The Influence of Cyclones on the BP Oil Spill

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Overview

The Deepwater Horizon explosion reopened debate on the role of synoptic weather features versus ocean currents in transporting the oil spill. Lagrangian models generally assume oil concentrations travel largely proportional (80-100%) to ocean currents' speed and direction, plus an additional 3% contribution from surface winds, diffused with each time step. However, cyclones are known to highly perturb water pollutants with positive and negative results. A mid-latitude cyclone expanded the Exxon Valdez oil spill over a large region, while in contrast Hurricane Henri (1979), in combination with a non-tropical low, cleansed the oil-polluted south Texas beaches (Gundlach et al. 1981).

We identified the late June to early July timeline as a period of interest since oil briefly impacted the Rigolets and western Mississippi coast, which represented the innermost penetration of oil pollution east of the Mississippi River. An important component to understanding the oil transport is to distinguish the influences behind this apex moment. An oil spill simulation was conducted for the period 20 June to 10 July 2010 to understand this inland transport. Scatterometer, HFR–derived currents, and buoy data as well as synoptic maps also facilitated this analysis.

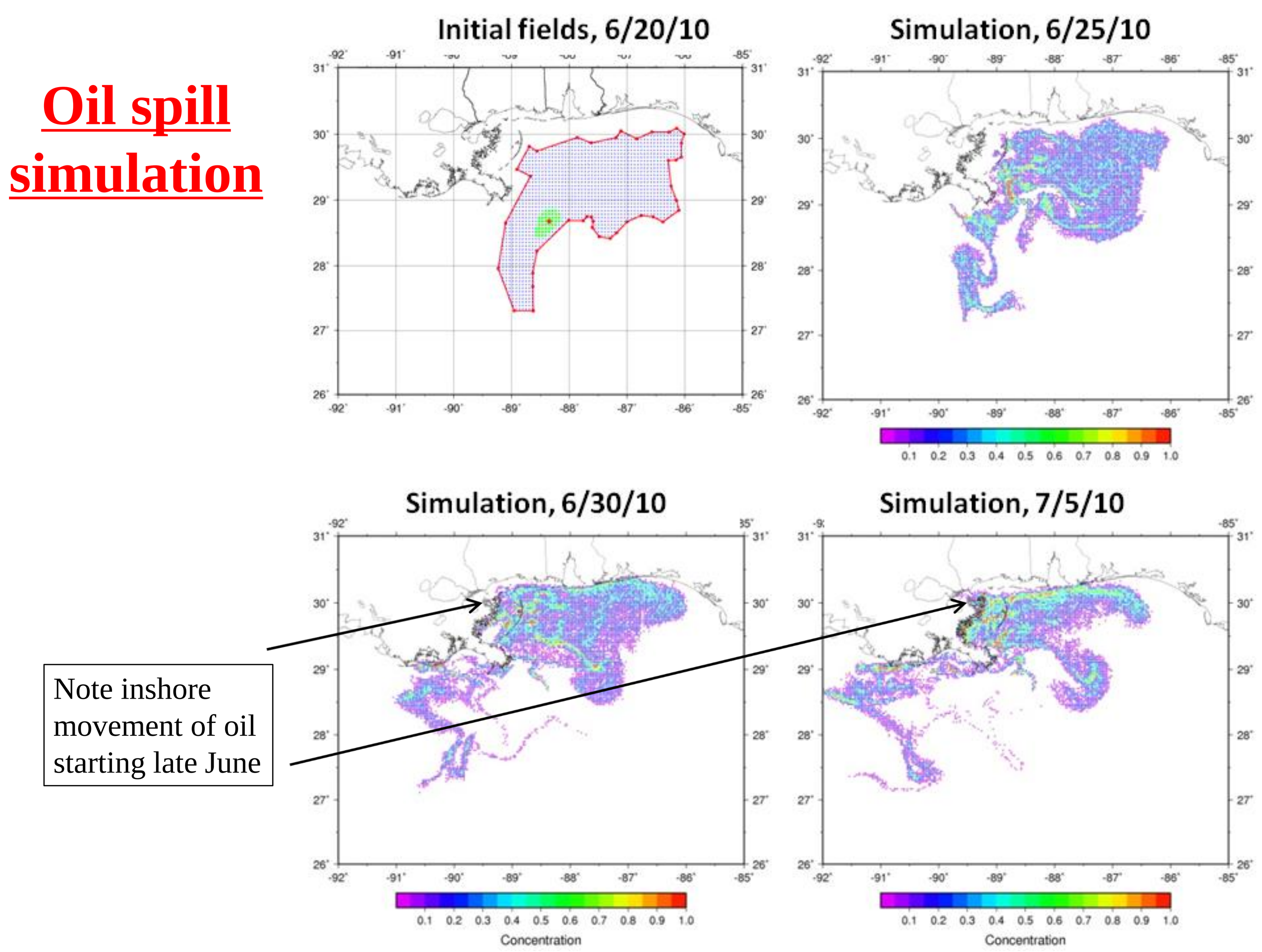
Model overview

We developed a Lagrangian particle tracker with random walk diffusion to simulate the oil spill from 20 June to 10 July 2010 (Hunter et al. 1993; Dimou and Adams 1993). Input consisted of latitude and longitude parcel positions in the oil-contaminated area, wind, current, and an array of pseudo-random numbers. In addition, new parcels were released at the location of the damaged Macondo rig at each timestep. Twenty-five parcels were released at each position, and when combined with a 10 $m^2 s^{-1}$ diffusion coefficient, resulted in a natural trajectory spread with time. Initialization was based on NASA MODIS satellite imagery, SAR imagery from http://www.cstars.miami.edu, NOAA's Office of Response and Restoration oil trajectory maps at http://response.restoration.noaa.gov, and the NOAA/NESDIS Satellite Analysis Branch (SAB) experimental surface oil analysis products at http://www.ssd.noaa.gov/PS/MPS/deepwater.html. The parcels were advected at 80% of the ocean current speed and at 3% of the wind speed. Bilinear interpolation was applied at each timestep to determine the currents and winds at each parcel position.

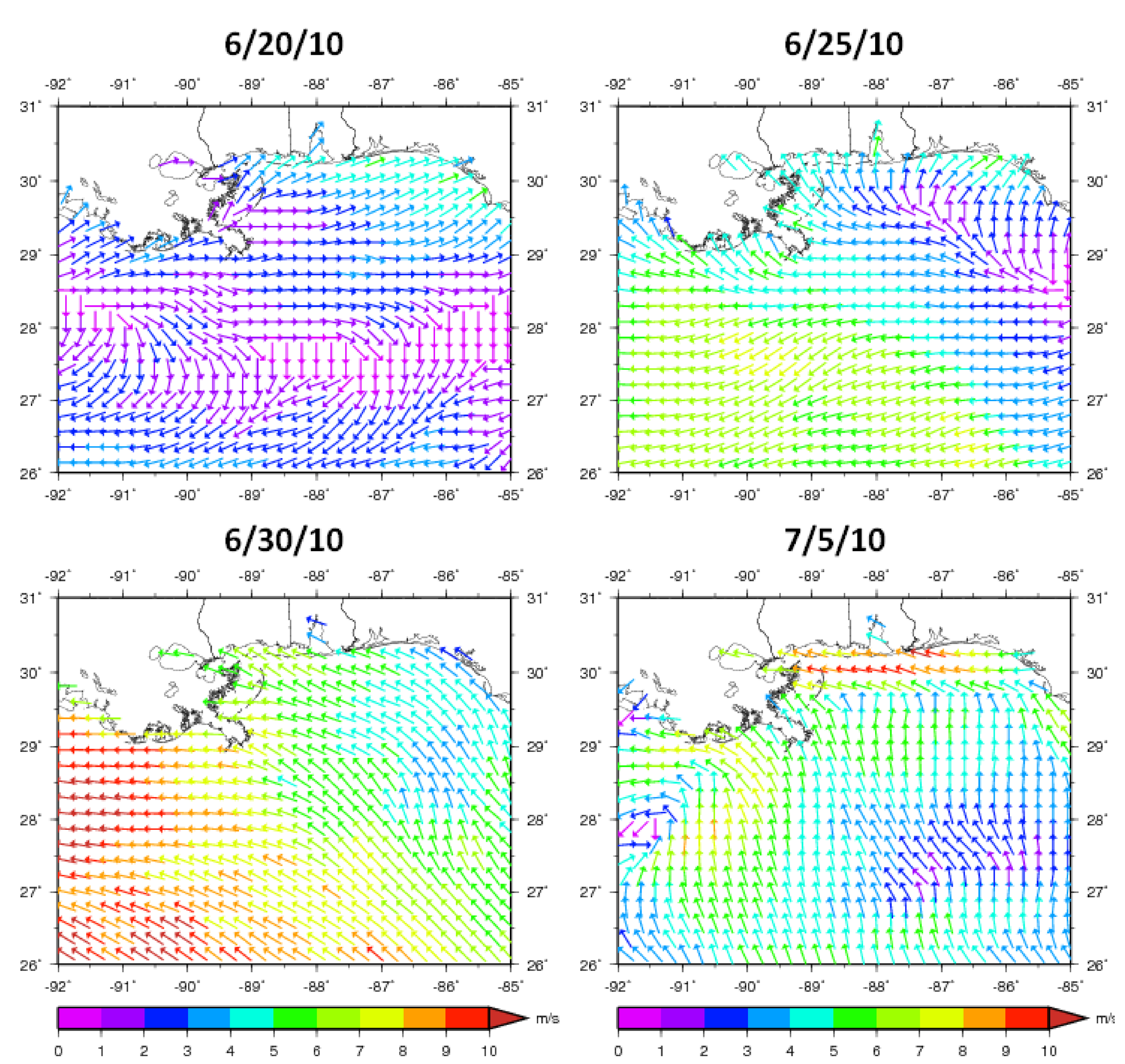
The pseudo-random numbers were uniformly distributed between 0 and 1 and generated by the efficient Mersenne Twister algorithm (Matsumoto and Kurita 1998). This modern technique has passed stringent "diehard" and NIS tests for randomness, and will generate an incredibly long sequence of numbers (2^{19937}-1) before repeating. The initial seed was randomly obtained from machine noise (/dev/urandom on Linux machines).

The 10-m wind and near-surface currents were provided from an operational, data assimilating forecast system run (Ko et al. 2003; 2008) by the Naval Oceanographic Office called the Navy Coastal Ocean Model (NCOM) in the Intra-Americas Sea (AMSEAS) domain, which covers the Gulf of Mexico and the Caribbean, and is interpolated to a 3-km Cartesian grid. The AMSEAS data includes tidal components and a dynamic water surface which fluctuates from wind forcing even capable of capturing storm surge events (Korobkin et al. 2010). The Coupled Ocean-Atmosphere Prediction System (COAMPS) provided the atmospheric forcing. The wind forcing (converted from wind stress) was validated against buoys using standard error metrics and vector correlation (Hanson et al. 1992; Crosby et al. 1993; Breaker et al. 1994). Little bias in wind speed and direction existed, with absolute errors of 1.4 ms^{-1} and 33 deg. These small errors are partially due to the mostly quiescent weather pattern and weak winds during this period. Ironically, vector correlations were low possibly due to natural directional fluctuations of weak winds; the use of vector correlations in weak pressure gradients requires further study.

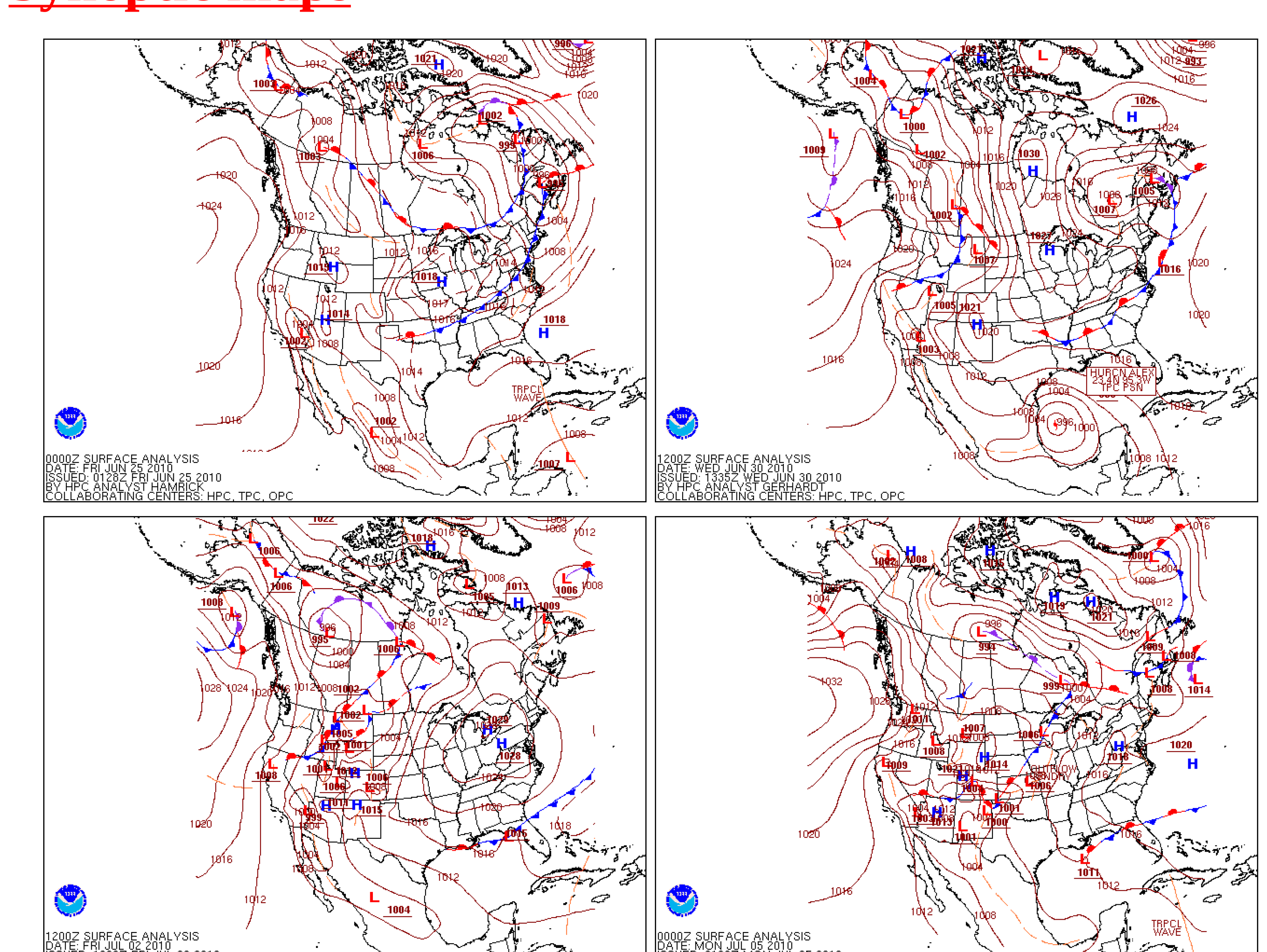
Oil spill simulation



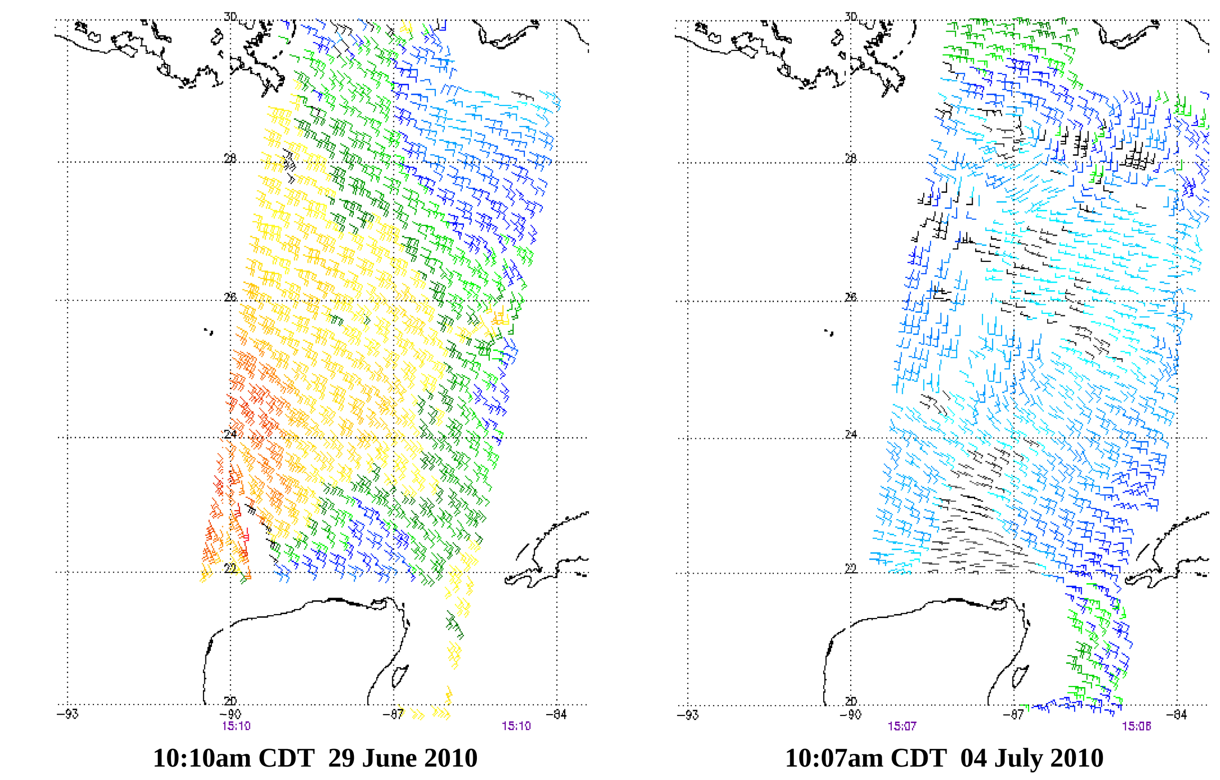
COAMPS winds



Synoptic maps

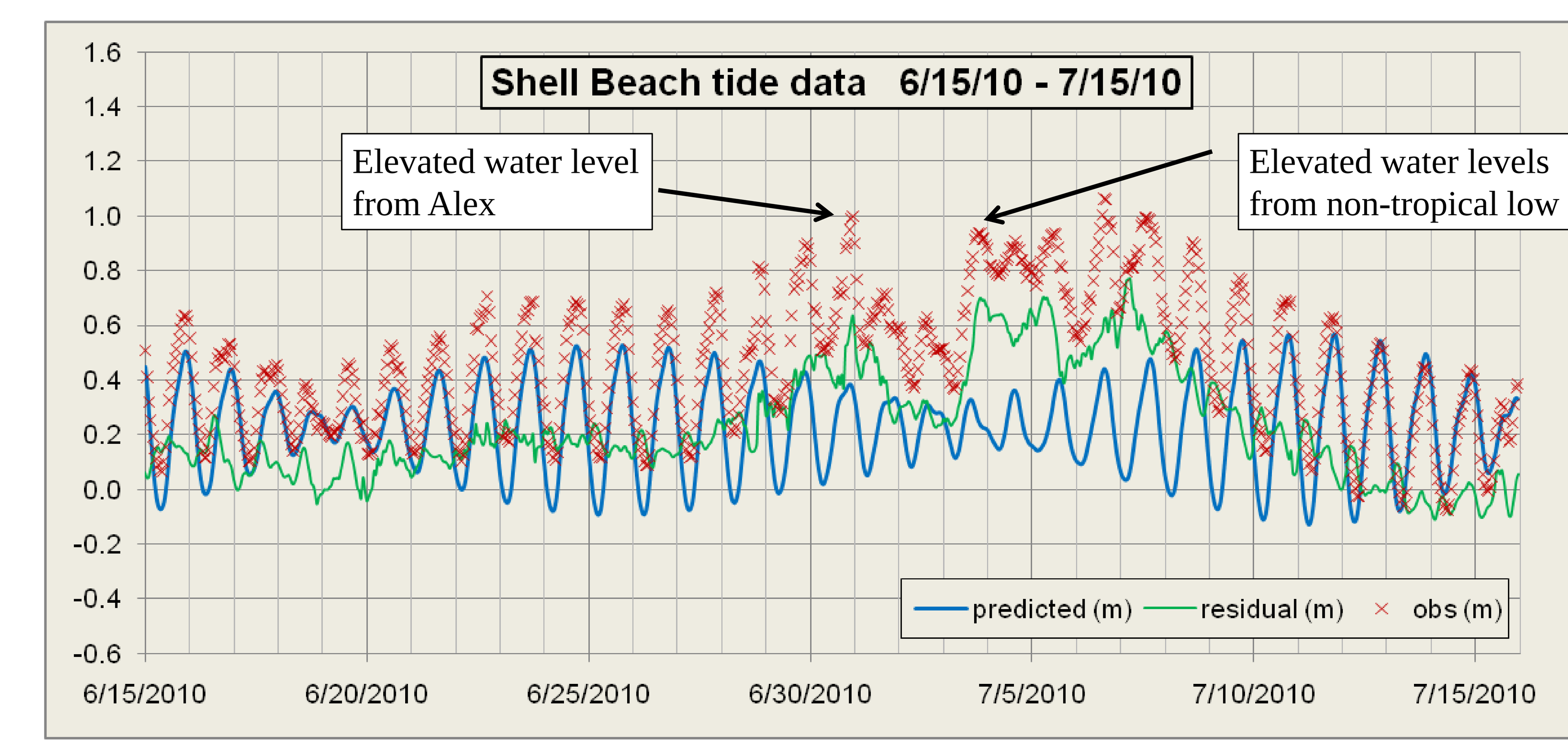


ASCAT plots showing fringe effects of Hurricane Alex and the non-tropical low



Imagery provided by NOAA/NESDIS/STAR

Time series of water levels at Shell Beach, LA



Data provided by NOAA/NOS/CO-OPS

Conclusion

An examination of the oil spill simulation, NCOM data, and in-situ observations show that two weather systems altered the currents and water levels such that oil was pushed into the western Mississippi Sound and the Rigolets. An easterly wind fetch from intensifying Hurricane Alex provided the first inland push, followed by a westward-drifting non-tropical low which had formed off the western edge of a Gulf cold front. In both cases, a weak pressure gradient was replaced by strong easterly winds which not only switched alongshore westerly coastal currents (not shown) to an easterly direction, but also increased inland water levels by 0.6-0.8 m as mini-surge events. These results show that cyclones can dramatically alter oil transport, even by fringe effects.

The study also showed that this modeling formulation was capable of reproducing the oil spill transport. Much of the ocean current (not shown) south of the Mississippi River delta was directed to the west, with oil impacting the Barataria Bay and Terrebonne Bay systems. To the east of the river system, the current moved towards Breton Sound, Alabama, and west Florida, and the oil propagated in a similar fashion. For the most part, only these cyclonic events altered this pattern, which pushed the oil into the western Mississippi Sound and its marshes. More analysis and a simulation of the entire event is being performed in follow-up BP research.