Survey-mode measurements and analysis

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Material from R. King, T. Herring, M. Floyd (MIT) and S. McClusky (now 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:

- 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 vs session length for network processing

Horizontal repeatability

Vertical repeatability

mm

16 refs 12 refs 8 refs 4 refs 3 refs 2 refs
0 1 2 3 4 5 6 7 8 9 10

mm

16 refs 12 refs 8 refs 4 refs 3 refs 2 refs
0 5 10 15 20 25 30

1 hr 2 hr 3 hr 6 hr 12 hr 24 hr

1 hr 2 hr 3 hr 6 hr 12 hr 24 hr
Measurement Strategies II: Monuments and Instrumentation

Issues in site and antenna selection:

- Monument stability
- Accessibility
- Ease of setup
- Multipath
- 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.

- **Tripod with optical or physical plummet**

  - Courtesy UNAVO web page

- **Mast**

  - Tech 2000 kit.

The Tech 2000 mast (Tech2K) is a portable, fixed-height antenna mount designed to be set up over traditional-style benchmarks where the survey point is a dimple. It is generally 5/8" all-thread with a dimple on the top cemented or epoxied into (and extruding from) rock. The antenna is elevated to obtain sufficient sky view. Although smaller and lighter options than a tripod are available, a tripod may still be the best option for some conditions, eliminating both height measurement errors and the need to measure the distance from ground level to the top of the mast. A standard tripod setup consists of an adjustable-height tripod that must be centered over the survey mark. Typically, we use a tripod that elevates the antenna to a height+0.18m+Spike+Mount (photograph and diagrams), which is used for non-permanent long-term sites.

For longer occupations, a bolt can be driven through a hole in the ground. The arrow tip is inserted directly into a benchmark's central point and the mast is secured and leveled by loosening the legs around the thread at the top of the mast, and three chains under tension that connect the upper part of the mast to anchor points in the ground. The setup is stable enough to be left unattended for months at a time. The setup error should be <1mm and stable enough to be left unattended for several days at a time. For longer occupations, a bolt can be driven through a hole in the ground with the antenna attached.

A fixed-height tripod, while lacking the flexibility of a standard tripod, eliminates both height measurement errors and the need to measure the distance from ground level to the top of the mast. A fixed antenna height is usually defined as a distance of 0.18 m above the survey mark. Setup error should be <1mm and stable enough to be left unattended for several days at a time. For longer occupations, a bolt can be driven through a hole in the ground with the antenna attached.

A simple cup with a brass adapter can be used where leveling the mount is not critical (e.g. a continuous, long-term campaign site). The setup is stable enough to be left unattended for several days at a time. This setup was used in the VELA site on the Soloman Islands (photograph and diagram), which was a continuous, long-term campaign site.

For permanent and non-permanent long-term sites, a tripod may still be the best option for some conditions, eliminating both height measurement errors and the need to measure the distance from ground level to the top of the mast. A fixed antenna height is usually defined as a distance of 0.18 m above the survey mark. Setup error should be <1mm and stable enough to be left unattended for several days at a time. For longer occupations, a bolt can be driven through a hole in the ground with the antenna attached.

The UNAVCO fixed-height leveling mount is a fixed-height leveling mount that is used for non-permanent long-term sites. It is generally 5/8" all-thread with a dimple on the top cemented or epoxied into (and extruding from) rock. The antenna is elevated to obtain sufficient sky view. Although smaller and lighter options than a tripod are available, a tripod may still be the best option for some conditions, eliminating both height measurement errors and the need to measure the distance from ground level to the top of the mast. A standard tripod setup consists of an adjustable-height tripod that must be centered over the survey mark. Typically, we use a tripod that elevates the antenna to a height+0.18m+Spike+Mount (photograph and diagrams), which is used for non-permanent long-term sites.

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For longer occupations, a bolt can be driven through a hole in the ground with the antenna attached.
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 though formal uncertainties 2 mm, 10mm due to high random noise (diffuse multipath or water vapor?) Note minimal long-period signal scattering. Long-term scatter 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 cGPS data to provide continuity and a tie to the ITRF
- Appropriate relative weighting needed in combining with cGPS data
- Antenna meta-data may be more complicated
- Heights may be problematic if different antennas used
- Seasonal errors behave differently than in cGPS data: best strategy is to observe at the same time of the year (unlike cGPS, 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 ~ 30 days to avoid biasing the position estimate from an incorrect velocity
  – Include cGPS data only on days when sGPS data are available to maintain common-mode cancellation
  – Strengthens the sGPS positions estimates within each survey and allows 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 cGPS estimates from each span to avoid overweighting the cGPS position estimates
  – Use a separate (ie.g PBO) analysis of the daily cGPS time series to get the appropriate RW (mar_neu) values for each cGPS site; use the median RW for the sGPS sites.

• See  sGPS_recipe.txt for detailed commands
Locations of one continuous (BURN) and 3 survey-mode sites for time series shown in next slides
Time series of monthly position estimates for continuous site BURN

Wrms ~ 1 mm N,E
~ 3 mm U

Rate uncertainties
< 0.2 mm/yr N,E
0.7 mm/yr U
do not include random walk added for velocity estimates
Next slide shows time series for survey-mode site 217U

Note consistency with nearby sites
Time series for survey-mode site 217U

Position estimates based on 8-24 hr occupations

Note < 1 mm rate uncertainties due to 7-yr time span
Next slide shows time series for survey-mode site SARG
Horizontal time series for survey-mode site SARG

Position estimates based on 8-24 hr occupations

Note 1 mm wrms and < 1 mm rate sigmas
Next slide shows time series for survey-mode site DALL

Note consistency with nearby sites except continuous site GWEN
Horizontal time series for survey-mode site DALL

Position estimates based on 8-24 hr occupations

Rate sigmas < 1 mm/yr and consistent with surrounding sites even with velocities determined essentially by two occupations 3 yrs apart