ESRI
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Analyzing Change over Space and Time

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THE SCIENCE OF WHERE™

Workshop Goal

The goal of this workshop is to provide educators at multiple levels (primary, secondary, community and technical college, university, and lifelong learning settings (museums, libraries, field camps) and multiple disciplines (geography, GIS, environmental studies, earth and biological sciences, sociology, and business) the confidence and skills necessary to teach about natural and human-caused changes on the Earth. These changes can be observed and analyzed from the local to the global scale and across multiple themes such as natural hazards, health, population, imagery. GIS will be the primary tool used to study these changes, through web mapping applications and the ArcGIS Online platform.

Change over space and time is an important topic for the 21st Century on our dynamic Earth. Changes from natural and human causes grow increasingly serious, are complex, and increasingly affect our everyday lives and the life of our communities. Because all of these changes occur at specific locations and often exhibit geographic patterns, relationships, and trends, GIS is an incredibly useful tool in which to analyze those changes. Teaching about Earth changes through GIS can foster skills in critical thinking, spatial thinking, working with data, communication, and can help students understand what is changing, why it is changing, and how they might be able to get involved in being a "change agent" to help their community and our world change for the better—to become a healthier, happier, more sustainable planet.

Workshop Outline

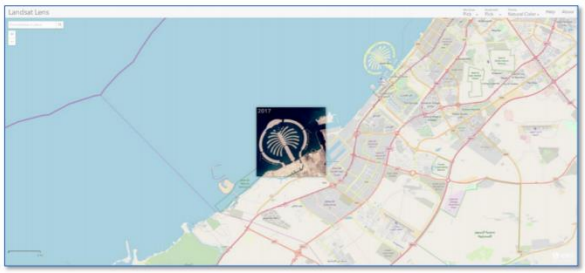
Many tools and data sets exist within the Esri ArcGIS platform to analyze change over space and time. This workshop will focus on the following 8 data sets and tools, with the belief that if you work through these examples, you will be able to examine other themes at different scales and using the same tools as well as additional tools.

1. Regional change analysis using Landsat imagery and maps in the Landsat Lens.
2. Regional change analysis using Sentinel-2 imagery in ArcGIS Online.
3. Regional change analysis using in-migration and out-migration by state and county.
4. Local change analysis using the Wayback imagery in ArcGIS Online.
5. Local change analysis using historical USGS topographic maps using a web mapping application and in ArcGIS Online.
6. Global Human Development Index change analysis using ArcGIS Online.
7. Regional change analysis using the story maps swipe tool.
8. Global health analysis using time animations.

1. Regional change analysis using Landsat imagery and maps in the Landsat Lens.

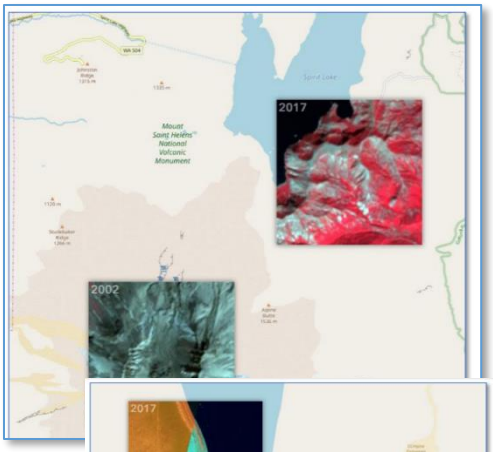
The Esri Landsat lens is based on Landsat data, a series of satellites that have been operated by NASA and the US Geological Survey since 1972. As the name implies, these satellites' mission is to record images not of outer space but of the land—the Earth's surface. They do so in a series of specific bands in the electromagnetic spectrum, including visible and infrared. In an infrared image, healthy vegetation appears red. The infrared imagery also allows for changes to be detected easily on the landscape. As one preface to using the next tool – the Landsat Lens -- consider spending some time discussing the electromagnetic spectrum with this resource from NASA (https://imagine.gsfc.nasa.gov/science/toolbox/emspectrum1.html)

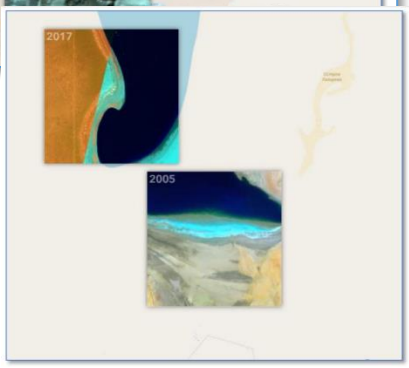
Access the Esri Landsat Lens: https://maps.esri.com/rc/landsat2/index.html.
The initial view will look similar to the graphic shown below, with a satellite image "lens"—a small portion of a satellite image, tools to the upper right of the map, and a find places and zoom tools to the upper left of the map.



1.1. Investigating Abu Dhabi. *The Landsat Lens tool can be used to display imagery in different spectral bands, dates, and locations around the world. Start in Abu Dhabi by selecting the small satellite image that appears and moving it along the coast so you can examine the "palm frond" developments that extend out into the water. Pan and examine the urban area of Abu Dhabi and note the sand covering nearly all of the surrounding rural area. When working with Landsat Lens, be patient as the images load and changes scale as you zoom and pan. Next, use Windows Pick to select a 2002 image of the area. You will now see 2 images, one from 2002, and the other from 2017, that you can use to explore the development into the water and the urban growth of the city into the surrounding desert.*

1.2. Investigate Mt St Helens. Use Bookmark Pick to select Mount Saint Helens. Use Windows Pick > Close All > then select 2002 and 2017. Change the Theme to Color Infrared so that healthy vegetation appears in bright red. What type of landform is Mt St Helens? What are the clues? To what cardinal direction did the modern-day blast occur? Questions such as this help ensure that your students are thinking spatially. How would you characterize vegetation re-growth on the slopes of Mt St Helens between 2002 and 2017?





1.3. Investigating the Aral Sea. Use Bookmark Pick > Aral Sea > Windows Pick > Close All > Choose 2005 and 2017 dates > Choose Agriculture Theme. The Aral Sea was once the 5th largest lake in the world. Describe 2 changes in the Aral Sea that have occurred. Consider the geographic questions of what is there, why is it there, and why should we care: Why is the Aral Sea shrinking? Why should we care? Global attention on the Aral Sea over the past 20 years has increased. Change dates to 2015 vs 2017. According to this data set, with this imagery and this tool, would you say that the global attention has slowed the rate of the Aral Sea's disappearance? The phrase, "according to this data set" is key when using GIS. All maps are imperfect—and some are very useful. Your analysis depends on the data you are using: Repeating this phrase encourages students to be critical of the data. Access 1-2 additional resources and compare them to whatever sources you are analyzing using GIS.

Pan across the Aral Sea region. Might the fact that it lies in 2 countries impact effective management? Ask students to name one positive and one negative impact from human alteration of the Aral Sea. The Aral Sea, like so many other issues in geography, is complex: Decisions were made on the landscape, with positive and negative impacts.

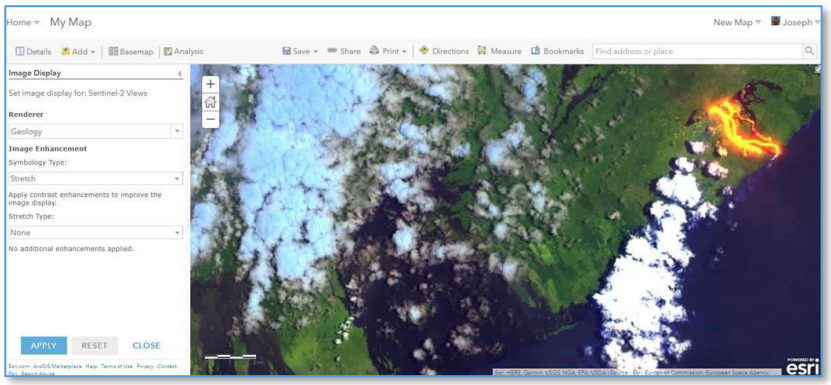
Use this tool to examine Lake Chad, Las Vegas Nevada USA, Gold Coast Australia development, China's Three Gorges Dam, and elsewhere. As with GIS tools, the advantage to the Landsat Lens is that you can investigate a wide variety of issues, themes, and places.

2. Regional change analysis using Sentinel-2 imagery and maps in ArcGIS Online.

The new Sentinel-2 imagery brings Copernicus, the world's largest single Earth observation program from the European Commission and the European Space Agency to ArcGIS Online. Esri makes the multi-spectral data quickly accessible using ArcGIS Image Server and publishes an image service through the ArcGIS Living Atlas of the World (Living Atlas). This service, hosted on the Amazon Web Services Infrastructure, includes all Sentinel-2 imagery back in time, enabling change to be studied, updated every 5-7 days. Image

analysis can be run directly on the service to create indexes displaying properties such as vegetation health or soil moisture as well as quantifying the changes over time.

Go to www.arcgis.com > sign in to your organizational account. Click on Map > Add Data > From ArcGIS Online, Add Sentinel-2 views by Esri > Zoom to Kilauea settlement lots > Image Display > Renderer > Geology with DRA (Dynamic Range Adjustment) which makes use of the SWIR (ShortWave Infrared) bands 1 and 2 – along with blue in the third band. Then > Filter the date to 05/23/2018. Pan to the lava shown in yellow in this band. Measure the length of the new lava from that day and make use of the Imagery with Labels or Open Street Map basemaps to determine the homes that are affected. Compare which of the homes shown in the UAV images in the this story map (https://esrimedia.maps.arcgis.com/apps/MapTour/index.html?appid=f959ab3b665148d19f460e0f8e418288) are affected. Discuss differences in black (visible) in UAV image vs yellow (Sentinel-2, SWIR). For more information, see Joseph's video on the Hangar Esri UAV story map and my video on the Sentinel-2 data. A video showing blue flame from methane in this exact rift zone makes for an excellent supplement: Hawaii volcano: blue flames burn in streets as methane escapes - YouTube . For more, see Joseph Kerski's essay in GeoNet: https://community.esri.com/community/education/blog/2018/06/29/using-two-new-tools-to-analyze-the-eruptions-in-kilauea Consider: Date filters to compare Kilauea eruption at other times, and other data you could use date filters to analyze change over time.

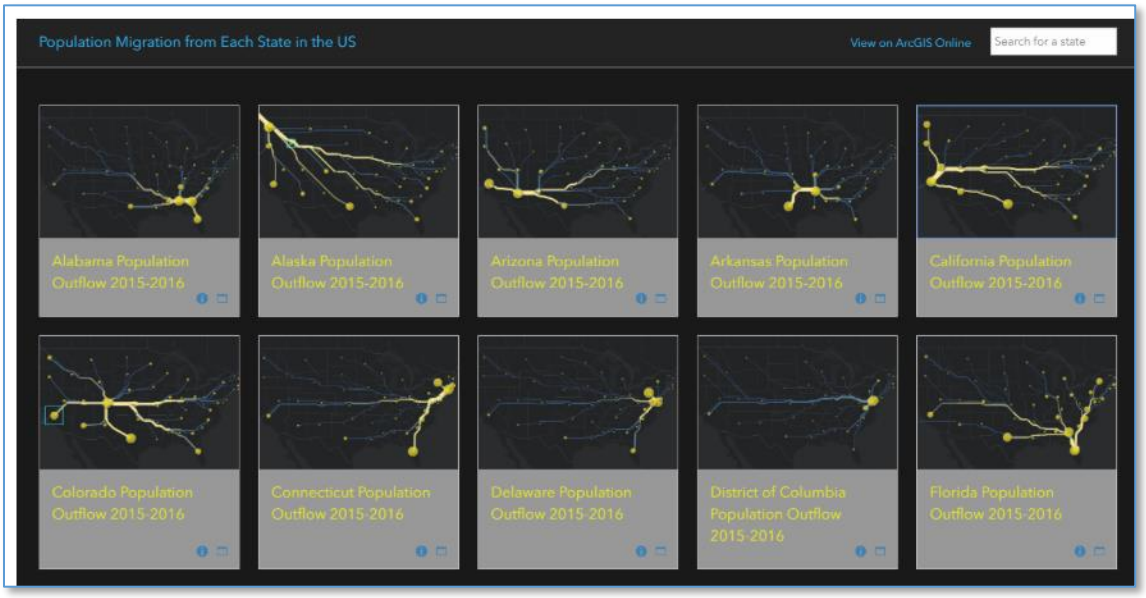


3. Regional change analysis using in-migration and out-migration by state and county.

When Americans move from one state to another, their change of residence is recorded by the IRS when they file taxes in a new state. The data was processed via the Distributive Flow Lines tool in ArcGIS Pro (as described here) for each state to visualize the quantity of population migration in both the inbound and outbound directions. Seeing population as a flow line may help reinforce in your instruction (in geography, sociology, AP Human Geography, environmental studies, etc.) that population in the USA is not stagnant.

State to state **outflow** migration. The flow lines are not literal paths for people, but rather a directional flow. The pop-up for each state shows how population migration has changed between 2011-2016 for each state. https://www.arcgis.com/apps/MinimalGallery/index.html?appid=586413c94b3e4a3dab22636206b718c5# Why do Texans tend to move to other warm states? Why do people who move out of North Dakota tend to move to Minnesota?

State to state **inflow** migration. This shows how population is moving toward each state from all other states. Note how many of the inflow patterns for a state are similar to a state's outflow migration and how many are different: https://www.arcgis.com/apps/MinimalGallery/index.html?appid=f26ab17257e34acd9e23c6a5fbdad3f5#



20 county level incoming and outgoing migration maps are listed as well:

https://www.esri.com/arcgis-blog/products/arcgis-online/mapping/visualizing-population-migration-by-where-people-filed-their-taxes/

Another related and wonderful tool is the US Census Bureau flow mapper: https://flowsmapper.geo.census.gov/map.html and the Esri Coolmap international migration flows: https://coolmaps.esri.com/#9

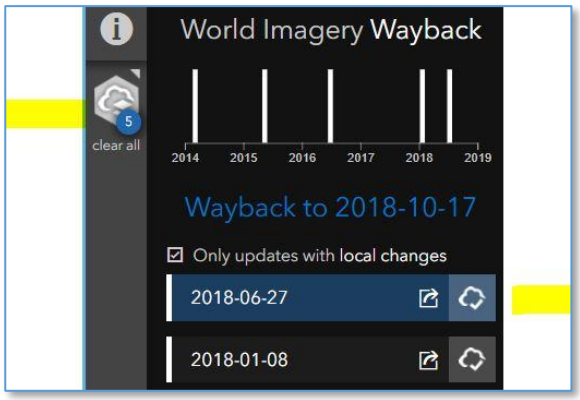
4. Local change analysis using the Wayback imagery in ArcGIS Online.

During 2018, 81 different dates of historical imagery for the past 5 years for the entire planet were placed inside ArcGIS via the World Imagery Wayback service. For more information, see this essay. This imagery is accessible in ArcGIS , ArcMap, and ArcGIS Pro, and with it, coastal erosion in England, deforestation in Indonesia, urban sprawl, mine land reclamation, changes in water levels or glacial extent, agriculture in Saudi Arabia, and other Earth changes can be examined.

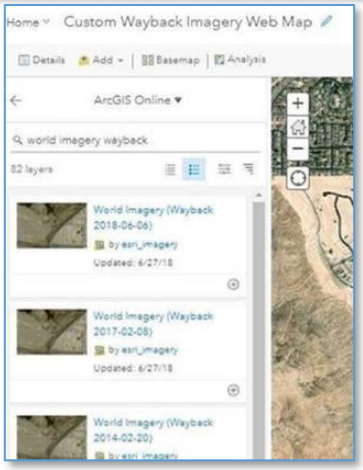
Start with the World Imagery Wayback app. This app, available simply through a web browser – https://livingatlas.arcgis.com/wayback/. Browse to a location of interest to you. The dates shown on the left side of the app represent the update of the Esri World Imagery service,

fed by multiple sources, private and public, from local and global sources and not necessarily the date where this specific location was flown.

Sample Wayback imagery for 30 July 2014 (left) and 4 years later, 27 June 2018 (right) in Colorado USA.

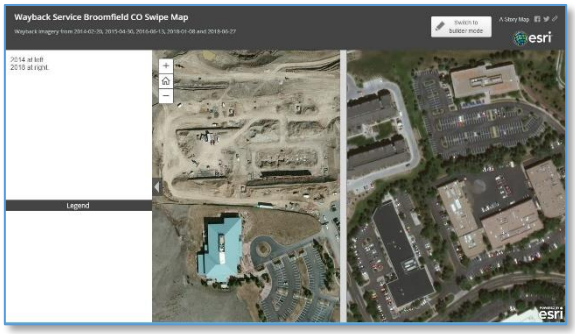


How can the use of the Wayback image service be extended for education and research? One way to do so is by creating a web **map** in ArcGIS from the Wayback app. Doing this will thus enable the user to use the functions in ArcGIS with the imagery, such as adding additional map layers, saving and sharing, measurement and analysis, and creating web mapping applications. To do this: Go to the app: https://livingatlas.arcgis.com/wayback/ > Navigate to an area of interest > Check on Only updates with local changes > Click the cloud icon to "add to cart" > Click the clear all icon top left to create a web map (shown at top left) > Save the web map.



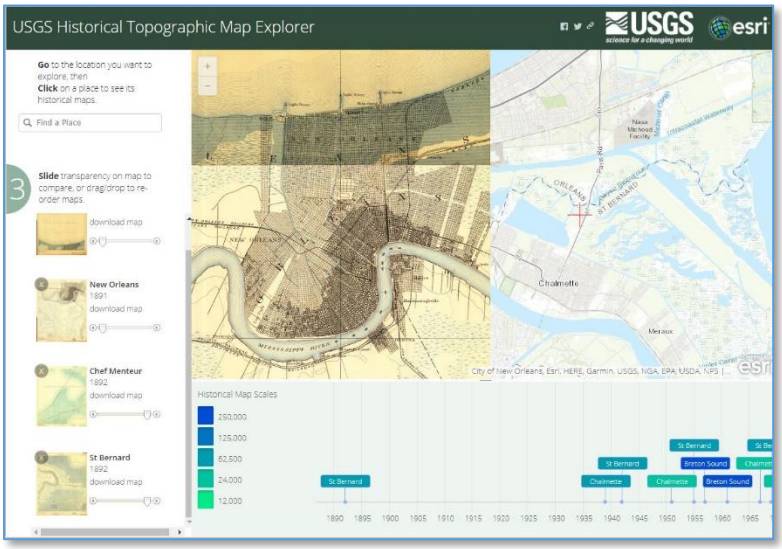
Open your web map. Now you can add layers to your map, including additional Wayback layers. To add the historical wayback imagery to this existing web map, you cannot add it from a URL as a WMTS layer, but you **can** use **ADD DATA** and search in ArcGIS (not Living Atlas), as shown, on world imagery wayback. The default sort order is relevance, but you can change it to sort by title or by oldest/newest. See results with 3 historical layers, along with the current image as a basemap.

Another way to dig deeper into change-over-space-and-time analysis with the Wayback image service is to create a swipe map, shown here along with a URL of a sample swipe map. You could also make a 3D scene for a historical perspective on the landscape, or perform analytics on the images in ArcGIS Pro (see my colleague's blog post here about bringing the data into Pro), and in other ways.

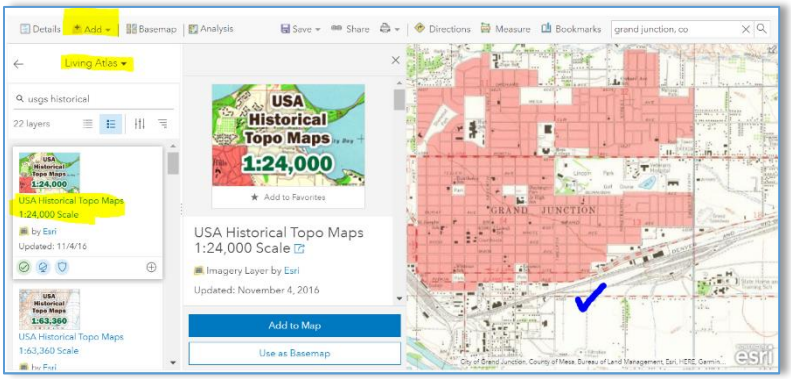


5. Local change analysis using historical USGS topographic maps using a web mapping application and in ArcGIS Online.

Physical and human-induced land-use and land-cover changes can be examined at a variety of scales using tens of thousands of USGS maps stretching back 100 years with the USGS Esri Historical Topographic Map Explorer: http://historicalmaps.arcgis.com/usgs/. Enter a US-based location, click on the map, and choose from the historical maps covering that area, comparing them to the present-day topographic basemap. Each map's transparency can be adjusted, allowing changes to be investigated. In New Orleans, the construction of levees, the Lake Pontchartrain Causeway, and draining of wetlands can be seen, along with below-sea-level contour lines that allow the physical setting of the city to be studied. The maps can also be downloaded in several formats including GeoTIFF from https://ngmdb.usgs.gov/topoview/viewer/



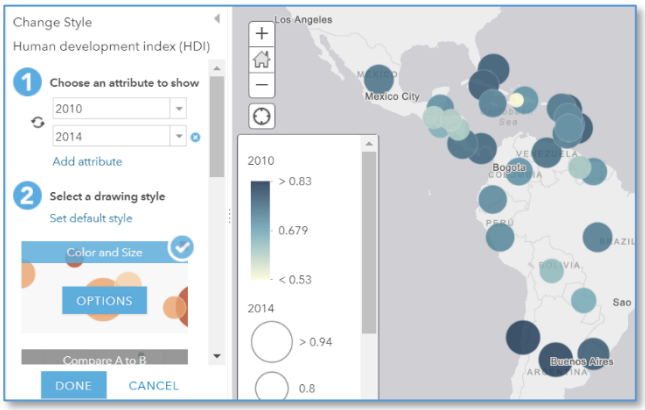
The maps can also be accessed in ArcGIS Online via the Add Data tool via the Living Atlas, and filtered on “Date on Map” as shown here for 1:24000 scale for a city in 1962.

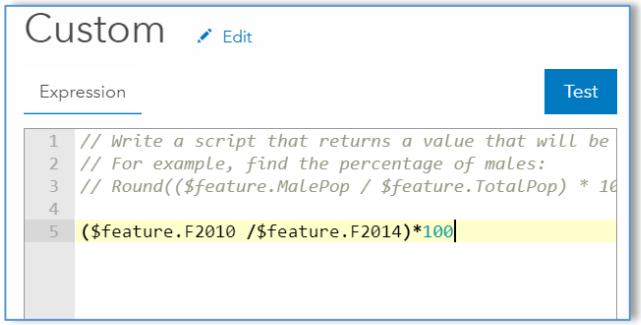


Supplementing the topographic map viewer with historical ground photographs can be used to analyze changes in land use, land cover, transportation, styles of clothing, things that society values, and more. Photos tied to maps include SepiaTown and Historypin. Some historical street images are embedded in Google maps via the Street View slider bar.

6. Global Human Development Index change analysis using ArcGIS Online.

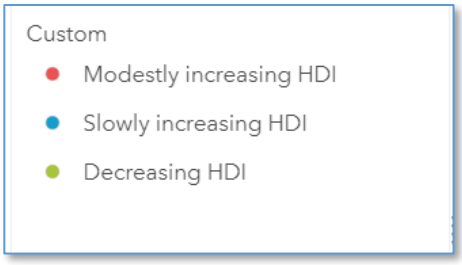
ArcGIS Online can be effectively used for change over space and time. Let’s focus on creating and using Arcade expressions to do so, using the Human Development Index (HDI) for world countries. Open the map: http://arcg.is/zeGLm or http://www.arcgis.com/home/webmap/viewer.html?webmap=2e332c3ba0ef44709b93df33613c5801. Sign in to your ArcGIS Online organizational account. First, use Change Style and add 2010 and 2014 to make a bi-variate map of both 2010 and 2014 HDI, as shown. Examine results. Next, use Change Style > new expression, and divide 2010 HDI by 2014 HDI and multiply by 100. The countries that have decreased in HDI will have a value over 100, so classify your data manually, adjusting the slider bar so that those over 100 will be in their own category. Which countries have (unfortunately) experienced an HDI decrease? What are a few reasons for the decrease?





To better distinguish countries where the HDI has been decreasing or only

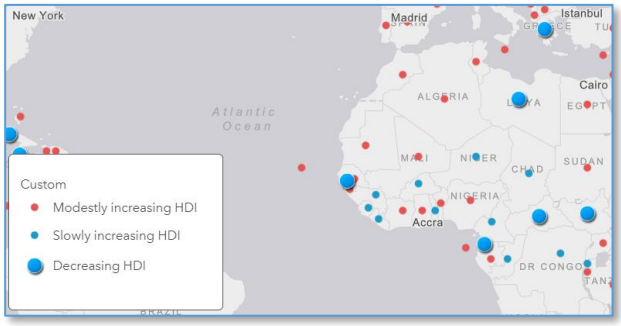
slowly increasing, use a custom Arcade expression so that the classes can be symbolized in a more distinguishable way:




```
var HDI = ($feature.F2010 /$feature.F2014)*100

when (HDI >= 100, "Decreasing HDI",
HDI < 95 && HDI >= 90, "Slowly increasing HDI",
"Modestly increasing HDI")
```

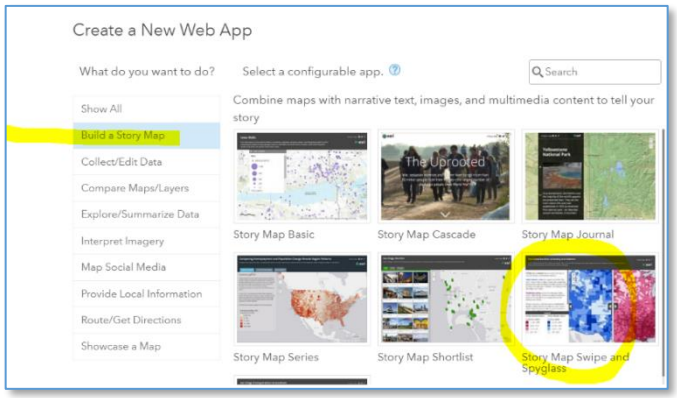
This results in a legend with 3 symbols of the same size but with different colors. Go to > Change Style to make the Decreasing HDI a large blue symbol, as shown on map:



Another way of focusing on countries where the HDI has been decreasing is to use the filter tool: Filter > 2010 is greater than 2014. Open the table and note the number of countries that met the criteria (11) and their spatial distribution.

7. Regional change analysis using the story maps swipe tool.

The swipe effect (that looks like a squeegee) is another way to visualize change over time for a set of variables, or even comparing between two themes (such as land use and land cover). One way to create a swipe map is to start with two web maps showing the same variable for two different time periods. This example will use showing traffic accident data that the author of this lesson has filtered for two different years and saved as two separate web maps.



Signed in to your ArcGIS Online organizational account, open the Traffic Accident Analysis 2013 web map:

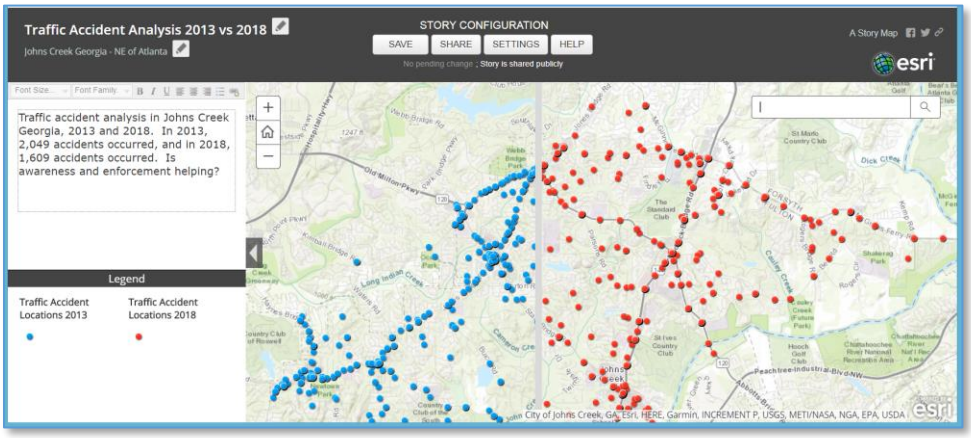
http://www.arcgis.com/home/webmap/viewer.html?webmap=bf9d5e4fbc6644758cc8f976505763aa

Save the map > Share > Create a web app > Build a story map > Story Map Swipe and Spyglass, as shown here.

Select the two map option. For the right side of the swipe, enter the following map ID:

f3dc9723d444406d973125f936f578cc

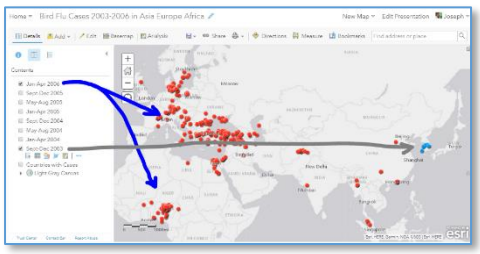
Feel free to edit the description and experiment with the template configuration options. Title and save your map.



On your new swipe map, examine the frequency and patterns of traffic accidents. In 2013, 2,049 accidents occurred, and in 2018, 1,609 accidents occurred in Johns Creek. Use the locator tool to input the following address: 11550 Jones Bridge Rd, Alpharetta, GA, 30022, USA. Examine this neighborhood which has traditionally seen many accidents. What are the land uses in this neighborhood? Is the accident situation improving? What further measures might be taken? See final swipe result here:
http://www.arcgis.com/apps/StorytellingSwipe/index.html?appid=4437867d8e0d4f39a0ef4fae024e42cd
For more information on creating swipe maps, see this tutorial:
https://storymaps.arcgis.com/en/app-list/swipe-spyglass/tutorial/. Think about: What other themes could you create swipe maps of?

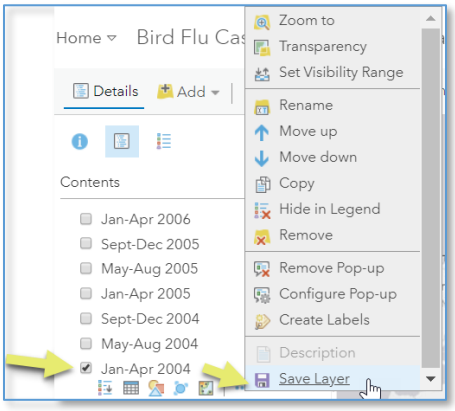
8. Global health analysis using time animations.

A time animation allows you to visualize such changes in your temporal data over time; one of the most commonly used time animation tools is a time slider that contains a play button and other tools that allow to analyze specific time periods that a data set covers. Let's focus on creating a time slider in ArcGIS Online.

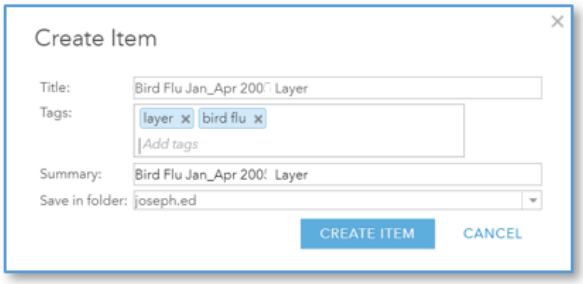


Start by opening the following map in ArcGIS Online and sign in with your organization credentials:
http://www.maps.arcgis.com/home/webmap/viewer.html?webmap=74621b6c0e0041d0897924fb28619711. Save the map to your own content in your own ArcGIS Online organization. Note how the layers can be turned on and off to simulate the change over time, as shown in the graphic above.

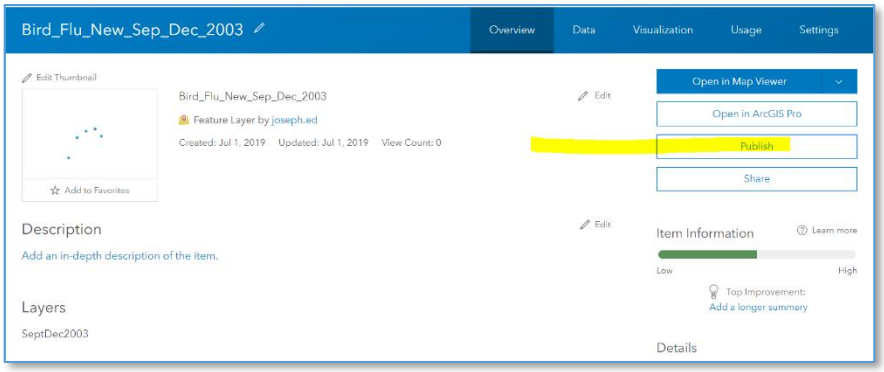
But to more fully understand patterns over space and time more fully, let's say you wanted to create a map where time has been animated and can be "played" with a time slider tool. To accomplish this, the map layers need to be turned into feature layers, and then turned into hosted feature layers with time enabled. To do this: (1) For each map layer in your web map, while logged in to your organizational subscription, use the ellipses … and save layer. Do this for all of the layers. See graphic.



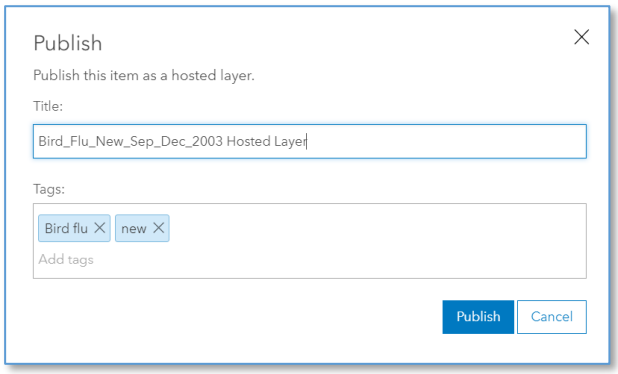
Fill out the Create Item dialog as you see fit, making sure you do not use any dashes in your layer names (see graphic) – only _ and spaces. Include "Layer" in the Title.



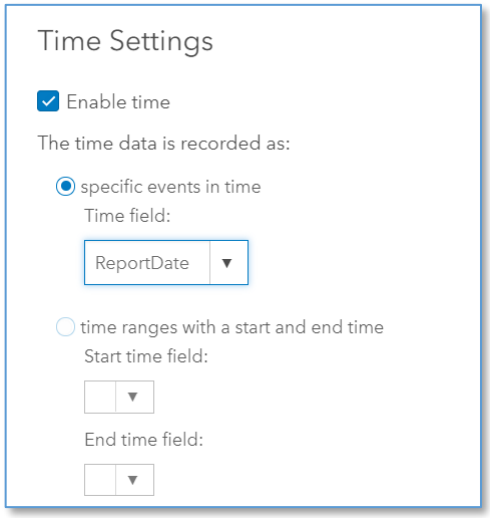
(2) When you are finished saving each layer as a feature layer, in your ArcGIS Online organization, go to > "Content" > click on the first saved layer in the content list > Publish.



When you publish your layer, name your layer with the word "hosted" in it (helpful for data management and when you are choosing layers to add to your map in the next step) (such as Bird Flu Sept_Dec 2003 Hosted Layer. >

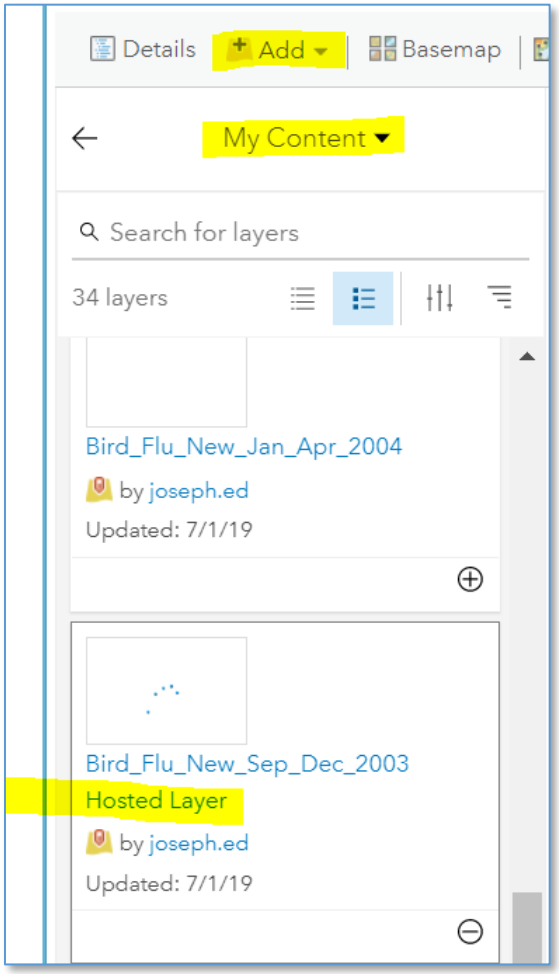


(3) For your new hosted layer, about midway down on the metadata for the layer, access Time Settings > Enable Time (see graphic) and > Save.

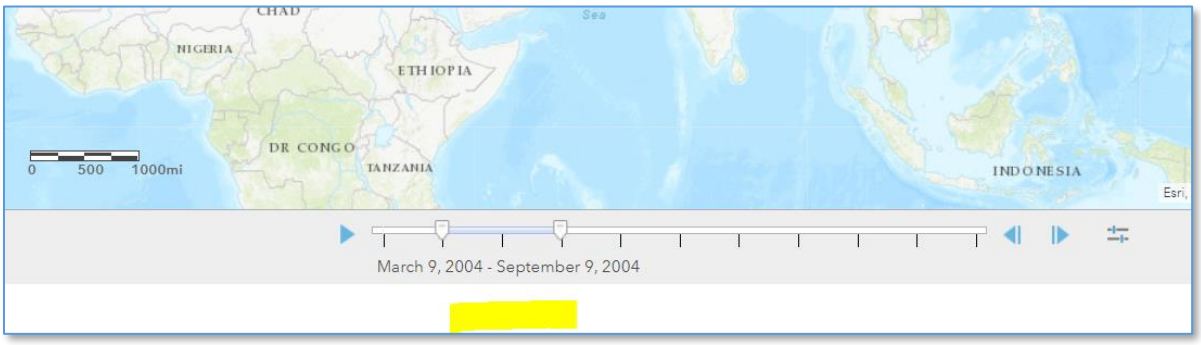


Repeat steps (1) (2) (3) for each of your layers. When you are done, you will have 8 hosted layers, each of which will be time enabled.

(4) Create > map > Name it: Bird Flu 2003-2006 Map with Time Animation. One at a time, Add Data > My Content > add your **hosted feature layers**, one at a time, as shown.

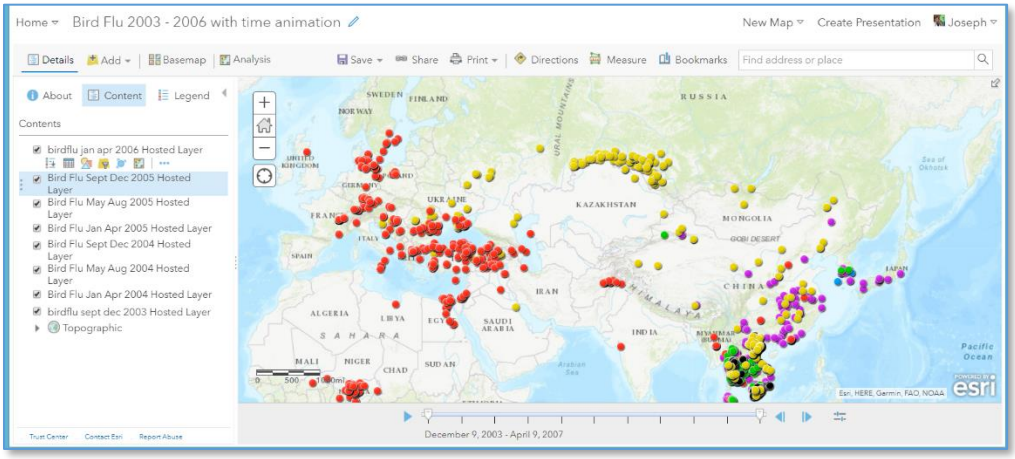


On your map: Move the layers so that the newest layer (2006) is on the top of the table of contents and the oldest at the bottom. Turn on all the layers. You should see a time animation player at the bottom of your map:



Move the endpoints fairly close together, as shown, and play animation OR move the active section of the timeline between the endpoints forward and backward. Verify that your data is displaying through time from 2003 to 2006. Save your map.

To view an example of a map where the animation has been enabled, see:



http://www.maps.arcgis.com/home/webmap/viewer.html?webmap=c83b8aed9ee244a7ae17c1d3147f2431

Map with time animation of bird flu 2003-2006.

Congratulations! You have analyzed change over space and time with 8 different maps, data sets, and apps, and gained skills and content knowledge along the way!

Tool	URL
ArcGIS Online	https://www.arcgis.com
Story Maps	https://storymaps.arcgis.com
Data Book and Blog	https://spatialreserves.wordpress.com

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