Gulf of Mexico Coastal Ocean Observing System Regional Association (GCOOS-RA)

GCOOS HF Radar Gap Analysis

Version 1.1

27 June 2008
(with a footnote added in 2009)

1 INTRODUCTION

Knowledge of surface conditions, and surface currents in particular, is fundamental to addressing most coastal ocean issues, including especially maritime transportation, natural and living resource exploitation, recreational boating and fishing, search and rescue, pollution cleanup, and tracking harmful algal blooms to name a few. Three dimensional circulation models of the Gulf will benefit from assimilating surface currents. Improvements in forecasting of coastal inundation events should result, which is of obvious importance and concern in the Gulf. Thus a high priority goal of the Gulf of Mexico Coastal Ocean Observing System (GCOOS) Regional Association (GCOOS-RA) is to develop the capacity to monitor the state of the ocean surface over the U.S. continental shelf of the Gulf of Mexico. This goal will be accomplished by developing over the next five years the foundation for a U.S. Gulf-wide surface current and wave observing system using High Frequency (HF) Radars.

Surface currents and waves are two of the U.S. Integrated Ocean Observing System (IOOS) core variables that have impacts on each of the seven societal goals of the IOOS (e.g., Malone and Hemsley 2007), and both can be monitored with HF Radar stations. Although the need for better monitoring of surface currents and waves has been repeatedly identified in stakeholder workshops held by the GCOOS, the present Gulf-wide observation system for surface currents and waves is sparse. Moreover, we need a sustained system and the modest existing HF Radar network is under constant threat of funding loss. The existing operational HF Radar network in the Gulf consists of three stations in the northeastern Gulf, three stations on the West Florida Shelf, and two stations in the Florida Straits. Although the Florida Straits is not in the Gulf of Mexico proper, the region includes the important outflow from the Gulf, and connects the Gulf of Mexico with the eastern open Atlantic via the Florida Current and Gulf Stream.

Two main types of HF Radars (CODAR, WERA) are available commercially and employ direction-finding (DF) algorithms and beam-forming (BF) techniques. In general, CODAR systems require less beach real estate for deployment, but the WERA systems have more degrees of freedom in data flow and hence more information can be gleaned from these instruments. Most importantly, directional wave spectra are available from WERA second order returns, but are of very limited use from CODAR systems. There needs to be a broader understanding of the data from these systems within the context of effective distances for both radial and vector surface current signatures, key wave parameters, directional wave spectra and wind directions over the radar footprints. In this context, a key issue is how well these remotely sensed signatures compare to *in-situ* measurements from conventional buoy measurements and how to combine data from different systems into a blended product of surface currents.

The geomorphology of the coastline in the Gulf of Mexico, and the annual threat of destructive hurricanes, present some difficult challenges in developing the HF Radar network in the Gulf and along the southeast U.S. A large fraction of the coastline is dominated by low lying barrier islands, marshes, deltas and lagoons that can require significant investments in infrastructure if stations at these difficult to reach locations are to be made resistant to passing tropical storms and hurricanes. Unlike many other coastal areas, protective coastal bluffs are not available as deployment sites. In the event of severe weather, evacuation is not a viable strategy for HF Radar equipment in many places in the Gulf, and so the development plan must address this through considerations of site selection, hardened infrastructure, or planning for inevitable loss of equipment. In some instances, acquiring quality surface measurements (waves and currents) is important in evaluation of storm surge and inundation models around the Gulf of Mexico. Thus hardening sites to withstand severe weather and acquire these data is central to one of the seven societal goals.

2 CONCEPTUAL DESIGN: HIGH FREQUENCY RADAR NETWORK

The GCOOS-RA envisions a network of HF Radar observing systems for surface currents and waves. This network would (1) continue operations of the existing operational High Frequency Radar (HFR) network (6 units) in the GCOOS region; (2) determine the status of units that once were operational and whether such units can be incorporated into the GCOOS HFR network; (3) develop a more complete understanding of quality control and quality assurance issues for different HFR systems and how to ensure compatibility and ability to combine measurements from different HFR systems; and (4) develop for the Gulf a plan for choosing particular HFR station types, operating frequencies, locations, and infrastructure plans for each site. We already have a preliminary plan for an HFR network, and that is described briefly here.

We intend to expand our HRF network to include 36 sites around U.S. Gulf coast. Tentative locations are shown in Figure 1. We are working with SECOORA to cover the west part of Florida. In addition to its 3 existing HFR stations on the West Florida Shelf and 2 stations in the Florida Straits, SECOORA will install and maintain the 5 new HFRs south and 1 new HFR north of the existing CODAR units on the West Florida Shelf. These new and existing HFR stations are important parts of the Gulf-wide HF Radar Network.

Figure 1. Tentative locations for HF radars for the Gulf-wide HFR network. Existing sites include six 5-MHz CODAR systems, 3 on the West Florida Shelf and 3 on the Mississippi-Alabama-Florida Coast; these are assumed to be maintained. The SERF sites are assumed to become operational and available. See Appendix for approximate years for installation.

We plan that most of the radars will be 10-12 MHz units because 5-8 MHz systems have three problems that make them less than optimal. First, there is a USCG licensing issue around the 5 MHz band. Second, the wave regime on the West Florida Shelf and possibly other locations is not optimal for these longer wavelengths. Third the 5-8 MHz systems may have too much diurnal variation in range. We will use a combination of CODAR and Wellen Radars (WERA). The initial system will be built over a period of about five years and will focus on measuring the offshore environment. Systems to monitor bays and estuaries may be added to the network as priorities evolve. Plans are to direct all data through the National Data Buoy Center. However, products will be served via the GCOOS Data Portal.

Additionally, a number of oil and gas companies intend to install High Frequency Radars on their platforms in deep water. As the HFRs are installed, GCOOS-RA will encourage them to make the data available through NDBC as part of the HFR network for the Gulf of Mexico. Chevron has a CODAR system on its Genesis Platform, which is about 150 miles south of New Orleans in ~800 m water depth; it is likely that Chevron will make the data available through NDBC. Shell intends to install an HFR in the area of their Brazos Lease Block offshore of Corpus Christi Bay with data transmitted through NDBC. BP may install an HFR on one or more of its offshore platforms and will consider the possibility of making the data available through NDBC. Industry plans to use CODAR units.

The GCOOS-RA intends to use both CODAR and WERA systems. Because it uses BF from phased array technology, the WERA is capable of determining the wave directional spectra and spatially map the evolving wave spectra from the second-order returns in the Doppler spectra. Although significant wave heights can be determined from CODAR data, the CODAR systems do not have the capability of determining directional waves. The capability to obtain directional waves is important in many parts of the coastal region of the Gulf. For example, both Southeast Florida Shelf WERA sites operated continuously during the passage of Hurricane Jeanne over the Florida Straits on 25 Sept 2004. Although it passed ~200 km to the north of the measurement domain, the local mean winds exceeded 20 ms^{-1} and rotated over 270°. The interaction of these wave fields from differing directions with the high lateral shear of the western edge of the Florida Current was observed every 10 min. The wind-wave component of the spectrum was observed to respond rapidly to the rotating wind-field, but effects of the horizontal current shear were observed in the off-wind angle of the wind-wave peak. Lower frequencies were often observed at large angles to the local wind. Understanding these wave impacts under various venues and differing atmospheric forcing conditions is critical to the GCOOS-RA and US National HF Radar Network. More recently, such remotely sensed wave signatures have been deemed of critical importance to the formulation of a national waves plan sponsored by the U.S. Army Corps of Engineers and NDBC (NOAA IOOS Program 2008). An important user group, consisting of the marine, environmental quality, and health agencies of the five Gulf Coast States, is pursuing through the Gulf of Mexico Alliance (GOMA) a project for establishing nutrient criteria and then for monitoring nutrients in the state waters. GOMA includes directional waves as one of their needed measurements (Gulf of Mexico Alliance 2008). GOMA also is pursuing restoration of coastal wetlands and coastal resiliency as two additional priority issues, for both of which directional waves are important (Gulf of Mexico Alliance 2006).

3 EXISTING RESOURCES

Within the Gulf of Mexico the only operational HFRs are located along portions of the northeastern Gulf, the West Florida Shelf, and Straits of Florida (Table 1). The University of Southern Mississippi (USM) Central Gulf of Mexico Ocean Observing System (CenGOOS) has CODAR stations in Gulfport, MS, Orange Beach, AL, and Destin, FL (Figure 2). Data and plots are available at the web site: http://www.cengoos.org/index.html. In addition to the existing HFR stations, funding has been identified for 2 new stations in Mississippi. These will be 25-MHz CODAR stations that USM will purchase to cover a portion of the western Mississippi Sound with funding in late summer or fall 2008 provided through the Minerals Management Service (MMS) Coastal Impact Assistance Program (CIAP).

The University of South Florida (USF) Coastal Ocean Monitoring and Prediction System (COMPS) has CODAR stations at Redington Shore, FL, Venice, FL, and Naples, FL (Figure 3). All offshore sea surface current speed and direction radial data are provided hourly via a dedicated phone line to a central processing station located at the University of South Florida/College of Marine Science in St. Petersburg, FL, where the data are processed and web served at http://seacoos.marine.usf.edu/HFRadar1/.

The major outflow region of the Gulf of Mexico is at the Florida Straits, which connect the Gulf with the North Atlantic Ocean. The University of Miami/Rosenstiel School of Marine and Atmospheric Sciences (UM) is currently operating two WERA High Frequency radars in Key Largo and Crandon Park on Key Biscayne (Figure 4); two additional WERAs are being installed. The radars transmit at 16-MHz and provide measurement of currents on the ocean's surface over a large area of the ocean off Miami, FL. Additional information is available at the web site: http://iwave.rsmas.miami.edu/wera/.

Table 1. HFR deployed in the Gulf of Mexico and Florida Straits.

Entity and HFR Type	Station Location	Status
CenGOOS/USM 5 MHz SeaSonde	Gulfport, MS	Being installed
CenGOOS/USM 5 MHz SeaSonde	Orange Beach, AL	Operational
CenGOOS/USM 5 MHz SeaSonde	Destin, FL	Operational
CenGOOS/USM 25MHz SeaSonde	Bay St. Louis, MS	Funding ~fall 2008
CenGOOS/USM 25MHz SeaSonde	Longbeach, MS	Funding ~fall 2008
COMPS/USF 5 MHz SeaSonde	Rd. Shores, FL	Operational
COMPS/Mote/Rutgers/USF 5 MHz SeaSonde	Venice, FL	Operational
COMPS/USF 5 MHz SeaSonde	Naples FL	Operational
UM 16 MHz, 16 element WERA	Crandon, FL	Operational
UM 16 MHz, 16 element WERA	Key Largo, FL	Operational
UM 16 MHz, 16 element WERA	Dania Beach, FL	Operational
UM 12 MHz, 16 element WERA	Virginia Key, FL	Being installed

Figure 2. CODAR systems over the Mississippi-Alabama Shelf together with locations of other data buoys and stations. From left to right the stations are Gulfport, MS, Orange Beach, AL, and Destin, FL.

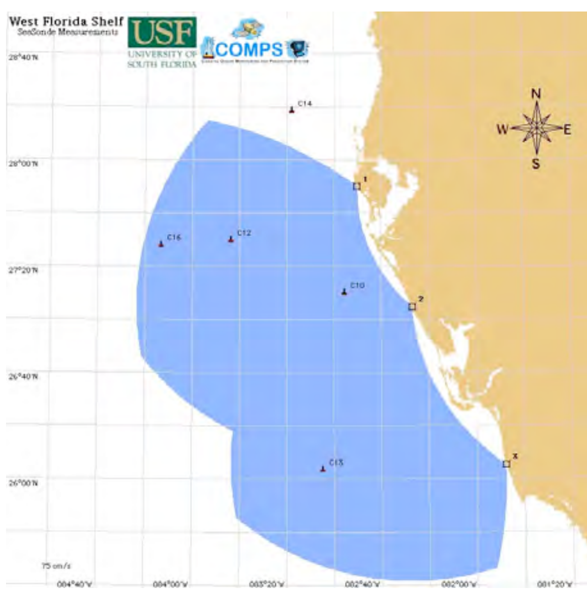

Figure 3. CODAR systems and coverage over the West Florida Shelf. Site 1 is at Reddington Shores, site 2 at Venice, and site 3 at Naples.

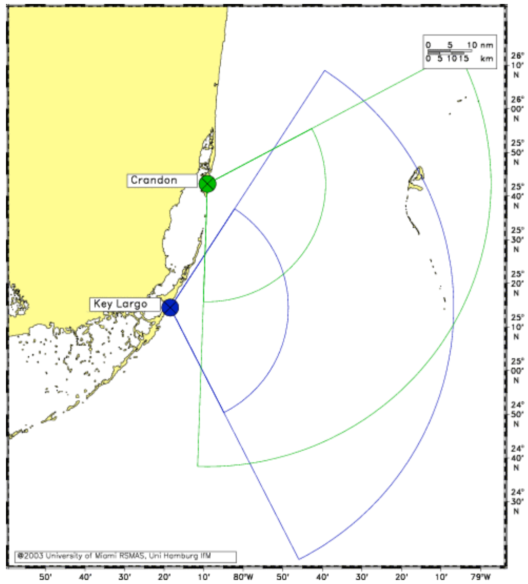

Figure 4. Two WERA systems in the Straits of Florida and their coverage.

There are a number of HFR sites that are not operational or are in planning (Table 2). These include six CODAR systems that were deployed as part of the Shoreline Environmental Research Facility (SERF) (http://www.serf.tamus.edu/ResearchProjects/HFRadar/). These consisted of four 13-MHz CODAR stations configured for the offshore Texas and two 25-MHz CODAR stations configured for Corpus Christi Bay. These units, funded by the Texas General Land Office, Texas Higher Education Coordinating Board, and National Science Foundation, have not been operational for some time. The future of these stations is uncertain at present[1]. However, we assume they will become operational and part of the U.S. Gulf HF Radar Network. Additionally, Shell Oil plans to integrate the systems it will install with any operational systems that are along the Texas coast; the Shell project is targeted for completion in winter 2009.

Table 2. HFR stations planned or not operational in the Gulf of Mexico and Florida Straits.

Entity and HFR Type	**Station Location**	**Status**
SERF/TAMU 13MHz SeaSonde	Rollover Pass, TX	Not operational.
SERF/TAMU 13MHz SeaSonde	Bay Harbor, TX	Not operational.
SERF/TAMU 13MHz SeaSonde	Matagorda Island, TX	Not operational.
SERF/TAMU 13MHz SeaSonde	Portofino, TX	Not operational.
SERF/TAMU 25MHz SeaSonde*	Corpus Christ Bay, TX	Not operational.
SERF/TAMU 25MHz SeaSonde*	Corpus Christ Bay, TX	Not operational.
COMPS/USF 12MHz, 12-el WERA	TBD within CODAR	On order
COMPS/USF 12MHz, 12-el WERA	TBD within CODAR	On order
FAU 25 MHz CODAR	Hilsborourogh Inlet	In procurement
FAU 25 MHz CODAR	Haulover Beach	In procurement

*Mobile unit.

[1] Subsequent to this analysis, the SERF units were permanently removed from the Gulf.

4 GAP ANALYSIS

Long-Range (>75 km range) HFR: There are no operational long-range HFR stations from Brownsville, TX, to Gulfport, MS (approximately 750 mi). USM 's long-range HFR stations cover the region from Gulfport, MS, to Destin, FL. Another gap exists from Destin, FL, to Redington Shores, FL (approximately 450 mi). USF's long-range HFR stations cover the region from Redington Shores to Naples, FL. The region between Naples, FL, down to the Keys (~ 250 mi) and over into the Miami, FL, area is the last GCOOS gap. Clearly the Texas and Louisiana coasts constitute the biggest gap in coverage and will necessitate a substantial investment in order achieve full coverage. Additionally, the geomorphology of much of the Louisiana coast may require much more expensive infrastructure developments for HFR installation than other coastal regions, with the exception of the Everglades region of Florida. This has been considered in a slower development of the LA HFR infrastructure relative to that of Texas and Florida.

Short- and Medium-Range HFR: Given the present and near-term IOOS funding levels, it is unrealistic to expect that anything approaching complete coverage of the U.S. Gulf Coast could be accomplished with short- and medium-range HFR stations during the next five years. Rather than focusing on the very large gaps in coverage with these types of stations, the next section will indicate prioritized regions for deployments.

Operational Conditions and Spares: The Gulf coast is highly susceptible to tropical storms and hurricane conditions that can destroy infrastructure and equipment. An issue is to plan for these events. This might be done by providing for spares, removing equipment when hurricanes threaten to strike, or “hurricane-proofing” the structures in/on which equipment is installed. To obtain maximum information for use in hurricane forecasting and emergency response (preferred option), the HFRs should be left up to run as long as the equipment lasts. This requires that funds be allocated to replace the equipment that inevitably will be lost. If no spares will be available, then the equipment will need to be evacuated; this is problematical. When a hurricane is about to strike a region, the people who live there like to secure their own property before trying to drive to a remote location to retrieve equipment. A plan will need to be developed whereby technical personnel at participating institutions outside the threatened region will evacuate the equipment, and the capability for rapid evacuation will be needed (e.g., use of trailers). Costs for this activity (personnel, travel, communications, equipment transport and storage, etc.) would need to be included. Hurricane-proofing will require proper engineering and is beyond the present scope of this HFR network plan.

Prioritization: At the present time the gaps in coverage are much larger than the regions that are covered, and funding for maintaining the existing stations is very uncertain. GCOOS-RA has submitted two proposals to NOAA for filling the gaps, but these proposals were not funded. The first proposal, submitted for FY2007 funding, would have resulted in much of the U.S. coastal Gulf covered by FY2010 with a combination of CODAR and WELLEN radar stations, built out under a phased implementation plan. Responding to criticisms by reviewers, in FY2008 a proposal was submitted to maintain the existing assets while developing a phased implementation plan for the entire US coastal Gulf; this proposal is being held for consideration for FY2009 funding.

Because surface currents have been deemed a priority in all of the various stakeholder workshops that GCOOS-RA has held (GCOOS-RA 2008) and have been identified as a key observation by the Gulf of Mexico Alliance, a key priority is to have the US Gulf Coast covered by long-distance (>75 km) radar systems with overlapping coverage sufficient to estimate 2-D surface current fields in these regions. Since the priority of wave measurements and forecasts is a close second to surface currents for Gulf stakeholders, where affordable it is preferable to install HFR equipment that can also measure directional wave information. A third priority is to have nested higher frequency radar systems in selected regions. A logical first choice for the higher frequency and higher spatial and temporal resolution systems is to cover regions with substantial ship and boat traffic. These regions include the six ports in the Gulf that have the NOAA Physical Oceanographic Real-Time System (PORTS) installed, as well as the Southwest Pass of the Mississippi River, Corpus Christi, TX, and Miami, FL. From west to east the 6 PORTS systems are: Houston/Galveston, TX, Sabine Neches, TX, Gulfport, MS, Pascagoula, MS, and Tampa Bay, FL. Importantly, in most of these locations barrier islands separate important navigable waters from the deeper open coast where lower frequency radar can be used for inferring surface currents. There is no reliable method to extrapolate the currents measured offshore of these barrier islands into the sounds so local HFR systems will be needed.

Gap in Data Compatibility Knowledge: In addition to the paucity of HF radar systems in the Gulf, another important gap is how to combine data from different HF radars into a Gulf coastal surface current map. Tables 3 and 4 show some of the different configurations for CODAR and WERA, respectively. An important issue is how to combine the radial data from these differing radars to form surface current vectors over the national networks. Low frequency HF Radars (4 to 8 MHz) have considerable range at the expense of horizontal resolution. By contrast, very high frequencies (typically 48-50 MHz) provide high spatial resolution (depending on bandwidth) for ports where tidal flows and winds impact ship traffic, and from a biological perspective, small-scale surface currents and the net transport affect movement of high/low salinity water, fish larval movement, and coral reef processes among others, but at the expense of range.

Table 3. CODAR Seasonde specifications and capabilities in long-range (~6Mhz) and medium-range (~25 MHz) systems (from Shay et al. 2007a)

Description	6 MHz	25 MHz
Range (km)	180-200	45
Resolution (km)	6-12	1-3
Depth (m)	2	0.5
Current Speed (cm s^{-1})	7	7
Vector Direction (°)	<10	<10
Pulse Width (μs)	1000	100
Pulse Repetition (s^{-1})	500	800
Peak Power (W)	80	40
Average Power (W)	40	40
Baseline Distance (km)	100	20

Table 4. Capabilities of the WERA system in Beam Forming (BF) using a phased array for the 8 and 16 MHz. The system can be configured in Direction Finding (DF) mode where the array is arranged in a square. For waves 16-elements are needed to resolve the directional part of the signals. (Adapted from Shay et al. 2007a & b)

Description	**8 MHz**	**16 MHz**	**30 MHz**
Range (km)	175-225	80-100	45
Resolution (km)	2.4-4.8	0.6-1.2	0.3-0.6
Depth of Measurement	1.4	0.7	0.4
Radial Current (cm s^{-1})	2	2	2
Vector Speed (cm s^{-1})	5	5	5
Vector Direction (°)	±3	±3	±3
Baseline Distance (km)	75-100	40-60	
Transmit Elements (Yagi)	4	4	4
Receive Elements (BF)	12-16	12-16	8-32
Receive Elements (DF)	4	4	4
Peak Power (W)	30	30	30

A research Pilot Project is needed. One was proposed by the GCOOS-RA in the FY2008 proposal that is on hold for possible funding in FY2009. That part of the proposal is to investigate how to effectively combine radials from a 25-MHz CODAR system and 16-MHz WERA system on the East Florida Shelf and then assess the same issue on the West Florida Shelf using a 12-MHz WERA with a 5-MHz CODAR (Figure 5). While Bragg wavelengths differ considerably (12.5 m versus 30 m), in the proposed research this issue will be systematically addressed by developing techniques and protocols to combine radial currents (and vectors) over the radar footprints.

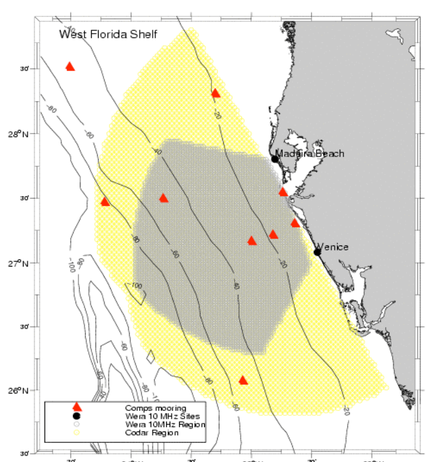

Figure 5. Approximate radial current coverage of a 12-MHz WERA system (gray) relative to radial measurements from 3 long-range, 5-MHz CODARs (yellow) on the West Florida Shelf. Red triangles represent COMPS mooring array operated by USF.

5 FIVE YEAR PLAN

The development of a five year plan for a national HFR system should not only consider how many stations of various types of HFR radar are needed in which particular locations (a difficult task in and of itself), but also how the system is going to be managed and by whom. What are the proper roles for the federal, state, and local governments, academia, and the private sector for this operational system? In particular, the IOOS organizations have not yet articulated well how the private sector can properly participate in the IOOS. For a successful national HFR program, these questions must be addressed early on in the process. In the FY2008 GCOOS-RA submission to NOAA, these questions were to be addressed within the Gulf. The cost estimates for a truly 24/7 operational system crucially depend upon the answers to these questions. That stated, a rough estimate of costs for a five-year plan follow. The assumptions used are:

1. The six existing 5-MHz CODAR units of USM and USF will be maintained and funded as part of the GCOOS-RA/SECOORA HF Radar network, but through another line of funding (Note if this funding fails, then these are priorities for GCOOS-RA funding).
2. The two existing 16-MHz WERA units of UM in the Florida Straits will be maintained and funded as part of the SECOORA HF Radar network, but through another line of funding (Note if this funding fails, then these are priorities for GCOOS-RA funding).
3. Three 13-MHz and two 25-MHz CODAR units from SERF and the Texas General Land Office will be made operational again and installed and maintained along the central Texas coast and in Corpus Christi Bay, but through another line of funding (Note if this funding fails, then these are priorities for GCOOS-RA funding).
4. SECOORA will be funded to cover the HF Radars along the Florida coast from Port Richey, FL, south through the Keys and Florida Straits (Note if this funding fails, then these are priorities for GCOOS-RA funding).
5. The plan will follow the model where the local lead is a PI at a participating institution; this may be changed to a system-wide radar manager position as the network develops.
6. Funding for salaries at a given institution only begin once they also are funded for deploying radar stations.
7. The academic institutions by state are:
   TX: Texas A&M University (TAMU System);
   LA: Louisiana State University (LSU);
   MS: University of Southern Mississippi (USM);
   AL: Dauphin Island Sea Lab (DISL);
   FL: Florida State University (FSU), University of South Florida (USF), University of Miami (UM), University of West Florida (UWF; possible involvement).
8. Each institution needs funding for 1 full time technician per two sites.
9. Each institution requires 4 months of data manager support; this may be changed to one or more system-wide data manager positions as the network develops.
10. Two cases are described: one covering only HF Radar acquisition and installation and the other also including operational costs (Note if these costs are funded by another line, then the plan the timing of installation of the network occurs earlier).
11. Spares are assumed to be provided through a pool in the national network. If no spares are so provided, then spares will need to be purchased due to damage by hurricanes and other energetic storms that may occur.

Assuming operating costs for new systems are NOT to be included in the five-year plan, the tentative schedule for installation of stations is given in Table 5 (see Appendix A). If operating costs are to be included in the five-year plan, then Table 6 shows the installation schedule with HF Radars moved later in time to accommodate the operational costs (see Appendix B).

Phase 1 Long-Range coverage: The US Gulf Coast could be covered with approximately 35 16-MHz HFRs (this excludes the Florida Straits, but includes the Keys). Where 5-MHz stations can be used this number can be reduced. However, there have been multiple cases of 5-MHz HFR stations causing interference with US Coast Guard communications and being shut down temporarily until a change in transmit frequency could be implemented. For example, USM has been successful in using 5-MHz CODAR systems, but USF has had interference issues with its 5-MHz systems and is transitioning to higher frequency systems. To avoid this problem, we plan to use the 16-MHz HFRs to obtain the long-range coverage for the U.S. Gulf. Additionally, since directional waves are important for this hurricane prone Gulf coast, we plan to install WERAs in most places.

Phase 2 Medium- and Short-range HFR: Short/Medium Range (SMR) HF Radars will be deployed if funding allows. These would be targeted to PORTS or busy transportation corridors. Priorities are the SMR HF Radars for AL Mobile Bay Outflow/PORTS, MS Pascagoula PORTS, and TX Sabine Neches/PORTS. Additional priorities are the SMR HF Radars for MS Gulfport PORTS and LA Southwest Pass. In out years SMR HF Radars are planned for FL Tampa Bay Outflow/PORTS and FL Miami. The later two may be covered by SECOORA. It is assumed SMR HFRs will be operational at TX Corpus Christi Bay, but under funding separate from this.

Table 5. Five-year plan and estimated costs for installation of the GCOOS-RA HF Radar network. This case covers costs only to acquire and install the new radars, including personnel. Spares are assumed to be available from a national pool if necessary. Total five-year cost is $9,846,650. (LR = Long-range; SMR = Short/medium Range) (See Appendix A and Figure A-1.)

	Tentative Institution	**Year 1 - LR**	**Year 2 - LR**	**Year 3 - LR**	**Year 4 - SMR**	**Year 5 – SMR**
Texas	TAMU	3 East*	2 South	1 South	none	2 Sabine Neches
Louisiana	LSU	1 West*	2 East	4 Central	1 West	2 Miss Riv (LR)
Mississippi	USM	none	none	none	2 Pascagoula	2 Gulfport
Alabama	DISL	none	none	none	2 Mobile Bay	none
Florida	FSU/UWF	2 Panhandle	none	none	none	none
	FSU	none	2 Big Bend**	1 Big Bend	none	none
	USF	none	none	none	2 N Central	none
	UM	none	none	none	none	none
Est. Cost		$1,840,020	$1,873,950	$1,901,790	$2,245,235	$1,985,455

* see Figure 6; ** see Figure 7

6 COST/BENEFIT ANALYSIS

No cost/benefit analyses for an HFR network have been found for the Gulf of Mexico.

Table 6. Five-year plan and estimated costs for installation of the GCOOS-RA HF Radar network, Long-range units. This case covers costs to acquire and install the new radars and to operate and maintain them, including new staff. Spares are assumed to be available from a national pool if necessary. Total five-year cost is $10,160,573. See Appendix B and Figure B-1.

	Tentative Institution	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Years 6-8**
Texas	TAMU	3 East*	1 South	1 South	1 South	none	none
Louisiana	LSU	1 West*	1 East	1 East	1 East	1 East	1/yr
Mississippi	USM	none	none	none	none	none	none
Alabama	DISL	none	none	none	none	none	none
Florida	FSU/UWF	1 Panhandle	1 Panhandle	none	none	none	none
	FSU	none	1 Big Bend**	1 Big Bend	1 Big Bend	none	none
	USF	none	none		none	1 N Central	1 N Central
	UM	none	none	none	none	none	none
Est. Cost		$2,022,616	$2,001,161	$1,919,205	$2,173,789	$2,043,801	

* see Figure 6; ** see Figure 7

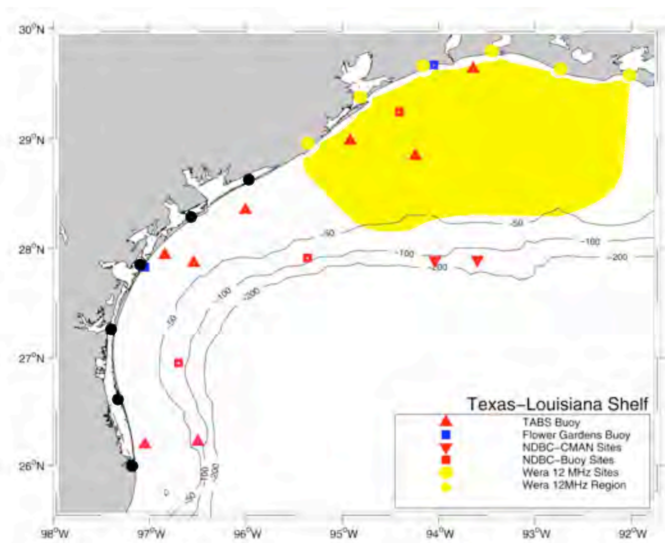

Figure 6. HF radar coverage on the Texas-Louisiana Coast. The first year installations are shown as yellow circles at the shore. The region of overlapping radials, where current vectors can be estimated, is shown in yellow. HFRs for years 2 and 3 are shown as black circles. Note the NDBC and TABS buoys in the region of overlap.

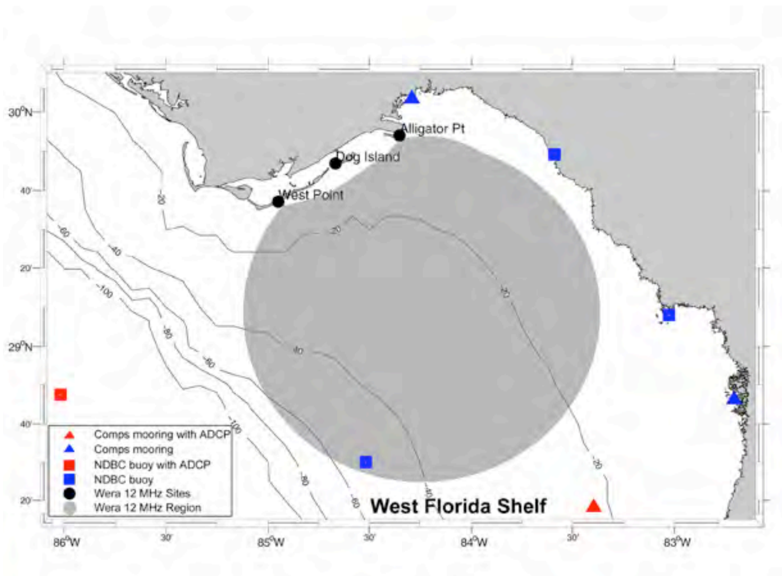

Figure 7. Potential sites for the 12-MHz WERA stations in the Florida Big Bend region.

7 PRODUCTS

Products are being produced by the operators of the 8 existing HF Radars. These products are available through the web sites (see the USM, USF, and UM sites noted in Section 2). Table 7 shows the products currently available. All of these groups also are automatically sending radials files to the NOAA HF Radar Server and Architecture Project, which has redundant servers at Scripps, NDBC, and Rutgers. UM is the first institution to serve WERA radials to this project. Additionally, the GCOOS-RA is building a Data Portal that will serve data as well as products identified as priorities for a broad segment of the stakeholders. Table 8 summarizes the societal benefits (users) of products that are contemplated. The seven societal goals of the U.S. Integrated Ocean Observing System (IOOS) identified in the table are:

1. Improve predictions of climate change and weather and their effects on coastal communities and the nation;
2. Protect and restore healthy coastal ecosystems more effectively;
3. Reduce public health risks;
4. Enable the sustained use of ocean and coastal resources;
5. Improve the safety and efficiency of maritime operations;
6. Improve national and homeland security; and
7. Mitigate the effects of natural hazards more effectively.

Additionally, the GCOOS-RA plans to develop outreach displays for targeted user groups showing availability and use of data and product and to use data in informal educational kiosk exhibits at aquariums or similar venues. Note that the intension to produce surface current fields require the development of techniques for integration of data from different radar systems and data assimilation into models.

Table 7. Products available from HFR operators in the GCOOS region.

Institution	Units	Products
UM	16-MHz WERA (2)	Data Radials to HFR Server Surface Current Maps (see Figure 8) Animations Longitude/Time Sections
USF	5-MHz CODAR (3)	Radials to HFR Server Surface Current Maps Animations
USM	5-MHz CODAR (3)	Data Radials to HFR Server Surface Current Maps

Table 8. Priority products and information for the GCOOS HF Radar Network and their societal benefits. The IOOS societal goals addressed by each benefit are identified by goal numbers in the list above.

Products and information	Societal benefits (uses)
Surface wave spectra	Boating safety 5 Prediction of beach erosion 4, 7 Surf and beach conditions 3, 4
Surface current fields	Search and rescue 3 Efficient marine transportation 5 Conditions for offshore operations 4, 5 Pollutant spill tracking 2, 3, 4
Outreach and Educational Materials	Public health 3 Ocean literacy

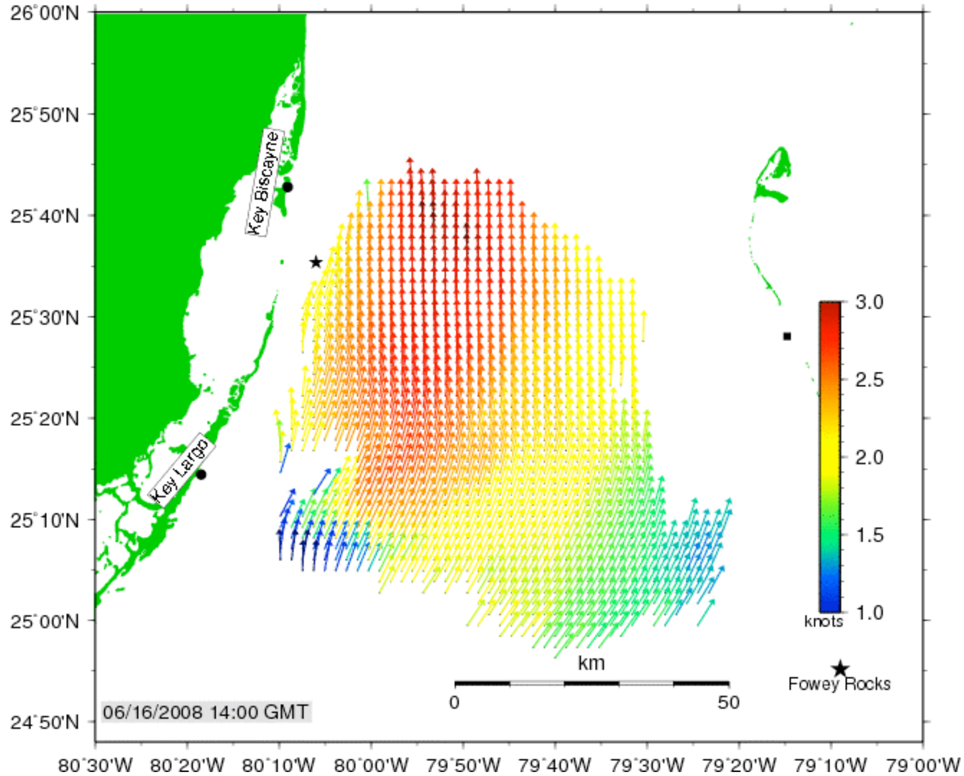

Figure 8. The image depicts recent hourly averaged surface currents plotted on a 2.4 km grid. The working range is somewhat reduced during periods of strong winds and high waves. Color refers to strength of the current in knots.

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APPENDIX A
COST ESTIMATE FOR ACQUISITION & INSTALLATION

GCOOS-RA: Stations north of Port Richey, FL
SECOORA: Stations south of and including Port Richey
Old SERF Stations on TX coast will be funded separately
Spares are assumed to be available through a national pool.

ASSUMPTIONS	**Acquisition and Installation Only**				
	YR 1	**YR 2**	**YR 3**	**YR 4**	**YR 5**
1 HFR Station (WERA)	$188,000	$188,000	$188,000	$188,000	$188,000
Supporting Equip for 1 HFR	$12,000	$12,000	$12,000	$12,000	$12,000
Total Equipment for 1 HFR	$200,000	$200,000	$200,000	$200,000	$200,000
Installation for 1 HFR	$100,000	$100,000	$100,000	$100,000	$100,000
Travel (per FTE Technician)	$4,200	$4,200	$4,200	$4,200	$4,200
Communications (per station per year)	$2,500	$2,500	$2,500	$2,500	$2,500
Number Radars by State					
TX	3	5	6	6	8
LA	1	3	7	8	10
MS	0	0	0	2	4
AL	0	0	0	2	2
FL	2	4	5	7	7
Total Stations	6	12	18	25	31
Total New Stations	6	6	6	7	6
Total HFR Equipment	$1,200,000	$1,200,000	$1,200,000	$1,400,000	$1,200,000
Total HFR Installation	$600,000	$600,000	$600,000	$700,000	$600,000
Cumulative Stations by Institution					
TAMU	3	5	6	6	8
LSU	1	3	7	8	10
USM	0	0	0	2	4
DISL	0	0	0	2	2
FSU or UWF	2	2	2	2	2
FSU	0	2	3	3	3
USF	0	0	0	2	2
UM-Rosenstiel School	0	0	0	0	0
Total	6	12	18	25	31
Number of technicians (FTE)	3.00	5.00	6.00	9.00	12.00
Number of data managers (FTE)	1.00	1.33	1.33	2.00	2.33
Number of PI/Radar Manager (FTE)	0.25	0.50	0.67	1.00	1.00
Travel + 45% overhead	$18,270	$30,450	$36,540	$54,810	$73,080
Comm + 45% overhead	$21,750	$43,500	$65,250	$90,625	$112,375
Yearly Total	$1,840,020	$1,873,950	$1,901,790	$2,245,435	$1,985,455
Five-Year Total = $9,846,650					

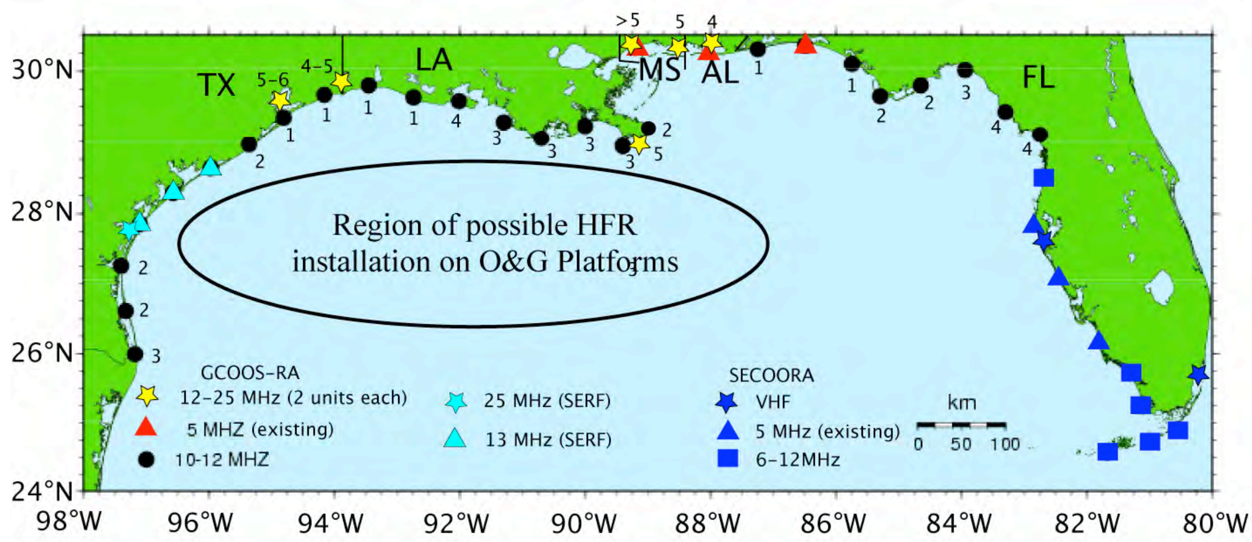

Figure A-1. Station locations and year of deployment for the acquisition and installation case.

APPENDIX B
COST ESTIMATE FOR ACQUISITION, INSTALLATION & OPERATION

GCOOS-RA: Stations north of Port Richey, FL
SECOORA: Stations south of and including Port Richey
Old SERF Stations on TX coast will be funded separately
Spares are assumed to be available through a national pool.

ASSUMPTIONS	Acquisition, Installation, and Operation of New (Map8)							
	YR 1	**YR 2**	**YR 3**	**YR 4**	**YR 5**	**YR 6**	**YR 7**	**YR 8**
1 HFR Station (WERA)	$188,000	$188,000	$188,000	$188,000	$188,000	$188,000	$188,000	$188,000
Supporting Equip for 1 HFR (e.g., trailer)	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000
Total Equipment for 1 HFR	$200,000	$200,000	$200,000	$200,000	$200,000	$200,000	$200,000	$200,000
Installation for 1 HFR (includes personnel)	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000
For Operations (1 tech/2 sites)								
1 Month Technician Support								
Salary Technician	$4,583	$4,583	$4,583	$4,583	$4,583	$4,583	$4,583	$4,583
Fringe (35%)	$1,604	$1,604	$1,604	$1,604	$1,604	$1,604	$1,604	$1,604
Overhead (45%)	$2,784	$2,784	$2,784	$2,784	$2,784	$2,784	$2,784	$2,784
Total for 1 Month Tech	$8,972	$8,972	$8,972	$8,972	$8,972	$8,972	$8,972	$8,972
1 Month Data Manager								
Salary	$6,500	$6,500	$6,500	$6,500	$6,500	$6,500	$6,500	$6,500
Fringe (30%)	$1,950	$1,950	$1,950	$1,950	$1,950	$1,950	$1,950	$1,950
Overhead (45%)	$3,803	$3,803	$3,803	$3,803	$3,803	$3,803	$3,803	$3,803
Total for 1 month	$12,253	$12,253	$12,253	$12,253	$12,253	$12,253	$12,253	$12,253
1 Month PI or Radar Manager Support								
RM/PI Oversight	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000
Fringe (26%)	$2,600	$2,600	$2,600	$2,600	$2,600	$2,600	$2,600	$2,600
Overhead (45%)	$5,670	$5,670	$5,670	$5,670	$5,670	$5,670	$5,670	$5,670
Total for 1 month	$18,270	$18,270	$18,270	$18,270	$18,270	$18,270	$18,270	$18,270
Travel (per FTE Technician)	$4,200	$4,200	$4,200	$4,200	$4,200	$4,200	$4,200	$4,200
Communications (per station per year)	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500
Number Radars by State								
TX	3	4	5	6	6	6	6	6
LA	1	2	3	4	5	6	7	8
MS	0	0	0	0	0	0	0	0
AL	0	0	0	0	0	0	0	0
FL	1	3	4	5	6	7	7	7
Total Stations	5	9	12	15	17	19	20	21
Total New Stations	5	4	3	3	2	2	1	1
Total HFR Equipment	$1,000,000	$800,000	$600,000	$600,000	$400,000	$400,000	$200,000	$200,000
Total HFR Installation	$500,000	$400,000	$300,000	$300,000	$200,000	$200,000	$100,000	$100,000
Total Spares (Assumed from a National Pool)								

Cumulative Stations by Institution								
TAMU	3	4	5	6	6	6	6	6
LSU	1	2	3	4	5	6	7	8
USM	0	0	0	0	0	0	0	0
DISL	0	0	0	0	0	0	0	0
FSU or UWF	1	2	2	2	2	2	2	2
FSU	0	1	2	3	3	3	3	3
USF	0	0	0	0	1	2	2	2
UM-Rosenstiel School	0	0	0	0	0	0	0	0
	5	9	12	15	17	19	20	21
Number of technicians (FTE)	2.50	4.50	6.00	7.50	8.50	9.50	10.00	10.50
Number of data managers (FTE)	1.00	1.00	1.00	1.00	1.33	1.33	1.33	1.33
Number of PI or Radar Manager (FTE)	0.33	0.50	0.67	1.00	1.00	1.00	1.00	1.00
Technicians	$269,156	$484,481	$645,975	$807,469	$915,131	$1,022,794	$1,076,625	$1,130,456
Data Managers	$147,030	$147,030	$147,030	$147,030	$196,040	$196,040	$196,040	$196,040
PI/Radar Manager	$73,080	$109,620	$146,160	$219,240	$219,240	$219,240	$219,240	$219,240
Travel + 45% OH	$15,225	$27,405	$36,540	$45,675	$51,765	$57,855	$60,900	$63,945
Comm + 45% OH	$18,125	$32,625	$43,500	$54,375	$61,625	$68,875	$72,500	$76,125
Yearly Total	$2,022,616	$2,001,161	$1,919,205	$2,173,789	$2,043,801	$2,164,804	$1,925,305	$1,985,806

Five-year cost = $10,160,573
Eight-year cost = $16,236,488

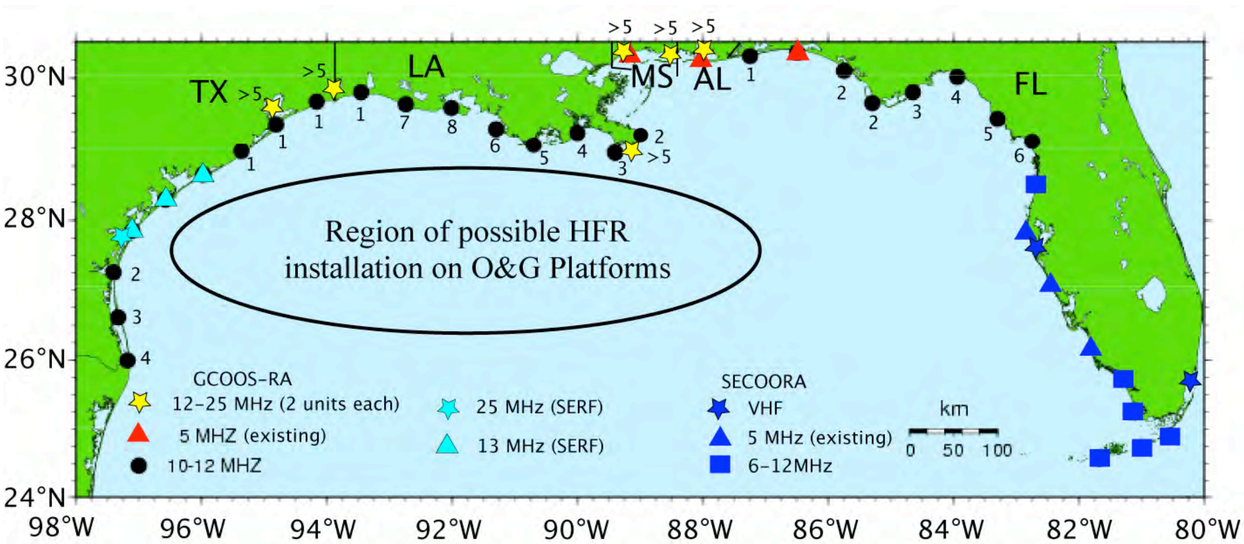

Figure B-1. Station locations and year of deployment for the acquisition, installation and operation case.