

GAMIT/GLOBK In A Day*

M. Floyd and T. Herring

Massachusetts Institute of Technology

GAGE/SAGE Science Workshop

Pre-Workshop Course

9–10 August 2021

http://geoweb.mit.edu/gg/courses/202108_GAGE-SAGE/

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

*Or two half-days in the world of virtual workshops

GNSS data from receiver
to processing input

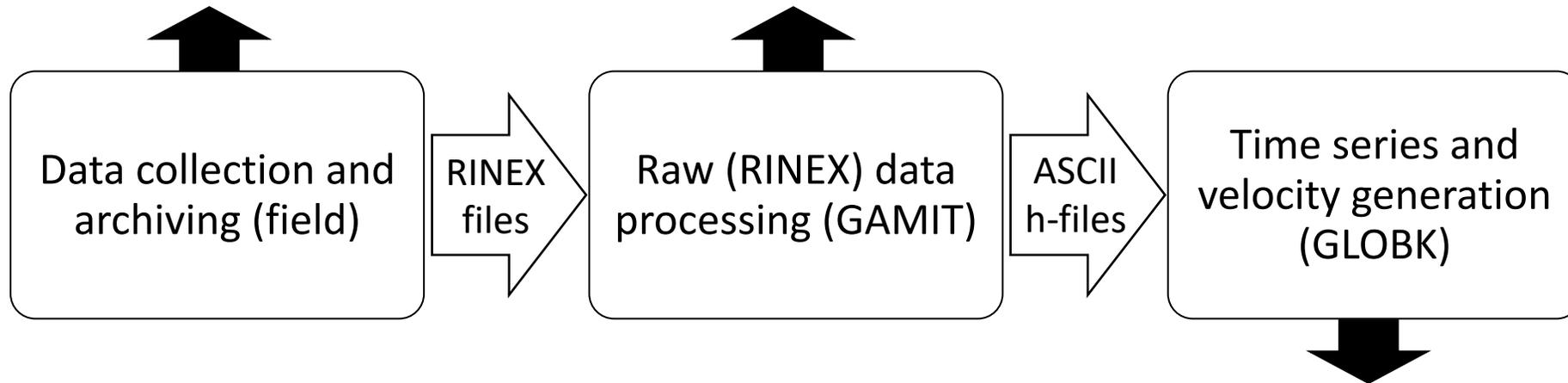
Basic stages of GAMIT/GLOBK for geoscience

Third-party programs

- `runpkr00`
- `teqc`
- etc.

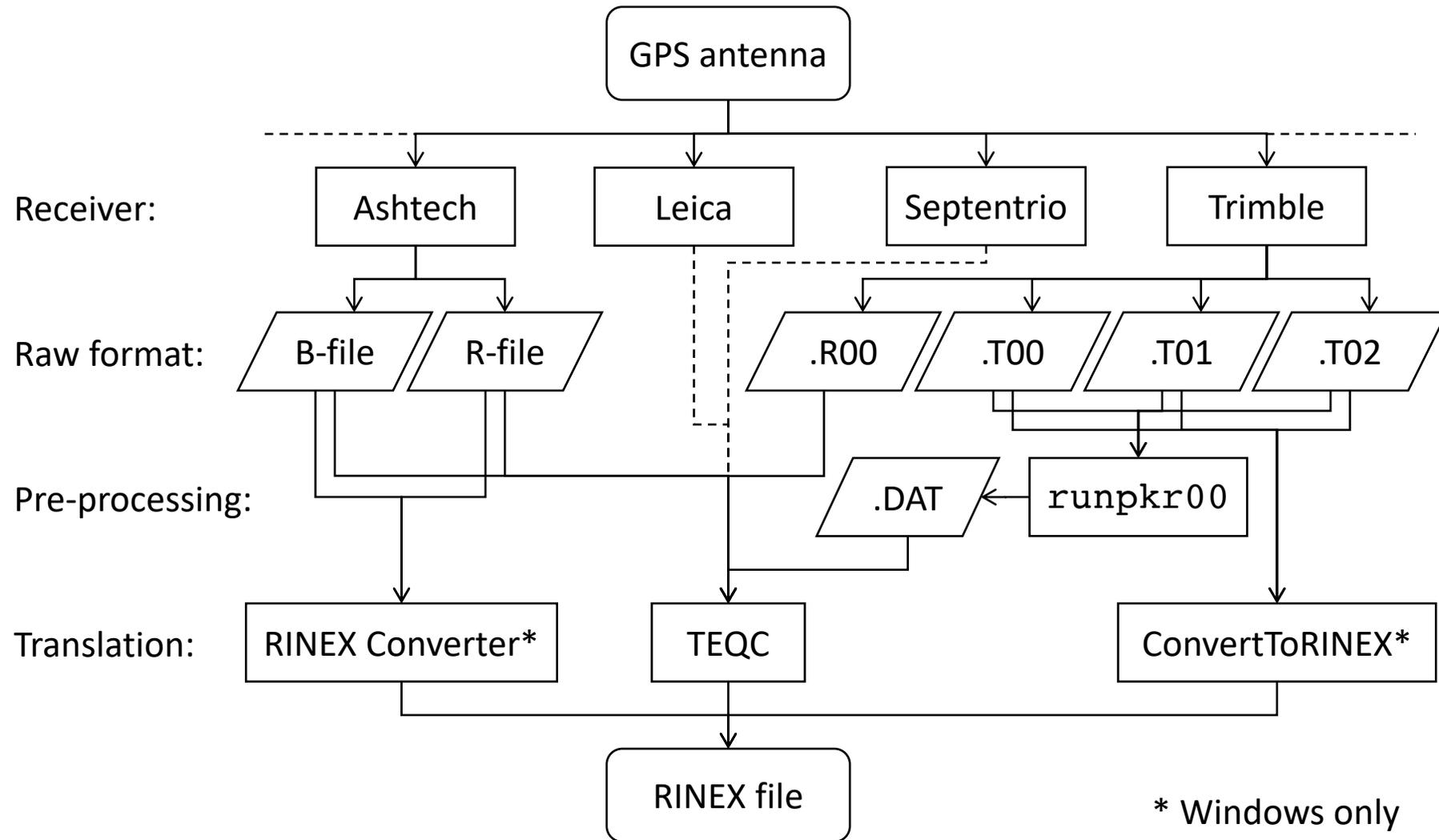


- `model` (model observations)
- `autcln` (cleans data)
- `solve` (solve for parameters)



- `glred` (time series)
- `globk` (velocities)

Raw data formats



Motivation for Receiver INdependent EXchange (RINEX) format

- All manufacturers have developed their own proprietary file formats for data storage specific to their receivers and processing software
 - Problems occur when processing data from another manufacturer's receiver
- RINEX developed by the Astronomical Institute of the University of Berne to allow easy and universal exchange of raw GPS data
 - Principal driver was the large European GPS campaign EUREF 89 - involved more than 60 GPS receivers of 4 different manufacturers.

RINEX formats

- RINEX 2
 - Short file names (explained in following slides)
- RINEX 3
 - Long file names (explained in following slides)
- GAMIT formerly worked with the RINEX 2 format and GPS observations only
- Support for RINEX 3 and GNSS (e.g. Galileo, BeiDou, etc.) observations are now available with GAMIT/GLOBK 10.61 and later
 - But RINEX 3 files need to be renamed, copied or linked with a RINEX 2 file name convention to be used (e.g. `sh_rename_rinex3`)

RINEX 2 data format

- Includes text file formats for:
 - observation (“o”) }
 - navigation (“n”) } most important for most users
 - meteorological (“m”)
 - ionospheric data (“i”)
- Latest definition at <ftp://igs.org/pub/data/format/rinex211.txt>
- Each file type consists of a header section and a data section
- Header section contains global information for the entire file and is placed at the beginning of the file.
 - Contains header labels in columns 61–80 for each line contained in the header section
 - These labels are mandatory and must appear exactly as per format description
- RINEX 2 filename convention:
 - For site “ssss”, on ordinal date (day-of-year) “ddd”, session “t” and year “yy”:
 - ssssdtdt.yyo (RINEX observation file, i.e. the site’s phase and code records)
 - ssssdtdt.yyn (RINEX navigation file, i.e. the broadcast ephemeris)
 - e.g., hers1270.03o is observation data for Herstmonceux, day 127, session 0, year 2003
- All dates and times in GPST

An example of RINEX 2 observation data

```

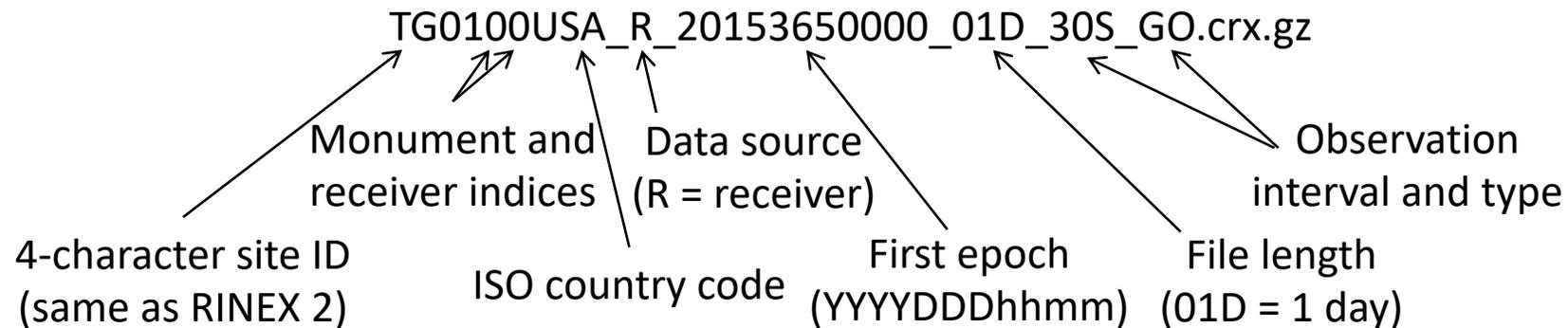
2          OBSERVATION DATA      G (GPS)          RINEX VERSION / TYPE
CCRINEXO V2.3.1 LH  NERC SLRF UK   08-MAY-03 00:05   PGM / RUN BY / DATE
CONCATENATED OBSERVATION FILES   COMMENT
ASRINEXO V2.9.10LH NERC SLRF UK   07-MAY-03 01:03   COMMENT
                                                    COMMENT
BIT 2 OF LLI (+4) FLAGS DATA COLLECTED UNDER "AS" CONDITION COMMENT
HERS                                                    MARKER NAME
13212M007                                             MARKER NUMBER
SLR HERSTMONCEUX      NERC UK          OBSERVER / AGENCY
LP03373              ASHTECH Z-XII3     CD00      REC # / TYPE / VERS
CR16688              ASH700936E        ANT # / TYPE
4033462.3686         23668.4540  4924295.3147   APPROX POSITION XYZ
0.0096              0.0000    0.0000        ANTENNA: DELTA H/E/N
1                    1                    WAVELENGTH FACT L1/2
7                    C1                   # / TYPES OF OBSERV
30                   L1                   INTERVAL
2003                 5                    7                    0                    1                    0.000000   TIME OF FIRST OBS
                                                    END OF HEADER
03 5 7 0 1 0.0000000 1 9 14 05 26 07 09 23 28 29 18
PRN14 24932856.904 -1781095.387 7 -1105164.20444 24932855.004 24932862.7814
      201.000 130.000
PRN05 22107202.735 -16063454.741 8 -12490326.44046 22107202.172 22107208.2924
      233.000 186.000
PRN26 22363532.304 -13299541.376 8 -10336679.45446 22363532.099 22363538.2454
      231.000 184.000
PRN07 22661645.377 -12116901.554 8 -9422108.07946 22661644.520 22661651.0584
      230.000 182.000
PRN09 20117144.686 -22534891.328 9 -17538374.49548 20117144.311 20117149.7184
      247.000 219.000
:
:

```

- PRN14
- PRN05
- PRN26
- PRN07
- PRN09
- :

RINEX 3 data format

- Must be able to accommodate increased number and complexity of observations from multi-GNSS observations (GPS, GLONASS, Galileo, BeiDou, etc.)
- Latest definition at <ftp://igs.org/pub/data/format/rinex303.pdf>
- Each file type consists of a header section and a data section
- Header section contains global information for the entire file and is placed at the beginning of the file.
 - Contains header labels in columns 61–80 for each line contained in the header section
 - These labels are mandatory and must appear exactly as per format description
- RINEX 3 filename convention is longer and more complicated than for RINEX 2, e.g.



An example of RINEX 3 observation data

```

3.02          OBSERVATION DATA      GPS(GPS)          RINEX VERSION / TYPE
cnvtToRINEX 2.29.0 Michael A Floyd  07-Jan-16 17:28 UTC PGM / RUN BY / DATE
-----
TG01          MARKER NAME
GEODETTIC    MARKER TYPE
M.Floyd / G.Funning MIT / UC Riverside OBSERVER / AGENCY
5049K72210    TRIMBLE NETR9           4.62          REC # / TYPE / VERS
60222738      TRM41249.00          NONE          ANT # / TYPE
-2698262.9000 -4182116.4000  3976198.2000  APPROX POSITION XYZ
-0.0160      0.0000           0.0000      ANTENNA: DELTA H/E/N
G  16 C1C C2W C2X C5X D1C D2W D2X D5X L1C L2W L2X L5X S1C SYS / # / OBS TYPES
      S2W S2X S5X                                     SYS / # / OBS TYPES
2015  12  31  0  0  0.00000000 GPS          TIME OF FIRST OBS
2015  12  31  23  59  30.00000000 GPS          TIME OF LAST OBS
0                                             RCV CLOCK OFFS APPL
G L1C 0.000000                                SYS / PHASE SHIFT
G L2X -0.250000                                SYS / PHASE SHIFT
G L5X 0.000000                                SYS / PHASE SHIFT
17                                             LEAP SECONDS
31                                             # OF SATELLITES
> 2015 12 31 00 00 0.00000000 0 9          END OF HEADER
G01 23837864.086 7 23837874.082 4 23837874.383 7 23837870.934
5                                         125268876.649
7  97612114.300 4  97612120.067 7  93544938.844
5      42.000           24.500           41.600           31.200

```

SYS / # / OBS TYPES
SYS / # / OBS TYPES

System now listed along with observation types

Observation codes more complicated than RINEX 2 (see Tables 4–10 of current RINEX 3(.03) document)

Compressing/Uncompressing RINEX

- File compression
 - “*.zip” files
 - Unzip using “unzip”, “pkzip” or “WinZip”
 - See <http://www.pkware.com/> or <http://www.winzip.com/>, or <http://www.7-zip.org/>
 - “*.??o.Z” (RINEX 2) and “*.rnx.gz” (RINEX 3) files (UNIX compress or gzip)
 - e.g., hers1270.03o.Z, TG0100USA_R_20153650000_01D_30S_GO.rnx.gz
 - Uncompress using “uncompress”, “gunzip”, “7zip”, “WinZip” or similar
 - “*.??d.Z” (RINEX 2) and “*.crx.gz” (RINEX 3) files (Hatanaka compression)
 - e.g., hers1270.03d.Z, TG0100USA_R_20153650000_01D_30S_GO.crx.gz
 - Need to uncompress as above to get *.??d and *.crx files
 - Then need to “unHatanaka” using CRX2RNX from <http://terras.gsi.go.jp/ja/crx2rnx.html>
 - Leica Geo Office uncompresses files automatically when using “Internet Download” tool
 - For manual import you need to uncompress the files manually

runpkr00 (Trimble raw to dat)

- Proprietary software from Trimble
- Maintained by UNAVCO nowadays
 - <http://facility.unavco.org/kb/questions/744/>
- Converts raw data from Trimble receiver to teqc-compatible input “dat”-file, e.g.

```
runpkr00 -g -adeimv <raw file> [dat-file root]
```
- Always use “-g” option and separately from other options

Pre-processing data

- Some level of data quality control may be performed prior to any data processing
- Utilities are available to perform simple but valuable tests
 - The most common example is TEQC (pronounced “tek”)
 - Translate, Edit, Quality Check
 - Translates common binary formats to RINEX format
 - Header editing, windowing, splicing of RINEX data
 - Quality check in “lite” mode (no navigation file) or “full” mode (navigation file available)
 - Download for free from <http://www.unavco.org/facility/software/teqc/teqc.html#executables>

Using teqc

- Be sure to use correct raw format

```
teqc -tr d <Trimble .dat file>
```

```
teqc -ash d <Ashtech B-file, etc.>
```

- Ability to control observations using “-O.obs” option

```
teqc -O.obs L1L2C1P2 -tr d <Trimble .dat file>
```

- Ability to control header information with other “-O.xxx” options

```
teqc -O.o "M. Floyd" -O.obs L1L2C1P2 -tr d <Trimble .dat file>
```

- May create and use a teqc configuration file for consistent information

```
teqc -config teqc.cfg -tr d <Trimble .dat file>
```

- Use a script or command line loop to create RINEX files in batch

Using teqc

- Quality Control (QC)

- In “lite” mode, teqc doesn’t know anything about the satellite positions

```
teqc +qc site1891.02o > teqc.log
```

- 7 files generated; use the -plots option to prevent all but the summary (‘S’) file being generated

- In “full” mode, additional information is available based on the satellite positions

```
teqc +qc -nav site1891.02n site1891.02o > teqc.log
```

- 9 files generated (elevation and azimuth of satellites)

- Full solution if navigation file matches observation file, e.g. site1891.02o and site1891.02n

```
teqc +qc site1891.02o > teqc.log
```

RINEX 3 translation

- `teqc` is not designed for RINEX 3
- Other programs are often available direct from the manufacturer, e.g. Trimble's `ConvertToRINEX`

Site ID clashes

- When naming a new site, check against lists of known site IDs to avoid clashing, e.g.
 - IERS station list (https://itrf.ign.fr/doc_ITRF/iers_sta_list.txt)
 - UNAVCO Data Archive Interface (<https://www.unavco.org/data/dai/>)
 - SOPAC Check Site ID (<http://sopac.ucsd.edu/checkSiteID.shtml>)
- If you have a site that is already named and clashes with a known site that is contained in GAMIT/GLOBK's default tables, e.g. station.info or igb14_comb.apr, then just be sure that the site information you intend to use is in the copy of the tables in your processing directory (more in later slides)

Site identification errors



Photograph by M. Floyd

Photograph by M. Floyd

Photograph by M. Floyd

Antenna setup errors

- Episodic survey setups can mean that measurements are not centered perfectly over a mark or the antenna height not measured accurately
- Note any inconsistencies for metadata files or later correction
- This can also happen for continuous sites, where incomplete, inaccurate or missing maintenance records



Log (metadata) and archive errors

Critical: antenna type (serial #);
height and type; monument ID

```

2.10      OBSERVATION DATA      G (GPS)      RINEX VE
teqc 2006Jul20      UNAVCO Archive Ops 20060725 16:48:29UTCPGM / RU
Solaris 5.9|UltraSparc Iii|cc -xarch=v9 SC5.5|=+|*Sparc
BIT 2 OF LLI FLAGS DATA COLLECTED UNDER A/S CONDITION
U626
U626
UNKNOWN      Stanford University
3414A05687    TRIMBLE 4000SSE      NP 5.71 / SP 1.26
3015A00136    TRM14532.00
-2683218.3014 -4185018.7102 3983204.9361
    1.4755      0.0000      0.0000
    1      1
    5      L1      L2      C1      P1      P2
30.0000

1994      9      28      16      7      30.0000000      GPS
94 9 28 16 7 30.0000000 0 5G 5G 6G17G20G24
2437477.48856 1792564.39355 22428902.4774
-548226.77657 -402556.82256 20834866.1484
-567509.56556 -371824.37155 22860949.9614
1203057.74657 883752.12057 20612879.2734
793138.12755 501650.82355 22928979.6334
    
```

L03662801 36028

GPS Daily Observation Log

Stanford University Session Name: U626-271-0

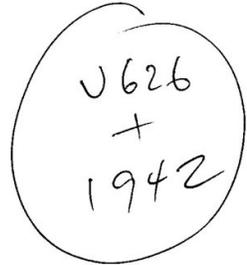
Station Name: <u>U626</u>	4-Char ID: <u>U626</u>
Location: <u>Geysers</u>	California
Observing Monument Inscription: <u>U626-1942</u>	

Operators: <u>Carl Chap</u>	Receiver: <u>Trimble 4000</u>
Agency: <u>Stanford U.</u>	Serial #: _____
	Antenna: " _____ "
	Serial #: <u>000140</u> Cable Length: <u>5</u>

PROGRAMMING

Elevation Mask: 10°
Collection Rate: 30°
Notes: _____

Sketch of Observing Monument



Antenna Height Above Mark in Meters		
Notch #	Before	After
1	<u>115.6m</u>	<u>115.6</u>
2	<u>115.5m</u>	<u>115.5</u>
3	<u>115.6m</u>	<u>115.6</u>
Average: <u>115.56</u>		
Ht. in Inches: <u>45 3/4"</u> <u>45 1/4"</u>		
Height Entered into Receiver: <u>115.56m</u>		
Magnetic Declination: <u>34.6°</u>		
Compass Reading: _____		

Observation Times	UTC Time	UTC Date	UTC Day	Local Time	Local Date
Scheduled Start Time:	_____	_____	_____	_____	_____
Scheduled End Time:	_____	_____	_____	_____	_____
Actual Start Time:	<u>16:07</u>	<u>271</u>	<u>271</u>	<u>9:07 AM</u>	<u>9/28/94</u>
Actual End Time:	<u>23:26</u>	<u>9/28</u>	<u>271</u>	<u>4:26 PM</u>	<u>9/28/94</u>
Daily Session Number:	_____	Session Name in Receiver: <u>271-0</u>			

Did anything abnormal or unusual occur? Yes No. Discuss any significant Problems.

END
Bubble Division high to South
← TRM

Prepare metadata

- Many user issues can be traced back to poor quality control of metadata (e.g. site information) or approximate coordinates
- Take time to ensure that information from the field or other site installation logs is included and formatted correctly for GAMIT
- This mostly concerns two files:
 - station.info contains information about site ID, antenna, receiver, antenna height, and start and stop times)
 - An a priori coordinate file, sometimes called the “l-file”, contains the approximate positions, and should be complete and accurate (to within at least a few m) for all sites

station.info

- Metadata of sites around the globe for which we know accurate information is listed in `~/gg/tables/station.info`
- Using the script `sh_upd_stnfo`, we can:
 - Truncate this file only to include the sites we intend to process, using the list written to `tables/sites.defaults`
 - Add sites from a variety of standard sources, e.g. the RINEX file header, assuming it is accurate, or IGS logs for publicly available global sites
- We can also add sites metadata manually, taking care to align columns exactly using whitespace characters (not tabs)

a priori coordinates file

- Coordinates of sites around the globe for which we know accurate coordinates are listed in `~/gg/tables/igb14_comb.apr`
 - This will be combined with whatever other file you list with “set aprf =” in `tables/process.defaults`, which is the file in which you may put your sites’ approximate coordinates
- We already saw one way of calculating an approximate position from RINEX data for unknown sites, using `teqc`
- GAMIT/GLOBK also has utilities to help with this
 - `sh_rx2apr`
 - `rx2apr`
- `sh_rx2apr` reads a RINEX 2 file (RINEX 3 currently not supported) and a broadcast ephemeris (satellite position) file, e.g.
 - `sh_rx2apr -site abdc1000.21o -nav brdc1000.21n`
 - `brdc1000.21n` can be downloaded with “`sh_get_nav -yr 2021 -doy 100`”
- It can also perform a relative calculation for greater accuracy using a reference site with known coordinates, e.g.
 - `sh_rx2apr -site abdc1000.21o -nav brdc1000.21n -ref monp1000.21o -apr ~/gg/tables/igb14_comb.apr`

Additional models and corrections

- Other than the information provided by the user and within the default tables in the GAMIT/GLOBK distribution, some additional files must be downloaded separately due to their size
- These are generally grid files of ocean tide loading, atmospheric loading and atmospheric delay models
- Download the required file(s) from `ftp://everest.mit.edu/pub/GRIDS/` to a `~/gg/GRIDS/` directory
 - Symbolic links in `~/gg/tables/` will then be complete automatically

Links to software

- **runpkr00**

<http://kb.unavco.org/kb/article/trimble-runpkr00-v5-40-latest-version-mac-osx-10-7-windows-xp-7-linux-solaris-744.html>

- **RINEX Converter**

<ftp://ftp.ashtech.com/Spectra-precision/Utility%20Software/RINEX%20Converter/>

- **TEQC**

<https://www.unavco.org/software/data-processing/teqc/teqc.html>

- **ConvertToRINEX**

http://www.trimble.com/support_trl.aspx?Nav=Collection-40773&pt=Trimble RINEX