Contents

Abstract . . . . . **iii**
Résumé français . . . . . *iii*
English abstract . . . . . *v*
Abbreviations . . . . . **xxiii**
1 Introduction **1**
1.1 Climate change, the carbon cycle and the land-ocean carbon transfer 1
1.2 Short reviews of main topics covered in this thesis 5
1.2.1 Land-ocean exports: From lithology to ocean 5
1.2.2 The fate of riverine exports in the ocean 10
1.2.3 Global ocean biogeochemical cycling 12
1.2.4 Biogeochemical dynamics of the coastal ocean 15
1.2.5 The global riverine carbon loop 19
1.3 Aims and research questions 22
2 Oceanic CO_2 outgassing and biological production hotspots induced by pre-industrial river loads of nutrients and carbon in a global modelling approach **29**
2.1 Introduction 30
2.2 Methods 35
2.2.1 Deriving pre-industrial riverine loads 35
Terrestrial dissolved and particulate organic matter characteristics *38*
Phosphorus *39*
Nitrogen and iron *42*
Dissolved inorganic carbon and alkalinity *43*
Silica *44*
2.2.2 Ocean Model Setup 45
Ocean Biogeochemistry *45*
Treatment of the river loads in the ocean biogeochemistry model *46*
Pre-industrial ocean biogeochemistry model simulations . . . *47*
2.2.3 Definition of coastal regions for analysis 48

2.3 Global weathering 49
2.3.1 Runoff, precipitation and temperature patterns 49
2.3.2 Global weathering yields and their spatial distribution . 51
2.4 Pre-industrial rivers loads 55
2.4.1 Global loads in context of published estimates 56
2.4.2 Spatial load distribution and identified hotspots 59
2.4.3 Exports to chosen coastal regions 63
2.5 Implications for the ocean biogeochemistry 64
2.5.1 Ocean state - An increased biogeochemical coastal sink . 65
2.5.2 Riverine-induced NPP hotspots 68
2.5.3 Riverine-induced CO_2 Outgassing 71
2.5.4 Sensitivity of the NPP and CO_2 flux in chosen coastal regions 72
2.6 Origins and fate of riverine carbon 75
2.7 Approach advantages and limitations 77
2.7.1 Rivers in an Earth System Model setting 77
2.7.2 Fate and consistence of terrestrial organic matter in the ocean 78
2.7.3 Arctic Ocean 79
2.8 Summary and conclusions 79
3 The efficient cross-shelf export of organic matter in the coastal ocean: Were continental shelves already a global pre-industrial CO_2 sink? 85
3.1 Introduction 86
3.2 Methods 93
3.2.1 Standard ocean model description 93
3.2.2 Model modifications and extensions 96
Consideration of POM mineralization in the coastal sediment *96*
Representation of riverine loads *96*
tDOM dynamics in the ocean *100*
3.2.3 Physical and biogeochemical indicators of continental shelves 102
Continental shelf definition *102*
Physical indicator: Shelf residence times (RTs) *103*
3.2.4 Biogeochemical Indicators: NPP, NPP_c, R_H, NEP and cross-shelf exports 105
3.2.5 Pre-industrial and present day simulations 106

3.3 Results and Discussion . . . 106
3.3.1 Implications of the model extensions for oceanic carbon cycling . . . 106
Global shelf area . . . *107*
Shelf sediment remineralization of POM . . . *107*
The oceanic fate of tDOM . . . *108*
Implications for global oceanic carbon cycle variables . . . *114*
3.3.2 Carbon cycling on continental shelves . . . 117
Physical variables: RT and MLD . . . *117*
Continental shelves organic carbon cycling (pre-industrial) . . . *123*
Modelled present day CO_2 flux in the context of present day estimates . . . *127*
Implications for the pre-industrial CO_2 flux . . . *131*
Spatial heterogeneity of the CO_2 flux on the Arctic shelves . . . *135*
Implications for the anthropogenic CO_2 sink . . . *136*
3.4 Model limitations . . . 137
3.5 Summary and conclusions . . . 138
4 The multifaceted 20th century perturbation of the oceanic carbon cycle: Could coastal ocean and river-induced NPP increases trump implications of increased open ocean stratification? . . . 141
4.1 Introduction . . . 142
4.2 Methods . . . 147
4.2.1 Overview of the model configuration . . . 148
4.2.2 Pre-industrial and anthropogenic perturbation of the land-sea fluxes . . . 150
4.2.3 Model initialization and transient simulations . . . 152
4.2.4 Definition of the coastal ocean in the TP04 configuration 155
4.3 Results and discussion . . . 156
4.3.1 Perturbations of riverine loads and of the physical ocean 156
4.3.2 20th century changes in coastal and open ocean nutrient limitation, NPP and CO_2 fluxes . . . 160
4.3.3 Perturbations of nutrient exports from the coastal zone . 171
4.3.4 Perturbation of global inorganic and organic carbon cycling in the coastal ocean . . . 177
4.3.5 Regional assessment of 20th century changes in NPP and CO_2 flux . . . 183
4.3.6 Implications for 20th century changes in subsurface oxygen levels . . . 190

4.4 Limitations of our model study 192
4.5 Summary and conclusions 194
5 Summary and conclusions 199
A Appendix 219
A.1 Freshwater Fluxes 219
A.2 Coastal Salinity and Nutrient Profiles 220
A.3 Derivation of carbon fluxes in the simplified coupled system . . 222
A.3.1 Terrestrial fluxes 222
A.3.2 Long-term ocean fluxes 222
A.4 Surface Nutrient profiles 226
Bibliography 229
Acknowledgements 261