

# Batch processing with `sh_gamit`

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GNSS Data Processing and Analysis with GAMIT/GLOBK and `track`

UNAVCO Headquarters, Boulder, Colorado, USA

18–22 July 2022

[https://geoweb.mit.edu/gg/courses/202207\\_UNAVCO/](https://geoweb.mit.edu/gg/courses/202207_UNAVCO/)

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

# Outline

- Setup, operation and options for GAMIT processing with `sh_gamit`
  - Directory structures
  - Main functions in GAMIT
    - Programs called that run the GAMIT processing
  - Files that are important in processing
  - Summary files
  - Residual plots
  - Problems that can happen and suggestions

# Overview of `sh_gamit`: Getting started

- `sh_setup` will create `tables/` directory, then local specifics can be set
  - In `tables/`, `process.defaults` and `sites.defaults` are the two main files that need to be edited; `sittbl.` may also need editing to ensure some constrained stations in the network to be processed; `sestbl.` is edited if non-standard processing.
  - In `tables/`, a priori coordinate (`.apr`) file created (name in `process.defaults`); additional coordinates are put into `tables/lfile`.
- Create `rinex/` directory (e.g. `mkdir rinex`) in which to store local RINEX files to be processed; RINEX data in public archives will automatically be downloaded
- `sh_gamit -expt <expt-name> -s <yr> <start-doy> <stop-doy>`
  - Common options are: `-orbit`, `-eops`, `-gnss`, `-netext`

# Directory structure

- Top level: global tables and survey directories
- Within each top-level directory:  
    brdc/ gfiles/ glbf/ gsoln/ igs/ rinex/ tables/  
    001/ 002/ ... (these directories are created as needed)
- Generally 50-60 sites is the largest network processed in GAMIT; networks larger than 99 stations require sub-netting of sites (see `net_sel`, `global_sel` and `sh_network_sel`)
- Tables are linked from day directories to experiment tables/ and then to `~/gg/tables/`
- GAMIT processing occurs in the day (<DDD>) directories
- GLOBK processing occurs in `gsoln/`

# Files provided or created automatically

- Satellite orbits
  - IGS SP3-files (tabular) and/or g-files (initial conditions (ICs) for GAMIT)
  - `arc` integrates to get t-files (tabular)
- Earth orientation parameters (EOPs: `ut1.`; `wob.`): downloaded if needed for current day
- Leap second file; linked to `gg/tables/` (update approximately yearly or with leap second announcements)
- Satellite clock (j-) files; from RINEX navigation (`brdc`) or SP3 file
- Receiver and antenna characteristics (`rcvant.dat`, `hi.dat`); linked to `gg/tables`
- Differential code biases (`dcb.dat`); updated monthly
- Antenna phase center models (`antmod.dat`); linked to `gg/tables/` (also needs to be updated when new antennas added)
- Lunar, solar and planetary ephemerides (`nbody`); linked to `gg/tables/`
  - Formerly tables (`soltab.`, `luntab.`, `nutabl.`) linked to `gg/tables/`, which needed to be updated yearly; no longer necessary
- Ocean tide grid (optional); linked to `gg/tables/` from `gg/GRIDS/`
- Atmospheric loading grid (optional); linked to `gg/tables/` from `gg/GRIDS/`; need to update yearly
- Mapping function grid (optional); linked to `gg/tables/` from `gg/GRIDS/`; need to update yearly

# Files you need to worry about

- RINEX files: local plus list in sites.defaults
- Control files
  - process.defaults : minor edits for each survey
  - sestbl. : experiment and models setup (unchanged for most processing)
  - sites.defaults : sites to include or omit and source of metadata
  - sittbl. : sites constrained for ambiguity resolution
  - globk.cmd : use\_site, apr\_neu, apr\_svs, apr\_wob, apr\_ut1, sig\_neu and mar\_neu commands
  - glorg.cmd : apr\_file, pos\_org, stab\_site commands
- a priori coordinates (.apr-file, l-file)
- Metadata (station.info)
- Differential code biases (dcb.dat); download current values once per month
- Satellite characteristics (svnav.dat); download current with each new launch
  - Now linked to igs\_metadata.snx, which is maintained by the IGS

# process.defaults

- Controls:
  - Data and processing directory structure
  - Some session parameters (e.g. start time, length and data interval, and apr-file name)
  - Peripheral book-keeping (e.g. files to compress, archive or delete, and email address for summary)

# sites.defaults

- Controls sites to be included in experiment of given name
  - Whether or not these sites should be downloaded from a public data server (use “ftprnx” flag)
  - Whether or not these sites should have their metadata updated from the RINEX file header (not recommended, particularly for continuous sites; use “xstinfo” flag)
- May use one sites.defaults file with multiple experiment names and use “-expt” option in `sh_gamit` to process only certain sites
- May use a different experiment setup for different days
  - `sh_gamit` will look first for “sites.defaults.YYYYDDD”, then a generic “sites.defaults” file



# autcln.cmd

- Controls all parts of the phase cleaning algorithm
- Defaults generally work well for all experiments
  - May occasionally wish to change:
    - elevation mask
    - criteria to keep more data from sites with bad a priori co-ordinates

# .apr-file

- Controls a priori (input) coordinates of sites
- Convergence of (non-linear) processing is about 1:1000, i.e. 10 m accuracy for a priori co-ordinate will result in final coordinate accurate to about 10 mm
  - Important to have good a priori coordinates
- Utilities include: `sh_rx2apr`
- The experiment l-file is initialized each day with the coordinates in the .apr-file specified in `process.defaults` (while retaining any entries added during prior processing for sites not in the .apr\_file)

# station.info

- Controls site occupation metadata
  - Site name
  - Start and stop times of occupation
  - Receiver and antenna information (types, serial numbers, firmware, heights)
- Utilities include `sh_upd_stnfo` which invokes program `mstinf`
- Options for metadata include
  - Pre-prepared station.info (`sh_upd_stnfo`, `make_stnfo`)
    - Must set “xstinfo” in `sites.defaults`
  - RINEX headers (`sh_gamit` default but may change soon)
    - Update station.info unless an entry already exists for the day being processed or “stinf\_unique” is set to “-u” in `process.defaults` and entry has not changed
    - Can be used with non-standard receiver and antenna names specified in `guess_rcvant.dat` (ideally your RINEX files have the IGS official receiver and antenna names. It is critical that this information is correct)
- **THIS IS A VERY IMPORTANT FILE!**
  - If you do not get this file correct (and verified) before processing, you may lose a lot of time reprocessing phase data at the GAMIT (slowest) stage

# sestbl. (“session table”)

- Controls processing setup
  - Observables to use (e.g. LC, L1+L2, etc.)
  - Experiment (orbits and EOPs) type
    - “BASELINE” solves for site coordinates only using fixed orbital parameters [default]
    - “ORBIT” solves for orbital parameters only using fixed site coordinates (from .apr-file)
    - “RELAX.” solves for both site and orbital parameters
  - Models used

# sittbl. (“sites table”)

- Controls:
  - Site-specific information for processing
    - Constraint (accuracy) of a priori coordinates in .apr-file

# sh\_gamit internal operation

- The following programs are run by the script:
- `makexp` and `makex` prepare the data
- `fixdrv` prepares the batch control files
- `arc` integrates GNSS satellite orbits
- `model` calculates theoretical (modeled) phase and partial derivatives of phase with respect to parameters
- `autc1n` repairs cycle slips, removes phase outliers, and resolves the wide-lane ambiguities
- `solve` estimates parameters via least-squares, resolving the narrow-lane ambiguities and creating an h-file for GLOBK (user constraints are removed in the h-file to allow reference frame definition)

# Steps in the standard GAMIT batch sequence

- `arc, model, autc1n, solve` for initial solution
  - 5-minute sampling, no ambiguity resolution (GCR only)
  - update lfile. for coordinates adjusted > 30 cm
  - look at: `autc1n.prefit.sum; q<expt>p.ddd`
- `model, autc1n, solve` for final solution
  - 2-minute sampling, ambiguity resolution
  - Look at: `autc1n.post.sum, q<expt>a.ddd`
- Final solution repeated if NRMS reduced by > 30% from initial solution, to assure good editing and linear adjustment of parameters (original final solution files overwritten)

# What solve produces

- Print output is the q-file, which records
  - in detail*
    - A constrained solution without ambiguities resolved (“GCR”)
    - A constrained solution with ambiguities resolved (“GCX”)
    - These are the solutions you should examine, along with the `autc1n` summary files, to assess the quality of the solution
  - and in summary only*
    - A loose solution without ambiguities resolved (“GLR”)
    - A loose solution with ambiguities resolved (“GLX”)
- Updated l-file for successive iterations or days
- Useful output for GLOBK is the h-file (analogous to the IGS standard SINEX file), which contains the parameters estimates and full covariance matrix.
- (There is also an o-file, which is just the q-file but in more machine-readable form, and is seldom used; and, if orbits adjusted, an updated g-file)



# A priori coordinates (`sh_gamit`)

- Create l-file in day directory by merging existing lfile. and apr\_file from ../tables/ (apr\_file has priority)
- If site not found in l-file
  - Use RINEX header coordinates (“set use\_rxc = Y” in process.defaults, good for modern (post selective availability, in 2000) data  
or
  - Use pseudorange data in RINEX file to estimate point position or differential position relative to a site in sites.defaults (“set use\_rxc = N”, default)
- During the `sh_gamit` run, the coordinates are updated (and copied to ../tables/lfile.) if they are in error by > 30 cm

# Ambiguity resolution

- (L2 – L1) integers resolved by `autcln` and passed to `solve` in the `n-` file (“LC\_AUTCLN” option in `sestbl`.)
  - Weak dependence on geometry
  - Need current differential code bias file `dcb.dat`
  - Use “LC\_HELP” for codeless data (before ~ 1995) or if problems (default max distance is 500 km)
- Narrow-lane (L1) resolved by `solve`
  - Strong dependence on phase noise and models
  - 5–10 cm constraints on a priori coordinates usually sufficient

# sh\_gamit\_<DDD>.summary (also email)

- Preamble

```
Input options -d 2002 30 31 32 33 -expt ncar -pres ELEV -yrest -netext a
Processing 2002 031 GPS week 1151 4 Raw 2
/data51/tah/SENH02/glob02/suomi/2002_031a
Disk Usage: 12678.4 Free 76447.4 Mbyte. Used 15%
```

- Summary Statistics (from autcln)

```
Number of stations used 4 Total xfiles 4
```

```
Postfit RMS rms, to and by satellite
```

```
RMS IT Site All 01 02 03 04 05 06 07 08 09 ...
```

```
RMS 20 ALL 4.8 4 5 6 5 5 4 5 4 5 ...
```

```
Best and Worst two sites:
```

```
RMS 20 TMGO 3.2 3 3 4 4 4 3 3 3 4 ...
```

```
RMS 20 SA09 4.6 4 4 5 4 5 4 4 4 5 ...
```

```
RMS 20 PLTC 5.4 4 5 5 6 5 4 5 5 6 ...
```

```
RMS 20 SA13 5.5 5 5 6 5 5 5 5 5 6 ...
```

# sh\_gamit\_<DDD>.summary (also email)

- Solution statistics from solve

Double difference statistics

Prefit nrms:	0.31280E+03	Postfit nrms:	0.21324E+00	(Constrained free)
Prefit nrms:	0.31185E+03	Postfit nrms:	0.21818E+00	(Constrained fixed)
Prefit nrms:	0.31272E+03	Postfit nrms:	0.20470E+00	(Loose free)
Prefit nrms:	0.31185E+03	Postfit nrms:	0.20756E+00	(Loose fixed)

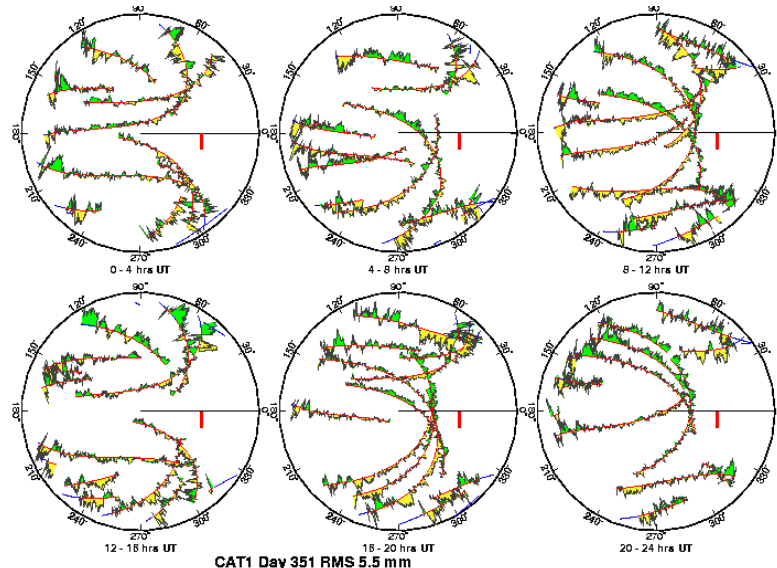
Number of double differences: 12447

Numbers of WL and NL biases 120    Percent fixed 95% WL    85% NL

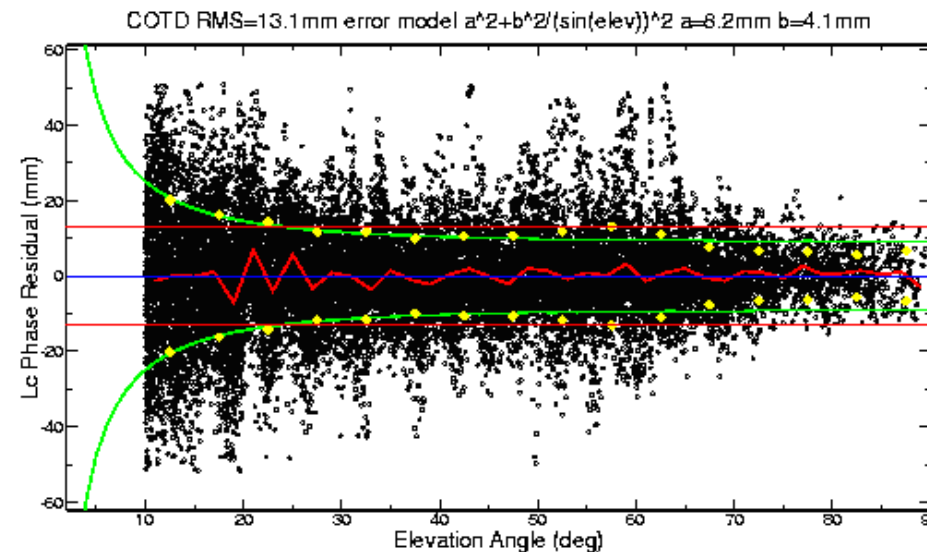
- Any large adjustments to positions (> 0.3 m) ...
- Things to note:
  - Number of stations matches expectation
  - Site postfit RMS values 3–10 mm
  - No stations with RMS = 0 ( implies no data retained by autcln )
  - Postfit nrms from solve ~ 0.2 for constrained and loose solutions
  - “Most” ambiguities resolved (70–85% for noisy days, > 90% for best)

# Phase residual plots

- Set with “-pres elev” in sh\_gamit command (requires GMT)
- Postscript files in day directory, by default converted to PNG in figs/ directory and then erased (requires GMT’s psconvert or ps2raster)
- Use to assess multipath, water vapor, and antenna phase center model

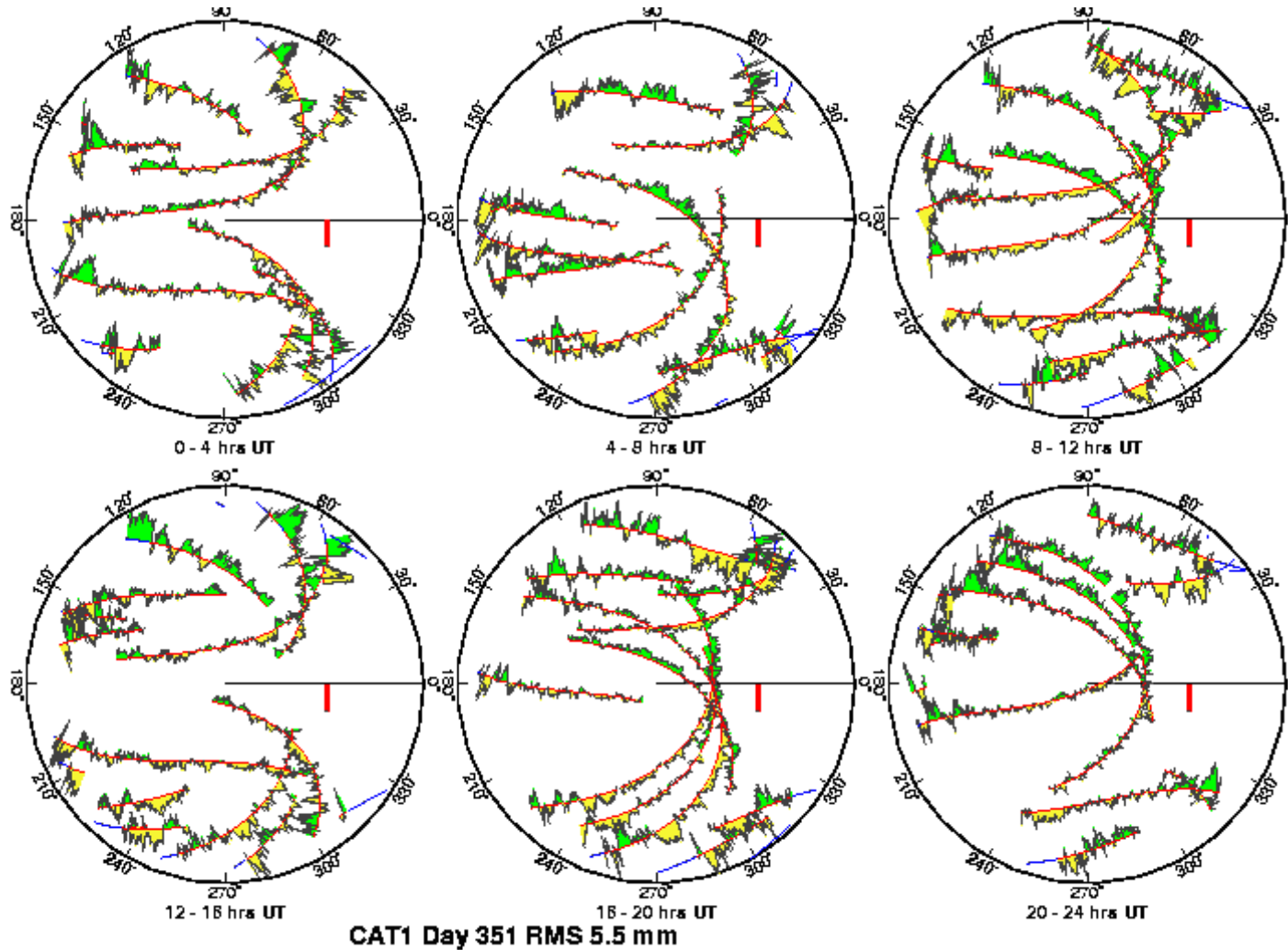


“Sky plot”



Phase vs elevation angle

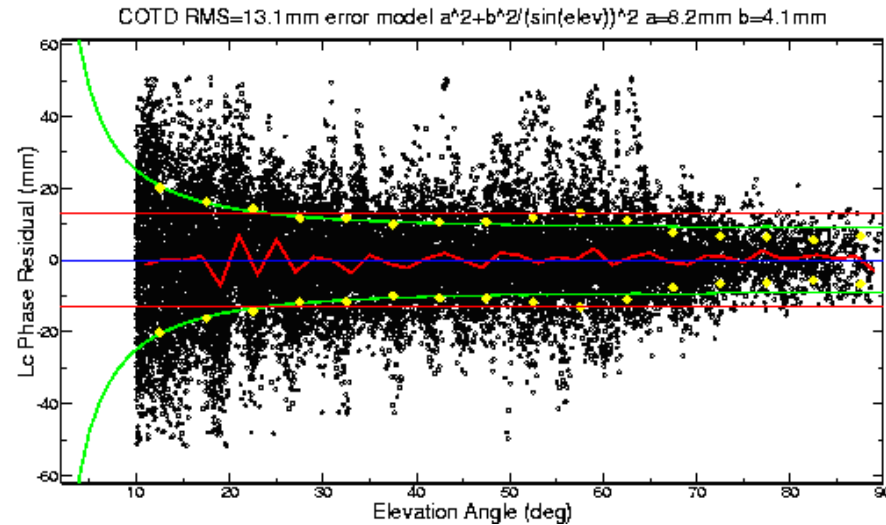
# Sky plots



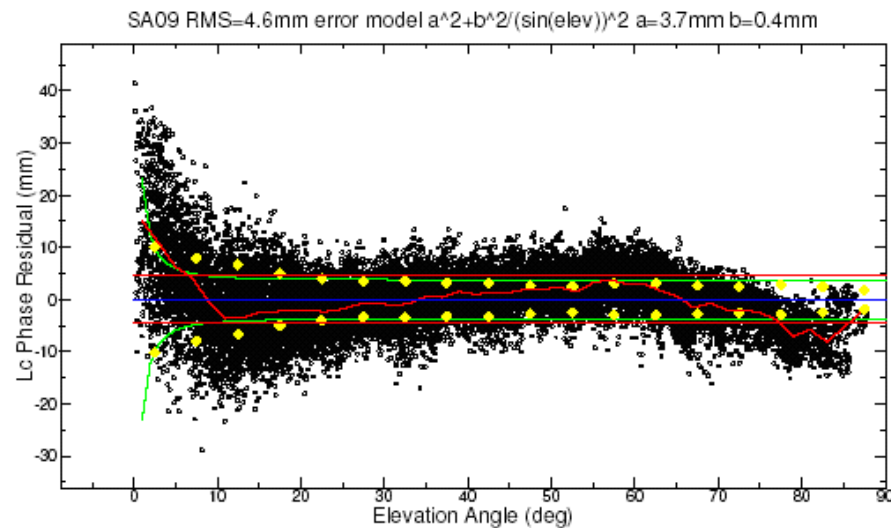
High residuals in the same place at different times suggest multipath

High residuals appearing in a given place only at one time suggest water vapor

# Phase vs elevation angle



Normal pattern: bands are high-frequency multipath; red is smoothing of individual values, showing no strong systematics. Mid-elevation angle noise could be atmospheric delay errors?



Bad pattern: systematic signature of smoothed values indicates a poor model of the antenna phase pattern (perhaps a misidentified antenna in station.info)

(Green lines show the elevation-dependent noise model shown at top and used to reweight the data in solve)

# What can go wrong?

- Site missing (not listed)
  - No RINEX data within session span: check RINEX file and/or `makex.expt.infor`
  - Too few data, x-file too small and not used: check RINEX file size, change “minxf” in `process.defaults`
- Site in solution but no data or adjustment
  - a priori coordinates > 10 m off: check range rms in `autcln.prefit.sum`,
    - run `sh_rx2apr` differentially for several RINEX files
  - bad receiver: examine RINEX files or initial c-files with `cvview`
- q-file nrms > 0.2
  - solution over-constrained: check GCX vs GLX nrms, rerun with only one site constrained in the `sittbl`.



# Problems with a priori coordinates

- Need to be good to  $< 10$  m to get through `autc1n`
- Safest source is a previous solution or a pseudorange solution using `svpos/svdiff (sh_rx2apr)`
- Range rms and bias flags added from `autc1n` summary file are a useful check
- Convergence is 1:100 to 1:1000 (1 m error in `.apr`-file can lead to 1–10 mm error in adjustment), hence automatic update of `l`-file for iteration of second GAMIT solution
- Watch for repeated updates in email summary as a sign of bad data

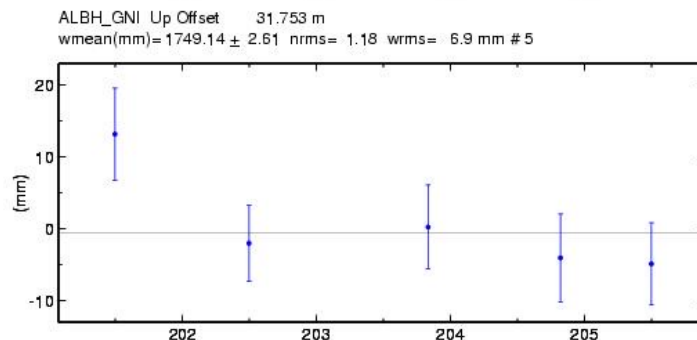
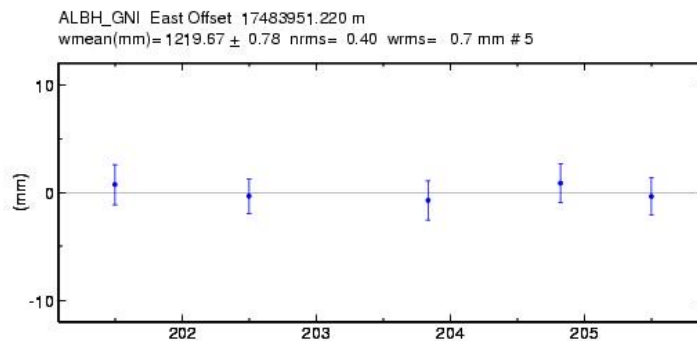
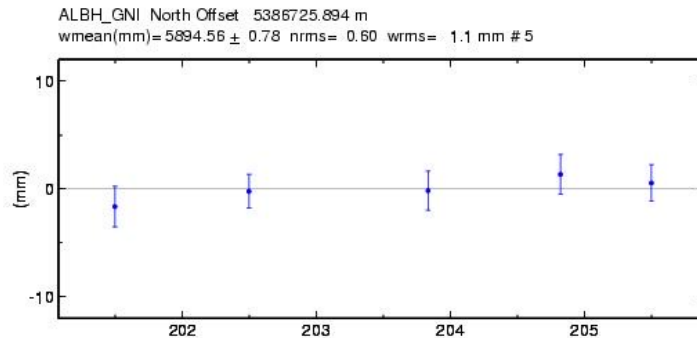
# Constraining the GAMIT solution

- Minimal (single-station) constraint is all that's needed for ambiguity resolution, but `sittbl` can list several to assure one
- Orbits can be fixed or tightly constrained (.005 ppm) for IGS orbits since at least 1996
  - Use of "BASELINE" mode with "igsf" orbits fixed now recommended for processing regions up to at least 6000 km
- Look for good ( $\sim 0.2$ ) loose (GLR/GLX) nrms but elevated constrained nrms (GCR/GCX) as indication of an over-constrained solution

# More subtle problems

- Site with high rms in autcln.post.sum
  - High multipath or water vapor: check sky plots of phase
  - Bad receiver: examine RINEX files or initial c-files with `cvview`
- Phase vs elevation angle plot large and systematic
  - Misidentified antenna (wrong PCV model)
  - Coupling between antenna and mount
- GAMIT results within normal range but time series shows outlier
  - Survey-mode: antenna not leveled and centered over mark
  - Change in multipath (water, objects) or water vapor
  - Snow on antenna
  - Incorrect ambiguity resolution (east component except for high latitudes)

# Example of understanding outliers

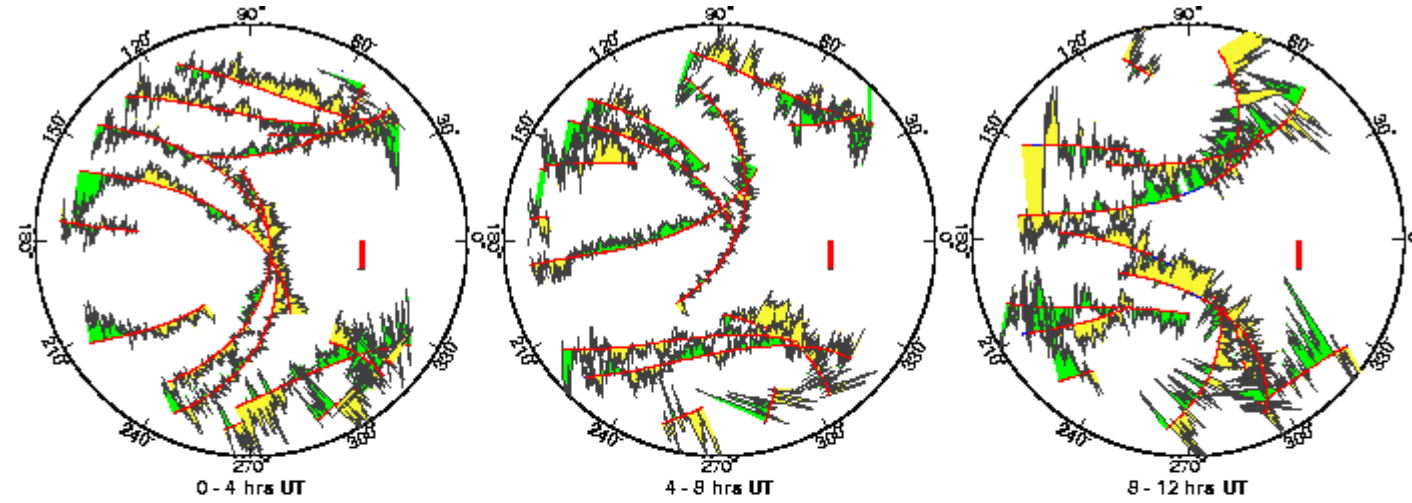


autc1n RMS:

- Day 201 9.6 mm
- Day 202 6.0 mm

Notice height outlier on day 201

## ALBH 2003 Day 201



## ALBH 2003 Day 202

