prakarn, Bangkok, Samut Sakhon, and Samut Songkram, have been severely eroded in totaling 18,594 Rai (1Rai=1,600 sq.meter) of the coastal lowland and 180,769 Rai of tidal mudflat areas.

When comparing the rate of sea level rise with land subsidence rate, we found that land subsidence rate causes severe coastal erosion in the upper Gulf of Thailand .The rate of land subsidence in the upper gulf of Thailand is found to be 11-35 mm/yr while the rate of sea level rise of the last Holocene maximum in the area is 16-26 mm/yr (Jarupongsakul 2007). Sea level rise caused sea intrusion which covered from Bangkok to Ayuttaya Province back 6,000 yrs ago. Land subsidence acts like relative sea level rise. Land subsidence together with sea level rise will cause coastal erosion by 65-85 m/yr in the next 20 yrs. If no any measure is implemented in the area, the coast should sink under seawater by average1.3 kilometers inland in totalling areas of 67,139 Rai in the next 20 yrs, by average 2.3 kilometers inland in totaling areas of 197,497 Rai in the next 50 yrs, and by average 7 kilometers inland in totaling areas of 405,428 Rai in the next 100 yrs (see Figure 1). Experience during the development of the Khun Samut Chin (KSC) 49A2 technology not only demonstrated a technical prototype for wave dissipation, but also provided an investment model for sharing of costs and a model for participation by the local community. The KSC 49A2 permeable breakwater consists of two parts. The first part comprises three rows of concrete columns of equilateral triangular cross-section. The side face of the columns are each 50 cm in width and the columns are 10 m. long. The three rows of columns were installed in the intertidal zone at a distance of 500 m. from and parallel to the present coastline. In each row the columns are 1.5 m. apart and the rows are spaced 1.5 m. apart as well. The breakwater was installed over a distance of 250m. in the pilot study at Ban Khunsamut Chin. In particular, the permeable barrier allows sediment accumulation that supports mangrove vegetation landward of the columns. This technology provides a more effective way of protecting against coastal erosion and trapping sediments landward of the breakwater.

This research has shown that the KSC 49A2 technology can be improved to protect against coastal erosion caused by future global sea-level rise in addition to protecting against local land subsidence. The new version of KSC 49A2 technology is call the Artificial Mangrove-belt barrier. Figure 1 shows how the Artificail Mangrove-belt barrier will be deployed. When sediment landward of the breakwater has built up sufficiently, mangrove forest can be planted and structures can be built behind the mangroves to protect roads and coastal villages from seawater flooding. The mangrove forest will reduce wave action and trap sediments. Natural growth will

raise the level of the mangrove forest in response to future sea-level rise. The concept and methodology of this pilot study is one of many approaches to research that aim to provide means to prevent or reduce the effects of natural disasters. It is generally agreed among climate research scientists that future weather conditions will be more variable than in the past, and it is likely that natural disasters will occur more frequently. The measures required to prevent coastal erosion problems will become more complex and difficult to implement.

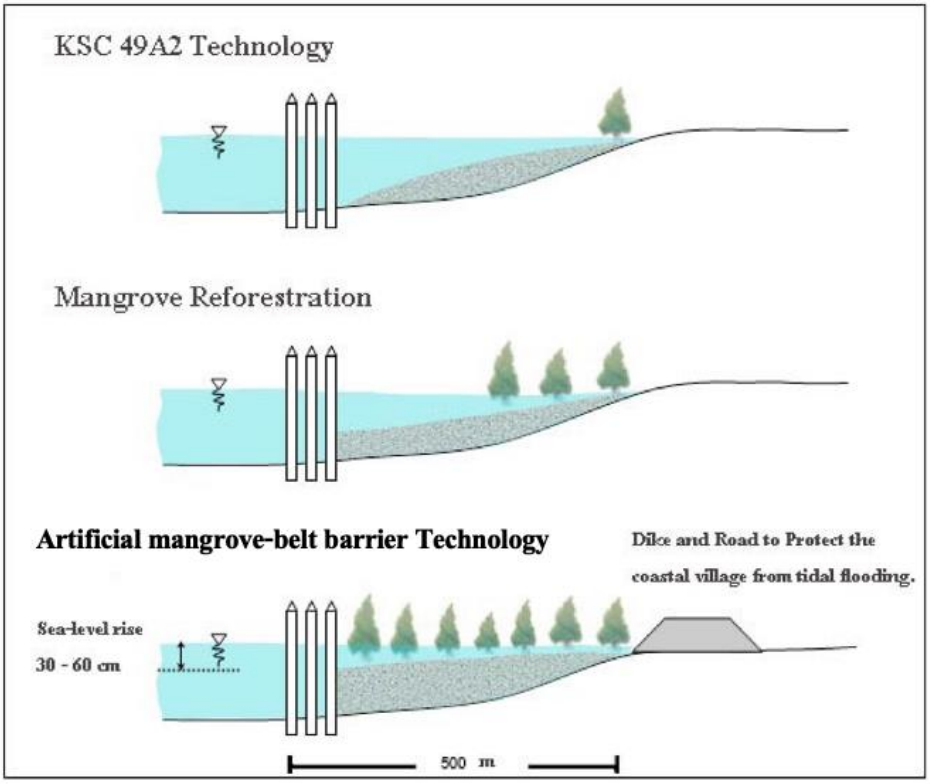

Figure 1. Integrated technology of artificial mangrove-belt barier accompanied with mangrove afforestation and coastal dykes.

Coastal landforms along the shoreline of Myeik area, Tanintharyi Region, Myanmar

Soe Moe Lwin
Department of Geology, Dagon University, Yangon, Myanmar
smlwin.sm@gmail.com; drsoemoelwingeol@myeikuniversity.edu.mm

We conducted a coastal landforms study, focusing on deposition and erosion characters along the shoreline of Myeik area, Tanintharyi Region**,** Myanmar. The aim of this study is to determine the coastal geomorphological features in the idea of contributing to a better understanding that may help planners in policy design for a sustainable development and management of the coastal region and its resources. On the other hand, it is a contribution to the geological knowledge of the Tanintharyi Region and promotes research regarding the shoreline and the effect of increasing marine activity and population, the strengthening of tourism industry in the study area. It also promotes research on this region regarding other factors such as the increasing marine activity, population in coastal areas, development of tourism, as well as a series of geological evolutionary processes that reflect in coastal morphology. Coastal landforms are valuable environmental, aesthetic, and recreational resources that are subject to natural processes as well as to the effects of human activities. The results of this study can provide a sound basis for sustainable planning and management of the Tanintharyi area. However, it is necessary to determine the influence of climatic change and other factors as the surf, along with the corresponding morphodynamical changes on coastal ecosystems and human activities.

China-ASEAN Cooperation in Marine Sedimentology: Progress and Prospects

Xin Shan
Key Laboratory of Marine Geology and Metallogeny, First Institute of Oceanography, Ministry of Natural Resources, Qingdao 266061, China
xfshi@fio.org.cn

Join area of Indian-Pacific Ocean (AIPO) adjacent to China-ASEAN and South Asia, are characterized by a strong land-sea interaction. It has a significant impact on the climate and environment of East and South Asia. Huge amounts of terrigenous sediments were discharged into the ocean by large rivers and numerous mountainous rivers that originated from the Tibetan Plateau, making AIPO the world's largest sediment source to sink system. The detailed and systematic sedimentological investigation on the area had not been conducted until the 20th century. Through cooperation with Thailand, Malaysia, Indonesia, Bangladesh and other countries, we have executed 20 joint cruises in the Gulf of Thailand, Andaman Sea, Sunda Shelf, offshore Sumatra, Bay of Bengal, and 5 joint surveys along the surrounding rivers. It is, for the first time, the most comprehensive sedimentological investigation of AIPO and 1:1,000,000 surface sediment type map of the area was compiled; We have tentatively established an effective provenance index system of South Asia and Southeast Asia continental margin, and identified the sediment source of the Gulf of Thailand, Andaman Sea, Sunda Shelf and Bay of Bengal. The sediment routing processes and mechanisms of large rivers (e.g., the Ganges, the Chao Phraya, the Irrawaddy, etc.) and mountainous rivers (the Pahang, the Kelantan) were revealed; We have also evaluated and made an assessment of heavy metal and organic matter pollution. The facies models of different time scales on typical seas were summarized. The late Quaternary evolution of salinity, temperature and productivity of the Southeast Indian Ocean reveals sea-level change, Asian monsoon strength, and the response of seaways and straits to paleoceanography. The achievements will underpin the construction of the Maritime Silk Road, provide references for marine environment protection and disaster prevention and reduction, and make contributions for cooperation between China and Southeast-South Asia countries. The next step cooperation will focus on modern observation of sedimentary processes, marine processes that are influenced by anthropogenic activities, continental shelf drilling programs, database establishment and database-driven marine sedimentology studies.

Dynamic Processes of the Curved Subduction System in Southeast Asia

Ding Weiwei
Second Institute of Oceanography, MNR, China-
wwding@sio.org.cn

Southeast Asia is located in an important regional geodynamic intersection zone surrounded by inward subduction systems on three sides, consisting the largest and most complicated convergent subduction system in the earth. The deep circulation and ultimate destination of the subducted material have always been an elusive scientific mystery, lacking both systematic scientific observation and accepted theoretical models. We present geophysical, geochemical and geodynamical models in last decades regarding the seismic tomographic deep structure, material exchanges and evolution history of the Curved Subduction System (CSS) in SE Asia, and identify remained challenges in constructing the deep mantle structure and quantifying the feedback between the subducting slab and the interior recycling materials relevant to the dynamic processes within the theme of mass and energy transfer. We propose that increased understanding of seismic tomography within the CSS, combined with geochemical analysis and computational geodynamic modelling, will aid clearer portrayal of the dynamic mechanisms controlling the evolution of such ring-shape subduction systems on Earth.

Tsunami sources in active tectonic setting: lessons learned from tsunami occurrences across Indonesian Archipelago during last two decades

Nugroho Dwi Hananto
National Agency for Research and Innovation, Indonesia (BRIN)
nugr001@brin.go.id

In the last 20 years only, the Andaman-Sumatra segmen of Sunda subduction has hosted three great earthquakes with Mw>8.4. One of the earthquake (M:9.2 Aceh, 2004) was one of the largest earthquake has ever seismically recorded. It ruptured about 1 200 km of earth's crust from Andaman to Sumatra that triggered a massive tsunami in Indian Ocean. This segmen also produced two tsunami earthquakes with Mw~7.8, one at Pangandaran West Java in 2006 and the other at Pagai Island, Mentawai in 2010. The tsunami earthquake is defined as an earthquake in moderate magnitude but triggered large localized tsunami in nearby coast/island. Palu earthquake in 2018 (M 7.5) triggered a massive localized tsunami in Palu Bay. Two other great earthquakes (Mw>8.2) on the subducting Indo-Australian plate offshore Aceh remarks the largest intra plate earthquakes ever recorded in modern seismological era. In contrary, there has been no shallow great earthquake in the Banda region. However, based on historical data documents and records from 1600 – 2015 have had occurred 85 tsunami or 40% of all tsunami generated across Indonesian Archipelago. These event may be related to earthquake triggered tsunami or liquefaction in coastal areas. Further studies of these event will allow a better strategy for mitigation and to improve the resilience of communities in coastal areas with similar tectonic setting.

Cenozoic magmatism in the South China Sea

Quanshu Yan
Key Laboratory of Marine Geology and Metallogeny, First Institute of Oceanography, MNR, Qingdao, Shandong 266061, China
yanquanshu@163.com

This study presents a review of available petrological, geochonological and geochemical data for Cenozoic igneous rocks in the South China Sea (SCS) and adjacent regions (e.g., Indochina block-Thailand and Vietnam, Leiqiong peninsula, etc) and a discussion of their petrogeneses and tectonic implications. The integration of these data with available geophysical and other geologic information led to the following tectono-magmatic model for the evolution of the SCS region. The geochonological and geochemical characteristics of the volcanics indicate an early period of bimodal volcanism (60–43 Ma or 32 Ma) at the northern margin of the SCS, followed by a period of relatively passive style volcanism during Cenozoic seafloor spreading (37 or 30–16 Ma) within the SCS, and post-spreading volcanism (tholeiitic series at 17–8 Ma, followed by alkali series from 8 Ma to present) in the entire SCS region. The geodynamic setting of the earlier volcanics was an extensional regime, which resulted from the collision between India and Eurasian plates since the earliest Cenozoic, and that of the post-spreading volcanics may be related to mantle plume magmatism in Hainan Island. In addition, the nascent Hainan plume may have played a significant role in the extension along the northern margin and seafloor spreading in the SCS.

Hydrocarbon accumulation in an active accretionary prism, a case study in the deepwater Rakhine Basin, Myanmar offshore

Xiwu Luan
Qingdao Institute of Marine Geology, China Geological Survey, Qingdao 266237, China
xluan@qnlm.ac.

The Rakhine Basin, Myanmar offshore has remained unproductive for a long time. The discovery of biogenic gas in 2004 and the followed dry wells in 2007 have made the exploration in this area more complicated. 2D/3D seismic data newly acquired after 2007 has been interpreted, distributions of anticline structures and turbidite channels have been mapped. Combined with the newly drilled well data and the regional geological setting analysis, a model for hydrocarbon accumulation has been established. We show that under deep-water environment and due to the thick sedimentary volume, neither the turbidite channels, nor the anticline structures can accumulate hydrocarbon alone. Only if turbidite channels pass across the anticline structures, hydrocarbons from the deep sour rocks will migrate upward through conduits to the anticline traps and fill into the turbidite sands overhead to form hydrocarbon reservoirs. The intersections of the turbidite channels and the anticline structures should be the main targets for future gas exploration in the deep-water Rahkine Basin, offshore Myanmar.

Impact of Climate Change on Forests in Cambodia

Kim Soben
Royal University of Agriculture, Cambodia
kimsoben@gmail.com

Cambodia is rich in forest resources, which play critical roles in local rural livelihoods, as well as providing valuable ecological and economic resources for the country's economic development. Managing forests sustainably and equitably will be essential for maintaining the ecological integrity of the country, maintaining freshwater supplies and protecting biodiversity. Approximately 80% of the Cambodians live in rural areas depend upon the forests to support many people's lives as a source of food, medicine and building products, and as a source of materials and goods for small business ventures. Forest degradation globally contributes around 17 %to Green House Gases (GHG) emissions, but in Cambodia represents the main factor in the country becoming a net emitter of GHGs. Climate change is one of the most environmental issues facing to the government. The study aimed at i) assessing the impact of climate change on NPP, Vegetation Carbon and Soil Organic Carbon using LPJ model; ii) projecting the spatial representation of Impact of climate change on NPP, Vegetation Carbon stocks, and Soil Organic Carbon. The Lund Potsdam Jena (LPJ) model combines process-based, large-scale representations of terrestrial vegetation dynamics and land-atmosphere carbon and water exchanges in a modular framework The model climate data requirements are benign as it requires only Temperature, Rainfall and Cloudiness as climatology inputs. Model validation is used for Net Primary Productivity (NPP), Vegetation Carbon (VegC), and Soil Organic Carbon (SoC). Obtaining observation of NPP, VegC, and SoC data for the region from the published literature or from the international databases and compare these with the LPJ projections (Spatially or non- spatially). As results, LPJ Simulated distribution on NPP in Cambodia using different scenarios including Baseline, RCP 8.5, and RCP 8.5 with control CO2 generated based on NPP, VegC, and SoC. Also, LPJ simulated soil carbon change (%) projection for Cambodia under the RCP 8.5 under the two scenarios of CO2 fertilization and no-CO2 fertilization.

The Evolution of Tropical Mangrove Channel Meander of Sungai Kerteh, Peninsular Malaysia

Hasrizal Bin Shaari
Universiti Malaysia Terengganu, Malaysia
riz@umt.edu.my

Meander channel is an important setting that preserved the history of landscape evolution of mangrove forest. Two short core sediments were sampled at the neck cutoff (KR1) and inside of meander (KR2) of Sungai Kerteh meander channel, Peninsular Malaysia to understand the evolution of this environment. We investigated the profile of sediment mean size, selected elements and total organic carbon (TOC) between neck cutoff (NC) and inside of meander (IM). Smaller standard deviation of sediment mean size at the NC (4.37±0.51 φ) than IM (4.43 ±1.76 φ) indicates a significant change in water velocity of this setting. The mean concentrations of elements in this study were in decreasing order as follows: Fe > Na > Mg > Mn > Ba > Sr. Higher average of TOC was recorded in the IM (2.74±1.42%) than NC (1.14±0.46%). A small change in sedimentation rate between upper (0.41 $cm.yr^{-1}$) and bottom (0.50 $cm.yr^{-1}$) part of core KR1 suggest that there was no significant difference in river water velocity at the NC. On the other hand, higher sedimentation rate at the upper (0.60 $cm.yr^{-1}$) than bottom (0.39 $cm.yr^{-1}$) part of core KR2 reflect the reduction of river water velocity at the IM due to the formation of new river flow near the NC. This condition caused an increasing accumulation pattern of selected elements and TOC from the depth ~60 cm towards coretop segment at the IM. This study is important in providing the information of landscape evolution effect based on the geochemistry of sediment.

seawater intrusion and bule economy in coastal areas

Xu Xiongyong
Four Institute of Oceanography Ministry of Natural Resources, Beihai 536015, China
xuxingyong@4io.org.cn; xuxingyong@fio.org.cn

Coastal zones, located at the interface between land and sea, are influenced by both marine and terrestrial processes. These drivers are highly dynamic and continually changed over time. As more and more national development based on the so-called “blue economy”, freshwater resources in coastal area have become a vital resource for sustaining the community and economy around the world. However, with the intensive water demands, groundwater pollution caused by seawater intrusion, by-products of urban residents, and industrial and agricultural production severe threatens freshwater resource. Seawater intrusion is widely regarded as a common environmental problem affecting groundwater in coastal areas. With a 1% mixing of seawater would render the groundwater no-potable and further induce soil salinization, ecological degradation, and decline in the quality of agricultural and industrial products. Consequently, it is important to identify the types and evolution of seawater intrusion that are related to the mechanism of intrusion to inform management actions. Data recorded from Laizhou Bay (China), Bangkok Bay (Thailand) and southern Bangladesh were examined statistically to investigate groundwater hydrochemical evolution processes, end element mixing, ratio end element mixing and Gibbs method. Our results indicate that 1) groundwater level dropping funnel caused by overexploitation was the direct causation of seawater intrusion in Laizhou Bay; 2) Groundwater close to rivers in the west and north of Bangkok Bay is more seriously affected by seawater intrusion; 3) Groundwater in southern Bangladesh is more seriously affected by local pollutants from residents, agriculture and industry rather than seawater intrusion.