GPS Carrier Phase vs. TWSTFT

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The "GeTT Guys"

- Gerhard Beutler
- Rolf Dach
- Gregor Dudle
- Frederick Overney
- Leon Prost
- Thomas Schildknecht
- Tim Springer

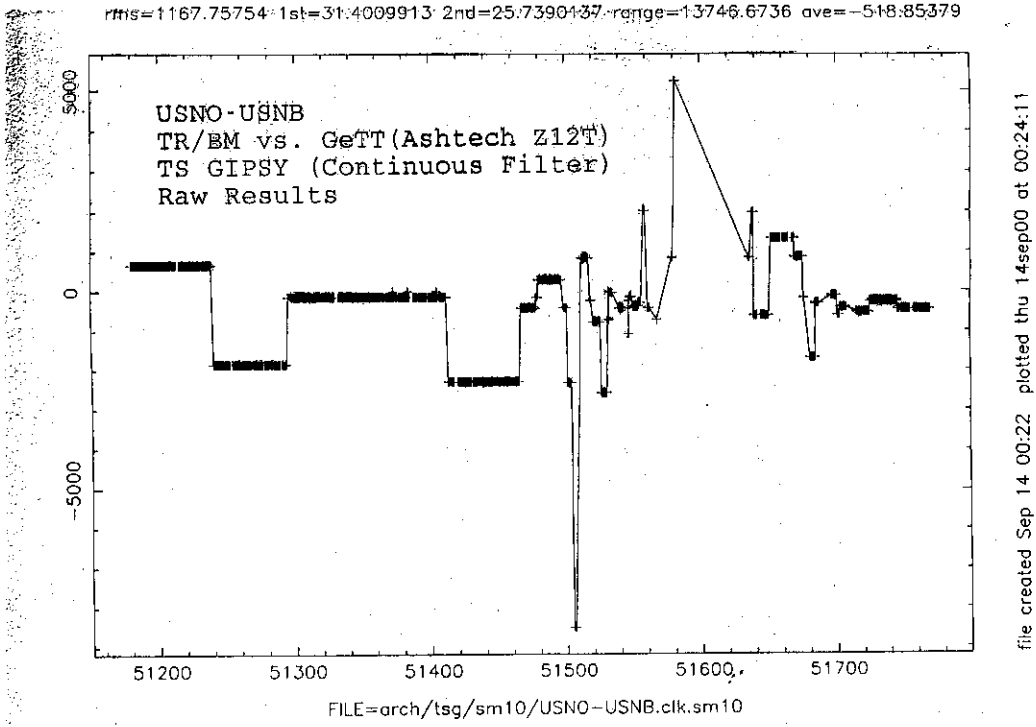
USNO Hardware: On Rebound

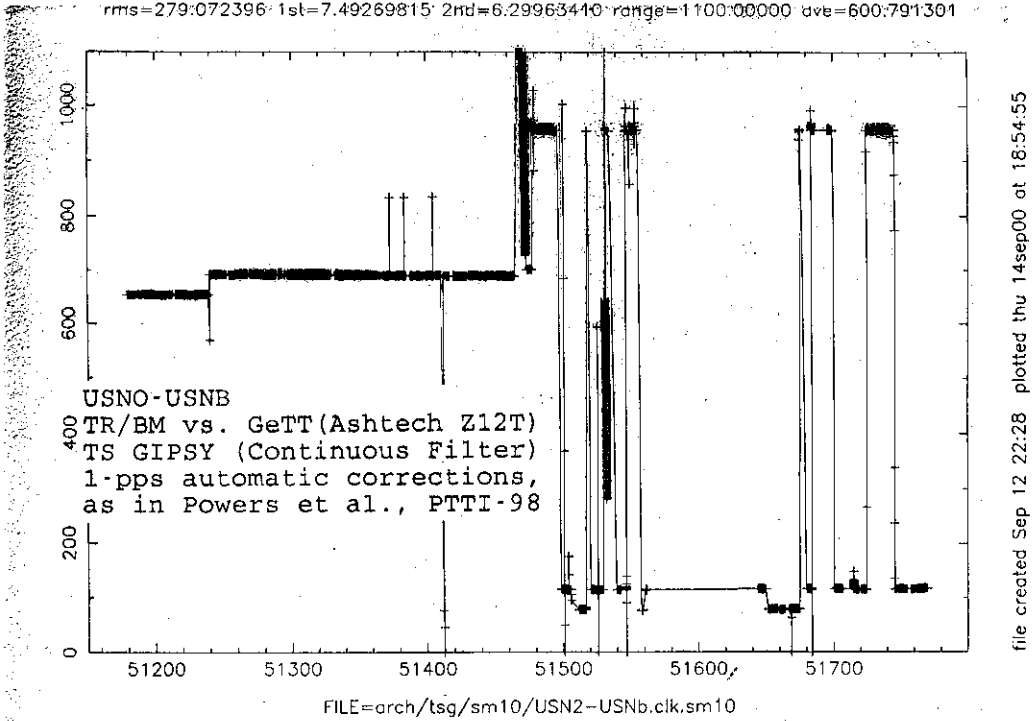
- TurboRogue to Benchmark conversion had problems

  but: "Powers Correction" being tested/developed,
  for "Roving Rogue" calibration and peace-of-mind

- TWSTT modems: tick-to-phase problem

  but: SATRE modems being installed


rms=1167.75754 1st=31.4009913 2nd=25.7390137 range=13746.6736 ave=-518.85379
USNO-USNB
TR/BM vs. GeTT(Ashtech Z12T)
TS GIPSY (Continuous Filter)
Raw Results
5000
0
-5000
51200
51300
51400
51500
51600
51700
FILE=arch/tsg/sm10/USNO-USNB.clk.sm10
file created Sep 14 00:22 plotted thu 14sep00 at 00:24:11


rms=279.072396 1st=7.49269815 2nd=6.29963410 range=1100.00000 ave=600.791301
USNO-USNB
TR/BM vs. GeTT(Ashtech Z12T)
TS GIPSY (Continuous Filter)
1-pps automatic corrections,
as in Powers et al., PTTI-98
0
200
400
600
800
1000
51200
51300
51400
51500
51600
51700
FILE=arch/tsg/sm10/USN2-USNb.clk.sm10
file created Sep 12 22:28 plotted thu 14sep00 at 18:54:55

OUTLINE/SUMMARY

- Zero Baseline: Ashtech Z-12/ Z-12T's can walk 8 ns. Even the GeTT may have jumped 3 ns recently.
- Short Baseline: TurboRogue/Benchmarks and TWSTT can walk 3 ns.
- USNO-AMC: Carrier Phase can walk 7 ns.
- USNO-Europe: Ashtech Z12 moved 10 ns.
- Diurnal Terms: Carrier Phase: .1 – .4 ns p/p, TWSTT: .4-.8 ns p/p
- Consistency Checks: Carrier Phase Analysis Noise: 1 ns p/p
  TWSTT Closure: <.2 ns RMS

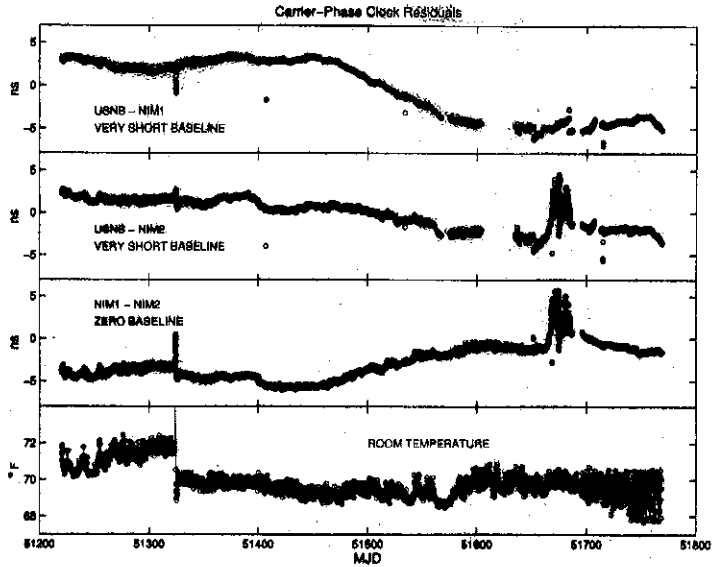
Zero Baseline Data

- Two NIMA Aschtech Z12's in same rack, with same antenna, and common clock.. Temperature usually within 2 deg C.

- GeTT (Aschtech Z12T) adjacent to them

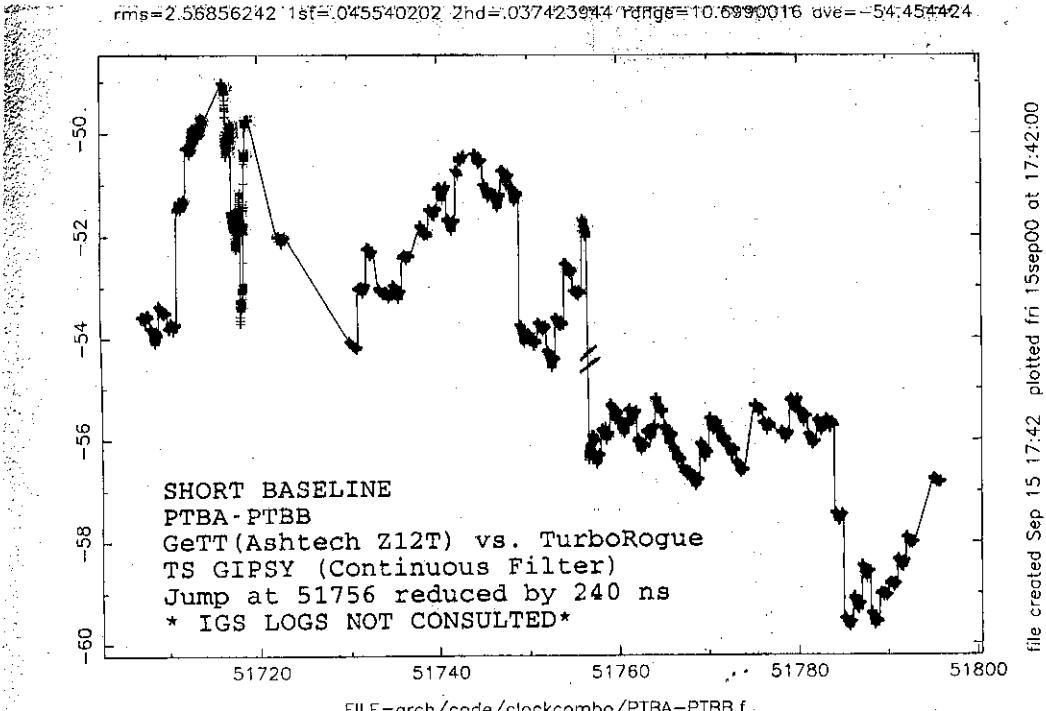
SHORT BASELINE — 95m

(USNO bldg78 bldg52)



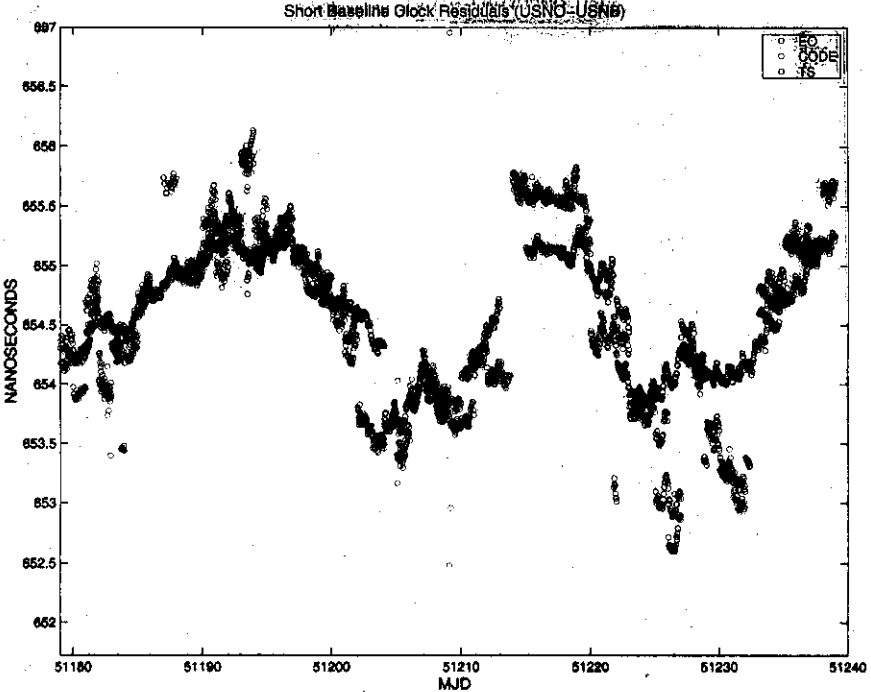
Short Baseline Data

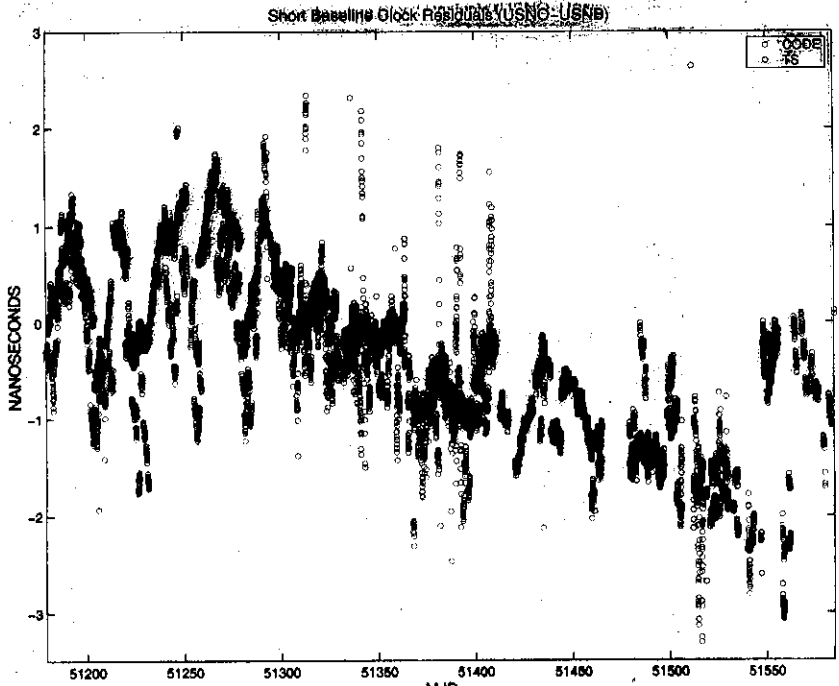
- PTBA vs. PTBB – inferences without logs
- USNO vs. USNB - in nearby buildings.
  Clock difference known to <1 ns p/p


rms=2.56856242 1st=.045540202 2nd=.037423944 range=10.6990016 ave=-54.454424
-50
-52
-54
-56
-58
-60
51720
51740
51760
51780
51800
SHORT BASELINE
PTBA-PTBB
GeTT(Ashtech Z12T) vs. TurboRogue
TS GIPSY (Continuous Filter)
Jump at 51756 reduced by 240 ns
* IGS LOGS NOT CONSULTED*
file created Sep 15 17:42 plotted fri 15sep00 at 17:42:00
FILE=arch/code/clockcombo/PTBA-PTBB.f

Day-Boundary Problem

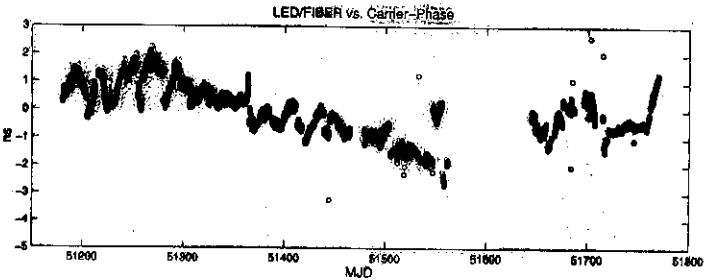
- Wonderful precision of IGS carrier phase obscured by 400 ps (best case) jumps at UT-midnight.
- Due to discarding Kalman filter values for ambiguities, atmosphere, etc. and fixed by "Continuous Filtering" (Senior et al, PTTI-99, but already done by many who didn't bother to publish).
- Risk: systematic analysis errors may propagate.
  (In which case you steer CF to old-style solutions)
- Use "Ground-truth" to assess techniques.

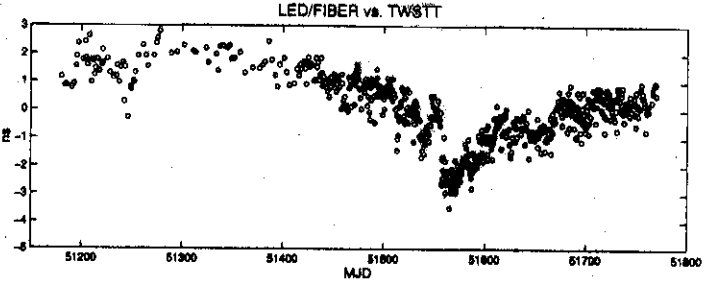

Short Baseline Clock Residuals (USNO - USNO)
EO
CODE
NANOSECONDS
MJD
657
656.5
656
655.5
655
654.5
654
653.5
653
652.5
652
51180
51190
51200
51210
51220
51230
51240


Short Baseline Clock Residuals (USNO - USNB)
CODE
FS
NANOSECONDS
MJD
3
2
1
0
-1
-2
-3
51200
51250
51300
51350
51400
51450
51500
51550

SHORT BASELINE — 95m

(USNO bldg78 bldg52)

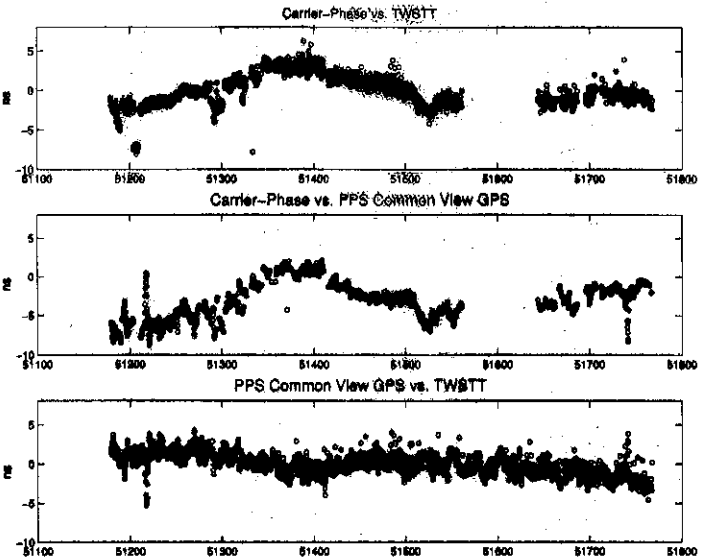




USNO-AMC

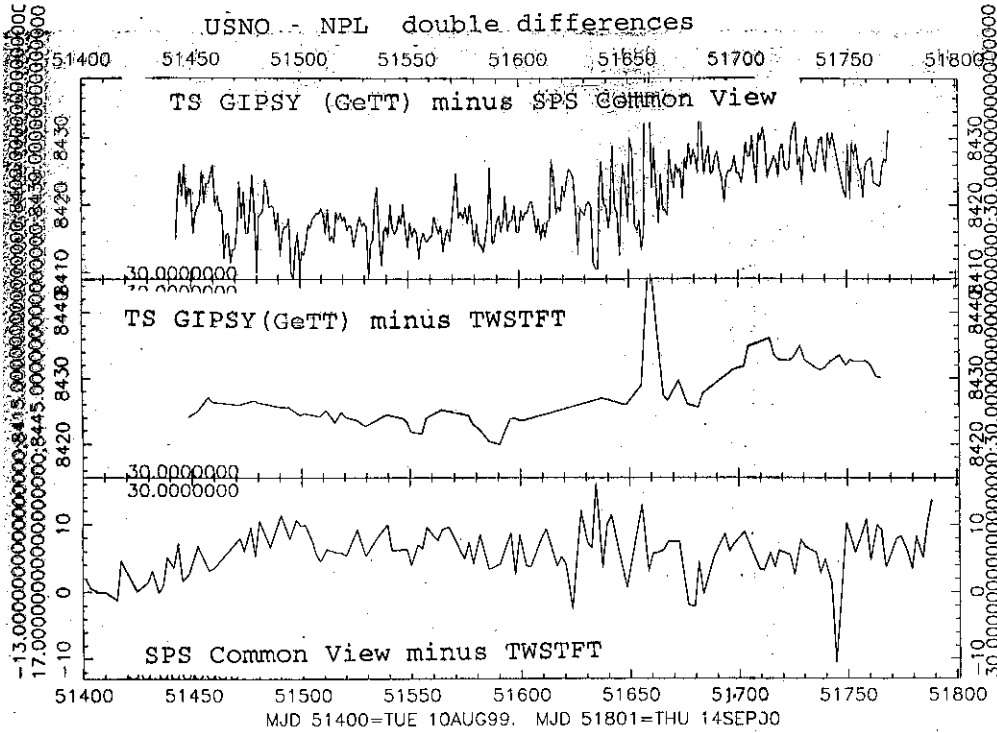
- TurboRogue/Benchmark at AMC
- Kristine Larsen's data are earlier
- Common View agrees more with TWSTT than with Carrier Phase

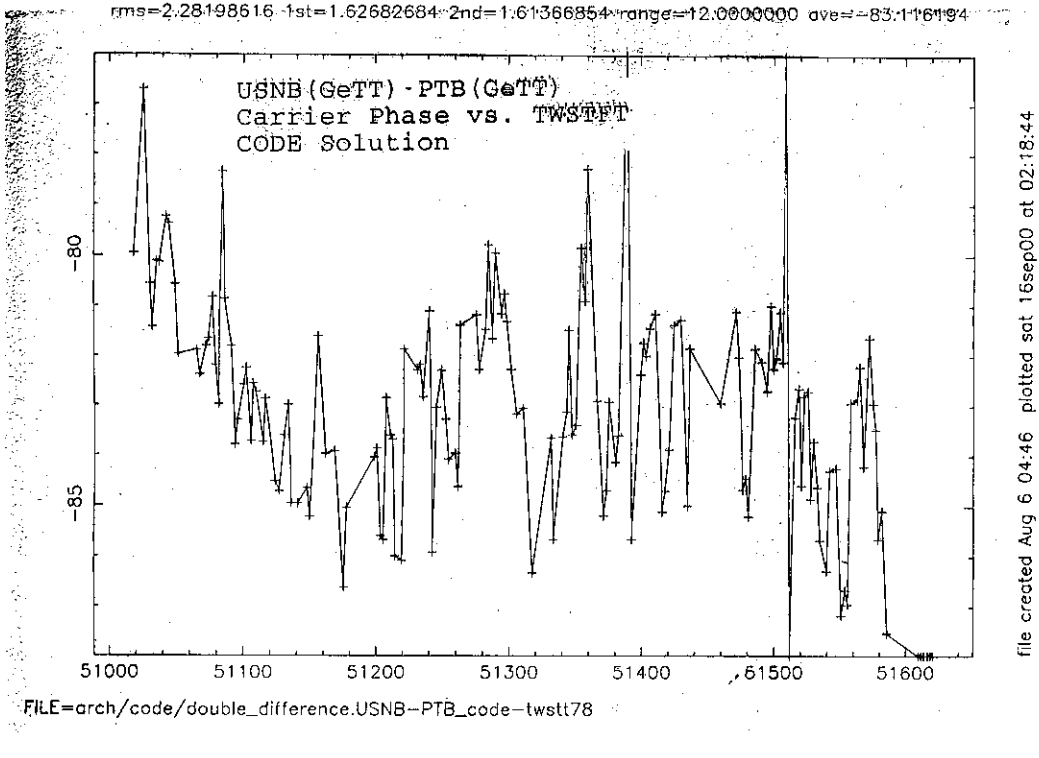
CONTINENTAL BASELINE—2500km *(USNO-AMC)*

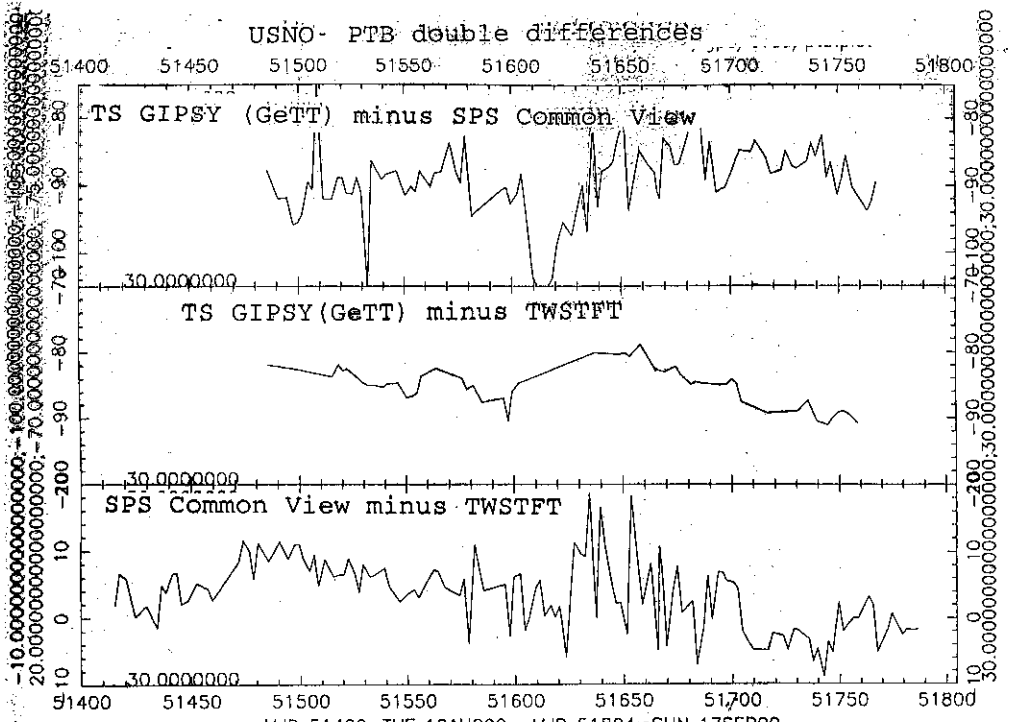


USNO to NPL and PTB

- NPL shows recent 10-ns jump in Carrier Phase vs. both TWSTT and Common View
- PTB shows TWSTT as "odd-man out"


USNO - NPL double differences
51400
51450
51500
51550
51600
51650
51700
51750
51800
TS GIPSY (GeTT) minus SPS Common View
8410
8420
8430
TS GIPSY(GeTT) minus TWSTFT
8440
8445
SPS Common View minus TWSTFT
-10
0
10
MJD 51400=TUE 10AUG99. MJD 51801=THU 14SEP00


rms=2.28198616 1st=1.62682684 2nd=1.61366854 range=12.0000000 ave=-83.1116194
USNB(GeTT) - PTB(GeTT)
Carrier Phase vs. TWSTFT
CODE Solution
-80
-85
51000
51100
51200
51300
51400
51500
51600
FILE=arch/code/double_difference.USNB-PTB_code-twstt78
file created Aug 6 04:46 plotted sat 16sep00 at 02:18:44


USNO- PTB double differences
51400
51450
51500
51550
51600
51650
51700
51750
51800
TS GIPSY (GeTT) minus SPS Common View
30.0000000
TS GIPSY(GeTT) minus TWSTFT
30.0000000
SPS Common View minus TWSTFT
30.0000000
MJD 51400=TUE 10AUG99. MJD 51804=SUN 17SEP00

Diurnal Terms

- Often worse in summer
- Larger diurnals probably due to bad cabling
- Carrier Phase: .1 – 1 ns peak/peak

  1 ns: HOB2, HRAO, MATE

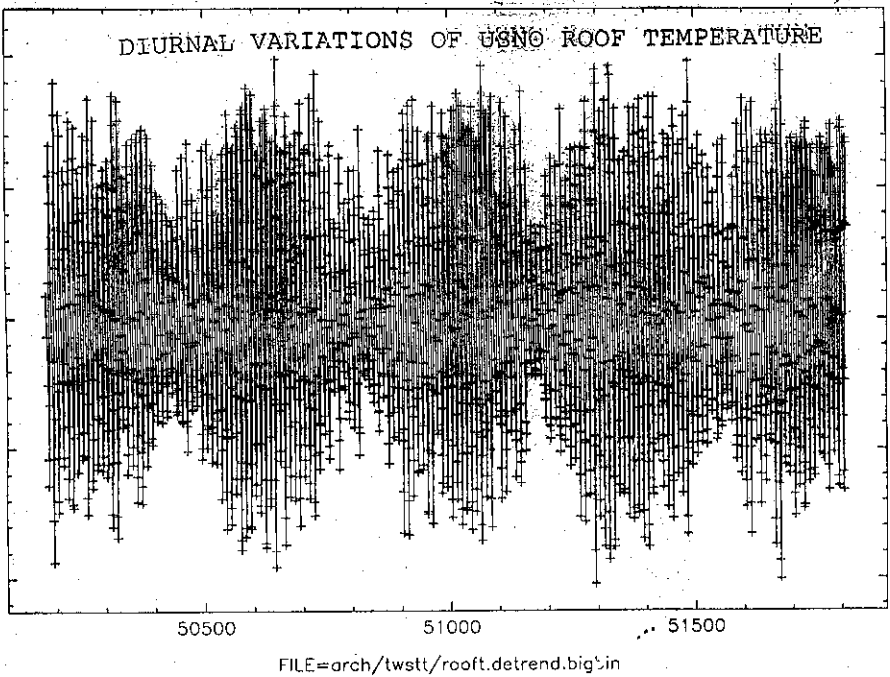
  .5 ns: PTBA,KOKB, NLIB,DRAO,GODE,FAIR?

  <.5 ns: ALGO, AMC2, PIE1,USNB, NRC1?
- USNO-AMC TWSTT: .6 ns p/p in summer
- Short-BL TWTT: .4-.8 ns p/p not seasonal

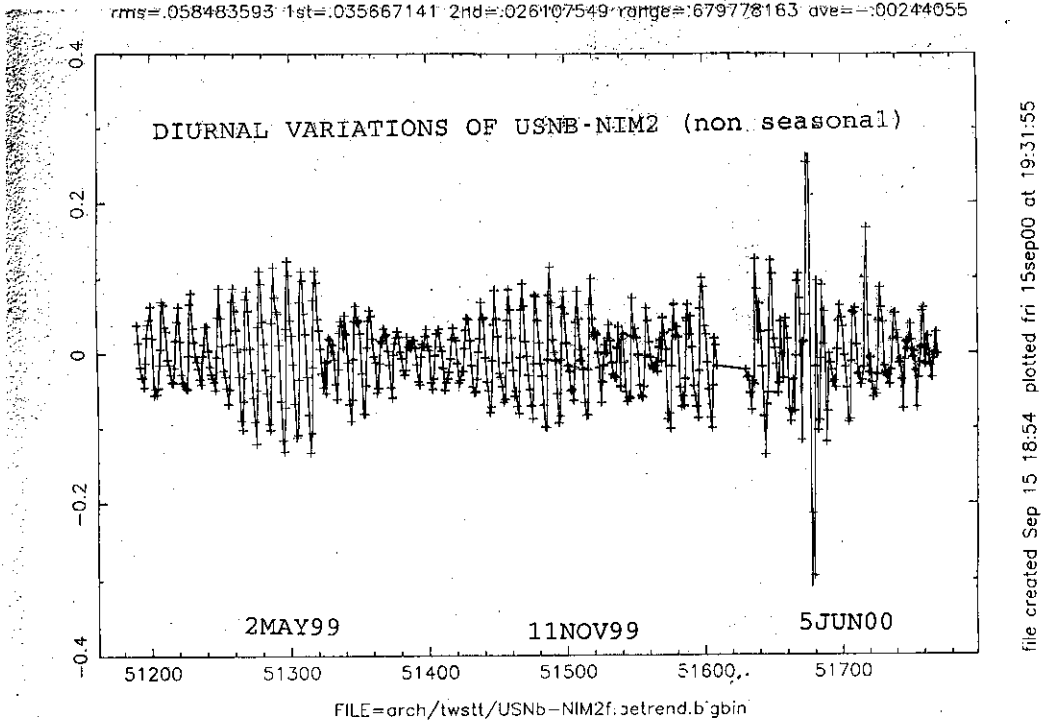
Diurnal Plots: How I made them

- Detrend data by subtracting 24-hour average from each point (12 hours before and after).
- What remains is the diurnal term (daily variation)
- Average the diurnal terms in 10-day batches.
- Plot the average diurnal term from MJD 50000 to 50010 as data from 50000 to 50010
    - 50000.0 is average detrended value at UT 0:00, 50000-50010
    - 50002.5 is average detrended value at UT 6:00, 50000-50010
    - 50005.0 is average detrended value at UT 12:00, 50000-50010
    - 50007.5 is average detrended value at UT 18:00, 50000-50010
    - 50010.0 is average detrended value at UT 0:00, 50010-50020

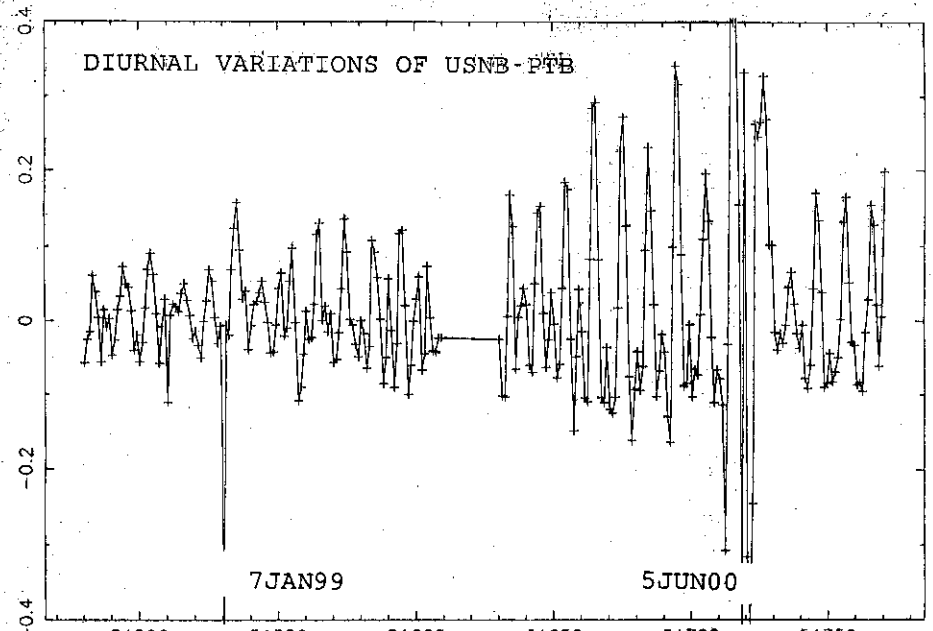
rms=4.65226656 1st=2.17416854 2nd=1.00109242 range=20.9680266 ave=-.01333777



file created Sep 15 18:45 plotted fri 15sep00 at 19:31:55

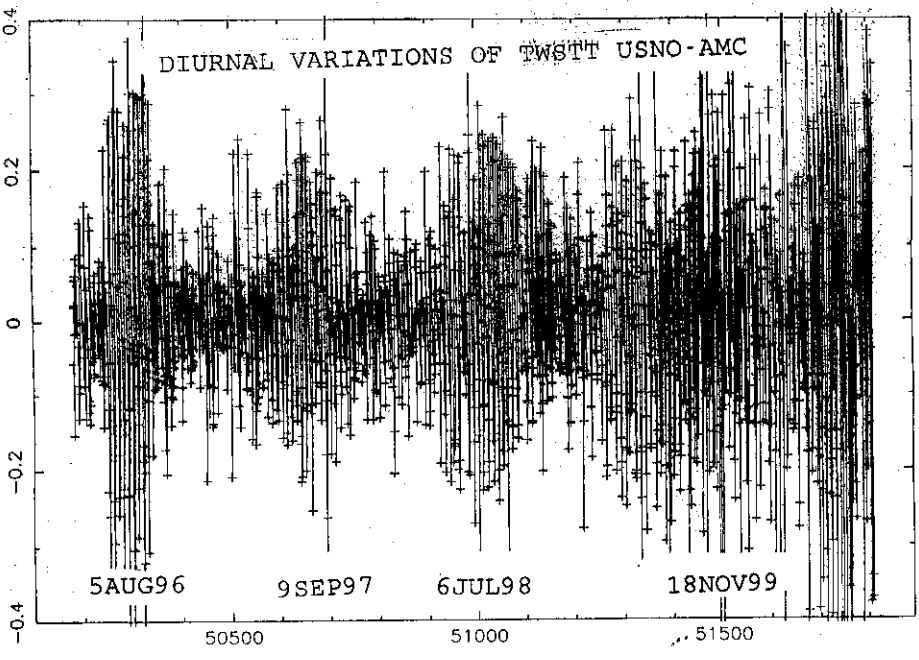

rms=.058483593 1st=.035667141 2nd=.026107549 range=.679778163 ave=-.00244055
DIURNAL VARIATIONS OF USNB-NIM2 (non seasonal)
0.4
0.2
0
-0.2
-0.4
2MAY99
11NOV99
5JUN00
51200
51300
51400
51500
51600
51700
FILE=arch/twstt/USNb-NIM2f.detrend.bigbin
file created Sep 15 18:54 plotted fri 15sep00 at 19:31:55

rms=.115021955 1st=.084281397 2nd=.071147261 range=.800000000 ave=.011906113

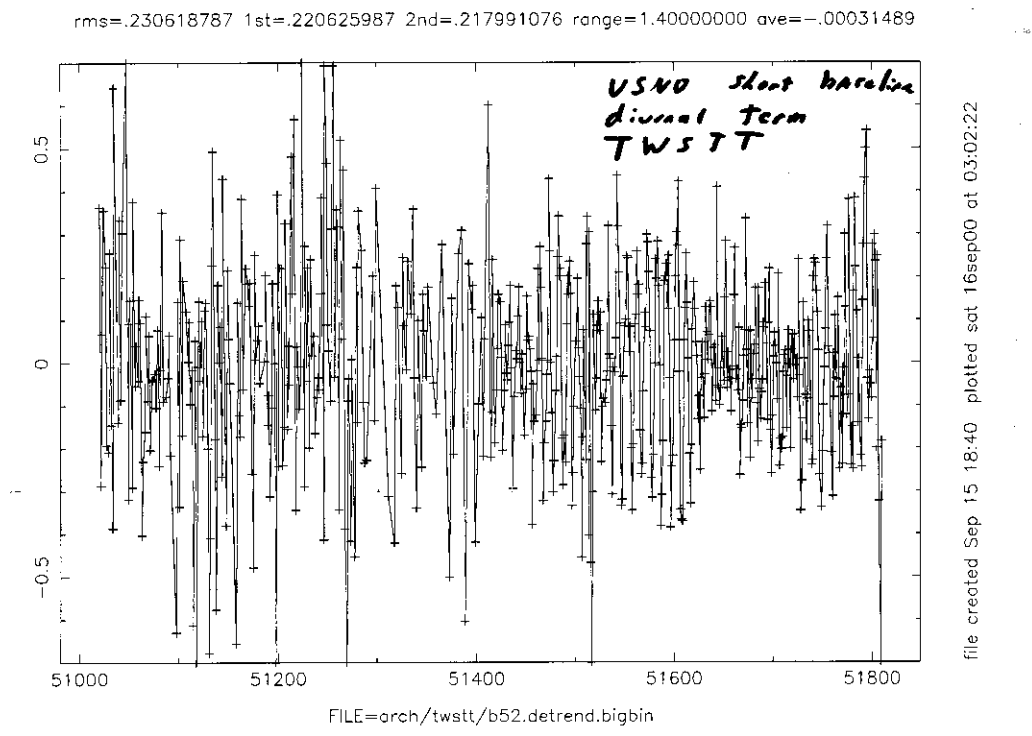


file created Sep 15 18:57 plotted fri 15sep00 at 19:31:55

rms=.143742802 1st=.120473002 2nd=.112234442 range=.800000000 ave=.003700881



file created Sep 15 18:33 plotted Fri 15sep00 at 19:31:44

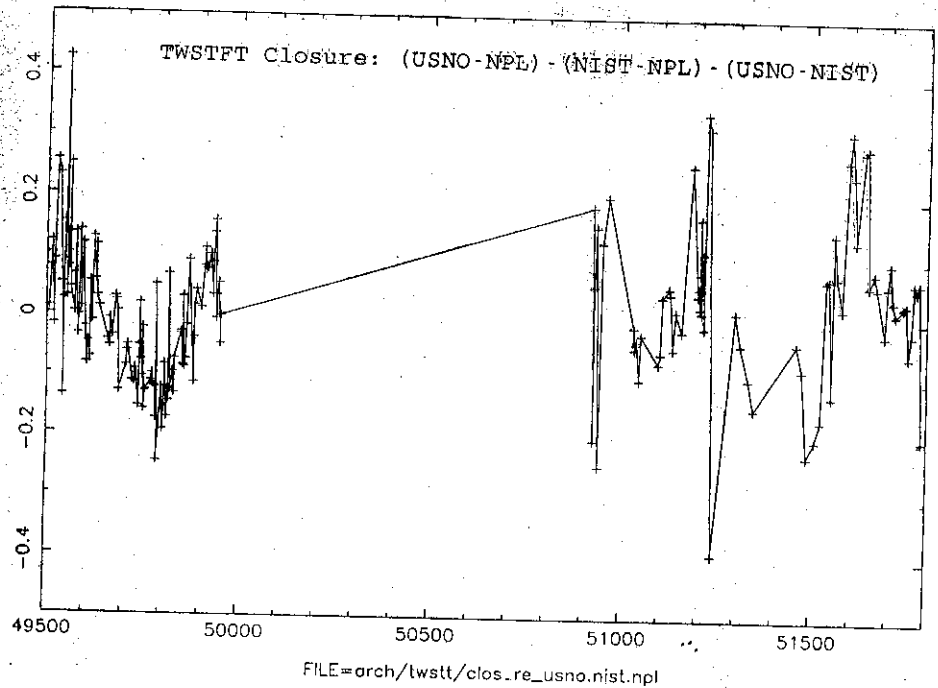

rms=.230618787 1st=.220625987 2nd=.217991076 range=1.40000000 ave=-.00031489
USNO short baseline
diurnal term
TWSTT
0.5
0
-0.5
51000
51200
51400
51600
51800
FILE=arch/twstt/b52.detrend.bigbin
file created Sep 15 18:40 plotted sat 16sep00 at 03:02:22

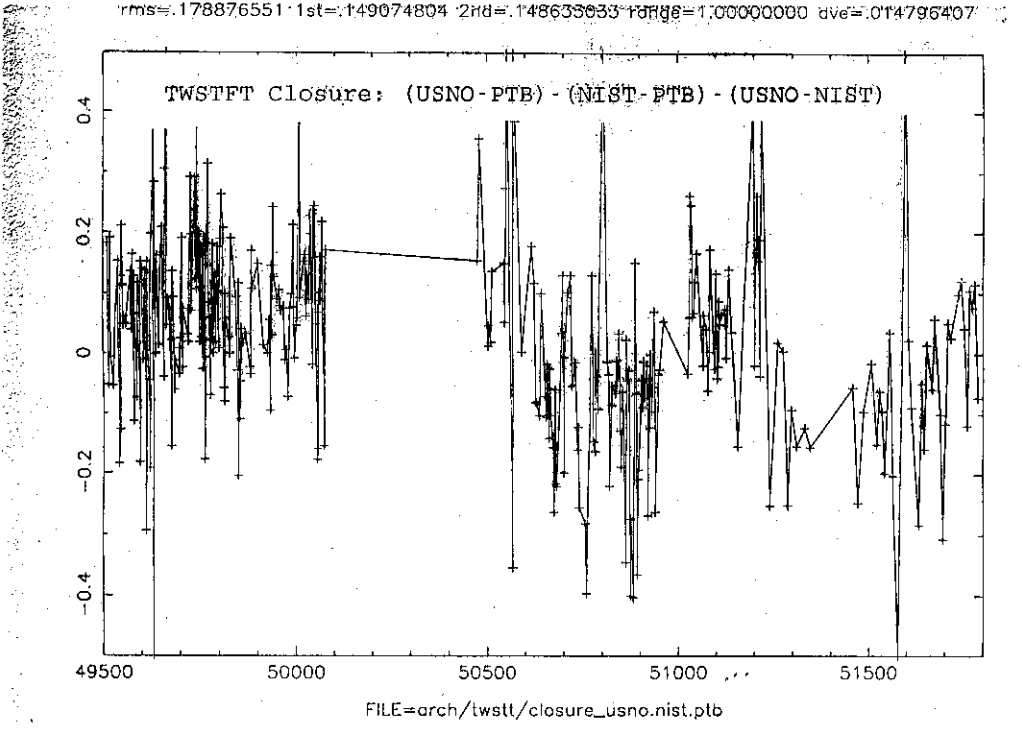
Diurnals – Eyeball Values
USNB (GeTT) is reference

- PTBA .4 ns summer, .3 ns winter
- NPL .4 ns (before recent cable upgrade)
- NIM1 was .2 ns summer, .1 ns winter (before upgrade)
- NIM2 was .2-.4 ns; now less (before upgrade)
- USNO .3 ns summer, .2 ns winter
- AMC .1 ns?
- TWSTT short baseline: <.4-.8 ns, not seasonal
- TWSTT USNO-AMC .8 ns summer, .4 ns winter
- LED-FIBER .06 ns

TWSTFT Closure

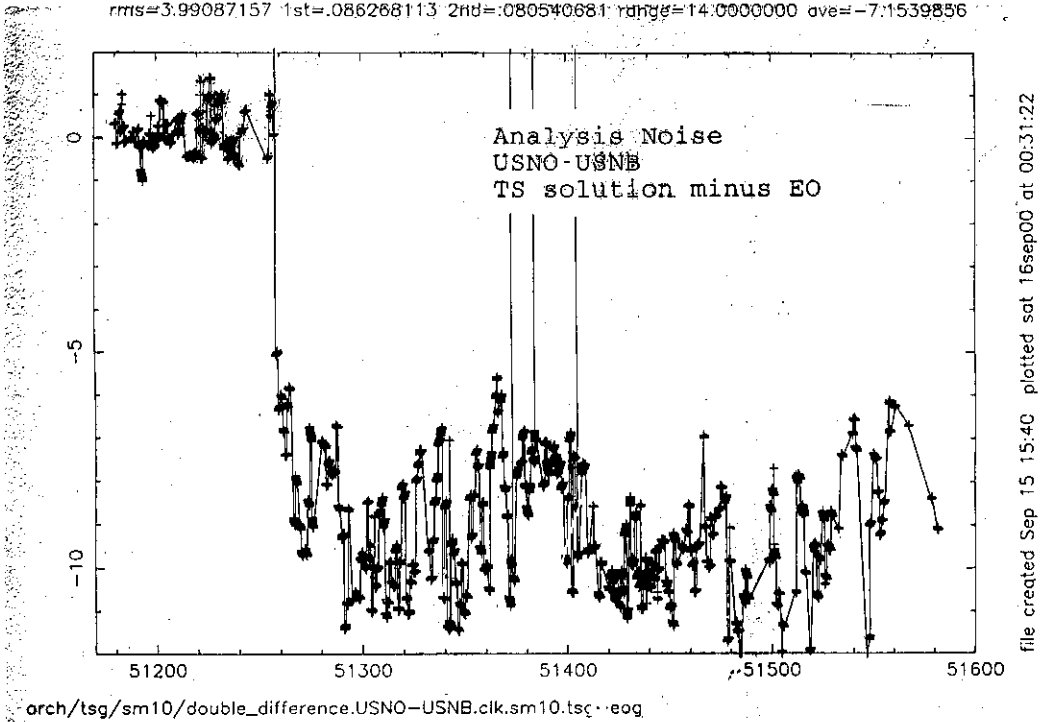
- Wednesdays only, since May, 1994
- USNO-Europe and NIST-Europe simultaneous, using INTELSAT satellite
- USNO-NIST , 3 hours later, with SBS-3 satellite
- .16 ns RMS using NPL
  .22 ns RMS using PTB


rms=.122469692 1st=.096715890 2nd=.094711610 range=.815999999 ave=.008111731
TWSTFT Closure: (USNO-NPL) - (NIST-NPL) - (USNO-NIST)
0.4
0.2
0
-0.2
-0.4
49500
50000
50500
51000
51500
FILE=arch/twstt/clos_re_usno.nist.npl
file created Sep 15 12:24 plotted fri 15sep00 at 21:49:22


rms=.178876551 1st=.149074804 2nd=.148633033 range=1.00000000 dve=.014796407
TWSTFT Closure: (USNO-PTB) - (NIST-PTB) - (USNO-NIST)
0.4
0.2
0
-0.2
-0.4
49500
50000
50500
51000
51500
FILE=arch/twstt/closure_usno.nist.ptb
file created Sep 15 12:24 plotted Fri 15sep00 at 21:49:00

Carrier Phase Analysis Noise

- Three Reductions: CODE, EO, TS
- CODE-EO: ~ 1 ns peak-to-peak
- TS – CODE, TS-EOG 2-3 ns peak-to-peak
- USNO-AMC similar to USNO-USNB


rms=3.99087157 1st=.086268113 2nd=.080540681 range=14.0000000 ave=-7.1539856
Analysis Noise
USNO-USNB
TS solution minus EO
0
-5
-10
51200
51300
51400
51500
51600
file created Sep 15 15:40 plotted sat 16sep00 at 00:31:22
arch/tsg/sm10/double_difference.USNO-USNB.clk.sm10.tsq - eog

Atmosphere and Orbit Errors

- Based on one site (AMC), and one day
- Lanyi vs. Neill jump AMC clock 10 ps
- Broadcast vs. rapid: up to 3 ns
- Rapid vs. Final: .5 ns bias

WAAS for Time Transfer

Satellites at fixed position, so

- Can use directional antenna
  - harder to jam
- Can use high-gain antenna
  - more signal to noise
- Continuous coverage
  - carrier-phase simplified
- Steered to GPS time, UTC (USNO)
  - excellent backup potential

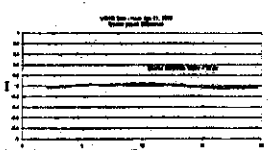
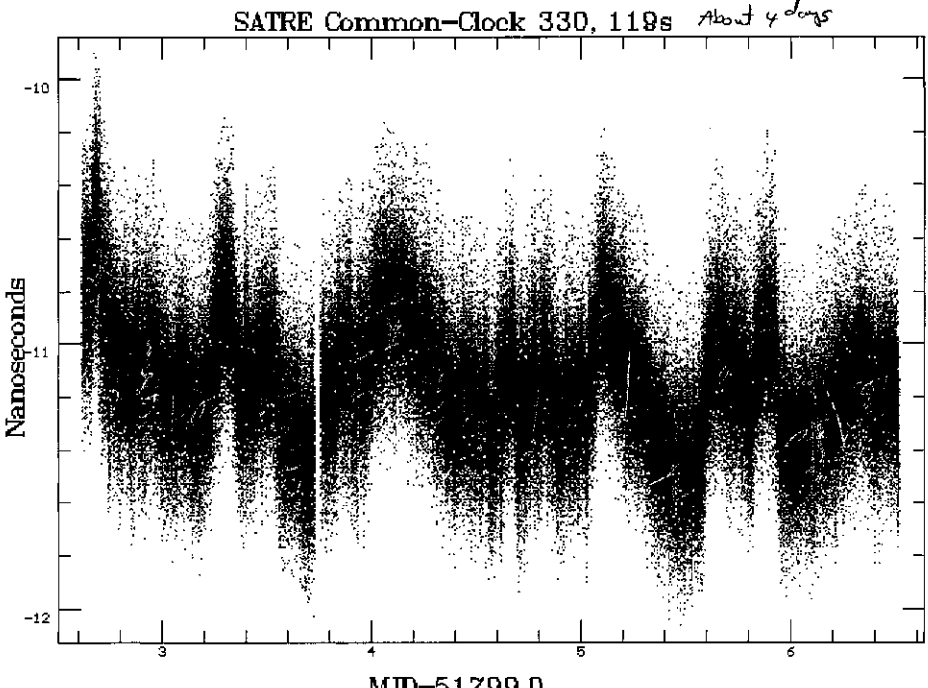
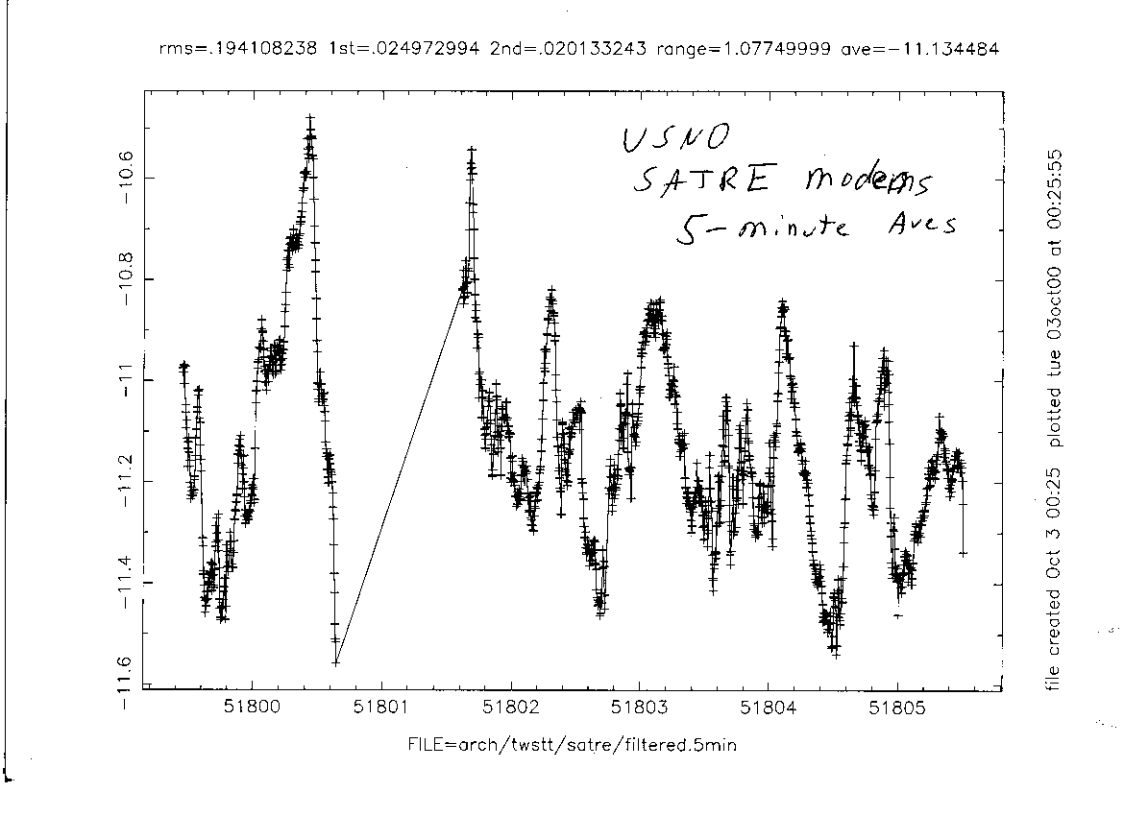
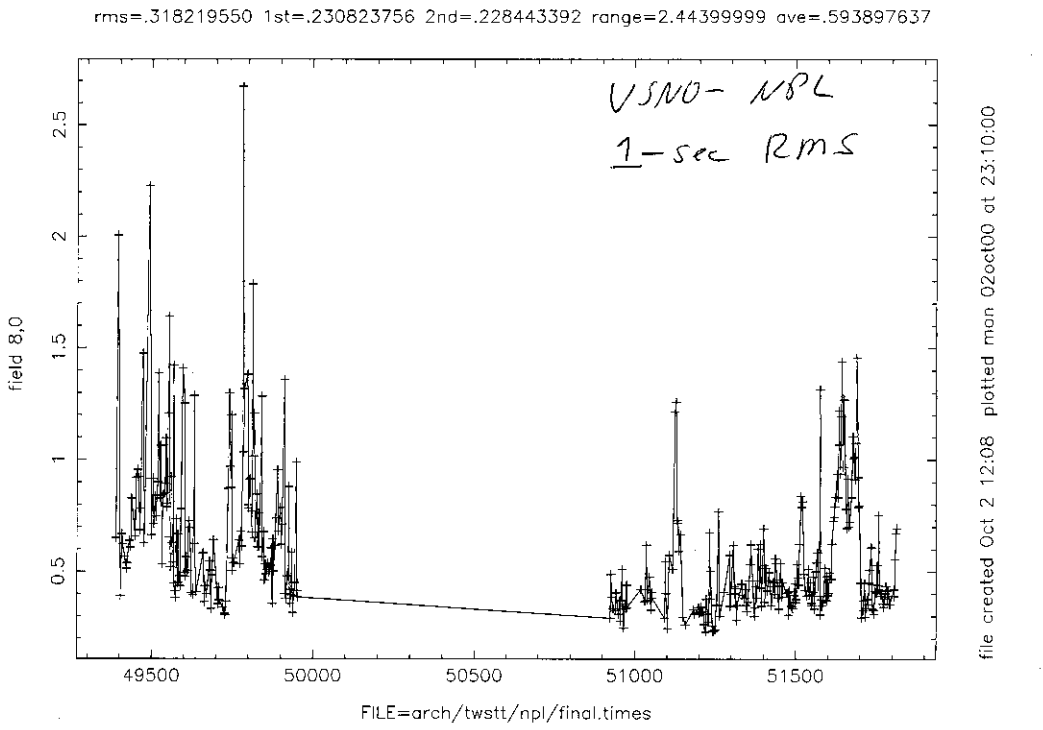


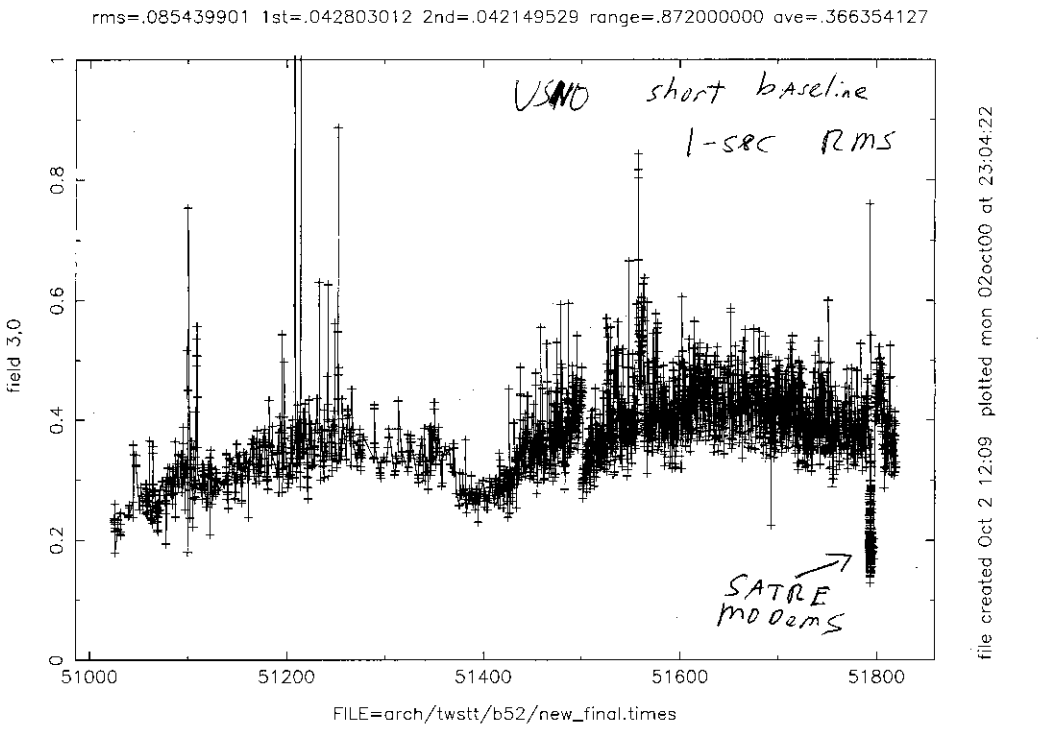
Figure 8 of Fenton et al, ION-NTM, January, 2000

/usr/opt/tempo/satre/data/filter6.out

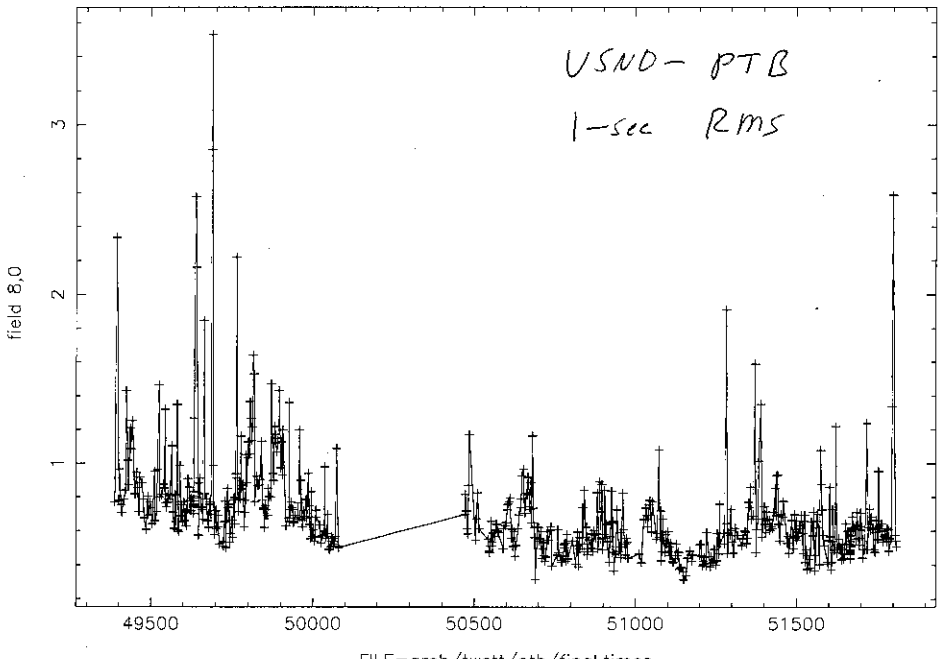



rms=.194108238 1st=.024972994 2nd=.020133243 range=1.07749999 ave=-11.134484
USNO
SATRE modems
5-minute Aves
-10.6
-10.8
-11
-11.2
-11.4
-11.6
51800
51801
51802
51803
51804
51805
FILE=arch/twstt/satre/filtered.5min
file created Oct 3 00:25 plotted tue 03oct00 at 00:25:55

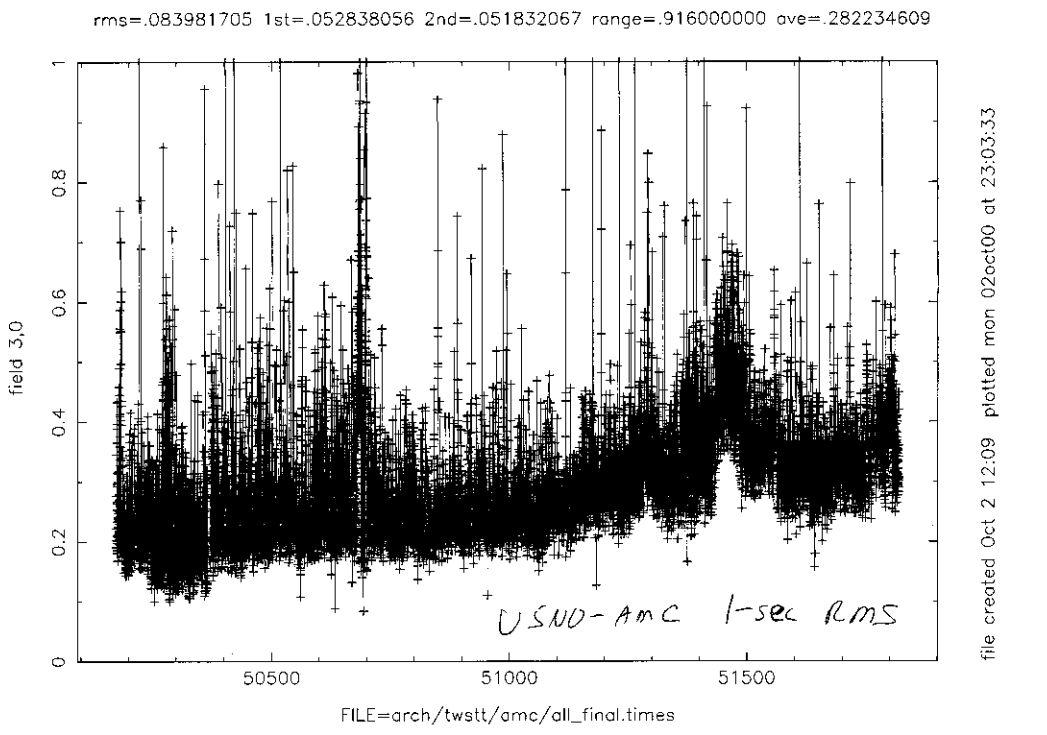

rms=.318219550 1st=.230823756 2nd=.228443392 range=2.44399999 ave=.593897637
USNO- NPL
1-sec RMS
field 8,0
0.5
1
1.5
2
2.5
49500
50000
50500
51000
51500
FILE=arch/twstt/npl/final.times
file created Oct 2 12:08 plotted mon 02oct00 at 23:10:00


rms=.085439901 1st=.042803012 2nd=.042149529 range=.872000000 ave=.366354127
VLNO short baseline
1-sec rms
SATRE
moderns
field 3,0
0
0.2
0.4
0.6
0.8
1
51000
51200
51400
51600
51800
FILE=arch/twstt/b52/new_final.times
file created Oct 2 12:09 plotted mon 02oct00 at 23:04:22

rms=.303433261 1st=.221101295 2nd=.204201680 range=3.21799999 ave=.695127591



file created Oct 2 12:08 plotted mon 02oct00 at 23:10:11


rms=.083981705 1st=.052838056 2nd=.051832067 range=.916000000 ave=.282234609
field 3,0
0
0.2
0.4
0.6
0.8
1
50500
51000
51500
FILE=arch/twstt/amc/all_final.times
USNO-AMC 1-sec RMS
file created Oct 2 12:09 plotted mon 02oct00 at 23:03:33

UNO SATRE MODEMS

Temperature testing next!