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Space Geodesy: The Cross-Disciplinary Earth science (Vening Meinesz Medal Lecture)

C. K. Shum
Division of Geodetic Science, School of Earth Sciences, The Ohio State University, Columbus, Ohio 43220, USA (ckshum@osu.edu)

Geodesy during the onset of the 21^{st} Century is evolving into a transformative cross-disciplinary Earth science field. The pioneers before or after the discipline Geodesy was defined include Galileo, Descartes, Kepler, Newton, Euler, Bernoulli, Kant, Laplace, Airy, Kelvin, Jeffreys, Chandler, Meinesz, Kaula, and others. The complicated dynamic processes of the Earth system manifested by interactions between the solid Earth and its fluid layers, including ocean, atmosphere, cryosphere and hydrosphere, and their feedbacks are linked with scientific problems such as global sea-level rise resulting from natural and anthropogenic climate change.

Advances in the precision and stability of geodetic and fundamental instrumentations, including clocks, satellite or quasar tracking sensors, altimetry and lidars, synthetic aperture radar interferometry (InSAR), InSAR altimetry, gravimetry and gradiometry, have enabled accentuate and transformative progress in cross-disciplinary Earth sciences. In particular, advances in the measurement of the gravity with modern free-fall methods have reached accuracies of 10-9 g ($\sim$1 μGal or 10 nm/s^2) or better, allowing accurate measurements of height changes at $\sim$3 mm relative to the Earth's center of mass, and mass transports within the Earth interior or its geophysical fluids, enabling global quantifications of climate-change signals. These contemporary space geodetic and *in situ* sensors include, but not limited to, satellite radar and laser altimetry/lidars, GNSS/SLR/VLBI/DORIS, InSAR, spaceborne gravimetry from GRACE (Gravity Recovery And Climate Experiment twin-satellite mission) and gradiometry from GOCE (Global Ocean Circulation Experiment), tide gauges, and hydrographic data (XBT/MBT/Argo).

The 2007 Intergovernmental Panel for Climate Change (IPCC) study, the Fourth Assessment Report (AR4), substantially narrowed the discrepancy between observation and the known geophysical causes of sea-level rise, but significant uncertainties remain, notably in the discrepancies of contributions from the ice-reservoirs (ice-sheet and mountain glaciers/ice caps) and our knowledge in the solid Earth glacial isostatic adjustment (GIA), to the present-day and 20^{th} Century global sea-level rise. Here we report our use of contemporary space geodetic observations and novel methodologies to address a few of the open Earth science questions, including the potential quantifications of the major geophysical contributions to or causing present-day global sea-level rise, and the subsequent narrowing of the current sea-level budget discrepancy.