MMA Memo 261
Position of MMA Equipment on Chajnantor

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Abstract

The geographic position of the MMA equipment container on Chajnantor, Chile, has been determined with a GPS navigation receiver to a horizontal precision of < 20 cm.

Introduction

Since 1995 April, NRAO has operated a suite of instruments at the Millimeter Array site near Cerro Chajnantor, Chile, to evaluate observing conditions (Radford & Holdaway 1998). These computer controlled instruments are housed in a steel container that supports a solar electric power system.

In 1998 June, a commercial Global Positioning System navigation receiver (Garmin GPS 35) was installed on the container roof to provide an absolute time reference for the instrument computers. The receiver antenna is mounted at the top of a solar panel bracket, about 3.26 m above the ground level. Except in the Table and in the final paragraph, all altitudes in this memo refer to the receiver position.

This receiver decodes the Standard Positioning Service (SPS) information, which is subject to degradation by Selective Availability (SA). Several techniques, including long term averaging, can be used to improve the precision of GPS position measurements (e. g., Maley et al. 1997). To precisely determine the position of the MMA equipment on Chajnantor, the GPS receiver output has been recorded every 15 minutes starting at 1998 November 26 UT 19:30. Measurements recorded through 1999 April 1 UT 17:30, over 11300 points, are analyzed in this memo.

Statistics

The mean position ($\mu = \sum x_i/N$) appears stationary over the 128 day study period (Figure 1). There is no significant difference between the position determined from the first half, the last half, or all of the data.

The measurements show an approximately normal distribution. The standard deviations of the ensemble ($\sigma^2 = \sum(x_i - \mu)^2/(N-1)$) are $\sigma = 0.5''$ (16 m) in latitude and longitude and $\sigma = 35$ m in altitude. These observed deviations are about half as large as those presented in the GPS SPS Signal Specification (1995), possibly because the GPS 35 receiver is capable of tracking up to 12 satellites simultaneously whereas the Specification distributions are based on tracking only four satellites.

At first glance, there are no obvious correlations between the measurements in the three axes (Figure 2). The linear correlation coefficients ($r_{xy} = \sum(x_i - \mu_x)(y_i - \mu_y)/[\sum(x_i - \mu_x)^2 \sum(y_i - \mu_y)^2]^{0.5}$) are, however, significantly larger ($> 10\sigma$) than expected for an ensemble of so many uncorrelated samples (Press et al. 1988). Systematically, measured positions are low in the SE and high in the NW.

If successive measurements, made 15 minutes apart, are uncorrelated, the uncertainty in the mean position ($\sigma/N^{0.5}$) is 15 cm in latitude, 16 cm in longitude, and 30 cm in altitude. The SPS Specification suggests measurements separated by more than 4 minutes are essentially uncorrelated. If, however, some effect imposes correlations between adjacent data, then the position uncertainty would be underestimated. To test for hidden sequential correlations, then, the measurement uncertainties were evaluated directly for successively longer averaging times. The sample variances were evaluated for the ensemble of the individual measurements, then for the ensemble of the averages of each pair of successive measurements, then for quartets, and so forth (Figure 3). By and large, the standard deviations follow the expected trend, decreasing with time$^{0.5}$. If successive measurements were correlated, the deviations would not decrease as quickly.

Datums and Comparisons

The GPS receiver reports latitude and longitude referenced to the World Geodetic System 1984 (WGS 84) datum (Mitby 1999) and altitudes above mean sea level. Differences between WGS 84 and the International Terrestrial Reference Frame (ITRF) are in the centimeter range worldwide (NIMA 1997). Published maps of the Chajnantor area use, however, the Provisional South American 1956 (SAm 56) datum, which differs from WGS 84 by some 400 m in this area. The mean position was translated to SAm 56 and to Universal Transverse Mercator (UTM) grid coordinates for both horizontal datums (Table) by linear interpolation from the output of the MADTRAN program (1996), which is based on the Molodensky formulae (NIMA 1997). The program indicates a transformation precision of ± 25 m ($0.8''$). A ground control survey, where known benchmarks are surveyed in both datums, is required to improve the transformation precision. Although there is no world vertical system currently defined to tie together local vertical systems, "there is never more than 2 m variance between leveling nets based on different mean sea level datums" (DMA 1983).

In 1996, a high resolution map of the Chajnantor area was prepared for NRAO from aerial photographs and maps produced by the Instituto de Geográfico Militar de Chile (Holdaway et al. 1996). The horizontal position determined from these GPS measurements agrees within 10 m with the nominal location of the container on this map. The GPS (ground) altitude is about 25 m higher than shown on the map.

Acknowledgements

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Chajnantor Position

	WGS 84	SAm 56
Latitude [South]	$23^\circ\ 1'\,22.391''$	$23^\circ\ 1'\ 9.39''$
	$\pm$ 5 mas	
Longitude [West]	$67^\circ\,45'\,17.743''$	$67^\circ\,45'\,11.44''$
	$\pm$ 5 mas	
UTM Zone 19:		
Northing	7 453 404 m	7 453 769 m
Easting	627 583 m	627 772 m
Altitude [a. m. s. l.]:		
receiver	5060.1 m	
	$\pm$ 0.3 m	
ground	5056.8 m	

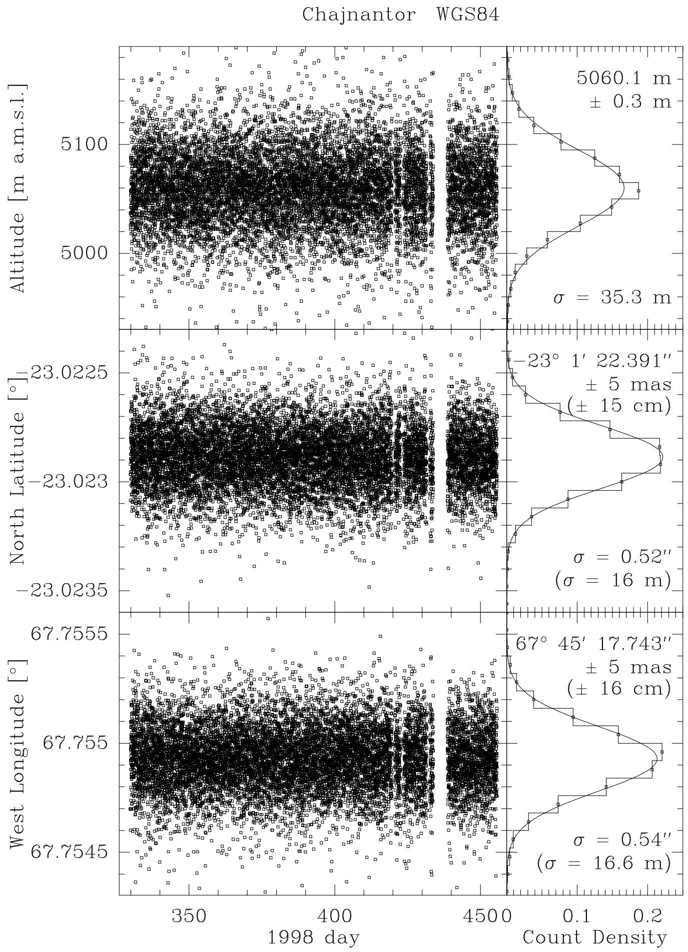

Figure 1: Measured positions of MMA equipment container on Chajnantor, Chile. In the right panels, the histograms show the actual distribution of the measured positions and the curves are normal (Gaussian) distributions for the parameters derived from the data. Note scale difference between latitude-longitude and altitude.

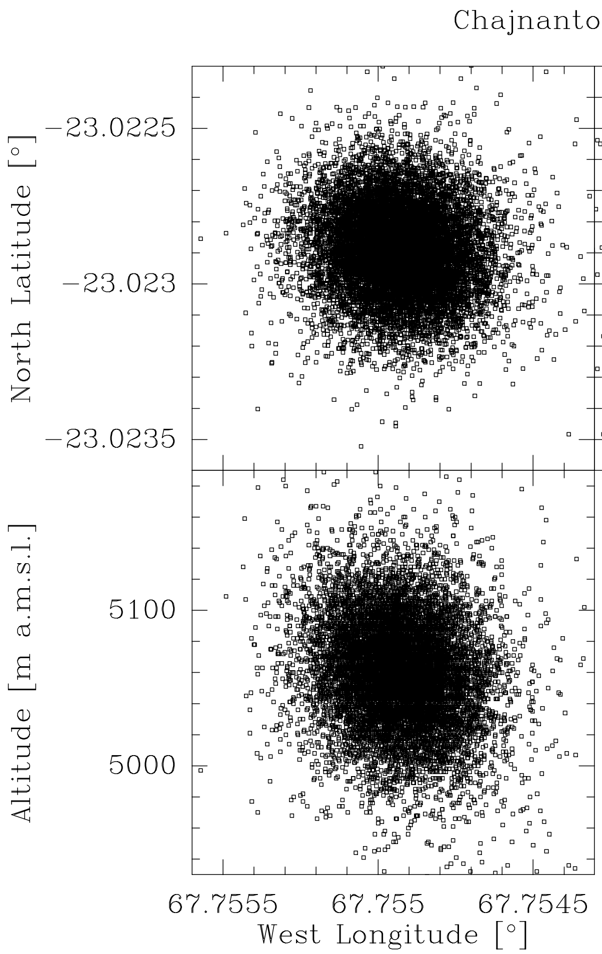

Figure 2: Measured positions and linear cross correlation coefficients.

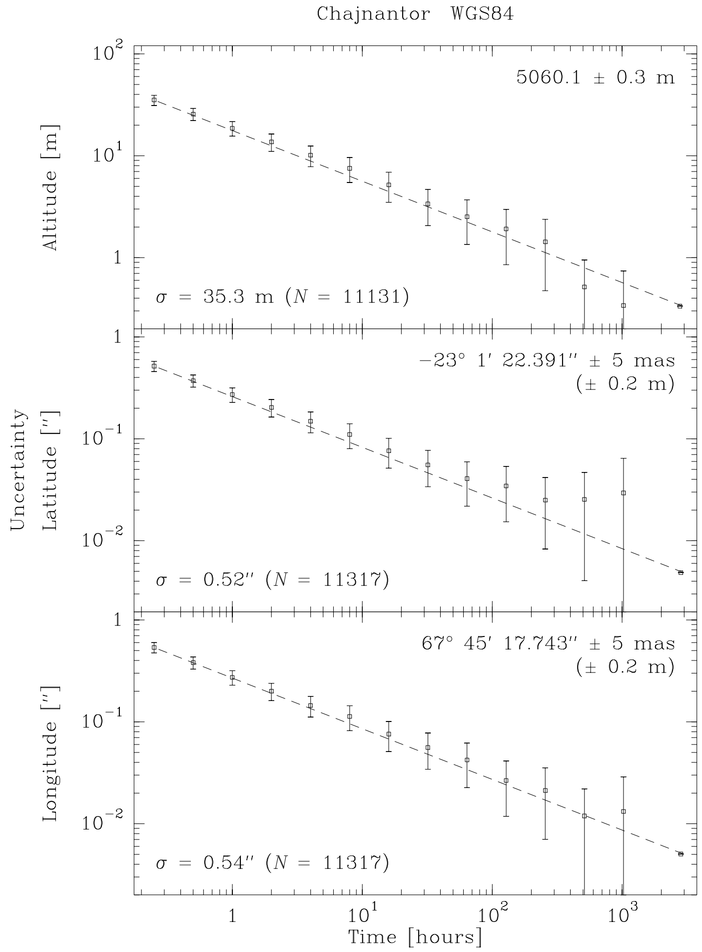

Figure 3: Measurement uncertainty for different averaging times. The error bars illustrate the sampling uncertainty for a normal distribution, $\sigma_\sigma/\sigma = (2/(N-1))^{1/4}$ (Bailey 1971). The dashed lines show the decrease with time$^{0.5}$ expected for for sequentially uncorrelated data.