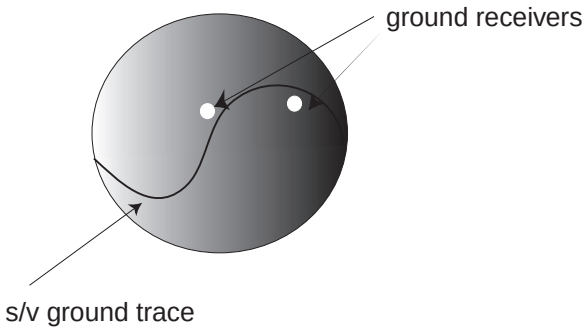
GPS & GIPSY/OASIS

Overview

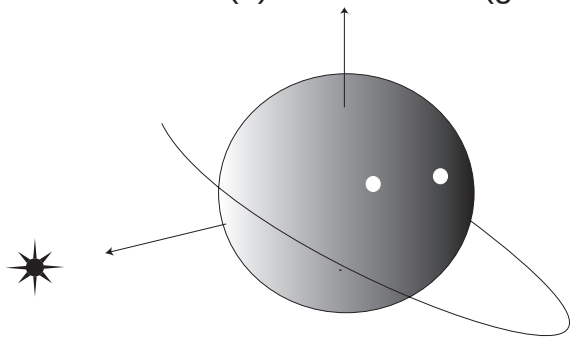
CONTENTS

GIPSY/OASIS: Conceptual Overview

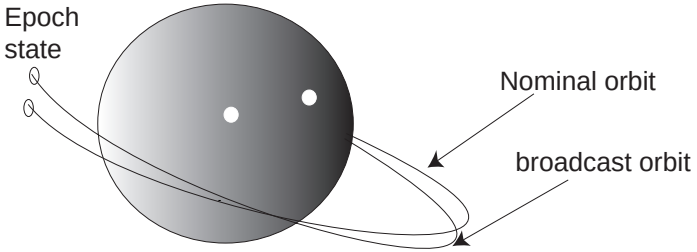
(1) Obtain ephemeris data files (ECEF)



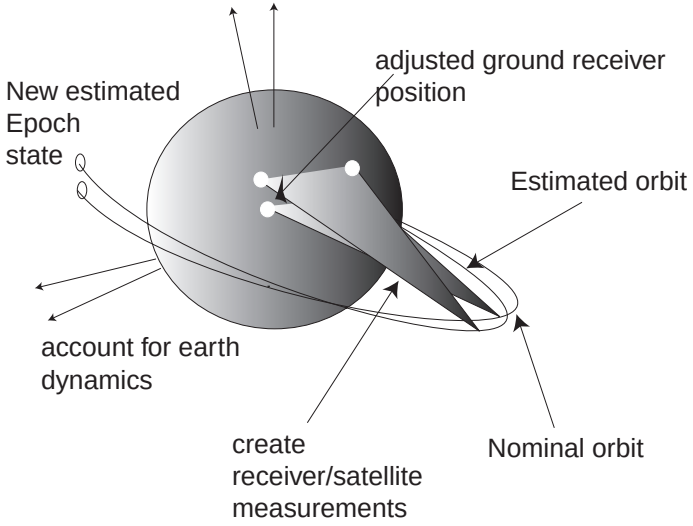
(2) ECEF to ECI (genoi)



(3) Fit a "nominal" orbit to broadcast orbit
(genoi < oi + trajedy)



(4) Linearize measurements & filter/estimate
(qregres & filter ...)

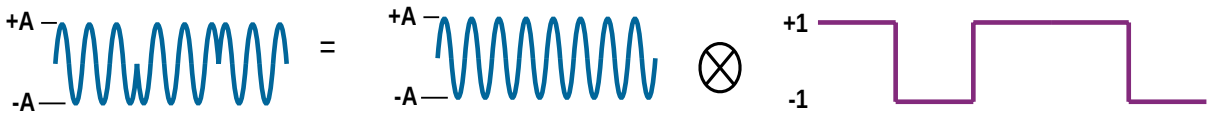


GIPSY/OASIS: Its Many Faces

	GIPSY Software Required	GIPSY Experience Required	Flexibility
Mail-in Service	No	None	No Options
GIPSY scripts	Yes	None	Very Limited
xt-gipsy	Yes	Yes; UNIX experience helpful	Flexible
Custom script	Yes	Yes; UNIX experience helpful	Most Flexible

The GPS Signal

BASIC GPS SIGNAL STRUCTURE



GPS Signal = L-Band Carrier Times Pseudorandom Squarewave Code @ 10.23 Mbs

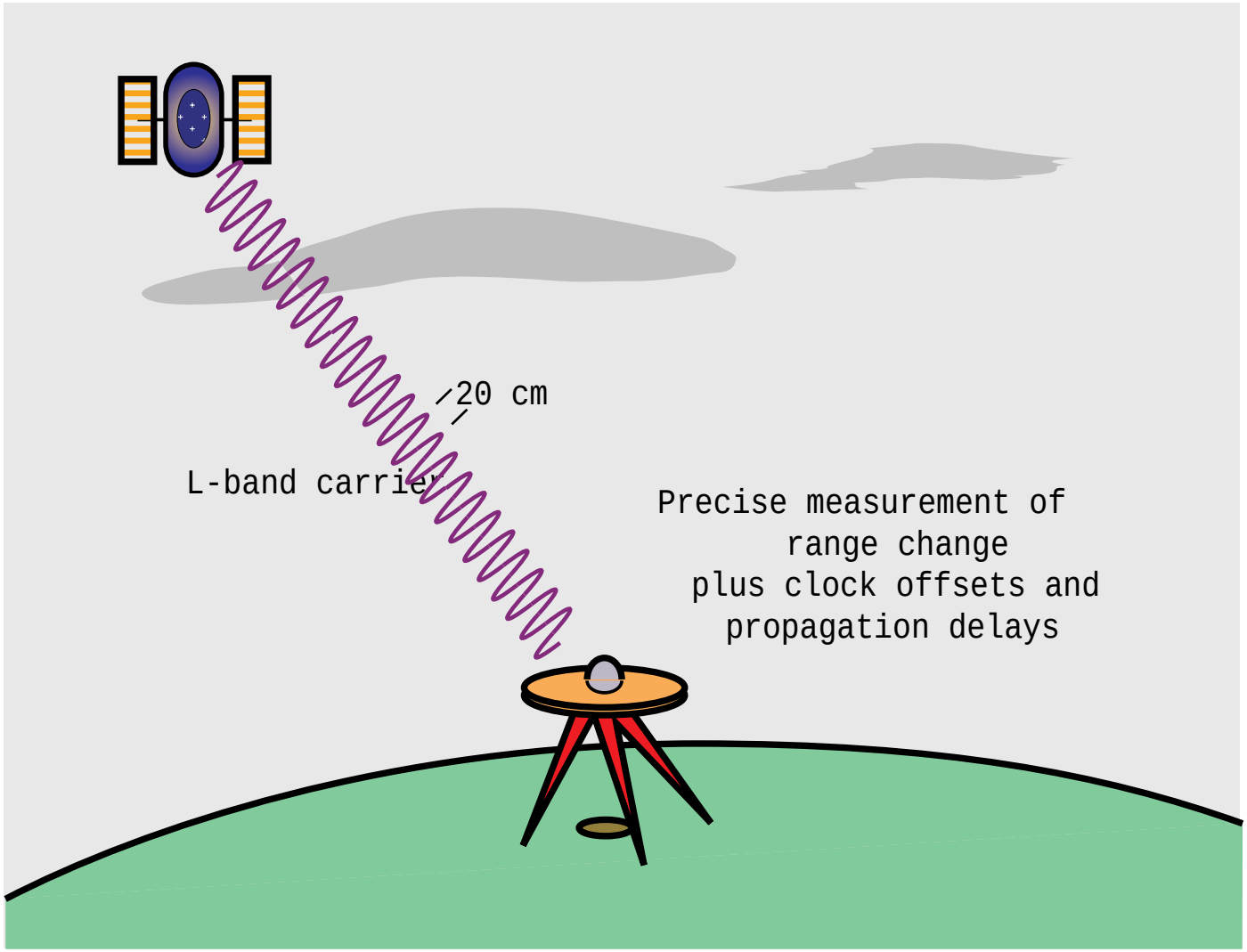
GPS Signal = **A cos(ω t)** X **P(t)**

L2(t) = **P(t) A cos(ω_2 t)**

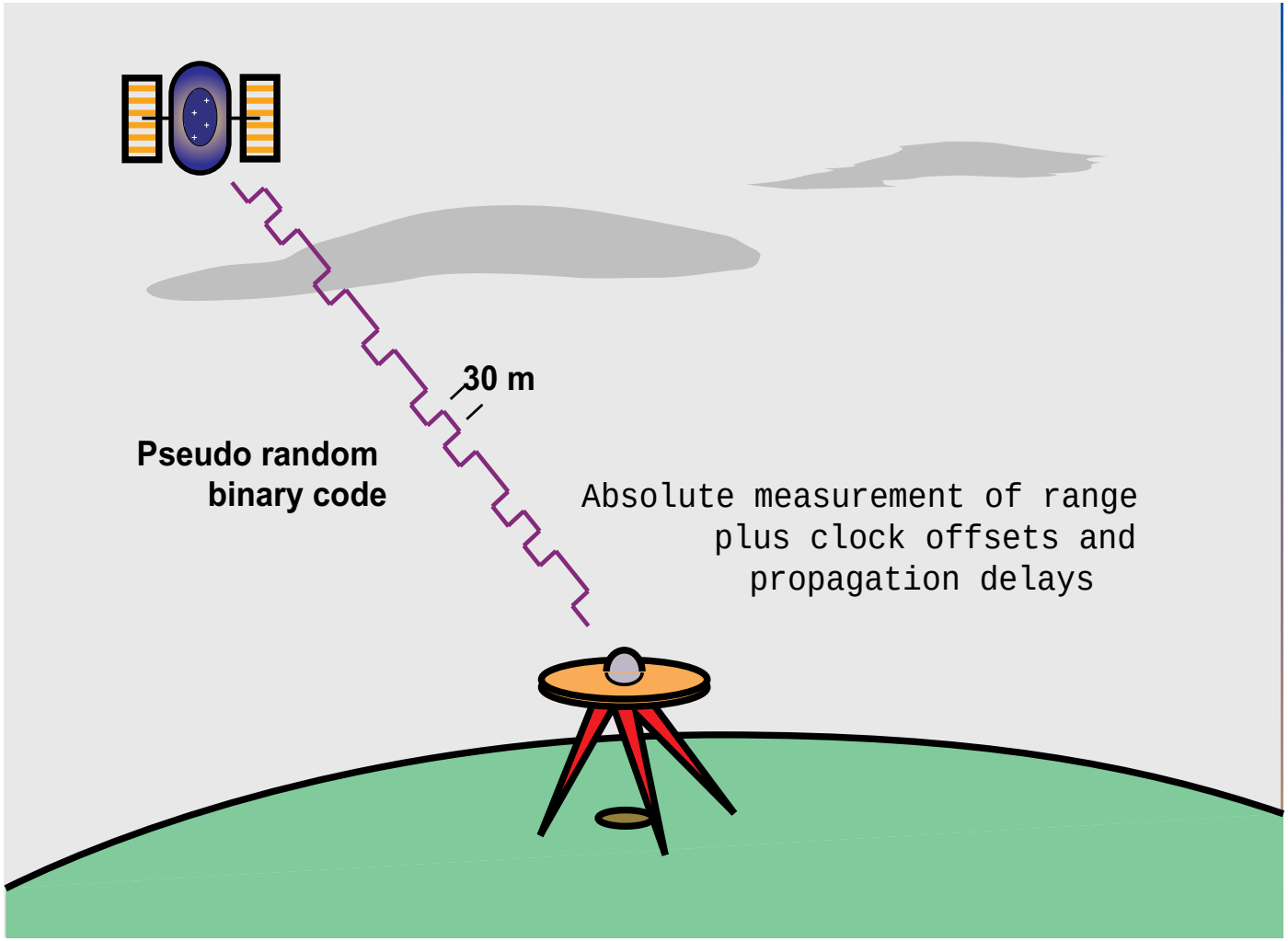
L1(t) = **P(t) B cos(ω_1t) + C(t) B' sin(ω_1t)** *(L1 Carrier = 1.57542 GHz)*

(Pseudorandom Squarewave Code @ 1.023 Mbs)

The Millimeter-precision Carrier Signal



The Meter-precision Pseudorange Code Signal



References

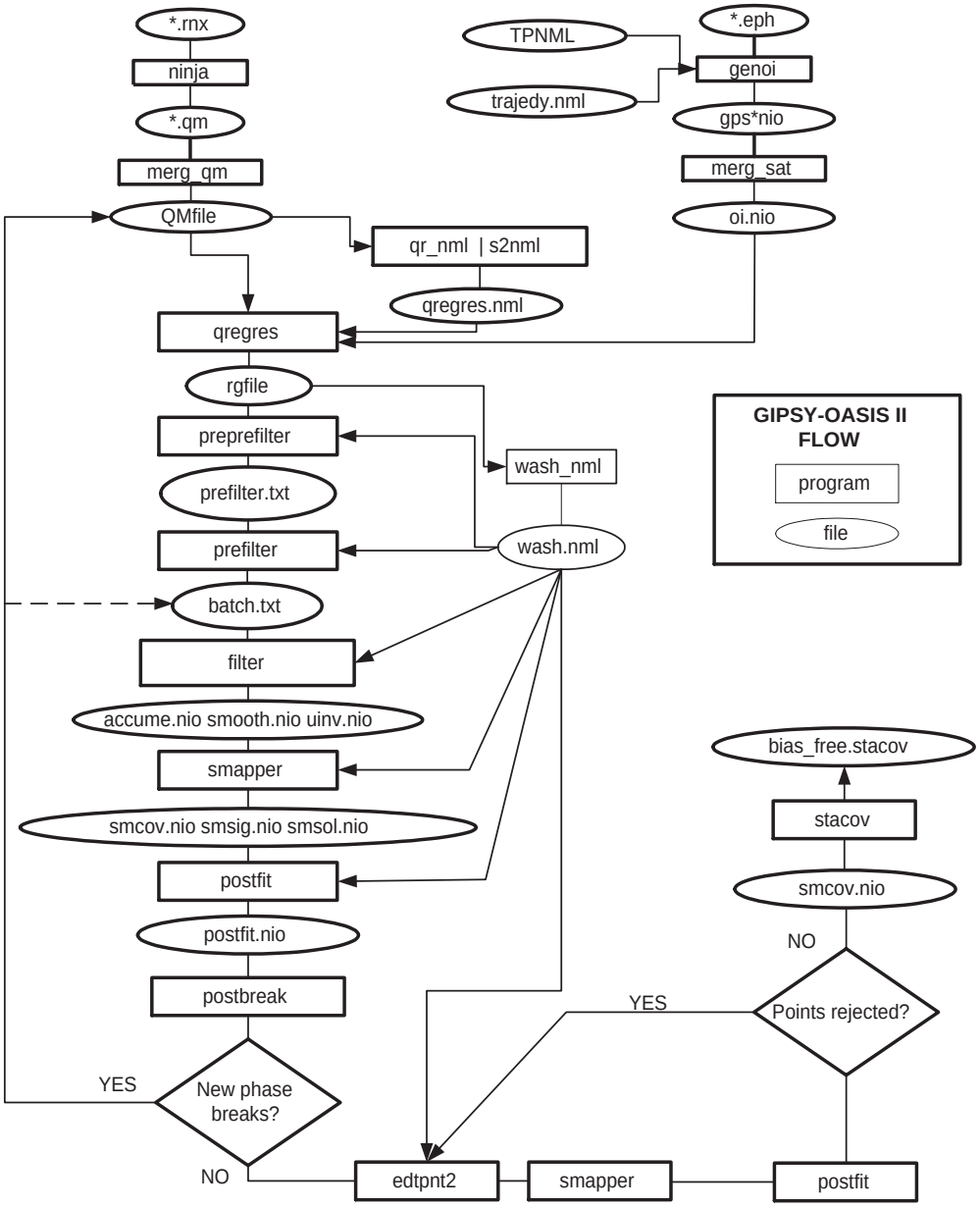
- GPS related
  - `http://gipsy.jpl.nasa.gov/`
  - *GPS Theory and Practise* by Hofmann-Wellenhof et al., 4th Ed., Springer '97.
  - *GPS Satellite Surveying* by Leick, 2nd Ed., John Wiley & Sons '95.
  - *Global Positioning System: Theory and Applications*, Parkinson et al., AIAA, '96.
  - *Satellite Geodesy* by de Seeber, Walter de Gruyter '93.
- Unix related
  - *The Unix C Shell Field Guide* by Anderson and Anderson, Prentice Hall '86

References (cont'd)

- GIPSY/OASIS related
  - *Introduction to GIPSY/OASIS* by Zumberge, Webb et al.
  - *GIPSY-OASIS II, How it works* by Gregorious, University of Newcastle upon Tyne, '96.
  - `/goa/source/*/USERGUIDE.TXT` by Muellershoen et al.
  - `/goa/file_formats/*`
  - Journal articles
  - News letters
- Estimation theory
  - *Factorization Methods for Discrete Sequential Estimation* by Bierman, Academic Press, '97.

GIPSY-OASIS II: Modular Overview

- Data Modules
  - Y_i
  - `ninja`
- Model Modules
  - $\underline{H},\ y_i \stackrel{\triangle}{=} Y_i - G(\underline{X}_i^*, t_i),\ \underline{x}(t) \stackrel{\triangle}{=} \underline{X}(t) - \underline{X}^*(t),\ \underline{\Phi}$
  - `genoi`, `qregres`
- Estimation Modules
  - $P,\ W,\ \underline{\widehat{x}}_k,\ Y - H\underline{\widehat{x}}$
  - `preprefilter`, `prefilter`, `filter`, `smapper`, `postfit`, `edtpnt2`
- Postprocessing Modules
  - `rd...` read & `sta...` station programs , Orbit utilities


*.rnx
ninja
*.qm
merg_qm
QMfile
TPNML
trajedy.nml
*.eph
genoi
gps*nio
merg_sat
oi.nio
qr_nml | s2nml
qregres.nml
qregres
rgfile
preprefilter
prefilter.txt
prefilter
batch.txt
filter
accume.nio smooth.nio uinv.nio
smapper
smcov.nio smsig.nio smsol.nio
postfit
postfit.nio
postbreak
YES
New phase breaks?
NO
wash_nml
wash.nml
GIPSY-OASIS II FLOW
program
file
bias_free.stacov
stacov
smcov.nio
NO
YES
Points rejected?
edtpnt2
smapper
postfit

On-line Help

Category	Example
`man`	`man vi`
`help`	`stacov help`
`-H`	`fltrnx -H`
no argument	`qregres`
`/goa/file_formats/*`	`tp_array`
`/goa/source/*/USERGUIDE.TXT`	`filter`, `smapper`, ...

Data Editing
in GIPSY/OASIS II: `ninja`

CONTENTS

- Data Types and Measurements
- RINEX
- The Data Editor (`ninja`)
  - Documentation
  - GIPSY-OASIS data flow
  - `ninja`'s `turbo edit`
  - `ninja` Usage
  - The `qmfile`

Data Types and Measurements

- GPS observables:
  - C_1,P_1, P_2, L_1 & L_2
  - Linearly combined to obtained the ionospheric-free combinations

$$\begin{aligned} LC &= a_2 L_1 - a_1 L2 \ , \\ PC &= a_2 P_1 - a_1 P_2 \ , \end{aligned}$$

where:

$$\begin{aligned} a_1 &= \frac{{f_2}^2}{({f_1}^2 - {f_2}^2)} = 1.5457 \text{ and} \\ a_2 &= a_1 + 1 = 2.5457, \end{aligned} \tag{28}$$

with f_1 and f_2 being the GPS frequencies at L_1 and L_2.

Note: I'm calling L_1 & L_2 what is sometimes referred as Φ_1 & Φ_2.

– or the so-called wide-lane combinations

$$\begin{aligned} L_w &= \frac{f_1 L_1 - f_2 L_2}{f_1 - f_2}, \\ &= \rho + d_{iono} + \frac{f_1 f_2}{f_1^2 - f_2^2} + \lambda_w b_w \ ; \\ P_w &= \frac{f_1 P_1 + f_2 P_2}{f_1 + f_2}, \\ &= \rho + d_{iono} + \frac{f_1 f_2}{f_1^2 - f_2^2} \ ; \end{aligned}$$

where

$$b_w = N_1 - N_2, \quad \lambda_w \equiv \frac{c}{f_1 - f_2} \approx 86.2 \text{ cm}.$$

RINEX

- RINEX:Receiver Independent Exchange Format
- Header
  - Station name and offset from monument
  - Data types
  - Time span of observations
- Observations:
  - Multi-line records (time sorted)
- Hatanaka compression
  - `crz2rnx`
  - `rnx2crz`

RINEX (cont'd)

Header

```
     2              OBSERVATION DATA                        RINEX VERSION / TYPE
TRRINEXO V2.3.2 UX  UNAVCO              05-JUN-95 07:36     PGM / RUN BY / DATE
Rinex conversion trimble data                               COMMENT
BIT 2 OF LLI (+4) FLAGS DATA COLLECTED UNDER "AS" CONDITION COMMENT
IISC                                                        MARKER NAME
                                                            MARKER NUMBER
sridevi             cmmacs                                  OBSERVER / AGENCY
3971                TRIMBLE 4000 SSE     5.71               REC # / TYPE / VERS
6253                TRIMBLE 4000 SST                        ANT # / TYPE
  1337942.1743  6070396.1085  1427920.4439                  APPROX POSITION XYZ
        1.2780        0.0000        0.0000                  ANTENNA: DELTA H/E/N
     1     1                                                WAVELENGTH FACT L1/2
     5    P1    L1    L2    P2    C1                        # / TYPES OF OBSERV
    15                                                      INTERVAL
  1995     6     1     0     0   15.000000                  TIME OF FIRST OBS
                                                            END OF HEADER
```

Observations

```
 95  6  1  0  0 15.0000000  0  7 14 18 31 28 19 22 29
                  15132479.32916  11830538.82459  21377492.1484   21377492.992
                  -1009284.67816   -761467.07359  22736836.1804   22736837.000
                    632539.66516    464192.93959  22280285.7854   22280287.344
  22679376.734    10958752.10815   8547003.92519  22679375.820
                   4667737.91513   3595210.07258  23928213.3754   23928213.773
                  37051661.89615  28872664.93459  23321772.3954   23321773.109
                   3786759.65917   2877937.33759  21462095.5944   21462097.141
 95  6  1  0  0 30.0000000  0  7 14 18 31 28 19 22 29
                  15201013.603 6  11883942.15049  21390534.1174   21390535.312
                  -1013310.142 6   -764603.81249  22736069.4924   22736070.711
                    634961.305 6    466079.93049  22280747.1954   22280748.719
  22685788.867    10992447.041 5   8573259.705 9  22685788.023
                   4690939.476 3   3613289.25546  23932629.7344   23932627.695
                  37138967.484 5  28940695.24349  23338386.2304   23338386.711
                   3795079.206 7   2884420.10049  21463678.6844   21463680.031
```

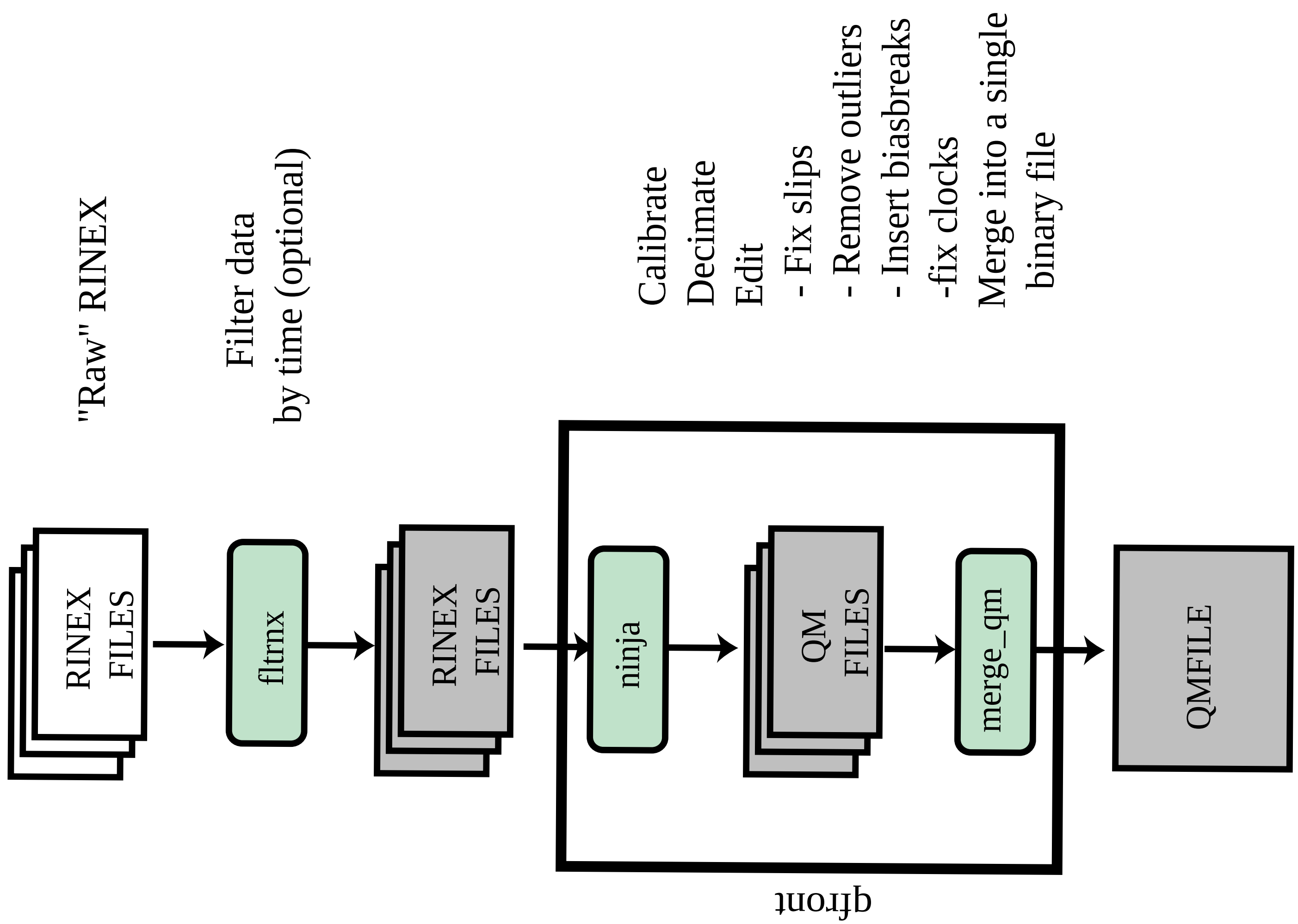
Record

GIPSY Data Editor (ninja)

Documentation

- `ninja`
- `ninja -H`
- `man ninja`
- In User's Manual, Part II: Data

GIPSY-OASIS Data FLow



ninja's turbo edit

- Undifferenced data editor
- Requires P_1, P_2, L_1 & L_2
- Editing decisions are independent of
  - Receiver clock & satellite clocks (SA)
  - Orbit, geometry & troposphere
  - Antenna motion (can be used for kinematic data)
- Editing decisions depend on
  - Low noise P_1 and P_2 (low multipath, $\mu_1 \sim \mu_2 < 60\ cm$)
  - "Smooth" ionosphere
    - implies high-rate data better
    - not too high rate (keep $\mu < 60\ cm$)

ninja Usage

```
Usage: ninja -i in_file
[-t out_interval(sec)] [-noedit] [-notedit] [-nosane][-nosmooth]
[-tbdbg] [-t1 data_windo_start] [-t2 data_window_end]
-q out_file [-a min_arc_length(min)] [-n station_name]
[-sat satellite_receiver_name] [-plt] [-ion tol_ion]
[-rms 6.0] [-L1] [-L2] [-LC] [-P1] [-P2] [-PC]

  A program to read in a file of GPS data, run
Turboedit, decimate to a desired  interval,
and write it out in one of several formats.
-i     Input file name. If given as a dash
       (-), the input is read from standard
       in (stdin).
-noedit Do not do any editing. In this case
       it will use the loss of lock flags
       in the  raw input file. This option
       should be used  ONLY when you are
       CERTAIN the raw file is  free of bad
       points and unflagged cycle slips.
-notedit Do not run Turboedit. In this case
       it will use the loss of lock flags
```

```
       in the  raw input file, and will flag
       discontinuities in L1-L2-polyfit(L2-L2)
-nosane        Do not flag discontinuities in L1-L2
       as phase breaks.
-nosmooth  Do not do carrier-aided smoothing of
       pseudorange.
       -nosmooth and -noedit should act as just
       a translator and decimator.
-a     Set the minimum arc length.
       DEFAULT=20 minutes
-t     Set the output data interval (seconds).
       DEFAULT = 360 secs
-t1    Set the data window start time
       (seconds past J2000). If not set, use
       all the data.
-t2    Set the data window end time (seconds
       past  J2000). If not set, use all the
       data.
-n     Override the station name. If not used,
       the station name is derived from the
       8th through 16th characters of the
       output file name.
-ion   Set the tolerance in cycles for the
       ionosphere when looking for narrowlane
```

```
       cycle slips
       DEFAULT = 15 cycles
-plt   make turboedit plots
-sat   Receiver is a satellite. Override the
       station name with sat name.
-tbdbg Turn on turboedit debug prints
-rms   Set the sensitivity to discontinuities
       in L1-L2. Jumps larger than Z*RMS will
       be flagged. If negative, use absolute value
       as of Z as limit of L1-L2 (m)
       DEFAULT= -.12
-L1 etc        Include this data type in the output
       Default: only LC and PC
       If one is given, all must be given
-q     Output format = "quick format"
       next item must be output file name
Maximum dimensions:
       maxrec  =  86400 max obs/sat-arc
       maxarc  =  200
       maxpoly =  10
       maxsat  =  50
       mbatch  =  200
```

The `qmfile`: internal, binary format

- Header
  - Station names
  - Satellite names
  - Epoch time
  - Data types
  - Sort order
- Observations
  - single-line record for each satellite/station pair (sorted)
- Utility: `dump_qm`, dumps contents of a `qmfile` to standard output

The qmfile (cont'd)

dump_qm QMfile

```
 8 24
ALGO      FAIR      HART      KOKB      MADR      SANT      TROM      YAR1
GPS16     GPS17     GPS24     GPS26     GPS27     GPS36     GPS22     GPS23     GPS28     GPS13     GPS14 ...
 -142862400.0
 15
 2
 24420
 1 3 4 5 2
           .0000   1  1  3  2         .000000  .0000E+00  2   21560.8485174       1.4114453
           .0000   1  1  6  2         .000000  .1984E-03  2   21560.8490195       -.3784441
           .0000   1  2  3  2         .000000  .0000E+00  2   21982.4790185       1.4147445
           .0000   1  2  6  2         .000000  .2454E-03  2   21982.4792785       -.3665632
           .0000   1  3  3  2         .000000  .0000E+00  2   24121.9901174       3.2742555
           .0000   1  3  6  2         .000000  .1604E-03  2   24121.9897954        .0660957
           .0000   1  4  3  2         .000000  .0000E+00  2   20958.8159921      -1.3057226
           .0000   1  4  6  2         .000000  .1351E-03  2   20958.8159550       -.2291538
           .0000   1  5  3  2         .000000  .0000E+00  2   24154.1991037       2.8503504
           .0000   1  5  6  2         .000000  .2772E-03  2   24154.1993284        .2407419
           .0000   1  6  3  2         .000000  .0000E+00  2   21207.8884300       -.7157080
           .0000   1  6  6  2         .000000  .1485E-03  2   21207.8884626       -.2464616
           .0000   2  2  3  2         .000000  .0000E+00  2   20286.6271743      -6.3325548
           .0000   2  2  6  2         .000000  .5101E-04  2   20286.6277070       -.5280421
           .0000   2  7  3  2         .000000  .0000E+00  2   21498.4723267      -6.7486934
           .0000   2  7  6  2         .000000  .1171E-03  2   21498.4723077        .0237086
.
.
.
```

The qmfile (cont'd)

dump_qm -n QMfile

```
 8 24
ALGO      FAIR      HART      KOKB      MADR      SANT      TROM      YAR1
GPS16     GPS17     GPS24     GPS26     GPS27     GPS36     GPS22     GPS23     GPS28     GPS13     GPS14 ...
 -142862400.0
 15
 2
 24420
 1 3 4 5 2
           .0000 ALGO     GPS16    LC   2         .000000  .0000E+00  2   21560.8485174       1.4114453
           .0000 ALGO     GPS16    PC   2         .000000  .1984E-03  2   21560.8490195       -.3784441
           .0000 ALGO     GPS17    LC   2         .000000  .0000E+00  2   21982.4790185       1.4147445
           .0000 ALGO     GPS17    PC   2         .000000  .2454E-03  2   21982.4792785       -.3665632
           .0000 ALGO     GPS24    LC   2         .000000  .0000E+00  2   24121.9901174       3.2742555
           .0000 ALGO     GPS24    PC   2         .000000  .1604E-03  2   24121.9897954        .0660957
           .0000 ALGO     GPS26    LC   2         .000000  .0000E+00  2   20958.8159921      -1.3057226
           .0000 ALGO     GPS26    PC   2         .000000  .1351E-03  2   20958.8159550       -.2291538
           .0000 ALGO     GPS27    LC   2         .000000  .0000E+00  2   24154.1991037       2.8503504
           .0000 ALGO     GPS27    PC   2         .000000  .2772E-03  2   24154.1993284        .2407419
           .0000 ALGO     GPS36    LC   2         .000000  .0000E+00  2   21207.8884300       -.7157080
           .0000 ALGO     GPS36    PC   2         .000000  .1485E-03  2   21207.8884626       -.2464616
           .0000 FAIR     GPS17    LC   2         .000000  .0000E+00  2   20286.6271743      -6.3325548
           .0000 FAIR     GPS17    PC   2         .000000  .5101E-04  2   20286.6277070       -.5280421
           .0000 FAIR     GPS22    LC   2         .000000  .0000E+00  2   21498.472
.
.
.
```