results-figures

November 9, 2015

1 Produce the figures for the numerical results

This IPython notebook produces the error x distance-size ratio figures for the section "Evaluation of the accuracy" of the article.

The data was calculated by the `tesseroid_vs_spherical_shell.ipynb` notebook and saved to CSV files in the `data` directory of the main repository.

1.1 Load the required libraries and set the plot defaults

We'll use the pandas library to load and manipulate the data. Plots will be made with matplotlib.

```
In [1]: %matplotlib inline
        from __future__ import division
        from IPython.display  import set_matplotlib_formats
        set_matplotlib_formats('svg')
        import pandas as pd
        import numpy as np
        from matplotlib import pyplot as plt
```

```
In [2]: plt.rcParams['axes.labelsize'] = 9.0  # fontsize of the x any y labels
        plt.rcParams['xtick.labelsize'] = 9.0  # fontsize of the tick labels
        plt.rcParams['ytick.labelsize'] = 9.0  # fontsize of the tick labels
        plt.rcParams['legend.fontsize'] = 9.0
        plt.rcParams['font.family'] = 'serif'
        plt.rcParams['font.serif'] = 'Computer Modern Roman'
        plt.rcParams['text.usetex'] = True  # use latex for all text handling
        plt.rcParams['text.color'] = '3a3a3a'
        plt.rcParams['figure.facecolor'] = 'white'
        plt.rcParams['axes.linewidth'] = 1
        plt.rcParams['axes.edgecolor'] = '3a3a3a'
        plt.rcParams['axes.facecolor'] = 'white'
        plt.rcParams['lines.linewidth'] = 1
        plt.rcParams['lines.markersize'] = 4
        plt.rcParams['xtick.major.size'] = 2
        plt.rcParams['ytick.major.size'] = 2
```

1.2 Load the spherical shell data

And load the computed shell effect per height so that we can calculate the relative difference.

```
In [3]: shell = pd.read_csv('../data/shell-per-height.csv', index_col=0)
```

```
In [4]: shell
```

Out[4]:

	gx	gxx	gxy	gxz	gy	gyy	gyz	gz	gzz
0	0	-0.350758	0	0	0	-0.350758	0	223.788630	0.701517
1	0	-0.349442	0	0	0	-0.349442	0	223.228471	0.698884
2	0	-0.342959	0	0	0	-0.342959	0	220.458972	0.685919
3	0	-0.327439	0	0	0	-0.327439	0	213.756587	0.654878
4	0	-0.311429	0	0	0	-0.311429	0	206.730999	0.622858

	pot	height
0	14278.021191	2000
1	14260.140521	10000
2	14171.404761	50000
3	13954.322847	150000
4	13723.086957	260000

1.3 Plot the error vs distance-size ratio for the 4 experiments

Load the computed differences between the shell and tesseroid effects for each experiment. We'll use the `groupby` method of the *pandas* `DataFrame` to compute the maximum absolute difference per distance-size ratio and keep that.

```
In [5]: def load_max_diff(fname):
            data = pd.read_csv(fname)
            return data.groupby(['size', 'ratio']).max()
```

```
In [6]: pole = load_max_diff('../data/difference-size-1-height-2000-pole.csv')
        equator = load_max_diff('../data/difference-size-1-height-2000-equator.csv')
        goce = load_max_diff('../data/difference-size-1-height-260000-pole.csv')
        big = load_max_diff('../data/difference-size-30-height-2000-pole.csv')
```

This is what the data looks like after taking the maximum difference per ratio.

```
In [7]: pole.head()
```

Out[7]:

		point	gx	gxx	gxy	gxz	gy
size	ratio						
1	0.0	99	769.086112	854.704698	26.822236	5372.013197	0.876313
	0.5	199	11.215857	85.182630	21.765414	45.271905	1.271564
	1.0	299	0.463330	19.514930	2.203664	13.430373	0.236333
	1.5	399	0.070450	1.144707	0.209287	0.557937	0.031353
	2.0	499	0.022737	0.149761	0.024231	0.120548	0.005499

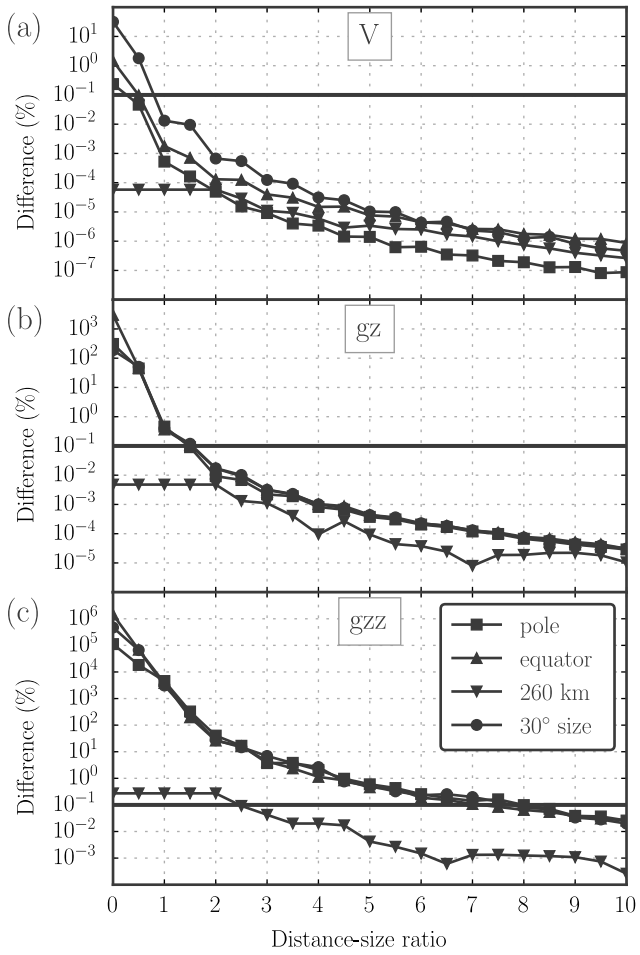
		gyy	gyz	gz	gzz	pot
size	ratio					
1	0.0	311.835644	27.800405	686.281514	782.758707	33.533012
	0.5	64.388814	13.539341	99.543785	128.777627	6.633058
	1.0	12.838965	8.384167	1.027770	32.012723	0.074944
	1.5	1.392990	0.662468	0.203132	2.289414	0.023323
	2.0	0.208828	0.123601	0.020666	0.283195	0.007042

Make a plot of the maximum relative difference as a function of the distance-size ratio used in the computations.

```
In [8]: ratio = pole.index.levels[1] # Get the unique values of the distance-size ratio used
```

```
In [9]: plotargs = dict(color='#3a3a3a', markeredgewidth=0.5, markeredgecolor='#3a3a3a')
        styles = "-s -^ -v -o".split()
```

```
fig, subplots = plt.subplots(3, 1, figsize=(3.33, 5), sharex='col')
axes = subplots.ravel()
fields = ['pot', 'gz', 'gzz']
titles = [r'V', r'gz', r'gzz']
subfigure = ['(a)', '(b)', '(c)']
for ax, f, title, sub in zip(axes, fields, titles, subfigure):
    ax.text(-0.21, 0.9, sub, fontsize=12, fontdict={'weight': 'bold'},
            transform=ax.transAxes)
    ax.text(0.5, 0.9, title, fontsize=11,
            horizontalalignment='center', verticalalignment='center',
            bbox={'facecolor': 'w',
                  'edgecolor': '#9b9b9b',
                  'linewidth': 0.5, 'pad': 8},
            transform=ax.transAxes)
    shell_low = np.abs(shell[shell.height == 2000][f].values)
    shell_high = np.abs(shell[shell.height == 260000][f].values)
    ax.plot(ratio, 100*pole[f]/shell_low, styles[0], label='pole',
            **plotargs)
    ax.plot(ratio, 100*equator[f]/shell_low, styles[1], label='equator',
            **plotargs)
    ax.plot(ratio, 100*goce[f]/shell_high, styles[2], label='260 km',
            **plotargs)
    ax.plot(ratio, 100*big[f]/shell_low, styles[3], label=r'$30^\circ$ size',
            **plotargs)
    ax.hlines(0.1, ratio.min(), ratio.max(), colors=['#3a3a3a'], linewidth=1.5)
    ax.set_xlim(ratio.min(), ratio.max())
    ax.set_yscale('log')
    ax.set_xticks(range(11))
    ax.set_yticks(ax.get_yticks()[2:-2])
    ax.set_ylabel('Difference (\\%)')
    ax.grid(True, linewidth=0.5, color='#aeaeae')
    ax.set_axisbelow(True)
    ax.minorticks_off()
ax = axes[-1]
ax.set_xlabel('Distance-size ratio')
ax.legend(borderpad=0.5, numpoints=1, bbox_to_anchor=(1, 1),
          fancybox=True, shadow=False, fontsize=9, )
plt.tight_layout(pad=0.3, h_pad=0, w_pad=0)
plt.subplots_adjust(hspace=0, wspace=0)
plt.savefig('../figs/distance-size-curves.eps') # Save the figure to an EPS
```



1.4 Plot the error curves for gzz for various heights

Load the data for the gzz difference per height. I'll use the pre-loaded spherical shell data to calculate the relative difference.

```
In [10]: gzz = pd.read_csv('../data/difference-gzz-per-height-size-1-pole.csv',
                           index_col=0).groupby(['height', 'ratio']).max()
```

This is what the first few lines of the data look like.

```
In [11]: gzz.head()
```

```
Out[11]:                      gzz
         height ratio
         2000   0.0    782.758707
                0.5    128.777627
                1.0     32.012723
                1.5      2.289414
                2.0      0.283195
```

```
In [12]: heights = gzz.index.levels[0].values # Get the unique values of the computation height
```

```
In [13]: heights
```

```
Out[13]: array([   2000.,   10000.,   50000.,  150000.,  260000.])
```

Now we'll make the difference x ratio plot with a curve for each height.

```
In [14]: color = '#3a3a3a'
         styles = "-s -^ -v -o -*".split()
         fig = plt.figure(figsize=(3.33, 3))
         ax = plt.subplot(111)
         for h, sty in zip(heights, styles):
             shell_value = np.abs(shell[shell.height == h]['gzz'].values)
             diff = 100*gzz.loc[int(h)]/shell_value
             markersize = 4
             if sty[-1] == '*':
                 markersize = 7
             ax.plot(ratio, diff, sty, label='{:.0f} km'.format(h/1000), color=color,
                     markeredgewidth=0.5, markeredgecolor=color, markersize=markersize)
         ax.hlines(0.1, ratio.min(), ratio.max(), colors=['#3a3a3a'], linewidth=1.5)
         ax.set_xlim(ratio.min(), ratio.max())
         ax.set_yscale('log')
         ax.set_xticks(range(11))
         ax.set_yticks(ax.get_yticks())
         ax.minorticks_off()
         ax.grid(True, linewidth=0.5, color='#aeaeae')
         ax.set_axisbelow(True)
         ax.set_ylabel('Difference (\\%)')
         ax.set_xlabel('Distance-size ratio')
         ax.legend(borderpad=0.5, numpoints=1, bbox_to_anchor=(1, 1),
                   fancybox=True, shadow=False, fontsize=9, )
         plt.tight_layout(pad=0.25, h_pad=0, w_pad=0)
         plt.subplots_adjust(hspace=0, wspace=0)
         plt.savefig('../figs/gzz-with-height.eps') # Save the figure to an EPS
```