Transport and Fate of Spilled Oil: Engineering Aspects

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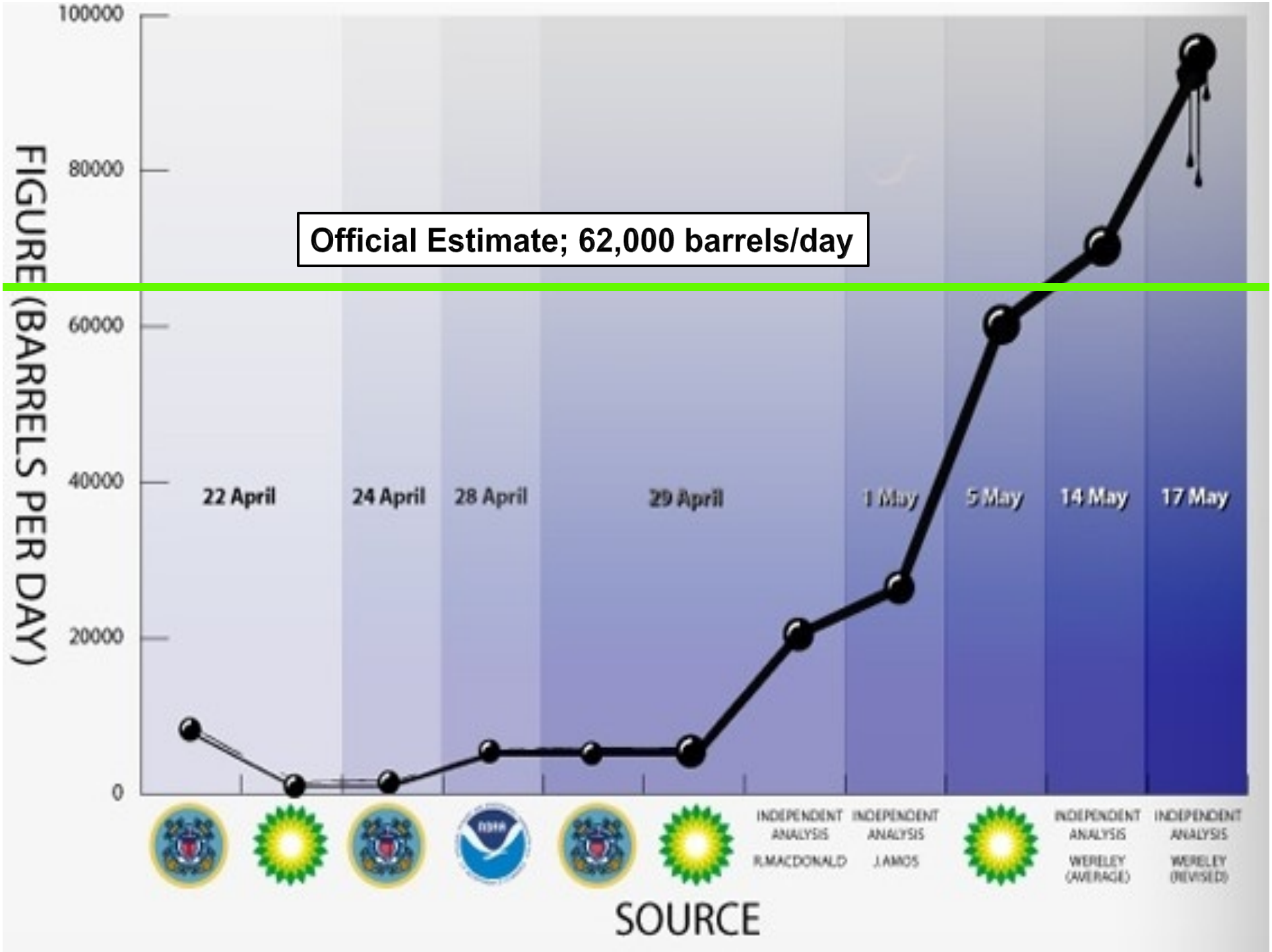
Outline

- Deepwater Horizon Spill (DHS) – Approximate Spill Size
- What Happens to the Spilled Oil?
- Air Quality Issues: UNO-MERIC Research Efforts
- Summary of Projects Proposed
- Potential Collaborators
- Conclusions

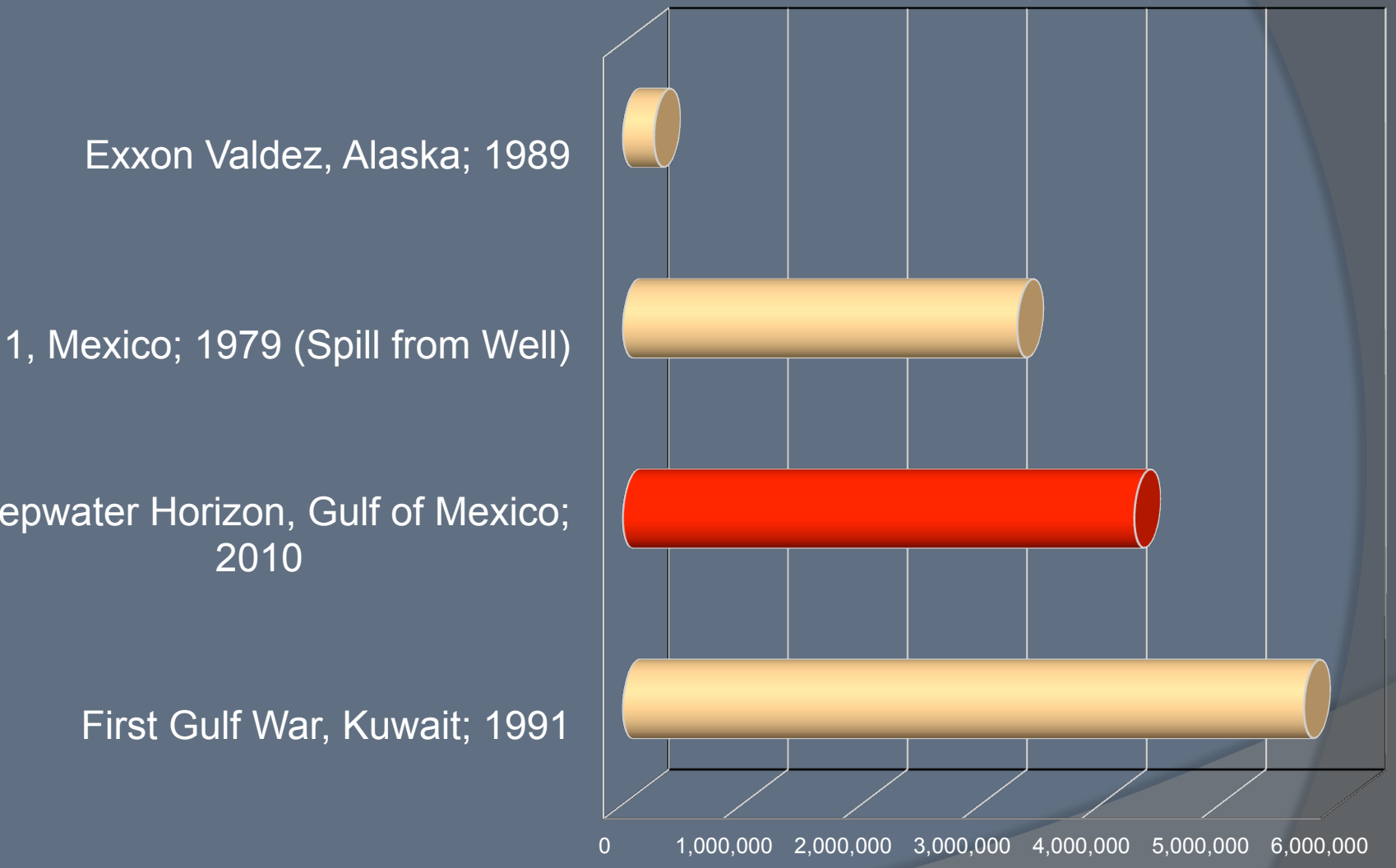
Deepwater Horizon Spill (DHS)

Approximate Spill Size


100000
80000
60000
40000
20000
0
FIGURE (BARRELS PER DAY)
Official Estimate; 62,000 barrels/day
22 April
24 April
28 April
29 April
1 May
5 May
14 May
17 May
INDEPENDENT ANALYSIS R.MACDONALD
INDEPENDENT ANALYSIS J.AMOS
INDEPENDENT ANALYSIS WERELEY (AVERAGE)
INDEPENDENT ANALYSIS WERELEY (REVISED)
SOURCE

Comparison of Spills

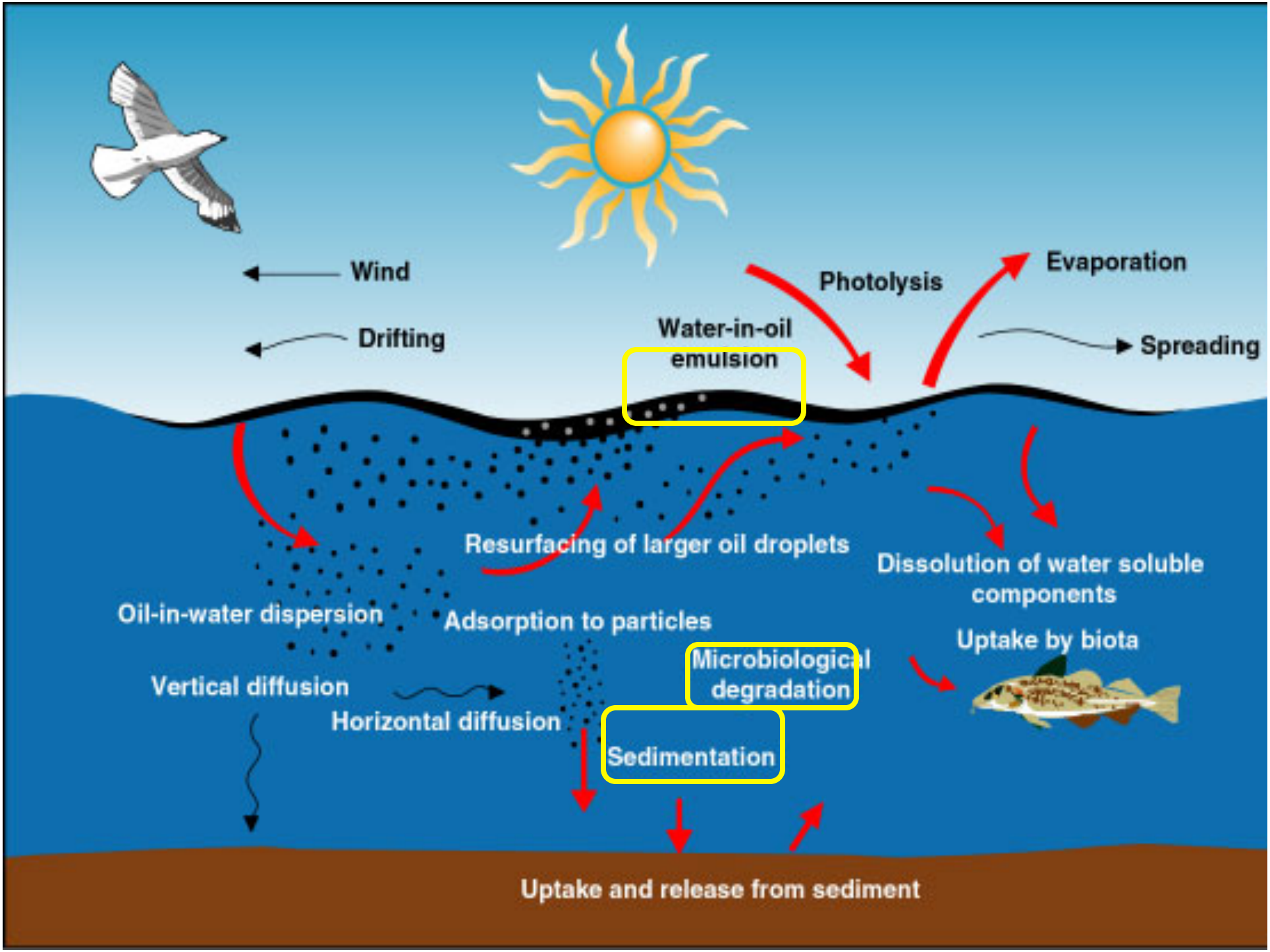
(Note: Some variability exists in the quantity reported among sources)



	First Gulf War, Kuwait; 1991	Deepwater Horizon, Gulf of Mexico; 2010	Ixtoc 1, Mexico; 1979 (Spill from Well)	Exxon Valdez, Alaska; 1989
■	5,700,000	4,280,000	3,300,000	260,000

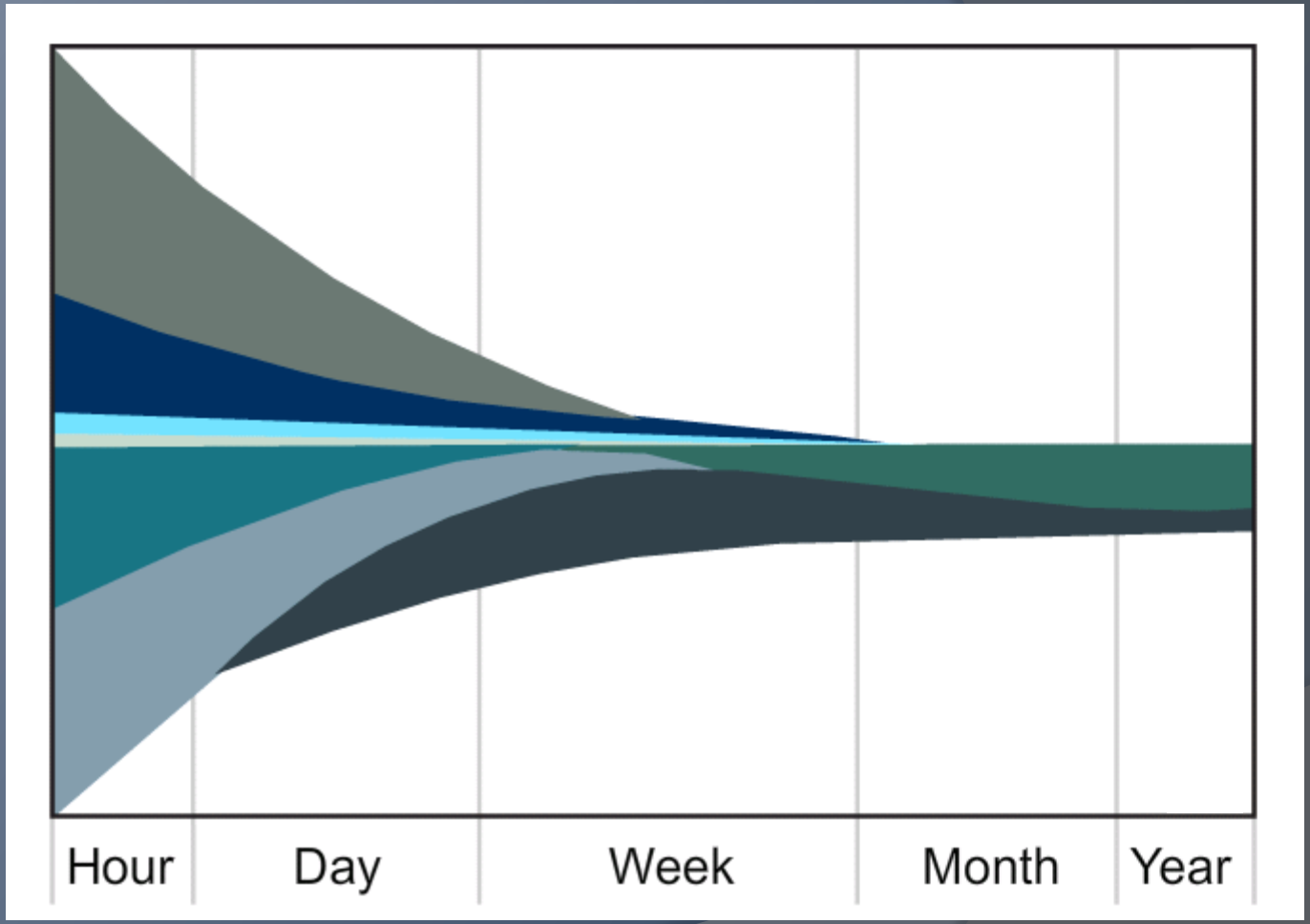
What Happens to the Spilled Oil?

Illustrations from the Literature


Wind
Drifting
Photolysis
Evaporation
Spreading
Water-in-oil emulsion
Resurfacing of larger oil droplets
Dissolution of water soluble components
Oil-in-water dispersion
Adsorption to particles
Uptake by biota
Microbiological degradation
Vertical diffusion
Horizontal diffusion
Sedimentation
Uptake and release from sediment

Weathering Over Time

- Spreading
- Evaporation
- Dispersion
- Dissolution
- Emulsification
- Oxidation
- Sedimentation
- Biodegradation



http://www.msnbc.msn.com/id/37517080/ns/disaster_in_the_gulf/

Fate and Transport Questions

- Release to air?
- In the water column?
- In the sediments / on the floor?
- On to the shoreline?
- Deposited in the wetlands?

Air Quality Issues

UNO Research Efforts

Factors that Influence Air Emissions from Spills

- Magnitude of spill
- Composition of crude and natural gas
- Characteristics of spill
- Hydrological conditions
- Meteorological conditions

Air: Important Questions

- What specific air pollutants were emitted from the spill and other related activities/sources?
- What were the quantities emitted?
- How did they change from April 20th to July 15th, 2010 and beyond?
- Relationships: Locations; Specific Compounds; Quantities emitted; Time scale
- Importance:
  - Air quality impacts; Exposures; Health risks (cancer and non-cancer) to the public and workers

Spill and Spill Related Sources of Air Emissions

- Direct release - Natural Gas (Methane and others)
- Evaporation (VOCs/HAPs; light and heavy organics)
- Burning (CO; CO_2; SO_2; NO_x; Others)
- Spill response equipment and vehicles (VOCs; NO_x; PM; CO; Heavy metals)
- Short term and long term remediation (by products of remediation)

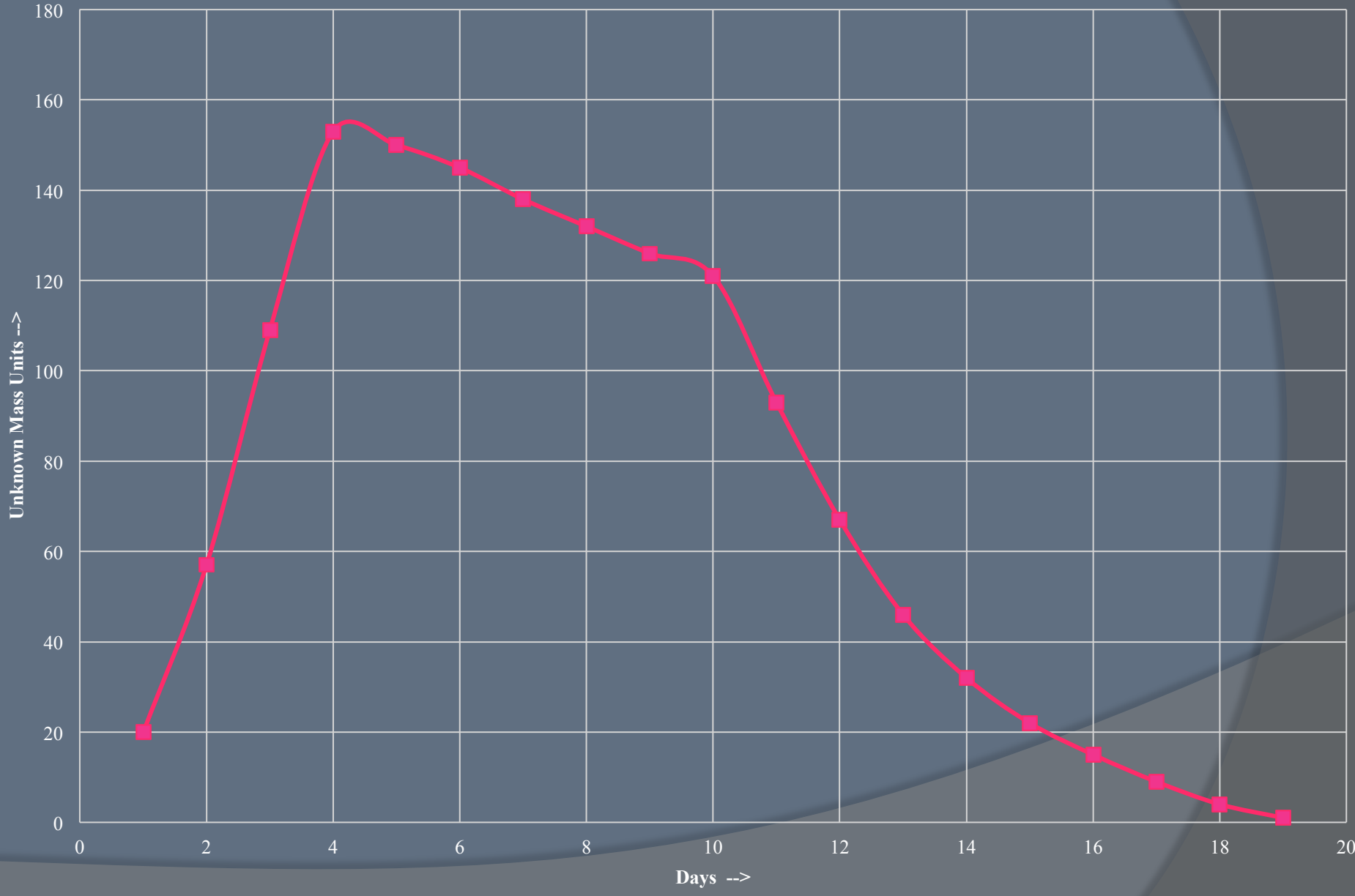
Methods to Estimate Emissions

- Kura # 1: Laboratory Simulation
  - To trace **evaporation** rate (emissions from crude only)
  - Build **emission spectrum**
- Kura # 2: Inverse Dispersion Modeling
  - To trace **emission** rate (emissions from spill and spill related sources)
  - Build **emission spectrum**

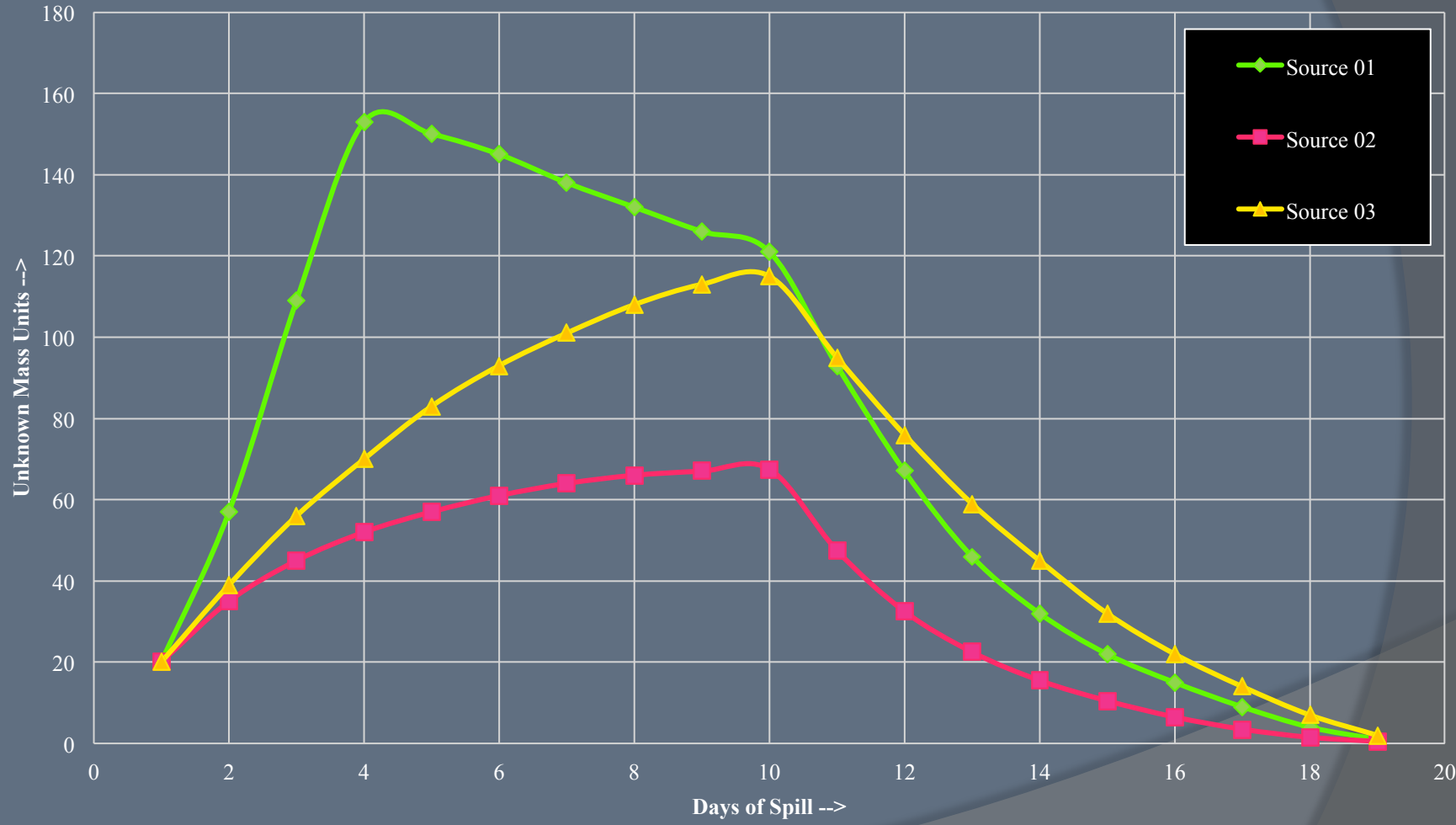
Emission Spectrum for 10-Day Hypothetical Spill (Unknown Mass Units)

Day	1	2	3	4	5	6	7	8	9	10	Total
1	20	-	-	-	-	-	-	-	-	-	20
2	17	40	-	-	-	-	-	-	-	-	57
3	15	34	60	-	-	-	-	-	-	-	109
4	12	30	51	60	-	-	-	-	-	-	153
5	10	24	45	51	20	-	-	-	-	-	150
6	7	20	36	45	17	20	-	-	-	-	145
7	6	14	30	36	15	17	20	-	-	-	138
8	5	12	21	30	12	15	17	20	-	-	132
9	3	10	18	21	10	12	15	17	20	-	126
10	1	6	15	18	7	10	12	15	17	20	121
11	-	2	9	15	6	7	10	12	15	17	93
12	-	-	3	9	5	6	7	10	12	15	67
13	-	-	-	3	3	5	6	7	10	12	46
14	-	-	-	-	1	3	5	6	7	10	32
15	-	-	-	-	-	1	3	5	6	7	22
16	-	-	-	-	-	-	1	3	5	6	15
17	-	-	-	-	-	-	-	1	3	5	9
18	-	-	-	-	-	-	-	-	1	3	4
19	-	-	-	-	-	-	-	-	-	1	1

Emission Spectrum for Unknown HAP



Emission Spectrum of Multiple Sources for an Unknown HAP



Kura #1: Lab-scale Wind Tunnel Study (Johnson, 2010)

Kura # 2: Inverse Dispersion Modeling

$$C = \frac{Q}{2\pi\sigma_y\sigma_z}\exp\left(-\frac{1}{2}\frac{y^2}{\sigma_y^2}\right)\left\{exp\left(-\frac{(z-H_e)^2}{2\sigma_z^2}\right)+exp\left(-\frac{(z+H_e)^2}{2\sigma_z^2}\right)\right\}$$

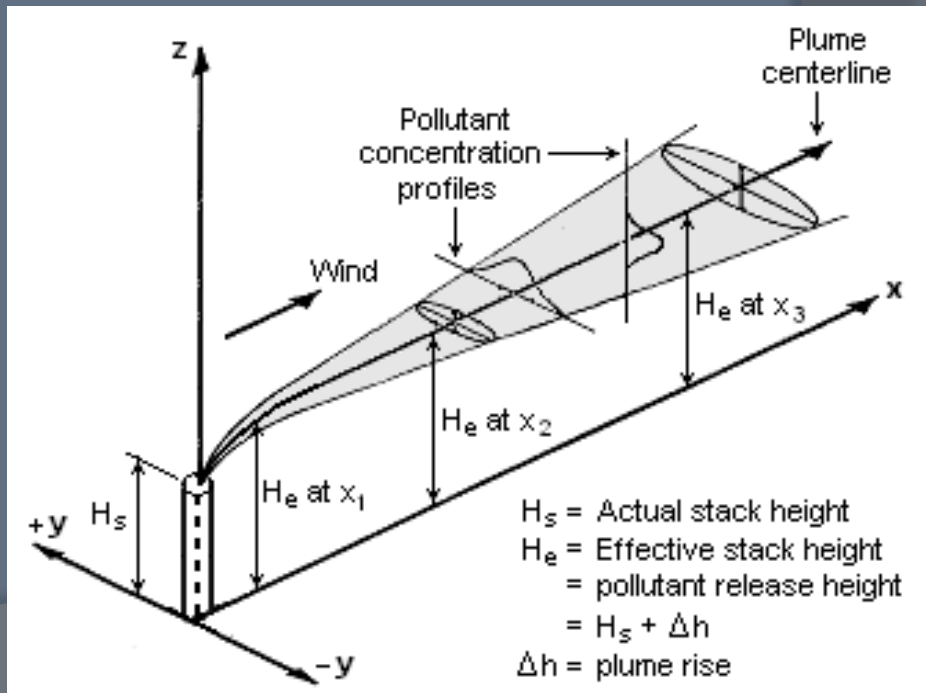
$$C=\frac{Q}{\pi u\sigma_y\sigma_z}\exp\left(-\frac{1}{2}\frac{y^2}{\sigma_y^2}\right)$$

$Z=H_e=0$

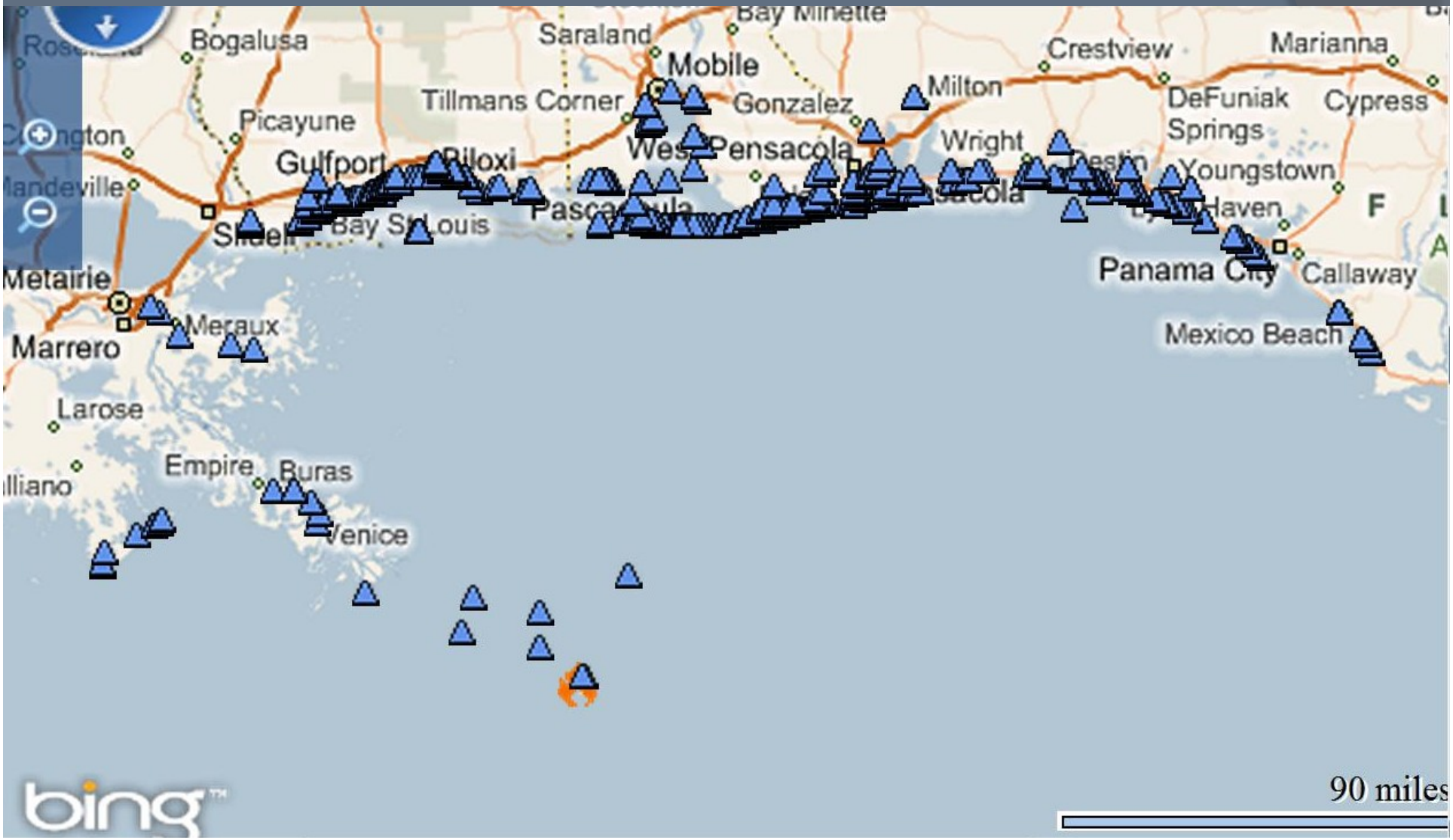
$$f=\frac{1}{\pi u\sigma_y\sigma_z}\exp\left(-\frac{1}{2}\frac{y^2}{\sigma_y^2}\right)$$

$$C_{i,j} = f(x,y)_{i,j} * Q_j$$

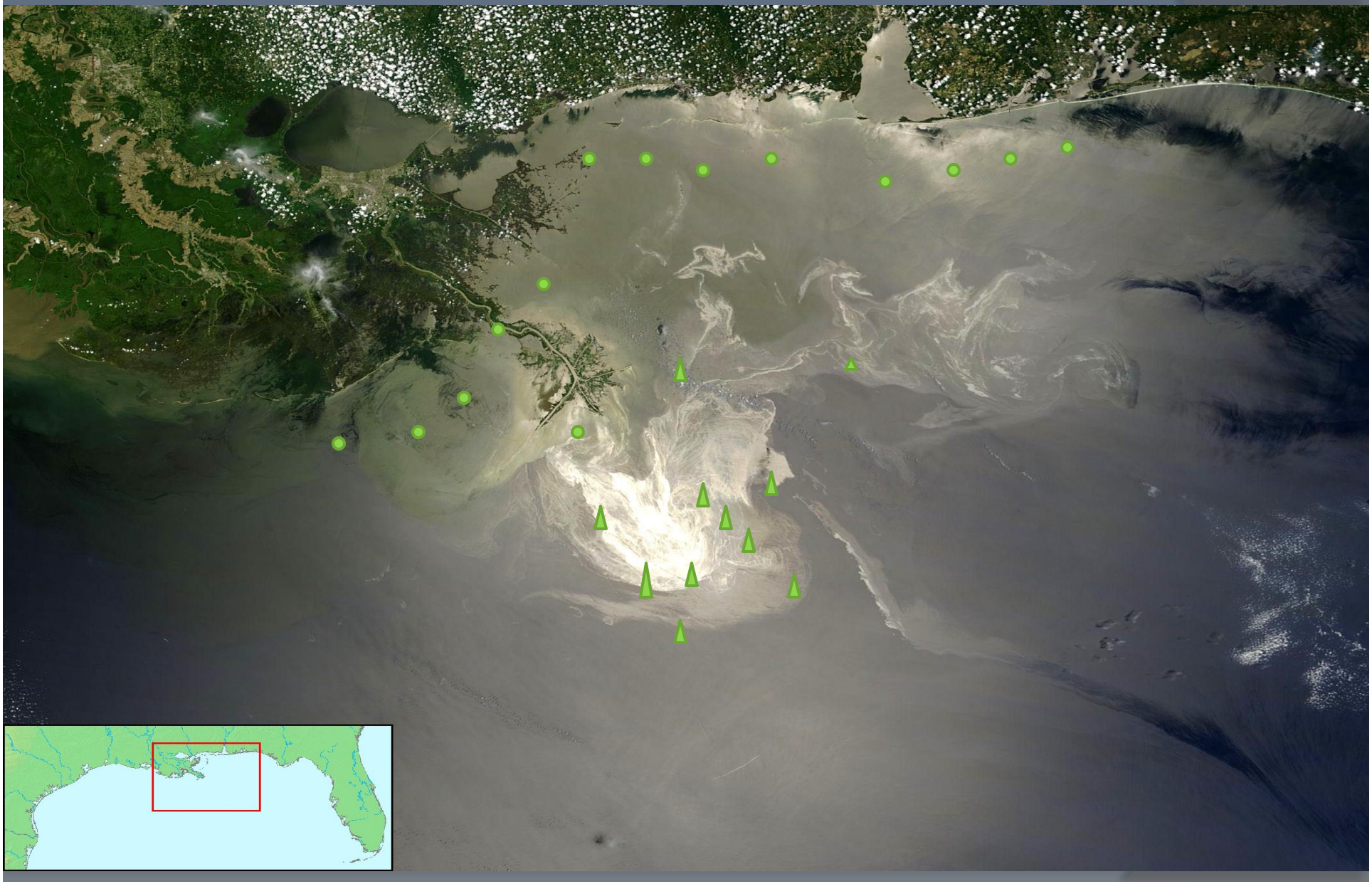
$$q = \mathbf{F}^{-1} c_{\mathbf{measured}}$$



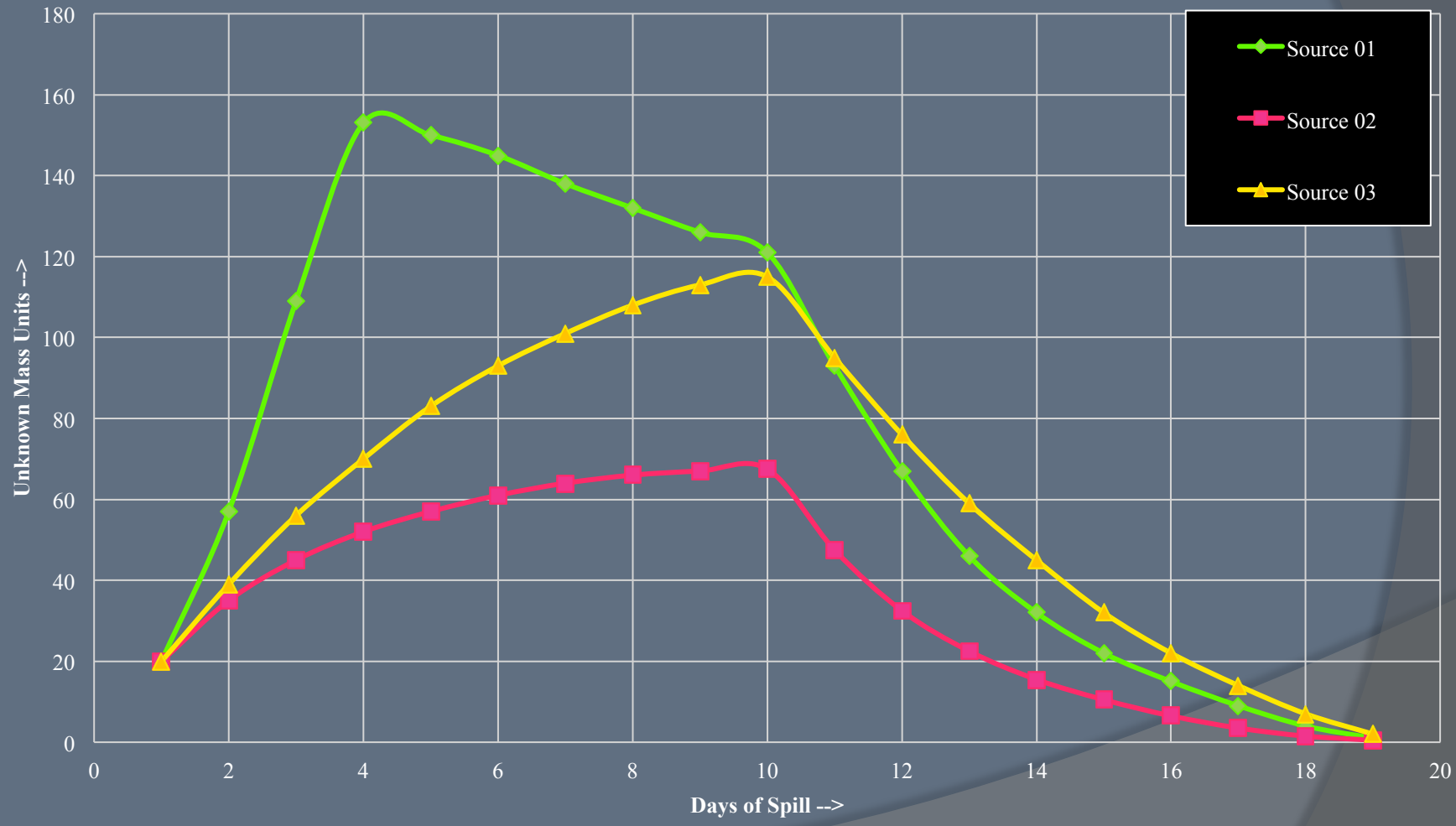
Air Monitoring Locations (PM_{10}; H_2S; VOCs; PAHs)



Inverse Gaussian Dispersion Modeling



Emission Spectrum of Multiple Sources for an Unknown HAP



Advantages of Inverse Dispersion Modeling (Kura # 2)

- No need to know actual oil leak quantities
- Quantities estimated are based on actual ambient concentrations recorded
- Allows identification of the emission locations (equally important in evaluating health risks)
- Ability to quantify a variety of VOCs or HAPs
- Ability to quantify emissions from spill response related activities such as burning, remediation etc. (e.g., PM, CO, CO_2, SO_2, NO_x)

Summary of Projects Proposed

Kura #1: Lab-scale Wind Tunnel Studies

- Proposal:
  - Design a lab-scale wind tunnel to simulate the spill conditions of the Deepwater Horizon Spill (DHS)
- Aims:
  - Identify and estimate emissions of important air pollutants from the DHS
  - Construct the emission spectra for all related air pollutants
- Benefits:
  - Evaluation of air quality impacts
  - Evaluation of public exposures to various compounds and the time periods
  - Inhalation-induced public health (cancer and non-cancer)
  - Better understanding to aid future strategies, policies, and management

Kura #2: Inverse Dispersion Modeling

- Proposal:
  - Conduct large scale inverse dispersion modeling studies to develop emission spectra for important air pollutants
- Aims:
  - Identify and estimate emissions of important air pollutants from the DHS and DHS related activities/sources
  - Construct the emission spectra for all related air pollutants
- Benefits:
  - Evaluation of air quality impacts
  - Evaluation of public exposures to various compounds and the time periods
  - Inhalation-induced public health (cancer and non-cancer)
  - Better understanding to aid future strategies, policies, and management

Kura #3: Evaluate Air Quality Impacts and Health Risks of DHS

- Proposal:
  - Perform dispersion modeling using the emission spectra from Kura # 2 (Inverse Dispersion Studies) to evaluate air quality impacts and inhalation-induced health risks
- Aims:
  - Identify and estimate emissions of important air pollutants from the DHS and DHS related activities/sources
  - Construct the emission spectra for all related air pollutants
- Benefits:
  - Evaluation of air quality impacts
  - Evaluation of public exposures to various compounds and the time periods
  - Inhalation-induced public health (cancer and non-cancer)
  - Better understanding to aid future strategies, policies, and management

Kura #4: Develop GIS-Based Decision Support System

- Proposal:
  - Develop a GIS-based Decision Support System to Understand Air Quality Impacts and Health Risks
- Aims:
  - Use results from Kura #2 and Kura #3 to develop a GIS-based Decision Support System
  - Display and understand air quality issues vis-à-vis various cancer and non-cancer standards (a) for various air pollutants, (b) various locations, and (c) various time periods
  - Display and understand increased probability of inhalation-induced health risks (a) from various air pollutants, (b) from all pollutants, (c) for various locations, and (d) for specific time periods
- Benefits:
  - Clear understanding of air quality and health impacts
  - Easy access
  - Facilitates risk communication effectively and scientifically
  - Prevents misconceptions

localhost:2020

localhost:2020

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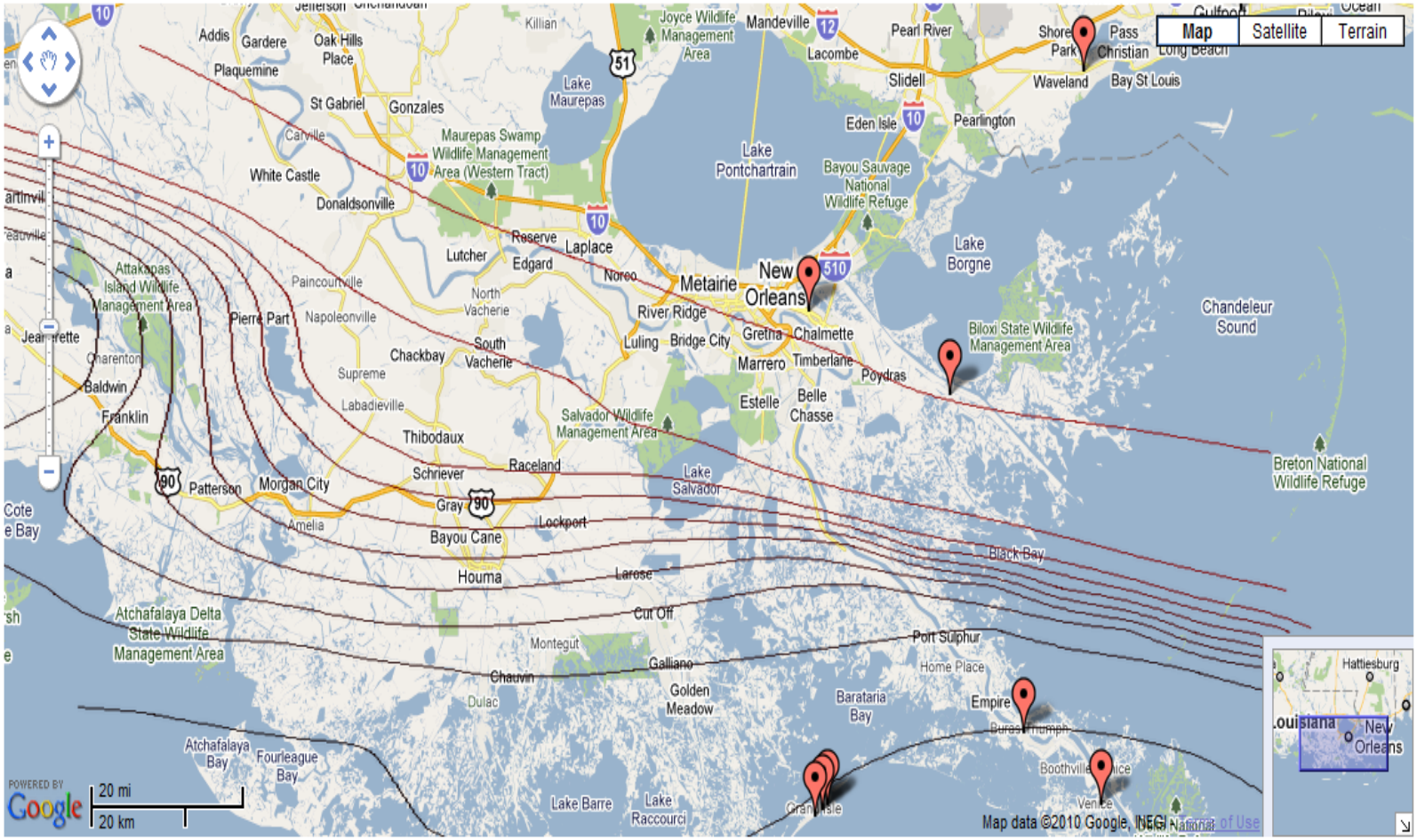
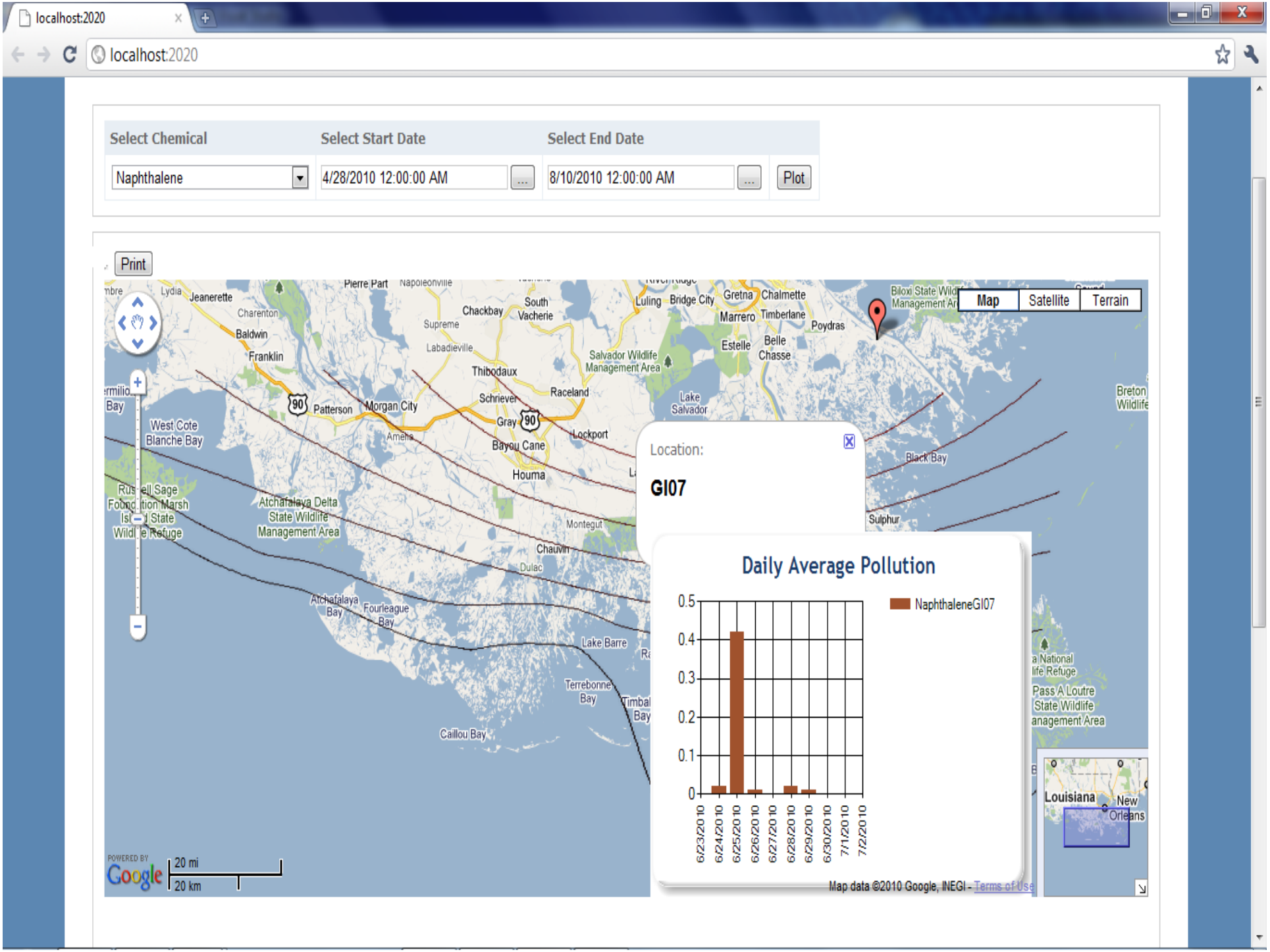
Naphthalene	4/28/2010 12:00:00 AM ...	8/10/2010 12:00:00 AM ...	Plot

Print

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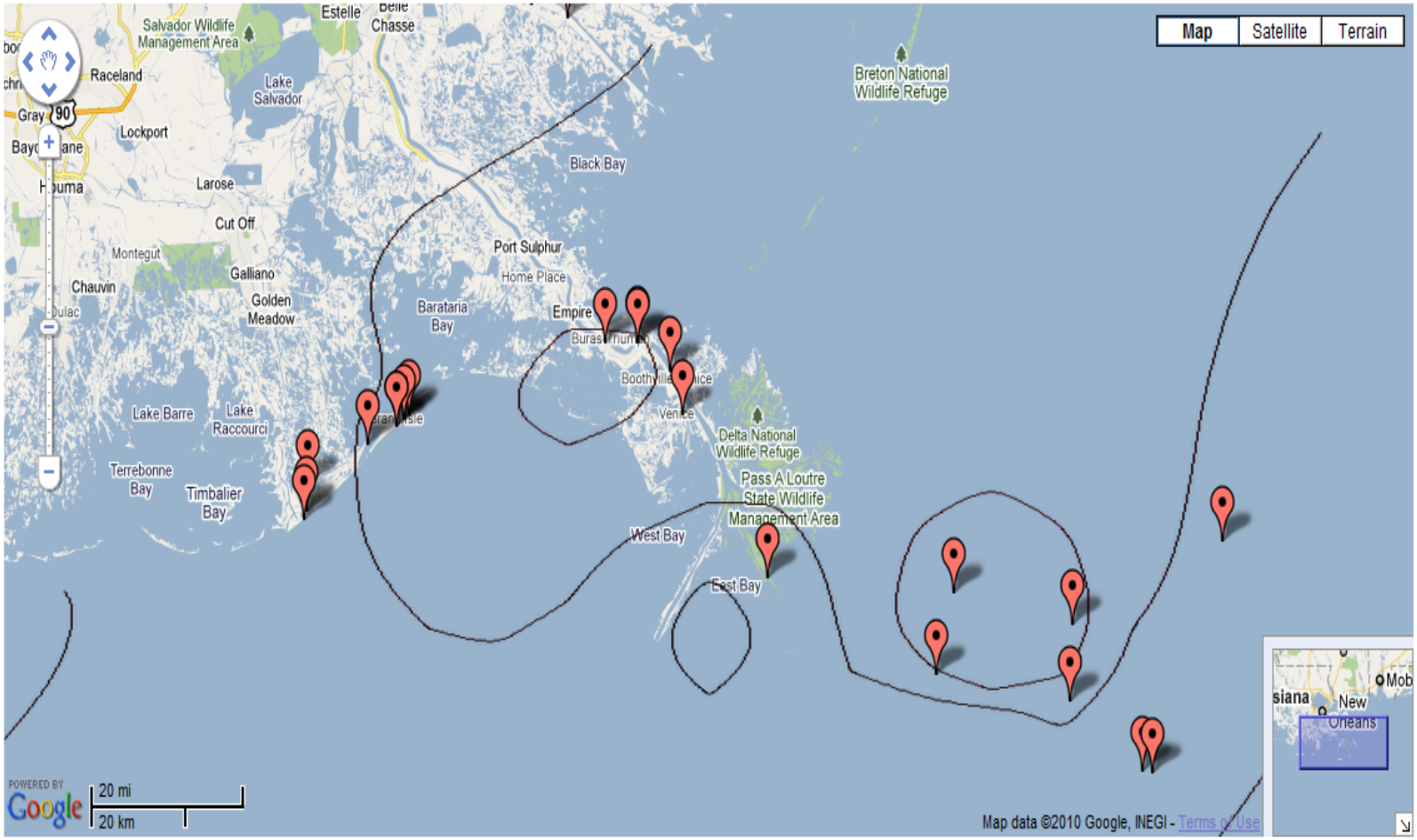
Select Start Date
Select End Date
Naphthalene
4/28/2010 12:00:00 AM
8/10/2010 12:00:00 AM
Plot
Print
Map
Satellite
Terrain
Location:
GI07
Daily Average Pollution
NaphthaleneGI07
0.5
0.4
0.3
0.2
0.1
0
6/23/2010
6/24/2010
6/25/2010
6/26/2010
6/27/2010
6/28/2010
6/29/2010
6/30/2010
7/1/2010
7/2/2010
Louisiana
New Orleans
Map data ©2010 Google, INEGI - Terms of Use
20 mi
20 km
Google

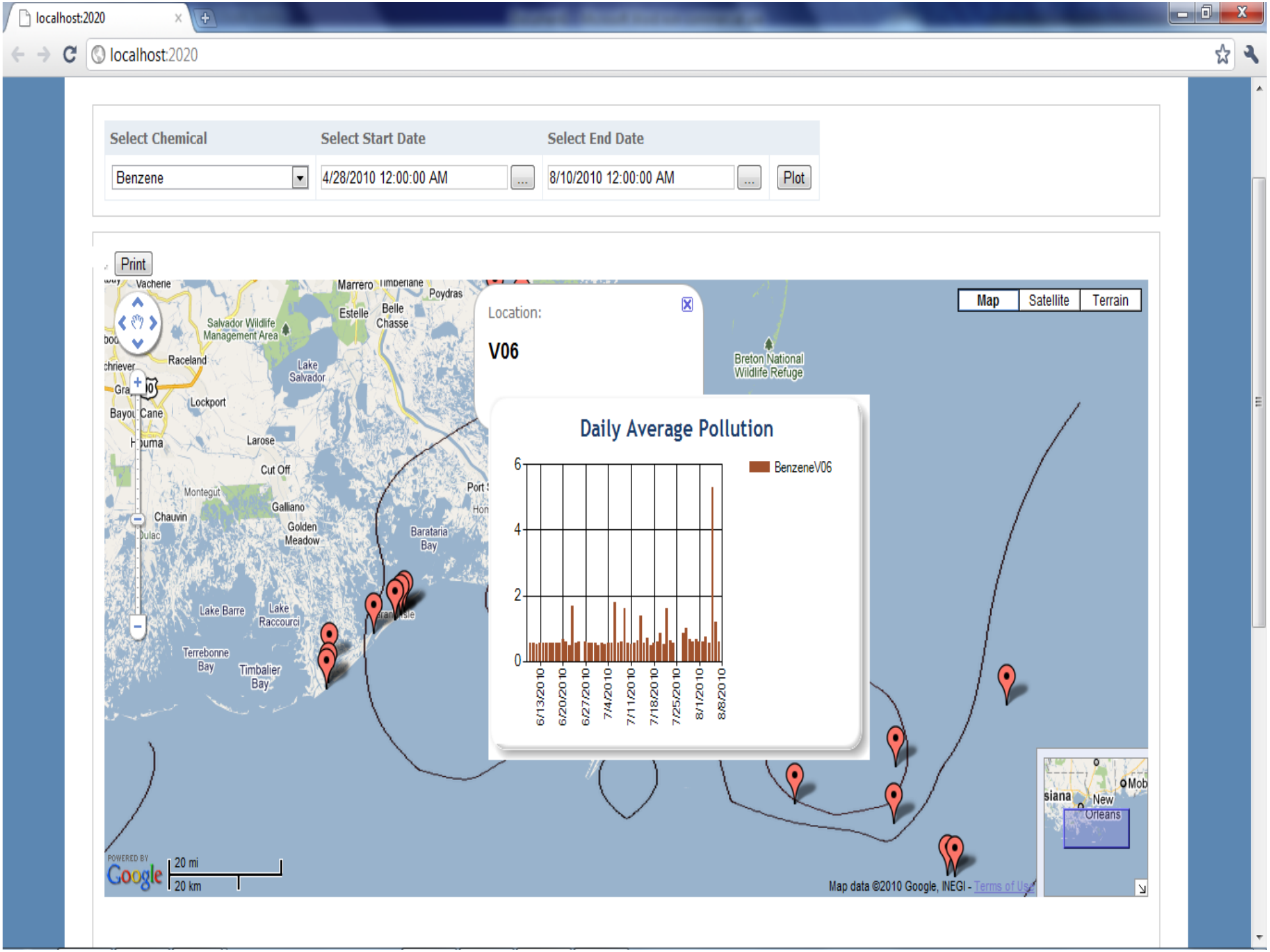
localhost:2020

localhost:2020

Select Chemical	Select Start Date	Select End Date	
Benzene	4/28/2010 12:00:00 AM ...	8/10/2010 12:00:00 AM ...	Plot

Print

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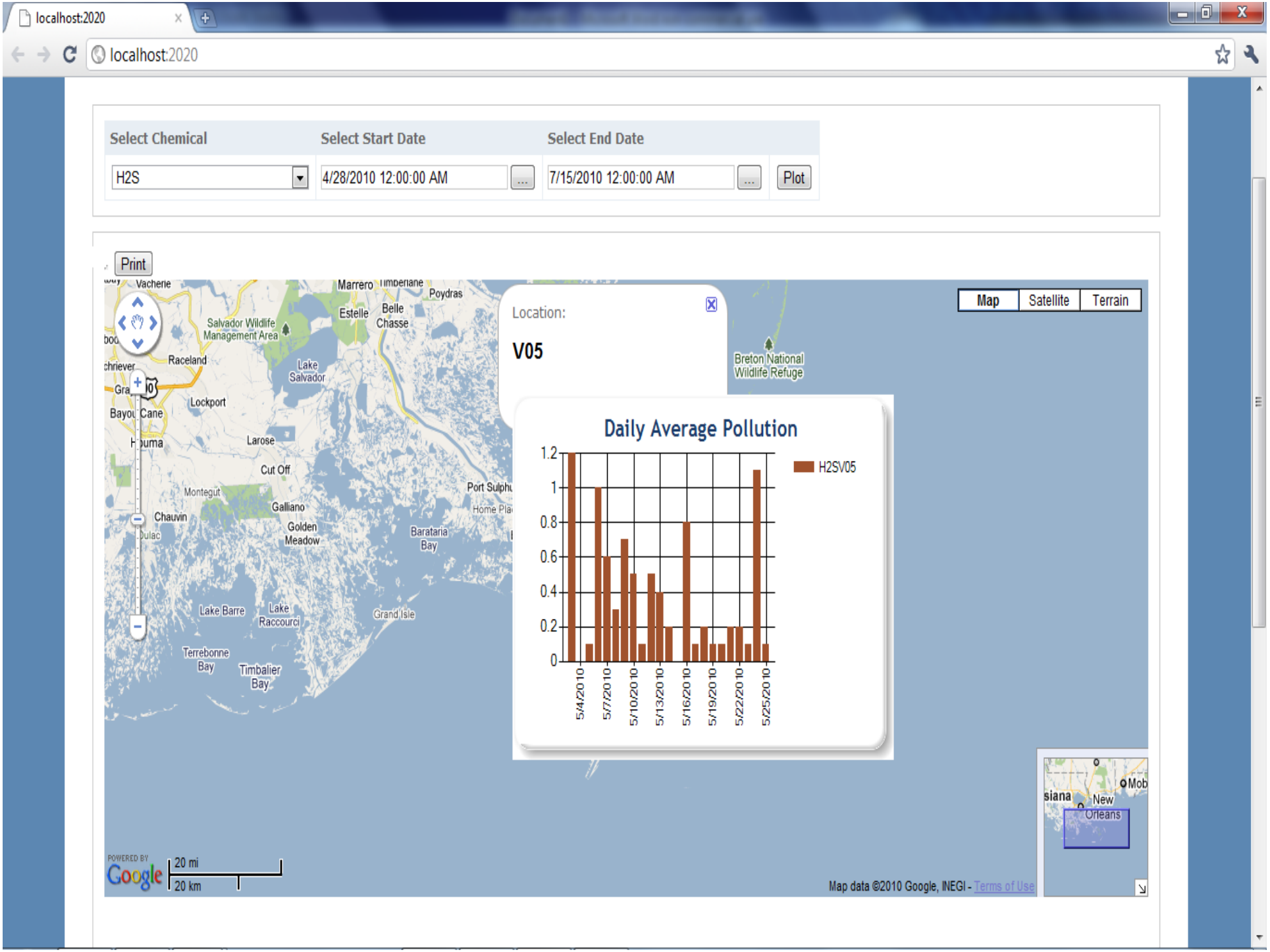
localhost:2020
Select Chemical
Select Start Date
Select End Date
Benzene
4/28/2010 12:00:00 AM
8/10/2010 12:00:00 AM
Plot
Print
Map
Satellite
Terrain
Location:
V06
Daily Average Pollution
BenzeneV06
6
4
2
0
6/13/2010
6/20/2010
6/27/2010
7/4/2010
7/11/2010
7/18/2010
7/25/2010
8/1/2010
8/8/2010
Breton National Wildlife Refuge
Salvador Wildlife Management Area
Lake Salvador
Raceland
Lockport
Larose
Cut Off
Galliano
Golden Meadow
Chauvin
Barataria Bay
Lake Barre
Lake Raccourci
Terrebonne Bay
Timbalier Bay
Estelle
Belle Chasse
Poydras
Marrero
Montegut
New Orleans
20 mi
20 km
Map data ©2010 Google, INEGI - Terms of Use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Select Chemical
Select Start Date
Select End Date
H2S
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7/15/2010 12:00:00 AM
Plot
Print
Map
Satellite
Terrain
Location:
V05
Daily Average Pollution
H2SV05
1.2
1
0.8
0.6
0.4
0.2
0
5/4/2010
5/7/2010
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5/13/2010
5/16/2010
5/19/2010
5/22/2010
5/25/2010
Salvador Wildlife Management Area
Raceland
Lockport
Larose
Cut Off
Montegut
Galliano
Golden Meadow
Chauvin
Lake Barre
Lake Raccourci
Terrebonne Bay
Timbalier Bay
Grand Isle
Barataria Bay
Estelle
Belle Chasse
Poydras
Lake Salvador
Breton National Wildlife Refuge
New Orleans
20 mi
20 km
Map data ©2010 Google, INEGI - Terms of Use

Kura #5

- Proposal:
  - A wearable personal chemical sensor that allows air quality monitoring that can accurately report the exposure level of the subject.

- Aims:
  - Enable ***accurate health studies***, in both the short and long terms, oil spill related diseases
    - providing spatial, temporal and personalized information in an efficient manner that are otherwise unavailable to conventional methods.
  - Help in protecting workers and fishermen who are more prone to exposing to higher level of oil spill related pollutants by providing warnings in minutes
  - Used as a disaster/pollution detector to provide early warnings and to help make decisions

Kura #6

- Proposal:
  - A low cost, portable, reliable, and user friendly device to help fishermen/FDA agents to determine the quality of the seafood
- Aims:
  - Provide a low cost, reliable, portable, and user friendly tool to ***ensure seafood quality*** (level of hydrocarbon) and re-establish consumers' confidence
  - Our proposed sensor will be tuned to sensitively pick up petroleum derivatives which can be used to indicate whether the seafood has been contaminated

Potential Collaborators (through MERIC)

- Dr. C. David Cooper, University of Central Florida
- Dr. Ashok Kumar, University of Toledo
- Dr. Danny Reibel, University of Texas at Austin
- Dr. Cristiane Surbeck, University of Mississippi
- Dr. Shankar Chellam, University of Houston
- Dr. Nongjian Tao, Arizona State University
- Dr. Francis Tsow, Arizona State University
- Dr. Jennifer L. Peel, Colorado State University
- Others: A few others from LSU, ULL, and Tulane

Conclusions

- Large scale efforts are needed to clearly understand air quality impacts
- Emission spectra for various air pollutants, development of software applications/models are needed
- UNO efforts will be valuable in assessing public health risks
- UNO is collaborating with many agencies and corporations to accomplish its goals and looking for research funding


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NEW ORLEANS

ASU Team Working with UNO

El Paso Team Supporting UNO


NO PISE
NO STEP

Thank you for your attention!

QUESTIONS?