Survey-mode measurements and analysis

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http://web.mit.edu/mfloyd/www/courses/gg/201706_UNAVCO/

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 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

<table>
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<th>Mast</th>
<th>Spike mount</th>
<th>Tripod with optical or physical plummet</th>
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<td>Site VELA in the Soloman Islands.</td>
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<td>Tech 2000 kit.</td>
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<td>Courtesy UNAVO web page</td>
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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

Cast plate

Concrete pillars

Glued punched coin

Driven rods

Drilled pin
Site identification errors
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

Photograph by M. Floyd
Log (metadata) and archive errors

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

2.10 OBSERVATION DATA G (GPS) RINEX VERSION/TYPE

2006Jul20 UNAVCO Archive Ops 20060725 16:48:29 UTC

Solaris 5.9|UltraSparc III|cc-xarch=v9 SC5.5|++-|Sparc

 COMMENT BIT 2 OF LLI FLAGS DATA COLLECTED UNDER A/S CONDITION

MARKER NAME: U626
MARKER NUMBER: U626
UNKNOWN Stanford University OBSERVER / AGENCY
3414A05687 TRIMBLE 4000SSE NP 5.71 / SP 1.26 REC # / TYPE / VERS
3015A00136 TRM14532.00 ANT # / TYPE
-2683218.3014 -4185018.7102 3983204.9361 APPROX POSITION XYZ
1.4755 0.0000 0.0000 ANTENNA: DELTA H/E/N
1 1 WAVELENGTH FACT L1/2
5 L1 L2 C1 P1 P2 # / TYPES OF OBSERV
30.0000 INTERVAL
1994 9 28 16 7 30.0000000 GPS TIME OF END OF HEADER

94 9 28 16 7 30.0000000 0 5G 5G 6G17G20G24
2437477.48856 1792564.39355 22428902.4774 22428904.7102
-548226.77657 -402556.82256 20834866.1484 -402556.82256
-567509.56556 -371824.37155 22860949.9614 -371824.37155
1203057.74657 883752.12057 20612879.2734 20612879.2734
793138.12755 501650.82355 22928979.6334 22928979.6334
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

Two 24-hr measurements in 2012 agree at 1 mm horizontal, 4 mm vertical though the formal uncertainties are 2 mm, 10 mm 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 instability?)
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 vertical. 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 incorrect a priori velocity
  • Include cGNSS data only on days when sGNSS data are available to maintain common-mode cancellation
  • Aggregation 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
RFHY_GAO North Offset  4443176.449 m
rate(mm/yr)= -312.11 ± 716.58 nrms= 1.84 wrms= 5.3 mm # 3

RFHY_GAO East Offset  3310588.142 m
rate(mm/yr)= -287.09 ± 560.34 nrms= 2.71 wrms= 6.1 mm # 3