Improved Hypoxia Modeling for Nutrient Control Decisions in the Gulf of Mexico

Shahid Habib[1], Ken Pickerring[1], Maria Tzortziou[2], Antonio Maninio[1], Fritz Policelli[1]
[1]NASA Goddard Space Flight Center
Greenbelt, Maryland
[2]University of Maryland
Baltimore, Maryland

Abstract

As required by the Harmful Algal Bloom and Hypoxia Research Control Act of 1998, the Mississippi River/ Gulf of Mexico Watershed Nutrient Task Force issued the 2001 Gulf Hypoxia Action Plan (updated in 2008). In response to the Gulf Hypoxia Action Plan of 2001 (updated in 2008), the EPA Gulf of Mexico Hypoxia Modeling and Monitoring Project has established a detailed model for the Mississippi-Attchafalaya River Basin which provides a capability to forecast the multi-source nutrient loading to the Gulf and the subsequent bio-geochemical processes leading to hypoxic conditions and subsequent effects on Gulf habitats and fisheries. The primary purpose of the EPA model is to characterize the impacts of nutrient management actions, or proposed actions on the spatial and temporal characteristics of the Gulf hypoxic zone. The model is expected to play a significant role in determining best practices and improved strategies for incentivizing nutrient reduction strategies, including installation of on-farm structures to reduce sediment and nutrient runoff, use of cover crops and other agricultural practices, restoration of wetlands and riparian buffers, improved waste water treatment and decreased industrial nitrogen emissions. These decisions are currently made in a fragmented way by federal, state, and local agencies, using a variety of small scale models and limited data. During the past three years, EPA has collected an enormous amount of in-situ data to be used in the model. We believe that the use of NASA satellite data products in the model and for long term validation of the model has the potential to significantly increase the accuracy and therefore the utility of the model for the decision making described above. This proposal addresses the Gulf of Mexico Alliance (GOMA) priority issue of reductions in nutrient inputs to coastal ecosystem. It further directly relates to water quality for healthy beaches and shellfish beds and wetland and coastal conservation restoration.

Introduction

The project is a joint partnership with the Environment Protection Agency and NASA. This work addresses Gulf of Mexico Alliance GOMA) priority issue of reductions in nutrient inputs to coastal ecosystem. It further directly relates to water quality for healthy beaches and shellfish beds and wetland and coastal conservation restoration. The hypoxic zone in the Northern Gulf of Mexico forms each summer and can extend up to 80 miles offshore and stretch from the discharge of the Mississippi River westward to coastal waters of Texas. The size of the hypoxic zone, Figure 1 varies considerably each year. In 2007, the size of the hypoxic zone was 20,500 km^2 approximately the size of Massachusetts. The current five year average (2003-2007) is 14,644 km2. The goal established by the Mississippi River Gulf of Mexico Watershed Nutrient Task Force (as stated in 2008 Gulf Hypoxia Action Plan), is to reduce the hypoxic zone to less than 5,000 km2 by year 2015. While it is recognized in the Gulf of Mexico Hypoxia Action Plan that this is an extremely ambitious goal unlikely to be achieved in the prescribed time frame

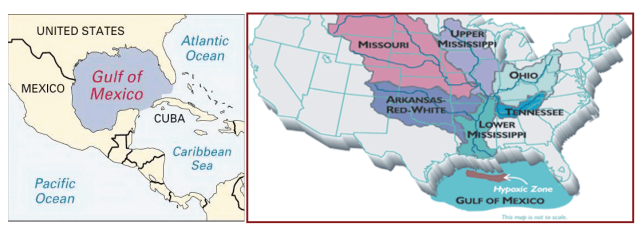

Figure 1. Gulf of Mexico hypoxic zone that varies around 20,000km^2 annually.

without significant additional resources, it is clear that actions taken in this direction can be expected to provide major benefits to the economic value to the Gulf of Mexico fisheries estimated to have been on the order of $744 million (*Adams et. al. 2004*) per year in 2001 findings.

Use of NASA Satellite Data

Multiple NASA products (*Habib, 2009*) as shown in Figure 2 are used to improve the EPA's Gulf of Mexico Modeling Framework (*Gulf of Mexico Hypoxia Modeling and Monitoring –* ***http://www.epa.gov/med/grosseile_site/gom.html***). Archived atmospheric chemistry, ocean color and precipitation products (shown in Table 1) and will be used in comparisons with the EPA's model generated precipitation, algal biomass and chemical composition products. The Ozone Monitoring Instrument (OMI), instrument on the Aura satellite, provides column amounts of NO2 and SO2, (among other products).

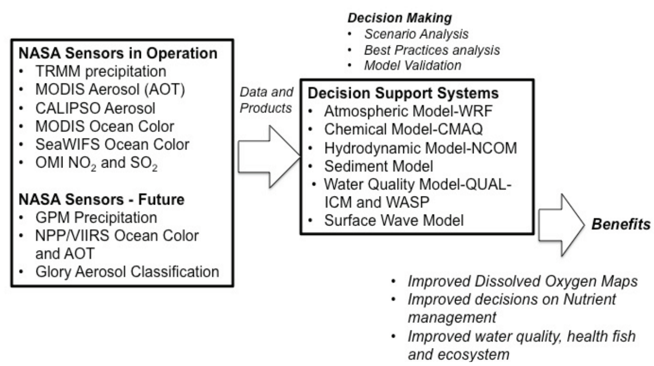

Figure 2. Enhancing EPA's decison support system using NASA satellite products.

NO2 is the most robust among OMI tropospheric trace gas products, determined in an atmospheric transmission window with little interference from other pollutants. Total slant column NO2 is accurately measured, and the tropospheric vertical column is computed by subtracting the stratospheric component, and adjusting the Air Mass Factor using global model-prescribed vertical profiles. OMI's UV hyperspectral measurements allow detection of SO2 emissions in the planetary boundary layer. Moderate-resolution Imaging Spectrometer - The MODIS instruments are flying on both Terra and Aqua satellites. This allows twice a day global coverage. MODIS provides aerosol extinction optical depth (AOD). AOD retrievals are subject to greater uncertainty over land than over water. In areas where there are no large aerosol plumes (e.g., smoke from biomass burning) in the free troposphere, MODIS AOD and boundary layer PM2.5 correlate well. Calipso **-** CALIOP (Cloud-Aerosol Lidar with Orthogonal Polarization) on the Calipso satellite, in the A-train constellation, contains a lidar which provides aerosol vertical profiles along the satellite orbit. It has limited spatial coverage but can be used in model evaluation. The TRMM Multisatellite Precipitation Analysis (*Huffman et al*., 2007) is available in near real-time and final form at fine time and space scales (3-hr, 0.25° × 0.25° lat./lon.) over 50° N-S. This product makes use of TRMM's microwave observations, along with passive microwave-based rain estimates from polar-orbiting instruments (e.g. AMSR, (2) SSMI/ DSMP, (2) AMSU/ POES), and all the geosynchronous IR sensors (Meteosat, GOES, GMS). The combined quasi-global rain map is produced by using TRMM to calibrate the estimates from all the other satellites, and then combining all the estimates into the TMPA final product. The calibrations are computed using monthly accumulations of matched data to ensure stability. MODIS and Seawifs Ocean Color – The SeaWiFS and MODIS instruments provide daily global coverage of ocean color at ~1 km spatial resolution. Satellite ocean color provides information on the biology and biogeochemistry within the ocean's surface. Products that can be derived from ocean color include chlorophyll, which roughly approximates algal biomass, particulate organic carbon (POC), which represents the amount of living and dead particles in the surface ocean, dissolved organic carbon (DOC), colored dissolved organic matter (CDOM), etc (*Mannino, et. al. 2008*).

Table 1. NASA ocean and atmospheric measurements, frequency and resolution.

Observation	Sensor	Resolution	Frequency
NO_2	OMI	13 x 24 km	Once per day
SO_2	OMI	13 x 24 km	Once per day
Aerosols Vertical Profile	CALIPSO	Vertical: 30 – 60 m	Approx. once per day
Aerosols Optical Thickness	MODIS	250 m Nadir	Twice per day
Precipitation	NOAA Multisensor Precipitation Estimator	4 km x 4km	hourly
Precipitation	TRMM/TMI and PR multisensor calibrated product –TMPA	0.25^{O} x 0.25^{O}	Every 3 hour near real time
Ocean Color	MODIS – Aqua	~ 1 km Nadir	Every 1-2 days
Ocean Color	SeaWIFS	~ 1.1 km Nadir	Every 1-2 days

References

Adams, Hernandez, and Kato, (2004) "Economic Significance of Gulf of Mexico Related to Population Income Employment Minerals, Fisheries and Shipping,", Ocean and Coastal Management, Vol. 47, Issues 11-12, pp 565-580.

Huffman, G. J., R. F. Adler, D. T. Bolvin, G. Gu, E. J. Nelkin, K. P. Bowman, Y. Hong, E. F. Stocker, and D. B. Wolff, The TRMM Multisatellite Precipitation Analysis (TMPA): Quasi-global, multiyear, conbined-sensor precipitation estimates at fine scales, (2007), J. of Hydrometeorology, 8, 38-55.

Levy, R.C., 2007. Retrieval of tropospheric aerosol properties over land from inversion of visible and near infrared spectral reflectance: Application over Maryland, PhD thesis, University of Maryland, College Park, MD, 236 pages.

Mannino, A., M.E. Russ and S.B. Hooker. 2008. Algorithm development for satellite-derived distributions of DOC and CDOM in the U.S. Middle Atlantic Bight. J. Geophys. Res., 113, C07051, doi:10.1029/2007JC004493.

Habib, S, "Utilizing Earth Science Observations for Applied Research", *Asian Journal of Geoinformatics*, Volume 9, No. 1, ISSN 1513-6728, March 2009.

Habib, S, Application of Satellite Observations to Manage Natural Disasters in the Lake Victoria Basin, IGARSS 2009