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Environmental Processes and the Natural and Anthropogenic Forcing in the Bohai Sea, Eastern Asia: Introduction

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Marginal Seas in Eastern Asia play a crucial role as a buffer belt related to the exchange of mass and energy between the Asian continent and the Pacific Ocean. The environmental and socio-economic importance of these marginal seas requires deep understanding of the interference between hydrological, meteorological, and oceanographic driving forces and its effect on the ecological status as background for sustainable management strategies. Those strategies are in particular required as the ecological functions are reduced because of an extensive exploitation of the marginal seas resources during the last decades. After a first anthology dealing with the Beibu Gulf (Harff *et al.* 2013), here a second Special Issue of the Journal of Coastal Research devoted to the Bohai Sea is presented. With this Special Issue it is anticipated to provide a broad overview about the different aspects of processes influencing the environment of the Bohai Sea. We include ground water flow into this scope as well as hydrographic processes, sea-level change, fluviatile impact and delta formation, coastal erosion and the biosphere's status. Light is also shed to anthropogenic impacts and coastal disasters. Correspondingly, the chapters are devoted to the different aspects on the Bohai Sea's environment:

An overview about the *hydrographic conditions* is given by Bian *et al.* The authors describe the principle features of the Bohai Sea's hydrodynamics, external forces, thermohaline patterns, tides, waves, currents and substance transport processes: The objective of the chapter is to provide a general picture of the hydrography of the Bohai Sea. By these means the work may be beneficial for studies in other disciplines, too. Gao *et al.* use a numerical ocean model to simulate mean *sea-level* change along the Bohai Sea coast for quantitative analysis of wind and air pressure influence on coastal mean sea-level variations. The authors discovered that seasonal mean sea-level variation caused by wind and air pressure accounts for about 70% of the variation of mean sea-level and concluded that the water transportation is of great importance for the seasonal variations of mean sea-level. Li *et al.* give a comprehensive insight into the changes of *tidal regimes* of the Bohai Sea in response to local mean sea-level rise. Model results show that under sea-level rise conditions the amplitude of the main semidiurnal (M_2) constituent decreases in most areas. However, it is necessary to consider the spatial distribution of sea-level rise when predicting future effects. The authors found that the tidal current magnitude decreases with mean sea-level rise and mention the influence on sediment transport nearby at the coast of Bohai and Laizhou Bay. The sediment transport regime and the coastal morphodynamics of the Bohai Sea are strongly dependent on the discharge of rivers, and here in particular the Yellow River that had formed one of the globally largest delta structures – the *Yellow River Delta* (YRD). Xing *et al.* determined erosion and accretion pattern of the subaqueous YRD, based on bathymetric and sediment discharge data from the Lijin station over the period of 1976 to 2004. The erosion and accumulation pattern of the subaqueous YRD showed significant spatial and temporal variability during this period, mainly reigned by changing sediment discharge. A comprehensive understanding of their driving mechanisms would be critical for the prediction of the evolution of the YRD in the context of global change. Zhang *et al.* used a set of Landsat satellite images to extract the instantaneous water line positions on coastal orthogonal sections of the northern Yellow River delta. By deploying statistical methods a decadal shoreline change of the northern Yellow River delta after the river deltaic course shift in 1976 was reconstructed. The coast erosion in the northern YRD was mainly influenced by regional hydrodynamic forces, and anthropogenically controlled sediment supply. Deng *et al.* have developed a model which can be used to simulate morphogenetic processes of the YRD and the adjacent Laizhou Bay based on an interrelation of riverine sediment supply, relative sea-level change and the effects of wind driven waves and nearshore currents. This model generalizes the standard Bruun rule model and generates Digital Elevation Model (DEM) scenarios on decadal to centennial time scales for the geological past and future. The basic concept is a dynamic equilibrium coastal profile evolution in adaption to the sediment budget in a spatially three-dimensional domain. For the parameterization historical maps of the southern Bohai Sea have been applied to reconstruct paleo-coastlines for the the 19th century for the comparison with a modern DEM. Gauge measurements provided the data for an estimation of trends in sea-level change for the Laizhou Bay on the decadal scale. Modern sea-level rise together with reduced riverine sediment supply caused by anthropogenic activities such as damming up-streams may change the depositional environment at the YRD and related areas of the Laizhou Bay from river dominated (progrational) to wave dominated (regressive) environment. In this respect, coastal erosion becomes increasingly important for the environmental management. *Dalledonne and Mayerle* have investigated the effect of storms on the morphodynamics of the Yantai coastal areas at the Shandong Pen-

insula, China. The authors developed a two-dimensional depth integrated morphodynamic model for prediction of the morphological changes during extreme events. The model covers the entire Bohai Sea with increasing grid resolution towards the coastal areas near Yantai. The 20 most severe storms (storm surges with sea-level of up to 1.7 m and significant wave heights up to 4.1 m) observed in the region from 2000 to 2013 were identified and reconstructed. The results showed that during the storms the levels of energy mainly due to waves and tidal currents are only relevant at the capes and some channels and straits along the Shandong Peninsula. The resulting morphological changes indicated that although there is an overall loss of seabed material, particularly during the peak of the storms, the beaches near Yantai recover quite quickly just a few days after the extreme events. An important role for the abrasion of the shore plays the supratidal land use. Wang *et al.* used nautical charts, topographic maps, high resolution remote sensing images and field observation to analyze the land use change at the supratidal zone and its coastal morphodynamic effects along the eastern coast of Laizhou Bay. According to these studies, the land use along the eastern coast of Laizhou Bay has been significantly changed during the last 50 years. The main evolutional trend is the transition from aeolian sandy land, woodland and farmland to aquaculture ponds and residential land since the early 1990s. The significant change in the supratidal zone has remarkably modified the boundary conditions of storm surges. Hydrodynamic modeling results show that the ocean dynamics near the coastline enhanced and caused severe erosion of the coastline, beach and underwater coastal sea slope along the eastern coast of Laizhou Bay over the last 30 years.

To understand the continent-ocean interaction one has to consider the whole fluviatile system including *smaller rivers* merging the Bohai Sea. Zou *et al.* have investigated hydrodynamic characteristic and salt flux within Xiaoqinghe River (XQR) estuary, which is a shallow estuarine system (water depth < 8 m) but exports substantial amount of nutrients and pollutants to the adjacent Laizhou Bay. Velocity and salinity profiles reveal river discharge dominated the seasonal variation of tidal elevation, longitudinal velocity, and salinity. The net salt flux is directed seaward during monsoon season and landward in non-monsoon seasons. Overall, tidal sloshing and Stokes' drift is the underlying process of salt transport while river discharge dominates its seasonal variation. This study revealed the inherent unsteadiness of the salt balance, and provides the scientific foundation for effective management of freshwater release from upstream during difference seasons. Wang *et al.* investigated *suspended sediment flux*, dispersal patterns and its possible mechanisms in the Bohai Sea based on the observations data in May and November, 2012, data retrieved from MODIS imageries and the ocean current data from HYCOM and realized an evident seasonal variability. During wintertime, the prevailing strong northerly winds and the related high wave heights re-suspended the sediment along the coast of the YRD that was transported into the Laizhou Bay along its western coast and exported to the Bohai Strait through the eastern Laizhou Bay enhanced by the coastal current. In the summer, less energetic environment together with the stratified water column was unfavorable to the sediment export to the Yellow Sea: Mostly of the sediment accumulates within the subaqueous delta. *In order to trace* the transport path of suspended matter Jiang *et al.* developed a new empirical model based on Geostationary Ocean Color Imager (GOCI) data for retrieving the median suspended particle size (d50), and analyzed the spatio-temporal variation in GOCI-retrieved d50 material over the Bohai Sea. The spatial pattern of particles in the Bohai Sea showed an obvious onshore-offshore gradient, which was smaller in the coastal waters, especially in the Laizhou Bay, the Bohai Bay, and the Liaodong Bay but larger at the Bohai Strait and the northwest part of central Bohai Sea. As driving forces for the median particle size distribution tide, wind, turbulence and riverine input can be idenfied. Not only particulate matter descending from river discharge contributes to the load of suspended matter transported from the Bohai to the Yellow Sea. Also sea bottom erosion has to be considered. Bottom geomorphological evolution and sediment distribution are under strong control of tidal forcing along China's coast. Tang *et al.* deploy a risk-based probabilistic concept to quantify and assess and to map the temporal-spatial risk of bottom erosion. According to this study, in the Yalujiang Estuary, West Korea Bay, north of the Bohai Bay and in the surroundings of the Laotieshan Channel in the Bohai Strait the highest risk of sea bottom erosion was identified which explains the occurrence of tidal sand ridges in the modeling domain. Only a few studies have been devoted by now to *seawater-groundwater exchange* in the tidal flats. Hou *et al.* report about monitoring data and preliminary analytical results on a typical transect in a silty tidal flat with large-scale seepage faces at the south coast of the Laizhou Bay. The "pair-wells method" was used to estimate the seawater-groundwater exchange rate. For 14 sites along a typical transect in the intertidal zone, the groundwater level, salinity and temperature have been measured for a time span of about one month from August 10 to September 12, 2014. Based on these measurements first quantitative estimates of seawater-groundwater exchange have been provided. Xing *et al.* contributed to the discussion of low salinity groundwater seeping to the Laizhou Bay because of the great importance of low-salinity groundwater reserves beneath the sea bottom and submarine groundwater discharges (SGD). In order to detect potential SGD Sea Surface Temperature (SST) anomalies has been analyzed using Landsat thermal images. At the nearshore scale, patchy cold water anomalies occur approximately in the same positions along the intertidal zone of the southern bay, where the unconfined aquifer discharges, independently of tide conditions. At the embayment scale, cold water anomalies spread out in the eastern Laizhou Bay where the confined aquifer is likely exposed. In-situ salinity investigation results support the presumption of SGD derived from remote sensing images in the eastern Laizhou Bay. A conceptual model for underground brine formation is presented by Gao *et al.* The authors explain the brine generation in relation to sea-level cycles since the Late Pleistocene. The authors assume that the underground brine was generated in the tidal flat and delta front under the effect of backflow-infiltration. The brine-producing reservoir was formed by a combined effect of sea-level drop, long-term evaporation and seasonal fluvial material input (sealing).

Biological base line studies provide an appropriate background for the estimation of the *bio-environmental status* of the Bohai Sea. Witkowski *et al.* have investigated the biodiversity of diatom (Bacillariophyceae) assemblages from the littoral zone of the Bohai and Yellow Sea in the Yantai region. The studies are based on cultures established from samples collected in different seasons

from marine littoral and supralittoral zones in 2013 and 2014. The first time diatom strains were cultured successfully, and the identification of these clones was determined by light and scanning electron microscopy (LM and SEM) and DNA sequencing of the nuclear-encoded small subunit ribosomal RNA (SSU) and chloroplast-encoded *rbc*L and *psb*C genes. DNA markers from these strains show greater than expected genetic diversity despite their very similar morphology and morphometrics. The data allow a comparison of littoral taxa from the Indian Ocean and Atlantic Ocean, the Red Sea and Adriatic Sea to their Yellow Sea counterparts. Microbiological investigation are important to assess the impact of anthropogenic activities to the biosphere. Li *et al*. studied along the Jiaolai River the effect of pollution on bacteria by microbiological (molecular) techniques. Cluster analysis revealed that bacterial communities were mainly distributed into groups corresponding to nitrate concentration. Two clone libraries were constructed to compare the bacterial composition of samples with high (J308) and moderate (J304) nitrate impact. Bacterial communities in the sediment were clearly differentiated by environmental nitrogen pollution, suggesting that nitrogen eutrophication was the main environmental problem influencing the Jiaolai River. The Bohai Sea Basin hosts remarkable oil resources. The exploitation and the transport of the natural oil is one of the serious potential threats of the marine environment. Liu *et al*. have analyzed the concern of the community living in the area potentially affected by an *oil spill*. The authors used a questionnaire and Choice Experiments (CEs) methodology to identify the values that groups of test persons assign to coastal resources. The study revealed correlations of income, education, number of children, and age to the willingness of the respondents to contribute personally to the restoration of the environment after an oil spill. Huang *et al*. have investigated the temporal and spatial variation of dissolved black carbon (DBC) in the Bohai Sea. The concentration of DBC showed a distinct decreasing trend from coastal to offshore, from internal Bohai Sea to outer Bohai Sea. The DBC distributions of four seasons differed largely but were consistent with the seasonal variations of ocean currents, suggesting that DBC would be a potential marker for hydro-dynamics study.

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