GOSTEAM Hands-on Activity Template *(Inquiry-based)*

Title:

Sea level rise impact on coastal areas

Short Description (Max 500 words):

Students will build an understanding and define potential impacts of sea level rise in their community and beyond, by measuring sea surface topography and communicating data and observations. Elevation data and overlay procedures will be introduced along with time-lapse representations for different sea-level rise projections. Although sea level rise seems to be inevitable, can we still raise awareness for the negative impacts to coastal regions worldwide?

Keywords (Up to 5):

Climate change, Sea Level Rise, Programming, Python, Satellite Data

Information about the Implementation

Age and language of the students:

		9-12	12-15	15-18	18+
Language: Greek	Age:	☐	☑	☑	☐

Number of Lessons – Duration (per lesson):

Number of Lessons: 1 Duration per Lesson: 45’

Subjects:

For which subject(s) the activity is usable, is it an interdisciplinary activity?

Science ☑

Physics ☑ Chemistry ☐ Biology ☐ Geosciences ☐ Environmental ☐ Other ☐

Technology ☑

Engineering ☑

Arts ☐

Mathematics ☑

Information about the Scenario

Curriculum and country:

Link of the current activity to the curriculum:

Country:	Greece	Class:	Secondary	Grade:	7 - 12

Topic: Environment, Geography, Programming

Objectives (Max 100 words):

Description of the learning objectives

Students will get introduced to:

They will explore and modify topographic maps as a means of studying sea level rise and how it will affect coastal areas (i.e. Aegean Sea).

Lesson on how to read a topographic map (Digital Terrain Models) seamlessly integrates with sea level rise via Python. Students then interpret the data for their assessment and run different sea level rise scenarios by visualizing their results.

Materials (Max 100 words):

Which resources and materials (software, hardware) are needed?

Material: Search Engines, Spatial Data, Maps and Online Support Material

Software: Python, QGIS (optionally)

Spatial concepts, skills, and abilities:

Which spatial concepts and skills are covered by the activity?

Spatial concepts:

Primitives: Identity/Name ☐ Location ☑ Space/Time ☑

Simple: Distance ☐ Direction ☐ Connectivity ☐ Movement ☐ Boundary ☐ Shape/Area ☐ Adjacency ☐

Difficult: Overlay ☐ Buffer ☐ Topology ☐ Coordinate ☐ Map ☐ Scale ☐ Shortest Path ☐ Navigation ☐ Surface ☑ Slope/Gradient ☐ Aspect ☐ Contour ☐

Complex: Interpolation ☐ Map Projection ☐ Spatial Dependency ☐

Other:

Spatial skills:

- [x] Map literacy
- [ ] Navigation/orientation
- [ ] Estimating distances and directions
- [ ] Recognizing and understanding patterns/Understand and identify models of spatial organization
- [ ] Select an ideal location based on the given spatial features
- [x] Visualization
- [ ] Understand and identify spatial correlations/ dependencies
- [ ] Categorize spatial entities/ geographic features and identify hierarchies
- [x] Compare spatial entities and draw analogies among them
- [ ] Identify/determine connections/relations
- [ ] Understanding scale in space and time
- [ ] Delineation of spatial regions/ zones based on given features/ properties

Short Description

Navigation/orientation: Finding one's way in unfamiliar environments, interpreting and giving walking and driving directions.
Estimating distances and directions: Measure paths, weighted distances, angles.
Map literacy: Using, interpreting/understanding, learning from, and communicating acquired spatial knowledge from maps, comprehension of geographic features represented as points, lines, or polygons.
Recognizing and understanding patterns/Understand and identify models of spatial organization. Delineation of spatial regions/zones based on given features/properties: Regionalization processes, pattern recognition and clustering identification in the 2d and/or the 3d world.
Select an ideal location based on the given spatial features: Single or multi-criteria siting and optimal areas identification.
Visualization: Visualizing spatial entities from written/oral verbal descriptions, from their 2d or graphical representations or through mental transformations; such as axis rotation or perspective taking.
Understand and identify spatial correlations/ dependencies: The ability to realize, identify and explain patterns, clusters and relevant spatial dependencies.
Categorize spatial entities/geographic features and identify hierarchies: Identify the hierarchical form of data and gradients between spatial entities.
Compare spatial entities and draw analogies among them: Calculate and compare different geometric objects' shapes, area and boundaries.
Identify/determine connections/relations: The ability to identify links and common characteristics among spatial entities and between humans and spatial entities.
Understanding scale in space and time: The understanding of changes/transitions through space and time for different spatio-temporal scales.

Geospatial concepts and spatial abilities documentation (see Section 3.2):
http://www.gosteam.eu/wp-content/uploads/2021/05/GOSTEAM_IO1_A1_final.pdf

Description of the activity in detail

Question Eliciting Activities

Provoke curiosity

Describe ways and materials that teachers will present to their students to attract their attention to the topic investigated.

Usually, the most effective way to provoke students' curiosity is by presenting an exciting video or a series of photos

How Earth Would Look If All The Ice Melted?

https://www.youtube.com/watch?v=VbiRNT_gWUQ

Propose preliminary explanations or hypotheses

Formulate the scientifically oriented questions that teachers will present to the students to trigger their engagement in thinking about the topic investigated based on their existing knowledge. Make these questions digitally available and easily usable, e.g., by integrating them in the materials described in the previous step.

It is best to ask these questions in the context of a relative discussion.

How do you think we monitor the sea level rise levels or potential impact?

Can we build simplified or more complex models for assessing the potential impact upon different scenarios (low impact scenario, high impact scenario etc.)?

Active Investigation

Plan and conduct simple investigation

Provide the teachers with a specific plan of the investigation that will take place. Offer instructions about the activities they students will need to perform and what kind of materials they may need. Describe ways that the teachers can use to facilitate the students to focus on evidence.

This is the phase in which students are being prepared for the subsequent phase of evidence gathering during observation.

An overview of the sea level rise phenomenon:

https://sealevel.nasa.gov/understanding-sea-level/global-sea-level/overview

Try out the following application!

https://coast.noaa.gov/slr/#/layer/slr/10/-8690282.31660882/4205754.250664386/6/satellite/none/0.8/2050/interHigh/midAccretion

Can you imagine how we can make projections of the potential sea level rise impact or even build such tools for other areas? What data do we need?

Creation

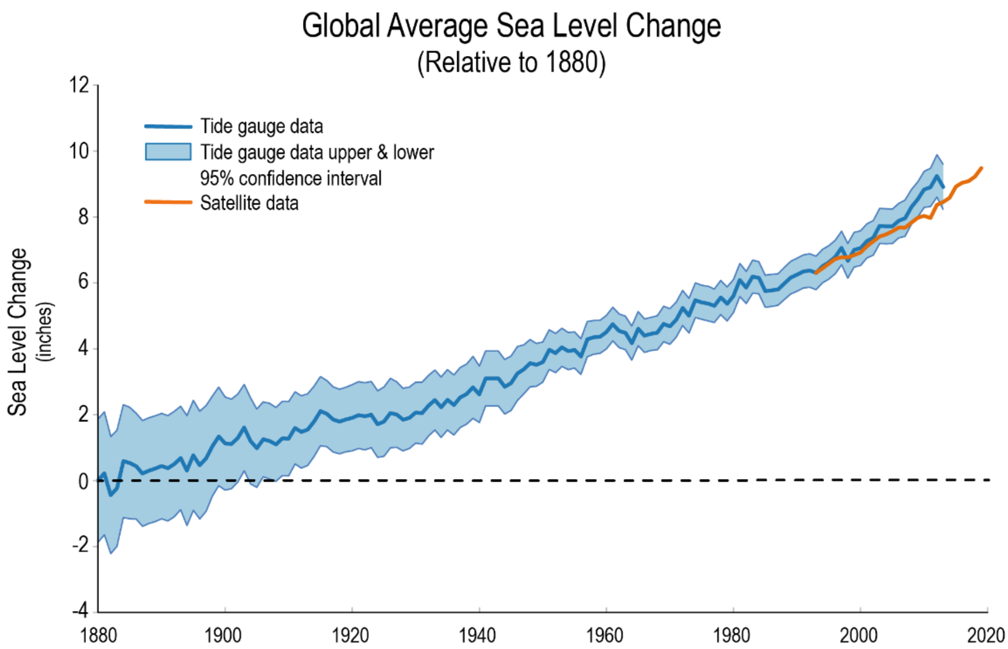
Gather evidence from observation

The selected resource (e.g., a simulation, an experiment, an animation, a graph, or other exhibit of similar nature) must provide students with an opportunity to collect evidence addressing the scientific questions presented in previous stages through direct or indirect observation. Provide guidance to the teacher organize and manage the activity most effectively and efficiently.

It is recommended to introduce group work at this stage. Guide the teachers to divide students in groups, each of which will be facilitated by the teacher to formulate and to evaluate explanations to the scientific questions based on the collected evidence.

Before the beginning of the activity, students are separated to groups of 2. One of the group members is responsible for the tasks' flowchart implementation, data acquisition and the appropriate steps to be followed during the activity. The second member is responsible for the results validation and communication, including the final report and the maps preparation.

CAN WE MODEL AND VISUALIZE THE GRAPH BELOW?



1. **Visit:** https://earthexplorer.usgs.gov/ and select Login button in order to Sign-up and create an account. Follow the steps needed to finalize and activate your account. By activating your account (via email), you can download data!

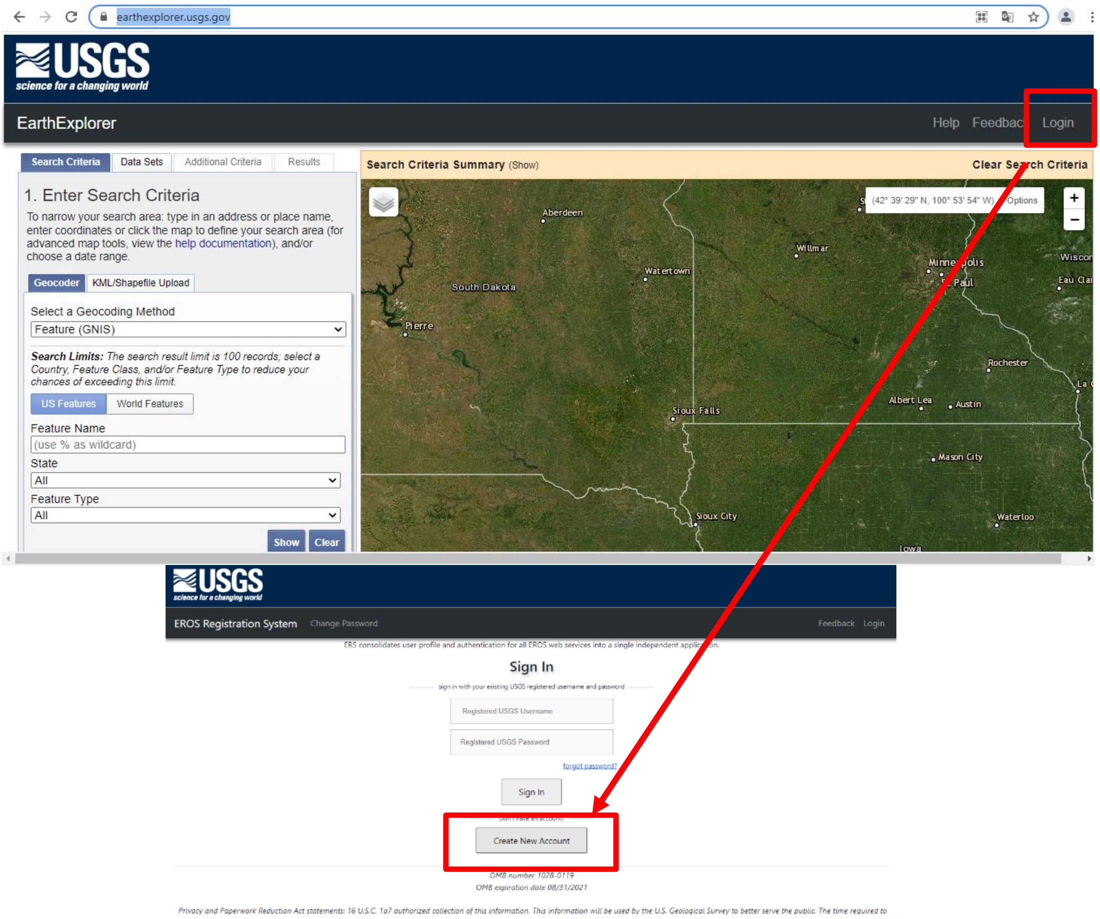


Figure 2: USGS Earth Explorer Interface

2. Download Digital Elevation Model (DEM) data using USGS platform (https://earthexplorer.usgs.gov/).

On the left of the website you can see 4 different tabs (Enter Search Criteria, Data Sets, Add. Criteria and Results). Follow the Steps below:

1. Zoom out on the map, navigate to your area of interest (definitely a coastal area for monitoring sea level rise impact).
2. Enter search criteria tab: Scroll down and after you zoom-in to your area (Step 1), click on “Use Map” for setting the boundaries to search for satellite images! (See Figure 3).
3. On the “Data sets” tab expand Digital Elevation category > SRTM > click on SRTM 1 Arc-second Global (see Figure 4).
4. Click on the Results button and you jump immediately on the Results tab.

5. Using the “foot” button see the boundaries of each image, select an image and press the disk with the green arrow button to download the image (Figure 5)!
6. Download the GeoTiff file!!!

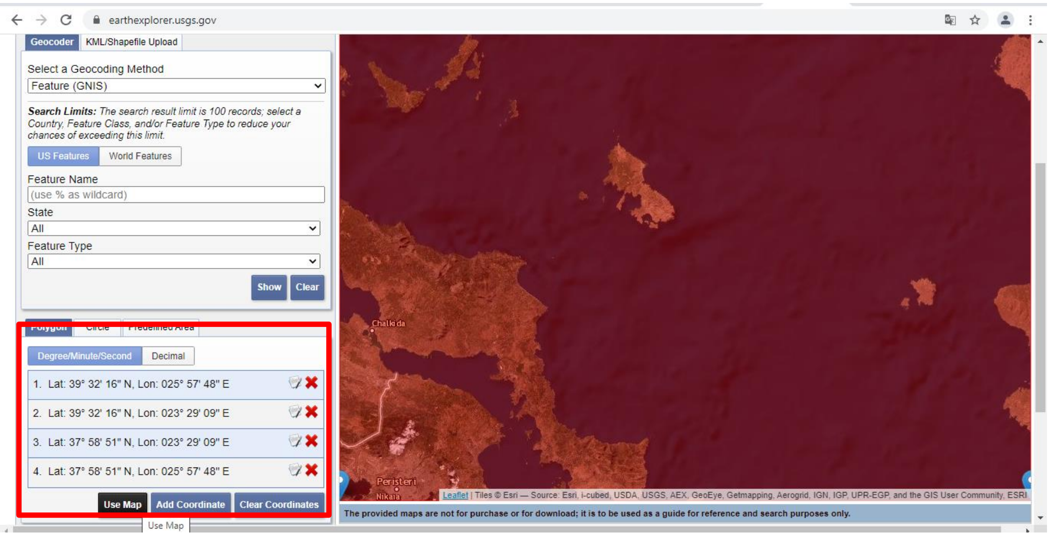


Figure 3: Select study area

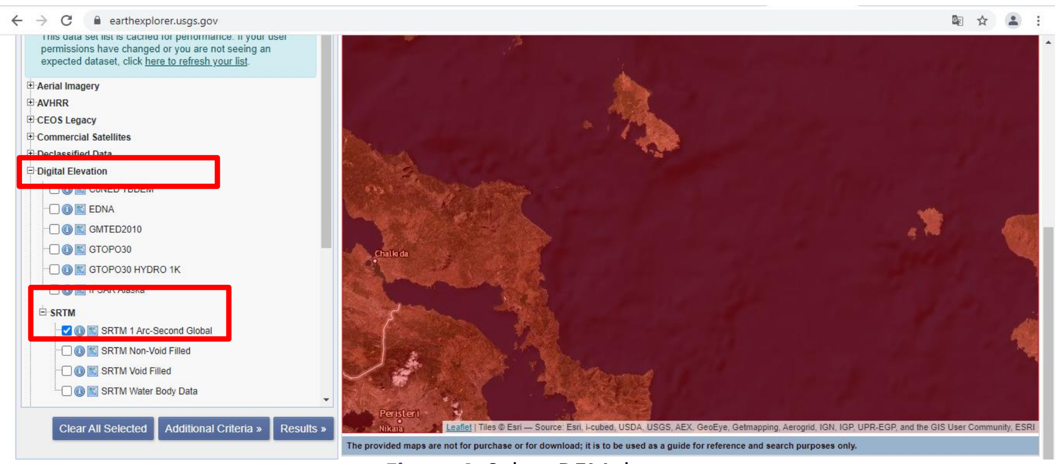


Figure 4: Select DEM dataset

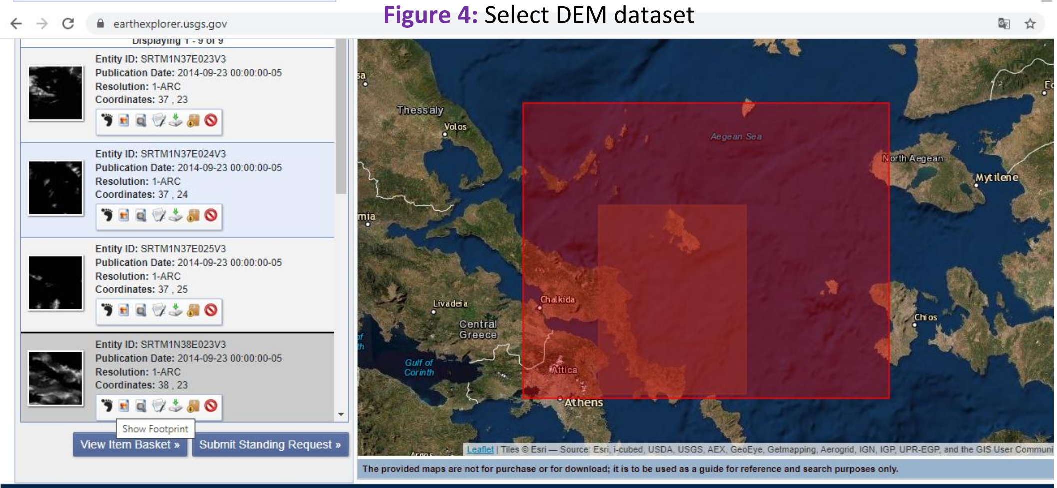


Figure 5: Inspect and download DEM data tiff file

After you download the GeoTiff file (.tif extension) see the images below in order to understand what exactly you have downloaded and what we will do during this Activity!

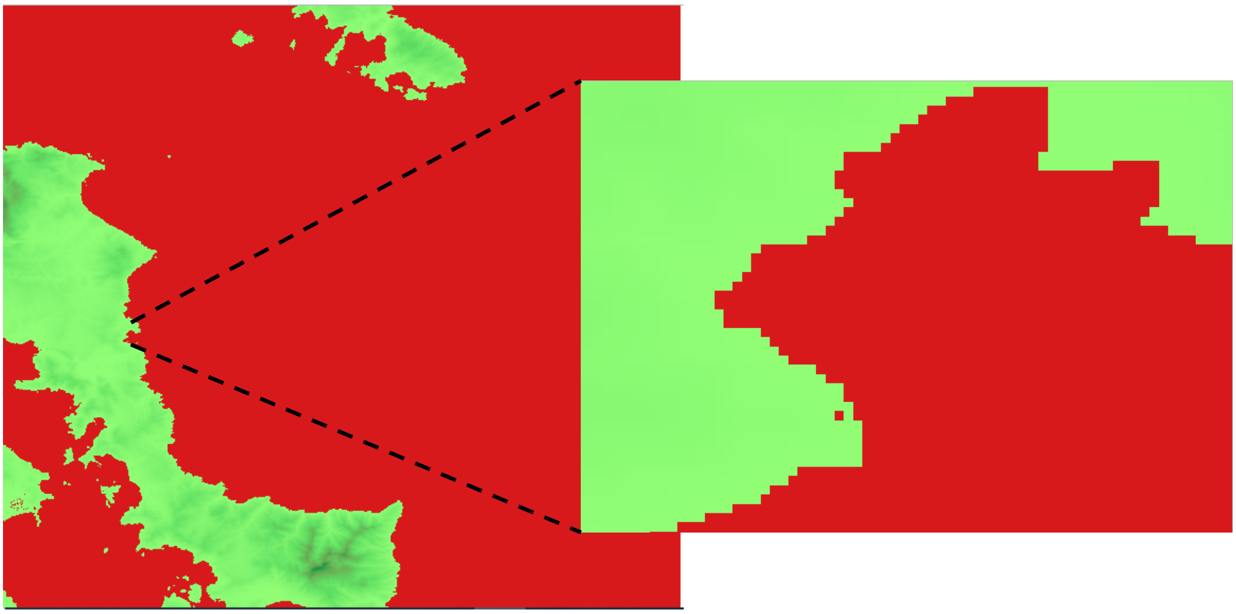


Figure 6: DEM data (image) comprised of different pixel values (heights or the sea)

Inspecting **Figure 6** we can see that we have an orthogonally shaped image with different colors. We can easily identify that the red color is the sea, and the green colors indicate land areas with different heights values (light green to dark green).

You can also see Figure 7 that demonstrates what actually a .tiff image is, particularly, a dense grid of georeferenced cells with different values. So, if we know the Axis origin coordinates, the number of rows and columns and the cell size, we can represent any variable we want or even process these data while we are working in the form of a matrix!

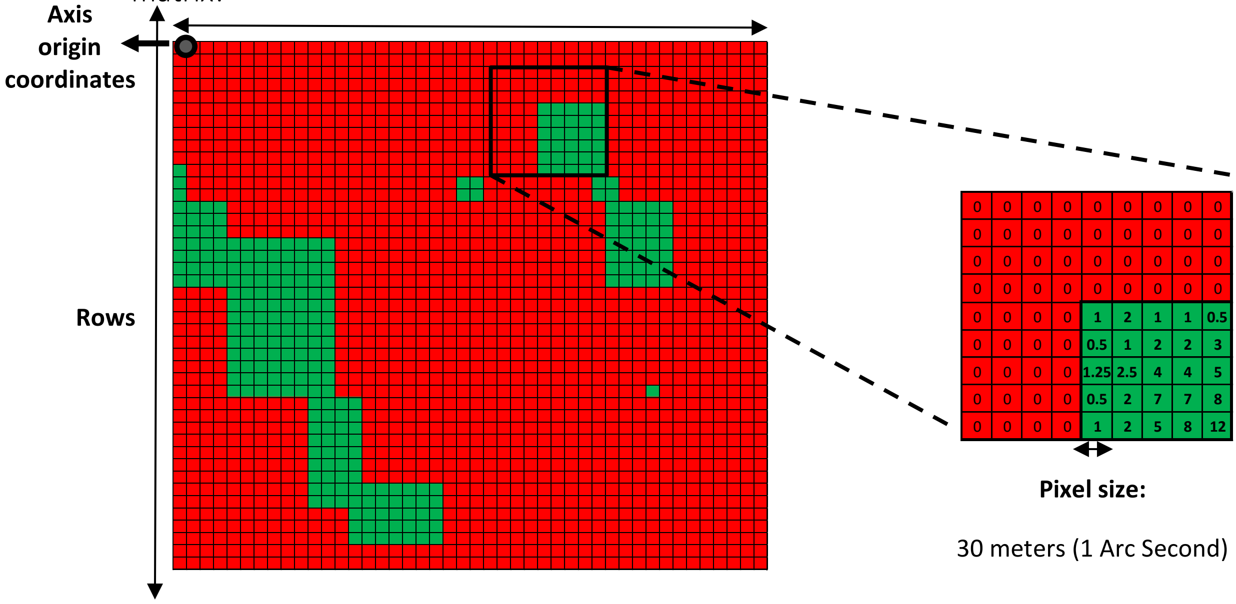


Figure 7: DEM data (image) explained in the form of pixels with different or the same values

Now you can ask students to think, what will happen if the sea level rises about 5 meters, or 12, or 20?

Having this image can we monitor the impact and how?

In a programming code, what Steps do we have to follow, in order to identify the impacted areas? **Remember that we already know the sea pixel values and the land heights values!**

Build a Pseudocode!

```
Load the appropriate libraries

Initiate the Sea Level Rise limit (i.e. 12 meters (!!!))

Load the input image

Transform the .tiff file to array

For every row of the array

        For every column of the array

                If pixel value is different than 0 (Sea)

                        If pixel value is below Sea Level Rise value

                                Set the pixel value as 99999

Transform array to image again

Plot the results
```

Trigger students interests by asking them, how many lines of code do they think the above-mentioned procedure is? (The answer is 17 or less than 17)

3. Download Python 3.8.8 from: https://www.python.org/downloads/windows/ Open the link provided and download Python 3.8.8 version for Windows (most probably for 64-bit, but you have to check your operating system characteristics).

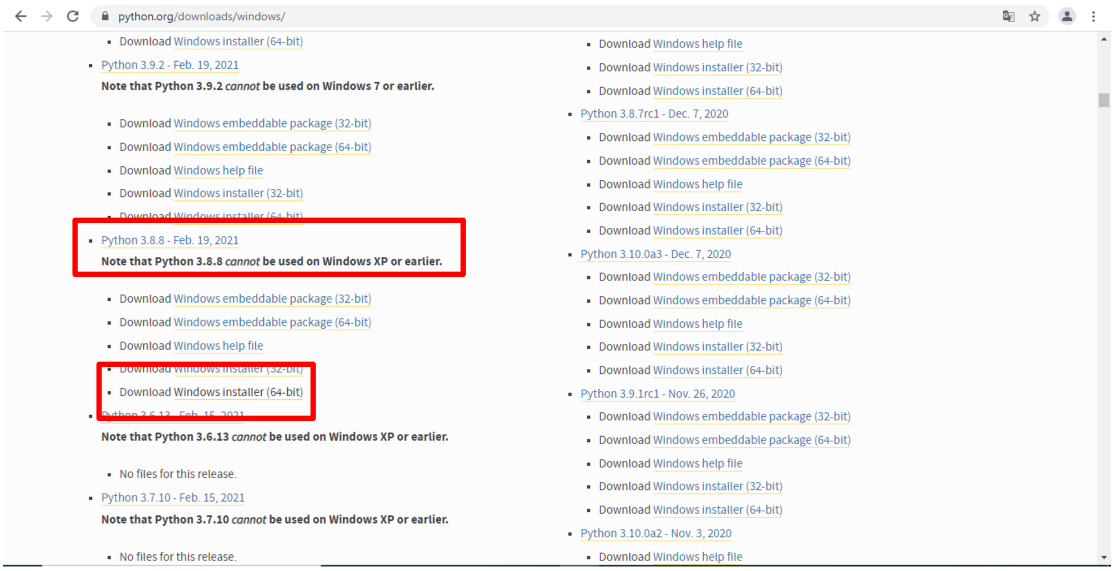


Figure 1: Python webpage and previous releases repository

After downloading the Windows installer you double-click on the .exe file and follow the instructions provided during installation.

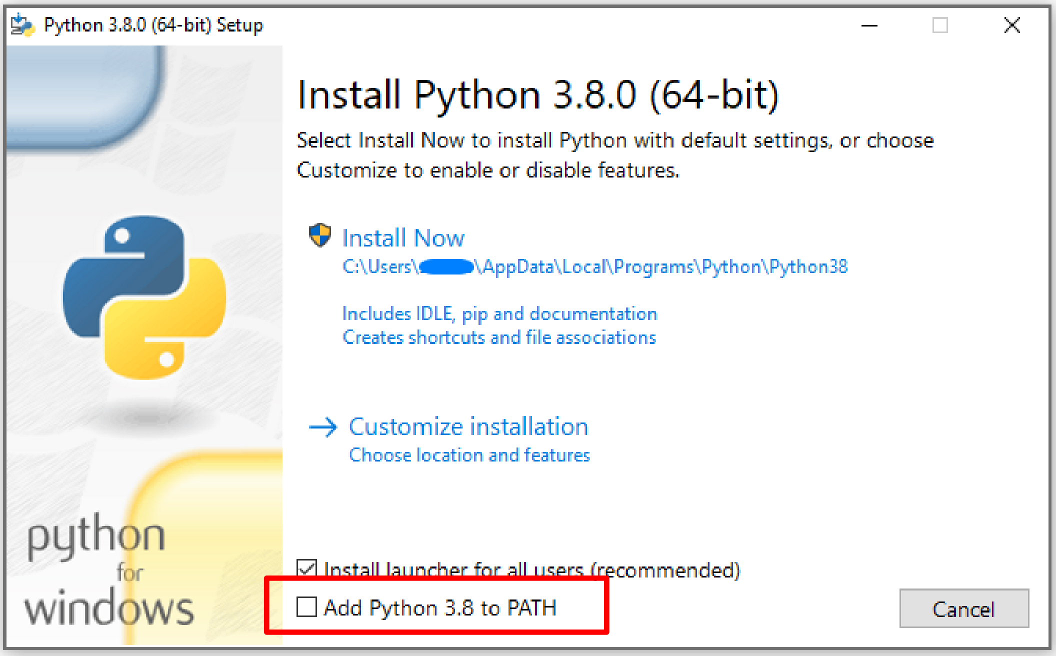


Figure 2: Python installation process add Python to Path

Important note: DO NOT FORGET TO SELECT TO ADD PYTHON PATH TO THE WINDOWS ENVIRONMENT DURING THE INSTALLATION PROCESS! (see Figure 2)

4. Install the appropriate Python libraries:

For this Activity we need to install:

Pillow: https://pillow.readthedocs.io/en/stable/

NumPy: https://numpy.org/

Matplotlib: https://matplotlib.org/

But why these libraries??? Remember what we want to do! We need to read image files, transform them to arrays and finally, to plot the results! Therefore, we need Pillow to open .tiff files (Digital Elevation Model - DEM). With NumPy we read and process the image values in the form of an array and finally, we plot our final array using Matplotlib in the form of an image with a colorscale.

To install these libraries you have to open Command Prompt (as Administrator). To succeed this, just type “cmd” on the Window search bar (bottom left), right-click on Command Prompt and select “Run as Administrator”.

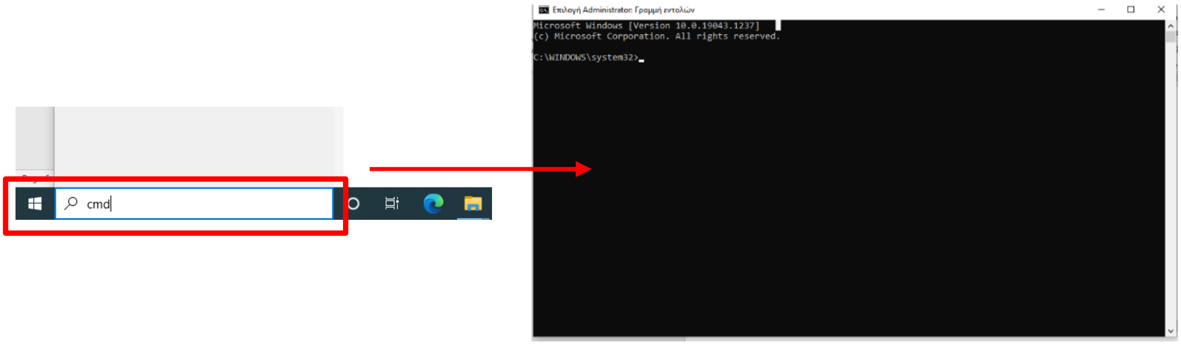


Figure 3: Open Command Prompt on Windows environment

On the Command Prompt just type:

1. pip install pillow (wait a few seconds to install the library)
2. pip install numpy (wait a few seconds to install the library)
3. pip install matplotlib (wait a few seconds to install the library and exit CMD)

To validate if the libraries were appropriately installed, open the Python IDLE, form the Start button on Windows > Python 3.8 > IDLE (Python 3.8, 64 bit). Then type “import PIL” and press ENTER, “import numpy” and press ENTER and the same steps using “import matplotlib”. See Figure 4.

If the libraries have been installed successfully, no message errors will appear (in red color)! E.g. if you type “importa pil” an error appears due to incorrect syntax or if the library is not properly installed the following message appears:

“ModuleNotFoundError: No module named 'library'”

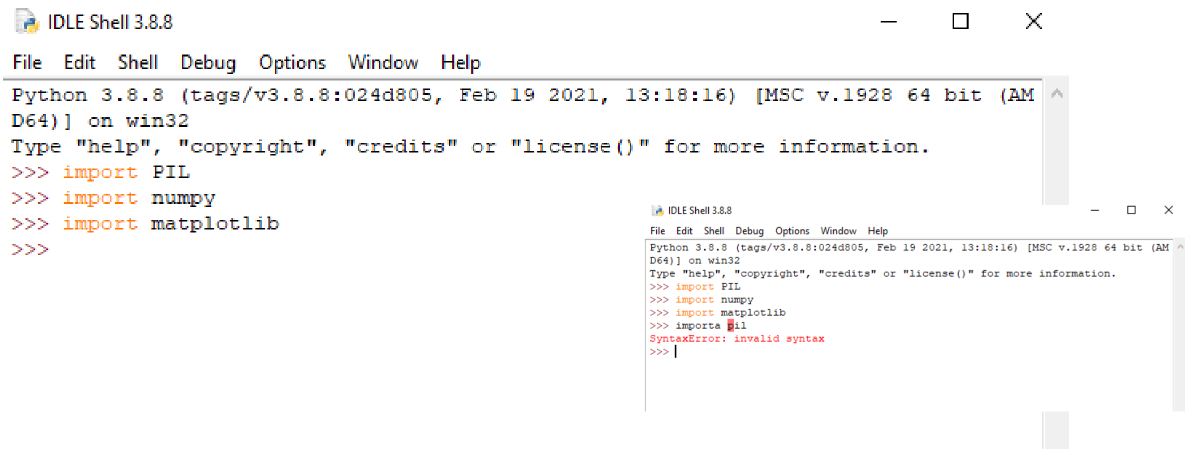
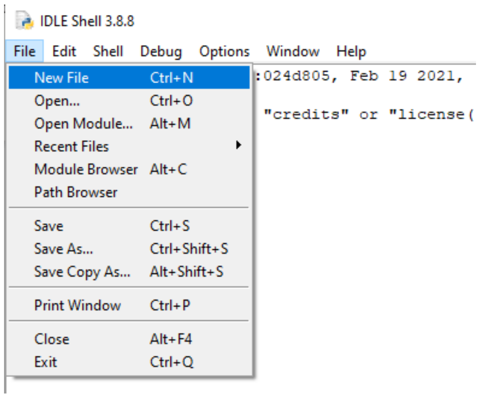


Figure 4: Check if the proposed libraries have been installed properly.
If not, an error appears (right image)

NOW WE ARE READY TO START CODING!!!

5. Create a new Python IDLE file and start coding

Open a new IDLE Shell and select File > New File and save your Python file (.py) to your working folder.



- On the new Python file ask from students to Load all appropriate libraries! They can search on Google how they can do it or the teacher can give an example (i.e. for the first library). See below the solution!

__from PIL import Image__ #import Image function from PIL
__import numpy as np__ #import NumPy with the code name np.
__import matplotlib.pyplot as plt__ #import pyplot function from matplotlib and name it as plt

- **Next Step is to load the Image file using Image function from PIL (pillow library) and plot the loaded image! Be careful on the double “\\” for the file path!**

im = Image.open('C:\\Users\\User\\Downloads\\n38_e024_1arc_v3.tif') #Load the image .tif file
im.show() #Plot Image

- Transform the Image you have loaded to array using Numpy and print the number of rows and columns. As the rows and columns increase, the processing time increases too!

imarray = np.array(im)   #Transform the .tif image to numpy array using array function
rows,cols = imarray.shape #Extract the array's columns and rows
print("The array has: ",rows," rows and ",cols, " columns") #Print the result

- Set the sea level rise value!

sea_level_rise = 25 #Initialize sea level rise parameter

- Parse all pixel values on the array using a for loop! You can go back on Figure 7 and explain what parsing means!

for i in range(0,rows):   #Parse all rows from 0 to the number of rows you have already printed
    for j in range(0,cols): #Parse all columns from 0 to the number of columns you have already printed

Important note: Explain to students that first we loop over all columns and then over all rows. So, in a 2 dimensional array the first value (cell) of the loop is (0,0) the second (0,1)….(0,3601), (1,0), (1,1)…..(1,3601),(2,0) etc.
ASK THEM ON THE ARRAY OF FIGURE 7 WHICH IS THE FIRST VALUE THAT THEIR CODE IS SEARCHING?

- Set which values we want to compare with the sea level cut-off value! Not the sea values (which is 0). They have to use one or more if statements.

if imarray[i][j]!=0:   #If cell i,j is on land then continue
  if imarray[i][j] <= sea_level_rise: #If cell i,j is on land and has value smaller than the sea level limit continue
        imarray[i][j] = 9999   #Change the cell value to 9999 (from the initial height value)

Explain to students that we use such a high score for the affected pixels in order to visualize the results much easier! We need a value of unique characteristics! Can 9999 be a height on ground? (NO! Mount Everest is below this value).
Also, can we reduce the above lines of code in 2 lines?

- Set which values we want to compare with the sea level cut-off value! Not the sea values (which is 0). They have to use one or more if statements.

plt.imshow(imarray) #Plot the resulted array!
plt.colorbar()   #Set a colorbar as legend
plt.show()   #Show the resulted image!

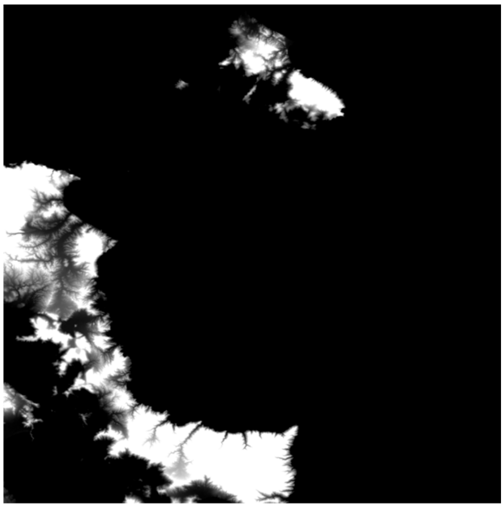
Students can search on alternate way to properly plot an array, or to change the colorbar colors etc.

FULL PYTHON CODE

```
from PIL import Image
import numpy as np
import matplotlib.pyplot as plt
im = Image.open('C:\\Users\\Username\\Downloads\\n38_e024_1arc_v3.tif')
im.show()
imarray = np.array(im)
```

```
rows,cols = imarray.shape
print("The array has: ",rows," rows and ",cols, " columns")
sea_level_rise = 50
for i in range(0,rows):
   for j in range(0,cols):
      if imarray[i][j]!=0:
         if imarray[i][j] <= sea_level_rise:
            imarray[i][j] = 9999
plt.imshow(imarray)
plt.colorbar()
plt.show()
```

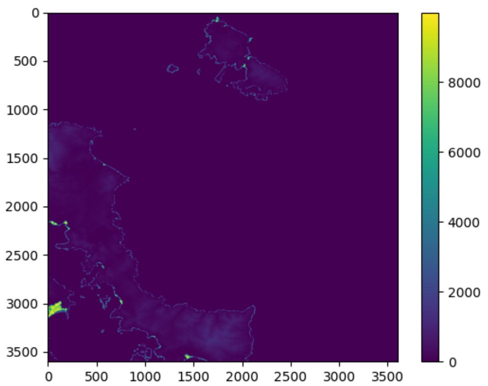
SEE THE RESULTS!!!



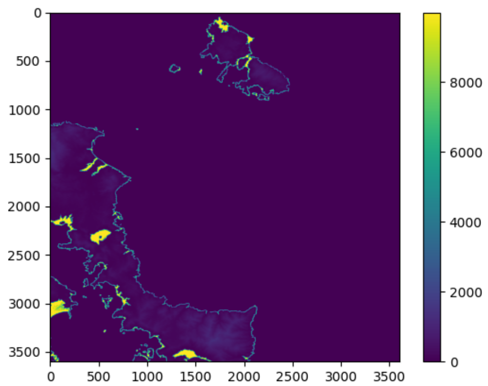
The initial Image you have downloaded from USGS!

Your processed results for 5m., 25m. and 50 m. of increase on the sea level!

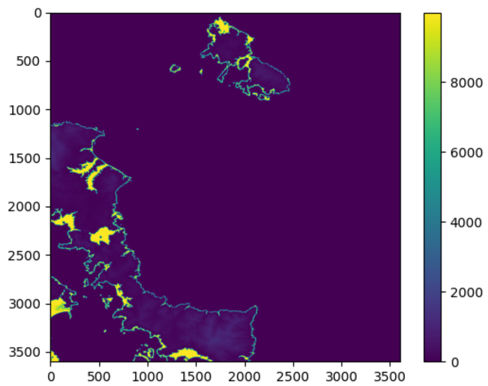
50 meters increase???? OK, it is impossible but don't forget about tsunamis and movies!



5 meters



25 meters



50 meters

Discussion

Explanation based on evidence

Encourage your students to provide correct explanations for the topic(s) investigated.

Describe ways and they can use to this end and give them directions how to discover them.

Why we don't see so many flooded areas on the 5 meters scenario?

First of all, we have to zoom in! Most importantly, we have to consider the data quality and resolution! Is it better to download an Image (DEM .tif file) of higher resolution? What actually resolution is?

Consider other explanations

The student to evaluate their own explanations in the light of alternative explanations, particularly those reflecting scientific understanding. Illustrate examples they can use and give them instructions how to locate them.

Ask students if their results seem to be correct?

For example, if we inspect the results we will see that some areas are flooded in spite of the fact that they are many meters (or kilometers) away from the coastline (they look like lakes!). **Why is that happening?**

How can we solve this problem?

Using cells' neighbours if conditional statements or using a second image with the distances of the mainland cells from the shoreline!

Reflection

Communicate explanation

Guide teachers to facilitate each student group to reflect on the previous experiences and to produce a report with its findings, presenting and justifying the proposed explanations to the other groups and the teacher.

Provide content and help the students to get familiarized and to become efficient in scientific writing.

A scientific poster is a visual communication tool summarizing students' work and encouraging conversation with colleagues. Ask from students to highlight the level of risk towards climate change and present message in a clear and logical way for mitigating sea level rise impact!

Guidelines:

https://younghs.com/2017/03/09/10-guidelines-for-an-awesome-poster/

Poster templates:

https://www.makesigns.com/SciPosters_Templates.aspx

https://www.posterpresentations.com/free-poster-templates.html

Follow-up activities and materials

Describe and direct the user to any follow-up activities or materials that can be used to wrap-up the hands-on activity.

These could include appropriate learning assessment and/or reminder materials (e.g., quizzes, games, other user-friendly tests), hints for further activities etc.

The ocean game:
https://www.latimes.com/projects/la-me-climate-change-ocean-game/
The sea is rising. Can you save your town?

Sustainable contact

Loukas Katikas (Email: lkatikas@ea.gr)

References (if any):

NASA Sea Level Change, Observation from Space: Understanding Sea Level

https://sealevel.nasa.gov/understanding-sea-level/global-sea-level/overview

Assessment (if any):