

# CROatian POsitioning System (CROPOS) – Services and Applications

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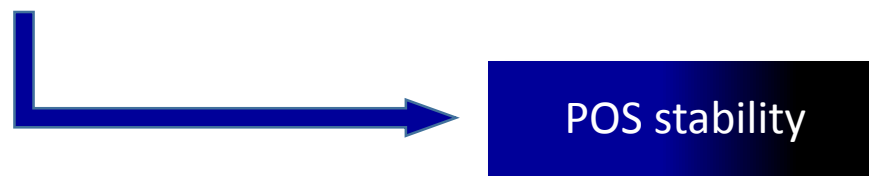


# Content

- Introduction
- A brief historical overview of CROPOS development
- CROPOS services and applications
- Conclusion
- ...???

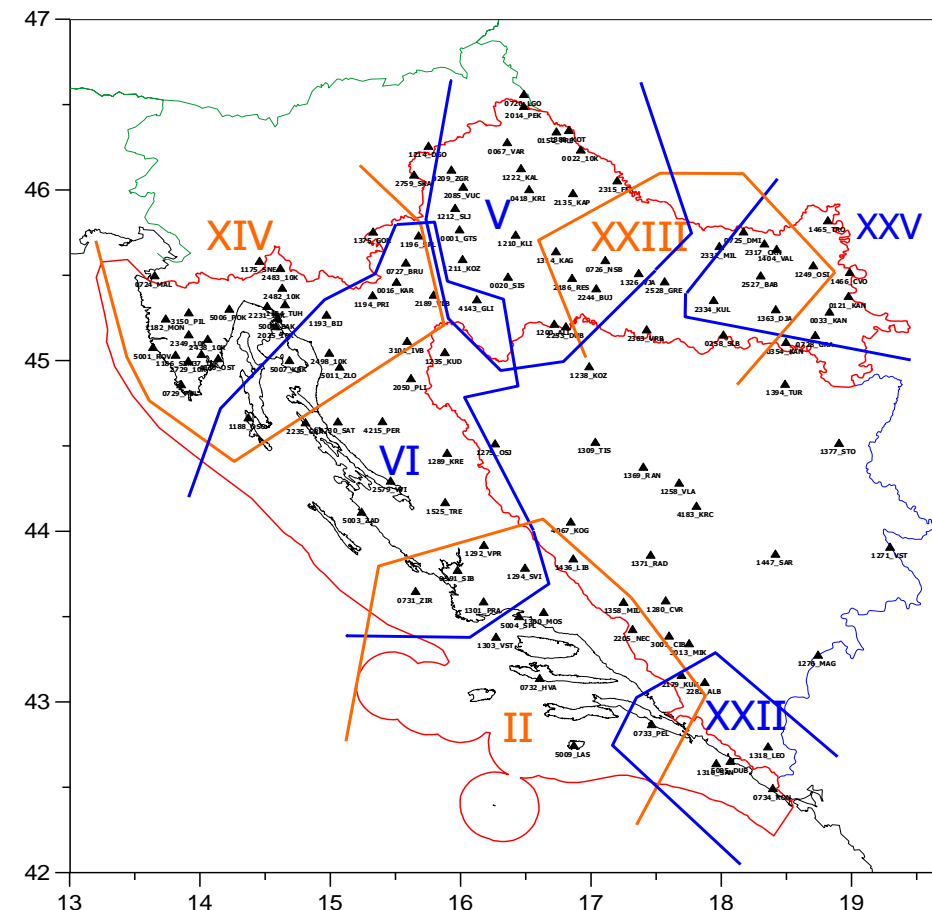
## National positioning systems (POS)

- Represent a state network of GPS/GNSS CORS
- Operability  $\Rightarrow$  365/24/7
- Republic of Croatia  $\Rightarrow$  *CRO*atian *PO*sitioning System (  CROPOS )
  - one of the most modern POS in region
  - among first with fully implemented 3D coordinate transformation model  $\Rightarrow$  T7D
  - enables modern approach to solving everyday geodetic tasks
- POS quality  $\Rightarrow$  measured by provided services quality to users
  - basic prerequisite



## Known historical facts...

- 1901 ⇒ Austrian-Hungarian Monarchy ⇒ HR1901 (HDKS) (+ HVRS1875)
  - astro-geodetic measurements by MGI
  - Hermannskögel; Bessel 1841; G-K projection (1924)
  - 7 blocks by conditional measurements ⇒ 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)



## Recent knows facts...

- In 2000 CSGA requested 3 expert studies from GEOF UNIZG:
  - for horizontal and gravimetric datum (prof. dr. sc. Tomislav Bašić),
  - for height datum (prof. dr. sc. Ladislav Feil) and
  - for cartographic projections (prof. dr. sc. Miljenko Lapaine)
- In 2001 studies were reviewed by foreign experts: E. Brockmann, B. - G. Harsson, J. Ihde
- In 2003 CSGA requested additional 3 studies from GEOF UNIZG for the final documentation on new geodetic datums
- On 4<sup>th</sup> August 2004 – Croatian Government ⇒ *Decree on establishing new official geodetic datums and map projections of the Republic of Croatia*

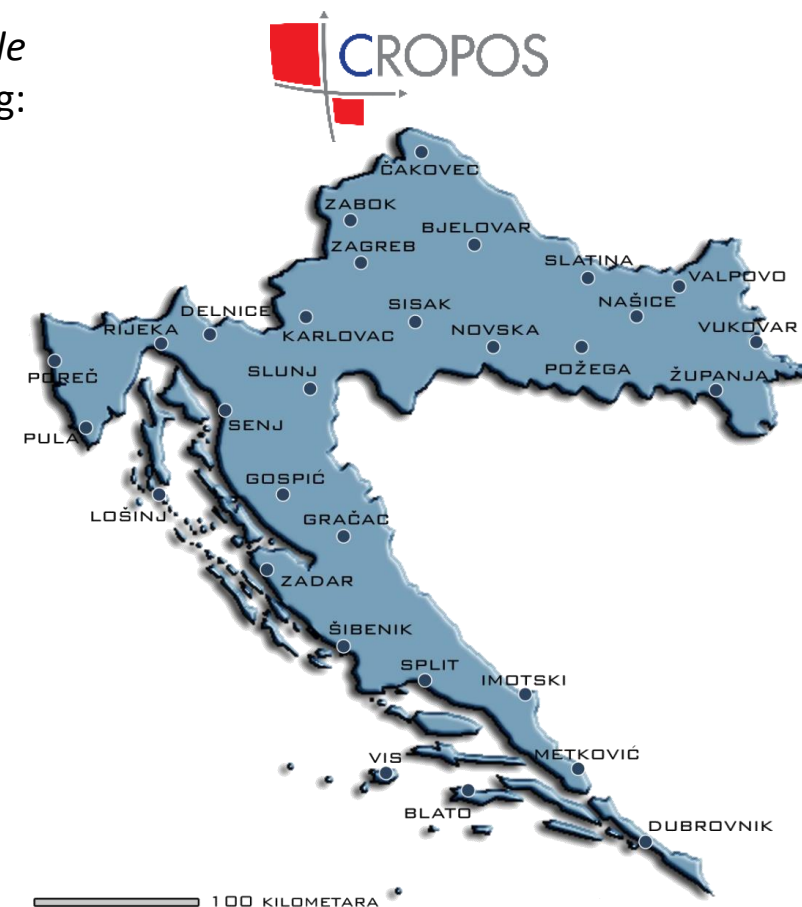
### Croatian Terrestrial Reference System 1996 (HTRS96)

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



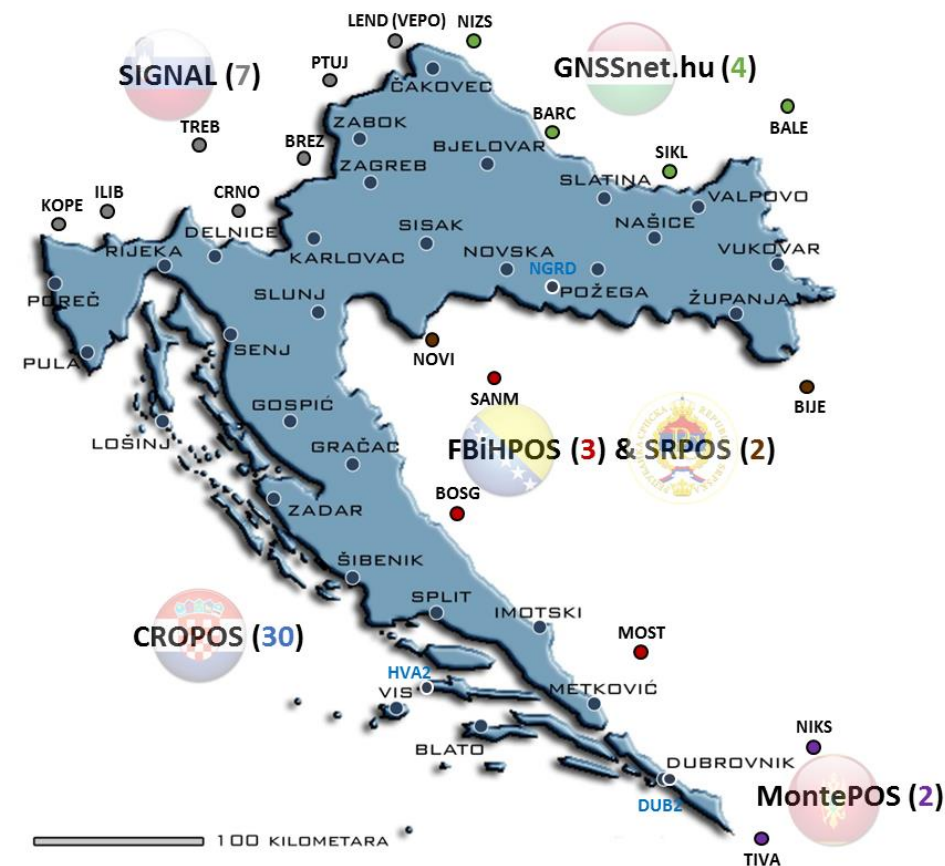
## Chronology of CROPOS development (1)

- November 2008 – representatives of EU Delegation in Zagreb, MIFIN and company *Trimble* Europe signed a contract on realization of Croatian national positioning system - financing: 75% PHARE-2005 programme + 25% State Budget
- 9<sup>th</sup> 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
    - VPPS  $\Rightarrow$  0.02 m (2D), 0.04 m (3D)
    - GPPS  $\Rightarrow$  < 1 cm
- CROPOS reference frame  $\Rightarrow$  ETRF2000 (R05) e2008.83 (24 h session; GPS Week: 1503)
- $\sigma_{\varphi} = 1.2$  mm;  $\sigma_{\lambda} = 1.1$  mm,  $\sigma_h = 3.4$  mm



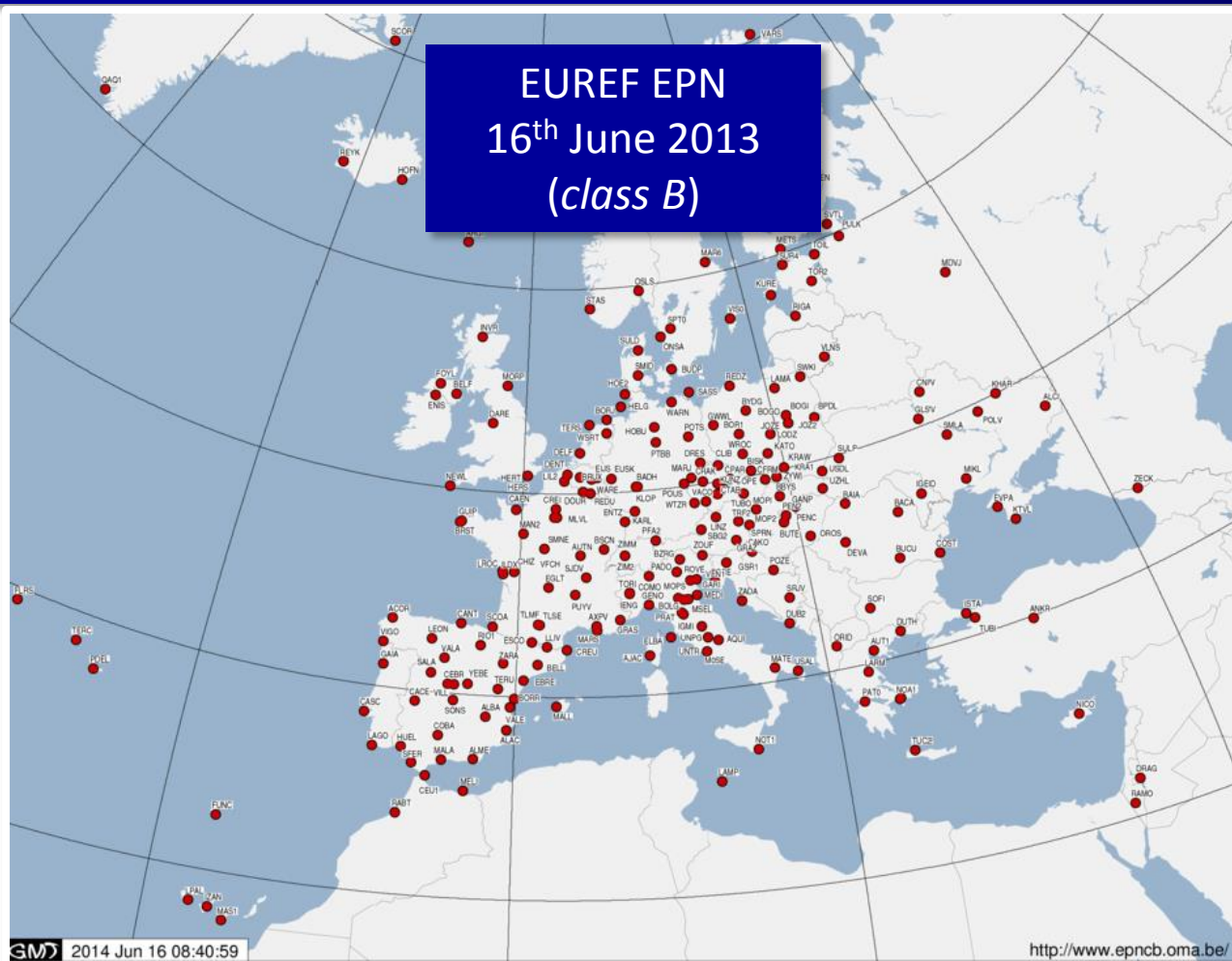
## Chronology of CROPOS development (2)

- 8<sup>th</sup> June 2009 – 1<sup>st</sup> CROPOS Conference – an agreement between GA of Slovenia, Hungary, Montenegro and Croatia on CORS data exchange:
  - SIGNAL (x7)
  - GNSSnet.hu (x4)
  - MontePOS-a (x2)
- IGS DUBI ⇒ EPN DUB2 (13.11.2011.; GPSW: 1712, DOY: 317)
- HVA2 (29.10.2012.; GPSW: 1712, DOY: 303) – Astronomical Observatory Hvar
- IGS OSJE ⇒ NGRD (14.07.2013.; GPSW: 1749; DOY: 195)
- December 2013 ⇒ FBiHPOS (x3) + SRPOS (x2)
- 4<sup>th</sup> March 2015 ⇒ CROPOS (x30) + DUB2 + HVA2 + NGRD = CROPOS (x33)
- Networked solution ⇒ **51** CORS





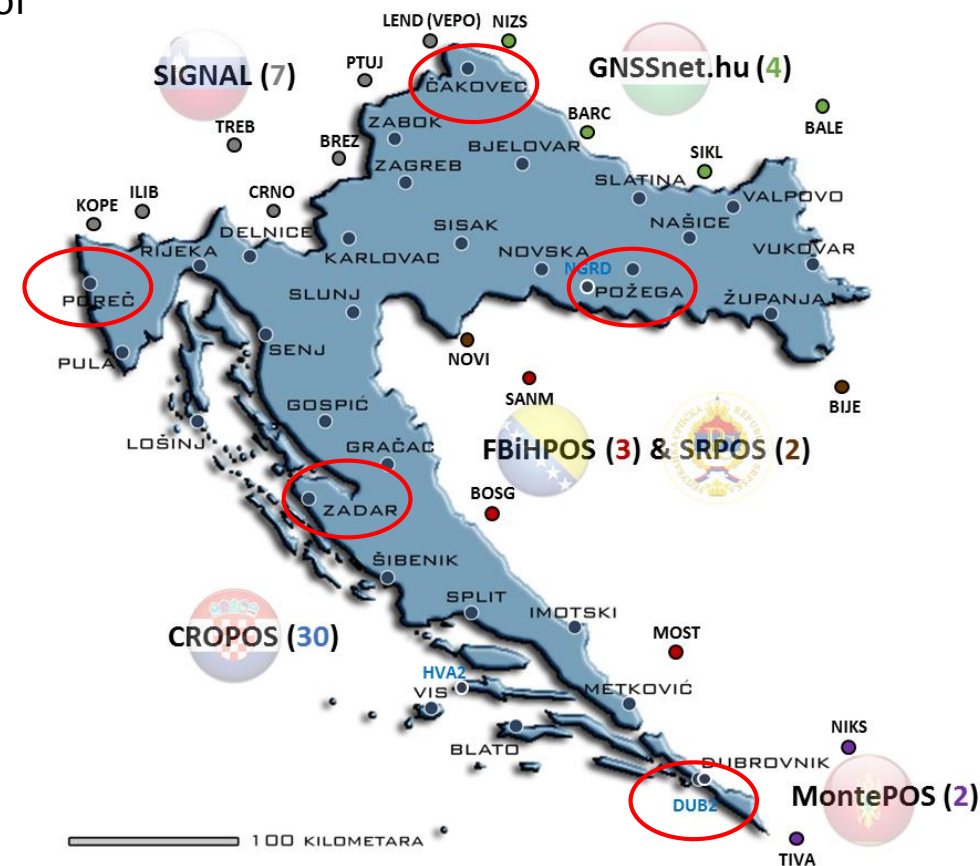
# Chronology of CROPOS development (2)



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## CROPOS services

**DPS** Real-time network solution  
 Code measurements  
 0.3 – 0.5 m

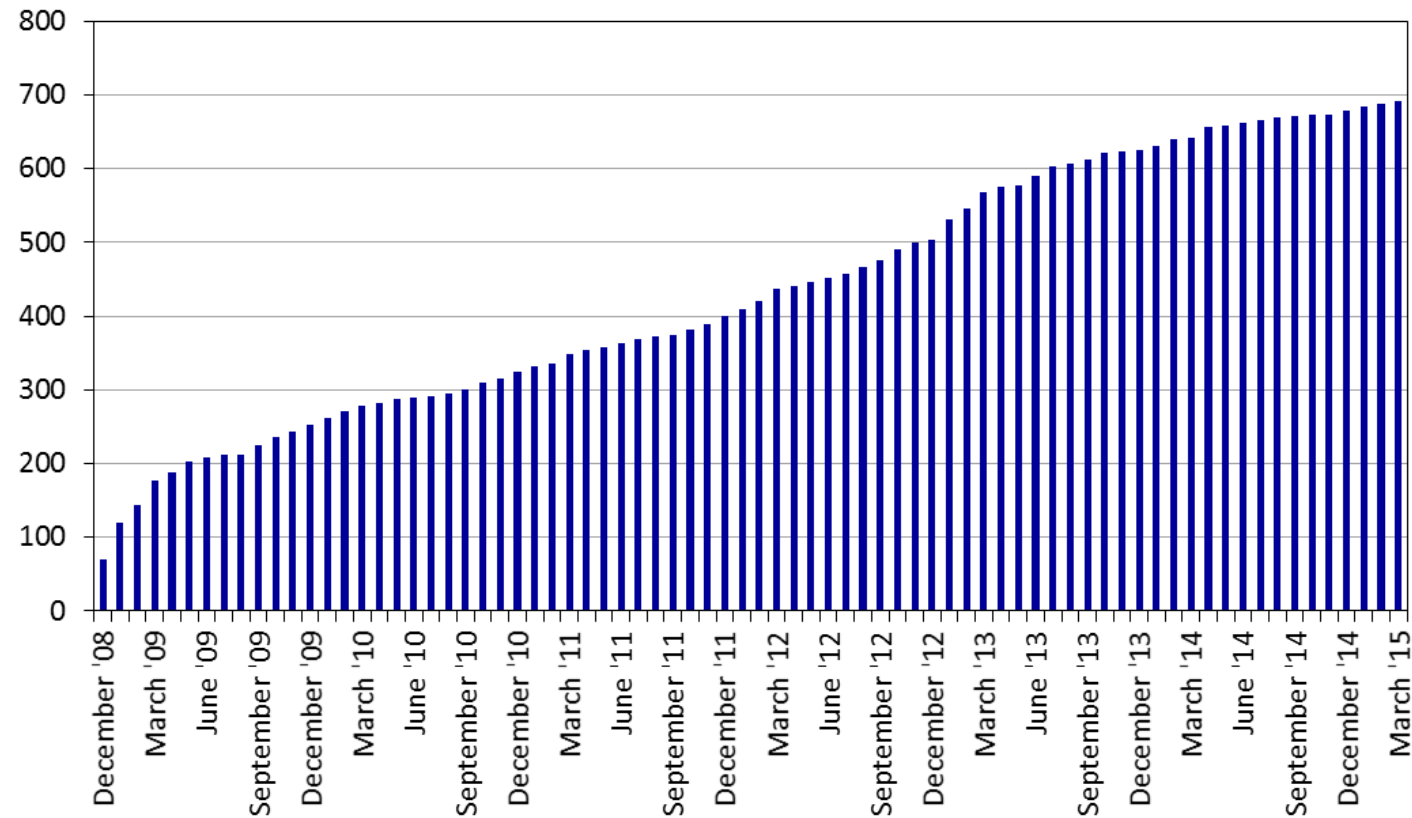
**VPPS** Real-time network solution  
 Phase measurements  
 0.02 (2D) – 0.04 m (3D)

**GPPS** Post-processing  
 RINEX, VRS RINEX  
 < 0.01 m

Data format	Unit	Price
RTCM 2.3	1 yr	1000 HRK (~135 €)
RTCM 2.3	1 min	0.35 HRK (~0.05 €)
RTCM 3.1	1 yr	5000 HRK (~675 €)
RINEX RINEX VRS	1 min	0.50 HRK (~0.07 €)

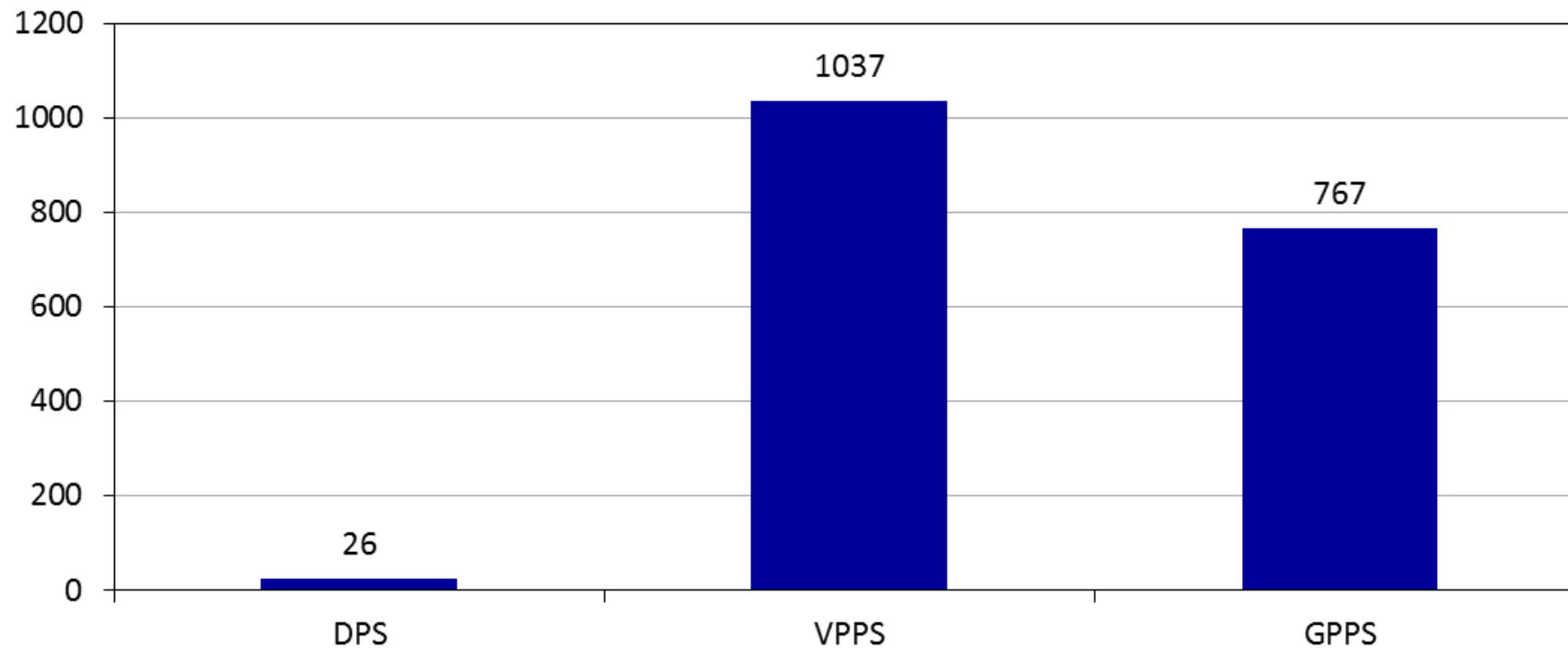
# CROPOS usage statistics - companies

Number of registered companies (till March 2015) - in total 692



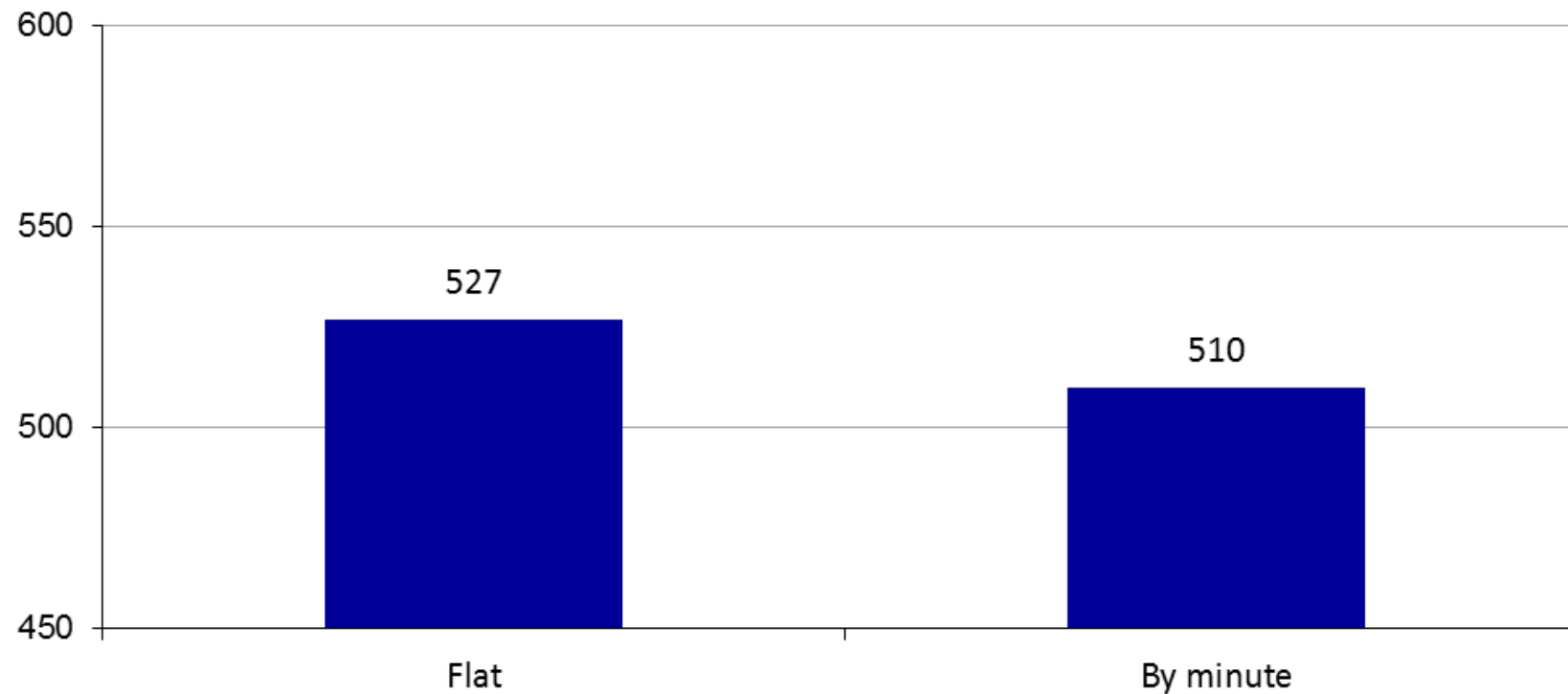
## CROPOS usage statistics - services

Number of users (user names) by services (till March 2015) - in total 1830



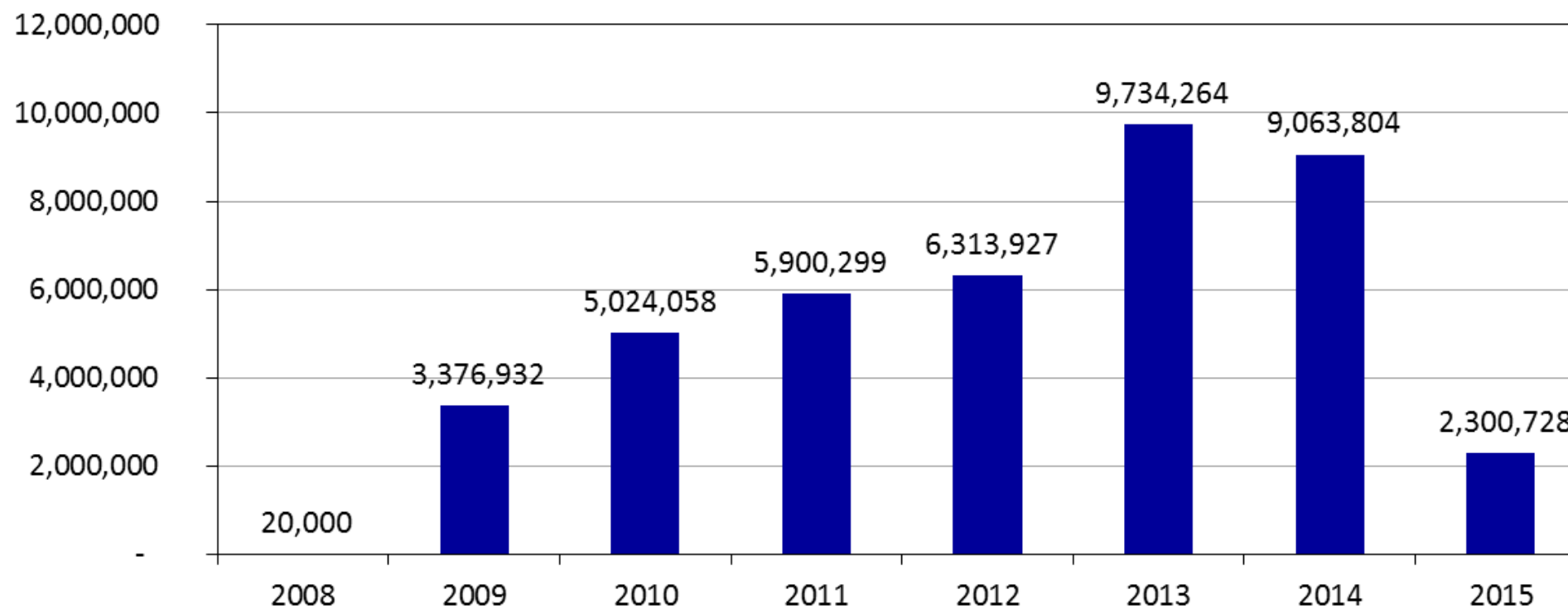
## CROPOS usage statistics – VPPS (1)

Number of users by payment model of VPPS - in total 1037



## CROPOS usage statistics – VPPS (2)

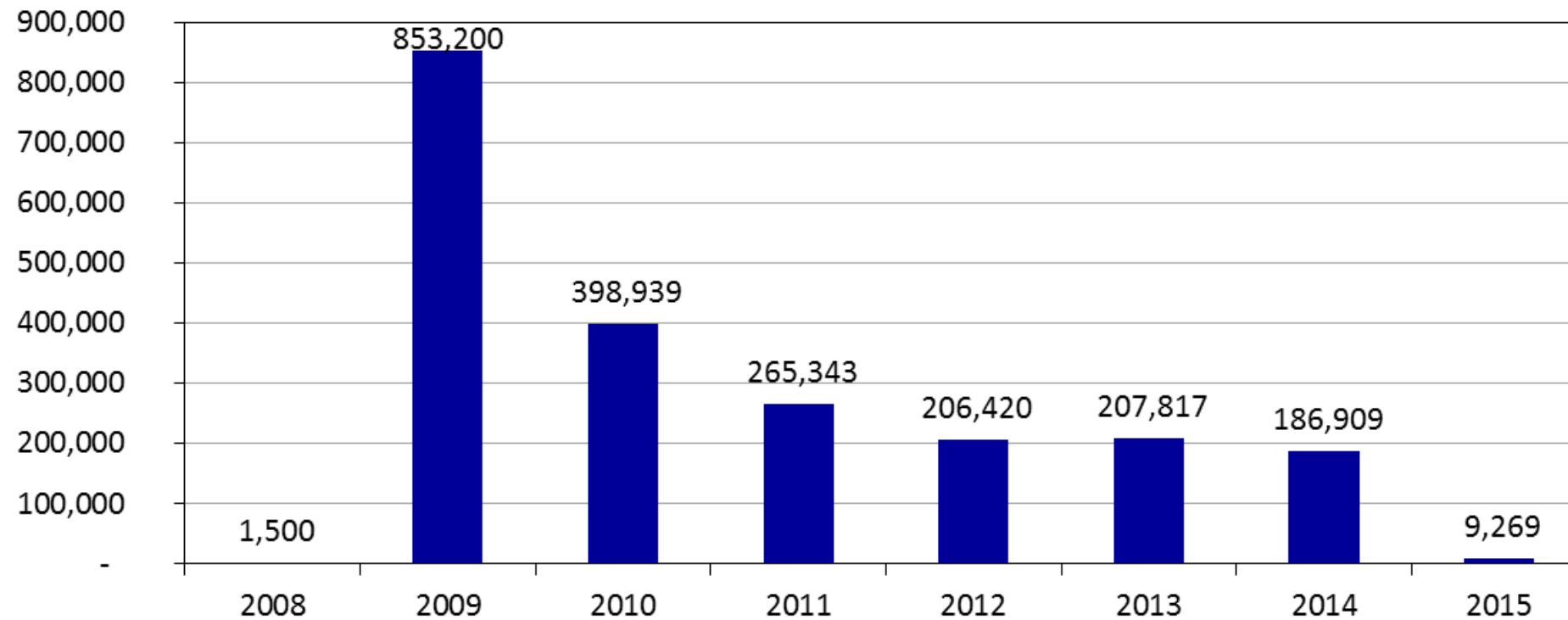
Usage of VPPS in minutes (till March 2015) - in total 39 433 284





## CROPOS usage statistics – GPPS

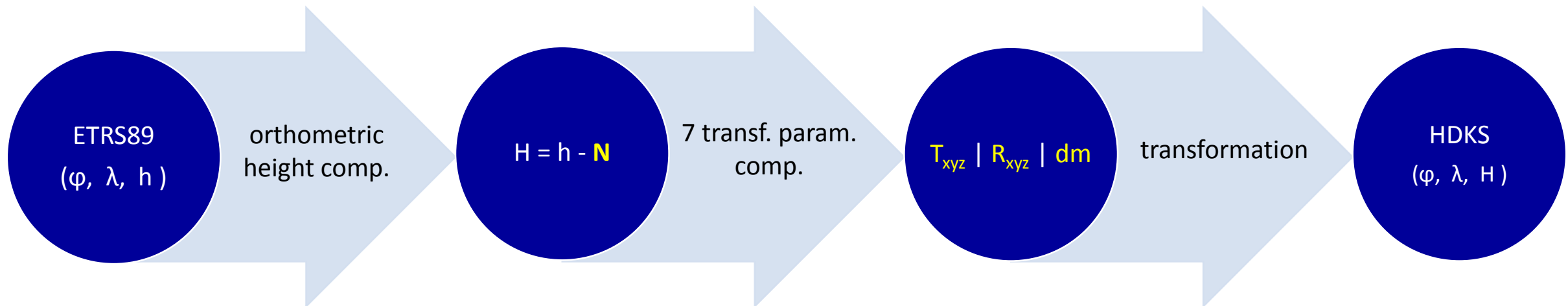
Usage of GPPS in minutes (till March 2015) - in total **2 120 128**



## Datums and coordinates

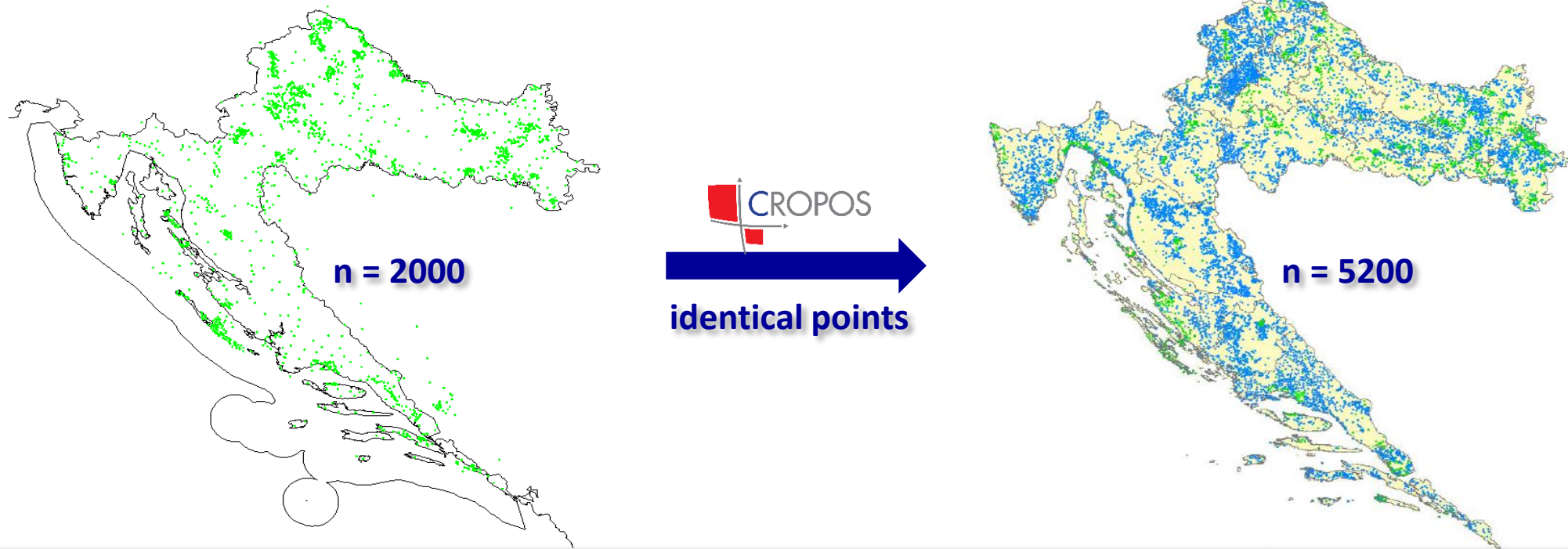
- *Decree on establishing new official geodetic datums and map projections of the Republic of Croatia (August 2004):*
  - horizontal datum: [HTRS96](#) (ETRS89, GRS80)
  - vertical datum: [HVRS71](#)
  - gravimetric datum: [HGRS03](#)
  - plane map projections: [HTRS96/TM](#), [HTRS96/LCC](#), UTM
- Coordinates:
  - CROPOS  $\Rightarrow$  [ETRF2000](#) (R05) e2008.83 (ETRS89; e1989.0), ellipsoid: [GRS80](#);  $\varphi$ ,  $\lambda$ ,  $h$  (X, Y, Z); ellipsoidal height: **h**
  - [HTRS96/TM](#)  $\Rightarrow$  ellipsoid: [GRS80](#); N, E, **H** (Transverse-Mercator projection); orthometric height: **H = h - N** ([HVRS71](#))
  - [HDKS](#)  $\Rightarrow$  ellipsoid: [Bessel 1841](#); y, x, **H** (Gauss-Krüger projection); orthometric height: **H = h - N** ([HVRS1875](#))

## ETRS89 <> HDKS (dual datum problem)



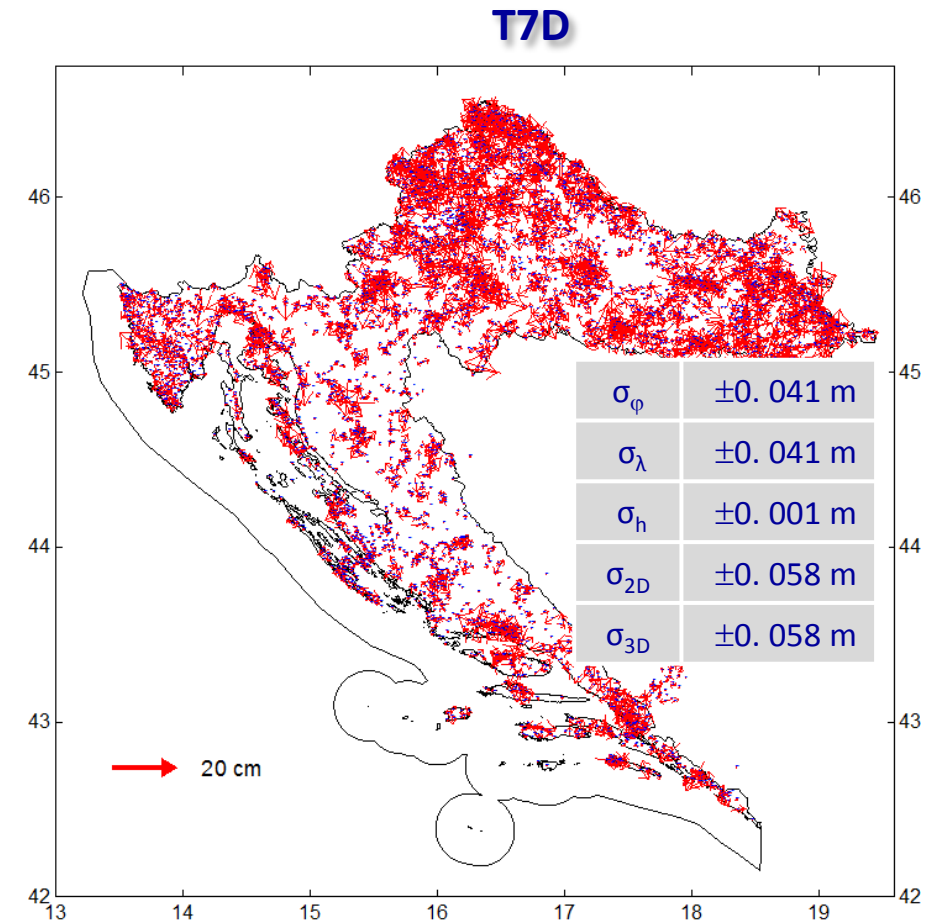
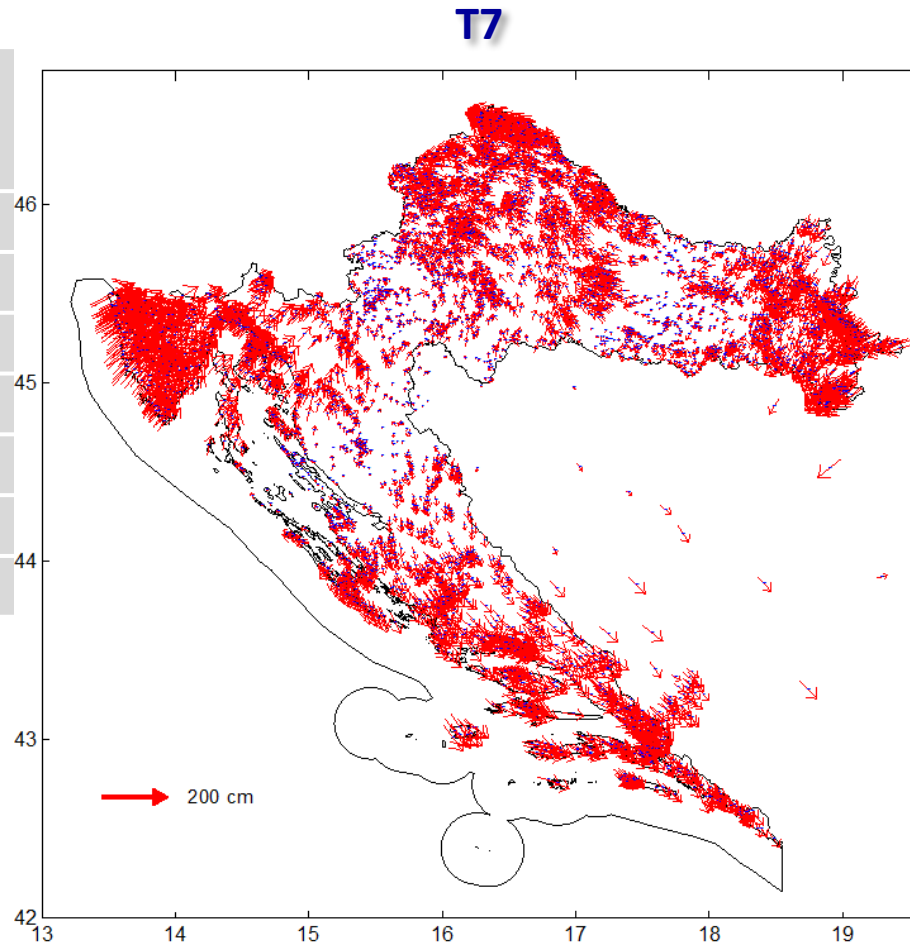
## Solution: new transformation model – 'T7D' (T7 + D) by Prof. Tomislav Bašić

- Unique transformation model **HTRS96**  $\Leftrightarrow$  **HDKS** - uniform, reliable and simple transformation system, primarily available to all users
- GRID transformation for the whole Croatian territory, consisting of **7-parameter transformation** and a proper raster predicted **values of distortion**, both in plane coordinates and height



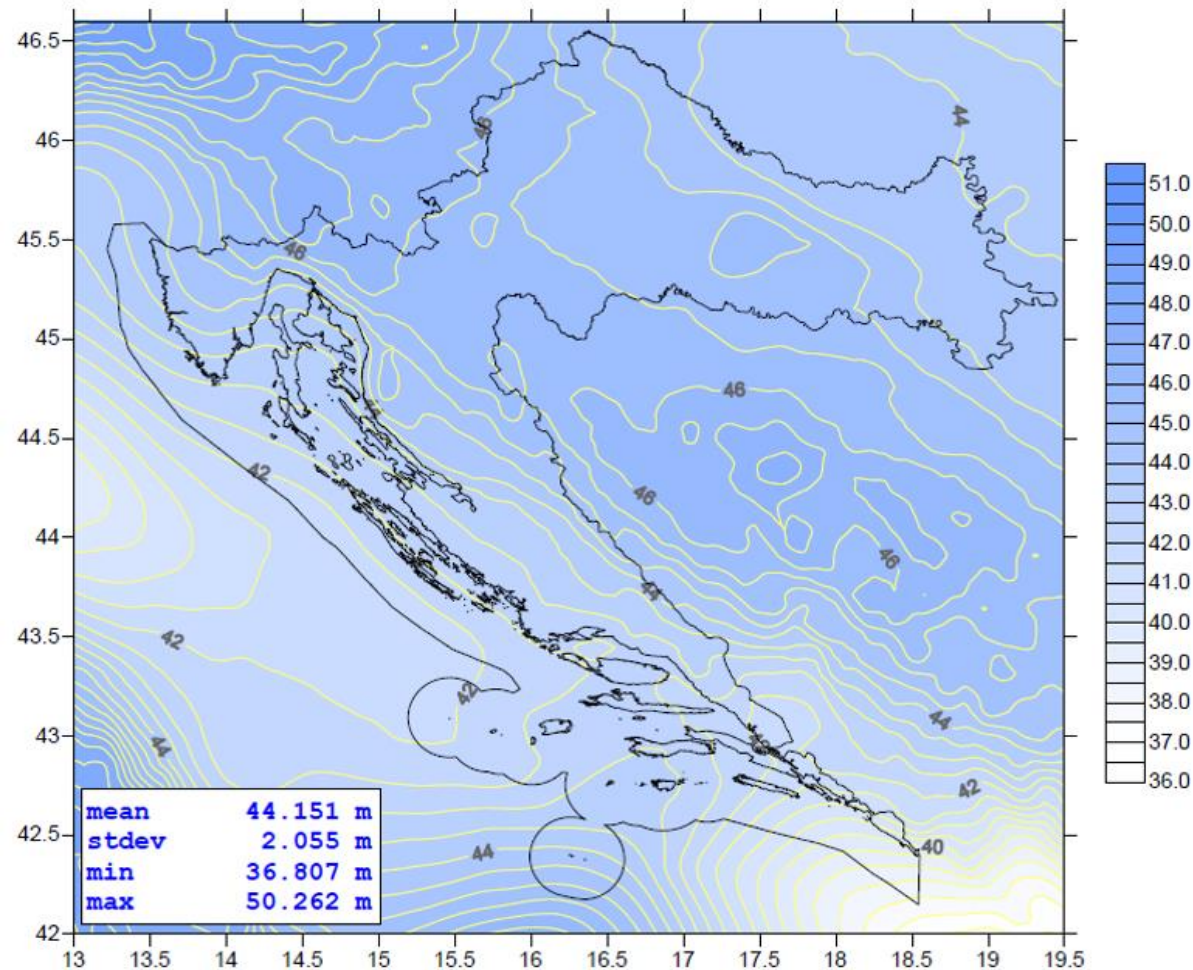
# T7 vs T7D

n = 5200	Transformation parameters	Accuracy estimation (m <sub>0</sub> =0.804 m)
Tx	-546.616 m	±0.593 m
Ty	-162.375 m	±0.657 m
Tz	-469.482 m	±0.586 m
Rx	5.90498 ″	±0.0189 ″
Ry	2.07397 ″	±0.0218 ″
Rz	-11.50994 ″	±0.0187 ″
μ	4.43885 ppm	±0.075 ppm



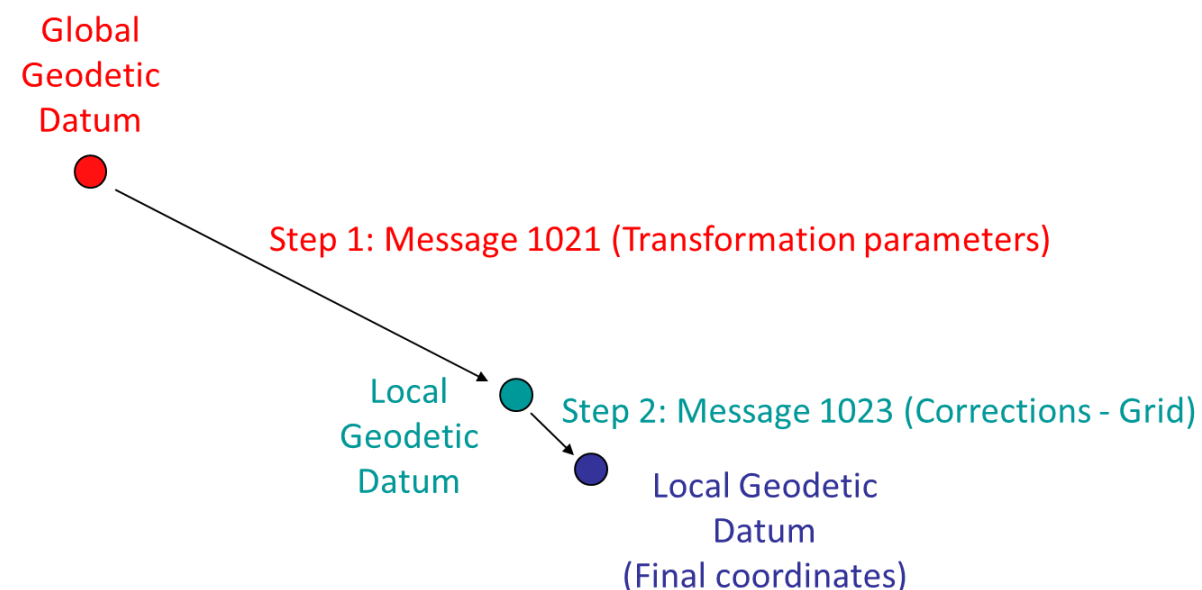
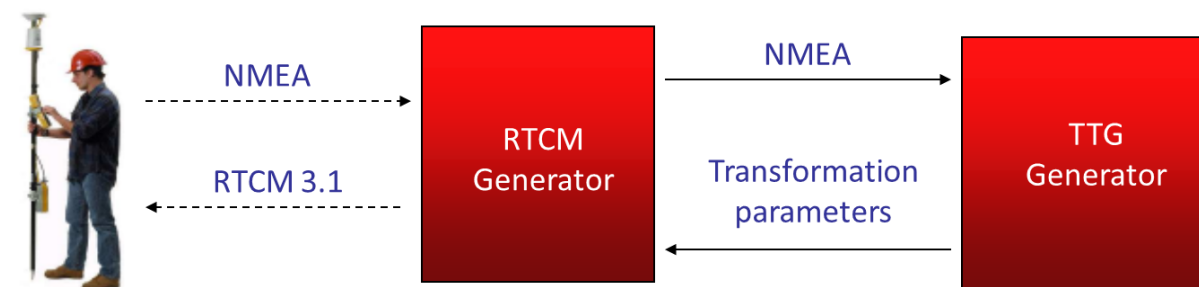


## 'HRG2009' geoid model by Prof. Tomislav Bašić



# Implementation of models in CROPOS

- **CROPOS\_VRS\_HTRS96** (3<sup>rd</sup> January 2011)
  - Start ellipsoid: GRS80 > Goal ellipsoid: GRS80 (a, b)
  - Transformation parameters (7P = 0.0)
  - Grid files: Geoid – HVRS71 (undulations N)  
Distortion (corrections = 0.0)
  
- **CROPOS\_VRS\_HDKS** (18<sup>th</sup> July 2011)
  - Start ellipsoid: GRS80 > Goal ellipsoid: Bessel 1841 (a, b)
  - Transformation parameters (7P: Tx, Ty, Tz, dm, Rx, Ry, Rz)
  - Grid files: Geoid – HVRS1875 (undulations N)  
Distortion (corrections)



# Scientific applications...CROPOS reference frame - stability

- No. of daily solutions: **1463 (4 years)**
- 16<sup>th</sup> November 2008 - 31<sup>st</sup> December 2012
- Mean epoch for **9<sup>th</sup> December 2010 e2010.94**
- Bernese 5.0** (AIUB)

[31 CROPOS + 7 SIGNAL + 4 GNSSnet.hu + 2 MontePOS]

+

[3 IGS\_RH (DUB2, DUBI, OSJE)]

+

[2 IGS (GOPE, POTS)]

+

5 IGS\_FIX (GRAZ, MATE, ZIMM, WTZR, PENC)



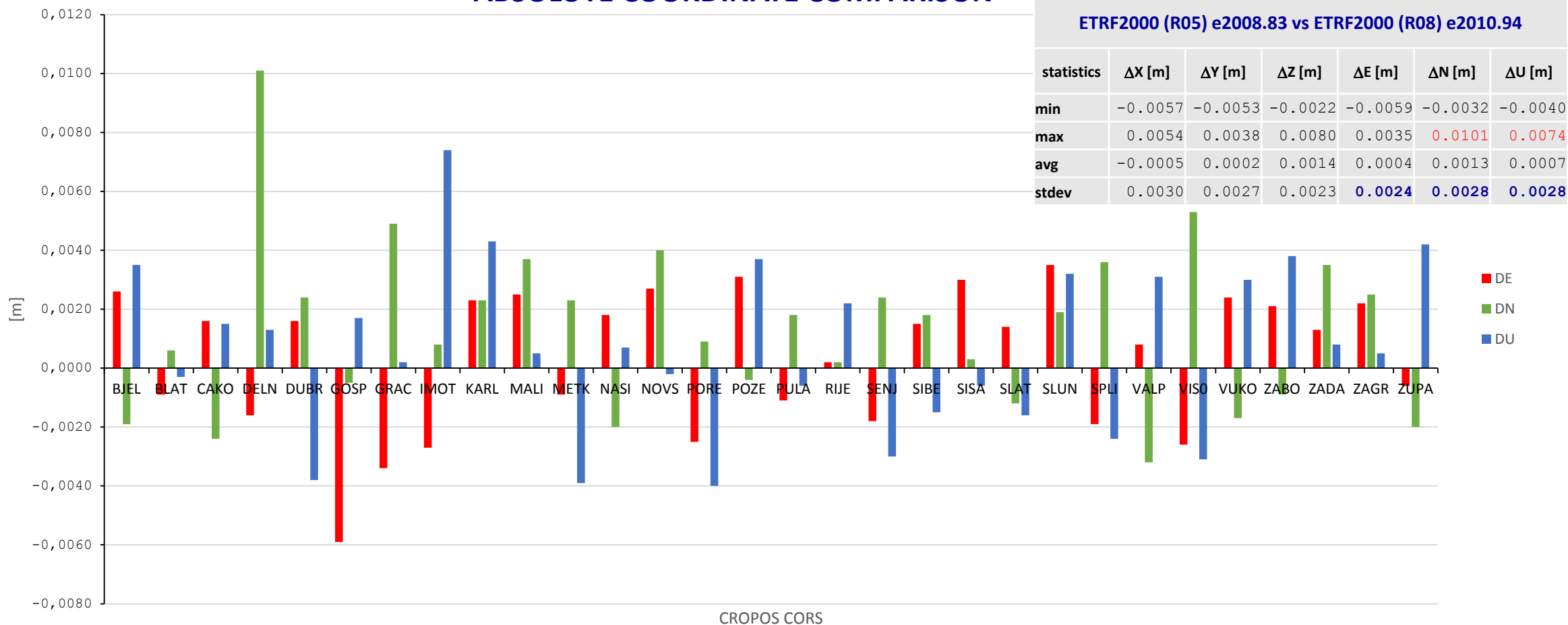
**54**

## Numerical indicators of input and output data

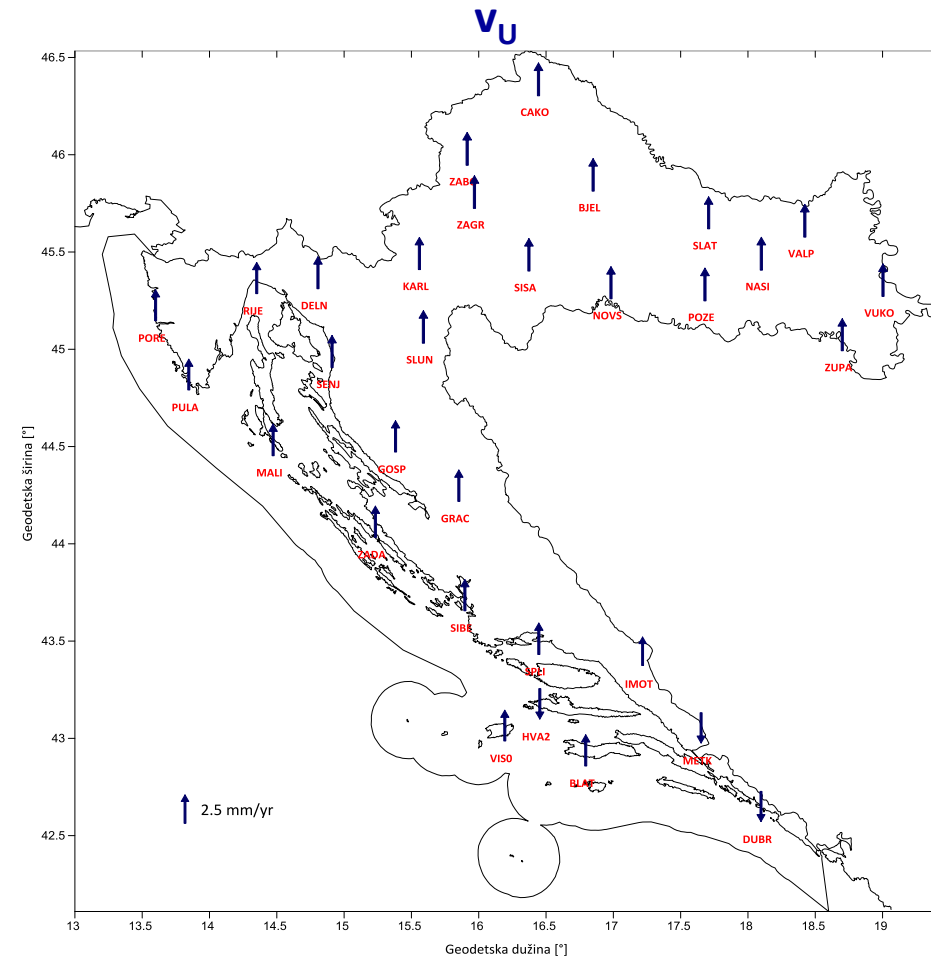
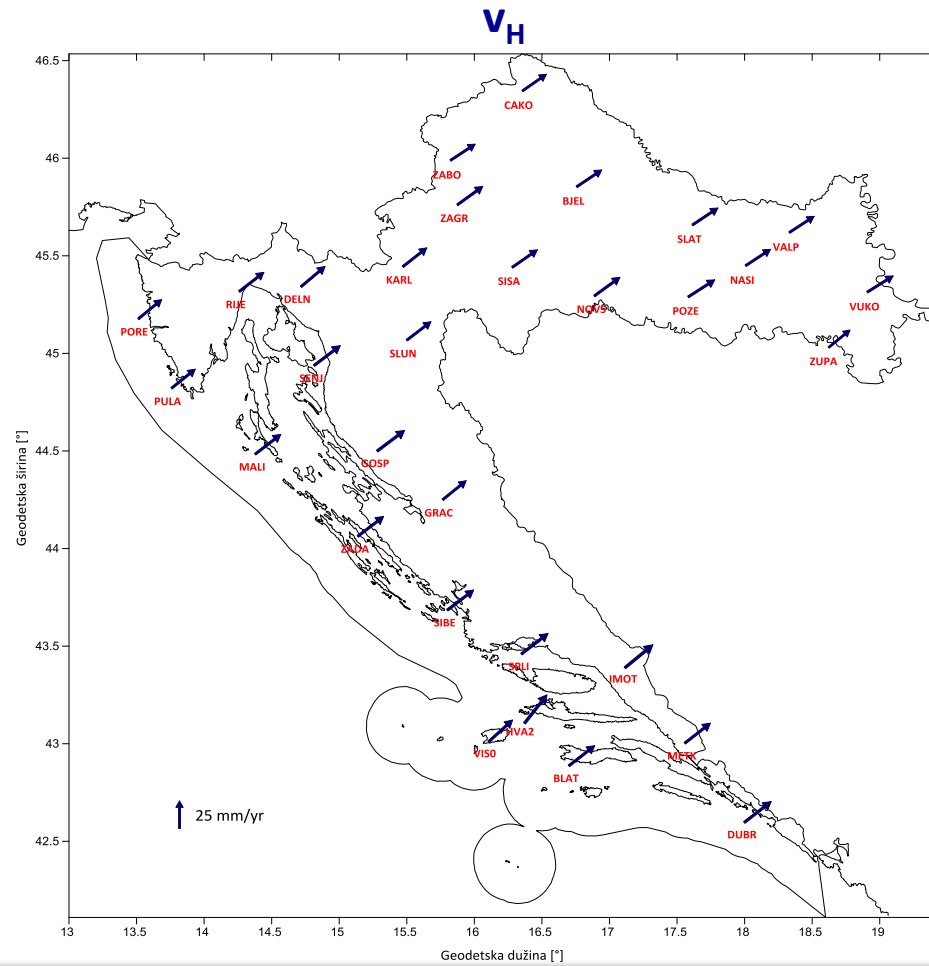
<b>Total number of daily solutions:</b>	<b>1463</b>
<b>Number of RINEX data files (15 sec.):</b>	69 894
<b>Total number of measurements (30 sec.; L1, L2, C/A, P):</b>	3 633 733 829
<b>Number of cycle slips (1<sup>st</sup> pass):</b>	1 570 933
<b>Number of marked measurements (1<sup>st</sup> pass):</b>	20 979 500
<b>GPSEST float solution (1<sup>st</sup> solution) - total number of unknowns:</b>	5 054 687
<b>Ambiguity calculation</b>	
<b>Input (L1 + L2):</b>	9 007 558
<b>Left (L1 + L2):</b>	2 892 870
<b>Solved:</b>	68%
<b>GPSEST fixed solution</b>	
<b>Total number of unknowns:</b>	2 769 124
<b>Coordinate unknowns:</b>	203 934
<b>Ambiguity unknowns:</b>	1 409 564
<b>Troposphere unknowns:</b>	384 812
<b>Number of measurements (L3):</b>	547 408 235

# GPS WEEK 1503 (7 daily solutions) vs GPS WEEK 1506-1721 (1463 daily solutions)

## ABSOLUTE COORDINATE COMPARISON



# CROPOS velocity model...geodynamics







## CROPOS...many possibilities

- Modern approach to solving navigation and positioning tasks at the territory of Republic of Croatia
- Fully implemented 3D 1 on 1 reversible transformation model (T7D)
- Long-term stability of CROPOS reference frame
- Scientific possibilities (plate tectonics, earthquake monitoring...)
- Future: GNSS meteorology, global geodetic points, real-time PPP...

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