

Latest efforts on new materialization of the Croatian terrestrial reference frame

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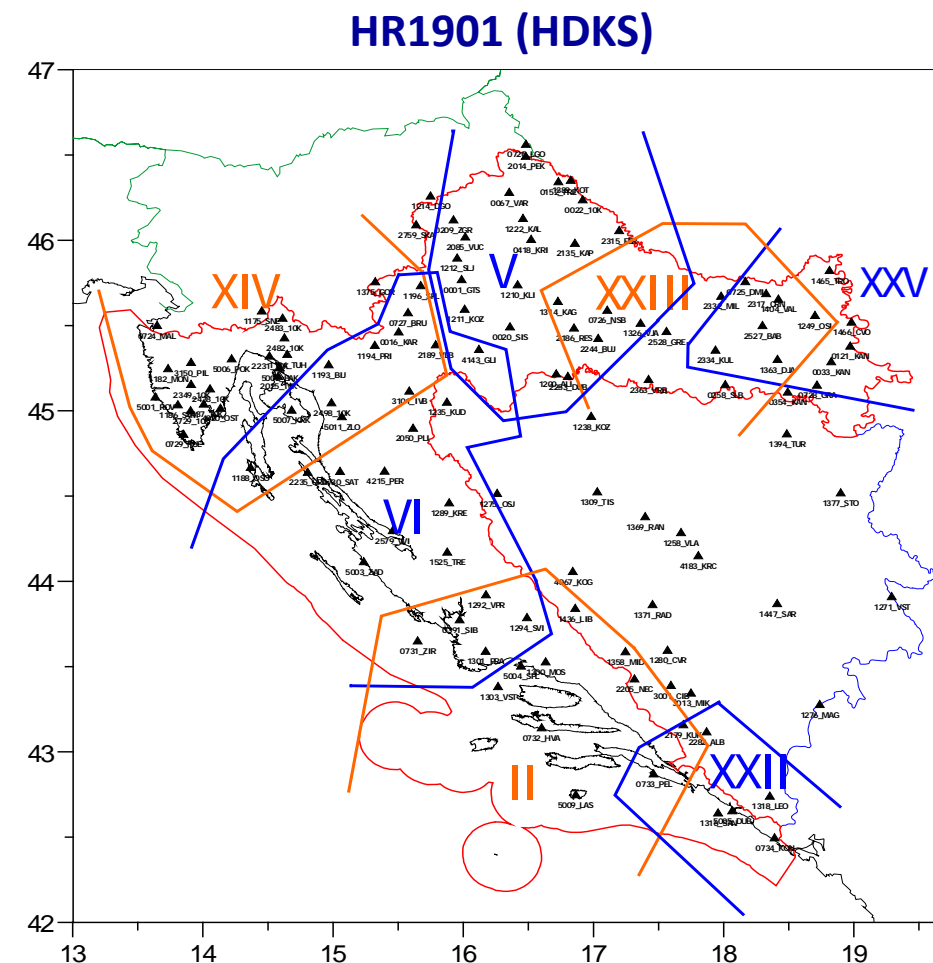


Content

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

Historical heritage...

- 1901 ⇒ A-H Monarchy ⇒ HR1901 (HDKS) ⇒ horizontal CRS
 - 1st order trigonometric network ⇒ astro-geodetic measurements by MGI
 - Hermannskögel; Bessel 1841; G-K map projection (1924)
 - 7 blocks separate blocks ⇒ 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)

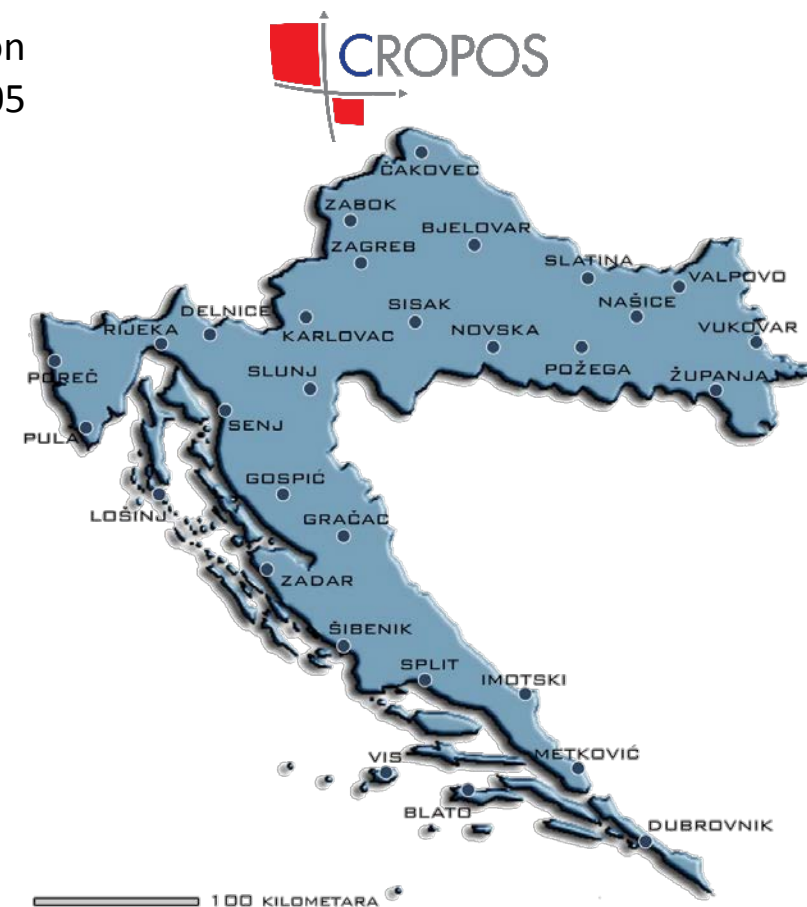
- ETRS89; GRS80 ⇒ system
- 78 permanently stabilized points (ITRF96, e1995.55 ⇒ ETRS89) ⇒ frame

HTRS96



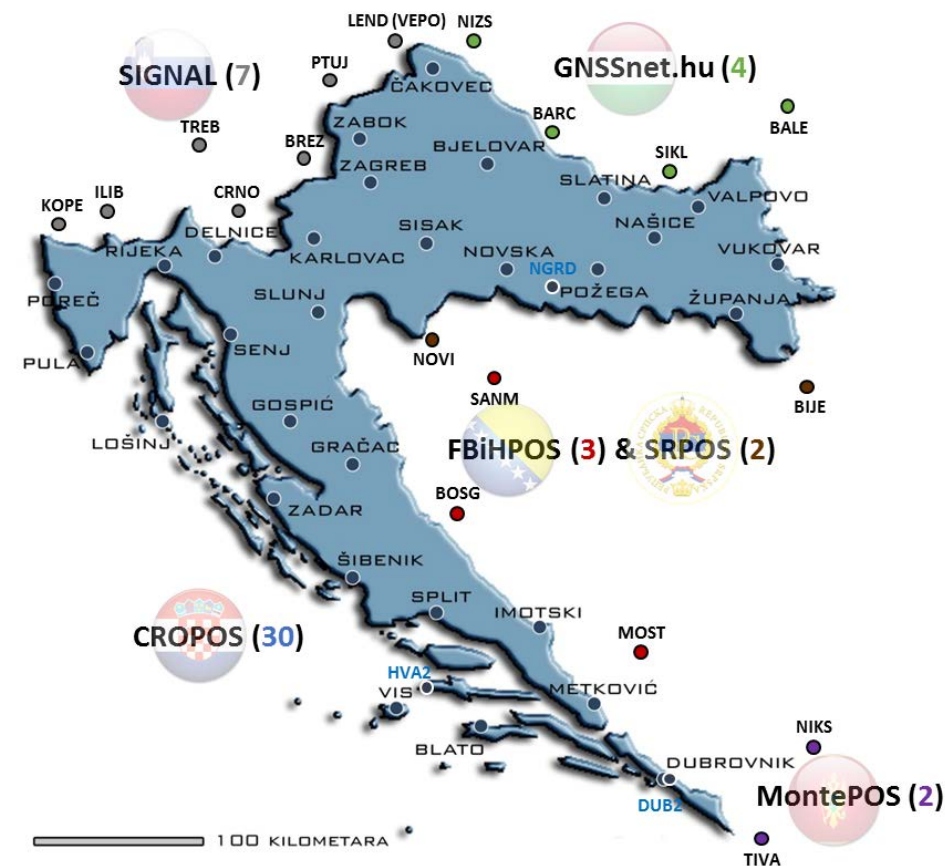
Chronology of CROPOS development (1)

- November 2008 – EU Delegation 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

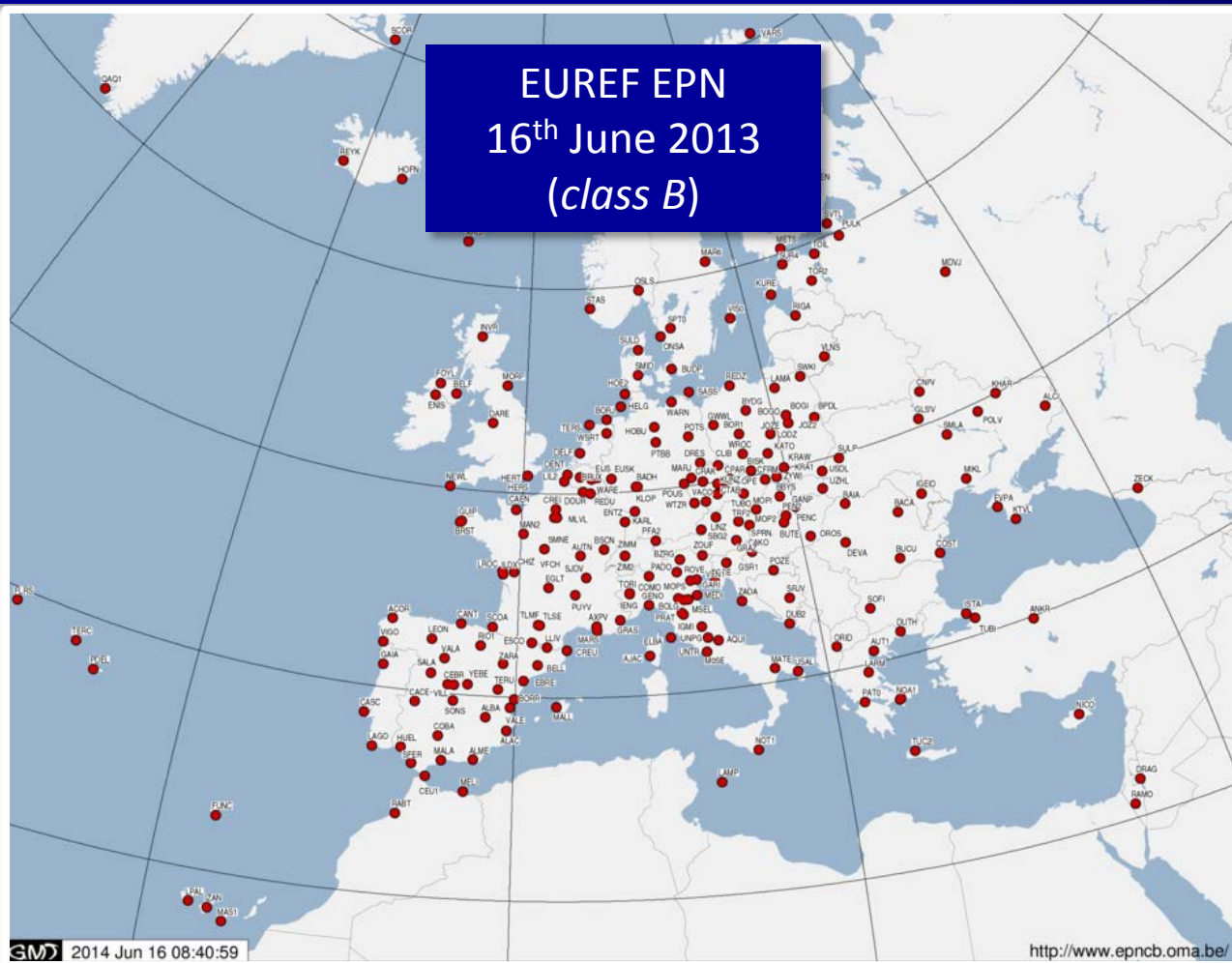


Chronology of CROPOS development (2)

- 8th June 2009 ⇒ 1st CROPOS Conference ⇒ an agreement between GA of Slovenia, Hungary, Montenegro and Croatia on CORS data exchange:
 - SIGNAL (x7)
 - GNSSnet.hu (x4)
 - MontePOS-a (x2)Networked solution ⇒ **43** CORS
- IGS DUBI ⇒ EPN DUB2 (13th November 2011)
- HVA2 (29th October 2012) – Astronomical Observatory Hvar
- IGS OSJE ⇒ NGRD (14th July 2013)
- December 2013 ⇒ FBiHPOS (x3) + SRPOS (x2)
- 4th March 2015 ⇒ CROPOS (x30) + DUB2 + HVA2 + NGRD = CROPOS (x33)
- Networked solution ⇒ **51** CORS

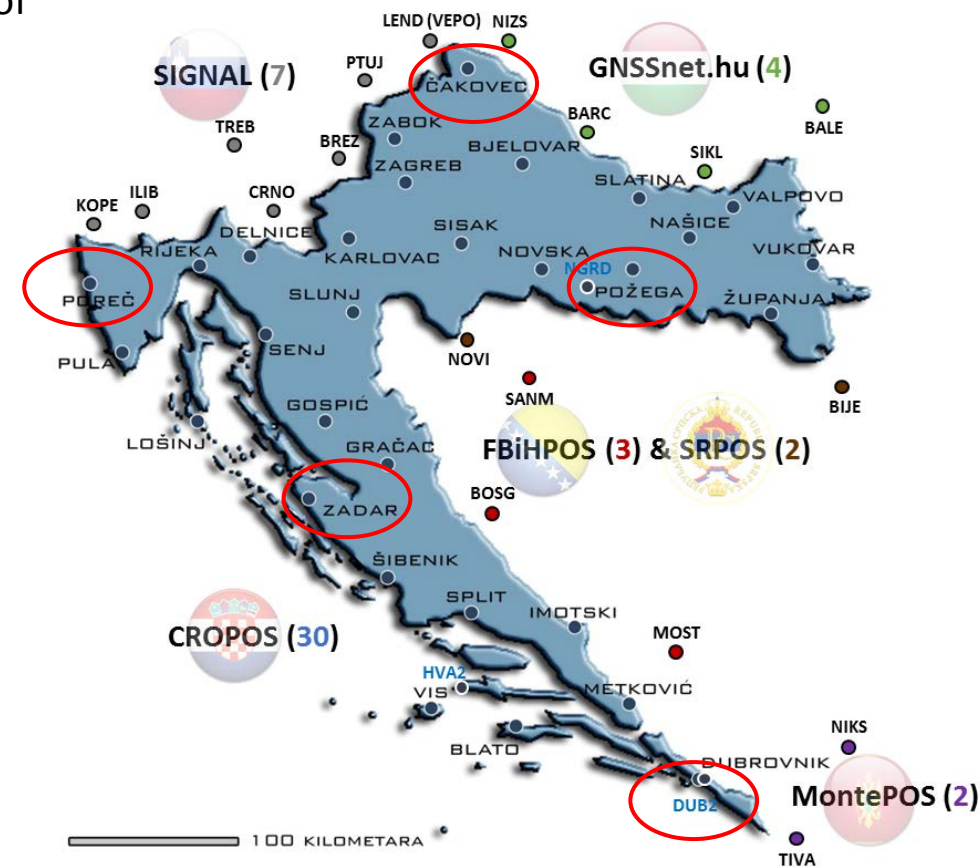


Chronology of CROPOS development (2)



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°

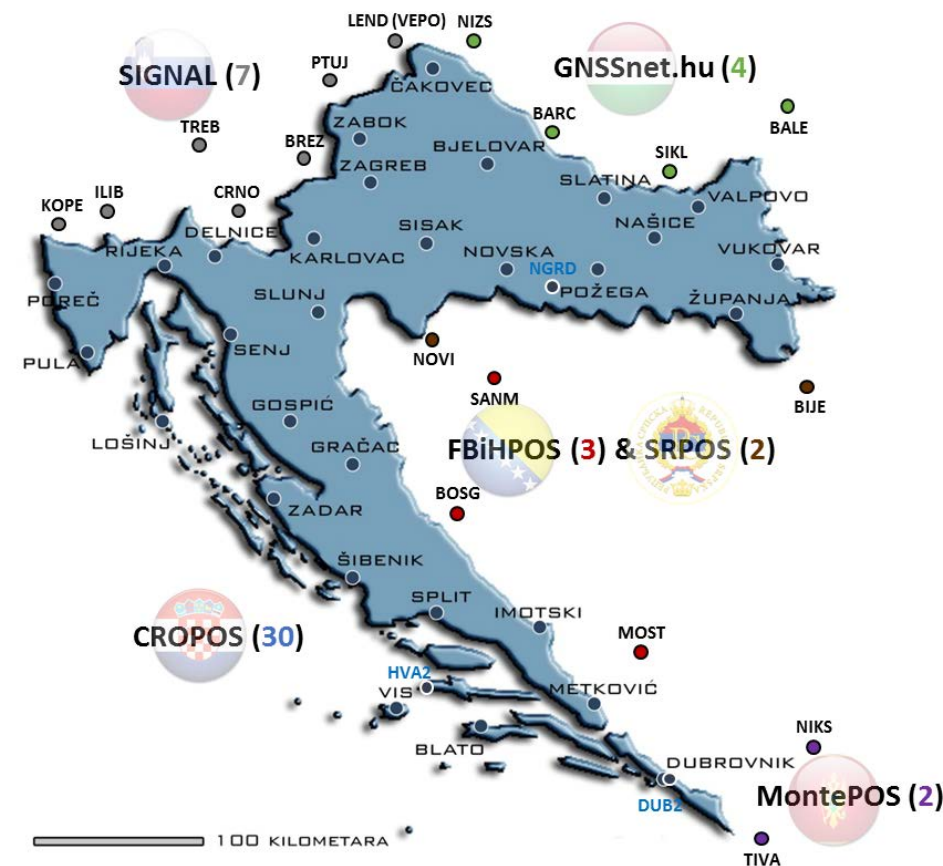
No.	Station	Year						Σ
		2008.	2009.	2010.	2011.	2012.	2013.	
50	BALE	0	0	299	362	351	271	1283
51	NIKS	0	0	294	312	266	264	1136
52	TIVA	0	0	293	340	351	260	1244
53	DUB2	0	0	0	46	364	271	681
54	HVA2	0	0	0	0	46	255	301
55	NGRD	0	0	0	0	0	77	77
Σ		1742	13870	17804	18313	18096	13069	82894

Combined networked solution...

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

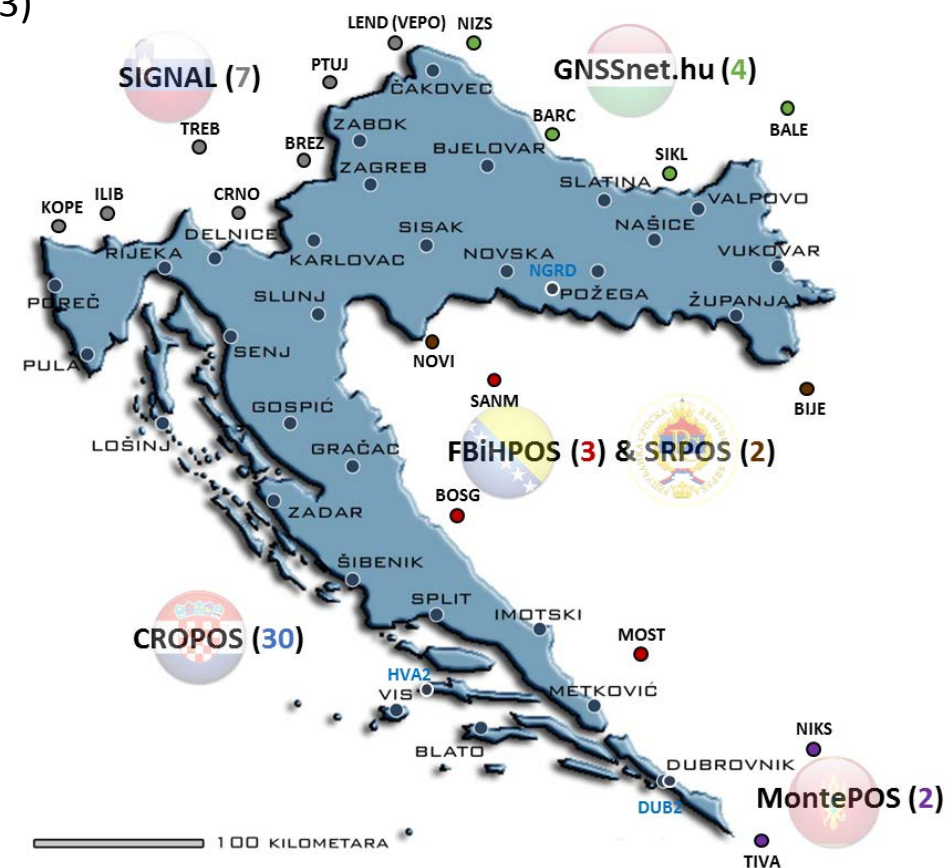
No. of sessions:	1741
No. of stations:	55
No. of vectors:	79 039
No. of meas.:	1 705 200 000
No. of parameters.:	2 975 877
σ_0 [mm]:	1.50

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



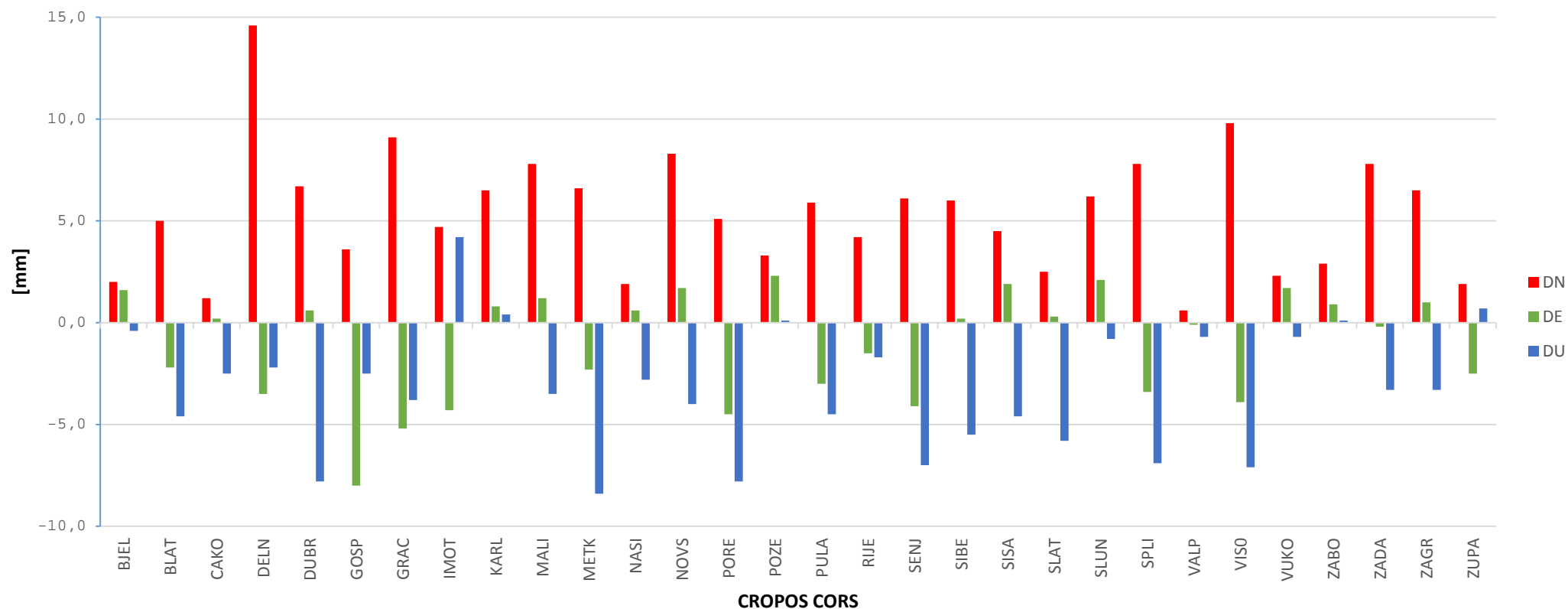
Absolute coordinate comparison in 30 CROPOS initial stations (1)

- 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



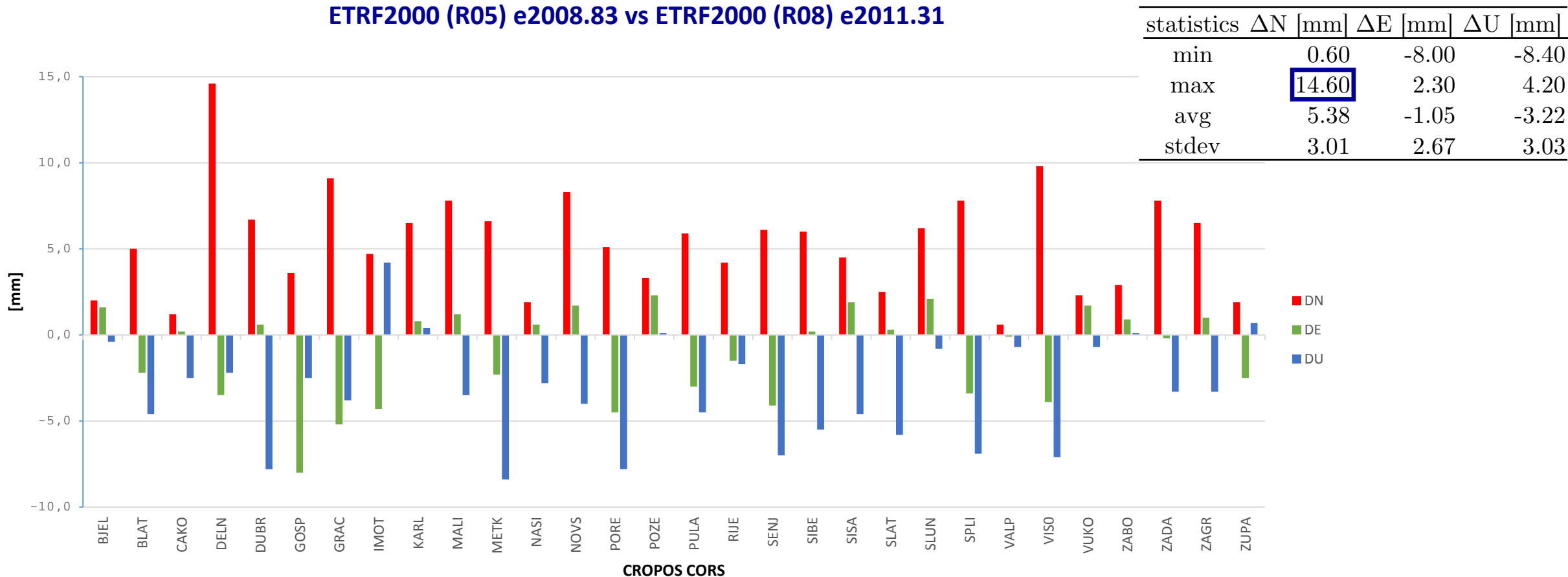
Absolute coordinate comparison in 30 CROPOS initial stations (2)

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



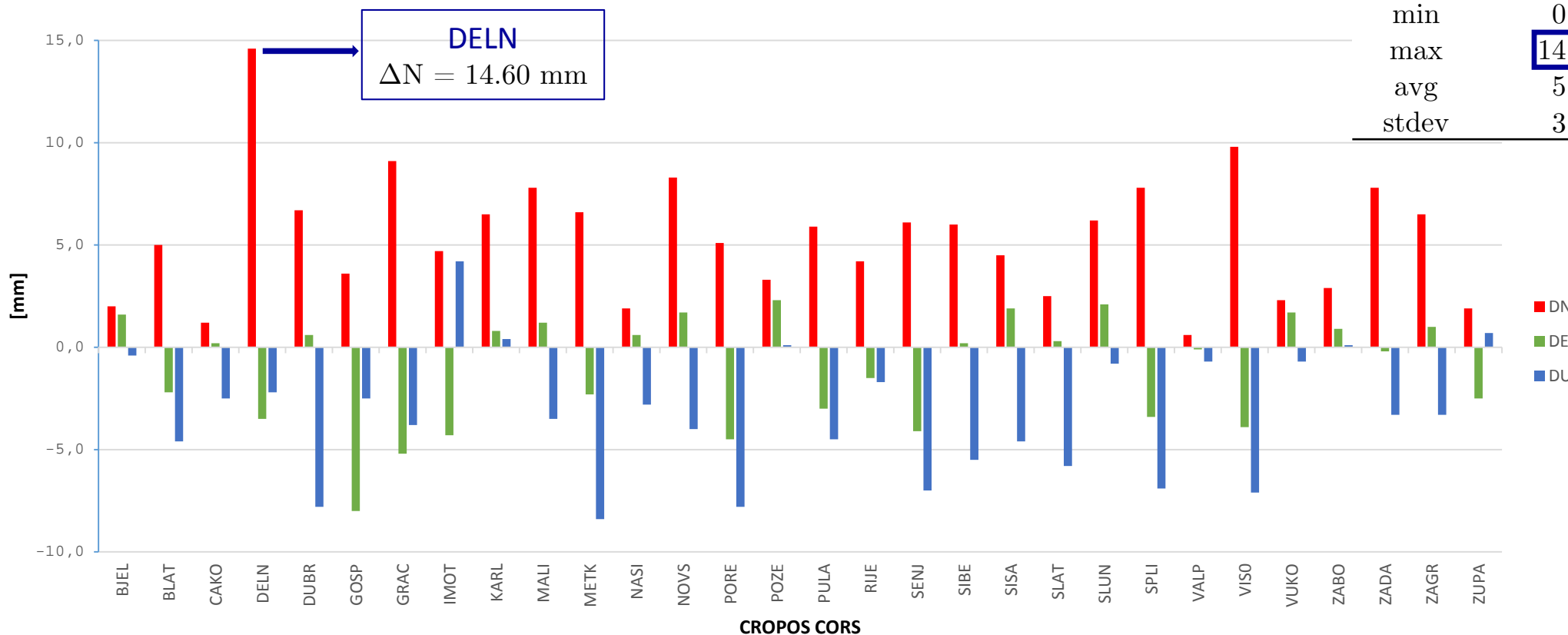
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Absolute coordinate comparison in 30 CROPOS initial stations (2)

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)

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

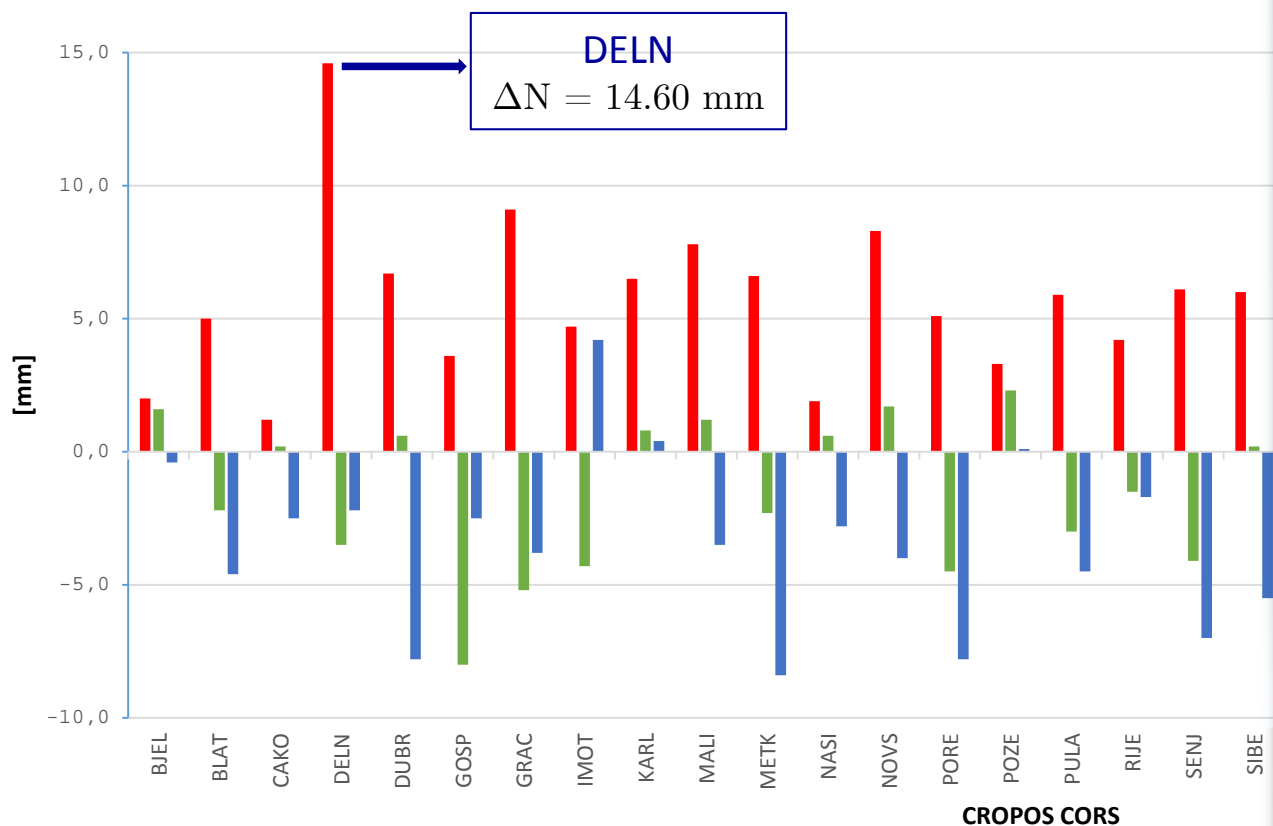
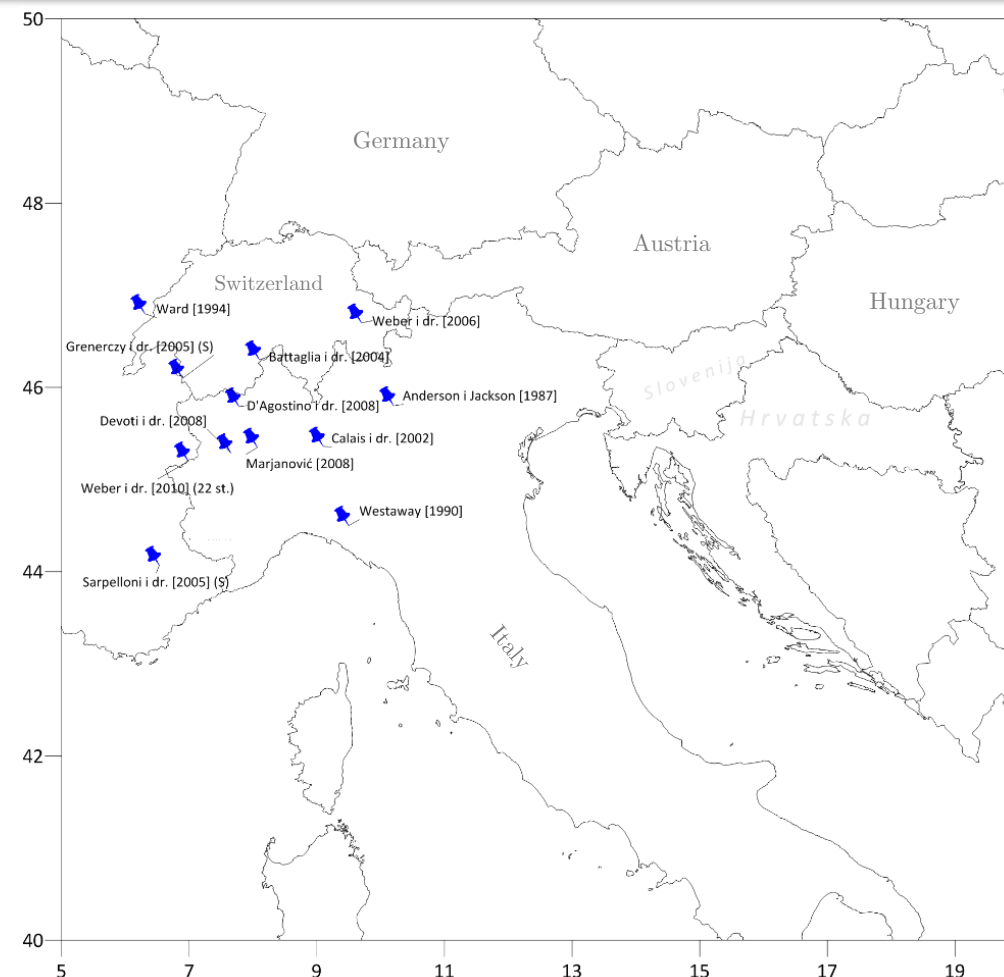


Plate tectonics – Adriatic microplate

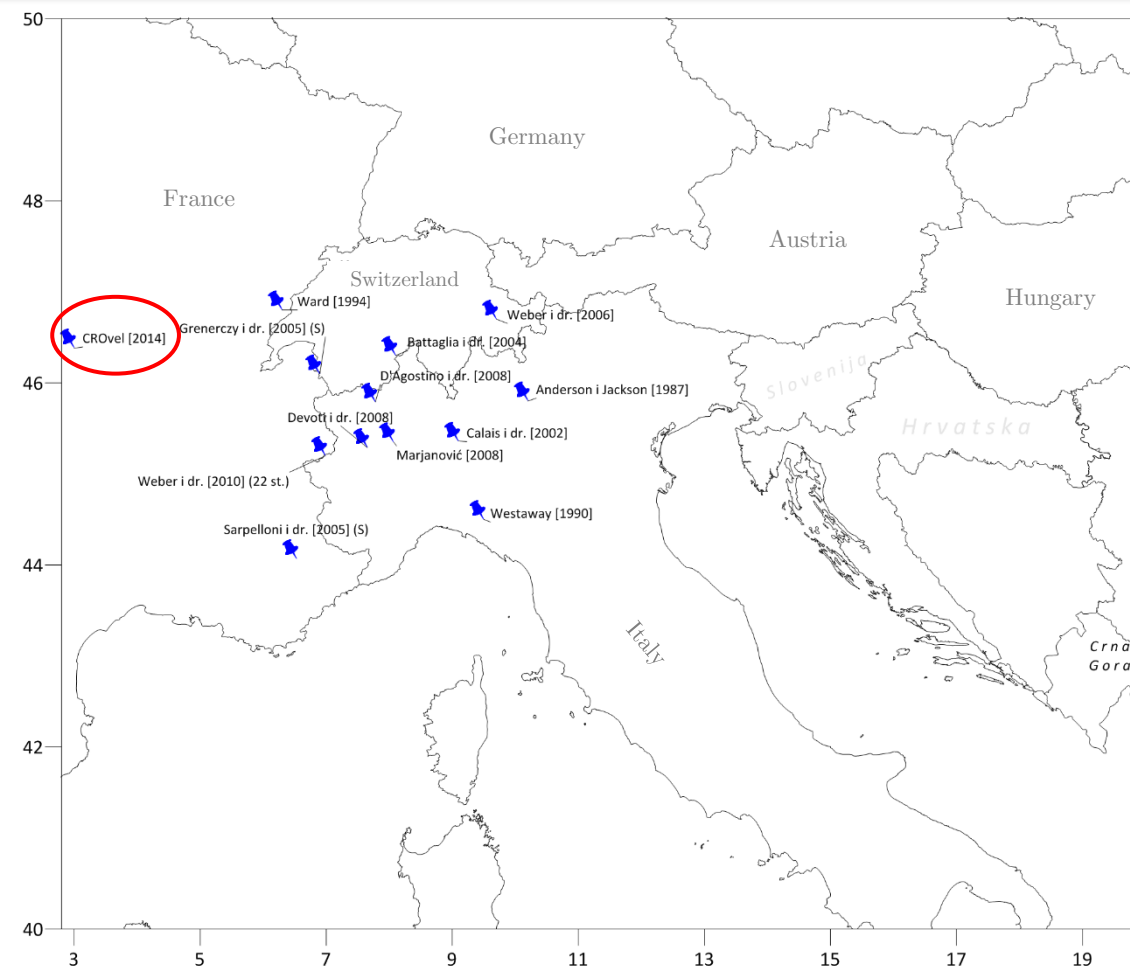
- Relative kinematic models of Adriatic microplate (previous researches)

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 (φ, λ, Ω)
 - ✓ $\varphi [^\circ] = 46.4$
 - ✓ $\lambda [^\circ] = 3.0$
 - ✓ $\Omega [^\circ/\text{mil. yr.}] = 0.2$



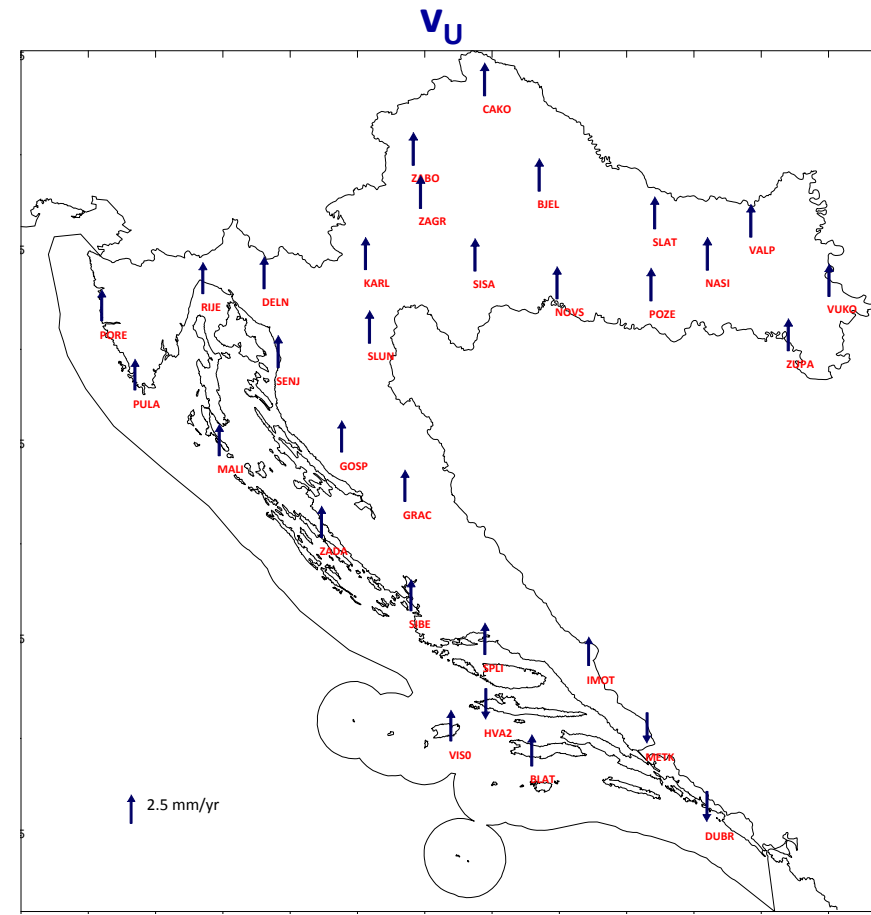
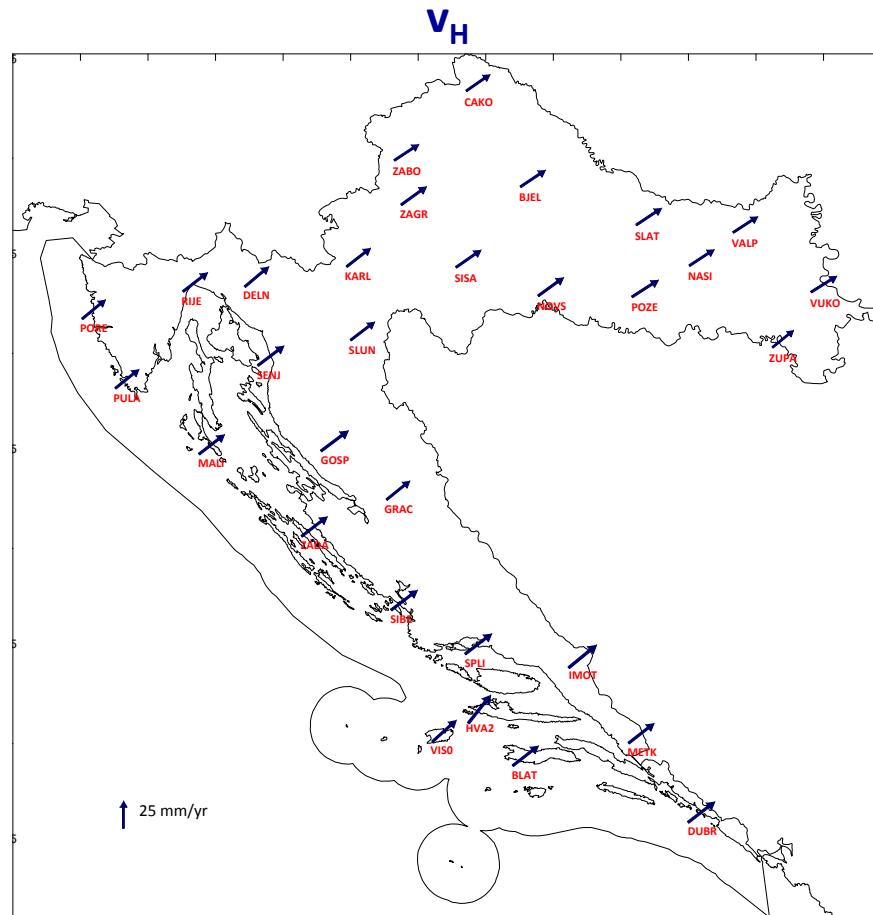
Absolute kinematic model *CRO-2014*

- 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)
 - ✓ $\phi [^\circ] = 44.0$
 - ✓ $\lambda [^\circ] = -116.5$
 - ✓ $\Omega [^\circ/\text{mil. yr.}] = 0.2$

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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