# ALMA Memo 312
# Refined Position of ALMA Equipment on Chajnantor

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**Abstract**

Recent discontinuation of the intentional degradtion of GPS signals permits a refined determination of the geographic position of the NRAO equipment container at the ALMA site near Cerro Chajnantor, Chile. Systematic effects limit, however, the precision to 30–60 cm horizontally and 2 m in altitude.

## Introduction

In 1998 June, a commercial Global Positioning System navigation receiver (Garmin GPS 35) was installed on the roof of the NRAO equipment container at the ALMA site near Cerro Chajnantor, Chile. Since 1998 November 26 UT 19:30, the receiver position has been recorded every 15 minutes. Recently, intentional degradation of GPS signals (Selective Availability) was discontinued (Clinton 2000), which permits refinement of the geographic position. Systematic effects now visible in the data limit, however, the precision.

## Degraded Data

Data recorded before 2000 May 2 UT 4:00 (Figure 1) were affected by SA degradation. In all, more than 35000 measurements were made during this period, which includes 11300 measurements reported earlier (Radford 1999). As noted previously, position offsets along the three orthogonal axes are correlated. Positions in the SE have systematically lower altitudes than those in the NW. The overall distribution of the measurements remained similar throughout the period, so the formal position uncertainty decreased as $N^{0.5}$, to $\pm\,9$ cm horizontally.

Because the mean position is not stationary, however, the true position uncertainty is larger. When the data are divided into successively longer subsets, the variance in the mean positions of the subsets decreases more slowly than exected for sequentially uncorrelated data (Figure 2). This behaviour was not apparent in the earlier analysis (Radford 1999), perhaps because of the smaller number of measurements. Taking into account the wander in the mean position, a better estimate of the position uncertainty is $\pm\,20$ mas ($\pm\,60$ cm) in each horizontal direction and $\pm\,2.5$ m in altitude.

## Undegraded Data

Data recorded after 2000 May 2 UT 4:00 are unaffected by SA. Since then, over 2500 measurements have been made (Figure 3). The width of the distribution is roughly four times smaller than observed when SA was active (Figure 1), although the distribution is slightly non-Gaussian. As a result, the result after only a month without SA is similar to 18 months with SA active.

In the absence of SA, a correlation between latitude and altitude becomes obvious (Figure 4). The sense of the correlation, however, is inverted compared with the earlier measurements. Now measured positions in the south have systematically higher altitudes than those in the north. Correlations with longitude are less clearcut. Indeed, the calculated values of all three correlation coefficients are negative, which is impossible because linear correlations should commute.

In addition, there is an obvious diurnal variation in the measured position (Figure 5). The amplitude, $\leq$ 10 m horizontally and $\leq$ 20 m in altitude, is much larger than plausible physical changes in the location of the receiver mount (tides, thermal expansion, etc.). The cause must be, therefore, instrinsic to the GPS, perhaps due to imprecision in the orbit data or to variations in satellite acquitision or in ionospheric transmission. This variation makes a substantial contribution to the overall scatter in the measurements, which would be two or three times smaller if the diurnal trend were removed.

As with the degraded data, the true position uncertainty is larger than the formal value. When the data are divided into successively longer subsets, excess variance is seen on most time scales (Figure 6). The diurnal variation explains the excess variance on scales of 1–20 h. On the longest time scale, the uncertainty is about 10–20 mas (30–60 cm) horizontally and 2 m in altitude.

## Configuration Surveying

The results (Table) have been translated from WGS84 to other datums of interest as described previously (Radford 1999). In the Table, the uncertainties reflect the excess variance seen on the longest time scale (Figure 6), but the figures show only the formal uncertainty.

Only modest surveying precision is necessary for the initial layout of ALMA configuration designs. Now SA has been discontinued, the instantaneous horizonal precision ($\approx 3.5$ m r. m. s.) obtained with a GPS navigation receiver is sufficient for this task.

## References


Bailey, D. E., 1971, Probability and Statistics, (Wiley)

Clinton, W. J., 2000 May 1, Statement by the President Regarding the United States' Decision to Stop Degrading Global Positioning System Accuracy (White House; http://www.pub.whitehouse.gov/uri-res/I2R?urn:pdi://oma.eop.gov.us/2000/5/2/7.text.1)

Radford, S. J. E., 1999, MMA Memo 261

GPS 35 Smart Antenna Technical Specification, 1998, Garmin Corp. (www.garmin.com)

Chajnantor Position

| | WGS 84 | SAm 56 |
|---|---|---|
| Latitude [South] | $23^\circ\ 1'\,22.480''$ | $23^\circ\ 1'\ 9.48''$ |
| | $\pm$ 6 mas | |
| Longitude [West] | $67^\circ\,45'\,17.743''$ | $67^\circ\,45'\,11.44''$ |
| | $\pm$ 20 mas | |
| UTM Zone 19: | | |
| Northing | 7 453 407 m | 7 453 772 m |
| Easting | 627 583 m | 627 772 m |
| Altitude [a. m. s. l.]: | | |
| receiver | 5059.8 m | |
| | $\pm$ 1.7 m | |
| ground | 5056.5 m | |

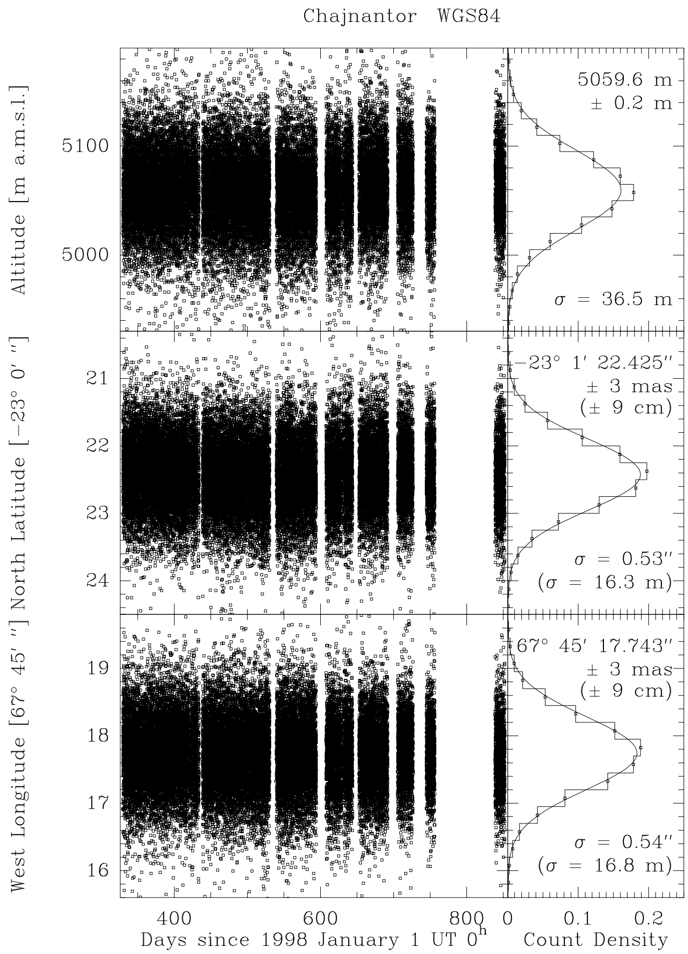


Figure 1: Measured positions of the NRAO equipment container on Chajnantor, Chile, from 1998 November 26 UT 19:30 until 2000 May 2 UT 4:00, when SA was active. In the right panels, the histograms show the actual distribution of the measured positions and the curves are normal (Gaussian) distributions for the parameters derived from the data. Note scale differences between latitude-longitude and altitude and between Figures 1 and 3.

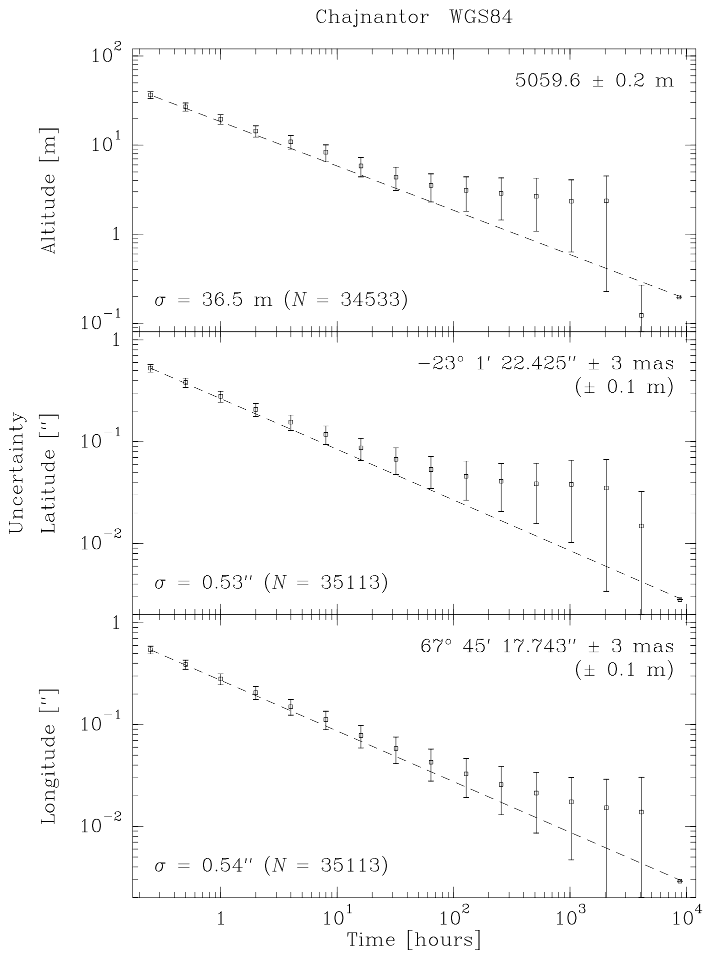


Figure 2: Variance in the mean positions for successively longer sets of measurements when SA was active. The error bars illustrate the sampling uncertainty for a normal distribution, $\sigma_\sigma/\sigma = (2/(N-1))^{1/4}$ (Bailey 1971). The dashed lines show the decrease with $N^{0.5}$ expected for for sequentially uncorrelated data.

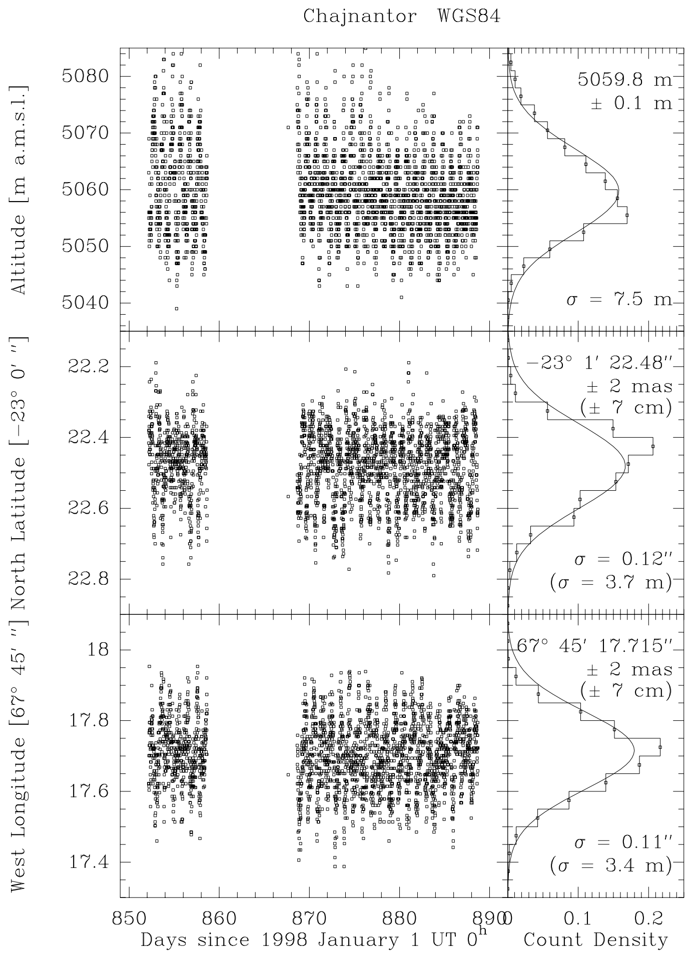


Figure 3: Measured positions of the NRAO equipment container on Chajnantor, Chile, after 2000 May 2 UT 4:00, when SA was discontinued. In the right panels, the histograms show the actual distribution of the measured positions and the curves are normal (Gaussian) distributions for the parameters derived from the data. Note scale difference between latitude-longitude and altitude and between Figures 1 and 3.

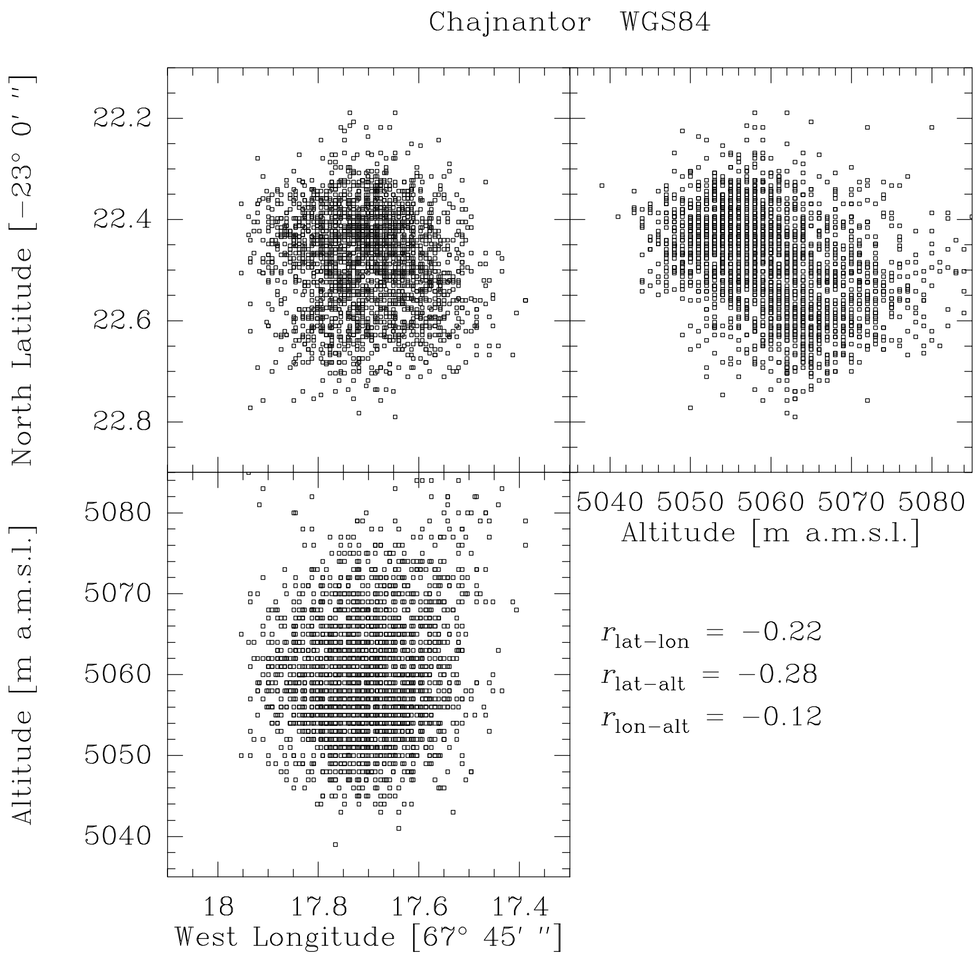


Figure 4: Positions measured after discontinuation of SA and linear cross correlation coefficients. Note scale difference between latitude-longitude and altitude; 0.1″ corresponds to 3.1 m.

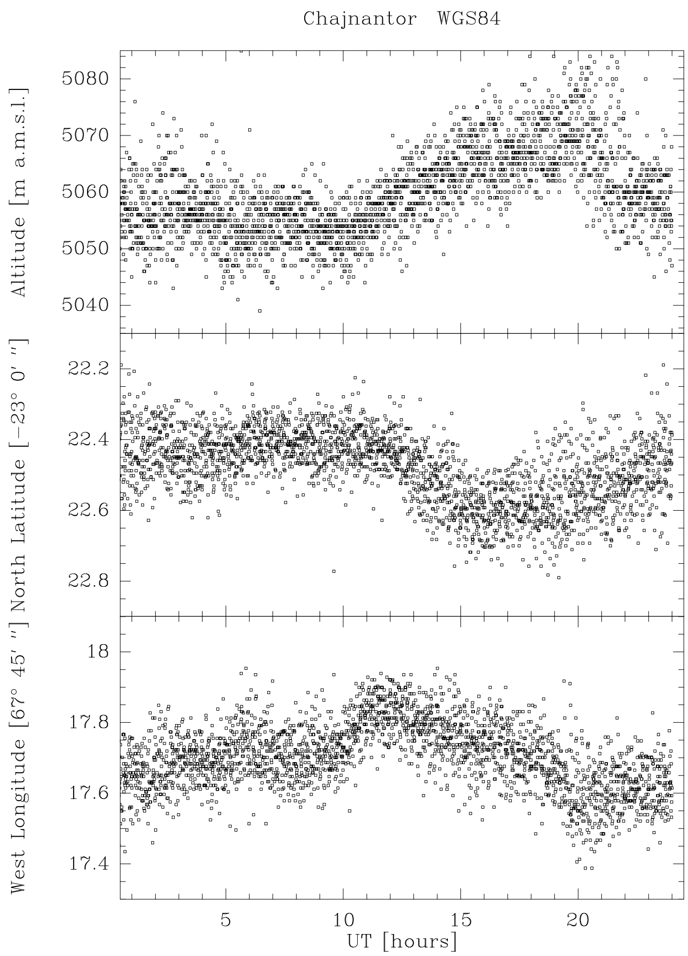


Figure 5: Diurnal variation of positions measured after discontinuation of SA. Note scale difference between latitude-longitude and altitude; $0.1''$ corresponds to 3.1 m.

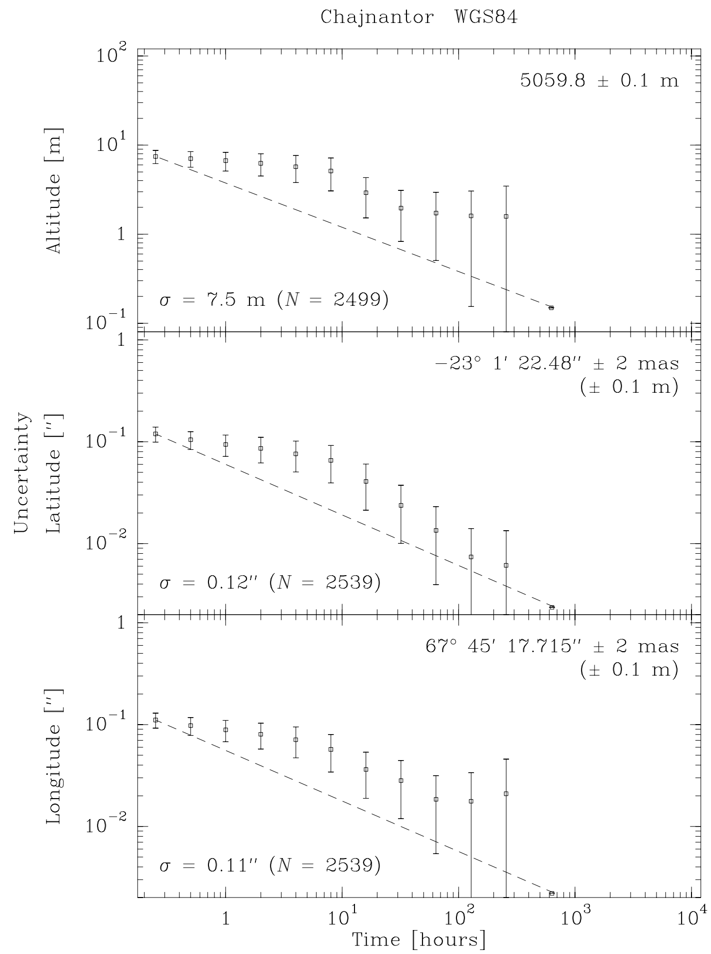


Figure 6: Variance in the mean positions for successively longer sets of measurements after SA was discontinued. The error bars illustrate the sampling uncertainty for a normal distribution, $\sigma_\sigma/\sigma = (2/(N-1))^{1/4}$ (Bailey 1971). The dashed lines show the decrease with $N^{0.5}$ expected for for sequentially uncorrelated data.