Deciphering the ultra-high Holocene record of tropical cyclones, monsoonal variations, and Himalayan erosional fluxes from the shelf canyon off Bangladesh

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Abstract

The anaerobic shelf canyon offshore Bangladesh contains a rapidly accumulated sequence of graded fine-sand-mud beds and finely laminated mud. The high annual sediment flux of 45 - 20 cm measured by ^{137}Cs and ^{210}Pb distributions for the last 50 years is due to the direct connection of the canyon head to submarine delta of the Ganges and Brahmaputra. A considerable amount of the world largest riverine freight of 1 – 2 billion tons is deposited in the submarine delta of these rivers. Waves and currents created by tropical cyclones mobilize the shallow marine and coastal sediments into turbid hyperpycnal water masses which move into the canyon and are partly deposited as a graded bed facies. These graded sequences can be directly correlated with the historical record of all cylones affecting the area. Canyon deposits also comprise a finely laminated facies that is assumed to be deposited during the high riverine terrigenous flux and increased marine productivity of the summer monsoons.

According to seismic records, an up to 1000 m thick sequence overlies a major erosional hiatus. This sequence is assumed to consist of mostly Holocene sediments. Thus, the graded sequences of the canyon sediments contain a high-resolution archive of tropical cyclones, which can be used to test the link of frequency of cyclones to climatic changes. Geochemical analysis of terrestrial material, terrigenous and organic carbon will indicate changes of the weathering regime reflecting the climatic conditions onshore and the onset of agriculture. Use of isotopic and cosmogenic compositions of the detrital mineral fraction will document changes of source areas and the dynamics of erosion. The marine organic fraction will reflect marine productivity changes. Radiocarbon dating of selected terrestrial or marine biomarkers could be used for dating the Holocene sequence.

Introduction

The monsoon of Southeast Asia governs the seasonal changes in the direction of heat and humidity transfer from the sea to the continent, the pattern of precipitation, and the cyclone activity. This system is one the major components determining the stability and variations of the global climate. During the Holocene the summer monsoon has been most effective at about 7000 years BP and its intensity has declined since then. The rivers Ganges and Brahmaputra drain the central monsoon area, i.e. the eastern Himalayas, and consequently their deltaic and offshore sediments have recorded these changes.

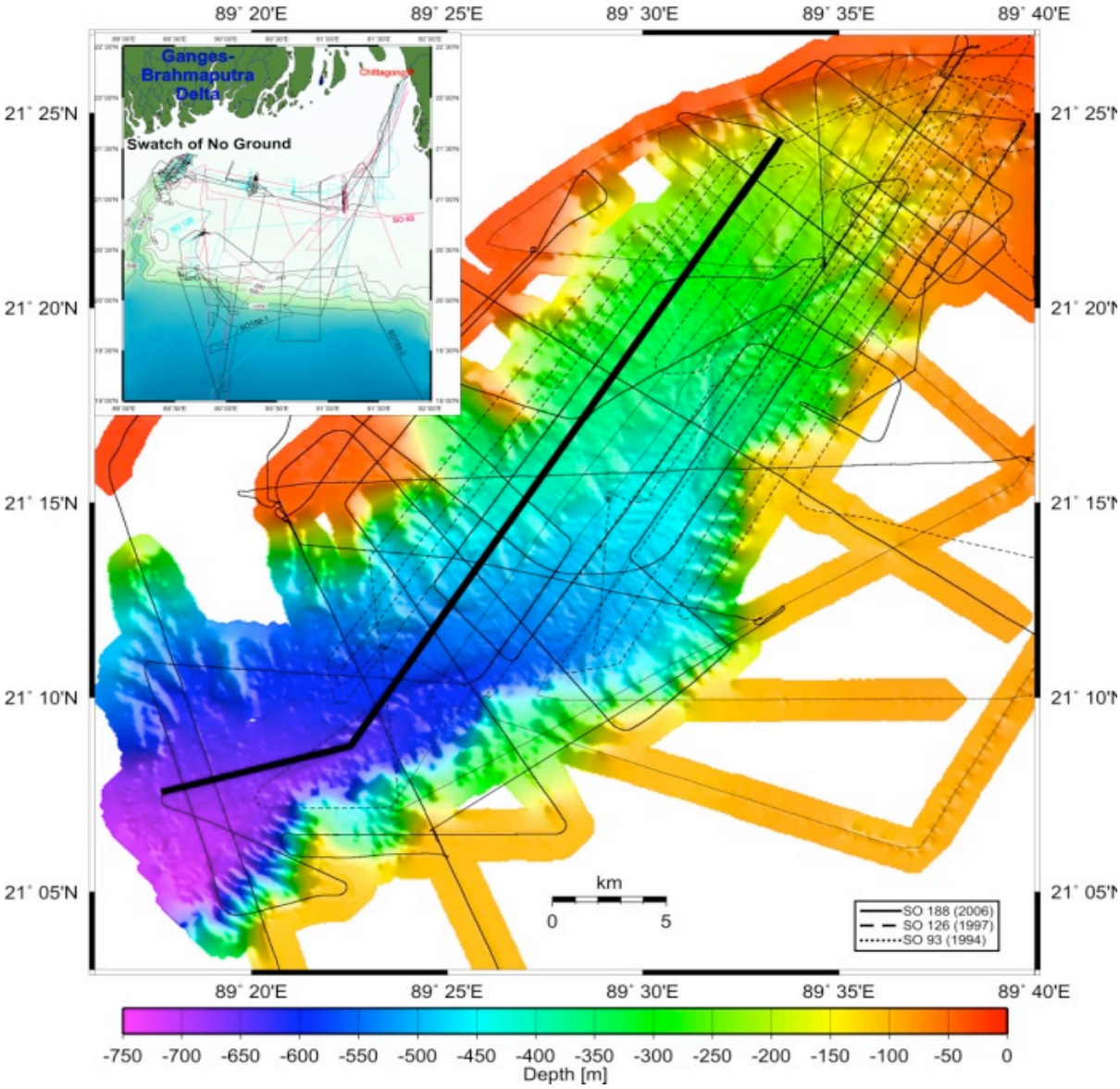

Fig. 1 Seismic lines and bathymetry.

Regional Setting and Previous Work

The shelf of Bangladesh is dissected by a deep canyon which serves as a conduit for the sediment transport from the delta to the deep-sea fan of the Bay of Bengal (Weber et al. 1997). The canyon which is named Swatch of No Ground (SONG) ends in an amphitheatre-like depression at 30 m water depth directly in the foreset beds of the submarine delta of the Ganges and Brahmaputra estuary (Fig. 1).

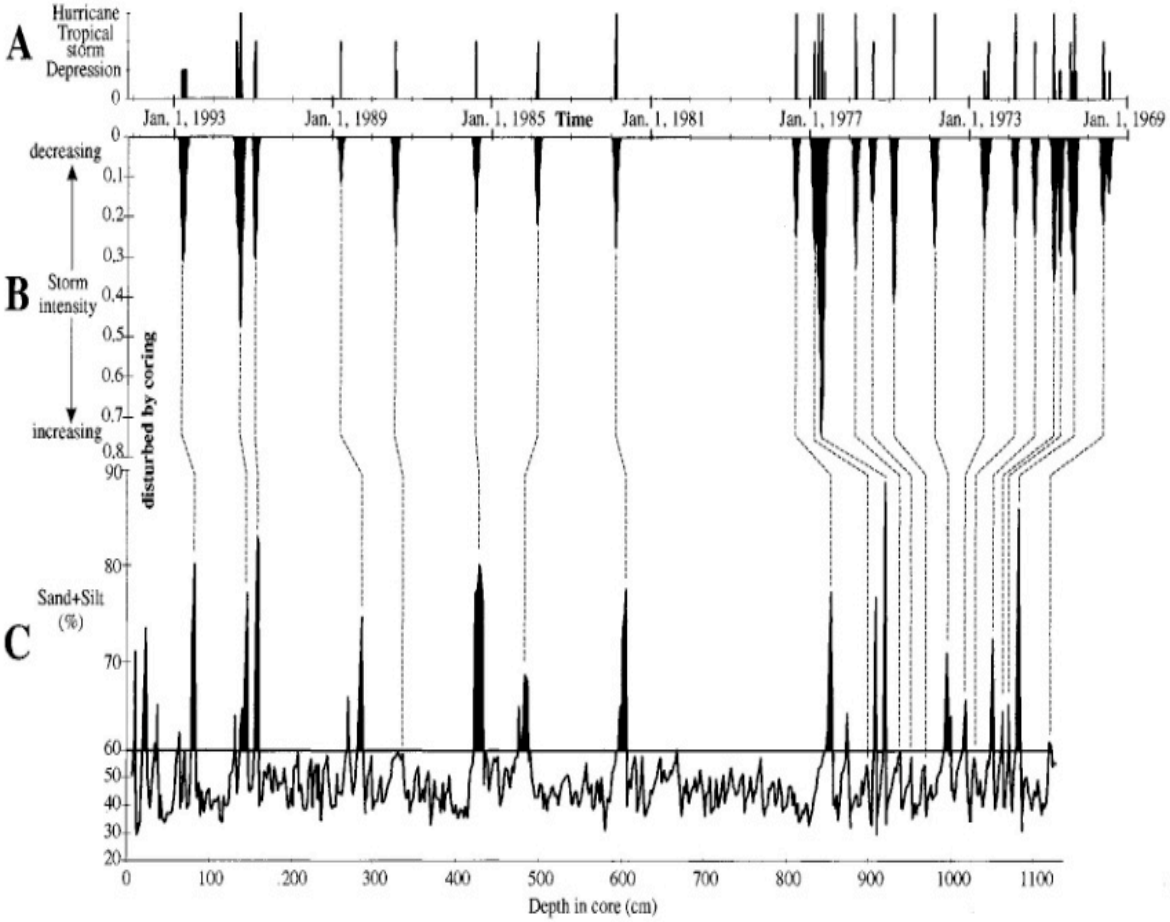

Fig. 2 Correlation of graded sequences with the historical record of cyclones (Kudrass et al.1998). The ^{137}Cs content increases towards the lower end of the 11,3 m long core. The increased frequency of cyclones in the seventies is well documented in the core.

The intersection of the canyon head with the submarine delta connects the canyon to the world highest riverine supply rate. Each year, one to two billion tonnes of material are transported by the Ganges-Brahmaputra during the high precipitation of the summer monsoon. The suspended material reaching the estuary consists mainly of fine sand, silt and clay. A significant part of the riverine material - about 30 % - is deposited in the submarine delta and the SONG (Kudrass et al.1998). Sedimentation rates of the submarine delta range between 10 and 0.1 cm per year, they increase to 20 cm to 45 cm in the SONG. The high sedimentary flux into the canyon with highly reactive mainly terrestrial organic material (less than 1 %) (Galy et al. 2007) produces anoxic conditions in the stagnant waters. Sediments in the canyon consist of three units: laminated muds, graded fine sand-silt-silty clay sequences and slumps. Slumped sediments are mostly confined to the canyon walls and rarely reach the centre of the canyon floor. The frequency of slumps may be related to earthquakes or cyclones mobilizing rapidly accumulated sediments at the margin of the canyon. Laminated

mud and graded sequences drape the canyon floor and its flanks. The graded sequences of the uppermost 11,3 m sediments can be easily correlated with the history of tropical cyclones since 1955 (dated by ^{210}Pb and ^{137}Cs) ((Fig. 2, Kudrass et al. 1998). Almost every tropical cyclone moving through the inner shelf of Bangladesh has left its signature in the SONG The grain-size distribution within the graded sequences indicates a deposition from hyperpycnal flows. The laminated muds seem to be deposited by tidal currents and floods during the summer monsoon when the fluvial transport reaches its maximum. In general, the sediments of the SONG are free of biogenic carbonate. Some sections, however, are slightly burrowed. The ubiquitous diatoms derive from fresh, brackish, and pelagic environments (Fenner pers.com.).

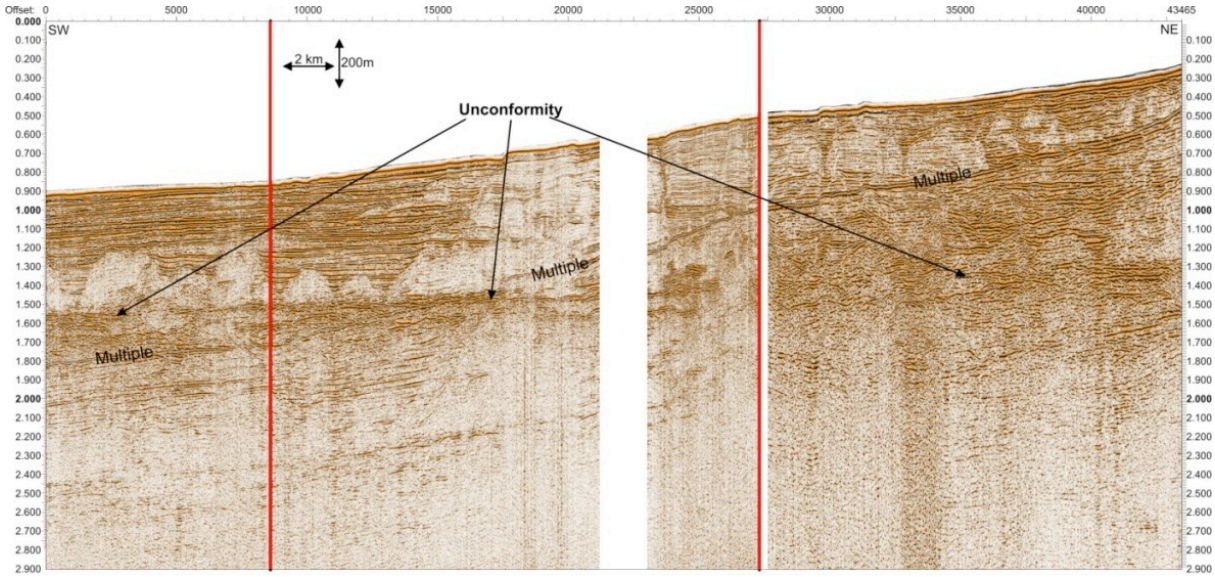

Fig. 3 Multichannel seismic profile along the thalweg of the SONG (see thick line in Fig.1 for location). Core with the cyclone record is recovered close to the NE part of the profile.

According to the seismic profiles the architecture of the canyon sediments is complex compromising faults, slumps, and filled channels (Fig. 3), however, thick packages of undisturbed sediments can easily identified. A major, probably erosive unconformity can be traced along the canyon thalweg at about 1200 below present sea level. Assuming similar sedimentation rates as the present ones, the unconformity could mark the last Glacial maximum, when the canyon formed a 200 km long fjord-like inlet (Fig.1). A 1 km thick sequence of probably undisturbed sediments could be recovered near the canyon head and a 500 m thick sequence at 700 m water depths. According to sediment echosounder profiles, the uppermost section of the sequences consists of parallel bedded sequences which drape the topography of deeper structures. Especially these cored sequences are mainly deposited by the high-density flow generated by cyclones. The lower sections of the sequences can be tentatively correlated to the progradation of the joint Ganges-Brahmaputra rivers in the early deglacial period when increased monsoonal precipitation (Weber et al. 1997) produced a massive terrigenous flux compensating the rising sea level (Goodbred & Kuehl 2000).

Expected outcome

The frequency variations of tropical cyclones affecting the northern rim of the Bay of Bengal can be directly obtained with very high resolution and reliability for the Holocene or parts of this period. In combination with other high-resolution climatic records (ice, lake deposits, speleothems, peat, marine sediments) the ultra-high resolution Holocene cyclone record can be used to test models of climatic and cyclonic variability in the monsoonal system. These

data can be used to understand the linkages between tropical cyclone dynamics and future natural and anthropogenic climate variability.

The geochemical composition of the terrigenous fraction will record responses of the Himalayan and Tibetan source areas to climatically tuned changes in glacial extent, hillslope erosion, and precipitation patterns. Consequently, the use of elemental and isotopic compositions will document changes in erosion distribution in the basin and relative inputs of Ganges and Brahmaputra sediments. Cosmogenic isotopic concentrations will be used to analyse changes in the rates and nature of erosion dynamics in the drainage basin. This will also give interesting constraints on anthropogenic forcing of soil erosion. The terrestrial organic carbon contains information on the vegetation onshore and may be supported by pollen analysis. The marine organic carbon reflects changes in productivity, sea surface temperature and probably salinity. Studies of diatoms and dinoflagellates may support the interpretation at critical time slices.

In summary, the SONG sediments contain a wealth of paleoenvironmental information with a time resolution of less than one month recording monsoonal precipitation, weathering conditions in the Himalaya, and paleooceanographic changes in the northern Bay of Bengal. First order information will be a probably almost complete Holocene record of tropical cyclones. This permits to test hypotheses of climatic control of tropical cyclones, hence to increase the tremendously important predictability of cyclones on short and long timescales.

Steps to achieve the goals

Defining drill sites to obtain a continuous record:

The acquired seismic multichannel data are used to trace discontinuities and to define continuous sections representing the Holocene.

Drilling at different sites can probably recover a complete Holocene composite record by hydraulic piston coring.

Reading and dating the palaeoenvironmental signals:

The graded storm deposits can be easily identified by a grain-size laser analysis. Indirectly multi-sensor core logging or XRF scanning can also produce reliable grain-size distributions. Bulk and molecular stable carbon isotopic analysis will be used to reconstruct the vegetation in the Ganges-Brahmaputra basin (Galy et al.,2007, 2008). The hydrogen isotopic composition of selected terrestrial biomarkers organic fraction will produce an integrated signal of the precipitation (Galy in prep.). The geochemical composition of the terrigenous fraction will indicate changes of weathering intensity onshore and thus reflect the climatic conditions onshore. Isotopic and elemental signatures (e.g., $^{87}Sr/^{86}Sr$, εNd, U/Pb of zircons, [Sr], etc) will be used to determine shifts in fluvial input and source terrains. Extraction of marine organic components and their isotopic and compositional analysis could reveal changes in productivity, temperature and perhaps salinity. ^{14}C dating is difficult as the conventional material is reworked. ^{14}C dating of marine components and of selected terrestrial biomarkers with very short residence time could be a powerful tool (Galy in prep.) Exact dating of these sediments is a crucial point in this project.

Literature

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