

# Batch processing with `sh_gamit`

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[http://geoweb.mit.edu/~floyd/courses/gg/201707\\_EOS/](http://geoweb.mit.edu/~floyd/courses/gg/201707_EOS/)

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

- To start `sh_setup` will create `/tables`, `/rinex`, `/gsoln` directories and then local specifics can be set.
  - In `tables/`, `process.defaults` and `sites.default` 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/`, apriori coordinate file created (name in `process.defaults`). Additional coordinates are put into `./tables/lfile`.
  - In `rinex/`, local RINEX files need to be copied in; `rinex` data in archives will automatically be downloaded
- `sh_gamit -expt [expt-name] -s [yr] [start-doy] [stop-doy]`
  - Common options are: `-dopt` `-copt` `-rx_doy_minus` `-netext`

# Directory structure

- Top level: global tables and survey directories
- Within each top-level directory:
  - brdc/ gfiles/ glbf/ gsoln/ igs/ rinex/ tables/  
day1/ day2/ (these directories are created as needed)
- Generally 50-60 sites is the largest network processed in GAMIT; larger numbers of 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 directories
- GLOBK processing occurs in `gsoln/`

# Files provided or created automatically

- Satellite orbits
  - IGS sp3-files (tabular) and/or g-files (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 ~yearly or when leap second)
- Satellite clock (j-) files — from RINEX navigation (brdc) file
- Rcvr/ant characteristics (rcvant.dat, hi.dat) — linked to gg/tables
- Differential code biases (dcb.dat) — update ~monthly
- Antenna phase center models (antmod.dat) — linked to gg/tables (also needs to be updated when new antennas added).
- Luni-solar ephemerides and nutation (soltab., luntab., nutabl.) linked to gg/tables (need to update yearly)
- Ocean tide grid (optional) – linked to gg/tables
- Atmospheric loading grid (optional) – need to update yearly
- Mapping function grid (optional) – 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\_comb.cmd : use\_site, apr\_neu, apr\_svs, apr\_wob, apr\_ut1, sig\_neu and mar\_neu commands
  - glorg\_comb.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 1/month
- Satellite characteristics (svnav.dat) – download current w/ each new launch

# 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 FTP 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 `makeex` prepare the data
- `fixdrv` prepares the batch control files
- `arc` integrates GPS 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 `autcln` 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 (use\_rxc=Y in process.defaults, good for modern (post SA, in 2000) data.or
  - Use pseudorange data in RINEX file to estimate point position or differential position relative to a site in sites.defaults (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 -yrexr -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 autc1n)

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

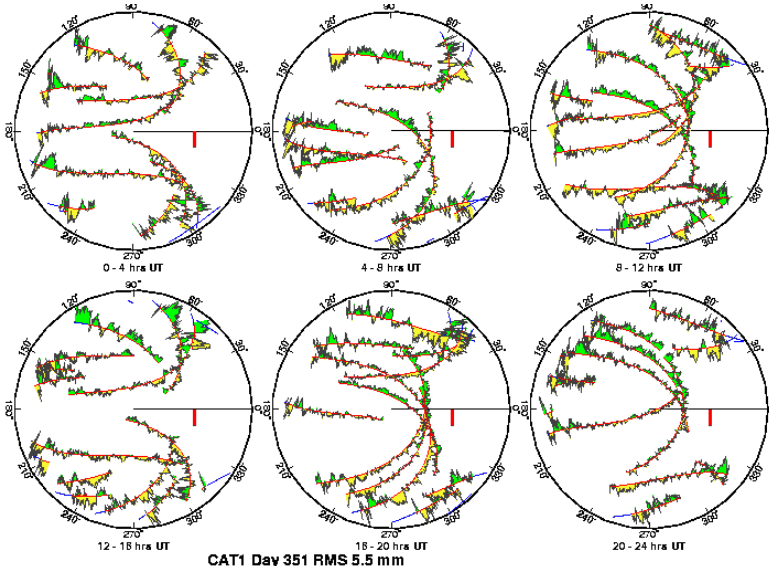
Any large adjustments to positions (> 0.3 m) ...

- Things to note:

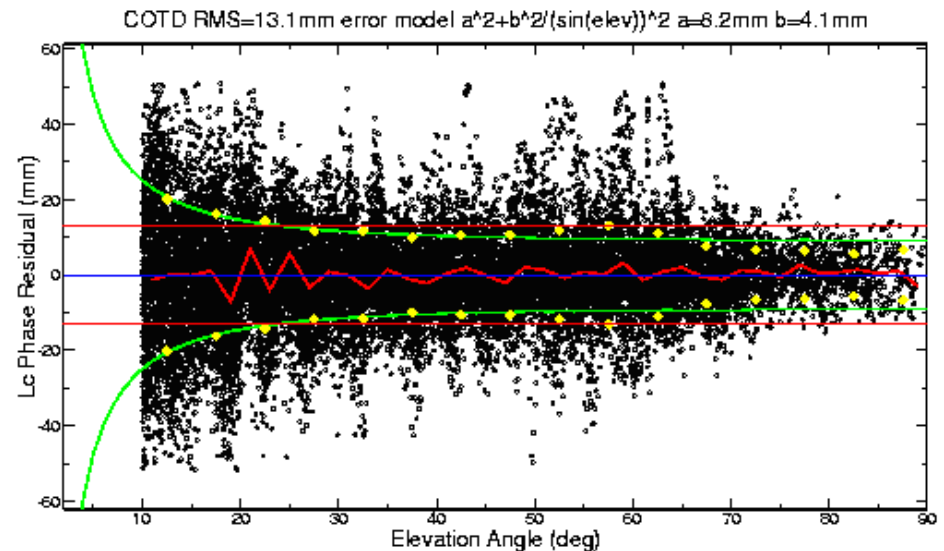
- Number of stations matches expectation
- Site postfit RMS values 3–10 mm
- No stations with RMS = 0 ( implies no data retained by `autcln` )
- Postfit nrms from `solve` ~ 0.2 for constrained and loose solutions
- “Most” ambiguities resolved (70–85% for noisy days, > 90% for best)

# 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

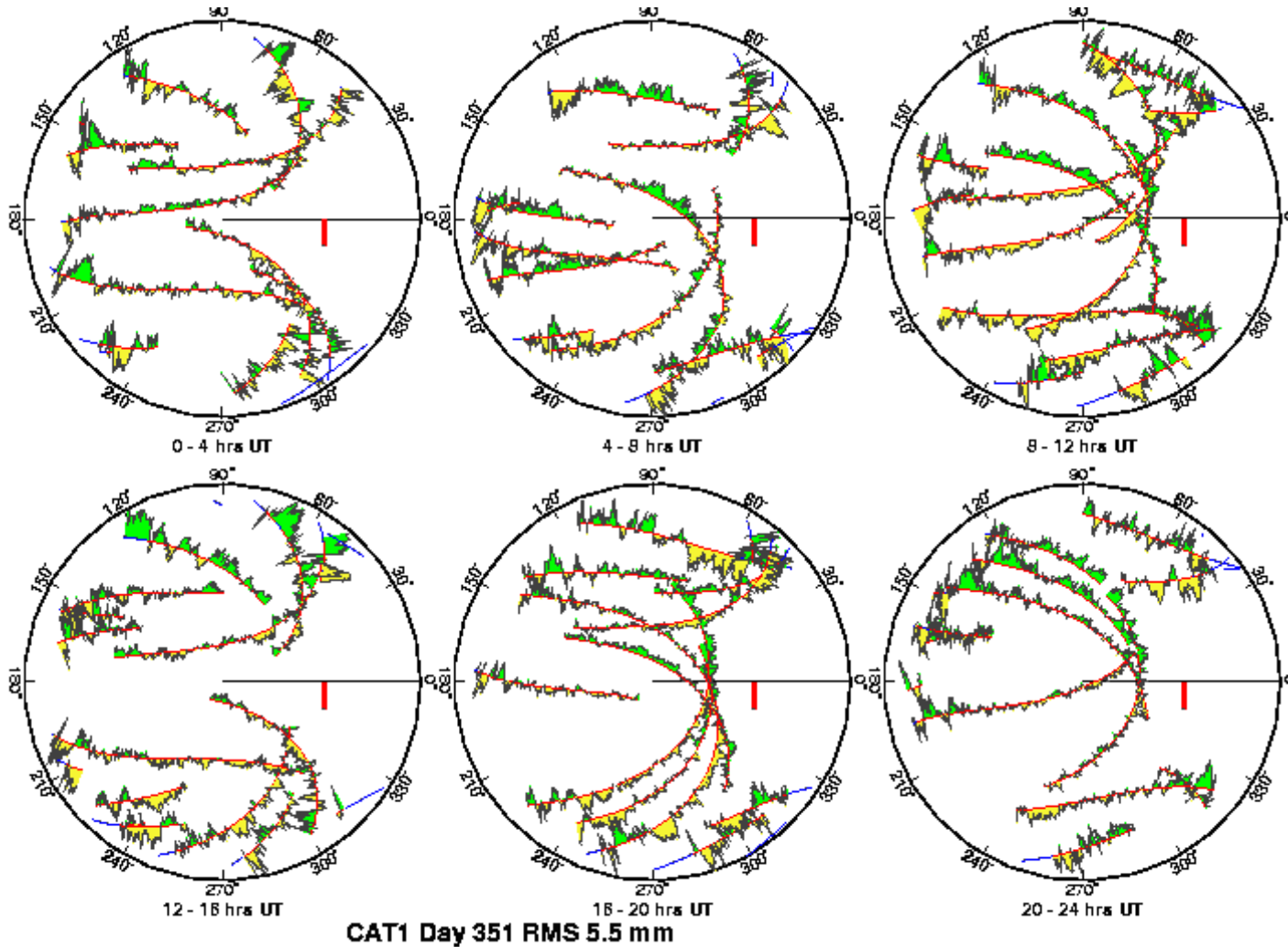


“Sky plot”



Phase vs elevation angle

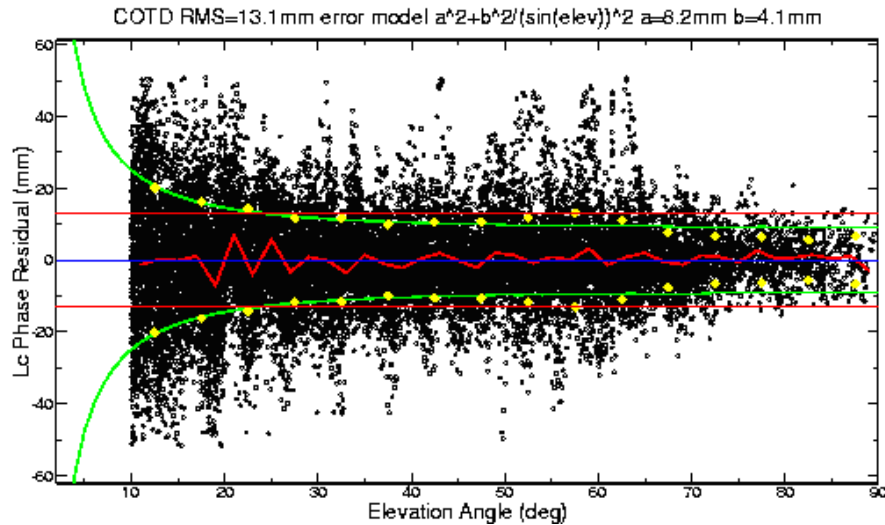
# Sky plots



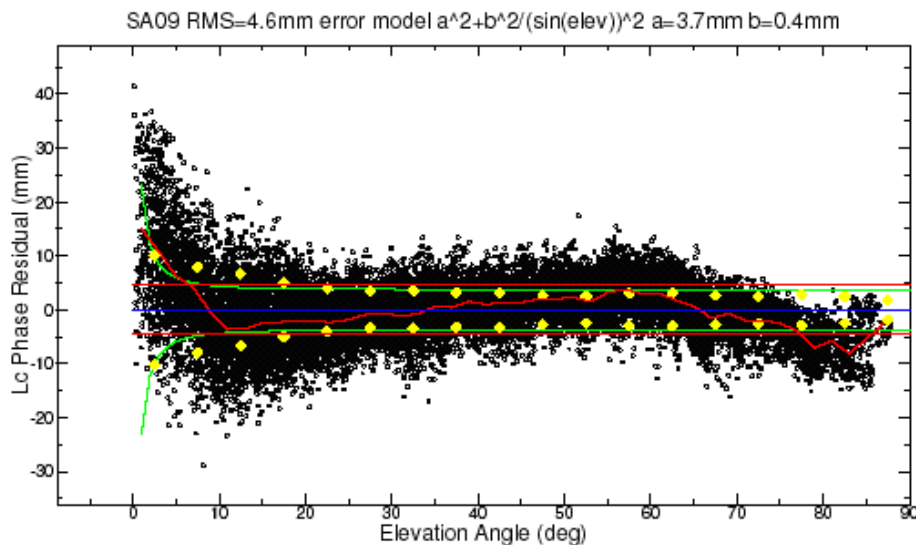
High residuals in the same place at different times suggest multipath

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

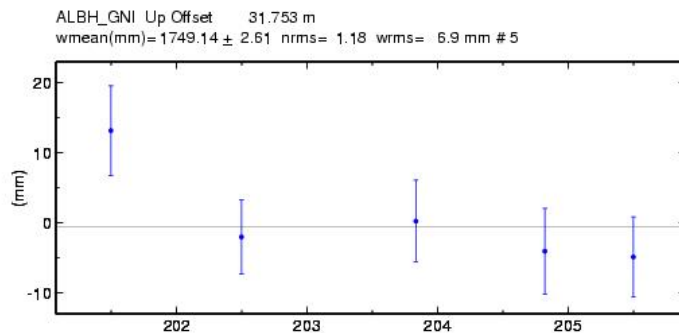
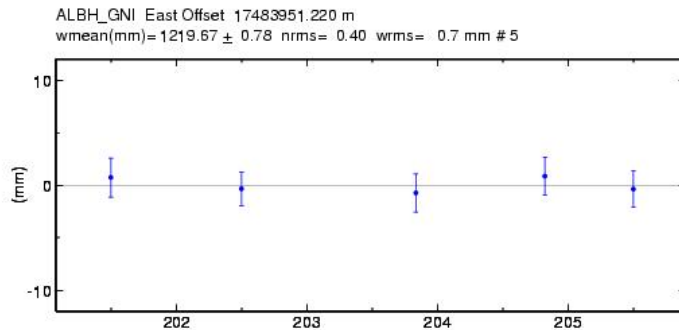
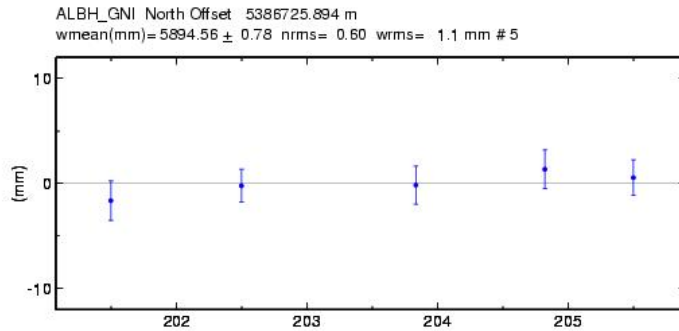
# Constraining the GAMIT solution

- 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 multipathing 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)

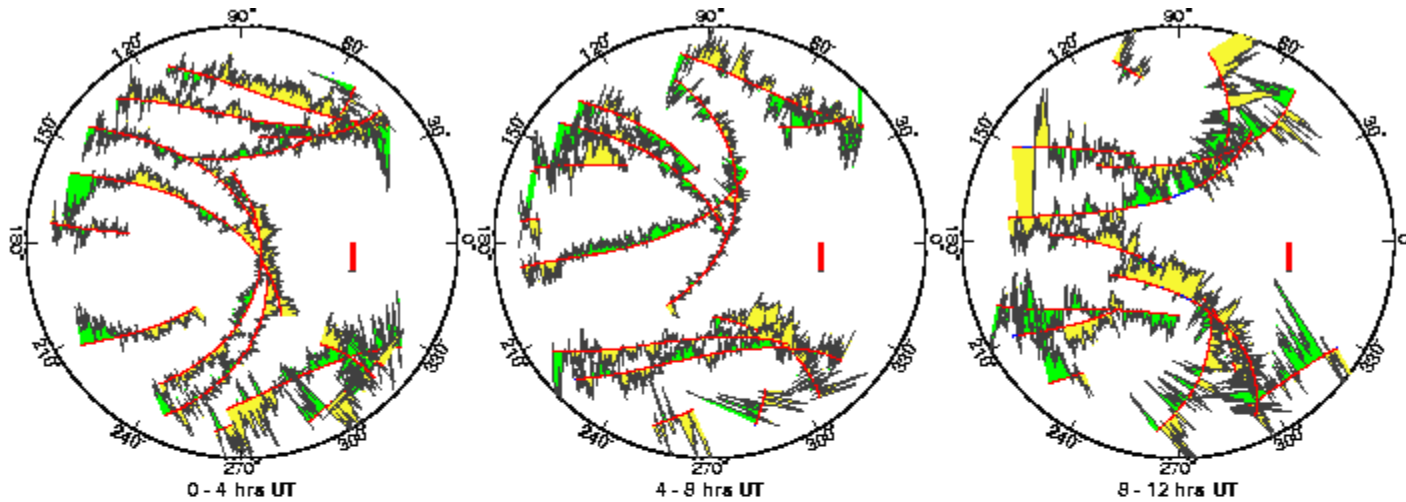
# Example of understanding outliers



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

