Projecting Oil Dispersion in the Gulf of Mexico, Straits of Florida, and Caribbean Sea Using Climatological Data from Drifting Buoys and Surface Winds

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Master of Professional Science
Weather, Climate, and Society

(Photo Source: Chinanews.com)

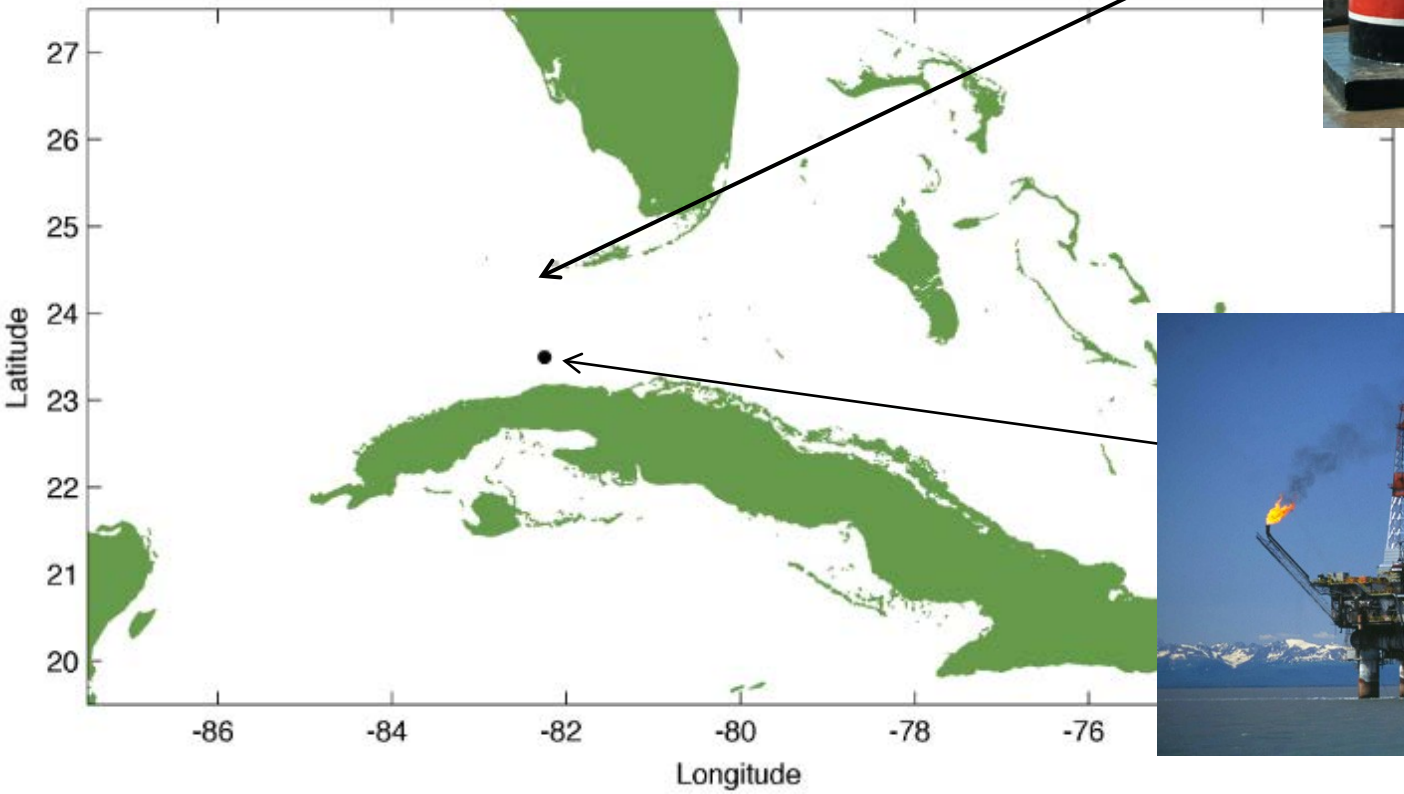
Outline:

- Inspiration
- Background
- Methods
- Results
- Recommendations

Inspiration

- Cuban Oil Exploration Near Florida Keys
  - 90 Miles Coast to Coast
    - ~65 Miles Coast to Exploration Site

Initial Area of Interest



(www.greenpeace.org)

Inspiration ⟷ Relative/Related Drifter Studies

Simulated Distribution of Marine Debris

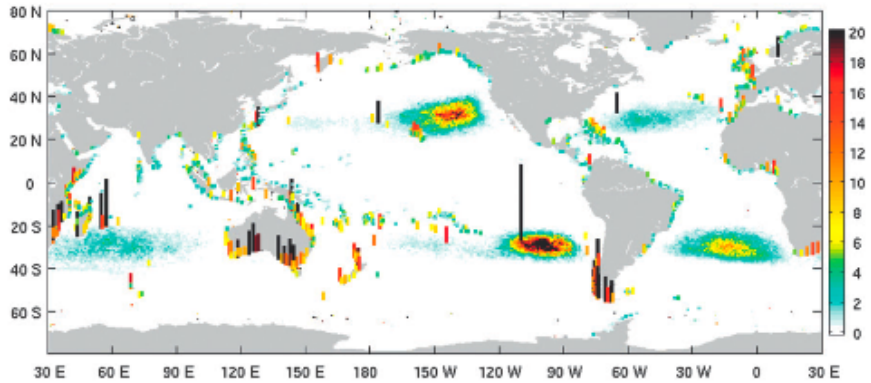
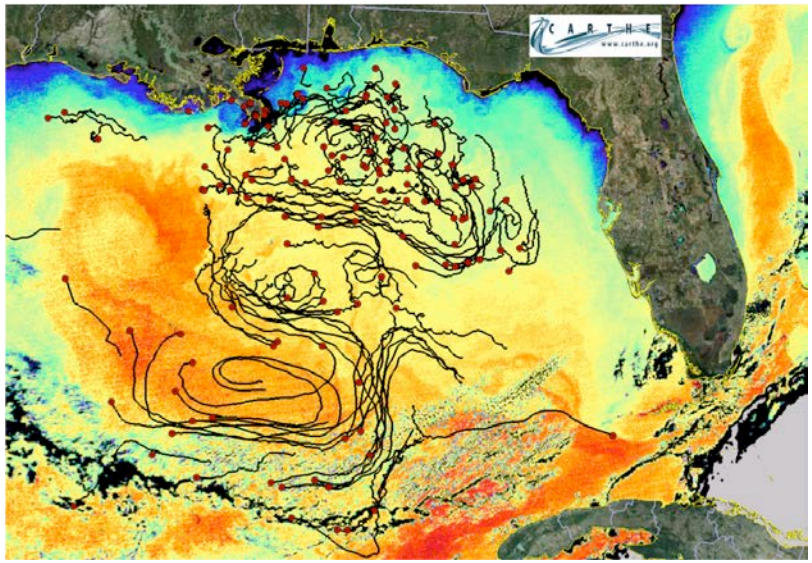


FIG. 9. Distribution of the concentration of floating marine debris in arbitrary units, after 10 years of integration from an initially homogeneous distribution of concentration unity. Vertical bars indicate the concentration of material that has washed ashore, with color corresponding to 10 times the value in the color bar.

Fig. 9 of Lumpkin, Maximenko, & Pazos (2012)

- NOAA's Marine Debris Tracking Web Site
  http://marinedebris.noaa.gov/
  - Mobile Applicaiton
    http://www.noaa.gov/features/o2_monitoring/marinedebris.html

Grand LAgrangian Deployment (GLAD)

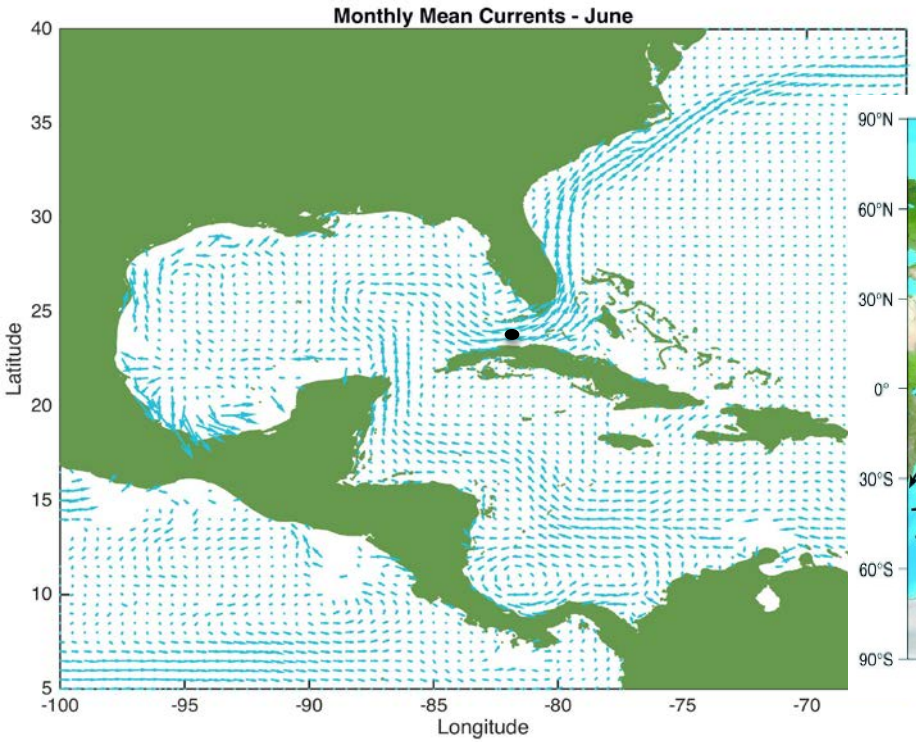


http://carthe.org/glad/

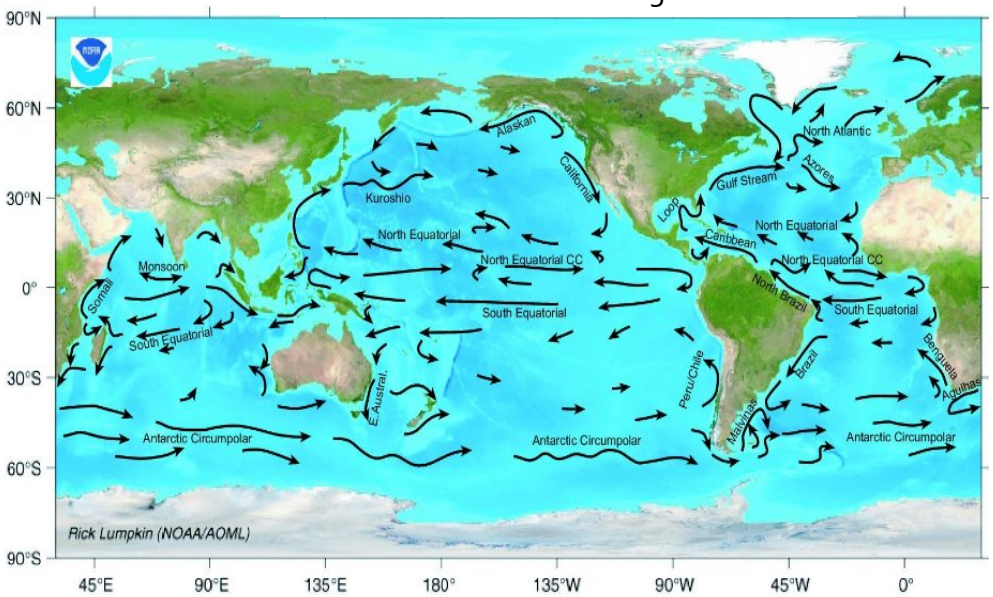
- Largest-sale experiment of its kind in the Gulf of Mexico.
  - More than 300 drifters deployed
- Numerous Outreach Activities!!
  - http://carthe.org/outreach/

Background

Cuban Oil Exploration with Mean Ocean Currents



Surface Ocean Current Diagram



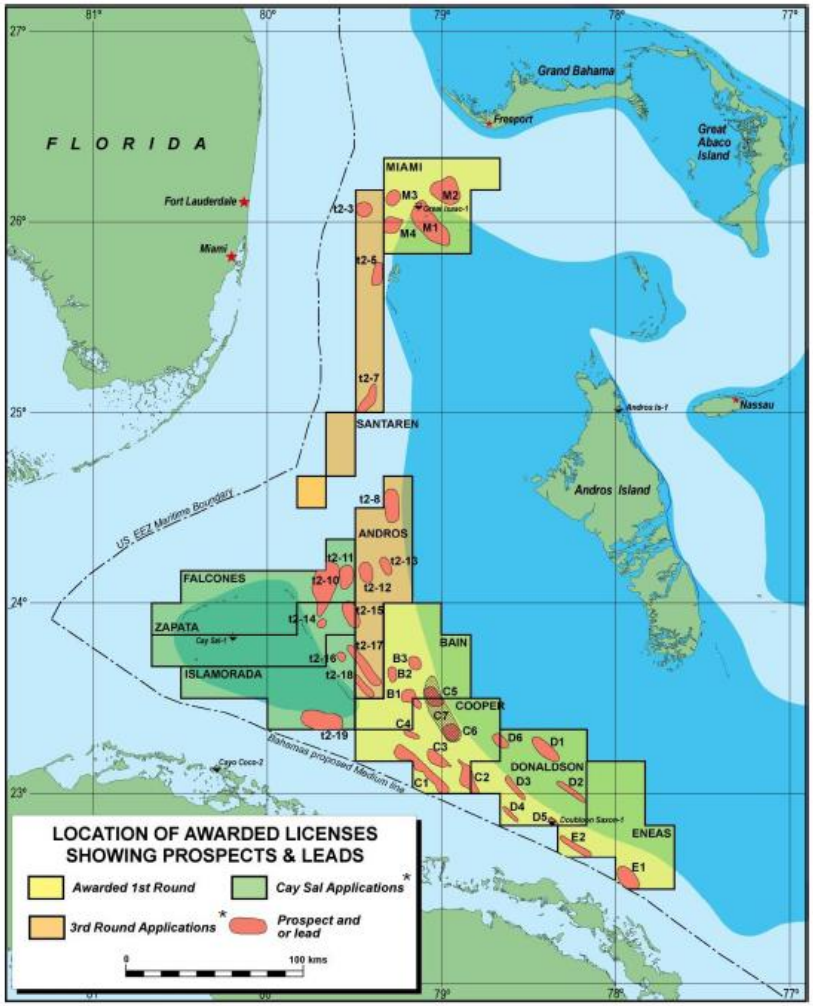
Lumpkin, R.

- Obtain/Ingest the Near-Surface Ocean Current Climatological Dataset Developed by Lumpkin & Johnson (2013)
  - One-Half Degree Resolution
    - Dataset downloaded from http://www.aoml.noaa.gov/phod/dac/dac_meanvel.php

Background

Regional Oil Exploration

- **Potentially Harmful Exploration Sites**
  - **Bahamas**
  - Belize
  - Cuba
  - Jamaica
  - Nicaragua
  - United States
    - Western Gulf of Mexico
    - Central Gulf of Mexico



http://www.energy-pedia.com/

Background

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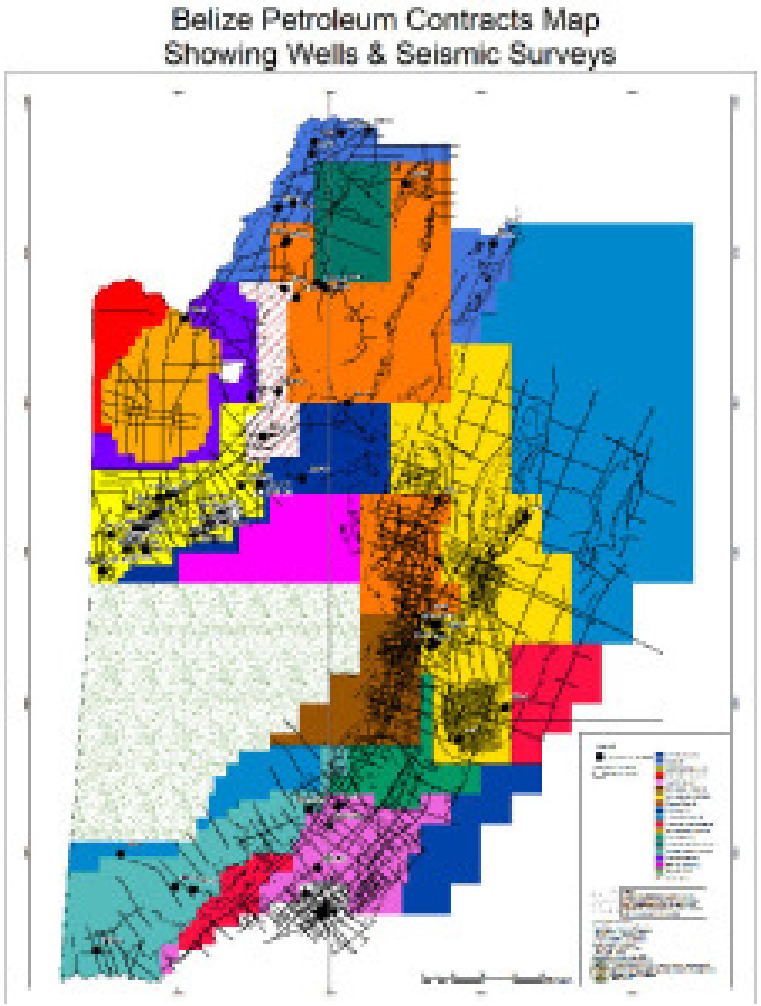

www.elawspotlight.wordpress.com/tag/belize/

Background

Regional Oil Exploration

- **Potentially Harmful Exploration Sites**
  - Bahamas
  - Belize
  - **Cuba**
  - Jamaica
  - Nicaragua
  - United States
    - Western Gulf of Mexico
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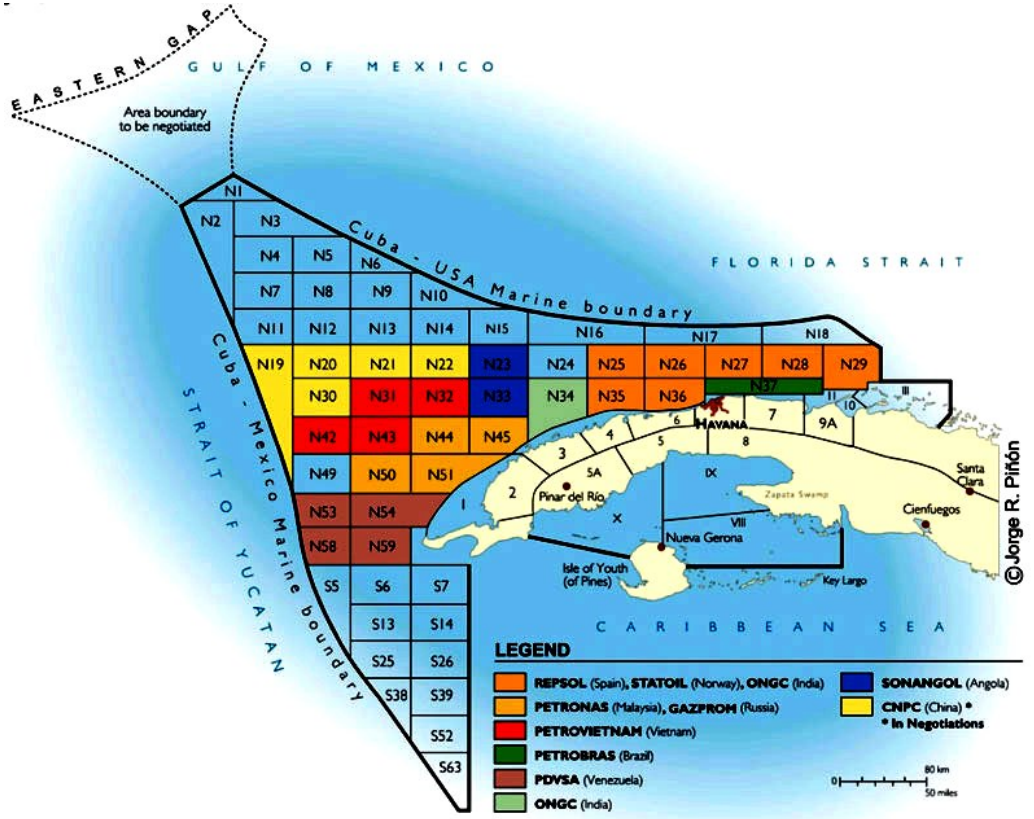

http://thecubaneconomy.com/

Background

Regional Oil Exploration

- **Potentially Harmful Exploration Sites**
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  - Cuba
  - **Jamaica**
  - Nicaragua
  - United States
    - Western Gulf of Mexico
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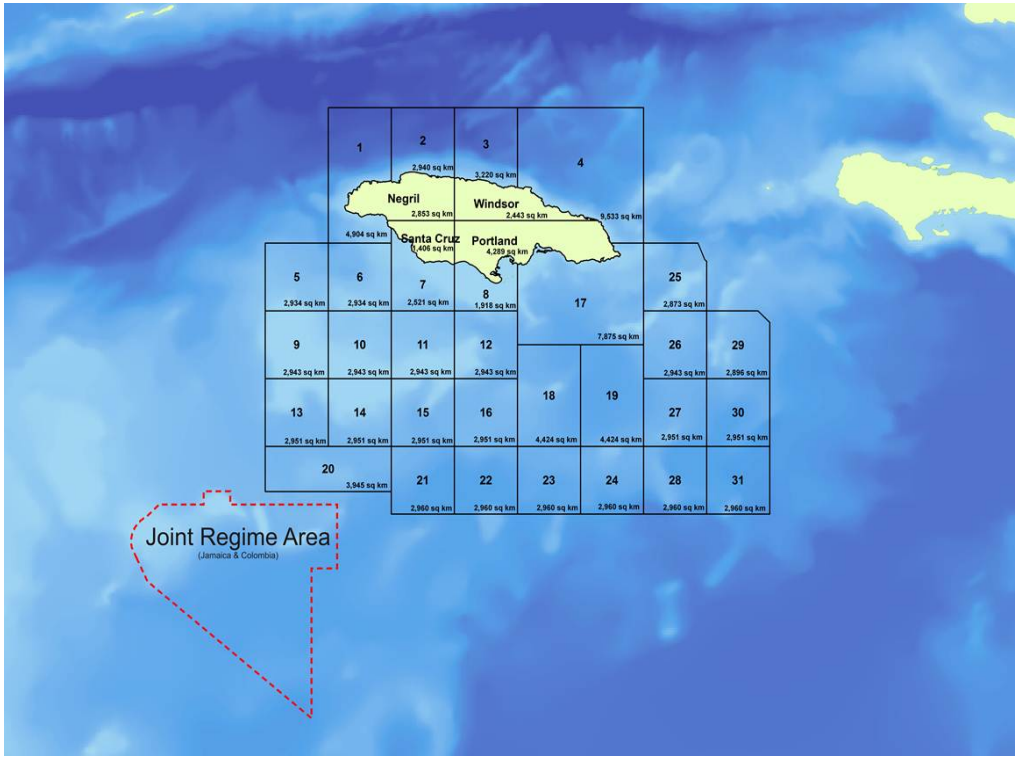

http://www.pcj.com/

Background

Regional Oil Exploration

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  - Belize
  - Cuba
  - Jamaica
  - **Nicaragua**
  - United States
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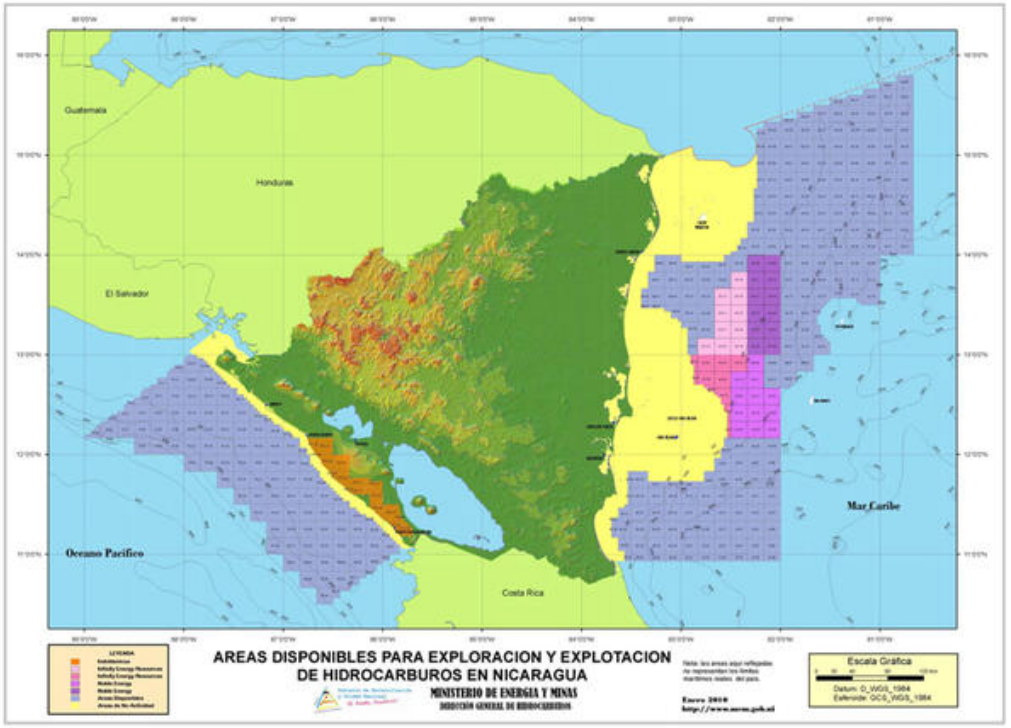

http://www.ticotimes.net/

Background

Regional Oil Exploration

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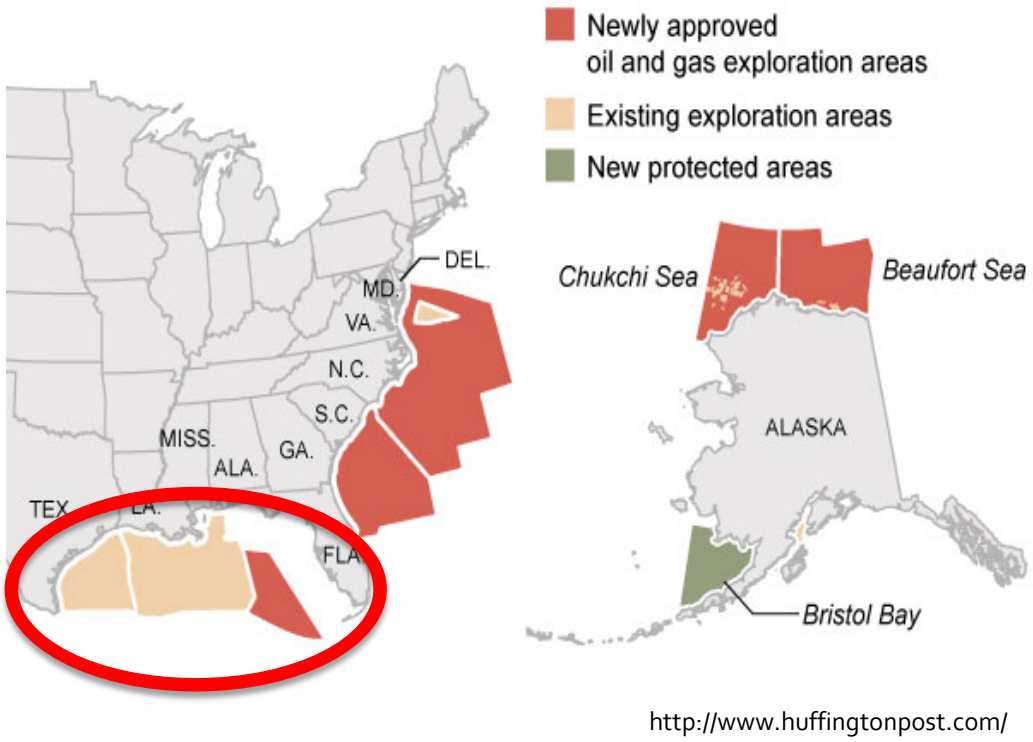
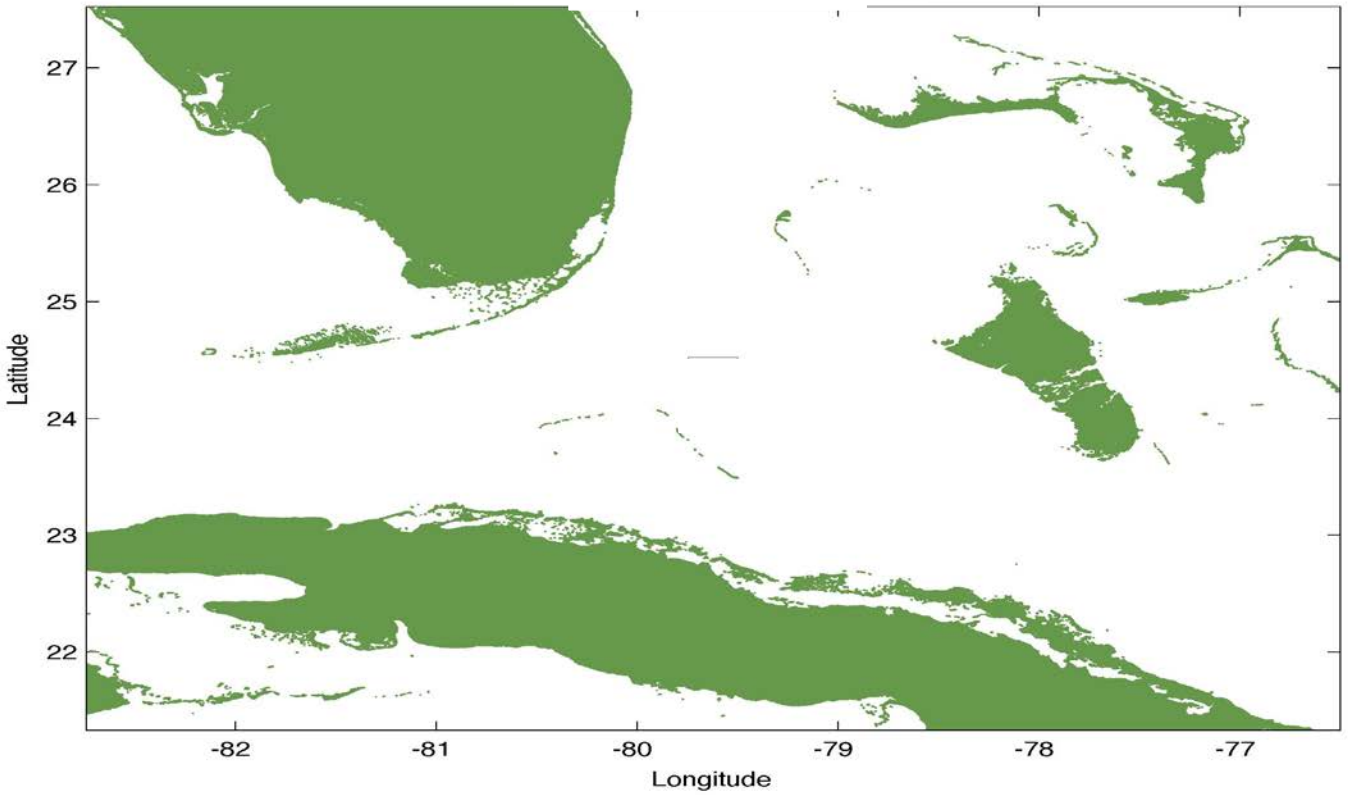


http://www.huffingtonpost.com/

Background

- Utilize High Resolution Bathymetry Data for Accurate Coastal Topography
  - Global Seafloor Topography from Satellite Altimetry and Ship Depth Soundings (Smith & Sandwell, 1997)

High Resolution Bathymetry



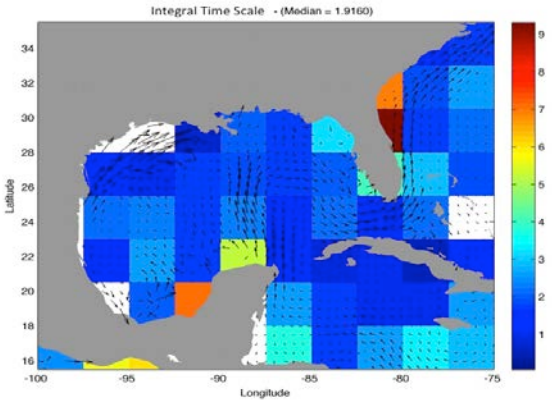
Methods

Create a First Order Lagrangian Stochastic Model (LSM)

- Incorporate Near-Surface Ocean Currents from Drifter Data
  (Lumpkin & Johnson, 2013)

  - Zeroth-Order LSM vs. First Order LSM
    - Zeroth-order LSM – Eddy component evolves as Markov Process
    - First order LSM – Eddy component retains some memory
      - Critical for a realistic model!

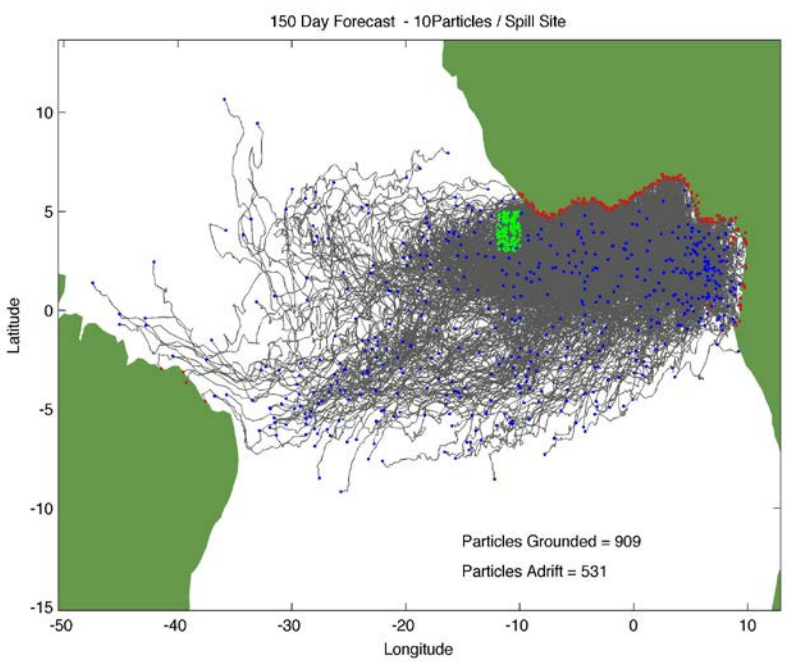
$$u'(i) = u'(i-1) + \Delta t * [- (u'(i-1) / T_L) + (\sqrt{2\sigma^2} / \sqrt{(T_L * \Delta t)}) * \Delta w]$$

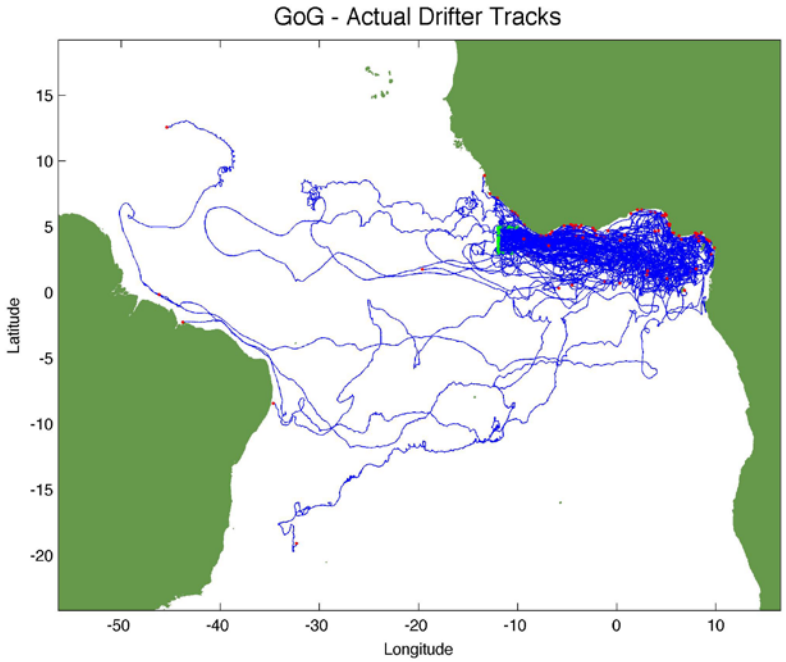


- Regional Integral Time Scale
  - Parsed and averaged from Lumpkin & Johnson (2013) Dataset
    - T_L = 1.9 Days

Methods

Ocean Current Model Validation (i.e. Without Wind Implementation)





- Identify Probability of Grounded/Picked Up Drifters

  Evaluating Where and Why Drifters Die

  (Lumpkin, Maximenko, & Pazos, 2012)

  http://www.aoml.noaa.gov/phod/dac/drifter_deaths.html

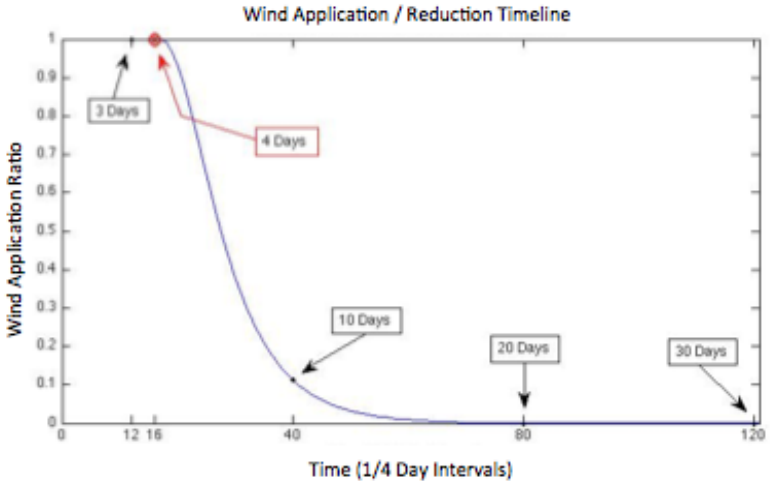
- 61% Ran Aground
- 68% Ran Aground

Methods

Wind Implementation

- Implement NCEP Regional (Mean) Wind Data
  - Downloaded from http://www.cdc.noaa.gov/cdc/data.ncep.reanalysis.html/#surface
    - Wind is the primary driver in horizontal diffusion from day 0 to 4

if T >= 4 days .... Wind = secant (- (T – 4 days) / 2 days)



$$loni(i) = lon(i-1) + \Delta t * (Uw(i) * Wind * R + u'(i)$$

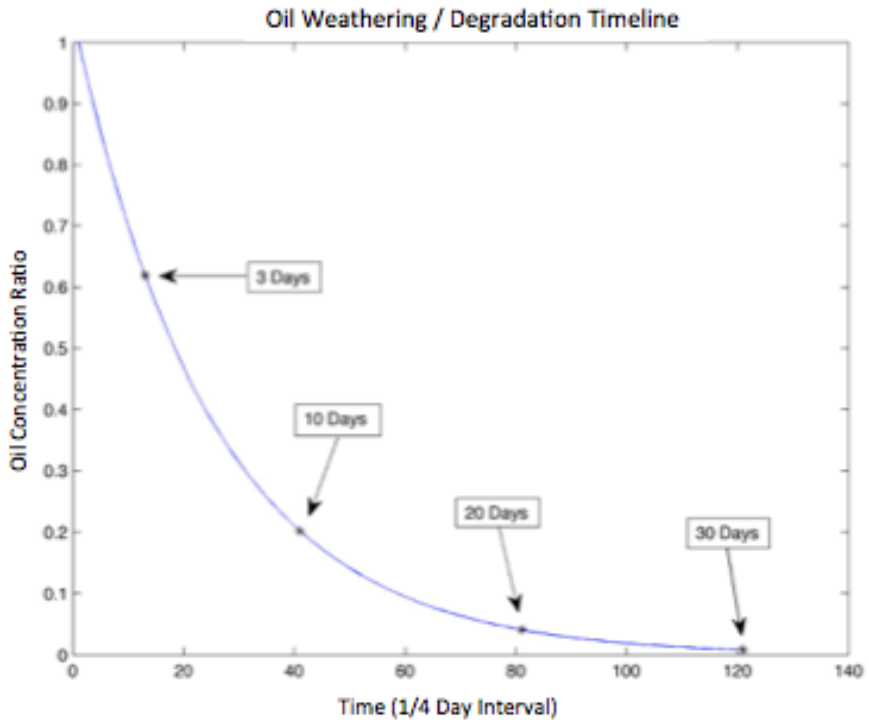
- Application of 01-06% wind rule, R, more accurately resembles an oil slick
  [Smith (1974); Stolzenbach, et al (1977); Huang (1983); and Lehr and Simecek-Beatty (2000)]

Methods

Oil Weathering / Degradation Implementation

- ~45% of the total oil mass will evaporate within 5 days (Aghajanloo and Pirooz, 2011)

$$weathering = e^{(-(TT/6.26\ days))}$$

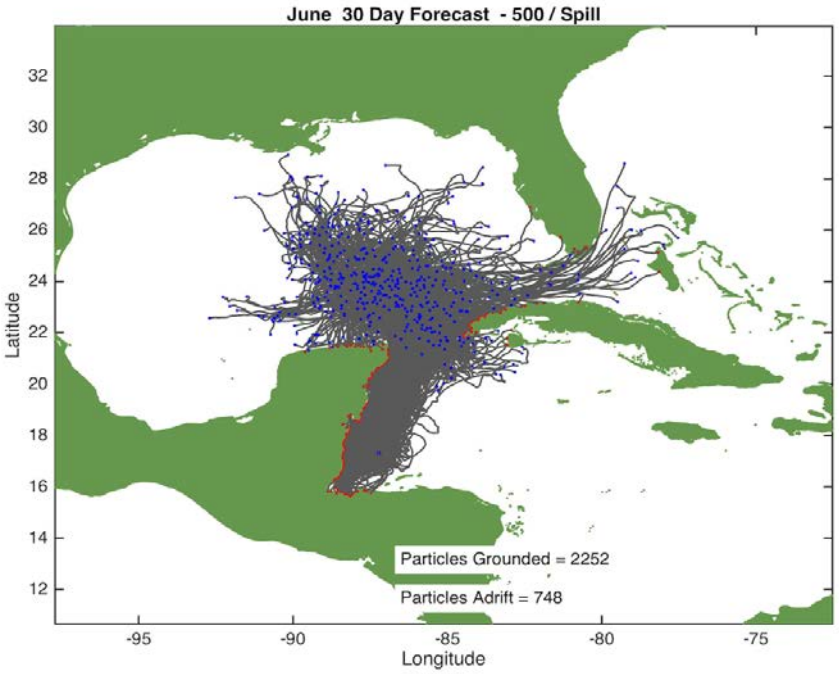


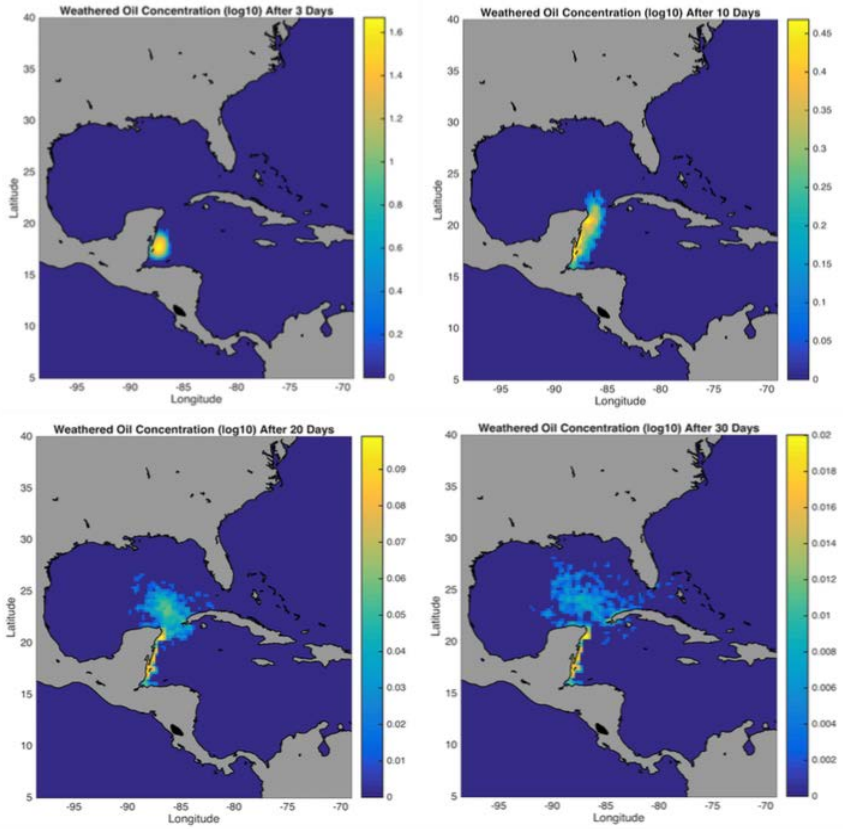
Methods

Oil Concentration

- Oil concentrations at 3,10,20,and 30 day intervals accurately depict spill impacts (Price et al., 2003)

Oil Concentration = (spillconc(lon,lat,i)) * weathering(k (i)))

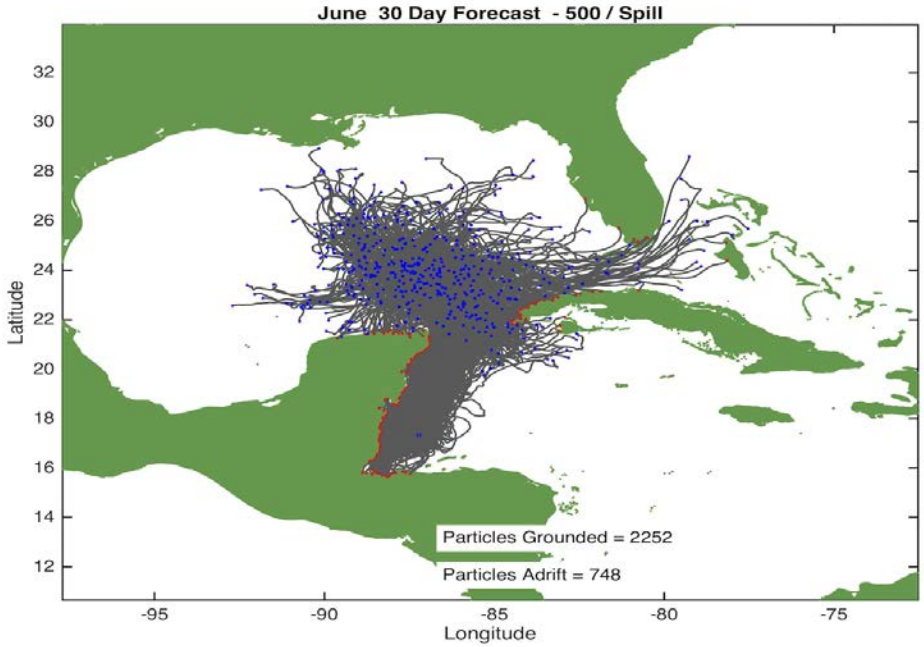




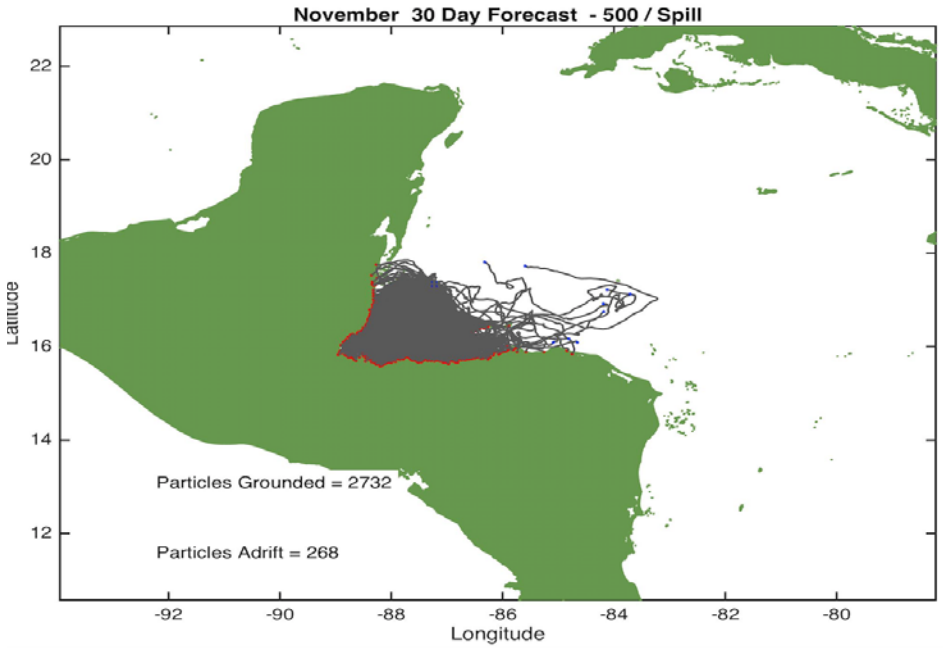
Results

- Annual Mean Ocean Data vs. Monthly Mean Ocean Data?
  - Identified significant monthly variations
    - Generated spills from each spill site during each month of the year.

Belize Simulation - June



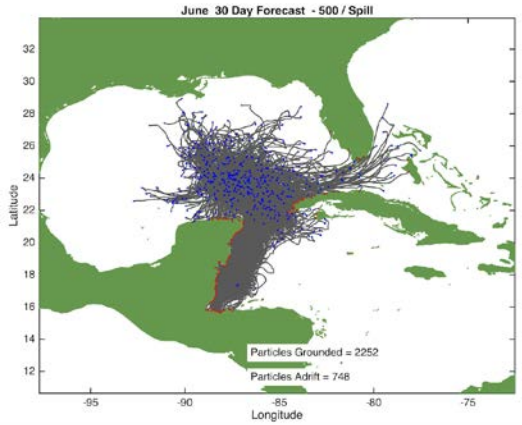
Belize Simulation - November



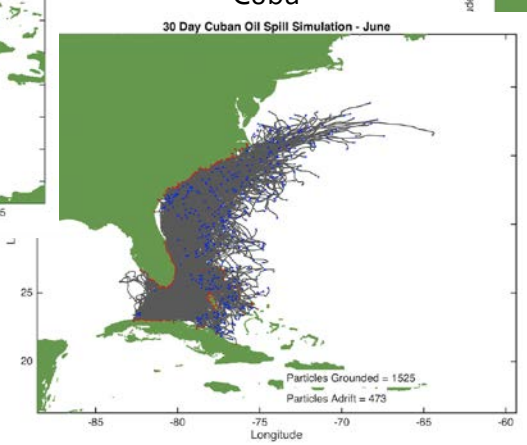
Results

- Simulate spills from each spill site during each month of the year
  - Confirmed Impact to U.S. resources from simulated spills from the following countries:
    - Belize
    - Cuba
    - Bahamas (all sites)
    - United States (both sites)

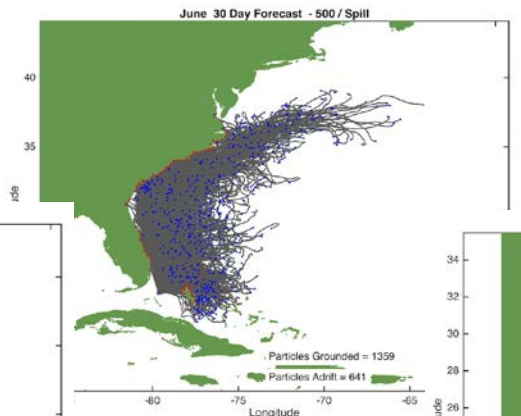
Belize



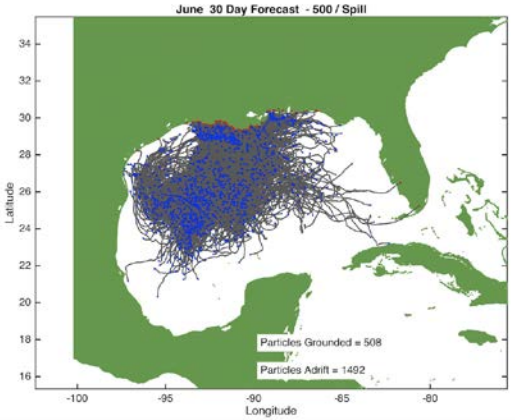
Cuba



Bahamas



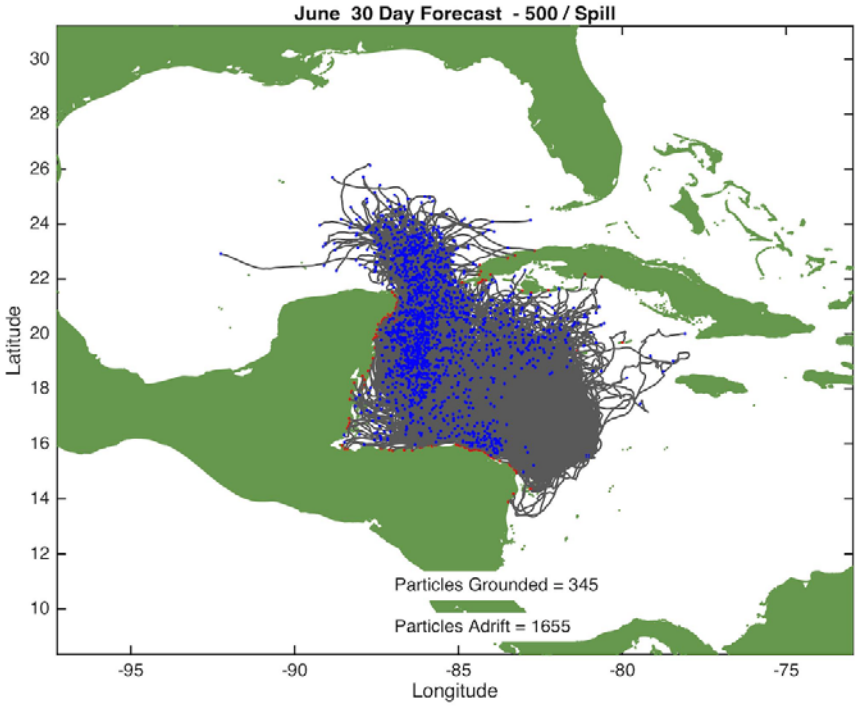
U.S.



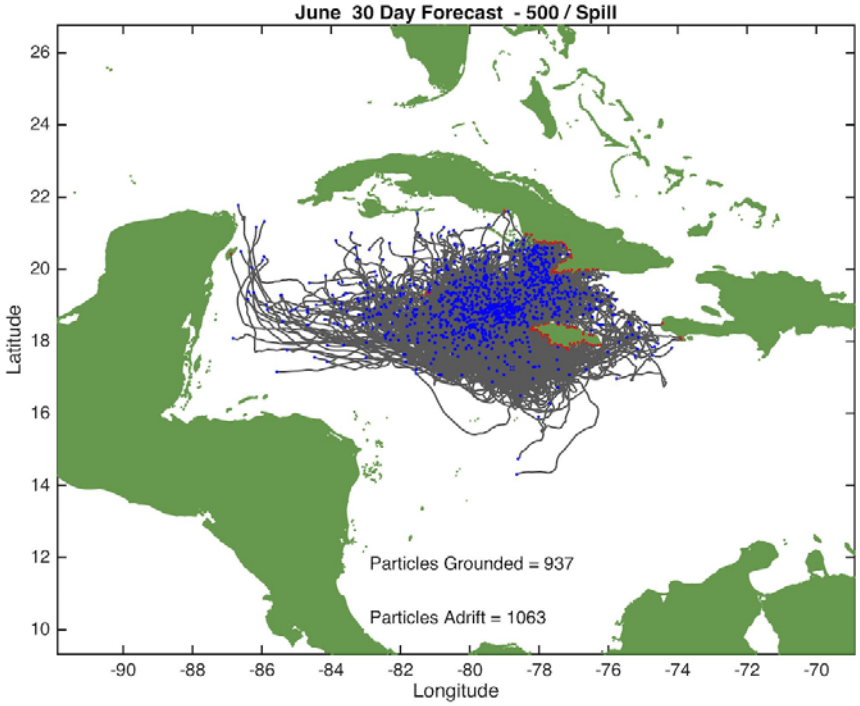
Results

- Simulate spills from each spill site during each month of the year

- Potential impact to U.S. resources from simulated spills from Nicaragua

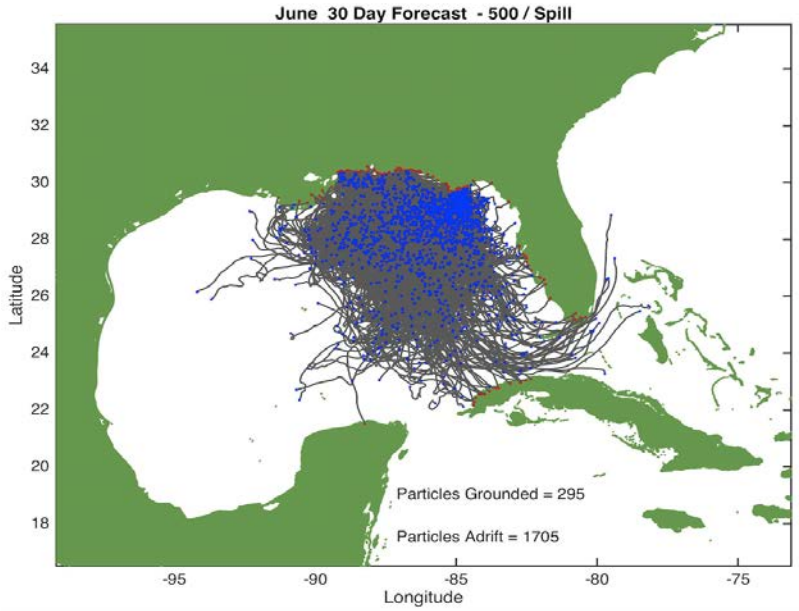


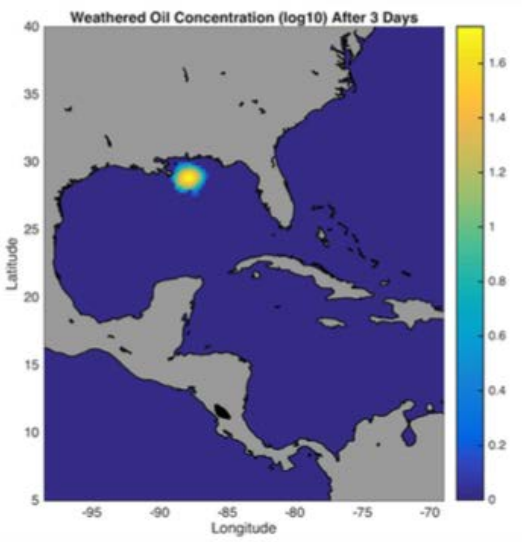
- Unlikely impact to U.S. resources from simulated spills from Jamaican

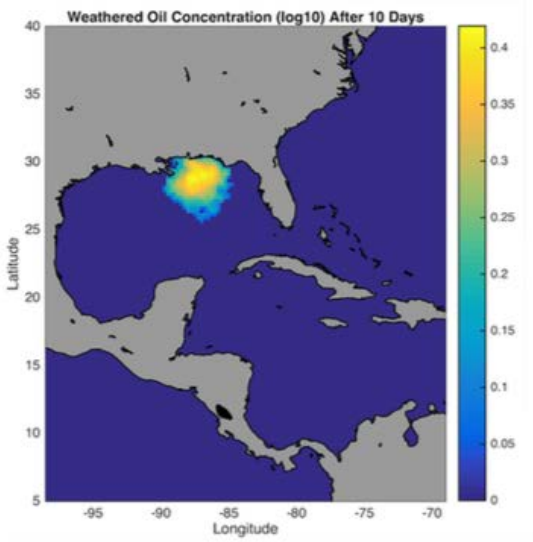


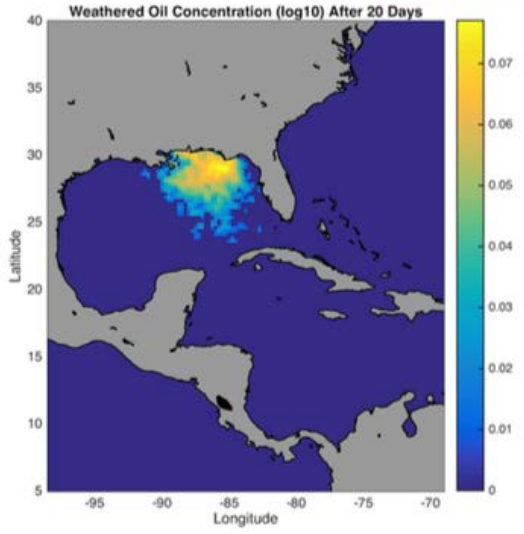
Results

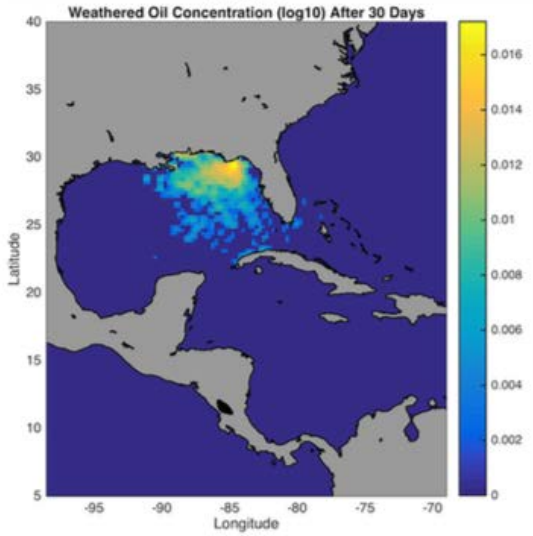
Simulated Spill – Deepwater Horizon Site





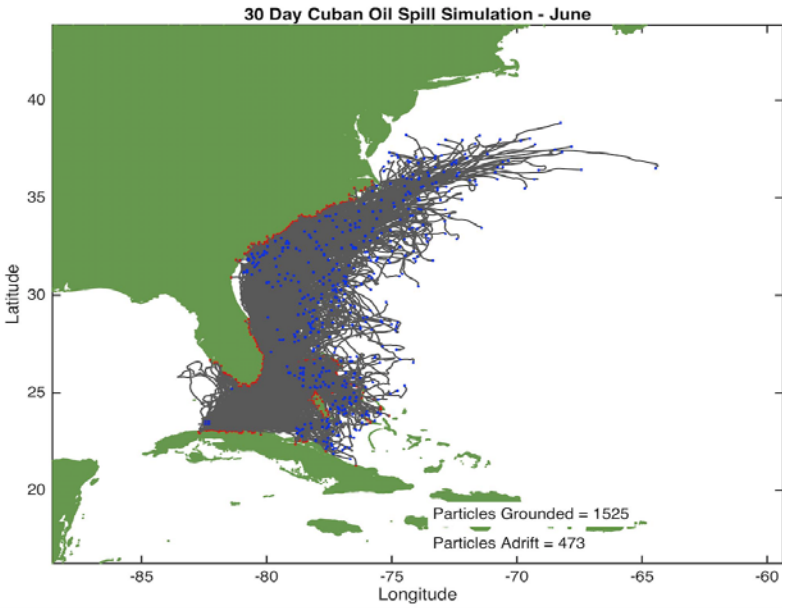


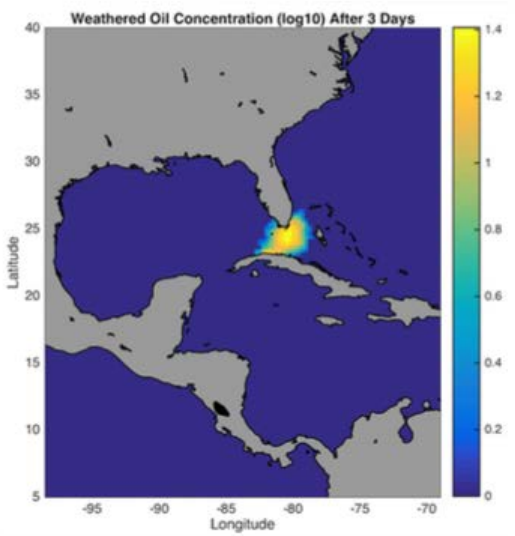


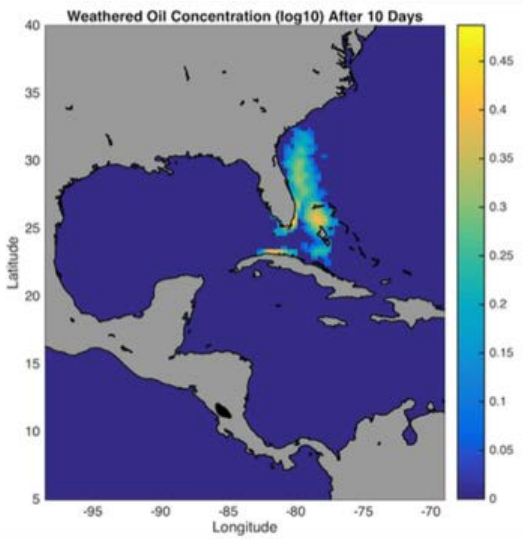


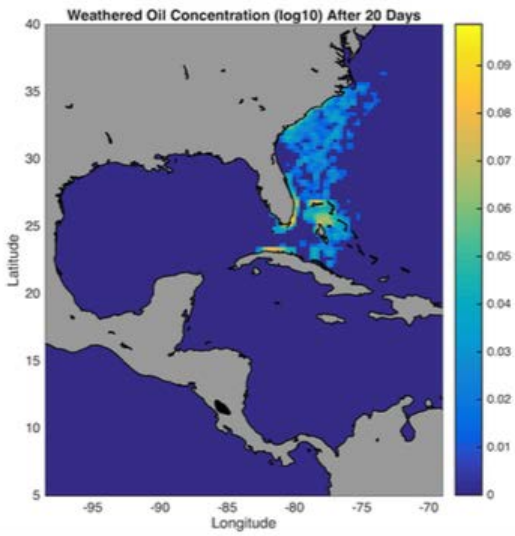
Results

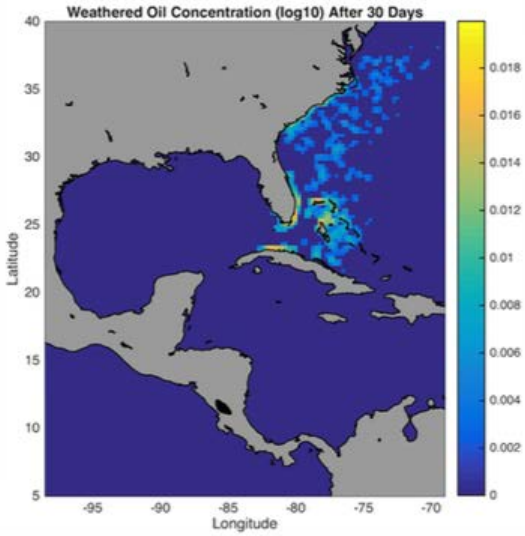
Simulated Spill – Cuban Exploration Site











Results

- Utilizing climatological data is a statistical advantage, as it provides historical perspective in the region.

- Negative effects from the Cuban site are immediately recognized.
  - A spill at the primary Cuban exploration site would reach U.S. resources, and make landfall, within a matter of hours/days.

- Current oil dispersion models need up-to-date data to determine potential impacts

- Predetermined projections can be used to:
  - Increase awareness
  - Adjust seasonal staffing requirements
  - Ensure oil cleaning materials are available

- These benefits could impact mitigation efforts and reduce the magnitude of a spill on local industry.

Methods

Outreach

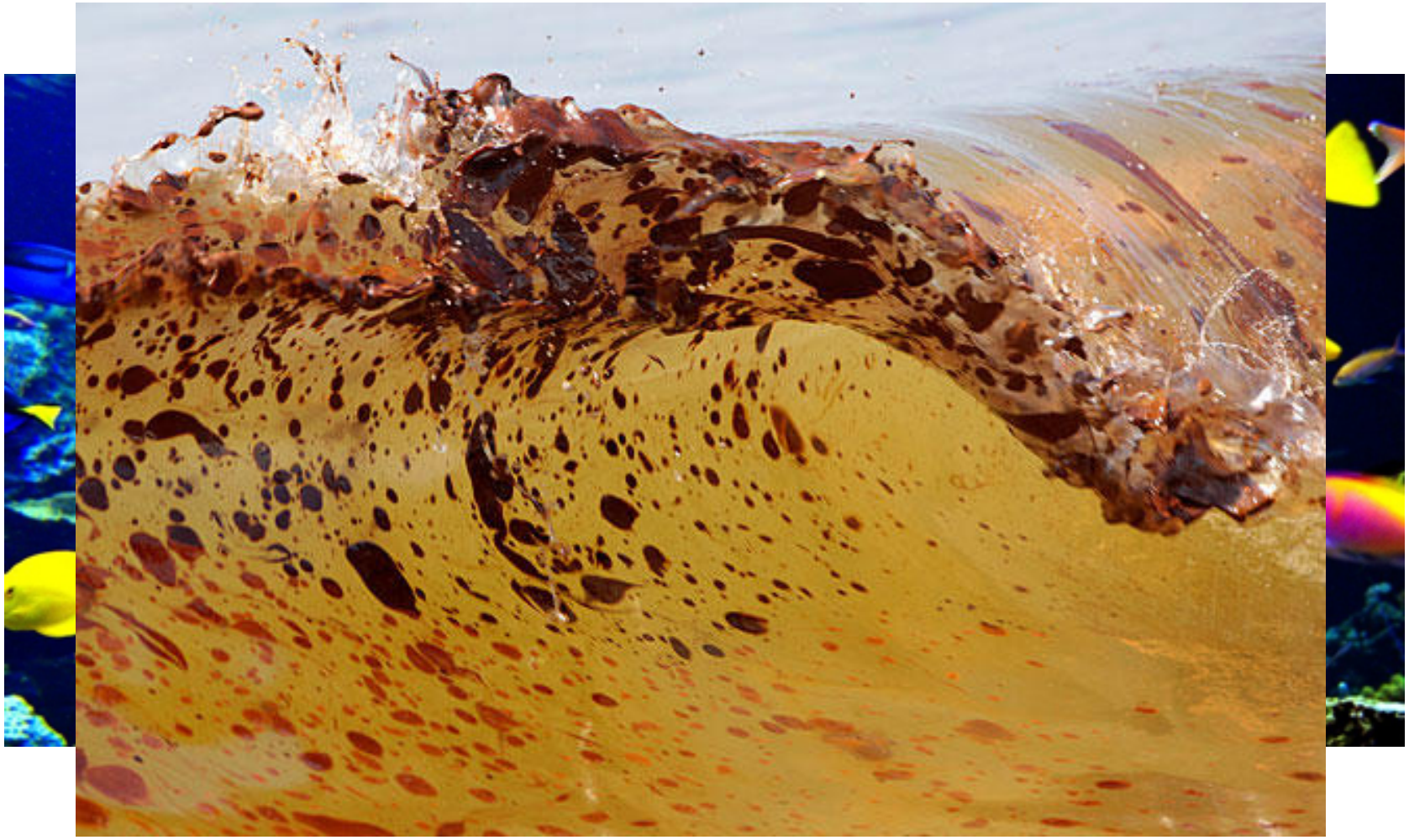
- Critical component of this project is community outreach and public awareness.
  - Work with the National Oceanic and Atmospheric Administration's (NOAA) Adopt a Drifter Program (ADP) to illustrate the use of drifter data to analyze this critical issue.
    - NOAA's ADP is dedicated to establishing scientific partnerships between schools around the world and to engage students (grades K-12) in activities and communication about ocean climate science.
  - Work with the Consortium for Advanced Research on the Transport of Hydrocarbons in the Environment (CARTHE) to highlight results and investigate regional activities further.

Recommendations / Future Work

- **Further work needed to:**
  - Incorporate vessel transit lines to/from ports within the Gulf of Mexico and Caribbean Sea
  - Run/store simulations throughout the area of interest, during each month.
    - Simulation results will be readily available.
    - Dissemination is more valuable.
  - Obtain additional public outreach partnerships to highlight the strengths of this model and encourage oil monitoring during times of statistically significant oil contamination occurrences.
    - U.S. Coast Guard
    - Coastal Planners
    - Fishery Fleets

- **Possible Improvements to the current model:**
  - Investigate the use of historical sea surface salinity and sea surface temperature measurements to improve oil weathering accuracy.

Thank You



Inspiration

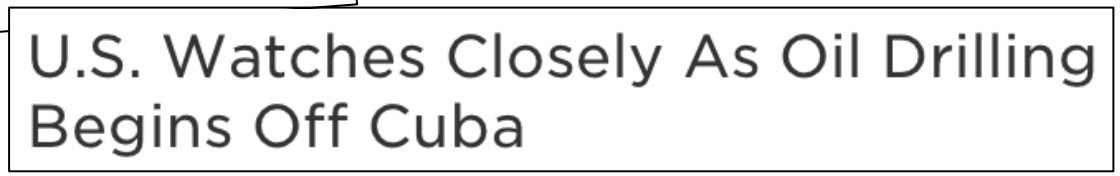
Publicity


U.S.

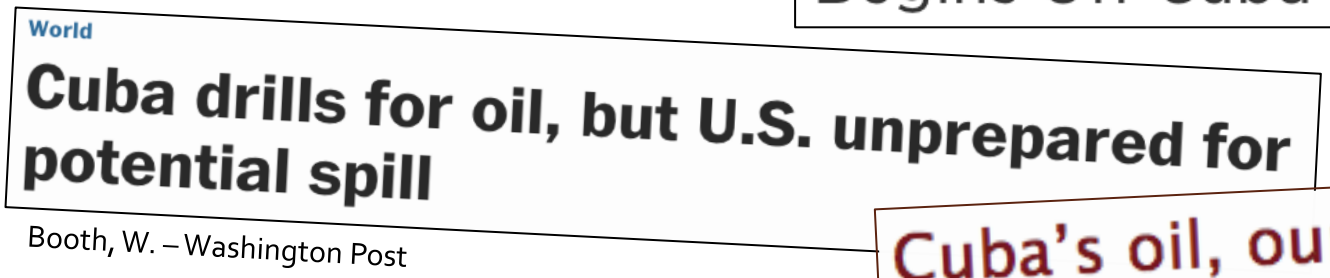
Florida Sees New Threat to Its Beaches

Deepwater Drilling Project in Cuban Waters Set to Launch Next Year Could Kick Off a Spate of Exploration in the Region

Gold, R. – Wall Street Journal

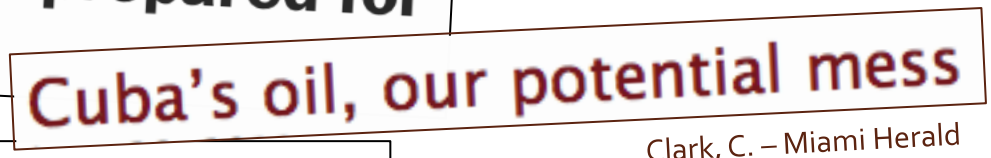

U.S. Watches Closely As Oil Drilling Begins Off Cuba

Allen, G. – NPR


World

Cuba drills for oil, but U.S. unprepared for potential spill

Booth, W. – Washington Post


Cuba's oil, our potential mess

Clark, C. – Miami Herald


Cuban oil project fuels US anxieties

Voss, M. – BBC News


Cuban Oil: Country's Ambitions Endanger Florida Coral Reefs and Coast

Bertrand, P. - International

Background

Regional Oil Exploration

- **Potentially Harmful Exploration Sites**
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    - Western Gulf of Mexico
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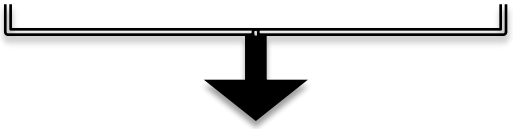

- Input Regional Exploration Sites into Matlab
- Overlay Exploration Sites Atop Smith and Sandwell (1997) High-Resolution Bathymetry Data

Area of Interest