Abstract. Through the use of fossil fuels as an energy source, mankind is slowly changing the constitution of the atmosphere. The emission of CO$_2$ and other greenhouse gases changes the radiative properties of the earth/atmosphere system, and as a result climate is expected to become warmer. As a starting point for the sea-level rise scenario discussed here it is assumed that the globally-averaged increase of surface air temperatures will amount to 2 to 4 °C in the second half of the next century (i.e. around 2085 AD). One of the consequences of this warming is an accelerated rise in sea level, caused by thermal expansion of ocean water and further retreat of mountain glaciers. The Greenland Ice Sheet will also decrease in size, but on the other hand, Antarctica is expected to grow slightly due to increased snowfall. Taken together, the projection for future sea level presented here suggest that by 2085 AD, global sea-level stand will be 28–66 cm higher than the present level, which implies a rate of sea-level rise of about 2 to 4 times that observed during the last 100 yr. Our scenario does not include a contribution resulting from the possible collapse of the West Antarctic Ice Sheet. If this collapse is indeed likely to occur after the major peripheral ice shelves have thinned considerably, the effects on sea level will be small in the coming 100 yr. First, the oceans surrounding Antarctica must have warmed sufficiently to reduce the winter sea-ice extent to allow circumpolar deep water to penetrate into the sub-shelf cavities, thus increasing basal melt rates on the ice shelves. Of course, on longer time scales, West Antarctica could become the major contributor to rising sea level.

1. Introduction

Many processes can cause sea level to change, regionally as well as globally. In fact, sea level has been rising and falling during the world’s history. During the last centuries, however, sea level has been rising so slowly that for most practical purposes it has been considered as being (nearly) constant. Adaptations of coastal areas have heretofore not posed too many problems and mankind has settled freely on the fringes of the world’s oceans, living in sensitive balance with the threats of the sea.

But there may be a change at hand upsetting this delicate balance. An accelerated rise in sea level is anticipated as one of the consequences of the greenhouse effect. The greenhouse warming was discussed in a companion paper (Van der Veen, 1987b) and its main conclusion is that global climate will become warmer in the next century. Model experiments suggest that this warming will be about 2 to 4 °C in the second half of the next century. The temperature increase will not be uniform, however. In the polar regions it is expected to be about three times the global average.

In order to assess the consequences of this warming for global sea level, it is
necessary to understand the factors controlling sea level, and to identify the potential contributors to an accelerated rise. This is done in the next section, while in Section 3 the sea-level rise as observed during the last 100 yr, and possible explanations for this rise, are discussed. Section 4 provides a projection of future sea level. The purpose of this scenario is not so much to give an accurate projection, as well to estimate the contribution of each potential source and to provide an order-of-magnitude estimate. Unfortunately, this seems to be the best that can be achieved at present, because of all the uncertainties involved.

2. Factors Controlling Sea Level

Although sea-level variations are not solely caused by climatic changes, we will regard sea level as a climatic parameter. Hence, short-term fluctuations such as wave set-up and tides, nor global tectonic effects are considered in the following. Before discussing the factors which cause sea-level variations, we define sea level. When the vertical displacements of the sea surface are measured at one particular site and averaged over the period of observation (which should be sufficiently large so that short-term fluctuations can be filtered out) the mean sea level (MSL) for that site is obtained. If the observations are extended over a longer period, changes in the MSL can readily be detected. These changes will be referred to as relative sea-level movements since they are specific for one particular site. These relative sea-level movements are caused by eustatic sea-level changes (i.e. changes in the global sea level relative to the centre of the earth) and apparent sea-level movements (caused by regional processes such as vertical crustal displacements). The latter give rise to large regional differences. For instance, in Louisiana (U.S.A.) about 100 km$^2$ of land is lost each year as a result of subsidence at a rate of 1 m per century, whereas in Finland (where the crust is still rising since the disappearance of the Fenno-Scandinavian Ice Sheet), the harbors become increasingly shallower.

Figure 1 is a scheme of the factors governing sea level. Of course there exist many feedback mechanisms (for instance the interaction between sea-level rise and ice-sheet retreat), but nevertheless we discuss these factors separately to get a better understanding of why sea-level changes occur.

2.1. Vertical Movements of the Earth's Surface

Vertical displacements of the earth's crust result in (regional) apparent sea-level changes, but can also lead to a global eustatic sea-level change when the volume of the ocean basin is altered. Crustal movements can be of tectonic or isostatic nature, or can be caused by very local processes as compaction or settling. In the latter case sediments are compressed by the weight of above-lying layers. The amount of compaction depends on the structure of the sediments. For instance