# TransdEM:

An open-source package for transdimensional Bayesian inversion of electromagnetic data in 1D layered media.

Version 1.0

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# Contents

# 1 Introduction

## 1.1 About the package

This document describes how to use the Julia[1] software package **TransdEM** perform transdimensional MCMC inversion for different EM data in 1D layered media. Here's a list of features currently supported in **TransdEM**:

- Forward modeling of MT/CSEM/TEM responses in 1D layered media
- Transdimensional MCMC inversion of 1D MT/CSEM/TEM data
- Statistical analysis of posterior probability distribution about model parameters (e.g., mean, median, and mode)
- Parallel transdimensional MCMC samplings

## 1.2 Installation

The package is compatible with Julia v0.7 or later versions (The LTS version v1.0.5 is recommended). To install the package, please refer to How do I add a local project to the import path in Julia. After installing the package, then go to the path (/yourpath/TransdEM/src/TBFwdSolver/deps), run **build.jl** to compile the external library of Dipole1D for primary field computations.

[1] http://julialang.org/

## 2 Files required by the package

There are two files required to run the **TransdEM** package: the data file and startup file. Each file is described in detail in the following sections.

## 3 Data File

The data file describes survey information. For current version, the file supported contains data from MT, CSEM and TEM surveys. Because these methods have different survey configuration and data types, their data file formats are designed to be different. Note that these data file formats are specific to the TransdEM package.

### 3.1 CSEM data file format

The CSEM data file contains information about CSEM surveys, including transmitter and receiver locations, frequencies, data types, and data values and associated standard errors. Following is an example of CSEM data file:

```
# Format:          CSEMData_1.0
# Description:     inline and broadside, two frequencies.
SeaLayer:         1000.0  3.2 (optional, required for marine CSEM case)
Dipole Length:       1.0      (optional, default value < 10)
Phase Convention:    lead     (optional, default value is "lead")
Source Location (m):         1
#        X            Y         Z     Azimuth      Dip
0.0         0.0       950.0    0.0         0.0
Receiver Location (m):      20
#          X          Y            Z
500.0        0.0      1000.0
...
10000.0        0.0      1000.0
Frequencies (Hz):       2
2.5000e-01
```

```
5.0000e-01
DataType:     2
ampEx
phsEy
Data Block:    80
# FreqNo. TxNo.   RxNo.  DTypeNo.  Value        Error
1     1      1      1      4.638014e-10    2.337142e-11
1     1      1      2     -2.717600e+01    2.864789e+00
1     1      2      1      3.641894e-11    1.689530e-12
1     1      2      2     -6.338186e+01    2.864789e+00
...
2     1     20      1      1.315654e-14    6.638414e-16
2     1     20      2     -1.741810e+02    2.864789e+00
```

The following is an brief explanation of the keywords of the CSEM data file.

- **Dipole Length**: followed by a real value, representing the length (in meters) of the electric dipole source. If the length is bigger than 10, then the transmitter will be treated as a finite length line source rather than a point dipole. This is optional, and the default value is less than 10, which means by default the source is regarded as a point dipole.

- **SeaLayer**: followed by two real values, representing the thickness (in meters) and conductivity (in S/m) of the seawater layer, respectively. This is optional, and required for marine CSEM case.

- **Phase Convention**: followed by a string. Phase "`lead`" corresponds to the $e^{iwt}$ time dependence, while phase "`lag`" corresponds to the $e^{-iwt}$ time dependence. This is optional, and the default value is "`lead`".

- **Source Location**: followed by an integer, which is the number of transmitters. The $x$, $y$, $z$ locations (in meters), the rotation angle (degrees clockwise from $x$) and the dip angle (degrees positive down) of transmitters are listed below it.

- **Receiver Location**: followed by an integer, which is the number of observation sites. The

$x$, $y$, $z$ locations (in meters) of sites are listed below it.

- **Frequencies**: followed by the number of frequencies, and the frequency values (in Hz) are listed below it.
- **DataType**: specify the data types used for inversion. For CSEM the allowed **DataType**s are the amplitude and phase of the electromagnetic fields.
- **Data Block**: followed by the number of data points, the maximum value of which is $N_{freq} * N_{source} * N_{site} * N_{type}$. A table of data parameters is given below it. The first column of the data table is the frequency index for each datum, the second column is the source/transmitter index, the third column is the site index and the fourth column gives the data type index. The last two columns give the corresponding data value and associated standard error.

### 3.2 MT data file format

The MT data file contains information about MT measurements. Different from the 1D CSEM data, the transmitter and receiver locations are not needed for 1D MT inversion. Following is an example of MT data file:

```
# Format:          MTData_1.0
# Description:     generated in Wed Mar 17 11:48:37 2021
Frequencies (Hz):      40
3.2000e+02
2.3957e+02
...
1.00000e-04
DataType:  2
realZxy
imagZxy
Data Block:    80
# FreqNo.  DTypeNo.    Value          Error
1        1    5.704015e-01    2.901863e-02
1        2    6.165296e-01    3.082017e-02
```

```
2         1     4.713291e-01     2.409851e-02
2         2     5.563706e-01     2.789044e-02
...
40         1     5.769041e-04     2.970454e-05
40         2     6.286499e-04     3.033997e-05
```

The following is an brief explanation of the keywords of the MT data file.

- **Frequencies**: followed by the number of frequencies, and the frequency values (in Hz) are listed below it.
- **DataType**: specify the data types used for inversion. For MT the allowed **DataType**s are the real and imaginary values of the MT impedance.
- **Data Block**: followed by the number of data points, the maximum value of which is $N_{freq} * N_{type}$. A table of data parameters is given below it. The first column of the data table is the frequency index for each datum, the second column gives the data type index. The last two columns give the corresponding data value and associated standard error.

### 3.3 TEM data file format

The TEM data file contains information about TEM surveys, including the size of the transmitter loop, and a table of time channels, data values and standard errors. Following is an example of TEM data file:

```
# Format:           TEMData_1.0
# Description:      generated in Tue Mar 23 15:00:14 2021
LoopWidth(m):       20  20
Data Block:    31
# timechannel        value            error
1.00000000e-06    1.827007e-02    9.400605e-04
1.25892541e-06    1.360854e-02    6.848484e-04
...
7.94328235e-04    2.079405e-09    1.053918e-09
1.00000000e-03    1.554934e-09    1.026795e-09
```

The following is an brief explanation of the keywords of the TEM data file.

- **LoopWidth**: followed by the length and width of the transmitter loop (in meters). For current version, only concentric loop configuration is supported.
- **Data Block**: followed by the number of data points. A table of data parameters is given below it. The first column gives the time channels (in seconds) of the TEM survey, while the second and third column give the corresponding data value (electromagnetic force) and associated standard error.

# 4 Startup File

The startup file describes the options that control the transdimensional MCMC inversion. It is composed of a list of option keywords and corresponding values. Following is an example of the startup file:

```
surveytype:      mt
datafile:        mt1data.dat
burninsamples:   300000
totalsamples:    1000000
numberoflayer:   2    30
minthickness(m): 100
zcoordinate(m):  1.0  50000.0 0.05
resistivity:     0.1 1e4 0.05
numberofbins:    400 400
credinterval:    0.9
```

The following is an brief explanation of the keywords of the startup file.

- **surveytype**: followed by a string indicating the type of EM surveys, which can be '`mt`', '`csem`' or '`tem`'.
- **datafile**: followed by a string that indicates the file name of the data file used in the inversion.
- **burninsamples**: number of samples for burn-in period used in the estimate of the posterior probability distribution.

- **totalsamples**: number of total samples the Markov chains will produce.
- **numberoflayer**: followed by two real values, which give the minimum and maximum number of layers allowed during the inversion.
- **minthickness**: indicates the minimum layer thickness (in meters) allowed during the inversion.
- **zcoordinate**: followed by three real values. The first two give the minimum and maximum depths (in meters) of the layer interfaces allowed during the inversion, the last one is the standard deviation (in percent) when perturbing the value of the interface depth.
- **resistivity**: followed by three real values. The first two indicates the lower and upper bounds for layer resistivities (in $\Omega m$), the last one is the standard deviation (in percent) when perturbing the value of the resistivity of the layers.
- **numberofbins**: followed by two integer values, which indicate the number of depth bins and resistivity bins for analyzing the posterior distribution of model parameters.
- **credinterval**: a real value between 0 and 1, which indicates the credible interval of interest.