EVIDENCE FOR NON-NEWTONIAN GRAVITY: STATUS OF THE AFGL EXPERIMENT JANUARY 1989

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ABSTRACT

In a test of Newton's inverse-square law of gravitation, we have compared gravity measurements on a 600 m tower with gravity estimates calculated from ground measurements. Originally we found a departure from the inverse-square law that asymptotically approached -500 ± 35 μGal (later modified to -500 ± 140 μGal) at the top of the tower, and which was suggestive of a rapidly attenuating non-Newtonian attractive force. With the eager help of critics who uncovered a subtle systematic error due to a surface sampling bias, we have succeeded over the past year in whittling down the effect to approximately -350 ± 110 μGal. The bias resulted from gravity measurements being taken at higher mean elevations than the average local terrain. Steps that we are taking to compensate for this bias should also help bring down the magnitudes of the solution uncertainties.

Last year we described and presented the results of the AFGL tower gravity experiment[1]. We had found significant differences between gravity measured at various elevations of a 600 m tall tower and gravity modeled from surface measurements using potential theory and the inverse-square law of gravitational attraction. We stated that "Unless these differences are artifacts of unsuspected errors, the data indicate that at the base of the tower there is a non-Newtonian attractive gravitational force that falls off rapidly with elevation." Searching for those unsuspected errors in 1988, we densified the surface gravity survey and refined our techniques for analyzing the data. We also had the help of critics who found our claims outrageous. The net result is that some unsuspected errors have been identified, generally tending to decrease the tower gravity differences from 500 μGal to approximately 350 μGal at the top of the tower. Nevertheless, the experiment and its reanalysis are still incomplete, so we are not ready to offer a final result.

Based on tests that we made before, during, and after the tower gravity measurements, we can definitively rule out any significant effects on our LaCoste & Romberg Model G gravimeter that are due to tower motions, radio frequency interference, magnetic effects, and atmospheric pressure changes. We calibrated the gravimeter's scale factor, and LaCoste & Romberg calibrated the screw error; both these calibrations were performed carefully and correctly. The potential errors that remain are due to data processing, deficiencies in analytic techniques, and sampling biases. We have thoroughly reviewed each of these sources.

Last year we had two independent data processing techniques for the upward continuation of the surface gravity data. (Since then we have added two more.) Both Method I (JET) and Method II (RET) gave essentially the same results for the tower gravity differences. Aside from a mistaken calculation of the initially published uncertainties of JET (which has been corrected[2] and, in any case, does not affect the upward continuation estimates), the largest unsuspected error source has been due to a sampling bias in elevation.

Bartlett and Tew[3] contend that we have overlooked the effect of a topographic low 400 m from the base of the tower; this causes a gravity low whose contribution to the upward continuation model could have been missed either because the mean elevation of our gravity measurement sites 400 m from the tower was not representative of the average terrain at that range (a sampling bias) or because our analytic techniques are insensitive to such relatively short wavelength gravity features. We agree that there was a small elevation sampling bias at 400 m which we have almost eliminated with additional measurements, but we disagree that some (or indeed *all*) of our analytic techniques are insensitive to such a feature. The value of Bartlett and Tew's critique is the inference that elevation sampling biases are potential error sources anywhere in the ground survey region. To our consternation, we found elevation biases as large as 5 m for measurement rings 1.6, 2.5 and 3.6 km from the tower and another maximum of 19 m in a ring 7.5 km from the tower. These biases were all in the same direction: our gravity measurements were made at higher mean elevations than the average local terrain. This reflects the fact that access roads in such gently sloping terrain tend to be high (avoiding the wet lowlands); we should expect exactly the opposite in mountainous terrain. To ameliorate the under-sampling of the lowlands, we densified our gravity base near the tower with 22 additional points. This substantially reduced the bias in sampled terrain, but it has not vanished. Further analysis and, possibly, data are needed.

One difficulty in compensating for elevation sampling biases is that the local topographic maps published by the USGS (U. S. Geological Survey) have their own elevation biases. The detailed vertical control of our own surveys agree fairly well with the USGS in the vicinity of spot elevations indicated on their maps. (These spot elevations are used as controls in the photogrammetric determinations of elevation contours.) Remote from the spot elevations, the USGS elevations differ from ours by as much as 6 m (two contour intervals). The mean bias is probably 1-1.5 m. To resolve this difference as best possible, the USGS is readjusting its digital elevation data base to our vertical control. After this is accomplished, we shall be able to analyze separately the slowly changing and relatively sparsely sampled Bouguer gravity field and the shorter wavelength and finely sampled (15 m grid) gravity field due to terrain.

The separation of the upward continuation into long-wavelength and short-wavelength effects should also significantly reduce the estimated error which, for JET at the top of the tower, currently stands at 110 $\times 10^{-8}$ m s^{-2} (1 sigma, down from 140 $\times 10^{-8}$ m s^{-2} prior to the addition of 22 survey points). Further tests and simulations are under way to strengthen our confidence in that estimate and to better define the accuracies of the other techniques.

REFERENCES

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2. A. J. Romaides, C. Jekeli, A. R. Lazarewicz, D. H. Eckhardt, and R. W. Sands, J. Geophys. Res. **94**, 1563 (1989).

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