

empymod

empymod.github.io

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Features I

- Calculates the complete (diffusion and wave phenomena) 3D electromagnetic field in a layered-earth model.
- Vertical transverse isotropic (VTI) resistivity $\rho^{h,v}$.
- VTI electric permittivity $\varepsilon_r^{h,v}$.
- VTI magnetic permeability $\mu_r^{h,v}$.
- Electric and magnetic sources and receivers.
- Wavenumber, frequency, and time domain.
- Arbitrary rotated, finite dipoles.

Features II

- Hankel transforms
 - Adaptive quadrature
 - Fast Hankel transform
 - Quadrature with extrapolation
- Fourier transforms
 - Sine/Cosine-transforms
 - Quadrature with extrapolation
 - Fast Fourier Transform
 - Logarithmic Fast Fourier Transform
- Analytical solutions
 - Complete full-space; f -domain
 - Diffusive half-space (only el. src & rec); f - & t -domains
 - Direct wave, reflected wave, airwave
 - TE-/TM-modes

Educational I: Understanding the code

Documented and referenced

Explicit, functional programming, no fancy stuff; easy to follow.

Main 4 files: 2192 lines of code; 2116 lines of comments

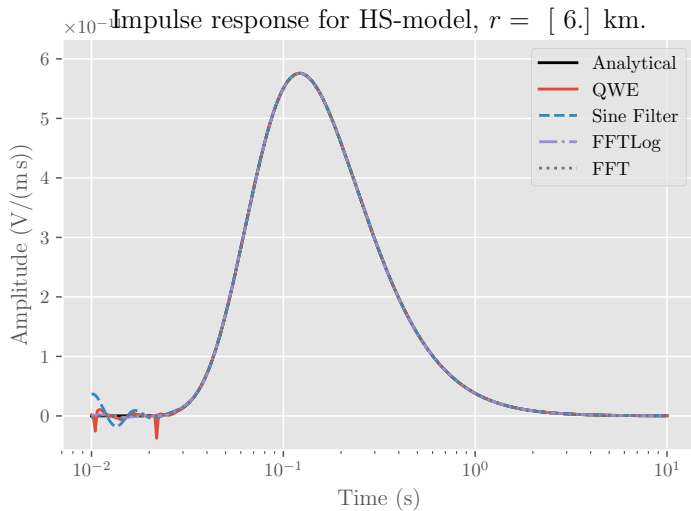
```
def reflections(depth, e_zH, Gam, lrec, lsrc, use_ne_eval):
    """ Calculate Rp, Rm.
```

```
    This function corresponds to equations 64/65 and
    A-11/A-12 in [Hunziker_et_al_2015]_. """
```

```
    if lrec < lsrc: # Rec above src layer: Pd not used
        # Eqs 89-94, A18-A23, B13-B15
        green = Pu*(Wu + pmw*Rm[:, :, 0, :])*fexp*Wd)
```

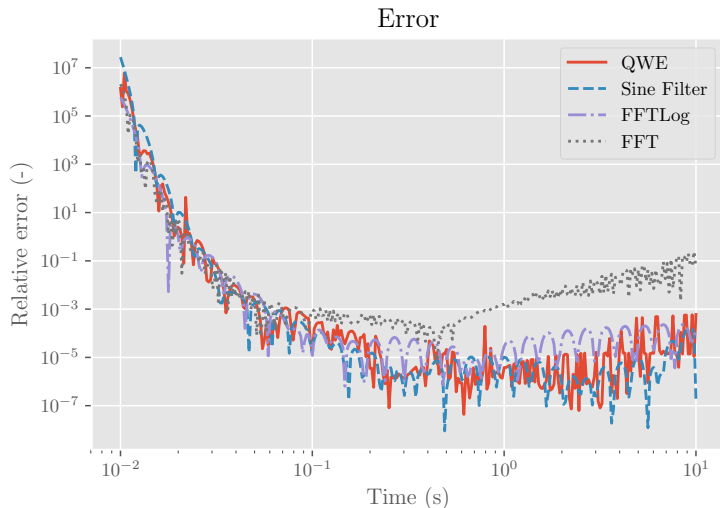
Educational II: Hankel and Fourier transforms

github.com/empymod/example-notebooks/2a_Time_Step-and-Impulse.ipynb



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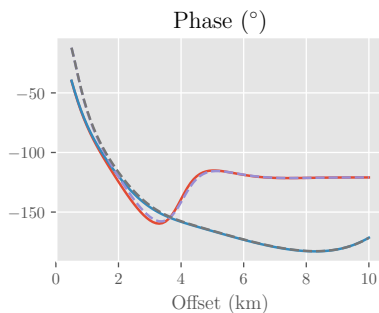
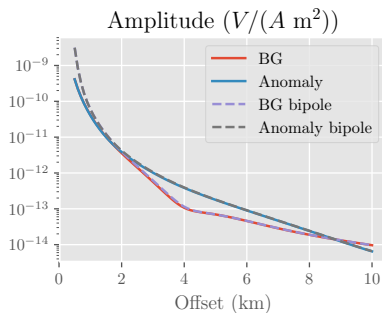
Method	# freq	min freq Hz	max freq Hz	time ms
FFTLog	60	1.8e-4	1.4e2	7
Sine-filter	116	5.3e-6	5.7e4	13
FFT	61	5.0e-4	5.2e2	640
QWE	173	3.4e-4	1.6e5	2113

Educational III: Point dipole vs finite dipoles

github.com/empymod/example-notebooks/1b_Frequency_Dipole-vs-Bipole.ipynb

Canonical model, point source versus 800 m dipole source.

Example Model: src-x, rec-x; $f = 1$ Hz



Educational IV: Diffusive approx. vs full wavefield

github.com/empymod/example-notebooks/3a_Full-Diffusive_comparison.ipynb

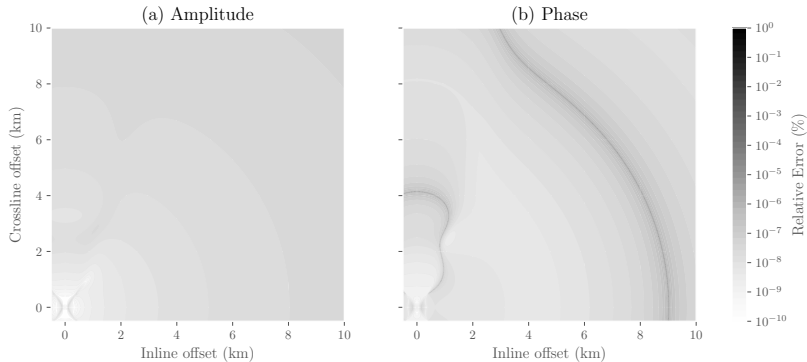
Frequency = 0.5 Hz;

$\varepsilon_{r;H} = \varepsilon_{r;V} = 1$;

$\mu_{r;H} = \mu_{r;V} = 1$

Analytical fullspace solution

Difference between full wavefield and diffusive approximation.



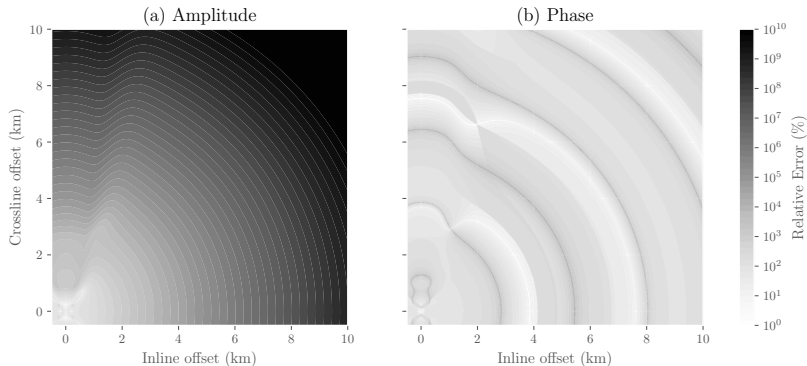
Educational IV: Diffusive approx. vs full wavefield

github.com/empymod/example-notebooks/3a_Full-Diffusive_comparison.ipynb

Frequency = 0.5 Hz; $\varepsilon_{r;H} = \varepsilon_{r;V} = 1$; $\mu_{r;H} = \mu_{r;V} = 10$

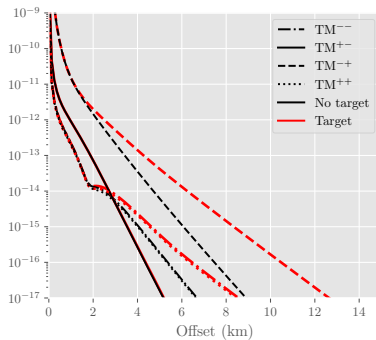
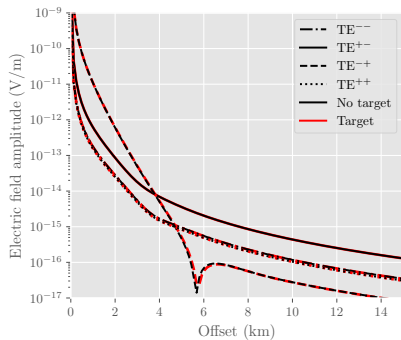
Analytical fullspace solution

Difference between full wavefield and diffusive approximation.



Educational V: TE/TM-split

github.com/empymod/example-notebooks/1c_TMTE-split.ipynb



Notebooks

Lots of examples (github.com/empymod)

The screenshot shows the GitHub repository page for **empymod**. The browser address bar displays <https://github.com/empymod>. The repository name is **empymod**, with a description: "An open-source full 3D electromagnetic modeller for 1D VTI media in Python." The repository URL is <https://empymod.github.io>. There are 0 repositories and 1 person associated with the repository.

Pinned repositories

- empymod**: An open-source full 3D electromagnetic modeller for 1D VTI media in Python. Python, 2 stars.
- empyscripts**: Add-ons for empymod. Python.
- example-notebooks**: Examples of the usage of empymod. Jupyter Notebook, 1 star.
- tmp-title**: Numerical Examples of the book "TODO ADD BOOK TITLE". Jupyter Notebook, 1 star.
- article-geo2017**: Werthmüller, D., 2017, An open-source full 3D electromagnetic modeler for 1D VTI media in Python: empymod: Geophysics, 82, WB9-WB19. Jupyter Notebook.
- article-tle2017**: Werthmüller, D., 2017, Getting started with controlled-source electromagnetic 1D modeling: The Leading Edge, 36, 352-355. Jupyter Notebook.

Installation

conda, pip, anaconda

- **Website:** empymod.github.io
- **Requirements:** Python3, NumPy, SciPy
- **Installation**
 - **pip:** `pip install empymod`
 - **Anaconda:** anaconda.com
conda: `conda install -c prisae empymod`
- **Anaconda-Navigator**
- **GitHub**

Installation

conda, pip, anaconda

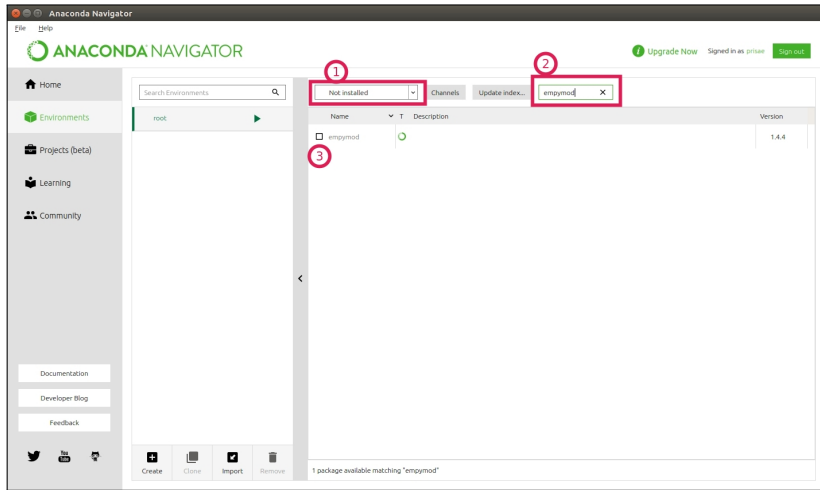
The screenshot shows the Anaconda Navigator interface. On the left is a sidebar with navigation options: Home, Environments, Projects (beta), Learning, and Community. The main area displays a list of installed channels. A modal window titled "Manage channels you want Navigator to include." is open, showing a list of channels with an "Add" button. The "prisen" channel is highlighted in red. Red arrows and circles 1, 2, and 3 indicate the "Channels" button, the "Add" button, and the "prisen" channel respectively.

Name	Type	Description	Version
prisen	Channel		0.1.0
anaconda	Channel		0.7.10
anaconda-fusion	Channel		custom
defaults	Channel		1.6.5
anaconda-project	Channel		0.8.0
asn1crypto	Channel		0.22.0
astroid	Channel		1.5.3
astropy	Channel	Community-developed python library for astronomy	2.0.2
babel	Channel	Utilities to internationalize and localize python applications	2.5.0
beckports	Channel		1.0
backports.shutil-get-terminal-size	Channel		1.0.0
backports.shutil-g...	Channel		1.0.0
beautifulsoup4	Channel	Python library designed for screen-scraping	4.6.0
bitarray	Channel	Efficient representation of arrays of booleans - c extension	0.8.1
bkcharts	Channel	Optional high level charts api built on top of bokeh	0.2

253 packages available

Installation

conda, pip, anaconda



Free and Open Source codes

en.wikipedia.org/wiki/Comparison_of_free_geophysics_software

- **SimPEG** simpeg.xyz
- **fatiando a terra** fatiando.org
- **PETGEM** petgem.bsc.es
- **pyGIMLi** pygimli.org
- **PyGMI** patrick-cole.github.io/pygmi
- **P223Suite** p223suite.sourceforge.net
- **DIPOLE1D, 2DMT** marineemlab.ucsd.edu
- **MARE2DEM** mare2dem.ucsd.edu
- **ga-aem** github.com/GeoscienceAustralia/ga-aem

Referencias



Werthmüller, D., 2017a

Getting started with controlled-source electromagnetic 1D modeling: The Leading Edge, 36, 352–355

doi: [10.1190/tle36040352.1](https://doi.org/10.1190/tle36040352.1)



Werthmüller, D., 2017b

An open-source full 3D electromagnetic modeler for 1D VTI media in Python: empymod: Geophysics, 82, WB9–WB19

doi: [10.1190/geo2016-0626.1](https://doi.org/10.1190/geo2016-0626.1)



Hunziker, J., J. Thorbecke, and E. Slob, 2015

The electromagnetic response in a layered vertical transverse isotropic medium: A new look at an old problem; Geophysics, 80, F1–F18

doi: [10.1190/geo2013-0411.1](https://doi.org/10.1190/geo2013-0411.1); software: software.seg.org/2015/0001



Key, K., 2012

Is the fast Hankel transform faster than quadrature?; Geophysics, 77, F21–F30

doi: [10.1190/GEO2011-0237.1](https://doi.org/10.1190/GEO2011-0237.1); software: software.seg.org/2012/0003



Slob, E., J. Hunziker, and W. A. Mulder, 2010

Green's tensors for the diffusive electric field in a VTI half-space; PIER, 107, 1–20

doi: [10.2528/PIER10052807](https://doi.org/10.2528/PIER10052807)