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INSIDE

New Gravity Model for Earth Science Studies

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Knowledge of Earth's gravity field has increased greatly in the past few years, due to the need for more precise knowledge of satellite orbits and for military purposes. However, there has been a favorable fallout for earth science. For several years, short-wavelength sea surface and gravity anomalies have been used to learn about the topography and tectonics of the seafloor, but new gravity data allow for studies of longer wavelength phenomena in the oceans—and on land as well.

Observational data about Earth's gravity field, from different sources, is incorporated in an Earth gravity model, which is a convenient way of describing the gravity field anywhere on Earth. The gravity model is a spherical harmonic series of the gravitational potential. The potential can then give the gravity field—i.e., both geoid and gravity anomalies. The coefficients of the terms of the spherical harmonic series have been determined by using satellite laser ranging for the lower degree and order terms (model JGM-l; Lerch et al., 1992) and by more extensive surface, or near-surface, databases for higher degree and order coefficients (model OSU91A; Rapp et al., 1991). Model JGM-1 was developed by a combined effort of the University of Texas Center for Space Research and the Gravity Modeling group at NASA Goddard Space Flight Center and is used here up to degree and order 70. Model OSU91A for degree and order 70 through 360 was developed by Ohio State University. These two models are joined here to give a full spherical harmonic expression through degree and order 360. This should show information about the gravity field down to a scale of approximately the circumference of Earth (40,000 km) divided by 360, or about 110 km.

This model gives comprehensive data for the variation of gravity over all the continents and oceans. While it is impracticable to develop a harmonic series detailed enough to show variations of a few tens of kilometers (along-track filtering of ERS-1 and Geosat and Seasat data are needed for that; see, e.g., Sandwell and Smith, 1992), the 360° model presented here highlights regional variations and more absolute values across the spatial spectrum.

The geoid and free-air gravity anomaly maps of Earth shown in Figure 1 were made from the combined 360° model. The geoid and gravity anomalies were calculated for each half degree, then interpolated to a 10 km grid. The geoid heights are shown as color shadings over the ETOPO5 topographic relief, which also has a 10 km gridding. The anomalies are shown as shaded relief referred to an ellipsoid whose inverse flattening factor is 298.2564. This 10 km gridded data set is convenient for crustal modeling.

Regarding the gravity anomaly map, one may comment on several interesting features. Lows of –40 to –90 mgal are seen over the Hudson Bay region, in the western North Atlantic, in the southern border of Australia, over the Pacific trenches, and off East Africa in the Indian Ocean. The well-known low south of India shows considerable detail; the northward track of India and other details are evident. Over land, the lows of central Africa, eastern Saudi Arabia, and north and south of the Himalayas are prominent. Highs are seen on the landward side of subduction zones, over the Alps and the Himalayas. The longer wavelength aspects of these lows and highs must be accounted for in theories of convection within Earth and continental drift.

The mid-ocean ridges are of special interest. The axis of the Mid-Atlantic Ridge has varying types of positive gravity anomalies; the larger anomalies are at higher latitudes, north and south. The faster spreading East Pacific Rise shows almost no anomaly. The Indian Ocean shows anomalies that have little relation to the axis of the Mid-Indian Ocean Ridge. Small

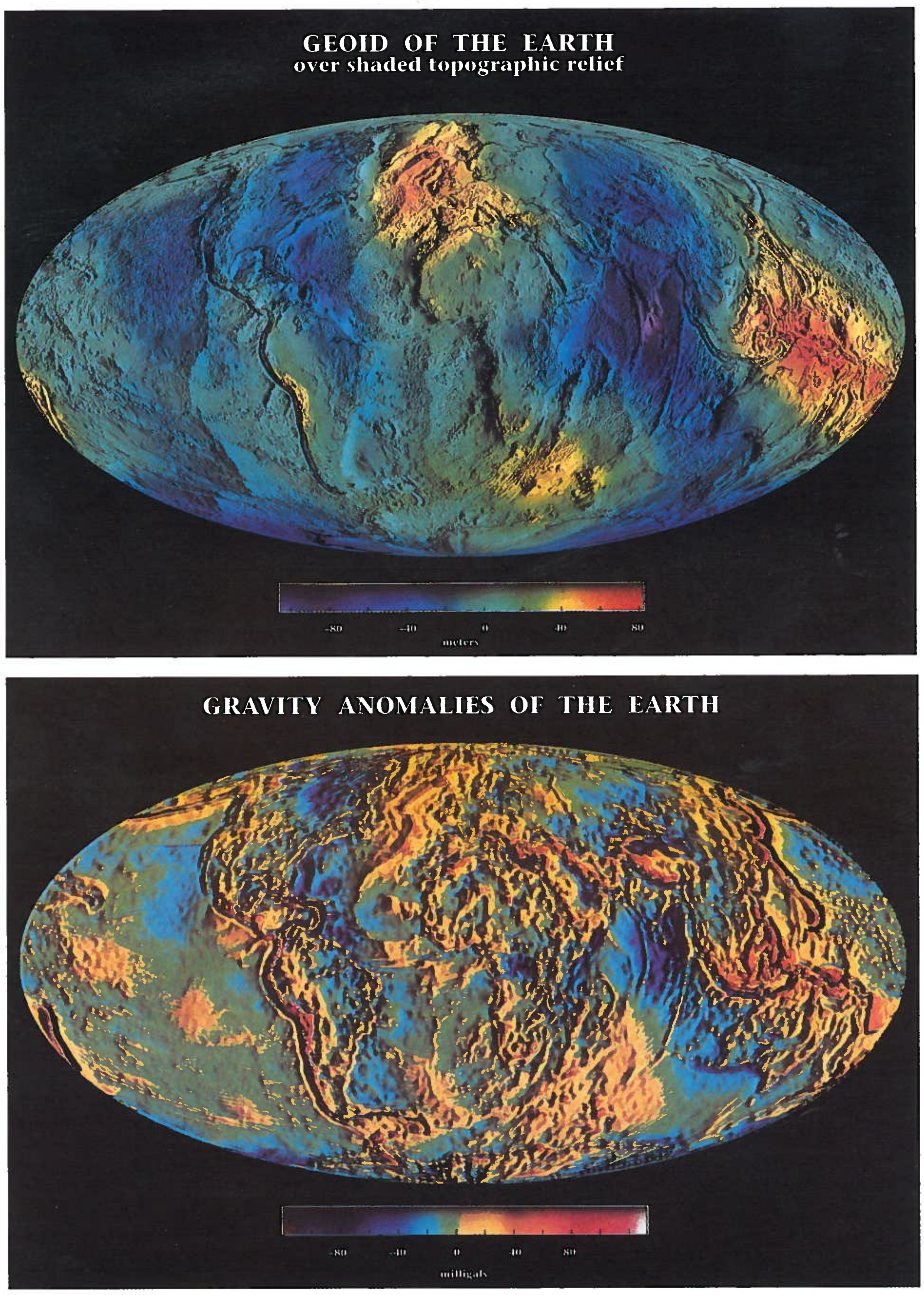

Figure 1. A: Geoid map of Earth, overlying shaded relief topography. B: Free-air gravity anomalies. Mollweide equal area projection.

and Sandwell (1992) found that gravity anomaly roughness was related to spreading rate. Our maps show this to be true for the Atlantic and East Pacific Rise, and perhaps south of Australia, but not in the Indian Ocean. For the North Atlantic Ridge, especially south of the Charlie-Gibbs Fracture Zone, there are smaller gravity anomaly highs that parallel the axial high.

All of the subduction zones around the Pacific, the arc systems of the Western Pacific, near the Caribbean and Scotia arcs, the Indonesian arc, and the Hellenic arc show sharp negatives, but so does the southern border of Australia and some parts of the Antarctic coast where no subduction zones have been postulated. Invariably, the land side of a subduction zone shows a high, usually exceeding 80 mgal. On the seaward side of a subduction zone there may be a lesser high extending to different distances from the trench, depending upon which zone is involved.

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WASHINGTON REPORT

Bruce F. Molnia

Washington Report provides the GSA membership with a window on the activities of the federal agencies, Congress and the legislative process, and international interactions that could impact the geoscience community. In future issues, Washington Report will present summaries of agency and interagency programs, track legislation, and present insights into Washington, D.C., geopolitics as they pertain to the geosciences.

Geology, Washington, D.C.–Style

Geology by Committee

The past few months have seen the release of two National Research Council (NRC) reports related to geologic hazards and their prevention. The reports, "Practical Lessons from the Loma Prieta Earthquake" and "Mt. Rainier: Active Cascade Volcano," represent an approach to geological problem solving significantly different from traditional field studies and map preparation. These reports are excellent examples of understanding and defining a problem by committee. The reports are informative, effective, well written, and timely. The Mount Rainier report is subtitled "Research Strategies for Mitigating Risk from a High, Snow-Clad Volcano in a Populous Region."

The concept of geology by committee is not new. For decades, environmental impact statements and special geological publications, such as symposium volumes, have been produced by committees or groups of scientists. Generally, environmental impact statements are prepared to serve as a compendium of information and a catalog of potential risks to be used in the decision-making process of a planned action. They are minimally circulated. Symposium volumes are generally technical geological publications aimed at peers in the earth science community.

These two NRC reports have different purposes. These reports, while useful to the earth science community, are not intended for earth scientists. They are aimed at the media, the Congress, state legislators, and federal and state government preparedness agencies such as the Federal Emergency Management Agency (FEMA). The ultimate target is the general public.

The Loma Prieta report presents 40 "practical lessons," each accompanied by a recommendation. Lloyd Cluff, chair of the committee that prepared the report, referring to both the Loma Prieta (1989) and Northridge (1994) quakes stated, "One of the most jarring lessons from these [quakes] may be that earthquake professionals have long known many of the things that could have been done to reduce the devastation. The aftermath of these earthquakes should make clear the need to close the gap between what scientists know about earthquake mitigation and what is used by governments and individuals."

Cluff hoped that the information in the Loma Prieta report, combined with the lessons from the Northridge quake, would cause governments in California and other areas with high probabilities of quake occurrence to "quickly take additional steps to reduce the risk of damage and injuries and to improve the ability of emergency services to respond to the needs of quake victims."

Among the lessons learned are: (L1) investments made in earthquake preparedness and hazard and risk mitigation paid off; (L2) government and business leaders were greatly surprised that earthquake professionals knew so much about the potential hazards of areas like San Francisco's Marina District, but that so little was done prior to the quake; (L3) uneven and inappropriate emergency responses resulted from the inability of emergency-response decision makers to know where the worst damage had actually occurred and from their dependence on news media reports; (L4) even where seismic geology was well known, surprises occurred; (L7) the intensity of seismic shaking is critically dependent upon the nature of the soil and shallow geologic structures; (L8) liquefaction mitigation methods worked, although significant liquefaction damage occurred in adjacent areas of unimproved ground; (L11) where specific geotechnical engineering measures had been taken to compact artificial fills, these fills performed well; (L12) with the appropriate application of existing knowledge and with more attention to detail, professionals could have significantly reduced the loss of life and damage; (L16) damage to many structures resulted from design or construction errors that should have been found during the building inspection process at the time of construction; (L22) extensive damage to transportation structures, such as older bridges, should be expected in other geographic areas in the event of an earthquake; (L24) the results of earthquake research have not been transferred to many potential users; (L28) disaster recovery laws are biased toward returning to pre-earthquake conditions, even when those conditions represent high earthquake risk; (L29) preexisting social problems such as homelessness will be made worse immediately after a destructive earthquake; (L30) there was an outpouring of unselfish concern even though the disaster response often created widespread confusion and coordination problems; (L31) rushed post-earthquake inspections of damaged buildings resulted in some inaccurate and emotional assessments that led to inappropriate actions, such as demolition, in the spirit of public safety; (L35) more effective public education is needed about risks related to natural gas leakage; (L37) many of the most successful mitigation efforts were the result of state legislation, yet many jurisdictions have not adopted seismic safety requirements to protect the local population; (L38) low-income people were most seriously impacted because they typically live in old, seismically weak buildings that are not properly maintained; (L39) international media coverage and increased earthquake awareness resulted from the quake coinciding with the World Series; and (L40) the recovery from destructive earthquakes is expensive for everybody. Perhaps the most important message is that mitigation activities are cost effective.

The Loma Prieta report is the result of a 1993 NRC–Earthquake Engineering Research Institute symposium held to analyze the results of research conducted on the earthquake. Symposium sponsors included the U.S. Geological Survey (USGS), the National Science Foundation, FEMA, and the National Institute of Standards and Technology.

The Mt. Rainier report states, "Mt. Rainier is capable of eruptions of small to very large magnitude"; "Explosive eruptions from Mount Rainier could send clouds of tephra high into the atmosphere ..."; "Major edifice failures, glacier outburst floods, and lahars could occur in the absence of volcanic eruptions ..."; and "Damage caused by debris flows could be substantial."

Like the Loma Prieta report, this report is also the result of a workshop. This one was held in 1992 to draft a research plan for the volcano. Mt. Rainier had previously been designated as a "decade volcano" as part of the United Nation's International Decade for Natural Disaster Reduction's Volcano Demonstration Project. Mt. Rainier was selected because it has an extensive but poorly studied geological and historical record of activity; it poses a hazard to surrounding, highly populated regions such as Seattle and

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In places in the South Pacific, east-west lineations are seen where the anomaly oscillates about zero. The same is seen in the Indian Ocean and central Atlantic. The lineations seem to be oriented in the direction of spreading and may or may not be related to the linear gravity anomalies that have been investigated near the Easter microplate in the Pacific.

With the new relaxing of East-West relations, new data sets will be released (e.g., see Kogan and McNutt, 1993), and improved higher order models will be made. Grids of geoid heights, gravity anomalies, and topographic data used in these figures are available via anonymous ftp to geodesy.gsfc.nasa.gov.

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