**Karst Hydrogeology and Geomorphology:**

**A virtual field experience using Google Earth, GIS, and TAK**

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**Summary**

Students will have the opportunity to select and virtually explore the hydrogeology and geomorphology of a karst landscape using Google Earth (or perhaps Google Mars or Google Moon if they so choose), lidar data-sourced DEM(s), geologic maps, GIS software, and topographic analysis software packages such that they gain an understanding of karst landscapes and their associated hazard risks, access to and analysis of internet-based remote sensing data, design of field strategy, and verbal and written communication of scientific information.

This activity incorporates and builds upon *Karst Hydrogeology: A virtual field introduction using Google Earth and GIS.* If you have already completed the introductory activity, use your results from that activity and continue onto this activity with step 3.f.

**Activity Description**

Karst aquifers supply drinking water to 25% of our world’s population. It is therefore important that we understand the drainage patterns, potential hazards to humans, and potential threats to water quality that are unique to karst.

Prior to beginning this activity, download and install the following software packages: Google Earth on web or desktop (<https://www.google.com/earth/versions/>); a GIS (QGIS is a free and open source option: <https://www.qgis.org/en/site/>); Topographic Analysis Kit (free, open source software package available at github: <https://github.com/amforte/Topographic-Analysis-Kit>)

1. Background. Review background information on karst and on the source of the digital elevation model (DEM) data used in this activity.

Background information on karst: <https://link.springer.com/article/10.1007/s10040-016-1519-3>, <https://kgs.uky.edu/kgsweb/olops/pub/kgs/ic04_12.pdf>,<https://en.wikipedia.org/wiki/Karst>, <http://www.igme.es/boletin/2016/127_1/BG_127-1_Art-9.pdf>.

Background on the Shuttle Radar Topography Mission (SRTM) to acquire the data used in the DEMs recommended in this activity:<https://www2.jpl.nasa.gov/srtm/>

1. Data acquisition.
	1. For an overview of karst aquifers on Earth, refer to the **World Karst Aquifer Map (WOKAM)**, available at <https://www.whymap.org/whymap/EN/Maps_Data/Wokam/wokam_node_en.html>. Use WOKAM to select an area of interest or browse Google Earth to search for karst landforms.
	2. As a base layer for GIS mapping of your karst area, load the WOKAM **shapefiles** to view the chosen area in the context of its broader karst region. WOKAM shapefiles can be found at <https://produktcenter.bgr.de/terraCatalog/OpenSearch.do?search=473d851c-4694-4050-a37f-ee421170eca8&type=/Query/OpenSearch.do> or in the attached zipped folder.
	3. Acquire topographic and geologic map information for your chosen karst landscape. For topography in the United States, Earth Explorer is a good source for **SRTM DEM files** (<https://earthexplorer.usgs.gov/>). For sites outside of the US you can still find DEM data, but may need to do additional internet searching to obtain it.
	4. Acquire geologic map data. Inside of the US, the **National Geologic Map Database** project should have what you need (<https://ngmdb.usgs.gov/ngmdb/ngmdb_home.html>). Outside of the US, it will vary country by country and more internet searching will be needed. Geologic information may be in a file format ready for import to a GIS or as a scanned image or pdf file.
2. Data processing.
	1. The DEM file then needs to be uploaded to a **GIS**. Check the properties of your DEM raster layer to see what coordinate reference system (CRS) it loaded in. For many DEMs, you will need to find the appropriate CRS and **reproject** the raster. For a review of the Universal Transverse Mercator (UTM) System, here is a link to the USGS fact sheet (<https://pubs.usgs.gov/fs/2001/0077/report.pdf>) and a world map of UTM zones (<https://maptools.com/tutorials/grid_zone_details>). Another option is to use an interactive online map (<https://mangomap.com/robertyoung/maps/69585/what-utm-zone-am-i-in->) to help determine the coordinate system for your location. The reproject task is performed by selecting the layer for the DEM raster data. Then click on the “raster” drop down menu. Go to “projections,” and select “Warp (reproject)...” Then select a complete path for output and give a name to the output file for the reprojected map data.
	2. After the project is in the correct CRS, you can then choose a color scheme (right click on the layer > “properties” > “style” > “render type” > “singleband pseudocolor” > “generate a new color map” > select the desired color band > “classify”) and make a **Hillshade** layer to better visualize the topography. To generate a Hillshade layer, again use the “raster” menu. Go to “Terrain analysis” > “Hillshade…”
		1. *Questions: What karst aquifer region did you select? What UTM Zone is this field site in? What colorband worked best for your visualization of the topography? What does the Hillshade function do? How is it helpful?*
	3. The next layer to upload to GIS is geologic map information.
		1. If the geologic map data is in a proper file format for GIS, it will most likely need to be reprojected to the same CRS as the elevation data (see step 3a).
		2. If the geologic map data is a scanned image, you have two options:
			1. Import the image to the GIS and Georeference it to align it with the map. The procedure for georeferencing analog images is covered in this webinar (<https://www.youtube.com/watch?v=WbMdNvQcCOs>); or
			2. Work side-by-side comparing the information from your geologic map with that on the GIS. This is less precise, but if you are careful you can make it work.
	4. To better understand the drainage patterns of this landscape, extract a set of topographic contour lines. Again use the “raster” menu. Go to “Extraction” > “Contour…” A good interval to start with a 20. If the contour lines end up looking too crowded or too spread out, you can make new contour layers with different intervals.
	5. Now that you have detailed topographic maps with contour intervals, you may want to revisit the rule of V’s for determining flow paths over land surfaces (<http://uncivilengineer.net/2017/07/14/watercourses-and-ridges-on-topographic-maps-why-the-vs/>).

If you have access to a printer, you can print out a paper copy of the map you built and draw the drainage patterns in with a pencil. There are two digital options for drawing in the water flow paths. For the first, you can export the image of their map in QGIS as png format. To do this go to the “Project” menu and select “Save as Image…” Then use a photo editor to draw flow paths on the map. If you have more GIS experience you may want to work directly in the GIS and make new vector layers to create surface flow paths.

* + 1. *Questions: Describe the flow paths you drew on your map. What was your reasoning for electing to draw the flow paths you did? What challenges or obstacles did you encounter while determining the routes water would take? How did you overcome the challenges/obstacles to determine the routes?*
	1. To determine flow paths more objectively, use a software designed with flow-routing algorithms. Here we will use Topographic Analysis Kit (TAK). You first need to give the software the output files name prefix and select the output directory. Then load the Reprojected DEM (tif file) into TAK. If it gives you an error regarding whole numbers, don’t worry, your file has still loaded correctly. Check the box labeled “Resample” and then click “Run MakeStreams.” This is as far as this activity goes as far with using TAK, but it is a powerful tool for doing geomorphological analysis. If you are curious, I recommend you check out the documentation at Github and explore it further on your own.
	2. From the TAK output file folder, drag and drop your new shapefile into the GIS. If you do not see your streams overlaying the topography, right click on your streams vector layer name. Go to “Properties” > “General” > “Coordinate Reference System.” Select the appropriate CRS. Click on “Update extents”, “Apply”, “OK.”
1. Data analysis.
	1. Compare the stream network predicted by TAK with the one you drew in step 11.  *What similarities or differences do you see between the two networks? Which one do you think is more accurate? Why?*
	2. Using your observations of the geology, the topography, and the hydrology, construct a geologic/geomorphic history of your study area. *What was the sequence of events at this site—consider in particular depositional, tectonic, and erosional events? How did the stream network (or lack thereof) evolve?*
2. Hypothesis formulation.
	1. Some events in your above history will be more hypothetical than others. Please state which events need additional testing to be able to defend them.
	2. What environmental or natural-disaster hazards do you think might be issues in this landscape? Why do you think this? Write these ideas in the form of additional hypotheses about this landscape.
3. Experimental design.
	1. What data would you need to collect to support or refute your hypotheses? Please speculate as to the kinds of results that may be obtained for different types of data and what implications those might have for each hypothesis.
	2. What field, laboratory, or numerical techniques would be required to obtain the data you need? Please be specific as if you were planning for field work, lab work, or numerical modeling.

Sharing science:

1. After completing the exercise, as an individual or as part of a small group, present your findings to the whole class.

2. Write a formally structured report (Title, author’s name, date, abstract, introduction, methods, results, discussion, conclusion). Within the report or as a separate document, reflect on your experience with this activity and assess your level of understanding before and after the activity of a.) Google Earth, b.) GIS, c.) UTM CRS, d.) topographic map interpretation, e.) TAK, e.) karst hydrogeology, f.) geologic history construction, g.) hypothesis formulation, and h.) scientific experiment design.