SIM 2: Sailbot Data Visualization

Objective:

Explore MATLAB programming techniques for data processing and visualization

Introduction:

In the summer of 2018, a Saildrone unmanned surface vehicle (USV) was launched to follow a course along the US/Mexico coast toward Guadalupe Island near Baja California. The USV was deployed to collect measurements in the California Current System. Vist the Baja Saildrone Project site to learn more.

Load the **sailbot_data.mat** file

```
% Your Code Here
load("sailbot_data.mat")
sailbot_data
```

```
sailbot_data = 86511×8 table
```

...

	time	latitude	longitude	air_temperature	wind_speed_u
1	11-Apr-2018 18:00:00	37.8113	-122.3980	12.9900	2.8500
2	11-Apr-2018 18:01:00	37.8124	-122.4006	13.1200	4.1200
3	11-Apr-2018 18:02:00	37.8129	-122.4035	13.0800	4.6600
4	11-Apr-2018 18:03:00	37.8134	-122.4062	12.9700	5.0900
5	11-Apr-2018 18:04:00	37.8139	-122.4091	12.9700	5.4000
6	11-Apr-2018 18:05:00	37.8143	-122.4120	12.8300	4.5300
7	11-Apr-2018 18:06:00	37.8145	-122.4149	12.8300	5.0300
8	11-Apr-2018 18:07:00	37.8147	-122.4177	12.8000	5.8300
9	11-Apr-2018 18:08:00	37.8150	-122.4204	12.7600	5.1700
10	11-Apr-2018 18:09:00	37.8151	-122.4231	12.7900	5.4900
11	11-Apr-2018 18:10:00	37.8153	-122.4259	12.7800	5.2800
12	11-Apr-2018 18:11:00	37.8154	-122.4287	12.7200	4.5000
13	11-Apr-2018 18:12:00	37.8155	-122.4314	12.8400	5.1400
14	11-Apr-2018 18:13:00	37.8157	-122.4342	12.6700	4.3400
15	11-Apr-2018 18:14:00	37.8159	-122.4371	12.6000	4.6800
16	11-Apr-2018 18:15:00	37.8161	-122.4399	12.5700	3.9000
17	11-Apr-2018 18:16:00	37.8163	-122.4428	12.5900	2.9500
18	11-Apr-2018 18:17:00	37.8164	-122.4456	12.5900	2.7300
19	11-Apr-2018 18:18:00	37.8165	-122.4485	12.4900	2.7600
20	11-Apr-2018 18:19:00	37.8169	-122.4513	12.5100	3.8800

	time	latitude	longitude	air_temperature	wind_speed_u
21	11-Apr-2018 18:20:00	37.8170	-122.4542	12.5900	3.2300
22	11-Apr-2018 18:21:00	37.8169	-122.4570	12.6300	3.7100
23	11-Apr-2018 18:22:00	37.8168	-122.4599	12.6200	3.7100
24	11-Apr-2018 18:23:00	37.8167	-122.4629	12.5500	2.8400
25	11-Apr-2018 18:24:00	37.8166	-122.4659	12.5900	3.0700
26	11-Apr-2018 18:25:00	37.8166	-122.4689	12.6100	3.8700
27	11-Apr-2018 18:26:00	37.8166	-122.4718	12.7300	3.7600
28	11-Apr-2018 18:27:00	37.8172	-122.4744	12.6100	4.5000
29	11-Apr-2018 18:28:00	37.8175	-122.4773	12.6200	4.0300
30	11-Apr-2018 18:29:00	37.8173	-122.4804	12.5900	3.8700
31	11-Apr-2018 18:30:00	37.8170	-122.4829	12.6500	3.5500
32	11-Apr-2018 18:31:00	37.8169	-122.4844	12.6800	3.1000
33	11-Apr-2018 18:32:00	37.8167	-122.4862	12.6200	2.6100
34	11-Apr-2018 18:33:00	37.8165	-122.4877	12.6000	3.2800
35	11-Apr-2018 18:34:00	37.8162	-122.4888	12.5300	3.4300
36	11-Apr-2018 18:35:00	37.8160	-122.4899	12.4800	3.4100
37	11-Apr-2018 18:36:00	37.8158	-122.4910	12.6500	3.3600
38	11-Apr-2018 18:37:00	37.8157	-122.4920	12.6600	3.2200
39	11-Apr-2018 18:38:00	37.8156	-122.4930	12.6000	3.4700
40	11-Apr-2018 18:39:00	37.8155	-122.4939	12.5700	4.7800
41	11-Apr-2018 18:40:00	37.8155	-122.4948	12.5400	4.3700
42	11-Apr-2018 18:41:00	37.8156	-122.4957	12.6200	4.6000
43	11-Apr-2018 18:42:00	37.8156	-122.4965	12.5800	4.5400
44	11-Apr-2018 18:43:00	37.8157	-122.4977	12.6300	4.7600
45	11-Apr-2018 18:44:00	37.8159	-122.4995	12.6400	4.9900
46	11-Apr-2018 18:45:00	37.8161	-122.5013	12.6200	5.2300
47	11-Apr-2018 18:46:00	37.8163	-122.5032	12.6100	5.0300
48	11-Apr-2018 18:47:00	37.8161	-122.5048	12.6100	5.7900
49	11-Apr-2018 18:48:00	37.8150	-122.5060	12.5300	5.3800
50	11-Apr-2018 18:49:00	37.8140	-122.5074	12.5900	5.6400
51	11-Apr-2018 18:50:00	37.8130	-122.5088	12.5900	5.6800
52	11-Apr-2018 18:51:00	37.8119	-122.5101	12.5300	5.6500
53	11-Apr-2018 18:52:00	37.8108	-122.5115	12.5700	5.6500

	time	latitude	longitude	air_temperature	wind_speed_u
54	11-Apr-2018 18:53:00	37.8098	-122.5129	12.5400	5.9100
55	11-Apr-2018 18:54:00	37.8088	-122.5144	12.5300	5.4000
56	11-Apr-2018 18:55:00	37.8078	-122.5159	12.6100	5.2800
57	11-Apr-2018 18:56:00	37.8067	-122.5173	12.6500	5.7900
58	11-Apr-2018 18:57:00	37.8058	-122.5187	12.6200	5.5100
59	11-Apr-2018 18:58:00	37.8050	-122.5201	12.6400	5.1000
60	11-Apr-2018 18:59:00	37.8051	-122.5217	12.6500	4.8100
61	11-Apr-2018 19:00:00	37.8053	-122.5236	12.6800	5.1900
62	11-Apr-2018 19:01:00	37.8055	-122.5254	12.6500	4.9100
63	11-Apr-2018 19:02:00	37.8057	-122.5271	12.6800	5.1400
64	11-Apr-2018 19:03:00	37.8057	-122.5287	12.6200	4.8800
65	11-Apr-2018 19:04:00	37.8048	-122.5300	12.6400	4.2800
66	11-Apr-2018 19:05:00	37.8040	-122.5313	12.6900	5.1500
67	11-Apr-2018 19:06:00	37.8031	-122.5328	12.6000	5.5100
68	11-Apr-2018 19:07:00	37.8022	-122.5343	12.6400	5.0600
69	11-Apr-2018 19:08:00	37.8012	-122.5356	12.5900	4.5500
70	11-Apr-2018 19:09:00	37.8003	-122.5369	12.6200	4.8300
71	11-Apr-2018 19:10:00	37.7994	-122.5382	12.5700	4.5000
72	11-Apr-2018 19:11:00	37.7985	-122.5395	12.5400	4.8100
73	11-Apr-2018 19:12:00	37.7976	-122.5408	12.5800	4.9900
74	11-Apr-2018 19:13:00	37.7967	-122.5422	12.5700	4.6500
75	11-Apr-2018 19:14:00	37.7960	-122.5434	12.5900	4.4800
76	11-Apr-2018 19:15:00	37.7953	-122.5445	12.5400	4.1300
77	11-Apr-2018 19:16:00	37.7948	-122.5454	12.5600	4.7500
78	11-Apr-2018 19:17:00	37.7941	-122.5465	12.5500	4.5300
79	11-Apr-2018 19:18:00	37.7934	-122.5475	12.5900	4.3000
80	11-Apr-2018 19:19:00	37.7928	-122.5485	12.5700	4.2400
81	11-Apr-2018 19:20:00	37.7922	-122.5496	12.5600	4.0700
82	11-Apr-2018 19:21:00	37.7916	-122.5506	12.5300	3.3800
83	11-Apr-2018 19:22:00	37.7910	-122.5515	12.5600	3.3900
84	11-Apr-2018 19:23:00	37.7903	-122.5523	12.6300	3.7300
85	11-Apr-2018 19:24:00	37.7896	-122.5533	12.6100	3.6900
86	11-Apr-2018 19:25:00	37.7890	-122.5542	12.6700	4.0300

	time	latitude	longitude	air_temperature	wind_speed_u
87	11-Apr-2018 19:26:00	37.7882	-122.5551	12.6300	3.9200
88	11-Apr-2018 19:27:00	37.7873	-122.5560	12.5900	4.1800
89	11-Apr-2018 19:28:00	37.7865	-122.5570	12.5700	3.8600
90	11-Apr-2018 19:29:00	37.7858	-122.5579	12.5900	3.5600
91	11-Apr-2018 19:30:00	37.7850	-122.5588	12.6000	4.1600
92	11-Apr-2018 19:31:00	37.7842	-122.5598	12.6000	3.7600
93	11-Apr-2018 19:32:00	37.7834	-122.5608	12.6200	4.1100
94	11-Apr-2018 19:33:00	37.7827	-122.5618	12.6600	3.8000
95	11-Apr-2018 19:34:00	37.7818	-122.5627	12.6400	3.6100
96	11-Apr-2018 19:35:00	37.7811	-122.5636	12.6500	3.3000
97	11-Apr-2018 19:36:00	37.7803	-122.5644	12.6300	3.2700
98	11-Apr-2018 19:37:00	37.7794	-122.5652	12.6700	3.3200
99	11-Apr-2018 19:38:00	37.7785	-122.5660	12.6800	3.6700
100	11-Apr-2018 19:39:00	37.7776	-122.5667	12.6100	3.3400

⋮

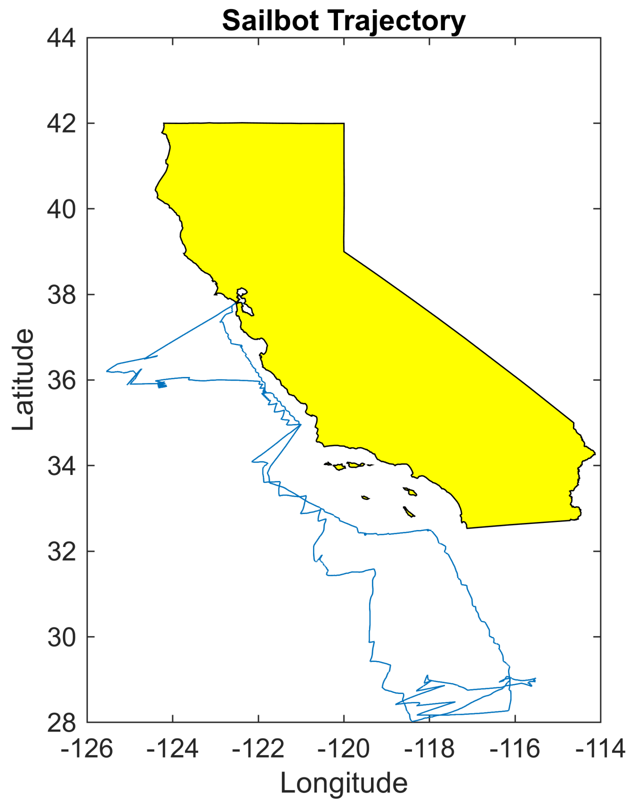
Step 1: Mapping

Plot the trajectory of the sailbot using the latitude and longitude values. Add a title and label the axes.

```
% Your Code Here
% You can use dot indexing to access table variables.
lat = sailbot_data.latitude;
long = sailbot_data.longitude;
plot(long, lat)
title("Sailbot Trajectory")
xlabel("Longitude")
ylabel("Latitude")
```

The code below adds a map of California using the Mapping Toolbox so you can see where the drone sailed relative to the coast.

```
% --- Do Not Edit ---
states = shaperead('usastatehi', 'UseGeoCoords', true);
handle = geoshow(states(5), ...
   'DefaultFaceColor', 'yellow', ...
   'DefaultEdgeColor', 'black');
```



Step 2: Wind Speed and Direction

Plot the wind around the coast of California. Bound the plot limits by:

- **Latitude: `35.8, 36.4`**
- **Longitude: -122.1, -121.7**

Display the wind velocity as vectors using the **`quiver`** function. The x component is `wind_speed_u` and the y component is `wind_speed_v`.

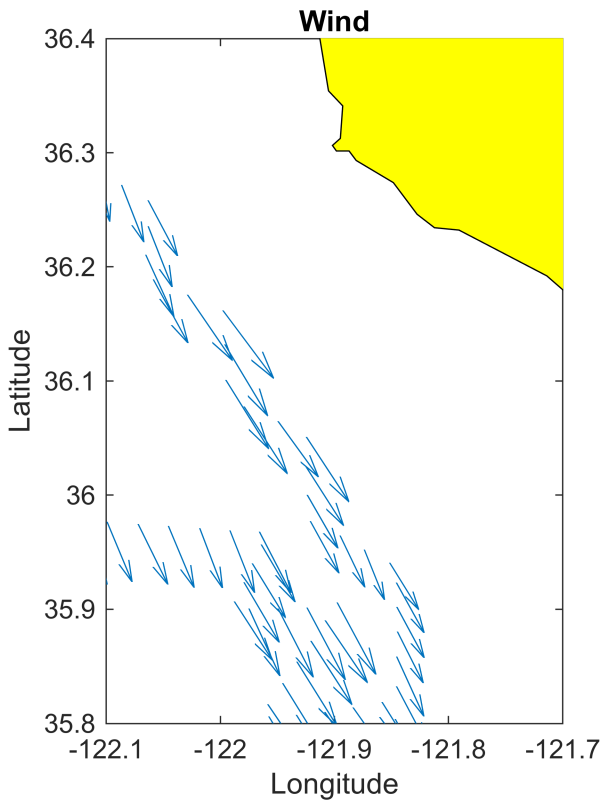
Only plot every 4th sample so the arrows don't overlap eachother.

Add a title and label the axes.

```
% Your Code Here
data = sailbot_data(1:4:end,:);
quiver(data.longitude,data.latitude,data.wind_speed_u,data.wind_speed_v)
xlim([-122.1 -121.7])
ylim([35.8 36.4])
title("Wind")
xlabel("Longitude")
ylabel("Latitude")
```

The code below adds a map of California using the Mapping Toolbox so you can see where the drone sailed relative to the coast.

```
% --- Do Not Edit ---
states = shaperead('usastatehi', 'UseGeoCoords', true);
handle = geoshow(states(5), ...
   'DefaultFaceColor', 'yellow', ...
   'DefaultEdgeColor', 'black');
```



Step 3: Air Temperature

Notice the air temperature has many `NaN` entries. This is because the air temperature is sampled every 5 minutes while the other sensors are sampled every minute. Use one or more logical selections to extract the valid air temperatures and their corresponding times from **07:00 May 11, 2018** to **14:00 May 12, 2018.**

Store the results in two new variables called **`air_temperature`** and **`time`** respectively.

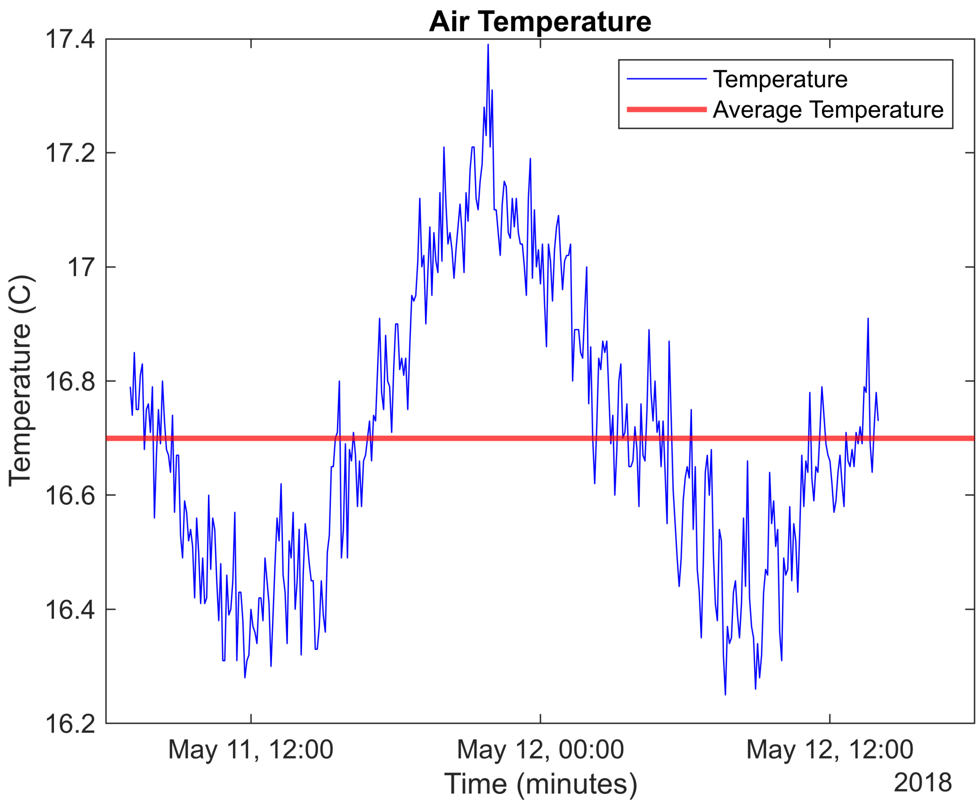
```
% Your Code Here
start_time = find(sailbot_data.time == datetime(2018,5,11,7,0,0));
end_time = find(sailbot_data.time == datetime(2018,5,12,14,0,0));
time = sailbot_data.time(start_time:end_time,:);
air_temperature = sailbot_data.air_temperature(start_time:end_time,:);
missing_idx = ~ismissing(air_temperature);
time = time(missing_idx);
air_temperature = air_temperature(missing_idx);
```

Use these variables to plot the temperature. Add the average temperature as a dashed red line using **`yline`**. Make sure your plot has a title, labels, and a legend.

```
% Your Code Here
plot(time,air_temperature,"b")
avg_temp = mean(air_temperature)
```

```
avg_temp = 16.6997
```

```
yline(avg_temp,"r","LineWidth",2)
title("Air Temperature")
xlabel("Time (minutes)")
ylabel("Temperature (C)")
legend(["Temperature" "Average Temperature"])
```



Fit the temperature to a sine wave using the equation below:

$$y = B + A\sin(Ft + P)$$

Where the coeffecients A, B, F, and P can be interpreted as:

- **A** temperature swing (average to peak)
- **B** average temperature
- **F** frequency (hours)
- **P** offset (hours)

The sliders are below are set to cover the appropriate ranges, try figuring out these values on your own first and then use the sliders to understand how changing each parameter affects the result.

```
peak = max(air_temperature);
A = peak - avg_temp
```

```
A = 0.6903
```

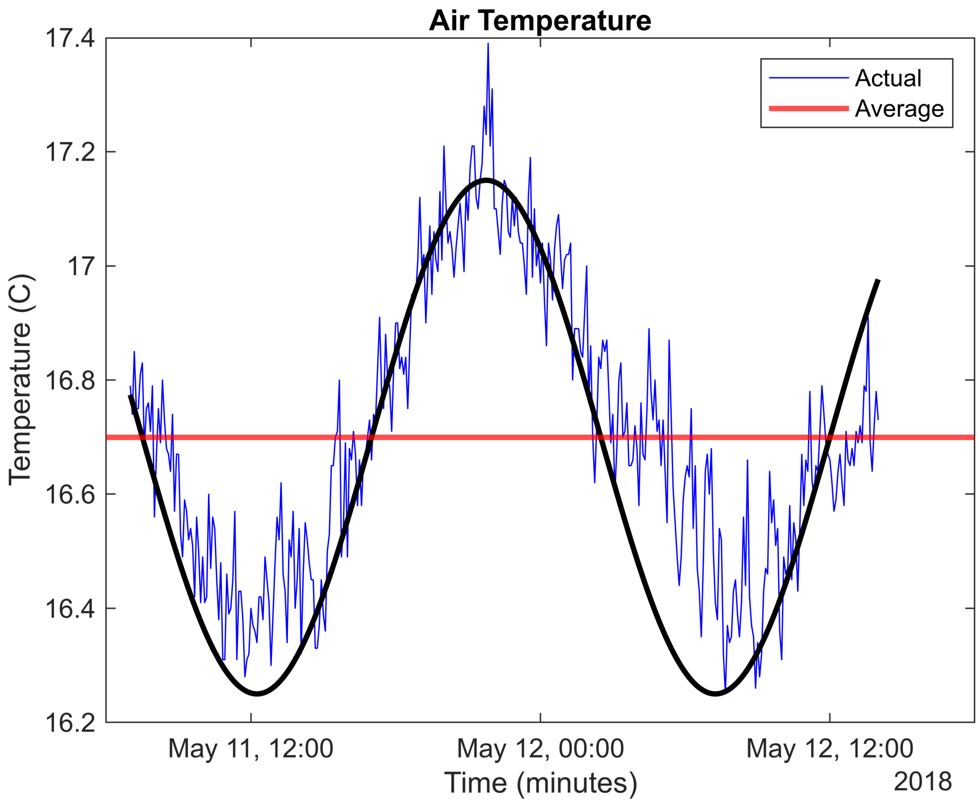
```
B = avg_temp
```

```
B = 16.6997
```

```
A = 0.45;
B = 16.7;
F = 19;
P = 9;
PERSIST_MODELS = true; % try changing this to true
```

Run the model and plot the result

```
% Do Not Edit
hold on
if ~exist("models","var")
    models = [];
end
if ~exist("time","var")
    fprintf("ERROR: The variable 'time' is missing, did you create it above?");
else
    total_time = minutes((time(end)-time(1)));
    t = 0:5:total_time;
    model = B + A*sin(2*pi/(F*60).*(t+P*60));
    h=plot(time,model,'k','LineWidth',2.0);
    models = [models h];
    if ~PERSIST_MODELS
        delete(models(1:end-1));
    end
    legend('Actual','Average');
end
hold off
```



Step 4: Data Analysis

Answer each of the questions below using MATLAB code, use **fprintf** to display your output

Question 1: What was the lowest sea temperature and where was it recorded (lat,long)?

```
% Your code here
[low_temp,low_idx] = min(sailbot_data.water_temperature);
low_lat = sailbot_data.latitude(low_idx);
low_long = sailbot_data.longitude(low_idx);
fprintf("Lowest temperature was " + low_long + " at (" + low_lat + ", " + low_long
+ ").")
```

```
Lowest temperature was -122.7743 at (37.6395, -122.7743).
```

Question 2: What was the lowest latitude reached by the saildrone?

```
% Your code here
bottom_lat = min(sailbot_data.latitude);
fprintf("The lowest latitude reached by the salidrone is " + bottom_lat + "
degrees.")
```

```
The lowest latitude reached by the salidrone is 28.0177 degrees.
```

Question 3: What was the strongest wind magnitude and when was it recorded?

```
% Your code here
lengths = sqrt(sailbot_data.wind_speed_u .^2 + sailbot_data.wind_speed_v .^2);
```

```
[strong, strong_idx] = max(lengths);
strong_lat = sailbot_data.latitude(strong_idx);
strong_long = sailbot_data.longitude(strong_idx);
fprintf("The strongest wind magnitude is " + strong + " which was recorded at " +
...
    strong_lat + " " + strong_long + " degrees.")
```

```
The strongest wind magnitude is 15.5108 which was recorded at 35.4325 -121.6662 degrees.
```