MACOORA
Mid-Atlantic Coastal Ocean Observing Regional Association

HF Radar Gap Analysis for the Mid-Atlantic Bight: Serving regional and sub-regional themes of Maritime Safety, Ecological Decision Making, Coastal Inundation and Water Quality.

Prepared for MACOORA by the MARCOOS PIs

I. MARCOOS

MACOORA formed the *Mid-Atlantic Regional Coastal Ocean Observing System (MARCOOS)* to generate quality controlled and sustained ocean observation and forecast products that fulfill user needs. MARCOOS products support the two priority regional themes and provide critical regional-scale input to MACOORA's nested sub-regional efforts on costal inundation and water quality. The first implementation phase of MARCOOS is an end-to-end regional ocean data acquisition, management, modeling and product-generation system in response to region-wide user needs in the thematic areas of ***Maritime Safety*** and ***Ecological Decision-Support***. MARCOOS will accomplish this by coordinating an extensive array of existing observational, data management, and modeling assets to generate and disseminate real-time data, nowcasts and forecasts of the ocean extending from Cape Cod to Cape Hatteras. This gap filling plan describes the present status of the HF radar component of MARCOOS and the needs and priorities for its expansion within the context of regional and sub-regional themes.

Regional Themes:

Maritime Safety: The Maritime Safety priority for MACOORA is evidenced by its focus on establishing the region-scale Mid-Atlantic HF Radar network. Measured surface current maps by the Mid-Atlantic HF Radar network are recognized (1) by the Coast Guard to improve their Search And Rescue (SAR) activities and (2) by NOAA HazMat to improve emergency response to hazardous spills. Nationally, the Coast Guard receives an average of 15 SAR calls per day, of which 12 are successful rescues. To reduce the lives lost, the critical USCG need is to optimize SAR operations to minimize search time. HF Radar information in the gap between the inshore NOAA PORTS and recommended offshore NDBC buoys will allow SAR operations to be optimized. The basic infrastructure for CODAR operations is in place to fill the gap. The community, in numerous MACOORA-wide meetings, has concluded that the existing observational infrastructure and resident expertise can be leveraged to produce sustainable products to improve Maritime Safety. Recent statistical comparisons between surface drifter trajectories, those produced by STPS and the pre-SAROPS methodology using climatology or nearest NOAA coastal station data indicate that the STPS/CODAR fields lead to more accurate results. In another recent study, comparisons between Coast Guard drifter-inferred currents and CODAR surface currents indicate *a factor of 2 improvement* *in uncertainty*, as compared to the existing models in the EDS and available to SAROPS. Thus, the USCG Office for Search And Rescue has concluded that by using CODAR currents (with their estimated uncertainty) in the existing EDS for SAROPS, an additional 50 lives per year will be saved at the national level.

Ecological Decision Making: Commercial and recreational fishing represent a multi-billion dollar industry in the Middle Atlantic (MA). Management of these resources is difficult as many of the species are migratory and poorly sampled using traditional strategies. An integrated regional perspective is required. Timing and migration patterns of living marine resources are strongly influenced by the structure of MA water properties. Unless regional hydrography is mapped on at least monthly time scales, it is difficult to assess the efficacy of fisheries management approaches based on marine protected areas, no fishing areas, marine reserves, and rotating closures. Regional hydrography and circulation from MARCOOS observations and models will facilitate analysis of the movement of water masses and their associated populations. This will assist interpretation of population breeding dynamics and connectivity. For species with mobile adult stages, retention-through-migration can effectively counteract the dispersing effect of physics. Species with less mobile juvenile or adult life stages (e.g. sea scallops) depend on circulation processes to maintain them within their habitat range. For example, scallops, the 2nd highest ex-vessel revenue in the Northeast fishery, contribute $431.5 million annually to the MA domain. MARCOOS modeling will provide spatial patterns of the MA physical ocean to fishery managers for use in their individual-based models of larval dispersal, settlement and recruitment.

Sub-regional themes:

Several efforts focusing on important sub-regional issues in the MA are supported and proposed. MARCOOS supports these efforts by providing the outer boundary forcing and other region-scale information.

Coastal Inundation: The NOAA Storm Surge Leadership Team and a MACOORA Coastal Managers Workshop determined from coastal stakeholder comments that improvements are required in the resolution and accuracy of storm-surge forecasting and improved integration of surge and overland flood models down to the street level. This is a focus of several sub-regions within the MARCOOS domain. The efforts which address those inundation issues rely on MARCOOS to provide operational, region-scale open boundary water level, current, temperature, and salinity fields.

Water Quality: The MARCOOS domain that extends across the EPA's designated Virginian Province contains nearly 25% of the US population. It is the most urbanized coastal region in the US, representing 24% of the national economy. Buoyant coastal currents in the MA are fed by many urbanized rivers, which provide anthropogenic inputs into coastal waters. Nutrient and organic matter loadings fuel hypoxia/anoxia, a focus of some sub-regional efforts which will benefit from information on shelf and within estuary circulation, density structure, waves and sea surface heights.

II. Present Status of the MARCOOS HF Radar Network

A Mid-Atlantic HF Radar network is now capable of providing surface current maps across the shelf from Cape Cod, MA to Cape Hatteras, NC during high sea state conditions associated with coastal storms. Nested within this shelf coverage are high resolution systems in the five sub-regions (Chesapeake Bay, Delaware Bay, NY Harbor, Long Island Sound and Southern New England Bays and Sounds). The network is made up of 26 sites directly supported by MARCOOS including 13 long range 5 MHz sites (Figure 1), 12 standard range 25 MHz sites (Figures 2-5), and a single medium range 13 MHz site in Sandy Hook, NJ (Figure 3). In addition to these MARCOOS supported sites, there are two other funded sites to be deployed in 2008, a 13 MHz system near Jones Beach, NY (Figure 3) and a 25 MHz system near Long Neck, DE (Figure 4), as well as a 25 MHz site already installed and operated by NOAA CO-OPS in Chesapeake Bay (Figure 5). The entire network is organized into a northern, central and southern region, each with a dedicated technician. The efforts throughout the region are coordinated through a single regional coordinator supported part time by MARCOOS.

III. Gap Filling:

Strategy:

The gap filling strategy for the Mid-Atlantic HF radar network is to build a 24/7 network that supports regional and sub-regional user needs through all sea state conditions. The present long range network provides full coverage across the region only during those high sea state conditions associated with coastal storms. Nested high resolution networks are forming but need to be expanded to fully support the local users within the estuaries. The priorities were set based on end user needs for complete data coverage across the region and continuous delivery of products and services. The plan focuses on filling existing gaps in three high priority categories:

1) Operational coastal sites
2) Technicians
3) Full site spares

The strategy requires a balance of long-range shelf wide coverage and nested higher resolution coverage near and within the major estuaries. In addition to coverage gaps, our users require consistent and continuous network coverage. To do this we must maintain the equipment and the real-time links to each site so that combined data products can be provided in near real-time. Recent reports from the ROWG community workshops cite the two major causes of real-time data dropouts as (i) communication failures and (ii) major hardware damage due to natural environmental events. As a network we are already working to overcome the impact of communications dropouts with redundant communications to each remote site. In the Mid-Atlantic Bight, the major environmental event that leads to prolonged system downtime is lightning and erosion related to coastal storms. In order to account for these types of dropouts, we must have a set of full site spares within each of the northern, central and southern sub-regions. They must be available so that when equipment is damaged due to lightning, technicians can immediately replace the damaged part and maintain the data stream to the larger network. In addition to these full site spares and new operational sites, there is a clear

Figure 1. Location of the existing long-range sites in the Mid-Atlantic. Distance between the sites are shown as colored lines (greater than 90 km: red; greater than 70 km and less than 90 km: yellow; and less than 70 km: green).

need for us to fill the technician gap maintaining and operating these systems. Our present network consists of 3 nearly full time technicians and a part-time coordinator. With a ratio of 1 technician for every 8.6 sites, we fall well short of the NOAA recommended 1 technician for every 3 sites.

Long-range sites:

The present long-range network includes 13 sites from Nauset, MA to Hatteras, NC (Figure 1). The range of 5 MHz long range systems depends on both the sea state (higher waves increase range) and the noise level (higher noise deceases range). At 5 MHz, the noise floor increases, reducing the range of the HF radars, particularly at night. Our strategy for filling the long-range gaps is a phased approach that reduces spacing between sites to account for variations in data coverage. CODAR recommends an optimal long-range site spacing of 90 km. This recommendation assumes a consistent range of 180 km for each site in the pair. The average coverage of the long-range systems in the Mid-Atlantic in 2007 was 182 km, representative of typical daytime range and consistent with the CODAR recommendation. Experience in the MAB, however, indicates the typical nighttime range decreases to about 140 km. Similar results are reported in the Gulf of Maine. For these ranges the optimal spacing between sites decreases from 90 km to 70 km. Gaps in the existing network were prioritized based on these thresholds. Gaps greater than 90 km will be filled first (threshold based on typical daytime coverage), followed by gaps greater than 70 km (threshold based on typical nighttime coverage).

The distance between each pair of sites is represented as a colored line based on the thresholds described above, over 90 km (red), between 90 km and 70 km (yellow), and less than 70 km (green). At 90 km separation, the area with acceptable GDOP is optimized for radial data extending at least 180 km from the site. The distances marked with the red lines in Figure 1 exceed this recommendation and provide complete coverage only during the strongest coastal storms when radial data ranges exceed 200 km. In the first year we will fill these largest gaps with 5 new long-range sites. These five highest priority gaps are listed below starting with the largest. The proposed location for the new site is indicated in the parentheses.

1) Block Island RI and Nantucket, MA (Martha's Vineyard)
2) Sandy Hook, NJ and Moriches, NY (Fire Island, NY)
3) Moriches, NY and Block Island, RI (Montauk, NY)
4) Back Bay, VA and Cedar Island, VA (Smith Island, VA)
5) Hatteras, NC and Duck, NC (Pea Island, NC)

In the second year we will target the three yellow lines toward the middle of our coverage. These gaps (less than 90 km but greater than 70 km) meet the criteria for the average daytime coverage but are too far apart when the coverage falls below 182 km (as we see with the MAB sites at night). In order to account for the nighttime reduction in coverage, these three gaps would be filled in year 2. These are located between (in order of gap size):

1) Assateague, MD and Wildwood, NJ (Delaware coast)
2) Loveladies, NJ and Sandy Hook, NJ (Southern Monmouth Co.)
3) Cedar Island, VA and Assateague, MD (Wallops Island, VA).

Once these eight gaps are filled, our long range network will be configured to provide consistent total vector coverage with acceptable GDOP throughout the fluctuations in the day/night radial coverage.

Standard range sites:

The gap filling focus within each sub-region is prioritized based on the needs of the local users as communicated through members of MACOORA, and its observing system MARCOOS. In each of the first three years, a single site will be added to each of the sub-region nests described below.

Block Island Sound/Rhode Island Sound: Present HF radar coverage of the southern New England sounds is limited to the region of Block Island Sound (BIS). This area is covered by the 3 standard range 25 MHz sites (Block Island, Misquamicut, and

Figure 2. Location of the existing 25 MHz sites (green), proposed 25 MHz (large red), and proposed 42 MHz sites (small red) in Rhode Island Sound and Buzzards Bay.

Montauk Point) operated by the Universities of Rhode Island and Connecticut (Figure 2). A large gap exists from eastern BIS to the eastern end of the adjoining Rhode Island Sound (RIS). Extending coverage eastward into RIS will provide surface current observations at the mouth of Narragansett Bay. Narragansett Bay has recently experienced severe summertime hypoxia in its upper reaches and a NOAA Coastal Hypoxia Research Program funded project (Modeling Tools to Predict Hypoxia/Anoxia in Upper Narragansett Bay) is focusing on understanding the biological and physical processes underlying this phenomenon. HF radar surface current observations at the mouth of the Bay will provide an important constraint on exchange between the Bay and Rhode Island Sound (RIS), which is presently lacking. Expanded HF radar coverage in BIS and RIS will also benefit the decision-making process for siting of offshore wind generation installations, which are planned for the Rhode Island coastal ocean. Three new HF radar sites are proposed to extend coverage to RIS, Point Judith and Sakonnet Point in Rhode Island, and Gay Head on Martha's Vineyard. Point Judith will be instrumented first, as observations from this site will overlap with those from Misquamicut to extend coverage to eastern BIS. Subsequently, we will install the site at Sakonnet Point to provide coverage of the Narragansett Bay mouth region. Installation of the final site at Gay Head will then provide surface current fields over the whole of RIS.

Buzzards Bay: We propose a trio of 42 MHz (~20km range) CODAR sites in Buzzards Bay at Smith Neck, West Island, and at Woods Hole to provide high resolution (~500m) in Buzzards Bay (Figure 2). This coverage will nest within the 25 MHz network expanded into Rhode Island Sound which in turn is nested within the lower resolution long-range network. The high resolution maps within Buzzards Bay will directly support response to oil spills, storm induced sea level surge, red tide blooms and hypoxic events. In addition the network will compliment existing observational elements within the bay including stations maintained by NOAA NDBC, SMAST, and the Massachusetts Long-Term Annual Embayment Water Property Sampling.

Long Island Sound: The existing coverage in the western part of the sound will be expanded east through coordination with the NERACOOS gap filling plan.

Figure 3. Location of the existing 25 MHz sites (green), new 13 MHz site to be deployed in 2008 (yellow), and proposed 25 MHz sites (large red) in the New York Harbor/Hudson River estuary.

New York Harbor High Resolution Expansion: The present higher-resolution network in the New York Harbor area consists of three 25 MHz sites operated by Rutgers University and Stevens Institute and Technology, a single 13 MHz site (HOMR) located in Sandy Hook, and a new 13 MHz site to be deployed on Fire Island in 2008 (Figure 3). Existing partnerships with NJ Department of Environmental Protection (NJDEP), Monmouth County Health Department (MCHD), Stevens Institute of Technology and

Rutgers University have utilized these data to characterize the relationships between the physical environment and nearshore water quality measurements. These interactions have identified a critical need to extend the MARCOOS coverage (1) from the harbor mouth into Raritan Bay and (2) from the offshore low resolution coverage (~ 7 mi. offshore) into the coast in order to better support local water quality activities. The first proposed HF Radar location to be filled in FY09 is a site along the southern coast of the Raritan Bay near Bayshore that has been occupied by a mobile NOAA site for the past year (Figure 3). This gap filling support could establish a permanent HF Radar system at this site, immediately filling this vacancy. The second site is targeted for the Monmouth County coast near the Wreck Pond outflow. Wreck Pond is the most significant recurring water quality problem area identified by both NJDEP and MCHD. Siting at Wreck Pond will extend the high resolution coverage down the northern New Jersey coast and provide a local measure of nearshore currents and waves at the outfall. This will give water resource decision makers at NJDEP and MCHD real-time observations of the fate of bacteria ridden water exiting the outfall during significant rain events. Since the Hudson River plume is highly variable and wind driven. Depending on the wind directions and duration, it can be forced along either the New Jersey or Long Island coasts, so it is important to provide high resolution coverage south and east of the Harbor mouth. To do this, the final site scheduled for FY11 of this effort will be located to the east of the Breezy Point site along the south coast of Long Island near Jones Beach. This system expansion will (1) support water quality managers by providing surface transport estimates of the bacteria responsible for beach closures during the summer high season; (2) be incorporated into the inundation prediction system; (3) be incorporated directly into the national data stream through coordination with the MARCOOS HF Radar team.

Delaware Bay: The current two-site configuration gives consistent coverage outside the Delaware Bay mouth, offshore to typical ranges of about 30 km (Figure 4). A third 25 MHz site for this network has been funded and is due to be installed summer 2008 near Long Neck, Delaware. This new site will extend the coverage to the south and provide new information about the bay outflow plume. This extended coverage will also improve our ability to track potential oil spills as they exit the bay. As part of this gap filling plan we propose the addition of three sites. The first two will be deployed inside the bay and will fill in the current baseline 'no data' region between the two existing sites on either side of the bay mouth. The northern site will be located near Stipson Island along the New Jersey coast and the southern site near Slaughter Beach along the Delaware coast (Figure 4). These sites will support products related to surface transport out of the bay and tracking potential oil spills near the Slaughter Beach lightering area along the south coast of the bay. The third site north of the bay mouth will extend the high resolution coverage north along the New Jersey Coast. The new coverage area will directly support existing modeling efforts and understanding of the nearshore currents for NJDEP applications related to beach closures and shellfish monitoring. This 6 site network will provide a full kinematic description of the Delaware Bay estuary and adjacent shelf circulation, including the nearshore coastal current.

Figure 4. Location of the existing 25 MHz sites (green), funded 25 MHz site to be installed in 2008 (yellow) and proposed 25 MHz sites (red), in the Delaware Bay estuary.

Chesapeake Bay: The lower Bay and Bay mouth inside the Capes is currently adequately covered with three 25 MHz sites (Figure 5). Oceanview (VIEW) and Chesapeake Bay Bridge Tunnel (CBBT) are currently supported through MARCOOS and the third site on Cape Henry (CPHN) is owned and operated by NOAA CO-OPS. The

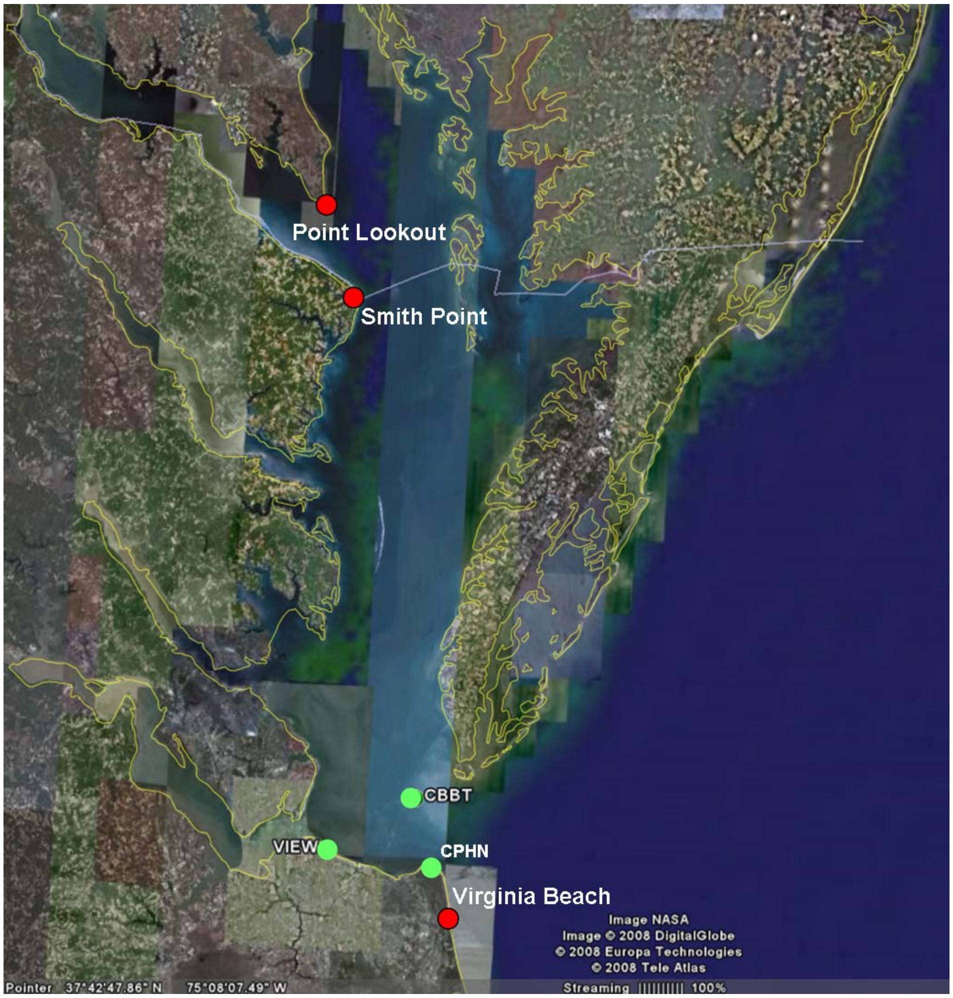

Figure 5. Location of the existing 25 MHz sites (green) and proposed 25 MHz sites (red) in the Chesapeake Bay estuary.

first gap to be filled in this sub-region will be a single standard range site outside the Bay mouth, south of Cape Henry in Virginia Beach. This extended coverage outside the Capes will overlap with an important area for SAR, commercial and recreational activities, and research regarding the Bay plume. The addition of this site will start the needed expansion south. The remaining two sites purchased in years 2 and 3 of this plan will be deployed inside the estuary where the Potomac River meets the bay (Figure 5). These sites will begin to provide surface current data over an area that is heavily used commercially and recreationally and the scene of former disasters. The data gap filled here will support ongoing search and rescue responses within the Bay.

Technicians:

The technicians will serve as a first responder to issues at the sites that disrupt data flow. Specifically they would.

1) Perform regular site hardware and software maintenance.
2) Maintain communication lines between radial and central sites.
3) Respond to site outages.
4) Diagnose and repair hardware/software failures.

The level of system reliability will be related to the level of support for the operation and maintenance. We also recognize the need to ensure that these technicians are well versed in the quality control and quality assurance of the data at both the radial and total vector level. The present support includes 3 technicians for 26 sites, a ratio of 1 technician for every 8.67 sites. Our goal through this gap filling proposal will be to get this ratio down to the national plan recommendation of 1 technician for every 3 sites. To do this we will build our technician team by three in each of the first four years and one additional technician in the final year. Even with the additional sites described in the previous section, the 13 additional technicians along with the present team of 3 will bring our ratio to 1 technician for every 3.2 sites by the end of the fifth year.

Full Site Spares:

Disruptions in the real-time data stream of any HF radar network are largely due to communication dropouts and environmental impacts. For our region these impacts are largely due to coastal storms and lightning. Both lead to potential hardware failures that require significant offsite repair. These types of outages cause large gaps in the real-time data stream. To overcome this gap in product delivery, we propose a phased plan to build up the spares for the network. By having distributed spare parts for each frequency operating in the three HF Radar operations sub-regions, we decrease our downtime resulting from significant hardware failure. The vendor recommends one to two full site spares for every ten sites operating in the network. For the Mid-Atlantic we propose the acquisition of both long and standard range spares. We will purchase full long-range site spares in years 1, 4, and 5 and full standard range spares in years 2, 3, and 4. This will allow us to place full site spares for long-range and standard-range frequencies in each of the HF operation regions (north, central, and south).

Collaboration across the RAs:

Collaborations between MACOORA, NERACOOS, SECOORA and CaRA HF Radar Networks continue to expand. CaRA and MACOORA will continue to collaborate on HF Radar through the DHS Center of Excellence for Port Security based at Stevens Institute of Technology. The Mid-Atlantic and South Atlantic Bight networks are linked at Cape Hatteras. MACOORA will handle gap filling and site support for sites starting at the existing Cape Hatteras site and extending northward. SECOORA will coordinate site priorities and operations south of Cape Hatteras.

The Mid Atlantic and Gulf of Maine long range HF Radar networks are linked at Cape Cod. Using the same criteria as the MAB (red gaps are > 90 km, yellow gaps are 90 km to 70 km, and green gaps are < 70 km), there are presently three large red gaps in

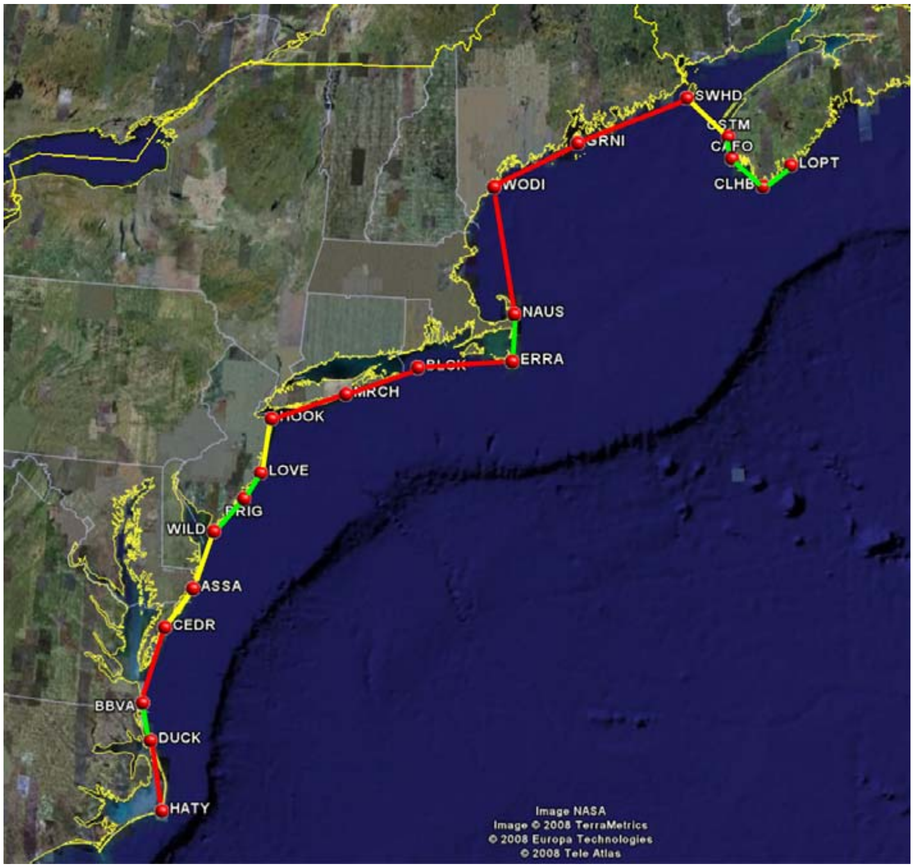

Figure 6. Location of the existing long-range sites in the Mid-Atlantic and Northeast. Distance between the sites are shown as colored lines (greater than 90 km: red; greater than 70 km and less than 90 km: yellow; and less than 70km: green).

the Gulf of Maine as shown in Figure 6. Based on discussions with NERACOOS and consistent with the MAB plan, we understand that NERACOOS proposes to fill the three red gaps in year 1 with three long range radar systems. One site will fill the small red gap between WODI and GRNI, transforming this section of coast into 2 acceptable green (<70 km) gaps. The middle size gap between GRNI and SWHD, with the addition of 1 new site, will be transformed into 1 green and 1 yellow gap. By placing a long range site at Cape Anne, the largest gap between NAUS and WODI will be transformed into two yellow gaps. The result after year 1 is the removal off all red gaps (> 90 km), leaving 3 marginal yellow gaps and 3 acceptable green gaps in its place. Again, consistent with the MAB plan, the three yellow gaps will be filled in year 2. The proposed build out is three new long range systems in year 1, and 3 new long range systems in year 2. Exact locations for the 6 new long range radars will be determined by NERACOOS.

IV. Budget:

	FY10	FY11	FY12	FY13	FY14	TOTAL
Operational Sites						
Long-range	$725K	$435K	$0	$0	$0	**$1,160K**
Standard-range	$650K	$650K	$650K	$0	$0	**$1,950K**
Site Support	$20K	$120K	$200K	$250K	$250K	**$840K**
Full Site Spares	$125K	$110K	$110K	$235K	$125K	**$705K**
Technicians	$375K	$750K	$1,125K	$1,500K	$1,625K	**$5,375K**
Total	**$1,895K**	**$2,065K**	**$2,085K**	**$1,985K**	**$2,000K**	**$10,030K**

Budget Justification:
Long-range Sites: The cost estimate for a long-range site (5 MHz) is $145K. This includes the cost of the equipment ($125K) and deployment (estimated at $20K/site, see below). The budget reflects the purchase of 5 sites in year one to fill the gaps between the sites more than 93 km apart and an additional 3 sites in year two to fill those gaps exceeding 70 km. At the end of the 5 year plan the number of long-range sites in the network will increase from 13 to 21.

Standard-range Sites: The cost estimate for the standard-range site (25 MHz) is $130K. This includes the cost of the equipment with the GPS timing option ($110K) and deployment costs (estimated at $20K/site, see below). The budget reflects the purchase of 5 standard-range sites in each of the first 3 years. At the end of the 5 year plan the number of standard-range sites in the network will increase from 12 to 28 and the number of medium-range sites will increase from 1 to 2. This includes the 15 sites acquired through this plan and the two new sites already funded but still to be deployed. At the end of the five year plan the number of higher resolution (13, 25, and 42 MHz) sites in the network will increase from 13 to 30.

Deployment Costs: Costs associated with the purchase and deployment of the new sites includes, power and phone installation, enclosures, guidelines, anchors, etc. In addition, these funds will support participation of vendor technicians for each installation.

Site Support: Funds are requested in support of site operation and minor maintenance. Costs are described below on a per site basis. These costs are estimated at $10K/site/year. Site costs include communications, power, backup media, and supplies. The communication costs are estimated at $208/month ($2,500/year). The vendor and method vary from cellular modems to satellite links depending on site location and available infrastructure. This estimate includes two lines of communications to each site as available. Power costs are estimated at $100/month ($1,200/year). These include utility bills to run the HF Radar equipment, computer, and air conditioner. Back up media include portable external hard drives (2 @ $300 each) and appropriate media

($400) for permanent back up of raw level data including range series and spectra. Supplies for each site include those needed for regular site maintenance excluding HF Radar system hardware (transmitters, receivers, antennas, etc.). Supplies will be site specific and include guide lines, stakes, electrical tape, back-up generators, etc.

Full Site Spares: Based on vendor recommendations we have dedicated our spare part acquisition to full site spares. The cost of a full spare is $125K for the long-range and $110K for the standard range. In this budget we will fill our spares requirements with a long-range in years 1, 4 and 5 and a standard range in years 2, 3, and 4. At the end of the 5 year plan there will be a full standard and long range spare in each of the three operations regions of the network (north, central, and south).

Technicians: The cost of a full-time technician is estimated at $125K/year. These costs include salary, fringe and appropriate overhead. The above budget supports additional technicians throughout the project and builds the workforce from the present number of 3 to 16 by the end of the fifth year.