Australian Government
Geoscience Australia

MTPy for magnetotelluric data analysis and visualisation

Alison Kirkby

on behalf of:

Jared Peacock, Fei Zhang, Rakib Hassan, Brenainn Moushall, Yingzhi Gou, Lars Krieger, Geoscience Australia MT team (Jingming Duan, Wenping Jiang, Darren Kyi, Adrian Hitchman), many other scientists, developers, and bug-finders, past and present…

Outline

Background

Overview of the modules

Installing MTPy

Using MTPy – practical demo

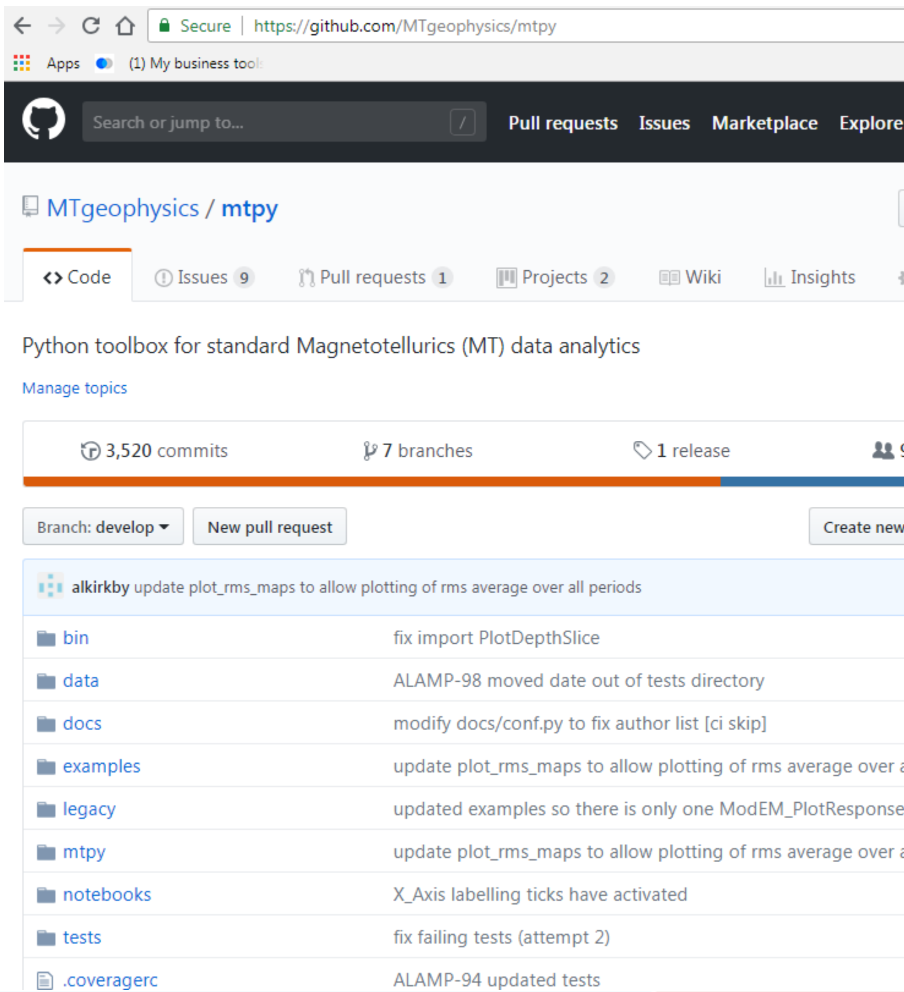
Background on MTPy

Initiated in 2013 at the University of Adelaide

- Jared Peacock, Lars Krieger, myself, others….

2016 - Geoscience Australia commenced development

- Clean up
- Testing suite & documentation
- Functionality development
- Apply software engineering “best practice”



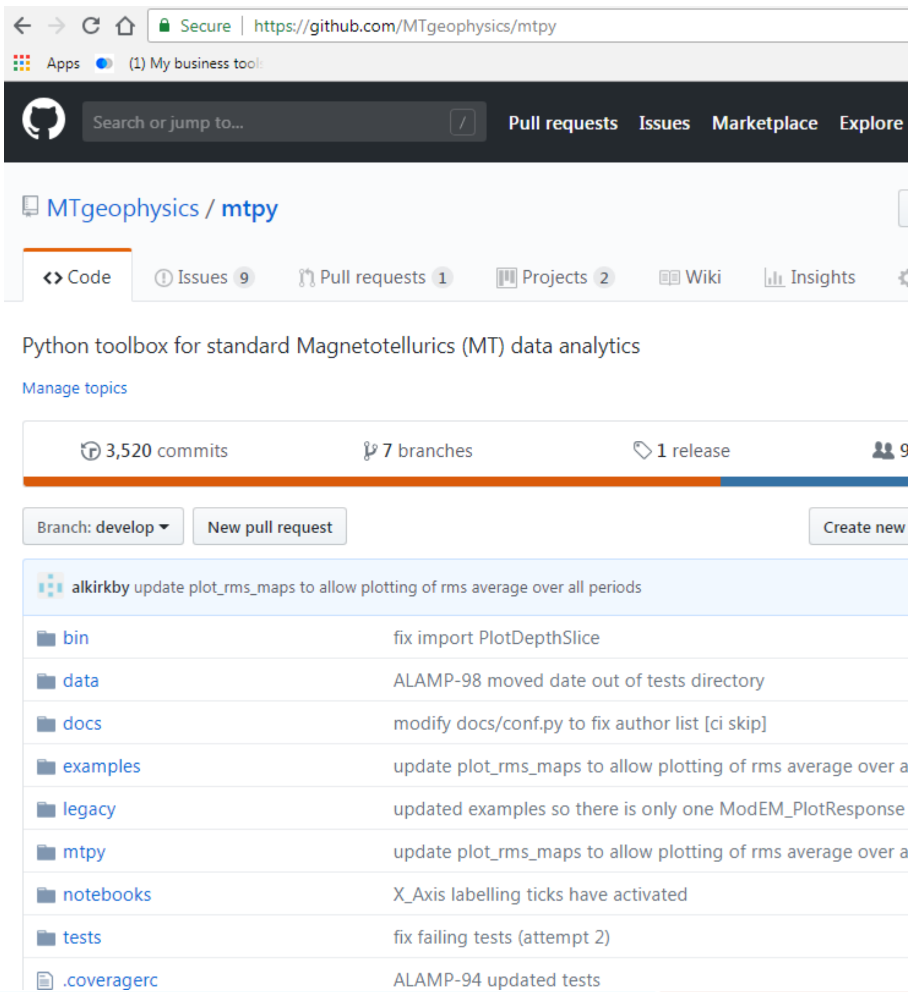
Background on MTPy

2017 - Moved to a new repository
https://github.com/MTgeophysics/mtpy

- Merged 2 versions

GA continues maintenance/development in collaboration with Jared Peacock at USGS

Look out for MTPy v. 2.0



MTPy access and usage

General Public License (3.0) – free, open source

However, as with most open source software:

- We provide no warranty
- If you modify the code, please link to the original

If you use MTPy we would appreciate it if you acknowledge the use of the software and provide a link to the repository, you can cite:

Krieger, L. & Peacock, J. 2014. A Python Toolbox for Magnetotellurics. Computers and Geosciences, v.72, p167-175

Kirkby, A., Zhang, F., Peacock, J., Hassan, R., & Duan, J. (2019). The MTPy software package for magnetotelluric data analysis and visualisation. Journal of Open Source Software, 4(37), 1358-1358. doi:10.21105/joss.01358

Please let us know of any bugs via the GitHub 'Issues' page

MTPy is....

A collection of tools to (hopefully) help you carry out processing, analysis, modelling, and visualisation of MT data

A work in progress

Largely script based

MTPy is not...

Perfect

Complete

Bug-free

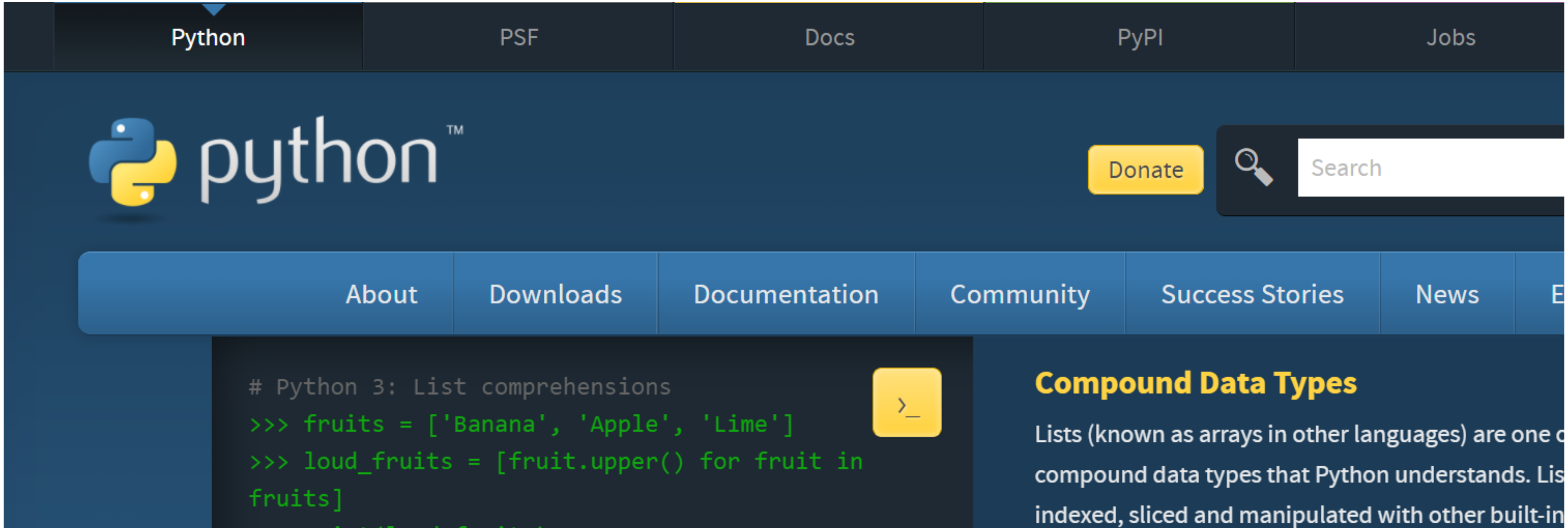
A black box

(i.e. we strongly advise to check your outputs and understand what you are doing)

Python

Useful to have some background knowledge of Python to get the most out of MTPy

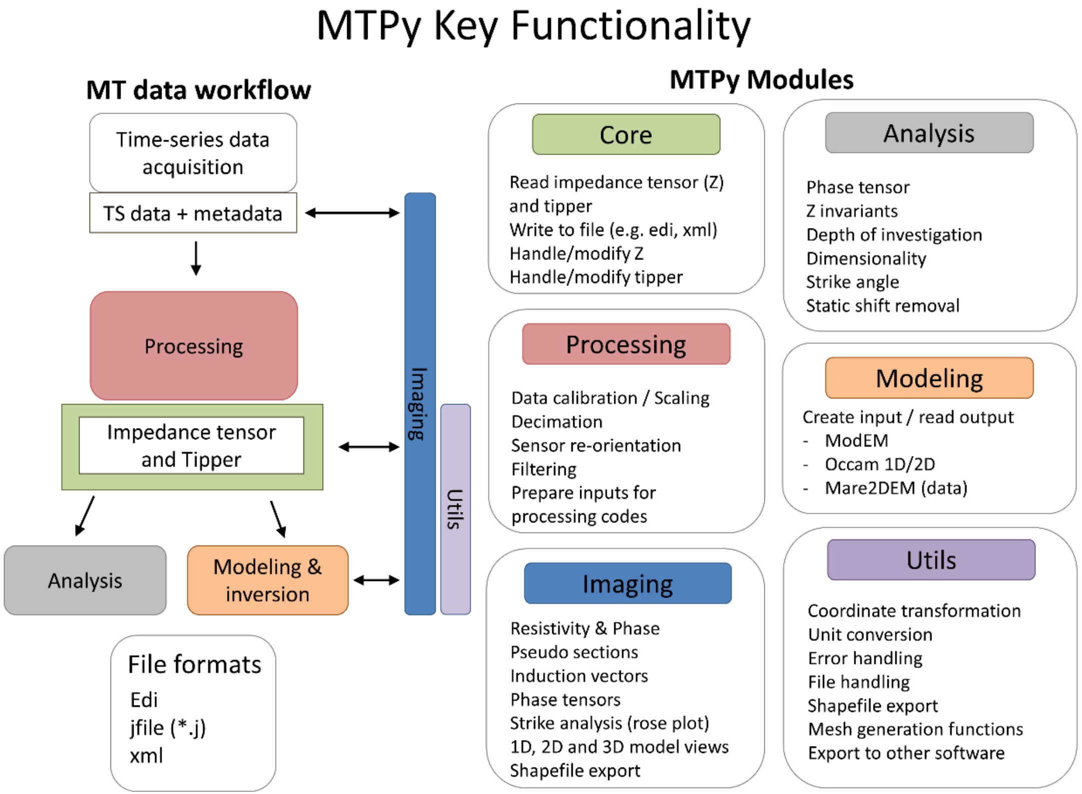
Lots of (free and paid) online resources and courses



MTPy overview

- Structured around the main analysis steps for MT
- Core, Processing, Analysis, Modeling, Imaging + Utils to support all functionality
- Interlinked
- This presentation will cover Core, Analysis, Imaging, Modeling, and Utils

MTPy structure (modified from Krieger and Peacock, 2014)



MTPy v2.0 – draft structure

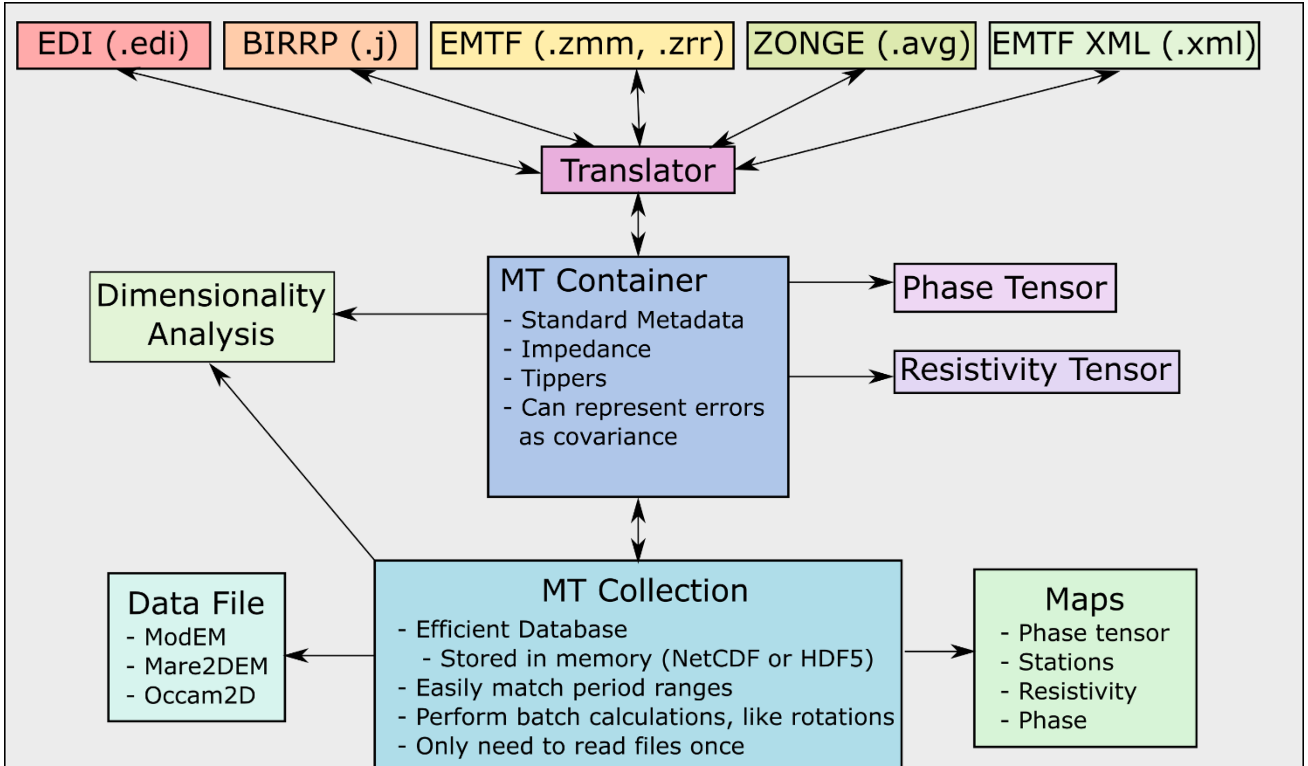


Image courtesy Jared Peacock

Core

Basic handling of frequency domain (processed) data

Reading in of station metadata (e.g. location etc)

Conversions from Z to apparent resistivity and phase and vice versa (via **utils** modules)

Functions include: reading edi file, rewriting, handling edi file set. Allows you to rewrite the data with some change made (e.g. interpolate onto different frequencies).

Some of the core modules link to **imaging** to allow plotting.

Analysis

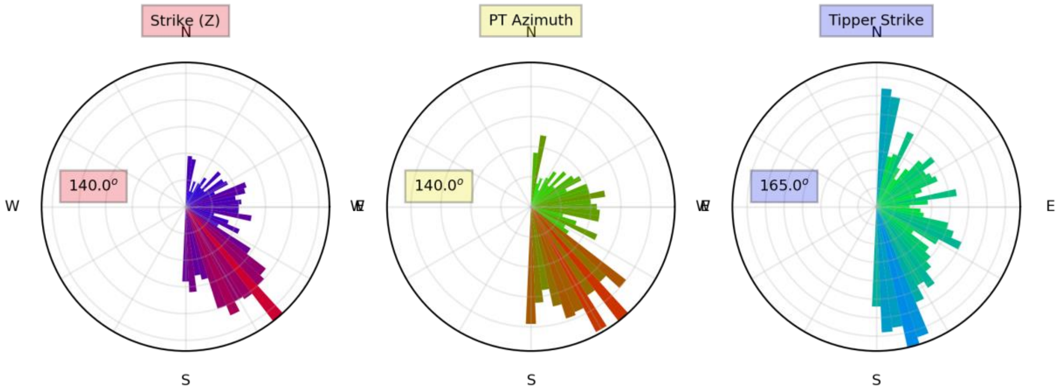
Covers analysis of MT data completed prior to modelling

Dimensionality, strike analysis, phase tensors, static shift calculation, penetration depth, invariants

Links with **core** for reading the data, **utils** to carry out some of the analyses and **imaging** to view the results

In this presentation we will cover:

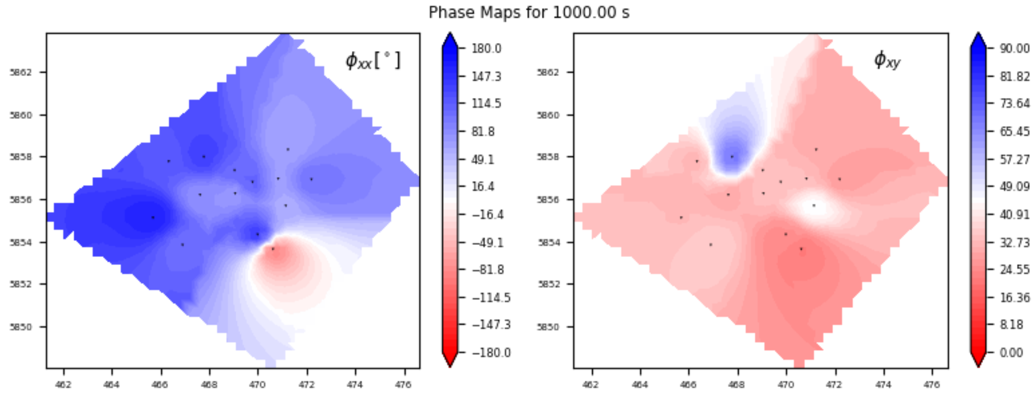
- dimensionality
- strike analysis
- phase tensor (plots)
- penetration depth

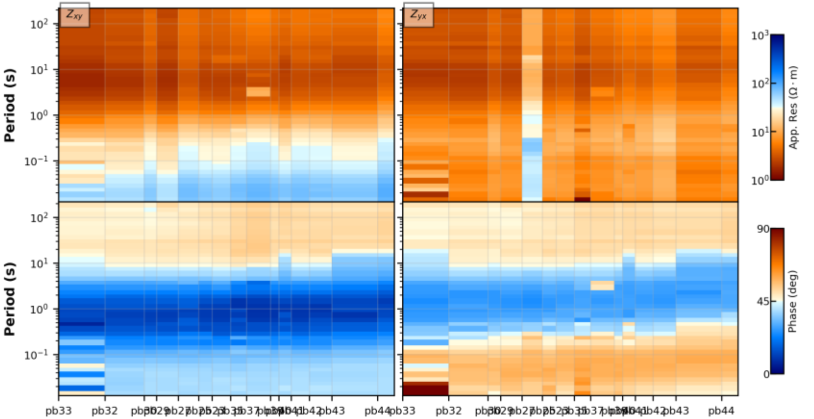


Imaging

Plotting of impedance/resistivity/phase data as well as the results from modules within **analysis**, **modeling**. Includes:

- Data plots (e.g. resistivity/phase at a single site and on maps)
- **Analysis** plots (e.g. strike angle, phase tensors, penetration depth)
- **Model** plots (e.g. data/response, resistivity model maps/slices)





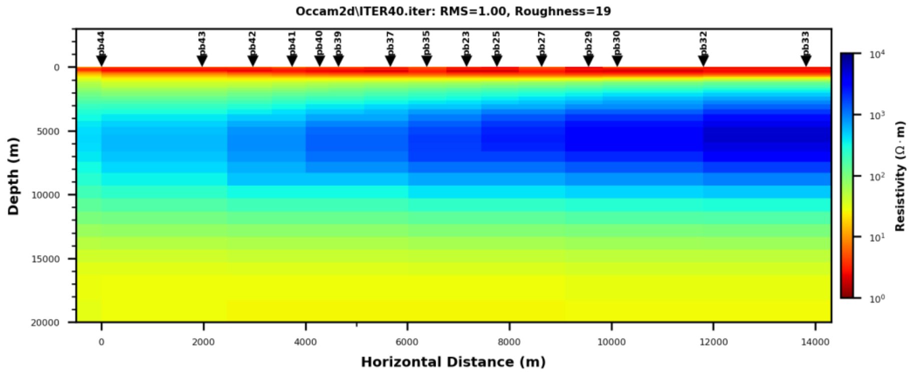
Modeling

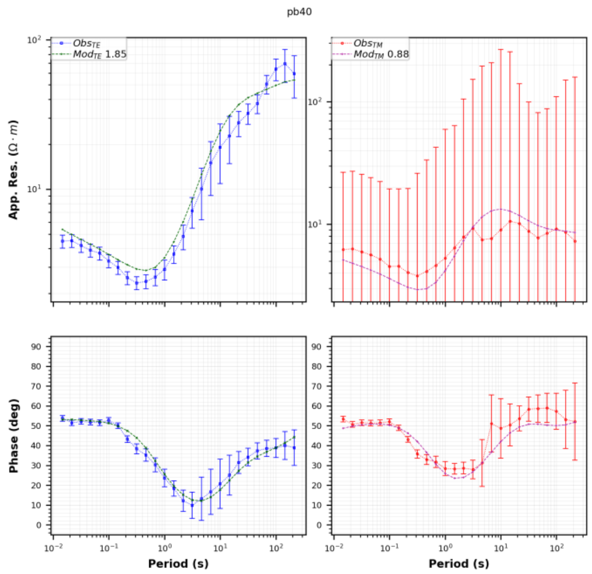
Wrapper for commonly used modelling/inversion packages

- Occam1D
- Occam2D
- Mare2DEM (data file only)
- ModEM

Creates input files and allows visualisation of outputs.

Also allows conversion of outputs to other formats (e.g. Gocad sgrid)





Utils

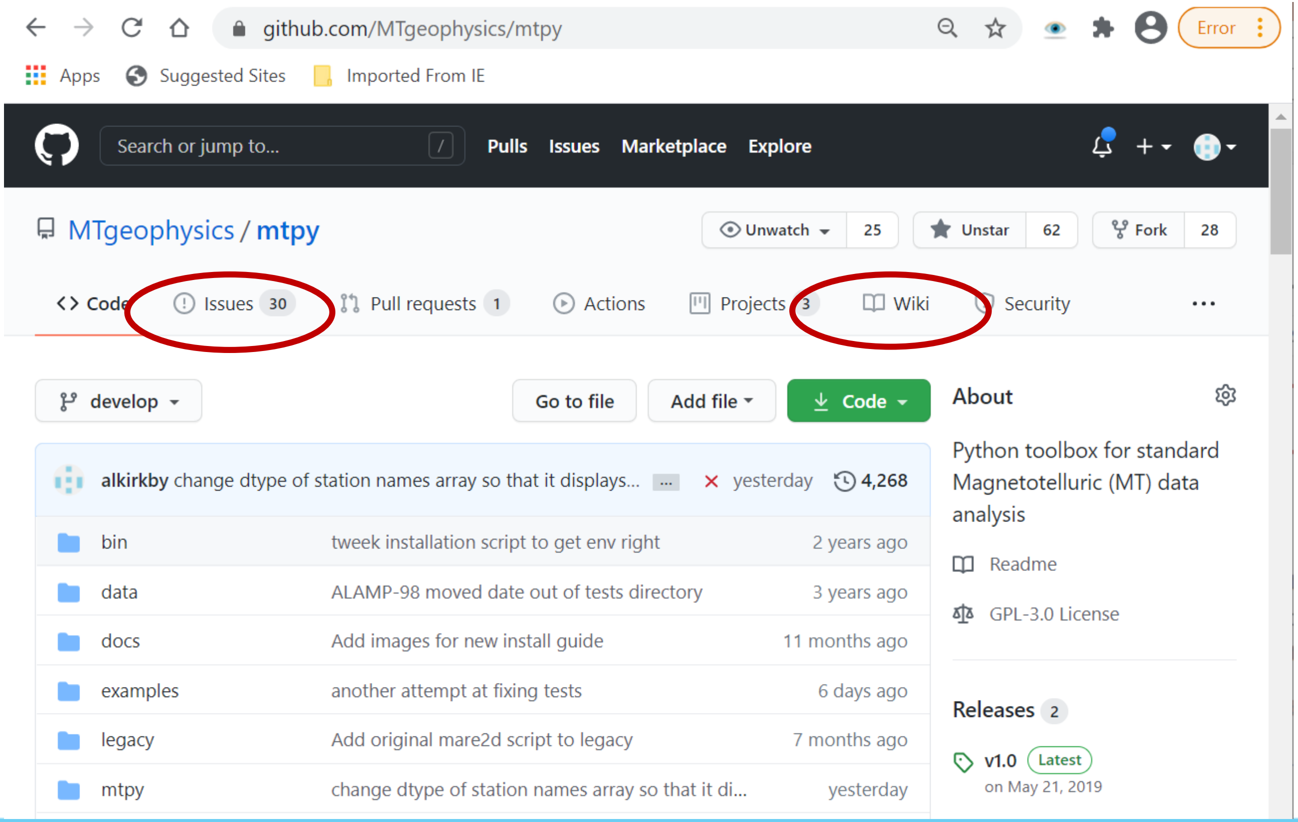
Contains much of the functionality that underlies all other modules, e.g.:

- Projections and transformations (gis_tools)
- Conversion to external formats (shapefiles, gocad, convert_modem_data_to_geogrid)
- Filehandling
- Calculator

+ more….

array2raster.py
Ascii_replace_res_values.py
basemap_tools.py
calculator.py
concatenate_input.py
configfile.py
convert_modem_data_to_geogrid.py
edi_folders.py
exceptions.py
filehandling.py
gis_tools.py
gocad.py
matplotlib_utils.py
mesh_tools.py
mtpy_decorator.py
mtpylog.py
plot_geotiff_imshow.py
plot_rms_iterations.py
shapefiles.py
shapefiles_creator.py

https://github.com/MTgeophysics/mtpy



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Apps Suggested Sites Imported From IE

Error

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Overview

A Python Toolbox for Magnetotelluric (MT) Data Processing, Analysis, Modelling and Visualization

- Home Page: https://github.com/MTgeophysics/mtpy
- API Documentation: http://mtpy2.readthedocs.io/en/develop/
- Issue tracking: https://github.com/MTgeophysics/mtpy/issues
- Installation Guide (Wiki Pages): https://github.com/MTgeophysics/mtpy/wiki
- User Guide: https://github.com/MTgeophysics/mtpy/blob/develop/docs/MTPy%20User%20Guide.pdf

Note that this repository has superseded the geophysics/mtpy and GeoscienceAustralia/mtpy2

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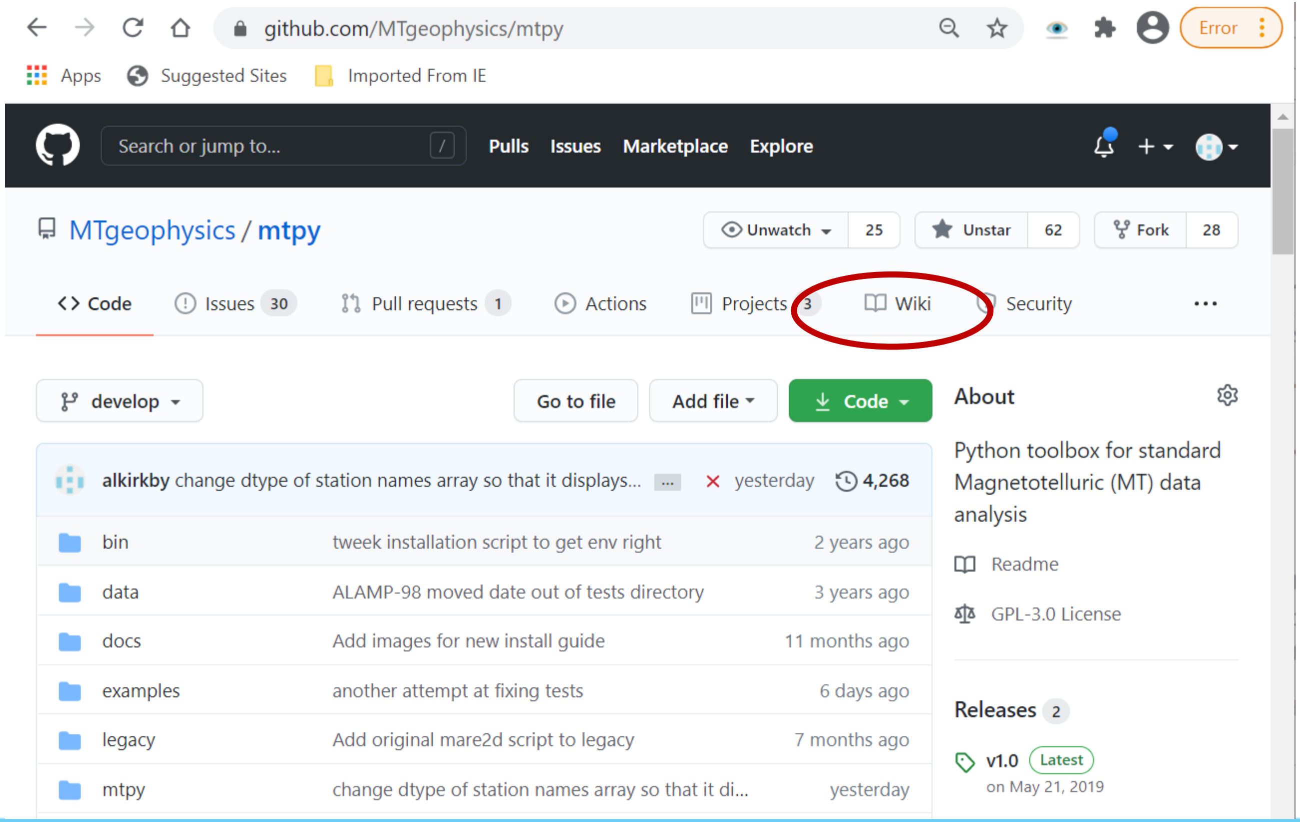
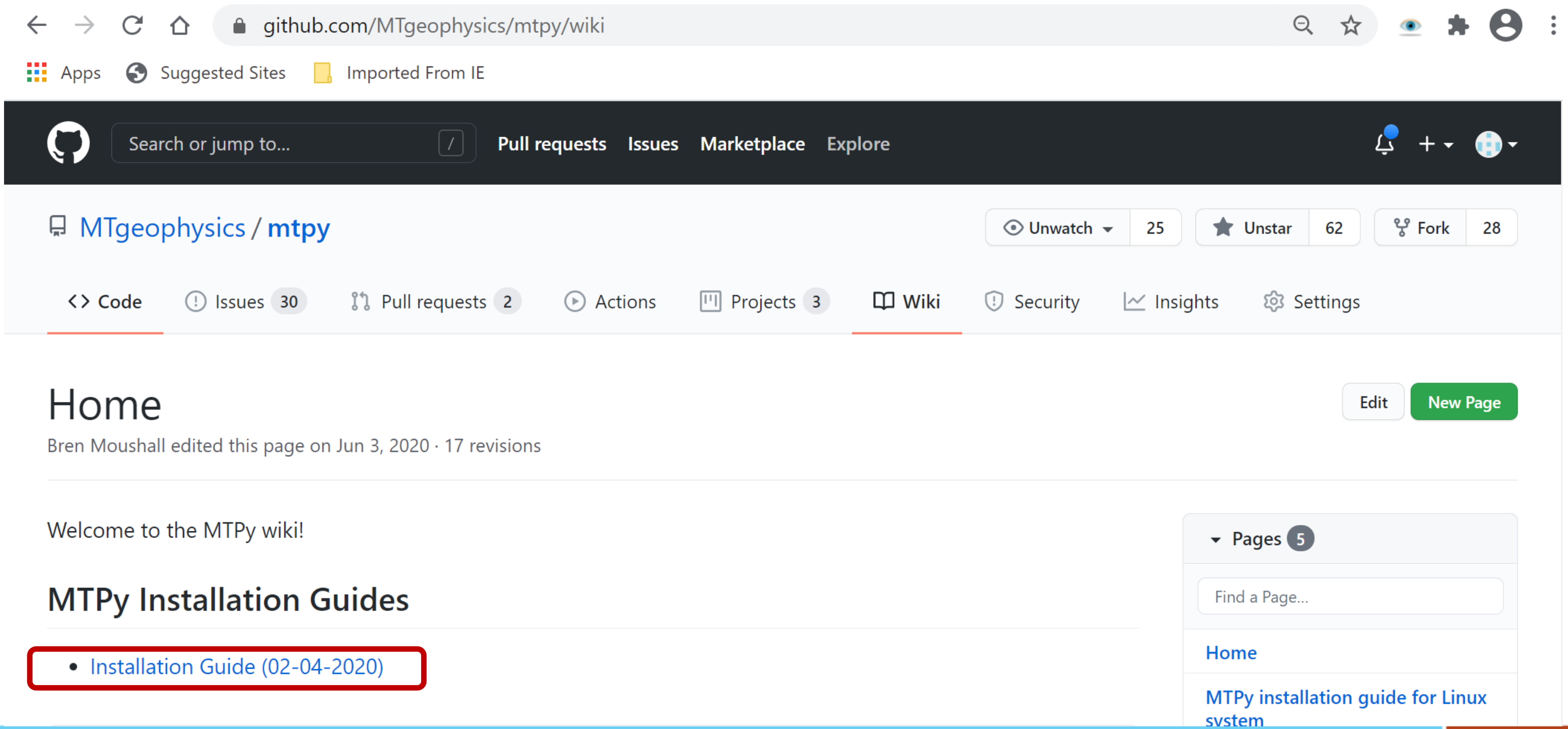


Wiki (Installation guide)

https://github.com/MTgeophysics/mtpy/wiki/MTPy-installation-guide-for-Windows-10-and-Ubuntu-18.04



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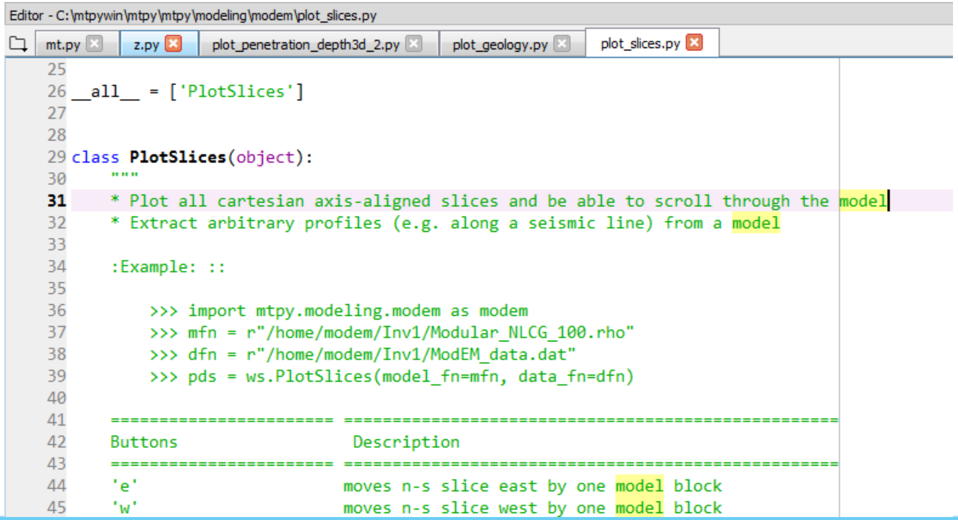
Documentation

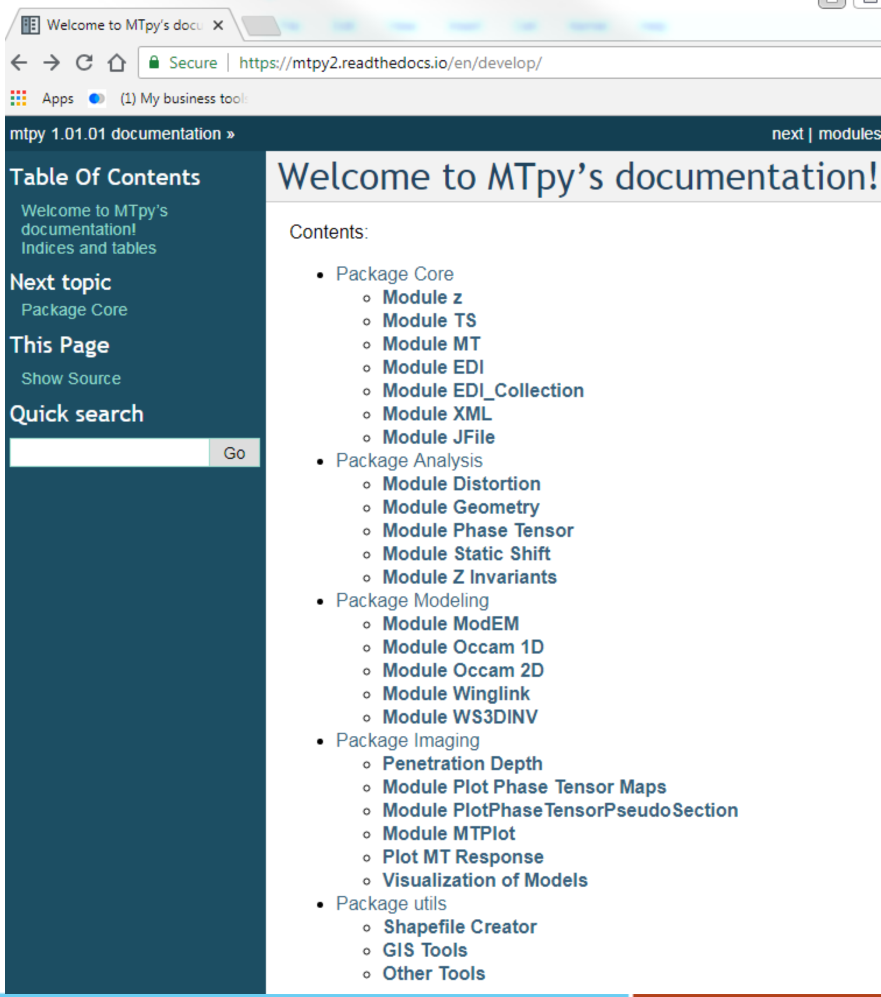
https://mtpy2.readthedocs.io/en/develop/

Pulled from comments in the modules

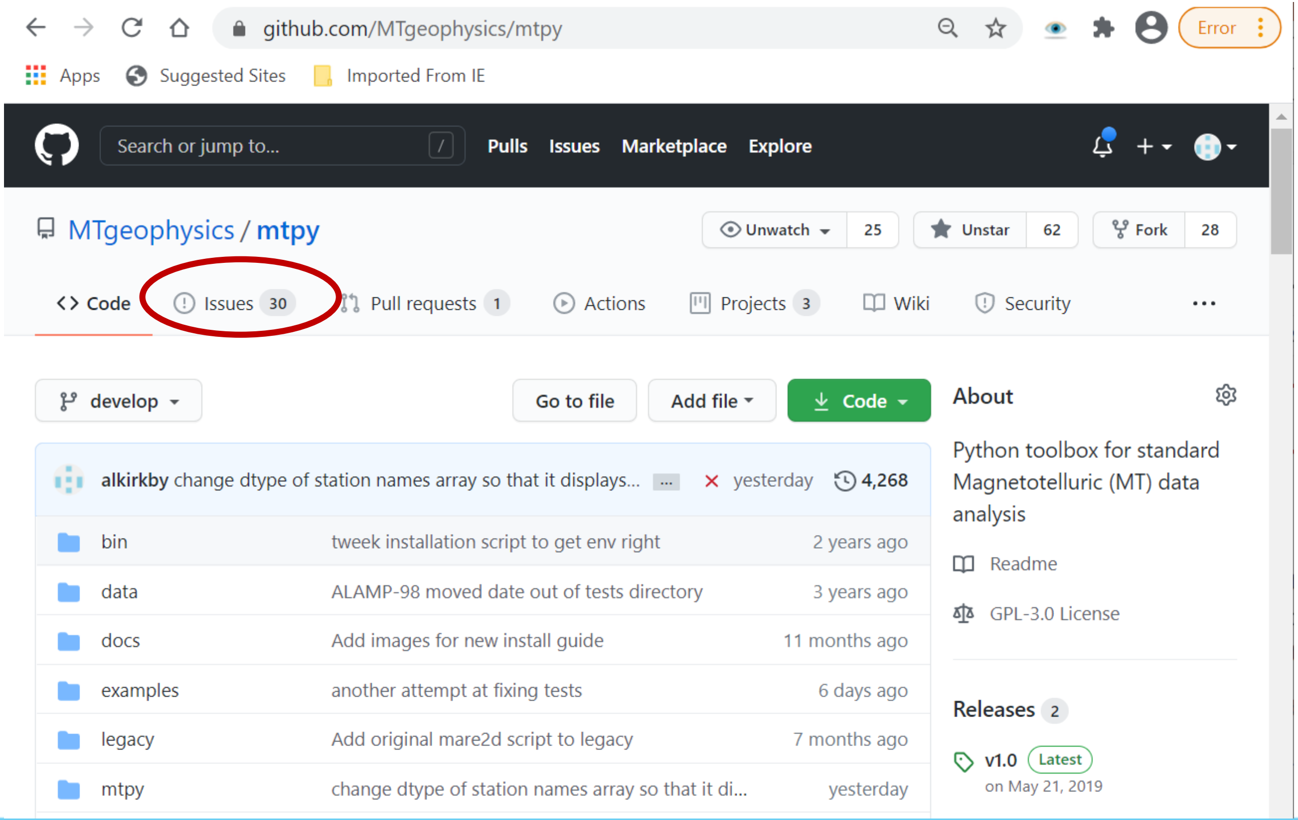
Some modules **may** be missing

If it's missing, let us know

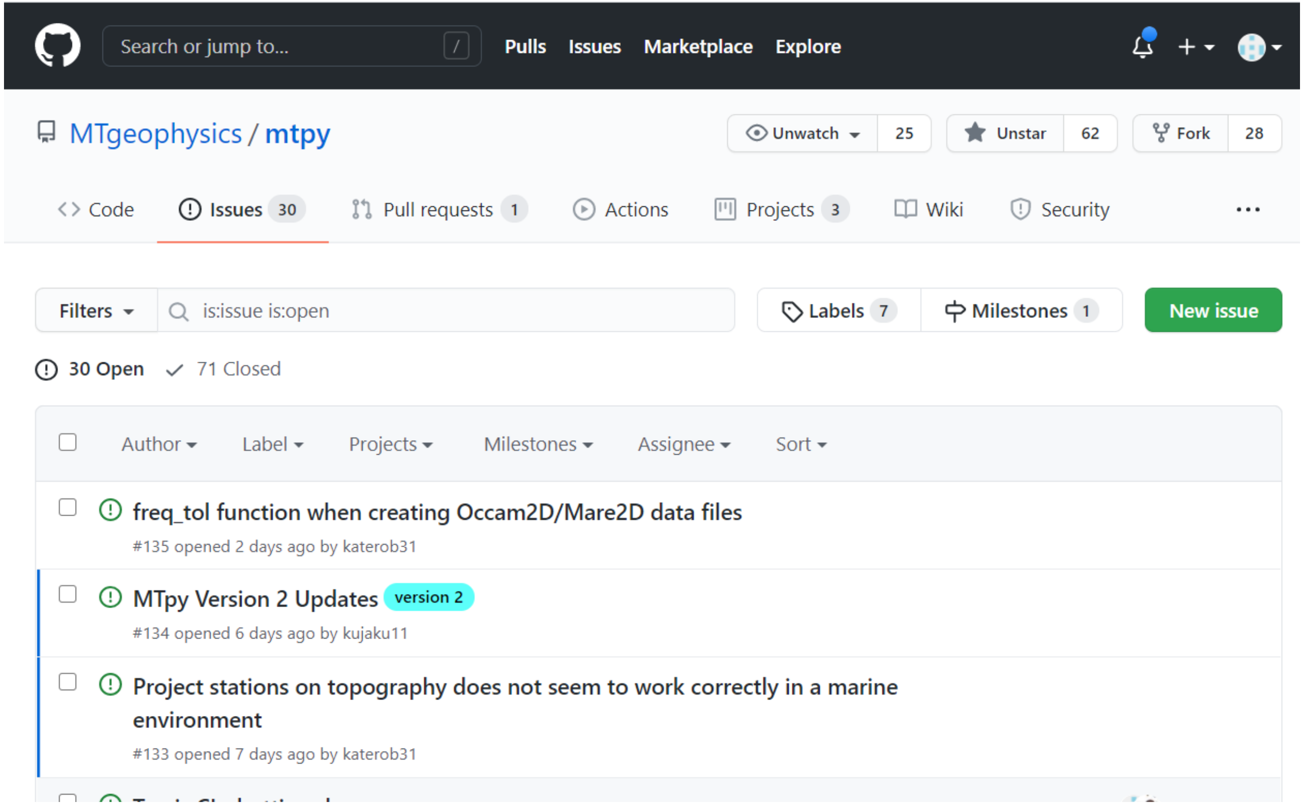




https://github.com/MTgeophysics/mtpy



Issues


Search or jump to...
Pulls
Issues
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MTgeophysics / mtpy
Unwatch 25
Unstar 62
Fork 28
Code
Issues 30
Pull requests 1
Actions
Projects 3
Wiki
Security
Filters
is:issue is:open
Labels 7
Milestones 1
New issue
30 Open
71 Closed
Author
Label
Projects
Milestones
Assignee
Sort
freq_tol function when creating Occam2D/Mare2D data files
#135 opened 2 days ago by katerob31
MTpy Version 2 Updates
version 2
#134 opened 6 days ago by kujaku11
Project stations on topography does not seem to work correctly in a marine environment
#133 opened 7 days ago by katerob31

Getting started - installing MTPy

We recommend installing the following:

- Anaconda Python distribution: https://anaconda.org/anaconda/python
- Git shell (if on windows) (e.g. git for windows https://git-scm.com/download/win)

We suggest installing these into a common directory so it does not interfere with other installations

Once these are installed, you can clone the MTPy repository

```
>> git clone https://github.com/MTgeophysics/mtpy.git
```

Getting started - installing MTPy

Install dependencies

cd mtpy

>> conda install gdal libgdal geopandas netcdf4 pyyaml

>> pip install obspy

To get updated MTPy (recommend doing this every day):

>> git pull

Examples folder

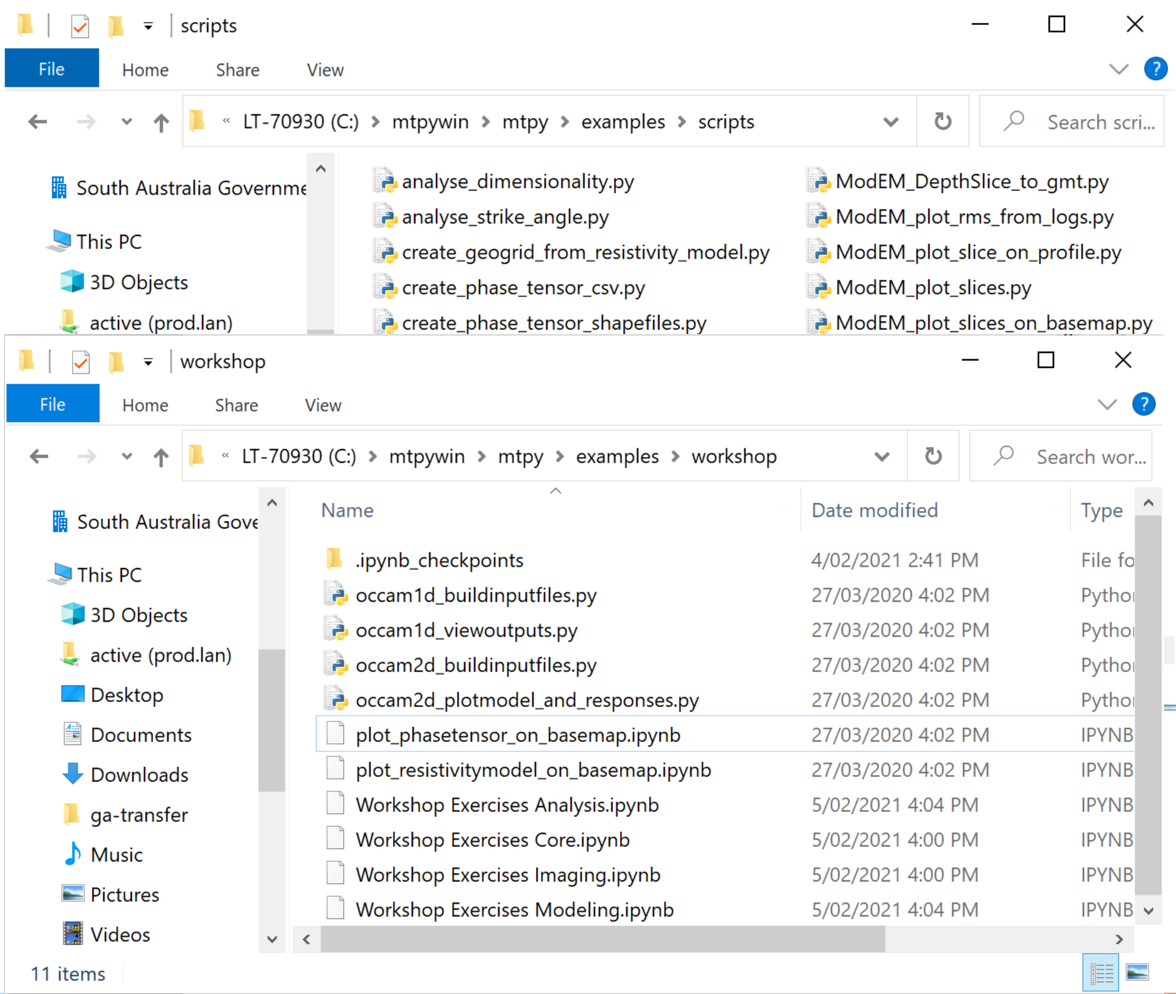
mtpy/examples/scripts

- Example scripts

mtpy/examples/notebooks &

mtpy/examples/workshop

- Example notebooks



Running MTPy

We recommend using either:

- Jupyter notebook, OR
- Development environment (e.g. Spyder, PyCharm)

Jupyter notebook

Web browser based

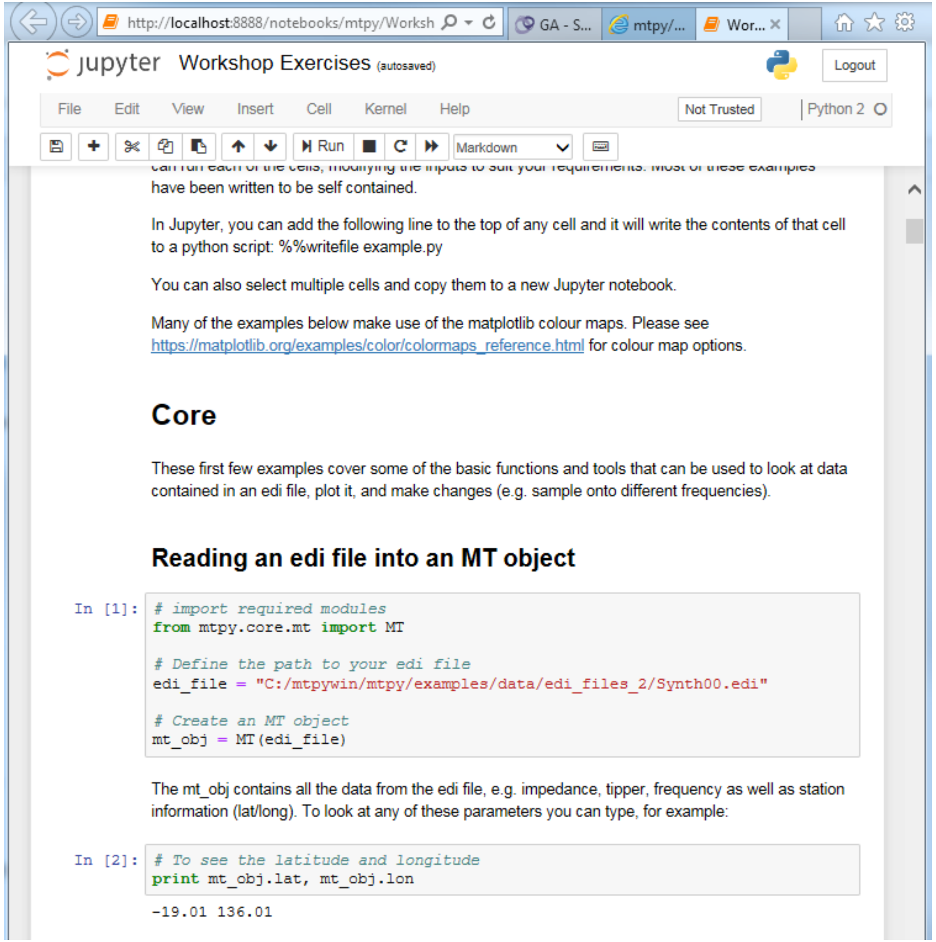
Run python code or comments

Run one cell at a time and it stores the result in memory

Can write individual cells to a python script %%writefile example.py

Can also export to latex, html – great for demonstration

The exercises for this workshop are in Jupyter format



Spyder

Interface for working with Python code

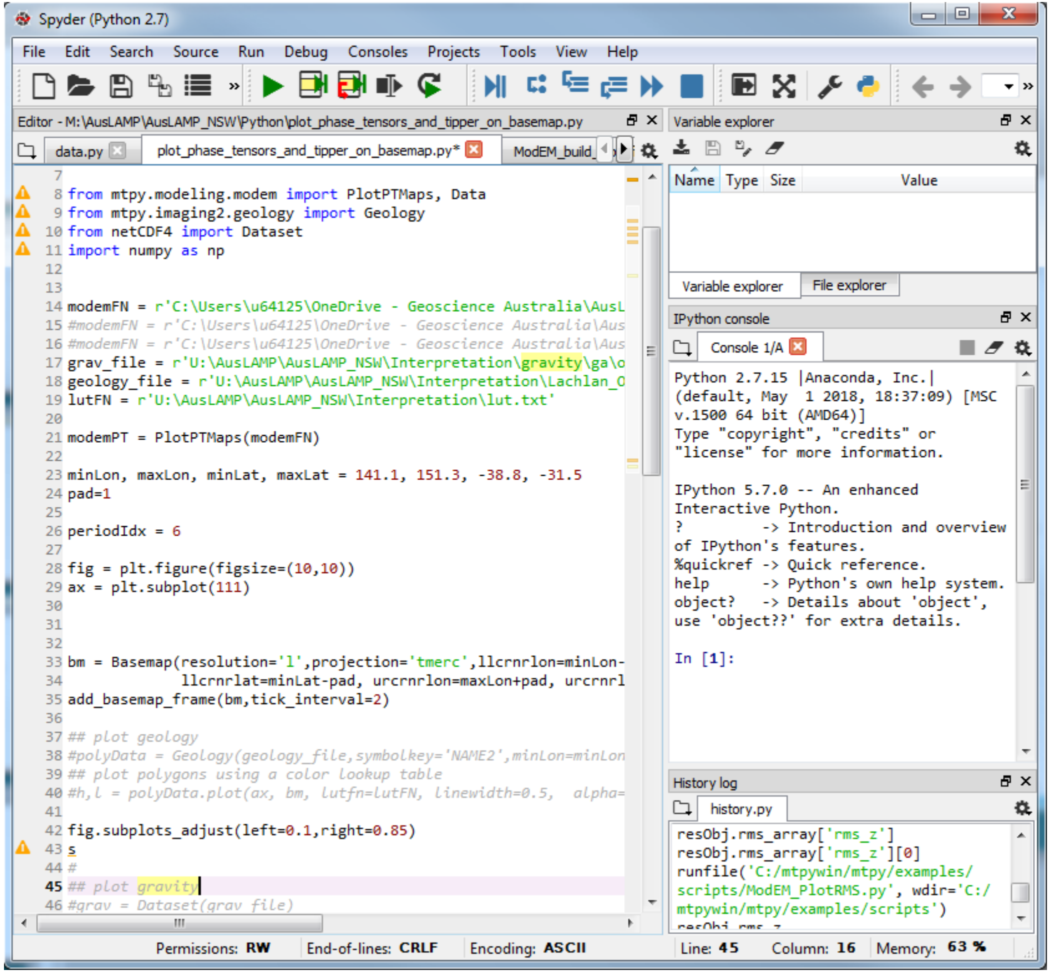
Interactive – warnings for syntax errors etc

Easy to read code

Stores variables in the console allowing you to inspect them later.

Options for pop-out / inline plots

Great for day-to-day use



Installation of Spyder/Jupyter

Neither of these are installed in the MTPy package so you will need to install them.

>> conda install jupyter

>> jupyter notebook &

AND/OR

>> conda install spyder

>> spyder &

A word on python objects

Most functions in MTPy underpinned by objects

MT object

- MT.lat, MT.lon, MT.elev, other standard metadata
- Z object (impedance tensor) and Tipper object

Z object

- Z.freq - Frequency array
- Z.z, Z.z_err, Z.resistivity, Z.resistivity_err, Z.phase, Z.phase_err, etc…

Apple


https://unsplash.com/photos/gDPaDDy6_WE

Apple.colour = red
Apple.width = 0.07 (m)
Apple.height = 0.08 (m)
Apple.compute_volume()

Practical use cases (using AusLAMP data!)

1. Reading, writing an edi file
2. Simple analysis tools (dimensionality, strike angle)
3. Plotting an edi file
4. Penetration depth (Niblett-Bostick transform)
5. Data plots (phase tensor, pseudosections)
6. Inputs and outputs for inversion

Dataset

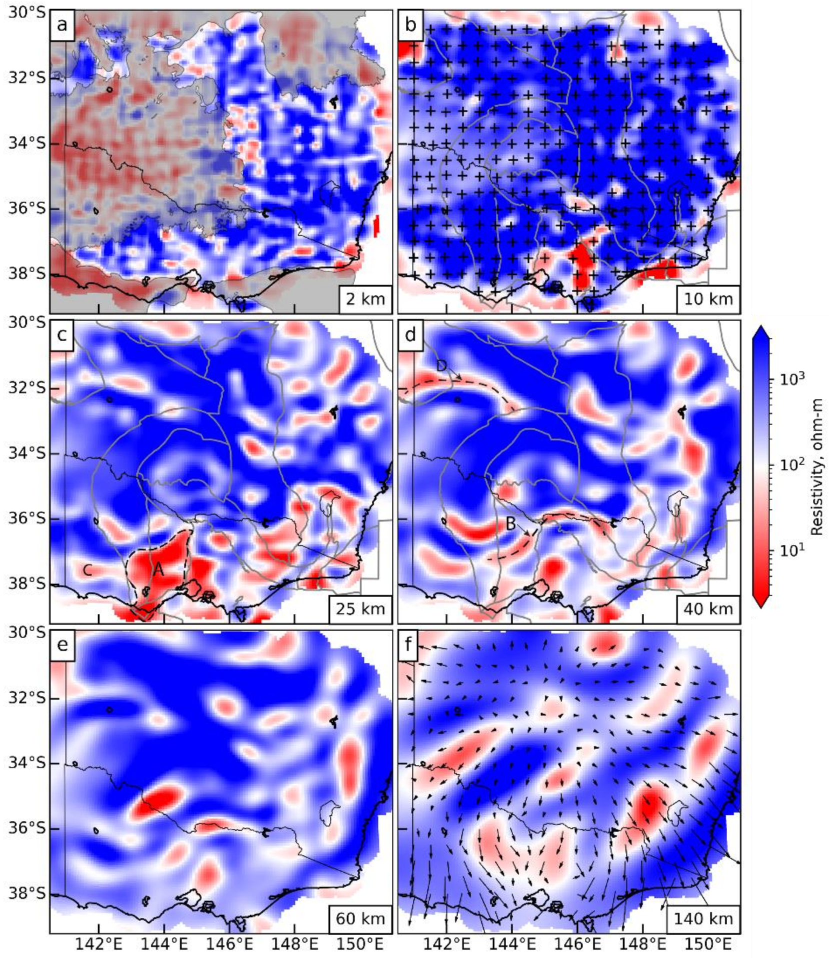
AusLAMP data from New South Wales and Victoria

If you want to see more…..

Data available from:
http://dx.doi.org/10.11636/Record.2020.011 (NSW) and
http://dx.doi.org/10.11636/Record.2018.021 (Victoria)

Model available from:
http://dx.doi.org/10.26186/131889

Paper (Kirkby et al 2020) available from:
https://doi.org/10.1016/j.tecto.2020.228560



Read an edi file into an MT object

```
# import required modules
from mtpy.core.mt import MT

# Define the path to your edi file
edi_file = r"C:\edifiles\E15.edi"

# Create an MT object
mt_obj = MT(edi_file)
```

Get station location

```
# To see the latitude and longitude
print(mt_obj.lat, mt_obj.lon)
```

```
-30.497572222222225 148.0434111111111
```

```
# To see the easting, northing, and elevation
print(mt_obj.east, mt_obj.north, mt_obj.elev)
```

```
600131.4714907524 6625614.777263684 134.0
```

Interrogate the data

```
# e.g. to see the frequencies in the file
print(mt_obj.Z.freq)
```

```
[2.00000e-01 1.56250e-01 1.25000e-01 1.00000e-01 7.93651e-02 6.32911e-02
 5.00000e-02 3.96825e-02 3.16456e-02 2.51256e-02 1.99203e-02 1.56250e-02
 1.25000e-02 1.00000e-02 7.93651e-03 6.32911e-03 5.00000e-03 3.96825e-03
 3.16456e-03 2.51256e-03 1.99203e-03 1.56250e-03 1.25000e-03 1.00000e-03
 7.93651e-04 6.32911e-04 5.00000e-04 3.96825e-04 3.16456e-04 2.51256e-04
 1.99203e-04 1.56250e-04 1.25000e-04 1.00000e-04 7.93651e-05 6.32911e-05
 5.00000e-05 3.96825e-05 3.16456e-05 2.51256e-05 1.99203e-05 1.56250e-05
 1.25000e-05 1.00000e-05]
```

Interrogate the data (cont'd)

```
print(mt_obj.Z.z)
```

```
[[[-5.456737e-02-0.0147217j   2.296910e+00+0.6397
567j ]
  [-1.869760e+00-0.9006823j   3.510076e-01-0.0603
598j ]]

 [[-1.001216e-01-0.06415853j  2.333180e+00+0.6731
247j ]
  [-1.789870e+00-0.8923373j   3.530071e-01-0.0458
7761j]]
```

```
print(mt_obj.Z.z_err)
```

```
 [[0.03469457 0.05178892]
  [0.02801203 0.04181375]]

 [[0.01620979 0.02159036]
  [0.01234237 0.01643919]]

 [[0.00705637 0.00857404]
  [0.00551617 0.00670258]]
```

```
print(mt_obj.Z.resistivity)
```

```
[[1.00940774e-02 1.79648772e+01]
 [1.36108586e+01 4.00845113e-01]]

[[5.65626070e-02 2.35873031e+01]
 [1.59996019e+01 5.06875071e-01]]

[[1.19901742e-01 2.95245908e+01]
 [1.91212334e+01 6.85415226e-01]]

[[2.03307091e-01 3.50150890e+01]
 [2.17167443e+01 8.51211575e-01]]
```

```
print(mt_obj.Z.phase)
```

```
[[-147.34800433   16.09290219]
 [-153.50151171   -7.40478723]]

[[-137.29146041   16.25317148]
 [-153.13346078    0.85364649]]

[[-118.14735977   16.63432523]
 [-152.02876069    5.70966883]]

[[ -99.20005198   17.31974842]
 [-149.55405135   13.14943136]]
```

Editing data

E.g. interpolate to 5 periods per decade

```
# 5 periods per decade from 10^-4 to 10^3 seconds
from mtpy.utils.calculator import get_period_list
new_freq_list = 1./get_period_list(10,3e3,5)

# Create new Z and Tipper objects containing interpolated data
new_Z_obj, new_Tipper_obj = mt_obj.interpolate(new_freq_list)

# Write a new edi file using the new data
mt_obj.write_mt_file(
            save_dir=r'C:\tmp',
            fn_basename='E15_5ppd',
            file_type='edi',
            new_Z_obj=new_Z_obj, # z object
            new_Tipper_obj=new_Tipper_obj, # tipper object
            longitude_format='LONG', # write longitudes as 'LONG'
            latlon_format='dd'# write as decimal degrees
)
```

```
'C:\\tmp\\E15_5ppd_2.edi'
```

Dimensionality

based on phase tensor ellipses (Caldwell et al 2004, Bibby et al 2005)

```
# Import required modules
from mtpy.analysis.geometry import dimensionality

#Have a look at the dimensionality
print(dimensionality(z_object = mt_obj.Z,
                     skew_threshold = 3, # threshold for 3D
                     eccentricity_threshold=0.1 # threshold for 2D
                     ))
```

```
[1 1 1 1 1 2 3 2 3 3 3 3 3 3 3 3 3 3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2
2 2 2 1
 2 3 1 1 1 1 1]
```

Strike angle

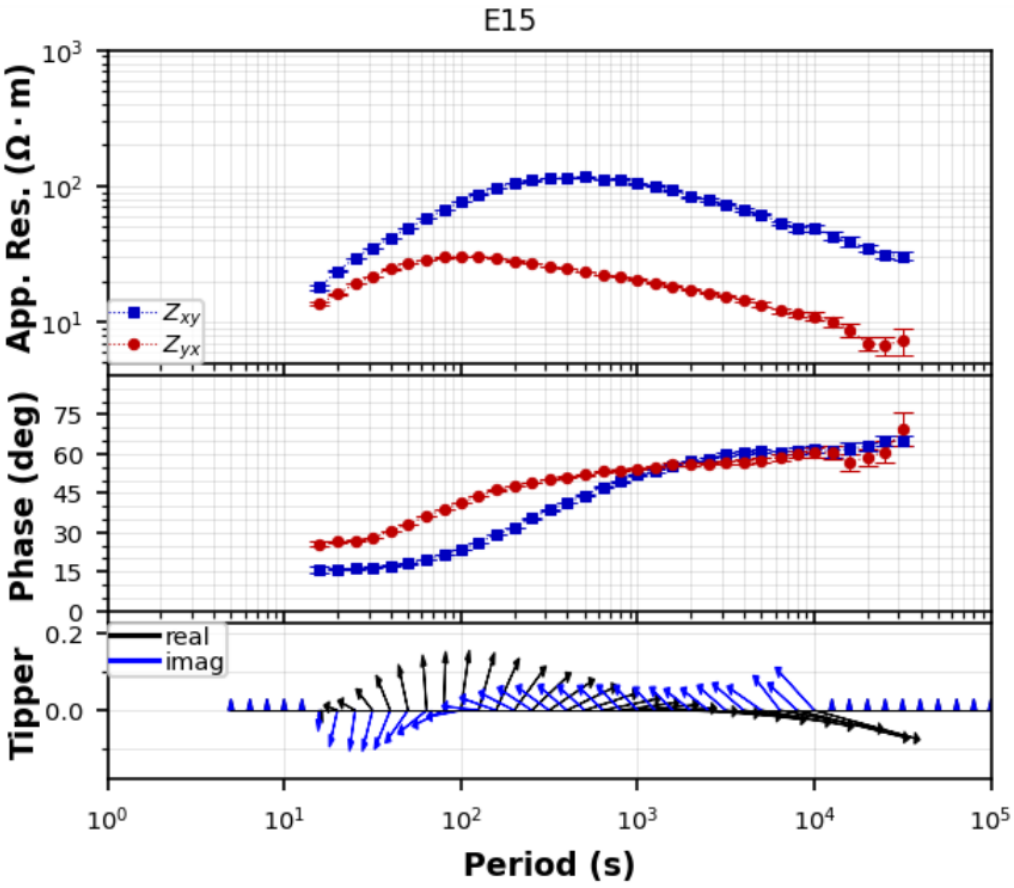
```
from mtpy.analysis.geometry import strike_angle

# calculate strike
strike = strike_angle(z_object = mt_obj.Z,
                      skew_threshold = 3, # threshold for 3D
                      eccentricity_threshold=0.1 # threshold for 2D
                     )

# display the strike angle for each frequency
# two columns because of 90 degree ambiguity in strike
print(strike)
```

```
[[ -4.24687911  85.75312089]
 [  0.53546544 -89.46453456]
 [  1.71204294 -88.28795706]
 [  2.14208192 -87.85791808]
 [         nan          nan]
 [  2.2151065  -87.7848935 ]
 [ -0.50130871  89.49869129]
 [         nan          nan]
```

Many other attributes, e.g. skew angle β, invariants, etc.…

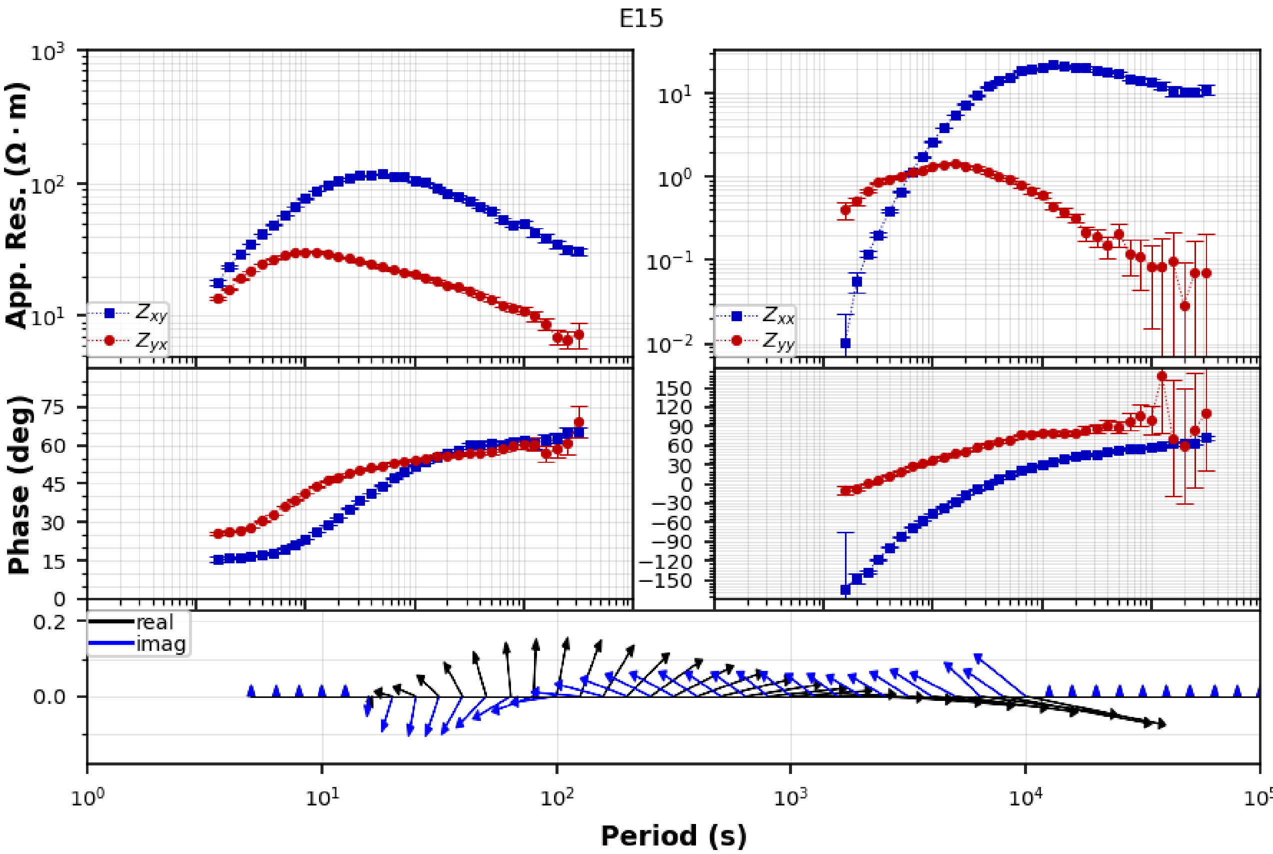
Plotting

```
ptobj = mt_obj.plot_mt_response(plot_num=
                                plot_tipper = 'yr
                                plot_pt='n',
                                fig_size=(4,3.5))
```



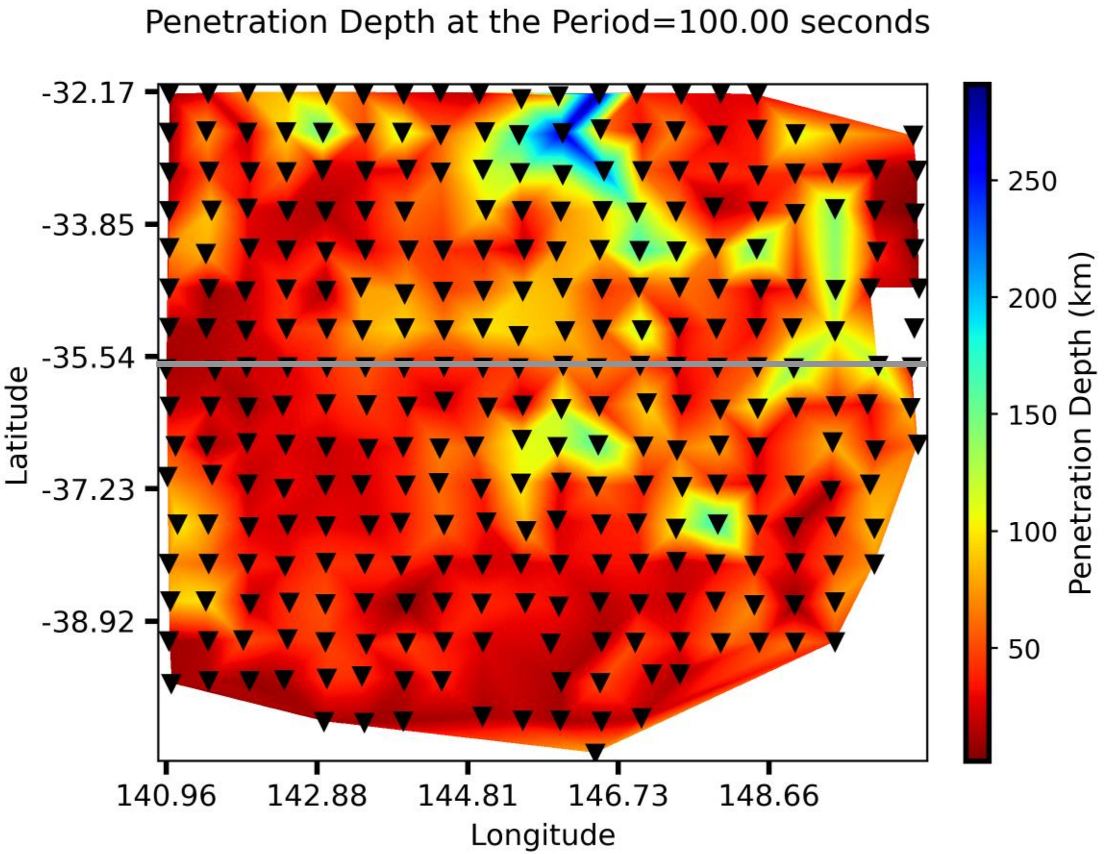
Plotting
(4 components)

```
ptobj = mt_obj.plot_mt_respon
                        plot_
                        plot_
                        fig_s
```



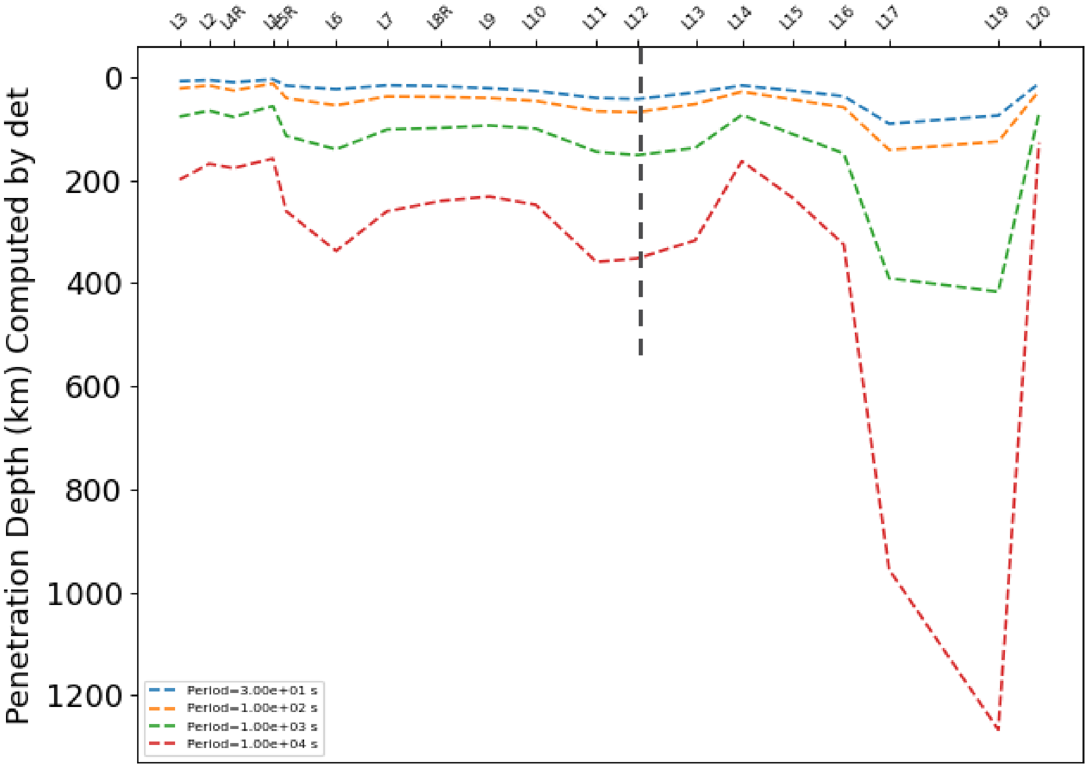
Penetration depth (3d)

```
#Import required modules
from mtpy.imaging import penetration_depth3d a

# Set path to edi files to include in the plo
edi_path = r'C:/data/edifiles'

# Create plot for 100s (determinant)
pen3d.plot_latlon_depth_profile(edi_path,
                                100., 'det',
                                showfig=True,
                                ptol=0.2,
                                savefig=True,
                                savepath=r'C:/
                                fontsize=11,
                                fig_dpi=400,
                                file_format='p
```



Penetration depth (2d)

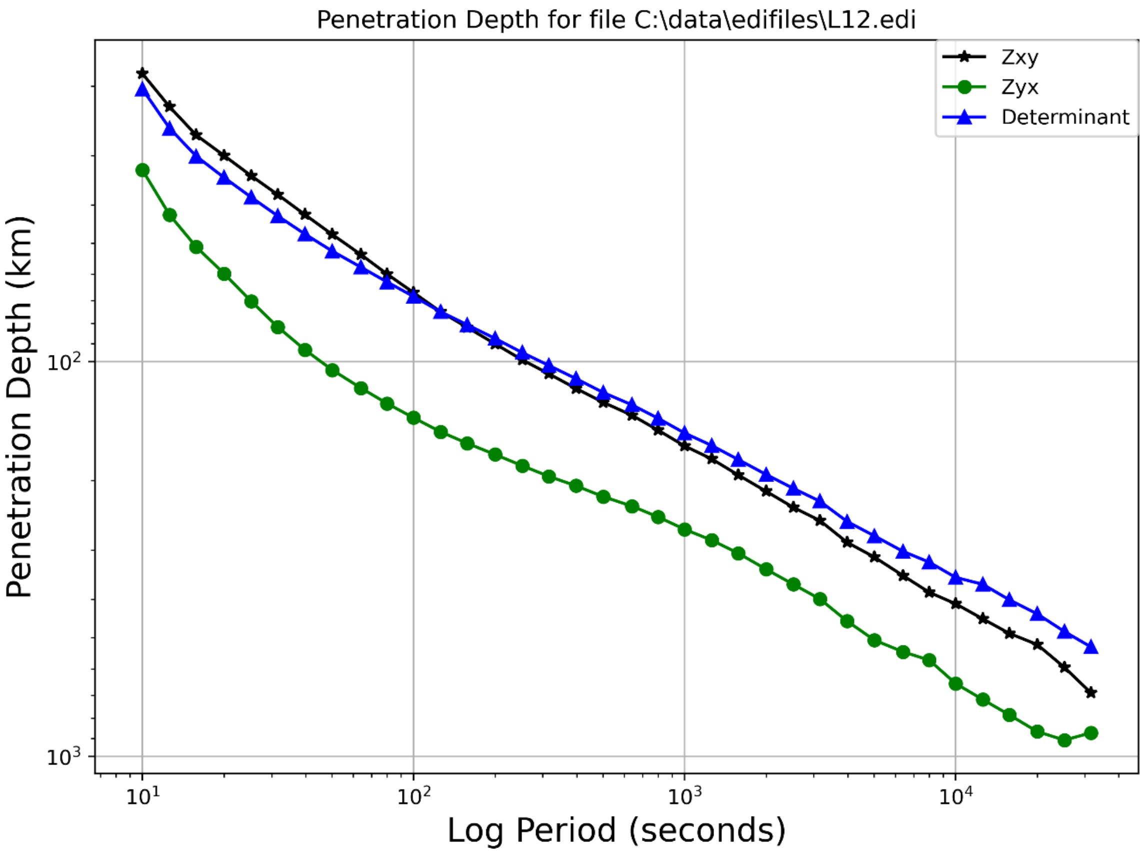
```
#Import required modules
from mtpy.imaging import penetration_depth2d

# path and list of edi files
edi_path = r'C:/data/edifiles'
edi_list = [os.path.join(edi_path,ff) for ff
            os.listdir(edi_path) if ff.start

# Choose indices of periods to plot
period_list = [30.,100.,1000.,10000.]

# Plot profiles for different modes ('det','
pen2d.plot2Dprofile(edi_path, period_list,
                    edi_list=edi_list,
                    ptol=0.2,
                    zcomponent='det',
                    period_by_index = False,
                    save=True,
                    savepath=r'C:\tmp\pen2d.
                    )
```



MT Penetration Depth Profile Over Stations.

Penetration depth (1d)

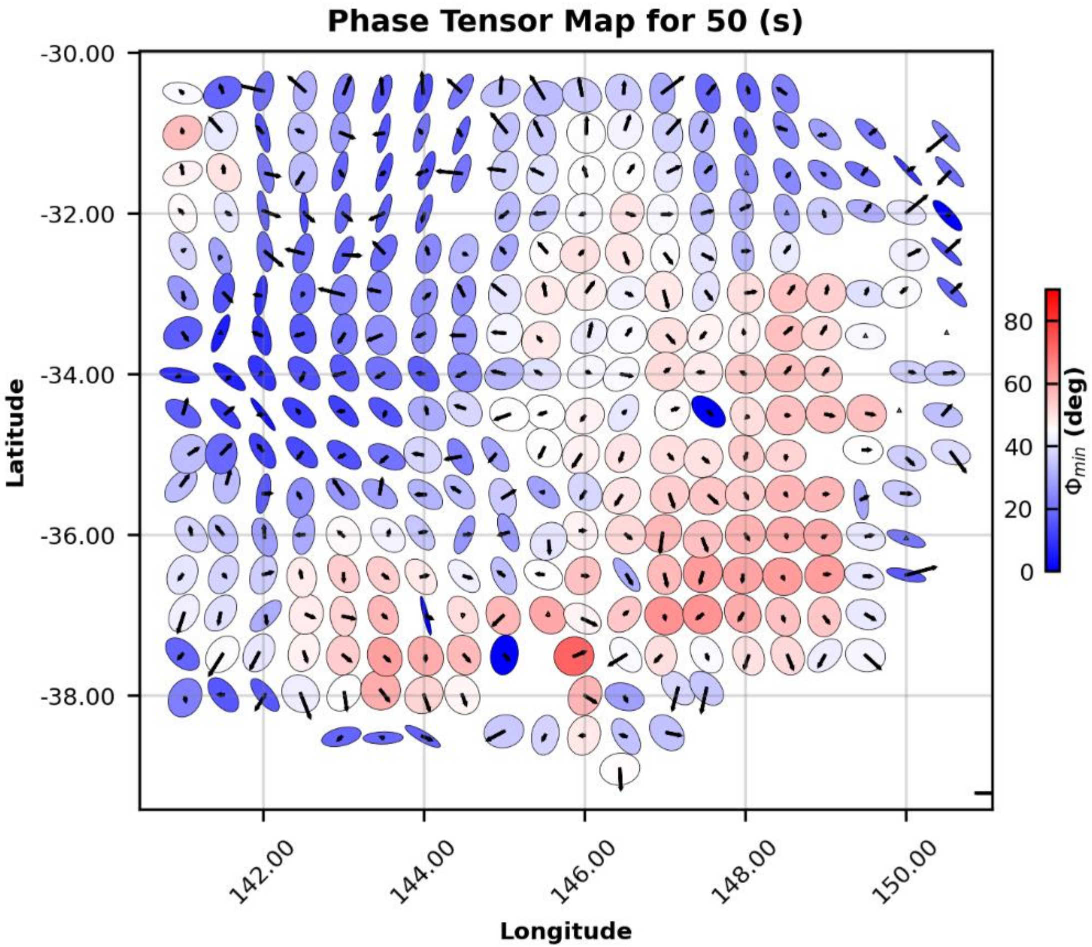
```
# Import required modules
import os
from mtpy.imaging import penetration_dep

# Define edi file
edi_file = r"C:/data/edifiles/L12.edi"

# Define file to save to
save_file = r"C:/tmp/penetration_depth1c

# Create a plot of penetration depth and
pd1d.plot_edi_file(edi_file,
                   savefile=save_file,
                   fig_dpi=400)
```



Phase tensor maps

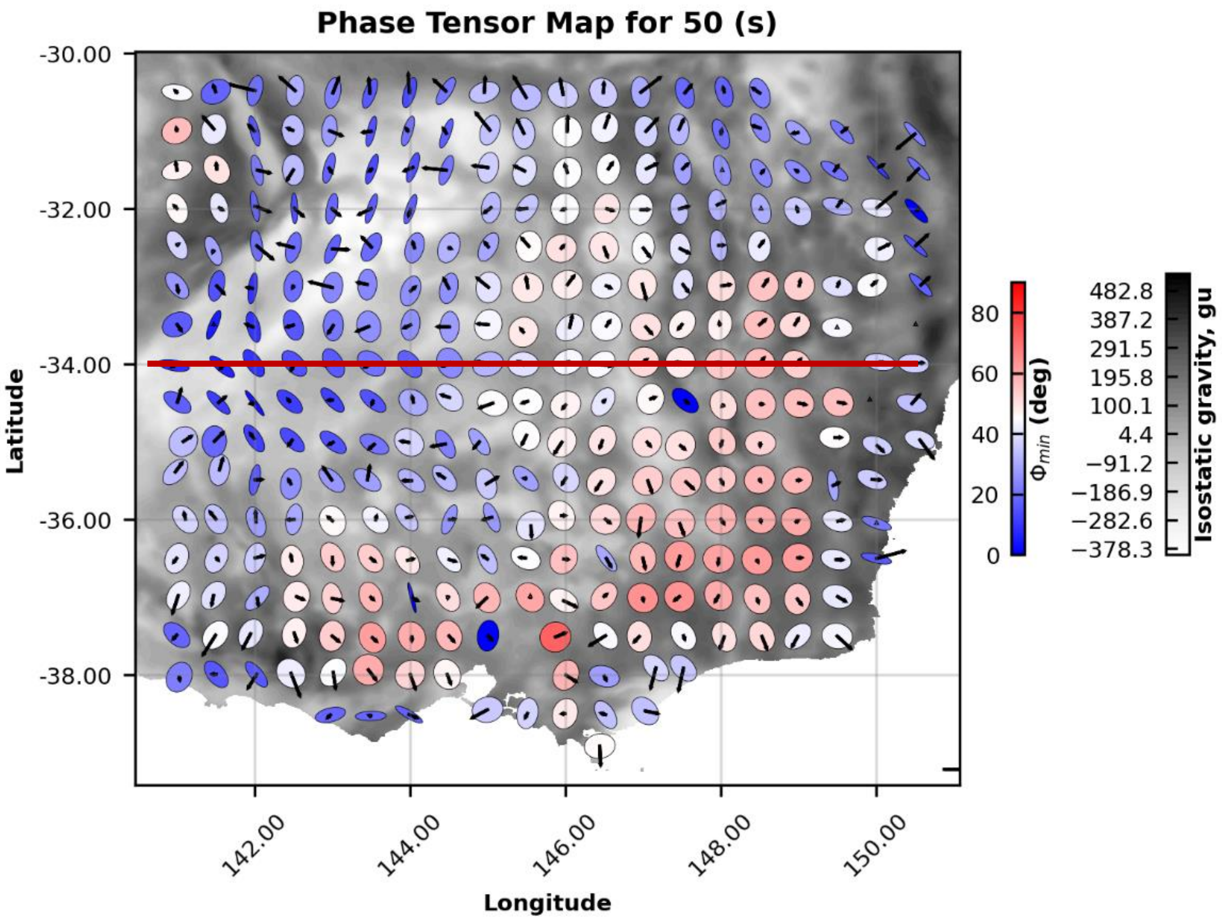
(Caldwell et al 2004, Bibby et al

```
# Import required modules
from mtpy.imaging.phase_tensor_maps import PlotPhase
import os

# directory containing edis
edi_path = r'C:/edifiles'

# gets edi file names as a list
edi_list = [os.path.join(edi_path,ff) for ff in \
            os.listdir(edi_path) if ff.endswith('.ed

# generate plot
ptmap = PlotPhaseTensorMaps(fn_list = edi_list,
                plot_freq = 0.02 , # frequency to p
                fig_size = (4,3), # dimensions of f
                xpad = 0.5, ypad =0.5, # pad around
                plot_tipper = 'yr', # 'y' + 'r' and
                edgecolor='k', # colour or None
                lw=0.2, # linewidth for the ellipse
                minorticks_on=False,
                ellipse_colorby='phimin',# or 'phim
                ellipse_range = [0,90],# [min,max,s
                ellipse_size=0.5, # ellipse scaling
                arrow_size=0.5,
                ellipse_cmap='bwr' # matplotlib col
                )
```



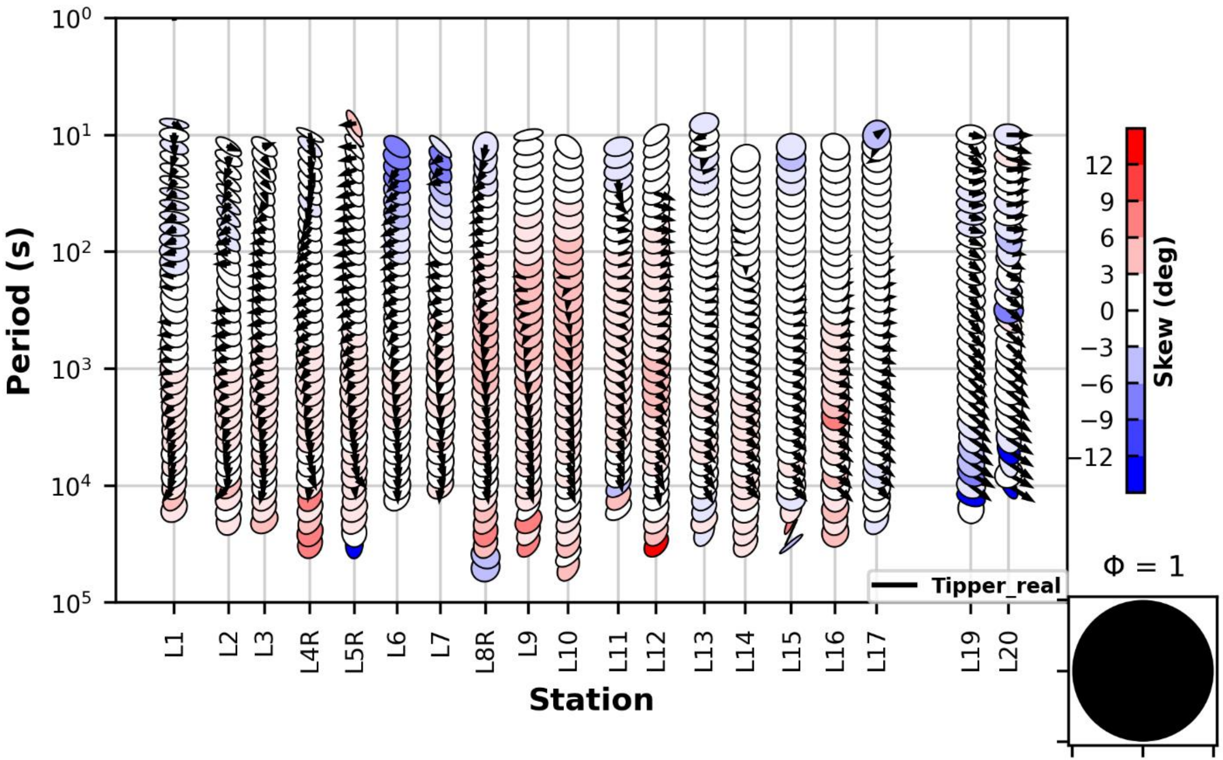
Phase tensors + gravity (for example)

```
# Import the netCDF4 module
from netCDF4 import Dataset
import numpy as np

# load a netcdf file
grav = Dataset(r'C:\data\Isostatic_v2_2(
glon, glat = np.meshgrid(grav.variables
                         grav.variables
vals = grav.variables['Band1'][:]


ptmap.plot(show=True,
           raster_dict={'lons':glon,
                        'lats':glat,
                        'vals':vals,
                        'levels':50,
                        'cmap':'Greys',
                        'cbar_title':'I:
                        'cbar_position'
```



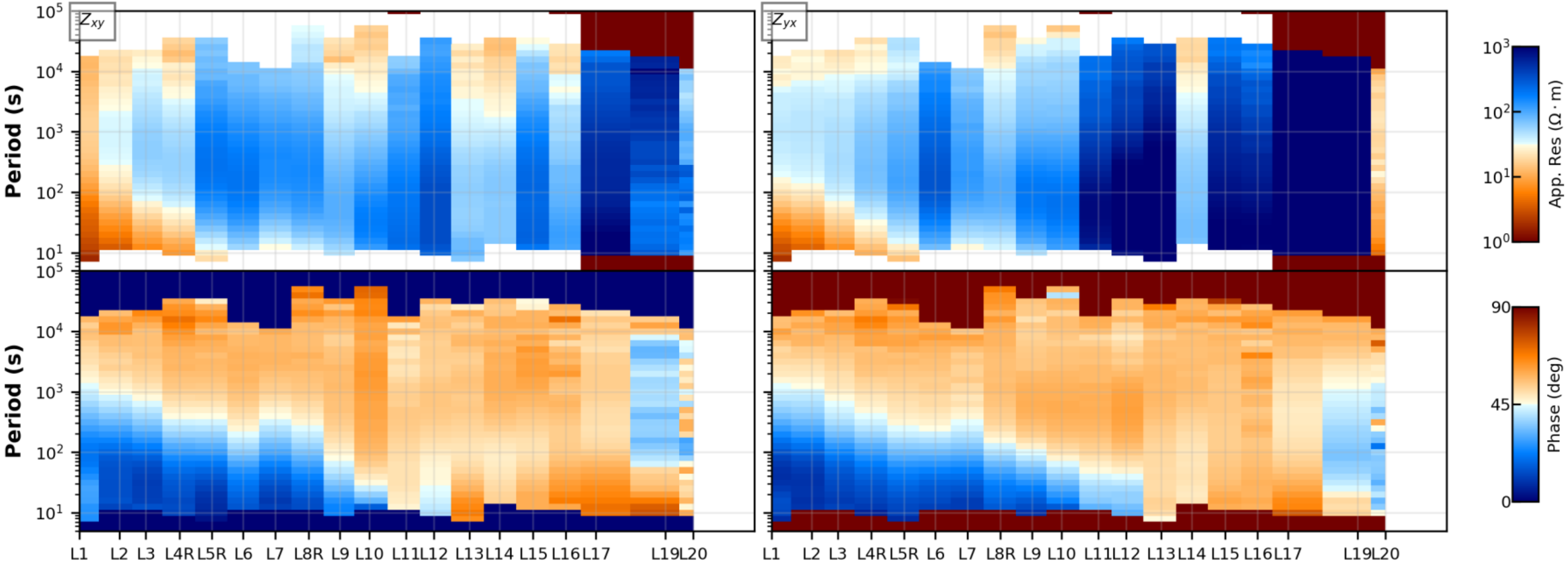
Phase tensor section

```
# import required modules
from mtpy.imaging.phase_tensor_pseudosecti
PlotPhaseTensorPseudoSection
import os

# path to edis and list
edi_path = r'C:/data/edifiles'
edi_list=[os.path.join(edi_path,edi) for e
          if ((edi.endswith('.edi')) and e

# dictionary containing ellipse properties
ellipse_dict = {'ellipse_colorby':'skew_se
                'ellipse_range':[-12,12,3]

# create a plot object
ptsection = PlotPhaseTensorPseudoSection(f
                linedir='ew', # 'ns' or 'e
                stretch=(6,8), # plot (x,y
                plot_tipper = 'yr', # plot
                                    # 'ri'
                ellipse_dict = ellipse_dic
                                 )

ptsection.plot()

ptsection.save_figure(save_fn = r'C:/tmp/P
                    fig_dpi=400)
```



Resistivity, phase pseudosection

```python
# Import required modules
import os
from mtpy.imaging.plotpseudosection import PlotResPhasePseudoSection

edi_path = r'C:\data\edifiles'
```



Creating inversion inputs

Available for:

Occam 1d

Occam 2d

Mare2DEM (data file only)

ModEM 3D

Occam 1D

This example demonstrates how to create input files for inversion of MT data using the Occam 1D code (Key 2009, Constable et al 1987) - http://marineemlab.ucsd.edu/Projects/Occam/1DCSEM/.

There are three input files.

- Data file, containing the data for inversion
- Model file (which contains the model mesh)
- Startup file - called by Occam1d and contains the data and model file names together with some control parameters for the inversion.

Occam 1D

```
# import required modules
import os
import mtpy.modeling.occam1d as mtoc1d

# full path to edi file and save path
edi_file = r'C:\data\edifiles\E6.edi'
savepath = r'C:\tmp\Occam1D_inv'

# create data file
ocd = mtoc1d.Data()
ocd.write_data_file(edi_file=edi_file,
                mode='te',   # 'te', 'tm', or 'det'
                save_path=savepath, # save path
                res_errorfloor=1.5, # error floor, %
                phase_errorfloor=0.75, # error floor, °
                remove_outofquadrant=True)
```

```
Wrote Data File to : C:\tmp\Occam1D_inv\Occam1d_Dat
aFile_TE.dat
```

```
# create model file
ocm = mtoc1d.Model(n_layers = 100, # number of layers
            target_depth = 150000,# model depth
                                  # before padding
            bottom_layer = 400000, # total depth
            z1_layer=200 # 1st layer thickness, m
            )
ocm.write_model_file(save_path=savepath)
```

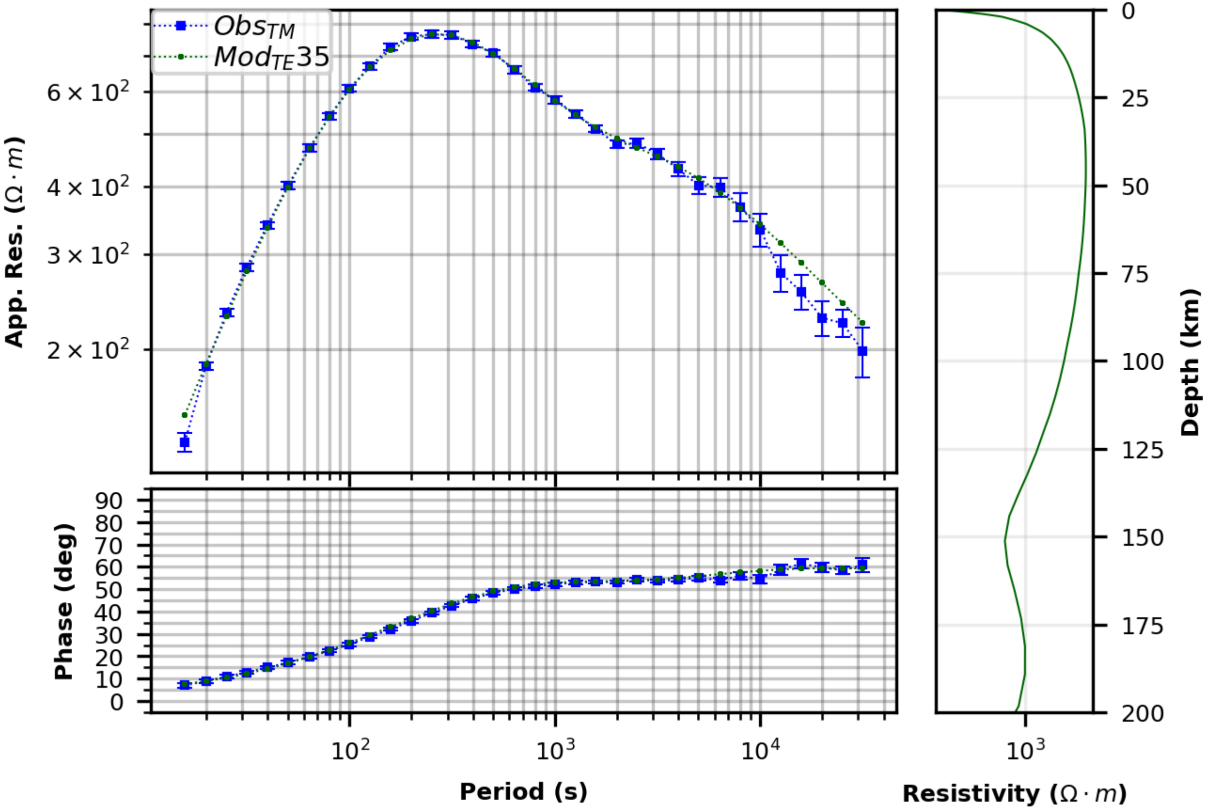
```
Wrote Model file: C:\tmp\Occam1D_inv\Model1D
```

```
# create startup file
ocs = mtoc1d.Startup(data_fn=ocd.data_fn,
            model_fn=ocm.model_fn,
            max_iter=200, # maximum iterations
            target_rms=1.0
            )
ocs.write_startup_file()
```

```
Wrote Input File: C:\tmp\Occam1D_inv\OccamStartup1D
```

Occam1d – viewing the outputs

```
import mtpy.modeling.occam1d as mtoc
import os.path as op

# working directory
wd = r'C:/tmp/Occam1d_inv'

# model, data, iter and response fil
modelfn = op.join(wd,'Model1D')
datafn = op.join(wd,'Occam1d_DataFil
iterfn  = op.join(wd,'ITER_35.iter')
respfn  = op.join(wd,'ITER_35.resp')

# plot the model and response
pr = mtoc1d.Plot1DResponse(data_te_f
                           model_fn =
                           resp_te_f
                           iter_te_f
                           depth_lim
                          fig_size =
```



ModEM

The example below demonstrates how to set up input files for 3D inversion using the ModEM inversion code (Egbert and Kelbert 2012; Kelbert et al. 2014)

The ModEM code has three compulsory input files:

- Model file - contains information on the mesh size and starting resistivity
- Data file - contains the impedance tensor and tipper data at each frequency and station locations
- Covariance file - contains model covariance parameters, which control smoothing

ModEM – Data file

- Created first
- Mesh then built around the stations
- Quite a few parameters to tweak, some shown here

```
import os
from mtpy.modeling.modem import Data
from mtpy.utils.calculator import get_period_list

# path containing edi files
edipath = r'C:/data/edifiles'

# find all files in edipath
edi_list = [os.path.join(edipath,ff) for ff in\
            os.listdir(edipath) if (ff.endswith('.edi'))]

# period list to interpolate to (e.g. 4 periods per decade)
period_list = get_period_list(1e-4,10,4)
```

```
# create a data object
do = Data(edi_list=edi_list,
          inv_mode = '1', # invert for Z + tipper
          save_path=r'C:/tmp/ModEM_inv',
          period_list=period_list,
          error_type_z='floor_egbert',# egbert = % of
                                      # sqrt(Zxy*Zyx)
          error_value_z=5., # error floor %
          error_type_tipper = 'floor_abs',
          error_value_tipper=0.01,
          model_epsg=28355)  # epsg code for model grid

# write data file
do.write_data_file()
```

ModEM – Model file

Create a model object (reads data object)

Creates a grid centred on the stations

A number of parameters can be tweaked

Option to add topography (arcgis ascii grid) e.g. etopo1 https://www.ngdc.noaa.gov/mgg/global/

```
from mtpy.modeling.modem import Model

# create a Model object
mo = Model(station_locations=do.station_locations,
           cell_size_east=7500,
           cell_size_north=7500,
           pad_north=7, # number padding cells N-S
           pad_east=7,# number padding cells E-W
           pad_z=6, # number of vertical padding cells
           pad_num=6, # number of cells before padding
           pad_stretch_v=1.6, # incr. factor padding (vertical)
           pad_stretch_h=1.9, # incr. factor padding (horizontal)
```

```
----------------
        Number of stations = 302
        Dimensions:
                e-w = 156
                n-s = 159
                z  = 101 (without 7 air layers)
        Extensions:
                e-w = 2530300.0 (m)
                n-s = 2552800.0 (m)
                0-z = 973200.0 (m)
        Stations rotated by: 0.0 deg clockwise positive from N

 ** Note ModEM does not accommodate mesh rotations, it assumes
    all coordinates are aligned to geographic N, E
    therefore rotating the stations will have a similar effect
    as rotating the mesh.
----------------
```

```
# project the stations on the topography
do.project_stations_on_topography(mo)
```

ModEM – Covariance file

Controls smoothing

Reads model file you have just created

Input smoothing value, number of times to apply smoothing

```
from mtpy.modeling.modem import Covariance

# create a covariance file
co = Covariance()
co.smoothing_east = 0.6
co.smoothing_north = 0.6
co.smoothing_z = 0.6
co.write_covariance_file(model_fn=mo.model_fn)
```

```
Reading C:/tmp/ModEM_inv\ModEM_Model_File.rho
```

ModEM – chec

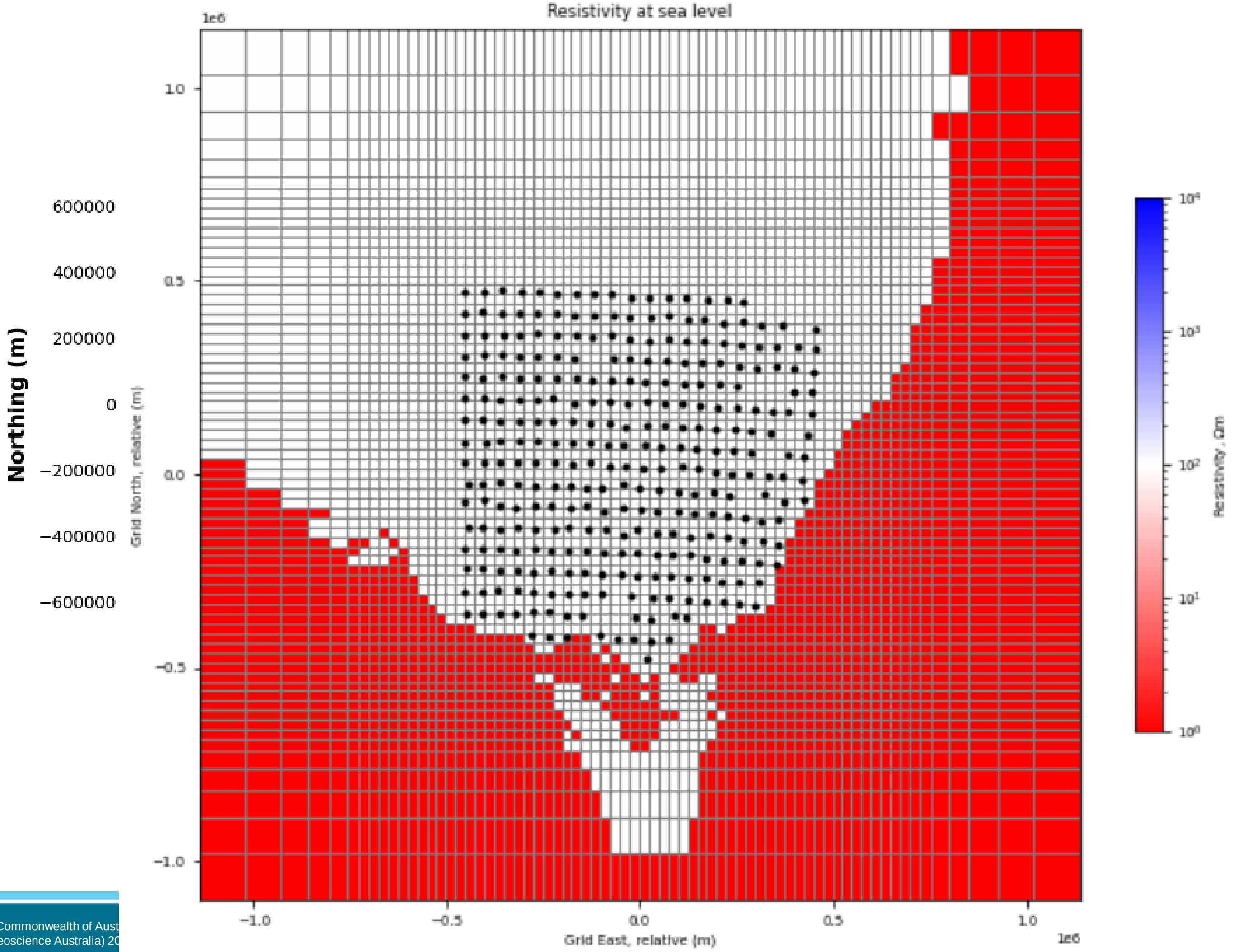
Good idea to open i addition….

Data file – can use t

Model – couple of qu

```
mo.plot_mesh()
```

```
mo.plot_sealevel_re
```



ModEM objects

```
from mtpy.modeling.modem import Model

wd = r'C:\data\modemfiles'

model_fn = os.path.join(wd,'Modular_MPI_NLCG_005.rho')

mObj = Model()
mObj.read_model_file(model_fn=model_fn)
```

```
mObj.res_model
```

```
array([[[3.00000841e-01, 3.00000841e-01, 3.00000841e-01, ...,
         8.83026395e+01, 9.33783949e+01, 9.70125159e+01],
        [3.00000841e-01, 3.00000841e-01, 3.00000841e-01, ...,
         8.49217293e+01, 9.13273222e+01, 9.60433834e+01],
        [3.00000841e-01, 3.00000841e-01, 3.00000841e-01, ...,
         8.31827504e+01, 9.01937379e+01, 9.54822150e+01],
```

```
mObj.grid_east
```

```
array([-1276400.,  -923600.,  -737900.,  -640200.,  -588800.,  -5
61700.,
        -547500.,  -540000.,  -532500.,  -525000.,  -517500.,  -5
10000.,
```

https://unsplash.com/photos/gDPaDDy6_WE

ModEM objects

```
from mtpy.modeling.modem import Data

data_fn = os.path.join(wd,'ModEM_Data.dat')

dObj = Data()
dObj.read_data_file(data_fn)
```

```
dObj.center_point.east, dObj.center_point.north
```

```
(array([378901.8964358]), array([6158864.73539792]))
```

```
dObj.period_list
```

```
array([6.40e+00, 1.00e+01, 1.58e+01, 2.52e+01, 3.98e+01, 6.40e+0
1,
       1.00e+02, 1.58e+02, 2.52e+02, 3.98e+02, 6.40e+02, 1.00e+0
3,
       1.58e+03, 2.52e+03, 3.98e+03, 6.40e+03, 1.00e+04, 1.58e+0
4,
       2.52e+04, 3.98e+04])
```

https://unsplash.com/photos/gDPaDDy6_WE

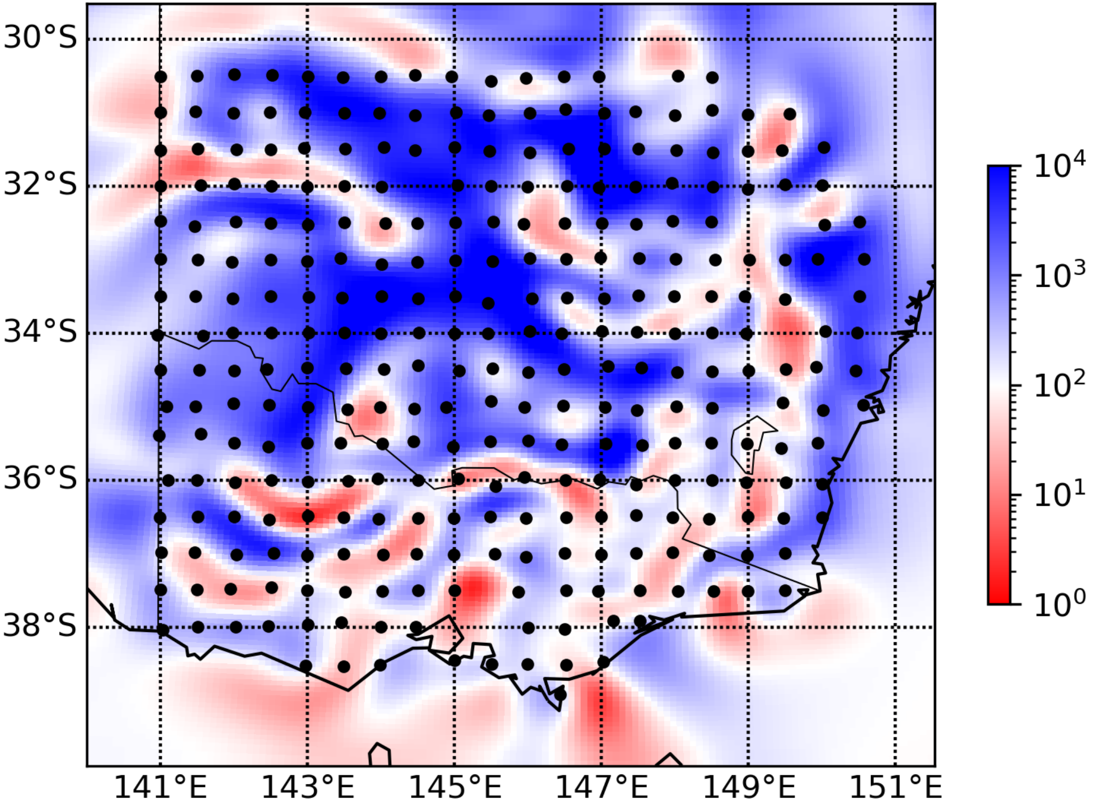
ModEM – Visualisation of outputs

Many tools to visualise outputs:

- Plotting depth slices and vertical slices
- Overlay with other datasets (e.g. geological linework, seismic)
- Export slices to ArcGIS, Gocad sgrid
- Visualise phase tensors (data, model and residual)
- RMS maps
- Plots of data and model response at individual stations

Depth Slice

```
import os
from mtpy.modeling.modem import PlotSlic

wd = r'C:\data\modemfiles'

model_fn = os.path.join(wd,'Modular_MPI_
data_fn = os.path.join(wd,'ModEM_Data.da
|
ps = PlotSlices(model_fn,
                data_fn=data_fn,
                model_epsg = 28355, # ep
                cmap='bwr_r', # color ma
                climits=(0,4), # log10(c
                plot_stations = True, # 
                draw_colorbar=True, # wh
                fig_size=(6,5),
                plot_yn='n')

ps.basemap_plot(40e3, # depth to plot (c
                save=True,
                save_path=savepath) # sa
```



Also.. Model Manipulator (soon)

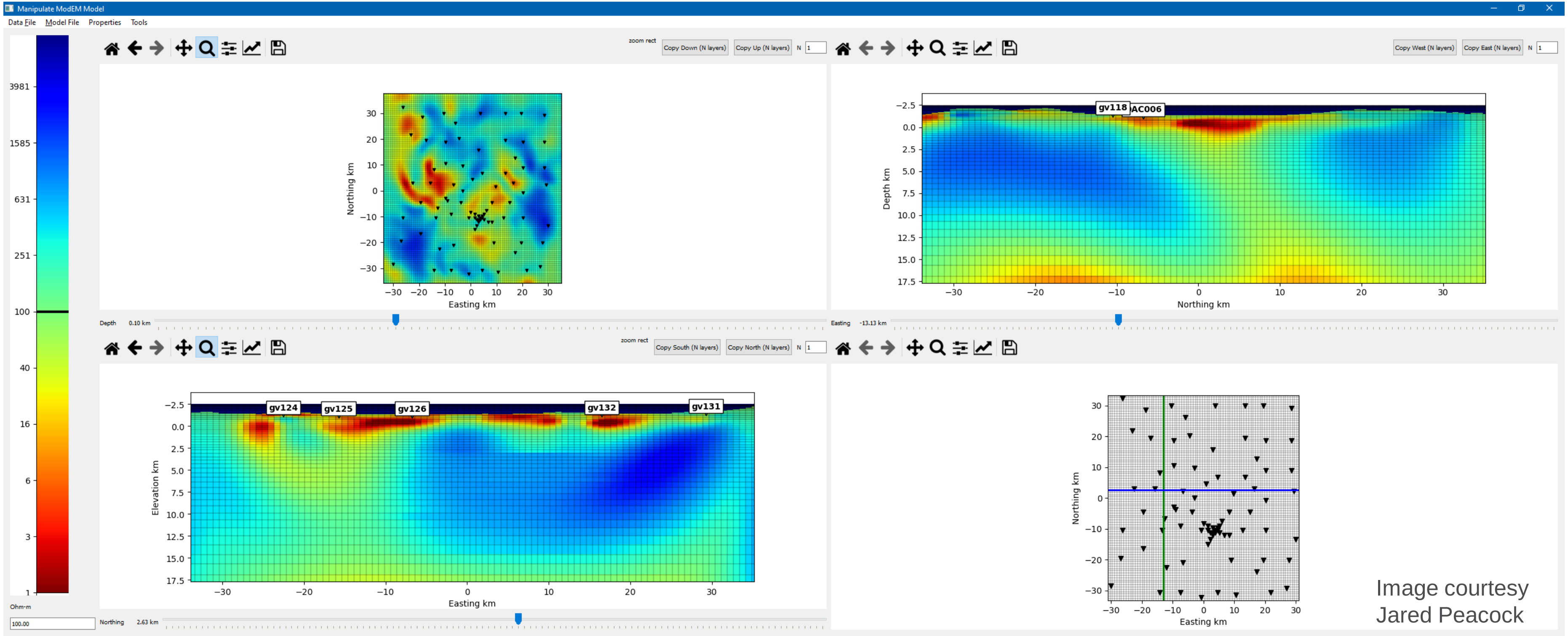
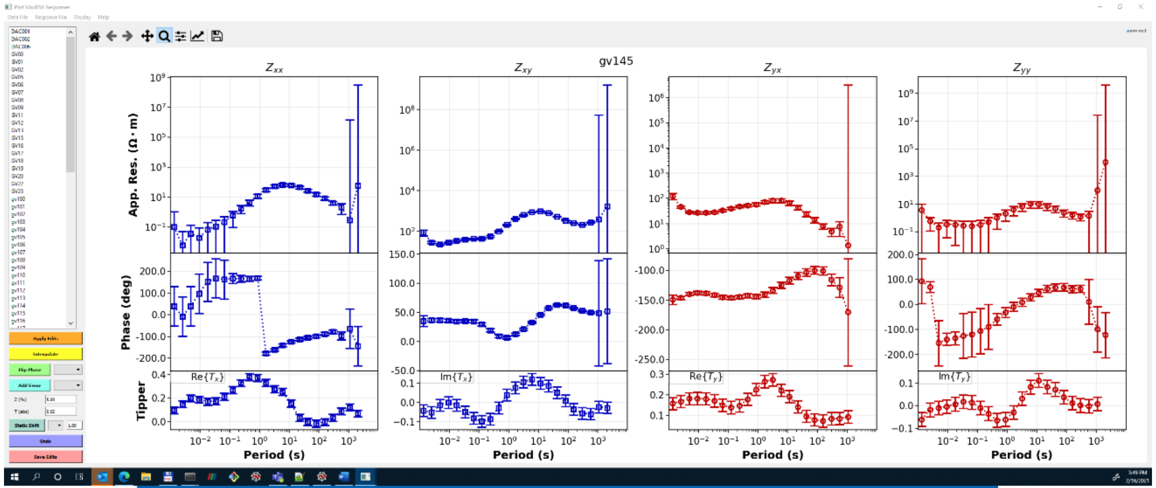


Image courtesy
Jared Peacock

Plot Response (interactive)



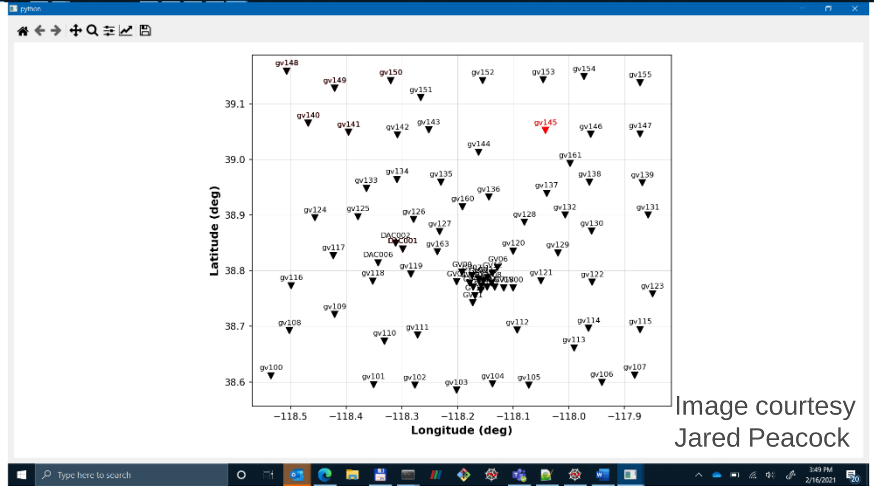
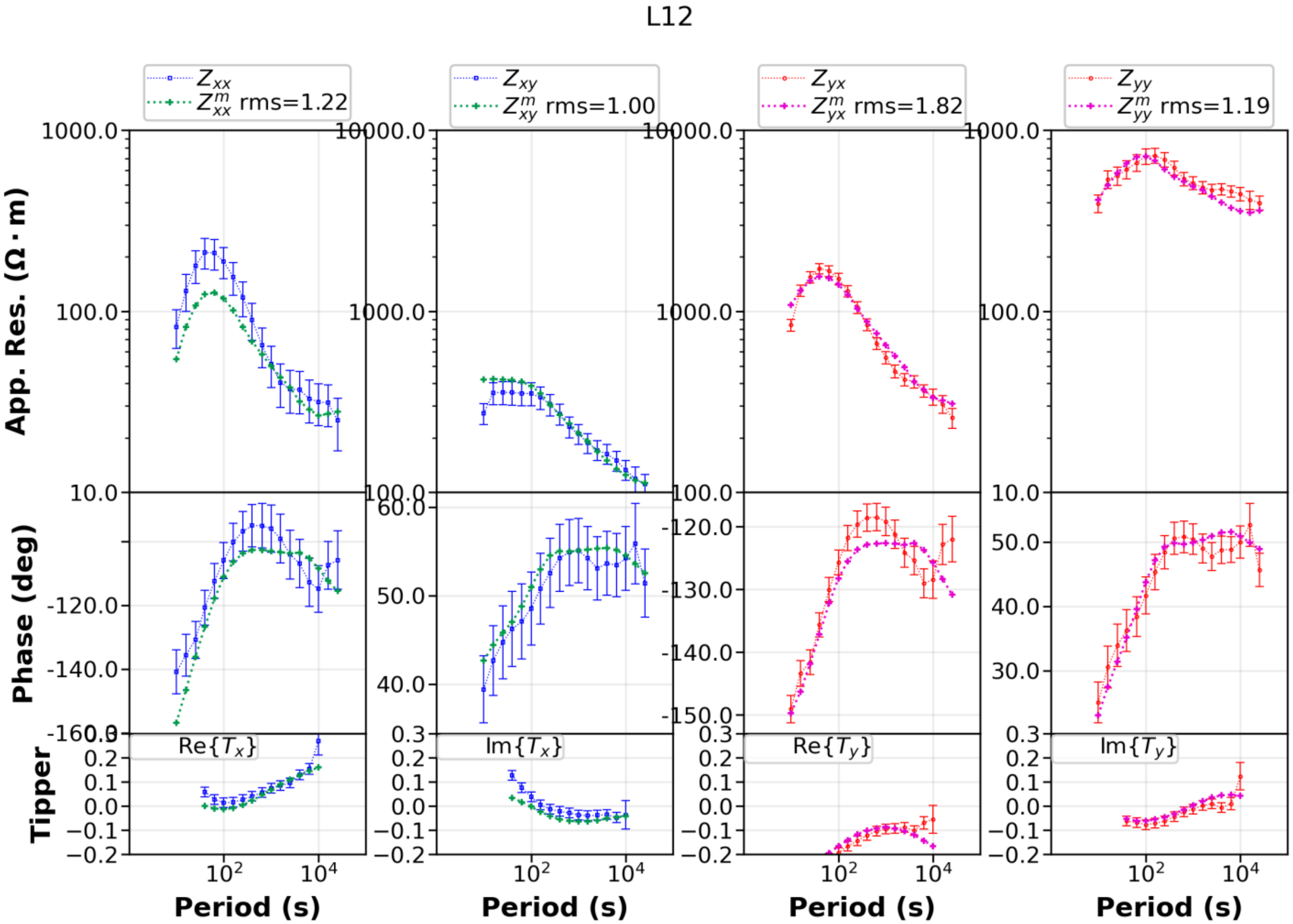


Image courtesy Jared Peacock

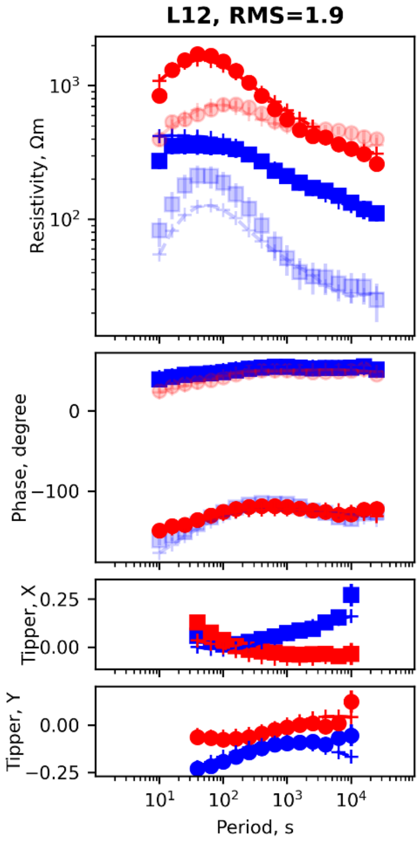
Plot Response

```
import os
from mtpy.modeling.modem

wd = r'C:\data\modemfile

resp_fn = os.path.join(w
data_fn = os.path.join(w

# make a plot object
ro = PlotResponse(data_f
                  resp_f
                  plot_t

                  plot_s
                  fig_si
                  font_s
                  plot_z
                  )
ro.save_plots = True
ro.plot()
```



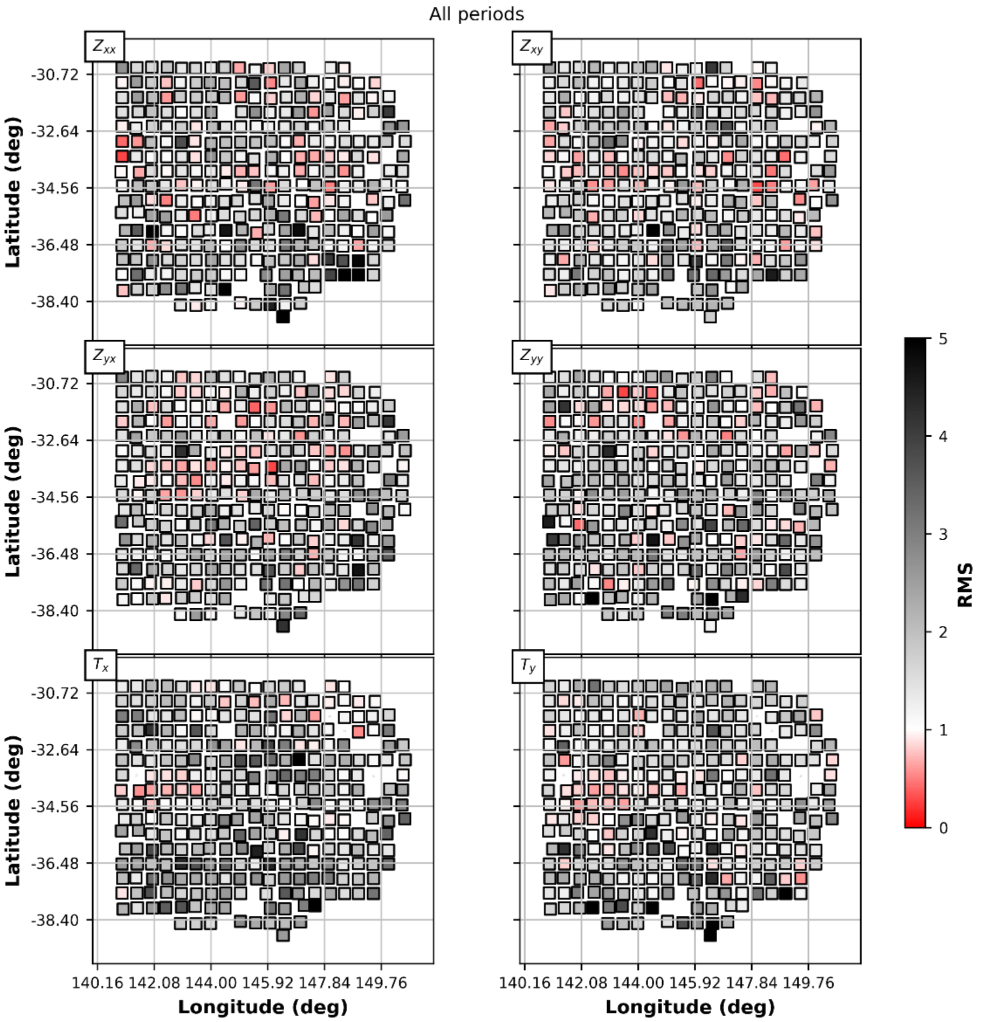
Plot Response (1 column)

```
import os
from mtpy.modeling.modem import PlotResponse

wd = r'C:\data\modemfiles'

model_fn = os.path.join(wd,'Modular_MPI_NLCG_005.rho')
resp_fn = os.path.join(wd,'Modular_MPI_NLCG_005.dat')
data_fn = os.path.join(wd,'ModEM_Data.dat')

# make a plot object
ro = PlotResponse(data_fn=os.path.join(wd,data_fn),
                  resp_fn=os.path.join(wd,resp_fn),
                  plot_type=['L12'], # station names list
                                     # or '1' to plot all stations
                  plot_style=3,  # 1 for 4-colums; 2 for 2-columns
                  fig_size=(3,6),
                  font_size=8,
                  plot_z=False,
                  )
ro.save_plots = True
ro.plot()
```



RMS maps

```
import os
import numpy as np
from mtpy.modeling.modem import PlotRMSMaps

wd = r'C:\data\modemfiles'
savepath = r'C:/tmp'

resid_fn = os.path.join(wd,'Modular_MPI_NLCG_

# create a RMS plot object
probj = PlotRMSMaps(resid_fn,
                    rms_min=0, # min rms for
                    rms_max=5, # max rms for
                    period_index='all', # 'al
                    fig_size=(7.5,8)
                   )

# save figure
probj.save_figure(save_path=savepath,
                  fig_close=False, # close fi
                  save_fig_dpi = 400 # resolu
                  )
```



Summary

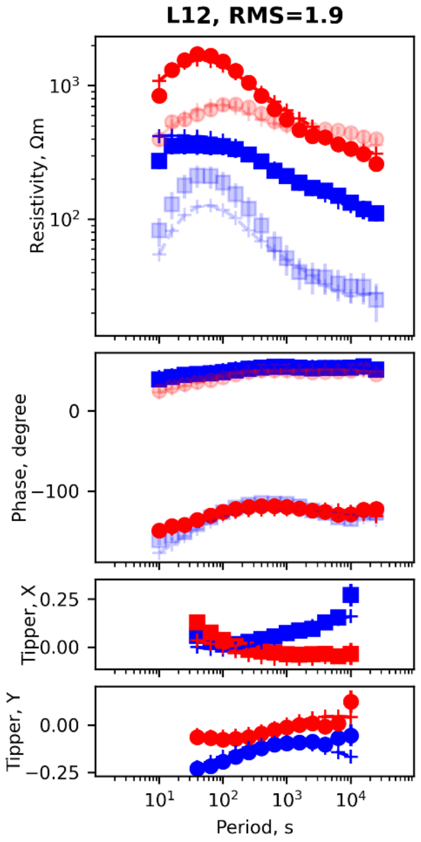
MTPy is a collection of tools to help with analysis and visualisation of MT data

Tools include:

- Reading, writing and visualisation of MT data
- Analysis tools
- Reading, writing and visualisation of commonly-used inversion inputs/outputs

Please report any bugs via issues page

v2.0 under scoping (so list any ideas in the “issues” page for v2.0)



Thank you!

https://github.com/MTgeophysics/mtpy