Surveying Coastal Ship Traffic With LANDSAT

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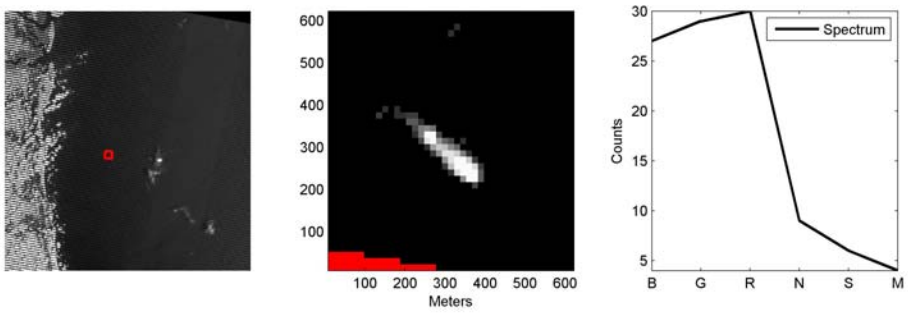
This paper reports on the effectiveness of using LANDSAT 7 images to study ship traffic patterns in coastal waters. This is an alternative to relying on cooperative ship reporting such as the Automatic Identification System (AIS) , a VHF communication protocol between ships and shore based stations. The benefits of using satellite imagery are the world wide coverage, especially in areas with limited or no other technologies for ship tracking, and the ability to detect uncooperative vessels (e.g., illegal fishing). Another advantage is coverage of vessels further out to sea. AIS range is about 35 km (although expected to increase with future upgrades); LANDSAT imagery is often available as far as 150 km from shore. And still another advantage is the availability of archived data for studies of historical trends. LANDSAT 7 has been operational since 1999 so there is now a 10 year archive of images.

Our case study used 10 year of archived images covering a significant portion of the Southeast US Right Whale critical habitat, an area along the Eastern US coast from Brunswick, NC to Jacksonville, FL, and extending 35 km offshore. Within this area there is significant cargo ship traffic into the commercial ports of Brunswick Fernandina, and Jacksonville, as well as Navy traffic into Naval Station Mayport. This is an area where in fact there is continuous ship data collections with the AIS and also with the Mandatory Ship Reporting System (MSRS). The MSRS is a special system and protocol for vessels of 300 gross tonnage or greater operating in NOAA designated right whale critical habitat areas. Thus there is data in these waters that is much better than from satellite imagery. However, it is precisely because of the AIS and MSRS that this area is especially suitable for testing and evaluating vessel traffic analysis with LANDSAT 7.

Coincidently, the MSRS and LANDSAT 7 became operational the same year (1999) and continue to the present. There is now a ten year overlap for comparative analysis. The early years of MSRS operations (1999-2002) provided data for conservation managers [Ward et al., 2005] . Subsequently new measures were implemented to minimize whale ship strikes such as speed limits and ship re routing. In more recent years (2006 to present) AIS data has been used to evaluate compliance [Mueller et al., 2009]. In this paper we compare ship traffic density determined by LANDSAT 7 imagery with the one derived by Ward et al. using MSRS, and compare individual ships detected in LANDSAT imagery (see Figure 1 for example) with the AIS data base used by Mueller et al. We also analyze the data for shifts and trends in the traffic pattern between the early and later years.



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sunElevation	63	deg	
sunAzimuth	110	deg	
utm Easting	483840	m	
utm Northing	3391380	m	
utmZone	17 N		
latitude	30.655	N	
longitude	-81.1687	W	
BGRNSM radianc	27 29 30...	counts	atmosphere corrected
ship wake head	129	deg	
heading	128	deg	
length	285	m	ship+wake
width	36	m	very approx.
filter	15		

Figure 1 Typical LANDSAT ship detection. UL: image of 100 km x 100 km area, red square indicating ship location, with a coastline on the left, some clouds apparent along the coastline and 50 km offshore; Center: zoom in on ship with panchromatic image (red indicating missing data) ; UR: radiance spectrum in atmosphere corrected counts for the visible (BGR) and IR (NSM) bands

The paper also discusses limitations with LANDSAT due to revisit rate and image resolution.

LANDSAT revisit rate is 16 days at best, but the actual revisit rate is subject to an image collection priority scheme and cloud cover. A typical useable revisit rate is one per two months, although there are some areas of the world with much better sampling. This is sufficient for statistical studies and historical trends but obviously not for real-time monitoring and enforcement applications.

Image resolution bears on the question of minimum detectable ship size, and ability to characterize the size, speed, and heading. LANDSAT resolution is 15 m in panchromatic and 30 m in the visible and IR spectral bands. The panchromatic is thus the primary band used for detection and vessel characterization. The minimum detectable ship length is one resolution cell, but a more realistic minimum length is 45 m feet. This is because discriminating vessels from clutter requires analysis of shape and spectra. We require ships to be elongated feature of three or more panchromatic cells with a major/minor axis ratio > 3. We also combined panchromatic with multispectral at 30 m resolution to further discriminate based on spectral radiances. Ships have a visible-to-IR ratio ~ 3 which is very distinctive from land, ocean sunglint, ocean surface surfactants, and shallow water bottom reflections. Clouds are also discriminated by a combination of spectra and shape.

The ability to measure vessel size with LANDSAT imagery is still being investigated and progress will be reported in the conference presentation. The current processing provides vessel width to within the panchromatic resolution cell size of 15 m. It may be possible to improve width accuracy to 8 m accuracy. At present the length is a combination of the vessel haul and some of the wake behind. A method of separating haul from wake is still under study.

Ship heading is very accurately determined from the wake-haul orientation. Ship speed, however, can not be estimated with LANDSAT resolution. Higher resolution imagery from SPOT, IKONOS, and QuickBird can do much better in characterizing vessel size, and even speed. However, LANDSAT imagery is a happy compromise of resolution and cost: a resolution that is adequate for detecting medium to large scale commercial vessels at a small cost. All LANDSAT imagery is available free as downloads from a USGS portal. The cost and time of processing LANDSAT images into ship data is minimal.

References

Leslie Ward, Gregory Silber, Rene Baumstark, and Tanya Pulfer, *Characterization of Ship Traffic in Right Whale Critical Habitat*, Coastal Management, 2005.

Mark Mueller, Stephanie Cain, and Leslie Ward, *Using The Automatic Identification System For North Atlantic Right Whale Research And Management In the Southeastern U.S. Calving Grounds*, Coastal GeoTools Conference, Myrtle Beach, SC, March 2009