John Clouse
ASEN 5090
HW1

Problem 1 (M/E 1-1):

a) $1'^{L} = 1852 = \left(\frac{1}{60}\right)^{\circ L} = 185200\,cm$

$\Rightarrow 1cm = 8.999 \times 10^{-8}$

$\Rightarrow$ $\boxed{\text{8 sig figs after decimal}}$ for 1 centimeter represented in degrees latitude

b) $(60)''^{L} = (6 \times 10^{1})''^{L} = 1.852 \times 10^{5}\,cm$

$\Rightarrow \left(\frac{6}{1.852} \times 10^{-4}\right)''^{L} = 1\,cm = 3.240 \times 10^{-4}$

$\Rightarrow$ $\boxed{\text{4 sig figs after decimal}}$ for 1 cm represented in arc seconds of latitude

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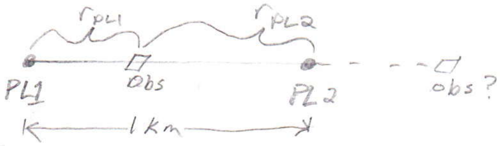
Problem 2 (M/E 1-4)



$\rho = r - \underset{\uparrow \text{clock bias}}{b}$

a) $\rho_{PL1} = 550 = r_{PL1} - b$

$\rho_{PL2} = 500 = r_{PL2} - b$ $\Rightarrow$ subtract $\Rightarrow$ $50 = r_{PL1} - r_{PL2} \Rightarrow r_{PL1} = 50 + r_{PL2}$

<u>between PLs</u>: $r_{PL1} + r_{PL2} = 1\text{ km}$

$r_{PL1} = 50 + 1000 - r_{PL1} \Rightarrow 2r_{PL1} = 1050 \Rightarrow \underline{r_{PL1} = 525}$

$b = r_{PL1} - 550$

$\boxed{b = -25\text{m}}$

<u>outside PLs</u>: $|r_{PL1} - r_{PL2}| = 1\text{ km}$

cannot be outside, as the given ρ's don't allow for it

b) $\rho_{PL1} = 400 = r_{PL1} - b$

$\rho_{PL2} = 1400 = r_{PL2} - b$ $\Rightarrow$ subtract $\Rightarrow$ $-1000 = r_{PL1} - r_{PL2} \Rightarrow r_{PL1} = r_{PL2} - 1000$

<u>between PLs</u>

$r_{PL1} = 1000 - r_{PL1} - 1000 \Rightarrow r_{PL1} = 0$

$400 = -b \Rightarrow \boxed{b = -400\text{m}}$

<u>outside PLs</u>

can't be outside PLs, since obs. is @ PL1

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Problem 3
see attached Matlab for calculations

SET A

$\sigma = 0.3$ ← further digits are meaningless with error in this digit
$\bar{X} = 0.5$ ← cannot have a mean with more precision than σ can give

SET D

$\sigma = 0.3$ ← further digits are meaningless with error in this digit
$\bar{X} = 35.5$ ← cannot have a mean w/ more precision than σ can provide.

HW1 Problem 3: Data means, standard deviations

```
fprintf('\n');
clearvars -except function_list pub_opt
close all

sets = [0.64 35.0495
0.23 35.0057
0.03 35.4955
0.95 35.2935
0.95 35.3393
0.47 35.4829
0.00 35.6245
0.15 35.4717
0.48 35.7321
0.63 35.4567
0.48 35.0233
0.51 35.7177
0.83 35.8106
0.36 35.3045
0.97 35.6869
0.36 35.0497
0.93 35.1555
0.76 35.7150
0.77 35.9912
0.58 35.3015
0.22 35.5324
0.44 35.9756
0.51 35.2991
0.23 35.2881
0.50 35.4022
0.40 35.8123
0.99 35.7386
0.40 35.5481
0.60 35.6242
0.64 35.6057
0.15 35.3499
0.64 35.6078
0.74 35.9811
0.21 35.3705
0.00 35.3342
0.11 35.0754
0.96 35.9829
0.17 35.3148
0.62 35.2739
0.89 35.7777
0.02 35.9086
0.95 35.2198
0.74 35.6107
0.92 35.7388
```

```
0.61 35.0868
0.58 35.2950
0.45 35.1099
0.10 35.1274
0.18 35.8981
0.27 35.2108
0.61 35.1533
0.20 35.7648
0.59 35.4782
0.86 35.5210
0.54 35.7101
0.67 35.9466
0.57 35.7073
0.38 35.8111
0.38 35.4244
0.43 35.0319
0.76 35.2876
0.95 35.0280
0.39 35.7167
0.38 35.7858
0.05 35.9689
0.62 35.5488
0.20 35.3710
0.23 35.9210
0.72 35.7704
0.73 35.3684
0.04 35.1719
0.19 35.9816
0.97 35.9579
0.73 35.2438
0.06 35.6814
0.76 35.6739
0.27 35.9643
0.07 35.4480
0.59 35.3081
0.62 35.3242
0.52 35.0885
0.16 35.4216
0.91 35.3046
0.45 35.2163
0.01 35.8429
0.25 35.1781
0.22 35.3168
0.32 35.2184
0.30 35.3783
0.08 35.4404
0.66 35.2360
0.53 35.0452
0.94 35.1010
0.12 35.9870
0.87 35.3898
0.98 35.4245
0.45 35.3079
0.29 35.1596
```

```
0.04 35.9471
0.12 35.8883];

means = mean(sets, 1)
standard_devs = std(sets, 0, 1)
set_max = max(sets)
set_min = min(sets)
```

```
means =

    0.4810   35.4877


standard_devs =

    0.2953    0.2952


set_max =

    0.9900   35.9912


set_min =

         0   35.0057
```

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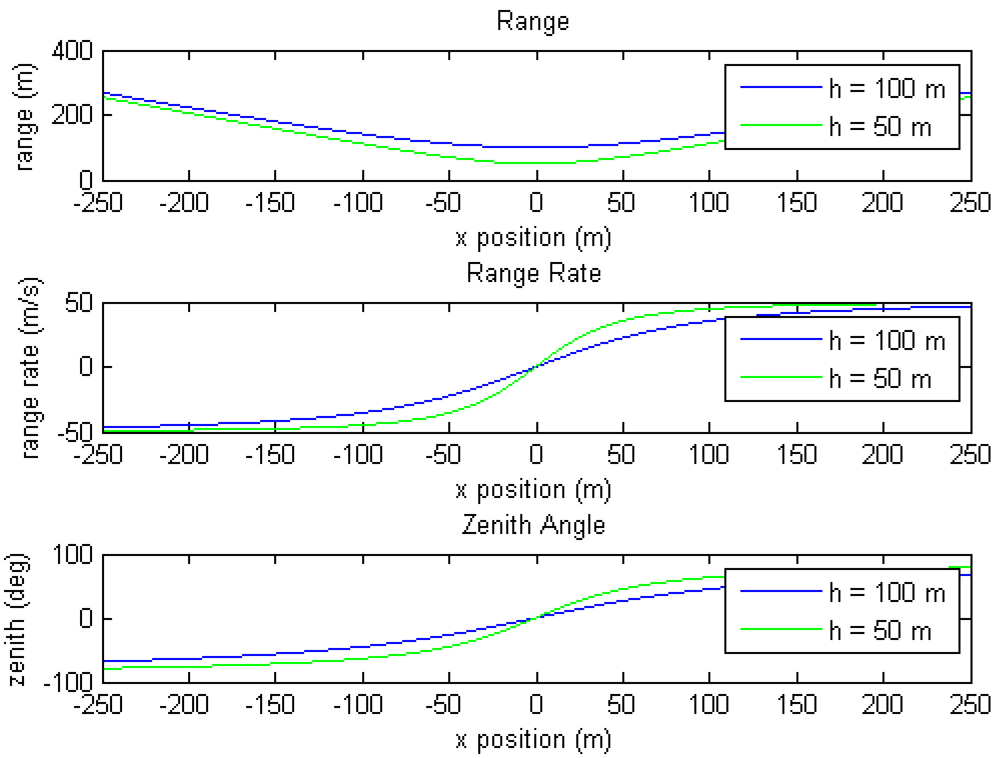
HW1 Problem 4: Ground station observations

```
fprintf('\n');
clearvars -except function_list pub_opt
close all

v = 50; %m/s
h = 100; %m
x0 = 250; %m

x = linspace(-x0, x0, x0*10);

range = sqrt(h*h + x.*x);
range_rate = x./range*v;
zenith = atan2(x,h);

h2 = 50; %m
range2 = sqrt(h2*h2 + x.*x);
range_rate2 = x./range2*v;
zenith2 = atan2(x,h2);

subplot(3,1,1)
plot(x, range)
hold on
plot(x, range2, 'g')
title('Range')
xlabel('x position (m)')
ylabel('range (m)')
legend('h = 100 m', 'h = 50 m')
subplot(3,1,2)
plot(x, range_rate)
hold on
plot(x, range_rate2, 'g')
title('Range Rate')
xlabel('x position (m)')
ylabel('range rate (m/s)')
legend('h = 100 m', 'h = 50 m')
subplot(3,1,3)
plot(x, zenith*180/pi)
hold on
plot(x, zenith2*180/pi, 'g')
title('Zenith Angle')
xlabel('x position (m)')
ylabel('zenith (deg)')
legend('h = 100 m', 'h = 50 m')

fprintf(['range:\n',...
    '\tthe slope is steep away from the ground station, making the\n',...
    '\tmeasurement more sensitive to changes in x (more accurate)\n.',...
    '\tHowever, it loses accuracy directly above. There are also not\n',...
    '\tunique x/range pairings, so another method must be used to \n',...
    '\tdetermine which side of the transmitter the receiver is on.\n',...
```

```
'\tLower values of h make the range measurement more accurate \n',...
'\tcloser to the transmitter\n',...
'range rate:\n',...
'\tThe slope is steep only near the transmitter, so it is not\n',...
'\taccurate at long distances.\n',...
'\tIt has unique x/range rate pairings, so you can tell which side\n',...
'\tof the transmitter the receiver is.\n',...
'\tLower values of h make the range rate measurement less accurate\n',...
'\tuntil the reciever is closest to the transmitter.\n',...
'Zenith angle:\n',...
'\tThe slope is steep only near the transmitter, so it is not\n',...
'\taccurate at long distances.\n',...
'\tIt has unique x/range rate pairings, so you can tell which side\n',...
'\tof the transmitter the receiver is.\n',...
'\tLower values of h make the range rate measurement less accurate\n',...
'\tuntil the reciever is closest to the transmitter.\n'])
```

```
range:
 the slope is steep away from the ground station, making the
 measurement more sensitive to changes in x (more accurate)
. However, it loses accuracy directly above. There are also not
 unique x/range pairings, so another method must be used to
 determine which side of the transmitter the receiver is on.
 Lower values of h make the range measurement more accurate
 closer to the transmitter
range rate:
 The slope is steep only near the transmitter, so it is not
 accurate at long distances.
 It has unique x/range rate pairings, so you can tell which side
 of the transmitter the receiver is.
 Lower values of h make the range rate measurement less accurate
 until the reciever is closest to the transmitter.
Zenith angle:
 The slope is steep only near the transmitter, so it is not
 accurate at long distances.
 It has unique x/range rate pairings, so you can tell which side
 of the transmitter the receiver is.
 Lower values of h make the range rate measurement less accurate
 until the reciever is closest to the transmitter.
```

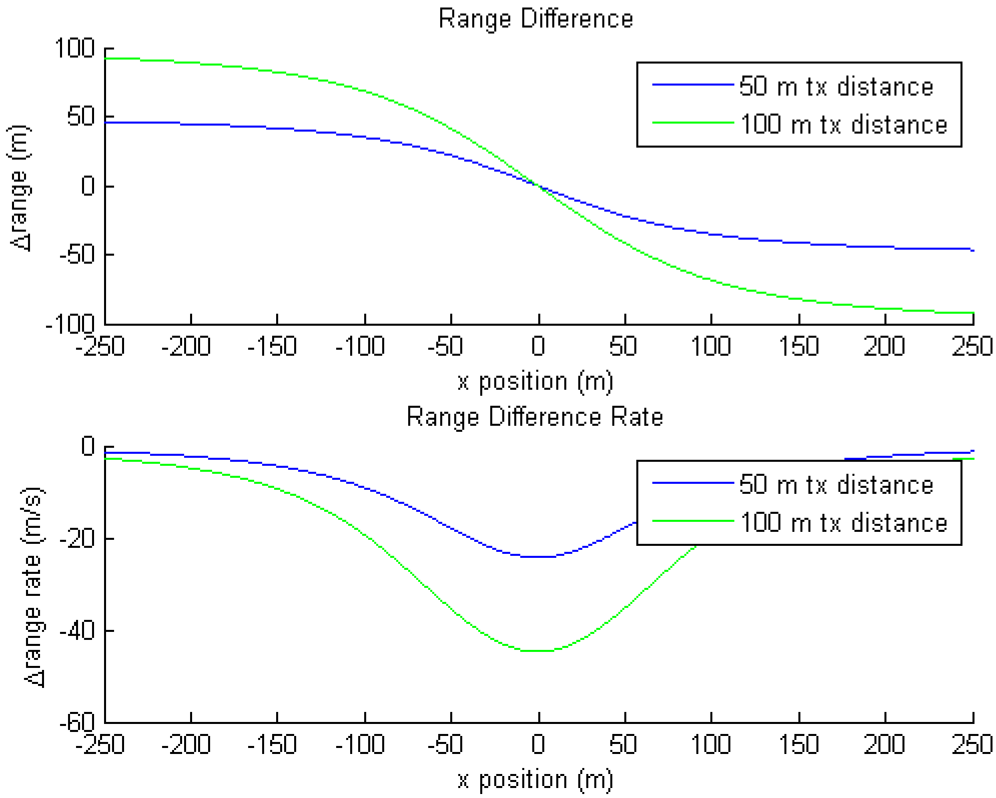


Hyperbolic multilateration

```
figure
hold on
color_opts = ['b';'g'; 'r'];
counter = 1;
for ground_station_spacing = [50 100];
    x1 = -ground_station_spacing/2; %m
    x2 = ground_station_spacing/2; %m
    r1 = sqrt((x1-x).*(x1-x) + h*h);
    r2 = sqrt((x2-x).*(x2-x) + h*h);
    d21 = r2 - r1;
    d21_dot = -(x2-x)./r2*v - -(x1-x)./r1*v;
    subplot(2,1,1)
    hold on
    plot(x, d21, color_opts(counter))
    title('Range Difference')
    xlabel('x position (m)')
    ylabel('\Deltarange (m)')
    legend('50 m tx distance', '100 m tx distance')
    subplot(2,1,2)
    hold on
    plot(x, d21_dot, color_opts(counter))
    title('Range Difference Rate')
    xlabel('x position (m)')
```

```
    ylabel('\Deltarange rate (m/s)')
    legend('50 m tx distance', '100 m tx distance')
    counter = counter + 1;
end
fprintf(['delta range:\n',...
    '\tthe slope is steep closer to the ground station, making the\n',...
    '\tmeasurement more sensitive to changes in x when it approaches \n',...
    '\tthe first transmitter.\n',...
    '\tThere are also unique x/delta-range pairings, so it is known\n',...
    '\twhere the receiver is wrt the transmitters\n',...
    '\tLarger transmitter distances result in more accuracy both between\n',...
    '\tand slightly beyond the transmitters\n',...
    'delta range rate:\n',...
    '\tThe slope is steep just as it approaches the transmitters.\n',...
    '\tIt does not have unique x/delta range rate pairings, so you cannot\n',...
    '\ttell which side of the midpoint the receiver is located.\n',...
    'Delta Range measurement seems most sufficient in this case\n'])
```

```
Warning: Ignoring extra legend entries.
Warning: Ignoring extra legend entries.
delta range:
 the slope is steep closer to the ground station, making the
 measurement more sensitive to changes in x when it approaches
 the first transmitter.
 There are also unique x/delta-range pairings, so it is known
 where the receiver is wrt the transmitters
 Larger transmitter distances result in more accuracy both between
 and slightly beyond the transmitters
delta range rate:
 The slope is steep just as it approaches the transmitters.
 It does not have unique x/delta range rate pairings, so you cannot
 tell which side of the midpoint the receiver is located.
Delta Range measurement seems most sufficient in this case
```



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