# Gulf of Mexico HAB-OFS Bulletin Guide

*Revised: October 11, 2016*

Harmful algal blooms (HABs) of the toxic dinoflagellate *Karenia brevis* (commonly called "red tides") occur nearly every year in coastal regions of the Gulf of Mexico and cause potential public health, economic and ecological impacts. The National Oceanic and Atmospheric Administration (NOAA) provides the Harmful Algal Bloom Operational Forecast System (HAB-OFS) Bulletin as a decision support tool to aid bloom response efforts and help mitigate impacts.

The HAB-OFS Bulletin contains forecasts for *K. brevis* blooms in the Gulf of Mexico, as follows:

1. ***Bloom formation at the coast (FL only)***
2. ***Transport (FL and TX)***
3. ***Intensification (FL only)***
4. ***Level of associated respiratory irritation (FL and TX)***

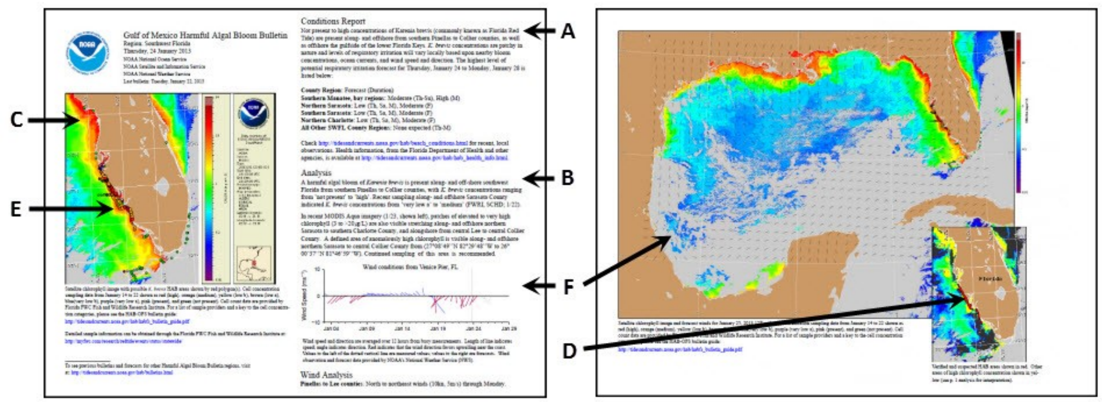
The forecasts are based on an analysis of information from HAB-OFS Contributors & Data Providers consisting of ocean color satellite imagery, observed and forecasted wind data from NOAA's National Weather Service and National Data Buoy Center, *K. brevis* cell concentration data from the states of Florida and Texas, modeled and observed currents from the Texas General Land Office's (TGLO) Texas Automated Buoy System (TX only), water optical properties from Mote Marine Lab and Texas A&M University and respiratory irritation observations from Mote Marine Lab (FL only) and the state of Texas.

HAB-OFS Bulletins are sent via email to a list of subscribers in the public health, natural resource and scientific fields. For the operational schedule, see About the Operational HAB Bulletin. A week after the HAB Bulletin has been issued, it is posted to the Bulletin Archive for public access.

Your feedback to improve the Bulletin and the HAB-OFS is welcome. Please send your comments to hab@noaa.gov.

## Understanding and Interpreting the Bulletin

The different parts of the HAB-OFS Bulletin are labeled A-F and explained in the following sections of the guide.




(A) ***Conditions Report***

The Conditions Report provides a summary of *K. brevis* activity within the region. When *K. brevis* cell concentrations are present, the Conditions Report indicates the general location and provides daily forecasts of the highest potential level of associated respiratory irritation based on *K. brevis* cell concentrations and prevailing winds.[1,2] Further information is provided on the HAB-OFS FAQ webpage. The Conditions Report was developed in collaboration with state and local agencies, tourist boards, and citizen groups to provide clear and accurate information to a non-technical audience. It is publically available on the HAB Operational Forecast System website along with links to forecast region maps.

(B) ***Analysis***

The Analysis section is intended for a technical audience and consists of a synthesis of data and forecasts to aid sample collection efforts and help mitigate impacts. The Analysis identifies locations and cell concentrations of confirmed *K. brevis* samples and summarizes reports of impacts on humans and marine animals. An interpretation of ocean color satellite imagery products, with reference to anomalously high chlorophyll concentrations (in µg/L) and suspected bloom locations is also provided. Based on the available data and forecast region, the Analysis may also include forecasts of potential bloom formation at the coast, transport and intensification. For a list of data types and sources, see the HAB-OFS Contributors & Data Providers webpage.

Email: **hab@noaa.gov**
Web: **http://tidesandcurrents.noaa.gov/hab**
Facebook: **http://www.facebook.com/Habredtidewatchnoaagov**

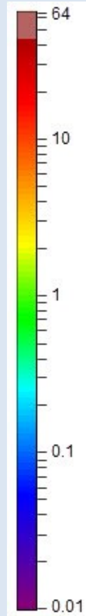
NOAA/National Ocean Service
**Center for Operational Oceanographic Products and Services (CO-OPS)**
**National Center for Coastal Ocean Science (NCCOS)**

# Bulletin Imagery

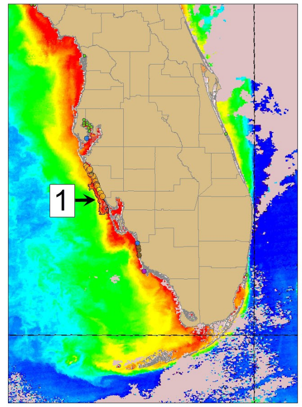
***Chlorophyll anomaly images flag areas with anomalously high chlorophyll. Ensemble images apply two algorithms (spectral shape 490nm and backscatter ratio $b_{bp}$) in addition to the chlorophyll anomaly to further refine K. brevis detection. The chlorophyll concentration scale for the Daily Chlorophyll and Average Chlorophyll images is shown at right. The Ensemble Image Pixel Coloration is shown below. Red polygons are used to highlight areas of suspected or confirmed K. brevis.***

**Ensemble Image Pixel Coloration**

- Chlorophyll anomaly only
- Spectral shape 490nm + Chlorophyll anomaly
- Backscatter ratio $b_{bp}$ + Chlorophyll anomaly
- Spectral shape 490nm + Backscatter ratio $b_{bp}$ + Chlorophyll anomaly
- No change
- Clouds, missing data
- Polygon flag

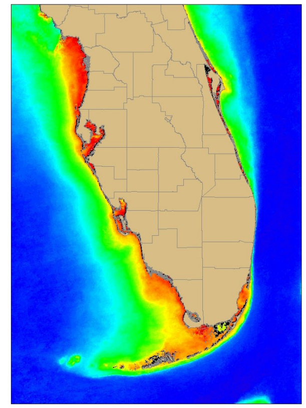



**Daily Chlorophyll**



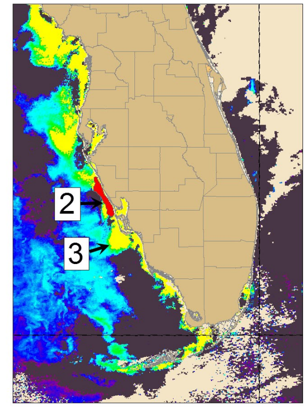

*A daily chlorophyll image with K. brevis cell concentrations marked is included on the first and last pages of the Bulletin.*

**Average Chlorophyll**



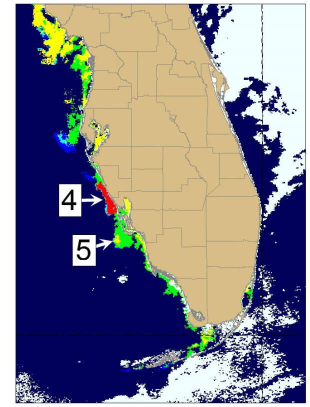
*The average chlorophyll for 60 days prior to the daily chlorophyll image is used to calculate the chlorophyll anomaly for each day, but not provided on the Bulletin.*

**Chlorophyll Anomaly**




*A chlorophyll anomaly image is derived from comparison of the daily and average chlorophyll images and is included on the back page of the Bulletin.*

**Ensemble**




*An ensemble image uses a combination of algorithms to refine K. brevis identification and may be included on the last page of the Bulletin instead of the chlorophyll anomaly image.*

***Labels:***

1) *The red polygon on the daily image (#1) was flagged by the ensemble and is the same as that in the ensemble image (#4).*
2) *The red polygon was selected by the HAB analyst to highlight a region that was flagged by the chlorophyll anomaly and is strongly suspected or has been confirmed to contain K. brevis based on the analysis of field data.*
3) *Regions flagged in yellow, like #3, contain anomalously high chlorophyll where no K. brevis bloom is suspected.*
4) *The red polygon was selected by the HAB analyst to highlight a region that was flagged by the ensemble and is strongly suspected or has been confirmed to contain K. brevis based on the analysis of field data.*
5) *Pixels in yellow, like #5, have been flagged by all 3 algorithms in the ensemble, but no K. brevis bloom is suspected.*

### (C) *Ocean Color Imagery*

Daily ocean color imagery from the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite is processed for chlorophyll by NOAA CoastWatch. The clearest and most recent chlorophyll image is selected for the HAB Bulletin with the region of interest displayed on the first page and an image of the entire Gulf of Mexico on the last page. Chlorophyll concentration units are displayed in milligrams per cubic meter, mg/m$^3$, which are equal to the units referenced in the analysis section (µg/L). The image legend shows the chlorophyll concentration that corresponds to the coloration on the satellite image (ranging between 0.01 and 64 mg/m$^3$). Red and orange areas on the satellite image indicate high chlorophyll concentrations, and blue and purple areas indicate very low chlorophyll concentrations.

While *K. brevis* blooms can cause high concentrations of chlorophyll, many non-toxic algae blooms also routinely produce high chlorophyll concentrations, so chlorophyll alone is not a reliable indicator of the presence of a bloom. For that reason, analysts select polygons that are derived from the anomaly and/or ensemble images (see next section) to outline areas of confirmed or probable *K. brevis* blooms based on the analysis of field data. However, the boundaries of a harmful bloom can extend beyond the polygon, and in some cases, part of the enclosed area may include a bloom of a non-toxic algae species.

### (D) *Chlorophyll Anomaly and Ensemble Imagery Products*

Chlorophyll anomalies show areas where the daily chlorophyll concentration is significantly higher than the average for a particular region. Imagery is processed using a chlorophyll algorithm that highlights areas of anomalously high chlorophyll by comparing daily real-time chlorophyll to a 60-day running mean ending two weeks prior to the present date.[3] A chlorophyll anomaly of 1 µg/L in the imagery can indicate a *K. brevis* bloom, since *K. brevis* blooms tend to be mono-specific once they are established. Chlorophyll anomalies flag areas that have undergone a rapid increase in chlorophyll, usually due to growth, aggregation, or resuspension. Since the surface waters along the Texas coast are prone to resuspension events, a revised chlorophyll anomaly product is used for the Texas bulletins that subtracts an estimate of the resuspended chlorophyll from the chlorophyll anomaly.[4]

The chlorophyll anomaly product is not specific to *K. brevis* and may also highlight areas of high chlorophyll created by blooms of non-toxic phytoplankton species. To refine *K. brevis* detection, an ensemble approach, recommended by Tomlinson et al. (2009) is used that combines the current chlorophyll anomaly with algorithms that target specific properties of *K. brevis* blooms. One of the algorithms accounts for the relative particulate backscatter of blooms[5] and the other looks at how *K. brevis* blooms change the spectral shape characteristics in the blue wavelengths (at 490 nm).[6]

The ensemble image or chlorophyll anomaly (when appropriate) is included as an inset on the last page. The image pixels are colored as shown on page 2. In both types of images the pixels are colored as follows: BLACK=no change and GRAY=clouds and pixels with missing data (such as areas outside the satellite swath). In the chlorophyll anomaly images only: GREEN=no significant change in chlorophyll and YELLOW=significant change in chlorophyll. The pixels are highlighted by the ensemble algorithm products as follows: BLUE=chlorophyll anomaly only, GREEN=spectral shape 490nm + chlorophyll anomaly, TURQUOISE=backscatter ratio $b_{bp}$ + chlorophyll anomaly, and YELLOW=spectral shape 490nm + backscatter ratio $b_{bp}$ + chlorophyll anomaly.

The HAB analyst selects and overlays a red polygon on the Bulletin images to highlight a region that was flagged by the chlorophyll anomaly and/or ensemble product that is strongly suspected to contain *K. brevis*, or has been confirmed to contain *K. brevis* based on the analysis of field data. An area is not identified as *K. brevis* unless field samples collected by the state confirm that *K. brevis* concentrations are present.

### (E) *Position and Concentration of Karenia brevis*

Cell count data are provided by the Florida Fish and Wildlife Conservation Commission Fish and Wildlife Research Institute and the Texas Parks and Wildlife Department (TPWD). Additional providers of water sample data and other *in situ* observations are listed on the HAB-OFS Contributors & Data Providers webpage. Cell concentration data for the most recent ten days are plotted on the chlorophyll image on the first and last page of the Bulletin (as in Figure 1). There is often a several-day delay between the sample collection date and the date the cell count data becomes available because of the need to verify algal species using microscopy. *K. brevis* cell concentrations are classified as shown in Table 1.

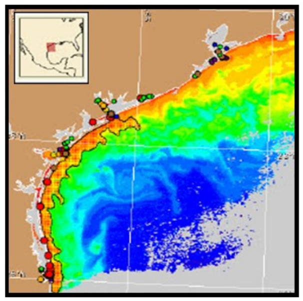


**Figure 1.** *(left) Cell concentration data plotted on the chlorophyll image for the coast of Texas.*

**Table 1.** *Karenia brevis* cell *concentration categories and associated cell count values (in cells per liter).*

| *Karenia brevis* Cell Conc. (cells/L) |
|---|
| Not Present |
| Present (1,000 cells or less) |
| Very Low a (>1,000 to <5,000) |
| Very Low b (5,000 to 10,000) |
| Low a (>10,000 to <50,000) |
| Low b (50,000 to 100,000) |
| Medium (>100,000 to 1,000,000) |
| High (>1,000,000) |

### (F) *Wind Data*

In both Florida and Texas, observed and forecasted surface wind speed and direction for the area of interest are used to forecast the potential level of associated respiratory irritation when there are *K. brevis* concentrations present.[2] In Florida, wind data is also used to forecast the potential for *K. brevis* bloom formation at the coast, intensification and transport.[2,7]

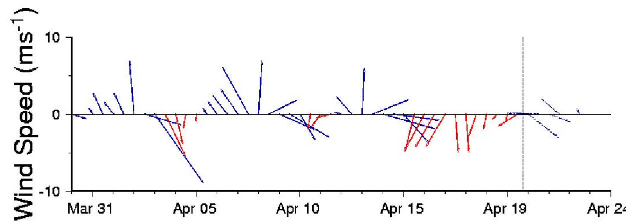



**Figure 2.** *Example of a windplot diagram. See section (F) for windplot description.*

A windplot diagram (Figure 2) shows wind speed (reported in meters per second) and direction averaged over 12 hours from measurements made at station buoys. These measurements are reported to the NOAA National Data Buoy Center. Observed values for the past three weeks are shown to the left of the dotted vertical line, which represents the present time, and forecasted values for the next five days are to the right of the dotted vertical line. The length of the vector represents wind speed, and the angle indicates the direction. For each vector, the tail is the end that starts at the "0" horizontal reference line; the arrow at the head of the vector indicates the direction the wind is blowing towards. Red indicates that the wind direction favors upwelling near the coast, which can promote *K. brevis* bloom formation at the coast when an offshore bloom is present or promote the intensification of a developing *K. brevis* bloom.[2,7]

A 24-hour forecast of wind direction and speed as predicted by the National Weather Service's Environmental Modeling Center is plotted over the image of the Gulf of Mexico on the last page of the Bulletin. The forecast is from the North American Mesoscale computer model. In this diagram, wind speed and direction are depicted as barbs, which point in the direction the wind originates from (Figures 3 and 4). The barb pennant symbol represents the wind speed.

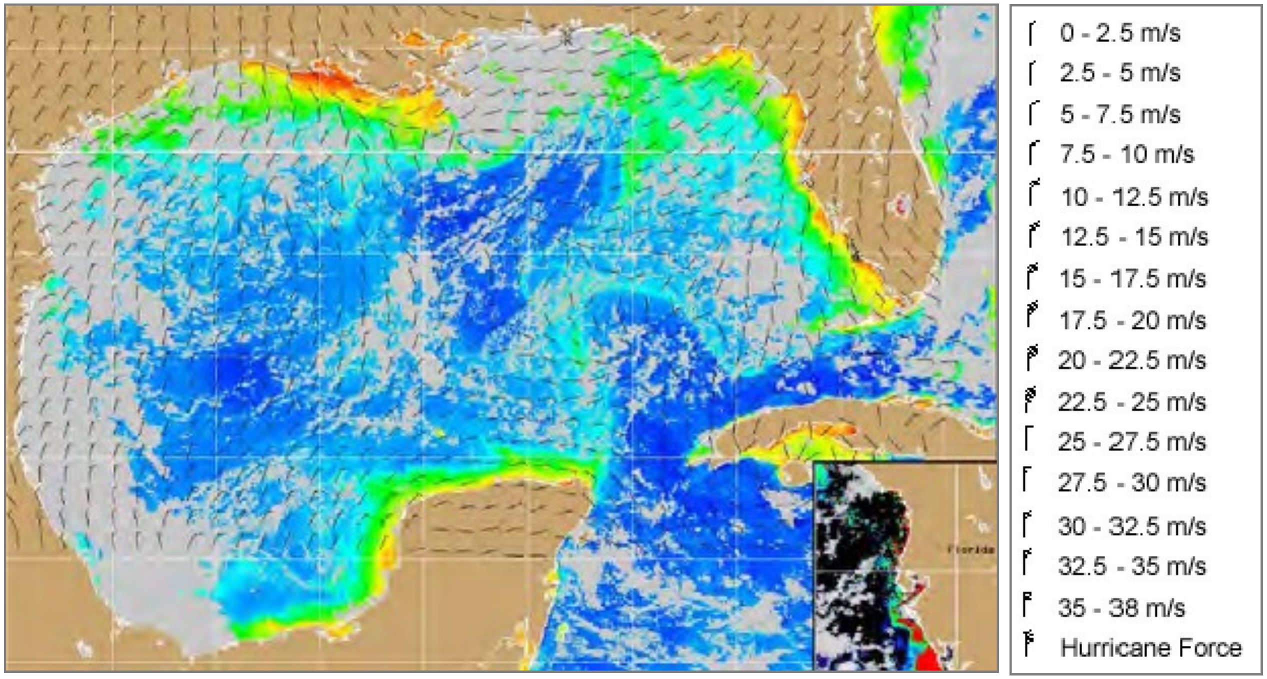



**Figure 3.** *(on left) Example of the wind barb layer denoting forecasted wind speed and direction for the Gulf of Mexico. (on right) Barb pennant symbols and the corresponding wind speed. Wind observation and forecast data are provided by NOAA's National Weather Service (NWS).*

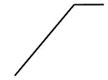


**Figure 4.** *Example of a wind barb indicating a wind speed of 5 to 7.5 meters per second (or 11.2 to 16.8 miles/hr) from the northeast.*

*Optical Sensors*

In order to help detect and track the movement of subsurface *K. brevis* blooms, optical sensors are deployed on autonomous underwater vehicles (AUV) or moored on piers. In Florida, the Optical Phytoplankton Detectors (OPD), developed by Mote, are deployed on AUVs or fixed platforms. The sensors identify *K. brevis* blooms by their absorbance signal and provide a Similarity Index (SI) value, which represents the fraction of *K. brevis* biomass in the phytoplankton community. In Texas, the Imaging FlowCytoBot is an automated underwater microscope with video and flow cytometric technology that captures high resolution photographs and allows for *in situ* concentration detection of planktonic organisms, including *K. brevis*.

*Respiratory Irritation Observations*

The HAB-OFS uses reports of respiratory irritation from the field to forecast potential levels of respiratory irritation and validate previous forecasts. At various beaches along the Gulf Coast of Florida,

## *Supplementary Data*

Additional data are used in the development of HAB nowcasts and forecasts but are not presented graphically in the Bulletins.

*Currents*

In Texas, observed and forecasted surface currents are used to forecast *K. brevis* bloom transport from the location it was last identified by field samples or satellite imagery (Figure 5). Analysts input surface current data from TGLO into the General NOAA Operational Modeling Environment (GNOME) particle transport model to estimate potential bloom transport direction and distance from known sample and/or anomalous feature locations. When a *K. brevis* bloom has not been identified, an estimate of the potential transport from Port Aransas is included in the Bulletin to indicate the influence of the general surface currents along the Texas coast over the next several days.

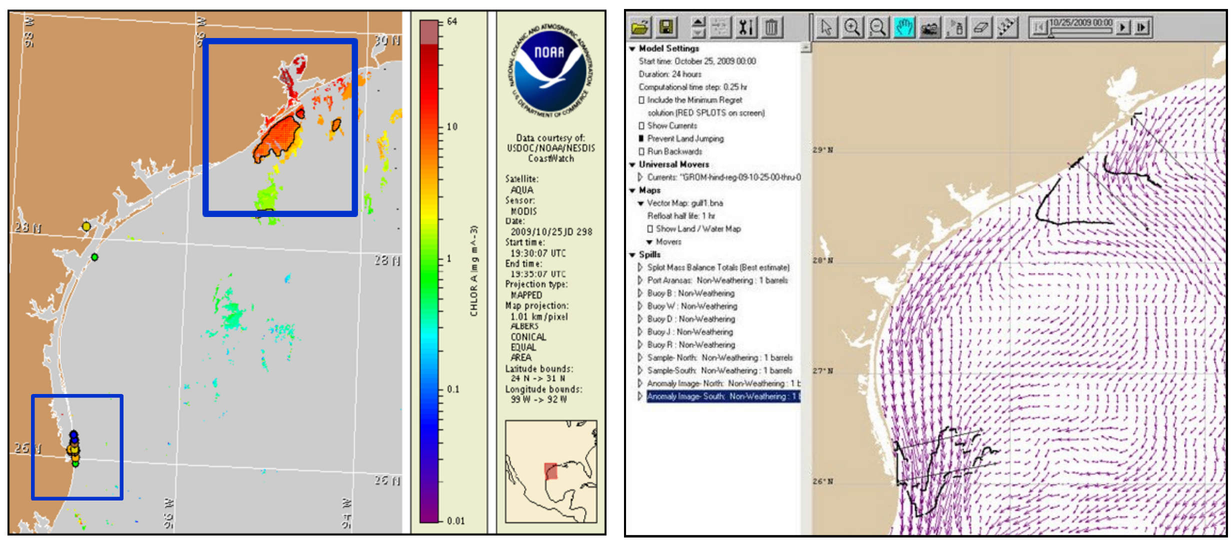


**Figure 5.** *(on left) Example of sample and anomalous feature locations highlighted in the Bulletin chlorophyll anomaly imagery. (on right) Using the GNOME particle transport model, analysts can input observed and forecast surface currents and known sample and feature locations to determine potential transport distance and direction.*

Mote has trained a network of lifeguards to assess the levels of respiratory irritation at their respective beaches twice daily. The observations are reported via smartphones and uploaded to the Beach Conditions Reporting System website. In Texas, TPWD reports of observed respiratory irritation are summarized on the Red Tide Current Status website.

*Assessments*
HAB-OFS forecast quality and bulletin utilization are evaluated regularly based on observational data and user feedback. Results are used to guide improvements. Visit the HAB-OFS Publications webpage to view the NOAA Technical Reports that have been prepared, summarizing assessments for Florida and Texas.

***References***


[1] Kirkpatrick, B., L.E. Fleming, D. Squicciarini, L.C. Backer, R. Clark, W. Abraham, J. Benson, Y.S. Cheng, D. Johnson, R. Pierce, J. Zaias, G.D. Bossart, and D.G. Baden. 2004. Literature review of Florida red tide: implications for human health effects. Harmful Algae. Volume 3. Pages 99 to 115.

[2] Stumpf, R.P., M.C. Tomlinson, J.A. Calkins, B. Kirkpatrick, K. Fisher, K. Nierenberg, R. Currier, and T.T. Wynne. 2009. Skill assessment for an operational algal bloom forecast system. Journal of Marine Systems. Volume 76. Pages 151 to 161.

[3] Stumpf, R.P., M.E. Culver, P.A. Tester, M. Tomlinson, G.J. Kirkpatrick, B.A. Pederson, E. Truby, V. Ransibrahmanukul, and M. Soracco. 2003. Monitoring *Karenia brevis* blooms in the Gulf of Mexico using satellite ocean color imagery and other data. Harmful Algae. Volume 2. Pages 147 to 160.

[4] Wynne, T.T., R.P. Stumpf, M.C. Tomlinson, V. Ransibrahmanakul, and T.A. Villareal. 2005. Detecting *Karenia brevis* blooms and algal resuspension in the western Gulf of Mexico with satellite ocean color imagery. Harmful Algae. Volume 4. Pages 992 to 1003.

[5] Cannizzaro, J., K. Carder, F. Chen, C. Heil, and G. Vargo. 2008. A novel technique for detection of the toxic dinoflagellate *Karenia brevis* in the Gulf of Mexico from remotely sensed ocean color data. Continental Shelf Research. Volume 28. Pages 137 to 158.

[6] Tomlinson, M.C., T.T. Wynne, and R.P. Stumpf. 2009. An evaluation of remote sensing techniques for enhanced detection of the toxic dinoflagellate, *Karenia brevis*. Remote Sensing of Environment. Volume 113. Pages 598 to 609.

[7] Stumpf, R.P., R.W. Litaker, L. Lanerolle, and P.A. Tester. 2008. Hydrodynamic accumulation of *Karenia* off the west coast of Florida. Continental Shelf Research. Volume 28. Pages 189 to 213.


## *Bulletin Contributors and Data Providers*

***Forecast Analysis & Operations***

- NOAA Center for Operational Oceanographic Products & Services (CO-OPS)

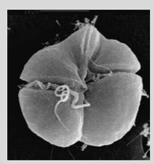
***Research & Development***

- NOAA National Center for Coastal Ocean Sciences (NCCOS)
- Academic & Scientific Community

***Technology***

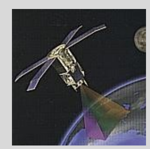
- NOAA Coastal Services Center (CSC)
- NOAA Center for Operational Oceanographic Products & Services (CO-OPS)

***In-Situ Samples &Health Reports***




- Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute (FWRI)
- Mote Marine Laboratory (MML)
- Collier County Engineering & Natural Resources Division (CCENRD)
- Sarasota County Health Department (SCHD)
- Texas Parks and Wildlife Department (TPWD)
- Texas A&M University (TAMU)
- Texas Department of State Health Services (DSHS)
- Alabama Department of Public Health (ADPH)
- Mississippi Department of Marine Resources (MDMR)

***Remote Sensing & Satellite Imagery***



- National Aeronautics & Space Administration (NASA)
- NOAA National Environmental, Satellite, Data, & Information Service (NESDIS)

***Wind & Ocean Current Data***

- NOAA National Weather Service
- NOAA National Data Buoy Center
- NOAA Office of Response & Restoration
- Texas General Land Office (TGLO)