EPOS GAMIT/GLOBK/Track Workshop Introduction

Thomas Herring, MIT
tah@mit.edu

Workshop Overview

- Web site http://geoweb.mit.edu/~simon/gtgk/Thessalonki12/
- Lectures and Tutorials: Day 1:
  1. Advanced modeling and diagnostic in GAMIT daily processing GAMIT Lecture: Overview of standard processing in GAMIT; daily session processing
  2. Advanced processing methods in GLOBK
  3. Tutorial session: Salton Sea data analysis around time of Magnitude 5.8 aftershock to El Major Cucapah April 4, 2010 Mw 7.2 earthquake. Demonstrates short session and globk combined processing.

Workshop Overview

- Lectures and Tutorials Day 2
  1. Basics of kinematic processing with module track
  2. Advanced tuning and diagnostics in track (some discussion of trackRT (real-time version) if interest)
  3. Tutorial: Kinematic data processing data set collected at MIT (display in Google Earth). Individual data sets can be processed here as well.
  4. Tutorial: Processing of El Mayo Cucapah earthquake April 2010 5-Hz data. Students may bring their own data for processing in this session if desired.

Workshop Overview

- Asking questions during the workshop is critical for getting the most from this course.
- Each participant can either ask or submit questions/issues in email to tah@mit.edu and these will be addressed during the tutorial session.
- Questions so far?
- General question: Interest in real-time data processing?

GPS overview

- For GPS processing, the critical information needed is range and phase data from a receiver collecting data from multiple GPS satellites and information about the orbits of the satellites (earth-fixed frame) and some information about clocks in satellites.
- In GAMIT, only crude clock information needed due to double-differencing.
- To integrate GPS orbits, information needed about rotation between earth-fixed and inertial space.
- For the most accurate GPS results, other ancillary information needed (e.g., atmospheric models, ocean tides, antenna and receiver biases).
- Program *track* (kinematic processing) can use just RINEX data files and SP3 GPS orbit files but GAMIT needs a full suite of additional files (track also can use some of these file). The main GAMIT processing script *sh_gamit* handles getting all these files.

GPS overview

- GAMIT processes GPS phase and range data files (RINEX format) usually for 24-hour sessions of data. For newer data collection (post 1996), orbits do not need to be estimated because IGS has very good combined orbits available.
- GLOBK combines together results from daily GPS processing and is used to generate velocity estimates and time-series products.
- In this workshop, basic familiarity with GAMIT/GLOBK processing is assumed and more advanced/subtle aspects of data processing will be addressed.

Observables in Data Processing

Fundamental observations

L1 phase = f1 x range (19 cm) L2 phase = f2 x range (24 cm)

C1 or P1 pseudorange used separately to get receiver clock offset (time). There are "Differential Code Biases" (DCB) between C1 and P1 and so the track method is important when receiver types are mixed>

To estimate parameters use doubly differenced

LC = 2.55 L1 - 1.98 L2 "Ionosphere-free phase combination" L1-cycles

PC = 2.55 P1 - 1.55 P2 "Ionosphere-free range combination" Meters

Double differencing (DD) removes clock fluctuations; LC removes almost all of ionosphere. Both DD and LC amplify noise (use L1, L2 directly for baselines < 1 km)

Observables

Auxiliary combinations for data editing and ambiguity resolution

"Geometry-free combination (LG)" or "Extra wide-lane" (EX-WL)

LG = L2 - f2/f1 L1 used in GAMIT (displayed in cview)

EX-WL = L1 - f1/f2 L2 used in TRACK

Removes all frequency-independent effects (geometric & atmosphere) but not multipath or ionosphere

Melbourne-Wubbena wide-Lane (MW-WL): phase/pseudorange combination that removes geometry and ionosphere; dominated by pseudorange noise

MW-WL = N1-N2=(L1-L2)-(ΔF/ΣF)(P1+P2) = (L1-L2)-0.12 (P1+P2)

Modeling the observations
I. Conceptual/Quantitative

- Motion of the satellites
  - Earth's gravity field (flattening 10 km; higher harmonics 100 m)
  - Attraction of Moon and Sun (100 m)
  - Solar radiation pressure (20 m)
- Motion of the Earth
  - Irregular rotation of the Earth (5 m)
  - Luni-solar solid-Earth tides (30 cm)
  - Loading due to the oceans, atmosphere, and surface water and ice (10 mm)
- Propagation of the signal
  - Neutral atmosphere (dry 6 m; wet 1 m)
  - Ionosphere (10 m but LC corrects to a few mm most of the time)
  - Variations in the phase centers of the ground and satellite antennas (10 cm)

* incompletely modeled

Modeling the observations
II. Software structure

- Satellite orbit
  - IGS tabulated ephemeris (Earth-fixed SP3 file) [track]
  - GAMIT tabulated ephemeris (t-file): numerical integration by arc in inertial space, fit to SP3 file, may be represented by its initial conditions (ICs) and radiation-pressure parameters; requires tabulated positions of Sun and Moon
- Motion of the Earth in inertial space [model or track]
  - Analytical models for precession and nutation (tabulated); IERS observed values for pole position (wobble), and axial rotation (UT1)
  - Analytical model of solid-Earth tides; global grids of ocean and atmospheric tidal loading
- Propagation of the signal [model or track]
  - Zenith hydrostatic (dry) delay (ZHD) from pressure (met-file, VMF1, or GPT)
  - Zenith wet delay (ZWD) [crudely modeled and estimated in solve or track]
  - ZHD and ZWD mapped to line-of-sight with mapping functions (VMF1 grid or GMT)
  - Variations in the phase centers of the ground and satellite antennas (ANTEX file)

Parameter Estimation

- Phase observations [solve or track]
  - Form double difference LC combination of L1 and L2 to cancel clocks & ionosphere
  - Apply a priori constraints
  - Estimate the coordinates, ZTD, and real-valued ambiguities
  - Form M-W WL and/or phase WL with ionospheric constraints to estimate and resolve the WL (L2-L1) integer ambiguities [autcln, solve, track]
  - Estimate and resolve the narrow-lane (NL) ambiguities
  - Estimate the coordinates and ZTD with WL and NL ambiguities fixed

  --- Estimation can be batch least squares [solve] or sequential (Kalman filter [track]
- Quasi-observations from phase solution (h-file) [globk]
  - Sequential (Kalman filter)
  - Epoch-by-epoch test of compatibility (chi2 increment) but batch output

Limits of GPS Accuracy

- Signal propagation effects
  - Signal scattering (antenna phase center / multipath)
  - Atmospheric delay (mainly water vapor)
  - Ionospheric effects
  - Receiver noise
- Unmodeled motions of the station
  - Monument instability
  - Loading of the crust by atmosphere, oceans, and surface water
- Unmodeled motions of the satellites
- Reference frame

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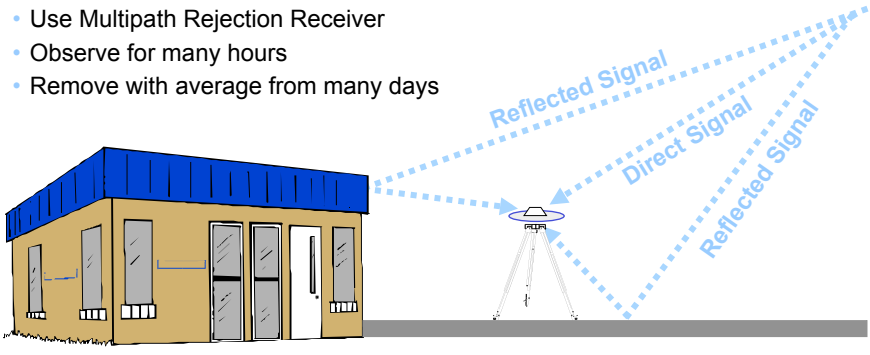
Multipath is interference between the direct and a far-field reflected signal (geometric optics apply)

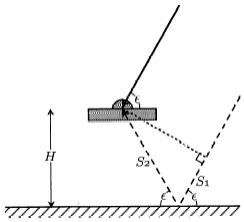
To mitigate the effects:

- Avoid Reflective Surfaces
- Use a Ground Plane Antenna
- Use Multipath Rejection Receiver
- Observe for many hours
- Remove with average from many days

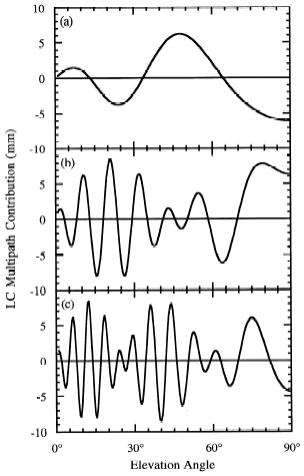


Station Characterization

- New output in autcln that summaries the elevation angle dependence of phase residuals. One line per site, average elevation angle in 1-degree bins (99.9 used if no data).
- Automatically written into autcln.post.sum and can be illustrative of problems.
- Shell script: sh_plot_elmean used
- Examples:



Simple geometry for incidence of a direct and reflected signal



Antenna Ht

0.15 m

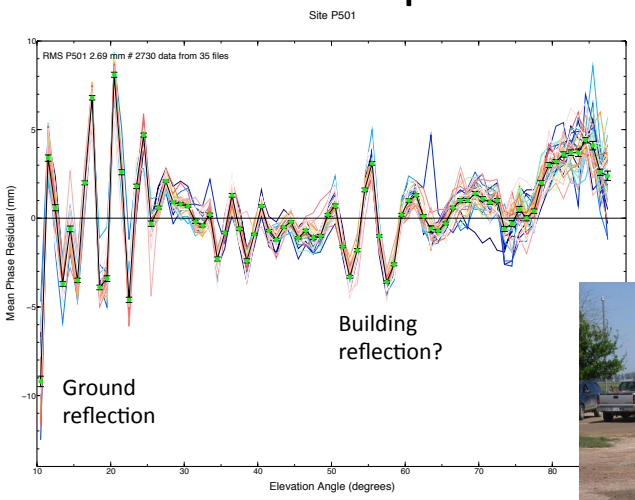
0.6 m

1 m

Multipath contributions to observed phase for three different antenna heights [From *Elosegui et al*, 1995]

Example P501

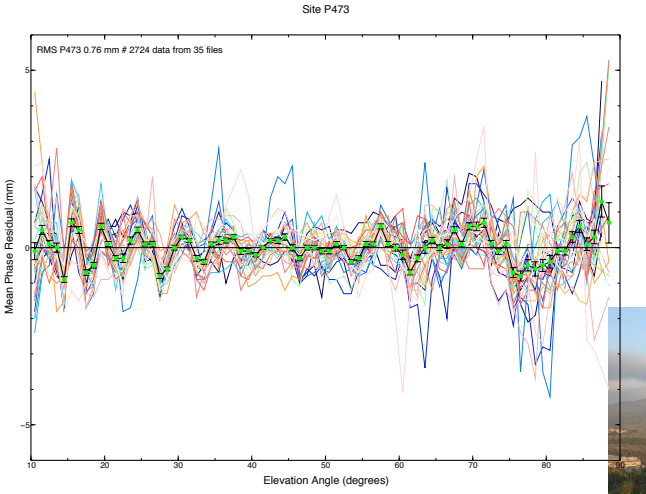
- Example of ground reflection and building



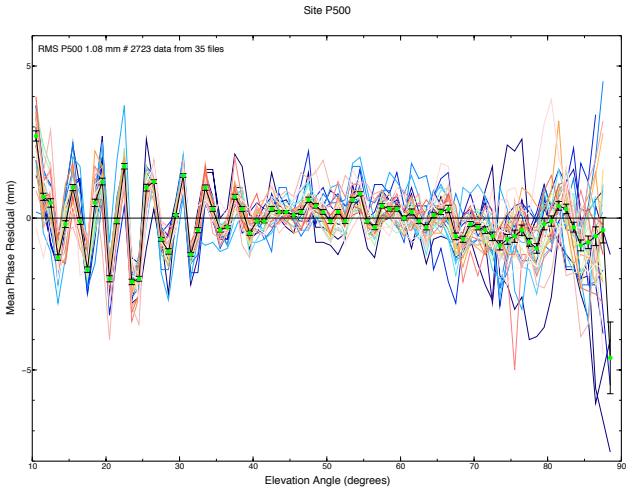
Color are different days; and symbols with error bars are mean.

P473

- Example with little ground reflection

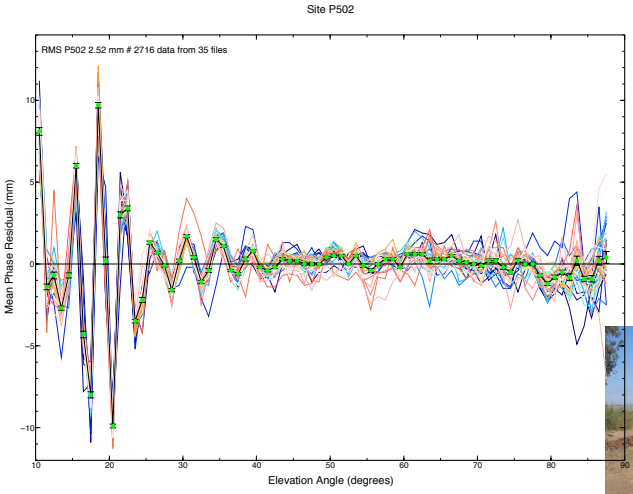


P500



- Large ground reflection; flat surface

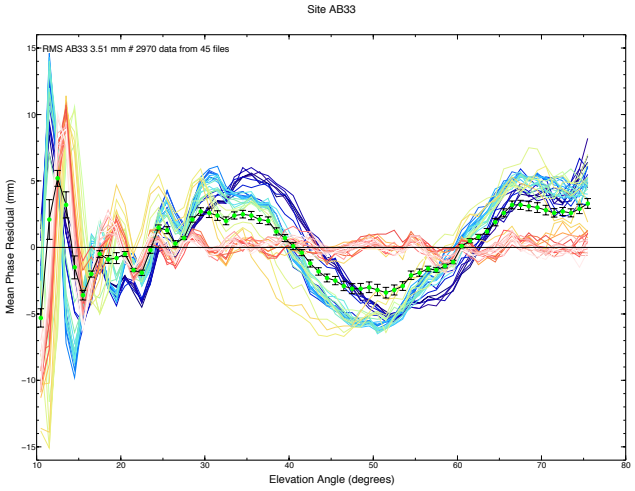
P502



- Strong Ground reflection

Site will be monitored to see how it changes as ground conditions change

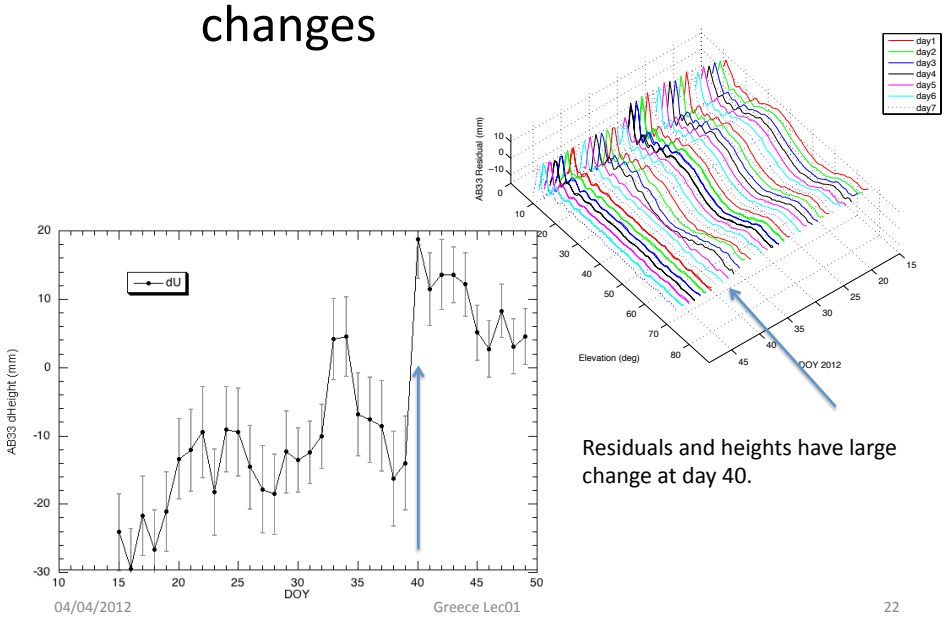
AB33



- Time variable signals. Alaskan site with snow accumulation and melting (believed)
- Colors span a 30-day interval. Site height changes when residuals change

Time series and changes

Height changes correspond to residual changes



Residuals and heights have large change at day 40.

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Loading use in GAMIT

- Atmospheric loading: This is still an area of active research and the optimum approach in terms of SNR of the loading calculations is not clear yet.
- There are three basic issues:
  - Short period tidally driven atmospheric loading signal. These are at the S1 and S2 tidal frequencies
  - Short period (sub-daily) non-tidal signals. Here the debate is on signal-to-noise ratio. If these are important, then need to be applied at the observational level.
  - Reference frame: Center of mass versus center of figure for corrections

Loading in GAMIT

- In sestbl. set
  - Use atl.grid = Y ! This turns of the tidal loading
  - Use atml.grid = Y ! Turns on 6-hrs gridded loading
- When these options are set; sh_gamit will link the day directory files to the ../tables directory for:
  - atl.grid This file normally links back to main tables directory because it is time independent
  - atml.grid in day directory is linked to atml.grid in local tables. In sh_links.tables (called from sh_setup) the atml.grid in tables is linked to ~/gg/tables/atml.grid.yyyy (if files already exist in local tables they are not updated).

Loading setup

- The loading files are available from ftp to everest.mit.edu in the GRIDS directory (they are large). The file names reflect the type of file:
  - 184674852 Jan 19 2011 atmdisp_ce.2010
  - 184674852 Jan 19 2011 atmdisp_cf.2010
  - 184674852 Jan 19 2011 atmdisp_cm.2010
  - 184800996 Feb 23 2011 atmfilt_ce.2010
  - 184800996 Feb 23 2011 atmfilt_cf.2010
  - 184800996 Feb 23 2011 atmfilt_cm.2010
  - 231626292 Feb 22 2011 vmf1grd.2010
- This year (as of 03/30/2012
  - 34941924 Mar 13 13:46 atmdisp_ce.2012_069
  - 34941924 Mar 13 13:46 atmdisp_cf.2012_069
  - 34941924 Mar 13 13:46 atmdisp_cm.2012_069
  - 28887012 Mar 13 13:57 atmfilt_ce.2012_057
  - 28887012 Mar 13 13:57 atmfilt_cf.2012_057
  - 28887012 Mar 13 14:02 atmfilt_cm.2012_057
  - 231626292 Mar 30 10:00 vmf1grd.2012_084
- Each of the yearly grid files is 185Mbytes so they are not small (also shown are the VMF1 grids if this option is used in processing.

Which load files to use?

- The CE, CF and CM are for different origins of the terrestrial reference frame. For orbit determination, the CM frame should be used and this would also be the case for using IGS orbits
- The filt (filtered) files should be used with the tide model but the debate is if the filtered series looses too much at sub-daily frequencies. The disp raw files should not be used with the tide model and the debate here is: is the 6hr spacing too coarse to capture the tides (and is the noise level too high).
- Future releases of globk will be able to add and remove daily averaged load signal (release summer 2012)
- Program atmtoasc can be used to generate values at specific locations. Experiment and see what happens.

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 unless running near-real-time.
- Mapping function grid (optional) – need to update yearly unless running near-real-time.

Summary

- High precision GPS (mm and better positioning) requires external information in additional to just the data and orbit information.
- Here we focused in new residual output and how to include loading in gamit solutions.
- Review of files that need to be kept up to date.
- The next lecture examines GLOBK. The tutorial session this afternoon will look at earthquake effected data set.