

# Batch processing with `sh_gamit`

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# 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 survey directory:
  - /tables /rinex /igs /gfiles /brdc /gsoln /glbf
  - /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 netsel, 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/

# Important files

- autcln.cmd
- process.defaults
- sestbl.
- sites.defaults
- sittbl.
- station.info
- apr-file

# 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

# 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
- apr-file specified in process.defaults is copied to experiment “l-file”

# station.info

- Controls:
  - site occupation metadata, e.g.
    - Site name
    - Start and stop times of occupation
    - Receiver and antenna information (types, serial numbers, firmware, heights)
- **THIS IS A VERY IMPORTANT FILE!**
- Utilities include: `sh_upd_stnfo` and `mstinf`

# sestbl. ("session table")

- Controls
  - Processing setup
    - Observables to use (e.g. LC, L1+L2, etc.)
    - Experiment (orbits and EOPs) type
    - 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 GPS satellite orbits
- `model` calculates theoretical (modeled) phase and partial derivatives of phase with respect to parameters
- `autcln` 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)

# Files you need to worry about

RINEX files – local plus list in sites.defaults

Control files

process.defaults – minor edits for each survey

sites.defaults – sites to include/omit; source of metadata

sestbl. – unchanged for most processing

sittbl. – sites constrained for ambiguity resolution

globk\_comb.cmd – use\_site, apr\_neu, apr\_svs, apr\_wob, apr\_ut1, sig\_neu,  
mar\_neu

glorg\_comb.cmd – apr\_file, pos\_org, stab\_site

A priori coordinates ( apr-file, l-file )

Meta-data (station.info)

Differential code biases (dcb.dat) – download current values 1/month

Satellite characteristics (svnav.dat) – download current w/ each new launch



# 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

# Options for metadata (station.info)

- Pre-prepared station.info (make\_stnfo, sh\_upd\_stnfo)
  - Must set xstinfo in sites.defaults
- RINEX headers (sh\_gamit default: 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.

# 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)
  - 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 (email)

- Contents (Purple is output):

```
Input options -d 2002 30 31 32 33 -expt ncar -pres ELEV -yrextr -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 (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

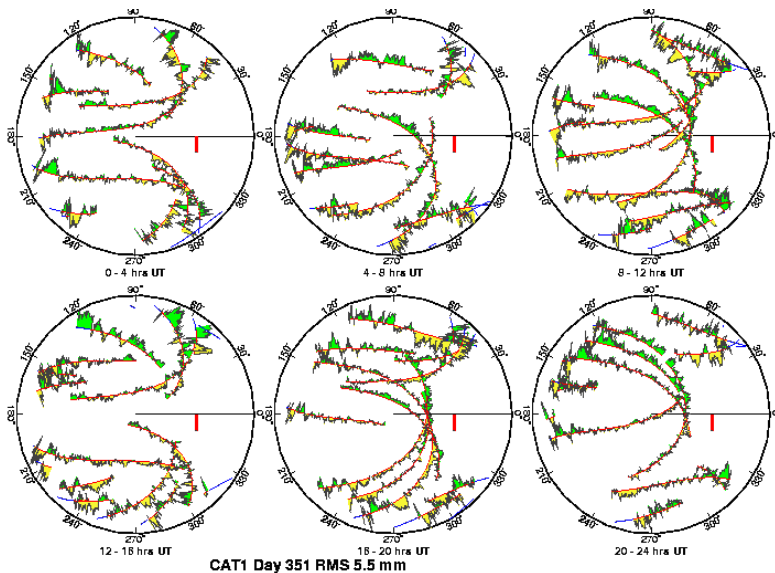
Any large adjustments to positions (>0.3 m)

## Things to note:

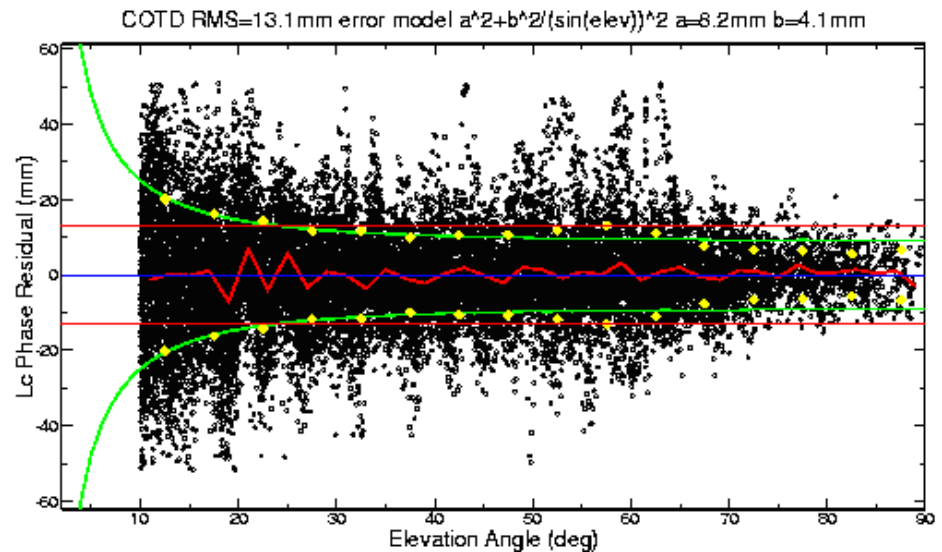
- Number of stations matches expectation
- Site postfit RMS values 3-10 mm
- No stations with RMS = 0 ( implies no data retained by *autcln* )
- Postfit nrms from *solve* ~0.2 for constrained and loose solutions
- “Most” ambiguities resolved (70-85% for noisy days, > 90% for best)

# Phase residual plots

- Set with -pres elev in sh\_gamit command line (requires GMT)
- Postscript files in day directory, by default converted to gif in /gifs directory and then erased (needs ImageMagik convert program).
- Use to assess multipath, water vapor, and antenna phase center model

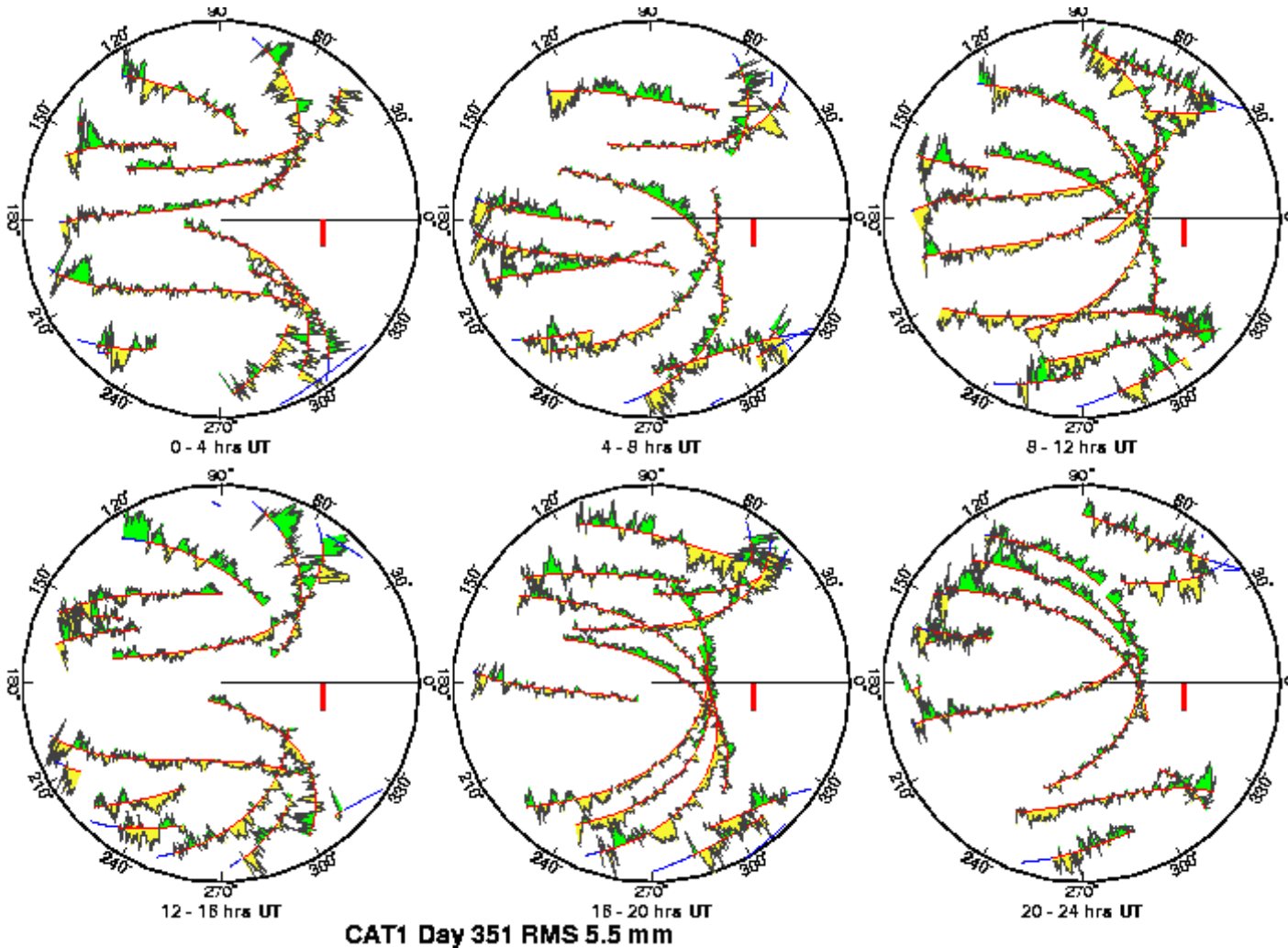


“Sky plot”



Phase vs elevation angle

# Sky plots

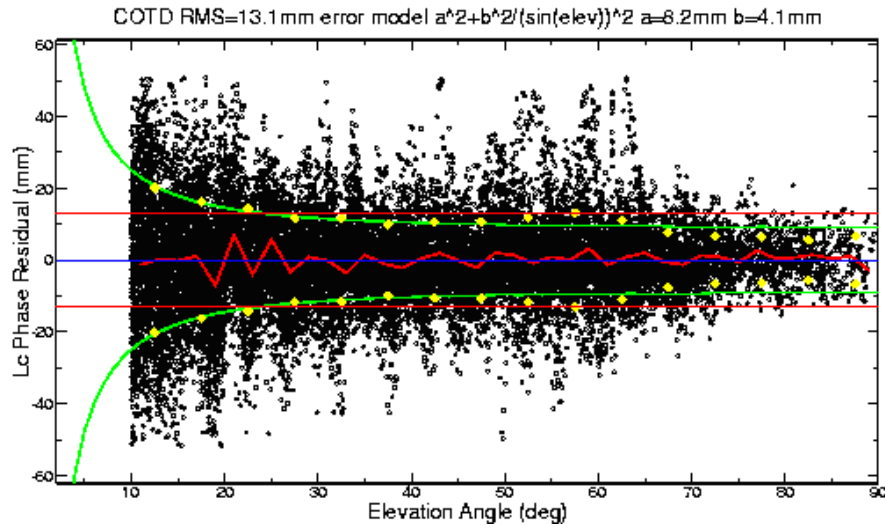


High residuals in the same place at different times suggest multipath

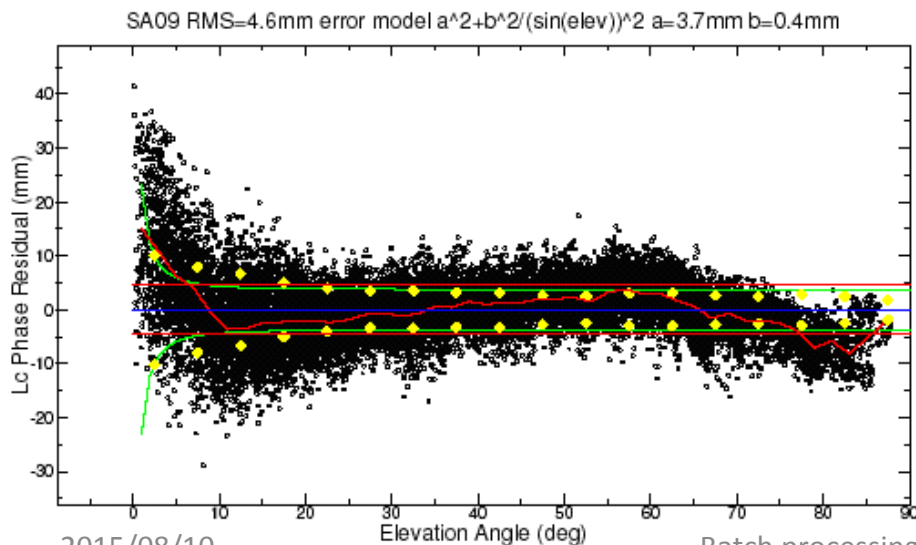
High residuals appearing in a given place only at one time suggest water vapor



# 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 cview
- Q-file nrms > 0.2
  - solution over-constrained: check GCX vs GLX nrms, rerun with only one site constrained

# Problems with a priori coordinates

- Need to be good to  $< 10$  m to get through autcln
- Safest source is a previous solution or a pseudorange solution using svpos/svdiff (sh\_rx2apr)
- Range rms and bias flags added from autcln summary file are a useful check
- Convergence is 1:100 to 1:1000 (1 m error in apr can lead to 1-10 mm error in adjustment)—hence automatic update of L-file for GAMIT 2nd solution
- Watch for repeated updates in email summary as a sign of bad data

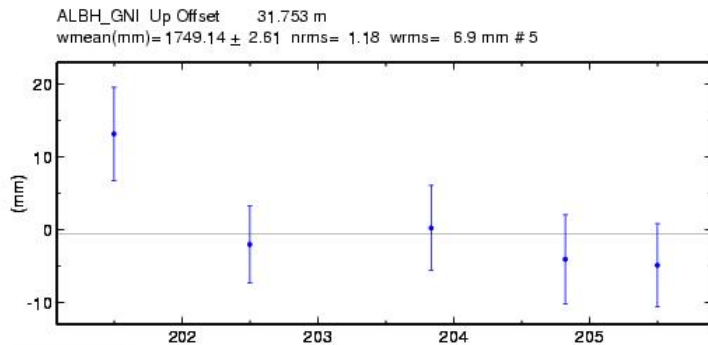
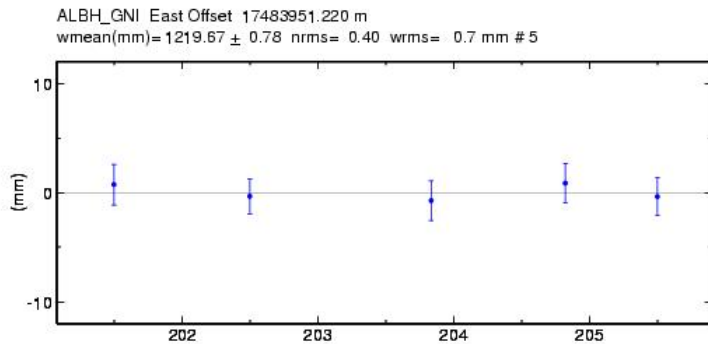
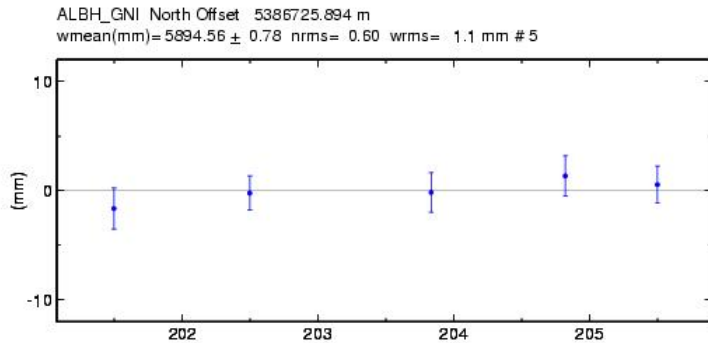
# Constraining the GAMIT solution

- 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 (no orbit estimated now recommended for regional processing.
- 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 cview
- 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)

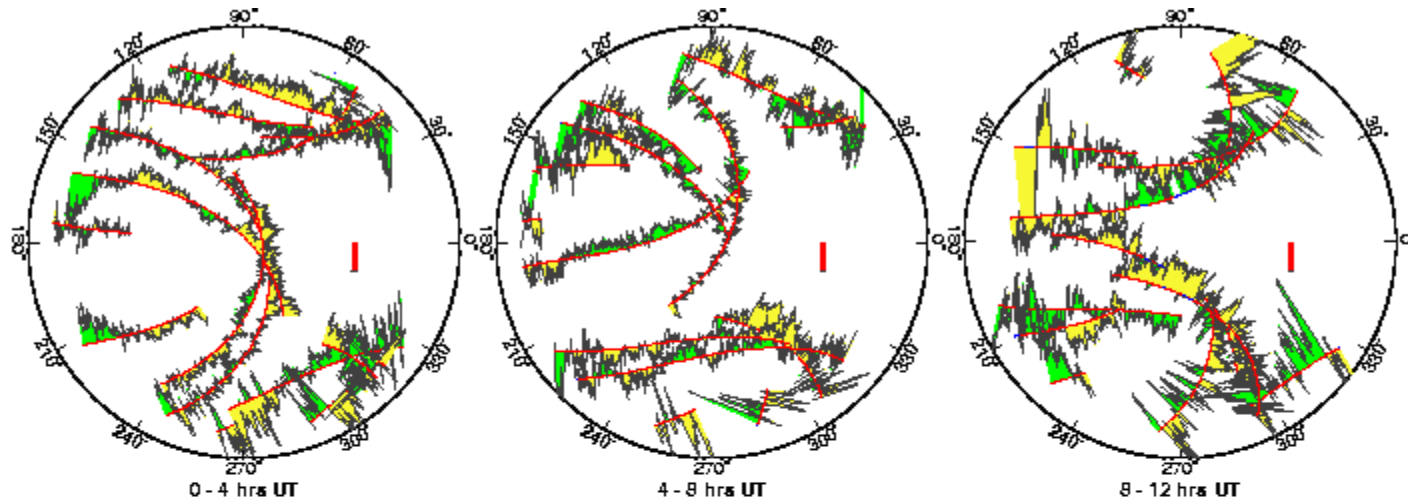
# Example of understanding outliers



## Autcln 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

