ITRF2008 Plate Motion Model

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Summary

Quality assessment of ITRF2008 solution has been undertaken, indicating the well performance of ITRF2008 determination of station positions and velocities, compared to past solutions, including ITRF2005. As a by-product, we estimated rotation poles for 15 tectonic plates, using a velocity field composed of 202 sites with long observation history. The main criteria selection are (1) the velocity formal error is less than 0.5 mm/yr and (2) the post fit residuals should not exceed the threshold of 1.5 mm/yr for each site. We evaluate the impact of correcting or not horizontal post glacial rebound effects before rotation pole estimation. We examine the quality of the ITRF2008 Plate Motion Model (ITRF2008 PMM) and the NNR uncertainty realization, using different possible estimation options and by comparisons to geological models.

Estimation of Plate Angular Velocities

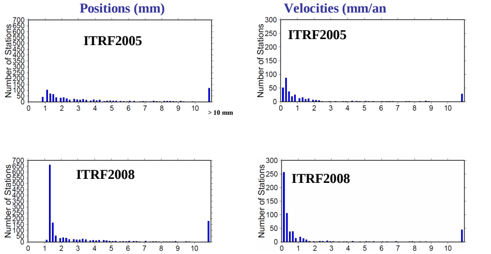
The observation model used for the estimation of plate angular velocities links the Euler vector ω_p with point velocity $\dot{X}_i$, of position vector X_i, located on plate p:

$$\dot{X}_i = \omega_p \times X_i$$

There are different alternatives to estimate plate angular velocities:

- Individual plate by plate estimations or global inversion of all plates together;
- Using full variance-covariance or diagonal terms only

Spherical formal errors



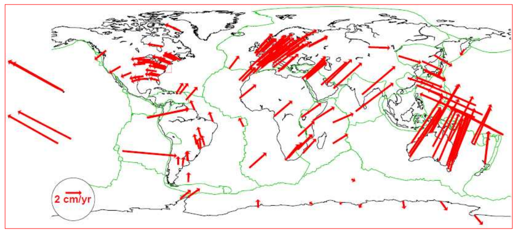


Figure 1. Horizontal velocities of the 203 selected sites for the ITRF2008 PMM estimation

Plate Motion and Post Glacial Rebound

- ITRF2008 linear velocities are impacted by PGR phenomena
- Northern Eurasia (EURA), North America (NOAM) and Antarctica (ANTA) are the most affected by PGR
- We corrected horizontal velocities of sites at ANTA, EURA and NOAM, by PGR predictions model [Peltier , 2004]
- Table 1 lists their angular velocities with (PGR-Y) and without (PGR-N) corrections

Table 1. Absolute Rotation Poles with and without PGR corrections

Plate	NS[a]	ω_x	ω_y	ω_z	ω	WRMS[b]	
		mas/y			°/m.y	E	N
ANTA-PGR-N	10	-0.230	-0.320	0.670	0.216	0.79	0.48
±		0.023	0.024	0.015	0.004		
ANTA-PGR-Y	10	-0.223	-0.330	0.671	0.217	0.87	0.70
±		0.027	0.028	0.017	0.005		
EURA-PGR-N	94	-0.096	-0.537	0.757	0.259	0.56	0.50
±		0.010	0.010	0.007	0.003		
EURA-PGR-Y	94	-0.105	-0.524	0.758	0.258	0.46	0.44
±		0.008	0.008	0.006	0.002		
EURA-PGR-N	56	-0.084	-0.531	0.764	0.259	0.27	0.27
±		0.006	0.006	0.005	0.002		
EURA-PGR-Y	56	-0.085	-0.514	0.775	0.259	0.26	0.27
±		0.006	0.006	0.005	0.002		
NOAM-PGR-N	74	0.047	-0.676	-0.061	0.189	0.46	0.74
±		0.011	0.009	0.009	0.003		
NOAM-PGR-Y	74	0.063	-0.682	-0.059	0.191	0.53	0.93
±		0.011	0.009	0.009	0.003		
NOAM-PGR-N	38	0.034	-0.667	-0.078	0.187	0.21	0.34
±		0.006	0.005	0.005	0.001		
NOAM-PGR-Y	38	0.042	-0.679	-0.073	0.190	0.31	0.43
±		0.007	0.006	0.006	0.002		

[a] Number of used sites
[b] Weighted Root Mean Scatter in East and North in mm/yr

- For ANTA, applying PGR corrections degrades the angular velocity estimate: Note the increase of WRMS in East and North
- For EURA, using 94 sites, PGR model improves the fit, while using 56 sites (excluding Fennoscandia sites) applying model corrections or not yields same results ==> PGR model performs efficiently in Fennoscandia regions
- For NOAM, using 74 sites, applying the PGR model degrades the fit, mostly in North, while using 38 sites the model corrections degrade equally the East and North components.
- Conclusion: do not apply PGR model corrections and avoid using sites in Fennoscandia regions.

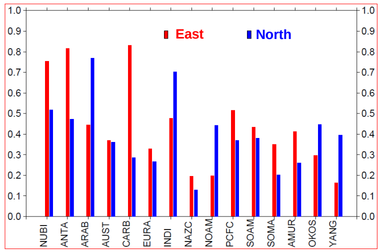


Figure 2: WRMS per plate in mm/yr

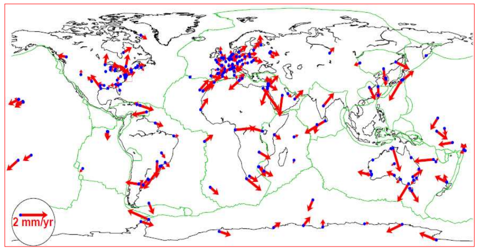


Figure 3: Post-fit residuals per site

Work in progress: Plate Motion and the Frame Origin

- How accurate is the ITRF2008 origin and whether it has significant drift ?
- But an origin drift can only be determined with respect to a known reference frame, e.g. 1.8 mm/yr Z-translation rate between ITRF2000 and ITRF2005.
- We can estimate an origin drift together with all plate angular velocities embedded in a global velocity field (Argus, 2007). The estimated origin drift should then be regarded as the drift of the selected velocity field with respect to a null velocity field, materialized by the selected sites. It is therefore subject to the network distribution (network effect)
- In case of significant origin drift, the estimated plate angular velocities would not be consistent with the ITRF2008, but rather with a translated frame by the estimated translation rates.

References

- Altamimi, Z., X. Collilieux, and L. Metivier (2011), ITRF2008: an improved solution of the International Terrestrial Reference Frame, Journal of Geodesy, doi:10.1007/s00190-011 0444-4
- Argus, D. F., and R. G. Gordon (1991), No-Net-Rotation Model of Current Plate Velocities Incorporating Plate Motion Model Nuvel-1, Geophys. Res. Lett., 18, 2038-2042.
- Argus, D. F. (2007), Dening the translational velocity of the reference frame of Earth, Geophys. J. I., 169, 830-838, doi:10.1111/j.1365-246X.2007.03344.x
- DeMets, C., R. G. Gordon, and D. F. Argus (2010), Geologically current plate motions, Geophys. J. I., pp. 1-80, doi:10.1111/j.1365-246X.2009.04491.x
- Peltier, W. R. (2004), Global glacial isostasy and the surface of the ice-age Earth: the ICE-5G (VM2) model and GRACE, Annu. Rev. Earth Planet. Sci., (32), 111-149, doi:10.1146/annurev.earth.32.082503.144359.

Estimation of ITRF2008 Plate Motion Model

- 203 sites are selected (see Figure 1) where the threshold of post-fit residuals are : 0.7 mm/yr for EURA & NOAM and 1.5 mm/yr for the other plates.
- No PGR corrections were applied
- The global WRMS values of this estimation are 0.50 and 0.40 mm/yr in east and north component, respectively.
- Table 2 lists the adopted ITRF2008 Plate Motion Model. Figure 1 illustrates the used velocities, Figure 2 the WRMS per plate and Figure 3 the post-fit residuals per site.

Table 2. ITRF2008 Absolute Rotation Poles

Plate	NS	ω_x	ω_y	ω_z	ω	WRMS	
		mas/y			°/m.y	E	N
AMUR	5	-0.133	-0.521	0.824	0.273	0.39	0.39
±		0.018	0.025	0.025	0.004		
ANTA	10	-0.225	-0.317	0.659	0.212	0.84	0.48
±		0.009	0.007	0.009	0.002		
ARAB	9	1.354	0.132	1.602	0.584	0.45	0.77
±		0.019	0.019	0.016	0.007		
AUST	22	1.516	1.176	1.209	0.630	0.42	0.36
±		0.009	0.008	0.008	0.002		
CARB	3	-0.032	-0.961	0.616	0.317	0.84	0.29
±		0.160	0.349	0.123	0.099		
EURA	56	-0.085	-0.533	0.774	0.262	0.37	0.26
±		0.011	0.007	0.012	0.003		
INDI	3	1.219	0.184	1.543	0.549	0.49	0.72
±		0.062	0.216	0.043	0.024		
NAZC	3	-0.331	-1.551	1.632	0.632	0.18	0.28
±		0.014	0.040	0.017	0.007		
NOAM	38	0.024	-0.654	-0.091	0.184	0.26	0.33
±		0.008	0.009	0.009	0.002		
NUBI	18	0.084	-0.616	0.766	0.274	0.79	0.52
±		0.007	0.007	0.009	0.002		
PCFC	13	-0.380	1.048	-2.186	0.682	0.57	0.38
±		0.014	0.009	0.010	0.003		
SOAM	13	-0.239	-0.324	-0.140	0.118	0.45	0.43
±		0.011	0.012	0.010	0.003		
SOMA	3	-0.071	-0.754	0.898	0.326	0.37	0.25
±		0.037	0.041	0.016	0.010		
OKOS	4	-0.170	-0.201	-0.162	0.086	0.35	0.53
±		0.032	0.025	0.035	0.005		
YANG	3	-0.175	-0.540	0.989	0.317	0.17	0.49
±		0.115	0.192	0.111	0.007		
ITRF2008-PMM						0.50	0.40

Comparisons to NNR-NUVEL-1A (NNR1A) and NNR-MORVEL56 (NNRM56)

- Table 3 lists the three rotation rates from TRF2008 to the two models, involving sites on different plates.
- We used sites where the post-fit residuals are less than 3 mm/yr.
- The first comparison involves the six major plates which were used in the initial alignment of ITRF2000 to NNR1A. It shows that the implicit alignment of ITRF2008 is quite satisfactory

Table 3. Rotation rate components from ITRF2008 to models

Model	NS	NP[a]	R_x	R_y	R_z	WRMS E	WRMS N
NNR-NUVEL-1A	139	6	0.004	-0.003	0.003	1.1	1.1
±			0.003	0.002	0.003		
NNR-NUVEL-1A	156	7	0.015	-0.010	0.014	1.1	1.1
±			0.003	0.002	0.003		
NNR-MORVEL65	171	12	0.053	-0.015	0.015	1.1	1.1
±			0.002	0.002	0.002		

[a] Number of plates. R_x, R_y and R_z are the rotation rate components in mas/yr

- The second comparison listed in Table 3 indicates that the ITRF2008 implicit alignement to NNR1A is still at the level of better than 1 mm/yr.
- The third comparison shows an X-rotation rate between ITRF2008 and NNRM56, equivalent to 1.5 mm/yr

==> The current uncertainty of the ITRF2008 NNR implicit realization, is at the level of 2 mm/yr.

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