Earth, Atmospheric & Planetary Sciences

EarthScope Consortium

GNSS data from receiver to processing input

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GNSS Data Processing and Analysis with GAMIT/GLOBK and `track`

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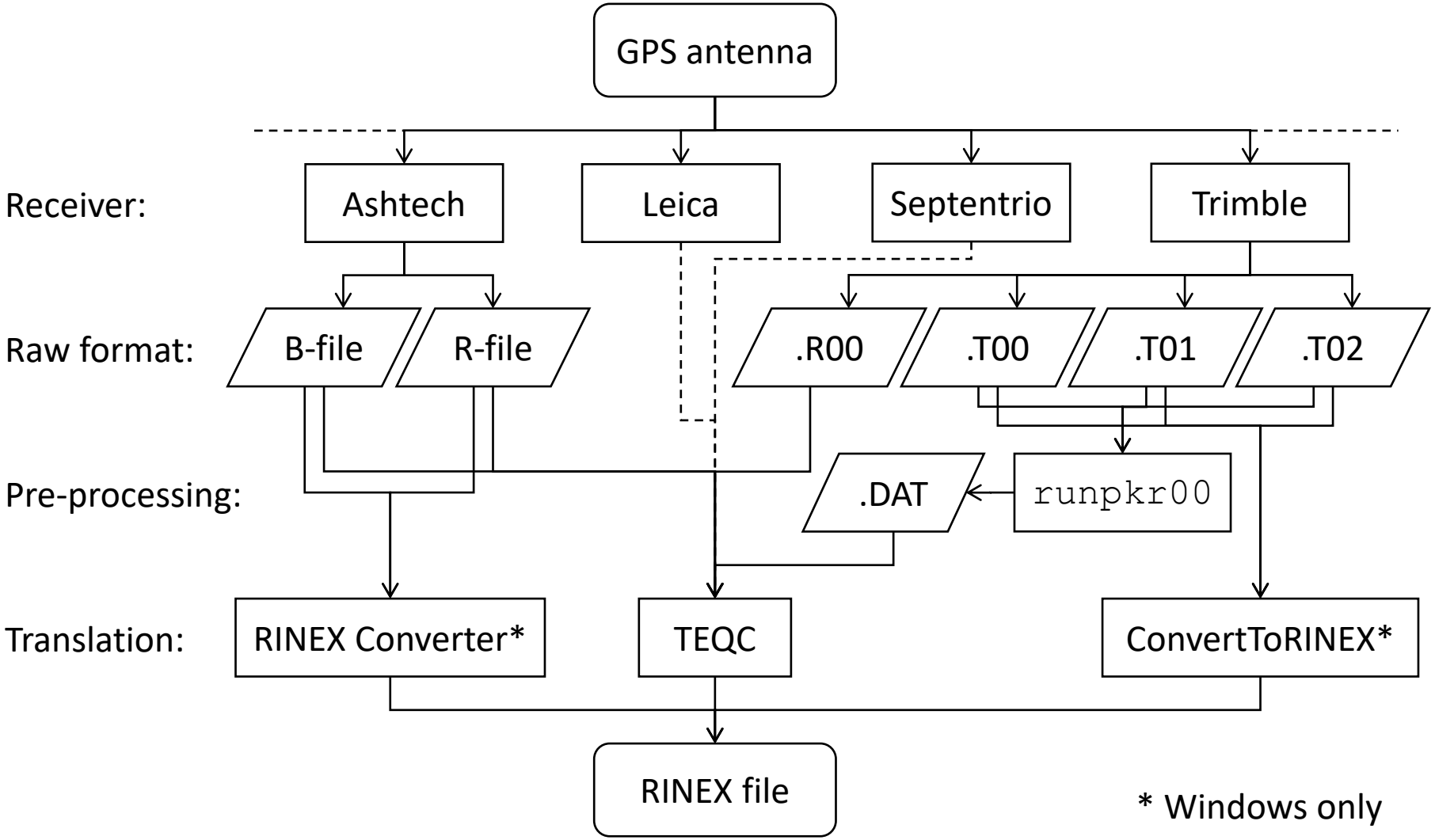
http://geoweb.mit.edu/gg/courses/202407_EarthScope/

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

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”)

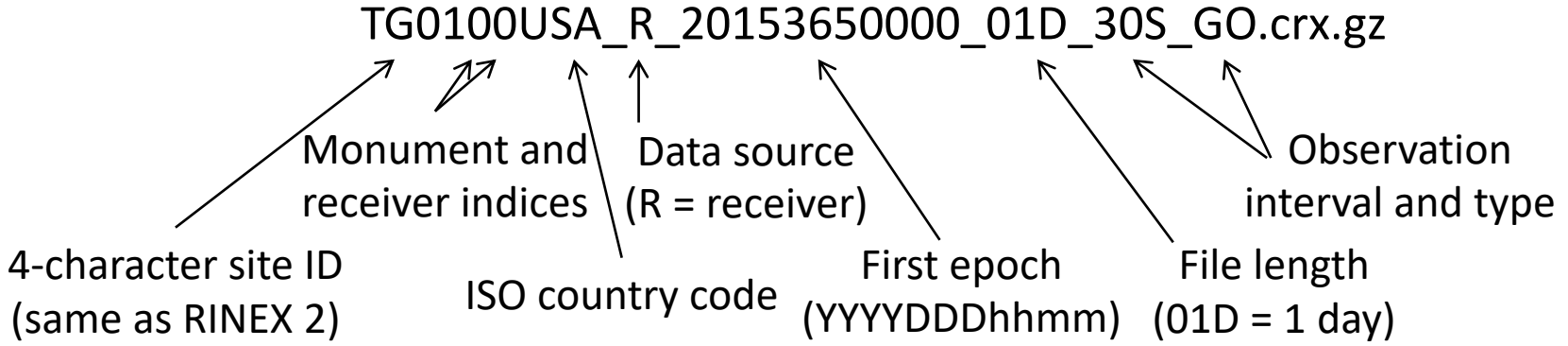
  } most important for most users
  - meteorological (“m”)
  - ionospheric data (“i”)
- Latest definition at https://files.igs.org/pub/data/format/rinex211.txt
- Each file type consists of a header section and a data section
- Header section contains global information for the entire file and is placed 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, *not* UTC, by convention

An example of RINEX 2 observation data

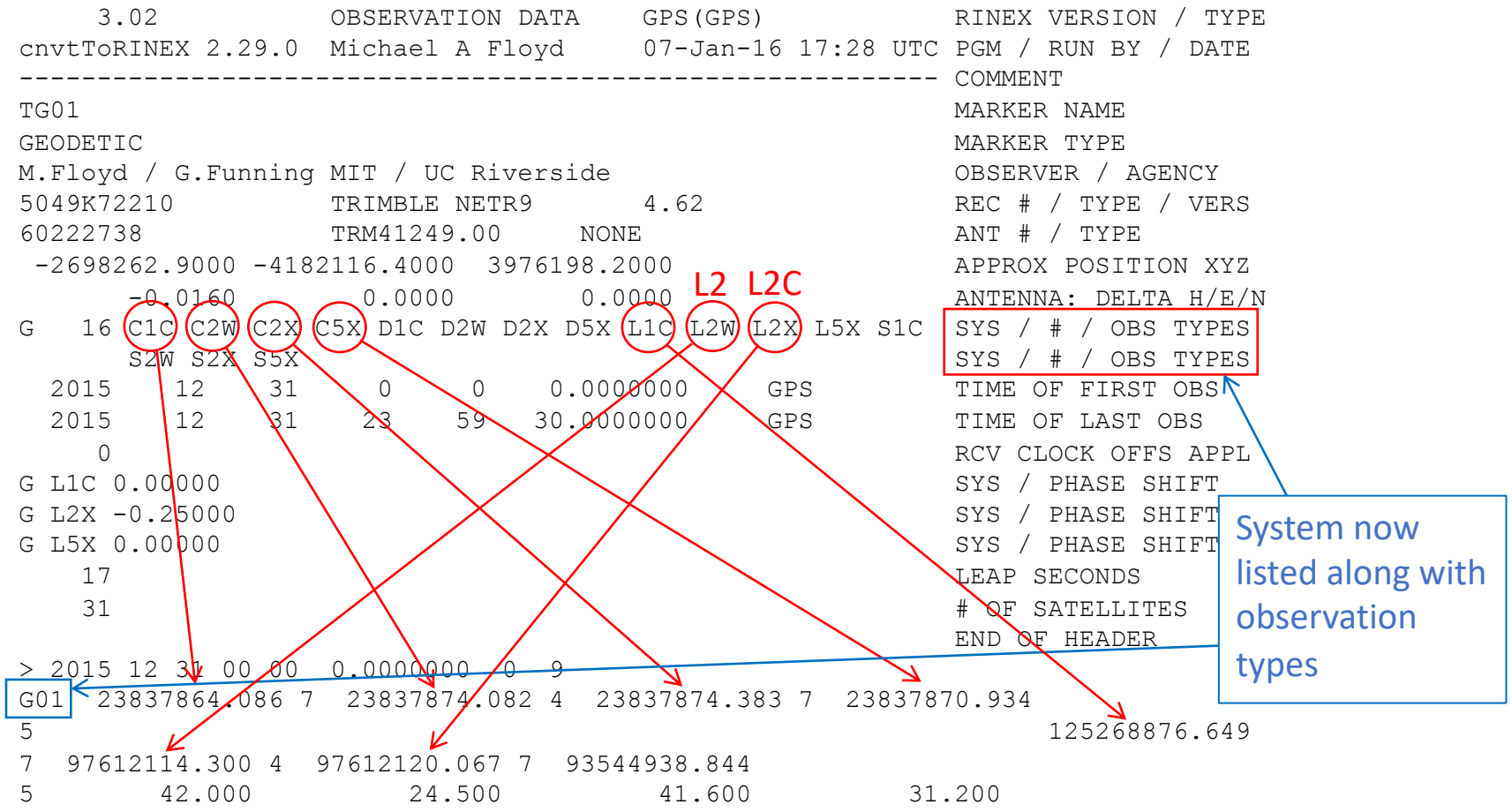
```
     2              OBSERVATION DATA    G (GPS)             RINEX VERSION / TYPE
CCRINEXO V2.3.1 LH  NERC SLRF UK        08-MAY-03 00:05     PGM / RUN BY / DATE
CONCATENATED OBSERVATION FILES                              COMMENT
ASRINEXO V2.9.10LH  NERC SLRF UK        07-MAY-03 01:03     COMMENT
                                                            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 and RINEX 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 .../rinex_4.01.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 3/4 observation data



Observation codes more complicated than RINEX 2 (see Tables 4–10 of current RINEX 4[.01] document)

Compressing/Uncompressing RINEX

- File compression
  - “*.zip” files
    - Unzip using “unzip”, “pkzip” or “WinZip”
    - See https://www.pkware.com/ or https://www.winzip.com/, or https://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 https://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 EarthScope nowadays
  - https://kb.unavco.org/article/trimble-runpkr00-latest-versions-744.html
- 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 https://www.unavco.org/software/data-processing/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`

Approximate position

- Accurate a priori coordinates necessary for good GNSS processing
- Run teqc to create RINEX observation and (broadcast) navigation files, e.g.
  ```
  teqc +nav abcd3650.14n +obs abcd3650.14o -tr d
  12343650.dat
  ```
- Run teqc in qc-mode on observation file with navigation file to get pseudorange-derived estimate of approximate coordinate, e.g.
  ```
  teqc +qc -nav abcd3650.14n abcd3650.14o
  ```
- May also be done using GAMIT/GLOBK's sh_rx2apr

Links to software

- runpkr00
  https://kb.unavco.org/article/trimble-runpkr00-latest-versions-744.html
- TPS2RIN Converter
  https://mytopcon.topconpositioning.com/support/products/tps2rin-converter
- TEQC
  https://www.unavco.org/software/data-processing/teqc/teqc.html
- ConvertToRINEX
  https://www.trimble.com/support_trl.aspx?Nav=Collection-40773&pt=Trimble%20RINEX