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Impact of geodetic satellite techniques on the CRS realization

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Introduction

The Global Geodetic Observing System (GGOS) of the International Association of Geodesy (IAG) aims at 1mm accuracy/precision by integrating the geodetic parameters from individual techniques. The Very Long Baseline Interferometry (VLBI), one of the major GGOS techniques, contributes to the realization of the International Terrestrial Reference System (ITRS) and Earth Orientation Parameters (EOP) together with geodetic satellite techniques: Global Navigation Satellite Systems (GNSS), Satellite Laser Ranging (SLR), and Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS). The VLBI is also the unique technique which realizes the International Celestial Reference System (ICRS). Up to now, the VLBI-derived Celestial Reference Frame (CRF) is not estimated but fixed in the computation of the Terrestrial Reference Frame (TRF) and the corresponding EOP series. However, EOP are the linking parameters between CRF and TRF, and due to existing correlations between the parameters the EOP will have an impact on the CRF if they are adjusted through an inter-technique combination. In this work, we simultaneously estimate CRF, TRF, and EOP using the VLBI, SLR, and GNSS data. In this poster, we focus on the effects of various EOP combination setups on the CRF. This will show the impact of geodetic satellite techniques on the CRS realization.

Input data & parameters

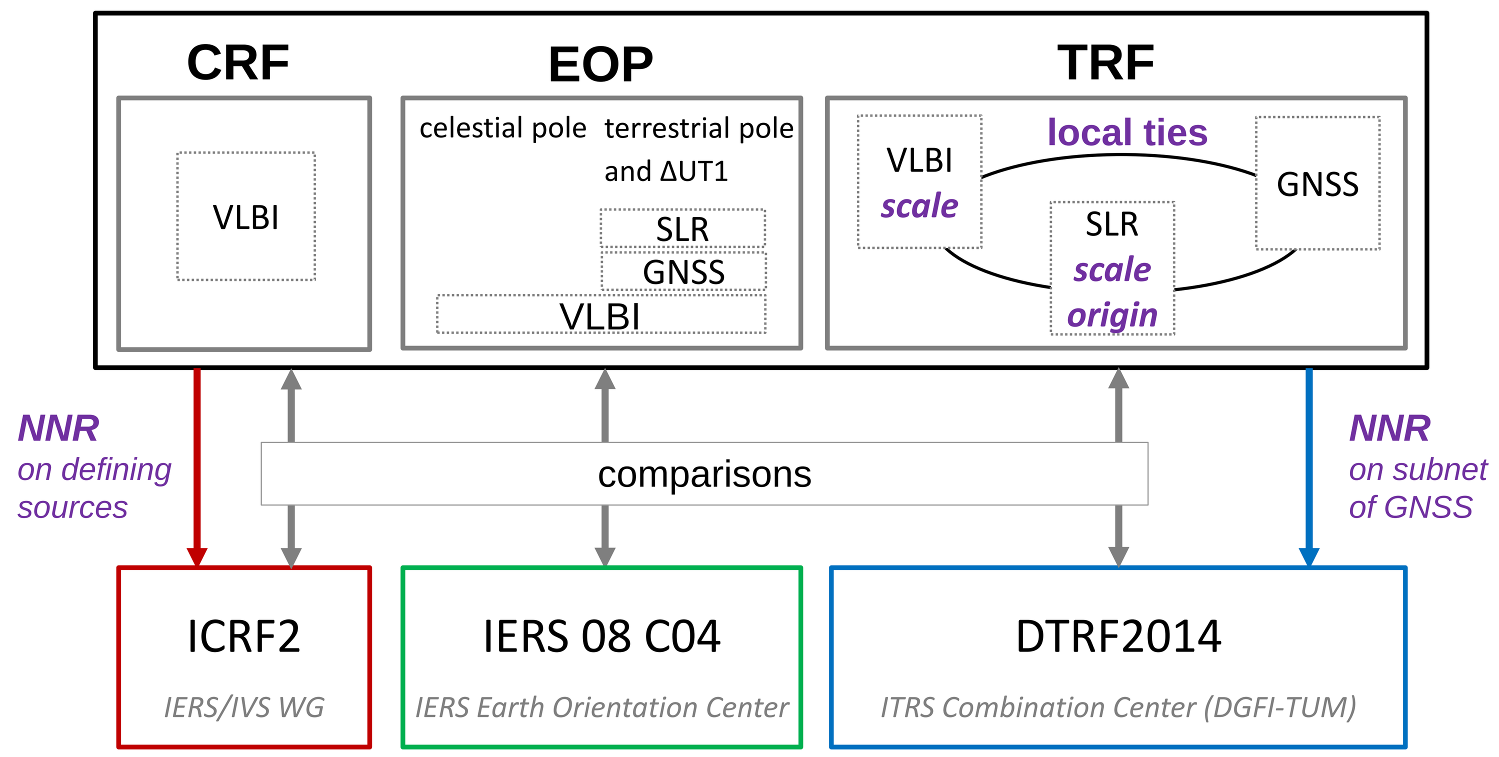
	GNSS	SLR	VLBI
Software	Bernese (CODE)	DOGS-OC (DGFI-TUM)	OCCAM (DGFI-TUM)
Resolution	daily	weekly	session-wise
Time span	January 2005 - December 2015		

- 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
- VLBI:
  - DGFI-TUM solution considering more than 1550 24-hour sessions (all types)
  - Stations contained in less than 10 sessions excluded
  - NNR condition w.r.t. ICRF2 defining sources
  - Special handling sources treated as arc parameters

Estimated parameters	GNSS	SLR	VLBI	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

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

- Four different EOP combination setups are tested to check the influence of combined EOP on the CRS realization.

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 selected based on the following statistical tests.

$$\Delta \mathrm{LT} = |\mathbf{LT}(t_{LT}) - (\mathbf{X}_1(t_{LT}) - \mathbf{X}_2(t_{LT}))|$$

The reference point difference vectors between single-technique multi-year solutions $(\mathbf{X}_1(t_{LT}) - \mathbf{X}_2(t_{LT}))$ are compared with ITRF2014 LTs $(\mathbf{LT}(t_{LT}))$. If $\Delta\mathrm{LT}$ is smaller than the defined value (here $\Delta\mathrm{LT} < 30mm$), the LT is introduced in the combination. The same holds for the velocities ($\Delta v < 1.5mm/yr$).

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.

Transformation parameters between CRFs

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

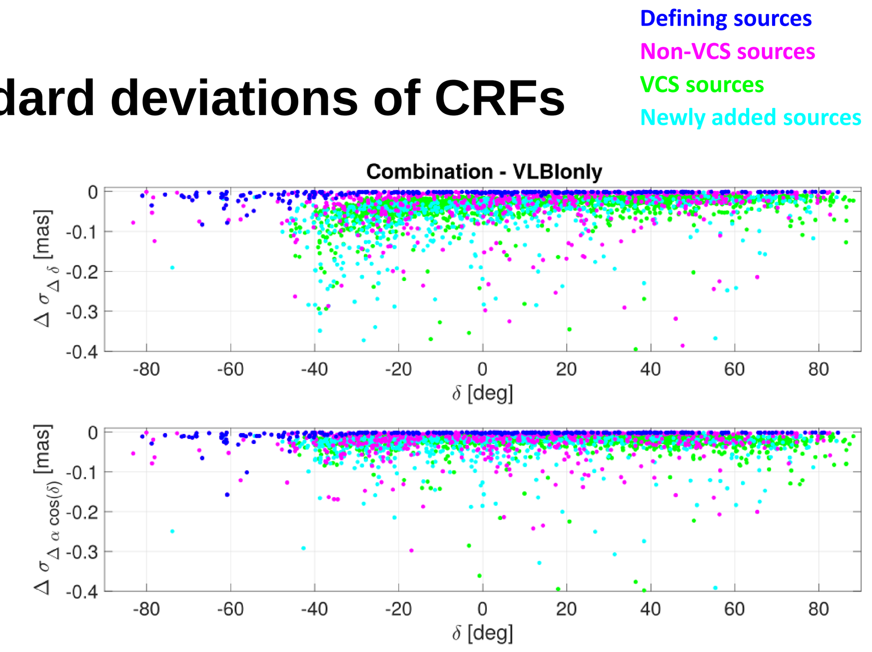
3 rotations,
2 slopes and
1 bias

- In order to analyze the impact of the EOP combination setups on the CRF, the transformation parameters between CRFs (Fey et al., 2009) are computed. Here, the harmonic terms 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.

Results

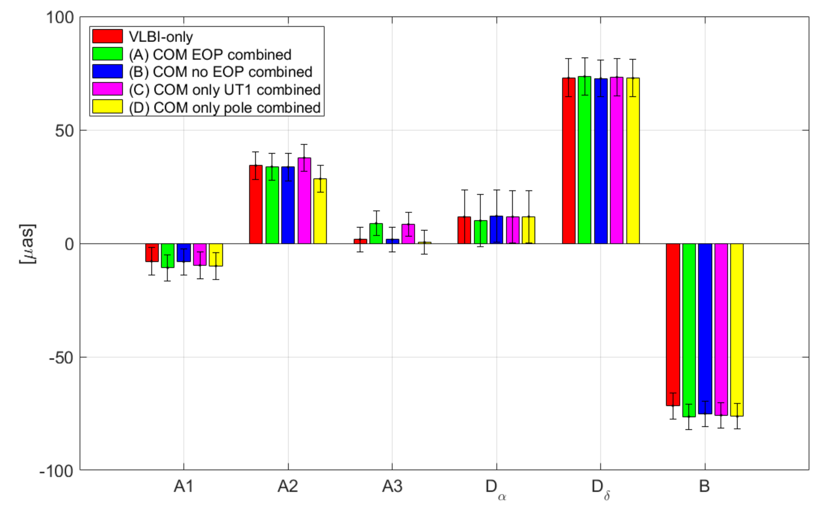
Combination impact on standard deviations of CRFs

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 the similar improvement of the standard deviation.

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



- 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.

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).**

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