homework4

February 12, 2019

In [1]:
```
import numpy as np
import matplotlib.pyplot as plt
```

In [2]:
```
k = 0.03
rho = 1300
C = 650
kappa = k/(rho*C)
```

In [3]:
```
T0 = -42
```

In [4]:
```
'''
Diurnal (Sols)
a_d: deg C
per_d: seconds
delta_d: meters
'''
a_d = 36
per_d = 88642.663
delta_d = np.sqrt(kappa*per_d/np.pi)
```

In [5]:
```
'''
Yearly (Seasonal)
a_y: deg C
per_y: seconds
delta_y: meters
'''
a_y = 11
per_y = 668.5991*per_d
delta_y = np.sqrt(kappa*per_y/np.pi)
```

In [6]:
```
# Estimated Heat Flux [W/m^2]
q = 0.031
```

In [7]:
```
'''
Insight Numbers
zmin: first thermistor depth [m]
zmax: last thermistor depth [m]
step: even thermistor spacing
```

```
        z: meters

        tmax: Mars year [s]
        t: seconds
        '''

        zmin = 0.50
        zmax = 4.5
        step = (zmax-zmin)/14
        z = np.arange(zmin,zmax,step)
        z = np.append(z,zmax)

        tmax = per_y
        t = np.arange(0,tmax,per_d)
```

```
In [8]: # meshgrid deletes last row (14,669)
        # Matlab meshgrid (15,669)
        tt,zz = np.meshgrid(t,z)
```

```
In [9]: # Calculate steady temperature field T(z)
        T1_steady = T0 + (q/k)*z
        T2_steady = T0 + (q/k)*zz
```

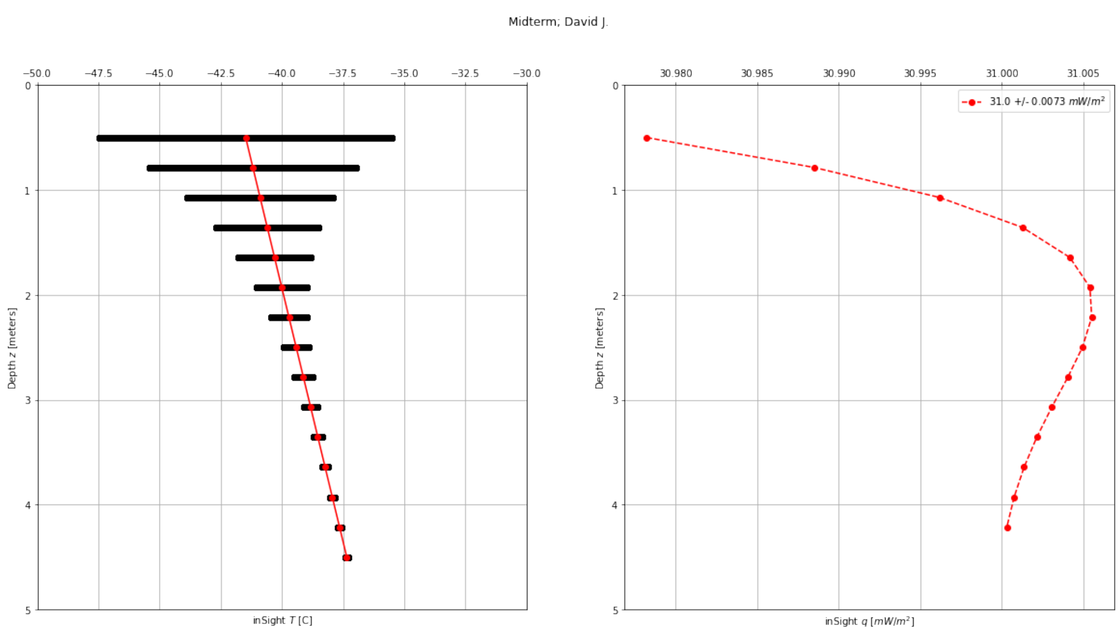
```
In [10]: # Calculate oscillatory temperature field T(t,z)
         T2_osc = a_y*np.exp(-zz/delta_y)*np.cos(2*np.pi*tt/per_y - zz/delta_y) +\
                  a_d*np.exp(-zz/delta_d)*np.cos(2*np.pi*tt/per_d - zz/delta_d)
```

```
In [11]: # Calculate T(t,z): z rows by t columns
         T2d = T2_steady + T2_osc
```

```
In [12]: TMean = [np.mean(T2d[i,:]) for i in range(0,len(T2d))]
```

```
In [13]: # creating figure for subplots
         fig,((ax1),(ax2)) = plt.subplots(1,2,figsize=(20,10))

         # looping through to plot temperature vs distance raw points
         for i in range(0,len(t)):
             if(i == 0):
                 ax1.plot(T2d[:,i],z,'ok')
             else:
                 ax1.plot(T2d[:,i],z,'ok')

         # plotting mean values over raw points
         ax1.plot(TMean,z,'-or')

         # Setting up for subplot 2
         # creating z list deleting last element
         q_year = [i for i in z]
         del q_year[-1]
```

```python
# creating temp list deleting last element
q_t = [i for i in TMean]
del q_t[-1]

# evaluating values using Fourier's Law
fourier = k*(TMean[-1] - q_t)/(z[-1] - q_year)

# plotting flux in subplot 2
current_label = r'%2.1f +/- %5.4f $mW/m^2$' %\
(1000*np.mean(fourier), 1000*np.std(fourier))
ax2.plot(1000*fourier,q_year,'r--o',label=current_label)

# configuration for subplot 1
ax1.axis([-50,-30,5,0])
ax1.set_ylabel(r'Depth $z$ [meters]')
ax1.set_xlabel(r'inSight $T$ [C]')
ax1.xaxis.set_ticks_position('top')
ax1.grid(True)

# configuration for subplot 2
ax2.set_ylim(5,0)
ax2.set_ylabel(r'Depth $z$ [meters]')
ax2.set_xlabel(r'inSight $q$ [$mW/m^2$]')
ax2.xaxis.set_ticks_position('top')
ax2.grid(True)
ax2.legend()

fig.suptitle('Midterm; David J.')

fig.savefig('midtermFig.png')
```



1 Midterm Open Questions

- Why is there systematic trend in the q(z) values? What controls this trend?
- And what would happen to q if random noise was (realistcally) included in this synthetic data set?

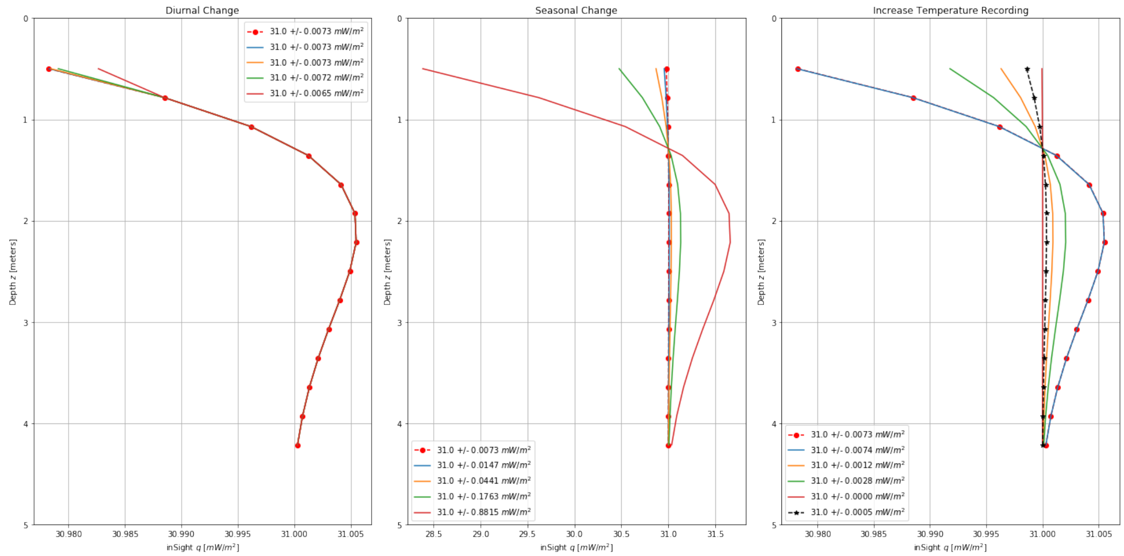
2 Problem 1

1. Make Plots to determine how the systematic trend in q(z) is affected by
   - Changing the amplitude of the daily thermal wave
   - Changing the amplitude of the sesonal thermal wave
   - Increasing the number of temperature measurements made per day
2. At $24\frac{samples}{day}$, to what degree will such trends affect the inSight mission q measurements?

```
In [14]: # creating figure for subplots
         fig2,((ax1),(ax2),(ax3)) = plt.subplots(1,3,figsize=(20,10))

         # initial curve plotted to all three subplots
         fourier0 = fourier

         current_label = r'%2.1f +/- %5.4f $mW/m^2$' %\
         (1000*np.mean(fourier), 1000*np.std(fourier))
         ax1.plot(1000*fourier,q_year,'r--o',label=current_label)
         ax2.plot(1000*fourier,q_year,'r--o',label=current_label)
         ax3.plot(1000*fourier,q_year,'r--o',label=current_label)

         # diurnal change by a factor of [2,3,4,5]
         # seasonal kept constant
         for i in range(2,6):
             a_d *= i

             T2_osc = a_y*np.exp(-zz/delta_y)*np.cos(2*np.pi*tt/per_y - zz/delta_y) +\
                 a_d*np.exp(-zz/delta_d)*np.cos(2*np.pi*tt/per_d - zz/delta_d)
             T2dd = T2_steady + T2_osc
             TMean = [np.mean(T2dd[j,:]) for j in range(0,len(T2dd))]

             q_t = [j for j in TMean]
             del q_t[-1]
             fourierd = k*(TMean[-1] - q_t)/(z[-1] - q_year)

             current_label = r'%2.1f +/- %5.4f $mW/m^2$' %\
             (1000*np.mean(fourierd), 1000*np.std(fourierd))
             ax1.plot(1000*fourierd,q_year,label=current_label)
```

```python
# diurnal reset
a_d = 36

# seasonal changed by a factor of [2,3,4,5]
# diurnal kept constant
for i in range(2,6):
    a_y *= i

    T2_osc = a_y*np.exp(-zz/delta_y)*np.cos(2*np.pi*tt/per_y - zz/delta_y) +\
        a_d*np.exp(-zz/delta_d)*np.cos(2*np.pi*tt/per_d - zz/delta_d)
    T2dy = T2_steady + T2_osc
    TMean = [np.mean(T2dy[j,:]) for j in range(0,len(T2dy))]

    q_t = [j for j in TMean]
    del q_t[-1]
    fouriery = k*(TMean[-1] - q_t)/(z[-1] - q_year)

    current_label = r'%2.1f +/- %5.4f $mW/m^2$' %\
    (1000*np.mean(fouriery), 1000*np.std(fouriery))
    ax2.plot(1000*fouriery,q_year,label=current_label)

# seasonal reset
a_y = 11

# temperature recording rate changed by a factor of [1/2,1/3,1/4,1/24]
for i in range(2,6):
    t = np.arange(0,tmax,per_d/i)
    tt,zz = np.meshgrid(t,z)

    T2_steadyt = T0 + (q/k)*zz
    T2_osct = a_y*np.exp(-zz/delta_y)*np.cos(2*np.pi*tt/per_y - zz/delta_y) +\
        a_d*np.exp(-zz/delta_d)*np.cos(2*np.pi*tt/per_d - zz/delta_d)
    T2dt = T2_steadyt + T2_osct
    TMean = [np.mean(T2dt[j,:]) for j in range(0,len(T2dt))]

    q_t = [j for j in TMean]
    del q_t[-1]
    fouriert = k*(TMean[-1] - q_t)/(z[-1] - q_year)

    current_label = r'%2.1f +/- %5.4f $mW/m^2$' %\
    (1000*np.mean(fouriert), 1000*np.std(fouriert))
    ax3.plot(1000*fouriert,q_year,label=current_label)

    # final case goes into 1/24 case
    if(i == 5):
        t = np.arange(0,tmax,per_d/24)
        tt,zz = np.meshgrid(t,z)
```

```
        T2_steadyt = T0 + (q/k)*zz
        T2_osct = a_y*np.exp(-zz/delta_y)*np.cos(2*np.pi*tt/per_y - zz/delta_y) +\
        a_d*np.exp(-zz/delta_d)*np.cos(2*np.pi*tt/per_d - zz/delta_d)
        T2dt = T2_steadyt + T2_osct
        TMean = [np.mean(T2dt[j,:]) for j in range(0,len(T2dt))]

        q_t = [j for j in TMean]
        del q_t[-1]
        fouriert = k*(TMean[-1] - q_t)/(z[-1] - q_year)

        current_label = r'%2.1f +/- %5.4f $mW/m^2$' %\
        (1000*np.mean(fouriert), 1000*np.std(fouriert))
        ax3.plot(1000*fouriert,q_year,'k--*',label=current_label)

# configuration for subplot 1
ax1.set_ylim(5,0)
ax1.set_ylabel(r'Depth $z$ [meters]')
ax1.set_xlabel(r'inSight $q$ [$mW/m^2$]')
ax1.set_title('Diurnal Change')
ax1.grid(True)
ax1.legend()

# configuration for subplot 2
ax2.set_ylim(5,0)
ax2.set_ylabel(r'Depth $z$ [meters]')
ax2.set_xlabel(r'inSight $q$ [$mW/m^2$]')
ax2.set_title('Seasonal Change')
ax2.grid(True)
ax2.legend()

# configuration for subplot 3
ax3.set_ylim(5,0)
ax3.set_ylabel(r'Depth $z$ [meters]')
ax3.set_xlabel(r'inSight $q$ [$mW/m^2$]')
ax3.set_title('Increase Temperature Recording')
ax3.grid(True)
ax3.legend()

plt.tight_layout()
fig2.savefig('problem1.png')
```



2.0.1 Remarks

From the plots, one can see that the diurnal change has a minimal effect on $q(z)$. However, the seasonal change and temperature increase have charts that differ a lot more.

1. For the seasonal change, this make sense. From an intuitive stand point, the seasons have a larger affect on the weather pattern, and from the equation the values having to do with seasons are much larger and affect the equation to a greater degree.

2. Increasing temperature recording also had an effect on the $q(z)$. While initially it followed the the given trend as the values increased the new temperature values began to flatten out. Which can be due to the fast rate of recording temperatures and not showing to much variation

3. The 24 $samples/day$ is described in the black line on the 3rd subplot. It also is eschewed, but only shows to be the start of going back down towards the given trend.

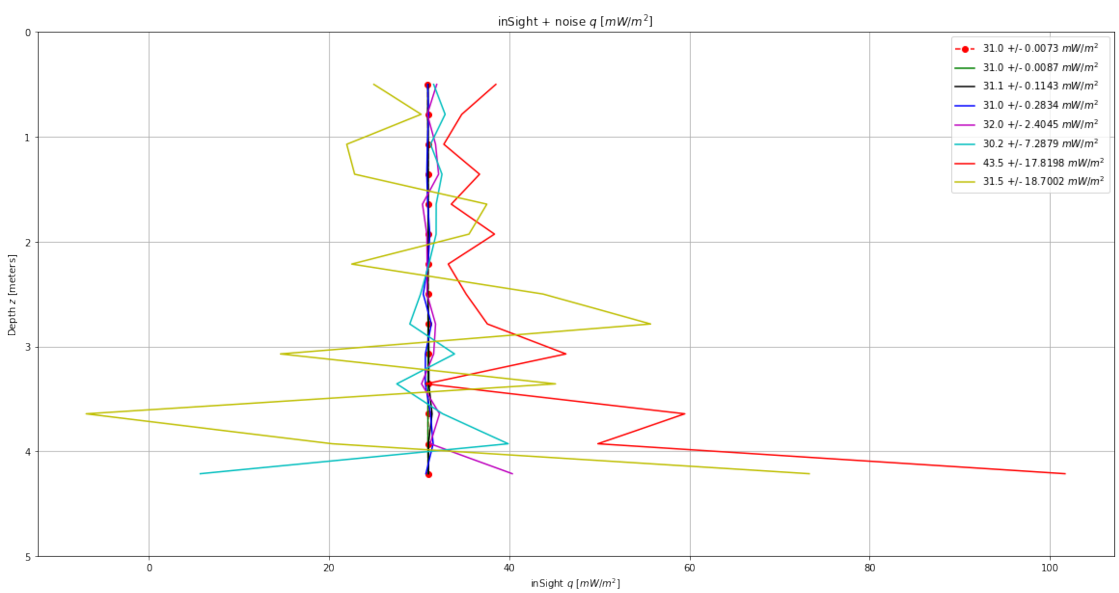
3 Problem 2

1. For our estimates of Martian conditions, make a plot showing how much random noise (as formulated in the Midterm Key) can be added to the system without compromising the q measurements.

   - Determine for what noise amplitude (if any) the measured heat flux departs from the known value by > 20%
   - With estimates of 6.5 milliKelvin variations on their thermistors, is noise likely to be an issue for the inSight mission?

In [15]:
```
# colors to be used for plots
styles = ['r--o','g','k','b','m','c','r','y']
```

```python
fig3 = plt.figure(figsize=(20,10))

# changing noise by a factor [0,1,2,3,4,5,6,7]^4
for i in range(0,8):
    noise = i**4*0.0065*np.random.randn(len(T2d),len(T2d[0]))
    T2dn = T2d + noise

    TnMean = [np.mean(T2dn[i,:]) for i in range(0,len(T2dn))]

    q_year = [i for i in z]
    del q_year[-1]

    q_t = [i for i in TnMean]
    del q_t[-1]

    fouriern = k*(TnMean[-1] - q_t)/(z[-1] - q_year)

    current_label = r'%2.1f +/- %5.4f $mW/m^2$' %\
    (1000*np.mean(fouriern), 1000*np.std(fouriern))
    plt.plot(1000*fouriern,q_year,styles[i],label=current_label)

# plot configuration
plt.legend()
plt.grid(True)
plt.title(r'inSight + noise $q$ [$mW/m^2$]')
plt.ylim(5,0)
plt.ylabel(r'Depth $z$ [meters]')
plt.xlabel(r'inSight $q$ [$mW/m^2$]')

fig3.savefig('problem2.png')
```



3.0.1 Remarks

1. The heat flux departs from the know at around $0.0065 * 6^4 = 8.424K$. This can be seen by the red curve on the plot. Furthermore, the standard deviation is much higher showing that values are changing a lot more leading to even more error, such as the blue curve which is within the 20% threshold, but with it's standard deviation of 7.2879 could also be greatly outside the bound.
2. Estimates of 6.5 milliKelvin, should not be a problem since with the noise the q stayed consistent and the standard deviation only went out by about .003.