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"Dynamics of Sandwaves under Combined Wave - Current Forcing and Mine Burial Processes", and "RIVET I and Mine Burial Analysis"

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LONG-TERM GOALS

Our long terms goals are to understand sediment transport processes, the relevant physical forcing processes and the resulting morphologic evolution of river mouths and tidal inlets and shoals. Specific goals include understanding bedform characteristics (ripple to sandwave and sandbar scale) in relation to wave- and current-forced mean and turbulent flow.

OBJECTIVES

1. Measure the currents, hydrodynamic boundary layer processes, sediment-transport processes and bedform evolution in energetic ebb-tidal shoal environments, where nonlinear interactions between waves and tidal currents are critically important to the sediment transport and the morphological response to changing forcing conditions.
2. Determine the mechanism responsible for the burial of mine-like objects in regions of active bedforms.
3. Develop instrumentation to make essential measurements for the above objectives. This includes autonomous and manned survey vessels with a carrier phase GPS and Doppler profilers for resolution of near bed turbulence and flow.

APPROACH

In order to measure the processes responsible for inlet morphologic change we conducted repeat bathymetric and hydrographic surveys along with in-situ time series measurements of water velocity (waves and currents), sediment transport (both suspended load and bedload via bedforms migration) and bed elevation. In 2011/12, we focused on measurements in New River Inlet, NC as part of the first phase of the rivers and inlets (RIVET) DRI. This measurements are described in our 2012 Annual report (http://www.onr.navy.mil/reports/FY12/lotrayk1.pdf) In 2012/13, our work focused on analysis of the data collected in 2012, with an emphasis on bedform geometry, migration and forcing due to stress from tidal flows (http://www.onr.navy.mil/reports/FY13/lotrayk1.pdf) .

In 2013/14, our effort were focused on obtaining measurements of mine burial processes and both large (100s m wavelength) and small (0.5 to 5 m wavelength) bedform dynamics on Wasque Shoals off the southeast corner of Martha's Vineyard, MA. In terms of mine burial, our approach is to examine the coupled bedform mine system as burial and scour processes are often closely coupled to bedform dynamics.

WORK COMPLETED

In November of 2013, we deployed the large quadpod developed for and previously used in the energetic environment of the Columbia River (http://www.onr.navy.mil/reports/FY13/logeyer.pdf) on Wasque Shoals in 6.5 m water depth (Figure 1). A cylindrical surrogate mine was deployed within the field of view of the imaging sonars. Unfortunately, when we attempted to recover the quadpod in January of 2014 the water depth at the quadpod location had changed to 4.5 m as a large sand wave had migrated over the frame, burying most of the sensors and making recovery impossible. By July of 2014, the crest of the sandwave had passed the frame allowing recovery of the some of the upper sensors via a scuba diving operation. In August of 2014, we recovered additional sensors and data loggers including the imaging sonar data. The lowest sensors including the pulse coherent Doppler and ADV data logger are still buried. Surveys of the large-scale bedforms surrounding the frame were conducted in October 2013, January 2014 and July 2014 (Figure 2).

Instrument Development

In New River inlet The REMUS-100 with the PPK-GPS surface piercing antenna prototype was completed and tested for stability in variety of conditions. The system proved stable in mild conditions, but struggled to both keep the antenna from becoming submerged in highly energetic conditions. The maximum vehicle speed of 3 m/s and GPS dropouts when submerged also hampered performance in energetic conditions. In order to rectify this in 2012 we developed a motorized kayak shipboard bathymetry and sidescan system to document the spatial variability of the bedform field. This system produced excellent data as stability was not an issue, and the operator could adapt the survey plan to changing conditions such the presence of absence of breaking waves. Based on the success of the motorized kayak, in 2013, in collaboration with H. Singh at WHOI we developed an autonomous version of the motorized Kayak (Figure 3). This vessel has an endurance of ~ 10hrs, navigation precision of less than 2 m r.m.s. cross track error in up to 2 m/s current and maximum speeds of 5 m/s. It has a Jet Drive impeller propulsion system allowing use in very shallow water and beach launching into the surf-zone. Based on the jet drive propulsion and kayak hull, it is referred to as the Jetyak. In 2013/14, we collected several high quality ADCP, PPK-GPS and bathymetry surveys with this vessel.

RESULTS

Hydrodynamic Forcing and Bedform Migration

At this site both large and small scale bedforms are present. The large scale bedforms have wavelengths of 200 to 500 m and heights of 2 to 3 m in water depths of 6.5 m in the troughs. These bedform consistently migrate east (Figure 2) in response to asymetrical tidal forcing (Figure 4c). The mean velocity in the direction of maximum variance (U) over the enitre record is 6 cm/s in the flood direction, but the mean of the peak flood velocities is 79 cm/s while the mean of the peak ebb flows is 60 cm/s. Due to the nonlinear dependence of bedload sediment trasnport with typical relatins of the

form $Q \sim U^3$, the peak flow values are much more important than the mean. The large scale sandwaves migrated approximately 150m in the period from Oct. 2013 to July 2014. Preliminary calculations suggest the volume of sediment moved due to this migration is consistent withing a factor two with commonly used bedload sediment transport formula's such the Meyer-Peter and Muller (1948) equation.

The rotary sonar imagery was only recently recovered thus full analysis has not been completed. The rotary sonar sampled every 20 minutes for 54 days. The sonar was set to sample 3 rotations with a 20 m range setting to meaure medium scale features, and the 3 more rotations were sampled with a 5 m range setting for higher resolution imagery of small scale features and mine burail processes. Examination of the imagery shows the small scale bedforms are tidally reversing megaripples with with wavelegnths of 1 m to 4 m (Figure 5). During lower flow velocities smaller scale ripples with wavelengths of 30 to 70 cm are present on the seafloor and are sometimes superimposed on the larger scale features. After 25 days of deployment the large scale bedform shown in the Jetyak surveys can be seen by the increasing bed elevation in the ABS data (Figure 4a)

Movies of the sonar imagery with long range setting are available at this Vimeo Link.

Mine Burial

At the beginning of the deployment a 75 cm long, 14 cm diameter, 30 kg cylinder was placed in the field of view of the rotary sidescan sonar (Figure 5). The density of this object was 2500 kg/m^3, denser than water satured sand with $\rho \sim 2500$ kg/m^3 , but less dense than typcial munitions with $\rho \sim 3000$ to 4000 kg/m^3. During the first 5 days of the deployemnt smaller (< 1 m wavelength) bedforms are present on the seafloor cylinder is exposed continously. At 5 days (-5 days from Dec. 1, 2013) into the deplyment there is a 3 m wave hieght event, the bedform size increases to approximately 2 m wavelength, and the cylinder is periodically buried under the migrating bedforms. During the wave venet the bedform stiil appear to migrate in response to tidal forcing. Further analysis will examine the role of wave forcing during this period. For the next 20 days the periodic burial continues untill a large scale bedform begin to increase the seafloor elvation at t = 15 days from Dec. 1, 2013. After this the cyliner is permananelty buried and is not visble in the sonar imagry. At 50 days into the deployment the rotary sonars and acoustic backscatter sensors mounted 1 m above the footpads were buried. In April of 2014 the crest of the large scale wave was over the tripod, and took untill July of 2014 for more of the frame to emerge from the flans of the large scale sand wave.

Movies of the sonar imagery with short range settings showing mine burial processes are available at this Vimeo Link.

IMPACT/APPLICATIONS

Analysis of this data set will lead an increased understanding of sediment transport processes in tidal inlets and the interactions between bedform evolution and mine burial. Ultimately, this will allow better prediction of the morphodynamic response of the system to variations in forcing parameters. Quantifying the relations between bedform geometry and frictional drag will also aid in an increased ability to model the flow field in environments such as this. The instrument and technique development will useful in a variety of future projects.

RELATED PROJECTS

Three grant numbers are included in this report as N00014-13-1-0767 ("Instrumentation for Plume, Sediment and Bed Dynamics in Energetic Coastal Environments: A Multibeam Sidescan Sonar and Portable Turbulance Profiler") is a DURIP to develop equipment for the science projects: N00014-11-1-0291 ("Dynamics of Sandwaves under Combined Wave - Current Forcing and Mine Burial Processes") and N00014-13-1-0368 ("RIVET I and Mine Burial Analysis"), which are highly related.

This project is also closely related to several other ONR efforts including our Columbia River Mouth Experiment, the OASIS project with John Trowbridge to measure wave boundary layer stresses in support of optical measurements of particle dynamics (Environmental Optics), and integrating the pcADPs on Geyer's MAST (Physical Oceanography). The DURIP was also used to develop equipment for those projects. This project is also closely related to a SERDP funded project in which Traykovski is investigating the mobility of UXO in strongly forced tidal flow environments and the surf-zone.

REFERENCES

Meyer-Peter, E., and R. Muller (1948), Formulas for bed-load transport, paper presented at Paper presented at 3rd Meeting. IAHR, Int. Assoc. Hydraul. Res, Stockholm.

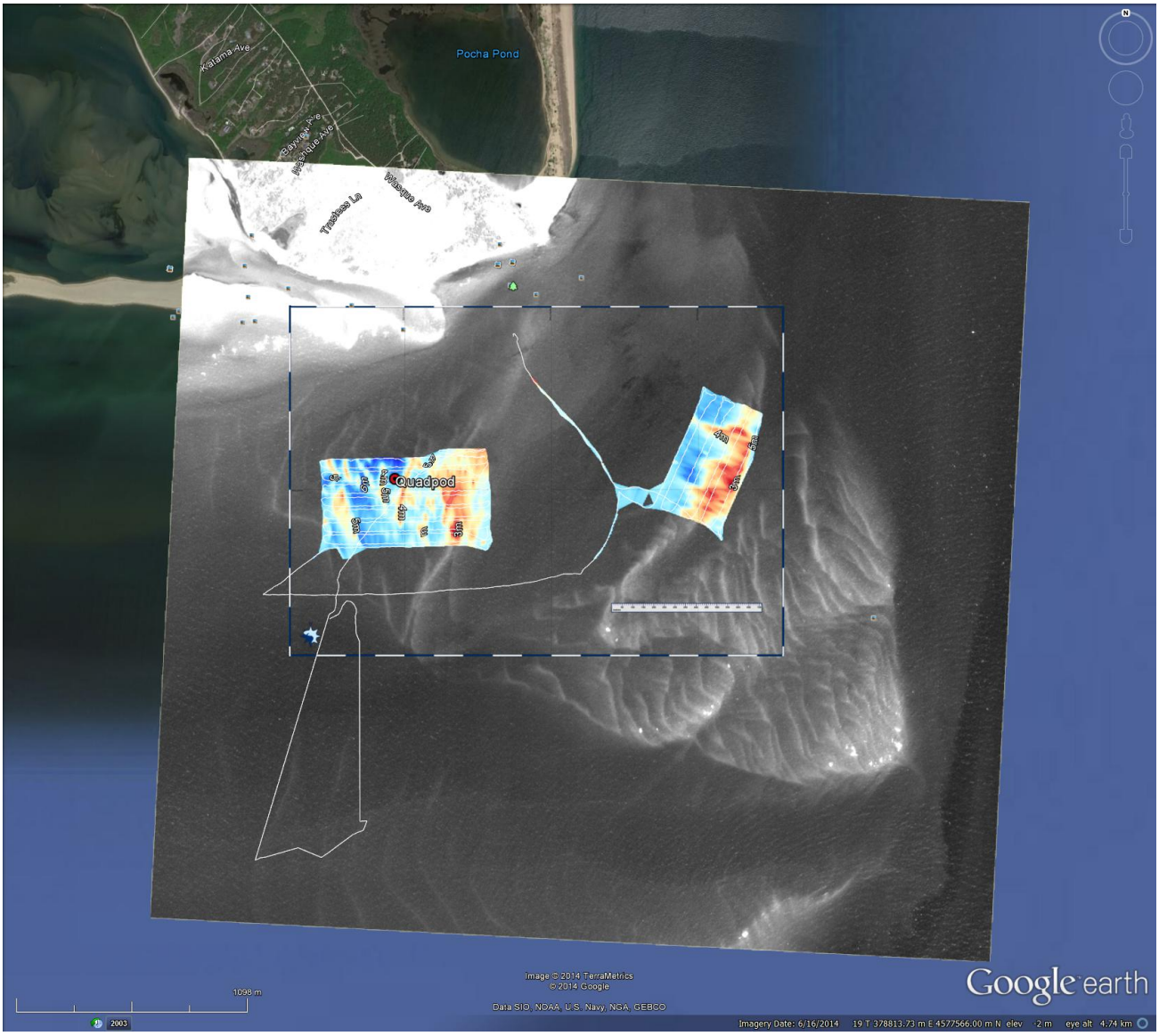


Figure 1. June, 2013 Pleiades Satellite Imagery of Wasque Shoals off the South East corner of Martha's Vineyard with bathymetry taken with the Jetyak ASV inset. The location of the quadpod deployed during the winter of 2013/14 is shown as a red circle

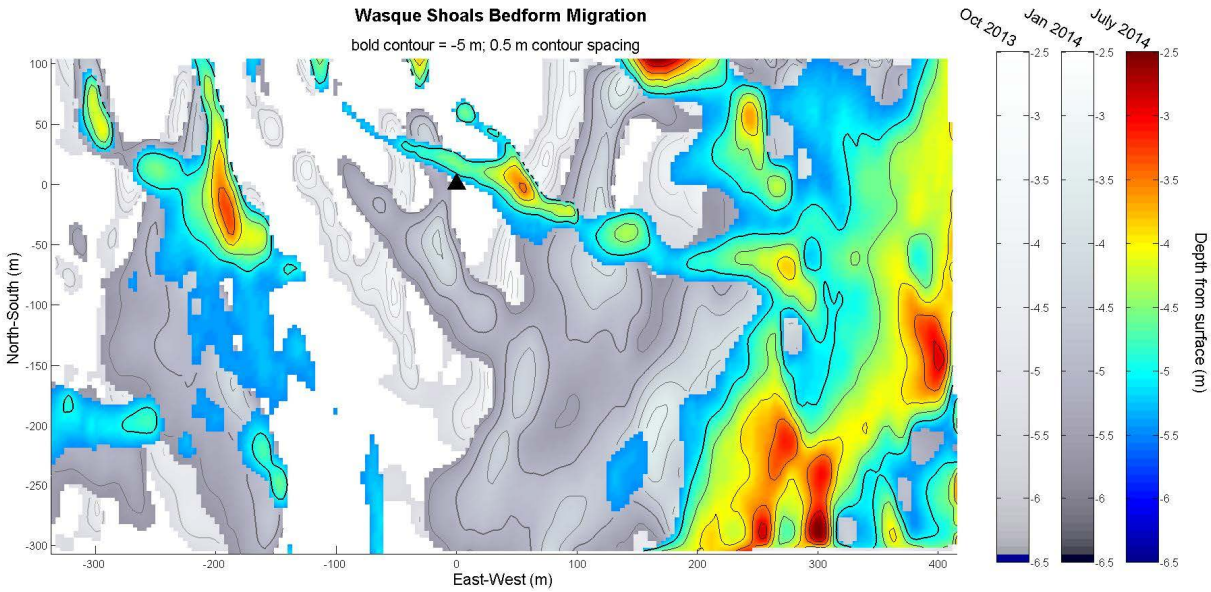


Figure 2. Bathymetric survey data from the JETYAK taken in Oct. 2013 (light gray), Jan 2014 (medium gray) and July 2014 (colored) showing north-eastward migration of large scale sandwaves. The bathymetry is contoured from 6.5 to 2.5 m depths, maximum depths in the troughs are ~ 7 m. The location of the quadpod is shown as a black triangle.

a)

b)

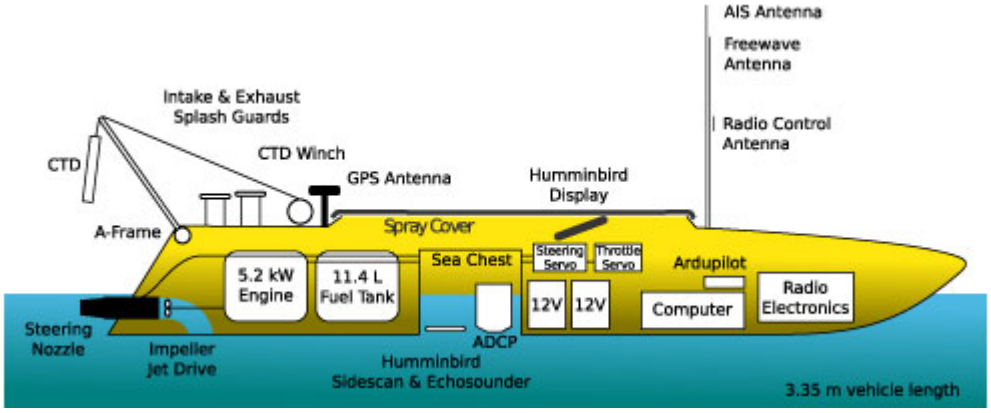


Figure 3. a) Photograph of the JETYAK underway at Wasque Shoals, MV b) Schematic Diagram of the JETYAK

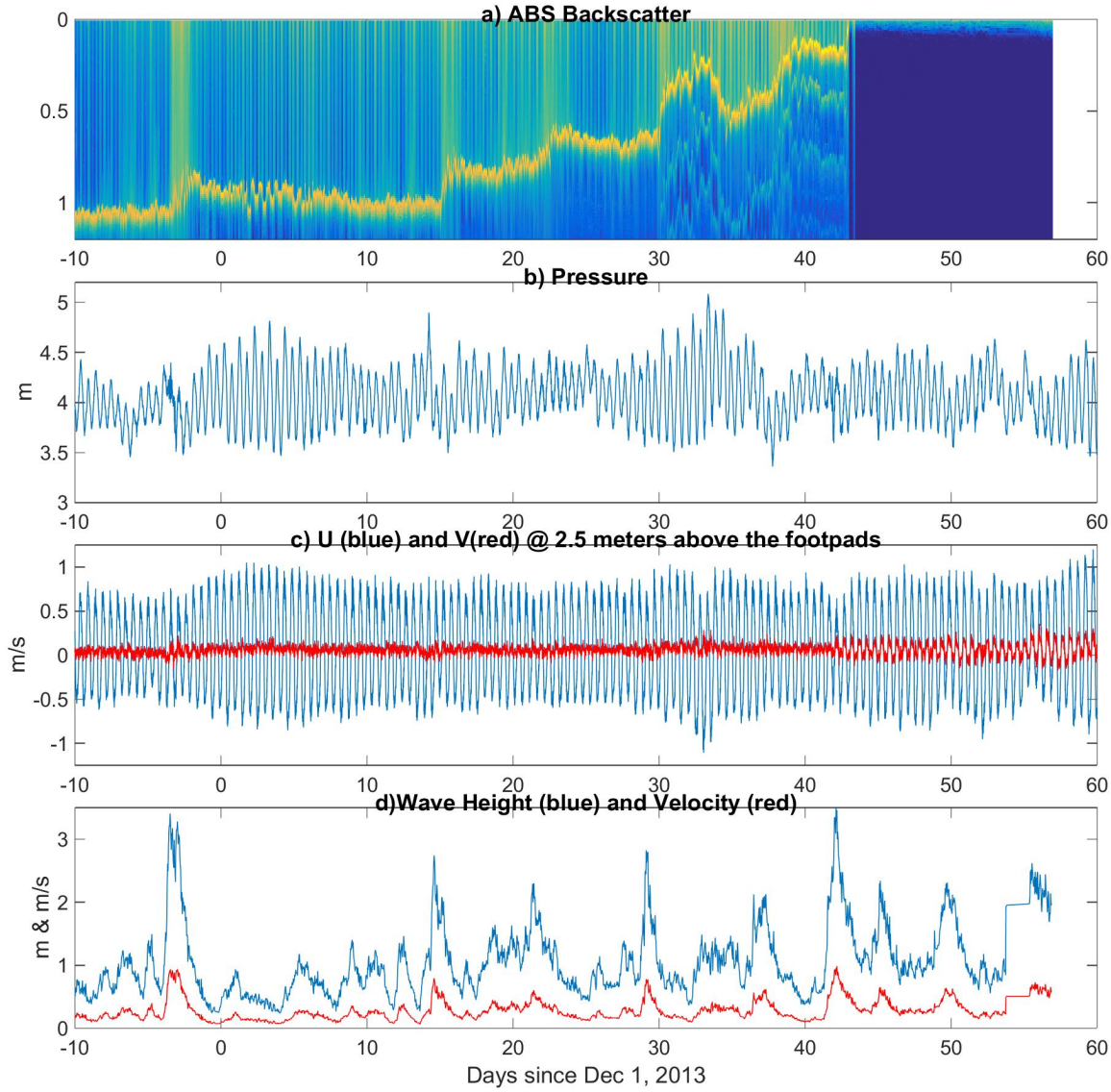
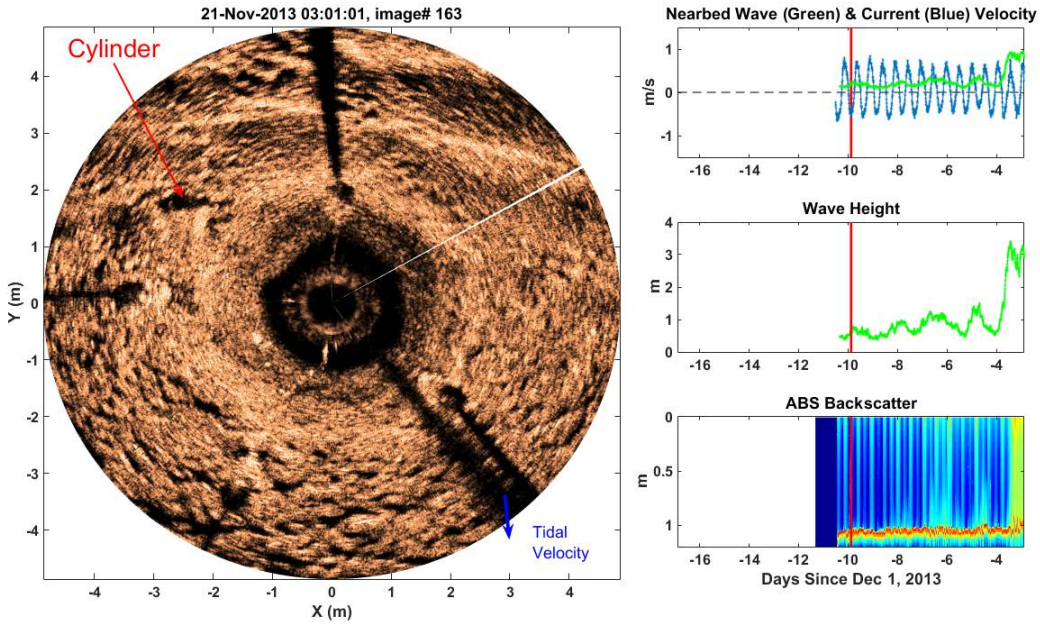


Figure 4. a) Acoustic Backscatter Sensor (ABS) profile time series showing periods of elevated suspended sand concentrations during wave events, and increasing bed elevation due to the migration of a large sand wave. Tidal time scale variation in bed elevation due small-scale bedform migration is also visible. b) Pressure time series form the Aquadopp current profiler. c) Flow velocity in the maximum variance direction (U, + is flood tide, blue) and minimum variance direction (V, + to the right of flood, red). d) Wave Height and velocity time series.

a)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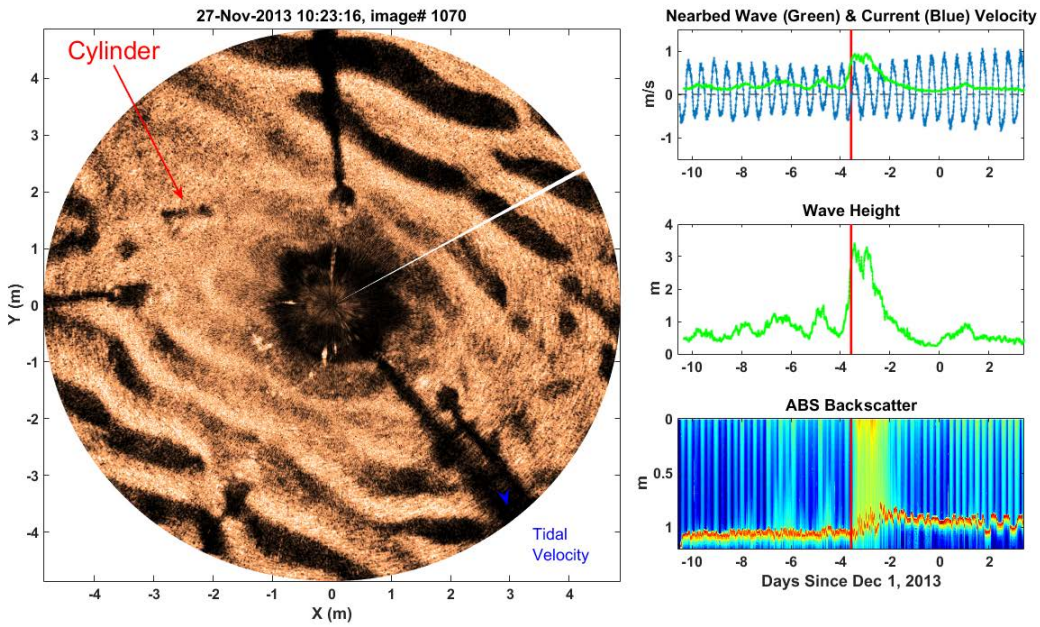
Cylinder
Tidal
Velocity
Y (m)
X (m)
Nearbed Wave (Green) & Current (Blue) Velocity
m/s
Wave Height
m
ABS Backscatter
m
Days Since Dec 1, 2013

b)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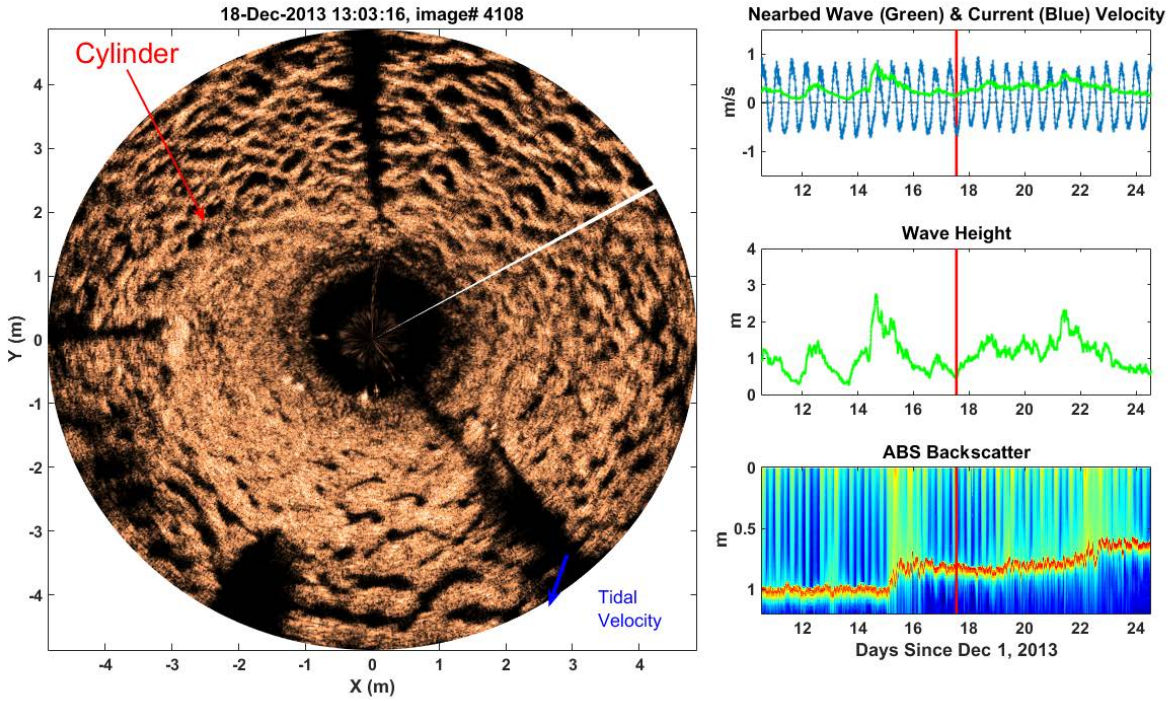
Tidal
Velocity
Y (m)
X (m)
Nearbed Wave (Green) & Current (Blue) Velocity
m/s
Wave Height
m
ABS Backscatter
m
Days Since Dec 1, 2013

c)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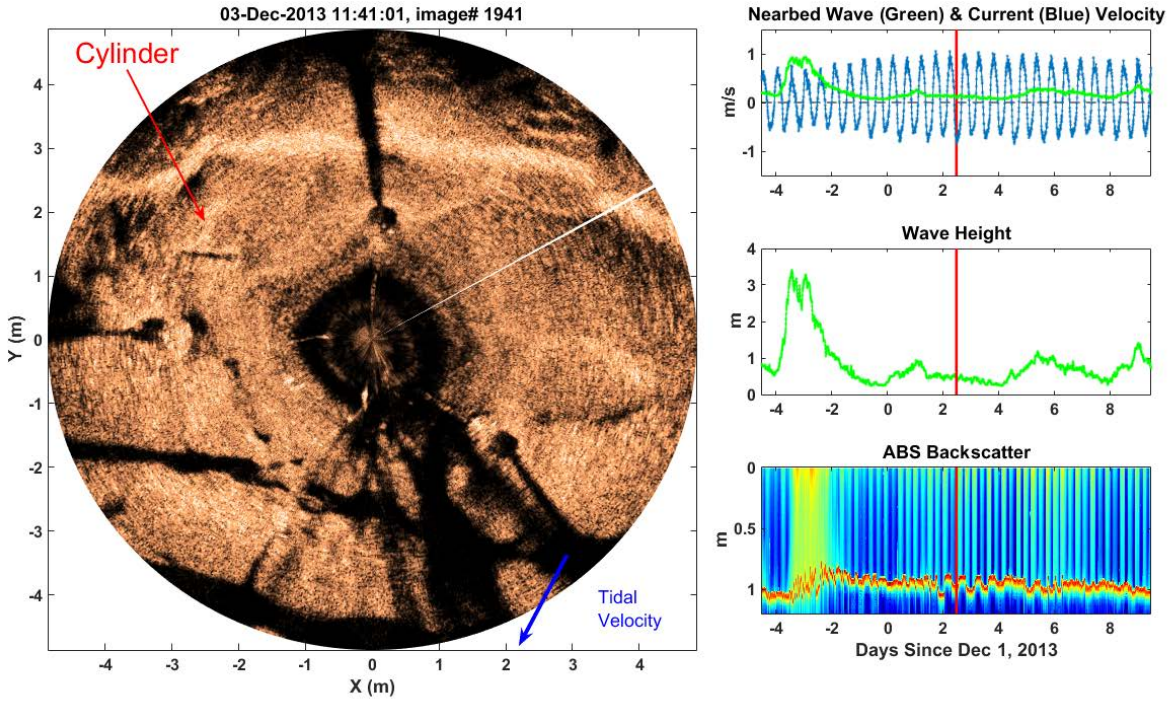
Cylinder
Tidal
Velocity
Y (m)
X (m)
Nearbed Wave (Green) & Current (Blue) Velocity
m/s
Wave Height
m
ABS Backscatter
m
Days Since Dec 1, 2013

d)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Cylinder
Tidal
Velocity
Y (m)
X (m)
Nearbed Wave (Green) & Current (Blue) Velocity
m/s
Wave Height
m
ABS Backscatter
m
Days Since Dec 1, 2013

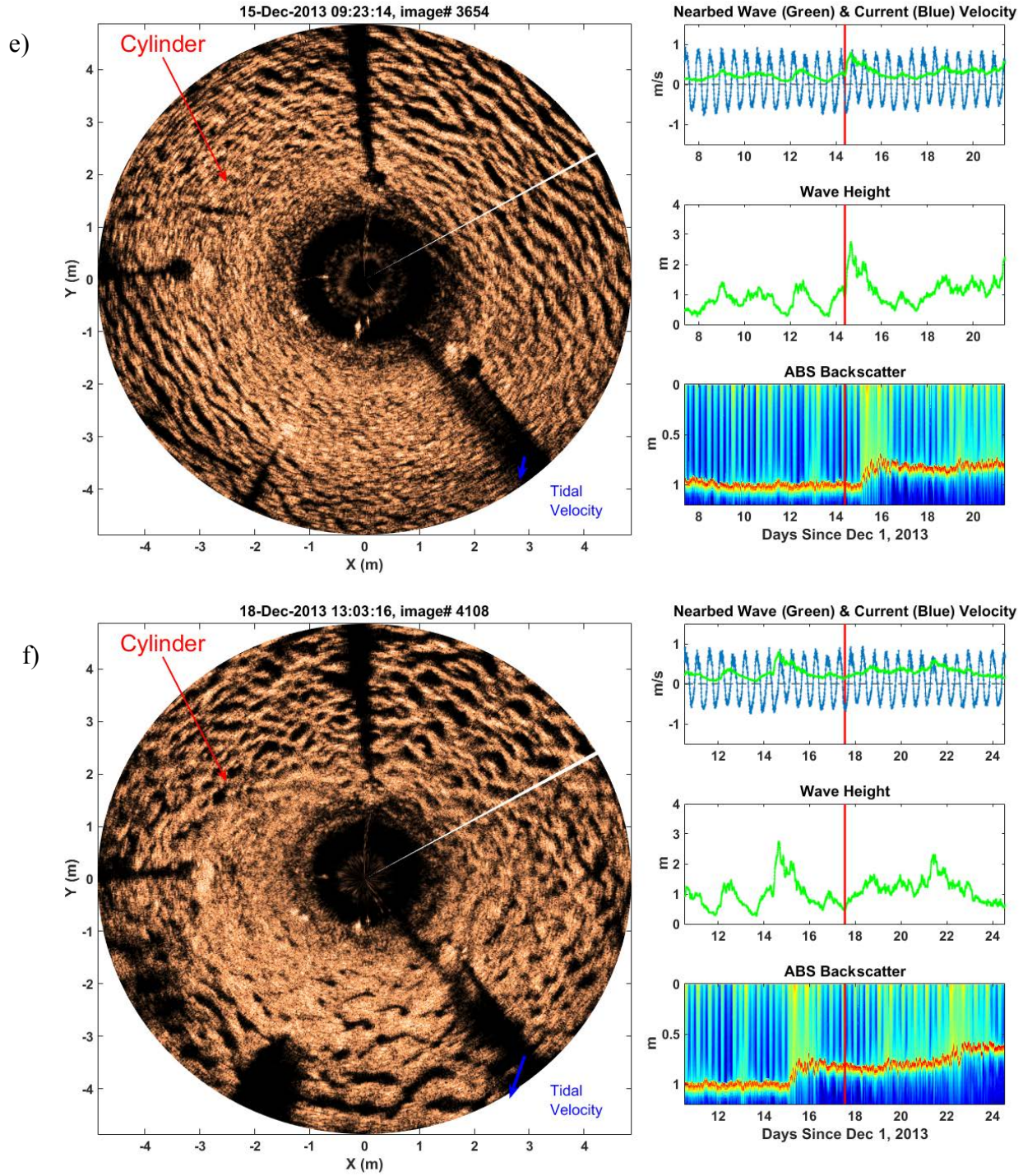

Figure 5. (a-e) Rotary Sidescan Sonar Imagery showing periodic burial and reappearance of a cylindrical object as small scale bedforms migrate due to tidal forcing. f) Once the bed elevation begins to increase due to the migration of large-scale bedform as shown in the ABS backscatter panel the object becomes permanently buried.