NASA CAN-02-OES-01

Sensor to User - Applying NASA/EOS Data to Coastal Zone Management Applications Developed from Integrated Analyses

(*Application Component - Final Report)*

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I. ABSTRACT

NASA and the Applied Coherent Technology Corp. (**ACT**) have been working under a Cooperative Agreement that uses NASA's data streams and ACT's architecture towards the implementation of Decision Support Tools for Coastal Management Applications. This effort directly involved NAVY/NRL-SSC, NOAA-NESDIS/CW/NCDDC, NOAA/NOS, and NOAA/CSC as team members.

Coastal management and research require real-time access to environmental data for analyses of changing ocean conditions. The coastal ocean is impacted by offshore mesoscale forcing as well as input from terrigenous land sources in response to human impact resulting from changing land uses. Monitoring and understanding the variability of the coastal ocean is critical for defining the dispersion of pollutants and chemical agents that impact our environment and potentially our homeland security.

ACT customized its existing architecture for demonstrating the ability/utility of integrating:

- **real-time satellite ocean properties (NRL/SSC),**
- **real-time observations (NASA,NOAA)**
- **numerical coastal and open ocean model output (NRL,NOAA)**
- **in-situ measurements (NOAA)**

for characterizing the ocean environment to support research efforts and operational programs at the National NASA Earth Sciences Applications Directorate (ESA) and NOAA. We enabled the integration of real-time databases of biological, chemical, and optical water properties using NASA Ocean Color and Sea Surface Temperature satellites, incorporating available coastal observations, and by operating ocean circulation models.

In particular, the architecture leverages on ACT's:

- WWW Information Processing Environment (**WIPE**) and
- ACT's Rapid Environmental Assessment Composition Tools (**ACT-REACT**).

This coastal observation architecture it is being demonstrated in the Gulf of Mexico at various temporal and spatial scales.

The system's architecture permits **direct interaction with the real-time data** for single-use or continuous automatic generation of user-specific customized products. Improved and customized satellite and model properties of the Gulf of Mexico were developed/demonstrated in concert with the analysts and provided through the ACT architecture.

NOAA/NOS has been working with ACT in expanding the demonstration to other applications and regions of interest, e.g Texas coast and Great Lakes region. *The resulting data and architecture in being evaluated this year by coastal manager and the researcher, providing them easy methods to test and understand ocean conditions through image and interactive displays of the local coastal ocean and meteorological conditions.*

II. Project Description

Applied Coherent Technology Corporation (**ACT**) and the Naval Research Laboratory (**NRLSSC**) Oceanographic Division, and our National Oceanographic and Atmospheric Administration (**NOAA**) partners, have been working in a cooperative agreement with NASA to maximize the value of NASA/EOS Earth science observations to decision makers related to coastal, marine, and ocean environments.

This final report concentrates on the component of the effort that ACT was primarily responsible for, i.e. the "Application Component" or architecture to facilitate that fusion/processing/analysis in a network centric manner. We are presently in the final year of our effort (which falls outside of the NASA funding period).

For completeness the following sub-sections provide the overall picture of the effort and may describe aspects of the collaboration with Naval Research Laboratory.

A. Our Original Overall Goals (with End Status)

ACT in collaboration with NRLSSC has been working under the REASoN CAN that integrates real-time ocean systematic measurements from NASA and NOAA satellites and available coastal observations along with coastal ocean model output into an automated real-time data base of ocean weather in the Gulf of Mexico. ACT in collaboration with NOAA expanded the project to other U.S. coastal areas and add additional NASA, NOAA, DoD and foreign data sources. The assemblage of the data combined with ACT's architecture (WIPE and ACT-REACT) allows methods for monitoring and detecting changes in the ocean environment on scales of hours, days, weeks and years which can be used for data manipulation and design of customized user specific products for coastal management.

The overall goal is to maximize the value of NASA's Earth Observing Satellites to the coastal management decision maker and educator. In particular the goals were:

- **provide an end to end pipeline** from EOS input, through data extraction services, emerging scientific algorithms, Web technologies, and applications – providing meaningful, easy to use environmental products to a diverse community of Coastal Zone Management decision makers.

  ***End Status*:** The end-to-end pipeline has been fine tuned and demonstrated leveraging in the ACT architecture (WIPE/REACT/MSHELL). NOOA is in the process of testing it for possible adoption by the HAB analysis group. In addition, *NASA teams have adopted many of the capabilities of the ACT WIPE/REACT architecture into on-going planetary missions, e.g. MRO/CRISM (JHU/APL), MESSENGER (JHU/APL), LRO/LROC (ASU), and CH-1/M3 (BROWN)* .

- **provide exciting new interoperability** between data supplier and end user with emphasis on GIS and Internet enabled applications to deliver high quality EOS based products.

  End Status: *The overall architecture has evolved to support different users, the data provider, the analysts, the decision makers, the managers, and the casual viewers. Different components were fine tuned to address the different spectrum of users.* That is,
  - ✓ WIPE server for automatic data ingestion and serving.
    (Ingests ALL relevant data streams from NASA/NOAA/NAVY)
  - ✓ ACT-REACT for fusing and analyzing the data.
    (A network centric workbench tool for the analyst.)
  - ✓ ACT-REACT-QuickMap for rapid access and browsing.
    (A simple to use tool for the managers and casual users.)

- **Ensure a smooth transition to the NPP/NPOESS era** by staying abreast of data constructs and providing a flexible architecture for the future.

  End Status: ACT pushed this as far as we could with the adoption of Open Soruce modules for data ingestion. The last step in the transition is Technology infusion and adoption. We are presently going over this state during the last (un-funded) year of the Cooperative Agreement effort.

B. Original Key Components to Address Objectives

To address our Goals and Objectives, the effort combined two key components. These are: '**Application Component'** and '**Product Research/Development'**.

(1) **Application Component** [**provided by ACT**] – providing a pipe-line architecture that addresses issues related to data ingestion, processing, distribution, access, and decision support.
  - Apply available MODIS Terra/Aqua, SeaWIFS, and AVHRR satellite data along with observational data, and coastal ocean model output to address Coastal Zone Management issues;
  - Automate product creation to permit applications experts to spend more time on product content/quality;
  - Expand an Internet-enabled system architecture to reach to all levels of applications provider and end-user; in particular the CoastWatch data system and its regional users.
  - Concentrate data/product distribution efforts on commonly-used formats, particularly in Geographic Information Systems.
  - Rapid adaptation and demonstration of new algorithms that generate relevant ocean properties to support Coastal Zone Management.

- Transition products to NPOESS Preparatory Project (NPP) Visible Infrared Imager Radiometer Suite (VIRIS) data when available.

(2) **Product Research/Development** component **[provided by NRLSSC]** – provides state of the art oceanographic expertise and research addressing issues related to generation of new geophysical data products as part of a production pipe-line.
    - Establish ocean properties for the Gulf of Mexico
    - Demonstrate rapid access for monitoring ocean conditions
    - Demonstrate real-time monitoring of ocean conditions
        - Remote Sensing bio-optical and thermal ocean properties (SeaWIFS, MODIS (AM, PM), AVHRR, NPP)
        - Modeling of the 3D physical ocean properties. NCOM/ HYCOM
    - Identify new applications of ocean properties for monitoring coastlines
        - New customized ocean products for target focus areas
        - Provide customized products using experimental monitoring

Study Area

The Gulf of Mexico represents a diverse ocean region in which both major ocean circulation and coastal circulation occur. The interaction of the Loop Current with coastal circulation represents significant impact of open ocean and coastal water properties. The Mississippi River outflow, in addition to other rivers discharging to the Gulf, makes this a complex ocean region with a number of bio-optical provinces and physical processes. Additionally there are a number of NOAA relevant issues which occur in the Gulf of Mexico including the HABs, Hypoxia and fresh water outflow. Therefore, we have suggested using the Gulf as prime area to initially demonstrate use of ocean properties to support coastal management decisions.

Methods and applications used in this project may be extended to other coastal regions around the country. It is expected that during this project, ACT, in conjunction with the NOAA partners, will extend the data flow provided by NOAA to other regions as well as integrate other sensors/models into this sensor-to-user architecture.

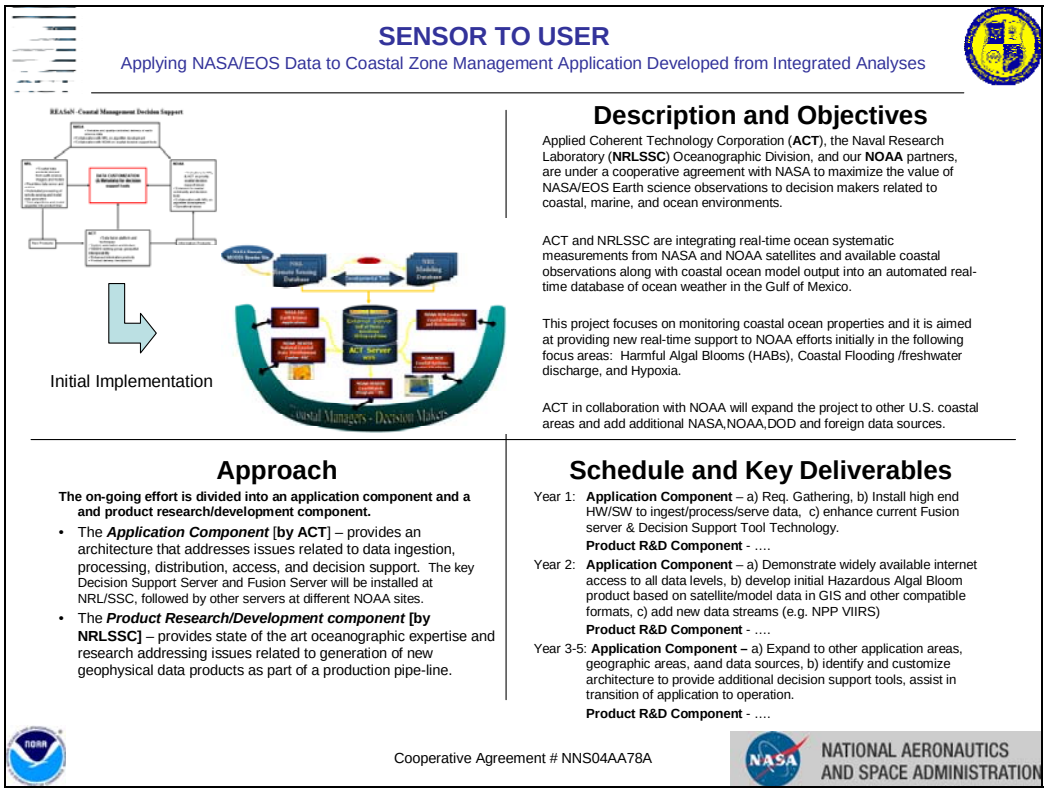


Figure 1 Quad Chart Summarizing Cooperative Agreement. Funded Period (5/2004-5/2009). We are presently on the unfunsed 6th year (per original proposal).

C. Target Application, Relevance, and Focus

We targeted the following high national priority application area**: Global Measurements and Predictions for Coastal Zone Management**. Our approach benefits decision support work in Disaster Management and other areas of national interest.

New NASA sensors, improved data-processing algorithms, and the spread of powerful personal computers with Internet access have made it possible to bring crucial data to decision makers. Ocean modeling has advanced to the point where forecasts of ocean conditions become meaningful both in terms of resolution and skill. One challenge is to transform the almost incomprehensible amount of multi-platform, multi-sensor, multi-spectral data into meaningful, quality-controlled, highly-tailored information products in a form compatible with the growing GIS community and other developing data standards. Forecasters, commercial fisherman, coastal zone managers, marine sanctuaries, and federal, state and local environmental agencies are among the end users of the information products which are crucial to coastal safety, environmental concerns, and national and local economies. Educators, too, can use this data to excite students and teach core scientific concepts, provided it is properly packaged in an easy-to-use form. The

audience for these data, imagery and applications output is growing: **75% of the world population will live within 100 kilometers of a coast by 2025.** CoastWatch currently has over 10,000 registered users, with many times this number of occasional users.

High resolution MODIS data, fused with SeaWiFS, QuickSCAT and other legacy POES/GOES sensors and combined with ocean observations and models, through technology upgrades, can produce a new decision-support product suite unlike anything now available to the Coastal Zone Management community.

This project focused on monitoring coastal ocean properties and it is was aimed at providing new real-time support to NOAA efforts initially in three areas that are major Program Focus Areas:

- **Harmful Algal Blooms (HABs)**
- Coastal flooding / freshwater discharge
- Hypoxia

With the guidance of NOAA/NOS, ACT worked on creating an implementation that facilitates adding other applications and expanding the application regions beyond the Gulf of Mexico.

D. Approaches for: Data Production, Distribution and User Support

Our approach for this Cooperative Agreement is to ingest multi-platform, multi-sensor, multi-variable data sets into ACT's existing system architecture which will fuse the data and allow users to analyze across data sets and create products from NASA and non-NASA earth observing systems, model data, and *in-situ* observations.

In order to meet the needs of researchers, decision makers and educators, we focused on providing a broad array of output options. *Our envisioned users will have access to* ***both data and products***. The data fusion platform allows them to access sensor data via the Internet, to query that data in four dimensions (x,y,z and time), and to apply algorithms on the fly. Coastal Management Zone decision makers have invested heavily in GIS systems, which are becoming a de-facto standard in data presentation and analysis, and ***we thus fully support GIS systems***.

Ocean environmental data is automatically generated each day for characterizing the ocean environment in the Gulf of Mexico. All satellite data for the Gulf of Mexico will be obtained from the NASA Direct Broadcast at NASA Stennis Space Center MODIS receiver and the NRLSSC SeaWIFS and POS receiver for the Gulf of Mexico. These data is processed within hours using the APS software package and stored in a data base. Since satellite imagery is highly contaminated by the cloud cover we propose to alleviate these problems by generating the following for analysis by the users:

- Individual satellite images

- Daily composite images (composite of all satellite images collected on that day)
- Latest pixel composites (most recent valid pixel within a week)
- Weekly composites
- Monthly composites
- Annual composites

The NCOM model is run each day for the Gulf of Mexico. The model is forced with auxiliary wind field and surface flux fields as well as assimilating sea surface height fields from altimetry data. Databases will be generated each day for the model outputs.

The ocean properties are processed at NRLSSC and placed in a 30 day revolving archive with over 900 ocean properties per day. NRLSSC will establish a Distributed Ocean Data Server (DODS)/ Open Source Project for a Network Data Access Protocol (OpenDAP) server for this project. DODS/OpenDAP is web based data server, developed within the Unidata Program Center at the University Corporation for Atmospheric Research (UCAR), initially for oceanographic applications.

For seamless integration and overlay, the satellite and model databases are in standard data formats. The target data formats for this project are based on current archiving formats as follows: satellite imagery within the data base would be stored in Hierarchal Data Format (HDF), and the ocean model output will be archived in the data base in Network Common Data Format (NetCDF).

Per the original plan, NRL/SSC produces approximately 300 satellite ocean properties and 600 physical ocean properties per day. This is a substantial number of ocean properties to assemble and maintain. However, as new advances in the products evolve, we expect that algorithms will change and the model outputs will change to meet the requests of the customers and this number will change in response to feedback. For example the output of the mixed layer depth, or the scattering to absorption ratio (used in HAB identification) can be used to replace existing products.

These ocean data coupled with the WIPE servers located at NOAA, ACT, NRLSSC and entered into the WIPE format. Limited access to the NRLSSC server and ACT server is provided to the NOAA Centers and NASA –ESA. *All direct customer interface is through NOAA.* New and improved ocean properties will be identified and coupled into the NRLSSC ocean property generation. Figure 6 highlights the initial program architecture that will be used at NRL-SSC[1].

[1] Since WIPE is a network centric architecture, ACT worked with NASA and NOAA to identify other sites for which WIPE servers can be located, e.g. NOAA/COASWATCH vs ACT facility.

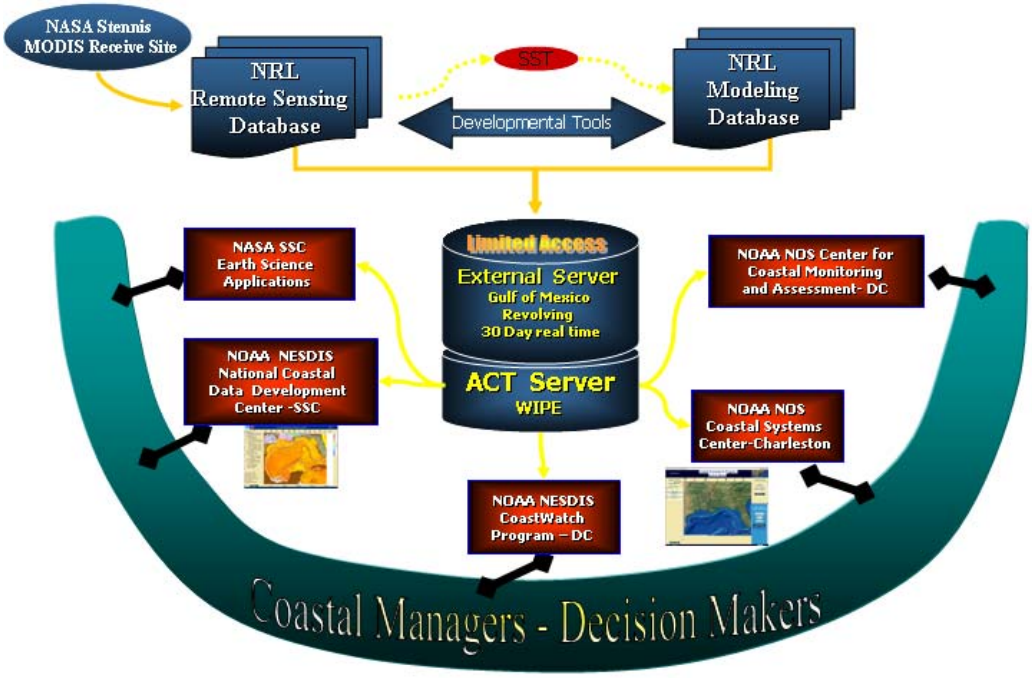
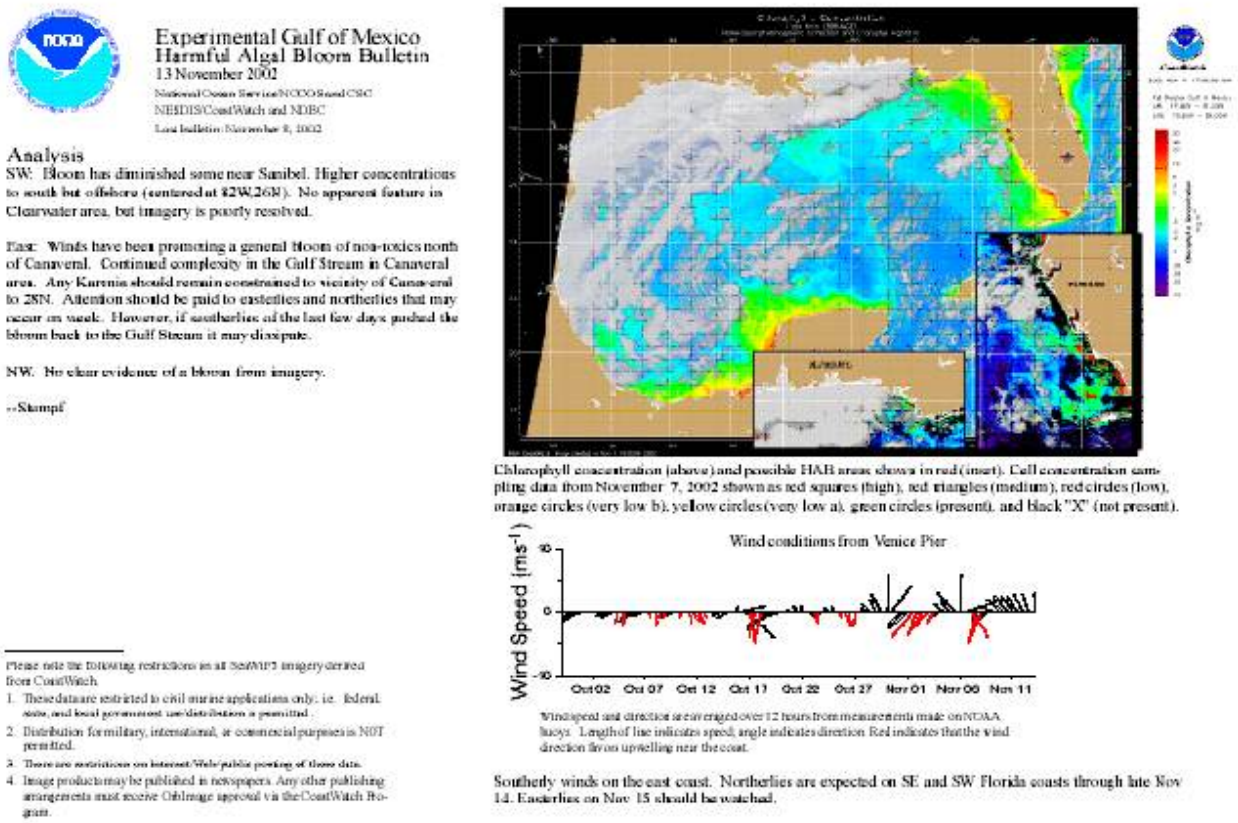


Figure 2. Initial Program Architecture

HAB Forecasting Application Example

The goal of the NOAA HAB Forecasting project is **"effective management of fisheries, public health, and ecosystem problems related to marine biotoxins and harmful algae"** (Anderson, Galloway and Joseph, 1993). Satellite monitoring can detect conditions suitable for bloom development and track a bloom as it moves, allowing users to predict when and where a coastal region would be affected by a bloom.

One of the many NOAA efforts on behalf of the coastal zone constituency is the Harmful Algal Bloom Bulletin. Figure 7 is a Gulf of Mexico example.



Experimental Gulf of Mexico
Harmful Algal Bloom Bulletin
13 November 2002
National Ocean Service/NCCO Stand CSC
NESDIS/CoastWatch and NDBC
Last bulletin: November 8, 2002

Analysis

SW: Bloom has diminished some near Sanibel. Higher concentrations to south but offshore (centered at 82W,26N). No apparent feature in Clearwater area, but imagery is poorly resolved.

East: Winds have been promoting a general bloom of non-toxics north of Canaveral. Continued complexity in the Gulf Stream in Canaveral area. Any Karenia should remain constrained to vicinity of Canaveral to 28N. Attention should be paid to easterlies and northerlies that may occur on week. However, if southerlies of the last few days pushed the bloom back to the Gulf Stream it may dissipate.

NW: No clear evidence of a bloom from imagery.

--Stumpf

Please note the following restrictions on all SeaWiFS imagery derived from CoastWatch.

1. These data are restricted to civil marine applications only; i.e. federal, state, and local government use/distribution is permitted.
2. Distribution for military, international, or commercial purposes is NOT permitted.
3. There are restrictions on Internet/Web/public posting of these data.
4. Image products may be published in newspapers. Any other publishing arrangements must receive OrbImage approval via the CoastWatch Program.

Chlorophyll concentration (above) and possible HAB areas shown in red (inset). Cell concentration sampling data from November 7, 2002 shown as red squares (high), red triangles (medium), red circles (low), orange circles (very low b), yellow circles (very low a), green circles (present), and black "X" (not present).

Windspeed and direction are averaged over 12 hours from measurements made on NOAA buoys. Length of line indicates speed, angle indicates direction. Red indicates that the wind direction flows upwelling near the coast.

Southerly winds on the east coast. Northerlies are expected on SE and SW Florida coasts through late Nov 14. Easterlies on Nov 15 should be watched.

Figure 3 Current Experimental NOAA HAB Bulletin

Our HAB GOAL under the Cooperative Agreement

Creating this product now requires significant time. The product requires gathering information from multiple sources (SeaWiFS satellite data and surface wind observations), making data cuts, adding analyses and text, and formatting for output. We planned to extend the capabilities of the ACT's WIPE application (described below) to partially automate this process. The new application will

serve MODIS, *in-situ* data, and ocean model predictions, automatically make data cuts (see subsets in figure 1) and create an output in the format required. Additionally hybrid products from integrated analyses will developed by NRLSSC will reside in the new application. The new application will allow the analyst to concentrate on analyzing the data and presenting a higher quality output to the end user. The user will be allowed to choose from a menu of output formats. The end result will be a more easily constructed higher quality and therefore more useful product.

E. Earth System Science User Support

We specifically targeted the Coastal Zone Management community based on the availability of specific NASA sensor data, our close working relationship with coastal zone managers, our in-depth knowledge of their challenges, and our plans for innovative product creation and distribution. We believe however, that our approach to filtering vast datasets down to usable volumes and formats can help application across many disciplines and thus, *as a later effort*, plan to expand this effort to other NOAA customers, to other coastal regions, and perhaps to the broader research community.

F. Management Approach Executed

Our effort involved four different organizations: NRLSSC, NOAA, NASA, and ACT. However, only ACT and NRLSSC were recipients of the funding and have the responsibility for project accomplishments.

- NRLSSC provided a real-time data stream of derived and modeled ocean properties
- ACT provided its custom COTS WWW Information Processing Environment (**WIPE**) architecture to serve this data stream and develop new ocean data products for the customer, i.e. the National Oceanographic and Atmospheric Administration (**NOAA**). *Using ACT's components a new capability called ACT-REACT was assembled to address the core requirements identified by the CA effort.*
- The NOAA Partners at NOS and NESDIS will be the extension of this effort into the coastal management community. Although unfunded, they are full participants in this proposal. NOAA highlight to ACT and NRLSSC operational issues and decision support issues. They collaborated with NRLSSC on algorithm development stemming from this integrated study. NOAA provided access to its POES and GOES data streams and also to other DoD, NASA, and foreign data streams.
- NASA provided the real-time EOS data stream and also collaborate with all parties on coastal support issues as well as scientific algorithm development. The interrelationship between the different groups is depicted in the Figure 9.

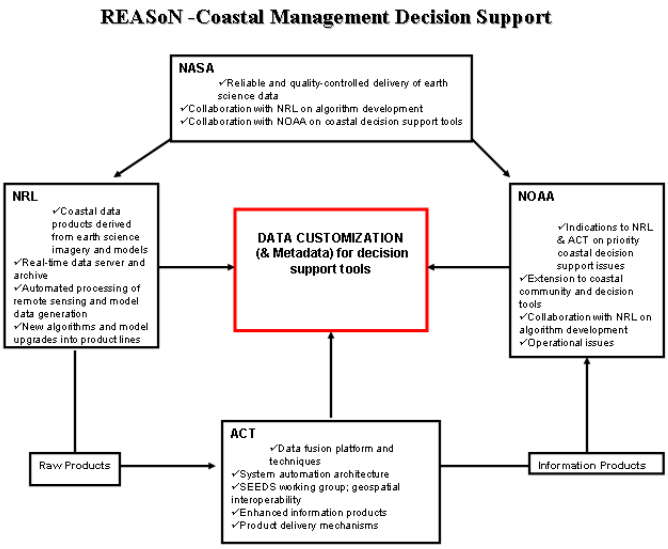


Figure 4. Cooperative Agreement organizational relationships.

G. NOAA and ACT Partnership

Although not funded by this project, NOAA/NESDIS was a full participant. NOAA is responsible to their myriad customers for a successful implementation of their Operational Oceanography vision. As such, they established the requirements and provide direction and guidance to ACT for technology innovation and application.

Interaction included expansion of access to CoastWatch current and future data and products via WIPE and REACT.

H. NRLSSC and ACT Interaction

The project was established as a joint effort between NRLSSC and ACT. The main components added by NRLSSC and ACT are: (1) NRLSSC providing a real-time data stream of derived and modeled ocean properties and (2) ACT determining methods to serve this data stream and develop new ocean data products for the customer (identified as National Oceanographic and Atmospheric Administration (NOAA)). NRLSSC has identified approximately 900 ocean properties per day in an organized data structure that will provide an enormous amount of real-time data to the ACT's WIPE environment.

For NRLSSC, ACT's effort provided a framework for serving their data to the customer and providing new capability to use these data. ACT's capability is critical for developing the infra-structure that will enable easy utility of NRLSSC data for customized product development. NRLSSC has developed new methods to determine real-time ocean properties as an extension of their research.

ACT's role is to enhance this research by providing a data delivery and analysis tools that are lacking within the customer community. By combining NRLSSC and ACT, our ability to monitor and provide methods for decision making in coastal areas are enhanced.

III. Approach Executed for the Application Component

The application component of this cooperative agreement presented ACT with real challenges in technology integration and implementation. It required a multi-year concentrated effort from a number of engineers and programmers at ACT. The end goal was simplicity in network centric data ingestion/process/fusion/analysis/publishing across many operating systems. The following provides the **roadmap followed together with examples of the outcome**. Early on, ACT's approach was strongly influenced from feedback by the cooperative agreement team members, the ESIP Technology Infusion Working Group, and the NASA planetary community (both operations and end-users).

A. Overview: Technology Development and Application

The core enabling technology is ACT's WWW Information Processing Environment[2] (**WIPE**). WIPE processes a subset of image and sensor data from NASA and non-NASA earth observing systems, model data, and *in-situ* observations. WIPE ingests over 200 environmental data streams, including legacy POES/GOES data, numerical model output, many surface observation types, climatology, bathymetry, and many others. It gives users ability to store and access all geo-spatially and temporally-referenced data through one simple interface. The user does not require knowledge of the original data format to access data or create products. The architecture allows for easy introduction of additional datasets. WIPE is widely deployed in support of NASA space missions.

WIPE uses a dual approach to data and product distribution. LAN/WAN/Internet users access the data interactively through a common web browser. The architecture allows everything from simple data query at cursor, to three-dimensional profiles, to creation of multi-layer and mosaicked images, and more. Users can create algorithms on the fly and run them against the data, with immediate results. Once algorithms are proven, they can be saved and repeatedly run against historical or new data.

WIPE also creates information products automatically, based on type of data, region of interest, projection, resolution, time stamp, desired output format, etc. *For example, in a deployment at the National Ice Center, WIPE ingests full DMSP OLS, AVHRR, QuickSCAT, RadarSat, SSMI and Numerical Model output data, extracts data subsets making geo-spatial and temporal cuts, places those products in a desired map projection (Polar Stereographic, Lambert Conformal , Mercator, ..) as specified, and outputs products in ERDAS Imagine (.img) (or GeoTiff, or …) format for viewing and/or downstream decision support system ingest. This automated flow - from sensor data input to user-specified product output - is the approach and technology that will tie us to our decision support and education customers.*

Out of the Box WIPE brings

- Automatic assimilation/processing of geo-spatial data.
- Rapid/interactive discovery, fusion, and distribution of data.
- Configurable from a single machine to a cluster of machines.

[2] Detail information can be found at http://www.actgate.com/home/wipe.htm

- Easy incorporation of new data formats for ingestion and delivery.
- Flexible WEB based GIS and image processing functionality.
- Efficient use of available bandwidth.
- Extensible via user-provided algorithms and applications.
- Simple client requirement standard web browser!
- Development Environment based on ACT's ProVIEW GUI and Interpreter Environment (MSHELL) ➔ This got repackaged under the CA as ACT-REACT.

As part of this cooperative agreement, ACT provided to our NOAA, NRL, and NASA partners, the WIPE/REACT/MSHELL systems , plus **customization**, administration, and tutorials, to address the identified/requirements of our partners.

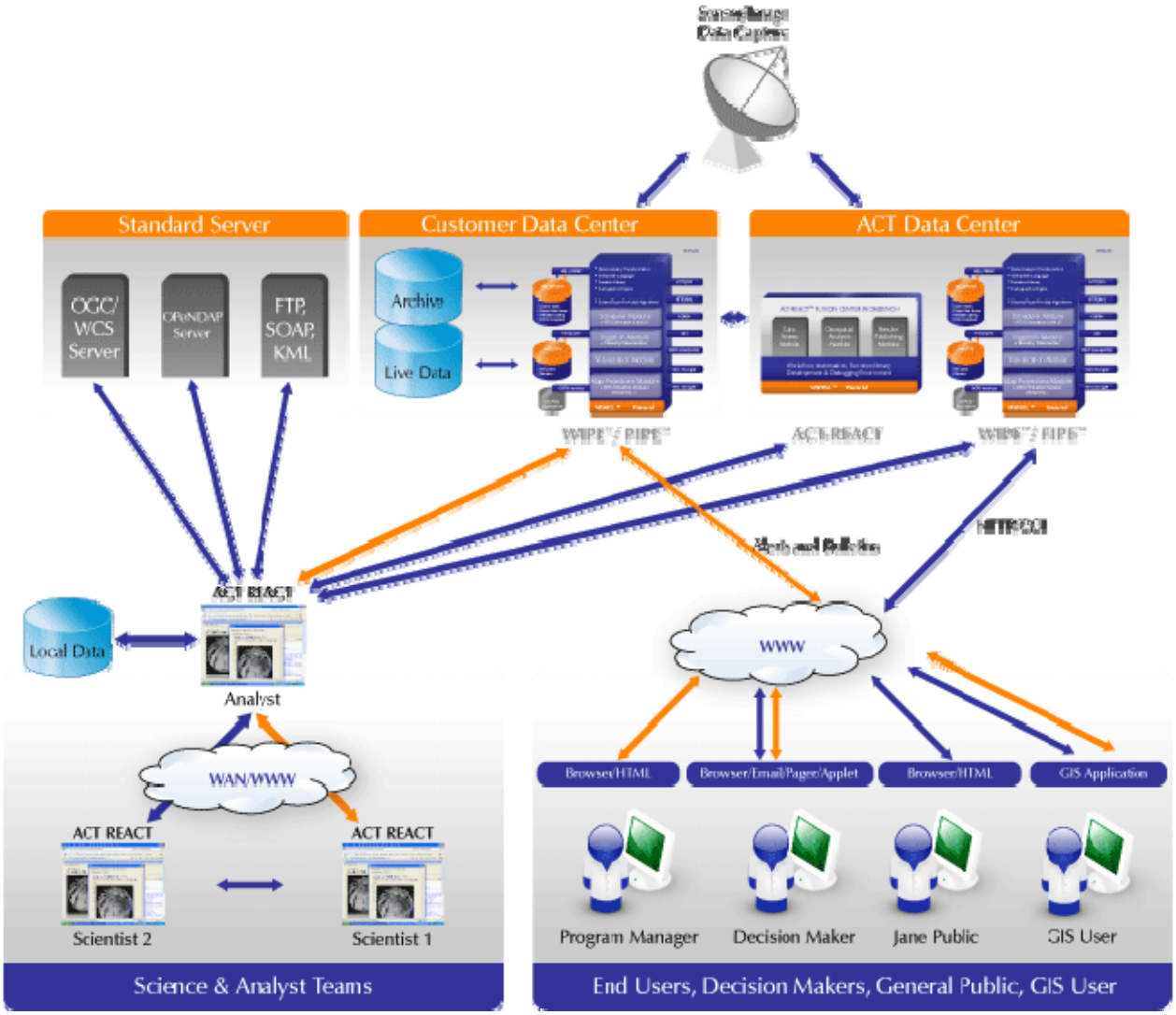


Figure 5. Simplified view of WIPE/REACT/MSHELL Architecture and relation to Users

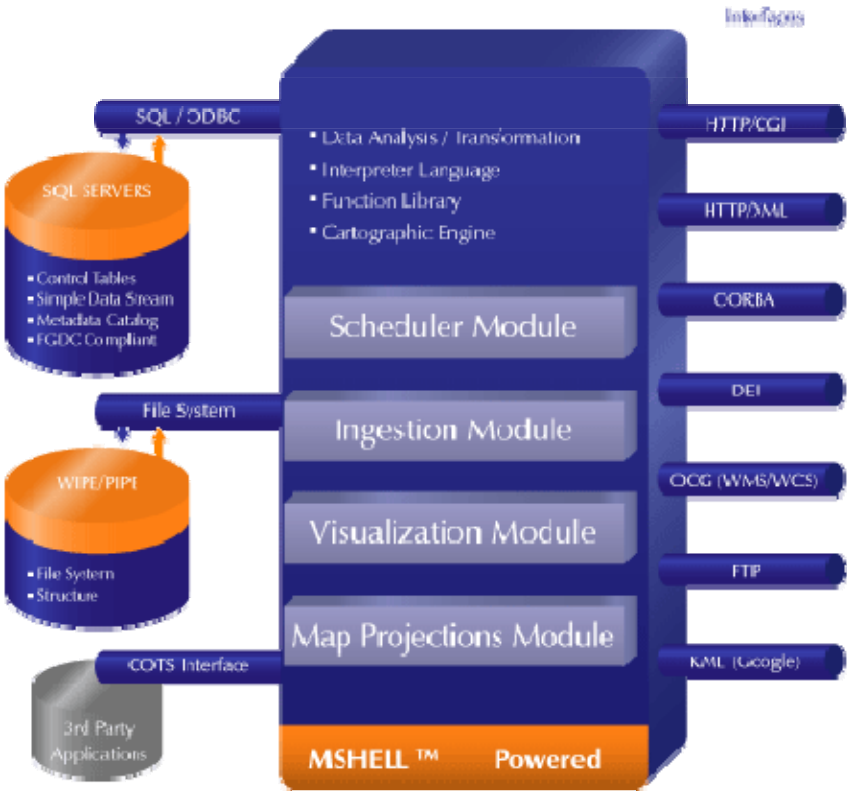


Figure 6. Simplified view of WIPE Server Components

NOAA Data System and CoastWatch Interface

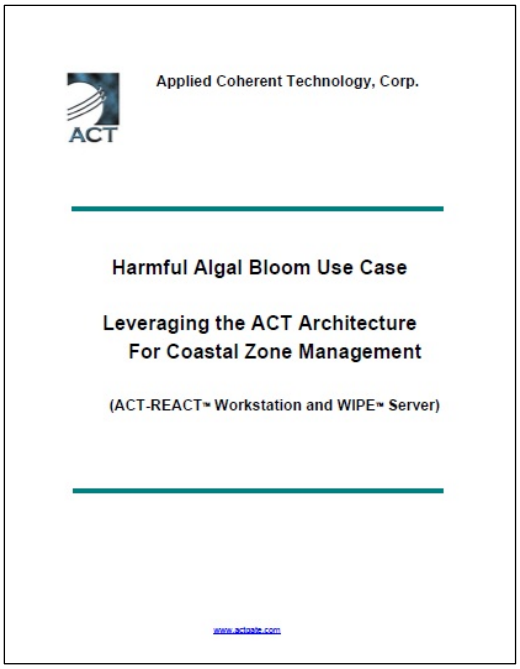
NOAA's CoastWatch Program makes environmental satellite data products and in-situ data available to Federal, state and local marine scientists, coastal resource managers, and the public. Managed by NOAA /NESDIS, the CoastWatch Program routinely processes satellite data in near-real-time. NOAA CoastWatch consists of two components: Central Operations and Regional Nodes. Seven regional nodes and a central office provide for the distribution pathway for CoastWatch data products. Central Operations, operated within NOAA/NESDIS, coordinates the processing, delivery, quality control and storage of data products. Other NOAA line offices participate in the NOAA CoastWatch Program by hosting equipment and personnel that make up a CoastWatch Regional Node providing for near real-time data distribution and regional scientific expertise to the local user community.

By folding the new data stream presentations of CoastWath, this project can easily exploit the valuable new data stream for coastal management applications in CoastWatch. When NPP VIIRS data becomes available, it will be high priority to add data and products from this sensor to the CoastWatch product suite, to lay the ground work for NPOESS NOAA products.

B. Identified Requirements

Most of the HAB requirements were captured in our **HAB Case Study**[3].
http://www.actgate.com/home/doc/ESIP_Case%20Study_Harmful_Algal_Bloom_Use_Case.pdf

This case study was done following the guidelines of the ESIP federation and as part of our Cooperative Agreement (CA) involvement with ESIP's Technology Infusion Working Group (TWIG).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Harmful Algal Bloom Use Case

Leveraging the ACT Architecture
For Coastal Zone Management

(ACT-REACT™ Workstation and WIPE™ Server)

www.actgate.com

In general the architecture component needed to be supportive of:

- DATA PRODUCER
- DATA ANALYST
- END-USER

Each type of user has different core needs, although they share common denominators.

After a number of meetings with NOAA/NOS, it was identified that the client side requirements in that fusion were too steep for just doing this in the WIPE JAVA-applet. It was proposed by ACT to then merge the ProVIEW + MSHELL + WIPE/Applet Capabilities into what is called now ACT-REACT (it stands for ACT's Rapid Environmental Assessment Composition Tools). In this way all the key capabilities identified by NOS can be addressed. The following table depicts the type of tool that we consider applies to the different type of users. They are all relevant for and end-to-end system.

User Type	WIPE (ingestion)	ACT-REACT (analysis/publishing)	ACT-REACT-QuickMap (rapid browsing)
Data Producer	HIGH	Medium	Medium
Data Analyst	LOW	HIGH	Medium
Decision Maker	LOW	LOW	HIGH
Casual End User	LOW	LOW	HIGH

The following sub-section provide an after the fact eagle view of the development path that took place for the different components. When possible we include screen shoots that better demonstrate the resulting capability.

[3] See (http://www.actgate.com/home/doc/ESIP_Case%20Study_Harmful_Algal_Bloom_Use_Case.pdf)

C. MSHELL – as the engine for WIPE and ACT-REACT

MSHELL is the engine used by both WIPE and REACT. More information on MSHELL can be found at

http://www.actgate.com/home/mshell.htm .

Our basic strategy is to make use of the same processing software engine at each node. This allows to bring data to a processing node or move algorithms to a processing node. Since all nodes can share algorithms this gives significant flexibility in how data is processed.

The following are high level enhancements/changes that were needed in MSHELL and **were achieved** under the effort:

- MSHELL bust be portable to all relevant Operating Systems
    - Portability to all platforms (LINUX flavors + Windows flavors + MAC/OS) forced us to identify early-on **TrollTech's Qt** as the core library that allow us to support all key platforms with their different system level calls and GUI calls
    - Qt provides fast, object oriented environment written in C++. Used by MANY Open Source and Commercial SW efforts.
- The Scripts tree contains generic and project specific functions, i.e. over 500 functions. As part of this effort:
    - **Specific script functions were written to facilitate access HDF files that use dense set of ground control points
    - Mapping functions were fine tune
    - Wrappers to JPL/NAIF/SPICE Library were added.
    - Wrappers to GDAL needed functions were added.
    - Wrappers to SOAP functions added.
    - **Shape file processing functions were fine tune
    - **Bi-directional Access between MSHELL and GUI interface
    - ****MSHELL distribution load to other MSHELL engines
        - Using SOAP
        - Adding new set of basic functions
- Maintain Documentation with application and on-line

D. WIPE: Technical Approach Followed

At a high level the following approach was followed (and achieved) in the customization of WIPE.

- **Configure WIPE to ingest **all HAB related data**
  - NRL HDFs
  - NOAA HDFs
  - NASA HDFs
  - …see table…
- Enhance WIPE's ability to generate custom products
  - HAB plots
  - RETRIEVAL OF HAB related files from NOAA and NRL
- **WIPE to behave as an OGC server
- *Enhance mapping functionality of WIPE.
  - * work with input products described in cartographic space.
  - * work with input products described in sensor space
    - This was critical for MODIS data described by a dense set of ground control points (GCPs)
- Enhance WIPE's ability to trigger alarms
- Install/Maintain WIPE servers in support of Cooperative Agreement
- ****Create custom interfaces to HAB related product
  - HAB summary products

DATA FORMAT SUPPORT (ONLY FORMATS SPECIFIC TO NRL/NOAA/NASA CA are being displayed)

Data Source	Format	Sub-datasets	Institution	Type	FGDX/XML	RAW Reader Status	Auto Scaling Reader	OS	WIPE	REACT	Population Scheme into WIPE
NRL											
NCOM-Salinity	**NRL-NetCDF**	volumetric	NRLSSC	MODEL	Not yet in WIPE	OK	YES	Win/Linux	Y	Y (ActiveLink)	push of sym.link
NCOM-SPEED	NRL-NetCDF	volumetric	NRLSSC	MODEL	Not yet in WIPE	OK	YES	Win/Linux	Y	Y (ActiveLink)	push of sym.link
NCOM-Surface-Elevation	NRL-NetCDF	N/A	NRLSSC	MODEL	Not yet in WIPE	OK	YES	Win/Linux	Y	Y (ActiveLink)	push of sym.link
NCOM-TEMP	NRL-NetCDF	volumetric	NRLSSC	MODEL	Not yet in WIPE	OK	YES	Win/Linux	Y	Y (ActiveLink)	push of sym.link
NCOM-U-velocity	NRL-NetCDF	volumetric	NRLSSC	MODEL	Not yet in WIPE	OK	YES	Win/Linux	Y	Y (ActiveLink)	push of sym.link
NCOM-V-velocity	NRL-NetCDF	volumetric	NRLSSC	MODEL	Not yet in WIPE	OK	YES	Win/Linux	Y	Y (ActiveLink)	push of sym.link
modlvl3_mosaic	**NRL-HDF**	MANY	NRLSSC		Not yet in WIPE	OK	YES	Win/Linux	Y	Y (ActiveLink)	push of sym.link
modllvl4_latest	NRL-HDF	MANY	NRLSSC		Not yet in WIPE	OK	YES	Win/Linux	Y		push of sym.link
NOAA CoastWatch											
GOES from NESDIS	N/A	N/A	NOAA/CW	OBS	Y	OK	N/A	Win/LINUX	Y	Y	push (ftp)
modis products	**GEOTIFF**	RGB	NOAA/CW	OBS dervied	Not yet in Place	OK	??	Win/Linux	Y	Y (ActiveLink)	push
mappend HDF	**CW HDF**	MANY	NOAA/CW	OBS + OBS Derived	Not yet in Place	OK	??	Win/Linux	Y	Y (ActiveLink)	push
mapped_masked HDF	CW HDF	MANY	NOAA/CW	OBS + OBS Derived	Not yet in Place	OK	??	Win/Linux	Y	Y (ActiveLink)	push
Swath HDF		MANY	NOAA/CW	OBS+ OBS Derived	Not yet in Place	??	??	??	??	??	
NASA BLUE Marble											
Modis Global Coverage 250m	GEOTIFF	N/A	NASA	OBS. composite	Not yet in WIPE	OK	N/A	Win/Linux		Y (ActiveLink)	only once
NASA											
MODIS L1B 250m	**HDF4**	MANY	NASA&NOAA	OBS	Not yet in WIPE	OK	N/A	Win/Linux	Y	Y (ActiveLink)	push
mod021km	HDF4	MANY	NASA&NOAA	OBS	Not yet in WIPE	OK	N/A	Win/Linux	Y	Y (ActiveLink)	push
NOS/HAB BULLETING											
Internal NOS products	**PCI/AUX**	1 or more	NOS	derived products	Not yet in WIPE	OK	float data	Win		Y(ActiveLink)	
MODIS/CW Chl. Anomaly	CW-HDF						?				pull (REACT/FTP)
MODIS/CW Chl. Anomaly	Geotiff						N/A				pull (REACT/FTP)
NDBC Buoy Data Files	text files						N/A				pull (REACT/HTTP)
NCEP NAM12 (winds)	GRIB						N/A				pull (REACT/HTTP)
OTHER											
NCOM-Speed-Virtual	N/A	N/A	WIPE/NRLSSC	derived	Not yet in WIPE	N/A	N/A	Win/LINUX	Y	N/A	
NCOM-particle-flow	N/A	N/A	WIPE/NRLSSC	derived	Not yet in WIPE			Win/LINUX			
NAVY/FNMOC											
many…	GRIB	volumetric	FNMOC	MODEL	Y	OK	N/A	Win/LINUX	Y	Y (not active)	pull (METCAST)

Figure 7 Data and format modalities added, e.g. NOAA/CW/HDF, NASA/HDF, NRL/HDF.

E. ACT-REACT: Technical Approach Followed

At a high level the following approach was followed (and achieved) in the customization of ACT-REACT .

1. ACT-REACT: High Level Technical Requirements

- Work with local and remote data
- **Support Interoperability with OGC+OpenDAP+FTP+… servers
- **Allow to have flexible ways of viewing and access the data
    - Fine layer control of the data layers
    - **Locate data in time and space over multiple servers
    - Add data probes to access actual data values at cursor position
- *Publish intermediate and final data products
- ***Create workflows (including new algorithms)
- **Publish workflows to server for use by other users
- Leverage on OpenSource Libraries or commercial
    - WIPE/PIPE
    - MSHELL
    - ProVIEW
    - Qt ➔ provides portable OS and GUI subsystem
    - GDAL ➔ provides open source raster IO library
    - Libcurl ➔ lower level network protocols
    - SOAP ➔ network based calls
    - SPICE ➔ Space Geometry library from JPL
- ACT-REACT would need a number of composition tools. That leverage directly on ACT's existing capabilities. The core components for ACT-REACT are a computational engine, an a simple to use GUI. We decided to use ACT's ProVIEW as a starting point that captures these two aspects, but added to it many of the NOS identified needs.

2. Graphical User Interface Evolution for ACT-REACT

- The ACT-REACT GUI is Wrapped around MSHELL (to leverage on the same processing engine)
  - Must Work on Windows+MAC/OS+Linux)
- Main Panel Captures ALL subpanels
  - Development Environment
    - Analysis Environment
    - Multiple Document Interface for multiple images
    - Ability to distribute the load via MSHELL calls
      - Use SOAP to achieve lower level calls
  - Project Panels (any planet any regions of interest)
    - Workflow builder Panel
      - MLT subpanel (multi-layer tree)
      - Expression layer builder
      - Remote Search Subpanel
        - Can interrogate multiple servers for
          - Data collections being served
          - Items available for a given ROI, TOI, Data Of Interest
      - Local Search Subpanel
      - Coincidental Data Panel
        - Allows to work with metadata from multiple servers towards locating coincidental data
    - Cartographic Viewer - Mapping Panel
      - Measuring tools
      - Overlay tools
      - History tools
      - Map Viewing Parameters (MVP) subpanel
        - Support all relevant map projections
        - Reproject on the fly
      - Publishing sub-panel
        - Map+workflow+target to WIPE server
        - Browsable and zoomable HTML based map
        - Google Earth via KML usage
      - Data prove inspector
        - Ability to plot values at a point or over a spatial path
        - Ability to download CSV file with values extracted
  - Decision Support Tool Panel (example customization ➔HAB)
    - Data Fusion

        - Access to all required data elements from different servers
    - Report Builder (customized for HAB)
        - Includes publishing to FTP server
        - Implements HAB analysis algorithms for winds
        - Implements trajectory algorithm from NRL
        - Implements HAB classification algorithm from NOS
- Maintain Documentation with Application and on-line

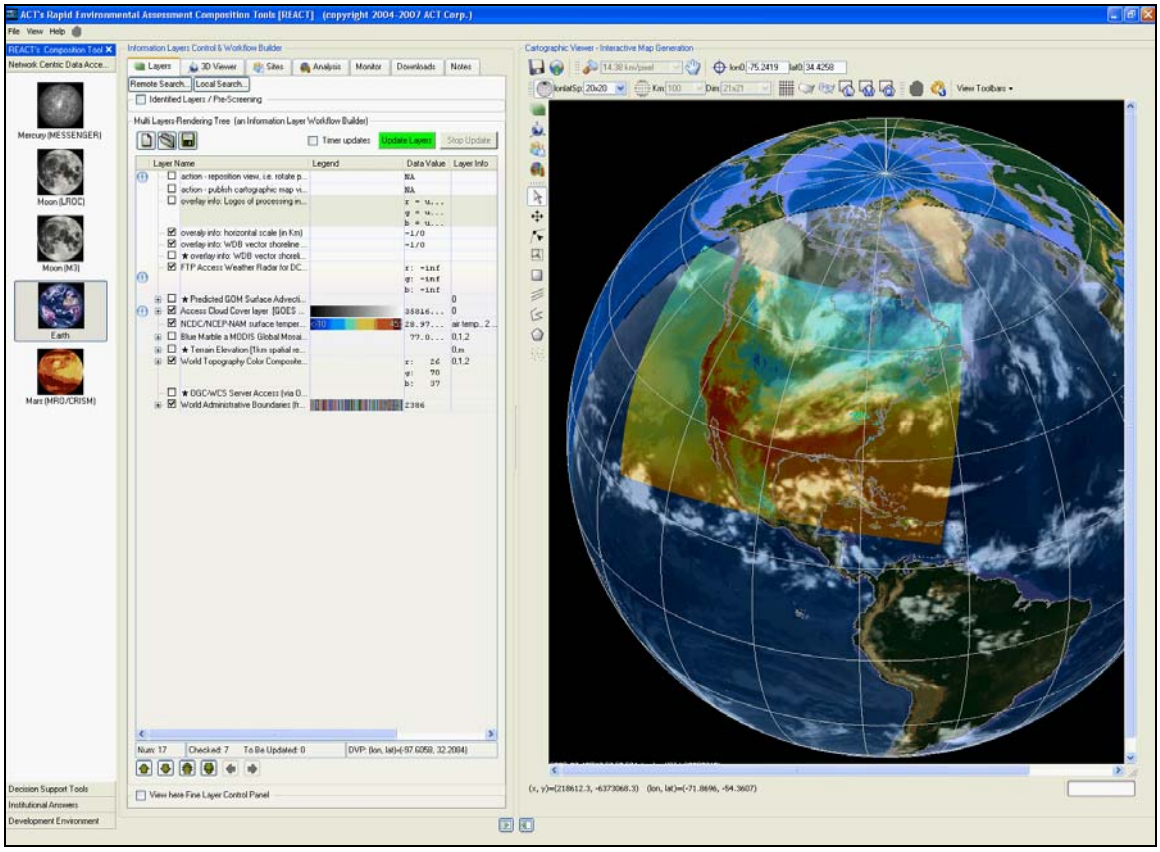

Figure 8 ACT-REACT Basic screen (showing most of the panels). Sources are local and remote. User have access to numeric values, and can request part of the workflow to execute on other machines.

F. Update Manager for ACT-REACT&WIPE[4]

It was identified that an update manager was needed as a critical component to keep capabilities synchronized under ALL operating system.

- It keeps users synchronized with
  - Scripts (general and custom)
  - Executables
  - New libraries
  - Basic Data Components, e.g. global basemaps
  - Workflows approved
  - Map viewing options
  - Project viewing options
  - Documentation and Tutorials
- The core technology at the lower level is based on **RSYNC**. A GUI interface was created that simplifies the interface between the server and the client machine.
- This allows to force how a team will have a common operational environment/picture, with flexibility to see things in a different way!

[4] http://www.actgate.com/fyeo/ACT-Product-Manager/download_info.htm to access ACT-REACT download page

G. Specific Processes Added for NASA, NRL, and NOAA

A number of custom specific processes were added into the ACT architecture per requires of NRL or NOAA. The following captures the key ones.

- NRL ➔Particle tracking algorithm
- NOAA/NOS ➔ HAB Classification Algorithm
- NOAA/NOS ➔ Wind Processing Algorithms for HAB
- NOAA/HAB ➔ Mimic Decision Support Panels used in HAB
- NOAA/CW ➔ Added CW lookup tables
- NOAA/NRL/NASA➔ locate coincidental data over different servers
- Handling of Specific Data Formats
    - NOAA HDF custom format (used by CoastWatch)
    - NRL HDF custom format (used for all MODIS products)
    - NRL NetCDF custom format (used for model data)
    - OpenDAP in support to NOAA
    - OGC WMS/WCS retrieval in support to NOAA

IV. Technical Barriers Found

Given the requirements, that were identified early on, ACT made the decision in the first year of the Cooperative Agreement to use Trolltech's Qt C++ library. This allowed us to achieve OS independent capabilities hence the components will work on all key platforms. We know this was not a bad decision since other key companies have been using the same approach on their high end applications, e.g. Google (Google Earth), Adove (Adove PhotoShop), Opera, Skype, KDE, …. It also allowed ACT to directly leverage in all the existing C and C++ based code that provides ACT's architecture with high performance capabilities.

Half way into the project, Trolltech introduced a MAJOR update in the Qt library, i.e. Qt3 has upgraded to Qt4. The differences between Qt3 and Qt4 were significant! This is an example on how technology is a moving target. We have been forced to upgrade all of our MSHELL and REACT code to the new Qt4 classes, otherwise the present effort would have resulted in staled capabilities. So, after concentrating on all the key NOAA and NRL requirements, during the 5th-6th year we started the porting all the ACT-REACT and MSHELL code to use the Qt4 library. This has consumed a year worth of un-planned work during the last year of the effort.

We are still finalizing the porting to Qt4. The plan release date for the Qt 4 version of ACT-REACT is Feb. 2010. The improvements are going to be worthwhile, but at a cost of significant amount of TIME.

It is important to emphasize that not doing this would have made the application obsolete in a short period of time.

V. CA - Application Component Results

A. Original Objectives ➔ End Result

The objectives of the cooperative agreement and the present end-results are:

- Generate new products and improve existing products from Earth science satellites and models to support coastal-ocean resource managers;
  ➔ACT's REACT facilitates the incorporation of new products into a production PIPE-line. Workflows can be tested and constructed in REACT for later systematic execution in WIPE. Early last year tested this in the implementation of a HAB classification algorithm provided by NOS.

- Integrate model and satellite output to address Coastal Management issues identified from NOAA and other partners;
  ➔ ACT-REACT was implemented to facilitate this capability in an interactive manner.

- Enable real-time ocean properties to be easily assembled and distributed into coastal products through web technology;
  ➔ ARCHITECTURE ALLOWS THIS.

- Automate product creation to permit applications experts to address product content/quality (more time on analysis of data products);
  ➔ ARCHITECTURE ALLOWS THIS

- Through partners, expand an Internet-enabled system architecture to reach to all levels of applications providers and end-users;
  ➔ ACT has achieved this as part of our support to planetary missions. But in the Earth Observing side it is TDB.

- Concentrate data/product distribution efforts on appropriate, commonly-used formats;
  ➔ ARCHITECTURE ALLOWS THIS

- Cooperate with NOAA NOS and NESDIS to ensure useful product creation and integration with current NOAA decision support tools and priority needs of the coastal resource management community;
  ➔ TO BE DISCUSSED IN REMAINING MONTHS

- Establish partnerships with NOAA, NASA, and NRLSSC in serving the coastal resource management community.
  ➔ TO BE IMPROVED IN REMAINING MONTHS

B. Application Component Milestones and End Status

The following tables summarize our high level milestones and criteria for the Application Component (ACT's role). It includes the end result associated to the original milestones.

#	Milestones (Year 1)	Criteria
A-1	Requirements Gathering	Complete intermediate user and end user requirements gathering to ensure appropriate direction. **RESULT: THIS WAS DONE. REQUIREMENTS FROM NRL AND NOAA WERE COLLECTED AND DRIVED THE APPROACH FOR THE FOLLOWING YEARS. SUMMARY OF REQUIREMENTS CAN BE FOUND BELOW:** **http://www.actgate.com/reason/reports/2ndProjectYear_2_3quarter.ppt**
A-2	Revisit Identified Requirements and how they are being addressed	Monthly meetings between PI, PM, and partners **RESULT: THIS PART WAS NOT EXECUTED AS PLANNED. THE AMOUNT OF CHANGES IN THE ARCHITECTURE WERE SO MANY THAT QUARTERLY REPORTS WERE USED TO COMMUNICATE STATUS. THE CAPABILITY EVOLVED INTO A SW SYSTEM THAT THE USER CAN DO SYSTEMATIC DOWNLOADS TO STAY UP TO DATE WITH THE LATEST CHANGES.** **CHANGES ARE REPORTED IN THE REACT APPLICATION VIA THE ACT-REACT MENU OPTION: 'HELP | REALEASE NOTES', i.e.** **http://www.actgate.com/home/react_log.php?e=229&m=1**
A-3	Install high end hardware for hosting data ingest, manipulation, product creation and distribution.	Capable of handling increased data volumes. Coordinate with NASA/NOAA for identification of site(s) to receive WIPE Servers HW/SW. **RESULT: PER NOAA's/NOS REQUEST THE SERVERS WERE INSTALLED AT NRL AND AT ACT. ALL Data for the last 5 years is accessible via the servers.**
A-4	Describe/document/publish approach on the web.	Program and end user review and comment. **RESULT: WEB PAGE WAS CREATED. DOWNLOAD SERVERS WERE CREATED FOR CLIENT APPLICATION.** **http://www.actgate.com/reason (Description/document)** **http://public.wipecentral.net/php/cw/cw_browser.php?&s_DataSet=CW_GOM** **(summary product pages)**
A-5	Enhance current technology in use at NESDIS for fusing satellite with other sensor, model and observation data into a single platform architecture.	MODIS and legacy data geo-referenced and time referenced for further processing. Be responsive to ALL the NOAA identified requirements on the WIPE server. **RESULT: FOLDED NOAA REQUIREMENTS INTO ACT-REACT AND WIPE APPLICATION. WE USE DATA IN NATIVE PROJECTION.**
A-6	Enhance technology in use at NRLSSC for fusing satellite with other sensor, model and observation data into a single platform architecture.	**Be responsive and address ALL the NRLSSC identified requirements on the WIPE server.** **RESULT: MOST OF NRL SUGGESTED CHANGES WERE INCORPORATED INTO BOTH WIPE AND REACT.**

#	Milestones(Year 2)	Criteria
A-7	Revisit Identified Requirements and how they are being addressed	Monthly meetings between PI, PM, and partners **RESULT: MONTHLY DID NOT TAKE PLACE AS EXPECTED. THE EMPHASIS SHIFTED INTO PUTTING TOGETHER THE ACT-REACT APPLICATION TO ADDRESS THE REQUIREMENTS AND PROVIDING AUTOMATIC UPDATES. THIS WAS A MAJOR UNDERTAKEN GIVEN THE MULTIPLE REQUIRENTS AND DATA SOURCES BEING ADDRESSED, and END-USER TYPES.**
A-8	Install high end hardware for hosting data ingest, manipulation, product creation and distribution.	Capable of handling increased data volumes. **Coordinate with NASA/NOAA for identification of site(s) to receive WIPE Servers HW/SW**. **RESULT: DONE. ONE SERVER AT NRLSSC AND OTHERS AT ACT (based on NOAA/NOS request)**
A-9	Develop initial satellite/model based tailored Hazardous Algal Bloom product to end user in GIS and/or other compatible format(s).	Scientists develop new algorithms, capabilities and apply satellite/model properties to HAB forecasting. Customer ability to view / process new HAB information. **RESULT: DONE VIA ACT-REACT. SEE PAGE XX FOR SAMPLE OUTPUT**
A-10	Demonstrate widely available Internet access to specified levels of satellite data and HAB product(s).	Widely dispersed interested parties interactively work with data sets on the server and create batch processed products. **RESULT: DONE VIA ACT-REACT , WIPE, and ACT-REACT-QuickMap** **http://www.actgate.com/home/images/browse_gom_particles_12_9_09_500mpp_over_72hrs.html**
A-11	Automate HAB Bulletin creation and distribution to the extent possible.	Science team concentrates on product quality, not format or distribution. **RESULT: DEMONSTRATED VIA REACT DECISION SUPPORT TOOLS (DST) WIZARD.**
A-12	Apply methods and lessons learned to the Near-Real-time Hypoxia Watch Project or other similar project chosen by a stakeholder.	Collect requirements for this or other high priority CZ Management issue and apply new capabilities in EOS data management and applications for problem solving. **RESULT: NOAA/NOS REQUESTED ACT TO ENABLE THE APPLICATION TO WORK OUTSIDE OF THE FLORIDA AREA AND INTO OTHER GOM AREAS (TEXAS) AND ALSO THE GREAT LAKES. Hypoxia applications were not explored.**
A-13	Verify approach and WIPE functionality continues to meet user requirements and adjust as necessary.	End-user satisfaction. This is an on-going process. **RESULT: EVOLVED INTO MORE CHANGES INTO ACT-REACT AND LESS INTO WIPE. THE LOAD WAS SHIFTED GIVEN THE FLEXIBILITY REQUESTED.**
A-14	Develop integrated process for receiving, fusing, processing and distributing satellite data and resulting products to stakeholders in their desired format.	Demonstrate accomplishment of stated goals. **RESULT: DONE TO THE LEVEL REQUESTED. OUR APPROACH TO IMPLEMENT AN INTEGRATED PROCESS HAS HIGH FLEXIBILITY.**
A-15	Add access to other present and future NASA/NOAA/DoD and foreign data, such a WindSat and NPP VIIRS.	Maintain currency with new sensors. **RESULT: PART OF OUR APPROACH WAS TO ADOPT THE OPEN SOURCE CONCEPTS (e.g. GDAL) ALLOWING EASIER ADOPTION WITH NEWER DATA STREAM FORMATS. THIS WAS DEMONSTRATED WITH THE ADDITION OF ALL THE HAB REQUIRED DATA STREAMS NEEDED BY THE SYSTEM. (see table in page 20)**

#	Milestones(Year 3-5)	Criteria
A-16	Revisit Identified Requirements and how they are being addressed	Monthly meetings between PI, PM, and partners **RESULT: SAME AS PREVIOUS YEARS.**
A-17	Install high end hardware for hosting data ingest, manipulation, product creation and distribution.	Capable of handling increased data volumes. **Coordinate with NASA for identification of site(s) to receive WIPE Servers HW/SW.** **RESULT: UPDATED HW SYSTEMS AT ACT. AT NRL/SSC. updated SW**
A-18	Expand to other application areas, geographic areas, and data sources.	Shift concentration from HAB to other application areas. **RESULT: UPDATED TO THE GREAT LAKES. UPDATED TO COAST OF TEXAS.**
A-19	Verify approach and WIPE functionality continues to meet user requirements and adjust as necessary.	End-user satisfaction. This is an on-going process. **RESULT: DEMONSTRATED TO NOS AND NRL FOR FEEDBACK. WORKED IN INCORPORATING WEB DISPLAY SUGGESTIONS. WORKED ON INTERFACING TO OTHER SERVERS, e.g. OPENDAP.**
A-20	Provide routine software updates as necessary.	Continual improvement. **RESULT: DONE VIA UPDATE MANAGER. THIS BECAME THE KEY METHOD OF PUSHING UPDATES AND NEW WORKFLOWS.** **NUMBER OF USERS REGISTERED FOR ACT-REACT UNDER HAB=32 out of 302 (over all NASA related projects [by the end of the CA])**
A-21	Identify and customize WIPE with new decision support tools	Capture DS logic from NRLSSC/NOAA, implement, and deliver via WWW interface. **DONE. IMPLEMENTATION IS SPLIT BETWEEN WIPE and ACT-REACT.**
A-22	Assist in the transition of applications to operations at NOAA	Full integration of capability into workflow. **RESULT: THE ACT-REACT LAYERS PANEL IS A WORKFLOW BUILDER. IT DICTATES WHICH ALGORITHMS ARE CALLED AND HOW THE DATA IS INTEGRATED/VISUALIZE.**

C. Metrics: Initial and End Status

The following Metrics were submitted for consideration in evaluating the state of the project and its success in meeting project and NASA objectives:

Input

- Gaps in the satellite and model data base due to uncontrolled events will be less than 48 hours
- Ocean model skill metrics will be developed from the project series. Skill will be assessed over the span of the project from refinements
- All real-time ocean data will be available

Outputs

- 100% of NRLSSC Gulf Coast Satellite Imagery accessible
  [status: achieved]
- 100% of NRLSSC GOM NCOM model output accessible
  [status: achieved]
- 100% of NOAA independent data stream to ACT accessible
  [status: achieved]
- Tailored coastal products generated from data through the ACT WIPE interface were produced interactively or automatically through the web interface
  [status: demonstrated via ACT-REACT and produced web pages]

Outcome

[The following have been demonstrated. Operational Usage is dependent on NOAA'a infusion.]

- From the internet, a user is able to retrieve a tailored geospatial product for a given coastal application /decision in a timely fashion
- From the internet, the user is able to retrieve multiple products from the data base and overlay the fields/data
- From the internet , the user is able to view the metadata of the data selected for study
- From the internet, a user is able to numerically correlate (in space and time) satellite image product with ocean model output derived fields with the ability to download the result.
- Data managers and providers are e able to construct an assessment the availability and utility (demand) of each ocean property through the web to focus and improve service. Identification of a time history of frequency of use, prime users, and architecture reliability will be easily analyzed.

Impact

- Access to a long-term data base of systematic satellite observations and real-time ocean model output advances our understanding the coastal system and is applied to a broad range of earth science and Coastal Management

D. Post Cooperative Agreement Plan

Upon completion of the CA term, we now have significant new applications and capabilities in place and our goal for maximizing the availability and application of new EOS data for the benefit of coastal stakeholders is largely met.

From the ACT perspective, we have the complete pipeline in place, from EOS data receipt, ingestion, fusion and analysis through creation of end user product.

After the end of the CA, ACT continues providing software upgrades for the installed WIPE servers for up to 1 year after the end of the CA, i.e. during the 6th year). This also includes updates of ACT-REACT. After the end of the 6th year, maintenance of software, hardware, data links, services, etc., will fall under the purview of service providers. NASA assistance or involvement will only be necessary to ensure continued data flow.

It is important to note that, there is on-going evolution on the ACT SW architecture, in the form of bug fixes to existing components and new:

- decision support tools,
- functions,
- syntax,
- scripts, and
- bindings to third party libraries.

For mission critical aspects, not keeping up with the maintenance/updates can have an adverse impact on the ability of the components to work under new machines and OS versions for Windows, MAC, and Linux.

The following link provides detail information of all the maintenance/updates taking place during the 6th year of the effort:

http://docs.google.com/View?id=dcvf4k5v_49gmpcdhdg

E. Adoption and Impact to NASA On-going Missions

Technology adoption and infusion of the refined architecture that resulted from this effort has been in some ways a hard milestone to achieve due to a number of barriers.

- The adoption in **NOAA/NOS** has been limited by a number of key factors:
    - Resistance to new ways.
    - Limited budget to support new ways
    - ACT being too involved with the addition of new un-existing capabilities

- The adoption at **NRL/Stennis** has been limited. It could be due to the fact that internal ways of doing things seem to be favored and prevail. NRL/SSC already had an in-house tool with aspects that overlap with WIPE (but not REACT).

The Good NEWS is that both WIPE/PIPE and ACT-REACT have found a strong and direct path into Science Operations Centers for a recognizable number of mission critical operations (note: links are provided to some public sites that contain information on some of the capabilities/tools or some of our support):

- NASA/MESSENGER
    - http://messenger.wipecentral.net/
- NASA/MRO/CRISM
    -
    - http://www.actgate.com/home/images/crism_react_qmapv3.pdf
- NASA/LRO/LROC
    - http://target.lroc.asu.edu/output/lroc/lroc_page.html
- NASA/Chandryan/M3
    - http://mare.actgate.com/m3_start/

It most of these missions the architecture it is used to ingest raw telemetry data and go all the way to global products that can access rapidly in order to monitor mission progress.

VI. Appendix

A. Useful Documents& Links

The following are key documents and links that complement/supplement this final report.

Description	Link
Documentation: MSHELL Manual	http://www.actgate.com/home/mshell.htm (overview) Actcual documentation comes with the application download.
Documentation: REACT GUI Manual	http://www.actgate.com/home/act-react.htm (overview). Actual documentation comes with the application download.
Documentation: HAB Case Study (from ACT)	http://www.actgate.com/home/doc/ESIP_Case%20Study_Harmful_Algal_Bloom_Use_Case.pdf
REASON Page at ACT	http://www.actgate.com/reason
REASON Data Products	http://public.wipecentral.net/php/cw/cw_browser.php?&s_DataSet=CW_GOM
ACT-REACT Download	http://www.actgate.com/fyeo/ACT-Product-Manager/download_info.htm
Web Data Access: QuickMap Example	http://www.actgate.com/home/images/browse_gom_particles_12_9_09_500mpp_over_72hrs.html

B. Script to Generate HAB Wind Products

The following has sample code associated to some modules implemented for NOAA and NRL.

```
FUNCTION [simage,outimage,ofile]=hab_wind_products[dummy]

/*
Buoy winds are obtained from www.ndbc.noaa.gov/data/realtime2.
We extract the last 3 weeks of data, calculate average windspeed, append
NAM12 forecast winds at each buoy location before generating the wind plots.
The buoy_table.txt file located on our ftp site lists the current buoys available through the system.

Model data is extracted from NCEP using NAM12 using NOMADS server

// EXAMPLE START
if(1){
        dummy=1
        dummy.text = "THLO1" // process only requested buoy
        dummy.text = "SGOF1"
        //dummy.text = "CSBF1"
        [simage,outimage,ofile]=hab_wind_products[dummy]
        view simage
}
if(1){
        dummy=1
        dummy.text = "" //  leave empty to extract ALL buoys
        [simage,outimage,ofile]=hab_wind_products[dummy]
        view simage
}
// EXAMPLE END
*/

//*****************************************************************************************************************
// SOURCE TABLE FOR BUOYS TO USE ARE BELOW and CONTROLLING INFO
//*****************************************************************************************************************
/* the following table was moved to an input file...
$table = "
Name#    Lat#    Lon#       Shore#  Upwelling#  Height#     Type#     Description#         URL#
DPIA1#   30.25#  -88.07#    90#     270,390#    17.4#       CMAN#     Dauphin Island, AL#  file:///csc/reef1/hab/buoy/fresh/
SRST2#   29.67#  -94.05#    70#     250,370#    13.4#       CMAN#     Sabine, TX#          file:///csc/reef1/hab/buoy/fresh/
PTAT2#   27.83#  -97.05#    30#     210,330#    14.9#       CMAN#     Port Aransas, TX#    file:///csc/reef1/hab/buoy/fresh/
CSBF1#   29.67#  -85.36#   -50#     310,430#    11.6#       CMAN#     Cape San Blas#       ?file:///csc/reef1/hab/buoy/fresh/
SGOF1#   29.41#  -84.86#    45#     225,345#    35.1#       CMAN#     Tyndall AFB Tower C# file:///csc/reef1/hab/buoy/fresh/
VENF1#   27.02#  -82.45#   -30#     330,450#    11.6#       CMAN#     Venice Pier, FL#     file:///csc/reef1/hab/buoy/fresh/
EGKF1#   27.60#  -82.76#   -30#     330,450#    10.0#       CMAN#     Egmont Key, FL#      file:///csc/reef1/hab/buoy/fresh/
42036#   28.51#  -84.51#   -30#     330,450#     5.0#       MOORED#   Station 42036, FL#   file:///csc/reef1/hab/buoy/fresh/
CDRF1#   29.14#  -83.03#    90#     270,390#    11.8#       CMAN#     Cedar Key, FL#       file:///csc/reef1/hab/buoy/fresh/
DRYF1#   24.60#  -82.90#   -80#     280,400#     5.7#       CMAN#     Dry Tortugas, FL#   ? file:///csc/reef1/hab/buoy/fresh/
SANF1#   24.50#  -81.90#  -105#     255,375#    13.1#       CMAN#     Sand Key, FL#        file:///csc/reef1/hab/buoy/fresh/
LKWF1#   26.61#  -80.03#  -170#     190,310#    13.7#       CMAN#     Lake Worth, FL#      file:///csc/reef1/hab/buoy/fresh/
SAUF1#   29.86#  -81.26#  -200#     160,280#    16.5#       CMAN#     St. Augustine, FL#   file:///csc/reef1/hab/buoy/fresh/
42055#   22.01#  -94.05#  -200#     160,280#    16.5#       CMAN#     campeche, MX#        file:///csc/reef1/hab/buoy/fresh/
```

```
THLO1#   41.83#  -83.19#  -200#     160,280#    16.5#       CMAN#     Toledo Light, OH#    file:///csc/reef1/hab/buoy/fresh/

"
*/

$tablePath = M_proviewdir::"/scripts_nasa_ca/hab_wind_analysis_sites.tab"
print "buoys used are controlled by the following input table file:\n\t"::$tablePath::"\n"
$table = readtext( $tablePath)
print "*******START - Winds Data Retriever********\n"
// get forecast values from NCEP/NAM12 latest model run
        // choose long&lat points from provided table
                    $lat = $table(1:nlines($table), 6:13); //$lat
                    $lon = $table(1:nlines($table),15:22); //$lon
                    llpts= complex(str2float($lon),str2float($lat))
                    if( strlen(dummy.text)){
                                // user wants to use only one buoy
                                pos=eqindexS($table,dummy.text)
                                if(pos.nrows){
                                            tableRpos = imag(pos(0,0))
                                            rpos = tableRpos-1
                                            llpts = llpts(rpos,:)
                                            print "buoy source to use:   \n\t\t"::$table(rpos+1,:)::"\n"
                                }else{
                                            print "error in hab_wind_products:  buoy name provided is not right\n"
                                            outimage = text2image(M_time ::"- error: requested buoy not recognized")
                                            simage   = outimage
                                            return
                                }
                    }
                    //llpnts
        // get forecast points from NOMADS server
        print "\tquery NCEP/NAM servers from recent model outputs... THIS CAN TAKE A MINUTE...\n"

        [time_v, uv_v ]=opendap_ncep_nam_time_series[ llpts' ]

        // time_v.text
        if(time_v.ncols==0){
                    print "accessing ncep data failed, ... will continue without forecast information\n"
        }else{
                    fTime_v = time_v*0
                    fmag        = uv_v.abs
                    // note usage of atan2: atan2(y,x), where y&x must be <=1 , angle returned is with respect to positive x-axis.

                    frot        = atan2(uv_v.imag,uv_v.real) // compute angle of forecast wind dir. Assumes this is where is coming from.
                                            //          with respect to x-axis and in radians. positive angles counter clockwise
                    frot        = -frot*(45/atan(1))    // convert to deg..  with positive angles clockwise with respect to x-axis
                    frot        = 90+frot   // now the angle is the comming wind direction, with respect to North and increasing clockwise
                    i = 0
                    while(i<time_v.nrows){
                                offset = dt2mjd(1::1::-1::0::0::0)
                                fTime_v(i,0) = time_v(i,0) + offset // forecast times in MJD representation
                                dt = mjd2dt( time_v(i,0) + offset )
                                //dt
                                //print "\n"
                                i = i+1
                    }
                    print "\tlast time extracted: \n\t\t"::float2str(dt)::"\n"
                    print "\n"
                    print "\tdone retrieving recent model ouput from  NCEP/NAM servers...\n"
        }

// start processing for buoy data
M_format            = "0000000.00000"
pos                 = eqindexS($table,"Upwelling")      // starting column for upwelling information
cpos                = real(pos(0,0))

$btable = $table(1:nlines($table),:)                                // extract data rows...
/*if(vartype($onlyUseBuoy)){
        $onlyUseBuoy
        recPos = eqindexS($table,$onlyUseBuoy)
        if(recPos.ncols){
                    $btable = $btable(recPos.imag,:)
                    $btable
                    asdfd
        }
}*/
if(strlen(dummy.text)==0){      // use all buoys
        $upwelling  = $btable(:,cpos:cpos+6)                        // range of columns is hardwired
        $buoys                  = $btable(:,0:4);                               // extract name of buoys
        $description            = $btable(:,70:89)
}else{                                          // only process one buoy
        $upwelling  = $btable(rpos,cpos:cpos+6)                     // range of columns is hardwired
        $buoys                  = $btable(rpos,0:4);                            // extract name of buoys
        $description            = $btable(rpos,70:89)
}
//get current time related information...
ctime                           = gmtimenow()
cModifiedJulianDate  = dt2mjd(ctime)
$myctime            = strSection(ctime.text,".",0,0);
$myctime            = smodify($myctime,"-","_");
$myctime            = smodify($myctime,":","_");
print "job started at: GMT="::$myctime


Nbuoys = nlines($buoys);        // number of buoys to process
H       = 12                    // # hours to  average together
navg    = H*6                   // # of  pnts to average together = H*6 , since there are 6 measurements per hr (every 10 minutes)
if(vartype(simage)){
        free simage
}
n=0;                                                        // starting point
while(n<Nbuoys){
        $path       = "http://www.ndbc.noaa.gov/data/realtime2/"::$buoys(n,:)::".cwind"     // contruct full path to html page
        print       "<h3>source: "::$path::"</h3><br>"
        status      = readtext_and_status($path);       // read wind data from WEB site
        if(status!=0){
                    print "... problem getting buoy data ... try later\n"
        }else{
                    if(strContains(status.text,"The page that you requested is not found")==0){
                                // we were able to make a retrive data connection.  desired result should be in status.text
                                $obs = status.text
                    }else{
                                $obs = ""
                                // try opening a ".txt" buoy
```

```
                        $path       = smodify($path,".cwind",".txt")
                        status2 = readtext_and_status($path);
// try again with .txt path
                        if(status2==0){
                                    print       "<h3>end-up using alternate source (with hourly data): "::$path::"</h3><br>"
                                    if(strContains(status.text,"The page that you requested is not found")==1){
                                                //2nd attempt... we were able to make a retrive data connection.
                                                $obs = "2nd attemp requested buoy data not found\n"
                                                print $obs
                                                $obs= status2.text
                                    }
                        }
            }
}

// note: the content of each record read is:
//          YYYY MM DD hh mm DIR  SPD GDR GSP GTIME
//for Continuous Winds (cwind)
//          DIR         Ten-minute average wind direction measurements in degrees clockwise from true North.
//          SPD         Ten-minute average wind speed values in m/s.
//          GDR         Direction, in degrees clockwise from true North, of the GSP, reported at the last hourly 10-minute segment.
//          GSP         Maximum 5-second peak gust during the measurement hour, reported at the last hourly 10-minute segment.
//          GMN         The minute of the hour that the GSP occurred, reported at the last hourly 10-minute segment.
// for Standard Meteorological Data (.txt)
//          YYYY MM DD hh mm DIR SPD  GST  WVHT   DPD   APD MWD   PRES  ATMP  WTMP  DEWP  VIS PTDY  TIDE
//
if(nlines($obs)>200){               // check that there is content in obs file .. there should be few thousand records...
            $x = $obs
            // remove spaces, tabs, ...
            $x = smodify($x," \t"," ");
            $x = smodify($x,"     "," ");
            $x = smodify($x,"    "," ");
            $x = smodify($x,"   "," ");
            $x = smodify($x,"  "," ");
            $x = smodify($x," ","");



            $hdr = $x(0,:)
            //print $hdr
            print "first 10 lines from data file\n"::$x(0:10,:)::"\n"   // first 10 records
            x = str2float($x)   ;

            if( strContains($path,".cwind") ){

                        if(strContains($x(1,0:10),"yr")){
                                    x = rmirror(x(2:x.nrows-1,:)) // it seems that now most files have two lines of header
                        }else{
                                    x = rmirror(x(1:x.nrows-1,:))
                        }

            }else{

                                    x = rmirror(x(2:x.nrows-1,:)) // since there are two lines of text on the hdr

            }
            mGMT = x(:,0:4)::zeros(x.nrows,3)   // measured times in GMT (stored in an array)
            jDate = dt2mjd(mGMT)';  // using modified Julian representation
            navg = (H/24)/median(jDate-shiftc(jDate,0,1))
                        // assum. equal interval sample ==> estimate samples needed to average H hours



            // apply time filtering
                        print "\t- filtering the data vectors..."
                        speed       = x(:,6)'
                        speedF      = spatf(speed,1,3,median)           // remove spikes
                        groi        = complex(0,0)::complex(speed.ncols-1,0)
                        speedF(groi)=speed(groi)
                        kernel      = ones(1,navg)/(navg)
                                    // compute  hourly averages, use 6*H for block of hours to use in the moving average windows.
                        speedF2 = convolt(kernel,speedF);   // compute mean of filtered data


                        dir         = x(:,5)'
                        dirF        = spatf(dir,1,3,median)             // remove spikes
                        dirF(groi) = dir(groi)
                        // perform filtering in the complex plane to avoid 0-360 discontinuities
                                    deg2rad= atan(1)/45
                                    dirFcmplx   = exp(sqrt(-1)*dirF*deg2rad)
                                    dirF2cmplx  = convolt(kernel,dirFcmplx)
                                    dirF2                   = imag(log(dirF2cmplx))/deg2rad
                                    groiN                   = ltindex(dirF2,0)
                                    if(groiN.ncols){
                                                dirF2(groiN) = dirF2(groiN)+ 360
                                    }
                                    plot0(dirF2)
                        //also perform filtering in the 1-d domain
                                    dirF2bad    = convolt(kernel,dirF);                         // compute mean of filtered data
                                    plot1(dirF2)

                        // apply same operations as above to time vector
                        jDateF                  = spatf(jDate,1,3,median);
                        jDateF(groi)            = jDate(groi)
                        jDateF2     = convolt(kernel,jDateF)

                        // get ready to generate HAB winds plot image
                        typeflag=11::8
                        speedF3     = speedF2(0,navg/2+1:speedF2.ncols-navg/2-1) // leave edges out of the filtering process
                        dirF3                   =   dirF2(0,navg/2+1:speedF2.ncols-navg/2-1)
                        dirF3bad    =dirF2bad(0,navg/2+1:speedF2.ncols-navg/2-1)
                        jDateF3                 = jDateF2(0,navg/2+1:speedF2.ncols-navg/2-1)

                        rotdeg                  = dirF3  ( (0,dirF3.ncols-1,navg)+sqrt(-1)*0  ) //decimate(dirF3,   1, navg)
                        rotdegBad   =dirF3bad( (0,dirF3.ncols-1,navg)+sqrt(-1)*0  ) //decimate(dirF3,   1, navg)


                        wmag0                   = speedF3( (0,dirF3.ncols-1,navg)+sqrt(-1)*0  ) //decimate(speedF3, 1, navg)
                        juldateF    = jDateF3( (0,dirF3.ncols-1,navg)+sqrt(-1)*0  ) //decimate(jDateF3, 1,navg);
                                    // associated Day&Time in modified julian format

                        // plot results of wind buoy wind filtering
                        plot_free_all();
```

```
                    // create some new plots using user provided ids
                    id0 = 0; id1 = 1; id2 = 2; id3 = 3; id4 = 4;
                    plot_open(id0, "")
                    plot_open(id1, "")

                    /*************************************/
                    /*          wind direction           */
                    /*************************************/
                              plot_xlabel(id0, "Modified Julian Date")
                              plot_ylabel(id0,"Wind Direction (comming from) [deg.from North]")
                              plot_title(id0,$buoys(n,:)::" - Buoy Wind Direction")
                              plot_view(id0)

                              // define curves ids
                              c0_0 = 0; c0_1 = 1; c0_2=2; c0_3 = 3
                              plot_curve_open(id0, c0_0, "Wind Direction")    // create the curve with a user provided id
                              plot_curve_data(id0, c0_0, jDate, dir)          // plot curve

                              plot_curve_open(id0, c0_1, "WDir. Aver (W/O -360 CHECKS)")
                                         // create the curve with a user provided id

                              plot_curve_data(id0, c0_1, juldateF, rotdegBad) // plot curve


                              plot_curve_open(id0, c0_2, "WDir. Aver.["::float2str(navg,"%3.0f")::"]")
                                         // create the curve with a user provided id

                              plot_curve_data(id0, c0_2, jDateF3, dirF3)      // plot curve

                              plot_curve_open(id0, c0_3, "WDir. Aver.&re-sampled")// create the curve with a user provided id
                              plot_curve_data(id0, c0_3, juldateF, rotdeg)    // plot curve



                              // change curve style
                              plot_curve_style( id0, c0_3, "lines")           // Sticks or Steps or NoCurve
                              plot_curve_symbol( id0, c0_3, "XCross") // Ellipse or XCross or Triangle
                    /*************************************/
                    /*          wind magnitude           */
                    /*************************************/
                              plot_xlabel(id1, "Modified Julian Date")
                              plot_ylabel(id1,"Wind Magnitude")
                              plot_title(id1,$buoys(n,:)::" - Buoy Wind Magnitude")
                              plot_view(id1)

                              // define curves ids
                              c0_0 = 0; c0_1 = 1; c0_2=2
                              plot_curve_open(id1, c0_0, "W.Mag.")            // create the curve with a user provided id
                              plot_curve_data(id1, c0_0, jDate, speed)        // plot curve

                              plot_curve_open(id1, c0_1, "W.Mag. Aver.["::float2str(navg,"%3.0f")::"]")
                              // create the curve with a user provided id

                              plot_curve_data(id1, c0_1, jDateF3, speedF3)    // plot curve

                              plot_curve_open(id1, c0_2, "W.Mag. Aver.&re-sampled")
                                         // create the curve with a user provided id

                              plot_curve_data(id1, c0_2, juldateF, wmag0)     // plot curve

                              // change curve style
                              plot_curve_style( id1, c0_2, "lines")           // Sticks or Steps or NoCurve
                              plot_curve_symbol( id1, c0_2, "XCross") // Ellipse or XCross or Triangle

          //end of time filtering block
          if( time_v.ncols){// append forecast values
                    rotdeg      = rotdeg::frot(:,n)'
                    wmag        = wmag0::fmag(:,n)'                           // check unit consistency!!
                    juldateF= juldateF:: fTime_v'
          }else{
                    wmag = wmag0
          }
          Spacing = H/2
          loc         = (0,wmag.ncols-1,1)*Spacing+100    //decimate( (0,dirF2.ncols-1,1), 1, navg) +100
          loc         = loc + sqrt(-1)*(100*(n+1))
          upwellrange =  str2float($upwelling(n,:))

          //****************************************
          // construct individual plot with legend...
          //****************************************
          tempImage= zeros(200, 800)
          $dummy = " ("::strSection($description(n,:),"#",0,0)::")"
          $buoyName = $buoys(n,:)
          $buoyPdesc= $buoyName::$dummy
          if(time_v.ncols){
                    foreCastpnt = wmag0.ncols
          }else{
                    foreCastpnt = -1// do not use forecast data
          }
          leaveOut = 0

          g = wdef(0,leaveOut,1,rotdeg.ncols-leaveOut);

          // buoy data wind direction is where the winds are comming from.
          // For the HAB buoy plots we want to show where the winds are going to, hence we add 180. [check this with NOS]
          //For the HAB buoy plots the upwellrange relates to the direction the winds are comming from.


[outimage]=hab_nos_buoy_plots[tempImage,$buoyPdesc,rotdeg(g)+180,wmag(g),typeflag,upwellrange+180,juldateF(g),foreCastpnt]
          // note: outimage.text has the table information used in the plot
          //outimage.text

          //*************************************
          // save constructed plot image to file
          //*************************************
          rgb         = outimage.LUT
          r           = xlut(outimage,rgb(0,:) )
          g           =xlut(outimage,rgb(1,:) )
          b           =xlut(outimage,rgb(2,:) )
          a           = r*0
          $ofile      = "$(REACT_DATA_DIR)/nasa_ca/noaa/winds/buoys/"::$myctime::"_"::$buoyName::".png"
          $ofile      = expand($ofile)
          print "\t- saving results to: "::$ofile
          //writeRGBA($ofile,r,g,b,a,"PNG");
```

```
                    writeRGB($ofile,r,g,b,"PNG");

                    //writeRGB("../session/habdst_history/buoy.png",r,g,b,"PNG");

                    //*********************
                    // build summary image
                    //*********************
                              if(vartype(simage)){
                                        simage = simage#255*ones(60,simage.ncols)#outimage
                              }else{
                                        simage = outimage
                              }
                              simage.LUT = outimage.LUT
                              view simage
                              simage.text = $ofile
                              simage.text = simage.text::"\n"::outimage.text
          }else{
                    print " \tWARNING: retrive buoy file content is too small.... ignoring this file!"
                    outimage = text2image(M_time::" - WARNING: retrive buoy file content is too small. Content follows...")
                    print $obs::"\n"
                    temp = zeros(200,800)
                    temp(0:,0:) = outimage
                    outimage = temp
                    $ofile = "none";
          }


          //pause(-1)
          n = n+1
}
if(vartype(simage)==0){
          simage = text2image("no product was generated")
}
//*************************************
// save aummary plot image to file
//*************************************
          temp        = ones(64,simage.ncols)*255#simage
          temp(1:,1:) = text2image("Summ. of Single plot")
          if( ncols(simage.LUT) >0){
                    temp.LUT = simage.LUT
          }else{
                    temp.LUT = (0,255,1,3)
          }
          simage      = temp      // now simage has a header text with description
          rgb         = simage.LUT
          r           = xlut(simage,rgb(0,:) )
          g           = xlut(simage,rgb(1,:) )
          b           = xlut(simage,rgb(2,:) )
          a           = r*0
          $ofile      = "$(REACT_DATA_DIR)/nasa_ca/noaa/winds/buoys/"::$myctime::"_"::"summary"::".png"
          $ofile      = expand($ofile)
          print "\t- saving results to: "::$ofile
          //writeRGBA($ofile,r,g,b,a,"PNG");
          writeRGB($ofile,r,g,b,"PNG");
          ofile = 1
          ofile.text = $ofile
 print "*****DONE - Winds Data Retriever *****"


/* just for testing
M_maxdim = 5000
simage2 = reada(ofile.text,"all")
view simage2
*/
```

C. Script to generate HAB Classification Scheme

The following has sample code associated to some modules implemented for NOAA and NRL.

```
FUNCTION [shape,bratio,chlA,habClass] = create_hab_class_product[$f,$g,fullDIM,$ofile]
/* This function computes   hab-classification product (using algorithm provided by S.Tomlinson at NOAA/NOS), i.e.
//                         "An evaluation of remote sensing techniques for enhanced detection of the toxic
//                         dinoflagellate, Karenia brevis,
//                         M.C. Tomlinson a,?, T.T. Wynne b, R.P. Stumpf ",
//                         Remote Sensing of Environment 113 (2009) 598-609.
// inputs:
//     $f        - use this file to get
//                         (a) chlorophyll A Anomaly
//                 e.g. from file name
//                         MODSCW_P2008349_1950_D61_P2008261_P2008321_GM03_closest_chlorANOMALY.hdf
//     $g        - use this file to get 'nlw' layers. nlw is the water leaving radiance at different wavelengths .
//                 This is another hdf file, e.g.
//                         MODSCW_P2008349_1950_GM03.hdf
//     fullDIM   - maximum size to use for output image.  If set to -1, it will use the full res of the input image.
//     $ofile    - output file with computed classification image, embedded in the original input HDF file, i.e.
//                 it is a copy of the $f file , but with the chl-Anom layer changed.
// outputs:
//     out                 - output array with computed classification image.
//     habClass            - array with HAB Classficication output
//
// QUESTIONS FOR NOAA:
//     Do we need to process each granule individually?
//     Do we need to create a composite of HabClass over the GOM?
//     What is the resulting file name?
//
// EXAMPLE START
        $f        = "//crism-
act/crism/software/act/react_data/nasa_ca/noaa/nos/shelly_hab_classification_test_files/modis/MODSCW_P2008349_1950_D61_
P2008261_P2008321_GM03_closest_chlorANOMALY.hdf"
        $g        = "//crism-
act/crism/software/act/react_data/nasa_ca/noaa/nos/shelly_hab_classification_test_files/modis/MODSCW_P2008349_1950_GM03
.hdf"

        fullDIM   = -1
        $ofile    = "q:/react/temp/out777.gsf";           // can be an empty string
        [shape,bratio,chlA,habClass] = create_hab_class_product[$f,$g,fullDIM,$ofile]
        view255   shape,0
        view255 bratio,1/0-1/0
        view255   habClass,-1
        view255 chlA

// EXAMPLE END
*/
MODISflag = strContains($f,"MODSCW")
if(MODISflag==1){
        if(strContains($f,"_closest_")){
                // we are OK based on Shelly's recommendatation of what file to use
        }else{
                stop_process("input MODIS file must be of _closest_  type, based on NOS request")
        }
}

// get some basic information from input HDF CW file, i.e. '$f'
        IN                  =-1
        IN.text             = "HDF4_SDS:UNKNOWN:\"":$f::"\":4"
        RCin                =-1
        tol                 = -1
        [xyout,LLout,INrows,INcols,inpcontrolf,GCP,geo_xform,RCout,dxc,dyc]= Map_Image_Geo_Info[IN,RCin,tol]


        if( (filesize($f)<=0)    ||  (filesize($g)<=0)   ){
                stop_process("in revised_chl_a_anomaly:  one of the input files can not be found.");
        }

        if(fullDIM==-1){
                M_maxdim            = max(INrows::INcols)
        }else{
                M_maxdim            = fullDIM
        }

        //load into memory the input files
            // chl_a_anom
                chl_a_anom          = zeros(INrows,INcols)
                npix_spc  =0        //interpixel spacing in bytes (0 = default, datatype size)
                nline_spc           =0//interline spacing in bytes  (0 = default, datatype size * buffer width)
                nband_spc           =0//interband spacing in bytes  (0 = default)
                xoff=0
                yoff=0
```

```
                    xsize               =INcols
                    ysize               =INrows
                    wf                  =0

                    fHDL                = gdal_open(IN.text)
                    band_map  = 1
                    status              =gdal_rasterio(fHDL, wf, xoff, yoff, xsize, ysize, chl_a_anom,    \\
                                        band_map, npix_spc, nline_spc, nband_spc)
                    status              = gdal_close(fHDL)



   if(1){ // apply algorithm
          // 1st step =====spectra shape related ==============
                    H                   = zeros(INrows,INcols)
                    L                   = zeros(INrows,INcols)
                    C                   = zeros(INrows,INcols)
                    chlA                = H*0

                    // load  spectra layers with water leaving radiance
                    if(MODISflag==1){ // modis case
                              wlow      = 443
                              wcenter = 488
                              whigh     = 531
                              //ibands            = 7::8::9    // L, C, H !!!!

                              //L
                              //HDF4_SDS:UNKNOWN:"//crism-
act/crism/software/act/react_data/nasa_ca/noaa/nos/shelly_hab_classification_test_files/modis/MODSCW_P2008349_1950_GM03
.hdf":7
                              //HDF4_SDS:UNKNOWN:"//crism-
act/crism/software/act/react_data/nasa_ca/noaa/nos/shelly_hab_classification_test_files/modis/MODSCW_P2008349_1950_GM03
.hdf":7
                              IN.text             ="HDF4_SDS:UNKNOWN:\"":$g::"\":7"
                              gHDL                = gdal_open(IN.text)
                              gdal_dataset_info_detail(gHDL)
                              status              = gdal_rasterio(gHDL, wf, xoff, yoff, xsize, ysize, L, 1, npix_spc,
nline_spc, nband_spc)
                              ndatav              = -1 // obtained by looking visually at the data
//gdal_get_raster_no_data_value(gHDL,1)
                              status              = gdal_close(gHDL)

                              // C
                              IN.text             ="HDF4_SDS:UNKNOWN:\"":$g::"\":8"
                              gHDL                = gdal_open(IN.text)
                              status              = gdal_rasterio(gHDL, wf, xoff, yoff, xsize, ysize, C, 1, npix_spc,
nline_spc, nband_spc)
                              ndatav              = -1 // obtained by looking visually at the data
//gdal_get_raster_no_data_value(gHDL,1)
                              status              = gdal_close(gHDL)

                              // H
                              IN.text             ="HDF4_SDS:UNKNOWN:\"":$g::"\":9"
                              gHDL                = gdal_open(IN.text)
                              status              = gdal_rasterio(gHDL, wf, xoff, yoff, xsize, ysize, H, 1, npix_spc,
nline_spc, nband_spc)
                              ndatav              = -1 // obtained by looking visually at the data
//gdal_get_raster_no_data_value(gHDL,1)
                              status              = gdal_close(gHDL)

                              // chlA

                              IN.text             ="HDF4_SDS:UNKNOWN:\"":$g::"\":0"
                              gHDL                = gdal_open(IN.text)
                              status              = gdal_rasterio(gHDL, wf, xoff, yoff, xsize, ysize, chlA, 1,
npix_spc, nline_spc, nband_spc)
                              ndatav              = -1 // obtained by looking visually at the data
//gdal_get_raster_no_data_value(gHDL,1)
                              status              = gdal_close(gHDL)


                    }else{
                              wlow      = 443
                              wcenter = 490
                              whigh     = 510
                    }

                    result    = C*0 + -999        // initialize to - 999

                    // identify pixels for which we have valid data
                              groiH               = gtindex(H,0)      // greater than index...
                              groiL               = gtindex(L,0)
                              groiC               = gtindex(C,0)

                              mask      = result*0
                              if(groiH.ncols){
                                        mask(groiH) = mask(groiH)+1
                              }
                              if(groiL.ncols){    // check if we have good pixels in groi443
                                        mask(groiL) = mask(groiL)+1
                              }
                              if(groiC.ncols){
                                        mask(groiC) = mask(groiC)+1
                              }
                              groi      = eqindex(mask,3)   // list of pixels where we have good data for all 3 bands
```

```
                    // only process identified pixels
                              shape = L*0
                              if(groi.ncols){
                                        cratio    =  (wcenter-wlow)/(whigh-wlow)
                                        temp      = C(groi) - L(groi) - ( H(groi)-L(groi)) * cratio
                                        shape(groi) = temp  // this is returned to REACT...
                              }


          //======================== 2nd step
          // compute backscatter at 555nm of any particles  (only for positive pixels)
                    nlw555  = H
                    groi      = gtindex(nlw555,0)
                    if(MODISflag){
                              // for modis
                              bpp555 = -0.00182 + 2.058*nlw555(groi)/185.33
                    }else{
                              // for seawifs
                              bpp555 = -0.00182 + 2.058*nlw555(groi)/185.33
                    }
                    bpp555Res = nlw555*0
                    if(groi.ncols){
                              bpp555Res(groi) = bpp555
                    }

          // compute backscatter at 555nm of any chlorophyll particles (only for groi2 type of pixels)

                    groi2               = gtindex( chl_a_anom,1)
                    if(groi2.ncols){
                              bpp555_chl          = 0.3*(chl_a_anom(groi2)^0.62 )*. ( 0.002 + 0.2*(0.5-
0.25*log10(chl_a_anom(groi2))))
                              bpp555_chlRes       = chl_a_anom*0
                              bpp555_chlRes(groi2) = bpp555_chl
                    }

          // compute backscatter ratio (only on those pixels that are non-zero for both cases above)
                    bratioMask = bpp555Res *. bpp555_chlRes
                    groi3     =  gtindex( bratioMask.abs , 0 )

                    bratio = chl_a_anom*0
                    if(groi3.ncols){
                              bratio(groi3) = bpp555Res(groi3)/.bpp555_chlRes(groi3)
                    }

          // 3rd step compute classification
                    // conditions to be look for are:
                    //        bratio < 2
                    //           and
                    //        shape < 0
                    //           and
                    //        chlA > 1
                    // Flag those pixels
                    // tests array against a constast

                    c2 =    (           1             *           1          *  maskofGT(chlA,1) * 107  )
                    c3 =    (           1             *  maskofLT(shape,0) *. maskofGT(chlA,1) * 183  )
                    c4 =    ( maskofLT(bratio,2)*.                          maskofGT(chlA,1) * 238  )
                    c5 =    ( maskofLT(bratio,2)*. maskofLT(shape,0) *. maskofGT(chlA,1) * 254 )

                    c  = maxof(c5,c4)
                    c  = maxof(c,c3)
                    c  = maxof(c,c2)    // c contains the composite of all masks together

                    habClass = c
                    view255 habClass,0
          // save the result clasification back on a copy the chlAnom file
          // Note: a) need to change the name , i.e. seconds to be set to 60
          //        b) can we change the metadata?   TBD
    }

    /*
    // copy input file $f to output file name specified
          status=sys_copy($f,$ofile)
          if(status!=0){
                    stop_process("fail to copy input file")
          }
    // replace layer with habClass
          IN.text             ="HDF4_SDS:UNKNOWN:\"":$ofile::"\":1"
          oHDL                = gdal_open(IN.text,1)        // open for write
          status              = gdal_rasterio(oHDL, 1, xoff, yoff, xsize, ysize, habClass, 1, 0, 0, 0)
          status              = gdal_close(oHDL)
    */

    // write the product as a standalone HDF image dataset
    $driver_name = "GTiff"
    $filename = $ofile
    size_vector = 1::ysize::xsize  // bands::rows::columns
    datatype_code = 6 // Float32
    hdl_new = gdal_create( $driver_name, $filename, size_vector, datatype_code, 0 )

    // set geo information

    // convert the proj reference from PROJ.4 to WKT
    osr_hdl = osr_new_spatial_reference( "" )
```

```
   status = osr_import_from_proj4( osr_hdl, inpcontrolf.text )
   $WKT = osr_export_to_wkt( osr_hdl )
   $proj4 = osr_export_to_proj4( osr_hdl )
   status = osr_destroy_spatial_reference( osr_hdl )

   status = gdal_set_geo_transform( hdl_new, geo_xform )
   status = gdal_set_projection( hdl_new, $WKT )

   // create a VRT wrapper
   // hdl_vrt = gdal_create_copy( "VRT", $filename::".vrt", hdl_new, 0 )
   // status = gdal_close( hdl_vrt )

   // write habClass
   wf = 1 // write
   status = gdal_rasterio( hdl_new, wf, xoff, yoff, xsize, ysize, habClass, 1, 0, 0, 0)
   status = gdal_close( hdl_new )


   //*************************************************
   // send email that process finished its execution
          $srvrIP = "207.87.28.34"
          $from     = "malaret@actgate.com"
          $to       = "malaret@actgate.com"
          $subject= "K. Breve Bloom Classification System"
          $message= \\
          "AUTOMATED RUN by NOS/ACT-WIPE Product Server
          Following the purchase of a SeaWiFS Chlorophyll-a Gulf of Mexico image, an anomaly event or events have been
detected and have been placed at the links below.
          Each anomaly dataset is the difference of the two respective datasets listed as 'Purchased Image' and
'Average Product'.
          All chlorophyll-a differences equal to or greater than 1.0 ug/l are flagged YELLOW.

          The CoastWatch Okeanos naming conventions can be found at the following link:
          ftp://okeanos.noaa.gov/pub/README_file_names.txt

          ANOMALY:
          ftp://spo.nos.noaa.gov/public/shelly/SWRCW_S2008335_195360_D61_S2008245_S2008305_GM03_mixed_chlorANOMALY.hdf
          ftp://spo.nos.noaa.gov/public/shelly/SWRCW_S2008335_195360_D61_S2008245_S2008305_GM03_mixed_chlorANOMALY.png
          ftp://spo.nos.noaa.gov/public/shelly/SWRCW_S2008335_195360_D61_S2008245_S2008305_GM03_mixed_chlorANOMALY.tif

          Purchased Image:
          ftp://spo.nos.noaa.gov/public/shelly/SWRCW_S2008335_195360_GM03_mixed_chlora.hdf
          ftp://spo.nos.noaa.gov/public/shelly/SWRCW_S2008335_195360_GM03_mixed_chlora.png
          ftp://spo.nos.noaa.gov/public/shelly/SWRCW_S2008335_195360_GM03_mixed_chlora.tif

          Average Product:
          ftp://spo.nos.noaa.gov/public/shelly/SWRCW_S2008245_S2008305_D61_GM03_mixed_chlora.hdf
          ftp://spo.nos.noaa.gov/public/shelly/SWRCW_S2008245_S2008305_D61_GM03_mixed_chlora.png
          ftp://spo.nos.noaa.gov/public/shelly/SWRCW_S2008245_S2008305_D61_GM03_mixed_chlora.tif
          "

          status = sys_sendmail($srvrIP,$from,$to,$subject,$message)



   if(0){
          if( strlen($ofile) ){
                    $odriver            = "GTiff"
                    $metadata =  ""
                    use_overviews       = 1
                    datatype_code       = 6

          [status]=write_array_to_mapfile[out,geo_xform,$ofile,$odriver,$metadata,use_overviews,datatype_code]
          }
   }
```