hypoTD　operation manual

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1. Introduction

HypoTD is a new relative hypocenter location software that uses a large number of template earthquakes. The HypoTD software is divided into three parts:

(1) Three kinds of data conversion software : Converts arrival time data.
(2) read_template: Registers template earthquakes.
(3) ateq_TD: Determines relative locations using HypoTD.

The software of ateq_td locates relative hypocenters as follows:

(1) Selects N sets of nearby template earthquakes.
(2) Determines relative hypocenters with the N sets of template earthquakes.
(3) Removes incorrect arrival time readings and noise events using the travel time residuals data computed in step 2.
(4) Determines hypocenters by minimizing the RMS of the travel time residuals using both the least squares and grid search methods.

Since the hypocenters of the template earthquakes contain errors due to the heterogeneity of the seismic velocity structure, it is recommended to conduct relocation using HypoTD two or three times.

There are three types of data conversion software, which can convert the following arrival time formats into the HypoTD format:

(1) Format of the JMA's unified hypocenter measurement data.
(2) Arrival-time picking files in Win format.
(3) Format of the arrival time data used in HypoDD.

The HypoTD software is written in FORTRAN.

2. Software name of　hypoTD and their function

(1) read_template
Registration of template earthquakes. The selection of template earthquakes are made according to the number of P and S wave arrival times.

(2) ateq_td
Hypocenter location software by hypoTD.

3. Directory

(1) Directories of data conversion software.

1) JMA_measure :Conversion of the Japan Meteorological Agency (JMA) unified earthquake catalog.

2) win_measure : Conversion of win-format arrival time files.

3) hypoDD_measure: Conversion of format used in hypoDD.

(2) Directories used in hypoTD

1) auto_td : Source code of hypoTD (ateq_td and read_template)

2) arriv :Hypocenter list and arrival time files with format of hypoTD.

3) etc :Velocity structure, Station data, Parameter files for the selection of template earthquakes and for the removal of low quality arrival time data.

4) event_dd : Hypocenter list of template earthquakes and relocation events.

5) arriv_dd : Hypocenter lists located by hypoTD.

4. The method of compile and run of data conversion software

(1) JMA_measure

1) Compile

cd JMA_measure

make

2) input data

Input file name of arrival time data into print.dat. If there are many files, input all.

Exsample of print.dat

measure_20240102_1.txt

3) run

./read_jma_arriv

(2) win format pick files

1) Compile

cd win_measure

make

2) input data

Input the directory name of win pick files into the print.dat. If there are many directories, input all.

Example

picks/1611

picks/1612

3) run

./read_win

(3) hypoDD format LV.pha or other name.

1) Compile

cd hypoDD_measure

make

2) input data

Input the fille name of hypoDD format file into print.dat

Example

LV.pha

3) run

./read_lv

5. The method of compile and run for the software of registering template earthquakes (read_template) and relative hypocenter location (hypoTD).

(1) Compile

cd auto_td

make

(2) run

./read_template

./ateq_td

(3) Input data for the two software

1) Station coordinate data

Example of station data (etc/stn_dd.dat)

NCJNA 37.176998 -121.844666 0.12

NCMTC 37.631550 -118.966064 0.23

NCAAR 39.2759 -121.027 0.11

NCAAS 38.4301 -121.11 2.33

NCABA 38.8793 -121.067 2.11

Stn Latitude Longitude Altitude(km)

2) Seismic velocity model data

File name: etc/vel_model.dat

The following is an example.

```
#   Component Name
 UD NS EW AZ AX AYMZ MX MY SZ SX SY TZ TX TY                !line 1
#   Select velmodel.   1;two layer gradient ,3:N Layer model N<50
 1                                                          !Line 2
# Land Vel model table Two layer
# 5.40 -59.0 7.75 -2.3 3.15 -59.0 4.35 -2.3   31.0
 6.00 -30.0 8.0 -2.3 3.53 -30.0 4.50 -2.3   40.0          !Line 3
#Ukawa     5.50 -53.49 7.80 -2.13 3.25 -44.68   4.41 -1.57   32.0
# Tohoku Univ   5.40 -59.0 7.796 -2.3 3.15 -59.0 4.40 -2.3   30.0
# Velmodel.
  6                                                         !Line 4
  -2.00   4.800   2.844                                     !Line 5
  0.50   4.950   2.931
  1.00   6.000   3.521
 24.00   6.648   3.858
 40.01   8.10    4.50
700.00 12.0      6.66
```

Line number without comment line

Line 1 Component Name Not used but do not remove.

Line 2 Selection of velocity model.

1 ; Two layered gradient velocity model 、

3 ; Multiple layer constant velocity model

Number of layer should be less than 50.

Line 3 Velocity parameters for the two layered velocity model

Values of P and S wave velocity at a depth in the two layered model is put in a case of the following parameters.

```
6.00 -30.0 8.0 -2.3 3.53 -30.0 4.50 -2.3   40.0          !Line 3
```

Layer 1 depth less than 40 km

$Vp=6.0*\{(R-dep)/R\}^{-30.0}$

$Vs=3.53*\{(R-dep)/R\}^{-30.0}$

Layer two deeper than 40 km.

$Vp=8.0*\{(Rm-dep)/Rm\}^{-2.3}$

$Vs=4.5*\{(Rm-dep)/Rm\}^{-2.3}$

Where, R=6371.05 Rm=6371.05-40.0

Line 4 Number of layers

From Line 5 Values of depth, P and S velocities.

Put surface depth negative so as to calculate travel times above the sea level.

3) hypocenter list and arrival time data for the registration of template earthquakes and relocation by hypoTD.

3.1) Hypocenter list

arriv/hypo_****.dat

3.2) arrival time data

arriv/arv_****.dat

These data are made by the conversion software of arrival time data in 3.

4) Parameter data indicating file name, period, study area etc

File name. etc/wave_dir.dat

Example of etc/wave_dir.dat

```
#  Comment line
    # 1) ./read_template     !Make event lists for ateq_td and rgister template EQ.
    # 2) ./ateq_td          !Re-locate hypocenters.
    #date from and date to
    2024 1 1                                                    !1   date from
    2024 1 13                                                   !2   date to
    #../etc/stn_test.dat                                        !3 station win format
    #../etc/jma_stn.dat                                         !3 station JMA
    #../etc/stn_dd.dat                                          !3 station hypoDD
    ../etc/station_Orkney.dat                                   !3 station Orkney
    # File name of Event list for re-location events
    #../event_dd/jp_noto.dat
    ../event_dd/jp_Orkney.dat                                   !4   file name of re-locate list
    # Latitude longitude and depth ranges of the study area by re-location
    -90.0   90.0 -180.0   180.0     -2.0   700.0       ! 5 All study area
    # 37.5   38.0 136.5   137.0     -2.0   100.0        ! 5 lat1,lat2,lon1,lon2,dep1,dep2
    # trigger waveform directory name     Eg. of file. trg/23/05/05/230505.144143
    ../trg        !Not used                                     !6 Not used
    # file name of the list selected as the template events.
    ../event_dd/template_Orkney.dat                  !7 File name of Templatelist
    # Minimum number of P and S wave readings used for   template events
    # Total number of template earthquakes must be less than 300000
    5    3                                                      !8 Template selection
    # pick file directory names used for the template events of ateq_dd
../arriv/hypo_2014.dat              !9 File name of earthquake list for the selection
../arriv/hypo_2015.dat              !10 of template earthquakes
```

Line number except comment line

Line 1-2 Period from and to (year month day)

Period data is used only in ./hypoTD.

Line 3 File name of station data.

Line 4 File name for the list of relocation.

Put some file name of relocation list. Any is OK.

Earthquake list for the relocation is created by running ./read_template.

This earthquake list is the input data of hypoTD.

Line 5 Coordinate of the Upper and lower limit of study area. They are latitude,longitude and depth ranges.

Line 6 Not used

Line 7 File name of the list of template earthquakes.

Put some name. ./read_template creates the list of template earthquake with the file name in line 7

This file is used for the input of ./ateq_TD.

Line 8 Threshold values of P and S wave arrival times for the selection of template earthquakes.

15 10

Np>=15, Ns>=10, where Np, Ns are the number of P and S wave arrival times.

Line 9,10,11,… File names of the earthquake list for the selected template earthquakes and for the relocation earthquake list(line 4).

6. How to change data and run hypoTD

(1) Make station coordinate data and put it on etc/****

(2) Change line 3 etc/wave_dir.dat according to your file name of station data.

(3) Change velocity model etc/velmodel.dat

(4) Change the format of your arrival time data with using one of the following format change software.

1) JMA catalogue, 2) Win format, 3) hypoDD

(5) run one of data conversion soft

./read_jma_arriv ./read_win ./read_lv

(6) Change date range Line 1 - 2 of etc/wave_dir.dat

(7) Change study area if required Line 5 of etc/wave_dir.dat

(8) Change file name of earthquake list according to one created by the data conversion soft

Line 9,10,.. of etc/wave_dir.dat

(9) Change file names of earthquake list, which will be created by ./read_template.

Any name is OK.

Line 4 relocation list name

Line 8 template earthquake list name

(10)cd auto_td

./read_template

(11) cd auto_td

./ateq_td

7. Parameters to discriminate outliers of arrival times and noise events.

etc/hypo_remove.dat

The following parameters are used for the relocation of earthquakes in the area with length of 2000km. It is not necessary to change except for study area less than 10 km.　Change line 1, minimum RMS in sec.

```
0.1             !1 err_min          Minimum sd_cross
2.0             !2 rat_stn_sd2    remove error picks sd2=2.0*sd
0.4             !3 sd_remove remove hypo when large sd (sec)
10.0             !4 dl_remove remove hypo when large location error (km)
0.2             !5 rat_err_eq remove hypo if 60% of large sd eq.
70.0            !6 del_lim_sd_change km
5.0             !7 Upper limit of magnitude whose S wave arrival are not used.
```

8. The method of two times of iterations of hypoTD

source hypoTD.com

The code of hypoTD.com

```
#   Iteration 0   ************
cp ../etc/wave_dir_org.dat ../etc/wave_dir.dat
./read_template
./ateq_td
cp -r ../arriv_dd ../arriv_dd_0
cp ../etc/wave_dir.dat ../etc/wave_dir_org.dat
cp ../etc/wave_dir_ita.dat ../etc/wave_dir.dat
# Iteration 1   ************
./read_template
rm ../arriv_dd/*
./ateq_td
cp -r ../arriv_dd ../arriv_dd_1
./read_template
```

./ateq_td
cp -r ../arriv_dd ../arriv_dd_2

9. Output of hypoTD

Relocated earthquake list is made in arriv_dd directory.
File name
arriv_dd/hypo_year.dat

format　120 byte fixed length asci file.

Example
　　421

```
 161130 0 5   0.00      7.71   0.00 37.1735 0.0000 141.3073 0.0000   13.83     0.00 2.30     6   17   17
2   0.13
 161130 011   0.00     35.46   0.00 37.2222 0.0000 141.5003 0.0000   28.66     0.00 1.60     6   10   13
3   0.17
 161130 0 5   0.00      7.71   0.00 37.1735 0.0000 141.3073 0.0000   13.83     0.00 2.30     6   17   17
2   0.13
```

Line 1 Number of events
From line 2
(year-2000), month, day,hour,minut,sec, origin time, error、Latitude error,Longitude, error, depth, error, Magnitude,
Number of P and S arrival time, Number of stations, event number, rps of relative hypocenter location
　hypoTD does not compute estimation errors of latitude, longitude and depth.
The format of hypocenter list.

```
          open(7,file=file_hypo,access='direct', form='formatted',
      1 recl=120,status='unknown')
          write(7,1303,rec=irece) cret,iy,im,id,ih,imin,sec,t,dt,
            1 phi,dphi,ram,dram,dep,ddep,fmag,nobsp,nobss,nobsall,
      1    c_temp,c_hypo_flag,irec_arv,sd_all_cross
1303     format(a1,1x,5i2,f6.2,f8.2,f6.2,f8.4,f7.4,f9.4,f7.4,
            1 2f7.2,f5.2,3i4,1x,2a1,i9,f6.2)
```

Cret return　Character*1
iy,im,id,ih,imin,sec　date
t,dt　origine time and its error
phi,dphi,ram,dram,dep,ddep　Latitude, longitude depth and their error
fmag　Magnitude

nobsp,nobss,nobsall ; Number of P, S arrivals and stations

c_temp,c_hypo_flag JMA earthquake flag character*1

irec_arv event number

sd_all_cross RMS of relative location