1. INTRODUCTION

The SPS-48E is a S-band, long range, air defense, volume scanning radar onboard US Navy aircraft carriers and large deck amphibious ships. It operates with multiple pencil beams in a mechanically rotating phased-array antenna that scans electronically in elevation, and completes a volume scan in 4 seconds. A Weather Extractor Computer (WEC) and a Weather Data Interface Card (WDIC) have been developed for the SPS-48E that provide Doppler data at the lowest three elevation scans and reflectivity data at all elevation scans in Universal Format (UF). The WEC and WDIC are part of the Hazardous Weather Detection and Display Capability (HWDDC) that provides real-time weather information to shipboard personnel. The HWDDC system taps into the SPS-48E radar returns without changing or interfering with the tactical target scanning configuration. See Maese et al. (2007) for more information on the SPS-48E and the HWDDC.

The Naval Research Laboratory (NRL), Monterey, CA, is working with SPAWAR Systems Center, San Diego, CA on their development of a system to transmit the UF files created by the HWDDC system onboard Navy ships to Fleet Numerical Meteorology and Oceanography Center (FNMOC) in Monterey. The plan is to incorporate the SPS-48E data into the Navy’s Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS®) forecast model and various nowcasting algorithms. The products from these nowcasts and forecasts would then be made available to all US Defense forces through the FNMOC net-centric information system.

In January of 2006, a prototype HWDDC was successfully tested with a land-based SPS-48E at Navy facilities in Dam Neck, VA (Harasti et al. 2006; Maese et al. 2007). Later in February of 2006, the HWDDC was deployed onboard the USS PELELIU (LAH5) for a 6-month, at-sea demonstration (Fig. 1). This paper demonstrates the weather extraction and nowcasting capability of the SPS-48E via the display and analysis of archived UF data obtained during the USS PELELIU’s encounter with hazardous weather near Hawaii on 22 February 2006. Quality control issues that are unique to radar data gathered on a ship at sea will also be demonstrated and discussed.

Fig. 1. The USS PELELIU, an amphibious assault ship, shown with the SPS-48E radar onboard.
2. WEATHER CONDITIONS AT-SEA

On 22 February 2006, the USS PELELIU encountered lines of showers and thunderstorms associated with a short-wave trough and low pressure center that traveled eastward just north of the Hawaiian Islands (Fig. 2). The commanding officer of the PELELIU used the real-time HWDDC display of the SPS-48E weather radar data to steer the ship around non-flyable storm cells into clear areas so that the ship could resume flight operations. The HWDDC thus enhanced operational safety and efficiency and provided considerable time and resource savings.

Fig. 2. Synoptic situation over the Eastern Pacific Ocean at 18 UTC 22 Feb 2006. A low pressure center and trough were located just north of the Hawaiian Islands as shown near bottom of this surface analysis and forecast chart obtained from the NOAA/NESDIS/NCDC/SRRS website.

3. ANALYSIS OF ARCHIVED UF FILES

The UF data files created by the HWDDC on 22 February 2006 were archived to disk for post-storm assessment and analysis. The data contained 266 volumes scans executed at a frequency of 5 minutes for approximately 22 hours. The SPS-48E beams are combined to yield full PPI scans at 22 different elevation angles ranging from 0.2° to 24°. The azimuthal resolution of the data is 1° and the range resolution is 0.915 km. The maximum range for reflectivity (radial velocity) data is 275 (52) km.

Figures 3 and 4 show PPI images of the SPS-48E reflectivity taken from the 0.2° elevation scan between 1527 and 2110 UTC 22 February 2006. A squall line is seen approaching the radar from the north-west which then passes over the radar near 1700 UTC, and dissipates as it continues to move toward the south-east. Note the bow echo forming in the parent storm toward the north and north-east from 1547 UTC onward.

Fig. 3. Sequence of PPI images of reflectivity taken from the SPS-48E 0.2° elevation scan for the times indicated. See text for a description of the weather. Note that intense sea clutter is seen within the first ~30 km of the radar, and ground clutter from the Hawaiian Islands is recognized by the bright red and pink reflectivity colors west toward south of the radar (the large island of Hawaii is seen toward the south-west). The black arrows show ghost islands, or false appendages to real islands, resulting from reflections off the ship’s mast. The ship heading was, from top to bottom, 144°, 176° and 247°, respectively.
Sea clutter is clearly seen concentric to the radar while decreasing in reflectivity intensity with range out to a radial distance of ~30 km. There is also scattered, speckled sea clutter of low intensity visible beyond 30 km range from the radar. A notch in the reflectivity of the sea clutter can also be seen clearly in Figure 3. This notch is created by the radar-beam shadow of the ship's mast shown in Fig. 1 when the radar is pointing in the direction of the mast. The mast can also produce artifacts in the data, which we will refer to here as "ghost islands". These artifacts are produced when the antenna is pointed slightly off the land clutter (island). Referring to Fig. 5, the beam is reflected off the forward mast, and travels towards the island at an angle off what the radar expects, as shown by the solid red line. The radar 'thinks' the beam is traveling the path of the blue dashed line, and thus, the reflected beam path actually causes the radar to show a ghost island, or a false appendage to a real island or mainland coastline, where it 'thinks' the beam was pointed to. The black arrows shown in Figs. 3 and 4 point to examples of such artifacts.

The newest version of HWDDC, which wasn't ready for the USS PELELIU's version, includes surface clutter filtering, point target removal, second trip echo resolution, velocity dealiasing and basic SNR threshold checks for velocity/spectrum width. Therefore, sea and ground clutter, such as that shown in Figs. 3 and 4, will...
be reduced in SPS-48E radar data used for weather information extraction at sea in the future. NRL-Monterey is working with Basic Commerce and Industries, Moorestown, NJ, and SPAWAR Systems Center, San Diego, CA, to design and implement a solution for the “ghost island” artifact problem. The radar data quality control methods described in Harasti et al. (2005) will also be implemented and adapted as necessary to deal with any remaining clutter and artifacts in the UF data.

4. TITAN STORM MOVEMENT FORECASTS

The three-dimensional radar reflectivity mosaic algorithm developed by Zhao et al. (2004) was also applied to the UF data obtained from the USS PELELIU on 22 February 2006. It was necessary to adapt the NRL UF data decoder and three-dimensional reflectivity mosaic system software to handle the moving radar coordinate system due to the ship’s velocity. Also, composite reflectivity data from the mosaic grid, covering 6.7° latitude by 7.1° longitude, were used by the NCAR TITAN the thunderstorm identification, tracking, analysis, and nowcasting (TITAN) software to produce short term (0-2 hour) forecasts of the SPS-48E data. TITAN can be used to extrapolate and trend existing areas of precipitation (delineated by a polygon representing a reflectivity threshold) out into the future. The software utilizes a sophisticated storm identification, analysis and tracking method that includes combinatorial optimization, and allowances for storm cell splits and mergers where applicable (Dixon and Weiner 1993).

Figure 6 shows the 30-minute TITAN forecasts of the 25 dBZ reflectivity contour of TITAN-determined storm cells at 1234 UTC 22 February 2006. TITAN is able to accurately forecast the position of the most of the tracked cells out to at least 20 minutes. In addition, TITAN’s forecasts of mergers, splits and dissipation of storm cells at other times were very successful. These additional results and more details of the overall accuracy of TITAN in this case will be presented at the conference.

5. SUMMARY AND FUTURE WORK

This paper demonstrates the capability of the SPS-48E data to provide valuable weather information that would be available in real-time on Navy nowcasting systems to support tactical decision making. Radar data quality control issues that are unique to a radar on a ship at sea are also demonstrated. Improved HWDDC and NRL software will be applied in the future to remedy these issues, in addition to seeking and implementing a solution to the “ghost island” artifact problem. This SPS-48E data and the adapted software will also be applied in the near future at FNMOC, Monterey, CA, to demonstrate radar data assimilation capability into the COAMPS® model. Various, useful nowcasting products, such as TITAN, will also be considered for the demonstration. The Navy aircraft carrier USS GEORGE WASHINGTON (CVN73) is being considered as a possible candidate in November 2007 to test the new HWDDC and provide the necessary UF data from the SPS-48E radar onboard for the demonstration at FNMOC in real-time.

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7. References


