Coordinate Systems and Projections: An Introduction

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Projection Engine
Transformations

Projections

Horizontal

Coordinate Systems
Horizontal Coordinate Systems
What does a coordinate system tell us?

Distance

Location

Direction
Two Kinds of Horizontal Coordinate Systems

- Geographic coordinate system
- Projected coordinate system
Geographic Coordinate System (GCS)

- 3D spherical surface
- Point P has:
  - Longitude – 80° E
  - Latitude – 50° N
Geographic Coordinate System (GCS)
Projected Coordinate System (PCS)
Horizontal Coordinate System

- Geographic Coordinate System
  - Prime Meridian
  - Datum
  - Spheroid
  - Angular Unit
Two Ways to Specify a Coordinate System

Well-known ID

Well-known text
Well-Known ID (WKID)

- All predefined coordinate systems have a WKID
Well-Known ID (WKID)

- WKID ≤ 32767: EPSG
  - EPSG Geodetic Parameter Dataset
  - http://www.epsg-registry.org/
Well-Known ID (WKID)

- WKID ≤ 32767: EPSG
  - EPSG Geodetic Parameter Dataset
  - http://www.epsg-registry.org/

- WKID > 32767: Esri
Well-Known ID (WKID)

- WKID ≤ 32767: EPSG
  - EPSG Geodetic Parameter Dataset
  - http://www.epsg-registry.org/

- WKID > 32767: Esri

- Any WKID may change
Well-Known Text (WKT)

GEOGCS["GCS_ETRS_1989",
   DATUM["D_ETRS_1989",
      SPHEROID["GRS_1980",6378137.0,298.257222101]],
   PRIMEM["Greenwich",0.0],
   UNIT["Degree",0.0174532925199433]]
Well-Known Text (WKT)

PROJCS["ETRS_1989_UTM_Zone_32N",
    GEOGCS["GCS_ETRS_1989",
        DATUM["D_ETRS_1989",
            SPHEROID["GRS_1980",6378137.0,298.257222101]],
        PRIMEM["Greenwich",0.0],
        UNIT["Degree",0.0174532925199433]],
    PROJECTION["Transverse_Mercator"],
    PARAMETER["False_Easting",500000.0],
    PARAMETER["False_Northing",0.0],
    PARAMETER["Central_Meridian",9.0],
    PARAMETER["Scale_Factor",0.9996],
    PARAMETER["Latitude_Of_Origin",0.0],
    UNIT["Meter",1.0]]

Projected coordinate system
Projections
Projecting to a Different Coordinate System
Our Map Projections

Aitoff
Albers
Azimuthal equidistant
Behrmann
Berghaus Star
Bonne
Cassini
Compact Miller
Crase Parabolic
Cube
Cylindrical equal-area
Double stereographic
Eckert Greifendorff
Eckert I
Eckert II
Eckert III
Eckert IV
Eckert V
Eckert VI
Equidistant conic
Equidistant cylindrical
Flat polar quartic
Fuller
Gall stereographic
Gauss Kruger
Gnomonic
Goode Homolosine
Hammer-Aitoff
Hotine oblique Mercator
IGAC Plano Cartesiano
Krovak
Laborde oblique Mercator
Lambert azimuthal equal-area
Lambert conformal conic
Local
Loximuthal
Mercator
Miller cylindrical
Mollweide
Natural Earth
Natural Earth II
New Zealand map grid
Ney modified conic
Orthographic
Patterson
Plate Carree
Polyconic
Quartic authalic
Rectified skew orthomorphc
Robinson
Sinusoidal
Stereographic
Times
Transverse cylindrical equal-area
Transverse Mercator
Two point equidistant
Van der Grinten I

Vertical near side perspective
Wagner IV
Wagner V
Wagner VII
Winkel I
Winkel II
Winkel Tripel

Azimuthal equidistant auxiliary sphere
Eckert IV auxiliary sphere
Eckert VI auxiliary sphere
Equidistant cylindrical auxiliary sphere
Gnomonic auxiliary sphere
Lambert azimuthal equal-area auxiliary sphere
Mercator auxiliary sphere
Miller cylindrical auxiliary sphere
Mollweide auxiliary sphere
Orthographic auxiliary sphere
Van der Grinten I auxiliary sphere
Why are there so many map projections?

- Shape
- Area
- Direction
- Distance

Illustration by Charles Preppernau, geolographer.xyz
Web Mercator Projection

Q: Which is bigger?

South America
Greenland
Antarctica
Web Mercator Projection

• Q: Which is bigger?

South America  ~  17 840 000 km²
Greenland      ~  2 166 000 km²
Antarctica     ~  14 000 000 km²
Web Mercator Projection vs. Reality
What is most important to preserve?

- Shape
- Area
- Direction
- Distance

Depends on what you are doing
Preserve Shape

- Stereographic
Preserve Area

- Albers equal-area conic
Preserve Area

- Albers equal-area conic
Preserve Direction and Distance

- Azimuthal equidistant
What is happening when we project data?

- Case 1: Both PCSs contain the same GCS

(x, y) PCS A1

(x, y) PCS A2

(lon, lat) (λ, φ) GCS A
What is happening when we project data?

- Case 1: Both PCSs contain the same GCS

\[ (x, y) \rightarrow \text{PCS A1} \rightarrow \text{GCS A} \rightarrow \text{PCS A2} \rightarrow (x, y) \]
What is happening when we project data?

- Case 1: Both PCSs contain the same GCS

(x, y)  PCS A1  (lon, lat)  GCS A  (λ, φ)  PCS A2  (x, y)
What is happening when we project data?

• Case 2: Each PCS contains a different GCS
What is happening when we project data?

- Case 2: Each PCS contains a different GCS

(x, y) → PCS A1 → Unproject → (lon, lat) → GCS A → (lon, φ)

(x, y) → PCS B1 → (lon, lat) → GCS B
What is happening when we project data?

Case 2: Each PCS contains a different GCS

- **Geographic (Datum) Transformation**

\[(x, y) \quad \text{PCS A1} \quad \text{Unproject} \quad \text{ PCS B1} \quad (x, y)\]

\[(\lambda, \varphi) \quad \text{GCS A} \quad \text{Geographic (Datum) Transformation} \quad \text{GCS B} \quad (\lambda, \varphi)\]
What is happening when we project data?

- Case 2: Each PCS contains a different GCS

\[ \text{PCS } A1 \quad (x, y) \quad \text{Unproject} \quad \text{PCS } B1 \quad (x, y) \]

\[ \text{GCS } A \quad (\text{lon, lat}) \quad (\lambda, \phi) \quad \text{Geographic (Datum) Transformation} \quad \text{GCS } B \quad (\text{lon, lat}) \quad (\lambda, \phi) \]
Transformations
Transforming Means Changing Datum

Earth-centered datum (WGS 84)

Earth’s surface

Data
Transforming Means Changing Datum

- Earth-centered datum (WGS 84)
- Local datum (NAD 27)

Data

Earth’s surface
Why do we need to transform our data?
Why do we need to transform our data?

WGS 1984

ED 1950
Geographic (Datum) Transformation

NAD 1927

NAD_1927_To_WGS_1984_1

WGS 1984
Geographic (Datum) Transformation

NAD 1927  ~NAD_1927_To_WGS_1984_1  WGS 1984

NAD 1927  NAD_1927_To_WGS_1984_1  WGS 1984
Defined for Certain Area

- 33 transformations:
  - NAD 27
  - WGS 84
How do I find transformations?
Now you understand…

Coordinate Systems

- Projecting your data
- Transforming your data
Resources

http://resources.arcgis.com/en/help
- ArcMap → Map → Map projections
- Developer Help
  - List of ArcGIS APIs

Lining Up Data in ArcGIS, Margaret Maher

ESRI Technical paper: Understanding Coordinate Management in the Geodatabase

ESRI Technical paper: Understanding Geometric Processing in ArcGIS
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