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AN EXPERIMENTAL COMPUTER ALGORITHM FOR SEAMOUNT MODEL PARAMETER--ETC(U)
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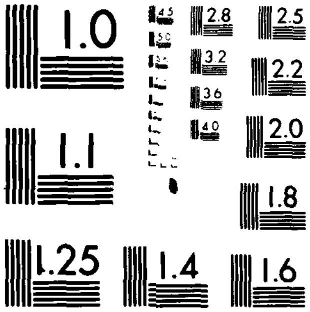
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This report formulates an experimental computer program for seamount model parameter estimation. The computer algorithm documented was designed to automatically recognize those characteristic perturbations among satellite radar altimetry data that indicate the presence of seamounts. Featured are a digital filter, a roughness detector, a physical model containing the potential theory associated with seamounts and specifying their effect on the sea surface and, finally, the estimator algorithm for the model parameters, in particular peak submergence depth. Also included are an error analysis and computer program checkout data.

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FOREWORD

This report documents some of the work undertaken to test the feasibility of extracting from GEOS-3 and SEASAT-A satellite radar altimetry certain data that indicate the location of seamounts and make possible the prediction of the depth of seamount peaks below the surface with the purpose of minimizing the hazard to submarine navigation caused by the presence of seamounts.

Dr. B. Zondek of the Space and Surface Systems Division contributed the matched filter and the model for the gravitational interaction of the seamount and its root with the sea surface. John Ellis of the Physical Sciences Software Branch coded the algorithm and performed the extensive computer work necessary for program checkout. Otherwise, the algorithm is the responsibility of the author who also implemented it (with the exception of the digital filter) on an electronic calculator to facilitate the computer program checkout.

The work documented here was done in the Space and Surface Systems Division and was funded as part of the development of computer programs connected with the evaluation of seamount survey techniques.

Released by:

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DISTRIBUTION

INTRODUCTION

Except for certain minor perturbations, the sea surface is an equipotential surface in the earth's gravity field. As such it is perpendicular everywhere to the gravity vector, which in the presence of a seamount,[1,2] tilts toward the seamount's center of gravity. This tilt in turn produces a surface elevation directly above the seamount.

Being artifacts of seamount gravitation, surface deflections of this kind (also called "seamount signatures") must reflect the shape of and the mass distribution within the seamount. Above the major seamounts, the maximal geoidal elevations may amount to several meters with corresponding maximal vertical deflections in excess of 10 arc sec. Signatures associated with major known seamounts are clearly seen on the satellite altimetry data tracks.[3-20] It is now widely accepted that seamount signatures can be separated from the noise and from the remaining features on these data records. Digital filtering and other mathematical pattern recognition methods are the obvious means to that end. Yet the technical implementation of the principle must still be demonstrated by a successful, published, automatic seamount survey based on satellite altimetry.

The present computer program is an experimental seamount detector. It was developed to test the feasibility of exploiting GEOS-3 and SEASAT-A radar altimetry with the purpose of identifying seamount overflights, of locating the seamount peaks (the seamounts themselves are several tens of kilometers wide, typically), and of "measuring" the submergence depths of the peaks. The mission-oriented aspect of this effort is that satellites can survey vast ocean areas much more inexpensively and faster than ships and that knowledge of the just-mentioned parameters over large regions would minimize the hazard to submarine navigation due to the presence of seamounts.

In essence, this seamount detector features a digital filter necessary to recognize and enhance the seamount signatures concealed among the radar altimetry data (consisting of geoid height and vertical deflection, suitably filtered),[21,22] a physical model[23] containing the seamount related potential theory, and a mathematical estimator for the physical seamount parameters, in particular peak submergence depth. The latter estimator adjusts the characteristic properties of the radar altimetry signature predicted from the theoretical model to the corresponding quantities among the empirical data. It is expected that this experimental detector algorithm differs from future, more advanced, automatic seamount detectors in the details of the solution for the seamount model parameters. Specifically, the present experimental version is founded on the assumption that the seamount slope is proportional to the maximal vertical deflection of the associated geoid height signature. The latter relationship had been devised by studying some 50 GEOS-3 radar altimetry data tracks crossing seamounts in the New England seamount province. The study was confined to that part of the world because a dense pattern of altimetry tracks and rather reliable bathymetry were both available there. Once determined from this empirical formula, the seamount slope angle is retained throughout the procedure. Applying the above mentioned seamount model,[2,3] the algorithm then iteratively varies the remaining seamount dimensions (width at the base, peak submergence depth) until the computed maximal geoid deviation above the seamount peak matches the altimetry signature height within a specified margin, attributing the resulting peak depth and base width to the actual seamount. Because of our very imperfect knowledge of the conditions in the crust and upper mantle undenearth seamounts (problem of seamount compensation), this procedure is executed twice per detection, separately for the cases of perfect isostasy and absence of root. The actual depth value is assumed to be bracketed by the depth estimates resulting from the two ideal cases. As an option, the depth estimation may additionally be performed for any desired degree of general compensation with full freedom in selecting seamount root height, width, and density excess over the mantle.

Computer coding and computer program checkout of this seamount detector have been completed. To evaluate its performance, it is now being applied to selected SEASAT-A altimetry tracks in various oceans. Already it appears that upon completing some required fine-tuning of its numerical parameters, this computer program will become a useful device for satellite altimetry data analysis.

One more detail should finally be mentioned. It was originally intended to write a seamount detector capable of fully automatic operation. But the numerical program checkout as well as the current evaluation using actual altimetry indicate that any operational success for seamount diagnostic would be considerably enhanced by human intervention. Parallel to the computer coding effort for the automatic detector, a computer graphics system was thus developed, which permits the visual scanning of altimetry data over large ocean areas. It generates charts of suitably filtered and edited altimetry that may be overlaid on bathymetric charts where such are available. Use of these chart data appears to greatly increase the effectiveness of the experimental automatic seamount detector. In fact, they may turn out to be indispensable for the success of any seamount survey now at least and in the near future.

EXPERIMENTAL COMPUTER ALGORITHM FOR SEAMOUNT MODEL PARAMETER ESTIMATION

SATELLITE RADAR ALTIMETRY DATA FORMAT

The satellite altimetry data to be processed by the seamount detector are available from permanent storage in the formats specified in Tables 1 through 4 (G. B. West, unpublished data, 1978). Select the type of altimetry desired, GEOS-3 or SEASAT-A, and extract from the header of the corresponding data file the time interval, Δt, in seconds and the subsatellite velocity, vs, in km/sec. From each segment of the altimetry data record, obtain for each data point (time instant, t_i, in seconds) the filered* geoid height, N_i, = $N(t_i)$, in meters, the deflection of the vertical, $\delta_i = \delta(t_i)$, in arc seconds, the latitude, $\varphi_i = \varphi(t_i)$, in radians and the longitude East, $\lambda_i = \lambda(t_i)$, in radians. Convert φ_i and λ_i to decimal fractions of degrees.

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*The reader is urged to keep in mind that, as said in the INTRODUCTION, the altimetry data serving as input to this seamount detector are not raw altimetry data tracks but result themselves from a filtering process explained in References 21 and 22. Here and in the following we shall refer to N_i and δ_i as "filtered" when wishing to emphasize their origin, by Kalman smoothing, from the raw satellite radar altimetry. With reference to the present seamount detector, N_i and δ_i will usually be considered "unfiltered" and named so as they are input data to the matched filter.

Table 1. GEOS-3 Satellite Radar Altimetry Data Filtered Along Track Geoid Heights and Vertical Deflections (Binary File Format, Header Record)

Word Number in Record	Format	Description
1	I	Filter word 2 = filtered, 3 = linear fit
2	I	Kalman-Wiener control - 0 - Wiener filter output 1 - Kalman filter output
3	I	Number of data points in track
4	I	Measurement type (40 = G or 41 = H)
5	I	Time system indicator
		Beginning time of data
6	F	Year
7	F	Day of year
8	F	Time of day (seconds from beginning of day)
9	F	Time interval
10	F	Subsatellite velocity (km/sec)
		Ending time of data
11	F	Year
12	F	Day of year
13	F	Time of day (sec from beginning of day)
14	A	Date of raw data tape
15	A	Date of reduction
16	F	Geoid height mean value over data track
17	F	Standard deviation with respect to the mean for geoid heights (M)
18	F	Deflection of the vertical mean value over data track
19	F	Standard deviation with respect to the mean for deflections of the vertical
20	I	Processing report 1-9 Ex. ellipsoid, filtering parameter, etc.
21	I	Mode
22	I	Data status word
23	I	Rev number
24	I	Total number of points on file (entire pass)
25	I	Number of segments in pass
26	I	Station number
27	I	Tide indicator 0 - Before tide correction 1 - After tide correction
28	F	Autocorrelation distance
29	F	Standard deviation of the noise
30	F	Standard deviation of the vertical deflection
31	F	Geoid height bias estimate (m)
32	F	Vertical deflection bias estimate (arc sec)
33	F	Vertical deflection uncertainty estimate (maximum)
34	F	Vertical deflection uncertainty estimate (steady-state)

Table 2. GEOS-3 Satellite Radar Altimetry Data Filtered Along Track Geoid Heights and Vertical Deflections (Binary File Format, Packed Data Record)

Word Number in Record	Format	Description
1	I	Filtered geoid height (m) (FGH) + raw geoid height (m) (RGH) + tide correction (m) (TC) + geoid height uncertainty estimate (m) (GHUE) Packed: $[(GH+500) \text{ x } 100] \text{ x } 10^9 + [(RGH+500) \text{ x } 10] \text{ x } 10^5 + [(TC+5) \text{ x } 100] \text{ x } 10^2 + [GHUE \text{ x } 100]$
2	I	Deflection of vertical in arc sec (DV) + latitude in rad (xLAT) + longitude in rad (xLON) Packed: $[(DV+500) \text{ x } 10] \text{ x } 10^{10} + [(xLAT+5) \text{ x } 10^4] \text{ x } 10^5$ $[xLON \text{ x } 10^4]$

Table 3. SEASAT-A Filtered Geoid Height Data File (Type FGD) Header Record (Common Header)

Word	Type	Approximate Range of Significance	Description
1	I	XXXX	Number of points in file
2	I	XXXXX	Rev number
3	I	XX	Starting year of segment
4	I	XXX	Starting day of segment
5	R	XXXXX.XXX	Starting seconds of segment (sec)
6	R	.XXXXXX	Time interval (sec)
7	A	YYDDD	Year and Julian day (right adjusted)
8	I	XXX	Altimeter mode
9	R	XXXX	Autocorrelation distance (km)
10	R	XX.XX	Standard deviation of data (m)
11	R	XX.XX	Standard deviation of geoid heights (m)
12	R	XX.XX	Standard deviation of vertical deflections (arc sec)
13	R	X.XX	RMS of filtered-raw differences (m)
14	R	±XXX	Maximum vertical deflection (arc sec)
15	R	X.XXX	Average velocity (km/sec)
16	R	X.XX	Antenna distance from satellite center of gravity (m)
17	R	XX.X	Radar instrument delay distance equivalent (cm)
18	R	±.XXX	Time correction (sec)
19	R		Spare

Table 4. **SEASAT-A** ***Filtered Geoid Height Data File*** **(Type FGD) Data Record (Common Data)**

Word	Type	Approximate Range of Significance	Description
1	R	±X.XXXXX	Latitude (rad)
2	R	X.XXXXX	Longitude (rad)
3	R	±XXX.XX	Geoid height (m)
4	R	±XXX.XX	Vertical deflection (arc sec)
5	R	±XXX.XX	Raw geoid height (m)
6	R	X.XX	Geoid height confidence bound (m)
7	R	XX.XX	Vertical deflection confidence bound (arc sec)
8	R	X.XX	Orbit uncertainty in geoid heights (m)
9	R	.XXX	Orbit uncertainty in vertical deflections (arc sec)
10	I	I_1 -- I_{14}	Flag word
11	R	XX.X	Significant wave height (m)
12	R	XX.X	σ - SWH (m)
13	R	XX	Automatic gain control (dB)
14	R	XX	σ - AGC (dB)
15	R	±.XX	Tilt/SWH correction (m)
16	R	X.XXX	Tilt (rad)
17	R	XX.X	Ionospheric correction (cm)
18	R	XXX	Atmospheric pressure (mb)
19	R	XXX.X	Dry tropospheric correction (cm)
20	R	XX.X	Wet tropospheric correction (cm)
21	R	±XX.XX	Tide (m)
22	R	X.XX	Barotropic correction (m)
23	R	XX	Wind speed (kn)
24	R	X.X	Wind direction (rad)
25	R	±X.XX	Sea state (SWH) correction (m)
26	R	XX.X	Alternate wet tropospheric corection (cm)
27	R	XX.X	Rain rate (mm/hr)
28	R	XXX.X	Steric correction (cm)
29	R		Spare
30	R		Spare

MATCHED FILTER

The matched filter (B. Zondek, unpublished data, 1980) is an optimized high-pass filter. To apply it to SEASAT-A data, the control card deck specified in Table 5 is required. Also, six data cards, "A" through "F," must follow the control card deck. The latter contains two SCOPE cards selecting the Revolution Number. By way of an example indicated by pencil arrows, a specific Device Set Number and a File Name are inserted. The six data cards determine the required calculations. They may be manipulated as follows.

Card A (selecting the filter type):
Col. 6 - 10: Enter "3" into Col. 10.
Replace this by a "0," if printout of unfiltered data plus counting numbers wanted.
Col. 11 - 13: Starting time T_1 in sec.
Col. 31 - 50: Terminating time T_2 in sec.

Card B (Use or omission of starting and terminating time):
Col. 5: Enter "0," if T_1 and T_2 to be ignored.
Enter "1," if T_1 and T_2 to be used.

Card C (Choice of printout):
Col. 5: Enter "0" for extended printout (14 digits for results and intermediate results). This is a program checkout mode. Enter "1" to facilitate printing, plus writing on a tape, of restricted output. This is the standard output format.
Enter "2," if desiring printing (only) of restricted output with ϵ choice.
Enter "3" to print and write on tape restricted output with ϵ choice.

Card D (Specifying number of filter tuning constants):
Col. 1 - 5: Enter number of filter tuning constants ρ. For each ρ, the computer program will process and print out the original SEASAT-A data track.

Card E (Specifying the filter tuning constants):
Col. 1 - 10:
Col. 11 - 20: Card may contain up to
Col. 21 - 30: eight different ρ values in
etc. F 10.9 format.
Col. 71 - 80:

Card F (ϵ card):
Given a value for ϵ, this card will prevent printing of a particular time line (geoid height and deflection of vertical versus time in sec), if $|\delta| < \epsilon$. Reasonable values for ϵ are $0.1 < \epsilon < 10$.

Adopt the following terminology: N_i are the "unfiltered geoid height" values, and δ_i are the "unfiltered vertical deflection" values. Application of the matched filter to N_i and δ_i will result in the $\hat{N}_i$ and $\hat{\delta}_i$ data tracks. $\hat{N}_i$ are the "filtered geoid heights" (in m) and $\hat{\delta}_i$ are the "filtered vertical deflections" (in arc sec). The index "i" is related to the time value t_i associated with the data values.

Note that, because of the nature of the filter algorithm, no filtered data values will be associated with the first few and the last few unfiltered data points. Thus, the first "data window" (see below for definition) on a data track shall start with the first available filtered geoid height and deflection of the vertical and the last data window shall end with the last available pair of filtered data values.

Application of the matched filter to GEOS-3 satellite altimetry is omitted from this report.

Table 5. Control Card Deck and Data Card Listing for Matched Filter

```
USER NUMBER (T400. P3, PL-100000)
CHARGE CODE, PASS WORD.
ATTACH, OLDBIN, BHPSABIN02, ID=N60,MR=1.
BEGIN, MOUNT, VSN=NUA022.  ---------->  Device Set Number
ATTACH, TAPE1, FGD01166, SN=NUA022,ID=NI4,MR=1.
ATTACH,SSLIB,ID=NV5.
ATTACH, SYSLIB.
LIBRARY, SYSLIB, SSLIB.                    File Name
LDSET (PRESET=INDEF)
OLDBIN.
EXIT.
DMP (0,202,421)
7/8/9
DATA CARD  "A"
DATA CARD  "B"
DATA CARD  "C"
DATA CARD  "D"
DATA CARD  "E"
DATA CARD  "F"
6/7/8/9
```

ROUGHNESS DETECTOR

Input Data

$\hat{N}_i$	Data track (filtered geoid height)	m
$\hat{\delta}_i$	Data track (filtered vertical deflection)	arc sec
ϵ	Parameter of matched filter	arc sec
Δt	Data step width, $\Delta t = t_i - t_{i-1}$	sec
vs	Subsatellite velocity	km/sec
L	Data window width (specified by user)	km
deln	Threshold parameter (specified by user)	m

Algorithm

1. Consider the filtered data tracks $\hat{N}_i$ and $\hat{\delta}_i$. Assign the value zero to all $\hat{N}_i$ that are negative. Specify data track "windows." The number of the data points within each window is

$$n = \mathrm{INT}\left(\frac{L}{vs\ \ \Delta t}\right) + 1 \tag{301}$$

Start the first window at the first data point not omitted by the filter, t_k, and calculate

$$SN_k = \sqrt{\frac{1}{n} \sum_{i=1}^{n} \left(\hat{N}_{k-1+i}\right)^2} \tag{302}$$

Do the same for the next window, $N_{k+1}, N_{k+2}, \ldots, N_{k+n}$, obtaining

$$SN_{k+1} = \sqrt{\frac{1}{n} \sum_{i=2}^{n+1} \left(\hat{N}_{k-1+i}\right)^2} \tag{303}$$

and for each following window, obtaining

$$SN_{k+v} = \sqrt{\frac{1}{n} \sum_{i=v+1}^{n+v} \left(\hat{N}_{k-1+i}\right)^2} \qquad (304)$$

until the data track N_i is exhausted.

2. From now on, consider only those windows for which $SN_v \geqslant$ deln. From the remaining windows, select those for which SN_v is larger than the SN values for the neighboring windows. (In case the set SN_v = fct(v) does not have a single peak but a "flat top," select that window that is associated with the middle of the flat top). From here on, the term "window" shall refer to a member of the just defined set of maximum-SN_v-windows.

Output Data

For each of these windows (characterized by maximum SN_v value), store and print out

$$\begin{array}{llll}
t_\mu & t_{\mu+1} & \cdots\cdots & t_{\mu+n-1} \\
\hat{N}_\mu & \hat{N}_{\mu+1} & \cdots\cdots & \hat{N}_{\mu+n-1} \\
\hat{\delta}_\mu & \hat{\delta}_{\mu+1} & \cdots\cdots & \hat{\delta}_{\mu+n-1} \\
SN_v & & & \\
N_\mu & N_{\mu+1} & \cdots\cdots & N_{\mu+n-1} \\
\delta_\mu & \delta_{\mu+1} & \cdots\cdots & \delta_{\mu+n-1}
\end{array}$$

Additional Details

1. To avoid disrupting the continuity of the data record across any seamount signature, assign to the filter parameter epsilon the value zero.

2. This means that the window search will now be conducted, without interruption, from the beginning to the end of any continuous portion of a particular data track.

3. Eliminate all data track portions that after application of the matched filter have a number points which is less than 1.5 to 2.0 times the number n of data points within the window, Equation (301).

SEAMOUNT LOCATOR

Subroutine "EXTR"

Known are three data points, i = 1, 2, 3, on a data track $y_i = y(x_i)$. Assume that these points bracket a maximum or minimum of the y_i values. The abscissa value, x_p, associated with the extremum of y_i is then

$$x_p = x_1 - \frac{bd}{2cd} \tag{401}$$

$$bd = \begin{vmatrix} y_2 - y_1 & (x_2 - x_1)^2 \\ y_3 - y_1 & (x_3 - x_1)^2 \end{vmatrix} \tag{402}$$

$$cd = \begin{vmatrix} x_2 - x_1 & y_2 - y_1 \\ x_3 - x_1 & y_3 - y_1 \end{vmatrix} \tag{403}$$

Subroutine "INTERPOL-1"

Known are three data points, i = 1, 2, 3, on a data track $y_i = y(x_i)$. Find, for a specified abscissa value, x_p, the ordinate value $y_p = y(x_p)$.

$$y_p = a + b\,(x_p - x_1) + c(x_p - x_1)^2 \tag{404}$$

$$a = y_1 \tag{405}$$

$$b = \frac{1}{d}\begin{vmatrix} y_2 - y_1 & (x_2 - x_1)^2 \\ y_3 - y_1 & (x_3 - x_1)^2 \end{vmatrix} \tag{406}$$

$$c = \frac{1}{d}\begin{vmatrix} x_2 - x_1 & y_2 - y_1 \\ x_3 - x_1 & y_3 - y_1 \end{vmatrix} \tag{407}$$

$$d = (x_2 - x_1)\,(x_3 - x_1)\,(x_3 - x_2) \tag{408}$$

Subroutine "INTERPOL-2"

Known are four data points, i = 1, 2, 3, 4, on a data track $y_i = y(x_i)$. Calculate, for a specified abscissa value, x_p, the ordinate value $y_p = y(x_p)$.

$$y_p = e + f(x_p - x_1) + g(x_p - x_1)^2 + h(x_p - x_1)^3 \tag{409}$$

$$e = y_1 \tag{410}$$

$$f = \frac{1}{\Delta}\begin{vmatrix} y_2 - y_1 & (x_2 - x_1)^2 & (x_2 - x_1)^3 \\ y_3 - y_1 & (x_3 - x_1)^2 & (x_3 - x_1)^3 \\ y_4 - y_1 & (x_4 - x_1)^2 & (x_4 - x_1)^3 \end{vmatrix} \tag{411}$$

$$g = \frac{1}{\Delta}\begin{vmatrix} x_2 - x_1 & y_2 - y_1 & (x_2 - x_1)^3 \\ x_3 - x_1 & y_3 - y_1 & (x_3 - x_1)^3 \\ x_4 - x_1 & y_4 - y_1 & (x_4 - x_1)^3 \end{vmatrix} \tag{412}$$

$$h = \frac{1}{\Delta}\begin{vmatrix} x_2 - x_1 & (x_2 - x_1)^2 & y_2 - y_1 \\ x_3 - x_1 & (x_3 - x_1)^2 & y_3 - y_1 \\ x_4 - x_1 & (x_4 - x_1)^2 & y_4 - y_1 \end{vmatrix} \tag{413}$$

$$\Delta = \begin{vmatrix} x_2 - x_1 & (x_2 - x_1)^2 & (x_2 - x_1)^3 \\ x_3 - x_1 & (x_3 - x_1)^2 & (x_3 - x_1)^3 \\ x_4 - x_1 & (x_4 - x_1)^2 & (x_4 - x_1)^3 \end{vmatrix} \tag{414}$$

Note Concerning the Subroutines

Optionally, the computer programmer may implement the above subroutines by any of the classical interpolation schemes. If desired, the polynomial coefficients can be evaluated by a least-squares fit method. Irrespective of the method chosen, it must however be kept in mind that rather frequently along the altimetry track, the argument values (time or distance - depending on the interpretation of x_i) will be large compared to the time required for a seamount overflight or to the seamount width, implying $x_i \gg (x_k - x_j)$. To avoid loss of significant digits during the evaluation of the determinants, it is advisable to first transform the x_i values to corresponding

x_i' values so that the origin of the x' system coincides with x_1, $x_i' = (x_i - x_1)$, implying $x_1' = 0$. The particular interpolation method chosen may then be executed. Subsequently, the results must be transformed back into the x/y coordinate system. Note that this precaution is unnecessary, if the subroutines are applied in the form specified above.

Input for Seamount Locator Algorithm

For each data window, have available

$N_i(t_i)$	Unfiltered geoid height	m
$\delta_i(t_i)$	Unfiltered vertical deflection	arc sec
t_i	Time argument	sec
λ_i	Longitude East from altimetry file	deg
φ_i	Latitude from altimetry file	deg

Seamount Locator Algorithm

For each of the specified data windows, now consider the unfiltered geoid heights, N_i, and the unfiltered deflections of the vertical, δ_i. Also keep in mind that it is possible to associate with the discrete number sets $N_i(t_i)$ and $\delta_i(t_i)$, the continuous functions $N(t)$ and $\delta(t)$ representing the geoid height and vertical deflection in the "real world" or simply being assumed to be suitable functions adapted to $N_i(t_i)$ and $\delta_i(t_i)$ by least-squares fit or other meaningful methods. For the present purpose, it is sufficient to postulate that $N(t)$ and $\delta(t)$ may be realized mathematically if needed. Perform the following calculations.

1. When traversing the window from the left to the right (proceeding from lower values of t_i to higher ones), expect to encounter negative δ_i values and, among them, an absolute minimum value. Consider the data point $\delta_i(t_i)$ associated with this minimum value plus the data point to the left and the data point to the right of it. Apply to these three data points the subroutine "EXTR" to find the abscissa value t_A belonging to the minimum of the curve $\delta(t)$ associated with the just specified three data points.

2. In the same manner, find the time value t_B associated with the absolute maximum value of $\delta_i(t_i)$ that will occur further down the data track but still within the data window.

3. Within the window, the data track $N_i(t_i)$ may be expected to have an absolute maximum. Find the data value representing this maximum. Also find the neighboring data points to the left and to the right of this maximum. Apply subroutine "EXTR" to find the time value t_{SM} of the maximum of N(t) related to the just-defined three data points.

4. Now apply subroutine "INTERPOL-1" to t_{SM} and the three data points on the N_i track from which t_{SM} was determined in step 3, obtaining $N(t_{SM}) = N_{SM}$.

5. Next, determine the four data points on the N_i track that are nearest to the time value t_A. Apply to them subroutine "INTERPOL-2" to evaluate the N value associated with t_A, $N(t_A) = N_A$.

6. Further, proceed as in step 5 to find $N(t_B) = N_B$.

7. Proceed as in step 5 to find $\delta(t_A) = \delta_A$.

8. Proceed as in step 6 to find $\delta(t_B) = \delta_B$.

9. Consider now the data tracks N_i and δ_i in the neighborhood of t_{SM}, in particular, the time value $t_i = t^-_{SM}$ just to the left of (prior to) t_{SM} and the time value $t_i = t^+_{SM}$ to the right of (following) t_{SM}. Note that $t^-_{SM} < t_{SM}$ and $t^+_{SM} > t_{SM}$. In the radar files, t^-_{SM} and t^+_{SM} are associated with the values of longitude East and latitude on the subsatellite track,

$t^-_{SM} \leftrightarrow \lambda^-_{SM}$ and φ^-_{SM}

$t^+_{SM} \leftrightarrow \lambda^+_{SM}$ and φ^+_{SM}

Evaluate the longitude East and the latitude of the "signature peak,"

$$\lambda_{SM} = \lambda^-_{SM} + \frac{\lambda^+_{SM} - \lambda^-_{SM}}{t^+_{SM} - t^-_{SM}} (t_{SM} - t^-_{SM}) \tag{415}$$

$$\varphi_{SM} = \varphi^-_{SM} + \frac{\varphi^+_{SM} - \varphi^-_{SM}}{t^+_{SM} - t^-_{SM}} (t_{SM} - t^-_{SM}) \tag{416}$$

10. Note that above the data were postulated to conform to the typical seamount altimetry pattern illustrated in Figure 1. If the data fail, altogether or in any essential detail to match this pattern, reject the data window.

Seamount Locator Output

For each data window successfully processed, store and list the following.

t_A	N_A	δ_A		
t_B	N_B	δ_B		
t_{SM}	N_{SM}		λ_{SM}	φ_{SM}

Seamount longitude and latitude are to be specified in decimal degrees as well as in degree - minute - second format.

CALCULATION OF INITIAL SEAMOUNT PARAMETERS

From the data output of the preceding computer program segments, calculate the following quantities for each data window successfully processed.

$$W_o = 2B_o \approx vs\,(t_B - t_A) \tag{501}$$

$$B_o = \frac{W_o}{2} \tag{502}$$

$$N_c \approx 1.7 \left[N_{SM} - \frac{1}{2}\,(N_B + N_A) \right] \tag{503}$$

$$\alpha_A \approx - \frac{\pi}{180}\,\frac{\delta_A}{3600} \tag{504}$$

$$\alpha_B \approx + \frac{\pi}{180}\,\frac{\delta_B}{3600} \tag{505}$$

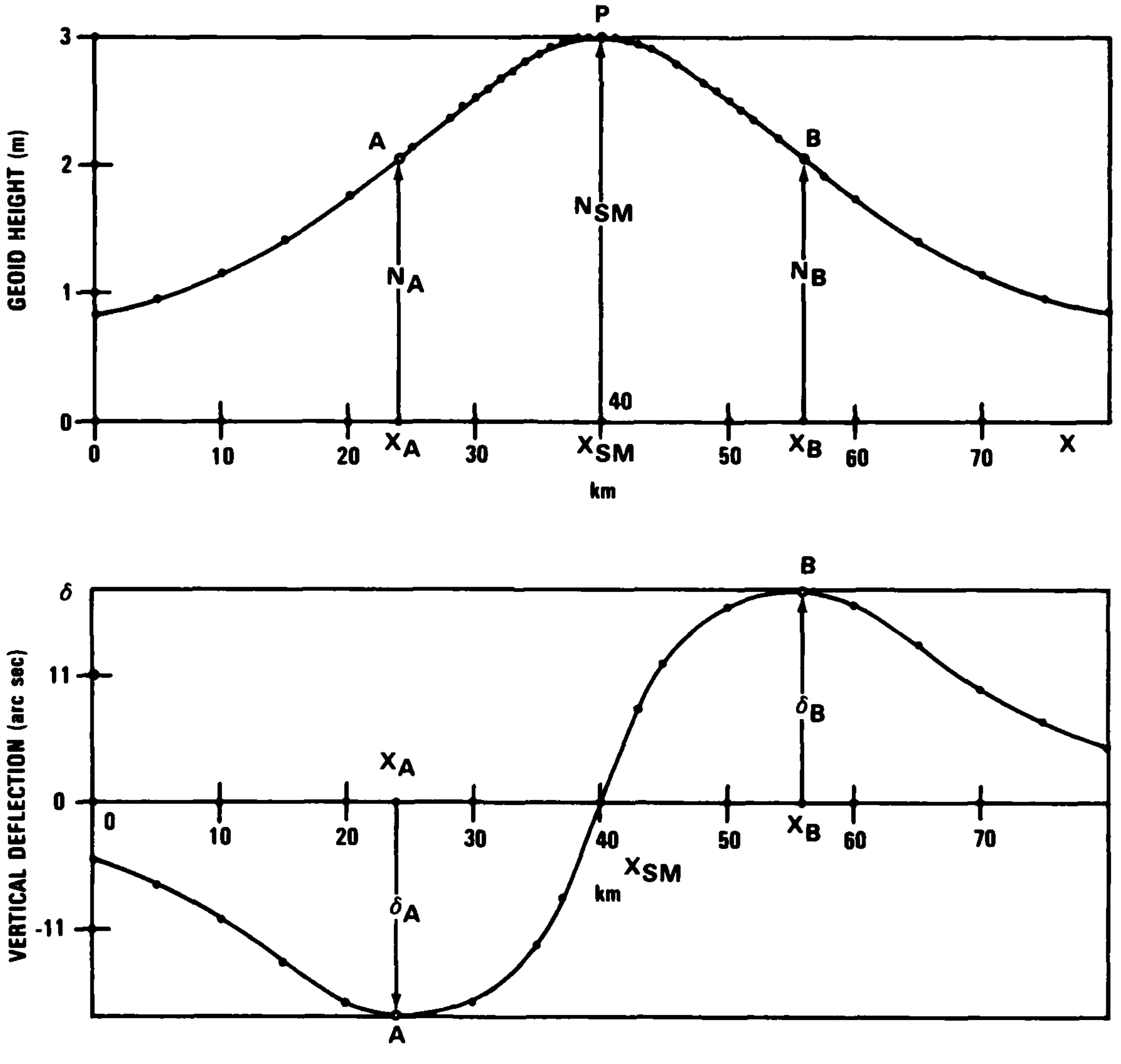

Figure 1. Typical Geoid Height Pattern and Vertical Deflection Above a Seamount

$$\varphi_A \approx (1.5E+05)\,\alpha_A \tag{506}$$

$$\varphi_B \approx (1.5E+05)\,\alpha_B \tag{507}$$

W_0 is the initial estimate of "seamount width at the base" in km. B_0 is the "seamount half width at the base" in km. N_C is the geoid elevation "observed" at the seamount center, in m, to be matched by the calculated geoid elevation during parameter adjustment. φ_A and φ_B are the estimated seamount slope angles in deg. α_A and α_B are the maximal signature slope angles in rad.

OCEAN DEPTH ALGORITHM

For each data window successfully processed, the ocean depth, D, at the seamount perimeter is required. Suitable ocean depth data[24] are available as averages over one-by-one degree surface area elements, as a permanent data file on the Dahlgren computer system. If necessary, convert D to meters.

ESTIMATION OF PEAK DEPTH

Subroutine "DN" - Input Data

D	Ocean depth at seamount perimeter	m
d_S or d	Depth of seamount peak	m
φ_S	Seamount slope angle	deg
H_S	Seamount height	m
T	Crustal thickness	m
B_R	Half width of seamount root as base	m
H_R	Depth, below crust, of seamount root	m
ρ_S	Seamount density	gr/m^3
ρ_W	Water density	gr/m^3
ρ_R	Root density	gr/m^3
ρ_M	Mantle density	gr/m^3
G/g	Ratio of Newton's constant to surface gravity	m^2/gr

If not otherwise specified, assume

ρ_S = 2.60 E+06 gr/m^3

ρ_W = 1.03 E+06 gr/m^3

ρ_R = 2.95 E+06 gr/m^3

ρ_M = 3.40 E+06 gr/m^3

G/g = 0.68024 E-14 m^2/gr

Subroutine "DN" - Algorithm

Reference is made to Figure 2. Perform the following calculations.

$$\alpha_S = \tan \varphi_S \tag{701}$$

$$\beta_S = d/H_S \tag{702}$$

$$\alpha_R = H_R/B_R \tag{703}$$

$$\beta_R = (D + T + H_R)/H_R \tag{704}$$

evaluate FU(α_S, β_S) (Subroutine "FU") (705)

evaluate FI (α_R, β_R) (Subroutine "FI") (706)

$$DNS = (\rho_S - \rho_W)\, H_S^2 \,\frac{G}{g}\, FU(\alpha_S, \beta_S) \tag{707}$$

$$DNR = (\rho_M - \rho_R)\, H_R^2 \,\frac{G}{g}\, FI(\alpha_R, \beta_R) \tag{708}$$

$$DN = DNS - DNR \tag{709}$$

Subroutine "DN" - Output

DNS in m

DNR in m

DN in m

Subroutine "FU"

$FU(\alpha, \beta) =$

$$= 2\pi \left[\frac{-\alpha^2 \beta^2}{2(1+\alpha^2)} + \frac{1+\alpha^2(1+\beta)}{2\alpha(1+\alpha^2)} \sqrt{1+\alpha^2 (1+\beta)^2} \right.$$

$$+ \frac{\alpha \beta^2}{2(1+\alpha^2)^{3/2}} \ln \left(\frac{\alpha \beta (\sqrt{1+\alpha^2} - \alpha)}{\sqrt{1+\alpha^2} \sqrt{1+\alpha^2(1+\beta)^2} - 1 - \alpha^2 (1+\beta)} \right)$$

$$\left. - \beta - \frac{1}{2} \right] \tag{710}$$

Subroutine "FI"

$FI(\alpha, \beta) =$

$$= 2\pi \left[\frac{\alpha^2 \beta^2}{2(1+\alpha^2)} + \frac{1-\alpha^2(\beta-1)}{2\alpha(1+\alpha^2)} \sqrt{1+\alpha^2(\beta-1)^2} \right.$$

$$+ \frac{\alpha \beta^2}{2(1+\alpha^2)^{3/2}} \ln \left(\frac{\alpha\beta(\sqrt{1+\alpha^2} + \alpha)}{\sqrt{1+\alpha^2} \sqrt{1+\alpha^2(\beta-1)^2} - 1 - \alpha^2(\beta-1)} \right)$$

$$\left. - \beta + \frac{1}{2} \right] \tag{711}$$

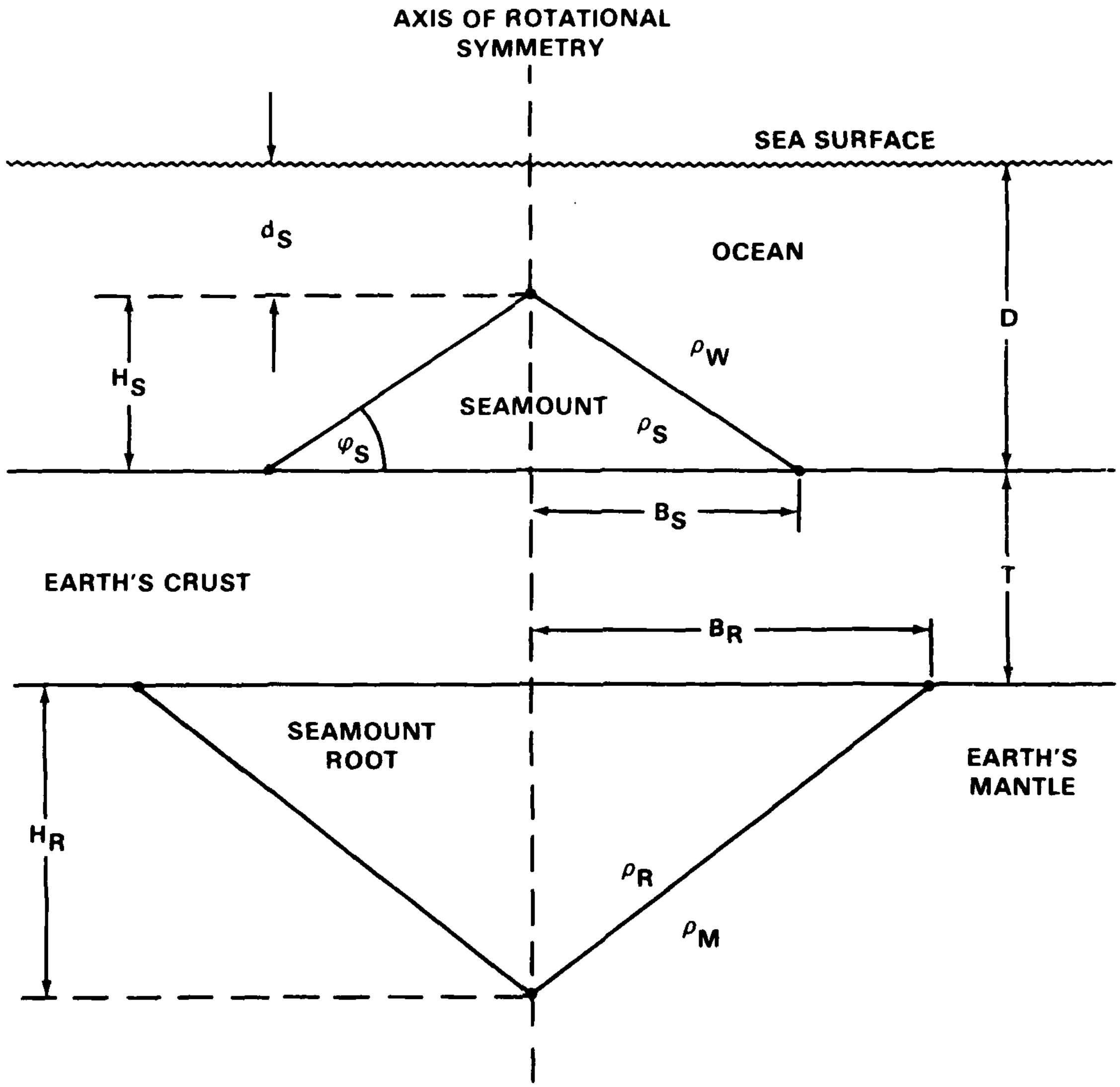

Figure 2. Geometry of Seamount Model

Estimation of Peak Depth for Isostatically Compensated Seamount-Input Data

G/g	Ratio of Newton's constant to surface gravity (user specified)	m^2/gr
ρ_S	Seamount density (user specified)	gr/m^3
ρ_W	Water density (user specified)	gr/m^3
ρ_R	Root density (user specified)	gr/m^3
ρ_M	Mantle density (user specified)	gr/m^3
D	Ocean depth at seamount perimeter	m
T	Crustal thickness (user specified)	m
φ_A	Seamount slope angles	deg
φ_B		
W_0	Initial estimate of seamount width at base	km
N_C	"Observed" geoid elevation above seamount peak	m

If not otherwise specified, assume for G/g and the four densities, the nominal values listed under "Subroutine "DN" - - Input Data."

Estimation of Peak Depth for Isostatically Compensated Seamount - - Removal of Ill-Conditioned Cases

Reference is made to Figure 2. Execute the following test. This test assumes that the seamount is as large as the estimated slope angle φ_S and the local ocean depth, D permit (peak is near surface • • • • • $d_S^* = 10$ m), thus producing the largest maximal geoid elevation DN* possible for the particular φ_S and D values. If DN* is smaller than the observed maximal geoid elevation N_C, the next program segment will be unable to perform the depth estimation unless certain corrective measures are taken as prescribed below.

$$\varphi_S = \frac{\varphi_A + \varphi_B}{2} \tag{712}$$

$$d_S^* = 10 \text{ m} \tag{713}$$

$$B_S^* = \frac{D - 10 \text{ m}}{\tan \varphi_S} \tag{714}$$

$$H_S^* = D - 10 \text{ m} \tag{715}$$

$$B_R^* = B_S^* \tag{716}$$

$$H_R^* = \frac{H_S^* (\rho_S - \rho_W)}{(\rho_M - \rho_R)} \tag{717}$$

$$DN^* = DN(D, d_S^*, \varphi_S, H_S^*, T, B_R^*, H_R^*) \tag{718}$$

$$DN^* \geqslant N_C \ ? \tag{719}$$

If yes, proceed with the next computer program segment. Otherwise, print out "CAUTION: ILL-CONDITIONED CASE," perform the assignment $N_C = DN^*$, and then proceed with the next computer program segment.

Estimation of Peak Depth for Isostatically Compensated Seamount - - Algorithm

Reference is made to Figure 2. Perform the following claculations.

$$\varphi_S = \frac{\varphi_A + \varphi_B}{2} \tag{720}$$

$$B_{S0} = 500 \, W_0 \tag{721}$$

$$d_0 = D - B_{S0} \tan \varphi_S \tag{722}$$

$$d_0 \leqslant 0 \ ? \tag{723}$$

If yes, execute Equations (724) and (725) and continue. Otherwise, ignore these two equations and continue.

$$d_0 = 10\ \mathrm{m} \tag{724}$$

$$B_{S0} = \frac{D - 10\ \mathrm{m}}{\tan \varphi_S} \tag{725}$$

$$H_{S0} = D - d_0 = B_{S0} \tan \varphi_S \tag{726}$$

$$B_{R0} = B_{S0} \tag{727}$$

$$H_{R0} = \frac{H_{S0}(\rho_S - \rho_W)}{(\rho_M - \rho_R)} \tag{728}$$

$$DN_0 = DN(D, d_0, \varphi_S, H_{S0}, T, B_{R0}, H_{R0}) \tag{729}$$

Also, calculate

$$B_{S1} = 0.8\ B_{S0} \tag{730}$$

$$d_1 = D - B_{S1} \tan \varphi_S \tag{731}$$

$$H_{S1} = B_{S1} \tan \varphi_S \tag{732}$$

$$B_{R1} = B_{S1} \tag{733}$$

$$H_{R1} = \frac{H_{S1}(\rho_S - \rho_W)}{(\rho_M - \rho_R)} \tag{734}$$

$$DN_1 = DN(D, d_1, \varphi_S, H_{S1}, T, B_{R1}, H_{R1}) \tag{735}$$

and estimate the seamount half width according to Figure 3.

$$B_{S2} = B_{S0} + \frac{B_{S1} - B_{S0}}{DN_1 - DN_0}(N_C - DN_0) \tag{736}$$

Further calculate

$$d_2 = D - B_{S2} \tan \varphi_S \tag{737}$$

$$H_{S2} = B_{S2} \tan \varphi_S \tag{738}$$

$$B_{R2} = B_{S2} \tag{739}$$

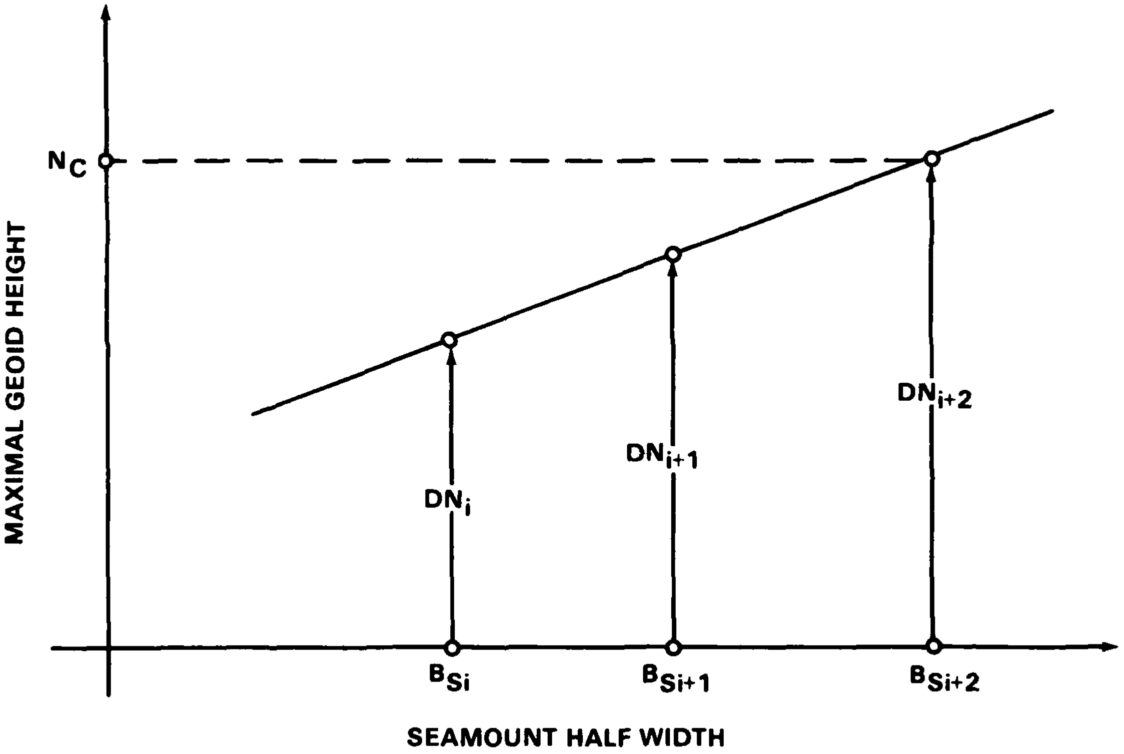

Figure 3. Linear Scheme for Estimation of Seamount Half Width (at Base)

$$H_{R2} = \frac{H_{S2}(\rho_S - \rho_W)}{(\rho_M - \rho_R)} \tag{740}$$

$$DN_2 = DN(D, d_2, \varphi_S, H_{S2}, T, B_{R2}, H_{R2}) \tag{741}$$

and use B_{S1}, DN_1, B_{S2}, and DN_2 to start the iterative routine

$$B_{S\ i+2} = B_{S\ i} + \frac{B_{S\ i+1} - B_{S\ i}}{DN_{i+1} - DN_i}(N_C - DN_i) \tag{742}$$

$$d_{i+2} = D - B_{S\ i+2} \tan \varphi_S \tag{743}$$

$$d_{i+2} \leqslant 0? \tag{744}$$

If yes, execute Equations (745) and (746) and continue. Otherwise, ignore these two equations and continue.

$$d_{i+2} = 10 \text{ m} \tag{745}$$

$$B_{S\ i+2} = \frac{D - 10 \text{ m}}{\tan \varphi_S} \tag{746}$$

$$H_{S\ i+2} = B_{S\ i+2} \tan \varphi_S \tag{747}$$

$$B_{R\ i+2} = B_{S\ i+2} \tag{748}$$

$$H_{R\ i+2} = \frac{H_{S\ i+2}(\rho_S - \rho_W)}{(\rho_M - \rho_R)} \tag{749}$$

$$DN_{i+2} = DN(D, d_{i+2}, \varphi_S, H_{S\ i+2}, T, B_{R\ i+2}, H_{R\ i+2}) \tag{750}$$

$$\epsilon_{i+2} = |N_C - DN_{i+2}| \tag{751}$$

$$\epsilon_{i+2} \leqslant 0.0001 \text{ m}? \tag{752}$$

If yes, stop and call the associated d_{i+2} "d_j." Exit from the iterative routine. Otherwise, reenter the iterative routine.

End of the iterative routine.

The estimated depth of the seamount peak is

$$d_{\text{isost. comp.}} = D - B_{Sj} \tan \varphi_S = d_j \tag{753}$$

where

$$B_{Sj} = B_{Si+2} \tag{754}$$

Estimation of Peak Depth for the Generally Compensated Seamount - - Input Data

G/g	Ratio to Newton's constant to surface gravity (user specified)	m^2/gr
ρ_S	Seamount density (user specified)	gr/m^3
ρ_W	Water density (user specified)	gr/m^3
ρ_R	Root density (user specified)	gr/m^3
ρ_M	Mantle density (user specified)	gr/m^3
D	Ocean depth at seamount perimeter	m
T	Crustal thickness (user specified)	m
φ_A φ_B	Seamount slope angles	deg
W_0	Initial estimate of seamount width at base	km
N_C	"Observed" geoid elevation above seamount peak	m
sk	Geometry factor (user specified)	
H_R	"Height" of seamount root (user specified)	m

If not otherwise specified, assume for G/g and the four densities the nominal values listed under "Subroutine DN - - Input Data."

Estimation of Peak Depth for Generally Compensated Seamount - - Removal of Ill-Conditioned Cases

Reference is made to Figure 2. Execute the following test. This test assumes that the seamount is as large as is compatible with the estimated seamount slope angle φ_S and the local ocean depth D (peak is near surface . . . . . $d_S^* = 10$ m), thus producing the largest maximal geoid elevation DN* possible for the particular φ_S and D values. If DN* is smaller than the observed maximal geoid elevation N_C, the next program segment will be unable to perform the depth estimation unless certain corrective measures are taken as prescribed below.

$$\varphi_S = \frac{\varphi_A + \varphi_B}{2} \qquad 755)$$

$$d_S^* = 10 \text{ m} \qquad (756)$$

$$B_S^* = \frac{D - 10 \text{ m}}{\tan \varphi_S} \qquad (757)$$

$$H_S^* = D - 10 \text{ m} \qquad (758)$$

$$B_R^* = sk\, B_S^* \qquad (759)$$

$$H_R^* = H_R \qquad (760)$$

$$DN^* = DN(D, d_S^*, \varphi_S, H_S^*, T, B_R^*, H_R^*) \qquad (761)$$

$$DN^* \geqslant N_C \text{ ?} \qquad (762)$$

If yes, proceed with the next computer program segment. Otherwise, print out: "CAUTION: ILL-CONDITIONED CASE," perform the assignment $N_C = DN^*$, and then proceed with the next computer program segment.

Estimation of Peak Depth for Generally Compensated Seamounts - - Algorithm

Reference is made to Figure 2. Perform the following calculations.

$$\varphi_S = \frac{\varphi_A + \varphi_B}{2} \qquad (763)$$

$$B_{S0} = 500\,W_0 \tag{764}$$

$$d_0 = D - B_{S0} \tan \varphi_S \tag{765}$$

$$d_0 \leqslant 0\ ? \tag{766}$$

If yes, execute Equations (767) and (768) and continue. Otherwise, ignore these two equations and continue.

$$d_0 = 10\text{ m} \tag{767}$$

$$B_{S0} = \frac{D - 10\text{ m}}{\tan \varphi_S} \tag{768}$$

$$H_{S0} = B_{S0} \tan \varphi_S \tag{769}$$

$$B_{R0} = sk\ B_{S0} \tag{770}$$

$$DN_0 = DN(D, d_0, \varphi_S, H_{S0}, T, B_{R0}, H_R) \tag{771}$$

Also, calculate

$$B_{S1} = 0.8\,B_{S0} \tag{772}$$

$$d_1 = D - B_{S1} \tan \varphi_S \tag{773}$$

$$H_{S1} = B_{S1} \tan \varphi_S \tag{774}$$

$$B_{R1} = B_{S1}\ sk \tag{775}$$

$$DN_1 = DN(D, d_1, \varphi_S, H_{S1}, T, B_{R1}, H_R) \tag{776}$$

and estimate the seamount half width according to Figure 3.

$$B_{S2} = B_{S0} + \frac{B_{S1} - B_{s0}}{DN_1 - DN_0}(N_C - DN_0) \tag{777}$$

Further calculate

$$d_2 = D - B_{S\,2} \tan \varphi_S \tag{778}$$

$$H_{S\,2} = B_{S\,2} \tan \varphi_S \tag{779}$$

$$B_{R\,2} = B_{S\,2}\, sk \tag{780}$$

$$DN_2 = DN(D, d_2, \varphi_S, H_{S\,2}, T, B_{R\,2}, H_R) \tag{781}$$

and use $B_{S\,1}$, DN_1, $B_{S\,2}$ and DN_2 to start the iterative routine.

$$B_{S\;i+2} = B_{S\;i} + \frac{B_{S\;i+1} - B_{S\;i}}{DN_{i+1} - DN_i} (N_C - DN_i) \tag{782}$$

$$d_{i+2} = D - B_{S\;i+2} \tan \varphi_S \tag{783}$$

$$d_{i+2} \leqslant 0 \;? \tag{784}$$

If yes, execute Equations (785) and (786) and continue. Otherwise, ignore these two equations and continue.

$$d_{i+2} = 10\text{ m} \tag{785}$$

$$B_{S\;i+2} = \frac{D - 10\text{ m}}{\tan \varphi_S} \tag{786}$$

$$H_{S\;i+2} = B_{S\;i+2} \tan \varphi_S \tag{787}$$

$$B_{R\;i+2} = B_{S\;i+2}\, sk \tag{788}$$

$$DN_{i+2} = DN(D, d_{i+2}, \varphi_S, H_{S\,i+2}, T, B_{R\;i+2}, H_R) \tag{789}$$

$$\epsilon_{i+2} = |N_C - DN_{i+2}| \tag{790}$$

$$\epsilon_{i+2} \leqslant 0.00001\text{ m} \;? \tag{791}$$

If yes, stop and call the associated d_{i+2} "d_j." Exit from the iterative routine. Otherwise, reenter the iterative routine.

End of the iterative routine.

The estimated depth of the seamount peak is

$$d_{\text{general comp.}} = D - B_{Sj} \tan \varphi_S = d_j \tag{792}$$

where

$$B_{Sj} = B_{S\,i+2} \tag{793}$$

Note that general compensation includes the total absence of a root as a subcase. To avoid singularities in Equations (704) and (706), one should not attempt to realize this case by setting H_R to zero but by assigning to it a very small value instead. H_R = 0.000001 m has proven to be a suitable choice.

Estimation of Peak Depth - Output Data

For the isostatically compensated seamount, store and print out (indicating the units)

G/g	m^2/gr
ρ_S	gr/m^3
ρ_W	gr/m^3
ρ_R	gr/m^3
ρ_M	gr/m^3
D	m
T	m
$\left.\begin{matrix}\varphi_A\\ \varphi_B\\ \varphi_S\end{matrix}\right\}$	deg
W_0	km

N_C	m
d_j	m
H_{Sj}	m
B_{Sj}	m
B_{Rj}	m
H_{Rj}	m
$d_{\text{isostat. comp.}}$	m
λ_{SM}	deg and deg-min-arc sec
φ_{SM}	deg and deg-min-arc sec

The index "j" above indicates that the quantities so labeled are the results from the last cycle of the iteration performed (values associated with d_j).

For the generally compensated seamount, store and print out (including the units)

G/g	m^2/gr
ρ_S	gr/m^3
ρ_w	gr/m^3
ρ_R	gr/m^3
ρ_M	gr/m^3
D	m
T	m
φ_A	deg
φ_B	
φ_S	
H_R	m
sk	

W_0	km		
N_C	m		
d_j	m		
H_{Sj}	m		
B_{Sj}	m		
B_{Rj}	m		
$d_{\text{general comp.}}$ or $d_{\text{uncomp.}}$ as applicable			m
λ_{SM}	deg	and	deg-min-arc sec
φ_{SM}	deg	and	deg-min-arc sec

The index "j" above indicates that the quantities so labeled are the results from the last cycle of the iteration performed (values associated with d_j).

ANALYSIS OF DATA DISPERSION

Input Data

Obtain the following from the SEASAT-A data track and/or data track header (Tables 3 and 4).

$\bar{\sigma}_N$	Calculated average of all σ_N (Word 6, Table 4) on data track under consideration. This is the average geoid height confidence bound.	m
$\bar{\sigma}_\delta$	Calculated average of all σ_δ (Word 7, Table 4) on data track under consideration. This is the average vertical deflection confidence bound.	arc sec
vs	Satellite subtrack velocity	m/sec
Δt	Time interval between data points	sec

Further, have available

R_E	Earth's "radius" (R_E = 6378000 m)	m

G/g, ρ_S, ρ_W, ρ_R, ρ_M, as specified above,

D	Ocean depth	m
ΔD	Uncertainty in ocean depth (user input). Normally, use a value of 10% of D.	m
T	Crustal thickness (user input)	m
ΔT	Uncertainty in crustal thickness (user input)	m
φ_A	Seamount slope angle	deg
φ_B	Seamount slope angle	deg
N_C	"Observed" geoid elevation above seamount peak	m
W_0	Initial estimate of seamount width as base	m
sk	Geometry factor for generally compensated seamount cases	
H_R	"Height" of root for generally compensated cases	m

Error Estimates

$$\Delta t_{SM} \approx \Delta t \qquad (794)$$

$$\Delta N_{SM} \approx \sigma_N \qquad (795)$$

$$\Delta\delta \approx \sigma_\delta \qquad (796)$$

$$\Delta t_A \approx \Delta t_B \approx \Delta t \qquad (797)$$

$$\Delta\alpha_A \approx \Delta\alpha_B \approx \frac{\pi}{180} \, \frac{\Delta\delta}{3600} \, \frac{\text{rad}}{\text{arc sec}} = \Delta\alpha \qquad (798)$$

$$\Delta\varphi_A \approx \Delta\varphi_B \approx (1.5E{+}05)\,\Delta\alpha \frac{\text{deg}}{\text{rad}} = \Delta\varphi_S \tag{799}$$

$$\Delta N_A \approx \Delta N_B \approx \Delta N_{SM} \approx \sigma_N \tag{800}$$

$$\Delta N_C \approx -0.3\, N_C \tag{801}$$

$$\Delta\lambda_{SM} \approx \Delta\varphi_{SM} \approx \frac{vs\ \Delta t}{R_E}\ \frac{180}{\pi}\,\text{deg} \tag{802}$$

$$\Delta W_0 \approx 2.8\ vs\ \Delta t \tag{803}$$

Data Dispersion for Isostatically Compensated Seamounts

Symbolize the computer routine that performs the peak depth estimation for isostatically compensated seamounts by

$$d_{\text{isostat. comp.}} = f(D, T, \varphi_A, \varphi_B, W_0, N_C) \tag{804}$$

Let

$$(d_{\text{isostat. comp.}})_{p + \Delta p}$$

symbolize an evaluation of the above function (computer routine) f(. . . . .) with all arguments nominal except the parameter "p" indicated. The latter shall enter the routine with a value perturbed by its error increment. Calculate

$$(d_{\text{isostat. comp.}})_{D+\Delta D}$$

$$(d_{\text{isostat. comp.}})_{T+\Delta T}$$

$$(d_{\text{isostat. comp.}})_{\varphi_A + \Delta\varphi_A} = (d_{\text{isostat. comp.}})_{\varphi_B + \Delta\varphi_B}$$

$$(d_{\text{isostat. comp.}})_{W_0 + \Delta W_0}$$

$$(d_{\text{isostat. comp.}})_{N_C + \Delta N_C}$$

and

$$(\Delta d)_{\Delta D} \approx (d_{\text{isostat. comp.}})_{D + \Delta D} - d_{\text{isostat. comp.}} \tag{805}$$

$$(\Delta d)_{\Delta T} \approx (d_{\text{isostat. comp.}})_{T + \Delta T} - d_{\text{isostat. comp.}} \tag{806}$$

$$(\Delta d)_{\Delta \varphi} \approx (d_{\text{isostat. comp.}})_{\varphi_{A,B} + \Delta\varphi_{A,B}} - d_{\text{isostat. comp.}} \tag{807}$$

$$(\Delta d)_{\Delta W_0} \approx (d_{\text{isostat. comp.}})_{W_0 + \Delta W_0} - d_{\text{isostat. comp.}} \tag{808}$$

$$(\Delta d)_{\Delta N_C} \approx (d_{\text{isostat. comp.}})_{N_C + \Delta N_C} - d_{\text{isostat. comp.}} \tag{809}$$

Data Dispersion Analysis for Generally Compensated Seamounts

Symbolize the computer routine that performs the peak depth estimation for generally compensated seamounts by

$$d_{\text{general comp.}} = g(D, T, \varphi_A, \varphi_B, W_0, N_C) \tag{810}$$

and calculate

$$(\Delta d)_{\Delta D} \approx (d_{\text{general comp.}})_{D + \Delta D} - d_{\text{general comp.}} \tag{811}$$

$$(\Delta d)_{\Delta T} \approx (d_{\text{general comp.}})_{T + \Delta T} - d_{\text{general comp.}} \tag{812}$$

$$(\Delta d)_{\Delta \varphi} \approx (d_{\text{general comp.}})_{\varphi_{A,B} + \Delta\varphi_{A,B}} - d_{\text{general comp.}} \tag{813}$$

$$(\Delta d)_{\Delta W_0} \approx (d_{\text{general comp.}})_{W_0 + \Delta W_0} - d_{\text{general comp.}} \tag{814}$$

$$(\Delta d)_{\Delta N_C} \approx (d_{\text{general comp.}})_{N_C + \Delta N_C} - d_{\text{general comp.}} \tag{815}$$

Additional Details Concerning the Data Dispersion Analysis

Note that the two algorithms indicated by Equations (804) and (810) depend on parameters other than the ones listed. For example, the densities are missing. sk and H_R are omitted from Equation (810). All these quantities were disregarded because the necessary quantitative data on the structure of the seamount/root system and on seamount composition were not available with the degree of accuracy that would make inclusion into a data dispersion study meaningful.

AUTOMATIC ANALYSIS OF SATELLITE ALTIMETRY

To perform an automatic seamount survey on SEASAT-A altimetry, first specify the desired data track per device set number and revolution number. Be aware that a SEASAT-A altimetry track is likely to consist of several distinct track segments. For each of these track segments, the present seamount detector will automatically perform the Matched Filter, the Roughness Detector, the Seamount Locator, and the Calculation of Initial Seamount Parameters. For each track segment, indicate the cases rejected and those retained for further processing. For the cases rejected as well as for those retained, print out the longitude λ_{SM} and the latitude φ_{SM} resulting from Equations (415) and (416).

For the valid detections, execute the Estimation of Peak Depth for Isostatically Compensated Seamounts plus the associated Analysis of Data Dispersion. Then execute the uncompensated subcase ($sk = 2$ and $H_R = 0.000001$ m) of the Estimation of Peak Depth for Generally Compensated Seamounts plus the associated Analysis of Data Dispersion.

Make provision for the user to execute, automatically for the entire data track or, optionally, for selected individual detections, the Estimation of Peak Depth for Generally Compensated Seamounts and the associated Analysis of Data Dispersion for arbitrarily specified values of sk and H_R.

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APPENDIX A

TRIAL DATA FOR COMPUTER PROGRAM CHECKOUT

Test Trajectory: SEASAT-A Revolution No. 1375
This is a North-East to South-West pass leading over Seamount Gregg in the New England Seamount Province and over Bermuda.

Test Object: Seamount Gregg in the New England Seamount Province.

Dimensions of Test Object:

$d_S \approx 1400$ m

$\varphi_S \approx 8.7$ deg

$W_S \approx 47$ km

$\lambda_{SM} \approx 61$ deg W = 299 deg E

$\varphi_{SM} \approx 38.9$ deg N

Source: Unclassified "CONTOUR SHEET 0707 (NAR-6)" made available to the author in July 1979 by CODE 3513, Naval Oceanographic Office, NSTL Station, Bay St. Louis, Miss. This is a bathymetric contour map containing Seamount Gregg.

Geophysical Constants:

$G/g = 0.68024$ E-14 m^2/gr

$\rho_S = 2.60$ E+06 gr/m^3

$\rho_W = 1.03$ E+06 gr/m^3

$\rho_R = 2.95$ E+06 gr/m^3

$\rho_M = 3.40$ E+06 gr/m^3

Procedure for Checkout Calculations:

The seamount detector computer program was applied to SEASAT-A Rev. No. 1375. Seamount Gregg was detected in due course. The computer exercised all segments of the above described algorithm. In particular, estimations of peak depth were performed for the isostatic case, the uncompensated case, and a generally compensated case characterized by specified values for sk and H_R. A complete data dispersion analysis was done for each of these three cases.

To verify the computer results, the entire algorithm from Program Segment "Calculation of Initial Seamount Parameters" on was coded by the author for use on a programmable electronic calculator. Starting with the output data of Program Segment "Seamount Locator," the rather vast system of calculator routines was exercised. All computer results were in the process duplicated to a sufficient number of digits.

ERROR ESTIMATES

$\bar{\sigma}_N$ = 0.041243731 m

$\bar{\sigma}_\delta$ = 0.83135406 arc sec

φs = 6.7840 km/sec

Δt = 0.490024 sec

ΔD = 10% of D = 0.1 D

ΔT = 600 m

$$\Delta\varphi_S \approx \Delta\varphi_{A/B} \approx \frac{\pi \text{ deg}}{1.8 \times 3.6} \; \frac{\bar{\sigma}_\delta}{\text{arc sec}} = 0.40305 \text{ deg}$$

$$\Delta W_0 \approx 2.8 \text{ vs } \Delta t \qquad = 9.3081 \text{ km}$$

$$\Delta N_C \approx - 0.3 N_C \qquad = - 0.4493 \text{ m}$$

TRIAL DATA FOR ISOSTATIC COMPENSATION

Nominal Case:

Data prior to estimation of peak depth:

(Ref: Program segment input data plus Equations (720) through (729))

$D = 5000$ m

$T = 5000$ m

$N_C = 1.4977448$ m

$\varphi_S = 9.8951328$ deg

$(B_S)_0 = 20711.482$ m

$(d_S)_0 = 1387.080712$ m

$(H_S)_0 = 3612.919288$ m

$(B_R)_0 = 20711.48200$ m

$(H_R)_0 = 12605.07396$ m

$(DN)_0 = 0.849684309$ m

Results of estimation of peak depth:

(Ref: Equations (754), (750), and (753))

$(B_S)_j = 26493.53167$ m

$(DN)_j = 1.497744767$ m

$(d_S)_j = (d_{\text{isostat. comp.}})_{\text{nominal}} = 378.4576320$ m

Perturbed Cases:

(For each case, the single parameter indicated is perturbed.)

1. $\Delta D = 10\%$ of $D = 500$ m

   $D \rightarrow D + \Delta D = 5500$ m

   $(B_S)_j = 27105.91440$ m

$(DN)_j = 1.497744736$ m

$(d_S)_j = (d_{isost.\ comp.})_{D+\Delta D} = 771.6333$ m

$(\Delta d_S)_{\Delta D} = 393.1757$ m

2. $\Delta T = 600$ m

$T \rightarrow T + \Delta T = 5600$ m

$(B_S)_j = 26157.90074$ m

$(DN)_j = 1.497744800$ m

$(d_S)_j = (d_{isost.\ comp.})_{T+\Delta T} = 437.0052$ m

$(\Delta d_S)_{\Delta T} = 58.5476$ m

3. $\Delta\varphi_S = 0.40305$ deg

$\varphi_s \rightarrow \varphi_S + \Delta\varphi_S = 10.2981828$ deg

$(B_S)_j = 25771.9928$ m

$(DN)_j = 1.49774479$ m

$(d_S)_j = (d_{isost.\ comp.})_{\varphi_S + \Delta\varphi_S} = 317.2795$ m

$(\Delta d_S)_{\Delta\varphi_S} = -61.1781$ m

4. $\Delta W_0 = 9.3081$ km

$(B_S)_0 \rightarrow (B_S)_0 + \frac{1}{2}\Delta W_0 = 25365.5340$ m

$(B_S)_j = 26493.5321$ m

$(DN)_j = 1.49774483$ m

$(d_s)_j = (d_{isost.\ comp.})_{B_{S0} + \frac{1}{2}\Delta W_0} = 378.4576$ m

$(\Delta d_S)_{\Delta W_0} = 0.0000$ m

5. $\Delta N_C = 0.44932344$ m

$N_C \rightarrow N_C + \Delta N_C = 1.04842136$ m

$(B_S)_j = 22682.94818$ m

$(DN)_j = 1.0482$ m

$(d_S)_j = (d_{\text{isost. comp.}})_{N_C + \Delta N_C} = 1043.1774$ m

$(\Delta d_S)_{\Delta N_C} = 664.7198$ m

TRIAL DATA FOR UNCOMPENSATED CASE

Nominal case:

Data prior to estimation of peak depth:

(Ref: Program segment input plus Equations (763) through (771))

$D = 5000$ m

$T = 5000$ m

$N_C = 1.4977448$ m

$\varphi_S = 9.8951328$ m

$(B_S)_0 = 20711.482$ m

$(d_S)_0 = 1387.080712$ m

$(H_S)_0 = 3612.919288$ m

$sk = 2$

$(B_R)_0 = 41422.96400$ m

$H_R = 0.000001$ m

$(DN)_0 = 1.871038679$ m

Results of estimation of peak depth:

(Ref: Equations (793), (789), and (792))

$(B_S)_j$ = 18891.02732 m

$(DN)_j$ = 1.497744794 m

$(d_S)_j = (d_{uncomp.})_{nominal}$ = 1704.641562 m

Perturbed Cases:

(For each case, the single parameter indicated is perturbed.)

1. $\Delta D = 500$ m

$D \rightarrow D + \Delta D = 5500$ m

$(B_S)_j = 19219.5224$ m

$(DN)_j = 1.49774479$ m

$(d_S)_j = (d_{uncomp.})_{D+\Delta D} = 2147.3388$ m

$(\Delta d_S)_{\Delta D} = 442.6972$ m

2. $\Delta T = 600$ m

$T \rightarrow T + \Delta T = 5600$ m

$(B_S)_j = 18891.0273$ m

$(DN)_j = 1.49774479$ m

$(d_S)_j = (d_{uncomp.})_{T+\Delta T} = 1704.6416$ m

$(\Delta d_S)_{\Delta T} = 0.000$ m (Root absent . . . effect of crustal thickness absent)

3. $\Delta\varphi_S = 0.40305$ m

$\varphi_S \rightarrow \varphi_S + \Delta\varphi_S = 10.2981828$ m

$(B_S)_j = 18539.6599$ m

$(DN)_j = 1.49774479$ m

$(d_S)_j = (d_{uncomp.})_{\varphi_S+\Delta\varphi_S} = 1631.3802$ m

$(\Delta d_S)_{\Delta\varphi_S} = -73.2614$ m

4. $\Delta W_0 = 9.3081$ km

$(B_S)_0 \rightarrow (B_S)_0 + \frac{1}{2}\Delta W_0 = 25365.4340$ m

$(B_S)_j = 18891.0273$ m

$(DN)_j = 1.49774479$ m

$(d_S)_j = (d_{uncomp.})_{B_{S0} + \frac{1}{2}\Delta W_0} = 1704.6416$ m

$(\Delta d_S)_{\Delta W_0} = 0.0000$ m

5. $\Delta N_C = -0.4493$ m

$N_C \rightarrow N_C + \Delta N_C = 1.04842136$ m

$(B_S)_j = 16332.7632$ m

$(DN)_j = 1.04842145$ m

$(d_S)_j = (d_{uncomp.})_{N_C+\Delta N_C} = 2150.9062$ m

$(\Delta d_S)_{\Delta N_C} = 446.2646$ m

TRIAL DATA FOR GENERALLY COMPENSATED CASE

Nominal Case:

Data prior to estimation of peak depth:

(Ref: Program segment input plus Equations (763) through (771))

$D = 5000$ m

$T = 5000$ m

$N_C = 1.4977448$ m

$\varphi_S = 9.8951328$ deg

$(B_S)_0 = 20711.482$ m

$(d_S)_0 = 1387.080712$ m

$(H_S)_0 = 3612.919288$ m

$sk = 2$

$(B_R)_0 = 41422.96400$ m

$H_R = 3700$ m

$(DN)_0 = 0.926434431$ m

Results of estimation of peak depth:

(Ref: Equations (793), (789), and (792))

$(B_S)_j = 23952.54037$ m

$(DN)_j = 1.497744778$ m

$(d_S)_j = (d_{\text{general comp.}})_{\text{nominal}} = 821.7091810$ m

Perturbed Cases:

(For each case, the single parameter indicated is perturbed.)

1. $\Delta D = 500 \text{ m}$

$D \rightarrow D + \Delta D = 5500 \text{ m}$

$(B_S)_j = 24354.7574 \text{ m}$

$(DN)_j = 1.49774473 \text{ m}$

$(d_S)_j = (d_{\text{gen. comp.}})_{D+\Delta D} = 1251.5463 \text{ m}$

$(\Delta d_S)_{\Delta D} = 429.8371 \text{ m}$

2. $\Delta T = 600 \text{ m}$

$T \rightarrow T + \Delta T = 5600 \text{ m}$

$(B_S)_j = 23849.9808 \text{ m}$

$(DN)_j = 1.49774479 \text{ m}$

$(d_S)_j = (d_{\text{gen. comp.}})_{T+\Delta T} = 839.5997 \text{ m}$

$(\Delta d_S)_{\Delta T} = 12.8905 \text{ m}$

3. $\Delta \varphi_S = 0.40305 \text{ deg}$

$\varphi_S \rightarrow \varphi_S + \Delta \varphi_S = 10.2981828 \text{ deg}$

$(B_S)_j = 23339.7922 \text{ m}$

$(DN)_j = 1.49774480 \text{ m}$

$(d_S)_j = (d_{\text{gen. comp.}})_{\varphi_S+\Delta\varphi_S} = 759.2056 \text{ m}$

$(\Delta d_S)_{\Delta\varphi_S} = -62.5036 \text{ m}$

4. $\Delta W_0 = 9.3081$ km

$(B_S)_0 \rightarrow (B_S)_0 + \frac{1}{2}\Delta W_0 = 25365.5340$ m

$(B_S)_j = 23952.5403$ m

$(DN)_j = 1.49774477$ m

$(d_S)_j = (d_{gen.\ comp.})_{B_{S0} + \frac{1}{2}\Delta W_0} = 821.7092$ m

$(\Delta d_S)_{\Delta W_0} = 0.0000$ m

5. $\Delta N_C = -0.4493$ m

$N_C \rightarrow N_C + \Delta N_C = 1.04842136$ m

$(B_S)_j = 21475.1599$ m

$(DN)_j = 1.048421461$ m

$(d_S)_j = (d_{gen.\ comp.})_{N_C + \Delta N_C} = 1253.8644$ m

$(\Delta d_S)_{\Delta N_C} = 432.1552$ m

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