NOAA Technical Memorandum NOS NGS-40

ALONG-TRACK DEFLECTION OF THE VERTICAL FROM SEASAT: GEBCO OVERLAYS

David T. Sandwell

Rockville, Md.
October 1984

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David T. Sandwell
National Geodetic Survey
Charting and Geodetic Services
National Ocean Service, NOAA
Rockville, Md. 20852

ABSTRACT. To provide easy access to the large number of Seasat altimeter observations, the National Geodetic Survey has produced overlays for the General Bathymetric Chart of the Oceans (GEBCO). Each of the 32 overlays displays along-track deflection of the vertical for either ascending or descending altimeter passes. In poorly charted southern ocean areas the complete coverage by the Seasat altimeter reveals many previously undetected features of the seafloor.

INTRODUCTION

The Seasat altimeter data set, described in the Geophysical Data Record Users Handbook (Lorell et al. 1980), consists of more than 4 million observations. These data are largely inaccessible to most scientists since it takes a great deal of computer time and human resources to process the data into a usable form. While a number of recent investigators have published the data as contour maps (Marsh and Martin 1982) and images (Dixon and Parke 1983; Haxby et al. 1983; Sandwell 1984), these displays are not suitable for detailed quantitative investigations for a number of reasons. First, formation of a detailed geoid height map from widely separated satellite profiles requires a high degree of interpolation, so in unsampled areas the geoid may be incorrect. Second, it is difficult to determine precise latitudes and longitudes of geoid features from the small figures printed in journals and magazines. Third, the images do not convey information concerning accuracy or repeatability of individual altimeter profiles. To remedy this situation, the National Geodetic Survey (NGS) produced 32 overlays for the GEBCO series (Canadian Hydrographic Service 1982). Each overlay displays along-track deflection of the vertical (i.e., sea surface slope) for either ascending or descending Seasat profiles. These overlays can be ordered from the National Geodetic Survey. (An order form is provided at the end of this publication.) Sheets of the GEBCO map series are available from Hydrographic Chart Distribution Office, Ottawa, Ontario, Canada, K1G 3N6.

DATA ANALYSIS

The major purposes of the overlays are to display the short wavelength information in the Seasat data and to convey information on data distribution and quality. As shown in a number of studies, shorter wavelength undulations in the marine geoid reflect features of the seafloor such as trenches (McAdoo 1981), spreading ridges (Haxby and Turcotte 1978), fracture zones (Sandwell and Schubert 1982) and large seamounts (Watts and Ribe 1984). In remote areas many seamounts and fracture zones have not been charted, so the Seasat data provide new information there. Shorter wavelengths are enhanced by differentiating each altimeter profile (Sandwell 1984). Except for differentiation, the data analysis, described here, was kept to a minimum.

The data were first corrected for path effects and instrument response using the correction factors described in Lorell et al. (1980). Data were edited when any of the flags in the geophysical data records were set to one. Data were also edited if the RMS, determined when forming the 1 per second averages from the 10 per second data, exceeded 0.2 m. Most bad data were eliminated by this latter procedure although it is apparent from the overlays that a few bad data points remain. Editing reduced the data set from 4.4 million points to 3.2 million points. Passes where ground tracks repeated to within 1 km of an earlier pass (i.e., days 262-283 of 1978) were also edited because they were redundant.

After editing, the data were separated into ascending and descending sets and further subdivided into passes. A pass consists of a series of data points with time gaps of less than 5 seconds. Each pass was then differentiated using the first difference formula. Along-track deflections, in units of microradians, were obtained by dividing the time derivative of the sea surface height profile by the satellite's ground speed. Longer wavelength (> 1000 km) geoid undulations have only a minor influence upon deflections of the vertical. For display purposes they were removed by subtracting deflections calculated from the PGS-S4 geoid model to degree and order 36 (Marsh and Martin 1982). Removal of the long wavelength field causes the deflection to be zero at the crest of a seamount, at a trench axis, and over flat seafloor. To remove the short wavelength noise (Brammer and Sailor 1980), which is amplified by differentiation, each pass was filtered with a low-pass Gaussian shaped filter (i.e., σ = 14 km).

GEBCO OVERLAYS

After processing both the ascending and descending passes, the data sets were divided into the 16 geographical regions shown in figure 1. Each region corresponds to one of the 16 regions of the GEBCO series (Canadian Hydrographic Service 1982). The GEBCO series, at a scale of 1:10 million, was chosen because it is the most recent global compilation of seafloor bathymetry. On each overlay, ascending (or descending) passes were plotted along the subsatellite track. Ascending and descending passes could not be plotted together because they interfere with one another. Deviations from the ground track represent deflection of the vertical. They are connected to the subsatellite track by straight lines. For sheets 1-4 and 13-16 there is a connecting line for each data point while sheets 5-12 have a connecting line for every other data point. The scale is 60 microradians per degree of longitude. Sheets can be ordered by using the order form on the last page of this publication.

INTERPRETATION

When interpreting the along-track deflection profiles one must keep in mind the direction of the satellite. For instance, when the altimeter encounters a large seamount, the deflection is first positive, then zero at the crest of the seamount and finally negative beyond the seamount crest. An example is shown in figure 2a. For a trench just the opposite occurs (fig. 2b). Fracture zones show mainly a positive or negative peak depending upon the sense of the age offset. For the example shown in figure 2c, the seafloor is younger on the right and older on the left. There are many other types of tectonic features that also have characteristic signatures in the deflection of the vertical (e.g., continental margins and spreading ridge axes).

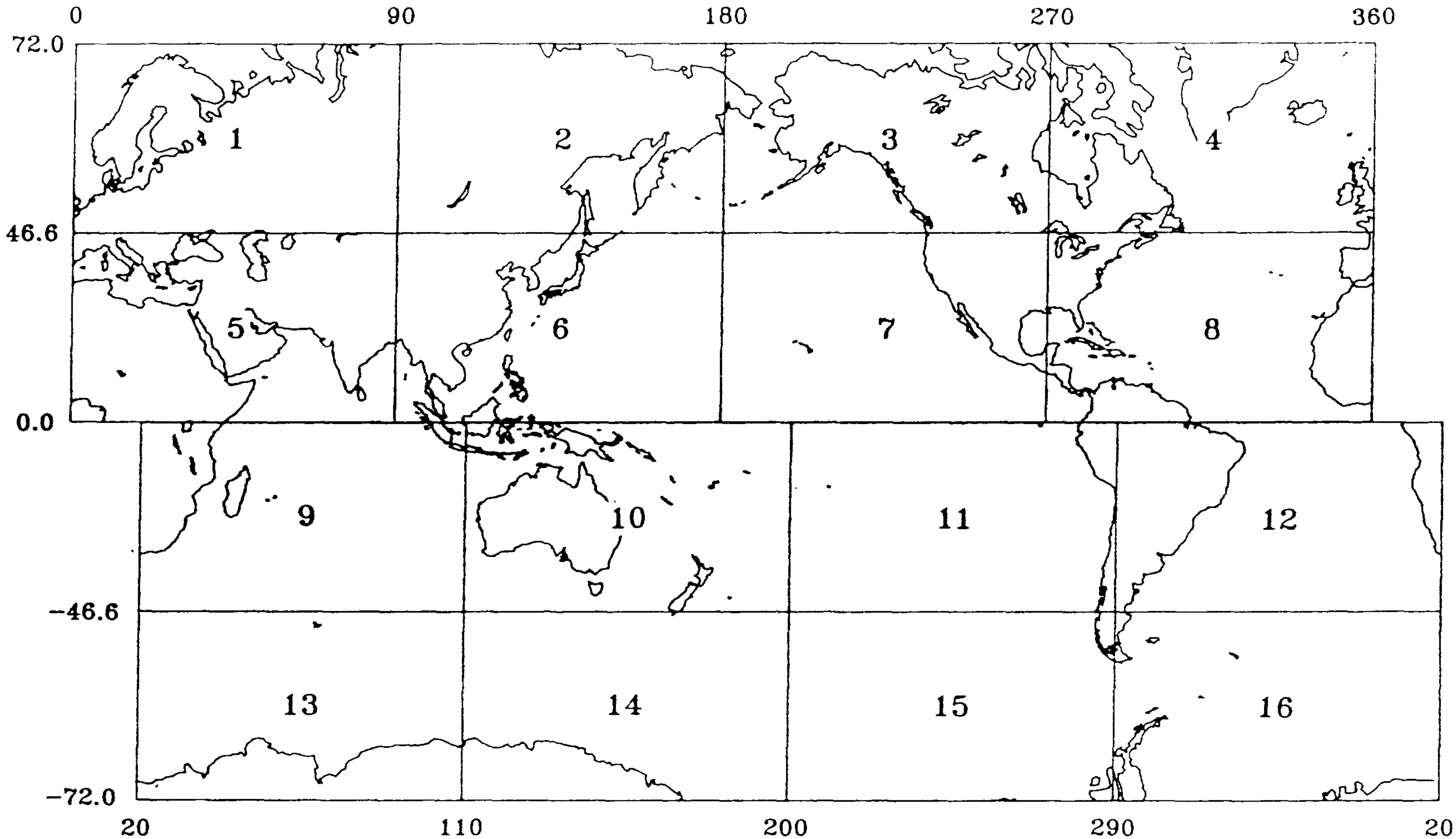

Figure 1. Sixteen geographical regions for the GEBCO overlays. There are two overlays for each area, one for ascending passes and the other for descending passes.

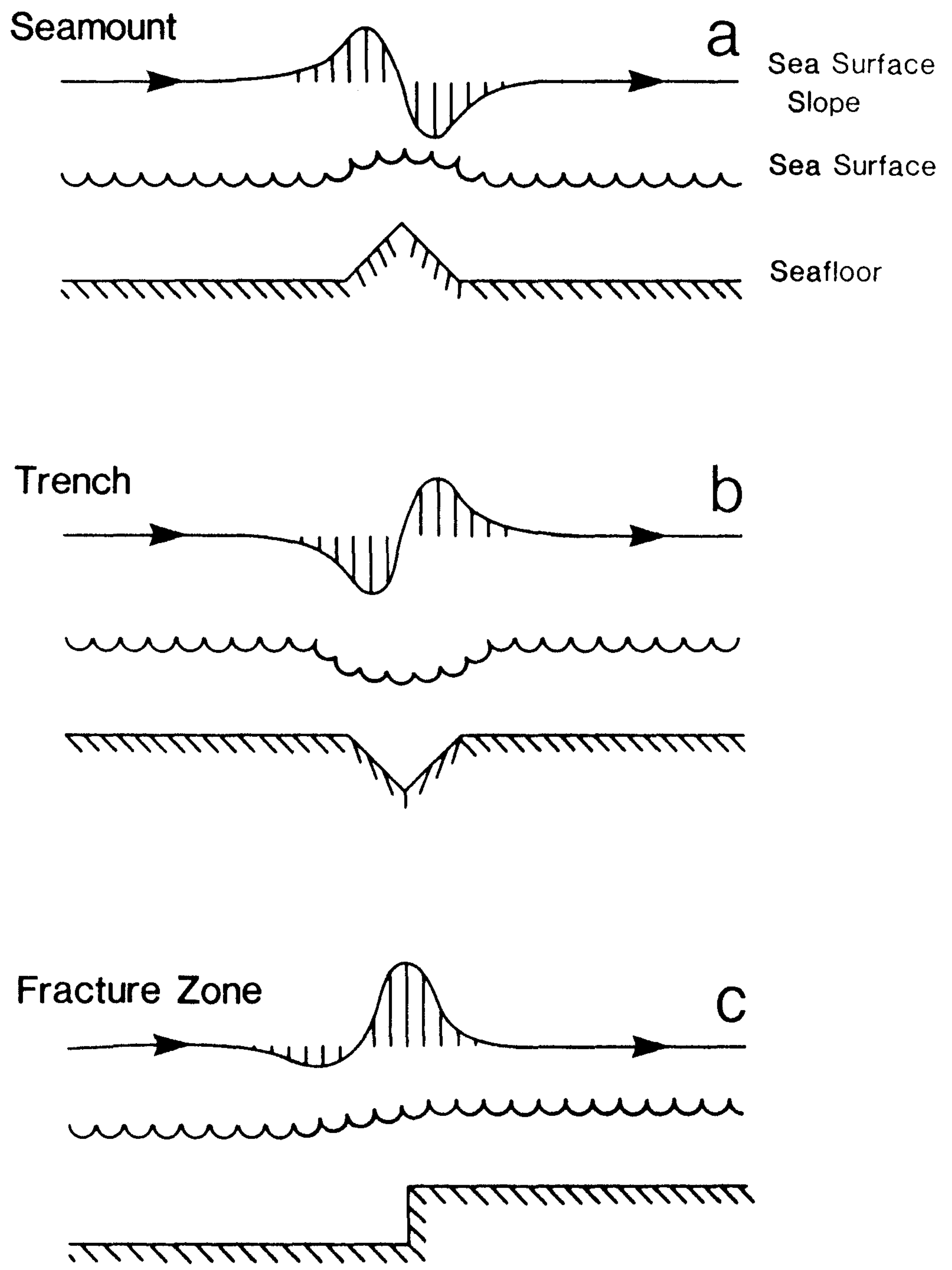

Figure 2. Characteristic deflection signatures for: (a) a seamount, (b) a trench, and (c) a fracture zone. Arrows indicate direction of satellite motion.

Examples of deflection of the vertical profiles across selected tectonic features are shown in figure 3. These ascending profiles were taken from the GEBCO overlays (reduced by 50 percent). The characteristic seamount signature is evident in the three profiles over Bermuda (fig. 3a). Every profile crossing the Aleutian Trench (fig. 3b) has the large trench signature. Profiles across the Mendocino Fracture Zone (fig. 3c) reveal the step in the seafloor at 40°N as well as the smaller step associated with the Pioneer Fracture Zone at 38°N. The Mendocino Fracture Zone signature extends more than 16,000 km from Cape Mendocino to Midway Island. Similar signatures with smaller amplitudes appear in other geographical areas covered by the GEBCO Charts.

While the correlation between deflection of the vertical and seafloor topography is generally high, it is nonunique. For instance, oceanic plateaus can have large topographic expressions and small deflections whereas areas of thick flat lying sediments can be associated with large deflections. In addition, Watts and Ribe (1984) show that two identical seamounts formed on lithosphere of different age can have deflection of the vertical signatures that differ by a factor of 2 or more. This nonunique relationship between seafloor topography and deflection of the vertical reflects the degree and mode of isostatic compensation as discussed in Sandwell (1984).

Although the amplitude relationship between topography and deflection is nonunique they still have the same phase. Except in areas of thick sediment cover, a signal on a deflection profile is associated with seafloor topography. The type of topography (e.g., seamount, fracture zone, or depression) can be determined from the morphology of the deflection profile. Many previously uncharted features can be found by comparing both ascending and descending overlays with the GEBCO series. We have found uncharted features in areas containing no bathymetric profiles where large deflection signatures appear on multiple satellite passes. These uncharted areas containing large deflection signatures are ideal sites for detailed bathymetric surveys.

ACKNOWLEDGMENTS

I thank Russell Agreen of NGS for supplying the Seasat data, and I am also grateful to the operators who spent many hours plotting the overlays.

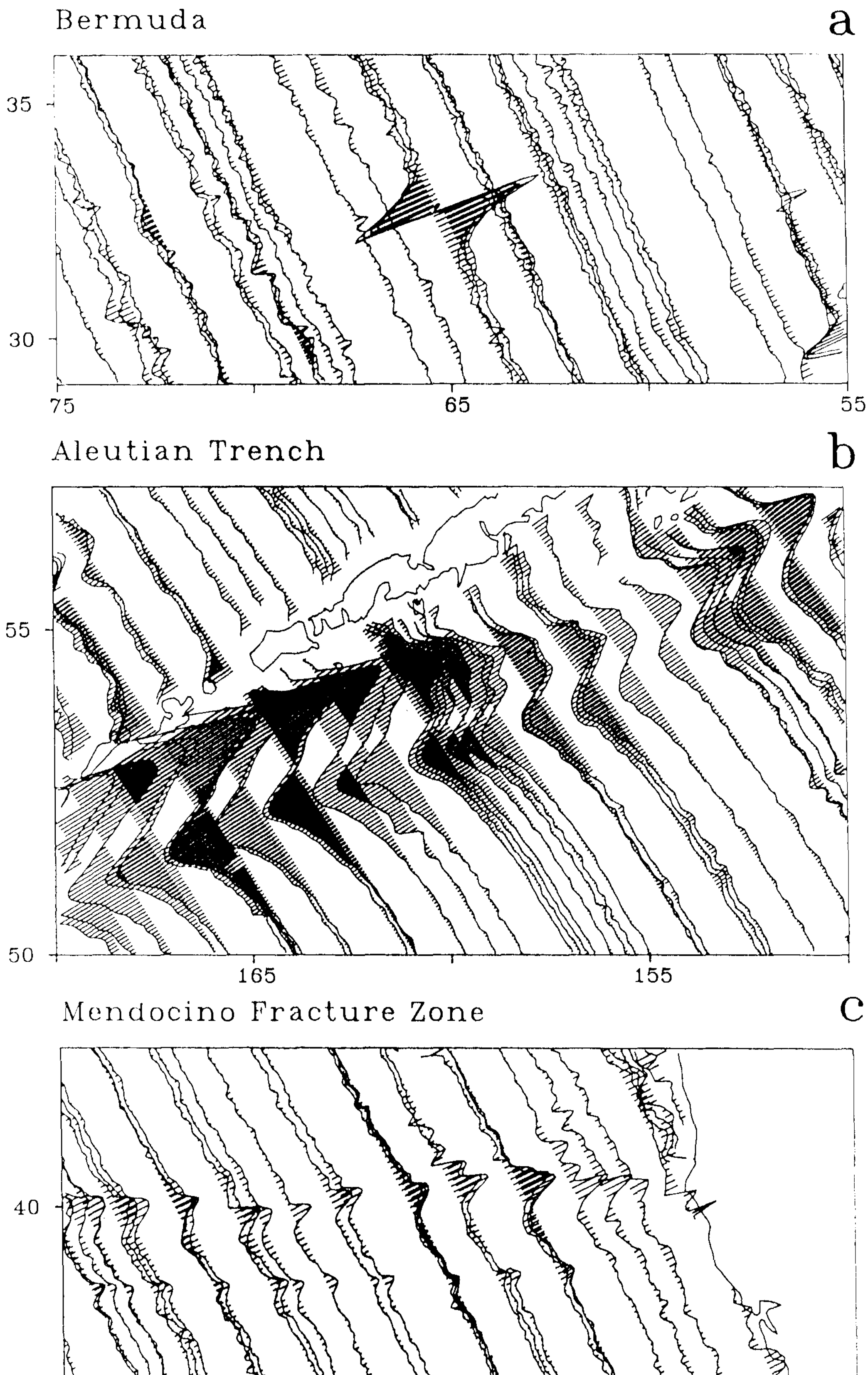

Figure 3. Examples of deflection of the vertical profiles over
(a) Bermuda, (b) the Aleutian Trench, and (c) the Mendocino Fracture Zone.

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Use form below to indicate desired sheet numbers (see fig. 1 of text) and satellite direction.

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