Survey-mode measurements and analysis

T. A. Herring[1] M. A. Floyd[1] M. Perry[2]
[1]*Massachusetts Institute of Technology, Cambridge, MA, USA*
[2]*University of Montana, Missoula, MT, USA*

GPS Data Processing and Analysis with GAMIT/GLOBK and `track`
Hotel Soluxe, Bishkek, Kyrgyzstan
2–7 July 2018

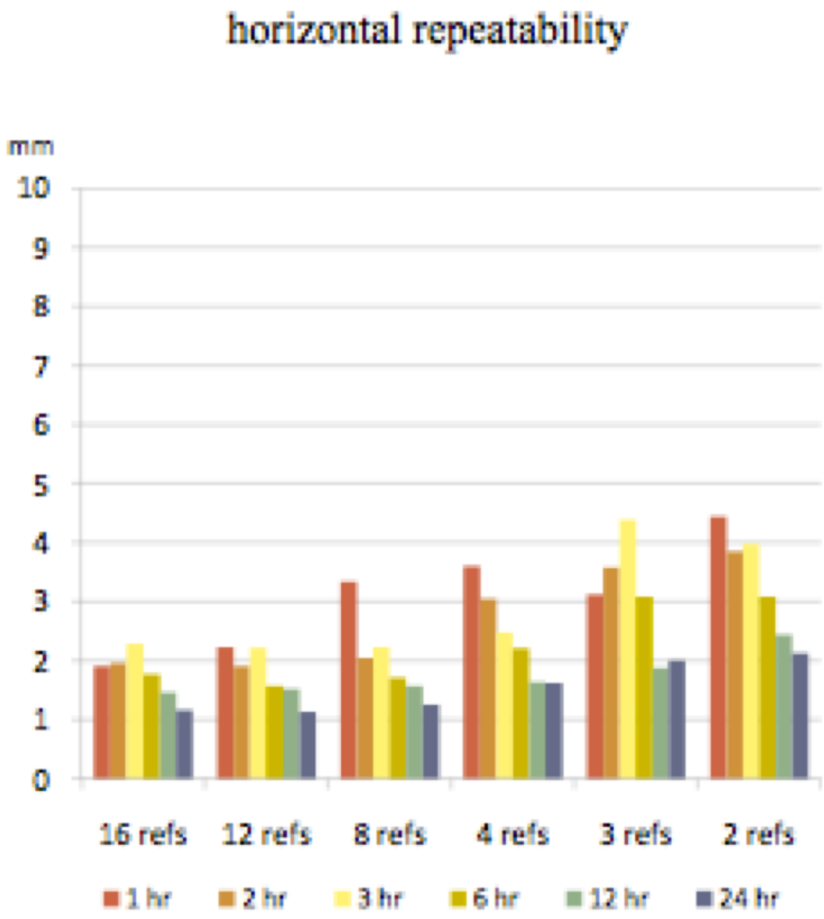
http://geoweb.mit.edu/~floyd/courses/gg/201807_Bishkek/

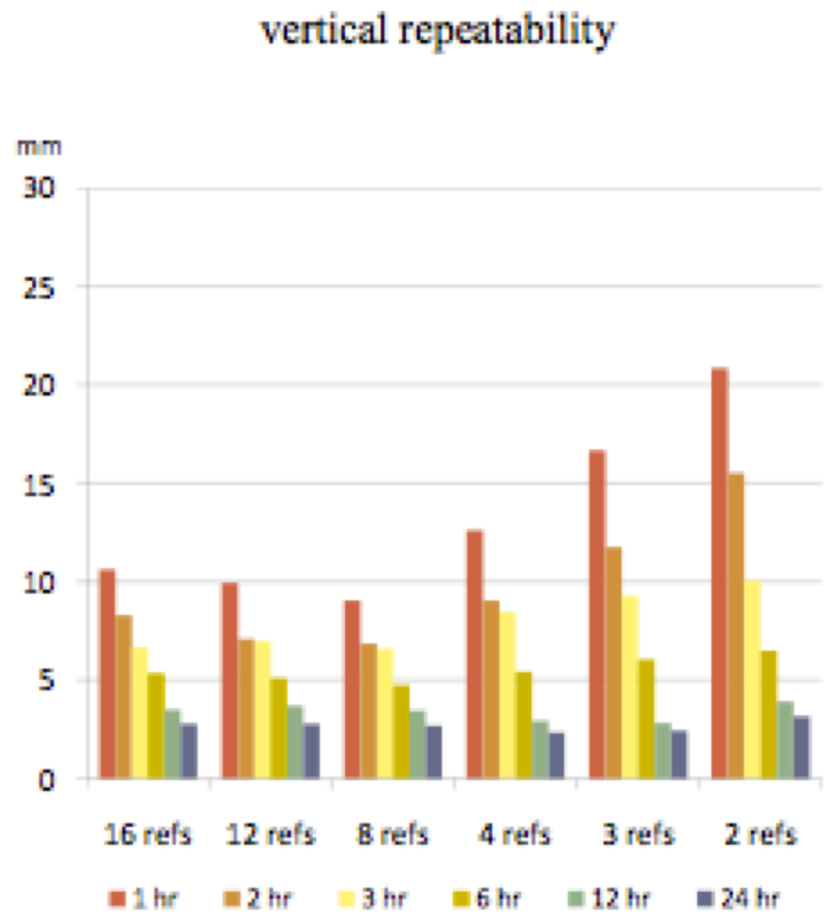
Material from R. W. King, T. A. Herring, M. A. Floyd (MIT) and S. C. McClusky (now at ANU)

Measurement strategies I
Occupation time

- Given time and personnel constraints, what are the trade-offs between between spatial and temporal density?
- Ideally, you would like for the white noise position uncertainty for an occupation to contribute to the velocity uncertainty at a level less than the usually dominant long-period correlated noise
- Typical white noise uncertainties (horizontal and vertical) as a function of occupation time are:
  - 6–8 hrs: 2–2.5 mm (H), 5–10 mm (V)
  - 12–24 hrs: 1.0–1.5 mm (H), 3–5 mm (V)
  - 36–48-hrs: 0.7–1.0 mm (H), 2–4 mm (V)
- Observations over 3 or more days will give you more redundancy
- Observations of 5 or more days will be necessary for mm-level vertical uncertainties
- If your region has few continuous stations, you should consider running one or two survey-mode stations for the entire time of the survey to provide continuity

Precision v session length for network processing





Measurement strategies II
Monuments and instrumentation

- Issues in site and antenna selection:
  - Monument identification
  - Monument stability
  - Accessibility
  - Ease of setup
  - Multipath
  - Log (metadata) errors
  - Vandalism
- There is no clear prescription for all cases

Let's look at some examples…

Three primary mounting options

Spike mount

Site VELA in the Soloman Islands.

Tech 2000 kit.

Mast

Tripod with optical or physical plummet

Courtesy UNAVCO web page

Surveyor's tripod

- Advantages:
  - Easily portable
  - Stable on flat ground
- Disadvantages:
  - Inconsistent height setup (variable multipath)
  - Easily disturbed

http://facility.unavco.org

Fixed-height mast (e.g. Tech2000)

- Advantages:
  - Automatically centered
  - Fixed height (reduces human error)
  - Stable
  - Identical multipath environment each setup
- Disadvantages:
  - Difficult first-time placement due to anchor installation (also requires large, hard surface)

http://facility.unavco.org

Spike mounts

- Advantages:
  - Fixed height
  - Low height reduces horizontal centering inaccuracy if slightly off level
  - Easily hidden from vandals
- Disadvantages:
  - Awkward to level precisely and orientate antenna
  - Proximity to ground may increase direct multipath signal

http://facility.unavco.org

Examples of survey marks

Site identification errors

Photograph by M. Floyd

Photograph by M. Floyd

Photograph by M. Floyd

Antenna setup errors

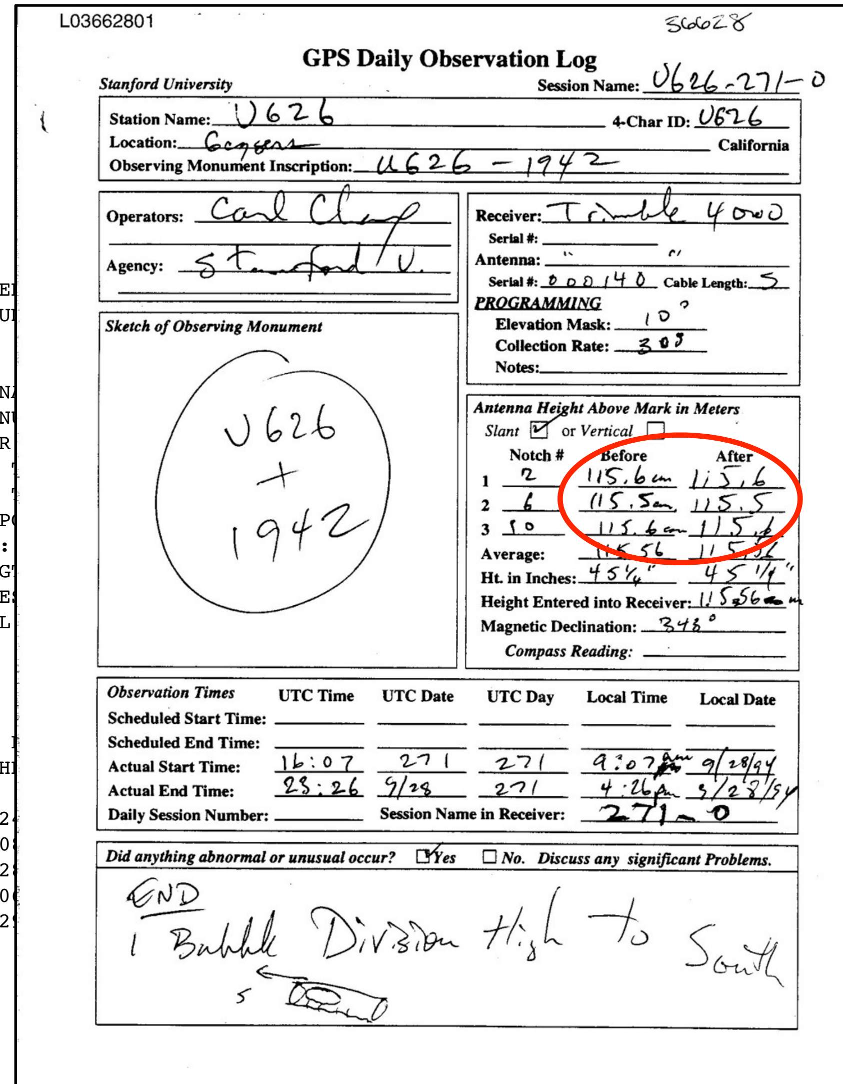
- Episodic survey setups can mean that measurements are not centered perfectly over a mark or the antenna height not measured accurately
- These measurements tend to exhibit an independent and random nature

Log (metadata) and archive errors

Critical: antenna type (serial #); height and type; monument id

```
     2.10           OBSERVATION DATA    G (GPS)             RINEX VE
teqc  2006Jul20     UNAVCO Archive Ops  20060725 16:48:29UTCPGM / RU
Solaris 5.9|UltraSparc IIi|cc -xarch=v9 SC5.5|=+-|*Sparc    COMMENT
BIT 2 OF LLI FLAGS DATA COLLECTED UNDER A/S CONDITION       COMMENT
U626                                                        MARKER N
U626                                                        MARKER N
UNKNOWN             Stanford University                     OBSERVER
3414A05687          TRIMBLE 4000SSE     NP 5.71 / SP 1.26   REC # / 
3015A00136          TRM14532.00                             ANT # / 
 -2683218.3014 -4185018.7102  3983204.9361                  APPROX P
        1.4755        0.0000        0.0000                  ANTENNA:
     1     1                                                WAVELENG
     5    L1    L2    C1    P1    P2                        # / TYPE
    30.0000                                                 INTERVAL


  1994     9    28    16     7   30.0000000     GPS         TIME OF 
                                                            END OF H
 94  9 28 16  7 30.0000000  0  5G 5G 6G17G20G24
   2437477.48856   1792564.39355  22428902.4774                   22
   -548226.77657   -402556.82256  20834866.1484                   20
   -567509.56556   -371824.37155  22860949.9614                   22
   1203057.74657    883752.12057  20612879.2734                   20
    793138.12755    501650.82355  22928979.6334                   22
```


L03662801

GPS Daily Observation Log

Stanford University — Session Name: U626-271-0

Station Name: U626 — 4-Char ID: U626

Location: Coggers — California

Observing Monument Inscription: U626 – 1942

Operators: Carl Clap — Agency: Stanford U.

Receiver: Trimble 4000 — Serial #: — Antenna: " — Serial #: 000140 — Cable Length: 5

PROGRAMMING — Elevation Mask: 10° — Collection Rate: 30s — Notes:

Sketch of Observing Monument: U626 + 1942

Antenna Height Above Mark in Meters — Slant ☑ or Vertical ☐

Notch #		Before	After
1	2	115.6cm	115.6
2	6	115.5cm	115.5
3	10	115.6cm	115.6
Average:		115.56	115.56
Ht. in Inches:		45 1/4"	45 1/4"

Height Entered into Receiver: 115.56cm

Magnetic Declination: 348°

Compass Reading:

Observation Times	UTC Time	UTC Date	UTC Day	Local Time	Local Date
Scheduled Start Time:					
Scheduled End Time:					
Actual Start Time:	16:07	271	271	9:07am	9/28/94
Actual End Time:	23:26	9/28	271	4:26pm	9/28/94

Daily Session Number: — Session Name in Receiver: 271-0

Did anything abnormal or unusual occur? ☑ Yes ☐ No. Discuss any significant Problems.

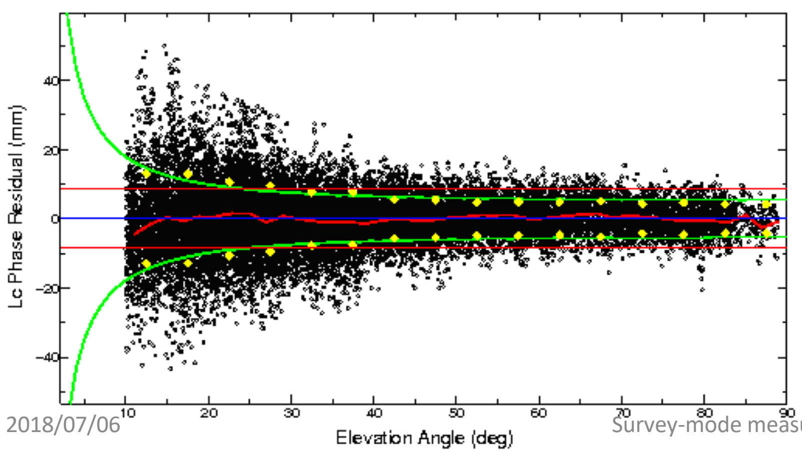
END

1 Bubble Division High to South

Low mount in a good environment

STVP
Steven’s Pass, Cascades Range in western Washington

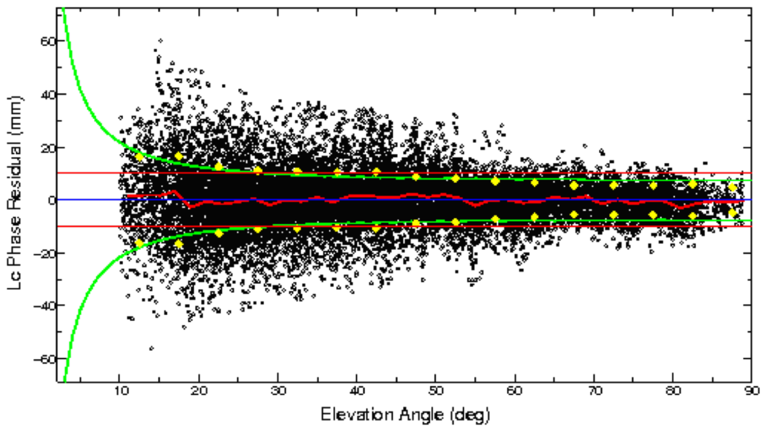
18-cm spike mount



No long-term repeatability yet, but 44 hrs of observations in 2012 give formal uncertainties 0.5 mm horizontal, 3 mm vertical. Note minimal long-period signal Scattering.

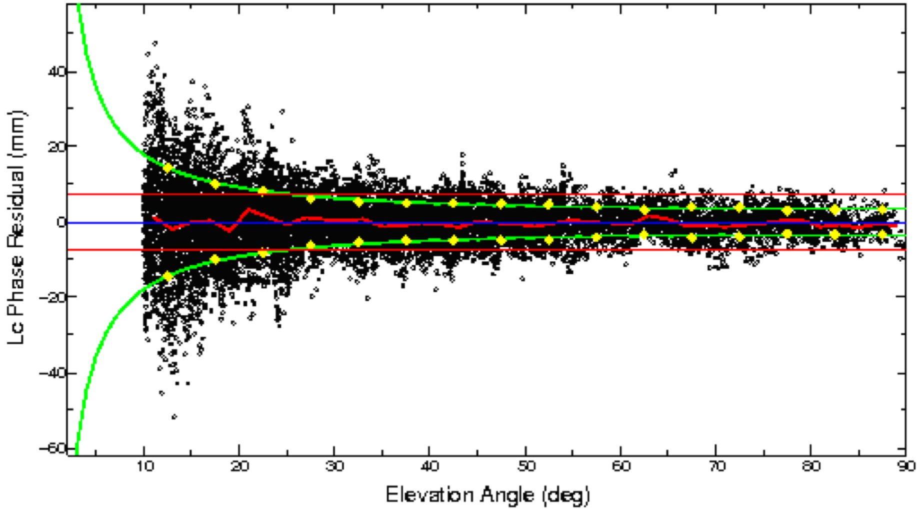
Low mount in a dirty environment

B059
Roadside meadow in western Washington
12.5-cm spike mount



Two 24-hr measurements in 2012 agree at 1 mm horizontal, 4 mm vertical though the formal uncertainties are 2 mm, 10mm due to high random noise (diffuse multipath or water vapor?) Note minimal long-period signal scattering. Long-term scatter is 3 mm horizontal, 5 mm vertical (monument instablity?)

High mount in a dirty environment



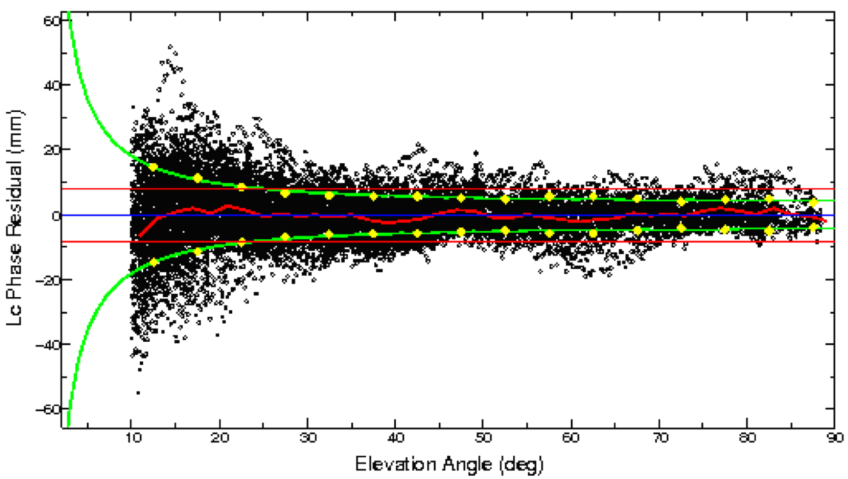
C033
Old survey mark in dirt in central Washington. Tripod mount. (Train blockage was short-lived)

2012 19-hr session and 5-hr session agree at 1.5 mm horizontal, 3 mm vertiical. Long-term repeatability 2 mm horizontal, 12 mm vertical.

Surprisingly little short-period multipath (dry dirt?)

Low mount on a slope

LYFR
Rocky river bank
in eastern
Oregon
12.5-cm spike
mount



Single 14-hr session . Long-period multipath due to slope and/or reflective rocks ?

Special characteristics of survey-mode data

- Editing is critical: every point counts
- Usually combined with cGNSS data to provide continuity and a tie to the ITRF
- Appropriate relative weighting needed in combining with cGNSS data
- Antenna meta-data may be more complicated
- Heights may be problematic if different antennas used
- Seasonal errors behave differently than in cGNSS data: best strategy is to observe at the same time of the year (unlike cGNSS, which has minimal seasonal sensitivity at 1.5, 2.5, 3.5 ….years total span)

Analysis strategy

- Generate time series and aggregated h-files for each survey
  - Use spans less than ~ 20 days to avoid biasing the position estimate from an in correct a priori velocity
  - Include cGNSS data only on days when sGNSS data are available to maintain common-mode cancellation
  - Aggregration of sGNSS positions estimate within each survey to allow better assessment of the long-term statistics
  - Edit carefully the daily values within each span
- Generate time series and a velocity using the aggregated h-files from a span of 3 or more years
  - Edit carefully the long-term time series
  - Add 0.5 of white noise ("sig_neu") to the cGNSS estimates from each span to avoid overweighting the cGPS position estimates
  - Use a separate (e.g. PBO) analysis of the daily cGNSS time series to get the appropriate RW ("mar_neu") values for each cGNSS site, then use the median RW for the sGNSS sites
- See sGPS_recipe.txt for detailed commands

Editing example