Comparison between Two methods to derive EOP from SLR data

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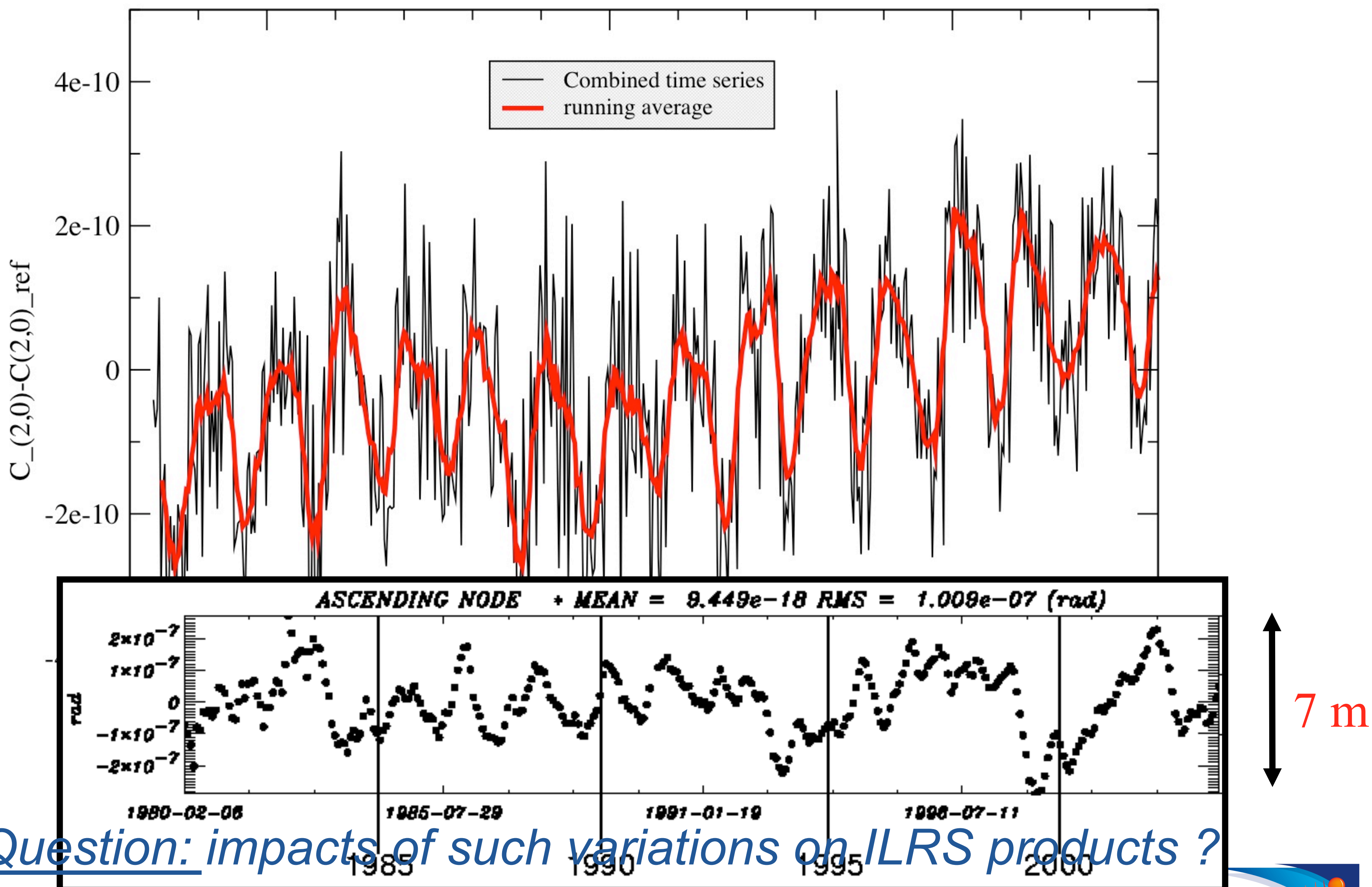
ILRS Technical Workshop 2009, Metsovo, Greece

EARTH TIME VARYING GRAVITY FIELD



Question: impacts of such variations on ILRS products ?

Rms on LA1 mean ascending node

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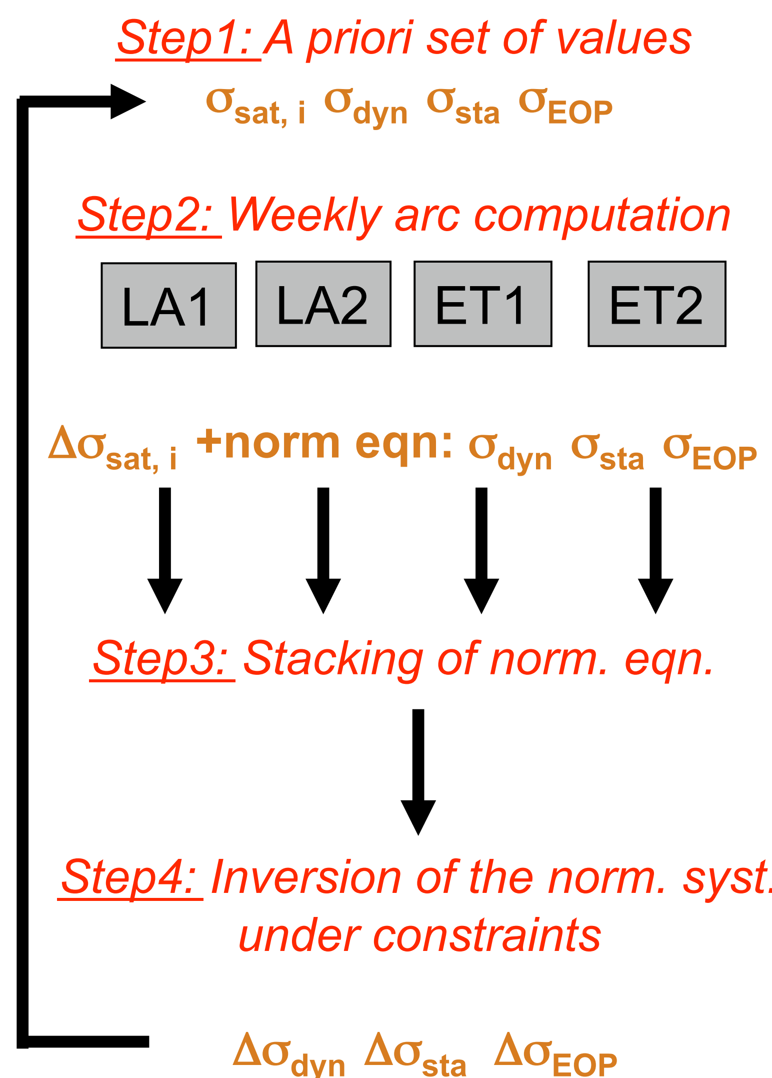
USUAL ANALYSIS SCHEMA

- Parameters to be delivered
  - SSC (SX SY SZ): 1 set per week
  - EOP (XP,YP,LOD): 1 set per day
  - *(GF, deg2 : 1 set per week)*

- 3 groups of parameters
  - Satellite-dependent: $\sigma_{sat,\ i}$
    - *Initial state vector*
    - *Empirical forces, NG forces*
  - « dynamical » parameters: σ_{dyn}
    - *Gravity field,*

      (static and time varying part)
  - « geometrical » parameters
    - *SSC:* σ_{sta}
    - *Earth rotation:* σ_{EOP}
- Normal system to be inverted:
  - Common and different periods
  - Common and different sensibilities
  - High correlations
  - Constraints required



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PARAMETERIZATION

- This study:
  - LA1 & LA2 weekly arcs
  - 2008-2009
- Orbit modelling:
  - According to ILRS/AWG guidelines
  - Empirical forces:
    - » *SRP coeff.,*
    - » *tangential bias, 1 tan. term at the orb.period,*
    - » *1 norm. term at the orb.period,*
  - EIGEN-GL04S_annual

```
2  0   -0.48416528113131E-03     0.00000000000000E+00  0.472779E-11  0.000000E+00
2  0 DOT 0.93926402706989E-11 0.00000000000000E+00  0.425211E-11  0.000000E+00
2  0 S1A 0.59433989810432E-10 0.00000000000000E+00  0.551652E-11  0.000000E+00
2  0 C1A 0.43058299645655E-10 0.00000000000000E+00  0.623151E-11  0.000000E+00
2  0 S2A-0.15597898669491E-10 0.00000000000000E+00  0.572817E-11  0.000000E+00
2  0 C2A 0.26946525902554E-10 0.00000000000000E+00  0.596527E-11  0.000000E+00
```

- Inversion of the norm. syst.
  - Classical approach: whole system under constraints
  - Original approach: decorrelating the « dynamics » from the « geometry »
    - *Once empirical coefficients and dynamical parameters are adjusted…*
    - *Dynamics: determination of remaining orbital errors (Hill model)*
    - *Geometry: partial derivatives of SSC and EOP, inversion of the norm. syst*

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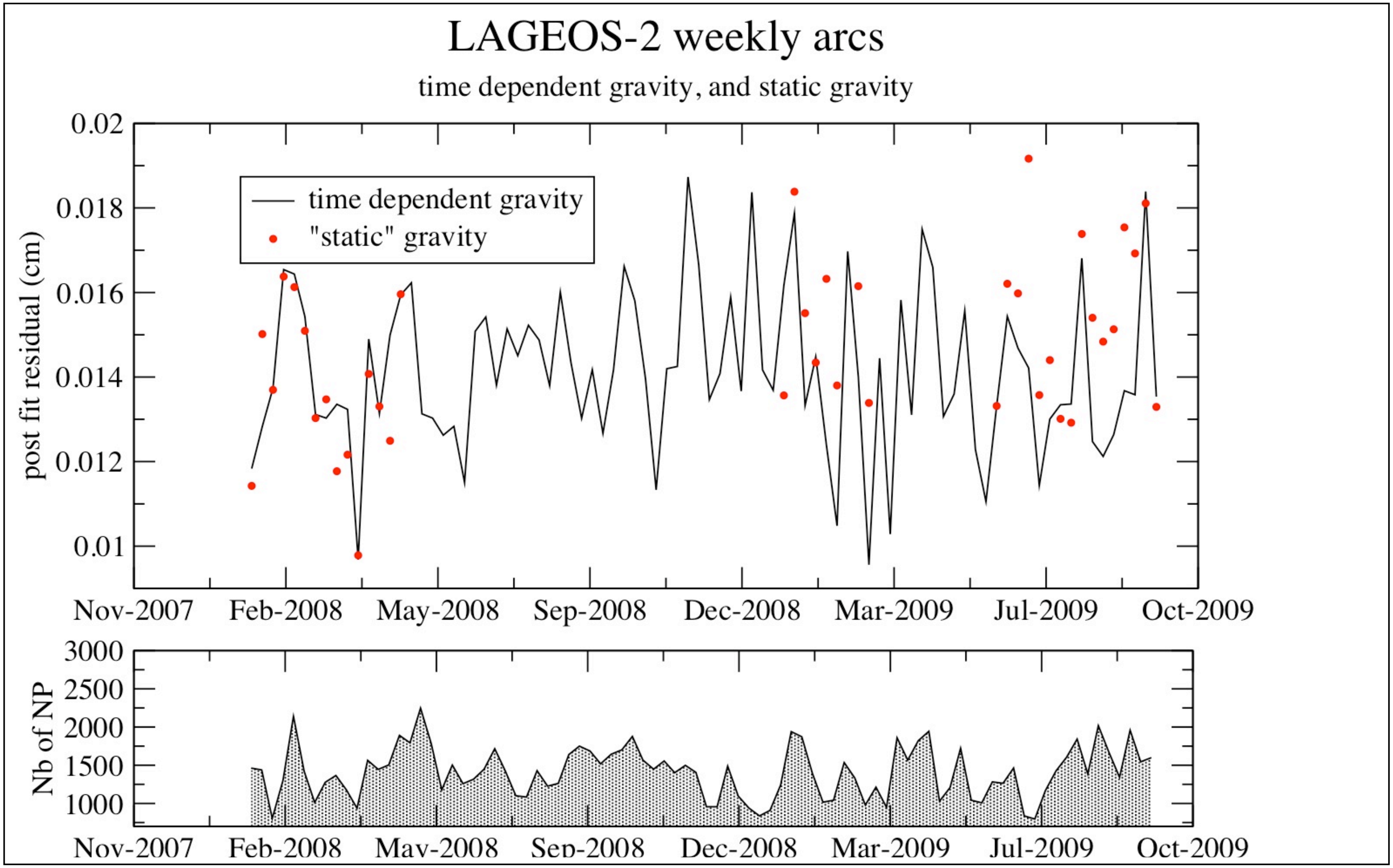
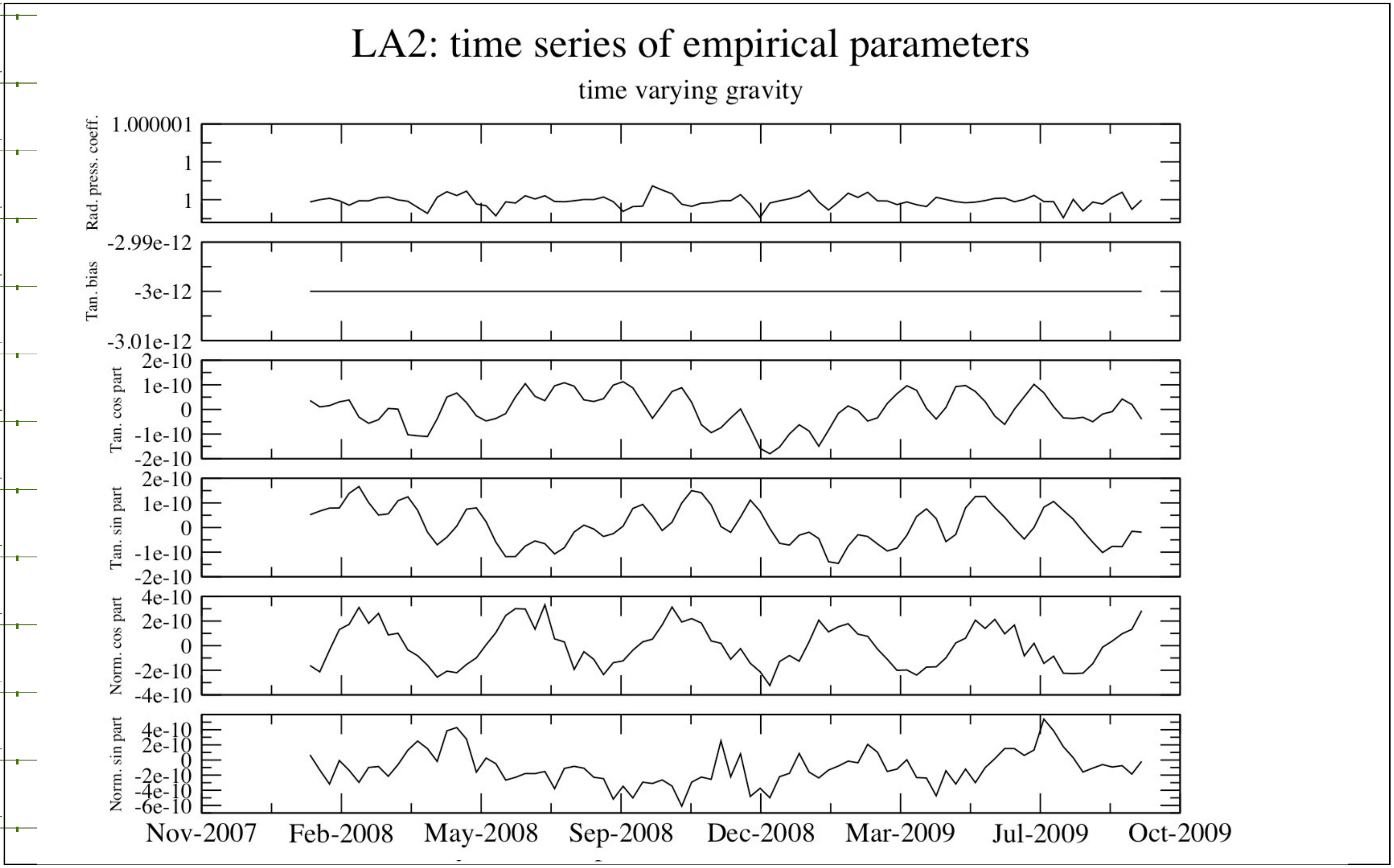
POST-FIT WEEKLY ARCS RESIDUALS



LA1-2, time-varying gravity: 0,9cm (min), 1.9cm (max), 1.4 cm (mean)

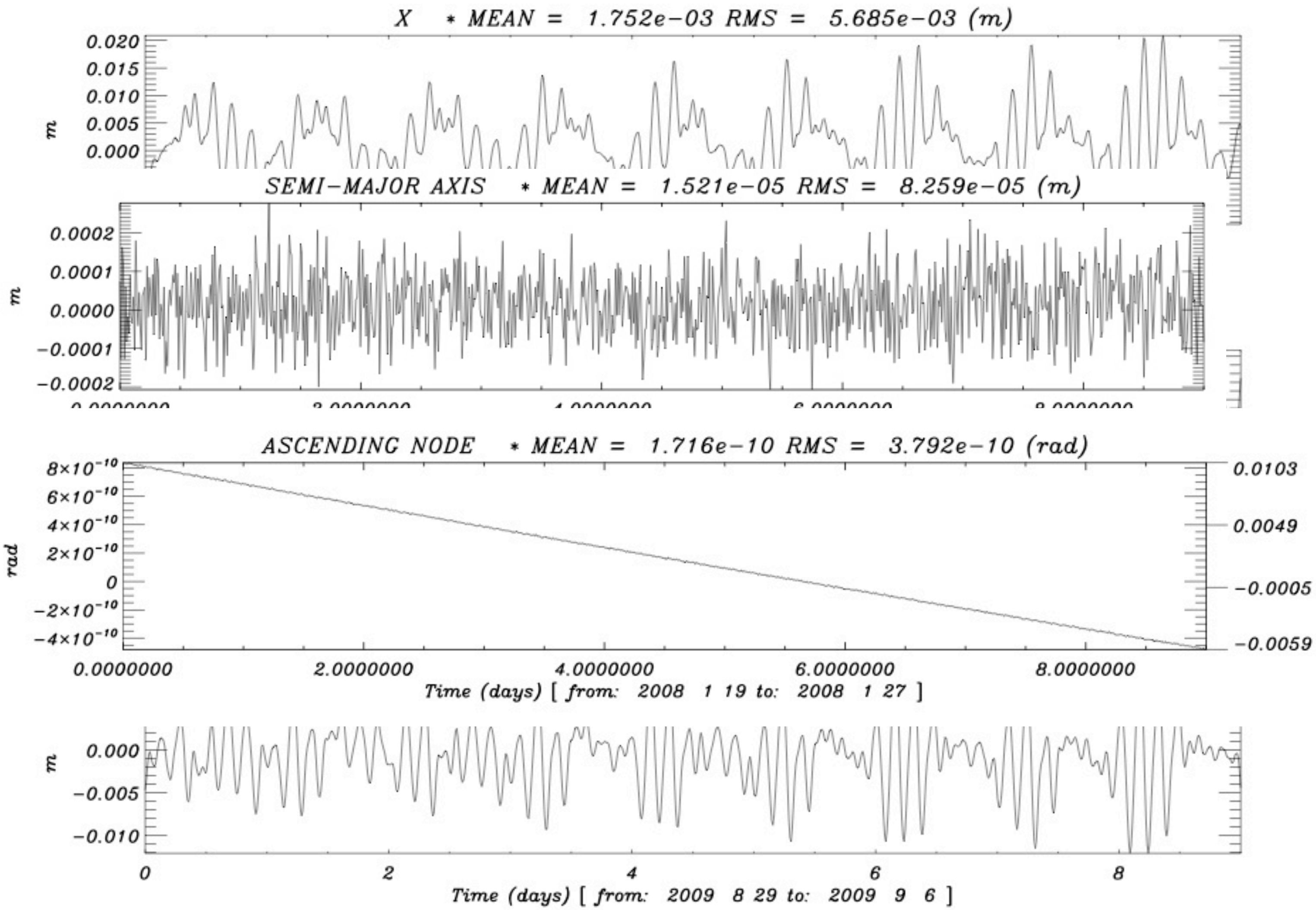
Empirical forces



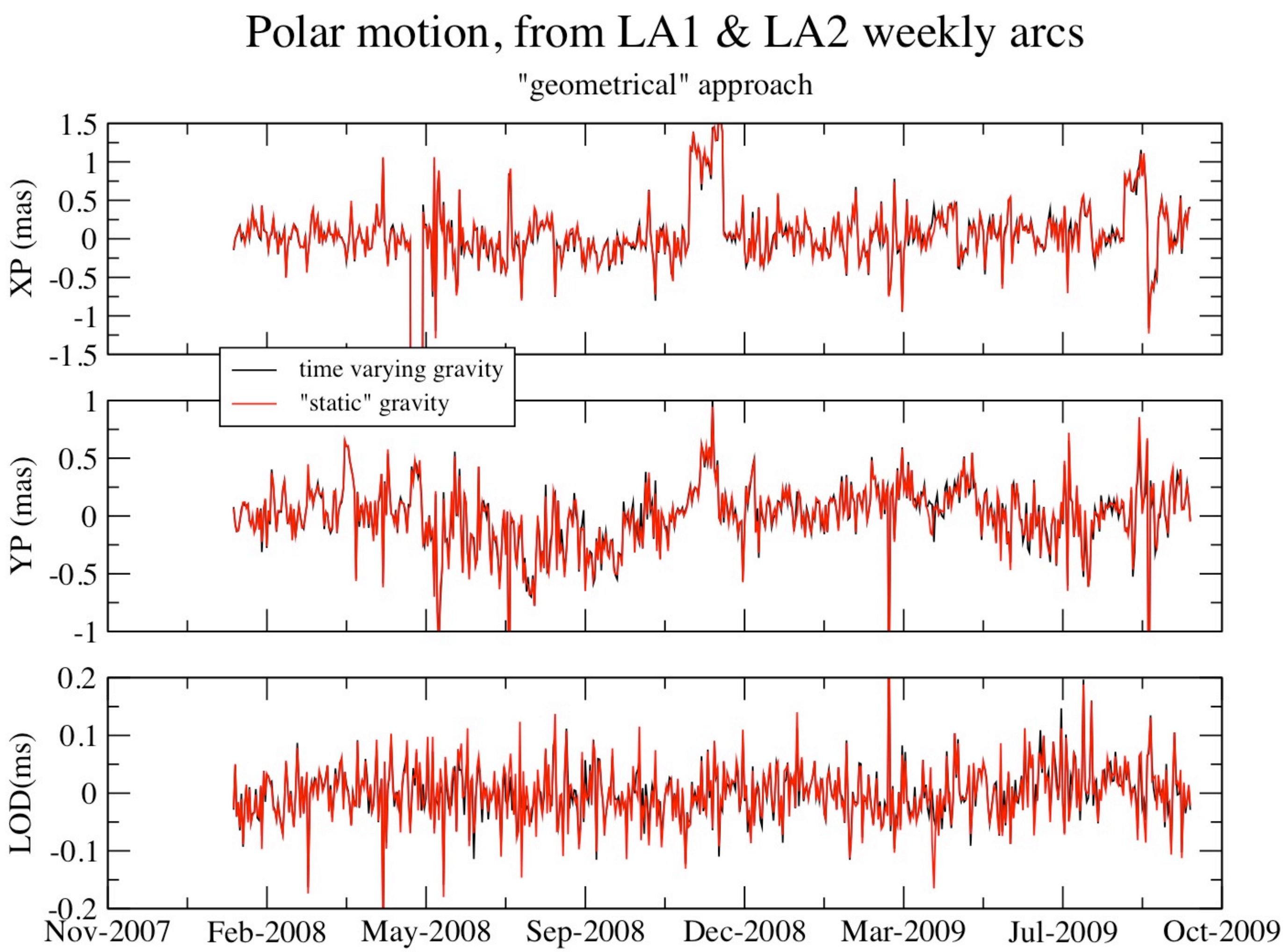
No significant difference between static and time-varying gravity

Orbit differences

LAGEOS II



Impact on the EOP



Helmert transformation

- Stations:

$$\begin{pmatrix} X_i \\ Y_i \\ Z_i \end{pmatrix} = \begin{pmatrix} X_i^0 \\ Y_i^0 \\ Z_i^0 \end{pmatrix} + \begin{bmatrix} 1 & 0 & 0 & X_i^0 & 0 & -Z_i^0 & Y_i^0 \\ 0 & 1 & 0 & Y_i^0 & Z_i^0 & 0 & -X_i^0 \\ 0 & 0 & 1 & Z_i^0 & -Y_i^0 & X_i^0 & 0 \end{bmatrix} . \begin{pmatrix} T_X \\ T_Y \\ T_Z \\ DD \\ R_X \\ R_Y \\ R_Z \end{pmatrix}$$

- EOP:

$$\begin{pmatrix} x_p \\ y_p \\ UT \end{pmatrix} = \begin{pmatrix} x_p^0 \\ y_p^0 \\ UT^0 \end{pmatrix} + \begin{bmatrix} 0 & -1 & 0 \\ -1 & 0 & 0 \\ 0 & 0 & 1/f \end{bmatrix} . \begin{pmatrix} R_X \\ R_Y \\ R_Z \end{pmatrix}$$

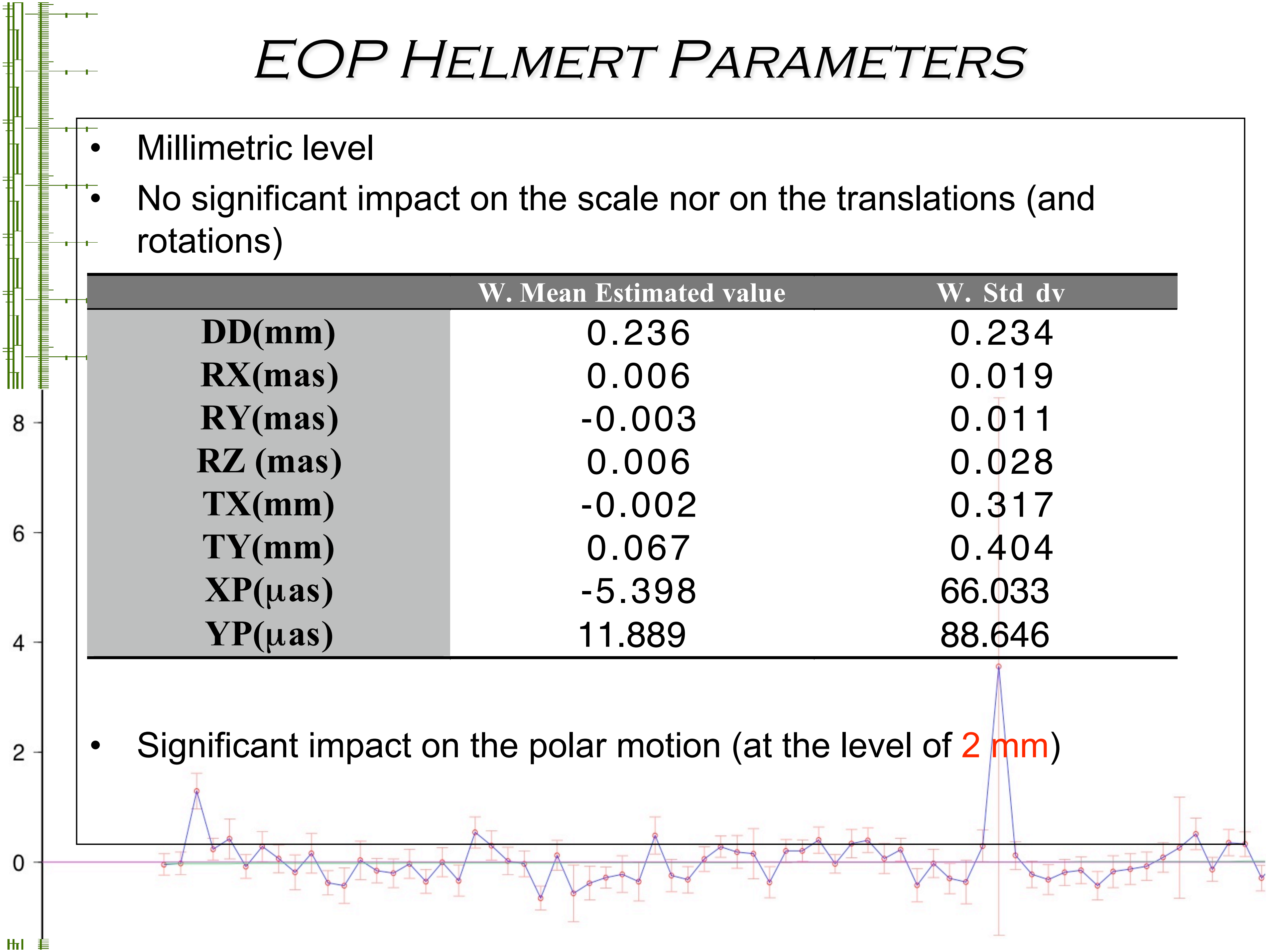
with $f = 1.002737909350795$

EOP Helmert Parameters

- Millimetric level
- No significant impact on the scale nor on the translations (and rotations)

	W. Mean Estimated value	W. Std dv
DD(mm)	0.236	0.234
RX(mas)	0.006	0.019
RY(mas)	-0.003	0.011
RZ (mas)	0.006	0.028
TX(mm)	-0.002	0.317
TY(mm)	0.067	0.404
XP(µas)	-5.398	66.033
YP(µas)	11.889	88.646

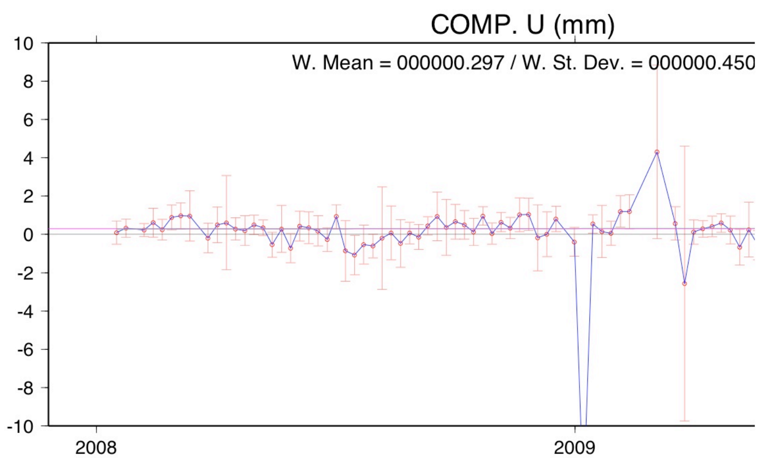
- Significant impact on the polar motion (at the level of 2 mm)



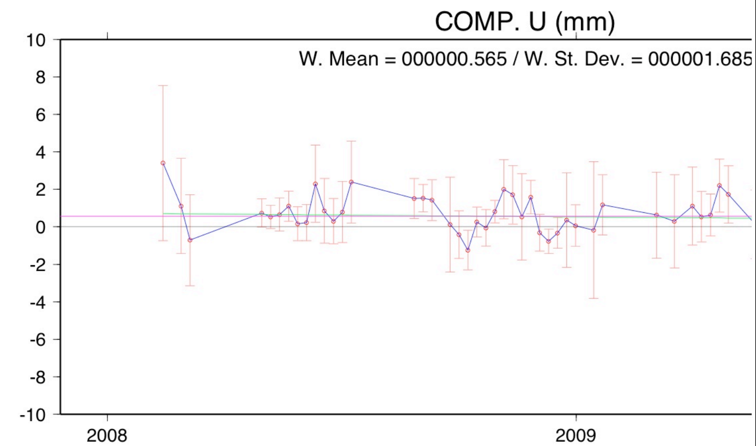
Impact on Station coordinates

- Millimetric or submillimetric level
  - On each component : E, N, U
- Examples:

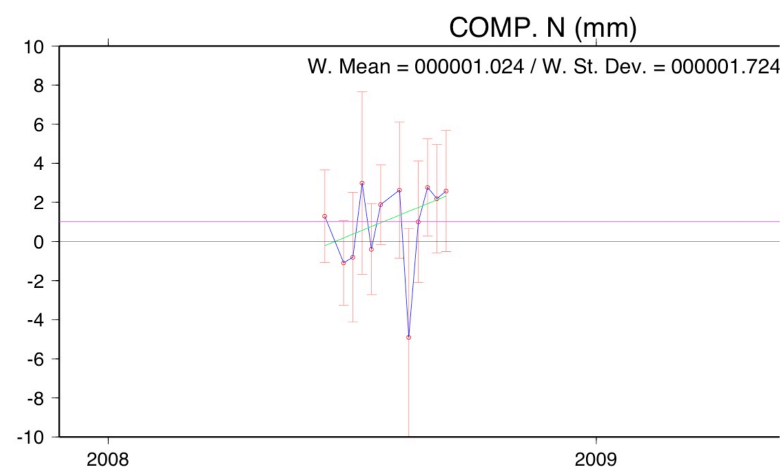
7834



1893



7403



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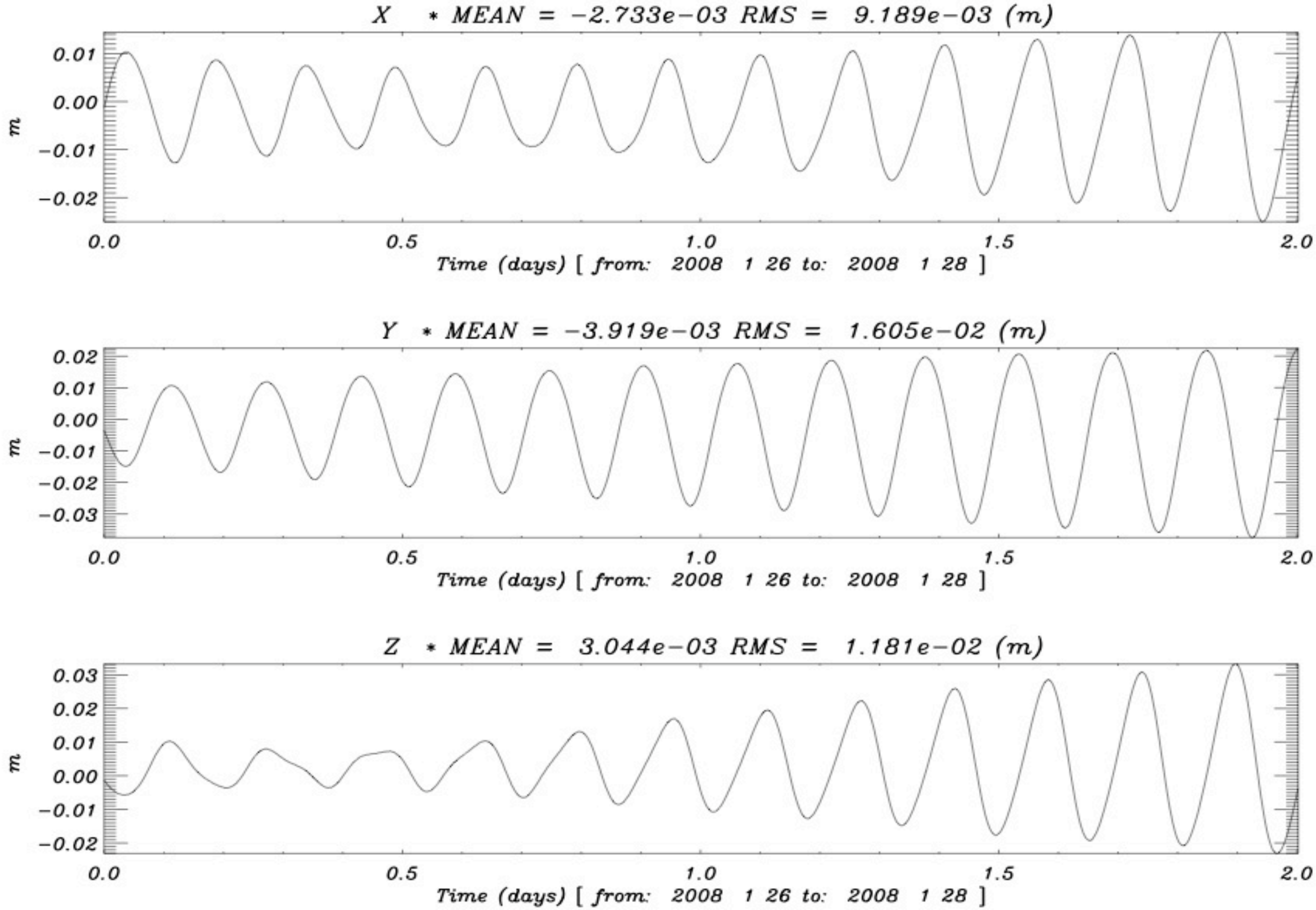
Conclusions



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THANK YOU !

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Géodésie spatiale : nécessité du multi technique

PRODUITS	LLR	VLBI	SLR	GPS/ GALILEO	DORIS	SST-ll
Repère extragalactique		***				
Rattachement au système solaire	***	*				
Rattachement à la Terre						
Précession-Nutation	**	***	*	*		
Temps Universel	*	***				
Rotation de la Terre						
Longueur du jour		***	*	**		
Mouvement du pôle		***	**	***	*	
Repère terrestre						
Homogénéité de la couverture mondiale		*	*	**	***	
Centre de masse (GM)			***	*	*	
Centre de figure		**				
Mouvement des plaques tectoniques		***	**	***	***	
Densification			*	***	**	
Orbitographie des satellites hauts						
Type : GPS/GALILEO			*	***		
Type LAGEOS, ETALON			***			
Orbitographie des satellites bas						
Type : TOPEX/Poséïdon, JASON-1			**	***	***	
Type : ERS, ENVISAT			**	***	***	
Type : CHAMP, GRACE			*	***		***
Champ de gravité						
Grandes longueurs d'onde (statique)			***	**	*	*
Moyennes et courtes longueurs d'onde (statique)			**	***	**	**
Variations temporelles			**	*		***

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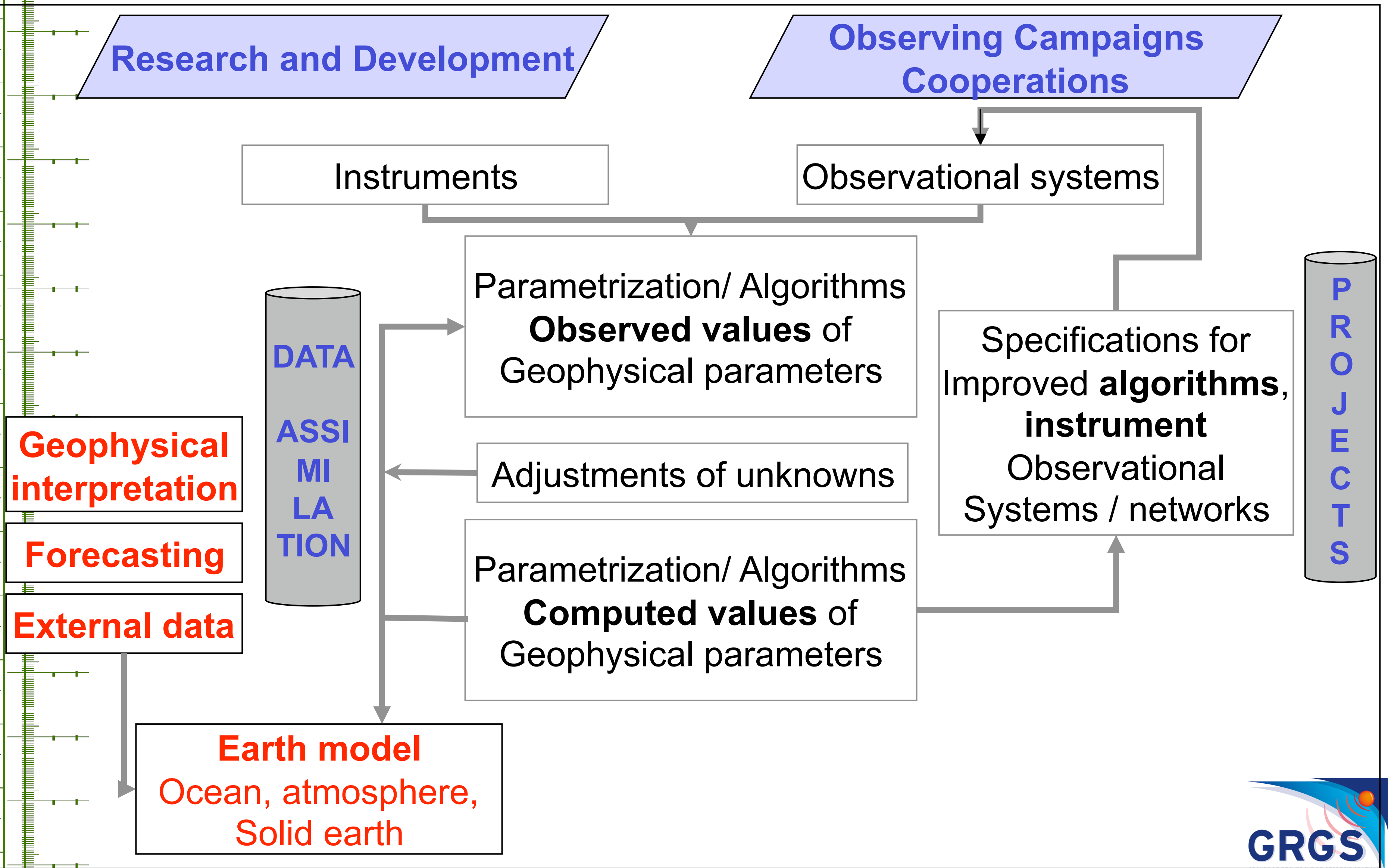
Le tableau de Lundquist

(d'après document NASA, 1969)



Le poids du laser

- Longues séries temporelles
  - Constellation de satellites géodésiques
  - Organisation des stations en réseau
  - Systèmes de référence
  - Champ de gravité
- Le laser indispensable :
  - Pour la définition des systèmes de référence terrestre
  - Pour les bas degrés du champ de gravité
- Questions scientifiques :
  - Modélisation cohérente des effets de charge
  - Interprétation des grands transferts de masse
  - Développements méthodologiques
  - Missions scientifiques spécifiques :
    - *Physique fondamentale*
    - *Mesures de distances sur de grandes distances*
- Le futur du laser

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GRGS ILRS Analysis center

- Staff:
  - OCA/Geoazur: F. Deleflie, O. Laurain, P. Exertier, B. de Saint-Jean
  - IGN/LAREG: D. Coulot
- Software:
  - GINS/DYNAMO (CNES/GRGS)
  - MATLO (IGN/LAREG/OCA/GRGS)
- Operational activities:
  - For ILRS: Weekly, and now daily, submissions
    - *pos+eop*
    - *based on LA1+LA2*
  - For GRGS internal validation and combinations: Weekly arcs
    - *Accounting as well for loading effects*
    - *Additionnaly: Gravity field time series*
- Other activities:
  - Reanalyses, over long periods of time
  - Specific projects: T2L2, calibration/validation altimetric measurements
  - Other satellites: STA, STE, AJI, ET1 & 2, *JAS1* and *JAS2*

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CHAINES DE TRAITEMENTS

- Prétraitement des données fournies par ILRS DCs:
  - Évolutions recommandations ILRS (AWG) quasiment mensuelles, format snx
  - Mises à jour : excentricités, biais des stations, données aberrantes
- Outils utilisés :
  - Orbitographie avec Gins
  - Inversion avec DYNAMO : approche « standard »
  - Inversion avec MATLO : traitement spécifique des erreurs d'orbite

- 12 étapes pour la production d'une solution sur une semaine :
  - Construction de l'arc d'orbite *LA1, LA2, ET1 ET2, autres*
  - Cumul et inversion des EQN par DYNAMO
  - Cumul et inversion des EQN par MATLO
  - Cumul et inversion des EQN combinée DYNAMO/MATLO
  - Mise en forme solution inversée et orbite

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Précorrections des mesures

START Year DOY (YYMMDD) at 00:00:00 [A]	STOP Year DOY (YYMMDD) at 00:00:00 [B]	Target-board-range dependent (mm)		Satellite-range dependent (mm)		Filter correction (090112) (mm) [5]	TOTAL Correction	
		PREVIOUS (080530) [1]	CURRENT (090112) [2]	PREVIOUS (080530) [3]	CURRENT (090112) [4]		PREVIOUS (080530) [6]=[1]+[3]	CURRENT (090112) [7]=[2]+[4]+[5]
1983 274 (831001)	**1994 013 (940113)**	-	-	-	-	**+1.5**	-	**+1.5**
1994 013 (940113)	**1994 274 (941001)**	-	**+6**	-	**SLRMail 0891**	**+1.5**	-	**+7.5+[4]**
1994 274 (941001)	1996 137 (960516)	-5.5	**+6**	+8	**SLRMail 0891**	**+1.5**	+2(2.5)	**+7.5+[4]**
1996 137 (960516)	1997 295 (971022)	-5.5	**+4**	+8	**SLRMail 0891**	**+1.5**	+2(2.5)	**+5.5+[4]**
1997 295 (971022)	1999 210 (990729)	-5.5	**+2**	+8	**SLRMail 0891**	**+1.5**	+2(2.5)	**+3.5+[4]**
1999 210 (990729)	2001 080 (010321)	-5.5	**+9**	+8	**SLRMail 0891**	**+1.5**	+2(2.5)	**+10.5+[4]**
2001 080 (010321)	2002 032 (020201)	-5.5	**0**	+8	**SLRMail 0891**	**+1.5**	+2(2.5)	**+1.5+[4]**
2002 032 (020201)	2002 277 (021004)	-5.5	**0**	0				
2002 277 (021004)	2006 200 (060719)	-5.5	**+13**	0				
2006 200 (060719)	2007 042 (070211)	-5.5	**+12**	0				
2007 042 (070211)	-	-	**0**	0				

Stn Pad ID	Name	Pulse Length (ps)	Detector	Regime (single, few, multi)	Editing Level (x s)	Calib. St. Error (mm)	LAGEOS St. error (mm)	LAGEOS CoM range (mm)	LAGEOS CoM ADOPTED (mm)
1873	Simeiz	350	PMT	No CNTL	2.0	60	70	248-244	246
1884	Riga	130	PMT	CNTLD s->m	2.0	10	15	252-248	250
7080	McDonald	200	MCP	CNTLD s->m	3.0	8.5	13	250-248	249
7090	Yaragadee	200	MCP	CNTLD f->m	3.0	4.5	10	250-248	249
7105	Greenbelt	200	MCP	CNTLD f->m	3.0	5	10	250-248	249
7110	Mon. Peak	200	MCP	CNTLD f->m	3.0	5	10	250-248	249
7124	Tahiti	200	MCP	CNTLD f->m	3.0	6	10	250-248	249
7237	Changchung	200	CSPAD	CNTLD s->m	2.5	10	15	250-245	248
7249	Beijing	200	CSPAD	No CNTL, m	2.5	8	15	255-247	251
7355	Urumqui	30	CSPAD	No CNTL	2.5	15	30	255-247	251
7405	Conception	200	CSPAD	CNTLD s	2.5	15	20	246-245	246
7501	Harteb.	200	PMT	CNTLD f->m	3.0	5	10	250-244	247
7806	Metsahovi	50	PMT	?	2.5	15	17	254-248	251
7810	Zimmerwald	300	CSPAD	CNTLD s->f	2.5	20	23	246-244	245
7811	Borowiec	40	PMT	No CNTL f	2.5	16	23	256-250	253
7824	San Fernando	100	CSPAD	No CNTL s->m	2.5	30	25	252-246	249
7825	Stromlo	10	CSPAD	CNTLD s->m	2.5	4	10	257-247	252
7832	Riyadh	100	CSPAD	CNTLD s->m	2.5	10	15	252-246	249
7835	Grasse	50	CSPAD	CNTLD s->m	2.5	6	15	255-246	250
7836	Potsdam	35	PMT	CNTLD s->m	2.5	10	20	256-252	254
7838	Simosato	100	MCP	CNTLD s->m	3.0	20	40	252-248	250
7839	Graz	35	CSPAD	No CNTL m	2.2	3	9	255-250	252
7839	Graz kHz	10	CSPAD	No CNTL s->f	2.2	3	9	255-250?	252
7840	Herstmonceux	100	CSPAD	CNTLD s	3.0	6	15	246-244	245
7840	Hx kHz	10	CSPAD	CNTLD s	-1.5,+2.5	3	9	245	245
7841	Potsdam 3	50	PMT	CNTLD s->f	2.5	10	18	254-248	251
7941	Matera	40	MCP	No CNTL m	3.0	1	5	252-248	250
8834	Wettzell	80	MCP	No CNTL f->m	2.5	10	20	252-248	250

- Station 7941 Range Bias (16 Feb to 22 Oct 2007)
- Station 7124 Range Bias (May to 1 July, 2004)
- Station 7210 Epoch Time Bias (2 June to 4 August 1999)
- Station 7105 Unrecoverable Epoch Time Bias (29 April to 3 May 1999)
- Station 7105 Epoch Time Bias (4-10 March 1999)
- Station 7110 Epoch Time Bias (25-26 November 1998)
- Station 7090 Epoch Time Bias (21 December 1998)
- Station 7210 Barometer Error (18 June 1996 to 24 November 1996)
- Station 7837 Epoch Time Bias (22 May 1998)
- Replacement SLR Data Issued for Stations (1864, 1868, 1870) (September 1996 to December 1997)
- Station 7090 Frequency Error (16-27 January 1998)
- Station 1884 Fixed Range Bias (1 January 1994 to 1 September 1997)
- Station 7810 Fixed Range Bias and Epoch Time Bias (10 July 1997 to 3 September 1997)
- Station 7810 Fixed Range Bias (9-17 July 1997)
- Station 7832 Epoch Time Bias (29 May 1997 to 25 June 1997)
- Station 7210 Epoch Time Bias (12 January 1988 to 2 December 1988)
- Station 7210 Epoch Time Bias (13 December 1995 to 15 June 1995)
- Station 7109 Epoch Time Bias (3-16 December 1996 and 9-17 January 1997)
- Station 7403 Epoch Time Bias (24 January 1997 to 10 March 1997)
- Station 7308 Epoch Time Bias (11-27 February 1997)
- Station 7109 Fixed Range Bias (9-17 January 1997)
- Recall of NASA SLR GPS Data (24 October 1996 to 2 December 1996)
- Station 7110 Fixed Range Bias (27 August 1996 to 2 October 1996)
- Station 7090 Epoch Timing Error (18 July 1996 to 02 August 1996)
- Station 7080 Barometer Error (6 March 1995 to 25 April 1996)
- Station 7840 Humidity Error (24 December 1995 to 12 February 1996)
- Station 7110 Barometer Error (15 April 1995 to 19 December 1995)
- Station 7109 Barometer Error (11-14 October 1995)
- Station 7543 Revised Eccentricities and Range Bias (1993)
- Station 7580 Revised Eccentricities and Range Bias (1992)
- Station 7587 Revised Eccentricities and Range Bias (1992)
- Station 7517 Revised Eccentricities and Range Bias (1992)
- Station 7525 Revised Eccentricities and Range Bias (1992)
- NASA Network Biases, in pdf, in MS Word, (1983 to 1992)
- GSFC-formed normal points from LAGEOS full-rate data (1976 to 1993)

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+FILE/COMMENT
This file sets up a SLR discontinuity file
in parallel to those already available and subject to
updates in the IGS and IVS community.

SOLUTION/DISCONTINUITY
----------------------
Confirmed and Probable
Commonly used models for time series analysis are:
"M" Models codes for coordinates time series analysis:
    P = Position
    V = Velocity
    A = Annual Periodicity
    S = Semi-Annual Periodicity
    E = Exponential Decay
 "A" Axis modeled:
    E,N,U = East, North, Up
    X,Y,Z = Geocentric XYZ
    -    = 3D

SOLUTION/DATAHANDLING
----------------------
"M" Models codes:
    X = Exclude/delete data
    R = Estimation of range bias recommended
    C = Target signature bias, Center-of-mass correction different to standard
    S = Stanford event counter bias, BIAS in millimeter to be added to all one-way ranges

 estimted values must be substacted from the one way observations
                    ##########
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