The Kinematic Reference Frame for ITRF

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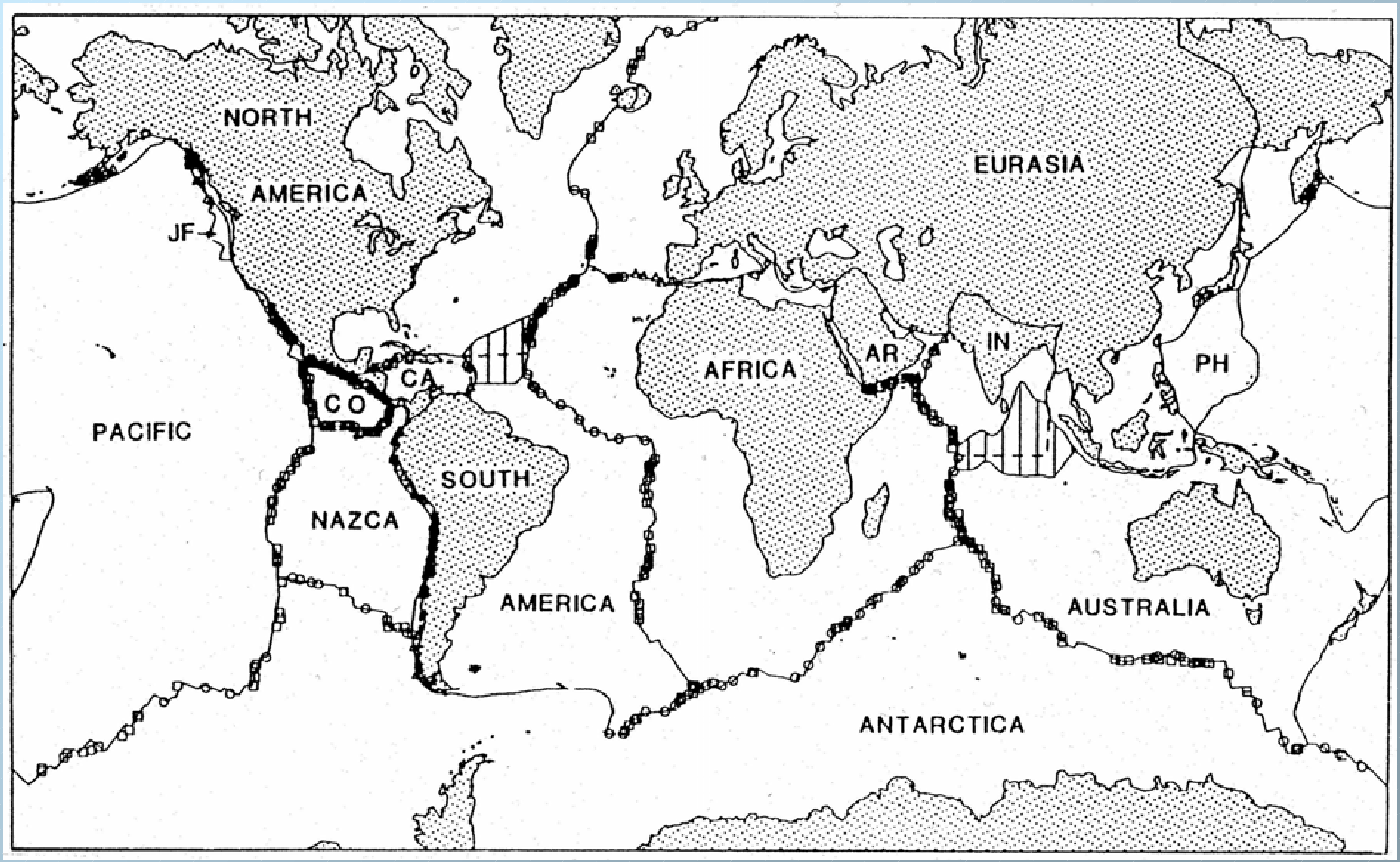
Motivation and Objectives

- The kinematic reference (condition of „no net rotation“ for point velocities) of the latest ITRF realizations is based on the geophysical NNR NUVEL-1A plate model.
- Major shortcomings of NNR NUVEL-1A are:
  - the velocities represent the average over 3 million years and are not identical with present-day motions;
  - the entire surface of the Earth is assumed to be covered by rigid plates, excluding intra-plate and inter-plate deformations.
- If NNR NUVEL-1A fulfils the „no net rotation“ condition without the deformation zones, it cannot fulfil it, too, when including them.
- The recent geophysical plate model PB2002 (Bird 2003) includes rigid plates and deformation zones. It shall be tested whether it can be used as the ITRF kinematic reference.

DGFI

NNR NUVEL-1A Plate Model (DeMets et al. 1994)

12 adjusted plate rotation vectors, vectors of 2 plates added



Deformation Zones (Gordon 1995)

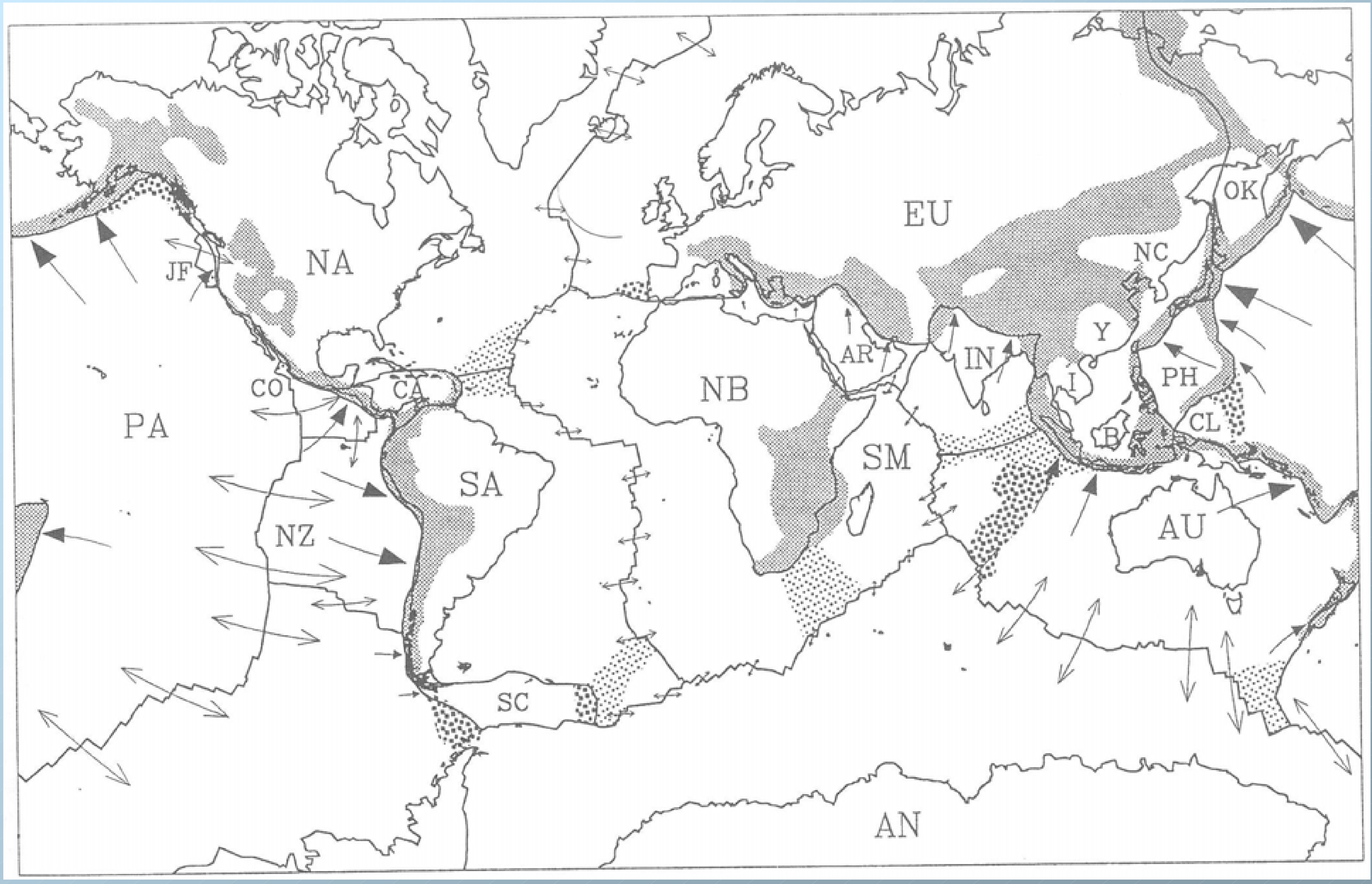
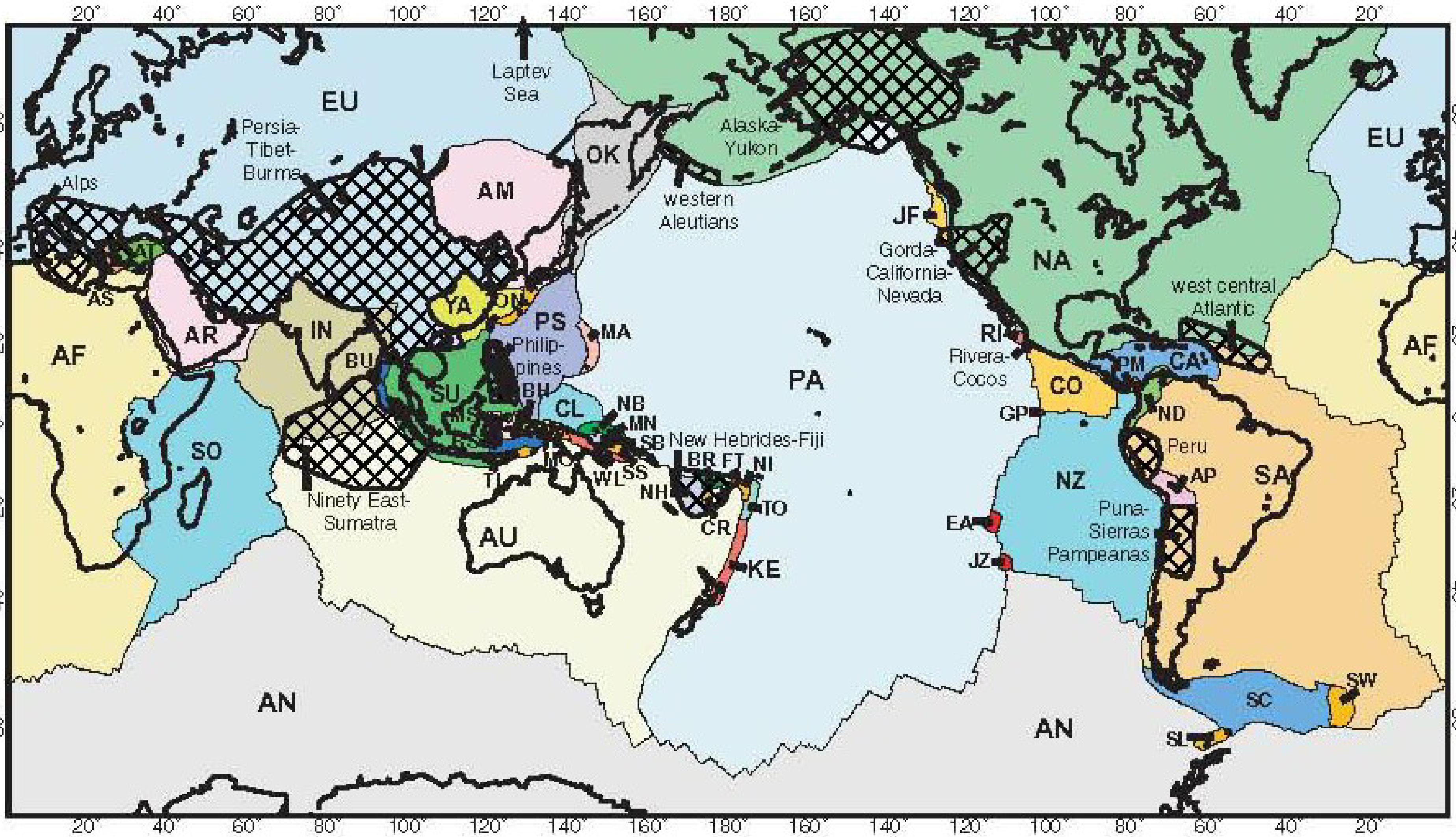
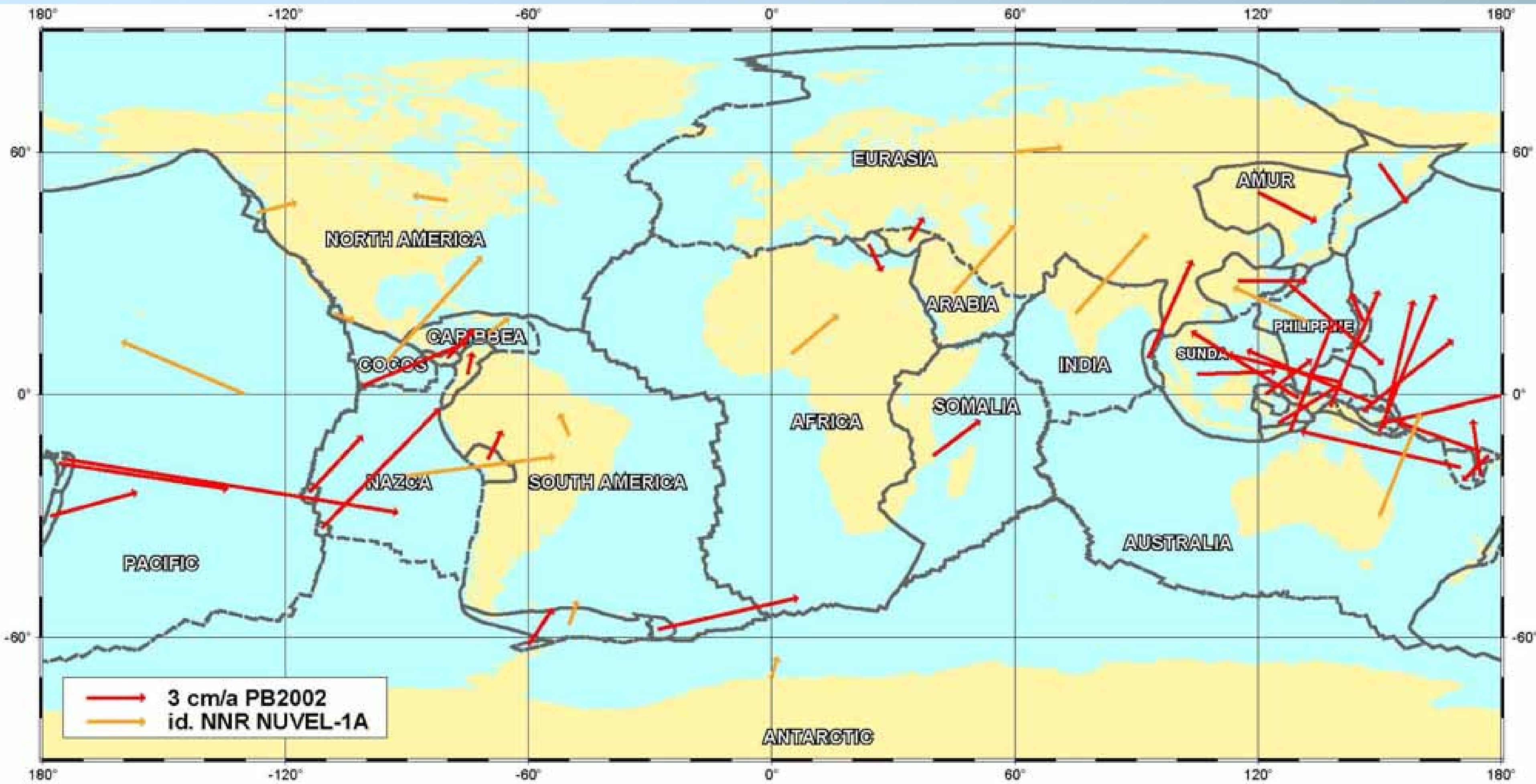


Plate Model PB2002 (Peter Bird 2003)



52 Plates, 13 Orogenes (Deformation Zones)

PB2002 Model Velocities



10 rotation vectors identical with NNR NUVEL-1A (De Mets et al. 1994)

Geodetic Input Data for Estimating the Plate Rotation Vectors (Actual Plate Kinematic Model, APKIM2004P)

Techn.	Time Span	Stations	Characteristics
GPS	1996 – 2004	227	Combined weekly solutions from IGS (official input for ITRF2004)
SLR	1985 – 2004	38	Weekly normal equations from DGFI (input to ILRS for ITRF2004)
VLBI	1984 – 2004	39	Sessions‘ normal equations from DGFI (input to IVS for ITRF2004)
DORIS	1993 – 2004	74	Weekly solutions from IGN (input to IDS for ITRF2004)
Total		378	Station occupations on rigid plates

All solutions were transformed to the ITRF2000 datum

GPS, SLR, VLBI, DORIS Data for APKIM2004P

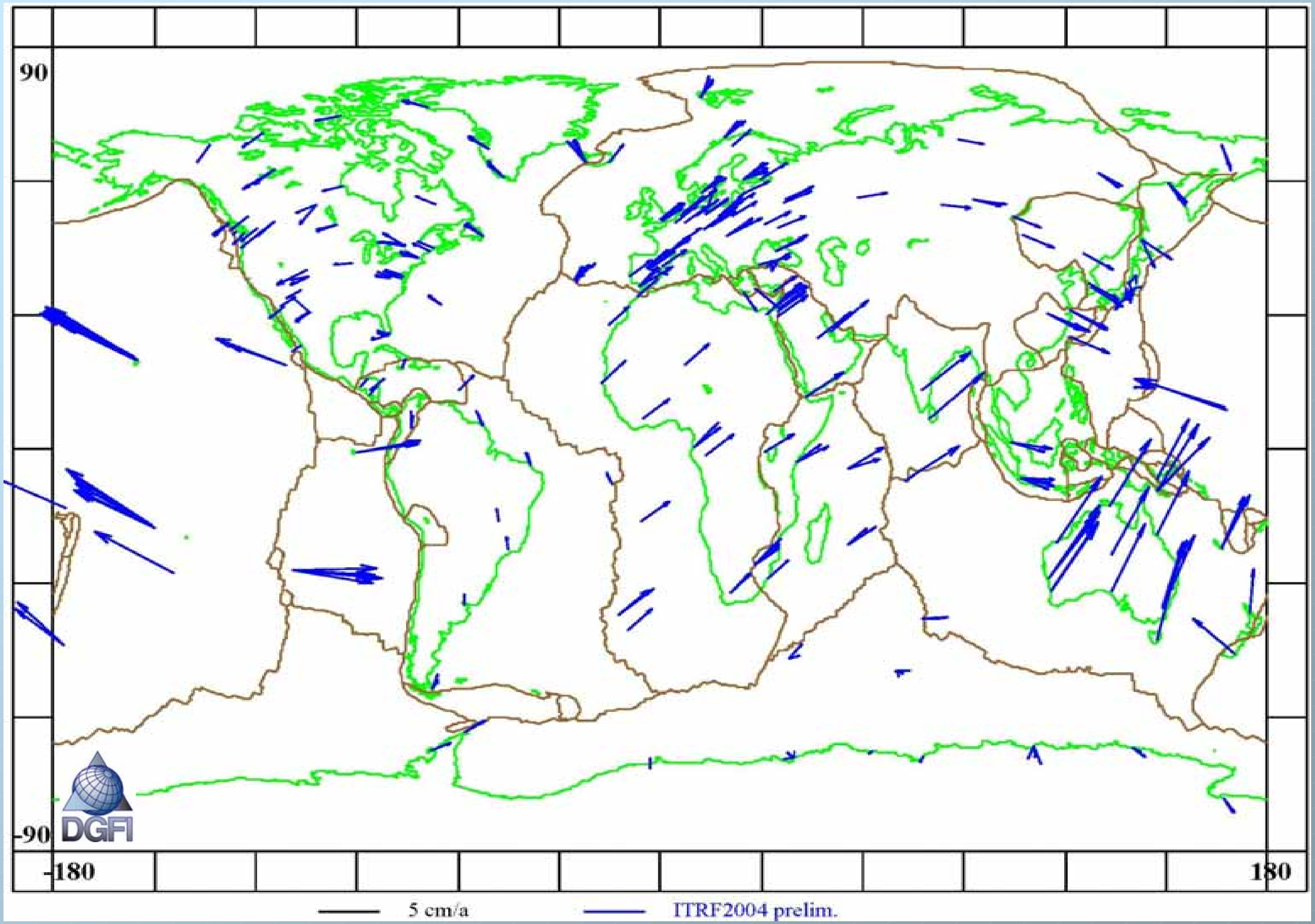
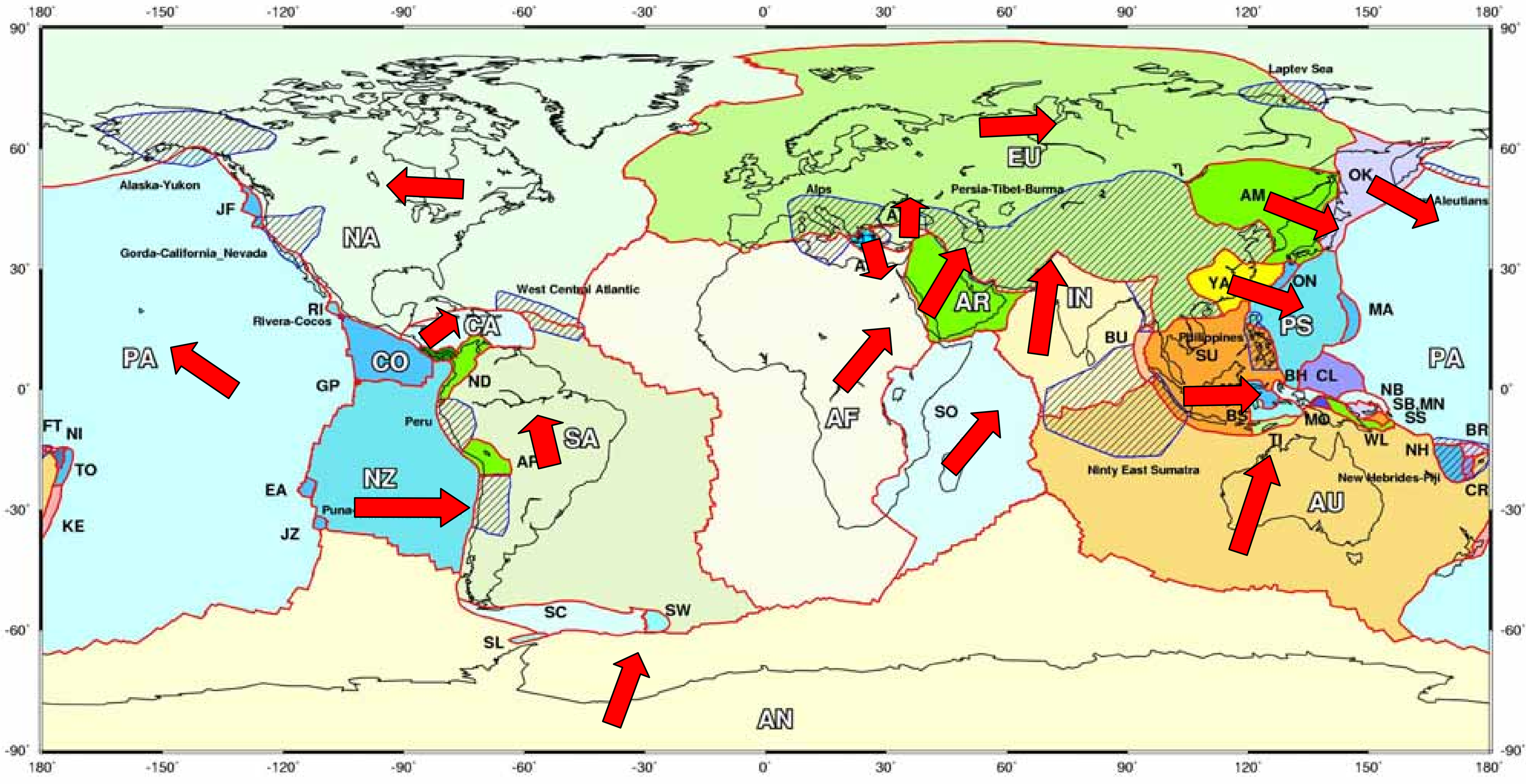


Plate Rotation Vectors Determinable from Present-Day Space Geodetic Observations



18 plates occupied by at least 2 geodetic stations of the global networks

Geodetic Modelling of Plate Rotations (APKIM)

Observation equation: $dx/dt = \Omega_i \times x_k + \Omega_D \times x_k + \Omega_G \times x_k$

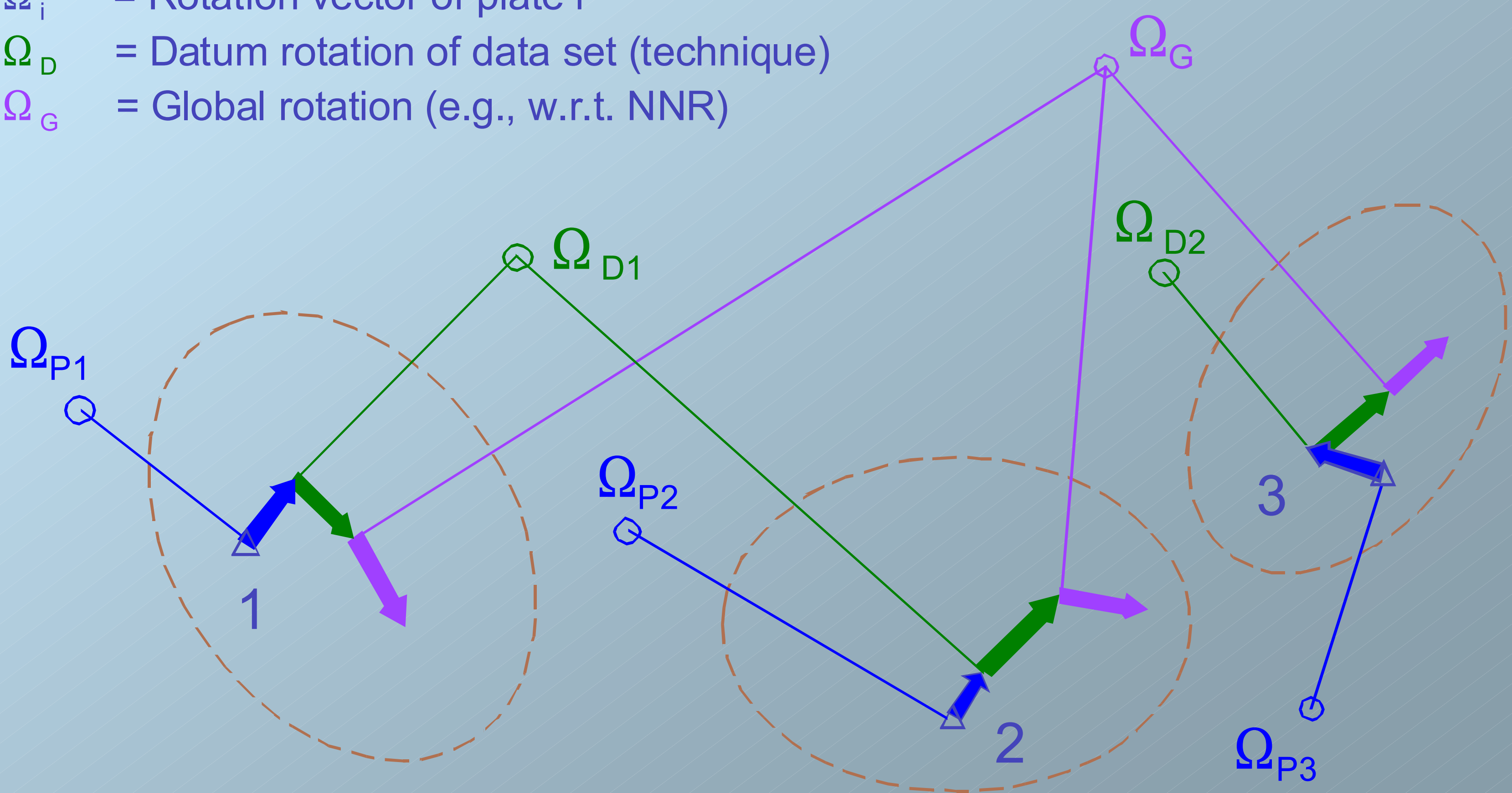
dx/dt = Velocity vector of station k

x_k = Position vector of station k

Ω_i = Rotation vector of plate i

Ω_D = Datum rotation of data set (technique)

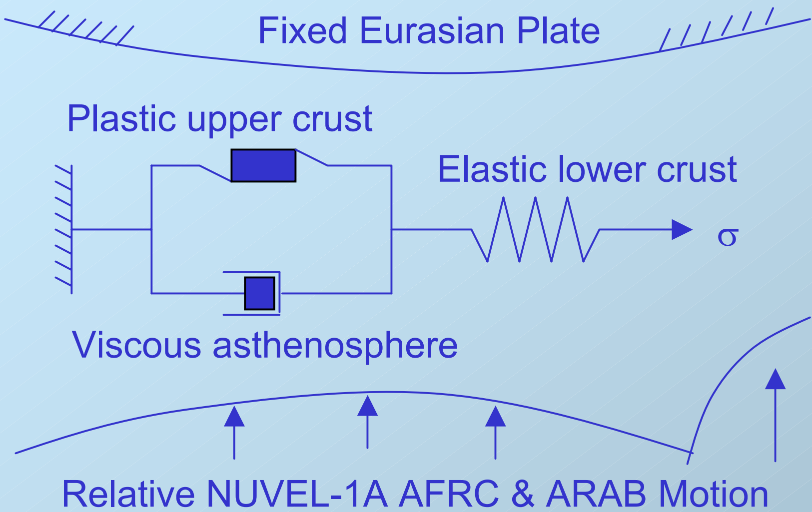
Ω_G = Global rotation (e.g., w.r.t. NNR)

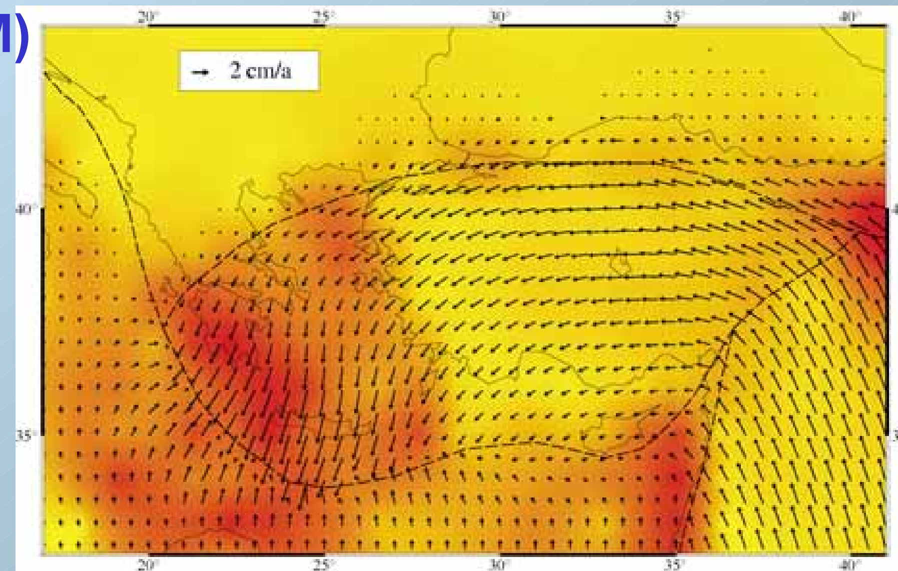


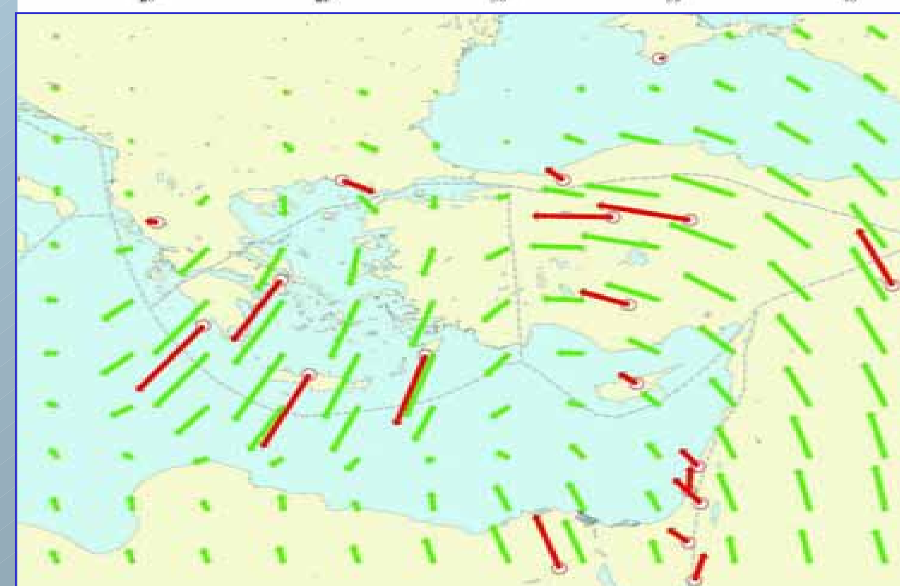
DGFI

Modelling of Crustal Deformation

Geophys. Finite Element Model (FEM)







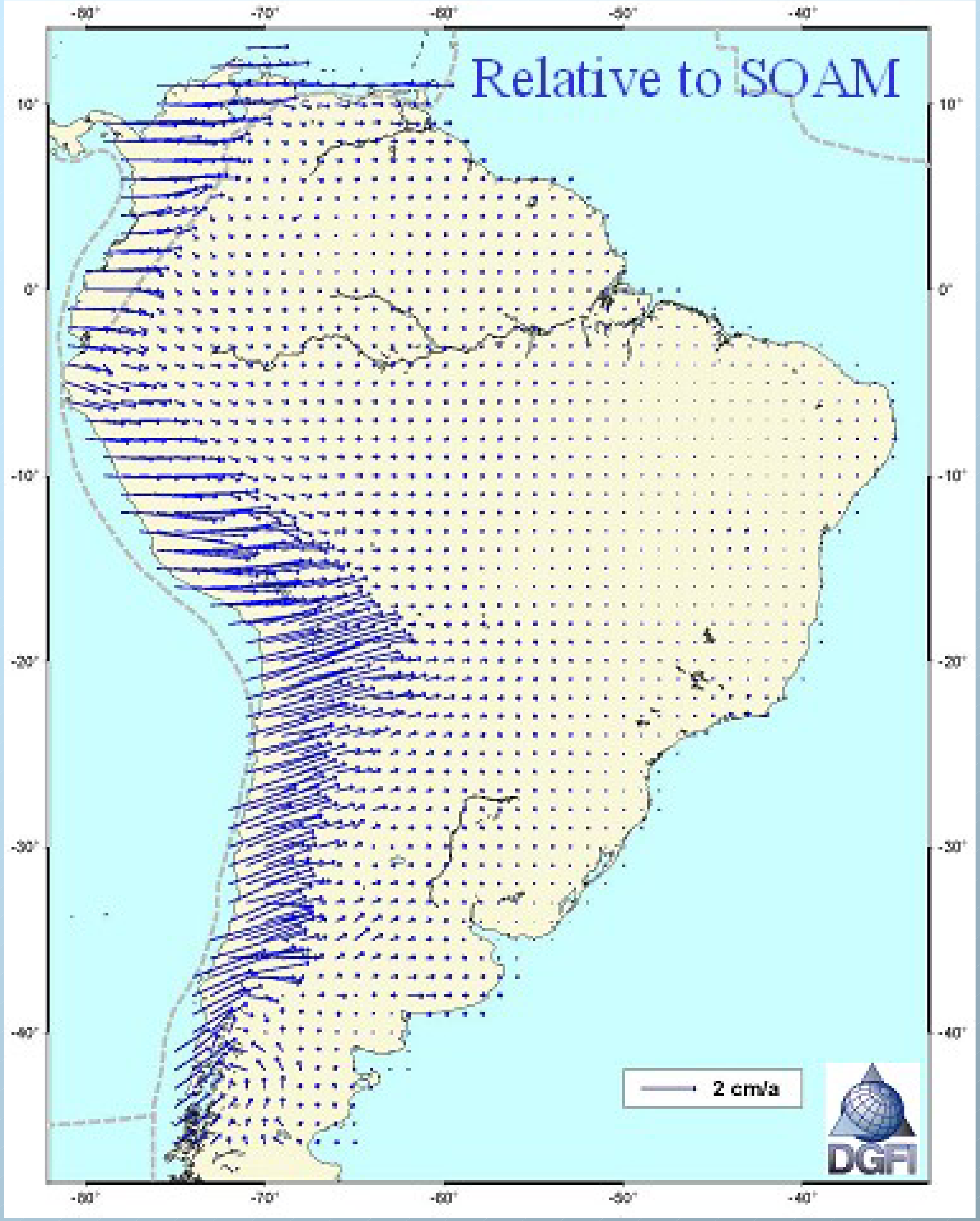
Least Squares Collocation (LSC)

$\underline{v}_{pred} = \underline{c}^T \, \underline{C}^{-1} \underline{v}_{obs}$

$\underline{v}$ = observed velocities

$\underline{C}$ = auto-covariance matrix of observed velocities

$\underline{c}$ = covariance matrix betw. observed and predicted



Combined FEM and LSC Model for SIRGAS

Input data:

SIRGAS 1995 ... 2000

IGS RNAAC-SIRGAS

CASA

SNAPP

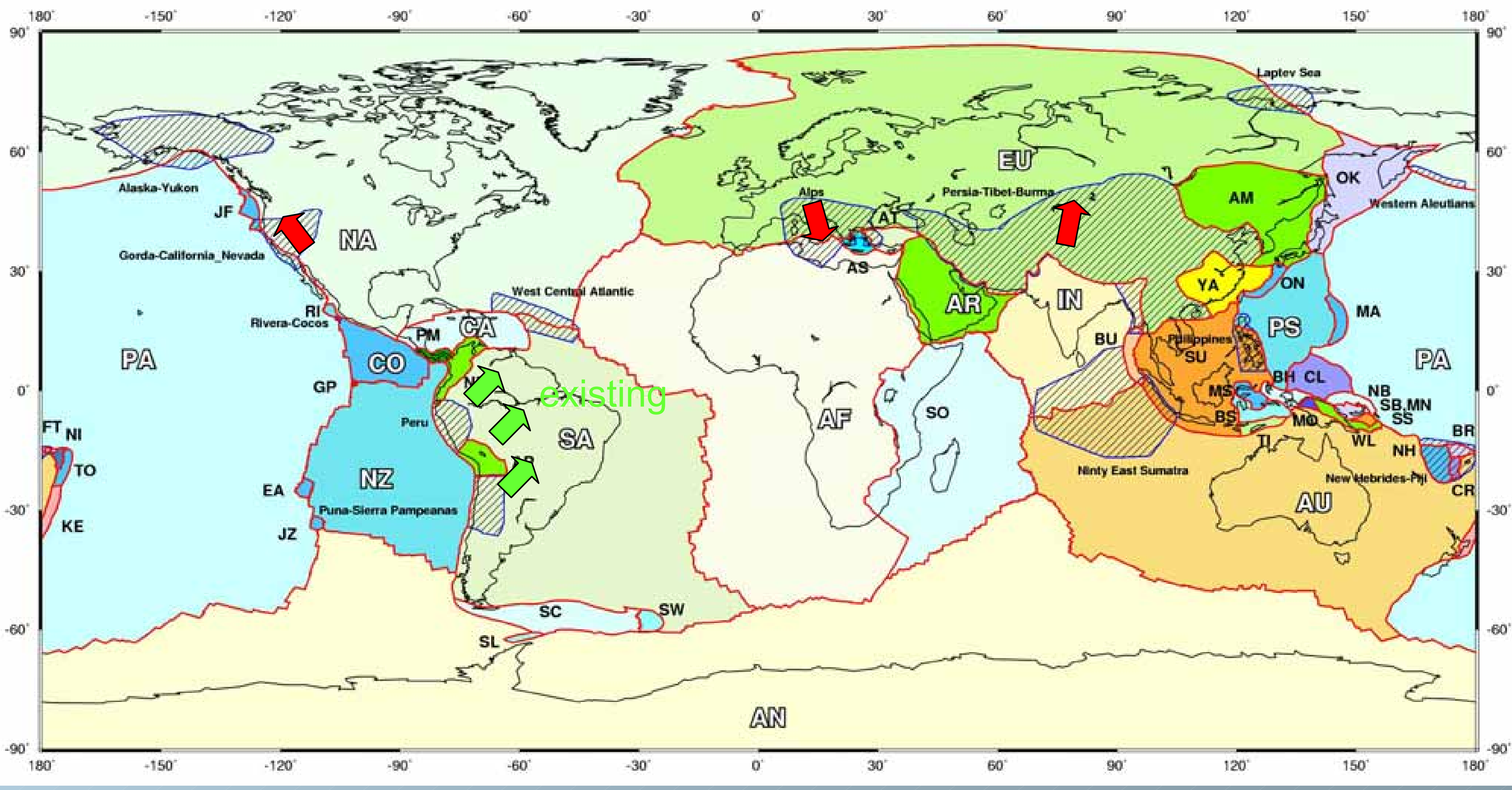
CAP

SAGA

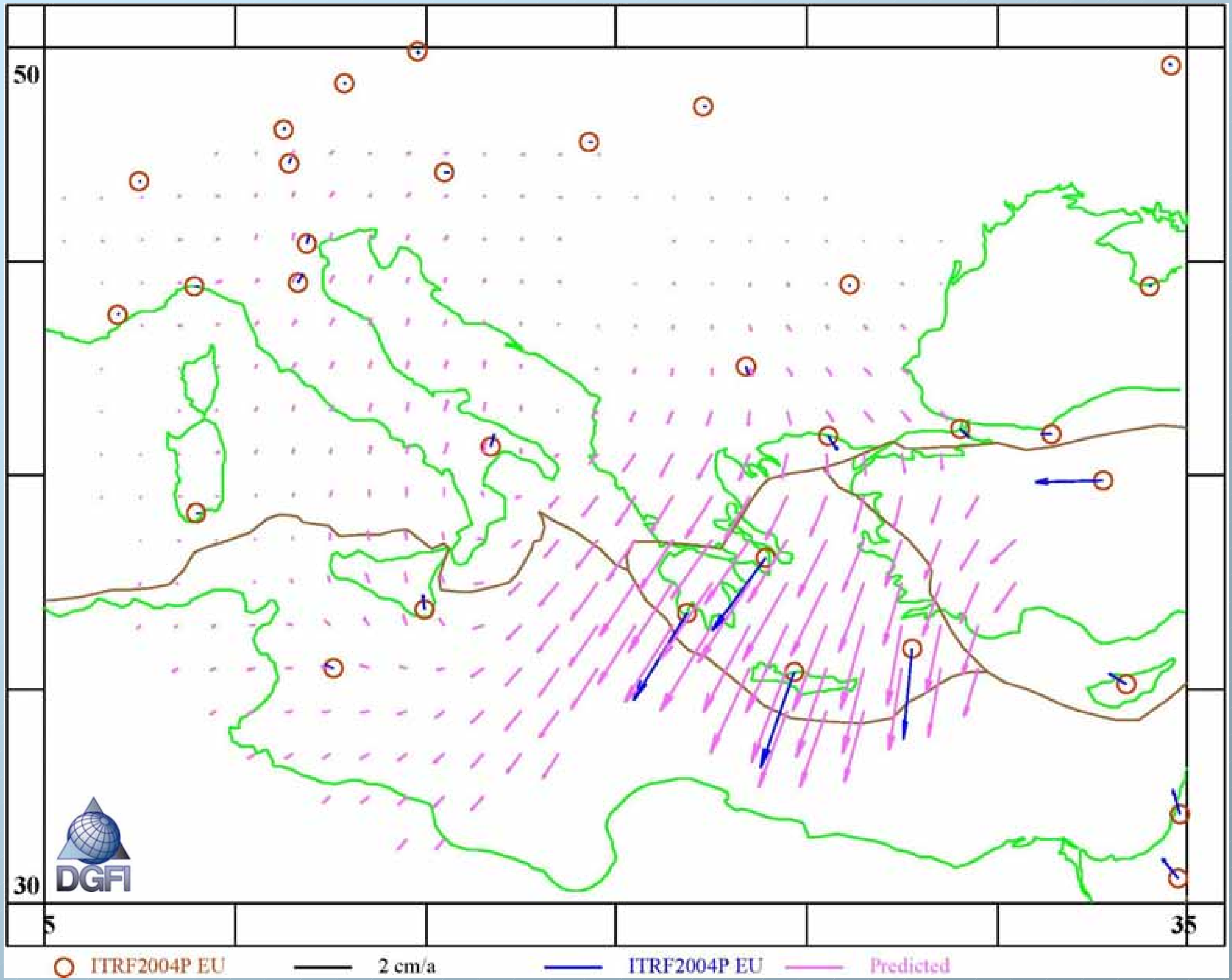
The deformation in the south-western part is not consistent with PB2002.

(Drewes and Heidbach, 2005)

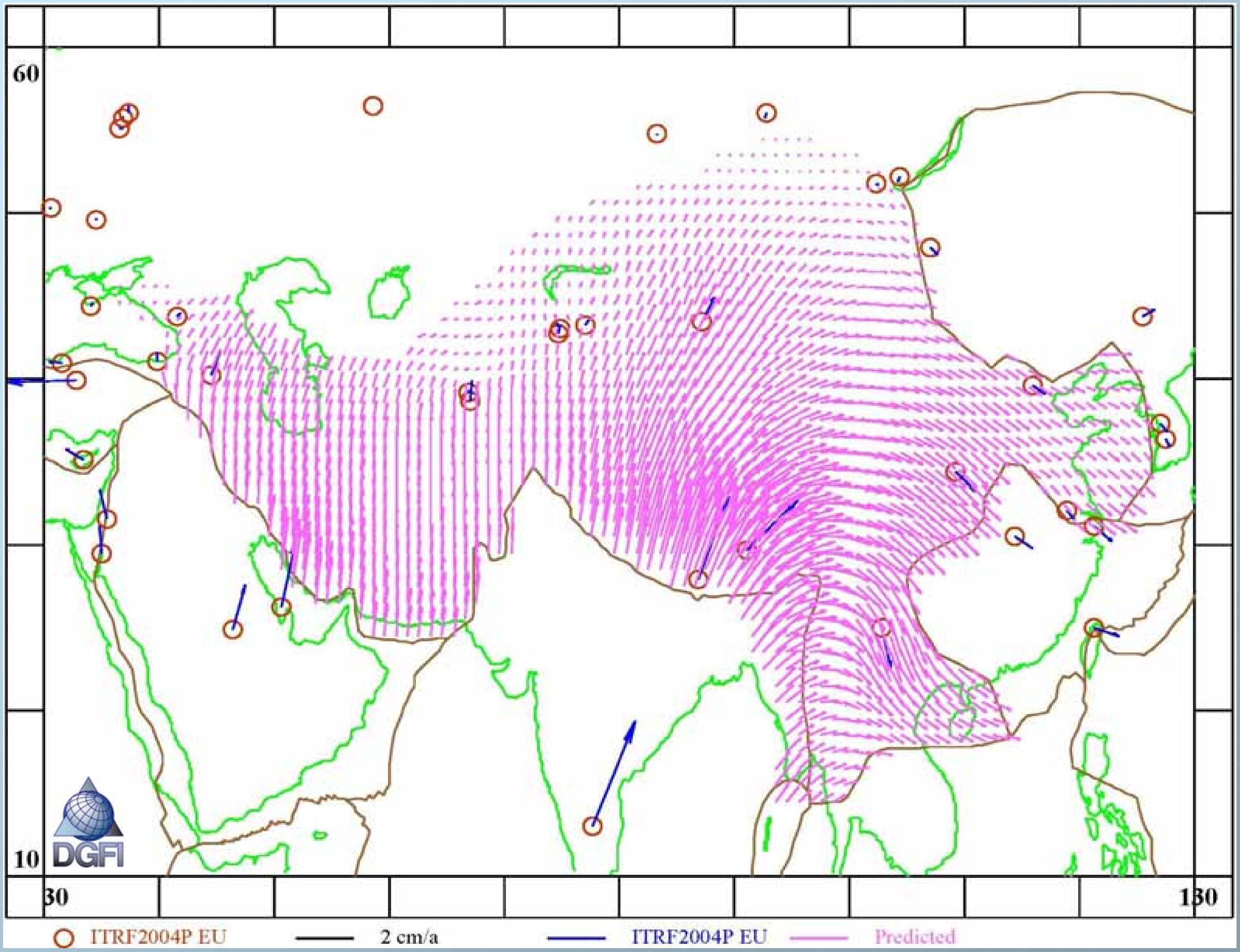
Modelled Deformation Zones of PB2002 in the Present Study



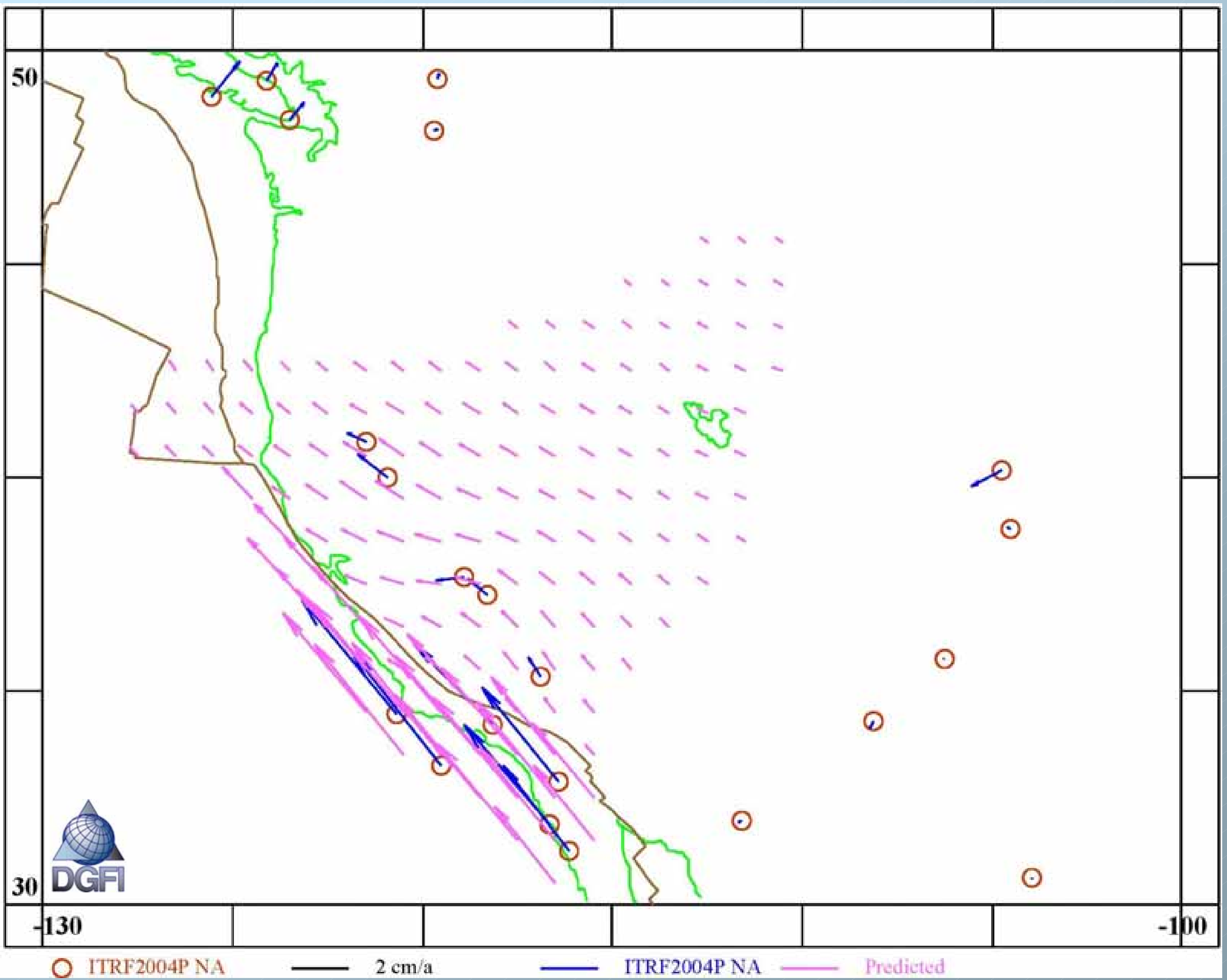
Deformation of Alps Orogene Using LSC



Deformation of Persia-Tibet-Burma from LSC



Deformation of Gorda-California-Nevada



Accomplishment of the NNR Condition

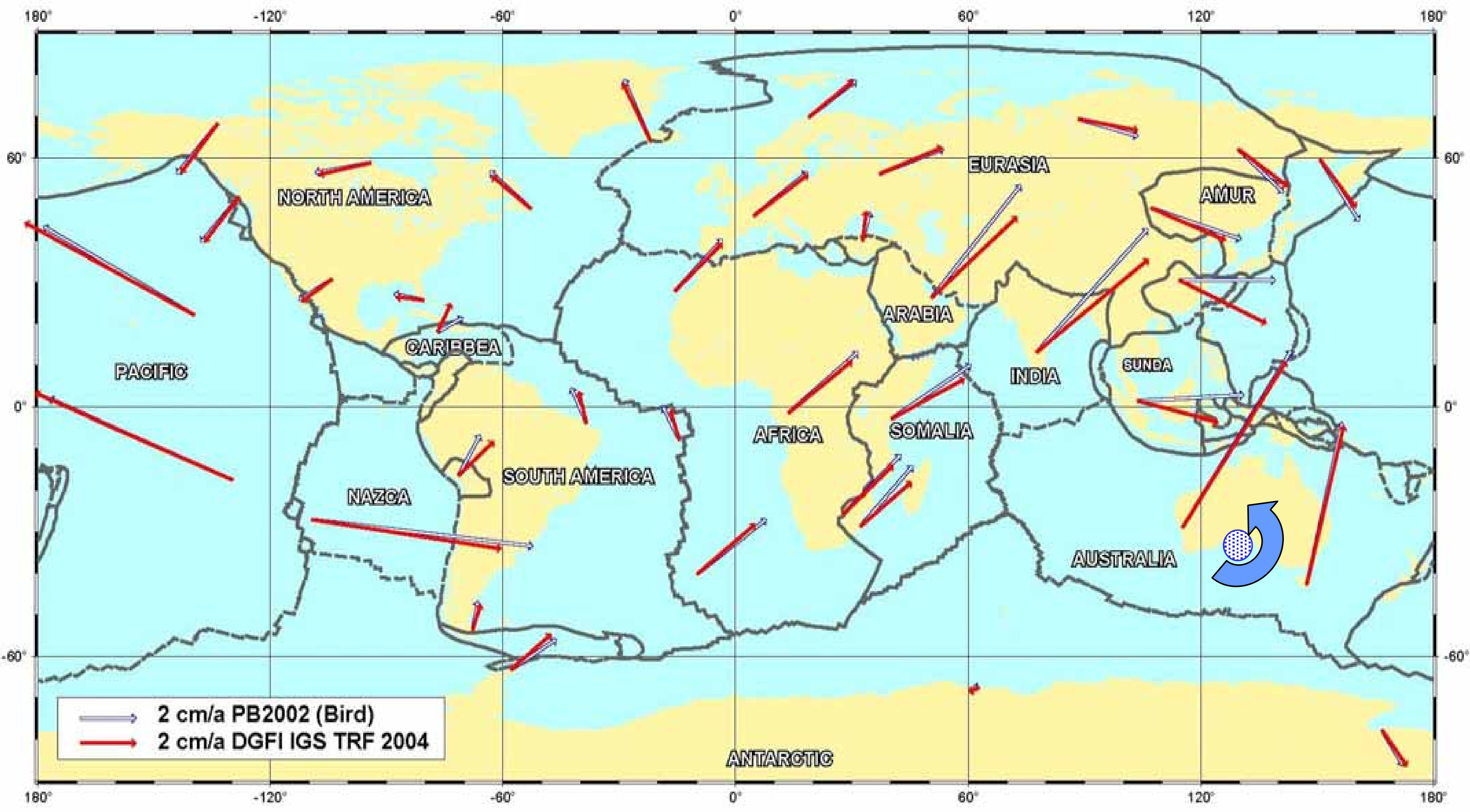
- An initial kinematic datum is arbitrarily chosen (here: IGS solution)
- Each element of a 1° × 1° grid of the Earth's surface is attributed to a plate or a deformation zone, respectively. The motion of the elements is computed from the plate rotations or the deformation model, respectively, in the initial datum.
- A common rotation vector of all grid elements is estimated by least squares adjustment with weights according to the size of the grid ($\cos \varphi$).
- The common rotation is subtracted from the individual rotations.

DGFI

APKIM2004P NNR and PB2002 Parameters

Plate Name	APKIM2004P NNR Phi [°]	Lambda [°]	Omega [°/Ma]	PB2002 Phi	Lambda	Omega
AF	51.2 ± 0.5	281.4 ± 1.7	0.276 ± 0.003*	50.6	286.1	0.291
AM	54.6 ± 6.1	255.0 ± 9.0	0.284 ± 0.011	44.3	261.6	0.308
AN	59.7 ± 0.7*	243.8 ± 1.4	0.238 ± 0.007	63.0	244.3	0.238
AR	50.8 ± 1.0*	5.9 ± 2.9*	0.577 ± 0.029	46.7	353.8	0.593
AT	40.4 ± 0.2	28.6 ± 0.3*	1.898 ± 0.081*	40.9	27.2	1.210
AU	33.3 ± 0.3	35.8 ± 0.6*	0.615 ± 0.003*	33.9	33.2	0.646
CA	30.8 ± 2.4	254.3 ± 6.9	0.192 ± 0.028*	34.0	272.4	0.291
EU	55.4 ± 0.6*	259.1 ± 0.6*	0.256 ± 0.002*	50.6	247.7	0.234
IN	52.5 ± 0.5*	6.8 ± 2.0*	0.514 ± 0.004*	45.5	0.3	0.545
NA	0.1 ± 0.8	278.8 ± 0.5*	0.204 ± 0.002	-2.4	274.1	0.207
NZ	45.6 ± 1.6	262.3 ± 1.0	0.658 ± 0.014*	47.8	259.9	0.743
OK	-37.1 ± 0.6*	305.0 ± 1.6*	0.455 ± 0.034*	31.8	262.3	0.236
PA	-65.1 ± 0.4*	109.3 ± 1.6	0.664 ± 0.004*	-63.0	107.3	0.641
SA	-12.0 ± 2.9*	244.0 ± 4.4	0.104 ± 0.003*	-25.3	235.6	0.116
SO	55.0 ± 1.2*	270.4 ± 2.3	0.310 ± 0.006*	49.8	266.7	0.348
SU	37.2 ± 5.5	274.7 ± 2.4*	0.434 ± 0.063	45.2	286.8	0.476
YA	66.2 ± 2.3	231.2 ±30.1	0.344 ± 0.038	66.8	209.5	0.393

Comparison APKIM2004P and PB2002



Ω (ITRF2000) w.r.t. NNR: 0.02 °/ Ma ≈ 2 mm/a at equator of rotation

Conclusions

- The presented study is a preliminary result for testing the suitability of PB2002 for geodetic modelling.
- The rotation vectors of 18 lithospheric plates can be estimated from geodetic observations. Most of them differ significantly from the geophysical PB2002 / NNR NUVEL-1A models.
- The kinematics of the major deformation zones (orogenes) can be modelled from the global data, too.
- The PB2002 model may serve as a geometric basis for solving the NNR condition of the kinematic reference frame of ITRF.
- For aligning the ITRF to the plate motion model, only stations situated on plates should be considered (no deformation zones).

Thank you!