Lab 9
EOF analysis

Handout – print version of Lecture on *Marine Modelling* March 18, 2019

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9.1

1 Outline

Outline

Plan for today:

- Review plotting coastlines and visualizing spatial data
- Perform EOF analysis
- Perform EOF reconstruction

9.2

2 Coastlines

Coastlines

For example:

Coastline data for Gulf of St. Lawrence, Labrador and Nova Scotia region file: `coastline_GSL_SS_labrador.dat`. Short script to plot: `plotting_coastline.m`:

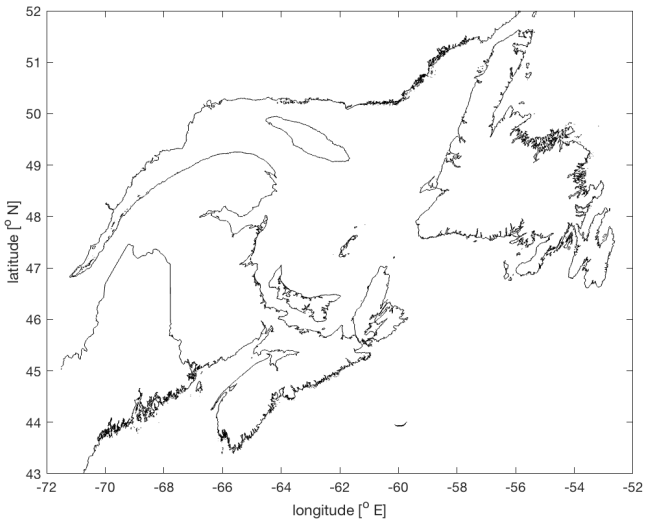
```
% plotting a coastline
load coastline_GSL_SS_labrador.dat

lon = coastline_GSL_SS_labrador(:,1);
lat = coastline_GSL_SS_labrador(:,2);

figure;
plot(lon,lat,'k-')
xlabel('longitude [^o E]')
ylabel('latitude [^o N]')
```

9.3

Coastlines



9.4

3 EOF analysis

EOF analysis

Monthly mean SeaWiFS surface chlorophyll concentrations for the coastal waters of New England (file: `SeaWiFS_chl_NewEngland.mat`)

It contains the following variables:

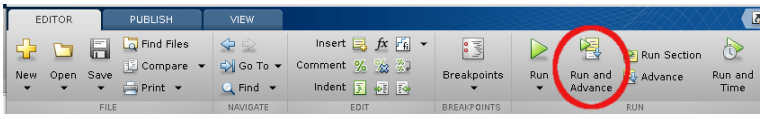
Name	Size	Bytes	Class
chl	35x51x71	1013880	double
date_str	1x35	4698	cell
lat	51x71	28968	double
lon	51x71	28968	double

Note that `date_str` is a **cell array**, which is a bit more flexible than an array and very useful for dealing with collections of strings. You can access the elements of `date_str` using curly brackets: `date_str{t}` .

9.5

Chl animation

Let's look at the chlorophyll data. We can create a simple animation of the data fields using a for-loop and the `pause` command. (Follow along using script: `EOF_chl_NewEngland.m`)



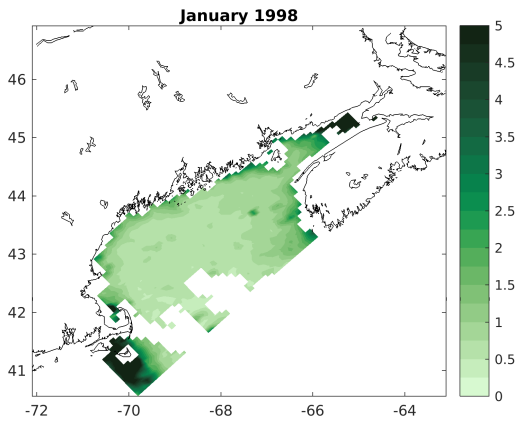

```
load SeaWiFS_chl_NewEngland

figure(1);
for t=1:size(chl,1)
    pcolor(lon,lat,squeeze(chl(t,:,:)))
    colormap(cmocean('algae',20))
    shading interp
    plotnewengland
    caxis([0 5])
    colorbar
    title(date_str{t})
```

```
    pause(0.2)
end
```

9.6

Chl animation



Note the missing values (land points and clouds) which would cause trouble for EOF analysis. We need to exclude them.

9.7

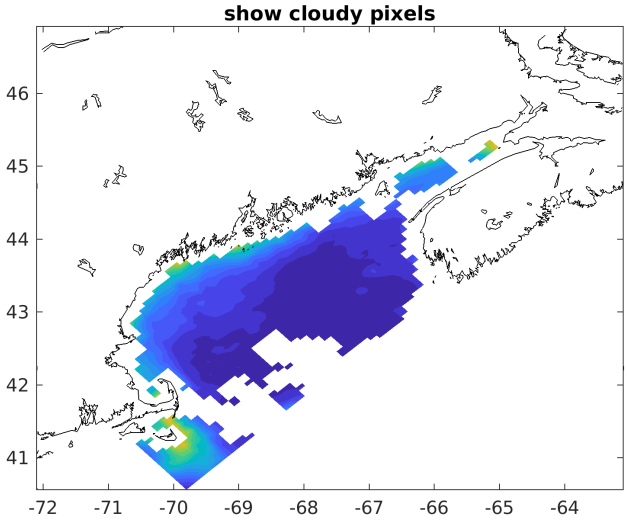
EOF chlorophyll

Let's look at all cloudy pixels.

```
test_clouds = sum(chl,1);
figure(2);
pcolor(lon,lat,squeeze(test_clouds))
colormap(parula(20))
shading interp
plotnewengland
title('show cloudy pixels')
```

9.8

EOF chlorophyll



9.9

EOF chlorophyll

```
% EOF analysis:
% 1) transform 3D chl array into 2D data matrix
%    and remove NaNs

% 1.1) determine land and cloud points (NaNs)
good_ind = ~isnan(test_clouds(:));

% 1.2) create 2D data matrix without NaNs
chl2D = nan(size(chl,1),sum(good_ind));
for t = 1:size(chl,1)
    x = chl(t,:);
    chl2D(t,:) = x(good_ind);
end

% 1.3) dimensions of our data matrix are:
[M, N] = size(chl2D);
```


EOF chlorophyll

```
% 2) calculate anomalies
chl2D_mn = mean(chl2D,1); % temporal averages
chl2D_an = chl2D-ones(M,1)*chl2D_mn; % anomalies

% 3) calculate eigenvalues
% and eigenvectors of cov-mat
% 3.1) calculate covariance matrix
C = chl2D_an'*chl2D_an/(M-1);

% 3.2) calculate SVD (and take the time)
tic
[U,S,V] = svd(C,0);
toc
disp('(for SVD only)')
```

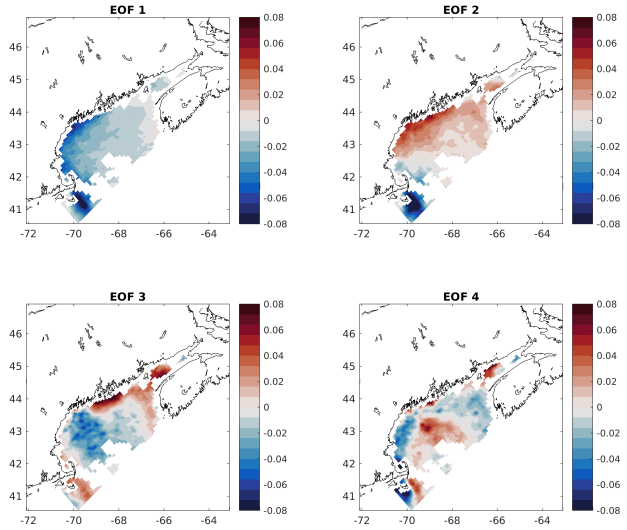

EOF chlorophyll

```
% 4) look at the first 4 EOFs,
% variance explained and scores
% 4.1) turn back into 2D matrices and plot EOFs
aux = NaN(size(chl,2)*size(chl,3),1);
EOF = cell(1,4);
figure(3);
cLim = [0.08, 0.08, 0.08, 0.08];
for i=1:4
    aux(good_ind) = V(:,i);
    EOF{i} = reshape(aux,size(chl,2),size(chl,3));
    % plot EOF
    subplot(2,2,i)
    pcolor(lon,lat,EOF{i}); shading interp
    colormap(cmocean('balance',20))
    caxis([-cLim(i),cLim(i)])
    plotnewengland; colorbar
```

```
    title(['EOF ' num2str(i)])
end
```

9.12

EOF chlorophyll



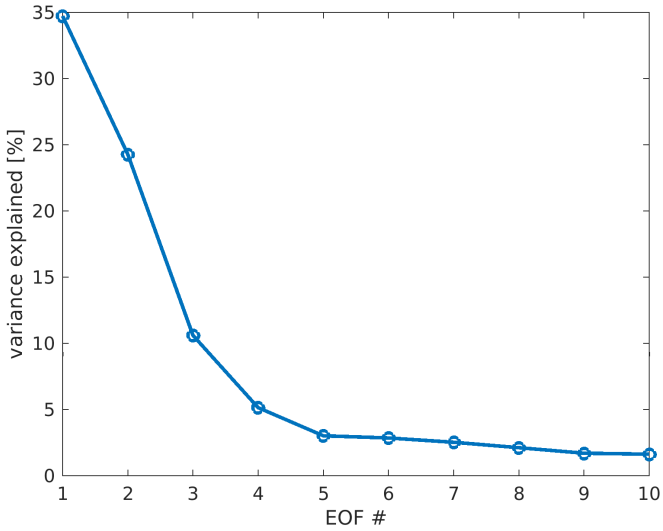
9.13

EOF chlorophyll

```
% 4.2) look at variance explained
var_explained = diag(S)/trace(S);
figure(4);
plot(var_explained(1:10)*100,'o-')
set(gca, 'XLim', [1,10]);
ylabel('variance explained [%]')
xlabel('EOF #')
```

9.14

EOF chlorophyll



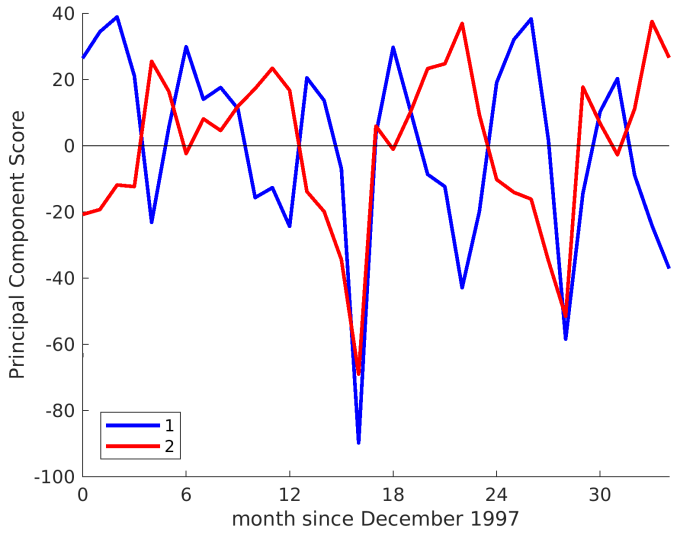
9.15

EOF chlorophyll

```
% 4.3) look at EOF amplitude through time
% (i.e. the PC scores)
score = cell(1,4);
for i=1:4
    score{i} = chl2D_an*V(:,i);
end
figure(5);
plot(0:length(score{1})-1,score{1},'b-','linewidth',2)
plot(0:length(score{2})-1,score{2},'r-','linewidth',2)
line([0, length(score{1})-1], [0, 0], 'Color', 'k');
set(gca, 'XLim', [0, length(score{1})-1], ...
         'XTick', 0:6:length(score{1}));
legend('1','2','Location','SouthWest')
xlabel(['month since ' date_str{1}])
ylabel('Principal Component Score')
```

9.16

EOF chlorophyll



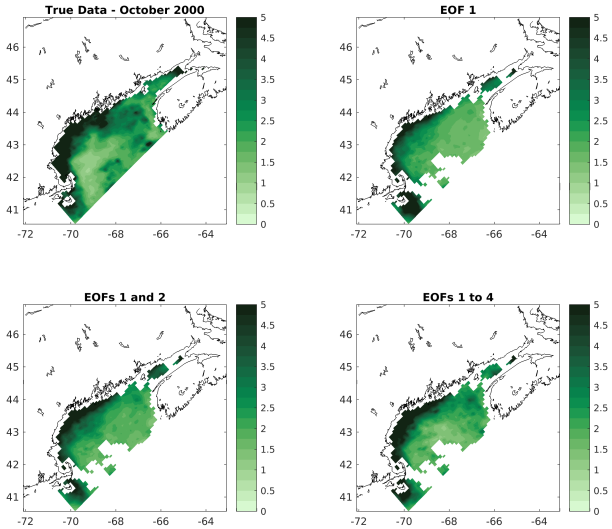
9.17

EOF chlorophyll exercise

Let's reconstruct the monthly chl data using the EOFs. Have a look at `EOF_reconstruction.m`. We'll do a stepwise reconstruction using the 1st EOF, 1st and 2nd EOFs, and EOFs 1 to 4. Can you spot the differences?

9.18

EOF chlorophyll exercise


True Data - October 2000
EOF 1
EOFs 1 and 2
EOFs 1 to 4
46
45
44
43
42
41
-72
-70
-68
-66
-64
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0

9.19