Determination of the Orbits of the Natural Satellites of Saturn from Optical Earth-based Observations.

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Abstract. The orbits of the main satellites of Saturn have been extensively studied, based on fits to a great number of ground-based astrometric observations starting from 1874. Ephemerides of the Saturnian system have been traditionally based on analytical theories. Among the recent major works are the analytical theories of Dourneau (1993), Harper & Taylor (1993) and Vienne & Duriez (1995). The precision of these theories, however, is insufficient to support the needs of the scientific operations of a spacecraft orbiting the Saturnian system such as Cassini. For this reason numerical integration is the preferred approach for the generation of highly accurate satellite ephemerides, such as those produced by JPL. These are the numerically integrated ephemerides of the eight major satellites of Saturn, as well as of Phoebe, Helene, Telesto and Calypso. They were obtained by fitting a combination of ground-based and HST astrometric observations, spacecraft tracking and spacecraft satellites images over the period 1966 to 2003 (Jacobson, 2004). With the aim to gain experience in satellite orbit determination for application to current and future Solar System exploration missions, we have undertaken to develop a new software tool named SOSYA (SOlar System Astrometry) for the precise determination of the orbits of planetary satellites in the Solar System. The first step has been to define an accurate dynamical model of the Saturnian system for ephemeris propagations together with an Earth-based, optical observations processing subsystem. The dynamical model is an extension of the model of Peters (1981) with later improvements by Jacobson (1999). The comparison between our numerically integrated ephemerides and those of JPL shows an rms over a period of 5 years on the order of 10 m and 7 m respectively for Mimas and Phoebe and on the order of 2-3 m for the other major satellites. As regards the integration of the variational equations we have verified that the partial derivatives exhibit the behaviour described by Hadjifotinou & Harper (1995) and Hadjifotinou and Ichtiaroglou (1997). We have used SOSYA to adjust the models of the orbits of the satellites of Saturn using a weighted least squares fit to the observational data. The set of adjustable dynamical parameters contains only position and velocity at epoch of the observed satellites Tethys, Dione, Titan, Hyperion, Iapetus and Phoebe. Our model has been adjusted to a total of 3153 observations covering the period between 1998 and 2007 and acquired with the Flagstaff Astrometric Scanning Transit Telescope (FASTT). The accuracy of the observations ranges from 0 R.08 (about 500 km at Saturn’s distance) to 0 R.25. The rms of the post-fit residuals we obtained are 0 R.161 and 0 R.177 in alfa and delta respectively. The accuracy of our solution is limited by the intrinsic accuracy of the observational data and by the relatively short period of time covered by the observations.