Geophysical Research Abstracts
Vol. 21, EGU2019-10211, 2019
EGU General Assembly 2019

Chasing consistency: joint determination of terrestrial and celestial reference frames

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Consistency in every aspect is essential for geodetic products of the highest quality. Inconsistencies may arise from different definitions or model choices and should be avoided in the analysis of space geodetic data sets, especially if they are to be combined. Resulting products, such as reference frames or Earth orientation parameters (EOP), typically benefit from consistent input data sets in terms of accuracy and precision. Currently, the official products of the International Earth Rotation and Reference Systems Service (IERS) are not fully consistent with each other. The International Terrestrial Reference Frame (ITRF) and the International Celestial Reference Frame (ICRF) are independently determined. While the former is based on a combination of all four geometric space-geodetic techniques, the latter is computed from VLBI data only. Between ITRF and ICRF, different scale definitions are applied, and in the case of the VLBI data, different observation correction models, resulting in inconsistencies. As a result, the EOP computed to be consistent with either ITRF or ICRF are not the same.

In this study, we portray our approach to eliminate inconsistencies between TRF/CRF/EOP by determining them jointly. Similar to JTRF2014, our frames are based on a time series of station coordinates, and in this case, also radio source coordinates. Instead of using a Kalman filter like it was done for JTRF2014, we opt for a square-root information filter (SRIF) to benefit from increased numerical stability. Using the SRIF allows us to perform the multi-technique combination at the normal equation level instead of the parameter level. Thus, the VLBI input data, which typically comes at the normal equation level, does not need to be inverted before being assimilated into the filter. The stochastic models of the different parameters in our state vector are carefully determined. Individual noise parameters are applied for each individual station and radio source, derived from non-tidal loading displacement time series and source structure found in radio source images, respectively. EOP dynamics are introduced as well, drawing from the decades-long experience of combining EOP products at JPL using filter algorithms.

Our combined TRF/EOP/CRF solution is based on the GNSS, SLR, and DORIS input files for ITRF2014 and a specifically computed VLBI solution that also contains radio source coordinate estimates. We evaluate our results by comparing the estimated coordinates and daily EOP time series to ITRF2014, ICRF3, and different external EOP time series produced by IERS, USNO, and JPL. In several test solutions based on different definitions and sub-datasets, we assess how each individual product benefits from the consistency gained from the combined determination.