**NASA DEVELOP National Program**

NASA Ames Research Center

**Summer 2015**

**Short Title: Gulf of Mexico Water Resources Project**

**Subtitle:** Utilizing NASA Earth Observations to detect factors contributing to hypoxic events in the southern Gulf of Mexico

**VPS Title:** Haunting the Gulf: Dead Zones Linger in Shallow Waters

**Project Team & Partners**

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**Partner Organizations**

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**Project Details**

**Applied Sciences National Applications Addressed:**

Water Resources

**Study Area:** Indices and models were performed in three study areas: (1)the Gulf of Mexico as a whole, (2)the coastal region along the southern end of the Bay of Campeche, and (3)the Usumacinta-Grijalva River Basin which extends through the Mexican States of Tabasco, Chiapas, and Campeche, as well as south into Guatemala.

**Study Period:** July 2000 - May 2015

**Earth Observations & Parameters**

Landsat 8, Operational Land Imager (OLI) – Floating Algal Index (FAI) and Normalized Difference Turbidity Index (NDTI) utilizing bands 2, 3, 4, 5, and 6. Data was utilized for years 2013-2014.

Aqua, MODIS – Level 3 SMI Products: Chlorophyll a (Chl), Remote Sensing Reflectance (Rrs), Sea Surface Temperature (SST) Photosynthetically Available Radiation (PAR), Colored Dissolved Organic Matter (CDOM). Data was utilized for years 2002 - 2014.

**Ancillary Datasets Utilized**

* USGS Earth Explorer - DEM
* NOAA National Centers for Environmental Information (NCEI) – dissolved oxygen
* EPA AIRNow PM2.5 dataset - PM2.5 measurements
* International Ocean Observing System (IOOS) Gulf of Mexico Coastal Ocean Observing System (GCOOS) buoy data - chlorophyll, dissolved oxygen, ocean currents, surface water temperature
* United Nations University Institute for Water, Environment, and Health (UNU-INWEH) - landuse, soil profiles
* Instituto Nacional de Estadística y Geografía (INEGI) – shapefiles of rivers and water bodies

**Models Utilized**

* Soil and Water Analysis Tool (SWAT)
* TerrSet - Earth Trends Modeler (ETM)

**Software Utilized**

ERDAS IMAGINE - land classification of Landsat imagery

Esri ArcGIS Desktop - Raster Manipulation/Analysis, Image Enhancement & Map Creation of Landsat ETM+, NPP VIIRS, Aqua/Terra MODIS

Clark Labs TerrSet - Modeling Earth trends, anomaly detection, time series analysis

**Project Overview**

The environmental health of the Grijalva-Usumacinta River Basin is essential for the survival and economic well-being of millions of people who rely on this ecosystem for drinking water, food, and other natural resources. However, an increasing frequency of hypoxic events and harmful algal blooms (HABs) have been observed in the lowlands and coastal regions of this system in recent years. This project utilized NASA Earth observations to detect these events and then relate their occurrences to nutrient and sediment loading from the Grijalva - Usumacinta River Basin. Results of this study will be used to aid local authorities in revising water quality standards in the region.

**Abstract**

Monitoring and better understanding harmful algal blooms and hypoxic events in the southern coastal areas of the Gulf of Mexico are important for mitigation of environmental degradation and watershed management. This study uncovered trends and dynamic characteristics of chlorophyll-a concentration, sea surface temperature, colored dissolved organic matter index, and photosynthetically available radiation, as evident in 8-day standard mapped image (SMI) products from the MODIS instrument on the Aqua platform from 2002-2015 using Clark Labs TerrSet Earth Trends Modeler (ETM). Additionally, sediment and nutrient loading values of the Grijalva-Usumacinta watershed were modeled using the Soil and Water Assessment Tool (SWAT). Normalized Difference Turbidity Index (NDTI) and Floating Algae Index (FAI) indices were generated using Landsat 8 Operational Land Imager (OLI) scenes for 2014-2015. These results indicated high levels of nutrient and sediment loading from the Grijalva-Usumancinta River Basin, correlating to high frequencies of hypoxic events and harmful algal blooms in the coastal region of the southern Gulf of Mexico.

**Community Concerns**

* The Grijalva-Usumacinta River Basin is an important source of drinking water, hydroelectric energy, fisheries, and other natural resources to the 6 million people who live within the region. This system is also one of the most important freshwater inflows to the Gulf of Mexico, second only to the Mississippi River Basin.
* Deforestation, slash and burn agricultural techniques, and industrial practices, along with other anthropogenic threats, have degraded the water quality in this watershed through increased erosion and nutrient loading.
* Since the early 2000s, increasing frequencies of hypoxic events and harmful algal blooms (HABs) have been observed along the coastal continental shelf surrounding the Grijalva-Usumacinta River Delta.
* Algal blooms are a cyclic and natural phenomena that occur in both coastal and freshwater systems worldwide. However, an unnatural influx of nutrients and organic matter has contributed to frequent and rapid algal proliferation events. This, in turn has resulted in persistent seasonal hypoxia and death of many marine organisms.
* Many blooms in recent years have been composed of toxin-producing algal species. These harmful algal blooms (HABs) have been implicated in eutrophication, fish kills, economic loss for fisheries, and human illness.

**Current Management Practices & Policies**

The federal government of Mexico has adopted a variety of laws aimed at the protection of surface and coastal water resources. Among these are The Federal Law of the Sea and the National Waters Law, which offer protection and regulatory standards for marine and surface water environments, respectively. Unfortunately, many of the current water quality standards are outdated and few are enforced (Gutierrez, 2008). Therefore, a current assessment of the region is required in order to create adequate environmental protection policies. Recently, partner organizations CiiMar-GoMC, UJAT, CONABIO, UABC, and CCGSS have collaborated to focus resources on implementing in-situ water quality monitoring and management strategies for both hypoxia and HABs (Alvarez Torres and Gold, 2012). They have also allocated resources toward utilizing NASA Earth Observations to assist in creating effective regulatory and management strategies. Additionally, the Federal Ministry of Health, through its directorship on Sanitary Risks Protection, is conducting surveys to identify and quantify the toxin-producing algal species that proliferate during HABs and red tide events.

**Decision Support Tools & Benefits**

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| **End-Product** | **Earth Observations Used** | **Benefit & Impact** |
| Time series of Normalized Difference Turbidity Index (NDTI), Floating Algal Index (FAI) | Landsat 8 OLI  | Display historical and current indicators of HABs |
| TerrSet ETM time series analysis, detection of chl, SST, PAR, and CDOM anomalies | Aqua MODIS Level III SMI products | Detect anomalies of known indicators of either hypoxic events or HABs |
| SWAT modeled nitrogen, phosphorus, and sediment load | In-situ data | Determine historical and projected nutrient and sediment influx from the Grijalva-Usumacinta watershed into the southern Gulf of Mexico |

**References**

Gutierrez, C. (2008). Standards and Thresholds for Wastewater Discharges in Mexico. In M. Schmidt, J. Glasson, L. Emmelin, and H. Helbron (Eds.), Standards and Thresholds for Impact Assessment (pp. 113–124). Berlin: Springer Verlag.

Alvarez Torres, P. and G. Gold. (2012). Monitoring in the Gulf of Mexico Large Marine Ecosystem: Hypoxia, HABIOS, and Monitoring Pilot Project. Presentation PowerPoint for Gulf of Mexico Alliance, All Hands Meeting. Corpus Christi, TX, 19 June 2012.

**Project Imagery**



**Caption:** Figure 1: Study area Alpha: The southern end of the Bay of Campeche surrounding the Grijalva-Usumacinta River Delta. Image Credit: Mexico Water Resources Team.

**Image:** MWR\_Alpha\_Study\_Area.jpg



**Caption:** Figure 2: Study area Beta: The Grijalva-Usumacinta River Basin. Image Credit: Mexico Water Resources Team.

**Image:** MWR\_Beta\_Study\_Area.jpg