Conference Summary

River Mouth Systems and Marginal Seas – Natural drivers and human impacts, 5-7 December 2022

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Preface

The online conference was organized as the "5th Marginal Seas Expert Meeting" of the scientific initiatives of the DDE Marginal Seas Task Group established in 2021 in the frame Deep-time Digital Earth (DDE) Big Science Program of the International Union of Geological Sciences (IUGS). The initiatives aim at the development of a general strategy for describing the processes in marginal seas holistically as an interaction between geo-, ecosystem, climate and socioeconomic systems during the late Pleistocene, Holocene, and Anthropocene. The general objective is to contribute to sustainable development of marginal seas to keep a balance between the protection of their natural environment and the economic use of their resources based on new data and new model driven cognition methods. The conferences organized so far help to pave the road to this general target. In the conclusion of the "4th Marginal Seas Expert Meeting" held along with the Baltic Earth Conference "Assessing the Baltic Sea Earth System", Jastarnia, Poland, 30 May - 3 June 2022, it was recommended to focus future research on river mouth systems as the interface between continental and adjacent marginal seas' environments comparatively for different climatic zones, geological settings and socio-economic requirements (https://baltic.earth/hel2022).

Following these recommendations, at the "5th Marginal Seas Expert Meeting" scientists from different continents and different disciplines presented lectures and discussed the driving forces and development of deltas, estuaries and coastal embayments which have been attractive places for people to settle along coastal zones over the long period of human settlement. The participants jointly debated the effects of climate change and anthropogenic activities in areas of densely populated river mouth systems related the marine and coastal environment. After a keynote lecture presented by Peter D. Clift: "Holocene, modern and future sediment transport through the mouths of the Pearl and Indus rivers", 44 lectures were grouped into four Topical Sessions: Session 1 "Climate change and river mouth systems", Session 2 "Human

activities and environmental impacts from the past to the future", Session 3 "Proxy-records and modern observations" and Session 4 "Advanced data management and modeling", each of them started with a key note lecture at the beginning and finalized with a special open discussion. In the following we summarize the results of the session and the final debate.

Session 1 (9 lectures)
Climate change and river mouth systems
Chair: Peter D. Clift, Marcus Reckermann

This session considered the impact that climate change has on sedimentation in river mouths, covering both short-term weather anomalies and longer term climate evolution during the Holocene. Changes in both amounts and seasonality of precipitation have influenced sediment supply to river mouths. Several Asian deltas have experienced reduced sediment supply in the late Holocene as summer monsoon rains reduced after the early Holocene climatic optimum.

Some systems, like the Han River of China, have shown very sharp reduction in the recent historical past, but in such cases it can be hard to isolate the effects of changing climate from the impact of anthropogenic activities. Reduced sediment supply to the mouths of rivers has resulted in landward retreat of coasts and barrier islands, while the associated salinization of coastal farmlands and increase in wetlands has had negative consequences for coastal communities. Such processes are occurring before the onset of major sea-level rise driven by global warming.

Changes in the storminess of the climate are also seen to be important, as revealed by studies of the Rhône delta where major storm events cause rapid sedimentation in the river mouth and efficient burial of carbon transported from upstream occurred in the aftermath of major storms. Sequestration of carbon in marine sediments is closely tied to the frequency and magnitude of flooding events. Continued global warming is expected to result in more storm activity in many regions and driven enhanced erosion and sediment delivery to river mouths.

Evolving atmospheric circulation patterns have changed the direction in which storm systems like typhoons are preferentially steered. These same changes in atmospheric flow patterns are also recognized to influence sediment transport in

nearshore settings. Seasonal reversal of surface currents influence the dispersal of sediment from river mouths. In the Mekong delta, strong sediment change during the summer monsoon is reworked to the southeast by winter monsoon winds.

In this session, it became clear that the systems presented are heavily affected by human activities, in addition to climate change. One important question which arises is how the relative impacts of climate change (sea-level rise, changing precipitation patterns, rising temperatures) and human modifications to the river mouths and upstream (river regulations, coastal infrastructure, land reclamations, sand extractions, etc.) on the future development of river mouths and coastal areas can be described and attributed. An attribution of these relative impacts will have helpful implications for coastal management.

Session 2 (18 lectures)
Human activities and environmental impacts from the past to the future
Chair: Niels Hovius, Anna B. Kowalska

Session 2 brought together presentations from science, engineering, social sciences and archaeology. The session has documented human use and impact of river mouth systems by a strong link between the natural and cultural trajectories on time scales from the Quaternary to the present. All the papers presented on the use of river estuaries and the impact of human activity on their current shape. As a result, we experience today the development from human use to human dominance of river mouth systems.
The presentation of the lectures and the discussion clearly showed how humans have dominated estuaries in the Quaternary to the present day and what are the geomorphic and ecological effects resulting from human activity. All presentations also revealed the impact on the natural environment.
The presentations given in Session 2 show that in almost all cases of estuarine and coastal research there is a scientific benefit to the interdisciplinary approach of archaeology and geological sciences. The protection of cultural heritage is of indisputable value for the holistic scientific study of estuary systems organized differently in different countries When examining estuary systems, it is essential to include the study of prehistoric and historical relics in addition to scientific research. In general, all soil investigations in coastal areas where cultural remains are expected

should use the synergy of integrated science and humanities. Spectacular results of the cooperation between archeology and geosciences have brought notable research results, for example, at the confluence of the Elbe and the Oder Rivers. The ensemble of presentations revealed not only a profound impact by people on modern coastal systems, but also, and ultimately, the vulnerability of most coastal development to dynamics and trends of the natural environment. Future projections, which is a goal of research, should definitely take into account reconstructions of the cultural past. For further research it is necessary to merge scientific, engineering and anthropological perspectives in studies of past, present and future river mouth systems. Our vision should be the systematic exploration of the role of river mouth systems in transmitting and filtering terrestrial signals and fluxes into the marine domain, and our collective responsibility for securing appropriate functioning of these systems for the benefit of humanity and the Earth's system.

Session 3 (11 lectures)

Proxy-records and modern observations

Chair: H. Gary Greene, Xinong Xie

Session 3 of the River Mouth Conference was a multidisciplinary session that included geomorphic and sedimentologic studies of rivers, river mouths, and offshore areas in India, South China Sea, and Baltic Sea, ranging from Indigenous cultural involvements in estuaries of southern Africa to using a proxy for calibrating historical temperature changes in the Baltic Sea. Presentations specific to river mouths included a study of erosional channels offshore the Mekong Delta that demonstrated an east to west littoral drift with 8 meters of erosion down drift of the delta and partial filling of the Gulf of Thailand. In contrast, another presentation showed that sediment deposited at the artificial mouth of the Vistula River in Poland is swept into a deep water depot-center preventing the formation of a typical river mouth delta. A presentation of a study in the Lingding Bay area of the South China Sea described the construction of two types of Bayhead deltas consisting of 1) river dominated, and 2) tidal dominated that were modeled to show the Coriolis effect and human impacts that were demonstrated by erosion and deposition of sediment. A paleo-environmental history interpreted from a sedimentary source-to-sink studies from large and small river systems was presented for an area offshore of Hainian Island together with a 700-year appraisal of

earthquakes interpreted from fine-grained turbidites at the base of a submarine canyon in Okinawa Trough was presented. A study of paleo-channels in the Bohai Central Basin documented a three-stage global regression, while another presentation focused on the comparison of lake, plain, and river sediments of the Hanjiang River area undertaken to understand the historical changes in sedimentary environments. A detailed presentation was given describing the development of the Szczecin Lagoon throughout the Holocene that showed the evolution from a wider braided river mouth to a dune enclosed lagoon that led to the concentration of anthropogenic Pb, Zn, organics, and calcium carbonates.

The rich tapestry of this session included a presentation describing the adaptive management of estuaries in S. Africa. This included social-cultural, economic, and ecological considerations in relation to natural alteration and enlightened the audience on the wisdom and abilities of indigenous people in addressing environmental problems. Although not a direct river mouth issue a presentation on the tectonic control of Brahmaputra River in India highlighted the importance of a large, presently eroding river island that is constricting the flow of a braided river. This study provided some insight into how geologic activity may influence rivers far removed from their distal ends. Finally, a method used for calibrating a downcore temperature proxy in the Baltic Sea that matches previous calibration standards was presented and confirmed the use of such methods in dating paleo-environmental conditions in that region.

Session 4 (5 lectures)
Advanced data management and modeling
Chair: Joanna Dudzińska-Nowak, Federica Foglini

Within Session 4 we discussed to five presentations related to various method used for monitoring, mapping and preserving natural and human environments, as well as reconstruction of paleoenvironments.
The session keynote presentation showed how acoustic remote sensing by means of high-resolution multibeam echosounder and sub-bottom profiler together with selective video inspections, can help in mapping and preserving the Underwater Cultural Heritage (UCH) in the Lagoon of Venice (Italy). The collected acoustic data not only help to reconstruct the paleoenvironments over the centuries, but, in this case, it also

provide new evidence of the presence of archaeological structures both over and within the seafloor and supports a new interpretation and quantitative description of the mapped structures shedding new light on the significance of the Roman occupation of the Venice Lagoon.

This work represents a starting point for a renovated effort of discovering, documenting, and preserving the highly valuable UCH in the Venice Lagoon. This methodology could then easily transferred to other coastal areas to preserve UCH around the world.

Reconstruction of the development of the southern Baltic Sea shoreline in the vicinity of the Vistula River mouth was presented based on application of alongshore quasi-continuous explorations related with an infinite number of virtual averaged n-profiles within the 4F model. This numerical model runs in a coherent spatial and temporal environment, combining past, present and future. The model includes ice sheet advance and retreat, marine transgression and regression, coastal erosion and accumulation.

Another presentation focused on biological aspects of the transformation processes of dissolved organic carbon (DOC) and its driving factors throughout the river-estuary-ocean continuum, using the example of the Changjiang Estuary in China. To better understanding the process, the study combined field observation and physics-biogeochemistry modeling using, unstructured grid, Finite-Volume Coastal Ocean Model (FVCOM), coupled with the European regional seas ecosystem model (ERSEM). In doing so a more complete picture of the DOC transport processes in this region was derived.

To support the Seafloor Management Plan in Greenland, a seafloor terrain model of nearly the entire Disko Bay region provided scientific baseline information about surface geology and sedimentary environments. The model was based on multiple multibeam bathymetry and backscatter datasets, seismic profiles and ground-truthing consisting of video footage from drop camera and benthic video sled. Furthermore, sediment samples were taken from grab and corers, and these show the key geological units in Disko Bay and characterize the scale of geomorphic features, which in turn affects the distribution and complexity of habitat zones.

The final presentation in this session showed a complex series of analyses leading to the discovery of a “Hainan Delta” in the Beibu Gulf. This is located on the northern continental shelf of the South China Sea, southwest of the Island of Hainan. The work

involved an interdisciplinary and unique data-set combined with numerical modeling approach.

The studies presented within the session clearly highlight the need for a broad, interdisciplinary approach. High-resolution mapping and modeling are effective methods for environmental reconstructions and to provide better understanding of the complex processes operating, as well as identifying conflicting areas in the overall scope of sustainable use of the oceans and marine resources.

General Summary

River mouths systems form the gateways between the continents to the oceans, serving as key areas worldwide for the historical and prehistoric phases of societal evolution. Over the long history of human settlement the overlapping of natural drivers and anthropogenic effects influence the evolution of the environment in these settings. The present time can be described as a transition from human use to human dominance of river mouth systems. Studying the interrelationships between natural and anthropogenic drivers is necessary for a deeper understanding of river mouth system development, in order to elaborate strategies for sustainable development of the environment. This is increasingly endangered by climate change and human activities. The concept of “Urban Seas” provides a valuable theme and serves as a basic concept for the sustainable development of river mouth systems. However, this concept has to be generalized by extension from “real-time” development of a river mouth system. Understanding the transition from the pristine “background” environment to the current of industrialization is critical. That means, the time span has to include the Holocene and the Anthropocene in order to detect the onset of human drivers of the system. Close co-operation between natural scientists, historians and archaeologists is needed for an interdisciplinary interpretation of proxy-data and for the historical reconstruction of paleo-environments. A synthesis of proxy-data, historical monitoring and real-time data and a generalized data acquisition concept are needed to compare river mouth systems of different climatic zones and geological settings as a base for the development of generalized models to describe specific river mouth systems. When collecting relevant data, socio-cultural, economic and ecological considerations regarding natural changes in the environment and their perception of indigenous people as valuable sources of information must be taken into account.