Summary

Owing to their excellent fossil record, planktonic foraminifera play an important role as proxies for the reconstruction of oceanic conditions over geological time scales (e.g. Kucera et al., 2005). These proxies include the chemical composition of their shells that records the properties of the ambient seawater to which the planktonic foraminifer was exposed during biomineralization (e.g. Kucera and Schönfeld, 2007). The aim of this thesis is to investigate how planktonic foraminifera record seasonal change and ocean perturbations such as are commonly produced by large eddies passing through the Mozambique Channel.

In chapter 2 seasonal and sub-seasonal patterns are investigated in a one-year time-series of species fluxes of planktonic foraminifera. In addition to the winter indicator species *Globigerinoides sacculifer*, I find that also *Globorotalia tumida*, *Globorotalia menardii* and *Globorotalia cultrata* exhibit clear winter maxima. *Candeina nitida* exhibits a minor late autumn 2008 and a more prominent summer bloom in 2009. Shell flux ratios of summer species *G. ruber* and winter species *G. trilobus* mimic the seasonal sea surface temperatures (SST) pattern, whereas flux ratios of *Neogloboquadrina dutertrei* and *Globorotalia scitula* correspond to winter mixed layer deepening. Superimposed on the seasonal trend, *Globigerinoides ruber* shows early flux maxima, with the onset of isotherm deepening during the passage of eddies. However eddy-correlated fluxes of *G. ruber* have a minor impact compared to seasonal forcing. On an annual basis, the flux-weighted species composition is very similar to that found in core top sediments taken across the channel. In general, the one-year seasonal flux intercepted by the sediment trap appears to be a relatively average year, while the time-averaged sediments appear to preserve both seasonal and eddy-generated fluxes. Based on previously published stable isotope and trace-metal data (Fallet et al., 2012; Birch et al., 2013; Steinhardt et al., 2014; 2015), annual flux based calculated isotope and trace metal-based proxies correspond well with values measured in sea floor sediments, albeit slightly elevated calculated potential annual flux-weighted Mg/Ca values for *G. ruber*. Recent warming in the southern Indian Ocean might explain the calculated offset between sediment and sea surface temperatures.

In chapter 3 the element composition of four species of planktonic foraminifera, collected by sediment traps, are compared to in situ water column conditions in the Mozambique Channel. Single-chamber trace element composition of these foraminifera reveals a close coupling with hydrographic changes induced by anticyclonic eddies. Single-chamber Mg/Ca values for the surface dwelling *Globigerinoides ruber* as well as the thermocline dwelling *Neogloboquadrina dutertrei* follow temperature changes and reduced temperature stratification
during eddy conditions. At greater depth, *Globorotalia scitula* and *Pulleniatina obliquiloculata* record stable temperatures and thus respond to hydrographic changes with habitat deepening. During eddy conditions the thermal gradient between the surface water and the thermocline is reduced whereas the gradient between thermocline and deep water is larger. This is reflected in a reduced difference in the Mg/Ca based temperatures between *G. ruber* and *N. dutertrei* and a larger difference in Mg/Ca based temperatures between *N. dutertrei* and *G. scitula*. The temperature difference between the two species, *N. dutertrei* and *G. scitula*, is greater than Mg/Ca calibration-related uncertainties and hence likely to be a proxy suitable for down-core application. Furthermore, test Mn/Ca values indicate a relationship between water column oxygenation and Mn incorporation in these planktonic foraminiferal species. Coinciding with a water column O₂ minimum, *P. obliquiloculata* and *G. scitula* record higher Mn/Ca values in line with water column variability in dissolved Mn concentrations, whereas near-surface dwelling *G. ruber* and shallow thermocline dwelling *N. dutertrei*, inhabit well oxygenated surface waters and show lower Mn/Ca values in their tests.

Chapter 4 investigates the vertical migration of planktonic foraminifera through the water column during life, meeting a range of depth-related conditions as they grow and calcify. Single-chamber Mg/Ca is combined with single shell δ¹⁸O and δ¹³C of surface water *Globigerinoides ruber*, the thermocline-dwelling *Neogloboquadrina dutertrei* and *Pulleniatina obliquiloculata* and the deep dweller *Globorotalia scitula* from the Mozambique Channel. Species-specific Mg/Ca, δ¹³C and δ¹⁸O data combined with a depth-resolved mass balance model confirm distinctive migration and calcification patterns for each species as a function of hydrography. Whereas single specimen δ¹⁸O does not always reveal changes in depth habitat related to hydrography (e.g. temperature), measured Mg/Ca differences of the last chambers can only be explained by migration in response to changes in temperature stratification. Results show that the single chamber Mg/Ca and single test δ¹⁸O are in agreement with each other and in line with the changes in hydrography induced by eddies. Whereas single chamber Mg/Ca values are most affected by eddy frequency, seasonality is reflected more clearly in single test δ¹⁸O.

In chapter 5 I investigate the calcite veneer, crust or cortex that some planktonic foraminifera form at the end of their lifecycle. This additional calcite layer may vary in structure, composition and thickness, potentially accounting for most of their total shell mass and thereby dominating the element and isotope signature of the whole shell. In this chapter I apply laser ablation ICP-MS profiling to assess variability in thickness and Mg/Ca composition of shell walls of three encrusting species derived from sediment traps. Compositionally, Mg/Ca is significantly lower in the crusts of *Neogloboquadrina dutertrei* and *Globorotalia scitula*, as well as in the cortex of
Pulleniatina obliquiloculata, independent of the species-specific Mg/Ca of their lamellar calcite shell. Wall thickness increased by nearly half of the total thickness in both crustal species and nearly a third in cortical P. obliquiloculata, regardless of their initial shell wall thickness. Crust thickness and Mg/Ca decreases towards the younger chambers in N. dutertrei and to a lesser extent, also in G. scitula. In contrast, the cortex of P. obliquiloculata shows a nearly constant thickness and uniform Mg/Ca over the complete specimen. Patterns in the thickness and Mg/Ca of the crust indicate that temperature is not the dominant factor controlling crust formation. Instead, I present a depth-resolved model explaining compositional differences within individuals and between successive chambers as well as compositional heterogeneity of the crust and lamellar calcite in all three species studied here.

In chapter 6 “Synthesis and perspectives”, results of the different chapters in this thesis are combined to calculate the potential differences of the various species used throughout the studies of this thesis. The calculation of the potential geochemistry (Mg/Ca and $\delta^{18}$O) takes into consideration shell fluxes and takes the differing crust and lamellar calcite components of the foraminiferal shell. Furthermore, this chapter also discusses issues that could potentially complicate the proposed eddy proxy. Also, inter- and intra-species differences of foraminiferal calcite U/Ca are discussed and compared to previous findings. Also, an attempt is made to speculate about promising research directions for the future.