MT Processing with BIRRP

Jared Peacock

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0.1 Getting Started

This manual briefly covers how to process MT data collected with the AuScope instruments using BIRRP, starting with the raw time series and producing and .edi file. The codes have been written in Python to interface with the Fortran code of Alan Chave that is BIRRP. Below are a few steps that need to be done before anything can be processed.

1. Install Python, this is a free object oriented computer language and can be found on the web. You will need version 2.6 or higher, though I'm not sure if it works with 3.0. If you are using Windows all the necessary base packages have been put together by the nice people at Pythonxy, you can download it on their website and install the latest version. If you're on linux all the necessary base packages can be found on the web, namely numpy, scipy, and matplotlib-1.0. Pythonxy comes with different consoles for running Python, such as IPython or Spyder, which is a Matlab type user interface. Test it all out make sure everything is running smoothly.

2. Next download the codes from Dropbox folder named MTProcessing, these codes should go into a directory that you will save all your codes to, this way it will automatically be added to the PYTHONPATH, if not you have to do it manually. The codes from the MTProcessing folder are:

   - BIRRPTools.py –Module for interacting with BIRRP
   - MTtools.py – Module for reading and writing .edi and manipulating them, filtering time series, etc.
   - MTPlotTools.py –Module for plotting MT responses from .edi files
   - Z.py –Module that can manipulate single .edi files
   - LatLongUTMconversion.py –Module that converts between UTM and lats and longs
   - TFtools.py –Module for estimating spectrograms of the data

- RunBIRRPSingleStation.py –This is the main script that you will be dealing with which will run a single station or multiple stations in series.

3. Download three example files that you will need to create in order to run the program.

   - StationInfoExample.txt –Example of a station information file
   - ProcessingInfoExample.txt –Example of a processing information file
   - AdvancedProcessingInfoExample.txt –Example of an advanced processing information file.

4. Download Birrp5.exe (for Windows) or Birrp5 (Linux) and bbconv.txt (the broadband calibration file), or download all the .f files and compile BIRRP for your own machine. A compiling guide is there if you need one.

0.2 Preparing the data

To run this version of a processing work flow you need 2 files, a tab delimited .txt file that contains the station parameters like location, dipole length, what type of magnetometers, etc. The other file contains all the parameters that BIRRP needs to process the station. To make the files use a spreadsheet program and then save as a tab delimited .txt or .csv file. These two files are described below.

From the field sheets you should have all the information for the station info file, so hopefully you took good notes. This file should have the following headers verbatim (bold font), but can be in any order, and any other headers you put in will be extra information put into the .edi files.

First is the station information file, see StationInfoExample.txt for an example.

0.3 Station Information File

This file contains the parameters of the survey like station name, location, dipole length etc. The important parameters that must be contained in the file with the following headers verbatim but in no particular order:

- **Station** → the station name like pb04
- **date** → the date which the station was deployed any format
- **mcomps** → number of components for that station, 4 for BX,BY,EX,EY and 5 for BX,BY,BZ,EX,EY
- **lat** → latitude in either decimal (-30.124) or time (-30:25:35.233)
- **long** → longitude in either decimal (-30.124) or time (-30:25:35.233)
- **easting** → easting in meters
- **northing** → northing in meters
- **zone** → zone of UTM quadrant

- **Note:** *input either lat and long or easting, northing and zone, everything is converted to lat and long in the end.*
- **elev** → elevation of station in meters
- **ex** → dipole length of ex electrode in meters, usually aligned with geomagnetic north.
- **ey** → dipole length of ey electrode in meters, usually aligned with geomagnetic east.
- **dlgain** → data logger gain data logger gain (very low=.1, low=1, high=2.5)
- **egain** → gain of the interface box normally set to 10 but can be set to 100.
- **magtype** → type of magnetic sensor **bb** for broadband induction coils and **lp** for long period fluxgate magnetometers.
- **magori** → orientation of magnetometers as BX is to the north and BY is to the east, or BX is parallel to strike and BY is perpendicular to strike. Enter as (N,E)=BX,BY or if measured vertical enter as (Z,N,E)=BZ,BX,BY
- **elecori** → orientation of electrodes. EX is either parallel to strike or to the north, EY is perpendicular to strike or to the east. Enter as N,E = EX,EY

Optional Parameters include: (note that any optional parameter will be included in the edi file, this makes it easier to retrace the experiment. Also, these do not need to be verbatim, they can be what ever you desire these are just suggestions.)

- **coil no (bx,by)** → coil numbers if measuring broadband.
- **dlbox** → data logger box number.
- **harddrive** → hard drive number
- **battery** → battery number
- **start volt** → starting voltage of battery.
- **end voltage** → end voltage of battery
- **box no** → auscope box number
- **notes** → any notes about the site like chewed cables, near a fence, large hawk stole one of the electrodes, etc.
- **cacherate** → length of files in HHMMSS, for 1 hour 010000, for 10 min 001000
- **df** → sampling frequency in Hz

Note: that the remote reference should be included in the station info file, otherwise might get an error when you run the program. If there is no remote reference don't worry about it.

0.4 Processing Info File

This file tells the program which station to process, what day(s) to process, the start and end times, etc. The necessary parameters in this file are under the verbatim headers:

- **station** → station name, should be verbatim of what the station folder is called.
- **day** → the day you want to process in UTM. It should be a three character string '000'.
- **start** → start time as a 6 character string hhmmss
- **stop** → stop time as a 6 character string hhmmss
- **rrstation** → remote reference station, should be verbatim of what the remote reference station was named.
- **rrstart** → start time of remote reference, note that if this is different than the start time of the station then you need to include the parameter *nskipr* which is the number of data points to skip on the remote reference.
- **rrstop** → stop time of the remote reference as a 6 character string hhmmss.
  - *If you want to process multiple days that are continuous in time, no gaps, then enter the consecutive days separated by a comma. '001,002,003'.*
  - *If there are segments from different days that you want to process for the same station separate the days by a semicolon. '001;003'*
  - *If there is a continuous time over a few days, then a gap and a segment later, just split the continuous days by a comma and the segment by a semicolon. '001,002;003'*
  - *The same goes for the start and stop time. start time for a continuous 3 days. '070000,000000,000000' and the corresponding stop time might be '240000,240000,050000'. If there are segments enter as '070000;040000;080000' and '210000;140000;120000'. And if there are continuous times and segments enter as '070000,000000;080000' and '240000,140000;120 Note that the day, start and stop should have the same number of commas and semicolons in the same spots.*
  - *Similar for the remote reference. If there are different remote references for each day enter with appropriate punctuation ('pbrt1';'pbrt2','pbrt1'). Otherwise it is assumed the same remote reference will be used for the entire time. This can be handy if you are remote referencing to other stations in the survey.*
- **mcomps** → number of components measured. 4 for BX,BY,EX,EY, 5 for BX,BY,BZ,EX,EY, etc.
- **dec** → decimation factor to down sample the data to get longer periods. If no decimation factor enter as 0 or 1. The factor is calculated as a multiple. If you want to go from 500 Hz to 50 Hz the decimation factor would be $500/50 = 10$.
- **df** → sampling frequency in Hz.

- **magori** $\rightarrow$ orientation of magnetic channels and needs to be in the order (Z,N,E) where Z is the vertical channel, N is the magnetic channel to the north or parallel to strike and E is the magnetic channel to the east of perpendicular to strike. If the channels get mixed up some how when plugging into the interface box such that BX is actually to the East enter as BZ,BY,BX. Similarly, if the fluxgate is place on its side instead of vertical down a hole input maybe BX,BY,BZ. If you input this wrong it will become apparent in the resistivity plots.

- **elecori** $\rightarrow$ orientation of electric channels as (N,E) or parallel and perpendicular. Again if the channels get mixed up some how input as EY,EX otherwise EX,EY.

- **rrmagori** $\rightarrow$ orientation of remote reference magnetic channels as (N,E). Here the vertical channel is not remote referenced. Again typical input is BX,BY and if channels get mixed up BY,BX.

- **cacherate** $\rightarrow$ is the length of the mini files set as hhmmss. For a 10 min cacherate enter '001000' and for a 1 hour cacherate enter as '010000'.

The optional inputs are the BIRRP parameters (in bold) which are defined below. There is the ability to run in advanced mode, but as of now only continuous single segments can be processed the parameters for this will be in blue. Also, you need to have a remote reference otherwise there will be an error. Parameters such as nread, nout, and npcs are computed from the data.

- **ilev** $\rightarrow$ 0 for basic mode and 1 for advanced mode *Default is 0*

- **nrr** $\rightarrow$ 0 for bounded influence, 1 for two stage processing *Default is 1*

- **tbw** $\rightarrow$ defined as the time bandwidth and is a measure of overlap between FFT segments. Between 0 and 4 for larger numbers there is more overlap and longer processing time, vise-versa for smaller values. *Default is 2*

- **nfft** $\rightarrow$ maximum length of FFT segment. Usually 2^n. At the moment nothing runs for $n > 16$.*Default is* $2^{16} = 65536$

- **nsctinc** $\rightarrow$ window section divisor 2 to divide by half. *Default is 2*

- **nsctmax** $\rightarrow$ number of decimations by 2 of the largest window. Usually $n-4$. This gives you the number of frequencies that it will put out as in basic mode only two Fourier coefficients are extracted for each window, so the number of frequencies is $2 \times nsctmax$. *Default is 12*

- **nf1** $\rightarrow$ 1^{st} frequency to extract from FFT window (≥ 3). *Default is 3*

- **nfinc** $\rightarrow$ frequency increment to extract from FFT window. *Default is 2*

- **nfsect** $\rightarrow$ number of frequencies to extract. *Default is 2*

- **mfft** $\rightarrow$ AR filter divisor. *Default is 2*

- **uin** $\rightarrow$ rejection of low end leverage point threshold, usually 0. *Default is 0*

- **ainlin** $\rightarrow$ residual rejection factor low end. *Default is 0*

- **ainuin** → rejection of high end leverage point threshold. The larger the number the less influence an outlier will have on the response. *Default is .99*

- **c2threshb** → coherence threshold value for magnetic channels (0-1), so anything with a coherence below this value will be omitted from transfer function estimation. *Default is 0*

- **c2threshe** → coherence threshold value (0-1), so anything with a coherence below this value will be omitted from transfer function estimation. *Default is 0, note the internal default of is .35*

- **nz** → Only input if number of inputs is 3, (0=separate from E, 1=E threshold, 2=E and B). *default is 0*

- **c2threshi** → Input only if number of number of outputs is 3 and nz=0. anything below this value will not be included in Tipper estimation. *Default is 0*

- **nlev** → the type of output files (0=Z; 1=Z,qq; 2=Z,qq,w; 3=Z,qq,w,d) . Usually 0

- **nz** → order of the pre-whitening filter (3 <> 15) or 0 if not desired. 5 is usually a good choice. *Default is 5*

- **imode** → File mode (0=ascii; 1=binary; 2=headerless ascii; 3=ascii in TS mode). *Default is 0*

- **jmode** → Input file mode (0=user defined; 1=start time YYYY-MM-DD HH:MM:SS) *Default is 0*

- **nfil** → Filter parameters (0=none; >0=input parameters; <0=filename). *Default is 0*

- **nskip** → input1,input2...) → number of point to skip from beginning of time series, if multiple time window enter as comma or semicolon separated with no spaces. *Default is 0*

- **nskipr** → input1,input2...) → number of point to skip from the beginning of the remote reference time series. If multiple enter as comma or semicolon separated with no spaces. *Default is 0*

- **thetae** → Rotation angles for electrics (relative to geomagnetic North)(N,E,rot). If magnetic declination is entered it will appear here. Note that rotation occurs from north clockwise. So if the declination is plus 10 degrees, the angle of rotation needs to be negative in BIRRP.

- **thetab** → Rotation angles for magnetics (relative to geomagnetic North)(N,E,rot). If magnetic declination is entered it will appear here. Note that rotation occurs from north clockwise. So if the declination is plus 10 degrees, the angle of rotation needs to be negative in BIRRP.

- **thetar** → Rotation angles for magnetics (relative to geomagnetic North)(N,E,rot) If magnetic declination is entered it will appear here. Note that rotation occurs from north clockwise. So if the declination is plus 10 degrees, the angle of rotation needs to be negative in BIRRP.

0.5 Outputs

As BIRRP finishes it outputs some files. From these files, four files are created: .edi, .dat, .coh, and .imp. The .dat file has apparent resistivity and phase information and .imp has impedance information. A good check it to make sure the real and imaginary components of the xy polarization are all positive and yx are all negative. A .log file is also written, this contains information of each time that station is run within the input time window. This can be useful to see which parameters worked better than others. It also contains the .dat and .coh each time it was run.

You can choose to make three plots. One plotting the xy and yx modes for apparent resistivity and phase. One plotting the xx and yy modes for apparent resistivity and phase. The third plotting the coherence of the two modes if 4 component MT is used or three modes if 5 component is used. The files can be saved to a folder as PDF's.

- Outputs
  - EDI file saved to: dirpath/station/day/CombSTtoET/BF/station.edi
  - Apparent resistivity and phase file saved to: dirpath/station/day/CombSTtoET/BF/station.dat
  - Coherence file saved to: dirpath/station/day/CombSTtoET/BF/station.coh
  - Impedance file saved to: dirpath/station/day/CombSTtoET/BF/station.imp
  - Log file saved to: dirpath/station/day/CombSTtoET/BF/station.log
  - Apparent resistivity and phase plots file saved to: dirpath/Plots/stationResxy.pdf and dirpath/Plots/stationResxy.pdf
  - Coherence plot saved to: dirpath/Plots/stationCoh.pdf

0.6 Trouble Shooting

Here are some common pitfalls that might be encountered. Because this program is written in Python, there are some nice callbacks. This means that the errors that it spits out can be traced back to the original source. So if you get an error try where the basic error comes from.

- **IOError File doesn't exist** → means that one of the files is not correct, most likely it wasn't typed in correctly or the drive isn't the same if you are using an external hard drive.
- **When BIRRP does not run properly:**
  - First check the script file and check to see that everything was entered as you expected.
  - Next check to make sure that all the combined files are of the same length and that the files exist. If they are not the same length check the raw data to see if there is a clear reason why. Sometimes the data loggers can miss some data points. If everything seems ok. delete the combined files and run again.
  - If uneven lengths of files are output from BIRRP, change the tbw parameter slightly and run again.
- **If outputs look like crap:**

- Check to make sure that the remote reference is aligned in time with the station. Sometimes if you remote reference to the same station for multiple days the program sees that the files are already combined but might not be the same length.
- Change some of the coherency parameters around, namely *cthreshe* or *cthreshb*. Also *aiuin* or *uin*.
- Check the time series again to make sure there's nothing fishy going on.