# This example focuses on quality controlling seawater pCO2 from deployment #6.

Load the data from the Pioneer Array Inshore Surface Mooring. Data has been compiled covering the period 10/11/2016 - 3/28/2018. This covers mooring deployments 5, 6, and 7. ISSM data was downloaded using the OOI provided M2M Matlab tools as netCDF files. Two data streams were downloaded ("Telemetered" and "Recovered Host"), and merged together into a single dataset for analysis. Datasets were converted to a Matlab Timetable for analysis.

```
load ISSM_for_Worked_Example.mat

%Data are in the format of at Matlab Timetable.

ISSM(1:10,:) % Display the first 10 rows of data.
```

```
ans = 10×18 timetable
```

...

| | DateTime | time | partial_pressure_co2_ssw | partial_pressure_co2_atm |
|---|---|---|---|---|
| 1 | 11-Oct-2016 1... | 3.6852e+09 | 408.7860 | 464.2206 |
| 2 | 11-Oct-2016 1... | 3.6852e+09 | 408.7057 | 464.3276 |
| 3 | 11-Oct-2016 1... | 3.6852e+09 | 408.6598 | 465.2391 |
| 4 | 11-Oct-2016 1... | 3.6852e+09 | 408.5794 | 466.1388 |
| 5 | 11-Oct-2016 1... | 3.6852e+09 | 408.5221 | 467.0442 |
| 6 | 11-Oct-2016 1... | 3.6852e+09 | 408.4417 | 467.9495 |
| 7 | 11-Oct-2016 1... | 3.6852e+09 | 408.3499 | 468.8554 |
| 8 | 11-Oct-2016 1... | 3.6852e+09 | 408.2810 | 469.7641 |
| 9 | 11-Oct-2016 1... | 3.6852e+09 | 408.1892 | 470.6723 |
| 10 | 11-Oct-2016 1... | 3.6852e+09 | 399.5988 | 463.3304 |

```
%Retime the data to hourly bins
ISSM = retime(ISSM,'hourly','mean');

ISSM(1:10,:) % Display the first 10 rows of data.
```

```
ans = 10×18 timetable
```

...

| | DateTime | time | partial_pressure_co2_ssw | partial_pressure_co2_atm |
|---|---|---|---|---|
| 1 | 11-Oct-2016 1... | 3.6852e+09 | 408.5016 | 467.1346 |
| 2 | 11-Oct-2016 1... | 3.6852e+09 | 399.4173 | 466.8501 |
| 3 | 11-Oct-2016 1... | 3.6852e+09 | 394.2174 | 466.0306 |
| 4 | 11-Oct-2016 1... | 3.6852e+09 | 389.7573 | 466.3291 |
| 5 | 11-Oct-2016 1... | 3.6852e+09 | 388.1098 | 463.4961 |

| | DateTime | time | partial_pressure_co2_ssw | partial_pressure_co2_atm |
|---|---|---|---|---|
| 6 | 11-Oct-2016 1... | 3.6852e+09 | 390.1357 | 463.0964 |
| 7 | 11-Oct-2016 2... | 3.6852e+09 | 391.1038 | 460.8731 |
| 8 | 11-Oct-2016 2... | 3.6852e+09 | 380.6468 | 462.0117 |
| 9 | 11-Oct-2016 2... | 3.6852e+09 | 391.8563 | 461.3813 |
| 10 | 11-Oct-2016 2... | 3.6852e+09 | 393.5846 | 460.0832 |

## Load the discrete data.

Discrete datasets were compiled from the OOI Alfresco Server. The "Discrete Summary" files are not available for the Pioneer 6 (AR18, shown for Leg C) or Pioneer 7 (AR24, shown for Leg B) cruises, so individual data files were downloaded and compiled into a single dataset. Data files included the carbonate data, CTD cast data, and Salinity. Included in the discrete dataset shown below are the surface measurements only as those are the most relevant to the sensors of interest on the surface mooring. No data are flagged as questionable (all 2s for the flags).

```
load ISSM_Discrete.mat

bottleOOI % Display the discrete observations
```

```
bottleOOI = 4×23 table
```

...

| | Station | Cruise | Cast | Niskin | DissolvedOxygenumolkg | Year | Month |
|---|---|---|---|---|---|---|---|
| 1 | ISSM | AR18-C | 1 | 7 | 289.7728 | 2017 | 6 |
| 2 | ISSM | AR18-C | 1 | 8 | 291.0916 | 2017 | 6 |
| 3 | ISSM | AR24B | 9 | 9 | 235.1445 | 2017 | 11 |
| 4 | ISSM | AR24B | 9 | 10 | 237.1524 | 2017 | 11 |

## Load the annotations

```
annotations = readtable('annotations.csv')
```

```
annotations = 34×20 table
```

...

| | id | category | startDate | endDate | description | ongoing |
|---|---|---|---|---|---|---|
| 1 | 21880 | 'Deployment' | '2014-12-14... | '2014-12-... | 'Deployment 0001... | '' |
| 2 | 21881 | 'Deployment' | '2015-05-09... | '2015-10-... | 'Deployment 0002... | '' |
| 3 | 21882 | 'Deployment' | '2015-10-21... | '2016-05-... | 'Deployment 0003... | '' |
| 4 | 21883 | 'Deployment' | '2015-10-21... | '2016-05-... | 'Deployment 0003... | '' |
| 5 | 21884 | 'Deployment' | '2016-05-28... | '2016-10-... | 'Deployment 0004... | '' |
| 6 | 21885 | 'Deployment' | '2016-05-28... | '2016-10-... | 'Deployment 0004... | '' |
| 7 | 21886 | 'Deployment' | '2016-10-11... | '2017-06-... | 'Deployment 0005... | '' |

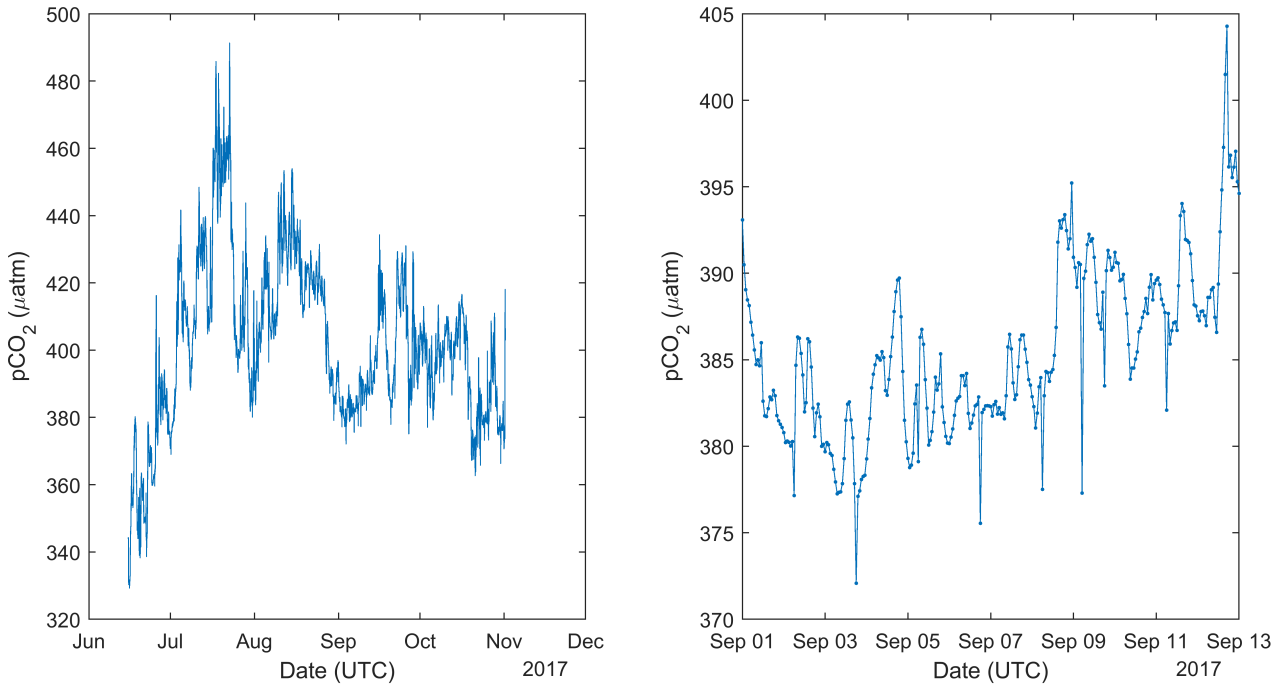
| | id | category | startDate | endDate | description | ongoing |
|---|---|---|---|---|---|---|
| 8 | 21887 | 'Deployment' | '2016-10-11... | '2017-06-... | 'Deployment 0005... | '' |
| 9 | 21888 | 'Deployment' | '2017-06-15... | '2017-11-... | 'Deployment 0006... | '' |
| 10 | 21889 | 'Deployment' | '2017-06-15... | '2017-11-... | 'Deployment 0006... | '' |
| 11 | 21891 | 'Deployment' | '2017-11-01... | '2018-03-... | 'Deployment 0007... | '' |
| 12 | 21890 | 'Deployment' | '2017-11-01... | '2018-03-... | 'Deployment 0007... | '' |
| 13 | 21892 | 'Deployment' | '2018-03-25... | '2018-10-... | 'Deployment 0008... | '' |
| 14 | 21893 | 'Deployment' | '2018-03-25... | '2018-10-... | 'Deployment 0008... | '' |
| 15 | 21875 | 'Status' | '2018-06-18... | '2018-09-... | '[not_operationa... | '' |
| 16 | 21895 | 'Deployment' | '2018-10-29... | '2019-04-... | 'Deployment 0009... | '' |
| 17 | 21894 | 'Deployment' | '2018-10-29... | '2019-04-... | 'Deployment 0009... | '' |
| 18 | 21879 | 'QC Result' | '2019-04-07... | '2019-09-... | '[QC suspect] UP... | '' |
| 19 | 21896 | 'Deployment' | '2019-04-07... | '2019-10-... | 'Deployment 0010... | '' |
| 20 | 21897 | 'Deployment' | '2019-04-07... | '2019-10-... | 'Deployment 0010... | '' |
| 21 | 44863 | 'Deployment' | '2019-04-07... | '2019-10-... | 'Deployment 0010... | '' |
| 22 | 41722 | 'Deployment' | '2019-09-26... | '2020-11-... | 'Deployment 0011... | '' |
| 23 | 21898 | 'Deployment' | '2019-09-26... | '2020-11-... | 'Deployment 0011... | '' |
| 24 | 21877 | 'Note' | '2019-11-04... | '2019-11-... | 'Deployment 11: ... | '' |
| 25 | 21876 | 'Status' | '2020-01-08... | '2020-11-... | '[not_operationa... | '' |
| 26 | 21878 | 'Status' | '2020-03-31... | '2020-11-... | '[not_operationa... | '' |
| 27 | 44347 | 'Deployment' | '2020-10-31... | '2021-03-... | 'Deployment 0012... | '' |
| 28 | 35834 | 'Deployment' | '2020-10-31... | '2021-03-... | 'Deployment 0012... | '' |
| 29 | 42672 | 'Deployment' | '2021-04-02... | '2021-11-... | 'Deployment 0013... | '' |
| 30 | 50113 | 'Deployment' | '2021-04-02... | '2021-11-... | 'Deployment 0013... | '' |
| 31 | 44457 | 'QC Result' | '2021-06-03... | '2021-11-... | '[QC suspect] De... | '' |
| 32 | 46170 | 'Note' | '2021-08-22... | '2022-04-... | 'Deployment 13: ... | 'true' |
| 33 | 49247 | 'Status' | '2021-08-22... | '2021-11-... | '[not_operationa... | '' |
| 34 | 49002 | 'Deployment' | '2021-11-01... | '2022-04-... | 'Deployment 0014... | 'true' |

No annotations are noted for Deployment 6.

## Graph the initial dataset from the deployment of interest.

```
fig = figure; fig.Units = 'Inches'; fig.Position = [0 0 10 5];
subplot(121);
plot(ISSM.DateTime(ISSM.deployment == 6),ISSM.partial_pressure_co2_ssw(ISSM.deployment == 6));
subplot(122);
plot(ISSM.DateTime(ISSM.deployment == 6),ISSM.partial_pressure_co2_ssw(ISSM.deployment == 6),'.
```

```
xlim([datetime([2017 9 1],'TimeZone','UTC') datetime([2017 9 13],'TimeZone','UTC')]);
```




The left panel shows the full dataset. The right panel shows a zoomed in interval from January 16, 2017 - February 4, 2017. The effects of the autozeroing function on the observations can be seen as sharp drops in the signal every 12 hours during the hours of 21:00 and 9:00.

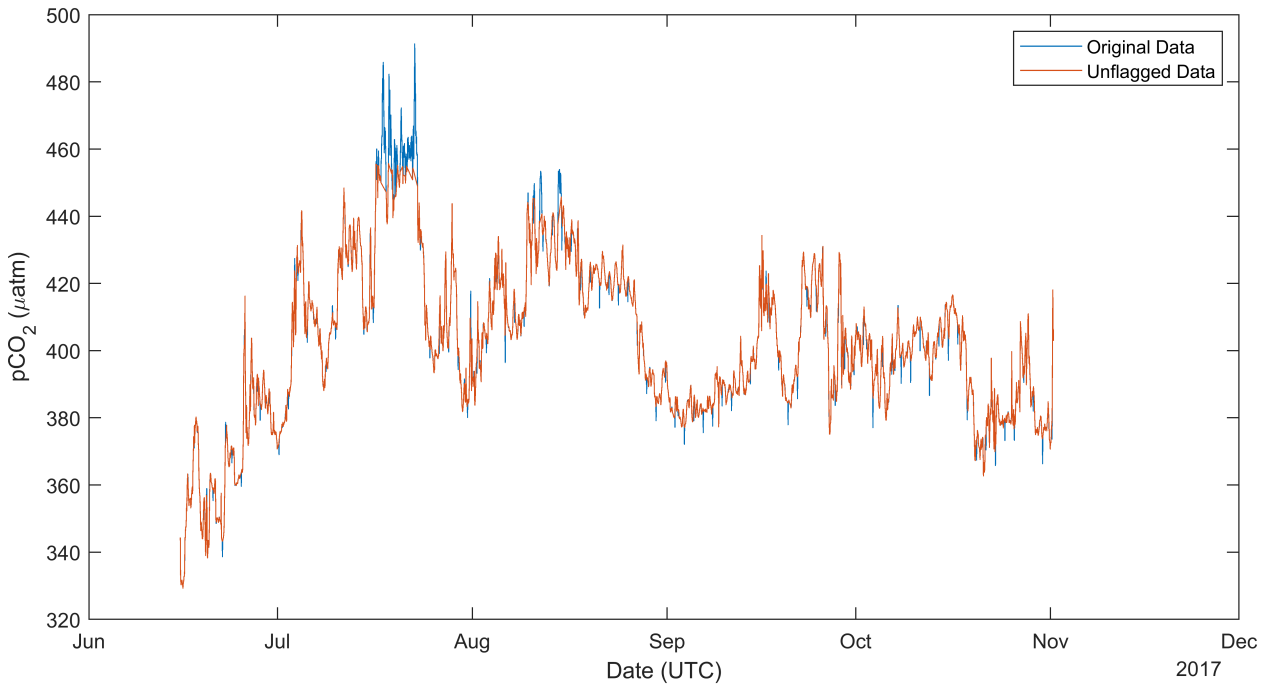
## Create an overall flag variable, apply the QARTOD flags, and flag the data during the autozeroing as bad.

```
I5 = find((hour(ISSM.DateTime) == 21 | hour(ISSM.DateTime) == 9) & ISSM.deployment == 5); %auto
I6 = find((hour(ISSM.DateTime) == 6 | hour(ISSM.DateTime) == 18) & ISSM.deployment == 6); %auto
I7 = find((hour(ISSM.DateTime) == 7 | hour(ISSM.DateTime) == 19) & ISSM.deployment == 7); %auto

ISSM.pCO2_flag = ones(height(ISSM),1).*2; %Create overall flag
ISSM.pCO2_flag(I5) = 5; ISSM.pCO2_flag(I6) = 5; ISSM.pCO2_flag(I7) = 5; % Flag autozero signal
ISSM.pCO2_flag(ISSM.partial_pressure_co2_ssw_qartod_results > 2) = 5; % Apply QARTOD flags for

fig = figure; fig.Units = 'Inches'; fig.Position = [0 0 10 5];
plot(ISSM.DateTime(ISSM.deployment == 6),ISSM.partial_pressure_co2_ssw(ISSM.deployment == 6));
plot(ISSM.DateTime(ISSM.pCO2_flag == 2 & (ISSM.deployment == 6)),ISSM.partial_pressure_co2_ssw(

legend('Original Data','Unflagged Data');
```




## Calculate the full carbonate system on the discrete sample data

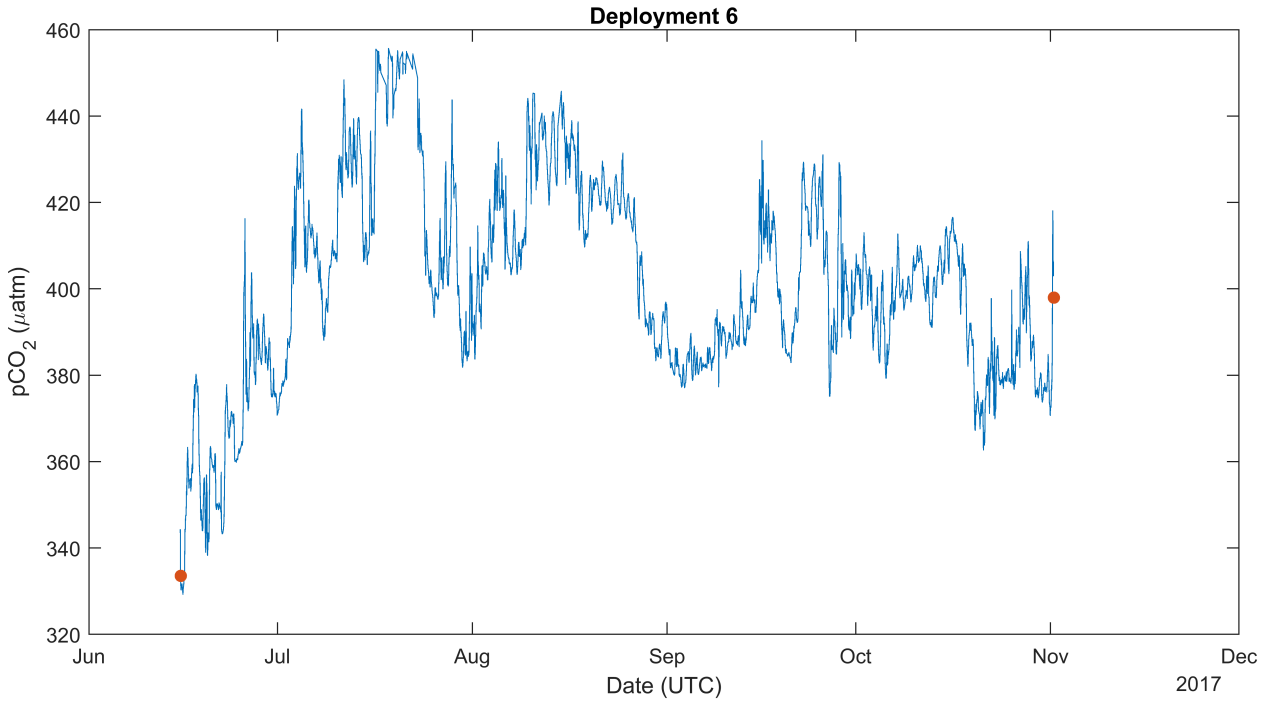
```
p = gsw_p_from_z(-bottleOOI.Depth,bottleOOI.Lat); %calculate sea pressure from bottle sample de

bottleOOI.DateTime = datetime(bottleOOI{:,6:11},'TimeZone','UTC');
```

Using CO2SYS for Matlab, quantify the full carbonate system from discrete pH and DIC samples. This calculation uses carbonic acid dissociation coefficients K1 and K2 from Leuker et al. (2000), sulfate dissociation constant KSO4 from Dickson (1990), total borate concentration from Lee et al. (2010), and HF dissociation coefficient KHF from Perez and Fraga (1987) were used in carbonate system calculations. Input temperature and pressure is set to the temperature and pressure that pH samples were processed at (25 degrees celcius, 0 dbar) and output temperature and pressure was set to insitu conditions.

```
Carb = CO2SYS(bottleOOI.pH,bottleOOI.DIC,3,2,bottleOOI.Salinity,bottleOOI.pHtemp,bottleOOI.Temp
Carb(Carb < -100) = nan; % eliminate -999 output


fig = figure; fig.Units = 'Inches'; fig.Position = [0 0 10 5];
plot(ISSM.DateTime(ISSM.pCO2_flag == 2 & ISSM.deployment == 6),ISSM.partial_pressure_co2_ssw(IS
xlabel('Date (UTC)'); ylabel('pCO_2 (\muatm)'); title('Deployment 6')
scatter(bottleOOI.DateTime,Carb(:,22),'filled');
```




## Quantify offset between discrete observations and sensor data

```
G = findgroups(bottleOOI.DateTime);
AverageCarb = splitapply(@nanmean,Carb,G); %Average duplicate samples together
SampleDate = splitapply(@nanmean,bottleOOI.DateTime,G);
TR1 = timerange(SampleDate(1)-hours(1.5),SampleDate(1)+hours(1.5));
TR2 = timerange(SampleDate(2)-hours(1.5),SampleDate(2)+hours(1.5));

ISSM_noflag = ISSM; % Create new variable to delete bad data from
ISSM_noflag.partial_pressure_co2_ssw(ISSM.pCO2_flag > 2) = nan; % Replace all the flagged data

X(1,1) = nanmean(ISSM_noflag.partial_pressure_co2_ssw(TR1)); %quantify mean sensor data during
X(2,1) = nanmean(ISSM_noflag.partial_pressure_co2_ssw(TR2)); %quantify mean sensor data during

Y = array2table(X,'VariableNames',{'partial_pressure_pco2_ssw'});
Y.discrete_pco2 = AverageCarb(:,22)
```

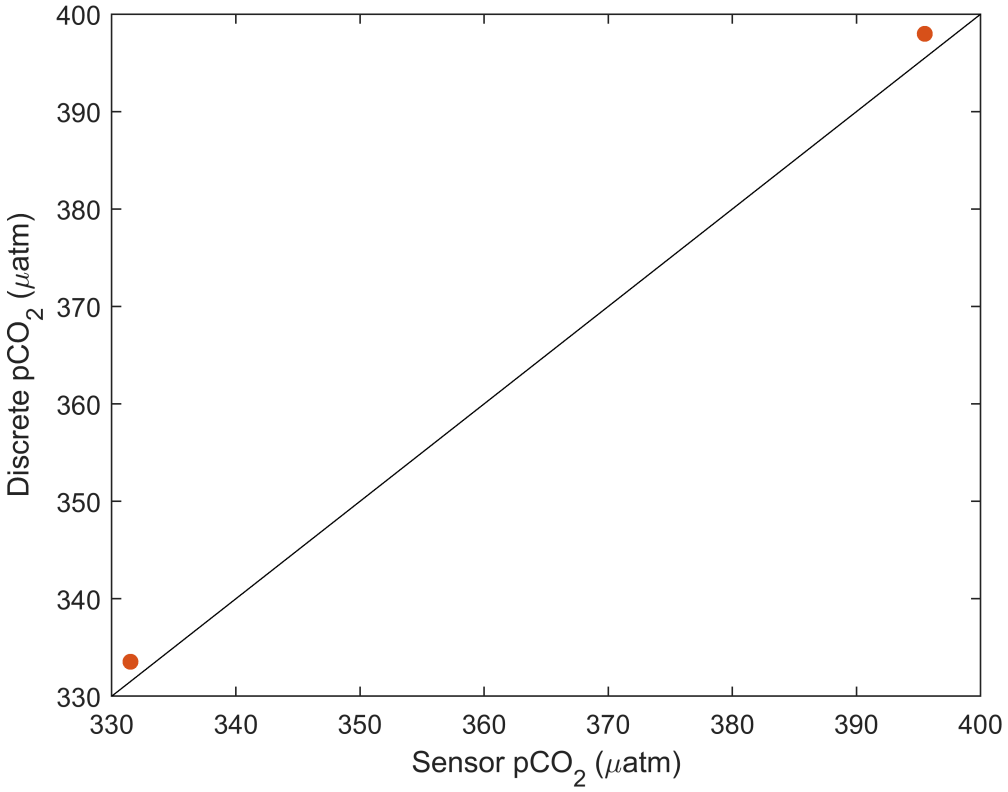
Y = 2×2 table

| | partial_pressure_pco2_ssw | discrete_pco2 |
|---|---|---|
| 1 | 331.5133 | 333.5220 |
| 2 | 395.4973 | 397.9683 |

Sensor pCO2 (partial_pressure_pco2_ssw) and the discrete observations match remarkably well, and likely well within the expected uncertainty of the carbonate system calculations. In this scenario, no offset correction is needed. However, an example offset correction between the sensors and discrete samples is given below, for reference.

```
fig = figure;
```

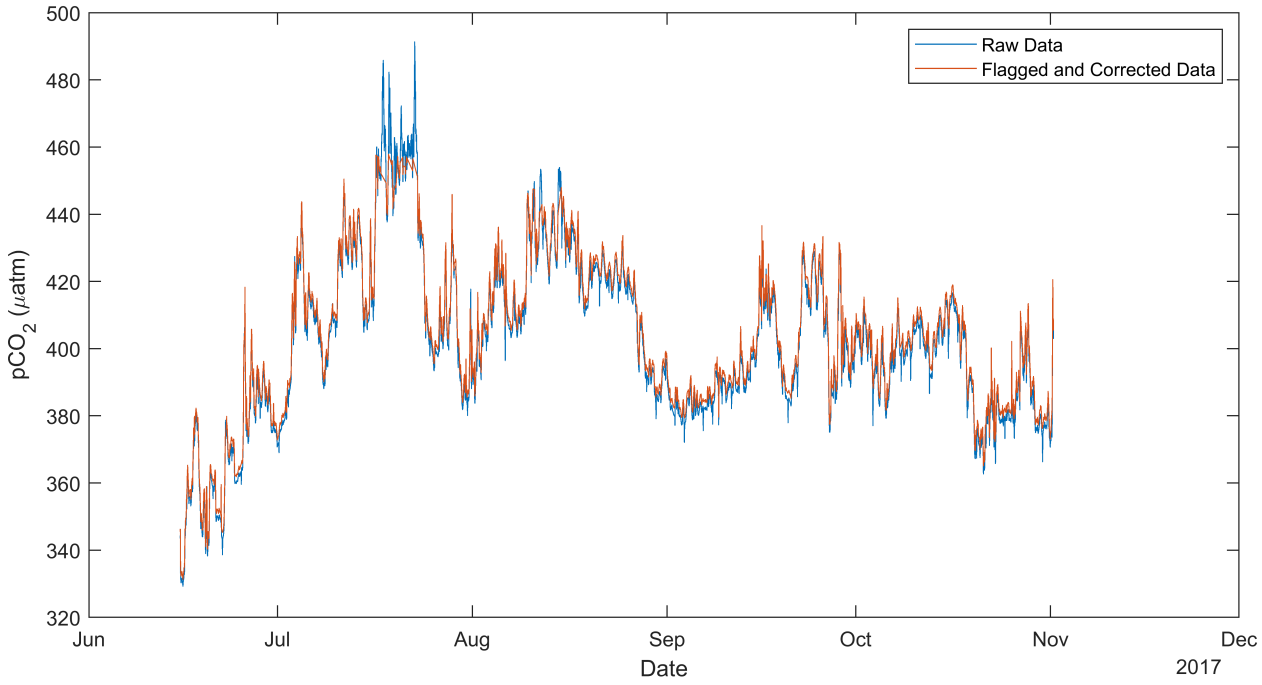
```
plot([330 400],[330 400],'k'); hold on;
scatter(Y.partial_pressure_pco2_ssw,Y.discrete_pco2,'filled'); set(gca,'box','on') ;
xlabel('Sensor pCO_2 (\muatm)'); ylabel('Discrete pCO_2 (\muatm)');
```




This figure illustrates how the sensor data compares to the discrete data. The black line is 1-1, so a slight offset is noticable, but consistent throughtout the timeseries.

```
offset = Y.partial_pressure_pco2_ssw-Y.discrete_pco2; %Quantify the offset between the discrete
f = fitlm(datenum(SampleDate),offset); %Use Matlab's numeric datenumber to calculate a linear c
timeseries_offset = predict(f,datenum(ISSM.DateTime(ISSM.deployment == 6)));
ISSM.partial_pressure_co2_ssw_Corrected = nan(height(ISSM),1);
ISSM.partial_pressure_co2_ssw_Corrected(ISSM.deployment == 6) = ISSM.partial_pressure_co2_ssw(I

fig = figure; fig.Units = 'Inches'; fig.Position = [0 0 10 5];
plot(ISSM.DateTime(ISSM.deployment == 6),ISSM.partial_pressure_co2_ssw(ISSM.deployment == 6));
plot(ISSM.DateTime(ISSM.deployment == 6 & ISSM.pCO2_flag < 3),ISSM.partial_pressure_co2_ssw_Cor
xlabel('Date'); ylabel('pCO_2 (\muatm)'); legend('Raw Data','Flagged and Corrected Data');
```


Raw Data
Flagged and Corrected Data
500
480
460
440
420
400
380
360
340
320
pCO2 (μatm)
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2017
Date