Understanding El Niño

Introduction

El Niño-Southern Oscillation (ENSO) is a periodic change (oscillation) in the ocean-atmosphere system in the tropical Pacific Ocean that influences weather conditions around the world. El Niño events are commonly associated with increased rainfall across the southern tier of the United States and especially in Peru, where high rainfall is often leads to destructive flooding. At the same time, El Niño conditions result in drought in regions of the western Pacific and are sometimes associated with devastating wild fires in Australia.

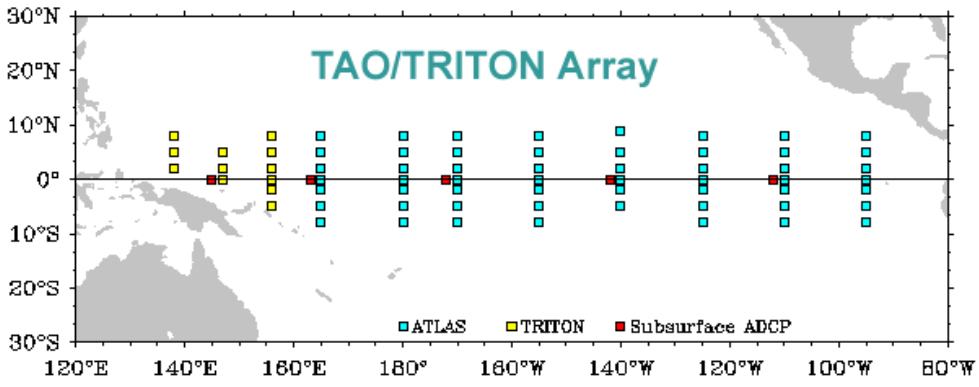
Because of the profound impact of ENSO on extreme weather conditions around the world, considerable effort goes into monitoring the meteorological and oceanographic conditions in the tropical Pacific that provide telltale signs of the arrival of El Niño and its counterpart La Niña. Early detection of changes in sea surface temperature, atmospheric pressure, and surface winds, among other variables, facilitates short term (a few months to a year) predictions of climate variations, allowing people to prepare for potential weather related impacts. In addition, these data help climatologists study the underlying causes of El Niño-Southern Oscillation.

The Tropical Atmosphere Ocean project (TAO) is a real-time observation system that collects data from a network of moored buoys in the equatorial Pacific Ocean. These observations facilitate the detection and study of ENSO and provide an ideal opportunity to investigate interactions between the atmosphere and ocean.

The homepage of the TAO program is:
http://www.pmel.noaa.gov/tao/index.shtml

(Clicking on the "Project overview" tab from the TAO home page will provide additional information about the TAO project and details about how the data is collected. You may also click on the "El Niño and La Niña" tab for more information on these phenomena.)

The map below, which was taken from the TAO website, shows the location of moorings in the tropical Pacific Ocean from which data are being collected and continuously sent back to shore based researchers. Each mooring location contains an array of sensors which measure surface weather conditions and temperature and salinity at a variety of depths below the surface. In addition the red station locations include acoustic doppler current profilers (ADCPs) which are able to measure the velocity of water movement (currents) at different depths in the ocean.



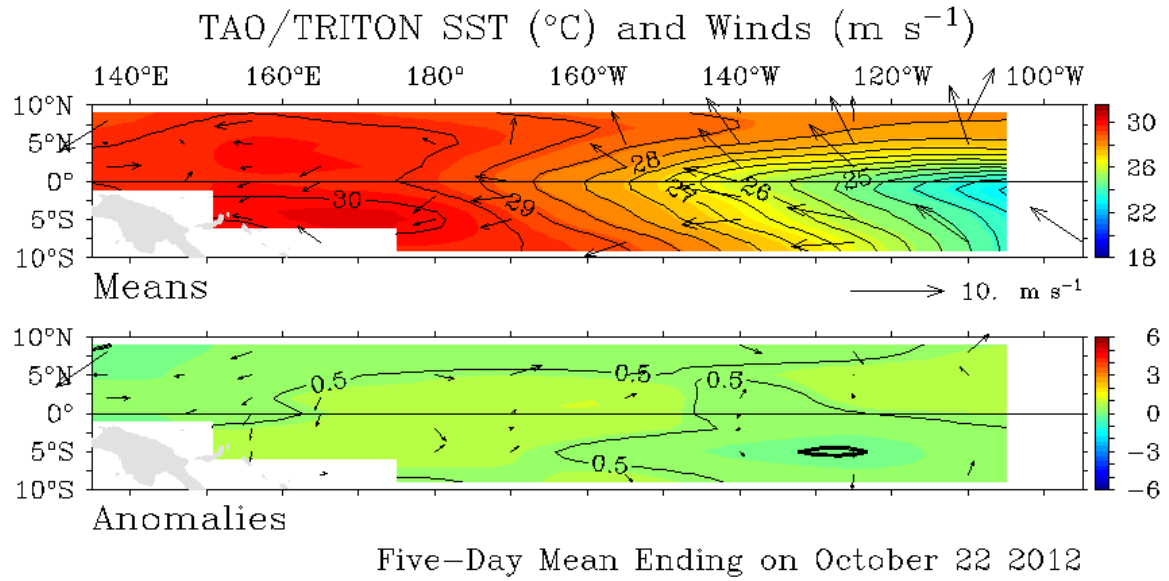
Overview of the Activity

For this exercise you will access archived data collected from TAO moorings and create plots that allow you to identify and interpret some of the characteristic features of El Niño and La Niña events. The objectives of this activity are:

(1) To develop observational and descriptive skills relevant to the interpretation and communication of complex (real) oceanographic data sets.
(2) To identify and interpret evidence of the connection between the atmosphere and the ocean
(3) To provide an introduction to some of the fundamental oceanographic features associated with ENSO events.

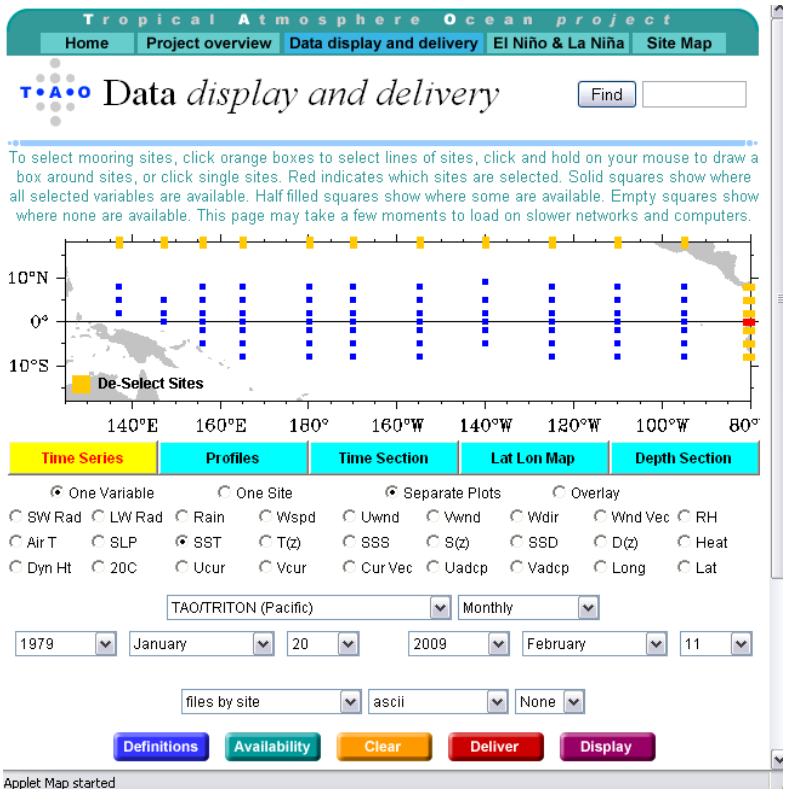
Getting Started

To begin this exercise you should click on the "Data Display" tab from the TAO homepage. This page displays a figure like the one shown below that depicts the most recent observations of sea surface temperature (color coded) and surface winds (as arrows) in the region. Note that the top figure shows observed temperatures and winds whereas the bottom panel show anomalies. Anomalies are the difference between the actual observed conditions and the long-term average conditions in the region. If the temperature anomalies are between light yellow, green and light blue in color then they are very close to long-term mean conditions, if the anomalies are red, conditions are warmer than normal, and if the anomalies are blue, conditions are cooler than normal. Likewise if the wind vectors (arrows) are short then winds are near average conditions, if they are long then wind speed (and direction) is different relative to normal. Take note of the fact that the Pacific Ocean spans the 180° longitude line where degrees longitude transition from degrees west of the prime meridian to degrees east of the prime meridian (which is runs through Greenwich England). Consequently the western pacific is located in the vicinity of 140° E to 180° E whereas the eastern Pacific is the region between 100° W and 140° W. *Make sure are comfortable interpreting these plots before moving on.*



Once you feel comfortable with what is being displayed in these figures it is now time to make plots from the archived data. Click on the link under the figure for "Display and Delivery Page"

You should see the following page:



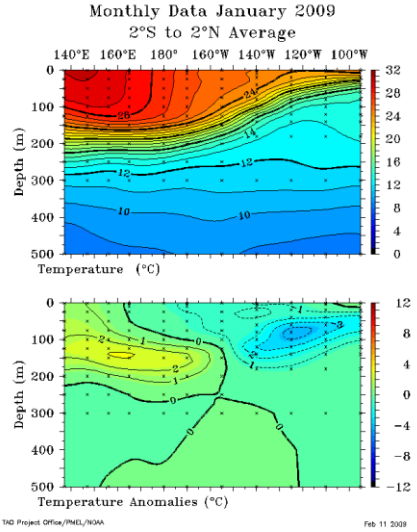
Step 1 – Create surface maps of normal, El Niño, and La Niña years:

To generate sea surface temperature and surface wind maps like the one shown on the previous page, follow these steps:

1. On the Data display and delivery page press the "clear" button to reset the program.
2. Press the "Lat Lon Map" button
3. Select a year and month using the pull down menus (you will do this 5 times for each of the month/year combinations listed below)
4. Press the display button – this should open up a new window with the appropriate figures in it.
5. By right-clicking on the image you can see a higher resolution version of it. By right clicking on the image you should be able to save the image or copy and paste it into a word processing document to include in your written response to this assignment.

You should create and save surface maps for the following periods:
January 1997 – typical of "normal conditions"
January 1998 – a very strong El Niño year
January 1999 – a very strong La Niña
January 1992 (note the data is more limited b/c there were fewer moorings in 1992)
January 2002

Step 2 – Create cross sections of temperature conditions across the equatorial pacific. These should look like the example below from January of 2009:



Again, the top panel shows actual temperatures and the bottom panel shows anomalies. The thermocline (region of rapid temperature change) is visible as the region where the temperature contours are most closely spaced.

Follow the following procedure to generate temperature cross sections:

1. Press the "Clear" button to reset the interface
2. Press the "Depth Section" button.
3. Select a year and month from the pull down menus.
4. Press the display button. (Again these images can be enlarged and copied/saved by clicking on them).

You should create and save cross sections for the same five periods for which you created surface maps.

Step 3 – ***Provide a written (typed) response to the following questions.***
***Note that questions 1 and 2 ask for purely descriptive answers based on your own observations of the available data – you shouldn't be making interpretations until you get to questions three, four, and five.*

1. Describe the characteristics of the equatorial Pacific during typical conditions (using the January 1997 observations as a guide). Your description should address the general pattern of sea surface temperature and winds and the vertical pattern of water temperatures across the equatorial Pacific, including a description of how the depth to the thermocline varies from west to east across the Pacific.
2. Describe how conditions during El Niño and La Niña differ from the typical conditions described above. Focus on the same features you described above.
3. Based on your descriptions above, how would characterize conditions during 1992 and 2002 – in other words are they most similar to typical, El Niño or La Niña conditions. Describe your reasoning.
4. Discuss when (if) upwelling and/or downwelling are likely occurring in the *eastern* equatorial pacific (near the Peruvian Coast). Describe the evidence for this or you line of reasoning. (Note: upwelling refers to the vertical movement of water when deep water is brought to the surface. Downwelling refers to the downward vertical movement of water).
5. Based on your observations of surface winds during El Niño and La Niña years and your understanding of atmospheric-ocean interactions, discuss how atmospheric processes may be linked to the changes that are occurring in the ocean during ENSO events.
6. This activity focuses essentially on changes in water temperature and surface winds in the tropical Pacific Ocean associated with ENSO events. In reality, ENSO involves many more oceanographic and climatic variables and a wider geographic area than is investigated here. Knowing that this activity has provided you with an incomplete overview of ENSO, *pose a question related to ENSO that you could investigate with access to additional data and describe how you could go about answering your question (in other words what data or observations would be needed to answer your question)*. Questions may take a variety of forms and address a nearly limitless variety of topics related to oceanographic, climatic, or biological process in different parts of the world, but they should be narrowly focused. For example, a question that you could investigate is: What is the relationship between the occurrence of El Niño and snowfall in New England? Think about what data would then be needed to answer this question.