EPN 6th LAC Workshop, October 22-23, 2008 Frankfurt am Main, Germany

EPN reprocessed daily data analysis. Interpretation of disturbances caused by selected factors

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Data

Daily solution (X, Y, Z and B, L, h) from **180 EPN stations** from period **1994-2007** reprocessed using Bernese 5.0 (some incomplete)

Main goals

- Which **factors** cause **disturbances** in daily solutions on EPN stations?
- What are the **reasons of errors – non-periodic disturbances** (preparing data for further time and ferquency analysis f.e. Wavelet Transformation by eliminating those disturbances)
- Do **models, methods and parameters** used in reprocessing allow us to eliminate ionosphere, tidal… influences?
- What are common features for **stations with the most reliable time series**? What are **the best locations for GPS antennas** on EPN stations?

Errors can be divided into:

- errors connected with movement of antenna;
- errors caused by environmental changes
- errors from reprocessing.

Comparison with other techniques or other GPS antennas in the close area.

Strategy of processing (models, parameters...) – Bernese 5.0

- **Basic Observable**: carrier phase only;
- **Elevation angle cutoff**: 3 degrees, elevation dependent weighting with cos(z);
- Only **GPS** observations;
- **Sampling rate**: 30 sec for data screening,180 sec for final solution;
- **Modeled observable**: double-differences, ionosphere-free linear combination;
- **Ground and Satellite antenna phase center calibrations**:

  IGS05 model (exceptions for some stations);
- **Troposphere:**

Dry-Niell as a priori model, estimation of zenith delay corrections at 1-hour intervals for each station.

Horizontal gradient parameter estimated for each station per day (TILTING), no a priori constraints.

Compute daily TRO files with cumulative coordinates input from weekly solution.

Saastamoinen-based dry component mapped with the Dry-Niell mapping function used as a priori model.

The Wet-Niell mapping function used to map the wet component.

Corrections to a priori model constrained to 5.0 m (abs) and 5.0 m (rel).

Estimate troposphere parameter in 1 hour intervals, save in daily normal equations and create from these the weekly solution.

Strategy of processing (models, parameters...) – Bernese 5.0

- **Ionosphere:**

  CODE global iono models (help to increase the number of resolved ambiguities in the QIF, the L5/L3 and the L1/L2 ambiguity resolution);

  For the final adjustment, ionosphere was canceled out due to ionosphere-free linear combination used.

- **Rejection criteria:**

  Daily RINEX observation files containing less than 50 percent of possible observation epochs

  are ignored.

  The described two-step preprocessing method eliminates outliers.

  Rejection Criterion of L3 outliers: 0.0020 m (normalized L1 zero-difference zenith value).

- **Satellite clock corrections:**

  Not estimated, but biases eliminated by forming double differences.

- **Receiver clock corrections:**

  Estimated as part of the biases preprocessing using code measurements,

  finally eliminated by forming double differences.

Strategy of processing (models, parameters...) – Bernese 5.0

- **Orbits and ERPs:** MDA orbits and ERPs;

  FESG/IPG REPROCESSING also using SATELLITE PROBLEMS from IGS reprocessing *(Steigenberger, P, M.. Rothacher, R. Dietrich, M. Fritsche, A. Rülke, and S. Vey (2006). Reprocessing of a global GPS network. Journal of Geophysical Research. Vol. 111, B05402)*;

- **Ambiguity:**

  QIF strategy used to resolve ambiguities in a baseline processing mode using **CODE global iono models** (for baselines up to 2000 km length);

  For baseline lengths shorter than 100 km - **L5/L3** approach;

  For baselines shorter than 10 km - **L1/L2** approach.

MODELS:

Planetary ephemeris: **DE405**

Ocean tides: **OT_CSRC**

The Earth geopotential is modeled using: **JGM3**

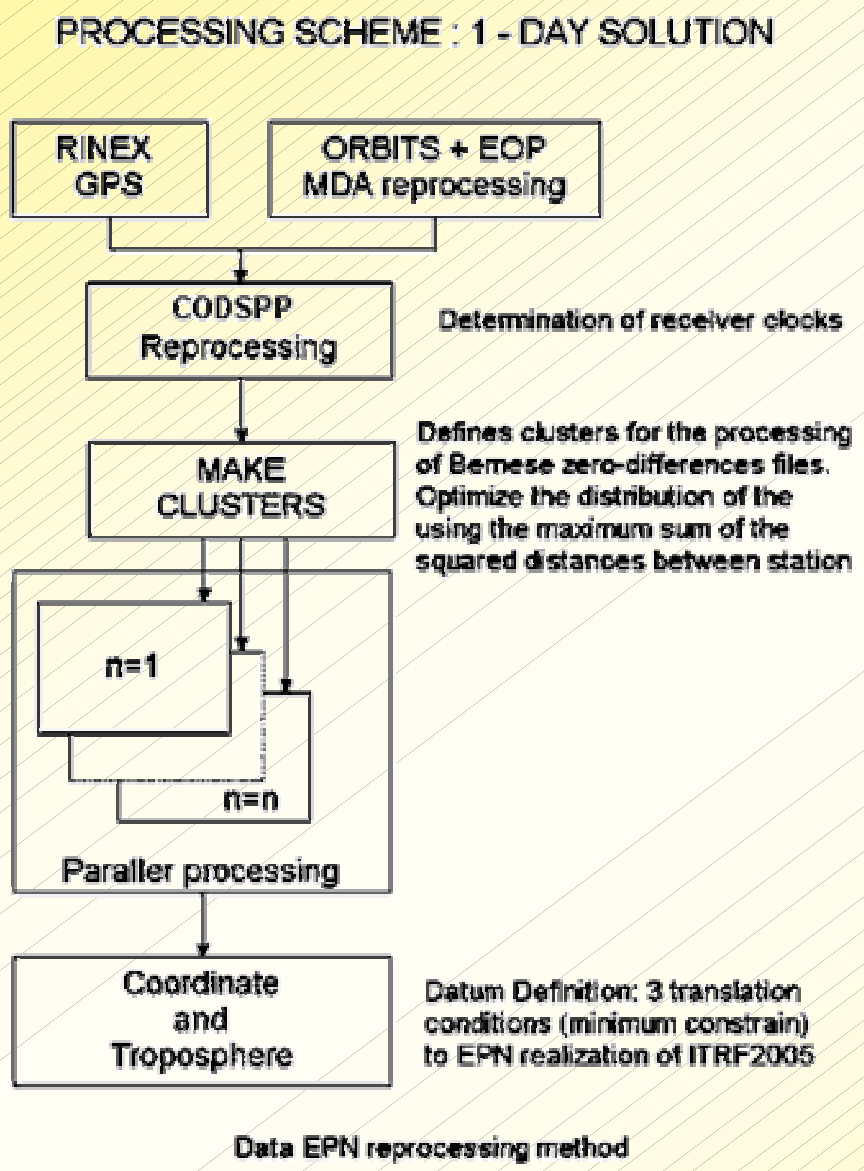
Nutation model: **IAU2000**

Subdaily pole model: **IERS2000**

Tidal displacements: Solid tides: according to the **IERS 1996/2000** standards

Ocean loading model: **FES2004**

Strategy of processing (models, parameters...) – Bernese 5.0



Parallel processing is the only way to decrease time of getting solutions.

We used MKCLUS (Bernese 5.0).

Every subnetwork created in MKCLUS consisted of about 50 stations.

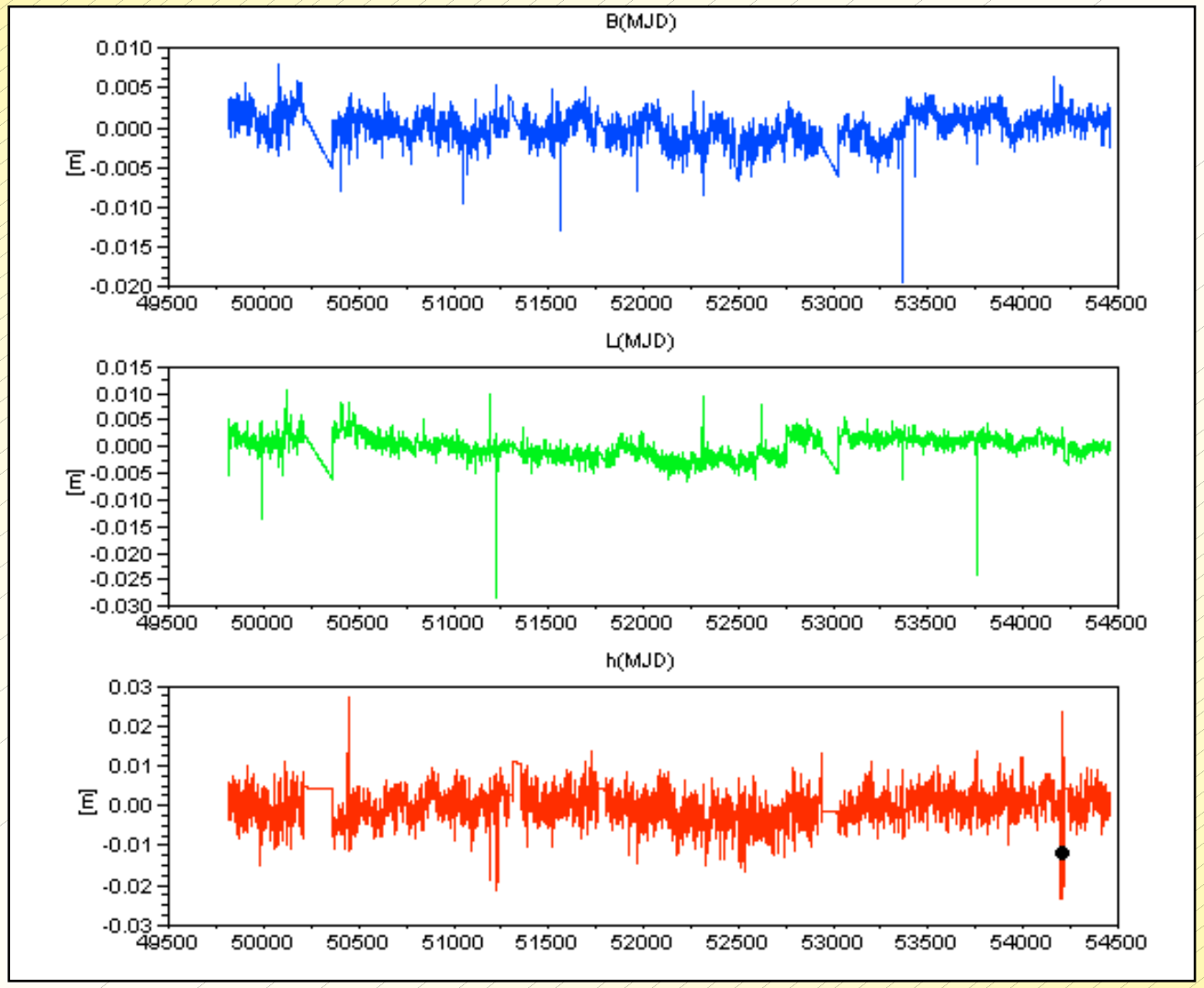
Modification on stations – changes of antenna's or receiver's type, software..

Some disturbances last for just few days, some modification cause permanent solutions' change.

Station **GRAS** (France)

Modification on stations – changes of antenna's or receiver's type, software..

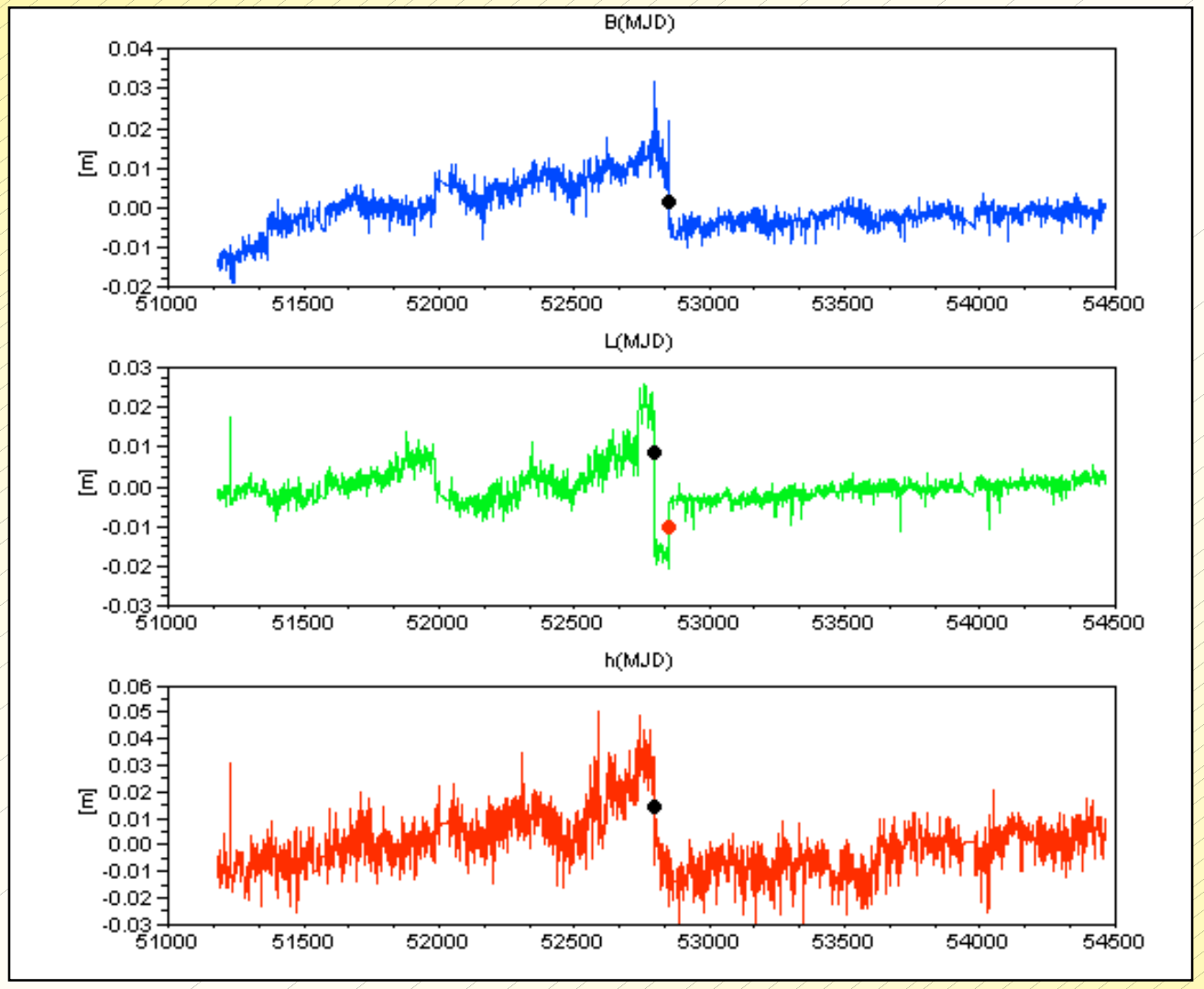
Some disturbances last for just few days, some modification cause permanent solutions' change.



Station **GRAS** (France): receiver's change:

TRIMBLE 4000SSI ⟶ ASHTECH UZ-12 ⟶ ASHTECH UZ-12

Modification on stations – changes of antenna's or receiver's type, software..



Station **CREU** (Spain):

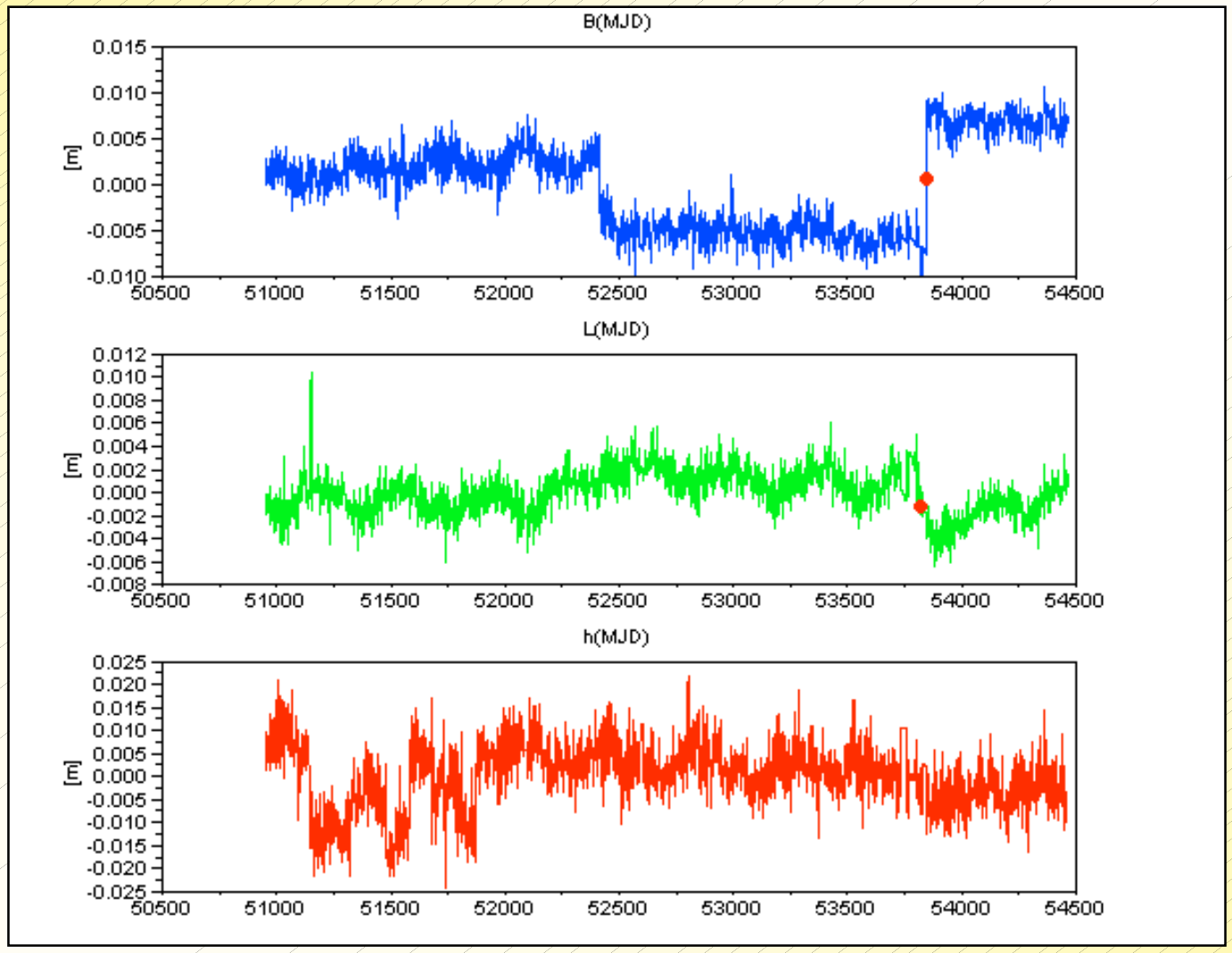
change of broken radome – identical new one (antenna type - TRM29659.00)

change of antenna's type: TRM29659.00 DOME → TRM41249.00 NONE

Modification on stations – changes of antenna's or receiver's type, software..

Station **UNPG** (Italy)

Modification on stations – changes of antenna's or receiver's type, software..



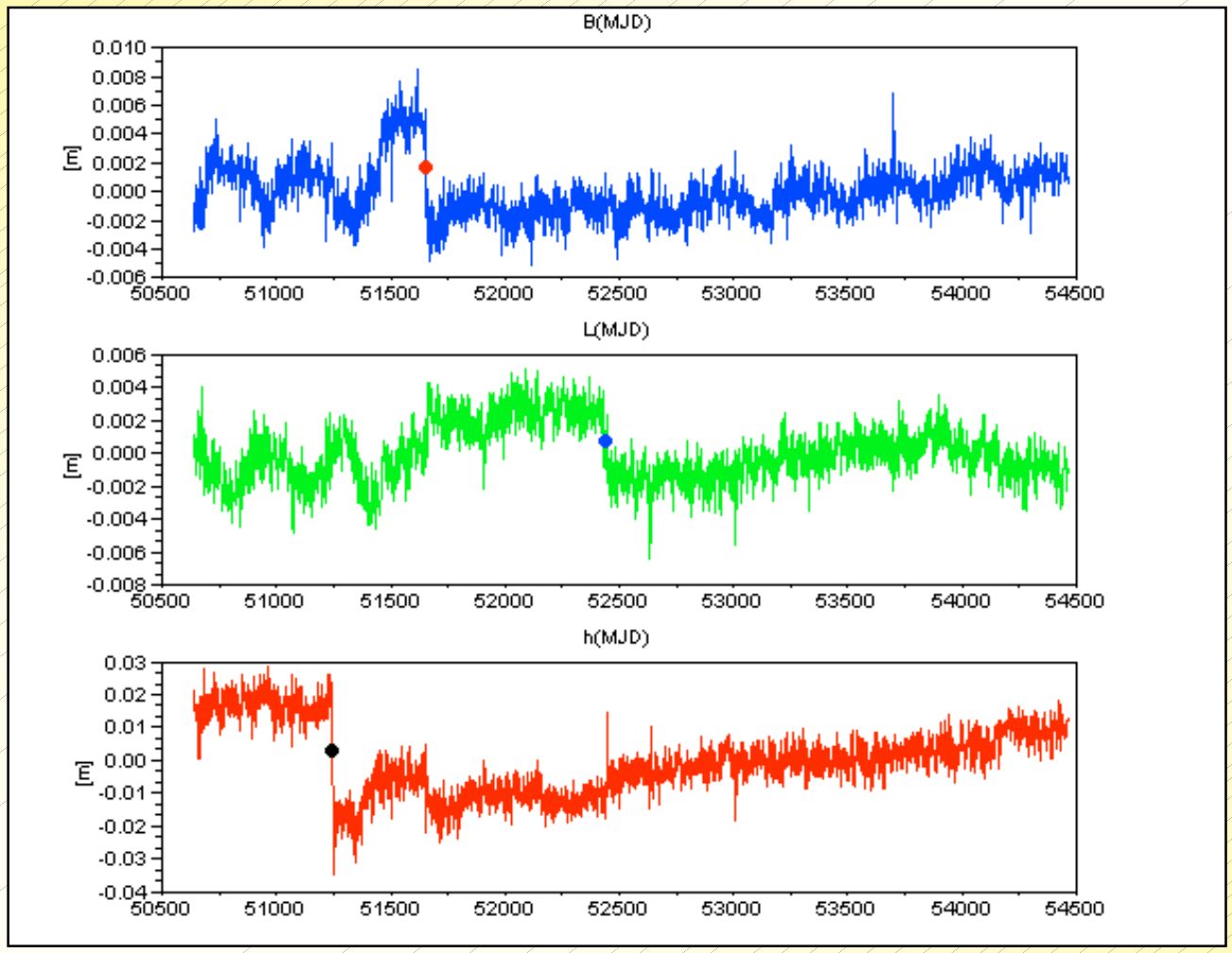
Station **UNPG** (Italy): change of receiver's type: ASHTECH Z-XII3 ⟶ TPS ODYSSEY_E

change of antenna's type: ASH700936D_M NONE ⟶ JPSREGANT_DD_E NONE

Modification on stations – changes of antenna's or receiver's type, software..

Station **HOBU** (Germany)

Modification on stations – changes of antenna's or receiver's type, software..



Station **HOBU** (Germany):

change of antenna's type: TRM22020.00+GP DOME → TRM14532.00 NONE

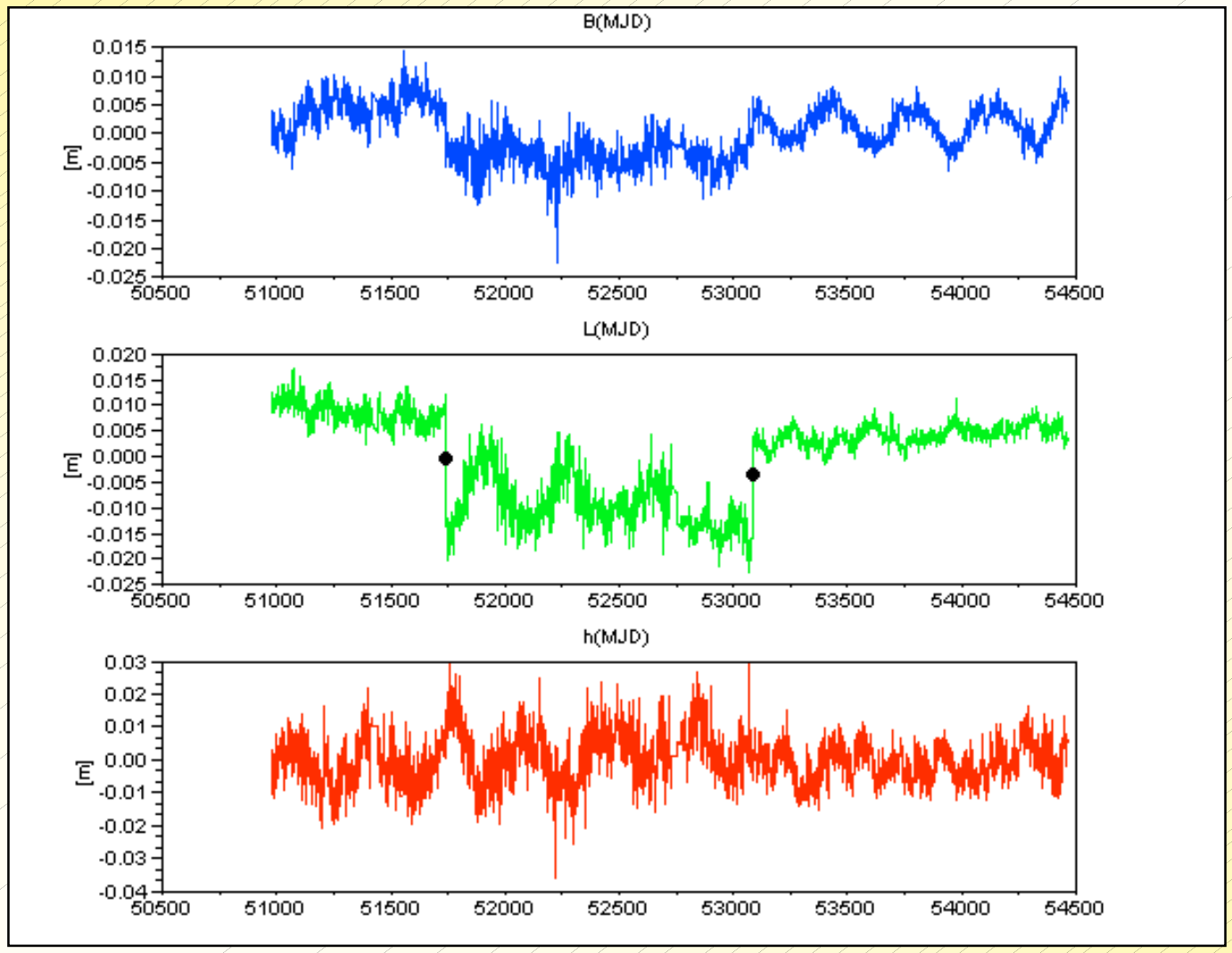
TRM23903.00 NONE → TRM29659.00 SNOW

TRM29659.00 SNOW → TRM33429.20+GP NONE

Modification on stations – changes of antenna's or receiver's type, software..

Station **RAMO** (Israel)

Modification on stations – changes of antenna's or receiver's type, software..



Station **RAMO** (Israel):

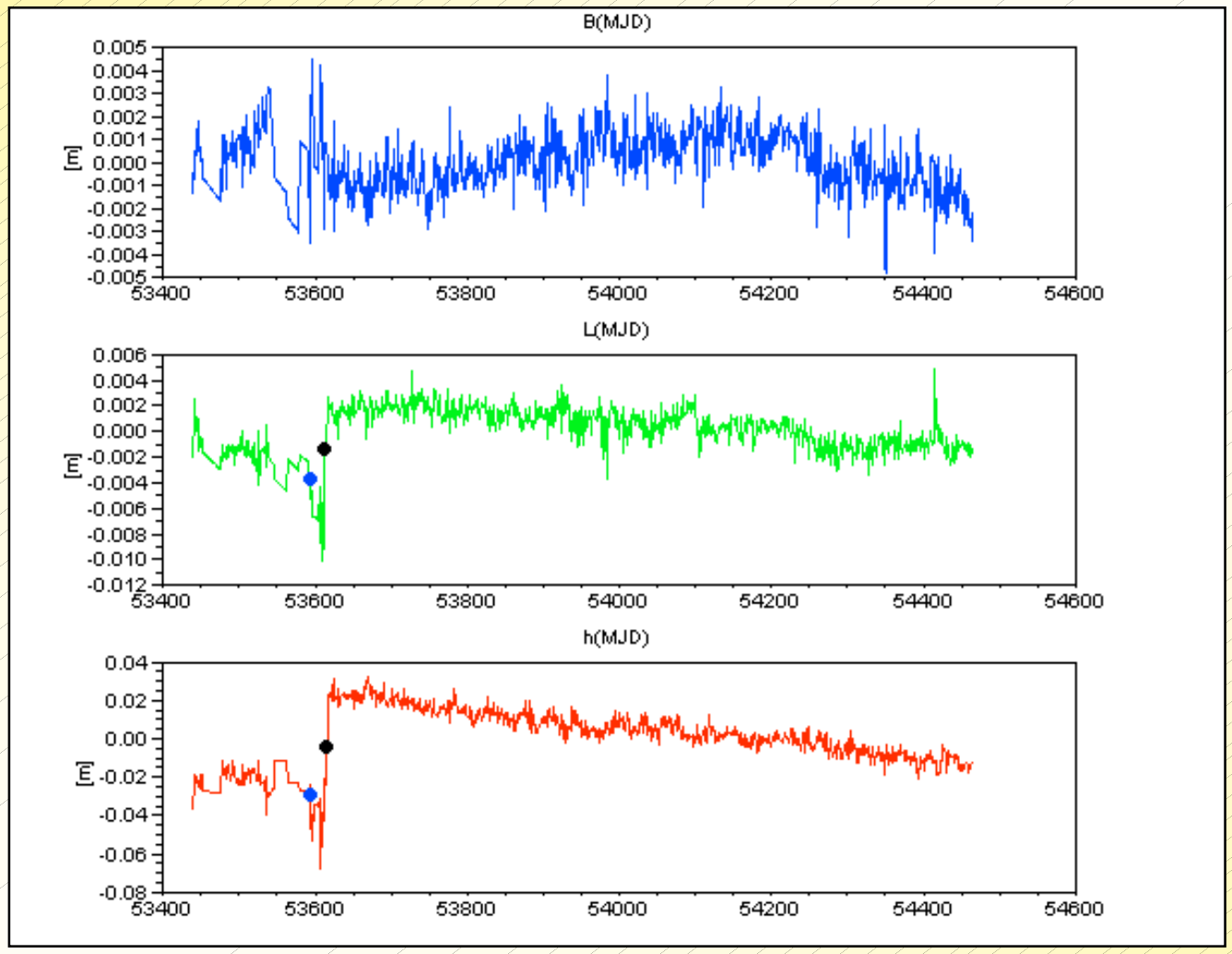
change of antenna type: ASH700936D_M → SNOW ASH701945B_M SNOW

change of antenna: ASH701945B_M SNOW → ASH701945B_M SNOW (the same type)

Modification on stations – changes of antenna's or receiver's type, software..

Station **POUS** (Czech Rep.)

Modification on stations – changes of antenna's or receiver's type, software..



Station **POUS** (Czech Rep.):

change of receiver's type: ASHTECH UZ-12 → ASHTECH Z18

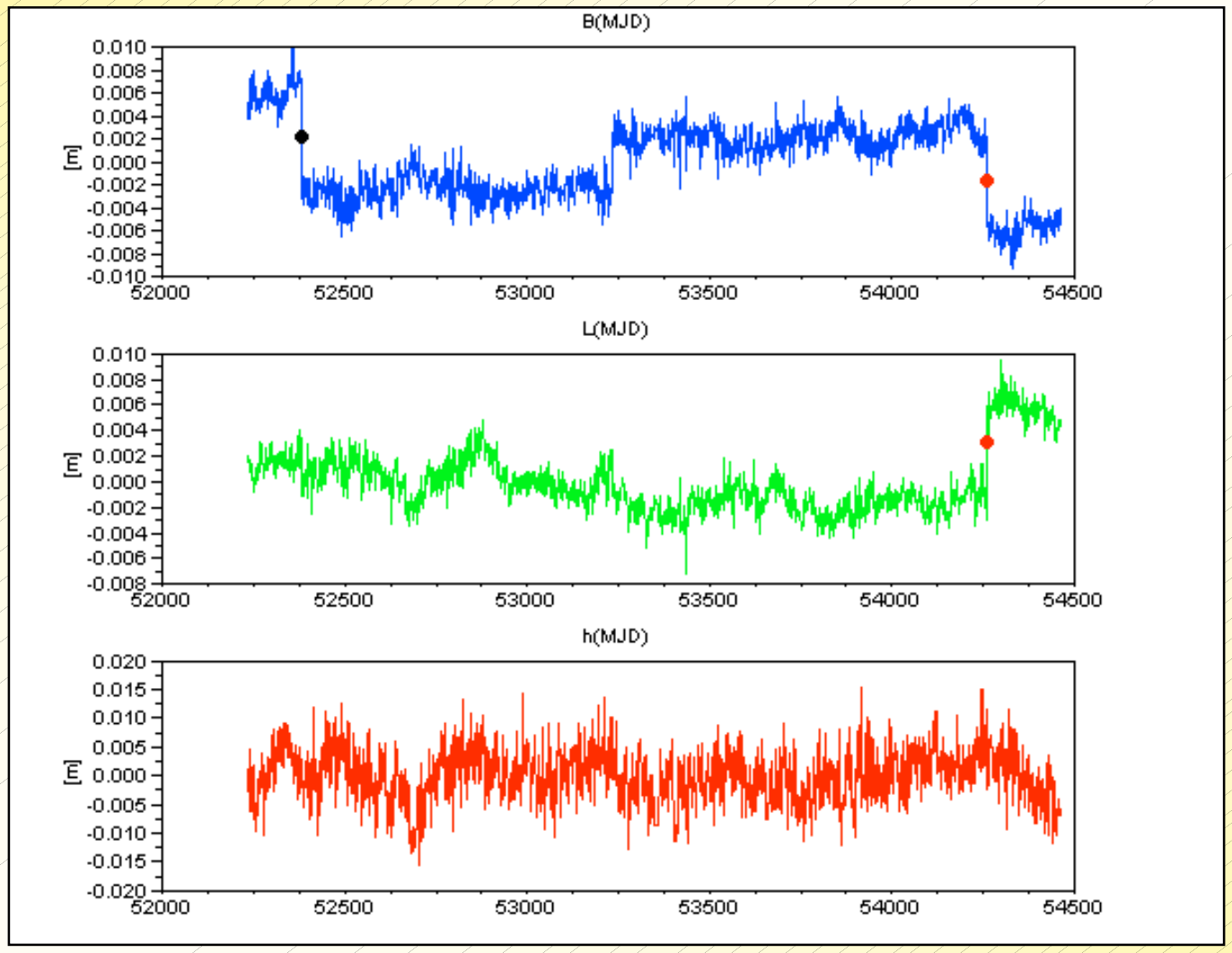
change of receiver's type: ASHTECH Z18 → TPS GB-1000

change of antenna type: ASH701946.2 SNOW → TPSCR3_GGD CONE

Modification on stations – changes of antenna's or receiver's type, software..

Station **OROS** (Hungary)

Modification on stations – changes of antenna's or receiver's type, software..



Station **OROS** (Hungary): change of antenna:

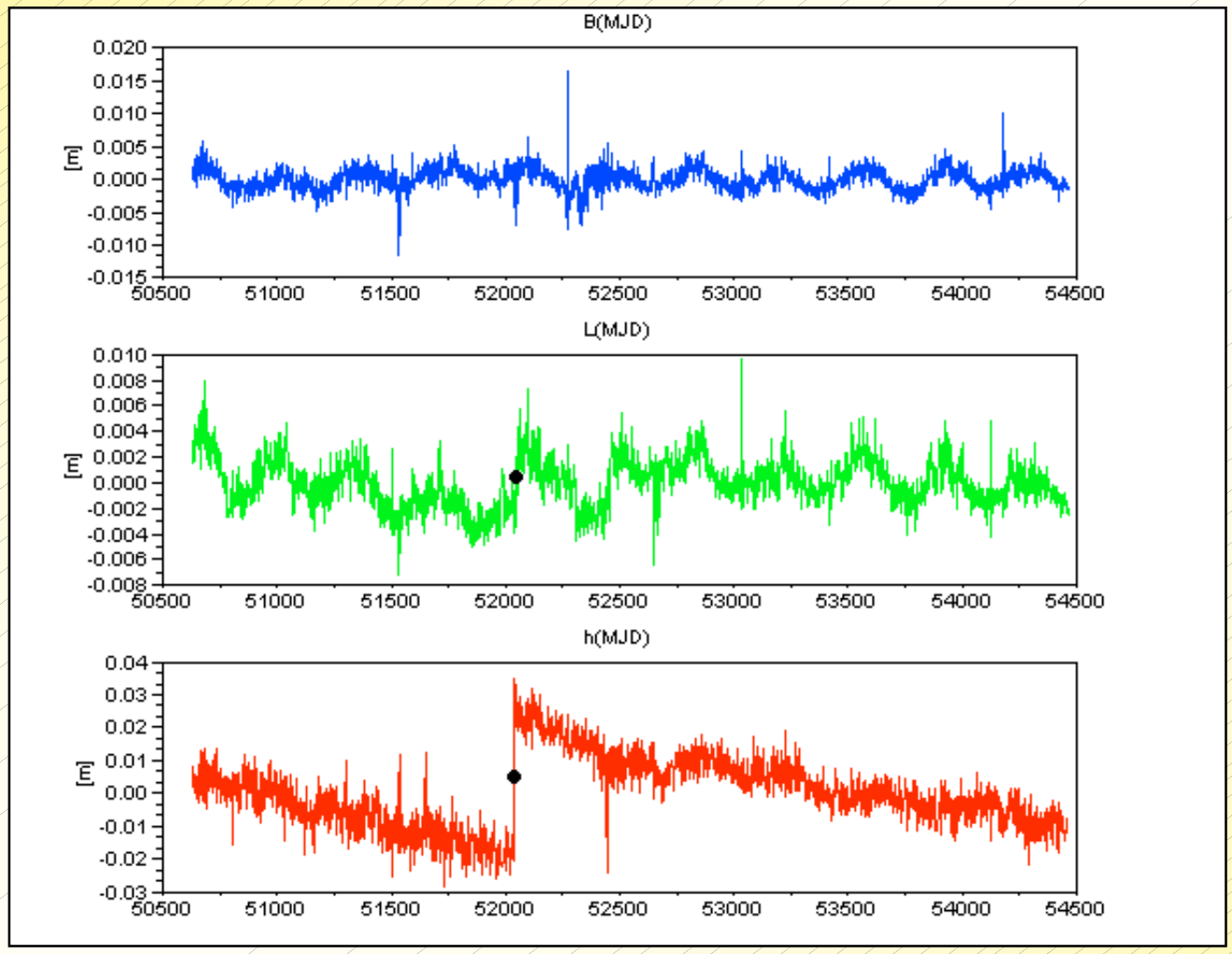
TRM14532.10 NONE → TRM14532.10 NONE (the same type)

TRM14532.10 NONE → LEIAT504 LEIS

Modification on stations – changes of antenna's or receiver's type, software..

Station **KARL** (Germany)

Modification on stations – changes of antenna's or receiver's type, software..



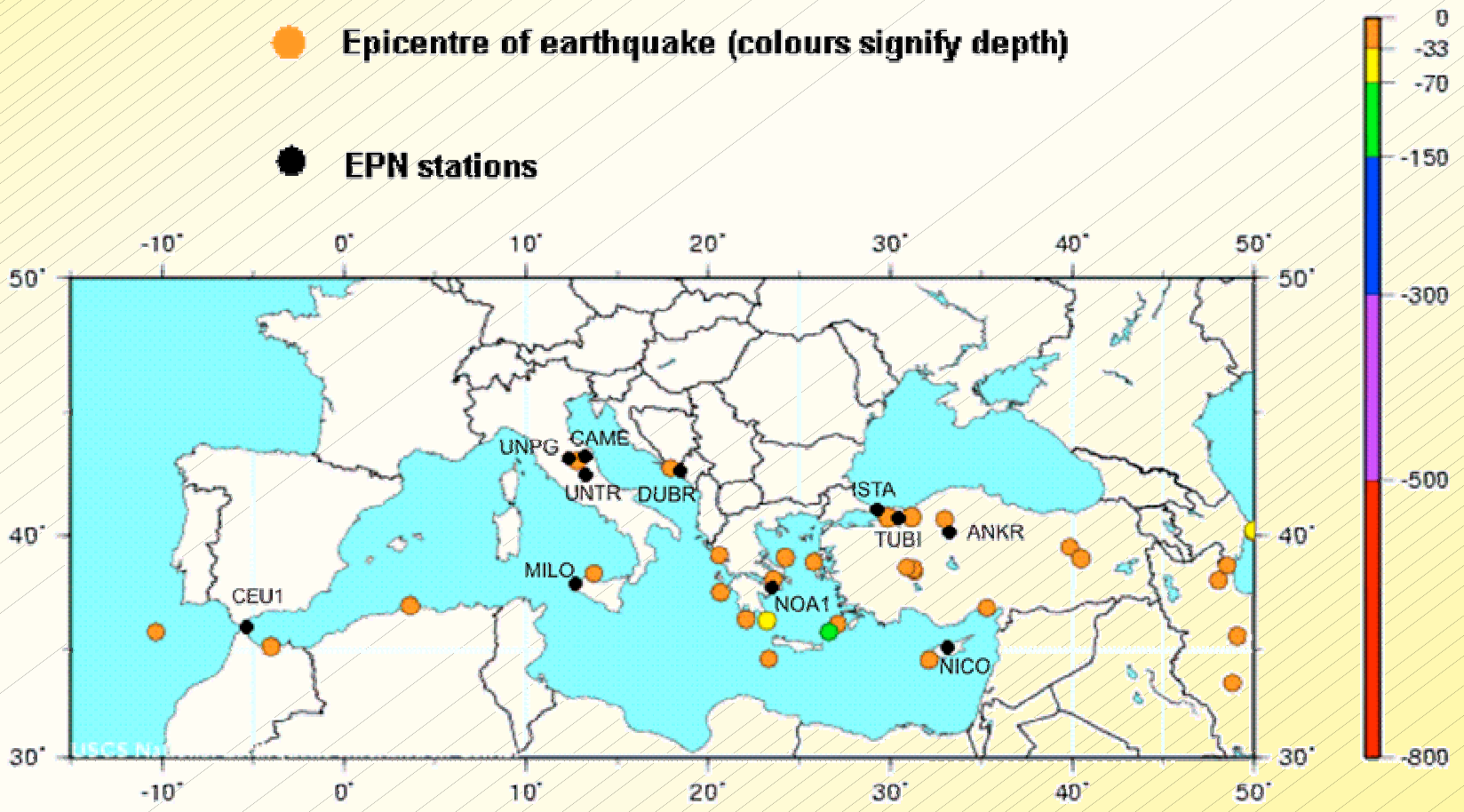
Station **KARL** (Germany): change of antenna's type: TRM22020.00+GP DOME → TRM29659.00 NONE

CONCLUSION: Modifications on station may cause serious changes in solutions – they have to be taken into consideration before further analysis.

Earthquakes

To find earthquakes' influence on station coordinates higher-rate solutions should be considered (eartquakes last briefly)- here we analized only few station to exclude this factor.

First we analized daily solutions from few stations, which are situated near epicentres of medium-magnitude eartquakes from USGS database (M>6 R) – especially South Europe.



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DATE	LATITUDE	LONGITUDE	MAGNITUDE	THE NEAREST EPN STATION
2004 02 24	35.142	-3.997	6.4	CEU1*
1997 09 26	43.084	12.812	6.4	CAME*, UNPG*, UNTR*
2002 09 06	38.381	13.701	6.0	MILO*
1996 09 05	42.803	17.936	6.0	DUBR*
2001 07 26	39.059	24.244	6.5	NOA1*
1999 08 17	40.748	29.864	7.6	TUBI
2000 06 06	40.693	32.992	6.0	ANKR
1996 10 09	34.556	32.126	6.8	NICO*

* lack of data

Earthquakes

Station **ANKR** (Turkey); date of earthquake – 6th June 2000, M=6.0, L(st, ep) = 90 km

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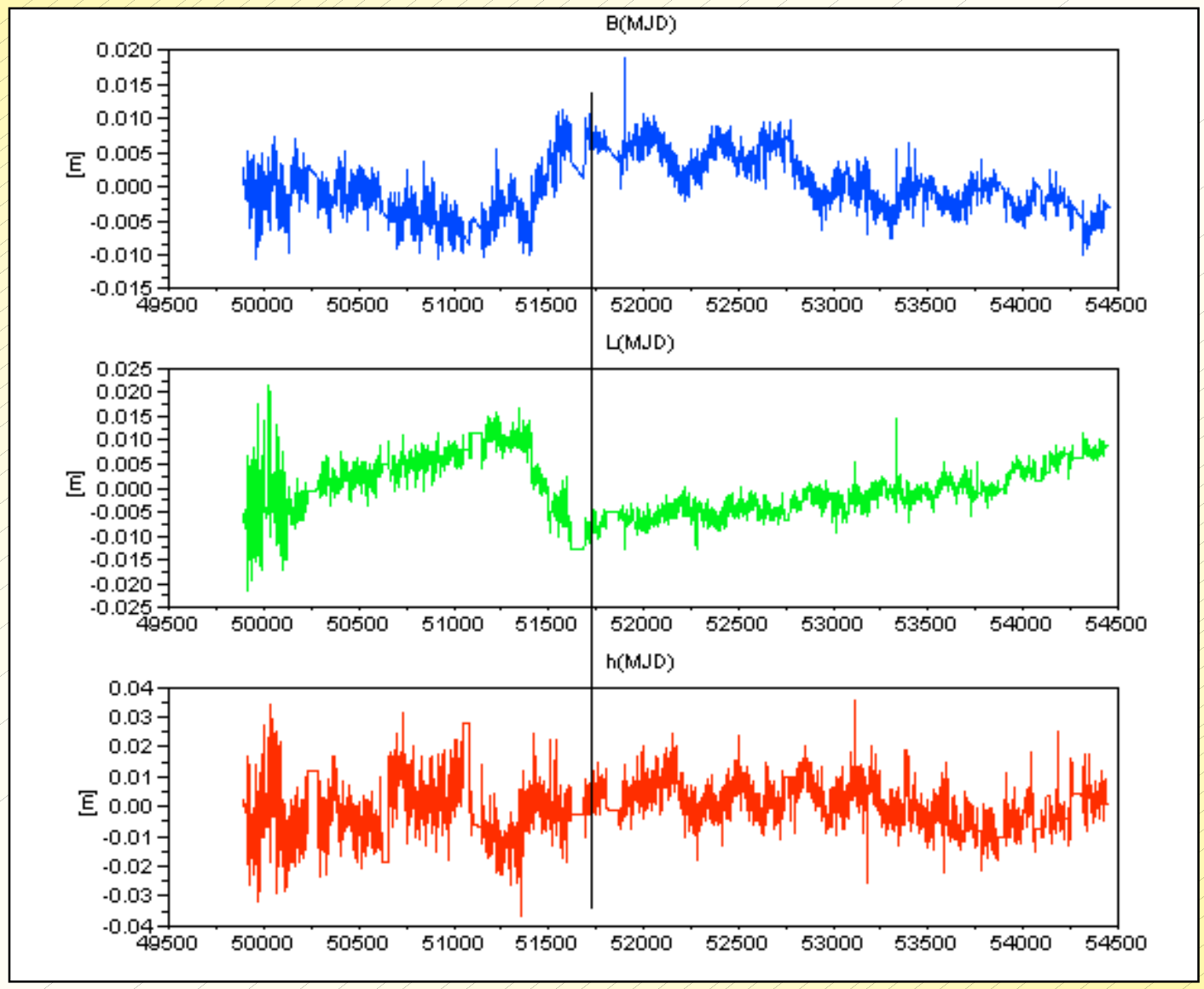

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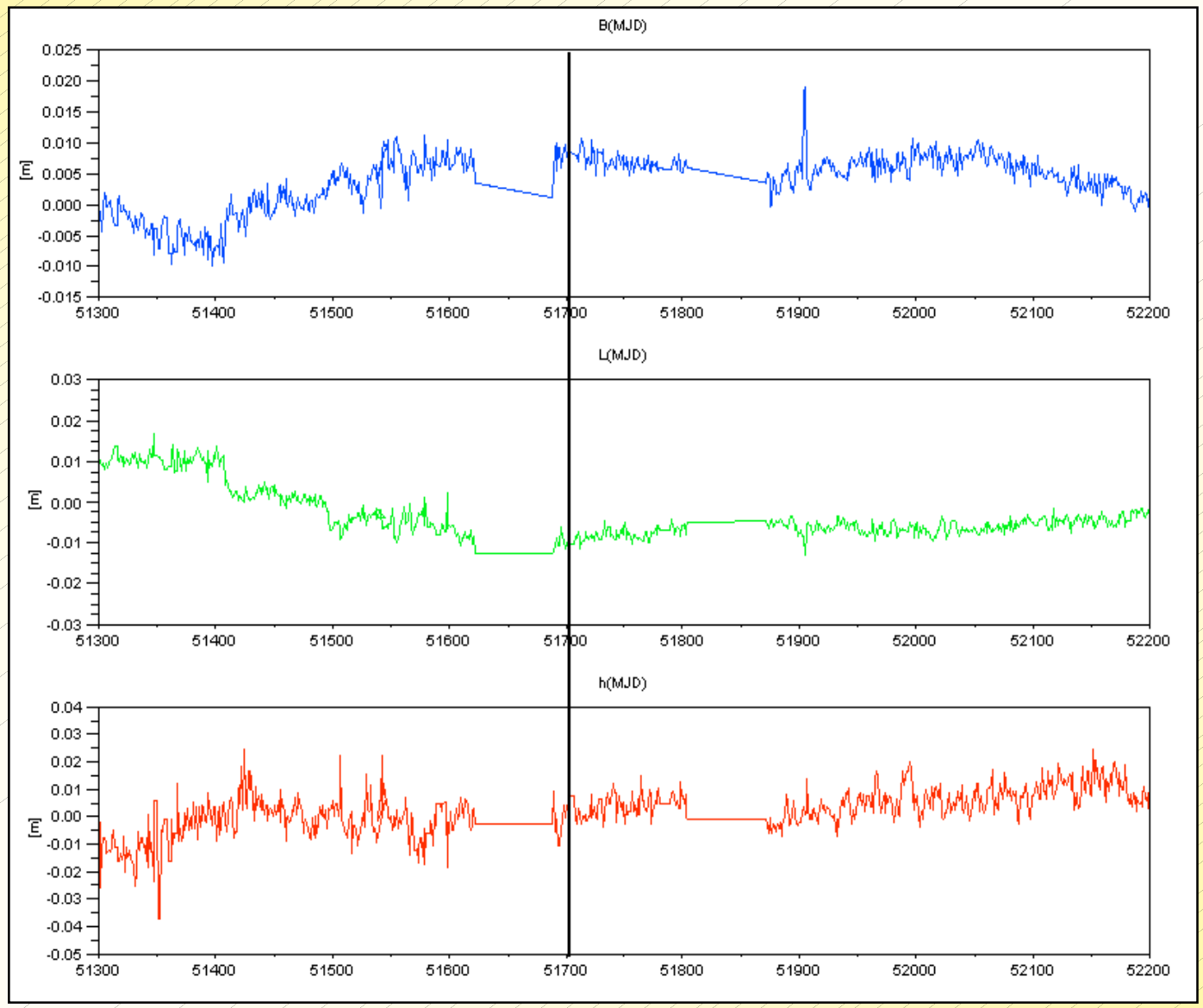
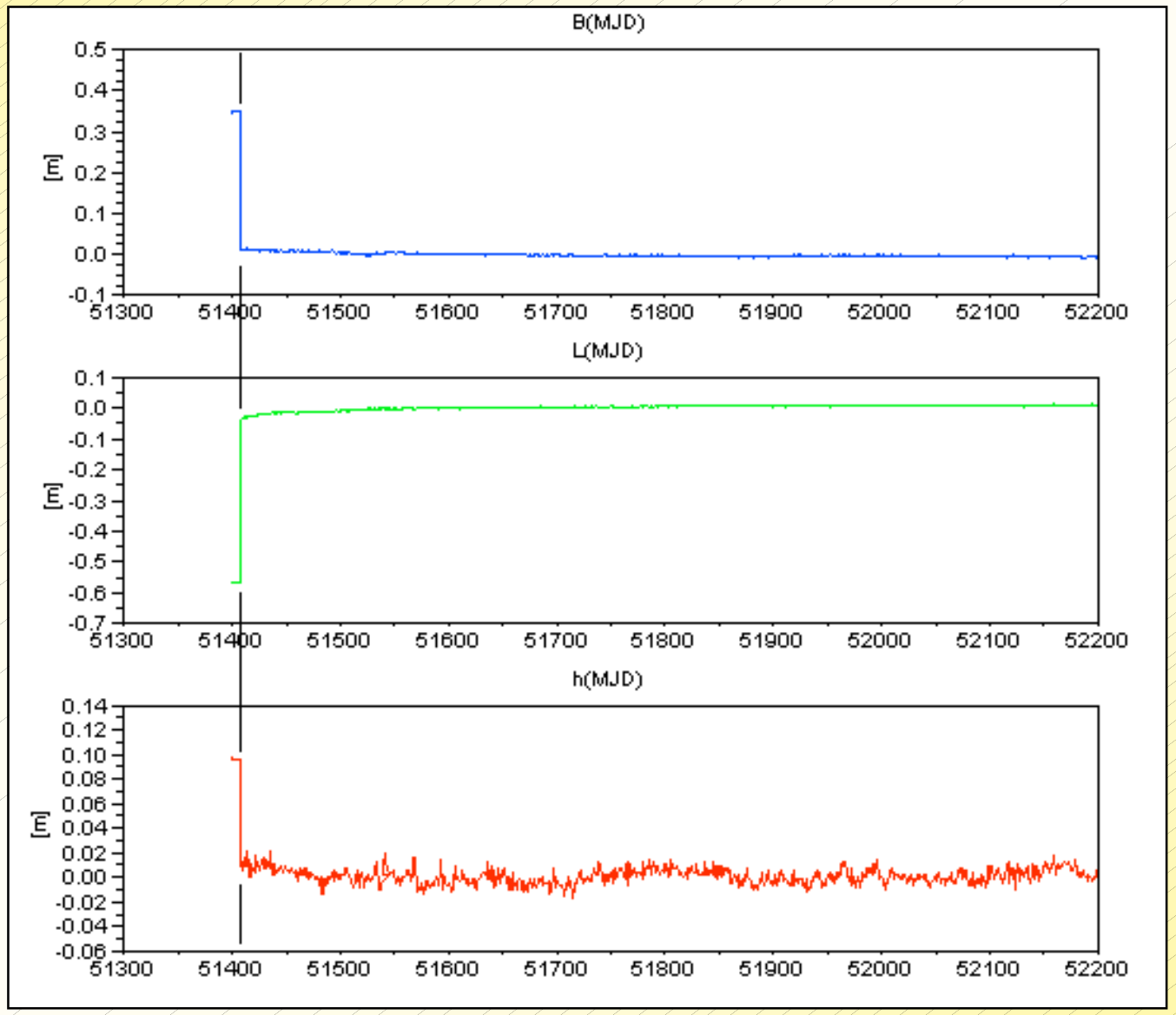


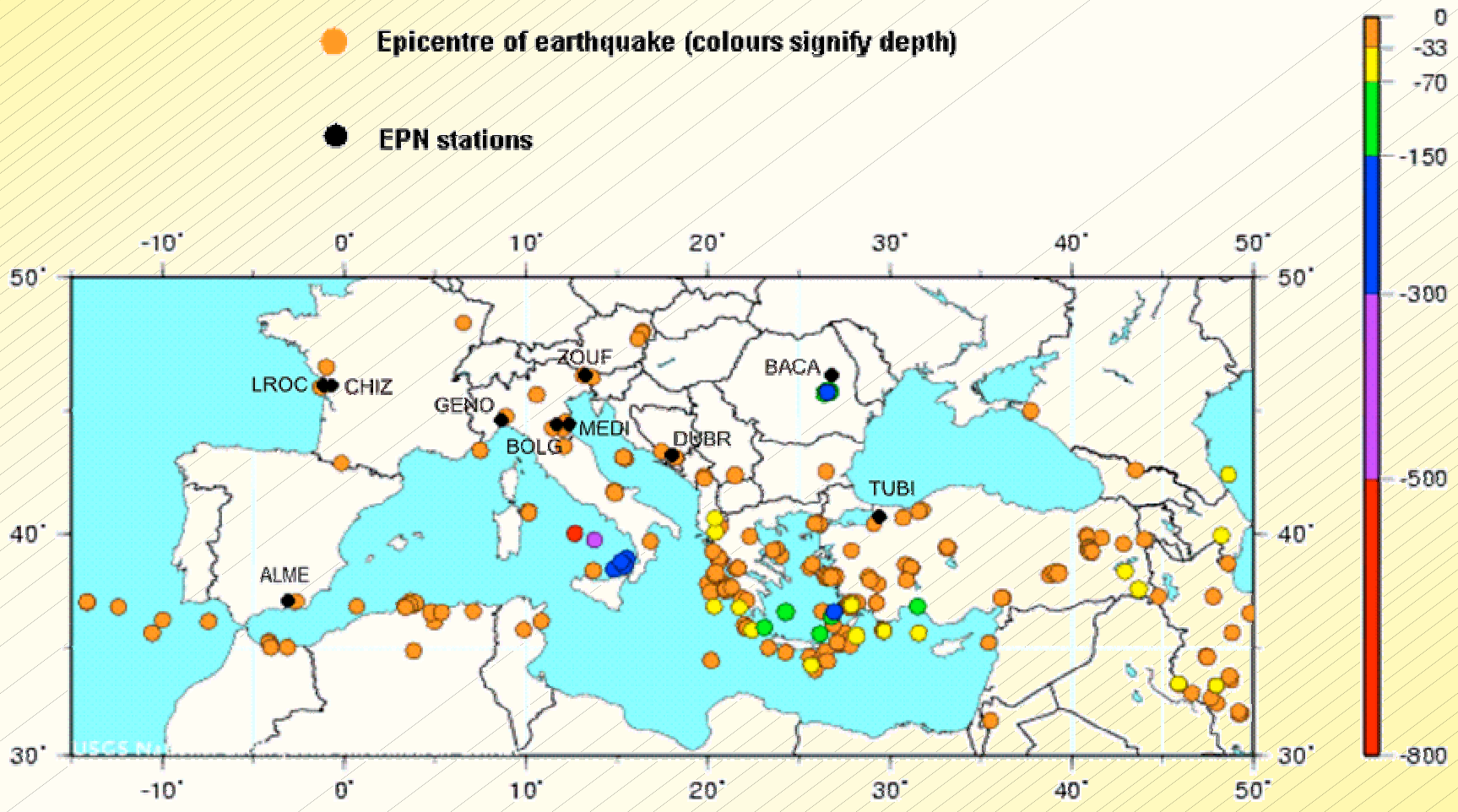
Earthquakes

Station **TUBI** (Turkey); date of earthquake – 17th August 1999, M=7.6, L(st, ep) = 42 km



Earthquakes

Due to lack of data, we checked also earthquakes with M>5 form period 2000-2007.



Earthquakes

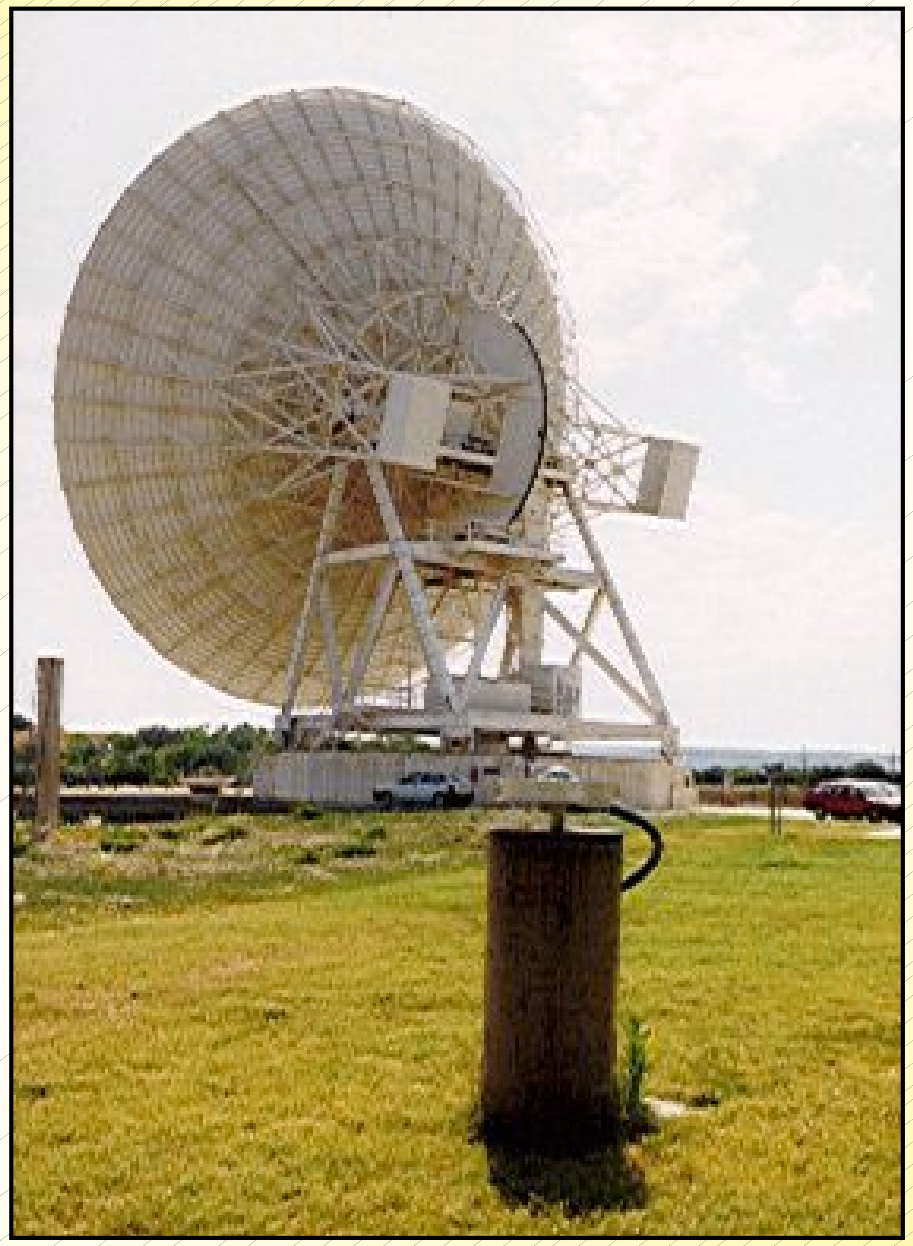
Due to lack of data, we checked also earthquakes with M>5 form period 2000-2007.

DATE	LATITUDE	LONGITUDE	MAGNITUDE	THE NEAREST EPN STATION
2002 02 04	37.103	-2.609	**5.0**	**ALME**
2001 06 08	46.690	-0.990	**5.0**	**CHIZ**
2005 04 18	45.930	-1.310	**5.0**	**LROC**
2003 04 11	44.792	8.892	**5.0**	**GENO**
2004 10 27	45.787	26.622	**5.9**	BACA*
2002 02 14	46.374	13.169	**5.3**	ZOUF*
2006 10 24	40.424	29.107	**5.0**	**TUBI**
2000 05 10	44.315	12.002	**5.0**	BOLG*, **MEDI**
2003 09 14	44.329	11.450	**5.3**	BOLG*, **MEDI**
2004 05 23	43.406	17.447	**5.0**	DUBR
2005 09 27	43.155	18.203	**5.0**	DUBR

***** lack of data

Earthquakes

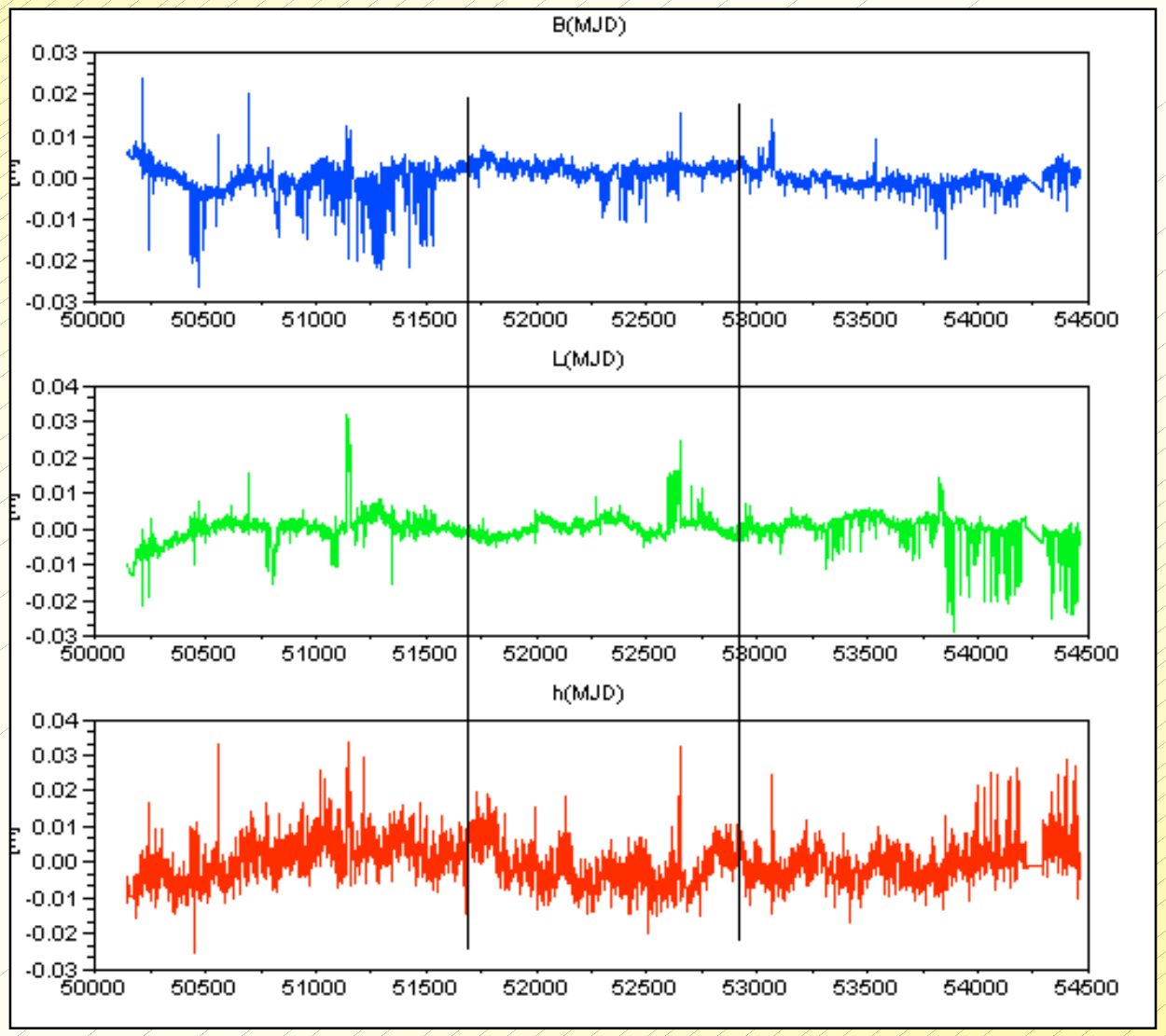
Station **MEDI** (Italy)



Earthquakes

Station **MEDI** (Italy); date of earthquake – 10th May 2000, M=5.0, L(st, ep) = 36 km

date of earthquake – 14th September 2003, M=5.3, L(st, ep) = 26 km



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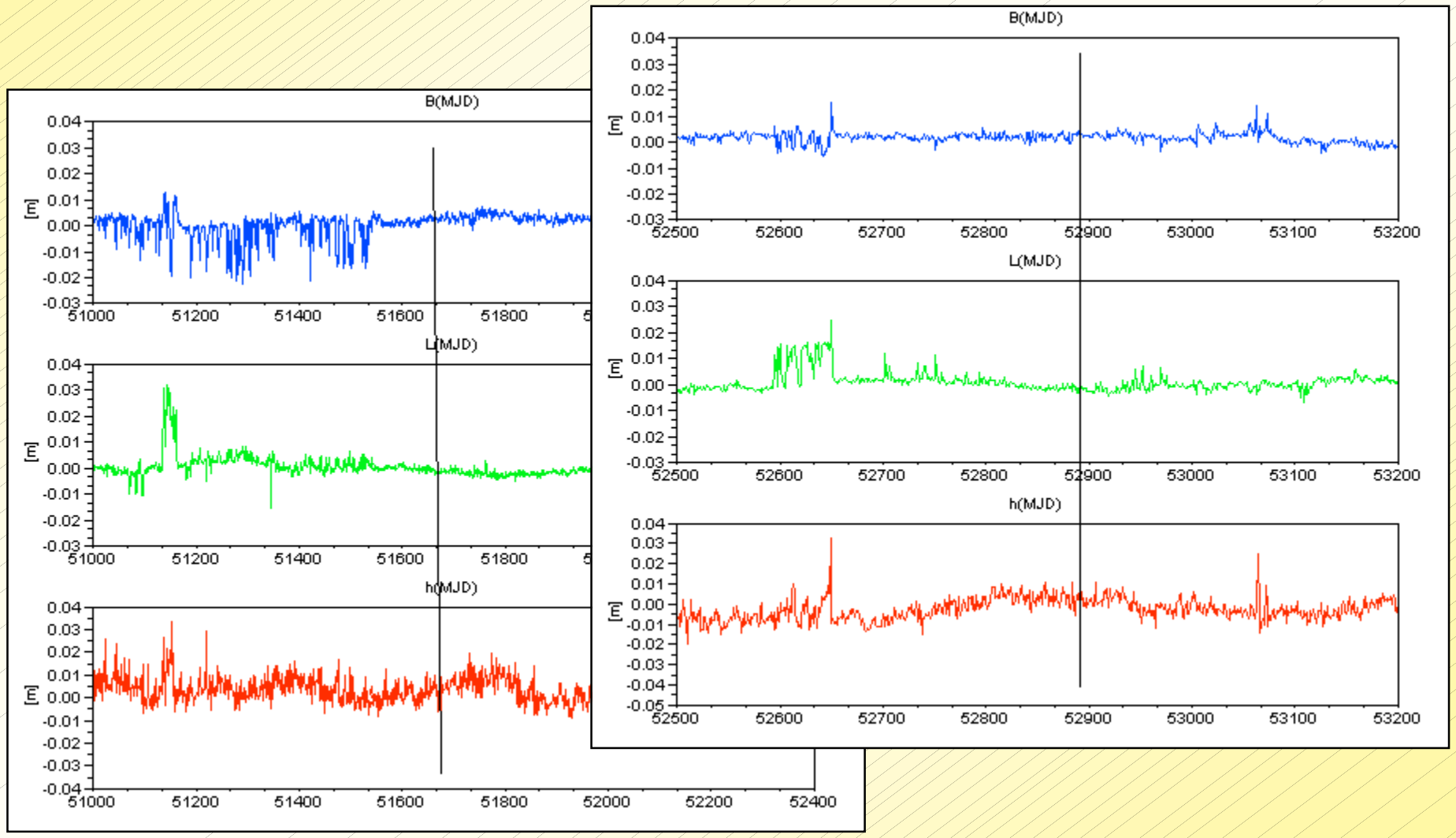
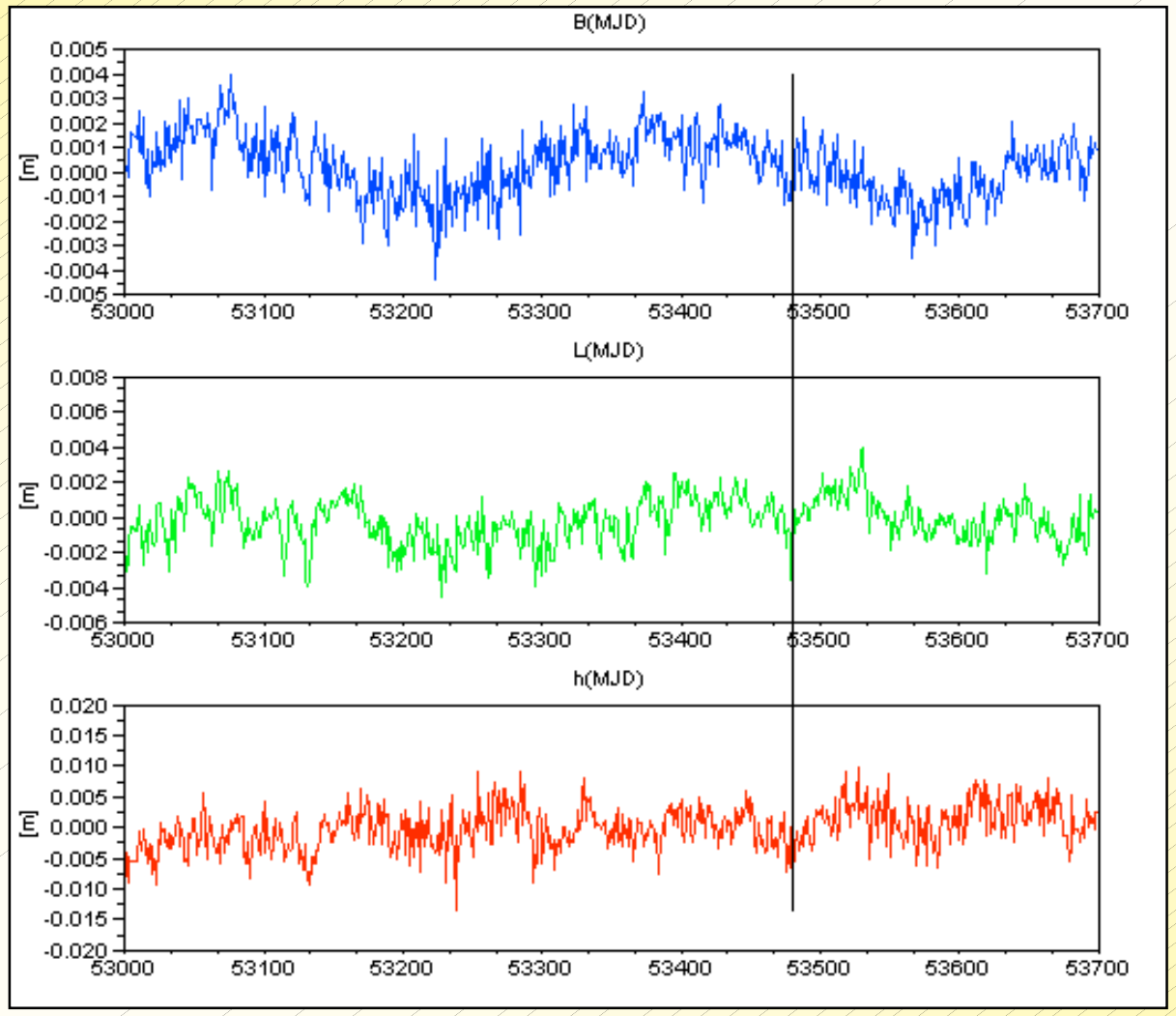


Earthquakes

Station **LROC** (France)

Earthquakes

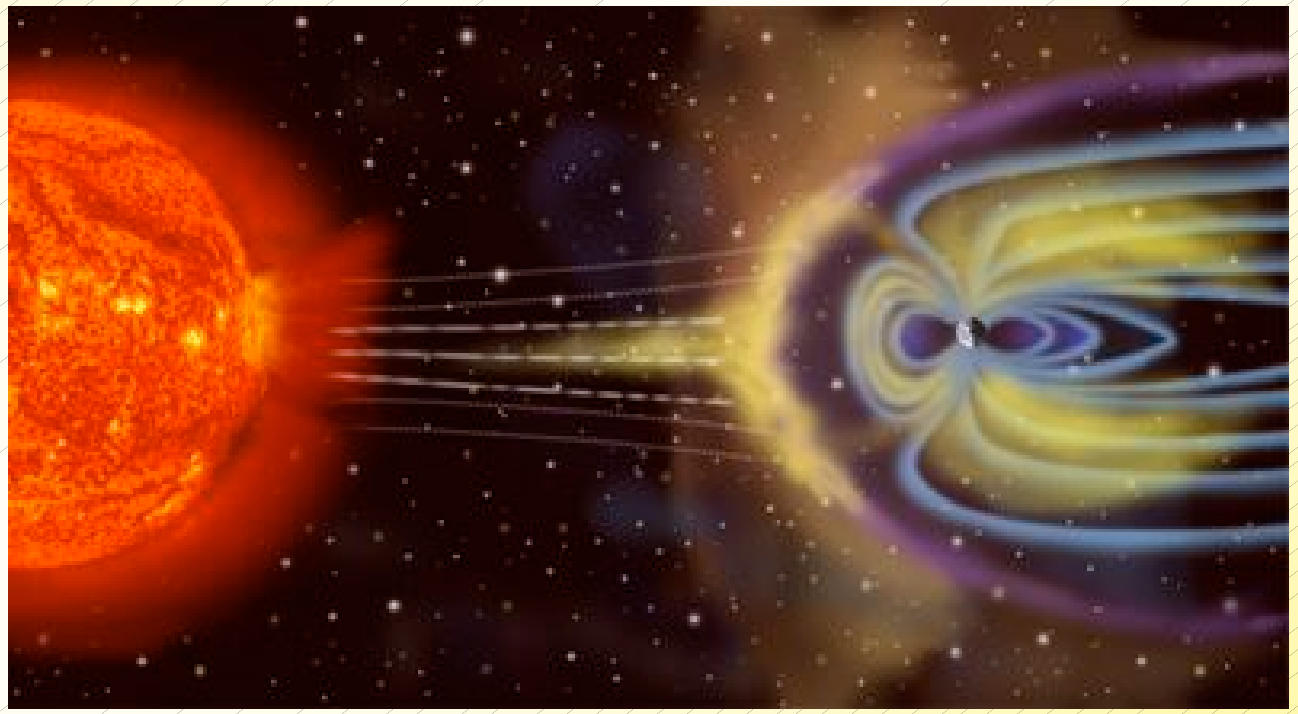
Station **LROC** (France); date of earthquake – 18th April 2005, M=5.0, L(st, ep) = 19 km



CONCLUSION: Earthquakes may cause permanent change of station's coordinates, but in general they do not have an influence on daily solution (maybe hourly?).

Magnetic storms – huge ionopheric disturbances

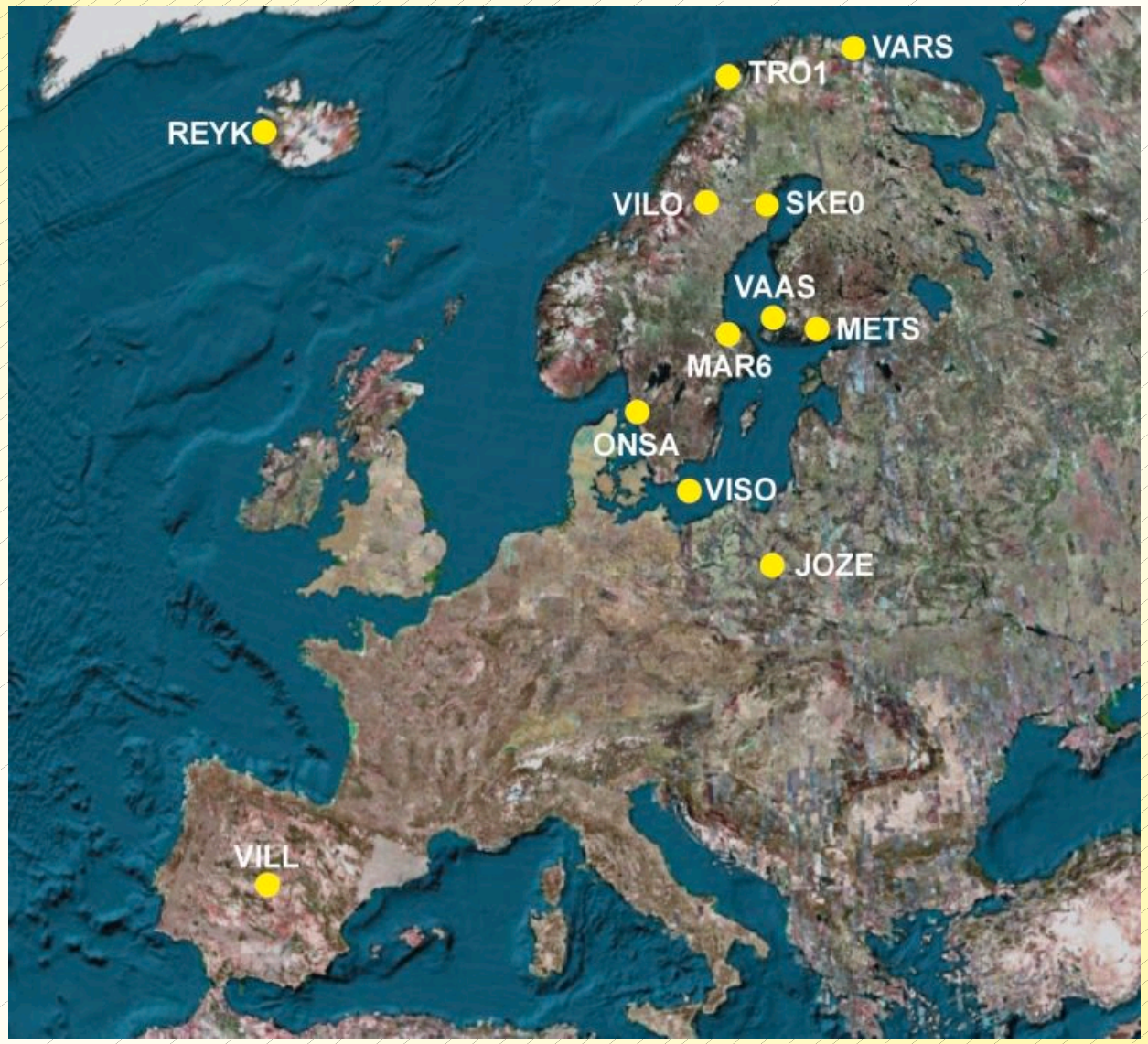
A geomagnetic storm is a temporary disturbance of the Earth's magnetosphere caused by a **solar wind shock wave** associated with solar coronal mass ejections. Usually it strikes the Earth's magnetic field 24 to 36 hours after the event. These solar wind pressure changes **modify the electric currents in the ionosphere**. Magnetic storms usually last 24 to 48 hours, but some may last for many days. As an example we analized solutions from station mainly situated in Northern Europe from period 29 X – 7 XI 2003, when very strong geomagnetic storm took place. It caused many problems with proper operation of different satelites.



www.wikipedia.com

Magnetic storms – huge ionopheric disturbances

Magnetic field's shape ionospheric stroms could especially affects northern stations.



Magnetic storms – huge ionopheric disturbances

Station **VARS** (Norway) B≈70º

Magnetic storms – huge ionopheric disturbances

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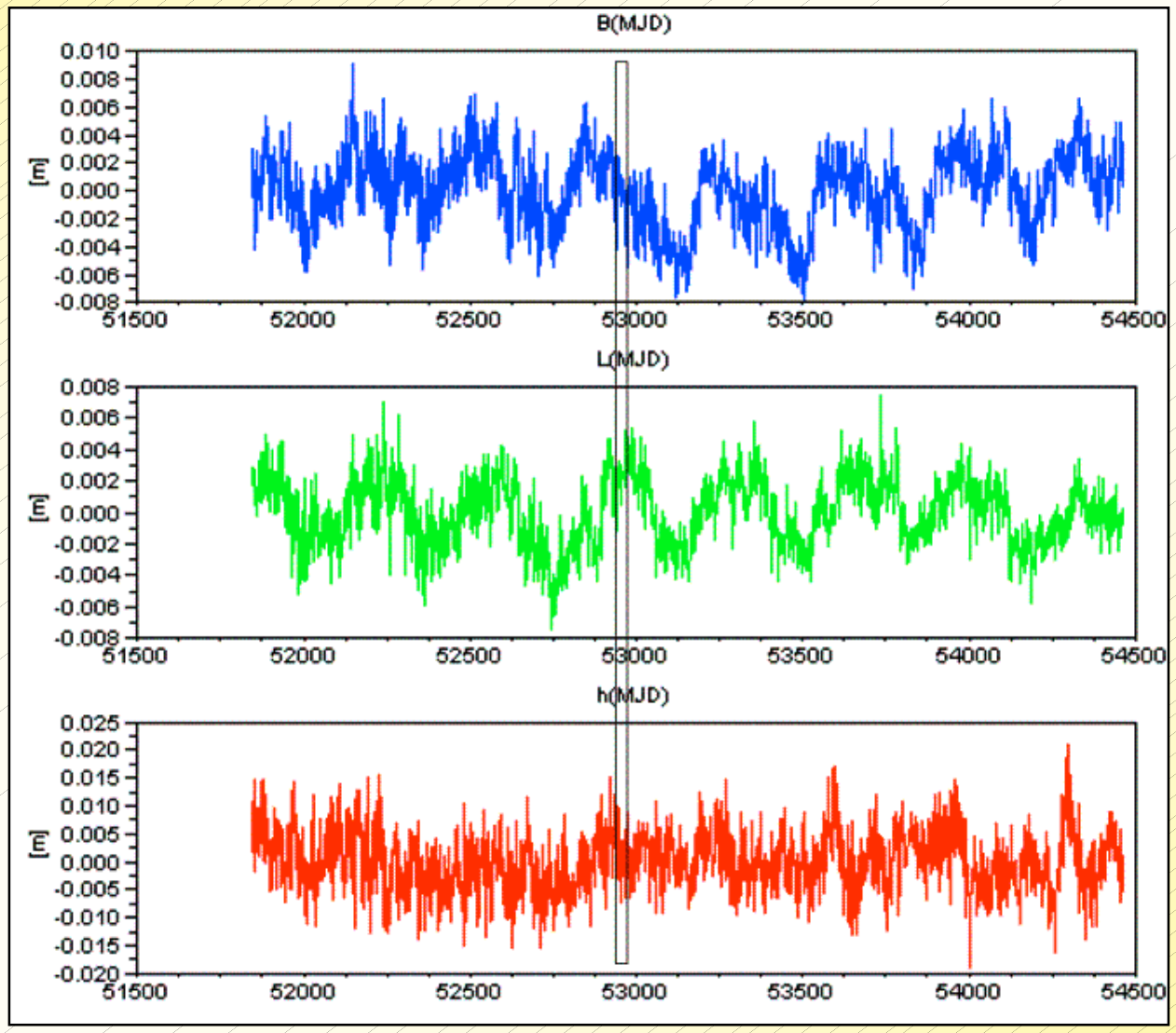
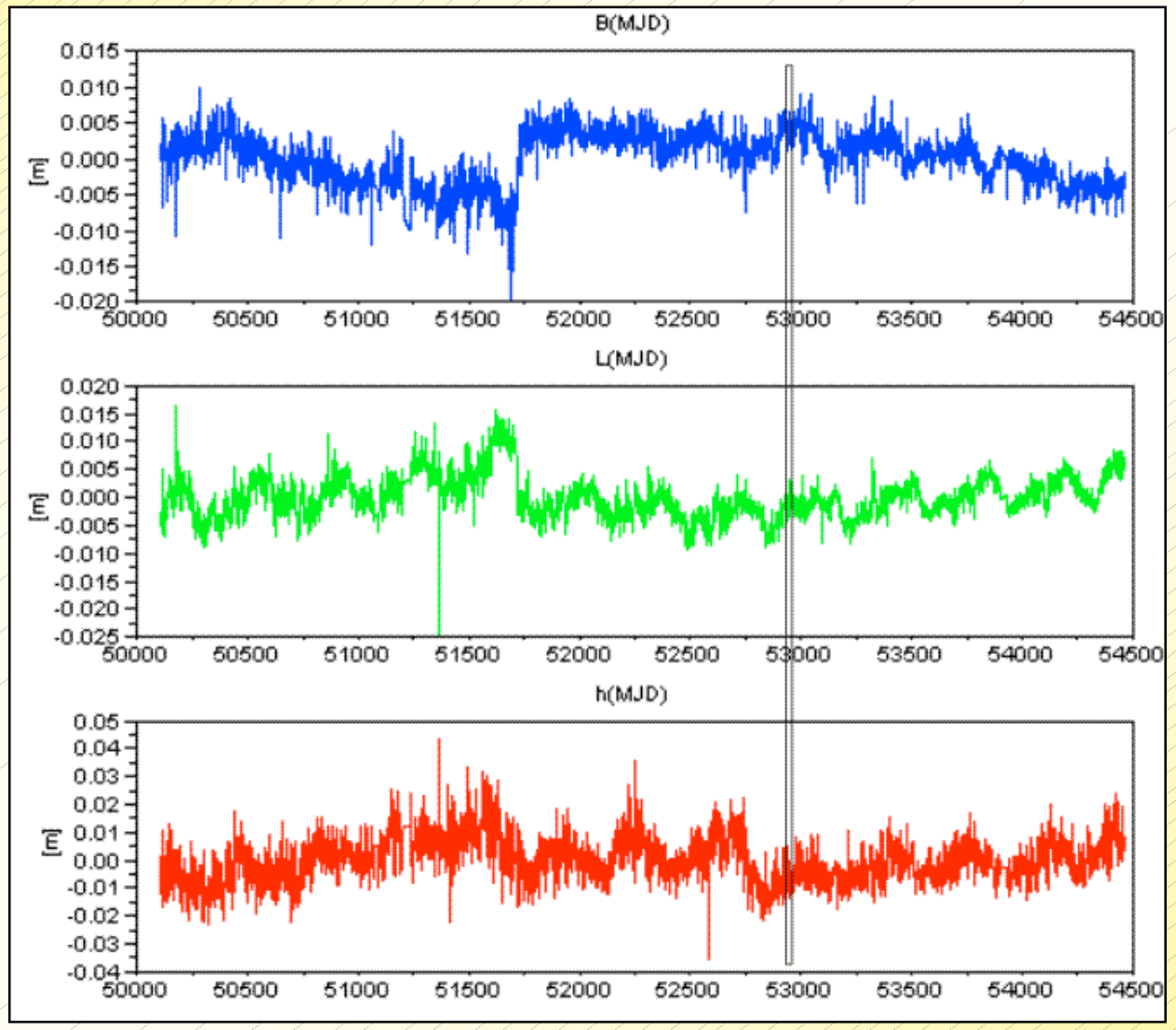


Magnetic storms – huge ionopheric disturbances

Station **REYK** (Iceland) B≈64º



Magnetic storms – huge ionopheric disturbances

Station **SKE0** (Sweden) B≈65º

Magnetic storms – huge ionopheric disturbances

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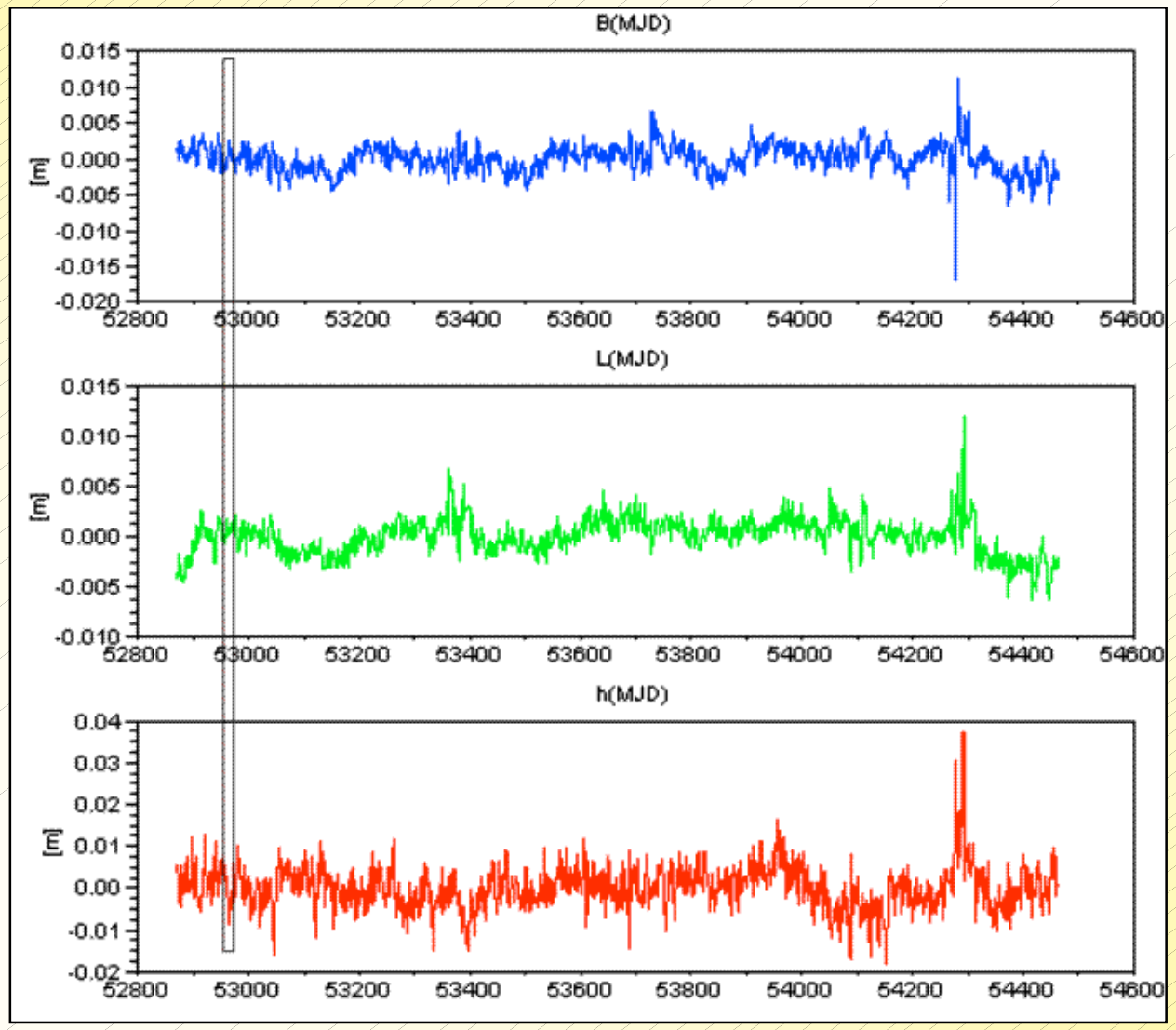
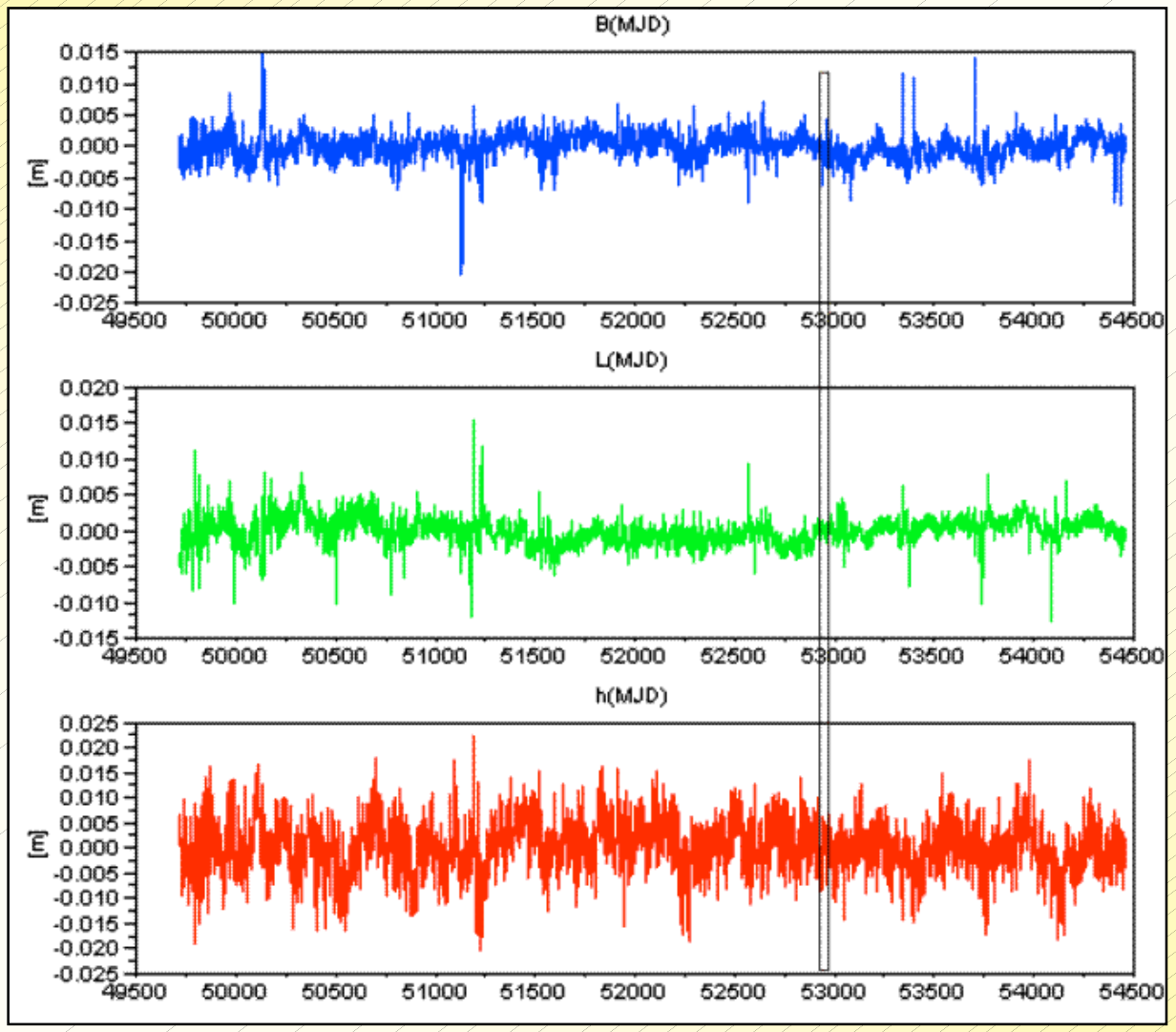


Magnetic storms – huge ionopheric disturbances

Station **METS** (Finland) B≈60º

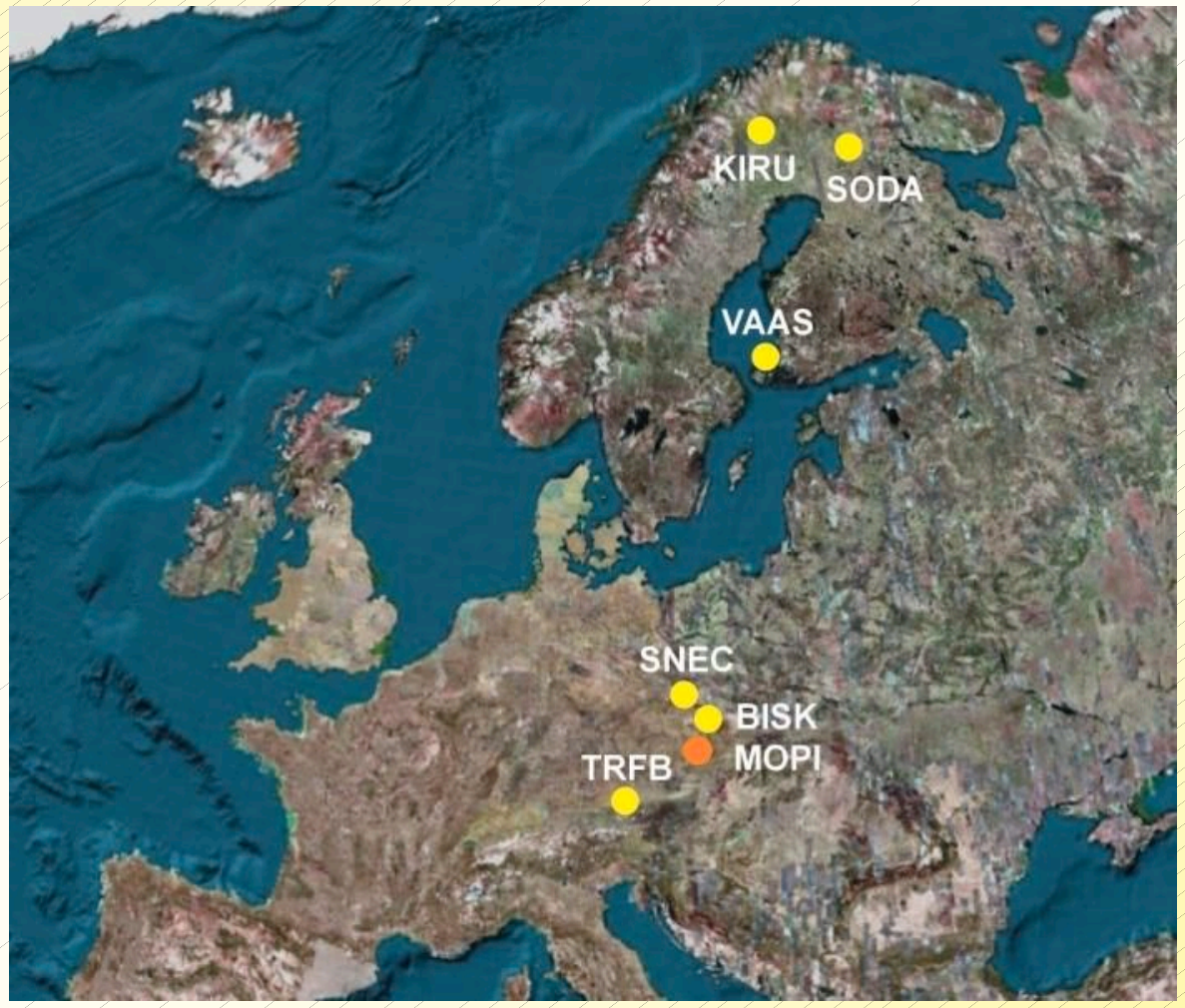


CONCLUSION: Ionosphere-free linear combination using during processing allow us not to worry about geomagnetic storms and their consequence for daily solutions.

Weather condition (snow cover)

Characteristic time series for those stations, where there is significant snow cover.

Some of those stations pointed out that snow accumulating over the antenna may cause discontinuity in time series.



Weather condition (snow cover)

Station **KIRU** (Sweden)

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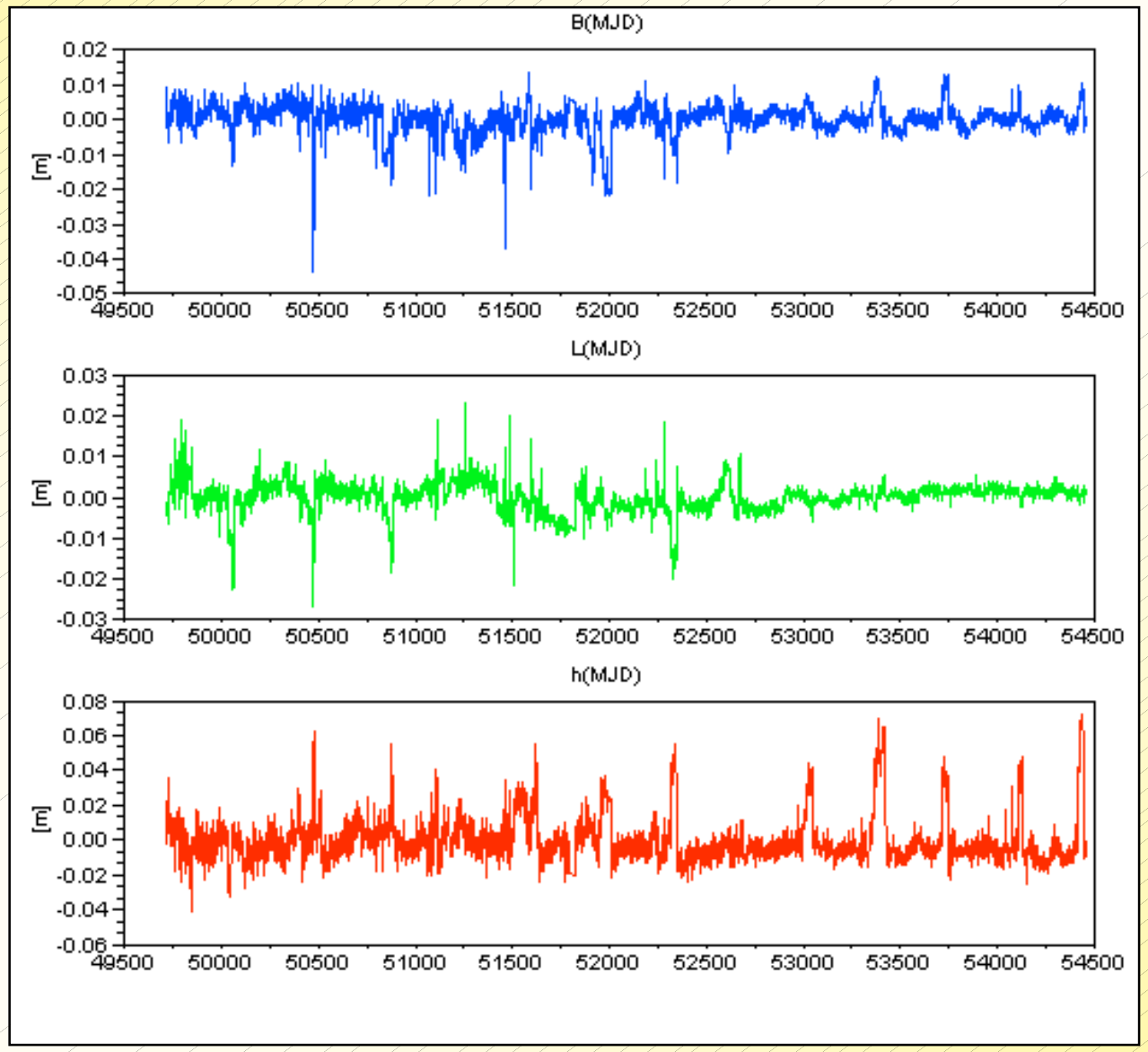

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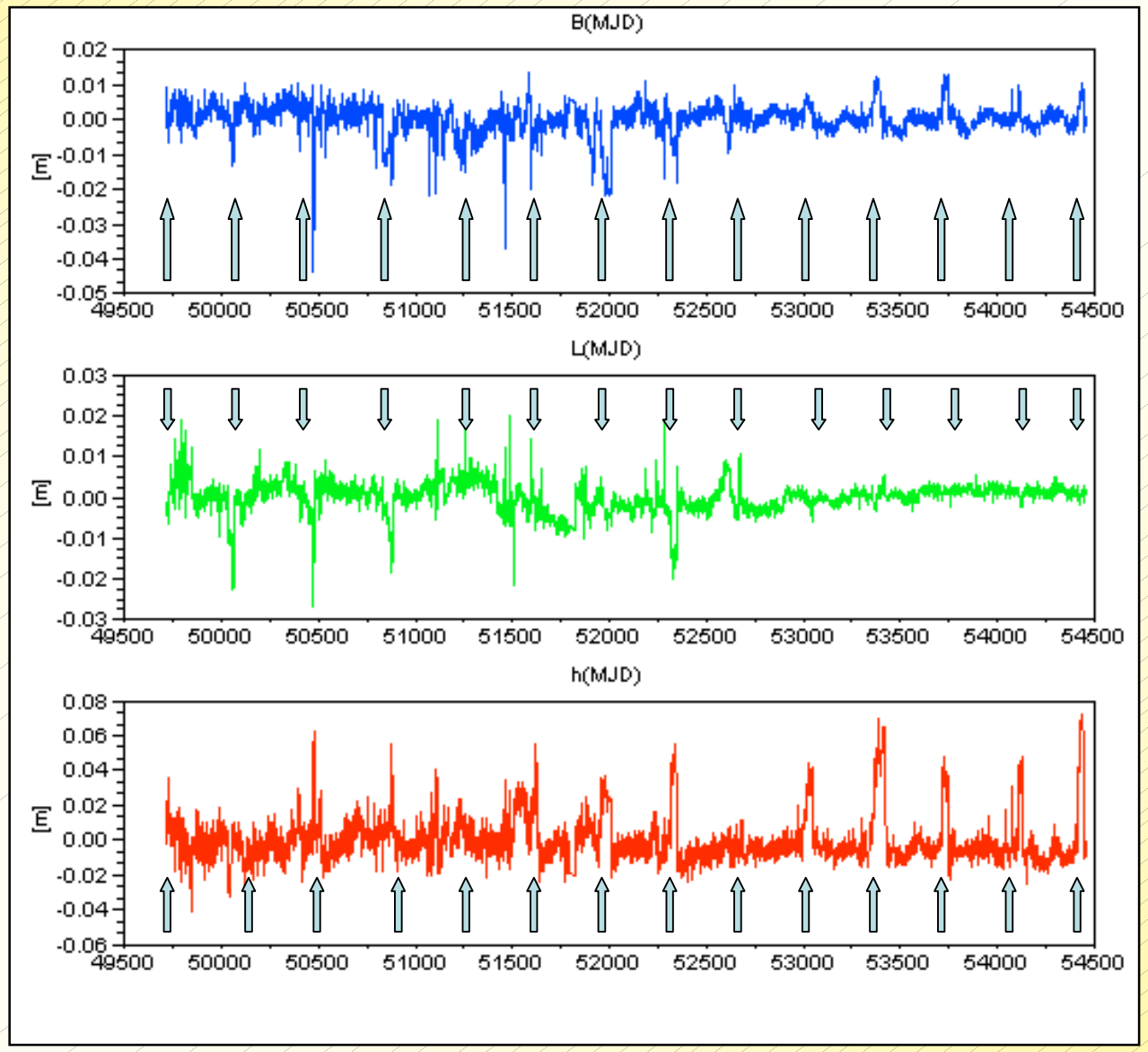
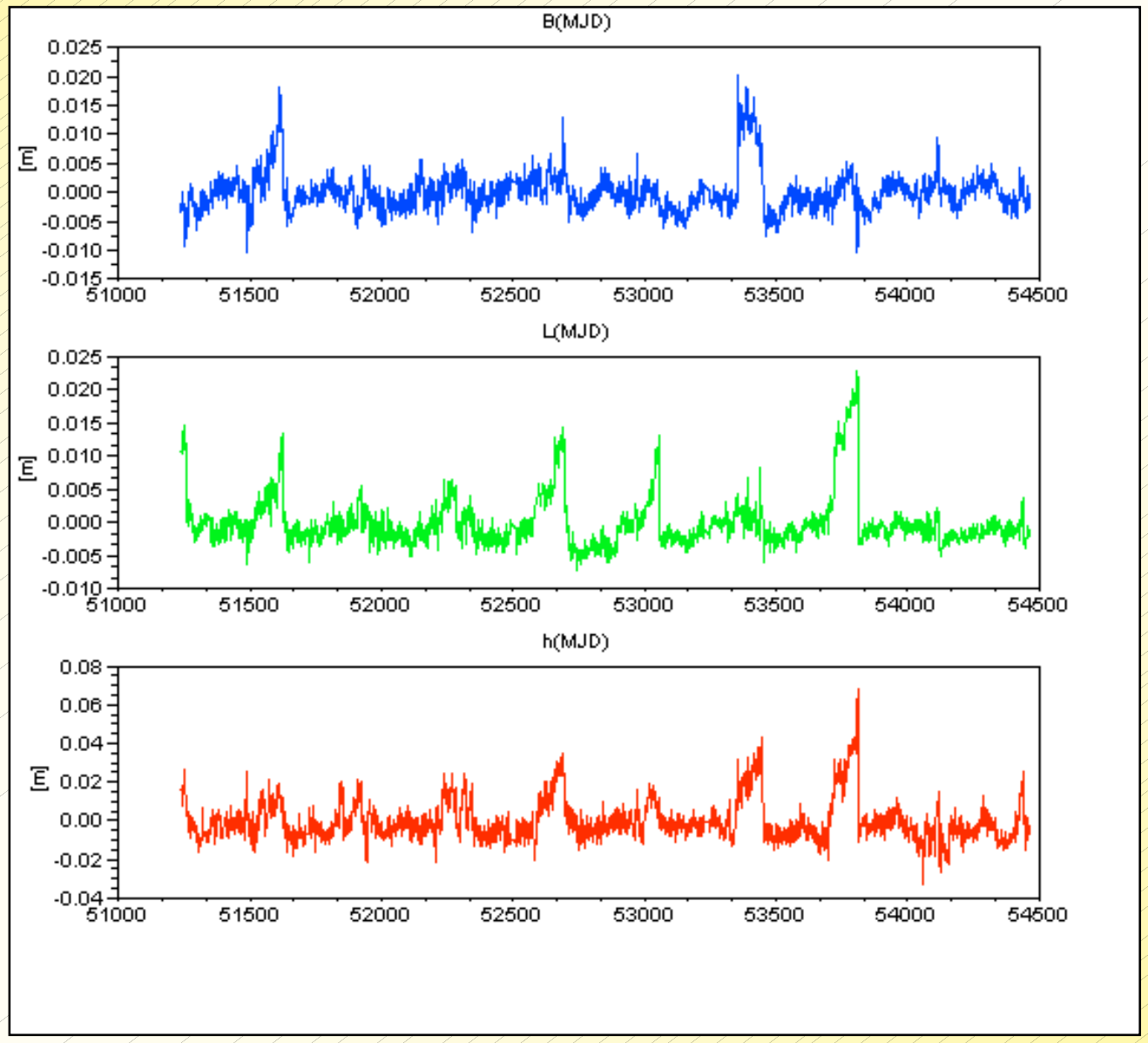


Weather condition (snow cover)

Station **SODA** (Finland)



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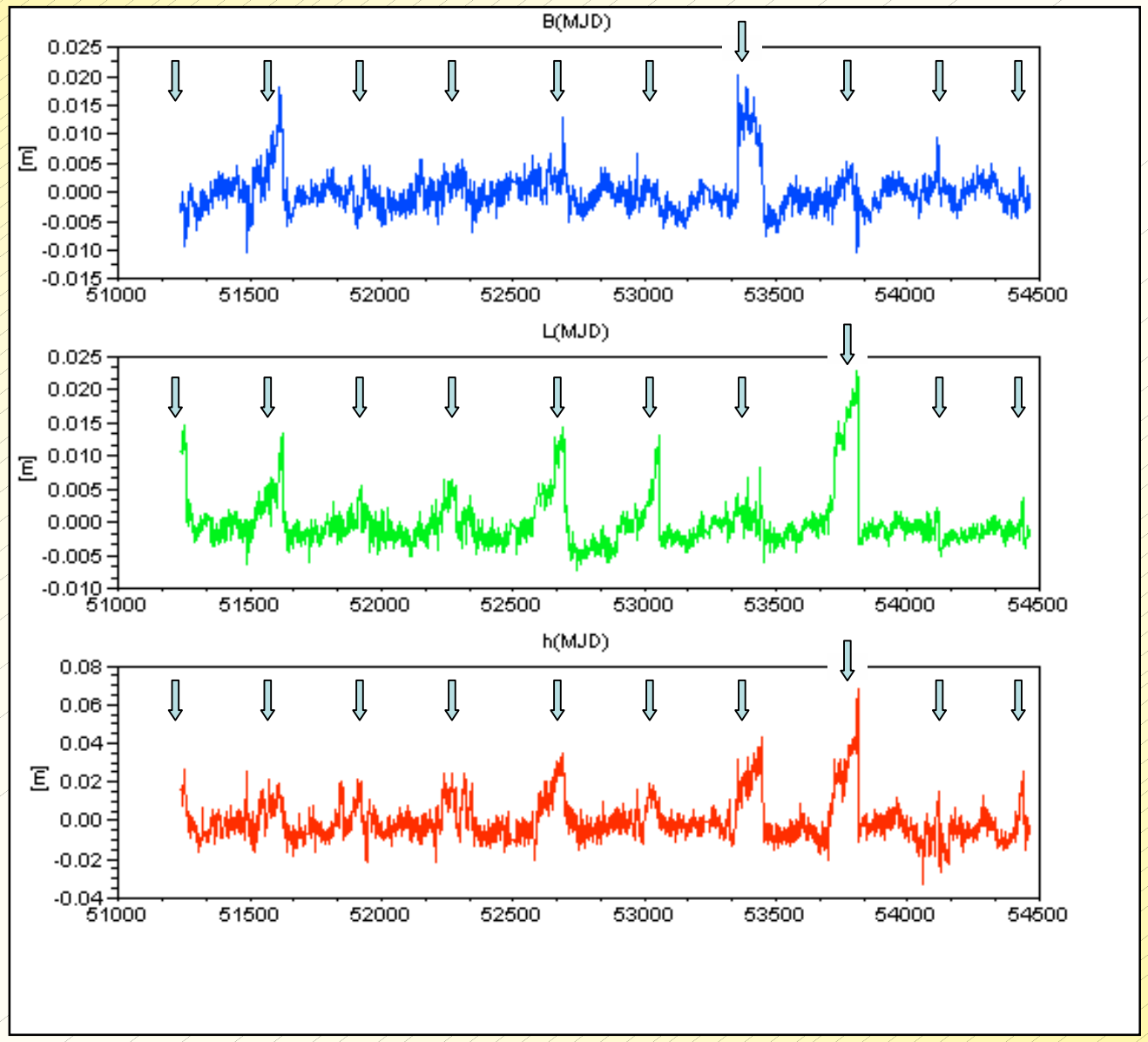

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Station **SNEC** (Czech Republic)

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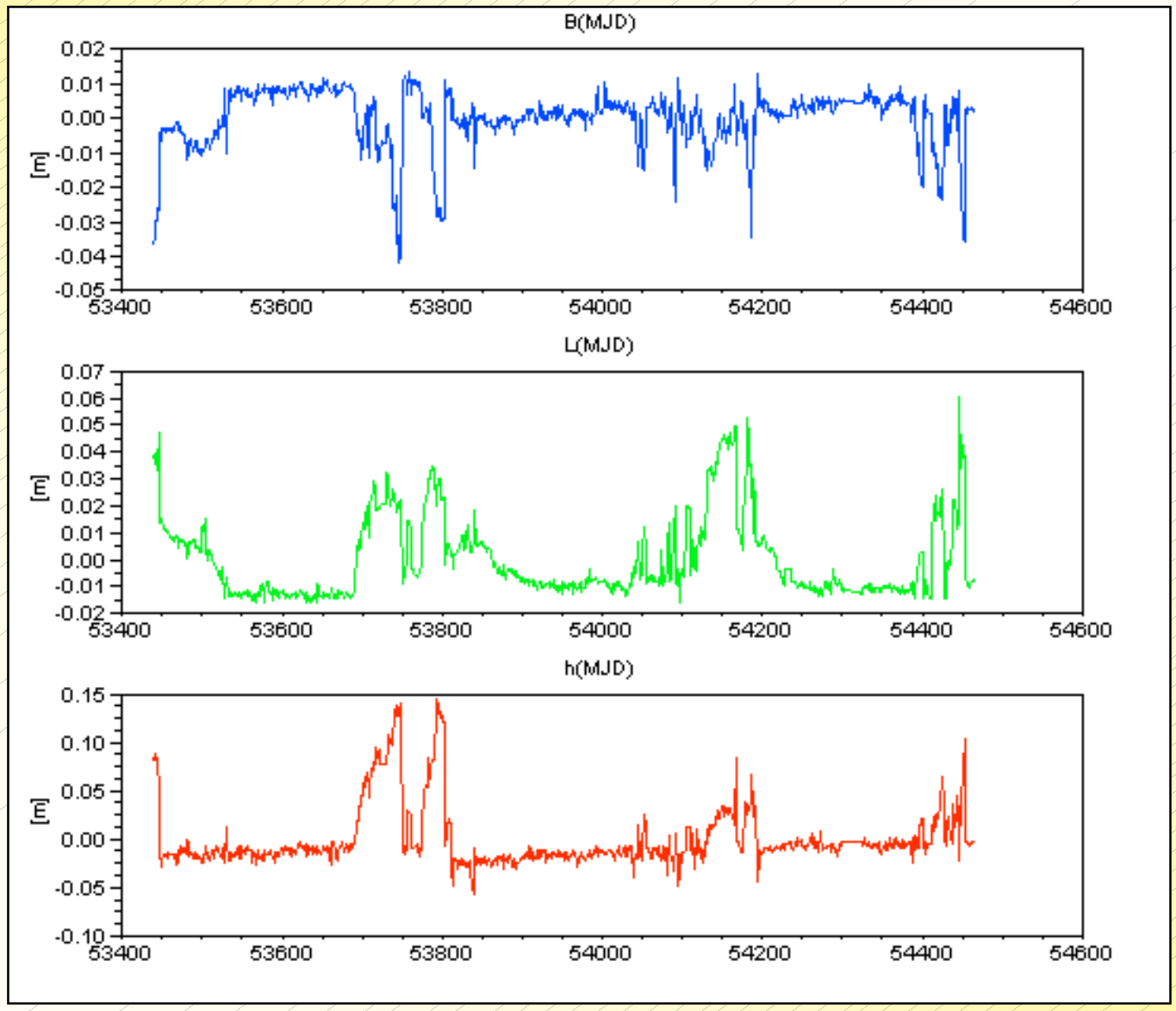

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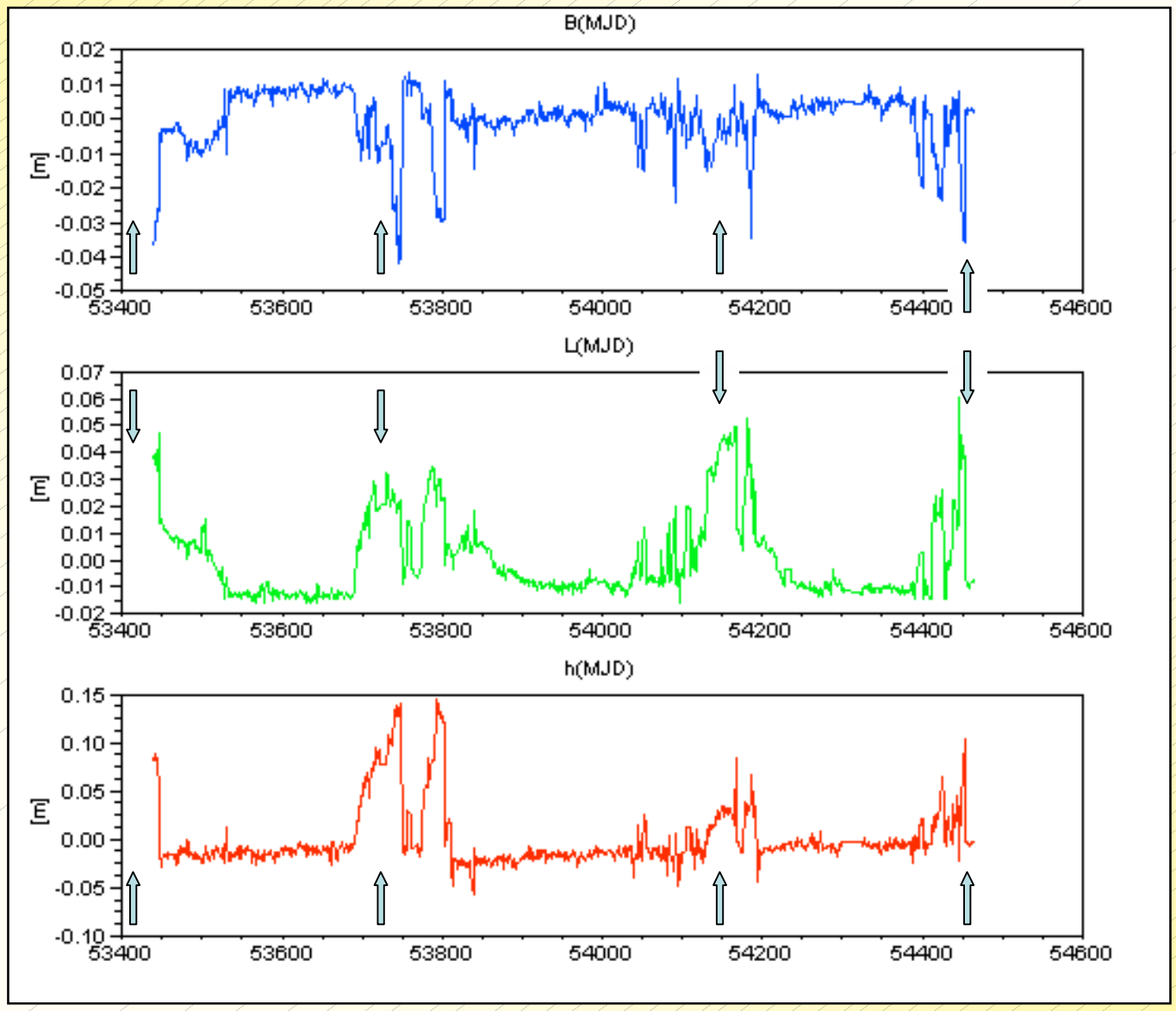

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Station VAAS (Finland)

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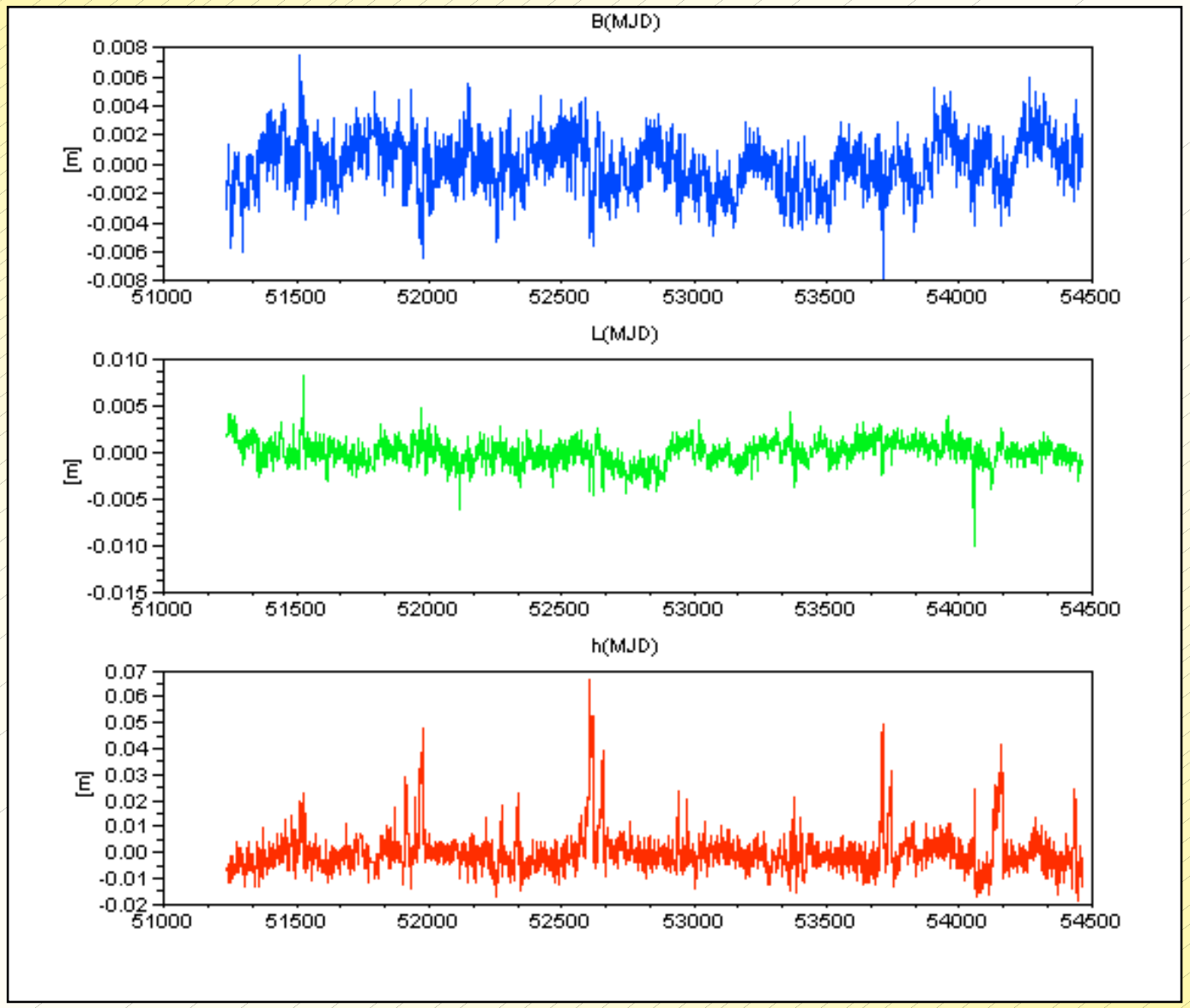

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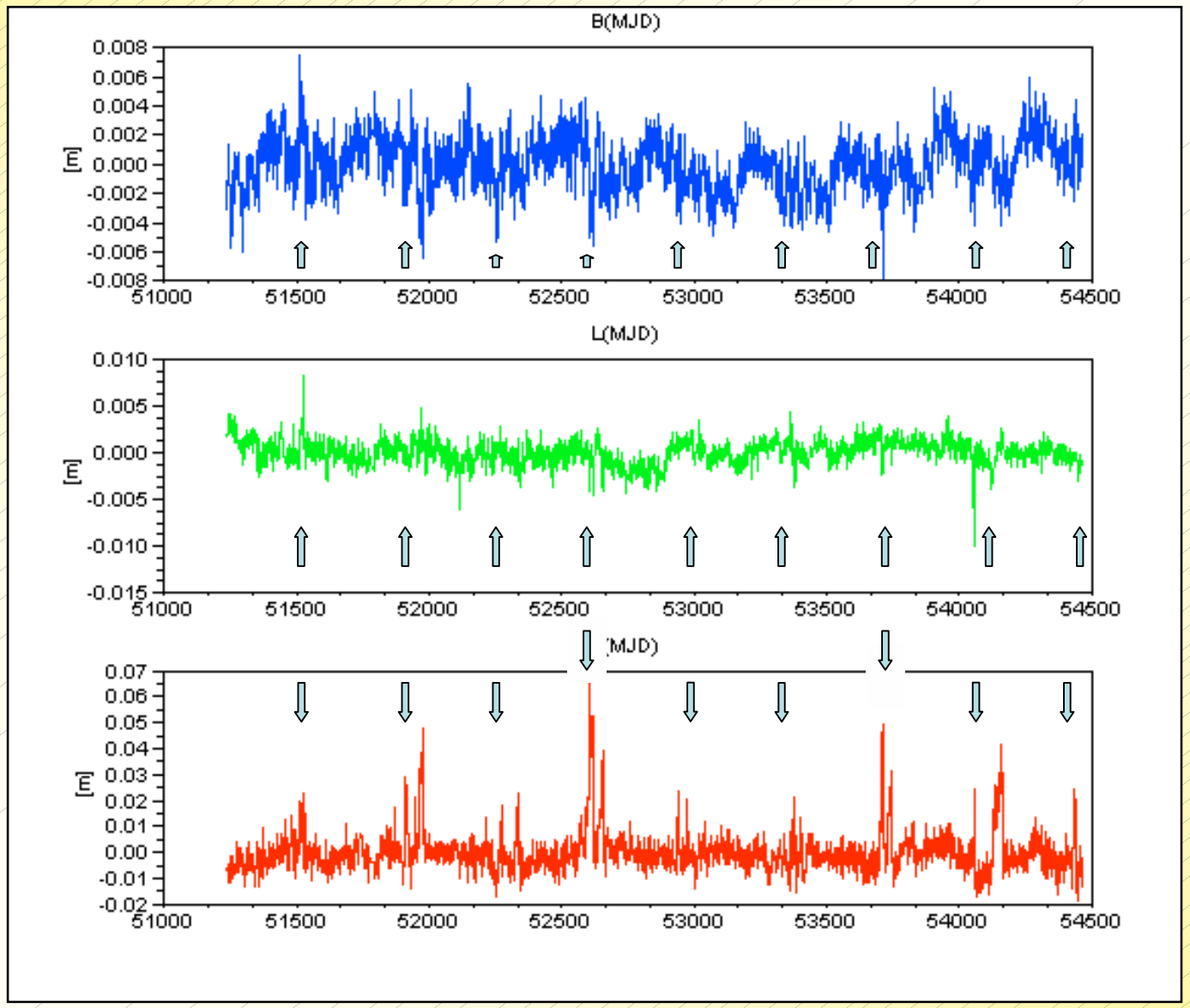
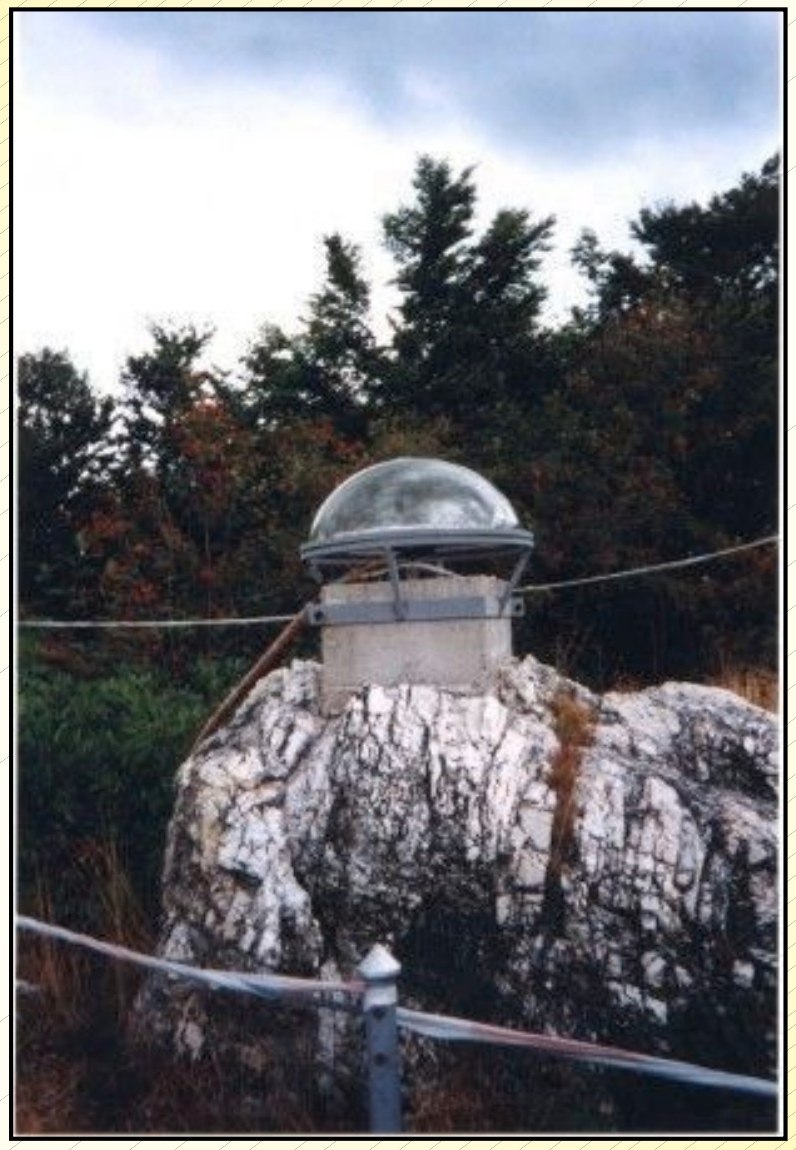


Weather condition (snow cover)

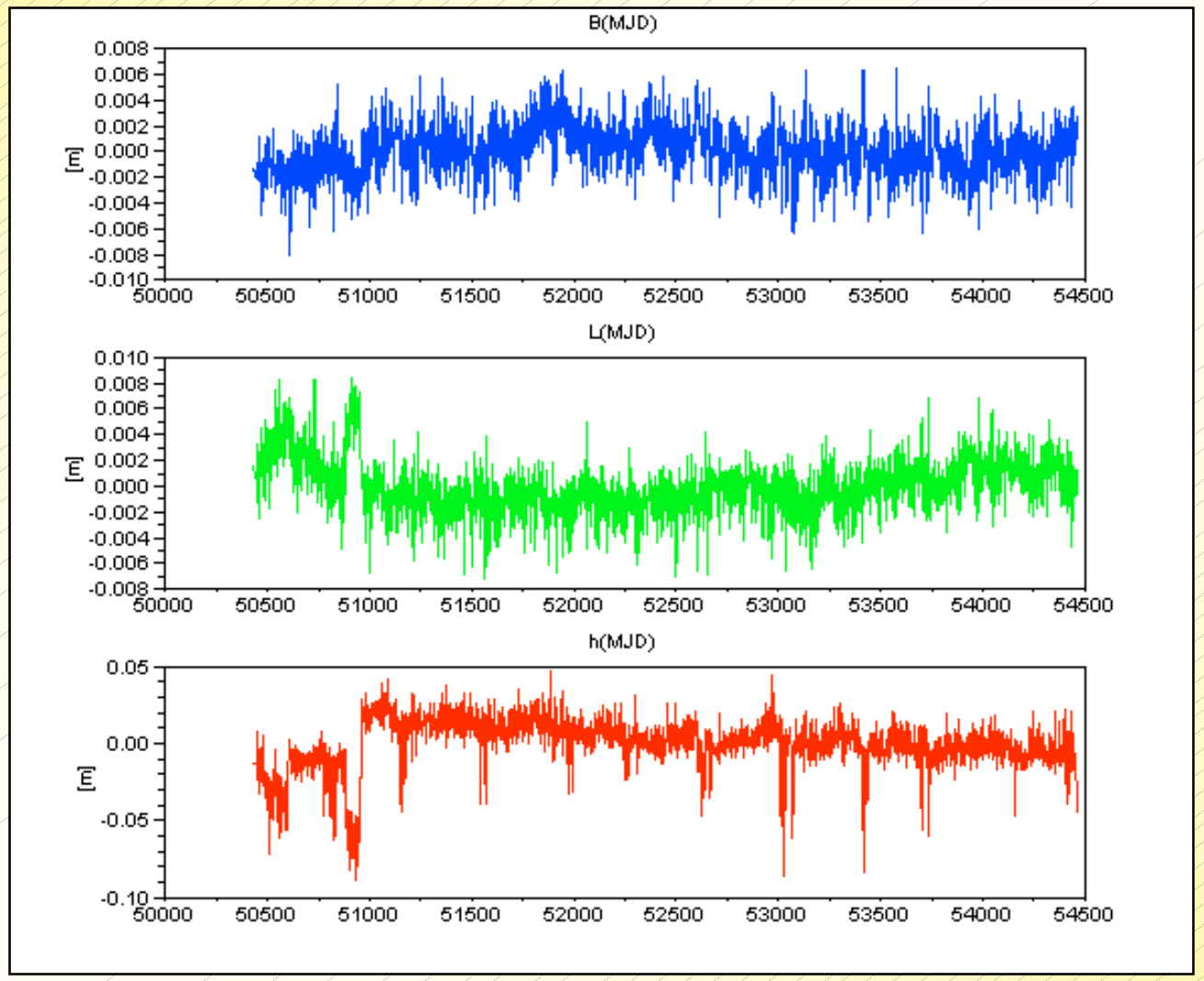
Station **MOPI** (Slovak Republic)



Meteorological data to further aalysis by courtesy of Mr J. Hefty and Mrs M. Igondova

Weather condition (snow cover)

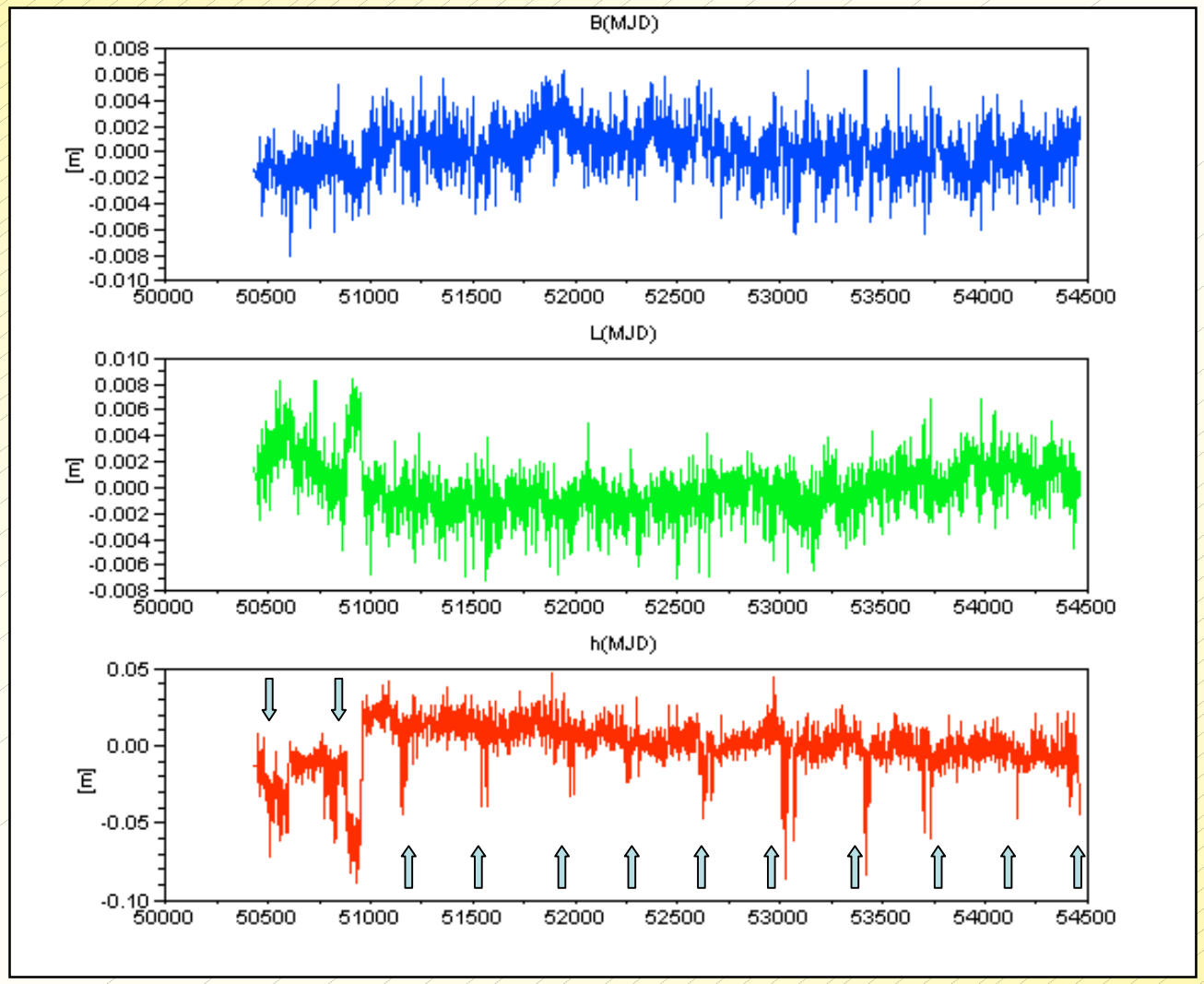
Station **MOPI** (Slovak Rep.) – different time series, but there are some similarities to previous ones



Meteorological data to further analysis by courtesy of Mr J. Hefty and Mrs M. Igondova

Weather condition (snow cover)

Station **MOPI** (Slovak Rep.) – different time series, but there are some similarities to previous ones

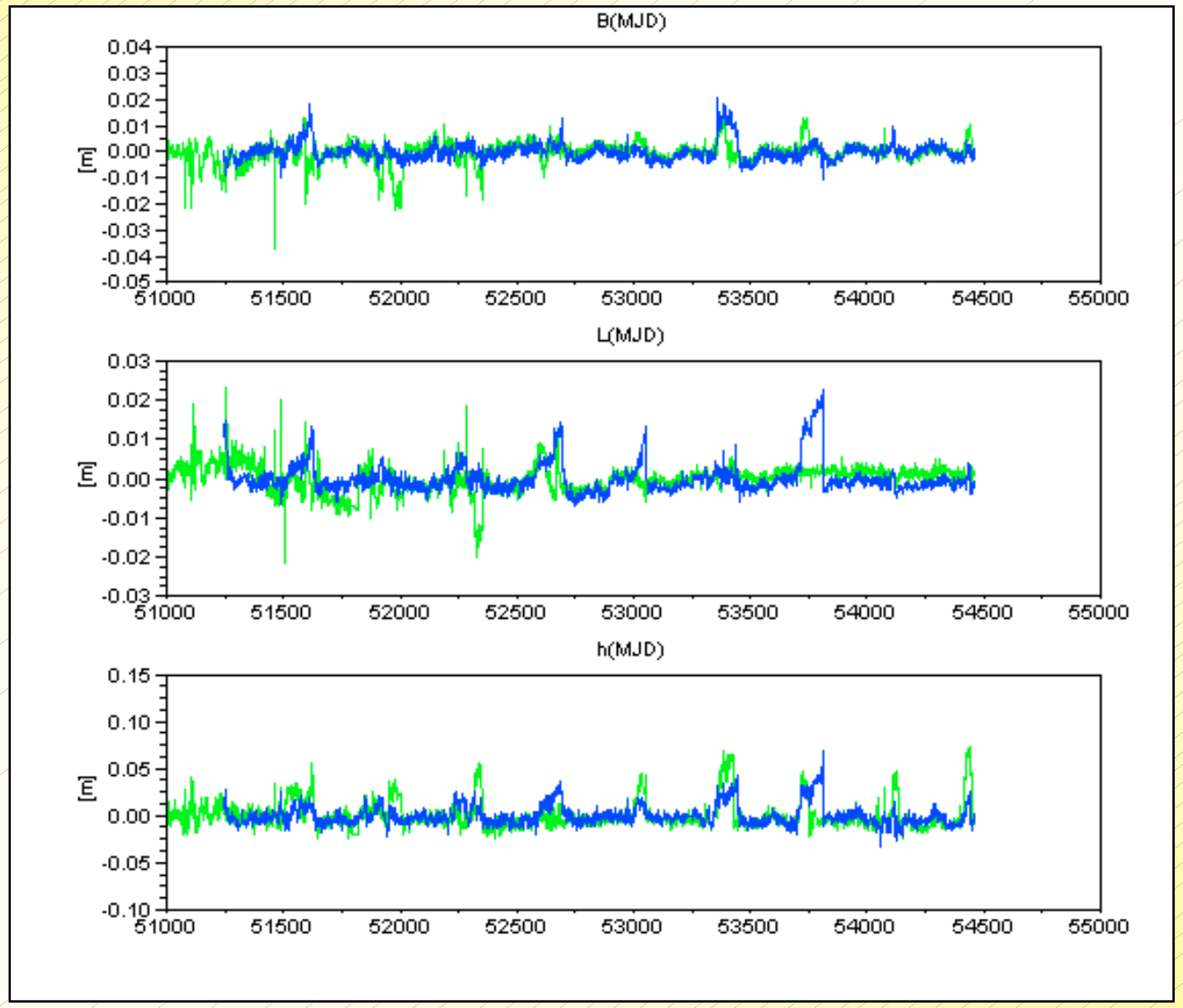


Meteorological data to further analysis by courtesy of Mr J. Hefty and Mrs M. Igondova

Weather condition (snow cover)

Superposition of time series for stations situated in the same area – similar weather conditions

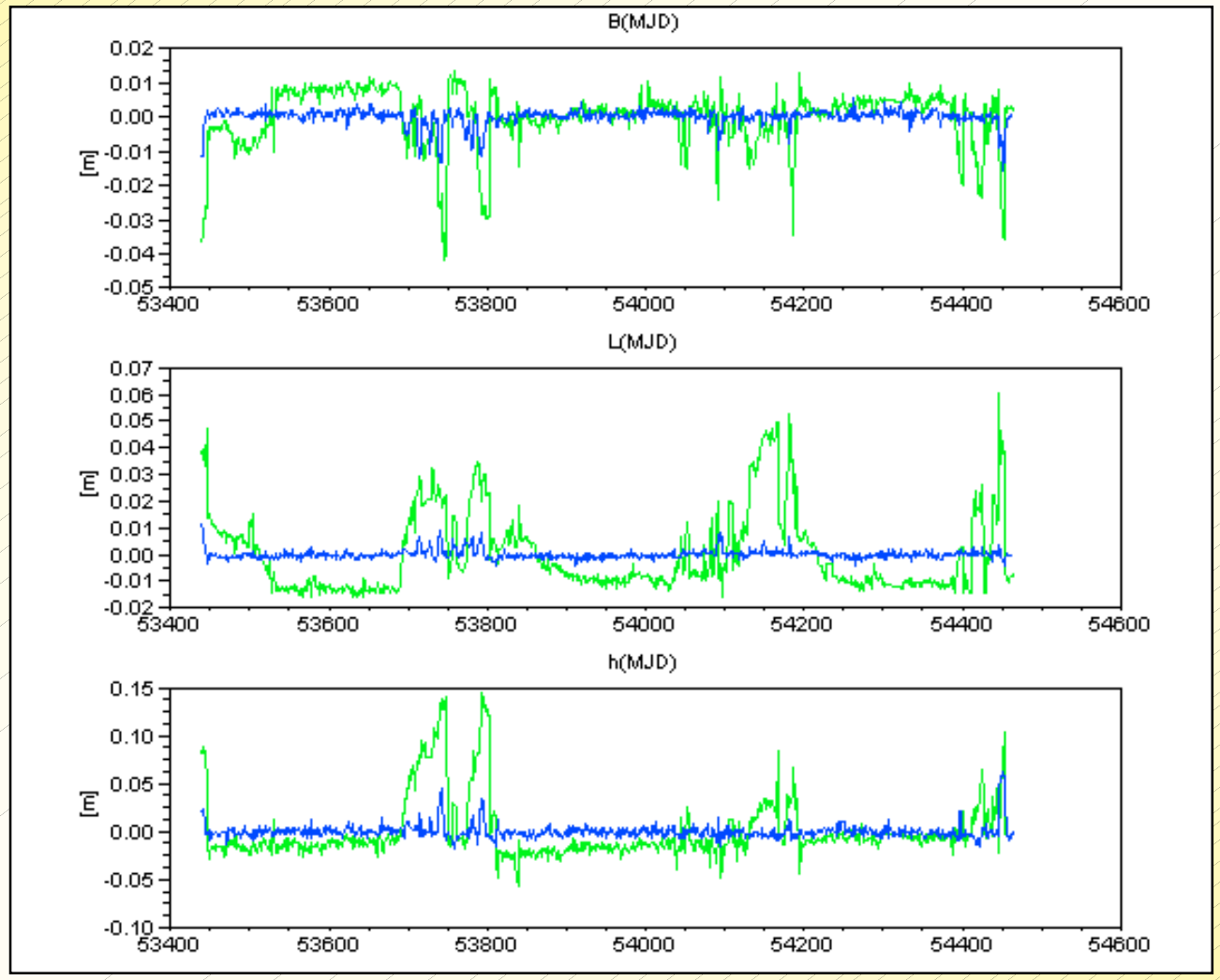
Stations: **KIRU** (Sweden) and **SODA** (Finland)



Weather condition (snow cover)

Superposition of time series for stations situated in the same area – similar weather conditions

Stations: **SNEC** (Czech Republic) and **BISK** (Czech Republic)



CONCLUSION: Snow cover may significantly disturb daily solutions (periodic factor increases t
amplitude of one-year tidal wave), it should be taken into consideration for some station.

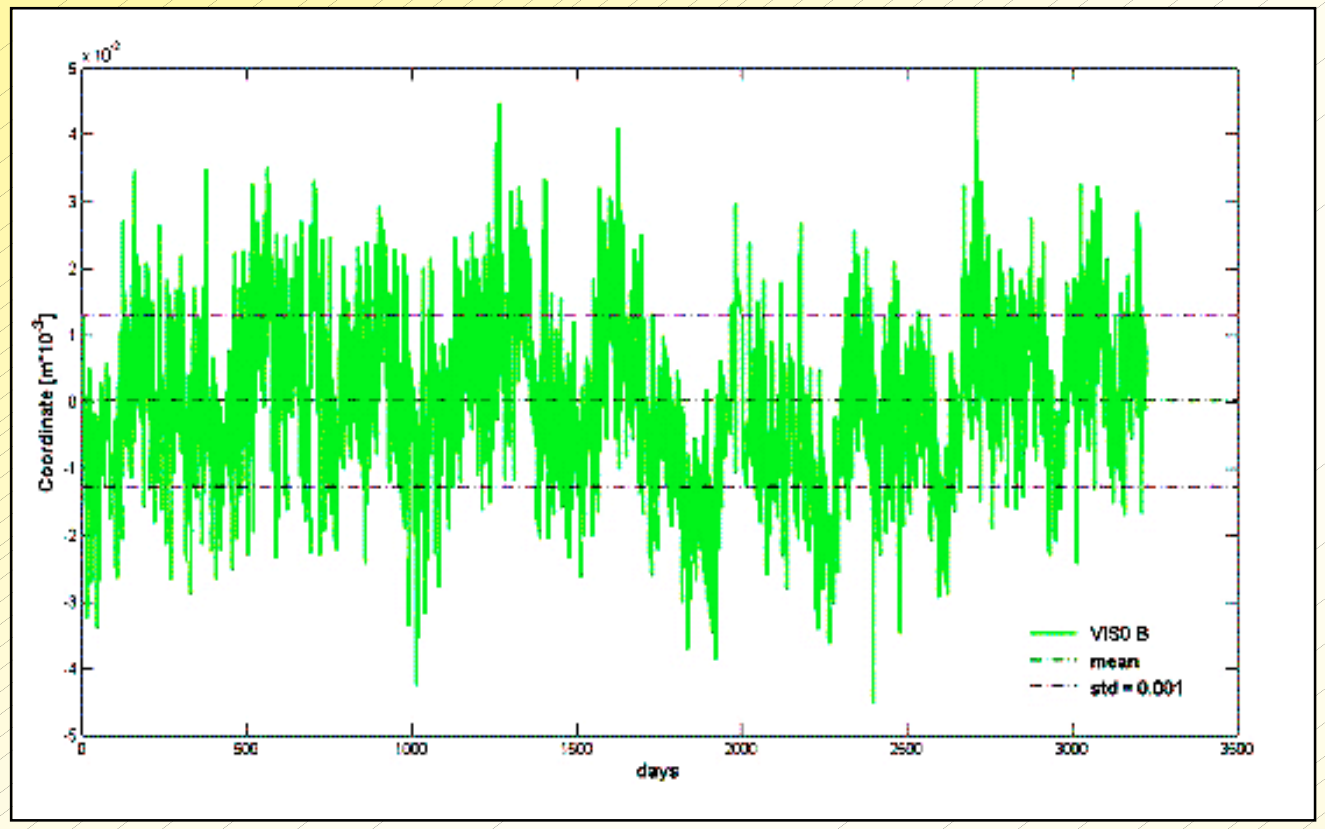
Statistics of time series from EPN station (in progress)

Before calculating statistical parameters (mean, variance, standard deviation…) time series should be corrected due to untypical disturbances.

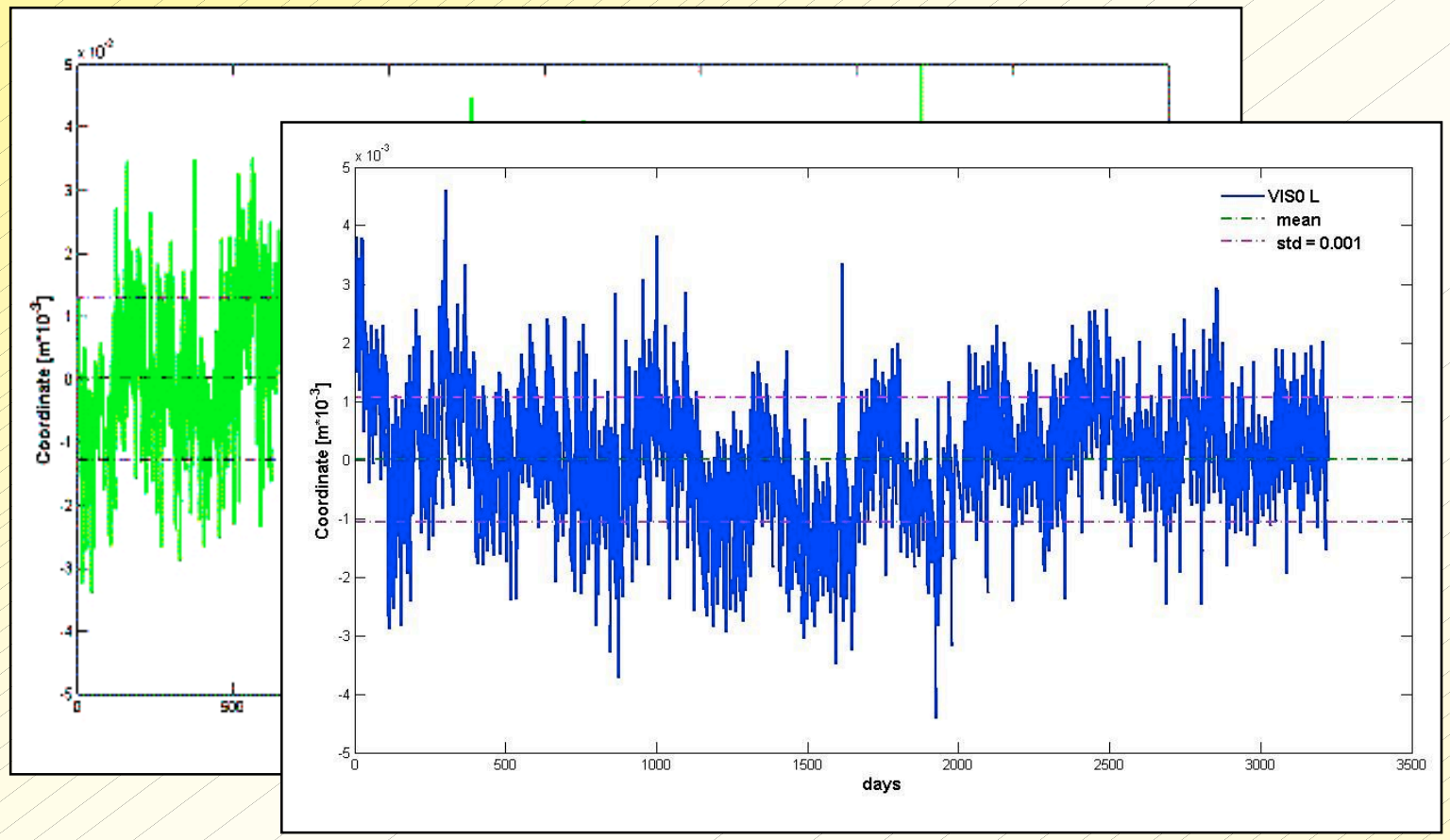
Such parameters can be helpful in estimation solutions' reliability.

Station **VISO** (Sweden)

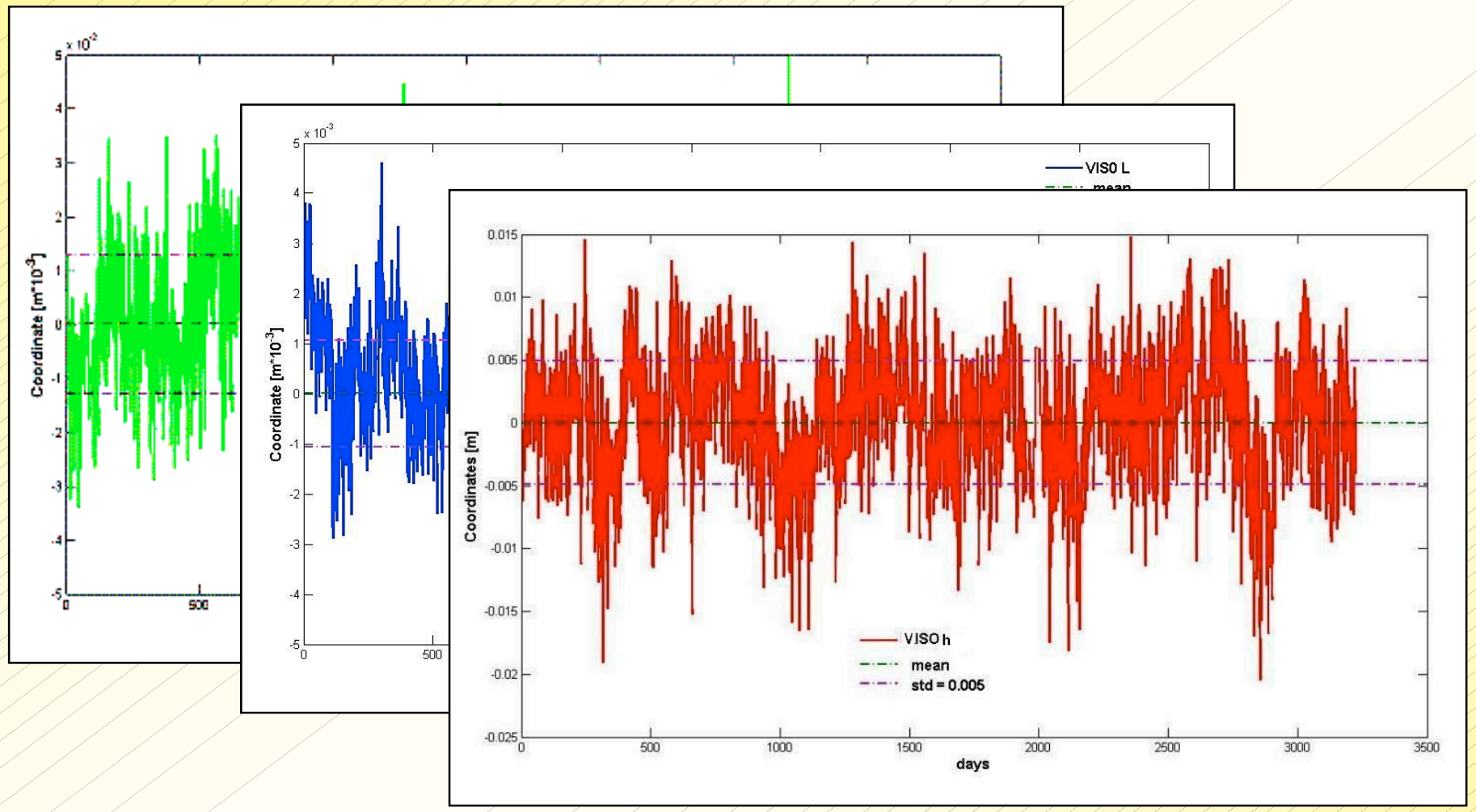
Statistics of time series from EPN station (in progress)



Statistics of time series from EPN station (in progress)



Statistics of time series from EPN station (in progress)



After analysing statistics of time series from different station we can draw some conclusions about conditions of proper station (especially antenna) localization and distinguish periodic disturbances corresponding to specific station from oscillation received from Wavelet Transformation (f.e. disturbances connected with high constructions' movement).

CONCLUSIONS:

- Modifications on station may cause serious changes in solutions – they have to be taken into consideration before further analysis;
- Earthquakes may cause permanent change of station's coordinates (displacement of antenna), but in general they do not have an influence on daily solution;
- Ionosphere-free linear combination using during processing allow us not to worry about geomagnetic storms and their consequence for daily solutions;
- Snow cover significantly disturbs daily solutions (periodic factor, it increases the amplitude of one-year tidal wave), it should be taken into consideration for some station.
- Simple statistics can be helpful in estimation solutions' reliability. Periodic disturbances corresponding to specific station should be determined due to distinguish them from oscillation received from following analysis (f.e. Wavelet Transformation).

THANK YOU