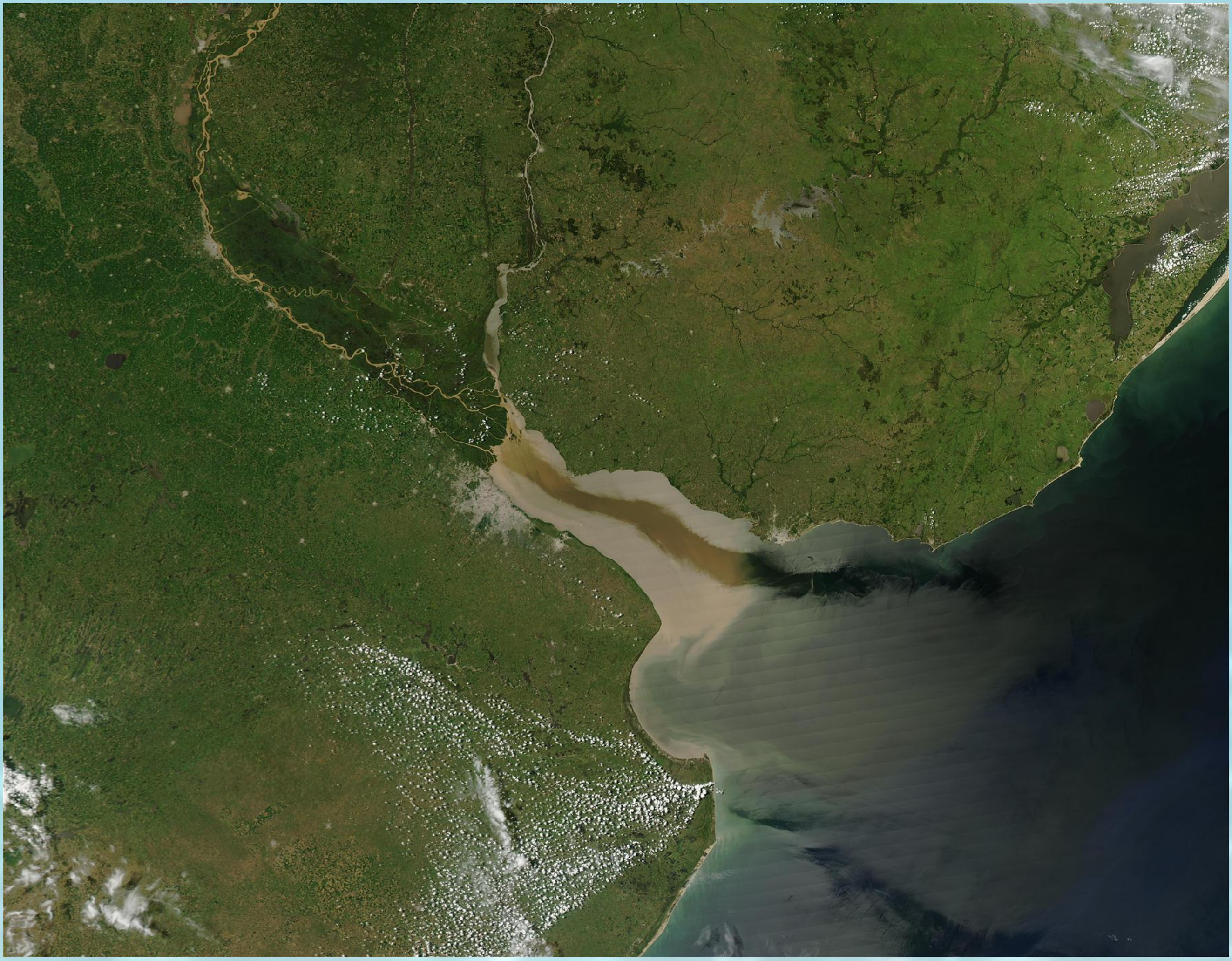
SCIENCE FOCUS: Colored Dissolved Organic Matter

Oh Black Water, Keep on Rollin'

Some rivers are just not willing to admit that they've finally reached the ocean.



Moderate Resolution Imaging Spectroradiometer (MODIS) image of the Rio de la Plata estuary (Argentina), with input of river water from the Uruguay and Parana rivers notably visible. Buenos Aires is the semi-circular gray area southeast of the inland end of the estuary. Click on the image for a larger version.

On January 26, 2003, the Moderate Resolution Imaging Spectroradiometer on NASA's Aqua satellite obtained the unique view of the Rio de la Plata estuary in Argentina shown on the previous page. The large (and very muddy) estuary receives fresh water from the Uruguay River and the much larger Parana River. Though dwarfed by the Amazon, the Parana is South America's second-largest river.

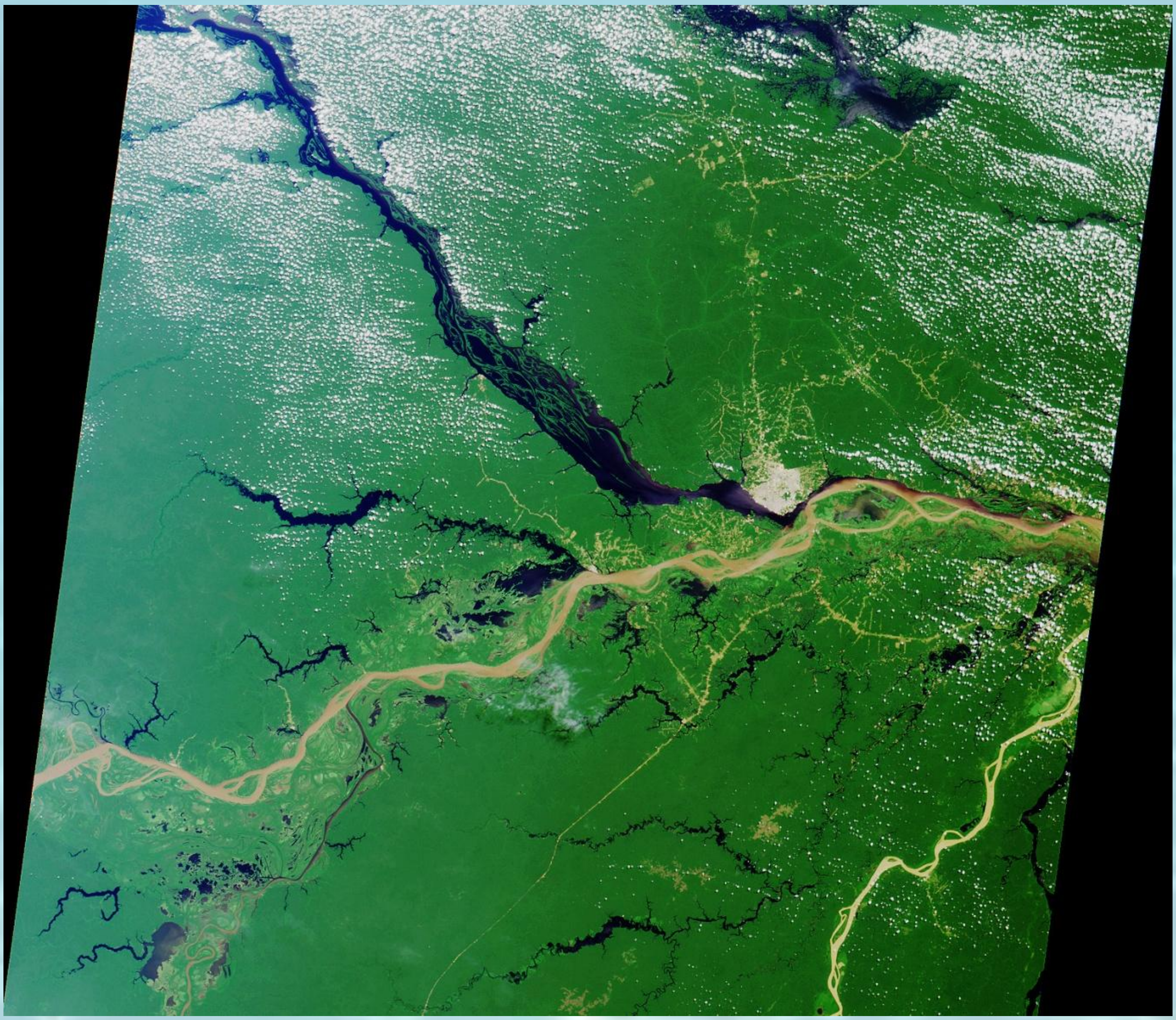
In this image, the input of the river waters is clearly visible as a dark black streak over the sediments on the bottom of the Rio de la Plata. The high visibility of the river water is due to a combination of factors. One factor is difference in the color of the riverborne sediments and the estuarine sediments. Another factor is that this particular viewing angle placed the estuary in the "sun glint" field of the MODIS instrument, where sunlight is reflected directly off the surface of the water into the instrument's optical system. While areas with sun glint must be omitted from ocean color data processing (because the reflected light interferes with the detection of light scattered and absorbed in the water), in this case the sun glint pattern may highlight a difference in the small waves on the surface of the water. This difference may be due to the organic matter carried in the river water, which can form a "slick" where the waves are suppressed. The expression "pouring oil on troubled waters" comes from the occasional practive of seafarers on sailing ships to pour oil on the ocean surface on a windy day, perhaps to allow crew members on a small boat to board the larger ship safely.

Although the river waters appear dark brown against the sediment in the estuary and even black as they enter the Atlantic, examination of the rivers upstream of the estuary indicates that the water isn't really black, or even dark. The sediments carried in the water color the waters light brown.

Even though the waters of the Parana and Uruguay Rivers are not black, they do carry a large amount of dissolved organic matter, some of which can actually have color. In straightforward fashion, scientists who study this stuff call it "colored dissolved organic matter" (CDOM for short).

The Black Water Rivers

There are rivers that do not carry a large amount of sediment, yet due to the geological characteristics of the region they flow through, they do contain a large amount of CDOM. These rivers are true "black water" rivers. Perhaps the most famous of these rivers is the Rio Negro ("black river") in Brazil. When the Rio Negro joins the Rio Solimoes at Manaus, Brazil, the mixture of its black water with the sediment-laden brown waters of the Rio Solimoes forms a remarkable contrast. It also forms the world's mightiest river, the Amazon. The images below, obtained by two instruments on NASA's Terra satellite, show the confluence of the Rio Negro and the Rio Solimoes at Manaus.



Multi-angle Imaging Radiometer (MISR) image of the confluence of the Rio Negro (from the northeast, with dark black water) and the Rio Solimoes (from the southeast, with light brown water) at Manaus, Brazil.

Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) image of the confluence of the Rio Negro (from the northeast, with dark black water) and the Rio Solimoes (from the southeast, with light brown water) at Manaus, Brazil.

Black water rivers occur due to a combination of geological and biological factors. They generally arise in watersheds with low relief, which means that erosion rates are low and the sediment load that they carry is minimal. They usually drain regions that have a significant wetland (otherwise known as swamp or marsh) areas, which provide a large amount of plant material that enters and decays in the water. The color of the water arises from the plant pigments that dissolve in the water. Commonly referred to as "tannins", these colored pigments are more accurately referred to as humic acids. The waters of these rivers are therefore somewhat acidic and low in dissolved oxygen concentration (due to the utilization of oxygen in the bacterial decay of plant matter), and the rivers are sometimes called "starvation rivers".

Though the Amazon carries a large amount of organic matter to the tropical Atlantic Ocean, the organic matter is not as apparent in remote sensing imagery as the sediments of the Amazon. The nutrients delivered to the ocean by the Amazon also foster phytoplankton blooms that disguise the colored organic matter content of the ocean.

Clear Water is SOUTH of Here

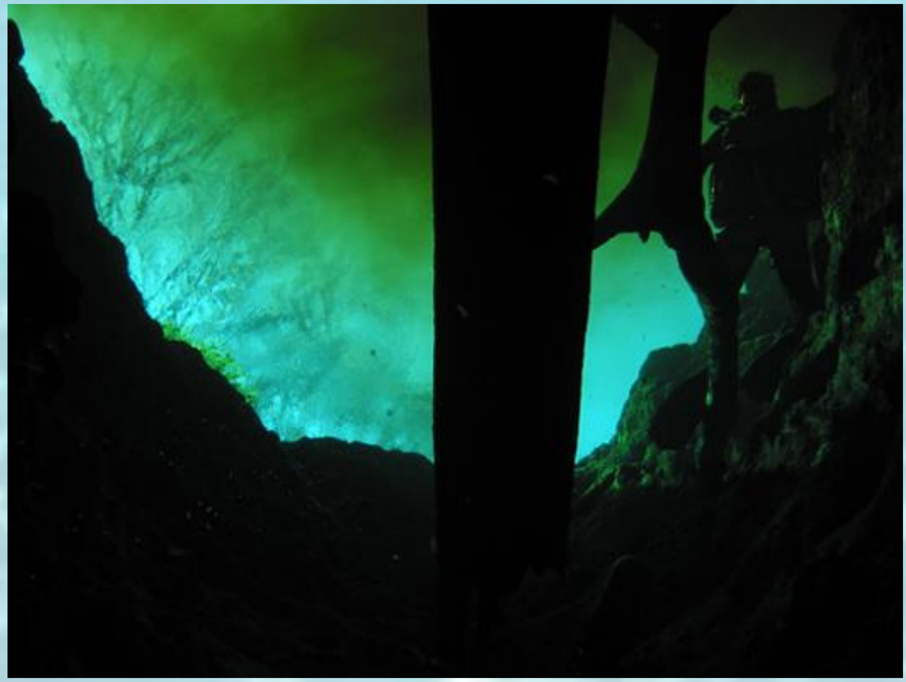
There are only a few places in the world where black water rivers directly enter the sea. One of the most notable places where this happens is the northeast Gulf of Mexico, where water the color of chicory coffee from the lazy Suwannee River enters the Gulf. The plume of colored dissolved organic matter from the Suwannee is clearly visible in the center of the SeaWiFS image excerpt below. Also note the sediments from the Apalachicola river at upper left, and Tampa Bay at lower right. (The city of Clearwater, Florida is on the Pinellas County peninsula north of Tampa Bay.)

Sea-viewing Wide Field-of-view Sensor (SeaWiFS) image excerpt of the northeast Gulf of Mexico and Florida, showing the black water (colored dissolved organic matter) plume of water from the Suwannee River at center.

The northeast corner of the Gulf of Mexico is *not* noted for its clear water; in fact, it's one of the most challenging places anywhere in the ocean to apply the algorithms that create ocean color data products. There are several factors in play: black water from the Suwannee and other coastal black water rivers; organic matter and sediments from the immense discharge of the Mississippi River; and the shallow depth and offshore extent of the seafloor on the West Florida continental shelf. This makes the region one of the best places to test advanced ocean color algorithms, because if they produce accurate results there, they must be pretty good!

CDOM, gelbstoff, marine humics (which are somewhat interchangeable terms for basically the same substance) absorb strongly in the blue portion of the visible electromagnetic spectrum. For SeaWiFS and MODIS, algorithms which detect and quantify CDOM and gelbstoff (and which correct for their presence in the calculation of chlorophyll concentration) use the bands centered at approximately 412 nanometers.

A unique aspect of the Florida black water rivers, particularly the Suwannee and its tributary, the Santa Fe River, is that these dark waters receive some of the clearest water in the world from the springs of the Florida aquifer. The mixing zone of this crystal-clear water with the tannin-stained water of the rivers looks fairly unusual from underwater, as shown in the picture below.



Underwater picture of the mixing of tannic water in the Santa Fe River and clear spring water from Ginnie Springs, in Florida Note diver at upper right for scale.

Fading Colors (Photochemistry)

It's an unfortunate fact that if a brightly colored fabric is exposed to the sun for long periods of time, it tends to fade. Sunlight causes the photochemical breakdown of the dye molecules that color the fabric. The organic compounds composing CDOM in the ocean are no different; it will absorb sunlight and be broken down by photochemical reactions. This process does several things. It results in the production of carbon dioxide and small amounts of other organic gases (such as carbon monoxide and methyl halogens), influencing gas exchange processes in the ocean and atmosphere; it affects the distribution and chemical "identity" of biologically important trace metals that may be bound to the organic matter; and it affects the future ability of CDOM to absorb energy from sunlight in the water column (photochemical fading).

In open ocean waters, almost all of the ultraviolet (UV) light is absorbed by CDOM. Because solar UV radiation is the most important part of the solar light spectrum driving marine photochemistry, enhancement of UV radiation due to atmospheric ozone depletion may have an important effect on all of the processes listed above. According to Dr. William Miller of the University of Georgia, the "perceived importance" of marine photochemistry "has grown over the last 15 years from a novelty source of radical compounds in the photic zone to a critical component controlling many chemical processes which play an essential role in aquatic carbon cycles". Any changes in the degree to which CDOM absorbs UV light in the ocean (via photochemical fading, or changes in the sources of CDOM to the oceans, i.e., rivers) will interact with processes controlling the solar intensity of UV radiation at the earth's surface (cloud cover, ozone depletion), providing feedbacks to global change.

Acknowledgments

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Links

A New Approach to Evaluating Spatial Variability of Photochemistry Based on Characterisation of Optical Water Type from Satellites (PDF document)

Impact of Photochemistry on Carbon Cycling in the Sea

Jau National Park, Brazil (Landsat 7 image of the Rio Negro)

Brazil—Manaus

Ashepoo-Combahee-Edisto (ACE) Basin Executive Summary—Environmental Conditions