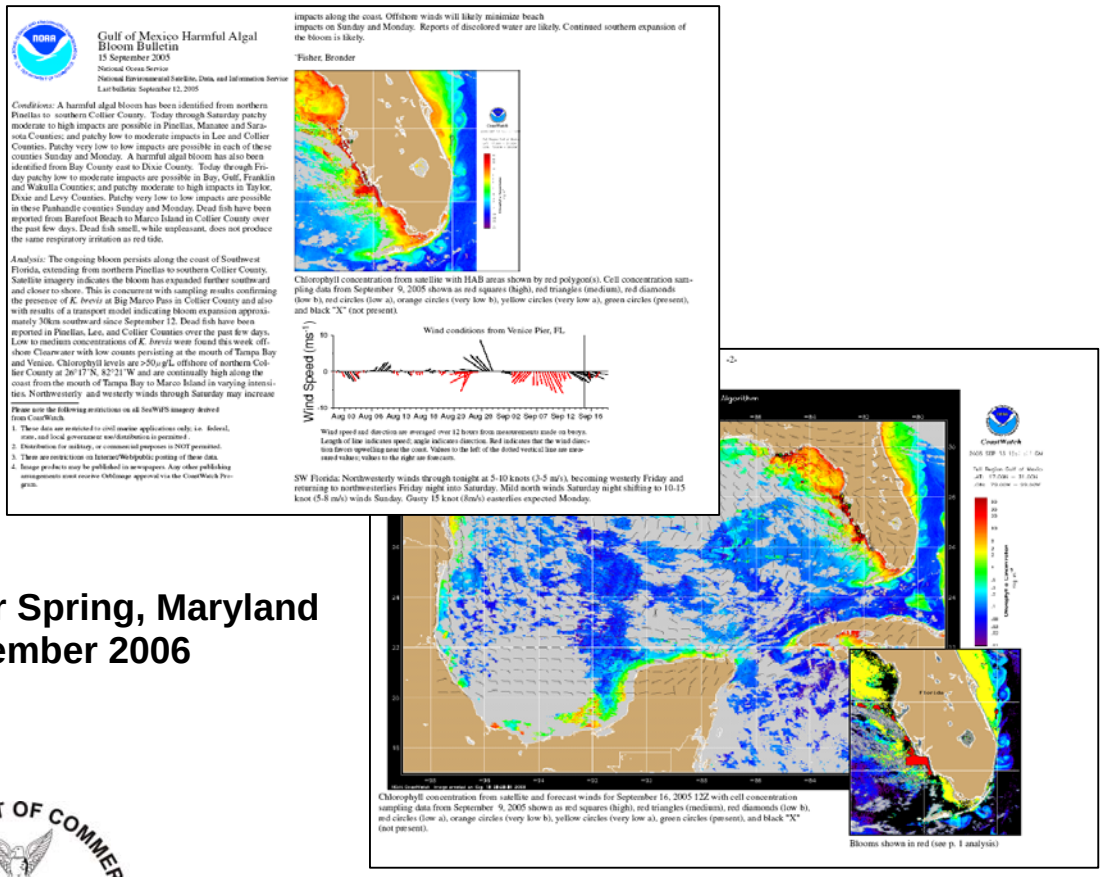
NOAA Technical Report NOS CO-OPS 047

Annual Report of the Gulf of Mexico Harmful Algal Bloom Operational Forecast System (GOM HAB-OFS):

October 1, 2004 to September 30, 2005 (Operational Year #1)



Silver Spring, Maryland
September 2006

noaa National Oceanic and Atmospheric Administration

U.S. DEPARTMENT OF COMMERCE
National Ocean Service
Center for Operational Oceanographic Products and Services

Center for Operational Oceanographic Products and Services
National Ocean Service
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October 1, 2004 to September 30, 2005 (Operational Year #1)

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National Oceanic and Atmospheric Administration

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EXECUTIVE SUMMARY

On October 1, 2004, a harmful algal bloom forecast system for the Gulf of Mexico was successfully transitioned from research to operational status, creating the Gulf of Mexico Harmful Algal Bloom Operational Forecast System (GOM HAB-OFS). During the following 52 week period 114 operational bulletins, containing 131 bloom forecasts, were disseminated to coastal resource managers, state and federal officials, and academic and research institutions. Two harmful and two non-harmful blooms were accurately identified by HAB forecasters and confirmed by *in situ* sampling. Bulletin utilization was confirmed for 90% of the total operational weeks and 78% of the total bulletins disseminated. 33 high priority bulletins containing pertinent information due to new bloom appearance or significant change in bloom location or intensity were disseminated with 93% confirmed utilization. In addition to overall utilization of the bulletin, success of the operational bulletins can be broken down into various forecast components to help determine needed enhancements to the system. A coastal impact forecast statement was included in 93% of the total bulletins produced, of which 54% were assessable and 98% of those assessable were confirmed accurate. Bloom transport was included in 83% of all forecasts, of which 66% were assessable and 93% of those assessable were confirmed accurate. Bloom intensification was included in 43% of all forecasts, of which 63% were assessable and 72% of those assessable were confirmed accurate. Change in spatial extent was included in 25% of all forecasts, of which 48% were assessable and 81% of those assessable were confirmed accurate. 90% of the total component forecasts disseminated were confirmed accurate. The results of this assessment will be utilized to enhance the operational forecast system, improving the accuracy of individual forecast components through increased bloom knowledge and advanced technology, as well as exploring additional methods to better assess the accuracy of issued forecasts.

1. INTRODUCTION

1.1 Background

Blooms of a toxic dinoflagellate, *Karenia brevis*, occur nearly every year on the Gulf coast of Florida, typically between August and December, and are reportedly the most common harmful algal bloom (HAB) occurring in the eastern Gulf of Mexico (Stumpf et al., 2003). Numerous fish kills and various marine bird and mammal deaths have been linked to *K. brevis* blooms, and very low levels (5,000µg/L) of *K. brevis* prompt the closure of shellfish beds to prevent Neurotoxic Shellfish Poisoning (NSP) in humans (Tomlinson et al., 2004). Under certain wind conditions, nearshore surface blooms release a potent brevetoxin aerosol that can produce respiratory illness and distress; thus prompting necessary advisories at afflicted beaches. In order to assist coastal managers in mitigating damages due to HABs, a new ecological forecast system for the Gulf of Mexico was developed through a multi-office effort of NOAA. In October 2004 this ecological forecast system was transitioned from research to operational status, creating the Gulf of Mexico HAB Operational Forecast System (GOM HAB-OFS). GOM HAB-OFS bulletins are produced twice weekly during active bloom events (once weekly during inactive bloom status) and provide information concerning the possible presence or confirmed identification of new blooms, and monitor existing blooms with forecasts of spatial bloom extents, movement, and intensification conditions (see Appendix for an example bulletin). The bulletins also report daily coastal impact statements that are publicly available via the Internet at http://www.csc.noaa.gov/crs/habf/. As a result of the bulletins' forecasts, advance cautionary notice can be issued to protect beachgoers from respiratory illness; necessary mitigation actions, such as closing shellfish beds, can be initiated before a bloom becomes a coastal hazard; and mass marine animal casualties can be minimized through advanced response. The bulletins identify potential areas of harmful algae using satellite imagery. By doing so, the bulletins provide advance notice to the Florida Department of Agriculture and Consumer Services (FDACS) to initiate sampling programs and confirm the identity of the feature in question. If the feature is found to contain *K. brevis* at a concentration level capable of causing human NSP when ingested, shellfish harvesting is prohibited by the FDACS in the region of the bloom and shellfish bed closures are listed on FDACS regional hotlines and via the Internet at http://www.floridaaquaculture.com. The bulletins also indicate potential geographic extents of presently confirmed blooms to allow for more effective field sampling. This, in turn, assists in confirming the extent and severity of a toxic bloom, aids technological development of forecasting methods, and enhances scientific knowledge of the HAB species.

1.2 Objective

The purpose of this report is to provide a performance overview of the GOM HAB-OFS' first year of operational status. More detailed discussions of the underlying technology are provided in Stumpf et. al. (2003) and Tomlinson et. al. (2004).

2. METHODS

2.1 Operations

On October 1, 2004, the Center for Operational Oceanographic Products and Services (CO-OPS) transitioned a new ecological forecast system for Harmful Algal Blooms (HABs) in the Gulf of Mexico from research to operational status in a collaborative effort with the National Centers for Coastal Ocean Science (NCCOS-science and research), the Coastal Services Center (CSC-technology development and public outreach), and the National Environmental Satellite, Data and Information Service (NESDIS-satellite ocean color imagery). This system is called the Gulf of Mexico Harmful Algal Bloom Operational Forecast System (GOM HAB-OFS). The GOM HAB-OFS involves a combination of automated processing and analysis using a Web-Based interface. SeaWiFS satellite ocean color imagery (available through NOAA's Coastwatch) is processed using a chlorophyll algorithm and analyzed in conjunction with chlorophyll anomaly imagery highlighting regions of elevated chlorophyll to determine the potential presence or existing boundaries of a harmful bloom (Stumpf et al., 2003). The bulletins also incorporate analysis of the following for bloom confirmation: past and forecasted winds available through the National Data Buoy Center (NDBC), the North American Mesoscale (NAM) model, and the National Weather Service (NWS), a wind transport model developed by NCCOS, and *in situ* sampling data from several organizations including the Florida Fish and Wildlife Research Institute (FWRI) and Mote Marine Laboratory (MML). These resources, coupled with scientific expertise, are employed to analyze and forecast HAB location, spatial extent, intensification, and potential beach impacts. Key successes leading to operational status included the training of multiple (5) forecasters, technology transfer, standardized operating procedures, consistency of analysis, and improved tools. Under the system's previous research status bulletins were issued only as personnel resources allowed and bloom occurrence dictated. The operational status enables regular dissemination of bulletins twice weekly to coastal resource managers, state and federal officials, and academic and research institutions to accommodate resource managers' sampling schedules and needs. In addition, the GOM HAB-OFS initiated a daily public conditions report identifying potential coastal impacts (available through the Web at http://www.csc.noaa.gov/crs/habf/index.html) and on-call forecaster response to inquiries and special case scenarios, including the dissemination of supplemental bulletins as events necessitate. The GOM HAB-OFS utilizes one central telephone number and email distribution address for responding to general public information requests. Information requests frequently involve inquiries concerning present bloom status or potential bloom impacts at specific locations and times for event planning; inquiries regarding the possible presence of a bloom from public users experiencing symptoms associated with *K. brevis*; general inquiries about *K. brevis* blooms and their occurrence; and users requesting to be added to the bulletin distribution list.

2.2 Skill Assessment

The operational forecast system is assessed annually to determine its level of success and to improve upon procedures and technology. The first annual skill assessment period extended from October 1, 2004 (the date bulletins were transitioned to operational status) to September 30, 2005. Over this 52 week period, 114 bulletins were issued with a total of 131 separate component forecasts. The assessment measures proficiency and accuracy in identifying the appearance of a new algal bloom, whether non-harmful or containing *Karenia brevis*, and in

forecasting four key bloom components for an ongoing *K. brevis* bloom: transport, intensification, change in extent, and degree of coastal impacts. The assessment also evaluates weekly utilization of bulletins by the user community. For each assessable bulletin the components forecasted were evaluated and marked 'confirmed accurate' or 'confirmed false' using post bulletin information including satellite imagery, *in situ* sample results, e-mail responses, media statements, and any disseminated public red tide/health reports. When impossible to verify or negate a forecast due to lack of information or clouded imagery, the forecasted component was denoted 'unconfirmed', and therefore not assessable. Over the 52 week assessment period, 3 HABs were identified and/or tracked in the operational bulletins. Two of these blooms were initially identified in bulletins as possible new HAB events using satellite imagery, and were later confirmed by sampling to contain *K. brevis*. The remaining bloom was first identified by field sampling and tracked in bulletins until its termination (details given in Section 3.1). Two additional blooms were accurately identified during this assessment period as non-harmful algal blooms.

2.3 Forecast Component Definitions

Transport: The direction (north, south, offshore, onshore, etc.) in which the bloom is likely to migrate based on wind and water flow conditions, the Coriolis effect, and Ekman transport. Example: 'Southerly transport of the bloom is expected over the weekend.'

Intensification: Expected change in *K. brevis* concentration (increase, decrease, no change) due to the presence or absence of existing or predicted upwelling favorable conditions. Example: 'Continued dissipation of the bloom is likely.'

Extent: Increase or decrease in bloom area. Extent is typically defined by whole or half county with an approximate 20 mile uncertainty. Example: 'Onshore bloom extent may expand to the south as far as Manatee County.'

Impact: Presence of adverse coastal conditions, including respiratory irritation and presence of dead fish. Levels range from no expected impacts to very low, low, moderate or high impacts; with adverse impacts most probable at moderate to high levels. Impact levels are based on the combined factors of wind strength and direction, *K. brevis* concentration and bloom proximity to shore. Example: 'Patchy moderate to high impacts are possible in southern Pinellas County through Monday.'

3. RESULTS

3.1 Annual Confirmed Bloom Details

The first bloom of the Fiscal Year 2004-2005 HAB season (referred to as Bloom Allie) was detected via satellite imagery near Marco Island, Florida on November 3, 2004 by operational HAB forecasters, and was confirmed by sampling reports the following week. The bloom moved slowly and steadily down the coast of southwest Florida until it reached the Florida Keys in late December 2004. Further southern movement was halted by the east-west landmass of the Keys, and the bloom remained relatively stable in location and strength north of the Keys for approximately two months. The bloom eventually split, with part of it traveling north, then west, around Key West before dissipating in the Florida Current south of the Keys. The additional portion of the bloom migrated slightly east and slipped through the straights near Marathon, FL, also dissipating in the Florida Current in late February 2005. Following its travels through the straights of the Florida Keys, forecasters watched for traces of *K. brevis* to resurface on the eastern coast of Florida. No HABs were reported in eastern Florida as a result of this bloom. There was a slight resurgence of a bloom northeast of Marathon in mid March 2005, almost a month after it seemed to have disappeared. Sampling was limited; however, chlorophyll levels remained high in the area for about six weeks. Genetic testing results are not available to determine whether the strains of the initial bloom and the small subsequent bloom in the Keys were related, although this is highly probable. NOAA issued a total of 48 bulletins covering this event, including both twice weekly bulletins and addendum bulletins as events deemed necessary.

The second bloom of the season (referred to as Bloom Bronder) developed into an extremely damaging event that affected much of western Florida. The bloom was detected via satellite imagery in early January 2005 and was quickly confirmed by *in situ* sampling data to be a harmful *K. brevis* bloom. It surfaced near Tampa Bay and migrated south to Sanibel and Captiva Islands, causing fish kills and approximately 40 manatee deaths in March before moving back north into the bay systems south of Tampa Bay. In late May 2005, the bloom migrated back out from the bays into coastal waters and rapidly expanded to cover much of the western coast of Florida. The resurgence had a significant impact along much of the southwest Florida coast, with massive fish kills, respiratory irritation, and discolored water reported in many coastal and bayside areas, including substantial impacts during the July 4, 2005 holiday weekend. Its widespread effects continued throughout the next several months, and were further magnified by the 2005 hurricane season. In late summer 2005, Hurricanes Katrina and Rita, in rapid succession, are suspected to have carried the bloom north into the Big Bend region of Florida where a *K. brevis* patch was identified shortly after the hurricane events. However, due to the lack of clear satellite imagery during these extreme weather events and the absence of genetic testing procedures, this presumed migration could not be proven with certainty. The large degree of upwelling and resuspension occurring throughout the month of September 2005 contributed to the bloom's persistence alongshore Southwest Florida. In late October, 10 months following its first appearance, the bloom began to dissipate, move offshore, and eventually be confirmed "not present" through sampling efforts. However, soon after its disappearance from the coast, an offshore bloom was detected west of Sarasota immediately following a resuspension event brought about by Hurricane Wilma. Again, it is likely these blooms were related, but lack of satellite and genetic evidence to support this theory required the offshore bloom to be classified as a new and separate event. Meanwhile, as the bloom migrated offshore and dissipated in

Southwest Florida, it persevered to the north in Dixie and Levy Counties, until slowly dissipating to "not present" status in late December, 4 months after its suspected migration.

The very active 2005 hurricane season had a tremendous effect on chlorophyll levels and *K. brevis* bloom activity along the Southwest Florida coast. The hurricanes greatly reduced satellite visibility during the weather events, limiting not only the ability to forecast bloom components and identify present extents, but also the ability to substantiate many forecasts that were generated. Sampling efforts were vital during these months. With an unusually late appearance in the year, relative to historically observed trends in this area, and prolonged existence of nearly 12 months, this unique bloom was an extremely costly and damaging event. A total of 91 bulletins were issued on this event, at a rate of twice weekly. Multiple verifications of forecasted conditions have been received from the public, coastal resource managers, and the media.

On September 1, 2005, immediately following Hurricane Katrina, a third bloom (Bloom Culver) was identified within and adjacent to Apalachicola Bay on the Florida Panhandle. While resuspended material following the hurricane inhibited initial bloom identification via satellite imagery, sampling efforts confirmed the presence of *K. brevis*, thus initiating bulletin analysis of the event on September 6, 2005. This bloom existed concordantly with the bloom just to the east in Dixie and Levy counties (Bloom Bronder); however, differing geographical originations deemed the blooms to be classified as separate and unique. At the height of Bloom Culver a great expanse of the northeastern Gulf of Mexico, from Big Bend through Alabama, was heavily impacted with numerous fish kills. The bloom coverage existed as a disconnected series of large, high chlorophyll patches. By the end of October, medium to high concentrations of *K. brevis* had been identified by *in situ* sampling (Alabama Dept. of Public Health), and the bloom had spread as far west as Alabama. Hurricane and resuspension activity made it difficult at times to distinguish *K. brevis* bloom extents from resuspension events, and cloud-obscured imagery produced additional difficulty in analyzing bloom components. Sampling reports were extremely important for determining regional impact conditions throughout the Panhandle, and narrowing impact forecasts to those areas most heavily impacted. In addition, a wind transport model developed by NCCOS was introduced and utilized by the analysts as an alternative method for identifying possible bloom locations and extents in instances when clear satellite imagery was not available. By the end of November 2005, the bloom patches had dissipated and were found primarily to the west of Cape San Blas and in the Apalachicola Bay vicinity. The bloom finally terminated in late December 2005. A total of 34 bulletins were issued for this event over 17 weeks.

3.2 Bulletin Utilization

Bulletin utilization was confirmed for 90% of the 52 total operational weeks in the first annual assessment period. Evidence of confirmed bulletin utilization included sampling response to cited bloom regions, media or public health reports identifying bulletin information, and written/phoned responses or inquiries based on bulletin analyses. Each bulletin was issued with low, medium or high priority. High priority bulletins typically request immediate action and contain pertinent information regarding appearance of a new bloom or significant change in bloom location or intensity. 93% of the operational bulletins issued with high priority status were confirmed utilized. Results of bulletin utilization are illustrated in Figure 1.

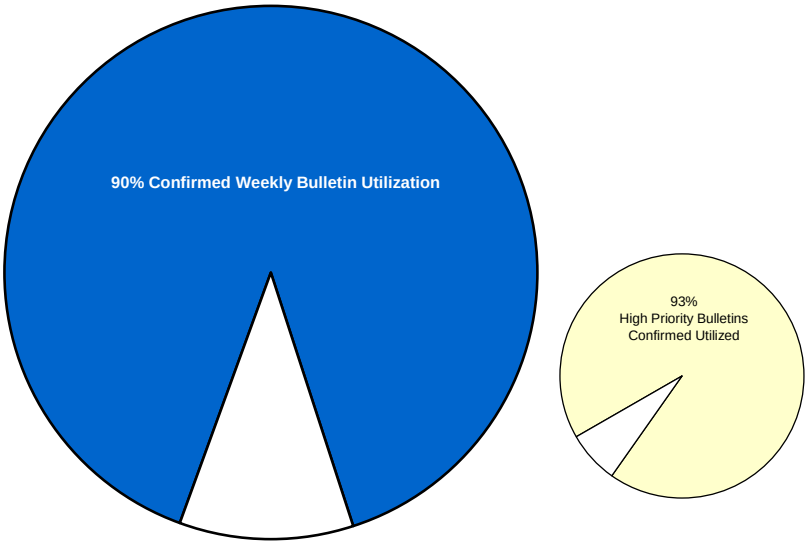

Figure 1. Confirmed weekly bulletin utilization and utilization of all bulletins disseminated as 'high priority'.

3.3 Forecast Skill

Forecasts were generated for four key bloom components: transport, intensification, extent and coastal impact, as described in Sections 2.1 and 2.3, and were confirmed accurate or false, contingent upon the availability of information, as described in Section 2.2. Figure 2 illustrates accuracy and confirmation percentages for each forecast component and all combined forecasts during the skill assessment period. '% Assessable' reflects the percentage of a particular component's total forecasts that could be confirmed either accurate or false with supporting post-bulletin information. Bloom transport was assessable for 66% of the total transport forecasts issued, with 93% of these forecasts confirmed accurate. Intensification was assessable for 63% of all intensification forecasts issued, with 72% of these forecasts confirmed accurate. Change in bloom extent was assessable for 48% of all extent forecasts issued, with 81% of these forecasts confirmed accurate. Degree of coastal impacts was assessable for 54% of all impact forecasts issued, with 98% of these forecasts confirmed accurate. Of the total combined forecasts issued, 60% were able to be assessed. 90% of the total combined forecasts were confirmed accurate.

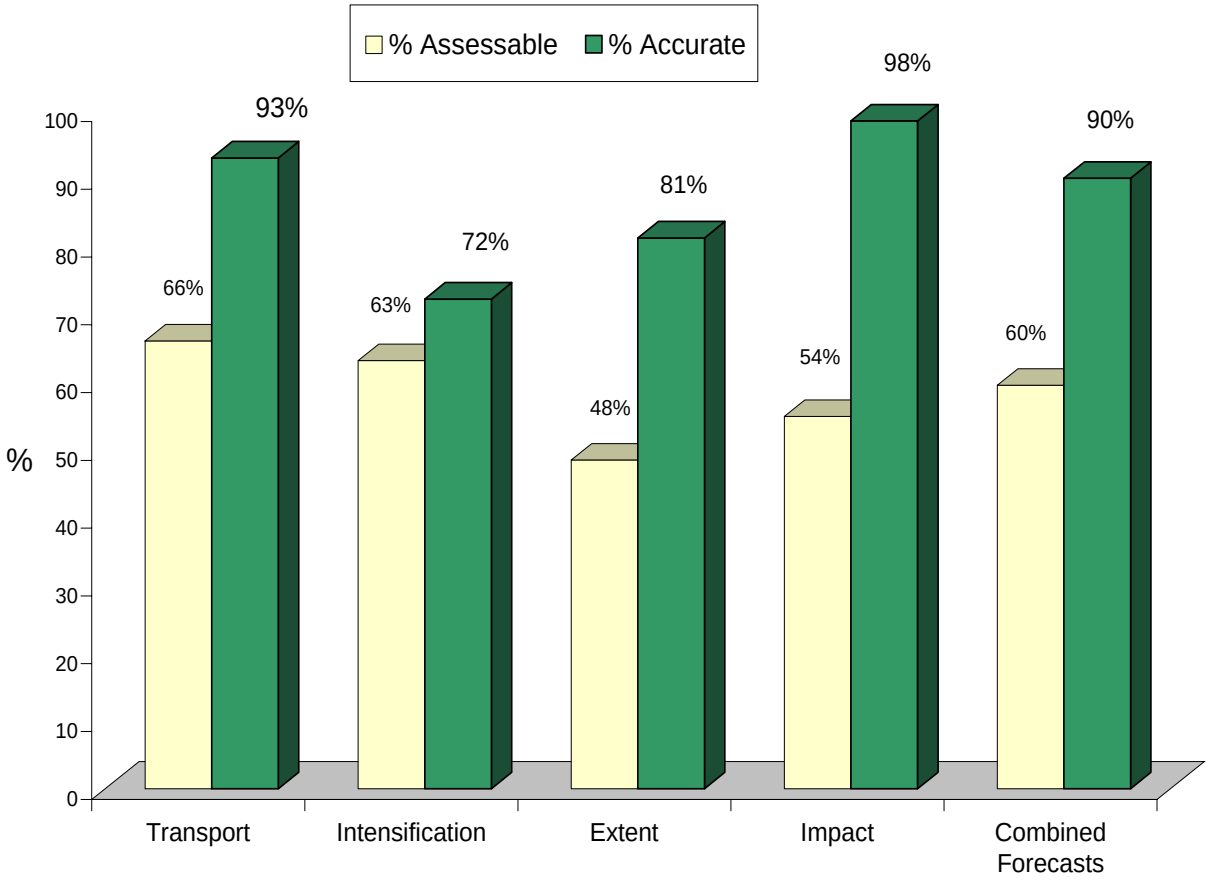

Figure 2. Forecasted bloom component accuracy and percent of forecasts able to be assessed using available post-bulletin information.

Of the total 114 operational bulletins issued, 93% contained public conditions text forecasting coastal impacts. Impact forecasts were based on bloom region, confirmed *K. brevis* concentrations, and wind conditions. Degrees of impact range from none to high, with moderate to high impacts indicating greater expectation of mild to chronic respiratory symptoms and/or dead fish at the coast. Figure 3 illustrates the accuracy and confirmation percentages for all assessable moderate and high impact forecasts issued during the skill assessment period. 78% of all moderate to high impact forecasts issued were assessable using reports of fish kills or respiratory irritation. 98% of the assessable impact forecasts were confirmed accurate.

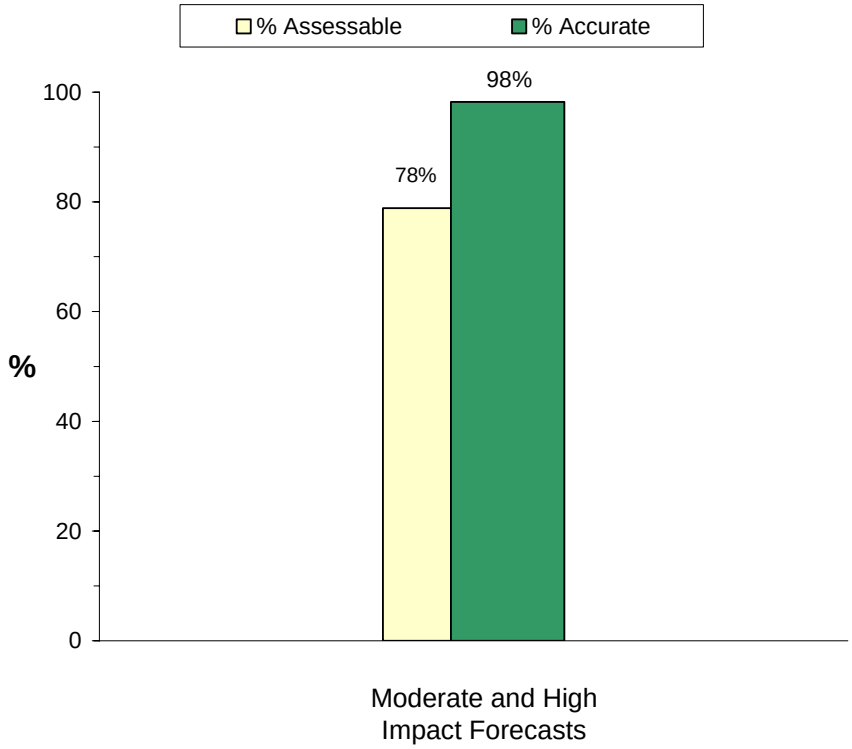

Figure 3. Coastal impact forecast assessment capability and accuracy.

In each bulletin, forecasts were provided for all presently confirmed *K. brevis* blooms based on available information; thus, each bulletin forecast included one or more of the forecasted bloom components. Transport direction was included in 83% of all forecasts, intensification was included in 43% of all forecasts, extent change was included in 25% of all forecasts, and degree of coastal impacts was forecasted in 93% of the total bulletins produced. Ideally, forecasting of all bloom components will become possible in each bulletin with the incorporation of more tools, capabilities, and increased knowledge of *K. brevis* blooms. These forecasting ability results are illustrated in Figure 4.

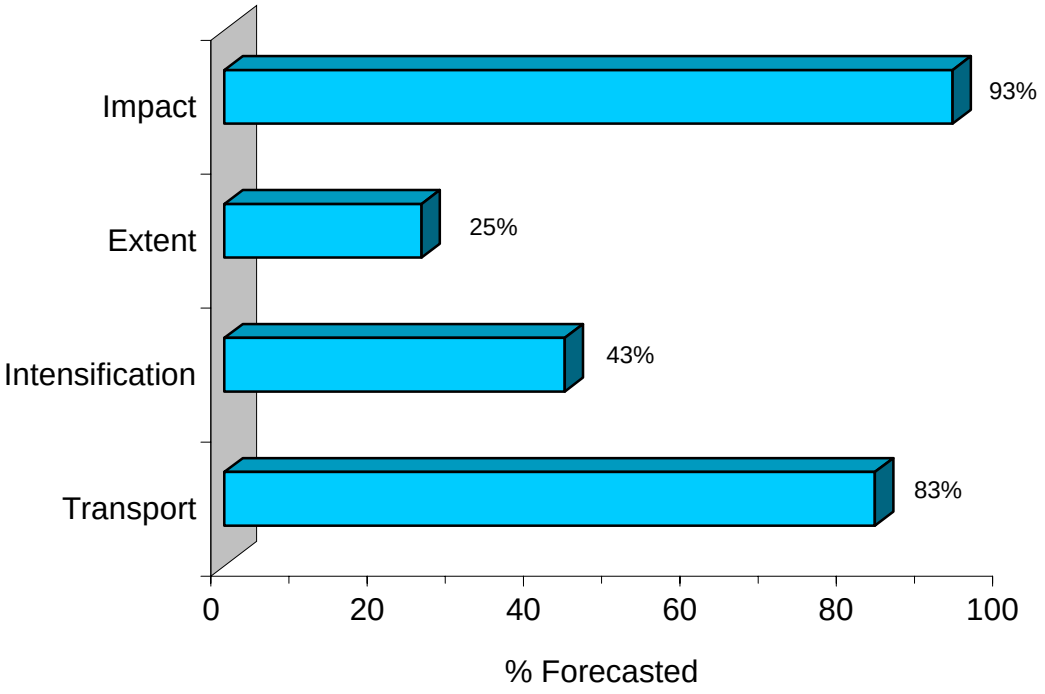

Figure 4. Forecasting frequency of each bloom component for the total bulletins disseminated using available satellite imagery and scientific information.

4. SUMMARY

On October 1, 2004, the Gulf of Mexico Harmful Algal Bloom Operational Forecast System (GOM HAB-OFS) was successfully transitioned from research to operational status. Over the following 52 week assessment period, 97 bulletins, including 131 bloom forecasts, were disseminated to coastal resource managers, state and federal officials, and academic and research institutions. During this period, two harmful and two non-harmful algal blooms were accurately identified in the operational bulletin using satellite imagery, and were later confirmed by *in situ* sampling. One additional harmful algal bloom was first identified by *in situ* sampling during a period of obscured imagery and was immediately tracked in operational bulletins until its termination. Bulletins were considered utilized if any portion of the document (illustrative or text) was cited by a user, or if bulletin information prompted a confirmable action by sampling programs, government officials or the public. Examples of bulletin utilization evidence included active sampling response at bulletin cited bloom regions, media or public health reports identifying bulletin information, and written or phoned responses and inquiries based on bulletin analyses. Bulletin utilization was confirmed for 90% of the total operational weeks and 78% of the total bulletins disseminated. 33 high priority bulletins were disseminated with 93% confirmed utilization. In addition to overall utilization of the bulletin, success of the operational bulletins can be broken down into various forecast components, to help determine needed enhancements. A coastal impact forecast statement indicating public conditions by county was included in 93% of the total bulletins produced, with 98% forecasting accuracy. These conditions reports were made publicly available via the Internet. Bloom transport was forecasted in 83% of the total bulletins disseminated, with a 93% forecasting success rate. Bloom intensification was forecasted in 43% of the total bulletins disseminated, with a 72% forecasting success rate. Change in spatial extent was forecasted in 25% of the total bulletins disseminated, with an 81% forecasting accuracy. 90% of all forecasts disseminated were confirmed accurate. The results of this assessment will be utilized to enhance the operational forecast system, improving the accuracy of individual forecast components through increased bloom knowledge and advanced technology; and additionally allow for further exploration into additional methods to better assess the accuracy of issued forecasts.

5. ACKNOWLEDGEMENTS

The success of the GOM HAB-OFS is due to the contributions of numerous individuals and organizations. Key NOAA individuals include Richard Stumpf and Michelle Tomlinson (National Centers for Coastal Ocean Science); Mary Culver, Andrew Meredith, Kirk Waters and Rebecca Love (Coastal Services Center); Michael Soracco and Kent Hughes (National Environmental Satellite Data and Information Service); and John Cassidy (Center for Operational Oceanographic Products and Services).

Other contributing organizations include the Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute (FWC-FWRI); Collier County Heath Department (CCHD); Mote Marine Laboratory (MML); OrbImage Corporation; NASA SeaWiFS project, NOAA's National Data Buoy Center (NDBC); and NOAA's National Weather Service (NWS).

6. REFERENCES

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Tomlinson, M.C., Stumpf R.P., Ransibrahmanakul, V., Truby, E.W., Kirkpatrick, G.J., Pederson, B.A., Vargo, G.A., & Heil, C.A. (2004). Evaluation of the use of SeaWiFS imagery for detecting *Karenia brevis* harmful algal blooms in the eastern Gulf of Mexico. *Remote Sens. Environ.*, 91, 293-303.

APPENDIX

Example Operational Bulletin

Gulf of Mexico Harmful Algal Bloom Bulletin

15 September 2005

National Ocean Service

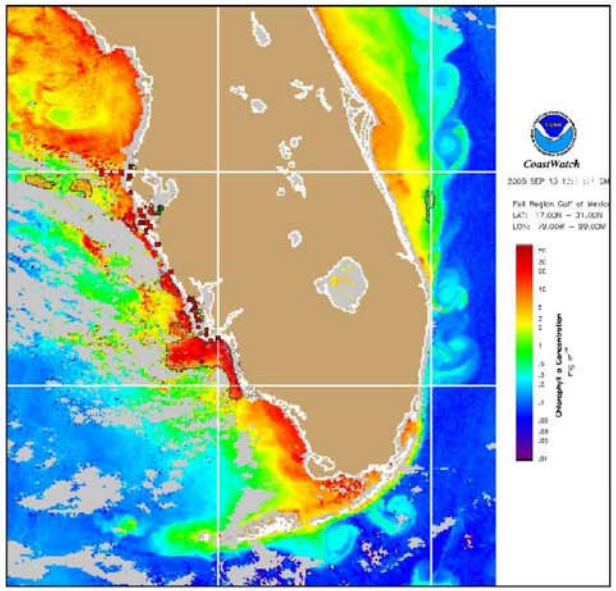
National Environmental Satellite, Data, and Information Service

Last bulletin: September 12, 2005

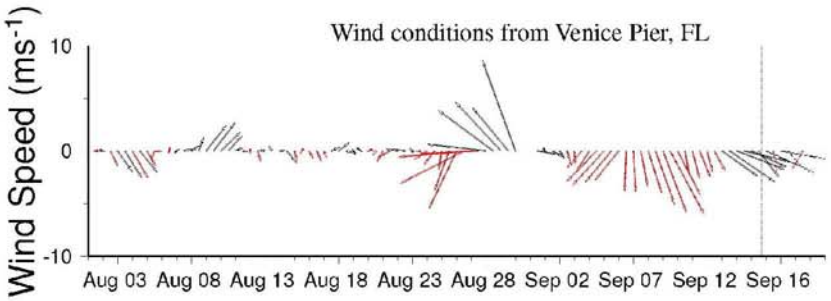
Conditions: A harmful algal bloom has been identified from northern Pinellas to southern Collier County. Today through Saturday patchy moderate to high impacts are possible in Pinellas, Manatee and Sarasota Counties; and patchy low to moderate impacts in Lee and Collier Counties. Patchy very low to low impacts are possible in each of these counties Sunday and Monday. A harmful algal bloom has also been identified from Bay County east to Dixie County. Today through Friday patchy low to moderate impacts are possible in Bay, Gulf, Franklin and Wakulla Counties; and patchy moderate to high impacts in Taylor, Dixie and Levy Counties. Patchy very low to low impacts are possible in these Panhandle counties Sunday and Monday. Dead fish have been reported from Barefoot Beach to Marco Island in Collier County over the past few days. Dead fish smell, while unpleasant, does not produce the same respiratory irritation as red tide.

Analysis: The ongoing bloom persists along the coast of Southwest Florida, extending from northern Pinellas to southern Collier County. Satellite imagery indicates the bloom has expanded further southward and closer to shore. This is concurrent with sampling results confirming the presence of *K. brevis* at Big Marco Pass in Collier County and also with results of a transport model indicating bloom expansion approximately 30km southward since September 12. Dead fish have been reported in Pinellas, Lee, and Collier Counties over the past few days. Low to medium concentrations of *K. brevis* were found this week offshore Clearwater with low counts persisting at the mouth of Tampa Bay and Venice. Chlorophyll levels are >50μg/L offshore of northern Collier County at 26°17'N, 82°21'W and are continually high along the coast from the mouth of Tampa Bay to Marco Island in varying intensities. Northwesterly and westerly winds through Saturday may increase impacts along the coast. Offshore winds will likely minimize beach impacts on Sunday and Monday. Reports of discolored water are likely. Continued southern expansion of the bloom is likely.

~Fisher, Bronder

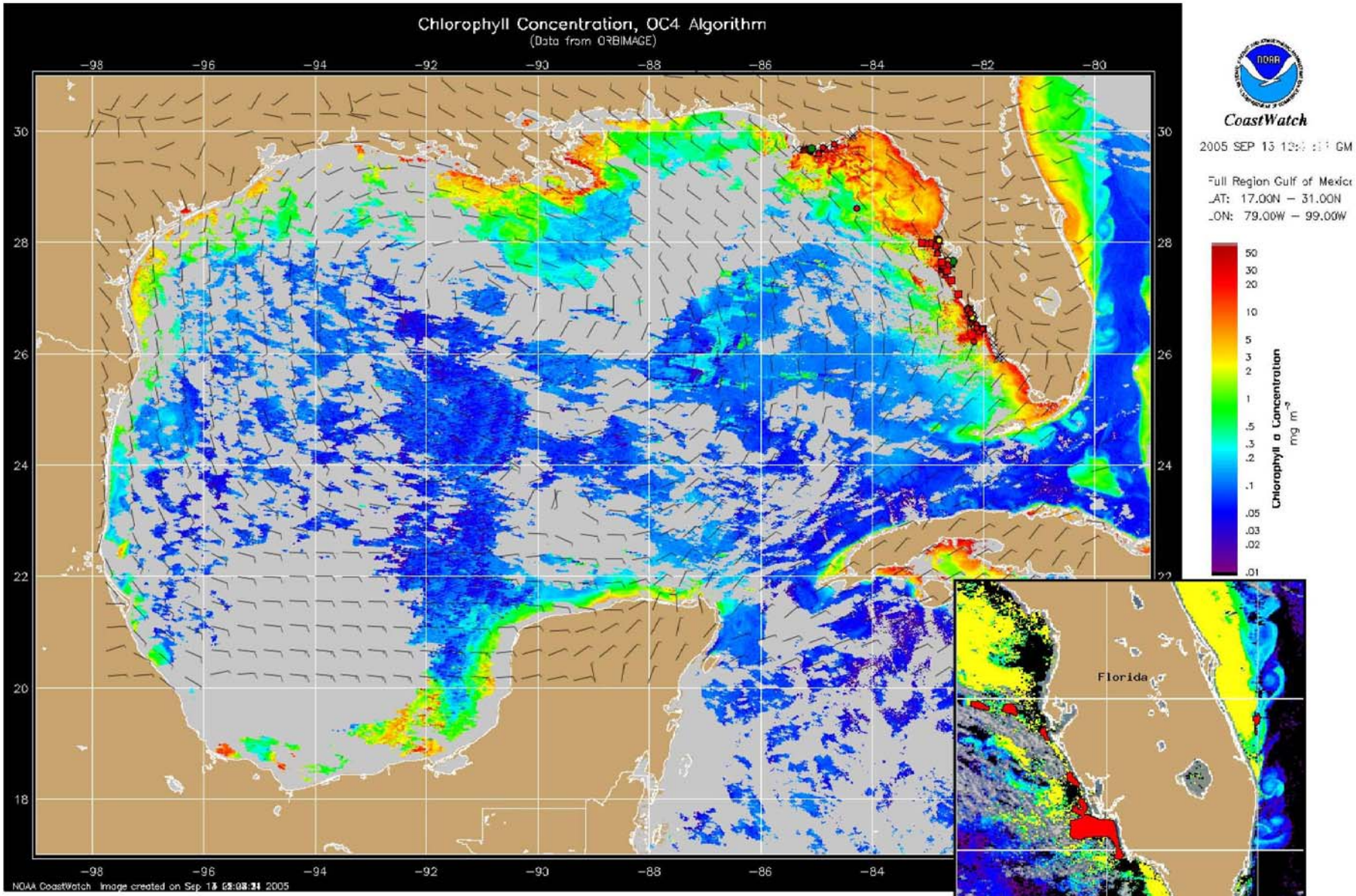


Chlorophyll concentration from satellite with HAB areas shown by red polygon(s). Cell concentration sampling data from September 9, 2005 shown as red squares (high), red triangles (medium), red diamonds (low b), red circles (low a), orange circles (very low b), yellow circles (very low a), green circles (present), and black "X" (not present).



Wind speed and direction are averaged over 12 hours from measurements made on buoys. Length of line indicates speed; angle indicates direction. Red indicates that the wind direction favors upwelling near the coast. Values to the left of the dotted vertical line are measured values; values to the right are forecasts.

SW Florida: Northwesterly winds through tonight at 5-10 knots (3-5 m/s), becoming westerly Friday and returning to northwesterlies Friday night into Saturday. Mild north winds Saturday night shifting to 10-15 knot (5-8 m/s) winds Sunday. Gusty 15 knot (8m/s) easterlies expected Monday.



Chlorophyll concentration from satellite and forecast winds for September 16, 2005 12Z with cell concentration sampling data from September 9, 2005 shown as red squares (high), red triangles (medium), red diamonds (low b), red circles (low a), orange circles (very low b), yellow circles (very low a), green circles (present), and black "X" (not present).

Blooms shown in red (see p. 1 analysis)