Sargassum Injury Assessment Plan: mapping using remote sensing

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For the
Mississippi Canyon 252 Trustees

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***Sargassum* Injury Assessment Plan: mapping using remote sensing**

Approval of this work plan is for the purposes of obtaining data for the Natural Resource Damage Assessment (NRDA). Each party reserves its rights to produce its own independent interpretations and analyses of any data collected pursuant to this, or other, work plans.

The trustees have developed a preliminary conceptual model of the DWH release, potential pathways and routes of exposure, and potential receptors. This preliminary model has informed the trustees' decision to pursue the studies outlined in the work plan. By signing this work plan and agreeing to fund the work outlined, BP is not endorsing the model articulated in the work plan.

APPROVED:

For Lisa DiPinto, Jessica White — 2/28/2012
NOAA Trustee Representative: — Date

for Richard Guidry — 3/9/2012
Louisiana Trustee Representative: — Date

Joyce Miley — 2/28/2012
BP Representative: — Date

Sargassum Injury Assessment Plan: mapping using remote sensing

The goal of this project is to map the distribution, abundance, and temporal patterns of *Sargassum* in the Gulf of Mexico for the period of the Deepwater Horizon (DWH) Oil Spill in 2010. This information will help provide a better understanding of the effect of oil on the pelagic component of the ocean ecosystem, and to provide ecosystem data for *sargassum*-associated aquatic species. An additional goal is to evaluate methods for detecting oil and oiled *Sargassum* using hyperspectral and multispectral remote sensing. Utilization of such methods could help to identify specific areas of *Sargassum* impacted by oil during the spill. This effort will be pursued with data collected prior to, throughout, and after the DWH spill event. The *Sargassum* mapping data generated by this effort will be useful for both the fish and sea turtle assessments.

The project will be implemented using a phased approach based on existing knowledge of algorithm fidelity and data availability on the feasibility to detect and quantify *Sargassum* in the Gulf of Mexico (see below for spectral examples). Phase 1 will refine the method to map *Sargassum* and differentiate it from oil. It includes two activities described below. Phase 2 will use independent data to validate the method and estimate uncertainties. Phase 3 will assess the spatial and temporal distributions of *Sargassum* during 2010. Phase 4 will be the retrospective analysis to determine baseline distributions (2000 – 2009) and the distributions in 2011. Decisions to move from one phase to the next will be made cooperatively after reviewing the results of prior phases.

Objectives

1. Using existing remote sensing datasets, develop a validated method that can differentiate among oil, oiled *Sargassum,* and un-oiled *Sargassum.*
2. Map *Sargassum* abundance and distribution in 2010.
3. Depending on results of Phases 1 -3, map *Sargassum* abundance and distribution from 2000-2009 and 2011.
4. Depending on method development, attempt to determine what percent of Sargassum was contaminated by oil during the spill.

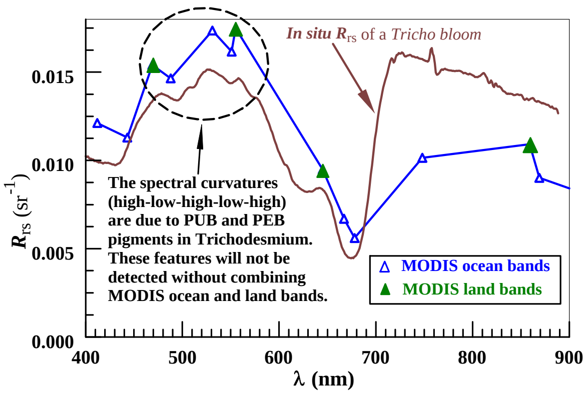
Background

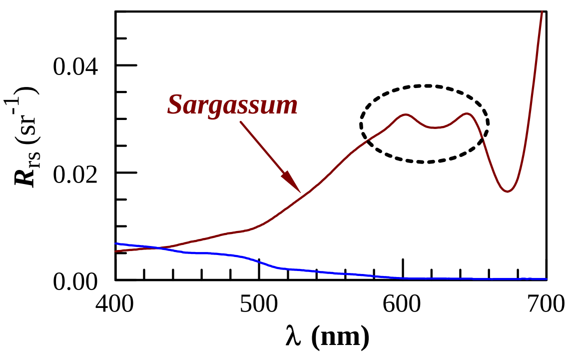
Pioneering case studies have used remote sensing (both satellite and airborne) to detect *Sargassum* and Trichodesmium spp. (Gower et al., 2006; Gower and King, 2008; Hu, 2009; Hu et al., 2010a; Marmorino et al., 2011). This work, however, will establish a documented, validated method, including field measurements and verification, to differentiate visually similar materials, i.e., *Sargassum* and oil slicks, using spectral analysis. Hyperspectral remote sensing data will be processed to identify areas of oil, water emulsions, *Sargassum*, and oiled *Sargassum* for dates and areas coincident with multispectral satellite data. This information will be used to define and map these materials using satellite remote sensing data. The remotely sensed maps of

Sargassum, oiled and non-oiled, will aid in assessing the impacts of oil released during the Deepwater Horizon spill on pelagic receptors.

Initial feasibility for this project has been assessed using existing data and published algorithms. Fig. 1 shows several digital photos of various materials in the Gulf of Mexico with similar appearances, while Fig. 2 shows their corresponding spectral shapes. Even though they appear similar to a human eye, their differences in spectral shapes at specific wavelength ranges make it possible to differentiate them using available hyperspectral data (e.g., from AVIRIS). Specifically, by examining the three spectral regions (1200 to 1700 nm for oil, 600 to 640 nm for *Sargassum*, and 450 to 570 nm for Trichodesmium) we can fingerprint and differentiate each target material. After identification, spectral magnitude (not shape) will be used to quantify the abundance of observed materials. In areas that do not have hyperspectral data, MODIS data (near daily coverage) will be used to examine the 450-570 nm spectral range for Trichodesmium (step 1), and then examine whether the reflectance continuously increases from 550 to 700 nm (oil) or decreases from 645 to 670 nm (*Sargassum*). Data analysis and validation developed under the first 2 phases will be used to map *Sargassum* for the northern Gulf of Mexico in 2010.

Fig. 1. Digital photos showing (from top left, clockwise) *Trichodesmium* algae mats, pelagic *Sargassum*, and weathered oil. Their typical reflectance spectral shapes are presented in Fig. 2.





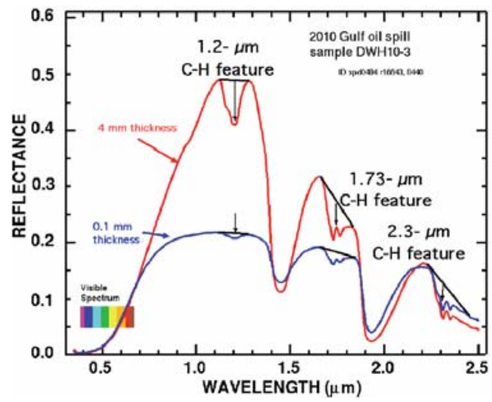


Fig. 2. Reflectance spectra from *Trichoesmium* algae mats (Hu et al., 2010a), pelagic *Sargassum* and nearby water (Hu, unpublished data), and surface oil (Clark et al., 2010).

MODIS is capable of detecting thin algae lines > 4-5 m in width once they form long slicks (> 500 m) (Hu et al., 2010b). However, while MODIS provides near daily and synoptic coverage of the entire GOM, it cannot capture small *Sargassum* patches and slicks. Landsat TM and ETM+ data at 30-m resolution will complement MODIS. Landsat provides coverage every 16 days for the same location and can be used to resolve *Sargassum* to an estimated limit of 2 m in slick width. Note that the Floating Algae Index (FAI) image can successfully remove most of the cloud contaminations, making it much easier to conduct further spectral analysis on outstanding features (Fig. 3).

This Plan will combine the advantages of AVIRIS, Landsat, and MODIS data to assess *Sargassum* abundance in both space and time. AVIRIS has higher spectral and spatial resolution (see below), but has limited coverage in both space and time. Its high accuracy enables AVIRIS data to “ground truth” mapping methods using more synoptic and frequent Landsat and MODIS observations. Table 1 lists the characteristics of Landsat and MODIS. While MODIS has full coverage of the entire Gulf of Mexico nearly every day, Landsat coverage is restricted primarily to coastal waters, except during the DWH oil spill when offshore data were also collected and made available to the public by the USGS (Fig. 4).

The plan will first develop an algorithm using concurrent AVIRIS (ground truth) and Landsat and MODIS data (Fig. 3), based on spectral analysis. The algorithm will be validated using an independent dataset containing all three concurrent measurements, with uncertainty estimates. Finally, the algorithm will be applied to data in 2010 and other years for large-scale and long-term assessments.

Table 1. Satellite data to be used to map *Sargassum*.

Sensor	Resolution*	Swath	Revisit	Bands	Period
MODIS/Terra	250m, 500m	2300 km	Near daily	Vis-nearIR	2000 – present
MODIS/Aqua	250m, 500m	2300 km	Near daily	Vis-nearIR	2002 – present
Landsat/TM5	30m	180 km	16 days	Vis-nearIR	1984 - present
Landsat/ETM+	30m	180 km	16 days	Vis-nearIR	1999 - present

*MODIS bands at 645 and 859 nm are 250-m resolution; 469, 555, 1240, and 1640 nm are 500-m resolution. Landsat bands at 485, 560, 660, 830, and 1650 nm are 30-m resolution. Once forming a long slick line occupying > 2 pixels, the targeted features must be at least 4-5 m in width for MODIS and 2-3 m for Landsat to be distinguishable in the image. MODIS data can be obtained from http://oceancolor.gsfc.nasa.gov; Landsat data can be obtained from http://glovis.usgs.gov. These data are freely available.

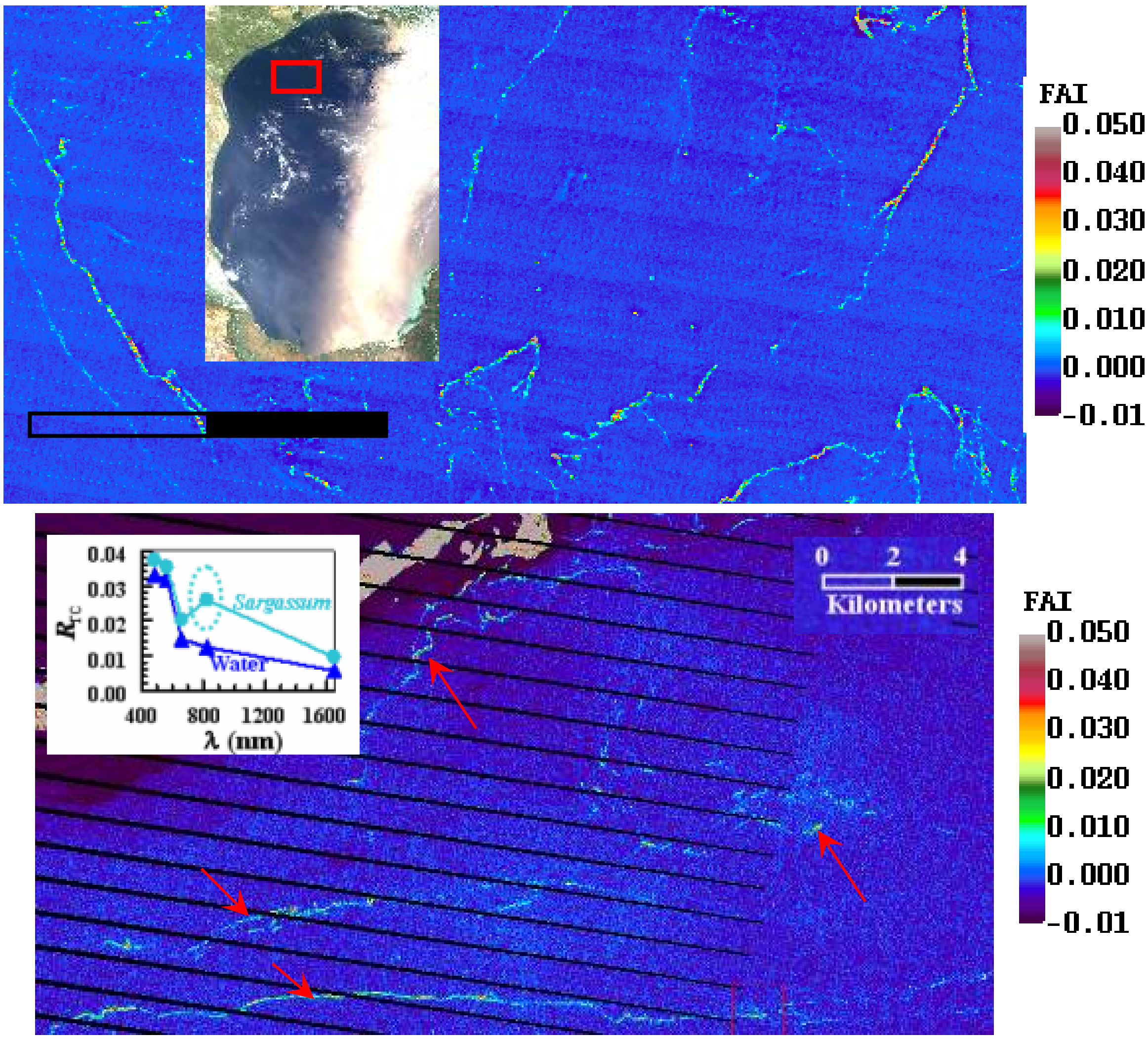


Fig. 3. Proof-of-concept for *Sargassum* mapping: MODIS (top) and Landsat (bottom) FAI (floating algae index) images in the western GOM and Florida Keys, respectively, showing the outstanding slicks. The spectral shapes of these slicks between 412 – 1240 nm are the same as those of *Sargassum*. Note the difference in their spatial scales.

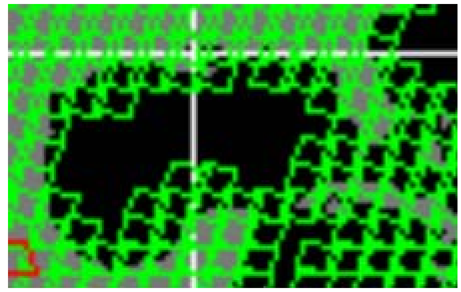


Fig. 4. Landsat/TM and ETM+ coverage over the GOM. Each square represents a 180x180 km^2 image.

Note that the spectral reflectance differentiating various materials shown in Fig. 2 were measured either *in situ* or in a laboratory controlled environment. From satellite or airborne measurements, several factors may complicate these classification schemes. These factors include the atmospheric interference (variable ozone, water vapor, and aerosols), variable solar/viewing geometry, possible sun glint contamination, radiometric calibration, and mixed image pixels. The algorithm will need to address these potential problems.

Phase I. Algorithm development

Phase 1 of this project will integrate what is known of spectral signatures and remote sensing capabilities with data collected from the September 2011 cruise, and data collected during the oil spill, to develop the necessary algorithm for MODIS and Landsat. AVIRIS data and field data will be used to ground truth. Phase 1 includes two activities, listed below.

Activity 1. Acquire and prepare the necessary remote sensing data
A number of datasets will be acquired and pre-processed as needed for execution of this Plan.

Data set: AVIRIS Airborne hyperspectral data
AVIRIS (Airborne Visible/Infrared Imaging Spectrometer) provides a hyperspectral dataset collected by NASA from an airplane. It provides 224 spectral bands from 380 to 2500 nm. AVIRIS ground resolution varies from 3.5 to 20m, dependent on collection altitude. These data provide a very high resolution but spatially-limited dataset. From May to October, 2010, NASA, USGS, and other groups collected AVIRIS data and field spectra near the spill area; these datasets are available for this Plan.

Tasks:

A. Determine status of AVIRIS data and select AVIRIS data for at least two days that are concurrent with Landsat and MODIS
B. Identify and complete preprocessing (viewing angles and flight line positions) for several images containing both oil and *Sargassum*
C. Post-process imagery to remove the atmospheric effects
D. Confirm whether spectral analysis to identify *Sargassum* is possible and determine what spectral features (e.g., those shown in Fig. 2) will be identified

Timeline:

- Acquisition of existing AVIRIS 2010 data appropriate for *Sargassum* mapping (complete)
- Pre-processing of AVIRIS data – (2 weeks)
- Post-processing of AVIRIS data – (2 weeks) after the preprocessing is complete

To be completed by:
USGS and USF

Cost:
- Preprocessing - $15K – 0.5 month FTE x 2 people (USGS)
- Post-processing - $15K – 0.5 month FTE x 2 people (USGS)

Data set: LANDSAT
Landsat TM and ETM+ instruments provide multi-spectral data coverage over the coastal ocean at a ground resolution of about 30 m, with a swath width of about 180 km (Table 1). The seven wide spectral bands cover the visible to thermal infrared wavelengths (B1: 0.45 – 0.52 µm; B2: 0.52 – 0.60 µm; B3: 0.63 – 0.69 µm; B4: 0.76 – 0.90 µm; B5: 1.55 – 1.75 µm; B6: 10.4 – 12.5 µm; B7: 2.08 – 2.35 µm). Due to its narrow swath width, revisit frequency is every 16 days. Conventionally, the entire Earth surface has been gridded, with each grid corresponding to a unique path/row number covering about 180 km x 180 km. For the purpose of land mapping, Landsat data only cover coastal zones, except for during the oil spill. For the same reason, Landsat instruments have much lower signal to noise ratios over the ocean than MODIS (Moderate Resolution Imaging Spectroradiometer, http://modis.gsfc.nasa.gov).

Tasks:

A. Secure all data necessary from LANDSAT 5 (1983 - present) and LANDSAT 7 (1999 - present)
   - Available at USGS Glovis at no cost (http://glovis.usgs.gov)
B. Identify 5 or more concurrent/coincident images from LANDSAT, AVIRIS and MODIS
C. Process to reflectance

Timeline:
- Several days
  - Acquiring a limited number of LANDSAT scenes is a low level effort compared with the other datasets.
  - All LANDSAT scenes during 2010 outside the spill time window have been processed and analyzed at the University of Southern Florida (USF).

To be completed by:
USF

Cost:
- $5K

Data set: MODIS

The MODIS instruments were launched in 1999 and 2002 onboard the satellites Terra and Aqua, respectively. Each instrument is equipped with 36 spectral bands covering the visible to the thermal infrared, with different purposes to study the land, ocean, and atmosphere (Table 1). Of these spectral bands, 9 were designed for the ocean color (reflectance) measurements at a ground resolution of about 1-km; 7 were designed for land surface reflectance measurements at a ground resolution of 250-m and 500-m. The large swath (about 2330 km) makes it possible to cover the entire Earth within 2 days using any of the two instruments, and sometimes it is possible to have two images per day covering the same locations. More information can be found at http://modis.gsfc.nasa.gov.

Tasks:

A. Secure data from 2000 - 2010
   - All data from 2000 to date are available at NASA GSFC (http://oceancolor.gsfc.nasa.gov)

B. Compile data after May 2010
   - MODIS from 2009 - 2011 have been processed and archived at USF (http://optics.marine.usf.edu)

C. Identify 5 or more concurrent/coincident images from MODIS, AVIRIS and LANDSAT

D. Reprocess the selected concurrent MODIS scenes
   - Scenes that will be compared to other datasets will need to be reprocessed with full-spectral coverage

Timeline:

- Image data acquisition (2 days)
- Spectral analysis, image processing (2 days)

To be completed by:
USF

Cost:

- $0

Data set: Airborne observational survey data for imagery ground truth

There are several observational datasets that may be useful for ground truthing the analysis of the remote sensing data. These include multi-year aerial survey data from Dauphin Island Sea Lab (DISL) and overflight observations that were generated by the DWH response and NRDA teams in 2010.

Tasks:

A. Incorporate Dauphin Island Sea Lab *Sargassum* data (complete)
B. Incorporate Dauphin Island Sea Lab photos for oil and *Sargassum* including concurrence with AVIRIS/Landsat/MODIS
C. Evaluate the OR&R PhotoLogger database for response and NRDA geo-tagged observational photos for oil and *Sargassum*
D. Incorporate photos of oil, *Sargassum* and mixed oil/*Sargassum* into PhotoLogger and ERMA

Timeline:
- unknown

To be completed by:
Sean Powers (Dauphin Island Marine Lab), George Graettinger (OR&R/SDB), other parties as appropriate

Cost:
- $10K Dauphin Island Marine Lab

Data Set: Environmental data (currents, circulation, wind, temperature)
Sargassum tends to aggregate on ocean fronts, and they may be dissipated by high winds. There may also be an optimal temperature range for *Sargassum* growth. Knowledge of these, and other environmental variables, may help understand *Sargassum* biomass distributions and their temporal changes.

Tasks:
A. Acquire applicable data available from NRL, NOAA NDBC buoys, MODIS color and SST imagery from 2000 to date

Timeline:
- Data collection for entire time-series (2 months)

To be completed by:
USF

Cost:
- $20K

Data set: Field measurement of *Sargassum*
Currently there are no data to relate spectral reflectance derived from satellites to 1) biomass per area and 2) carbon nitrogen content per area. Nor have reflectance spectrum measured *in situ* from *Sargassum* been published in either refereed or grey literature. However, unpublished lab spectral data from 2010, and unprocessed spectral data from 2011 cruises do exist. This field derived component will be used to develop algorithms to relate spectral reflectance to biomass and carbon nitrogen content, and to allow remote-sensing based distribution estimates, if a quantitative assessment instead of relative changes is desired. The field data will also be used to develop the method to spectrally differentiate *Sargassum* from oil and unoiled *Sargassum* from oiled *Sargassum*.

Tasks:
A. Determine if the field measurements made in 2010 and 2011 are appropriate.
   - Analyze the data collected in Fall 2011.
   - Secure and analyze any other relevant measurements
B. Consider additional field data collection needs if the data are not sufficient (collections would be made under a separate addendum).

C. Determine the biomass and carbon nitrogen content per area (m^2) of *Sargassum*.
D. Develop a method to correlate spectral measurements to carbon and nitrogen content.

Timeline:

- Field sampling (complete)
- Field sampling analysis (~2 months)

To be completed by:
B. Lapointe of Florida Atlantic University/Harbor Branch Oceanographic Institute and USF

Data Analysis Cost:

- $15K, USF
- $15K, Lapointe

Activity 2. Data synthesis, spectral analysis, method development

Existing methods to detect and quantify the relative patterns of *Sargassum* rely mainly on the reflectance "red-edge" in the 700-800 nm (NIR), where many other materials (including oil) in the ocean also show similar red edge effects. Examining the visible spectrum can separate Trichodesmium mats from others, yet the method for differentiating *Sargassum* from oil and unoiled from oiled *Sargassum* is yet to be developed. Because they may be spatially similar (i.e., all can form thin surface slicks), the spectral analysis will be used to develop spectral fingerprints of these materials. Field measurements will be made to define spectral signatures, and develop and implement algorithms to apply to satellite data.

Tasks:

A. Develop method to differentiate *Sargassum* using remote sensing data
   - This step will rely on all above, and will be a labor intensive and iterative process.
B. Develop detection limit for *Sargassum* for the satellite sensors
   - Define the minimum patch sizes that can be detected for the platforms used.
   - This work will leverage the AVIRIS data for the lower resolution images
C. Develop uncertainty estimates when Landsat and MODIS are used for *Sargassum* mapping

- Satellite data suffer from atmospheric interference and large pixels. Thus, AVIRIS data will be used to ground truth, and to gauge the uncertainty in, the *Sargassum* estimates (weight per area) after pixel unmixing and spectral shape/magnitude analyses. Basically, if only a partial pixel (from either Landsat or MODIS) contains *Sargassum*, the spectral reflectance of that pixel is a linear mixture of *Sargassum* reflectance and non-Sargassum reflectance (usually water). Their individual proportions can be determined by examining the reflectance magnitude between Landsat/MODIS (large pixels) and AVIRIS (smaller pixels). Statistics such as Root-Mean-Square differences and standard deviations will be used to describe uncertainty.

Timeline:

- 3 – 5 months
- The uncertainty in this timeline estimate is due to potential problems that may be encountered during spectral finger printing, pixel un-mixing, and other factors related to the various surface features (e.g., sun glint contamination).
- Dr. Hu will need to train 1 - 2 people on various techniques and "methods."

To be completed by:

USF and USGS

Cost:

• USGS:	2 months x 2 people	$60K
• USF	7 person months	$101K
	Total	$161K

Products/Deliverables:

The output of this step is a documented method and implemented computer code and procedure (including visual examination, manual delineation, and visual interpretation) to spectrally differentiate *Sargassum* from oil (and oiled *Sargassum*) and develop estimated *Sargassum* biomass (if applicable), along with an algorithm describing any uncertainties with the method.

The mapping team will provide an update to the Trustees and BP on the method development to facilitate the decision to move into Phase 2.

Phase II. Algorithm Validation

Activity 3. Validation and Accuracy assessment

Once Activity 2 is complete the method will be tested using a different set of LANDSAT and MODIS scenes in combination with other datasets developed in Activity 1. This work will validate the methodology and clear the way for performing wider analyses and generating large scale datasets.

Tasks:

A. Identify 2010 and/or 2011 LANDSAT and MODIS images representing up to 8 candidate combinations of environmental conditions coincident with AVIRIS (independent from those used in the algorithm development)

    - Several representative scenarios will be chosen for high/low wind, strong/weak circulation, and warm/cold temperatures. We will analyze up to 8 candidate combinations of environmental conditions.

B. Perform analysis to estimate coverage of the three classes
    - Classes: *Sargassum*, non-*Sargassum*, (i.e., oil or other vegetation), and oil-contaminated *Sargassum*

C. Perform validation and accuracy assessment on the output of 3B using independent airborne data (sightings/photos and hyperspectral) and/or in situ biomass
    - The accuracy assessment includes uncertainty statistics such as Room-Mean-Square difference and standard deviations in the weight per area estimates.

Timeline:

- 3 months

To be completed by:

USGS and USF

Cost:

• USGS:	1 months x 2 people	$30K
• USF	6 person months	$71K
	Total	$101K

Products/Deliverables:

The output of this step is an uncertainty matrix of the major results of the *Sargassum* detection work: 1) classification result 2) area coverage with biomass estimates and 3) initial limitations of measure (how much *Sargassum* must be present for identification).

The mapping team will provide an interim progress report to Trustees and BP to facilitate the decision to pursue Phase III and Phase IV.

Phase III. Spatial and temporal distributions of *Sargassum* in 2010

Activity 4. Initial assessment

With the validated method we will begin larger scale analyses. The focus of this activity will be to analyze the *Sargassum* community for 2010 in the Gulf of Mexico. Biomass, distribution and density will be analyzed for three time periods: before the spill, during the summer of 2010 and after dissipation of surface oil in mid to late fall, 2010. Some sample results, based on simple visualization, are presented in Fig. 3. Once validated with the developed algorithm, the imagery products will provide estimates of weight per area and total weight in the study region for the image date. A time series of such images will establish the temporal changes of *Sargassum* abundance.

Tasks:

A. Determine 2010 *Sargassum* biomass distribution and density during three timeframes before, during, and after surface oiling has dissipated
   - Generate these data within one week (or other reasonable timeframe that will allow modeling)
   - R. Hardy has already generated the 2010 Landsat map without the oil spill time window. The work needs to include that window and include MODIS (more frequent observations but at much lower spatial resolution)

B. Determine whether there was a change in distribution and density across the three periods.

C. Depending on method development, attempt to determine what percent of *Sargassum* was contaminated by oil during the spill*

Timeline:

- 3 months

To be completed by:

USF

Cost:

- USF 7 person months $81K

Products/Deliverables:

The output of this step will be a spatial/temporal distribution map of *Sargassum* before, during, and after surface oiling has dissipated.

* Note: We currently do not have a developed method for differentiating oil-contaminated *Sargassum* from uncontaminated *Sargassum*. Nor do we have a method to differentiate oil from *Sargassum*. The figures shown above are for *in situ* and laboratory measurements. The result of this task is subject to developing an acceptable method in Phase I and Phase II.

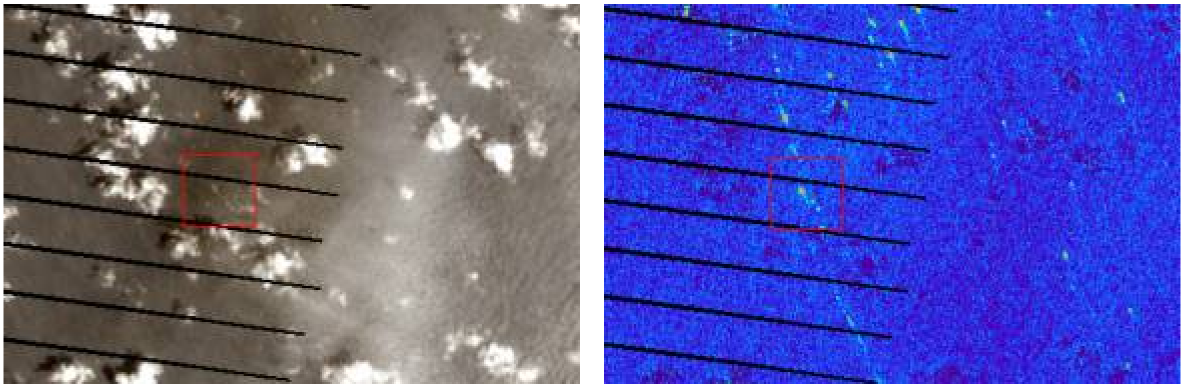
Phase IV. Historical baseline and post-spill changes.

Temporal scope

While documenting short-term (annual or seasonal) changes may be straightforward given available validated algorithms, interpreting these changes requires an understanding of the mean condition and natural variability. This approach has been used in Hu et al. (2011) to examine post-spill phytoplankton fluorescence changes using 2002 – 2009 MODIS data as the baseline. Similarly, NOAA's Coral Watch Program used 1985-1993 (9 years) sea surface temperature data to establish an SST baseline to assess anomaly events (http://ceosplenary17.noaa.gov/satellite/methodology/methodology.html). The Gulf of Mexico experienced several hurricanes during 2004 and 2005 which may have had a significant effect on the ecosystem during those years. To establish a statistically meaningful baseline for *Sargassum* distribution and abundance, the data need to cover a number of years free from significant storm effects. Thus, we will begin assessing pre-2010 data in 2000.

Separating oil sheens from *Sargassum*

Natural seeps will not interfere with this Plan because seeps generate thin oil sheens. It is straightforward to differentiate oil sheens from *Sargassum* in both MODIS and Landsat images, because oil sheens are either spectrally flat (i.e., smooth in reflectance spectra) or have relatively lower NIR reflectance, while *Sargassum* has a reflectance peak in the near-infrared (700 – 900 nm) (e.g., Hu et al., 2009). When running the FAI, various features in the true-color (RGB) image (thin clouds, cloud shadows, waves, fog) disappear (Fig. 5). Oil sheens show no contrast or negative contrast in FAI images (i.e., darker slicks, Fig. 6), while *Sargassum* shows positive contrast (Fig. 3, Fig. 5). The example in Figure 6 shows the approach for detecting oil sheens from natural seeps. The purple color in the FAI image indicates negative contrast, distinguishable from *Sargassum* in other images with positive contrast (e.g., Fig. 3). This technique will enable accurate separation of oil sheens (along with other artifacts such as waves and cloud shadow) from *Sargassum* in 2000-2009 as well as in 2011.



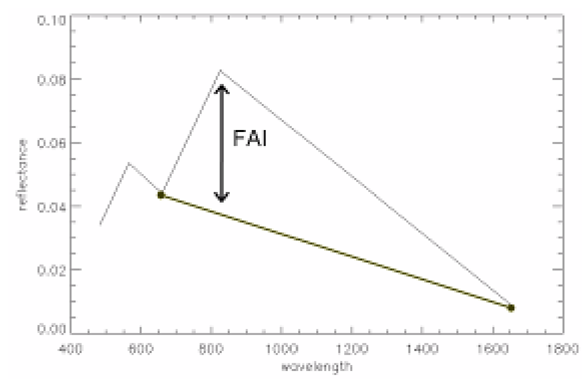


Fig. 5. Landsat ETM+ images showing (clockwise from top left) true-color RGB image, floating algae index (FAI, Hu, 2009) image, and spectral shape extracted from the red box. This shape is typical for pelagic *Sargassum*.

Fig. 6. MODIS true-color RGB (left) and FAI (right) images showing oil sheens from natural seeps. Note that these slicks have relatively lower NIR reflectance, resulting in negative contrast in the FAI image (purple color). In contrast, *Sargassum* has relatively higher NIR reflectance, resulting in positive contrast in the FAI image (Fig. 3).

Activity 5. Long-term time series to document change

This step will extend Activity 4 by including other years (presumably 2000 – 2009, and also 2011), with four objectives:

1. Document seasonality of *Sargassum* distribution;
2. Document inter-annual variability of *Sargassum* distribution;
3. Attempt to understand what drives the natural variability of *Sargassum*;
4. Document whether the post-spill *Sargassum* size is statistically different from previous years during the same season/months (e.g., Hu et al., 2011)

Timeline:

- 8 months

To be completed by:

USF

Cost:

- USF 8 person months $101K

Products/Deliverables:

The output of this step includes: 1) baseline information (maps and figures) on historical *Sargassum* distributions; 2) analysis of seasonal and inter-annual changes in relation to environmental conditions (temperature and wind); 3) statistical analysis of post-spill *Sargassum* distributions in comparison with baseline.

Data Handling and Sharing
MC 252 NRDA chain-of-custody procedures will be observed at all times for all NRDA samples. All samples will be transferred with appropriate chain-of-custody forms.

All field and laboratory data will be collected, managed and stored in accordance with written SOPs. The appropriate training on particular equipment or in the conduct of specific field studies for all personnel involved with the project shall be documented and those records shall be kept on file for the duration of this project.

For chemical analyses that are identified in the Analytical Quality Assurance Plan (AQAP, version 3.0, December 2011), each laboratory shall simultaneously deliver raw data, including all necessary metadata, generated as part of this work plan as a Laboratory Analytical Data Package (LADP) to the trustee Data Management Team (DMT), the Louisiana Oil Spill Coordinator's Office (LOSCO) on behalf of the State of Louisiana, and to BP (or CardnoENTRIX on behalf of BP). The electronic data deliverable (EDD) spreadsheet with pre-validated analytical results, which is a component of the complete LADP, will also be delivered to the secure FTP drop box maintained by the trustees' DMT. Any preliminary data distributed to the DMT shall also be distributed to LOSCO and to BP (or CardnoENTRIX on behalf of BP). Thereafter, the DMT will validate and perform quality assurance/quality control (QA/QC) procedures on the LADP consistent with the authorized Analytical Quality Assurance Plan, after which time the validated/QA/QC'd data shall be made available simultaneously to all trustees and BP (or CardnoENTRIX on behalf of BP). Any questions raised on the validated/QA/QC results shall be handled per the procedures in the Analytical Quality Assurance Plan and the issue and results shall be distributed to all parties. In the interest of maintaining one consistent data set for use by all parties, only the validated/QA/QC'd data set released by the DMT shall be considered the consensus data set. In order to ensure reliability of the consensus data and full review by the parties, no party shall publish consensus data until 7 days after such data has been made available to the parties. Also, the LADP shall not be released by the DMT, LOSCO, BP or CardnoENTRIX prior to validation/QA/QC absent a showing of critical operational need. Should any party show a critical operational need for data prior to validation/QA/QC, any released data will be clearly marked "preliminary/unvalidated" and will be made available equally to all trustees and to BP (or CardnoENTRIX on behalf of BP).
This plan will be implemented consistent with existing trustee regulations and policies. All applicable state and federal permits will be obtained prior to conducting work. All analytical and non-analytical data will be provided to BP/CardnoENTRIX and all trustees within a reasonable timeframe. All samples collected pursuant to this Addendum will be submitted to laboratories that are operated in a manner that is consistent with the guidelines of the Analytical Quality Assurance Plan for the Mississippi Canyon (Deepwater Horizon) Natural Resource Damage Assessment (version 3.0).

For non-chemical analyses or chemical analyses that fall outside the scope of the AQAP, each laboratory (i.e. any testing facility analyzing samples) shall simultaneously deliver raw data, including all necessary metadata generated as part of this work plan as a Laboratory Analytical Data Package (LADP) to the trustee Data Management Team (DMT), the Louisiana Oil Spill Coordinator's Office (LOSCO) on behalf of the State of Louisiana and to BP (or CardnoENTRIX on behalf of BP). The LADP shall contain analytical results, all supporting information used in calculating results, and other metadata needed to facilitate data verification (review) or validation by a third party. Once the LADP has been reviewed internally or by a designated project manager overseeing the laboratory work, it shall be submitted to the Trustee Data Management Team (DMT) via the secure FTP drop box maintained by the DMT with copies transmitted to LOSCO and BP. The DMT will coordinate with each laboratory through the lab's designated project manager to determine the appropriate format and required content for each type of data set. As laboratory review processes are completed, each laboratory shall upload results, additional metadata and quality control information, and other information determined to be appropriate to support these data (i.e., sample tracking forms, laboratory data sheets, and COC forms) to [redacted], with copies to LOSCO and BP. The DMT will pair field sample information with the laboratory results and perform a completeness check to ascertain that the laboratory information matches up properly with field sample information and all field information has associated laboratory information. Thereafter, the DMT shall make the data and associated laboratory data deliverable available simultaneously to all trustees and BP (or CardnoENTRIX on behalf of BP) on [redacted] Any questions about the data as posted on [redacted] shall be handled consistent with the procedures in Section 7.2 of the AQAP and the issue and resolution shall be recorded on [redacted] and distributed to all parties. In the interest of maintaining one consistent data set for use by all parties, only the DMT checked data shall be considered consensus data. In order to ensure reliability of the consensus data and full review by the parties, no party shall publish consensus data until 14 days after such data have been made available to the parties. Also, raw or preliminary data shall not be released by the DMT, LOSCO, BP or CardnoENTRIX prior to the DMT completeness check absent a showing of critical operational need. Should any party show a critical operational need for data prior to finalization of the completeness check, any released data shall be clearly marked "preliminary" and will be made available equally to all trustees and to BP (or CardnoENTRIX on behalf of BP).

Sample Retention

All materials associated with the collection or analysis of samples under these protocols or pursuant to any approved work plan, including any remains of samples and, including remains of extracts created during or remaining after analytical testing, must be preserved and disposed of in accordance with the preservation and disposal requirements set forth in Pretrial Orders ("PTOs") # 1, # 30, #35, # 37, #39 and #43 and any other applicable Court Orders governing tangible items that are or may be issued in MDL No. 2179 IN RE: Oil Spill by the Oil Rig "DEEPWATER HORIZON" (E.D. LA 2010). Destructive analytical testing of oil, dispersant or sediment samples may only be conducted in accordance with PTO # 37, paragraph 11, and PTO # 39, paragraph 11. Circumstances and procedures governing preservation and disposal of sample materials by the trustees must be set forth in a written protocol that is approved by the state or federal agency whose employees or contractors are in possession or control of such materials and must comply with the provisions of PTOs # 1, # 30, # 35, 37, #39 and #43.

Durable Equipment

All durable equipment (such as cameras, GPS, etc.) purchased by BP for this study will be returned to BP or their designated representatives at the conclusion of its use for this study unless otherwise agreed.

Budget Estimate and Timeline Summary

<u>PHASE I</u>

Activity 1:	Acquire and prepare the necessary remote sensing data	
	Data set: AVIRIS Airborne hyperspectral data	$30K
	Timeline: 4 weeks	
	To be completed by: USGS and USF	
	Cost: Preprocessing – 15K	
	Cost: Post-processing – 15K	
	Data set: LANDSAT	$5K
	Timeline: 1 week	
	To be completed by: USF	
	Data set: MODIS	$0
	Timeline: 1 week	
	To be completed by: USF	
	Data set: Airborne observational survey data for imagery ground truth	$10K
	Timeline: unknown	
	To be completed by: Dauphin Island Marine Lab, (OR&R/SDB)	
	Data Set: Environmental data (currents, circulation, wind, temperature)	$20K
	Timeline: 2 months	
	To be completed by: USF	
	Data set: Field measurement of *Sargassum*	$0
	Timeline: 2 months	
	To be completed by: FAU/HBOI and USF	
	Cost: Covered in different plan	
	Estimated Total Timeline: 6 months (+/-)	
	Estimated Total Cost:	**~$65K**
Activity 2:	Data synthesis, spectral analysis, method development	
	Timeline: 3 – 5 months	
	To be completed by: USF and USGS	
	Cost:	~$161K
Phase I	**Timeline: 9 – 11 months**	**~$226K**

<u>PHASE II:</u>

Activity 3:	Validation and Accuracy assessment	
	Timeline: 3 months	
	To be completed by: USGS and USF	
	Cost:	~ $101 K
Phase II	**Timeline: 3 months.**	**~ $101K**

<u>PHASE III:</u>

Activity 4:	Initial assessment Timeline: 3 months To be completed by: USF	~ $81 K

<u>PHASE IV:</u>

Activity 5:	Long-term time series to document change Timeline: 8 months To be completed by: USF	~ $101 K
Total	**Timeline: 23-25 months**	**$509K**

The Parties acknowledge that this budget is an estimate and that actual costs may prove to be higher. BP's commitment to fund the costs of this work includes any additional reasonable costs within the scope of this approved work plan that may arise. The trustees will make a good faith effort to notify BP in advance of any such increased costs

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