

GLOBAL SEA RISE: A REDETERMINATION

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Abstract. It is well established that sea level trends obtained from tide gauge records shorter than about 50-60 years are corrupted by interdecadal sea level variation. However, only a fraction (<25%) of even the long records exhibit globally consistent trends, because of vertical crustal movements. The coherent trends are from tide gauges not at collisional plate boundaries, and not located in or near areas deeply ice-covered during the last glaciation. Douglas (1991), using ICE-3G values for the postglacial (PGR) rebound correction, found 21 usable records (minimum length 60 years, average 76) in 9 oceanographic groups that gave a mean trend for global sea level rise of $1.8 \text{ mm/yr} \pm 0.1$ for the period 1880–1980. In that analysis, a significant inconsistency of PGR-corrected U.S. east coast trends was noted, but not resolved. Now, even after eliminating those trends, more (24) long records (minimum 60 years, average 83) are available, including series in the southern hemisphere not previously used. The mean trend of 9 groups made up of the newly-selected records is also $1.8 \text{ mm/yr} \pm 0.1$ for global sea level rise over the last 100+ years. A somewhat smaller set of longer records in 8 groups (minimum 70 years, average 91) gives $1.9 \text{ mm/yr} \pm 0.1$ for the mean trend. These values are about an order of magnitude larger than the average over the last few millennia. The recent (in historical terms) dramatic increase in the rate of global sea level rise has not been explained, and no acceleration during the last century has been detected. This situation requires additional investigation and confirmation. VLBI/GPS/absolute gravity measurements of crustal motions can be employed to correct many long (60+ years) tide gauge records not now usable because of vertical crustal movements, improving the geographic coverage of sea level trends. Direct altimetric satellite determinations of global sea level rise from satellites such as TOPEX/POSEIDON and its successors can provide an independent estimate in possibly a decade or so, and thereby ascertain whether or not there has been any recent change in the rate of global sea level rise.

1. Introduction

The issue of global sea level rise (GSLR) has aroused much interest because it is of both great practical and scientific importance. As a practical issue, GSLR has major impacts on most coastal regions. For discussions of these impacts, see Bird (1993), Warrick et al., (1993), and Nicholls and Leatherman (1994). They document the serious consequences of even a few-mm/yr increase of sea level. As a scientific issue, GSLR is a unique indicator of global climate change, potentially providing a means for evaluating climate models via their hindcasts and forecasts.

Summaries and reviews of the issue of global sea level rise (GSLR) normally state that the value over the last 100 years or so lies between 1 and 2 mm/yr (e.g., Warrick et al., 1995). Douglas (1995) reviewed the more than one dozen studies and determinations of GSLR from tide gauge data made since 1980, and noted that all but one of the most recent estimates (1989 and later) conclude that global (eustatic) sea level has risen during this century at a rate much closer to 2 mm/yr than 1 mm/yr (Peltier and Tushingham, 1989; Trupin and Wahr, 1990; Douglas, 1991). This is

not to say that there is a consensus concerning the rate of rise of eustatic sea level; some authors do not agree that it can be measured at all. Barnett (1984), Pirazzoli (1989), Emery and Aubrey (1991), and Groger and Plag (1993) all argue that the existing tide gauge record is inadequate for the task of determining a global value for sea level rise. Douglas (1995) considered their arguments, and concluded that in each case the authors depended on sea level records of insufficient length and/or from unsuitable sites to reach their conclusions. These issues are considered again below.

It is interesting that an accurate estimate of GSLR may not in fact present an accurate picture of the thermal expansion of the oceans and addition of melt water. Chao (1991) and Gornitz et al. (1995) calculate that during the last 40–50 years an additional amount of water equivalent to 0.7–0.9 mm/yr of GSLR has been stored in large and small reservoirs and other sinks, so that a much higher contemporary rate of GSLR than derived from tide gauge trends is being masked.

The contemporary value of GSLR stands in sharp contrast to the rate during the previous several millennia. During that time, GSLR was apparently about an order of magnitude less (Flemming, 1978, 1982; Flemming and Webb, 1986; Kearney and Stevenson, 1991; Shennan and Woodworth, 1992; Varekamp et al., 1992; Peltier (this issue); Gornitz, 1995b; Kearney, 1996). In contrast, for the next century various authors contend that global sea level will rise at a faster rate than at present because of global warming. The Intergovernmental Panel on Climate Change (IPCC) report (Houghton et al., 1990) gives for the “business-as-usual” scenario of global warming an additional sea level change of 18 cm by 2030 and 44 cm by 2070 (the latest IPCC Sea Level assessment (Warrick et al., 1995) gives a somewhat smaller, but still significantly increased value.) Church et al. (1991), calculate a rise of 35 cm by 2050. Woodworth (1990) and Douglas (1992) have shown that such increases require an *acceleration* of sea level an order of magnitude greater (about $0.1\text{--}0.2\text{ mm year}^{-2}$) than the negligible acceleration observed in the global tide gauge record of the last century. It is essential to further evaluate the GSLR during the late Holocene through more field investigations, and refine and verify estimates for the period of the recording tide gauge. But tide gauge results will always suffer from the fact of their poor geographic distribution, as eloquently discussed by Groger and Plag (1993). Indeed, the very existence of altimeter satellites such as TOPEX/POSEIDON is due to the inherent limitations of any conceivable tide gauge network! Satellite altimetry of TOPEX/POSEIDON quality has both the requisite precision and geographic coverage to determine the current rate of GSLR in a reasonable time (perhaps one or two decades), and further detect variations in global and regional SLR that might accompany global warming.