Oil Spill and Sea Surface Effects Over Gulf of Mexico Using WRF and Satellite Data

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(91 st AMS Annual Meeting, Seattle, Washington, January 23-27, 2011)

Abstract

An enormous amount of oil at a staggering rate of at least 35,000 barrels/day, had been gushing into the Gulf of Mexico for over three months after April 20, 2010 due to the explosion of Deep Horizon oil rig located at 52 miles southeast of Venice, Louisiana, USA. It is estimated that in a month over 3.5 million gallons, and in three months over 200 million gallons of oil has been poured out into the Gulf due to the oil spill since the time of the accident. The surface area of the oil spill is continuously increasing (over 500 square miles) and may spread to Atlantic Ocean and beyond, causing fears in all kinds of community that the slick can go into catastrophic to influence nature for changes over a wide range of factors from environment to ecology. In continuation of our earlier studies on the interplay of climate variability, we investigate sea surface temperature (SST) changes and surface weather circulations due to the oil spill over Gulf of Mexico. In the present study, we use Weather Research Forecast (WRF) model output and satellite data over the Gulf of Mexico to examine the oil effects on SST and possible weather patterns that could trigger favorable tropical cyclone heat potential (TCHP) conditions to develop into a tropical cyclone/hurricane. The WRF model simulations were carried out along with satellite observations for the period June 1 -3, 2010 considered about a month after the Deep Horizon accident. The model showed about 30 C increase in SST due to the oil spill, in agreement with the observed satellite data. Consequently, the associated changes in wind directions over the Gulf has indicated greater spreading of the oil by the loop currents and pushing it toward the coast. The heat potentials have shown elevated values of about 80 J/cm3 that has potential to develop a tropical disturbance into severe storm had it been triggered by the disturbance such as the forecasted tropical storm on June 1, 2010. We noticed contrasting effects of oil spill on weather patterns representative of high pressure versus increasing trends of SST and TCHP over the region during the period of study.

Motivation: Deep Horizon Oil Rig Accident and Environmental Impact

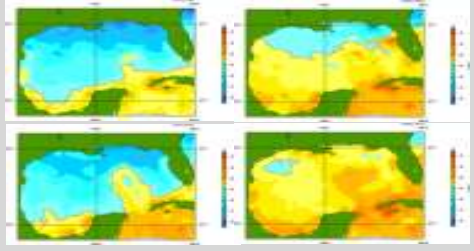
April 20, 2010: explosion of Deep Horizon oil rig located at 52 miles southeast of Venice, Louisiana, USA and led to a massive and widespread oil spill in Gulf of Mexico

In over a month more than 3.5 million gallons oil has been poured out into the Gulf due to the oil spill. The surface area of the oil spill spread over a vast areas, over 5000 square miles, causing fears in all kinds of community that the slick can go into catastrophic to influence nature for changes over a wide range of factors from environment to ecology. (Photo: National Geographic News (2010). Published May 18

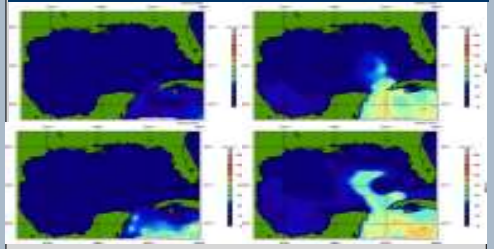
Objectives

In the present study, we investigate the Gulf of Mexico oil spill effects on the environmental changes in the atmospheric circulations using Weather Research Forecast (WRF) model simulations, and effects on the sea surface temperature (SST), and tropical cyclone heat potential (TCHP), using satellite data. Compared to the month of June climatology of SST (270 C), the satellite data showed during the month of May – June, 2010 very high SSTs (a peak of about 310C) corresponding to an increase of about 30 C much higher than expected due to seasonal heating. The corresponding heat potentials over the Gulf have shown elevated values of about 80 J/cm3 that has potential to develop tropical disturbances into severe storms. Therefore, the WRF model simulations were carried out for the period June 1- 3, 2010 which is about a month after the Deep Horizon accident and also the onset of hurricane season in order to see the combined effects of oil slick on the changes due to the seasonal heating in the region. Figures are taken from NOAA.

Gulf of Mexico: Satellite charts of SSTs on April 20 and May 20 of, 2009 (top) in comparison with the corresponding charts of 2010 (bottom)



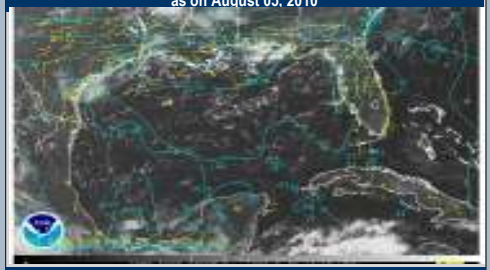
Gulf of Mexico: Satellite charts of TCHPs on April 20 and May 20 of, 2009 (top) in comparison with the corresponding charts of 2010 (bottom)



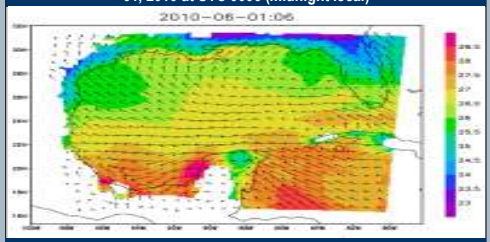
Weather Modeling Simulations

The weather modeling simulations were run using NCAR Advanced Research Weather Research Forecast (ARW) model (version 3.1) developed by NCAR. The model is run for the period June 1 to 3, 2010 primarily in view of the predominant changes in SST and wind patterns that started to show up as result of the impact of the growing oil slick in the region. Secondarily, the first week of June happened to be the beginning of the hurricane season and the tropical disturbances are predicted to be happening in the region.

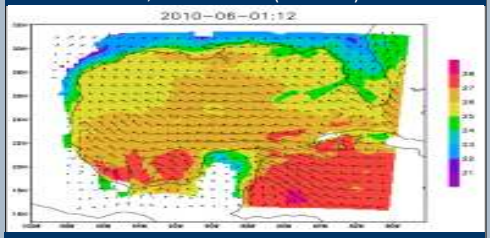
Overlay of wind, sea level pressure and SST over the Gulf of Mexico as on August 05, 2010



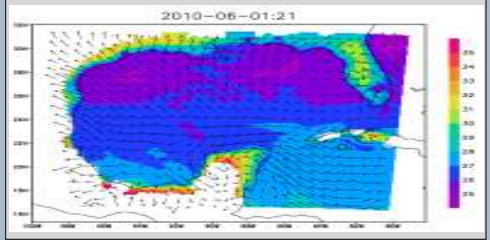
Modeling simulations of wind and SST over Gulf of Mexico, as on June 01, 2010 at UTC 0006 (midnight local)



Modeling simulations of wind and SST over Gulf of Mexico, as on June 01, 2010 at UTC 0012 (06 am local)



Modeling simulations of wind and SST over Gulf of Mexico, as on June 01, 2010 at UTC 0021 (03 pm local)



Satellite Observations

The satellite observations in the Gulf Coast show higher SST in the range of 28 – 310 C overall the region (Figures 2) corresponding to an increase of 2 – 30 C, as compared with the period of June SST climatology of 270C. During the period May 1 to June 15, 2010, the buoy data also shows high SSTs ranging from 880F (310 C) to 960 F (360 C) but not corresponding changes in the dew points. The heat potential chart shows a maximum of about 80 J/cm3 over the oil slick area, corresponding to an increase of 60 J/ cm3 comparing with the climatology of 20 J/cm3.

Results and Discussion

Model simulations of wind patterns overlaid on SST on June 1, 2010 at three instants of the day – midnight, morning, and afternoon. Similar patterns were observed for the remaining days of the simulations period of June 1 – 3, 2010. The model simulated weather circulation patterns in the Gulf Coast region, and captured the observed high SSTs and it also correspond to the higher heat potentials (TCHP). Wind patterns of clockwise circulation of high pressure system related to the eddies, have been observed near and over the oil spill during midnight and morning hours at 6.00 am local (1200 UTC). A strong South-Easterly and weak westerly flow associated with sea breeze circulation and anti cyclonic circulation is also observed during afternoon at 3 pm local (2100 UTC). Based on ocean-atmosphere coupled system, we presume that the altered wind patterns of high pressure system are responsible for increase in higher SSTs like that in El Niño conditions [20] in the region. Normally, a cyclonic cool eddy is associated with upwelling of cold and nutrient-rich water from the deep Gulf toward the surface. If the widely spread massive oil slick overlays a cyclonic (cool) eddy, the oil slick could limit the evaporation of the water and hence suppress the otherwise upwelling. The suppression of upwelling can lead to lowering of evaporation and increasing of SST and therefore alter the wind patterns from easterly to westerly associated with the loop current and eddy as seen in the model simulations.

Summary

The model over the Gulf of Mexico during the period of study June 01- 03, 2010 about a month after the Deep Horizon accident, have shown significant changes in the wind patterns in the atmosphere, and captured the observed high SSTs which also correspond to higher TCHP. The changes in the wind patterns are associated with the loop current and eddy currents masked by the oil slick in the region and the corresponding wind reversal is a manifestation of a high pressure system, like the one that would be formed in El Niño conditions. The high leads to limiting of evaporation and hence an increase of SSTs. The blocking high induced by anomalous changes in the weather patterns associated with the loop current and eddies, may also lead to a reduction in frequency and strength, and deviation of track of tropical storms, particularly major hurricanes that tend to pass towards the US Gulf coast region.

Acknowledgements/Contact information

•Center for University Scholars (JSU), for travel grant, and Dr. John Colonias, Chair, Technology Department, Jackson State University for his interest and encouragement in the work; NOAA for providing images and information; Mr. John Young, GIS, eCenter, JSU for the preparation of the presentation

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