Generating velocity solutions with `globk`

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GPS Data Processing and Analysis with GAMIT/GLOBK and `track`
Addis Ababa University, Ethiopia
24–25 & 27–29 November 2017

http://geoweb.mit.edu/~floyd/courses/gg/201711_AAU/

Material from R. W. King, T. A. Herring, M. A. Floyd (MIT) and S. C. McClusky (now at ANU)

Overview

- Basics of “velocity” solutions
  - Invoked with “apr_neu all xx xx xx <NEU velocity sigmas>”
- Strategies for setting up solutions (they can take a long time to run)
- Strategies for speeding up solutions.
- Methods for “cleaning up” potential problems
- Different reference frame realizations
- Some examples.
- *These solutions involve making decisions about how to treat data and the type of solution to be created – lots of decisions*

GLOBK velocity solutions

- The aim of these solutions is to combine many years of data to generate position, velocity, offset, and postseismic parameter estimates. Not uncommon to have 10000 parameters in these solutions.
- Input requirements for these solutions:
  - a priori coordinate and velocity file. Used as a check on positions in daily solutions (for editing of bad solutions) and adjustments are a priori values (a priori sigmas are for these values)
  - Earthquake file which specifies when earthquakes, discontinuities, and mis-named stations affect solution. Critical that this file correctly describe data.
  - Process noise parameters for each station. Critical for generating realistic standard deviations for the velocity estimates (`sh_gen_stats`).

Velocity solution strategies

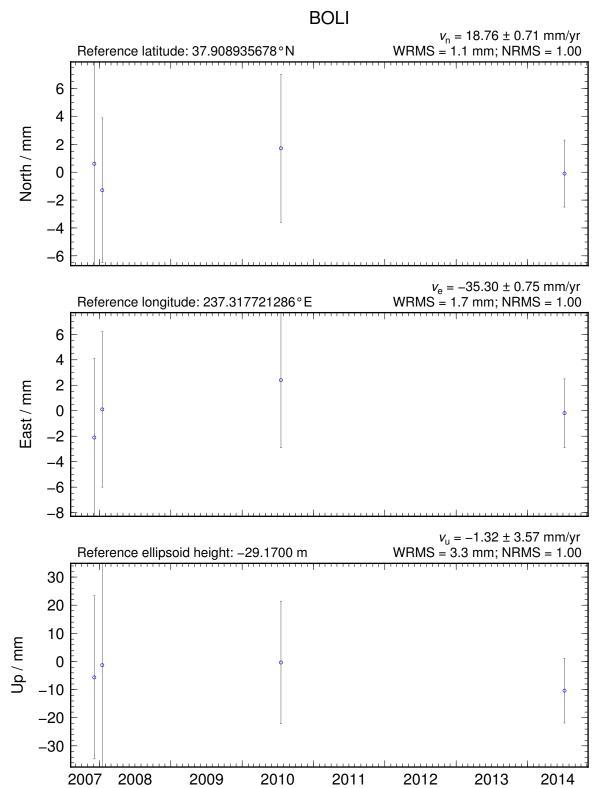
- In general careful setup (i.e., correct apriori coordinate, earthquake file and process noise files) is needed since each run that corrects a problem can take several days. Incorrect solutions may not complete correctly and results may be subtly wrong.
- General strategy for iteratively generating velocity solution:
  - Define a core-set of sites (usually 20-200 sites) where the solution runs quickly. Test files on this solutions and use the coordinate/velocity estimates to form the reference frame for time series generation.
  - Time series using these reference frame sites and then test (RMS scatter, discontinuity tests) to form a more complete earthquake and apriori coordinate/velocity files.
  - Steps above are repeated, usually increasing number of stations until solution is complete. As new stations are added missed discontinuities and bad process noise models can cause problems.
- Aim here is make sure that when a large solution is run (maybe several days of CPU time) that the run completes successfully.

Before velocity runs

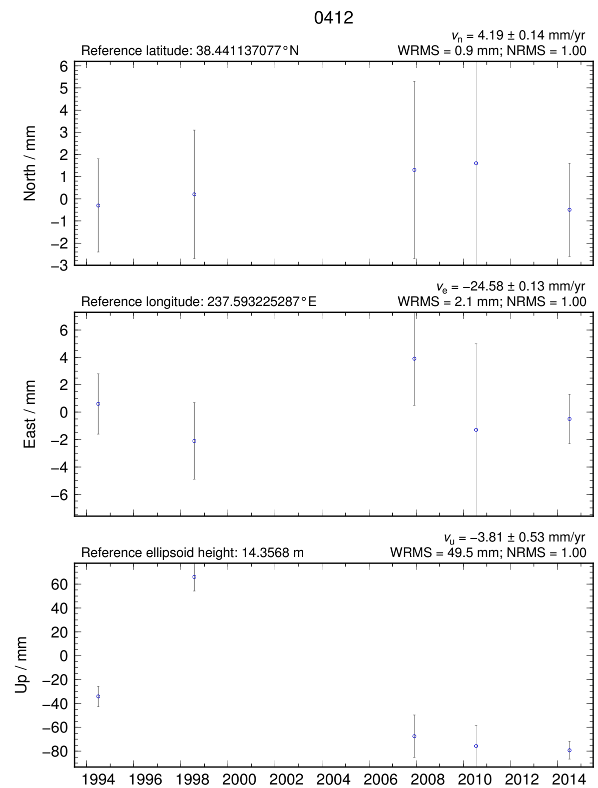
- Surveys may be combined into one solution per survey
- No need to re-run `glred` again to see long-term time series
- Multiple ".org"-files may be read by `tssum` or `sh_plot_pos`
  - `tssum ts_pos mit.final_igb08 -R survey1_comb.org survey2_comb.org ...`
    - `ts_pos is the name of a directory for the .pos files. (. can be used)`
  - `sh_plot_pos -f survey1_comb.org survey2_comb.org -k ...`

Example: Long-term time series for survey sites

Reasonable repeatability



Outlier in vertical



Excluding outliers or segments of data

- Create "rename" file records and add to `globk` command file's "eq_file" option, e.g.

```
rename PTRB     PTRB_XPS h1407080610_nb4a
rename PTRB     PTRB_XPS 2014 07 07 18 00 2014 07 08 18 30
rename ABCD     ABCD_XCL 2013 07 08 00 00
```

- "XPS" will not exclude data from `glred` (so still visible in time series) but will exclude data from `globk` (combination or velocity solution)
- "XCL" will exclude data from all `glred` or `globk` runs

Run `globk`

- Create new ".gdl"-file with *combined* binary h-files, e.g. from vsoln/, assuming standard directory hierarchy
    - `ls ../*/gsoln/*.GLX > vsoln.glx.gdl`
- Optionally run `glist` to see size of solution
    - Recommended to prevent problems during long `globk` run
    - `glist` can read earthquake file and `globk` use site type commands. (Useful if a `globk` solution seems to be missing or has extra sites.)
- Run `globk`
    - This may take many hours for very large/long velocity solutions
    - Use `tsfit` with earthquake file to generate a priori site coordinates. Be careful if ~/gg/tables/itrf08_xxx.apr files also used because some site names permutations may have inconsistent coordinates (use `unify_apr` to be safe)

`glorg` for different reference frames

- No need to re-run `globk` every time you want
- `glorg` is usually called from `globk` command file ("org_cmd" option) but `glorg` may be run separately
- `globk 6 globk_vel.prt globk_vel.log globk_vel.gdl globk_vel.cmd`
- `glorg globk_vel_noam.org ERAS:… glorg_vel.cmd vel.com`
- Must have saved the ".com"-file!
  - e.g. "com_file @.com"
  - Do not use "del_scra yes" in `globk` command file
  - "apr_neu" must be loosely constrained ("apr_rot" and "apr_tran" will also need to be used for sestbl. "BASELINE" experiment solutions.

Use of equates

- With earthquakes and discontinuities, there can be many site names for the same physically location:
  - Equate commands in `glorg` allow the velocity adjustments at these sites to be made the same (or constrained to be the same within a specified sigma)
  - “eq_dist” allows site separate by distance to equated (and constrained in latest `glorg`).
  - “eq_4char” equates sites with same 4-character name (useful to stop equates at sites that share antennas).
  - Chi-squared increments of equates allows assessment of equates (use “un_equate” for large chi-squared values)
  - Use “FIXA” option to make a priori the same for equated sites (better to use consistent a priori file).

Uses of `sh_gen_stats`

- Velocity solutions are often iterative:
  - Generate time series using some reference frame sites (IGb08 sites initially for example).
  - Fit to the time series (`tsfit`) to:
    - Find outliers, nature of earthquakes (log needed?), discontinuities
    - Self consistent a priori file.
    - Used FOGMEx model (realistic sigma) to get process noise model and list of low-correlated noise reference frame sites). Use “stabrad” option for dense networks
  - Run `globk` velocity solution to refine reference frame site coordinates and velocities
  - Re-generate time series and repeat.

Some comparisons: Approach

- Use `sh_exglk -f <soln.org> -vel <soln.vel> -rmdup`
  to extract velocity estimates (`rmdup` removes equated sites with the same estimates)
- Program `velrot` allows fields to be compared (change frames and merge fields as well). For example:
  `velrot solna.vel nam08 solnb.vel IGS08 '' '' '' '' N`
  compares to solutions directly (use "RT" instead of "N" to allow rotation and translation rates). Use `grep '^S '` to get statistics.

Comparisons: Decimation

Decimation: Different days of week (1996-2015 solution, small subset of sites):

```
Un-aligned fields
compare 1 NMT_vel_150418_day1.vel NMT_vel_150418_day3.vel
S Component North    #    75 WMean  -0.00 WRMS   0.04 mm/yr, NRMS   0.198
S Component East     #    75 WMean  -0.02 WRMS   0.04 mm/yr, NRMS   0.203
S Component Up       #    75 WMean   0.03 WRMS   0.16 mm/yr, NRMS   0.180
S Component Horz     #    75 WMean  -0.01 WRMS   0.04 mm/yr, NRMS   0.200
compare 2 NMT_vel_150418_day1.vel NMT_vel_150418_day5.vel
S Component North    #    74 WMean  -0.01 WRMS   0.04 mm/yr, NRMS   0.207
S Component East     #    74 WMean  -0.02 WRMS   0.05 mm/yr, NRMS   0.225
S Component Up       #    74 WMean   0.04 WRMS   0.19 mm/yr, NRMS   0.212
S Component Horz     #    74 WMean  -0.01 WRMS   0.04 mm/yr, NRMS   0.217
compare 3 NMT_vel_150418_day3.vel NMT_vel_150418_day5.vel
S Component North    #    76 WMean  -0.01 WRMS   0.03 mm/yr, NRMS   0.177
S Component East     #    76 WMean  -0.01 WRMS   0.03 mm/yr, NRMS   0.161
S Component Up       #    76 WMean   0.01 WRMS   0.13 mm/yr, NRMS   0.142
S Component Horz     #    76 WMean  -0.01 WRMS   0.03 mm/yr, NRMS   0.169
```

Comparison: Time series vs GLOBK

- PBO Combined analyses:

```
Un-aligned fields (no rotation and translation).
compare 1 PBO_vel_150425.vel PBO_vel_150425KF.vel
S Component North    #  2105 WMean  -0.01 WRMS   0.12 mm/yr, NRMS   0.925
S Component East     #  2105 WMean  -0.00 WRMS   0.13 mm/yr, NRMS   0.934
S Component Up       #  2105 WMean   0.02 WRMS   0.31 mm/yr, NRMS   0.871
S Component Horz     #  2105 WMean  -0.01 WRMS   0.12 mm/yr, NRMS   0.929
compare 4 PBO_vel_150425.vel PBO_vel_150425_NAM08.vel
S Component North    #  1972 WMean   0.03 WRMS   0.13 mm/yr, NRMS   0.965
S Component East     #  1972 WMean   0.02 WRMS   0.15 mm/yr, NRMS   1.049
S Component Up       #  1972 WMean  -0.07 WRMS   0.41 mm/yr, NRMS   0.943
S Component Horz     #  1972 WMean   0.02 WRMS   0.14 mm/yr, NRMS   1.008
compare 7 PBO_vel_150425KF.vel PBO_vel_150425_NAM08.vel
S Component North    #  1969 WMean   0.04 WRMS   0.16 mm/yr, NRMS   0.952
S Component East     #  1969 WMean   0.02 WRMS   0.17 mm/yr, NRMS   0.967
S Component Up       #  1969 WMean  -0.08 WRMS   0.44 mm/yr, NRMS   0.935
S Component Horz     #  1969 WMean   0.03 WRMS   0.16 mm/yr, NRMS   0.959
```

PBO_vel_150425.vel: tsfit solution to time series

PBO_vel_150425KF.vel: tsfit Kalman filter solution to timeseries

PBO_vel_150425_NAM08.vel: GLOBK combined velocity solution (NMT+CWU), decimated 7 days, 28-subnet combination. Reference frame realization to NAM08 frame sites (~600)

See Herring et al., Reviews of Geophysics, 2016 for more detailed comparisons.

Final comments

- Practice large solutions with decimated data sets and small networks (run time increased cubically with number of stations)
- Make sure your a priori coordinates files are consistent (especially with equates)
  - Use the out_aprf command in tsfit to generate an apriori which is consistent with your timeseries estimates.