

# **ANALYSIS OF THE EARTH'S CENTER OF MASS PERIODICAL MOVEMENTS**

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**In 2009 INASAN (ina) Doris Analysis Center installed new version GIPSY-OASIS II software developed by JPL with updated DORIS part of GIPSY developed by IGN/JPL (Linux version 5.0). We just installed the latest version (Linux version 6.0).**

# List of INASAN products provided to the IDS (May 2011)

Product	Latest version	Span
<b>Sinex weekly free network solutions</b>	<b>inawd07</b>	<b>1993.0 - 2011.0</b>
<b>Geocenter</b>	<b>ina10wd01</b>	<b>1993.0 - 2011.0</b>
<b>EOP-series</b>	<b>ina10wd01</b>	<b>1993.0 - 2011.0</b>
<b>STCD-series</b>	<b>ina10wd01</b>	<b>1993.0 - 2010.8</b>

# **In 2009 INASAN AC fully reprocessed all DORIS data for 1993.0-2010.0 with the new software and new models**

## **Old models:**

- 1) elevation cutoff angle = 15 degrees**
- 2) the gravity field is GGM01C (120x120)**
- 3) solar radiation pressure coefficients were estimated**
- 4) Lanyi tropospheric mapping function was used**
- 5) atmospheric density model DTM94 as a priori**
- 6) estimating atmospheric drag every 6 hrs for SPOT's and every 24 hrs for TOPEX**
- 7) polar motion rates were estimated**

## **New models:**

- 1) elevation cutoff angle = 15 degrees and data downweighting at low elevation were applied**
- 2) the gravity field is GGM02C (120x120)**
- 3) fixing daily coefficients for solar radiation pressure models**
- 4) Niell tropospheric mapping function was used**
- 5) atmospheric density model DTM2000 as a priori**
- 6) estimating atmospheric drag every 1 hr**
- 7) polar motion rates were not estimated**

# Studies of geocenter movements

## ***1) The linear regression analysis (LRA)***

$$J(t) = a_0 + b_0t + A_0 \sin\left(\frac{2\pi}{T}(t - t_0) + \varphi_0\right),$$

*$A_0$  – amplitude of the signal*

*$T$  – period of the signal (in years)*

*$\varphi_0$  – initial phase of the signal*

*$a_0$  – offset*

*$b_0$  – trend*

*$t_0$  – initial time (1st January)*

*$t$  – time*

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# Comparison INA geocenter times series (old-ina05wd01 and new-ina10wd01) with IGN geocenter times series

AC Tz	Time series	Span	Tx				Ty					
			Annual	Semiannual	Annual	Semiannual	Annual					
			A1	Phi	A2	Phi	A1	Phi	A2	Phi	A1	
			(mm)	(deg)	(mm)	(deg)	(mm)	(deg)	(mm)	(deg)	(mm)	
<b>IGN</b>	<b>ign09wd01</b>	<b>1993.0- 2010.0</b>	<b>5.6</b>	<b>106.9</b>	<b>5.5</b>	<b>358.6</b>	<b>4.7</b>	<b>319.4</b>	<b>7.6</b>	<b>350.9</b>	<b>2.2</b>	<b>289.7</b>
			<b>33.5</b>	<b>357.9</b>	<b>0.2</b>	<b>3.9</b>	<b>0.3</b>	<b>3.3</b>	<b>0.04</b>	<b>6.7</b>	<b>0.3</b>	<b>3.4</b>
			<b>0.9</b>	<b>47.0</b>	<b>1.4</b>	<b>2.5</b>						
<b>INA</b>	<b>ina05wd01</b>	<b>1993.0- 2010.0</b>	<b>6.8</b>	<b>110.3</b>	<b>0.5</b>	<b>270.4</b>	<b>5.4</b>	<b>317.7</b>	<b>9.4</b>	<b>353.2</b>	<b>27.2</b>	<b>291.1</b>
			<b>6.3</b>	<b>303.8</b>		<b>2010.0</b>	<b>0.3</b>	<b>5.0</b>	<b>0.4</b>	<b>57.4</b>	<b>3.3</b>	<b>6.7</b>
			<b>3.1</b>	<b>1.0</b>	<b>5.0</b>	<b>0.5</b>	<b>23.0</b>					
<b>INA</b>	<b>ina10wd01</b>	<b>1993.0- 2010.0</b>	<b>4.7</b>	<b>100.2</b>	<b>5.6</b>	<b>350.6</b>	<b>4.6</b>	<b>307.4</b>	<b>11.4</b>	<b>347.2</b>	<b>6.2</b>	<b>261.8</b>
			<b>30.2</b>	<b>351.3</b>					<b>2010.0</b>	<b>0.4</b>	<b>6.4</b>	
			<b>0.4</b>	<b>5.3</b>	<b>0.2</b>	<b>17.5</b>	<b>0.8</b>	<b>6.0</b>	<b>2.9</b>	<b>19.8</b>	<b>2.1</b>	<b>5.5</b>

## ***2) Dynamic regression modeling (DRM method)***

- **Trend-stability estimation**
- **Estimation and removal of trend component**
- **Estimation of harmonic components (spectral and wavelet analysis)**
- **Development GARCH model for the residuals from previous step**
- **Application of Kalman's filter**

# Comparison of geocenter motion variations by LRA and DRM methods for ina05wd01 time series (1993.0-2009.0)

Method	Harmonics periods (years)	Tx Annual Semian.	Ty Annual Semian.	Tz Annual Semian.
LRA	0.5; 1	6.7	5.5	28.9
DRM	0.15; ~0.5; ~1; ~2; ~3; ~5	5.9 2.1	6.1 1.1	24.2 11.1



# DRM forecasting model of the weekly geocenter positions for 2008 (X)

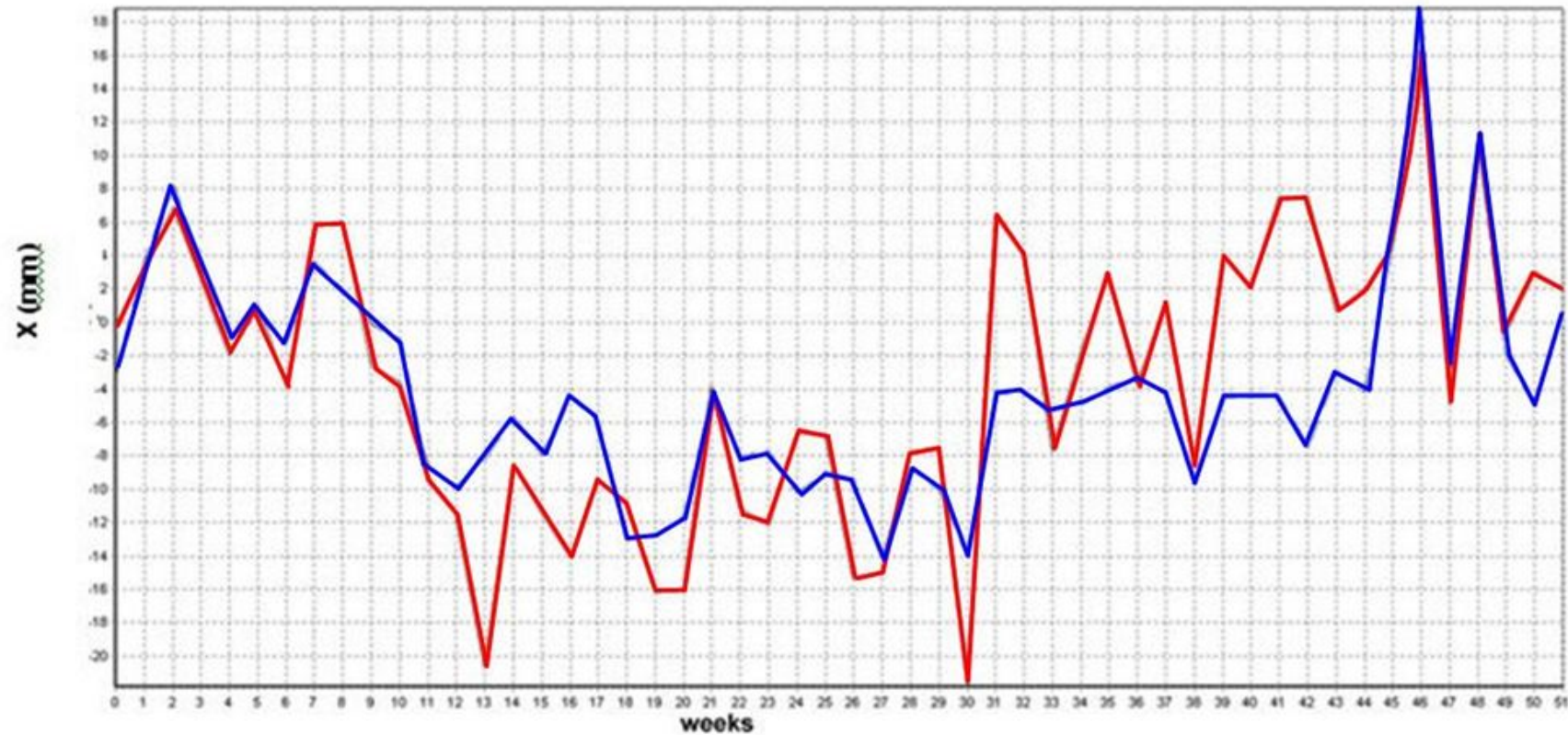


Fig.1. X geocenter coordinate, evaluated at INA DORIS Analysis center (red line) and simulated by the model (blue line) for the 2008 year.

# DRM forecasting model of the weekly geocenter positions for 2008 (Y)

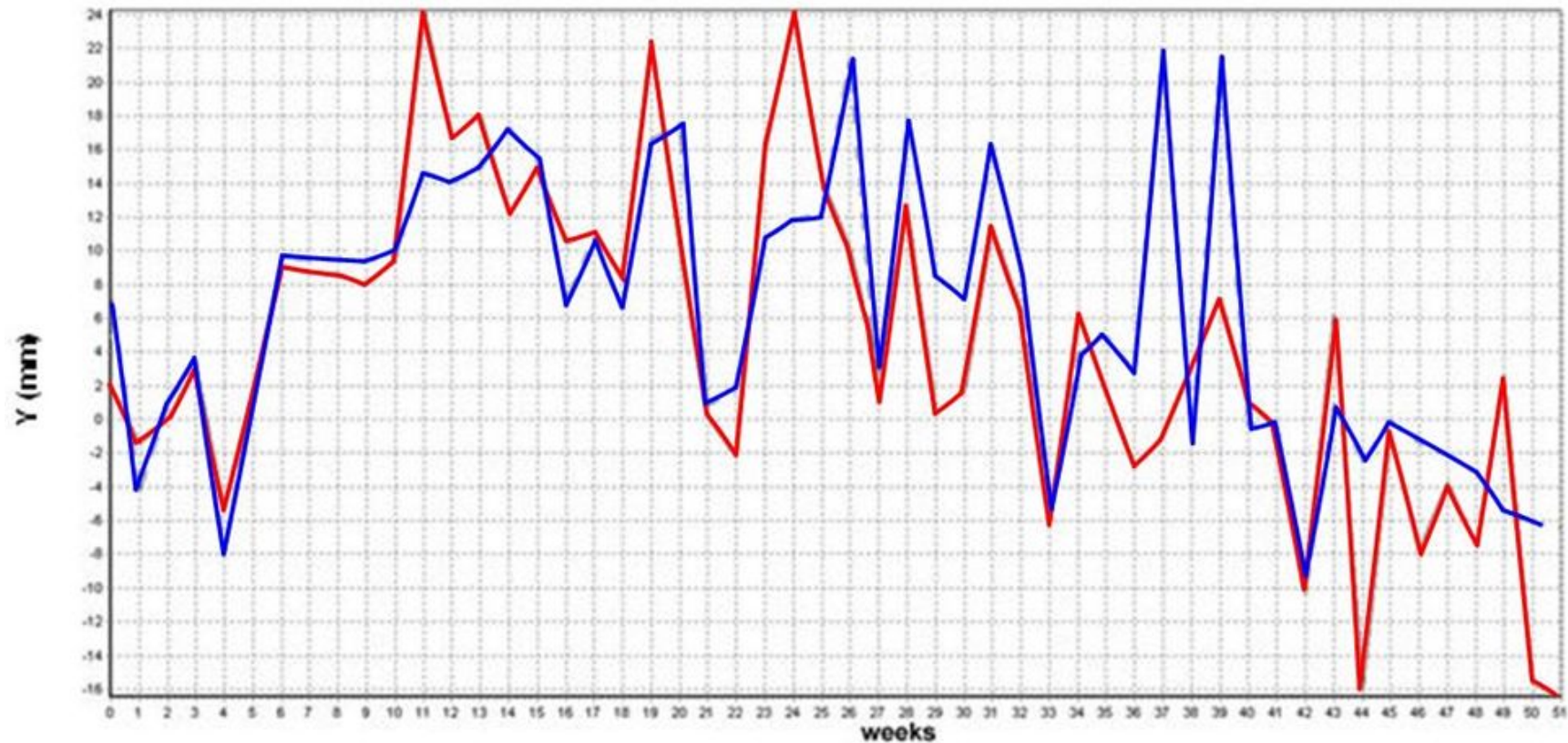


Fig. 2. Y geocenter coordinate, evaluated at INA DORIS Analysis center (red line) and simulated by the model (blue line) for the 2008 year.

# DRM forecasting model of the weekly geocenter positions for 2008 (Z)

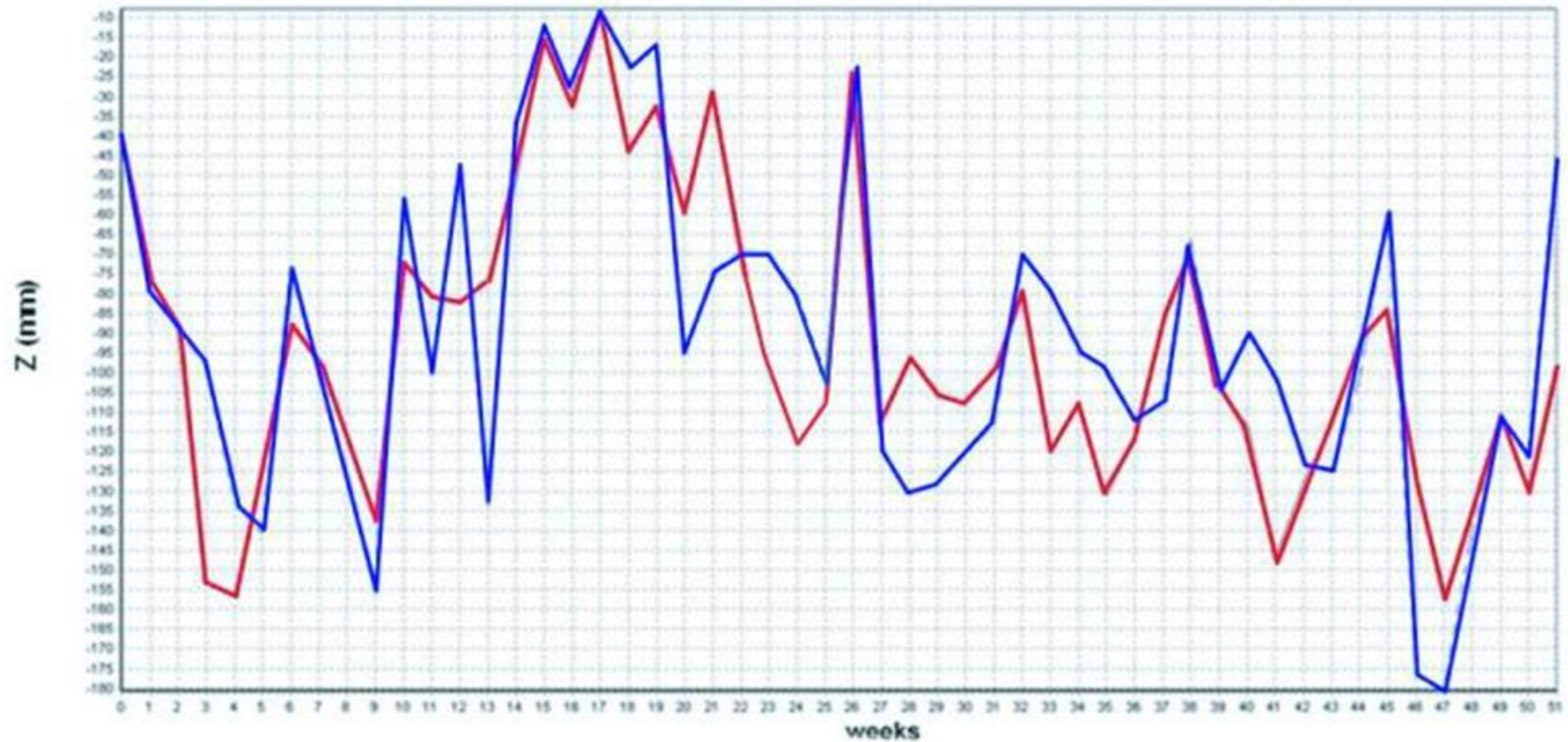


Fig. 3. Z geocenter coordinate, evaluated at INA DORIS Analysis center (red line) and simulated by the model (blue line) for the 2008 year.



# Forecasting results

Time interval (weeks)	Correlation coefficient			RMS (mm)	
	X	Y	Z	X	Y
<b>First 10 weeks</b>	0.852	0.949	0.815	2.24 12.92	2.26
<b>52 (whole year)</b>	0.786	0.766	0.802	7.01 29.13	7.52

# Two time series were compared:

## *DORIS*

- <ftp://cddis.gsfc.nasa.gov/pub/doris/products/geoc/ina05wd01.geoc.Z> (1993.0 - 2007.0)

## *GPS*

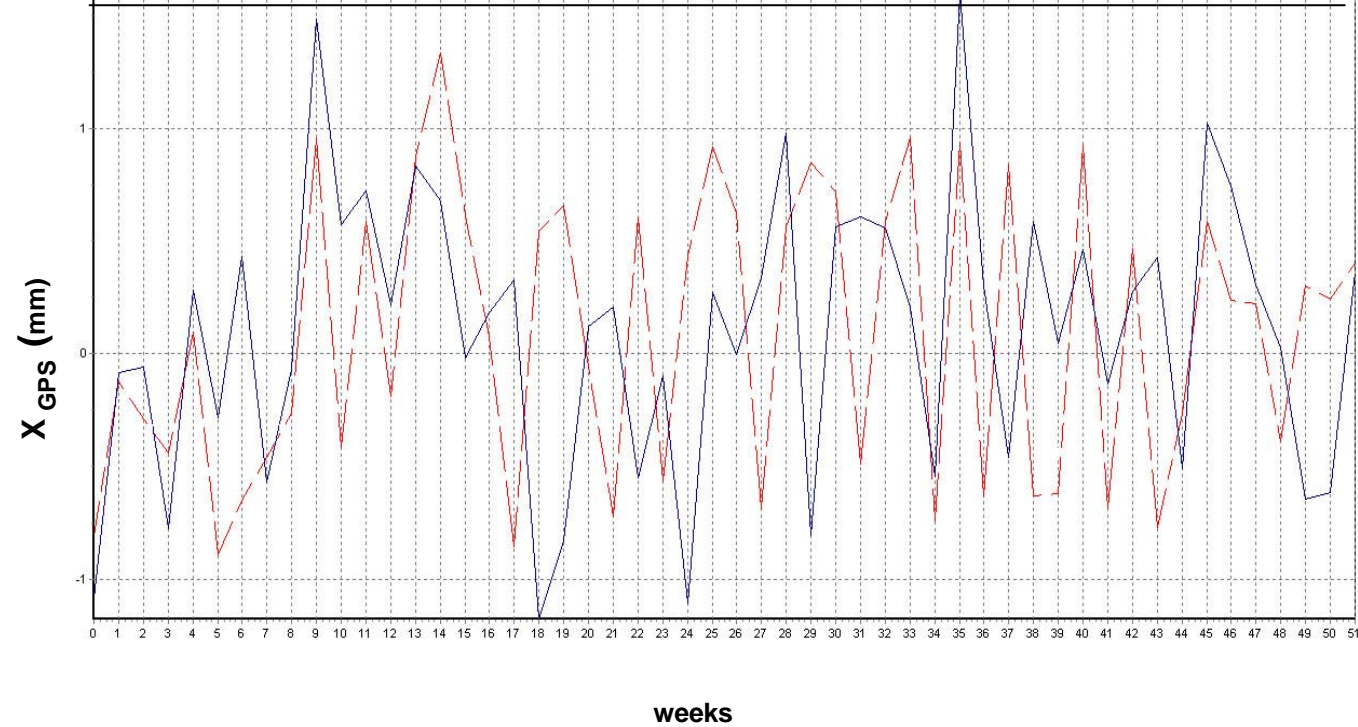
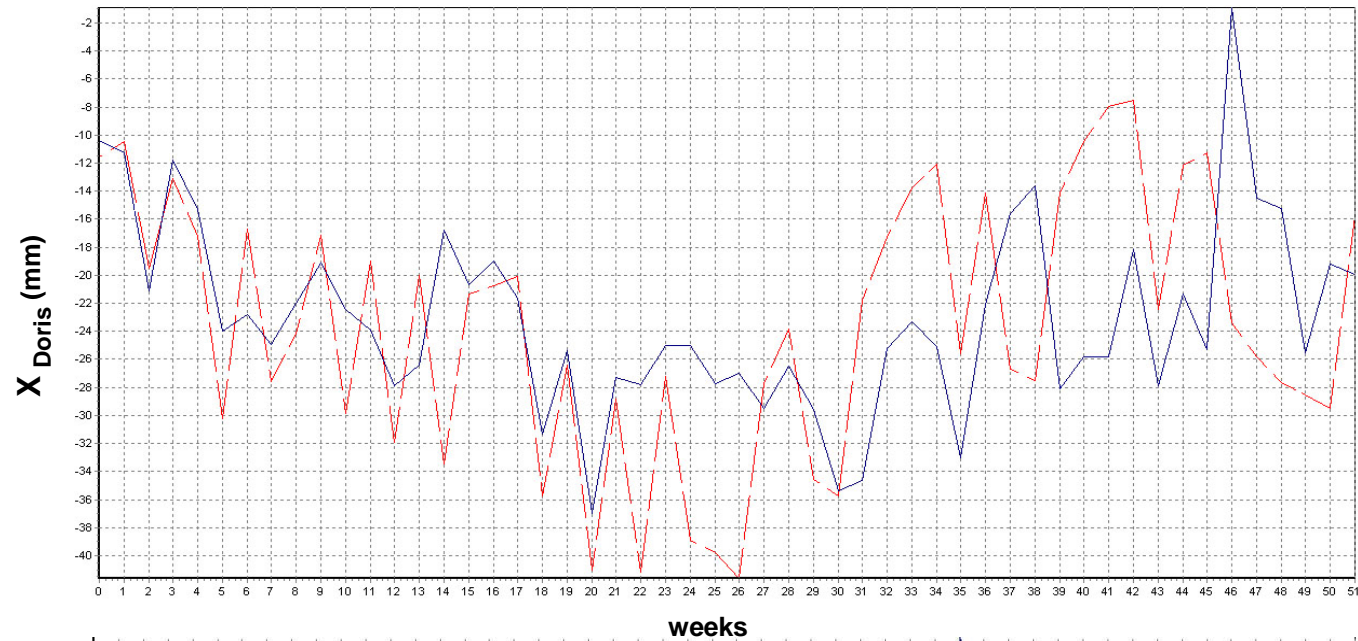
- <ftp://sideshow.jpl.nasa.gov/pub/usrs/mbh> (1993.0 - 2007.0)

## Results of DRM analysis (DORIS)

Periods		Weeks								
X	The whole time series		8	13	17		25		52	170
	Interval 1	4		13	19		25		57	
	Interval 2	3,5			18	21	25		57	
	Interval 3	3,5	10	12	17	22			55	
Y	The whole time series	3	8				25	40	52	75
	Interval 1	4	8				25		57	
	Interval 2				16		25		57	
	Interval 3	3,5	10	13					55	
Z	The whole time series		7,8,10		17				52	226
	Interval 1	3	8,10		18				57	
	Interval 2	4	8,10	13				29	57	
	Interval 3	2,5	10				24		55	

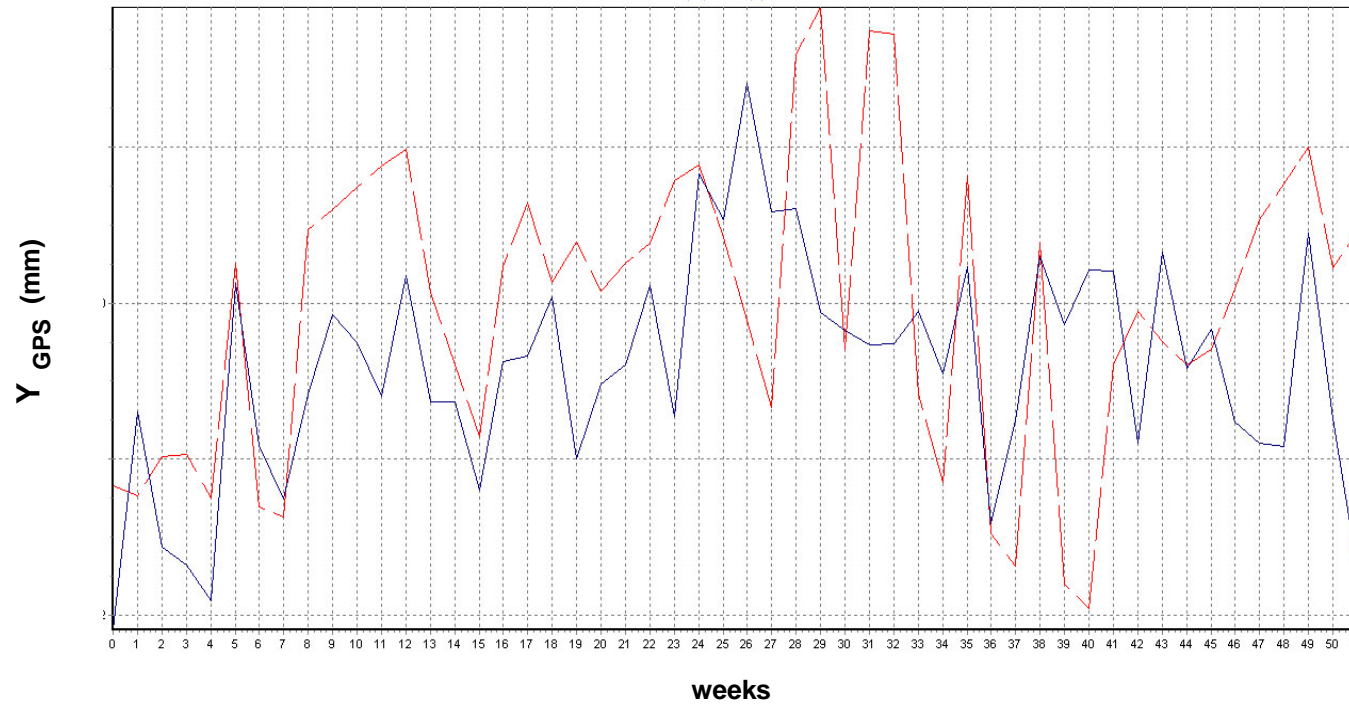
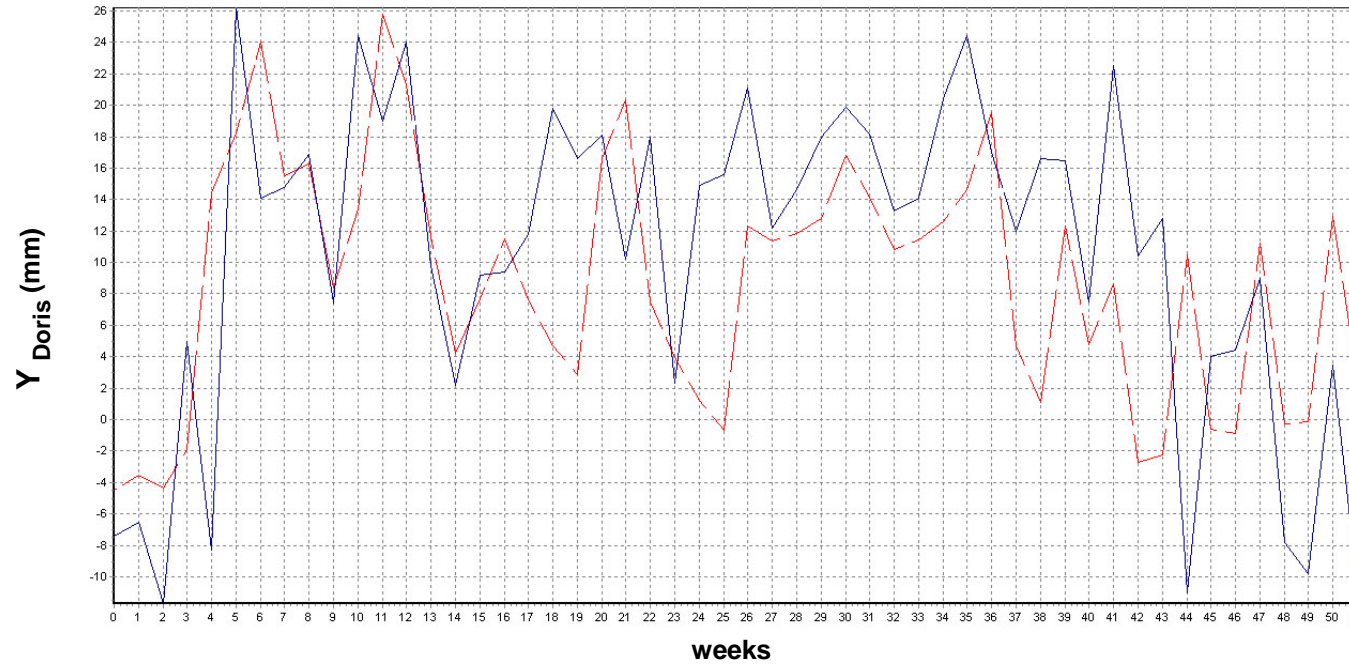
## Results of DRM analysis (GPS)

Periods		Weeks								
<b>X</b>	<b>The whole time series</b>	<b>4</b>	<b>8</b>				<b>26</b>		<b>48</b>	<b>170</b>
	<b>Interval 1</b>	<b>4</b>	<b>10</b>						<b>48</b>	
	<b>Interval 2</b>	<b>3,5</b>				<b>23</b>		<b>29</b>	<b>57</b>	
	<b>Interval 3</b>	<b>2,6</b>				<b>22</b>		<b>28</b>	<b>55</b>	
<b>Y</b>	<b>The whole time series</b>			<b>11,13</b>		<b>21</b>	<b>25</b>		<b>52</b>	
	<b>Interval 1</b>	<b>4</b>		<b>11</b>		<b>23</b>			<b>52,57</b>	
	<b>Interval 2</b>				<b>16</b>		<b>25</b>		<b>57</b>	
	<b>Interval 3</b>	<b>4</b>	<b>8</b>					<b>31</b>	<b>55</b>	
<b>Z</b>	<b>The whole time series</b>		<b>7,10</b>		<b>16,17</b>				<b>52</b>	
	<b>Interval 1</b>		<b>10</b>		<b>16</b>				<b>52</b>	
	<b>Interval 2</b>	<b>2</b>	<b>10</b>					<b>29</b>		
	<b>Interval 3</b>	<b>3</b>	<b>7,10</b>	<b>12</b>	<b>16</b>	<b>22</b>			<b>55</b>	

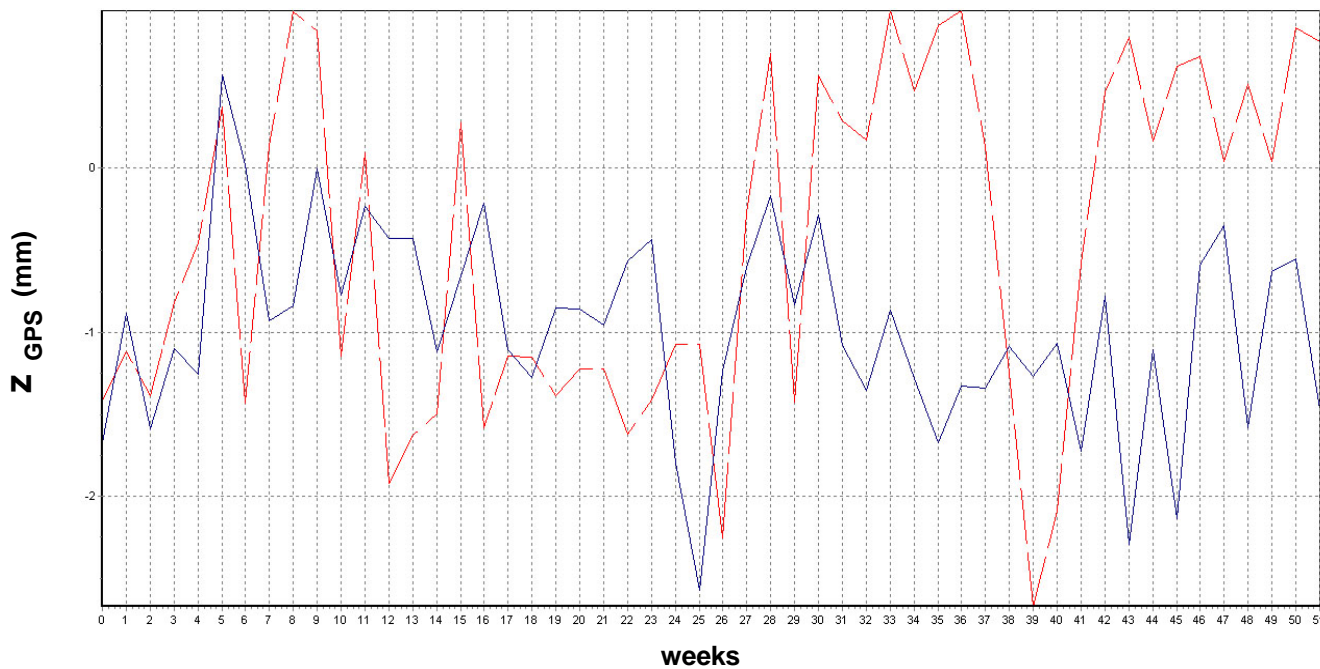
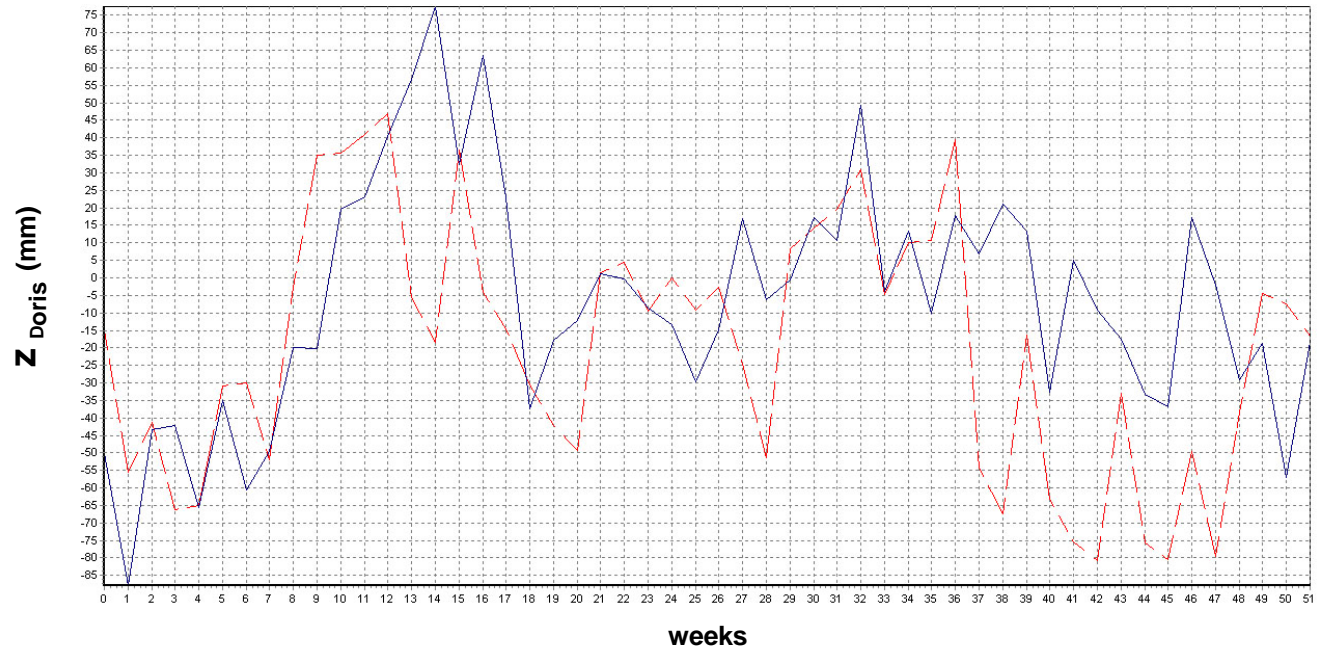


**DRM forecasting model of the weekly geocenter positions for 2006 (X-component). Blue line – evaluated, red line –simulated.**





**DRM forecasting model of the weekly geocenter positions for 2006 (Y-component). Blue line – evaluated, red line –simulated.**



**DRM forecasting model of the weekly geocenter positions for 2006 (Z-component). Blue line – evaluated, red line –simulated.**

# Correlation coefficients between observations and predictions for geocenter motion

Component	Weeks						
	52	25	15	10	8	6	4
	<i>DORIS</i>						
<b>X</b>	<b>0,375</b>	<b>0,772</b>	<b>0,640</b>	<b>0,868</b>	<b>0,868</b>	<b>0,943</b>	<b>0,970</b>
<b>Y</b>	<b>0,540</b>	<b>0,609</b>	<b>0,772</b>	<b>0,741</b>	<b>0,721</b>	<b>0,627</b>	<b>0,951</b>
<b>Z</b>	<b>0,450</b>	<b>0,614</b>	<b>0,640</b>	<b>0,675</b>	<b>0,298</b>	<b>0,387</b>	<b>0,488</b>
	<i>GPS</i>						
<b>X</b>	<b>0,220</b>	<b>0,232</b>	<b>0,753</b>	<b>0,797</b>	<b>0,448</b>	<b>0,722</b>	<b>0,923</b>
<b>Y</b>	<b>0,375</b>	<b>0,765</b>	<b>0,789</b>	<b>0,745</b>	<b>0,661</b>	<b>0,786</b>	<b>0,409</b>
<b>Z</b>	<b>0,0583</b>	<b>0,327</b>	<b>0,422</b>	<b>0,616</b>	<b>0,718</b>	<b>0,740</b>	<b>0,972</b>

# Conclusions (future plans)

- **We just installed the latest Gipsy version (Linux 6.0) and planning to reprocess all Doris data with the new models and all satellites.**
- **The first attempt to develop a mathematical model of the geocenter motion with DRM approach has been made.**
- **DRM model may be used for predictions of the geocenter motion during the next 10 - 25 weeks for DORIS and 6 – 25 weeks for GPS.**
- **Further investigations with DRM model DORIS, GPS and SLR time series of geocenter motion are planned.**