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The Deflection of the Vertical, from Bouguer to Vening-Meinesz, and Beyond – the unsung hero of geodesy and geophysics

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When thinking of gravity in geodesy and geophysics, one usually thinks of its magnitude, often referred to a reference field, the normal gravity. It is, after all, the free-air gravity anomaly that plays the significant role in terrestrial data bases that lead to Earth Gravitational Models (such as EGM96 or EGM2008) for a multitude of geodetic and geophysical applications. It is the Bouguer anomaly that geologists and exploration geophysicists use to infer deep crustal density anomalies. Yet, it was also Pierre Bouguer (1698-1758) who, using the measured direction of gravity, was the first to endeavor a determination of Earth's mean density (to "weigh the Earth"), that is, by observing the deflection of the vertical due to Mount Chimborazo in Ecuador. Bouguer's results, moreover, sowed initial seeds for the theories of isostasy. With these auspicious beginnings, the deflection of the vertical has been an important, if not illustrious, player in geodetic history that continues to the present day. Neglecting the vertical deflection in fundamental surveying campaigns in the mid to late 18th century (e.g., Lacaille in South Africa and Méchain and Delambre in France) led to errors in the perceived shape of the Earth, as well as its scale that influenced the definition of the length of a meter. The vertical deflection, though generally excluded from modern EGM developments, nevertheless forms a valuable resource to validate such models. It is also the vertical deflection that is indispensable for precision autonomous navigation (i.e., without external aids such as GPS) using inertial measurement units. It is the deflection of the vertical that, measured solely along horizontal lines, would readily provide geoid undulation profiles, essential for the modernization of height systems (i.e., vertical geodetic control) without the laborious and traditional methods of spirit leveling. But, measuring the deflection of the vertical is itself an arduous undertaking and this has essentially contributed to its neglect and/or underusage. Even Vening-Meinesz's formulas of convolution with gravity anomalies do not greatly facilitate its determination. This presentation offers a review of the many roles the vertical deflection has, or could have, played over the centuries, how it has been measured or computed, and how gravity gradiometry might eventually awaken its full potential.