

IERS COL-WG project GRGS COMBINATION CENTRE

R. Biancale⁽¹⁾, J-Y. Richard⁽²⁾, D. Gambis⁽²⁾, C. Bizouard⁽²⁾, T. Carlucci⁽²⁾

(1) GRGS, CNES Toulouse

(2) GRGS, Paris Observatory, SYRTE

Outlook

- Delivered normal equations
- Combination strategy at GRGS
- Preliminary Results
- Conclusion & Prospects

Combinaison multi-techniques for ITRF2013 COL comparison

technique	GPS	DORIS		VLBI	SLR	LLR
period	4372 daily NEQ, Period January 1 st 2002 to December 30 th 2013 GPS week 1147 to 1773	NEQ per 3,5d arc length & per satellite: 106/106 Jason2, 99/99 Jason1, 104/104 Envisat, 58 Spot2, 104 Spot4, 107 Spot5 over the whoole year 2009	989 weekly NEQ Multi- satellites 1993 – 2011	30 th December 2001 – 24 th August 2013 , 604 weekly NEQ	2009: 74 weekly NEQ LAGEOS-1, 74 NEQ LAGEOS- 2, 74 NEQ ETALON-1, 74 NEQ ETALON-2	7-January- 1990 to 8- December- 2013 820 Weekly NEQ
Satellites	GPS – Glonass Constellation , between 23 and 55 GNSS satellites	Doris Laser: Envisat, Jason-1, Jason- 2 Doris Doppler: Envisat, Jason-1, Jason-2, spot2,4,5	Spot-2,3,4,5 Envisat Jason-1,2 Topex Cryosat-2		Lageos1 Lageos2 Etalon-1 Etalon-2	
parameters	One set of stations coordinates EOP (Xp,Yp and Rates, LOD and Nutations corrections) Tropospheric parameters for collocated sites (zenith delays & N/E gradients) over stations @ 01,03,05,07,09,1 1,13,15,17,19,21 ,23	Pole: PX, PY, UT1 @ 0h,6h,12h,18h Nutation NX, NY @ 0h et 12h Stations SX, SY, SZ 1/week *troposphere MZB @2h. East & North gradients 1 pt/d *Doppler frequency offset @ 2h. *Orbital elements EX, EY, EZ, EXP, EYP, EZP 1pt /arc *résistance (drag) & portance atmosphérique *pression de radiation solaire 1pt/arc. *biais tangentiel 1pt/jour 21h *biais normal 1pt/jour 21h *biais axe X & Y du satellite 1pt début d'arc *force de radiation n°1 à 8 par arc *émissivité du panneau n°1 à 8 par arc * coefficients champ de gravite composante cosinus & sinus GCN cosinus, GSN sinus degré 0 a 40	Pole: PX, PY @ 00:00,06:00,12: 00,18:00 Stations: SX, SY, SZ mercredi @12:00	Pole : PX, PY @ 12h UT1-TAI : PT @ 12h Nutation : NX, NY @ 12h Stations : SX,SY,SZ @1/sem Quasars : QRA, QDE @ 1/sem Troposphere: biais zénithal MZB des stations @ 02h	Pole & UT: PX, PY , PT@12:00 Stations: SX, SY, SZ 1/w@12:00 Station range Biais	Pole & UT: PX, PY , PT@12:00 NX, NY @00H - 12H Stations & Lunar Reflectors: SX, SY, SZ 1/w@12:00

MAIN PARAMETERS RECOMMENDED for the ITRF2013 comparison campaign

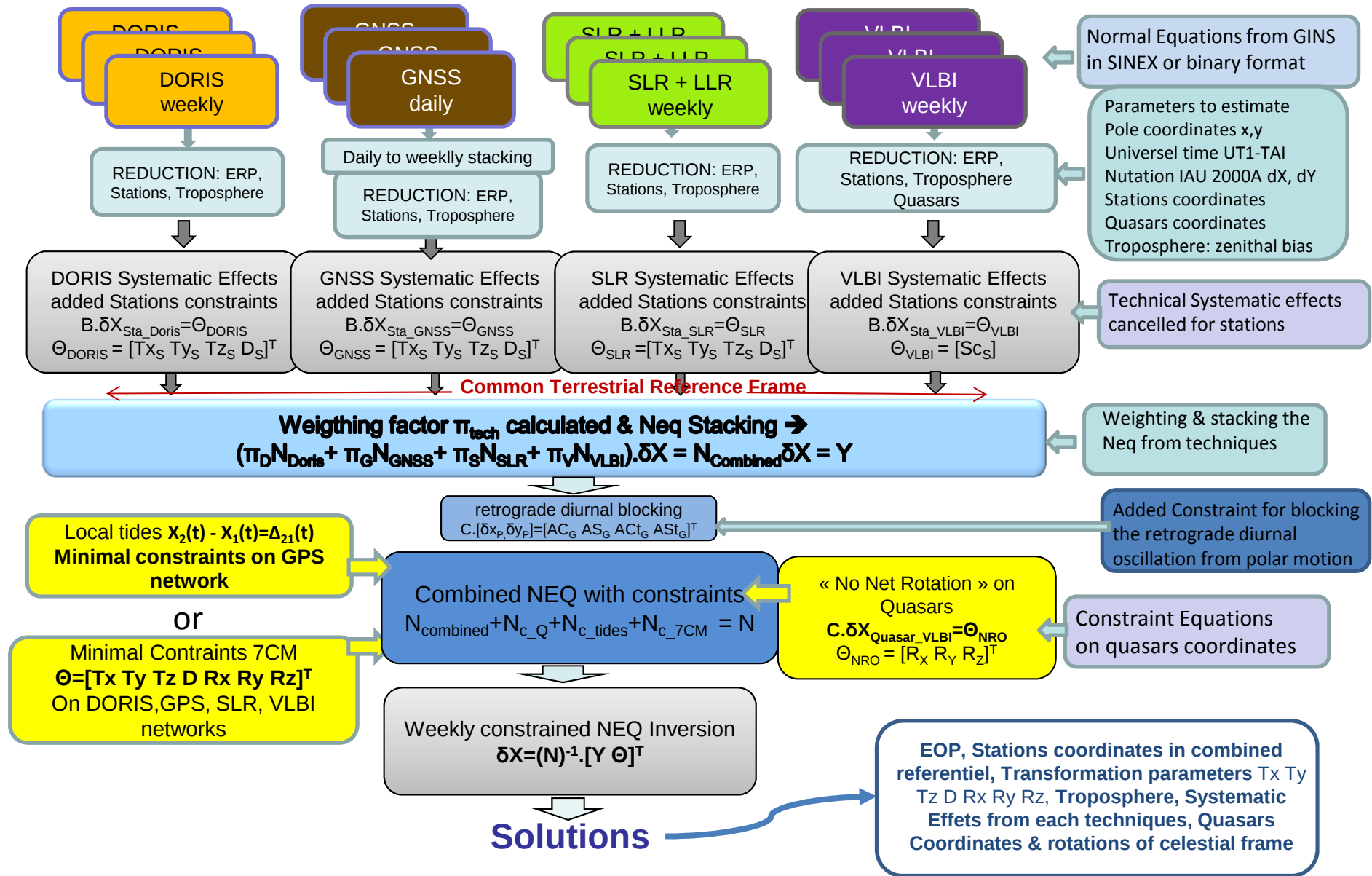
Parameters	SINEX format	GINs format	Sampling	Initial values
Polar motion	XPO, YPO	PX, PY	PWL @ 12Hr	IERS EOP 08-C04 series Interpolated @12h
Delta time UT1-TAI	UT1	PT	PWL @ 12Hr	IERS EOP 08-C04 series Interpolated @12h
Nutation angles X, Y corrections to the IAU2000A/2006 model	NUT_X, NUT_Y	NX, NY	PWL @ 12Hr	Set to 0.0
Station coordinates	STAX, STAY, STAZ	SX, SY, SZ	1/w @ mid epoch	ITRF2008
Radio sources coordinates right ascension & declination	RS_RA, RS_DE	QRA, QDE	1/w @ mid epoch	ICRF2
Added parameters not used for ITRF2013 purposes but proposed for GRGS studies				
Zenithal Troposphere Delay for wet component limited for stations (*)	ZBIAS : Adjustment of the wet component to the model	MZB	Every 2-hours: 00, 02, 04, ...20, 22hr per day	GPT/GMF model for radio waves and Mendes/Pavlis for optical waves
Troposphere gradient north & east limited for stations (*)	TGETOT, TGNTOT	MGE, MGN	1 pt/d @ 00Hr	gradient troposphérique per day and per station
Possible parameters for future investments				
Polar motion rate	XPOR, YPOR	PXR, PYR	1pt/d @ 12Hr	Set to 0.0
Length of Day LOD	LOD	PTR	1pt/d @ 12Hr	IERS EOP 08-C04 LOD Interpolated @12h
Rate for nutation angle	NUTR_X, NUTR_Y	NXR, NYR	1pt/d PWL @ 12Hr	Set to 0.0

* Hartebeesthoek, Concepcion, Greenbelt, Mount Stromlo, Papeete Tahiti, Kokee Park, NyAlesund

Main Recommended MODELS for the ITRF2013 comparison campaign

Reference System	
Earth reference system	IGb08 for GNSS & DORIS, ITRF2008 for SLR VTRF2008 for VLBI
Celestial reference system	inertial J2000
Polar motion & UT1	IERS C04 08
Precession/nutation	IERS 2010 using NRO origin
Displacement of reference points	
Solid Earth tidal displacement	IERS2010 Conventions
Tidal ocean loading	FES2012
Tidal atmospheric loading	S1/S2 Ray & Ponte (2003)
Non tidal atmospheric loading	none
Solid pole tide displacement	IERS2010 Conventions
Gravity	
Gravity field (static)	EIGEN-6S2
Gravity field (time varying)	EIGEN-6S2 up to degree 12 including time variable terms up to degree 12 (bias & drift per yr from 2002 to 2012, periodic 18.6, 1, 0.5yrs)
Solid Earth tides	IERS2010 conventions
Ocean tides	FES 2012 (32 principal waves, + 60 admittance waves) up to degree 12
Atmospheric gravity	3hr ERA-interim / ECMWF up to degree 12 for GNSS
Non tidal oceanic gravity	TUGO R12 up to degree 12 for GNSS, 50 for DORIS
Atmospheric tides	none (considered through the ECMWF atmospheric data)
Earth pole tide	IERS2010 conventions
Ocean pole tide	Desai 2002 up to degree 12
Third bodies	Sun, Moon, Mars, Venus, Jupiter, Saturn, Uranus and Neptune ephemeris : DE421 (JPL)
Troposphere	
Troposphere Model	GPT2/VMF1
Troposphere correction	one zenith delay/2hour (wet tropo scale factor adjusted) + one daily tropospheric gradient per station & per day in North & East directions
Ionosphere	Second order corrections using igs final TEC maps / First order corrected using iono free measurements
Atmospheric drag	DTM 94
Relativity	Schwarzschild model + Lense-Thirring + geodetic precession

GRGS Multi-Techniques Combination Strategy at the weekly bases



Stations	DORIS Doppler	DORIS Laser	GNSS	SLR	LLR	VLBI
GRASSE, France	10002S018			10002S002	10002S002	
Toulouse, France	10003S005		10003M009			
Reykjavik, Iceland	10202S003		10202M001			
Ny-Alesund, Norway	10317S005		10317M003			10317S003
Metsahovi, Finland	10503S015		10503M005			
Graz, Austria			11001M002	11001S002		
Kitab, Uzbekistan	12334S006		12334M001			
Simeiz, Ukraine			12337M002	12337S006		
Kiev, Ukraine			12356M001	12356S001		
Matera, Italy			12734M008		12734S008	
Hailsham, United Kingd		13212S001	13212M010	13212S001		
Zimmerwald, Switzerlan		14001S007	14001M004	14001S997		
Potsdam, Germany		14106S011	14106M003	14106S011		
Bad Koetzting, Germany		14201S018	14201M010	14201S018		14201S004
RIYADH , Saudi Arabia		20101S001		20101S001		
Wuhan, P.R. China	21602S005		21602M001			
Krugersdorp, South Afr			30302M004	30302M003		
Libreville, Gabon	32809S004		32809M002			
Algonquin Park, Canada			40104M002			40104S001
Fairbanks, United Stat	40408S005		40408M001			40408S002
Kokee Park, Waimea, USA	40424S009		40424M004			40424S007
Westford, USA			40440S020			40440S003
Fort Davis, USA,MCDONALD			40442M012	40442M006	40442M006	
Greenbelt, United Stat	40451S176	40451M105	40451M123	40451M105		40451M105
Laguna Mountains, USA	40497S009	40497M001	40497M004	40497M001		40497M001
Ensenada, Mexico	41609S002		40508M002			
San Juan, Argentina				41508S003		41508S003
Eusebio, Brazil			41602M002			41602S001
Easter Island, Chile	41703S009		41703M007			
Santiago, Chile	41705S009		41705M003			
Concepcion, Chile			41719M002	41719M001		41719M001
Puerto Ayora, Ecuador	42005S001		42005M002			
Lima II, Peru	42202S007	42202M003				42202M003
Thule Airbase, Greenla nd	43001S005		43001M002			
YARRAGADEE, Australia	50107S011	50107M001		50107M001		50107M001
Canberra, Australia	50119S004	50119S003	50119M001 / M002	50119S003		50119S003
Waitangi, New Zealand	50207S001		50207M001			
Port aux Francais, Ker TAHITI	91201S005		91201M002	92201M007		
Antarctic base of Dum	91501S003		91501M001			
NOUMEA, FRANCE	92701S003		92701M005			
Kourou, French Guyana	97301S004		97301M210			
Le Tampon, France	97401S002		97401M003			

**DORIS, GNSS,
SLR, LLR &
VLBI links**

Local-Ties for

COLOCATED
STATIONS
between
techniques

31 selected stations for mutualizing tropospheric parameters

Stations	DOMES
GRASSE, France	10002
Toulouse, France	10003
Reykjavik, Iceland	10202
Ny-Alesund, Norway	10317
Metsahovi, Finland	10503
Kitab, Uzbekistan	12334
Wettzell, Germany	14201
Wuhan, P.R. China	21602
Libreville, Gabon	32809
Algonquin Park, Canada	40104
Fairbanks, United Stat	40408
Kokee Park, Waimea, USA	40424
WESTFORD, USA	40440
Greenbelt, United Stat	40451
Laguna Mountains, USA	40497
Forteleza, Brazil	41602
Ensenada, Mexico	41609
Easter Island, Chile	41703
Santiago, Chile	41705
Concepcion, Chile	41719
Puerto Ayora, Ecuador	42005
Lima II, Peru	42202
Thule Airbase, Greenland	43001
YARRAGADEE, Australia	50107
Canberra, Australia	50119
Waitangi, New Zealand	50207
KERGUELEN ISLANDS	91201
Antarctic base of Dum	91501
NOUMEA, FRANCE	92701
Kourou, French Guyana	97301
Le Tampon, France	97401

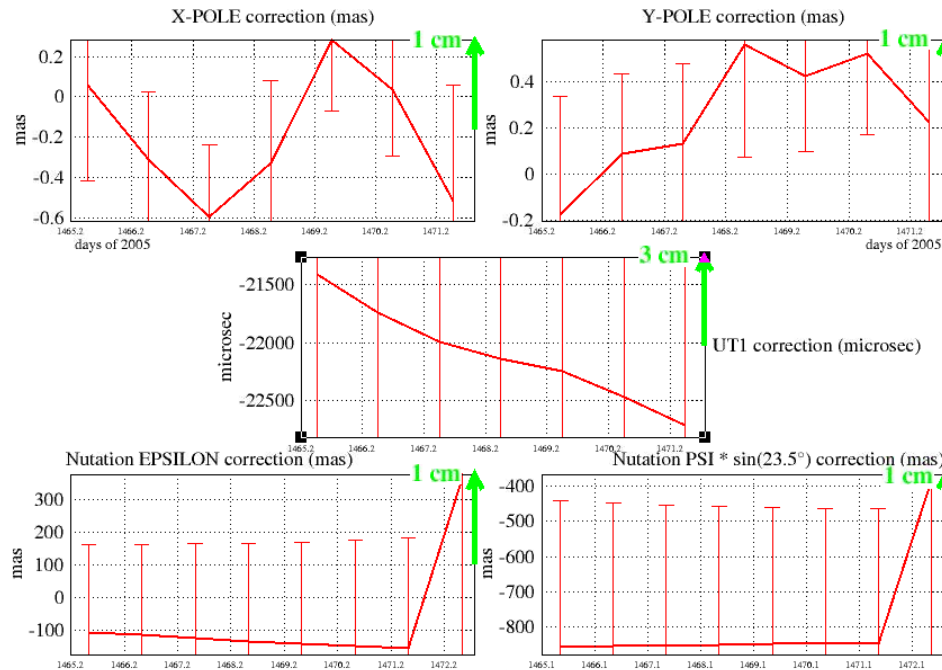
11 stations located over the SAA region, for DORIS Jason1 observations, excluded from Doris Datum

Stations	DOMES
HARTEBEESTHOEK, SOUTH AFRICA, SLR Mark	30302M003
Ascension Island, BRITISH	30602
TRISTAN DA CUNHA, BRITISH	30604
SAINTE-HELENA, BRITISH	30606
LIBREVILLE Gabon	32809
SAL ISLAND, CAPE VERDE	39601
EASTER ISLAND	41703
Santiago, Chile	41705
SANTA CRUZ ISLAND, ECUADOR	42005
Arequipa, Peru	42202
Kourou, French Guyana	97301

DORIS GRGS multi-satellites Jason2 & 1, Envisat, Spot2,4,5

GPS week 1513, 04-10 January 2009, Pole & UT estimated @12H with Nutation

- Weekly combination of Doppler satellites
- Blocking diurnal retrograde amplitude, Stations coordinates & SAA stations,
- Systematics effect cancelled, 7 Minimal constraints over Doris stations & 7CM for SAA stations
- Tropospheric parameters



NX & NY @12H for the 1st day of #week+1

1 NX & NY measurements outside the week interval is very different
du to the terms in the normal equation outside the week interval

Parameter PX

Nb_lignes : 7
Statistiques NON pond??s : moy = -0.19728 ; ec_type (std_dev) = 0.302475 ; ec_quad_moy (rms) = 0.361124
Statistiques pond??s : moy = -0.167417 ; ec_type (std_dev) = 0.303889 ; ec_quad_moy (rms) = 0.346954

Parameter PY

Nb_lignes : 7
Statistiques NON pond??s : moy = 0.252218 ; ec_type (std_dev) = 0.244619 ; ec_quad_moy (rms) = 0.351358
Statistiques pond??s : moy = 0.271424 ; ec_type (std_dev) = 0.219788 ; ec_quad_moy (rms) = 0.349253

Parameter PT

Nb_lignes : 7
Statistiques NON pond??s : moy = -22099.5 ; ec_type (std_dev) = 403.857 ; ec_quad_moy (rms) = 22103.2
Statistiques pond??s : moy = -22114.5 ; ec_type (std_dev) = 318.966 ; ec_quad_moy (rms) = 22116.8

Parameter NX

Nb_lignes : 8
Statistiques NON pond??s : moy = -71.6643 ; ec_type (std_dev) = 164.924 ; ec_quad_moy (rms) = 179.821
Statistiques pond??s : moy = -128.784 ; ec_type (std_dev) = 37.8569 ; ec_quad_moy (rms) = 134.233

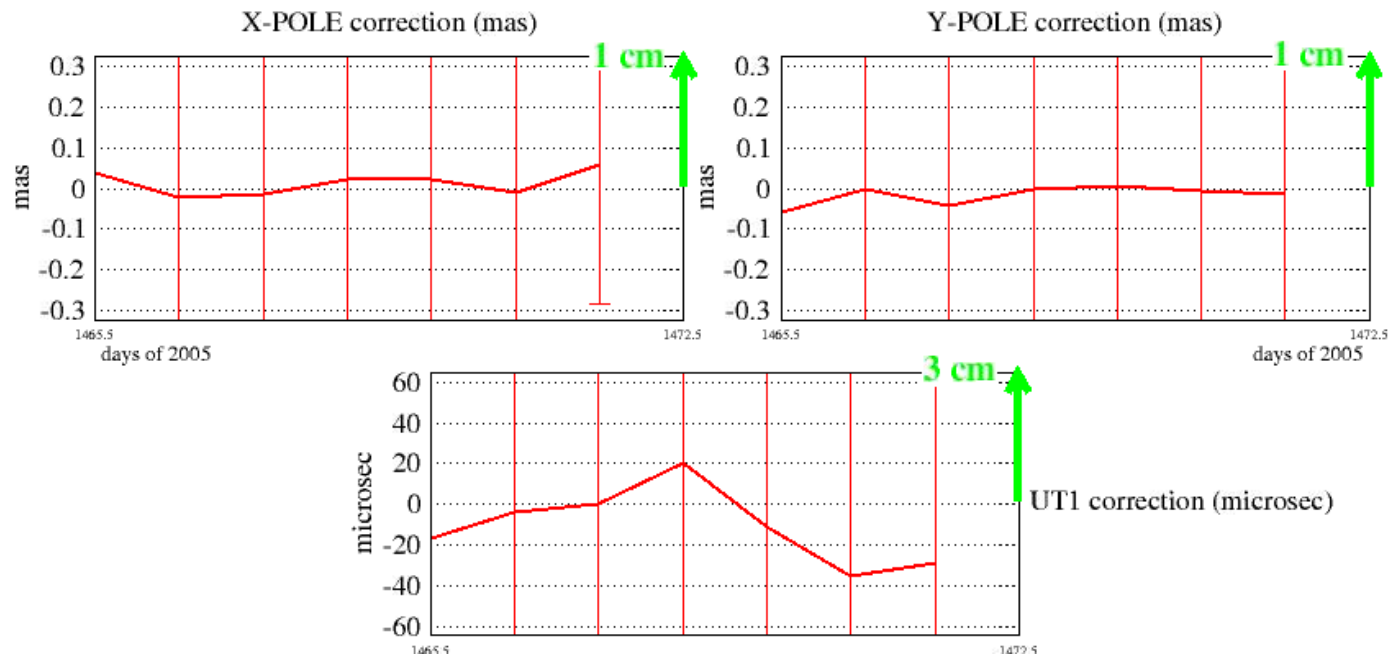
Parameter NY

Nb_lignes : 8
Statistiques NON pond??s : moy = -794.292 ; ec_type (std_dev) = 155.995 ; ec_quad_moy (rms) = 809.466
Statistiques pond??s : moy = -850.197 ; ec_type (std_dev) = 36.8528 ; ec_quad_moy (rms) = 850.996

GPS GRGS

GPS week 1513, 04-10 January 2009, Pole UT & Rates estimated, with

- Systematics effect cancelled (origin & scale), 7 Minimal constraints over GPS networks, stations
- Tropospheric parameters fixed



Parameter PX

Nb_lignes : 7

Statistiques NON pond??s : moy = 0.0137876 ; ec_type (std_dev) = 0.0275316 ; ec_quad_moy (rms) = 0.030791

Statistiques pond??s : moy = 0.0148175 ; ec_type (std_dev) = 0.0278535 ; ec_quad_moy (rms) = 0.0315496

Parameter PY

Nb_lignes : 7

Statistiques NON pond??s : moy = -0.0168359 ; ec_type (std_dev) = 0.0216838 ; ec_quad_moy (rms) = 0.0274524

Statistiques pond??s : moy = -0.016368 ; ec_type (std_dev) = 0.0212876 ; ec_quad_moy (rms) = 0.0268528

Parameter PT

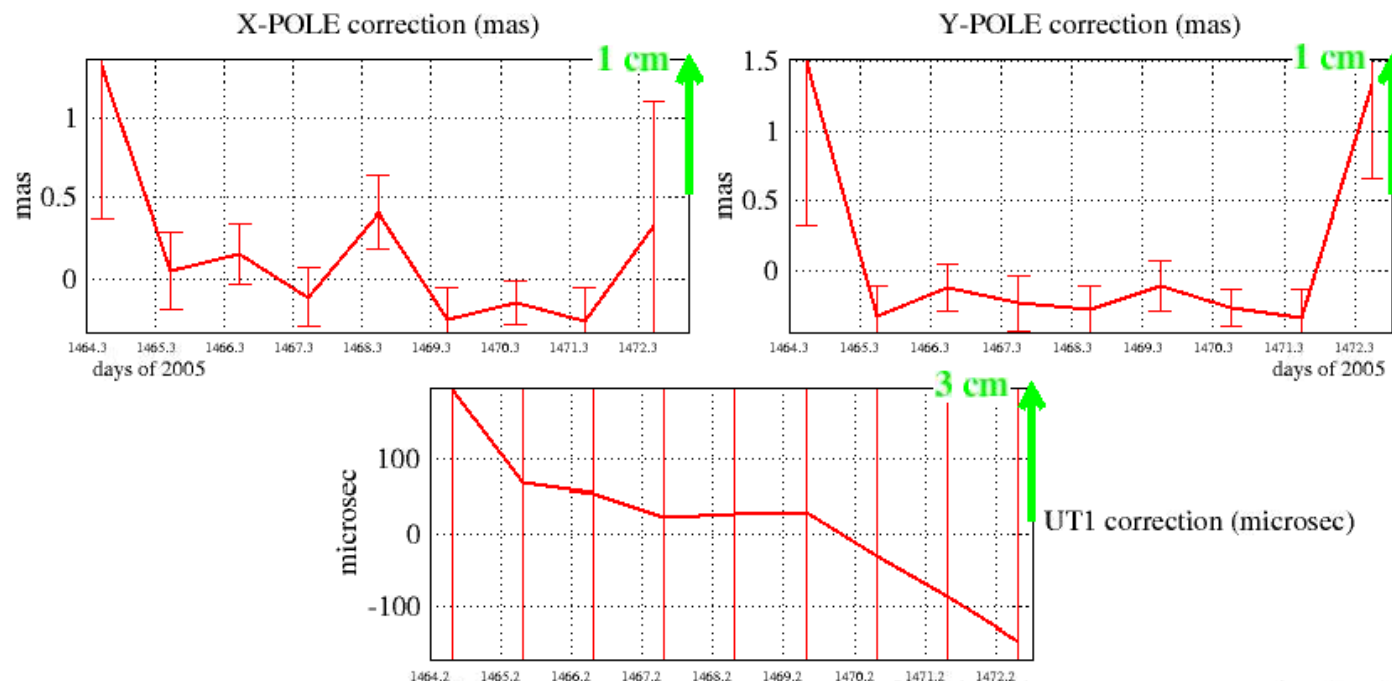
Nb_lignes : 7

Statistiques NON pond??s : moy = -10.7237 ; ec_type (std_dev) = 17.2857 ; ec_quad_moy (rms) = 20.3419

Statistiques pond??s : moy = -10.71 ; ec_type (std_dev) = 17.467 ; ec_quad_moy (rms) = 20.489

SLR GRGS

GPS week 1513, 04-10 January 2009, Pole & UT estimated



Parameter PX

Nb_lignes : 9

Statistiques NON pond??s : moy = 0.16844 ; ec_type (std_dev) = 0.461867 ; ec_quad_moy (rms) = 0.491623

Statistiques pond??s : moy = -0.0370285 ; ec_type (std_dev) = 0.230304 ; ec_quad_moy (rms) = 0.233261

Parameter PY

Nb_lignes : 9

Statistiques NON pond??s : moy = 0.130766 ; ec_type (std_dev) = 0.696885 ; ec_quad_moy (rms) = 0.709047

Statistiques pond??s : moy = -0.212816 ; ec_type (std_dev) = 0.202367 ; ec_quad_moy (rms) = 0.293672

Parameter PT

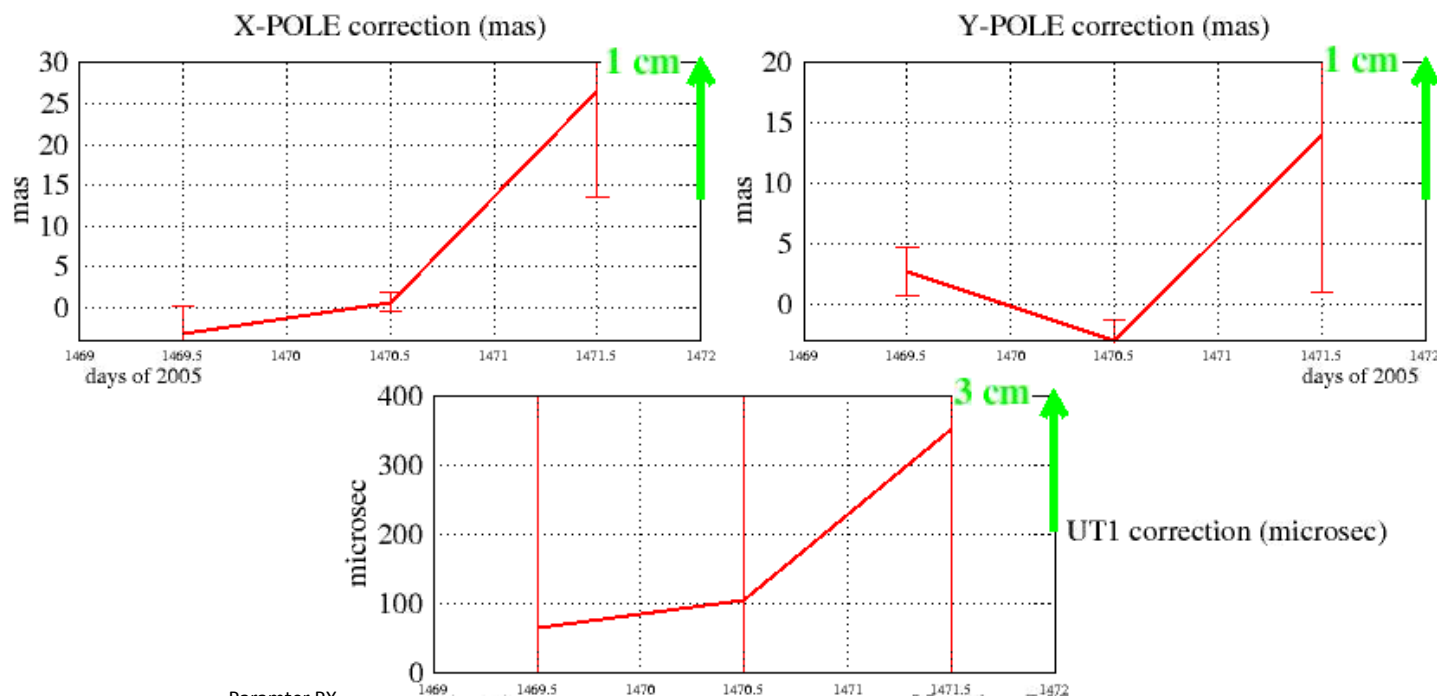
Nb_lignes : 9

Statistiques NON pond??s : moy = 15.1914 ; ec_type (std_dev) = 91.383 ; ec_quad_moy (rms) = 92.6371

Statistiques pond??s : moy = 93.9876 ; ec_type (std_dev) = 57.6483 ; ec_quad_moy (rms) = 110.259

VLBI GRGS

R1 – R4 session stacked over the week 04-10 January 2009 – week GPS 1513



Paramter PX

Nb_lignes : 3

Statistiques NON pond??s : moy = 8.04227 ; ec_type (std_dev) = 13.152 ; ec_quad_moy (rms) = 15.416

Statistiques pond??s : moy = 0.468882 ; ec_type (std_dev) = 2.49268 ; ec_quad_moy (rms) = 2.5364

ParameterPY

Nb_lignes : 3

Statistiques NON pond??s : moy = 4.56572 ; ec_type (std_dev) = 7.06048 ; ec_quad_moy (rms) = 8.40811

Statistiques pond??s : moy = -0.437437 ; ec_type (std_dev) = 3.13389 ; ec_quad_moy (rms) = 3.16427

ParameterPT

Nb_lignes : 3

Statistiques NON pond??s : moy = 175.385 ; ec_type (std_dev) = 126.435 ; ec_quad_moy (rms) = 216.207

Statistiques pond??s : moy = 175.369 ; ec_type (std_dev) = 126.429 ; ec_quad_moy (rms) = 216.191

Combination DORIS, GPS, SLR+LLR, VLBI

Pole & UT only

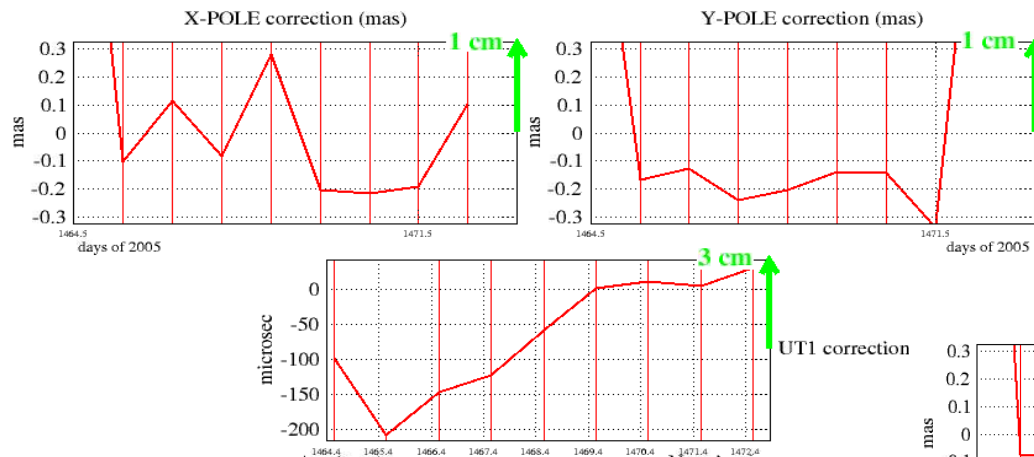
Helmert weighing

0.6208E-02 1 jml CRC/cumul_doris_GRGS_090104_ebf_red_diurne_12h

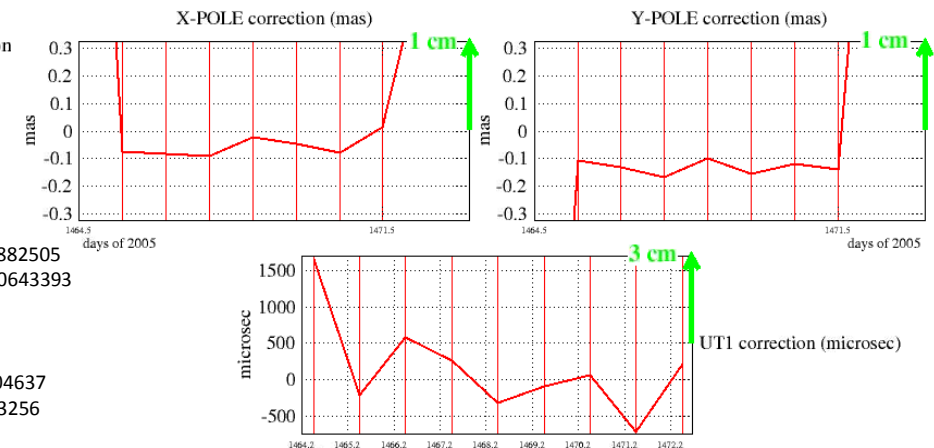
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0.1021E+01 1 jml CRC/cumul_slr_GRGS_21552_red

0.2127E-01 1 jml CRC/cumul_vlbi_GRGS_02_syst_12h



Pole & UT only
Unitary weighing



Parameter PX

Nb_lignes : 9

Statistiques NON pond??s : moy = 0.318769 ; ec_type (std_dev) = 0.822922 ; ec_quad_moy (rms) = 0.882505

Statistiques pond??s : moy = -0.0522764 ; ec_type (std_dev) = 0.0375063 ; ec_quad_moy (rms) = 0.0643393

ParameterPY

Nb_lignes : 9

Statistiques NON pond??s : moy = -0.212584 ; ec_type (std_dev) = 1.02454 ; ec_quad_moy (rms) = 1.04637

Statistiques pond??s : moy = -0.130021 ; ec_type (std_dev) = 0.0258209 ; ec_quad_moy (rms) = 0.13256

ParameterPT

Nb_lignes : 9

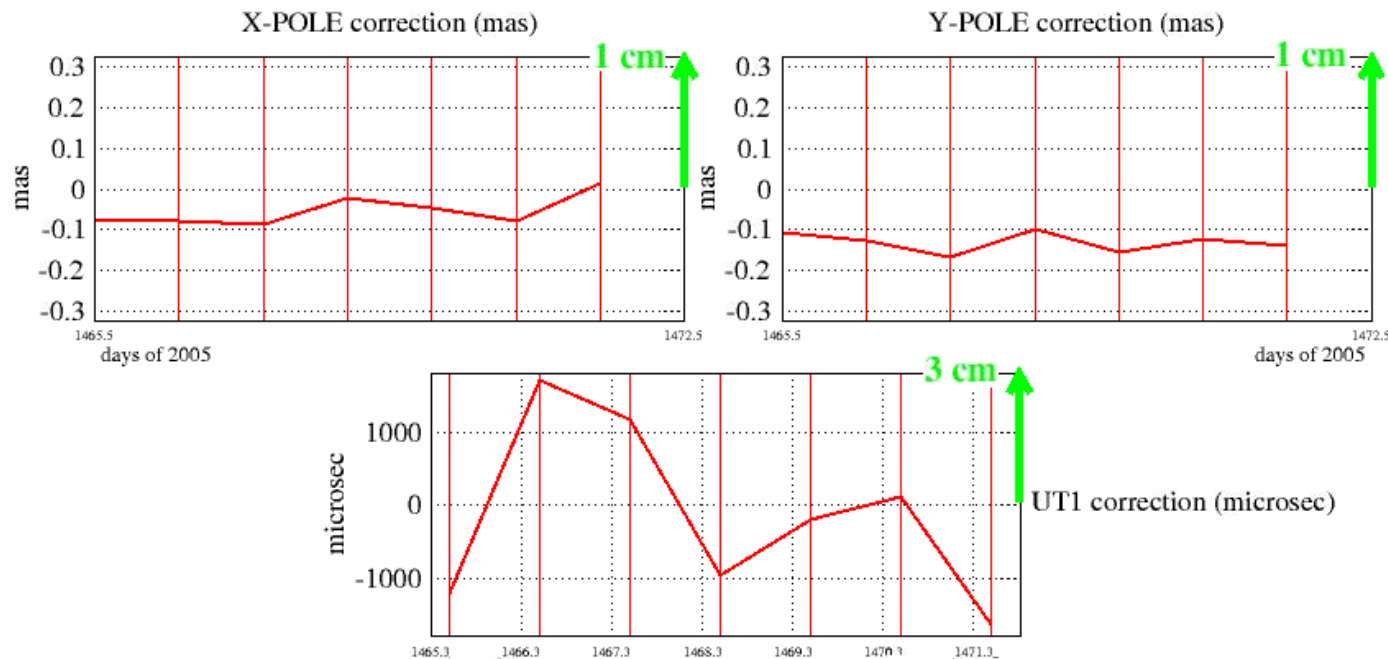
Statistiques NON pond??s : moy = 158.426 ; ec_type (std_dev) = 634.383 ; ec_quad_moy (rms) = 653.866

Statistiques pond??s : moy = 22.608 ; ec_type (std_dev) = 135.938 ; ec_quad_moy (rms) = 137.805

Combination DORIS, GPS, VLBI

Without SLR technique SLR

DORIS + GPS + VLBI unitary weighting, Pole & UT only



Parameter PX

Nb_lignes : 7

Statistiques NON pond??s : moy = -0.0529281 ; ec_type (std_dev) = 0.0343206 ; ec_quad_moy (rms) = 0.0630815

Statistiques pond??s : moy = -0.051457 ; ec_type (std_dev) = 0.0351425 ; ec_quad_moy (rms) = 0.0623123

Parameter PY

Nb_lignes : 7

Statistiques NON pond??s : moy = -0.129677 ; ec_type (std_dev) = 0.0231066 ; ec_quad_moy (rms) = 0.13172

Statistiques pond??s : moy = -0.129941 ; ec_type (std_dev) = 0.0227714 ; ec_quad_moy (rms) = 0.131921

Parameter PT

Nb_lignes : 7

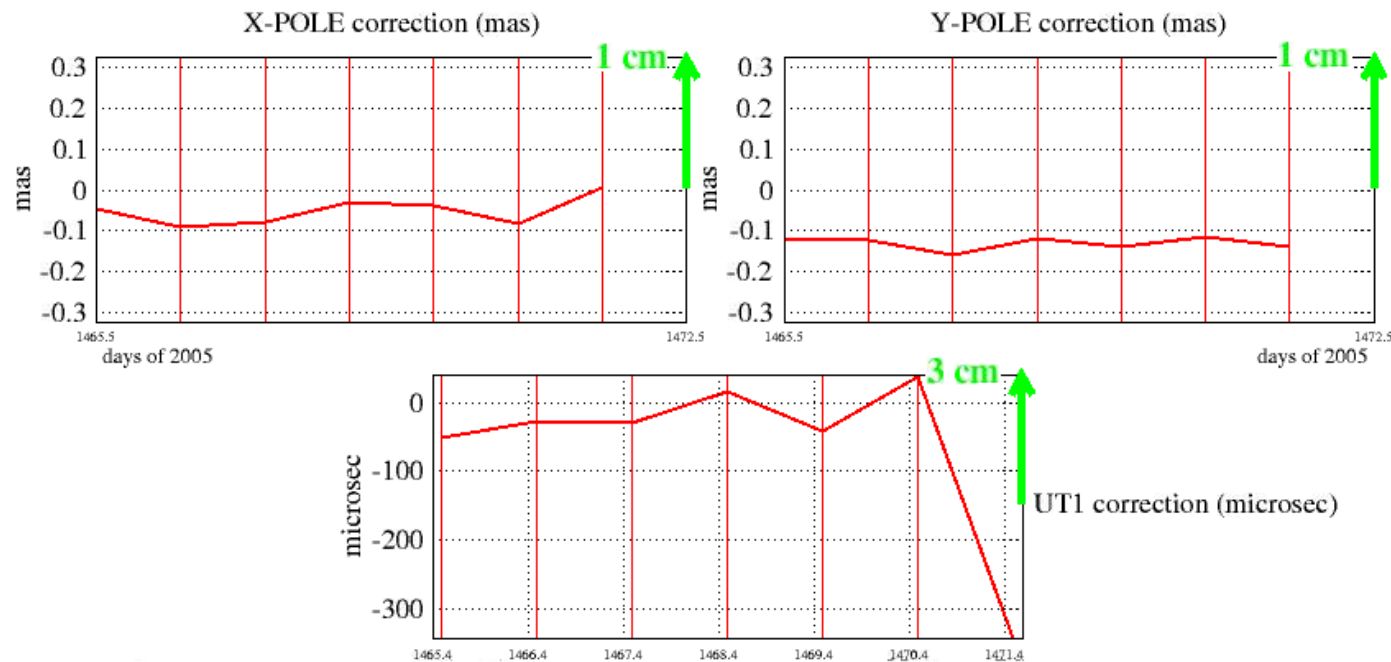
Statistiques NON pond??s : moy = -134.792 ; ec_type (std_dev) = 1145.99 ; ec_quad_moy (rms) = 1153.89

Statistiques pond??s : moy = 50.8986 ; ec_type (std_dev) = 249.073 ; ec_quad_moy (rms) = 254.221

Combination GPS, VLBI

Without SLR technique SLR

GPS + VLBI unitary weighing, Pole & UT only



Parameter PX
Nb_lignes : 7
Statistiques NON pond??s : moy = -0.0511671 ; ec_type (std_dev) = 0.0319713 ; ec_quad_moy (rms) = 0.0603344
Statistiques pond??s : moy = -0.0500409 ; ec_type (std_dev) = 0.0326134 ; ec_quad_moy (rms) = 0.0597304

Parameter PY
Nb_lignes : 7
Statistiques NON pond??s : moy = -0.129773 ; ec_type (std_dev) = 0.0152552 ; ec_quad_moy (rms) = 0.130666
Statistiques pond??s : moy = -0.129791 ; ec_type (std_dev) = 0.0151803 ; ec_quad_moy (rms) = 0.130676

Parameter PT
Nb_lignes : 7
Statistiques NON pond??s : moy = -63.1364 ; ec_type (std_dev) = 118.645 ; ec_quad_moy (rms) = 134.398
Statistiques pond??s : moy = 18.6894 ; ec_type (std_dev) = 43.9255 ; ec_quad_moy (rms) = 47.7362

Conclusion & Prospects

- Discarding parameters out of the nominal week from the normal equation
- Identifying why solutions for single technique are not equivalent using the combination process or the inversion of the single normal equation technique
- Statistics over stations coordinates & transformation parameters of each technique & systematics effects
- Estimated the amplitude and the impact of the troposphere parameters mutualized for the selected stations
- Determination of quasar coordinates and the NNR parameters