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Editorial

Problems with Assessment of Sea Level Rise Impact on Low-Lying Coastal Regions including River Deltas

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Densely populated and developed low-lying coastal regions, including deltas of large rivers, their sea coasts, and hydrographic systems belong to the most vulnerable geographical objects under global climatic warming and, particularly, to the level rise in the World Ocean and related seas as well as a further intensification of extreme hydrometeorological phenomena.

The global climate warming caused thermal seawater expansion, intensification of melting of cover glaciers, and increase in precipitation. The global warming in the XX century, particularly in its second half, gained supporting evidence on the basis of observational data. These climate changes caused the level rise of the World Ocean and the seas connected with it; over the last decades this rise became more rapid. Over the period of 1961–2003, the ocean level increased at a mean rate of 1.8±0.5 mm/year, while over the period of 1993–2003, the rate of the ocean level rise reached 3.1±0.7 mm/year, on the average. The further considerable ocean level rise is predicted in the future.

The problem of transfer of the eustatic rise of the World Ocean level into the related seas, particularly inland seas, is important and interesting but insufficiently studied yet. The proper water balance and changes in its components as well as a geological factor, including tectonic manifestation, play an important part in level variations in these seas. Therefore, the rate of the level rise in certain seas may be lower or higher than in the ocean. For example, with the level rise of the Atlantic Ocean (in the mid-20th century) equal to 1.7 mm/year, the level of the Mediterranean Sea increased at a mean rate of only 1.2 mm/year, and the rate of the level rise in the Black Sea and the Sea of Azov was 2.5 and 2.0 mm/year, respectively; the rate of the level rise at various points of the coasts of these seas could differ essentially from the mean values mentioned.

The water level rise in the oceans and seas brings a great threat to lowlands of coastal areas. Large, developed and populated deltas, particularly deltas in Southern, Eastern, and Southeastern Asia, are the most endangered areas. The sea level rise leads to inundation of low-lying coastal lands, including deltaic areas; backwater phenomena in rivers, saltwater intrusion into natural watercourses, artificial canals, and aquifers; deterioration of soils, wetlands, and vegetation cover; wave-induced erosion of coasts and coastline retreat. The sea level rise can increase a risk of flood disaster, damage of port facilities and coastal structures, destroy buildings, farmlands, drainage and irrigation systems, dykes, roads, etc.

The impeding hazard to river deltas in the 21st century is aggravated by the anticipated increase in the flow of many rivers and attendant floods of a fluvial origin. In addition to this, one can expect further intensification of tropical and extra-tropical cyclones and other extreme hydrometeorological phenomena, which often cause disastrous floods in river deltas.

It must be emphasized that in the 21st century, low-lying regions, including river deltas, will be under a great influence of not only the eustatic rise of the sea level at a rate of ≥5 mm/year but also under the influence of the so-called relative sea level rise (RSLR). The RSLR is a real sea level rise relative to the earth surface in coastal regions; it represents a sum of the eustatic rise of the sea level connected with the changes of water volume in the sea and the level rise caused by land subsidence. The land subsidence, which is typical of the majority of river deltas of the world, results from sinking of the Earth crust (many deltas are located in the areas of such tectonic troughs), compaction and dewatering of loose and relatively recent deltaic deposits as well as the impact of human-induced factor, i.e., pumping out of groundwater, oil, and gas in deltas. According to the estimates, the impact of natural and, particularly human-induced land subsidence may be much superior to the impact of the eustatic rise of the sea level. The RSLR value in some large deltas of the world exceeds 5 mm/year; this value reaches 10–20 mm/year in the deltas of the Ganges and Brahmaputra, Niger, and Chao Phraya rivers. The land subsidence in the Po River delta was caused by pumping out of methane; the land subsidence in the Chao Phraya River delta was caused by groundwater pumping out for water supply of the town of Bangkok; the land subsidence in the Niger River delta was caused by oil and groundwater pumping out.

Unfortunately, the theoretical problems related to the studies of the impact of sea level rise on river deltas have received insufficient attention in the scientific literature so far.

The inundation of deltaic maritime areas by seawater is the most evident and yet the most harmful consequence of the sea level rise for deltas. The experience gained in studying the response of deltas of the rivers emptying into the Caspian Sea to the recent considerable level rise in this water body has made it possible to reveal some regularities in the inundation of deltas. Over the period of 1978–1995, the considerable predominance of input components of the Caspian Sea water budget over output components (primarily, due to the increased water runoff of the Volga River) resulted in a rise of the mean annual level of the Caspian Sea by 2.35 m (the mean rate of the level rise was 13.1 cm/year).

The consequences of the Caspian Sea level rise turned out to be different in different deltas. The comparison of space photographs of the deltas revealed that over the period of the sea level rise the Sulak River delta area had decreased from 70.6 to 45.1 km^2, i.e., by 36%, as a result of inundation; the Kura River delta had decreased from 189 to 114 km^2, i.e., by 40%. The maritime belt (up to 15–20 km wide) of the Ural River delta was inundated and the delta area had decreased from about 522 to 280–300 km^2. In spite of the Caspian Sea level rise, progradation of the delta of the Terek River into the sea at the mouth of the main delta branch went on; this progradation reached 1.4 km. The delta coastline at the Volga River mouth virtually remained unchanged in the last 40 years.

Such different response of the Caspian river deltas to the level rise of the receiving water body is primarily due to differences in the features of the nearshore zone of river mouths and surface configuration of deltas as well as due to the sediment yield value of these rivers. The nearshore zone at the mouths of the Terek, Sulak, and Kura rivers is rather deep, while it is moderately shallow at the Ural River mouth; the mean annual water level at the delta coastline at all these mouths was always in agreement with the mean Caspian Sea level; therefore, changes in these levels were synchronous and similar. The Volga River mouth has an extremely wide and shallow nearshore zone; at the low level of the Caspian Sea, the direct connection between the delta branches and the sea is broken and the water level in the area of the delta coastline appears to be higher than the sea level. The Caspian Sea level rise over the period of 1978–1995 resulted in gradual inundation of the shallow part of the nearshore zone.

Three cases are possible at river mouths with deep nearshore zones. The first, the river sediment yield is insignificant, the backwater prism caused by the sea level rise is not filled with river sediments, passive inundation of the delta surface is observed; sediments move in transit through the river channel into the sea and partially deposit in the channel in the zone of backwater. The second, river sediments only partially fill the backwater prism, and part of the maritime zone of the delta gets inundated by sea water. The third, the river sediment yield is significant, the backwater prism is filled with river sediments, sediments deposit in the channel and, in spite of the sea level rise, the delta goes on prograding into the sea.

The first case was typical of the Sulak and Kura river deltas, whose sediment yield considerably decreased after the construction of the Chirkei Reservoir in 1974 and the Mingechaur Reservoir in 1952 on these rivers, respectively. Different situation, typical of the third case, was observed at the mouth of the main branch of the Terek River delta. The river sediment yield was rather considerable and its total value exceeded the volume of the backwater prism.

More impressing data on delta inundation as a result of the sea level rise are cited in the scientific literature. For example, over the period of 1980–1990, the mean retreat of the coast at a rate of 4.2 km/year into peripheral parts of the delta was recorded at the Mississippi River mouth, where the relative sea level rise (with regard to the considerable land subsidence) reached 10–12 mm/year, and the total wetland loss as a result of inundation was about 100 km^2/year.

Further research should be aimed both at applying the discussed approaches and prediction methods to the deltas of particular rivers of the world and at developing these approaches to the assessment of possible changes under the environmental conditions of river deltas under the impact of the expected considerable sea level rise and to the assessment of other hydrometeorological consequences of the global warming.