```
% file SIOC 221A HW 9 - monthly
%
% author Julia Dohner
%
% due date December 13, 2017

% analysis of monthly flask-collected co2 data at Mauna Loa, La Jolla↙
and
% the South Pole stations

clear all; close all;

%% load CO2 data

dataMLO = fopen('monthly_data/monthly_flask_co2_mlo_JLD.txt');
dataLJO = fopen('monthly_data/monthly_flask_co2_ljo_JLD.txt');
dataSPO = fopen('monthly_data/monthly_flask_co2_spo_JLD.txt');

valsMLO = textscan(dataMLO, '%f %f', ...
    'delimiter','\t');
valsLJO = textscan(dataLJO, '%f %f', ...
    'delimiter','\t');
valsSPO = textscan(dataSPO, '%f %f', ...
    'delimiter','\t');

fclose(dataMLO);
fclose(dataLJO);
fclose(dataSPO);

% format of .txt files is year, co2 value
LJOyear = valsLJO{1};
LJOco2 = valsLJO{2};

MLOyear = valsMLO{1};
MLOco2 = valsMLO{2};

SPOyear = valsSPO{1};
SPOco2 = valsSPO{2};

% remove flagged data
for i = 1:length(MLOco2)
    if MLOco2(i) == -99.99
```

```
        MLOco2(i) = nan;
    end
end
for i = 1:length(LJOco2)
    if LJOco2(i) == -99.99
        LJOco2(i) = nan;
    end
end
for i = 1:length(SPOco2)
    if SPOco2(i) == -99.99
        SPOco2(i) = nan;
    end
end

% remove nan's
addpath↙
('/Users/juliadohner/Documents/MATLAB/SIOC_221A/HW9/Inpaint_nans/Inpa↙
int_nans');
MLOco2 = inpaint_nans(MLOco2);
LJOco2 = inpaint_nans(LJOco2);
SPOco2 = inpaint_nans(SPOco2);


%% inspect spacing of data

% inspect time spacing between measurements
MLO_t_diff = diff(MLOyear);
LJO_t_diff = diff(LJOyear);
SPO_t_diff = diff(SPOyear);

% figure
% plot(1:length(MLOyear)-1,MLO_t_diff);
% figure
% plot(1:length(LJOyear)-1,LJO_t_diff);
% figure
% plot(1:length(SPOyear)-1,SPO_t_diff);

minDiffLJO = min(LJO_t_diff);
maxDiffLJO = max(LJO_t_diff);
minDiffMLO = min(MLO_t_diff);
maxDiffMLO = max(MLO_t_diff);
minDiffSPO = min(SPO_t_diff);
```

```
maxDiffSPO = max(SPO_t_diff);

% too big differences in time increments of daily LJO flask sampling,↙
will try
% monthly data instead

% update: time differences range between 0.0767 and 0.0850 years for↙
both
% MLO and LJO records (difference of 0.0083) or ~3 days, deemed small
% enough difference in time increments
% read: counts in my book as even spacing

%% shorten data to same lengths

startYear = LJOyear(1,1); % latest start
endYear = SPOyear(length(SPOyear),1); % earliest end
startIndex_LJO = find(LJOyear == startYear);
startIndex_MLO = find(MLOyear == startYear);
startIndex_SPO = find(SPOyear == startYear);
endIndex_LJO = find(LJOyear == endYear);
endIndex_MLO = find(MLOyear == endYear);
endIndex_SPO = find(SPOyear == endYear);

% create new vectors
LJOco2_2 = LJOco2(startIndex_LJO:endIndex_LJO);
LJOyear_2 = LJOyear(startIndex_LJO:endIndex_LJO);
MLOco2_2 = MLOco2(startIndex_MLO:endIndex_MLO);
MLOyear_2 = MLOyear(startIndex_MLO:endIndex_MLO);
SPOco2_2 = SPOco2(startIndex_SPO:endIndex_SPO);
SPOyear_2 = SPOyear(startIndex_SPO:endIndex_SPO);

% plot timeseries
figure('name','Atmospheric CO2 Timeseries');
plot(LJOyear_2,LJOco2_2, MLOyear_2,MLOco2_2,SPOyear_2,SPOco2_2);
xlabel('\fontsize{14}year')
ylabel('\fontsize{14}ppm')
%title('\fontsize{20}Atmospheric CO2 Records')
legend('\fontsize{18}La Jolla Station','\fontsize{18}Mauna Loa',↙
'\fontsize{18}South Pole','Location','southeast');


%% compute spectra (from in-class coherence example)
```

```
N = length(LJOco2_2);
Nseg = 8; % number of segments splitting data into
segment_length = N/Nseg; % length of each chunk of data (aka segment↙
length)
M = segment_length/2;


% 72-long segments
LJO_use = [reshape(LJOco2_2,segment_length,Nseg)];
MLO_use=[reshape(MLOco2_2,segment_length,Nseg)];
SPO_use=[reshape(SPOco2_2,segment_length,Nseg)];

LJO_ft=fft(detrend(LJO_use).*(hann(segment_length)*ones(1,Nseg)));
MLO_ft=fft(detrend(MLO_use).*(hann(segment_length)*ones(1,Nseg)));
SPO_ft=fft(detrend(SPO_use).*(hann(segment_length)*ones(1,Nseg)));

LJO_spec=sum(abs(LJO_ft(1:M+1,:)).^2,2)/N; % sum over all spectra↙
(2nd dim)
LJO_spec(2:end)=LJO_spec(2:end)*2; % multiply by 2 to make up for↙
lost energy

MLO_spec=sum(abs(MLO_ft(1:M+1,:)).^2,2)/N;
MLO_spec(2:end)=MLO_spec(2:end)*2;

SPO_spec=sum(abs(SPO_ft(1:M+1,:)).^2,2)/N;
SPO_spec(2:end)=SPO_spec(2:end)*2;

%% uncertainty estimate on spectra

nu = 1.9*2*Nseg; % DOF = 2*number of segments*1.9 (1.9 for the↙
Hanning)
err_high = nu/chi2inv(0.05/2,nu);
err_low = nu/chi2inv(1-0.05/2,nu);
ratio_chi2 = err_high/err_low;

%% plot spectra

frequency=(1:M+1)/(segment_length/12);
frequency = frequency';

figure('name','Power Spectra of CO2 Records');
```

```
loglog(frequency,LJO_spec,  ...
    frequency, MLO_spec,  ...
    frequency, SPO_spec, [.2 .2],[err_low err_high]*5)
axis([0 10 -1000 1000])
xlabel('\fontsize{14}cycles per year')
ylabel('\fontsize{14}ppm^2/cpy')
title('\fontsize{16}Power Spectra of CO2 Records')
legend('\fontsize{12}La Jolla Station','\fontsize{12}Mauna Loa↙
Station', '\fontsize{12}South Pole','\fontsize{12}Uncertainty↙
Estimate','Location','northeast');

%% compute coherence

% compute cross covariance of LJO/MLO
ccLM=sum(LJO_ft(1:M+1,:).*conj(MLO_ft(1:M+1,:)),2)/N;
ccLM(2:end)=ccLM(2:end)*2;
% compute coherence
C_LM=abs(ccLM)./sqrt(LJO_spec.*MLO_spec);
phase_LM = atan2(-imag(ccLM),real(ccLM));
deltaPhase_LM = sqrt((1-C_LM.^2)./(abs(C_LM).^2*2*Nseg));

% compute cross covariance of MLO/SPO
ccMS=sum(MLO_ft(1:M+1,:).*conj(SPO_ft(1:M+1,:)),2)/N;
ccMS(2:end)=ccMS(2:end)*2;
% compute coherence
C_MS=abs(ccMS)./sqrt(MLO_spec.*SPO_spec);
phase_MS = atan2(-imag(ccMS),real(ccMS));
deltaPhase_MS = sqrt((1-C_MS.^2)./(abs(C_MS).^2*2*Nseg));

%% uncertainty estimate

alpha = 0.05; % 95% confidence level
gamma_threshold= sqrt(1-alpha^(1/(Nseg-1)));


%% plot the coherence

figure('name','Coherence Plots of CO2 Records');
subplot(2,1,1)
plot(frequency, C_LM,[frequency(1) frequency(end)],[gamma_threshold↙
gamma_threshold]);
axis tight;
```

```
xlabel('\fontsize{14}cycles per year')
ylabel('\fontsize{14}coherence')
title('\fontsize{16}Coherence of CO2 Records (LJO and MLO)')
legend('\fontsize{12}La Jolla vs. Mauna Loa','\fontsize{12}↙
Uncertainty Threshold','Location','northeast');

subplot(2,1,2)
plot(frequency, C_MS,[frequency(1) frequency(end)],[gamma_threshold↙
gamma_threshold]);
axis tight
xlabel('\fontsize{14}cycles per year')
ylabel('\fontsize{14}coherence')
title('\fontsize{16}Coherence of CO2 Records (MLO and SPO)')
legend('\fontsize{12}Mauna Loa vs. South Pole','\fontsize{12}↙
Uncertainty Threshold','Location','northeast');


%% plot the phase

figure('name','Phase Plots');
subplot(2,1,1)
semilogx(frequency,[phase_LM phase_LM+deltaPhase_LM phase_LM-↙
deltaPhase_LM]);
refline(0,pi);
refline(0,-pi);
xlabel('\fontsize{14}cycles per year')
ylabel('\fontsize{14}phase')
title('\fontsize{16}Phase Plot for Mauna Loa and La Jolla Coherence')
legend('\fontsize{12}phase', 'phase+delta phase','phase-delta↙
phase','Location','northwest');
axis tight

subplot(2,1,2)
semilogx(frequency,[phase_MS phase_MS+deltaPhase_MS phase_MS-↙
deltaPhase_MS]);
refline(0,pi);
refline(0,-pi);
xlabel('\fontsize{14}cycles per year')
ylabel('\fontsize{14}phase')
title('\fontsize{16}Phase Plot for Mauna Loa and South Pole↙
Coherence')
legend('\fontsize{12}phase', 'phase+delta phase','phase-delta↙
```

```
phase','Location','northwest');
axis tight
```