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Marginal Seas - Past and Future

Online, 16 - 17 December 2020

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Cover photo: Baltic Sea coast, Schleswig-Holstein, Germany (Marcus Reckermann)

Marginal Seas – Past and Future

Online Conference, 16 - 17 December 2020

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University of Szczecin
Institute of
Marine and Environmental Sciences
Poland

and the
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at Helmholtz-Zentrum Geesthacht, Germany

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Preface

This conference shall continue the discussion based on an initiative "Eurasian Marginal Seas – Past and Future (EMS)" that was launched by a network of scientists from Belgium, Canada, China, Germany, Italy, Japan, Malaysia, Poland, Russia, Spain, UK, and USA during the annual conference of the International Association for Mathematical Geosciences "IAMG 2019", to be embedded into the Deep-time Digitial Earth (DDE) Big Science Program of the International Union of Geological Sciences (IUGS).

The general target of the initiative is to elaborate a generally accessible methodology based on big data analyses and numerical modeling to answer the following questions:

1. How did marginal seas of different climatic zones and tectonic settings change their paleogeography, paleoceanography, and paleoenvironment during the natural climate and environmental variations of the Last Glacial Cycle (last 130 kyr)?
2. What are the future expectations for the development of marginal seas and their coastal zones facing the challenge of climate change and increasing human impact on the environment for this century?
3. What strategies for sustainable development of the marine and coastal realm can help to keep a balance between the protection of the environment and the economic use of marginal sea resources?

During our first "EMS Expert Meeting" held at Guangzhou in November 2019, we realized that we need more research results in basic science before we can start in a next step to develop management concepts based on numerical modeling in order to protect the environment and use the resources of marginal seas. Therefore, we have structured the second EMS Expert Meeting that will be held online on December 16/17 2020 into three Topical Sessions. The first one is devoted to the interdisciplinary description of climate with geo/eco/anthroposphere. The second one covers the interaction of marginal seas and society. The presentations of the third session dealing with data management and visualization (mapping) shall build the bridge to the next step on our roadmap: generating scenarios of the geological past and future developments by the application of numerical models.

In the conference, we approach global topics of marginal seas research. However, we pay special attention to the Baltic Sea, as many processes of marginal seas can be studied in it like in a natural laboratory.

Topical Sessions

(1) Geo-, Eco- and Climate System

Lectures and discussions will on the one hand explain the links between processes of the geo-, eco-, and climate system as complex cause-effect relationships. On the other hand, interdisciplinary approaches to describe these relationships using models have to be discussed. In terms of time, we focus our studies on the Last Glacial Cycle (LGC), the climatic variation of which mainly dominates today's marginal seas. For the spatial scale, a key question is the local to regional differentiation and global connection of geo-processes as hierarchical system.

(2) Marginal Seas and Society

The focus of this topic is on the relationship between geo-, eco, climate system and the anthroposphere in terms of the resource exploitation of the marginal seas. The change in the role of human societies from the passive adaptation of survival strategies during the late Pleistocene to the active role of changing the natural environment in the Anthropocene is of particular consideration. A key to understanding this active role is exploring the perception that societies have had of the environment as an opportunity or a threat, depending on the state of societal development and its regional variation. Future projections should be highlighted based on climate change scenarios as driving forces based on the IPCC models.

(3) Scaling / Mapping / Data –Management

For a reflection of geoprocesses by models from the global to the regional level, which allow both historical reconstruction and future projection, a harmonization of geodata and their international accessibility are required. A basic task is the visualization of maps of both empirical data and model results. The focus of this topic is on formatting, harmonization and mapping of marginal sea data.

Jan Harff
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Online Conference on

Marginal Seas – Past and Future

16-17 December 2020
All times in Central European Time (CET)

December 16, 2020

13:00 **Opening and Introduction**

13:00 **Technical Instruction**
Marcus Reckermann

13:05 **Welcome addresses**
Chair: Jan Harff

Prof. Waldemar Surosz	Chairman of the Polish Scientific Committee on Oceanic Research Polish Academy of Sciences, patron
Prof. Andrzej Skrendo	Vice-Rector for Science of the University of Szczecin, host
Dr. Marcus Reckermann	International Baltic Earth Secretariat, Helmholtz-Zentrum Geesthacht, main co-organizer

13:15 Introduction to the conference
Jan Harff

Scientific Sessions

(1) Geo-, Eco- and Climate System (Peter Clift, Markus Meier)

Chair: Peter Clift

13:20 **Postglacial changes in relative sea level: a comparative study for the Baltic Sea and the South China Sea**
Andreas Groh and Jan Harff

13:40 **Challenges in modelling of the Last Glacial Cycle and their implications for marginal seas**
Eduardo Zorita

14:00	**Comparison study on climate changes based on temperature between Guangdong-Hong Kong-Macao Greater Bay and European area** Bing Wang
14:20	**Paleoenvironmental changes of marginal seas during the Last Glacial Cycle** Helge Arz, Antje Wegwerth, Olaf Dellwig, Jérôme Kaiser, Markus Czymzik, Norbert Nowakzyk and Frank Lamy
14:40	**Coastal seas and hypoxia** Markus Meier
15:00	**Marginal Seas' Ecosystem's dynamics** Corinna Schrum
15:20	**Break**
	Chair: Markus Meier
15:40	**Natural and anthropogenic impacts on ecosystems of marginal seas: reconstruction and assessment tools** Teresa Radziejewska and Andrzej Witkowski
16:00	**Paleo-ecology related to the Last Glacial Cycle** Jinpeng Zhang and Chixin Chen
16:20	**Sea-level change during the Last Glacial Cycle** Karl Stattegger
16:40	**Climatic, sea level and anthropogenic controls on fluvial sediment transport in East Asia** Peter D. Clift
17:00	**Model approaches for alongshore sediment transport - a case study of the sandy Baltic coast for the period of 1948-2015** Wenyan Zhang
17:20	**Geology and coastal processes of Eurasian Arctic Marginal Seas** Daria Ryabchuk, Evgeniy Petrov, Vladimir Zhamoida and Pavel Rekant
17:40	**Discussion** Moderation: Markus Meier
18:00	**End of day 1**

December 17, 2020

(2) Marginal Seas and Society (Jan-Marcin Węsławski, Hans von Storch)

Chair: Jan-Marcin Węsławski

12:00 **The significance of sea-level change and ancient submerged landscapes in human dispersal: A geoarchaeological perspective**
Geoff Bailey and Hayley Cawthra

12:20 **Marginal sea ecosystem services under threats: case studies of anthropogenic fingerprint in marine ecosystems in proximity to Megacities**
Joanna J. Waniek, Emilie Strady, Kerstin Schiele and Friederike Kunz

12:40 **Biogeochemistry-ecosystem-human interactions in the Chinese marginal seas**
Sumei Liu

13:00 **Perceptions of an endangered Baltic Sea**
Hans von Storch

13:20 **How to develop coastal sea system understanding connecting natural and human sciences?**
Anders Omstedt

Chair: Hans von Storch

13:40 **Multiple drivers of Earth system changes in marginal seas: the example of the Baltic Sea region**
Marcus Reckermann et al. (24 co-authors)

14:00 **Impacts of changing society and climate on nutrient loading to the Baltic Sea**
Sampo Pihlainen, Marianne Zandersen, Kari Hyytiäinen, Hans Estrup Andersen, Alena Bartosova, Bo Gustafsson, Mohamed Jabloun, Michelle McCrackin, H.E. Markus Meier, Jørgen E. Olesen, Sofia Saraiva, Dennis Swaney and Hans Thodsen

14:20 **The role of culture, tradition and indigenous knowledge in coastal management**
Kevin Parnell

14:40 **What is more important - education, tradition or public media for our opinion about Baltic Sea?**
Jan Marcin Węsławski, Joanna Piwowarczyk and Katarzyna Boni

15:00 break

(3) Scaling / Mapping / Data –Management (Federica Foglini, Jan Harff)

Chair: Jan Harff

15:20 **Ocean Sediment Data, Integrated, Local to Global, for Modelling the Marginal Seas (dbSEABED Project)**
Chris Jenkins

15:40 **Spatial data integration and harmonization in the Adriatic Sea – how to make data FAIR (*F*indable, *A*ccessible *I*nteroperable and *R*esearchable) for habitat and geological mapping**
Federica Foglini and Valentina Grande

Chair: Federica Foglini

16:00 **EMODnet: Mapping the European shelf geology**
Kristine Asch and the EMODnet Geology participants

16:20 **Marine benthic habitat mapping - A case study from the Salish Sea**
H. Gary Greene

16:40 **Remote sensing in monitoring and management of the coastal zone - the southern Baltic Sea example**
Joanna Dudzinska-Nowak and Wenyan Zhang

17:00 **Discussion**
Moderation: Jan Harff

18:00 **End of day 2 and farewell**

Conference website:
https://baltic.earth/EMS2/

Session 1

Geo-, Eco- and Climate System

Postglacial changes in relative sea level: a comparative study for the Baltic Sea and the South China Sea

Andreas Groh[1] and Jan Harff[2]

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Changes in relative sea-level (RSL) and sediment supply are important drivers of coastal evolution on a wide range of temporal and spatial scales. The adaption of RSL following changes in continental ice masses results from an interaction of crustal deformations and changes of the Earth's gravity field. They are triggered by both the changing glacial load and corresponding water loading. These interactions, together known as glacial isostatic adjustment (GIA), can be consistently described the sea level equation (SLE). The SLE is applicable to long-term signals, e.g. following the waning of the Pleistocene ice sheets, as well as to instantaneous changes related to present-day ice mass changes.
Here, we revisit the principles of GIA and discuss the different components of RSL by means of predictions based on up-to-date GIA models. The Baltic Sea serves as a study area, representative for formerly glaciated regions and their surroundings (near-field), where RSL is dominated by crustal deformations induced by changing glacial loads. As a second test site, the South China Sea and the Beibu Gulf in particular are considered. In regions far away from the former centers of glaciation (far-field), load-induced changes of the Earth's gravity field are the major contributors to RSL changes. For the Beibu Gulf we also model additional crustal deformations caused by sediment loads accumulated since Marine Isotopic Stage (MIS) 4. The temporal evolution of the deformations as well as their spatial patterns are compared to modeled deformations solely caused by GIA. Finally, spatial patterns of present-day changes in RSL caused by the vanishing Pleistocene ice sheets are compared to those induced by recent mass changes of the ice sheets in Greenland and Antarctica. The latter are derived from more than 15 years of satellite gravimetry data acquired by the GRACE and GRACE Follow-on missions.

Challenges in modelling of the Last Glacial Cycle and their implications for marginal seas

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The simulation of the glacial-interglacial variations of Earth's climate is a computationally daunting task. Until recently, this task could only be partially accomplished by using simplified models, so called Intermediate Complexity Models (ICM), which represented the different climate subsystems and their interactions in a simplified manner. More importantly for us, their spatial resolution with which they represented the atmosphere and the ocean was too coarse - of the order of several thousands of kilometers- to realistically be able to incorporate marginal seas.

Complex Earth System Models (ESM), of the same type as used to project future climate, are starting to be used to simulate the last glacial cycle. Their spatial resolution is much finer than that of ICM - of the order of 100 km - but it may still be insufficient to realistically simulate small-scale process relevant for the dynamics of marginal seas. Earth System Models incorporate the major climate subsystems - atmosphere, ocean , land biosphere - but they still lack two important components of the glacial-interglacial dynamics, namely a fully interactive carbon cycle and the dynamics of the ice-sheets. Even then, they are computationally very expensive, so that only very few simulations and only over parts of the glacial cycle are available. One main message is that so far there exist no climate simulation covering the last glacial cycle with a comprehensive Earth System model.

The so far available simulations can be classified as equilibrium simulations and transient simulations. Equilibrium simulations target a specific and fixed point in time, e.g. the Younger Dryas. The model simulates the mean climate of that point in time with unchanged external forcing (orbital parameters and greenhouse gas concentrations, land ice-sheets). These simulations do not represent a temporal evolution. Transient simulations, in contrast, target a temporal window, for instance, the Last Deglaciation, and simulate the climate evolution through that temporal window by driving the model with time-varying external forcings. These latter simulations are usually much more costly in terms of computer resources.

In this contributions, we review some of the available climate simulations and ongoing simulation projects, addressing their limitations and what can be learned from them bearing in mind the objective of dynamics of marginal seas. Most available simulations have been performed with ICM, and therefore due to their their course resolution, have limited direct value for the dynamics of marginal seas. They, however, can provide insights about large-scale climate patterns, like the Asian Monsoon or westerly winds, that can be relevant for marginal seas. Currently, there exists only one transient simulation with an ESM. This simulation with the model CCSM3, denoted Trace21, covers the Last Deglaciation, with a spatial resolution of about 3.7 degrees.

A currently ongoing project Palmod (www.palmod.de) aims at simulating the climate of the last 130 kyears with a comprehensive ESM, with an interactive global carbon cycle and interactive ice-sheets. If this extremely ambitious project is successful, the Earth’s last glacial cycle will be simulated by solely driving a state-of-art climate model with the varying orbital parameters.

Comparison study on climate changes based on temperature between Guangdong-Hong Kong-Macao Greater Bay and European area

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To analyze long-term climate changes between South China (Guangdong-Hong Kong-Macao Greater Bay) and European area, author selects three SE Asian stations (Guangzhou, Hong Kong Observation, Macao) and five Europe stations (Stockholm, Milan, Wien, Bologna, Praha-Klementinum) as representative stations for those areas, which have more than 100- or 200-years temperature datasets. Base on Ensemble Empirical Mode Decomposition (EEMD) and Mann-Kendall methods, this study focus on the multi-scale temperature fluctuation and mutation point extraction in the past. The multi-scale analysis show that there are 4 time-scale changes in both Guangdong-Hong Kong-Macao Greater Bay and European area. They are interannual scale, interdecadal scale, century scale and trend, but the fluctuation periods of different time-scale are different in both regions especially on the interdecadal scale and century scale. For the interannual scale, the results show little difference with 2-4a in SE Asia and 3-7a in Europe. In Guangdong-Hong Kong-Macao Greater Bay, the interdecadal scales are 10-14a, 30-75a, while 11-14a,21-28a,50-75a in the European area. For century scale, there are 100-125a and 140-156a in European area, while about 150a period in Guangdong-Hong Kong-Macao Greater Bay area. The temperature change trends reveal that Guangdong-Hong Kong-Macao Greater Bay area experienced remarkable increase rate after 1960. While, in the European area temperature has risen since 1880 and obviously increased after 1980. Meanwhile, it is to be remarkable that the growth rate in coastal area is greater than that inland area in both areas. The mutation test show that the mutation point in Guangdong-Hong Kong-Macao Greater Bay is 1970 (only Hong Kong observation station past significance test of 95%). While in the European area, the mutation point is 1950 in Milan station and 1970 in Praha-Klementinum station, which both past significance test of 95%.

Paleoenvironmental changes of marginal seas during the Last Glacial Cycle

Helge W. Arz[1], Antje Wegwerth[1], Olaf Dellwig[1], Jérôme Kaiser[1], Markus Czymzik[1], Norbert Nowakzyk[2], and Frank Lamy[3]

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A comparison of paleoenvironmental studies based on radiocarbon and paleomagnetically dated sediment records from the Black Sea and the Red Sea exemplarily demonstrate the exceptional sensitivity of such marginal sea systems to changes in sea-level and regional climate during the last glacial cycle. Most prominent are the environmental shifts during glacial-interglacial transitions accompanied by major hydrological imbalances in the basins in response to global sea-level, local/regional evaporation/precipitation changes, and e.g., melt water input. These transitions are punctuated by millennial-scale climate events such as the Younger Dryas cold spell mostly originating/amplified in the large ocean basins and transmitted atmospherically to the regional systems. Even more prominent are the abrupt millennial-scale changes that occurred during the overall unstable climate of the last ice age, the so-called Dansgaard-Oeschger cycles. The Eurasian inland propagation of temperature anomalies during glacial millennial-scale climate variability could be accurately detected in our Black Sea/Red Sea records. Moreover, by using the composition of major and trace elements in the sediments, terrestrial plant-derived n-alkane flux, and Sr/Ca from benthic ostracods, the variability of riverine and aeolian input, salinity, and productivity in the SE Black Sea region in response to the Northern Hemisphere climate oscillations could be well captured. Understanding the underlying cause-effect relationships of these rapid climate changes, however, is often hampered due to the lack of a detailed and reliable age control of these multi-proxy records. Complementary to climate simulations, several chronostratigraphic approaches exist to overcome this problem, such as detailed radiocarbon dating, paleomagnetic investigations, tephrochronology, and 10-Be synchronization. These tools become particularly important for investigating multi-centennial climate variability and distinct climate events, such as the 4.2 drought event, during the generally more stable Holocene epoch. While hydro-climatic records from the Black Sea and the northern Red Sea region show pronounced and coherent Holocene multi-centennial variations, the basins experienced very contrasting redox changes, underling the particular sensitivity of marginal seas to oxygen depletion.

Hypoxia in Marginal Seas

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During the past five decades, the global oceanic oxygen content has decreased (Schmidtko et al., 2017; Breitburg et al., 2018). In particular, marginal seas suffer worldwide from oxygen depletion resulting in hypoxic area or `dead zones' with absent higher forms of life at the sea bottom (Fennel and Testa, 2019). Since the 1960s, hypoxia has spread exponentially (Diaz & Rosenberg, 2008). In addition to human impact also changing climate might have contributed to this spreading. Marginal seas are particularly vulnerable to changing climate because of the potential impacts related, inter alia, to global sea level rise, temperature increase, and deoxygenation, changing hydrological cycles and nutrient supply (SROCC, 2019). To disentangle the various drivers of hypoxia we developed a modelling approach based on historical reconstructions and dynamical downscaling and investigated bottom oxygen concentrations in past (Meier et al., 2012; 2018; 2019) and future (Meier et al., 2011; Saraiva et al., 2019) climates. We selected the marginal sea with the world-largest man-made hypoxic area, the Baltic Sea (Carstensen et al., 2014). Today the size of hypoxic area in the Baltic is equal to the size of the Republic of Ireland (about 70,000 km2 or 19% of the total area) (Hansson et al., 2019). However, hypoxia was also observed during the Holocene Thermal Maximum and during the Medieval Climate Anomaly (Zillen and Conley, 2010). We compared model results of the past 8000 years (Warden et al., 2017; Schimanke et al., 2012) and projections of the future 100 years (Saraiva et al., 2019) and discussed the challenges and knowledge gaps. Further, we compared the drivers of hypoxia in the Baltic Sea with those in other marginal seas, such as the northern Gulf of Mexico, Chesapeake Bay, the Gulf of St. Lawrence, the northwestern Black Sea, the northern Adriatic Sea and the East China Sea (Fennel and Testa, 2019; Gilbert et al., 2010), with the aim to upscale results.

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Natural and anthropogenic impacts on ecosystems of marginal seas: detection, reconstruction and assessment tools

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Marginal seas worldwide belong to the most dynamic ecosystems, having been always subject to numerous pressures, both natural and anthropogenic. Those pressures have changed and are changing the basic environmental characteristics through impacts produced on abiotic and biotic ecosystem components. In the pre-industrial times, the major drivers of change were natural forces, associated with processes operating on large spatial and temporal scales. Knowledge on the type and time-course of those changes and their underlying drivers is acquired through geological studies on sediment cores and the (micro)palaeontological multi-proxy-based research. The latter employs techniques such as transfer functions developed from detailed analyses of individual proxies and allowing to reconstruct the sequence of environmental changes induced by, inter alia, climate forcing and early anthropogenic effects. Knowledge on the type and time-course of (pre)historical changes in the marginal sea ecosystem is important, as it helps to understand the resilience potential of the ecosystem with respect to changes produced during the industrial era. These are primarily anthropogenic in nature. The extent of those changes is assessed, on the spatial and temporal scale, through environmental monitoring which provides data and underpinnings for environmental assessments. Of major importance among the latter is the assessment of cumulative impacts, understood as a net result of interactions of pressures from one or more sources as well as from different exposures, time lags, and/or threshold responses. At present, the cumulative impact assessment in a marine environment constitutes a major challenge for science and management alike. However, cumulative impacts have to be assessed to minimise uncertainty and to increase reliability of models and projections of future developments in a marginal sea area.

The diatom in Pearl River Estuary (N South China Sea) and adjacent delta related to Last Glacial Cycle

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As the second larger river in China and top twenty large rivers in the world, the Pearl River in South China discharges fresh water over 3330*108 m3/year, carrying about 85.8*106 tons suspend particles to the northern South China Sea (SCS) in annual mean level. The widely continental shelf over 170 km in the northern SCS has bear-loading most part of terrestrial matters released from Pearl River catchment. The strong interaction of land-sea occurs at there within a climate transition zone from tropical to subtropical. In the coastal zone, the sedimentary system was shifting among bay-estuary-delta following the global sea-level adjustment during the Last Glacial Cycle in Late Quaternary, in term of delta deposition was created or submerged or destroyed. On the land, previous researchers made results that the Quaternary sediment stratum thickness is not so large, around 50 m. And the “present” Pearl River Delta was constructed overlapping on second marine unit in a stage of ca. 25 - 44 kyr. BP with transgression and a stage since ca. 7 kyr. BP after transgression (first marine unit), interrupting by the sea-level drop in Wurm glacial and deglacial. While, a debate point around the second marine stratum in Pearl River delta and estuary area is MIS3 or MIS5, or even older.
To understand the complicated sedimentary change in this area, the microfossil at here, diatom makes a valuable role to identify the sedimentary environment change, on the basic of its relative widely ecological distribution in freshwater, brackish water or marine condition. The diatomological and sedimentary study on the Pearl River Estuary and adjacent area has preliminary results:

1) fossil diatom within brackish water and marine conditions are widely recorded in the second marine stratum in Pearl River Estuary. The geological time correlate to marine isotope stage 5 (MIS5). In the drilling cores including from Hongkong water area, there have more marine units. May they record the pre-late-Pleistocene transgression related to global sea-level change.
2) the higher diatom absolutely abundances record in the Holocene stratum, practically in the early Holocene, indicating the heavily precipitation related to strong summer monsoon happened in the east Asian. In the early Holocene, the foraminifera were lack even disappeared, compared to abundance diatom, which is similar to core record in Beibu Gulf (NW SCS), making sense of regional correlation in the N-SCS.
3) the anomaly phenomena of depositional environment in ca. 4 - 2.5 kyr. BP was recorded in sedimentary core, which could relate to regression occurred after the middle Holocene optimize.
4) in the late Holocene, regional accumulation rate was enhanced, which offered a potential capability to recognize the higher resolution sedimentary record and paleo-climate analysis. We recognize hydrodynamic condition happened during the Medieval warmer period. This is an important discovery for climate change research around millennial scale fluctuation.
5) did relative sea-level has rising in Pearl River Estuary and adjacent area in past 400 years? The diatom record track on warmer water species appeared relative higher abundance in past 400 years in the sedimentary core nearby the coast in this area.

According to previous study and present work, we make outlook to further work to drill the shelf of northern South China Sea, in order to understand the regional respond to interglacial-glacial cycles in Quaternary in term of long-term scale. And here makes an outlook to understand what trendy of micro-organism (like diatom) change in Pearly River Estuary and adjacent area in next one hundred years, following the sea-level rising and climate warming tendency.

Sea-level change during the last glacial cycle

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Polar ice sheets are principal drivers of sea-level change at global and regional scales. The impacts of the waxing and waning of polar ice sheets constitute the global eustatic component of sea-level change throughout the last glacial cycle and influence also marginal seas twofold: (i) as direct glacio-isostatic response in the near-field region, e.g. the Baltic Sea, and (ii) by controlling large-scale sea-level fluctuations worldwide, e.g. the South China Sea.

The last glacial cycle started with the sea-level highstand of Marine Isotope Stage (MIS) 5 e (128 – 116 ka BP) reaching 6-9 m above present mean sea-level (pmsl). Then sl dropped down in an oscillatory way to the lowstand of 120 – 125 m below pmsl during the Last Glacial Maximum (LGM) / MIS 2, 26 – 20 ka BP. Both extreme values are supported by field data while the fluctuations in between are reconstructed mainly from proxy data, namely stable O-isotope records measured in foraminifera of the open ocean which are used to estimate the global ice-volume. Recent sequence-stratigraphic studies in the SCS confirm the sea-level reconstructions.

Geological data and numerical modelling facilitate precise reconstructions of the deglacial sea-level rise (slr) following the LGM lowstand. Ice melt and slr did not proceed linearly and additional complexity results from specific regional conditions of glacio-isostatic adjustment. The western South China Sea is a favourable region to reconstruct the eustatic component due to the far-field setting and the low morphological gradient of the formerly exposed Sunda Shelf which allows to follow the deglacial marine flooding in detail. The first phase of deglacial slr started abruptly at 19.5 ka BP with an initial slr of 11 m and rates up to 16 mm/yr. After a period of moderate slr a major sea-level jump of about 16 m and rates of 40 mm/yr occurred between 14.7 and 14.3 ka BP, recognized as meltwater pulse 1A. Then sea level rose almost linearly at an average rate of about 9 mm/yr for the next 5000 years. This record matches well with coral-reef records from Tahiti and Barbados and with glacial isostatic adjustment modelling results. Between 9.0 and 8.2 cal ka BP we observe a third phase of accelerated slr with an offset of about 18m and rates up to 35 mm/yr in the paleo-Mekong valley on the South Vietnam shelf and the Cambodian lowlands associated with a shoreline retreat of more than 200 km. Sea-level reached a highstand in the middle Holocene (6.7 – 5.0 ka BP) exceeding pmsl by 1.5 to 3 m and dropped down then until the beginning of the 20th century when sea level started to rise again.

The last phase of accelerated slr can be compared with the initial flooding of the Baltic Sea, the Littorina transgression. Rapid marine flooding started first through the Great Belt and the former Dana River valley and later through the shallower Øre Sund. Sea level rose in the Kiel Bay and the Great Belt area during the first phase of the marine transgression from 27 m to 14 m below pmsl between 9.0 and 8.5 ka BP and slowed down thereafter. After 5.0 ka BP sea level rose slowly from around 2 m below pmsl and reached pmsl between 2.0 and 1.0 ka BP modulated by minor secondary oscillations.

Climatic, Sea level and Anthropogenic Controls on Fluvial Sediment Transport in East Asia

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The East Asian summer monsoon exerts the primary control over rates of erosion and chemical weathering in East Asian river systems. On million year timescales erosion is controlled by patterns of bedrock uplift and in general more sediment is delivered to the ocean when the monsoon is strong than when it is weak.

Since the last glacial maximum (LGM) rates of sedimentation increased as the Asian monsoon intensified. The sediment being delivered to the ocean also became more chemically altered. This was only partly the result of faster rates of chemical weathering driven by warmer temperatures and higher humidity during the Early Holocene, and partly reflects reworking. Aggradation of sediment in river valleys in the headwaters of many Asian catchments that accumulates during glacial times provides a store of sediment which can then be released later, especially during monsoon weakening since the middle Holocene. Reduction in sediment load in the reduced discharge in the rivers since that time means that the water in the stream is available for eroding valley fills and incising terraces.

This sediment is delivered to the ocean, but is often stored on the continental shelf or advected along the coast rather than being delivered to the deep water in basins such as the South China Sea. This reflects the sea level rise providing abundant accommodation space close to the river mouth. The continental shelves themselves, which are exposed during the glacial maximum form a source of sediment into the deeper water. Strong monsoon at the start of the Holocene drives erosion of the weathered soils formed when the shelves are exposed. This reworking continued until they are inundated during the deglaciation. This recycling of sediment from incised valleys, floodplains and the continental shelves is one of the reasons that the sediment found on the continental slope shows strong weathering associated with times of strong monsoon. Some of the chemical weathering is occurring over relatively long periods of time during the glacial sea level lowstand when the monsoon was relatively weak. However, even at slow rates of alteration significant degrees of weathering can occur if sufficient time is allowed.

Such is the extent of continental margins in East and SE Asia that this may be a significant source of chemical weathering and CO2 drawdown which would have intensified the last glacial. In more recent times (<5 k.y.) early civilizations settled in the floodplains in East Asia and were responsible for exacerbating the recycling of sediment into the deep water as a result of the spread of agriculture breaking up the shallow sediment surface and liberating material into the rivers. Modern river compositions cannot be used as proxies for the same rivers prior to 5 ka. Since the mid 20th Century

Model approaches for alongshore sediment transport - a case study of the Baltic coast for the period of 1948-2015

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Alongshore sediment transport (LST) and subsequent coastal morphological change have been studied by coastal engineers, geomorphologists and oceanographers for more than five decades, but their reliable quantification remains still to be a very challenging task in a modelling perspective (Cooper et al., 2018). It is common that field measured LST rate differs by 0.2 to 5 times from the model predictions, and the differences of predicted LST values by different models can be off by a factor of 10 to 100 (Davies et al., 2002). Due to the complexity of natural coastal systems, including variability in geological and morphological configurations and internal/external driving forcing, it is desirable to develop regional (mesoscale) modeling approaches that can be adapted to particular coastal environments, e.g. tideless, wave-dominated Baltic Sea coast.

The Glacial Isostatic Adjustment (GIA) and eustatic sea level change impose a first-order control on the coastline change along the Baltic Sea (Harff et al., 2017). In the mildly subsiding southern and south-eastern Baltic Sea coastal region that is mainly composed of sandy beaches, dunes and moraine cliffs, wind- and wave-driven alongshore currents and storm surges are the major natural drivers for LST and consequent erosion/accretion (Zhang et al., 2015). Coastal engineering measures such as construction of piers, breakwaters and beach nourishments modulate LST at scales much larger than their dimensions.

Remote-sensing derived coastline change provides useful means for assessment of numerical modelling approaches for LST. In this study, we use satellite-derived coastline change of the Baltic Sea for the period 2007-2016 (https://www.emodnet-geology.eu/map-viewer/?p=coastal_behavior) to test numerical models based on two most widely used formula for LST estimate, namely the CERC equation (USACE, 1984) and the Kamphuis equation (Kamphuis, 1991), combined with wave time series from validated model hindcast (https://www.coastdat.de/data/index.php.en), high-resolution bathymetry (1/16 x 1/16 arc minutes, https://www.emodnet-bathymetry.eu/data-products), sediment map (grain size and lithology, https://www.emodnet-geology.eu/) and concept of dynamic equilibrium shore profile evolution (Deng et al., 2014). Results indicate that despite of large variability at local spatial scales (10 to 103 m-scale), the models are able to capture coastline change patterns at mesoscale (104 m-scale) with a first order accuracy (50% from the measured values). Best model performance is achieved in areas with weak wave energy (annual mean <1000 J/m2) and large wave incidence angle (>20º). Uncertainty increases along with enhancement of wave energy and/or decrease of incidence angle. Model results based on the Kamphuis91 equation is typically 1.5 to 3 times lower than that based on the CERC equation. We found that the former performs better in low wave-energy conditions (mean wave breaking height of less than 1 m) while the latter is more suitable for high wave-energy conditions. The proposed modelling approach proves to be a useful tool to reconstruct historical coastline change and project future scenarios at mesoscale. However, caution needs to be taken in interpretation of the results especially in areas characterized by significant anthropogenic modulations.

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Geology and coastal processes of Eurasian Arctic Marginal Seas

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Arctic Marginal Seas represent a huge area characterized by extreme variety of bedrock and Quaternary geology, tectonic, high potential of mineral resources, and numerous unsolved problems of geological history. Different aspects of Arctic Marginal Seas geological mapping is in the focus of international projects. Seamless broadscale geological and tectonic maps were complied in 2016-2020 in frame of international projects Atlas of Geological Maps of the Circumpolar Arctic at 1:5M scale and International Geological and Tectonic map of Asia at 1:5M scale– IGMA-ITMA 5000. Transboundary maps of the Barents Sea were presented in Atlas "Geological history of the Barents Sea" [Smerlor, Petrov, 2009] and produced in frame of EMODnet-geology project. Despite intensive recent scientifical research [Hughes et al., 2016; Dowdeswell et al. (Ed.), 2016; Flemming et al. (Ed.), 2017; Thornes et al., 2020] and national geological mapping projects in Norway and Russia [Gusev et al., 2012; Map of Quaternary deposits of Russian Federation 1:2.5M scale, 2013] there are still a lot of disputable questions - from fundamental problems of different Quaternary Ice Sheets extension, time and mechanism of deglaciation, Holocene sea-level change in different Arctic Marginal Seas – to questions of local palaeogeographical reconstructions and different submerged glacial and postglacial seabed forms development. In 2018-2020 new data about Quaternary deposits, recent sedimentology and sea-bed morphology of the Eastern Arctic (the East Siberian Sea) was received in frame of VSEGEI marine geological mapping of 1:1M scale of R56-60 and S55-56 sheets.

Problem of coastal erosion – recent status, trends of Holocene development, and forecast – is very important for Russian Arctic. The total coastline of Russian Arctic Marginal seas is about 40000 km. More than 15000 km (or 38%) are eroding and retreating [Kalinina et al., 1992]. On coasts composed of easily eroded Quaternary deposits (the Laptev Sea, the East Siberian Sea, the northern coast of Yamal Peninsula in the Kara Sea) the rate of shoreline retreat reaches 3-12 m/year as a result of thermal erosion [Kaplin et al., 1991; Aibulatov, 2005]. Shores consisted of unconsolidated sediments within permafrost areas demonstrate the highest erosion rates (up to 15-20 m/year) [Are, 1980]. In the Far East (the Bering Sea, the Sea of Okhotsk, the Sea of Japan) about 50% (about 4000 km) of coasts suffer from erosion [Kalinina et. al, 1992; Aibulatov, 2005]. Uplifting coasts of Western Barents and White Sea and north-western Gulf of Finland located within Baltic Crystalline Shield do not suffer from coastal erosion, contrary to coast of Pechora Sea (the Eastern Barents Sea). It is important to mention, that coastal geological hazards can be considered to be climate-dependent, with a comprehensive understanding of the main trends of climate change being important for prediction and mitigation of future damage to coastal infrastructure and selection of adaptation strategy.

Session 2

Marginal Seas and Society

The significance of sea-level change and ancient submerged landscapes in human dispersal: A geoarchaeological perspective

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Our interest in marginal seas is in the drowned human landscapes of the continental shelf that now lie below present sea level, a theme of world-wide significance. Sea levels have been lower than present almost everywhere for 90 per cent of the last glacial-interglacial cycle, hiding shorelines and coastal landscapes that contain some of the most important archaeological evidence for human history during the past ~125,000 years, including the beginnings of seafaring, intensification in the exploitation of marine resources, colonisation of deglaciated regions and new continents, and very likely population growth and increasingly sedentary settlements, all well before the advent of agriculture. At the last glacial maximum, low sea levels exposed 22 million km2 of new territory around the world's continental margins, much of it offering some of the most ecologically attractive territory available for human settlement.

Investigating the human and archaeological dimension of this underwater world to the level of detail and resolution required for archaeological objectives poses enormous challenges, of which the biggest is the discovery and systematic investigation of archaeological sites. Various modelling procedures can contribute to the task and require input from a wide range of marine sciences. These include:

(1) Modelling, at a regional 'human' scale, of the geology, hydrology, vegetation and topography of these drowned landscapes, their spatial and geographical variation, and their variation over time with changes in sea levels and palaeoclimate
(2) Predictive modelling of the likely location of archaeological sites in the light of results under (1) that can help to target the search for archaeological sites using remote sensing methods and diver investigation
(3) Modelling of the ways in which original features of the landscape and archaeological sites and materials might have been variously transformed, destroyed or obscured by marine processes of erosion or sedimentation associated with marine transgression. This is a critical step in the discovery of archaeological sites, since not all predicted locations of archaeological material will have an equal likelihood of preservation and discovery
(4) Modelling of human demographic responses to changes in the geographical extent and rate of change of territory and resources available for human exploitation and settlement with changing sea levels and palaeoclimate. Data on past coastal adaptations can inform future expectations.

Before the era of permanent settlements on the coast, and probably for most settlements before the modern era, the possibility for building work to protect coastal settlements from sea level rise was very limited. The best examples come from the construction of a seawall at the ~7000-year-old early Neolithic site of Tel Hreiz in Israel, and from the use in many hunter-gatherer societies of accumulated shell deposits either intentionally, or as a byproduct of repeated use of the same location for shellfood consumption, to raise the occupation area above the flood level. In most cases, however, and especially in relation to long-term cumulative sea-level rise, the only option was for settlements to retreat inland. That in its turn raises questions about the impact of such shifts in relation to wider patterns of settlement and human demography.

Investigations motivated by archaeological questions of this sort may, in their turn, contribute new information to sea-level and climatic modelling, and more generally to an understanding of the threats to both the underwater and on-land cultural heritage posed by present and future sea-level rise.

Marginal sea ecosystem services under threats: case studies of anthropogenic fingerprint in marine ecosystems in proximity to Megacities

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Worldwide, shelf areas are the most productive regions in the world oceans but represent only 7% of the ocean surface and less than 0.5% of the ocean volume. Their proximity to the land masses makes them particularly important for understanding the exchange processes between coastal regions and the open ocean, in terms of energy and mass transfer, control of anthropogenic and terrestrial fluxes, transport, distribution and deposition of pollutants, and primary production. Coastal seas react rapidly to environmental changes on different time and space scales as their carbon turnover rates are only a few days to weeks. The amount of organic material reaching the seafloor and being buried in sediments is higher in shelf areas compared to the open ocean. Shelf seas are therefore hotspots of chemical degradation processes as well as redox reactions in the sediments (e.g. denitrification, reduction of trace metals) strongly impacting the C, N, P and Fe cycles. In this context, the pollutants introduced are of importance, which have an adverse effect on the ecosystem. The consequences of climate change on the one hand and anthropogenic influences on the other hand are only fragmentarily known in the coastal ocean. In the recent past, large metropolitan areas have emerged along the coasts (Seitzinger et al., 2012; UNESCO 2016), which have drawn on the resources of the hinterland and catchment areas and are exerting steadily increasing pressure on the coastal environment due to the industrialization of the regions. In 1970 the United Nations identified three megacities, the number rose to 10 by 1990 and 28 in 2014, with prediction of 40 megacities world wide by 2030. Many of those being located in the worlds least developed or threshold countries.

The development of coastal megacities on the Asian continent, especially in China with a simultaneous industrialization of the hinterland, is omnipresent (UNESCO, 2016). However, the consequences for the coastal regions of these anthropogenic interventions are only rudimentarily understood and studied, especially with regard to eutrophication, trace metals and modern/emerging pollutants (microplastics, hormones, personal care products). In this study we are seeking to explore the following questions:

- To what extent is the "fingerprint" of the megacities in marginal seas mapped and/or modified by the prevailing hydrographic conditions on the shelf and within the estuaries?
- What is the function of the sediments in these regions with respect to anthropogenic pressure, in particular the introduced pollutants (e.g. trace metals, microplastics, UV filters, personal care products)?

In this study we will present first examples for the Pearl River Estuary and the northern shelf of South China Sea regarding organic pollutants; and trace metals from the Saigon-Dongnai river estuary crossing the conglomeration of Ho Chi Minh City and the role played by the mangrove's sediment on the metal transfer to the sea region as well as access the ecosystem services of the selected regions. Second, we will show how ecosystem functioning in the region and the capacity to supply ecosystem services are connected, and finally the selected results will be put into wide perspective highlighting the need for action on the global scale.

The selected marginal seas offer a unique opportunity to investigate the impact of climatic and anthropogenic pressures on the marine ecosystem, as their distinct shelf areas play a key function in the land-ocean interaction. According to the 2007 IPCC report, Southeast Asia and the South China Sea will also experience a temperature increase of up to 6°C by 2100. This temperature rise will be accompanied by increased precipitation and extreme weather conditions, with obvious consequences for the land, the people living there and the marine ecosystems.

Biogeochemistry-ecosystem-human interactions in the Chinese marginal seas

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The Chinese marginal seas are surrounded by land regions with rapid population rise and economic development. Thus are facing with rapid environmental changes and have imposed on the already stressed marine ecosystems affected by climate change. The Huanghe estuary and adjacent Bohai is given as an example to address the response of biogeochemical variation and change to drivers. The Bohai, being an important commercial fish habitat and sea farm base, has been known for high primary production in the Chinese marginal seas, however, the Bohai is experiencing biogeochemical variations, such as eutrophication, pollution, and changing freshwater input and course shifts, massive and intensive aquaculture, over-fishing, excess land reclamation, and land use change; the effects of which may have disproportionately large impacts, which restricted the sustainability of Bohai ecosystem. This presentation will overview temporal trends in hydrological and biogeochemical data, the drivers of biogeochemical variations, and ecosystem and societal responses. This case study is vital in order to understand how biogeochemistry-ecosystem-human interactions in the Huanghe estuary and Bohai and extrapolate globally to predict and prevent similar marginal seas from experiencing major societal and ecosystem responses to biogeochemistry variations due to human influences.

Adapting to the variety of manifestations of climate change at shores of the Baltic Sea

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Climate change at the shores of semi-enclosed water bodies of complicated shape becomes evident via unexpected and often nontrivial patterns of changes in the properties of atmospheric and hydrodynamic forces that drive coastal processes. The overall storminess and wind speed in strong storms have not substantially increased the Baltic Sea basin. The increase in air temperature has led to significant decrease in the severity and length of the ice season. As a consequence, late autumn and winter storms exert an increasing pressure on sedimentary shores. They may cause a larger number of high storm surges than in the past because of the lack of protective ice cover and thus may require specific adaptation measures.

There is increasing evidence that changes in atmospheric forcing, first of all the broadening of the North Atlantic storm track to the north-east, have affected pathways of some storm cyclones in the Baltic Sea region. These modifications have apparently led to changes in the directional structure of strong winds. The implications include a rotation of geostrophic air-flow direction in part of the Baltic Sea, change in the typical wave directions in the Baltic Sea proper, and production of sequences of atmospheric forcing events that push large amounts of water into the Baltic Sea. A direct consequence is a rapid increase in extreme water levels in certain (but not all) locations of the eastern Baltic Sea.

It is natural that different locations of this water body of extremely complicated shape exhibit substantially different reactions to the changes in forcing. Extreme water levels increase at a rate of up to 10 mm/yr at the “downwind” eastern shores of the Gulf of Riga and Gulf of Finland. This rate is much smaller (3–4 mm/yr) in the rest of the Baltic Sea. While the amplitude of the seasonal course of water level is increasing in most of the Baltic Sea, it clearly decreases in Latvian waters where also the signal of global sea level rise is suppressed. Moreover, the processes that drive the extremes are not necessarily statistically stationary and advanced mathematical methods may be required for their adequate description.

This variety of manifestations of changes in forcing may lead to radically different reactions of different shore segments of the Baltic Sea to the changing climate. A rotation in wave directions in strong wave storms has led to substantial changes in the magnitude of wave-driven net sediment transport along the eastern Baltic Sea shore. Further course of this process may greatly change the pattern of erosion, transit and accumulation areas in this region and seriously decrease the safety levels in small harbours that are designed to offer protection against winds and waves from a certain direction.

Adaptation to these changes may include a modification of maintenance schemes and reconstruction strategies of affected harbours and waterways as well as a major revision of plans for coastal protection and beach nourishment. An increase in extreme water levels in densely populated coastal sections requires a number of additional adaptive measures, from a modification of insurance policy and implementation of early warning systems to specific safety regulations for (re)location and construction of critical infrastructure, and for planning of evacuation measures.

To better understand the potential of the listed changes on the course of coastal processes and to adequately estimate possible implications of the consequences of such changes, it is important to develop the ability for high-resolution numerical modelling of drivers and processes in affected areas together with advanced mathematical methods for adequate estimates of extremes, analysis of worst-case scenarios and at least qualitative understanding of cumulative effects of combinations of simultaneously acting unfavourable processes.

How to develop a marginal sea system understanding by connecting natural and human sciences?

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Natural sciences provide mounting evidence on multiple stress on the coast and its ecosystems (e.g., World Ocean Review, 2017). Human sciences (the arts and humanities) describe the deep emotional and social connection to the sea (Omstedt, 2020). However, there is a large gap between marine understanding and treatment of the sea, which illustrates a weak coupling between facts and feelings. With increasing population and urbanization, often in large cities along the coasts, human alienation may increase and reduce society's support for environmental protection. Facts are not enough; instead, a deeper understanding of human behavior and attitudes is needed.

Humans are an integral component of the marginal sea system, but natural scientists often treat them as a black box from which effects of emissions are prescribed, such as concentrations of nutrients and carbon. To deepen the knowledge and open the human box, one needs to consider large differences in time, space scales, culture, and tradition. For example, the time scale is vital as perceptions of the sea have gone from being seen as an unlimited resource to a limited resource now in danger. Still, the sea is often treated as an unlimited resource, but, e.g., overfishing, climate change, plastic waste, and medicine products all challenging the sea's limits.

Two recent works for the ocean are also relevant for the marginal seas. In the first, Caudet et al. (2020) outline a roadmap for using the UN Decade of Ocean Science for sustainable development. In this roadmap, some recommendations are 1) Stronger science integration (goes slow). 2. Ocean-observation systems (relevant data to support good science). 3. Improved science-policy interfaces (science diplomacy and communication) 4. New partnerships backed by 5) A new ocean-climate finance system and 6) Improved ocean literacy and education (to modify social norms and behaviors).

In the second, Franke et al. (2020) suggest an ocean-health framework that needs to include observation to detect stability (resilience), integrity (production), and beauty (diversity). However, a healthy marginal sea is only possible when humans and the sea are in harmony, depending on how we interact. Processes fostering progress or deterioration of health are here viewed to be aligned with the UN Sustainability Development Goals.

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Multiple factors of Earth system changes in the Baltic Sea region

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Feedbacks within the complex regional Earth system (e.g. the atmosphere, land surfaces, water bodies, biosphere, biogeochemistry, geology) may be complicated and difficult to disentangle, more so when human behavior (i.e. the anthroposphere) is involved. The different factors of change may affect each other, synchronously or cumulatively, creating negative or positive feedback effects. While the direct impact of an effect may be straightforward and easy to detect and explain, the indirect effects are mostly more difficult to uncover. Extreme precipitation events have meteorological causes, which may be connected with changing climate, but the impacts of such events on the human environment, like flooding, damage or drying crops may be caused or exacerbated by human design (impervious surfaces or other land use changes like mono-cultural agriculture). Therefore, we are facing a complex system of effects and feedbacks between climatic and non-climatic factors. Moreover, politically motivated management decisions, which have no or little natural scientific groundings, may have stronger impacts than natural ones and may be even more unpredictable than those.

The intention of this paper is to make a simple and rough inventory of factors and connections, covering the above aspects as far as possible; information on individual factors will have to be limited and just of overview character. The use of this paper, thus, should be to serve as an easily accessible introduction to this topic, with an emphasis on the Baltic Sea region, while most aspects can be transferred to similar marginal sea regions of the world. We would like to elaborate the relationships of the different factors with climate change on the one hand, and between the different factors on the other hand. As humans are heavily involved, socio-economic issues have a strong relevance on most factors and connections described here.

Climate and other human-induced factors are regionally very different, and the warming with its direct and indirect consequences (e.g. sea level rise, hydrological changes) affects all natural processes and may impact other factors. Here, we make an inventory of different factors including climate change, and assess how they may interact, as far as there is evidence in the scientific literature. Some factors may be completely independent from the warming; others may directly or indirectly be influenced by the warming. The list of factors treated here cannot be complete and should be updated continuously.

This paper is part of the Baltic Earth Assessment Reports (BEAR) and was initiated by the Baltic Earth Working Group on “Multiple Drivers” and the dedicated Baltic Earth Workshop “Multiple drivers for Earth system changes in the Baltic Sea region” in Tallinn, Estonia in November 2018.

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Impacts of changing society and climate on nutrient loading to the Baltic Sea

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This paper studies the relative importance of societal drivers and changing climate on anthropogenic nutrient inputs of the Baltic Sea. Shared Socioeconomic Pathways and Representative Concentration Pathways are extended at temporal and spatial scales relevant for the most contributing sectors. Extended socioeconomic and climate scenarios are then used as inputs for spatially and temporally detailed models for population and land use change, and their subsequent impact on nutrient loading is computed. According to the model simulations, several factors of varying influence may either increase or decrease total nutrient loads. In general, societal drivers outweigh the impacts of changing climate. Food demand is the most impactful driver, strongly affecting land use and nutrient loads from agricultural lands in the long run. In order to reach the good environmental status of the Baltic Sea, additional nutrient abatement efforts should focus on phosphorus rather than nitrogen. Agriculture is the most important sector to be addressed under the conditions of gradually increasing precipitation in the region and increasing global demand for food.

Keywords: agriculture, climate adaptation, eutrophication, integrated modelling, long-term projections, wastewater treatment

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The role of culture, tradition and indigenous knowledge in coastal management

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Introduction
We expect coastal management plans and decisions to be based on quality science incorporating solid theory and empirical evidence, perhaps modified by socio-economic imperatives, interpreted by competent practitioners and with a goal of sustainability. However, less tangible factors including history, culture, tradition, tenure systems, indigenous knowledge, and anecdotal evidence also play a part in the coastal management process. While there is most often a willingness to incorporate all types of knowledge in the planning and decision making process, something incorporated into the concept of Integrated Coastal Zone Management (ICZM), actually doing so is more complicated, often leading to disappointment amongst stakeholders and claims of exclusion. In the past, coastal management has been typically reactive, and frequently perceived solely as being coastal hazard management. Management mistakes, of which there are plenty of examples, have frequently been attributed to lack of knowledge, but that excuse is becoming much harder to justify. Coastal management practitioners now have available an abundance of different sorts of knowledge, but face difficulties in determining its validity and in its integration. In this presentation, issues associated with some of these less tangible factors are explored, in a number of cultural settings.

Reconciling science and other knowledge systems
Scientific (including social science) investigation, the reporting of results and their use in management processes, is well established and understood, but traditional or indigenous knowledge and its use is less well established. Confidence in the value of the different systems increases each time it is shown that their findings converge, and examples can be found in, for example, geomorphic interpretations and in conservation methods.

Property rights, coastal setbacks and coastal erosion
There is little debate that one of the most effective coastal management practices is the provision, as much as possible, of a coastal setback or buffer in which only non-permanent structures are permitted. Healthy beaches can survive, providing continued amenity and ecosystem services, if they have room to migrate, but in many societies private property rights dominate whereby the right to protect a property line is virtually unassailable, where, if exercised, makes the loss of beach amenity inevitable. The use of so called 'coastal protection' structures such as seawalls, provides an excellent example of conflict between private property rights and public property rights. Some places still have an opportunity to retain effective setbacks due to traditional attitudes on where to comfortably live, or the historical context such as is the case in some ex-Soviet states (e.g. Estonia) due to past limits on access and building near the coast. In some societies (e.g. Torres Strait, Australia), the ability to retreat when there is coastal change has been a traditional necessity, but modern construction techniques and imposed tenure systems have made retreat almost impossible.

Rights of nature and mixed management systems
'Rights of Nature' is a growing legal and jurisprudential movement that promotes rights to ecosystems equivalent to human rights, and elements of it are now found in the laws of a number of countries (e.g. New Zealand, where a river has been granted the legal rights of personhood). The possibility of mixed coastal management systems, based on the rights of nature, traditional management systems and different types of knowledge are discussed.

Attitudes towards the coastal sea – challenge for the interdisciplinary science

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International treaty's, joint political agendas (like those set by UN or World Summit) present recommendations for the nature conservation or coastal management, that are addressed globally. We propose a hypothesis to be tested, that explains different attitudes in societies towards the coastal sea and its management. We assume that contrasting communities in countries like Japan, Indonesia, Poland and Germany represent different tradition, history and contemporary approach with regard to the coastal sea. The sea users (stakeholders) in all those countries are grouped in the main categories with regard to their relations to the sea: the source of income (e.g. fisherman, industry) , part of the property (e.g. government agency), cause of loss (all those whom sea claims land or infrastructure), source of spiritual value (sense of identity, place, wellbeing).

We assume, that some parts of the society will behave in a similar way regardless the country of origin – e.g. young, educated, middle class use to be liberal and environmentally concerned, and react alike for the new international regulations. Their relations to the sea is mainly socio-cultural. The fisherman and those of traditional jobs linked to the sea, are similar in their conservative approach, while the class of governmental professional emploees represent the current policy of their respective countries. Those professionals treat the sea as a source of income. The spiritual values of the sea are most important for the small, established groups of local inhabitants as well as for the visitors – recreationists, who seek the uniqueness of place and stress relieving contact with the sea.

Some of those attitudes are contradictory, some are synergical – e.g. nature conservationists have negative image in the eyes of all the other groups, as they are those, who limit the access and uses of the sea for the others. The wide spread marine education – ocean literacy is a main tool to solve the potential conflicts and obtain the positive response to the international regulations.

It is also interesting to observe the differences between island nations (Indonesia, i.e. Bali, and Japan) which has strong historical, economical and spiritual ties to the sea and countries where being surrounded by water does not influence the identity. Also the threat pose by the sea is much more visible and plausible in the island countries.

Another important factor is the connection of religion and religious believes with nature. How that would influence reactions of Balinese to the changes in the policy? Bali is an hindu island, with a very strong presence of everyday rituals connected with nature; nature, culture and humans are forming a triangle that cannot exists without each other – that changes the attitude of the Balinese towards nature.

It would be also valuable to look at the attitudes in regards to cultural dimension theory proposed by Hofstede, in which Asian cultures differ from Western cultures when it comes to individualism (IDV), power distance (PDI), uncertainty avoidance (UAI), and masculinity (MAS) (another models can be used, i.e. Inglehart-Welzel cultural map of the world). We can assume that countries scoring high on IDV will have more difficulties with complying with the new policy.

Session 3

Scaling/Mapping/Data Management

Ocean Sediment Data, Integrated, Local to Global, for Modelling the Marginal Seas (dbSEABED Project)

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Data on the sediment/rock composition of the surficial and buried parts of the seafloor is a critical input to models of the seafloor environment - whether they are process-numerical or machine-learning in style. Seabed composition data is complex (unlike bathymetric data), multi-parameter, and strongly influenced by the collection and analysis methods.
A long project, dbSEABED, has steadily amassed geological, compositional and physical properties data for over 6 million seafloor sites from shore to abyss, in all parts of the oceans. Open published data are overwhelmingly the source of the data. Efficiency of data accuracy, including software-enacted data quality filters, was the key to entering such large amounts of diverse data.
The research field of the project is sedimentology/stratigraphy/ecology, with application of advanced Heterogeneous Data Integration computer and math methods. A feature of the collection is the calibrated use of word-based data (alongside numerical analysis data), which is critical for reducing sparsity and potential data biases.
The database outputs include multiparameter point-wise, vector and gridded data. They have been used by collaborators in fields as diverse as global carbon budgets, marine groundwater chemistries, global deep-sea carbonate dissolution, underwater acoustics, fish ecology, study of hurricane impacts on continental shelves and slopes, deep-sea coral ecology, and fate of man-made objects at the seabed. The range of applications has been very gratifying. The outputs cover study-areas ranging in scale from worldwide, to the entire Arctic Ocean, to Gladstone harbor (Austr.). The database deals with sub-bottom stratigraphy of the seabed, a feature which could assist with the proposal of Marginal Seas modelling
The lecture will summarize the structure, content and application of dbSEABED data.

Spatial data integration and harmonization in the Adriatic Sea – how to make data FAIR (Findable, Accessible Interoperable and Researchable) for habitat and geological mapping

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The Adriatic Sea is a land-locked basin (ca. 200×800 km) of the marginal Mediterranean Sea, which has been shaped during the Cenozic buildup of the Alpine orogens, driven by the Africa-Eurasia plate convergence. The basin is relatively shallow, almost rectangular and can be divided into three sub basins: 1) the northern Adriatic, a broad shelf with depths shallower than 100 m connected to the biggest lagoon in the Mediterranean sea (the lagoon of Venice), 2) the middle Adriatic shelf basin, (270 m depth) and 3) the Southern Adriatic basin, with a depression of about 1200 m. It is characterized by an anticlockwise oceanographic circulation and multiple geo-biological facets. In this perspective, a substantial amount of heterogeneous data regarding geological, oceanographic, biological, and anthropogenic aspects and their interaction has been gathered through the years from different sources and for multiple scopes by the CNR ISMAR-ISP community.

To overcome challenges in data heterogeneity and fragmentation, to enable efficient data integration, and to ensure data FAIRness (FAIR: Findable, Interoperable, accessible and researchable) a 'Spatial Relational Database Management System' (RDBMS: Geodatabase) was created for the Adriatic Sea based on adapted INSPIRE guidelines, linked with a WebGIS (i.e. a web-based version of a geographical information system) and a metadata catalogue This spatial data infrastructure is also accessible via a Virtual Research Environment developed within the framework of the Horizon 2020 EVER-EST project. The EVER-EST VRE is a multidisciplinary platform based on research objects, which aggregate information in a form that can be processed by both humans and machines and that follow FAIR data principles. Research objects provide the basis for the development of e-infrastructures for preserving, sharing and reusing scientific data and knowledge within and across communities.

The integration and harmonization of this heterogeneous data sources is also the key to further develop interoperability with European marine data management infrastructures for handling and exchanging high variety of multidisciplinary data (e.g. EMODnet, SeaDataNet).

This paper shows and discuss the main steps and challenges to make the spatial data FAIR for habitat and geological mapping in the perspective of generating scenarios of the geological past and future developments by the application of numerical models.

EMODnet: Mapping the European shelf geology

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Although many European countries have comprehensive and highly varied geodata from their marine area, these data often remain incompatible across borders. However, pan-European studies and research for decision makers in politics, industry (e.g. regarding marine resources, wind-farm operators, etc.) and research, as well as planning for the offshore area, are dependent on harmonised geological datasets. The European Marine Observation and Data Network (EMODnet) was established by the European Commission (Directorate General for Maritime Affairs and Fisheries, DG MARE) in 2007 to mitigate this situation. Seven thematic projects, the 'lots' are responsible for the various characteristics of the European Seas within EMODnet: Bathymetry, Geology, Seabed Habitats, Chemistry, Biology, Physics and Human Activities.

EMODnet Geology, led by the Finnish Geological Survey, GTK) started in 2009, encompasses the following themes: seabed substrate, seafloor geology, coastal behaviour, events and probabilities, marine minerals and submerged landscape. All data can be downloaded from the EMODnet Geology portal: https://www.emodnet.eu/en/geology. BGR is leading the work package, seafloor geology (i.e. essentially the European shelf) to compile and harmonise the pre-Quaternary and Quaternary offshore geology and the geomorphology of the European Seas. This includes to date 36 partner organisations.

The seafloor geology compilation is based on the data from the EMODnet Geology partners (mainly geological survey organisations) and is derived from off-shore geophysical surveys (e.g. echo soundings or seismic profilers) and sampling (drilling or dredging). The major challenges are the heterogeneity of the data provided, with respect to the semantics, geometry, age and detail:

- The participating partner organisations has developed their own national /regional methods and classification systems as well as the legends upon which the geological information is mapped;
- some regions are investigated in comparatively high detail while others may be mapped in synthetic scales and/or discontinuously;
- Portrayal rules (colours, symbols) and map keys show great variation.

In order to ensure data interoperability and to present the resulting digital maps in a homogeneous way the information requires semantically and geometrically harmonisation. Thus, within the project standard feature types, vocabularies and map keys are defined, underpinned by existing standards such as the data specification of the EU Directive INSPIRE.

This presentation displays the background and aims of EMODnet Geology, demonstrates the harmonisation challenges and presents the results achieved so far.

Marine Benthic Habitat Mapping – A Case Study from the Salish Sea

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The Salish Sea is a marginal inland sea of the Northeast Pacific Ocean and consists of waterways associated with the Archipelagoes of the San Juan Islands of Washington State, USA and British Columbia, Canada. A diversity of habitats exists on the seafloor of the archipelagoes, the result of present and past tectonic and glacial activity. Consequently, a great diversity of flora and fauna occupy these habitats. In addition, this is a region of increasing commercial intensification such as shipping, fishing, recreation, and tourism, all of which have the potential to impact marine benthic habitats. For example, the potential of exporting more Canadian oil from its west coast ports will bring more tanker traffic to the Salish Sea and increase the risk for oil spills. Salmon, a major sport and commercial fisheries within the region, on the other hand are declining in population. This decline is not well understood but may be the result of global warming, decline of forage fish such as herring and sand lance, or overfishing, or a combination of these and other environmental factors.

In an attempt to understand the Salish Sea marine benthic habitats' dynamics, utility, and susceptibility to alterations a major seafloor mapping project is being conducted based on the geologic and geomorphologic interpretations of marine geophysical, geological, and biological data. This project consists of collecting and interpretation of multiple types of data consisting of multibeam echosounder (MBES) bathymetry and backscatter, unmanned aerial vehicle photos, acoustic sub-bottom profiles, seafloor samples and photographs, piston cores, and submersible observations. From these data detailed marine benthic habitat maps have been constructed that are being used to evaluate the presence and health of such flora habitats as eelgrass (Zostra marina) and such fauna habitats as rockfish (Sebastes spp.) and the forage fish Pacific sands lance (Ammodytes personatus), to mention a few habitat types that are being studied. This presentation and paper will focus primarily on the case study of Pacific sand lance (PSL) habitat.

PSL is a critical forage fish for a variety of mammals, birds and fish including minke whales and salmon as it preys upon zooplankton and acts as an energy transfer species from the lower to higher trophic levels. Pacific sand lance (PSL) seeks refuge and overwinters in sand-wave fields consisting of dynamic bedforms. The species prefers loosely packed, well-aerated, well-sorted, medium- to coarse-grain sand that it can easily burrow into. Such geomorphic features as active dynamic bedforms provide preferable habitats for PSL and depends on specific and unique oceanographic processes that can maintain the habitat's morphology and grain sizes. Understanding these processes is essential in forecasting alteration or destruction of such features, including changes that may be brought about by sea level rise, and impacts from seafloor infrastructure developments or sinkable oil spills. A well-studied sand-wave field in the San Juan Archipelago, which has been reported to harbor up to 12 million PSA was recently examined using the five-person submersible Cyclops 1. Observations, video recordings, and photography from this vehicle allowed for the assessment of modern seafloor processes that can be used along with fish and sediment sample data to determine physical preferences this fish needs to sustain its population. Changes in the seafloor current regime, sediment source, and anthropogenic disturbances can critically alter these dynamic bedforms. This case study provides insight into the structure of these bedforms, their composition, their persistence, their resilience to disturbance, and the susceptibility as an impact to seafloor infrastructure and to being impacted as a critical forage fish habitat.

Remote sensing in monitoring and management of the coastal zone – the southern Baltic Sea example

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Marginal sea coasts, especially when they are built from unconsolidated sediments, are very sensitive to global climatic and environmental changes. Investigated southern Baltic Sea coasts, includes dune coast composed of Holocene marine and Aeolian accumulation sediments, mainly sands and also some sections of cliff coast, composed of unconsolidated Pleistocene sediments, mainly glacial till and sands. Morphogenetic coastal processes of these coasts are determined by a complex interplay of the geological setting, eustatic sea-level change, glacio-isostatic adjustment, wave-driven sediment dynamics, storm surges, and aeolian processes acting on different time scales.

In terms of the presently observed increase of number and intensity of storm events and a general deficiency of sediments in the coastal zone, the determination of the accurate size and spatio-temporal distributions of changes occurring on the coast and volume of sediment taking part in sediment balance, are the most important issues to resolve for broadly defined coastal safety.

The numerical models, available to reconstruct the past and predict future coastal changes, need appropriate and accurate numerical data. The most important are hydro-meteorological inputs but using also information about coastal morphology and the magnitudes, structures, and spatial distribution of changes occurring within the coastal zone, the obtained model results can be more reliable. This information can be obtained with high precision based on remote sensing data like airborne photographs and airborne laser scanning technology (ALS; LiDAR- Light Detection and Ranging) or with lower precision based on satellite data. These methods are especially useful for quick data registration for large areas where access e.g. because of the narrow beach and cliff height can be difficult and traditional survey and photogrammetric methods are not feasible.

The observed considerable temporal and spatial variability of changes taking place in neighboring, geologically uniform coastal segments which are similar also in terms of evolutionary trends, points also, beyond the precision and accuracy of the measurements, to the importance of the appropriate selection of representative sites at which to forecast the magnitude of coastal changes. Not less important than the observation site location is also the selection of periods of time for the analyses. Inaccurate measurement, an accidental location, and a too-short period of observations, not accounting for the hydro-meteorological variability, may substantially bias the forecast and pose a potential threat for the infrastructure planned to be deployed at such sites.

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