Deutsches Geodätisches Forschungsinstitut
Technische Universität München
(DGFI-TUM)

Contribution of satellite techniques to CRS realization

Younghee Kwak, Manuela Seitz, Mathis Bloßfeld, Detlef Angermann, Michael Gerstl, and Matthias Glomsda
Deutsches Geodätisches Forschungsinstitut der Technischen Universität München (DGFI-TUM)
(younghee.kwak@tum.de)

1. Input data & parameters

Table 1. Input data

	VLBI	GNSS	SLR
Software	OCCAM (DGFI-TUM)	Bernese (CODE)	DOGS-OC (DGFI-TUM)
Resolution	session-wise	daily	weekly

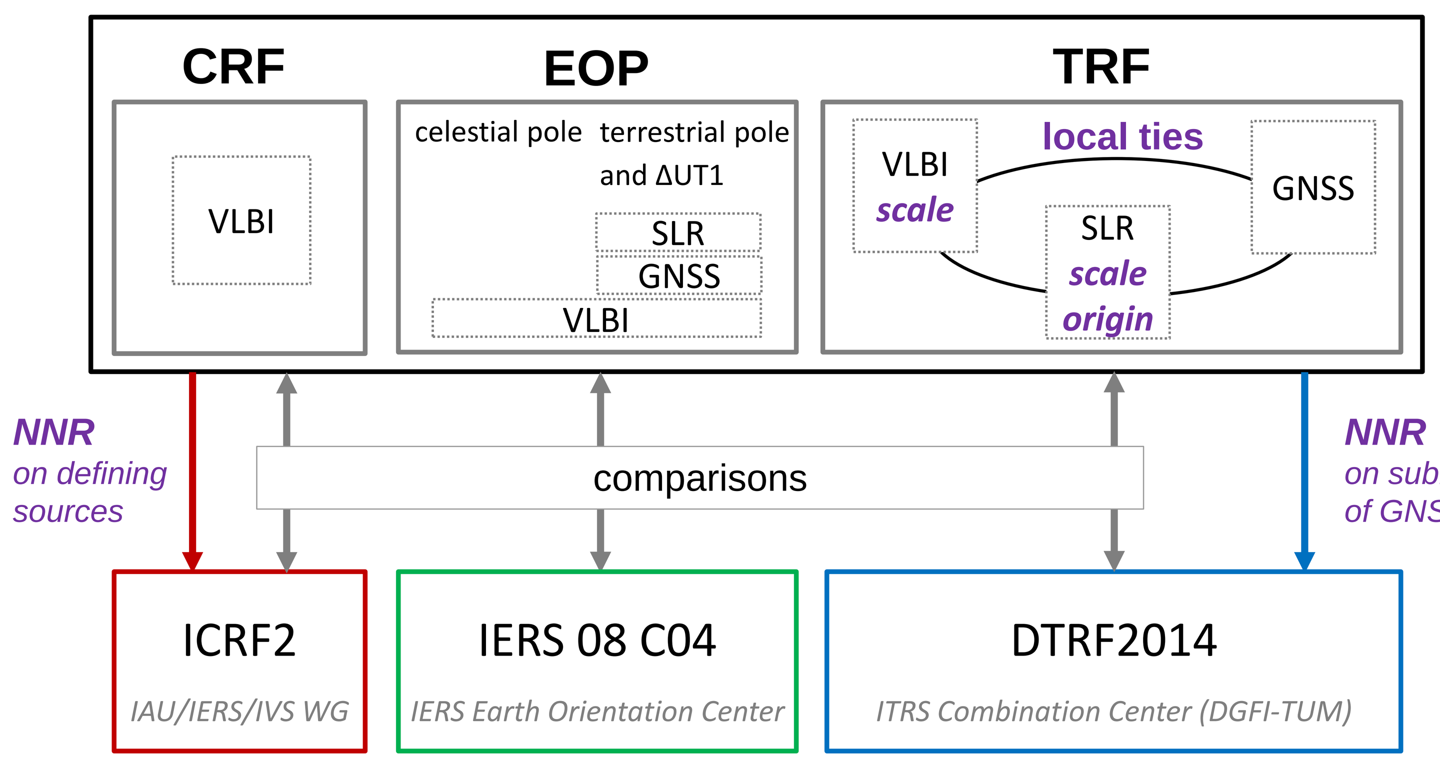
- Period: January 2005 - December 2015
- VLBI:
  - DGFI-TUM solution (dgf2009a, 1550 24-hour sessions)
  - NNR condition w.r.t. ICRF2 defining sources
  - Stations contained in less than 10 sessions excluded
  - Special handling sources treated as arc parameters
- GNSS:
  - CODE contribution to repro2/ITRF2014 ("cf2"), complemented by operational solutions ("cof") for the latest months
- SLR:
  - DGFI-TUM solution based on LAGEOS-1/2
  - 7-day orbits
  - Stations with less than 10 normal points excluded

Table 2. Estimated parameters

Estimated parameters	VLBI	GNSS	SLR	Combination
Station coordinates & velocities (TRF)	X	X	X	X
Source coordinates (CRF)	X			X
Terrestrial x-/y-pole	X	X	X	X
UT1-UTC	X	(X)	(X)	X
Celestial X-/Y-pole	X			X

2. Combination

Consistent combination at the normal equation level



The origin is realized in the SLR-only solutions, and the scale is realized in the SLR-only and VLBI-only solutions intrinsically.

Combination setups

- To assess the impact of the geodetic satellite technique on the CRS realization, four different EOP combinations are set up.

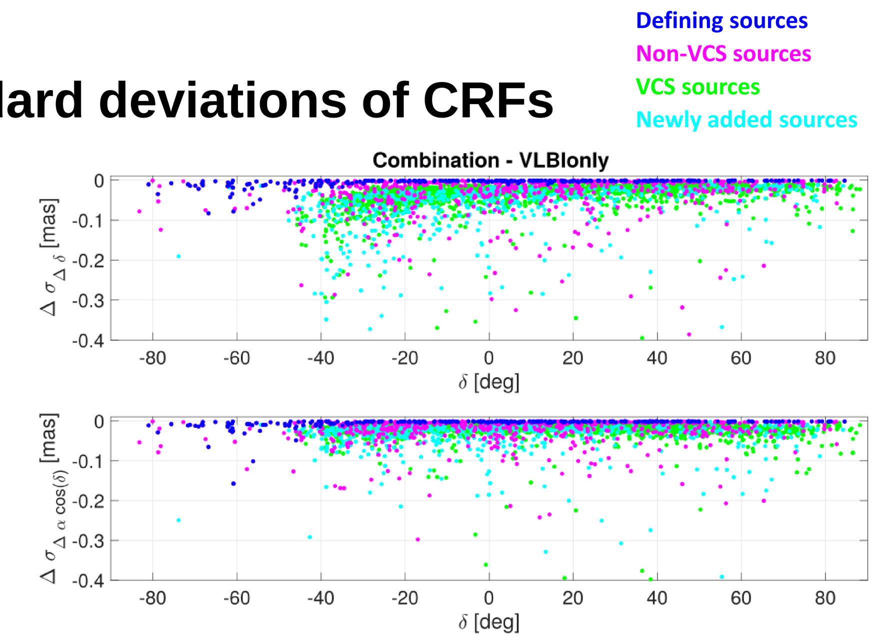
Solutions	Which EOP are combined?
A	all
B	none
C	ΔUT1 only
D	x/y-pole only

- The local tie (LT) and velocity constraints at the co-located sites are introduced. In total, the LT and velocity constraints at 32 GNSS-GNSS, 23 GNSS-VLBI, 30 GNSS-SLR, and 4 SLR-VLBI co-located sites are introduced. More details can be found in Kwak et al. (2018)

3. Results

Combination impact on standard deviations of CRFs

- After combination, the standard deviations of the source coordinates are reduced, i.e. improved. The standard deviations of the declinations for the VCS sources (only observed in the regional VLBA network) and newly added sources (not included in ICRF2 but mostly observed in the VCS-II campaign) are improved significantly in the southern hemisphere.



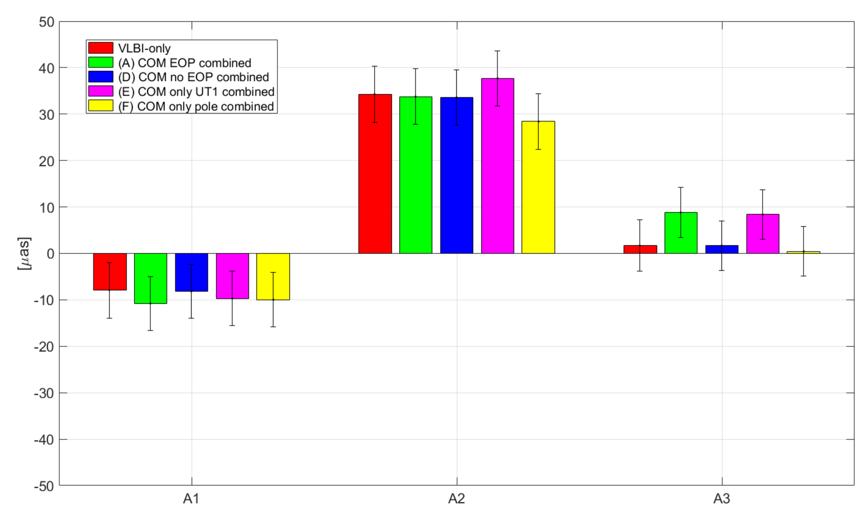
Every combination setup has a similar improvement of the standard deviation.

Transformation parameters w.r.t. ICRF2 (using defining sources)

- In order to analyze the contribution of the EOP combination setups to the CRF, the transformation parameters between CRFs (Fey et al., 2009) are computed. Here, the harmonic oscillations in right ascension and declination are ignored.
- Since 2010, a bias in the declination of the sources on the southern hemisphere appears w.r.t ICRF2. In our analysis, this effect is not considered.

$$\Delta\alpha = A_1 \tan\delta \cos\alpha + A_2 \tan\delta \sin\alpha - A_3 + D_\alpha(\delta - \delta_0)$$
$$\Delta\delta = -A_1 \sin\alpha + A_2 \cos\alpha + D_\delta(\delta - \delta_0) + B_\delta$$

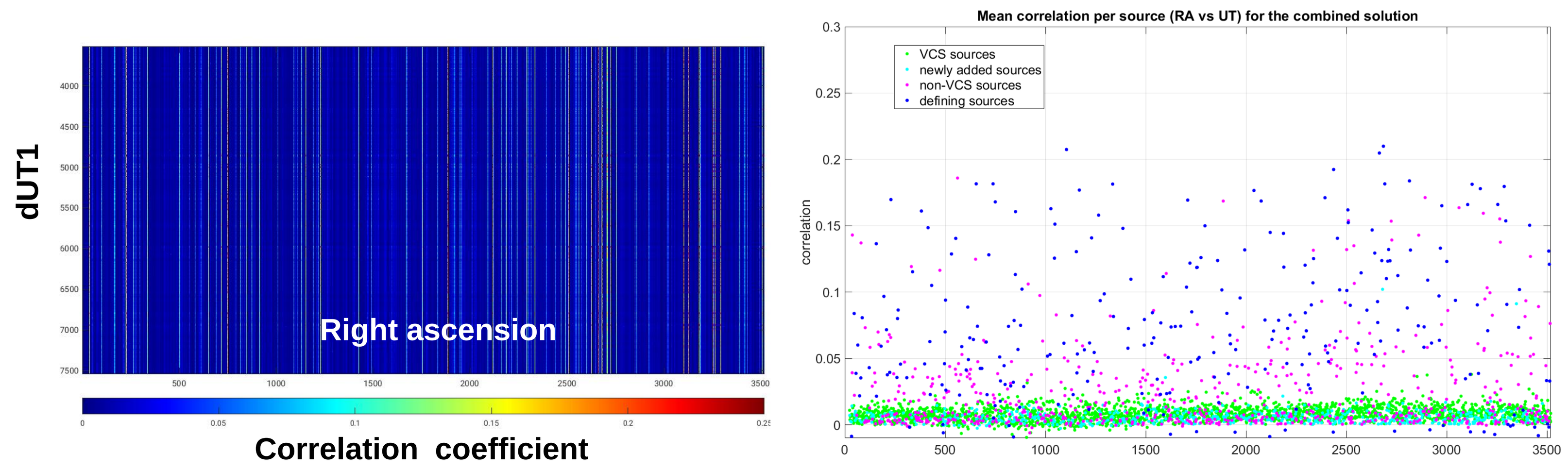
3 rotations, 2 slopes and 1 bias



- If no EOP are combined (**B**), the CRF is hardly influenced by the combination.
- The combination of the terrestrial pole coordinates only (**D**) improves the agreement with ICRF2 (A2 and A3 components agree better than the VLBI-only solution).
- The combination (**A** and **C**) of ΔUT1 mainly affects the CRF z-rotation.

The declination bias impacts the other CRF transformation parameters and thus rotation components (A1, A2, and A3) are estimated even though we apply the NNR condition.

Correlation between CRF and Earth orientation parameters



- When ΔUT1 is combined, the correlation with right ascension becomes higher, especially for the defining sources. Eventually, it causes a frame rotation (z-axis).

4. Conclusion

- A consistent realization of CRF, TRF, and EOP by combining VLBI, SLR and GNSS data (2005-2015) is conducted.
- The standard deviations of the estimated CRF benefit from the combination (in comparison with the VLBI-only solution)
- If no EOP are combined, the CRF of the combined solution is almost identical with the VLBI-only solution.
- The estimated CRF benefits from combining terrestrial pole coordinates, whereas the combination of ΔUT1 causes a rotation around the z-axis.
- **Further investigations on various local tie setups and weightings can be found in Kwak et al. (2018).**

Abbreviation list

EOP: Earth Orientation Parameters
GNSS: Global Navigation Satellite System
IERS: International Earth Rotation and Reference Systems Service
ICRF/ITRF: International Celestial/Terrestrial Reference Frame
ICRS/ITRS: International Celestial/Terrestrial Reference System
IVS: International VLBI Service for Geodesy and Astrometry
LT: Local tie
SLR: Satellite Laser Ranging
VCS: VLBA Calibrator Survey
VLBA: Very Long Baseline Array
VLBI: Very Long Baseline interferometry

References

Fey AL, Gordon D, Jacobs CS (eds) (2009) The Second Realization of the International Celestial Reference Frame by Very Long Baseline Interferometry. IERS Technical Note, No. 35.
Kwak, Y., Bloßfeld, M., Schmid, R. et al. (2018) Consistent realization of Celestial and Terrestrial Reference Frames. J Geod. https://doi.org/10.1007/s00190-018-1130-6