An Analysis of Historical Salinity and Sea Surface Evaluation Data For the Hudson River

Alison-Catherine King[1], Robert Chant[2]

[1]Humboldt State University, Arcata CA, [2]Rutgers University, Institute of Marine and Coastal Sciences, New Brunswick, NJ

Contact Info: ack14@humboldt.edu

Introduction

Long term records of salinity, water quality, or sea surface height can be important indices of change in estuarine systems. Physical conditions in an estuary are controlled by three dominant phenomena: 1) the freshwater flow in the river, 2) the tidal variations at the downstream ocean end, and 3) the surface mass and heat transfer which depends on local meteorological conditions.

In the Hudson River, freshwater inflow and tidal variation dominate the physical conditions of the system. Heavy urbanization exists in the Hudson River watershed and freshwater discharge can be heavily modulated by water management practices and meteorological processes such as droughts or high precipitation. The effects of tidal forcing in the estuary can be influenced by spring-neap cycling or dredging activities associated with maintaining navigational channels for cargo vessels.

I will gather and examine these data sets to identify how factors such as floods, drought, spring/neap cycles, dredging, and water management have impacted, or have been indexed by, water quality in the estuary.

Geometry of the Hudson River

- The following information was obtained by the Oak Ridge National Laboratories and the U.S. Coast and Geodetic Survey.
- In figure 1, the cross-sectional area of the Hudson River gradually increases within the 120-mile section of the estuary from the upstream end at Troy Dam to the Haverstraw Bay area, 38 miles upstream from the Battery. The minimum area of the channel is approximately 10,000 sq. ft in the vicinity of the Troy Dam; the maximum area is more than 400,000 sq. ft at Haverstraw Bay.
- The cross-sectional area sharply decreases downstream of Haverstraw Bay to less than 180,000 sq. ft in the vicinity of the George Washington Bridge, and it again increases in the last 10-mile section of the river to more than 300,000 sq. ft at the Battery.
- These relatively significant variations in the geometric characteristics of the river channel directly affect the local values of all the physical conditions of the river flow, and they also indirectly influence the distributions and the behavioral patterns of various aquatic biota in the estuary.

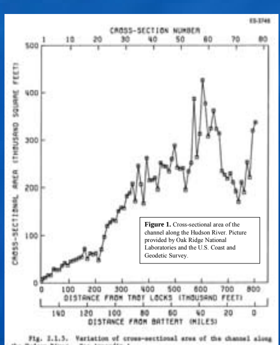


Figure 1. Cross-sectional area of the channel along the Hudson River. Picture provided by Oak Ridge National Laboratories and the U.S. Coast and Geodetic Survey.

Fig. 2.1.3. Variation of cross-sectional area of the channel along the Hudson River. See Appendix A.

Historical Salinity Datasets

- Variability in salinity, for instance, could be used to infer how natural processes (tides, remote forcing, drought, climate change) and anthropogenic activities (alterations in water management, river dredging, sewage discharge) impact a particular estuarine system.
- The maximum salt concentrations in the estuary occur during the summer months when the net freshwater flow rates decrease to their minimum values (see figure 2).

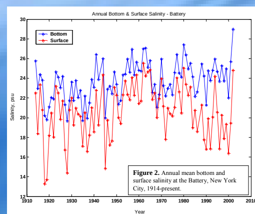


Figure 2. Annual mean bottom and surface salinity at the Battery, New York City, 1914-present.

- Due to the dominating effect of the tidal flows in the Hudson estuary, stratification conditions are modulated by the spring/neap cycle.
- In the Hudson River estuary, time series exist for such parameters as surface and bottom salinity, temperature, dissolved oxygen, suspended sediment, and nutrients dating back as far as 1914. Some of these data appear to contain distinct signals, which may be associated with changes in the Hudson river estuary (see figure 3 & 4).

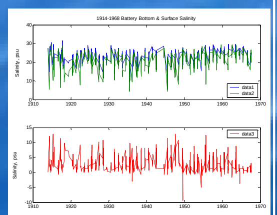


Figure 3. 1914-1968 Bottom(data1)/Surface(data2) Salinity, difference(data3)

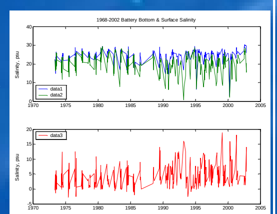


Figure 4. 1965-2002 Bottom(data1)/Surface(data2) Salinity, difference(data3).

Salinity Levels from the Battery & Mt. St. Vincent

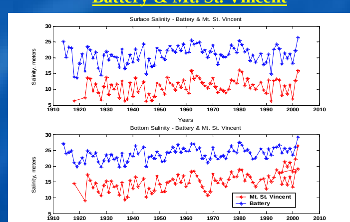


Figure 5. 1917-2002 Surface/Bottom Salinity at Battery and Mt. St. Vincent.

- The salinity distributions along the river primarily depends on the freshwater flow conditions and secondarily on the tidal flow conditions in the estuary. The salinity conditions at the downstream ocean end at the Battery exceed 24 parts per thousand during the summer months (see figure 5).
- The salinity intrusion in the estuary based on the location of the salt front (defined as 1.0 part per thousand) moves rapidly along the estuary with the changes in the freshwater flow conditions.

Tidal/Freshwater Flow Conditions

- The reversing tidal flow conditions in the estuary are controlled by the complex periodic tidal height variations at the ocean end of the estuary. The maximum high-high water level at the Battery exceeds 4.0 ft and the minimum low-low water level drops below 3.8 ft relative to long-term mean water level at the Battery.
- The periodic variations of the tidal level at the downstream end of the estuary result in periodic tidal flow conditions which gradually decrease along the estuary toward the upstream end of Troy (Green Island).
- The local maximum tidal flow rates vary between approximately 300,000 cfs and 460,000 cfs at the Battery during the summer months depending on the combined effects of the tidal elevations at the ocean end and the freshwater flow conditions in the river.
- The major freshwater inflow to the Hudson River is from the river flow at Green Island. The flow rates obtained from measurements at Green Island near the Troy Dam constitute 60% to 85% of the total fresh water entering the estuary during the summer months. Most of the remaining freshwater entering the estuary comes from tributaries in its northern section.

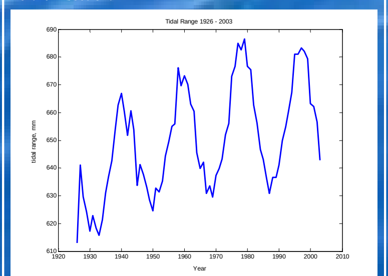
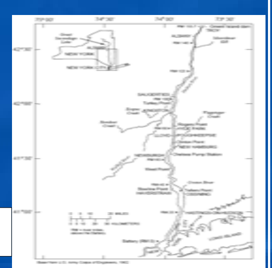


Figure 6. Tidal Range from 1926 – 2003 at the Battery.

- The tidal reach of the Hudson River between Green Island at Troy and the Battery is 152 miles, a drowned-river estuary with a mean bed slope of 0.0002 ft/ft; mean tidal range is about 5.5 ft. (see figure 6).
- The flow conditions in the Hudson River are dominated by the periodic tidal characteristics from the downstream end at the Battery to the upstream end at Green Island from the influence of the ocean.
- The net freshwater flow in the river does contribute significantly to the hydrodynamic conditions; however, it controls the important water quality variables, including the temperature and the salinity distributions along the estuary.

Figure 7. Tidal Hudson River area. Picture provided by Oak Ridge National Laboratories and the U.S. Coast and Geodetic Survey. (Mt. St. Vincent is located just below Hastings on Hudson).



Historical Discharge

Distinctive flood/drought patterns have existed (see figure 8 & 9).

- From 1917-1928, a period of moderation seemed to exist; few to no droughts and floods. Only a few high water events: the flow is consistently near seasonal means.
- From 1929-1966 there are wild swings of many high water events to low water events, commonly in the same year. 1960-1966 was particularly dry period with over 100 days of low flow events in seven years.
- 1977 to present begins a flood rich period with very little true drought. In fact, a severe drought impacting river discharge hasn't occurred since 1966, although 1998 came close.

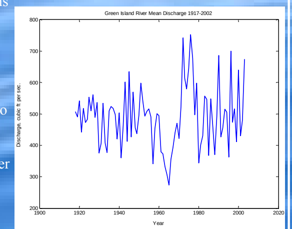


Figure 8. Green Island discharge 1917-2004.

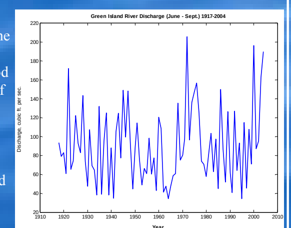


Figure 9. Green Island discharge for the summer months between 1917-2004.

Spring & Neap Tides

The data shows very little dependence on lag of river flow.

- Figure 10 & 11 indicates the following when comparing Spring & Neap Tides:
  - ΔS ~ Mt. St. Vincent (surface – bottom) Salinity = POOR (Spring & Neap)
  - ΔS ~ Battery (surface – bottom) Salinity = GOOD (Spring & Neap), higher during spring tide
  - ΔS ~ Battery – Mt. St. Vincent (surface) Salinity = POOR (Spring & Neap)
  - ΔS ~ Battery - Mt. St. Vincent (bottom) Salinity = GOOD (Spring), POOR (Neap)

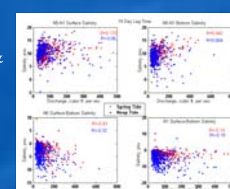


Figure 10. Represents a 15 day lag time between the Battery (N5) and Mt. St. Vincent (N1)

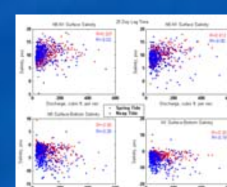


Figure 11. Represents a 25 day lag time between the Battery (N5) and Mt. St. Vincent (N1)

Sea Level Heights

- The historic sea-level rise from tide-gauge records at the Battery shows a rate of 2.73 mm/yr. (see figure 12). This historic rise in sea-level is most likely linked to the observed global increase in temperature over the same period.
- Sea level has been rising on average, between 1 to 2.5 mm/yr for the last 80 years.
- The recent sea-level rise comes from the thermal expansion of the upper ocean layers and melting of mountain glaciers.
- According to NOAA a broad region of the mid-Atlantic coastline is sinking slowly due to the glacial rebound effect.
- As sea-level rises, coastal storms penetrate farther inland, increasing the vulnerability of these areas through the loss of wetlands, increased flooding, and the increase of salt-water intrusion into major aquifers and estuaries.

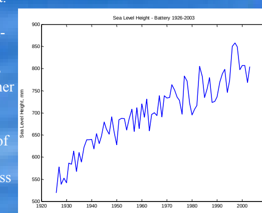


Figure 12. Annual Mean Sea-Level Height 1926-2003 at the Battery.

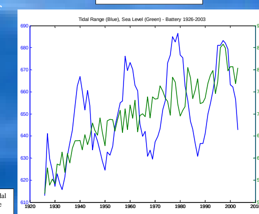


Figure 13. A comparison of tidal range and sea-level height at the Battery from 1926-2003.

Figure 14. It has been said that if the polar ice sheets were to completely melt, sea-level would rise by 70 m (200 ft). If this were to happen the Statue of Liberty would just be visible at the Battery. (from K. Miller, Rutgers University)

Summary

This project has been intended to explore these long term data sets in an effort to identify the main processes impacting the Hudson River estuary during the past 90 years. What did we see? Long term trends in sea-level rise, decadal scale variability in river discharge, relationship in river flow and salinity – that appears to be modulated by tidal forcing. Best relationship between water management projects, droughts, channel deepening, and long term data sets it will be apparent the correlations between various aspects of historical salinity data sets, tidal/fresh water flow conditions, historical discharge data sets, and sea level heights, as well as between spring/neap cycles, and the geometry of the Hudson River.

Acknowledgements

John A. Quinlan, Judith P. Grassle, Louis Bowers, Chip Haldeman, J. Fredrick Grassle, Elias Hunter, Keleigh Tepel-McAllister, C. Grant Law

Fellow RIOS Interns and the entire RIOS team.