SMS-303: Integrative marine sciences III.

Answers to assignment #2

Background: The deepwater Horizon was a deepwater, dynamically positioned, semi-submersible offshore oil drilling rig.

It exploded on April 20th 2010 while drilling in the Gulf of Mexico at a location 1,259 m deep. On April 22nd 2010, Deepwater Horizon sank, leaving the well gushing at the sea floor. A cap sealed the leak on July 15th and no oil is believed to have been gushing since.

The total amount of oil released into the ocean is estimated at 7×10^5 m^3 of oil (Crone and Tolstoy, 2010), or 5×10^6 barrels of oil (NOAA, 2010). Note that 1 m^3 = 6.3 barrels which suggest that these two estimate are within 30% of each other.

1. As far as is known, what was the fate of the oil to date (20pts)?

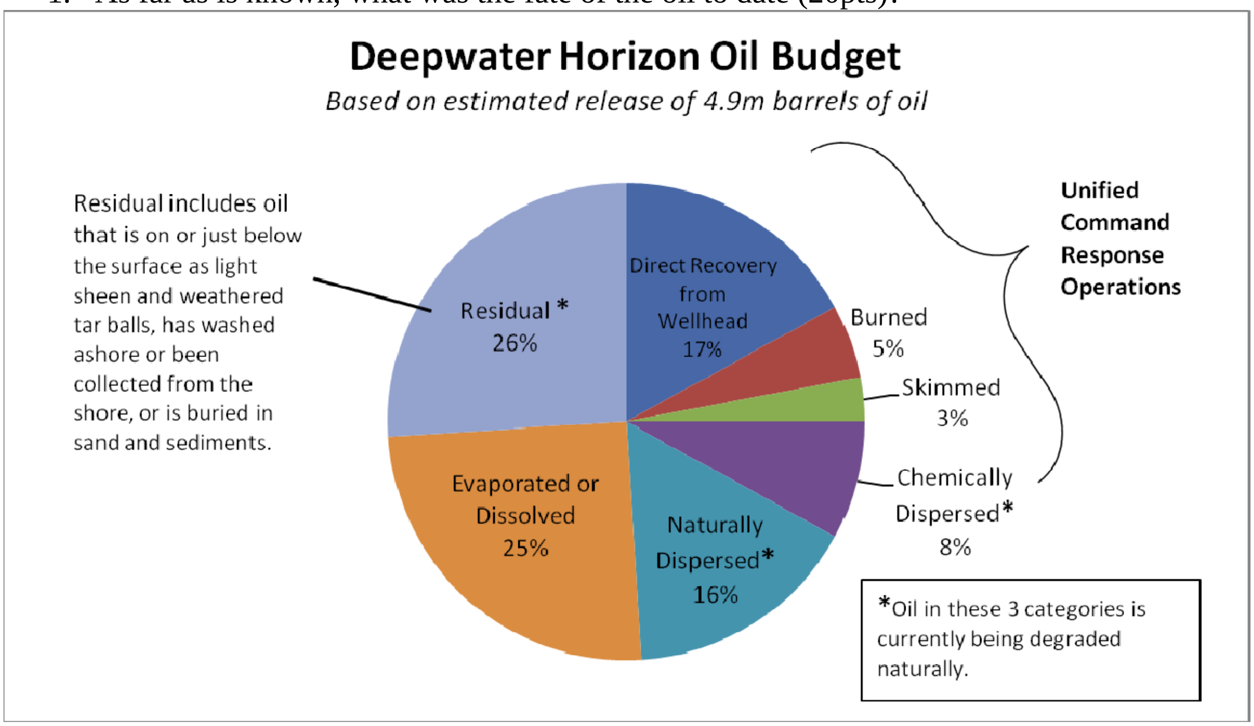

Figure 1. Fate of Deep Horizon Oil based on the inter-agency report (NOAA, 2010)

From a NOAA report released on august 4th: (text at: NOAA, 2010): " In summary, it is estimated that burning, skimming and direct recovery from the wellhead removed one quarter (25%) of the oil released from the wellhead. One quarter (25%) of the total oil naturally evaporated or dissolved, and just less than one quarter (24%) was dispersed (either naturally or as a result of operations) as microscopic droplets into Gulf waters. The residual amount — just over one quarter (26%) — is either on or just below the surface as light sheen and weathered tar balls, has washed ashore or been collected from the shore, or is buried in sand and sediments. Oil in the residual and dispersed categories is in the process of being degraded."

The oil that spilled from the Deepwater Horizon normally floats. Some of the oil washed on shore and has covered significant lengths of beach in the GOM. Traces of oil have been found along 640 miles of beaches from the Florida panhandle through Alabama, Mississippi and to Louisiana (see interactive map at: http://gomex.erma.noaa.gov/erma.html). However, some of the oil can get sticky and pick up particles, like sand, that eventually make it heavy and cause it to sink. This is less likely to happen in the open ocean, but can happen in near-shore areas, such as if the oil is near a shallow sand bar or washes onto the beach and is then washed back out to sea by waves (http://www.restorethegulf.gov/release/2010/10/02/subsurface-oil-monitoring-overview). About 26% of the oil released is in these categories (Fig. 1).

25% of the oil was recovered by skimmers or directly or burned (Fig. 1).

Another 25% evaporated or dissolved (Fig. 1).

The remainder 24% of the oil became subsurface oil, that which was dispersed with dispersant or naturally and remained in the water column in the form of tiny drops, is slowly being consumed by bacteria (as attested by reduction in oxygen levels within the plumes).

Degradation of oil also occurs by photo-oxidation, an inorganic process, where absorbed short wave radiation (UV and near-UV light oxidizes the oil molecule).

2. What mixing processes need to be taken into account for parts of the oil which propagated to different depths (25pts)?

Near the bottom, mixing due to shear in the bottom boundary layer is important. The shear is due to the currents flowing over a stagnant bottom (the no slip condition). Currents are driven by density gradients and tides.

In the water column mixing by shear instabilities and breaking internal waves will dominate with potential contributions from double diffusion and smaller from biological mixing.

Near the surface, wind mixing and breaking waves will dominate mixing, with entrainment of new water at the bottom of the surface mixed layer being important as well. Convective mixing (due to surface cooling) will be important at night, during winter and when dry air flowing over the Gulf causes enhanced evaporation (in these cases less heat is gained than lost at the surface).

3. What mixing processes are likely to dominate at the surface in different seasons (25pts)?

Convective mixing (due to surface cooling) will be important in the fall and winter when the atmosphere is cooler than the water (+added evaporative cooling from dry air coming from deserts) resulting in convective mixing to depth. During hurricane season (Aug->Dec) strong winds will drive wind mixing near the surface.

Seasonal modulation in river inputs (for example from the Mississippi) can increase mixing by entraining salty water in the estuaries (shear due to river flow) but can also decrease mixing by enhancing stratification near the surface.

4. How did the addition of a dispersant to the oil change how the oil propagated? Did it change the likely mixing mechanisms affecting the oil? (20pts)

Addition of dispersant to oil is designed to remove the oil from the surface. Addition of dispersant causes formation of tiny drops of oil and dispersant which break away from the surface and mix into the water column where microorganism can act on it. Tiny drops have much more surface to volume ratio compared to a large slick or blob accelerating mixing and chemical processes.

5. What is the difference between stirring and mixing (10pts)?

Stirring is reversible, mixing is not. Stirring accelerate mixing.

Crone T.J, Tolstoy M., 2010. Magnitude of the 2010 Gulf of Mexico Oil Leak. *Science*. DOI: 10.1126/science.1195840

NOAA, 2010, BP Deepwater Horizon Oil Budget: What Happened To the Oil? http://www.noaanews.noaa.gov/stories2010/PDFs/OilBudget_description_%2083final.pdf