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Forecasting inshore red tide blooms using recent past offshore conditions on the West Florida Shelf

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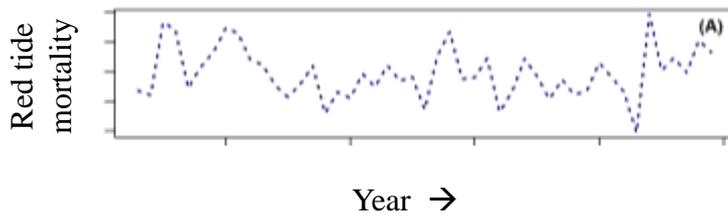
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2013

- John Walter develops index of red tide severity

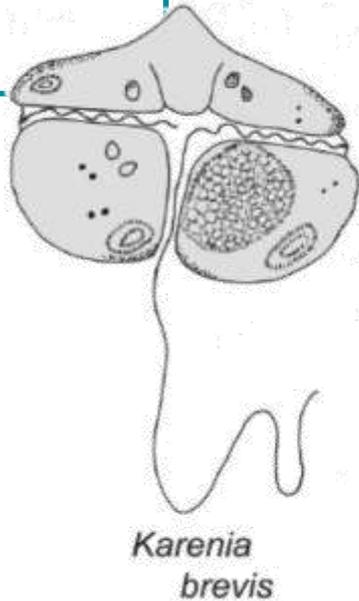


What does it kill?

- Red grouper:
- *2005 event caused 3-fold increase in natural mortality rate*
- *2005 red tide: 11,000 metric tons*
- *2004 landings: 1,500 metric tons*
- *2005 landings: 543 metric tons*
- *2006 landings: 416 metric tons*

2016

- Marissa Rykowski, UM undergrad thesis
- Short-term forecasting
- Public health warnings

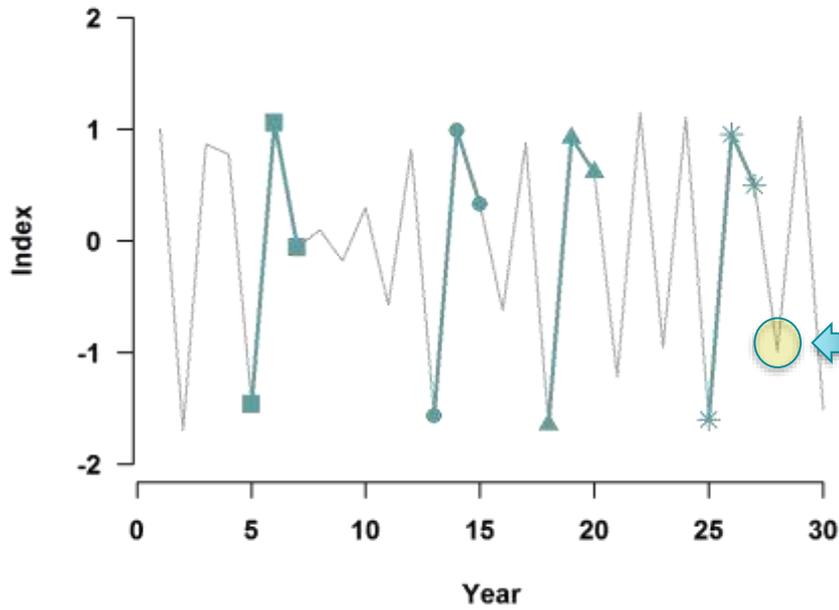


What is red tide?

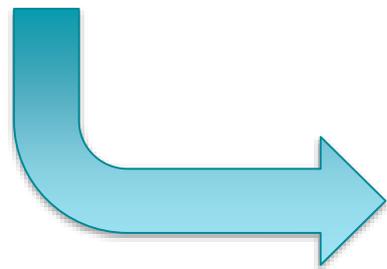
- “Red tide” dinoflagellate *Karenia brevis*
- Marine animals death via acute exposure or bioaccumulation of brevetoxin
- Causes hypoxic water conditions
- Events in the Gulf of Mexico reported approximately every decade since the latter half of the 1800s
- Neurotoxic shellfish poisoning
- Public health threats form aerosolized brevetoxin

Empirical dynamic modeling (EDM)

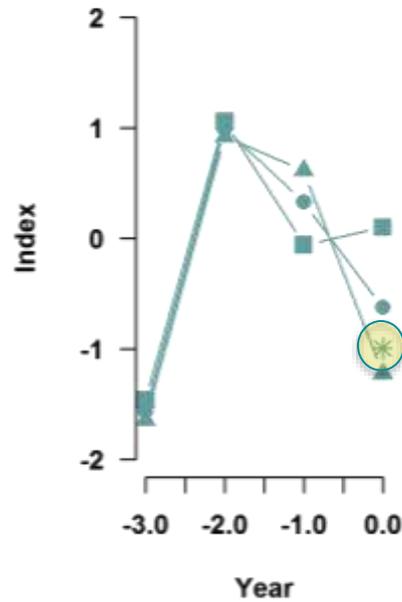
- Suite of methods for time series forecasting
- Non-parametric approach
- No equations used to represent system dynamics (i.e. no mechanistic equations)
- Past events used to forecast near-term future events
- Developed by : Dr. George Sugihara, SCRIPPS.
- His former students: Hao Ye, Ethan Deyle, Sarah Glaser



(1) We want to predict this point



(2) Identify and retain similar vectors



(3) Use similar vectors to make a prediction

EDM utilizes dynamical similarities between sequences of observations to make forecasts

What if we have multiple time series from the same system?

State Space Reconstruction: Time Series and Dynamic Systems

A supplemental simulation and animation for
“Detecting Causality in Complex Ecosystems”

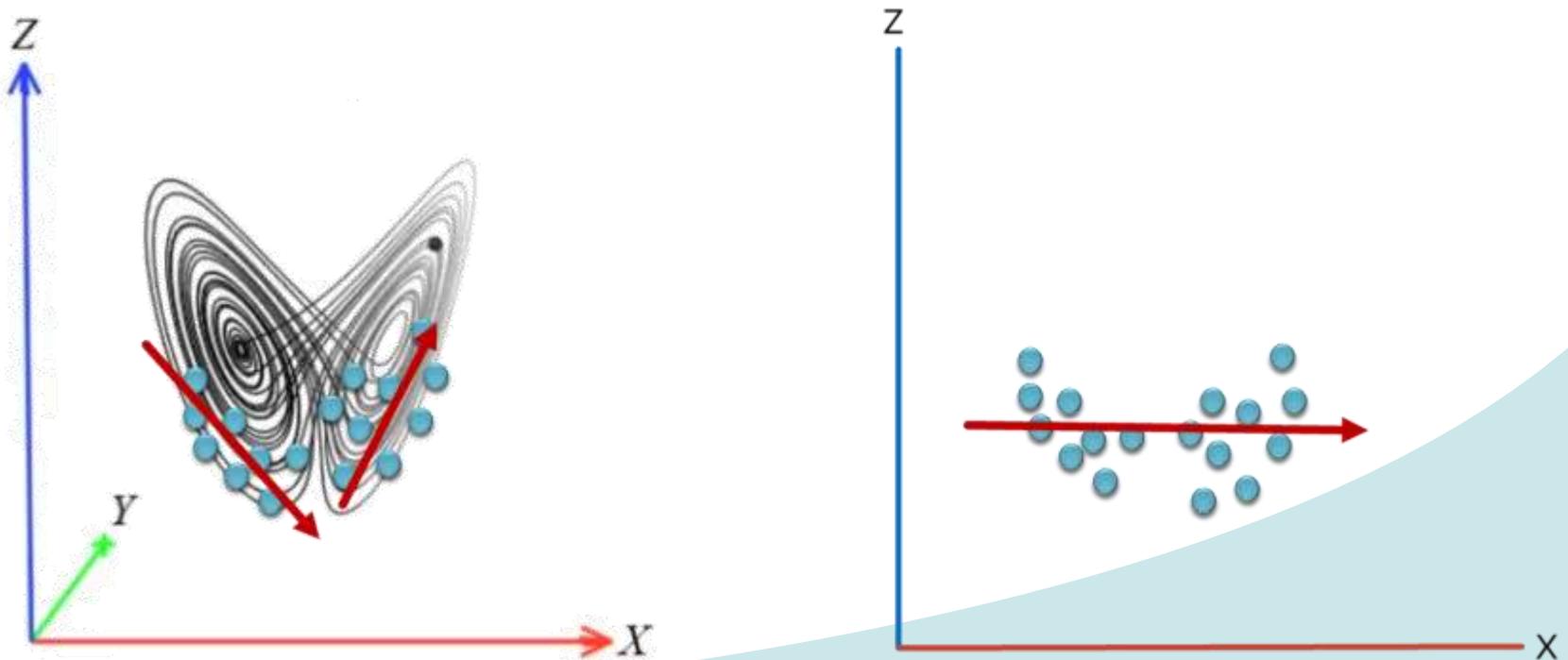
George Sugihara, Robert May, Hao Ye, Chih-hao Hsieh,
Ethan Deyle, Mike Fogarty, and Stephan Munch

animation by: Peter Sugihara, Hao Ye, and George Sugihara

© August 2012

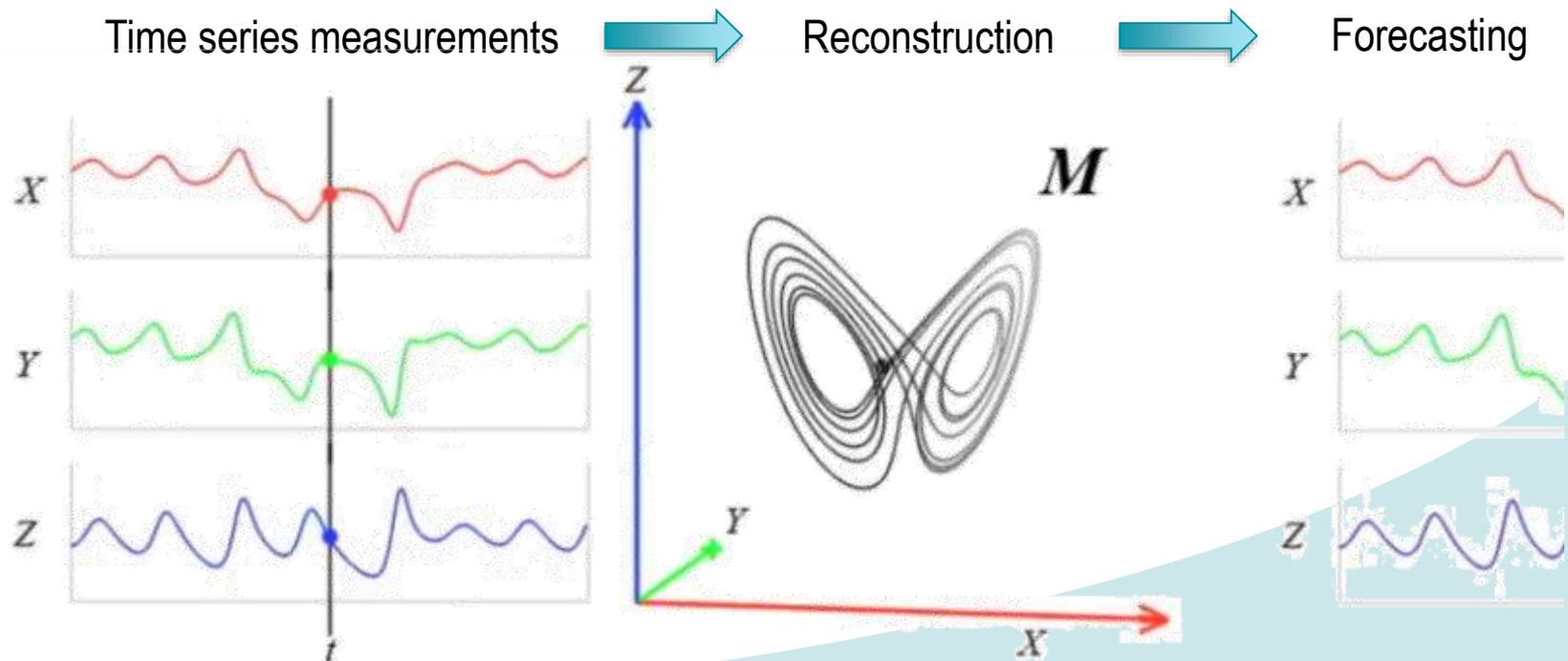
Concept #1: Circumstances under which variables interact are of central importance

- Relationships depend on system state
- Identifying key predictive variables is often insufficient for forecasting
- EDM useful for high dimensionally systems, where non-linear dynamics are pervasive (Conversely, additive linear models may perform poorly)



Concept #2: Time series preserve essential properties of the original system

- Theorem proven by Takens (1981)
- Reconstruction based on information contained in time series
- Therefore: forecasting possible without functional equations
(although EDM can also be informative about causative relationships)



Concept #1: Circumstances under which variables interact are of central importance

“...red tide typically initiates offshore in nutrient-poor waters and then moves toward shore under favorable winds and currents, where growth may be stimulated by additional nutrients from coastal runoff, or where accumulation may occur due to convergence of waters along fronts. Several hypotheses have been proposed, yet testing of these hypotheses has been a challenging task and no conclusive mechanism for HAB formation has been identified.”

– Hu et al. 2005, Remote Sensing of Environment 97: 311 – 321

Concept #1: Circumstances under which variables interact are of central importance

*“Weisberg et al. ... emphasize that predictive models of *K. brevis* dynamics require a complete set of ocean observations... and [are] capable of describing both biological and oceanographic parameters in three dimensions.”*

- Dortch 2009, Harmful Algae 8:547-548

Concept #1: Circumstances under which variables interact are of central importance

- Bio-physical modeling of WFS has intuitive appeal, may be best path forward
 - Structural mathematical models have obviously contributed greatly to ecological fields
 - Non-parametric EDM may be a complementary means of ecological forecasting
- 

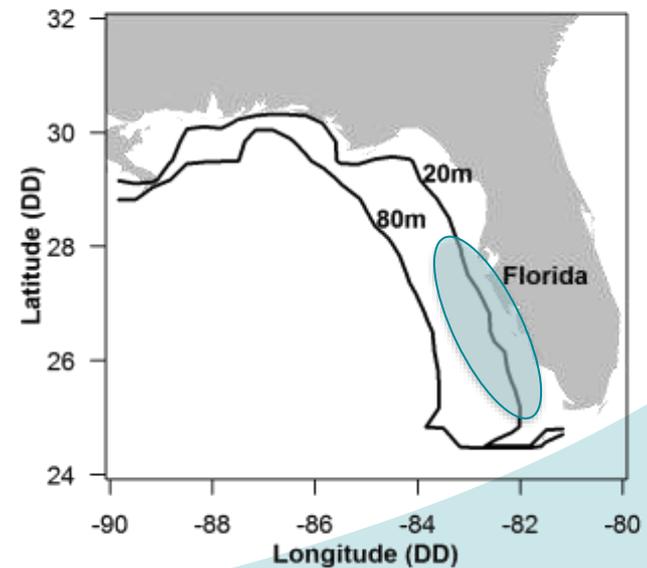
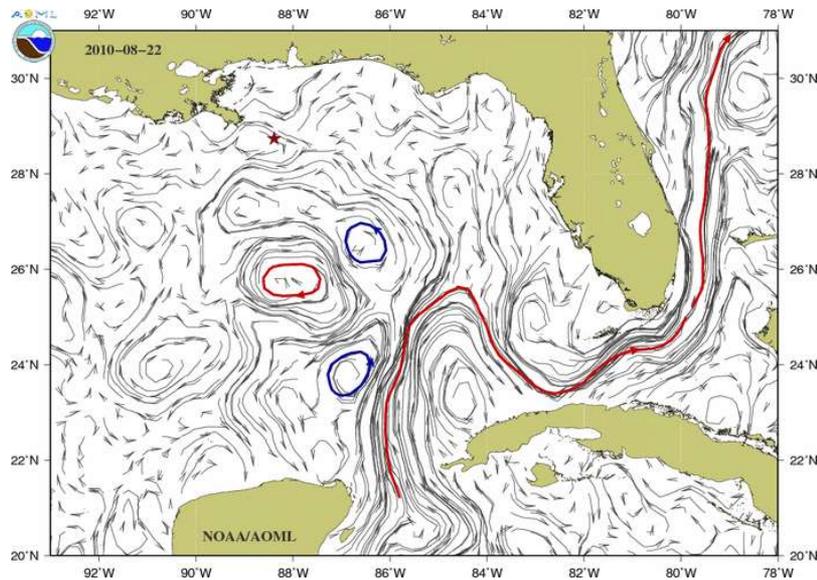
Concept #2: Time series preserve essential properties of the original system

- Satellite derived products, each with unique “view” of environment
- Can we reconstruct essential properties of WFS that lead to red tide events?
- Proxy environmental time series:
 - Sea surface temperature
 - Loop current position
 - Morel backscatter for algae
 - NASA SeaWiFS OC4 chlorophyll
 - Chlorophyll anomaly Stumpf et al. 2003
 - Carder ratio
 - CMbbp marine algae backscatter
 - Rrs670 reflectance t 670 nm
 - ssnLw490 spectral shape at 490 nm
 - HAB ensemble algorithm

* Many caveats / over-simplification of WFS dynamics? *

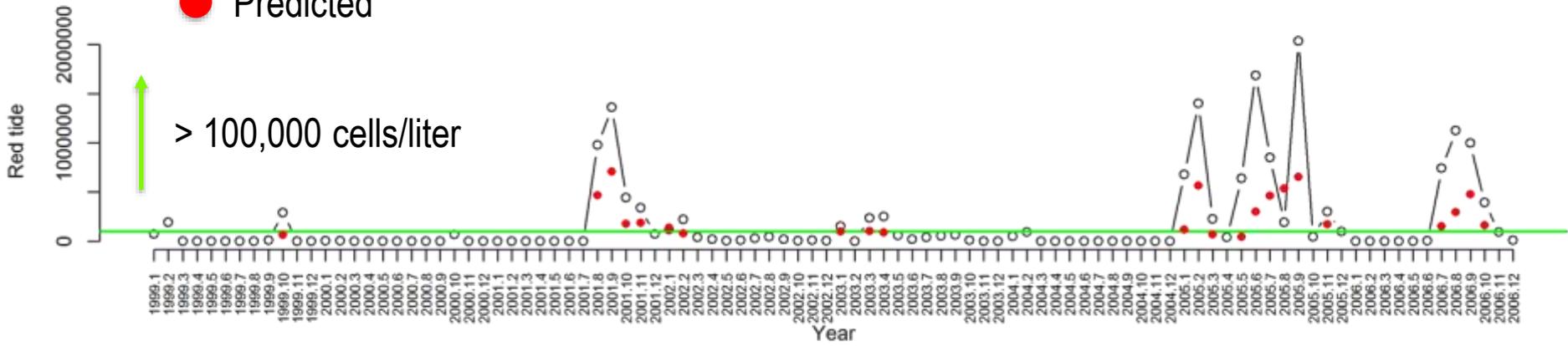
A few technical notes before we move on...

- Proxy times series are incomplete, require informed discussions with oceanographers
- Spatial and temporal partitioning needs careful re-consideration
- Red tide data – event response data



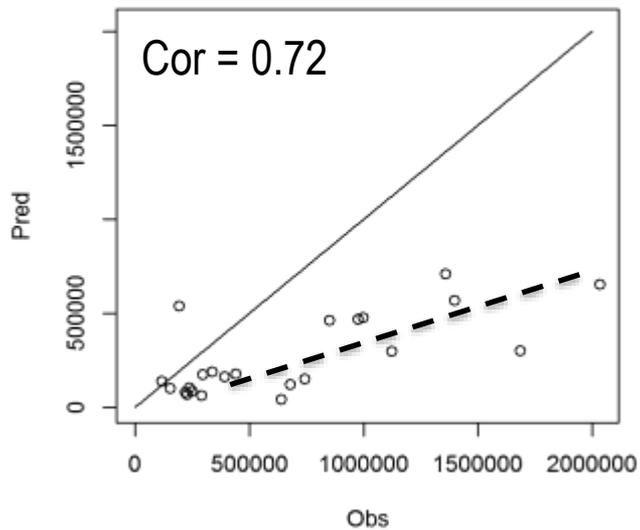
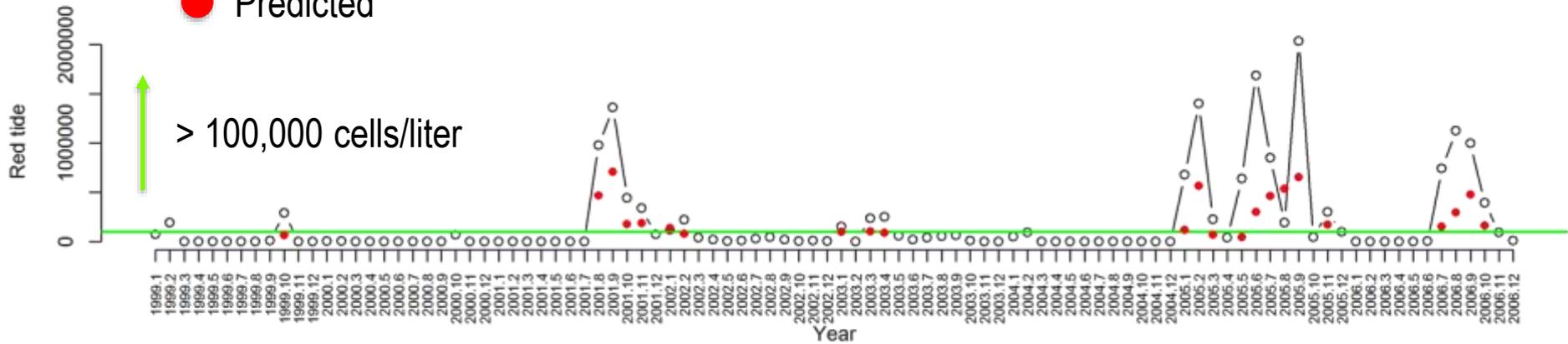
Preliminary forecasting skill

- Observed *K. brevis* density
- Predicted

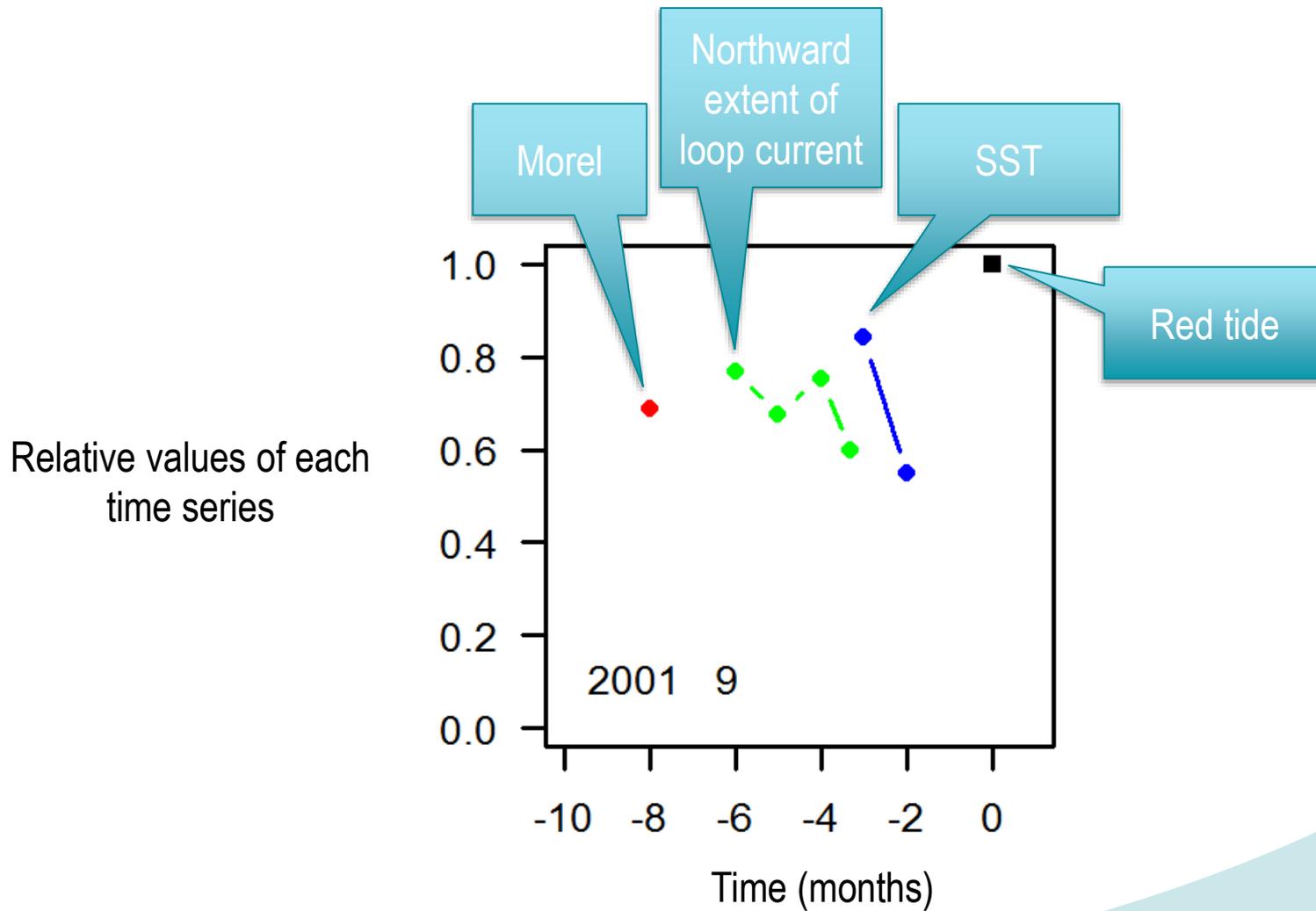


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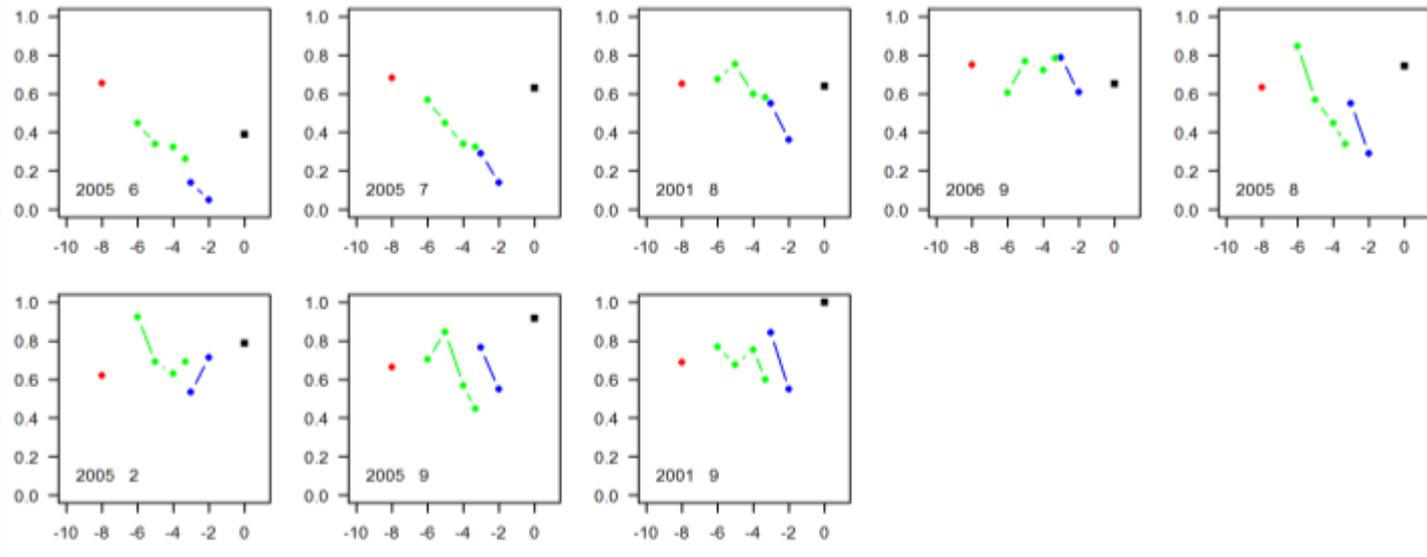


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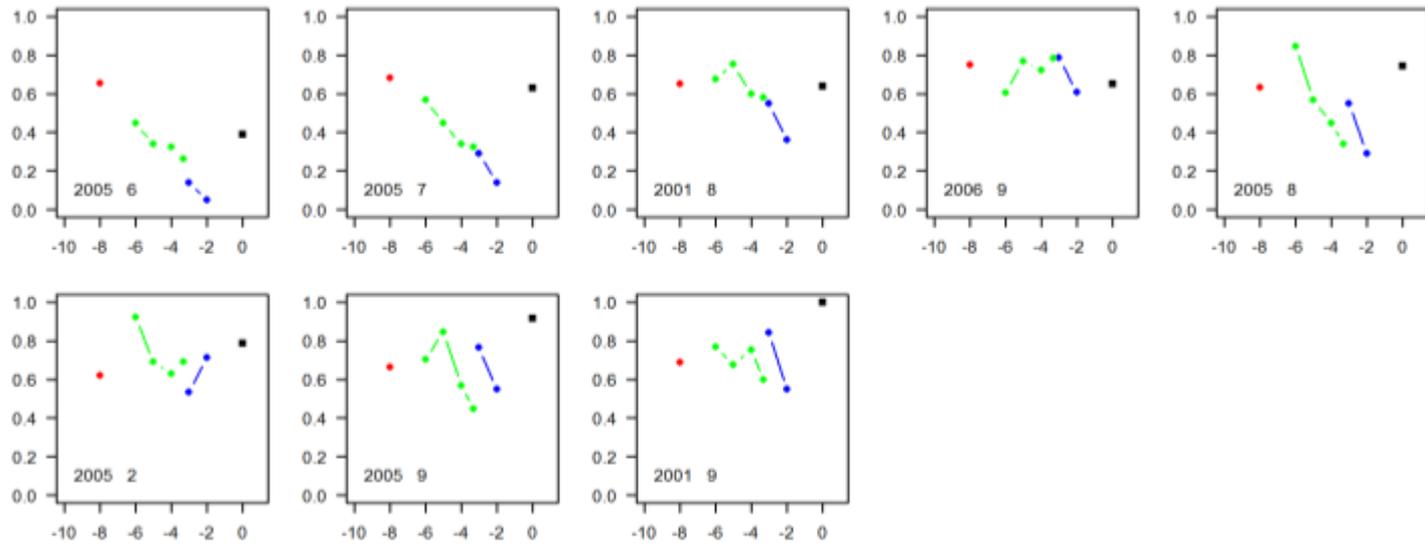
Most severe events



- Patterns detected in modeling building that led to the most severe events
 - Defining circumstances is key to predictive modeling
 - Magnitude + spatial patterns + timing of patterns
 - state dependent system behavior (non-linear system behavior)

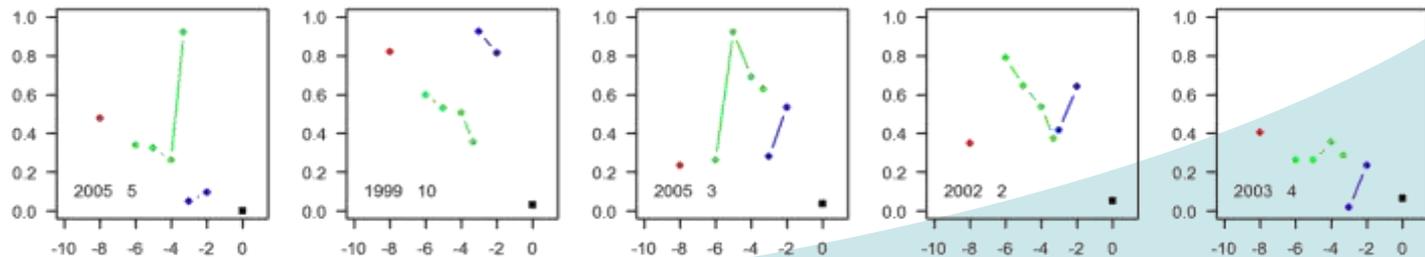
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Most severe events



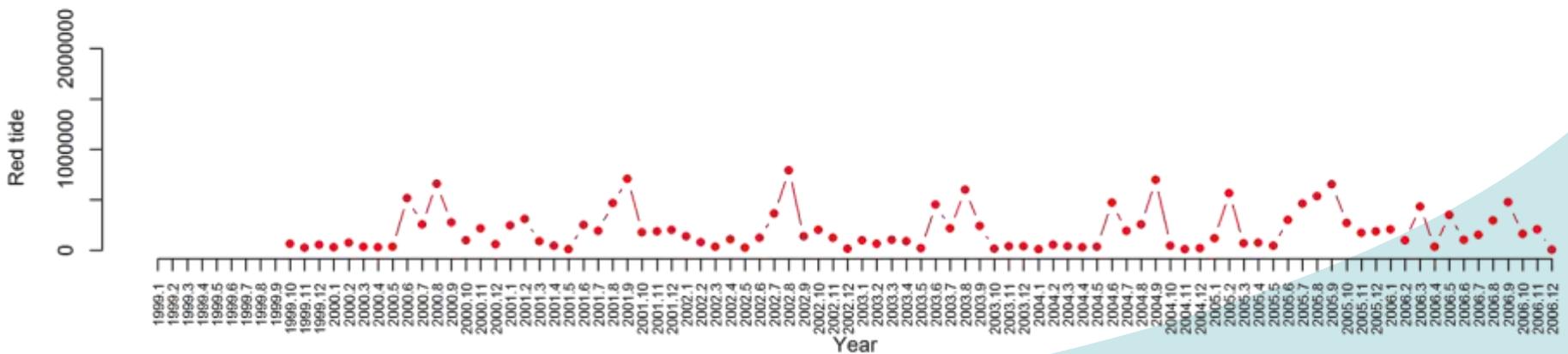
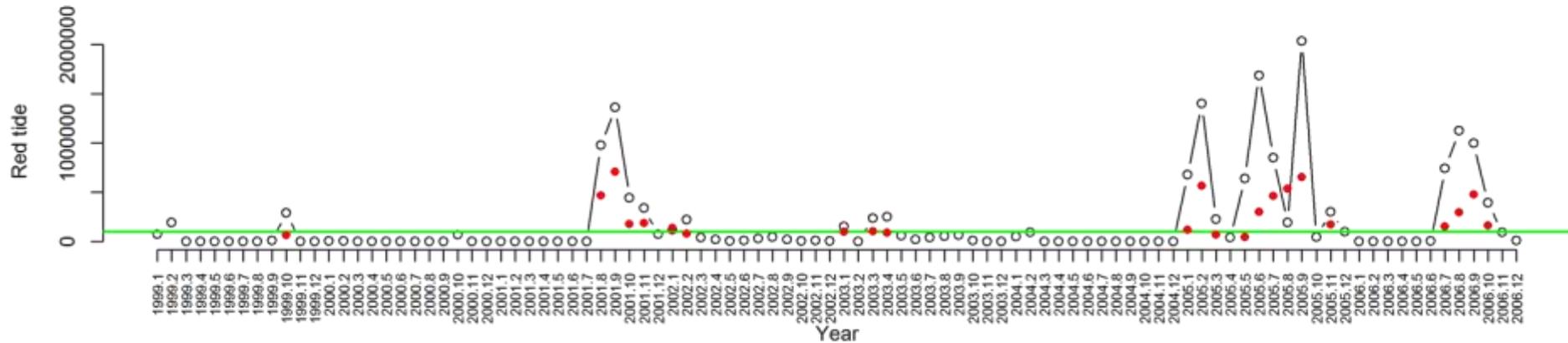
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Least severe events



Concept #2: Time series preserve essential properties of the original system

- Proxy time series to generate a more complete red tide index





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Conclusions

- Commentary on EDM methodology
- Process, not product
- Incomplete forecasting product, much work to be done
- Useful in forecasting high dimensionality or non-linear ecological systems?



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