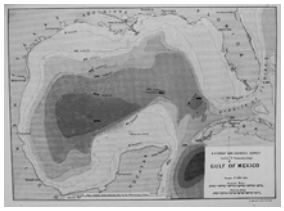
The Gulf of Mexico:
Understanding America's Sea



Coast and Geodetic Survey personnel developed the first realistic bathymetric map of any oceanic basin (above) from 3,000 soundings taken on the Survey Steamer, *Blake*, between 1873 and 1875 in the Gulf of Mexico

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The Gulf of Mexico is a semi-enclosed basin of the ocean. With the Caribbean Sea it constitutes America's *Inland Sea.**

The Gulf is bordered by five states in the United States (Florida, Alabama, Mississippi, Louisiana and Texas), six in Mexico (Tamaulipas, Veracruz, Tabasco, Campeche, Yucatan and Quintana Roo), and Cuba.

Of the *semi-enclosed seas*, the Gulf of Mexico is the most intensely investigated and maybe the best understood.

*** Words printed in italics are defined in the pdf glossary listed on the references page**

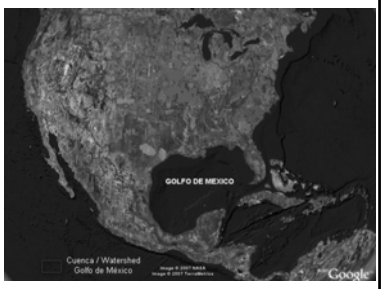
Surface area:
1,500,000 sq km (580,000 sq mi)

West to East extent:
1,600 km (994 mi)

North to South extent:
900 km (559 mi)

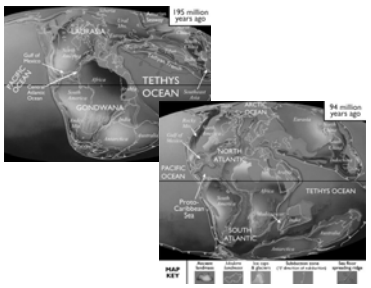
20 major fresh-water river systems drain into the Gulf, and near 65% of all river volume (and pollution) flows into this massive body of water through the Mississippi River Delta.

In many ways the Gulf of Mexico is like every other part of the ocean. But there are also differences. This presentation discusses the origins of the Gulf of Mexico and makes some comparisons to other parts of the world's ocean in the context of the four traditional disciplines of oceanography: Geology, Physics, Chemistry, and Biology.



The Gulf began to form 195 million years ago when North America began separating from Africa as a result of a rift forming between the plates currently known as the North and South American continents.

By 94 million years ago the Gulf was receiving sediment from North America even though much of it was under water. Sedimentation continues today via the Mississippi River delta, resulting in thick deposits around the edges of the Gulf.



Thickness of Deposits:

Interior of US Gulf Coast states:	>2 km
Coast of US Gulf Coast states	
West of the Mississippi River:	10 km
East of the Mississippi River:	5 km
Offshore of Louisiana:	16 km

GEOLOGY

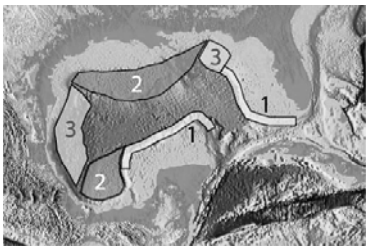
http://www.paleoportal.org/index.php?globalnav=time_space&sectionnav=period&period_id=9

The underwater topography of the coastal Gulf of Mexico is different from that of the Atlantic Coast.

Area '3' is similar to the Atlantic Coast in the relatively narrow width of the *continental shelf* and moderate width of the *continental slope*.

Area '1' has a wide continental shelf consisting of *carbonate platform* created by reef-building organisms (like coral) more than 250 million years ago. The continental slope is very narrow, and therefore steep.

Area '2' is the thick deposit from the Mississippi River delta. The deposit extends the width of both continental shelf and slope.

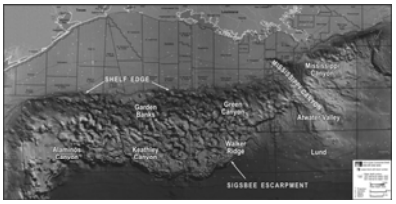


GEOLOGY

http--oceanexplorer_noaa_gov-explorations-02mexico-background-brinepool-gulf_salt_220.htm

A *multibeam bathymetry* map of the northwestern and northern Gulf of Mexico continental shelf and slope shows the topography of the area affected by river deposition, as well as an ancestral outlet of the Mississippi River (the Mississippi Canyon).

This area is the site of numerous oil and natural gas platforms. The many millions of years of organic and mineral sediment deposition via the Mississippi River has resulted in productive oil deposits.



GEOLOGY

http://oceanexplorer.noaa.gov/explorations/06mexico/background/geology/media/gulf_600.html

Shoreline Length
~5,700 km, Florida to Yucatan
~380 km, Cuba
>27,000 km, Shoreline including US bays

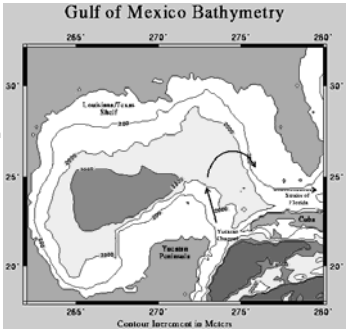
Basin Topography
38% Shallow, intertidal <20 m
22% Continental Shelf, 20-180 m
20% Continental Rise, 180-3000 m
20% Abyss, >3000 m

Sigsbee Deep: ~4000 m

Mean Depth: 1615 m

Volume: 2,400,000 km^3

Notice that the deepest part of the Gulf – the Sigsbee Deep (Darkest blue on the figure) is between the two portions of the salt layer. This is where oceanic crust *extruded* to separate them.



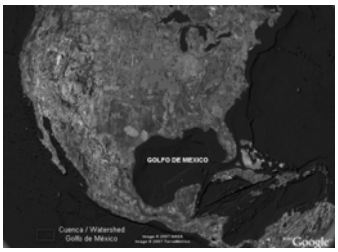
GEOLOGY

http://www.gulfbase.org/facts.php
http://www.intecmar.usb.ve/CoMLCaribbean/Summaries/summary_BoGoM.htm
http://ocean.colorado.edu/~kantha/Altimetry/gulf_of_mexico.html

A primary factor in the chemistry of the Gulf of Mexico is salinity. More than 150 rivers contribute freshwater to the Gulf. The Mississippi River makes the greatest contribution (64% of the total flow), and the total of all US drainage to the Gulf is 84% of the flow. Rivers in Mexico and Cuba contribute the rest. Freshwater vents on the southwest shelf of Florida also contribute freshwater.

Because of these freshwater sources, salinity in the Gulf averages 28-32 ppt, as compared to 35 ppt in the rest of the ocean.

Some parts of the Gulf have higher average salinity than the world ocean. This may be attributed to the existence of brine *seep*s on the seafloor, which contribute water of ~200 ppt to the mix. These form where subsurface salt migrates to the surface and dissolves.



CHEMISTRY

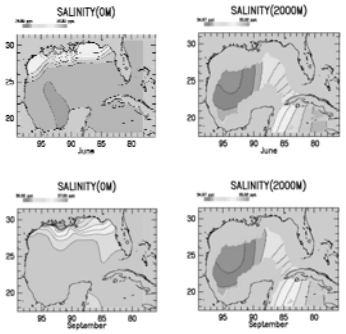
http://www.golfo-de-mexico.org
http://www.coast-nopp.org/resource_guide/elem_mid_school/physical_param_acts/saline.html

Gulf of Mexico salinity varies seasonally, with depth, and laterally.

The figures use a color scheme that changes on each figure to maximize the resolution of visible change. Keep in mind that the highest and lowest values are not the same on all plots. Check the rainbow legend to find the max and min.

September highs and June lows illustrated in the surface water figures have to do with the balance of freshwater runoff of US rivers (maximum in spring) and evaporation (maximum in summer).

There is less seasonal and lateral variation in deep waters, and these waters are more reflective of the 35 ppt average of the world ocean.



CHEMISTRY

http://www.dynalysis.com/Projects/projects.html

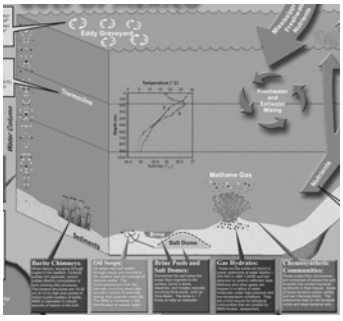
Get a copy of this excellent poster by contacting the MMS http://www.gomr.mms.gov/homepg/lagniapp/lagniapp.html

Brine Pools, barite chimneys, and oil seeps are features of the Gulf seafloor that influence it's chemistry. All are closely related to the deposition of salt through the geologic history of the Gulf.

Brine pools form by dissolution of salt that has migrated to the surface. Barite chimneys (~20cm high) occur when barium (frequently found in the salt layer) meets sulfate in the in the sea water. Oil seeps are caused by the migration of oil from reservoir rock to the surface (frequently near salt domes).

Gas hydrates (methane seeps) are another feature of the Gulf floor. These are formed where ice contains hydrocarbon like methane in its crystalline lattice. They occur at low temperature and high pressure (~300-500 m).

All of these features are associated with unusual communities. Chemosynthetic communities (in which bacterial oxidize sulfide for an energy source and therefore provide organic matter for tubeworms and mussels to eat) are found near gas hydrates and oil seeps.



CHEMISTRY

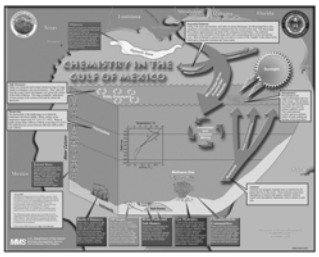
http://www.gomr.mms.gov/homepg/lagniapp/lagniapp.html

No discussion of Gulf chemistry would be complete without considering the input of nutrients from the rivers that drain the Gulf watershed. These nutrients include nitrogen, phosphorus and silicon which phytoplankton use to photosynthesize in the presence of sunlight.

The microscopic algae use N and P to make their organic parts, while they use the Si to *precipitate* biogenic silica for their tests (shells).

The large freshwater inflow contributes to a large phytoplankton population and encourages productive food webs and healthy commercial fisheries throughout the Gulf of Mexico.

Falling particles from dead phytoplankton, zooplankton and fecal pellets deliver the organic material to the bottom of the Gulf where decomposition of the organic material releases the nutrients to the deep water.

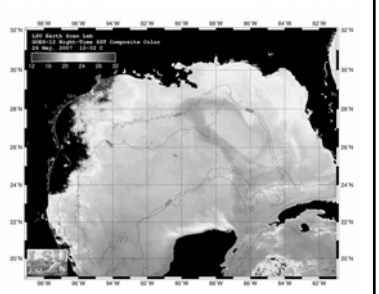


CHEMISTRY

http://www.gomr.mms.gov/homepg/lagniapp/lagniapp.html

Circulation in the Gulf of Mexico is part of the large-scale ocean circulation that connects different basins and moves water while balancing heat exchange between polar and equatorial oceans. Surface circulation is most easily observed using *sea surface temperature* images obtained from satellites.

This thermal figure is built by collecting and coding similarly *pixels* around the "warmest pixel" in a group from a sequence of night time imagery (obtained every 30 minutes) spanning about 10 hours. The pixel size is ~ 4km in size.

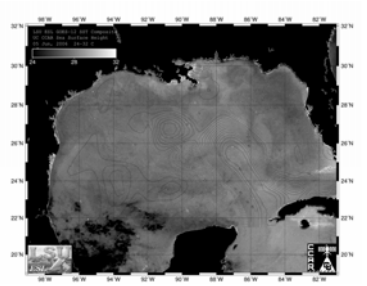


PHYSICS

http://www.esl.lsu.edu/research/CMI-GOES/s

Sea surface height is related to sea surface temperature in part by the relationship between temperature and density. Hotter water will have greater height because it is less dense.

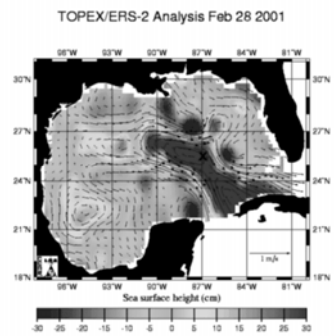
This figure shows a hill of higher water coming into the Gulf from the Caribbean via the Yucatan Strait.



PHYSICS

http://www.esl.lsu.edu/research/CMI-GOES/s

Another factor that contributes to sea-surface height is *flow velocity*. Clockwise (*anticyclonic*) flow coincides with high central pressure and pushes water up to make a small hill in the middle of circulating *gyres*. Arrows show direction and relative speed of water.



PHYSICS

http://www.csi.lsu.edu/physi.ocean.asp

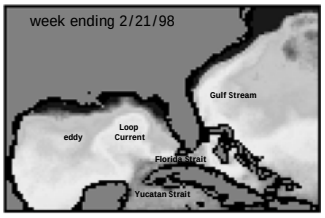
The Loop Current connects waters of the Gulf to the Caribbean and the Atlantic Ocean, where they join with the Gulf Stream to become one of the strongest currents in the world's ocean.

Warm water flows north through the Yucatan Strait, runs clockwise and exits through the Straits of Florida.

The Loop Current extends farther north in summer, and not as far in winter.

Sometimes the loop becomes unstable and an *eddy* (usually also clockwise) separates from the flow and drifts to the west. The figure shows an eddy as a roughly circular warm feature to the west of the warmer Loop Current.

Watch the Loop Current evolve and the eddy dissipate over a period of 6 weeks in 1998.



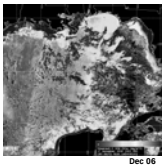
PHYSICS

http://www.ssmi.com/rss_research/viewing_ocean_currents_with_sst.html

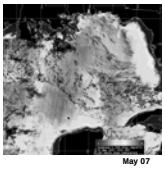
Chlorophyll *a* is a pigment produced by phytoplankton that thrive in the nutrient rich coastal waters of the Gulf. The images show variation in the amounts of chlorophyll *a* – and thus phytoplankton production – in the eastern Gulf of Mexico for specific dates. The rainbow legend has two small white numbers – in all cases the number on the left is 0 and the number on the right is 4 (mg/cm^3). But the color of 4 is darker in the May figure. So what does this say about production in May versus December this year?

The figures were produced using the Ocean Color Monitor (OCM), a satellite image used to estimate chlorophyll *a* concentrations as well as to quantify suspended sediments. This imagery has relatively high resolution, with pixels = 360m, while other types have 1km pixels.

Keep in mind that these measurements can be affected by many factors including suspended sediment. So, realize the limits of the technique while interpreting the patterns.



Dec 06



May 07

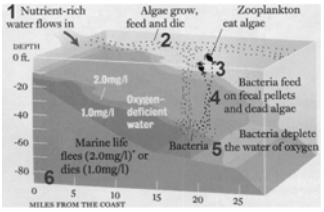
BIOLOGY

http://www.esl.lsu.edu/imagery/ocm/web/ocm_archive.php?day=2&month=1&year=2007&jpegtype=gom

The Gulf coast receives large volumes of river water from the Mississippi and Atchafalaya Rivers. The rivers flood from spring into summer, producing a stratified (layered) water column of dense, cooler seawater, overlain by lighter, warmer freshwater.

The nutrient rich water above fuels large phytoplankton blooms on the shelf. Phytoplankton incorporates oxygen into the upper layer of water.

The stratification is associated with a pycnocline (rapid vertical change in density) across which oxygen from the surface layer cannot pass. But dead organic matter does fall through and consumes oxygen through decomposition. This begins as a natural process.



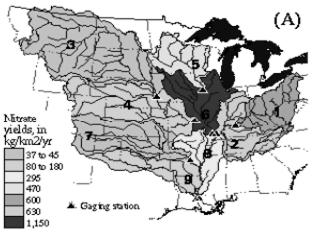
BIOLOGY

http://www.gulfhypoxia.net/overview/#What_is_Hypoxia

In recent decades, greater quantities of nutrients being delivered by the Mississippi and Atchafalaya Rivers have caused blooms of plankton that contribute large amounts of organic material to bottom waters, resulting in a large area of oxygen depletion, known as hypoxia, off of the Louisiana and sometimes Texas Coasts.

This is known as the 'dead zone.' The process of hypoxia formation is similar to that which occurs in many estuaries along highly populated parts of the Gulf coast.

It results from the use of artificial fertilizers that runoff into the rivers, as well as discharges of municipal sewage or livestock manure.



BIOLOGY

(Goolsby et al., 1999)

The issue of hypoxia illustrates an extremely important ecological fact.

Biology in the Gulf of Mexico is highly related to *abiotic* factors: chemical (nutrient), physical (stratification), and geological (river) factors.

Likewise, biology, by the presence of specific organisms, may change the way that the abiotic processes manifest.

Example:
As a result of hypoxia and changes in phytoplankton populations, we are likely to see deposition of highly organic sediments or different types of biogenic sediment.

Changes in the food web might result in different ratios of nutrients present in the water column at any given time.

The same principles apply throughout the Gulf. The types of organisms that can be observed are highly related to the abiotic environment (including climate, which was not discussed here).

Where the plume of the Mississippi River enters the Gulf of Mexico, muddy, nutrient rich, brown water mixes with clear, blue ocean water, but the demarcation between the two water bodies is frequently clearly visible. The location of the exciting vision changes with the prevailing wind direction, wind velocity and volume of river flow

BIOLOGY

Cohttp://www.gulfhypoxia.net/overview/#What_is_Hypoxiaurtesy of N. Rabalais

Therefore, in the Gulf we see many types of animals that are observed in the world ocean, but their distribution is determined by the abiotic features and processes that have been discussed in this presentation.

In this case, the occurrence of mammals is linked to variations in the depth of water around the Gulf: dolphins on the continental shelf, sperm whales on the continental slope and deeper. Blue whales have not been observed in the Gulf.

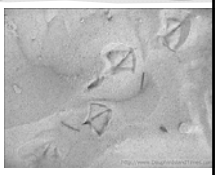
BIOLOGY

http://www.gomr.mms.gov/images_opt/graphics/lagniapp/whalebig.jpg

Sediment composition and texture controls shoreline *infauna* with specific types of organisms associated with fine grained silt and clay versus sandy beaches.

The amount of sediment carried in the water is also important, so Louisiana shores with high suspended sediment concentrations are less likely to see horseshoe crabs than any of the other US Gulf coastal beaches.

Florida has sandy beaches, but the sand is made of calcium carbonate, which comes with its own specific *faunal assemblage*.



BIOLOGY

www.mexico-with-heart.com ; www.bertaut.com/reatfish25.html
www.dauphinislandtimes.com/photos
www.naplesharnptoninn.com/app_1163882466.php

The Gulf is one of the most productive parts of the world ocean (http://www.gulfbase.org/facts.php).

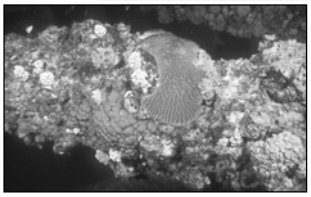
Nutrients delivered by land encourage productive food webs that foster many commercially and recreationally valuable fisheries (from top right, clockwise: oyster, menhaden, shrimp, redfish).

BIOLOGY

www.dnr.state.md.us/.../easternoyster.asp;
www.samford.edu/schools/artsci/biology/zoology/vertzoo-05s/index.htm;
www.csusm.edu/dgarcia/; www.dnr.state.md.us/mydnr/CreatureFeature/reddrum.asp

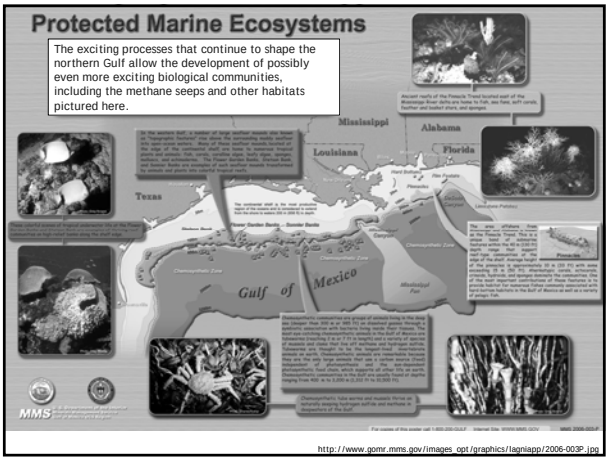
Shallow Florida and Yucatan platforms allow growth of coral reef and associated diverse fauna.

Corals are also found far from the suspended sediment that would suffocate them on the Louisiana-Texas coast in deep offshore waters, made accessible to the necessary sunlight by *salt domes* (Flower Garden Banks) and oil rigs (as shown in figure).

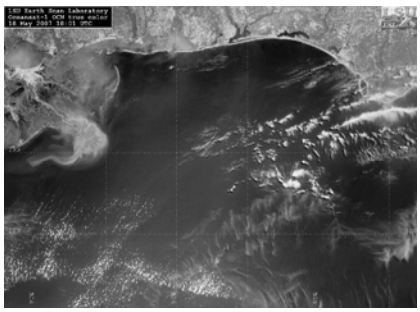


BIOLOGY

Photos courtesy of P. Sammarco



http://www.gomr.mms.gov/images_opt/graphics/lagniapp/2006-003P.jpg



… thus ends a brief natural history of the Gulf of Mexico …

I have included some details that may require clarification and left out many broad issues.
Please contact me via Moodle discussion or email if you have a question or would like to learn more. Jessica.Kastler@usm.edu. You may call me at 228 872 4269.

http://www.esl.lsu.edu/