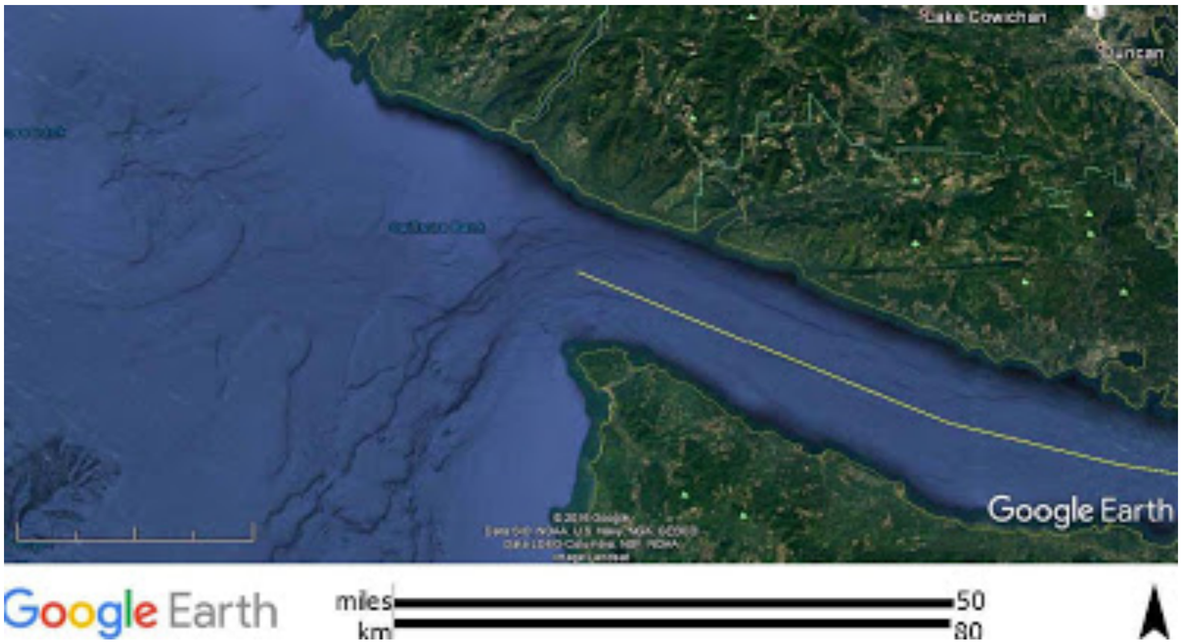
Swiftsure Bank Border Dispute

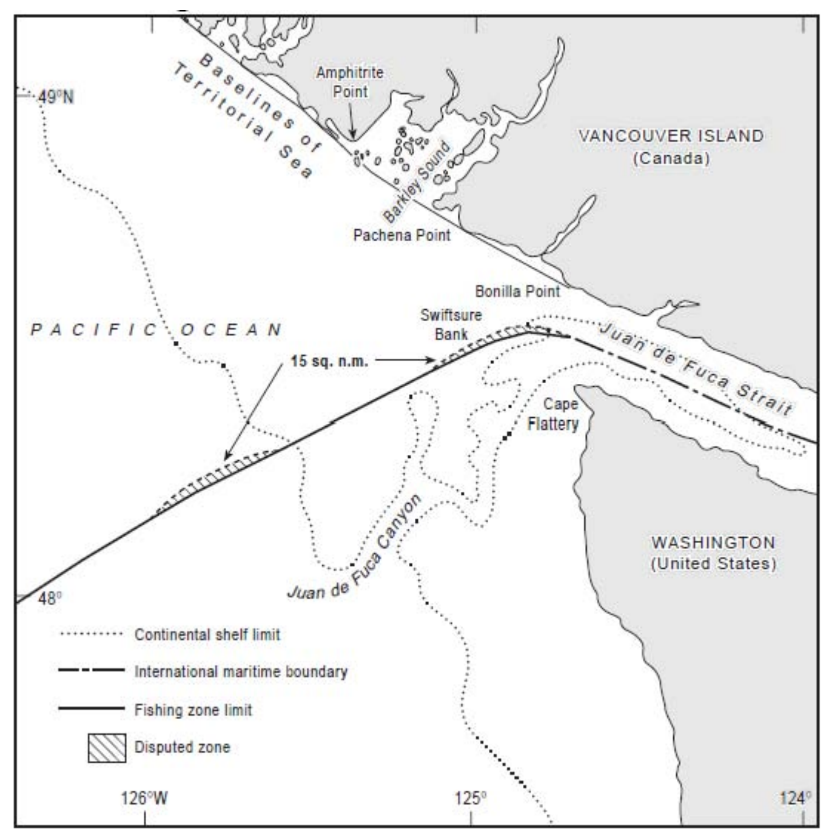


"A new border dispute arose in 1977 when nations began laying claim to coastal waters."

"Google Earth ends the U.S. - Canada boundary at the mouth of the Strait of Juan de Fuca."

"The question beyond the entrance of the strait uses the same principle as within the strait. The line is drawn equidistant between the two shores."

"Hence, the border in the ocean takes trend line to the southwest beyond the strait."



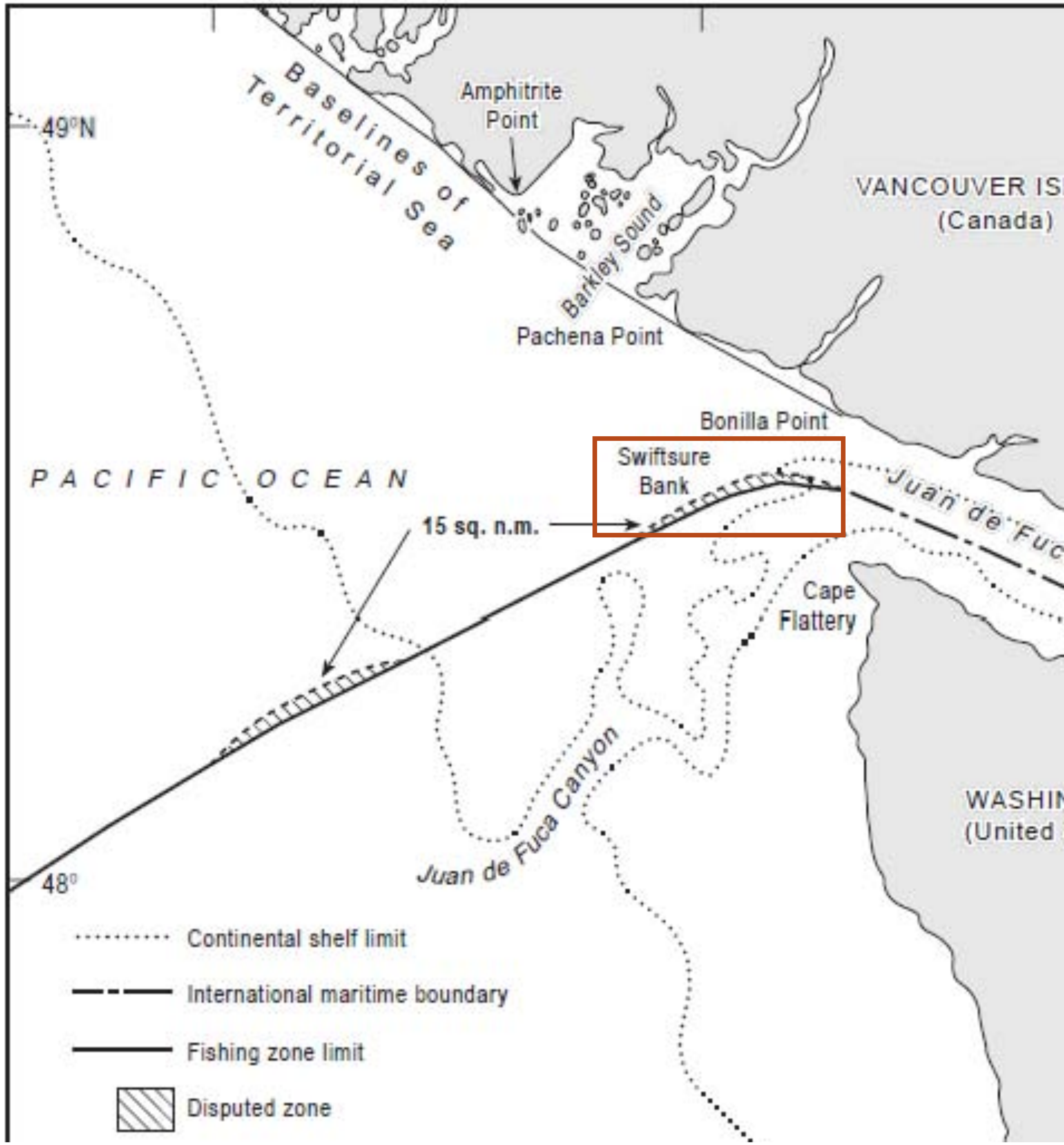
https://washingtonlandscape.blogspot.com/2016/11/swiftsure-bank-border-dispute.html

Swiftsure Bank Border Dispute

"The line is drawn equidistant between the two shores. Hence, the border in the ocean takes trend line to the southwest beyond the strait."

"The dispute has to do with where one starts to draw the line from the coast. The Americans used the low water line off the northwest coast. The Canadians used as starting point a line drawn along the Vancouver Island shore from point to point."

"Swiftsure is touted by fishing charter folks on both sides of the border."



Swiftsure Bank Border Dispute

"The line is drawn equidistant between the two shores. Hence, the border in the ocean takes trend line to the southwest beyond the strait."

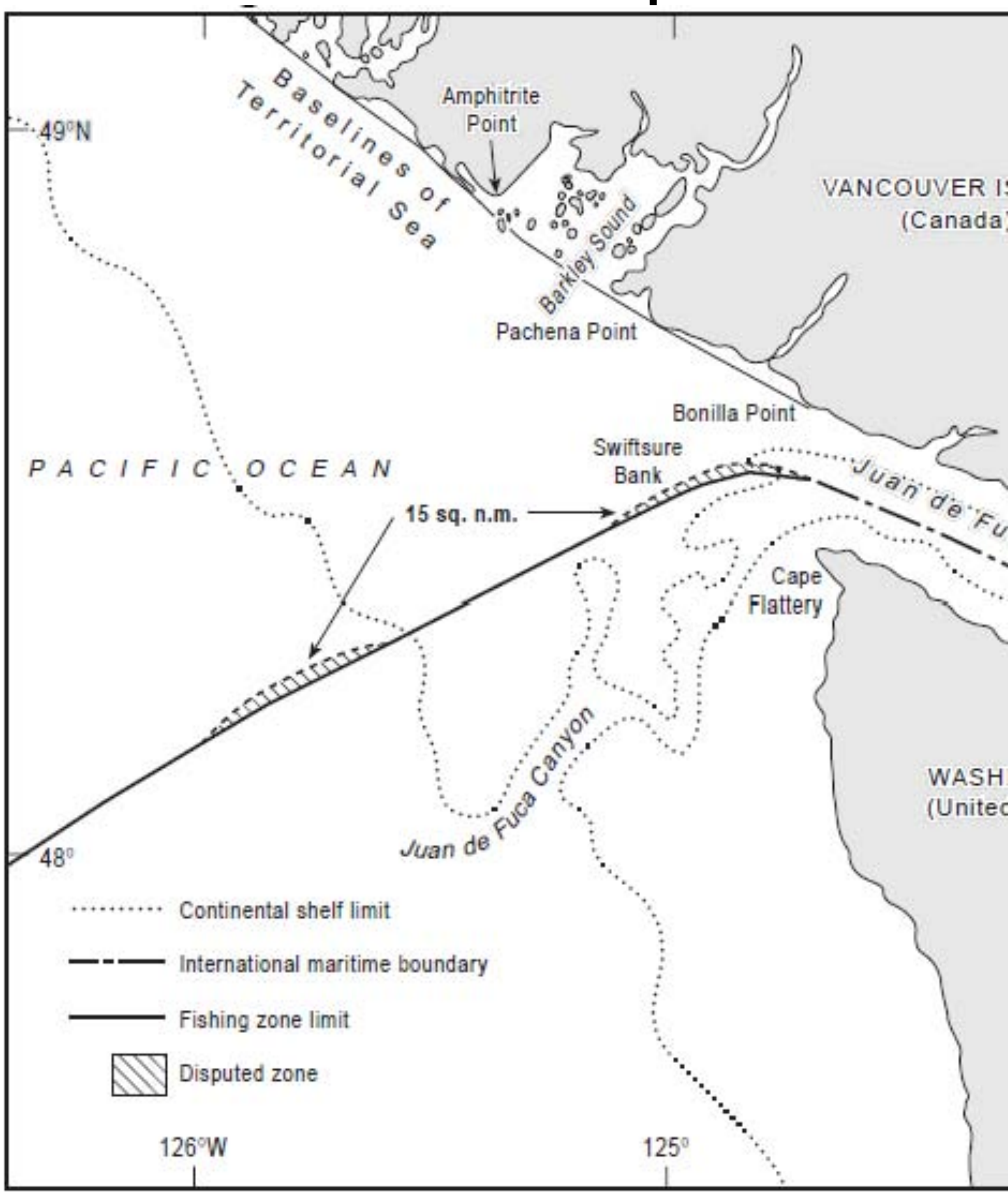
Today's Question:

Even if we can agree on the 'equidistant' method…

Even if we can agree on which coastlines to use…

How does one draw such a line?

Note for the curious: Delimitation of maritime borders is not just a technical issue! See, e.g., http://www.un.org/Depts/los/nippon/unnff_programme_home/fellows_pages/fellows_papers/dundua_0607_georgia.pdf

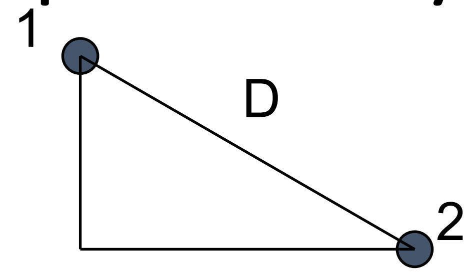


Geography 360
November 20, 2016

Spatial Analyses Involving Distance

1. *Today's item of interest: Drawing the US/Canada Maritime Border*
2. *Questions and Announcements*
3. *Some Spatial Analyses Involving Distance*
   - Distance measures
   - Spatial Joins
   - Thiessen Polygons / Voronoi Diagrams

Distance: At the heart of much of spatial analysis.



GIS default: "Euclidean" distance in an 'absolute' or 'Newtonian' space.

Use Pythagorean theorem for distance:

$$D = \sqrt{\left(x_2 - x_1\right)^2 + \left(y_2 - y_1\right)^2}$$

But what is 'distance' when your points are not on a (Euclidean) plane?

Spherical case: Use "Great circles" as your "geodesics"

Using the Haversine formula for distance:
(You don't need to know the formula!)

Where:
ϕ are latitudes,
λ are longitudes,
R is the earth's radius

$a = \sin^2(\Delta\phi/2) + \cos(\phi_1)*\cos(\phi_2)*\sin^2(\Delta\lambda/2)$

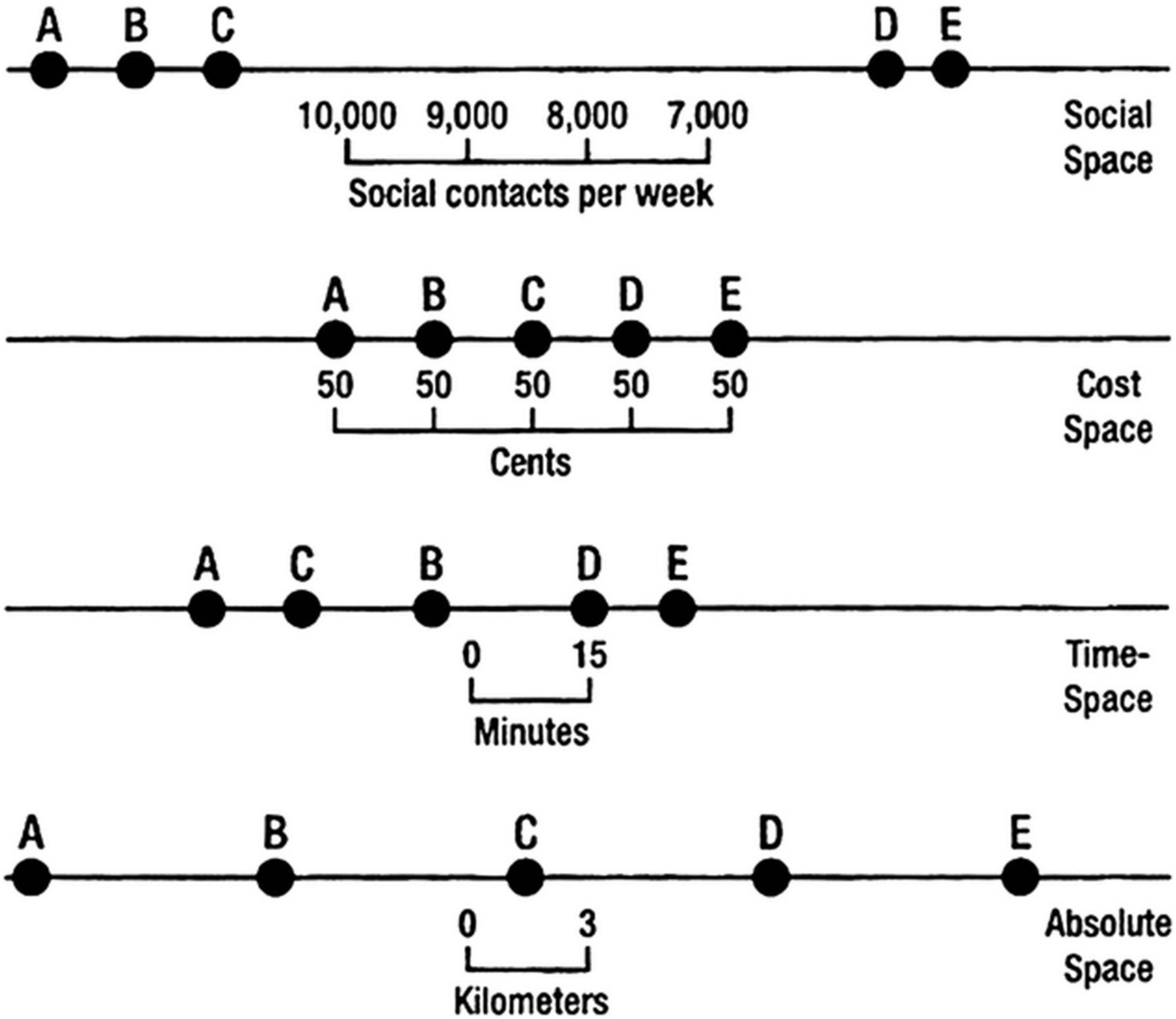
$c = 2*\mathrm{atan2}(\sqrt{a}, \sqrt{(1-a)})$

Then, distance (on a sphere) = R*c

(see: http://www.movable-type.co.uk/scripts/latlong.html and http://blogs.law.harvard.edu/cqtwo/2009/09/08/whats-the-cheapest-flight-west-from-la/)

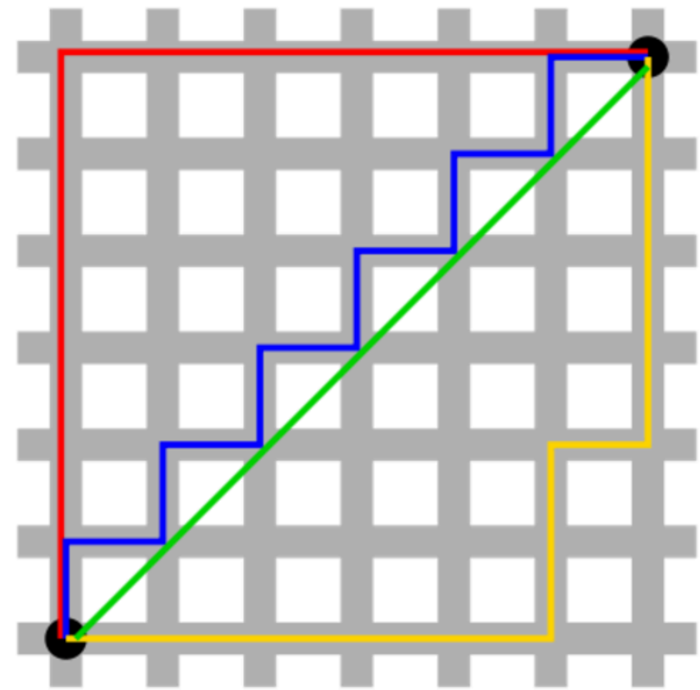
The most relevant distance measures are often *sociospatial:*

They do not use the simple space given us by Euclid and Newton, even if that's the default commercial GIS gives us.



Source: Abler et al., 1971.

Manhattan Distance, or *Taxicab Geometry*



Taxicab geometry versus Euclidean distance: In taxicab geometry, the red, yellow, and blue paths all have the shortest length of 12. In Euclidean geometry, the green line has length $6\sqrt{2} \approx 8.49$, and is the unique shortest path.

https://en.wikipedia.org/wiki/Taxicab_geometry

What can you do with 'distance'?

Spatial Joins

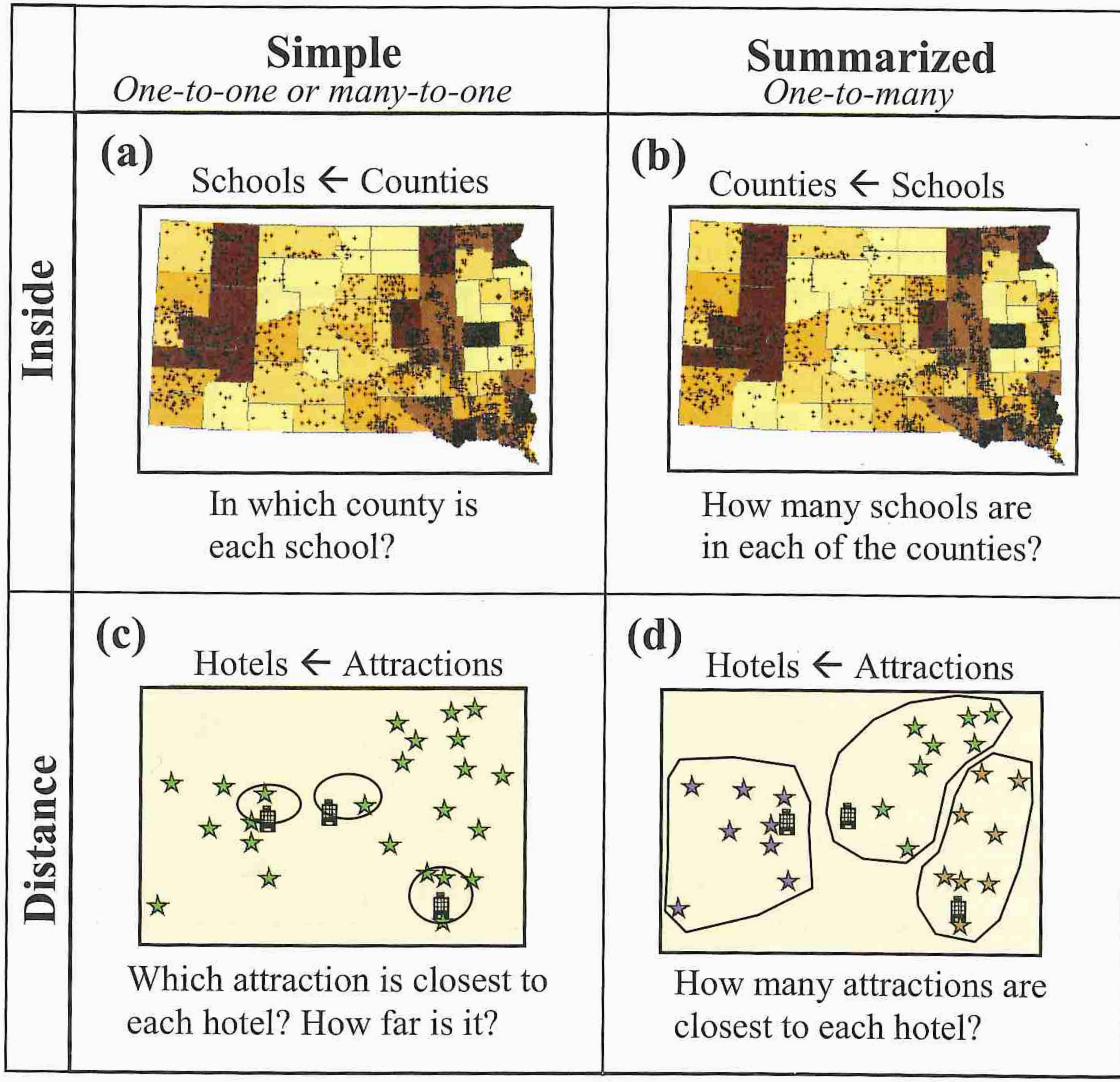


Fig. 9.5. Matrix of spatial joins resulting from different choices of destination table, spatial condition (inside or distance), and cardinality

From Price 2016 in your Tutorial

Distance spatial joins: ‘Simple’

(a)

NAME	POP2007
Adair Village	594
Adams	309
Adrian	144
Albany	44957
Aloha	48048

NAME	TYPE
Astoria Regional	Regional
Eastern Oregon Regional	Regional
Klamath Falls International	International
Mahlon Sweet Field	
Mcnary Field	

NAME	POP200	airports_NAME	TYPE	Distance
Adair Village	594	Mcnary Field		31539
Adams	309	Eastern Oregon Regional	Regional	23161
Adrian	144	Eastern Oregon Regional	Regional	258469
Albany	44957	Mcnary Field		31420
Aloha	48048	Portland Intl	Internatio	24056

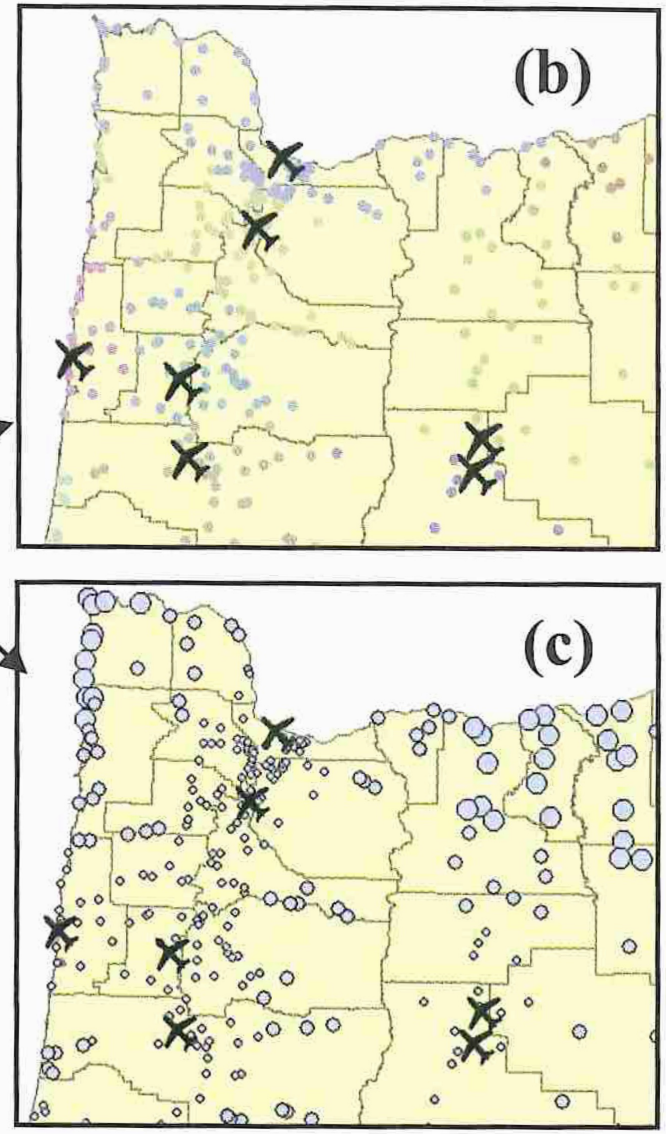


Fig. 9.2. A distance spatial join between cities and airports: (a) joined tables; (b) unique values map based on the airport name; (c) graduated symbol map based on distance

From Price 2016 in your Tutorial

Distance spatial joins: ‘Summarized’

In Figure 9.2, imagine reversing the join so that airports is the destination layer and cities is the source layer. Each airport has many cities that are closer to it than to any other airport. Instead of attaching the single closest city, a summarized join finds all of the cities closer to the airport and calculates one or more statistics, for example, the sum of the city populations. Then for each airport we would know the total number of people being served by that airport (i.e., the sum of the populations of the cities that are closer to that airport than to any other). Figure 9.4a shows the

NAME	TYPE	Count	Sum_POP
Rogue Valley Intern	Interna	22	192645
Astoria Regional	Region	14	34898
Mahlon Sweet Field		23	266623
Klamath Falls Intern	Interna	8	46110
North Bend Muni	Munici	21	99896

(a)

(b)

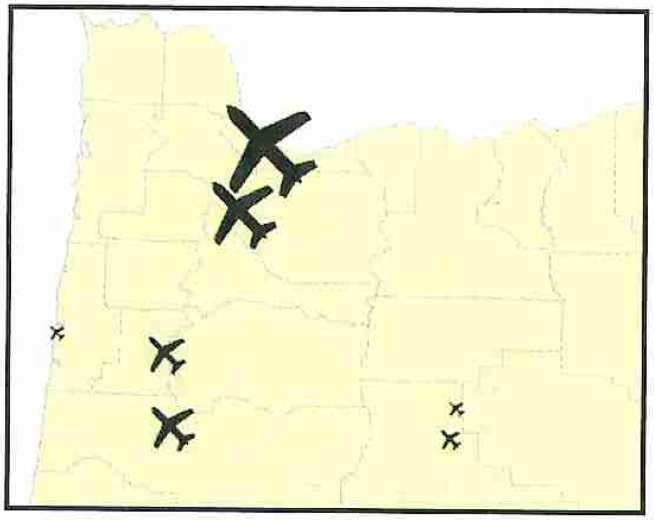


Fig. 9.4. A summarized spatial join: (a) output table; (b) map based on sum of population served

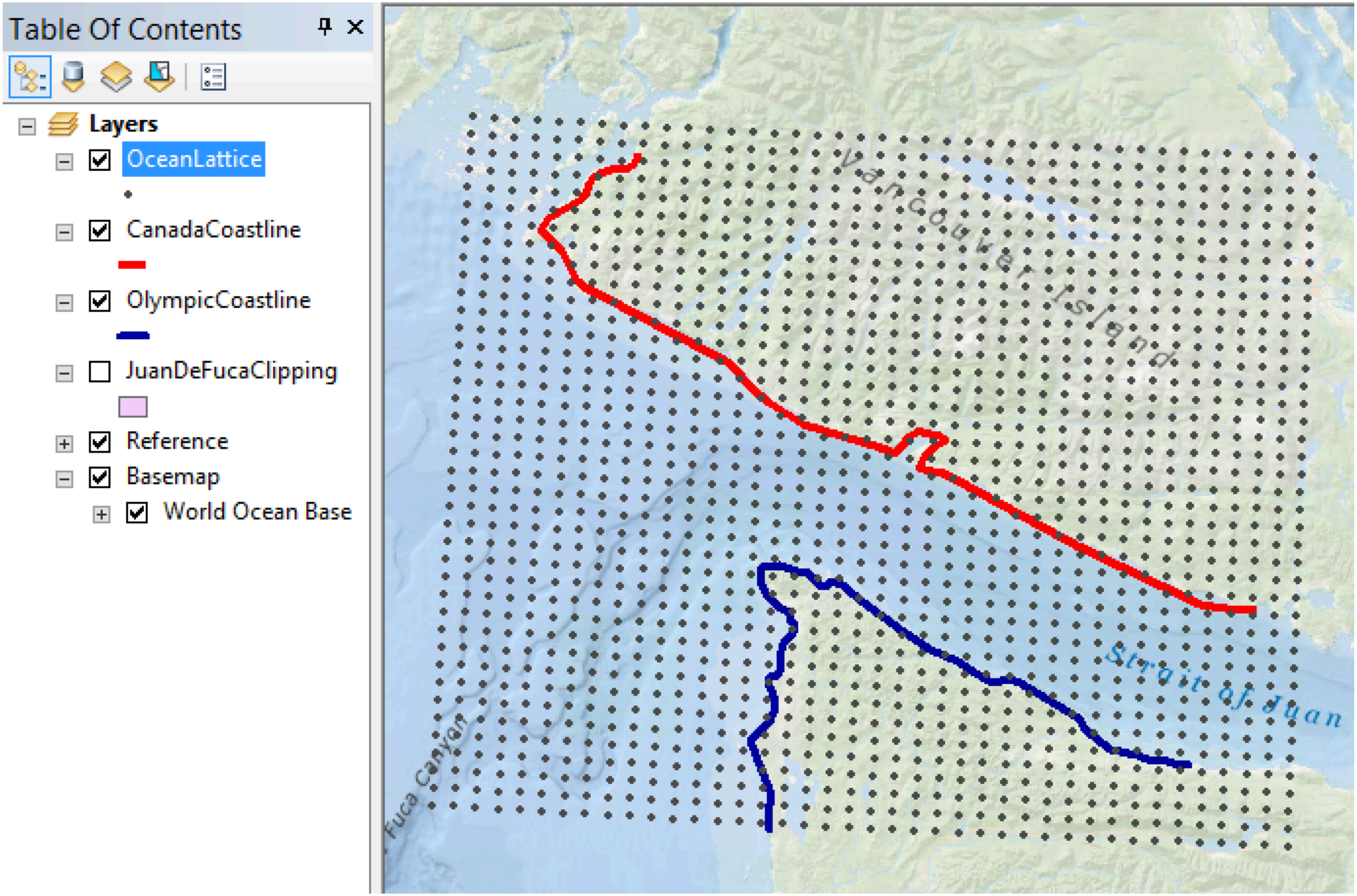
From Price 2016 in your Tutorial

One way to draw the maritime border: *Using simple distance spatial joins*

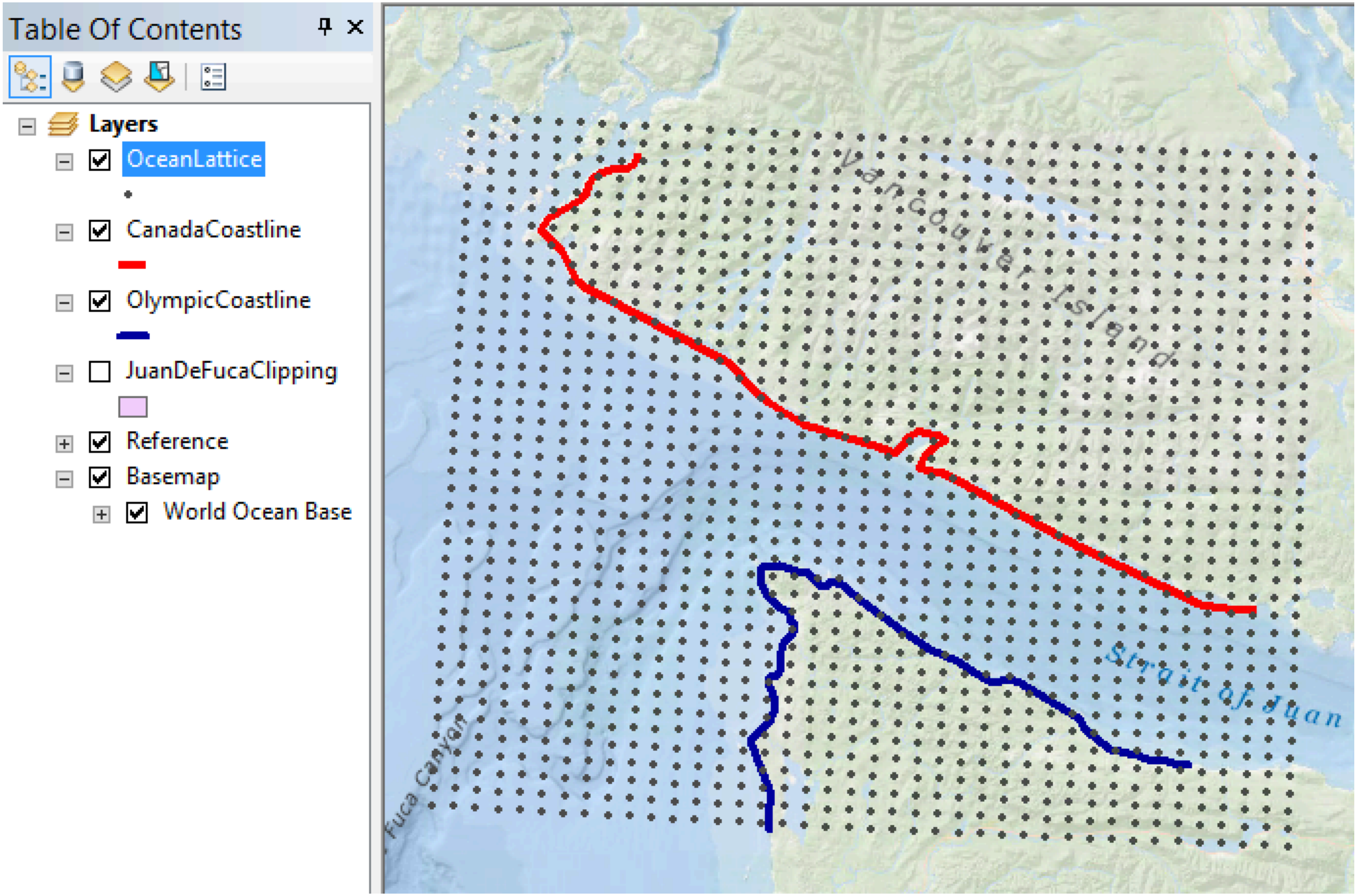
From Price 2016 in your Tutorial

Table 9.1. Join types are available for each combination of feature geometries in a spatial join. The second feature type is the destination layer in each case.

Geometry Type	Join Type	Example
Points to points	Simple distance	Find the hospital closest to each town.
	Summarized distance	Find all the towns closer to one hospital than to any other hospital.
Lines to points	Simple distance	Find the water main closest to the proposed building site.
	Summarized inside	Find the total voltage of all electric lines meeting at a substation.
Polygons to points	Simple inside	Find the soil type that underlies each gas station.
	Simple distance	Find the lake that is closest to each campground.
Points to lines	Simple distance	Find the elementary school that is closest to each residential street.
	Summarized distance	Find the total number of septic systems closer to a particular stream than to any other stream.
Lines to lines	Summarized inside	Find the number of roads that cross each river.
	Simple inside	Give a section of hiking trail the attributes of the road it follows for a short distance.
Polygons to lines	Summarized inside	Give a stream the average erosion index of the soil types it crosses.
	Simple distance	Find the lake closest to a hiking trail or the national park within which a road lies.
Points to polygons	Summarized inside	Find the total number of schools and students in a county.
	Simple distance	Find the town that is closest to a lake. A point inside a polygon is given a distance of zero.
Lines to polygons	Summarized inside	Find the total number of rivers crossing a state.
	Simple distance	Find the carrying capacity of the closest power lines to an industrial site.
Polygons to polygons	Summarized inside	Find the total population of all counties that intersect part of a watershed.
	Simple inside	Find the county within which a lake falls completely.



First draw a lattice mesh of points using the 'Create Fishnet' tool.
Then, (use spatial joins to) see which coastline each point is closest to!



We will use two simple distance spatial joins:

1. Linking each Ocean Lattice Point to the closest (point on the) CanadaCoastline.
2. Linking each Ocean Lattice Point to the closest (point on the) OlympicCoastline.

We will use two simple distance spatial joins:

1. Linking each Ocean Lattice Point to the closest (point on the) CanadaCoastline.
2. Linking each Ocean Lattice Point to the closest (point on the) OlympicCoastline.

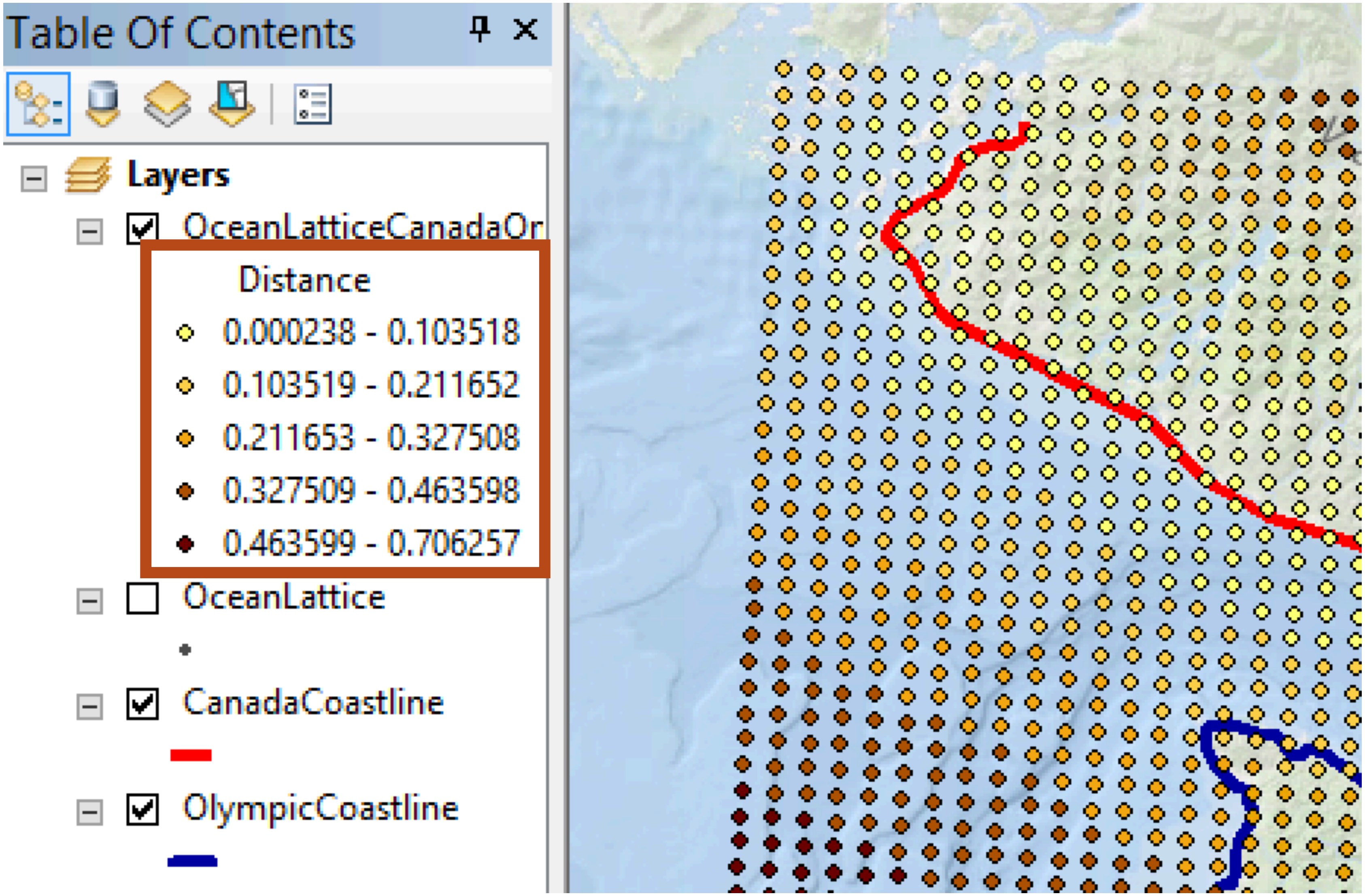
But what does that mean?

- Those are actually each simple distance joins that join a line (a coastline layer) to points (the ocean lattice points).
- …But doesn't each coastline layer have only one line?
- YES. In doing each of the spatial joins, it therefore isn't in question which coastline will be joined to the point. The goal is to have the *shortest distance* between the point and the closest point on a particular coastline be added as an attribute to each lattice point. We do it twice, once for each coastline, to get the shortest distances from each point to each coast as separate attribute values.
- And then we can compare distances from each point to the (nearest point) on each coastline—by subtracting them.
- Where the distances are equal, the difference is 0. That is the border line. Visually, you can infer that on a map if you classify all points with the differences in distances > 0 to be one color and all points where the differences in distance are < 0 to be another color. I have done that for you two slides below from here.
  - If you want the border line itself as a line data layer, you could use a tool from the "interpolation" toolbox in ArcMap (such as "IDW") to create a raster approximation of the differences-of-distances surface, then use the "Contour List" tool to get the differences-of-distances = 0 contour line. That is a smoothed estimation of the border.
- You'll see most of this over the next few slides.

Note: I could have accomplished most of the above via a single spatial join if I had a layer that had both US and Canadian coastlines in it. Then, joining those coastlines to the points would allow each point to be associated with the closest coastline. That's perhaps a cleaner way of doing some parts of this, though it may have been a little less straightforward to then create a quality line layer containing the actual borderline using that method, so I didn't demonstrate it to you here.

Ok, interesting enough, but what do I need to know how to do for the quiz?

- Don't worry--you don't need to be able to remember (or figure out) how to use spatial joins to draw a border on the quiz! This is just me trying to provide you with an example that goes beyond the examples in the tutorials. I wanted to show how basic GIS operations can help answer real-world problems that don't immediately seem to be reducible to something like a spatial join (here, the insight that allowed the spatial join to be a part of the solution was really the idea that you can add a mesh of points).
- For the quiz, you should have a sense for the different types of spatial joins and for when you might want to use them. You may need to be able to provide examples. Can you compare and contrast how spatial joins and non-spatial attribute joins work? Can you compare and contrast when you would use an overlay operation versus when you would use a spatial join? Your tutorial should help on this. Your study guide will speak to this in several ways, as well. Your final project may also help you consolidate this learning, depending on what you seek to do. As you plan your project, think about how spatial joins might be useful to you! How could spatial joins let you bring a new type of information (from a different kind of layer) into your analysis?



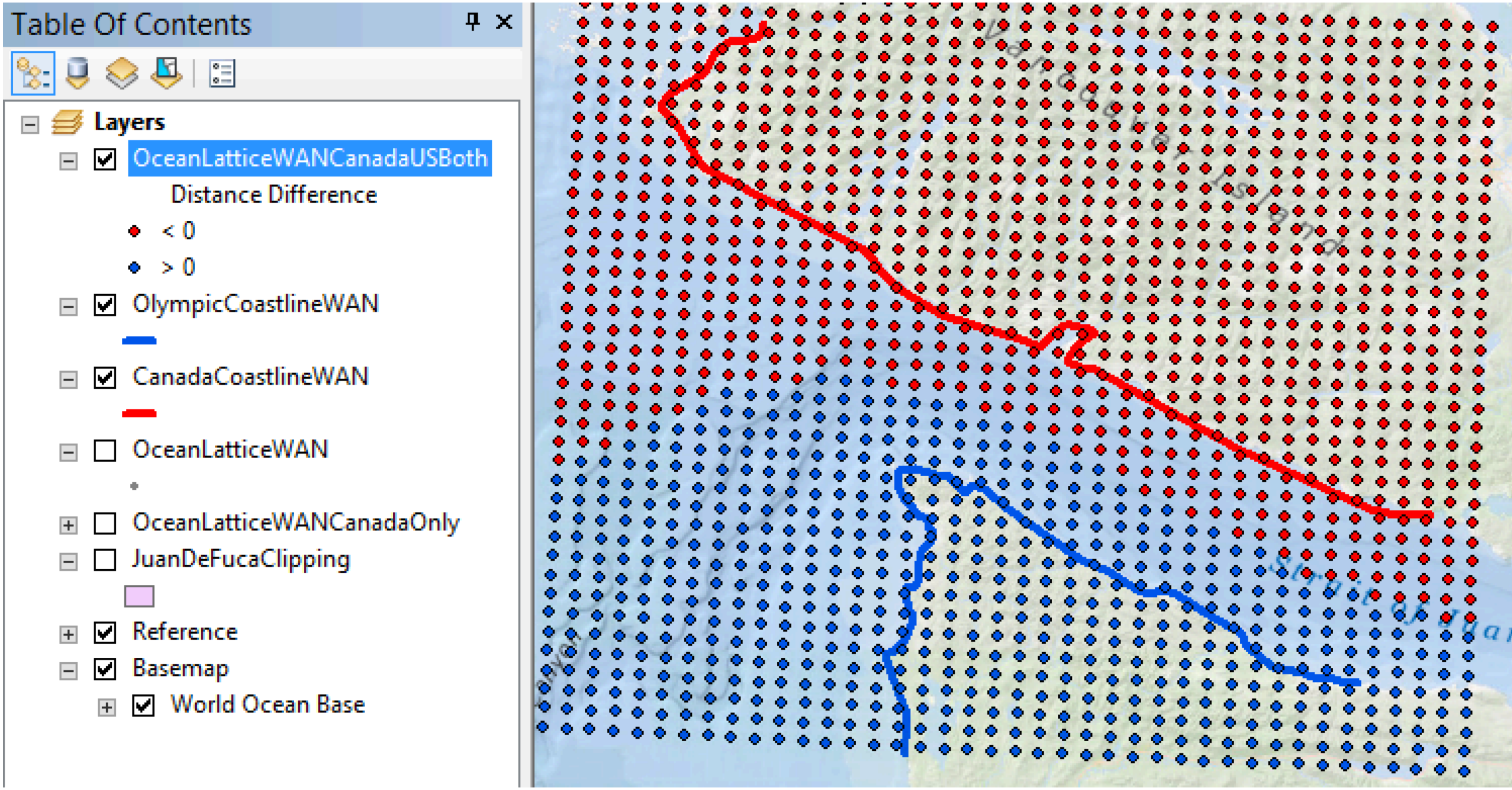
Always check your work to see if it makes sense.

Here, my data frame was in State Plane Washington North…

But these numbers are in degrees, not in feet.

What went wrong? My data files were stored in lat-long.

To fix, I used the 'Project' tool to reproject all datafiles to State Plane Wash. N.



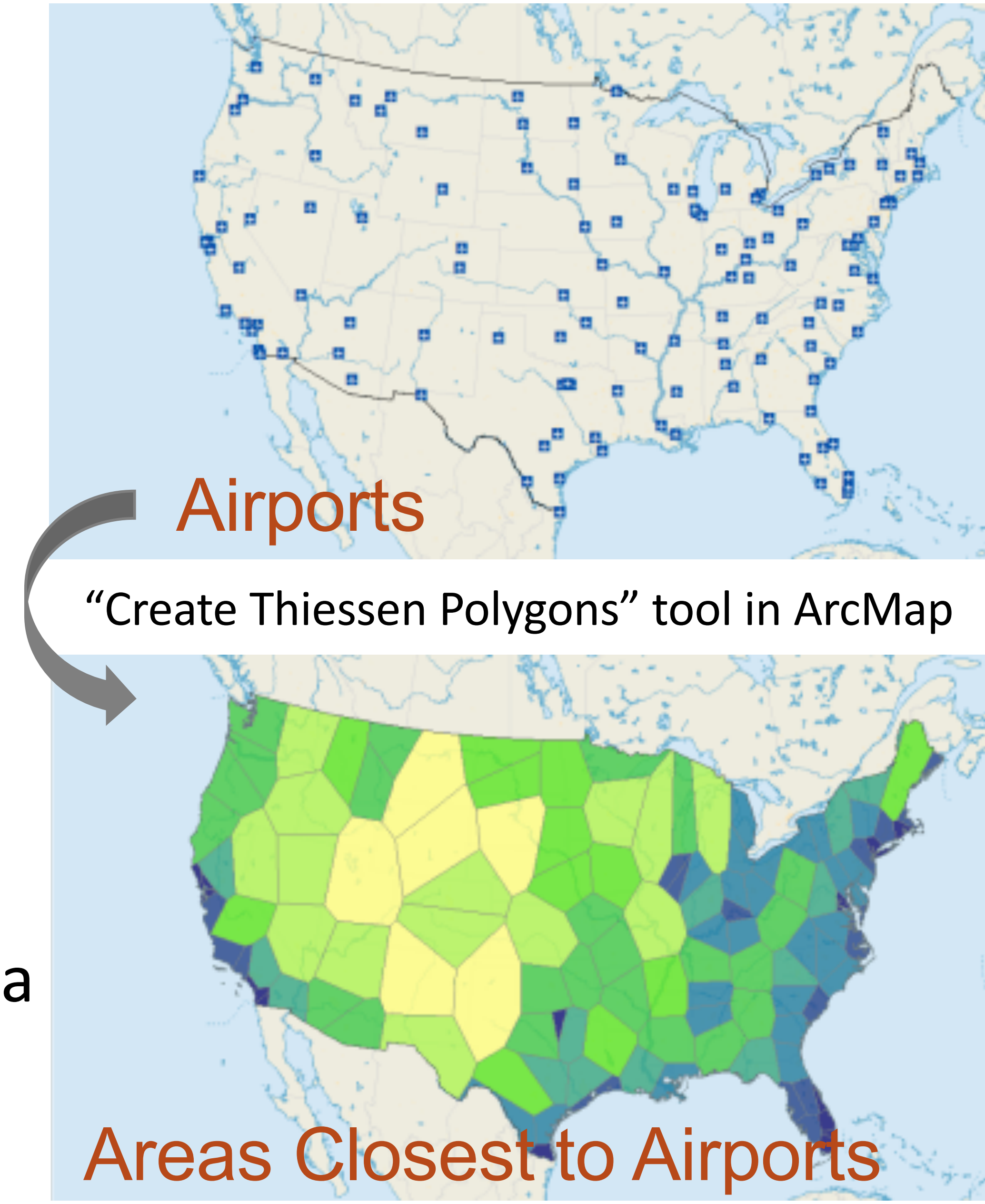
Here I have:

- Done the simple distance joins
- Used ‘Field Calculator’ to subtract the two distances from each other.
- The border is where the distances are equal == the difference is 0!

Another spatial analysis approach using distance:

Find the ‘Thiessen Polygons’ for a set of points.

(also called the Voronoi diagram)



http://gisgeography.com/voronoi-diagram-thiessen-polygons/

Thiessen Polygons:

“Polygons generated from a set of sample points. Each Thiessen polygon defines an area of influence around its sample point, so that any location inside the polygon is closer to that point than any of the other sample points.”

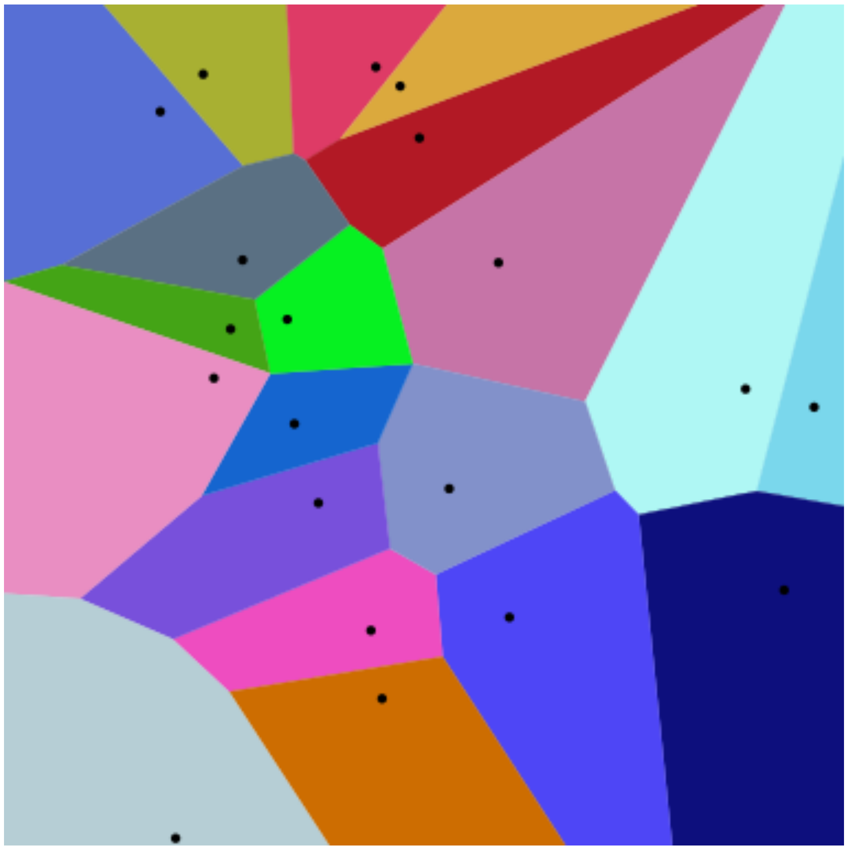
http://support.esri.com/other-resources/gis-dictionary/term/Thiessen%20polygons

Uses include:

- Finding facility service areas
- Finding places for new facilities
- Estimating an average value over a surface
- Lots more:
  https://en.wikipedia.org/wiki/Voronoi_diagram#Applications

You can change what ‘distance’ you are using to calculate Thiessen Polygons / Voronoi Diagrams.

[Euclidean distance](#) versus... [Manhattan distance](#)



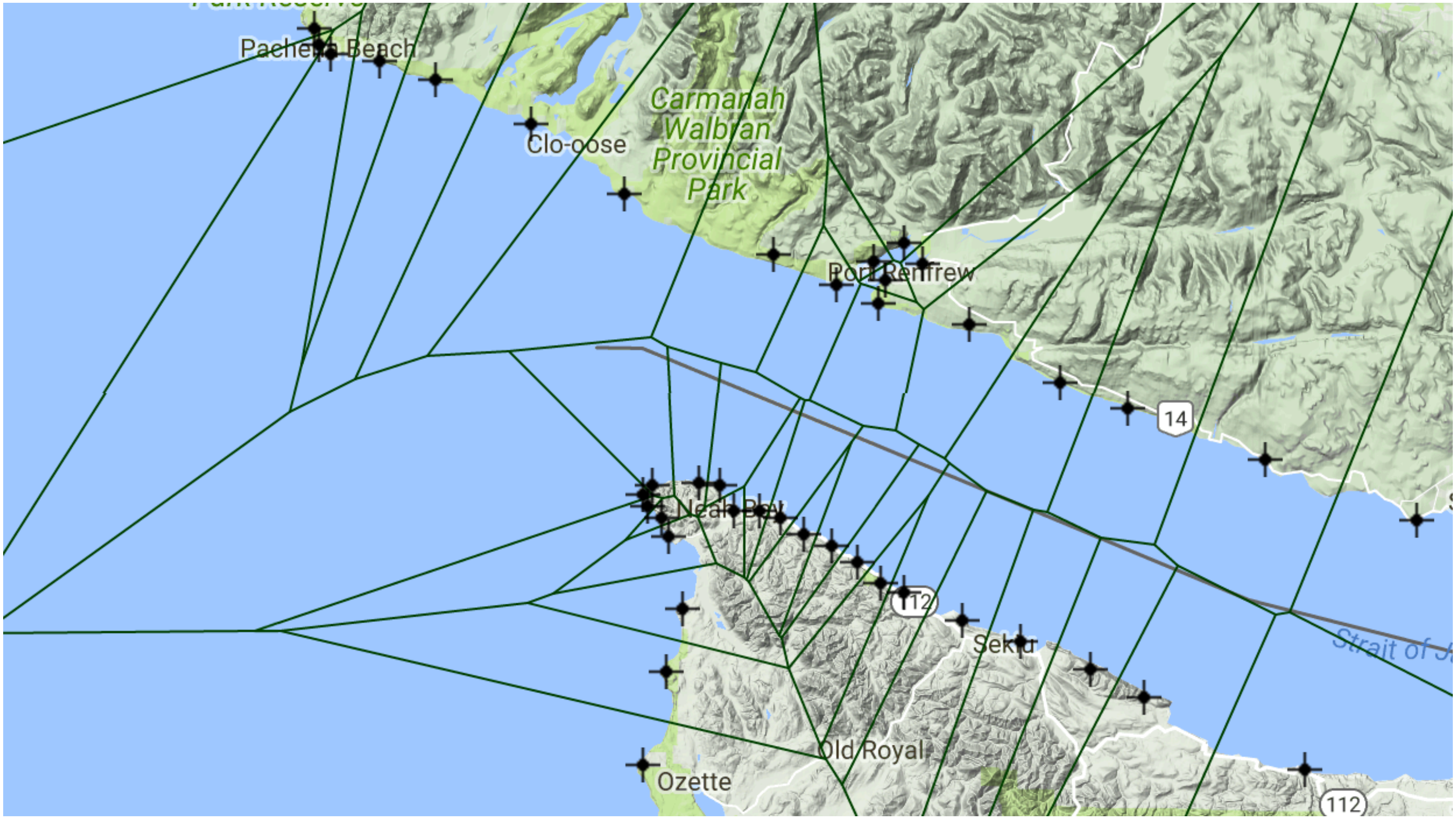
World Airports Spherical Voronoi:
https://www.jasondavies.com/maps/voronoi/airports/

Thiessen Polygons (or Voronoi diagram) Interactive Examples to Learn From:

- Abstract and interactive:
  https://bl.ocks.org/mbostock/4060366

- Drawing the points for your own spherical-distance Voronois on a Mercator map:
  http://lpetrich.org/Science/GeometryDemo/GeometryDemo_GMap.html

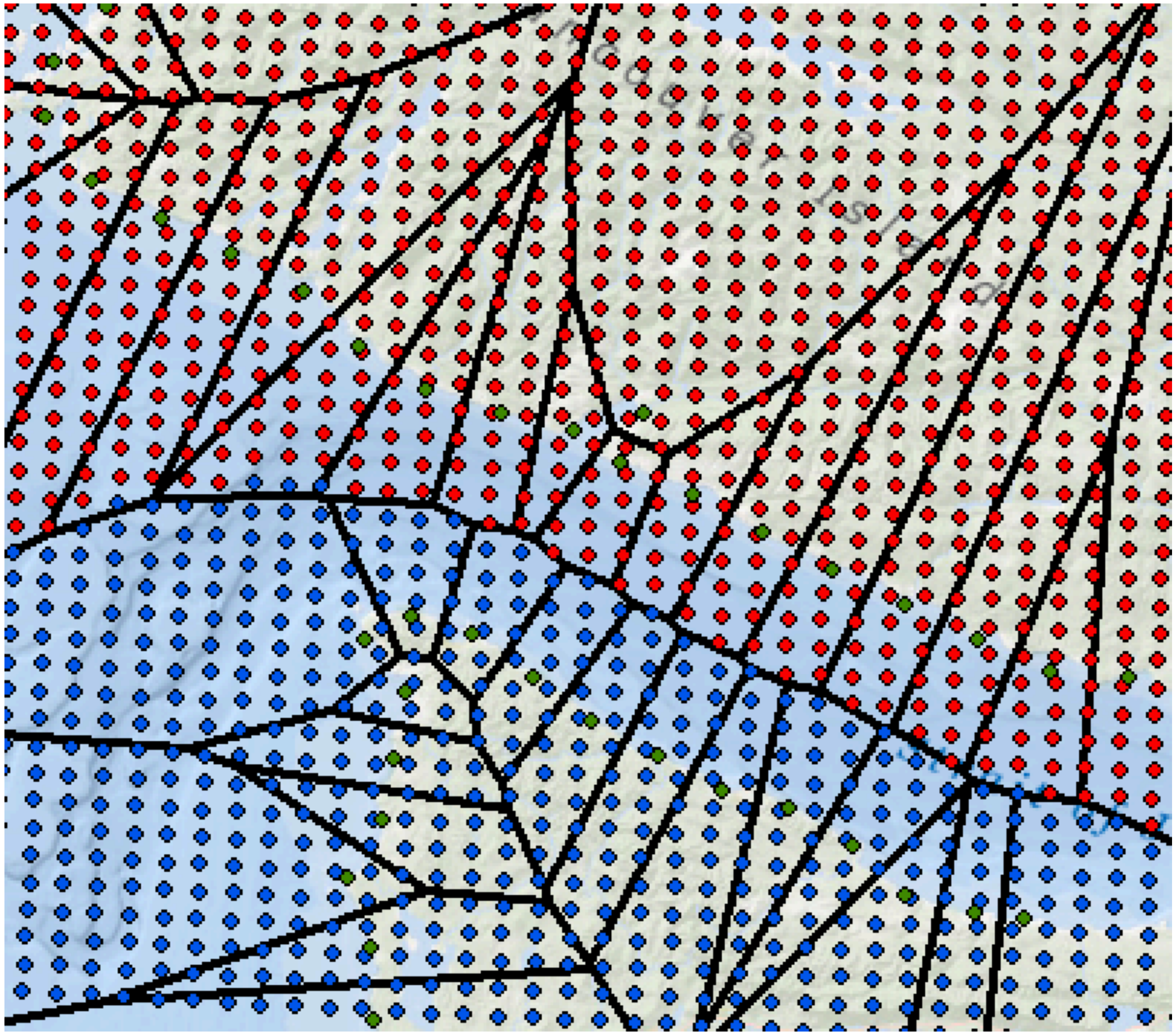
Drawing the maritime border: Where the Thiessen Polygons meet



Drawn using: http://lpetrich.org/Science/GeometryDemo/GeometryDemo_GMap.html

Optional Challenge: Can you reproduce the Swiftsure Bank dispute using this interactive tool?

Drawing the maritime border: Spatial Joins vs. Thiessen Polygons



Just for your information (not for any quizzes):

These are similar results, but the Thiessen Polygon approach is likely more efficient, algorithmically.

Thiessen Polygons: O(n log n) where there are n points in the shorelines. See: https://en.wikipedia.org/wiki/Fortune%27s_algorithm

Spatial joins: O(n x y) if x is the number of longitudinal lattice points and y, the # of latitudinal points.