Overview of post-processing with GLOBK

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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 program/function: Define origin plus other things
  - Output options
  - Flow of programs

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

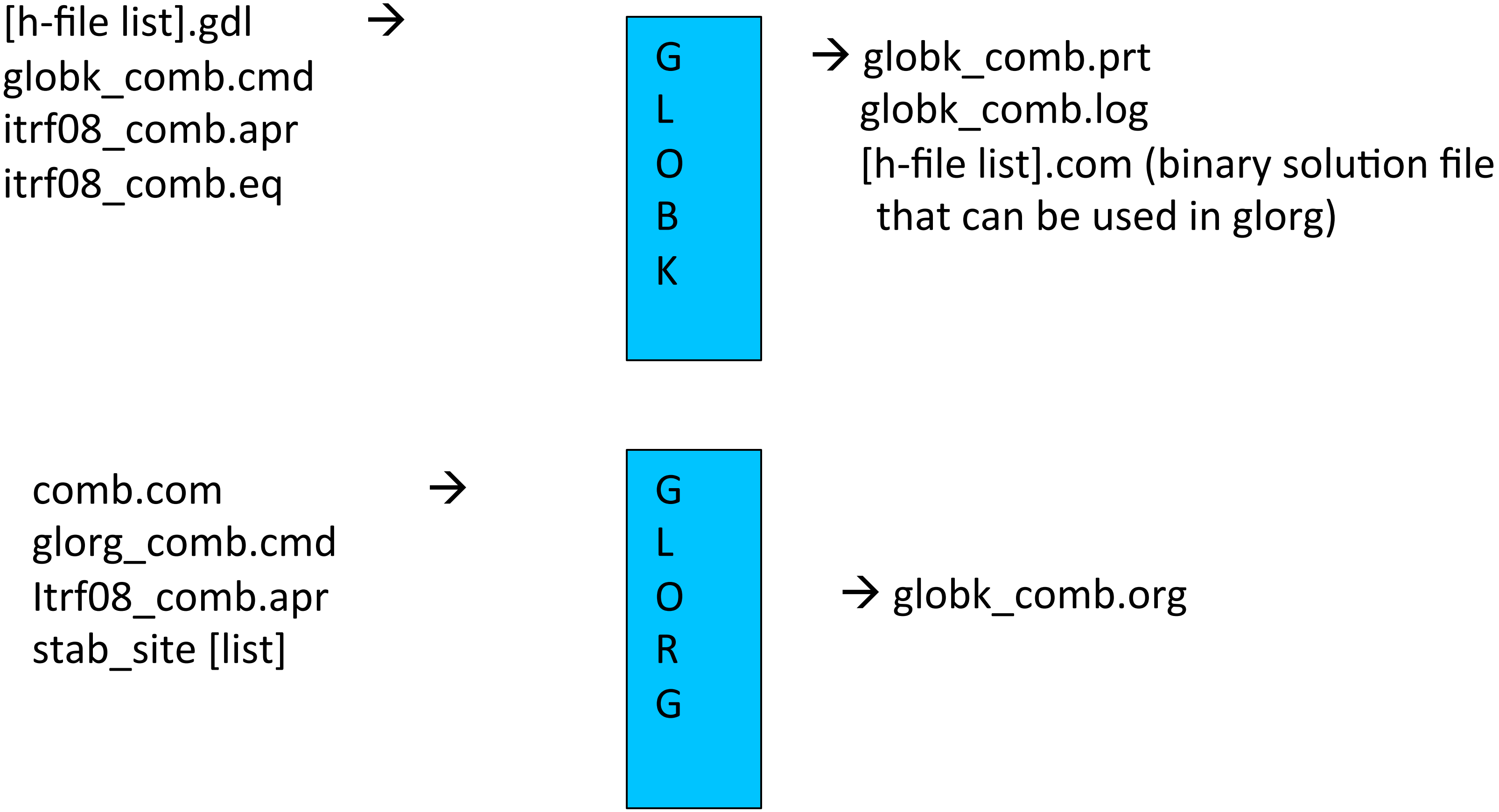
- Repeatability analysis (glred)
  - individual sessions
  - combine regional and global files for orbit control and reference frame (orbit control is not so important anymore; IGS orbits are very good apriori)
- Combine sessions to get average position over survey
  - connects stations observed separately
  - reduces number of h-files to be used for velocities
- Combine averaged positions to estimate velocities
  - and/or earthquake offsets and post-seismic motion
- When globk is run in parallel in the same directory, care should be used in scratch file names (discussed later)

Processing stages

- HTOGLB generates input binary h-files.
- GLOBK has distinct modules that are used:
  - Initialization: Header information from the binary h-files are read to determine the nature of the solutions i.e., parameters in the state vector, all site names accounting for offsets and earthquakes etc.
  - Forward Kalman filter: Binary h-files are combined to generate solution. Normally most parameters are loosely constrained.
  - Possible backwards smoothing filter (not that common)
  - Simple output of the solution (program GLOUT: generates .prt file)
  - Reference frame realized solution and post-solution constraints. Generates .org file. Program GLORG can be used separately for multiple realizations and constraints.
  - Saving binary version of solution for additional processing (out_glb and GLSAVE program).
- Modules in GLOBK can be called with in GLOBK as subroutines or run externally as stand-alone programs (program names are lower case)

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_comb.apr
itrf08_comb.eq

GLOBK

→ globk_comb.prt
globk_comb.log
[h-file list].com (binary solution file
that can be used in glorg)

comb.com →
glorg_comb.cmd
Itrf08_comb.apr
stab_site [list]

GLORG

→ globk_comb.org

Names of files here can be chosen arbitrarily.

GLOBK command files

- GLOBK is controlled by a command file that "instructs" the program what to do.
- The command file contain the following classes of commands:
  - Estimation command: Tells globk what to estimate and constraints on apriori values and temporal behavior of the parameters. apr_xxx and mar_xxx commands.
  - Apriori information commands: Coordinates, discontinuity times, selection of sites
  - Output (types and files), and control commands (e.g., to run glorg)
- GLORG (post-processing program/module) also has its own command file.
- The simplest globk command can have one line:
  apr_neu all 10 10 10 0 0 0
  but in general have several other commons commands (see examples in ~/gg/tables/globk_xxxx.cmd and ~/gg/tables/glorg_xxxx.cmd

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. Com_file command must be used in globk command file for glorg to run by itself.

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 (all except .sol must be named and commands need to be top of globk command file)
- 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 surrounded by stations with well defined motions).

Data Editing

- To account for temporal correlations in time series we typically use random-walk (RW) process noise with the mar_neu command (units m^2/ 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 (apr_tran in globk if GAMIT BASELINE choice of experiment)
  - 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

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, a run sequential Kalman Filter. 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. Can be an issue when estimating orbits (RELAX mode) if MIT GLX file use different modelling (e.g. Albedo, gravity field)
  - 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, tscon, tsfit -- time series analysis (batch)

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

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?