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 310°C) 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 HRF 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.

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 0600 (06 am local)

Modeling simulations of wind and SST over Gulf of Mexico, as on June 01, 2010 at UTC 0012 (03 pm local)

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

Modeling simulations of wind and SST over Gulf of Mexico, as on June 01, 2010 at UTC 0912 (06 am local)

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

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 220 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 storms on June 1, 2010. We note that 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 of oil has been poured out into the Gulf due to the oil spill. The surface area of the oil spill spread over a vast area, 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. (Image: National Geographic News (2010), Published May 18, http://news.nationalgeographic.com/news/2010/05/100518-gulf-mexico-oil-spill-loop-current-science-environment)

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. Secondly, 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.

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°C – 3°C. June climatology of SST (270°C) is much higher than expected due to seasonal heating. The heat-potential chart shows a maximum of about 80 J/cm³ over 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-Easternly and weak westerly flow associated with sea breeze circulation and anti-cyclone 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 (2010) in the region. Normally, a cyclonic cold 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 (cold) 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 warming of SST and therefore 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 lead time 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.

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