exercise 4
observing the year-to-year, or interannual, variation of sea surface temperature (sst)

This exercise is an open-ended exploration of the El Niño phenomena in the eastern Equatorial Pacific Ocean. To embark on this exploration, you must be able to do the following Exercise 3 procedures in *SEE Image*.

- Open a series of images and create a stack (Step B)
- Apply the SST LUT to the stack (Step B)
- Calibrate the stack (Step C)
- Use the Density Slice Tool (Step D)
- Animate a stack (Step E)
- Make a montage from a stack (Step F)
- Use the 'Analyze/Measure' command to find the mean and standard deviation of a rectangular selection in each image of a stack and create a time-series from these data (Step J).

qualitative observation of long-term interannual variability

Do A and B now.

A

set up see image

1—Start *SEE Image* by double clicking on its icon

SEE Image 2.56/ppc

2—Select 'Options/Preferences.'

3—Make sure the 'Undo & Clipboard Buffer Size' is set to >500 k and that "Invert Y-Coordinates" is NOT selected. Click OK. *(If these preferences were already set and you didn't have to change anything, no message box will appear. Skip to step 8.)*

4—Click OK again to close the message box you'll see.

5—Select 'File/Record Preferences.'

6—Select 'File/Quit' to exit *SEE Image.*

7—Restart *SEE Image.*

8—Select 'Special/Load Macros.' Go to Desktop | HD | SEE Image | Macros | SEE_macros. Click Open.

B

build and calibrate a stack

1—Select 'File/Import'. Go to Desktop | HD | SEE Image | Data | Oceans | sstex4. Double click the Decembers folder.

2—Click "Open All" then click OK to open the December images for all 17 years from 1982–1998.

3—Select 'Options/Preferences' and click on "Display slice titles only."

4—Select 'Stacks/Windows to Stack' to create a stack of December images with the file names displayed.

5—Select 'Options/Color Table/SST' to apply the color LUT to the stack.

6—Calibrate the stack.

Using the tools in *SEE Image* that you are familiar with from the first three exercises, explore the long-term variation of the global SST and record your observations. Here are some suggestions for your exploration.

Start by simply moving through the stack one image at a time using the < and > keys (shift comma and shift period keys, respectively) until you are familiar with the data and can record some general comments about SST throughout the 17 year period.

Use the Density Slice Tool (Exercise 3, Step D) to highlight the warmest ~27°C–31°C) SSTs and observe how they vary throughout the years.

1a. In which 2 years does this range of SSTs cover the **largest** area?

__________ and __________

1b. In which 2 years does this range of SSTs cover the **smallest** area?

__________ and __________

2. How does the geographic distribution of SST differ between the years when the area covered is high as compared with years when the area covered is low?

Create a montage from the images in the stack and use the selection and drawing tools to isolate regions (the Equatorial Pacific is a good region to look at) in order to make it easier to compare them visually. Remember, a selection made on the top image in a stack automatically appears on every image in the stack when it's displayed.

C

make a montage

1—Select 'Stacks/Make Montage' and fill out the dialog

box as follows: Columns: 4; Rows: 4 (2 if you want to look at 8 years at a time); Scale Factor: 0; First Slice: 1; Last Slice: 16 (8 if you want to look at the first 8 years initially); Increment: 1. Check "Borders" but do not check "Number Slices." Click OK.

Do C now.

It might be easier to look at just 8 years at a time in the montage by modifying the "Rows" and 'Last Slice" choices to "2" and "8" respectively. Then if you want to see just the last 8 years, use "2" and "16." Try using the Density Slice Tool on your montage to highlight the warmest SSTs.

3. Record your observations.

If you drew lines on the images in the Montage or altered them by cutting out sections, now is the time to close this montage and work again with the original stack of 17 December images.

Finally, create a movie of the 17 years. You can also use the Density Slice Tool when animating. Try it!

D

animate your stack

1—Select 'Stacks/Animate.'

Do D now.

4. Record anything new you observe.

Based on your observations using the Density Slice Tool on the Stack of images, making a montage from the stack, and animating the stack, answer the following questions.

5. Which *SEE Image* tools made it easiest for you to observe the interannual variation of SST?

6. Where in the oceans did you notice the largest variability from one year to the next?

7a. Which years appeared anomalous; that is, which years looked very different from the other years?

7b. Why are these years anomalous?

8. What other general comments can you make regarding the interannual variations of SST?

quantitative observations of long-term interannual variability in the eastern equatorial pacific ocean

Now you'll use the SEE Image Set Scale function to scale the image such that 1 pixel is equivalent to approximately 1° of latitude or longitude — 1° of latitude is approximately equal to 111.0 kilometers. This "calibration" of the image scale will permit you to answer the questions that follow quantitatively.

Do E 1–8 now.

E

scaling your stack

1—If necessary, reopen the December images and put them in a stack. Add the SST LUT and calibrate the stack if it hasn't already been done.

2—Reconfigure the Density Slick Tool so that the warmest SSTs are highlighted by the Density Slice.

3—Select 'Analyze/Reset.'

4—Select 'Analyze/Set Scale.'

NOTE: For this to work correctly, you must set up the dialog box exactly in the order instructed, even though it jumps around the dialog box a bit.

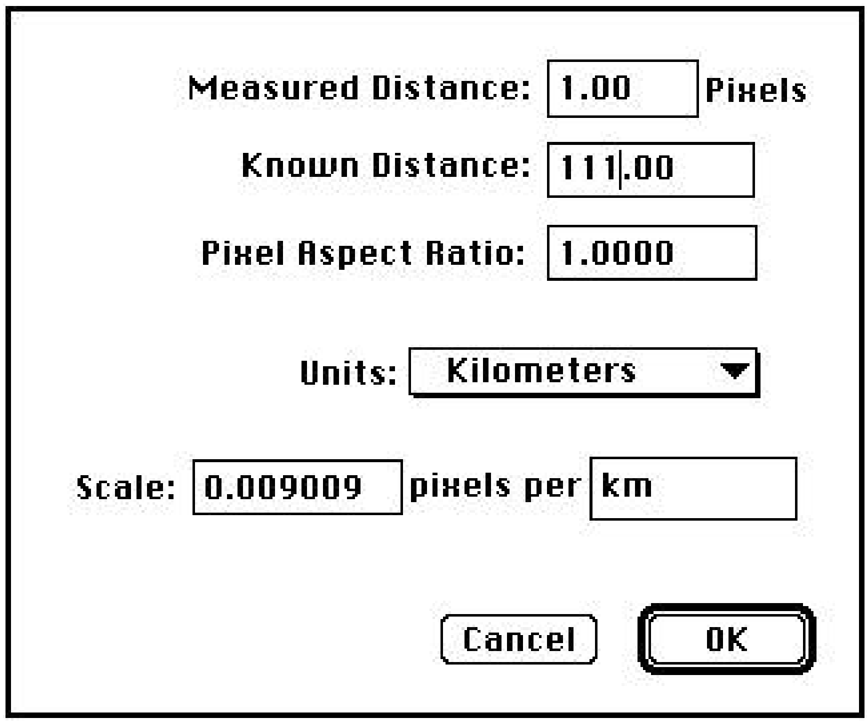
- Set Known Distance to "111."
- Go down to Units and click and drag the menu bar to select "Kilometers."
- Go back up and set Measured Distance to "1."
- Make sure that the Pixel Aspect Ratio is set to 1 and the Scale reads 0.009009. Click OK.

5—Select the Rectangle Tool from the Tools Window and us it to select the image only (don't select any annotations or the color legend), by clicking and dragging a rectangle around just the image.

6—Select 'Analyze/Reset.'

7—Make sure your stack is positioned with December 1982 on top; use the [.>] or [,<] keys if necessary.

8. Select 'Analyze/Show Results' and move the results window so you can see both it and the image stack.



Now you're ready to measure the area of the region of warmest SSTs you highlighted with the Density Slice Tool. If the Density Slice is not active, please make it active now and highlight temperatures between about 27°C and 31°C.In which 2 years does this range of SSTs cover the **largest** area, and what is the area in square km?

E

scaling your stack, continued

9. Select 'Analyze/Options' and make sure Area, Mean Density, and Standard Deviation are all selected.

10. Select 'Analyze/Measure' to measure the area covered by the Density Slice. Step through the stack using this command for each image and noting the results in the Results Window. When you've measured each of the 17 Decembers, you can use the measurements in the Results Window to answer quantitatively some questions you were asked previously.

Results

	Area	Mean	S.D.
1.	109878680.00	28.24	1.00
2.	103656576.00	28.04	0.94
3.	95808096.00	27.91	0.89
4.	100539360.00	28.03	0.99
5.	106687536.00	28.08	0.96
6.	111689864.00	28.23	0.99
7.	96313256.00	27.99	0.90
8.	104260304.00	28.02	0.95
9.	107106456.00	28.13	0.96
10.	105430800.00	28.04	0.97
11.	97693208.00	28.02	0.92
12.	107081808.00	28.09	0.96
13.	105085808.00	28.15	1.01
14.	104666896.00	28.15	0.96
15.	102017880.00	28.13	1.00
16.	124429776.00	28.33	0.99
17.	106256304.00	28.18	1.00

Do E 9 and 10 now.

9a. Year: ________ Area Covered: ________________________

9b. Year: ________ Area Covered: ________________________

In which 2 years does this range of SSTs cover the **smallest** area, and what is the area in square Km?

10a. Year: ________ Area Covered: ________________________

10b. Year: ________ Area Covered: ________________________

11. How does the geographic distribution of SST differ between the years when the area covered is high as compared to years when the area covered is low?

Review questions 1–8 and adjust your answers now that you have collected some quantitative information about the area, mean, and standard deviation of the region of warmest SST as highlighted by the Density Slice Tool.

As you've probably figured out, even though the human eye is a very sensitive instrument, it's hard to observe very subtle changes in SST from year to year. That's why scientists also use quantitative techniques involving statistics and the creation of time-series to discern such changes. You'll now create some time-series of mean SST and standard deviation for a very interesting region of Earth's oceans: the eastern Equatorial Pacific.

Do F now.

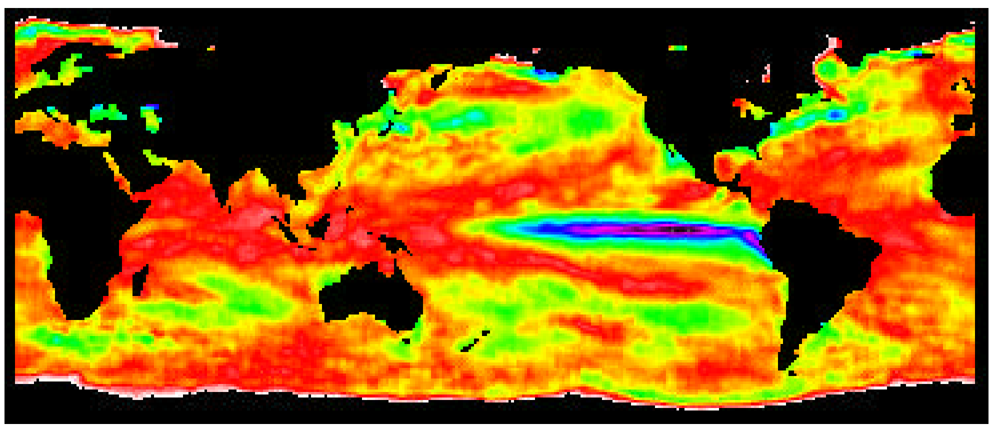
F

make time-series from your stack

1—You should still have all 17 Decembers in a stack. If not, create it now, apply the SST LUT to it, and calibrate it.

2—Select 'Special/Load Macros' and go to the Macros folder in the SEE Image folder. Choose "SEE_Macros" and click OK. Now when you select the Special pull-down menu you'll see a list of the available macros. These will come in very handy for your exploration of this large data set.

3—Select 'Special/CalcSDStack' to generate an image of the standard deviation at each pixel over all images in your stack. You'll be asked to name the resulting standard deviation image. Be sure to save it in TIFF format.



The resulting image of standard deviation is automatically calibrated such that the values shown in the Info Window, when you move the cursor around the image, represent the standard deviation in °C of each pixel in the image.

12. Study this image and describe in which regions of the ocean there is the most variability over time.

13. How does this statistical result compare with your qualitative observations from the previous section?

Do G now.

G

make time-series from your stack

1 — Choose the Freehand Tool or the Polygon Tool from the Tools Window. Using the image of standard deviation as a reference, use either selection tool to select the region of high standard deviation in the eastern Equatorial Pacific Ocean on the top image of the stack, being careful to avoid land.

2 — Select 'Analyze/Reset' to clear all measurements.

3 — Select 'Analyze/Options' and choose "mean density" and "standard deviation."

4 — Select 'Analyze/Show Results' and position the Results Window so you can see both it and the images.

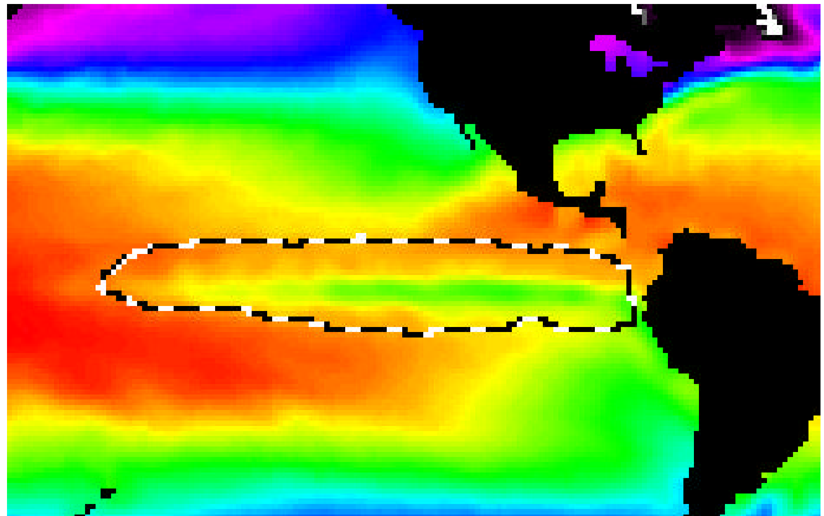
5 — Select 'Analyze/Measure.' You'll see the mean and standard deviation for the region you selected on the December 1982 image appear in the Results Window.

6 — Use the > key to move to the next window in the stack (December 1983) and notice that your region selection automatically appears on this image.

7 — Select 'Analyze/Measure' again. There are now two measurements in the Results Window, one for each month.

8 — Use the > key to move through the stack a month at a time, computing the mean and standard deviation for each month with 'Analyze/Measure.'

9 — Once you've done this for all Decembers, select 'File/Save As' to save the Results Window, naming it "Eq_Pac_82_98(measurements)."



Results

	Mean	S.D.
1.	28.31	1.02
2.	25.67	1.76
3.	24.96	1.71
4.	25.58	2.11
5.	26.87	1.85
6.	27.09	1.57
7.	24.52	1.94
8.	25.90	1.91
9.	26.30	2.09
10.	27.21	1.83
11.	26.16	1.95
12.	26.31	1.80
13.	26.99	1.75
14.	25.44	1.81
15.	25.47	2.03
16.	28.64	0.78
17.	25.09	1.71

14a. Now create plots of the means and standard deviations as a function of year either by hand (Exercise 3 has blanks you can use) or using a plotting package you have. For the first one, plot the year on the x-axis and the mean SST on the y-axis. The second plot should also have year on the x-axis, but the y-axis should be the standard deviation for the region.

14b. Write a discussion interpreting the plots, including reasons for the trends and magnitudes of the curves.

using climatological sst data to explore interannual variation and el niño

You'll now work with an interesting data set called a "climatology." In meteorological terms, the word "climate" refers to the average pattern of weather in a region. An example may help:

> If on a day in July you're asked, "What's the weather been like in New Orleans?" you might answer, "Today it's clear and cool, but yesterday was hot and muggy." On the other hand, if you're asked, "What's the climate like during the summer in New Orleans?" it would be correct to answer, "In the summer it's hot and muggy."

The climate of a region is quantified by computing very long-term averages of the weather of the region.

In the oceans, climatologies are similarly computed. In this exercise, the SST climatology you'll work with was computed as the average of a given month over many years. There are 12 monthly files in this climatology data set of SST. The spatial resolution of this data set is identical to the monthly averaged SST data set you've been working with.

H

build a stack of "climatologies"

1 — Go to Desktop | HD | SEE Image | Data | Oceans | sstex4 and double click on the "climate" folder. Click "Open All" to import the 12 monthly climatological SST files. Put them into a stack, apply the SST LUT, and calibrate the top image. Become familiar with this data set as you have done in other exercises.

2 — Select 'File/Open' and open the standard deviation TIFF image you created previously from the 17 Decembers.

3 — Use one of the selection tools to select a region of highest standard deviation in the eastern Equatorial Pacific on the top (January) image of the stack of monthly climatological images, being careful to avoid the land mask.

4 — Select 'Analyze/Reset' to clear all previous measurements.

5 — Select 'Analyze/Show Results'

6 — Select 'Analyze/Options' and choose "mean" and standard deviation."

7 — Select 'Analyze/Measure' to record the mean and standard deviation for each of the 12 monthly climatological images in the stack. Save the Results Window for reference.

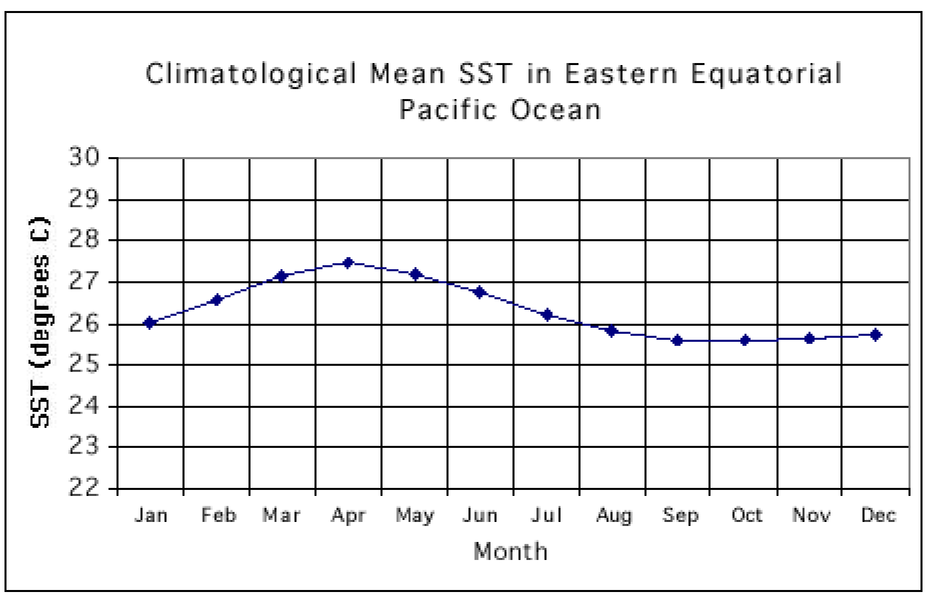
Do H now.

The quantitative part of this exercise involves creating time-series plots to observe how SST in the eastern Equatorial Pacific varies during and between El Niño years.

Results

	Mean	S.D.
1.	26.02	1.11
2.	26.59	0.68
3.	27.12	0.57
4.	27.47	0.73
5.	27.17	1.10
6.	26.78	1.46
7.	26.23	1.81
8.	25.82	2.07
9.	25.61	2.12
10.	25.60	2.07
11.	25.66	1.84
12.	25.75	1.63

A time series plot of these results would look like this.



Close both the stack of climatological images and the standard deviation image.

The class should split into small “research teams.” Each team will gather data and plot a time-series of mean SST and the standard deviation for a different year for the eastern equatorial Pacific. Use 1982, 1983, 1986, 1987, 1991, 1992, 1992, 1993, 1996, 1997, and 1998.

I

make time-series plots

1—Import the 12 monthly mean SST images for the year that your “research team” has been assigned. Put them in a stack, apply the SST LUT, and calibrate the top image in the stack.

2—Load the standard deviation image you previously created from the 17 Decembers.

3—Select ‘Analyze/Reset’ to clear previous measurements.

4—Using the standard deviation image as a guide, use one of the selection tools to select the region of highest standard deviation in the eastern Equatorial Pacific, and, as before, generate a time-series of the SST means and standard deviation in this region for your particular year.

Do I now.

15a. As a point of comparison, all groups should create one plot of the climatological SST for all the years (1982–1998) as a function of time at the chosen area of interest within the eastern equatorial Pacific.

15b. Now create a similar plot for your chosen year for roughly the same area in the equatorial Pacific.

Get together and compare all years that show El Niño conditions in the eastern equatorial Pacific.

After sharing your information with the other “research teams,” discuss the following questions regarding the El Niño/Southern Oscillation.

16a. Which years were El Niño years?

16b. Which were not El Niño years?

17. Rank the El Niño years from the strongest, most severe to the weakest.

For each El Niño year,

18a. When did it begin?

18b. When did it end?

18c. When did it reach peak strength?

If there's still time in your lab, or as an independent project, try doing the same time-series exercise as above but with the western Equatorial Pacific Ocean region and compare your results to the curves for the eastern Equatorial Pacific Ocean.

Also try using "Image Math" to create anomaly fields based on the climatological SST data (as in Exercise 3). For instance, subtract the December climatology from the image for December '82, '83, '96, and '97. Compare these difference (also called anomaly) fields.

end of sea surface temperature computer lab exercise 4