Blooms in the Bay: modeling spatiotemporal chlorophyll-a dynamics exhibiting high inter-annual variability

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BACKGROUND

Florida Bay's position within the landscape (Fig. 1A) makes it an integrative indicator of upstream terrestrial disturbance. Consequently, the ecological integrity of Florida Bay has waned as development has increased on the Florida peninsula, as has been made particularly evident through the recurrence and persistence of widespread, ecologically devastating algal blooms (Fig. 1B).

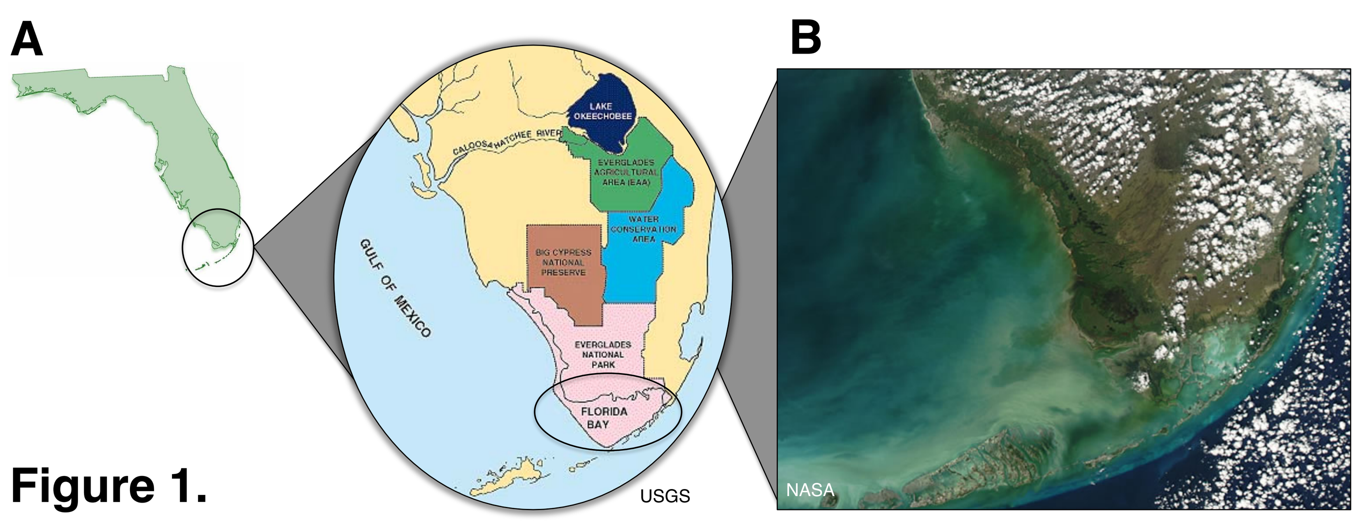


Figure 1.

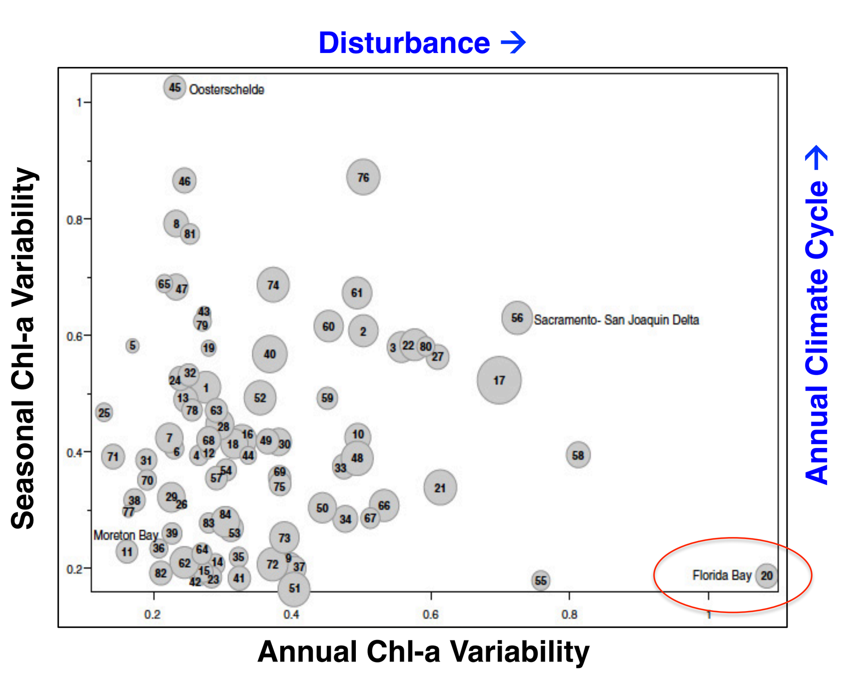


Figure 2.[1] The algal dynamic of Florida Bay exhibits high inter-annual variability and low seasonality as compared to other estuarine-coastal systems (Fig. 2), thus making this system challenging to model deterministically.

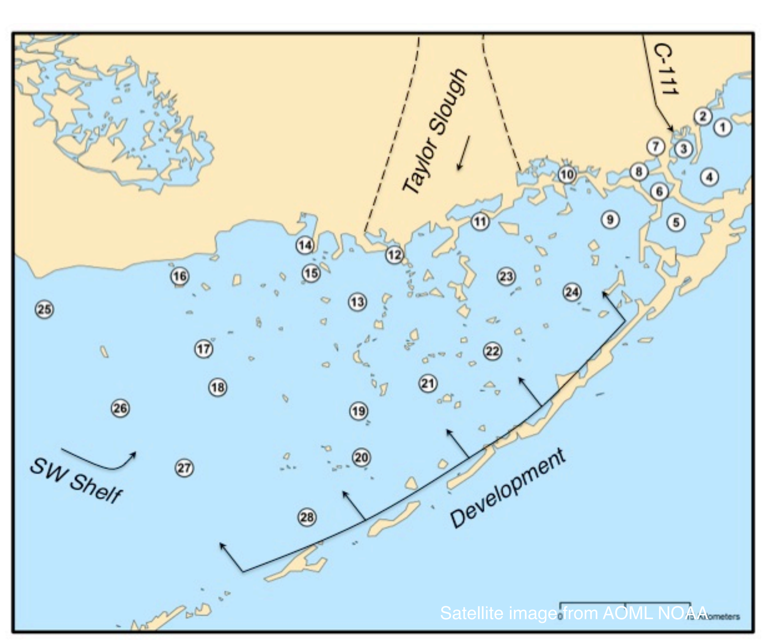


Figure 3. A long-term water quality monitoring program was implemented by the Southeast Environmental Research Center (SERC), with 28 spatially distributed stations in Florida Bay. Possible water quality drivers shown.

OBJECTIVE

Deterministically model the spatiotemporal algal dynamic across the expanse of Florida Bay.

METHODS

Quantile Regression (QR)
Regression on quantiles of the response variable's probability distribution.

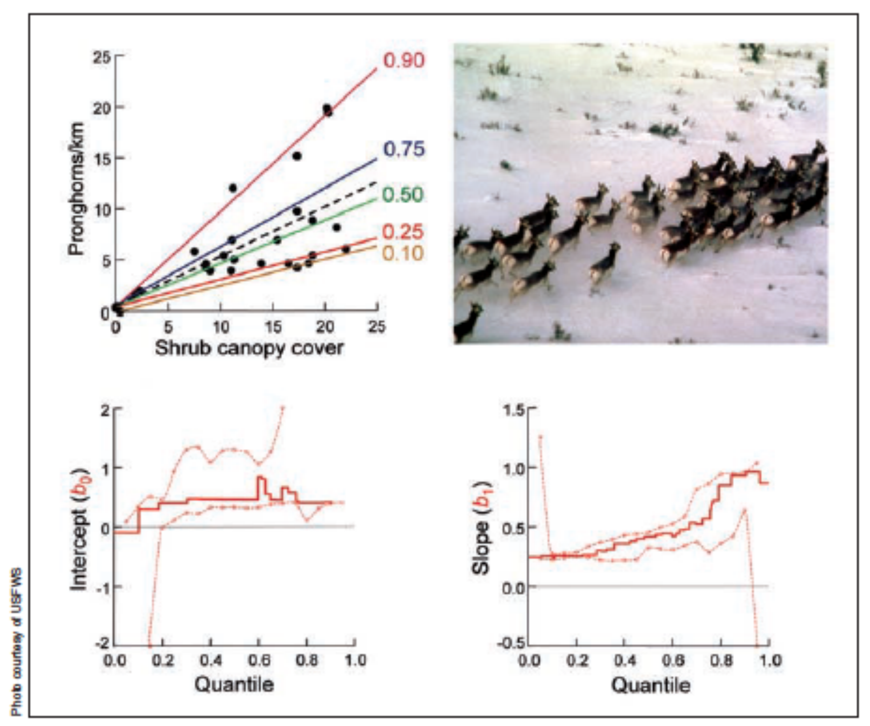


Figure 4.[2] An example of QR. QR has gained popularity in ecological data analysis due to its ability to describe unequal rates of change.

Quantile Selection

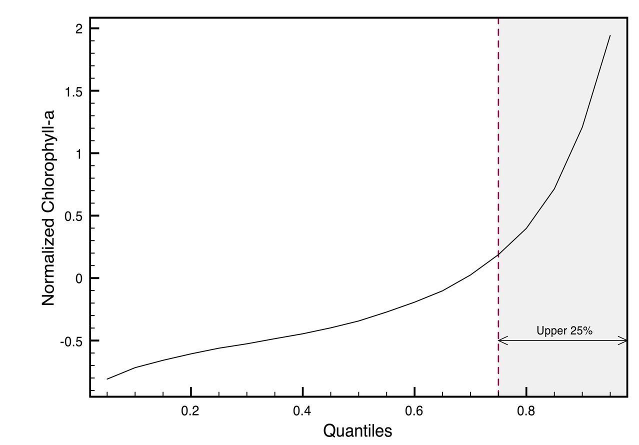


Figure 5. Chlorophyll-a quantiles. Due to the visible change in dynamic, QR was applied above & below the 0.75 quantile threshold.

Nash-Sutcliffe Efficiency (NSE)

$$NSE = 1 - \frac{\sum_0^t (Y_{Obs}^t - Y_{Sim}^t)^2}{\sum_0^t (Y_{Obs}^t - \overline{Y_{Obs}})^2}$$

Water Quality Data

- Monthly, 1992 – 2008
- 28 stations (Figure 3)
- Normalized by station

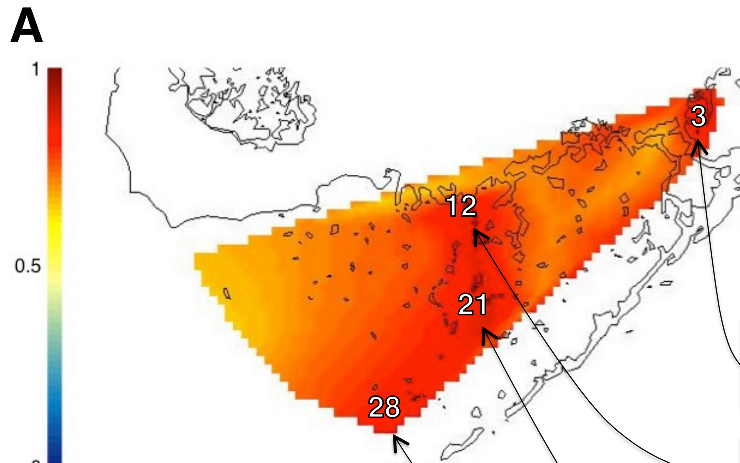
RESULTS

Model, with good fit [NSE_{avg} = 0.76 (0.63 – 0.88)]:

$$Chla_k(\tau|t) = \beta_{o,k}(\tau) + \beta_{Chla,k}(\tau)Chla_k(t-1) + \beta_{DIN,k}(\tau)DIN_k(t) + \beta_{TP,k}(\tau)TP_k(t) + \beta_{TOC,k}(\tau)TOC_k(t) + \beta_{Turb,k}(\tau)Turb_k(t)$$

The final model includes a common set of normalized explanatory variables with unique coefficients per site and quantile.

k	Location
τ	Quantile
Chla	Chlorophyll-a
DIN	Dissolved Inorganic Nitrogen
TP	Total Phosphorus
TOC	Total Organic Carbon
Turb	Turbidity



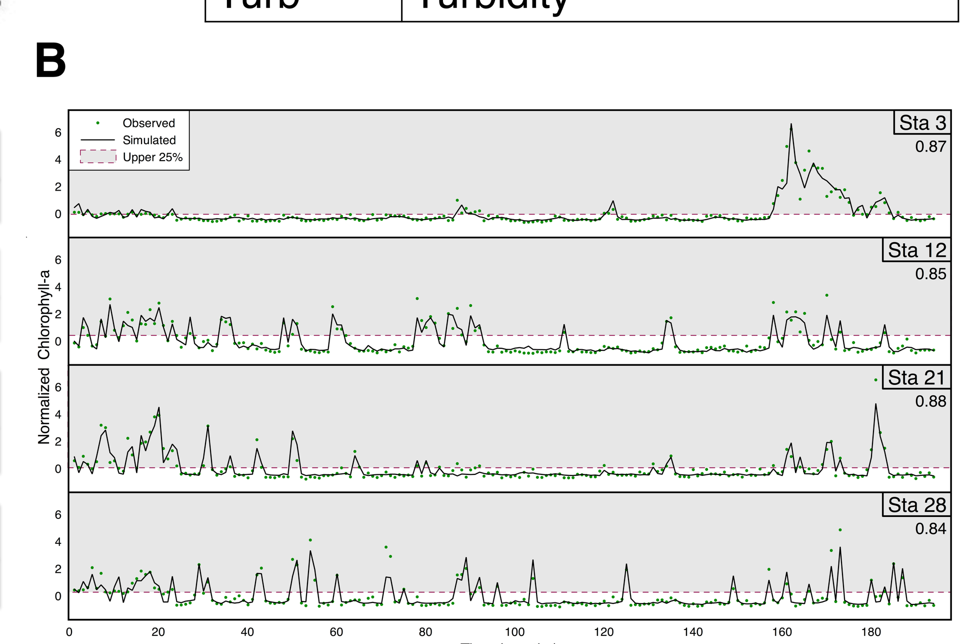


Figure 6.
A) Interpolated spatial distribution of NSE coefficients,
B) observed and simulated data from 4 representative stations. NSE listed below station number in each plot.

DISCUSSION

Results suggest that the relative importance of bloom drivers changes between extreme and normal conditions.

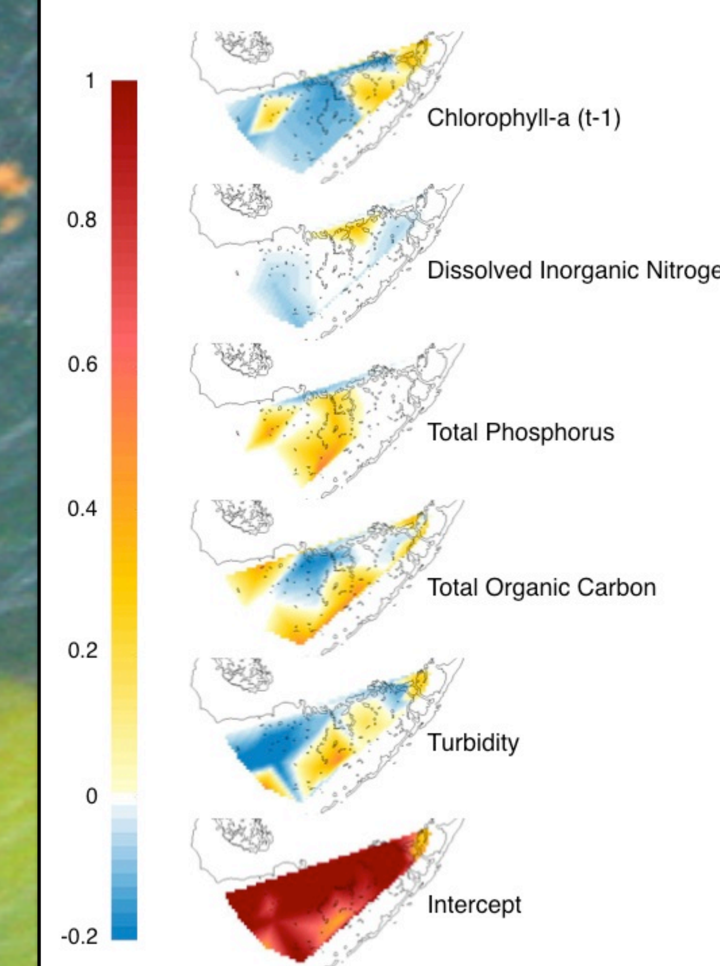


Figure 7. Maps of the differences between quantile regression coefficients, $\beta_{upper25\%}$ - $\beta_{lower75\%}$. A value of 0 corresponds to no change between quantiles.

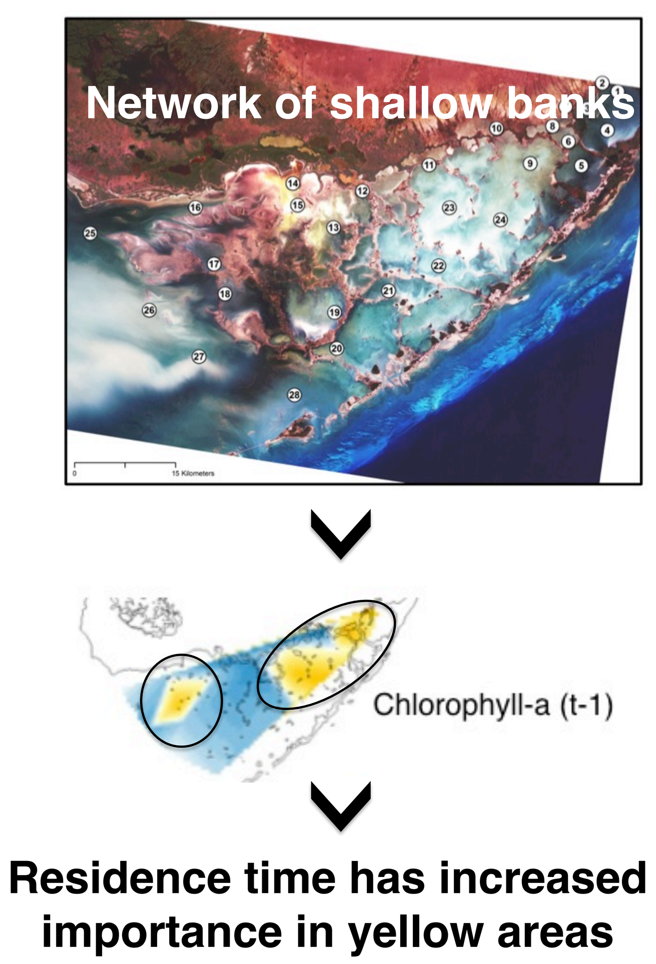


Figure 8. Coefficient maps (Fig. 7) can translate water quality time series data into spatial, mechanistic explanations of the system's dynamics.

CONCLUSION

This analysis reveals how the relative importance of each bloom driver varies across the expanse of the Bay. Residence time appears to be an influential factor in the NE region and in shallow basins; turbidity and TOC play a greater role in higher flow areas. These geographic patterns provide clues as to how these blooms flourish in Florida Bay.

ACKNOWLEDGEMENTS & REFERENCES

This material is based upon work supported by the National Science Foundation Graduate Research Fellowship under Grant No. DGE-0802270.

Data were provided by the SERC-FIU Water Quality Monitoring Network which is supported by SFWMD/SERC Cooperative Agreement #4600000352 as well as EPA Agreement #X7-96410603-3.

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[2] Cade, B. S., & Noon, B. R. (2003). A gentle introduction to quantile regression for ecologists. *Frontiers in Ecology and the Environment*, *1*(8), 412-420.

Background photo: Florida Fish and Wildlife Conservation Commission (FWC)