Chapter 1
Introduction

Global carbon cycle plays a key role in the matter and energy fluxes of the Earth system. Carbon cycle links all the components of the Earth system: land, ocean and the atmosphere (Emerson and Hedges 2008). Since respiration and photosynthesis are the two fundamental processes in the carbon cycle, CO_2 becomes the crucial carrier of the matter in the environment.

Last few decades of mankind history are characterized by a rapid socio-economic transformation and, resulting from this, global changes. The greenhouse effect is one of the most appreciable and best recognized among all the global changes symptoms. It is believed that the mankind emits to the atmosphere approximately 22 Pg of carbon dioxide (CO_2) each year. The anthropogenic CO_2 emission causes alterations of carbon fluxes between the Earth's compartments and thus disturbs natural carbon cycling (IPCC 2007). Approximately 40% of the anthropogenic CO_2 is stored in the ocean. Thus, understanding the role of the marine carbon cycle in global and regional climate regulation is one of the major objectives of present-day oceanography.

The so-called biological pump plays a key role among the processes that govern the uptake of atmospheric CO_2 by the ocean. Biological pump is forced by the photosynthesis that transforms CO_2 into organic constituents of phytoplankton cells. After death and lyses of the cells, organic components are spilled out to become dissolved and particulate components of seawater. Significant part of the dead organic matter is mineralized in the water column, while its portion is deposited into sediments where is further mineralized. A fraction of the deposited organic matter escapes mineralization and is eventually buried into subsurface sediments. It has been estimated that, globally, from 0.01 to 1% of organic carbon originating from the primary production is buried in marine sediments and thus is excluded from the immediate carbon cycle (Rullkötter 2006).

Shelf seas play a key role in the global oceanic fluxes of matter and energy (Thomas et al. 2009). Although they make up a little over 7% of the global sea surface and less than 0.5% of the ocean seawater volume, shelf seas are

K. Kuliński and J. Pempkowiak, *Carbon Cycling in the Baltic Sea*,
Geoplanet: Earth and Planetary Sciences, DOI: 10.1007/978-3-642-19388-0_1,

responsible for 15–30% of marine primary production and, as much as, 80% of organic matter burial (Walsh 1991; Borges 2005; Bozec et al. 2005; Chen and Borges 2009). These features of shelf seas are caused by the high biological activity they support, activity that is driven by nutrients inputs from all of the adjacent environments (Gattuso et al. 1998; Pätsch and Kühn 2008; Thomas et al. 2009).

As a consequence of the high biological productivity, most global shelf seas are believed to act as net sinks for anthropogenic CO_2 (e.g., Chen et al. 2003; Borges et al. 2005; Chen and Borges 2009). Moreover, the CO_2 loads absorbed by shelf seas exceed those reported for the open ocean (Chen and Borges 2009; Takahashi et al. 2009). On the other hand it has been suggested recently that, in contrast to open shelf seas, some near-shore zones are identified as sources of CO_2 to the atmosphere (Chen and Borges 2009; Liu et al. 2010a). This is due to the large organic matter loads from land undergoing mineralization in well oxygenated seawater. Consequently, detailed studies of the carbon cycle in shelf seas are still required in order to clarify their role in the global carbon cycle. Although several attempts have been made to quantify the role of shelf seas in global CO_2 fluxes (Andersson and Mackenzie 2004; Thomas et al. 2004; Tsunogai et al. 1999), validation of the conclusions from these studies must be based on compilations of the results of detailed local studies. These enable the multifarious locally specific processes influencing CO_2 exchange between seawater and the atmosphere to be taken into consideration (Borges 2005; Borges et al. 2005; Chen and Borges 2009).

The Baltic Sea is a spatially and temporally highly diverse ecosystem (Dippner et al. 2008; Helcom 2009). This is the reason behind the significant discrepancies in the CO_2 air-sea exchange results reported in the literature (Ohlson 1990; Thomas and Schneider 1999; Thomas et al. 2003; Algesten et al. 2004, 2006; Kuss et al. 2006; Wesslander et al. 2010). Although the Bothnian Sea and the Gulf of Bothnia are considered to be a net source of CO_2 to the atmosphere (Algesten et al. 2004, 2006), the Baltic Proper with adjacent gulfs is believed to be an area within the European shelf, where the atmospheric CO_2 is absorbed despite the proven high spatial and temporal variability of CO_2 partial pressure in seawater (pCO_2) (Ohlson 1990; Thomas and Schneider 1999; Thomas et al. 2003; Kuss et al. 2006; Chen and Borges 2009). The calculated, final direction of the CO_2 exchange through the sea surface seems to be related to the boundary processes, specifically sinks and sources of carbon in the sea (Thomas et al. 2003). Although the biogeochemical processes governing the carbon cycle in the Baltic Sea are well defined qualitatively, quantification of carbon fluxes still requires detailed investigations.

The results regarding pCO_2 measurements in the Baltic, reported in the literature, were collected mostly at stations located in the open waters of the Baltic Sea. The near-shore zones and areas adjacent to river mouths have been largely omitted from pCO_2 measurements. However, these regions of the Baltic Sea are likely to be of special importance for CO_2 cycling, since it has been demonstrated worldwide that near-shore zones and river mouths are important sources of CO_2 to the atmosphere due to the high loads of terrestrial carbon (Frankignoulle et al.

1998; Borges 2005; Chen and Borges 2009; Liu et al. 2010b). The rivers flowing into the Baltic Sea drain an area that is more than four times larger than that of the sea itself. Moreover, the water volume the rivers discharge annually to the Baltic Sea amounts to almost 2% of the total Baltic capacity (Lass and Matthäus 2008), and is characterized by, both dissolved and particulate, organic matter concentrations that are several times larger than those in seawater.

The aspects mentioned above were the motivation for the authors to write this book and present a state-of-the-art comprehensive description of all the boundary carbon fluxes that provide the carbon budget for the entire Baltic Sea. The resulting budget indicate that the Baltic, as a whole, acts as a source of carbon dioxide to the atmosphere. However, if the Gulf of Bothnia is excluded, the remaining area turns into a net, strong, absorber of CO_2.

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