Extending ESA's NAPEOS S/W System for Ocean Tide Parameter Recovery

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Abstract

Ocean tides represent a fairly large source of perturbations in the motion of a close Earth satellite. Accurate models of the tidal field over the oceans have been available in the recent years both as a result of extensive numerical integrations of the Laplace tidal equations, e.g. the FES series of models, or from the analysis of satellite altimetry data, as exemplified by the CSR and the GOT series of models. The recent GOCE mission and the allied GRACE mission, however, represent two space geodetic missions which due to their low altitude are ideally suited to tidal analysis. In particular, its 250 km altitude orbit makes GOCE the most sensitive satellite to ocean tide perturbations and a test-bed for the application of classical orbit perturbation analysis methods to recover tidal parameters. Several analysis procedures can be devised, but the direct numerical integration of the orbital motion with an extensive force model remains a fundamental tool. The means to perform this type of analysis has been identified in ESA's NAPEOS s/w system. This is a portable navigation software system for Earth Observation missions, providing many capabilities, among which orbit determination and prediction and parameter estimation. NAPEOS is fully written in Fortran 90. The estimation of ocean tide parameters, however, is not currently implemented in the system. Although none of the authors has been involved in any phase of the development of the system, it was decided to take up the challenge and implement this capability. About a dozen modules of NAPEOS were modified, in particular the BAHN and MULTIARC programs for normal equation stacking and handling. Regarding BAHN we extended the *central body structure* to include the ocean tide parameters characteristics, i.e. tidal constituents, order and degree of parameter, harmonic type (C or S) and direction (prograde or retrograde). Correspondingly, an extension of the *satellite structure* has been necessary, since this is the driver for the numerical integration of the satellite dynamical state and of the variational partials (both state transition and sensitivity matrices). Regarding MULTIARC the upgrade has involved essentially the normal equation file output to contain the ocean tide parameters characteristics. We will report on the strategy used to perform the upgrade, the analysis methodology and the preliminary results obtained. We will also report on the background analysis to define the subset of

ocean tide parameters whose solution can be attempted based on the orbit geometry and the aliasing conditions associated with the length of the data span. This has been achieved using both a fully analytic approach based on a Kaula-type theory and a completely numerical approach to obtain the tidal perturbation spectrum based on an improved Kyner and Bennett formulation for integrating small perturbations about a secularly precessing orbit.