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Updating indices of red tide severity for incorporation into stock assessments for the shallow-water grouper complex in the Gulf of Mexico

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Introduction

A binary index of red tide severity (1998-2010) (Walter et al. 2013) was included in the base stock assessment model for Gulf of Mexico (GOM) gag (*Mycteroperca microlepis*) and red grouper (*Epinephelus morio*). The purpose of this working paper is to update the indices of red tide severity using Moderate Resolution Imaging Spectroradiometer (MODIS) satellite data.

Methods

The original index of red tide severity produced for SEDAR 33 were developed using Sea-viewing Wide Field-of-view Sensor (SeaWiFS) satellite data which were operational from September 1998 through December 2010 (Walter et al. 2013). This methodology followed for this study were nearly identical to Walter et al. (2013), with the exception of using MODIS satellite data instead of SeaWiFS. MODIS satellite sensors have been operational since July 2002 and are commonly used to detect and track harmful algal blooms (Hu et al. 2005; Hu et al. 2011). Although both SeaWiFS and MODIS products have been used to detect red tide events (Carvalho et al. 2007), slight differences exist between the two data sources. For example, data loss due to sun glint is more prevalent in MODIS imagery than in SeaWiFS imagery (Tomlinson et al. 2009).

Notable issues with MODIS

Operational differences were identified between SeaWiFS and MODIS satellites. For SeaWiFS, a telescope spins perpendicular to the satellite and captures a signal (1 pixel) every millisecond. In contrast, MODIS satellites possess 8-9 sensors and a mirror which rotates before it gets to the telescope. As a result of the various sensors in MODIS, errors and inconsistencies may be more prevalent, as opposed to SeaWiFS which had a single sensor.

Data derived from MODIS show instabilities in terms of a swath which masks data and degrades data quality within ~200 km of the swath, essentially creating false data adjacent to the swath. The presence of the swath follows a 16 day cycle, with the swath impacting satellite data on the West Florida Shelf for five of the 16 days (Figure 1). Satellite products near the swath show a distinct striping pattern, which is a characteristic of the MODIS satellite sensor. Additional data processing was required for the MODIS satellite data to exclude all values within 200 km of the swath to ensure the removal of false data.

Comparison between MODIS and SeaWiFS red tide indices

Red tide index values were compared between SeaWiFS and MODIS satellite data to evaluate the similarity in derived indices between satellite sources using the same model. The difference between indices as a percentage was calculated using the following equation:

$$\Delta Index_y\,(\%) = \frac{\left(MODIS_y - SeaWiFS_y\right)}{SeaWiFS_y} \times 100$$

where $MODIS_y$ and $SeaWiFS_y$ are the respective index values derived from each satellite source for a given year y.

Results

Comparison between MODIS and SeaWiFS satellite data

Initial concerns over the variability in MODIS derived products were addressed by examining products derived from MODIS on consecutive days. As expected, the highest correlations were evident when data were assigned to a 1 km by 1 km grid and averaged for each week (Figure 2). However, the spread of correlation values for each derived product suggests that considerable variability exists within the data products produced by MODIS. Investigations into this issue are ongoing, as we continue to explore ways to filter the MODIS data.

When averaged across years, correlations between MODIS and SeaWiFS products ranged from 0.6 for the Chlorophyll anomaly to 0.89 for Chlorophyll (Figure 3). Derived products such as Carder, Chlorophyll and CMbbp were highly correlated (> 0.8) throughout the time series, with other products revealing moderate correlations (0.6 – 0.7) across the time series (Figure 3).

Comparison between MODIS and SeaWiFS red tide indices

The derived red tide index values were similar between satellite data sources, although MODIS estimates tended to produce higher standard errors compared to the SeaWiFS satellite data (Table 1). No systematic differences between satellite data sources were observed for the red tide indices (Figure 4). Relative trends in estimated red tide indices were generally similar between satellite data sources, with 2005 exhibiting the largest value among indices and data sources (Figure 4).

Red tides in recent years

The 2014 through 2017 red tide index values for all calculated indices were roughly half the calculated index values for 2005 using the MODIS satellite data (Table 1). The magnitude of the MCP index during all three years using MODIS satellite data was below the threshold value (0.135 for MODIS) estimated using the original models and the MODIS satellite data, suggesting that these red tide events were minimal compared to the 2005 event.

Based on the model-based prediction approach using derived satellite products, the predicted probability of a red tide bloom in 2005 was high throughout much of the West Florida Shelf during summer and fall months (Figure 5). In contrast, no red tide bloom was detected during 2010 (Figure 6). During 2014, the predicted probability of a red tide bloom was relatively high in the Big Bend region from July through November (Figure 7), although the spatial extent was much smaller compared to the 2005 event. The spatial extent of high probabilities of a red tide bloom was relatively small during both 2015 (Figure 8) and 2016 (Figure 9), again supporting the notion that the red tide events during these years were not as severe as in 2005. During 2017, the predicted probability of a red tide bloom was relatively high off Tampa Bay in September and October and in the Big Bend region from November through December (Figure 10).

Discussion

Initial attempts to calibrate between SeaWiFS and MODIS data were unsuccessful due to the high variability in the MODIS data. Even after removing data adjacent to the swath, correlations between daily MODIS products remain lower than desired. Research is ongoing to further refine the red tide index using MODIS satellite data.

Acknowledgements

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Table 1. Comparison of red tide indices and index standard errors (SE) using SeaWiFS and MODIS satellite data sources and the model restricted to only waters greater than 10 meters. Note that the threshold index is based on thresholds of 0.0785 and 0.135 for SeaWiFS and MODIS, respectively.

Year	SeaWiFS			MODIS			ΔIndex
	Index	SE	Threshold	Index	SE	Threshold	(%)
10mMCP75							
2003	0.059	0.002	0	0.070	0.008	0	18.0
2004	0.049	0.001	0	0.061	0.007	0	25.3
2005	0.148	0.005	1	0.151	0.012	1	2.2
2006	0.058	0.002	0	0.054	0.005	0	-7.7
2007	0.045	0.002	0	0.034	0.005	0	-25.5
2008	0.057	0.002	0	0.039	0.006	0	-31.1
2009	0.028	0.001	0	0.036	0.005	0	29.6
2010	0.058	0.002	0	0.034	0.005	0	-41.1
2011	-	-	-	0.035	0.005	0	-
2012	-	-	-	0.040	0.005	0	-
2013	-	-	-	0.062	0.007	0	-
2014	-	-	-	0.070	0.009	0	-
2015	-	-	-	0.061	0.007	0	-
2016	-	-	-	0.053	0.006	0	-
2017	-	-	-	0.069	0.008	0	-

Figure 1. Progression of swath (black) across the Gulf of Mexico which is a characteristic of the MODIS satellite sensor and not an issue for the SeaWiFS satellite sensor.

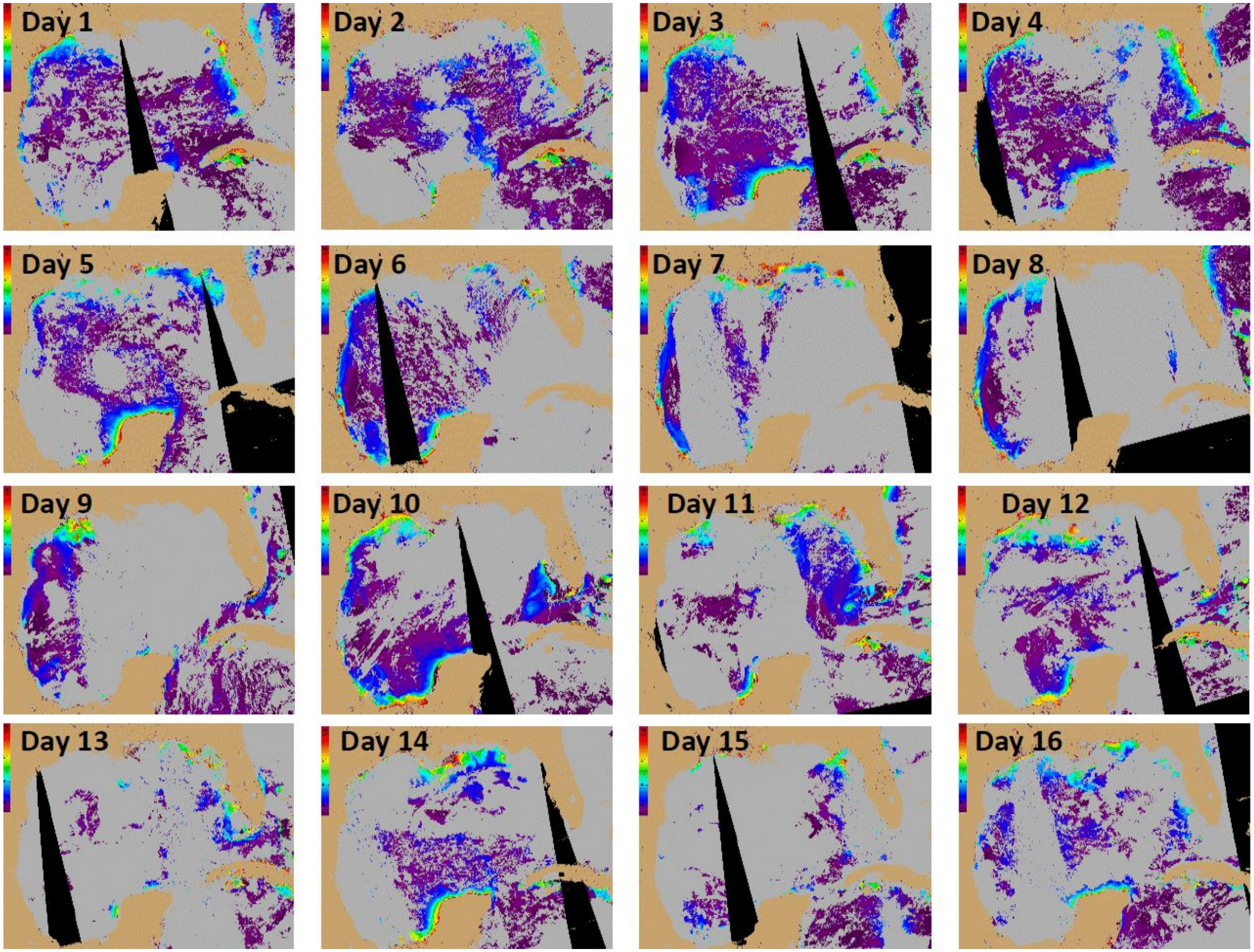

Figure 2. Daily and weekly correlations between MODIS-derived satellite data products extracted by 1 and 22 km grid cells. Note that daily correlations are between subsequent dates (i.e., correlation between MODIS data extracted on days 1 and 2, days 2 and 3, etc.).

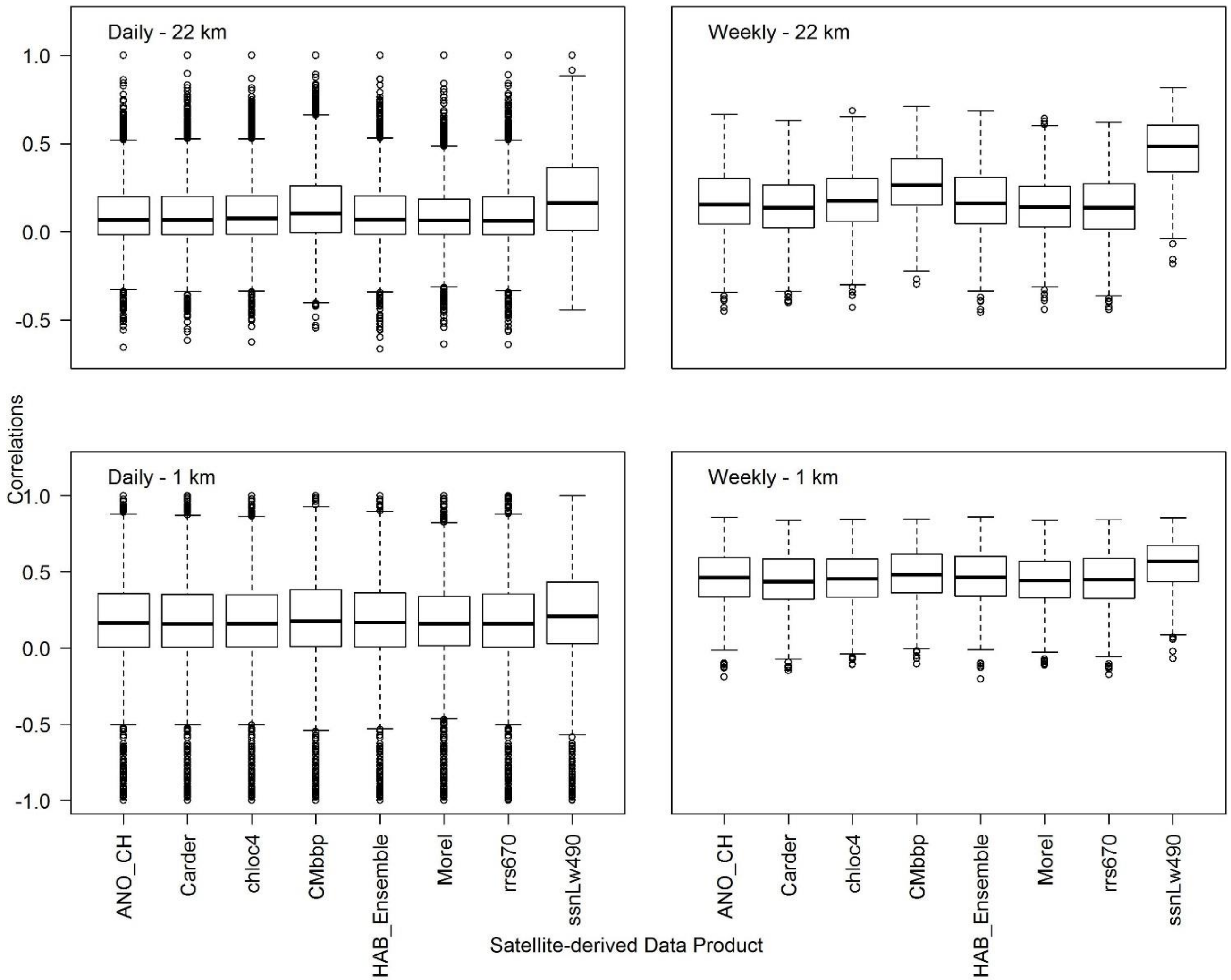

Figure 3. Annual and overall Pearson's (top panel) and Spearman's (bottom panel) correlation coefficients between SeaWiFS and MODIS satellite-derived products between 2003 and 2010.

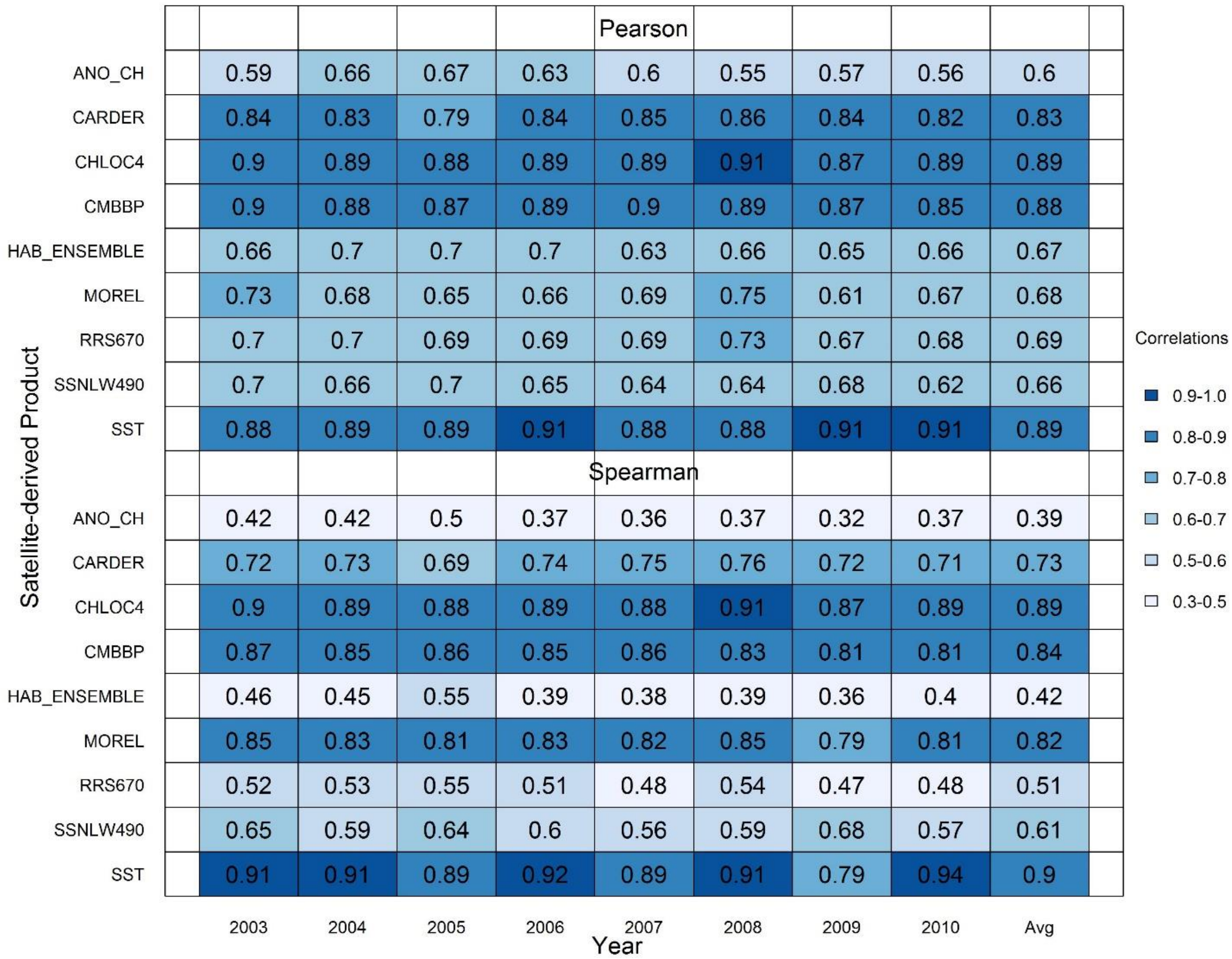

Figure 4. Comparison of relative indices of red tide severity and standard errors (vertical bars) derived from SeaWiFS (black) and MODIS (gray) using the model with depths greater than 10 m (i.e., best model based on SeaWiFS analysis). The right panels show the linear relationship. Dashed lines in top left panel identify the thresholds identified for SeaWiFS (black) and MODIS (gray) and in right panels identify the 1:1 line.

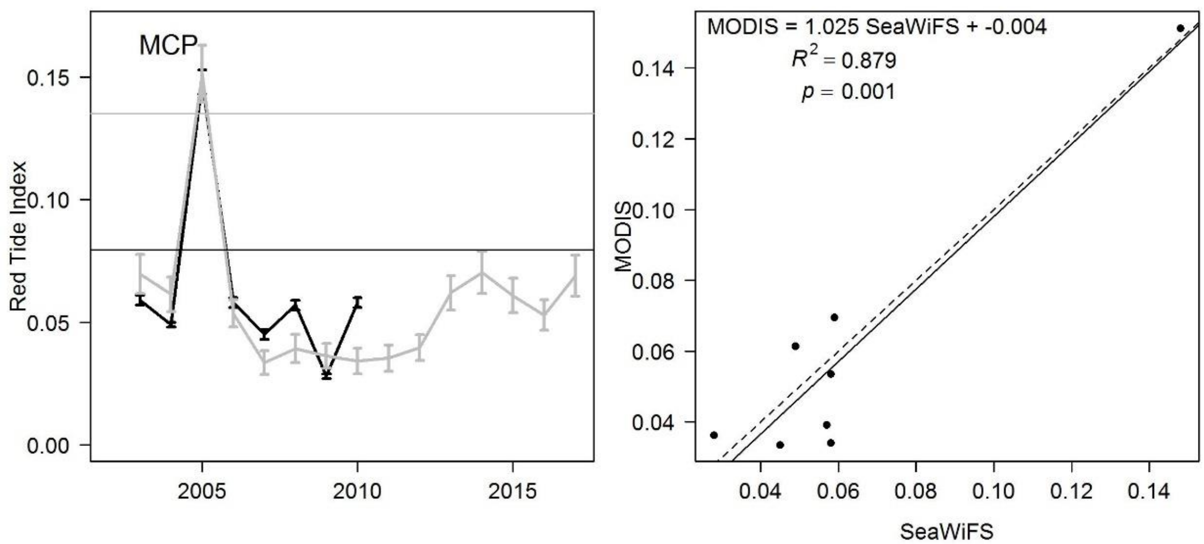

Figure 5. Monthly average predicted presence and average standard errors of prediction of algal concentrations greater than 100,000 cells per liter for July-December during 2005, a year with a severe red tide.

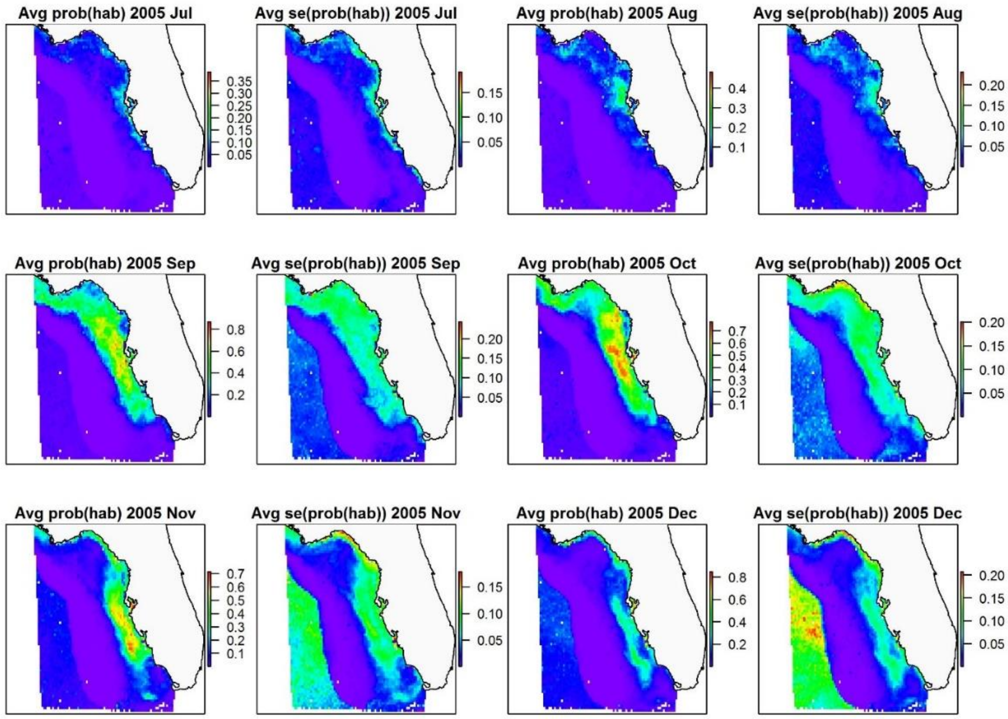

Figure 6. Monthly average predicted presence and average standard errors of prediction of algal concentrations greater than 100,000 cells per liter for July-December during 2010, a year with no red tide identified.

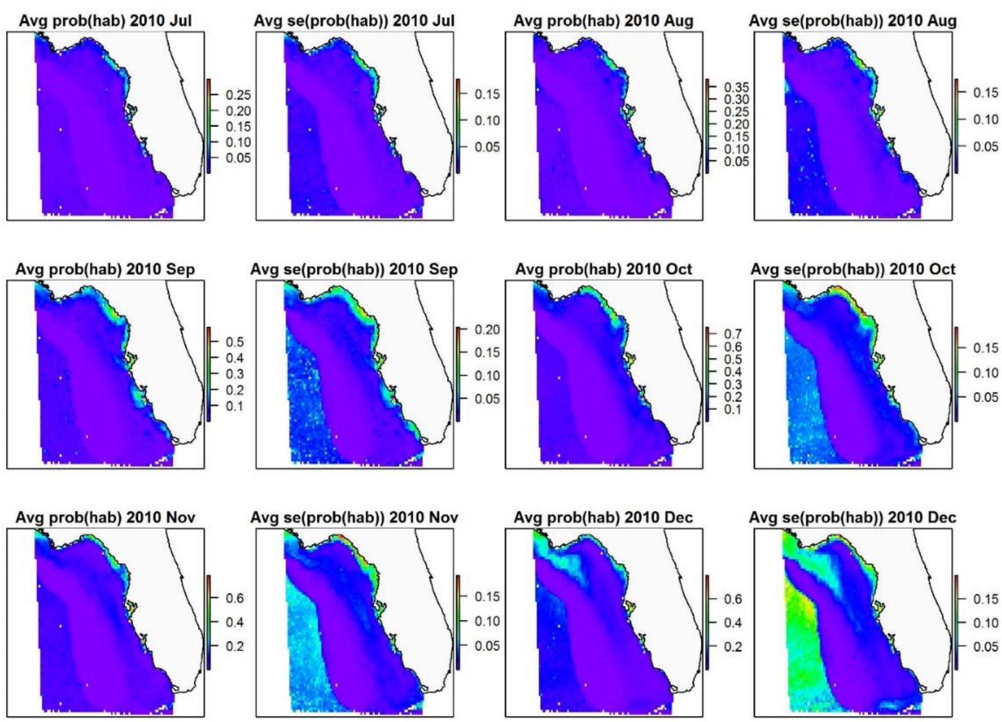

Figure 7. Monthly average predicted presence and average standard errors of prediction of algal concentrations greater than 100,000 cells per liter for July-December during 2014, a year of concern regarding the magnitude of the red tide event based on anecdotal observations.

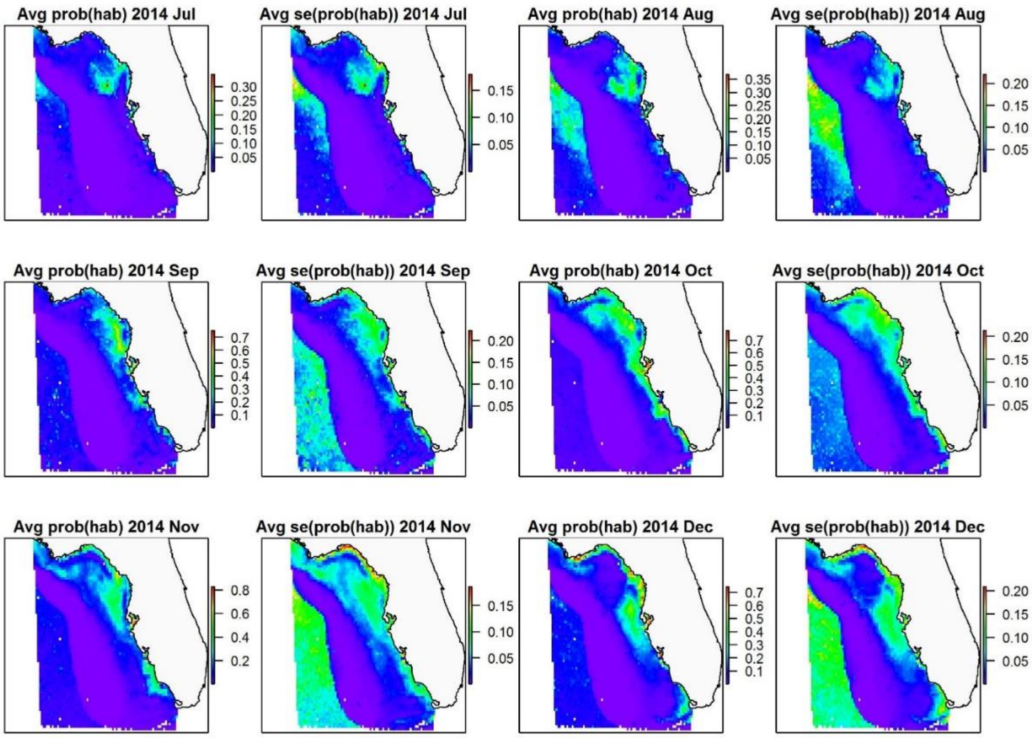

Figure 8. Monthly average predicted presence and average standard errors of prediction of algal concentrations greater than 100,000 cells per liter for July-December during 2015, a year of concern regarding the magnitude of the red tide event based on anecdotal observations.

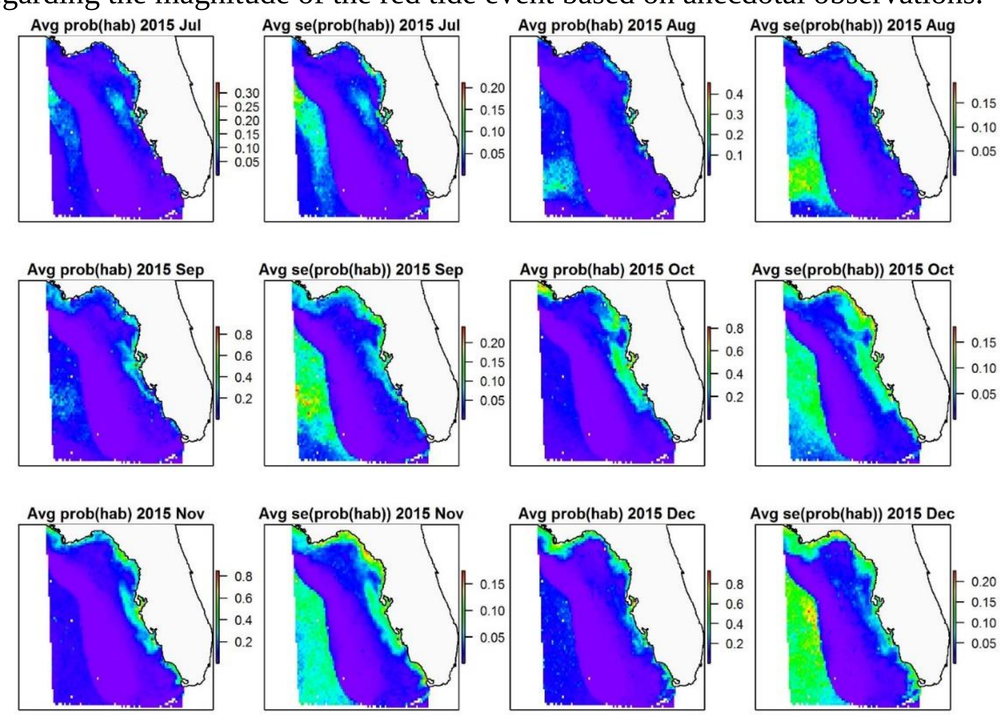

Figure 9. Monthly average predicted presence and average standard errors of prediction of algal concentrations greater than 100,000 cells per liter for July-December during 2016, a year of concern regarding the magnitude of the red tide event based on anecdotal observations.

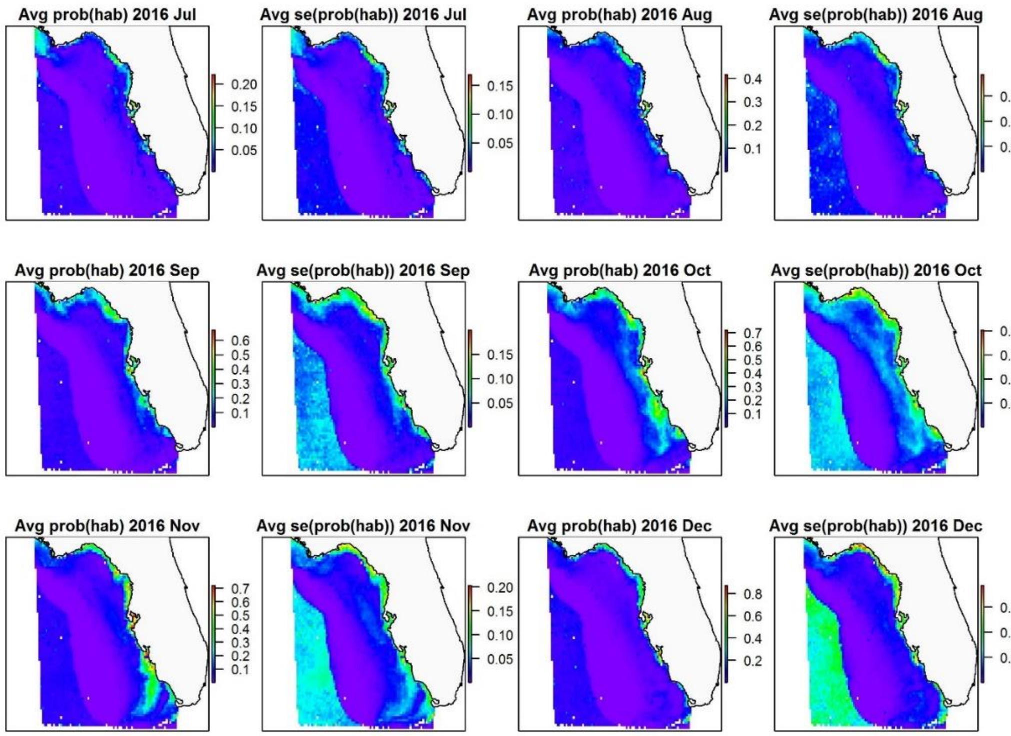

Figure 10. Monthly average predicted presence and average standard errors of prediction of algal concentrations greater than 100,000 cells per liter for July-December during 2017, a year of concern regarding the magnitude of the red tide event based on anecdotal observations.