Man, Water, and Global Sea Level

I'd like to call attention to an anthropogenic influence on global sea level change. Although far less interesting for geophysicists who study natural processes, the phenomenon in question has made a significant difference, and hence ought to be taken into account in the sea level budget.

Observational evidence shows that the global sea level has risen at the rate of 1.6–2 mm/yr for the last several decades [e.g., Trupin and Wahr, 1990; Douglas, 1991]. How much of the rise results from natural fluctuation, how much is anthropogenic, and what are the sources and mechanisms of the rise are among the key questions asked in this era of concerns about enhanced greenhouse effect and global warming. Presumably, as the global temperature rises, the sea level will rise for two reasons: thermal expansion (the steric change), and addition of water (the eustatic change). A primary candidate for the source of the latter is melting land ice in the form of polar ice sheets and mountain glaciers. Practically nothing useful is known about the present-day mass balance of the polar ice [Zwally, 1989; Douglas et al., 1990]. The best estimate for the rate of mountain glacier mass wastage, based on scanty data, amounts to a contribution of 0.46 (±0.26) mm/yr of higher sea level between 1900–1984 [Meier, 1984].

Yet, let us take a close look at a modern human activity that has impacted the eustatic sea level in a more direct manner than the purported greenhouse effect—water resource management on land. In terms of the mass involved, water management is by far the most efficient way by which we have altered our environment. Inasmuch as the total water mass is conserved, the land’s loss is the ocean’s gain and vice versa. The question then is: Has water management made any appreciable difference in the sea level? Here, I present well-documented data to argue that it has.

The amount of water used in land irrigation, which is ultimately (although often indirectly) deposited in the ocean, can be great. The rapid diminishing of the world’s fourth largest lake, the Aral Sea, is a shocking consequence of decades of diverting the river that used to replenish this inland lake. The complete disappearance of the Aral Sea would mean a loss of about 1000 km$^3$ of water (1 km$^3$ of water weighs 10$^{12}$ kg) to the ocean [National Academy of Sciences, 1990], raising the global sea level by a total of about 3 mm. The Caspian Sea, the world’s largest lake, is similarly losing 10 km$^3$ of water annually. In another example, some 300 km$^3$ of ground water has been pumped from the High Plains Aquifer in the midwestern United States since 1940 [Chao, 1988], which corresponds to 1 mm of higher sea level. But none of these come close to the amount of water that has been impounded in artificial reservoirs throughout the world.

Ever since the early 1950s, the world has seen intensive construction of artificial reservoirs. By 1972, some 10,000 reservoirs were in operation or under construction, with a total capacity of about 5,000 km$^3$ (only 143 reservoirs are larger than 5 km$^3$, but they account for more than 80% of the total capacity) [UNESCO, 1978]. A more up-to-date list of the largest reservoirs is given by Chao [1988], which also shows that the growth of the total capacity with time was essentially linear, if not at an accelerated rate. This means that in 1991 the amount of water impounded has doubled since 1972, reaching a total of as much as 10,000 km$^3$. This estimate is probably still a lower bound because not included is the reservoir water that inevitably seeps through the ground and is eventually reflected in the rise of local groundwater.

How much is 10,000 km$^3$ of water? It is about equivalent to the total atmospheric moisture, or about 10 times the Earth’s biological water [UNESCO, 1978]. If allowed to spill, it is enough to cover the whole land area to a depth of 10 cm. In terms of sea level, it corresponds to a drop of about 3 cm. This has happened steadily over the past 40 years, amounting to a rate of sea level drop of about −0.7 mm/yr; and the trend presumably continues. Of course, this water impoundment does not explain any of the observed sea level rise. On the contrary, it makes the explanation more dire by requiring more input water in the ocean water budget than would be needed otherwise. In particular, the rate of −0.7 mm/yr is significantly larger (in magnitude) than, and hence more than compensates for, the amount attributed to mountain glacier wastage—B. Fong Chao, NASA Goddard Space Flight Center

References


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