New Mexico Small Business Assistance (NMSBA)

SlugTide How-to Guide

Contents

A Note

Work in this document was performed using a local Mac version of MATLAB. It goes through several a couple examples of the SlugTide workflow with base path, `<SlugTide>`, which represents the following path:

`/Users/jportiz/Documents/research/nmsba/SlugTide-copy/`

B Example 1: Xue et al., 2013

Based on data from the Xue et al. (2013) paper:

L. Xue, H.-B. Li, E. E. Brodsky, Z.-Q. Xu, Y. Kano, H. Wang, J. J. Mori, J.-L. Si, J.-L. Pei, W. Zhang, G. Yang, Z.-M. Sun, and Y. Huang. Continuous Permeability Measurements Record Healing Inside the Wenchuan Earthquake Fault Zone. *Science*, 340(6140):1555–1559, 2013. doi: 10.1126/science.1237237

1. Create the working SlugTide directory

Create the folder `Xue2013_Example` with all thirteen (13) MATLAB files. This will be the working directory and should contain:

- `avg_amp_phase.m`
- `BuildWell.m`
- `importfile.m`
- `InitiateWells.m`
- `LoadTides.m`
- `MasterWell.m`
- `nanmean.m`
- `nanstd.m`
- `PlotOriginalWL.m`
- `PlotWellResponse.m`
- `UserParam.m`
- `WaterResp_general_interp.m`
- `water_respon_time.m`

The functions `nanmean.m` and `nanstd.m` are included with this package as they are not standard in every MATLAB installation but are used in the SlugTide codes.

You will also need to copy in the water level data file from this study (`waterlevel.csv`). It can be downloaded from `https://www.science.org/doi/suppl/10.1126/science.1237237/suppl_file/waterlevel.zip`. The preview of the original downloaded data file is below:

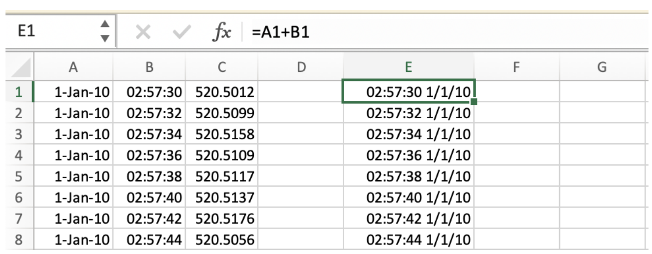
waterlevel.csv

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
The water level data set of WFSD-1.
The first column: day
The second column: hour:min:sec
The third column : depth m
The time is the local Beijing time, and the depth is the water height above the pressure sensor.
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
01-Jan-2010 02:57:30 520.501200
01-Jan-2010 02:57:32 520.509900
01-Jan-2010 02:57:34 520.515800
01-Jan-2010 02:57:36 520.510900
```

2. Prepare the data files

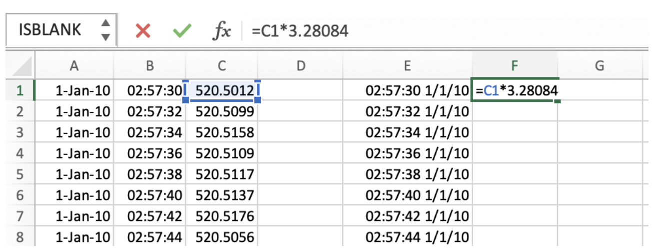
Create individual .csv files for your data as columns of numeric data only. If you have an unusual format, the easiest way to get started is to save the data as two columns of text with the first column being days from 00:00:00 0/0/000 (MATLAB datenum convention) and the second being your water level depth. We refer to this as the "Simple" format (Format code S).

I chose to import the `waterlevel.csv` file into Excel and format it as described above (2 columns; 00:00:00 0/0/0000). This is then saved as `waterlevel_preprocessed.csv`.


E1 =A1+B1

	A	B	C	D	E	F	G
1	1-Jan-10	02:57:30	520.5012		02:57:30 1/1/10		
2	1-Jan-10	02:57:32	520.5099		02:57:32 1/1/10		
3	1-Jan-10	02:57:34	520.5158		02:57:34 1/1/10		
4	1-Jan-10	02:57:36	520.5109		02:57:36 1/1/10		
5	1-Jan-10	02:57:38	520.5117		02:57:38 1/1/10		
6	1-Jan-10	02:57:40	520.5137		02:57:40 1/1/10		
7	1-Jan-10	02:57:42	520.5176		02:57:42 1/1/10		
8	1-Jan-10	02:57:44	520.5056		02:57:44 1/1/10		

Figure 1. Example of how to combine the date and time in Excel. Excel will default to putting the date before the time, so you need to then choose "Format > Cells" and select "Custom". Then enter the following into the box: `hh:mm:ss m/d/yy`.


ISBLANK =C1*3.28084

	A	B	C	D	E	F	G
1	1-Jan-10	02:57:30	520.5012		02:57:30 1/1/10	=C1*3.28084	
2	1-Jan-10	02:57:32	520.5099		02:57:32 1/1/10		
3	1-Jan-10	02:57:34	520.5158		02:57:34 1/1/10		
4	1-Jan-10	02:57:36	520.5109		02:57:36 1/1/10		
5	1-Jan-10	02:57:38	520.5117		02:57:38 1/1/10		
6	1-Jan-10	02:57:40	520.5137		02:57:40 1/1/10		
7	1-Jan-10	02:57:42	520.5176		02:57:42 1/1/10		
8	1-Jan-10	02:57:44	520.5056		02:57:44 1/1/10		

Figure 2. Convert the water level from meters to feet.

The resulting .csv file exported from Excel looks like this:

Note: The original data file provided by the author has an issue where there is a blank cell in the water level column when the time changes to midnight (00:00:00). A hacky fix is to use excel to delete the rows where there is a blank cell (the following website is a useful resource: https://www.howtoexcel.org/delete-blank-rows/).

For this reason, I have

	A	B	C	D	E	F	G
1	02:57:30 1/1/10	1707.68116					
2	02:57:32 1/1/10	1707.7097					
3	02:57:34 1/1/10	1707.72906					
4	02:57:36 1/1/10	1707.71298					
5	02:57:38 1/1/10	1707.71561					
6	02:57:40 1/1/10	1707.72217					
7	02:57:42 1/1/10	1707.73496					
8	02:57:44 1/1/10	1707.69559					

Figure 3. Resulting two column format that is then saved as a .csv file (`waterlevel_preprocessed.csv`).

37874	1-Jan-10	23:59:56	520.6005			
37875	1-Jan-10	23:59:58	520.5983			
37876	2-Jan-10	520.6012				
37877	2-Jan-10	00:00:02	520.6016			
37878	2-Jan-10	00:00:04	520.6027			
37879	2-Jan-10	00:00:06	520.5994			
37880	2-Jan-10	00:00:08	520.6037			

Figure 4. Issue with midnight data entries in the original data file.

3. Import the data (`importfile.m`)

For this step, you can either: (a) preprocess your .csv file to match one of the pre-defined formats or (b) edit the `importfile` function to better match your data structure.

The predefined formats are listed in the SlugTide documentation (Could include them eventually…).

The `importfile` function is called later in the `BuildWell.m` script. The `BuildWell.m` script can have multiple `importfile` calls depending on the user-defined "format" of the data file you want to import (e.g., 'S', 'A', 'B', etc).

4. Create the TideSynth directory

Create a folder in your working directory called "TideSynth" (if it does not already exist).

Create the synthetic tide files for the wells. Use SPOTL or another program (see A for details on how to do this). Each well processed needs to have its own synthetic tide file.

Save the synthetic tide files for all the wells in the dataset in a separate folder "TideSynth" within the directory folder containing the .csv data files and MATLAB codes.

For the well in Xue et al. (2013), the relevant SPOTL input parameters are listed below:

- Lat/long: 31.1°N, 103.7°E
- Start date: 1/1/2010
- End date: 8/6/2011
- Time zone: "Local Beijing time" (China Standard Time [UTC-8])

Make sure you consider the time zone of your well data vs the time zone of the SPOTL output (UTC).

Performed these calculations in: `/home/jportiz/software/spotl/working/Xue2013`

- Ran `strains_wfsd-1.scr`
- Ran `compile_areal_strains.py`

5. Modify the parameters for the dataset (**UserParam.m**)

- Open UserParam.m and edit the parameters for the test being studied. Parameters from this file are used within later steps in the process to calculate and plot the tidal response. Updating the parameters in this part of the code will negate the necessity to edit some of the individual steps later in the process.

- If there are earthquake occurrences in the data, see the note on Earthquakes in the introduction. Note: the earthquake mentioned in this study occurred in 2008, so the analysis here is looking at the permeability "healing" that occurred in the years after the earthquake.

Add more details to this eventually…

6. Set up the initial structure of wells for the test (**InitiateWells.m**)

The `InitiateWells.m` script sets up the initial structure for the wells, which is input into building the Well structure for the dataset (`BuildWell.m`). Initially in `InitiateWells.m`, there are inputs for three wells, one per pre-defined format ('S', 'A' and 'B'). The user will need to copy and paste the set of inputs by format 'S','A', or 'B' for the rest of the wells in their dataset using these predetermined formats. Users can change the parameters and add wells as needed within `InitiateWells.m` for their test. If the user is adding different formats, they will need to update `importfile.m` and `BuildWell.m` (steps 3 and 8, respectively) in addition to `InitiateWells.m`.

Add detailed instructions on this…

NOTE: for some reason, the script does not like a `WellInitial(iWell).startrow` value of 1 or 2 for this dataset… Using a higher value (e.g., 152) seems to help. (Try to figure out why this is).

- depth to open interval: 800 m (2624.67 ft)

7. If using the quick method (utilizing **UserParam.m** and **InitiateWells.m**, following preprocessing), skip to Step 15: **MasterWell.m**

Steps 8 through 14 (CHECK THESE NUMBERS) describe the process of calculating and plotting the tidal response, with instructions on where to edit if needed.

Exception: If the user has made changes to `InitiateWells`, be sure to make the necessary corresponding changes as described above.

8. Load tide data (**LoadTides.m**)

Note: Nothing is required from the user for this step.

This function loads the synthetic tides into the data structure within `BuildWell.m`

This code calls variables established in `UserParam.m`.

a. Call the time interval of the synthetic tide data.

```
UserParam;
...
t=Well.t0_tide(i)+(0:length(y)-1)'*Tide_dt;
```

9. Build the Well structure for the dataset (**Buildwell.m**)

This function calls variables established in `UserParam.m`.

This part of the code is written as a function that sets up the Well Structure for the dataset through an `if elseif` loop using the formats as assigned to the wells in `InitiateWells.m`.

Add more info later…

10. Plot original water level (`PlotOriginalWL.m`)

Plot the water level per well/port from the original data (not the interpolated data). This can be useful for identifying time periods with noisy data, and for checking the times of earthquakes (if present).

This code calls variables established in `UserParam.m`.

1. If there is an earthquake in the data, uncomment all earthquake related code in `PlotOriginalWL.m`, designated by:

   ```
   %%%% EQ.
   ```

2. Establish time of EQ, if present in the data:

   ```
   EQ_t=datenum(EQtime)+cUTC; %%%%UTC %%%% EQ
   ```

3. Establish time frame to plot (these variables are set in `UserParam.m`):

   ```
   xlim([datenum(PlotTime1) datenum(PlotTime2)])
   ```

4. Plots are saved in both .pdf and .png file formats (see 5).

11. Calculate the tidal components (`water_respon_time.m`)

This function performs the Fourier analysis and calculates the tidal components called within `WaterResp_general`

The code calculates the response of the M2, S2, K1 and O1 tidal components. Other tidal components may be added within this function, as needed for the particular tidal study.

12. Calculate the tidal response (`WaterResp_general_interp.m`)

This code calls variables established in `UserParam.m`. The sign convention for these calculations is extension positive.

13. Plot the Phase and Amplitude response (`PlotWellResponse.m`)

This code calls variables established in `UserParam.m`.

14. Calculate and plot the average amplitude and phase for wells with multiple ports over a specified time frame; `avg_amp_phase.m`

This in an additional code that plots the average amplitude and phase response in wells with depth of the ports for study of vertical control on tidal response.

Plots are saved in both .pdf and .png file formats (e.g., Figure 7).

15. Process the dataset (`MasterWell.m`)

This code calls variables established in `UserParam.m` and `InitiateWells.m`.

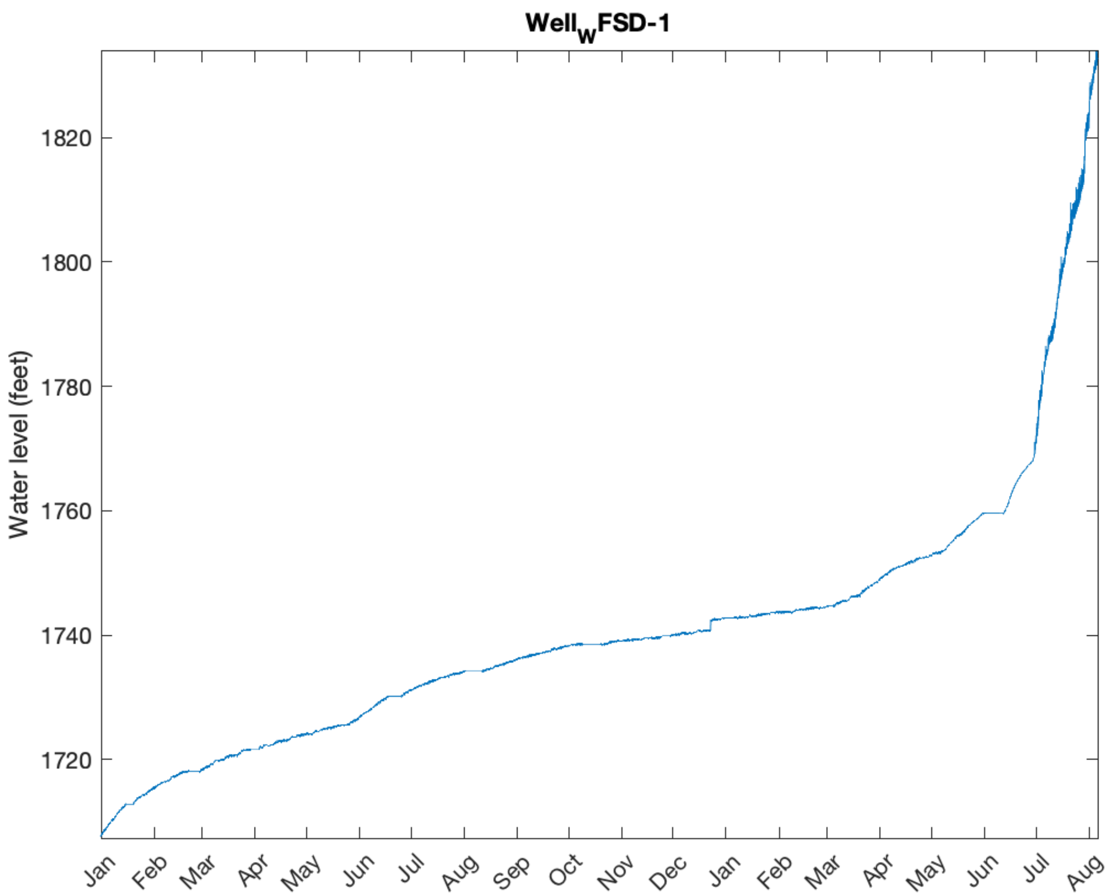


Figure 5. Original water levels plot (before data interpolation); `Well_WFSD-1_1_ori.pdf`.

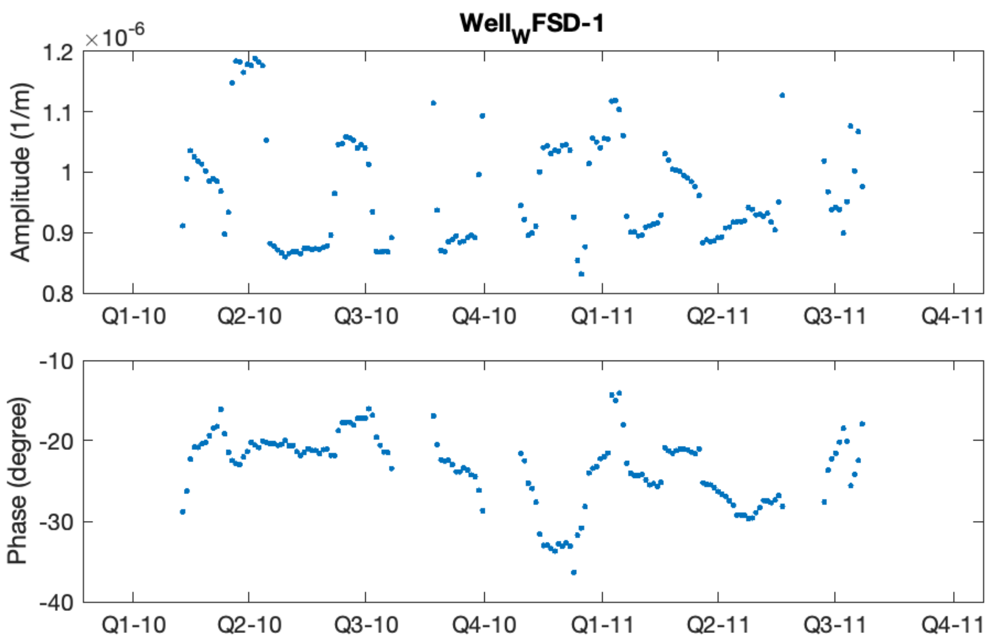


Figure 6. Phase response and amplitudes; `Well_WFSD-1_1_amp_pha.png`.

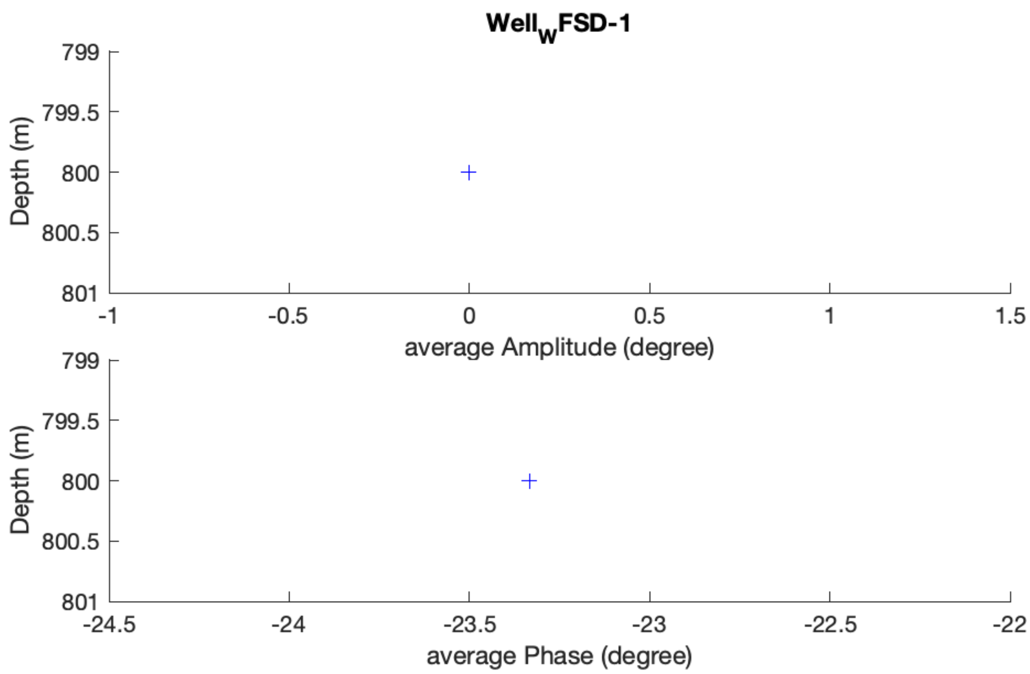


Figure 7. Average phase response and amplitudes; `Well_WFSD-1_1_avg_amp_pha.png`.

References

D. C. Agnew. Scripps Institution of Oceanography Technical Report SPOTL : Some Programs for Ocean- Tide Loading. Technical report, 2012.

L. Xue, H.-B. Li, E. E. Brodsky, Z.-Q. Xu, Y. Kano, H. Wang, J. J. Mori, J.-L. Si, J.-L. Pei, W. Zhang, G. Yang, Z.-M. Sun, and Y. Huang. Continuous Permeability Measurements Record Healing Inside the Wenchuan Earthquake Fault Zone. *Science*, 340(6140):1555–1559, 2013. doi: 10.1126/science.1237237.

Appendices

Appendix A SPOTL

Use: Used for calculating theoretical areal strain.
Source: SPOTL source code can be downloaded for free at https://igppweb.ucsd.edu/~agnew/Spotl/spotlmain.html.
License: All the code is freely available (in both the monetary and open-source usages of "free"). Additional discussion is included in the distribution. Use of the code should be cited as (Agnew, 2012).

I had to modify a few lines of the Makefile and other scripts in order to get it to compile correctly on my machine. I used the GFORTRAN compiler on Linux.

We are interested in areal strain (or volumetric strain) but ERTID does not provide it directly. To retrieve it, you just need to compute the horizontal strain in two perpendicular directions (e.g., azimuth 0° and 90°, as below) and sum up the quantities. The included script produces two output files, "th0" and "th90", with these two strain time series.

SPOTL/ERTID Script

```
#!/bin/sh
# Calculate theoretical earth tides with ertid at PZ-01
#----outputs strain along azimuth 0 and 90 -- add together to get areal strain
../bin/ertid << END
2007 143  0
2007 226  0
0.0833333333333333333333333333333333333333
t
32.4045
-115.2343
0
0
2
0
90
th0
th90
END
```