Marine and terrestrial input to sediment core GeoB 8331-4 offshore Oranje River mouth driven by Holocene South African environmental change

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The BMBF funded project RAIN (Regional Archives for Integrated iNvestigations) attempts to reconstruct the complex climate history of southern Africa at the continental – marine interface. The unique position of core GeoB 8331-4; offshore Oranje River facilitates the simultaneous analysis of climate signals from two different climate zones. On the one hand, the sediment influx from the Oranje River mouth is driven by precipitation changes in it´s source region; the Drakensberge mountain range (Compton & Maake 2007) and thus records changes in the ICTZ-driven summer rainfall zone on the south African east coast. On the other hand, variations in local riverine input and marine productivity reflect changes in the west coast oceanic and atmospheric circulation systems such as the Southern Hemispheric Westerlies. We aim to capture the various signals in the sediment and attribute them to source regions and driving factors.

Here we present first insights into variations in the carbonate, organic and clastic sediment components provided by initial XRF and infrared spectrometry analysis. According to lipid biomarker analysis the organic material at the core site is mainly of terrestrial origin. Furthermore, diatom analyses reveal that a substantial part of the biogenic silica may be associated to terrestrial diatom species and phytoliths. The organic sediment content reflected by the biogenic silica and total organic carbon concentrations as well as the Br/Ti ratio, is thus assumed to be a terrestrial signal. It shows a decreasing trend throughout the Holocene which may reflect a decrease in vegetation in either the east African Oranje River catchment area or the catchment area of local west coast rivers such as the Holgat River. This trend is mirrored in the Ti/Rb ratio as the main source of clastic material at the core site is also fluvial. A lower fluvial transport capacity during a drier late Holocene would have reduced the terrigenous input to core site. The carbonate sediment content recorded in the Ca/Ti ratio and the total inorganic carbon concentration reveals an opposing, increasing trend since the early Holocene. This may be driven by dilution/dissolution effects from an increased fluvial/organic input during the mid-early Holocene.

In concordance with this study, wetter than present conditions have previously been suggested for the early-mid Holocene (11-6ka) in the eastern South African summer rainfall zone (e.g. Dupont et al. 2011). This may have produced the strong early-mid Holocene terrestrial/fluvial signal at the core site, as the rainfall and vegetation would have been increased in the eastern Oranje River catchment. Furthermore, it has been suggested that the Southern Hemispheric Westerlies were shifted to the north in the aftermaths of the last glacial, producing heavier winter rainfalls along the western South African coast (Chase et al. 2007). This could additionally have lead to an increased terrestrial input from local rivers to the sediment site in the early-mid Holocene.

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Holocene hydrological and vegetation changes in the Orange River catchment, Southern Africa

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The Orange River as the major river in South Africa is the principal source of terrigenous sediment in the mudbelt offshore western South Africa (Compton et al. 2010). Most of the sediment deposited by the river originates from the easternmost catchment area (Drakensberg escarpment, eastern South Africa), dominated by the summer rainfall zone (SRZ) (Compton et al. 2010). The SRZ covers the eastern part and central southern Africa. However, southwestern South Africa is influenced by the winter rainfall zone (WRZ) (Tyson & Preston-Whyte 2000). For most parts of southern Africa there is a lack of high-resolution and continuous records due to the persistent dryness. Therefore, gaps remain in the reconstruction of Holocene climate variability and the existing regional-scale paleoclimatic studies show partly contrasting results for the environmental conditions (e.g. Chase & Meadows 2007). For instance, so far it is unclear if the mid-Holocene was wet or dry in the SRZ and how the SRZ shifts during the Holocene.

Our investigations give insights into centennial to millennial variations of climate variability in the Orange River catchment. These studies are embedded in the German-South African BMBF-funded project RAIN (Regional Archives for Integrated iNvestigations). We investigated the sediment core GeoB8331-4 located offshore the Orange River mouth. The core covers the last 10 ka. (Herbert & Compton 2007). Plant-derived *n*-alkanes and their compound-specific isotopes, δD and $\delta^{13}C$, provide insights into paleohydrological conditions and past vegetation changes, e.g. variations in C_4 contribution (e.g. Collins et al. 2013). Preliminary results of the *n*-alkane distributions suggest input derived from terrestrial higher plants, mainly grasses. Furthermore, first results of δD_{C31} and $\delta^{13}C_{C31}$ indicate drier conditions and higher C_3 contribution during the early Holocene than today. An increasing trend of wetter conditions and a higher amount of C_4 vegetation is recorded for the mid- and late Holocene. The wettest conditions in the Orange River catchment are recorded between 4 – 2 ka BP with a slightly decreasing trend until today.

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Late Holocene water balance changes in Groenvlei, a coastal lake in South Africa, as indicated by microfossil analysis

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Ostracods and foraminifers are the main microfossil groups to be used in a German-South African research project on climate and coastal evolution of South Africa targeting the late Quaternary. The cooperative project RAIN (Regional Archives for Integrated iNvestigations) is funded by the German Ministry for Education and Research. We analyse cores from lagoons, estuaries and coastal lakes in order to reconstruct changes in regional palaeoenvironmental conditions by multi-proxy studies. Here we present results of a 121 cm gravity sediment core from one of the studied coastal lakes called Groenvlei which was taken at 34°01.796' S and 22°51.409' E from a water depth of 5.8 m covering the past 4,200 cal BP.

Groenvlei is a closed lake in the Wilderness area, Southern Cape, South Africa and was aim of a first field campaign. The following environmental parameters were measured at four stations in October 2013: salinity (psu): 2.3, dissolved-oxygen concentration: 99.5 %, and pH: 8.81. Surface sediment samples contain a low diversity brackish water ostracod fauna with *Physocypria*, *Gomphocythere* and *Chrissia* cf. *hodgsoni* dominating and a few foraminifers as *Miliammina fusca* and trochamminids in the shallow water. Surface samples from the central part of the lake did not provide any foraminifer tests.

The sediments of Groenvlei mainly consist of autochthonous carbonates. Ostracods are present in all studied samples. The upper half of the core yields several hundreds to thousands of valves per cm^3, whereas very low abundances are characteristic for the older part. Foraminifers are only present in some samples scattered over the core and in very low numbers. They show a bad state of preservation in all cases. Hence, we regard the foraminifers as redeposited.

Based on the abundances of the different ostracod species and the Renkonen similarity index, four zones can be distinguished: The basal Zone I (4200-3600 cal BP) is characterized by dominant *Paracypris* sp. and *Sclerochilus* sp. Low abundances shows *Loxoconcha* sp. at this part. A shift in the spectrum of species is remarkable in Zone II (3600-2920 cal BP). *Sarscypridopsis* sp. and *Zonocypris* sp. have large quantities and the species of Zone I reach their minimum values. Zone III (2920-700 cal BP) looks similar to Zone I and *Paracypris* sp. reaches again more than 80 % in this section. The upper Zone IV (700 cal BP-present) yields a fauna as in the modern surface samples from Groenvlei.

Relying on a quantitative analysis of species distribution patterns and sedimentological parameters, we reconstruct the following development for the studied core: The decreasing trend of the brackish water ostracod *Paracypris* sp. and the limitation of ostracod taxa with marine origin to the lower part of the core indicate first mesohaline salinity evolving to oligohaline conditions in the upper part as today. Salinity variations are also indicated by changes in the mineralogy. During periods of high salinities aragonite is the dominant carbonate mineral, whereas times of lower salinities are mainly characterized by the deposition of calcite. A distinctively higher proportion of the phytal ostracod genera *Sarscypridopsis* and *Zonocypris* in Zone II was caused by the development of a dense submerged macrophytal cover disappearing thereafter. The general lack of autochthonous foraminifer associations points to a continuous separation from the sea for the entire studied period because mesohaline waters could house brackish water foraminifers as documented from present day estuaries of the region. Hence, we assume salinity to be a climatic signal reflecting changes in precipitation/evaporation ratio and not an ongoing separation from the sea. A late Holocene tendency of increasing precipitation is concluded.

RAIN (Regional Archives for Integrated iNvestigations): A project using terrestrial and marine archives for the assessment of Late Quaternary climate variability and environmental change in southern Africa

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The RAIN project is an interdisciplinary approach to investigate the climate evolution and ecosystem change around several archives from three different climate zones of southern Africa: The winter rainfall zone (WRZ) located at the south-western tip of the continent, the year-round rainfall zone (YRZ) as a transition area and the summer rainfall zone (SRZ) covering the remainder of the sub-continent. The climate of southern Africa is strongly influenced by alterations of ocean currents, such as the Agulhas and the Benguela currents. Therefore, RAIN aims to assess both marine and terrestrial records to improve the knowledge about land-ocean interactions during the Late Quaternary.

The RAIN project is funded by the German Federal Ministry of Education and Research (BMBF) and is divided in sub-projects focusing on different research topics such as lacustrine sediments, micropaleontology, biomarker studies, and marine sediments. Within these interlinked sub-projects a wide range of methods is used to generate and compare various multi-proxy records from all climate zones of southern Africa. The applied methods include analyses such as grain size distribution, biological analyses like pollen, diatoms or ostracods and (in-)organic geochemical analyses, such as XRF-scanning or isotope ratios of biomarkers.

Here we focus on lacustrine sediments: two field campaigns have been carried out, the first in October 2013 to several coastal lakes in the Wilderness Embayment at the Southern Cape Coast, which is part of the YRZ, the second in May 2014 to Verlorenvlei, a lake in the WRZ near the coast to the Atlantic Ocean. First results from laboratory work as well as first interpretation approaches for the obtained sediment cores will be provided in this contribution.

During the fieldwork in the Wilderness area it was possible to recover a 30.5 m long sediment core from Eilandvlei, a brackish lake that is connected to the Indian Ocean via an estuary. Radiocarbon dating reveals a basal age of about 10,300 cal. BP. Up to now, this ultra-high-resoultion record of environmental change during the Holocene represents a unique discovery for southern Africa. Using Ca and Sr XRF-scanning data from this sediment core, different phases of deposition can be reconstructed. While high Ca and Sr values can be linked to periods when the deposition of marine sediments was dominant, low Ca and Sr values are indicative for times during which the sediments were mainly characterized by a terrestrial origin.

Furthermore, we present first results from a sediment core from Groenvlei, another lake in the Wilderness region that has recently no connection to the ocean. The sediments of this lake are predominantly autochthonous carbonates. As XRD results show, there have been phases when calcite sedimentation was dominant indicating a salinity similar to recent conditions. In contrast, during periods when aragonite was the dominant carbonate phase, it can be assumed that the lake water of Groenvlei was characterized by higher salinities. These higher salinities are either caused by an aboveground, direct connection to the ocean or by a lower precipitation/evaporation ratio. The latter seems to be more probable, since there is a general lack of autochthonous foraminifera associations in the recovered sediment core.

Investigation to Holocene vegetation dynamics in western South Africa

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South Africa, located at the interface between tropical and subtropical climate zones as well as between the Indian and Atlantic oceans, is an important region for Quaternary environmental research and Holocene climatic history. It is influenced by both atmospheric and oceanic circulation systems. The alternating seasonal dominance of these systems results in a strong gradient in precipitation from the west to east of South Africa, which is divided into three rainfall zones: a winter rainfall zone (WRZ), a year-round rainfall zone (YRZ) and a summer rainfall zone (SRZ). Although South Africa is known to have experienced phases of significant climate change, paleoenvironmental evidences of the region are often fragmentary due to incomplete sediment archives and a scarcity of precisely dated terrestrial materials. To better understand the millennial to multi-decadal driving forces of regional climate and vegetation, we need more information about the Holocene evolution of continental hydrology. However, the driving forces of continental hydrology during the Holocene are debated and four different drivers of regional climate have been proposed: 1) effects of sea surface temperature on continental hydrology; 2) solar forcing; 3) strength and latitudinal position of the westerlies; 4) intensification of human activities.

From a 887cm long gravity core (GeoB 8331-4) covering the last 9.9ka recovered just south of the Orange River mouth from the inner continental-shelf, we generated a pollen and microcharcoal record to reconstruct the Holocene climate and vegetation of South Africa. Pollen is mainly transported by the Orange River from its catchment area in the SRZ. Additionally, there is continuous supply of pollen from the Cape region delivered by the SE trade winds. Pollen from five different biomes has been found: Succulent Karoo, Nama Karoo, desert, savanna and Fynbos.

Presence of Renosterbos vegetation (Fynbos biome) is indicated by a percentage maximum of *Stoebe*-type pollen prior to 9.4ka, probably implying a northward shift or extension of WRZ. The expansion of Amaranthaceae /Chenopodiaceae, *Tribulus* and Aizoaceae between 9.4-8.9ka suggests warmer and drier conditions with more desert and Succulent Karoo. After 8.9ka, a rather moist savanna rich in grasses but with few trees expands and establishes between 6.4-3.1ka, implying increased summer rainfall. The low representation of Fynbos elements indicates retraction of WRZ southwards. After 3.1 ka, frequent occurrence of trees and shrubs pollen indicates the development of a more woody savanna compared to the open grass savanna of the middle Holocene, suggesting a southward shift of SRZ. Effects of human activities such as overgrazing and agriculture, are detected for the last 200 years.

Contrasting climate developments occurred in the SRZ and WRZ during the last 9.9ka. For the WRZ, the records suggest relatively humid conditions during the early Holocene resulting from an equatorward shift of westerlies. Climate in the WRZ, gradually deteriorated towards the mid Holocene, while the opposite is found for the SRZ. The mid Holocene amelioration of SRZ may be attributed to a southward shift of the Intertropical Convergence Zone.