

# Generating velocity solutions with GLOBK

T. A. Herring      M. A. Floyd  
*Massachusetts Institute of Technology*

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Korea Institute of Geoscience and Mineral Resources (KIGAM)  
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Material from T. A. Herring, R. W. King, M. A. Floyd (MIT) and S. C. McClusky (now 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:
  - Apriori coordinate and velocity file. Used as a check on positions in daily solutions (for editing of bad solutions) and adjustments are apriori values (apriori 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.

# General methods for increasing speed and to allow for parallel runs

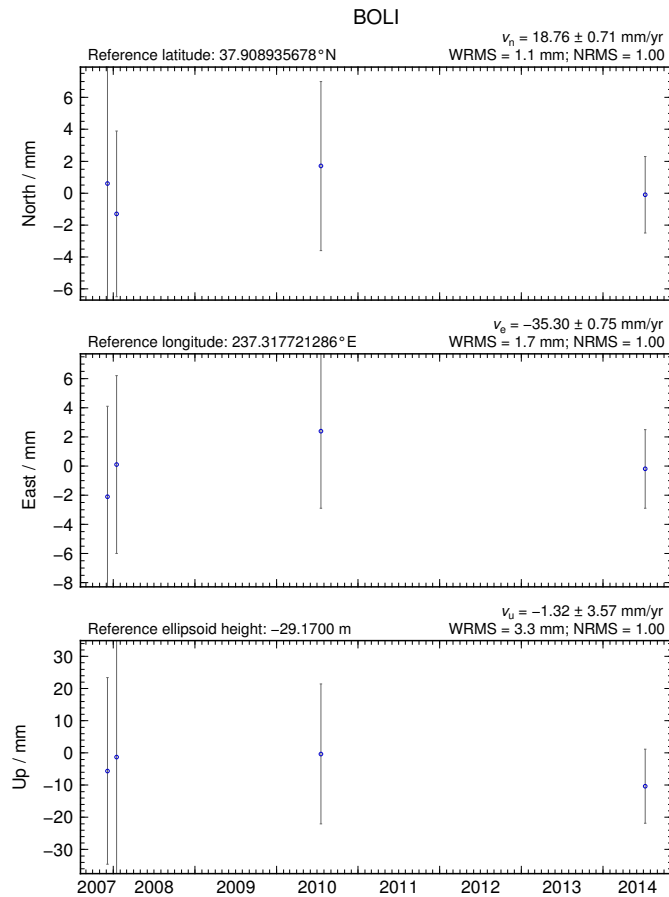
- Approaches to increase speed:
  - Pre-combine daily solutions into weekly to monthly solutions and use these combined solutions in the velocity solutions. There are many advantages to this approach:
    - Runs are much faster. Each processing step takes about the same time with the monthly as a daily file but there are 30 fewer files so 30 times faster.
    - Numerical rounding errors are much better when monthlies are used
    - MIDP output option refers the solutions to the middle of the month. (Earlier versions used last day of month as reference time, natural time for a sequential Kalman filter.
    - Random walk process noise models correct when velocity NOT estimated in combinations.
    - Care needed here when eq\_log is used for solutions far away in time from the earthquake.
  - Run decimated solutions (e.g., one day per week). Works fine and changing start day does not have large effect due to correlated noise models. Care needed when different start day results are combined to avoid white noise sigma reduction.
  - Sub-netting in GLOBK to generate each solution with smaller number of stations. Sub-net velocity solutions are combined with GLOBK. Use netsel with -rw option to make GLOBK use\_site list (Current PBO approach)

# Before velocity runs

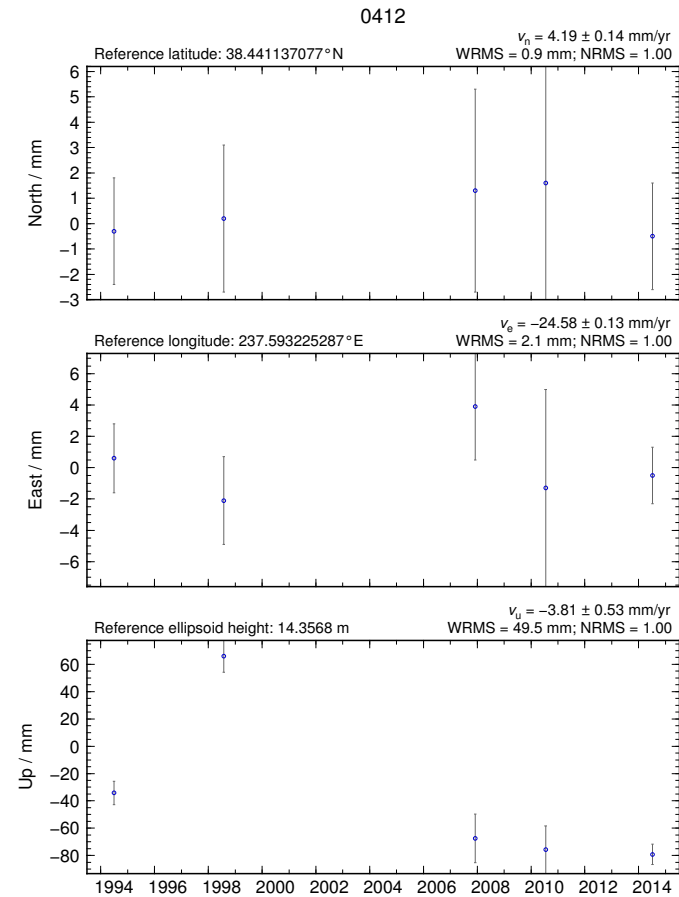
- Surveys may be combined into one solution per survey
- No need to re-run glred again to see long-term time series
- Multiple “.org”-files may be read by tssum or sh\_plot\_pos
  - `tssum pos mit.final_igb08 -R survey1_comb.org survey2_comb.org ...`
  - `sh_plot_pos -f survey1_comb.org survey2_comb.org -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 apriori 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 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 allow 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 apriori the same for equated sites (better to use consistent apriori 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 apriori 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 remove 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)

# Final comments

- Practice large solutions with decimated data sets and small networks (run time increased cubically with number of stations).
- Make sure your apriori coordinates files are consistent (especially with equates).