



Generating velocity solutions with `globk`

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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

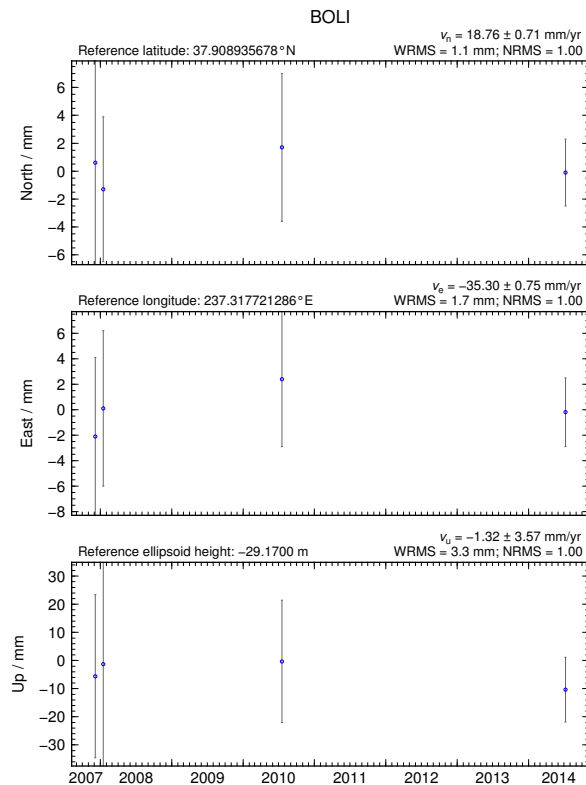
- In general careful setup (i.e., correct apriori coordinate, earthquake file and process noise files) is needed since each run that corrects a problem can take several days. Incorrect solutions may not complete correctly and results may be subtly wrong.
- General strategy for iteratively generating 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

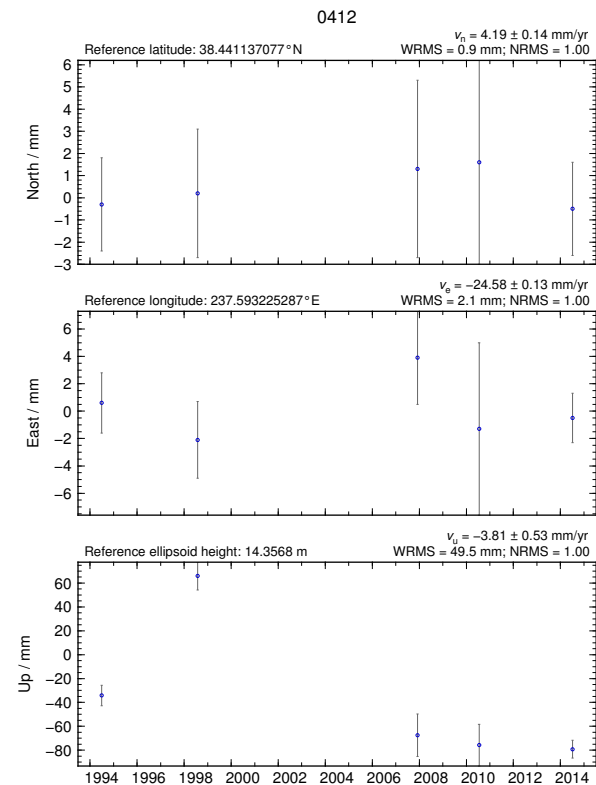
- Surveys may be combined into one solution per survey
- No need to re-run `glred` again to see long-term time series
- Multiple “.org”-files may be read by `tssum` or `sh_plot_pos`
 - `tssum ts_pos mit.final_igb08 -R survey1_comb.org survey2_comb.org ...`
 - `ts_pos` is the name of a directory for the `.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 `g1obk` 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 `g1red` (so still visible in time series) but will exclude data from `g1obk` (combination or velocity solution)
- “XCL” will exclude data from all `g1red` or `g1obk` 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)

glogrg for different reference frames

- No need to re-run globk every time you want
- glogrg is usually called from globk command file (“org_cmd” option) but glogrg may be run separately
- globk 6 globk_vel.prt globk_vel.log globk_vel.gdl
globk_vel.cmd
- glogrg globk_vel_noam.org ERAS:... glogrg_vel.cmd vel.com
- Must have saved the “.com”-file!
 - e.g. “com_file @.com”
 - Do not use “del_scrayes” 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 `g1org` 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 `g1org`).
 - “`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 `g1obk` velocity solution to refine reference frame site coordinates and velocities
 - Re-generate time series and repeat.

Some comparisons: Approach

- Use `sh_exgk -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.