

3.6.2.9 Jet Propulsion Laboratory (JPL)

Introduction The uncertainty in our knowledge of the Earth's changing orientation in space is a major source of error in tracking and navigating interplanetary spacecraft. Because the Earth's orientation changes rapidly and unpredictably, measurements must be acquired frequently and processed rapidly in order to meet the near-real-time Earth orientation requirements of the interplanetary spacecraft navigation teams. These requirements are currently met at JPL by using the global positioning system (GPS) to provide daily determinations of polar motion and length-of-day within 24 hours of acquisition. Single baseline very long baseline interferometry (VLBI) measurements are taken twice-per-month by the Time and Earth Motion Precision Observations (TEMPO) project in order to provide the benchmark Universal Time (UT) measurements between which the GPS length-of-day measurements are integrated. The Kalman Earth Orientation Filter (KEOF) is then used to combine the GPS polar motion and length-of-day measurements with the TEMPO VLBI variation-of-latitude and UT0 measurements, along with other publicly available Earth orientation measurements including proxy measurements such as atmospheric angular momentum (AAM), in order to generate and deliver the required polar motion and UT1 Earth orientation parameters to the spacecraft navigation teams.

Data Products Reference series of Earth orientation parameters are generated annually at JPL. During 2008, three such reference series were generated: (1) SPACE2007, consisting of values and rates for polar motion and UT1 spanning September 28, 1976 to March 29, 2008 at daily intervals, was generated by combining Earth orientation measurements taken by the space-geodetic techniques of lunar and satellite laser ranging (SLR), VLBI, and GPS; (2) COMB2007, consisting of values and rates for polar motion and UT1 spanning January 20, 1962 to March 29, 2008 at daily intervals, was generated by additionally including the BIH optical astrometric measurements with the space-geodetic measurements used to generate SPACE2007; and (3) POLE2007, consisting of values and rates for just polar motion spanning January 20, 1900 to March 22, 2008 at monthly intervals, was generated by additionally including the ILS optical astrometric measurements with the other optical astrometric and space-geodetic measurements used to generate COMB2007. These three reference series can be obtained by anonymous ftp to <ftp://euler.jpl.nasa.gov/keof/combinations/2007>. A report describing the generation of these series (Ratcliff and Gross, 2009) is also available at this site.

The near-real-time Earth orientation requirements of the interplanetary spacecraft navigation teams are met by once-per-day updating the annually generated reference series. The updated

Earth orientation series are generated by additionally incorporating measurements that are rapidly available such as the GPS measurements from the JPL Analysis Center of the IGS and the AAM measurements from the National Centers for Environmental Prediction (NCEP) that are used as proxy length-of-day measurements. In addition, short-term predictions of the EOPs are produced. The updated and predicted EOP series can be obtained by anonymous ftp to <ftp://euler.jpl.nasa.gov/keof/predictions>.

Research activities

Research activities during 2008 were largely concerned with a comprehensive review of the models and procedures used by KEOF to combine and predict Earth orientation parameters (Chin et al., 2009). This bottom-up review included an examination of the available EOP measurements, of the stochastic and observation models used by KEOF, and of the Kalman filter algorithm employed by KEOF. A number of possible ways to improve KEOF's performance were identified, including:

- refining the polar motion excitation models, including use of nonidentical random walk models for the x- and y-components as well as enhancements with AR-1 models and additional annual/semi-annual periodic components;
- incorporating all or part of the 1- to 7.5-day lead time AAM forecast data from NCEP in addition to the 5-day lead-time data that is currently being used;
- incorporating GPS polar motion rate measurements as well as additional GPS length-of-day measurements;
- using the Rauch-Tung-Striebel smoother in place of the backward filtering and forward-backward combination procedures currently used by KEOF.

Many of these improvements are currently being implemented in KEOF.

Acknowledgments

The work described in this paper was performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

References

- Chin, T. M., R. S. Gross, D. H. Boggs, and J. T. Ratcliff, Dynamical and observation models in the Kalman Earth orientation filter, *The Interplanetary Network Progress Report*, 42–176, Jet Propulsion Laboratory, Pasadena, Calif., Feb. 15, 2009.
- Ratcliff, J. T., and R. S. Gross, Combinations of Earth orientation measurements: SPACE2007, COMB2007, and POLE2007, Jet Propulsion Laboratory Publ. 09-18, 26 pp., Pasadena, Calif., 2009.

Richard Gross