Building Historical Maps for **Cityscapes**

An Online Discovery Tool for Urban and Cultural Studies

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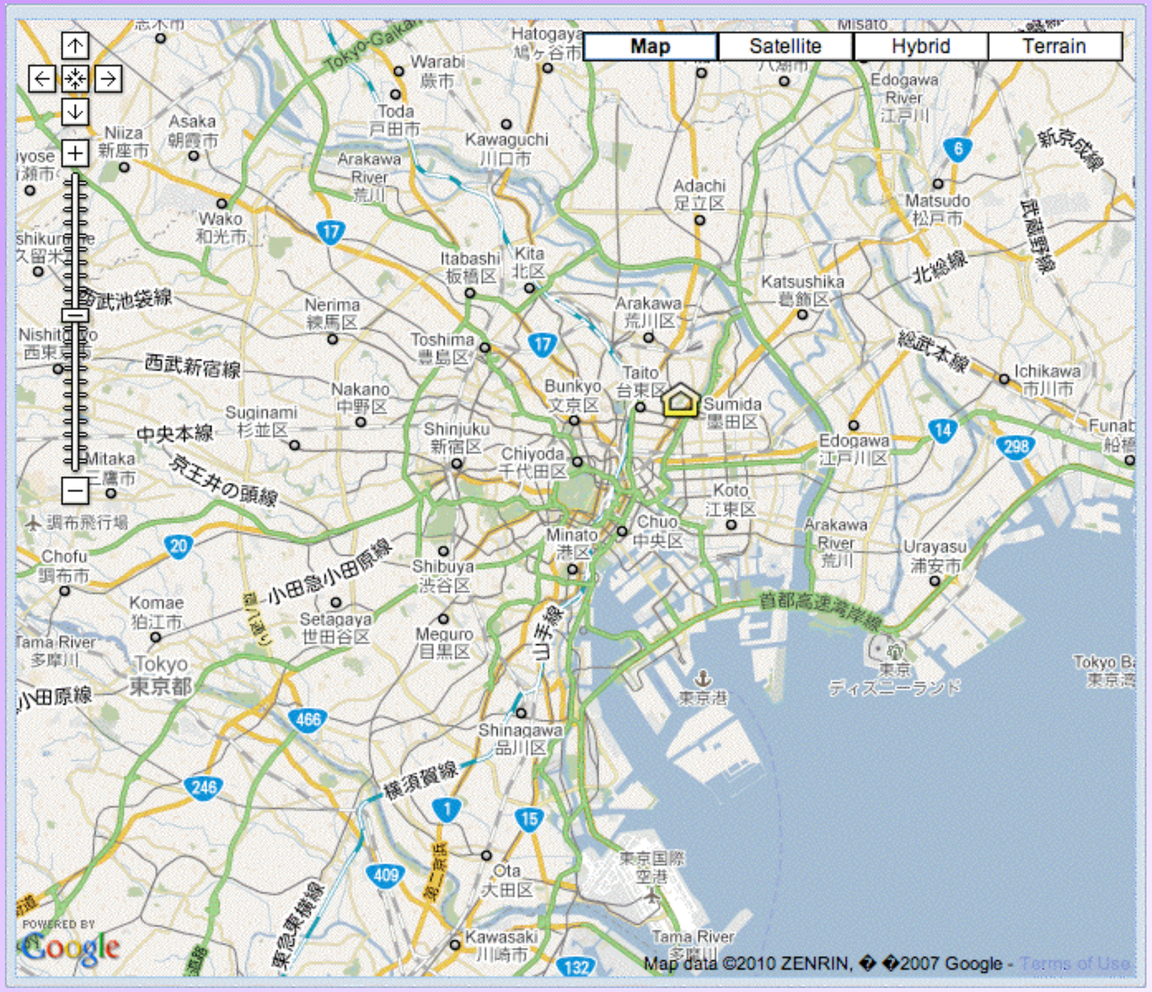
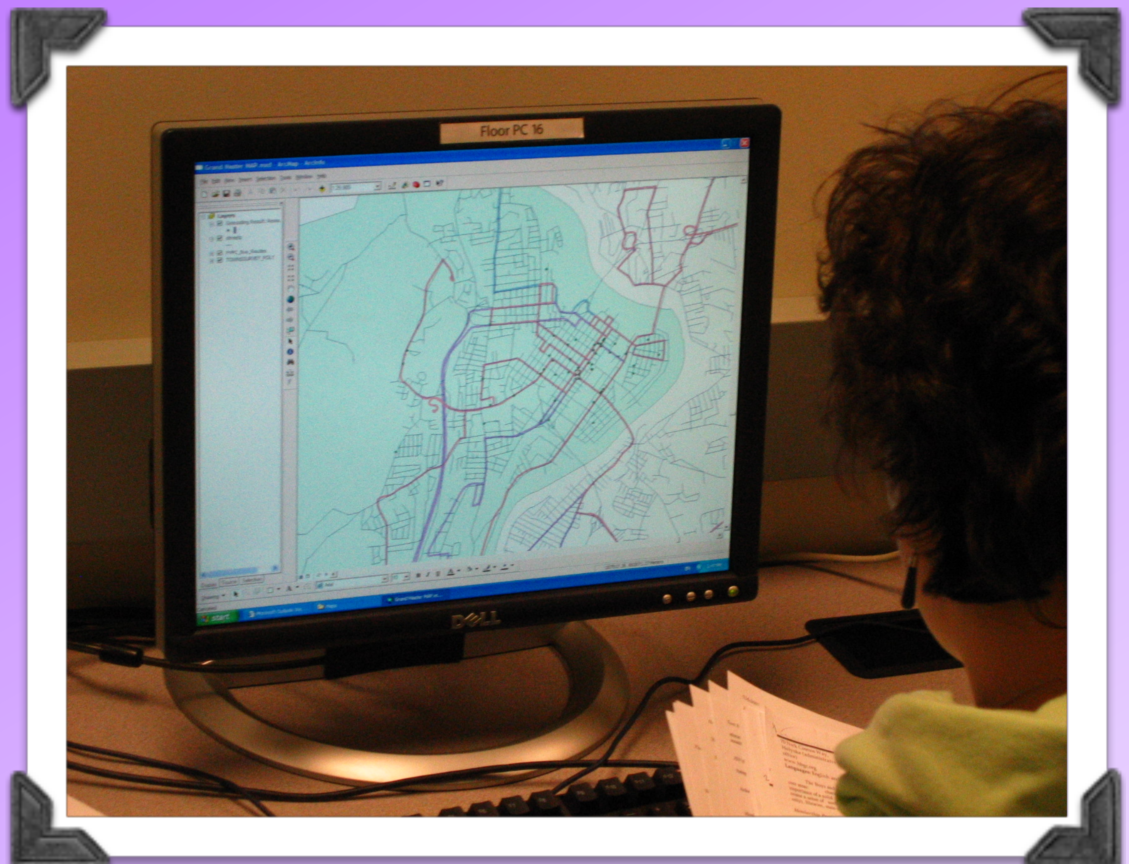


Presentation Overview

- Amherst College & GIS
- Reinventing Tokyo
- Cityscapes
- Imagining Paris
- Image Processing
- Georeferencing
- Google Maps Tiling
- GTiler Geoprocessing Script



Amherst College

- A liberal-arts college
- 1600 students,
  almost all in residence
- 1:8 faculty-student ratio
- GIS Education:
  * Interterm Community-Based Course (9 in Jan. 2010)
  * Minor use in geology classes until last year (a visitor!)
  * Occasional use of Google Earth for class and projects
  * Heaviest use for research, ~one thesis student a year

Simplifying Geographic Discovery

- Most of our professors feel GIS is too time-consuming for casual use during a semester.
- Some professors *do* understand the value of thinking geographically.

Encyclopedia of Edo-Meiji-Tokyo Digital Map or *Superimposed Map* (Epipi Company, 2004)

- Samuel Morse, professor of History of Art and of Asian Languages and Civilizations, showed me a Tokyo mapping app: ⊕ zooming ⊕ layering ⊖ CD-based ⊖ in Japanese ⊖ $$

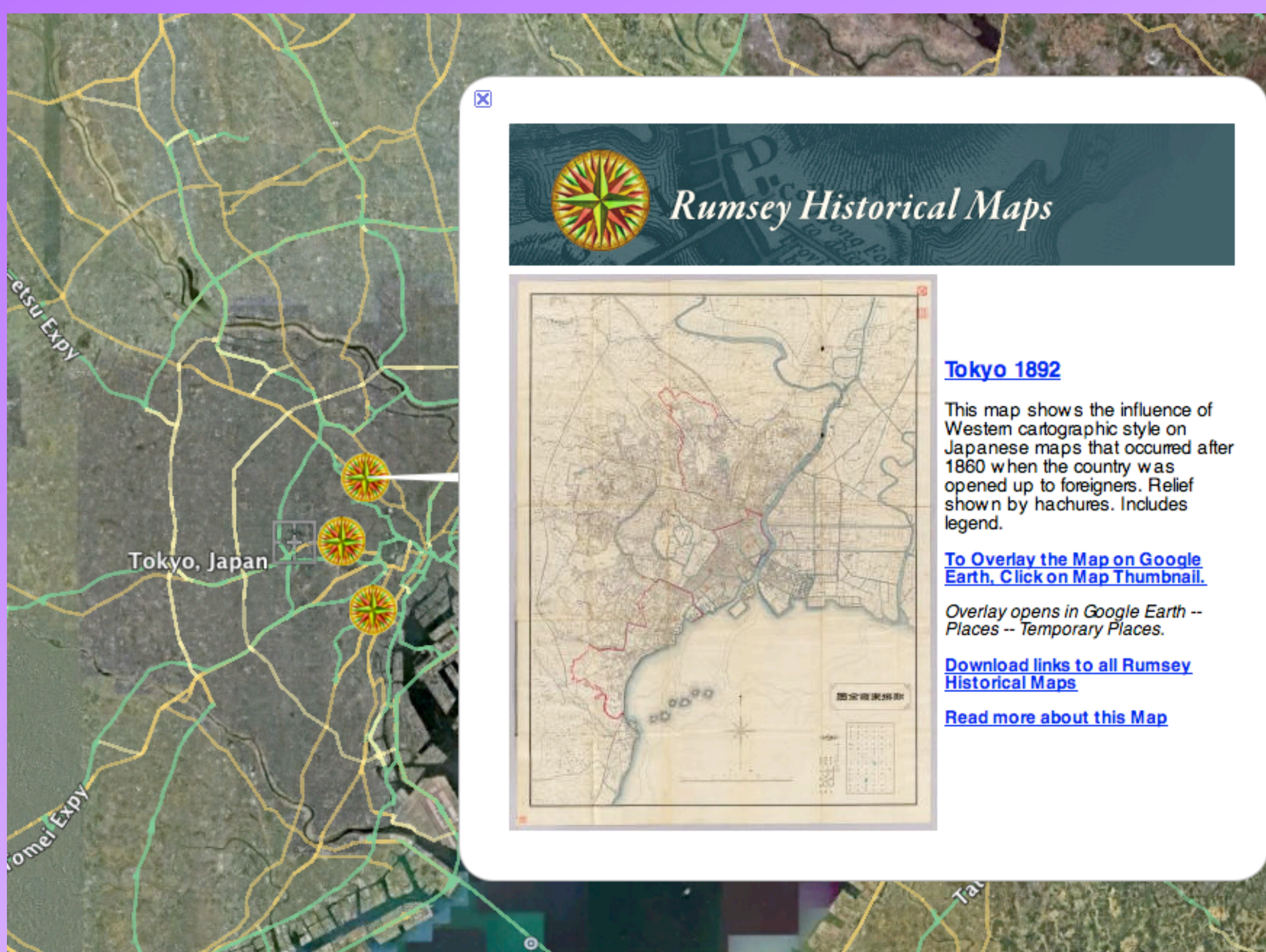
Reinventing Tokyo

- Professor Morse, along with Prof. Trent Maxey (ALC & History) and Prof. Tim Van Compernolle (ALC & Film and Media Studies), were developing a new course.
- *Reinventing Tokyo: The Art, Literature, and Politics of Japan's Modern Capital*
  "Tokyo is the political, cultural, and economic center of Japan, the largest urban conglomeration on the planet, holding 35 million people…. Since its founding 400 years ago, when a small fishing village became Edo, the castle headquarters of the Tokugawa shoguns, the city has been reinvented multiple times…"

Fishing Village, Flying Crane, and Mount Fuji

Google Tokyo

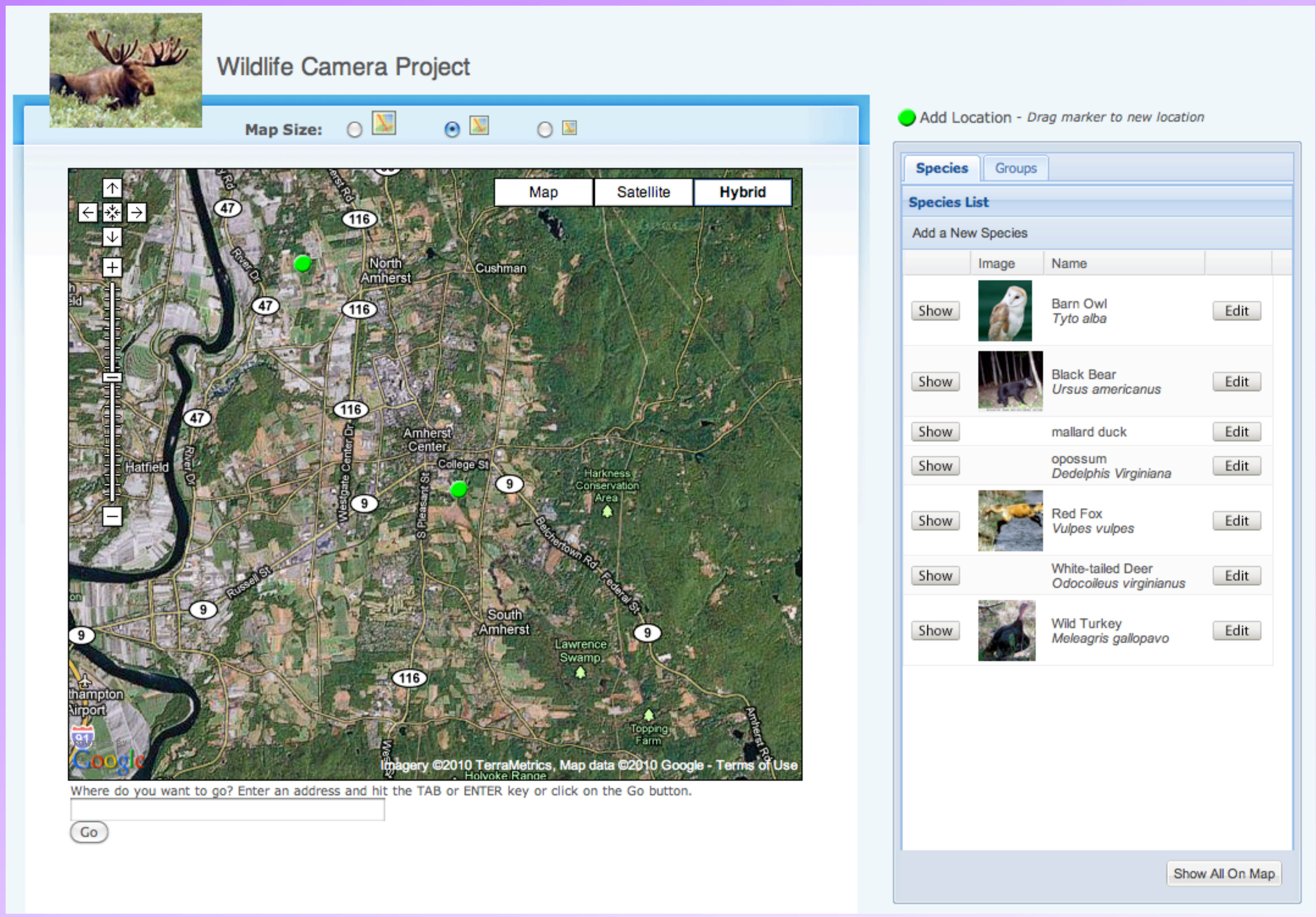
- I demonstrated Google Earth and its Rumsey Historical Maps, and we discussed how their students could use it to build presentations with added content such as images, audio, and video.



⊕ zooming
⊕ layering+transparency
⊕ multimedia balloons
⊕ 3D buildings
⊕ semi-web-based
⊙ semi-georeferenced
⊖ HTML formatting

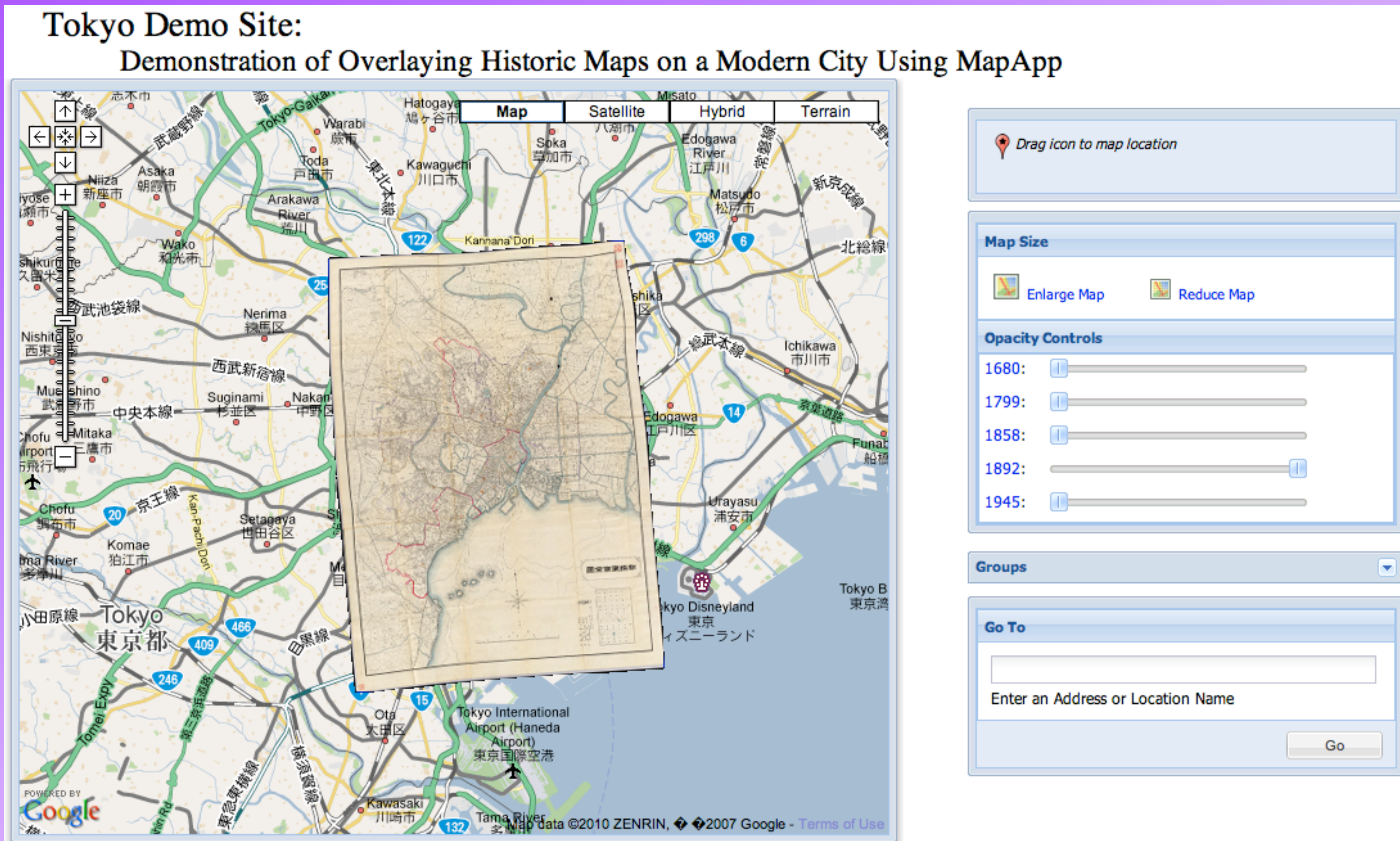
Amherst Web Maps

- Scott Payne, the director of my group, suggested we build our own platform using Google Maps.
- My colleague, Paul Chapin, had already built a Google web map to store photographic observations of wildlife.



Cityscapes Tokyo

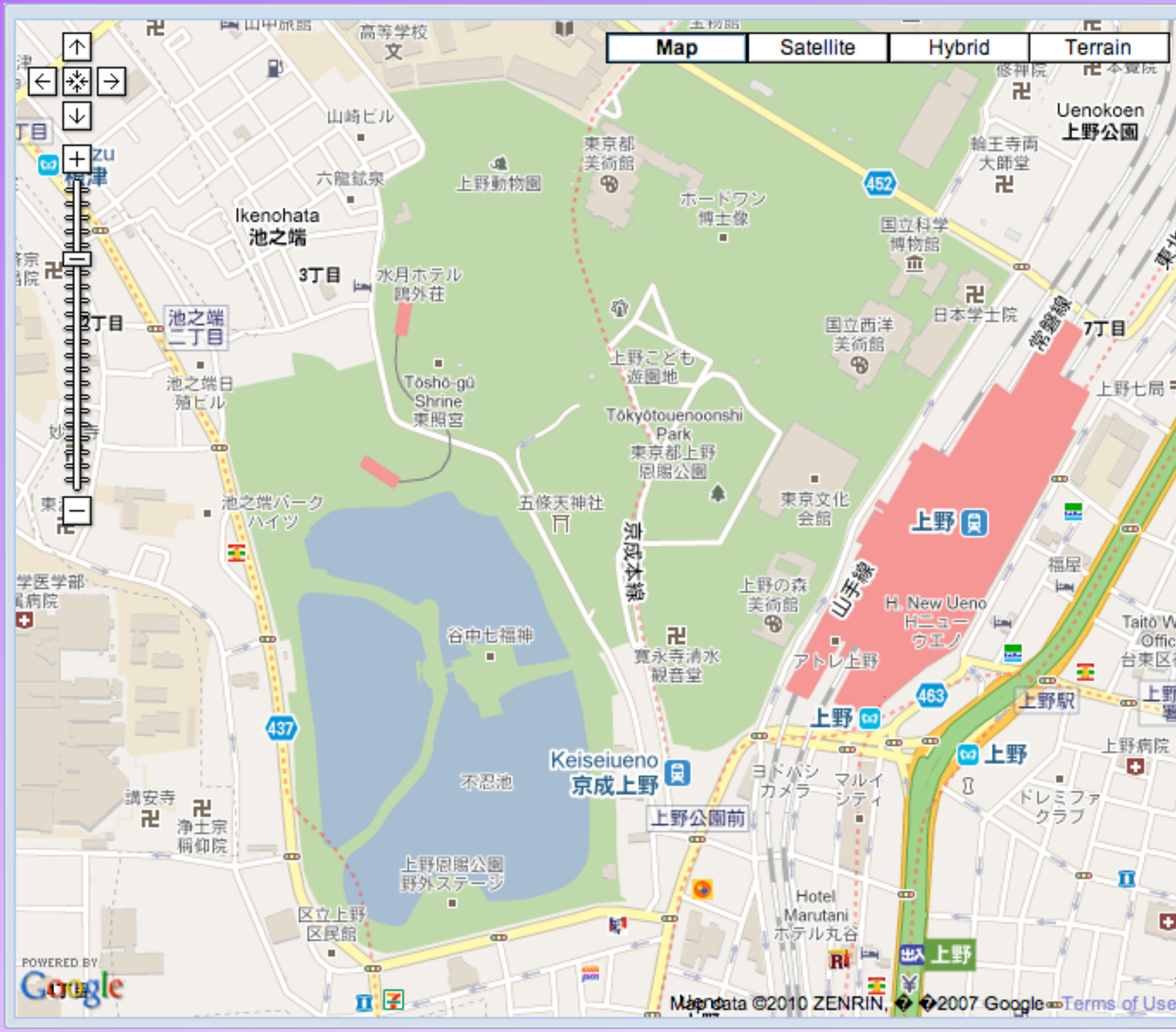
http://ats.amherst.edu/tokyodemo



Building Historical Maps for Cityscapes, An Online Discovery Tool for Urban and Cultural Studies

Cityscapes Features

- ⊕ zooming
- ⊕ layering
- ⊕ transparency
- ⊕ fully web-based
- ⊕ Google-provided map service with vector features, satellite imagery, and terrain
- ⊕ and more!

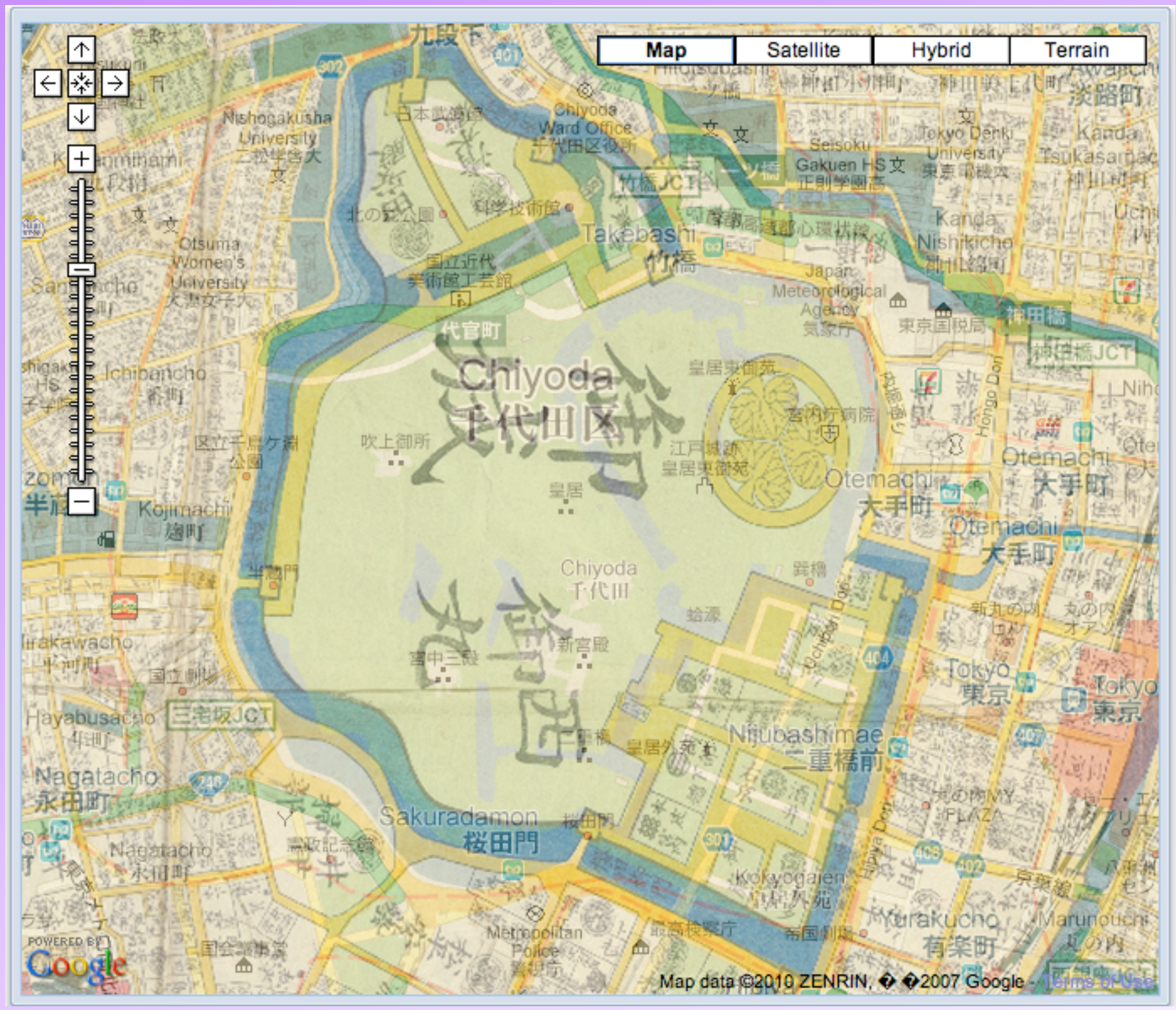


Cityscapes Feature: Georeferencing

- Cityscapes historical maps are closely georeferenced:

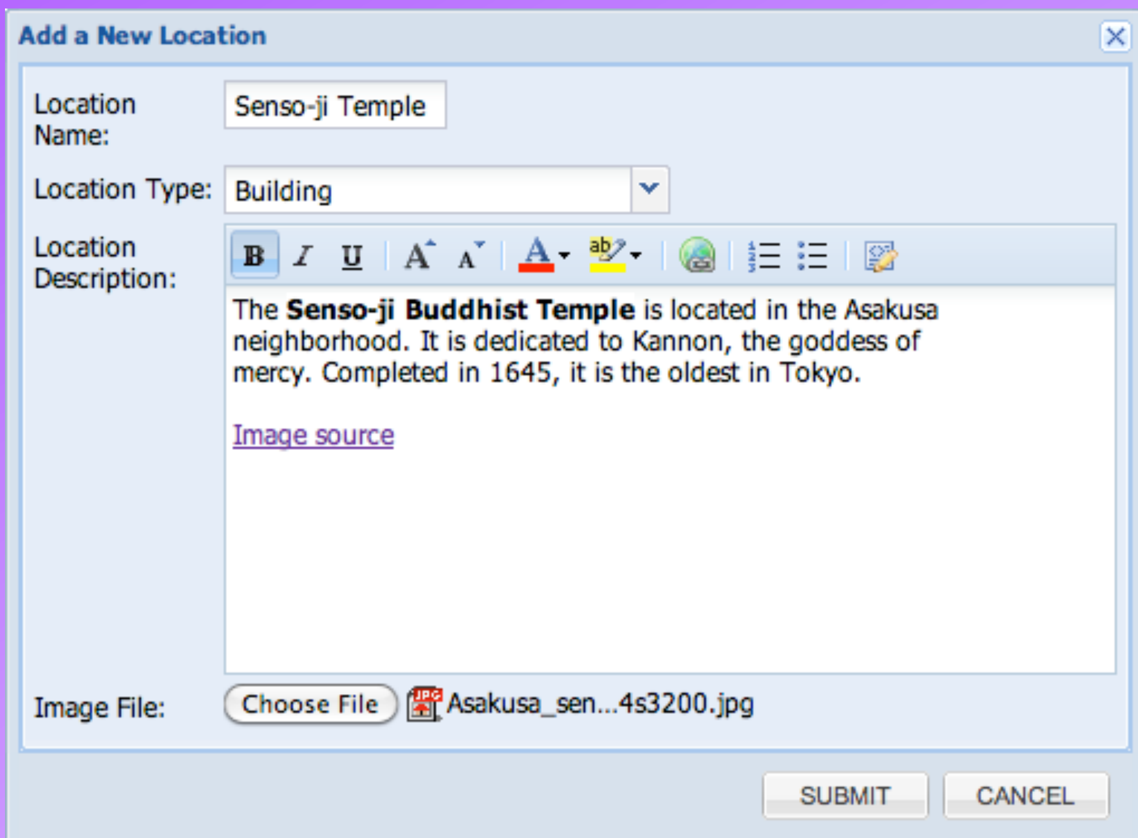
Google Earth

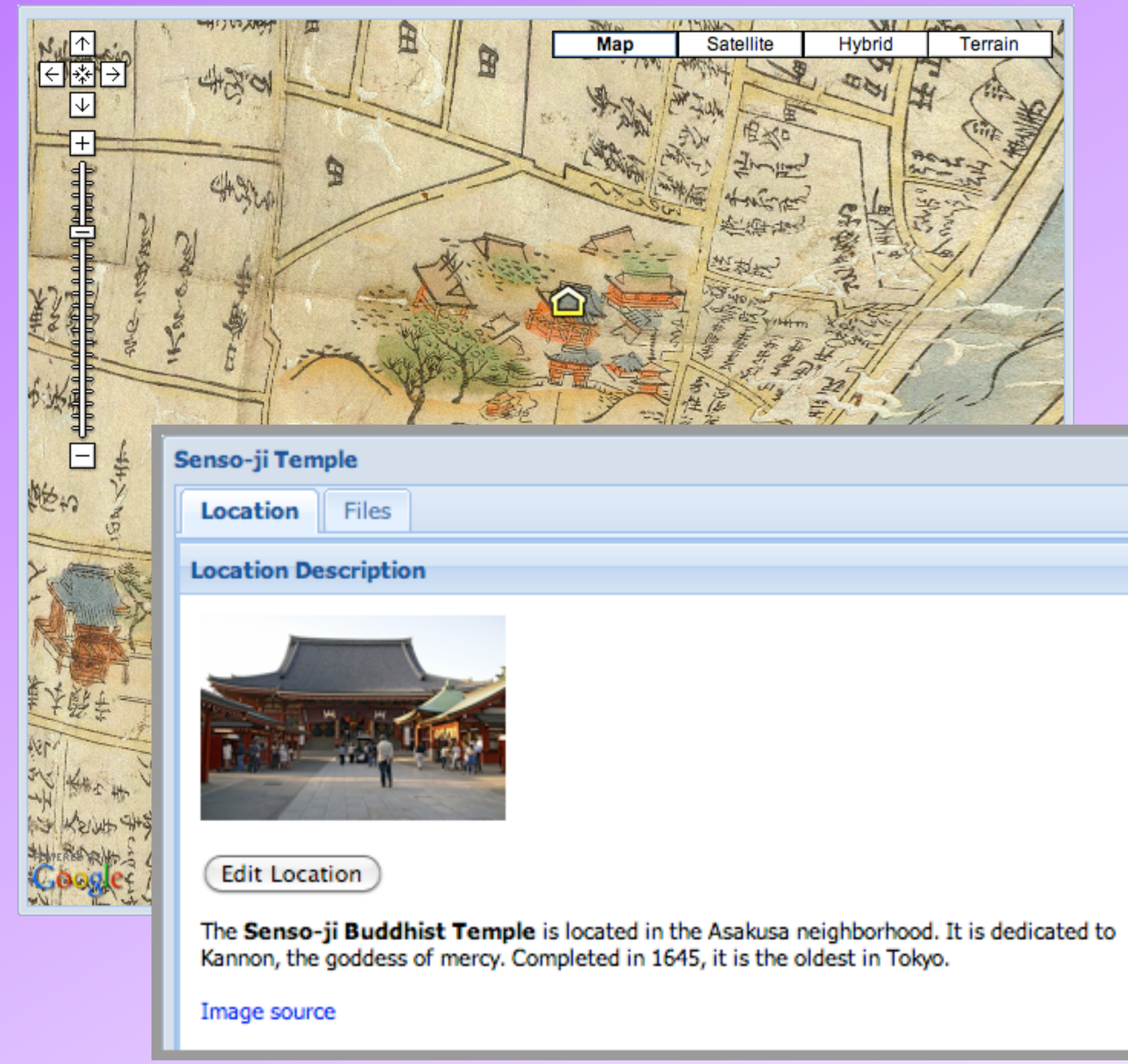
Cityscapes



Cityscapes Feature: Content Balloons

- ⊕ content balloons provide structured media inclusion

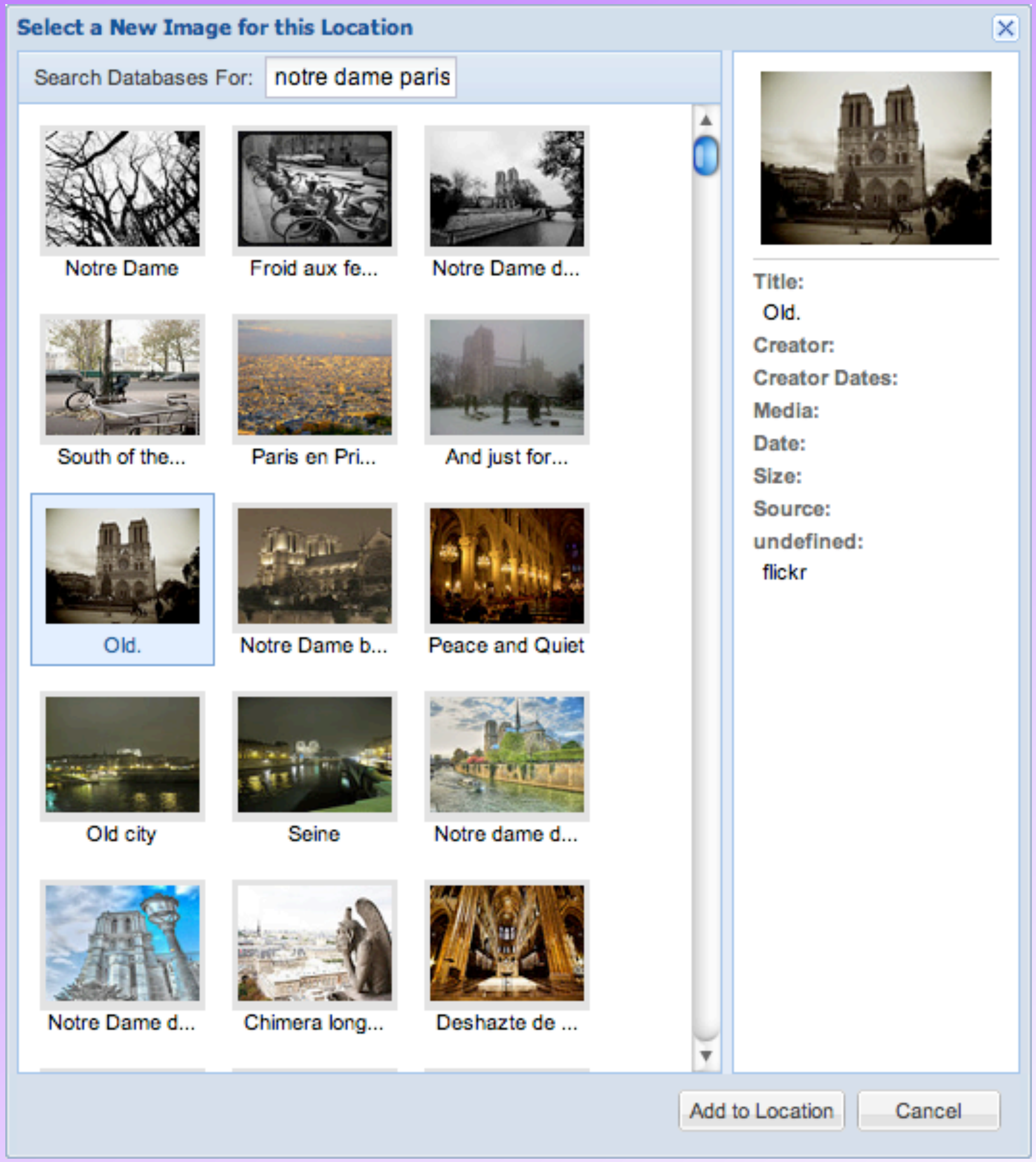




- ⊕ dialogues don't require knowledge of HTML
- ⊕ created using the Ext JS "Rich Internet Application Framework"

Cityscapes Feature: Multimedia

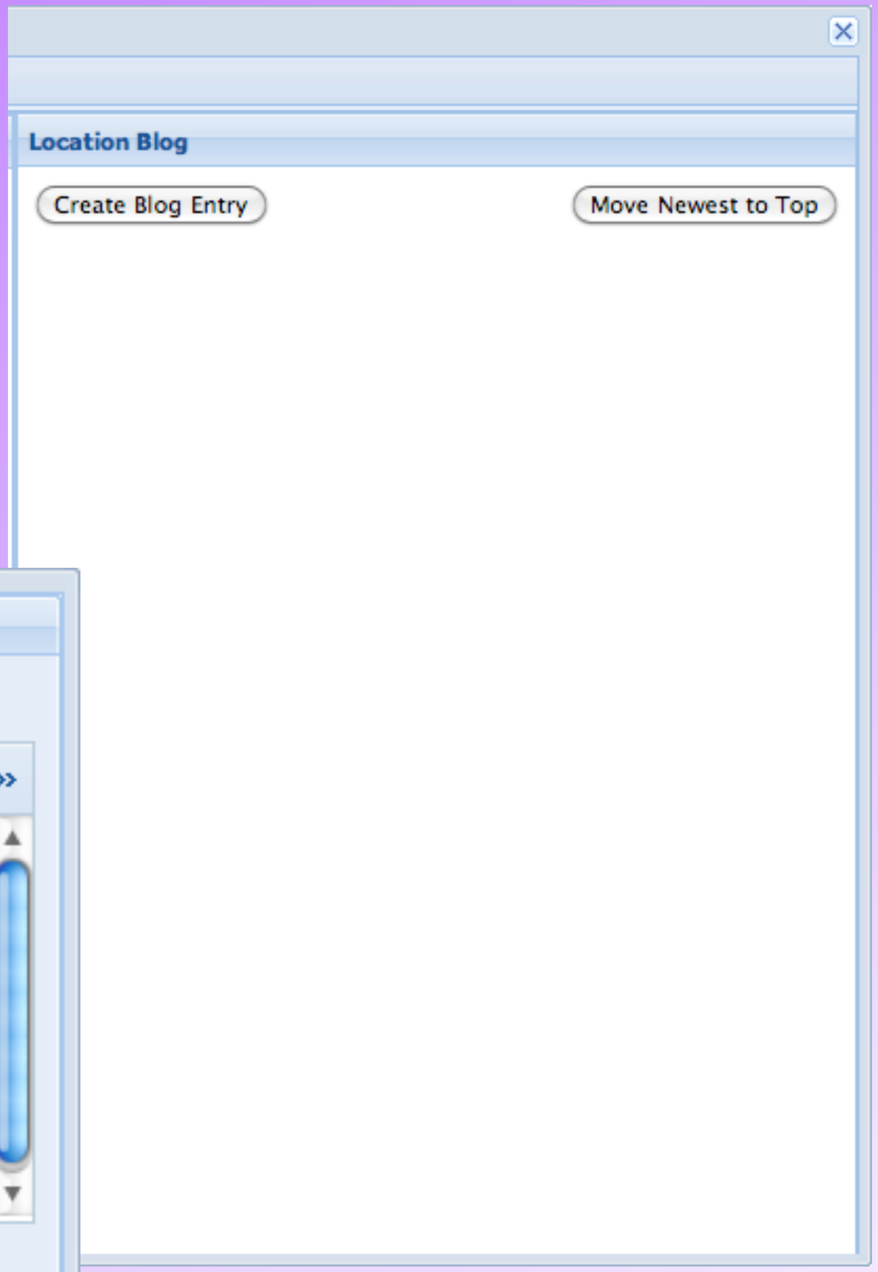
- content balloons can include image thumbnails and display them in a dedicated viewer.
- images can be from different collections:
  - DigiTool (Amherst)
  - Luna (Smith College)
  - Flickr (provided by students and others)

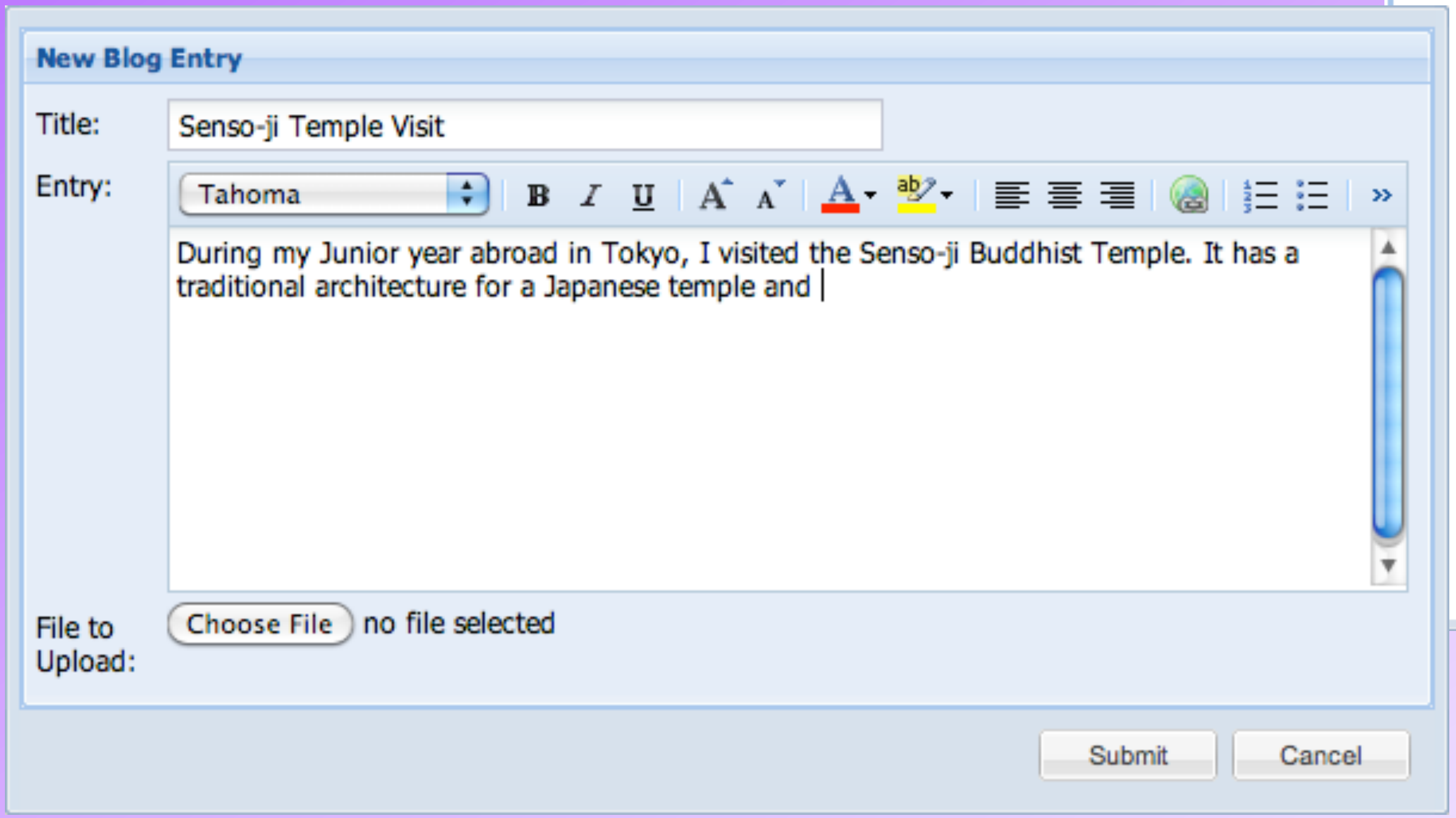


The database interface was programmed by another colleague, Miodrag Glumac.

Cityscapes Feature: Location Blogging

- Location balloons can have blogs associated with them, allowing conversations about the location and included media.

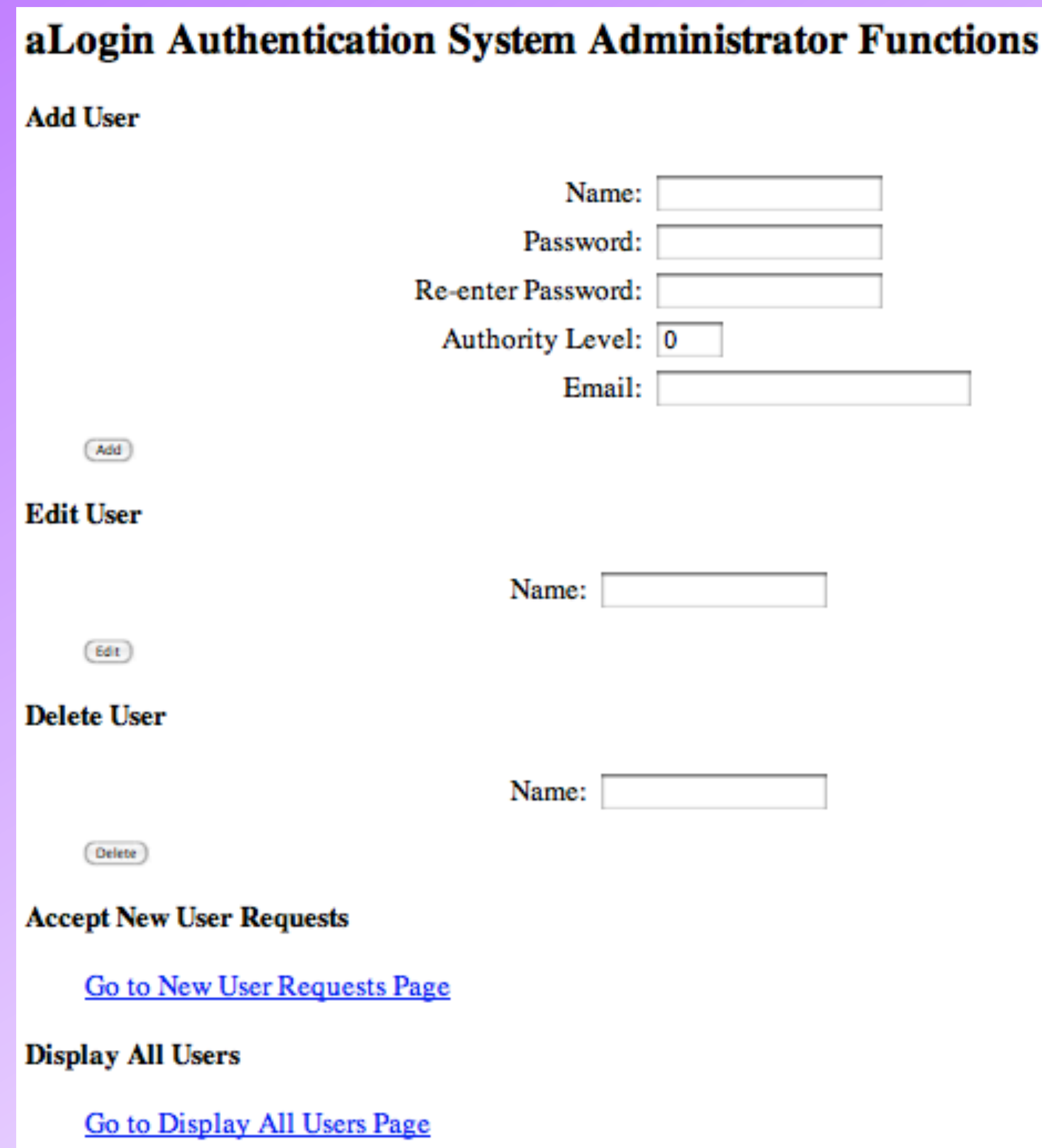


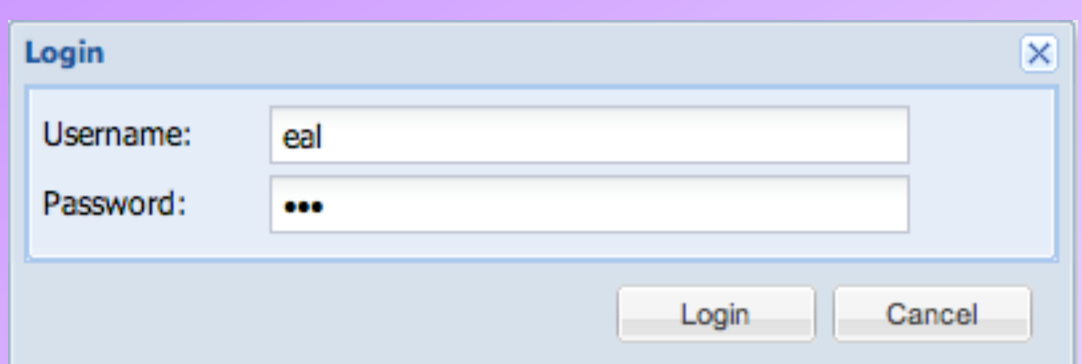


Cityscapes Feature: Access Control

Privacy of student projects is important.*

- ⊕ Cityscape balloons are created outside of Google maps, so their content is *not* web-searchable.
- ⊕ Built-in access control and groups for classes.





* e.g. Family Educational Rights and Privacy Act (FERPA)

Cityscapes –

Some negatives of the platform:

⊖ many staff hours

⊖ some maps are topologically incorrect

⊖ occasional bugs

⊖ no 3D buildings (as of yet)

⊖ many digital images obtained from other libraries, who often claim copyright — getting permission to open to the public is problematic.

Imagining Paris

- Professor Ron Rosbottom (French & European Studies) also expressed interest in our project.

Boulevard des Capucines, Paris
Claude Monet, 1873

- *Pariscape: Imagining Paris in the Twentieth Century*
  "Paris has been for centuries one of the exemplary sites of our urban sensibility, a city that has indelibly and controversially influenced the twentieth-century imagination. Poets, novelists and essayists, painters, photographers and film-makers: all have made use of Paris and its cityscape to examine relationships among technology, literature, city planning, art, social organizations, politics and what we might call the urban imagination."

- Also working with Smith College, Prof. Hélène Visentin (French), GIS Specialist Jon Caris, and student georeferencing specialist Zoë Zaferiou.

Cityscapes Paris

http://ats.amherst.edu/parisdemo

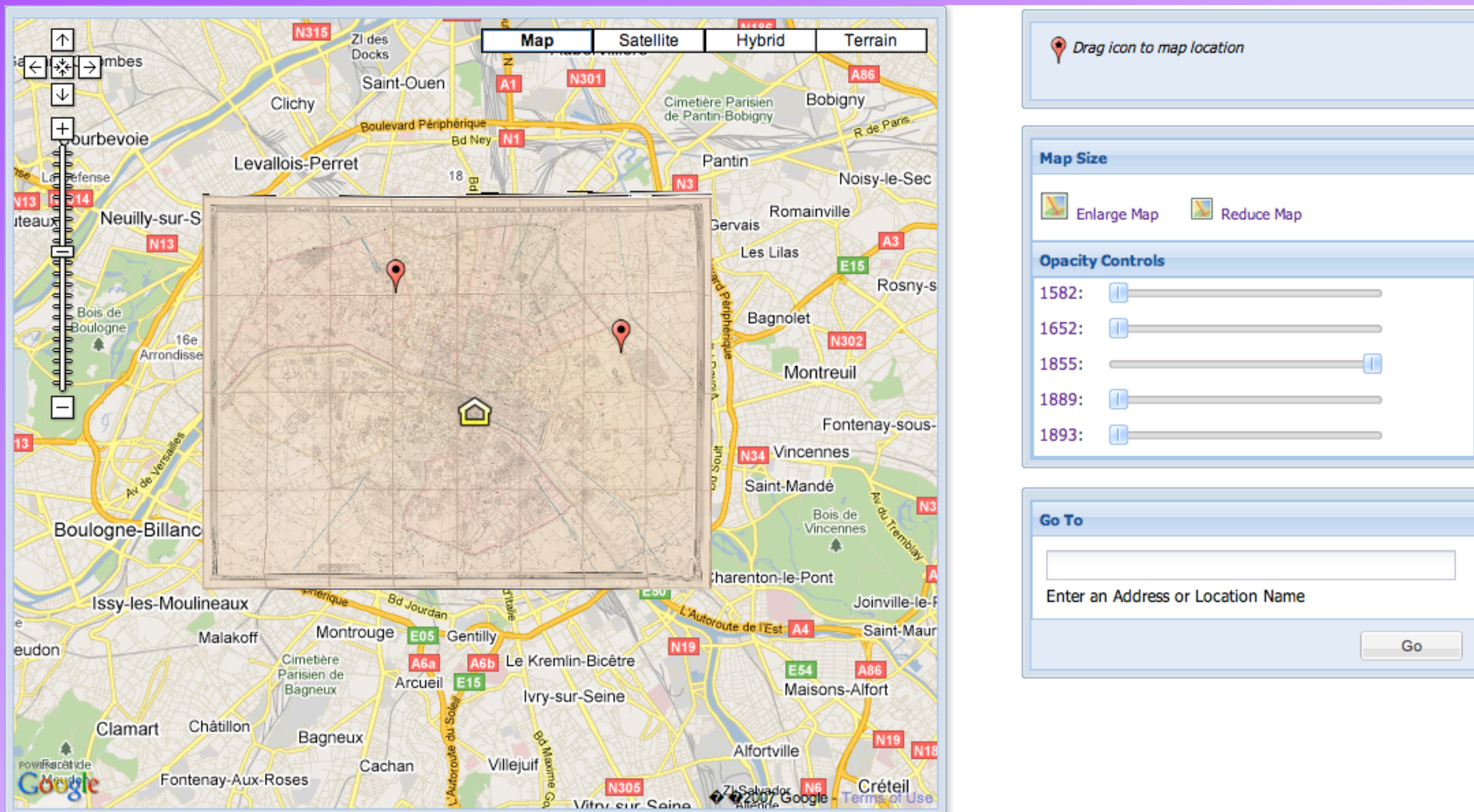


Image Sources

- Scanned maps were obtained from historical map collections at our institutions,
- And from those available on-line, specifically:

The University of California at Berkeley's East Asian Library

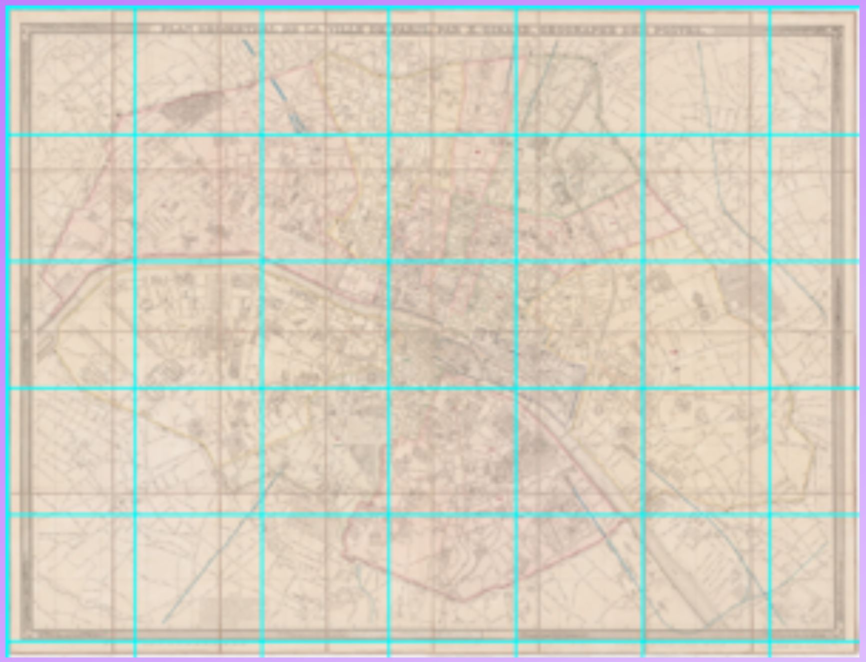
Photo Courtesy of Sébastien Bertrand

Photo Courtesy of Will Hart

The Harvard University Libraries

The David Rumsey Historical Map Collection

Map Image Processing



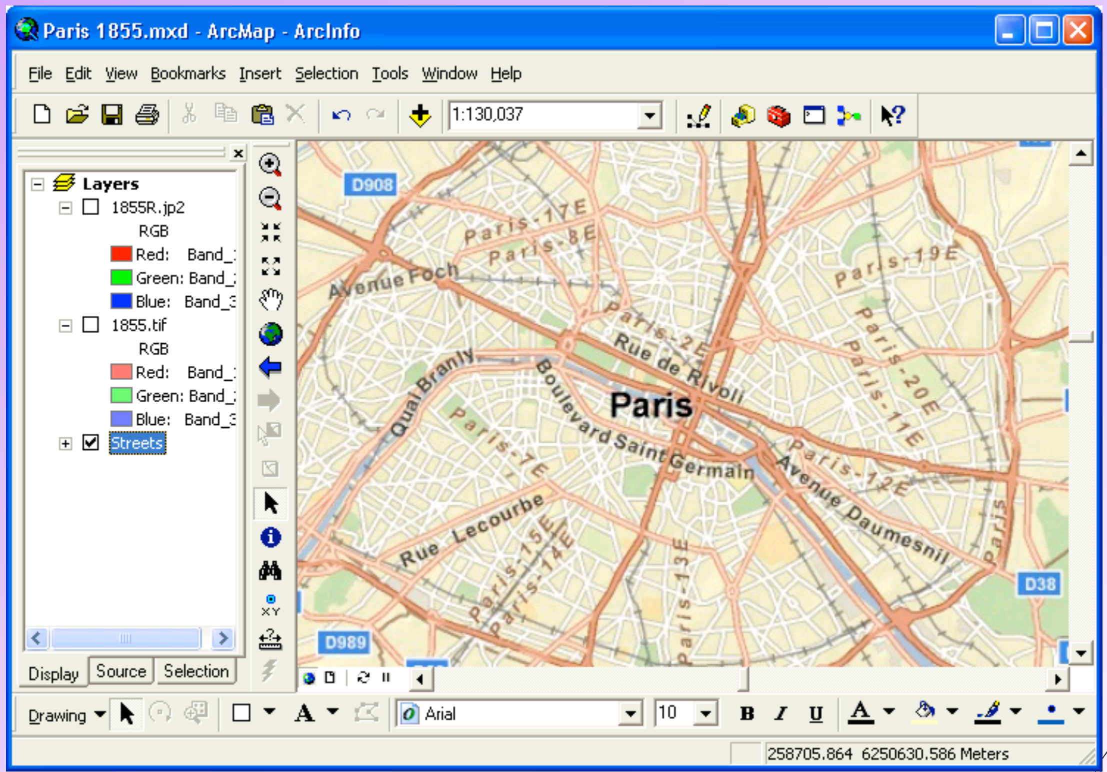
- Images were downloaded at the highest available resolution.
- Typically images were limited to disjoint pieces ~2048 pixels^2, e.g.:

  http://ids.lib.harvard.edu/ids/view/Converter?id=7157748&c=jpgnocap&s=1&r=0&x=0&y=0&w=2400&h=2400

- These needed to be stitched together with Photoshop, etc.
- The maps were trimmed of unnecessary margins.
- The resulting maps were usually on the order of 10K pixels^2, with a scale of 1-2 meters per pixel.

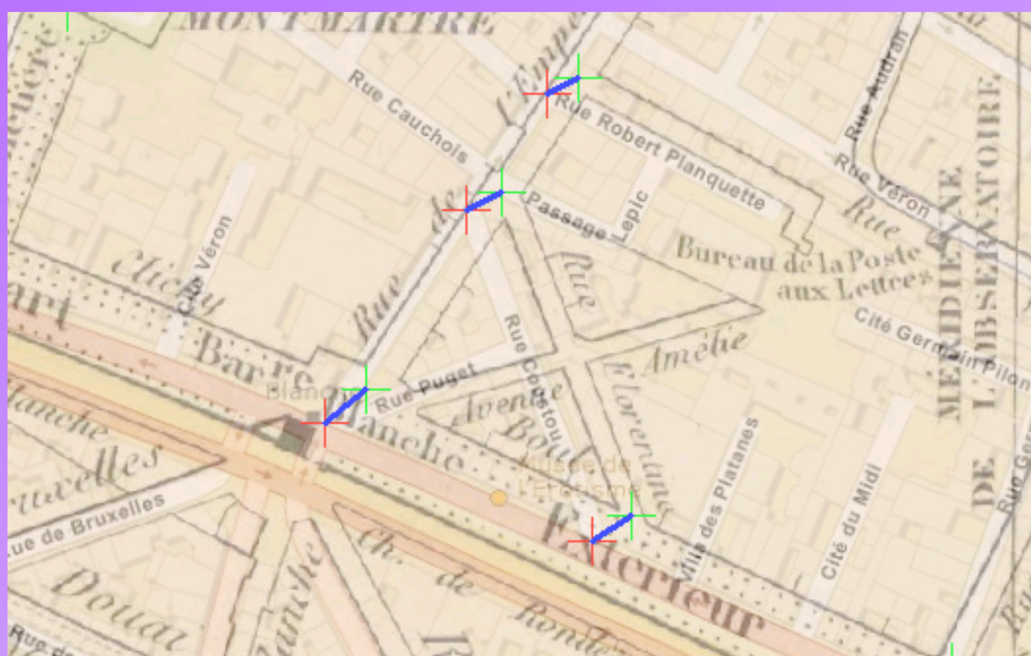
Georeferencing with ArcGIS

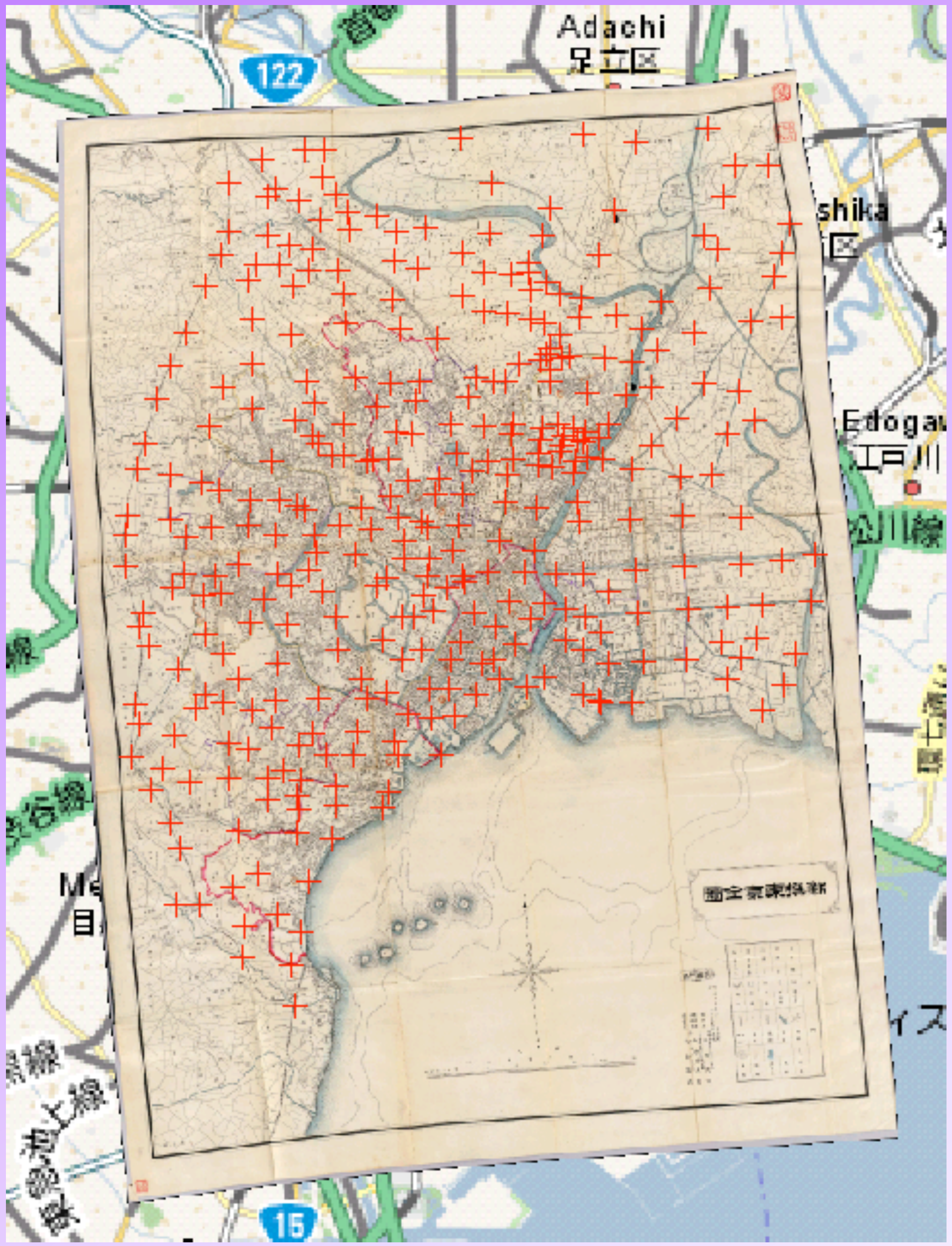
- ArcGIS is a very convenient platform for georeferencing images to a map background.
- Best to use the projection **WGS84 Web Mercator (Auxiliary Sphere)** to georeference, since that's what Google uses. *Don't* use "Google Mercator"!
- As a background, the ArcGIS Map Service **World Street Map** had great performance (Google tiles initially used, but much slower).



Georeferencing: Control Points

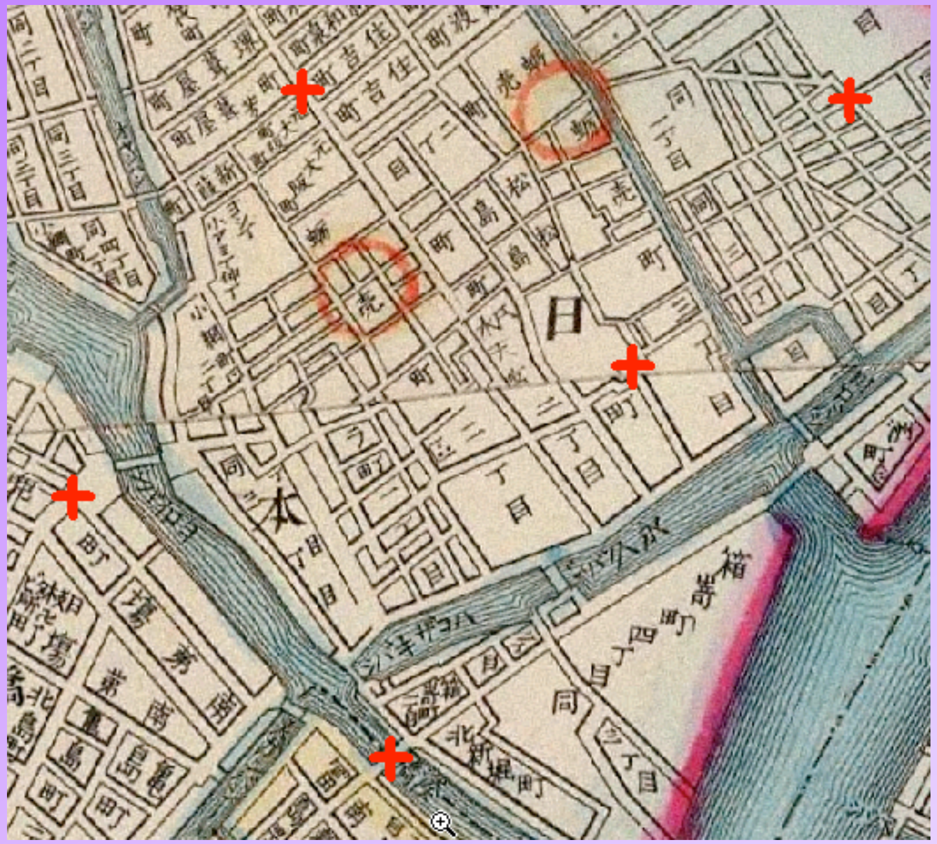
- Control points align two maps at locations that are recognizable on both:





- The Cityscapes maps varied from having many hundreds to several thousands of control points!

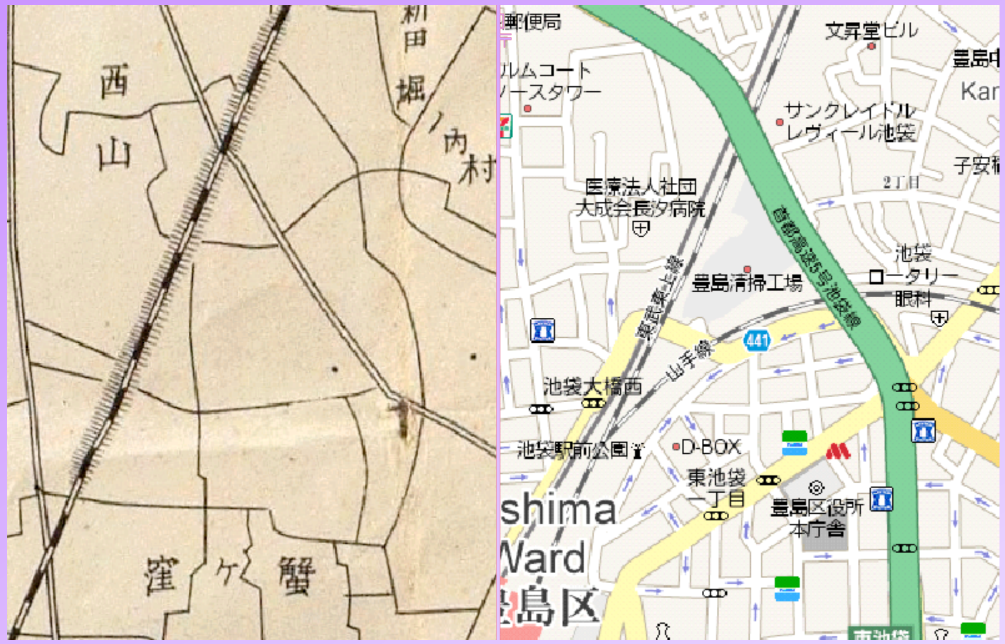
Georeferencing: Control Point Choice



- Streets are recognized by their pattern of connections, so intersections are by far the most important locations to add control points.
  - Not all intersections need to be georeferenced, if they're close enough to be recognizable.
  - Urban areas require more control points to help distinguish adjacent streets.
- Intersections with railroads, rivers, streams, and canals can also be used.

Georeferencing: Cautions

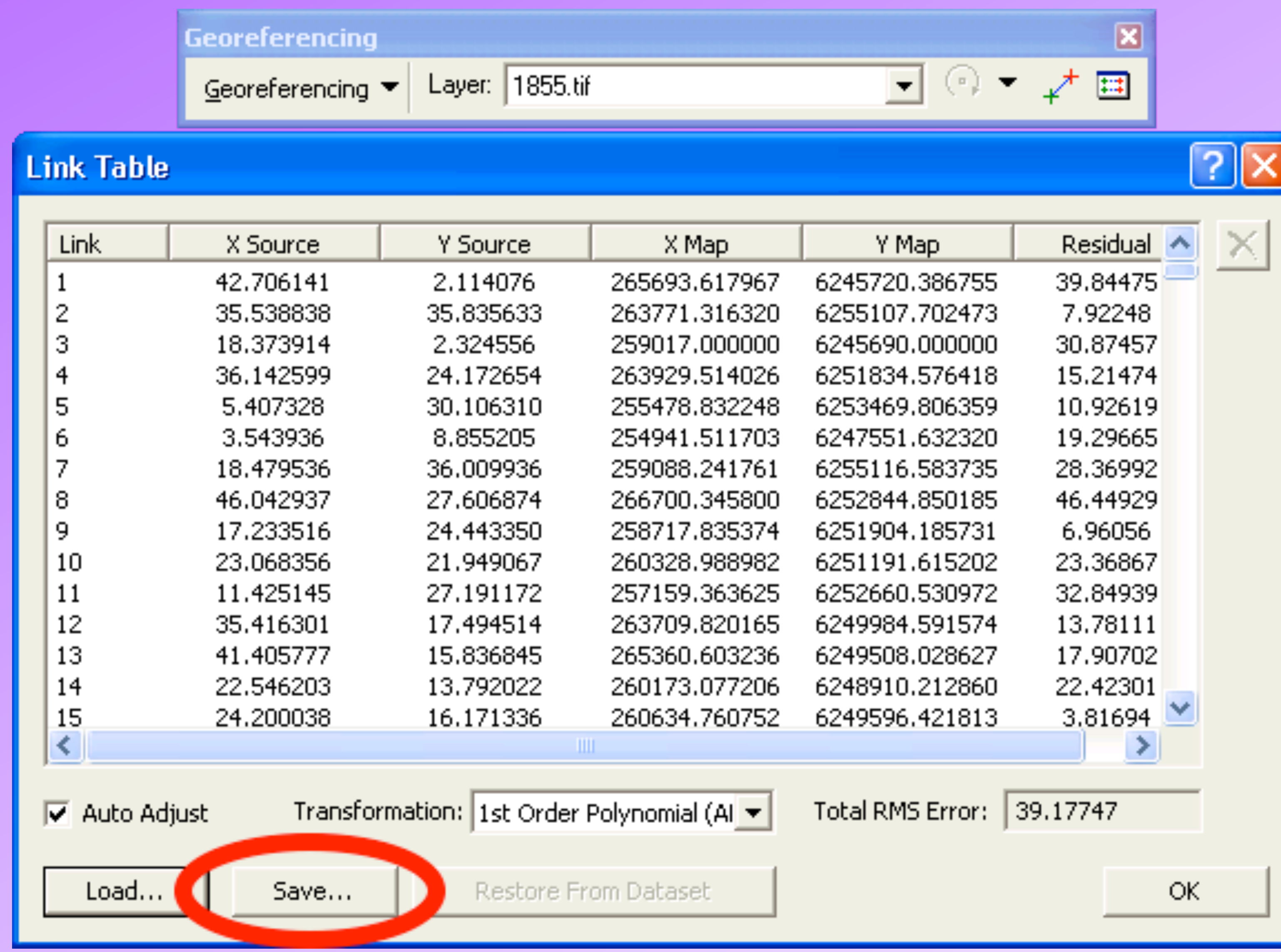
- Seldom will streets on two maps completely align; if the difference is small or extreme, leave as-is.
- Streets, railroads, and rivers can all change over time!
  - ✳ Streets are often built and rerouted, while rivers meander.
  - ✳ If there is no obvious relation, leave as-is.



- Deliberate abstractions are common!
  - ✳ Roads and railroads on a printed map are often widened to be distinguishable, which can “bump” other features.

Georeferencing Tips: Link Table

- Important! ArcGIS doesn't remember links if it closes, even *after saving* a map document!! (it only saves a temporary image!)



Link	X Source	Y Source	X Map	Y Map	Residual
1	42.706141	2.114076	265693.617967	6245720.386755	39.84475
2	35.538838	35.835633	263771.316320	6255107.702473	7.92248
3	18.373914	2.324556	259017.000000	6245690.000000	30.87457
4	36.142599	24.172654	263929.514026	6251834.576418	15.21474
5	5.407328	30.106310	255478.832248	6253469.806359	10.92619
6	3.543936	8.855205	254941.511703	6247551.632320	19.29665
7	18.479536	36.009936	259088.241761	6255116.583735	28.36992
8	46.042937	27.606874	266700.345800	6252844.850185	46.44929
9	17.233516	24.443350	258717.835374	6251904.185731	6.96056
10	23.068356	21.949067	260328.988982	6251191.615202	23.36867
11	11.425145	27.191172	257159.363625	6252660.530972	32.84939
12	35.416301	17.494514	263709.820165	6249984.591574	13.78111
13	41.405777	15.836845	265360.603236	6249508.028627	17.90702
14	22.546203	13.792022	260173.077206	6248910.212860	22.42301
15	24.200038	16.171336	260634.760752	6249596.421813	3.81694

- Therefore, regular saving of the link table is essential, and reloaded when ArcGIS restarts.

Georeferencing Tips: Seeing Better

- To see map details for both the raster and the underlying map, set the raster to ~40-50% transparency.

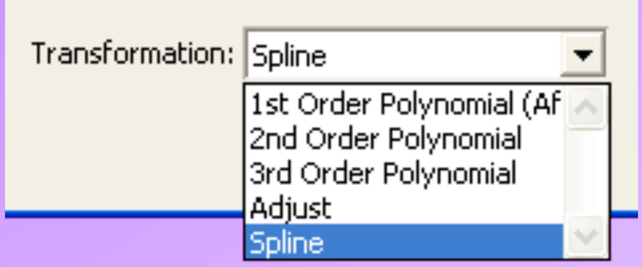
  - Changing screen brightness, if possible, can also help.

- Use the Magnifier in a small window at level 2 to distinguish map details while retaining context:

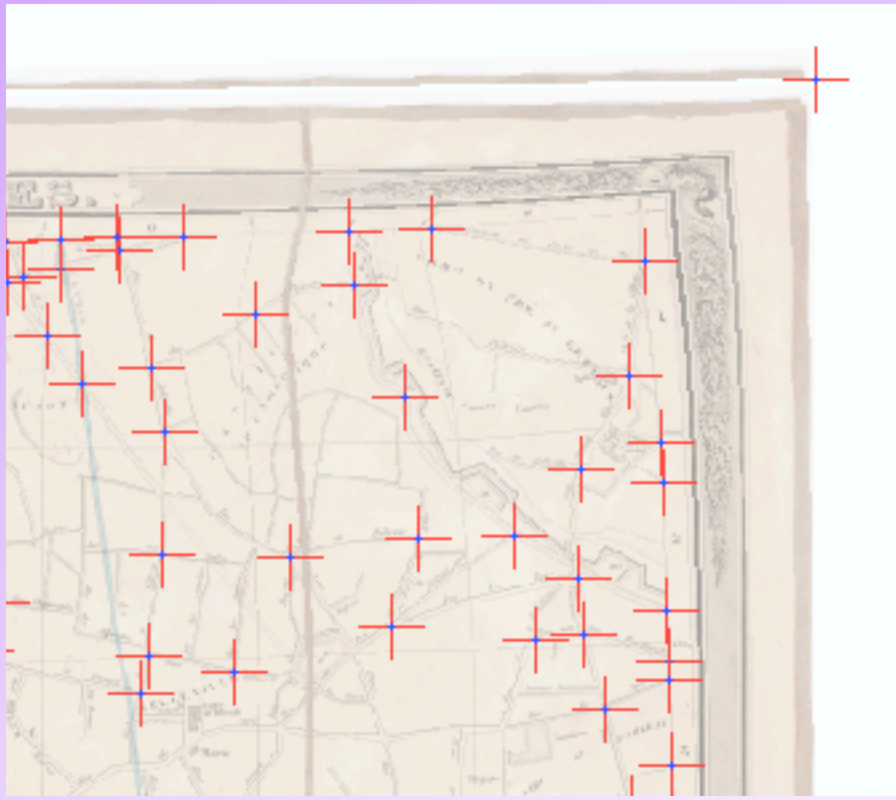
  - **Start** > **All Programs** > **Accessories** > **Accessibility**

Georeferencing Tips: Transformations

- *Spline* is the best transformation, an exact-fit method, but it becomes very slow after a few hundred points.



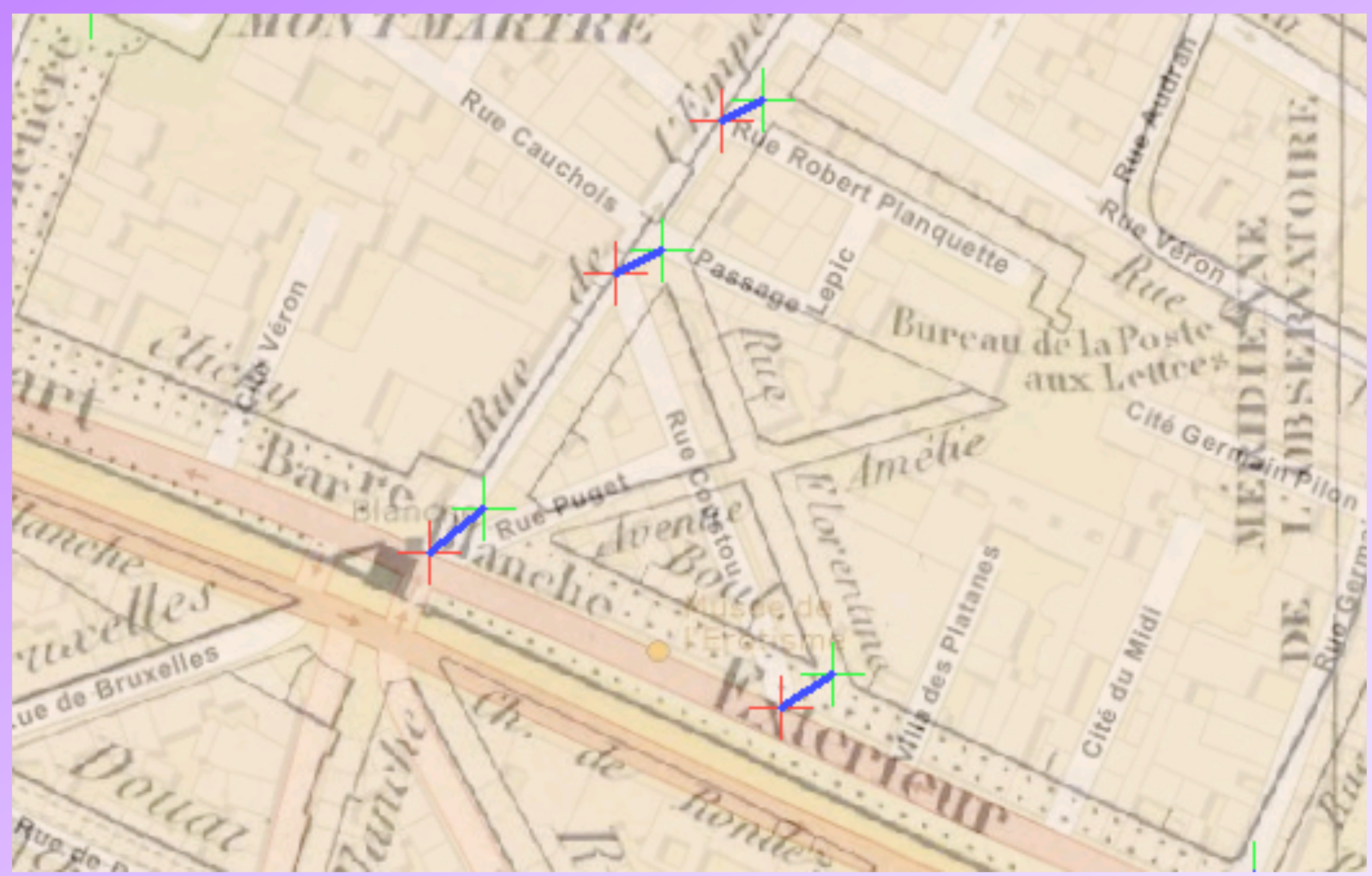
- *Adjust* is close-fitting and much faster, but it has discontinuities along the outer control points. **Solution:**



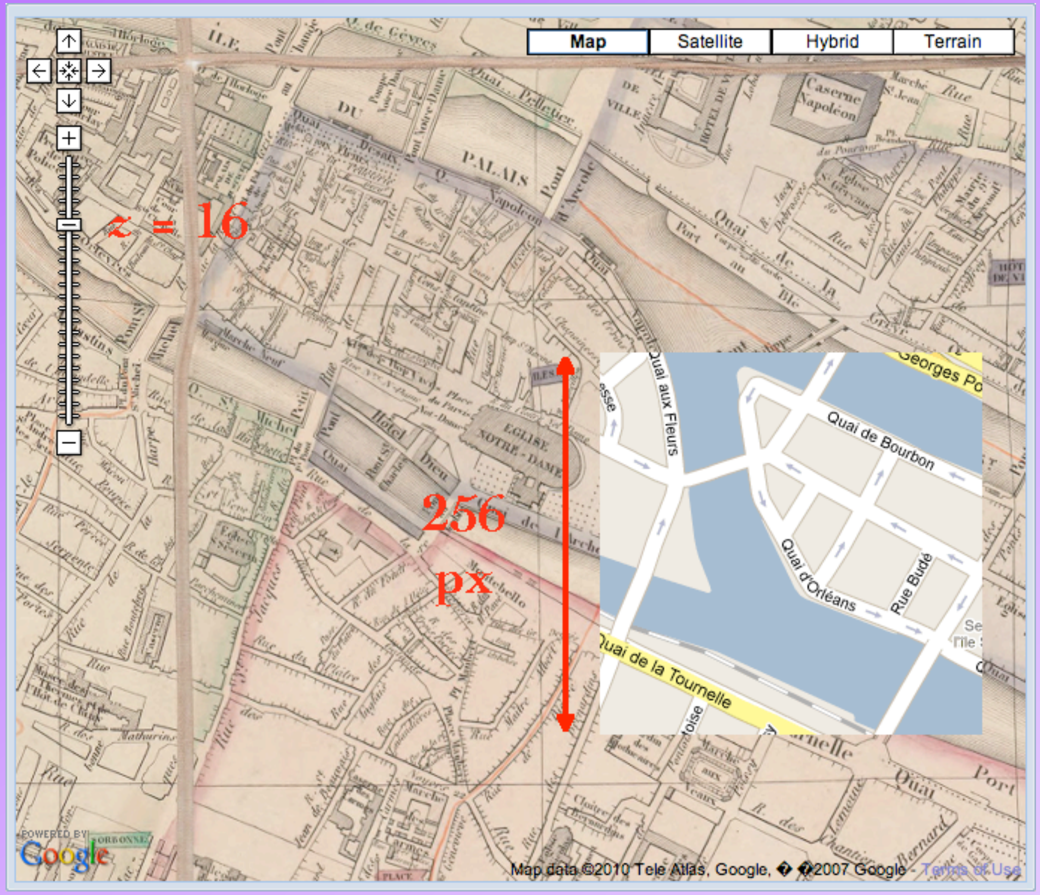
  1) Georeference the edges of the image early with Spline; then,
  2) Pin the corners of the map.
  3) Additional points at the borders must be moved parallel thereto, to avoid distortion.

Georeferencing Tips: Placing Points

- If the location of a new control point is not obvious, switching temporarily to a *First-Order Polynomial (Affine)* transformation is useful to see the "motion" of surrounding control points.



Google Tiles



- Google tiles are square and $256 = 2^8$ pixels across.
- The Mercator pixel size is:

$$\mathrm{cellSize}(z) = 2\pi r / 2^{z+8}$$

where $r = 6378137$ m is the equatorial radius, and z is the Google zoom level.

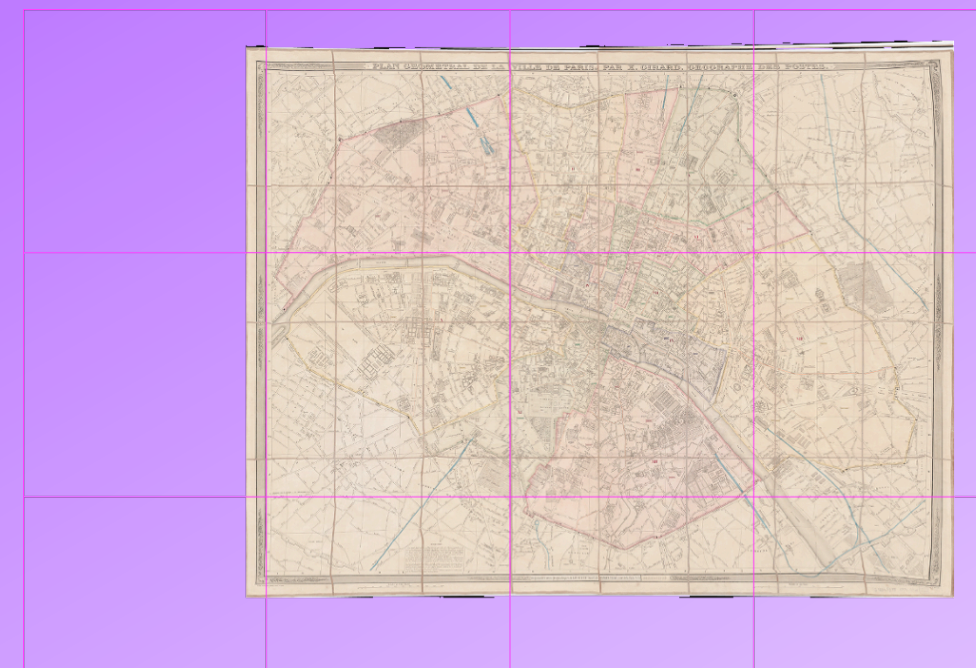
  * By definition, $z = 0$ produces a single tile covering the Earth exclusive of the polar regions (a distance of $2\pi r$).
  * Incrementing the zoom level doubles the number of tiles.

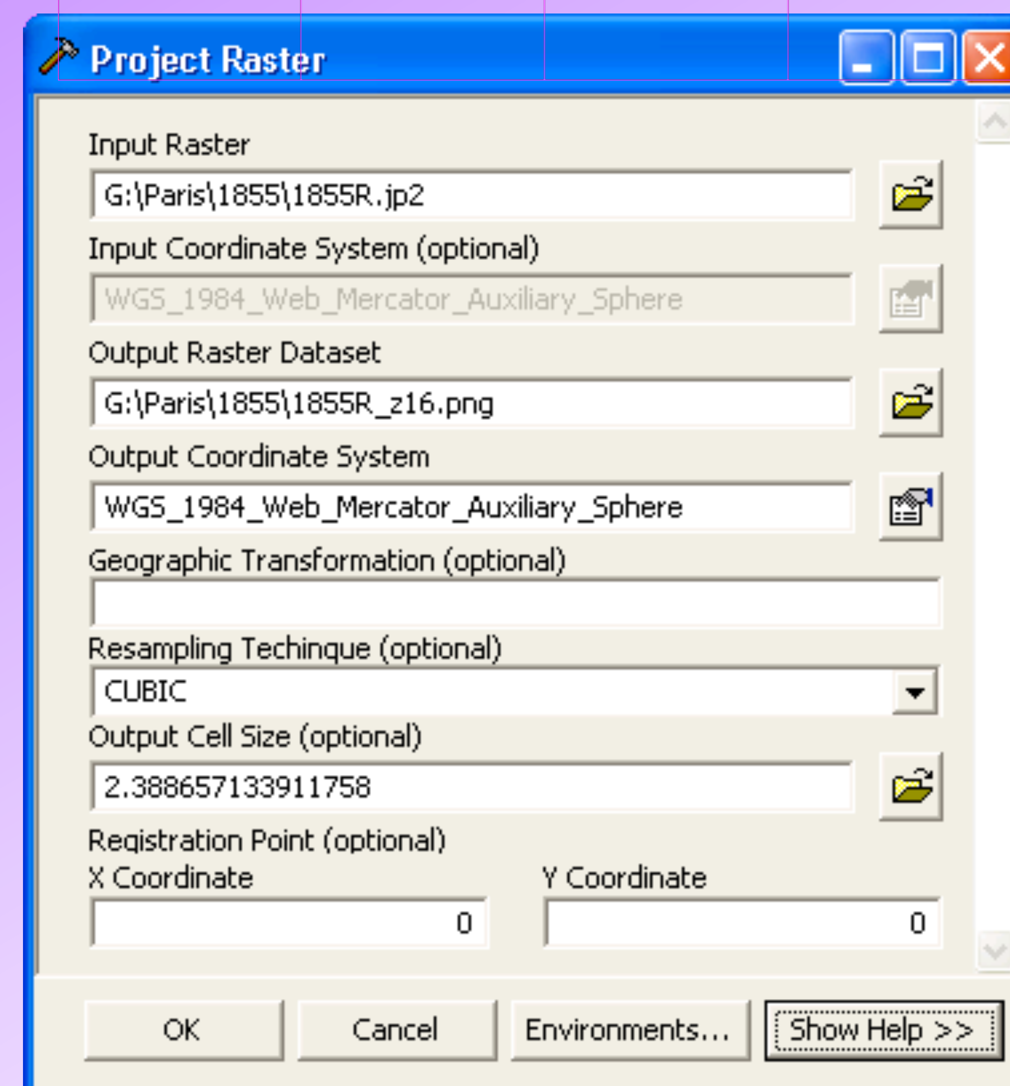
- The zoom levels for large cities like Tokyo or Paris range from about 17 (1.2 m/px) to 7 (1.2 Km/px).

Rescaling to Tile Space

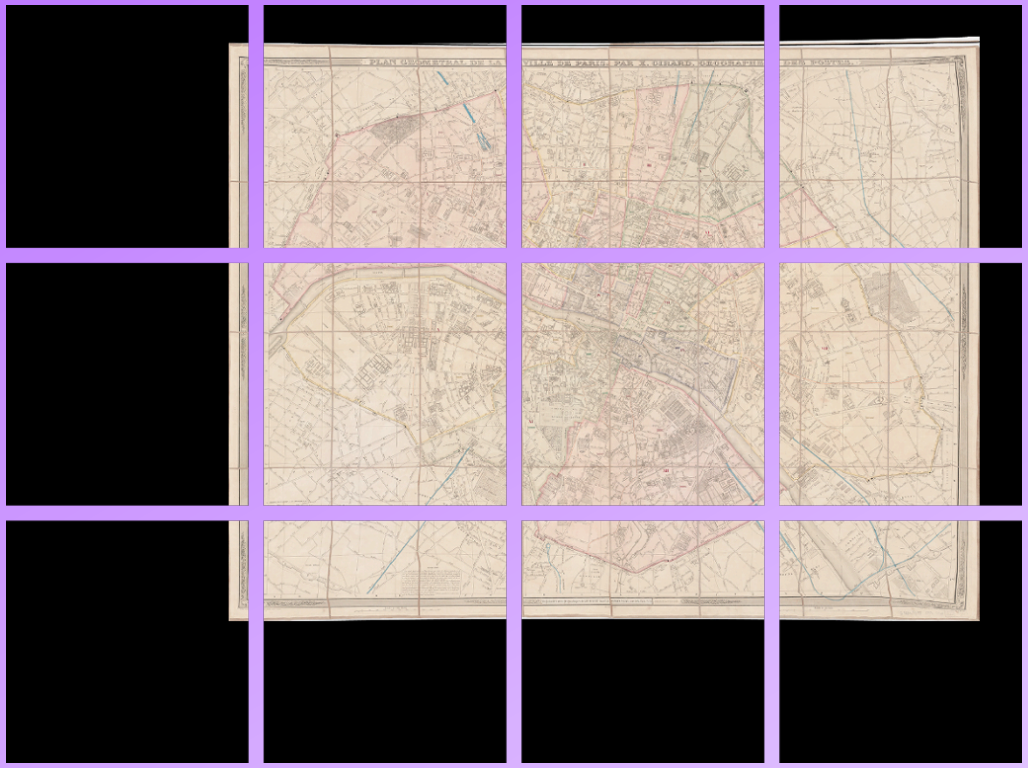
- A scanned, rectified map must be rescaled to the appropriate cell size using:
  ArcToolbox >
  Data Management >
  Projections and Transformations >
  Raster > Project Raster

- Project Raster can force a raster to a Google pixel boundary by specifying a registration point of (0, 0) — unlike Resample.





Tile Coverage



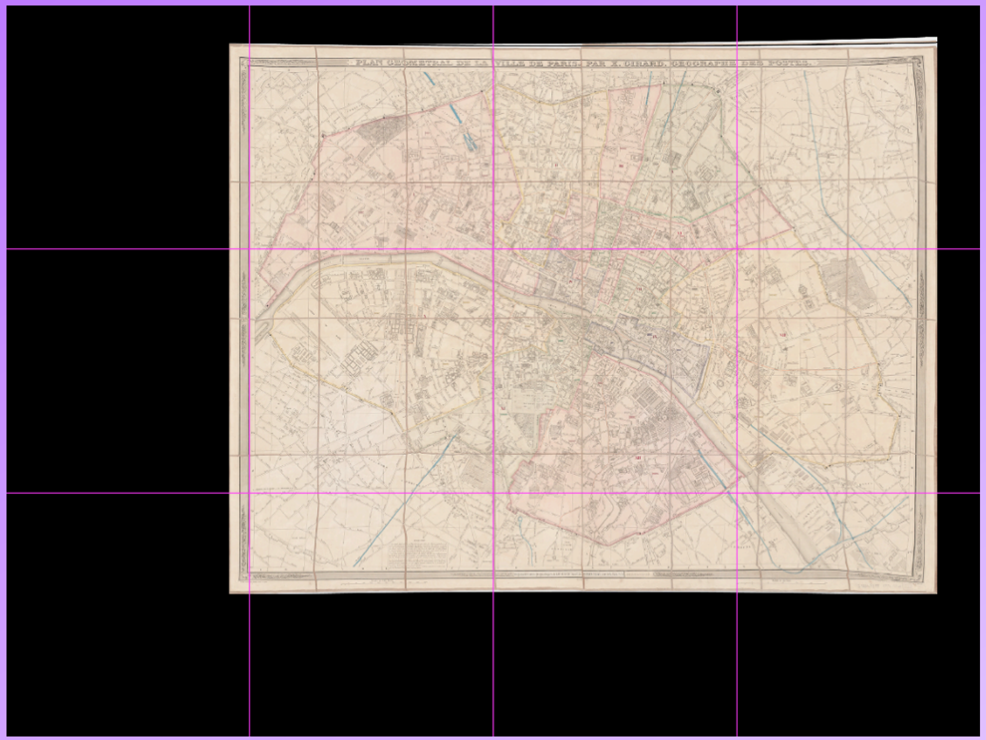
- Rescaled images typically overlap many tiles, but lie completely within one tile at the smallest scales.
- For a given zoom level, Google tiles are indexed from 0 to $2^z - 1$, west to east and *north to south*.
- For a given spherical Mercator position (lx, ly), the Google tile indices are given by:

$$tx(lx, z) = \mathrm{floor}\left(2^{z-1} \left(1 + lx / (\pi r) \right) \right)$$

$$ty(ly, z) = \mathrm{floor}\left(2^{z-1} \left(1 - ly / (\pi r) \right) \right)$$

- So, the image extent yields the tile coverage.

Extending the Image



- An image must be padded with NoData around its edge to fill it out to the extent of the covering tiles.
- The Mercator coordinates of the northwest corner of a tile (tx, ty) are given by the inverse formulae:

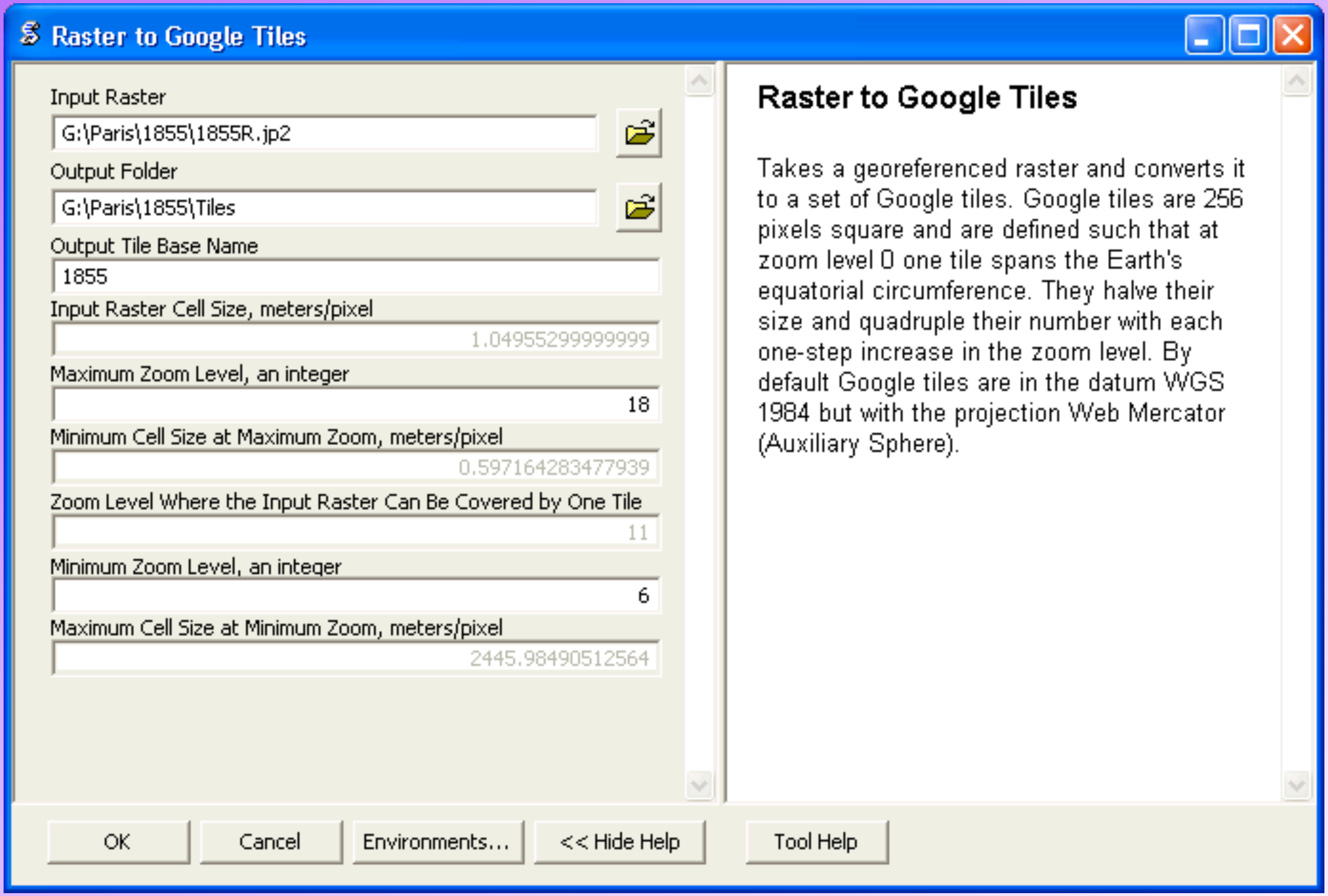
  $$lx(tx, z) = \pi r \, (tx / 2^{z-1} - 1)$$

  $$ly(ty, z) = \pi r \, (1 - ty / 2^{z-1})$$

  which can be used to calculate the padding.
- So, the covering tile indices yield the size of the extended image, always a multiple of 256 pixels.

GTiler Script

- Tiling a georeferenced and rescaled image can be effected with programs such as Photoshop, etc.



- But, to automate the process, I wrote a Python script.

GTiler Procedure

- GTiler first rescales the georeferenced image.
- Extending the rescaled image with ArcGIS is a two-step process:

  1. Create a background raster the size of the final image but filled with NoData;
  2. Mosaic the background and image together.

- The extended image is turned into tiles by clipping it multiple times.

GTiler Execution

Raster to Google Tiles

Completed

Close

<< Details

☐ Close this dialog when completed successfully

```
Executing: GTiler.py G:\Paris\1855\1855R.jp2 G:\Paris\1855\Tiles 1855 1.04955299999999 11
76.4370282851763 11 11 76.4370282851763
Start Time: Tue Dec 07 21:06:34 2010
Running script GTiler.py...
Input Raster = "G:\Paris\1855\1855R.jp2"
     Raster bands = 3
     Raster Pixel Type = 8_BIT_UNSIGNED
Output Folder = "G:\Paris\1855\Tiles"
Output Tile Base Name = "1855"
Zoom level range = [11, 11]
Cell size range = [76.4370282852, 76.4370282852]
z = 11:
     Cell size = 76.4370282852
     Creating Z Raster...
            Z Raster Extent:
                  X Range = [253971.755115, 268187.950500]
                  Y Range = [6245030.286391, 6256196.480758]
            Indices of Tiles Covering Z Raster:
                  X Range = [1036, 1037]
                  Y Range = [704, 704]
            Extent of Tiles Covering Z Raster:
                  X Range = [234814.550892, 273950.309374]
                  Y Range = [6242153.477881, 6261721.357122]
     Creating Background Raster from the Extent of the Covering Tiles...
     Mosaicking together the Background Raster and the Z Raster...
     Clipping the Extended Z Raster into tiles in "G:\Paris\1855\Tiles\1855_z11"...
            Creating tile 1855_z11-00-00.png...
            Creating tile 1855_z11-01-00.png...
End Time: Tue Dec 07 21:10:07 2010 (Elapsed Time: 3 minutes 33 seconds)
```

Contact Information

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