

Satellite Images Track "Black Water" Event off Florida Coast

A mass of dark water, at times exceeding 60 km in diameter and spinning slowly in a clockwise eddy, occupied most of the Florida Bight between January and March 2002, capturing the attention of fishermen, the public, and government agencies. The "black water," as it was dubbed in the national and international press (for example, see <http://www.naplesnews.com>), was first reported by fishery pilots in the Florida Bight in January 2002. Fishermen reported that fish were not to be found in the black water and there were dead sponges in the vicinity, suggesting that the area could be a "dead zone" similar to the one found every summer off the Louisiana coast.

However, samples collected from dark patches observed in January and March 2002 showed that waters were replete with oxygen and that dark patches, while containing the red tide organism *K. brevis*, were dominated by a non-toxic *Rhizosoleniaceae* diatom bloom, with chlorophyll-*a* concentrations as high as about 10 mg/m³ and inorganic nutrient concentrations typical of the latter stages of a coastal phytoplankton bloom. Normal levels of chlorophyll-*a* are around 1 mg/m³. The mid-March survey also found a *Mnemiopsis* jellyfish bloom. News reports speculated that the black water was caused by pollution or even global warming. However, in 1878, similar "dark-colored water, coming apparently from the mainland of Florida" between Key West and the Dry Tortugas, accompanied by red tide and dead fish [Mayer, 1903; Kusek et al., 1999], suggest a naturally occurring phenomenon.

In mid-March 2002, a multi-disciplinary and multi-institutional team of scientists began exchanging data and ideas to help determine the origin and cause of the dark water (updates available at http://www.floridamarine.org/features/view_article.asp?id=15348). Some water samples collected from the dark water showed optical characteristics typical of productive coastal marine waters with minimal estuarine influence, while others were similar to those of decaying *Thalassia* and mangrove litter, suggesting an Everglades estuarine origin. It might be possible that both influences were significant during different phases of the month-long bloom. However, samples collected in March may not adequately characterize the January/February black water, and the field data alone cannot provide a complete answer.

Satellites provide us with a great advantage over the tools available in 1878, thus allowing more educated inferences on what may have caused the black water phenomenon. Indeed, the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) and the Moderate Resolution Imaging Spectroradiometer (MODIS) observed dark imagery all during the autumn along the central west Florida Shelf while researchers conducted red tide surveys. This water entered Florida Bight in late 2001 (Figure 1). Figure 2 shows two SeaWiFS images taken on 9 January and 4 February 2002. In the 9 January "true-color" composite, two small dark, brownish patches can be seen. The 4 February image shows a much larger patch. However, when a spectramatching optimization algorithm [Lee et al.,

1999] is used to remove turbidity to obtain the total absorption coefficient in these anomalous waters (Figures 2c-d), the black water patch, defined by the absorption alone, has similar spatial coverage in the January and February images, as indicated by the green-yellow-red colors around Florida Bight.

Figures 2c-d suggest that river runoff from the Everglades through the Ten-Thousand Island estuary may have played a role in the formation of the black water; salinity gradients measured during January and February may support this possibility. In addition, a bloom of red tide (*K. brevis*) has persisted in the south Florida coastal waters since August 2001 (images available at http://imars.usf.edu/~hu/black_water/imgs/swf/). The dark water patch was observed about 50 km off Charlotte Harbor in late 2001 (Figure 1) and moved slowly into the Florida Bight, where it spun with a clockwise motion during December and January. It then drifted to the southwest in March, reaching Key West and moving through the passes in the Keys.

Numerical circulation model simulations and surface drifters confirmed this circulation pattern and the presence of a clockwise eddy (anti-cyclone) in the Florida Bight in early 2002. This information suggests that the "black water" may be the result of advection and concentration by the coastal ocean circulation of a patch of the *K. brevis* bloom off central Florida. This bloom patch, plus the ecological perturbations associated with it, formed into a coherent and persistent "black water" patch in the Florida Bight. This is confirmed by the presence of *K. brevis* in the mid-March black water patch. Hence, river discharge is unlikely

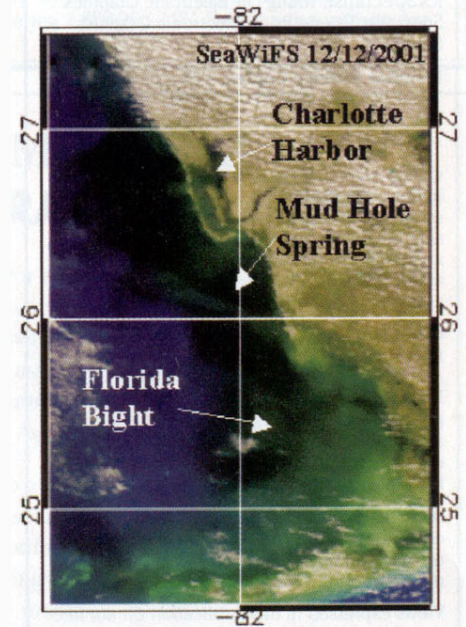


Fig. 1. This SeaWiFS true-color image taken on 12 December 2001 shows dark water patches near Charlotte Harbor and Florida Bight.

to have been a dominant factor, although some of the coloration in the Florida Bight may have been caused by local river discharges because they are sources of silicate necessary to transform the early-stage *K. brevis* bloom into the later-stage *Rhizosoleniaceae* diatom bloom. However, the required nutrient may also come from some salt water springs in

Florida Coast (cont. on page 285)

Florida Coast (cont. from page 281)

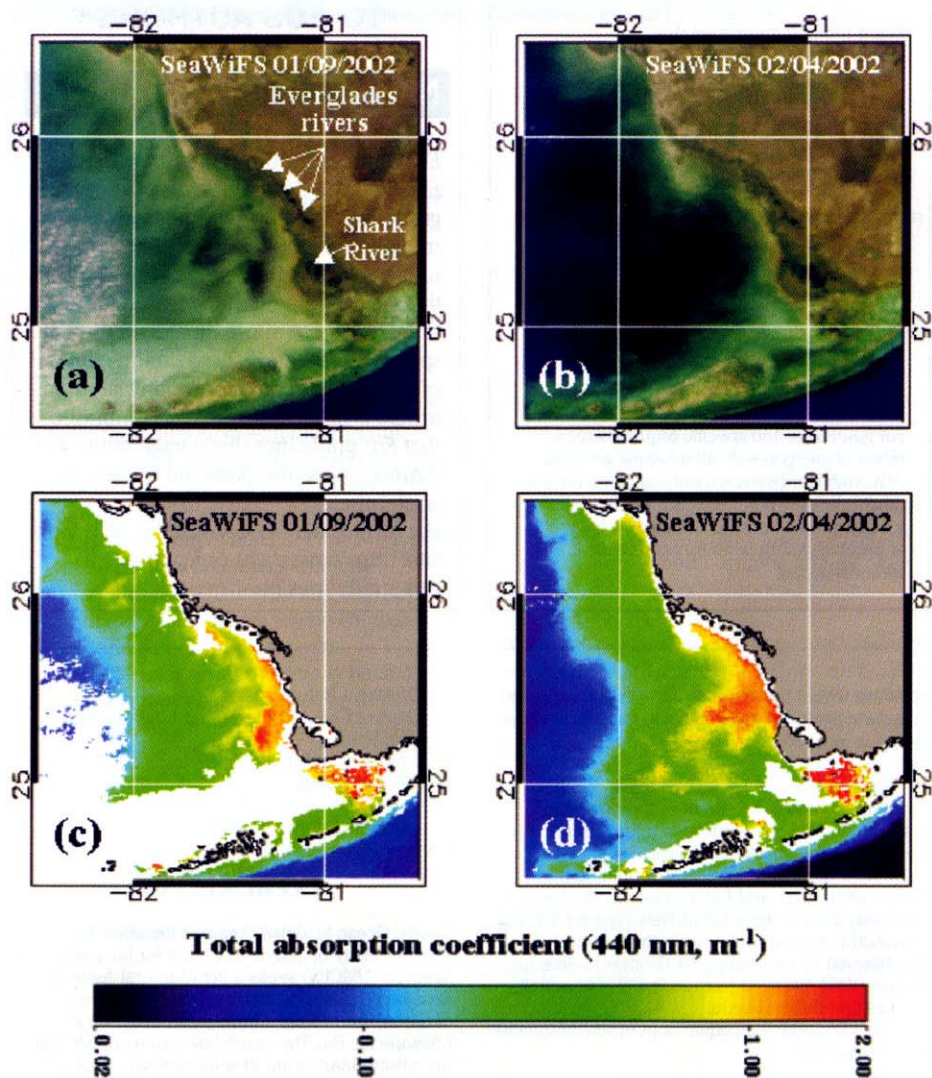


Fig. 2. (a & b) These SeaWiFS true-color images were taken on 9 January and 4 February 2002, respectively. The dark water patches in Florida Bight have been reported as “black water”; (c & d) Total absorption coefficient was obtained with an optimization algorithm to remove the color effects caused by backscattering (a proxy for turbidity), as shown in part (a). The white color represents algorithm failure caused by extreme turbidity or clouds. Results were validated with field measurements collected by University of South Florida and Florida International University researchers. The color legend applies to c & d only.

the vicinity—for example, Mud Hole Spring in Figure 1—that carry 20–40 times more silicate than the surrounding waters [Fanning *et al.*, 1981].

Satellite images revealed that the black water reached the Dry Tortugas in late March and that it was then slowly advected into the Florida current. While there were reports of mortality of bottom communities and observations of selective die-offs of certain sponge species near Key West as the black water moved through the passes, the impact of the black water on the Florida Keys National Marine Sanctuary is yet to be determined. A preliminary survey of permanent stations was conducted in April, and additional surveys will be conducted later this year.

The event is a clear example of why a robust system of continuous, real-time ocean observations is important (e.g., <http://imars.usf.edu>; <http://comps.marine.usf.edu>). Oceanographic satellites are an important component of this observing system because they help trace the origin and fate of such water masses over great distances. But the system needs to include key biological, chemical, and physical parameters that can only be obtained in situ. The integration of the few observations available in late 2001 and early 2002 demonstrated the need for a widespread automated coastal ocean observing system that can help validate the satellite data and provide relevant, timely information to coastal resource managers, communities, fishermen, and scientists.

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