

1N-29060

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ALTIMETER MEASUREMENTS FOR THE DETERMINATION
OF THE EARTH'S GRAVITY FIELD

NASA GRANT NAG5-746

Semiannual Research Progress/Status Report
for the period
March 18, 1986 – September 14, 1986

Submitted to

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September 25, 1986

(NASA-CR-176893)	ALTIMETER MEASUREMENTS FOR	N86-32912
THE DETERMINATION OF THE EARTH'S GRAVITY		
FIELD Semiannual Research Progress/Status		
Report, 18 Mar. - 14 Sep. 1986 (Texas Univ.)		Unclas
9 p.	CSCI 08N G3/46	44644

ALTIMETER MEASUREMENTS FOR THE DETERMINATION OF THE EARTH'S GRAVITY FIELD

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INTRODUCTION

The University of Texas Center for Space Research (UT/CSR) research efforts under NASA Grant NAG5-746 during the time period from March 18, 1986, to September 14, 1986, have concentrated on the following areas:

- Refining altimeter and altimeter crossover measurement models for precise orbit determination and for the solution of the earth's gravity field,
- Performing experiments using altimeter data for the improvement of precise satellite ephemerides,
- Analyzing an optimal relative data weighting algorithm to combine various data types in the solution of the gravity field.

ALTIMETER MODEL REFINEMENT

A model of the quasi-stationary sea surface topography (SST) was implemented in the University of Texas Orbit Processor (UTOPIA). The model uses a surface spherical harmonics representation of the Levitus model of the SST, and it includes the capability to estimate the SST model in terms of spherical harmonics coefficients using altimeter data. The model of SST is part of the dynamically consistent altimeter measurement model which includes the modeling of the dynamical effect of the global ocean surface on the satellite orbit.

Software development efforts are underway to implement the capability for the computation and generation of altimeter crossover measurements for the general case of two altimetric satellites.

ALTIMETER CROSSOVER EXPERIMENTS

Orbit determination experiments using altimeter crossover observations were performed. Altimeter crossover and ground-based tracking data were used to determine SEASAT 12-day arc with orbit epoch beginning at July 7, 1978. When resonant coefficients and 10×10 gravity field coefficients were solved using crossovers and tracking data, the SEASAT orbit was computed with a better accuracy. A simulation experiment was then performed to confirm the above results. In conclusion, the use of crossover measurements significantly improves the radial component of the estimated orbit. The improvements in the geopotential gained from processing crossover measurements will reduce the geographically correlated orbit error.

Further experiments using both direct altimeter and altimeter crossover data will be performed to assess the ability of these data types in the role of orbit determination and mapping of geophysical parameters.

APPLICATION OF ALTIMETER DATA

A new technique was developed to interpolate unevenly spaced GEOS-3 and SEASAT altimeter data to generate the mean sea surface, or marine geoid, with high resolution. Green functions of the biharmonic operator, in any number of dimensions, are used for minimum curvature interpolation of irregularly spaced data points. The interpolating curve (or surface) is a linear combination of Green functions centered at each data point. In one (or two) dimensions, this technique is equivalent to cubic spline (or bicubic spline) interpolation, while in three dimensions, it corresponds to multiquadratic interpolation. Although this new technique is relatively slow, it is more flexible than the spline method since both slopes and values can be used to find a surface. Moreover, noisy data can be fit in a least-squares sense by reducing the number of model parameters. These properties are well suited for interpolating irregularly spaced satellite altimeter profiles. The long wavelength radial orbit error is suppressed by differentiating each profile. The shorter wavelength noise is

reduced by the least-squares fit to nearby profiles. Using this technique with 0.5 million GEOS-3 and SEASAT data points, it was found that the marine geoid of the areas covering the Gulf of Mexico and the Caribbean are highly correlated with the sea floor topography. This suggests that similar applications in more remote areas may reveal new features of the sea floor. Future plans include application of altimeter data to produce a high resolution global ocean surface map. GEOSAT altimeter data, if available, will be included.

RELATIVE DATA WEIGHTING

An optimal relative data weighting algorithm was developed to combine various data types for the solution of the earth's gravity field. The algorithm minimizes the error introduced by the observation noise and scales the *a priori* variances for an optimal solution. Evaluations and experiments are underway to examine the ability of the data weighting algorithm for the optimal solution of the earth's gravity field.

PUBLICATIONS/CONFERENCES

The following is a list of publications and conference presentations pertinent to the research activities under NASA Grant NAG5-746:

- *Altimeter Crossover Experiments*, R. S. Nerem, C. K. Shum, and J. R. Ries. Presented at the Sixth UT/GSFC TOPEX Gravity Model Development Meeting held at The University of Texas at Austin, April 8–10, 1986.
- *Altimeter Crossover Methods for Precision Orbit Determination*, C. K. Shum, B. E. Schutz, B. D. Tapley, B. H. Zhang, and R. S. Nerem. Abstract submitted to the Fall Meeting of the American Geophysical Union, San Francisco, California, December 1986. A copy of the abstract is included in Appendix A.
- *Biharmonic Spline Interpolation of GEOS-3 and SEASAT Altimeter Data*, D. T. Sandwell.

Submitted to EOS for publication. Abstract submitted to the Fall Meeting of the American Geophysical Union, San Francisco, California, December 1986. A copy of the abstract is included in Appendix B.

APPENDIX A

ALTIMETER CROSSOVER METHODS FOR PRECISION ORBIT DETERMINATION

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The ability of satellite-borne radar altimeter data to measure the global ocean surface with sub-centimeter accuracy provides a unique data set to aid precision orbit determination as well as to map the earth's gravity field and its geoid. Although satellite altimetry has a distinct advantage in its global distribution of data, consideration of possible error sources when altimeter data are directly used for orbit determination and geophysical mapping suggests several disadvantages. In particular, long wavelength oceanographic features and nontemporal ocean topography can be absorbed into the orbit when altimeter data are directly used. Altimeter crossover data, which eliminate the dependence on the nontemporal ocean topography, provide a valuable data set in its global coverage. In this investigation, techniques to employ altimeter crossover data to perform precision orbit determination and to recover geophysical parameters have been developed. New techniques of using dual or multiple satellite crossover data for precision orbit determination and geodetic parameter mapping have been investigated.

Acknowledgment: This research was supported by NASA under Contract No. NAG 5-746.

1. 1986 Fall Meeting
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APPENDIX B

BIHARMONIC SPLINE INTERPOLATION OF GEOS-3 AND SEASAT ALTIMETER DATA

ABSTRACT

Green functions of the biharmonic operator, in any number of dimensions, are used for minimum curvature interpolation of irregularly spaced data points. The interpolating curve (or surface) is a linear combination of Green functions centered at each data point. In one (or two) dimensions, this technique is equivalent to cubic spline (or bicubic spline) interpolation, while in three dimensions, it corresponds to multiquadratic interpolation. Although this new technique is relatively slow, it is more flexible than the spline method since both slopes and values can be used to find a surface. Moreover, noisy data can be fit in a least-squares sense by reducing the number of model parameters. These properties are well suited for interpolating irregularly spaced satellite altimeter profiles. The long wavelength radial orbit error is suppressed by differentiating each profile. The shorter wavelength noise is reduced by the least-squares fit to nearby profiles. Using this technique with 0.5 million GEOS-3 and SEASAT data points, it was found that the marine geoid of the Caribbean area is highly correlated with the sea floor topography. This suggests that similar applications in more remote areas may reveal new features of the sea floor.