###### Lab 13—Geographical Information Systems (GIS)

**Activity A: Karst hydrogeology: a virtual ﬁeld experience using © Google Earth, GIS, and TAK (Bosch, 2021)**

A1 Summary

Students will have the opportunity to select and virtually explore the hydrogeology and geomorphology of a karst land- scape using © Google Earth, lidar-data-sourced DEM(s), and GIS software (QGIS) such that they gain an understanding of karst landscapes and their associated hazards, can access and analyze internet-based remote sensing data, and employ verbal and written communication of scientiﬁc information.

A2 Activity description

About 16.5 % of the world’s population lives on karst (Goldscheider et al., 2020). It is therefore important that we under- stand 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/](http://www.google.com/earth/versions/%3B); last access: 13 June 2021) and a GIS (QGIS is a free and open-source option; [https://www.qgis.org/en/site/](http://www.qgis.org/en/site/%3B); last access: 13 June 2021).

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 is available from [https: //link.springer.com/article/10.1007/](https://link.springer.com/article/10.1007/s10040-016-1519-3)

[s10040-016-1519-3](https://link.springer.com/article/10.1007/s10040-016-1519-3) [(last access: 13 June 2021), https://kgs.uky.edu/kgsweb/](https://kgs.uky.edu/kgsweb/olops/pub/kgs/ic04_12.pdf)

[olops/pub/kgs/ic04\_12.pdf (last access: 13 June 2021),](https://kgs.uky.edu/kgsweb/olops/pub/kgs/ic04_12.pdf) https://en.wikipedia.org/wiki/Karst (last access: [13 June 2021), and http://www.igme.es/boletin/2016/ 127\_1/BG\_127-1\_Art-9.pdf (last access: 13 June 2021).](http://www.igme.es/boletin/2016/127_1/BG_127-1_Art-9.pdf)

Background on speciﬁc karst areas you can explore during this activity can be found at the following URLs:

* [Central Kentucky Karst, USA, at https://www. usgs.gov/science-support/osqi/yes/national-parks/ mammoth-cave-national-park (last access:](https://www.usgs.gov/science-support/osqi/yes/national-parks/mammoth-cave-national-park) [13 June 2021), http://www.igme.es/boletin/2016/ 127\_1/BG\_127-1\_Art-9.pdf (last access: 13 June 2021)](http://www.igme.es/boletin/2016/127_1/BG_127-1_Art-9.pdf).
* El Sótano de las Golondrinas, Mexico, at <http://www.mexicancaves.org/bul/bul2.pdf> (last access: 13 June 2021)
* [Caverna de Santana, Brazil, at https://en.wikipedia.org/ wiki/Caverna\_Santana (last access: 13 June 2021)](https://en.wikipedia.org/wiki/Caverna_Santana)
* [Sof Omar Cave, Ethiopia, at https://en.wikipedia.org/ wiki/Sof\_Omar\_Caves (last access: 13 June 2021)](https://en.wikipedia.org/wiki/Sof_Omar_Caves)
* Postojna Cave, Slovenia, at <https://www.postojnska-jama.eu/en/> (last access: 13 June 2021), [https://www.slovenia.info/en/stories/karst](http://www.slovenia.info/en/stories/karst) (last access: 13 June 2021), <https://izrk.zrc-sazu.si/en/predstavitev> (last access: 13 June 2021)
* [Tenglong Cave, China, at https://en.wikipedia.org/wiki/ Tenglong\_Cave (last access: 13 June 2021)](https://en.wikipedia.org/wiki/Tenglong_Cave)
* [Waitomo Cave, New Zealand, at https://www. newzealand.com/us/waitomo-caves/ (last access:](https://www.newzealand.com/us/waitomo-caves/) [13 June 2021), https://en.wikipedia.org/wiki/Waitomo\_ Glowworm\_Caves (last access: 13 June 2021).](https://en.wikipedia.org/wiki/Waitomo_%20Glowworm_Caves)

Background on the Shuttle Radar Topography Mission (SRTM) to acquire the data used in the DEMs recommended in this activity can be found at <https://www2.jpl.nasa.gov/srtm/> (last access: 13 June 2021)

For an overview of karst aquifers on Earth, refer to the World Karst Aquifer Map (WOKAM), avail- [able at https://www.whymap.org/whymap/EN/Maps\_Data/ Wokam/wokam\_node\_en.html (last access: 13 June 2021).](https://www.whymap.org/whymap/EN/Maps_Data/Wokam/wokam_node_en.html) Use the WOKAM to select an area of interest, browse © Google Earth to search for karst landforms, or use one of the following links to go directly to a karst area:

* Google Earth – Caverna de Santana, Brazil, available at [https://earth.google.com/web/search/Caverna+ de+Santana (last access: 13 June 2021).](%20https://earth.google.com/web/search/Caverna+%20de+Santana%20%20(last%20access:%2013%20June%202021).)
* Google Earth – Central Kentucky Karst, USA, avail[able at https://earth.google.com/web/search/Smiths+ Grove (last access: 13 June 2021).](https://earth.google.com/web/search/Smiths%2B%20Grove)
* Google Earth – El Sótano de las Golondrinas, Mexico, available at [https://earth.google.com/web/search/ Sotano+Golondrinas](https://earth.google.com/web/search/%20Sotano+Golondrinas) (last access: 13 June 2021).
* Google Earth – Postojna Cave, Slovenia, available at [https://earth.google.com/web/search/Postojna+Cave](https://earth.google.com/web/search/Postojna+Cave%20) (last access: 13 June 2021).
* Google Earth – Sof Omar Cave, Ethiopia, available at <https://earth.google.com/web/search/Holqa> (last access: 13 June 2021).
* Google Earth – Tenglong Cave, China, available at <https://earth.google.com/web/search/Tenglong+Cave> (last access: 13 June 2021).
* Google Earth – Waitomo Cave, New Zealand, available at [https://earth.google.com/web/search/Waitomo+Cave](https://earth.google.com/web/search/Waitomo+Cave%20) (last access: 13 June 2021).

1. Data acquisition – acquire topographic information for your chosen karst landscape. For locations in the United States, EarthExplorer is a good source for SRTM

DEM ﬁles (<https://earthexplorer.usgs.gov/>, last access: 13 June 2021). For sites outside of the USA, you can still ﬁnd DEM data but may need to do additional inter net searching to obtain it.

1. 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 CRS it is 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, consult the USGS fact sheet (<https://pubs.usgs.gov/fs/2001/0077/report.pdf>; last access: 13 June 2021) and a world [map of UTM zones (https://maptools.com/tutorials/ grid\_zone\_details; last access: 13 June 2021).](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-; last access: 13 June 2021)](https://mangomap.com/robertyoung/maps/%2069585/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” dropdown menu. Go to “Projections” and select “Warp (reproject). . . ” Select a complete path for the 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, use the “raster” menu again. Go to “Terrain analysis” *>* “Hillshade. . . ”.
      1. Questions: what karst aquifer region did you select? What UTM zone is this ﬁeld site in? What color band worked best for your visualization of the topography? What does the Hillshade function do? How is it helpful?
   3. To better understand the drainage patterns of this landscape, extract a set of topographic contour lines. Open the “raster” menu. Go to “Extraction” *>* “Contour. . . ” A good interval to start with is 20. If the contour lines end up looking too crowded or too spread out, you can make new con- tour layers with different intervals.
   4. 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 (https://d32ogoqmya1dw8.cloudfront.net/ﬁles/teachearth/activities/watercourses\_ridges\_topographic\_maps\_why\_vs.pdf](https://d32ogoqmya1dw8.cloudfront.net/%EF%AC%81les/teachearth/activities/watercourses_ridges_topographic_maps_why_vs.pdf); last access: 13 June 2021). 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 in a .png format. To do this, go to the “Project” menu and select “Save as Image. .. ”, and 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 challenges or obstacles did you encounter while determining the routes water would take?

Sharing science

* Write a formally structured report (including the title, author’s name, date, introduction, methods, results, discussion, and 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, and (e) karst hydrogeology.

**Activity B: Karst hydrogeology: a virtual ﬁeld experience, alternate workflow using Google Earth, and the National Geologic Map Database project of the USGS**

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# B1 Summary

Students will have the opportunity to select and virtually explore the hydrogeology and geomorphology of a karst landscape using © Google Earth and the National Geologic Map Database project of the USGS such that they gain an understanding of karst landscapes and their associated hazards, can access and analyze internet-based remote sensing data, and employ written communication of scientiﬁc information.

# B2 Activity description

About 16.5 % of the world’s population lives on karst (Goldscheider et al., 2020). 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.

## 1. Background – review background information on karst

Background information on karst is available from <https://link.springer.com/article/10.1007/s10040-016-1519-3> (last access: 13 June 2021), <https://kgs.uky.edu/kgsweb/olops/pub/kgs/ic04_12.pdf> (last access: 13 June 2021), <https://en.wikipedia.org/wiki/Karst> (last access: 13 June 2021), and <http://www.igme.es/boletin/2016/127_1/BG_127-1_Art-9.pdf> (last access: 13 June 2021).

Background on speciﬁc karst areas you can explore during this activity can be found at the following URLs:

– Central Kentucky Karst, USA, at <https://www.usgs.gov/science-support/osqi/yes/national-parks/mammoth-cave-national-park> (last access: 13 June 2021), <http://www.igme.es/boletin/2016/127_1/BG_127-1_Art-9.pdf> (last access: 13 June 2021)

– El Sótano de las Golondrinas, Mexico, at <http://www.mexicancaves.org/bul/bul2.pdf> (last access: 13 June 2021)

– Caverna de Santana, Brazil, at <https://en.wikipedia.org/wiki/Caverna_Santana> (last access: 13 June 2021)

– Sof Omar Cave, Ethiopia, at <https://en.wikipedia.org/wiki/Sof_Omar_Caves> (last access: 13 June 2021)

– Postojna Cave, Slovenia, at <https://www.postojnska-jama.eu/en/> (last access: 13 June 2021), <https://www.slovenia.info/en/stories/karst> (last access: 13 June 2021), <https://izrk.zrc-sazu.si/en/predstavitev> (last access: 13 June 2021)

– Tenglong Cave, China, at <https://en.wikipedia.org/wiki/Tenglong_Cave> (last access: 13 June 2021)

– Waitomo Cave, New Zealand, at <https://www.newzealand.com/us/waitomo-caves/> (last access: 13 June 2021), <https://en.wikipedia.org/wiki/Waitomo_Glowworm_Caves> (last access: 13 June 2021).

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> (last access: 13 June 2021). Use the WOKAM to select an area of interest, browse © Google Earth to search for karst landforms, or use one of the following links to go directly to a karst area:

– Google Earth – Caverna de Santana, Brazil, available at <https://earth.google.com/web/search/Caverna+de+Santana> (last access: 13 June 2021).

– Google Earth – Central Kentucky Karst, USA, available at <https://earth.google.com/web/search/Smiths+Grove> (last access: 13 June 2021).

– Google Earth – El Sótano de las Golondrinas, Mexico, available at <https://earth.google.com/web/search/Sotano+Golondrinas> (last access: 13 June 2021).

– Google Earth – Postojna Cave, Slovenia, available at <https://earth.google.com/web/search/Postojna+Cave> (last access: 13 June 2021).

– Google Earth – Sof Omar Cave, Ethiopia, available at <https://earth.google.com/web/search/Holqa> (last access: 13 June 2021).

– Google Earth – Tenglong Cave, China, available at <https://earth.google.com/web/search/Tenglong+Cave> (last access: 13 June 2021).

– Google Earth – Waitomo Cave, New Zealand, available at <https://earth.google.com/web/search/Waitomo+Cave> (last access: 13 June 2021).

## 2. Data acquisition – acquire topographic information for your chosen karst landscape.

To access a map, go to the [topoView](https://ngmdb.usgs.gov/topoview/viewer/#4/39.98/-100.06) interface (Links to an external site: <https://ngmdb.usgs.gov/topoview/viewer/#4/39.98/-100.06>) for the National Geologic Map Database project of the USGS. Click on the map of the United States in an area that interests you. A list of available maps should appear on the right-hand side of the screen. Above the list, click on "date" to display the newest maps at the top. Select and download a recent map that you would like to use for this lab.

Additionally, the USGS has created a great tutorial video (with embedded closed-captioning) for how to access topographical maps from a mobile device (<https://www.usgs.gov/media/videos/using-us-topo-and-historic-topo-maps-your-mobile-device>; last access: 13 June 2021).

## 3. Data analysis—where does the water flow?

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 (see linked pdf). If you have access to a printer, you can print out a paper copy of the map and draw the drainage patterns in with a pencil. If you prefer, you may use an image of the map in a photo editor (or other tool of preference) to digitally draw ﬂow paths on the map.

4. Sharing your science

Write a formally structured report (including the title, author’s name, date, introduction, methods, results, discussion, and conclusion).

Be sure to address the following questions in your report:

* What karst aquifer region did you select?
* Where is this region located?
* What is the climate of this region?
* Why is this location a significant karst region?
* Who lives in this region?
* Describe the ﬂow paths you drew on your map.
* What challenges or obstacles did you encounter while determining the routes water would take?
* Reﬂect on your experience with this activity and assess your level of understanding before and after the activity of (a) © Google Earth, (b) topographic map interpretation, and (c) karst hydrogeology.

***NOTES***