

**** Example of processing a complex set of multiyear observations ****

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Data set: Three years for surveys in multiple parts of
the eastern-Mediterranean/Caucasus

Strategy:

- combine daily sGPS GAMIT processing with cGPS h-files
- aggregate the processing by survey length up to about 30 days
- use survey-combined H-files to get long-term repeatabilities and velocities

Assumed directory structure:

/EMed

/2004 /2006 /2008 /tables /vsoln /emed_rinex

Under each year (experiment) directory is the usual structure for sh_gamit and sh_glred (e.g. /tables, /[day-number], /rinex, /gsoln, etc.. However, we have stored all of the RINEX files, in a separately directory elsewhere on the system. We'll call this directory /emed_rinex, and beneath this level will be sub-directories organized by country and year, e.g., /azerbaijan/2004. (This scheme is optional.)

Step 1: Determine the temporal and spatial distribution of the data

For example, if the data are stored in directories by country and year, within each RINEX directory you can use sh_get_times to obtain a list, e.g. in emed_rinex/azerbaijan/2004, type
'sh_get_data -sort -f *.04o > times.azer04.sorted', where the file times.azer04.sorted will have

shik2672.04o	2004	267	13:31	269	13:42	48:11	5784	3
khid2672.04o	2004	267	13:39	269	13:41	48:2	5766	3
kurd2731.04o	2004	273	05:06	275	05:13	48:7	11553	3
yevl2735.04o	2004	273	07:58	275	08:01	48:3	11536	3
ayaq2730.04o	2004	273	09:44	275	08:38	46:54	5630	3
kebe2821.04o	2004	282	09:36	284	07:59	46:23	11137	3
qurd2821.04o	2004	282	11:32	284	08:02	44:30	10681	3
shek2841.04o	2004	284	10:13	286	07:05	44:52	10771	3
kate2840.04o	2004	284	13:23	286	11:32	46:9	11046	3
saly2960.04o	2004	296	07:51	298	07:59	48:8	11554	3
bile2960.04o	2004	296	09:13	298	09:16	48:3	11535	3
lenk2960.04o	2004	296	11:57	298	06:02	42:5	5051	3

and in emedrinex/georgia/2004/rinex,

type 'sh_get_times -sort -f *.04o > times.georgia.sorted'

zinv2730.04o	2004	273	13:15	274	13:14	23:59	2878	2
zinv2740.04o	2004	274	14:23	275	14:19	23:56	2873	2
pasn2750.04o	2004	275	18:01	276	14:24	20:23	2447	2
pasn2760.04o	2004	276	14:25	277	14:19	23:54	2869	2

pasn2770.04o	2004	277	14:51	277	19:01	4:10	502	1
kazb2780.04o	2004	278	06:31	279	06:29	23:58	2876	2
kazb2790.04o	2004	279	06:30	279	18:04	11:34	1389	1
kazb2791.04o	2004	279	18:05	280	06:50	12:45	1531	2
kudi2810.04o	2004	281	10:11	282	06:29	20:18	2436	2
kudi2820.04o	2004	282	06:30	282	18:04	11:34	1389	1
kudi2830.04o	2004	282	18:05	283	10:22	16:17	1955	2
ingu2840.04o	2004	284	14:46	285	14:24	23:38	2836	2
ingu2850.04o	2004	285	14:25	286	14:19	23:54	2869	2
shua2870.04o	2004	287	10:31	288	10:14	23:43	5692	2
shua2880.04o	2004	288	10:15	289	06:29	20:14	2429	2
shua2881.04o	2004	289	06:30	289	10:21	3:51	464	1

So we have survey-mode data for days 267-269, 273-289. Note that all of the Azeri data span parts of three days, so the default setting 'rx_doy_minus 1' in process.defaults will not be sufficient to pick up the data two days earlier. We can change this in process.defaults or make it explicit in the sh_gamit command line.

Step 2: Set up the control files for the first year

Run sh_setup to put templates or actual files you'll need into
EMed/2004/tables.

From the /2004 level type 'sh_setup -yr 2004'

Edit process.defaults and sites.defaults for this year.

Make appropriate changes to the template process.defaults:

```
# Directory path for RINEX archives (search all levels)
set rnxwnd = "/emed_rinex"
# H-files archive
set hfnd = /net/everest/raid6/ftp/pub/MIT_GLL/H04
# Set compress (copts), delete (dopts) and archive (aopts) options.
set copts = ( o q mkx )
set dopts = ( D ao b c g i j k m p ps t x y )
```

The rnxwnd option will cause sh_gamit to make links for all RINEX files within the requested span from from the 2004/rinex directory to the /emed_rinex/azerbaijan/2004/rinex and /emed_rinex/georgia/2004/rinex directories. The copt/dopt settings shown here represent a space-saving approach, retaining only the files you are likely to view unless something goes wrong. We rarely use the option to put some files in an archive directory, preferring to save only the minimal files in the day directories themselves.

Make appropriate changes to the template sites.defaults to automatically download and include in the processing (by being present in 2004/rinex) the ITRF08 sites you wish to use to tie the local h-files to the MIT global files (at present the site name entries must be lowercase):

```

# Tie stations for MIT global h-files, used also for GAMIT
constraints
# North
  bucu_gps emed ftprnx
# West
  ankr_gps emed ftprnx
# Central
  nssp_gps emed ftprnx
# South
  tela_gps emed ftprnx
# East
  kit3_gps emed ftprnx

```

Make the appropriate changes to the template sites.defaults to provide moderate ITRF08 constraints in the GAMIT processing to help in resolving ambiguities:

```

SITE          FIX    --COORD.CONSTR.--
  << default for regional stations >>
ALL           NNN    100.  100.  100.
  << IGS core stations >>
BUCU BUCU_GPS   NNN    0.050 0.050  0.05
TELA TELA_GPS   NNN    0.050 0.050  0.05
KIT3 KIT3_GPS   NNN    0.050 0.050  0.05

```

Step 3: Create station.info

In 2004/tables, which will contain the MIT version of station.info, type

```
sh_upd_stnfo -ref station.info -w station.info.mit -l sd
```

which will result in the output file having only the entries for sites listed with ftprnx in sites.defaults.

Using the log sheets as a guide, in emed_rinex/azerbaijan/2004/rinex and emedrinex/georgia/2004/rinex, create survey-specific station.info entries manually (editor or using 'make_stnfo') or using 'sh_upd_stnfo -f *.04o' to create entries from the RINEX headers and then editing any entries that need to be changed. The starting file must be named station.info since it is continually concatenated with the information from each new RINEX file; and the starting file must have a legitimate set of headers though these do not need to match those in files you wish to merge such as the MIT station.info file. Rename these survey-specific files to , e.g. station.info.azer04, and copy them to 2004/tables. Then merge the files:

```
sh_upd_stnfo -ref station.info.mit -merge station.info.azer04 station.info.georgia04
```

which will create a merged file, station.info.new, which you should rename to station.info for processing.

Step 4: Do the GAMIT processing

```
sh_gamit -expt emed -c -s 2004 267 269 -pres ELEV -rx_doy_minus 2 >&! sh_gamit.log
sh_gamit -expt emed -c -s 2004 273 289 -pres ELEV -rx_doy_minus 2 >&! sh_gamit.log
```

The `-c` option prevents the compression of the RINEX files at the end of processing each day. Since the "files" in 2004/rinex are actually links to /emed_rinex directories, if the compression takes place, you'll get a (compressed) copy of the RINEX files in EMed/2004/rinex, unnecessarily duplicating the files in /emed_rinex.

After each day is run, you'll get an email copy of the `sh_gamit_[ddd].summary` file for that day. Check it for sites included, norms, ambiguities resolved, and failed editing (`autcln rms 0.`). Fix any problems and rerun those days.

Step 5: Generate the daily time series for editing

If not there already, edit /2004/gsoln/globk_comb.cmd to add a "contingent/option" line for saving an output h-file:

```
COMB out_glb H-----_EMED.GLX
```

This command will be executed only if you include `'-globk_cmd_prefit COMB'` in the `sh_glred` command line.

Edit `glorg_comb.cmd` to specify the stabilization you want for the time series (`apr_file`, `stab_site` list, parameters to be estimated). Then type

```
sh_glred -s 2004 267 2004 289 -expt emed -local -opt H G T >&! sh_glred.log
```

Setting `'-local'` instructs `sh_glred` to use MIT global h-files only for days on which a day directory exists (i.e. days for which you have survey-mode data). The output of this command will be a `gdl` file, log file, and org file for each day and the usual output of `sh_plot_pos`: a `tsfit` sum file, postscript plots of time series for each station and histograms of `nrms` and `wrms`. (Using `E` instead of `T` for `-opt` will invoke `ensum` and `sh_plotcrd` rather than `tsfit` and `sh_plot_pos`; we plan to phase out this plotting scheme in 2016.)

Check the stabilization by typing in /gsoln

```
grep 'POS STAT' *.org
```

The number of sites in the stabilization should be what you expected (4 or more for translation-only, 8 or more well-distributed sites for translation +rotation), the `wrms` values should be 1-3 mm, and the `nrms` values less than ~2.

View all the plots (`'gs *.ps'`) and note any outliers or noisy segments. (With a data set that has multiple surveys within a year, you might create sub-directories below /gsoln, e.g. /gsoln/plots_267-289, in which to store the plots.)

Notes:

```

ardt 267-269 downweight (DW) by adding 6 mm; check long-term plots
      later
arga 282 U-30, DW 100
atht 269 N-5 E-10 308 E+5
boyl 270-272 DW 4
bucu 286 N+3 287 U-10
cagl 265-268 DW 5 291 E+7 293 U+15
madr 282-283 E+5 290 E+5
ozdm 267-269 N/E slope DW 15 or DW 267 15 LT E favors 267 N favors
      268-269
reun 257 U+20
torl 273-275 DW 5
triz 269 U+40
zeck 286 N+5 287 U-15

```

Since experience has shown that with the standard data weighting in GAMIT using the autcln rms produces short-term nrms with a median value of about 0.7 (see pshist_nrms.SUM.emed), I treat any single value or nrms that is greater than 1.5 (twice the median) as a two-sigma (95% level) outlier and apply a downweight by adding white noise with sig_neu, either enough to make the nrms about 1.0 or to increase the error bar to be significantly greater than the value of the outlier. In the case of an outlier, adding only enough white noise to equal the residual is not as objective as adding enough noise to make the outlier of negligible weight, so you should pay attention to how much the reweighted outlier is biasing the position estimate. If your primary interest is horizontal deformation, you might be very generous in the noise added to vertical outliers so as to prevent their having any effect on the horizontals.

Generate sig_neu reweights using 'grw' and add these to globk_comb.cmd using, e.g. 'source ../../tables/emed_comb.reweights'.

Step 6: Generate the combined h-file for the survey

```
sh_glred -s 2004 267 2004 289 -ncomb 32 -globk_cmd_prefix COMB -expt emed -opt G
```

which will create H040923_EMED.GLX and globk_emed_04267-289.org, the latter to be checked for appropriate chi2 increments (~1.0) in the stacking.

*** Steps 1-6 to be repeated for each survey. ***

Step 7: Generate the multi-year time series

Working in a directory parallel to the survey/year directories, e.g. EMed/vsoln, create the multi-year gdl file by, e.g.

```
ls ../../???/gsoln/H*GLX > emed.gdl
```

Copy into /vsoln the template files globk_long.cmd and glorg_long.cmd from ~gg/tables and edit them for your analysis, generally needing to change only the use_site list (or 'sourced' file) and a list of edits

in the globk command file, and the stab_list list in the glorg command file.

As a check on severe conflicts due to misnamed sites, and on the application of renames for instrumental changes and earthquakes, it's a good idea at this point to run 'glist', which reads the h-files, applies renames, and compares the coordinates with those in the apr_file:

```
glist emed.gdl emed.glist +1 ../tables/itrf08_comb.eq:../tables/emed_renames.eq  
' ' ../tables/itrf08_comb.apr >! glist.out
```

The glist.out file will echo coordinate differences, and the emed.glist file will list all of the sites and their epochs. If you want to generate an explicit use_site list at this point, based on proximity and adequate epochs and time span, you can run 'glist2cmd' (type to see help).

Now to generate the time series, run glred in /vsoln (sh_glred works only for daily processing):

```
rm globk_rep.prt globk_rep.org globk_rep.log  
glred 6 globk_rep.prt globk_rep.log emed.gdl globk_long.cmd >&! glred.out  
mv globk_rep.org globk_rep_130708a.org
```

where I've used the current date and a letter extent to identify the solution. The 'rm' step is to remove any leftover files since the new ones will be concatenated onto the end of any old ones of the same name.

Again check the stabilization quality with

```
grep 'POS STAT' globk_rep_130708a.org
```

Then, perhaps in a sub-directory (e.g. /plots),

```
sh_plot_pos -f ../globk_rep_130708a.org -r -t1 1993-001 -t2 2013-060-30 -h - -k -v
```

View the plots ('gs *.ps') and make note of any problems:

```
bgnt 04 E+8  
blot 04(1) N-50 E-35 typo?  
bucu 04 systematic cf later, DW 5  
cnca N nrms 1.6 DW N only, 5  
garb 06 N-10  
gr02 N nrms 1.8 DW 5 both  
hoss DW N 4
```

As noted in the lecture, the small number of epochs (even for the cGPS, after aggregation) means that you have to be careful to remove or down-weight any outliers or noisy segments. As with the daily time series, the typical long-term nrms median is about 0.7, so I use the same "1.5 threshold" to indicate a 2-sigma outlier.

Step 8: Perform a velocity solution

As with continuous data, we must consider the effect of temporally correlated noise in the estimates and uncertainties of the velocities. So although we cannot determine objectively the character of correlated noise for sites with only a few epochs, to obtain a realistic uncertainty, we must nevertheless include some in the solution. For GLOBK, this is usually accomplished by applying a random walk using the `mar_neu` command. The value to use could be determined from prior experience in other regions, from the median of the values estimated for cGPS stations in your region, or, iteratively from a validation of the velocities against a model. A reasonable value to start would be 1 mm/sqrt(yr) for the horizontals and 3 mm/sqrt(yr) for the verticals, e.g.

```
mar_neu all .000001 .000001 .000009 0 0 0
```

Run the velocity solution:

```
rm globk_vel.prt globk_vel.org globk_vel.log
globk 6 globk_vel.prt globk_vel.log emed.gdl globk_long.cmd VEL >&! glred.out
mv globk_vel.org globk_vel_130708a.org
```

where the VEL option refers to the VEL keywords in `globk_long.cmd` and `glorg_long.cmd` which turn on velocity estimation. This scheme allows you to use the same command files for repeatabilities as for velocities without any explicit editing. With the `org_opt` setting in the template (CMDS GLDF PSUM VSUM FIXA RNRP), all of the information you need to evaluate both the stacking (`globk`) and the stabilized solution (`glorg`) will appear in the `glorg` print file, `globk_vel.org`. Things to check are the `chi2` increments from the stacking (all should be of order ~1.0), the stabilization (number of sites retained in the iteration, and the N E U rms and nrms values), and the uncertainties of the velocity estimates (1-2 mm/yr or less horizontal for a 3-year span of data using at least 12 hrs of data each year and a random-walk of 1 mm/sqrt(yr)).

Step 9: Generate the times series for the velocity solution

In principle, the statistics relevant to the velocity solution should flow from time series generated with a stabilization that includes all of the well-determined sites in the solution. If your solution has a strong IGS cGPS component over the full span, then the improvement using the regional stations will be minor. On the other hand, if some or all of your epochs are weak in IGS coverage, using the regional stations in the stabilization is quite important to evaluate the actual scatter of each station's epoch-by-epoch positions without confusion added by a weak stabilization at some epochs. To get the new times series, create an `apr` file from your velocity solution,

```
sh_exglk -f globk_vel_130708a.org -apr vel_130708a.apr
```

Next create a site_site list with all of the sites that have reasonably good position and velocity uncertainties. A utility to help with this is 'vel2stab'.

Then repeat Step 7 with the new apr-file (only) and the new stabilization list. If this time series provides new information about the editing/weighting of the coordinate estimates, then you should repeat the velocity solution (Step 8) and generation of the time series (Step 9).