GAMIT: Daily GPS processing
Lecture 2

Thomas Herring,
tah@mit.edu
GAMIT Overview

• Discuss the setup, operation and options for GAMIT processing with sh_gamit

• Areas:
  – 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.
Basics

• The scripts that control gamit and globk all have built in help which can be evoked by typing name. (~/gg/com contains all of the scripts used;~/gg/gamit/bin and ~/gg/kf/bin contain the program executables; kf programs also have help output.

• Once software is installed; user selects data to be processed over some interval of time and uses sh_gamit for the processing. Globk is used after the daily processing to combine results and set the reference frame.
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; siitbl. may also need editing to ensure some constrained stations in the network to be processed; seetbl. 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: -netext -yrext
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
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, autcln, solve* for initial solution
  – 5-minute sampling, no ambiguity resolution (GCR only)
  – update lfile. for coordinates adjusted > 30 cm
  – look at --> autcln.prefit.sum, q<expt>p.ddd

• model, autcln, solve for final solution
  – 2-minute sampling, ambiguity resolution
  – Look at --> autcln.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)
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 (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 dcb.dat file
  – 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 -yrext -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

<table>
<thead>
<tr>
<th>RMS</th>
<th>IT Site</th>
<th>All</th>
<th>01</th>
<th>02</th>
<th>03</th>
<th>04</th>
<th>05</th>
<th>06</th>
<th>07</th>
<th>08</th>
<th>09</th>
<th>...</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMS 20</td>
<td>ALL</td>
<td>4.8</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>...</td>
</tr>
</tbody>
</table>

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  | 5  | ... |
| 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   Perscent 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
High residuals in the same place at different times suggest multiple path.

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 makeex.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
Problems with a priori coordinates

- Need to be good to $< 10$ m to get through autcIn
- Safest source is a previous solution or a pseudorange solution using svpos/svdiff (sh_rx2apr)
- Range rms and bias flags added from autcIn 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 (0.005 ppm) for IGS orbits since at least 1996. Use of baseline mode (no orbit estimated now recommended for regional processing.

• Look for good (~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 (discussed during height section)

• 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
GPS adjustments to atmospheric zenith delay for 29 June, 2003; southern Vancouver Island (ALBH) and northern coastal California (ALEN). Estimates at 2-hr intervals.
Summary

• The sh_gamit script is used to automate processing and once set-up usually operates with no human interaction.

• In tutorial session, we will set up run to illustrate operation.