3.6.3 Jet Propulsion Laboratory (JPL)

Introduction

The Jet Propulsion Laboratory is continuing to develop an approach to determining ITRF-like terrestrial reference frames based upon the use of a Kalman filter/smoother (Wu et al., 2015). Kalman filters are commonly used to estimate the parameters of some system when a stochastic model of the system is available and when the data contain noise. For the purpose of determining a terrestrial reference frame, the system consists of the positions and velocities of geodetic observing stations and associated EOPs along with their full covariance matrices. The data consist of time series of observed VLBI, SLR, GNSS, and DORIS station positions and EOPs along with the data measurement covariance matrices. In addition, measurements from ground surveys of the positions of reference marks of co-located stations are used to tie the technique-specific station networks to each other. The Kalman filter and smoother for reference frame determination software (KALREF) being developed at JPL combines these measurements to determine ITRF-like reference frames subject to constraints imposed on the allowed evolution of the station positions. KALREF includes options for constraining the stations to move linearly or to move linearly and seasonally. Through the use of stochastic models for the process noise, the station positions can be constrained to exactly follow this linear or linear and seasonal motion (by setting the process noise to zero), to exactly recover the observed station positions (by setting the process noise to a large value), or to follow a smoothed path (by setting the process noise to some intermediate value). The sequential estimation approach to determining terrestrial reference frames that is being developed at JPL has been used to determine JTRF2014, JPL's realization of a terrestrial reference frame using the ITRF2014 input data sets (Abbondanza et al., 2017).

During 2018, besides continuing to analyze the JTRF2014 solution, JPL also continued to both explore the possibility of accounting for regional deformation of the crust and mantle when determining TRFs and to develop a sequential estimation approach to jointly determine terrestrial and celestial reference frames (CRFs).

JTRF2014

An article comparing and contrasting JPL's sequential estimation approach to determining terrestrial reference frames to the approaches taken by IGN and DGFI has been written (Abbondanza et al., 2019). By representing the TRF by time series of smoothed station positions, JPL's approach results in a sub-secular reference frame wherein the frame origin is the quasi-instantaneous center-of-mass of the Earth system as given by SLR and the frame scale is the quasi-instantaneous average of the VLBI and SLR scales. In contrast, the IGN and DGFI approaches result in secular frames that capture the long-term, mean origin and scale.

Regional Deformation

Current generation terrestrial reference frames, like JTRF2014, suffer from biases introduced by the space-time sampling pattern of the input space-geodetic measurements, particularly by the gaps in the spatial distribution and temporal history of the space-geodetic observing stations. During 2018, JPL continued its efforts to improve terrestrial reference frames by developing procedures to account for gaps in the spatial distribution and temporal history of observing stations by: (1) reconstructing the history of the deformation of the Earth's global surface from GRACE measurements and geophysical fluid models of the processes that are causing the Earth's surface to be deformed and observing stations to be displaced, (2) using the reconstructed deformation field to construct spatial and temporal correlations of the expected station displacements, and (3) including the spatial and temporal correlations in a Kalman filter solution for an ITRF-like reference frame. By accounting for gaps in the spatial distribution and temporal history of observing stations when determining the frame, biases caused by those gaps are expected to be reduced, particularly in the geocenter and scale parameters of the frame because those parameters are determined solely from observations taken by the non-uniformly distributed SLR and VLBI stations.

During 2018, GRACE gravity data and atmospheric, oceanic, and hydrologic loading models continued to be used to compute the correlation between the GRACE-observed or modeled load at some test point on the Earth's surface (e.g., a space-geodetic observing station) and all other grid points of the data or model. After removing linear trends as well as annual and semiannual periodic terms from each data set, the spatial correlation patterns from these data sets generally agreed with each other on regional (sub-continental) scales, but major disagreements were seen on larger (inter-continental) scales. A regional filter on the correlation maps was therefore applied in order to extract only the continental-scale spatial patterns common in all the data sets. Trial reference frame solutions using the continental-scale correlations were determined with the geocenter and scale parameters of the solutions being found to exhibit improved stability and closer agreement to the ITRF2014 geocenter and scale.

Joint Determination of Terrestrial and Celestial Reference Frames

Currently, terrestrial and celestial reference frames are determined separately from each other. This leads to inconsistencies between the frames and the Earth Orientation Parameters (EOPs) that link them together, consequently degrading their quality. During 2018, JPL continued its efforts to improve terrestrial reference frames by continuing to develop the capability to jointly and consistently determine the TRF with the CRF and EOPs. To do this, KALREF is being extended to include the processing of celestial pole offsets and source coordinates. This will allow the proper motions of radio sources, which are not accounted for in current CRF solutions, to be taken into account.

References

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