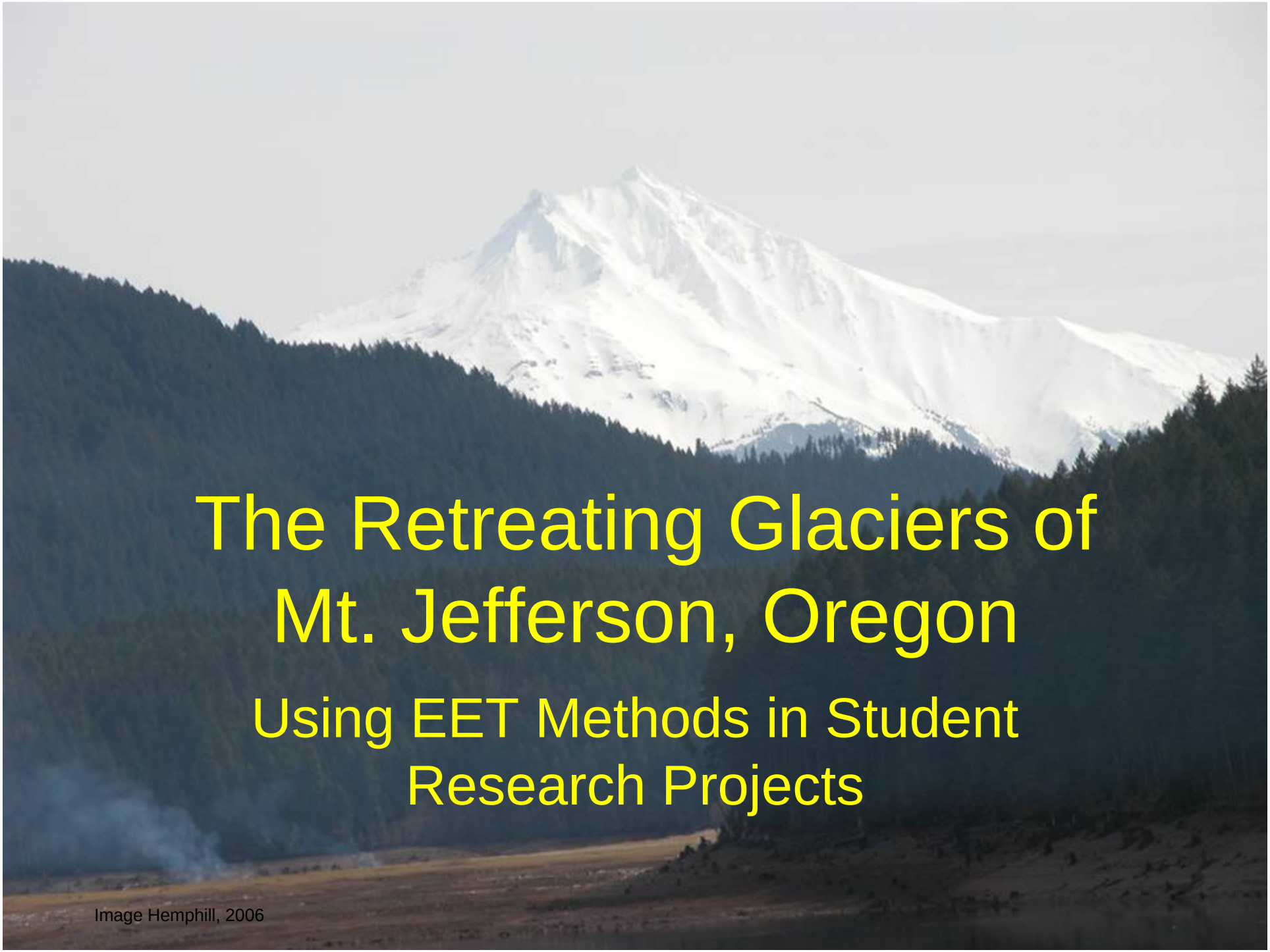


The Retreating Glaciers of Mt. Jefferson, Oregon

Using EET Methods in Student Research Projects

Image Hemphill, 2006

Earth Exploration Toolbook: Chapters Used

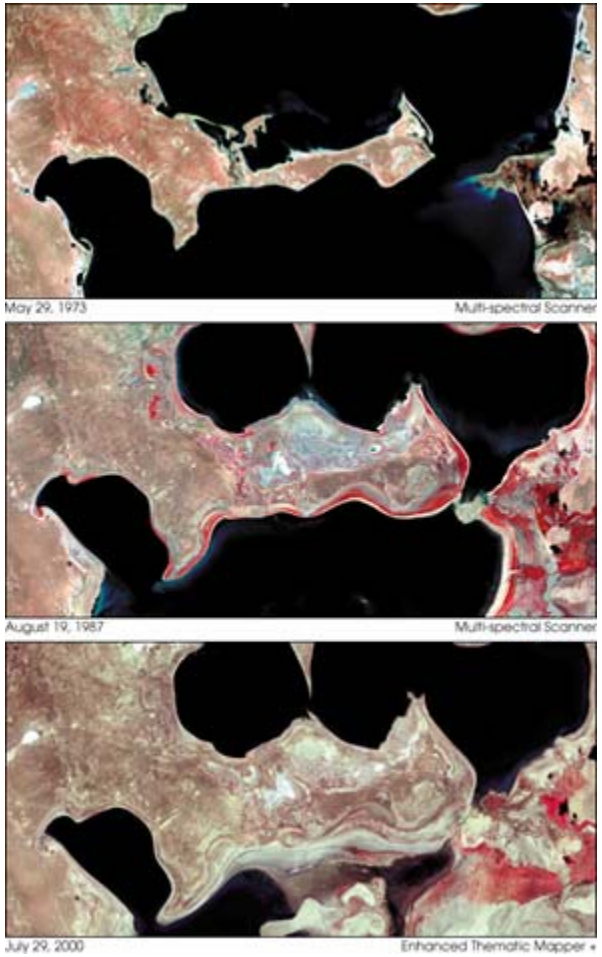
- Measuring Distance and Area in Satellite Images (2004)
  - Data: MODIS Images
  - Analysis Tool: Image J
  - Author: LuAnn Dahlman
  - http://serc.carleton.edu/eet/workshops/measuring_images.html
- Is Greenland Melting?
  - Data: CIRES
  - Analysis Tool: My World GIS (Trial)
  - Authors: Betsy Youngman, David Smith, Russel Huff
  - http://serc.carleton.edu/eet/workshops/greenland.html

Case Study: The Shrinking Aral Sea
Measuring Distance and Area in Satellite Images

http://serc.carleton.edu/eet/measure_sat2/case_study.html

- The Aral Sea, central Asia
- Modis & Landsat Satellite Image Data:
  - 1973, 1987, 2000
- Problem: To Measure Decline of Fresh Water Sea From 1973 to 2000
- Analysis Tool: Free ImageJ Measuring Tool from NIH

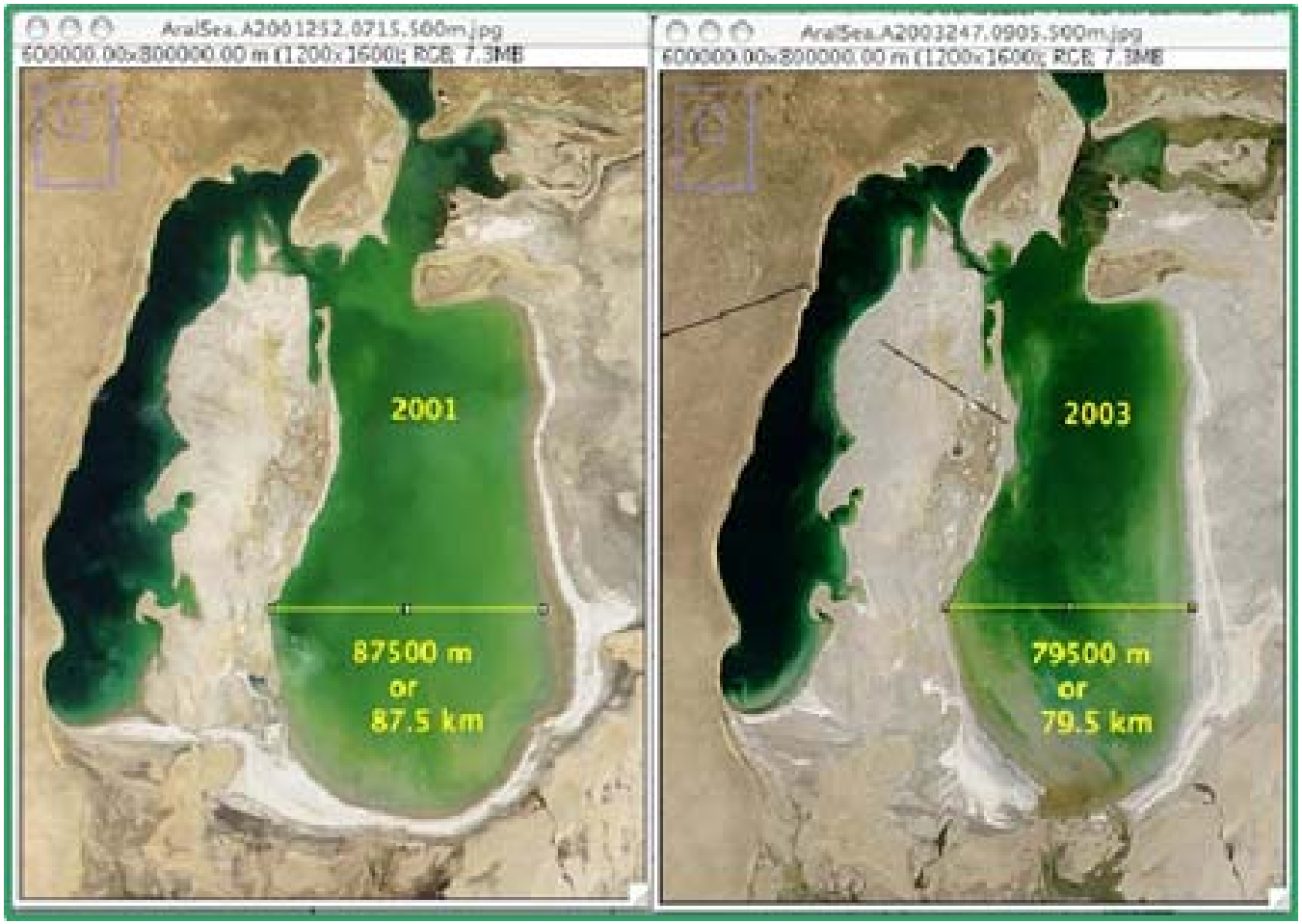
http://rsb.info.nih.gov/ij/download.html



From http://earthobservatory.nasa.gov/images/imagerecords/1000/1396/landsat_aral_triptych.jpg

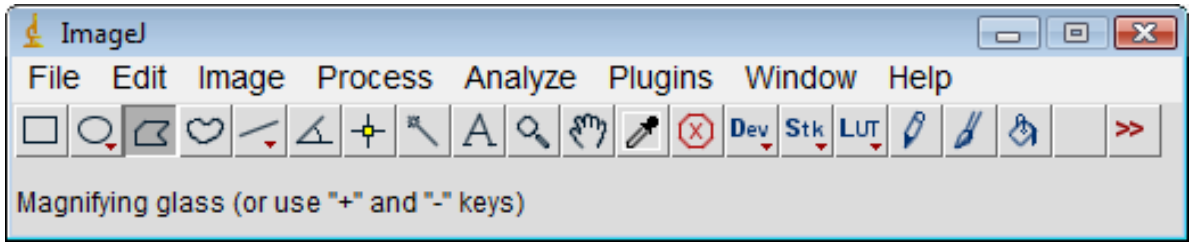
Aral Sea: MODIS 2001, 2003

Calibrating NIH Image J Measurement Tool



From http://serc.carleton.edu/images/eet/measure_sat2/example_output.v2.jpg

Analyze Images: ImageJ



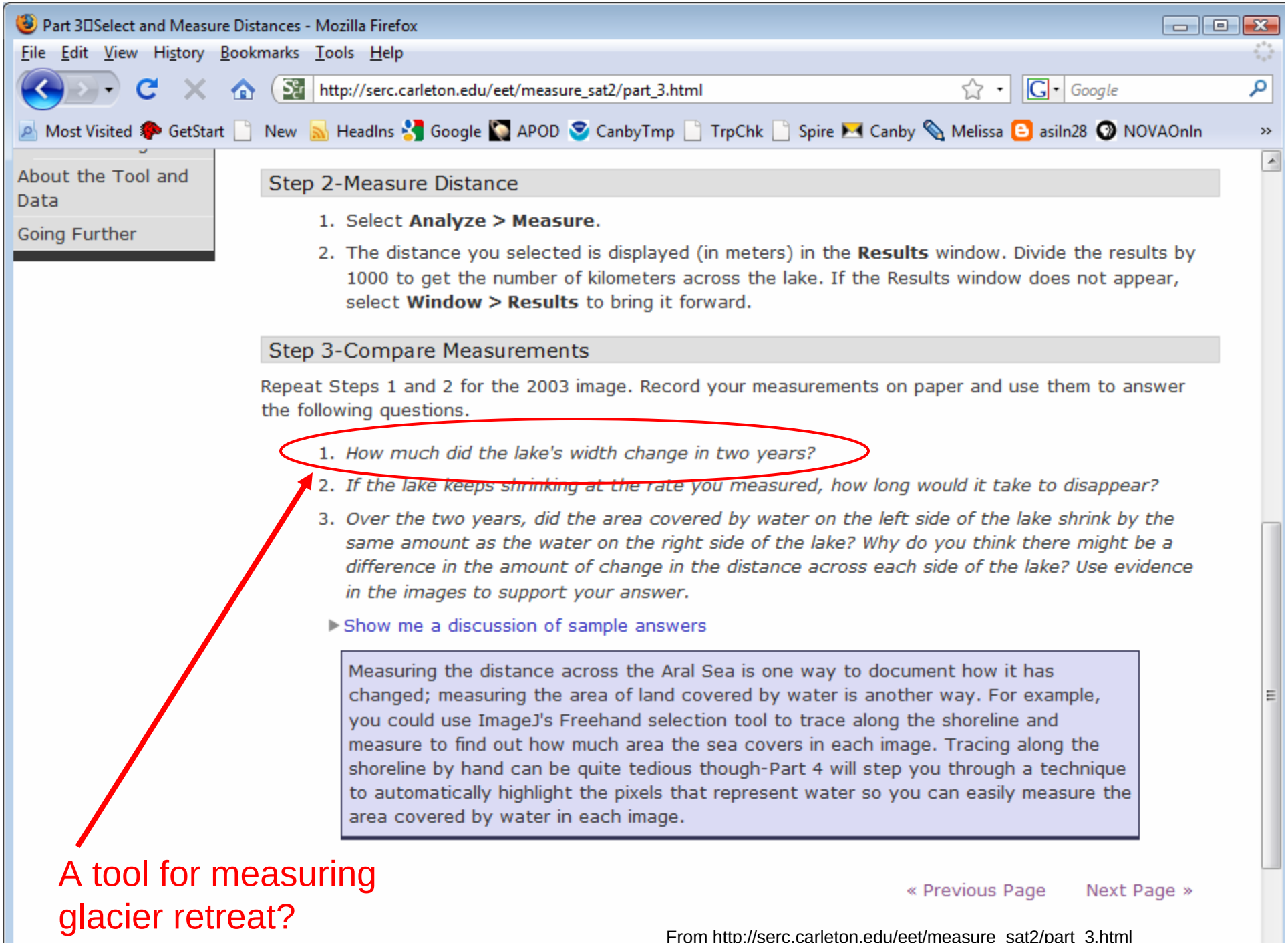
- ImageJ (ij.jar) written by George Silva at NIH for microscopic images, freely distributed.
- Older versions use 8-bit Grayscale images
- Requires calibration
- Measuring tools: length, perimeter, angle
- Analysis tools: histograms, plot profiles, surface plots
  - Measure area using thresholding

ImageJ: Measuring Tools

"This image shows the Aral Sea on June 3, 2001. The yellow line shows the former shoreline of this shrinking lake. The red line is the border between Kazakhstan to the north and Uzbekistan to the south. "

The yellow perimeter outline is made with ImageJ

From http://serc.carleton.edu/eet/measure_sat2/index.html



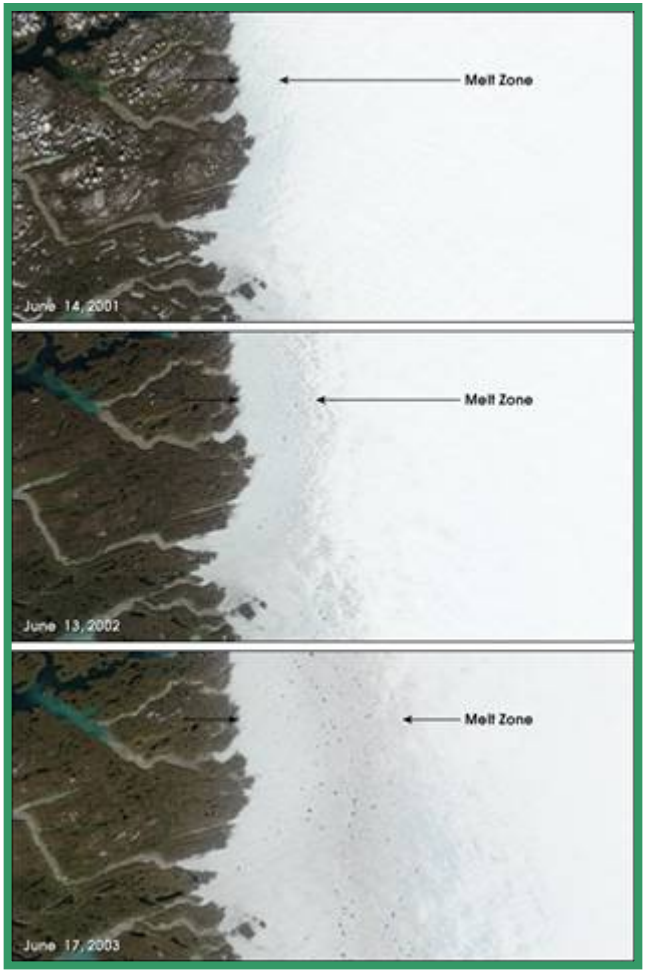
A tool for measuring glacier retreat?

From http://serc.carleton.edu/eet/measure_sat2/part_3.html

Is Greenland Melting?

An EET Data Analysis Workshop

http://serc.carleton.edu/eet/greenlandmelt/index.html

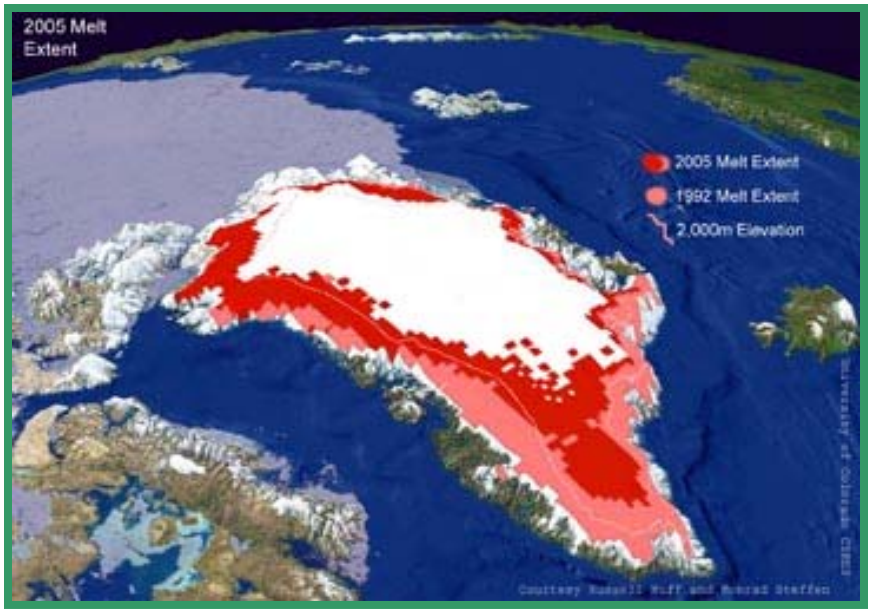


From http://serc.carleton.edu/images/eet/greenlandmelt/zone_surface_melting_greenland.jpg

- Greenland Ice Sheet
- Problem: Study the retreat of ice sheet over 1992-2003
- Data Source: GIS ice sheet image file: climate_change_greenland.m3rz (http://serc.carleton.edu)
- Tool: My World GIS (http://www.myworldgis.org/; Trial (www.pasco.com/myworld)

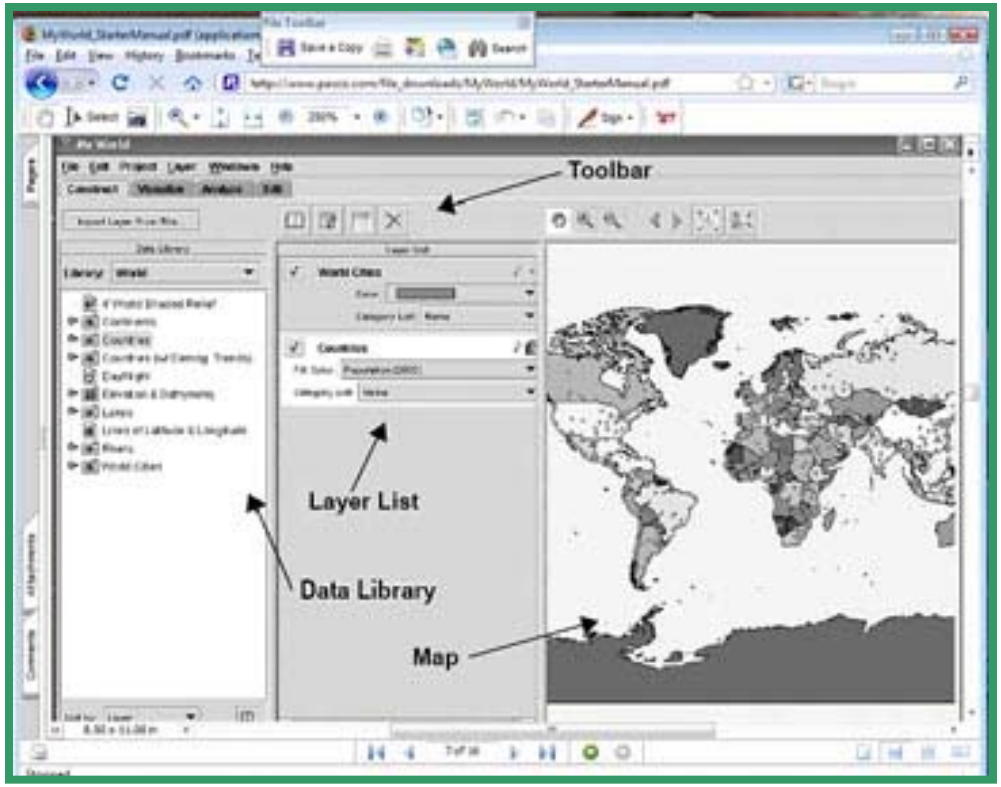
Measuring Greenland Ice Sheet Retreat: My World GIS

- My World GIS
- 45-day trial
- PASCO
- GIS for students
- Layers



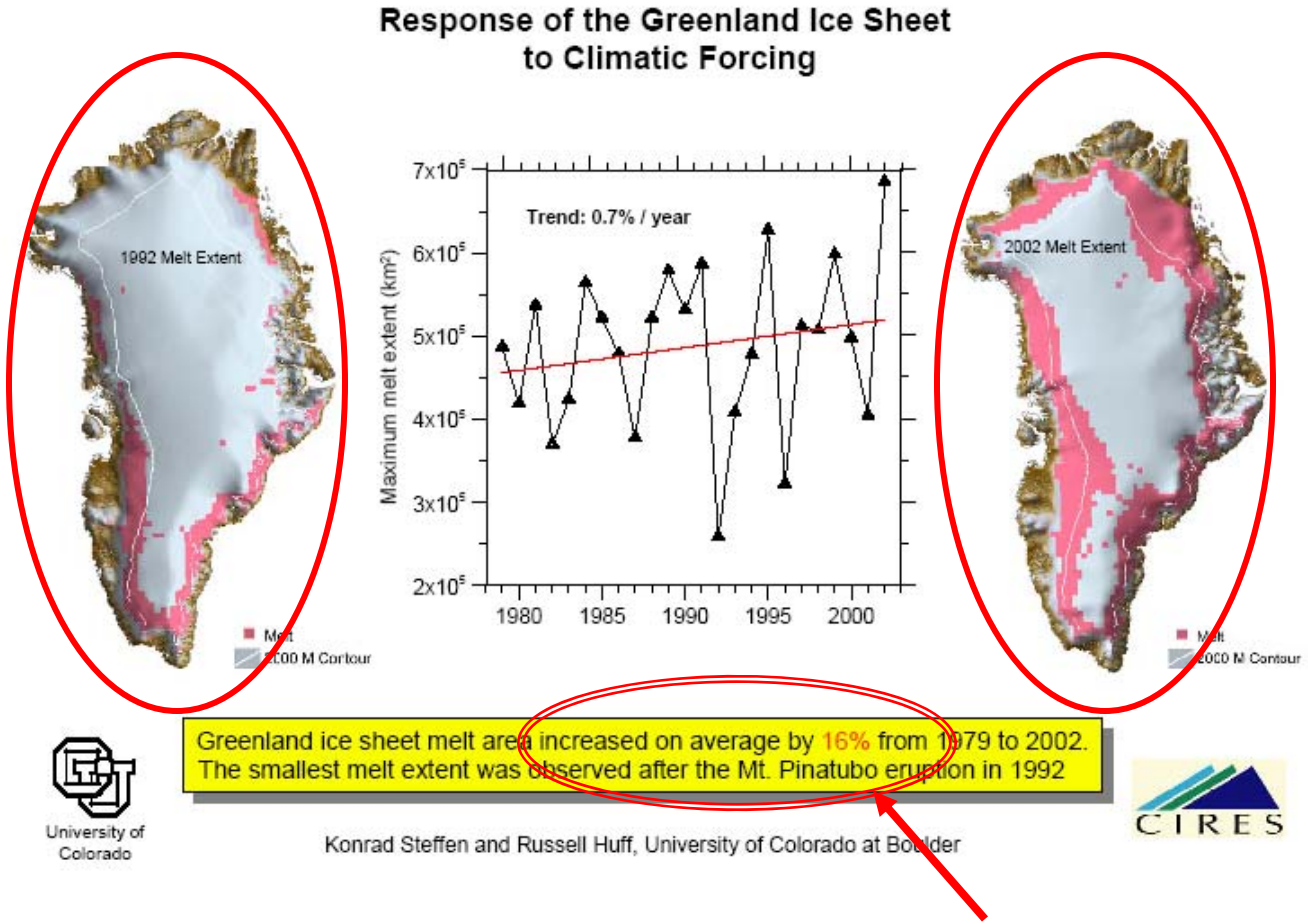
From http://serc.carleton.edu/images/eet/greenlandmelt/melt2005and1992.5inch.jpg

My World GIS
Sample Page



From http://www.pasco.com/file_downloads/MyWorld/MyWorld_StarterManual.pdf p.7.

Is Greenland Melting? Image showing decline 1979 -2002



A way to measure glacier retreat?

From http://serc.carleton.edu/files/eet/greenlandmelt/greenland_melting_pdf.pdf

Measuring Mt. Jefferson Glacier Retreat over Time: EET Tools

- Student independent research project
- Two high school Juniors
- Time in and out of class: 40+ hrs
- Problem: The retreat of glaciers on Mt. Jefferson over ~50 years, 1949-2000.
- Data: Images from Web & Portland State University
- Tools: ImageJ and ArcView 3.1

Oregon Volcano Glaciers

Mt Jefferson

NASA Image from http://glaciers.research.pdx.edu/states/oregon.php

Views of Mt Jefferson

1984 and 2005

View from east, 10/06/1984
(Lyn Topinka)

View from west, 12/08/2005
(Mike Doukas)

View from north, 12/08/2005
(Mike Doukas)

Credit to USGS Cascade Volcano Observatory

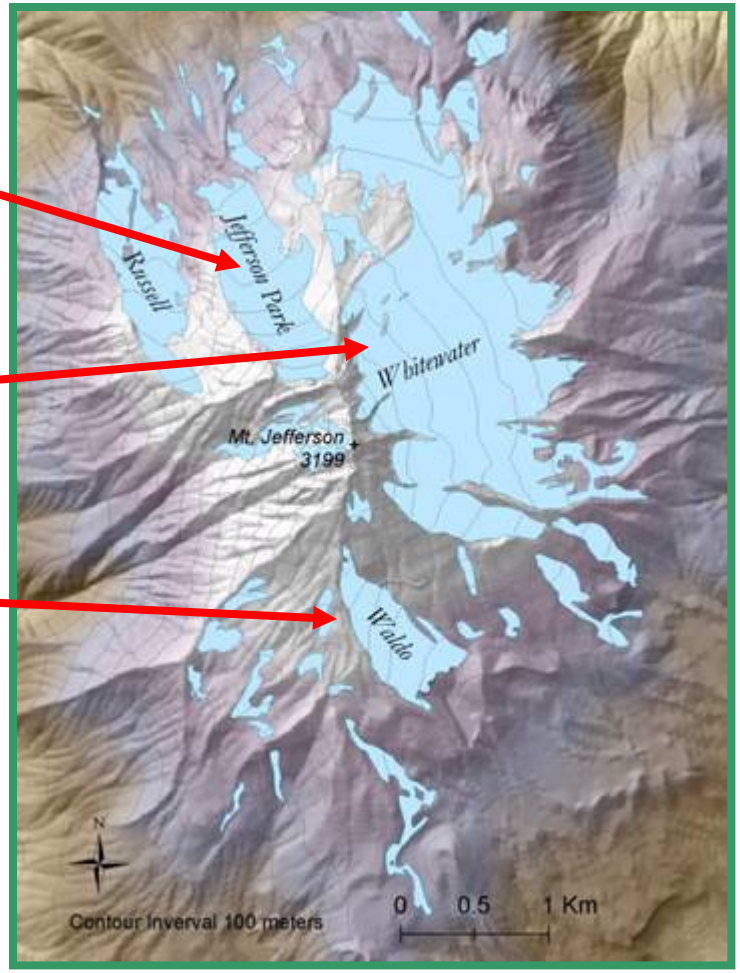
Finding Glacier Images

- Target three Mt. Jefferson glaciers & find images of those glaciers over 50 years.
- Search Web, Libraries, PSU geography department.
- Use mapped, aerial or satellite images. For aerial photos, if possible, obtain geo-referenced images.
- Google Earth offers aerial images of glaciers, with latitude, longitude, elevation, scale

Source: Google Earth, Image June 29, 2005

Target Mt. Jefferson Glaciers

- Jefferson Park Glacier
- Whitewater Glacier
- Waldo Glacier
- Most images used were from the image library of PSU Geography & Geology Dept.



From http://glaciers.research.pdx.edu/images/oregon/jeff_crop_full_image.png

Measuring Mt Jefferson Glaciers

- Method 1. Import glacier images into ImageJ (NIH). Calibrated and use line tool to outline glacier images. Used Aral Sea image outline method. First method tried.

- Method 2: Import glacier images into Arcview GIS 3.1. Outline glaciers. Follow Greenland Melting procedure. Geo-reference unreferenced aerial photos--difficult for students to do on their own.

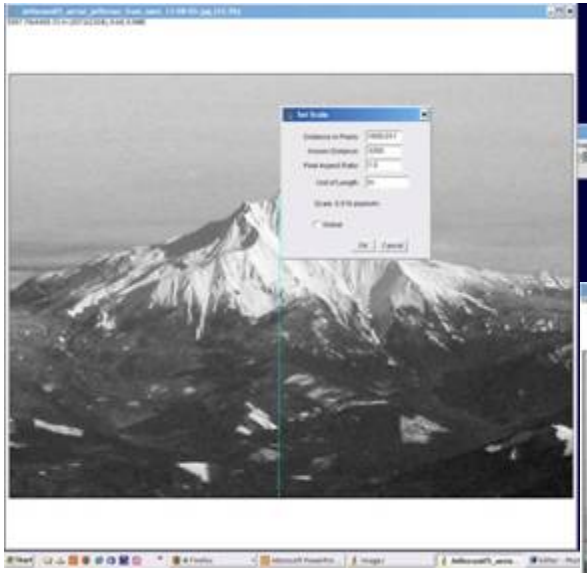
- For either method, best to prepare or obtain geo-referenced images.

Students' ImageJ method

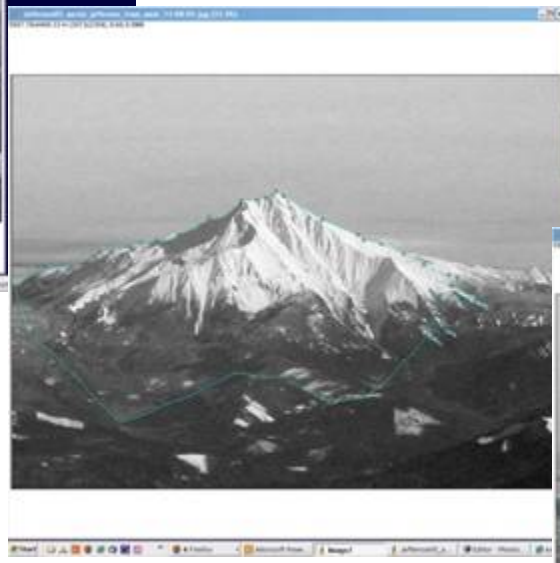
- Outlined the "white area" of each glacier
- Measure to get relative total area, average size and area fraction
- Not geo-referenced

Image Source: USGS Cascades Volcano Observatory

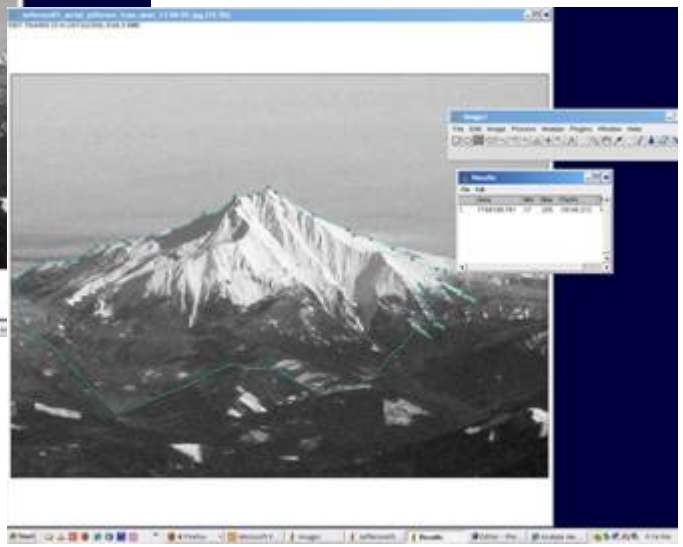
Example ImageJ Measurement for Snow Extent of Mt Jefferson



Set Up: Use Line tool to measure pixels. Set scale to known number of units. (In this image of Mt Jefferson, a height of ~3,200 m is used although not measured from sea level.)



Use Analyze Menu, select Set Measurement. Check Area, Perimeter. Use Polygon tool to outline snow area.



To see results, Click Analyze and then click Measure.

Students' Arcview 3.1 Method

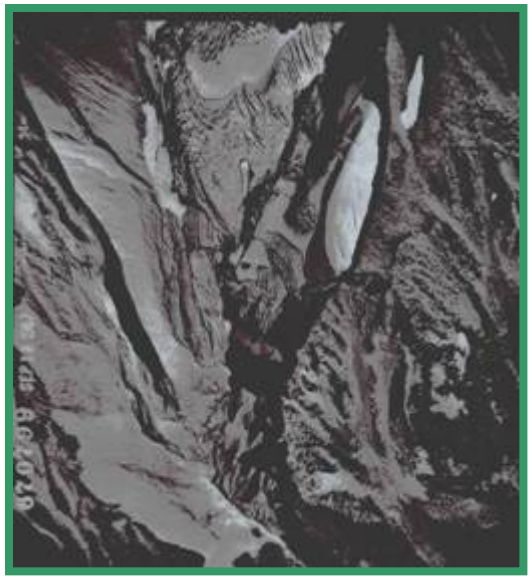
Map of Mt Jefferson Glaciers, 1949

Satellite Image of Mt. Jefferson Glaciers, 2000

- Obtained glacier images
  - 1949 mapped; 1967 aerial; 2000 satellite
  - Source: Portland State University Geography & Geology Dept.
- Calculated glacier areas in1949 mapped & 2000 satellite images in ArcView 3.1
- Geo-referenced 1967 aerial photographs and tabulated areas in ArcView 3.1
- Compared changes in areas for the 3 glaciers for the 3 years

Image Source: PSU Geography & Geology Dept

Selected Aerial Images of Glaciers in 1967



Jefferson Park Glacier

Whitewater Glacier

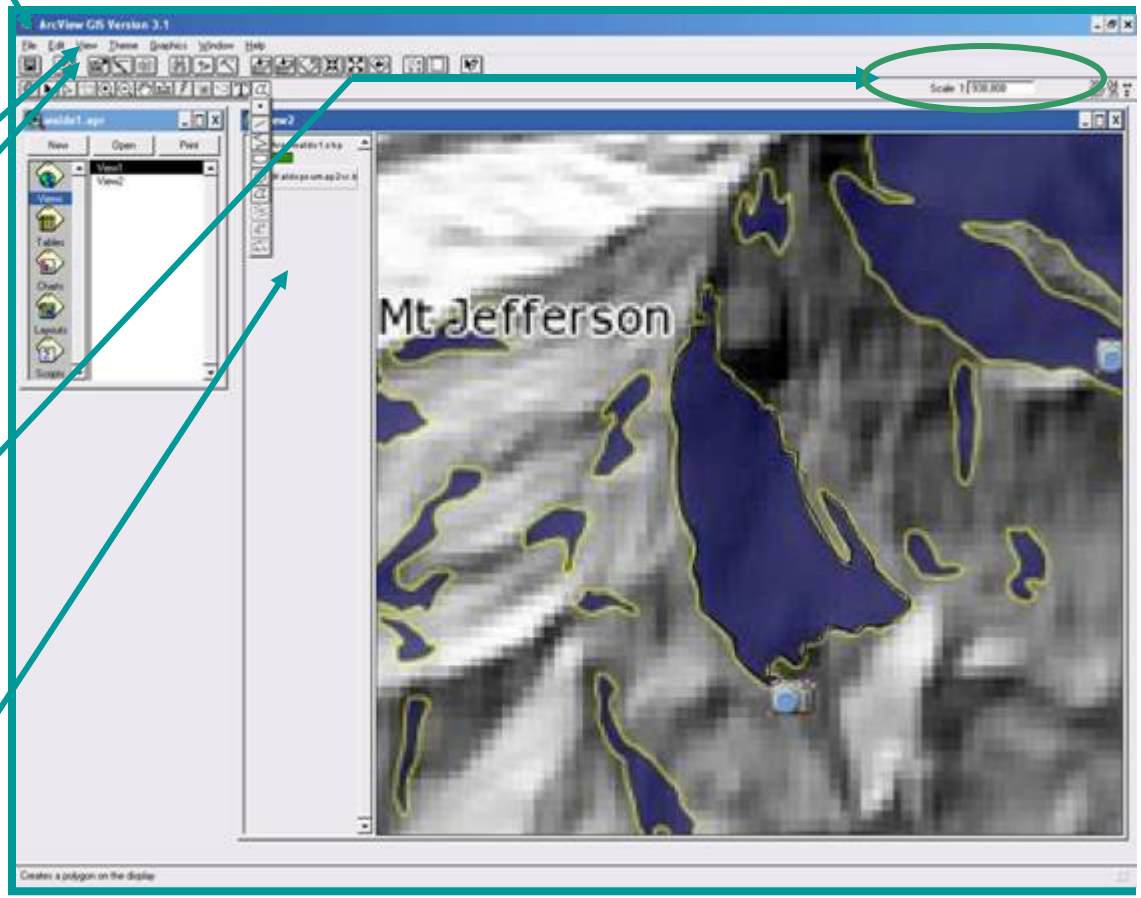
Waldo Glacier

1967 images used in study were geo-referenced by students with help from PSU.

Original aerial images from Portland State University Geography & Geology Dept.

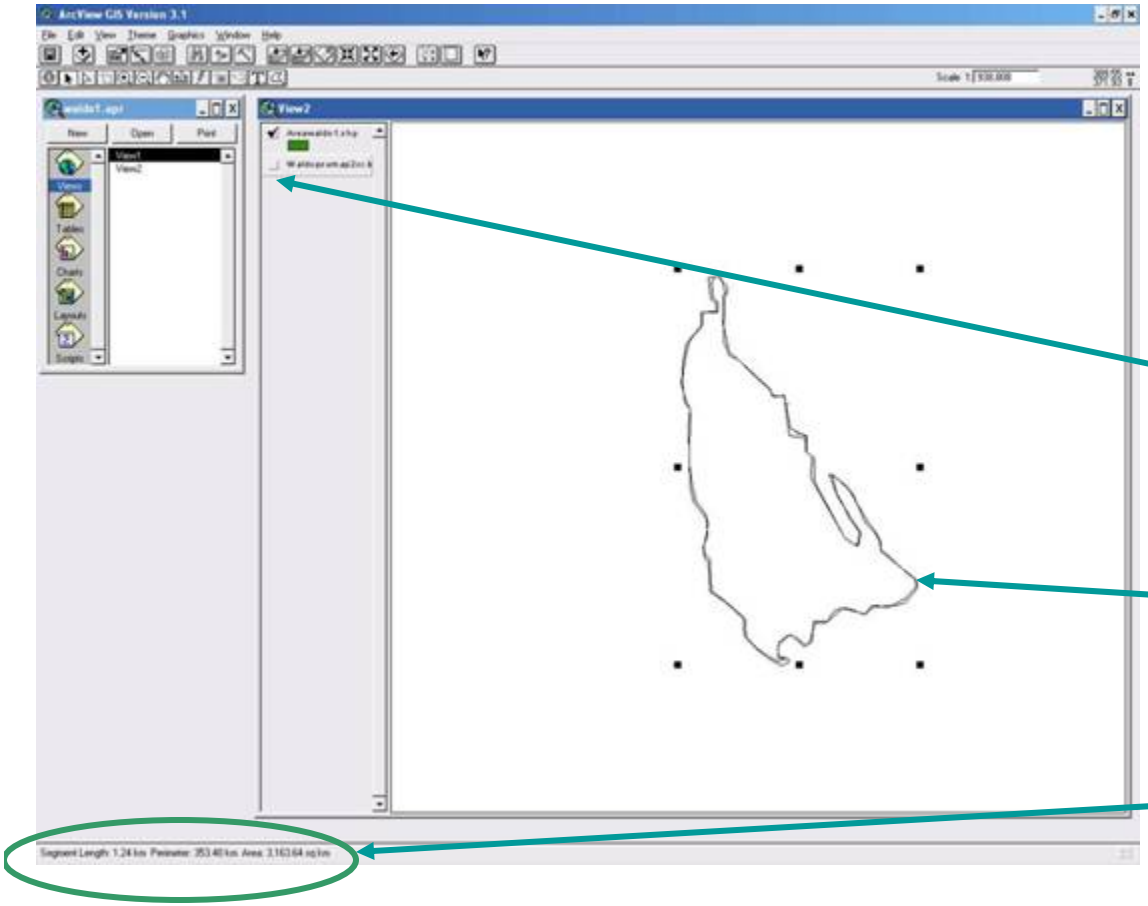
Arcview Image Calculation Example

- In Arcview 3.1, open a new project (.apr) and save as a new name.
- Click View and then Add Theme
- Select Glacier image (.bmp) as an Image Source; check box to turn on layer
- Set Units under View/ Properties and Scale
- Using Polygon tool, outline glacier, clicking at each vertex to anchor the polygon



Map Image source: http://glaciers.geos.pdx.edu/ , no date

Example Arcview Area Calculation



- Using irregular polygon tool, outline the glacier extent (zoom image)
- Turn off image by unchecking box
- Select the polygon using the select tool.
- Perimeter and area for the polygon are shown in lower left hand corner.

Geo-referencing Images

•For older aerial photos, distortion may not have been removed.

•To compare a map with an aerial photo, first register the same points on each so they align with each other. Like using push pins between the two images.

•Geo-referencing aligns the photo with the map. You can use the map data, e.g., coordinates, for the photo.

Students' Result Table

Data Table (Areas in meter^2)

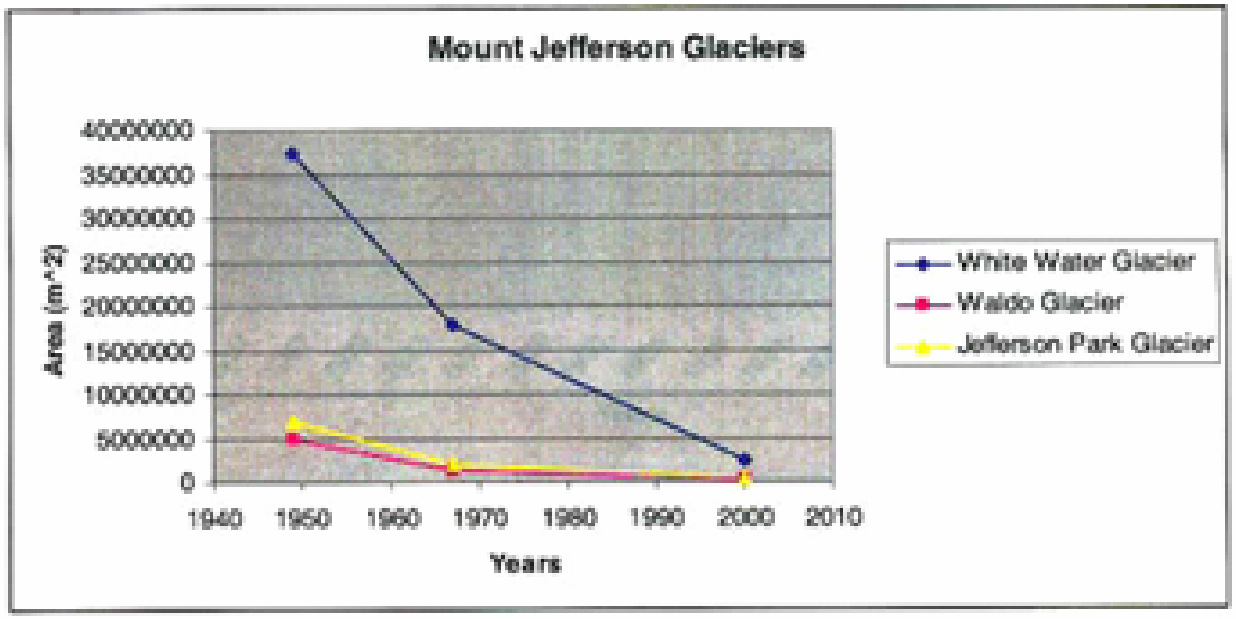
	1949	1967	2000
White Water Glacier	37261782.11	17866056.96	2420704.89
Waldo Glacier	4813587.92	1348294.31	252429.03
Jefferson Park Glacier	6990024.12	2052486.49	477509.58

Mt Jefferson Glacier Retreat Percent			
Glacier	Percent Loss by Year		
	1949	1967	2000
Whitewater	0.00	52.05	**93.50**
Waldo	0.00	71.99	**94.76**
Jefferson Park	0.00	70.64	**93.16**

Calculated percent loss based on student area data

Students' Results

Data Graph



Graph of decline in area of three Mt Jefferson Glaciers

Conclusions

- Students concluded that three Mt Jefferson glaciers had decreased in area from 1949 to 2000.

- A comparison of their glacier measurements with average temperature and average precipitation from 1961 to 2000 suggested that the decrease in glacier surface area followed an increase of annual average temperature of ~0.5^{o} C and a decrease in average rainfall of between 3” and 4” in Jefferson County.

- They suggested that one explanation for the large decrease in extent of the three glaciers may be global warming.

Limits & Sources of Error

- Geo-referenced Images. Glacier images first used were not geo-referenced. Geo-referencing of images done by students with help from PSU Geography & Geology Dept.
- Student-estimated glacier borders using mouse to trace outlines
- Steep Arcview 3.1 learning curve. Students tried to geo-reference 1967 images themselves, but had to go through step-by-step directions at PSU
- Student data tables in report did not use significant digits.
- Images may reflect differences in climate, seasonal changes, temperature, time of year, image size, & angle of image in addition to rainfall.

Suggestions for Repeating

- For High School students, use My World GIS
- Obtain/use geo-referenced images/maps; Google Earth may serve to provide aerial/satellite images with latitude, longitude, elevation, and scale.
- Determine glacier volume rather than area
- For older students, find or write simple instructions for geo-referencing images
- Keep maps, images collected for student projects for future use.

Resources

- ESRI Arcview 3.1
- NIH ImageJ
- Glacier and Mt. Jefferson images from web, USGS, and Portland State University Geography and Geology Dept
- Oregon climatology temperature and precipitation records
- Google Earth Images
- USGS Mt. Jefferson Images
- EET chapters and online workshops

Acknowledgements

- The students who invested significant effort and time in their project

- Portland State University Geology and Geography Department for providing map/aerial photos, satellite photo of the 3 glaciers for 1949, 1967, 2000 and for working with students to geo-reference the 1967 photos.

- USGS Cascade Volcano Observatory

- Oregon Climate Service

- Earth Exploration Toolbook online workshops