Geophysical Research Abstracts
Vol. 17, EGU2015-7735, 2015
EGU General Assembly 2015
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Effect of Numerical Error on Gravity Field Estimation for GRACE and Future Gravity Missions

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In recent decades, gravity field determination from low Earth orbiting satellites, such as the Gravity Recovery and Climate Experiment (GRACE), has become increasingly more effective due to the incorporation of high accuracy measurement devices. Since instrumentation quality will only increase in the near future and the gravity field determination process is computationally and numerically intensive, numerical error from the use of double precision arithmetic will eventually become a prominent error source. While using double-extended or quadruple precision arithmetic will reduce these errors, the numerical limitations of current orbit determination algorithms and processes must be accurately identified and quantified in order to adequately inform the science data processing techniques of future gravity missions.

The most obvious numerical limitation in the orbit determination process is evident in the comparison of measured observables with computed values, derived from mathematical models relating the satellites' numerically integrated state to the observable. Significant error in the computed trajectory will corrupt this comparison and induce error in the least squares solution of the gravitational field. In addition, errors in the numerically computed trajectory propagate into the evaluation of the mathematical measurement model's partial derivatives. These errors amalgamate in turn with numerical error from the computation of the state transition matrix, computed using the variational equations of motion, in the least squares mapping matrix. Finally, the solution of the linearized least squares system, computed using a QR factorization, is also susceptible to numerical error. Certain interesting combinations of each of these numerical errors are examined in the framework of GRACE gravity field determination to analyze and quantify their effects on gravity field recovery.