

Appendix

This appendix section describes details of the multibeam survey conducted at the mouth of San Francisco Bay. The first section details the methodology in acquiring the data and preparing it for analysis. The second section describes one of the more technical aspects of the data analysis alluded to in the main body of the article.

Methods

The mouth of San Francisco Bay was mapped using a Reson 8101 multibeam sonar system aboard the R/V VenTresca operated by the Sea Floor Mapping Lab at the California State University of Monterey Bay, between September 15 and October 31, 2004, and between September 17 and October 30, 2005. Passes over the bedform field were completed October 17, 18, 25 and 30, 2004, and September 17, 18, and October 30, 2005. Each pass took only 10-12 minutes so the giant sand wave migration during that short time period is small. The 8101 operates at 240 kHz and measures relative water depths within a 150° swath consisting of 101 1.5° x 1.5° beams. This transducer geometry makes the 8101 capable of taking up to 3,000 soundings per second with a swath coverage of up to 7.4 times the water depth. A total of 1138 multibeam survey lines were run. A Trimble 4700 GPS generated position and attitude data with differential corrections provided by a Trimble ProBeacon receiver. Horizontal positional accuracy of this system is typically +/- 1-2 cm. Attitude (pitch, roll, yaw, and heave) data were generated at 200 Hz by a TSS Position and Orientation System, Marine Vessel (POS-MV). Attitude accuracy for the POS/MV pitch, roll and yaw measurements averaged +/-0.03°, while heave accuracy was maintained at +/-5% or 5 cm. Sonar, position, and attitude data were logged in XTF format using a Triton Elics Isis data acquisition system running Isis Sonar software. Multibeam data were monitored in real-time using the 8101 Sonar Processor control interface and 2-D and 3-D display windows in the Isis Sonar and DelphMap software. Survey planning and navigation were performed using Coastal Oceanographics Hypack Max software. Surface-to-seafloor profiles of the speed of sound through the water were collected periodically during the surveys with an Applied Microsystems Limited (AML) SV+ sound velocity profiler. These profiles were used to correct for variations in sound velocity due to salinity and temperature changes throughout the water column.

Shipboard data were post-processed using CARIS Hydrographic Information Processing System (HIPS) 5.4 software. Tide and SVP (sound velocity profile) corrections were applied, and the sounding data were cleaned to remove erroneous soundings. The HIPS refraction coefficient editor was used where necessary to reduce artifacts due to inadequate sound velocity compensation. The 1138 survey lines yielded a total of 1,108,456,315 soundings.

For the mouth of SF Bay the tides were obtained from the NOAA/NOS co-ops website (http://www.co-ops.nos.noaa.gov/data_res.html). We applied the verified tides from the tide gauge at San Francisco-Fort Point using a six-minute interval at MLLW. For the rest of the area that was surveyed, we took the verified tides from the NOS website and subtracted the difference of predicted tides from the San Francisco, Golden Gate minus the predicted tides at the San Francisco Bar. The predicted tides from the

Golden Gate and SF Bar were taken from the program Tides and Currents Lite. The vertical error arising from the tide corrections is estimated at +/- 12 cm.

Grids for each of the sand wave migration surveys were created from the cleaned xyz files of the bedform field using a weighted moving average method. Measurements of sand wave position, slope, wavelength and height were determined (Table 1) using tools in ArcGis[®], Fledermaus[®] and MatLab[®]. Analysis of bedform characteristics from the individual surveys was then performed to quantify wavelength, orientation, amplitude, slope, etc.. Difference maps between surveys were generated to quantify the spatial offset through time of the bedform field, migration rates, and bedform morphology evolution. Tidal currents were modeled using Delft3D[®] and validated by current velocity and water level measurements.

Sand wave migration measurements

Repeated surveys indicate that the sand wave field is highly mobile. Between successive sampling periods, the individual sand wave crests moved either seaward or shoreward several meters. The lower panel of Fig. 2 (main article) illustrates the differences in bathymetry that occurred between the first two surveys, approximately one day apart. The thicker blue and red bands represent accretion and erosion due to the seaward migration of a sand wave crest. The finer scale bands indicate the migration of smaller-scale sand waves up the more gently sloping side of the giant sand waves.

There is an apparent correlation between instantaneous water level and crest locations during the four 2004 surveys, though a similar correlation is not apparent for the trough positions (Appendix Fig. 1). This supports the supposition that the bedforms are actively responding to the unusually strong tidal currents, with small daily changes in shape.

Table 1. Summary bedform statistics based on the 4 surveys over the centerline of the bedform field.

General statistics-19 sand waves, all surveys

82.4	avg wavelength (m)
149.9	max wavelength (m)
31.9	min wavelength (m)
10.4	avg lee (deg)
18.8	max lee (deg)
1.8	min lee (deg)
-5.9	avg stoss (deg)
-10.3	max stoss (deg)
-2.4	min stoss (deg)
3.2	avg stoss:lee
6.1	max stoss:lee
0.7	min stoss:lee

6.0 avg height (m)

9.9 max height (m)

1.8 min height (m)

Bedform position relative to position during first survey- 13 sand waves analyzed

-2.3 avg crest position (m)

2.6 max flood crest position (m)

-5.7 max ebb crest position (m)

-0.3 avg trough position (m)

6.6 max flood trough position (m)

-5.9 max ebb trough position (m)

-2.9 avg final crest position (m)

-1.4 avg final sand wave position (m)

-0.7 avg final trough position (m)

Total bedform movement relative to position during first survey- 13 sand waves analyzed

4.0 avg max crest movement (m)

7.1 max crest movement (m)

1.9 min crest movement (m)

3.1 avg max trough movement (m)

6.9 max trough movement (m)

0.6 min trough movement (m)

Flow Area Statistics

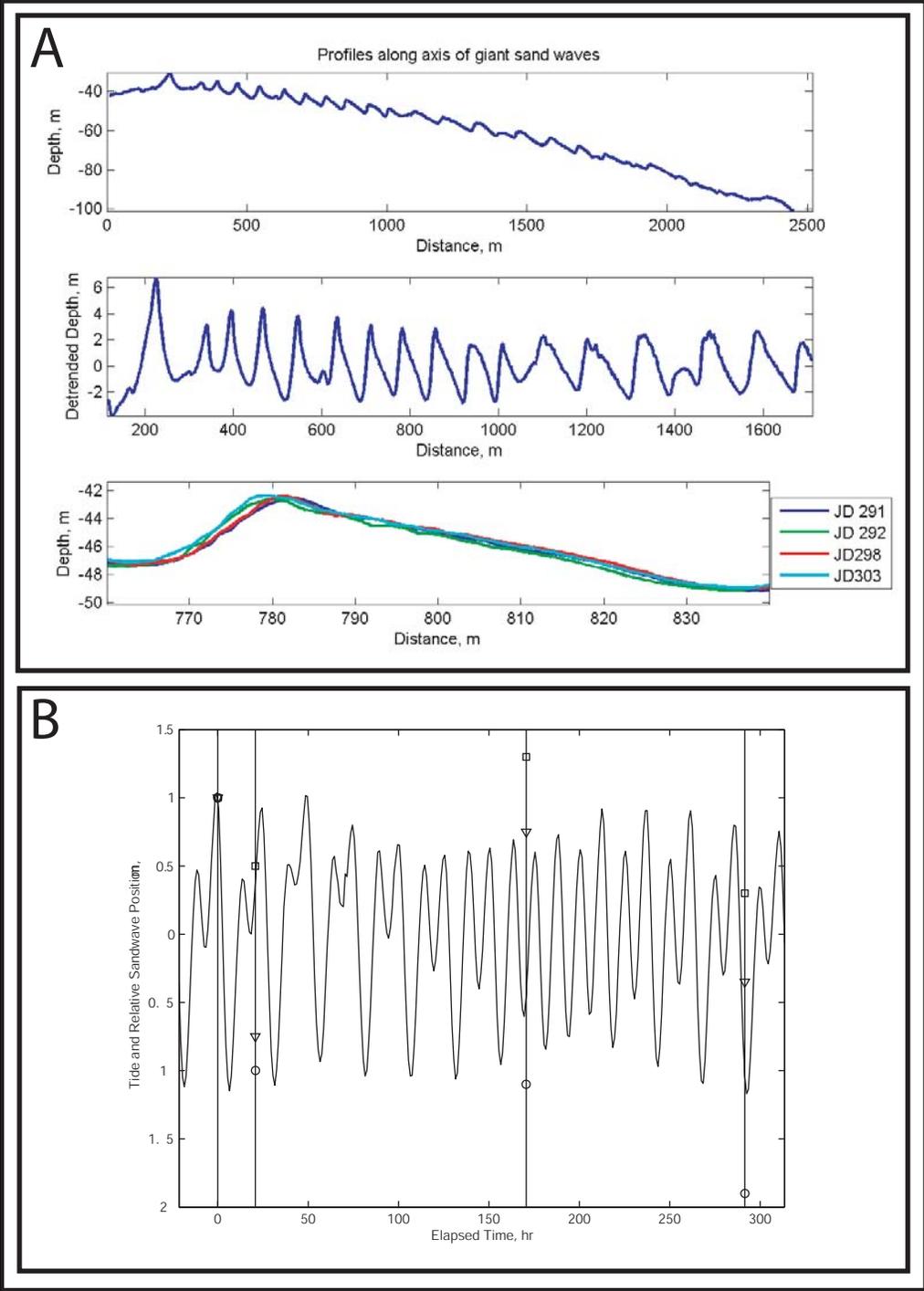
3.9 km² dune field surface area

241 to 229 large-scale sand wave orientation (deg)

241 to 263 superimposed sand wave orientation (deg)

Appendix Figure Captions

Appendix Fig. 1. A) Profile along the main axis of the sand waves (see Fig. 2) in the survey (upper panel) with detrended profiles (middle panel). Bottom panel shows the position of a single sand wave for each of the four 2004 surveys. B) Average sand wave position through time with relative position and tidal elevation on the y-axis. The squares are the trough, triangles are entire wave, and circles are the crest.



Appendix Figure 1