ATMO 611 – Satellite Data Applications Lab Assignment #8

50 Points Total Available

Finding El Niño (ENSO) – DUE Friday November 17th, 2017

This lab will give you some experience with the MODIS SST Product. Questions to be answered are labeled **Q1**, **Q2**, etc. and are highlighted in Red. More guidance will be provided as to how detailed a response I am expecting for each question or the specificity of the answer. Matlab coding on your own are highlighted in Green as **C1**, **C2**, etc.

1 BACKGROUND

First we'll identify the right period for us to investigate using MODIS SST and TRMM Precipitation data. We'll start by answering a few questions about ENSO and the time periods for which we have available with MODIS. Note, this is not meant to be an exhaustive exercise looking at ENSO events of different types. Since some of you don't have experience with El Niño data well first need to look up some information on El Niño events and how we use data to say that one is happening. Use Google and Google Scholar or textbooks to find this information and representative figures.

Q1 – (10 points) ENSO Introduction:

a) (3 pts) Provide a brief description of the El Niño Southern Oscillation (ENSO) phenomena. Make sure to mention what happens to Sea Surface Temperature and Precipitation patterns during an El Niño event as compared to the "Normal" situation.

b) (1 pt) What is the value of the commonly used "threshold temperature anomaly" (above) for an event to be considered an El Niño event?

c) (1 pt) Typically, we use a running mean of the SST anomalies. How many months are typically included in the running mean? How many consecutive months need to be above the threshold to be considered an El Niño event?

d) (2 pts) Find a diagram or pair of diagrams to show Pacific SST and precipitation during a "Normal" year and an "El Niño" Year.

e) (2 pts) Provide a description of the "Niño 3.4 Box" including what the latitudinal and longitudinal boundaries. Why is the box commonly used?

f) (1 pt) Include a diagram (you can download it from Google) to show where the Niño 3.4 box is located is located.

1) Choosing an El Niño Event to investigate using the Nino 3.4 Index.

Now we're going to use the Nino 3.4 index that you just defined in the previous section. We'll download the index and plot it to help us choose an event that fits within the Aqua MODIS data time frame.

Go to the following link:

http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_change.shtml

This will bring you to a webpage for the ONI (or Oceanic Nino Index). At the very bottom of the page there is a link to an ascii text file (Monthly Niño-3.4 index). Simply right click and save this file as a .txt or copy it into notepad and save it as a .txt file on to your computer so you can load it into MATLAB. If you don't want to use a .txt file you can import it into Excel (it's "SPACE" delimited) and you can and save it as a .csv file. That way you can still use your normal 'dlmread' function that we've used the rest of the semester.

After downloading the file and changing the formatting to .csv (if you want) you can click on the link to see what is included. This file has monthly data from 1950 to October 2017. The monthly Niño-3.4 index from this site uses centered 30-year base periods (ClimAdjust) that are provided in this text file.

There are 5 columns.

Column 1 – Year
Column 2 – Month
Column 3 – Total
Column 4 – Climatology Adjusted
Column 5 – Anomaly

NOTE: There are column headers (with WORDS). MATLAB HATES TEXT. We'll need to tell MATLAB to skip the first row and start with the real data. We'll also need to use code to deal with 'serial date' to get the years and dates on the x-axis. Now it's time to load this file into MATLAB and make a figure to help us decide when El Niño and La Niña events occurred in the past.

C1 – (5 points) ON YOUR OWN CODE:

a) Load your Niño 3.4 Index file (use dlmread if you've convered it from .txt). If you're using the .txt version use MATLAB help to figure out how to import it.

HINT: Remember that you'll need to tell MATLAB to skip the first row to avoid the text header. Do this by changing the location of the start of the file loading (normal and no-header examples below) change highlighed in yellow.

```
Your_Variable_Name_Normal_No_Header = dlmread('Your_File_Name.csv',',',0,0);

Your_Variable_Name_Skip_Header = dlmread('Your_File_Name.csv',',',1,0);
```

b) Use the information in the columns to convert your year and month columns to the MATLAB 'serial date' format.

Hint: When plotting the data you'll need to convert the year and month information into a Matlab Serial Date. See below. You'll also need to use the function "datenum" when you plot your mean value against the new serial data array you'll create.

```
% Converting the Year and Month Data to MATLAB Serial Date Format
% First getting the variables I want
NINO34_Year_Array = NINO34_File(:,1);      % Column 1 is the year
NINO34_Month_Array = NINO34_File(:,2);     % Column 2 is the month
%
[NINO34_rows, NINO34_cols] = size(NINO34_Year_Array);    % you need to know the size of
the array
%
Day = 00;                                       % there is no hour data
NINO34_Day_Array = zeros(NINO34_rows,1);              % set up a blank array
Hour = 00;                                      % there is no hour data
NINO34_Hour_Array = zeros(NINO34_rows,1);             % set up a blank array
Minute = 00;                                    % there is no minute data
NINO34_Minute_Array = zeros(NINO34_rows,1);           % set up a blank array
```

```
Second = 00;                                           % set up a second array
NINO34_Second_Array = zeros(NINO34_rows,1);                  % there is no second data
%
% Making the full date arrays
Full_Date_NINO34 = [NINO34_Year_Array, NINO34_Month_Array, NINO34_Day_Array,
NINO34_Hour_Array, NINO34_Minute_Array, NINO34_Second_Array]; % concatenates everything
%
% Array for saving Serial Date
Serial_NINO34 = zeros(NINO34_rows,1);
%
rownino34 = 1                                                 % this starts your loop
for rownino34 = 1:NINO34_rows                                 % go from 1- NINO34_rows
    vector_nino34 = Full_Date_NINO34(rownino34,:);
    serial_num_nino34 = datenum(vector_nino34);               % convert to serial number
    Serial_NINO34(rownino34,1) = serial_num_nino34;
    rownino34 = rownino34 +1;
end
%
% save the NEW Serial number file
dlmwrite('Serial_Date_Nino_34.csv', Serial_NINO34,'delimiter', ',', 'precision', 15);
```

c) Make a figure using your new serial date and the Column 5 Anomaly data. Make sure to include a title and axes labels. Save this figure to include in the lab.

d) This is not an ideal figure to identify El Niño events that overlap with Aqua MODIS and it's not clear when the events surpass the threshold described in Q1. We're going to make a better figure.

i) Change your figure code to zoom in on Jan 2000 to October 2017 to accommodate for the MODIS Data records. You can do this by changing which rows you're plotting. In the example code below I'm plotting EVERYTHING (the entire record) which is what is indicated by the ":" in x(:,:) and NINO34_File(:,5).

```
plot(Serial_NINO34(:,:), NINO34_File(:,5), 'k', 'LineWidth',3);
```

For both you can specify the row numbers that correspond to the desired years. For example, if I only wanted to look at 2015 it would look something like this:

```
plot(Serial_NINO34(781:792,:), NINO34_File(781:792,5), 'k', 'LineWidth',3);
```

ii) Using the example code below rotate the serial date so that it makes it easier to for you to read the month and year. You'll need to go to the link below to download a helper code called "xticklabel-rotate" from the file exchange site at mathworks.com

http://www.mathworks.com/matlabcentral/fileexchange/3486-xticklabel-rotate

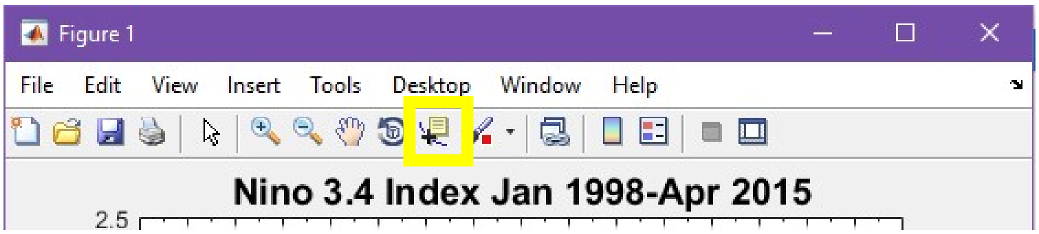
save this file and extract the file from the zipfile and save it with your data file. It needs to be in the same folder so your code can call it during this stage.

```
NumTicks = 17;                     % Number of ticks on the plot
L = get(gca,'XLim');               % Find the Length of the x-axis array
set(gca,'XTick',linspace(L(1),L(2),NumTicks))        % Set the Limits
datetick('x','mmm yyyy','keeplimits', 'keepticks')   % Adding the datetick
xticklabel_rotate;                                   % Calling x-ticklabel_rotate
set(gca,'XMinorTick','on','YMinorTick','on')         % Making the axis
```

iii) Save this figure to include with your lab.

Q2 – (5 points) Identifying Potential El Niño Events:

a) (4 pts) Using your second zoomed in figure and the data file, identify time periods during which the Niño 3.4 index value is above the threshold identified in Q1 b) for the required length of time as identified in Q1 c) or longer. There will be five time periods that satisfy these conditions. Include start month-year and end month-year as well as the total number of months. You can use the Matlab cursor to find when you're above +0.5 (look at the "Y" value). Or, you can open your Niño 3.4 file and check the values in that way.

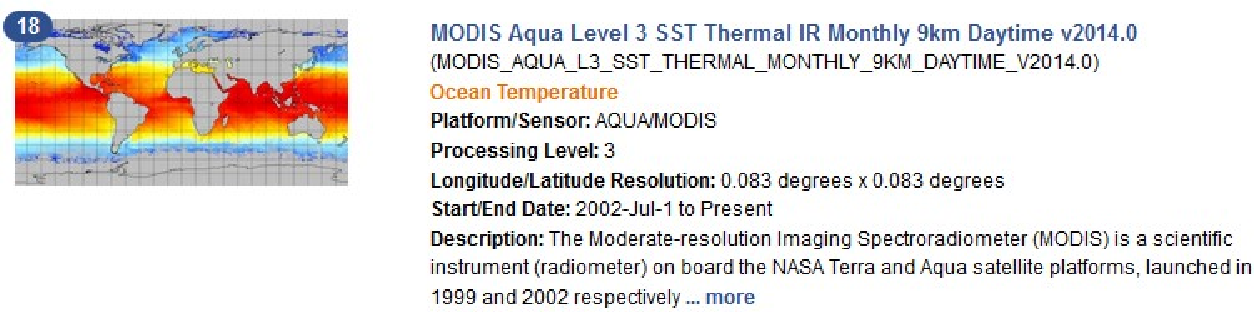


b) (1 pt) Of the four time periods which has the highest SST Anomaly (provide start and end dates)? Does this fall within the Aqua MODIS data range?

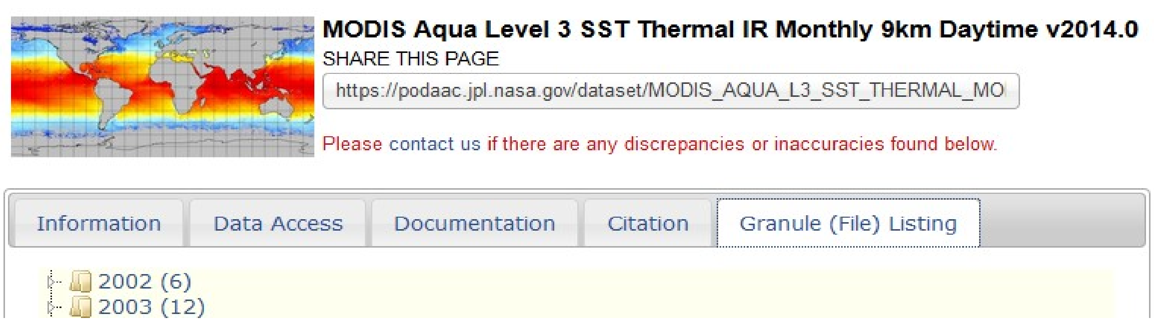
2 DOWNLOADING MODIS SST DATA

We're going to choose data associated with the time period you identified in Q2b) (November 2014 through May 2016 data, 19 total files) and we'll download data from the JPL PODAAC Data Access website. Scroll down, go to page 2 and then choose number "18" which is MODIS Aqua Level 3 SST Thermal IR Monthly 9km Daytime.

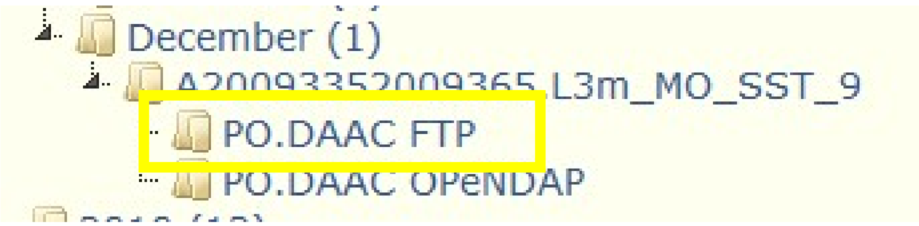
http://podaac.jpl.nasa.gov/datasetlist?ids=Collections:TemporalResolution&values=MODIS_L3_SST:Monthly&view=list#

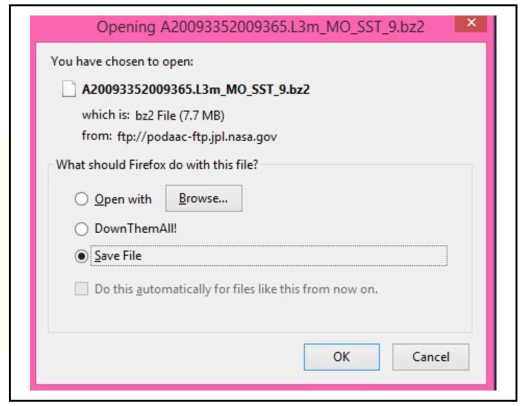


Click on the Data Title and then Click on "Granule (File) Listing"



From the Granule (File) Lising page you can select the year and month for the data you want to download. You need to download these files individually by selecting the Year, then the month and then select the PO.DAAC FTP option. This will allow you to download the 19 individual files.





a) NOTE once you download these files you'll see that they are in NetCDF format because they have the ".nc" extension. You'll learn how to open these types of files in this lab.

2 "CLIMATOLOGICAL" MODIS SST DATA and PSEUDOANOMALIES

a) Now it's time to load the files into Matlab so you can manipulate the data and make figures. You'll need to load ALL 19 files.

C2 – (20 points) ON YOUR OWN CODE (with help):

a) Load your MODIS SST data files into Matlab.

Hint: NetCDF is similar to HDF in that you need to know what the variable names, scale factors and offsets are. Unfortunately, you can't just drag and drop at NetCDF file in matlab and have it open up a nice interface. I use "Panoply" from NASA GISS to sneak a peak in the file to find this information. You can download Panoply for future use from the link below. I will be giving you the information you need this time.

https://www.giss.nasa.gov/tools/panoply/download/

The variable name is "sst" and the info (obtained via Panoply is as follows):

```
short sst(lat=2160, lon=4320);
  :long_name = "Sea Surface Temperature";
  :scale_factor = 0.005f; // float
  :add_offset = 0.0f; // float
  :units = "degree_C";
  :standard_name = "sea_surface_temperature";
  :_FillValue = -32767S; // short
  :valid_min = -1000S; // short
  :valid_max = 10000S; // short
  :display_scale = "linear";
  :display_min = -2.0f; // float
  :display_max = 45.0f; // float
  :_ChunkSizes = 22, 44; // int
```

Once you have this information we can write code to ope our NetCDF files, extract the variables and then do all the regular adjustments. See Code below:

```
% Learning how to open and read NetCDF files
%~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
% OPENING the netcdf file.
% In this particular code you need to know the file name ahead of time and
% enter it in the format shown below:
%         ncid = netcdf.open('filename.nc','NOWRITE');
% where:
%     ncid is the
%     netcdf.open is the function/command that tells matlab to open the
%         file it has the format netcdf.open(source,mode). The source is
%         your data file. The mode can be one of three options: NOWRITE
%         which is read only, WRITE which gives you read-write access and
%         SHARE which gives you synchronous updating ability
%     'filename.nc' is where you would replace "filename" with your real
%     fileame. Note that if your file is NOT .nc this code will not work
%     'NOWRITE' is used when you only want to read data from a file
%
%~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
% Opening the file and giving naming it based on the month and year
% (so we can open all the files in one script)
ncid_2009_04 = netcdf.open('A20090912009120.L3m_MO_SST_sst_9km.nc','NOWRITE');
%
%~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
% Getting the Latitude and Longitude out of the files. We'll only use our
% "first" file to do this.
lat_id_2009_04 = netcdf.inqVarID(ncid_2009_04,'lat');
datalat_2009_04 = netcdf.getVar(ncid_2009_04,lat_id_2009_04);
sst_latitude_data = datalat_2009_04(:,:);
dlmwrite('MODIS_SST_latitude.csv', sst_latitude_data,'delimiter',',','precision',15);
%
lon_id_2009_04 = netcdf.inqVarID(ncid_2009_04,'lon');
datalon_2009_04 = netcdf.getVar(ncid_2009_04,lon_id_2009_04);
sst_longitude_data = datalon_2009_04(:,:);
dlmwrite('MODIS_SST_longitude.csv', sst_longitude_data,'delimiter',',','precision',15);
%~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
% Taking out the SST Variable
sst_id_2009_04 = netcdf.inqVarID(ncid_2009_04,'sst');
sst_data_2009_04 = netcdf.getVar(ncid_2009_04,sst_id_2009_04);
netcdf.close(ncid_2009_04);
```

HINT: Make sure to close each NetCDF file after you've extracted your data array. This will help keep your memory from getting overloaded!

b) Automate the code or load them all 16 files separately, your choice.

c) Now that you have a usable variable (sst_data_2009_04) you'll need to turn the data double, replace the missing data (-32767) with NaNs and scale it (check the metadata provided above for the scale and offsets).

d) Once you've loaded and prepared the data we're going to make a three dimensional file to make it easier to calculate the mean in each grid cell for the 16 month period:

```
% Create 3-D arrays to store your Monthly Data Arrays
%
 MODIS_SST_16_Month_Concat = zeros(4320, 2160, 16); % Making a sixteen element array
%
% Putting the Prepped Data into the Arrays
MODIS_SST_16_Month_Concat(:,:,1) = sst_data_2009_04_scaled;
```

```
MODIS_SST_16_Month_Concat(:,:,2) = sst_data_2009_05_scaled;
MODIS_SST_16_Month_Concat(:,:,3) = sst_data_2009_06_scaled;   (you can fill in the rest)
%  (include files all the way through July 2010 to fill in through (:,:16)
% Calculate the mean over the 16th month period
MODIS_SST_16_Mean = nanmean(MODIS_SST_16_Month_Concat, 3); % Takes mean ignoring NaNs.
```

e) Make a figure of this 16 month mean SST pattern and save it to include in with the lab. Use pcolor to get the best image. If your image is ALL BLACK you'll need to "Edit" the figure once it is generated by going to "Edit" and then "Current Object Properties" once there you need to set the "Edges" option under "Property Editor – Surface" to "no line." After you do that the color map should appear. Save this average map to include with your lab.

HINT: The Map is not Oriented in the way you are used to. You are going to have to manipulate the array to make it the standard map orientation by using the "rot90" and "fliplr" functions. The rot90 function can be used to go 90, 180, 270. I suggest puttin gthe rotation and flipping lines of code right after your MODIS_SST_16_Mean line.

```
For 90 degree rotation:  B = rot90(A,1)    where A is your original array and B is your new rotated array
For 180 degree rotation:  B = rot90(A,2)   where A is your original array and B is your new rotated array
For 270 degree rotation:  B = rot90(A,3)   where A is your original array and B is your new rotated array
```

For Flipping:

```
B = fliplr(A)   This is very straight forward where A is your original array and B is the flipped array
```

HINT: You'll need to make a different Lat and Lon generator to accommodate the high resolution or use the lat and lon arrays that you saved earlier (either will work):

```
% Creating Latitude and Longitude Arrays
MODIS_SST_Lon = [-179.2385:0.083:179.2385]'; % This is in the correct alignment
MODIS_SST_Lat_updown = [-89.5985:0.083:89.5985]'; % This is upside down (S on top of N)
MODIS_SST_Lat = flipud(MODIS_SST_Lat_updown); % flipud "flips" the array upside down
```

e) Next, using the 16 month mean calculate monthly anomaly maps by taking the individual monthly data files and subtracting the 16 month mean. This way you can determine if, during an invidiual month, the data values are higher or lower than the calculated mean.

HINT: You'll have to rotate and flip ALL the individual months too to calculate the anomalies…. Go back and add that into your code! You can then make an ALREADY Flipped and Rotated Mean file and you wouldn't have to rotate and flip it separately…. As you can see you can modify and improve your code as you become aware of how the data is structured and oriented. Don't get too attached to code, it can change and evolve over time!

f) Plot the anomaly maps for the individual months of December 2014, November 2015 and May 2016 and include them with the lab write up. (Use a color bar range of -2.5 to 2.5 and the JET colormap)

```
caxis ([-2.5 2.5])
colormap ('jet')
```

Q3 – (7 points) Describing the Average and Difference Maps (you should have 4 plots):

a) (2 pts) For the 19 year average, in what regions do we see the highest average SST? In what regions do we see the lowest average SST? Estimate the SST values for these regions using the matlab cursor to get more accurate values then by eye-balling the colors.

b) (1 pt) For the anomaly maps (December 2014, November 2015, May 2016) – How do these map differ in the equatorial Pacific and off the western coast of South America?

c) (1 pt) Using your Nino 3.4 file look up the SST, Climatologically Adjusted SST and the Nino 3.4 Index value for each of these months and fill out this table. How do these values relate to their corresponding figures?

Month	TOTAL (Temp)	Climate Adjusted (Temp)	ONI (Nino 3.4 Index)
December 2014			
November 2015			
May 2016			

e) (3 pts) Why don't we see the characteristic SST warming in the Pacific with our anomaly calculation? What would we need to do in order to determine accurate global SST anomalies?

3 LAB REPORT WRITE UP - Provide the following in digital or paper format by Friday, November 17th, 2017:

1) (2 points) – A brief summary/conclusion of the labs main goal.
2) (25 points) – Coding questions C1-C4 and Figures
    - Figure 1) El Nino & Normal Example
    - Figure 2) Nino 3.4 box diagram
    - Figure 3) Full Nino 3.4 Record from 1950-2015
    - Figure 4) Nino 3.4 Record for only 1998-2015
    - Figure 5) 19 year mean MODIS SST
    - Figure 6) December 2014 SST 'Anomaly'
    - Figure 7) November 2015 SST 'Anomlay'
    - Figure 8) May 2015 SST 'Anomaly'
3) (22 points) – Science/Interpretations Question Q1, Q2, Q3, and Q4
4) (1 point) – emailing code