

Florida Bay in Four Easy Pieces

Box model developed to estimate evaporation from Florida Bay also proves adept at predicting monthly variation in salinity and calculating residence time.

Salinity in Florida Bay varies widely with season and from year to year. Several factors contribute to this variation. One of these is freshwater runoff from the Everglades, which has been reduced by the construction and operation of the Central and South Florida Project. Understanding how these factors combine to control salinity holds the key to understanding threats to the bay's ecosystem and assessing opportunities to mitigate these through hydrologic restoration in the Everglades.

Recent research has taken a step toward attaining this understanding and providing predictive tools. This comes in the form of a

simple mass balance model that is capable of predicting salinity variations in Florida Bay, albeit only for regional averages, Figure 1. Predictive capability of this model has been verified by comparing calculated salinity values with observations over a period of three years, Figure 2.

This model marks a milestone in progress toward the ultimate goal of implementing a fully hydrodynamic model of Florida Bay. The water balance data assembled in the course of developing this model is also needed to implement the hydrodynamic model, and the predictive ability of this simple model establishes a minimum target

Figure 1: The box model divides Florida Bay into four regions based on observed patterns in water quality (Boyer et al 1997, Nuttle et al. 2000). Monthly salinity and rainfall data are aggregated within each region. Salinity at SB1 and SB2 provide boundary conditions for exchange with regions 2 and 4. Freshwater runoff also enters region 1. Evaporation and exchanges between regions are estimated by optimization.

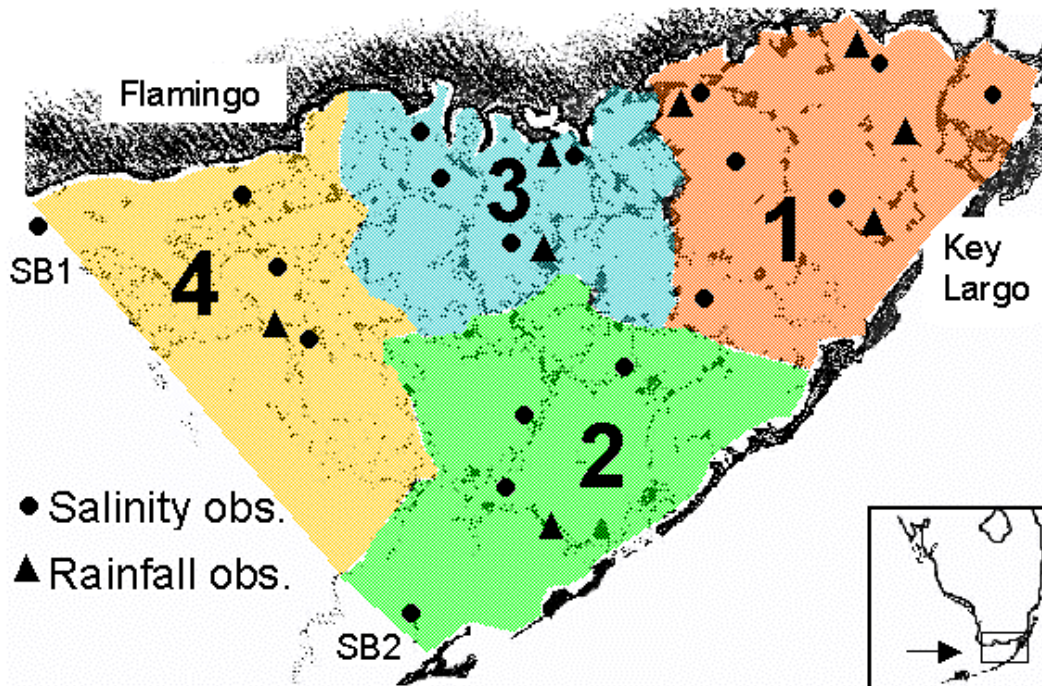
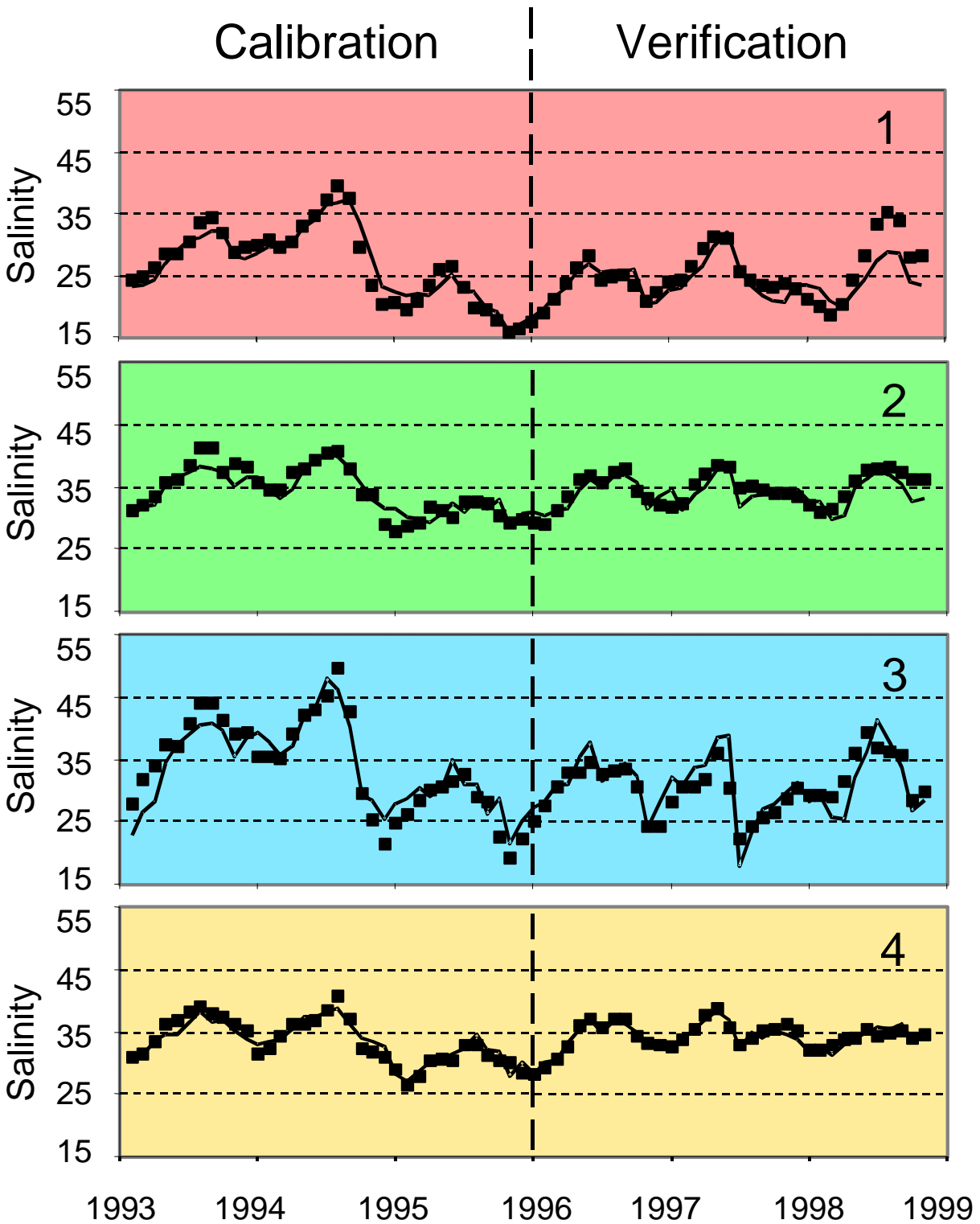


Figure 2: Box model calculations reproduce observed variation in regional salinity in Florida Bay with a standard error of 2 psu overall. The model was calibrated to fit salinity data in the first half of the data set. Comparison of predictions with salinity values in the second half of the data set test the predictive power of the model. The model error is the same for both periods. Panel numbers refer to region in model.



for the accuracy that can be expected from a more detailed hydrodynamic model.

The mass balance model, i.e. “box model,” was developed to estimate evaporation from Florida Bay by analyzing data on salinity, rainfall and direct runoff from the Everglades. Other elements of evaporation research will use stable isotopes of oxygen and hydrogen, the Priestly-Taylor energy budget method, and the vapor flux-Dalton Law formula to derive independent estimates. Combined, these different results will provide a robust estimate of the mean evaporation rate.

The sensitivity of the Florida Bay ecosystem to restoration activities depends in large part on the role of runoff in the freshwater budget. Runoff is known to be small (~9 cm/yr) compared to direct rainfall (98 cm/yr, Nuttle et al., 2000), but its influence really depends on the magnitude of runoff relative to the net of rainfall minus evaporation. Therefore, knowledge of evaporation is essential to planning restoration.

The box model calculates salinity from variation in the net supply of freshwater in each region and the exchange of water between regions and with the Gulf of Mexico. Rainfall and salinity are measured in the bay, and runoff is estimated from measured flows in Taylor Slough and the C111 canal that discharge into the mangrove wetlands north of the Florida Bay, Table 1. Fitting predictions of the model to observed salinity produces estimates for the unknown winter and summer evaporation rates.

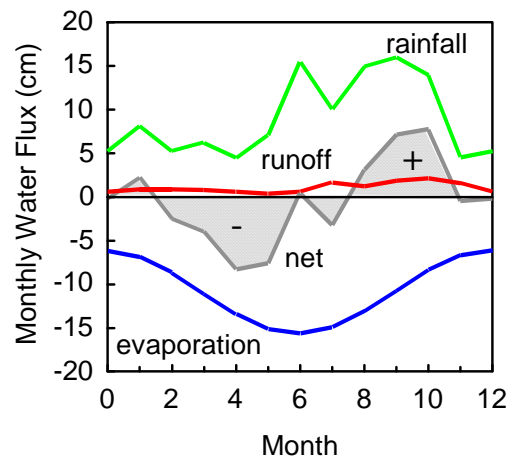
Average annual evaporation is estimated to be 131 cm/yr; about 8 cm/month in winter and 14 cm/month in summer. This annual evaporation rate is about 20% greater than estimated previously by Nuttle et al. (2000) based on analysis of a more limited data set using a steady-state salinity model.

Estimated evaporation exceeds the sum of rainfall and runoff, and this is consistent with the observation that Florida Bay is slightly hypersaline on average. The balance in net freshwater supply fluctuates between positive and negative values during the year, Figure 3.

Table 1: Summary of input data and results

Input Data	Region			
	1	2	3	4
Rainfall (avg.) (cm/month)	9.5	8.5	10.3	9.6
Runoff (avg.) ($10^6 \text{ m}^3/\text{mon}$)	26.7	n/a	n/a	n/a
Salinity				
average	26.1	34.6	32.2	33.9
s.d.	5.5	3.4	6.4	3.0
Model Error				
calibration s.e. (93-95)	1.8	1.7	3.0	1.2
validation s.e. (96-98)	2.6	1.6	2.9	0.7

Figure 3: Evaporation is the largest single flux of freshwater in Florida Bay. Runoff is a small component of the water balance, but it accounts for about a third of the positive net freshwater supply that occurs during late summer. Runoff plays a greater role in the water balance in the northeast, near the point of discharge.



Calibration of the box model also provides an estimate of the monthly volumes of water exchanged between adjacent regions. These can be used to investigate residence times in the bay, information that is needed to understand the processes that control nutrient concentrations and plankton blooms in the bay, Figure 4.

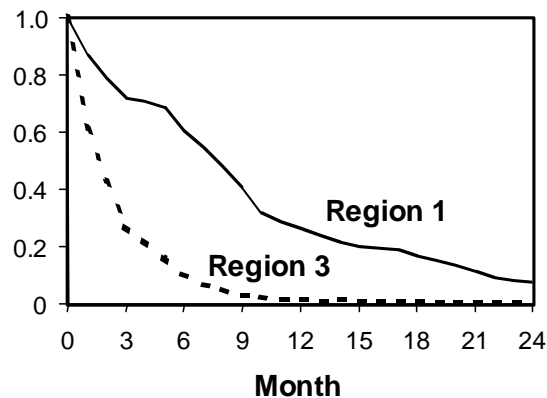
So far, the model discounts any influence of freshwater flowing into Florida Bay as groundwater. This is because no reliable estimates exist for this flux on the temporal and spatial scales considered here. In general, neglecting of any freshwater source will result in evaporation being underestimated. If groundwater represents a large source of freshwater, then this fact will be apparent when results of different methods of estimating evaporation are compared.

Several investigators have documented very high rates of groundwater inflow at discrete locations within the Bay, so this is a concern. Possible sources, i.e. freshwater sources, for this inflow are not well known, and some believe that this may be recycled water from Florida Bay. The model and data used here could also be used to investigate hypotheses about the magnitude of fresh groundwater inflow once the evaporation rate is constrained by the additional measurements that are being made.

Acknowledgement

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Figure 4: Simulated dissipation of a conservative tracer provides a measure of residence times in Florida Bay. The residence time of a water parcel in Region 1 is about three times that in Region 3, where hypersaline conditions form and persist.



References

- Boyer, J.N., J.W. Fourqurean, and R.D. Jones. 1997. Spatial characterization of water quality in Florida Bay and Whitewater Bay by multivariate analyses: zones of similar influence. *Estuaries* 20: 743-758.
- Nuttle, W.K., J.W. Fourqurean, B.J. Cosby, J.C. Zieman, and M.B. Robblee 2000. [Influence of net freshwater supply on salinity in Florida Bay](#). *Water Resources Research* 36:1805-1822.

Additional Work

The following study applies this mass balance model to analyze a different 7-year set of salinity data:

- Kelble, C.R., E.M. Johns, W.K. Nuttle, T.N. Lee, R.H. Smith, P.B. Ortner, 2007. [Salinity Patterns of Florida Bay](#). *Coastal Estuarine and Shelf Science* 71:318-334.

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