1. Introduction

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5. Why doesn’t my data show up (where I expect it)?

6. OK, now why don’t my layers line up?
Please, just make it stop
Introduction
Who is Ian?

- A geospatial consultant at Astun Technology
- A developer of GeoTools and GeoServer
- Someone who helps people who are wrong on the internet
Why do I (we) need to know this stuff?
What every GIS user should know about projections

Why do I (we) need to know this stuff?

**Projections, Coordinate Reference Systems, and all that Jazz**

- Projected vs. Geographic
- Coordinate Reference System (CRS)/Spatial Reference System (SRS)
- Spherical, Ellipsoid, Geoid, Datum
Map Projection(s)

In cartography, a map projection is a way to flatten a globe’s surface into a plane in order to make a map. This requires a systematic transformation of the latitudes and longitudes of locations from the surface of the globe into locations on a plane. All projections of a sphere on a plane necessarily distort the surface in some way and to some extent. Depending on the purpose of the map, some distortions are acceptable and others are not; therefore, different map projections exist in order to preserve some properties of the sphere-like body at the expense of other properties.

Wikipedia
Geoids and Datums

(via Dragons8mycat's blog)
What every GIS user should know about projections

Why do I (we) need to know this stuff?

Common Projections

Plate Carrée

Web Mercator
Local Projections

OSGB National Grid

OSGB National Grid
Seriously, I just want to draw a map!
Consider the newly, independent Republic of Sussex, it has acquired missiles with a range of 1000km and 5000km, where can it threaten?
What every GIS user should know about projections

Seriously, I just want to draw a map!

Easy (but wrong)
What every GIS user should know about projections

Seriously, I just want to draw a map!

Convert degrees to metres?

- Everyone Wikipedia knows that 1 degree is 111 km
- So 1000km = 1000/111km = 9.009009 degrees
Wrong answer
So I need metres - Web Mercator!
Still not right?
What every GIS user should know about projections

Seriously, I just want to draw a map!

Centre the projection on Sussex
What every GIS user should know about projections

Seriously, I just want to draw a map!
Conclusions

- **Never** calculate a buffer in degrees
- **Never** do any geographical analysis in Web Mercator
- Try to find an equal area projection if **and only if** your process is related to the area of the unit
Spherical Geometry Fun
Which line is shortest?
Distances

- On a Plane
  - Given two points \((x_1, y_1)\) and \((x_2, y_2)\)
  - \[ d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \]

- On a Sphere
  - Given two points \((\lambda_1, \phi_1)\) and \((\lambda_2, \phi_2)\)
  - \[ \Delta \sigma = \arctan \frac{\sqrt{(\cos \phi_2 \sin(\Delta \lambda)^2 + (\cos \phi_1 \sin \phi_2 - \sin \phi_1 \cos \phi_2 \cos(\Delta \lambda))^2)}}{\sin \phi_1 \sin \phi_2 - \cos \phi_1 \cos \phi_2 \cos(\Delta \lambda)} \]
  - \[ d = r \Delta \sigma \]

- On an Ellipsoid
How many degrees do the angles of a triangle sum to?

- Consider the WGS:84 points:
  - POINT(0 0)
  - POINT(90 0)
  - POINT(0 90)
A right angle triangle?
What every GIS user should know about projections

Spherical Geometry Fun

Or a right angle in every corner?
Conclusion

- Spherical geometry will make your head hurt
- There is a reason Euclid (and everyone else) avoided it
- Where possible transform to a local cartesian projection
- Otherwise be very careful with your assumptions
- Use some else’s code - Do Not Write this yourself
What every GIS user should know about projections

Why doesn’t my data show up (where I expect it)?
What every GIS user should know about projections

Why doesn’t my data show up (where I expect it)?

Shall we play a game?

- Where is (51.0, 0.0)?
- Is it different than (0.0, 51.0)?
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Why doesn't my data show up (where I expect it)?
What every GIS user should know about projections

Why doesn’t my data show up (where I expect it)?

So nothing - without Metadata!

- EPSG:4326 (WGS84, LAT/LON)
- EPSG:4326 (WGS84, LON/LAT)
- EPSG:2163 (US National Atlas)
- EPSG:32717 (WGS84-UTM17S)
- EPSG:31287 (MGI/ Austria Lambert)
- EPSG:3857 (Web Mercator)
What every GIS user should know about projections

OK, now why don’t my layers line up?
What every GIS user should know about projections

OK, now why don’t my layers line up?

Two Layers in Pennsylvania State Plane
OK, now why don’t my layers line up?

Why don’t my map layers line up?

- Neither layer came with a `.prj` file so I guessed PA S :-)  
- Seems like one is in PA North (ftUS) and the other is PA North (m)
What every GIS user should know about projections

OK, now why don’t my layers line up?

How do I reproject my data

- Don’t use Set CRS - this just changes the metadata
- Unless there is no metadata in that case it’s fine if you know the right value
- Save (export) your data and select the new CRS you would like
When base maps go wrong

Add Natural Earth Coastline (EPSG:4326)
Adding in some Open Street Map Background (EPSG:3857)
What every GIS user should know about projections

Why don’t my map layers line up?

- The projections don’t match
- OSM is in EPSG:3857
- I have no idea why QGIS doesn’t reproject them but with Quick Map Services it doesn’t!
What every GIS user should know about projections

OK, now why don’t my layers line up?

Set the project to EPSG:3857 if you use QuickMapServices
What every GIS user should know about projections

OK, now why don’t my layers line up?

Now you see it...
What every GIS user should know about projections

OK, now why don’t my layers line up?

...Now you don’t
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OK, now why don’t my layers line up?

No projection -> Default projection

- Ordnance Survey believe they don’t (always) need to add a projection!
- QGIS default “default” CRS is EPSG:4326 (WGS:84)
- This is the only time you should ever use Set Layer CRS
- Override the default to EPSG:27700 in settings
What every GIS user should know about projections

OK, now why don’t my layers line up?
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OK, now why don’t my layers line up?

Visit Null Island

- Null Island - where the Prime meridian crosses the Equator
- Or where your data is if you tell QGIS that your WGS84 coordinates are in Web Mercator
Conclusion

- Coordinates with out a projection are meaningless numbers
- If there is no projection supplied look in the metadata
- Fix your input data once, don’t rely on remembering every time
- Look at the range of the bounding box to give clues
  - +/− 180 and +/− 90 probably a geographic projection
  - +/− 1000000000 probably in metres or feet.
What every GIS user should know about projections

Please, just make it stop
I use PostGIS so I can use GEOGRAPHY and ignore all this!

- You can use the geography data type (in exchange for many fewer functions) and much slower performance with most operations (on order of 10 times slower).
- ST_Transform is a fairly cheap process, so it’s okay to run it for each geometry if you keep functional indexes on the transformations of the form CREATE INDEX idx_geomt ON sometable USING gist(ST_Transform(geom,some_srid) and then use ST_DWithin(a.geom, ST_Transform(sometable.geom,some_srid), some_distance) for distance checking. Now when ST_DWithin is used with the transformed geometry, the function spatial index will kick in to help.
Failing that just be careful

- Try not to store data in formats without explicit internal metadata about projection
  - Prefer databases, GeoPackage or PostGIS, to Shapefiles or CSV
  - Prefer GeoTIff to World files or ASCII grids
- Never ship a file without a projection and metadata describing it
- Reproject to a relevant projection early in your workflow
Conclusions

- **Degrees and Metres**
  - *Never* calculate a buffer in degrees
  - *Never* do any geographical analysis in Web Mercator
  - Try to find an equal area projection if **and only if** your process is related to the area of the unit

- **Spherical geometry will make your head hurt**
  - There is a reason Euclid (and everyone else) avoided it
  - Where possible transform to a local cartesian projection
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    - +/- 180 and +/- 90 probably a geographic projection
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The End

- A copy of this talk can be found at http://www.ianturton.com/talks/
- All 6K+ questions about projections on GIS StackExchange - https://gis.stackexchange.com/questions/tagged/coordinate-system