Rapidinv.py, release 18.0

A short user guide

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1. Introduction

1. Introduction

Rapidinv is a Python script which has been developed at the University of Hamburg, University of Potsdam and GFZ Potsdam with the goal of simplifying the process of point and kinematic inversion using the Kiwi Tools (kinherd.org). Several applications and studies used this code to the purpose of source inversion, spanning over a broad range of magnitude from Mw 0 of microseismicity induced by mining (Sen et al. 2013) to Mw 8 of large destructive earthquake at teleseismic distances (e.g. Cesca et al. 2009, Heimann 2011). Further specific relevant applications include Buforn et al. 2011, Cesca et al. 2011a,b, Custodio et al. 2012.

Version 18 includes has been modified to support Python3 and GMT5.

The inversion procedure adopts the eikonal source model (Heimann et al. 2008) and a multi-step inversion strategy, as explained in Cesca et al. (2010, 2013). The inversion is carried out in the following three main steps:

Step 1 Focal mechanism inversion
This is expected to be done in the frequency domain, by fitting amplitude spectra.
Source parameters retrieved after this inversion step are: strike, dip, rake (4 possible configurations), scalar moment, source depth.
Full moment tensor may be also derived (Step 1b)

Step 2 Centroid location inversion
This is expected to be done in the time domain, by fitting displacement time traces.
Source parameters retrieved after this inversion step are: strike, dip, rake (2 possible configurations), centroid relative location (North, East, Time offset).
Full moment tensor with polarity and decomposition may also be derived (Step 2b)

Step 3 Kinematic inversion
This can be done both in the time or frequency domain.
Source parameters retrieved after this inversion step are: strike, dip, rake (1 configuration corresponding to true fault plane orientation), radius, area, rupture velocity, nucleation point coordinates (along-strike, down-dip), rupture time, average slip.

2. Variants

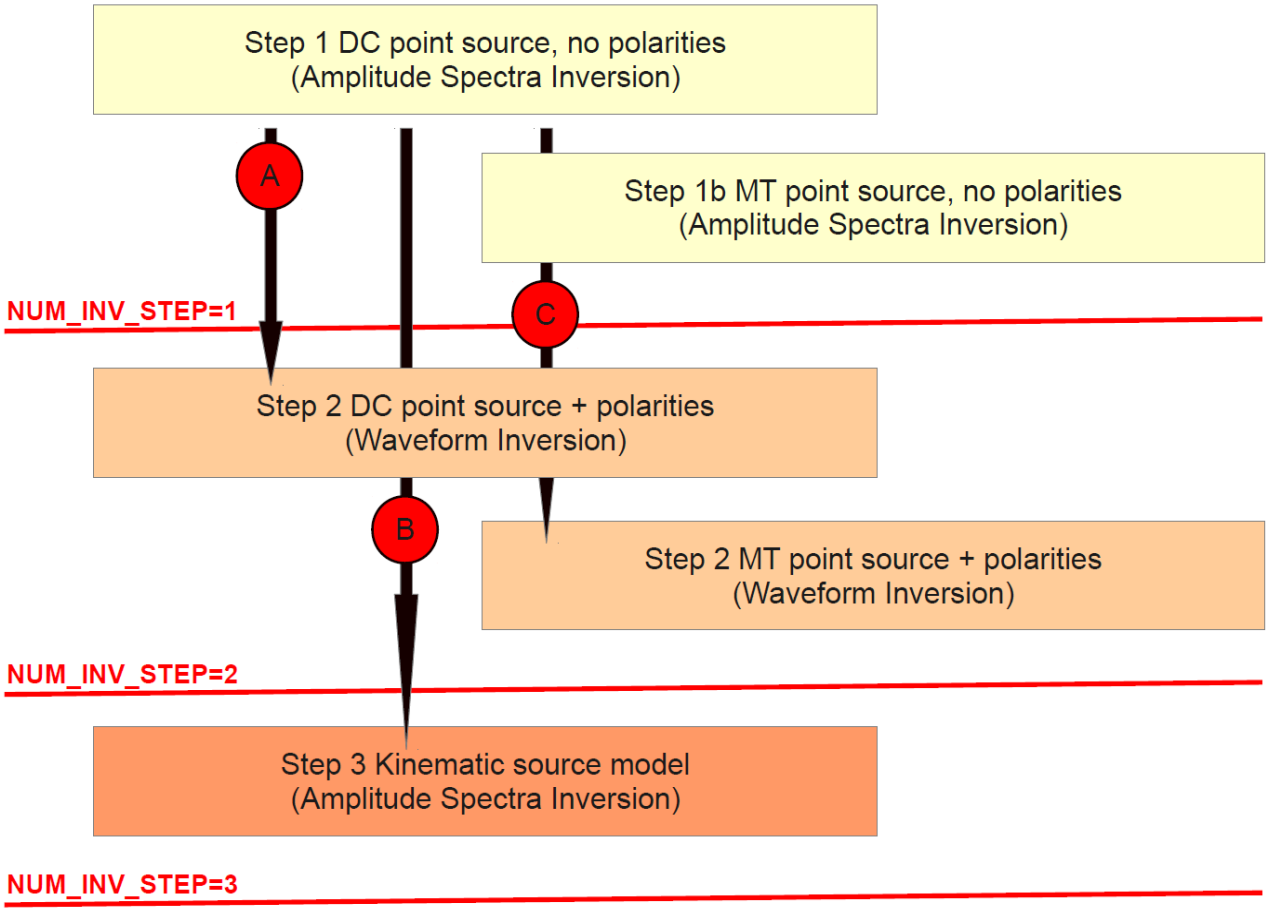
Currently, there are three main ways to run the inversion (you can change from one approach to the other by properly setting the variables NUM_INV_STEPS and SW_FULLMT, see section 5):

DC point source inversion
Perform (double couple, DC) point source inversion

Full MT point source inversion
Perform point source inversion and retrieve both DC and full moment tensor (MT) models

Kinematic source inversion
Perform point source (with or without MT solution) and kinematic source inversion

The following sketch illustrates the work flow for these approaches (indicated by letters A, B and C respectively):



3. Getting started

The following steps are required prior to the inversion:

The Kiwi Tools

Kiwi tools do the internal job of seismogram generation, data processing, misfit calculation and inversion. The user should at first install the Kiwi package following instructions at http://kinherd.org.

Data

Data have to be processed in advance and be saved using the expected naming (e.g. DISPL.STAT.BHZ or DISPL.NET.STAT.CODE.R) and formats (currently rapidinv and Kiwi tools handle ASCII and miniSEED, SAC is no longer supported).
A text file with station information must be saved in the data directory (for file format, see variable STAT_INP_FILE in paragraph 5 of this guide).

Green's functions database

Green's functions have to be generated in advance (e.g. using GEMINI, QSEIS or other synthetic seismogram generator code for 1D layered Earth models). They have to be stored into Kiwi GFDB files.
Green's functions database handling tools are available within the Kiwi tools (http://kinherd.org).

Moment tensor processing

The Mopad tool (Krieger and Heimann, submitted), in particular files ***mopad.py*** and ***mopad.pyc*** must be accessible from the working directory, to perform moment tensor decomposition and plots

Notes

In former versions, arrival times for P and S phases had to be generated in advance and stored into a separate directory, with proper names. This feature is no longer supported in ***rapidinv12*** and later versions. Arrival times are now available within the Kiwi Tools for a global model; it is still possible to create own phase files.
SAC format is also no longer supported for data.

Ready

You are now ready to start your inversion!

4. Running the code

The inversion can be prepared and executed, following these steps:

1) Copy to your working directory the files:
   rapidinv18 (python script)

2) Create the config directory and copy there the files:
   config/rapidinv.defaults (default values of inversion variables)
   config/rapidinv.acceptables (acceptable formats of inversion variables)

3) Build your specific input file (one per inversion), ***config/event.inp***
   This should have a similar format as ***rapidinv.defaults***, but only with variables with different values than the default ones.

   The idea is that ***rapidinv.defaults*** contains all existing variables and their values, while ***event.inp*** only contains few specific variables.

   Specific variables should include:
   DATA_DIR: path to the data directory for the chosen event
   INVERSION_DIR: path to the result directory. This directory will be created (any existing directory with this name is removed). It is required that the parent directory exists!

   Empty and commented lines (starting with #) in ***rapidinv.defaults*** and ***rapidinv.inputfile*** are ignored

   All variables are described in the next paragraph.

   When the inversion is performed the ***rapidinv.defaults*** will be first read and variable assigned accordingly. Then, the ***event.inp*** will be read and mentioned variable will be updated. If a variable is assigned more times, the last assignment will be used (as it overwrites previous assignments). Finally a (very rough) test will be performed to ensure variable format is consistent to ***rapidinv.acceptables***

4) Run the python script
   ./rapidinv18 config/event.inp

   rapidinv18 internally calls many times different Kiwi tools (basically ***gfdb_info***, to check spacing and sampling of Greens functions, and ***minimizer***, for several purposes). ***minimizer*** input files (***minimizer.inp****) are created and passed to ***minimizer***, whose answers are stored in minimizer output files (***minimizer.out****). Both input and output files for minimizer are saved into the result directory (variable INVERSION_DIR), where they can be checked if needed.

5) Check inversion
   Check if the inversion was successful (“Ho finito!”) or not (error messages will appear if the process was interrupted – unfortunately a complete list of warning and error messages is not yet available).

6) Plot results
   Postscript and text files with results will be saved in the result directory. One or more plot files should be available in your result directory (see variable INVERSION_DIR), depending on the inversion approach:

   step1.ptsolution.ps (results after step 1, DC model, no polarities)
   step1.mtsolution.ps (results after step 1b, MT model, no polarities)
   step2.ptsolution.ps (results after step 2, DC model + polarities)

step2.mtsolution.ps (results after step 2b, MT model + polarities)
step3.eiksolution.ps (results after step 3, kinematic model)
apparentduration.ps (fast directivity inversion, test version)

5. Blackboard variables

A list of the possible variables is given below.
For each variable the default value, the acceptable format and a short description are given.
The variable are here divided in 8 sections, depending on their usage.

This 8 sections are considered:

5.1 Blackboard variables, general usage

5.2 Blackboard variables, inversion step1

5.3 Blackboard variables, plotting step1

5.4 Blackboard variables, inversion step2

5.5 Blackboard variables, plotting step2

5.6 Blackboard variables, inversion step3

5.7 Blackboard variables, plotting step3

5.8 Blackboard variables, unused in version 12.0

Within each section variables are listed in alphabetical order.

For each variable, the default (***rapidinv.defaults***) and acceptable (***rapidinv.acceptables***) values are given; defaults value are indicative and may change for specific versions of ***rapidinv.defaults***.
Then, a description of the variable usage is given.

5.1 Blackboard variables, general

CHANNEL
Default: *BH*
Acceptable: *BH|HH|...*
It is used to access data files. If ALL is chosen, data file names with any possible ending are used. Otherwise only those ending with the proper channel name.

COMP_2_USE
Default: *uar*
Acceptable: *string*
The string should include one letter for each spatial component to consider. Letter follow the convention from kinherd.org:
d: down
u: up
n: North
s: South
e: East
w: West
r: transversal, rightward as seen from source to receiver
l: transversal, leftward as seen from source to receiver
a: radial, away from source
c: radial, backward to source

CONFIDENCE_INT
Default: *68*
Acceptable: *68|95|99*
Confidence interval for bootstrap approach.

DATA_DIR
Default: */scratch/local2/simone/KINHERD/DATA/COLFIORITO*
Acceptable: *string*
Path to the directory containing all data and station information.

DATA_FILE
Default: *9726900*
Acceptable: *string*
Defines the name which will be given to processed data. The name should refer to the event name, as it will be additionally used for plotting event information.

DATA_FORMAT
Default: *mseed*
Acceptable: *table|mseed*
Expected format of input displacement data (see kinherd.org for more details). Note that sac format is no longer supported.

DAY
Default: *0000*
Acceptable: *integer*
Day of the earthquake. It is used only if SW_TRACES0TIME is set to False.

DIST_AZI_FILE
Default: *distazi.dat*
Acceptable: *string*
Name of the output file with information concerning epicentral distances and azimuth of station, with respect to the earthquake location.

DISTRIBUTION
Default: *normal*
Acceptable: *normal|unknown*
Expected parameter distribution; used for statistical analysis following bootstrap.

EPIC_DIST_MAX
Default: *4500*
Acceptable: *positive*
Maximum epicentral distance to consider for all steps (closest stations will not be used for the inversion).

EPIC_DIST_MIN
Default: *500*
Acceptable: *positive*
Minimum epicentral distance to consider (closest stations will not be used for the inversion).

GF_INTERPOLATION
Default: *nearest_neighbor*
Acceptable: *nearest_neighbor|bilinear*
Defines the method to spatially interpolate between existing Green´s functions (from the database).

GMT_VERSION
Default: *5*
Acceptable: *4|5*
Defines the GMT version.

HOUR
Default: *00*
Acceptable: *integer*
Hour of the earthquake time (origin time). It is used only if SW_TRACES0TIME is set to False.

INVERSION_DIR
Default: *./9726900*
Acceptable: *string*
Path to the directory where all output files will be saved.
The directory is created by the code, but its parent directory must exist (e.g. if INVERSION_DIR=/scratch/RESULT/EV1 this is created if /scratch/RESULT is an existing directory).

LATITUDE_NORTH
Default: *45*
Acceptable: *float*
Original latitude (North, in degrees) of the epicenter. Further relocation will be relative to this value.

LEVEL_RELAMP
Default: *50*
Acceptable: *positive*
Define the ratio between the trace amplitude and the average amplitude above which the trace is excluded from the inversion (e.g. for a value 50, all traces with amplitudes 50 times larger or smaller than the average amplitude are removed). It is only used if SW_FILTERNOISY is set to True.

LEVEL_S2N
Default: *0.666*
Acceptable: *positive*
Define the signal-to-noise ratio used to exclude a trace from the inversion. It is only used if SW_FILTERNOISY is set to True.

LONGITUDE_EAST
Default: *45*
Acceptable: *float*
Original longitude (East, in degrees) of the epicenter. Further relocation will be relative to this value.

MAX_STAT_2_PLOT
Default: *30*
Acceptable: *integer*
Number of stations (currently, traces). Valid for plots after all inversion steps.

MAX_DEP_GFDB
Default: *40000*
Acceptable: *float*
Maximum depth (in meters) for the Green function database. If set will constrain the extended source geometry.

MIN_DEP_GFDB
Default: *0*
Acceptable: *float*
Minimum depth (in meters) for the Green function database. If set will constrain the extended source geometry.

MIN
Default: *00*
Acceptable: *integer*
Minute of the earthquake time (origin time). It is used only if SW_TRACES0TIME is set to False.

MONTH
Default: *00*
Acceptable: *integer*
Month of the earthquake. It is used only if SW_TRACES0TIME is set to False.

NOISE_WINDOW
Default: *4mintot0*

Acceptable: *4mintot0|before|after*
Define the time window to evaluate noise level. 4Mintot0: 4 minutes length finishing at origin time; before: before tapered data used for inversion step 1; after: after tapered data used for inversion step 1.
It is only used if SW_FILTERNOISY is set to True.

NUM_BOOTSTRAP
Default: *200*
Acceptable: *integer*
Number of virtual receiver configurations used during bootstrap.

NUM_INV_STEPS
Default: *3*
Acceptable: *integer*
Number of inversion steps to realize (1=only focal mechanism, 2= focal mechanism and centroid location, 3=full point and kinematic inversion).

ORIG_TIME
Default: *0*
Acceptable: *float*
Can be used to introduce a fixed time offset (in seconds), with respect to data (e.g. if it is known that 0 time in data does not correspond to origin time).

ORIG_NORTH_SHIFT
Default: *0*
Acceptable: *float*
Can be used to introduce a fixed North location offset (in meters), with respect to given latitude (e.g. if it is known that location is incorrect).

ORIG_EAST_SHIFT
Default: *0*
Acceptable: *float*
Can be used to introduce a fixed East location offset (in meters), with respect to given longitude (e.g. if it is known that location is incorrect).

RISE_TIME
Default: *1*
Acceptable: *positive*
Rise time used for point source inversion (for kinematic inversion this is fixed internally – see the code for details).

SCALING_FACTOR
Default: *1*
Acceptable: *float*
Coefficient to multiply to Green's functions to obtain correct amplitudes (sometimes needed to correct GFs, depending on parameters used for their calculation).

SEC
Default: *00*
Acceptable: *float*
Second of the earthquake time (origin time). It is used only if SW_TRACES0TIME is set to False.

STAT_INP_FILE
Default: *stations.dat*
Acceptable: *string*
Path to the input file with list of stations to be used. Take care that the full path to the file is now required (in former versions, until rapidinv17, the variable hosted the station file name only, requiring that such file, with the proper format, should exist and be saved in the data directory DATA_DIR).
The file format is the following:

There must be one line for each station
Each line has 4 terms divided by spaces, which are:
Station code (integer): has no effect, e.g. use progressive number or any station code
Station name (string): this must be consistent with station data names (e.g. station name JHJ2 expects data file as DISPL.JHJ2.BHZ or similar)
Latitude (float): in degrees, North
Longitude (float): in degrees, East

All stations here indicated will be considered. If data are missing, station will be excluded. If data are partially missing, only existing components will be used. If data files exist, but the station name is not included in the list, data will not be used.

STAT_OUT_FILE
Default: *stations.used*
Acceptable: *string*

Name of the output file with information concerning used stations.

SW_APPLY_TAPER
Default: *True*
Acceptable: *boolean*
Apply tapers in time domain.
For each inversion step, they are defined by specific variables.

SW_FILTERNOISY
Default: *True*
Acceptable: *boolean*
If set to true, remove traces which seems to be noisy and/or have an average amplitude several times larger/smaller than the average of all traces (indicating wrong restitution).
If set to true, noise will be evaluated during specific time windows, according to the variable NOISE_WINDOW.

SW_TRACES0TIME
Default: *False*
Acceptable: *boolean*
Set to true assume waveform traces have 0 as origin time (e.g. 1.1.1970). Set to false assume waveform traces have origin at the earthquake origin time (defined through variables YEAR, MONTH, DAY, HOUR, MIN, SEC).

SW_WEIGHT_DIST
Default: *False*
Acceptable: *boolean*
Apply a distance-dependent weight, w: w = station_epicentral_distance / maximal_epic_distance.

YEAR
Default: *0000*
Acceptable: *integer*
Year of the earthquake. It is used only if SW_TRACES0TIME is set to False.

5.2 Blackboard variables, inversion step 1

BP_F1_STEP1
Default: *0.01*
Acceptable: *float*
First frequency (in Hz) of a 4-points trapezoidal or cosine frequency bandpass to apply at inversion step 1.

BP_F2_STEP1
Default: *0.01*
Acceptable: *float*
Second frequency (in Hz) of a 4-points trapezoidal or cosine frequency bandpass to apply at inversion step 1.

BP_F3_STEP1
Default: *0.01*
Acceptable: *float*
Third frequency (in Hz) of a 4-points trapezoidal or cosine frequency bandpass to apply at inversion step 1.

BP_F4_STEP1
Default: *0.01*
Acceptable: *float*
Fourth frequency (in Hz) of a 4-points trapezoidal or cosine frequency bandpass to apply at inversion step 1.

DATA_PLOT_STEP1
Default: *amsp*
Acceptable: *amsp*|*seis*
Define if data format for plotting result after inversion step 1:
amsp: amplitude spectra
seis: displacements

DEPTH_BOTTOMLIM
Default: *0*
Acceptable: *float*
Minimum accepted depth (km) after inversion step 1 (all other solutions will be removed, even if presenting a better fit).

DEPTH_STEP
Default: *20*
Acceptable: *float*
Increment of depth (km) to define the group of starting configuration, during inversion step 1.

DEPTH_UPPERLIM
Default: *100*
Acceptable: *float*
Minimum accepted depth (km) after inversion step 1 (all other solutions will be removed, even if presenting a better fit).

DEPTH_1
Default: *20*
Acceptable: *float*
Minimum depth (km) to define the group of starting configuration, during inversion step 1.

DEPTH_2
Default: *40*
Acceptable: *float*
Maximum depth (km) to define the group of starting configuration, during inversion step 1.

DIP_STEP
Default: *0*
Acceptable: *float*
Increment of strike angle (degrees) to define the group of starting configuration, during inversion step 1.

DIP_1
Default: *90*
Acceptable: *float*
Minimum strike angle (degrees) to define the group of starting configuration, during inversion step 1.

DIP_2
Default: *90*
Acceptable: *float*
Maximum strike angle (degrees) to define the group of starting configuration, during inversion step 1.

EFFECTIVE_DT_ST1
Default: *0.5*
Acceptable: *postive*
Value of “Effective-dt” to be use for synthetic seismogram generation at step 1. Large values reconstruct extended source by less dense point source discretization, which is faster but less accurate (for further info, see kinherd.org).

GFDB_STEP1
Default: */scratch/local2/gfdb/gemini-10000km*
Acceptable: *string*
Defines the Green´s functions database which will be used to calculate synthetic seismogram during the inversion step 1.

INV_MODE_STEP1
Default: *invert_dmsds*
Acceptable: *invert_dmsdsok*|*invert_dmsds*|*invert_dmsdst*|*invert_dmsdst2x*|*invert_msds*|*invert_dsds*|*invert_sds*|*invert_dm*|*invert_dmt*|*invert_m*|*grid*
Defines the strategy to carry out inversion step 1. The following possibilities are allowed:
i***nvert_dmsdsok***: 4 stages gradient inversion
(1) scalar moment
(2) scalar moment, strike, dip, rake (at the same time)
(3) scalar depth, strike, dip, rake (at the same time)
(4) scalar moment, depth, strike, dip, rake (at the same time)
invert_dmsds: first gradient inversion for scalar moment and depth (inverted at the same time), then second gradient inversion for scalar moment, depth, strike, dip, rake (at the same time).
invert_dmsdst: currently unused (set to work as invert_dmsds)
invert_dmsdst2x: 4 stages gradient inversion
(1) scalar moment and depth (at the same time)
(2) scalar moment, depth, strike, dip, rake (at the same time)
(3) strike, dip, rake (at the same time)
(4) rise-time
invert_msds: gradient inversion of scalar moment, strike, dip and rake (inverted at the same time)
invert_dsds: gradient inversion of depth, strike, dip and rake (inverted at the same time)
invert_sds: gradient inversion of strike, dip and rake (inverted at the same time)
invert_dm: gradient inversion of scalar moment and depth (inverted at the same time)
invert_dmt: currently unused (set to work as invert_dm)
invert_m: gradient inversion of scalar moment
grid: grid walk, no gradient method applied

INVERS_MET_STEP1
Default: *minimize_lm*
Acceptable: *minimize_lm*
Choose the gradient inversion method for inversion step 1. Applied if INV_MODE_STEP1 is not equal to **grid**. Currently only Levenberg-Marquardt is implemented.

LOOPS_SDS_CONF
Default: *1*
Acceptable: *integer*
Number of iterative loops of inversion step 1.
If larger than 1, new inversions will be carried out using starting configurations each time closer to the best solution after the prior iteration.

MISFIT_MET_STEP1
Default: *ampspec_l1norm*|*ampspec_l2norm*|*l1norm*|*l2norm*
Acceptable: *string*
This variable defines the method to calculate the misfit during inversion step 1. The following values are admitted:
ampspec_l1norm: amplitude spectra will be compared, using L1 norm
ampspec_l2norm: amplitude spectra will be compared, using L2 norm
l1norm: time traces will be compared, using L1 norm
l2norm: time traces will be compared, using L2 norm

PHASES_TO_USE_ST1
Default: *a*
Acceptable: *string*
This variable defines which seismic phases should be used for inversion step 1. The following values (or a combination of them) are accepted:
p: P phases (on all used components, as defined in COMP_2_USE)
s: S phases (on all used components, as defined in COMP_2_USE)
b: Bodywaves (P on vertical component, S on remaining components)
r: Surface waves (on all used components, as defined in COMP_2_USE)
a: Full waveform (on all used components, as defined in COMP_2_USE)

x: Fixed length (on all used components, as defined in COMP_2_USE); this simulates continuous incoming data
flow, which is cut for all stations with a given length.
f: "Fast" inversion; this is a default combination of full waveform (for closest stations, all components) and bodywaves (for far stations, phases and components as in mode ***b***); check the script for details.

RAKE_STEP
Default: *90*
Acceptable: *float*
Increment of rake angle (degrees) to define the group of starting configuration, during inversion step 1.

RAKE_1
Default: *0*
Acceptable: *float*
Minimum rake angle (degrees) to define the group of starting configuration, during inversion step 1.

RAKE_2
Default: *180*
Acceptable: *float*
Maximum rake angle (degrees) to define the group of starting configuration, during inversion step 1.

REDUCE_SDS_CONF
Default: *3*
Acceptable: *integer*
If more iterations are required for inversion step 1 (LOOPS_SDS_CONF > 1), this value defines how should be modified the increment for strike, dip and rake at subsequent iterations (e.g. strike varied from 0 to 90 with step 30 at first iteration; REDUCE_SDS_CONF is set to 3; best strike after first inversion is 42 ==> in the second iteration, strike will vary from 12=42-30 to 72=42+30 with step 10=round(30/3); and so on).
Only used if LOOPS_SDS_CONF is larger than 1.

REDUCE_DEP_CONF
Default: *3*
Acceptable: *integer*
Equal as REDUCE_SDS_CONF, but for source depth.
Only used if LOOPS_SDS_CONF is larger than 1.

SCAL_MOM_STEP
Default: *1e18*
Acceptable: *positive*
Increment of scalar moment (Nm) to define the group of starting configuration, during inversion step 1.

SCAL_MOM_1
Default: *1e18*
Acceptable: *positive*
Minimum scalar moment (Nm) to define the group of starting configuration, during inversion step 1.

SCAL_MOM_2
Default: *1e18*
Acceptable: *positive*
Maximum scalar moment (Nm) to define the group of starting configuration, during inversion step 1.

STRIKE_STEP
Default: *90*
Acceptable: *float*
Increment of strike angle (degrees) to define the group of starting configuration, during inversion step 1.

STRIKE_1
Default: *0*
Acceptable: *float*
Minimum strike angle (degrees) to define the group of starting configuration, during inversion step 1.

STRIKE_2
Default: *180*
Acceptable: *float*
Maximum strike angle (degrees) to define the group of starting configuration, during inversion step 1.

SW_FIXTAPER_ST1
Default: *True*
Acceptable: *boolean*
Choose automatically the length of time window if full waveform inversion is chosen (***a*** is activated in PHASES_TO_USE_ST1). If true, the length in seconds (wila) is decided by the following equation:
wila = (0.36 * epicentral_distance_in_km) + 60

and the value of WIN_LENGTH_A_ST1 is ignored.

SW_RAPIDSTEP1
Default: *False*
Acceptable: *boolean*
Switch to improve the fastness of inversion step 1.
Instead of defining the group of starting configurations based on variables STRIKE_1, STRIKE_2, STRIKE_STEP, DIP_1, DIP_2, DIP_STEP, RAKE_1, RAKE_2, RAKE_STEP, it ignores them and use 10 default configurations of strike-dip-rake (they are hard-coded, check the python script for details).

WEIGHT_A_ST1
Default: *1.00*
Acceptable: *float*
Defines a weight for the time window for phase ***a*** during inversion step 1.
It is used only if ***a*** or ***f*** mode is activated in PHASES_TO_USE_ST1.

WEIGHT_P_ST1
Default: *1.00*
Acceptable: *float*
Defines a weight for the time window for phase ***a*** during inversion step 1.
It is used only if ***p***, ***b*** or ***f*** mode is activated in PHASES_TO_USE_ST1.

WEIGHT_R_ST1
Default: *0.10*
Acceptable: *float*
Defines a weight for the time window for phase ***r*** during inversion step 1.
It is used only if ***r*** mode is activated in PHASES_TO_USE_ST1.

WEIGHT_S_ST1
Default: *0.25*
Acceptable: *float*
Defines a weight for the time window for phase ***s*** during inversion step 1.
It is used only if ***s***, ***b*** or ***f*** mode is activated in PHASES_TO_USE_ST1.

WIN_LENGTH_A_ST1
Default: *1800*
Acceptable: *float*
Defines the length (s) of the time window for phase ***a*** during inversion step 1.
It is used only if ***a*** or ***f*** mode is activated in PHASES_TO_USE_ST1.

WIN_LENGTH_P_ST1
Default: *1800*
Acceptable: *float*
Defines the length (s) of the time window for phase ***p*** during inversion step 1.
It is used only if ***p***, ***b*** or ***f*** mode is activated in PHASES_TO_USE_ST1.

WIN_LENGTH_R_ST1
Default: *1800*
Acceptable: *float*
Defines the length (s) of the time window for phase ***r*** during inversion step 1.
It is used only if ***r*** mode is activated in PHASES_TO_USE_ST1.

WIN_LENGTH_S_ST1
Default: *1800*
Acceptable: *float*
Defines the length (s) of the time window for phase ***s*** during inversion step 1.
It is used only if ***s***, ***b*** or ***f*** mode is activated in PHASES_TO_USE_ST1.

WIN_LENGTH_X_ST1
Default: *1800*
Acceptable: *float*
Defines the length (s) of the time window for phase ***x*** during inversion step 1.
It is used only if ***x*** mode is activated in PHASES_TO_USE_ST1.

WIN_START_A_ST1
Default: *0.02*
Acceptable: *float*
Defines the starting time of the time window for phase ***a*** during inversion step 1. The value indicates the position of theoretical first P phase within the time window, defined as percentage of the window length (e.g. 0.02 for a window length of 100s, indicates that the window will start 2 seconds before the theoretical first P phase arrival time – which then comes at 2% of the window length).
It is used only if ***a*** or ***f*** mode is activated in PHASES_TO_USE_ST1.

WIN_START_P_ST1
Default: *0.25*
Acceptable: *float*
Defines the starting time of the time window for phase ***p*** during inversion step 1. The value indicates the position of theoretical first P phase within the time window, defined as percentage of the window length (e.g. 0.02 for a window length of 100s, indicates that the window will start 2 seconds before the theoretical first P phase arrival time – which then comes at 2% of the window length).
It is used only if ***p***, ***b*** or ***f*** mode is activated in PHASES_TO_USE_ST1.

WIN_START_R_ST1
Default: *0.15*
Acceptable: *float*
Defines the starting time of the time window for phase ***r*** during inversion step 1. The value indicates the position of theoretical surface wave phase within the time window, defined as percentage of the window length (e.g. 0.02 for a window length of 100s, indicates that the window will start 2 seconds before the theoretical surface wave phase– which then comes at 2% of the window length). Surface wave phase time is internally hard-coded as $t_S/0.95$, where t_S is the heoretical first S phase arrival time.
It is used only if ***r*** mode is activated in PHASES_TO_USE_ST1.

WIN_START_S_ST1
Default: *0.25*
Acceptable: *float*
Defines the starting time of the time window for phase ***s*** during inversion step 1. The value indicates the position of theoretical first S phase within the time window, defined as percentage of the window length (e.g. 0.02 for a window length of 100s, indicates that the window will start 2 seconds before the theoretical first S phase arrival time – which then comes at 2% of the window length).
It is used only if ***s***, ***b*** or ***f*** mode is activated in PHASES_TO_USE_ST1.

WIN_START_X_ST1
Default: *0.0*
Acceptable: *float*
Defines the starting time (s) of the time window for phase ***x*** during inversion step 1.
It is used only if ***x*** mode is activated in PHASES_TO_USE_ST1.

WIN_TAPER_A_ST1
Default: *0.01*
Acceptable: *float*
Defines the tapering of the time window for phase ***x*** during inversion step 1. A taper is applied in the time domain, smoothing the time window at both sides. The length of the smoothed part of each side is defined by the given real value, which is defined as a percentage of the time window length (e.g. 0.01 of a window length of 100s will produce smoothing along the first and last second of the time window).
It is used only if ***x*** mode is activated in PHASES_TO_USE_ST1.

WIN_TAPER_P_ST1
Default: *0.10*
Acceptable: *float*
Defines the tapering of the time window for phase ***p*** during inversion step 1. A taper is applied in the time domain, smoothing the time window at both sides. The length of the smoothed part of each side is defined by the given real value, which is defined as a percentage of the time window length (e.g. 0.01 of a window length of 100s will produce smoothing along the first and last second of the time window).
It is used only if ***p***, ***b*** or ***f*** mode is activated in PHASES_TO_USE_ST1.

WIN_TAPER_R_ST1
Default: *0.10*
Acceptable: *float*
Defines the tapering of the time window for phase ***r*** during inversion step 1. A taper is applied in the time domain, smoothing the time window at both sides. The length of the smoothed part of each side is defined by the given real value, which is defined as a percentage of the time window length (e.g. 0.01 of a window length of 100s will produce smoothing along the first and last second of the time window).
It is used only if ***r*** mode is activated in PHASES_TO_USE_ST1.

WIN_TAPER_S_ST1
Default: *0.10*
Acceptable: *float*
Defines the tapering of the time window for phase ***s*** during inversion step 1. A taper is applied in the time domain, smoothing the time window at both sides. The length of the smoothed part of each side is defined by the given real value, which is defined as a percentage of the time window length (e.g. 0.01 of a window length of 100s will produce smoothing along the first and last second of the time window).
It is used only if ***s***, ***b*** or ***f*** mode is activated in PHASES_TO_USE_ST1.

5.3 Blackboard variables, inversion step 1

AMPL_PLOT_STEP1
Default: *amax*
Acceptable: amax|norm
Defines the amplitudes of time series or amplitude spectra for plotting results after inversion step 3:
amax: amplitudes of different traces have the same scale (true amplitudes can be better seen).
norm: amplitudes are normalized, they are enlarged to the maximal possible scale (fit is better seen).

FILT_PLOT_STEP1
Default: *filtered*
Acceptable: *plain|filtered|tapered*
Defines the format of time series for plotting results after inversion step 1.
It is used only if DATA_PLOT_STEP1 is ***seis*.**
Acceptable values are plain, filtered (bandpass applied) and tapered (time-domain taper applied).

LEN_PLOT_STEP1
Default: *1000*
Acceptable: *integer*
Defines the length (s) of time series for plotting results after inversion step 1.
It is used only if DATA_PLOT_STEP1 is ***seis*.**

MISFIT_SDS_RANGE
Default: *10*
Acceptable: *integer*
Defines the maximal variation (degrees) of strike, dip and rake angles with respect to the best solution, for plotting of misfit versus angles curves**.**

MISFIT_SDS_RANGE
Default: *2*
Acceptable: *integer*
Defines the increment (degrees) of strike, dip and rake angles for plotting of misfit versus angles curves**.**

MISFIT_DEP_RANGE
Default: *10*
Acceptable: *integer*
Defines the maximal variation (km) of depth with respect to the best solution, for plotting of misfit versus depth curve**.**

MISFIT_DEP_RANGE
Default: *2*
Acceptable: *integer*
Defines the increment (km) of depth for plotting of misfit versus depth curve**.**

START_PLOT_STEP1
Default: *0*
Acceptable: *float*
Defines the starting time (s) of time series for plotting results after inversion step 1.
It is used only if DATA_PLOT_STEP1 is ***seis*.**

SW_APPDURATION
Default: *False*
Acceptable: *boolean*
If set to “True” performs the fast inversion of directivity. This is based on the inversion of the apparent rise time at single stations, with the best DC model obtained in inversion step 1. The applied bandpass is the one defined for inversion step 3 (variables BP_F*_STEP3 are used). Results are summarized in the file apparentdurations.ps. For more detail on the approach see Cesca et al. 2011a.

TICK_PLOT_STEP1
Default: *500*
Acceptable: *integer*
Defines the ticks (s) of time series for plotting results after inversion step 1.
It is used only if DATA_PLOT_STEP1 is ***seis*.**

5.4 Blackboard variables, inversion step 2

BP_F1_STEP2
Default: *0.01*
Acceptable: *float*
First frequency (in Hz) of a 4-points trapezoidal or cosine frequency bandpass to apply at inversion step 2.

BP_F2_STEP2
Default: *0.01*
Acceptable: *float*
Second frequency (in Hz) of a 4-points trapezoidal or cosine frequency bandpass to apply at inversion step 2.

BP_F3_STEP2
Default: *0.01*
Acceptable: *float*
Third frequency (in Hz) of a 4-points trapezoidal or cosine frequency bandpass to apply at inversion step 2.

BP_F4_STEP2
Default: *0.01*
Acceptable: *float*
Fourth frequency (in Hz) of a 4-points trapezoidal or cosine frequency bandpass to apply at inversion step 2.

CC_SHIFT1
Default: *-5*
Acceptable: *float*
Minimum shift for crosscorrelation of time series during inversion step 2.

CC_SHIFT2
Default: *5*
Acceptable: *float*
Maximum shift for crosscorrelation of time series during inversion step 2.

DATA_PLOT_STEP2
Default: *amsp*
Acceptable: *amsp*|*seis*
Define if data format for plotting result after inversion step 2:
amsp: amplitude spectra
seis: displacements

EFFECTIVE_DT_ST2
Default: *0.5*
Acceptable: *postive*
Value of "Effective-dt" to be use for synthetic seismogram generation at step 2. Large values reconstruct extended source by less dense point source discretization, which is faster but less accurate (for further info, see kinherd.org).

EPIC_DIST_MAXLOC
Default: *4500*
Acceptable: *positive*
Additional constraint on maximum epicentral distance to consider for inversion step 2 (where maximum distance will be the minimum between EPIC_DIST_MAX and EPIC_DIST_MAXLOC).

GFDB_STEP2
Default: */scratch/local2/gfdb/gemini-10000km*
Acceptable: *string*
Defines the Green´s functions database used to calculate synthetic seismogram during inversion step 2.

INV_MODE_STEP2
Default: *invert_m*
Acceptable: *invert_tnem*|*invert_tne*|*invert_m*|*grid*
Defines the strategy to carry out inversion step 2. The following possibilities are allowed:
invert_tnem: 3 stages gradient inversion
(1) time offset
(2) north and east relative location (at the same time)
(3) scalar moment
invert_tne: 2 stages gradient inversion
(1) time offset
(2) north and east relative location (at the same time)
invert_m: gradient inversion of scalar moment
grid: grid walk, no gradient method applied

INVERS_MET_STEP2
Default: *minimize_lm*
Acceptable: *minimize_lm*
Choose the gradient inversion method for inversion step 2. Applied if INV_MODE_STEP1 is not equal to **grid**. Currently only Levenberg-Marquardt is implemented.

LOOPS_LOC_CONF
Default: *1*
Acceptable: *integer*
Number of iterative loops of inversion step 2.
If larger than 1, new inversions will be carried out using starting configurations each time closer to the best solution after the prior iteration.

MISFIT_MET_STEP2
Default: *ampspec_l1norm|ampspec_l2norm|l1norm|l2norm*
Acceptable: *string*
This variable defines the method to calculate the misfit during inversion step 2. The following values are admitted:
ampspec_l1norm: amplitude spectra will be compared, using L1 norm
ampspec_l2norm: amplitude spectra will be compared, using L2 norm
l1norm: time traces will be compared, using L1 norm
l2norm: time traces will be compared, using L2 norm

PHASES_TO_USE_ST2
Default: *a*
Acceptable: *string*
This variable defines which seismic phases should be used for inversion step 2. The following values (or a combination of them) are accepted:
p: P phases (on all used components, as defined in COMP_2_USE)
s: S phases (on all used components, as defined in COMP_2_USE)
b: Bodywaves (P on vertical component, S on remaining components)
r: Surface waves (on all used components, as defined in COMP_2_USE)
a: Full waveform (on all used components, as defined in COMP_2_USE)
x: Fixed length (on all used components, as defined in COMP_2_USE); this simulates continuous incoming data
flow, which is cut for all stations with a given length.
f: "Fast" inversion; this is a default combination of full waveform (for closest stations, all components) and bodywaves (for far stations, phases and components as in mode ***b***); check the script for details.

REDUCE_LOC_CONF
Default: *3*
Acceptable: *integer*
If more iterations are required for inversion step 2 (LOOPS_LOC_CONF > 2), this value defines how should be modified the increment for relative locations (North, East, Vertical) at subsequent iterations
(e.g. relative location North varied from -120 to 120 km with step 30 at first iteration; REDUCE_LOC_CONF is set to 3; best relative location North after first inversion is -20 ==> in the second iteration, strike will vary from -50=-20-30 to 20=-20+30 with step 10=round(30/3); and so on).
Only used if LOOPS_LOC_CONF is larger than 1.

REL_DEPTH_STEP
Default: *1000*
Acceptable: *float*
Increment of relative location along vertical direction (meters, positive with depth) to define the group of starting configuration, during inversion step 2.

REL_DEPTH_1
Default: *0*
Acceptable: *float*
Minimum relative location along vertical direction (meters, positive with depth) to define the group of starting configuration, during inversion step 2.

REL_DEPTH_2
Default: *0*
Acceptable: *float*
Maximum relative location along vertical direction (meters, positive with depth) to define the group of starting configuration, during inversion step 2.

REL_EAST_STEP
Default: *1000*
Acceptable: *float*
Increment of relative location along East direction (meters) to define the group of starting configuration, during inversion step 2.

REL_EAST_1
Default: *-5000*
Acceptable: *float*
Minimum relative location along East direction (meters) to define the group of starting configuration, during inversion step 2.

REL_EAST_2
Default: *5000*
Acceptable: *float*
Maximum relative location along East direction (meters) to define the group of starting configuration, during inversion step 2.

REL_NORTH_STEP
Default: *1000*
Acceptable: *float*
Increment of relative location along North direction (meters) to define the group of starting configuration, during inversion step 2.

REL_NORTH_1
Default: *-5000*
Acceptable: *float*
Minimum relative location along North direction (meters) to define the group of starting configuration, during inversion step 2.

REL_NORTH_2
Default: *5000*
Acceptable: *float*
Maximum relative location along North direction (meters) to define the group of starting configuration, during inversion step 2.

REL_TIME_STEP
Default: *1*
Acceptable: *float*
Increment of relative time offset (seconds) to define the group of starting configuration, during inversion step 2.

REL_TIME_1
Default: *-1*
Acceptable: *float*
Minimum relative time offset (seconds) to define the group of starting configuration, during inversion step 2.

REL_TIME_2
Default: *6*
Acceptable: *float*
Maximum relative time offset (seconds) to define the group of starting configuration, during inversion step 2.

SW_FIXTAPER_ST2
Default: *True*
Acceptable: *boolean*
Choose automatically the length of time window if full waveform inversion is chosen (***a*** is activated in PHASES_TO_USE_ST2).
If true, the length in seconds (wila) is decided by the following equation:
wila = (0.36 * epicentral_distance_in_km) + 60
and the value of WIN_LENGTH_A_ST2 is ignored.

SW_VERTICAL_ST2
Default: *False*
Acceptable: *boolean*
If true, only considered vertical component for inversion step 2 (sometime phases are clearer there).

WEIGHT_A_ST2
Default: *1.00*
Acceptable: *float*
Defines a weight for the time window for phase ***a*** during inversion step 2.
It is used only if ***a*** or ***f*** mode is activated in PHASES_TO_USE_ST2.

WEIGHT_P_ST2
Default: *1.00*
Acceptable: *float*
Defines a weight for the time window for phase ***a*** during inversion step 2.
It is used only if ***p***, ***b*** or ***f*** mode is activated in PHASES_TO_USE_ST2.

WEIGHT_R_ST2
Default: *0.10*
Acceptable: *float*
Defines a weight for the time window for phase ***r*** during inversion step 2.
It is used only if ***r*** mode is activated in PHASES_TO_USE_ST2.

WEIGHT_S_ST2
Default: *0.25*
Acceptable: *float*
Defines a weight for the time window for phase ***s*** during inversion step 2.
It is used only if ***s***, ***b*** or ***f*** mode is activated in PHASES_TO_USE_ST2.

WIN_LENGTH_A_ST2
Default: *1800*
Acceptable: *float*
Defines the length (s) of the time window for phase ***a*** during inversion step 2.
It is used only if ***a*** or ***f*** mode is activated in PHASES_TO_USE_ST2.

WIN_LENGTH_P_ST2
Default: *1800*
Acceptable: *float*
Defines the length (s) of the time window for phase ***p*** during inversion step 2.
It is used only if ***p***, ***b*** or ***f*** mode is activated in PHASES_TO_USE_ST2.

WIN_LENGTH_R_ST2
Default: *1800*
Acceptable: *float*
Defines the length (s) of the time window for phase ***r*** during inversion step 2.
It is used only if ***r*** mode is activated in PHASES_TO_USE_ST2.

WIN_LENGTH_S_ST2
Default: *1800*
Acceptable: *float*
Defines the length (s) of the time window for phase ***s*** during inversion step 2.
It is used only if ***s***, ***b*** or ***f*** mode is activated in PHASES_TO_USE_ST2.

WIN_LENGTH_X_ST2
Default: *1800*
Acceptable: *float*
Defines the length (s) of the time window for phase ***x*** during inversion step 2.
It is used only if ***x*** mode is activated in PHASES_TO_USE_ST2.

WIN_START_A_ST2
Default: *0.02*
Acceptable: *float*
Defines the starting time of the time window for phase ***a*** during inversion step 2. The value indicates the position of theoretical first P phase within the time window, defined as percentage of the window length (e.g. 0.02 for a window length of 100s, indicates that the window will start 2 seconds before the theoretical first P phase arrival time – which then comes at 2% of the window length).
It is used only if ***a*** or ***f*** mode is activated in PHASES_TO_USE_ST2.

WIN_START_P_ST2
Default: *0.25*
Acceptable: *float*
Defines the starting time of the time window for phase ***p*** during inversion step 2. The value indicates the position of theoretical first P phase within the time window, defined as percentage of the window length (e.g. 0.02 for a window length of 100s, indicates that the window will start 2 seconds before the theoretical first P phase arrival time – which then comes at 2% of the window length).
It is used only if ***p***, ***b*** or ***f*** mode is activated in PHASES_TO_USE_ST2.

WIN_START_S_ST2
Default: *0.25*
Acceptable: *float*
Defines the starting time of the time window for phase ***s*** during inversion step 2. The value indicates the position of theoretical first S phase within the time window, defined as percentage of the window length (e.g. 0.02 for a window length of 100s, indicates that the window will start 2 seconds before the theoretical first S phase arrival time – which then comes at 2% of the window length).
It is used only if ***s***, ***b*** or ***f*** mode is activated in PHASES_TO_USE_ST2.

WIN_START_R_ST2
Default: *0.15*
Acceptable: *float*

Defines the starting time of the time window for phase ***r*** during inversion step 2. The value indicates the position of theoretical surface wave phase within the time window, defined as percentage of the window length (e.g. 0.02 for a window length of 100s, indicates that the window will start 2 seconds before the theoretical surface wave phase– which then comes at 2% of the window length). Surface wave phase time is internally hard-coded as $t_S/0.95$, where t_S is the heoretical first S phase arrival time.
It is used only if ***r*** mode is activated in PHASES_TO_USE_ST2.

WIN_START_X_ST2
Default: *0.0*
Acceptable: *float*
Defines the starting time (s) of the time window for phase ***x*** during inversion step 2.
It is used only if ***x*** mode is activated in PHASES_TO_USE_ST2.

WIN_TAPER_A_ST2
Default: *0.01*
Acceptable: *float*
Defines the tapering of the time window for phase ***x*** during inversion step 2. A taper is applied in the time domain, smoothing the time window at both sides. The length of the smoothed part of each side is defined by the given real value, which is defined as a percentage of the time window length (e.g. 0.01 of a window length of 100s will produce smoothing along the first and last second of the time window).
It is used only if ***x*** mode is activated in PHASES_TO_USE_ST2.

WIN_TAPER_P_ST2
Default: *0.10*
Acceptable: *float*
Defines the tapering of the time window for phase ***p*** during inversion step 2. A taper is applied in the time domain, smoothing the time window at both sides. The length of the smoothed part of each side is defined by the given real value, which is defined as a percentage of the time window length (e.g. 0.01 of a window length of 100s will produce smoothing along the first and last second of the time window).
It is used only if ***p***, ***b*** or ***f*** mode is activated in PHASES_TO_USE_ST2.

WIN_TAPER_R_ST2
Default: *0.10*
Acceptable: *float*
Defines the tapering of the time window for phase ***r*** during inversion step 2. A taper is applied in the time domain, smoothing the time window at both sides. The length of the smoothed part of each side is defined by the given real value, which is defined as a percentage of the time window length (e.g. 0.01 of a window length of 100s will produce smoothing along the first and last second of the time window).
It is used only if ***r*** mode is activated in PHASES_TO_USE_ST2.

WIN_TAPER_S_ST2
Default: *0.10*
Acceptable: *float*
Defines the tapering of the time window for phase ***s*** during inversion step 2. A taper is applied in the time domain, smoothing the time window at both sides. The length of the smoothed part of each side is defined by the given real value, which is defined as a percentage of the time window length (e.g. 0.01 of a window length of 100s will produce smoothing along the first and last second of the time window).
It is used only if ***s***, ***b*** or ***f*** mode is activated in PHASES_TO_USE_ST2.

5.5 Blackboard variables, inversion step 2

AMPL_PLOT_STEP2
Default: *amax*
Acceptable: amax|norm
Defines the amplitudes of time series or amplitude spectra for plotting results after inversion step 3:
amax: amplitudes of different traces have the same scale (true amplitudes can be better seen).
norm: amplitudes are normalized, they are enlarged to the maximal possible scale (fit is better seen).

FILT_PLOT_STEP2
Default: *filtered*
Acceptable: *plain*|*filtered*|*tapered*
Defines the format of time series for plotting results after inversion step 2.
It is used only if DATA_PLOT_STEP2 is ***seis*.**
Acceptable values are plain, filtered (bandpass applied) and tapered (time-domain taper applied).

LEN_PLOT_STEP2
Default: *1000*
Acceptable: *integer*
Defines the length (s) of time series for plotting results after inversion step 2.
It is used only if DATA_PLOT_STEP2 is ***seis*.**

START_PLOT_STEP2
Default: *0*
Acceptable: *float*
Defines the starting time (s) of time series for plotting results after inversion step 2.
It is used only if DATA_PLOT_STEP2 is ***seis*.**

TICK_PLOT_STEP2
Default: *500*
Acceptable: *integer*
Defines the ticks (s) of time series for plotting results after inversion step 2.
It is used only if DATA_PLOT_STEP2 is ***seis*.**

5.6 Blackboard variables, inversion step 3

BP_F1_STEP3
Default: *0.01*
Acceptable: *float*
First frequency (in Hz) of a 4-points trapezoidal or cosine frequency bandpass to apply at inversion step 3.

BP_F2_STEP3
Default: *0.01*
Acceptable: *float*
Second frequency (in Hz) of a 4-points trapezoidal or cosine frequency bandpass to apply at inversion step 3.

BP_F3_STEP3
Default: *0.01*
Acceptable: *float*
Third frequency (in Hz) of a 4-points trapezoidal or cosine frequency bandpass to apply at inversion step 3.

BP_F4_STEP3
Default: *0.01*
Acceptable: *float*
Fourth frequency (in Hz) of a 4-points trapezoidal or cosine frequency bandpass to apply at inversion step 3.

DATA_PLOT_STEP3
Default: *amsp*
Acceptable: *amsp*|*seis*
Define if data format for plotting result after inversion step 3:
amsp: amplitude spectra
seis: displacements

EFFECTIVE_DT_ST3
Default: *0.5*
Acceptable: *postive*
Value of "Effective-dt" to be use for synthetic seismogram generation at step 3. Large values reconstruct extended source by less dense point source discretization, which is faster but less accurate (for further info, see kinherd.org).

EPIC_DIST_MAXKIN
Default: *4500*
Acceptable: *positive*
Additional constraint on maximum epicentral distance to consider for inversion step 3 (where maximum distance will be the minimum between EPIC_DIST_MAX and EPIC_DIST_MAXKIN).

GFDB_STEP3
Default: */scratch/local2/gfdb/gemini-10000km*
Acceptable: *string*
Defines the Green´s functions database used to calculate synthetic seismogram during the inversion step 3.

INV_MODE_STEP3
Default: *grid*
Acceptable: *invert_rnv*|*invert_r*|*grid*|*ccgrid*
Defines the strategy to carry out inversion step 3. The following possibilities are allowed:
i***nvert_rnv***: gradient inversion of radius, nucleation coordinates and relative rupture velocity (inverted at the same time)
invert_r: gradient inversion of radius
grid: grid walk, no gradient method applied
ccgrid: grid walk, no gradient method applied: misfit is evaluated after trace alignment.

INVERS_MET_STEP3
Default: *minimize_lm*
Acceptable: *minimize_lm*
Choose the gradient inversion method for inversion step 3. Applied if INV_MODE_STEP1 is not equal to **grid** nor **ccgrid**.
Currently only Levenberg-Marquardt is implemented.

KIN_CC_SHIFT1
Default: *-5*
Acceptable: *float*
Minimum shift for crosscorrelation of time series during inversion step 3.

KIN_CC_SHIFT2
Default: *5*

Acceptable: *float*
Maximum shift for crosscorrelation of time series during inversion step 3.

KIN_RISETIME
Default: 1
Acceptable positive
Risetime to be used for inversion step 3.
It is used only if SW_AUTORISETIME is equal to False.

MIN_KIN_BOTTOM
Default: 10
Acceptable positive
Under development. Keep unchanged.

MISFIT_MET_STEP3
Default: *ampspec_l1norm|ampspec_l2norm|l1norm|l2norm*
Acceptable: *string*
This variable defines the method to calculate the misfit during inversion step 3. The following values are admitted:
ampspec_l1norm: amplitude spectra will be compared, using L1 norm
ampspec_l2norm: amplitude spectra will be compared, using L2 norm
l1norm: time traces will be compared, using L1 norm
l2norm: time traces will be compared, using L2 norm

PHASES_TO_USE_ST3
Default: *a*
Acceptable: *string*
This variable defines which seismic phases should be used for inversion step 1. The following values (or a combination of them) are accepted:
p: P phases (on all used components, as defined in COMP_2_USE)
s: S phases (on all used components, as defined in COMP_2_USE)
b: Bodywaves (P on vertical component, S on remaining components)
r: Surface waves (on all used components, as defined in COMP_2_USE)
a: Full waveform (on all used components, as defined in COMP_2_USE)
x: Fixed length (on all used components, as defined in COMP_2_USE); this simulates continuous incoming data
flow, which is cut for all stations with a given length.
f: "Fast" inversion; this is a default combination of full waveform (for closest stations, all components) and bodywaves (for far stations, phases and components as in mode ***b***); check the script for details.

REL_RUPT_VEL_S
Default: *0.1*
Acceptable: *float*
Increment of relative rupture velocity used for starting configurations of eikonal source models during inversion step3.

REL_RUPT_VEL_1
Default: *0.9*
Acceptable: *float*
Minimum relative rupture velocity used for starting configurations of eikonal source models during inversion step3.

REL_RUPT_VEL_2
Default: *0.9*
Acceptable: *float*
Maximum relative rupture velocity used for starting configurations of eikonal source models during inversion step3.

SW_FIXTAPER_ST3
Default: *True*
Acceptable: *boolean*
Choose automatically the length of time window if full waveform inversion is chosen (***a*** is activated in PHASES_TO_USE_ST3).
If true ignores the value of WIN_LENGTH_A_ST3 and calculates the length in seconds (wila) by:
wila = (0.36 * epicentral_distance_in_km) + 60

ST_GOODSTATIONS
Default: *1*
Acceptable: *1|2*
Only used if SE_GOODSTATIONS is set to True. Define the inversion step (1 or 2) misfit which is used to remove unfitting stations for further kinematic inversion.

SW_RELOCATE
Default: *False*
Acceptable: *boolean*
Switch to use the centroid location after inversion step 2, when running inversion step3 (True: shifted location in time and space will be used, False: original location will be used).

SW_AUTORISETIME
Default: *False*
Acceptable: *boolean*
Switch to calculate rise time as 1/3 of point source duration (empirical approximation for circular ruptures).
If equal to False, the value from variables KIN_RISETIME will be used.

SW_BPRISETIME
Default: *True*
Acceptable: *boolean*
Switch to fix the rise time (even after SW_AUTORISETIME or KIN_RISETIME) within a range of accepted values. Minimum accepted value: 1/(3*BP_F3_STEP3); Maximum accepted value: 2/(BP_F3_ST3).

SW_GOODSTATIONS
Default: *True*
Acceptable: *boolean*
Remove those traces with a bad fit after inversion step 1 or 2 (according to variable ST_GOODSTATIONS), from inversion step 3 (the idea is that, if they do not fit well at low frequency, they will do worse for higher frequency and artificially bias kinematic results).
If equal to False, all stations within the chosen epicentral distances range will be used.

SW_INVSMOM_ST3
Default: *False*
Acceptable: *boolean*
Set to True, to invert again for scalar moment at inversion step 3.
Under development, not fully tested, not recommended (anyway, time consuming).

WEIGHT_A_ST3
Default: *1.00*
Acceptable: *float*
Defines a weight for the time window for phase ***a*** during inversion step 3.
It is used only if ***a*** or ***f*** mode is activated in PHASES_TO_USE_ST3.

WEIGHT_P_ST3
Default: *1.00*
Acceptable: *float*
Defines a weight for the time window for phase ***a*** during inversion step 3.
It is used only if ***p***, ***b*** or ***f*** mode is activated in PHASES_TO_USE_ST3.

WEIGHT_R_ST3
Default: *0.10*
Acceptable: *float*
Defines a weight for the time window for phase ***r*** during inversion step 3.
It is used only if ***r*** mode is activated in PHASES_TO_USE_ST3.

WEIGHT_S_ST3
Default: *0.25*
Acceptable: *float*
Defines a weight for the time window for phase ***s*** during inversion step 3.
It is used only if ***s***, ***b*** or ***f*** mode is activated in PHASES_TO_USE_ST3.

WIN_LENGTH_A_ST3
Default: *1800*
Acceptable: *float*
Defines the length (s) of the time window for phase ***a*** during inversion step 3.
It is used only if ***a*** or ***f*** mode is activated in PHASES_TO_USE_ST3.

WIN_LENGTH_P_ST3
Default: *1800*
Acceptable: *float*
Defines the length (s) of the time window for phase ***p*** during inversion step 3.
It is used only if ***p***, ***b*** or ***f*** mode is activated in PHASES_TO_USE_ST3.

WIN_LENGTH_R_ST3
Default: *1800*
Acceptable: *float*
Defines the length (s) of the time window for phase ***r*** during inversion step 3.

It is used only if ***r*** mode is activated in PHASES_TO_USE_ST3.

WIN_LENGTH_S_ST3
Default: *1800*
Acceptable: *float*
Defines the length (s) of the time window for phase ***s*** during inversion step 3.
It is used only if ***s***, ***b*** or ***f*** mode is activated in PHASES_TO_USE_ST3.

WIN_LENGTH_X_ST3
Default: *1800*
Acceptable: *float*
Defines the length (s) of the time window for phase ***x*** during inversion step 3.
It is used only if ***x*** mode is activated in PHASES_TO_USE_ST3.

WIN_START_A_ST3
Default: *0.02*
Acceptable: *float*
Defines the starting time of the time window for phase ***a*** during inversion step 3. The value indicates the position of theoretical first P phase within the time window, defined as percentage of the window length (e.g. 0.02 for a window length of 100s, indicates that the window will start 2 seconds before the theoretical first P phase arrival time – which then comes at 2% of the window length).
It is used only if ***a*** or ***f*** mode is activated in PHASES_TO_USE_ST3.

WIN_START_P_ST3
Default: *0.25*
Acceptable: *float*
Defines the starting time of the time window for phase ***p*** during inversion step 3. The value indicates the position of theoretical first P phase within the time window, defined as percentage of the window length (e.g. 0.02 for a window length of 100s, indicates that the window will start 2 seconds before the theoretical first P phase arrival time – which then comes at 2% of the window length).
It is used only if ***p***, ***b*** or ***f*** mode is activated in PHASES_TO_USE_ST3.

WIN_START_R_ST3
Default: *0.15*
Acceptable: *float*
Defines the starting time of the time window for phase ***r*** during inversion step 3. The value indicates the position of theoretical surface wave phase within the time window, defined as percentage of the window length (e.g. 0.02 for a window length of 100s, indicates that the window will start 2 seconds before the theoretical surface wave phase– which then comes at 2% of the window length). Surface wave phase time is internally hard-coded as $t_S/0.95$, where t_S is the heoretical first S phase arrival time.
It is used only if ***r*** mode is activated in PHASES_TO_USE_ST3.

WIN_START_S_ST3
Default: *0.25*
Acceptable: *float*
Defines the starting time of the time window for phase ***s*** during inversion step 3. The value indicates the position of theoretical first S phase within the time window, defined as percentage of the window length (e.g. 0.02 for a window length of 100s, indicates that the window will start 2 seconds before the theoretical first S phase arrival time – which then comes at 2% of the window length).
It is used only if ***s***, ***b*** or ***f*** mode is activated in PHASES_TO_USE_ST3.

WIN_START_X_ST3
Default: *0.0*
Acceptable: *float*
Defines the starting time (s) of the time window for phase ***x*** during inversion step 3.
It is used only if ***x*** mode is activated in PHASES_TO_USE_ST3.

WIN_TAPER_A_ST3
Default: *0.01*
Acceptable: *float*
Defines the tapering of the time window for phase ***x*** during inversion step 3. A taper is applied in the time domain, smoothing the time window at both sides. The length of the smoothed part of each side is defined by the given real value, which is defined as a percentage of the time window length (e.g. 0.01 of a window length of 100s will produce smoothing along the first and last second of the time window).
It is used only if ***x*** mode is activated in PHASES_TO_USE_ST3.

WIN_TAPER_P_ST3
Default: *0.10*
Acceptable: *float*
Defines the tapering of the time window for phase ***p*** during inversion step 3. A taper is applied in the time domain, smoothing the time window at both sides. The length of the smoothed part of each side is defined by the given real value, which is defined as a percentage of the time window length (e.g. 0.01 of a window length of

100s will produce smoothing along the first and last second of the time window).
It is used only if ***p***, ***b*** or ***f*** mode is activated in PHASES_TO_USE_ST3.

WIN_TAPER_R_ST3
Default: 0.10
Acceptable: float
Defines the tapering of the time window for phase ***r*** during inversion step 3. A taper is applied in the time domain, smoothing the time window at both sides. The length of the smoothed part of each side is defined by the given real value, which is defined as a percentage of the time window length (e.g. 0.01 of a window length of 100s will produce smoothing along the first and last second of the time window).
It is used only if ***r*** mode is activated in PHASES_TO_USE_ST3.

WIN_TAPER_S_ST3
Default: 0.10
Acceptable: float
Defines the tapering of the time window for phase ***s*** during inversion step 3. A taper is applied in the time domain, smoothing the time window at both sides. The length of the smoothed part of each side is defined by the given real value, which is defined as a percentage of the time window length (e.g. 0.01 of a window length of 100s will produce smoothing along the first and last second of the time window).
It is used only if ***s***, ***b*** or ***f*** mode is activated in PHASES_TO_USE_ST.3

5.7 Blackboard variables, inversion step 3

AMPL_PLOT_STEP3
Default: *amax*
Acceptable: amax|norm
Defines the amplitudes of time series or amplitude spectra for plotting results after inversion step 3:
amax: amplitudes of different traces have the same scale (true amplitudes can be better seen).
norm: amplitudes are normalized, they are enlarged to the maximal possible scale (fit is better seen).

FILT_PLOT_STEP3
Default: *filtered*
Acceptable: *plain*|*filtered*|*tapered*
Defines the format of time series for plotting results after inversion step 3.
It is used only if DATA_PLOT_STEP3 is ***seis*.**
Acceptable values are plain, filtered (bandpass applied) and tapered (time-domain taper applied).

LEN_PLOT_STEP3
Default: *1000*
Acceptable: *integer*
Defines the length (s) of time series for plotting results after inversion step 3.
It is used only if DATA_PLOT_STEP3 is ***seis*.**

MIN_KIN_BOTTOM
Default: *10*
Acceptable: *positive*
Minimum accepted value for the bottom constrain of the eikonal source model. The value is given in km. Accept positive values, increasing with depth**.**

START_PLOT_STEP3
Default: *0*
Acceptable: *float*
Defines the starting time (s) of time series for plotting results after inversion step 3.
It is used only if DATA_PLOT_STEP3 is ***seis*.**

SW_INVSMOM_ST3
Default: *False*
Acceptable: *boolean*
If set to true, additionally run a grid walk over scalar moments (from 0.5 to 1.5 step 0.1, with respect to point source scalar moment estimation)**.**

TICK_PLOT_STEP3
Default: *500*
Acceptable: *integer*
Defines the ticks (s) of time series for plotting results after inversion step 3.
It is used only if DATA_PLOT_STEP3 is ***seis*.**

5.8 Blackboard variables, currently unused

ARR_TIMES_DIR
Default: */scratch/local2/simone/KINHERD/TTT/PREM*
Acceptable: *string*
Currently unused. Formerly: path to the directory containing arrival time information.

ARR_TIMES_MODEL
Default: *prem*
Acceptable: *stringak135|iasp91|prem*
Currently unused. Formerly: earth model to use for calculation of theoretical arrival times (should be consistent with Green´s functions model).

JULIAN
Default: *269*
Acceptable: *integer*
Currently unused. May be need for plotting earthquake information.

LOOPS_KIN_CONF
Default: *1*
Acceptable: *integer*
Currently unused.
[Number of iterative loops of inversion step 3.
If larger than 1, new inversions will be carried out using starting configurations each time closer to the best solution after the prior iteration.]

MSEC
Default: *300*
Acceptable: *integer*
Currently unused. May be need for plotting earthquake information.

NUKL_X_STEP
Default: *2000*
Acceptable: *integer*
Currently unused. May be need to implement iterations in inversion step 3.

NUKL_Y_STEP
Default: *2000*
Acceptable: *integer*
Currently unused. May be need to implement iterations in inversion step 3.

RADIUS_STEP
Default: *2000*
Acceptable: *integer*
Currently unused. May be need to implement iterations in inversion step 3.

REDUCE_EIK_CONF
Default: *3*
Acceptable: *integer*
Currently unused.
[If more iterations are required for inversion step 3 (LOOPS_EIK_CONF > 2), this value defines how should be modified the increment for radius and nucleations coordinates (x, y) at subsequent iterations
(e.g. radius varied from 4 to 20 km with step 4 at first iteration; REDUCE_EIK_CONF is set to 4; best radius after first inversion is 12 ==> in the second iteration, strike will vary from 8=12-4 to 16=12+4 with step 1=round(4/1); and so on). Only used if LOOPS_EIK_CONF is larger than 1.]

RISE_TIME_1
Default: *1*
Acceptable: *positive*
Currently unused. Has been replaced by RISE_TIME.

RISE_TIME_2
Default: *1*
Acceptable: *positive*
Currently unused. May be need to test a range of rise times (with RISE_TIME_1 and RISE_TIME_STEP).

RISE_TIME_STEP
Default: *1*
Acceptable: *positive*
Currently unused. May be need to test a range of rise times (with RISE_TIME_1 and RISE_TIME_2).

MAXNUMTRAC

Default: *integer*
Acceptable: *28*
Currently unused.

NUM_PROCESSORS
Default: *1*
Acceptable: *integer*
Under development towards parallel processing. Keep unchanged (or improve the code!).

SW_MAXNUMTRAC
Default: *False*
Acceptable: *boolean*
Currently unused.

SW_SKIPMOHO
Default: *False*
Acceptable: *boolean*
Currently unused.

6. Credits/Acknowledgements

The original development, further extensions, and applications of the Kiwi tools have been possible thanks to the following research projects:

DFG/BMBF project KINHERD

BMBF project RAPID (Programme GEOTECHNOLOGIEN)

BMBF project MINE (Programme GEOTECHNOLOGIEN)

DFG project LAMAS

The codes have been developed at the Institute of Geophysics, University of Hamburg. The following people contributed to the development of the codes: Sebastian Heimann, Simone Cesca, Torsten Dahm, Lars Krieger, Alexander Rohr and Ali Tolga Şen.

The Kiwi tools and rapidinv code, in different versions, have been used so far by many reasearch groups and in a wide range of seismicity environments. The following references section includes all currently published/submitted works, as well as references cited in the manual text.

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Hamburg, 29.2.2012