A model of present-day tectonic plate motions from 12 years of DORIS measurements

L. Soudarin[1], J.F. Crétaux[2]

[1] *CLS, Collecte Localisation Satellites, Ramonville, France*
[2] *LEGOS/GRGS, Toulouse, France*

Submitted to Journal of Geodesy –DORIS special issue

Summary

1. Introduction
2. Velocity determination
3. Horizontal motions
4. Plate motion model
5. Somalia/Africa plate pair
6. Azores Triple Junction
7. Conclusion

Summary

1. Introduction
2. Velocity determination
3. Horizontal motions
4. Plate motion model
5. Somalia/Africa plate pair
6. Azores Triple Junction
7. Conclusion

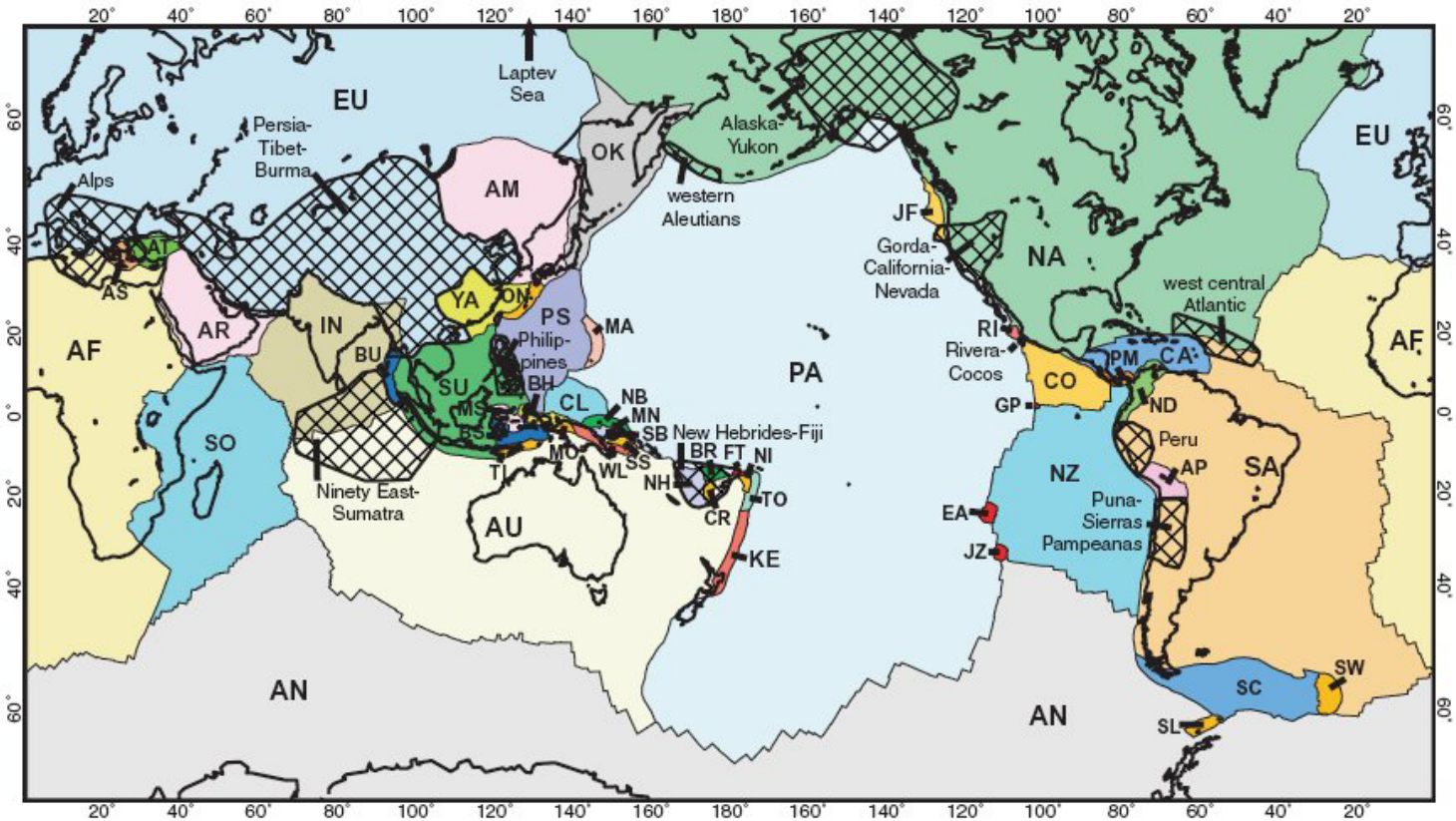
Objective

Current DORIS solution for horizontal motion of 57 DORIS sites, over 1993-2004

Compare to our previous model in Crétaux et al. 1998:

- Time interval arises from 4 to 12 years
- Number of sites increases from 45 to 57

The PB2002 model of plate boundaries (Bird, 2003)



- 52 plates: 14 large plates (NUVEL-1A) and 38 small plates
- 13 « orogens » (cross-hatched areas) i.e. regions of mountain-formation, or at least topographic roughening. In orogens, an Eulerian plate model is no expected to be accurate

Summary

1. Introduction
2. Velocity determination
3. Horizontal motions
4. Plate motion model
5. Somalia/Africa plate pair
6. Azores Triple Junction
7. Conclusion

DORIS data analyzed

12 years of DORIS observations: Jan. 1993 – Dec. 2004

SPOT-2 (Jan. 1993 - Dec. 2004)
SPOT-3 (Nov. 1993 - Nov. 1996)
SPOT-4 (from May 1998)
SPOT-5 (from June 2002)
TOPEX/Poseidon (until Oct. 2004)
Envisat (from Jul. 2002)

Computation strategy (1)

Construction of the multiyear multi-satellite matrix from the monthly multi-satellite matrices

1. In the monthly matrices, a different name is given to the stations before and after breaks, and during spurious periods according to the lists of breaks and periods to delete from the “IDS recommendations for ITRF2004” (http://ids.cls.fr/html/report/IDS_for_ITRF2004_v1_0.pdf),

2. Combination of the monthly multi-satellite matrices

3. DORIS-DORIS geodetic local ties added with associated uncertainties as provided by the IGN/SIMB.

Computation strategy (2)

4. Velocity constrains added for sites occupied by 2 or 3 stations successively in time (i.e. antenna position different on successive periods), or where a break in the time series is observed (assuming that the velocity is the same before and after), in order to obtain only one motion vector for each site.

- Solution for the stations coordinates and velocities obtained by inversion of the global matrix, assuming purely linear variation in time, and using minimal constrains to express the coordinate and velocity sets into ITRF2000

Summary

1. Introduction
2. Velocity determination
3. Horizontal motions
4. Plate motion model
5. Somalia/Africa plate pair
6. Azores Triple Junction
7. Conclusion

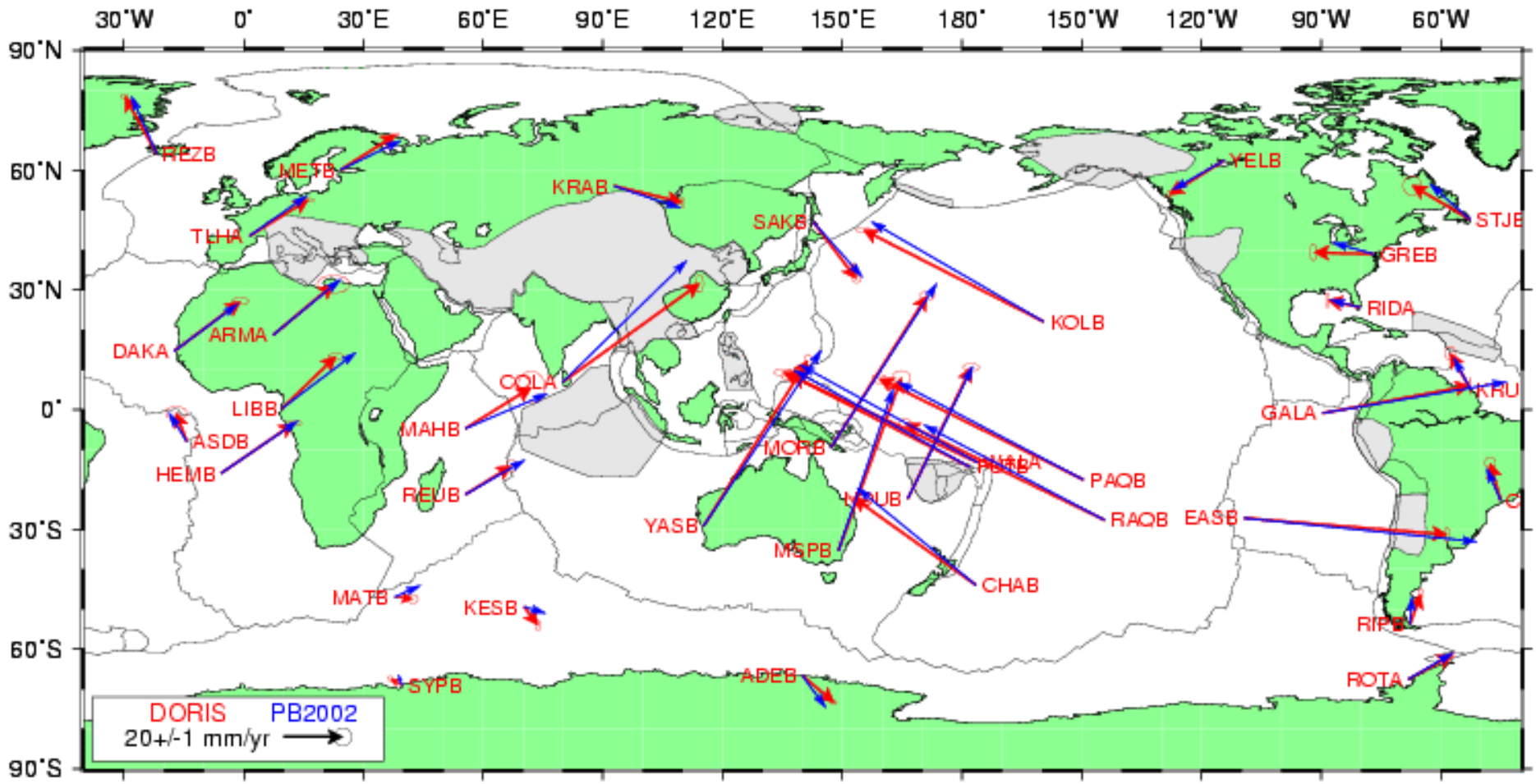
Horizontal motions

We present the horizontal motions of 57 sites with at least 4 years of observations (except Mahe, 2nd site of the Somalia plate, start in June 2001)

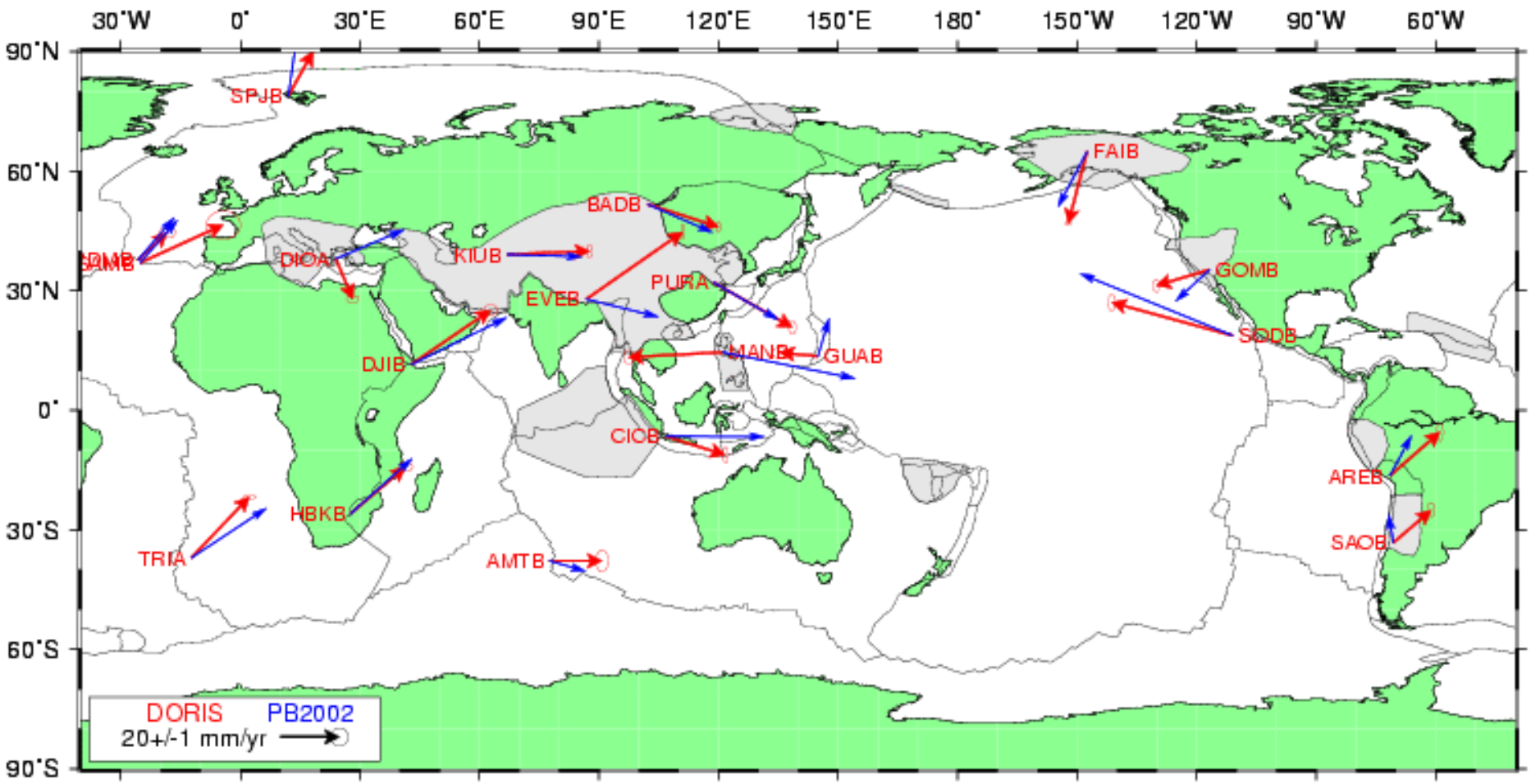
- 37 assumed to be located in stable plate interiors

- 20 in active deformations zones, close to plate boundaries or in « orogens »

Sites in stable plate interiors



Sites in deformation zones



Summary

1. Introduction
2. Velocity determination
3. Horizontal motions
4. Plate motion model
5. Somalia/Africa plate pair
6. Azores Triple Junction
7. Conclusion

LCAVEL-1

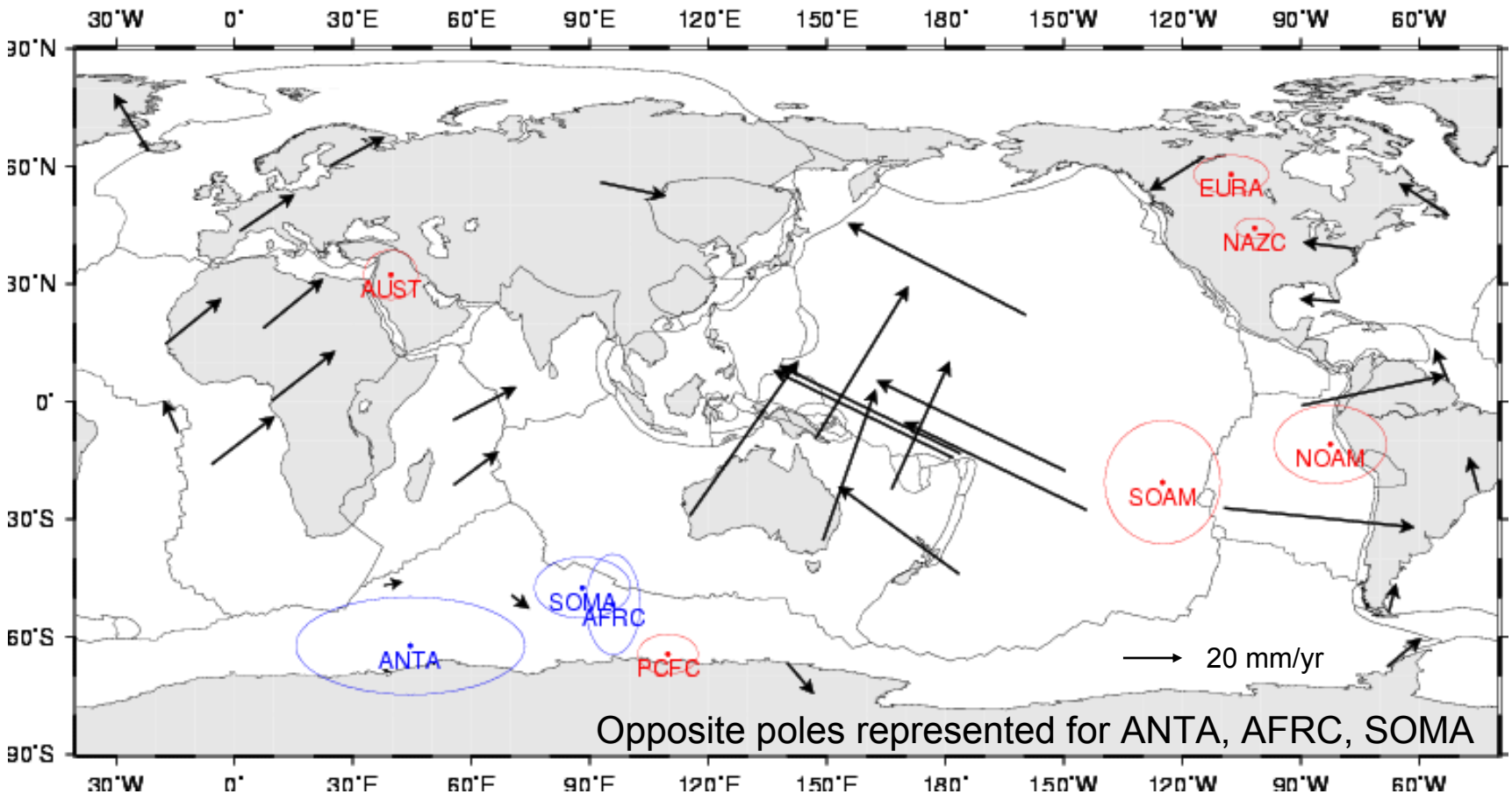
•Model of motion for 9 plates
•35 sites selected:

Africa = Nubia (AFRC) 4 | Antarctica (ANTA) 5 | Australia (AUST) 4
Eurasia (EURA) 3 | Nazca (NAZC) 2 | North-America (NOAM) 5
Pacific (PCFC) 6 | South-America (SOAM) 4 | Somalia (SOMA) 2

plate	ωx	ωy	ωz
AFRC	0.016 ± 0.024	-0.157 ± 0.007	0.200 ± 0.007
ANTA	-0.071 ± 0.007	-0.070 ± 0.007	0.190 ± 0.013
AUST	0.394 ± 0.011	0.326 ± 0.009	0.324 ± 0.008
EURA	-0.038 ± 0.010	-0.119 ± 0.009	0.200 ± 0.014
NAZC	-0.093 ± 0.010	-0.451 ± 0.027	0.449 ± 0.011
NOAM	0.027 ± 0.007	-0.203 ± 0.008	-0.039 ± 0.010
PCFC	-0.099 ± 0.011	0.276 ± 0.006	-0.612 ± 0.006
SOAM	-0.063 ± 0.010	-0.090 ± 0.009	-0.041 ± 0.008
SOMA	-0.006 ± 0.012	-0.197 ± 0.017	0.215 ± 0.011

Plate rotation vectors of the LCAVEL-1 model. Units are deg/Myr

Poles of rotation and predicted velocities



Differences Obs. – Mod. Velocities < 4.6 mm/yr mean= 2.5 mm/yr

Larger differences for the Antartica's stations

Comparison to other models

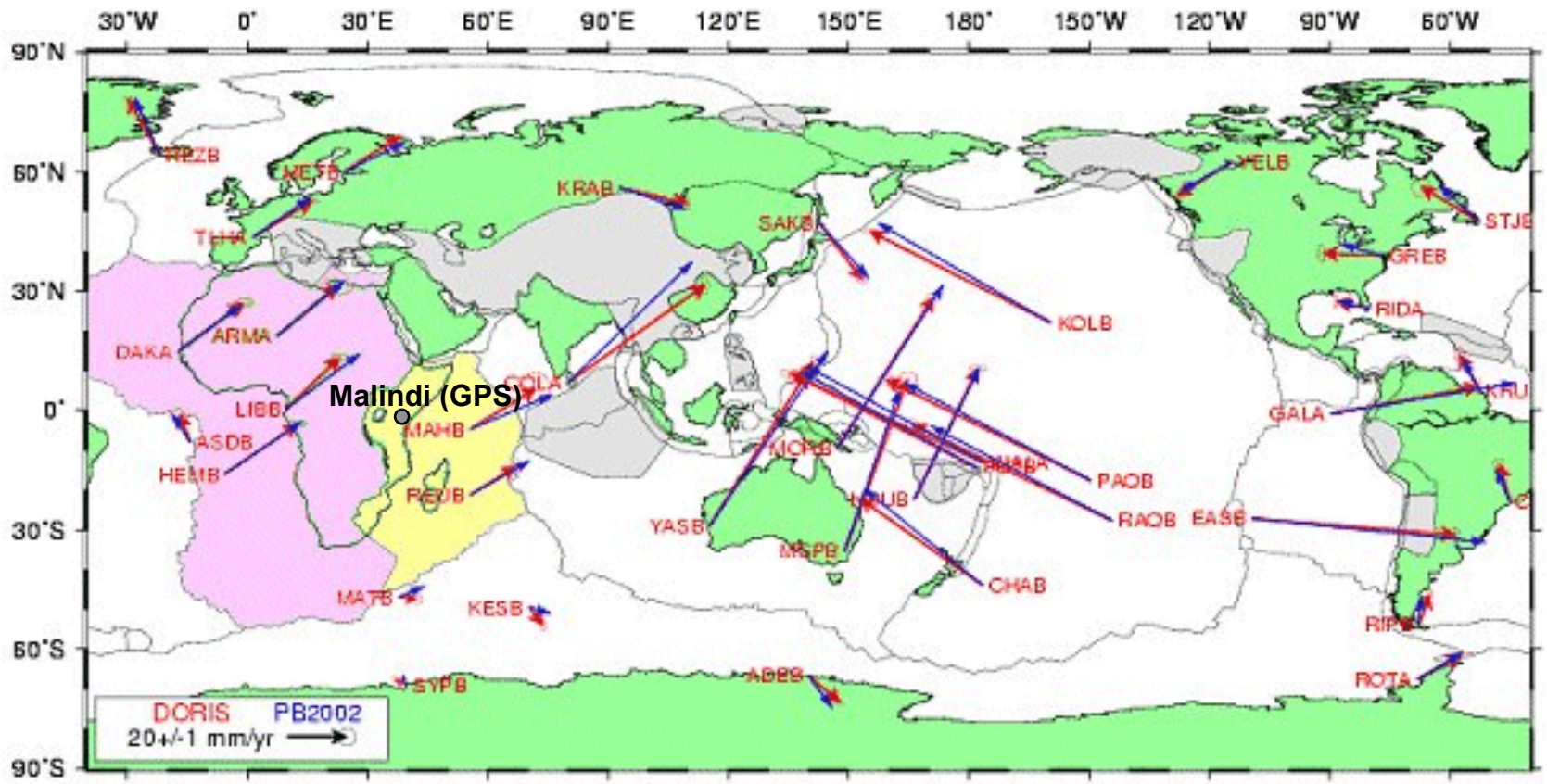
	LCAVEL			PB2002			REVEL			GSRM-1			APKIM2000		
plate	Lat °N	Lon °E	rate °/Myr	lat °N	lon °E	rate °/Myr	lat °N	lon °E	rate °/Myr	lat °N	lon °E	rate °/Myr	lat °N	lon °E	rate °/Myr
AFRC	61,12	-75,10	0,927	59,16	-73,17	0,927	61,03	-71,80	0,903	61,09	-75,99	0,939	61,68	-76,72	0,922
ANTA	66,61	-85,41	0,875	64,32	-83,98	0,870	65,96	-85,38	0,857	65,77	-87,28	0,881	66,75	-87,86	0,886
AUST	62,09	5,83	1,060	60,08	1,74	1,074	61,39	6,19	1,080	62,24	4,31	1,063	62,59	4,96	1,067
EURA	63,79	-81,18	0,905	61,07	-85,82	0,859	63,49	-78,33	0,903	62,78	-82,68	0,923	63,60	-80,89	0,912
NAZC	55,58	-89,52	1,286	55,58	-90,10	1,360	55,41	-87,29	1,267	55,19	-89,55	1,272	55,68	-88,09	1,273
NOAM	49,13	-75,29	0,758	48,71	-78,17	0,749	50,38	-72,11	0,755	50,78	-77,88	0,768	51,25	-75,53	0,756
SOAM	57,21	-84,38	0,679	55,00	-85,75	0,637	58,54	-82,70	0,637	57,10	-86,94	0,667	59,53	-85,37	0,654
SOMA	59,78	-78,90	0,957	58,79	-81,64	0,978	61,82	-80,62	0,952	62,70	-70,52	0,929	60,24	-81,06	0,937

- Discrepancies less than 4.5 deg in lat., 11 deg in lon., 0.06 °/Myr in rate except for Somalia
- Largest differences of rotation rates for Antarctica (0.02 °/Myr) and South-America (0.03 °/Myr)
- Predicted velocities agree within 2-3 mm/yr on average with GSRM, REVEL, APKIM
- For NAZCA, slower motion than the geological model PB2002, as noted by GSRM, REVEL, APKIM and other models (Angerman et al. 1999; Norabuena et al. 1999)

Summary

1. Introduction
2. Velocity determination
3. Horizontal motions
4. Plate motion model
5. Somalia/Africa plate pair
6. Azores Triple Junction
7. Conclusion

SOMA/AFRC (1)


30°W
0°
30°E
60°E
90°E
120°E
150°E
180°
150°W
120°W
90°W
60°W
90°N
60°N
30°N
0°
30°S
60°S
90°S
KRAB
SAKB
KOLB
HELB
STJB
GREB
RIDA
KRU
GALA
DAKA
ARMA
LIBB
ASDB
HEMB
MAHB
COLA
NOVB
PAOB
RAOB
EASB
YASB
MSPB
CHAB
MATB
KESB
SYPB
ADEB
ROTA
Malindi (GPS)
DORIS
PB2002
20+/-1 mm/yr

SOMA/AFRC (2)

model	Lat. (°N)	Long. (°E)	ω (°Myr^{-1})
LCAVEL-1	-18.10	60.75	0.048
With MALI (GPS)	-10.45	66.06	0.043
APKIM2000	-2.95	50.35	0.044
GSRM-1	-23.3	21.9	0.028
REVEL	-35.49	24.02	0.085
Jestin et al. 1994	-55.73	19.76	0.052
Chu et Gordon 1999	-27.3	36.2	0.089

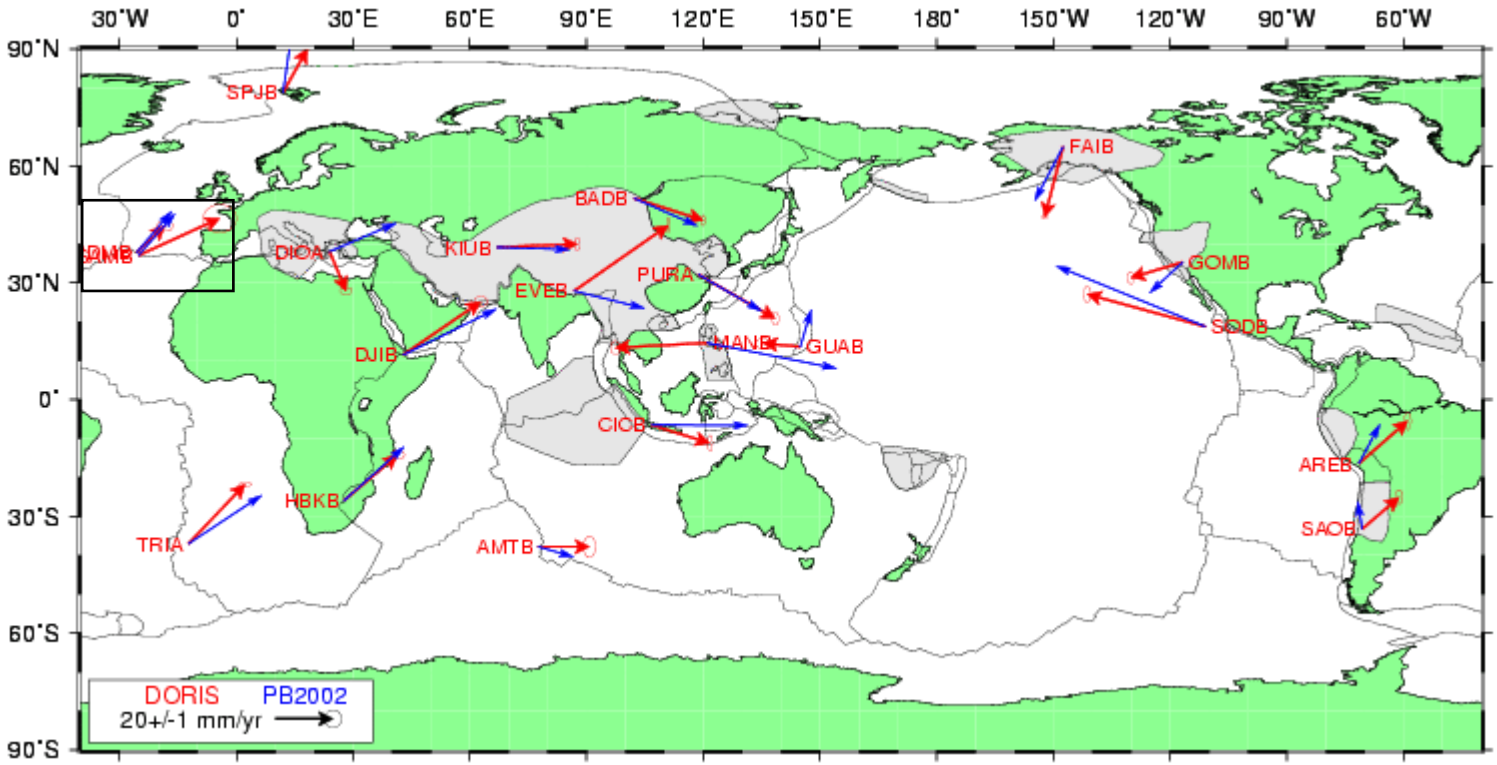
- Angular velocities from LCAVEL, LCAVEL+Malindi, APKIM agree with Jestin et al. 1994 (geological data): 0.04 - 0.05°/Myr
- Longitude: LCAVEL and APKIM coherent within 10°
- Latitude: LCAVEL, GSRM, Chu and Gordon 1999 coherent within 10°

→ Africa and Somalia move independently with a slow relative angular velocity of 0.05 to 0.09 °/Myr.

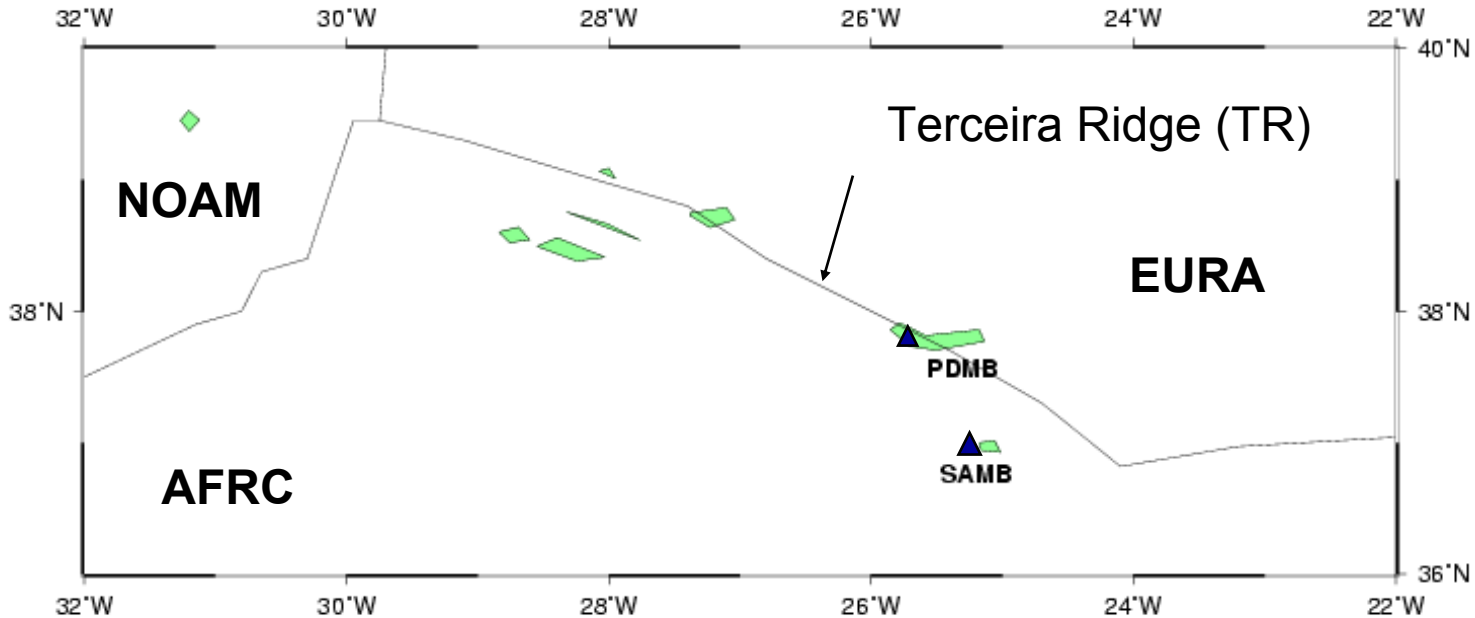
Summary

1. Introduction
2. Velocity determination
3. Horizontal motions
4. Plate motion model
5. Somalia/Africa plate pair
6. Azores Triple Junction
7. Conclusion

Azores Triple Junction (1)



Azores Triple Junction (2)



Understanding of the dynamic of the Azores Triple Junction (ATJ) is difficult:

- Very slow sea floor spreding rates at the TR (< 1cm/yr)
- Nature and location of the TR still in debate

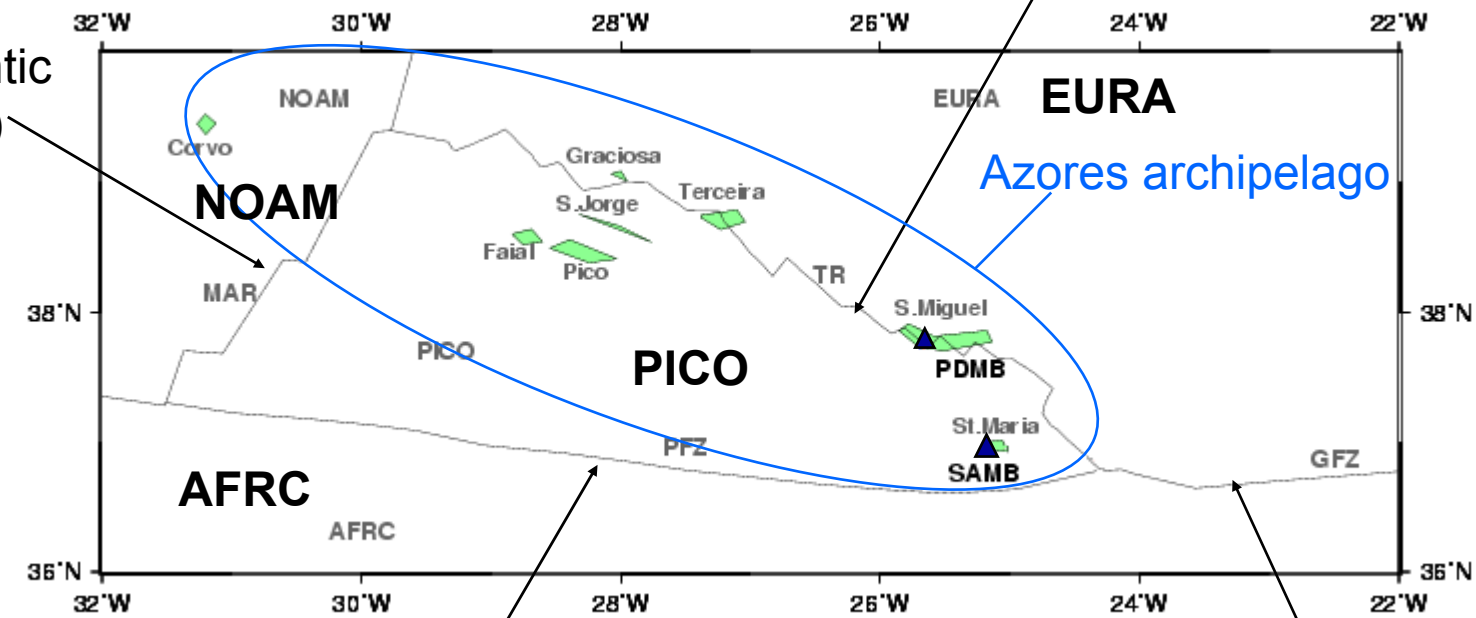
Other issue:

possible existence of a micro-plate (Pico)

Azores Triple Junction (3)

Terceira Ridge (TR)
(digital file from Matias et al. 2005)

Middle Atlantic
Ridge(MAR)

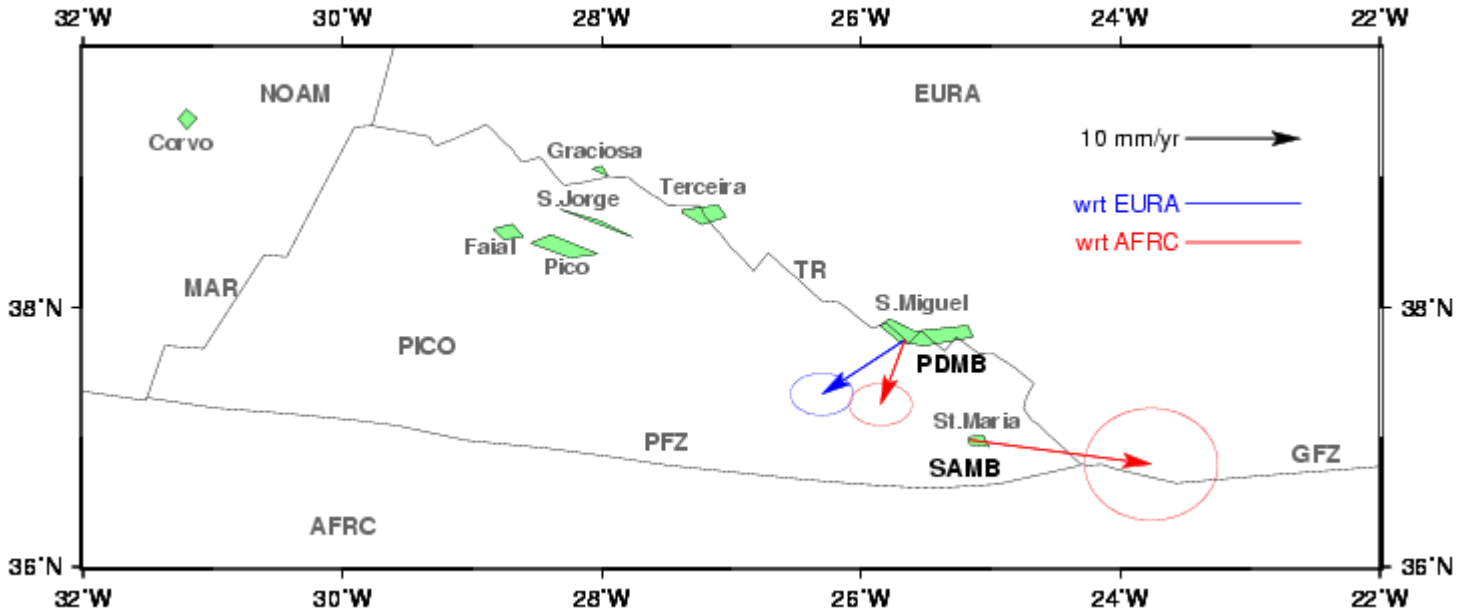


Pico Fracture Zone (PFZ)
or East Azores Fracture Zone
(digital file from Matias et al. 2005)

Gloria Fracture Zone (GFZ)

Azores Triple Junction (4)

DORIS velocities



Azores Triple Junction (5)

Punta Delgada :

7.9 mm/yr relative to Eurasia SW direction perpendicular to the ridge at the position of San Miguel Island

- Agreement with the opening rate of the TR (7.6 mm/yr according to Oliveira et al. 2004)

(TR near the Island of San Miguel presents volcanic activity and high seismicity - several big earthquakes over the last hundreds of years)

Santa Maria:

16.0 mm/yr relative to Africa Eastward

- Region south of TR could not be considered as stable part of the African plate.

  This corroborates the hypothesis of a micro-plate (PICO)

Summary

1. Introduction
2. Velocity determination
3. Horizontal motions
4. Plate motion model
5. Somalia/Africa plate pair
6. Azores Triple Junction
7. Conclusion

Conclusion

LCAVEL-1: plate motion model for 9 plates based on 12 years of DORIS observations

Precision of the DORIS velocities better than 3 mm/yr when compared with the model predictions.

A new pole of rotation for the Somalia plate is proposed

DORIS provides informations for the measurement of the dynamic of ATJ.

Perspectives for the next years: improvement expected with the new stations recently installed (Male on India plate, Crozet on Antarctica…)