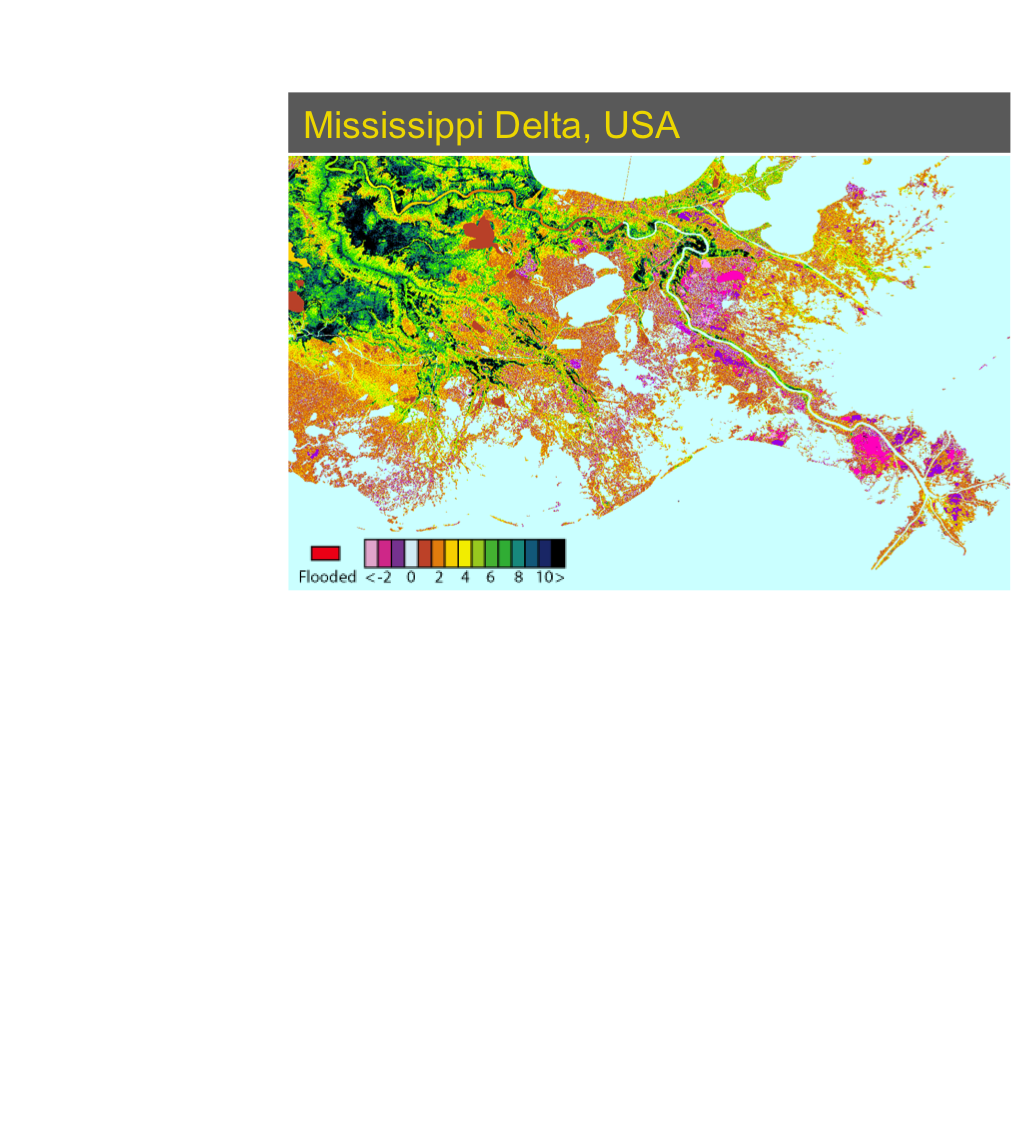
**Sinking Deltas and Global Sea Level Rise**

**(Student version)**

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1. **Introduction**

Many of the world’s largest deltas are densely populated and heavily farmed. Worldwide 500 million people live in low-lying deltas. Now many of their inhabitants are becoming increasingly vulnerable to flooding and conversions of their land to open ocean, especially under the background of heavy human activities and global warming. Syvitski et al. (2009) studied 33 deltas all over the world and found that in the past decade, 85% of the deltas experienced severe flooding. The 33 major deltas combined have > 100,000 km2 at elevation < 2 m above sea level, and > 26,000 km2 at elevation < 0 m. The following figure shows the topography of Mississippi Delta, which has a large proportion of land at elevation less than +2 m (in pink, purple and white).



*Figure 1. Topography of Mississippi Delta, USA*

Figure 2 shows the Krishna delta, India, which is classified under the “in great peril” category, because sediment supply to the delta is reduced by ~94 percent. In this photo, sand bags are being places at side of the road to Banki to protect low-lying land from floodwaters of overflowing Mahanadi River.

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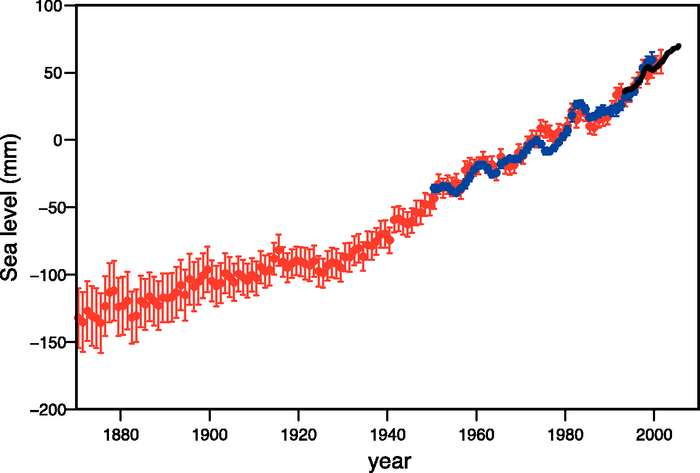
*Figure 2. Enforcing riverbanks in the Krishna Delta, India*

Key paper:

*Syvitski, J.P.M, Kettner, A.J., Overeem, I., et al., 2009. Sinking deltas due to human activities. Nature Geoscience, doi: 10.1038/NGEO0629*

**2 Questions**

**Question 1**



*Figure 3: Annual averages of the global mean sea level (mm). The red curve shows reconstructed sea level fields since 1870; the blue curve shows coastal tide gauge measurements since 1950 and the black curve is based on satellite altimetry. The red and blue curves are deviations from their averages for 1961 to 1990, and the black curve is the deviation from the average of the red curve for the period 1993 to 2001. Error bars show 90% confidence intervals. (Figure modified from IPCC, 2007)*

*1A*  Figure 3 shows global sea level rise over the last century. Estimate the average annual sea level rise rate from the graph. What has caused sea-level rise? Please explain?

*1B* Use the data in the Excell worksheet to calculate the seawater depth changes caused by thermal expansion. How much will global sea level rise if the temperature increases 2 °C according to the relationship? Look up the ICPP report of 2007 and find out the ‘best estimates’ of how much of the global sea level rise can be be attributed to thermal expansion? <http://www.ipcc.ch/>, look under AR4, 2007.

What is the role of other factors, how much do they contribute?

*1C* Why this is important to our society and environment?

**Question 2**

Relative sea level is defined as sea level related to the level of the continental crust. Relative sea level changes can thus be caused by absolute changes of the sea level and/or by absolute movements of the continental crust (Angremond & Pluim-Van Der Velden, 2001). River deltas are complex systems, because the amount of sediment deposited can load down the continental crust and thus significantly influences its evolution process.

*2A* Annual elevation changes for several deltas are given in the Excell worksheet, as observed from long-term tide gauges (this data is archieved at the PSMSL-the permanent service for mean sea level, http://www.psmsl.org/). Please plot relative sea level rise in the selected deltas, calculate trendlines, and derive the longterm annual relative sea-level rise rate. How do the trends compare to global averaged sea-level rise data?

*2B* Can you explain why this happened? Which factors do you think may influence this process? (Helpful References: Bohannon, 2010; Tornqvist, et al., 2008; Hyndman, D.W.S, 2009)

**Question 3**

From the plot you generated in question 2, you can see that different deltas have different ‘sinking rates’. There is a lot of debate on the causes of this relative sinking and it is not always resolved what is the dominant factor.

What are potential causes of subsidence for the selected individual delta systems?

3A Potential cause of subsidence in the Mississippi River delta?

3B Potential cause of subsidence of Ganges delta?

3C Potential cause of subsidence of the Chao Phraya River delta?

3D Potential cause of subsidence of the Magdalena delta?

**Question 4**

As a delta is sinking, how will this process influence the environment and society?

**Question 5**

Subsidence in deltas is a problem; what can humans do to slow down this process?

**3 References**

Bohannon, J., 2010. The Nile Delta’s Sinking Future. Science, 327, 5972, pp. 1444~1447.

Doi: 10.1126/science.327.5972.1444

Corben, R. and Writer, I., 2009. Bangkok’s Future Filled with Floods.

( <http://www.irrawaddymedia.com/article.php?art_id=17263>)

D'Angremond, K., Pluim-Van Der Velden, E.T.J.M., 2001. Introduction Coastal Engineering, p18-19.

Meier, M.F., Wahr, J.M., 2002. Sea level is rising: Do we know why? PNAS, 99(10): 6524~6526.

Doi: 10.1073/pnas.112214499

Milliman J.D., Haq, B.U.(eds.), 1996. Subsidence of the Ganges-Brahmaputra Delta of Bangladesh and Associated Drainage, Sedimentation and Salinity Problems in Sea-Level Rise and Coastal Subsidence, 169-192.

Morton, R.A., Bernier, J.C., Barras, J.A., Ferina, N.F., 2005. Historical Subsidence and Wetland Loss in the Mississippi Delta Plain. Gulf Coast Association of Geological Societies Transaction, 55: 555~571.

Prasad, 2009. Sinking Indian deltas put millions at risk (<http://www.thehindu.com/sci-tech/article23086.ece>)

Reed, C. Where sinking land meets rising water, 2009. Global change(74): 32~35.

Tornqvist, T. E., Wallace, D.J., Storms, J.E.A., et al., 2008. Mississippi Delta subsidence primarily caused by compaction of Holocene strata. Nature Geoscience, 1: 173-176.

Subsidence Due to Groundwater Extraction Venice, Italy in Natural hazards and disasters, Hyndman, D.W.s (ed.), 2009. (http://books.google.com/books?id=8jg5oRWHXmcC&pg=PA242&lpg=PA242&dq=delta+sinking+groundwater&source=bl&ots=d2\_qhGsbt7&sig=4j3doVpQnKSb5tPZOR4uRb8EC9I&hl=en&ei=yX\_RTcnVF8Ta0QGH4dmEDg&sa=X&oi=book\_result&ct=result&resnum=7&ved=0CEIQ6AEwBg#v=onepage&q=delta%20sinking%20groundwater&f=false)