GAMIT/GLOBK In A Day

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http://geoweb.mit.edu/gg/courses/202303_GAGE-SAGE/

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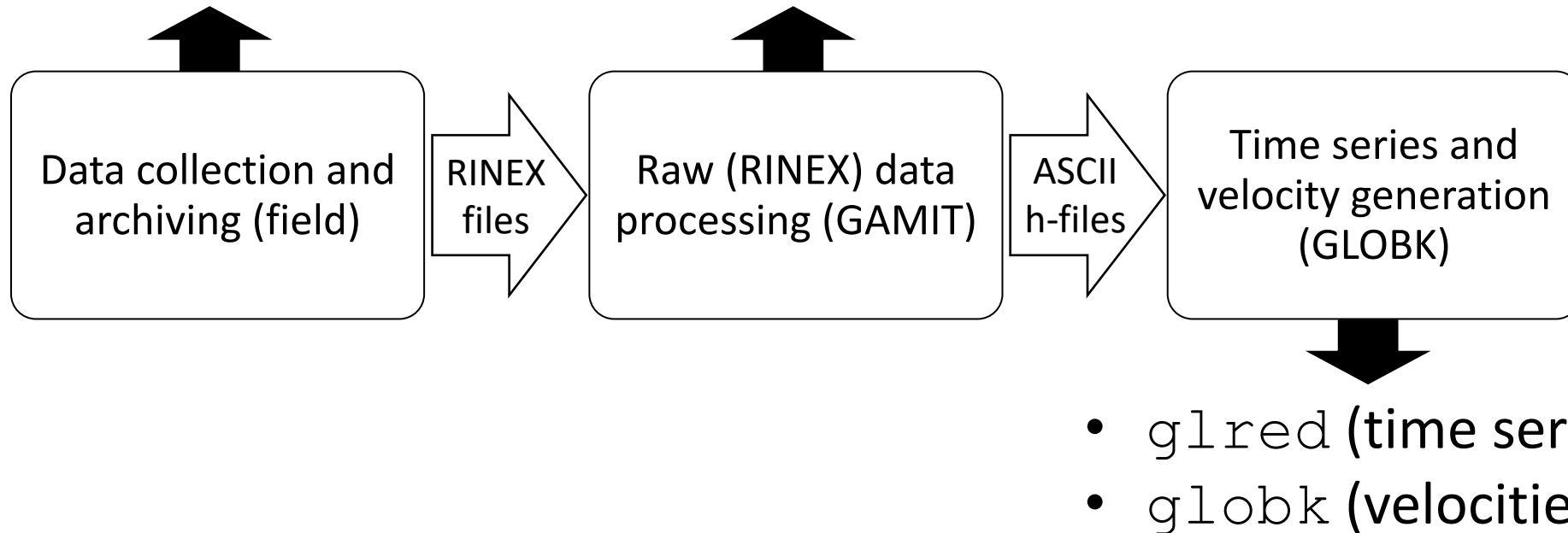# GNSS data from receiver to processing input

Basic stages of GAMIT/GLOBK for geoscience
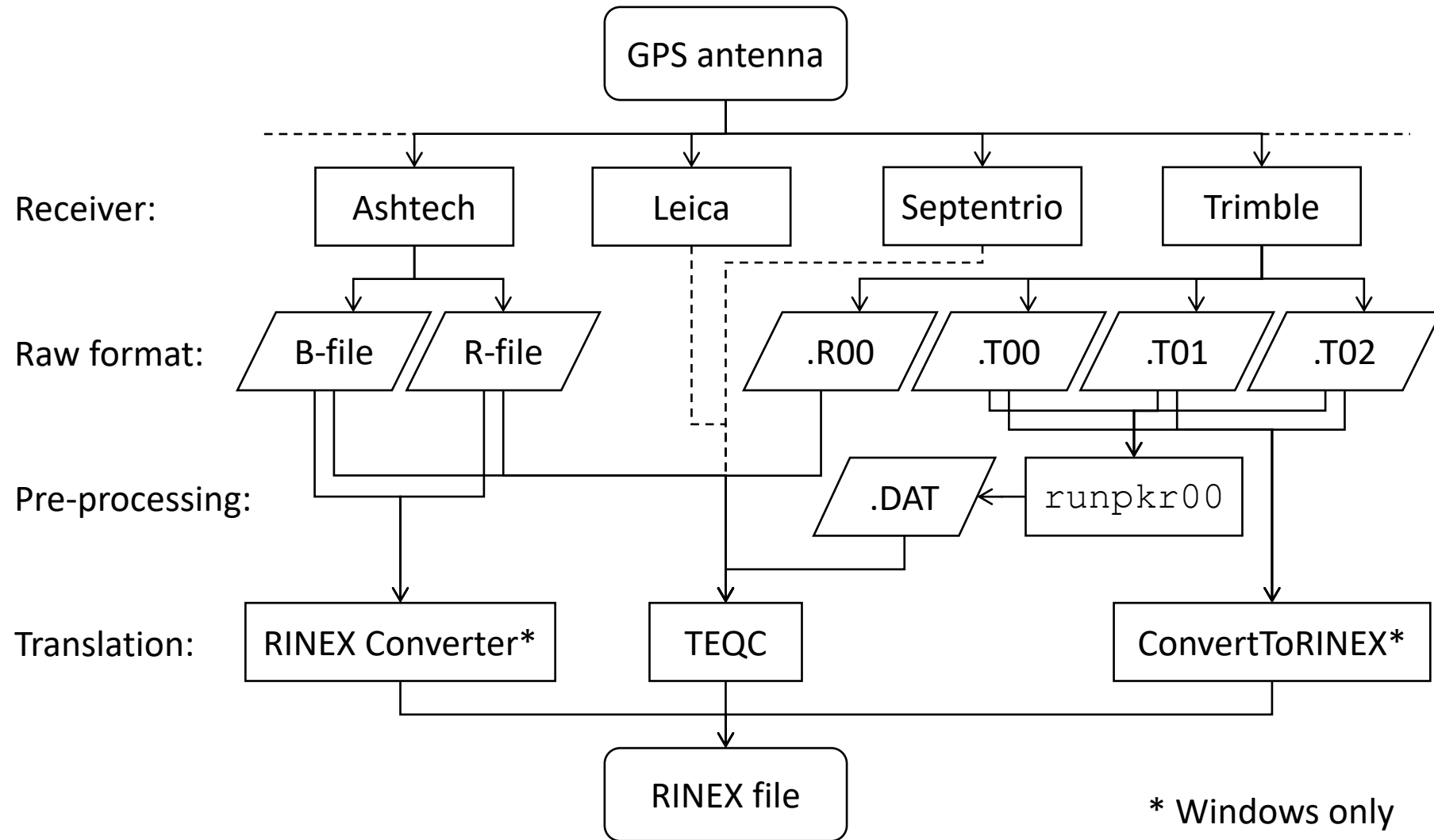
Third-party programs
- `runpkr00`
- `teqc`
- etc.

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

Data collection and archiving (field)

RINEX files

Raw (RINEX) data processing (GAMIT)

ASCII h-files

Time series and velocity generation (GLOBK)

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

Raw data formats

GNSS data from receiver to processing input

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 and RINEX 4
  - Long file names (explained in following slides)
- GAMIT formerly worked with the RINEX 2 format and GPS observations only
- Support for RINEX 3/4 and GNSS (e.g. Galileo, BeiDou, etc.) observations are available with GAMIT/GLOBK 10.61 and later
  - But RINEX 3/4 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 https://files.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":
    - ssssdddt.yyo (RINEX observation file, i.e. the site's phase and code records)
    - ssssdddt.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    L1    L2    P1    P2    S1    S2          # / TYPES OF OBSERV
      30                                                   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
    :                        :
```
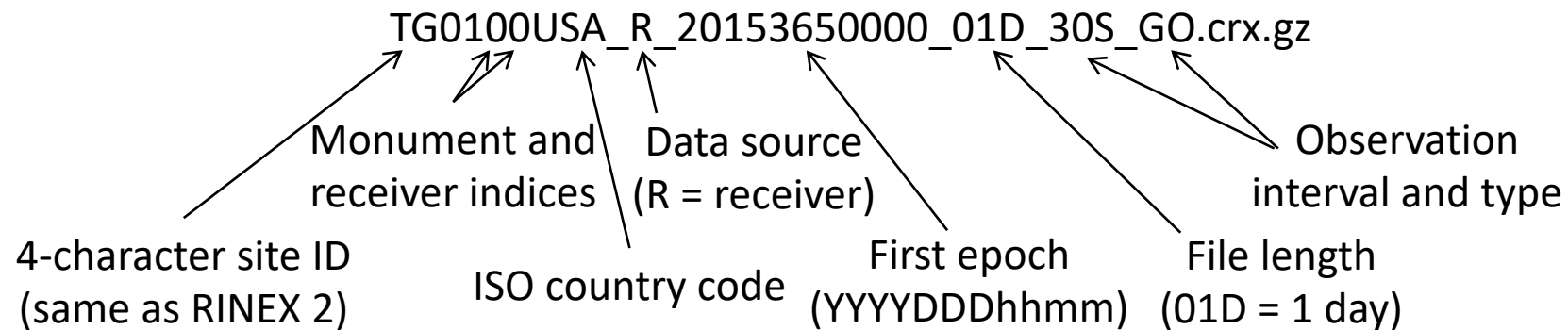
RINEX 3/4 data format

- Must be able to accommodate increased number and complexity of observations from multi-GNSS observations (GPS, GLONASS, Galileo, BeiDou, etc.)

- Latest definition at https://files.igs.org/pub/data/format/rinex305.pdf or https://files.igs.org/pub/data/format/rinex_4.00.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 3/4 filename convention is longer and more complicated than for RINEX 2, e.g.

TG0100USA_R_20153650000_01D_30S_GO.crx.gz

Monument and receiver indices

Data source (R = receiver)

Observation interval and type

4-character site ID (same as RINEX 2)

ISO country code

First epoch (YYYYDDDhhmm)

File length (01D = 1 day)

An example of RINEX 3/4 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
----------------------------------------------------------- COMMENT
TG01                                                        MARKER NAME
GEODETIC                                                    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    L2  L2C   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    0.0000000      GPS      TIME OF FIRST OBS
    2015    12    31    23    59   30.0000000      GPS      TIME OF LAST OBS
       0                                                    RCV CLOCK OFFS APPL
G L1C 0.00000                                               SYS / PHASE SHIFT
G L2X -0.25000                                              SYS / PHASE SHIFT
G L5X 0.00000                                               SYS / PHASE SHIFT
      17                                                    LEAP SECONDS
      31                                                    # OF SATELLITES
                                                            END OF HEADER
> 2015 12 31 00 00  0.0000000  0  9
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
```

Observation codes more complicated than RINEX 2 (see Tables 4–10 of current RINEX 3(.05) document)

System now listed along with observation types

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 3/4
- 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

GNSS data from receiver to processing input

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

Photograph by M. Floyd

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    COMMENT
BIT 2 OF LLI FLAGS DATA COLLECTED UNDER A/S CONDITION       COMMENT
U626                                                        MARKER N
U626                                                        MARKER N
UNKNOWN              Stanford University                    OBSERVER
3414A05687          TRIMBLE 4000SSE      NP 5.71 / SP 1.26  REC # /
3015A00136          TRM14532.00                             ANT # /
-2683218.3014 -4185018.7102  3983204.9361                  APPROX P
         1.4755          0.0000          0.0000             ANTENNA:
        1       1                                           WAVELENG
        5    L1    L2    C1    P1    P2                      # / TYPE
       30.0000                                              INTERVAL


  1994      9    28    16     7   30.0000000     GPS        TIME OF
                                                            END OF H

  94  9 28 16   7 30.0000000  0  5G 5G 6G17G20G24
     2437477.48856     1792564.39355   22428902.4774        22
     -548226.77657     -402556.82256   20834866.1484        20
     -567509.56556     -371824.37155   22860949.9614        22
     1203057.74657      883752.12057   20612879.2734        20
      793138.12755      501650.82355   22928979.6334        22
```

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 3/4 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