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New GPS Reference Station in Brazil

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Abstract. In 1989, the U.S. National Oceanic and Atmospheric Administration (NOAA) initiated a project, together with the University of Sao Paulo, the Brazilian Institute for Space Research (INPE), and Universidade Presbiteriana Mackenzie (Sao Paulo), to build a very long baseline interferometry (VLBI) radio observatory near Fortaleza, Brazil. The site is on the northeast coast of the country about 4 degrees south of the equator, near the center of the geodetic VLBI network. A 14.2-meter diameter antenna was moved from Green Bank, West Virginia in late 1992, and erected and outfitted by mid-1993. The first full VLBI observing session began on 6 July 1993. In May 1993, NOAA installed a co-located GPS station, FORT, consisting of a dimpled steel plate monument emplaced near a corner of the rooftop of the one-storey control building and an AOA Dorne Margolin model T chokering antenna mounted with its preamp fixed 64.3 cm above the reference point. The original antenna was replaced by a similar unit in the same location on 20 March 2000, the only difference being that the low-noise amplifier had been retrofitted with an Ashtech unit. A conical radome has covered the antenna throughout the history of the station. The radome has never been calibrated for its effect on radio wave propagation. FORT has been part of the IGS network since its installation. Unlike most GPS stations, FORT has access to the ultra-stable H-maser frequency standard that is required for VLBI observations. The importance of having an accurate local tie measured between the reference points of the co-located VLBI and GPS systems was recognized from the beginning. This is indispensable for tying together the technique frames forming the ITRF. There are only about 30 such VLBI-GPS tie sites around the world and only a handful of those have accurate locally surveyed ties. NOAA personnel led the survey campaign to measure this tie during 11-30 Sept. 1993, with assistance from Brazilian colleagues. In Sept. 2005, NOAA personnel returned to Fortaleza to install a new, modern GPS station at the site. It was decided that a new receiver should be installed together with a new antenna and antenna mount design a short distance from the old station in order to make improvements in the GPS installation and to provide an observational overlap with the old station. The new station, BRFT, consists of a Leica LEIAT504 antenna (no radome) sitting atop a 1.5-meter tall steel tripod near another corner of the same rooftop. A SCIGN leveling mount is welded to the top of the tripod structure to provide the geodetic reference point. The BRFT receiver is a Leica GRX1200PRO, which also uses the local H-maser standard. Observations began on 6 Sept. 2005. Early geodetic results indicate that the new station performs very well. As was hoped, the new antenna mount design seems to have reduced the effects of code multipath by a large amount. The first 5 months of simultaneous data between FORT and BRFT have been used to determine the local tie between these two GPS reference points to the mm level. This vector can be used to update the local VLBI-GPS tie, although there are indications that the 1993 tie may be biased. A test of removing the conical radome over the old GPS antenna indicates that is has shifted the station height by about 16 mm downward, explaining most of the bias.

1. Original Fortaleza GPS Station – FORT

2. Summary Comparison of Configurations & Data Metrics

- both stations located near different corners on the rooftop of the same one-storey building
- TEQC metrics (7 bottom lines) assume 10° elevation cutoff
- for period of data overlap (17 September 2005 – 18 February 2006)

Aspect	FORT	BRFT
DOMES no.	41602M001	41602M002
install date	13 May 1993	6 September 2005
monument	dimpled steel disk on roof of one-storey bldg	dimpled point within SCIGN leveling mount
mount	aluminum backplane braced to roof and parapet	1.5-m tall steel tripod on roof of one-storey bldg
antenna	AOAD/M_TA_NGS	LEIAT504
radome	conical (uncalibrated)	none
height offset	0.643 m	0.0083 m
receiver	ROGUE SNR-8000	LEICA GRX1200PRO
firmware	3.2.32.11	2.12
clock	external Sigma Tau H-maser	external Sigma Tau H-maser
no. overlap	111	154 days
mean no. obs	18610	26970 per day
mean deleted	2507.9	1.4 per day
mean % usable	67.1	98.9 per day
mean MP1	0.33	0.28 m
mean MP2	0.98	0.34 m
mean slips	49.6	61.5 per day

3. New GPS Station – BRFT

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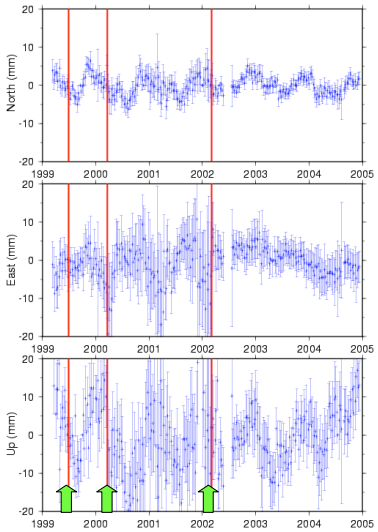
4. Time Series of FORT Weekly Position Residuals from IGS



- NEU weekly residuals for FORT
- from IGS combined frame by R. Ferland (NRCanada)
- residuals generated from stacking by Z. Altamimi (IGN)

- events marked by red lines:
  1) 1999.5: new firmware
  2) 2000.2: new antenna
  3) 2002.2: new firmware (to fix TR L2 tracking)

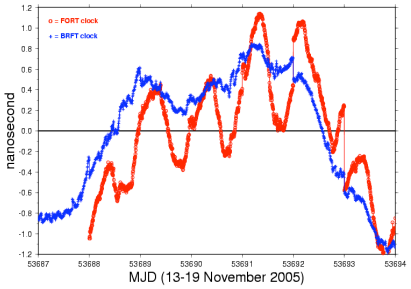
- wtd annual fits, before & after 2002.2 firmware update:

	1999-2002.2	2002.2-2005
N:	2.46 ± 0.26	2.01 ± 0.22
E:	2.36 ± 0.69 ▶	1.06 ± 0.48
U:	8.34 ± 0.96 ▶	4.32 ± 0.79

- annual E,U signals halved after 2002.2 firmware change

- proves at least some geodetic "signals" are related to instrumentation effects

5. Comparison of FORT & BRFT GPS Receiver Clocks w.r.t. IGS Time

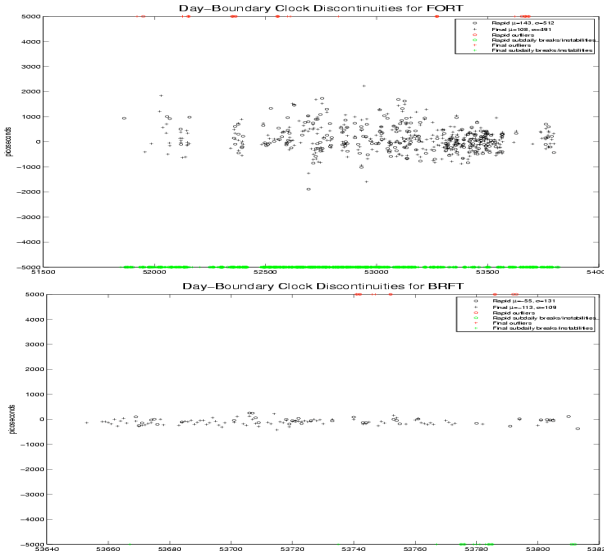


- FORT & BRFT clocks
- from IGS combined clocks by K. Senior (NRL)
- linear trend removed from each
- both receive 5 MHz input from same Sigma Tau H-maser

- environmental sensitivity is evidently much improved for BRFT

- probably due to use of Andrew LDF4-50 heliax phase stable antenna cable

6. Comparison of FORT & BRFT Day-Boundary Clock Discontinuities



- day-boundary clock discontinuities from IGS combined clock products by K. Senior (NRL)
- measures clock accuracy & presumably reflects local pseudorange multipath conditions
- long-wavelength (i.e., near-field) code multipath most important
- for 24-hr arc with code obs δ = 1 m, clock accuracy should be ~120 ps
- actual performance varies enormously among IGS stations (must have H-maser)

- so far, BRFT day-jumps (RMS ~120 ps) are far less than for FORT (RMS ~500 ps)

- implies near-field code multipath conditions are much better at BRFT than at FORT
- presumably related to new antenna mount design

7. FORT → BRFT Tie & BRFT Coordinates in IGb00 Frame

FORT (41602M001) → BRFT (41602M002) GPS tie

	dX (m)	dY (m)	dZ (m)	epoch YYYY:DOY:secnd
Wtd mean	6.9258	5.1913	-0.3336	2005:339:43200
Wtd RMS	.0022	.0017	.0003	

Inferred BRFT (41602M002) coordinates in IGb00 frame

	X (m)	Y (m)	Z (m)	epoch YYYY:DOY:secnd
coordinates	4985393.5480	-3954993.3971	-428426.8034	1998:001:00000
uncertainty	0.00413	0.00367	0.00221	
velocity	-0.001887	-0.003463	0.010888	m/yr
uncertainty	0.001378	0.001189	0.000530	

- based on 111 days of simultaneous 24-hr data from 27 Sept 2005 thru 24 Feb 2006
- used standard dual-frequency, double-differenced carrier phase analysis

8. FORT GPS → Fortaleza VLBI Survey Tie

FORT GPS (41602M001) → Fortaleza VLBI (41602S001) Survey tie

dX (m)	dY (m)	dZ (m)	epoch YYYY:DOY:secnd
-16.5977	-21.7320	-45.8047	1993:263:43200

- conventional survey by Glover et al. (1994); accuracy estimated as 2-3 mm per component

9. Effect of FORT Radome

FORT-No Radome (41602M001) → BRFT (41602M002) GPS tie

	dX (m)	dY (m)	dZ (m)	epoch YYYY:DOY:secnd
Wtd mean	6.9134	5.2012	-0.3324	2006:071:00000
Wtd RMS	.0022	.0016	.0003	

FORT-With Radome → FORT-No Radome Offset

dN (m)	dE (m)	dU (m)	epoch YYYY:DOY:secnd
-0.00013	-0.00005	0.01591	2006:071:00000

- effect of FORT radome almost purely a downward bias of about 16 mm (based on 16 days)
- largely accounts for discrepancy in FORT GPS → VLBI tie found by Ray & Altamimi (2005)