GLOBK: Combination methods
Lecture 03

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GLOBK Overview

- Here we review the main features of globk and glred.
- Topics:
  - Program flow
  - Kalman filtering
  - Globk files and estimation rules
  - Glorg progam/function: Define origin plus other things
  - Output options
  - Flow of programs
  - sh_glred: Globk equivalent of sh_gamit
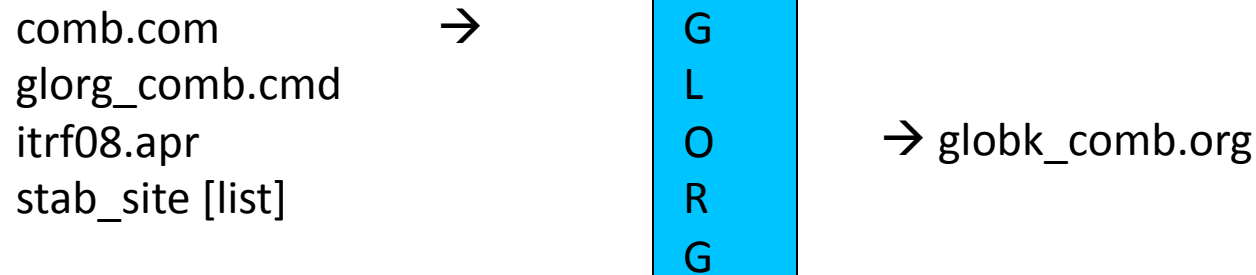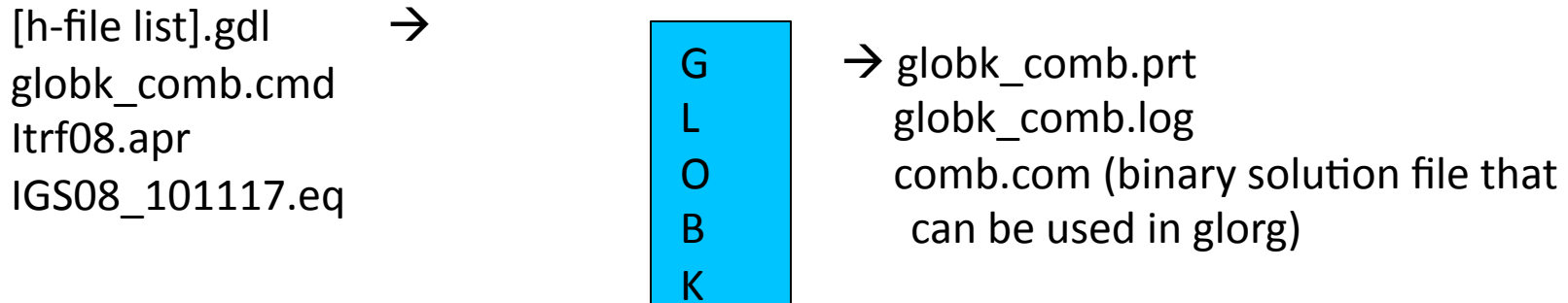
GLOBK Purpose

- GLOBK is a suite of programs designed to combine geodetic results together. GPS phase processing can take a considerable time and GLOBK provides a fast method for make large network solutions, combining many days to years of data together and studying alternative parameterization and reference frames for the velocities of sites.

- GLOBK uses as data input, quasi-observation files called binary h-files which contain geodetic solutions with loosely constrained full covariance information.   These files can generated from gamit solutions or SINEX files.

- GLOBK is a smoothing Kalman filter and can incorporate random walk process noise in its estimation (method for accounting for temporally correlated noise in time series).

- Its two main uses are to generate velocity field estimates and time series in a well-defined and often different reference frames. (It can also be used to merge large networks of GPS sites).

Common applications of GLOBK

- Repeatability analysis (glred)
  - individual sessions
  - combine regional and global files for orbit control and reference frame (orbit control is not so important anymore; IGS orbits are very good apriori)
- Combine sessions to get average position over survey
  - connects stations observed separately
  - reduces number of h-files to be used for velocities
- Combine averaged positions to estimate velocities
  - and/or earthquake offsets and post-seismic motion

GLOBK Function and File Flow

htoglb: Translate GAMIT h-files to (e.g., hemeda.10256) to globk
         h-files (e.g. h1009131200_emed.glx

[h-file list].gdl   →
globk_comb.cmd
Itrf08.apr
IGS08_101117.eq

G
L
O
B
K

→ globk_comb.prt
   globk_comb.log
   comb.com (binary solution file that
    can be used in glorg)

comb.com   →
glorg_comb.cmd
itrf08.apr
stab_site [list]

G
L
O
R
G

→ globk_comb.org

Names of files here can be chosen arbitrarily.

GLOBK file name conventions

- GLOBK uses arbitrary file names but there are some conventions used:
  - Binary h-files from htoglb: .glx is bias fixed, .glr is bias free (normally not used)
  - List of binary h-files to process: .gdl extent
  - GLOBK and GLORG command files: globk_<type>.cmd and glorg_<type>.cmd
  - Output files: print file (no glorg reference frame) .prt (often not output); glorg output .org; log file .log
  - Apriori coordinate files: .apr
  - Earthquake and rename file: .eq
  - Lists of stabilization sites (used with source command): .stab

Kalman Filtering

- Equivalent to sequential least-squares estimation but allowing for stochastic processes, usually a 1st-order Gauss-Markov process

- GLOBK allows a random walk for coordinates, EOP, network translation and scale, and satellite parameters; variance grows linearly with time

- Because a Kalman filter works with covariance matrices (rather than normal matrices), all parameters must have a priori constraints (usually loose)

See *Herring et al*. [1990] and *Dong et al*. [1998] for a more thorough description as applied to geodetic analysis

GLOBK Structural Confusions

- globk and glred are the same program with (slightly) different ways of treating the h-file (gdl) list:
  - globk: all h-files in combined in a single solution
  - glred: each h-file generates a separate solution (unless followed by a +). glred is a small program that generates sub-set .gdl files and runs globk.

- Two types of solution files:
  - h-files for saving and external exchange (backward compatible)
  - com/sol file is internal, format changes with versions

- glorg called by globk/glred or run separately to apply generalized constraints to solution and estimate plate rotations

GLOBK files

- User supplied
  - command files (may include 'source' files)
  - gdl list of h-files
  - binary h-files (created from SINEX or GAMIT h-)
  - apr file(s) (optional but recommended)
  - EOP (in_pmu file, optional but recommended)
  - eq_file (optional, but must appear at top)

- Generated by globk
  - srt, com, sol , svs (must be named and come first)

- Output files
  - screen, log, prt, org and output h-file

GLOBK file handling

- log, prt, org files are concatenated, so should be removed or renamed unless you want them together (e.g. glred). The 'eras' option can be used in the prt_opt and org_opt command in the globk command file to erase these files (should not be used with glred).

- com, srt, sol files are overwritten; com/sol should not be renamed since the original sol file name is imbedded in the com file

- Automatic naming using wild-cards is available for com, srt, sol, org, and output h-files (i.e., name used depends on name of .gdl file; needed for parallel processing.)

Estimation commands rules

- For a parameter to estimated in globk, apr_xxx command must be used where xxx is a parameter type (e.g., neu, svs, wob, ut1, atm)
- If a parameter is not mentioned, it does not appear in the solution, but if it appears in the h-file (i.e, estimated in GAMIT), its uncertainty is implicit in the globk solution; e.g., if orbits are estimated in GAMIT and you want them constrained in globk, use apr_svs. If apr_svs is not used, orbits are left constrained.
- If zero given as a priori sigma, then parameter is not estimated (effectively left unconstrained)
- To force a parameter to it's a priori value, use F as the a priori sigma
- Parameters estimated in glorg must be kept loose in globk ; if rotation or scale is not estimated in glorg, it must be tightly constrained in globk

Earth Orientation Parameters (EOP)

- Normally used in two forms:
  - Global network of stations (allows rotation in glorg)
    - apr_wob 10 10 1 1
    - apr_ut1 10 1
  - Regional network (constrained). When constrained this way system is not free to rotate so xrot, yrot, zrot should not be used in pos_org command(see pos_org in glorg)
    - apr_wob .2 .2 .02 .02
    - apr_ut1 .2 .02
- In many analyses, the global form is used even for regional networks in order to allow rotation estimation in glorg. (Care is needed if network is not not surrounded by stations with well defined motions).
- When using BASELINE option in gamit sestbl. apr_wob and apr_ut1 must be used to allow rotations. For multiday sessions, mar_wob and mar_ut1 should also be used.

Data Editing

- To account for temporal correlations in time series we typically use random-walk (RW) process noise with the mar_neu command (units m2/yr)
- Typical values are 2.5E-8 (0.5 mm in 1 yr) to 4E-6 (2 mm in 1 yr)

    mar_neu all   2.5E-8 2.5E-8 2.5E8 0 0 0

    mar_neu chdu 4E-6 4E-6 4e-6 0 0 0

- The sh_gen_stat command can used to generate process noise estimates provided sufficiently large number of position estimates are available.
- To down-weight noisy segments or equalize continuous and survey-mode data in a combined h-file, can add random noise (units are m)

    sig_neu all .001 .001 .003

    sig_neu ankr   .005 .005 .020   2002 10 1 0 0   2002 11 30 24 0

    sig_neu   EMED0504   .010 .010 .1

- To remove an outlier, can down-weight severely or rename

    sig_neu ankr   .1 .1 .1   2002 10 1 0 0   2002 10 1 24 0

    rename ankr_gps ankr_xcl 2002 10 1 0 0 2002 10 1 24 0 (eq_file)

GLORG

- Invoked by globk to apply generalized constraints after h-files are stacked and loose solution performed; can be run as a separate program using the com/sol files from globk

- Also allows linking of parameters and estimation of Euler poles

- Parameters estimated in glorg must be kept loose in globk (coodinates, EOP, scale)

- GLORG is used to define and refine the reference frame for GLOBK solutions.

Invoking GLORG from globk command file

- The globk command file contains commands that cause glorg to run when globk completes the solution combination:
  - org_cmd < glorg command file name > ---invokes glorg
  - org_opt   < options for output >
  - org_out   < output file name >: Normally not used because name will be generated from prt file name in the globk runstring.
- If org_out is not given then the extent on the print file name is replaced with org

GLORG Commands

- apr_file – Need not be the same as for globk; needs to contain values only for sites used for stabilization and sites for which coordinates or velocities are equated
- pos_org, rate_org – Control what parameters are estimated in stabilization
  - xtran ytran ztran – allows translation
  - xrot yrot zrot – allows rotation
  - scale – allows rescaling of system (if used, estimate scale in globk; apr_scale and possibly mar_scale)
- cnd_hgtv – Control relative weights of heights (variances, nominally 10 but increasing value will reduce heights effecting horizontal position estimates; 1000 is good for this)
- stab_ite – # of iterations and sigma-cutoff to remove a site
- stab_site – List of sites to use in stabilization

Controlling Print Output

- crt_opt, prt_opt, org_opt specify output options for screen, print and org files
- globk/glorg help gives all options, main ones are:
  - ERAS -- erase file before writing (normally files appended)
  - NOPR -- Do not write output (e.g., for globk when invoking glorg)
  - BLEN -- Baseline lengths
  - BRAT -- baseline rates when velocities estimated
  - RNRP -- generates reports on differences in parameter estimates after renames.
  - FIXA -- makes apriori coordinates and velocities consistent when equates are used in glorg (can sometimes fail in complicated rename scenarios--best if apr_file is provided with consistent values)
  - VSUM -- Lat/long summary of velocity (needed to plot velocities)
  - PSUM -- Lat/long position summary
  - GDLF --Include list of hfiles and chi**2 increments from run
  - CMDS -- Echos globk command file into output file

Handling Steps due to Earthquakes (or instrument changes)

- **Level 1 (always necessary)**
    Rename the site, either automatically (e.g. Wenchuan, May 2008)
        <Code> <Lat> <Long>   <Radius> <Depth> <epoch>
    eq_def   WC 31.099 103.279 1000   20   2008 5 12 6 28
    eq_rename WC   forces rename, e.g. CHDU_GPS --> CHDU_GWC
    eq_cosei   to specify spatially dependent constraints on position adjustments

- or explicitly (for non-tectonic steps)
    rename iisc_gps iisc_1ps 1995 10 1 2 0 0   1999 12 1 5 0
            ! Antenna swap from Trimble SST to AOA choke ring
    rename lake_gps lake_xhi 2002 1 12 0 0 2002 1 12 24 0

- Commands put in the eq_file (not globk command file)
- Effect is to make the site's coordinates and velocities independent in the solution
- The script sh_makeeqdef can be used to generate an eq definition file bases on the NEIDC seismic catalog and program stinf_to_rename can used to generate renames due to antenna changes.

Handling Steps due to Earthquakes (or instrument changes)

- **Level 2 (almost always desirable)**
- In glorg equate the velocities, either explicitly

  equate iisc_gps ndot iisc_1ps ndot
  equate iisc_gps edot iisc_1ps edot
  equate iisc_gps udot iisc_1ps udot

- or automatically

  eq_dist 1000 ndot
  eq_dist 1000 edot
  eq_dist 1000 udot
  unequate chdu_gps ndot chdu_gwc ndot
  unequate chdu_gps edot chdu_gwc edot
  unequate chdu_gps udot chdu_gwc udot

- Effect is to (re)link the adjustment (should be used with the FIXA option)
- Can create a soft link with "constrain" command (so that values are not forced to be exactly the same.
- Equates are applied to adjustments to apriori coordinates, so in general these should be the same (FIXA option will often do this automatically; unify_apr is another method).

Handling Steps due to Earthquakes (or instrument changes)

- **Level 3 (often useful to improve far-field velocities)**
- Equate the positions when a site within the EQ radius has a small displacement

  equate xian_gps npos xian_gwc npos

  equate xian_gps epos xian_gwc epos

  equate xian_gps upos xian_gwc upos

- May be used in conjunction with a model, applied as an offset in a rename command (need to be very careful with approach or offsets can applied multiple times).

  rename xian_gwc xian_gwc 2008 5 12 6 28 -0.003 0.004 0.001 NEU

- Offsetting the coordinates in the globk apr_file

Program Flow

- Read all the h-file headers to determine their contents (sites, other parameters, epoch range)
- Apply renames as requested in the eq_file
- Sort the h-file list forward or backward in time (srt_dir)
- Initialize the Kalman filter with the a priori constraints (apr_xxx)
- Read in the h-files, one at a time, compute the chi2 increment, coordinate adjustment, and rotation implied by the new data; if within tolerance (max_chii), update the solution and write the chi2 increment to the log file
- Write the solution to the sol_file and prt file (and optionally to a new h-file)
- Optionally invoke glorg to apply generalized constraints
  - Apply the constraints (iterative "stabilization")
  - Apply linkage of parameters (equate, constrain, force), computing the chi2 increment for each
  - Estimate plate rotations (plate command)
  - Write the solution to the org file (glorg prt file)

Things GLOBK cannot do

- Repair mistakes in original analysis
  - cycle slips
  - wrong antenna phase center models
- Resolve ambiguities
  - (would make files too large)
- Overcome non-linear effects
  - As in GAMIT, adjustments must be less than ~ 30 cm
- But GLOBK can delete stations
  - can help avoid contaminating solution

Apr Files in GLOBK Processing

- GAMIT
  - 10 m accuracy for all sites for cycle-slip repair
  - < 30 cm final adjustment for linearity (1st solution guarantees)
  - ~5 cm accuracy in constrained site(s) for ambiguity resolution
- globk
  - If invoking glorg for reference frame, apr_file usually optional in globk
  - If not invoking glorg, need accurate apr_file entries for constrained sites
  - For complicated renames and equates, apr_file may be needed in globk
- glorg
  - Apr_file needs coodinates only for reference sites and equates

What can go wrong ?

- globk
  - H-files not used: removed automatically for high chi2, coordinate adjustment, or rotation (max_chii command)
  - High chi2 increment: inconsistent data
  - Station "missing": not present in h-file or renamed out (use glist)

- glorg
  - Stabilization fails: too-few sites in stabilization
  - Large uncertainties: poor stabilization
  - Too-small uncertainties for some stabilization sites: rotation parameters absorbing coordinate adjustment
  - High chi2 in equate: inconsistent data
  - Wrong velocity for equated sites: unmatched apriori

Associated programs

- htoglb – Translates various ascii solution files into GLOBK h-files (GAMIT h-files, SINEX)
- glbtosnx -- Generates SINEX files from binary h-files
- glist -- lists the contents of a series of h-files
- hfupd -- Updates binary h-files for changes in station.info or sinex header file (distributed by IGS)
- ensum, enfit, tscom, tsfit -- time series analysis (batch)

- Matlab derived programs (interactive):
  - velview -- displays and analyzes velocity fields
  - tsview -- displays and analyses time series.

sh_glred script

- A convenient way to run globk/glorg to generate time series:
  sh_glred –s 2011 256 2011 303 -opt H G E

- Requires user-constructed command files in /gsoln
  (globk_comb.cmd and glorg_comb.cmd : eq_file, apr_file, use_site
  list, stab_stie list, ..) Copy templates from gg/tables and edit for
  your network.

- Automatically creates one gdl file per day (unlike glred when run
  directly, which may have a single gdl file with h-files for many days

- With the 'E' option, will invoke sh_plotcrd (calling 'ensum') to
  extract coordintes from the org files and plot them.

- Additional options allow automatic download of global h-files from
  MIT or SOPAC and combination with the local h-files

Suggested Directory Structure for Multi-year Processing

/project
  /YYY1   /YYY2 . . .   /vsoln   /tables
    /tables   /gsoln   /DDD . . .

Notes
- Experiment/project directory names do not have to match the sh_gamit 4-character expt name
- Experiment-wide tables (e.g. apr, eq/rename, use_site, edit files) may reside in top-level or yearly /tables (just get the path right in the globk/glorg command files)
- Can add multiple 'solution' directories at the top level for different analyses
- Copy templates for globk_vel.cmd and glorg_vel.cmd from gg/tables to /vsoln and edit
- Generate h-file list in /vsoln using, .e.g. ' ls YYY?/gsoln/h*glx > project.gdl '

Steps in Multi-year Analysis

- Generate daily time series for each year or partial year using sh_glred ; create edit commands as appropriate (sig_neu and/or xcl renames)
- Optionally aggregate the days into weekly, monthly, or survey-length H-files using sh_glred with the –ncomb option and out_glb specified in globk_comb.cmd.
- Generate a multi-year time series using glred/glorg and sh_plotcrd; repeat with reweighting
- Perform a velocity solution using globk/glorg; plot with sh_plotvel
- Extract a new stabilization apr file from the velocity solution
- Repeat the multi-year time series using the new apr file and a stab_site list expanded to include all well-determined CGPS and SGPS sites

- Note: It may be convenient to use the 'source' option in globk_comb.cmd and globk_vel.cmd to include use_site, stab_site, and sig_neu lists (see templates)

GLOBK Commands for Multi-year Solutions

In /voln directory:

- Repeatabilities

  glred 6 globk.comb.prt globk.comb.log project.gdl
     globk_comb.cmd

  sh_plotcrd –f globk_comb.org –s long

- Velocities

  globk 6 globk_vel.prt globk_vel.log project.gdl   globk_vel.cmd

  sh_plotvel   -f globk_vel.org   -R244.5/25140.5/46.5

Eq_file entry for Maule earthquake

* EQ_DEF M 8.8

```
eq_def MA  -36.030  -72.850   3539.0     26.0 2010  2 27  6 34  190.4683
eq_rename MA
eq_coseis MA  0.001 0.001 0.001    190.468    190.468    190.468
eq_log MA  1.0 0.001 0.001 0.001    190.468    190.468    190.468
```

(or ftp the file Maule.eq from chandler.mit.edu, (mitg) dd incoming/lima)

Convenient Methods of Creating Edit Commands

To eliminate a data point (station/epoch), you can put into the eq_file commands of the form

  rename areq areq_xcl 2009 3 5 0 0 2009 3 5 24 0

which you can create with a specified sigma-cutoff in tsview (interactive) or tsfit (batch); you can also create the commands with a mouse click in tsview

To downweight horizontal and/or vertical data points (station/epoch), you can put into the globk command file (perhaps using 'source daily.reweights') commands of the form

  sig_neu areq   0.010 .010 .100 2009 3 5 0 0 2009 3 5 24 0

which you can create with a few keystrokes by using program grw

 grw areq 09 64 64 10 100

   (day 64 is 5 March; units here are mm, but m in sig_neu)

   ('grw' stands for 'globk reweight'. It appends to a file temp.out)

NOTE: If you are referencing a combined h-file (more than 1 day), the date range given for the rename or sig_neu command must encompass the range of the h-file times.

Summary

- GLOBK has many features and due to its evolution, there are often multiple ways of doing the same or similar things.

- There is extensive help in the ~/gg/help/ directory and discussion in the documentation.

- GLOBK is where all the major analysis decisions are made and hence can be quite complex for large analyses.

- Experimentation and testing your ideas of how different options effect the results is one the best ways to learn the software (e.g., what happens to position/velocity estimates if the apr_tran command is added to the globk command file? How do my estimates and uncertainties change if the apr_neu and mar_neu commands are changed?