HASH: A FORTRAN Program for Computing Earthquake First-Motion Focal Mechanisms – v1.2 – January 31, 2008

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INTRODUCTION:

Focal mechanisms of small earthquakes are typically determined from P-wave first-motion polarities. These fault plane solutions are notoriously sensitive to various sources of error, including imperfect knowledge of the seismic velocity structure. To address this problem, we have developed a new method (called HASH, for HArdebeck & SHearer) for producing more stable focal mechanisms. This method generates a set of acceptable mechanisms for each event given the various sources of uncertainty, and returns the most likely mechanism. Mechanism quality is assigned based on the solution stability with respect to model uncertainty, represented by the spread of the acceptable mechanisms.

This technique has been shown to produce more accurate focal mechanisms than prior methods for cases in which we believe the correct mechanisms are known. For example, the mechanisms for clusters of events with similar seismic waveforms in the Northridge, California, aftershock sequence are more similar (Hardebeck & Shearer, 2002; Shearer et al., 2003), and the mechanisms of events along the San Andreas, Calaveras and Sergeant Faults in northern California are more consistent with the fault orientations delineated by earthquake locations (Kilb & Hardebeck, 2006). We have also expanded this technique to include S-wave to P-wave amplitude ratios.

This manual is intended to help researchers run HASH on their own data sets. The source code may be obtained at: http://quake.wr.usgs.gov/research/software/#HASH. The methodology is discussed in more detail in our publications. Please cite these papers if you use our codes. Thank you!

- Hardebeck, Jeanne L. and Peter M. Shearer, A new method for determining first-motion focal mechanisms, *Bulletin of the Seismological Society of America*, 92, 2264-2276, 2002.

- Hardebeck, Jeanne L. and Peter M. Shearer, Using S/P Amplitude Ratios to Constrain the Focal Mechanisms of Small Earthquakes, *Bulletin of the Seismological Society of America*, 93, 2434-2444, 2003.

As described in our papers, this technique uses a grid-search to determine P-wave polarity first-motion (or P-polarity and S/P amplitude ratio) focal mechanisms. For each earthquake, a set of acceptable mechanisms is found. The spread of the acceptable mechanisms determines the uncertainty and the assigned solution quality. The set of acceptable mechanisms takes into account the uncertainty in polarity measurements, event location, and takeoff angle (velocity model.) Therefore, you will need an estimate of the rate of polarity errors in your data, an estimate of the location uncertainty, and an estimate of the takeoff angle uncertainty (which can be represented as a set of possible 1D velocity models for your region.)

We've tried to make the code as input-format independent as possible. The idea is to have a main driver code that does the I/O and gets the input data into the internal arrays, and subroutines that do the actual computation of the focal mechanisms and uncertainties and deal with the station locations and the seismic velocity models. To use for different networks and data formats, you should only have to edit the main driver code and the station subroutines.

The code was developed while we were primarily using data from the Southern California Seismic Network (SCSN – also sometimes called TriNet), obtained through the Southern California Earthquake Data Center (SCEDC). Therefore the example formats are similar to the standard distribution formats of SCEDC phase data, and we occasionally refer to the SCSN or the SCEDC. We also refer to FPFIT, which is currently the most widely used focal mechanism program, see Reasenberg & Oppenheimer (1985). The new example 4, added for the release of HASH 1.2, uses the current SCEDC phase and station formats as of January 2008, including 5-character station names.

The programs are in FORTRAN 77, and have been tested by the authors on Sun workstations of various configurations, and a Mac G4 running OSX (FORTRAN 77 compiler available from FINK: http://fink.sourceforge.net/). Others have used the codes on Linux. Please contact the authors if any changes need to be made to run on other platforms. And of course please let us know if you discover any bugs.

OVERVIEW:

The following files should appear in the HASH directory.

Source Code:

- hash_driver1.f \
- hash_driver2.f - example main driver programs
- hash_driver3.f /
- hash_driver4.f - NEW EXAMPLE, updated SCEDC formats, 5 character stations
- hash_driver5.f - NEW EXAMPLE, SIMULPS format for 3D ray tracing
- fmamp_subs.f - subroutines for computing focal mechanisms, P and S/P
- fmech_subs.f - subroutines for computing focal mechanisms, P only
- pol_subs.f - polarity distribution/misfit routines
- station_subs.f - station location/polarity reversal routines
- station_subs_5char.f - NEW, 5 character station location/polarity routines
- uncert_subs.f - subroutines to compute mechanism uncertainty
- util_subs.f - utility subroutines
- vel_subs.f - subroutines for seismic velocity tables

Include Files:

- param.inc - some parameters to set array sizes
- rot.inc - determine the grid spacing for focal mechanism search
- vel.inc - velocity table parameters

Makefile:

- Makefile

Example Control Files (correspond to example driver programs):

- example1.inp: Example with P polarity data only, take-off angle uncertainties are specified in the input.
- example2.inp: Example with P polarity data only, take-off angle uncertainties are represented by a suite of 1D velocity models.
- example3.inp: Example with P polarity and S/P amplitude data, take-off angle uncertainties are represented by a suite of 1D velocity models.
- example4.inp: NEW EXAMPLE, like example2.inp, but with updated SCEDC formats, 5 character stations.
- example5.inp: NEW EXAMPLE, like example2.inp, but using azimuth and take-off angles from a SIMULPS-like format file, for 3D ray-tracing

Example Data Files:

- north1.phase - P polarity phase file, for example 1
- north2.phase - P polarity phase file, for examples 2 & 3
- north3.amp - P and S amplitude file, for example 3
- north3.statcor - station S/P ratio correction, for example 3
- north4.phase - NEW EXAMPLE, P polarity phase file in updated SCEDC format
- north5.simul - NEW EXAMPLE, azimuth and take-off angles from SIMULPS
- scsn.stations - station locations, for examples 2 & 3
- scsn.stations_5char - NEW 5 character station locations, for example 4
- scsn.reverse - station polarity reversals, all examples
- vz.socal, etc - 1D velocity models, for examples 2 & 3

Example Output Files:

- example1.out - preferred mechanisms, example 1
- example1.out2 - set of acceptable mechanisms, example 1
- example2.out - preferred mechanisms, example 2
- example2.out2 - set of acceptable mechanisms, example 2
- example3.out - preferred mechanisms, example 3
- example4.out - NEW, preferred mechanisms, example 4
- example4.out2 - NEW, set of acceptable mechanisms, example 4
- example5.out - NEW, preferred mechanisms, example 5
- example5.out2 - NEW, set of acceptable mechanisms, example 5

To Compile, type "make hash_driverX", where “X” is the example number, 1, 2, 3, 4 or 5. To Run, type "hash_driverX" and it runs interactively, or type "hash_driverX < exampleX.inp" to run using the given control file. If the codes have compiled and are running correctly, the generated output files should closely match the provided examples. NOTE: The generated output may not *exactly* match the samples output. The input for each Monte Carlo trial is selected randomly, so if there is a difference in random number generation, this can lead to a small difference in output. Because of this, sometimes the solutions are slightly different by a few degrees (very small compared to the uncertainty), or the other nodal plane is listed, so the files aren't strictly identical.

RUNNING THE CODE:

Computing Focal Mechanisms:

The driver, or main, program is primarily for input and output. The actual computation of the focal mechanism for each event is done in three subroutine calls from the main program. You should edit the main driver routines to most efficiently get your data formats into the arrays passed to these subroutines.

1. Computing the set of acceptable mechanisms.

Separate but similar subroutines are used depending on whether or not you wish to use S/P amplitude ratios in addition to P-wave polarities. The inputs to both subroutines include the P-wave polarities (and S/P amplitude ratios) for the event at a set of stations, and the azimuth and takeoff angle to each station. An estimate of uncertainty in these inputs is also required, in order to test the stability of the focal mechanism solutions.

The uncertainty in the azimuth and takeoff angle is represented by multiple sets of reasonable values of these angles. It's assumed that these values come from repeated trials, for instance each trial for a different event depth and/or velocity model. For example, for trial number 5, the event location and velocity model are held fixed, and the resulting azimuth and takeoff angles for the 7th station are stored in `p_azi_mc(7,5)` and `p_the_mc(7,5)`, for the 8th station are stored in `p_azi_mc(8,5)` and `p_the_mc(8,5)`, etc. The polarity, pick quality, and S/P ratios are the same for each trial, and for the 7th station they are given in `p_pol(7)`, `p_qual(7)`, and `sp_amp(7)`, etc. The number of trials is given by `nmc`, and the number of station observations is given by `npsta`. A set of acceptable mechanisms will be constructed for each trial, and these will be combined to make the set of acceptable mechanisms for this event.

The uncertainty in the P-wave polarity picks is accounted for by specifying how many polarity errors are acceptable. The returned set of acceptable mechanisms will include mechanisms with up to this many misfit polarities. The number of allowed polarity misfits is defined as the number of misfit polarities for the best-fit solution plus an additional `nextra`. If this total number of allowed misfits is less than `ntotal`, then `ntotal` is used as the number of allowed misfits. We usually use a value of `ntotal` equal to the total number of polarity observations times the known rate of polarity errors for the network, therefore allowing for at least the expected number of polarity misfits. We usually use a `nextra` half of `ntotal`. Similarly, for the S/P amplitude ratios, the allowed log10(S/P) misfit is defined as the best-fit solution misfit plus `qextra`, or `qtotal` if this is greater. We usually used `qtotal` equal to the total number of S/P observations times the estimated average uncertainty, and `qextra` half of `qtotal`.

There are two additional control parameters: `dang`, which specifies the resolution of the focal mechanism grid search, and `maxout`, which gives the maximum desired number of acceptable focal mechanisms output.

The total number of acceptable mechanisms found is given by `nf` (but a maximum of `maxout` are returned.) For each acceptable mechanism, the mechanism parameters and the normal vectors to the two nodal planes are returned.

For P-wave polarity data only:

```
subroutine FOCALMC(p_azi_mc,p_the_mc,p_pol,p_qual,npsta,nmc,
dang,maxout,nextra,ntotal,nf,strike,dip,rake,faults,slips)
```

Inputs:

- `p_azi_mc(npsta,nmc)` - azimuth to station from event (degrees E of N)
- `p_the_mc(npsta,nmc)` - takeoff angle (degrees from vertical: up=0; <90 up-going; >90 down-going)
- `p_pol(npsta)` - first motion, 1=up, -1=down
- `p_qual(npsta)` - quality, 0=impulsive, 1=emergent
- `npsta` - number of first motion observations
- `nmc` - number of trials, ie number of possible azimuth/ takeoff angle pairs given for each station
- `dang` - angle spacing for grid search (degrees)
- `maxout` - maximum number of fault planes to return: if more are found, a random selection will be returned
- `nextra` - number of additional misfits allowed
- `ntotal` - minimum number of total allowed misfits

Outputs:

- `nf` - number of focal mechanisms found
- `strike(min(maxout,nf))` - strike (the choice of the "fault" and
- `dip(min(maxout,nf))` - dip "auxiliary" plane is arbitrary.)
- `rake(min(maxout,nf))` - rake
- `faults(3,min(maxout,nf))` - fault normal vector
- `slips(3,min(maxout,nf))` - slip vector

For P-wave polarity and S/P amplitude ratio data:

```
subroutine FOCALAMP_MC(p_azi_mc,p_the_mc,sp_amp,p_pol,npsta,nmc,
dang,maxout,nextra,ntotal,qextra,qtotal,nf,strike,dip,rake,
faults,slips)
```

Inputs:

- `p_azi_mc(npsta,nmc)` - azimuth to station from event (degrees E of N)
- `p_the_mc(npsta,nmc)` - takeoff angle (degrees from vertical: up=0; <90 up-going; >90 down-going)
- `sp_amp(npsta)` - amplitude ratios, log10(S/P)
- `p_pol(npsta)` - first motion, 1=up, -1=down
- `npsta` - number of observations
- `nmc` - number of trials, ie number of possible azimuth/ takeoff angle pairs given for each station
- `dang` - angle spacing for grid search

- `maxout` - maximum number of fault planes to return: if more are found, a random selection will be returned
- `nextra` - number of additional polarity misfits allowed
- `ntotal` - minimum number of total allowed polarity misfits
- `qextra` - additional amplitude misfit allowed
- `qtotal` - minimum allowed total amplitude misfit

Outputs:

- `nf` - number of fault planes found
- `strike(min(maxout,nf))` - strike (the choice of the "fault" and
- `dip(min(maxout,nf))` - dip "auxiliary" plane is arbitrary.)
- `rake(min(maxout,nf))` - rake
- `faults(3,min(maxout,nf))` - fault normal vector
- `slips(3,min(maxout,nf))` - slip vector/ normal to auxiliary plane

2. Computing the preferred, or most probable, mechanism.

After the set of acceptable mechanisms is computed, they are used to determine the preferred mechanism and some estimates of the quality of the solution. The preferred solution, or the most probable solution, is the average of the acceptable fault plane solutions after outliers have been removed. Two types of uncertainty are computed, the RMS difference of the acceptable nodal planes from the preferred planes, and the probability that the real mechanism is "close" to the preferred mechanism, with a user-specified angle defining "close." If there are clustered outliers, alternative solutions (or "multiples") are found based on those outliers. You can set the minimum probability for the multiples (ie ignore multiples with a low probability.)

```
subroutine MECH_PROB(nf,norm1in,norm2in,cangle,str_avg,
dip_avg,rak_avg,prob,rms_diff)
```

Inputs:

- `nf` - number of fault planes
- `norm1(3,nf)` - normal to fault plane
- `norm2(3,nf)` - slip vector/ normal to auxiliary plane
- `cangle` - mechanisms are "close" if less than this angle apart (degrees)
- `prob_max` - cut-off probability for multiples

Output:

- `nstln` - number of solutions (multiples) returned
- `str_avg(nstln)` - strike of each solution
- `dip_avg(nstln)` - dip of each solution
- `rak_avg(nstln)` - rake of each solution
- `prob(nstln)` - percent of mechanisms "close" to average mechanism
- `rms_diff(2,nstln)` - RMS angular difference (degrees) of all planes to average plane (1=fault plane, 2=auxiliary plane)

3. Computing the data misfit for the preferred mechanism.

The final step is to find the data misfit for the preferred mechanism. Separate but similar subroutines are used depending on whether S/P ratios are used along with P-polarity data.

The input is the set of polarity (and amplitude ratio) observations for the stations, the azimuth and takeoff angle to each station (only one set of angles this time, use the preferred values), and the preferred mechanism. The outputs are `mfrac`, the weighted fraction of misfit polarities (like the weighted misfit returned by FPFIT); and `stdr`, the station distribution ratio (also like the station distribution ratio of FPFIT.) If S/P amplitude ratios are used, the average log10(S/P) misfit, `mavg`, is also computed.

For P-wave polarity data only:

```
subroutine GET_MISF(npol,p_azi_mc,p_the_mc,p_pol,p_qual,
str_avg,dip_avg,rak_avg,mfrac,stdr)
```

Inputs:

- `npol` - number of polarity observations
- `p_azi_mc(npol)` - azimuths
- `p_the_mc(npol)` - takeoff angles
- `p_pol(npol)` - polarity observations
- `p_qual(npol)` - polarity quality
- `str_avg,dip_avg,rak_avg` - preferred mechanism

Outputs:

- `mfrac` - weighted fraction misfit polarities
- `stdr` - station distribution ratio

For P-wave polarity and S/P amplitude ratio data:

```
subroutine GET_MISF_AMP(npol,p_azi_mc,p_the_mc,sp_ratio,p_pol,
str_avg,dip_avg,rak_avg,mfrac,mavg,stdr)
```

Inputs:

- `npol` - number of observations
- `p_azi_mc(npol)` - azimuths
- `p_the_mc(npol)` - takeoff angles
- `sp_ratio(npol)` - S/P ratios
- `p_pol(npol)` - polarity observations
- `str_avg,dip_avg,rak_avg` - preferred mechanism

Outputs:

- `mfrac` - weighted fraction misfit polarities
- `mavg` - average log10(S/P) misfit
- `stdr` - station distribution ratio

Input and Data Preparation:

As mentioned earlier, we recommend loading your data into the input arrays in the most efficient manner possible, given your file formats, etc. We have included some example driver programs illustrating how one might do this. These examples use data from one of the Northridge, California, similar event clusters discussed by Hardebeck & Shearer (2002), Shearer et al. (2003), and Hardebeck & Shearer (2003).

In example 1, we assume that we have already computed the azimuth and takeoff angle to each station, and have estimated the uncertainty of both of these angles. The input format (file: north1.phase) is a modified version of the standard FPFIT input format, expanded to include the azimuth and takeoff angle uncertainties. In this case much of the data can be read directly into the input arrays. The azimuth and takeoff angle for each trial are computed by randomly selecting values from normal distributions with the given average value and standard deviation.

Because there are known to be periods of time in which some stations have reversed polarity (up appears as down, and vice-versa), the subroutine `CHECK_POL` is called to check each station for a polarity reversal at the time of the earthquake. The polarity reversal file format (file: scsn.reverse) is exactly the same as for FPFIT.

A few control parameters are read in. The parameters `dang`, `nmc`, `maxout`, and `cangle` are passed directly to the focal mechanism subroutines, and are described above. The parameter `badfrac` is the user's estimate of the error rate for (impulsive) polarities in the data set, and is used to compute `nextra` and `ntotal`, as described above.

The additional parameters are used to select what data is included in the input arrays. The parameter `delmax` is the maximum source-station distance. The minimum required number of polarity data is given by `npolmin`, and the maximum acceptable data gaps in the azimuth and takeoff angle directions are given by `max_agap` and `max_pgap`. Focal mechanisms are not found for events not meeting these last two criteria.

In example 2, we assume that we don't have a good idea of the uncertainty in the azimuth and takeoff angles. A 1D ray-tracing routine is used to compute the takeoff angles for plausible velocity models (the azimuth to a station is the same for any 1D model.) Each trial uses a different combination of (gradient) velocity model and perturbed source depth to compute a set of takeoff angles.

The polarity input is given in another format similar to FPFIT (file: north2.phase.) Because the azimuth and takeoff angle to each station is being computed, a file with station names and locations is needed (file: scsn.stations.) The subroutine `GETSTAT_TRI` is used to look up the station locations.

The velocity models are read in (files: vz.socal, etc), and a set of take-off angle tables are generated, by a call to the subroutine `MK_TABLE`. The takeoff angles for a given source-station range and event depth are found by a call to the subroutine `GET_TTS`. The first argument to this subroutine indicates which of the 1D velocity models to use.

In example 3, S/P amplitude ratios are also used. An additional input file with the P and S amplitudes, as well as the noise levels prior to the arrival of the P and S waves, is included (file: north3.amp.) We apply a station correction of a constant shift in log10(S/P) (Hardebeck & Shearer, 2003), and therefore need to input a file with these corrections (file: north3.statcor.)

Two additional control parameters are also needed. We limit the S/P observations to those waveforms with signal to noise ratio of at least `ratmin`. In order to estimate the allowed log10(S/P) misfit (`qextra` and `qtotal`, above), an estimate of the log10(S/P) uncertainty is given by `qbadfrac`. For this example, it is very important that each event have a unique ID number, as the ID is used to match the P-polarity and S/P amplitudes from different files.

NEW: Example 4 is an update to the most recent SCEDC formats, which include 5-character stations names.

NEW: Example 5 uses output from the program SIMULPS (Evans et al., 1994) to get the azimuth and take-off angles. This is useful for computing focal mechanisms with ray-tracing in a 3D velocity model.

You can edit these examples to match your data format. You will probably need to change the file format for the location/polarity input files (these formats are indicated with comments.) You will probably also need to alter the station subroutines `GETSTAT_TRI` and `CHECK_POL` (file: station_subs.f) to match the format of your station lists. The idea of these subroutines is to have two look-up tables, one to get the location of a given station, and the other to check for known polarity reversals. Storing the stations in alphabetical order allows for quicker searching.

Include Files:

param.inc – sets maximum size of input/output arrays

- `npick0` - maximum number of picks per event
- `nmc0` - maximum number of trials of location/take-off angles
- `nmax0` - maximum number of acceptable mechanisms output

rot.inc – sets the minimum grid angle size, and the corresponding maximum number of grid points and possible stored mechanisms (need to be changed together)

- `dang0` - minimum grid spacing (degrees)
- `ncoor` - number of test mechanisms

vel.inc – parameters for the 1D ray tracer (if used)

- `nx0` - maximum number of rows in table (range direction)
- `nd0` - maximum number of columns in table (depth direction)
- `nindex` - maximum number of 1D models/ tables
- `dep1` - minimum event depth (km)
- `dep2` - maximum event depth (km)
- `dep3` - depth step for table (km), ((`dep2-dep1`)/`dep3`)+1 ≤ `nd0`
- `del1` - minimum source-station range (km)
- `del2` - maximum source-station range (km)
- `del3` - depth step for range (km), ((`del2-del1`)/`del3`)+1 ≤ `nx0`
- `pmin` - minimum ray parameter
- `nump` - number of rays traced

Output:

The output format is something that you can alter to fit your needs. Our examples typically generate two output files, one with a single line per earthquake giving the preferred mechanism, and a second file with a list of all of the acceptable mechanisms for each event. We have developed the following mechanism quality criteria, you may wish to develop your own. Initial tests (Kilb & Hardebeck, 2005) show that the best single-parameter indicator of mechanism quality is the average RMS fault plane uncertainty, 0.5*(`rms_diff(1)`+`rms_diff(2)`), with values ≤ 35° indicating the best mechanisms.

quality (`qual`)	average misfit (`mfrac`)	RMS fault plane uncertainty	station distribution ratio (`stdr`)	mechanism probability (`prob`)
A	≤ 0.15	≤ 25°	≥ 0.5	≥ 0.8
B	≤ 0.20	≤ 35°	≥ 0.4	≥ 0.6
C	≤ 0.30	≤ 45°	≥ 0.3	≥ 0.7
D	maximum azimuthal gap ≤ 90°, maximum takeoff angle gap ≤ 60°			
E	maximum azimuthal gap > 90°, maximum takeoff angle gap > 60°			
F	fewer than 8 polarities			

FILE FORMATS:

These are the input and output file formats as used in the examples. If your data is in a different format, we suggest editing the driver code to be consistent with your format, instead of writing format conversion routines.

Input Files:

P-polarity Files:

Example 1: north1.phase, Similar to FPFIT input file:

Event line:

columns	format	value
1-10	5i2	origin time, year, month, day, hour, minute
11-14	f4.2	origin time, seconds
15-16	i2	latitude, degrees
17	a1	latitude, 'S'=south
18-21	f4.2	latitude, minutes
22-24	i3	longitude, degrees
25	a1	longitude, 'E'=east
26-29	f4.2	longitude, minutes
30-34	f5.2	depth, km
35-36	f2.1	magnitude
81-88	2f4.2	horizontal and vertical uncertainty, km

123-138	a16	event ID

Polarity lines:

columns	format	value
1-4	a4	station name
7	a1	polarity : U, u, +, D, d, or -
8	i1	quality: 0=good quality, 1=lower quality, etc
59-62	f4.1	source-station distance (km)
66-68	i3	takeoff angle
79-81	i3	azimuth
83-85	i3	takeoff angle uncertainty ** NOT in standard FPFIT files
87-89	i3	azimuth uncertainty ** NOT in standard FPFIT files

Example 2: north2.phase, Similar to *old* SCEDC phase format:

Event line:

columns	format	value
1-4	i4	origin time, year
5-12	4i2	origin time, month, day, hour, minute
13-17	f5.2	origin time, seconds
18-19	i2	latitude, degrees
20	a1	latitude, 'S'=south
21-25	f5.2	latitude, minutes
26-28	i3	longitude, degrees
29	a1	longitude, 'E'=east
30-34	f5.2	longitude, minutes
35-39	f5.2	depth, km
89-93	f5.2	horizontal location uncertainty, km
95-99	f5.2	vertical location uncertainty, km
140-143	f4.2	magnitude
150-165	a16	event ID

Polarity lines:

columns	format	value
1-4	a4	station name
6-7	a2	station network
10-12	a3	station component
14	a1	P onset, I or E
16	a1	P polarity : U, u, +, D, d, or -

Example 4: north4.phase, Similar to *NEW* SCEDC phase format:

Event line:

columns	format	value
1-4	i4	origin time, year
5-12	4i2	origin time, month, day, hour, minute
13-16	f4.2	origin time, seconds
17-18	i2	latitude, degrees
19	a1	latitude, 'S'=south
20-23	f4.2	latitude, minutes
24-26	i3	longitude, degrees
27	a1	longitude, 'E'=east
28-31	f4.2	longitude, minutes
32-36	f5.2	depth, km
131-146	a16	event ID
148-150	f3.2	magnitude

Polarity lines:

columns	format	value
1-5	a5	station name
6-7	a2	station network
10-12	a3	station component
14	a1	P onset, i, I, e or E
16	a1	P polarity : U, u, +, D, d, or -

S/P Amplitude Files:

Example 3: *north3.amp*:

Event line:

----

free format: event_ID number_of_observations

Amplitude lines:

columns	format	value
1-4	a4	station name
6-8	a3	station network

10-11	a2	station component
29-38	f10.3	noise level before P arrival
40-49	f10.3	P amplitude (arbitrary units)
51-60	f10.3	noise level before S arrival
62-71	f10.3	S amplitude (same units as P)

SIMULPS 3D ray-tracing Files:

Example 5: *north5.simulps*:

Event line:

columns	format	value
2-7	3i2	origin time, year, month, day
9-12	2i2	origin time, hour, minute
14-18	f5.2	origin time, seconds
20-21	i2	latitude, degrees
22	a1	latitude, 'S'=south
23-27	f5.2	latitude, minutes
29-31	i3	longitude, degrees
32	a1	longitude, 'E'=east
33-37	f5.2	longitude, minutes
39-44	f6.2	depth, km
48-51	f4.2	magnitude
56-63	a8	event ID

Station lines:

columns	format	value
2-5	a4	station name
7-11	f5.1	range
12-15	i4	azimuth
16-19	i4	take-off angle
66-69	f4.0	azimuth uncertainty ** NOT in standard SIMULPS files
70-73	f4.0	take-off uncertainty ** NOT in standard SIMULPS files

Velocity Model Files:

Velocity files, free format:
  depth(km)   P_velocity(km/s)

Station Files:

Station location files – must be alphabetical by station name

Old SCEDC format (examples 1-3, 5; station_subs.f; scsn.stations)

columns	format	value
1-4	a4	station name
6-8	a3	station component
42-50	f9.5	station latitude (degrees, signed)
52-61	f10.5	station longitude (degrees, signed)
63-67	i5	station elevation (meters)
91-92	a2	network code

NEW SCEDC format (example 4; station_subs_5char.f; scsn.stations_5char)

columns	format	value
1-2	a2	network code
5-9	a5	station name
11-13	a3	station component
61-69	f9.5	station latitude (degrees, signed)
71-80	f10.5	station longitude (degrees, signed)
82-86	i5	station elevation (meters)

Polarity reversal file (same format as FPFIT)

columns	format	value
1-4(5)	a4(5)	station name
6-9	i4	beginning of reversal: year
10-11	i2	month
12-13	i2	day
15-18	i4	end of reversal: year
19-20	i2	month
21-22	i2	day

Output Files:

Output File 1: preferred mechanisms (1 line per event)

columns	format	value

1-16	a16	event name (e.g. cuspid for SCEC events)
18-21	i4	origin time, year
23-24	i2	origin time, month
26-27	i2	origin time, day
29-30	i2	origin time, hour
32-33	i2	origin time, minute
35-40	f6.3	origin time, second
42	a1	event type (L-local, R-regional, T-teleseism Q-quarry, D-dubious or duplicate event)
44-48	f5.3	magnitude
50	a1	magnitude type:
		e energy magnitude
		w moment magnitude
		b body-wave magnitude
		s surface-wave magnitude
		l local (Wood-Anderson)
		c coda amplitude magnitude
		h heliocorder magnitude
		d coda duration magnitude
52-60	f9.5	hypocenter latitude (decimal degrees)
62-71	f10.5	hypocenter longitude (decimal degrees)
73-79	f7.3	hypocenter depth (km)
81	a1	location quality (SCEC qualities)
		A rms< 0.15, erh< 1 km erz< 2 km
		B rms< 0.30, erh< 2.5 km erz< 5 km
		C rms< 0.50, erh< 5 km ---
		D greater than above
		E erh> 90 km or < 3 stations
83-89	f7.3	RMS from SCEC or L-2 norm type locations
91-97	f7.3	horizontal error (km)
99-105	f7.3	depth error (km)
107-113	f7.3	origin time error (sec)
117-120	i4	number of picks used in the location
122-125	i4	number of P picks
127-130	i4	number of S picks
132-135	i4	focal mechanism strike (degrees)
137-139	i3	focal mechanism dip (degrees)
141-144	i4	focal mechanism rake (degrees)
148-149	i2	fault plane uncertainty (degrees)
151-152	i2	auxiliary plane uncertainty (degrees)
154-156	i3	number of P first motion polarities
158-159	i2	weighted percent misfit of first motions
161	a1	focal mechanism quality: A-F
163-165	i3	probability mechanism close to solution
167-168	i2	100*(station distribution ratio)

170-172	i3	number of S/P ratios
174-176	i3	100*(average log10(S/P) misfit)
178	a1	multiple flag (* if there are multiples for this event)

Output File 2: set of acceptable mechanisms (multiple lines per event)

Event line:

columns	format	value
1-4	i4	origin time, year
6-7	i2	origin time, month
9-10	i2	origin time, day
12-13	i2	origin time, hour
15-16	i2	origin time, minute
18-23	f6.3	origin time, second
26-28	f3.1	magnitude
30-38	f9.4	hypocenter latitude (decimal degrees)
40-49	f10.4	hypocenter longitude (decimal degrees)
51-56	f6.2	hypocenter depth (km)
58-65	f8.4	horizontal error (km)
67-74	f8.4	depth error (km)
76-80	i5	number of P first motion polarities
82-86	i5	number of acceptable mechanisms output
88-103	a16	event name
105-111	f7.1	focal mechanism strike (degrees)
113-118	f6.1	focal mechanism dip (degrees)
120-126	f7.1	focal mechanism rake (degrees)
128-133	f6.1	fault plane uncertainty (degrees)
135-140	f6.1	auxiliary plane uncertainty (degrees)
142-148	f7.3	weighted fraction misfit of first motions
151	a1	focal mechanism quality: A-F
153-159	f7.3	probability mechanism close to solution
161-164	f4.2	station distribution ratio

Mechanism lines:

columns	format	value
6-14	f9.2	focal mechanism strike (degrees)
15-23	f9.2	focal mechanism dip (degrees)
24-32	f9.2	focal mechanism rake (degrees)
33-41	f9.4	normal vector to fault plane, x (N) component
42-50	f9.4	normal vector to fault plane, y (E) component

51-59	f9.4	normal vector to fault plane, z (D) component
60-68	f9.4	normal vector to auxiliary plane, x (N) component
69-77	f9.4	normal vector to auxiliary plane, y (E) component
78-86	f9.4	normal vector to auxiliary plane, z (D) component

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