Global Position of TDS

GPS, USGS, TOPO and Lat/Long at Tierra del Sol

by John Mood

I am constitutionally curious & an admitted nit-picker. When I want to know something, I want to know it precisely. Thus it was that more than a decade ago, I determined to my satisfaction the longitude, latitude & altitude of my apartment in Ocean Beach, my observing trailer in the desert, & SDAA's observing site at Tierra del Sol, all by the use of a USGS (United States Geological Service) 7.5 minute X 7.5 minute, 1:24000 map at the Ocean Beach branch of the San Diego Library.

Then, in '94, someone asked on the blackboard in the men's room at TdeS, what the lat & long there was, & someone else had written in a figure that didn't match mine. I inquired into the origin of this figure, whereupon I 1st learned of GPS (Global Positioning System). This is a series of (originally) 24 satellites (now 36 to ensure that at least 28 are in service at all times) orbiting the earth from which one can receive signals from at least 4 at any one time that will give the long, lat & alt of a hand-held GPS receiver. I inquired further & determined to my satisfaction that the system at that time was not nearly as accurate as the map I had used.

But others in our club were not convinced. I knew that some professional astronomers at the University of Arizona had, in '92, come to TdeS to time an asteroid's occultation of a star. Their results were published in IAUC (International Astronomical Union Circular) # 5898 (29 November 1993). Thus, to bolster my claim, I wrote them & asked what figure they used for long & lat & alt at TdeS, & how they determined it. They wrote back & told me they'd used GPS & gave me the figures they used, with the margins of error in each case. [N.B. A statistic without the margin of error is useless for serious consideration.] Then they added the following statement: "You could probably do even better from a 7-minute USGS map since there is still some level of introduced error in the GPS signal."

Well, did I feel vindicated! & so, ever since then, I've used in my "SkyWatch" column the figure I obtained using my millimeter ruler on the USGS map.

> *It was an extraordinarily bitter day, I remember, zero by the thermometer. But considering it was Christmas Eve there was nothing...extraordinary about that.*

Fast forward 6 years. I was the 1st person I knew to get a computer ('84), but virtually the last to be able to get online (Summer, 2000). When I did so, I discovered SDAA's superb web site, www.sdaa.org, about which I'd hitherto been quite ignorant. Then a couple of months ago, two curious figures appeared in the web site, giving as the lat of the bathroom [!!] at TdeS 32.61384°N & the long of116.33278°W.

I was instantly struck by 4 things about those figures. 1st, no professional astronomer, navigator or surveyor would use such numbers. They all always give lat & long in degrees, minutes & seconds, & if any decimals occur, they are of seconds. 2nd, no source was given for the figures, immediately calling them into question. 3rd, no margin of error was given [see above]. Leading to 4th, what is known in statistics as the "spurious precision fallacy," in which many decimal points are given to foster the illusion of extreme accuracy, when in fact the margin of error cancels it out. That is, if lat is 32.61384° but the margin of error is ± 0.03, then the final 3 decimal digits are completely spurious & unreliable, indeed, meaningless.

So, once again, I inquired, of experts this time, getting packets of material & numerous phones calls from USGS scientists in Denver. (I was pleased to see that government scientists are still approachable, even eager, in discussing their work, as my wife Stephanie & I had learned back in the '80s when we were freelance professional science writers.) From them, I quickly learned several things. 1st, the source of the new figures was indeed a hand-held GPS receiver, which now can give lat/long in that odd decimal form. 2nd, the DoD (Department of Defense, or as I call it, the Department of Death -- when I was a teenager it was officially known as the WAR Department) had deliberately introduced into GPS an error of up to 100 m (328 ft), known as "S.A.," "Selective Availability" (don't you love bureaucratic language?). This was done in order to foil our villainous enemies; talk about paranoia! But on 1 May 2000, Pres. Bill Clinton rescinded that margin of error, so that now the GPS receivers could get more accurate signals. 3rd, the receivers themselves had improved considerably in the intervening years.

My curiousity wanted to know more, e.g., what was being received? The Denver scientists didn't know but sent me material which did -- it is EMS (electromagnetic spectrum) microwaves of 1200-1500 MHz, i.e., waves of around around 30-40 cm in length (12-16 inches); your microwave oven has waves of about 4½ inches). Also, there are 3 levels of GPS accuracy. "C/A" (coarse acquisition) is what the hand-held receivers get. "P" (precision) is what the military use & is more accurate. Most accurate is "uncoded," which uses "P" without knowing the code but with special processors; professional surveyors use this with huge truck-borne GPS receivers costing $30,000.00 & which have an accuracy of 1 cm (0.4 inch)!

I also embarrassingly learned that the figure I'd been using for years in "SkyWatch" was off by a half mile in latitude, due to the fact that I'd added instead of subtracted! Even the lat figure from the arizona astronomers said so, but I didn't notice.

Whew! Egg all over my face.

> *It was a glorious bright day, I remember, fifty by the heliometer, but already the sun was sinking down into the...down among the dead.*

I wanted to know the real lat & long at TdeS, meaning I had to find out the margin of error of these GPS receivers. I borrowed a top-of-the-line Magellan GPS ColorTRAK Satellite Navigator (manufacturer's list price $580, available from Edmund Scientific for $360). The accompanying manufacturer's booklet, dated '97, claims a margin of error of 25m (82 ft), not counting (the now discontinued) S.A. I called local stores; one told me the margin of error was about 200 yards (600 ft), another that it was 100 ft, still another "a few feet" which I challenged leading him to change that to 25m, obviously remembering the booklet. Another source was an account of an Australian yacht race (of $1 mill + boats) which said their GPS margin of error was 20m (65½ ft).

I also borrowed an older Magellan GPS 300, retail price about $100.00, but found it too coarse for our purposes.

I tested the borrowed ColorTRAK GPS receiver at 5 Bench Marks around the county. BMs are brass disks permanently placed in rock or stable ground. & give great accuracy for lat, long, & alt. When I say "great accuracy," I mean it. 2 of the BMs I used had been measured in '98 & thereby improved their figures by 7 - 9 inches over the '92 measure!!!

The receiver I used gives lat & long in deg, min & sec, but if one keeps it stationary (not walking or on a boat), it also starts "averaging" the signals from the satellites, thereby giving lat & long also in deg & min only, the latter to 3 decimal figures). One should allow at least 7 minutes of averaging, which I always did, & the resulting figures should be more accurate. Also, the receiver should be placed so that it can receive signals from all around the horizon; if a wall, or a person, is in the way, it can't receive the necessary satellite signals.

The receiver was quite unreliable on alt, zooming around during averaging by more than100 feet with no pattern discernible except a tendency to get lower as the averaging went on. I wasn't surprised; the Arizona astronomers had given the alt at TdeS as 1135m ±76m (that's ±249 feet!).

Here are the results I obtained at the 5 BMs. I give the actual lat/long according to USGS quadrant statistics & then what my receiver said. The difference I give in feet is calculated using 101.67 ft per sec lat & 85.47 ft per sec long (at our lat). [I'll explain later how I arrived at these figures.] & so I myself don't commit the "spurious precision fallacy," I'll use rounded off numbers, obviating the need for margin of error. I've also converted the averaging figures from deg & min with decimals to deg, min & sec. Non-nit-pickers can skip the next 5 paragraphs & go directly to "Summary."

SDGPS 17 near Montgomery field:----

Actual -- 32° 49' 06.33421" N lat & 117° 08' 52.18823" W long.

My receiver --- 33 ft off in lat & 15.5 ft off in long. When averaging for 10 minutes, the long held steady at 117° 08' 52.2" (only 1 ft off!), but the lat went from 32° 49' 6.42" to 6.48" & 6.54" (the last figure is almost 21 ft off). The averaged figures are significantly better. {Actually, my friend did this one & reported the figures to me.}

SDGPS 23 on Cabrillo Point:----

Actual -- 32° 40' 19.97673" N lat & 117° 14' 25.91762" W long.

Mine --- 4+ft off in lat & 5 ft off in long. Averaging yielded 32° 40' 19.92" N (almost 6 ft off) & 117° 14' 25.92' W (2 ft off).

I did it again a half hour later & the averaging gave 20.1" N (8 ft off the 1st reading = 14 ft off BM) & 25.86" W (more than 5 ft E of 1st reading = 3 ft off BM). [See TOPO, below.]

SDPR 12 on the western edge of Borrego Springs:---

Actual -- 33° 15' 23.92883" N lat, 116°23' 57.33306" W long.

Mine --- 1+ ft off in lat, up to 28.5 ft off in long. Averaging for 7 minutes gave 33° 15' 24.12" N, then 24.06", 7+ ft off in lat, & 116° 23' 57.72" W which fluctuated down & back up finally to 57.3" (almost 3 ft off).

USGS 11AAR near PegLeg Monument 7 miles east of Borrego Springs:----

Actual -- 33° 17' 44.4742" N lat, 116°17' 54.78059" W long.

Mine -- 53+ ft off in lat & almost 19 ft off in long. Averaging gave 33° 17' 44.46" N, then 44.48", finally 44.58" (almost 11 ft off), & 116° 17' 54.72" W (5+ ft off). [See TOPO, below.]

SDGPS 31 -- 25 ft up a rock face on the S side of E bound I-8 past Jacumba (imagine me clambering up that!):---

Actual -- 32° 38' 01.66407" N lat, 116° 08' 59.31923" W long.

Mine --- 34 ft off in lat & 27.5 ft off in long. Averaging gave 32° 38' 1.8" N (almost 14 ft off) & 116° 08' 59.34" W (1.75 ft off).

Summary:--

Averaging usually gave better figures, but not always (see SDGPS 23, both averagings, & SDPR 12). & as SDGPS 23's 2 different readings show, the GPS can give different figures at different times (due to positioning of the satellites). This also happened at my house where I got readings in front & in back (separated by approx 80 ft in long) on 2 different days. The averaging was off on all 7 of the 8 figures, & once the GPS gave an entire additional sec in lat to my back yard.

> *It was a howling wild day, I remember, a hundred by the anemometer. The wind was tearing up the dead pines and sweeping them...away.*

My conclusion is that the top-of-the-line hand-held GPS receiver I was using has an average margin of error of at least ±1 sec in both lat & long, i.e., 100.67 ft lat & 85.47 ft long. Sure, it read closer than that at times, but farther at others. That's what margin of error is designed to take into account. When I told this to a USGS scientist at Denver, he expressed surprise at how small it was. Perhaps I was being too liberal.

On to Tierra del Sol. I arrived early afternoon of Sat., 23 Dec., a star party night, expecting to see people. No one was there, the gate was locked, & I had neglected to bring along the combination. Fortunately, the new "prison fence" had been built, in the process of which a neat path encircles the observing site. Before the $15K "boondoggle fence," no human could get within 200 yards of my Pad # 35 except through the front gate. Now, anyone can walk right up to it.

After climbing the fence, I took my GPS reading on my telescope pier at pad # 35. The initial reading in lat was 32° 37' 06" N which quickly changed to 07" & then to 36' 48", 47", 46" & 48". Meanwhile, in long I got 116° 20' 20" W, then 21", then 19' 56". Averaging gave 32° 36' 47.46"N, then 47.52", & 116° 19' 55.56" W, then 55.62" & 55.68".

With our determined margin of error, my GPS receiver thus gives the lat at my pier as 32° 36' 48" N & the long is 116° 19' 56"W.

It was an exceedingly dry day, I remember, zero by the hygrometer. Ideal weather, for my lumbago...

But I wasn't finished. There's the trusty USGS 7.5 min, 1:24000 maps. The O.B. library no longer had them, so I went to the main library downtown, where I made a happy discovery. The maps were not in a book as they had been at O.B., but were single sheets, & at least twice as large, making measurements much more precise. These must have been what the Arizona astronomers had in mind!

I was in 7th Heaven. With 50cm (c.18") ruler, magnifying glass & calculator in hand, I had 2 long lovely Sunday sessions with these maps, figuring not only the lat long & alt of TdeS, but of my house & trailer as well.

1st, alt. The contour lines are so clear & only 20 ft apart that extremely accurate results were obtained. The altitude at our observing site is 3700 ft at the entrance & 3710 ft at the west side of the bathroom, ±5 ft in both cases.

Each map has lat & long precisely indicated, plus a standard measuring rod of feet & meters.

I used my 50 cm ruler to measure each & found that 7000 ft = 89 mm; thus 1 mm + 78.65 ft.

Also, 2 min 30 sec of lat = 192 mm; thus 1 mm = 0.78 sec lat & 1 sec lat = 1.28 mm. That was how I figured 1 sec lat = 100.67 ft, agreeing well with my years earlier estimate of 101.2 ft. [See TOPO, below.]

2 min 30 sec of long = 163 mm; thus 1 mm = 0.92 sec long & 1 sec long = 1.09 mm. That was how I figured 1 sec long = 85.47 feet, agreeing well with my years earlier estimate of 86 ft. [See TOPO, below.]

I then proceeded to measure lat & long at TdeS. Again, I summarize my findings:

Entrance -- 32° 36' 49.2"N lat., & 116° 19' 59.1" W long.

Middle of west side of bathroom -- 32° 36' 48.1" N lat & 116° 19' 55.4" W long.

My pier -- 32° 36' 46.9" N lat (1" off from GPS above) & 116° 19' 52.6" W long (more than 3" off from GPS above).

I made an additional check on accuracy by actually measuring distances at Tde S with a 100 ft tape measure. The actual distance from the west fence to my pier at Pad # 35 is 550 feet; the distance as calculated on the map (using 1 mm + 78.65 ft; see above) is 540 feet. Thus, I give the margin of error for the above lat & long at TdeS as ±0.1", far superior to GPS.

Repeat: The most accurate determination of the bathroom at TdeS using the USGS 7.5' 1:24000 map is:

Lat -- 32° 36' 48" N ±0.1"
Long -- 116° 19' 55" W ±0.1"
Alt -- 3710 ft ±5

& this will henceforth be the figure I shall use in my "SkyWatch" column.

Now for TOPO, a computer program based on the USGS maps. As I implied, I'm a Komputer Klutz, so I depended on a friend who actually installed it on my computer but did all the work himself.

The TOPO figures for BM SDGPS 23 (see above) were off 1" in lat & 4" in long. The TOPO figures for USGS 11AAR (see above) were off almost 3.5" in lat & 5.78" in long. In determing the distance in feet of a degree of lat TOPO's figure for was 1" = 101.2 ft, exactly my original determination. But as we saw, the USGS map gives 100.67 ft, which is what I used. In long, TOPO gave 1" = 86.24 ft, while my original calculation was 86 ft. USGS map gives 85.47 ft, which is what I used. Thus, I conclude that TOPO is only barely as accurate as GPS but not nearly so accurate as the USGS map.

As for MapQuest & other such online sources, anyone who went to the SDAA banquet in January learned that the map to the Karl Strauss Beer Garden derived from MapQuest had a couple of major errors. So once again, I conclude that the Arizona Astronomers were right. The USGS map is the best available resource for alt, lat & long, short of hiring a professional surveyor with one of those $30,000.00 GPS receivers.

Thanks to friends David Fox & Stu Seymour for the use of their GPS receivers, to David Fox for TOPO, & to SDAA member Dennis Ritz for the use of his tape measure.

Thanks to Mike Montoya & Dale Benson, USGS Scientists in Denver for generous sharing of time, expertise & material, & for patiently answering all my uninformed questions.

Quotations are from Nobel Prize winner Samuel Beckett's play, Endgame (1958).