WALDIM Program

Instructions Guide

Documentation related to the paper:
Martí, A., Queralt, P. and Ledo, J., 2009. WALDIM: A code for the dimensionality analysis of magnetotelluric data using the Rotational Invariants of the Magnetotelluric Tensor, Computers and Geosciences, 35, 2295-2303.

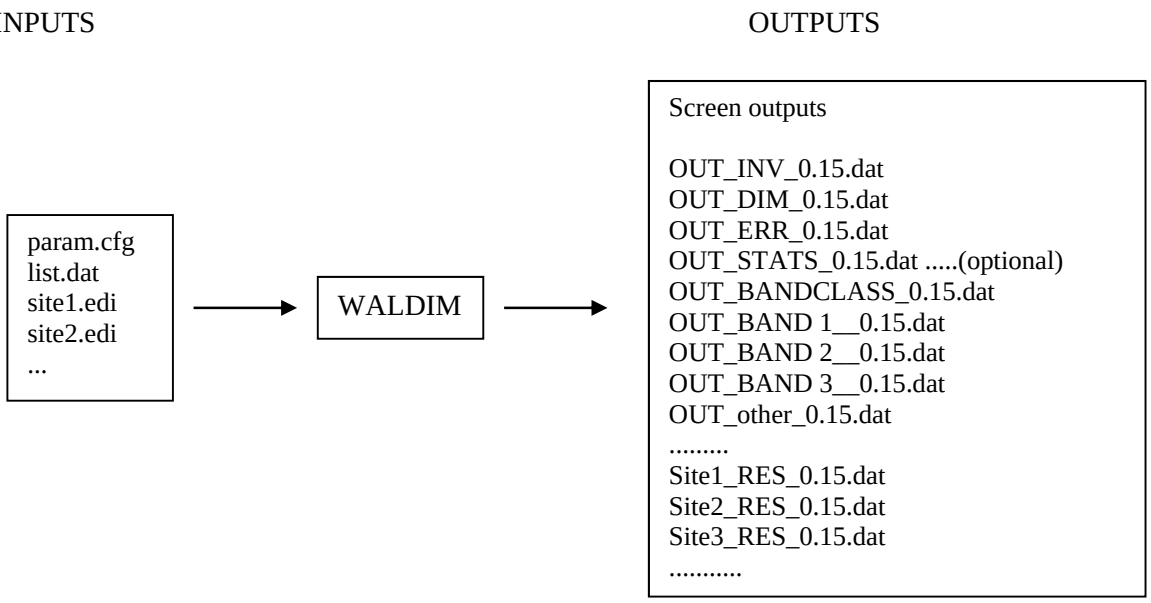
Version 1.2: modified to identify anisotropy hints, as described in the paper:
Martí, A., Queralt, P., Ledo, J. and Farquharson, C., 2010. Dimensionality imprint of electrical anisotropy in magnetotelluric responses, Physics of the Earth and Planetary Interiors, 182, 139-151.

In this new version the program identifies possible hints of anisotropy, related to anisotropy over homogeneous backgrounds (anis-hint1) or over a 2D structure (anis-hint2). However, these hints are obtained from the analysis at particular sites and periods. Other hints (anisotropy over a layered medium) can be picked afterwards by the user by identifying specific dimensionality patterns among neighboring sites and close periods.
When anisotropy is aligned with measurement axes, it cannot be identified.
Inherently to the MT method, anisotropy cannot be identified in a 3D medium.

Compilation:
The sources of the program WALDIM are the main code **WALDIM1.2.f** and the complementary codes **inoutdata1.2.f**, which reads the input and generates the outputs; and the code **external1.2.f**, which contains the functions called from the main code. The executable file is **WALDIM1.2 (or WALDIM1.2.exe)**. Compiling and linking instructions are in the file **Makefile**. This file is a very simple makefile in order to run the compilation. One must put or delete "#" according to the Fortran compiler and computer system. Please customize this.

Running the program:

Diagram with default files names



INPUTS:

When running the program, the following inputs are needed:

A. Input parameters (input files and program options): these can be read from the keyboard as they are asked at the beginning of the program, or can be read from the file **param.cfg**.

These input parameters are:

- File with EDI files names and coordinates (input file no. 1) [Default: list.dat].
- Units for impedances in EDI files (**M**= m/s; **F**=km/s $\left(=\frac{mV/km}{nT}\right)$(field units); **Z** = Ohm)

[Default: F (km/s) (the most usual].

- Threshold value for Invariants I_3 to I_7: $\boldsymbol{\tau}$. (Recommended value between 0.1 and 0.2) [default: 0.15]
- Threshold value for Q: $\boldsymbol{\tau_Q}$ (recommended value 0.1 or lower) [default: 0.1].
- EDI files contain errors (**Y/N**)? (Usually **Y** for raw data and **N** for synthetic data) [default: Y].

    If **Y**: using errors in EDI files (**y**/**n**)? [default: Y].

        If **n**: error percentage (%)? [default: 5].

    If **N**: error percentage (%)? [default: 5].

        - Average in bands (**y/n**)?: [default: Y].

            If **y**:

            - Minimum period to average? [Default: 0.001].

- Maximum period to average? [Default: 10000].
- Number of bands per decade? [Default: 1].

- Root name for output files [Default: OUT].
- Writing file with all parameters and errors (Y/N)? [Default: Y]

B. Input Files (Two files: list file + x edifiles, one for each site):

1. File containing a list of all sites with their coordinates, in the following format:
1rst row: header information.
2nd row: number of sites (free format).
3rd and following rows: EDI file name (WITHOUT EXTENSION ".EDI"), latitude and longitude (both in decimal degrees or sexagesimal degrees).

Example:

INFO
1
site001 41:31:00 1:41:00

---

2. EDI files (Wight, 1988) containing impedances (as opposed to spectra): one file for each site (file names read from file **1)**.

OUTPUTS:

C. List of output parameters and dimensionality types (displayed in output files listed in **D**., and/ or on the screen):

I_1, I_2, I_3, I_4, I_5, I_6, I_7, Q (referred to in the program as I_8). (I_1, I_2 in km/s; the rest are dimensionless).

St_1: 1D apparent resistivity (ohm·m) computed from I_1 and I_2 assuming a 1D model.

St_2: 1D phase computed from I_1 and I_2 assuming a 1D model.

St_3 and St_4: strike directions (degrees) corresponding to a 2D model.

St_5: strike directions (degrees) corresponding to a 3D/2D model.

St_6 and St_7: ϕ_1 and ϕ_2 distortion angles (degrees) (linear combinations of twist and shear).

St_8 and St_9: twist and shear angles (degrees).

$errSt_1$ to $errSt_9$: errors of parameters St_1 to St_9.

All strike directions are determined positive clockwise from the north, taking into account the rotation angle (ROT) read from EDI files.

Dimensionality types (DIM):

0: UNDETERMINED,

1: 1D,

2: 2D,

3: 3D/2D only twist,

4: 3D/2D general,

5: 3D,

6: 3D/2D with diagonal regional tensor

7: 3D/2D or 3D/1D indistinguishable

8: Anisotropy hint 1: homogeneous anisotropic medium

9: Anisotropy hint 2: anisotropic body within a 2D medium

Statistical parameters (optional output, file OUT+_STATS_+τ+.dat):

True: Parameter value computed directly.

Err: Parameter error using classical error propagation.

Sta: Parameter value computed randomly.

Dev: Parameter error computed statistically.

Bias: Difference between true and sta, normalized.

If averaging in bands (files OUT+_BAND 1_+τ+.dat, OUT+_BAND 2__+τ+.dat, etc.)

Band: number of band

T1: minimum period in a band for a specific site.

T2: maximum period in a band for a specific site.

Nper: number of periods in a band for a specific site (excluding undetermined cases).

Cont: parameter stating whether strike angle has been determined (1) or not (0). Useful to display strike angles.

Scale: length of the strike arrows (inversely proportional to strike error). Useful for plotting.

Strikecomp: strike value * (-1). Useful for certain plotting packages.

Other indicators (file OUT+_other_+τ+.dat):

Impxy_rot and Impyx_rot: impedances rotated to the strike direction.

Skew and ph_s_skew: Skew and Phase Sensitive Skew (Bahr (1988) parameters).

D. Output files (5 Files + n Files (one for each band) + x Files (one for each site)):

ROOT: Root name for output files [Default: OUT].
τ: threshold value used for dimensionality analysis.

1. ROOT+"_INV_"+τ+".dat" [Default: OUT_INV_0.15.dat]: table with invariant values and errors for all sites and periods: Site, Longitude, Latitude, F(Hz), T(s), *I*(1 to 7), *Q*, err*I*(1 to 7) and err*Q*.

2. ROOT+"_DIM_"+τ+".dat" [Default: OUT_DIM_0.15.dat]: file with dimensionality for all sites and periods with relevant information if 2D or 3D/2D: Site, Longitude, Latitude, F(Hz), T(s), DIM, St_3, $errSt_3$, St_4, $errSt_4$, St_5, $errSt_5$, St_6, $errSt_6$, St_7, $errSt_7$.

3. ROOT+"_ERR_"+τ+".dat" [Default: OUT_ERR_0.15.dat]: file with dimensionality, invariants, related parameters (St) and errors for all sites and periods: Site, Longitude, Latitude, F(Hz), log (F), Per (s), ROT, DIM, *I*(1 to 7), *Q*, St(1 to 9), err*I*(1 to 7), err*Q*, errSt(1 to 9).

4. Optional file: ROOT+"_STATS_"+τ+".dat" [Default: OUT_STATS_0.15.dat]: file with true values, statistical values, errors, and biases for all invariants and related parameters for all sites and periods: Site, Longitude, Latitude, F(Hz), Per (s) + for each parameter: true, err, stat, dev,bias.

5. ROOT+"_BANDCLASS_"+τ+".dat" [Default: OUT_BANDCLASS_0.15.dat]: file with dimensionality results classified in period bands, for all sites and all bands. Site, Longitude, Latitude, BAND, T1, T2, number of periods in the band, strike, errstrike, twist, errtwist, shear, errshear, cont, scale, strikecomp.

6. ROOT+"_BAND"+B+τ+".dat" [Default: OUT_BANDCLASS_0.15.dat]: file with dimensionality results for band "B" for all sites: Site, Longitude, Latitude, nper, strike, errstrike, twist, errtwist, shear, errshear, cont, scale, strikecomp. (ONE FILE FOR EACH BAND).

7. EDISITENAME+"_RES_"+τ+".dat" (e.g.:"site001_RES_0.15.DAT): file with dimensionality results for each site. This file is divided in two blocks: 1) dimensionality results for each period, and 2) dimensionality averages in bands. (ONE FILE FOR EACH SITE).
Block 1: Site, Longitude, Latitude, F(Hz), Per (s), DIM, strike, errstrike, twist, errtwist, shear, errshear.

Block 2: Site, Longitude, Latitude, BAND, Tmin, Tmax, number of periods in the band, strike, errstrike, twist, errtwist, shear, errshear, cont, scale, strikecomp.

8. ROOT+"_other_"+τ+".dat" [Default: OUT_other_0.15.dat]: file with other indicators used to assess 2D, 3D/2D or 3D dimensionalities: Site, Per(s), DIM, strike (2D or 3D/2D, Impxy_rot (2D), Impyx_rot (2D), twist (3D/2D), shear (3D/2D), I7 (3D), skew, ph_s_skew.

E. Screen Outputs:

- Error or warning messages regarding input parameters, EDI files, overwriting existing files…
- Summary of dimensionality results: total number of periods (from all sites) and total number of cases for each dimensionality type.

If band averaging:

- Minimum and maximum period, total number of bands and period range for each band.

DATA EXAMPLE:

An example is included, which consists of 3 folders with:

1) Input data of site 85_314 from the the COPROD2 dataset (param.cfg, list-cop.dat, cop314.edi, folder "coprod314-inputs"):

2) Outputs from the former version of the code waldim1.1 (folder "coprod314-outputs-v1.1-old)

Summary of the results:

1D up to 10 s,

3D/2D from 10 s to 1000 s. According to the invariants it would have been 2D but the resulting strikes st3 and st4 are different, and hence dimensionality was assumed as 3D/2D with strike = st5.

3) Outputs from the current version of the code, waldim1.2 (folder "coprod314-outputs)

Summary of results:

1D up to 10 s,

ANIS-HINT2, FROM 10 s to 1000 s. Consistent with the criteria from Martí et al. 2010.

If you publish results obtained from the use of the code, please refer to the works:

Martí, A., Queralt, P. and Ledo, J., 2009. WALDIM: A code for the dimensionality analysis of magnetotelluric data using the Rotational Invariants of the Magnetotelluric Tensor, Computers and Geosciences, 35, 2295-2303.

Martí, A., Queralt, P., Ledo, J. and Farquharson, C., 2010. Dimensionality imprint of electrical anisotropy in magnetotelluric responses, Physics of the Earth and Planetary Interiors, 182, 139-151.

Any doubts, questions, suggestions … please contact the author:

Anna Martí

Departament de Geodinàmica i Geofísica, Facultat de Geologia, GEOMODELS Research Institute, Universitat de Barcelona, C/Martí i Franquès s/n, 08028 Barcelona, Spain

annamarti@ub.edu