VLBI Estimates of Vertical Crustal Motion in Europe

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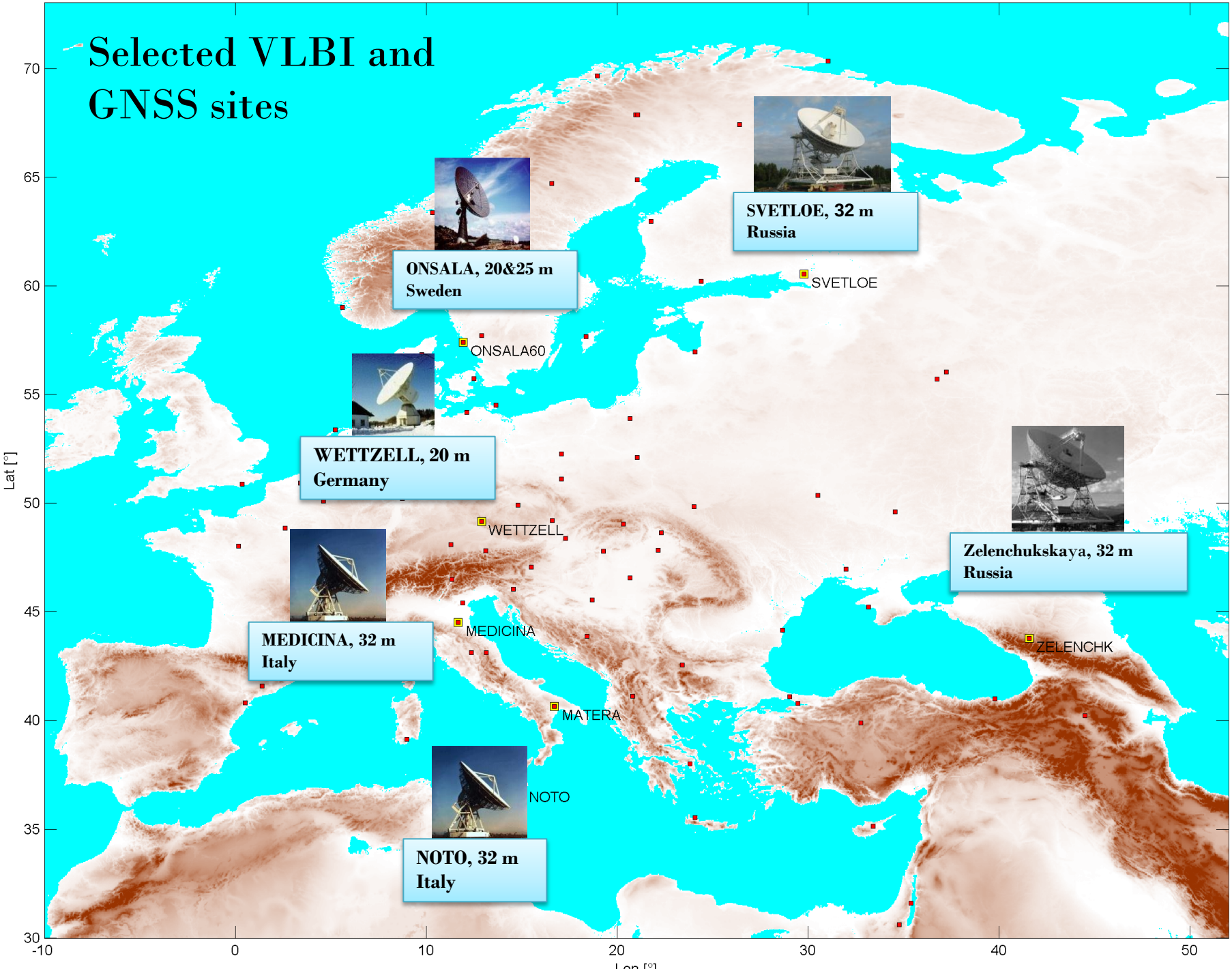
aims of this study

- to detemine the vertical crustal motion in Europe by means of analysing European VLBI sessions carried out from 1990 to 2010 within the International VLBI Service for Geodesy and Astrometry (IVS), IVS-Europe.
- to compare IVS-Europe VieVS solution results with GNSS-EUREF solution.
- to compare our radial velocity estimates to those of the previous study carried out by Campbell et al., 2002, ITRF2005, and VTRF2008 velocities.


Selected VLBI and GNSS sites
ONSALA, 20&25 m
Sweden
SVETLOE, 32 m
Russia
SVETLOE
ONSALA60
WETTZELL, 20 m
Germany
WETTZELL
Zelenchukskaya, 32 m
Russia
MEDICINA, 32 m
Italy
MEDICINA
ZELENCHK
MATERA
NOTO
NOTO, 32 m
Italy
Lat [°]
Lon [°]
70
65
60
55
50
45
40
35
30
-10
0
10
20
30
40
50

IVS-Europe sessions have been carried out regularly (6 to 12 sessions per year) since late 1989.

objectives of these IVS-Europe sessions are

- to determine crustal motion in Europe
- to contribute providing a **stable reference frame for Europe** (ETRF) with other space geodetic techniques.

Data Analysis for Crustal Motion

ANALYSIS

IVS European Sessions were analysed by the **VieVS VLBI Analysis Software** developed at *Institut für Geodaesie und Geophysik* of *Technische Universitaet Wien*.

PRODUCED TIME SERIES

After the estimation of the adjusted coordinates of the antennas at the respective time epochs, **position time series** of each antenna were produced.

LS ESTIMATION

The determination of the VLBI station velocities was carried out by a least-squares fit of a first order polynomial to the position time series.

LS Estimation -1

LINEAR FUNCTION

$$dX = X_t - X_{t0} = a_0 + a_1(t - t_0) + \varepsilon_t$$

ESTIMATED PARAMETERS

a_0 **Offset; difference between VTRF 2008 coordinates and new TRF coordinates at epoch 2000.0**

a_1 **Trend; velocity in global cartesian**

t_0 **2000.0 reference epoch**

t **Epochs of position estimates**

X_t **New TRF coordinates**

X_{t0} **VTRF 2008 coordinates**

ε_t **Post fit observational residuals**

Stations	Velocities from IVS-Europe Sessions Analysis (cm/year)			Velocities of ITRF 2005 (cm/year)			Velocities of VTRF 2008 (cm/year)		
	Vx	Vy	Vz	Vx	Vy	Vz	Vx	Vy	Vz
MATERA	-1.83	1.90	1.49	-1.80	1.89	1.55	-1.86	1.89	1.47
MEDICINA	-1.83	1.87	1.11	-1.82	1.88	1.10	-1.79	1.88	1.13
WETTZELL	-1.56	1.70	1.03	-1.56	1.68	1.04	-1.57	1.70	1.03
ONSALA60	-1.38	1.46	1.08	-1.37	1.44	1.09	-1.40	1.44	1.06
SVETLOE	-1.94	1.17	0.74	-1.68	1.43	0.88	-1.83	1.22	0.83
NYALES20	-1.40	0.73	1.05	-1.42	0.71	1.02	-1.42	0.73	1.08

Table 1. VieVS solution velocity vectors of IVS-Europe Sessions and inter-technique combined TRF solutions of ITRF-2005 and VTRF-2008 (all solutions are at epoch 2000.0)

in global cartesian coordinate system

Conversion of from global cartesian coordinate system to the local topocentric coordinates

$$\begin{bmatrix} d_{North} \\ d_{East} \\ d_{Up} \end{bmatrix} = T * \begin{bmatrix} d_X \\ d_Y \\ d_Z \end{bmatrix}$$

d_NEU dX

$$T = \begin{bmatrix} -\sin\varphi\cos\lambda & -\sin\varphi\sin\lambda & \cos\varphi \\ -\sin\lambda & \cos\lambda & 0 \\ \cos\varphi\cos\lambda & \cos\varphi\sin\lambda & \sin\varphi \end{bmatrix}$$

φ λ latitude and longitude of station

LS Estimation -2

LINEAR FUNCTION

$$d\_NEU = b_0 + b_1(t - t_0) + \varepsilon_{NEU(t)}$$

ESTIMATED PARAMETERS

b_0 **Offset; difference between VTRF 2008 coordinates and new TRF coordinates at epoch 2000.0**

b_1 **Trend; velocity in local topocentric coordinate system**

$$\begin{bmatrix} V_{North} \\ V_{East} \\ V_{Up} \end{bmatrix}$$

t_0 **2000.0 reference epoch**

t **Parameter estimation epoch**

$\varepsilon_{NEU(t)}$ **Post fit observational residuals**

Stations	Velocities of IVS-Europe Session Analysis (cm/year)			Velocities of ITRF 2005 (cm/year)			Velocities of VTRF 2008 (cm/year)		
	V_{North}	V_{East}	V_{Up}	V_{North}	V_{East}	V_{Up}	V_{North}	V_{East}	V_{up}
MATERA	1.92	2.35	0.03	1.95	2.33	0.11	1.92	2.35	0.02
MEDICINA	1.77	2.20	-0.23	1.77	2.21	-0.23	1.77	2.20	-0.19
WETTZELL	1.54	2.00	0.03	1.55	1.99	0.04	1.55	2.01	0.03
ONSALA60	1.47	1.71	0.35	1.47	1.69	0.36	1.47	1.70	0.32
SVETLOE	1.31	2.07	0.04	1.08	2.08	0.40	1.26	1.97	0.24
NYALES20	1.40	1.00	0.81	1.42	0.99	0.76	1.42	1.01	0.82

Table 3. IVS-Europe Sessions VieVS solution velocity vectors in north, east and radial directions

in local topocentric coordinate system

Comparison of estimated velocities from IVS-Europe sessions VieVS solution with those of corresponding ITRF 2005 and VTRF 2008 solutions

Stations	differences between IVS-Europe Sessions and ITRF 2005 (cm/year)			differences between IVS-Europe Sessions and VTRF 2008 (cm/year)		
	V_{North}	V_{East}	V_{Up}	V_{North}	V_{East}	V_{up}
MATERA	-0.03	0.02	-0.08	0.00	0.00	0.01
MEDICINA	0.00	-0.01	-0.00	0.00	0.00	-0.04
WETTZELL	-0.01	0.01	-0.01	-0.01	-0.01	0.00
ONSALA60	0.00	0.02	-0.01	0.00	0.01	0.03
NYALES20	-0.02	0.01	0.04	-0.02	-0.01	-0.01

Table 4. Differences between IVS-European Sessions VieVS solution velocity vectors in north, east and radial directions

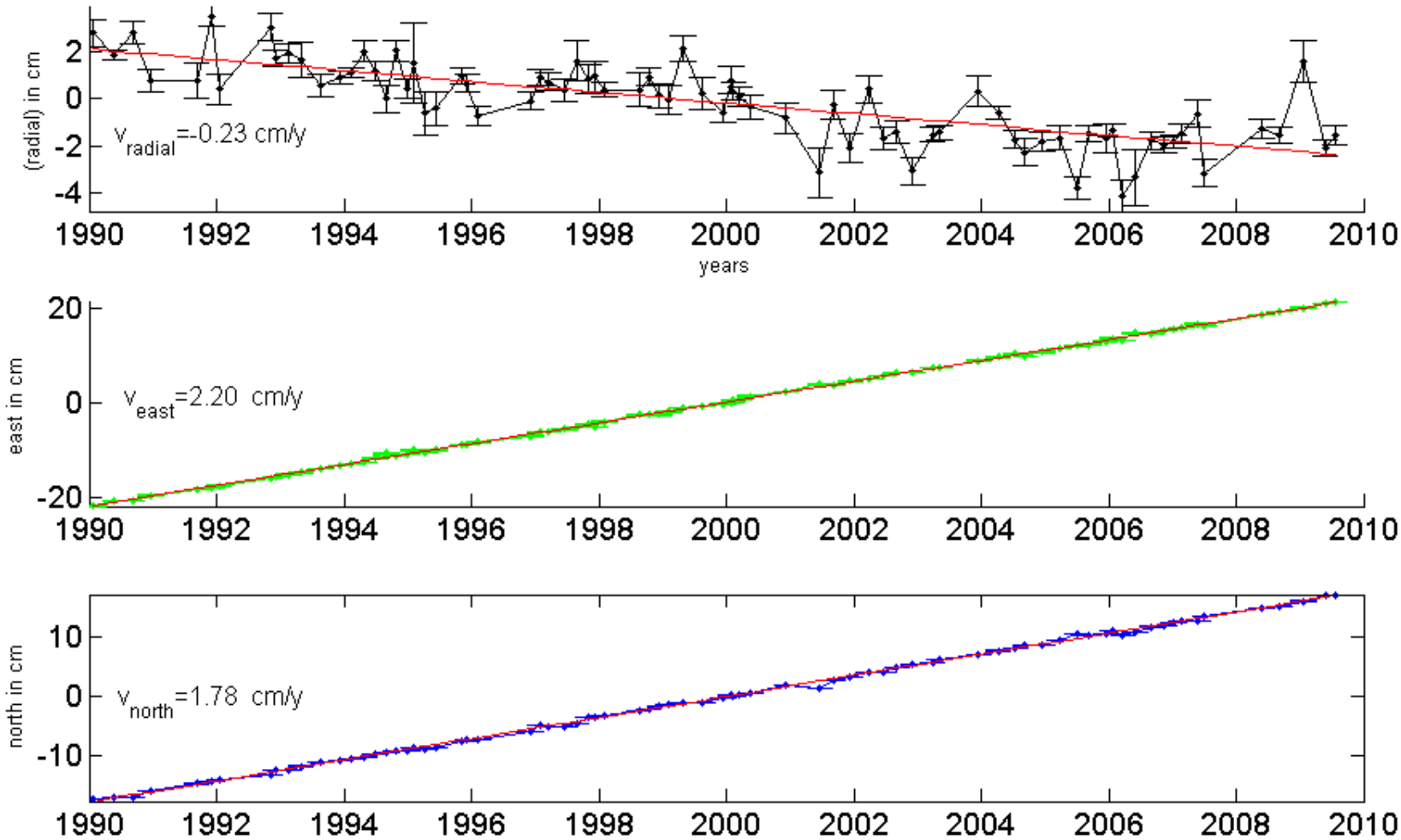
in local topocentric coordinate system

$$test\_value = \frac{estimate}{formal\ error} > t_{0.95,f}$$

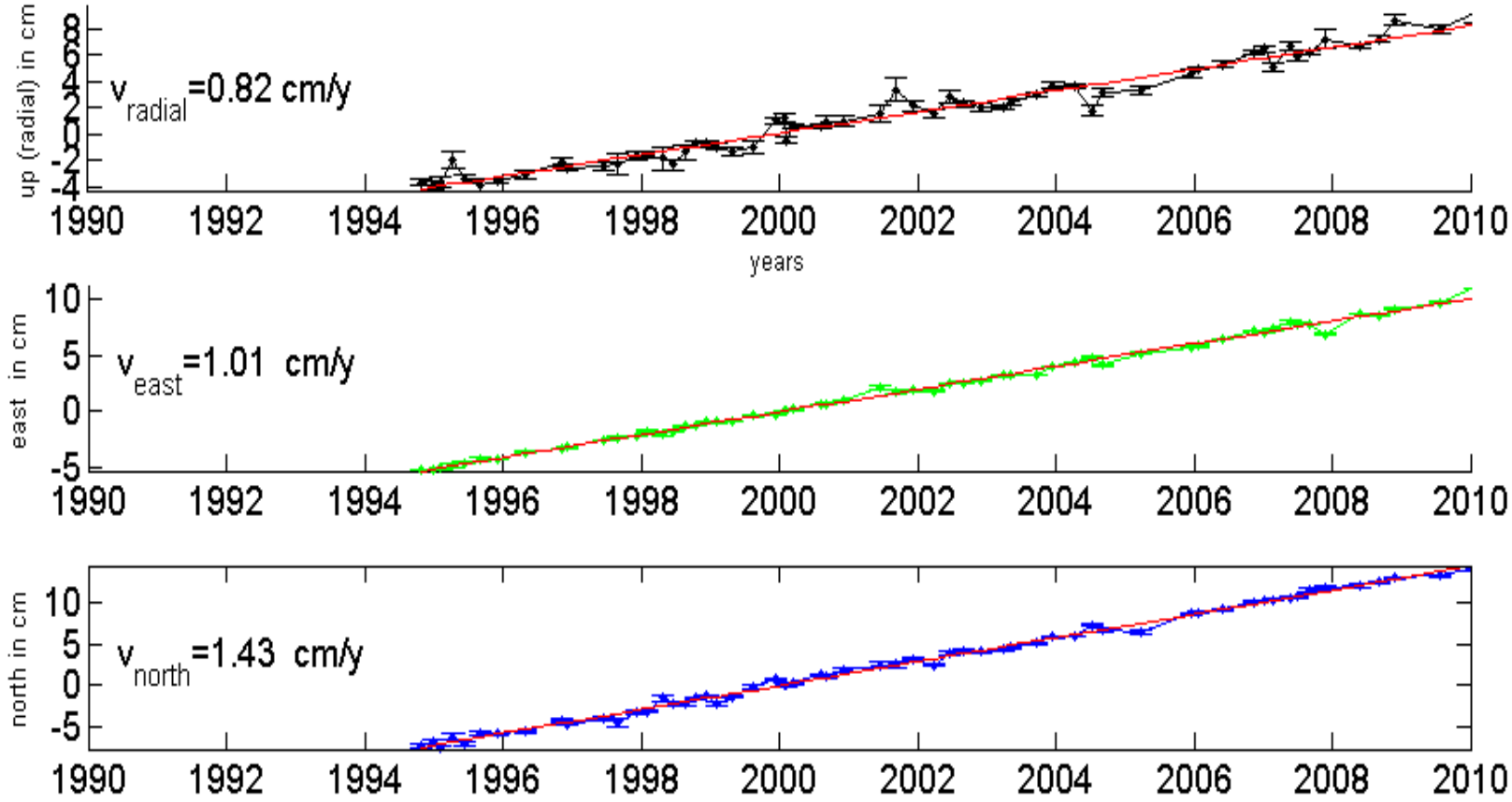
f : degrees of freedoom 0.95 : confidence level

Parameter estimates are statistically significant…

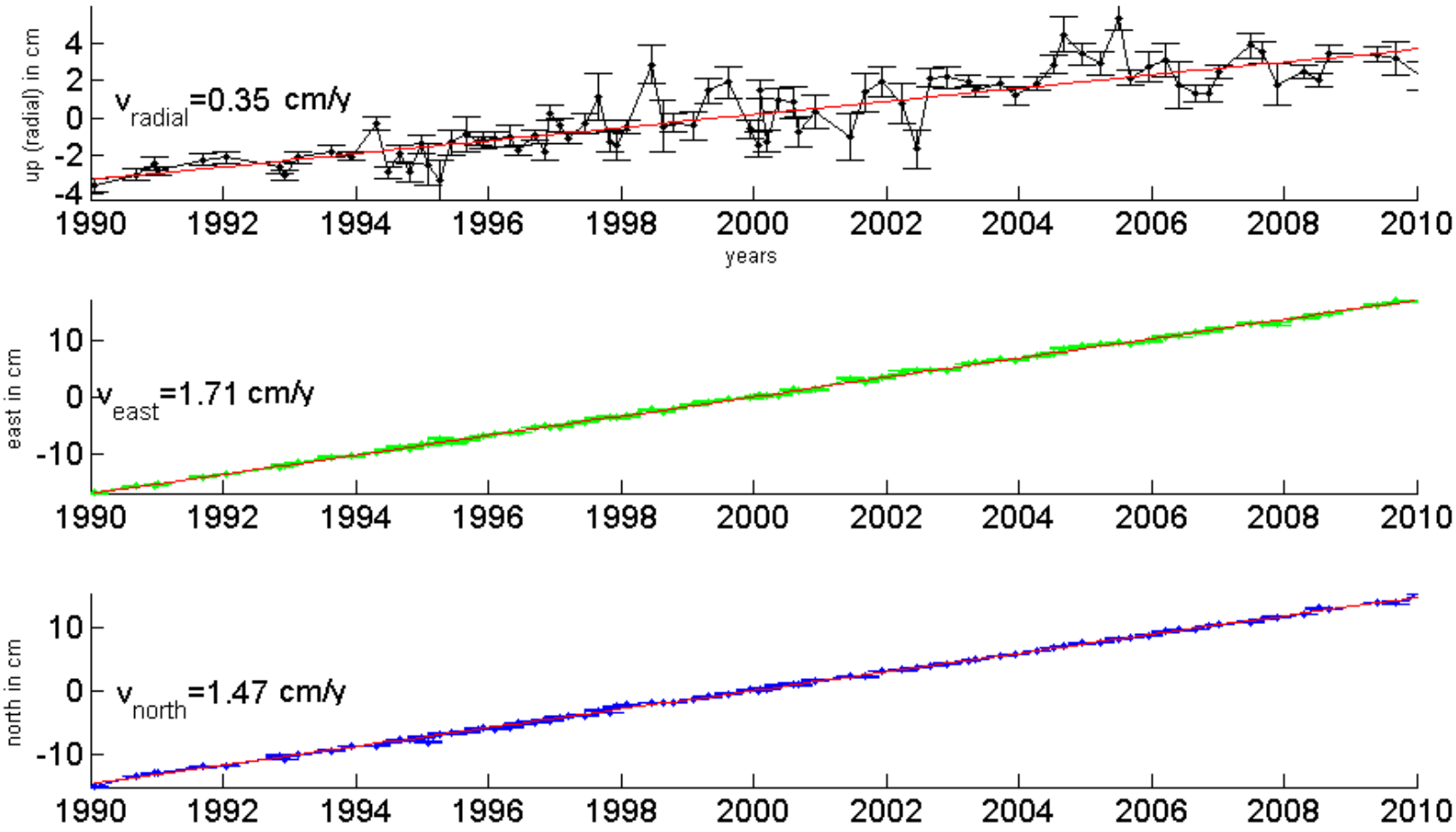
VieVS-TRF Solutions of IVS-Europe Sessions, VLBI Antenna: MEDICINA epoch 2000.0



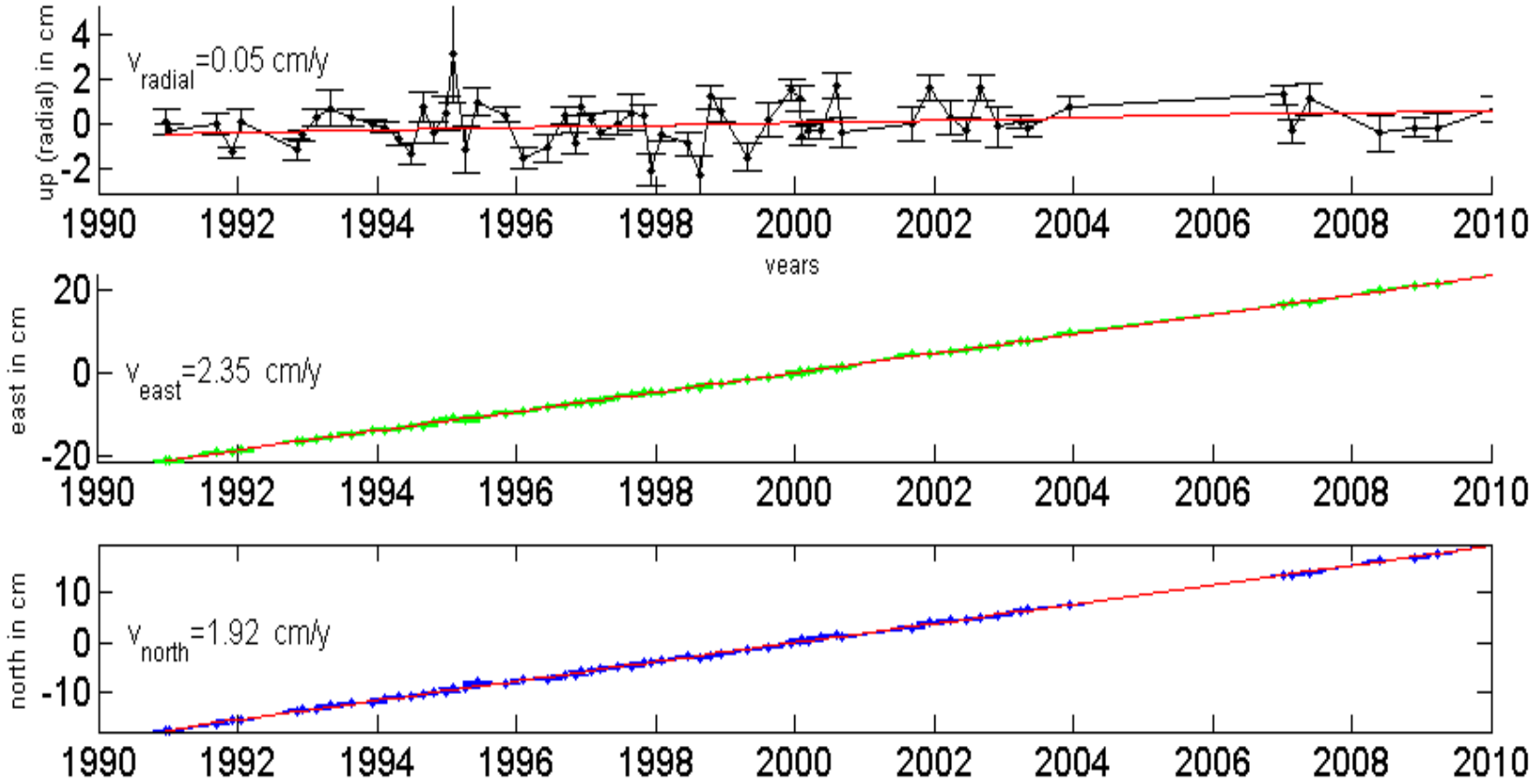
VieVS-TRF Solutions of IVS-Europe Sessions, VLBI Antenna: NYALES20 epoch 2000.0



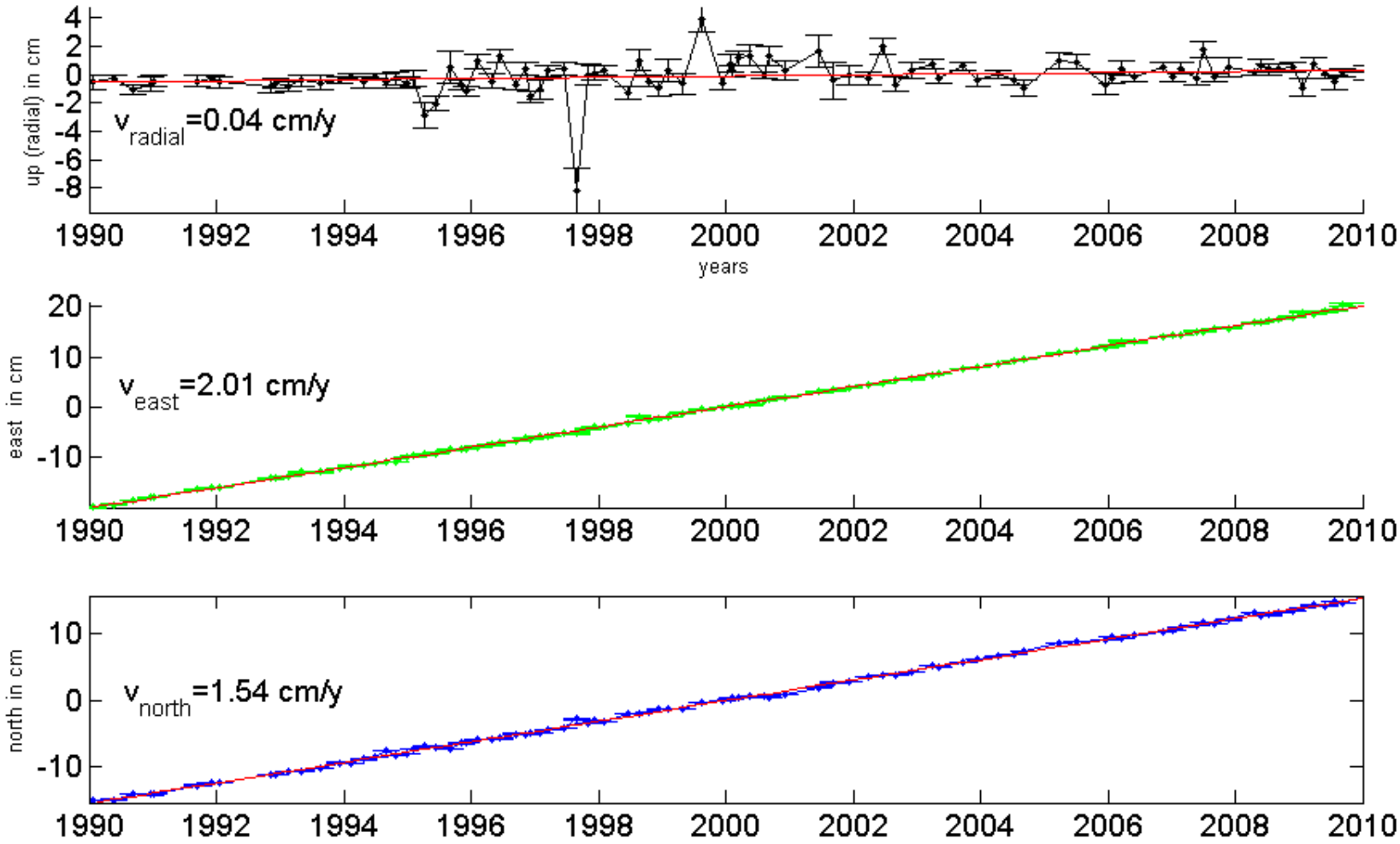
VieVS-TRF Solutions of IVS-Europe Sessions, VLBI Antenna: ONSALA60 epoch 2000.0

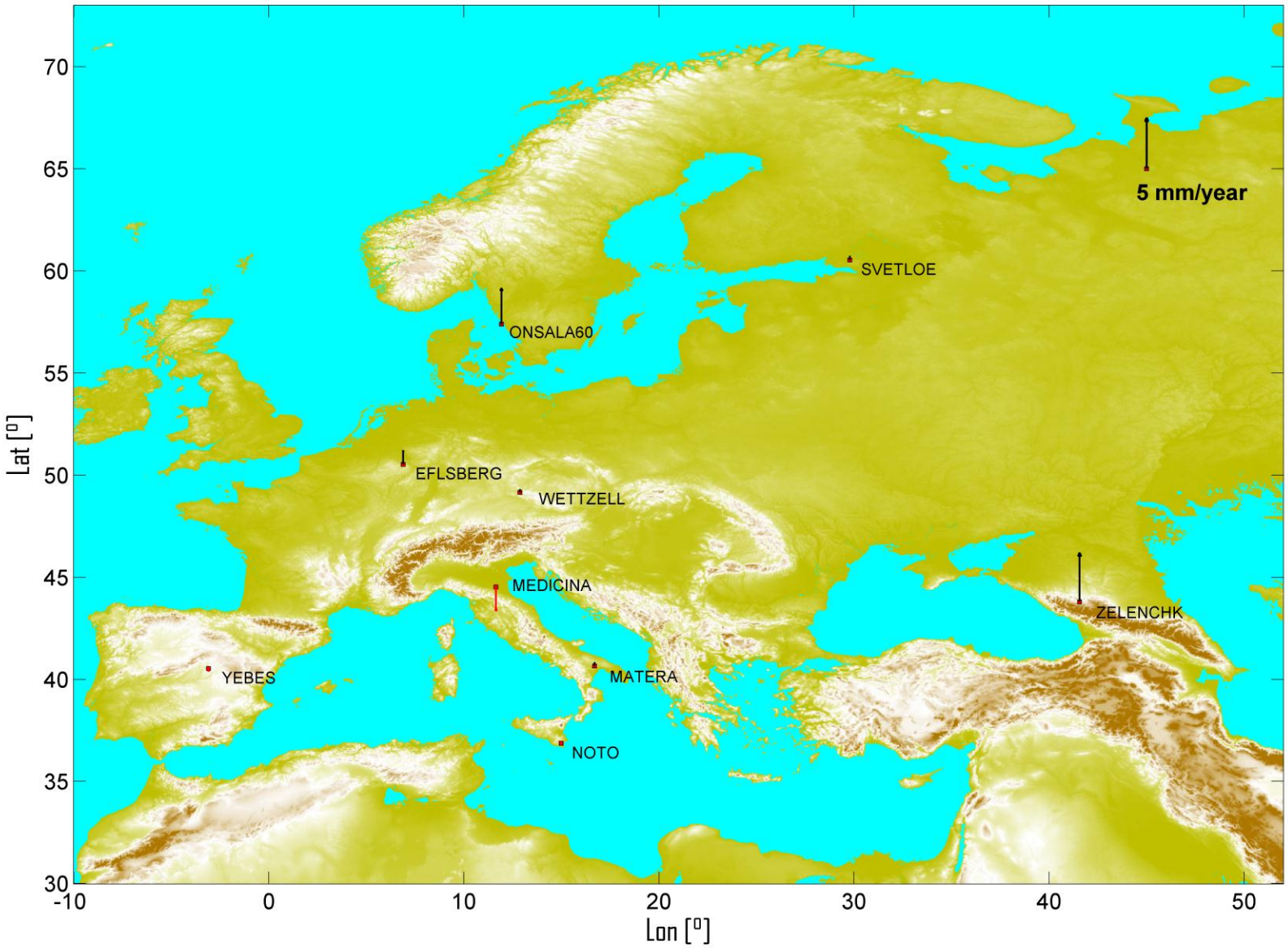


VieVS-TRF Solutions of IVS-Europe Sessions, VLBI Antenna: MATERA epoch 2000.0

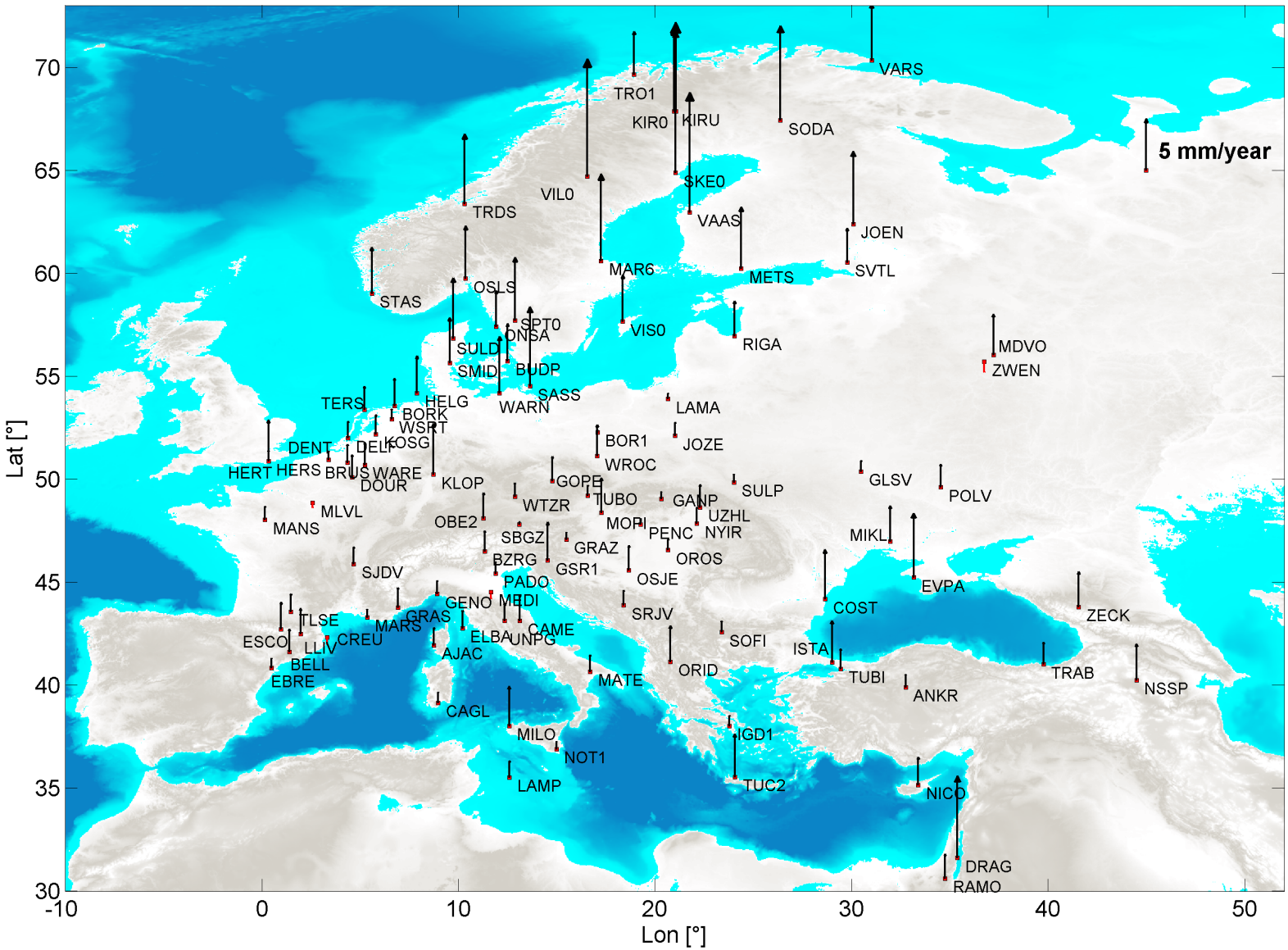


VieVS-TRF Solutions of IVS-Europe Sessions, VLBI Antenna: WETTZELL epoch 2000.0





Radial velocity estimates from **IVS-Europe VLBI solution** coordinate time series



Radial velocity estimates from **GNSS-EUREF solution** coordinate time series

CALCULATION OF TRANSFORMATION PARAMETERS BETWEEN TRF SOLUTIONS

$$\begin{bmatrix} X_1 \\ Y_1 \\ Z_1 \\ X_2 \\ Y_2 \\ Z_2 \\ \dots \end{bmatrix} = \begin{bmatrix} X_{01} \\ Y_{01} \\ Z_{01} \\ X_{02} \\ Y_{02} \\ Z_{02} \\ \dots \end{bmatrix} + \begin{bmatrix} 1 & 0 & 0 & X_{01} & 0 & -Z_{01} & Y_{01} \\ 0 & 1 & 0 & Y_{01} & Z_{01} & 0 & -X_{01} \\ 0 & 0 & 1 & Z_{01} & -Y_{01} & X_{01} & 0 \\ 1 & 0 & 0 & X_{02} & 0 & -Z_{02} & Y_{02} \\ 0 & 1 & 0 & Y_{02} & Z_{02} & 0 & -X_{02} \\ 0 & 0 & 1 & Z_{02} & -Y_{02} & X_{02} & 0 \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \end{bmatrix} \begin{bmatrix} T_X \\ T_Y \\ T_Z \\ \mu \\ \alpha \\ \beta \\ \gamma \end{bmatrix}$$

translations

scale

rotations

The transformation between two reference frames can be formulated as a Helmert transformation, e.g. an a priori reference frame (VTRF 2008, ITRF 2005) and the estimated network (IVS Europe Solution).

3D transformation between IVS- Europe Sessions VieVS Solution and ITRF 2005 at epoch 2000.0

Tx cm	Ty cm	Tz cm	scale ppb	alpha (mas)	alpha (mas)	alpha (mas)
-2.9	11.6	0.0	0.4	0.9	3.1	0.8

3D transformation between IVS- Europe Sessions VieVS Solution and VTRF 2008 at epoch 2000.0

Tx cm	Ty cm	Tz cm	scale ppb	alpha (mas)	alpha (mas)	alpha (mas)
0.0	0.8	0.5	-0.8	0.1	0.1	-0.3

CONCLUSIONS

- Onsala and Ny-Alesund are rising at rates of 4 and 8 mm/year respectively,
- subsidence of Medicina is about 2mm/year,
- uplift motions of Wettzell and Matera below 1mm/year may not be significant,
- IVS-Europe sessions radial position time series estimated by VieVS software are compatible with the EUREF solution at co-located sites in direction and more or less in magnitude,
- The transformation parameters between IVS-Europe VieVS Solution and global TRF solutions (ITRF 2005 and VTRF 2008) are relatively larger to those of transformation parameters between different ITRF solutions due to mainly;
  - fixing EOPs to their a priories and not estimating (in our solution)
  - the VLBI sites contributing IVS-Europe sessions cover a regional area, Europe (only 1/3 of the northern hemisphere).

Our results agree with those of the previous study done by Campbell et al., 2002, who were using the first 10 years of IVS-Europe sessions.

REFERENCES

J. Campbell, R. Haas,A.Nothnagel (2002). **Measurement of Vertical Crustal Motion in Europe**, Research Networks Training and Mobility of Researchers, Geodetic Institute, University of Bonn, (on behalf of European Commission).

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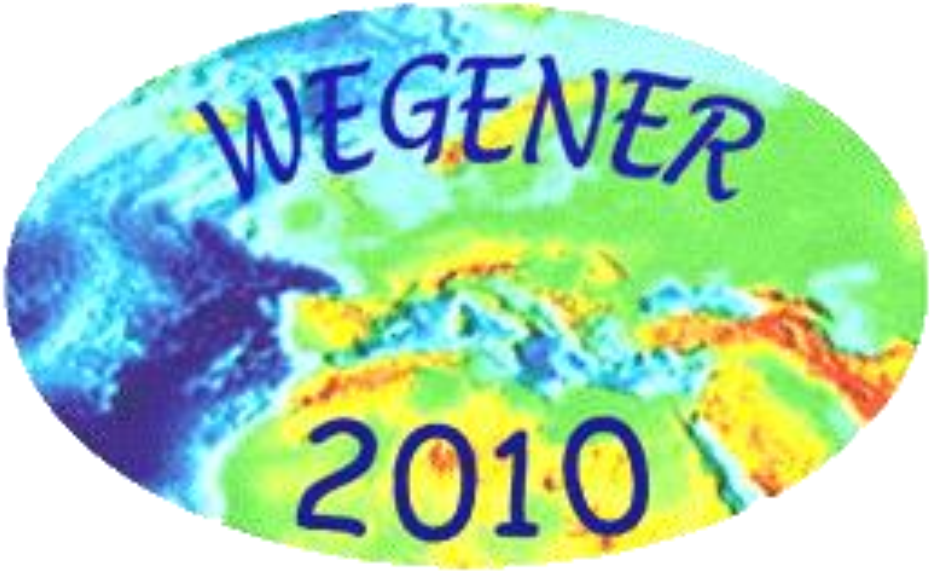

Thanks for your attention!!