

Latest efforts on new materialization of the Croatian terrestrial reference frame

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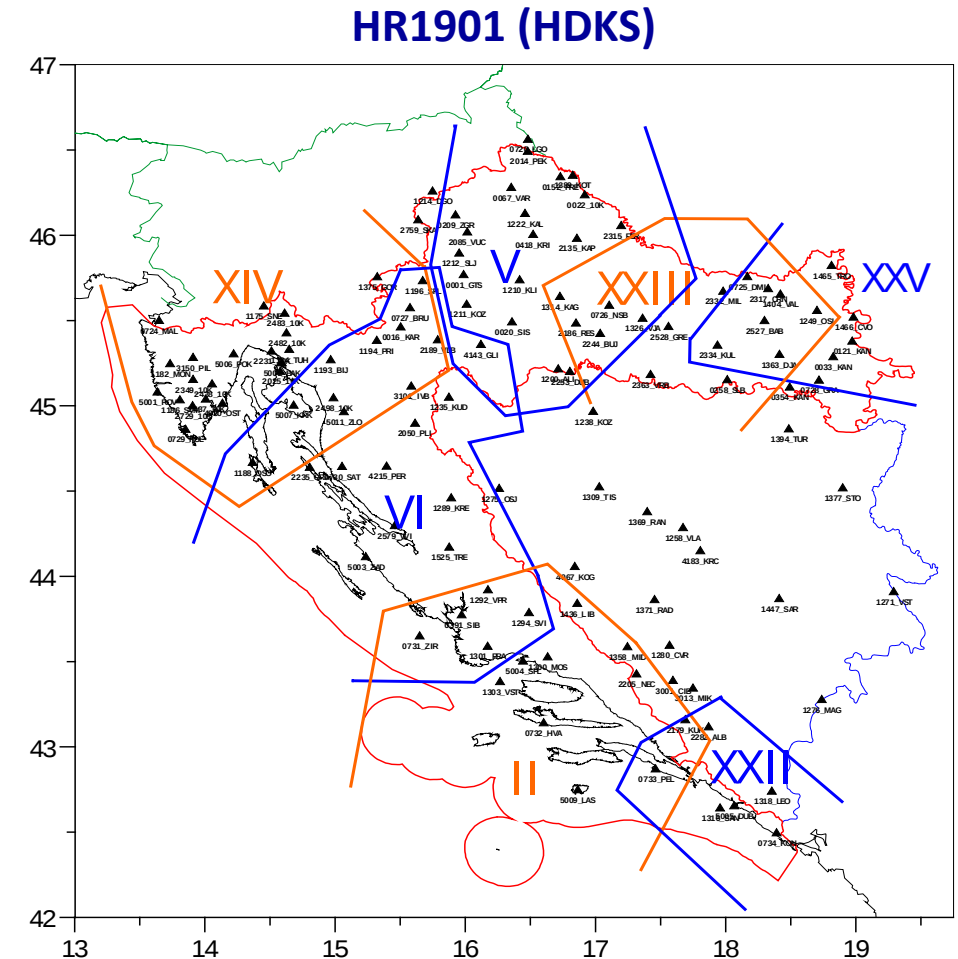


Content

- Introduction – Croatian coordinate reference systems
- An overview of CROPOS development
- CROPOS reference frame
- Conclusion
- ...???

Historical heritage...

- 1901 $\Rightarrow$ A-H Monarchy $\Rightarrow$ HR1901 (HDKS) $\Rightarrow$ horizontal CRS
 - 1st order trigonometric network $\Rightarrow$ astro-geodetic measurements by MGI
 - Hermannskögel; Bessel 1841; G-K map projection (1924)
 - 7 blocks separate blocks $\Rightarrow$ inhomogeneity
- reasons for introducing changes:
 - following European modern trends
 - bad documentation
 - clear inhomogeneity (1-2 m at State level, few dm at County level and ~10 cm at City level)



Official reference systems and frames...

- In 2000 CSGA requested 3 expert studies from GEO UNIZG:
 - for horizontal and gravimetric datum (prof. dr. sc. Tomislav Bašić),
 - for height datum (late prof. dr. sc. Ladislav Feil) &
 - for cartographic projections (prof. dr. sc. Miljenko Lapaine)
- In 2001 studies were reviewed by foreign experts: E. Brockmann, B. - G. Harsson, J. Ihde
- On 4th August 2004 ⇒ Croatian Government ⇒ *Decree on establishing new official geodetic datums and map projections of the Republic of Croatia*



Croatian Terrestrial Reference System 1996 (HTRS96)

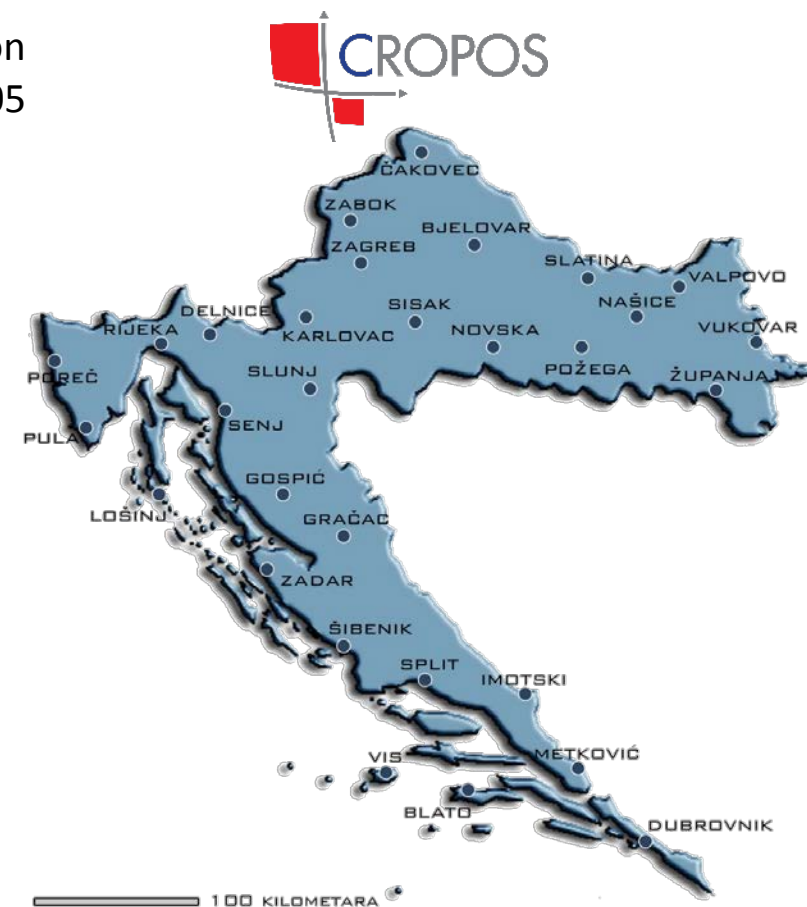
- ETRS89; GRS80 ⇒ **system**
- 78 permanently stabilized points (ITRF96, e1995.55 ⇒ ETRS89) ⇒ **frame**

HTRS96



Chronology of CROPOS development (1)

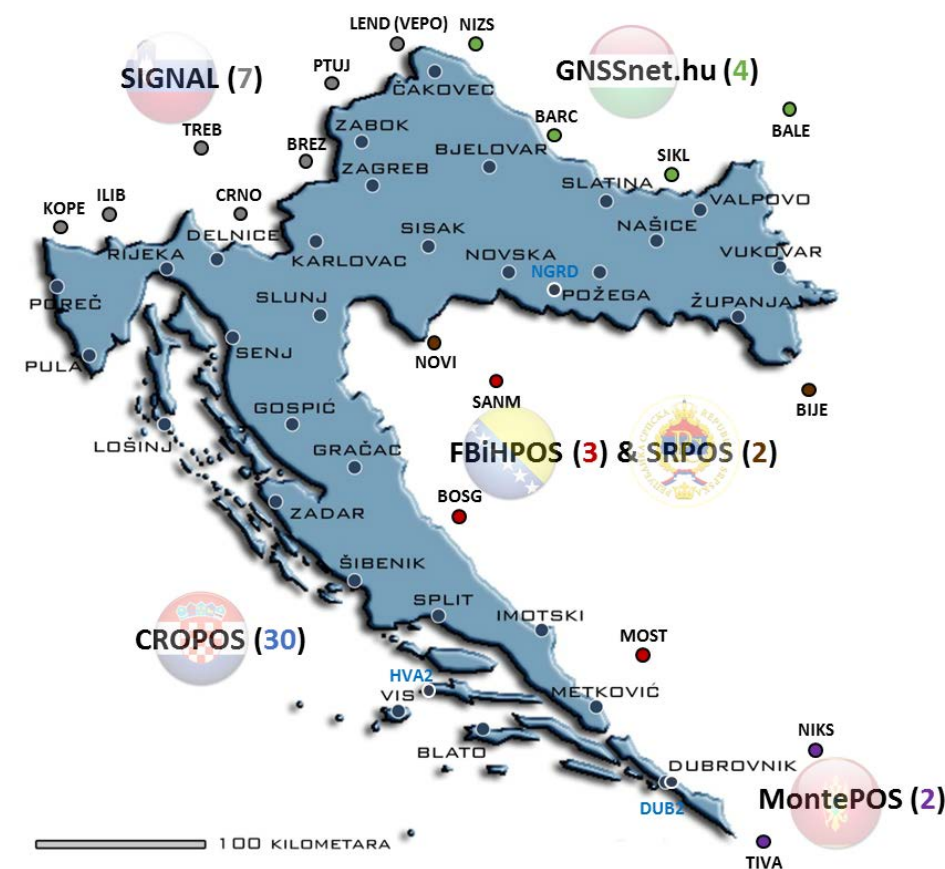
- November 2008 – EU Delegacy in Zagreb + MIFIN + *Trimble Europe* – contract on realization of Croatian national positioning system - financing: 75% PHARE-2005 programme + 25% State Budget
- 9th December 2008 – CSGA introduced CROPOS to its official public use:
 - 30 reference GNSS CORS - d ~ 70 km
 - 365/24/7 - 3 services:
 - DPS $\Rightarrow$ 0.3 - 0.5 m
 - HPPS (VPPS) $\Rightarrow$ 0.02 m (2D), 0.04 m (3D)
 - GPPS $\Rightarrow$ < 1 cm
- CROPOS reference frame $\Rightarrow$ ETRF2000 (R05) e2008.83 (24 h sessions; GPS Week: 1503)
- $\sigma_N = 1.2$ mm; $\sigma_E = 1.1$ mm, $\sigma_U = 3.4$ mm



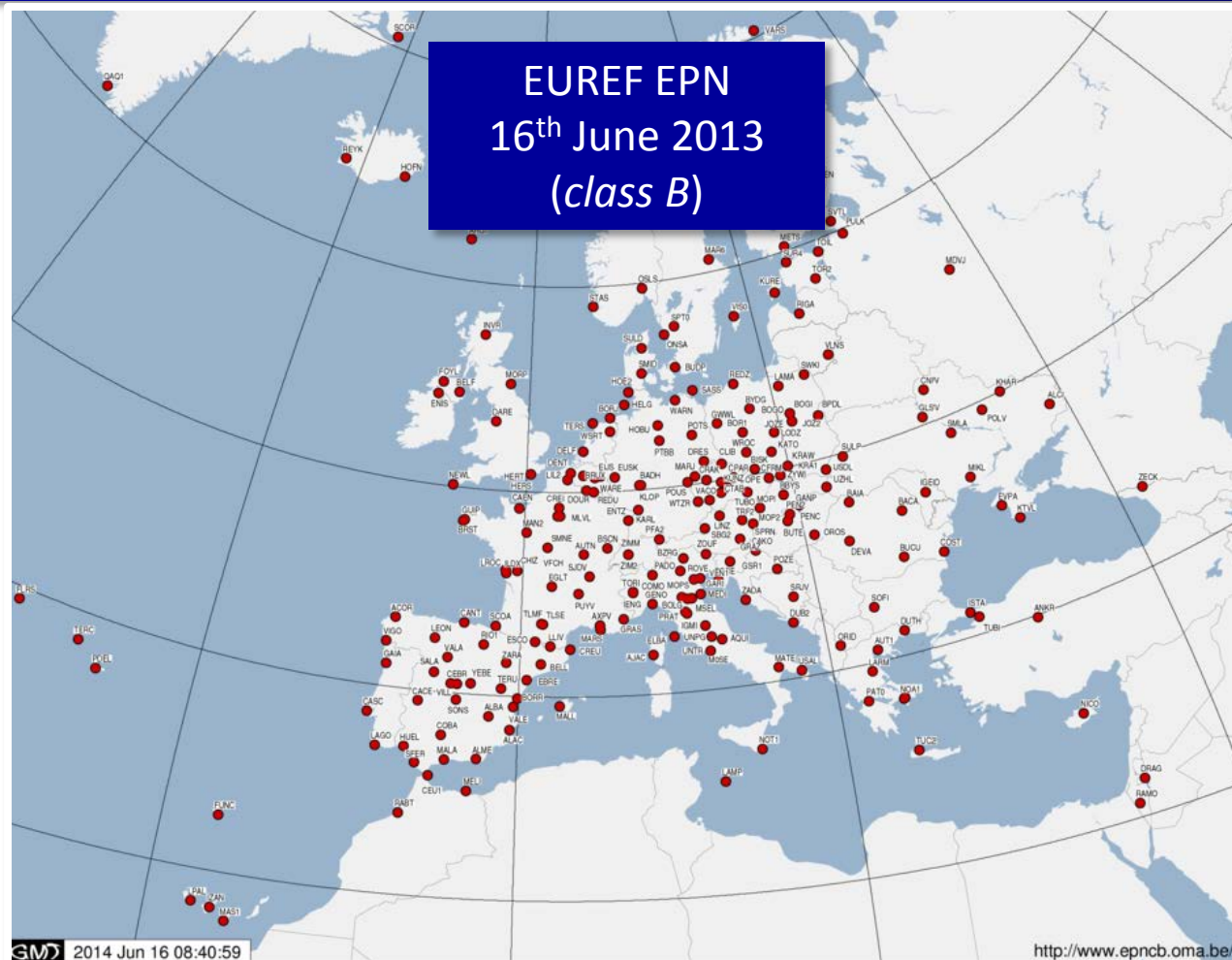
Chronology of CROPOS development (2)

- 8th June 2009 $\Rightarrow$ 1st CROPOS Conference $\Rightarrow$ an agreement between GA of Slovenia, Hungary, Montenegro and Croatia on CORS data exchange:
 - SIGNAL (x7)
 - GNSSnet.hu (x4)
 - MontePOS-a (x2)

Networked solution $\Rightarrow$ 43 CORS
- IGS DUBI $\Rightarrow$ EPN DUB2 (13th November 2011)
- HVA2 (29th October 2012) – Astronomical Observatory Hvar
- IGS OSJE $\Rightarrow$ NGRD (14th July 2013)
- December 2013 $\Rightarrow$ FBiHPOS (x3) + SRPOS (x2)
- 4th March 2015 $\Rightarrow$ CROPOS (x30) + DUB2 + HVA2 + NGRD = CROPOS (x33)
- Networked solution $\Rightarrow$ 51 CORS

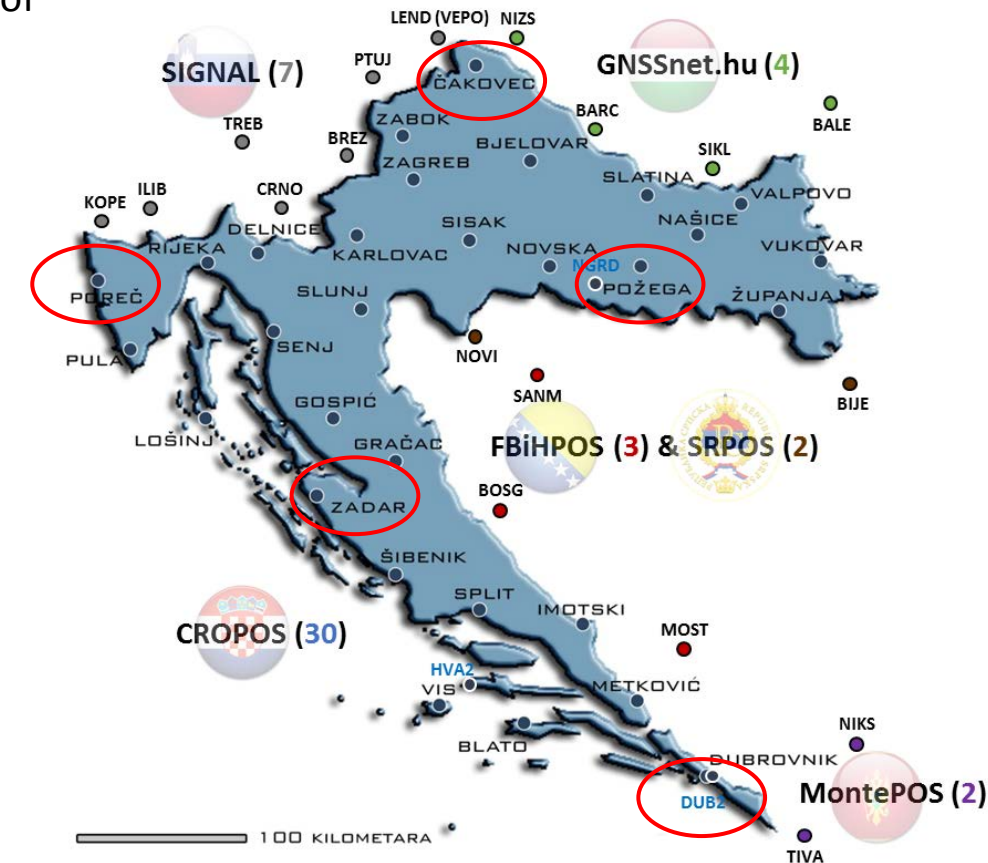


Chronology of CROPOS development (2)



een GA of

x33)



Data processing...

- Time span $\Rightarrow$ from 16th November 2008 to 30th September 2013 $\Rightarrow$ **4.87** years
- Total of 55 stations:
 - ✓ 30 + 3 (DUB2, HVA2 i NGRD) CROPOS,
 - ✓ 7 SIGNAL,
 - ✓ 4 GNSSnet.hu,
 - ✓ 2 MontePOS,
 - ✓ 5 EPN/IGS control (GOPE, PENC i POTS | DUBI i OSJE) &
 - ✓ 4 EPN reference (GRAZ, MATE, WTZR i ZIMM).
- Bernese 5.0* (AIUB)
- 82 894 RINEX files (GPS measurements in 15 sec. interval) x 15 MB/RINEX = **1.243** TB
- IGS precise orbits; elevation mask 5°

No.	Station	Year						Σ
		2008.	2009.	2010.	2011.	2012.	2013.	
50	BALE	0	0	299	362	351	271	1283
51	NIKS	0	0	294	312	266	264	1136
52	TIVA	0	0	293	340	351	260	1244
53	DUB2	0	0	0	46	364	271	681
54	HVA2	0	0	0	0	46	255	301
55	NGRD	0	0	0	0	0	77	77
Σ		1742	13870	17804	18313	18096	13069	82894

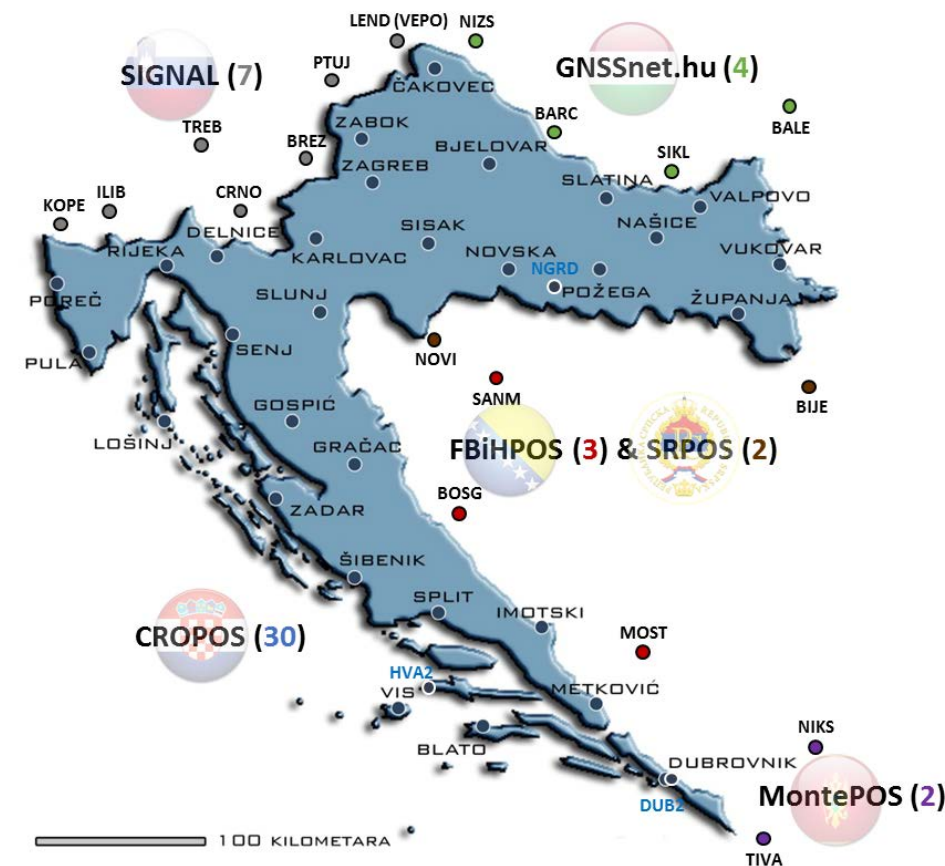
Combined networked solution...

- 1741 daily solutions (ADDNEQ2)
- ITRF2008; mean epoch $\Rightarrow$ 24th April 2011 (e 2011.31)
- Combined networked solution - statistics:

No. of sessions:	1741
No. of stations:	55
No. of vectors:	79 039
No. of meas.:	1 705 200 000
No. of parameters.:	2 975 877
σ_0 [mm]:	1.50

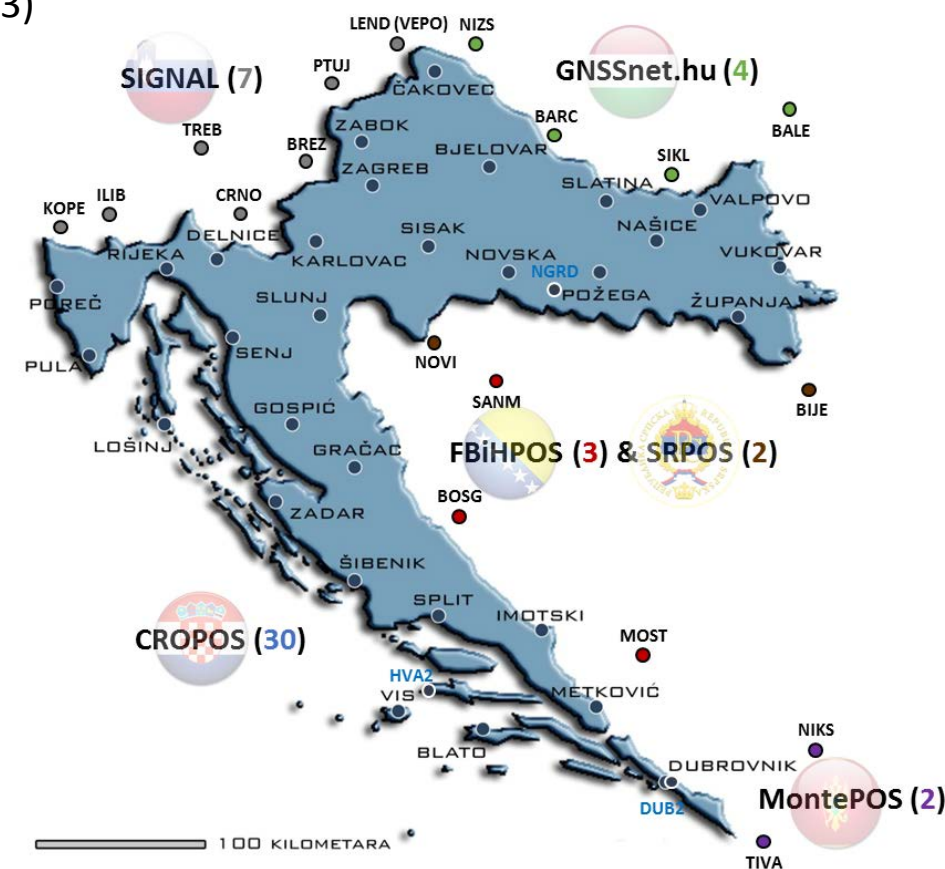
- Adjustment accuracy:

- ✓ $\sigma_N = 1.79$ mm
- ✓ $\sigma_E = 2.25$ mm
- ✓ $\sigma_U = 2.38$ mm



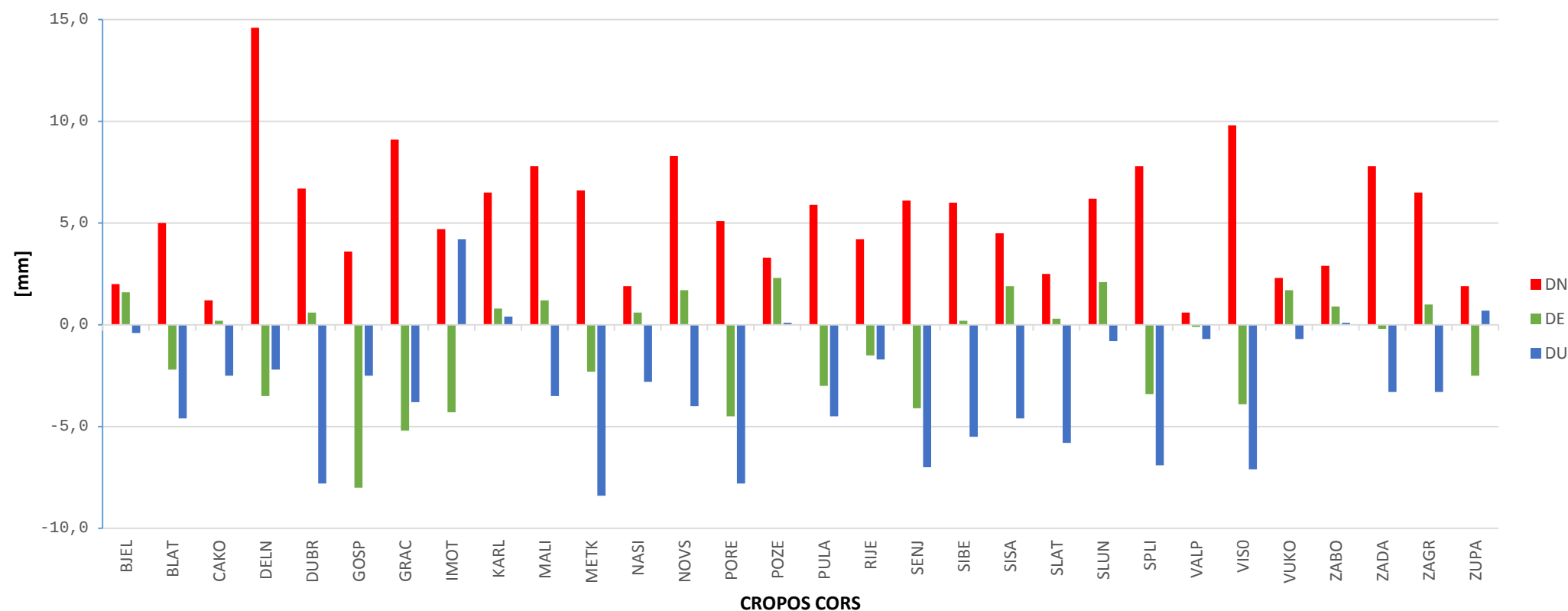
Absolute coordinate comparison in 30 CROPOS initial stations (1)

- Initial adjustment of CROPOS (30 st.) $\Rightarrow$ ITRF2005, e2008.83 (7 d.s. in GPSW: 1503)
- Networked solution (51 st.) $\Rightarrow$ ITRF2008, e2011.31 (1741 d.s.)
- EUREF TWG recommendation $\Rightarrow$ ETRF2000
- 14-parameter transformation:
 - ✓ ETRF2000 (R05), e 2008.83
 - ✓ ETRF2000 (R08), e 2011.31



Absolute coordinate comparison in 30 CROPOS initial stations (2)

ETRF2000 (R05) e2008.83 vs ETRF2000 (R08) e2011.31

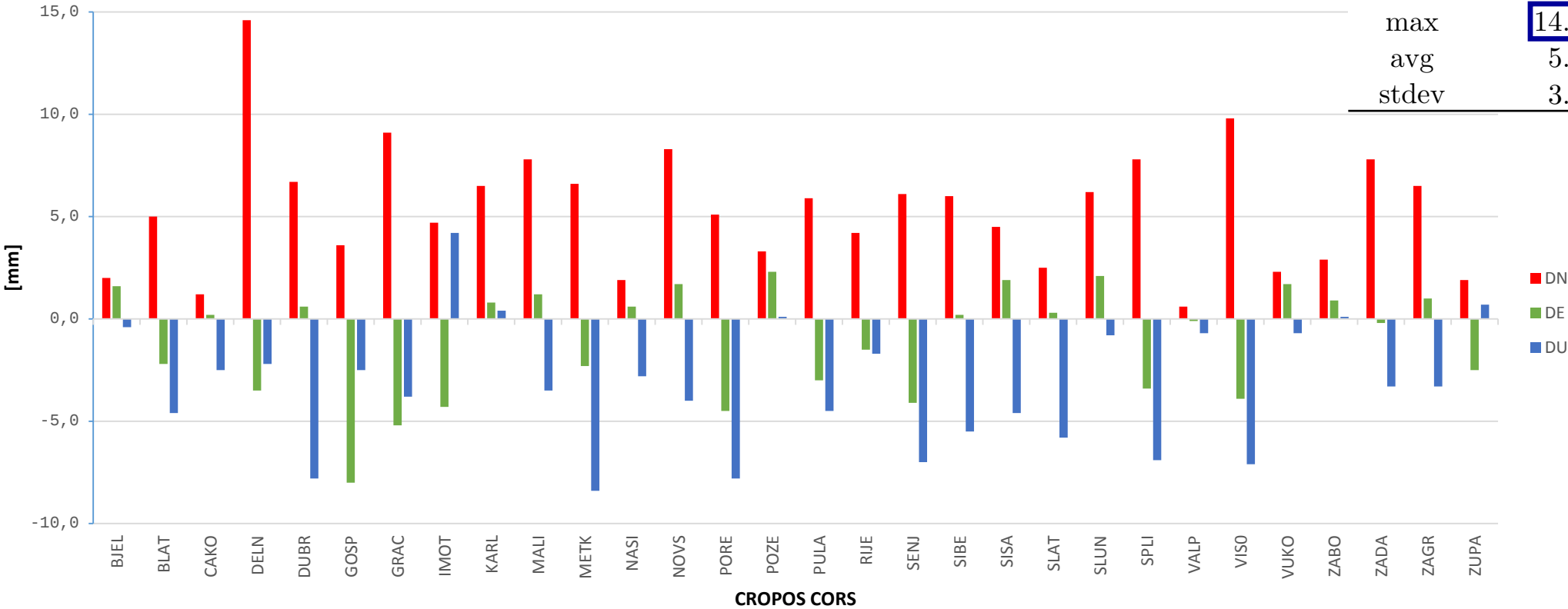




Absolute coordinate comparison in 30 CROPOS initial stations (2)

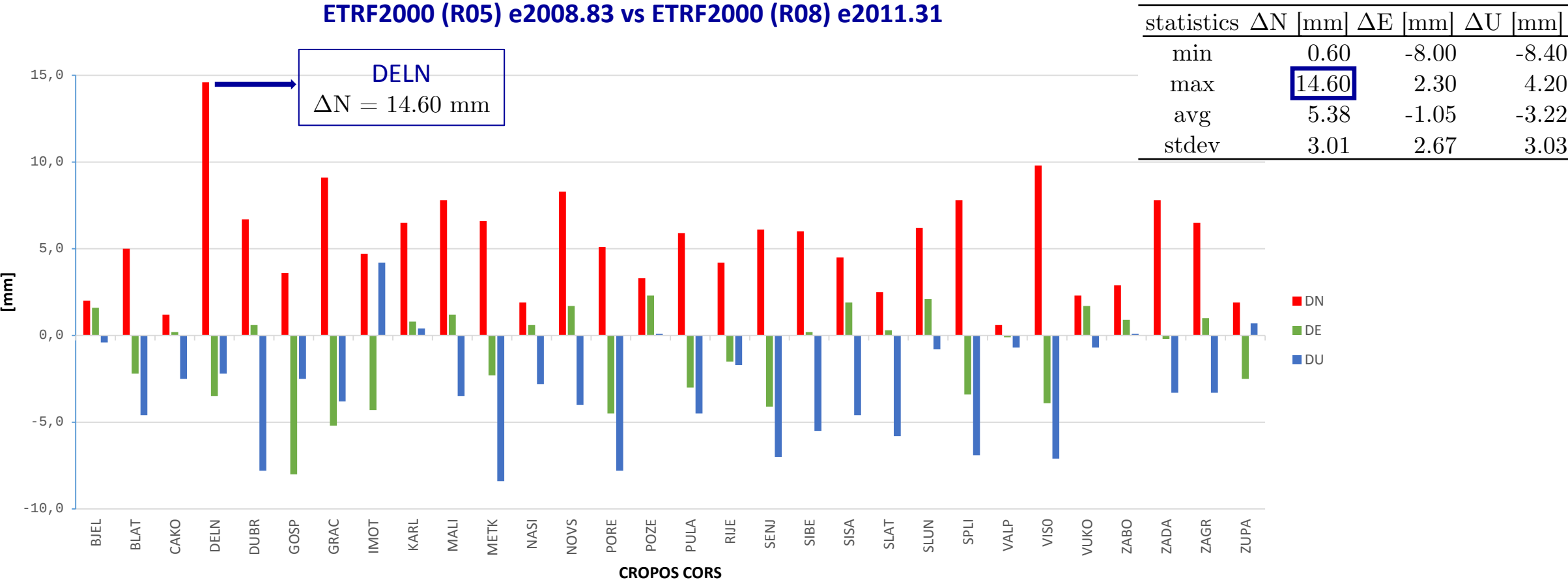
ETRF2000 (R05) e2008.83 vs ETRF2000 (R08) e2011.31

statistics	ΔN [mm]	ΔE [mm]	ΔU [mm]
min	0.60	-8.00	-8.40
max	14.60	2.30	4.20
avg	5.38	-1.05	-3.22
stdev	3.01	2.67	3.03

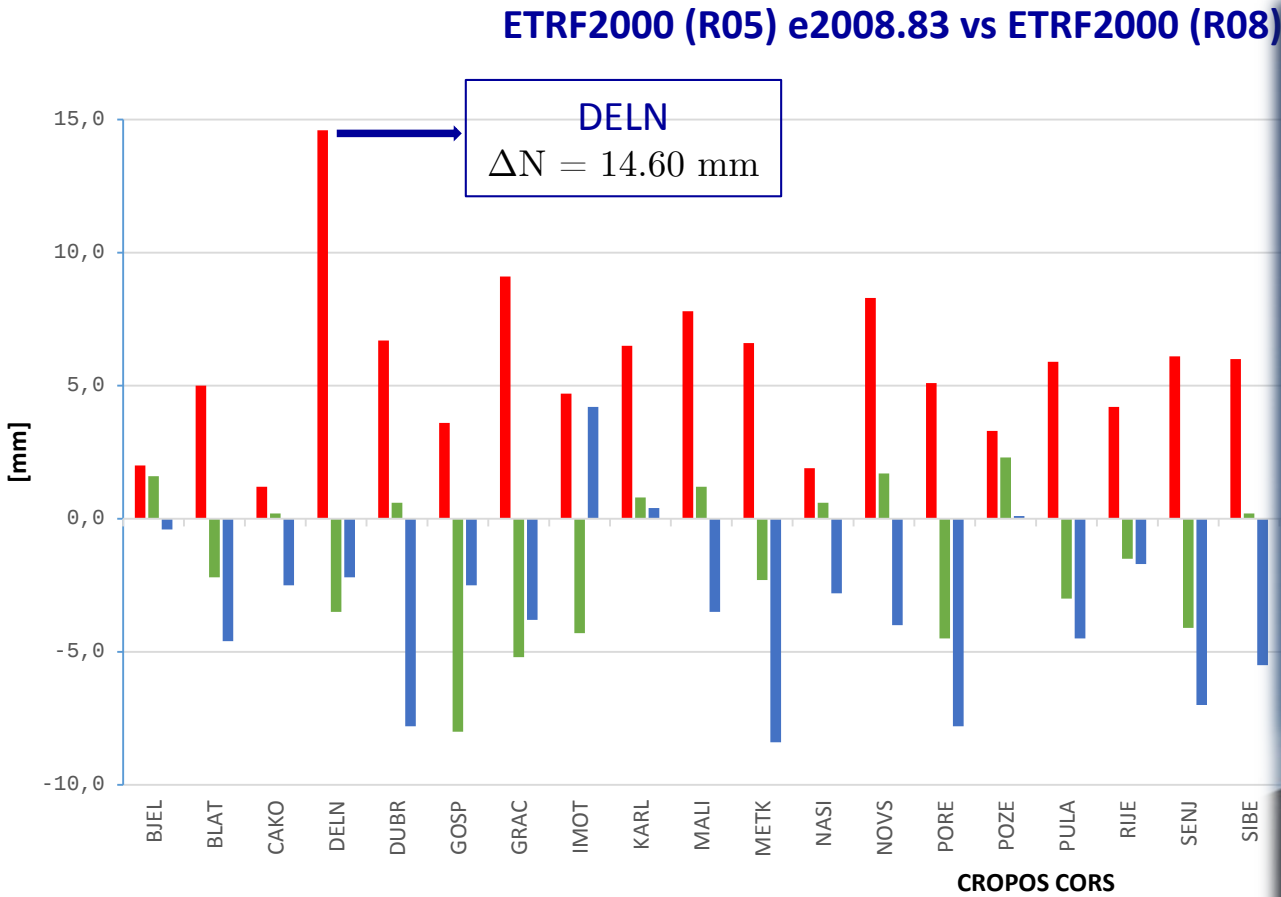




Absolute coordinate comparison in 30 CROPOS initial stations (2)



Absolute coordinate comparison in 30 CROPOS initial stations (2)

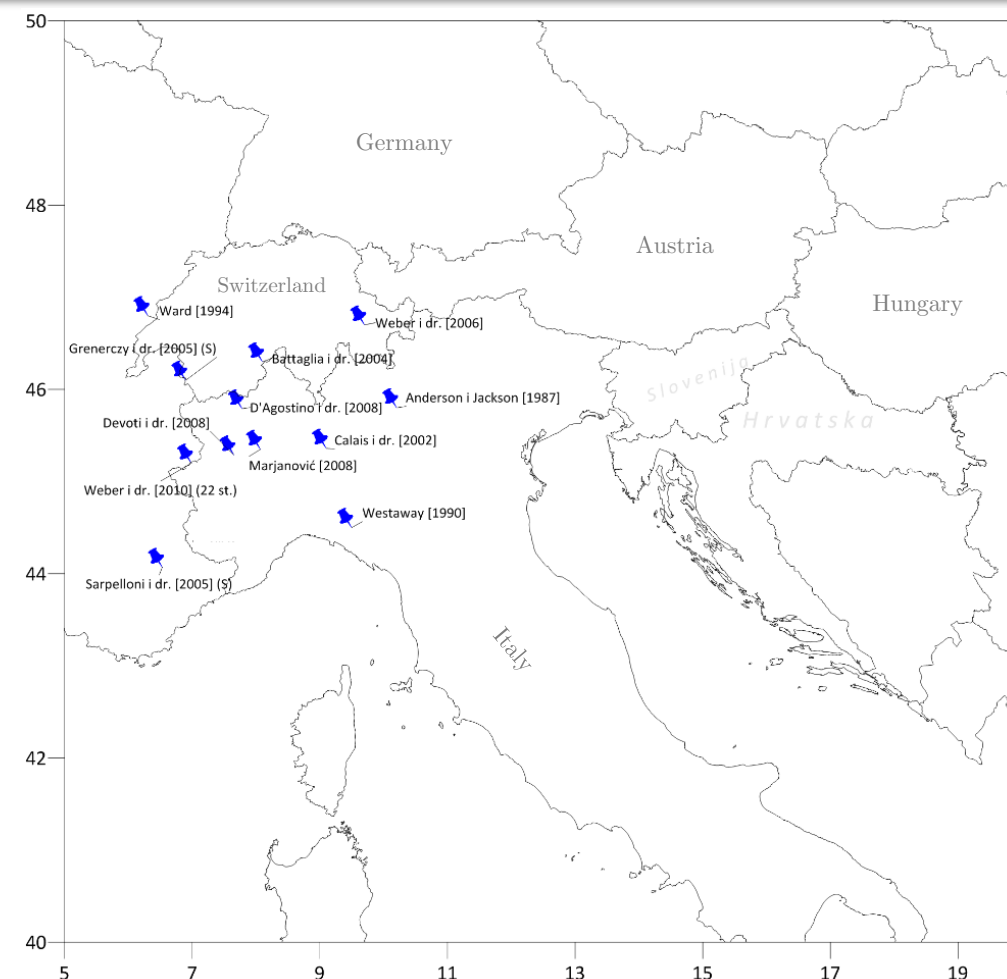


Lokacija	4 ID	No	%	05.04.2010.	
				RMSmp1 [m]	RMSmp2 [m]
Bjelovar	BJEL	101	100	0.36	0.42
Blato	BLAT	124	98	0.37	0.41
Čakovec	CAKO	102	100	0.36	0.44
Delnice	DELN	123	100	0.44	0.55

Plate tectonics – Adriatic microplate

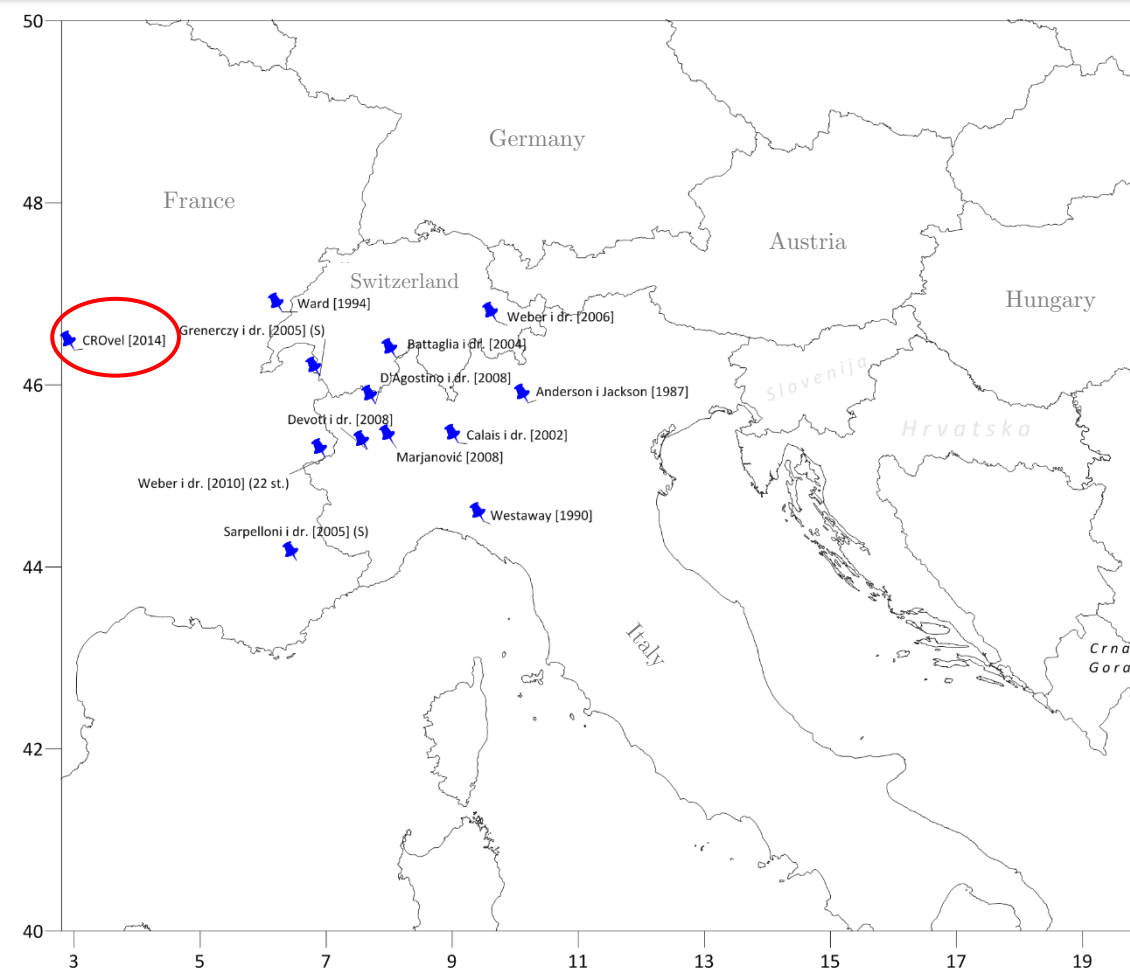
- Relative kinematic models of Adriatic microplate (previous researches)

Authors	φ [°]	λ [°]	Ω [° / mil. yr.]
Anderson i Jackson [1987]	45.80	10.20	-
Westaway [1990]	44.50	9.50	-
Ward [1994]	46.80	6.30	0.290
Calais i dr. [2002]	45.36	9.10	0.520
Battaglia i dr. [2004]	46.30	8.10	0.900
Grenerczy i dr. [2005] (S)	46.10	6.90	0.350
Serpelloni i dr. [2005] (S)	44.07	6.53	0.244
Weber i dr. [2006]	46.70	9.70	0.400
Grenerczy i Kenyeres [2006]	46.10	7.70	0.350
Devoti i dr. [2008]	45.29	7.65	0.216
D'Agostino i dr. [2008]	45.79	7.78	0.309
Marjanović [2008]	45.35	8.07	0.185
Weber i dr. [2010] (22 st.)	45.20	6.99	0.341



Relative kinematic model *CROvel*

- No. of stations: 23
- No. of measurements (n): 69
- No. of unknowns (u): 3
- $\sigma_0 = 0.12$
- Euler pole components - $P(\varphi, \lambda, \Omega)$
 - ✓ $\varphi [^\circ] = 46.4$
 - ✓ $\lambda [^\circ] = 3.0$
 - ✓ $\Omega [^\circ/\text{mil. yr.}] = 0.2$



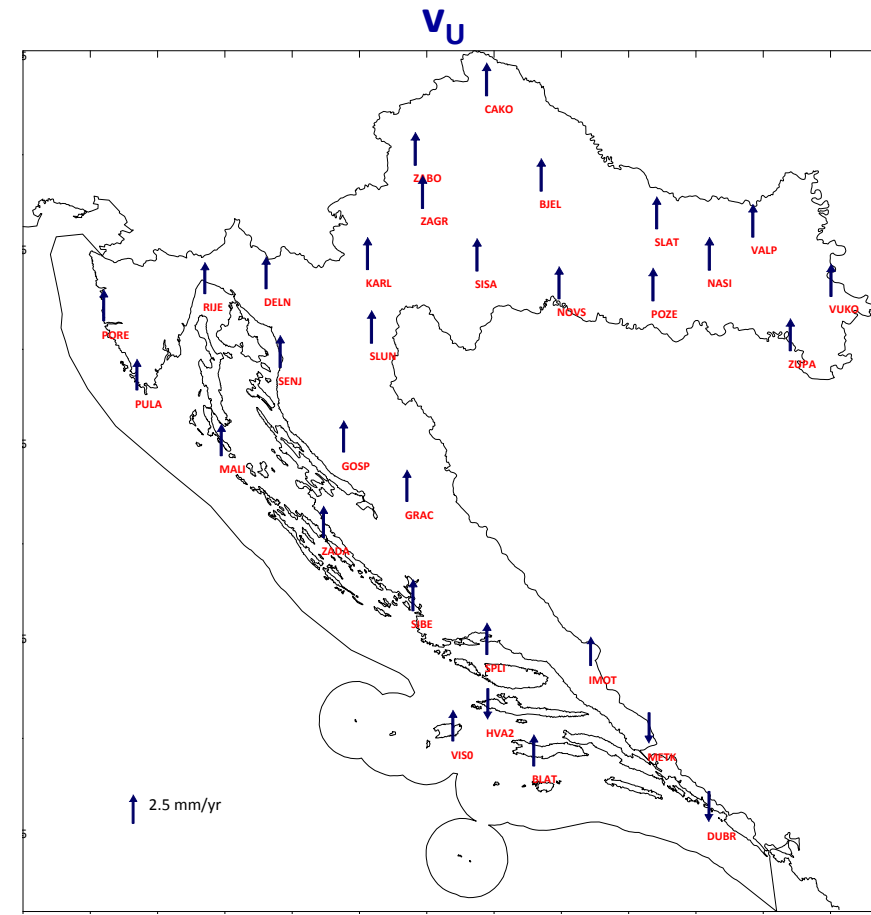
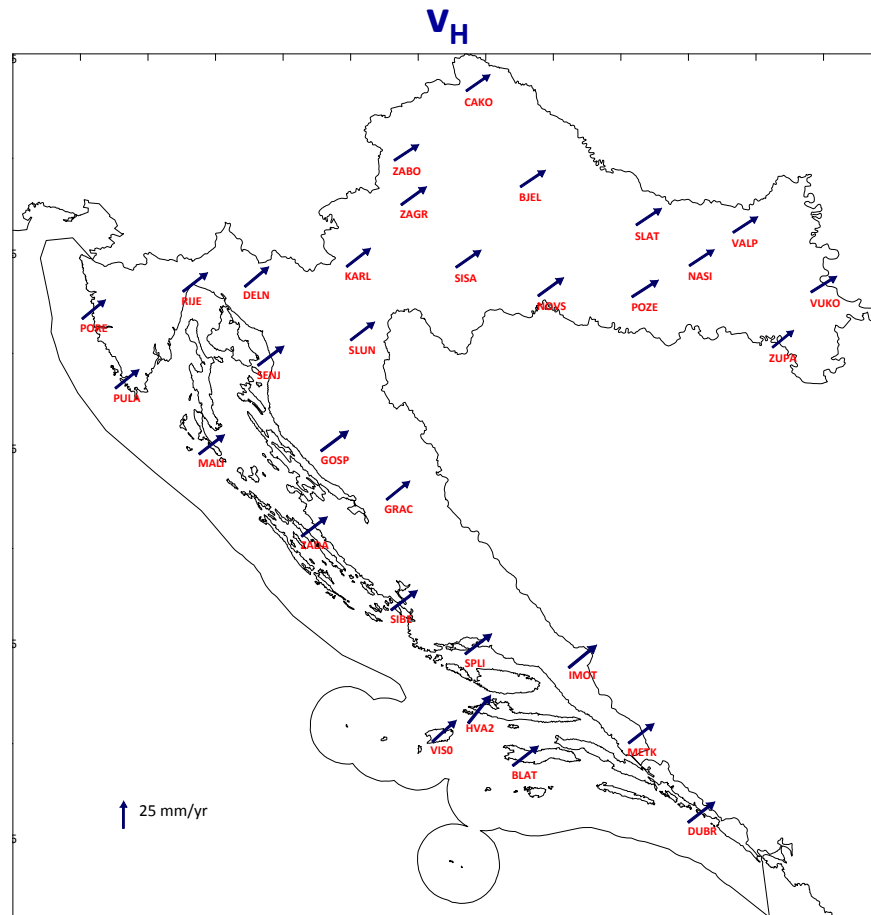
Absolute kinematic model *CRO-2014*

- No. of stations: 47
- No. of measurements (n): 141
- No. of unknowns (u): 3
- $\sigma_0 = 0.15$
- Euler pole components - P (φ , λ , Ω)
 - ✓ $\varphi [^\circ] = 44.0$
 - ✓ $\lambda [^\circ] = -116.5$
 - ✓ $\Omega [^\circ/\text{mil. yr.}] = 0.2$

Comparison of *CRO-2014* with global kinematic models

Statistics	NNR-NUVEL-1A			APKIM2000			ITRF2005			ITRF2008		
	ΔV_N	ΔV_E	ΔV_U	ΔV_N	ΔV_E	ΔV_U	ΔV_N	ΔV_E	ΔV_U	ΔV_N	ΔV_E	ΔV_U
	[mm/yr.]			[mm/yr.]			[mm/yr.]			[mm/yr.]		
MIN.	0.1	-1.0	0.0	-1.3	-1.5	0.0	-2.1	-1.4	-0.1	-2.3	-1.3	-0.1
MAX.	0.5	-0.3	0.0	0.0	0.4	0.0	-0.8	0.6	0.0	-1.2	0.4	0.0
AVG.	0.2	-0.8	0.0	-1.0	-0.8	0.0	-1.8	-0.7	0.0	-2.1	-0.7	-0.1
ST.DEV.	0.1	0.1	0.0	0.2	0.3	0.0	0.2	0.3	0.0	0.2	0.3	0.0

CRO-2014 velocities...



CROPOS reference frame...

- Preliminary results of absolute coordinate comparison show existence of stability
- Proposition for densification of 78 frame stations with CROPOS stations
- *CROvel* $\Rightarrow$ dependancy of network configuration (selected stations for computation); short time span
- *CRO-2014* $\Rightarrow$ relative good consistency with global kinematic models
- Future: GNSS meteorology, global geodetic points, real-time PPP...

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