

Plate Motion Models From Space Geodesy: The Case of ITRF2008



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Outline

- **Introduction**
- **ITRF2008 Plate Motion Model (ITRF2008-PMM)**
 - **Site selection**
 - **Plate Motion and Post Glacial Rebound**
 - **ITRF2008-PMM & origin rate bias**
 - **Comparisons to geological models**
 - **No Net Rotation Condition**
- **Conclusion**

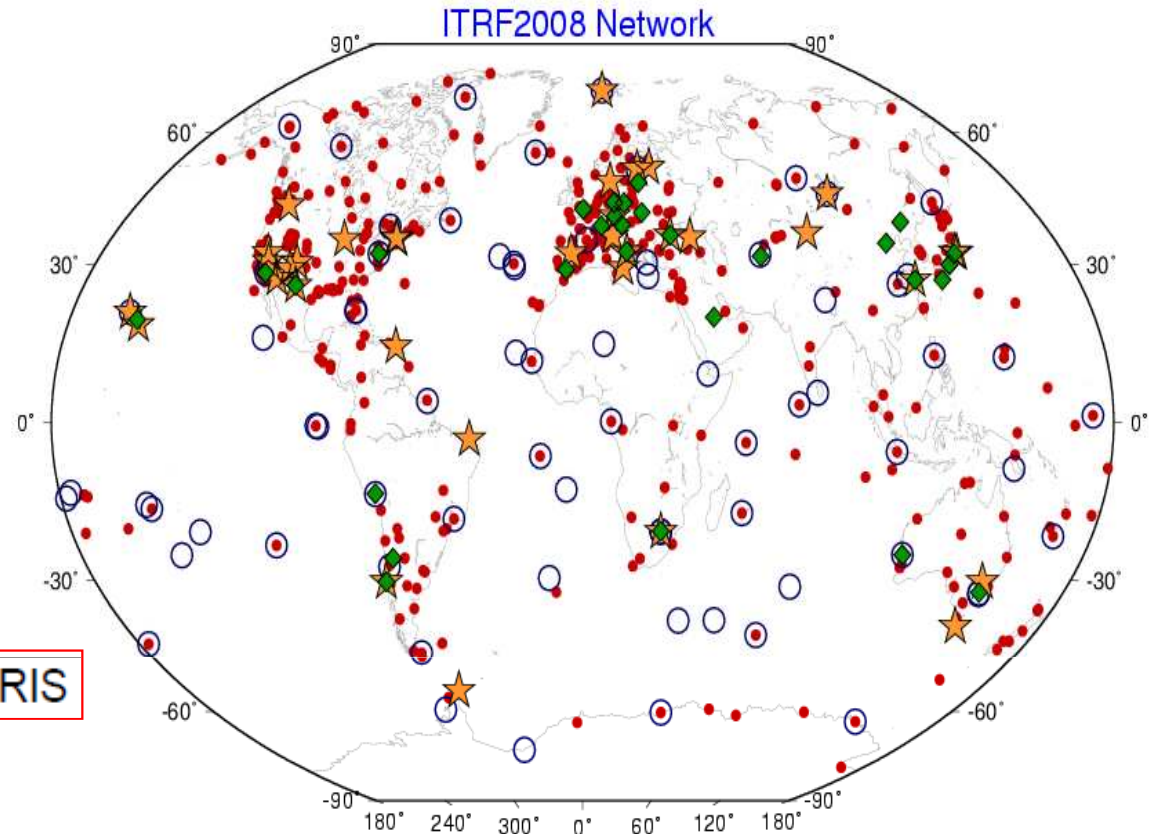
ITRF2008

580 sites (934 stations)

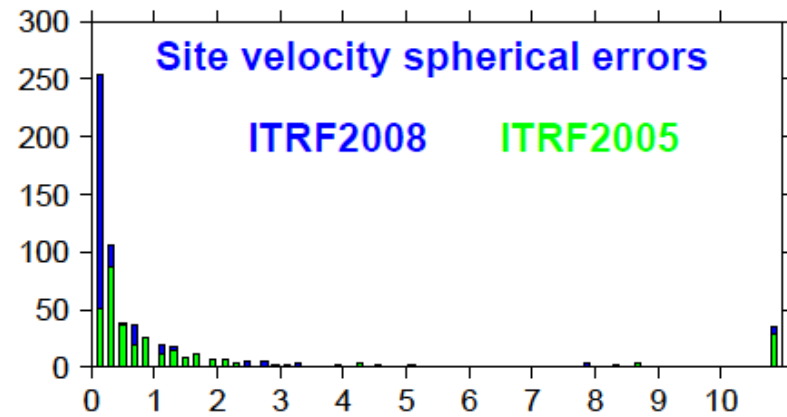
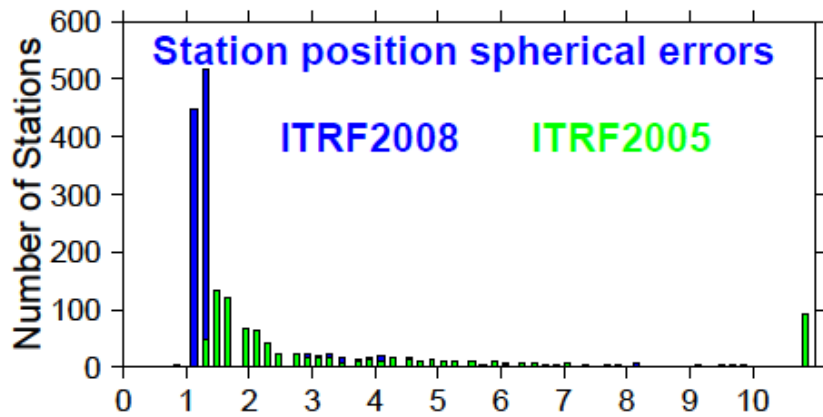
463 Sites North

111 Sites South

Reprocessed solutions
of 4 techniques



Precision gain:



Introduction

- **Ex. of Geological tectonic relative plate motion models**
 - RM2 (Minster and Jordan, 1978)
 - NUVEL-1 & 1A (Demets et al. 1990, 1994)
 - Bird (2003)
 - MORVEL (Demets et al. 2010)
- **Average lithosphere motion over ~0.78 to 3.16 Ma**
- **Assume rigid plates**
- **Absolute NNR models were derived from the above, e.g.:**
 - **AM02 (Minster & Jordan, 1978)**
 - **NNR-NUVEL-1A (Argus et al. 1991)**
 - **NNR-MORVEL56 (Argus et al. 2011)**
- **Space Geodesy provides site velocities which are then used to estimate plate angular velocities**

Our Continents

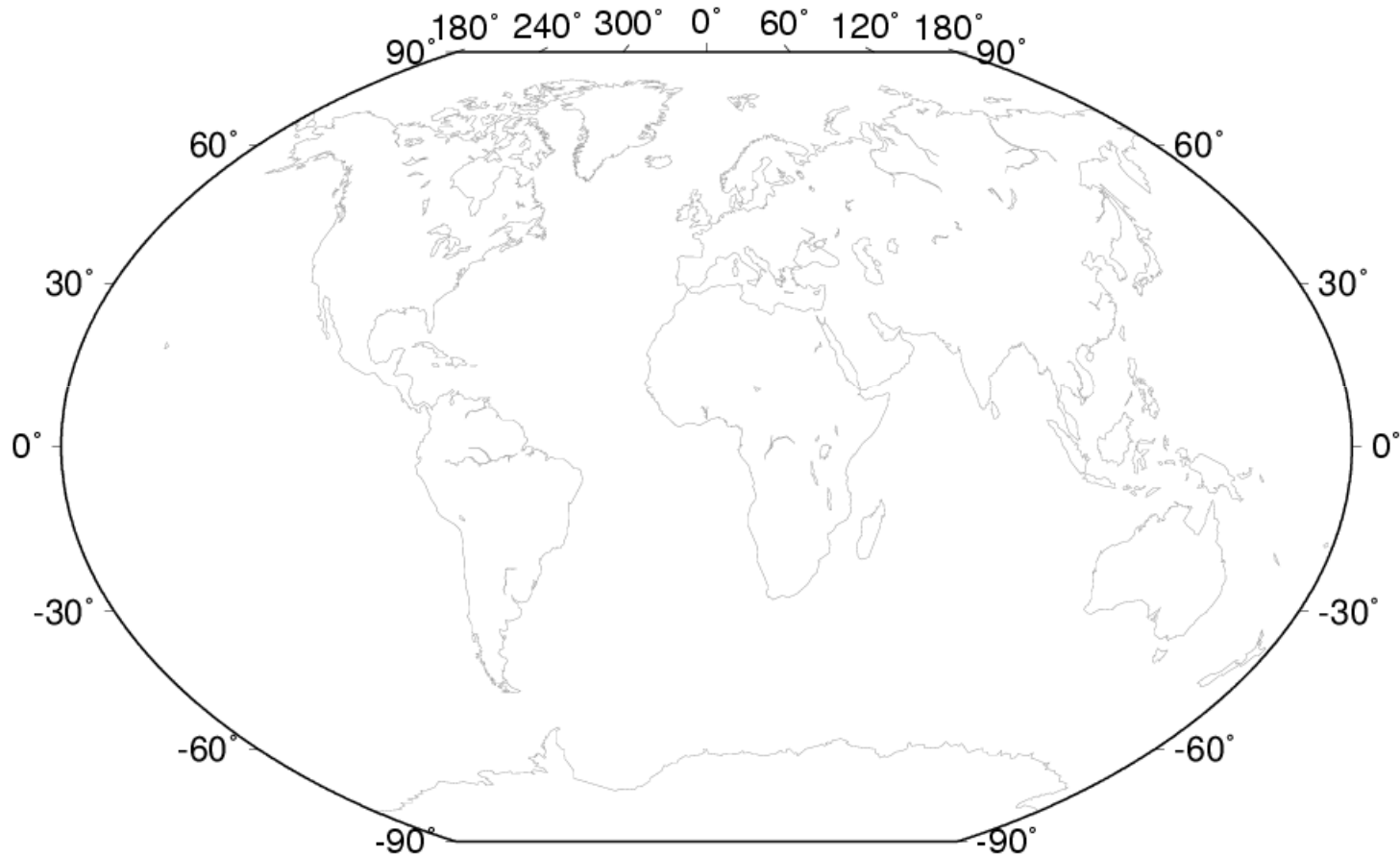


Plate boundaries: Bird (2003) and MORVEL (2010)

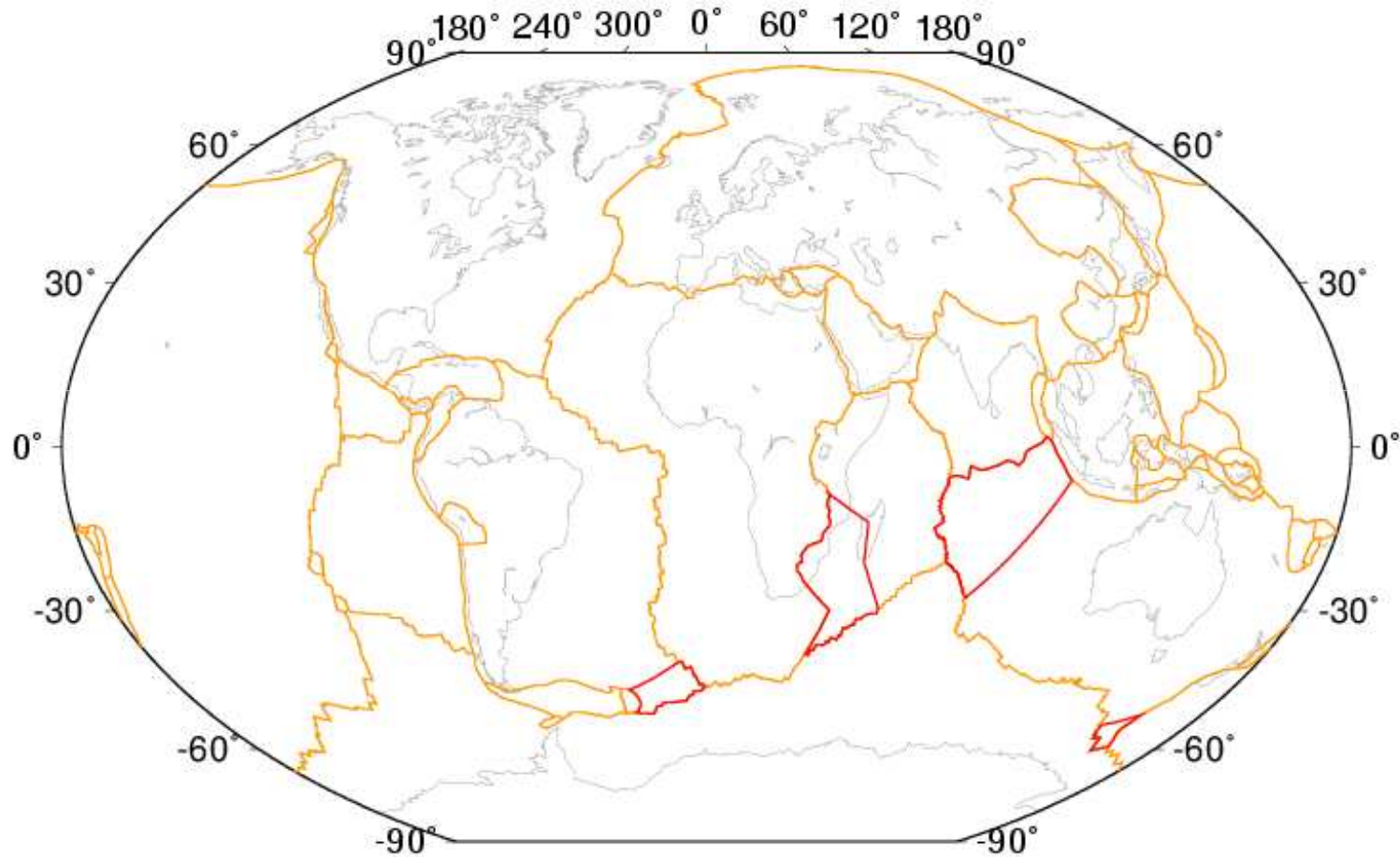
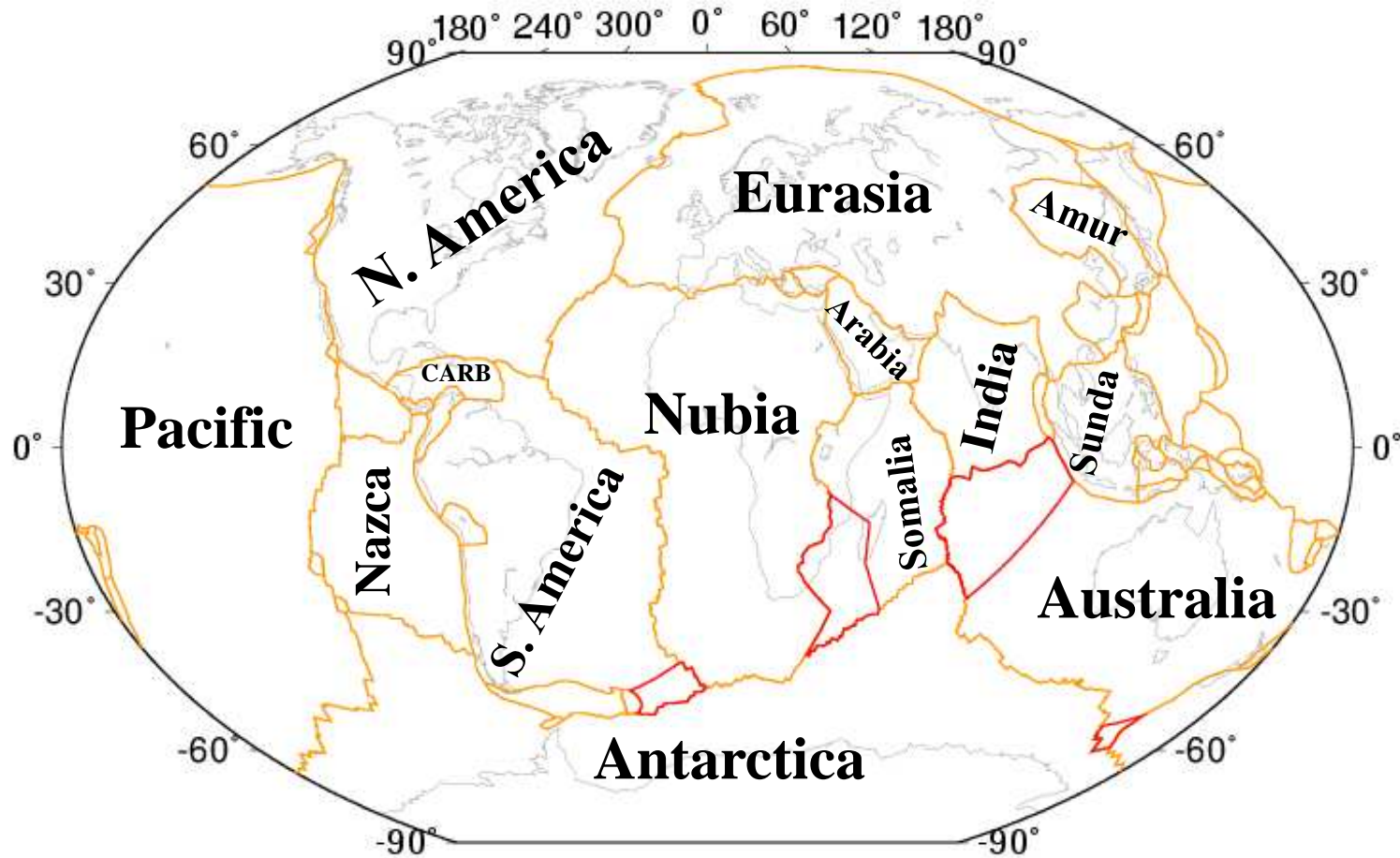


Plate boundaries: Bird (2003) and MORVEL (2010)

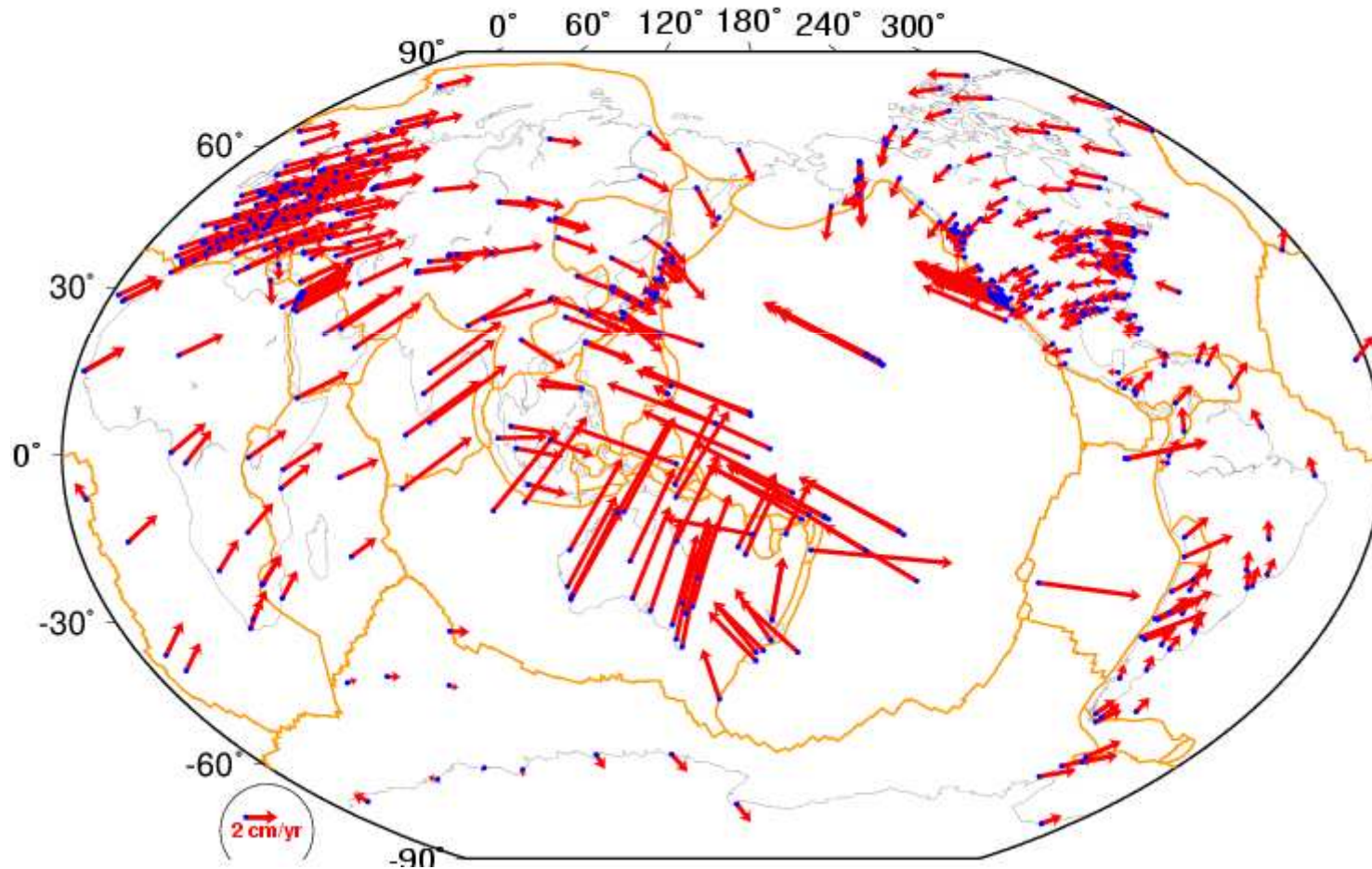


Site Selection Criteria

- **Time span > 3 years**
- **Far from plate boundaries: 100km from Bird (2003) boundaries**
- **Exclude sites in deformation zones (Kreemer et al., 2006)**
- **Reject points from area of Post Glacial Rebound**
- **Reject points with post-fit residuals > threshold**
- **The selected velocity field should have minimum Origin Rate Bias (ORB)**

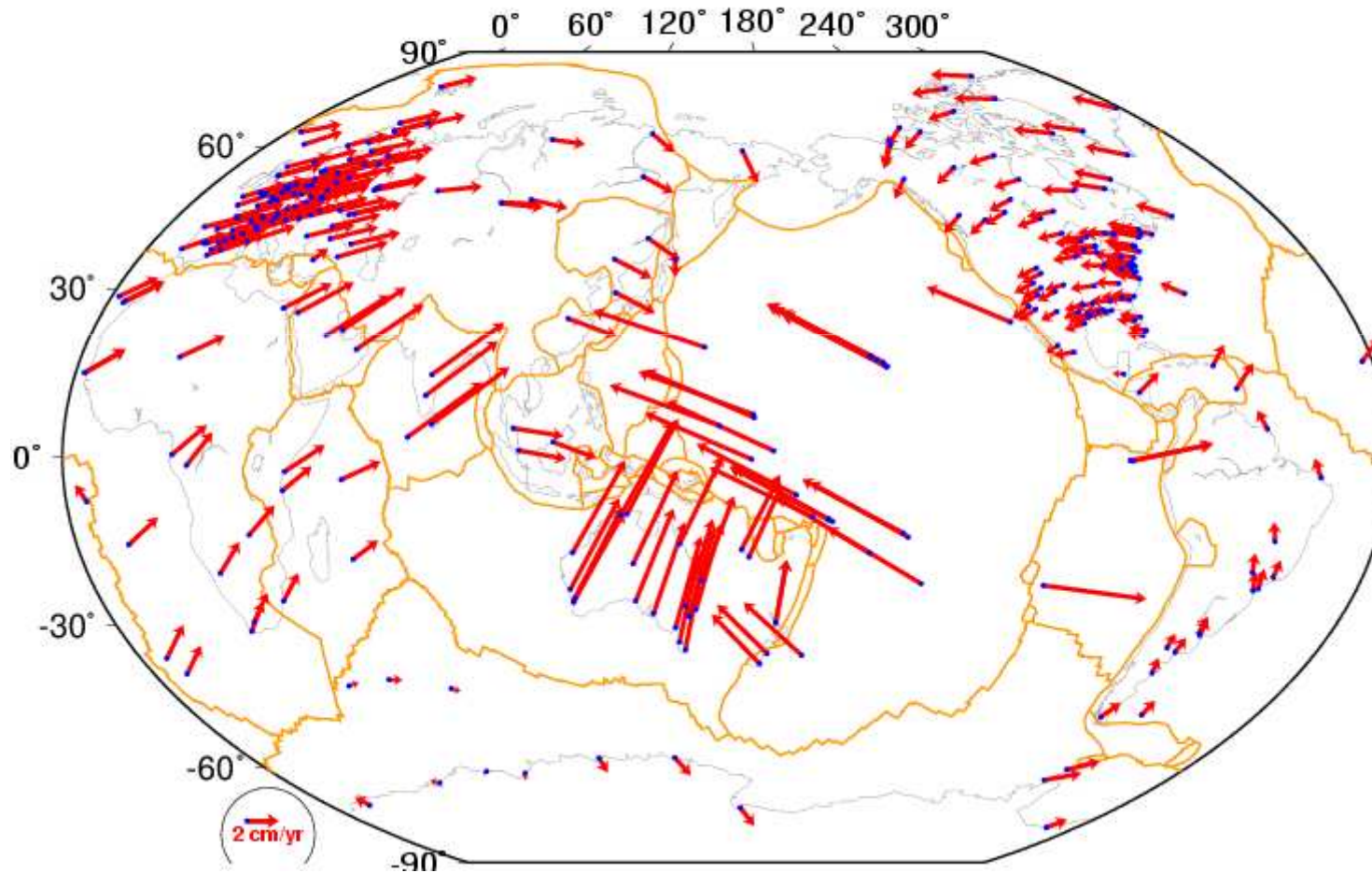
ALL ITRF2008 Site Velocities: time-span > 3 yrs

509 sites



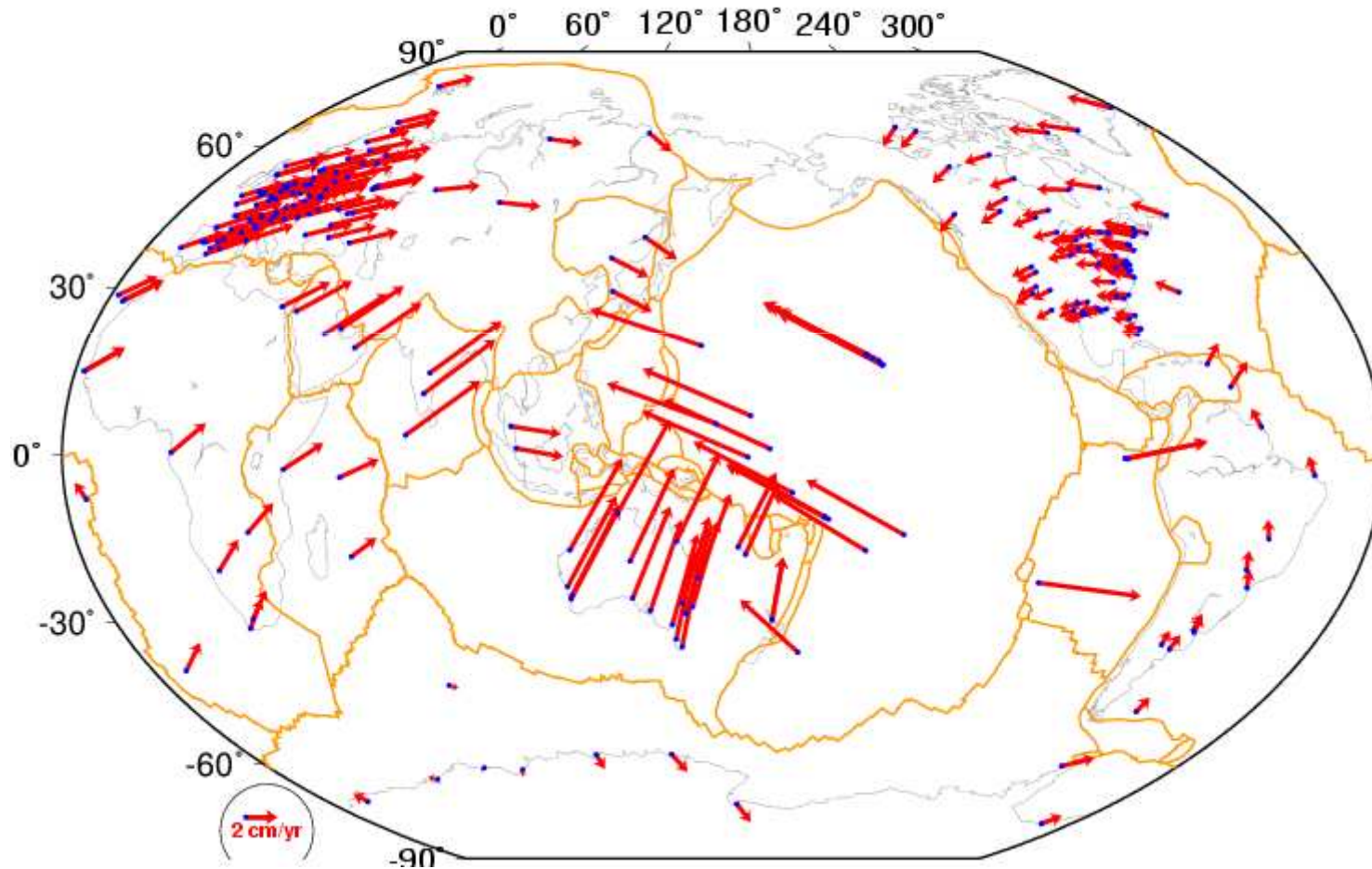
Selected ITRF2008 Site Velocities: Far from Plate Boundaries and deformation zones

316 sites



Selected ITRF2008 Site Velocities: Plate ang. vel. post-fit residuals < 1.5 mm/yr

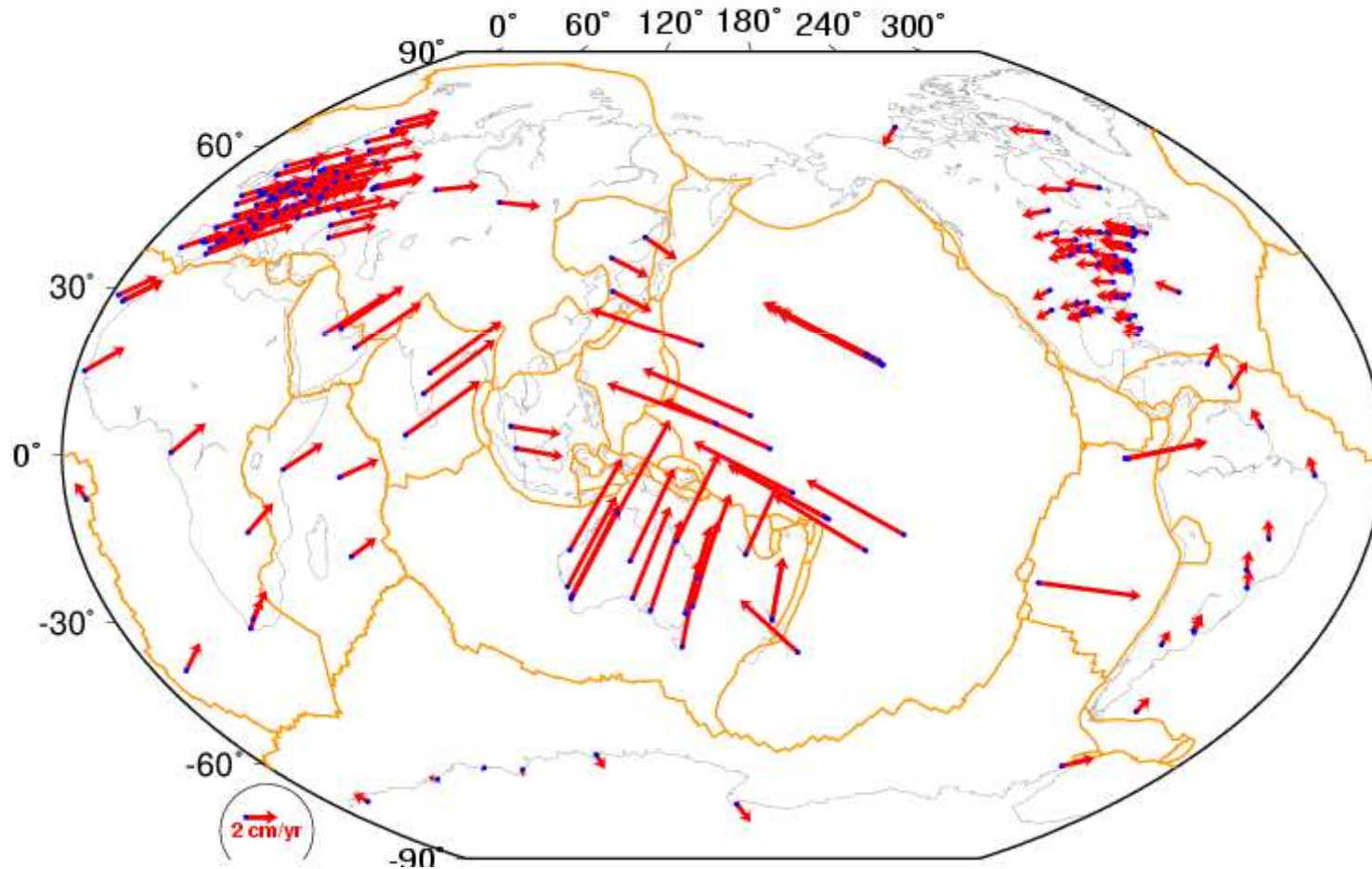
253 sites



Selected ITRF2008 Site Velocities

Plate ang. vel. post-fit residuals < 1 mm/yr

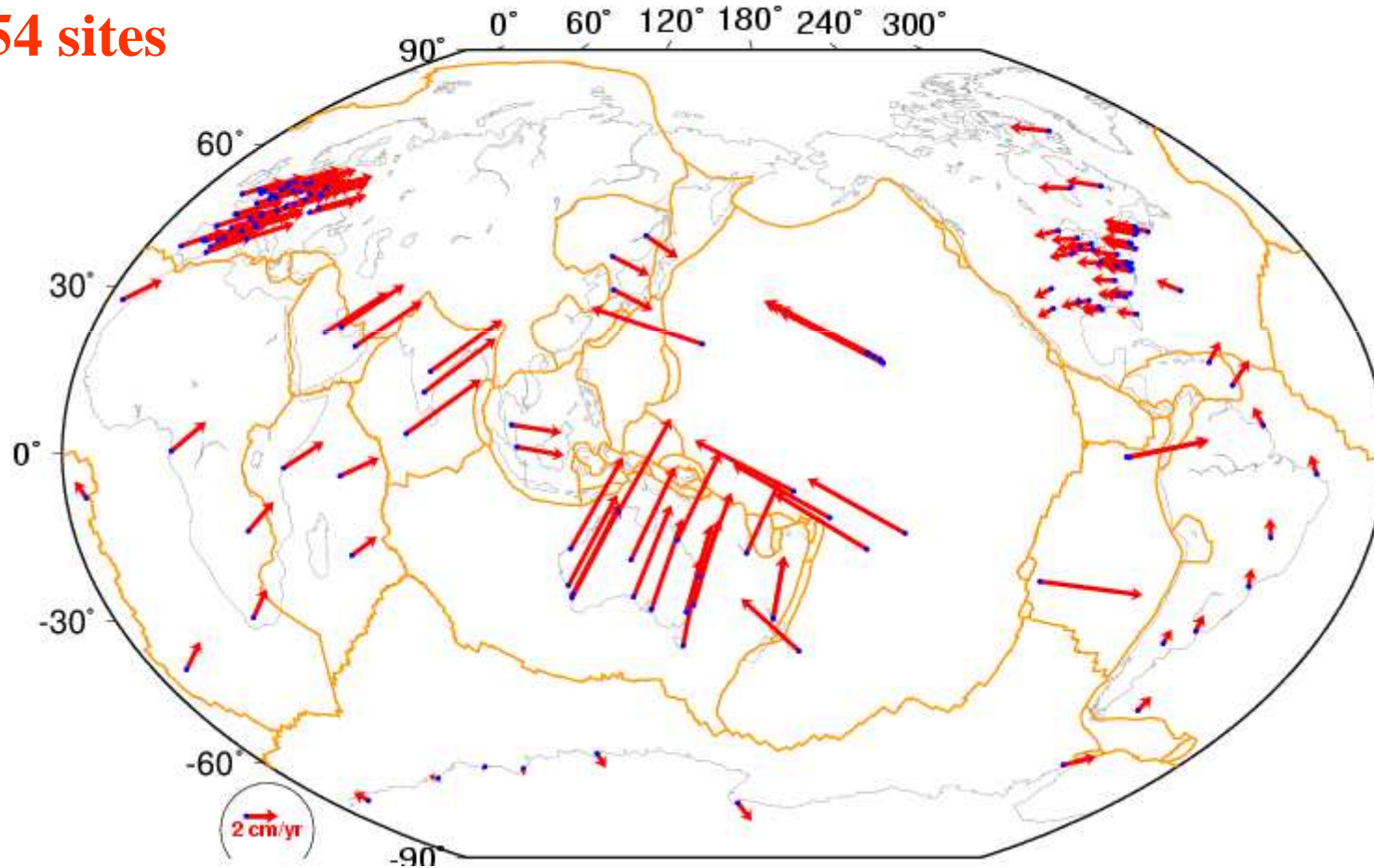
205 sites



ITRF2008 Site Velocities: Final Selection

- Post-fit residuals < 0.7 mm/yr for EURA and NOAM
- and < 1 mm/yr for the other plates

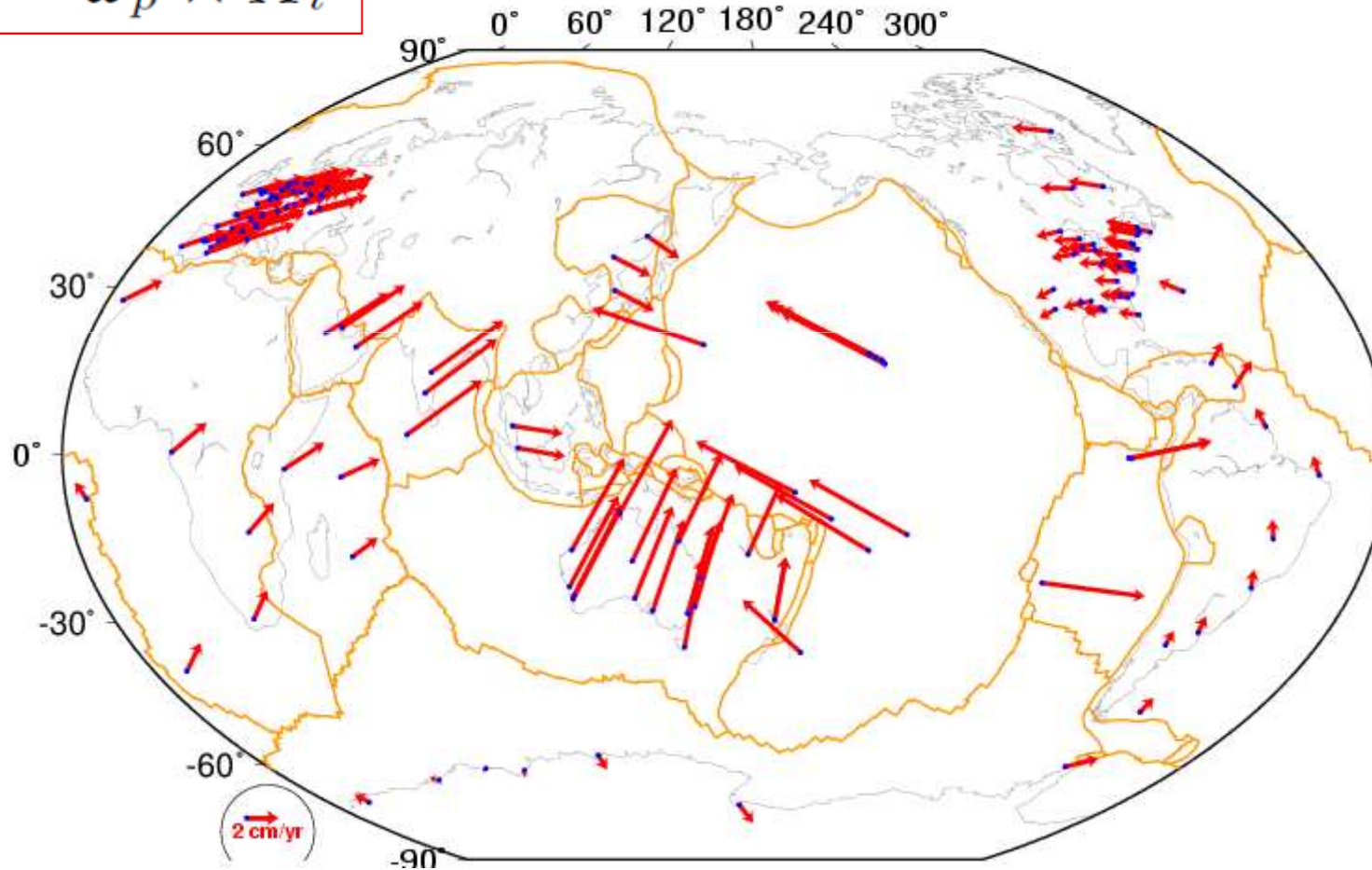
154 sites



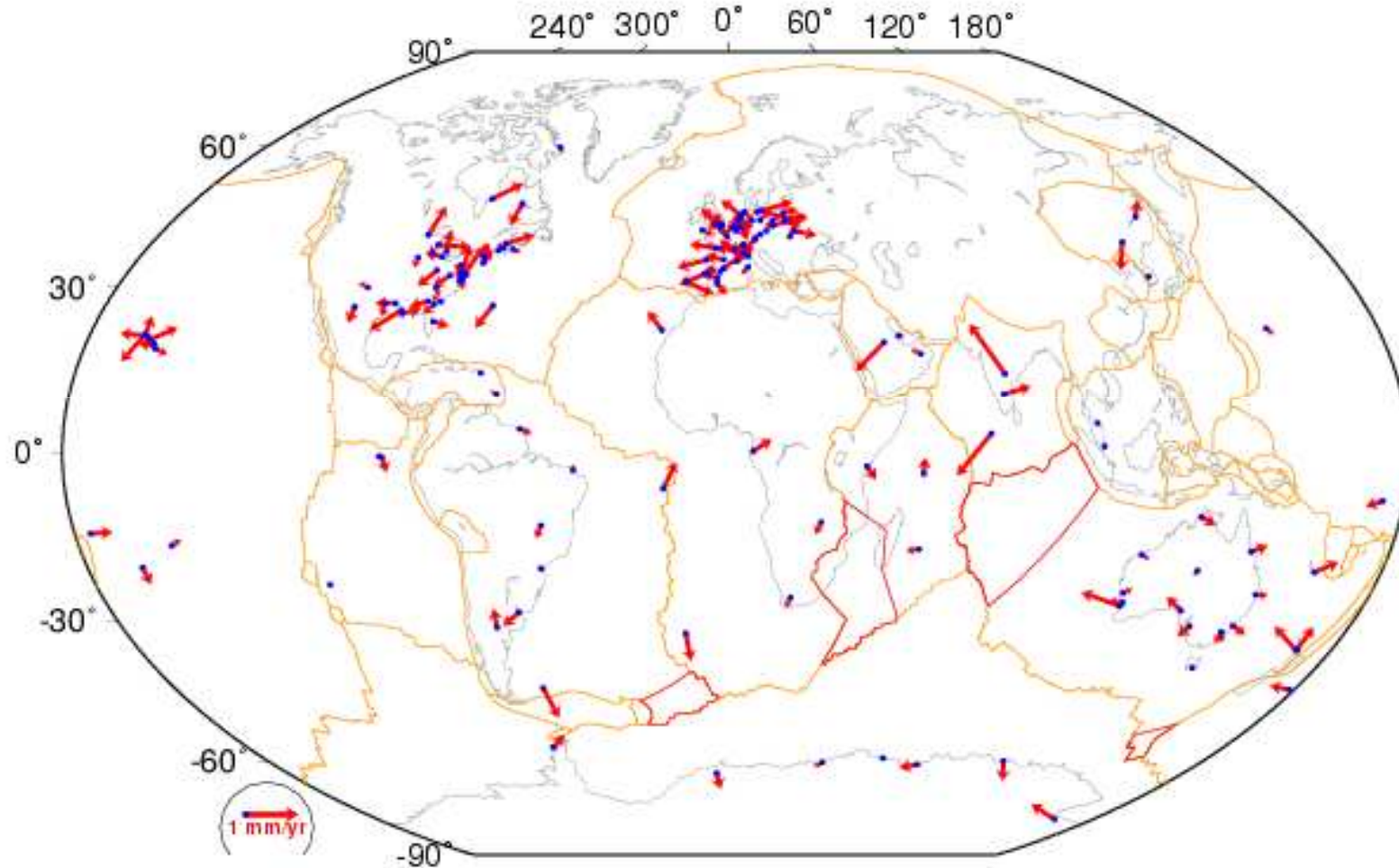
Selected Site Velocities

Plate angular velocity ω_p is estimated by:

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

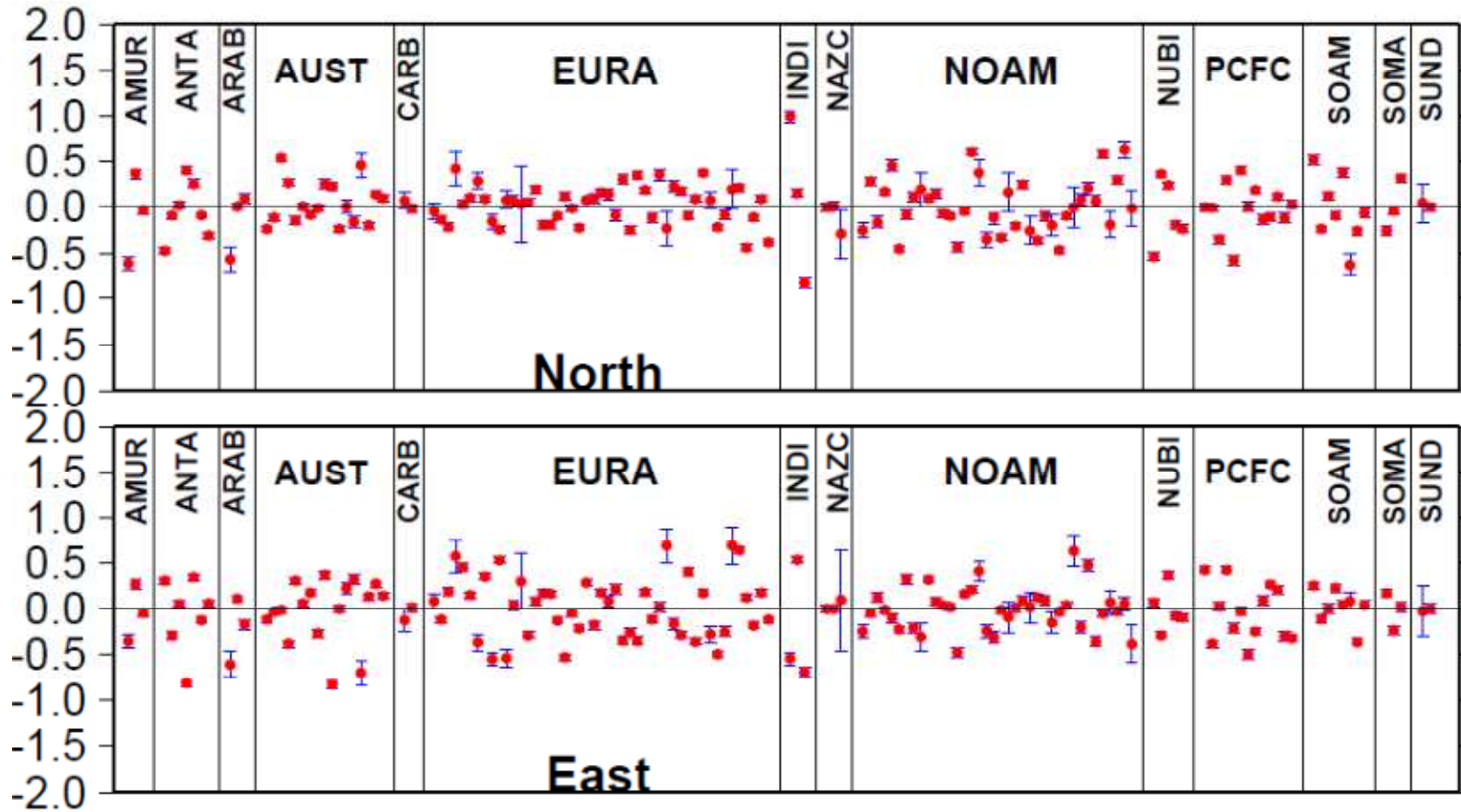


Geographic distribution of site residual velocities



Warning: Unit 2 mm/yr

Site residual velocities



WRMS (mm/a) per plate

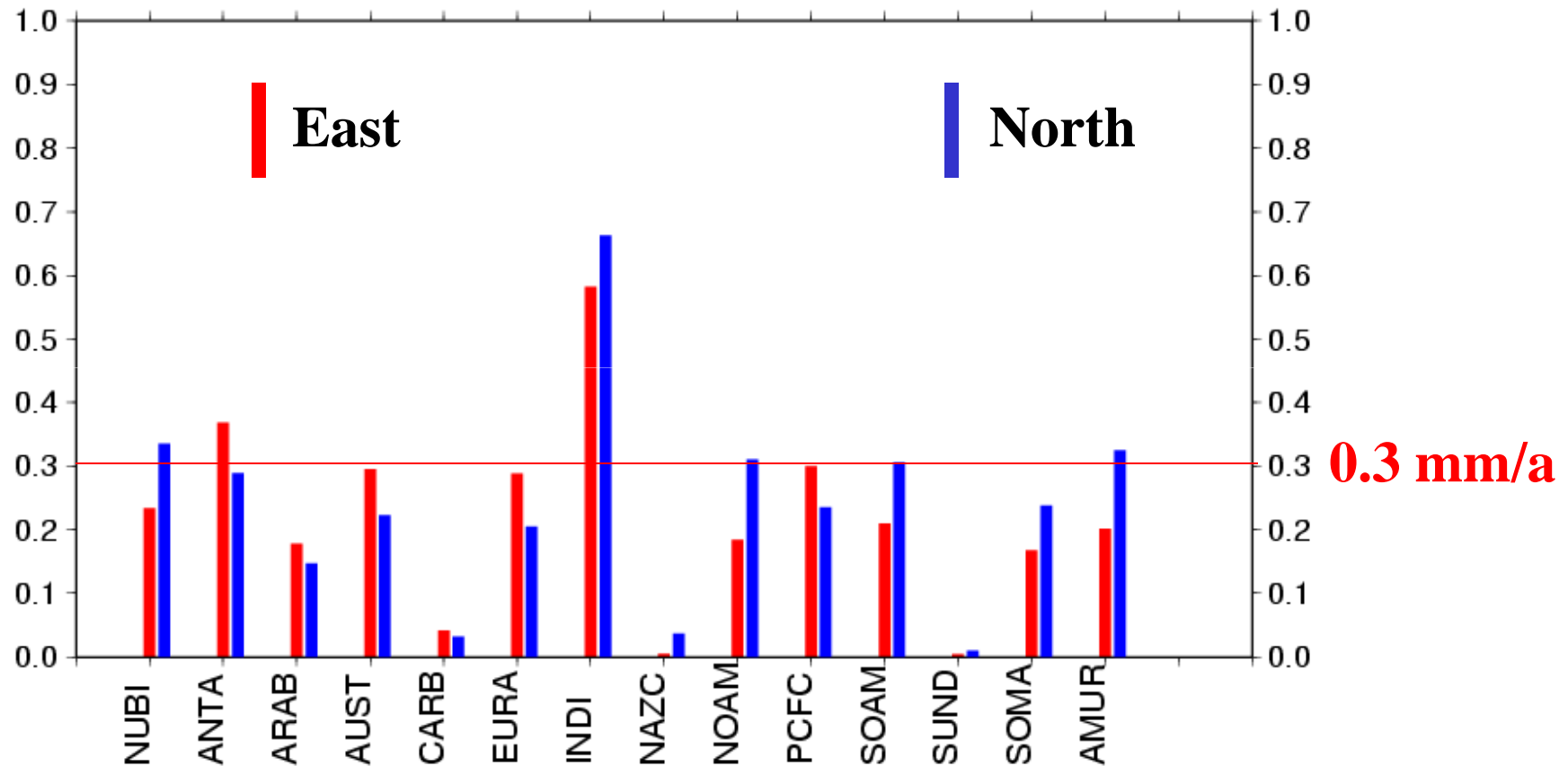
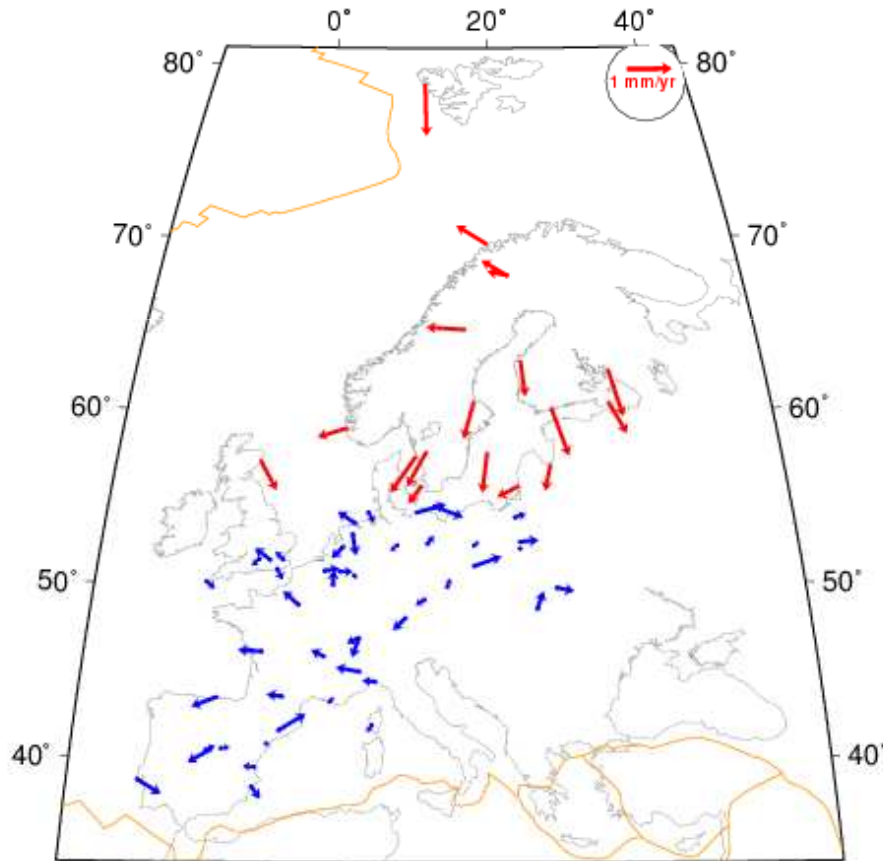


Plate motion and Post Glacial Rebound

Residuals after removing EURA rotation pole

Blue : points used

Red : points rejected



We tested three models

- **Schotman and Vermeersen [2005]** improves the fit in EURA, but degrades in NOAM & ANTA

- **VM2 & VM4 [Peltier 2004]** improves partially the fit in EURA & degrades in NOAM & ANTA

ITRF2008 PMM and origin stability

- Z-translation rate (\dot{T}_z) induces a north velocity change by:

$$d\dot{N} = \dot{T}_z \times \cos(\phi)$$

- Plate angular velocity ω_p is estimated by: $\dot{X}_i = \omega_p \times X_i$

- In order to evaluate the velocity field origin stability, an Origin Rate Bias (ORB), \dot{T} , could be added, so that:

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

- Similar approach used by Argus et al. (2010) & Kogan & Steblov (2008) & found different values for ORB
- **ITRF2008 ORB is ~0.5 mm/yr (Wu et al., 2011)**
- **But, the ORB is subject to the network geometry and residual distribution, see next.**

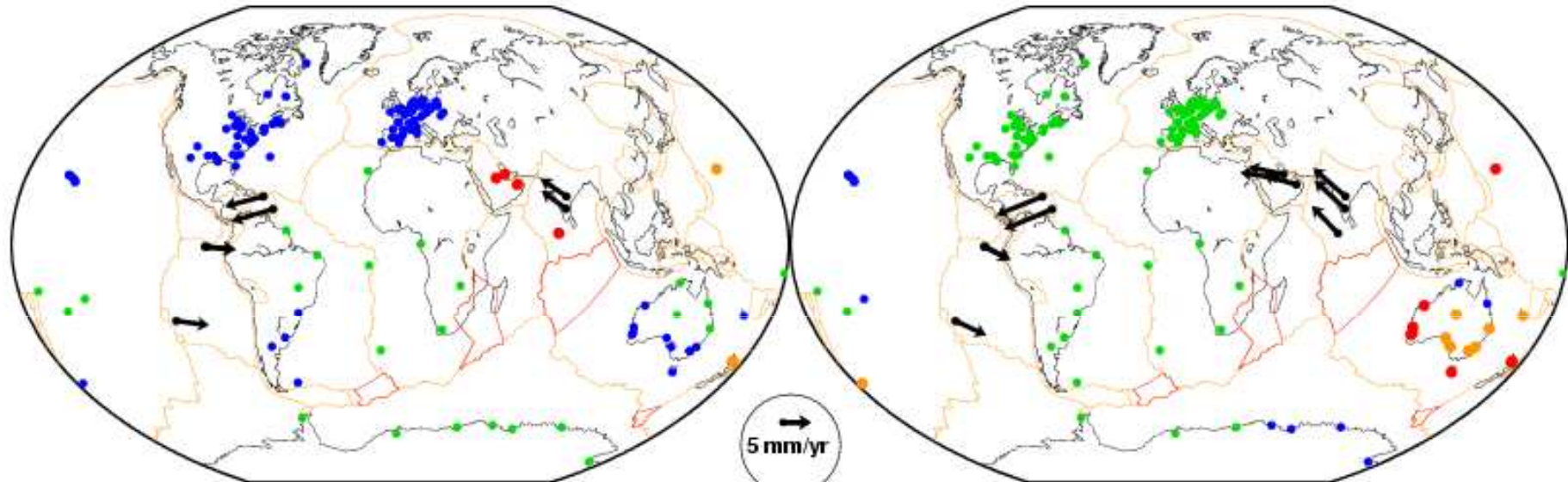
Translation rates

Number of sites			\dot{T}_x	\dot{T}_y	\dot{T}_z
Total	EURA	NOAM	mm/a		
253	88	71	0.35	-0.14	1.19
Residuals < 1.5 mm/a			± 0.16	± 0.22	± 0.16
205	76	49	0.42	-0.07	0.29
Residuals < 1.0 mm/a			± 0.13	± 0.21	± 0.17
168	47	38	0.32	-0.09	-0.03
Residuals < 1.0			± 0.12	± 0.20	± 0.17
	0.7	0.7			
154	47	38	0.09	-0.09	0.01
Residuals < 1.0			± 0.12	± 0.20	± 0.18
& reject 14 sites					

Comparison btw NNR-NUVEL-1A and NNR-MORVEL56

Raw velocity differences

After rotation rate transformation



RMS:

East : 2.2 mm/yr

North: 1.5 mm/yr

- **Green:** 1-2 mm/yr
- **Blue :** 2-3 mm/yr
- **Orange:** 3-4 mm/yr
- **Red :** 4-5 mm/yr
- ←● **Black :** > 5 mm/yr

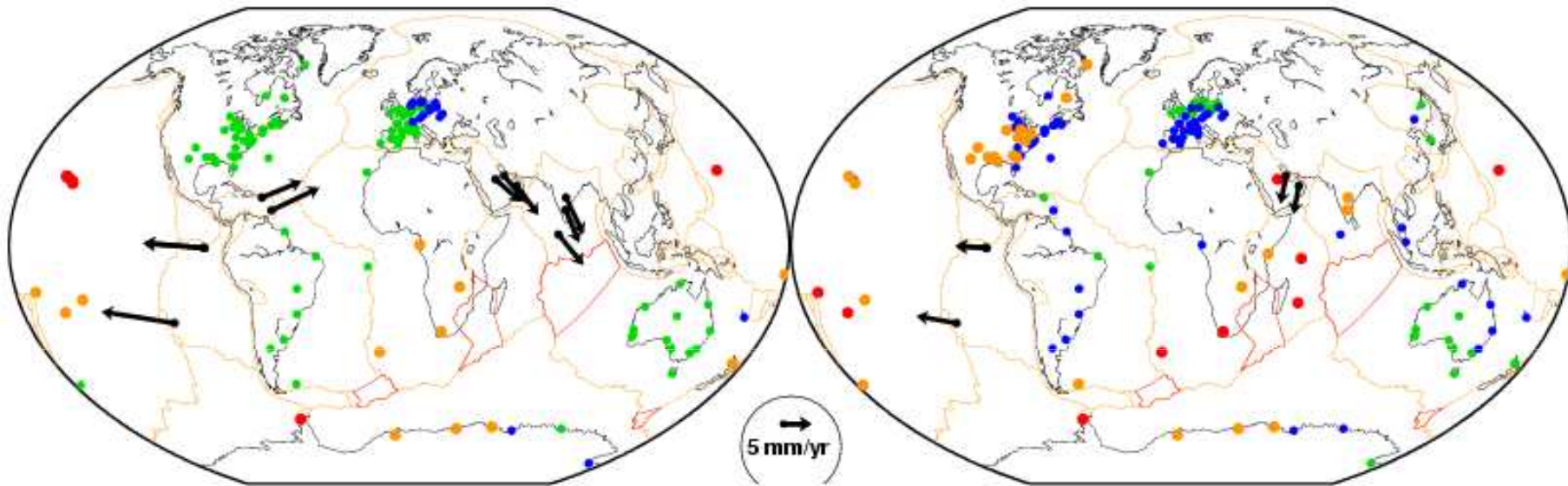
RMS:

East : 2.1 mm/yr

North: 1.4 mm/yr

Comparison btw ITRF2008 and NNR-NUVEL-1A and NNR-MORVEL56

Raw velocity differences



NNR-NUVEL-1A

RMS:

East : 2.4 mm/yr

North: 1.9 mm/yr

- Green: 1-2 mm/yr
- Blue : 2-3 mm/yr
- Orange: 3-4 mm/yr
- Red : 4-5 mm/yr
- ←● Black : > 5 mm/yr

NNR-MORVEL56

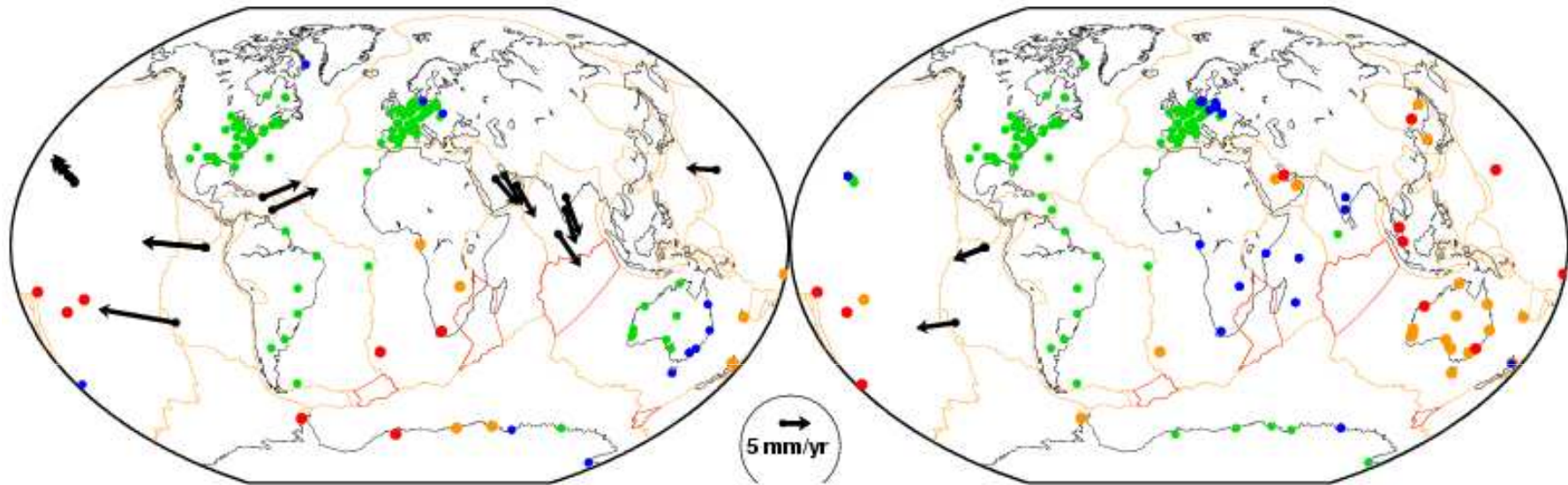
RMS:

East : 1.9 mm/yr

North: 2.1 mm/yr

Comparison btw ITRF2008 and NNR-NUVEL-1 and NNR-MORVEL56

Velocity differences after rot. rate transformation



NNR-NUVEL-1A

RMS:

East : 2.5 mm/yr

North: 2.0 mm/yr

- Green: 1-2 mm/yr
- Blue : 2-3 mm/yr
- Orange: 3-4 mm/yr
- Red : 4-5 mm/yr
- ←● Black : > 5 mm/yr

NNR-MORVEL56

RMS:

East : 1.7 mm/yr

North: 1.7 mm/yr

Summary of comparisons btw ITRF2008 and NNR-NUVEL-1A and NNR-MORVEL56

	Rotation Rate mm/a	# Sites	RMS East mm/a	RMS North mm/a	# Plates
NNR-NUVEL-1A – NNR-MORVEL56	~1.8	118/146	2.1	1.4	7/11
NNR-NUVEL-1A – ITRF2008 PMM	~1.0	112/146	2.5	2.0	7/11
NNR-MORVEL – ITR2008 PMM	~2.5	119/154	1.7	1.7	10/14

Rigid plate motion concept

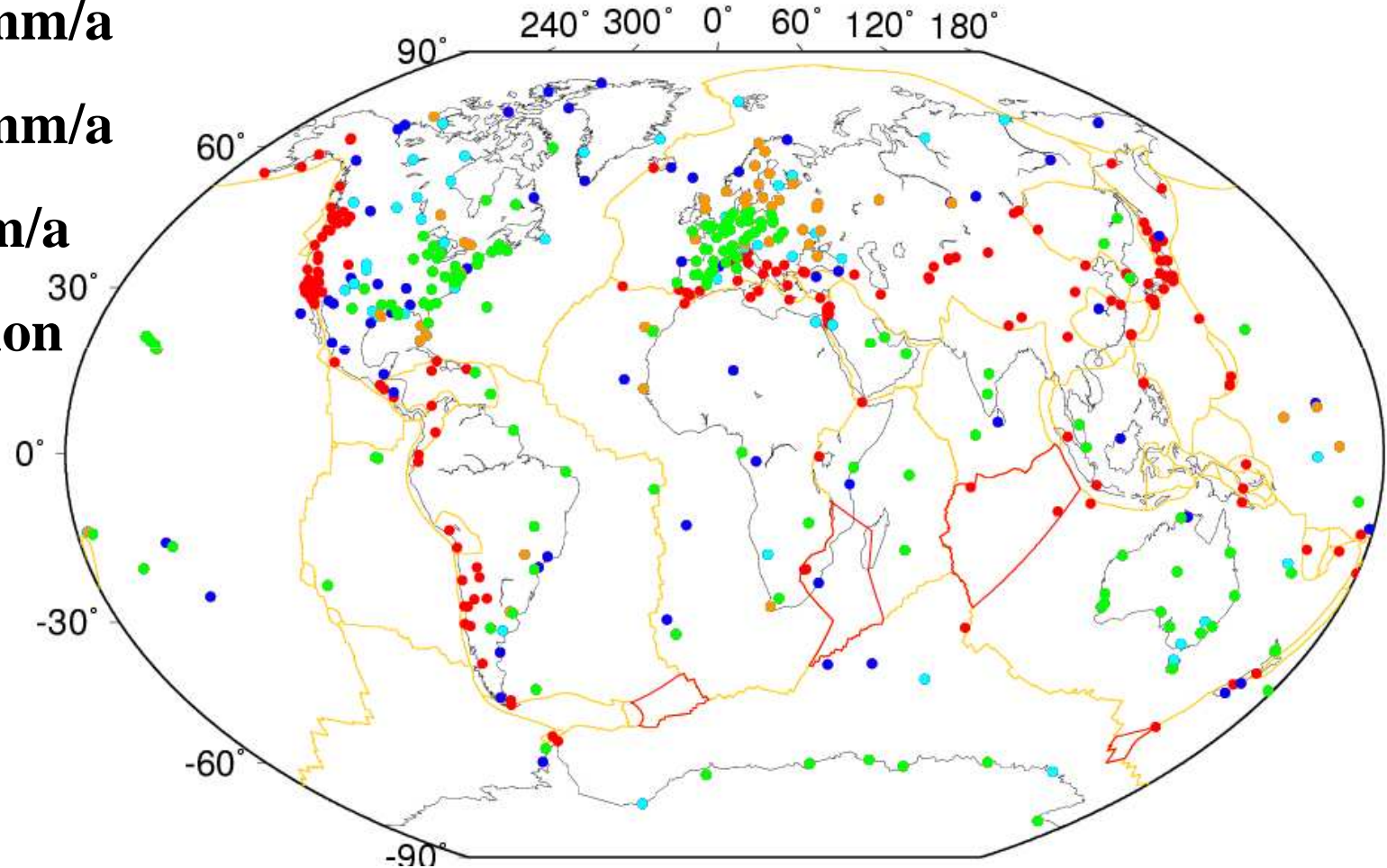
- Plate boundaries and deformation area

- Res > 1.5 mm/a

- Res < 1.5 mm/a

- Res < 1 mm/a

- Final selction



Conclusion

- Estimation of a precise plate motion model consistent with ITRF2008: WRMS **0.3 mm/a**
- ITRF2008-PMM has negligible Origin Rate Bias
- Comparison to geological models (using our site selection)
 - X-rotation rate of **1.8 mm/a** btw NNR-MORVEL56 & NNR-NUVEL-1A
 - Comparisons btw ITRF2008-PMM &
 - NNR-NUVEL-1A Rot.: **1 mm/a** RMS **2.5 mm/a**
 - NNR-MORVEL56 Rot.: **2.5 mm/a** RMS **1.7 mm/a**
 - **Australia plate in NNR-MORVEL56 has large site residual velocities up to 4.6 mm/a, when compared to NNR-NUVEL-1A or ITRF2008-PMM**
 - ITRF2008 implicit realization of the No-Net-Rotation Condition is not better than **~ 2 mm/a**