Seasonal Prediction of Harmful Algal Blooms Caused by *Karenia brevis* on the West Florida Shelf Using Satellite Altimetry Data

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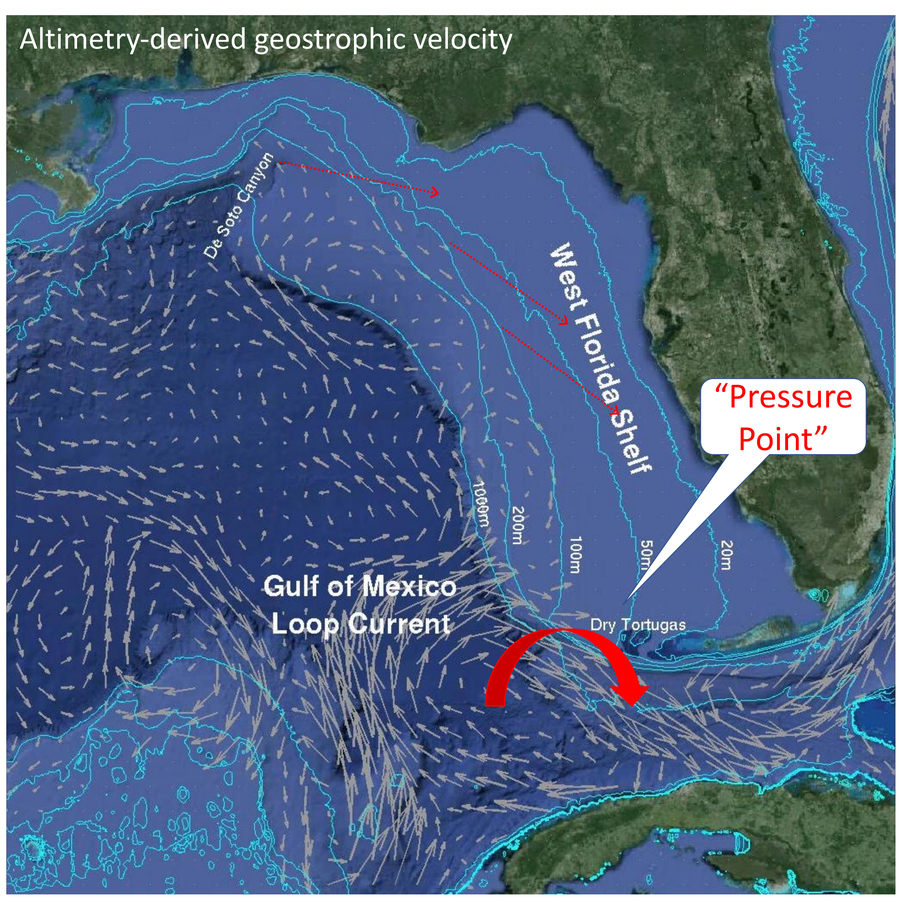
Abstract

Blooms of the toxic dinoflagellate *Karenia brevis* occur frequently on the west coast of Florida, killing fish and other marine life, threatening public health and adversely impacting local economies. Based on analysis of satellite altimetry data, a seasonal prediction tool was developed for the occurrence of major *K. brevis* harmful algal blooms on the West Florida Shelf (WFS). The seasonal prediction is based on a hypothesis that interactions by the Gulf of Mexico Loop Current with the shelf slope under certain conditions can flush the WFS, change its residence time, and reset nutrient structure in ways that may obviate bloom development. The Self-Organizing Map (SOM), a machine learning technique, is used to identify such Loop Current patterns and their cumulative duration of occurrences from satellite altimetry data. This serves as an indicator of offshore forcing of anomalous upwelling. The presence (or absence) of the anomalous upwelling during the formative season for *K. brevis* blooms is found to be consistent with the occurrence of (or lack of) severe WFS coastal blooms later in the year. Considering both the hindcasts for years 1993 – 2015 and the forecasts for recent years (2016 – 2022) relative to *K. brevis* field observations, the seasonal predictor is found to be successful in 25 of 30 years.

Hypothesis on *K. brevis* Harmful Algal Bloom Offshore Forcing



Loop Current interactions with the shelf slope near the Dry Tortugas can set the shelf in an upwelling motion. This critical location is called the "pressure point" of the WFS.

Physical oceanography:

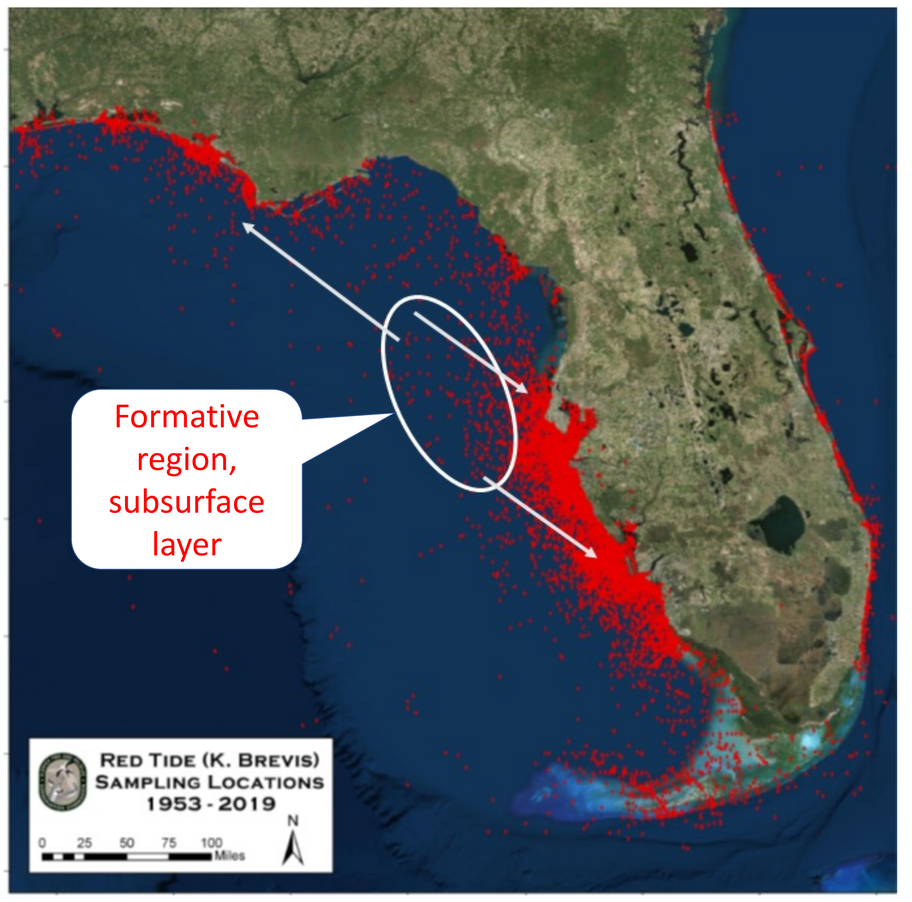
- Protracted upwelling circulation can flush the shelf effectively, resulting in shorter residence time (T_o). Without such upwelling, not flushed, longer T_o.

Biological oceanography:

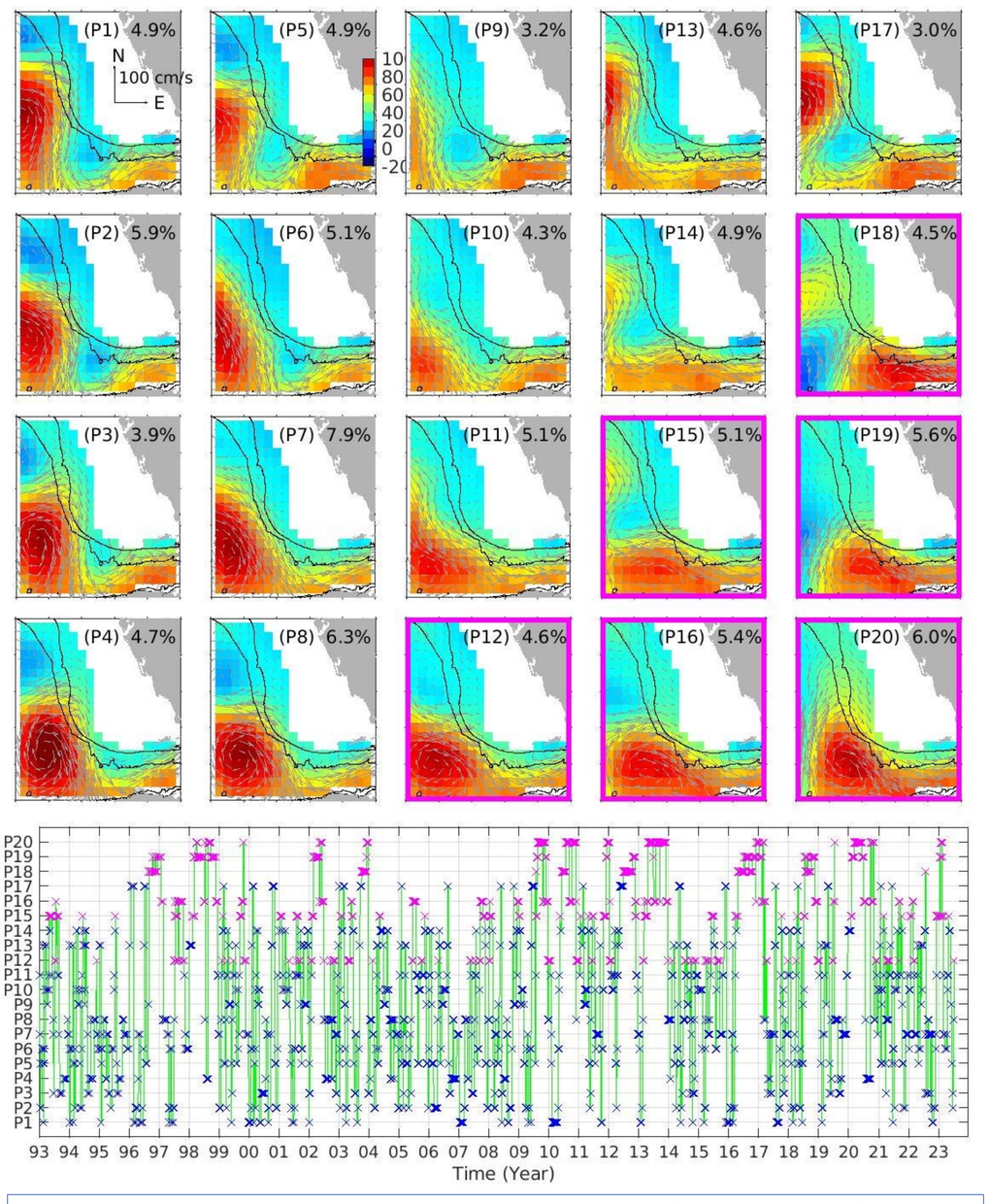
- Upwelling can transport inorganic nutrients of deeper ocean origin onto the shelf, changing the nutrient structure on the shelf.
- High nutrient levels favor diatoms over dinoflagellates, thereby suppressing *K. brevis* development.
- Without such upwelling, the mid-shelf tends to be oligotrophic, thereby favoring *K. brevis* development.

Seasonal Forecast (Binary):

Persistent upwelling in formative season (spring – early summer), there will be no major red tide in fall season. Without such upwelling, there may be red tide.



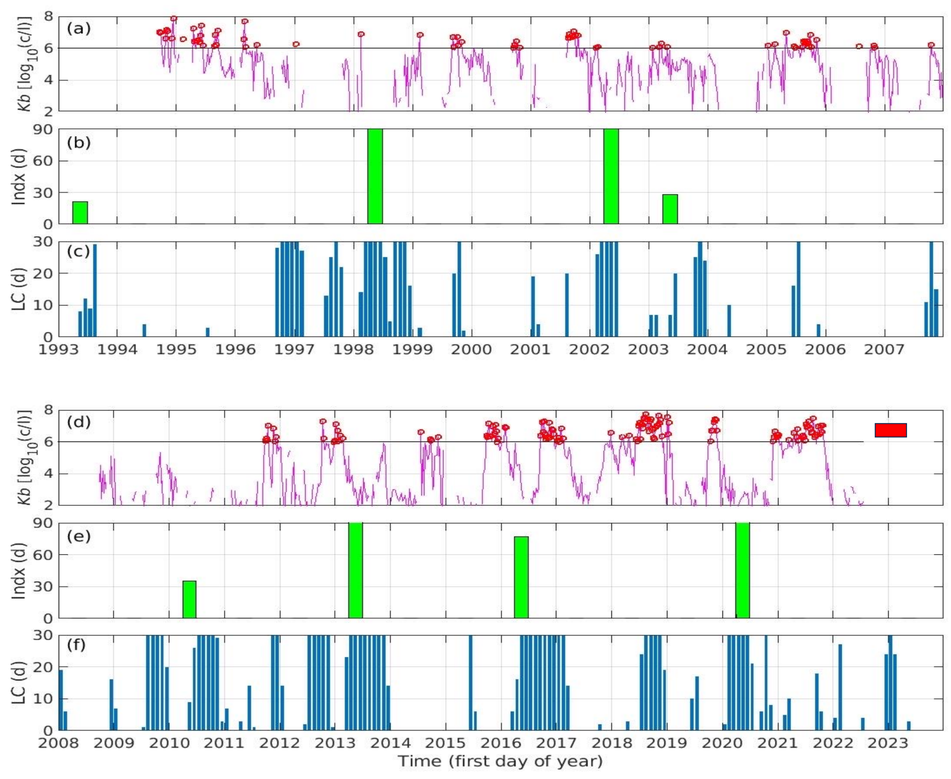
Seasonal Forecast o f *K. brevis* Red Tide on the West Florida Shelf



Machine learning analysis of satellite altimetry data (*Liu et al.*, 2016) using the SOM. Top 20 panels: characteristic patterns; Bottom panel, the Best Matching Units time series, indicating the evolution of the current patterns.

Relevant patterns: The Loop Current interacts with the shelf/slope at the WFS "pressure point."

Liu et al. (2016), Offshore forcing on the "pressure point" of the West Florida Shelf: Anomalous upwelling and its influence on harmful algal blooms, *J. Geophys. Res. Oceans*, 121, 5501-5515, doi:10.1002/2016JC011938



a&d: weekly averages of the highest 5 *K. brevis* cell counts (magenta lines), the black line indicating the major bloom threshold (10^6cells/L) and red being cell counts exceeding this.

b&e: a "pressure point" forcing index (green bars), the cumulative days for which the relevant SOM patterns occurred in spring to early summer (4/1 to 6/30) for at least 7 days in each of at least two months.

d&f: the number of days for which the relevant patterns occurred in each month (blue bars).

Year	Persistent offshore forcing in spring & early summer (√)	Major blooms (×)	No major fall bloom (√) or the earlier year bloom reduced intensity (√*)	Outlier years (F)
1993	√		√	
1994, 1995, 1996		×		
1997			√*	F
1998	√		√*	
1999, 200, 2001		×		
2002	√		√	
2003	√		√	
2004			√	F
2005, 2006, 2007		×		
2008			√	F
2009			√	F
2010	√		√	
2011		×		
2012		×		
2013	√		√*	
2014		×		
2015		×		
2016	√	×		F
2017		×		
2018		×		
2019		×		
2020	√		√	
2021		×		
2022		×		
2023		×		(?)

Once formed offshore at subsurface layer, *K. brevis* cells need onshore transport mechanisms to reach coastal area: the Loop Current offshore forcing and/or local winds (cold fronts) driven coastal upwelling.

Loop Current "pressure point" forcing accounts for major *K. brevis* blooms on the West Florida Shelf.

Seasonal prediction:
No major bloom 7/8
Major bloom 19/23

25 out of 30 years followed the major bloom criteria defined herein.