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DOGS-RI: the VLBI software of DGFI-TUM

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Introduction

The Deutsches Geodätisches Forschungsinstitut at Technische Universität München (DGFI-TUM) is one of the Analysis Centers (AC) of the International VLBI Service for Geodesy and Astrometry (IVS). After years of using OCCAM (see Titov et al. [2004]) as the main Very Long Baseline Interferometry (VLBI) analysis software, DGFI-TUM started to implement and apply a proprietary library called DOGS-RI (Radio Interferometry). It is part of the DGFI Orbit and Geodetic parameter estimation Software package (DOGS) and hence intended to ensure a consistent combination with other space geodetic techniques. In this contribution, we describe the technical and methodological approaches of DOGS-RI, which comprise models from both former and the latest IERS Conventions and thus offer a great flexibility in parameterizing VLBI observations.

DOGS Software Package

The DGFI Orbit and Geodetic parameter estimation Software (DOGS) consists of three major parts (see Gerstl et al. [2000]):

- **DOGS-RI** (Radio Interferometry) processes VLBI experiments,
- **DOGS-OC** (Orbit Computation) performs Precise Orbit Determination (POD) based on satellite observations (currently mainly SLR and DORIS), and
- **DOGS-CS** (Combination & Solution) aggregates the distinct results of any space geodetic technique (if available in the SINEX format) on the normal equation level.

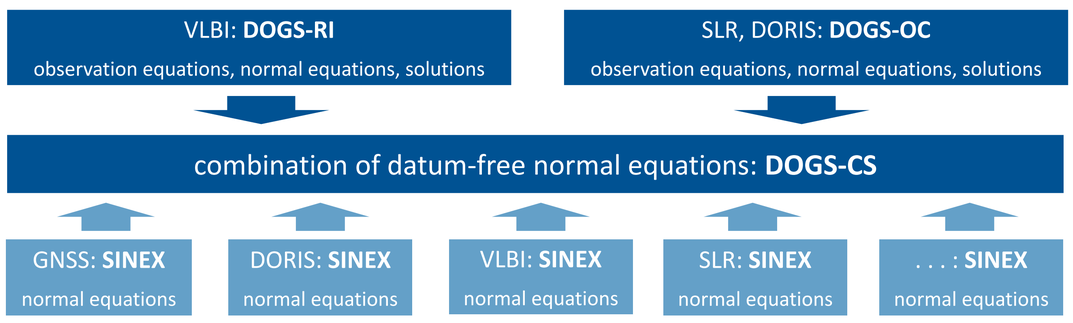

Figure 1: *Consistent combination of various space geodetic techniques with the DGFI Orbit and Geodetic parameter estimation Software package (DOGS). Light blue boxes refer to external data.*

IVS Contribution *dgf2018a*

Since February 2018, DGFI-TUM uses DOGS-RI to provide normal equations for VLBI experiments to the IVS Combination Centers in its role as Analysis Center (AC). The new *daily sinex* contribution *dgf2018a* succeeds the predecessor *dgf2009a*, which was generated with OCCAM. Figures 3 and 4 exemplarily show that the solutions obtained with DOGS-RI well match those of the other ACs.

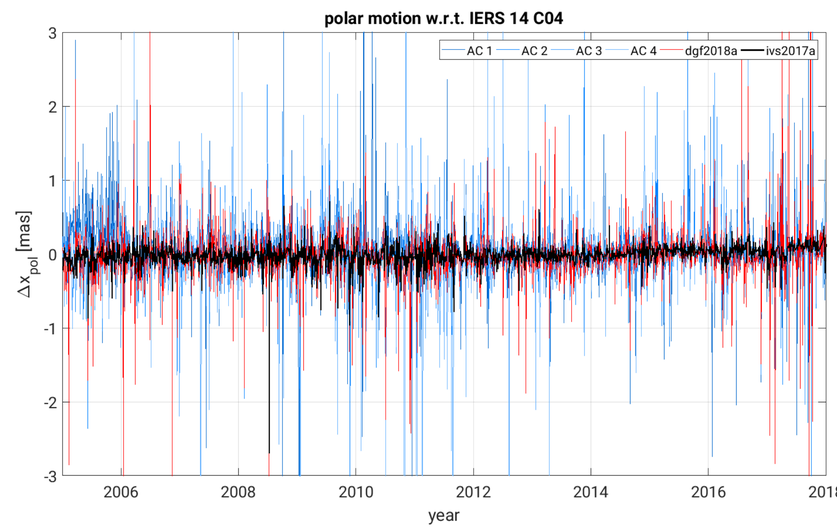

Figure 3: *Differences (per Analysis Center, including the combined solution ivs2017a) between the estimated value for EOP x_{pol} and the corresponding value as provided by the IERS 14 C04 series .*

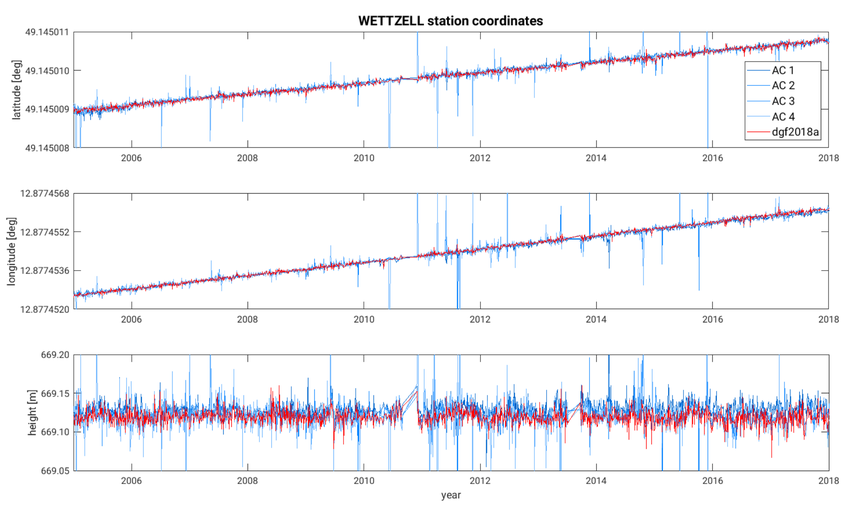

Figure 4: *Ellipsoidal coordinates as estimated by distinct Analysis Centers for Geodetic Observatory Wettzell. The height component reveals the most significant variation among the contributors.*

DOGS-RI (Radio Interferometry)

DGFI-TUM's proprietary VLBI software DOGS-RI is based on a two-step least-squares estimation (the classic Gauss-Markov model) with intermediate outlier detection. Several output formats are available to support further analysis and processing.

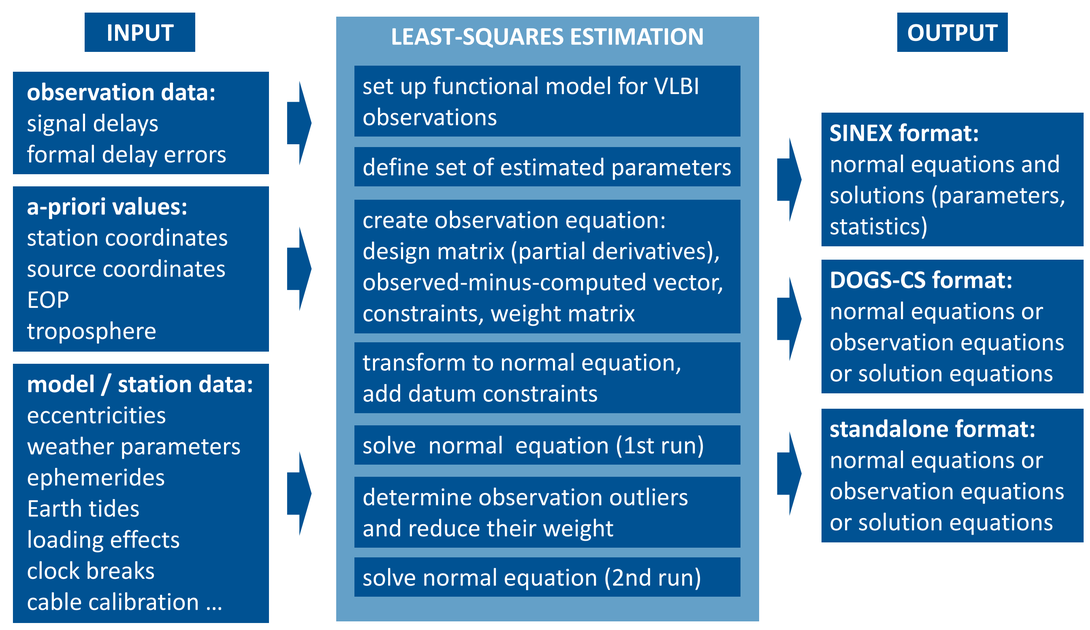

Figure 2: *Schematic workflow of processing VLBI data with DOGS-RI.*

DOGS-RI is written in FORTRAN and hence can adopt existing routines for geodetic applications. It offers great flexibility by containing a wide range of geophysical and signal delay models of previous and current IERS Conventions. Furthermore, a multitude of mathematical functions and interpolation types is available for the representation of estimated parameters. For a-priori station positions, all major terrestrial reference frames (ITRF, JTRF, DTRF) can be chosen. The current settings are listed in table 1.

component	standard setup in DOGS-RI
input data formats	classic MK3 / NGS or recent vgosDB
estimated parameters	station and source coordinates, Earth Orientation Parameters (EOP), tropospheric and station clocks parameters
a-priori station positions	ITRF2014
a-priori EOP	IERS 14 C04 with cubic interpolation
a-priori gradients	TU Vienna model with cubic interpolation
tropospheric mapping functions	VMF1 with cubic interpolation
precession / nutation	IAU 2006/2000A
celestial pole offsets	ΔX_{CIP}, ΔY_{CIP} (CIO based)
delay model	IERS 1996
solid Earth and pole tides	IERS Conventions 2010
tidal ocean loading	FES2004
atmosphere loading	Petrov & Boy (2003)

Table 1: *Standard settings for VLBI software DOGS-RI.*

Ongoing Development

DOGS-RI is constantly tested and further developments are made. For example:

- VLBI observations are still suffering from jumps in the stations' frequency standards (clock breaks). The manual detection shall be replaced by an automatic approach.
- Sometimes data is missing in the vgosDB, especially meteorological data. We want to implement procedures to establish the missing data independently.
- The classic least-squares estimation (Gauss-Markov model) is vulnerable to observation outliers. The existing identification routines (data snooping and BIBER, see Titov et al. [2004]) shall be refined and extended. One approach is to use robust estimators such as the minimization of the sum of absolute (residual) values. For these, outliers are less disruptive and more clearly attributable to residuals with exceptionally high values.

References

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