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Overview of post-processing with GLOBK

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GLOBK overview

- Here we review the main features of `globk` and `glred`
  - Program flow
  - Kalman filtering
  - GLOBK files and estimation rules
  - `glorg` program/function: Define origin plus other things
  - Output options
  - Flow of programs
- Always keep in mind that there are often multiple ways to do effectively the same thing. A good self-test is to see if you can think of some of these.
- All GLOBK programs have extensive help which is printed if no arguments are given (~/gg/help/ typically contains the help files).

GLOBK purpose

- GLOBK is a suite of programs designed to combine geodetic results together. GNSS 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 GNSS sites or different GNSS processing).

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 or to combine GNSS solutions.
  - 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

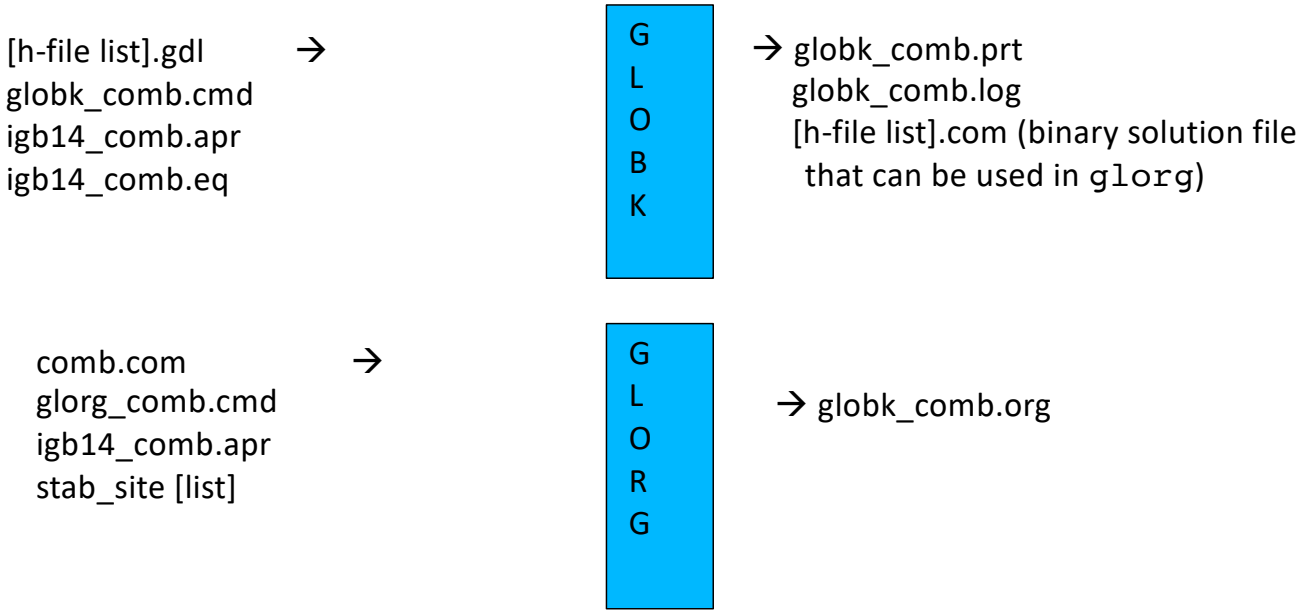
- `htoglb` generates input binary h-files.
- GLOBK has distinct modules that are used:
  - Initialization: Header information from the binary h-files are read to determine the nature of the solutions i.e., parameters in the state vector, all site names accounting for offsets and earthquakes etc.
  - 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" option in command file and `glsave` program).
- Modules in GLOBK can be called within GLOBK as subroutines or run externally as stand-alone programs (program names are lower case)

Using non-GAMIT files in `htoglb`

- `htoglb` can convert other types of solution/covariance matrix files into GLOBK binary h-files.
- There are caveats when this is done because these other file formats don't contain the same meta data as the GAMIT h-files.
- For GAGE/PBO Frame resolved SINEX files:
  - Use the -d=R option to apply rotation loosening (-d=RT also loosens translation).
  - -m=512 (allocate 512 Mb memory) is needed from more recent files
  - There are "loose" SINEX files for which -d=TR is not needed except for CWU files which are not loose (these are the submitted AC files)
- IGS SINEX files
  - Use -s option for name translation with point codes. -d=R should also be used also.
  - Variance-covariance matrix will need scaling depending on AC (scaling value supplied in .gdl file). COD solution of more difference from unity (~10^{-4})

GLOBK function and file flow

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



Names of files here can be chosen arbitrarily and use of ”wild cards” in command file is possible

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.
  - a priori 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.cmd and ~/gg/tables/glorg.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), .gls for SINEX derived files.
  - 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 first-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 "+" in .gdl-file). `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-files)
  - .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 or new date/time designations; 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 its 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.
- “Loose” constraints are apriori sigmas large compared to how well the parameter can be estimated without constraints.

Earth orientation parameters (EOPs)

- Normally used in two forms:
  - Global network of stations (allows rotation in `glorg`): Units are mill-arc-seconds and mas/day. 1 mas = 30 mm on the surface of the Earth (6371 km).

```
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 .25 .25  .1 .1
apr_ut1 .25  .2
```

- 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 (coordinate data)

- 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 2.5×10^{-8} m^2/yr (0.5 mm in 1 yr) to 4×10^{-6} m^2/yr (2 mm in 1 yr)

```
mar_neu all   2.5e-8 2.5e-8 2.5e-8  0 0 0
mar_neu chdu  4e-6   4e-6   4e-6    0 0 0
```

- `sh_gen_stats` can used to generate process noise estimates provided sufficiently time series have large number of position estimates. (glred and tssum/tsfit)
- 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 01 00 00 2002 11 30 24 00
sig_neu all  EMED0504   .010 .010 .1   ! EMED0504 string is in h-file name
```

- To remove an outlier, can down-weight severely or rename (in eq_file)

```
sig_neu ankr  .1 .1 .1  2002 10 01 00 00 2002 10 01 24 00
rename ankr_gps ankr_xcl 2002 10 01 00 00 2002 10 01 24 00
```

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`
  - Site coodinates
  - EOPs (for estimation of rotation)
  - Scale
- `glorg` is used to define and refine the reference frame for `globk` solutions. No strain is introduced into networks when this approach is used provided original h-files are loosely constrained.

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 a priori 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 chi^2 increment, coordinate adjustment, and rotation implied by the new data; if within tolerance (max_chii), update the solution and write the χ^2 increment to the log file.
- (optional: Back filter run; recent versions of GLOBK allow reference frame realization and binary h-file output in back solution).
- 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 χ2 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 (first 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`
  - EXTENDED entries that allow periodic terms and post-seismic models.
- `glorg`
  - apr_file needs coordinates only for reference sites and equates

What can go wrong?

- `globk`
  - h-files not used: removed automatically for high χ^2, coordinate adjustment, or rotation (max_chii command)
  - High χ^2 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: Use as many as possible for robustness.
  - Large uncertainties: poor stabilization or sub-networks not connected
  - Uncertainties too small for some stabilization sites: rotation parameters absorbing coordinate adjustment
  - High χ^2 in equate: inconsistent data
  - Wrong velocity for equated sites: unmatched a priori.

Iteration of solutions

- A common approach is repeated runs of globk and glred.

(1) Run glred with igb14_comb.apr and igb14_hierarchy.stab_site (include igb14.eq in globk) to generate time series for all sites.

(2) Use tssum and tsfit and sh_gen_stats to get process noise models.

(3) Run globk to combine all data and use igb14_comb.apr and igb14_hierarchy.stab_site (include igb14.eq in globk) to get globally aligned coordinates and velocities.

(4) Extract positions and velocities (sh_exglk) to get coordinates and velocities of all sites in network and use these coordinates as apriori; add local sites with small correlated noise to stabilization list (additional file and use source command).

(5) Go back to step with refined local reference frame. Iterate to improve local coordinates and process noise models.

Associated programs

- `htoglb`: Translates various ASCII solution files (GAMIT h-files, SINEX) into GLOBK binary h-files
- `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). Only eccentricity can be fixed.
- `tssum`, `tsfit`, `tscon`: 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 values in the “apr_neu” and “mar_neu” commands are changed?
- Experimentation is the best way to learn.