# Pushing the Operational Sea State Limits in the Collection of Multi-beam Sonar Data

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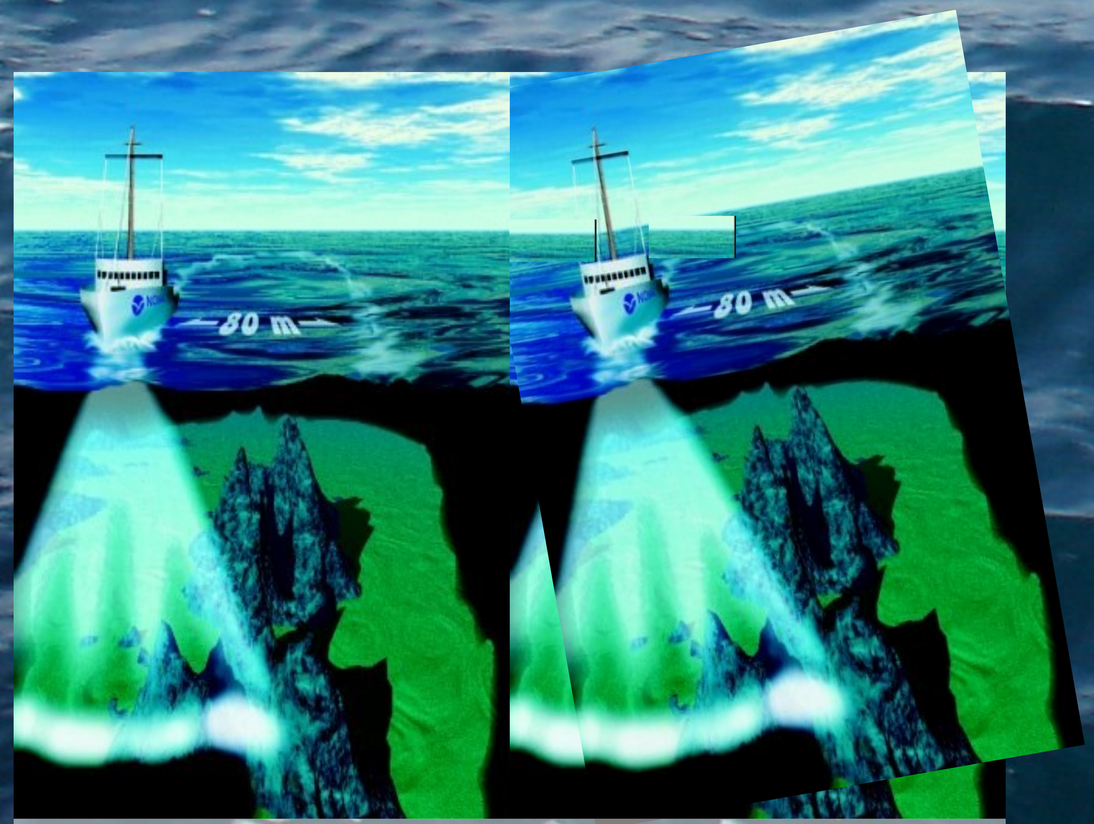
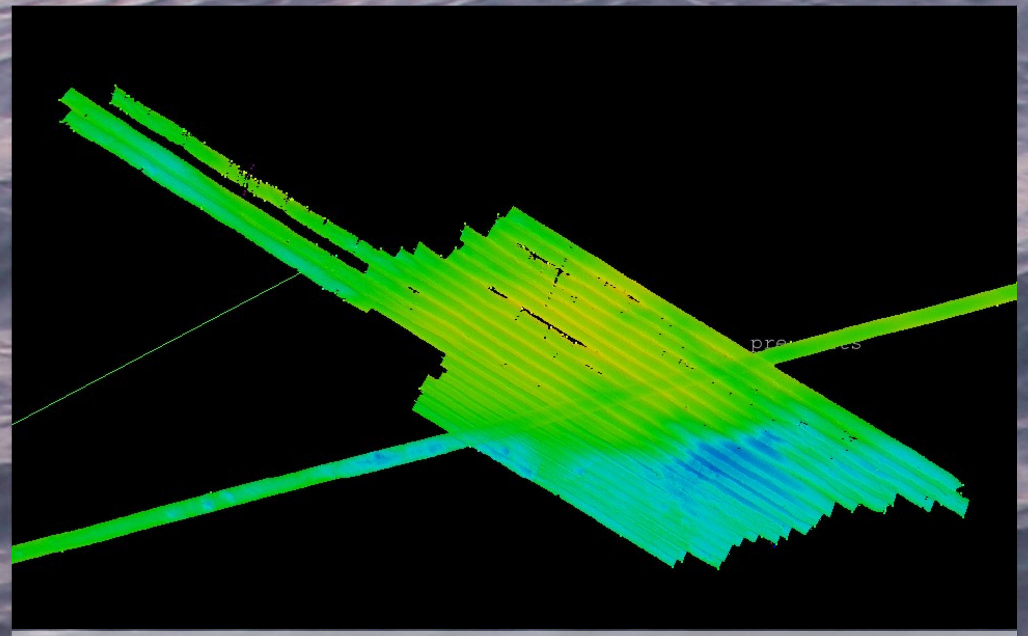
## Abstract

Multi-beam sonar has proved to be an invaluable tool for quickly mapping large areas of sea floor. A multi-beam system can map the bottom with sub-meter resolution in a favorable sea state. However this accuracy requires a sophisticated array of attitude instruments to correct for the ship's movement. These systems have their limitations, particularly in rough seas. For example, the angle of wave approach will change the errors in the data. Using a Simrad EM1002 system, bathymetric data were collected on the mid-continental shelf off the coast of Charleston, SC in January 2008 from the NOAA Ship NANCY FOSTER. These data were then processed with Caris HIPS 6.1 software. The heavy sea state encountered produced significant roll of the ship, resulting in the appearance of a concave bottom, which can also result in an incorrect sound velocity profile. Therefore, by changing the profile, the software corrected for the ship's roll.

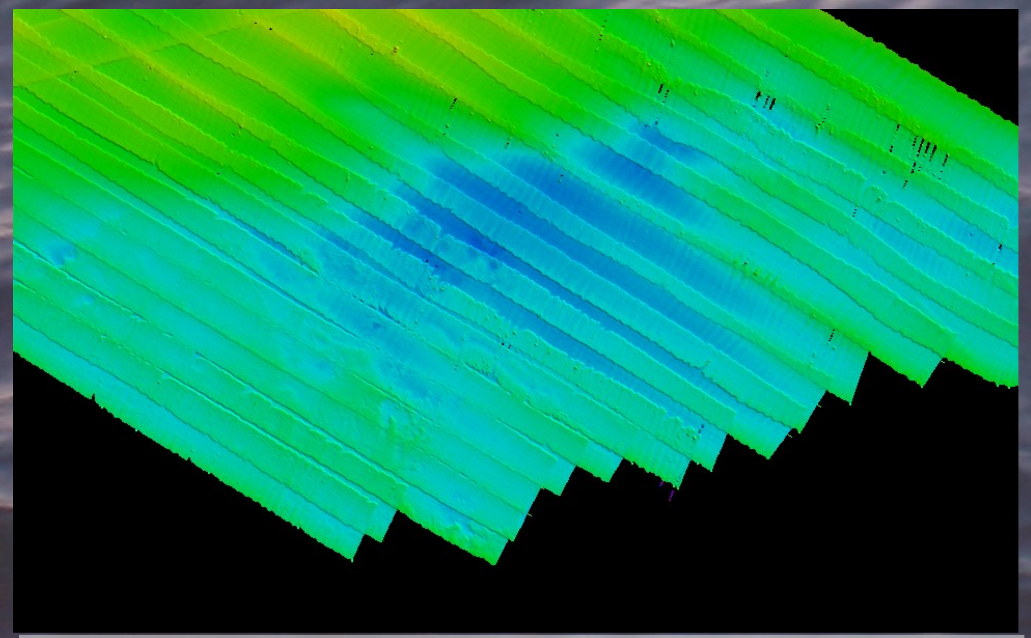


The ship on the left is operating in calm seas. The ship on the right is experiencing roll caused by waves. Notice how the beams are being directed to the ship's port side (to the right in the image). The "ping" must now travel through the water column longer, thereby amplifying any problem with the sound velocity correction. The longer transit time can confuse the computer and make it think that the bottom is curving upwards, as seen in the striping pattern to the right.

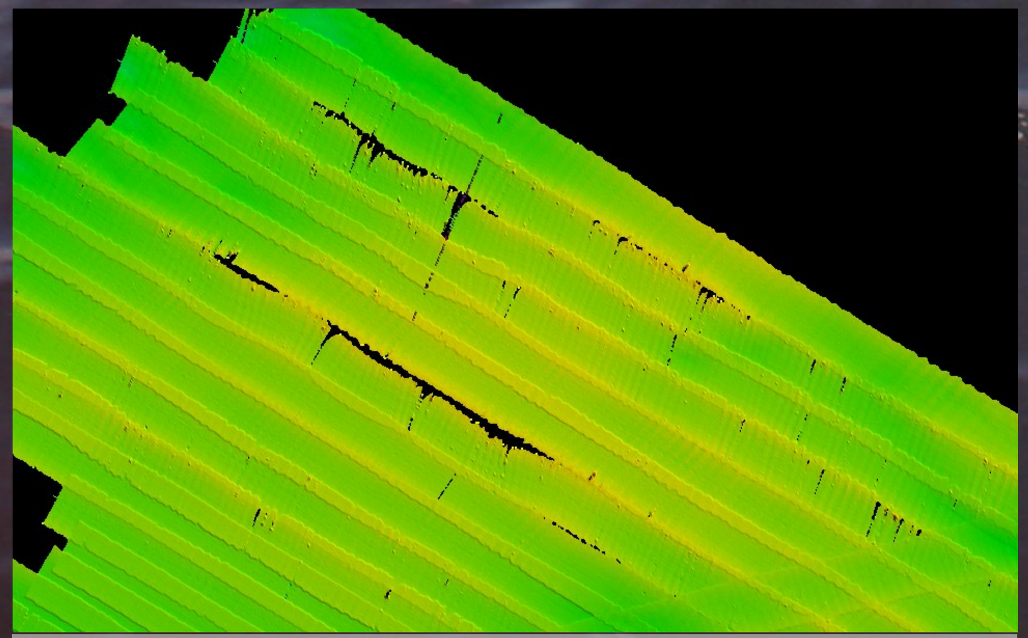
## Pre-Processing



An overview of an area just east of the Transect Meanders that was mapped two years ago. One can see that this is not a very accurate representation of what the sea floor looks like. The general shape is visible, however most of the features are obscured by the poor data.

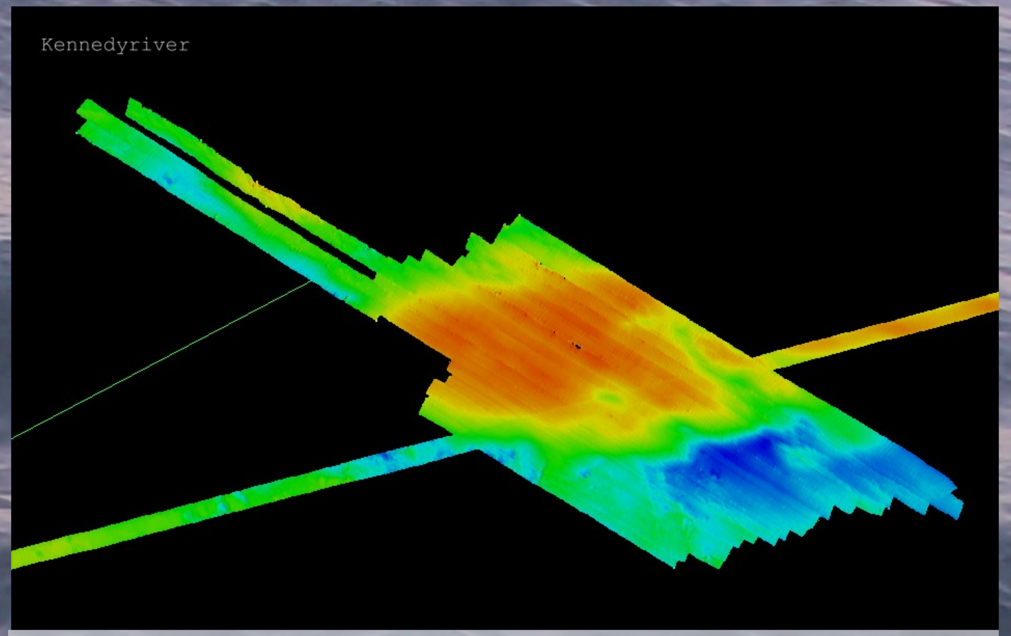


The striping is a result of the roll being greater than what the system can correct for. So, the raw data are being displayed as a concave surface. Each time the ship makes a pass it interprets an unrealistic concave bottom. Therefore, when the software, Caris HIPS, attempts to draw the bottom including multiple lines it reads the line overlaps as being a shallower topographic feature. This causes the striping pattern in the bathymetry.

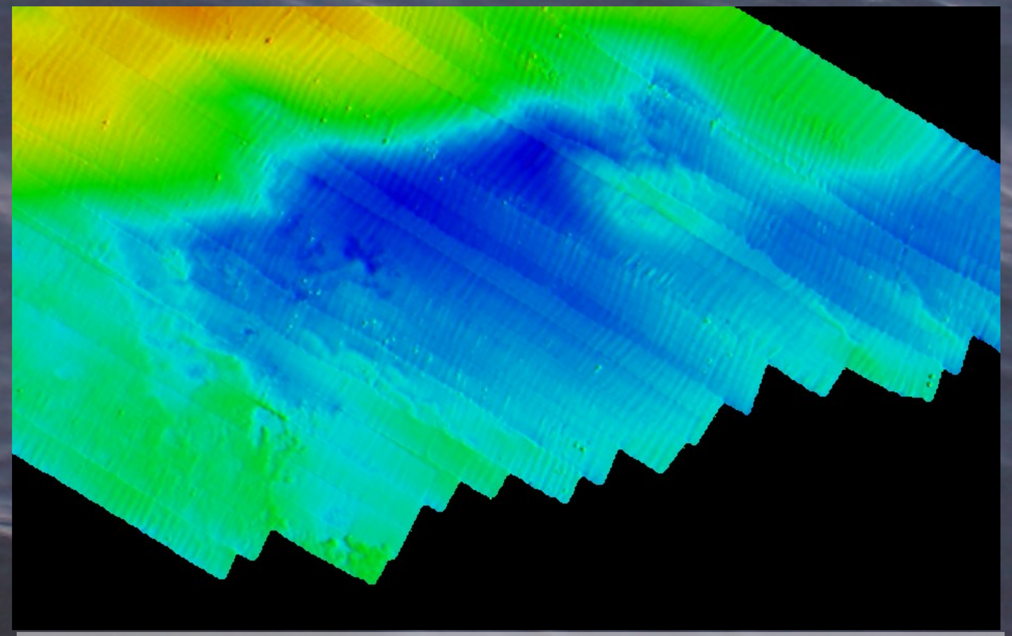


Gaps in the mapped seafloor surface are the result of missing or corrupted data. The long stripe running with the ship's track line is due to the ship getting off course so the swath of the sonar system did not overlap. This is a common occurrence, and the frequency of occurrence increases with an increase in the sea state. The data gaps that are perpendicular to track lines are a direct result of the ship encountering waves. When the ship breaks through a large wave there are bubbles injected into the water column that can stop the sound wave from reaching the seafloor, so the software program interprets it as missing data.

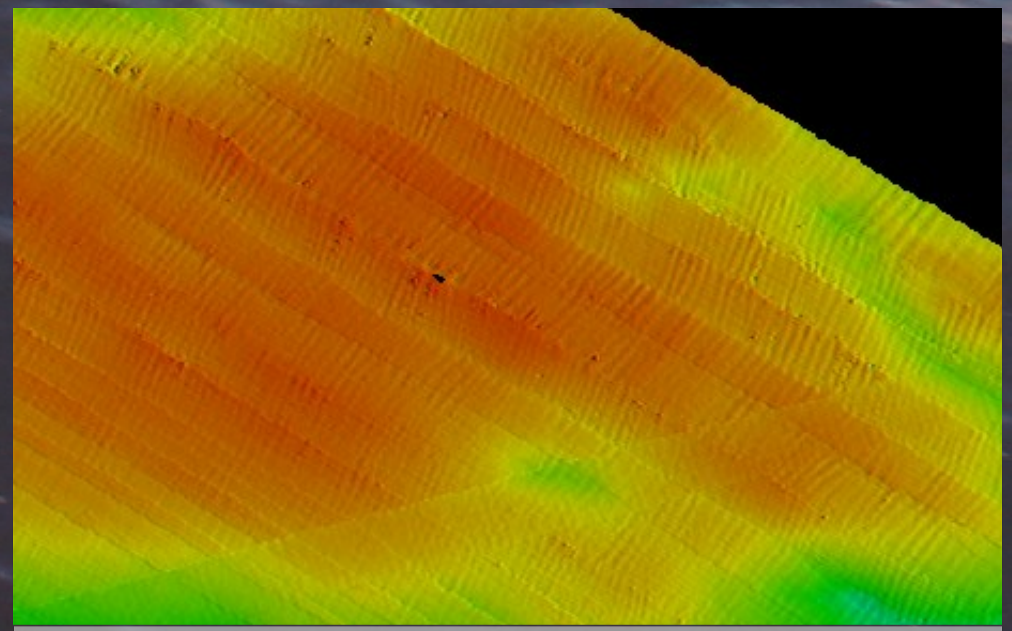
## Post Processing




Seafloor features are much easier to see after the data have been processed to removed the artifacts identified in the Pre-Processing panels (to the left). The sand body is more defined and the deeper areas have more definition. There are still artifacts visible, due to two separate problems: (1) Data are still not completely corrected for tidal differences. At the time of publishing we were still waiting to receive the tide correction file from NOAA; and (2) The rolling pattern, called HEAVE, that is perpendicular to the track lines is due to the sea state and is an artifact that is currently not possible to remove.



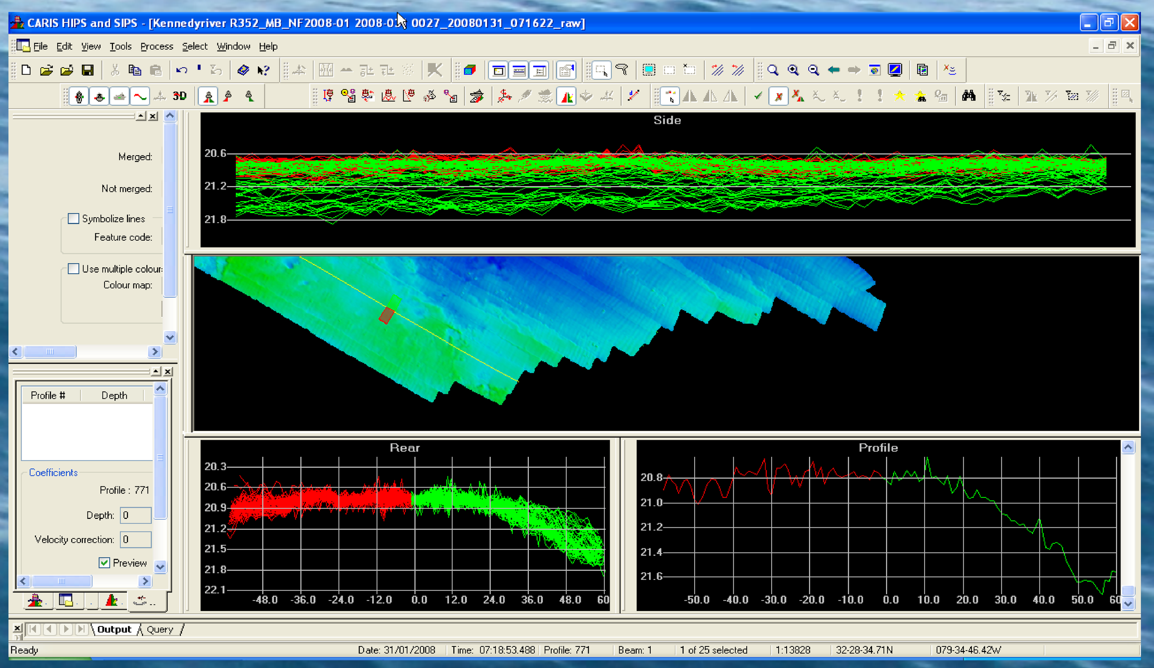
The striping was removed by changing the sound velocity profile. This "tricked" the software program into correcting for the roll, thereby removing the striping.



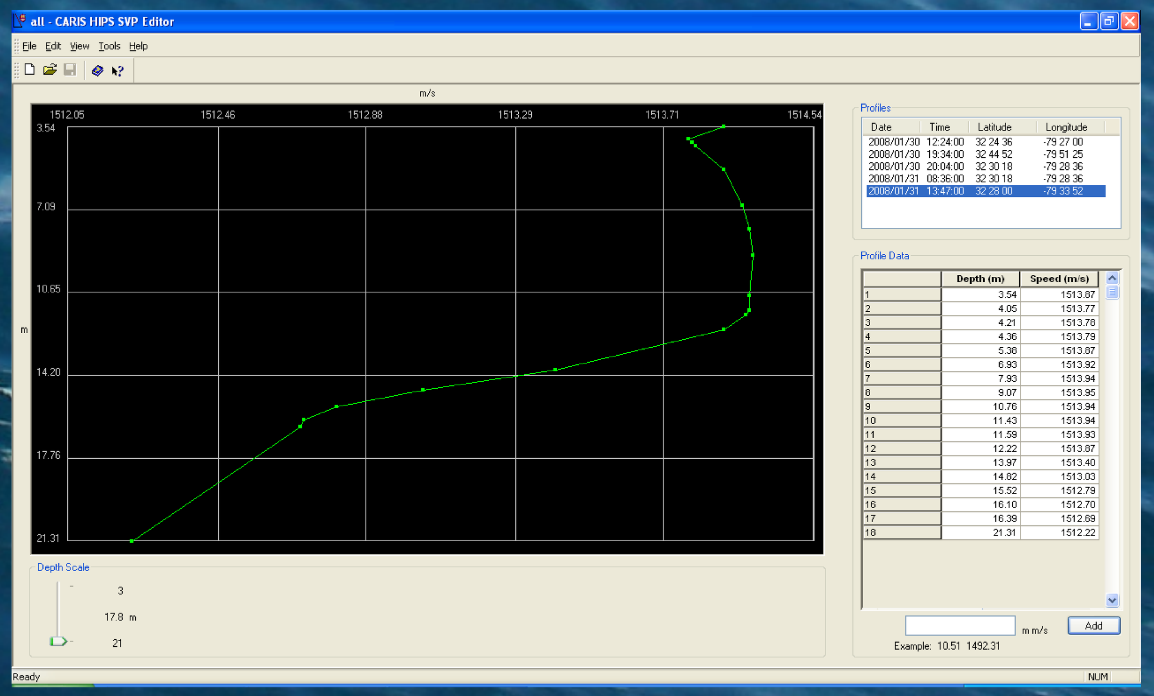
The holes were removed by the Interpolation function within Caris HIPS. I used a 5x5 pixel matrix. The program averages the depth of all data points within the 5x5 matrix and fills the missing data areas.

## The Fix

Since the artifacts appeared to be a problem with the sound velocity profile, the first course of action was to attempt to correct it with swath editor's refraction editor. (below)



However since the problem turned out to be with the water column's sound velocity, the refraction editor was not able to correct for the concave surface. Therefore it was necessary to write a new sound velocity profile that would correct for the roll. Within Caris HIPS it is possible to write a new sound velocity profile, however it is easier to create it in Excel and import in as an .xml file.



The best way to determine the appropriate sound velocity is to average the recorded velocity from the ship. Then, 'finding' the sound velocity that best corrects the data concavity is simply a game of trial and error.